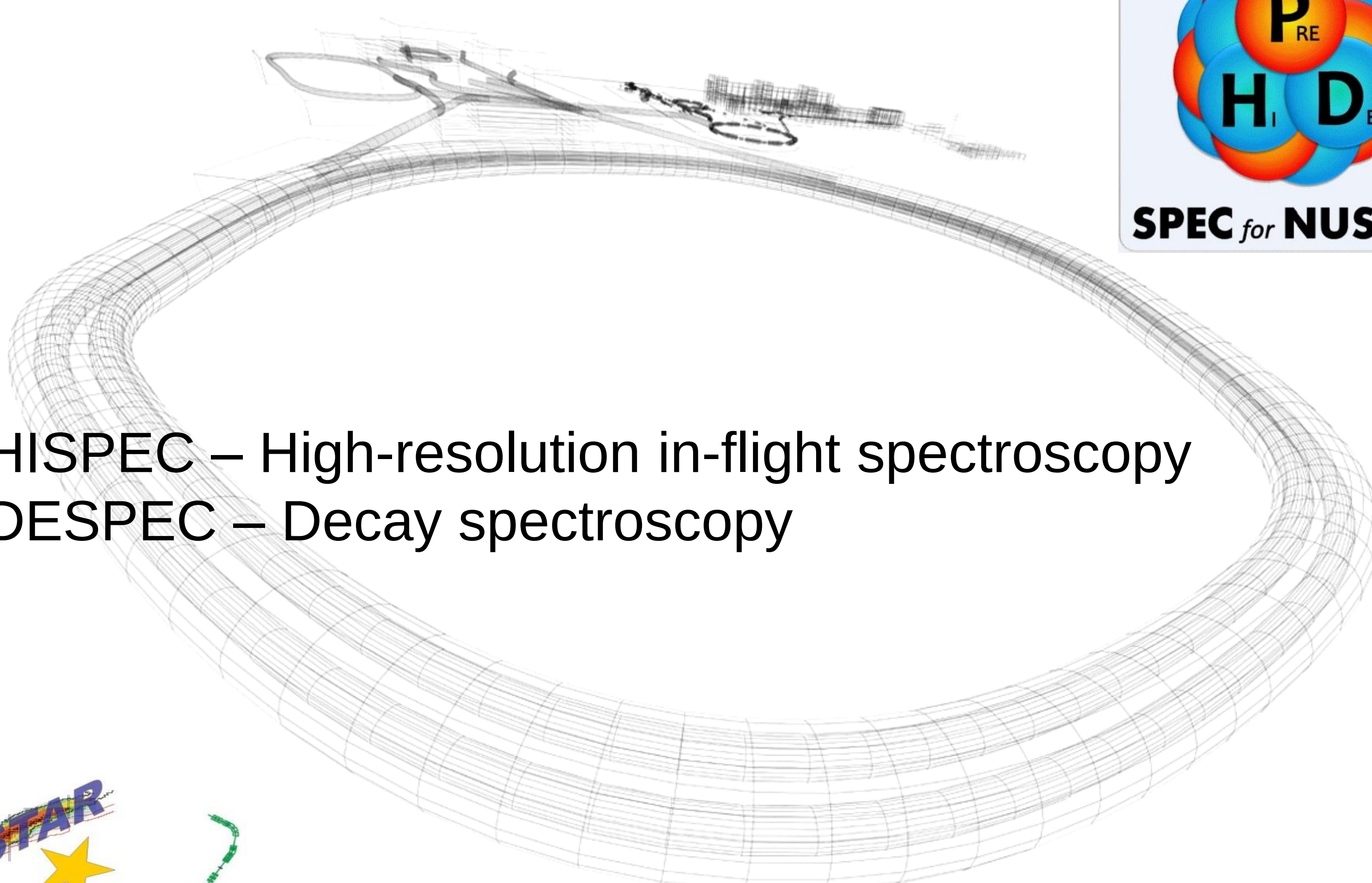
The HISPEC/DESPEC project at FAIR



HISPEC – High-resolution in-flight spectroscopy
DESPEC – Decay spectroscopy

Zsolt Podolyák

PAC (March 2005) results : HISPEC DESPEC

The PAC feels that the value of the science is indisputable and an important component of research at the future FAIR facility. The need for the measurements in this proposal is high.

For intermediate energies, HIPSPEC uses methods that are technically feasible and will benefit from the implementation of the forward fraction of AGATA. The experiments are well conceived and should produce excellent physics.

DESPEC is a natural exploitation of the rare exotic nuclei beams that emanate from FAIR. Decay spectroscopy of new nuclei is one of the key elements of exotic nucleus research. The experiments will employ highly segmented detectors to overcome the problem of gamma-flash from the degrading foil that slows the beams to 10 MeV/u, which will affect the performance in the sub-ms half life regime. It is noted that the distance to the final slowing down foil can be of the order of 10 meters which should lessen the effect of the photon shower and possibly allow standard clover detectors to be used in place of the complex highly segmented system. The design of the segmented gamma- and the high-resolution neutron-detector arrays should be pursued with high priority.

PAC (March 2005) cont.

However, for low energies, there are several perceived problems in the experimental configuration as proposed. In particular, beam identification at 5 MeV/u is an area that requires considerable R&D. The beam characteristics will impact the design of any subsequent detector array and beam tracking/identification system. Despite initial simulations, there is evidently significantly more work that has to be done in this area. Further simulations and design studies depend crucially on the progress of the LEB design. Another possibility to improve the low energy beam quality is to use cooled and slowed down beams from the NESR. Studies of this possibility must take into account the fairly long slowing down times to Coulomb Barrier energies (ca. 60 s, which, though would still enable 68Ni and 132Sn beams). The collaboration has made the case for a large solid angle magnetic spectrometer; however, this case is too general and does not specify which physics problems it will address. The spectrometer also has to adapt to the large momentum spread of any recoil products. This proposal should have laid out a better structure for the development of the technically challenging instrumentation for slowed down beams. It is important that this R&D be pursued, but a better framework has to be found, and the collaboration should work more cohesively towards this direction. It should be noted, though, that the collaboration is very large and diverse and represents a large number of areas of particular expertise.

PAC (March 2005) cont. (summary)

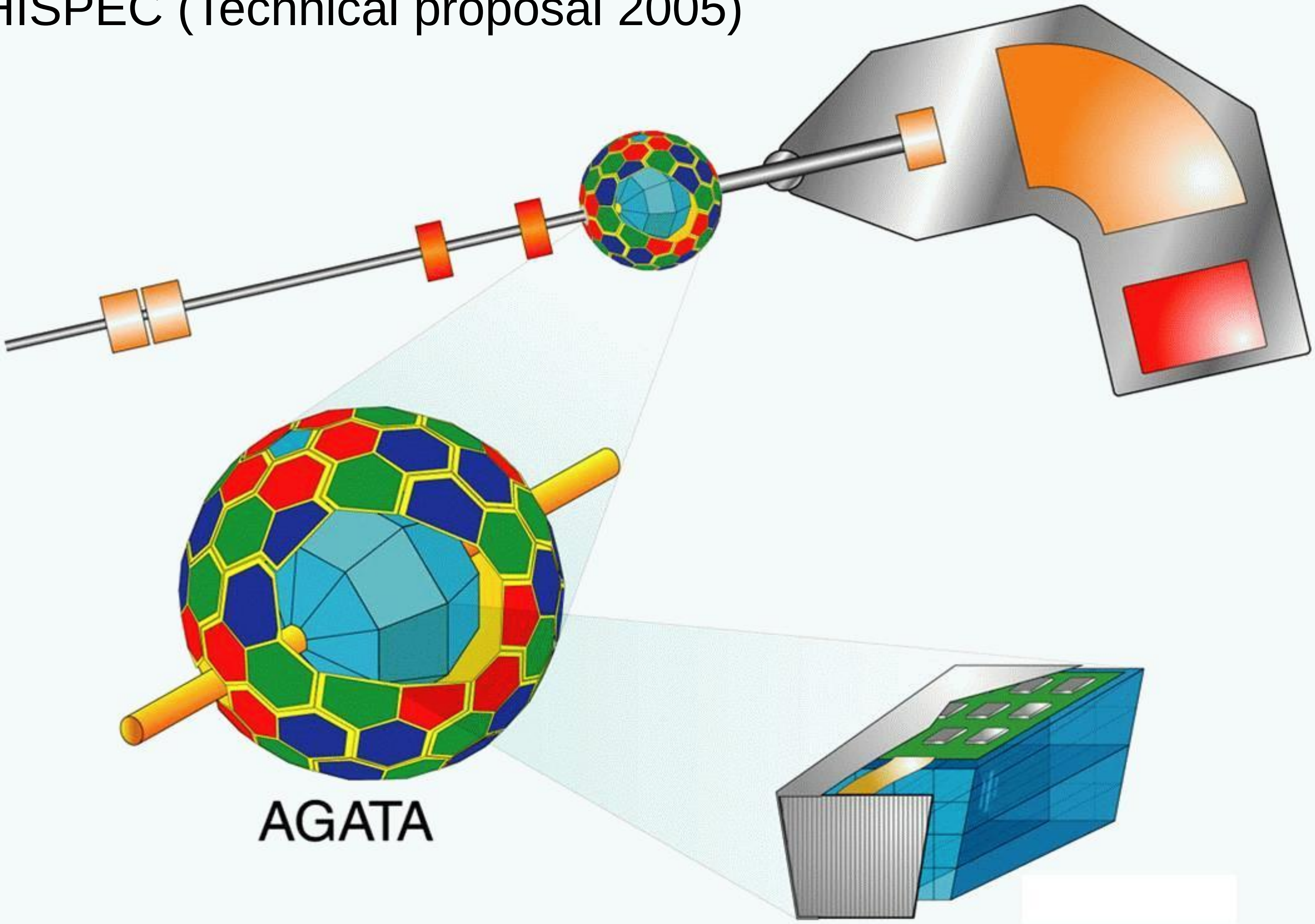
Overall, the HISPEC/DESPEC proposal is unique to FAIR for exotic nuclei that cannot be produced in reasonable quantities at other fragmentation facilities or for refractory elements that cannot be produced at ISOL facilities. Additionally, the high energy part of HISPEC is unique to FAIR for exotic nuclei that cannot be produced in reasonable quantities at other fragmentation facilities and for the study of double fragmentation. The present RISING program at the FRS provides an excellent R&D study ground for the key design problems of the entire proposal.

