The physics case and status of HIE-ISOLDE

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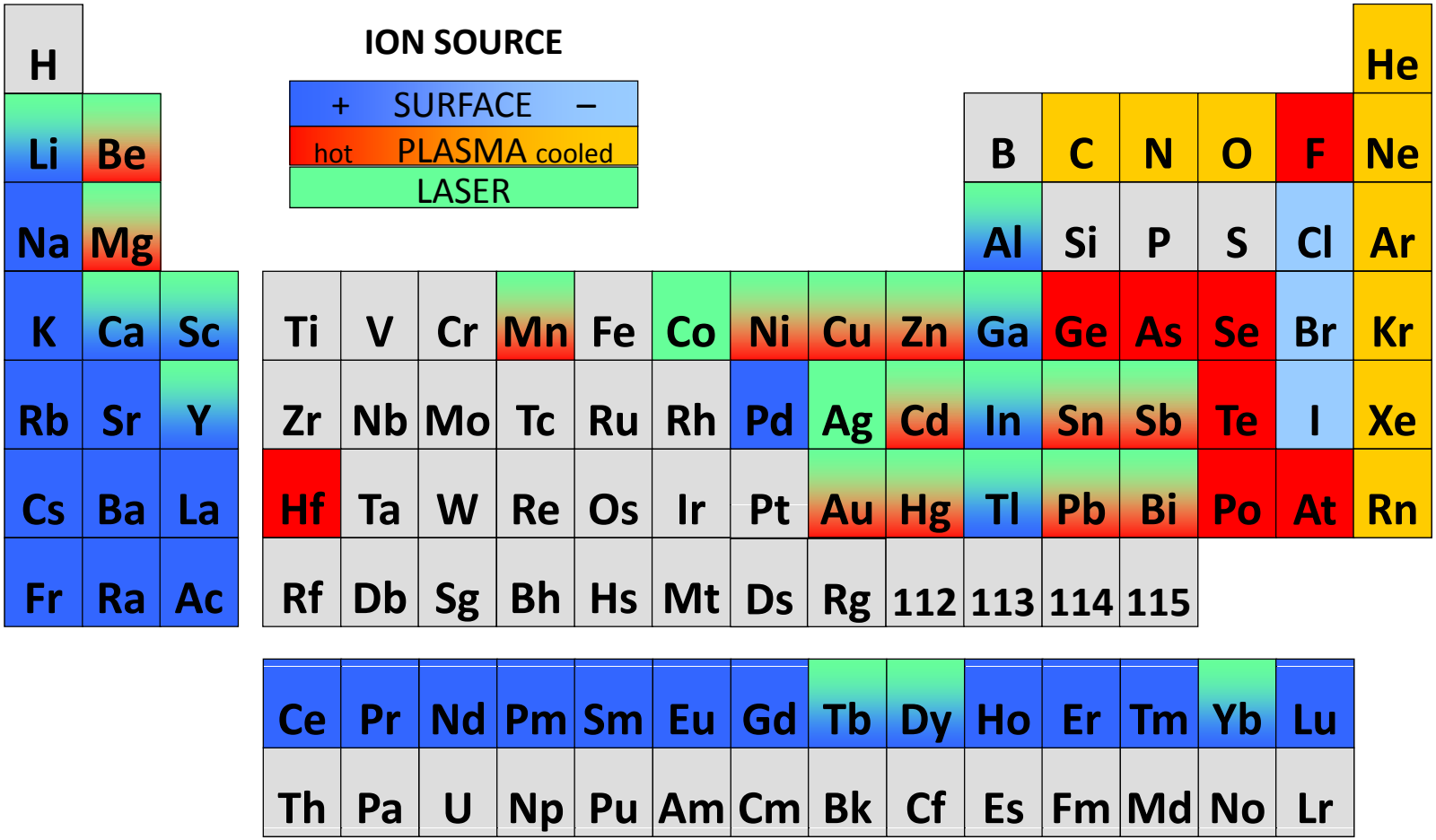
The HIE-ISOLDE Project

ISOLDE today offers the largest range of available isotopes of any ISOL facility worldwide (>600 radioactive isotopes of >60 elements) in an energy range between 60 keV and 3 AMeV.

HIE-ISOLDE aims at increasing the range of elements, the purity of the beams, the intensity by a factor 10 and their energy up to 10 AMeV.

HIE-ISOLDE will play an important role in the network of ISOL facilities preparing EURISOL (with SPIRAL2 and SPES).

Increased number of elements, increased selectivity



Increased number of elements, increased selectivity

Continuous target - ion source development (talks by Gottberg - Marsh; P23, P24, P25, P27, P30)

- New target materials
- n-converter developments
- Ion-source developments
- Transfer line
- Laser ion source (Knut and Alice Wallenberg foundation grant)
  - ❖ LARIS off-line test bench
  - ❖ Replacement of Copper Vapour Laser by new Syrah Dye lasers
  - ❖ Installation of three Ti:sapphire laser units
    - ➢ *Isomeric beams are possible*
- In-trap decay

Continuous improvement in ion-optical properties

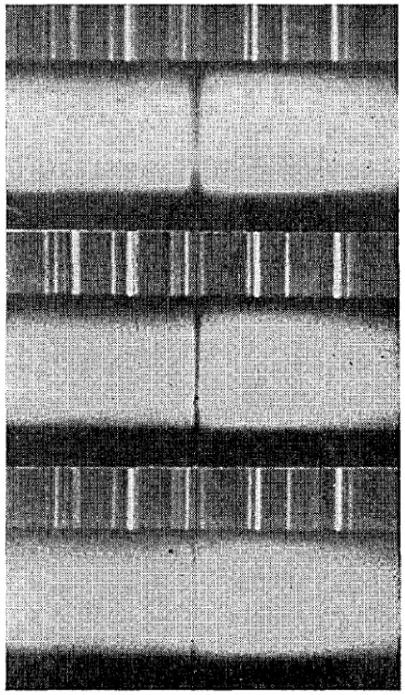
- ISCOOL : RFQ cooler buncher
- HRS higher mass resolving power

An example: Astatine

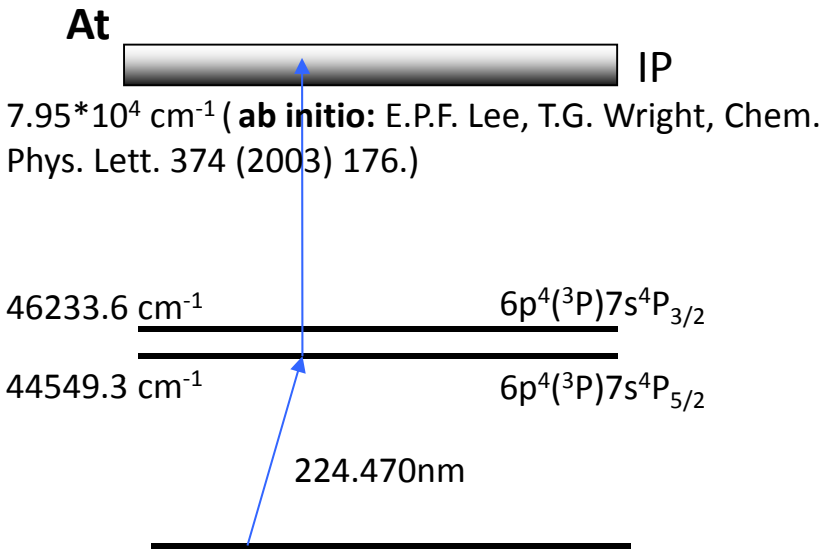
Guinness World Records has dubbed this element the rarest on Earth, stating: "Only around 25 g of the element astatine occurring naturally". Isaac Asimov, in a 1957 essay on large numbers, scientific notation, and the size of the atom, wrote that in "all of North and South America to a depth of ten miles", the number of astatine atoms at any time is "only a trillion".

Previously produced at ISOLDE non-selectively in plasma ion source

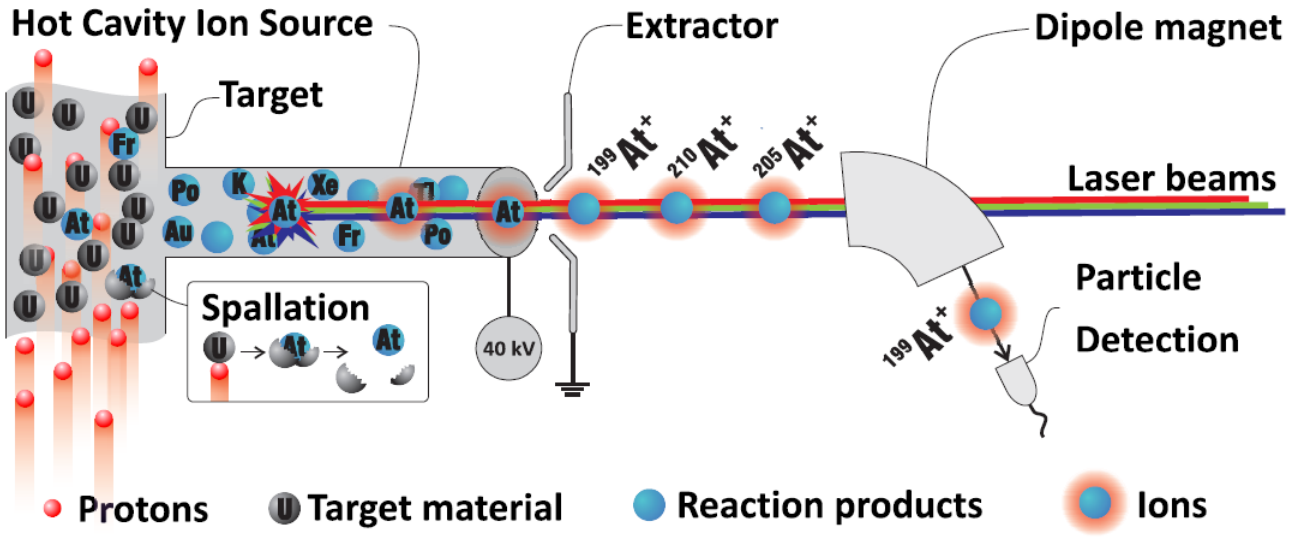
Is laser ionization possible?

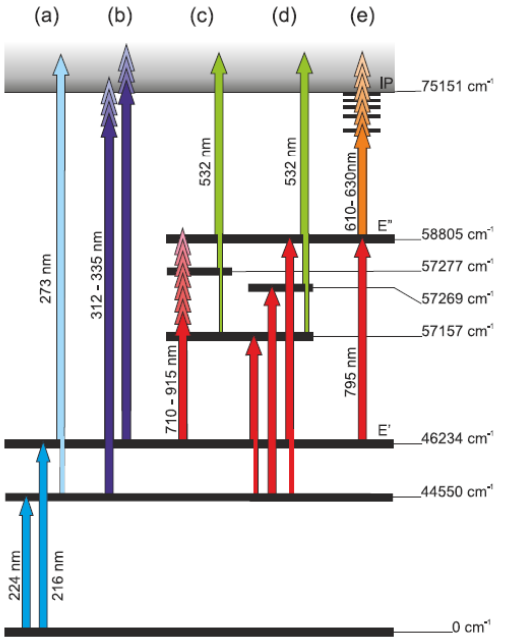


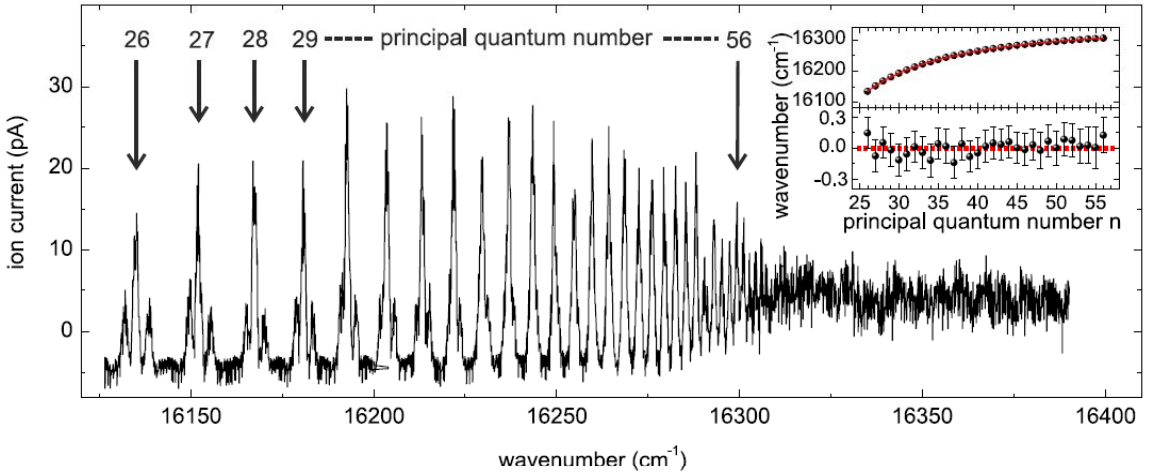
R. McLaughlin. Absorption Spectrum of Astatine. *Optical Society of America*,54 (1964) 965-967.



