Grant Agreement No: 262025

AIDA

Advanced European Infrastructures for Detectors at Accelerators

Seventh Framework Programme, Capacities Specific Programme, Research Infrastructures, Combination of Collaborative Project and Coordination and Support Action

PROJECT FINAL REPORT

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	Name	**Partner**	**Date**
Authored by	All Work Package Coordinators	CERN, CNRS, DESY, INFN, JSI, MPG-MPP, CSIC	20/03/2015
Edited by	A. Szeberenyi, L. Lapadatescu, L. Serin, S. Stavrev	CERN, CNRS	23/03/2015
Reviewed by	Steering Committee	CERN, CNRS, DESY, INFN, JSI, MPG-MPP, CSIC	26/03/2015
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Name of the scientific representative of the project's coordinator, Title and Organisation:	Laurent Serin, Scientific Coordinator, CNRS
Tel:	+33 1 64 46 8501
Fax:	+33 1 69 07 94 04
Email:	Laurent.Serin@cern.ch
Project website address:	http://cern.ch/aida

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I. PUBLISHABLE SUMMARY

1. EXECUTIVE SUMMARY

After four years of activity, AIDA has coordinated a joint European effort for detector R&D and significantly improved a number of key European research infrastructures enabling advanced detector development for the high energy physics community. The project has achieved the scientific objectives and technical goals defined in Annex I of the Grant Agreement. The activities completed in all work packages will have an impact on the development of detector technologies for future accelerators:

-Generic detector description software toolkits for data processing applications in HEP experiments were developed and are being used by the ILD, CLICdp and the three FCC detectors.

-Various technologies to meet the requirements of future pixel detectors, such as integration of pixel sensors with CMOS read-out circuits and the fabrication of TSVs for interconnection, were investigated. The large aspect ratio TSV technology proved successful and it can now be applied to almost any ASIC. Furthermore, two sets of IP blocks (65 nm CMOS and 180 nm SOI CMOS) were defined, designed and tested and serve as basis for a shared library of designs of readout chips for future detectors.

-Strong links with the European detector industry were established by AIDA through the organization of a series of events with key experts from industry and academia. In total, 7 Academia-meets-Industry events with more than 100 participating companies were organized. An interactive tool, called Collaboration Spotting to analyse different technologies using publications and patents was developed and is also being used by communities other than HEP.

-A total of 691 researchers carried out 202 projects at European test beam and irradiation facilities (CERN, DESY, JSI, UCL, KIT) in the framework of the AIDA Transnational Access activities where the contractual commitments in terms of access units were largely exceeded. The impact on detector R&D can be assessed by the significant number of publications resulting from Transnational Access activities: 121 for the full project duration.

-AIDA contributed to the improvement and equipment of irradiation and test beam lines: new beam line characterisation infrastructure was installed, commissioned at Frascati and is now available to facility users, a new proton irradiation facility, IRRAD, was designed and constructed in the CERN PS East Area, a new gamma irradiation facility, GIF++, recently constructed in the CERN North Area was equipped to welcome users. An online database, called IMHOTEP, on the properties of irradiated material and components was developed and populated with data. A new beam tracking telescope was commissioned and is now available to users. The TASD detector was commissioned and is operational and the MIND detector has been redesigned for the benefit of the neutrino community. In the framework of AIDA, the CERN and DESY EDMS systems became operational as data management platforms for common test beam experiments and contain about 150 documents each. The common DAQ is also operational and is used by the telescope community.

-New detector prototypes (precision pixel detectors, gaseous and silicon tracking devices, highly granular calorimeters) were evaluated and characterized under AIDA, for the benefit of the European detector R&D community. The gaseous tracking detector was upgraded at DESY with a superconducting magnet and is being used by many groups. The CERN MPGD workshop is producing large area detectors. The infrastructures to test novel, highly granular calorimeter concepts, including electronics were also developed. In addition, a dedicated Silicon micro-strips telescope was developed so that a large-scale common test beam can now be scheduled at CERN facilities.

The R&D performed within AIDA will strengthen the excellence of the European detector community and its leading role in the major HEP experiments. Besides the direct impact on European detector research and industry, AIDA has indirect impact on the society at large. This is showcased by the organization of student tutorials and in particular by the number of PhD students (78) that have contributed to AIDA activities. Furthermore, some of the technologies and software developed within AIDA (ASICs, CMOS sensors, Geant4) can be used in applications outside of particle physics such as medical instrumentation, environmental monitoring and space science.

2. PROJECT CONTEXT AND OBJECTIVES

2.1 CONTEXT

The success of experimental particle physics, such as the 2012 discovery of the Higgs boson at CERN relies on cutting-edge technologies in the field of both accelerators and detectors. The LHC experiments like ATLAS and CMS are an impressive result of a 10-year detector R&D phase with many tests (particle beam and irradiation), followed by almost another decade of construction to be operational for the LHC start-up in 2010. New challenges are now opening up by the upgrade of the detectors for the High Luminosity LHC, the leptons colliders (B factory, ILC, CLIC, etc.), the Future Circular Collider (FCC) programme at CERN and the new neutrinos detectors for long baseline projects.

In line with the European Strategy for Particle Physics[1], AIDA (http://cern.ch/aida) addressed the upgrade, improvement and integration of key research infrastructures in Europe, enabled the development of advanced detector technologies and software, also providing transnational access to these facilities. By focusing on common R&D and use of such infrastructure, the project integrated the detector development community, encouraging cross fertilization of ideas and results, and providing a coherent framework for the main technical developments of detector R&D in Europe.

This project included a large consortium of 38 beneficiaries, covering a large fraction of the European community of detector R&D for particle physics. The collaboration aimed at taking advantage of the world-class infrastructures existing in Europe for the advancement of research on detectors for future accelerator facilities, enabling Europe to remain at the forefront of particle physics.

2.2 PROJECT OBJECTIVES

The project included a Management and Communication work package, three Networking work packages, three Transnational Access and two Joint Research Activities.

2.2.1 Management and communication

In addition to running the project, following-up the deliverables and milestones and maximizing its scientific and technical output for the High Energy Physics (HEP) community, an important management objective was to strengthen the collaborative aspects between the partners towards new ideas/projects within and outside the scope of AIDA.

WP number	WP Coordinator
1	Laurent Serin (CERN, CNRS-LAL)
2	Pere Mato Vila (CERN), Frank Gaede (CERN, DESY)
3	Valerio Re (INFN) , Hans-Günther Moser (MPG-MPP)
4	Jean-Marie Le Goff (CERN)
5	Marcel Stanitzki (DESY)
6	Horst Breuker (CERN)
7	Marko Mikuz (JSI)
8	Michael Moll (CERN), Giovanni Mazzitelli (INFN-LNF)
9	Marcel Vos (IFIC Valencia), Vincent Boudry (CNRS-LLR)

[1] http://cern.ch/council-strategygroup/Strategy_Statement.pdf

2.2.2 Networking activities

AIDA had three networking activities: WP2 (Development of software common tools), WP3 (Microelectronics and detector/electronics integration) and WP4 (Relations with industry). These networking activities were the suitable places to share technologies and explore new promising ideas.

WP2 aimed at creating a network to develop new software tools that could be used by the whole HEP community. The focus thereby was on creating reusable software packages that were central to the data processing in particle physics detectors, such as the description of detector geometry and material properties. This included misalignment tools for the reconstruction of charged particle tracks, and algorithms for combining these tracks with calorimeter showers into fully reconstructed particles, following the so called Particle Flow paradigm. These software tools were expected to be designed in a framework-independent way, so that they could be reused beyond the specific context or experiment in which they have been originally developed. The work was organized in two scientific tasks. Task 2.2 ,"Geometry Toolkit for HEP", aimed at improving and unifying the description of complex geometrical shapes, and creating software infrastructure to describe complete particle physics detectors to a high level of detail for the purpose of simulation and reconstruction. Task 2.3 or "Reconstruction toolkit for HEP" provided generic software tools and algorithms for track finding and fitting, detector alignment and particle flow reconstruction for highly granular calorimeters.

WP3 aimed to establish a network of groups working collaboratively on advanced semiconductor technologies and high density interconnection processes for applications in particle physics at HEP facilities. The main motivation came from the strict requirements set on pixel detectors for tracking and vertexing at future particle physics experiments at HL-LHC, B factories and Linear Colliders. To go beyond the state-of-the-art, the main issues were studying low-mass high-bandwidth applications with radiation hardness capabilities and low power consumption, offering complex functionality with small pixel size and without dead regions. The interfaces and interconnects of sensors to electronic readout integrated circuits are a key challenge for new research infrastructures. New technologies like 3D integration and small scale CMOS and SOI technologies have the potential to provide solutions to these issues. This WP assessed the possibilities of 3D integration (Task 3.2) and provided IP blocks for these advanced ASIC technologies (Task 3.3). These IP blocks provided the basis for a common library that could be shared among microelectronic designers, simplifying the development of new detector readout chips.

WP4 addressed relations with industry which plays a crucial role in the construction of large particle physics experiments. The huge number of detector components would make use of the most advanced technologies that are expected to reach full industrial maturity after the end of the project. Extremely challenging requirements of future HEP experiments call for close collaboration between academia and industry. This collaboration should start as early as possible and address prototyping at the R&D stage, through to qualification testing and later tendering and purchasing. Within the above context, the overall goal of WP4 was to address the technology needs, specifications and trends in several areas of particle physics over the next 5-10 years, via relations between the particle physics experimental community and industry, organized on topical academia-industry workshops. These interactions also looked at spin-off applications, including collaboration and co-development with other fields where this might be relevant. This networking activity emphasised the relevance of particle physics detector R&D to other areas of research, as well as to society in general.

2.2.3 Transnational access

Testing detector prototype performance using particle beams is a mandatory step to assess the viability of technologies and geometries before the final design of a detector, or to calibrate assembled modules. Similarly, irradiation facilities are essential to select materials and components that can withstand the radiation environment of future experiments. Granting access to these facilities to European R&D teams is therefore of prime importance, especially for young PhD/students for whom these tests are essential training in instrumentation.

The Transnational access activities were organized along two ways, benefitting from world-class European Infrastructures:

- Test beam facilities at DESY-**WP5** (low energy electrons and positrons) and CERN-**WP6** (wide range of particles and energy).
- Irradiation facilities, mainly targeted to cover the LHC detectors upgrade in terms of flux and particles types, at the TRIGA-Mark-II reactor for neutron irradiations at JSI in Slovenia; the Neutron Irradiation Facility, Light Ion Irradiation Facility and Gamma Irradiation Facility at UCL in Belgium and the Compact Cyclotron for proton irradiations at KIT in Germany (**WP7**) and at CERN for protons and mixed field irradiations (WP6).

2.2.4 Joint research activities

The two JRA activities were WP8 (Improvement and equipment of irradiation and test beam lines) and WP9 (Advanced infrastructure for detector R&D). They were mainly focused on upgrading existing detector infrastructures or creating new ones in view of the new challenges to be tackled.

WP8 aimed at upgrading test beams and irradiation facilities to match the requirements of the new experiments, testing materials and components for their performance in a radiation field and coordinating beam tests of the Linear Collider community and providing a common DAQ (data acquisition) for these tests. Particular objectives were to study the implementation of a low energy beam line at CERN for neutrino experiments, to improve the Frascati Beam Test Facility user infrastructure, to design a new proton irradiation facility at CERN and deliver part of its infrastructure (movable tables, cold boxes, beam and fluence monitoring). Further deliverables were the creation of a public online database on the properties of irradiated materials and components and irradiation tests on specific items, the design and construction of neutrino physics prototype detectors (TASD and MIND), user infrastructure for the new gamma irradiation facility GIF++ at CERN and the commissioning of a beam telescope to be produced by WP9. Finally, test beam activities needed to be fostered through infrastructure projects providing a powerful and unified control and acquisition system and an engineering data management system framework serving as a central data management platform for large international HEP collaborations.

WP9 aimed at the development of common infrastructure, accessible under the Transnational Access (TA) scheme, in support of the detector R&D programmes in Europe. The activity was organized around three HEP detector fields: gaseous detectors, pixel and Silicon detectors, and finally calorimeters. In the first one, the goal was to upgrade the gaseous tracking test stand for the Time Projection Chamber at DESY (refurbished solenoid, readout electronics) and to extend the capability of the CERN Micro Pattern Gas Detector workshop to produce larger area chambers. Measuring the position accuracy performance of many detectors needs a very precise external measurement to be compared with. Such an apparatus is in large demand in the community. While an FP6-EUDET pixel telescope was already in use under the AIDA TA, the objective was to deliver a new one, based permanently at CERN and satisfying the user community in terms of excellent spatial resolution but also providing LHC-style time resolution and self-triggering capability with an upgraded infrastructure (power supply, CO_2 cooling plant, etc.). For the calorimeter application, the resolution requirements are relaxed but the area to cover is larger, therefore a beam telescope with micro strips had to be built. New trends in calorimetry are towards ultra-granular detector to apply particle flow reconstruction. Various absorbers and sensitive media needed to be explored as well as detector readout: dedicated infrastructures for these tests were produced. Finally the matching of the simulation of hadronic showers to data was a key element to be assessed with the recorded test-beam data.

3. THE MAIN S&T RESULTS / FOREGROUND

3.1 AIDA NETWORKING ACTIVITIES

AIDA had three networking activities: WP2 (Development of software common tools), WP3 (Microelectronics and detector/electronics integration) and WP4 (Relations with industry).

3.1.1 Development of common software tools (WP2)

Geometry Toolkit for HEP

The main result of this task was the development of a generic detector description software toolkit for simulation and reconstruction applications in HEP experiments such as Linear Collider, LHC and the recently launched FCC study.

A detailed and realistic description of the detector geometry and its material properties is an essential component for the development of almost all data processing applications in HEP experiments. This is particularly true for the case of Monte Carlo simulations, where the exact knowledge of the position, shape and material contents of every detector component is crucial for the accuracy of the simulated detector response and underlying physics. For the subsequent processing steps of digitization and reconstruction it is equally important to have an accurate description of the detector geometry, which should ideally be created from the same source in order to avoid possible inconsistencies. The *DD4hep* (Detector Description for HEP) software package, developed in AIDA, is a generic geometry toolkit that builds on the two most widely used software packages in HEP: Geant4 and ROOT. It combines their independent geometry implementations into one consistent detector description model, which is augmented with an extension mechanism for attaching user defined data objects at every level of the geometrical hierarchy. Thereby it allows providing all the physical properties of the individual detector components that are needed at every step of the data processing, such as alignment constants, measurement surfaces or visualization attributes. Through this mechanism it is possible to provide appropriate and consistent views on to the detector geometry for simulation, reconstruction, analysis and visualization of HEP data from one single source.

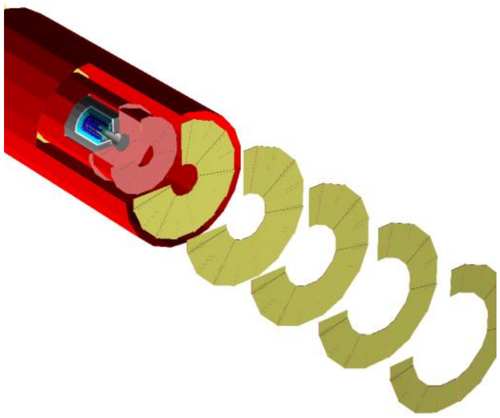

Figure 1: Inner tracking detectors (VXD, SIT, FTD) of the ILD detector concept for the ILC in a DD4hep based geometry model.

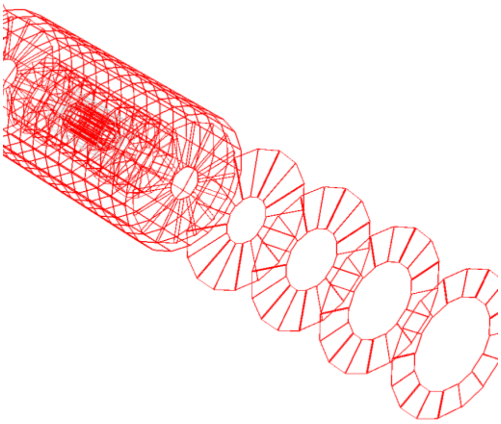

Figure 2: Measurement surfaces attached to the sensitive detector elements used for track reconstruction.

The sub-package *DDRec* consists of a set of generic pre-defined data structures and application interfaces providing the additional information needed for reconstruction, such as for example measurement surfaces with material properties (automatically averaged along given thicknesses from the detailed model) for the purpose of track fitting. Figure 1 and 2 show an example of the inner tracking detectors of the ILD detector with the assigned measurement surfaces. ILD, CLICdp and the three FCC detector design studies now actively use *DD4hep*.

As mentioned above, Geant4 and ROOT have both independent implementations of geometry libraries, at the cores of which are the description of basic geometrical shapes and the functionality to compose them into arbitrary complex detector setups and to navigate in these. It is estimated that 70-80% of the effort for code maintenance is due to these geometrical primitives in both implementations. In order to overcome this situation the *USolids* package was developed in AIDA. After the creation of an extensive testing suite for all shape implementations and the corresponding geometrical methods, such as *isPointInside*() or *distanceToOut*(), a detailed benchmarking between the two existing implementations was performed in order to select the best algorithms for the new unified library. Figure 3 shows the basic shapes implemented so far. Wherever possible, new and more efficient algorithms with significantly better performance have been developed, such as for *Multi-Union*, *Tessellated Solid*, *Polyhedra*, and *Polycone*. Figure 4 shows an example of such a benchmark.

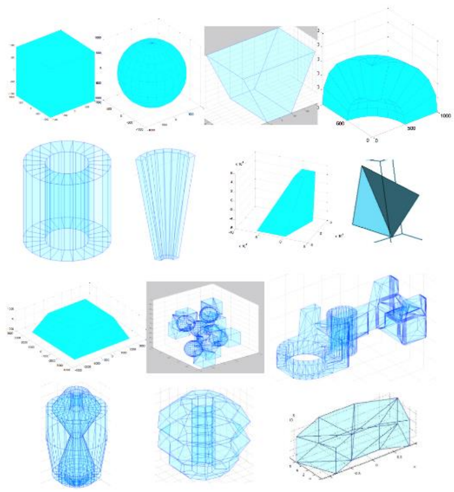

Figure 3: Basic shapes implemented in the USolids library.

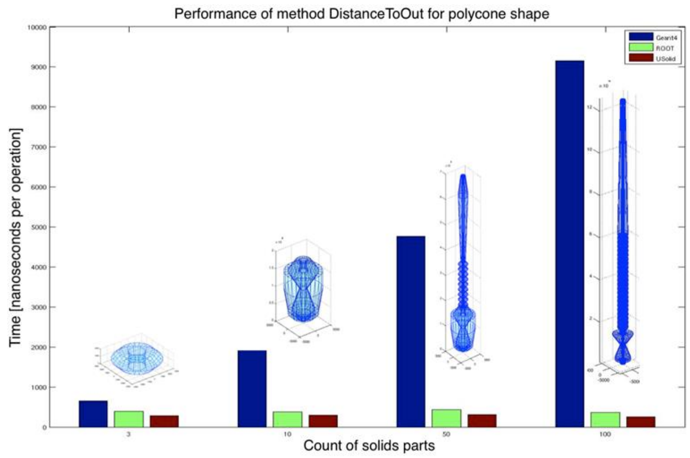

Figure 4: Comparing the performance of DistanceToOut USolid implementations with respect the number of Z sections.

USolids was first released in Geant4 10.0 as an optional component and will eventually become the new standard. It is planned to also integrate *USolids* into ROOT soon.

Reconstruction Toolkit for HEP

A generic pattern recognition, track fitting and alignment software were developed in this task as well as an advanced particle flow software framework. These tools are already in use by the LC, LHC and neutrino physics communities.

Tracking toolkit

The reconstruction of the momentum and path of charged particles forms an essential part of data processing in HEP experiments. The task is typically divided into the two steps of finding the track, the pattern recognition; and into computing the best set of parameters using fitting algorithms such as Kalman-filters or the General Broken Lines (GBL) algorithm. Tools for both steps have been developed and combined through the definition of an abstract interface that links both tasks without coupling them directly, allowing the choice of the best combination of pattern recognition and track fitting tools. In order to take material effects like multiple scattering and energy loss into account, detailed knowledge of the detector geometry is essential. This is provided through the *DDRec* interface into the *DD4hep* detector model. Figure 5 shows the schematic view of the new ILD tracking software.

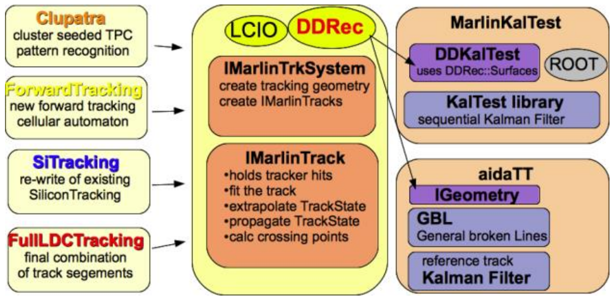

Figure 5: Schematic view of new ILD tracking software where the pattern recognition algorithms are programmed against the IMarlinTrk interface and thus independent of the actual track fitting algorithm used.

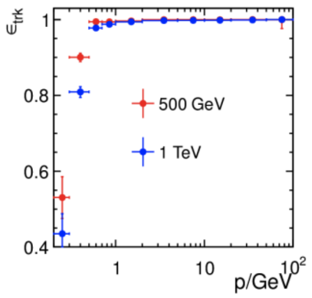

Figure 6: Track finding efficiency for prompt tracks in ttbar events at the ILC with 500GeV and 1 TeV center of mass energy respectively, as a function of momentum.

The tracking tools have been partially developed in the context of the CMS experiment, preparing for the Run 2 of the LHC with its envisaged high pile-up environment and partly in the context of the ILD detector concept for International Linear Collider (see Figure 6). Immediate application to both experiments demonstrates the usability of the software tools. Care has been taken to have as little as possible dependencies to the actual frameworks in order to allow for the re-use of the tracking tools.

Alignment Software Tools

The accurate determination of the positions of elements of a detector is essential for obtaining the optimal detector performance. Therefore alignment methods, which evaluate the position of detector elements, are needed for any particle physics experiment. A software package called *BACH* (Basic Alignment and Reconstruction Chain) has been written to provide a common tool for the alignment of telescope-like detectors. It describes the complete analysis chain of a telescope detector, from simulation to reconstruction. The initial version of this tool has been applied to support the operations of the Timepix telescope supported in WP8 (see Figure 7).

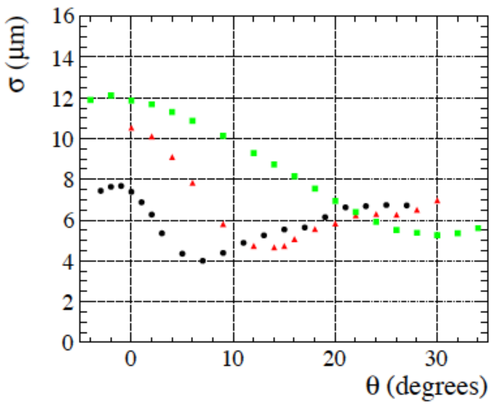

Figure 7: Resolution versus track angle at 60V bias voltage for 150µm (green) 200µm (red) and 300µm (black) thick prototype Silicon pixel sensors with TimePix ASIC using the BACH alignment software and the TimePix telescope.

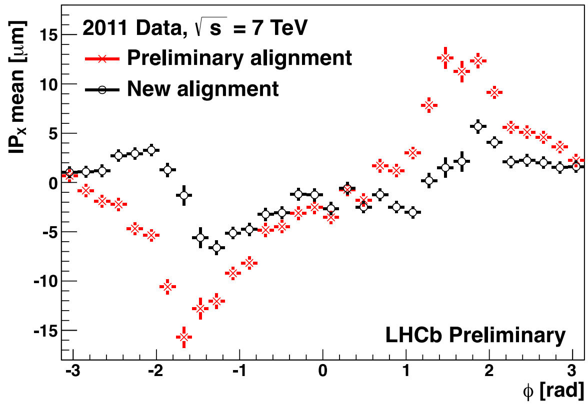

Figure 8: Mean of Impact Parameter versus the azimuthal angle for LHCb data events using old and new alignment procedures of the VELO detector that correct for weak modes.

In parallel, tools for monitoring the misalignment and allowing for the correction of weak modes of the vertex detector (VELO) of the LHCb experiment have been developed and helped to improve the Impact Parameter resolution as shown in Figure 8.

Particle Flow Software Tools

Particle Flow reconstruction of highly granular detectors is a relatively novel concept in particle physics. Due to the nature of the problem, the pattern recognition algorithms tend to be complex and involve many steps. Furthermore, the large number of energy deposits requires a robust and efficient software framework. The *PandoraPFA* software toolkit provides such a framework for implementing advanced particle flow and pattern recognition algorithms that can be used across multiple projects and experiments. To demonstrate its effectiveness, a first version of a complete set of particle flow reconstruction algorithms have been implemented and benchmarked in the context of the ILC and CLIC detectors, shown in Figure 9 and Figure 10.

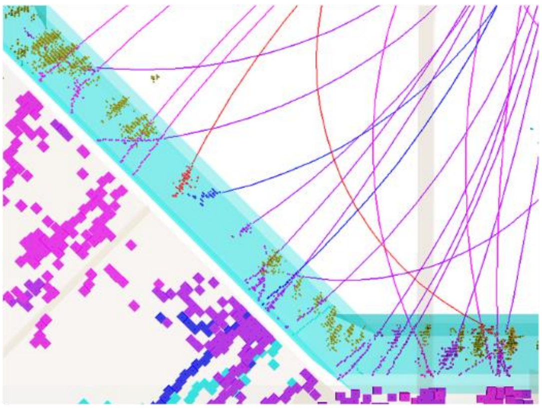

Figure 9: Particle flow objects (PFOs) reconstructed by PandoraPFA in the ILD detector: charged particles (dark blue); photons (mustard yellow); electrons (red) and neutral hadrons (light blue).

