Final review meeting of the JST-EU joined research program "Superconductivity"

Monday 9th March 2015
JST Tokyo Headquarters(K's Gobancho)

SuperIron

Exploring the potential of Iron-based Superconductors

Jun-ichi Shimoyama — *The University of Tokyo*

Marina Putti — *CNR-SPIN*

www.super-iron.eu

European Partners

PI: M Putti

Japanese Partners

PI: J-I Shimoyama

- M Putti, CNR-SPIN (Italy)
- J Karpinski, EPFL (Switzerland)
- B Holzapfel IFW (Germany)
- D Johrendt, LMU (Germany)
- M Eisterer, TU (Austria)

- J-I Shimoyama THE UNIVERSITY OF TOKYO
- T Kiss, Kyushu University
- H Eisaki, AIST
- Y Takano, NIMS

Outline

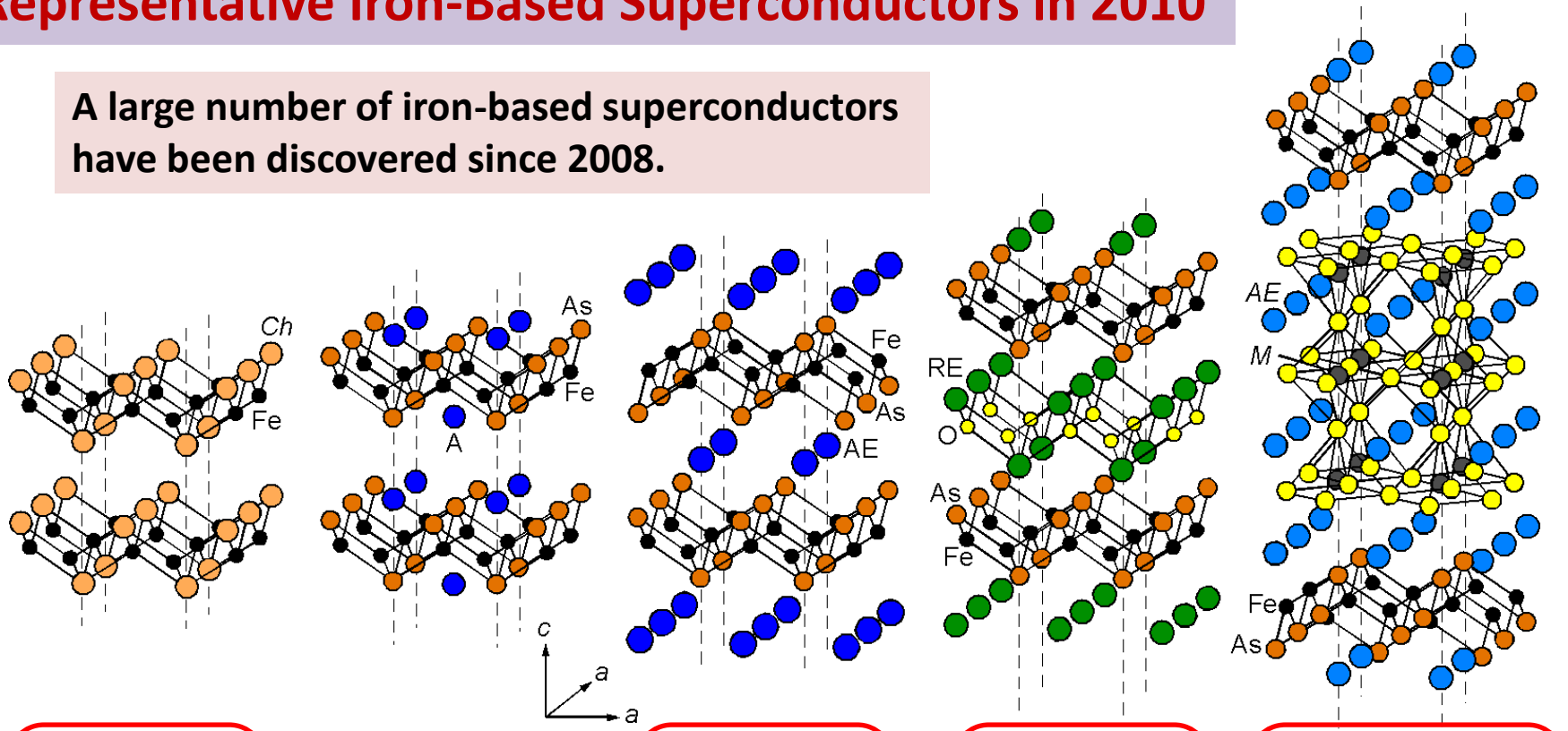
1. Introduction
2. New Superconductors
3. Synthesis of High Quality Superconductors
4. Tuning of Superconducting Properties
5. Thin Films
6. Evaluation of Grain Boundary Characteristics
7. Fabrication of High Performance Tapes
8. Modelling
9. Summary on Publications, Patents and Exchanges
10. Conclusions

Introduction

by J-i Shimoyama

Representative Iron-Based Superconductors in 2010

A large number of iron-based superconductors have been discovered since 2008.