This proposal is on track for 2010 except for the low-energy part of HISPEC that needs considerable R&D, and design work. This part of the proposal would benefit from an early and clear definition of the beam quality and parameters following degrading to Coulomb barrier energies. There is a close connection between the beam specifications, the design of the beam identification and tracking system, the civil engineering for the experimental area, and the space requirements. These issues must be addressed promptly and in a coordinated way.

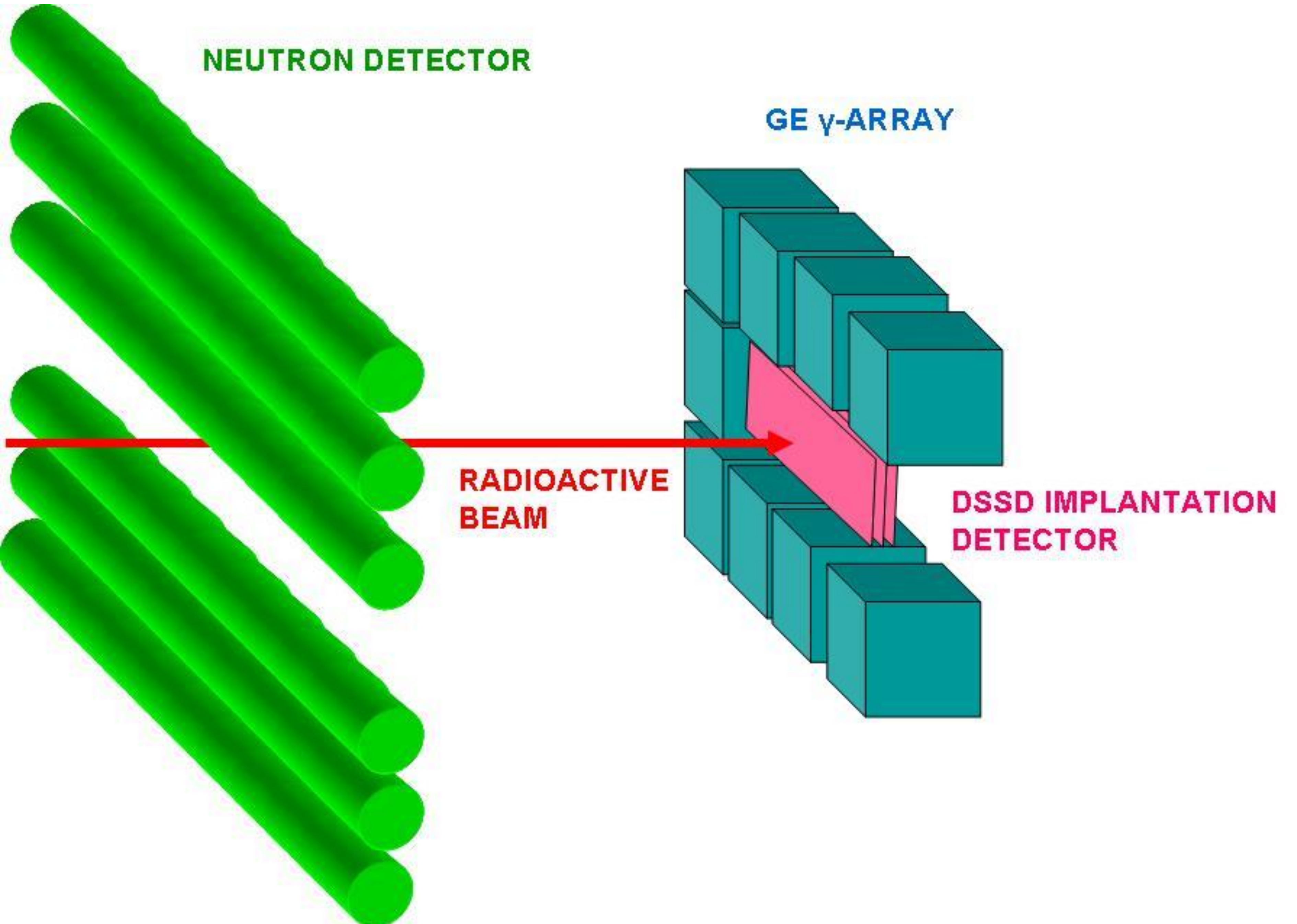
Part of the basic research program as defined by the CDR	✓
Part of the core experimental facility of FAIR	yes

The experiment is approved, on the basis of the LOI and the TP, to work towards the TDR.
The approval of the low energy part depends on the resolution of the open issues.

HISPEC (Technical proposal 2005)



DESPEC (Technical proposal 2005)



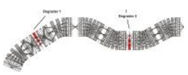
NUSTAR – The project

	Super-FRS	RIB production, separation, and identification
PSP	**Experiment**	**Description**
1.2.2	**HISPEC/ DESPEC**	In-beam γ-spectroscopy at low and intermediate energy, n-decay, high-resolution γ-, β-, α-, p-, spectroscopy
1.2.3	**MATS**	In-trap mass measurements and decay studies
1.2.4	**LaSpec**	Laser spectroscopy
1.2.5	**R^{3}B**	Kinematical complete reactions with relativistic radioactive beams
1.2.6	**ILIMA**	Large-scale scans of mass and lifetimes of nuclei in ground and isomeric states
1.2.10	**Super-FRS**	High-resolution spectrometer experiments
1.2.11	**SHE**	Synthesis and study of super-heavy elements
1.2.8	**ELISe(*)**	Elastic, inelastic, and quasi-free e^--A scattering
1.2.9	**EXL(*)**	Light-ion scattering reactions in inverse kinematics

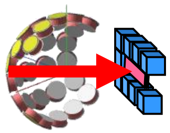
(*) NESR required – alternative/intermediate “operation” within MSV under discussion.
SHE physics case to be evaluated.