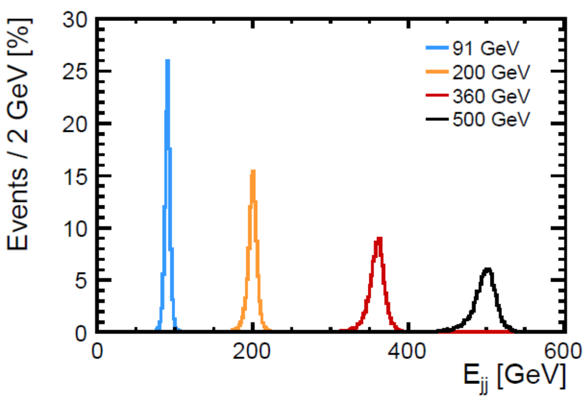

Figure 10: Total reconstructed di-jet energy distributions for $Z \rightarrow uu/dd/ss$ at various center of mass energies.

Furthermore, interfaces and algorithms have been provided that enable *PandoraPFA* to be used for studies for future neutrino experiments, both LBNE in the US and LBNO in Europe, by reconstructing events in LAr-TPCs.

Trigger Simulation

Developing a new tracking detector using full Monte Carlo simulations is a rather time consuming process since it requires a significant effort to implement each new detailed geometry model and adaptation of the pattern recognition algorithms involved. For the expected high multiplicities of charged particles at the HL-LHC a fast track trigger at first level with an optimized tracker layout will have to be implemented in the CMS experiment. The *tkLayout* tool was developed to address this issue. It allows for rapid evaluation of different tracker geometries and their key characteristics, such as material budget, resolution and trigger performance.

3.1.2 Microelectronics and detector/electronics integration (WP3)

New pixel detectors are requiring better spatial resolution and small occupancy in high density tracks environment, therefore small pixel size and reduced material are mandatory. 3D interconnection is the most promising way to solve this issue and the exploration of these technologies was the main activity of this WP. For such a process, dedicated and more and more complex ASICs, need to be designed: creating a common library of IP blocks is therefore an added value for the HEP community.

3D interconnection

The technologies investigated for the 3D interconnection between the sensors and readout chips for the fabrication of pixel detectors, led to many diverse results. Large diameter TSVs have proven to be a mature technology for detectors of the next decade. Thanks to the latest technology they can be applied to almost any ASIC. On the other hand, processes aiming for high density interconnections with high aspect ratio, narrow vias provided mixed results.

This activity was structured in eight subprojects testing different 3D technologies using different vendors. The original objectives of these subprojects were:

a) Interconnection of the ATLAS FEI4 chips to sensors using bump bonding from Fraunhofer-IZM (large interconnection pitch).
b) Interconnection of MEDIPIX3 chips to pixel sensors using the CEA-LETI process.
c) Interconnection of chips from Tezzaron/Chartered to edgeless sensors and/or CMOS sensors using an advanced interconnection process (T-MICRO or others).
d) Readout ASICs in 65nm technology interconnected using the CEA-LETI or EMFT process.
e) Interconnection of ATLAS FEI4 chips to sensors using SLID interconnection from Fraunhofer-EMFT.
f) 3D interconnection of 2 layers of Geiger-Mode APD arrays with integrated readout in Tezzaron/Chartered technology.
g) Interconnection of the two layers of a 2-Tier readout ASIC for a CZT pixel sensor using the Fraunhofer-EMFT SLID technology.

Since the subprojects explored different technologies with various challenges, it could not be expected that all of them produced the same level of results over the timespan of the project. Some subprojects investigated 3D technologies which have the potential to lead to high-density 3D interconnection processes but still face technological challenges. Others used more mature technologies. They do not offer highest interconnection density but can still lead to substantial improvements of the detector performance. As expected these latter projects turned out to be the most successful ones. This was the case for the subproject (b) using a technology offered by CEA-LETI (Figure 11) for which a demonstrator has been built. Large diameter TSVs provided access from a metal redistribution layer on the backside to the chip's IO pads. Other subprojects focusing on similar technologies (large low aspect ratio vias at the periphery for backside connectivity) were quite successful as well: (a) using the FEI3 chip with a Fraunhofer IZM technology and (g) with T-Micro. In summary, the TSV technology is available and can be applied as "via-last technology" to almost any ASIC. Interconnection technology is less of a challenge as standard bump bonding will suffice.

Figure 11: An X-ray image (flat field corrected) of a small fish head taken using a TSV-processed Medipix3 chip which has been flip chip bonded to a Silicon sensor. The chip has 256 x 256 pixels on a pitch of 55µm. The readout is performed through the BGA contacts on the back of the ASIC. The origin of the circular artefact is not known

On the other hand, projects which aimed for high density interconnections with high aspect ratio, narrow vias were less successful. For the interconnection standard bump bonding had to be replaced by more advanced technologies. The SLID technology was tried in three projects with mixed results. A successful SLID interconnection could be demonstrated by subproject (e) using a process by Fraunhofer EMFT. However the yield was low and results could not (yet) be reproduced by (g) using the same process by EMFT. A third project (c) which used a SLID technology by Fraunhofer IMS has not been evaluated yet. Equally narrow TSVs were used with mixed results also. While Fraunhofer EMFT did not succeed with the Tungsten filling of narrow vias in project (e) the identical technology worked for (g). This indicates that the process is not yet fully stabilized and large fluctuation of quality and yield occur.

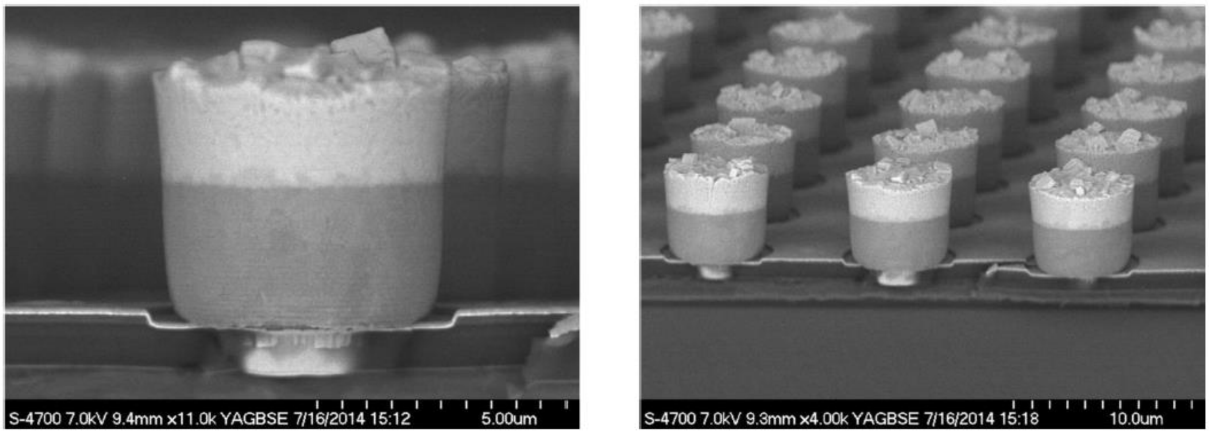

Figure 12: Images of bumps for the SLID interconnection at IMS for the sub-project. The diameter of a bump is 5 µm, the pitch 10 µm.

The most advanced 3D processes use "via-first technologies". In this case one is bound to a specific ASIC technology and a vendor supporting this process. Such a possibility was offered by Tezzaron, as a Multi Project Wafer (MPW) at the time the project started. Since this was the most advanced technology accessible it was mandatory within this framework to try and assess this technology. A 'proof of principle' of the process could be achieved, nevertheless it became obvious that it is technically still very difficult and at the end it took more than four years to produce chips with very low yield. Some subprojects suffered from the non-availability of the Tezzaron 3D integration process. While the project (f) essentially stopped after completion of the design, the project (c) redirected its efforts towards evaluating a new interconnection technology based on SLID offered by Fraunhofer IMS.

Shareable IP blocs

Two sets of IP blocks (65 nm CMOS and 180 nm SOI CMOS) were defined, designed and tested serving as basis for a shared library of future designs of readout chips for pixel detectors.

The goal was to promote the creation of a network of designers developing a shareable library of circuit blocks that can be used by the community in various detector readout chips. The evolution of microelectronics towards miniaturization (also called "CMOS scaling") brings along an increased complexity of the technology itself and of the design tools, as well as much larger costs. As compared to consumer electronics, the HEP community is a low-volume customer that has to approach advanced CMOS processes in a collaborative way in order to be successful. Two different technologies were chosen in order to address the requirements of different detector applications. The 65 nm CMOS node was chosen for the first set of IP blocks in view of the development of new readout chips with high functional density, high data rate capability and high radiation hardness, complying with the requirements of the next generation of pixel detectors at HL-LHC (High Luminosity LHC) in the next decade and at CLIC. Among the various available technology options, the Low Power (LP) flavor of the 65 nm process was selected because it was considered to be the most interesting option in view of the design of mixed-signal (analog and digital) chips. CERN negotiated and signed a contract with TSMC (the CMOS foundry) and IMEC (the CMOS broker), and a multi-part nondisclosure agreement (NDA) was distributed to the WP3 institutions. This NDA administrative phase took much more time than anticipated (2 years), thus delaying the work. As soon the NDA was signed a full 65 nm CMOS design kit (prepared by CERN) was distributed to AIDA beneficiaries. In parallel, micro-electronic design groups had nevertheless an individual access to the 65 nm TSMC process through the standard Europractice service. These made it possible to design and submit IP blocks in this technology. Several blocks were designed and fabricated, including bandgap voltage references, general purpose ADC, I/O pads, LVDS transmitters and receivers, and temperature sensors. Soft IPs (SRAM compiler, FIFO pixel cell readout unit) were also designed. Designs and test results for these blocks were discussed and shared among the community. The full experimental validation of the blocks is still a work in progress that is expected to continue among the partners in the course of the design of the new readout chips for HEP detector applications.

A second set of blocks was designed in a 180 nm SOI CMOS process and was more focused on readout integrated circuits for calorimeters or time proportional chambers. These detectors set demanding requirements in terms of analogue performance parameters such as large dynamic range, high speed, low noise and low offset, high voltage capability and need of precise capacitors and resistors. The 180 nm node was chosen to fulfil these requirements.

Figure 13: Naked dies with 180 nm CMOS X-FAB process.

The XT018 process is a X-FAB 180 nm modular trench isolated, high voltage SOI CMOS technology. It is based on SOI wafers and the industrial standard single poly with up to six metal layers 0.18µm drawn gate length process, integrated with high voltage and Non-Volatile-Memory modules. This platform is specifically designed for a new generation of cost-effective "Super Smart Power" technology. This technology fulfils the requirements of new readout chips that will be designed to equip the next generation of calorimeters and detectors at HL-LHC, at CLIC and at ILC. The high voltage capability also offers solutions for pixel sensor design. The 6 metal layers are quite interesting to design chips with analogue and digital parts. The access of the HEP community to this technology has been coordinated and, all the designs gathered together before submitting them to X-FAB foundry. These blocks have been submitted in July 2014. A lot of 10 dies was received at the end of December 2014. Figure 13 shows a photo of a die. Evaluation has started and will continue over the next months, with successful preliminary results already available.

3.1.3 Relations with industry (WP4)

Seven Academia-Industry matching events (AIME) with more than 100 participating companies were organized by WP4 and helped fostering new collaborations with industry, enlarging their manufacturing capabilities to meet the needs of detector technologies. An interactive tool, called Collaboration Spotting, to analyse different technologies using publications and patents was developed by WP4. The tool is a valuable asset for both academia and industry and is also used by communities beyond HEP.

AIDA focused on developing and applying a platform of exchange (matching events) between academic and industrial players with a view of matching the technology needs of future detectors with the capability of industry to meet these needs. Early industry-academia collaborations are expected to contribute to the improvement of the quality and pricing of industrial offerings, to give industry the possibility of testing new techniques and pushing their technical capability further, and possibly in a later stage deploy the newly developed technologies in other research disciplines and/or industrial applications. The Academia-industry matching concept consists in putting together academic and industry experts to discuss trends, needs and capabilities in relation with narrow technical topics of interest to detectors and requiring an important R&D activity in collaboration with industry.

In total, since the AIDA kick-off meeting in February 2011, seven Academia Industry Matching topical Events (3 by AIDA and 4 in collaboration with HEPTech) and four national events with a wider focus in relation with detector technologies were organized covering most of the technology fields of importance for detectors at accelerators.

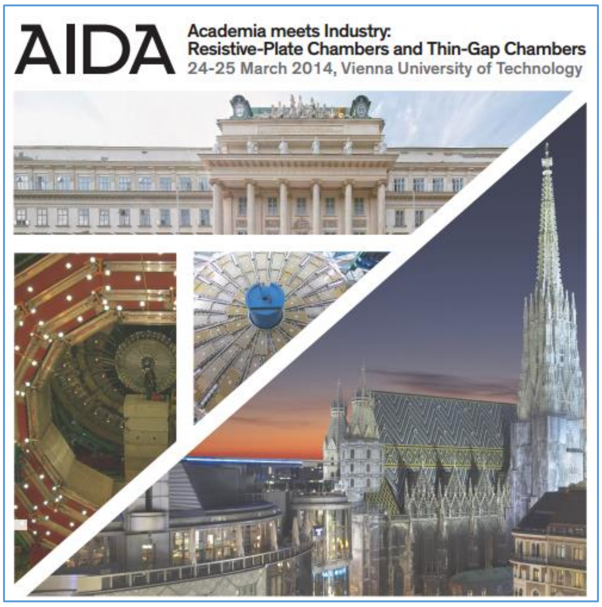

Figure 14: Poster of the Academia Industry Matching Event on Resistive-Plate Chambers and Thin-Gap Chambers in 2014.

Topics of AIME events under AIDA

- Solid-State Position Sensitive Detectors
- Advanced interconnections for chip packaging in future detectors
- Resistive-Plate Chambers and Thin-Gap Chambers
- Silicon-Photomultipliers*
- Micro Pattern Gaseous Detectors*
- Neutron Detection with MPGDs*
- Controls for Accelerators and Detectors*

** Events co-organized with HepTech.*

These events and their preparations have been conducted through an analysis based on the technology under focus at the event, its readiness level and its possible use in other research disciplines than particle physics or in industry. A total of 611 people attended these events with an average of 87 participants per event. The attendance was linked to the size of the academic community of interest and to the number of companies having manufacturing and/or integrating capability. A total of 101 companies attended the seven events for an average of 14 companies per event. For technology topics where Europe could meet the needs of academia, the percentage of EU industry at the event was about 90% or above. This percentage went down to 70% when the leading industry for a technology topic is in the US and/or Asia. This was clearly the case for 3D interconnections where key industry players are outside Europe.

The analysis concluded that interactions between academia and industry strongly depend on the type and readiness level of the technology under focus and its use in detectors. For each academia-industry matching event, a deep understanding of academic expectations and a good knowledge of the possible industrial applications are required to increase the chances of early R&D collaborations with industry. For instance, when the main challenge lies in motivating industrial partners to invest in sophisticated production lines for building detectors, Academia must convince industry that such detectors have a real market potential beyond particle physics and to this end physicists must often devote some of their resources to building proof-of-concept devices and even pre-industrial prototypes. This is typically the case for gaseous detectors that have to demonstrate cost-effective use in applications such as ore mining or muon tomography scanners.

Attracting students in undertaking scientific studies and contributing to the training of future physicists and engineers is an integral part of the physics community's responsibility. To this end, the Weizmann Institute has developed ten TGC-based detector demonstrators for high school students to view cosmic rays and understand how gaseous detectors operate. Other institutions in AIDA have developed demonstrators for high schools and universities using other technologies. Industry is needed to take over academia to address the growing demand of educational detector toolkits for high-school physics students. This can also constitute an attractive aspect for motivating industry in partnering with academia to acquire the technology.

Most of the detector projects related to AIDA are entering the pre-construction phase, therefore future matching events will have to account for the detector dimension in addition to the work already undertaken at the technology level. This is of particular importance for projects where specific technology combinations or scale of usage may unveil new problems calling for additional R&D to complement the selected solutions. For instance providing detector alignment and cooling, or supplying power to various components without compromising the detector efficiency while minimizing consumptions are issues that will need to be addressed in future matching events together with the technologies of concern.

Within this work package, CERN developed a graph-based interactive tool called Collaboration Spotting that processes all the publications and patents related to a particular technology topic and displays various graphs to assist organizers in identifying key players, monitoring and assessing the impact of a workshop, and understanding better how technologies develop and mature.

As an example, the graphs below on Figure 15 show the main industry (red) and academic (blue) organisations for Through Silicon Vias (TSV), one of the technologies addressed at the AIME on 3D interconnections with the help of Collaboration Spotting.

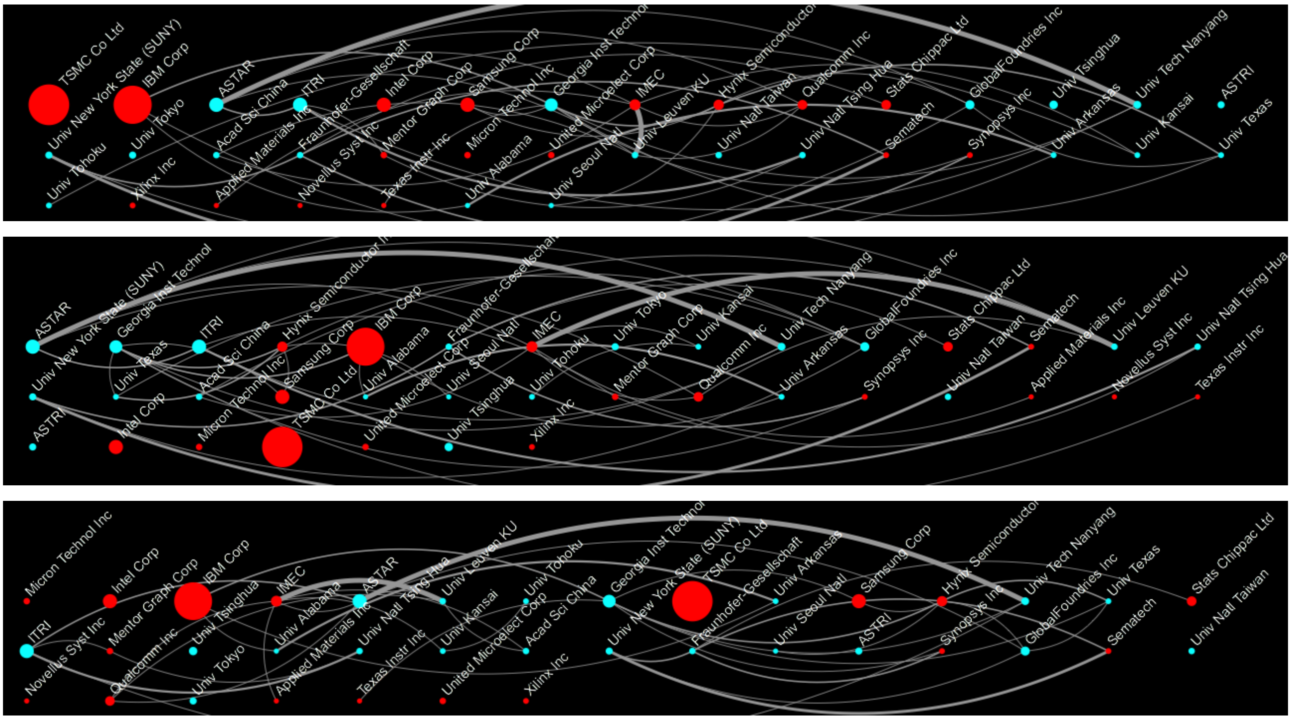

Figure 15: Snapshot of the organisation landscape sorted by size for TSV (top)
Snapshot of the organisation landscape sorted by connectivity for TSV (middle)
Snapshot of the organisation landscape sorted by impact for TSV (bottom).

From these graphs, one can clearly identify key industrial players and how they collaborate with one another and with academia. Looking into their respective publications and patents will provide a good insight on their contributions to TSV and on the maturity of the technology.

The technologies addressed in the matching events have been processed and are regrouped in a graph called technology landscape along with other technologies from particle and nuclear physics. In this graph, individual vertices correspond to technologies, and edges between two vertices to papers and/or patents related to the technologies of the corresponding vertices. From each technology vertex, the organisation, subject category and author keyword landscapes are fully accessible. Navigating across these graphs can either be achieved via a technology vertex or using vertices of one landscape to access other landscapes related to a specific technology. In any graphs, histograms showing the distribution of publications and patents across the years are available.

3.2 AIDA TRANSNATIONAL ACCESS

Two kinds of facilities were offered under AIDA Transnational Access:

- test beam with electrons, positrons, muons and pions at DESY and CERN;
- irradiation facilities at the TRIGA-Mark-II reactor at JSI in Slovenia for neutrons irradiation, at the Neutron Irradiation Facility, Light Ion Irradiation Facility and Gamma Irradiation Facility at UCL in Belgium, the Compact Cyclotron for proton irradiations at KIT in Germany and the proton and mixed field irradiation facilities at CERN.

The beam units offered by CERN and DESY are free of charge and the EC funding was mostly dedicated to the support of users. For most of the irradiation campaigns on the other hand, the users did not come on site and the irradiation operation was done by facility manpower: the EC funding was therefore mostly used for the beam units and to ship back the irradiated components to the users.

Test beam facilities

354 users benefitted from transnational access to the test beam facilities at DESY and CERN. The two facilities exceeded the access units committed by about a factor of 2 and 3 respectively.

Europe has two world class facilities to test particle detectors with beams, which are highly demanded in the HEP community:

- CERN is unique with its PS and SPS beam lines offering a wide variety of particles (electron, muon, pion and proton) from GeV up to more than 250 GeV. The facility has provided 1,768 beams units (8h shifts) to 160 users (contractual commitment: 600 units);
- DESY provides high energetic particles in the multi-GeV range. Due to its easy handling, the DESY test beam is an excellent facility for early prototype testing where many accesses to the beam area might be required. The facility has provided 71.2 beams units (beam weeks) to 194 users (contractual commitment: 40 units).

Both sites benefited also of the EUDET/AIDA telescope as illustrated in Figure 16. DESY was also offering a dedicated infrastructure for the test of gaseous detectors and their electronics upgraded under AIDA (see section 3.3).

Over the AIDA timespan, due to the long accelerator LHC shutdown, the CERN test-beam has been available only in 2011-2012, well complemented by DESY test beam available over the remaining periods. Figure 17 and Figure 18 show respectively the breakdown of team supported by technology and by scientific community at each facility. The large fraction of trackers tests, mostly from the LHC community, reflected clearly that the most challenging detectors to be upgraded are foreseen to be those of the HL-LHC. The new ATLAS inner B layer (IBL) installed recently in the experiment benefitted a lot also from the TA for the qualification of production modules and validation of performance. All these tests were using pixel telescopes supported by AIDA. The CALICE collaboration underwent a few test-beam at CERN with the AIDA Tungsten infrastructure which revealed to be quite useful to validate the hadronic showers models. The test of the SiW calorimeter validated mostly the technical aspects as electronics or DAQ. The DESY TPC has been intensively used for test of GEM and micromegas detectors with novel amplifications structure or new electronics readout.

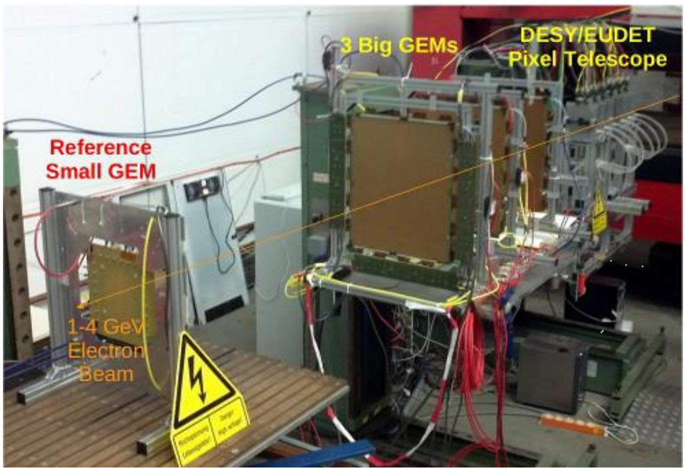

Figure 16: View of experimental set-up at DESY using pixel telescope

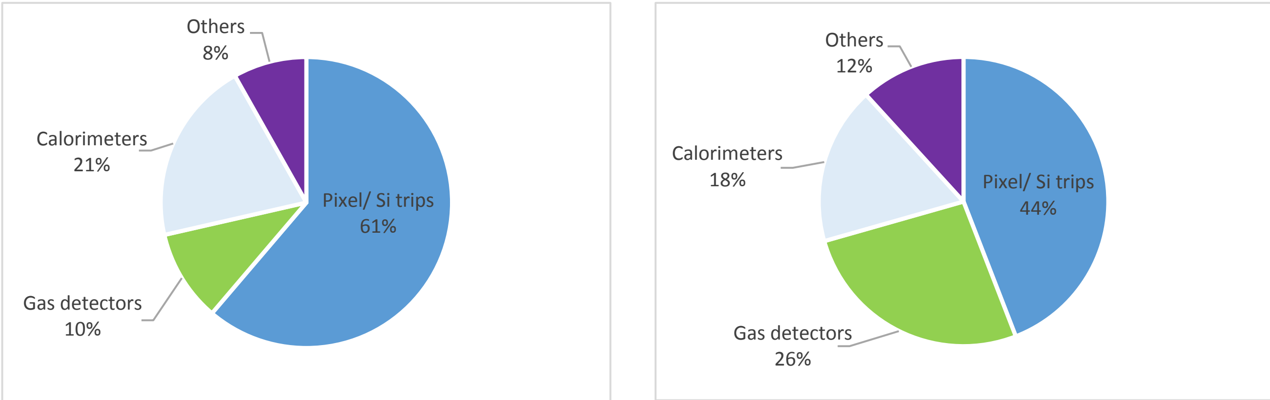

Figure 17: Users supported at CERN (left) and DESY (right) by detector technology

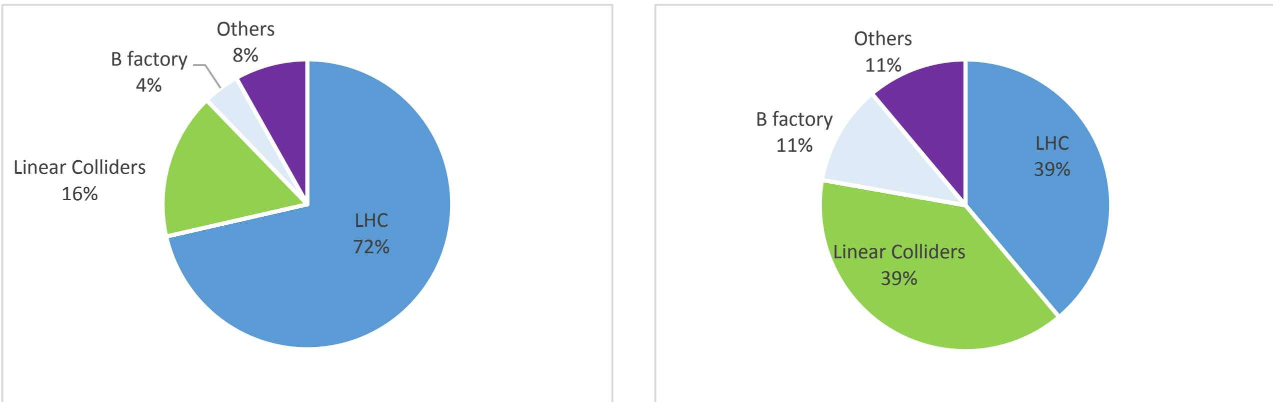

Figure 18: Users supported at CERN (left) and DESY (right) by scientific community

Irradiation Facilities Transnational access

337 users benefitted from transnational access to the irradiation facilities at CERN IRRAD East Hall, JSI, UCL and KIT, either by being present on site to conduct their experiments or by sending samples to the facilities to be irradiated. All the access units committed by the four irradiation facilities were delivered and three of them exceeded the contractual commitments.