An example: Astatine Letter of intent I86 (UCx target (150 g/cm^2))

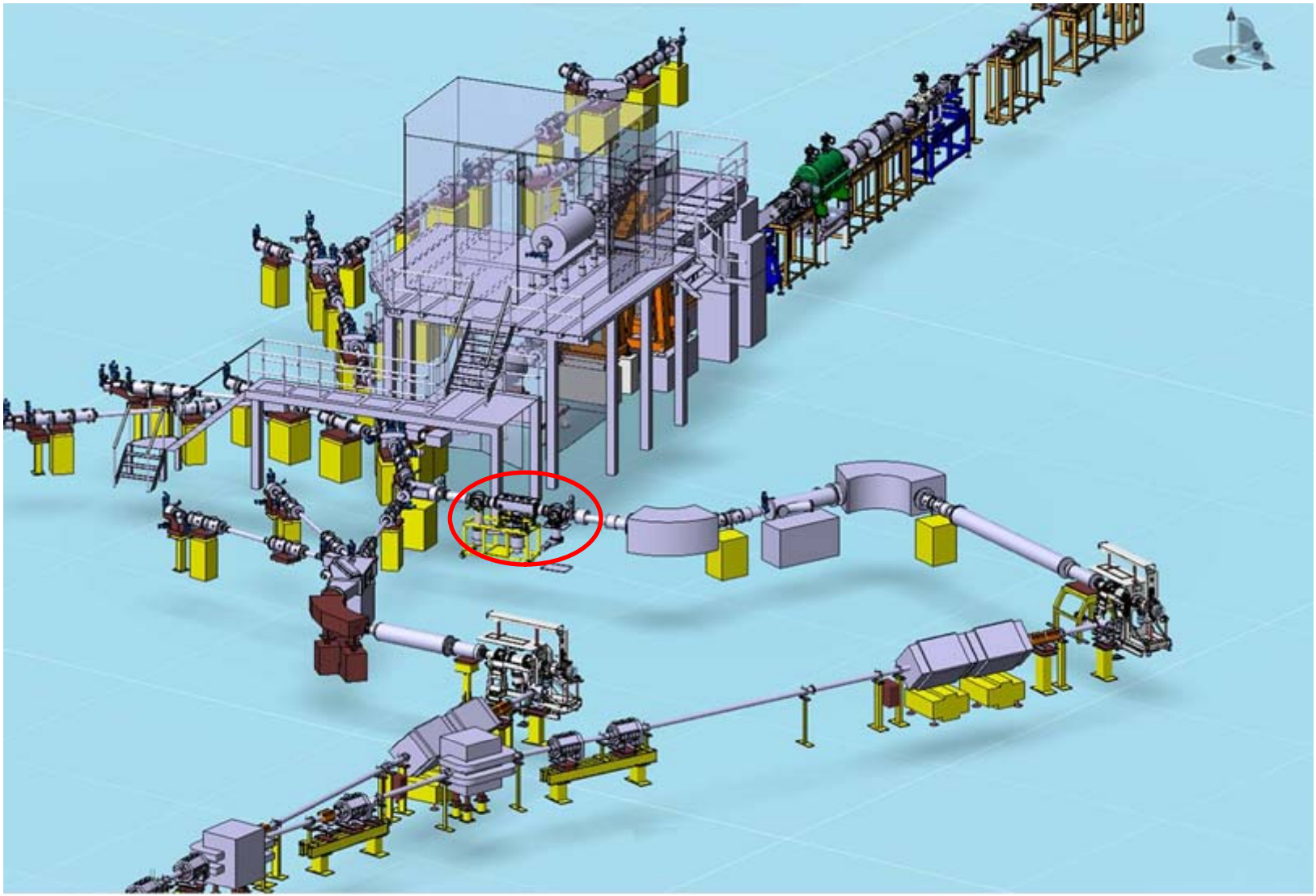






IP = 9.317510 (84) eV S. Rothe P29

Increased beam quality: ISCOOL



Increased selectivity: ISCOOL - COLLAPS

How does it work?

Major background in collinear laser spectroscopy :

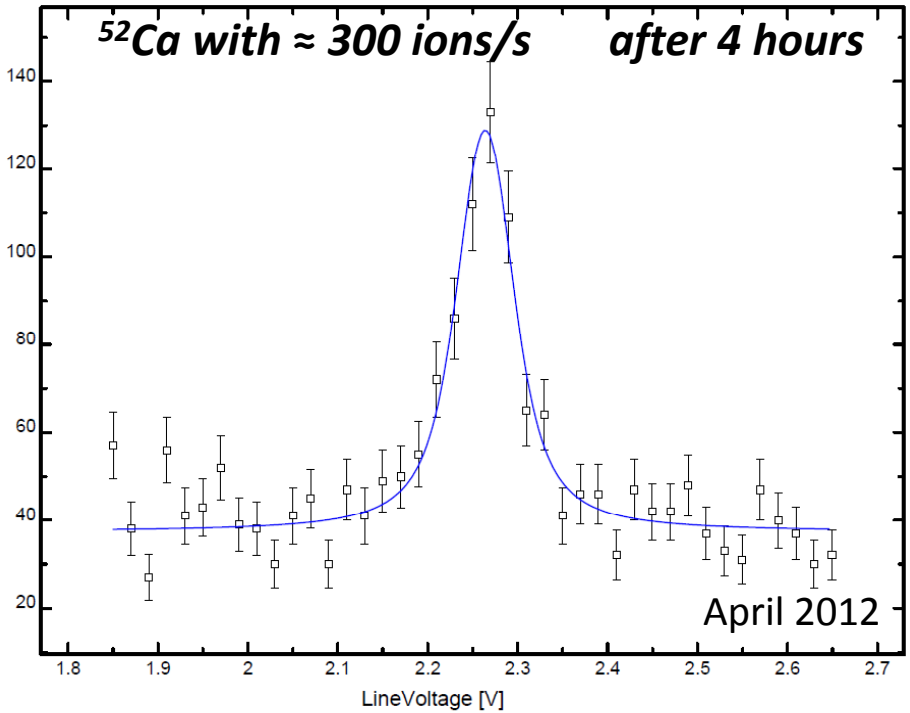
-PMT dark counts + scattered laser light.

Limits sensitivity to **≈ few x 10^5 ions/s.**

- **Bunching the ion beam means we only count when the ions are in front of the PMT's.**
- 100 ms accumulation in ISCOOL + 3µs bunch width gives **≈ 3x10^4 background suppression.**

Now sensitive to a few 100 ions/s.

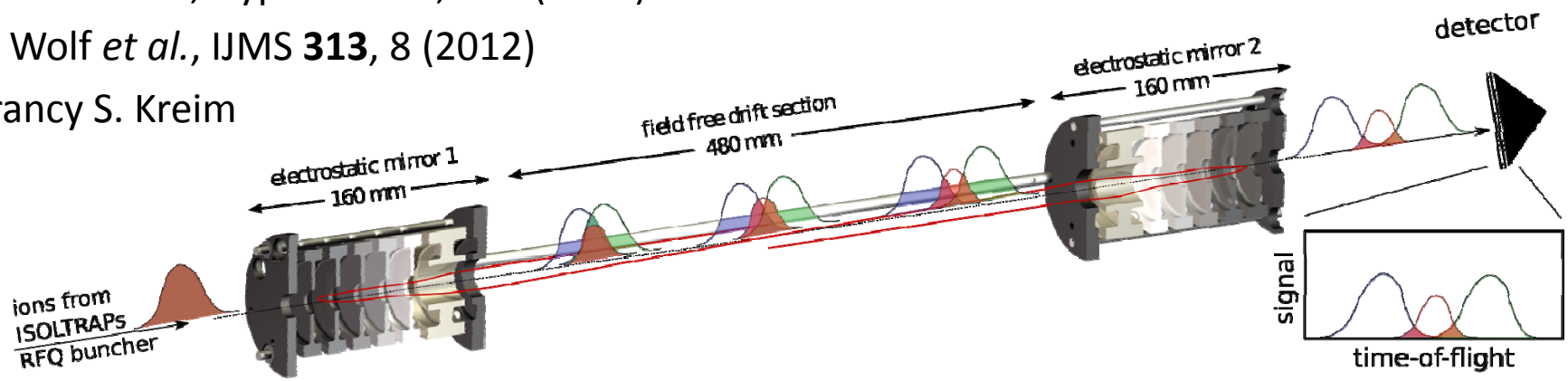
(transparancy Mark Bissell, talks Yordanov - Flanagan)



Increased beam quality: MR-TOF mass separator

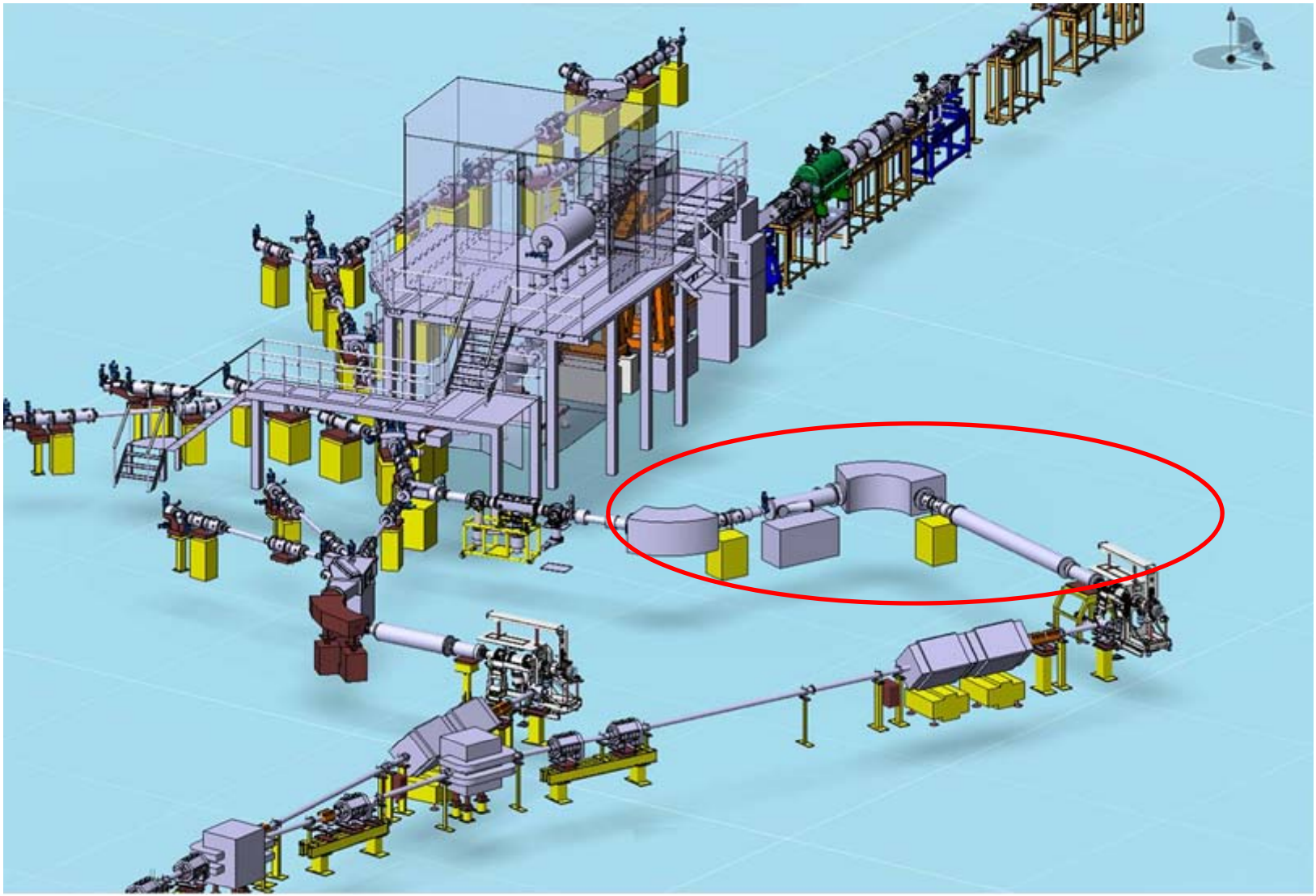
- R. N. Wolf *et al.*, Hyp. Int. **199**, 115 (2011)
- R. N. Wolf *et al.*, IJMS **313**, 8 (2012)