Complementarity of NUSTAR experiments

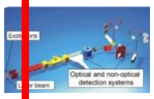
Super-FRS



HISPEC/ DESPEC

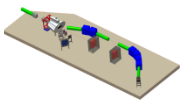


LASPEC

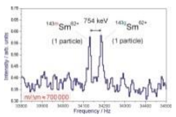


MATS

R3B

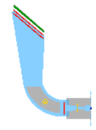


ILIMA



SHE

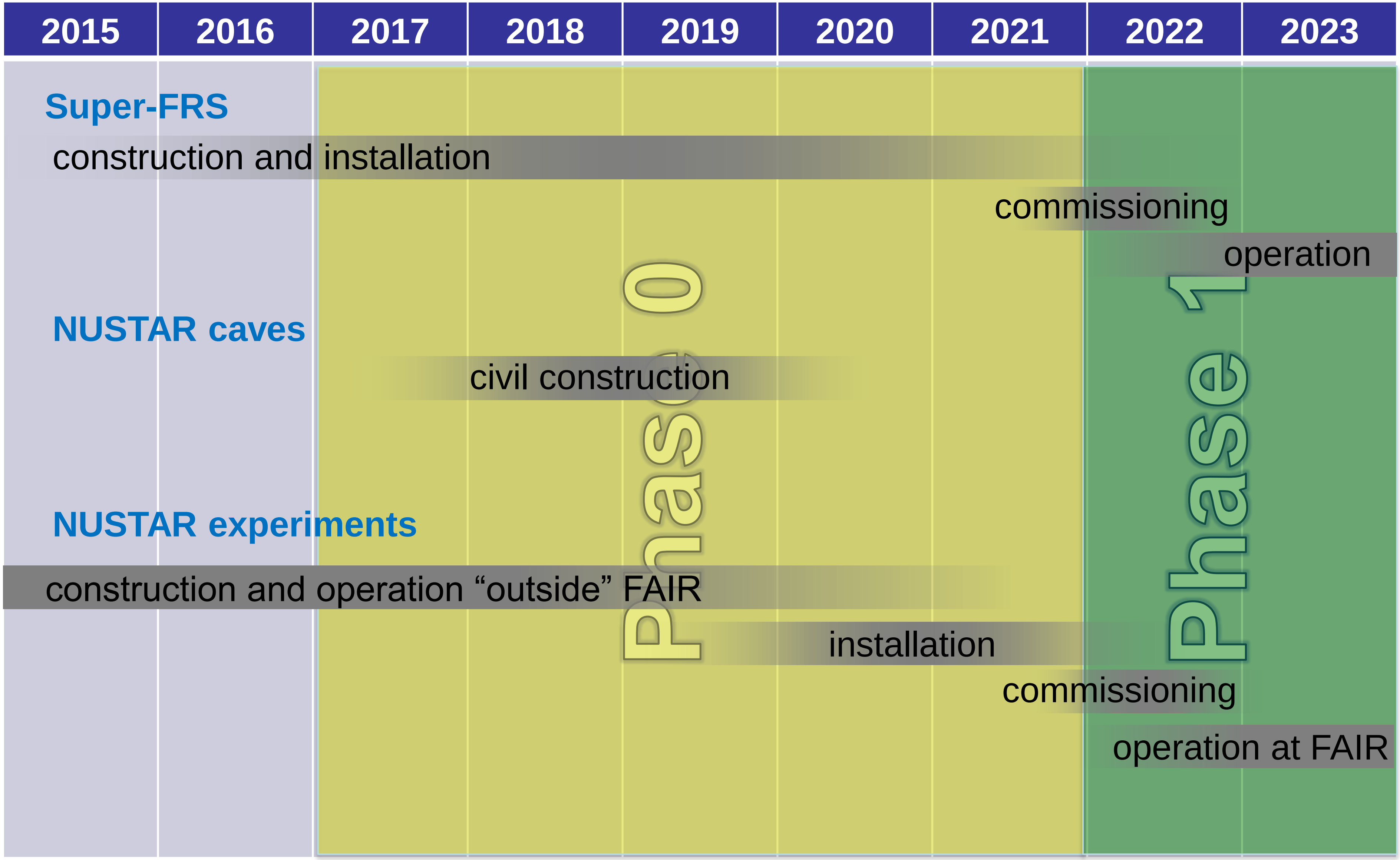
ELISE



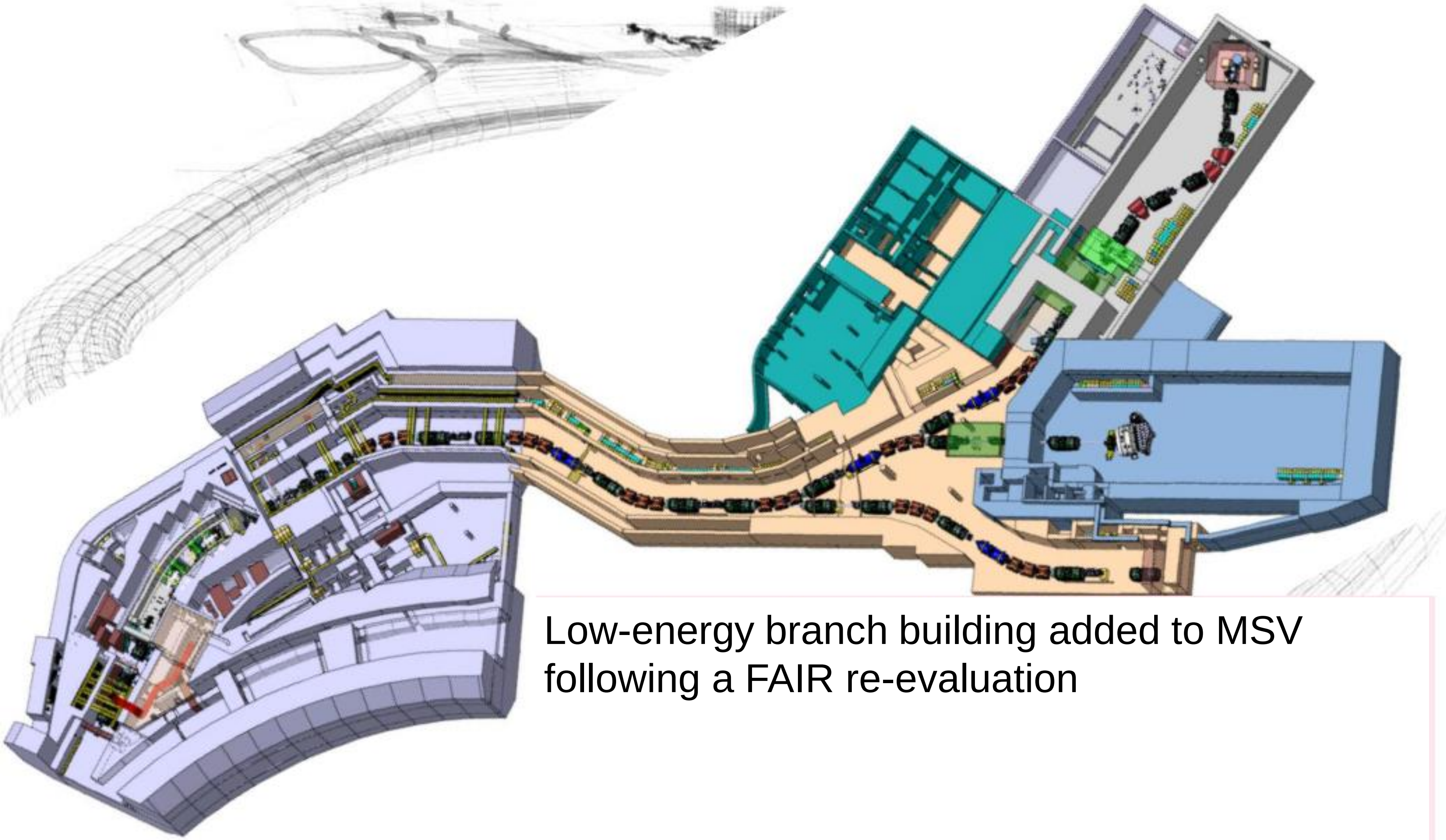
EXL

	Super-FRS	HISPEC/DESPEC	LASPEC	MATS	R3B	ILIMA	SHE	ELISe	EXL
Masses		Q-values, isomers		dressed ions, highest precision	unbound nuclei	bare ions, mapping study	precision mass of SHEs		
Half-lives	ps...ns-range	dressed ions, ms...s			resonance width, decay up to 100ns	bare ions, ms…years	µs...days		
Matter radii	interaction x-section				interaction x-section				matter densitiy distribution
Charge radii	charge-changing cross sections		mean square radii		charge-changing cross sections			charge density distribution	
Single-particle structure	high resolution, angular momentum	high-resolution particle and γ-ray spectroscopy	magnetic moments, nucl. spins	evolution of shell str., pairing int., valence nucl.	quasi-free knockout, short-range and tensor	evolution of shell closures, pairing corr.	shell structure of SHEs		low momentum transfers
Collective behavior		electromag. transitions	quadrupole moments	halo structure	dipole response	changes in deformation		electromag. transitions	monopole resonance
EoS					polarizability, neutron skin			neutron skin ➔	neturon skin, Compressibility
Exotic Systems	bound mesons, hypernuclei, nucleon res.								