FeCh	AFeAs	$AEFe_2As_2$	REFeAsO	$(Fe_2As_2)(AE_4M_3O_8)$
[11]	**[111]**	**[122]**	**[1111]**	**[PB: 22438]**
Ch: Se, Te, S	A: Li, Na	AE: Ba, Sr	RE: rare earth	*M* : (Sc,Ti), (Mg,Ti)
T_c~15 K	**T_c~18 K**	**T_c~38 K**	**T_c~55 K**	**T_c~47 K**
simple As-free high T_c by pressure		high H_{c2} low anisotropy various doping	very high H_{c2} various doping	tunable lattice various doping

Major Purpose of SUPER-IRON Through 3.5 Years Project

Exploration of derivable potential of iron-based superconductors

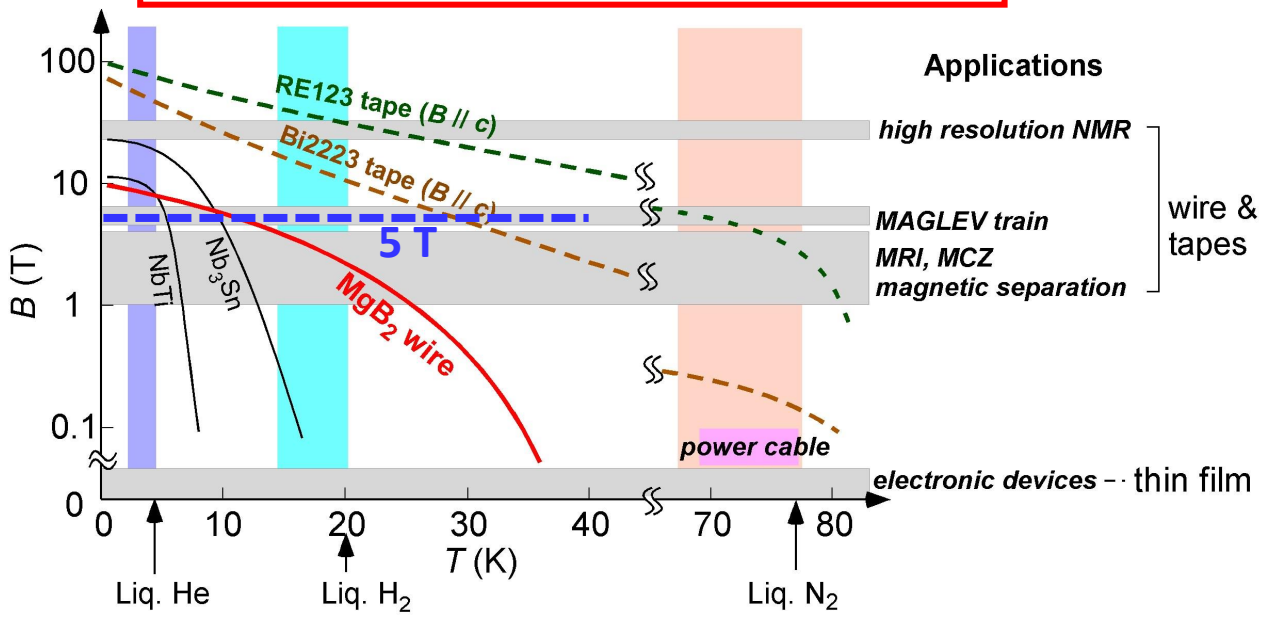
to judge whether they are promising materials or not

Criterion for judgment

$J_c > 10^5$ A cm^{-2} in 5 T (up to 15 K) ⇨ $J_E > 10^4$ A cm^{-2} (tapes or wires)

Applicable conditions of superconducting materials

$J_E > 10^4$ A cm^{-2} for long length conductors



Objectives of SUPER-IRON

1. **Developing preparation methods**
   of single crystals, thin films, and polycrystals

2. **Qualifying the ultimate potential of iron-based superconductors for high field applications**,
   after optimization of sample quality and grain boundary properties

3. **Comparison the developable potential with that of already existing superconductors** (HTSC, MgB_2, Nb based SC)