Transparancy S. Kreim

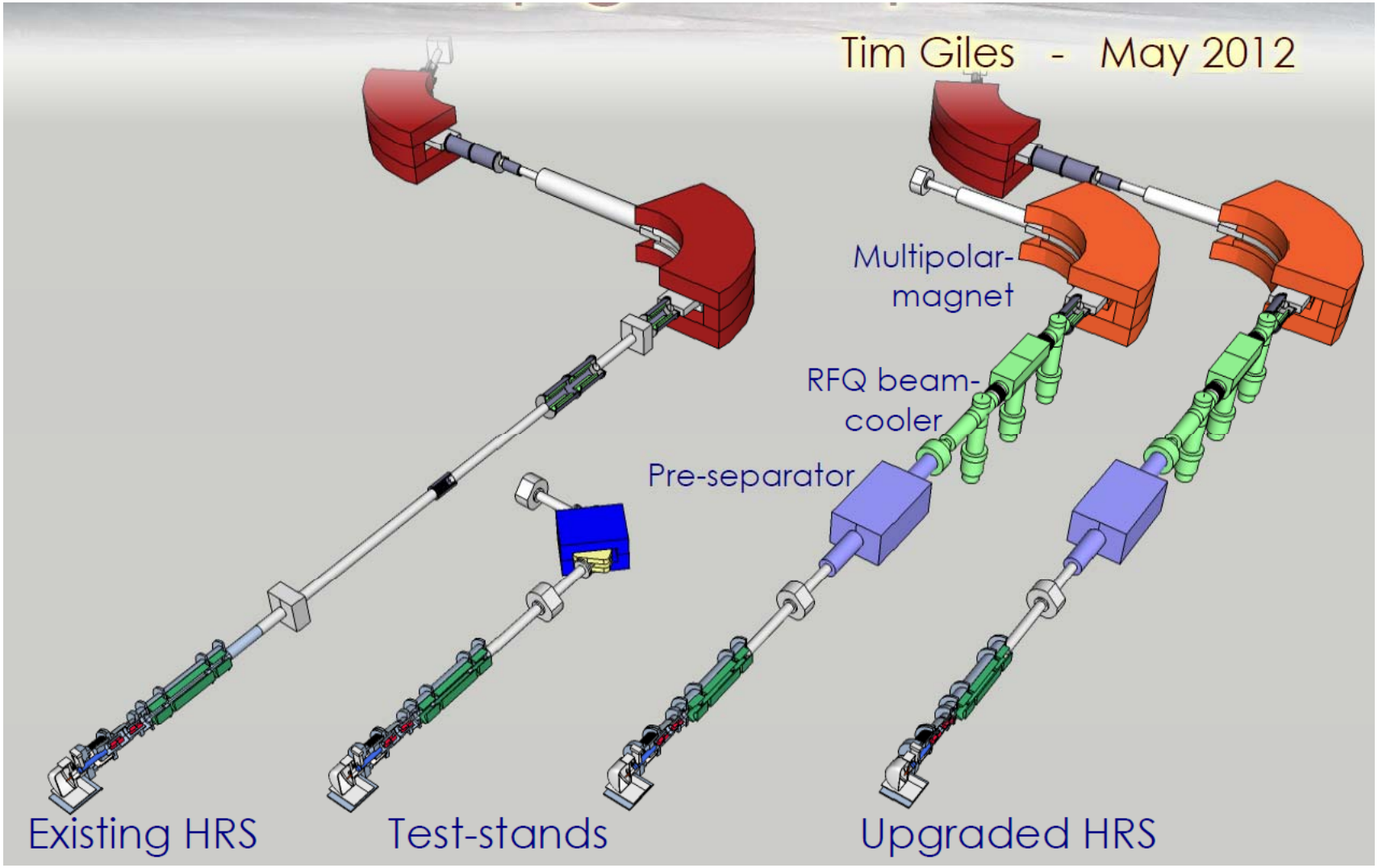


- Direct mass measurements of radionuclides with half-lives in the low ms-range become possible with the MR-TOF mass separator
- Higher proton intensity within HIE-ISOLDE will increase the yield for nuclei with extreme proton-to-neutron ratios
- The achievable uncertainty will allow to study nuclear structure like the disappearance of magic numbers or shell closures with masses at the limits of stability

Increased beam quality: design studies for HRS



Increased beam quality: design studies for HRS



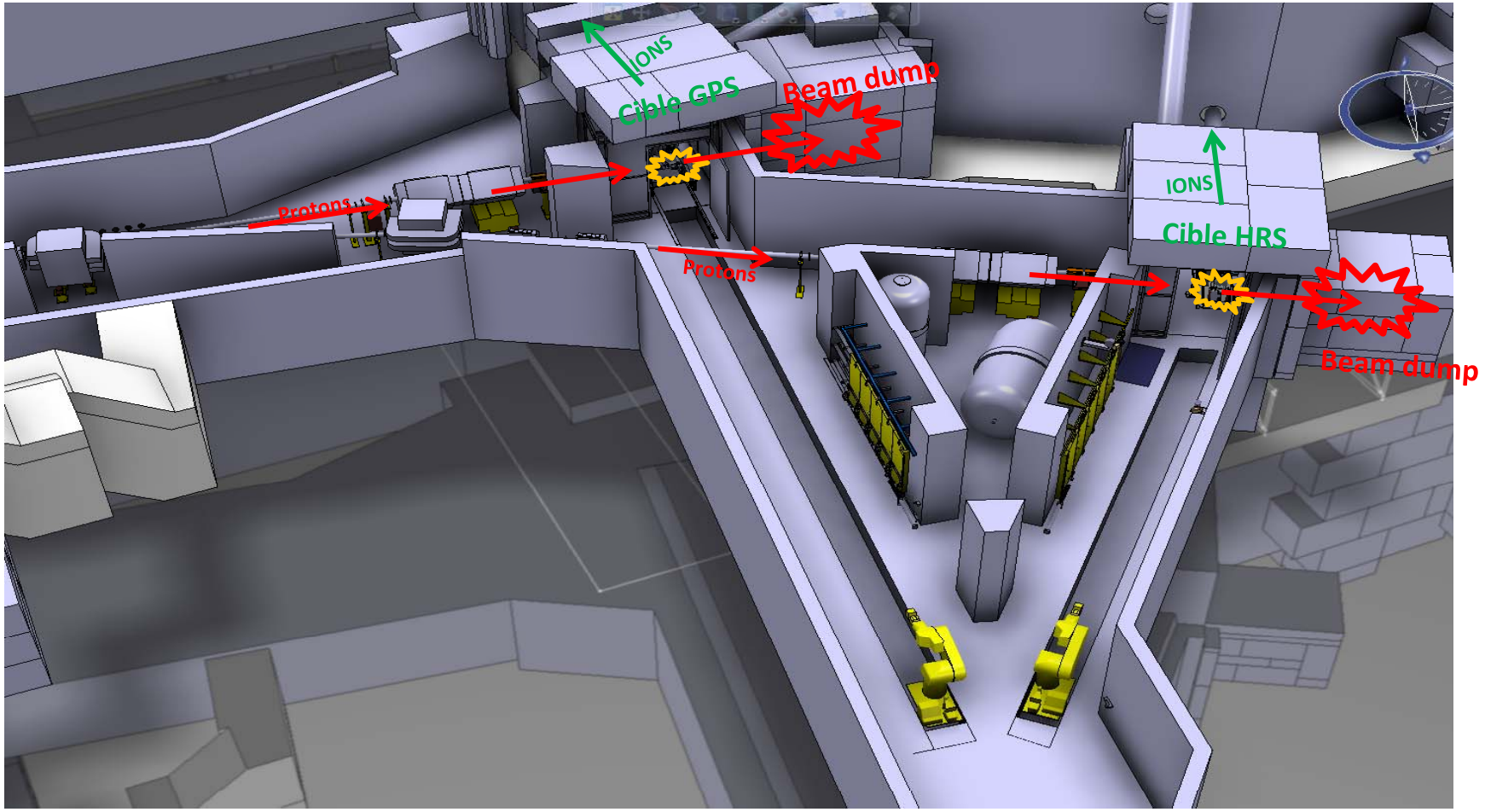
Increased intensity: design study for 10 kW beams

- Possible scenarios arising from the Linac 4 (4 μA) and the Booster upgrade (1.4 => 2 GeV) and the shorter cycle time.
- Need to upgrade the targets, target stations and infrastructure to accommodate a x4 increase in beam power.

Intensity (p/pulse)	Intensity (μA)	Energy (GeV)	Cycle (s)	Power (kW)
3 X 10^{13}	2	1.4	1.2	2.8
6 x 10^{13}	4	1.4	1.2	5.6
6 x 10^{13}	4	1.4	0.9	7
6 x 10^{13}	4	2	1.2	8
6 x 10^{13}	4	2	0.9	10

based on transparancies from R. Catherall

Increased intensity: design study for 10 kW beams



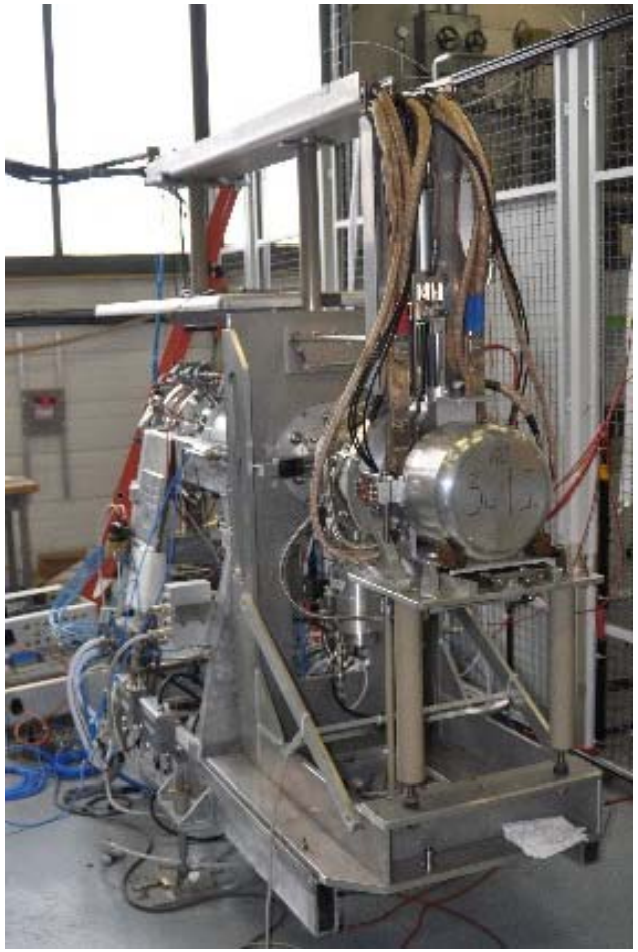
Increased intensity: target and front end design

Issues to be addressed

- Targets
  - ❖Target lifetime, material science, ion source optimization, geometry, energy deposition, handling, elimination pathway.
- Front Ends
  - ❖Material resistance, maintenance, optics, vacuum systems, remote operation…