The AIDA irradiation facilities were selecting and providing support according to the community needs and their complementarity:

The TRIGA-Mark-II reactor at JSI in Slovenia delivered fast neutron fluences up to 10^{16} cm^{-2} within one hour. The unit of access is a reactor hour, including sample preparation, cool off and handling neutron irradiations, as no users came on site but preferred to ship their components. Over the project, 630 units (beam hour) were provided under the TA with a high demand (540 committed). The JSI TA facility was mainly used to irradiate sensors, electronics and module prototypes to the extremely high doses expected at HL-LHC (>80%). Sensors included planar Silicon, 3-D Silicon, HV-CMOS and diamond. A limited proportion of projects dealt with irradiation of devices for the B-factories and the linear collider. One of the highlights resulting from AIDA TA to JSI reactor was the choice and verification of sensor technology for the module prototypes of ATLAS IBL, the pixel layer closest to the beam instated into the existing pixel detector. The required benchmark fluence is $6x10^{15} n_{eq}/cm^2$. Several of the prototype sensors and modules were irradiated. The results of module tests were published in 2012 and served as the basis for validation of the module technology.

The KIT compact cyclotron in Germany runs at 25 MeV and 1-2 μA and provided fluences up $5x10^{15} n_{eq}/cm^2$, which can be reached easily with an accessible area of 40x15 cm^2. Over the project, 160 units (beam hour) were provided (160 committed), and similarly to JSI no user came on site. The TA was exclusively used to irradiate trackers components (sensors, readout chips) for LHC experiments again with the ATLAS IBL sensors, a R&D project of CMS to validate radiation hardness of thin Silicon sensor materials (CMS HPK campaign), the validation of radiation hardness of the new digital CMS Pixel Readout Chip and non-uniform irradiations of ATLAS AFP and LHCb VELO. For instance the CMS R&D project campaign resulted in 9 publications and 3 PhD theses and provided the basic knowledge on which the CMS Collaboration bases its decision on the sensor material for the production of a new Tracker in 2018.

The CRC Facility at UCL in Belgium has various irradiation facilities (fast neutrons, protons and heavy ions) providing moderate fluences (~10^{14} 1-MeV n_{eq}/cm^2 in ~24h) but allowing readout and control of DUT during irradiations. Also, and complementary to the two other facilities, larger detector area can be covered. Over the project, 275 units (beam hour) were provided (250 committed), as well as user support on site. About half of the users had projects related to the LHC, while the other half were linked to NA62 experiment or material tests. Complex objects as readout chips were irradiated, focusing not only on the fluence but also on the behaviour of the samples. With online monitoring of the component response along the radiation dose Single Event Effects could be studied. An interesting result has also been obtained with the irradiation of optical fibre developed by LHCb for which a fast transparency recovery has been observed.

The CERN irradiation facilities in the PS East Hall (proton and mixed field) were made available to 23 users from 5 projects. A total of 264 units (8h shifts) were provided (200 committed). In preparation for the luminosity upgrade of the LHC (HL-LHC), the CMS Tracker Collaboration evaluated the best sensor material for a new tracker to be optimized for higher peak and integrated luminosity with respect to the present tracker. Experiments around the development of a new kind of radiation monitoring device for CERN IRRAD East Hall were also carried out.

3.3 AIDA JOINT RESEARCH ACTIVITIES

The two JRA activities were WP8 (Improvement and equipment of irradiation and test beam lines) and WP9 (Advanced infrastructure for detector R&D).

3.3.1 Improvement and equipment of irradiation and test beam lines (WP8)

Detector design, construction and operation closely link with test beam availability, to validate prototypes under realistic conditions or calibrate production modules. Similarly, irradiation facilities are essential to select materials and components for the radiation environment of future experiments. This work package aimed at adapting test beams and irradiation facilities to the requirements of these experiments, testing materials and components for their performance in a radiation field and coordinating beam tests of the Linear Collider community and providing a common DAQ for these tests.

Test beam infrastructure at CERN and Frascati

The possible implementation of a new beam line in the H8 beam of CERN North Area, able to provide 1-9 GeV/c electrons, pions and muons was studied. The Frascati beam line has been upgraded and commissioned with new beam characterisation equipment now available for facility users.

At CERN a design study was conducted for low-energy 1 to 9 GeV/c electron, pion and muon beams needed by neutrino detector community. The specification of the beam line has been documented by the neutrino community. Two beam layout adapted to the available space in the H8 beam line of the CERN SPS North Area, have been proposed. One of them is displayed in Figure 19.

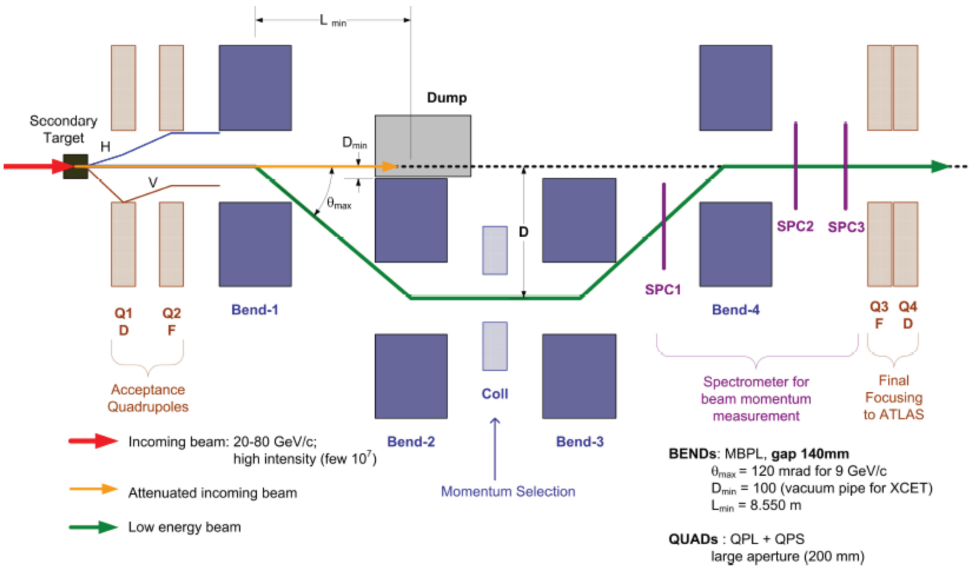

Figure 19: Schematic of beam layout for very low energy beam in H8.

The design challenges and optimization steps in the production of low-energy particles has been investigated and the optimization studies, mainly the choice of geometrical parameters and material of the secondary target from where the low-energy particles emerge, has been performed using Monte Carlo simulation codes. For instance with the same layout Figure 20 shows the transport of low energy electron.

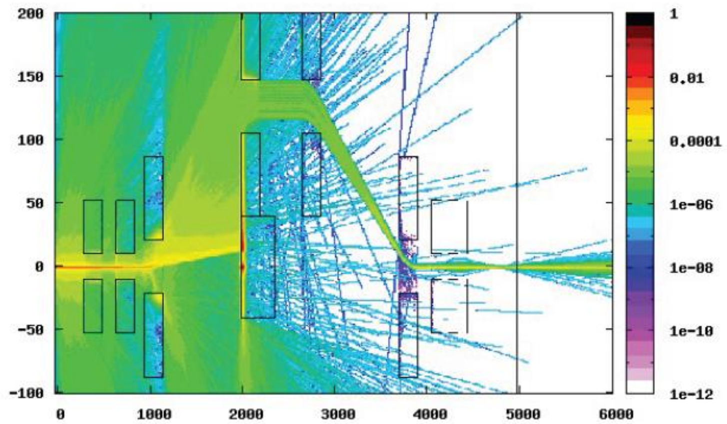

Figure 20: Particle trajectories with the same layout for a low energy electron beam of 9GeV/c.

The optimized beam layout and optics for the tertiary branch aimed to momentum select the low-energy particles and maximize the beam transmission allowing in a single configuration to switch between different particle types and momenta. Possible implementation of the new beam line in the H8 beam of CERN North Area was studied and documented.

At FRASCATI the test beam infrastructure has been successfully completed. Moreover, the BTF (Beam Test Facility) user access in Frascati during the 4 years has been of an average of about 220 days/year, 8 days/group, 20 groups/year. In summary, over the project duration, the following activities were achieved:

- Equipping the facility with a remote controlled table: The table was designed, tested and is operational since spring 2011. The characteristics of this equipment shown in Figure 21 are described in a note[2].
- Equipping the facility of beam tracing system with a resolution lower than 100 μm: A 3D track system has been developed at the Frascati Laboratory. It consists of a compact TPC with 4 cm drift, and a triple GEM structure as readout system. Since 2012, the tracker system has been tested at BTF in various conditions of particle multiplicity. A resolution of 80 μm for a single particle has been measured when correlating data with a MEDIPIX telescope.
- Qualifying the BTF beam energy spread: A LYSO calorimeter prepared originally as a SuperB prototype has been commissioned as a monitor for the beam energy at the BTF Facility and its energy resolution has been studied (see Figure 22). A correction factor has been applied, evaluated by Monte Carlo simulation, to subtract the contribution of the leakage contribution. A good energy resolution is obtained also in this configuration, with a constant term of about 3%.
- DAQ and beam diagnostics integration. The BTF multipurpose DAQ system has been continuously updated and developed during the four years in order to host new devices (remote controlled table, MEDIPIX, neutrons monitors, environmental station, etc) and develop a Graphical Users Interface for users.

[2] AIDA-NOTE-2012-003 “Remote test bench equipped with service movable platform in two axis”.

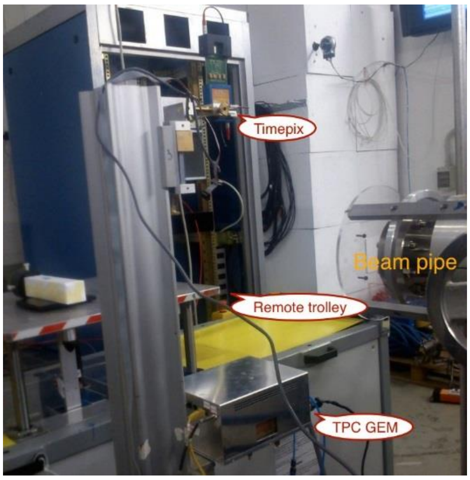

Figure 21: Remote trolley, TPC GEM and TIMEPIX as available at the BTF facility.

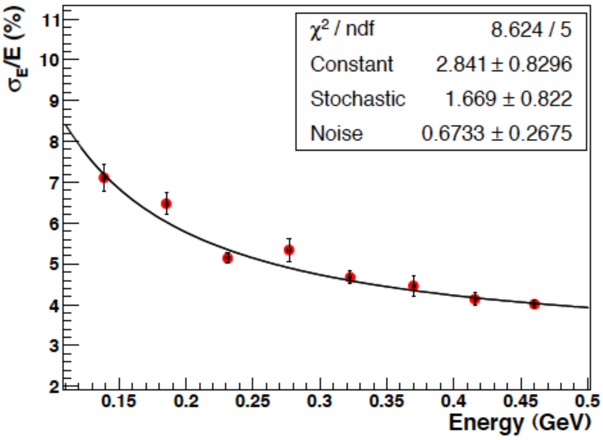

Figure 22: Measurements of LYSO energy resolution for the characterisation of the Frascati test beam. SiPM readout is used.

Moreover, the user experience feedback at the BTF over these four years has been very positive and benefitted from the continuous integration of new diagnostics, and DAQ upgrade.

CERN PS proton & mixed-field irradiation facilities

A new proton irradiation facility (IRRAD) has been designed and constructed in the CERN PS East Area, going well-beyond the design study that was originally foreseen in AIDA.

Based on previous studies performed at CERN, the need and requirements for irradiation facilities at CERN based on slow extracted proton beams were re-evaluated, confirmed and consolidated within this work package. The CERN East Area was found to be an appropriate location to place a facility that combines a proton and a mixed-field irradiation facility in one single beam line. In collaboration with several CERN departments the layout of the facility was conceived and optimized. Dedicated FLUKA simulation studies on the facility configuration and shielding were performed in the framework of AIDA and used to converge towards an optimized facility layout in compliance with all relevant safety regulations. The construction of the facility was approved in 2012 by the CERN management and started in the end of 2013 with the dismantling of the existing infrastructure in the relevant beam lines of the East Area. The overall new infrastructure contains a proton and a mixed irradiation field facility. The proton facility is based on a design study and implementation plan performed in the framework of the AIDA project and shown in Figure 23 and Figure 24.

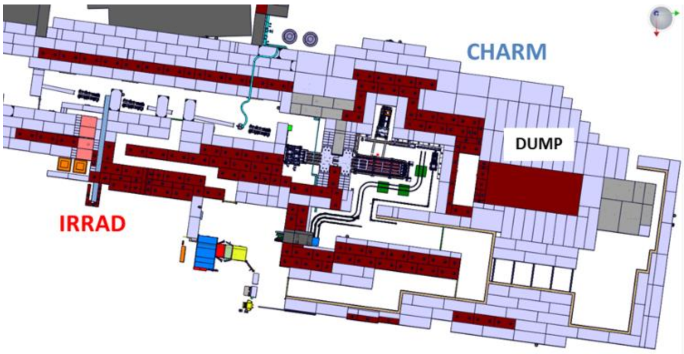

Figure 23: Layout of the new combined EA-IRRAD facility implemented on the T8 beam-line: the proton area, IRRAD (upstream), is followed by the mixed-field area CHARM (downstream).

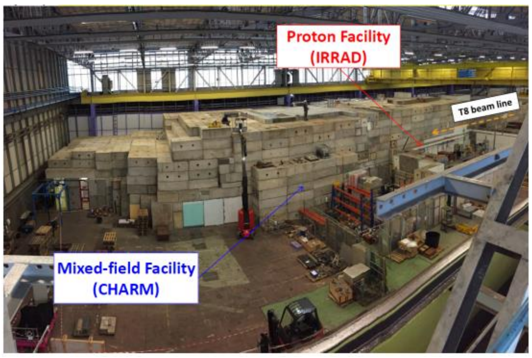

Figure 24: Photo of the irradiation facilities in the CERN East Area. The positions of the facilities behind the shielding and the direction of the proton beam in the T8 beam line are indicated.

As shown in Figure 23, the new proton irradiation facility (named IRRAD) has been constructed upstream of the new mixed-field facility (named CHARM). The proton facility (IRRAD) bunker is subdivided in three zones according to the nature of the samples to be irradiated. The first zone is dedicated to the irradiation of "light" materials such as small Silicon detectors, the second zone to the irradiation of intermediate materials such as electronic cards and components, while the third zone is optimized to perform irradiation experiments on "high-Z" materials such as samples of calorimeter crystals. In this last zone, it is also possible to perform irradiations in cryogenic conditions using a dedicated setup operating with liquid Helium. Moreover, a fourth zone, in a partially shielded area, is equipped for the installation of readout electronics and/or DAQ systems that need to be close to the Devices Under Test (DUT) during irradiation. A picture of the facilities is given in Figure 24. The commissioning started in October 2014 and in November/December 2014 a first irradiation campaign for facility users was performed. At the proton facility a total of 177 objects for users from various Experiments (CMS, RADMON, ATLAS, RD18, LHCb) and the accelerator sector (CERN-BE) have been exposed to the 24 GeV/c proton beam.

Part of the proton facility (IRRAD) equipment was also produced in the framework of this task and commissioned in the period of October to December 2014. Remote controlled tables have been designed, constructed, tested at CERN and finally installed in the irradiation facility for the first irradiation experiments in November 2014. A shuttle system that is carrying devices under test from the counting room directly into the beam area has been designed and constructed by the CERN team and installed in the irradiation facility as well. Part of the irradiation experiments have to be performed in cold boxes with typical temperatures around -20°C in order to provide realistic operational conditions for the components under test during the irradiation experiment. Cold boxes have been designed and produced (see Figure 25), tested in-situ at the Birmingham irradiation facility and finally delivered to CERN at the end of 2014 and will be commissioned with beam at CERN in the first irradiation campaign in 2015.

Figure 25: One of the cold boxes delivered to CERN at the end of 2014.

Figure 26: VUTEG-5-AIDA fluence monitor installed in the laboratory of the irradiation facility at CERN (December 2014).

Finally, a fluence monitoring system VUTEG-5-AIDA (Figure 26) based on the direct relation between carrier recombination lifetime in Silicon (Si) and density of radiation induced extended defects has been built. In this apparatus, the measurements are performed in a contactless manner on pure Si wafer fragments using a microwave absorption technique. The sample chamber is temperature controlled and provides a 1D scanning possibility to measure beam profiles. This apparatus will remain operational at CERN up to 2016 included.

Qualification of components and common database

An online database called IMHOTEP on the properties of irradiated materials and components was developed and populated with data. More than 270 records with historical and new data were added to the database.

This task aimed for testing and documenting data on radiation damage to materials and components. It started with a review on existing data and experience from LHC irradiation and a definition of an irradiation test program and then continued with the testing of materials and components. Finally, an online database on material and component radiation testing was developed and implemented.

The performed irradiation tests focussed on a series of electronic devices, pixel sensors, inorganic scintillators and composite materials, epoxy raisins and other components relevant for HEP applications. The results can be accessed through the online database IMHOTEP. This database has been produced to provide a common point of reference for detectors, electronic components and materials used in detector construction at CERN and elsewhere for HEP detectors and accelerators. Figure 27 and Figure 28 show the welcome page of the online database and give an example of a search result page.

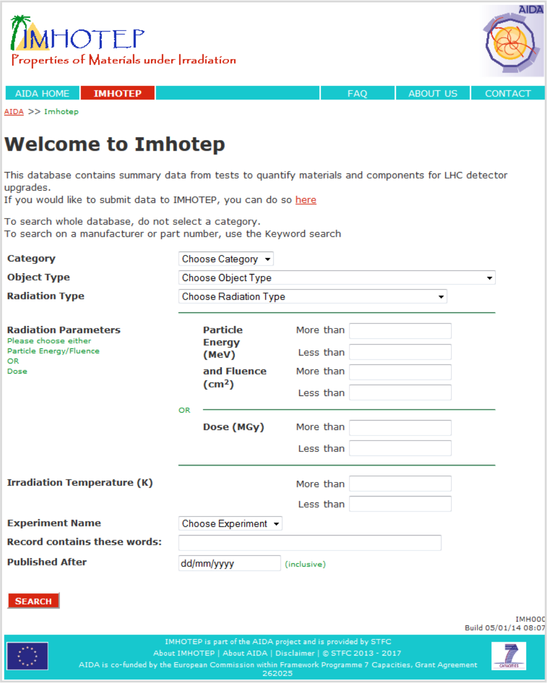

Figure 27: Imhotep welcome screen, database searches are entered here.

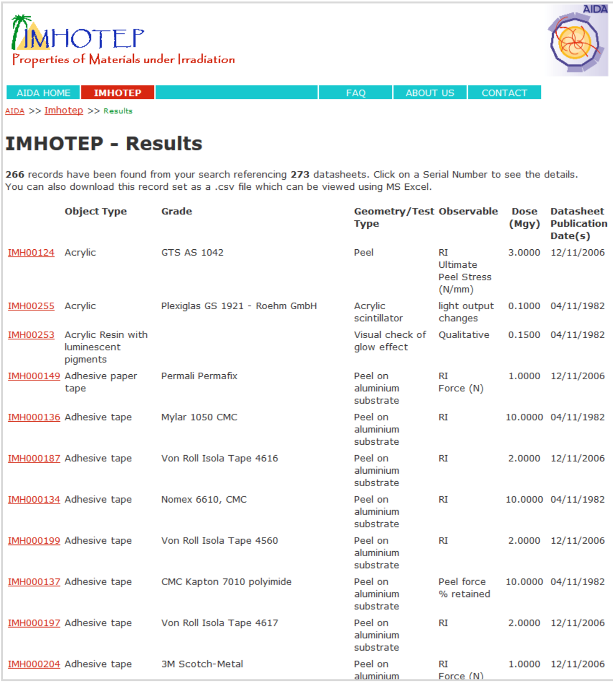

Figure 28: Imhotep results screen showing results for a search on "materials".

Currently the database holds over 270 records while historical and new data is being added. The database relates closely to the LHC detector and machine upgrade efforts in that it is the easiest way to locate relevant test data on radiation damage tolerance tests. Potentially, the database is relevant to most HEP projects worldwide such as the future lepton colliders (ILC, CLIC) or hadrons colliders (FCC). It is planned to support and promote the development of the database at STFC-RAL on a "best efforts" basis to ensure its long term operation and benefit to the community.

Commissioning of a beam tracking telescope

The task provided technical support for the use of the beam telescope at DESY and CERN. The AIDA beam tracking telescope was commissioned and is now also available to users.

A pixel beam telescope (constructed during the FP6-EUDET project) based on six CMOS sensors (Mimosa26) with its Trigger Logic Unit (TLU), the EUDAQ framework, the offline reconstruction software based library and the EUTelescope library, have been in much demand throughout all the AIDA project years. Within the AIDA project, the development of the EUDET telescope was further extended and thus it was renamed as the AIDA telescope. This was developed in WP9 and it became a system capable of integrating devices of different readout type with high efficiency. It has been demonstrated that monolithic sensors and hybrid type detectors can be efficiently used as constructing blocks for a test-beam telescope. Using different detector technologies in one setup can be eventually very beneficial for detector R&D programs. The final AIDA telescope configuration brings together the high spatial resolution of Mimosa26 sensors and the self-triggering and time resolution features of FEI4 based detectors. The test-beam telescope was also extended in terms of cooling and powering infrastructure. A new central dead-time-free trigger logic unit (miniTLU) and data acquisition framework (EUDAQ2.0) have been developed to provide LHC-speed response with one-trigger-per-particle operating mode and a synchronous clock for all connected devices. The offline software framework includes the test-beam telescope data reconstruction and analysis package EUTelescope v1.0 based and a rich system of offline software development tools with user and developer forum. The AIDA test-beam telescope has been commissioned with the FEI4 based detector as triggering and time-stamping plane and Detector Control System for regular temperature and humidity control of the DUT. The complete Large Area Telescope was tested in November 2014 completing the commissioning of the telescope in the AIDA framework.

TASD and MIND: Prototype detectors for neutrino physics

TASD was commissioned at the MICE beam line in the UK and is performing beyond expectations. The MIND detector has been redesigned, and its components selected, procured and tested for a future construction.

The task included the study of prototypes of future neutrino detectors and the design and implementation of two prototype detectors: a Totally Active Scintillator Detector (TASD), mainly for electron charge identification, and a Magnetized Iron Neutrino Detector (MIND) mainly for muon charge identification.

The TASD was designed, constructed and commissioned in laboratory during summer 2013, before being installed for tests (Figure 29) at the end of the Muon Ionization Cooling Experiment (MICE) beam line in September 2013 as no CERN beams were available. The data analysis performed during last year showed an effective rejection of the 11.7% electron contamination in the beam and a muon sample purity of 99.85%, performing well above the requirement of 99% purity. No dead channels were observed, and only 2 out of 5,664 channels were mismatched mechanically, an achievement when taking into consideration the complexity of the fiber bundles and testament to the dedication of the technical teams that were relatively inexperienced in the handling of optical fibers at the beginning of the project.

Figure 29: EMR installation in the MICE beam line. Left: patch panels, Center: control rack (not in final position), Right: cabling.

With the announcement of the Daya Bay results of March 2012 indicating a shift in prospects for neutrino facilities worldwide, the initial plans to build a standard MIND prototype were reformulated within the AIDA consortium to design a MIND in line with requirements for future experiments and useful for the European HEP community. The result was a redesign of the magnetization of the iron plates enabling better muon charge identification efficiencies at lower momenta, down to 1 GeV/c. Moreover, an extensive testing of the electronics with prototype evaluation boards, the 8400 plastic scintillator bars, and several types of Silicon photomultipliers fully validated the design.

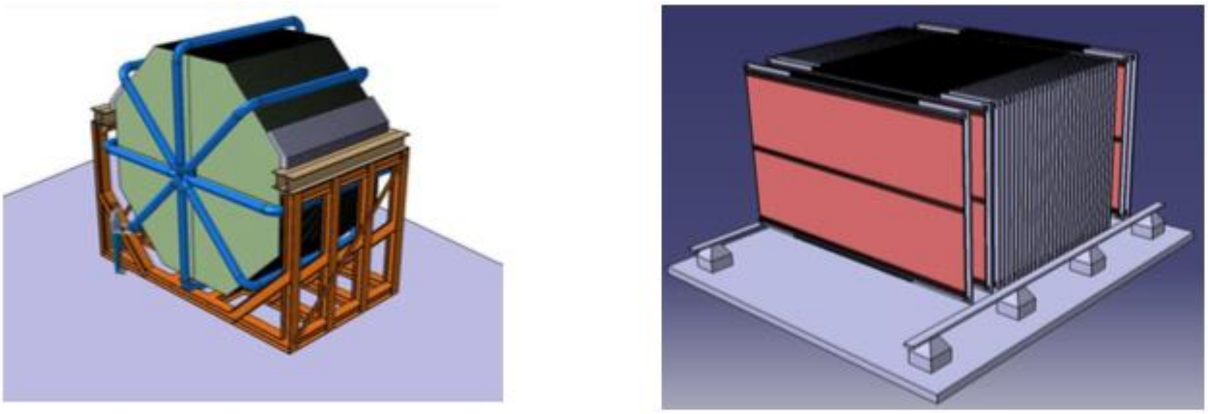

Figure 30: Left) Traditional approach to MIND magnet design, with one or more transmission lines around all iron plates. Right) New design proposed for the AIDA MIND where every individual iron plate has its own coil windings, leading to increased modularity and flexibility in choosing optimal separation gap between plates.