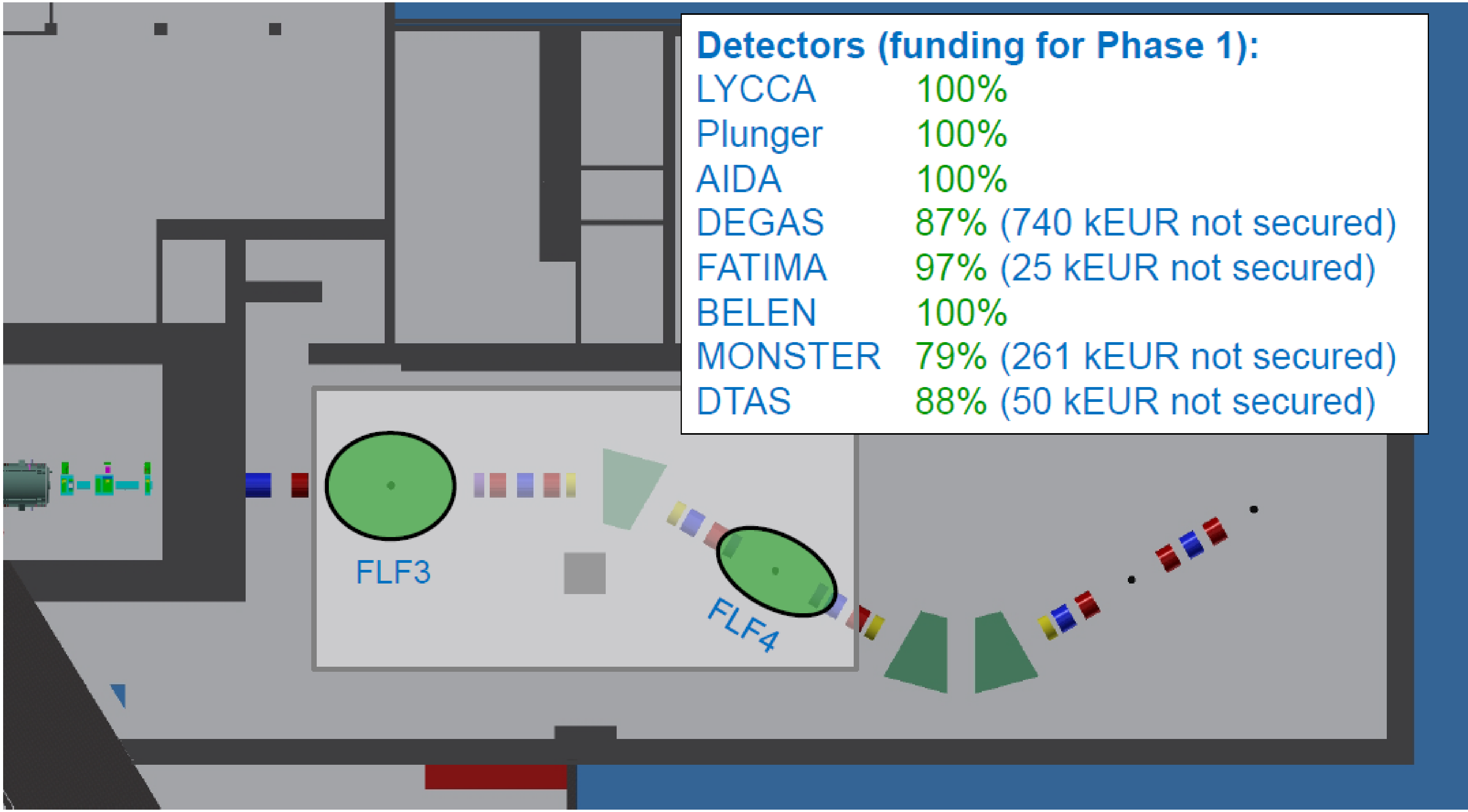
Scenario for phase 0 and phase



Low-energy branch

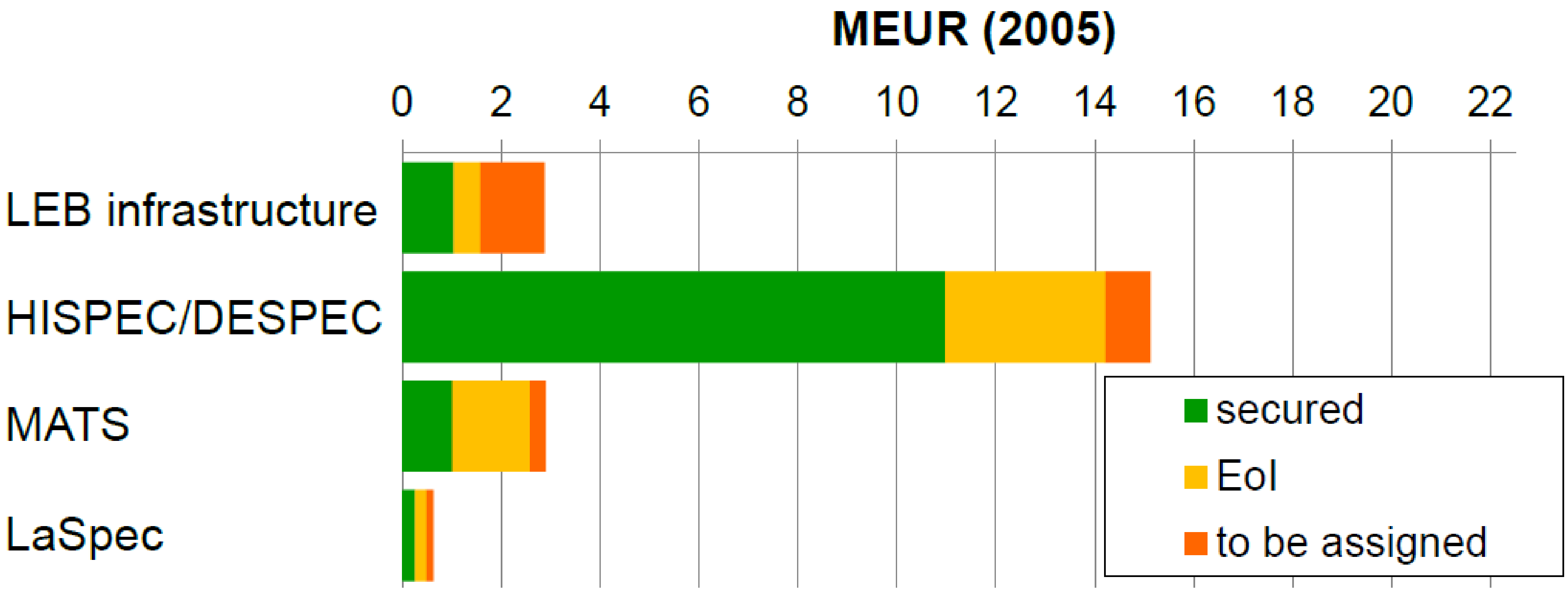


Low-energy branch building added to MSV following a FAIR re-evaluation



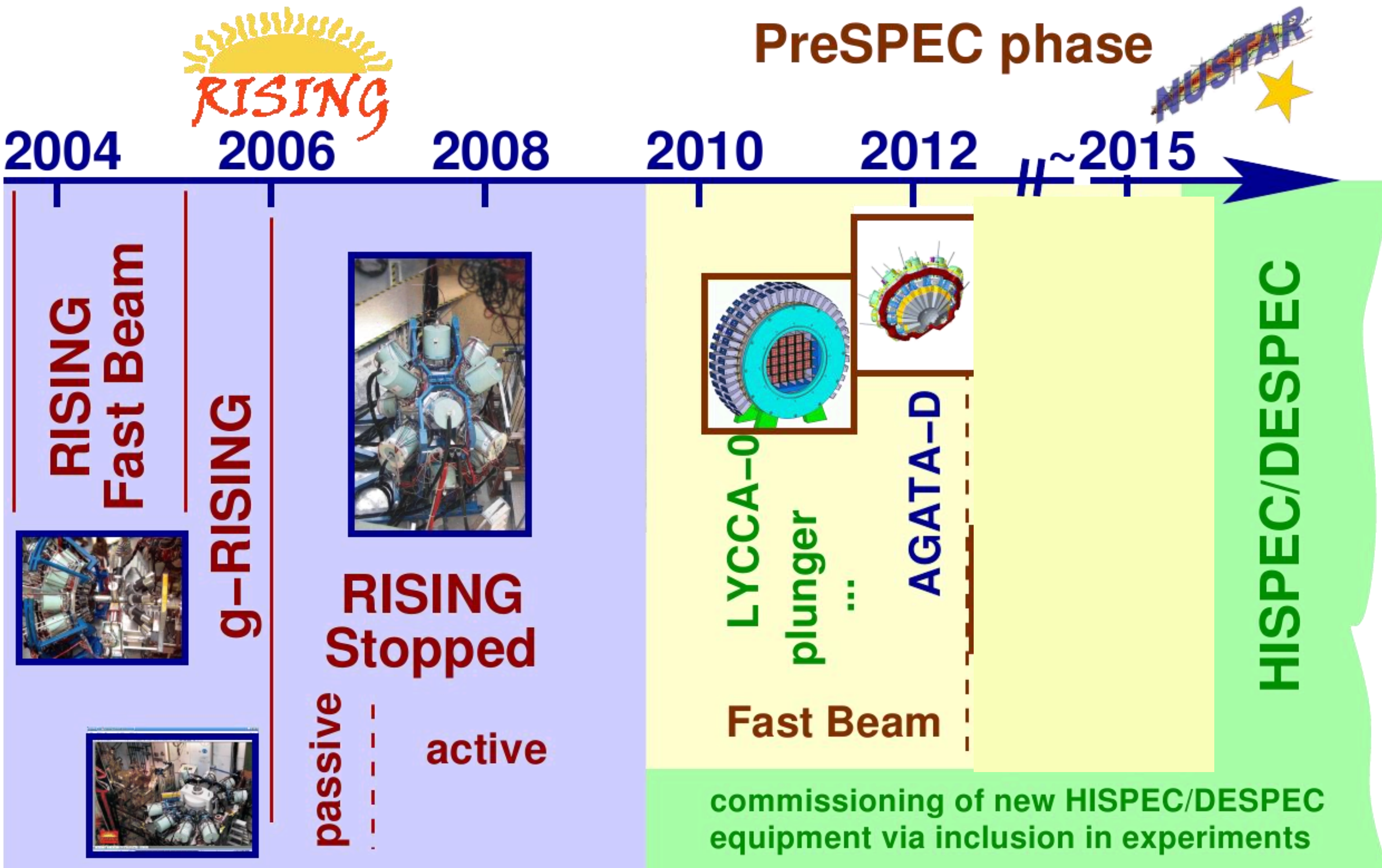
Detectors (funding for Phase 1):

LYCCA	100%
Plunger	100%
AIDA	100%
DEGAS	87% (740 kEUR not secured)
FATIMA	97% (25 kEUR not secured)
BELEN	100%
MONSTER	79% (261 kEUR not secured)
DTAS	88% (50 kEUR not secured)