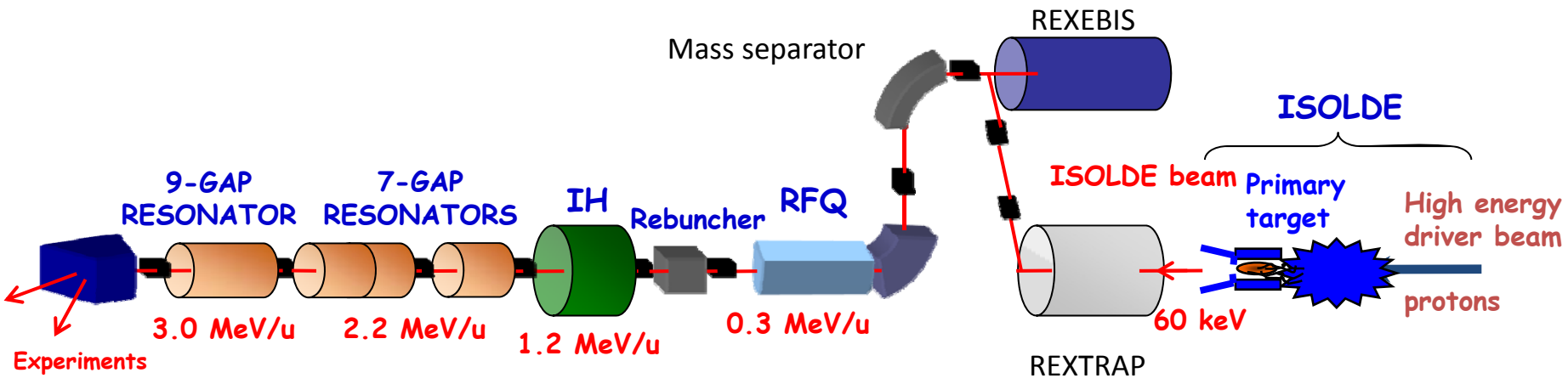
Starting point

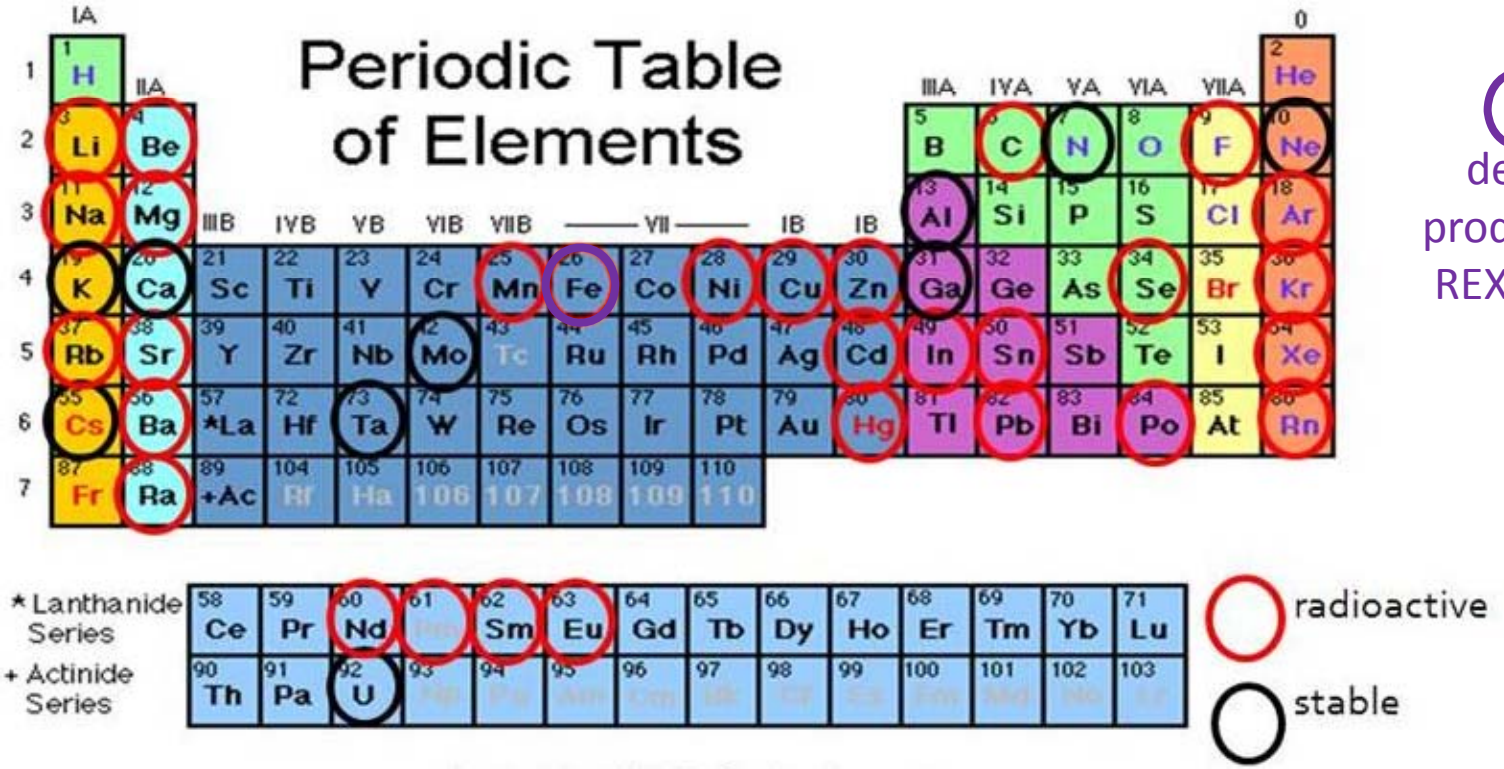
- Simulation of radiation levels



FE#6 – a step towards HIE-ISOLDE

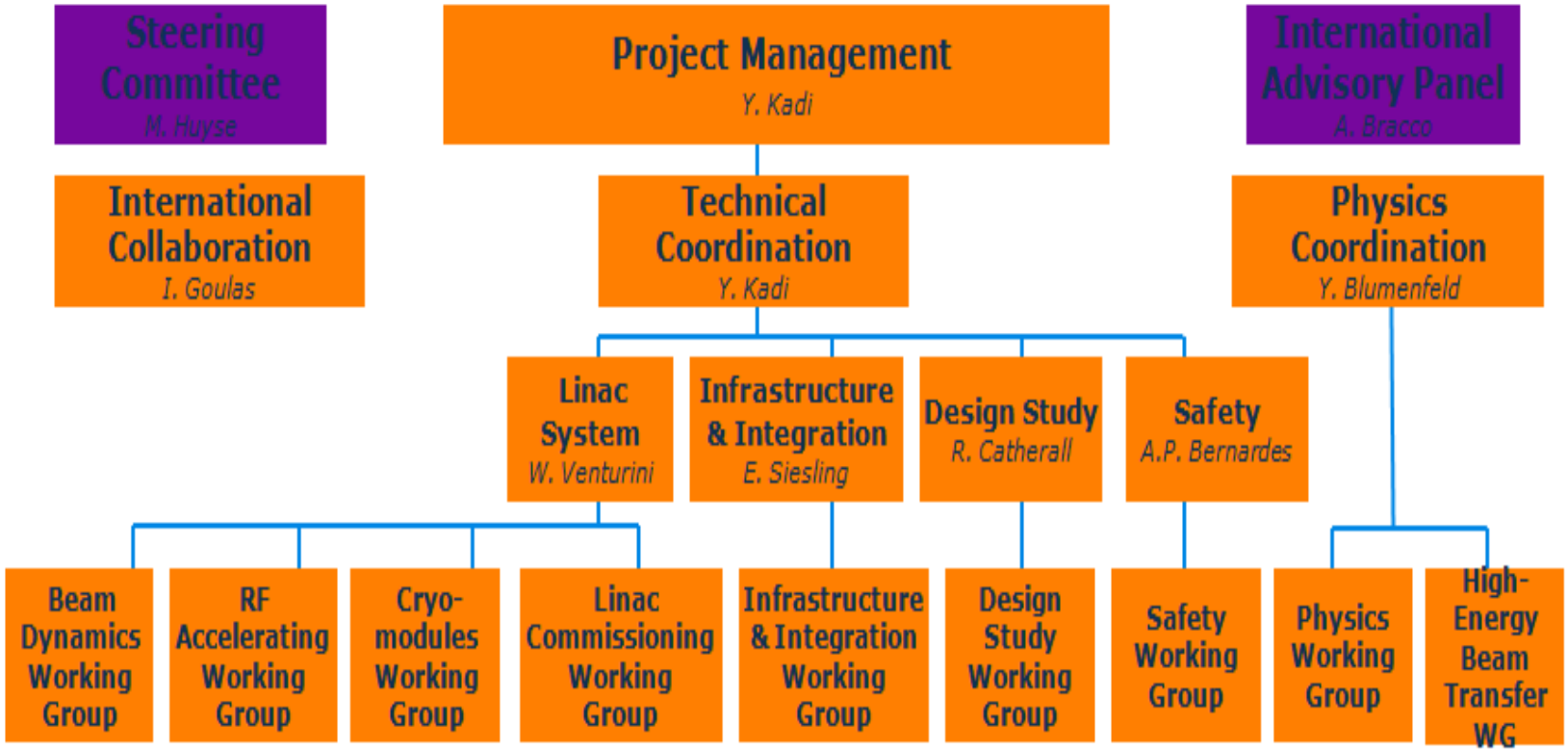
REX-ISOLDE


REXEBIS
Mass separator
ISOLDE
ISOLDE beam
Primary target
High energy driver beam
protons
9-GAP RESONATOR
7-GAP RESONATORS
IH
Rebuncher
RFQ
3.0 MeV/u
2.2 MeV/u
1.2 MeV/u
0.3 MeV/u
60 keV
Experiments
REXTRAP


Periodic Table of Elements
decay product in REXTRAP
radioactive
stable
* Lanthanide Series
+ Actinide Series