Work Packages To Achieve Purpose Through EU-Japan Collaboration

WP1: Iron-based material preparation

WP2: Advanced characterization

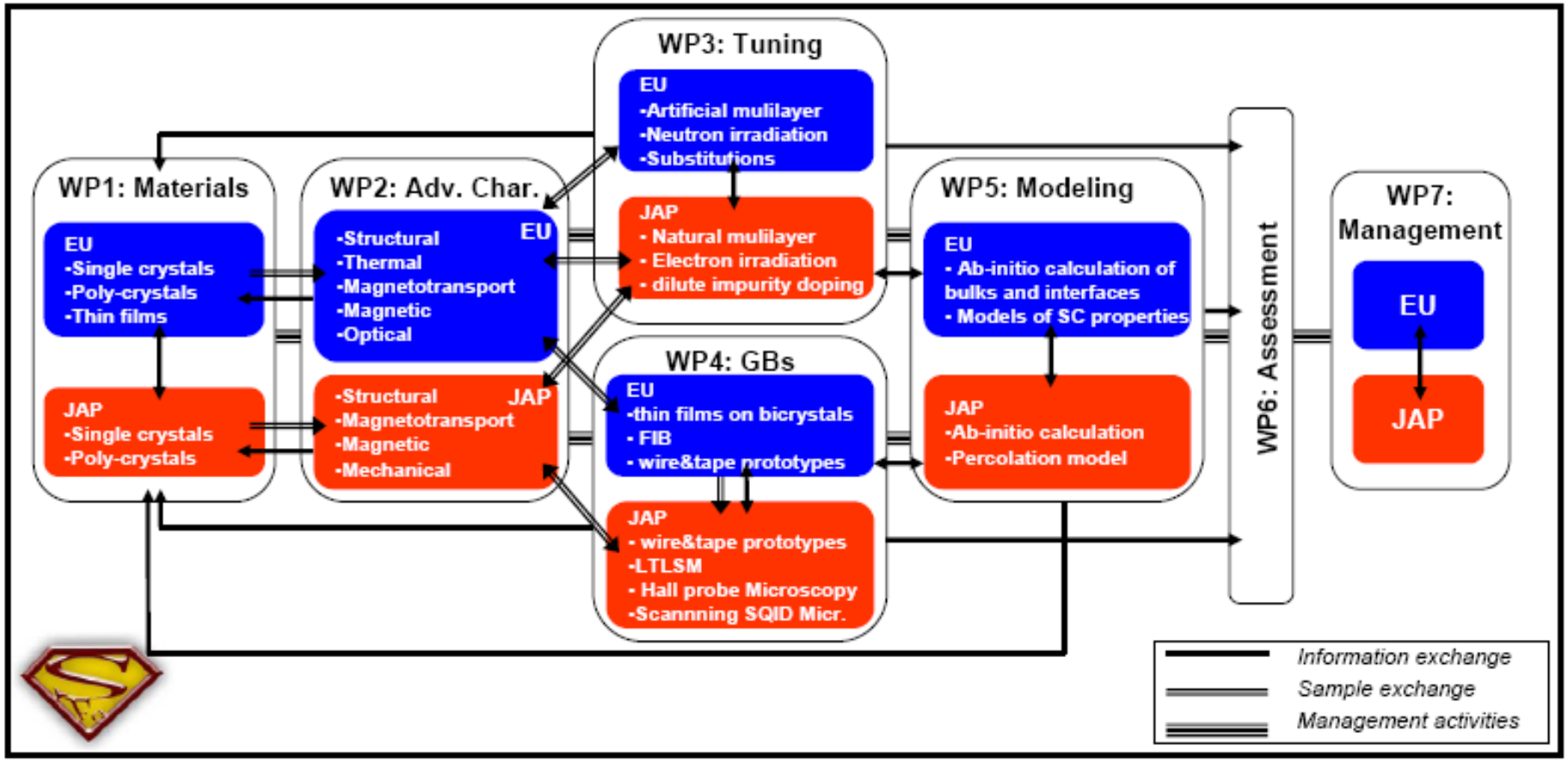
WP3: Tuning of the superconducting properties