Missing funds for:
Infrastructure,
DEGAS phase 2,
MONSTER

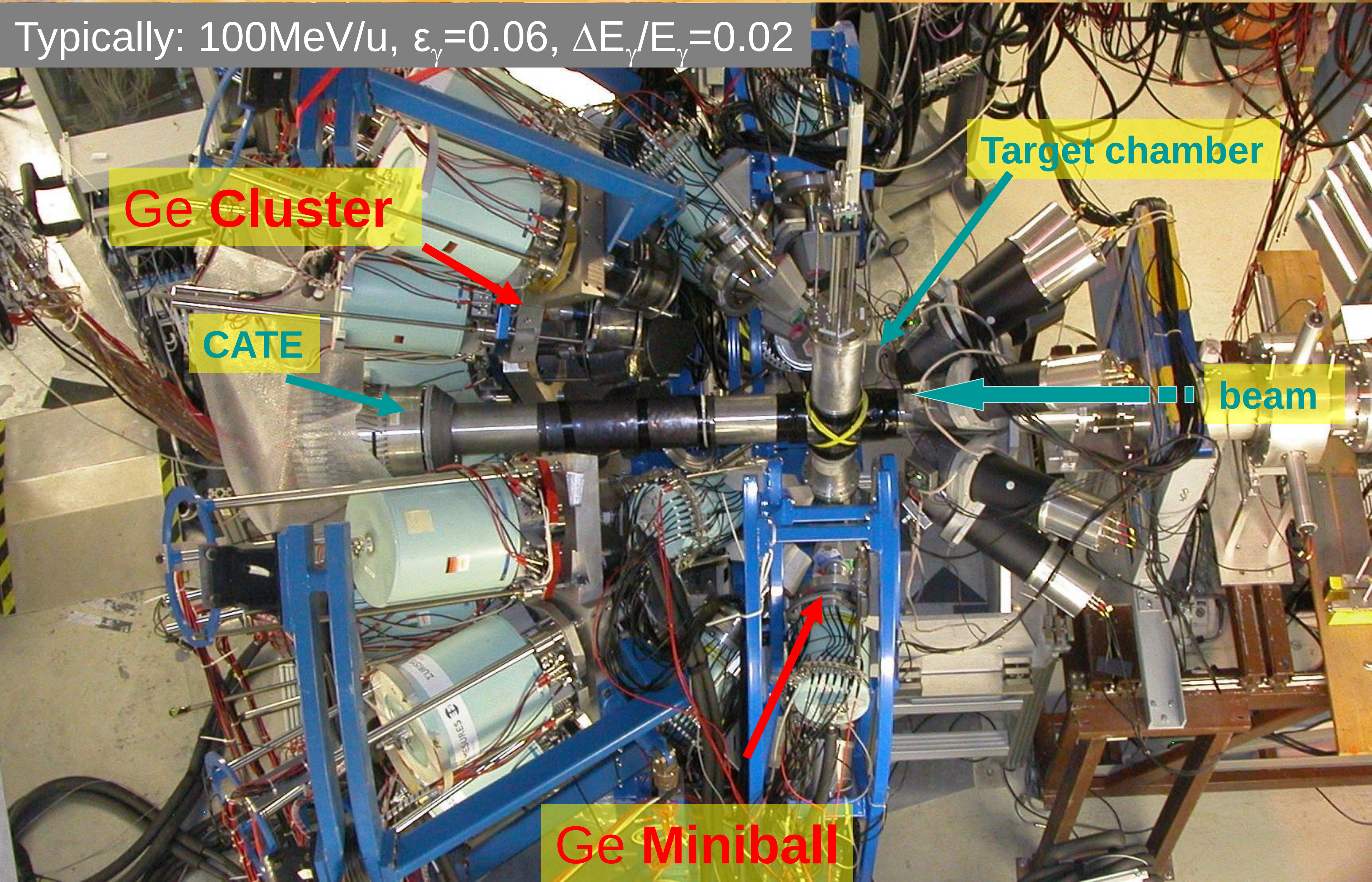
γ-ray spectroscopy at GSI (and FRS)

