Lepton Universality: Summary report

Marie Curie project 271987

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The aim of the project was the upgrade of the CEDAR detector (a Cherenkov particle tagger) for the operation in a very high intensity beam at the NA62 experiment at CERN, the flagship of the near-future European kaon research programme. This crucial part of equipment is essential for the experiment to reach an unprecedented precision, and opens a range of new possibilities to probe indirectly the nature of new physics at the TeV energy scale, including Lepton Universality tests at record sensitivity. The project involved the development and tests of electronics, data acquisition, monitoring and detector simulation tools, and optimization of the detector performance.

The TEL62 data acquisition circuit board (which in an adaptation of a board developed for the LHCb experiment at the LHC collider at CERN) is employed for the CEDAR electronic read-out. The full readout chain involving a light-emitting diode (LED), a photomultiplier (PMT), a preamplifier, a Time-Over-Threshold NINO board, a Time-to-Digital-Converted (TDC) and a TEL62 board plus a data acquisition PC was set up and tested in order to identify the limitations of the system in terms of maximum signal rate. The TDC to be used the data taking was tested together with TEL62 board with 40 MHz and 80 MHz internal clock. Testing the TDC at 80 MHz clock necessitated an upgrade of TELL1 firmware. The rate tests have been conducted with both regular pulses and randomly generated pulses (the latter simulating asynchronous arrival of kaons). The preamplifier designed for the high radiation environment was found to be too noisy and caused loss in time precision. As a consequence of the test, the decision to remove preamplifier, and connect PMTs directly to NINO with a differential cable was taken. Further tests were performed and it has been demonstrated that the readout chain works correctly in this mode. The other major result of these studies is the confirmation that at the signal rate of 3–5 MHz per channel (as expected from detector simulations) the readout inefficiency is very small or negligible, thanks to adopting a 80 MHz clock.

The developed readout hardware, as well as the event reconstruction and online monitoring software have been designed and largely integrated into the general NA62 framework. The CEDAR detector performance has been studied during a test beam at CERN carried out in September 2011. A set of photodetectors of the modern type to be used by the NA62 experiment, and the full chain of the new fast electronics and the new data acquisition and event reconstruction software has been tested and validated, which allowed a successful measurement of light collection efficiency by the new PMTs during the test run.

A detailed model of the CEDAR detector based on the GEANT4 simulation package has been developed, and fully integrated into the software framework of the NA62 experiment. The simulation has reached a high level of detail, including precise geometry description, measured transmittances of lenses and reflectivities of the mirror and cone surfaces, and quantum efficiencies of the photomultipliers. A realistic digitization code was developed to model the performance of the photodetectors. A package allowing to run fast CEDAR performance studies in a stand-alone mode has been deigned, to enable the performance and behaviour of the detector to be simulated and optimized following the hardware tests.

The advanced simulation framework allowed interpreting the results of the 2011 test beam, and validating the overall measured light yield by comparison to the simulations. The comparison to data samples taken with various geometrical configurations of photodetectors was crucial to validate the quality of the simulation. The light collection system for the physics data

taking of the NA62 experiment at full luminosity (scheduled for 2014) has been optimized: the light yield has been computed for a variety geometrical configurations. A major result was the definition of a layout of optical components and PMTs with optimal light collection efficiency, and optimized photon rates per PMT. The final choice of the design will be validated during the test run in 2012. Another important result was the justification of the need to introduce additional light-focusing lenses for optimal light collection. The simulation also allowed the study of different gases as Cherenkov light medium and the background contamination in the kaon identification procedure.

The Fellow has obtained practical skills with readout electronics and devising laboratory settings to perform electronics tests. He obtained additional expertise with particle physics simulation toolkits, detector optimization and software design. Also, working in a team at a British university, the Fellow has enhanced his capabilities to communicate in English (which is not his native language) and presentation skills. Finally, the Fellow has received valuable experience in the supervision of undergraduate and graduate students.

The above achievements open a concrete way to fully integrate the CEDAR detector into the NA62 experiment at CERN, which is pre-requisite for achieving the goals of the experiment in the studies of rare decays and lepton universality tests. Contributing to the success of NA62, which is one of major current particle physics experiments in Europe and the largest kaon project of the decade in the world, will help boost the European claim to remain the leading centre of particle physics research, which continues answering fundamental questions and producing knowledge exchange and spin-off technologies. The success of the NA62 experiment will consolidate European leadership in Standard Model tests in the lepton sector and in rare kaon decays.