WP4: The issue of Grain Boundaries

WP5: Modelling

WP6: Assessment

WP7: Management



Developing preparation methods

Single crystals
EPFL
AIST,NIMS

Thin films
IFW
CNR

Poly crystals
LMU, CNR
UT, AIST

Wires and tapes
CNR
NIMS

Advanced characterization

Structural
IFW, LMU
AIST, NIMS

Magnetic, thermal, transport
IFW,CNR,TUW, EPFL
AIST, NIMS, UT

Local probe of SC properties
TUW
KU

Tuning of the superconducting properties

Particle irradiation

TUW

TU

Impurity doping

LMU

TU

Multilayers

IFW, CNR

TU

Theoretical modeling of the effect of impurities

CNR

IFW

The issue of grain boundaries

thin films on bicrystals

IFW

CNR

Theoretical modeling of interfaces

CNR

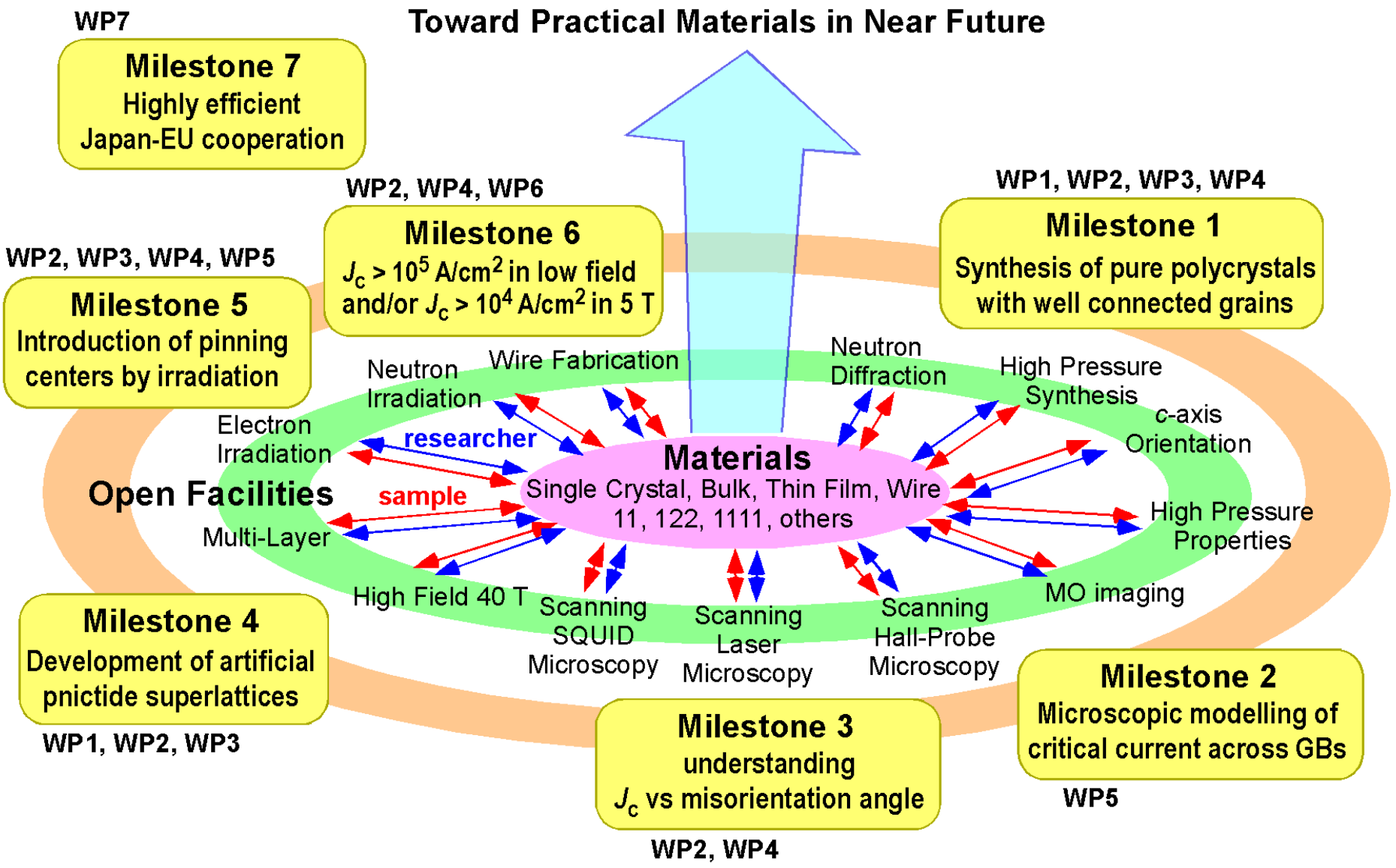
IFW

Realization of wire-tape prototypes

IFW,CNR

NIMS, AIST

Concept of SUPER-IRON



New Superconductors

by J-i Shimoyama

UT → PB, 112, BiOS

AIST → PB, 112, others

NIMS → BiS

EPFL → 42214

LMU → $[(Li_{0.8}Fe_{0.2})OH]FeSe$

Synthesis of High Quality Superconductors

by J-i Shimoyama

UT → 1111, PB

AIST → 122, 112, 111

NIMS → 11

EPFL → 1111sc

LMU → 1111

Tuning of Superconducting Properties

by J-i Shimoyama

UT → 1111, PB

AIST → 122sc

NIMS → 1111

EPFL → 1111sc

LMU → 1111

TUW → 1111, 122

THIN FILMS

by M Putti

IFW → 122 thin films

CNR → 11 thin films

KU → scanning Hall probe microscopy

TUW → Angle-resolved transport measurements

☑ Effect of the strain

☑ Optimization of the superconducting properties

EVALUATION OF GRAIN BOUNDARY CHARACTERISTICS

by M Putti

UT → 1111 and 122 bulks

CNR → 11 bulks

KU → Scanning Hall probe microscopy

TUW → transport measurements and modelling

☑ Optimization of sinthesys processes

☑ Systematic studies of the intergrain J_c

FABRICATION OF TECHNOLOGICAL CONDUCTORS

by M Putti

NIMS → 11 PIT wires/tapes

CNR → 11 &122 PIT wires/tapes

AIST → 122 PIT tapes

IFW → 122 coated conductors

☑ Improvement of the phase purity and density

☑ Biaxially texturing on technical substrates

THEORETICAL RESULTS
by M Putti

CNR → ab-initio calculation

IFW → modelling

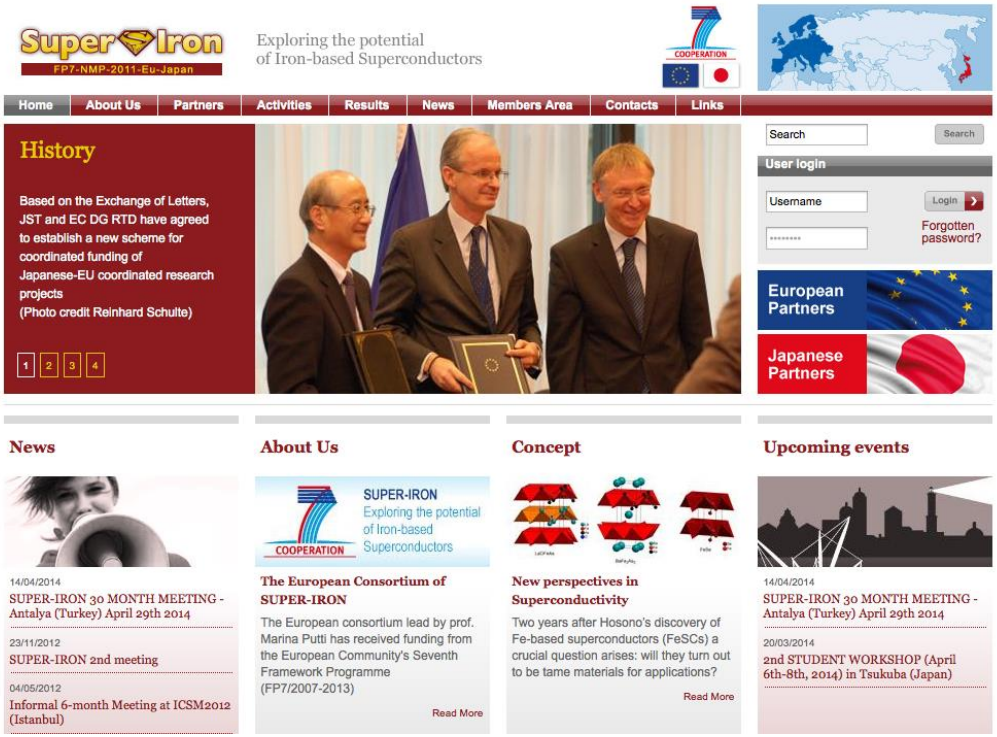
- ☑ Theoretical **Interpretation** of experimental results
- ☑ Theoretical **Understanding** of New Materials
- ☑ **Predictions** of New Superconductors