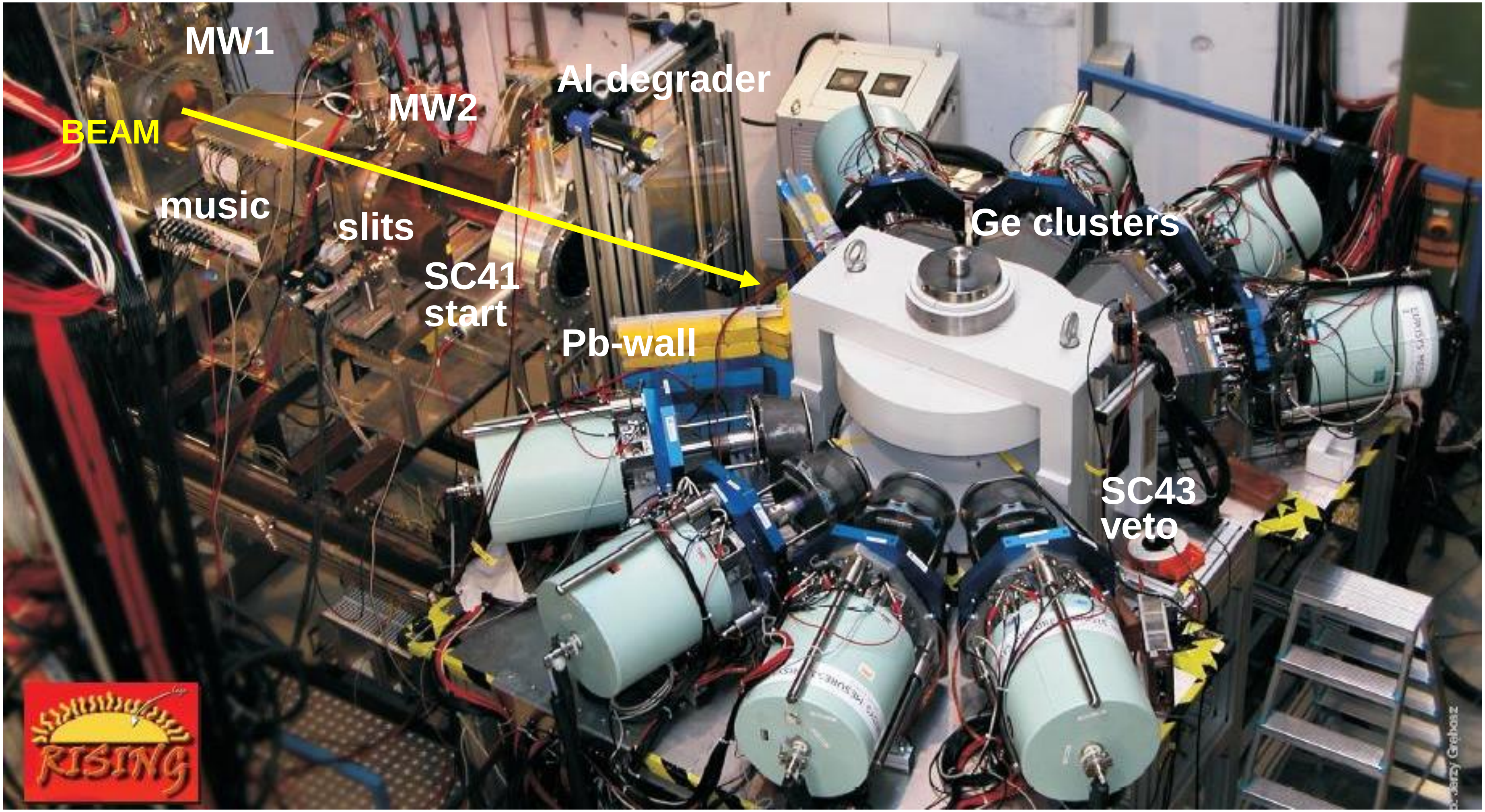


AGATA 2012-2014

RISING γ-array for fast beams

Typically: 100MeV/u, ε_γ=0.06, $\Delta E_\gamma/E_\gamma$=0.02





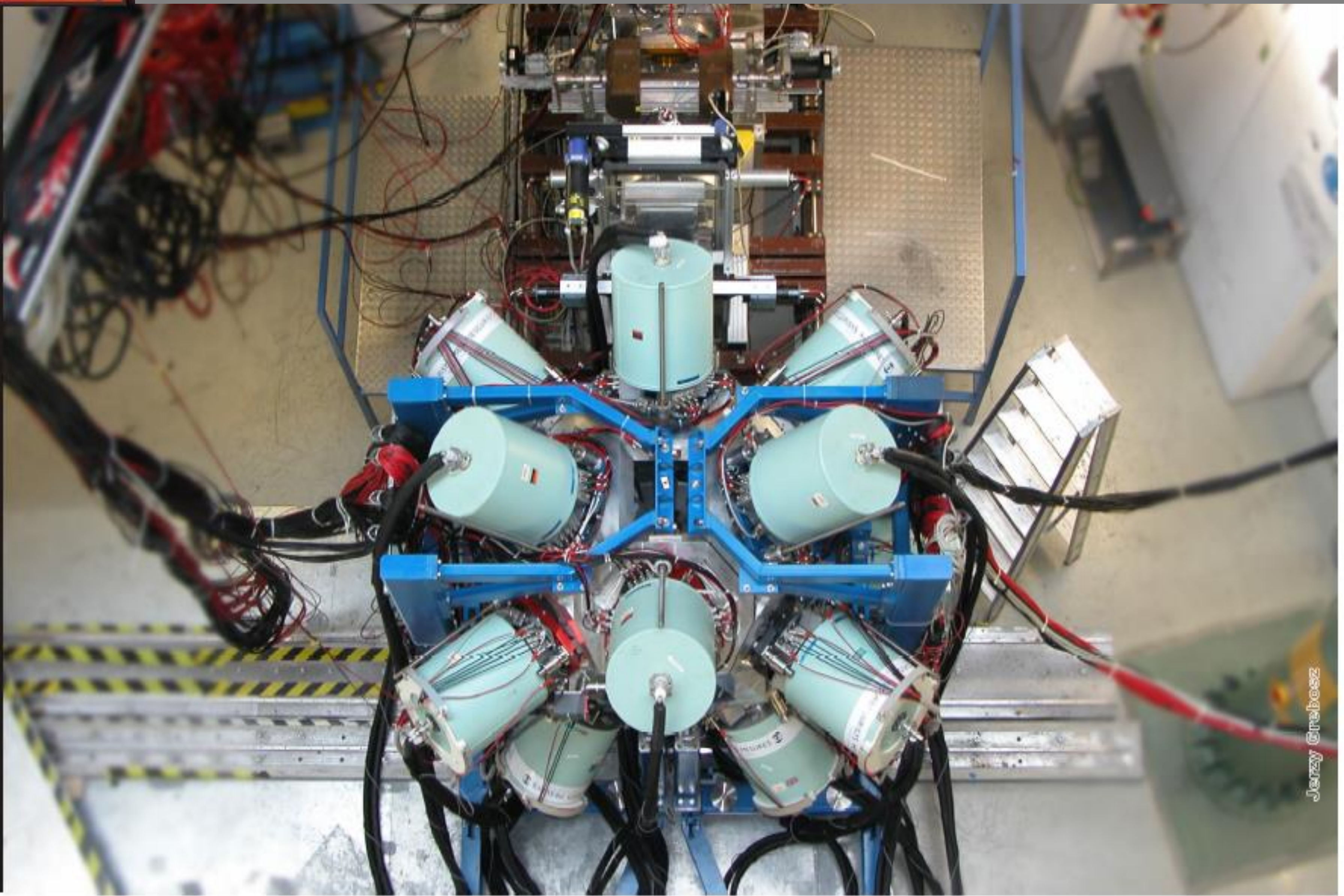
4 clusters with BGO anticompton shields and short collimators
4 clusters with the former RISING shields
Total efficiency (Eu source) = 1.9 – 2.3 %

Stopped Rising Array @ GSI: 15 x 7 element CLUSTERs

ε_γ =11% at 1.3 MeV, 20% at 550 keV, 35% at 100 keV

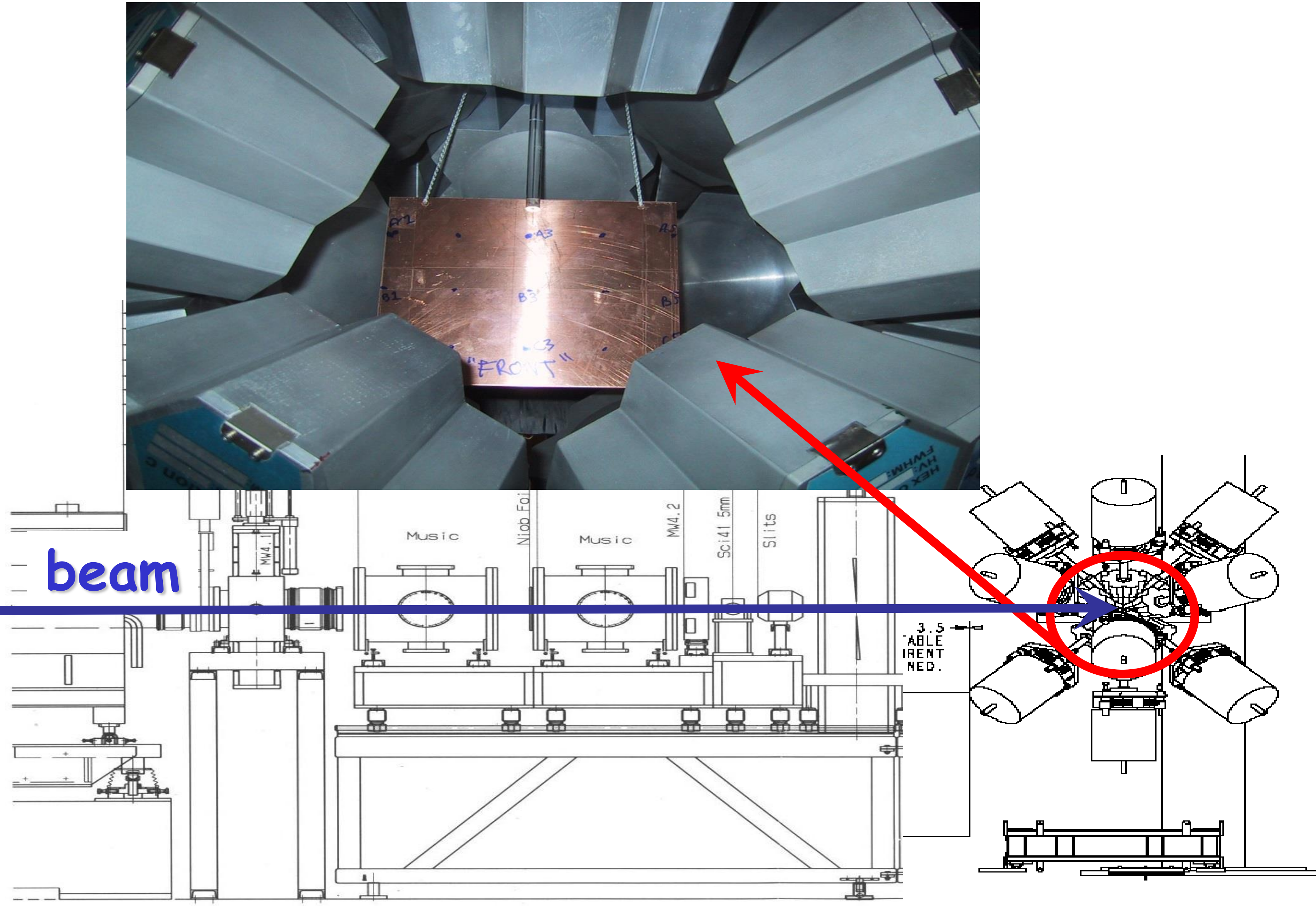
flight time ~300ns

stopped beam setup

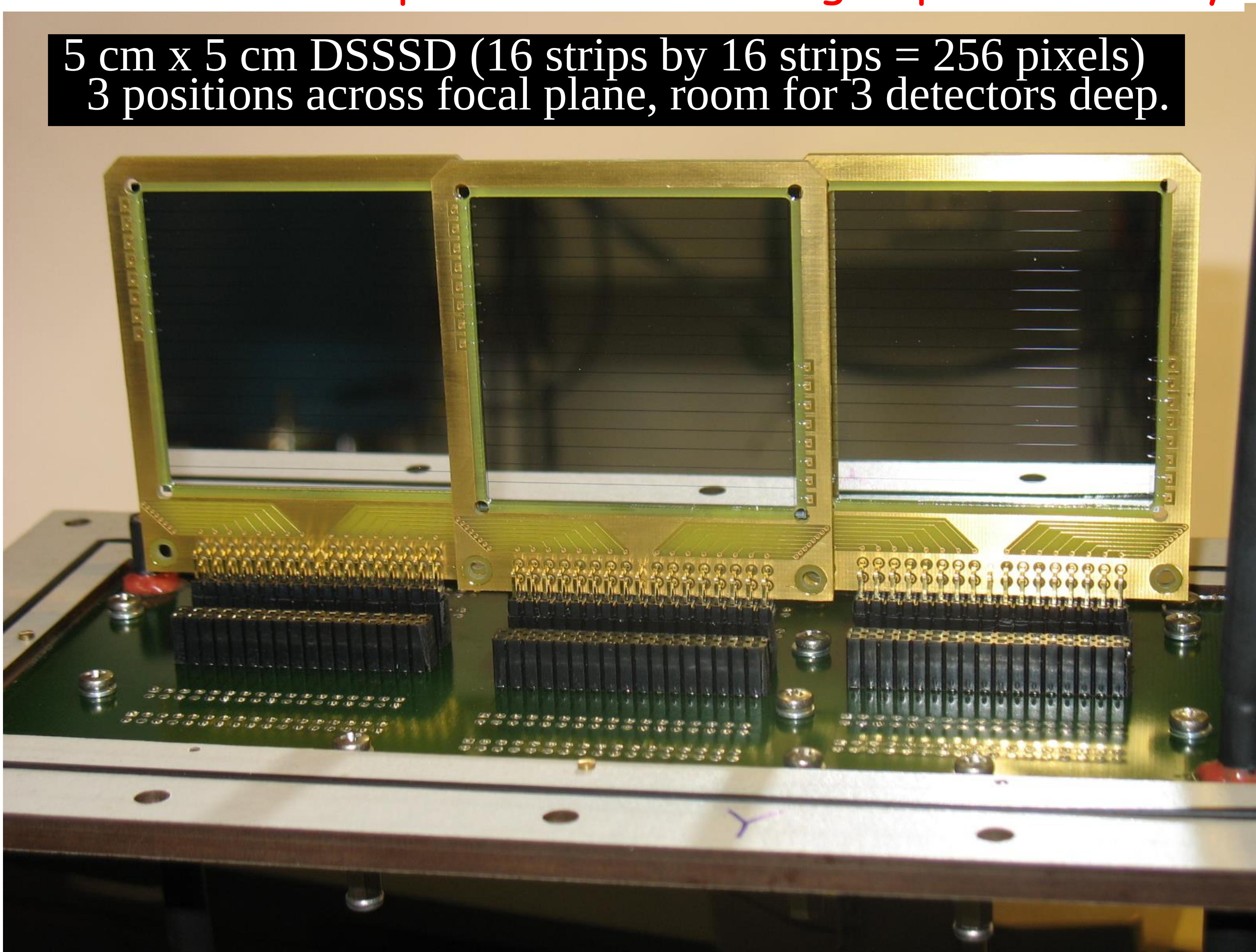


Passive stopper:

For isomeric decays, T1/2< 1 ms

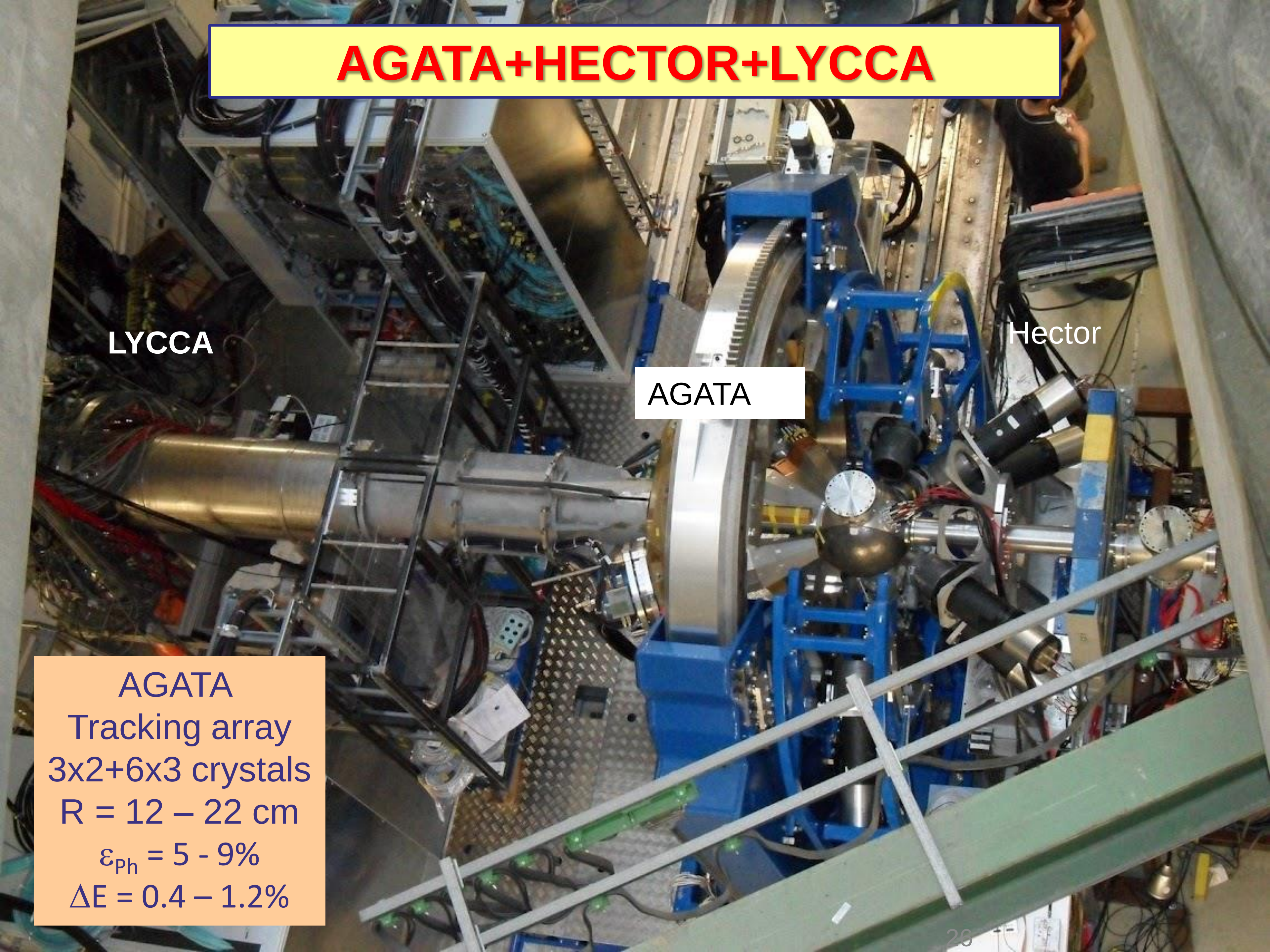


Active stopper:
correlation between implantation and charged particle decay



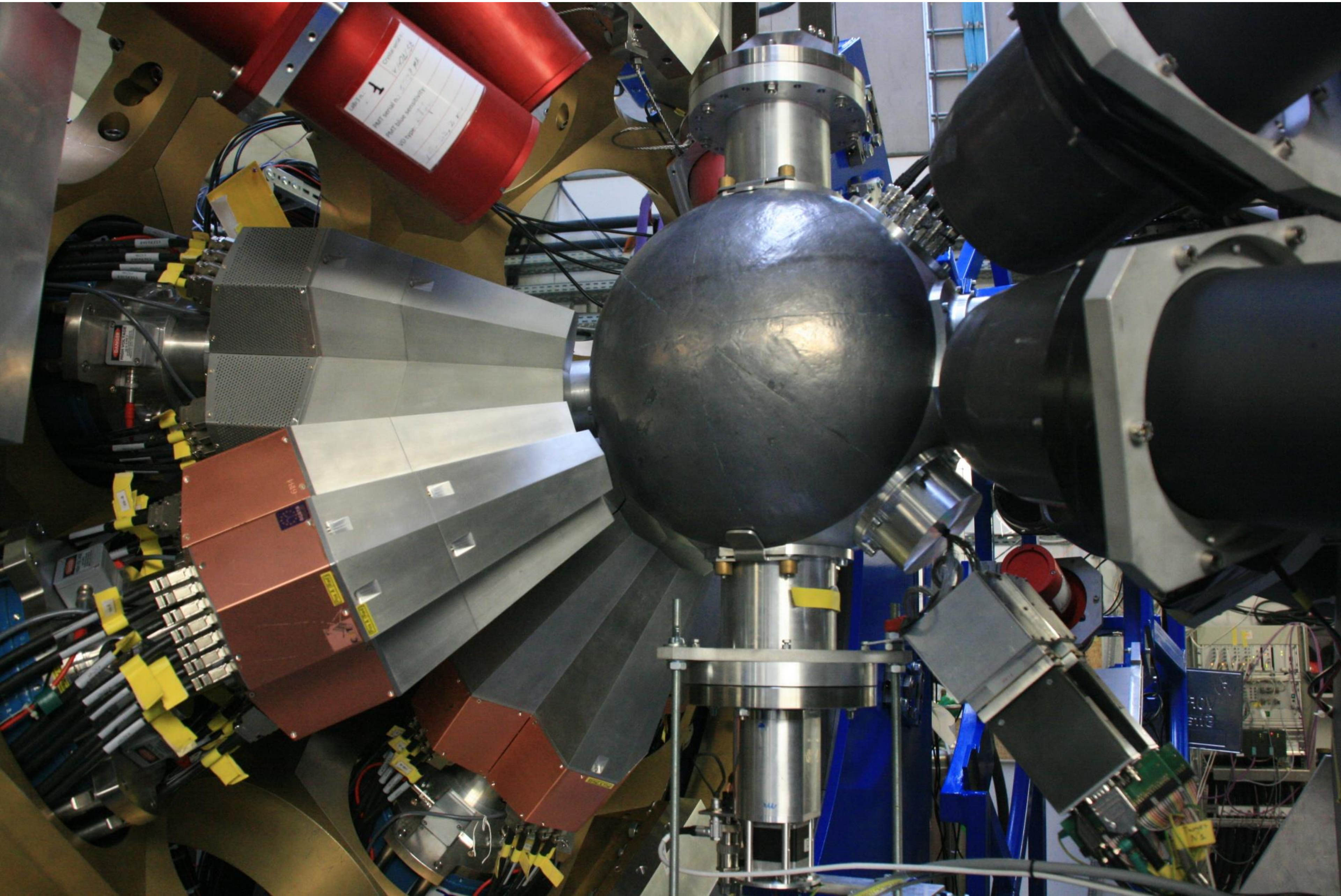
R. Kumar et al., NIM A 598 (2009) 754.