The MIND prototype (Figure 30) has been integrated in the CERN Neutrino Platform approved in 2014, which foresees some space and resources allocated to neutrino detector prototypes in a dedicated zone in the North Area building EHN1.

GIF++: A new gamma irradiation facility

The GIF++ facility was constructed in the CERN North Area. It includes a beam tracker, cosmic tracker, radiation dosimeters, gas and environmental sensors, DCS and DAQ systems to best meet user needs.

In 2014 the new gamma irradiation facility GIF++ was constructed at CERN. The facility will be a fundamental tool for the preparation of detectors to be installed at the HL-LHC. The facility makes use of a 14 TBq ^{137}Cs source (Eγ=662 keV) and a 100 GeV/c muon beam. When no beam will be available, cosmic rays can be used for testing purposes. To best profit of the facility capabilities several user infrastructure items have been realized and delivered in the framework of AIDA: beam-tracker, cosmic tracker, radiation dosimeters, gas/environmental sensors, DCS and DAQ systems. Particular care has been devoted to the flexibility of the infrastructure in order to avoid, whenever possible, duplication of the work load on the users.

The **Beam Tracker** consists of two doublets of TGC chambers that have been installed in front (see Figure 31) and in the back of the GIF++ facility containing a pad readout in each plane (to provide the trigger), a high precision readout in each plane (to provide a precise vertical coordinate) and a second coordinate in each plane to provide, using a group of wires, the horizontal coordinate. The doublets were tested with the quasi-final electronics, which was also used for the installation of the tracker. The tracking detectors for GIF++ have thus achieved their expected performance. However, they will still profit from an upgrade of the electronics planned for mid-2015, which will further improve the performance and the radiation tolerance of the overall tracking system.

The **Cosmic Ray Telescope** is based on RPCs and has been designed to combine different needs, from offering large area coverage to provide reliable comic tracks. It consists of two main sub-systems: a wide-angle tracker located below the ceiling and a large area confirmation plane installed below the floor. The top telescope consists of 5 detectors 50x100 cm^2 suspended from the ceiling or sustained by a support at about 4.5 m from the floor. The gas gap and the front-end electronics have been conceived to withstand the high photon flux generated by the GIF++ irradiator. The time resolution on a single gas gap is 400ps and operation up to 20 kHz/cm^2 without loss in performance has been demonstrated. The confirmation plane installed below the floor consists of two large area RPC doublets (280x120cm^2 each, see Figure 32). All in all, the telescope was equipped with about 500 channels and offers maximum possible solid angle coverage within the facility. The high time resolution of the RPCs allows providing a sufficiently clean prompt trigger to the DAQ while the offline tracking allows discarding the spurious triggers for the detectors being tested outside of the ground instrumented area.

The **Radiation Monitoring System** for control of the absorbed dose during the irradiation of sub-detectors at GIF++ has been designed, constructed and tested. The monitoring concept is based on the use of two types of RadFET detectors with different sensitivity reaching up to 10KGy. The system itself has been extensively tested and calibrated in the old GIF facility.

The **Gas and Environmental Sensors** consist of 10 measurement stations recording temperature, humidity and pressure. A basic **Detector Control System** setup has been realized and is ready to include hardware needed by the fixed detectors as well as by the detectors under test. Finally, the **DAQ** system has been successfully tested with the beam tracker TGC chambers and RPC chambers of the cosmic tracker. The system is ready.

Figure 31: Doublets of TGC's mounted in the front part of the GIF++ facility. The front end electronics is covered by the Faraday cages. The tracker is mounted on rails so that it can be moved out of the beam-line.

Figure 32: Photo of a large cosmic ray telescope chamber during assembly.

Common test beam experiments and Common DAQ

The CERN and DESY EDMS systems are fully operational as data management platforms, containing about 150 documents each. The common DAQ is also operational and is used by the telescope community.

An important aspect of the AIDA infrastructure project was to provide a powerful and unified control and acquisition system and an engineering data management system framework serving as a central data management platform for large international HEP collaborations and more specific also for the AIDA infrastructure developments within WP9. Significant progress was made on the tools and framework needed for a unified DAQ system, which will become the foundation of the common DAQ system for the LC collider detectors tests. During AIDA, the concept of a common DAQ was developed and tested. Parts of the system were in intense use by the telescope community, the global system has undergone bench tests. A planned common system test at CERN could not take place since at the time of proposal the long shutdown of the CERN accelerator complex was not scheduled.

Data taking with limited combination of detectors took place, however, during 2014. The AIDA engineering data management system has been installed on servers at DESY, is fully operational and is already serving several detector projects as data management platform. At the time of writing this report, some 150 documents have been committed to the DESY instance of the system, for a range of projects. About the same number of documents is available on the CERN instance.

3.3.2 Advanced infrastructure for detector R&D (WP9)

The activity of the work package has been organized around the three main technologies used in particle physics: gaseous detectors (Time Projection Chamber, muons chambers), solid state detectors (Pixel and Silicon micro-strips) and the calorimeters. Designing and validating these detectors requires up to date infrastructures.

Gaseous detector facilities

The DESY gaseous tracking detectors have been upgraded proving to be a unique facility for the test of Micro Pattern Gas Detectors (MPGDs). The CERN MPGD workshop capability has been improved and large area detectors are now produced.

Micromegas and GEMs detectors are very promising for the next detector generation colliders assuming large area chambers can be produced. The CERN Micro Pattern Gas Detector workshop has therefore been equipped with new machines extending their capability to produced large area PCBs and commissioned with AIDA resources. This new large-area line has already produced structures for more than 10 projects. Large-scale production is envisaged, among others, for the upgrade of the ATLAS muon chambers (the new small muon wheel) or the CMS phase 2 upgrade. An example of such a prototype is displayed in Figure 33.

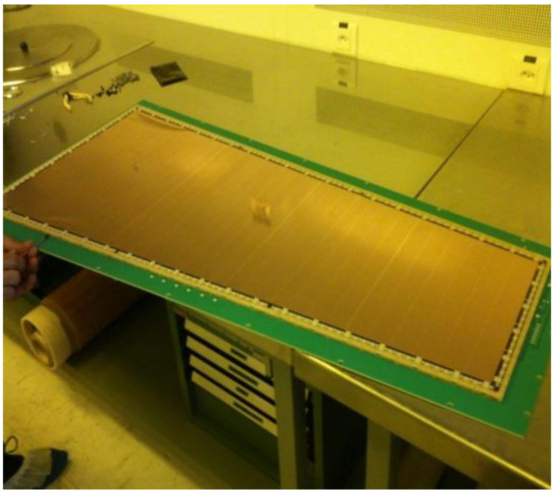

Figure 33: Large area GEM muon chamber prototype for the CMS experiment

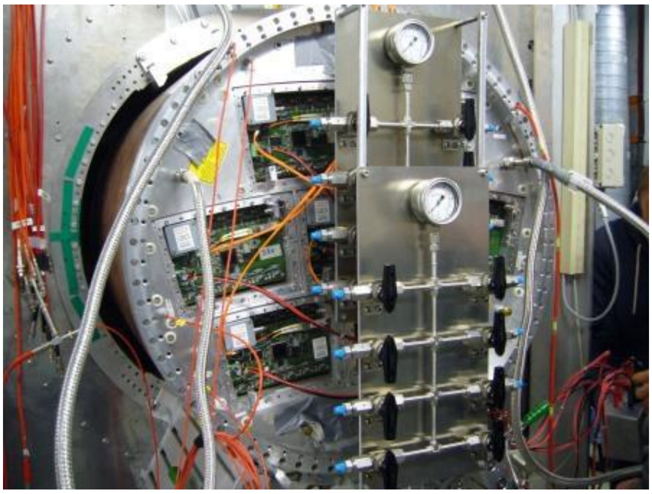

Figure 34: The PCMAG endplate instrumented with micromegas readout at the DESY TPC facility.

The gaseous tracking facility at DESY includes a large-bore 1 Tesla solenoid PCMAG, with an endplate that can be instrumented for test with different TPC readout electronics (see Figure 34). The solenoid magnet has been refurbished allowing now long operation period.

Several readout schemes for gaseous detectors have been developed under AIDA. One of the most recent additions is the pixelated readout that uses an evolution of the Front End chip of solid-state pixel detectors to read out the signal that is formed in the gas. The InGRID structure has a miniature gas amplification structure, with a granularity of several tens of microns interfaced to the 55 μm readout granularity of the MediPix chips. Beam tests showed that a large area can be reliably instrumented. The spatial resolution is found to reach the limit due to diffusion of the charge carriers while drifting through the gas volume (see Figure 35).

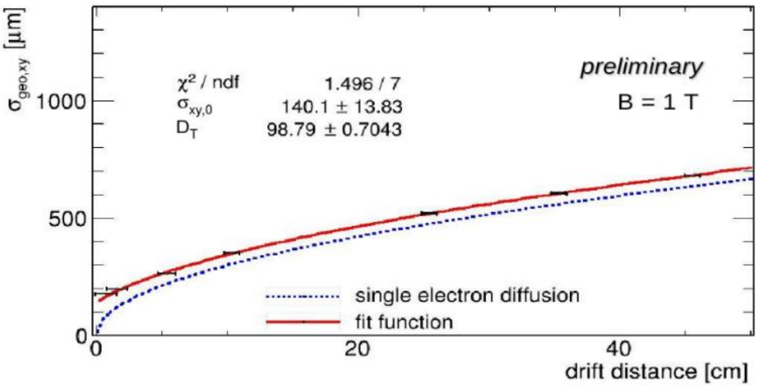

Figure 35: Spatial resolution versus drift distance measured in a beam test in the large TPC test infrastructure at DESY compared to the expectation limit given by diffusion.

These new AIDA infrastructures play a key role in gaseous detector R&D, where the workshop provides novel amplification structures for detector prototypes and the large TPC test area at DESY is the unique test bed to evaluate their performance.

Pixel Beam Telescope

The AIDA beam telescope infrastructure, including new telescope planes and arm, FEI4 readout and a CO_2 cooling plant was delivered.

The beam telescope developed under EUDET, and several additional copies made afterwards, are available to users under the AIDA TA scheme. AIDA furthermore provided a large-area telescope arm and fast arm and extended the ancillary infrastructure (DAQ, offline software, Detector Control System and CO_2 cooling plant).

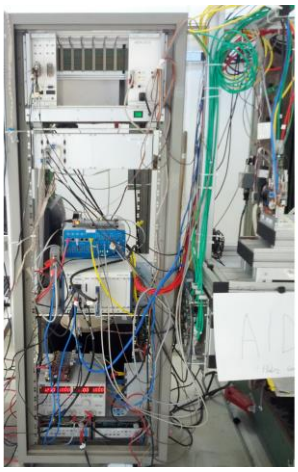

Figure 36: Commissioning of the AIDA telescope in July 2014 in the CERN PS T9 beam line: (left) The AIDA telescope rack contains (top-to-bottom) DCS, TLU and miniTLU, NI readout for Mimosa26 sensors. USBPIX readout for FEI4 module on top of the three channel TTi power supply and power supplies for Mimosa sensors and electronics. (right) The photo shows an upstream look at the telescope sensor planes with the FEI4 plane being mounted as the most downstream plane (on the left of the picture).

Large-area telescope arm

The large-area SALAT plane exploits the MIMOSA-28 CMOS pixel sensors, currently the largest of its kind dedicated to charged particle detection. To achieve the excellent spatial resolution of ~3.5 µm required for a precise reconstruction of the particle trajectory the detector is segmented into square pixels with an area of 20.7 x 20.7 µm^2. Each sensor has a total of 960 x 928 columns and rows, for a sensitive area of 19.9 mm^2 x 19.2 mm^2 = 3.8 cm^2. The large-area planes are assembled using four such sensors tiled onto a thin mylar foil. The material in the path of the particles is limited to 50 µm of mylar (with a radiation length X_0 = 28.7 cm) and 50 µm of Silicon of the thinned MIMOSA sensors. This ensures that the trajectory can be extrapolated to the device under test with a precision of a few microns even in relatively low energy beams, such as the test beams at DESY.

The readout architecture is based on a column parallel readout with amplification and correlated double sampling within each pixel. Each column is terminated with a high precision, offset compensating, discriminator and is read out in a rolling shutter mode at a frequency of 5 MHz (200 ns/row). The MIMOSA-28 architecture is adapted for a hit rate in excess of 10^6 hits/cm^2/s, while dissipating a power below 150 mW/cm^2 operating at room temperature (30°C). The large-area telescope arm was delivered to AIDA in 2014 and commissioned in the CERN beam line (see Figure 36).

Fast telescope arm

One of the aims of the beam telescope task of the AIDA project was to further broaden the user base of the EUDET telescope, and in particular to attract more users from the R&D community involved in the upgrades of the LHC experiments. Much work has gone on within the project to integrate LHC-style readout chips with the MIMOSA-based telescope. The choice of technology is a hybrid pixel sensor equipped with the FEI4 readout developed for the ATLAS pixel detector. The pixel matrix of the FE-I4 consists of rectangular pixels arranged in 80 columns with 250 µm pitch and 336 rows with 50 µm pitch, resulting in a total sensitive size of 18.6 × 20 mm^2. The ASIC is built in CMOS technology with a feature size of 130 nm. A dedicated PCB that accommodates 4 FEI4 chips (QUAD PCB) has been designed and produced. The successful tests in the lab and beam with two FEI4 modules placed on the PCB, the other two being placed later, have demonstrated good performance of the quad-plane PCB.

The presence of one or several FEI4 layers in the telescope offers several additional functionalities:

The FEI4 plane can be used to define a Region-of-Interest of arbitrary shape in the trigger. The FE-I4 chip can amplify and discriminate the signal of the charge generated in the sensor. Each pixel has embedded the same analog circuitry, which outputs a rectangular pulse that is high as long as the signal is above an adjustable threshold. This pulse is further processed digitally by the standard readout but it can also act as an input to a wired OR - the HitOR feature of all pixels. The connection of each pixel to the HitOR is configurable through the Enable HitOR local pixel register. The OR of all pixel signals is fed into the trigger logic unit (TLU) to create a trigger signal and distribute it to all the attached planes. Thus, users can program the active area of the telescope trigger, a feature that is very helpful when very small devices are tested. This feature was tested and proven to work in a test beam that involved the MIMOSA telescope, the FEI4 RoI plane and a DEPFET device under test.

The FEI4 planes are also used to provide a time stamp that tags a particle as “in time” or “out of time” with respect to the fast clock of the LHC tracking and vertexing devices. In the synchronous trigger distribution mode the DAQ systems participating in the test-beam are expected to accept and record a clock cycle number for every incoming trigger. In this operation mode some detector systems (like Mimosa26) can have up to a hundred particles in one readout packet, sharing one coarse granularity time-stamp, which have to be associated to a list of fine trigger timestamps from the TLU without space information of the particles. In order to solve the space-time matching problem a fast detector based on ATLAS FEI4 chip has been foreseen in the AIDA telescope. The FEI4 based module provides a flexible triggering capabilities and in case it is included in the readout data stream also the time-stamping for every particle triggered by the TLU. The intrinsic FEI4 resolution is limited to a single LHC machine bunch-crossing, which corresponds to 25 ns. The overall timing resolution below 1 ns can be obtained from the AIDA TLU and the space pointing resolution coming from the six Mimosa26 planes, to be kept at about 2 μm.

The Timepix chip family is considered as an alternative for the high rate test-beam telescope. The Timepix telescope, built by the Medipix and LHCb collaboration, was made available within the AIDA Transnational Access and offers similar performance in terms of the average resolution and time resolution at high beam energies. The Timepix modules integration in the EUDET telescope (TLU handshake, EUDAQ, and EUTelescope reconstruction package) has been performed by CLICpix collaboration. This has demonstrated the possibilities to use same user interface at beam tests for detectors with continuous readout (Mimosa26), trigger based readout (FEI4), and shutter based system (Timepix).

Further developments include all ancillary systems (Trigger Logic Unit, EuDAQ data acquisition system, EuTelescope offline analysis framework, detector control system and new CO_2 cooling plant).

Among the many results obtained with the telescope infrastructure the beam tests of the ATLAS Inner B-layer prototypes are among the most important. This new layer for the ATLAS vertex detector was installed recently, and is currently operated successfully in the experiment. During the long R&D period that preceded its construction, numerous prototypes were submitted to beam tests to evaluate their response to high-energy charged particles. These included two sensor designs (both the classical planar pixels that are used in the central part of the detector and the novel 3D pixel detectors used in the most forward and backward sections). Prototypes were furthermore irradiated to the unprecedented fluence of non-ionizing radiation that the detector must survive during its lifetime in the LHC. The ATLAS IBL collaboration routinely used the telescope made available under the AIDA TA funding to measure the trajectory of particles in the CERN and DESY beam lines[3].

The telescope infrastructure attracts a large and growing community of users.

Calorimeter Infrastructure

The infrastructure to test novel, highly granular calorimeter concepts was developed, including a large Tungsten structure, front-end electronics and a micro-strip telescope. Data recorded with these prototypes enabled new more precise validation of the hadronic shower simulation models.

Ultra-granular calorimeters (or imaging calorimeters) constitutes the direction to follow to achieve the needed performance, especially jet resolution in the new collider experiments. Various absorber and sensitive media, and dedicated readout (ASICs) should be explored. Several stacks to study the response of novel, ultra-granular calorimeter concepts to electrons (for EM calorimetry) and pions (for hadronic calorimetry) have been built including their electronics readout. These include a Si-W EM prototype, an HCAL stack that can be equipped with digital or analog readout, a special Tungsten

[3] ATLAS IBL collaboration, Prototype ATLAS IBL modules using the FE-I4A Frontend readout chip, JINST 7 (2012) P11010.

stack that studies the performance of this compact absorber material, and a Forward Calorimeter. In addition, a micro-strip detector setup that provides an entry point for particles entering the calorimeter has been built.

The building of ‘central’ highly granular electromagnetic calorimeter cumulates many technical challenges: the high density of channels (typically a 1,000-fold w.r.t. classic calorimetry) to be treated with integrated electronics, which has to be low-power and passively cooled, low noise and cross-talk, limited dead material and ‘invisible’ – yet rigid – mechanical structure. The forward calorimeters should handle much higher rates in confined and radiation-hard environment. Some dedicated developments required to build fore-coming realistic prototypes have been supported by AIDA and are described below.

Front-end electronics for central calorimeters

The 2nd generation of the ‘ROC ASICs’ fits the basic needs for the central highly granular calorimeters: signal pre-amplification and triggering, signal shaping and digitisation in one single unit handling 32 to 64 channels, with versions adapted to all the sensors: SKIROC2 [Si-W ECAL], SPIROC2 [AHCAL], HARDROC2 [GRPC–SDHCAL], MICROROC [Micromega–SDHCAL].

In the scope of AIDA, an improved design for 3rd generation of ROC chips was developed, where the channels are handled independently to perform on-chip zero suppression, and an I2C link with triple voting was integrated for the control of the ASIC, to allow handling larger number of chips in a single detector unit and radiation tolerance. HARDROC3 is the first of the 3rd generation ASIC. A first limited engineering run funded through AIDA allowed for the validation on electronics test benches and the correction of minor errors. A larger production has been launched in January 2015. It will allow for testing in real condition with the SDHCAL (below).

Silicon-Tungsten electromagnetic calorimeter – Si-W ECAL

The Si-W ECAL of CALICE is probably the central calorimeter where the instrumental and technological and industrialisation requirements are the most entangled. They mostly concentrate on the design of the modular ‘base unit’ of detectors (dubbed ASU), stitched together to form detection elements (dubbed SLABs). Each ASU is 18×18 cm² wide. It connects Silicon sensors to 16 SKIROC2 ASICs (for a total of 1,024 channels), and to its 2 neighbouring ASU’s. AIDA contributed to support the incremental designs and tests of the first complete ASU (see Figure 37).

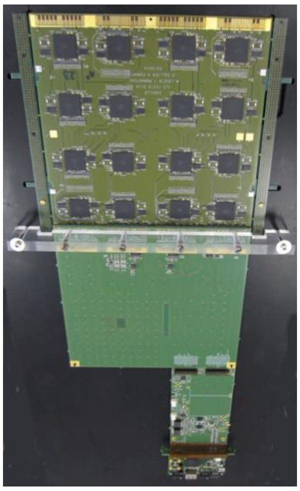

Figure 37: PCB with ASICs for 18×18 cm² Si-W ECAL.

Beam tests with up to eight single-ASU SLAB’s with a detection area of 9×9 cm^2 (a single wafer) were performed in 2012 and 2013. Signal to noise ratio not lower than 10:1 was achieved. With the conclusion of the beam tests in 2012 and 2013 small design defects were found and corrected, validating the concept and implementation of the ECAL layers. The first full ASU with 16 ASICs and 4 wafers is ongoing and four Si wafers have already been glued onto a PCB with success. A quality certified assembly chain has also been built and used for this complete test.

Analogue hadronic calorimeter – AHCAL

Figure 38: Electronic board for analogue HCAL prototype.

For the analogue HCAL, the challenge concerns the production of a large quantity of small scintillator tiles (typically 3×3 cm²) ensuring uniformity and their optical-mechanical mounting onto readout boards (dubbed HBU) while maintaining a calibrated response. New active modules were developed during the AIDA project. Their realisation is based on a network of groups working on the optimization of the design, which allowed e.g. for the first time to test fibre-less scintillating tiles while keeping a good uniformity of the response. Readout electronics, similar to that of the Silicon ECAL described before, was used.

The efforts culminated recently in a beam test with hadrons at the CERN PS in 2014 to assess the new design: altogether 8 small layers (featuring 1 HBU) and four big layers (4 HBUs) were tested in a steel structure with shape and size compatible with a large detector such as ILD. The channel wise power supply, developed within AIDA, will be also integrated soon into the setup.

This beam test has been conducted jointly with an electromagnetic calorimeter that is also based on the scintillation technique (built outside the scope of AIDA) as well as recently with one layer of the Si-W ECAL layers mentioned above. This was the first use of the infrastructure for combined calorimeter beam tests, including common DAQ SW.

Semi-digital GRPC hadronic calorimeter – GRPC-SDHCAL

The hadronic calorimetry for ILC using Glass Resistive Plate Chambers (GRPC), small cells (1×1 cm²) and a semi-digital readout faces two challenges: keeping gaseous sensors uniform and integrating their readout over large area (typically up to 3 m²) in a confined space. For LHC detectors the recovery time of classic RPC (~10 ms) is problematic. AIDA helped addressing these issues.

Large RPC detectors (2–3 m^2), their readout electronics and self-supporting mechanical frame to host them have been designed. A novel gas distribution scheme (see Figure 39) inside the RPC detectors was conceived to insure uniform irrigation with reduced dead space and a single side service.

The new HARDROC3 ASIC improves the readout of RPC detectors with both the zero-suppression and I2C protocols. Electronics boards adapted to large detectors with reduced cost are being designed.

The work on the chambers as introduced above opened the possibility to work on chambers that can sustain high rates, i.e. bigger than 100 Hz/cm^2. Beam tests with this kind of chambers were conducted in 2013 at the DESY beam test facility.

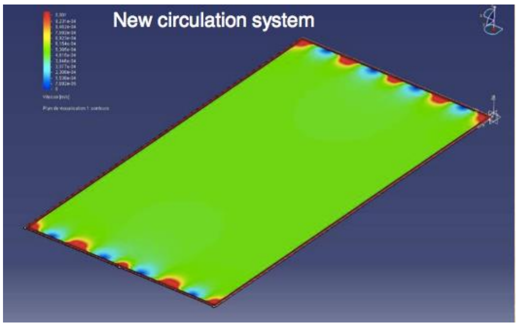

Figure 39: Mechanical simulation of 2×1 m² chamber showing effect of new gas circulation

Forward calorimeters – FCAL

The forward calorimetry, ensuring in particular luminosity measurement and beam position feedback, has to cope with specific issues: high rates, high radiation and high mechanical precision. A multilayer Tungsten structure was built to serve the last two issues. It includes: a mechanical structure housing up to 30 sandwich type Si-W modules, ten precisely thinned (accuracy of ~50um) Tungsten absorber plates, and four prototype detector modules, each one containing a Si or GaAs pad sensor, a 32-channel readout board with dedicated front-end and ADC ASICs and a FPGA based back-end electronics. After commissioning the functionality of the multilayer calorimeter structure was demonstrated with beams of hadrons, muons and electrons. Further prototype structures of a laser alignment system based on a) semi-transparent Silicon sensors for relative measurements in transversal direction, and b) Frequency Scanning Interferometry (FSI) for absolute position measurement, were also built. Preliminary measurements demonstrated its feasibility for the final alignment system. The built infrastructure will be used in future test-beams of forward calorimeters, in particular for the BeamCal and LumiCal studies.

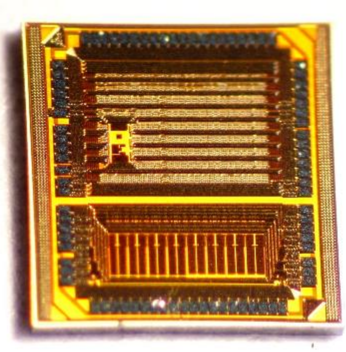

Figure 40: 8-channel ADC ASIC for forward calorimeters.

For future larger tests, multi-channel adapted readout electronics was missing: two 8-channel ASICs were designed and fabricated in deep sub-micron CMOS 130 nm technology, one handling the front-end and the second an ADC (see Figure 40). Performances were found to be similar to the ones of the older CMOS 0.35um technology. However, the new ASICs fulfil all critical requirements of the final calorimeter, dissipating an order of magnitude less power, allowing power-pulsed operation, and being radiation-hard. These new ASICs will be the core of a next generation compact detector module.