QUANTITATIVE ASSESSMENT
by M Putti

- ☑ Dissemination
- ☑ Exploitation
- ☑ Training
- ☑ Recruitment
- ☑ Follow up

Project's website: www.super-iron.eu

Dissemination



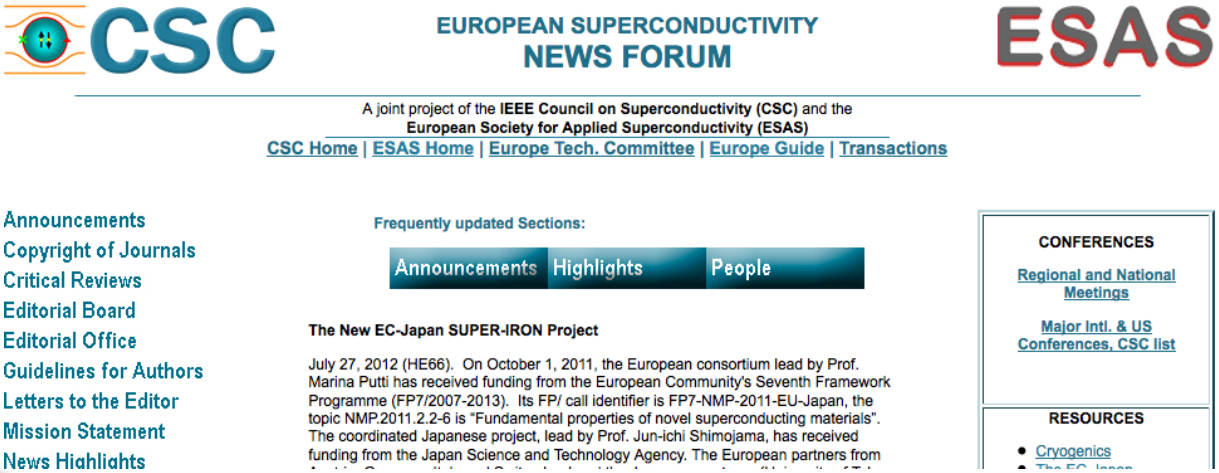
Wednesday September 18th from 16:15 to 18:30

[3A-EL] Squid Applications Room Libeccio 176

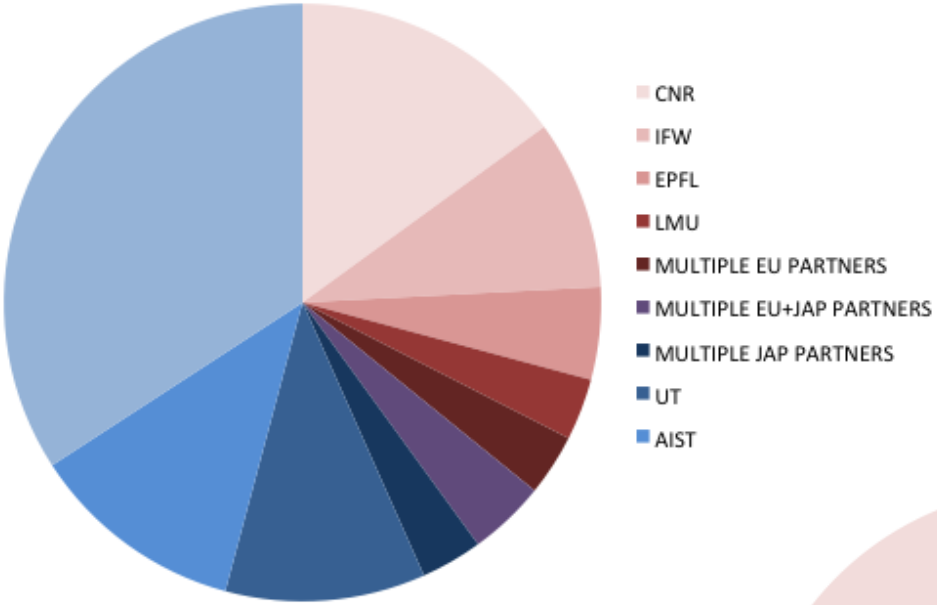
[3A-MA1] Fe-based Superconductors - Bulks and Tapes (hosted by SUPER-IRON EU-Japan project) Room Maestrale 177

[3A-MA2] Pinning and Flux Dynamics I - in memory of John Clem Room Levante e Ponente 179

[3A-SS] HTS Conductor Form - The Device Builders' Point of View Room Scirocco 180