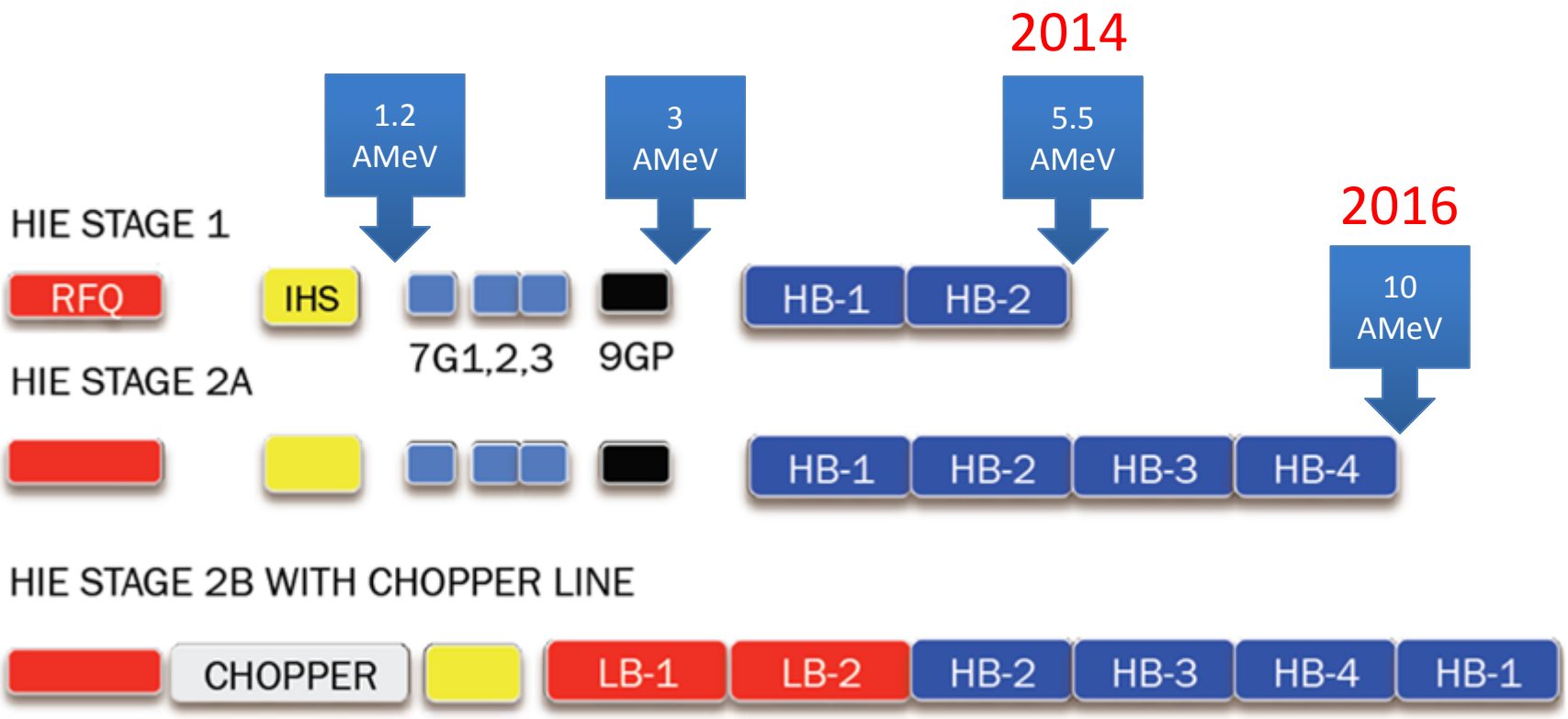
Energy upgrade

http://hie-isolde.web.cern.ch/hie-isolde/



see P1 Vandoni

Staged energy upgrade

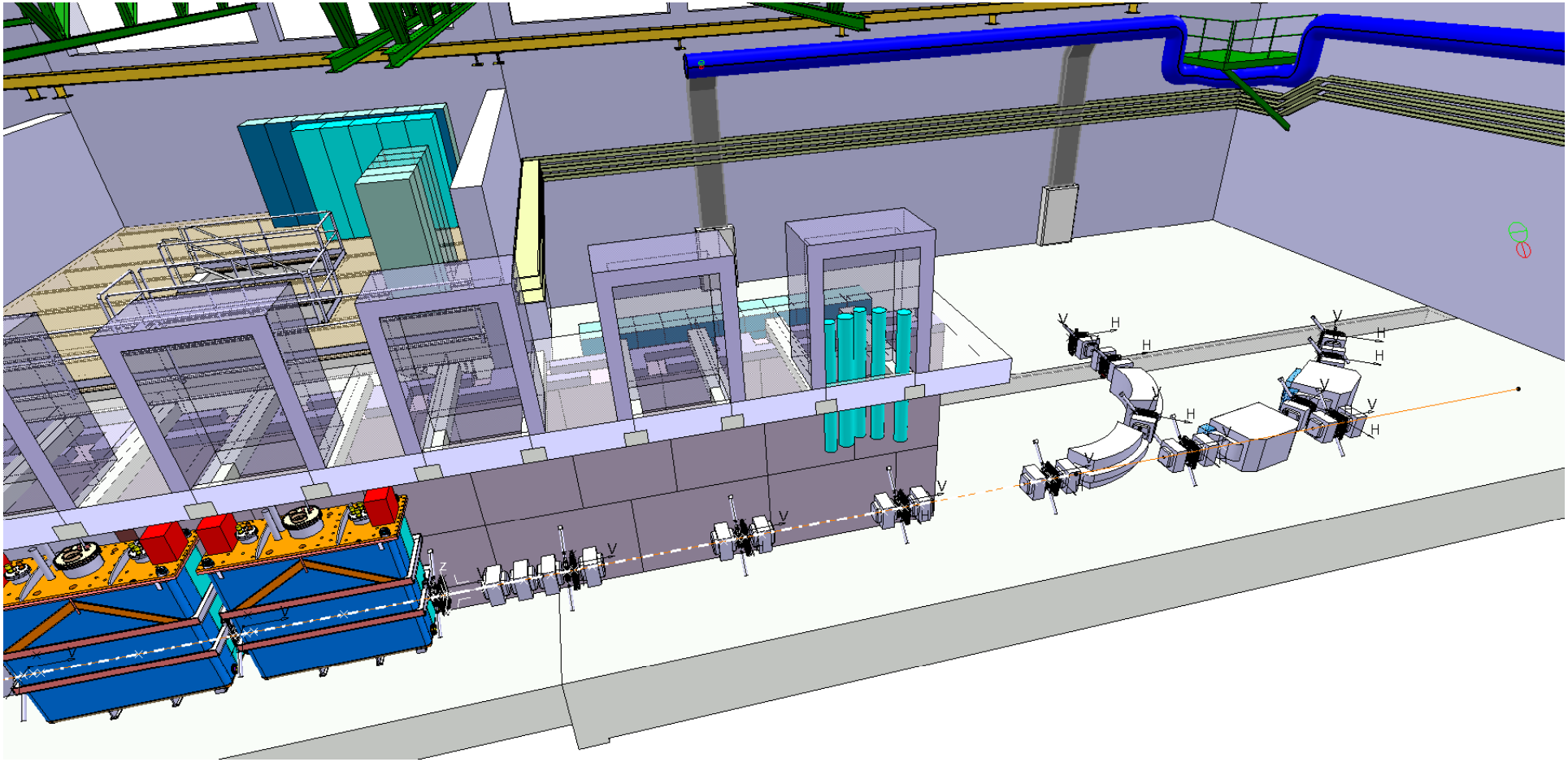


Construction work for the compressor and cold box building

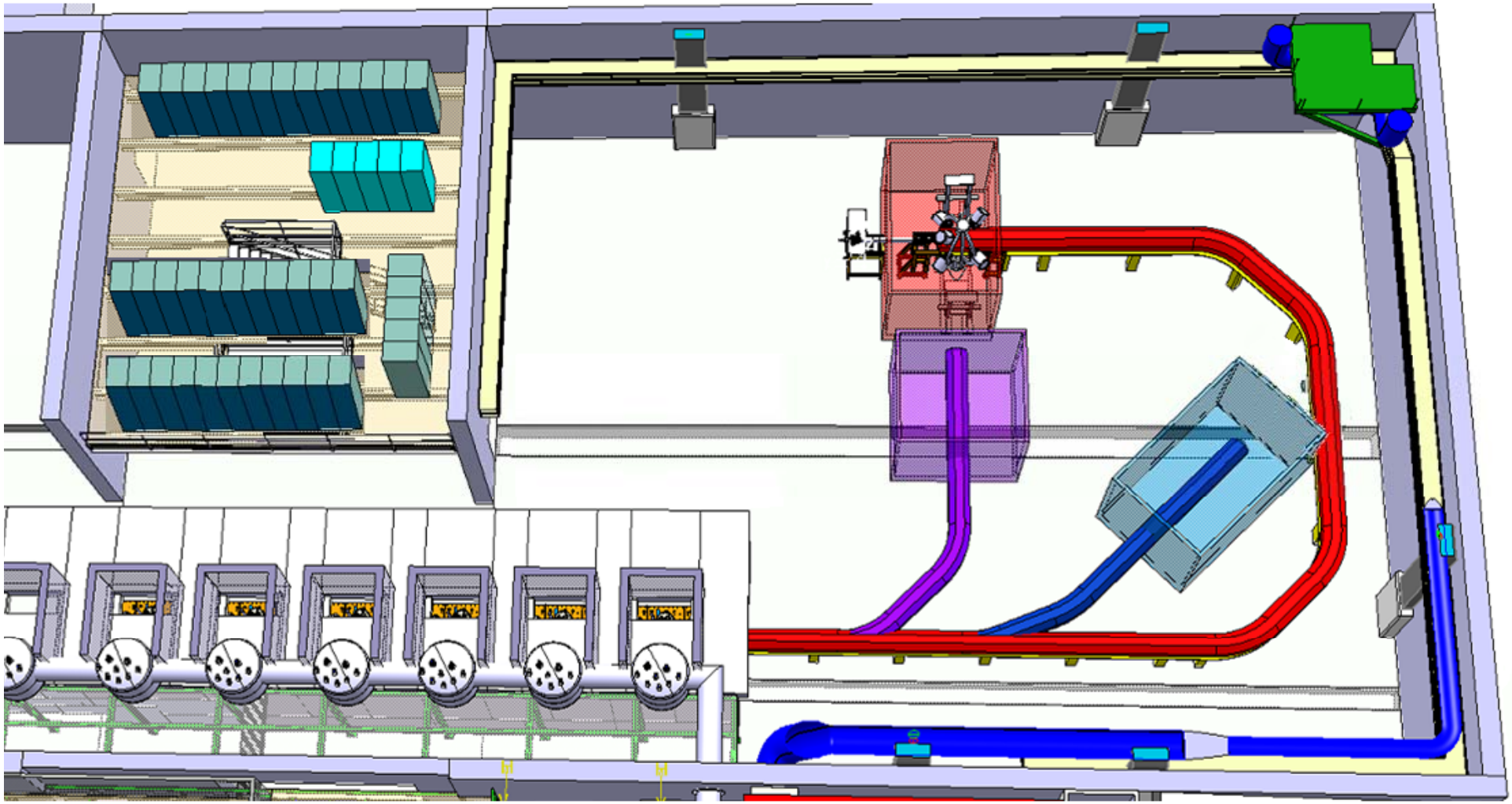
Compressor and Cold Box Building

Civil Engineering finished summer 2012

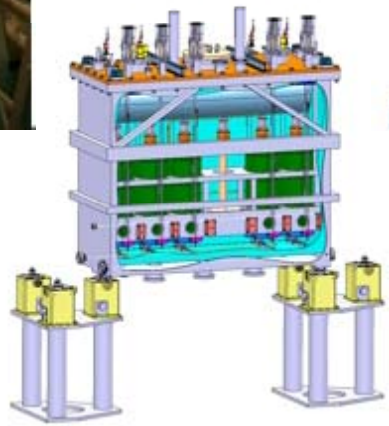
Phase 1: Experimental hall (5 AMeV 2014)

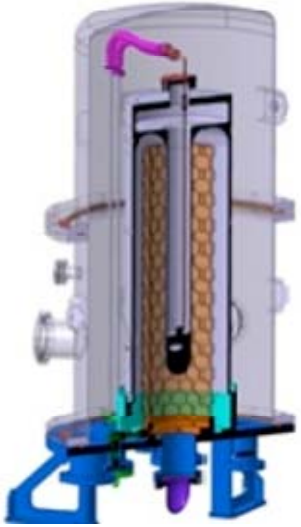


Phase 2: Experimental hall (10 AMeV 2016)