Hadronic shower validation

An important step was the creation of a Tungsten calorimeter stack that allows to characterize for the first time the performance of this material for deep and compact calorimeters at high-energy colliders using different sensitive media (scintillating tiles, RPCs, etc.).

This infrastructure, together with the above prototypes has been used in many test beams especially with hadron particles at CERN. These ultra-granular calorimeter readout allows to characterize in detail the longitudinal and lateral profile of the hadronic shower that develops in the stacked layers of absorber and sensitive material. The longitudinal and radial shower developments are shown in Figure 41 and Figure 42 respectively. Further studies revealed the differences in time structure in Tungsten compared to more conventional steel structures[4]. The observed lateral and longitudinal shower developments, as well as its time structure, were compared carefully with the predictions of several models. Remarkably good agreement was observed for the QGSP_BERT_HP physics list, which is used extensively in the LHC experiments.

[4] The CALICE collaboration, The time structure of hadronic showers in highly granular calorimeters with Tungsten and Steel absorbers, JINST 9 (2014), P07022.

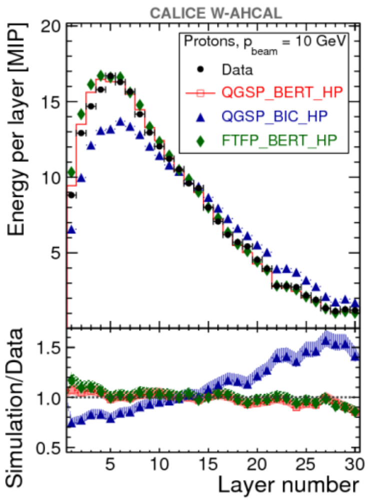

Figure 41: Longitudinal shower profile for 10 GeV protons in a Tungsten calorimeter stack.

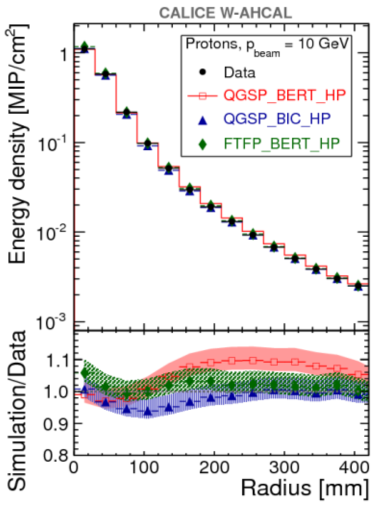

Figure 42: Radial shower profile under the same conditions[5]*.*

A device to provide a precise reference position ("entry point") for the granular calorimetry infrastructure was built. This mini-telescope is based on conventional micro-strip detector technology. Two photographs of the position-sensitive micro-strip detectors can be seen in Figure 43 and 44. The system furthermore includes a complete readout system and the required software. The device was tested in a beam of particles, satisfying all requirement. More advanced components were produced in the project and can be used in the future extension of this infrastructure.

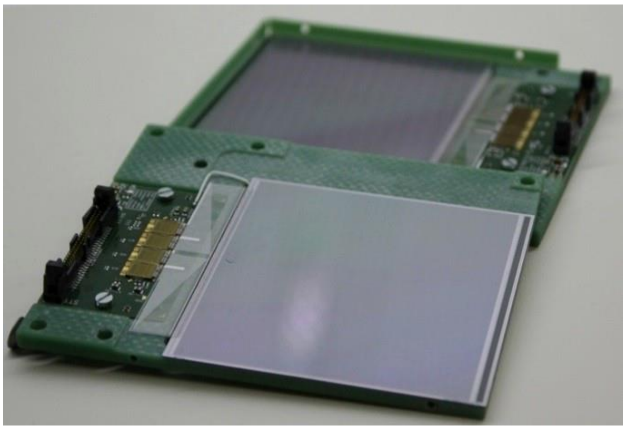

Figure 43: Micro-strip sensors used to construct the mini-telescope.

Figure 44: The assembled telescope.

The micro-strip telescope is currently available for use with the calorimeter infrastructure. Due to the LS1 shutdown of all CERN accelerators, no test of the deliverable with high-energy hadrons was possible so far. Operation of the mini-telescope together with the calorimeter moreover is expected to happen in 2015.

[5] Figures 41 and 42 are from: The CALICE collaboration, Shower development of particles with momenta from 1 to 10 GeV in the CALICE Scintillator-Tungsten HCAL, JINST 9 (2014) P01004.

4. POTENTIAL IMPACT, DISSEMINATION, EXPLOITATION OF RESULTS

4.1 STRATEGIC IMPACT

4.1.1 Contribution to policy developments

The AIDA participants, representing the major European laboratories, research institutes and universities in the field of detector development at accelerators, have an impact at several levels, from scientific and technological implementations to policy developments. In particular, AIDA contributed to the update of the European Strategy for Particle Physics in 2013 demonstrating the need for coherent and coordinated detector R&D and advanced infrastructures in Europe such as irradiation and test-beam facilities. As the main detector R&D forum, catalysing future global projects (HL-LHC, ILC, CLIC, B factory, neutrinos long baseline etc.), AIDA organized a common feedback to the topic consultation for integrating research infrastructures in 2012, followed by a successful proposal (AIDA-2020) to the H2020 call in September 2014. After four years, the project has been recognized as the most appropriate framework to discuss detector infrastructure upgrades and implement common cross-project developments in Europe.

4.1.2 Well-coordinated research programmes and priorities

Detector development projects have always been quite diverse and focused on the needs of the individual experiment. The AIDA Integrated Activity took up the challenge to create a concerted detector R&D effort throughout Europe, to increase the efficiency and impact of the detector development cycle, and to maximise the synergy between different communities, including the LHC upgrade, Linear Colliders and Neutrino facilities. Strong collaborations have been established in most of the activities, especially in the software and micro-electronics networks. The simulation and reconstruction packages developed jointly by the LC and LHC groups are now used in a wider community, i.e. the FCC study and future neutrino experiments. Most of the 3D integration sub-projects brought together groups with interest in different future experiments (B factory, CLIC, ILC, all LHC experiments including ALICE). In a similar way, the new AIDA telescope emerged from the shared efforts of ILC, ATLAS and CMS groups. AIDA has also setup the foundation of new collaboration: ultra-granular calorimetry is now extended from the LC community to FCC and HL-LHC. The gaseous detector originally focused only on MGPD at LC are now used in HL-LHC (ATLAS muon inner wheel) and the RPC are now included. Finally the upgrade of the irradiation facility at CERN is going beyond the detector development itself, as also requested by the accelerator community (IRRAD).

The successful efforts of AIDA to bring together the diverse detector community has also been demonstrated in the planning and submission of the new AIDA-2020 project. During the proposal preparation phase several groups outside of AIDA expressed interest in participating in AIDA-2020, thus showing clear appreciation of the concerted efforts in this field.

4.1.3 Developments of world-class infrastructures (JRA)

The EC contribution in supporting the AIDA project catalysed a collaborative approach to advanced detector development throughout Europe and facilitated the implementation of world-class infrastructures that require joint research spanning many countries and European facilities. Developing these infrastructures allows Europe to retain its leading position in particle physics. The

AIDA joint research activities have delivered key developments, concepts and designs for test beam and irradiation facilities and advanced detector infrastructures.

In the framework of AIDA, CERN, DESY and BTF Frascati have greatly boosted the R&D, testing and commissioning work of their detector infrastructures. The upgrade of the equipment of these facilities was required to provide instrumentation to evaluate accurately the performance of the tested prototypes. The BTF is now able to provide precise characteristics of its beam to the users. The DESY gaseous infrastructure, and its large aperture solenoid (PCMAG), is unique in Europe to characterize MGPDs and their readout electronics. The DESY and CERN beam lines are now equipped with excellent resolution beam telescopes; for instance large-area and fast telescope arms can now be used at CERN. Providing cutting-edge equipment and related data acquisition and software improves the efficiency of the beam-allocated time to users. It also provides an easier access to smaller size groups, not involved in large collaborations or coming from other scientific fields. Beam telescopes were used by more than 50 % of the users at CERN and DESY. One third of DESY users also benefitted from the PCMAG. The calorimeter Tungsten infrastructure at CERN was used by various groups of the CALICE project, including users from the US.

The impact will be even more visible in the future, as the AIDA test and irradiation facilities have been prepared in view of future challenges, namely the next generation of HEP colliders. In this context, it has to be mentioned that the infrastructures upgraded or developed through AIDA have unique testing capabilities, e.g. the test beam and irradiation facilities of CERN.

Another major impact delivered by the project is the new radiation facility in the CERN East Area, of which the construction and commissioning were not originally foreseen during the lifetime of AIDA. However, the AIDA community with the help of its Advisory Committee in collaboration with several CERN departments succeeded in convincing the CERN management to go beyond the design and perform the construction during the course of AIDA. The construction of the facility was approved in 2012 by the CERN management and started in the end of 2013 with the dismantling of the infrastructure of one closed experiment (DIRAC) in the relevant beam lines of the East Area. This facility will act as a crucial component for radiation testing for the community and its future collider projects (detector and accelerator). The radiation testing and the implementation of a public radiation damage on materials and components database has an even wider scope, reaching well beyond the HEP community. All technical applications operating in and suffering from intense radiation or radiation fields like e.g. space, nuclear or medical applications benefit from the collection and sharing of the data provided in the database. Furthermore, collaborations across different sectors in radiation damage R&D are fostered by making the accumulated data and the corresponding contact points of expertise easily available.

4.1.4 Knowledge sharing and excellent research institutions

The knowledge sharing aspect of AIDA's impact was primarily achieved by the excellent networking (NA) and transnational access (TA) activities.

Opening six facilities across Europe to scientists far beyond the consortium members allowed 202 groups (projects) from 26 countries to bring their experiments to the world class TA infrastructures.

- The ATLAS collaboration recently build a new vertex layer at small radius (IBL) to improve its b quark identification capability. The two technologies used (planar pixel and 3D sensor) have been validated through radiation tests at KIT and JSI. The position resolution has been measured under various conditions on many modules before and after irradiation with the beam telescope both at DESY and CERN depending of their respective availability. The impact of AIDA is described in a number of ATLAS publications. The ATLAS IBL has been installed in 2014 and is operational for the LHC restart in 2015.

- The CALICE collaboration has been exploring the development of ultra-granular calorimeters both for electromagnetic and hadronic showers. The data recorded by the test-beams at CERN and DESY with their prototypes provided a set of new data, allowing the detailed study of the hadronic shower characteristics longitudinally and laterally and also their time structure. Such information is crucial for reliable detector simulations.
- Non-HEP or non-EU-home-based experiments also made an efficient use of AIDA TA: the nuclear physics CBM experiment at the future FAIR facility in Germany, the Belle II experiment at Japan and the SPS tracker from JLab (US) demonstrated the value of the unique detector facilities of AIDA.

The large LHC experiments consist of several tens of millions of lines of code developed by hundreds of scientists, and since parts of this code have been developed specifically for each experiment, it contains a significant amount of duplication. Under the software NA activity, AIDA has helped in developing the culture of generic software that can be re-used in many places for future projects, beyond the AIDA community. In this sense, the HEP community is getting organized around the idea of a HEP Software Foundation[6] to encourage collaboration and software re-use. AIDA has provided a good example and is the proof that this approach is not only feasible, but also desirable. The project has demonstrated that generic software tools can be developed and can be used by several experiments at the same time. The packages and software toolkits developed in AIDA have been tested and evaluated in real use-cases for the experiments in the wide community, covering from the LHC, the Linear Collider and more recently the Future Circular Collider.

In the last 20 years, microelectronics has been the key element to use new technologies for the HEP detectors or improve their performance. However the complexity of the new readout and the quickly evolving technologies (not driven by HEP needs but more by the computing and telecommunication industries) make a networking approach unavoidable and necessitate sharing results and experience. The microelectronics NA of AIDA explored various novel technology options for the interconnection of detectors and readout chips, including the 3D integration techniques that appear to be a rather promising tool for the design of future pixel detectors. The novel technologies can be more or less aggressive and risky, depending on the density of interconnections and of vertical vias (Through Silicon Vias) across the Silicon substrates. “Via last processes” with large TSVs in the periphery are mature in a sense that only minor R&D is needed. They could be envisaged as baseline technology for new detectors in the next decade. For the more advanced technologies, further basic R&D has to be performed, especially in terms of reliability. The creation of circuit libraries in advanced microelectronic technologies (65 nm CMOS and 180 nm SOI CMOS) has a large impact in view of the design of detector readout chips for the next generation of HEP experiments. The network of microelectronic designers established by AIDA makes it possible to tackle the huge complexity of these technologies and to devise the development of large mixed-signal integrated circuits satisfying extremely demanding performance requirements in terms of radiation tolerance, functional density, and capability of handling huge data rates. Part of the IP blocks designed in 65 nm will be used by the RD53[7] collaboration at CERN.

[6] http://hepsoftwarefoundation.org

[7] www.cern.ch/RD53/

The main benefit of AIDA is the enhanced expertise and knowledge that flows from carrying out the project, thereby fostering the excellence of the participating universities and research institutes.

4.1.5 Relations between academia and industry in Europe

AIDA has introduced the concept of Academia-Industry Matching Events focusing on specific technologies, which have proven to be very successful. They have also been adopted both by other communities in particle physics, such as the micro-pattern gaseous community (RD51) or accelerator communities (cryogenics, superconducting magnets, vacuum technologies and beam monitoring), and also by other communities outside particle physics. In particular the Extreme Light Infrastructures (ELI) and XFEL have organised two events using the same concept, focusing on laser technologies, and are planning more. In some cases, new partnership between academia and industry has been established, but in most of the events it especially helps to bridge the gap between academic institutes able to conduct innovative R&D and industry, which might need to industrialize the process of these detectors elements.

An interesting impact of the project on relations between academia and industry is generated from the graph-based interactive tool, ColSpotting[8], whose kick-off idea has been emerging from AIDA. It offers the possibility to widen the range of pertinent industrial players to more than those currently in the procurement database of Research Infrastructures. A systematic search of players for each key technology can provide a rich overview of the industrial landscape for a particular scientific domain and foster R&D collaboration between academia and industry. European companies having a leading role in the development of a particular technology can easily be identified and invited to attend matching events and therefore increase their chances to take part in challenging development activities that very often can be reused in various applications with societal impact.

4.1.6 Wider benefits to European science and society

The Networking and Joint Research Activities of AIDA have brought some fundamental advances that drive particle detector development: software design and simulation tools, novel micro-electronics and 3D interconnection techniques, and advanced gaseous, pixel and Silicon detector technologies.

These developments match the needs of the future generation of particle physics experiments but have also significant impact on other European or global research infrastructures using similar detector components and technologies, such as the ones used by the nuclear physics, astrophysics, space science, synchrotron and spallation source communities.

In addition to direct utilisation and further detector R&D in the scientific fields mentioned above, the detector technologies developed and advanced by AIDA are expected to lead to collaborations with industry concerning applications with wide societal impact, for example medical equipment, environmental and radiation monitoring systems, and novel inspection and safety devices.

78 PhD students have been involved in AIDA and benefited from the networking and collaborative opportunities offered within the project. These young researchers have acquired technical skills and valuable practical experience in a multi-disciplinary and international environment. Past experience of the particle physics community shows that about half of these PhD students would pursue careers ultimately outside the area of scientific research, and many of them would be recruited by industry.

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[8] http://cern.ch/collspotting

The impact of AIDA on the society at large can therefore be seen in two main directions. First, direct impact of development and sharing of novel technologies for sensors, microelectronics and integrated systems. Then the indirect impact of technology transfer through industrial R&D projects and uptake of promising technologies in a wide range of applications, as well as training of the next generation of scientists and engineers.

AIDA has contributed significantly to providing excellent practical training to young researchers via the Student Tutorials organized during the Annual Events. In total, 74 students from and outside the AIDA consortium attended these events, 16 with financial support of AIDA. The topics covered by these tutorials were: Solid State Detectors, Gaseous Detectors in HEP, Trigger, DAQ and Control System.

Examples of successful knowledge transfer from particle physics to other areas include medical imaging. Some of the ASICs developed for HEP under AIDA are already successfully applied in e.g. medical imaging (PET), material characterisation, radiation monitoring and volcanology (see Figure 45). The improvements in Geant4 may be used in enhanced simulations for medical and space applications. The CMOS sensors and MEDIPIX developed in AIDA can also be used for medical applications or in the ALICE experiment.

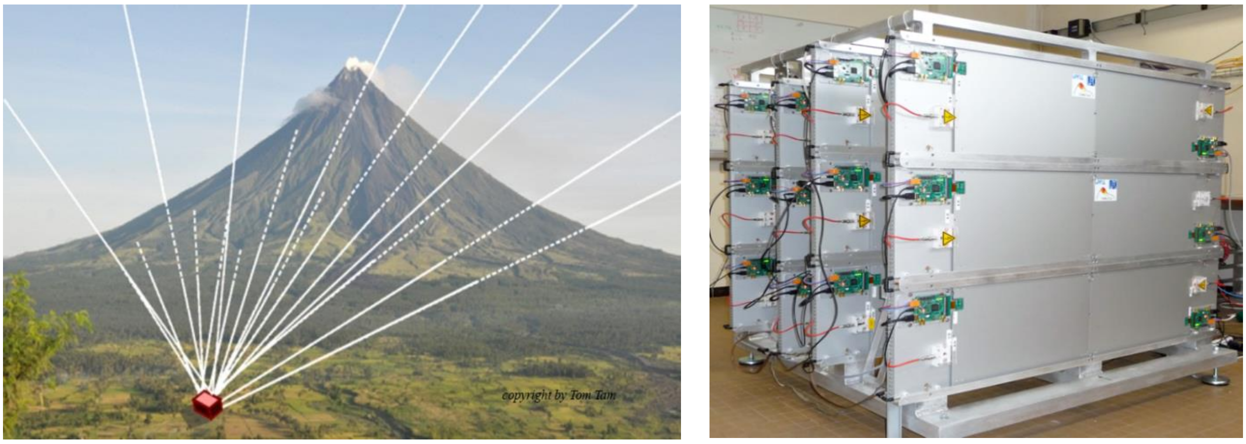


Figure 45: Tomuvol detector with RPCs for volcano muongraphy.

The Collaboration Spotting tool, developed under AIDA, provides very useful means of visualising patterns and particular data arrangements that helps understanding the technology landscape and unravelling innovation mechanisms beyond the physics community. A further analysis of the underlying concepts has confirmed that this graph-based interactive tool can potentially be used to visualise other data sources than publications and patents. Financial data, project and procurement data but also genomics are amongst the data sources under evaluation at the moment. Ultimately, the tool is expected to provide users means of building combinations of interactive graphs processed from any datasets in relation with Big Data, produced in various scientific disciplines.

4.2 DISSEMINATION AND EXPLOITATION

The Communication and dissemination Task 1.2 ensured the flow of information within the AIDA community and targeted audiences such as the wider scientific community, industry, and the general public, by developing and implementing effective communication tools.

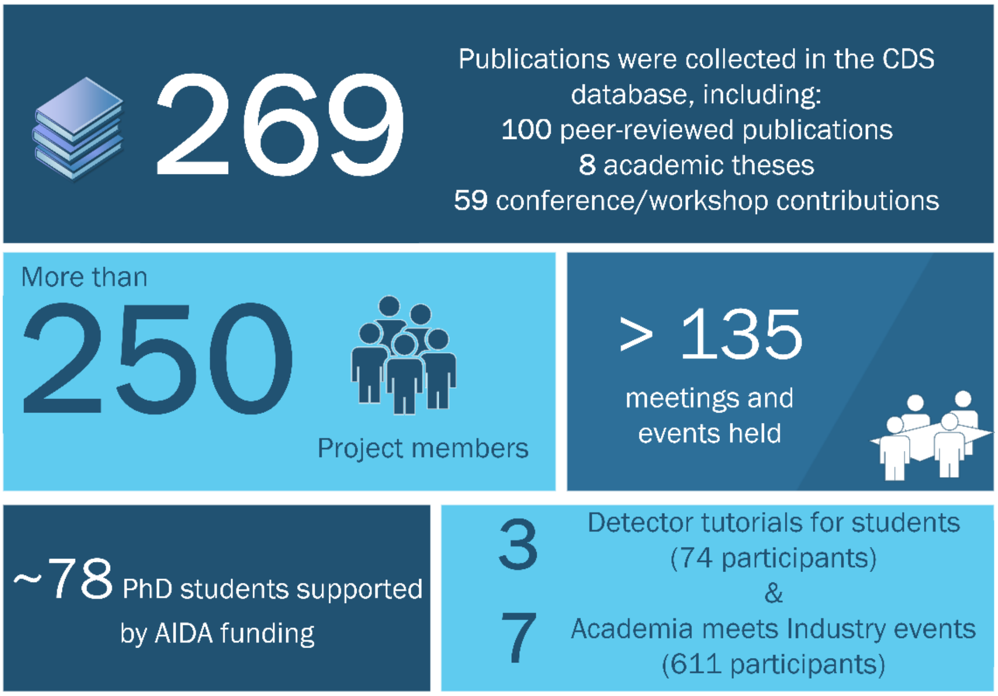


Figure 46: Outcome of AIDA dissemination, knowledge sharing and training activities.

4.2.1 Dissemination tools and activities

Website

The AIDA website (http://cern.ch/aida) was the main communication tool for storage and dissemination of project results. It was created in January 2011, before the start of the project, and was maintained with Work Package highlights, news and event announcements and the project results collected under the Deliverables and Milestones sections. To reach the general public, an Education and Outreach section was developed in period 2 and features educational resources related to detectors in general and also information about schools for young researchers to participate in. The website was also one of the main sources of information for the scientific community interested to apply to AIDA Transnational Access. It is to be noted that the average number of visitors per month (565) exceeded the AIDA members by at least a factor of 2 and was even higher during AIDA-related events. The AIDA website visitors were searching for information about the project, opportunities for transnational access, as well as project-related events and results. The figure below, shows the top-visited website pages for the project duration, with noticeable peaks during the last year of the project and an increase in searches related to AIDA results.

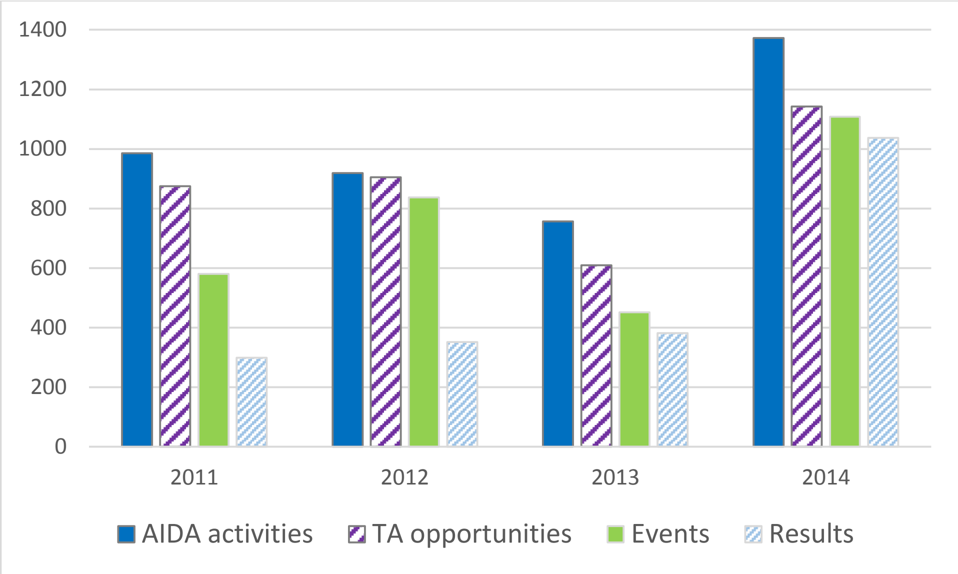


Figure 47: Number of top-visited AIDA website pages during the project duration.

Publications and reports

All the AIDA publications and reports are available in open access and can be browsed on the AIDA CDS collection by type, work package or keywords. As of 31st of March 2015, the total number of publications added to the AIDA CDS collection amounted to (excluding the deliverable and milestone reports):

Academic theses	*Status reports*	*Misc.*	*Journal publications*[9]	*Scientific/ Technical Notes*	*Presentations*	*Conference/ Workshop contributions*	***Total***
8	7	16	120	23	36	59	**269**

In addition, AIDA has produced 55 deliverable reports and 32 milestone reports.

Scientific and technical results were published in peer-reviewed publications such as:

- *Journal of Instrumentation (JINST)* – **46** publications
- *Nuclear Instruments and Methods in Physics Research A (NIM A)* – **43** publications

In addition, **13** publications were submitted to the Instrumentation and Detector section of the Open Access arXiv.org database.

AIDA results were also presented by project members at major international conferences including:

- *Workshop on Vertex Detectors (Vertex)* – **10** presentations and/or proceedings
- *IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)* – **9** presentations and/or proceedings
- *Technology and Instrumentation in Particle Physics (TIPP)* – **7** presentations and/or proceedings

[9] This includes publications in peer-reviewed journals, publications submitted to arXiv.org, and pre-prints prior to the final publication.

- *Calorimetry for High Energy Physics Frontier (CHEF)* – **5** presentations and/or proceedings
- *International Conference on Calorimetry in High Energy Physics (Calor)* – **4** presentations and/or proceedings
- *Topical Workshop on Electronics for Particle Physics (TWEPP)* – **2** presentations and/or proceedings
- *Computing in High Energy and Nuclear Physics (CHEP)* – **2** presentations and/or proceedings

A number of AIDA feature-articles were published in the CERN Bulletin, CERN Courier, PH Newsletter or LC Newsline with topics ranging from the development of a versatile beam telescope, the commissioning of the AIDA telescope, the completion of the calorimeter test beam programme to opportunities for access to AIDA test beam and irradiation facilities and general information about the project.

The project was promoted with a factsheet for the European Commission, developed in period 1.

For the detailed list of peer-reviewed publications and dissemination activities, see Annex I.

AIDA Annual Meetings

The Annual Meetings gathered participants from about 80 institutes and laboratories from 23 countries and represented an opportunity for the AIDA community to discuss the project scientific and technical achievements. Posters for the Annual Meetings were designed and then distributed to AIDA participants so that the events could be suitably advertised.