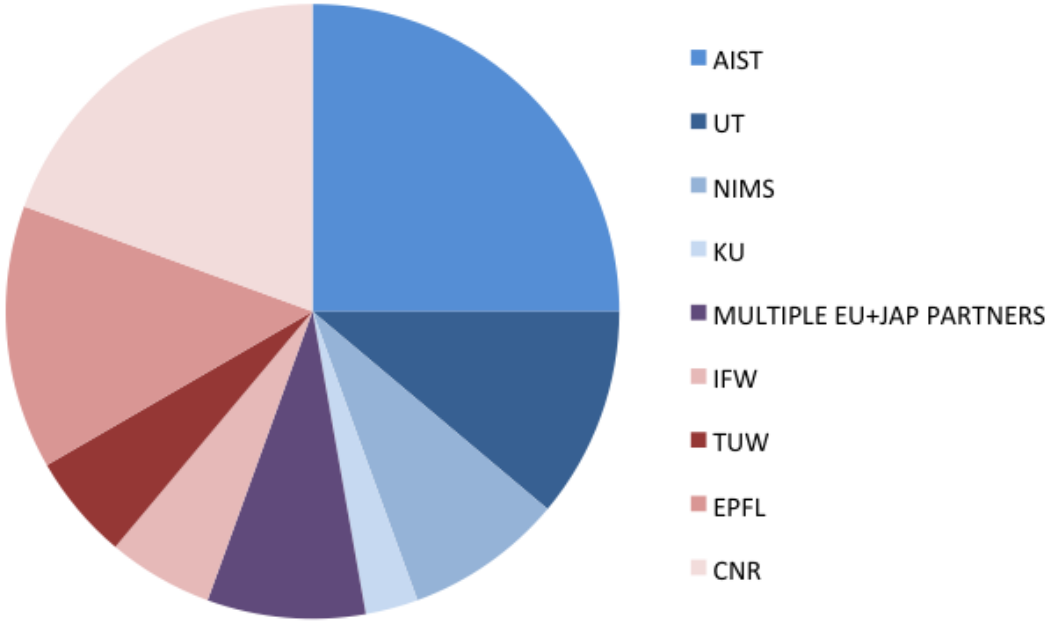


Dissemination



120 pubblications
on Intern. Journ.
13 by multiple partners

159 communications
17 joint (Eu&Jap partners)
36 invited talks



Exploitation

Two patents by AIST group

- **new superconductors and synthesis**
- **Phosphorous superconductors and their application**

Meetings

Kick-off meeting
Genova, December 2011

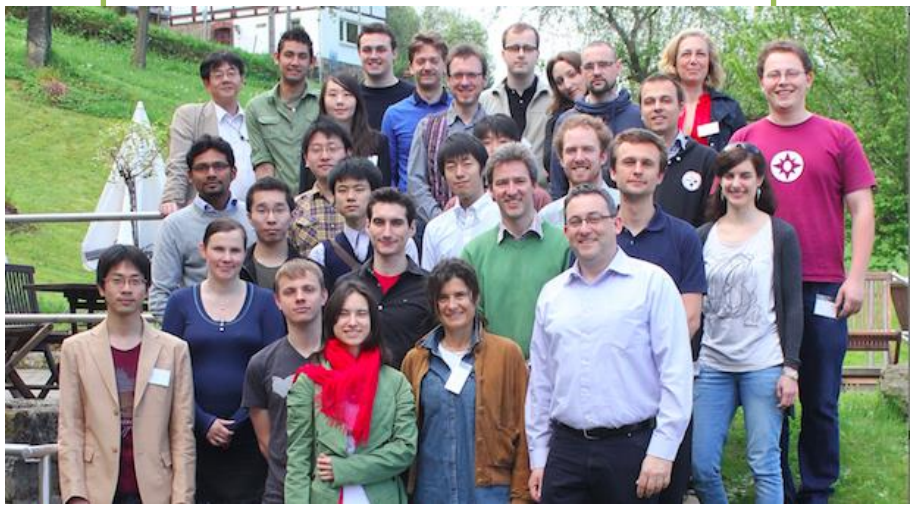
2nd meeting
Yamanaka Dormitory-naito Seminar House,
November, 30th - December 2nd, 2012

3rd meeting
Genova, September 2013

Final meeting
JST Tokyo Headquarters,
Science Plaza,
10th-11th March, 2015

Training of young researchers

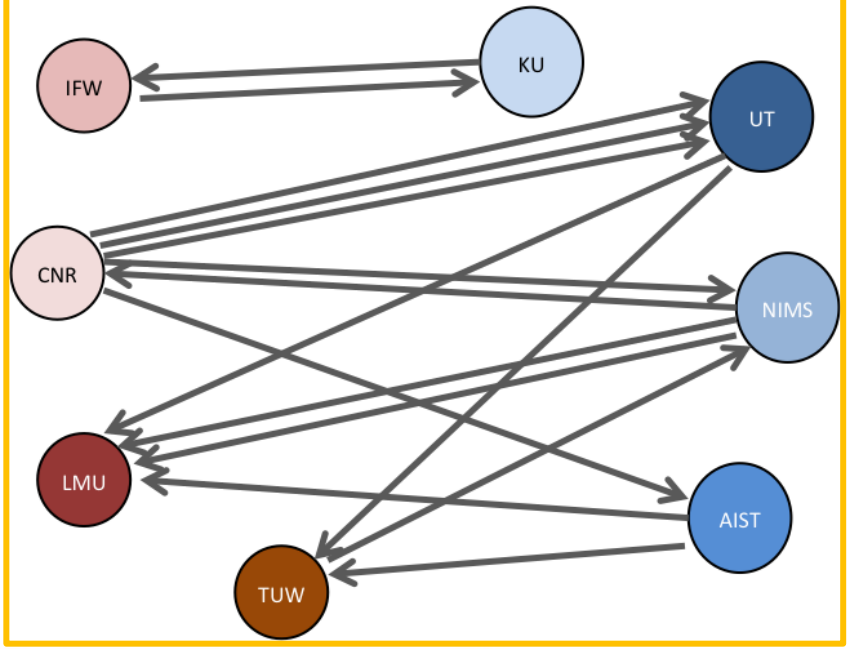
First Student Workshop:
Bad Schandau (Germany), May 2013
(21 participants)