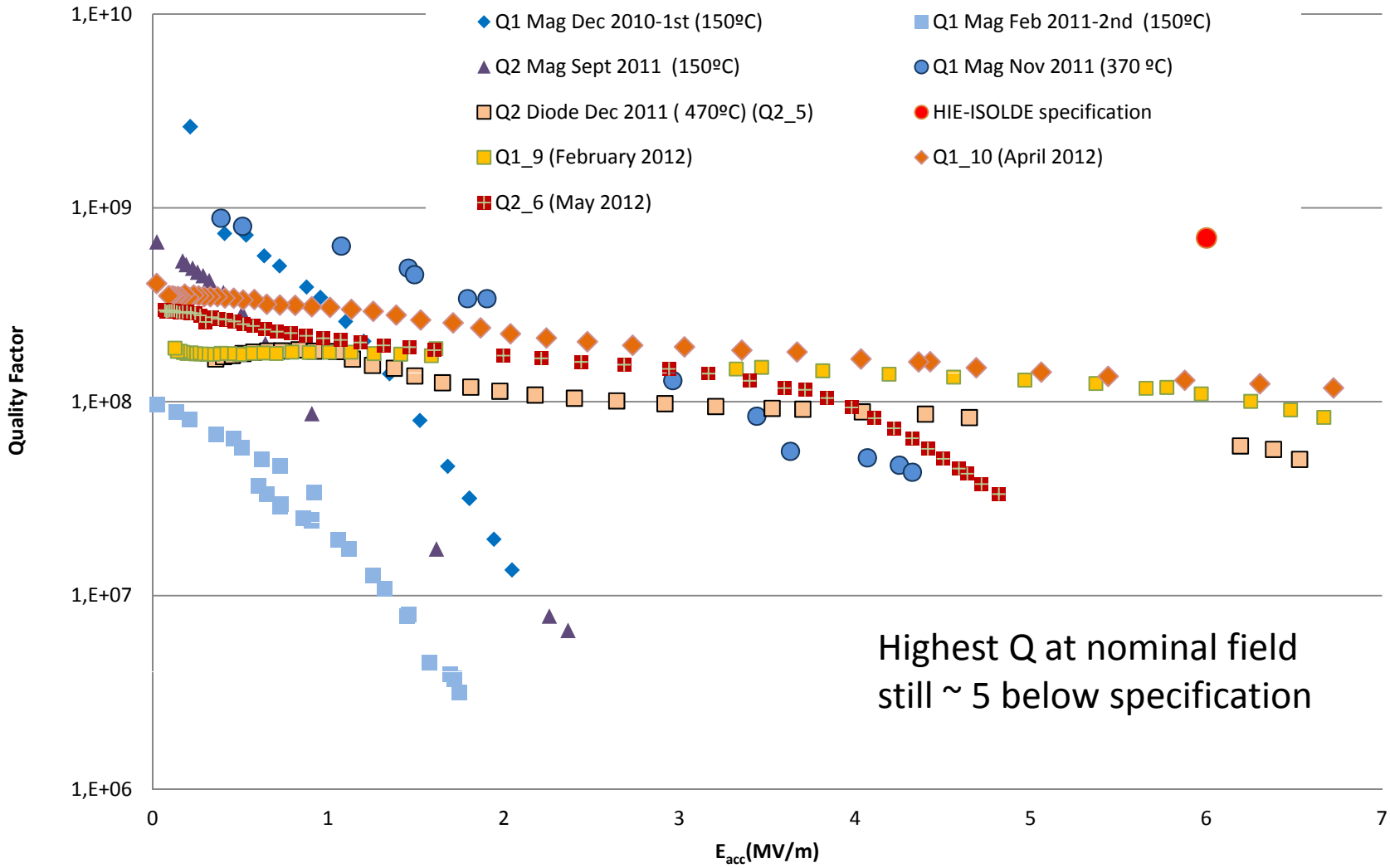


Cavity tests: Nb coating on Cu substrate





Cavity performance to date

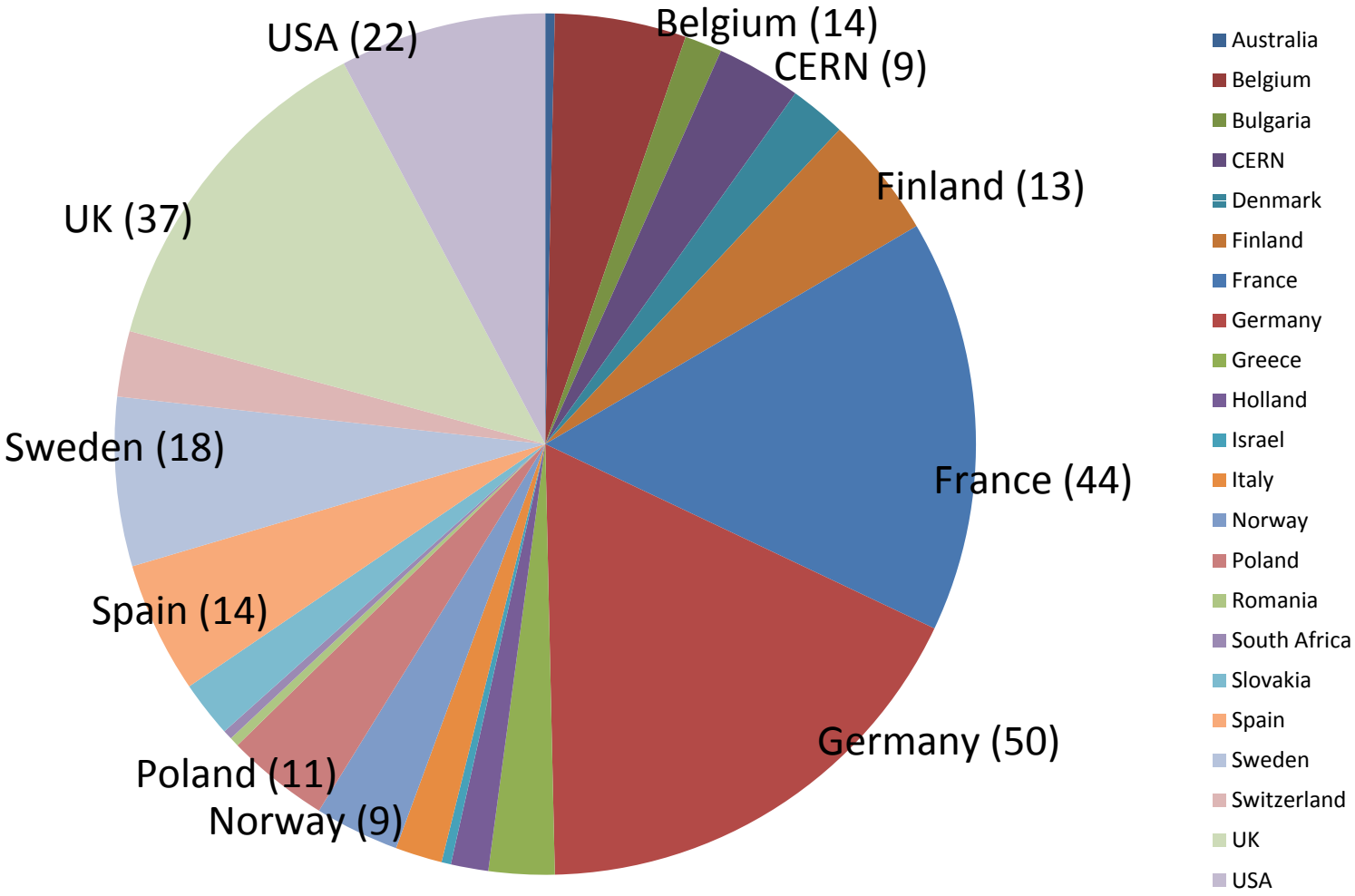


Call for LOI (Deadline May 2010, discussed at INTC June 2010)

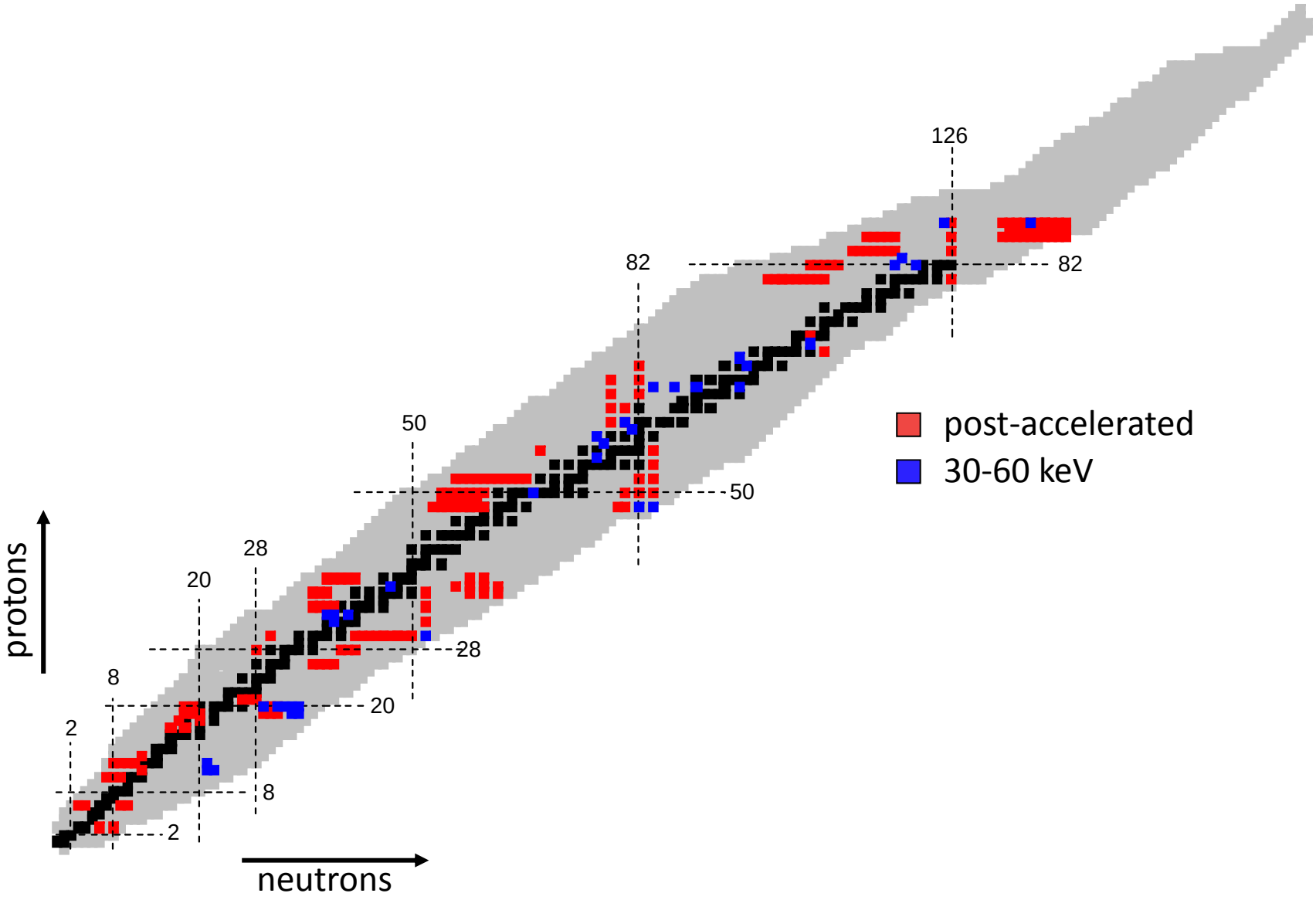
- 34 Letters submitted
- 284 Participants from 76 Laboratories in 22 Countries
- 30 LOIs make use of the Energy and Intensity increases; 4 of the intensity upgrade only
- Major mechanisms are Coulex (13) and transfer (16); elastic scattering (3); fission (2)
- (3) letters concern masses and moments; (4) astrophysics and (5) major new instrumentation
- Major subjects: Nuclear shapes ; Shell evolution; Halo properties; Nuclear astrophysics

Call for HIE-ISOLDE Proposals (5 AMeV) INTC November 2012

LOI participants per country



LOI spread over the whole chart of nuclei, typically ISOLDE



Instrumentation for energetic beams

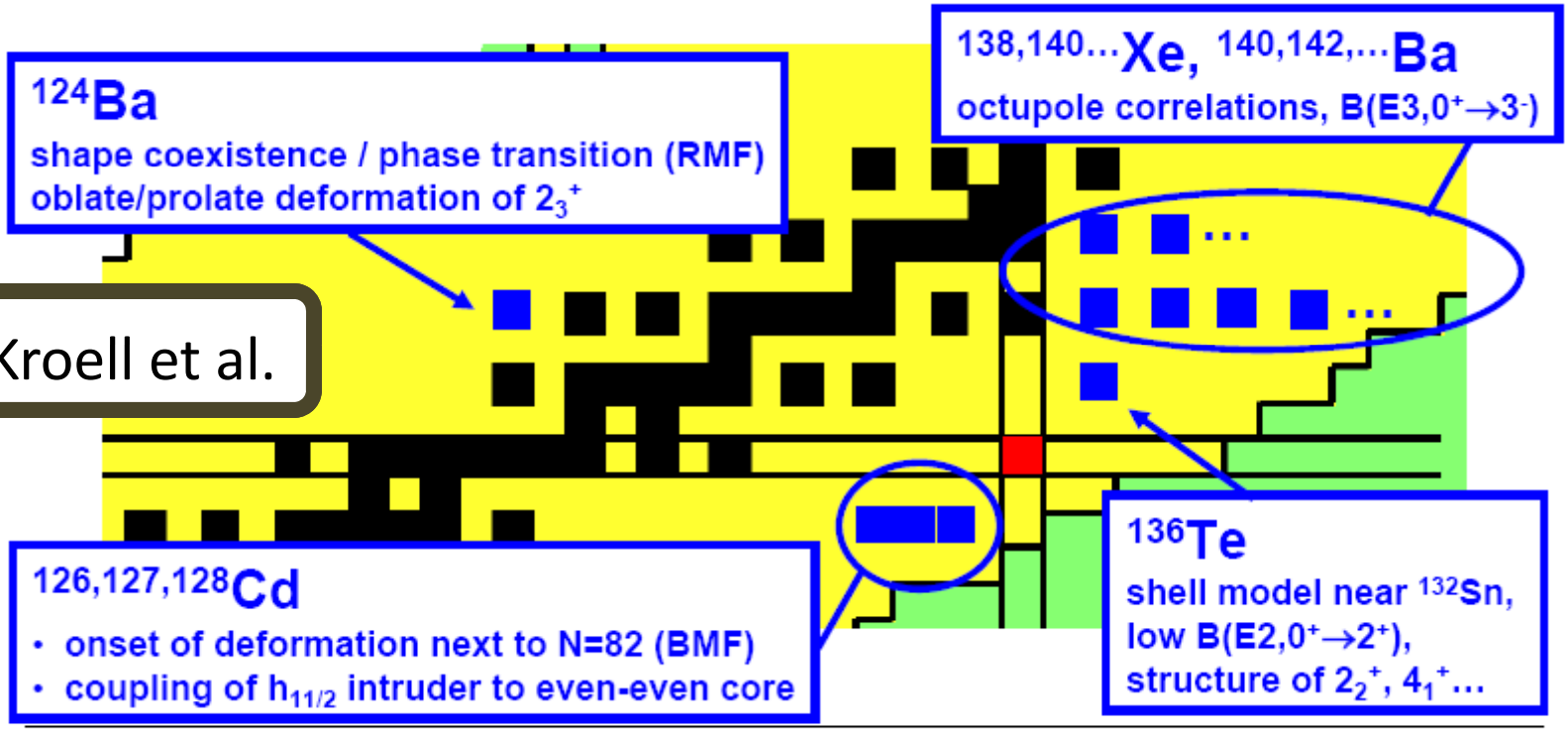
- Main workhorse : MINIBALL + TREX
- New detectors :
  - ❖ Active Target MAYA/ACTAR
  - ❖ Electron detection SAGE
  - ❖ Charged particle detection HELIOS
  - ❖ PARIS (**P**hoton **A**rray for studies with **R**adioactive **I**on and **S**table beams)
  - ❖ GASPARD (**GA**mma **S**pectroscopy and **PA**rticle **D**etection)
  - ❖ Neutron detectors
- Magnetic spectrometer
- Storage Ring *(talk Riccardo Raabe)*
- Special requirements
  - ❖ Time of Flight detection => buncher + chopper
  - ❖ Slow EBIS extraction
  - ❖ Beam spot