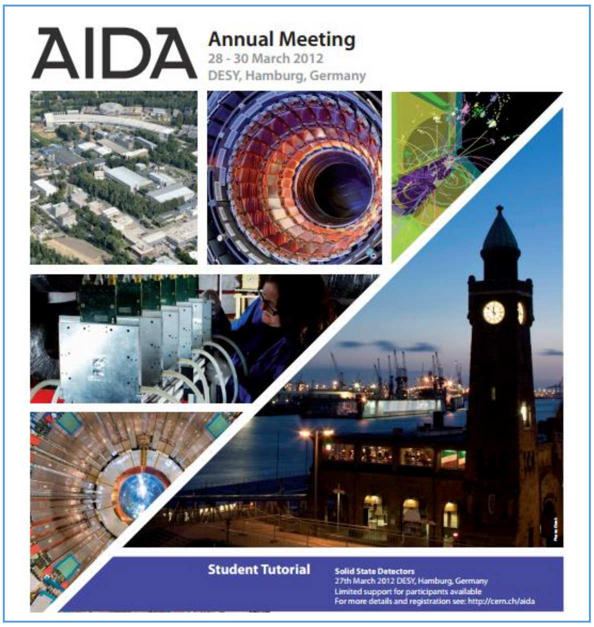


Figure 48: Poster of the AIDA 1st Annual Meeting held at DESY (March 2012).

Figure 49: Poster of the AIDA 2nd Annual Meeting held at INFN-LNF (April 2013).

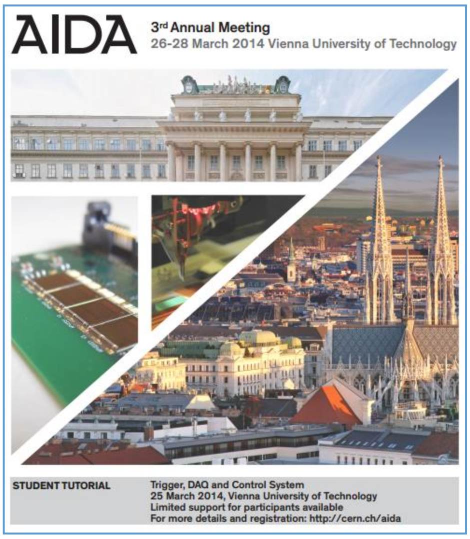


Figure 50: Poster of the AIDA 3rd Annual Meeting held at TU Vienna (March 2014).

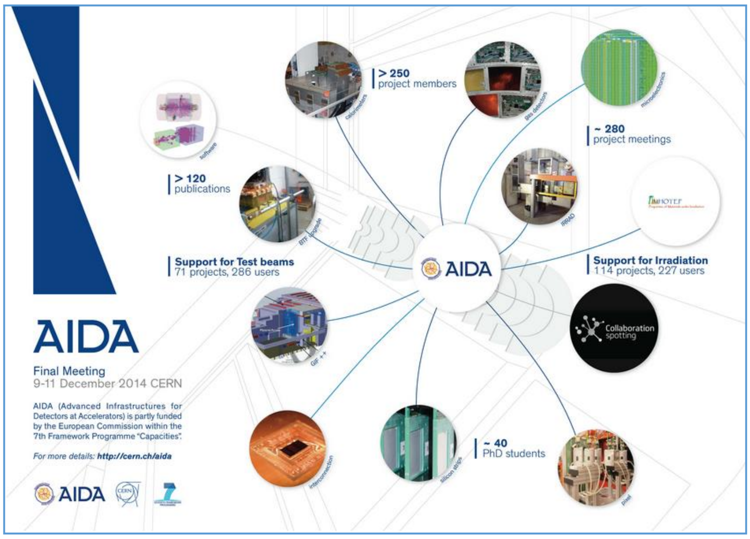


Figure 51: Poster of the AIDA Final Meeting held at CERN (December 2014).

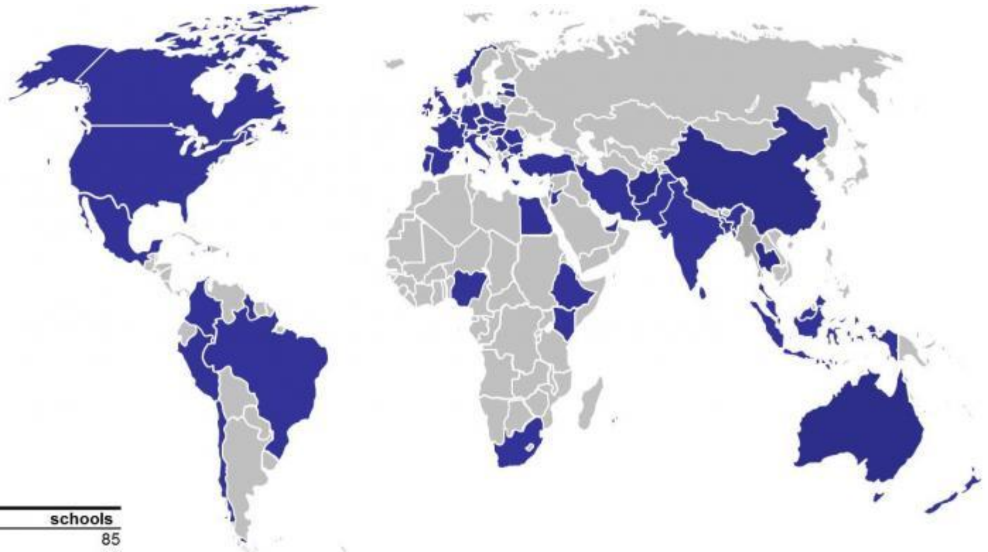
To reach young researchers, half-day public tutorials were organized during the Annual Meetings. The aim of these tutorials was to feature topics interesting for students from within and outside the Consortium. In total, 3 Student Tutorials were organized:

1. Solid State Detectors – 30 participants
2. Gaseous Detectors in HEP – 30 participants
3. Trigger, DAQ and Control System – 14 participants

Outreach activities

Many of the AIDA outreach activities were targeted to students. The project provided financial support to students participating at the EIROforum School on Instrumentation 2013 and the 5th International School of Trigger and Data Acquisition 2014. At these events, there were invited talks given by AIDA members. Furthermore, students were asked to prepare and present a poster on their research activities. One of the test beams equipped under the framework of AIDA was made available for a team of school students to run an experiment in 2014. The same competition with the same beamline (that will be available under AIDA-2020) is currently ongoing[10].

[10] http://home.web.cern.ch/students-educators/spotlight/2013/competition-beam-line-schools



Country	schools								
Italy	85								
Spain	66								
United States	45	Netherlands	6	Egypt	3	Jordan	1		
United Kingdom	43	Singapore	5	Slovakia	3	Mauritius	1	Belgium	1
India	28	South Africa	5	New Zealand	2	China	1	Sri Lanka	1
Greece	19	Indonesia	4	Czech Republic	2	Kuwait	1	Cyprus	1
Germany	17	Hungary	4	Brazil	2	Nigeria	1	Malta	1
Canada	13	Austria	4	Norway	2	Malaysia	1	Qatar	1
Poland	10	Mexico	4	Serbia	2	Ethiopia	1	UAE	1
Switzerland	8	Ireland	4	Slovenia	2	Haiti	1	Israel	1
France	7	Iran	3	Bulgaria	2	Pakistan	1	Chile	1
Portugal	7	Colombia	3	Australia	2	Guyana	1	Bangladesh	1
Romania	6	Estonia	3	Afghanistan	2	Peru	1	Kenya	1
Turkey	6	Thailand	3	Lebanon	1	Latvia	1	**Total**	**455**

Figure 52: World map showing the locations, in blue, of the 455 teams registered for the beam line for schools competition (Image: Kristin Kaltenhauser).

II. USE AND DISSEMINATION OF FOREGROUND

SECTION A: DISSEMINATION MEASURES (PUBLIC)

The Tables A1 and A2 are in Annex I.

SECTION B: EXPLOITABLE FOREGROUND (PUBLIC)

List of applications for patents

Table B1: List of applications for patents, trademarks, registered designs, etc.					
Type of IP Rights: Patents, Trademarks, Registered designs, Utility models, Others	Confidential (yes, no)	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant(s) (as on the application)
Dosimeter VUTEG-5-AIDA-M*	no	Beginning of 2017	VUTEG-5-AIDA-M	Profiling the proton beam	CERN
National patent	yes	July 2016	Nr. 2014 141 Pr-6531 (Lithuanian State Patent Bureau)	Method and instrumentation for measurement of large fluences and doses of high energy irradiations	Vilnius university, E.Gaubas, T.Ceponis, V.Kalesinskas, J.V.Vaitkus

* The patent application is under preparation and will be submitted shortly.

Exploitable foreground

Table B2: Exploitable foreground										
WP	**Foreground no.**	**Type of Exploitable Foreground[11]**	**Description of exploitable foreground (relevant deliverable)**	**Confidential (yes, no)**	**Foreseen embargo date dd/mm/yyyy**	**Exploitable product(s) or measure(s)**	**Sector(s) of application[12]**	**Timetable, commercial or any other use**	**Patents or other IPR exploitation (licences)**	**Owner & Other Beneficiary(s) involved**
2	1	GAK	Central code repositories and other infrastructure for software development (D2.2)	No	N/A	Service infrastructure	HEP Experiments	Small & Medium term	-	HEP Community
2	2	GAK	Software toolkit for detector geometry, materials and detection technologies y, materials and detection technologies (D2.3, D2.7)	No	N/A	Software tools	HEP Experiments	Small & Medium term	-	HEP Community
2	3	GAK	Software toolkit with tracking algorithms (D2.4, D2.6, D2.8)	No	N/A	Software tools	HEP Experiments	Small & Medium term	-	HEP Community
2	4	GAK	Particle Flow Analysis software tools (D2.5, D2.9)	No	N/A	Software tools	HEP Experiments	Small & Medium term	-	HEP Community
2	5	GAK	Alignment software tools (D2.10)	No	N/A	Software tools	HEP Experiments	Small & Medium term	-	HEP Community
2	6	GAK	Trigger simulation software tools (D2.11)	No	N/A	Software tools	HEP Experiments	Small & Medium term	-	HEP Community

[11] Type of foreground: General advancement of knowledge, Commercial exploitation of R&D results, Exploitation of R&D results via standards, exploitation of results through EU policies, exploitation of results through (social) innovation.

[12] Type of sector (NACE nomenclature): http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

3	7	GAK	Components for 3D pixel detectors: sensors and electronics readout (D3.2, D3.3, D3.5, D3.6)	No	N/A	Reports, demonstrators, samples	Detectors for particle physics and synchrotron radiation experiments	Small & Medium term	-	Detector communities
3	8	GAK	Functional blocks : 65 nm CMOS technology (D3.4), 180nm SOI technology (D3.9)	No	N/A	IP blocks	HEP and synchrotron radiation experiments. .Medical imaging	Small & Medium term	-	Detector communities
3	9	GAK	Tests and assessment of 3D technologies for pixel detectors (D3.7, D3.8, D3.10)	No	N/A	Device prototypes, reports	Detectors for particle physics and synchrotron radiation experiments	Small, Medium & Long term	-	Detector communities
4	10	GAK	Roadmap with key technologies and specifications for future particle physics projects (D4.1)	No	N/A	Report	HEP	Medium & Long term	-	Detector communities
4	11	EUP	New graph-based interactive tool, ColSpotting	No	N/A	Software	All scientific domains	Small, Medium & Long term	-	CERN
5, 6	12	GAK	Scientific results of novel detector components with test beam facilities (D5.1, D6.1)	No	N/A	Reports, publications; easy handling and user-friendly TB facility	HEP Experiments; Nuclear Physics Experiments, Generic Detector R&D	Small, Medium & Long term	-	DESY, CERN, HEP & Detector communities
7	13	GAK	Assessment of radiation-hard sensor and electronics technologies for HL-LHC (D6.2, D7.1, D7.2, D7.3)	No	N/A	Measurement of prototypes	HEP, Fusion	Small, Medium & Long term	-	HEP detector community

8	14	GAK	Common DAQ infrastructures and interfaces for linear collider test beams (D8.2, D8.8)	No	N/A	DAQ infrastructure (software + hardware) and documentation	HEP	Small & Medium term	-	HEP Community
8	15	GAK	Design and implementation study of a low energy beam in the range of 1 to 10 GeV for neutrino physics, and novel neutrinos detectors (D8.3, D8.11)	No	N/A	Report on the design study and detector prototypes	HEP	Medium term		Accelerator and neutrino communities
8	16	GAK	Design study and implementation of new upgraded irradiation facilities at CERN (D8.4, D8.10)	No	N/A	New unique irradiation facility	HEP	Small & Medium term	VUTEG-5-AIDA-M Nr.2014 141 Pr-6531	CERN, HEP community
8	17	GAK	Tracking telescope at CERN and DESY test-beam lines (D8.5, D9.4)	No	N/A	Fully functioning tracking telescope available to test beam users	HEP	Small & Medium term	-	HEP community
8	18	GAK	GIF ++ user infrastructure (detector and DCS) (D8.6)	No	N/A	User friendly and efficient gamma irradiation facility with particle beam	HEP	Small & Medium term	-	CERN, HEP community
8	19	GAK	Database with results of irradiation on components or materials (D8.1, D8.7)	No	N/A	Online database on radiation effects/damage on components and materials	HEP, nuclear, rad.medicine, space R&D	Small, Medium & long term	-	RAL and HEP community

8	20	GAK	Beam test infrastructure at Frascati (D8.9)	No	N/A	Flexible and user friendly test beam infrastructure	HEP	Small & Medium term	-	BTF and its user community
9	21	GAK	MGPD development infrastructure (D9.2)	No	N/A	Number or large areas detectors produced	HEP, Heavy ion community	Small & Medium term	-	CERN and the detector community
9	22	GAK	Gaseous detector infrastructure : large TPC infrastructure (D9.3) and pixel readout (D9.6)	No	N/A	Fully functioning TPC infrastructure, equipped with electronics available to users	HEP, Heavy ion community	Small & Medium term	-	DESY and the detector community
9	23	GAK	Infrastructure for thermo-mechanical measurements (D9.1)	No	N/A	Available for users measurements	HEP	Small & Medium term	-	CSIC and he detector community
9	24	GAK	Integrated telescope arm (D9.4)	No	N/A	Telescope available for users in CERN beam line	HEP	Small & Medium term	-	Detector community
9	25	GAK	Silicon micro-strips ladders (D9.5)	No	N/A	Available for combined beam test	HEP	Small & Medium term	-	Detector community
9	26	GAK	Integrated infrastructure for highly granular calorimeters (D9.7)	No	N/A	Infrastructure operational and prototypes available	HEP	Small & Medium term	-	Detector community

9	27	GAK	Adequation of GEANT4 simulation of hadronic showers (D9.9)	No	N/A	Comparison results presented at conference and in scientific publications	HEP	Small & Medium term	-	HEP
9	28	GAK	Infrastructure performance and utilisation (D9.8)	No	N/A	Statistics of users of infrastructure	HEP	Small & Medium term	-	HEP

WP	Foreground no.	Its purpose	How the foreground might be exploited and by whom	IPR exploitable measures taken or intended	Further research necessary, if any	Potential/expected impact (quantify where possible)
2	1	Provide access to code and documentation of software tools	Used by developers and users of the software tools	-	Infrastructure will be maintained for the coming years by CERN and DESY	Can be used also for future HEP software projects
2	2	Provide consistent and efficient detector geometry description tools	Will be used by ILC, CLIC and FCC and possibly others for developing new particle physics detectors	-	Improvement and maintenance will continue beyond the AIDA project	Provide a “ready-to-use” solution for new HEP experiments and test beams
2	3	Provide tracking tools for existing and new HEP physics experiments	Will be used by ILC, CLIC, LHC and possibly others for developing new particle physics detectors	-	Improvement and maintenance will continue beyond the AIDA project. The software is currently adapted to the new CLIC detector model with an all Silicon-tracker.	Will greatly simplify the maintenance of the LC reconstruction software and provide a starting point for new experiments.
2	4	Provide a software toolkit and framework for the development of particle flow based reconstruction with highly granular calorimeters.	Currently used by CLIC and ILC and will be used for new Neutrino experiments.	-	Improvement and maintenance will continue beyond the AIDA project.	Can be easily adapted to novel detector concepts with sufficiently high-granular calorimeters.

2	5	Provide alignment tools and strategies for telescopes and real tracking detectors.	Tools are used for the Timepix telescope (WP9) and the VELO detector of LHCb. Will be used to develop alignment strategies for the ILD detector.	-	Improvement and maintenance will continue beyond the AIDA project.	Tools will simplify alignment procedures for future telescope based test beam campaigns.
2	6	Provide a fast simulation of tracking detector layouts and trigger performance.	Tool is currently used for optimizing the tracking detector for the CMS upgrade program.	-	Improvement and maintenance will continue beyond the AIDA project.	Tool can be used for optimizing tracking detector layouts at other HEP experiments.
3	7	Construct high precision, low mass tracking detectors for future particle physics experiments. X-ray imaging detectors for synchrotron radiation experiments	LHC collaboration and AIDA-2020 project	-	Some components need further R&D to improve properties like yield or spatial resolution	Advanced detectors with improved spatial resolution, reduced material budget, higher data bandwidth, less power consumption
3	8	Provide library validated IP blocs library to micro-electronics designers	Design of complex ASICs for detector readout	-	Performance test still to be validated, in particular after irradiation	Advanced detectors for HEP but also application to medical imaging, ,volcanology
3	9	Construct high precision, low mass tracking detectors for future particle physics experiments. X-ray imaging detectors for synchrotron radiation experiments	LHC collaboration and AIDA-2020 project	-	Some R&D is required for high density via last technologies, especially concerning yield. Via first (or middle) technologies require substantial R&D with a reliable industrial partner	Advanced detectors with improved spatial resolution, reduced material budget, higher data bandwidth, less power consumption
4	10	Identify key industrial players on specific technologies	HEP community	-	Add technologies to the roadmap	Complete overview and positioning of the European industrial landscape on all emerging technologies
4	11	Advanced graph-based analytics for big data	EC-JRC	Proprietary software	Generalization of the tool to the exploitation of data of any type.	New analytics tools accessible to everyone.
5,6	12	Development of novel detectors for future accelerators	HEP community	-	No	Upgrade of the LHC, design of the LC detectors
7	13	Mimic high radiation environment at LHC upgrade	HEP detector community, Accelerator community, ITER instrumentation	-	Follow up on technology developments	Radiation-hard detectors in HEP, new accelerators and fusion reactors

8	14	Provide DAQ to read various sub-detectors in combined test beam	LC community	-	Long data taking period with beam	Input to final design of LC experiments
8	15	Prepare the European community to the future long baseline project	Neutrino community		Build and test with beam the final MIND prototype	European contribution to next neutrino worldwide project
8	16	Design, build and commission with users' equipment a upgraded irradiation facility at CERN	Detector and accelerator community	1 patent application filed 1 patent application under preparation	No	Design of ATLAS and CMS phase II upgrade. Accelerator components for future hadron machines
8	17	User support and commissioning of pixel tracking beam telescope	Beam test users at CERN	-	No	Quality of scientific results from test-beam at CERN
8	18	Provide user's equipment at new GIF++ facility at CERN	HEP community	-	Final commissioning of RPC chambers	Design of ATLAS and CMS phase II upgrade. Accelerator components for future hadron machines
8	19	Provide database with irradiated components results	Detector and accelerator community	-	Continuous filling of database with new results	Choice of materials for HL-LHC
8	20	Provide fully equipped beam line to users	Beam test users at BTF	-	Provide photon beam	Quality of scientific results from test-beam at BTF
9	21	Upgrade CERN MGPD workshop to produce large area detectors	Detector community	-	No	Upgrade of ATLAS and CMS muon chambers
9	22	Provide fully equipped gaseous detector infrastructure	Detector community	-	Add a Silicon strips telescope	Input to final design of LC experiments
9	23	Provide infrastructure for thermo-mechanical measurements	Detector community	-	No	Improved spatial resolution for pixel detectors
9	24	Provide telescope arms for excellent spatial resolution and high speed response	Beam test users at CERN	-	No	Upgrade of tracking detectors for phase II in ATLAS and CMS
9	25	Provide precise entry point for calorimeter tests	CALICE community and AIDA-2020	-	No	Advanced particle flow algorithms

9	26	Study of the ultra-granular calorimetry	CALICE, CMS and AIDA-2020	-	Combined beam test with large area detectors	Choice of calorimeters for LC experiments, CMS and FCC
9	27	Validation of GEANT4 hadronic showers models	HEP and GEANT4 users	-	Complete analysis of data recorded	Scientific results of all HEP experiments
9	28	Demonstrate that the AIDA infrastructure has been used and to assess its performance	HEP community	-	No	Making available test infrastructure for novel detectors in order to match their more and more stringent requirements

ANNEX I: LIST OF PUBLICATIONS

Table A1: List of scientific (peer reviewed) publications										
No	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[13]	Is/Will open access[14] provided to this publication?
1	A study of high-energy proton induced damage in cerium fluoride in comparison with measurements in lead tungstate calorimeter crystals	Dissertori, G.	Nucl. Instrum. Methods Phys. Res A	622	Elsevier	NL	2010	41-44	CDS link	Yes
2	Analysis of data recorded by the LCTPC equipped with a two layer GEM-system	Ljunggren, M. et al	Physics Procedia	37	Elsevier	NL	2011	583-590	CDS link	Yes
3	Simulations of planar pixel sensors for the ATLAS high luminosity upgrade	Calderini,G. et al.	Nucl. Instrum. Methods Phys. Res. A	636	Elsevier	NL	2011	37-41	CDS link	Yes
4	Position resolution and efficiency measurements with large scale TGC's	Mikenberg, G. Milstein, D. Smakhtin, V. et al	Nucl. Instrum. Methods Phys. Res. A	628	Elsevier	NL	2011	177-181	CDS link	Yes
5	Characterisation of n-in-p pixel sensors for high radiation environments	Casse, G	Nucl. Instrum. Methods Phys. Res. A	650	Elsevier	NL	2011	140-144	CDS link	Yes

[13] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).

[14] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

6	Characterization of Thin Pixel Sensor Modules Interconnected with SLID Technology Irradiated to a Fluence of $2{\cdot}10^{15}$ neq /cm^2	Weigell, P et al	JINST	Volume 6 Issue 12	IOP Publishing	UK	2011	-	CDS Link	Yes
7	Experimental and numerical characterization of the neutron field produced in the n@BTF Frascati photo-neutron source	Bedogni, R. et al	Nucl. Instrum. Methods Phys. Res. A	659	Elsevier	NL	2011	373-377	CDS Link	Yes
8	Pixel 2010: A résumé	Wermes, N	Nucl. Instrum. Methods Phys. Res. A	650	Elsevier	NL	2011	245-252	CDS Link	Yes
9	Optimization of Strip Isolation for Silicon Sensors	Valentan, M et al	Physics Procedia	37	Elsevier	NL	2011	891-898	CDS Link	Yes
10	Recent progress in the development of 3D deep n-well CMOS MAPS	Traversi, G et al.	JINST	7	IOP Publishing	UK	2012	C02007	CDS link	Yes
11	A visualization of the damage in Lead Tungstate calorimeter crystals after exposure to high-energy hadrons	Dissertori, G.	Nucl. Instrum. Methods Phys. Res. A	684	Elsevier	NL	2012	57-62	CDS link	Yes
12	Hadronic energy resolution of a highly granular scintillator-steel hadron calorimeter using software compensation techniques	Adloff, C et al	JINST	7	IOP Publishing	UK	2012	P09017	CDS link	Yes
13	KLauS – A charge readout and fast discrimination chip for silicon photomultipliers	Dorn, M. et. al	JINST	Volume 7, Issue 01	IOP Publishing	UK	2012	-	CDS link	Yes
14	Study of the response and photon-counting resolution of silicon photomultipliers using a generic simulation framework	Eckert, P. et. al	JINST	Volume 7, Issue 08	IOP Publishing	UK	2012	-	CDS link	Yes
15	A parametrization of the energy loss distributions of charged particles and its applications for silicon detectors	Siklér, F	Nucl. Instrum. Methods Phys. Res. A	691	Elsevier	NL	2012	16-29	CDS link	Yes
16	Hadronic energy resolution of a highly granular scintillator-steel calorimeter using software compensation techniques	Adloff, C. et al.	JINST	7	SISSA & IOP Publishing	UK	2012	P09017	CDS link	Yes

17	Investigation of the radiation hardness of GaAs sensors in an electron beam	Afanaciev, K. et al.	JINST	8	SISSA & IOP Publishin g	UK	2012	P11022	CDS link	Yes
18	Planar Pixel Sensors for the ATLAS Upgrade: Beam Tests results	Weingarten, J. et al	JINST	7	IOP Publishin g	UK	2012	P10028	CDS link	Yes
19	High granularity Semi-Digital Hadronic Calorimeter using GRPCs	Mannai, S.	Nucl. Instrum. Methods Phys. Res. A	718	Elba-Italy	NL	2012	-	CDS link	Yes
20	Characterization of new hybrid pixel module concepts for the ATLAS Insertable B-Layer upgrade	Bachkaus, M., et al.	JINST	7	IOP Publishin g	UK	2012	C01050	CDS link	Yes
21	The Shunt-LDO regulator to power the upgraded ATLAS pixel detector	Gonella, L., et al.	JINST	7	IOP Publishin g	UK	2012	C01034	CDS link	Yes
22	A via last TSV process applied to ATLAS pixel detector modules: proof of principle demonstration	Gonella, L., et al.	JINST	7	IOP Publishin g	UK	2012	P08008	CDS link	Yes
23	The FE-I4 pixel readout system-on-chip resubmission for the insertable B-Layer project	Zivkovic, V, Barbero, M., et al.	JINST	7	IOP Publishin g	UK	2012	C02050	CDS link	Yes
24	Operation of a GEM-TPC with pixel readout	Brezina, C. et al.	IEEE Trans. Nucl. Sci.	59 No. 6	IEEE	USA	2012	3221-3228	CDS link	Yes
25	Thin n-in-p pixel sensors and the SLID-ICV vertical integration technology for the ATLAS upgrade at the HL-LHC	Macchiolo A. et al	Nucl. Instrum. Methods Phys. Res. A	731	Elsevier	NL	2012	210-215	CDS link	Yes
26	A test beam set-up for the characterization of the Geiger-mode avalanche photodiode technology for particle tracking	Vilella, E. et al.	Nucl. Instrum. Methods Phys. Res. A	694	Elsevier	NL	2012	199-204	CDS link	Yes