Second Student Workshop:
Tsukuba (Japan) April 2014
(24 participants)

exchanges of young researchers is important for their scientific formation and also for strengthening the connection and inter cultural awareness

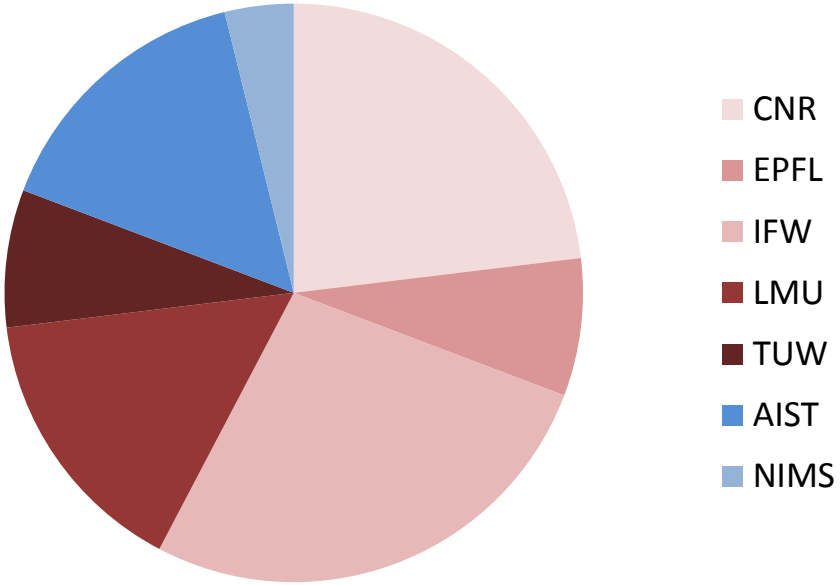
Researcher exchanges



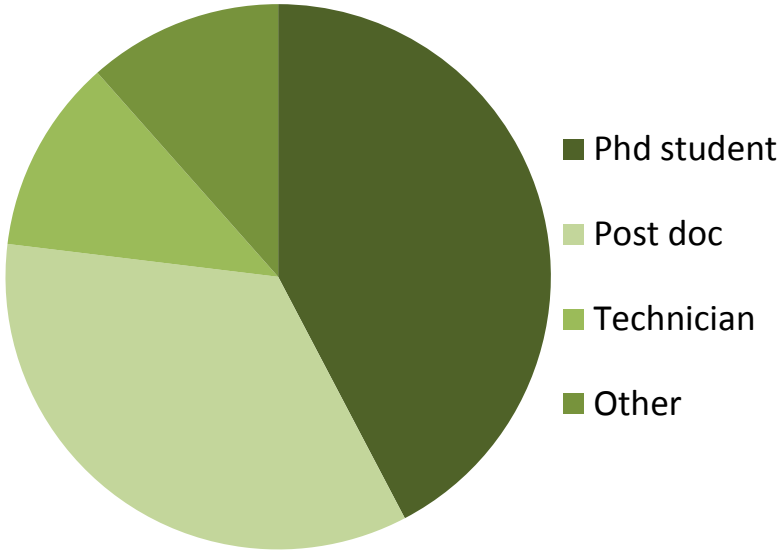
Recruitment

Personnel recruited on fixed term contracts

Partners involved



Contract type



26 contracts stipulated

Follow-up

New collaborative project, 2015-2020,

SuperIron II

Will be signed by:

The Department of Applied Chemistry, University of Tokyo **(TU)**
The Kyushu University **(KU)**
The National Institute of Advanced Science and Technology **(AIST)**
The National Institute for Materials Science **(NIMS)**
The Consiglio Nazionale delle Ricerca – Istituto Superconduttori, materiali innovativi e dispositivi **(CNR-SPIN)**
The Ecole Polytechnique Fédérale de Lausanne **(EPFL)**
The Leibniz Institut fur Festkorper – und Werkstoffforschung Dresden e.V. **(IFW)**
The Ludwig – Maximilians University LMU
Department of Chemistry The Vienna University of Technology **(TUW)**,
Department of Physics of the University of Genova (UNIGE)