Coulomb excitation and transfer in the n-rich Sn region

Coulomb excitation

TECHNISCHE UNIVERSITÄT DARMSTADT

Higher energies at HIE-ISOLDE enable
… multiple Coulomb excitation
… population of high lying states, e.g. 3^- states (for ^{140}Xe: 10 x σ @ REX)



June 23, 2010 | 37th INTC Meeting @ CERN | TU Darmstadt | Thorsten Kröll | 3

Transfer in Ni region

- ^{68}Ni(d,p) and ^{80}Zn(d,p) N=41 and N=51 single-neutron states ($g_{9/2}$, $d_{5/2}$, $s_{1/2}$, $d_{3/2}$)
- (t,α) reactions on ^{76,78,80}Zn:
- study single-proton states in ^{75,77,79}Cu ($2p_{3/2}$, $1f_{5/2}$, $1f_{7/2}$)
- ^{66}Ni(t,p) to characterize 0^+ states in ^{68}Ni
- ^{80}Zn(^{10}Be,^{12}C): spectroscopy of ^{78}Ni

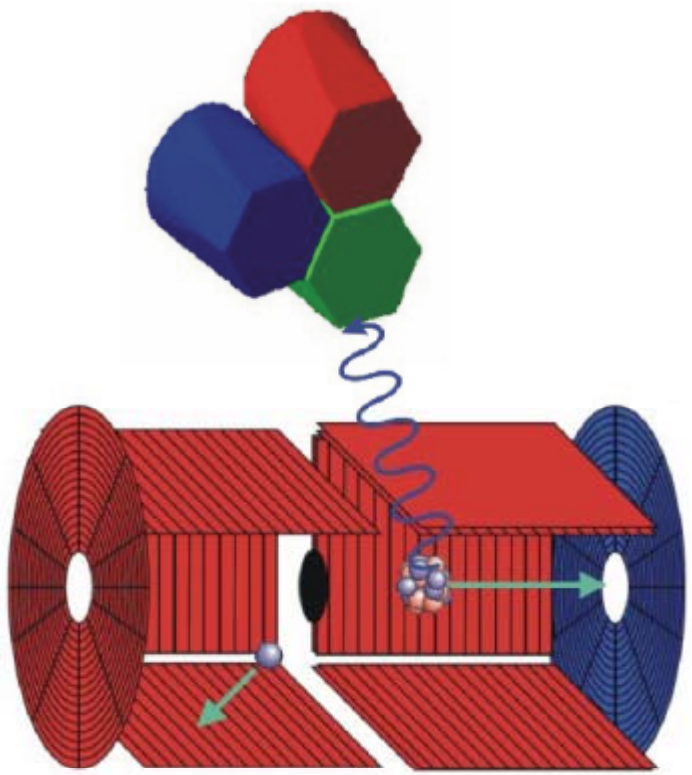
Higher energies at HIE-ISOLDE allow for transfer reactions also with heavy beams!

The n-rich Ni region: transfer measurements

Experiments today: Jan Diriken, Jytte Elseviers, Riccardo Orlandi

^{66}Ni(d,p) ^{66}Ni(t,p) ^{78}Zn(d,p)

- 3-4·10^{6} pps, thickness 500 µg/cm^{2} (tritium 40 µg/cm^{2})
- Very rich γ spectrum
- Poor energy resolution for particles, threshold problem
- Population of isomers through delayed particle-γ coincidence in the beam dump



transparancies from Riccardo Raabe

The n-rich Ni region: transfer measurements

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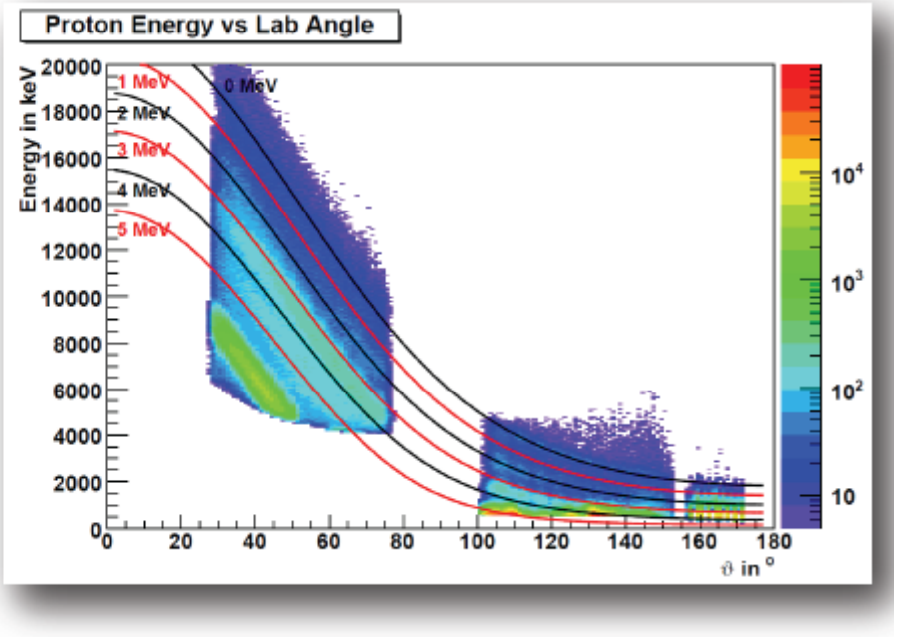

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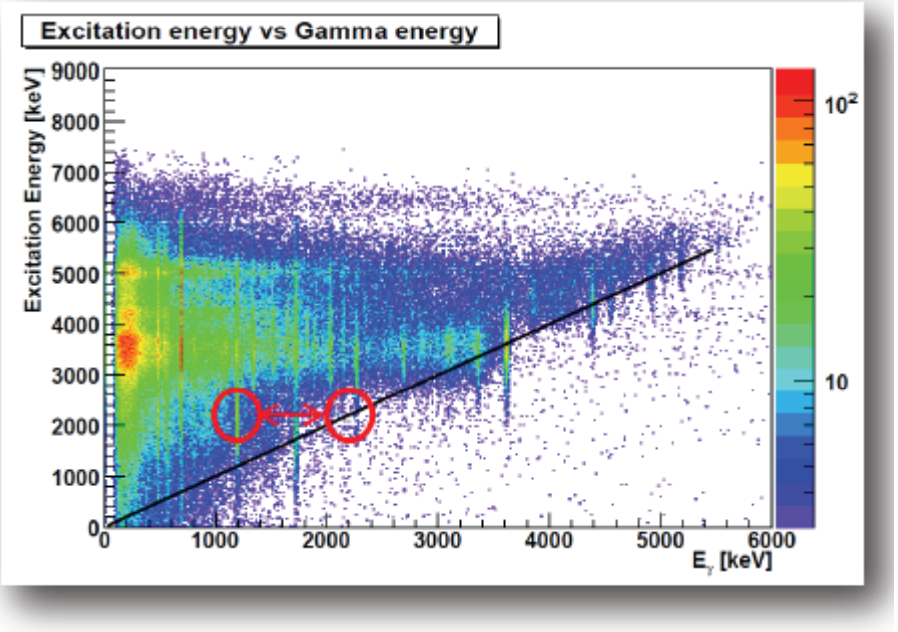
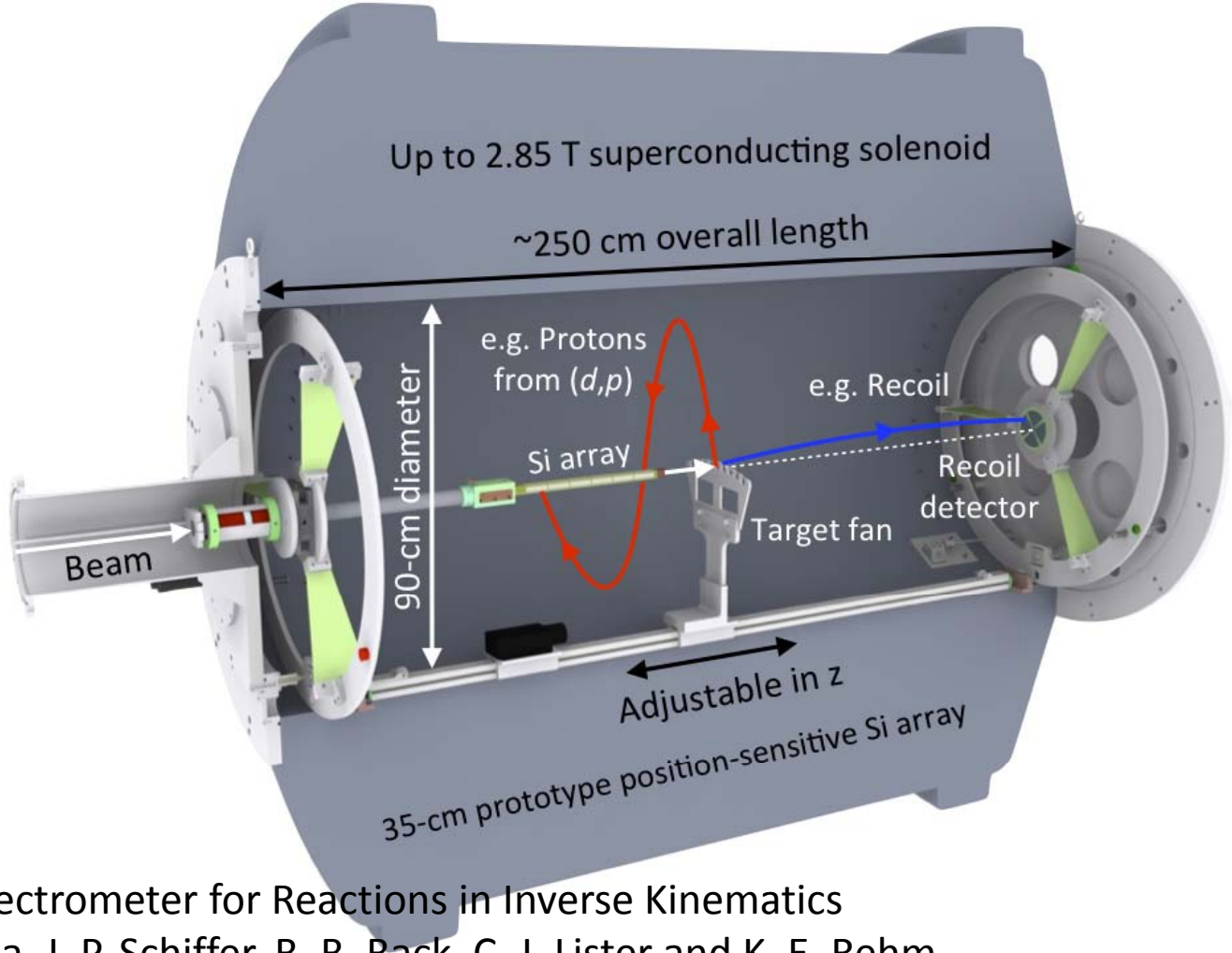