27	Characterisation of micro-strip and pixel silicon detectors before and after hadron irradiation	Allport, P.	JINST	7	IOP Publishin g	UK	2012	C01105	CDS link	Yes
28	Studies for the detector control system of the ATLAS pixel at the HL-LHC	Püllen, L	JINST	7	IOP	UK	2012	C02053	CDS link	Yes
29	Acquisition System and Detector Interface for Power Pulsed Detectors	Cornat, R	Physics Procedia	37	Elsevier	NL	2012	1791-1798	CDS link	Yes
30	SLID-ICV Vertical Integration Technology for the ATLAS Pixel Upgrades	Macchiolo, A et al.	Physics Procedia	37	Elsevier	NL	2012	1009–1015	CDS link	Yes
31	First Investigation of a novel 2D position sensitive semiconductor detector concept	Bassignana, D. et al.	JINST	7	IOP Publishin g	UK	2012	P02005	CDS link	Yes
32	Development of a novel 2D position-sensitive semiconductor detector concept	Bassignana, D. et al.	JINST	7	IOP Publishin g	UK	2012	C04008	CDS link	Yes
33	Influence of the Fiber Coating Type on the Strain Response of Proton-Irradiated Fiber Bragg Gratings	Curras,E. et al	IEEE Trans. Nucl. Sci.	59 No. 4	IEEE	USA	2012	937-942	CDS Link	Yes
34	Prototype ATLAS IBL Modules using the FE-I4A	The IBL ATLAS Collaboration	JINST	Volume 7 Issue 11	IOP Publishin g	UK	2012	-	CDS Link	Yes
35	A parametrisation of the energy loss distributions of charged particles and its applications for silicon detectors	Sikler, F	Nucl. Instrum. Methods Phys. Res., A	691	Elsevier	NL	2012	16-29	CDS Link	Yes
36	Recent progress of the ATLAS Planar Pixel Sensor R&D Project	Bomben, M	Physics Procedia	37	Elsevier	NL	2012	940-949	CDS Link	Yes
37	Characterization of a tagged γ-ray beam line at the DAFNE Beam Test Facility	Cattaneo, P W	Nucl. Instrum. Methods Phys. Res. A	674	Elsevier	NL	2012	55-66	CDS Link	Yes
38	Characterization of a commercial 65 nm CMOS technology for SLHC applications	Bonacini, S. et al	JINST	Volume 7 Issue 1	IOP Publishin g	UK	2012	-	CDS Link	Yes

39	Evaporative CO2 cooling using microchannels etched in silicon for the future LHCb vertex detector	Nomerotski, A. et al.	JINST	8	IOP Publishing	UK	2012	P04004	CDS link	Yes
40	A totally active scintillator calorimeter for the Muon Ionization Cooling Experiment (MICE). Design and construction	Asfandiyarov, R.	Nucl. Instrum. Methods Phys. Res. A	732	Elsevier	NL	2013	-	CDS link	Yes
41	Performance of Particle Flow Calorimetry at CLIC	Marshall, J. et al	Nucl. Instrum. Methods Phys. Res. A	A700	Elsevier	NL	2013	153-162	CDS link	Yes
42	Shower development of particles with momenta from 1 to 10 GeV in the CALICE Scintillator-Tungsten HCAL	Adloff, C. et al	JINST	9	IOP Publishing	UK	2013	P01004	CDS link	Yes
43	Track finding in silicon trackers with a small number of layers	Frühwirth, R.	Nucl. Instrum. Methods Phys. Res. A	732	Elsevier	NL	2013	95-98	CDS link	Yes
44	Track segments in hadronic showers in a highly granular scintillator-steel hadron calorimeter	Adloff, C. et al.	JINST	8	SISSA & IOP Publishing	UK	2013	P09001	CDS link	Yes
45	Validation of GEANT4 Monte Carlo Models with a Highly Granular Scintillator-Steel Hadron Calorimeter	Adloff, C. et al.	JINST	8	SISSA & IOP Publishing	UK	2013	P07005	CDS link	Yes
46	Forward tracking at the next e+e− collider part II: experimental challenges and detector design	Aplin, S. Boronat, M. Dannheim, D. et al.	JINST	8	SISSA & IOP Publishing	UK	2013	T06001	CDS link	Yes
47	Irradiation and beam tests qualification for ATLAS IBL Pixel Modules	Rubinskiy, I.	Nucl. Instrum. Methods Phys. Res. A	699	Elsevier	NL	2013	P6771	CDS link	Yes
48	Construction and testing of a large scale prototype of a silicon tungsten electromagnetic calorimeter for a future lepton collider	Rouëné, J.	Nucl. Instrum. Methods Phys. Res. A	372	Elsevier	NL	2013	470	CDS link	Yes

49	Development of Edgeless n-on-p Planar Pixel Sensors for future ATLAS Upgrades	Bomben, M. et al	Nucl. Instrum. Methods Phys. Res. A	712	Elsevier	NL	2013	41-47	CDS link	Yes
50	Novel Silicon n-on-p Edgeless Planar Pixel Sensors for the ATLAS upgrade	Bomben, M. et al	Nucl. Instrum. Methods Phys. Res. A	730	Elsevier	NL	2013	215-219	CDS link	Yes
51	A 10MS/s 8-bit charge-redistribution ADC for hybrid pixel applications in 65m CMOS	Kishishita, T., et al.	Nucl. Instrum. Methods Phys. Res. A	732	Elsevier	NL	2013	506-510	CDS link	Yes
52	Prototype of a gigabit data transmitter in 65 nm CMOS for DEPFET pixel detectors at Belle-II	Kishishita, T., et al.	Nucl. Instrum. Methods Phys. Res. A	718	Elsevier	NL	2013	168-172	CDS link	Yes
53	Experience with 3D integration technologies in the framework of the ATLAS pixel detector upgrade for the HL-LHC	Arutinov, D et al.	Nucl. Instrum. Methods Phys. Res. A	731	Elsevier	NL	2013	97-102	CDS link	Yes
54	High-voltage pixel detectors in commercial CMOS technologies for ATLAS, CLIC and Mu3e experiments	Bachkaus, M., et al.	Nucl. Instrum. Methods Phys. Res. A	731	Elsevier	NL	2013	131-136	CDS link	Yes
55	Characterization of the FE-I4B pixel readout chip production run for the ATLAS Insertable B-layer upgrade	Bachkaus, M., et al.	JINST	8	IOP Publishing	UK	2013	C03013	CDS link	Yes
56	SEU tolerant memory design for the ATLAS pixel readout chip	Menouni, M. Arutinov, D. et al.	JINST	8	IOP Publishing	UK	2013	C02026	CDS link	Yes
57	R&D Paths of Pixel Detectors for Vertex Tracking and Radiation Imaging	Battaglia, M., Wermes, N., et al.	Nucl. Instrum. Methods Phys. Res. A	716	Elsevier	NL	2013	29-45	CDS link	Yes
58	The Birmingham Irradiation Facility	Marin-Reyes, H	Nucl. Instrum. Methods Phys. Res. A	730	Elsevier	NL	2013	101-104	CDS link	Yes
59	3D integration of Geiger-mode avalanche photodiodes aimed to very high fill-factor pixels for future linear colliders	Vilella, E. et al.	Nucl. Instrum. Methods Phys. Res. A	731	Elsevier	NL	2013	103-108	CDS link	Yes

60	Results with p-type pixel sensors with different geometries for the HL-LHC	Allport, P.	Nucl. Instrum. Methods Phys. Res. A	731	Elsevier	NL	2013	216-218	CDS link	Yes
61	Degradation of charge sharing after neutron irradiation in strip silicon detectors with different geometries	Casse, G.	Nucl. Instrum. Methods Phys. Res. A	730	Elsevier	NL	2013	54-57	CDS link	Yes
62	Prototypes for components of a control system for the ATLAS pixel detector at the HL-LHC	Püllen, L	JINST	8	IOP Publishin g	UK	2013	C03019	CDS link	Yes
63	DEPFET active pixel detectors for a future linear e+e− collider	Alonso, O. et al.	IEEE Trans. Nucl. Sci.	Volume 60, issue 6	IEEE	USA	2013	1457-1465	CDS link	Yes
64	2D position sensitive microstrip sensors with charge division along the strip: Studies on the position measurement error	Bassignana, D. et al	Nucl. Instrum. Methods Phys. Res. A	732	Elsevier	NL	2013	186 89	CDS link	Yes
65	Radiation resistance of double-type double-sided 3D pixel sensors	Fernandez, M et al.	Nucl. Instrum. Methods Phys. Res. A	732	Elsevier	NL	2013	137 140	CDS link	Yes
66	InGrid-based X-ray detector for low background searches	Krieger, C. et al	Nucl. Instrum. Methods Phys. Res. A	729	Elsevier	NL	2013	905-909	CDS Link	Yes
67	T3B - An Experiment to measure the Time Structure of Hadronic Showers	Simon,F et al	JINST	Volume 8 Issue 12	IOP Publishin g	UK	2013	-	CDS Link	Yes
68	Beam Test Studies of 3D Pixel Sensors Irradiated Non-Uniformly for the ATLAS Forward Physics Detector	Grinstein,S et al	Nucl. Instrum. Methods Phys. Res. A	730	Elsevier	NL	2013	28-32	CDS Link	Yes
69	Recent Results of the ATLAS Upgrade Planar Pixel Sensors R&D Project	Weigell,P	Nucl. Instrum. Methods Phys. Res. A	731	Elsevier	NL	2013	177- 182	CDS Link	Yes
70	Planar Pixel Sensors for the ATLAS tracker upgrade at HL-LHC	Gallrapp,C	Nucl. Instrum. Methods Phys. Res. A	718	Elsevier	NL	2013	323-324	CDS Link	Yes

71	Novel Silicon n-in-p Pixel Sensors for the future ATLAS Upgrades	La Rosa, A et al	Nucl. Instrum. Methods Phys. Res. A	718	Elsevier	NL	2013	329-330	CDS Link	Yes
72	The Timepix Telescope for High Performance Particle Tracking	Kazuyoshi, A. et al	Nucl. Instrum. Methods Phys. Res. A	723	Elsevier	NL	2013	47-54	CDS Link	Yes
73	Results on damage induced by high-energy protons in LYSO calorimeter crystals	Dissertori, G.	Nucl. Instrum. Methods Phys. Res. A	745	Elsevier	NL	2014	1-6	CDS link	Yes
74	KLauS: an ASIC for silicon photomultiplier readout and its application in a setup for production testing of scintillating tiles	Briggl, K. et. al	JINST	9	IOP Publishin g	UK	2014	C02013	CDS link	Yes
75	Development of scalable frequency and power Phase-Locked Loop in 130 nm CMOS technology	Firlej, M. et al	JINST	9	IOP Publishin g	UK	2014	C02006	CDS link	Yes
76	A fast, low-power, 6-bit SAR ADC for readout of strip detectors in the LHCb Upgrade experiment	Firlej, M. et al	JINST	9	IOP Publishin g	UK	2014	P07006	CDS link	Yes
77	The Time Structure of Hadronic Showers in Highly Granular Calorimeters with Tungsten and Steel Absorbers	Adloff, C. et al.	JINST	9	SISSA & IOP Publishin g	UK	2014	P07022	CDS link	Yes
78	Beam test performance of the SKIROC2 ASIC	Frisson, F. et al.	Nucl. Instrum. Methods Phys. Res. A	778	Elsevier	NL	2014	78-84	CDS link	Yes
79	Acquisition and control command system for power pulsed detectors	Cornat, R.	JINST	9	SISSA & IOP Publishin g	UK	2014	C01030	CDS link	Yes
80	Fractal Dimension of Particle Showers Measured in a Highly Granular Calorimeter	Ruan, M. et al.	Phys. Rev. Lett	112	APS	USA	2014	012001	CDS link	Yes

81	Software digitizer for high granular gaseous detector	Haddad, Y. Ruan, M. and Boudry, V.	JINST	9	IOP Publishing	UK	2014	C11016	CDS link	Yes
82	Development of Edgeless Silicon Pixel Sensors on p-type substrate for the ATLAS High-Luminosity Upgrade	Calderini, G. et al	Nucl. Instrum. Methods Phys. Res. A	765	Elsevier	NL	2014	146-150	CDS link	Yes
83	Electrical characterization of thin edgeless N-on-p planar pixel sensors for ATLAS upgrades	Bomben, M. et al	JINST	9	IOP Publishing	UK	2014	C05020	CDS link	Yes
84	Selected results from the static characterization of edgeless n-on-p planar pixel sensors for ATLAS upgrades	Bomben, M. et al	JINST	9	IOP Publishing	UK	2014	C01063	CDS link	Yes
85	Test results of the first 3D-IC prototype chip developed in the framework of HL-LHC/ATLAS hybrid pixel upgrade	Arutinov, D et al.	JINST	9	IOP Publishing	UK	2014	C02031	CDS link	Yes
86	Implementation of configurable FEI4 trigger plane for the AIDA telescope	Obermann, T. et al.	JINST	9	IOP Publishing	UK	2014	C03035	CDS link	Yes
87	Pixel front-end development in 65 nm CMOS technology	Havranek, M et al.	JINST	9	IOP Publishing	UK	2014	C01003	CDS link	Yes
88	Radiation-hard Active Pixel Sensors for HL-LHC Detector Upgrades based on HV-CMOS Technology	Miccci, A. Gonella, L, et al.	JINST	9	IOP Publishing	UK	2014	C05064	CDS link	Yes
89	Flip chip assembly of thinned chips for hybrid pixel detector applications	Fritzsch, T. Hügging, F. et al.	JINST	9	IOP Publishing	UK	2014	C05039	CDS link	Yes
90	The RD53 Collaboration's SystemVerilog-UVM Simulation Framework and its General Applicability to Design of Advanced Pixel Readout Chips	Marconi, S. Hemperek, T. et al.	JINST	9	IOP Publishing	UK	2014	P10005	CDS link	Yes

91	GOSSIPO-4: Evaluation of a Novel PLL-Based TDC-Technique for the Readout of GridPix-Detectors	Brezina, C. et al.	IEEE Trans. Nucl. Sci.	61 No. 2	IEEE	USA	2014	1007-1014	CDS link	Yes
92	The charge pump PLL clock generator designed for the 1.56 ns bin size time-to-digital converter pixel array of the Timepix3 readout ASIC	Fu, Y. et al.	JINST	9	IOP Publishing	UK	2014	C01052	CDS link	Yes
93	The Pixel-TPC: first results from an 8-InGrid module	Lupberger, M.	JINST	9	IOP Publishing	UK	2014	C01033	CDS link	Yes
94	Digital column readout architectures for hybrid pixel detector readout chips	Poikela, T. et al.	JINST	9	IOP Publishing	UK	2014	C01007	CDS link	Yes
95	Production and characterization of SLID interconnected n-in-p pixel modules with 75 micron thin silicon sensors	Andricek, L. et al	Nucl. Instrum. Methods Phys. Res. A	758	Elsevier	NL	2014	3043	CDS link	Yes
96	The C-RORC PCIe Card and its Application in the ALICE and ATLAS Experiments	Borga, A et al	JINST	10	IOP Publishing	UK	2014	C02022	CDS link	Yes
97	Identification of circles from data points using the Legendre transform	Alexopoulos,T. et al	Nucl. Instrum. Methods Phys. Res. A	745	Elsevier	NL	2014	16-23	CDS Link	Yes
98	Development of front-end electronics for LumiCal detector in CMOS 130 nm technology	Firlej, M. et al	JINST	10	IOP Publishing	UK	2015	C01018	CDS link	Yes
99	Upgrade to the Birmingham Irradiation Facility	Parker, K	Nucl. Instrum. Methods Phys. Res. A	TBC	Elsevier	NL	2015	-	CDS link	Yes
100	Physical limitations to the spatial resolution of solid-state detectors	Boronat, M. et al.	IEEE Trans. Nucl. Sci.	Volume:62 , Issue: 1	IEEE	USA	2015	381-386	CDS link	Yes

Table A2: Other publications								
No Link	Type of publications[15]	Lead author	Title	Date	Place	Type of audience[16]	Size of audience	Countries addressed
1 CDS link	Conference	Becker, K	Radiation hard components for the control system of a future ATLAS pixel detector	2010	Aachen, Germany	Scientific community	-	International
2 CDS link	Conference	Re, V	The SuperB Silicon Vertex Tracker and 3D vertical integration	2011	Rust, Austria	Scientific community	-	International
3 CDS link	Conference	Barbero, M et al.	The FE-I4 Pixel Readout Chip and the IBL Module	2011	Rust, Austria	Scientific community	-	International
4 CDS link	Conference	Mikenberg, G. Milstein, D. Smakhtin, V. et al	Test of special resolution and trigger efficiency	2011	Valencia, Spain	Scientific community	-	International
5 CDS link	Conference	Hartbrich, O	Recent Advances of the Engineering Prototype of the CALICE Analog Hadron Calorimeter	2011	Granada, Spain	Scientific community	-	International
6 CDS link	Conference	Rubinskiy, I.	Irradiation and beam tests qualification for ATLAS IBL Pixel Modules	2011	Taipei, Taiwan	Scientific community	-	International
7 CDS link	Presentation	Rosca, A.	Electron Reconstruction in the Beam Cal International Workshop on Future Linear Colliders, (LCWS11)	2011	Granada, Spain	Scientific community	-	International
8 CDS link	Presentation	Boudry, V	Second generation DAQ for CALICE beam tests, International Workshop on Future Linear Colliders (LCWS11)	2011	Granada, Spain	Scientific community	-	International

[15]Type of publications: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[16] Type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

9 CDS link	Poster	Cornat, R	DAQ systems for 10^8 channels detectors: design and system level simulations, Topical Workshop on Electronics for Particle Physics (TWEPP11)	2011	Vienna, Austria	Scientific community	-	International
10 CDS link	Conference	Ruan, M	Fractal dimension analysis in a highly granular calorimeter, 14th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT 2011)	2011	Uxbridge, West London, UK	Scientific community	-	International
11 CDS link	Conference	Ruan, M	Druid, displaying root module used for linear collider detectors, 14th International Workshop on Advanced Computing and Analysis Techniques in Physics Research (ACAT 2011)	2011	Uxbridge, UK	Scientific community	-	International
12 CDS link	Academic Dissertation	Ljunggren,M.	High Momentum Resolution tracking In a Linear Collider	2011	Lund, Sweden	Scientific community	-	International
13 CDS link	Status Report	Klempt, W. et al	ANL visit for exploring possibility of a tungsten RPC DHCAL test setup	2011	Geneva Switzerland	Scientific community	-	International
14 CDS link	Article/ Misc	Kahle, K.	CERN launches AIDA project	2011	Geneva Switzerland	Scientific community	-	International
15 CDS link	Article/ Misc	Kahle, K.	AIDA makes EU-funded access to European facilities available	2011	Geneva Switzerland	Scientific community	-	International
16 CDS link	Article/ Misc	Gilraen Wyles, N	AIDA – pushing the boundaries of European particle detector research	2011	Geneva Switzerland	Scientific community	-	International
17 CDS link	Scientific/ Technical note	Lebbos, E et al	East Area Irradiation Test Facility: Preliminary FLUKA calculations	2011	Geneva Switzerland	Scientific community	-	International
18 CDS link	Conference	Marchiori,G	Recent results of the ATLAS Upgrade Planar Pixel Sensors R&D Project	2011	Florence, Italy	Scientific community	-	International
19 CDS link	Conference	Eckert, P.	Simulation of Silicon Photomultipliers, PhotoDet 2012	2012	Orsay, France	Scientific community	-	International
20 CDS link	arXiv.org	Hermberg, B	Commissioning of the Testbeam Prototype of theCALICE Tile Hadron Calorimeter	2012	Anaheim, USA	Scientific community	-	International

21 CDS link	Presentation	Hartbrich, O	Status of the CALICE Scintillator HCAL Engineering Prototype	2012	Arlington, USA	Scientific community	-	International
22 CDS link	Conference	Marshall, J	The Pandora software development kit, CHEP 2012	2012	New York USA	Scientific community	-	International
23 CDS link	Presentation	Zawiejski,L	LumiCal alignment system, status report, 21st FCAL Collaboration Workshop	2012	CERN Switzerland	Scientific community	-	International
24 CDS link	Conference	Dissertori, G	Performance studies of scintillating ceramic samples exposed to ionizing radiation	2012	Anaheim, USA	Scientific community	-	International
25 CDS link	Presentation	Ramilli, M	Validation of hadronic models using CALICE highly granular calorimeters, 15th International Conference on Calorimetry in High Energy Physics	2012	Santa Fe, New Mexico	Scientific community	-	International
26 CDS link	Presentation	Terwort, M	Realization and Tests of the Highly Granular CALICE Engineering Calorimeter Prototypes, 15th International Conference on Calorimetry in High Energy Physics	2012	Santa Fe, New Mexico	Scientific community	-	International
27 CDS link	Conference	De Lentdecker, G.	Development of the data acquisition system of a large TPC for the ILC, IEEE Real Time Conference 2012	2012	Berkeley, USA	Scientific community	150	International
28 CDS link	Academic thesis	Glattauer, R	Track Reconstruction in the Forward Region of the Detector ILD at the Electron-Positron Linear Collider ILC	2012	Vienna, Austria	Scientific community	-	International
29 CDS link	Conference	Glattauer, R	Forward Tracking in the ILD Detector	2012	-	Scientific community	-	International
30 CDS link	Academic thesis	Lettenbichler, J	Pattern recognition in the Silicon Vertex Detector of the Belle II experiment	2012	Vienna, Austria	Scientific community	-	International
31 CDS link	Conference	Rubinskiy, I	An EUDET/AIDA Pixel Beam Telescope for Detector Development Volume 37, 2012, Pages 923–931 Proceedings for TIPP 2011	2012	-	Scientific community	-	International

32 CDS link	Conference	Perrey, H.,	An EUDET/AIDA Pixel Beam Telescope for Detector Development IEEE Nuclear Science Symposium 2012, IEEE NSS 2012	2012	Anaheim, USA	Scientific community	-	International
33 CDS link	Presentation	Rosca, A.	FCAL software status and performance studies ILD Workshop 2012	2012	Fukuoka, Japan	Scientific community	-	International
34 CDS link	Presentation	Frisson, T.	SiW ECAL Technological Prototype - Test beam results, LCWS2012	2012	Arlington, USA	Scientific Community	-	International
35 CDS link	Presentation	Dieguez et al.	Design of a FE ASIC in TSMC-65nm for Si tracking at the ILC , International Workshop on Future Linear Colliders (LCWS) 2012	2012	Arlington, USA	Scientific community	-	International
36 CDS link	Presentation	Vilella et al.	3D integration of Geiger-mode avalanche photodiodes for future linear colliders, 6th International Workshop on Semiconductor Pixel Detectors for Particles and Imaging (PIXEL 2012)	2012	Inawashiro, Japan	Scientific community	-	International
37 CDS link	Poster/ Misc	Tekorius, A et al	Dosimetry of background irradiations of accelerators based on hadrons fluence dependent carrier lifetime measurements" Materials of the international conference "Radiation Interaction with Material and Its Use in Technologies 2012" (2012) p.p.282-285	2012	Kaunas, Lithuania	Scientific community	>300	International
38 CDS link	Conference	Laktineh,I	High-Rate Glass Resistive Plate Chambers For LHC Muon Detectors Upgrade	2012	Anaheim, CA	Scientific community	-	International
39 CDS link	Scientific/ Technical note	Iaydjiev,P	Test a prototype of a Micro Controller Unit (µCU) for the control and reading of the RADMON radiation detectors – LAAS 1600 and REM 250	2012	CERN	Scientific community	-	International
40 CDS link	Conference	Moser, H.-G.	3D Interconnection with TSV, Proceedings of the International Conference on Vertex Detectors (Vertex2012)	2012	Jeju, Korea	Scientific community	-	International

41 [CDS link]	Scientific/ Technical note	Hedberg, V. et al	Development of the Readout System for a TPC at the future Linear Collider	2012	Lund, Sweden	Scientific community	-	International
42 [CDS link]	Scientific/ Technical note	Marshall J. et al.	Particle Flow Performance at CLIC	2012	Cambridge and CERN	Scientific community	-	International
43 [CDS link]	Scientific/ Technical note	Dannheim, D et al.	Beam tests with the CALICE tungsten analog hadronic calorimeter prototype	2012	CERN	Scientific community	-	International
44 [CDS link]	Scientific/ Technical note	Lucaci-Timoce, A et al.	Shower development of particles with momenta from 1 to 10 GeV in the CALICE Scintillator-Tungsten HCAL	2012	CERN + other institutes	Scientific community	-	International
45 [CDS link]	Status Report	The AIDA Collaboration	PROJECT INTERIM ACTIVITY REPORT FOR YEAR 1 : Public Version	2012	Geneva Switzerland	Scientific community	-	International
46 [CDS link]	Misc	The AIDA Collaboration	Topic proposal for integrating and opening existing national research infrastructures - AIDA contribution	2012	Geneva Switzerland	Scientific community	-	International
47 [CDS link]	Misc	The AIDA Collaboration	AIDA contribution to the European Strategy on Infrastructure for detector R&D	2012	Geneva Switzerland	Scientific community	-	International
48 [CDS link]	Misc	The AIDA Collaboration	DG Research AIDA Project Description	2012	Geneva Switzerland	Scientific community	-	International
49 [CDS link]	Scientific/ Technical note	Buonomo, B et al	Remote test bench equipped with service movable platoform in two axis : Manual instruction and warnings	2012	Geneva Switzerland	Scientific community	-	International
50 [CDS link]	Scientific/ Technical note	Obermann,T. et al	Implementation of a Configurable FE-I4 Trigger Plane for the AIDA Telescope	2012	Bonn, Germany	Scientific community	-	International
51 [CDS link]	Conference	Seller, P. et al	Through Silicon Via Redistribution of I/O Pads	2012	California USA	Scientific community	-	International
52 [CDS link]	Conference	Maj, P.et al	Tests of the First Three-Dimensionally Integrated	2012	Jeju Republic Of Korea	Scientific community	-	International
53 [CDS link]	Conference	Traversi, G. et al	Perspectives of 65 nm CMOS technologies for high performance front-end electronics	2012	Jeju Republic Of Korea	Scientific community	-	International