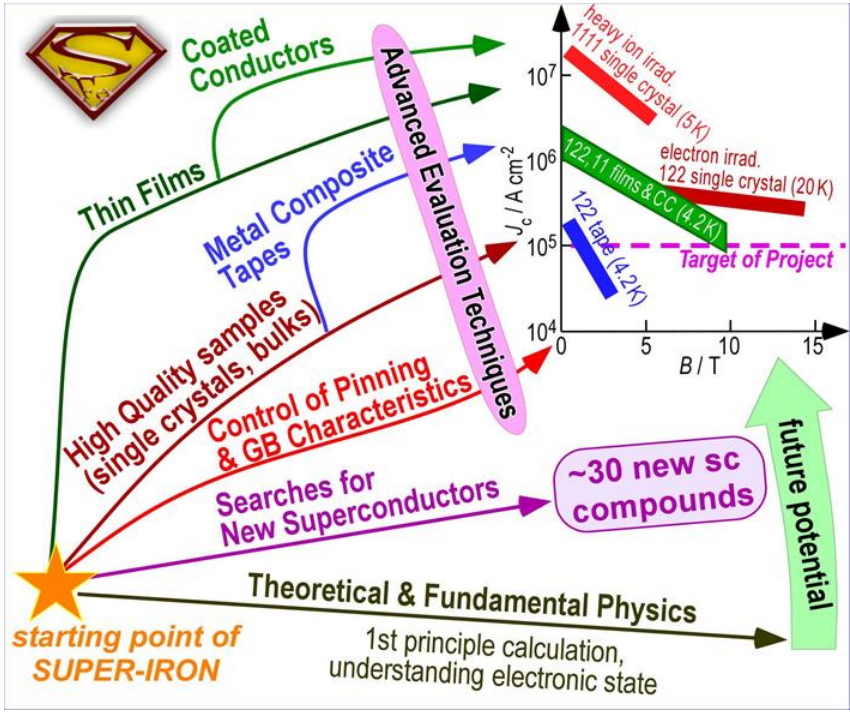
CONCLUSION

by J-i Shimoyama

Through the group-to-group collaboration between EU and Japan along SUPER-IRON, we have proved that iron-based superconductors have strong potentials for application, in particular for high field generation.

The ultimate potential of iron-based superconductor has not been well excavated yet. Grain boundary issues have not been optimized thus far.

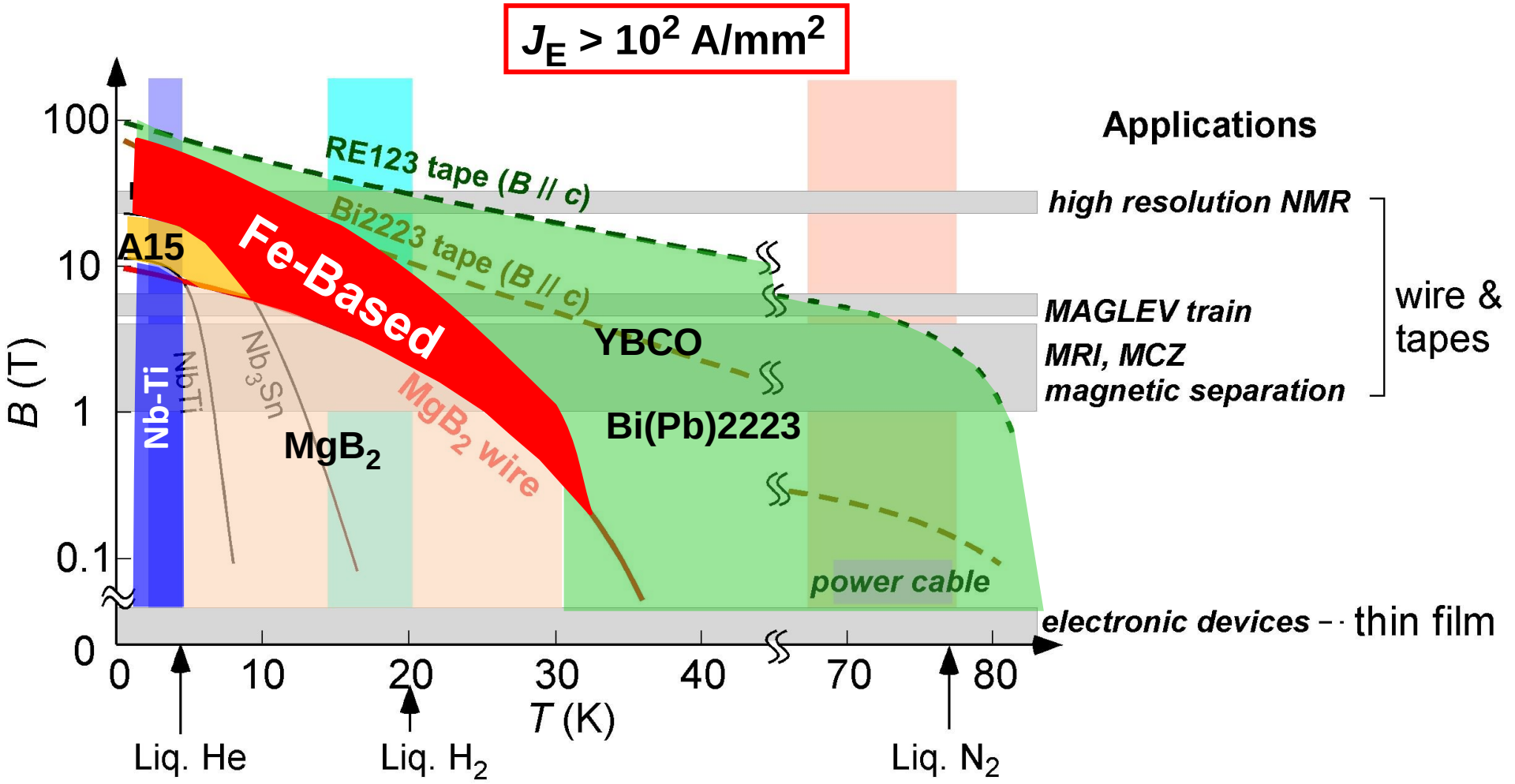
There is a large room remaining for the improvement of material performance of iron-based superconductors, **GROWING MATERIAL**.



Next Steps

1. Selection of the best family/doping/strain which optimize the superconducting phase diagram (T_c, H_{c2}, J_c)
2. Demonstration of the feasibility and reproducibility of optimized properties on large scale
3. Development of a scalable and industrially appealing method for the production of first generation cables as for iron-based superconductors.

Application of Superconducting Materials in Future



Conditions for practical applications of iron-based superconductors;
high performance, long length, homogeneous, high productivity, low cost, etc.

Thank you.