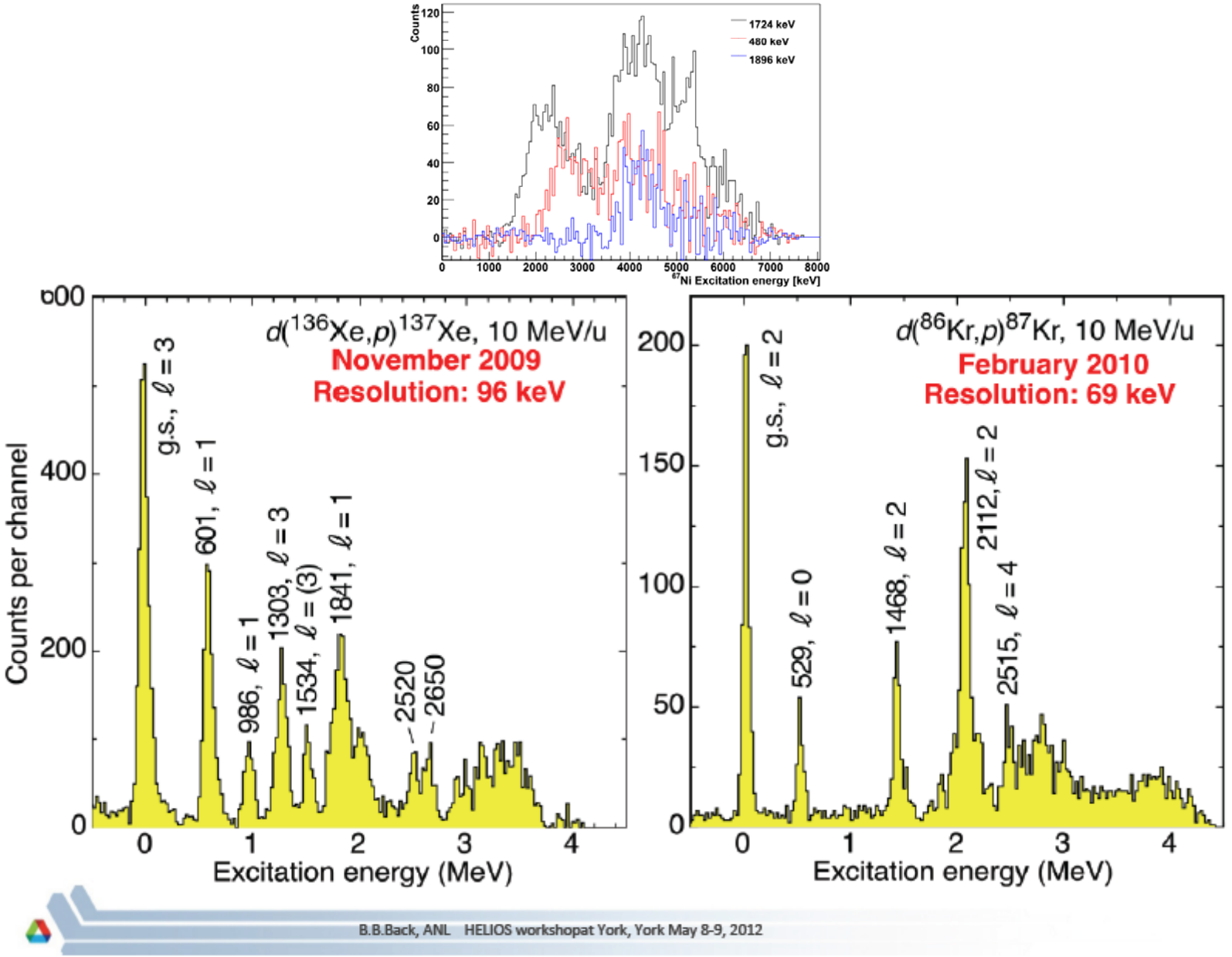
HELIcal Orbit Spectrometer at ISOLDE

Workshop on the Helical Orbit Spectrometer at HIE-ISOLDE York, 08- 09 May 2012



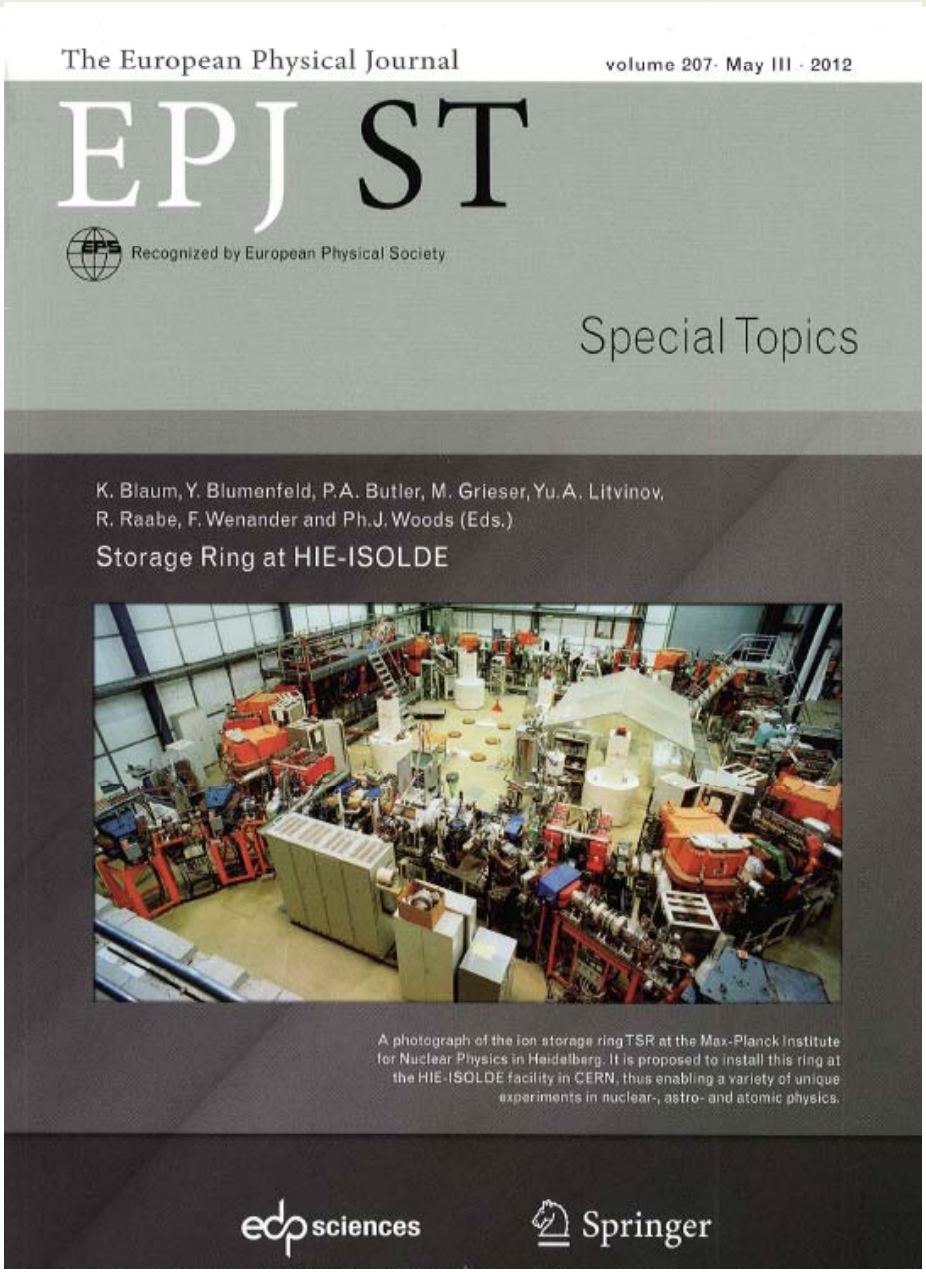
A Solenoid Spectrometer for Reactions in Inverse Kinematics
A. H. Wuosmaa, J. P. Schiffer, B. B. Back, C. J. Lister and K. E. Rehm.
Nucl. Instrum. Methods Phys. Res. A580, 1290 (2007)

HELIcal Orbit Spectrometer at ISOLDE



B.B.Back, ANL HELIOS workshopat York, York May 8-9, 2012

TSR@ISOLDE



(see talk Raabe)

TSR@ISOLDE

Advantages

With respect to in-flight storage rings

- High intensity
- Cooler beams

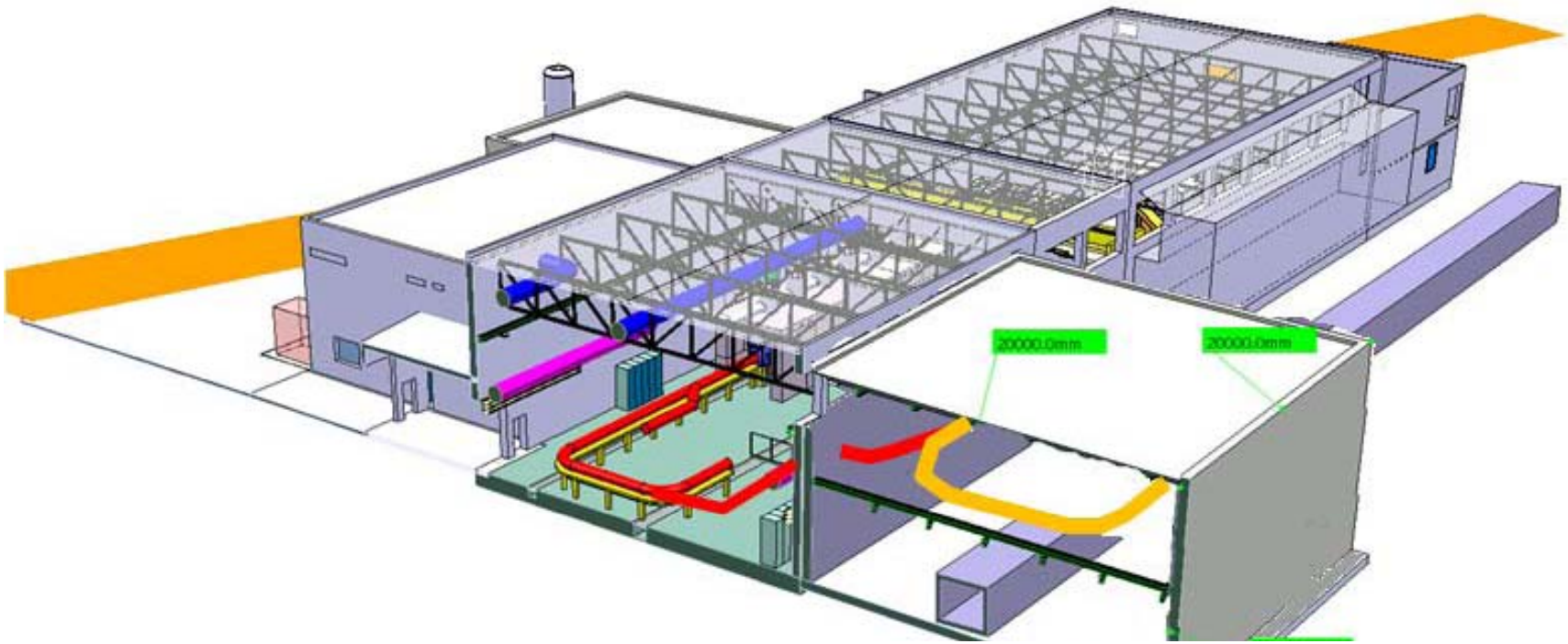
With respect to “direct” beams

- Less background (target, beam dump)
- Improved resolution
- CW beam

Physics programme

- Astrophysics
  Capture, transfer reactions
  ^{7}Be half life
- Atomic physics
  Effects on half lives
  Di- electronic recombination
- Nuclear physics
  Reaction studies
  Isomeric states
  Halo states
  Laser spectroscopy
- Neutrino physics

TSR@ISOLDE



Installation of TSR@ISOLDE

	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Funding												
Building construction work												
Building infrastructure												
disassembly of TSR at MPIK												
Transport to CERN												
Assembly of TSR@ISOLDE												
Power and Electronics												
Begin Commissioning												

Conclusions

- HIE ISOLDE will offer an unmatched variety of beams at energies ranging from 60 kV to 5A MeV (2014) and to 10A MeV (2016).
- A design study is performed to profit from the developments at the PSB and LINAC4 in order to cope with 10 kW beams.
- 34 LOIs have been submitted promising a rich physics program.
  - ❖ Proposals for HIE-ISOLDE for experiments at 5 AMeV will be discussed on the INTC of November 2012
- It will be efficient to share detectors between HIE-ISOLDE, SPES and SPIRAL2.
- These 3 facilities will pave the way towards EURISOL if the community coordinates its efforts.