54 CDS link	Conference	Dierlamm, A	Characterisation of silicon sensor materials and designs for the CMS Tracker Upgrade	2012	Jeju Republic Of Korea	Scientific community	-	International
55 CDS link	Conference	Dalla Betta, G-F. et al	3D silicon sensors: irradiation results	2012	Jeju Republic Of Korea	Scientific community	-	International
56 CDS link	Conference	Viella, E et al.	Geiger-Mode Avalanche Photodiodes in Particle Detection	2012	Granada, Spain	Scientific community	1000	International
57 CDS link	Conference	Ruan, M	Shower fractal dimension analysis in a highly-granular calorimeter, 2nd International Conference on Mathematical Modeling in Physical Sciences (IC-MSQUARE 2013) :,	2013	Prague, Czech Republic	Scientific community	-	International
58 CDS link	Conference	Thomson, M	The Pandora software development kit, CHEF 2013/ Pandora Particle Flow Algorithm	2013	Paris, France	Scientific community	-	International
59 CDS link	Presentation	Thomson, M	Particle Flow Calorimetry, “Physics at the Terasale”	2013	Mainz, Germany	Scientific community	-	International
60 CDS link	Presentation	Mikenberg, G	Did the LHC Detectors meet our Expectations?	2013	Vienna, Austria	Scientific community	200	International
61 CDS link	Presentation	Wierba,W.	FCAL integration and alignment, LCWS 2013	2013	Tokyo Japan	Scientific community	-	International
62 CDS link	Poster/ Misc	Dannheim, D	Validation of hadron shower models using data from CALICE, The 2013 European Physical Society Conference on High Energy Physics	2013	Stockholm, Sweden	Scientific community	-	International
63 CDS link	Presentation	Moron, J	Readout electronics for LumiCal detector - present status and new development, European Linear Collider Workshop ECFA	2013	Hamburg, Germany	Scientific community	-	International
64 CDS link	Conference	Lopez, I.	Characterization and Beam Tests Results of Non-Uniformly Irradiated 3D Pixel Sensors for HEP Experiments	2013	Marseille, France.	Scientific community	-	International
65 CDS link	Presentation	Hügging, F.	Upgrades of the ATLAS Pixel Detector – From IBL to Phase 2, Vertex 2013	2013	Starnberg, Germany	Scientific community	-	International

66 CDS link	Presentation	Moron, J	Development of variable sampling rate, low power 10-bit SAR ADC in 130 nm IBM technology, TWEPP 2013 - Topical Workshop on Electronics for Particle Physics	2013	Perugia, Italy	Scientific community	-	International
67 CDS link	Conference	Szalay, M	The Time Structure of Hadronic Showers in Calorimeters with Scintillator and with Gas Readout, 14th ICATPP Conference on Astroparticle, Particle, Space Physics and Detectors for Physics Applications	2013	Como, Italy	Scientific community	-	International
68 CDS link	Conference	Macchiolo A.et al	Development of active edge pixel sensors and four side buttable modules using vertical integration technologies	2013	Hiroshima Japan	Scientific community	-	International
69 CDS link	Presentation	Wierba, W	The forward calorimetry for future linear collider – big challenge in detector building, Proceedings of the CHEF 2013 International Conference, Paris 2013, p 198	2013	Paris France	Scientific community	-	International
70 CDS link	Presentation	Ramilli, M	Towards hadronic shower timing with CALICE Analog Hadron Calorimeter, Calorimetry for High Energy Frontier	2013	Paris, France	Scientific community	-	International
71 CDS link	Conference	Krüger, K	Integration concepts for highly granular scintillator-based calorimeters, Calorimetry for High Energy Frontier	2013	Paris, France	Scientific community	-	International
72 CDS link	Presentation	Chadeeva, M	Characteristics of hadronic showers in the CALICE AHCAL, Calorimetry for High Energy Frontier	2013	Paris, France	Scientific community	-	International
73 CDS link	Presentation	Wierba,W.	Laser alignment system – current status report, 22th FCAL Collaboration Workshop	2013	Cracow, Poland	Scientific community	-	International
74 CDS link	Status Report	Ties Behnke, T. Abramowicz, H. et al	The International Linear Collider Technical Design Report - Volume 4: Detectors, arXiv:1306.6329	2013	-	Scientific community	-	International
75 CDS link	Conference	Eckstein, D.	CMS Outer Tracker Upgrade Plans PoS(Vertex 2013) 22nd International Workshop on Vertex Detectors, Vertex 2013	2013	Lake Starnberg, Germany	Scientific community	-	International

76 CDS link	Presentation	Frisson, T.	R&D for a highly granular SiW ECAL and analysis of beam tesT data, CHEF2013	2013	Paris, France	Scientific community	-	International
77 CDS link	Conference	Ruan, M	ARBOR, a new approach of the Particle Flow Algorithm, International Conference on Calorimetry for the High Energy Frontier (CHEF 2013)	2013	Paris, France	Scientific community	-	International
78 CDS link	Conference	Haddad, Y	First Results of the SDHCAL technological prototype, International Conference on Calorimetry for the High Energy Frontier (CHEF 2013)	2013	Paris, France	Scientific community	-	International
79 CDS link	Poster/ Misc	Mitev, G	"Radiation Monitoring at GIF++", poster 3rd EIROforum School on Instrumentation, CERN 2013	2013	CERN	Scientific community	-	International
80 CDS link	Conference	Vilella, E	SPADs for Vertex Tracker detectors in Future Colliders, 22nd International Workshop on Vertex Detectors, VERTEX	2013	Starnberg, Germany	Scientific community	-	International
81 CDS link	arXiv.org	Ruan, M	Druid, event display for the linear collider	2013	-	Scientific community	-	International
82 CDS link	Presentation	Iaydjiev,P	"Radiation Monitoring at New CERN Radiation Facility GIF++", XXIV International Symposium on Nuclear Electronics and Computing (NEC'2013) – CERN, JINR, INRNE,Varna, Bulgaria	2013	Varna, Bulgaria	Scientific community	-	International
83 CDS link	Conference	Tran, T.H.	ILD SiW ECAL and sDHCAL dimension-performance optimisation, International Workshop on Future Linear Colliders (LCWS13)	2013	Tokyo, Japan	Scientific community	-	International
84 CDS link	Scientific/ Technical note	Steen, A	Tracking within Hadronic Showers in the SDHCAL prototype using Hough Transform Technique	2013	-	Scientific community	-	International
85 CDS link	arXiv.org	Poeschl, R.	Calorimetry for Lepton Collider Experiments – CALICE results and activities	2013	-	Scientific community	-	International
86 CDS link	Scientific/ Technical note	Nash, W. et al.	Beam Profiling through Wire Chamber Tracking	2013	CERN, Switzerland	Scientific community	-	International

87 CDS link	Scientific/Technical note	D. Dannheim et al.	Particle Identification with Cherenkov detectors in the 2011 CALICE Tungsten Analog Hadronic Calorimeter Test Beam at the CERN SPS	2013	Geneva, Switzerland	Scientific community	-	International
88 CDS link	Scientific/Technical note	Lucaci-Timoce, A. et al	Shower development of particles with momenta from 10 to 100 GeV in the CALICE Scintillator-Tungsten HCAL	2013	CERN + other institutes	Scientific community	-	International
89 CDS link	Academic dissertation	Shi, L.	Characterization of a Compact, High Resolution Readout System for Micro Pattern Gaseous Detectors	2013	Lund, Sweden	Scientific community	-	International
90 CDS link	Conference	Reinecke, M	Performance of the Large Scale Prototypes of the CALICE Tile Hadron Calorimeter, IEEE NSS-MIC 2013	2013	Seoul, South Korea	Scientific community	-	International
91 CDS link	Conference	Polak, I	A Fast Calibration System for SiPM Based Scintillator HCAL Detector, IEEE NSS-MIC 2013	2013	Seoul, South Korea	Scientific community	-	International
92 CDS link	Academic Dissertation	Menzen, R.et al	InGrid based TPC readout	2013	Bonn, Germany	Scientific community	-	International
93 CDS link	Article/ Misc	Dafni, T. et al	Micropattern-detector experts meet in Zaragoza	2013	Geneva Switzerland	Scientific community	-	International
94 CDS link	Newsletter/Misc	Rubinsky, I.	Commissioning tests of the AIDA telescope	2013	Geneva Switzerland	Scientific community	-	International
95 CDS link	Article/ Misc	Sefkow, F. et al	AIDA: Concerted Calorimeter Development, CERN Bulletin	2013	Geneva Switzerland	Scientific community	-	International
96 CDS link	Newsletter/ Misc	Vos, M. et al	Pixel party	2013	Bristol UK	Scientific community	-	International
97 CDS link	Conference	Re, V	The path towards the application of new microelectronic technologies in the AIDA community	2013	Lake Starnberg Germany	Scientific community	-	International
98 CDS link	Conference	Seguin-Moreau, N et al	ROC chips for imaging calorimetry at the International Linear Collider	2013	Paris France	Scientific community	-	International
99 CDS link	Conference	Frank, M et al	DD4hep: A Detector Description Toolkit for High Energy Physics Experiments	2013	Amsterdam, Netherlands	Scientific community	-	International

100 CDS link	Conference	Agocs, A. et al	Collaboration Spotting	2013	Rio De Janeiro, Brazil	Scientific community	-	International
101 CDS link	Conference	Bassignana, D. et al	2D Position Sensitive Microstrip Sensors with Charge Division Along the Strip: Studies on the position measurement error	2013	Vienna Austria	Scientific community	-	International
102 CDS link	arXiv	Andricek,L et al	SLID Interconnected n-in-p Pixel Modules with 75 Micrometer Thin Silicon Sensors	2013	Geneva Switzerland	Scientific community	-	International
103 CDS link	Conference	Briggl, K et al.	Characterization results and first applications of KLauS - an ASIC for SiPM charge and fast discrimination readout	2013	Seoul, Korea	Scientific community	-	International
104 CDS link	Conference	French, R	Scanning facility to irradiate mechanical structures for the LHC upgrade programme	2014	-	Scientific community	-	International
105 CDS link	Conference	Zawiejski,L.	Progress in the LumiCal alignment, 25th FCAL Collaboration Workshop, it will appear in the workshop Proceedings	2014	Belgrade, Serbia	Scientific community	-	International
106 CDS link	Scientific/Technical note	Cvach, J. et al	Characterization of the Gain Dependence on Temperature in Silicon Photomultipliers	2014	Geneva, Switzerland	Scientific community	-	International
107 CDS link	Academic Dissertation	Asfandiyarov, R	Totally Active Scintillator Tracker-Calorimeter for the Muon Ionization Cooling Experiment	2014	Geneva, Switzerland	Scientific community	-	International
108 CDS link	ArXiv	Cvach, J. et al	Gain stabilization of SiPMs	2014	Tokyo, Japan	Scientific community	-	International
109 CDS link	Presentation	Sicking, E	Comparison of test beam data from imaging calorimeters with GEANT4 simulations, 37th International Conference on High Energy Physics	2014	Valencia, Spain	Scientific community	-	International
110 CDS link	Misc	Krüger, K	Prototype tests for a highly granular scintillator-based hadron calorimeter, 15th International Conference on Calorimetry in High Energy Physics	2014	Giessen, Germany	Scientific community	-	International
111 CDS link	Conference	Sicking, E	Shower characteristics of particles with momenta up to 100 GeV in the CALICE Scintillator-Tungsten HCAL, 15th International Conference on Calorimetry in High Energy Physics	2014	Giessen, Germany	Scientific community	-	International

112 CDS link	Conference	Chadeeva, M	Hadron shower decomposition in a highly granular calorimeter, 16th International Conference on Calorimetry in High Energy Physics	2014	Giessen, Germany	Scientific community	-	International
113 CDS link	Conference	Szalay, M	The time structure of hadronic showers in calorimeters with scintillator and with gas readout	2014	Giessen, Germany	Scientific community	-	International
114 CDS link	Conference	Gkotse, B	A New High-intensity Proton Irradiation Facility at the CERN PS East Area Technology and Instrumentation in Particle Physics 2014	2014	Amsterdam, Netherlands	Scientific community	-	International
115 CDS link	Conference	Jakel, M.R	CERN GIF++ : A new irradiation facility to test large-area particle detectors for the high-luminosity LHC program Technology and Instrumentation in Particle Physics 2014	2014	Amsterdam, Netherlands	Scientific community	-	International
116 CDS link	Presentation	Moron, J	Development of front-end electronics for LumiCal detector in CMOS 130 nm technology, TWEPP 2014 - Topical Workshop on Electronics for Particle Physics	2014	Aix en Provence, France	Scientific community	-	International
117 CDS link	Conference	Hedberg, V. et al	Front-end electronics and readout system for the ILD TPC, Topical Workshop on Electronics for Particle Physics	2014	-	Scientific community	-	International
118 CDS link	Presentation	Wierba, W.	Laser alignment system status and future plans, 24th FCAL Collaboration Workshop	2014	Bucharest, Romania	Scientific community	-	International
119 CDS link	arXiv.org	Lettenbichler, J	Demonstrator of the Belle II Online Tracking and Pixel	2014	-	Scientific community	-	International
120 CDS link	Presentation	Diener, R.	LCTPC Setup at the DESY Testbeam, Americas Workshop on Linear Colliders 2014, AWLC14, 05/12/2014 - 05/16/2014	2014	Batavia, USA	Scientific community	-	International
121 CDS link	Presentation	Voutsinas, G. G. Gaede, F.	Progress in Track Reconstruction ILD Meeting 2014	2014	Oshu, Japan	Scientific community	-	International

122 CDS link	Presentation	Rubinskiy, I Perrey, H	An EUDET/AIDA Pixel Beam Telescope for Detector Development TIPP 2014, Amsterdam	2014	Amsterdam	Scientific community	-	International
123 CDS link	Presentation	Cornat, R	Technological Prototype of a Silicon-tungsten Imaging Electromagnetic Calorimeter, TWEPP2014	2014	Aix-en-Provence,France	Scientific community	-	International
124 CDS link	Academic thesis	Rouëné, J.	A Highly Granular Silicon-Tungsten Electromagnetic Calorimeter and Top Quark Production at the International Linear Collider, LAL 14-154	2014	Orsay, France	Academic community	-	International
125 CDS link	presentation	Vilella et al.	Strategies for using GAPDs as tracker detectors in future linear colliders, 37th International Conference on High Energy Physics (ICHEP 2014)	2014	Valencia, España	Scientific community	-	International
126 CDS link	Poster/ Misc	Alonso et al.	Readout electronics for the Silicon micro-strip detector of the ILD concept, , 37th International Conference on High Energy Physics (ICHEP 2014)	2014	Valencia, España	Scientific community	-	International
127 CDS link	arXiv.org	Bilki, B.	Pion and proton showers in the CALICE scintillator-steel analogue hadron calorimeter	2014	-	Scientific community	-	International
128 CDS link	Conference	Gaede, F	Track reconstruction at the ILC: the ILD tracking software	2014	-	Scientific community	-	International
129 CDS link	arXiv.org	Darbo, G et al	Experience on 3D Silicon Sensors for ATLAS IBL	2014	-	Scientific community	-	International
130 CDS link	arXiv.org	van der Kolk, N	Testing Hadronic Interaction Models using a Highly Granular Silicon-Tungsten Calorimeter	2014	-	Scientific community	-	International
131 CDS link	arXiv.org	Calderini, G. et al	Achievements of the ATLAS Upgrade Planar Pixel Sensors R&D Project	2014	-	Scientific community	-	International
132 CDS link	arXiv.org	Abramowicz, H. et al.	Performance of fully instrumented detector planes of the forward calorimeter of a Linear Collider detector	2014	-	Scientific community	-	International

133 [CDS link]	arXiv.org	Abramowicz, H. et al.	ECFA Detector R&D Panel, Review Report	2014	-	Scientific community	-	International
134 [CDS link]	Conference	Pöschl, R.	R&D for a highly granular silicon tungsten electromagnetic calorimeter	2014	-	Scientific community	-	International
135 [CDS link]	Status Report	Zawiejski, L	The optical alignment sytem for luminosity detector at ILC, Report on-line, Report No. 2071/PH	2014	Cracow, Poland	Scientific community	-	International
136 [CDS link]	Presentation	Boudry, V.	Development of technological prototype of silicon-tungsten electromagnetic calorimeter for ILD, 3rd International Conference on Technology and Instrumentation in Particle Physics (TIPP 2014)	2014	Amsterdam, Netherland	Scientific community	-	International
137 [CDS link]	Presentation	Gastaldi, F	A scalable gigabit data acquisition system for calorimeters for linear collider, 3rd International Conference on Technology and Instrumentation in Particle Physics (TIPP 2014)	2014	Amsterdam Netherland	Scientific community	-	International
138 [CDS link]	Scientific/ Technical note	Chadeeva, M	Extraction of h/e and calorimeter response from fits to the longitudinal shower profiles in the CALICE Sc-Fe AHCAL	2014	-	Scientific community	-	International
139 [CDS link]	Scientific/ Technical note	Chadeeva, M	Parametrisation of hadron shower profiles in the CALICE Sc-Fe AHCAL	2014	-	Scientific community	-	International
140 [CDS link]	Scientific/ Technical note	Bergauer, T.	Silicon micro-strip ladders	2014	Vienna, Austria	Scientific community	-	International
141 [CDS link]	Scientific/ Technical note	Bron, S	EASIROC and CITIROC chip studies for neutrino detector prototypes	2014	Geneva, Switzerland	Scientific community	-	International
142 [CDS link]	Status Report	Hedberg, V. et al	Front-end Electronics for the TPC in ILD; a Status Report April 2014	2014	Lund, Sweden	Scientific community	-	International
143 [CDS link]	Conference	Levy, A	CLICdp Overview: Overview of physics potential at CLIC	2014	Crete, Greece	Scientific community	263	International

144 CDS link	arXiv.org	Noah, E	Proposal for SPS beam time for the baby MIND and TASD neutrino detector prototypes	2014	Geneva, Switzerland	Scientific community	-	International
145 CDS link	Academic thesis	Obermann, T. et al	Development of a test beam telescope based on the ATLAS front end ASIC FE-I4	2014	Bonn, Germany	Scientific community	-	International
146 CDS link	Scientific/ Technical note	Kersten, S	The AIDA DCS2 System	2014	Geneva Switzerland	Scientific community	-	International
147 CDS link	Scientific/ Technical note	Kersten, S. et al	The AIDA DCS1 System	2014	Geneva Switzerland	Scientific community	-	International
148 CDS link	Scientific/ Technical note	Borghi, S. et al	AIDA Alignment package user guide	2014	Manchester UK	Scientific community	-	International
149 CDS link	Presentation	Simon, F	The Time Structure of Hadronic Showers in Analog and Digital Calorimeters confronted with Simulations, International Conference on Technology and Instrumentation in Particle Physics 2014	2014	Amsterdam, The Netherlands	Scientific community	-	International
150 CDS link	Presentation	Klempt, W	Shower characteristics of particles with momenta from up to 100 GeV in the CALICE Scintillator-Tungsten HCAL, International Conference on Technology and Instrumentation in Particle Physics 2014	2014	Amsterdam, The Netherlands	Scientific community	-	International
151 CDS link	Conference	Neubüser, C	Analogue, Digital and Semi-Digital Energy Reconstruction in the CALICE AHCAL, International Conference on Technology and Instrumentation in Particle Physics 2014	2014	Amsterdam, The Netherlands	Scientific community	-	International
152 CDS link	Conference	Neuhaus, S	A neural network z-vertex trigger for Belle II	2014	Prague, Czech Republic	Scientific community	-	International
153 CDS link	Conference	Gastaldi, F et al.	A scalable gigabit data acquisition system for calorimeters for linear collider	2014	Netherlands	Scientific community	-	International
154 CDS link	Presentation	De Aguiar, F. Oscar,A	Evaporative CO2 microchannel cooling for the LHCb VELO Pixel Upgrade	2014	Ontario, Canada	Scientific community	-	International

155 CDS link	Scientific/ Technical note	Rubinskiy, I et al.	EUTelescope 1.0: Reconstruction Software for the AIDA Testbeam Telescope	2015	Hamburg, Germany	Scientific community	-	International
156 CDS link	Scientific/ Technical note	Rubinskiy, I	Evolving the DAQ and Analysis Software of the AIDA Telescope: Toward high rates and one-trigger-per-particle Operation	2015	-	Scientific community	-	International
157 CDS link	Conference	Citterio, M	Evaluating Multi-Gigabit Transceivers (MGT) for Use in High Energy Physics Through Proton Irradiation. Submitted to The Nuclear and Space Radiation Effects Conference (NSREC) 2015	2015	Boston, USA	Scientific community	-	International
158 CDS link	Scientific/Technical note	Puigdengoles, C Grinstein, S.	Design and operation of a QUAD PCB for the AIDA beam telescope	2015	-	Scientific community	-	International
159 CDS link	Status Report	Hedberg, V. et al	Final AIDA report on the development of readout electronics for a TPC and some future prospects	2015	Lund, Sweden	Scientific community	-	International
160 CDS link	Status Report	Noah, E	AIDA MIND redesign status	2015	-	Scientific community	-	International

ANNEX II: GLOSSARY

ASIC	Application-Specific Integrated Circuit
AIME	Academia-Industry Matching Event
BACH	Basic Alignment and Reconstruction Chain
BTF	Beam Test Facility
CALICE	CAlorimeter for LInear Collider Experiment
CDS	CERN Document Server
DHCAL	Digital Hadron Calorimeter
CHEF	Calorimetry for High Energy Physics Frontier
CHEP	Computing in High Energy and Nuclear Physics
CLIC	Compact Linear Collider
CMOS	Complementary Metal Oxide Semiconductor
CMS	Compact Muon Solenoid
DAQ	Data Acquisition
DUT	Device Under Test
DCS	Detector Control System
ECAL	Electromagnetic CALorimeter
EDMS	Electronic Document Management System
EUDET	FP6 project - Detector R&D towards the International Linear Collider
FCC	Future Circular Collider
FLUKA	A multi-particle transport code for simulation
GBL	General Broken Lines
GEM	Gas Electron Multiplier
GRPC	Glass Resistive Plate Chambers
JRA	Joint Research Activities
HARDROC3	Hadronic Calorimeter Read Out Chip
HCAL	Hadron Calorimeter
HEP	High Energy Physics
HL-LHC	High Luminosity Large Hadron Collider
IBL	Insertable B Layer
ILC	International Linear Collider
IRRAD	Irradiation facility at CERN
IP	Intellectual Property
LHC	Large Hadron Collider

LYSO	$Lu_{1.8}Y_{0.2}SiO_5(Ce))$ cristal
MEDIPIX	Readout Chip for pixel detector
MPGD	Micro Pattern Gas Detector
MICE	Muon Ionization Cooling Experiment
MIND	Magnetized Iron Neutrino Detector
MPW	Multi Project Wafer
NA	Networking Activities
PET	Positron Emission Tomography
RADMON	Radiation Monitors
RPC	Resistive Plate Chamber
ROOT	Data analysis framework
SALAT	Single Arm Large Area Telescope
SDHCAL	Semi Digital Hadronic Calorimeter
SLID	Solid-Liquid-InterDiffusion
SOI	Silicon on Insulator
TA	Transnational Access
TASD	Totally Active Scintillator Detector
TGC	Thin Gap Chamber
TIPP	Technology and Instrumentation in Particle Physics
TLU	Timing Logic Unit
TSV	Through Silicon Vias
TWEPP	Topical Workshop on Electronics for Particle Physics
VELO	LHCb Vertex Detector

ANNEX III: LIST OF AIDA BENEFICIARIES

No	Name	Short name	Country
1	European Organization for Nuclear Research	CERN	IEIO[17]
2	Oesterreichische Akademie der Wissenschaften	OEAW	Austria
3	Université Catholique de Louvain	UCL	Belgium
4	Université Libre de Bruxelles	ULB	Belgium
5	Institute of Nuclear Research and Nuclear Energy - Bulgarian Academy of Sciences	INRNE	Bulgaria
6	Academy of Sciences of the Czech Republic - Institute of Physics (Fyzikalni Ustav Av Cr V.V.I)	IPASCR	Czech Republic
7	Commissariat à l'Energie Atomique et aux Energies Alternatives	CEA	France
8	Centre National de la Recherche Scientifique	CNRS	France
9	Stiftung Deutsches Elektronen-Synchrotron	DESY	Germany
10	Karlsruher Institut Fuer Technologie	KIT	Germany
11	Max Planck Gesellschaft zur Foerderung der Wissenschaften	MPG-MPP	Germany
12	Rheinische Friedrich-Wilhelms-Universitat Bonn	UBONN	Germany
13	Bergische Universitaet Wuppertal	Wuppertal	Germany
15	Magyar Tudomanyos Akademia Wigner Fizikai Kutatokozpont	WIGNER RCP	Hungary
16	Tel Aviv University	TAU	Israel
17	Weizmann Institute of Science	Weizmann	Israel
18	Istituto Nazionale di Fisica Nucleare	INFN	Italy
19	Vilniaus Universitetas	VU	Lithuania
20	Stichting voor Fundamenteel Onderzoek der Materie	FOM	Netherlands
21	Universitetet i Bergen	UiB	Norway
22	Akademia Gorniczo-Hutnicza im. Stanislawa Staszica w Krakowie	AGH-UST	Poland
23	The Henryk Niewodniczanski Institute of Nuclear Physics, Polish Academy of Sciences	IFJPAN	Poland
24	Institut Jožef Stefan	JSI	Slovenia
25	Agencia Estatal Consejo Superior de Investigaciones Cientificas	CSIC	Spain
26	Universitat de Barcelona	UB	Spain
27	Uppsala Universitet	UU	Sweden

[17] International European Interest Organisation

28	Lunds Universitet	ULund	Sweden
29	Université de Genève	UNIGE	Switzerland
30	Royal Holloway and Bedford New College	RHUL	UK
31	Science and Technology Facilities Council	STFC	UK
32	The Chancellor, Masters and Scholars of the University of Cambridge	UCAM	UK
33	University of Glasgow	UNIGLA	UK
34	University of Liverpool	UNILIV	UK
35	University of Bristol	UNIBRIS	UK
36	The Chancellor, Masters and Scholars of the University of Oxford	UOXF.DL	UK
37	University of Sheffield	USFD	UK
38	University of Manchester	UNIMAN	UK
40	Institute of Accelerating Systems and Applications	IASA	Greece