AGATA+HECTOR+LYCCA

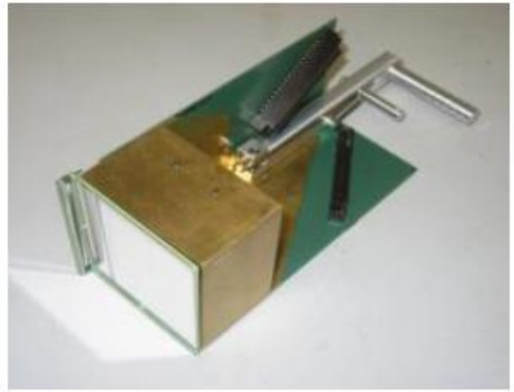


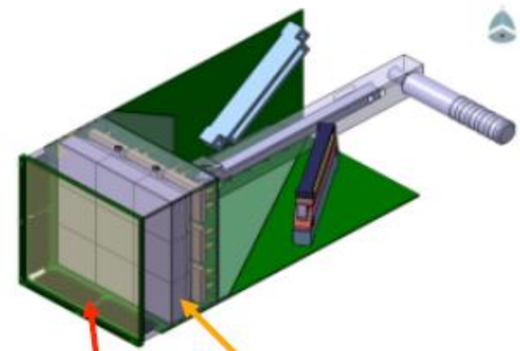
AGATA
Tracking array
3x2+6x3 crystals
R = 12 – 22 cm
ε_{Ph} = 5 - 9%
ΔE = 0.4 – 1.2%

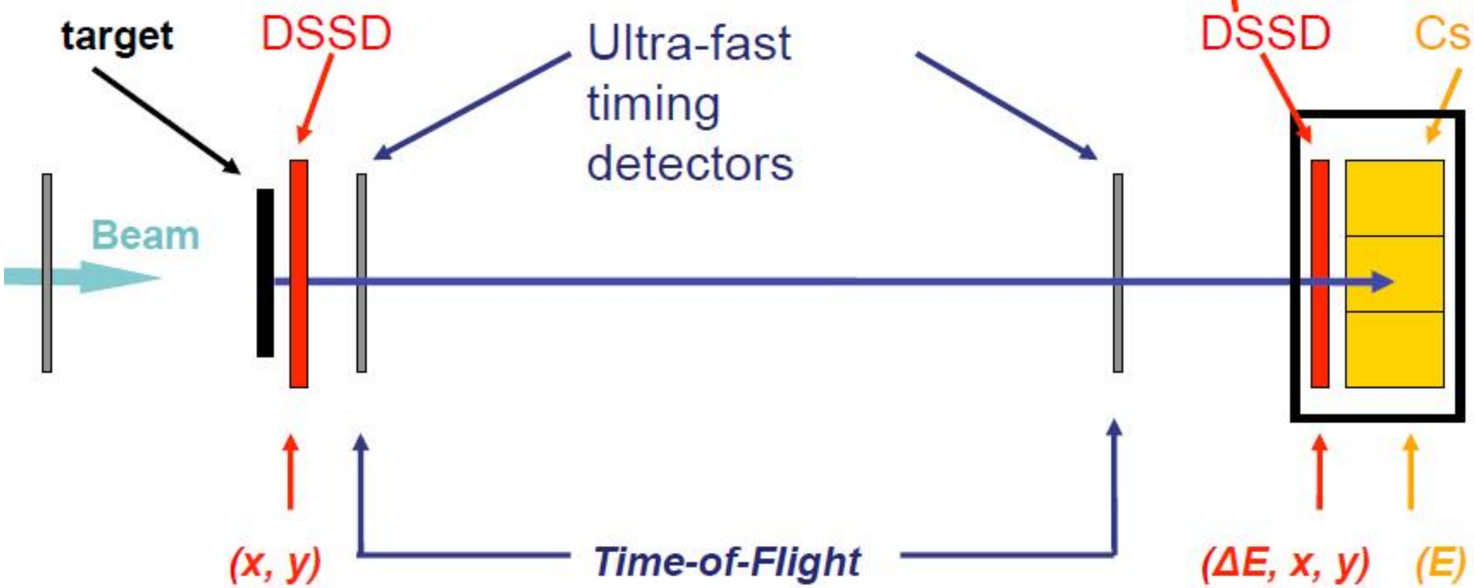
AGATA demonstrator at GSI (Germany) ~20 crystals



HISPEC: high-resolution in-flight spectroscopy







Time of flight measurement: diamond, Si or **plastic**?

LYCCA: P.Golubev et al., NIM. A723 , 55 (2013)

LYCCA TOF solutions:

Plastic-plastic:

Δt (FWHM)= 61 ps => 43 ps for one detector (requirement=100ps)

Δ A (FWHM)=0.5

This is within specifications and this solution is used in the AGATA campaign

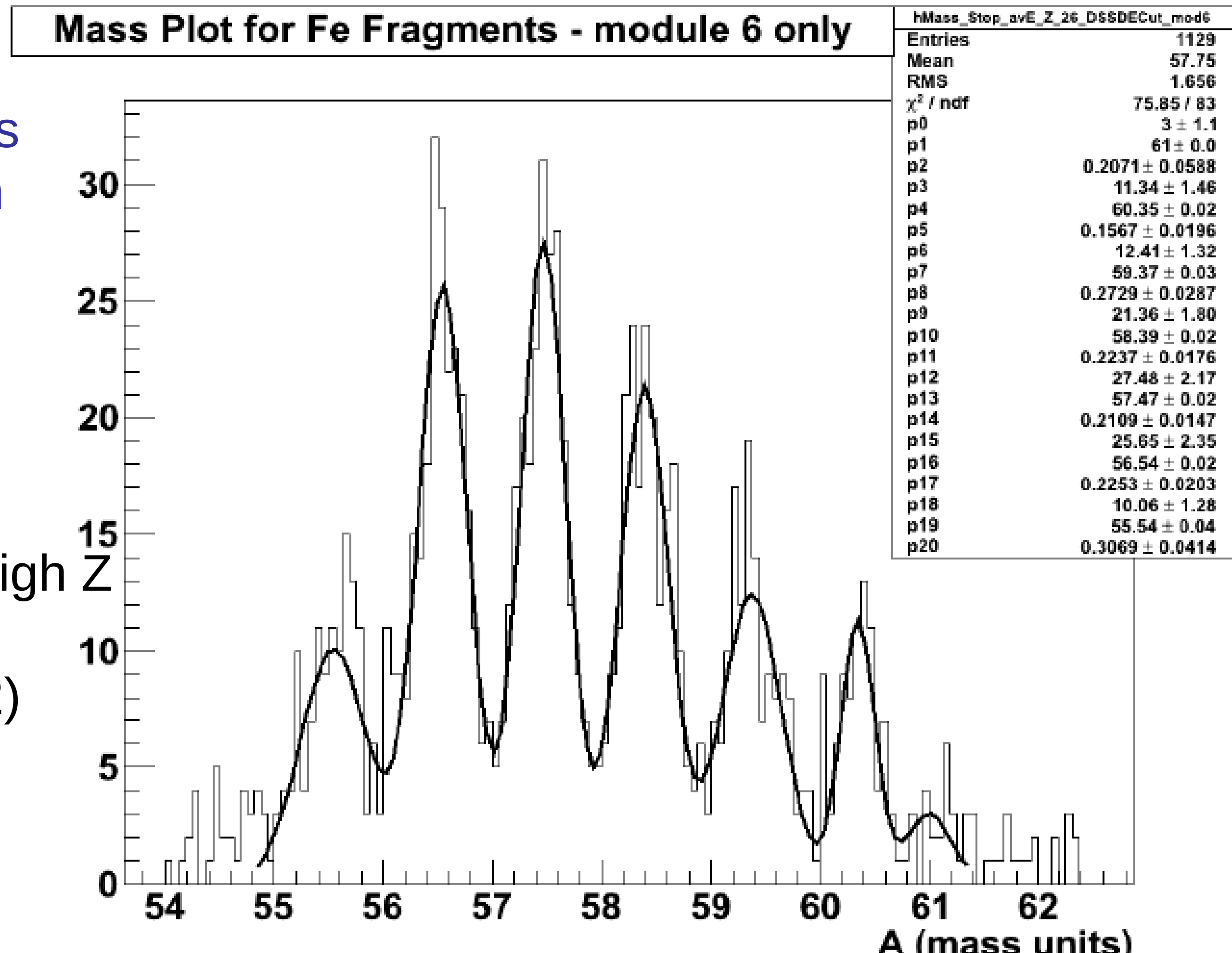


Figure 6: Mass plot for Fe fragments fitted to obtain sigma values for each mass peak. Outside peaks are poorly fitted.

L. Scruton, Univ. of York

Diamond-plastic:

Home made diamond:

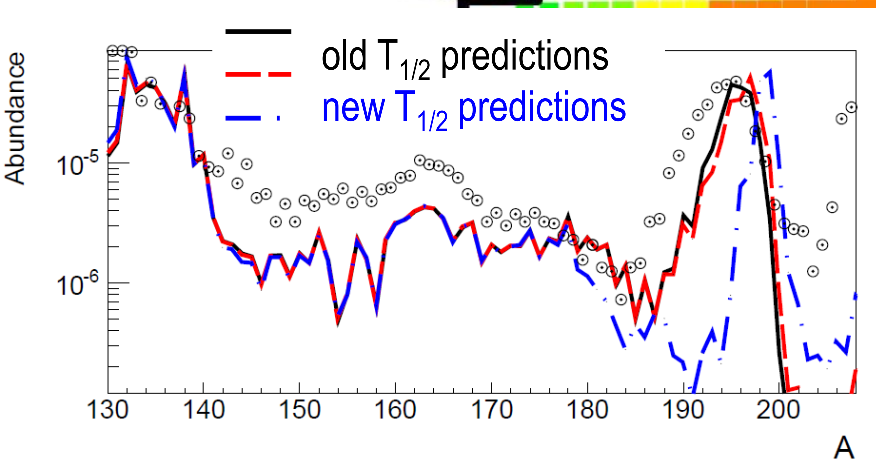
Δ t (FWHM) < 100 ps for high Z

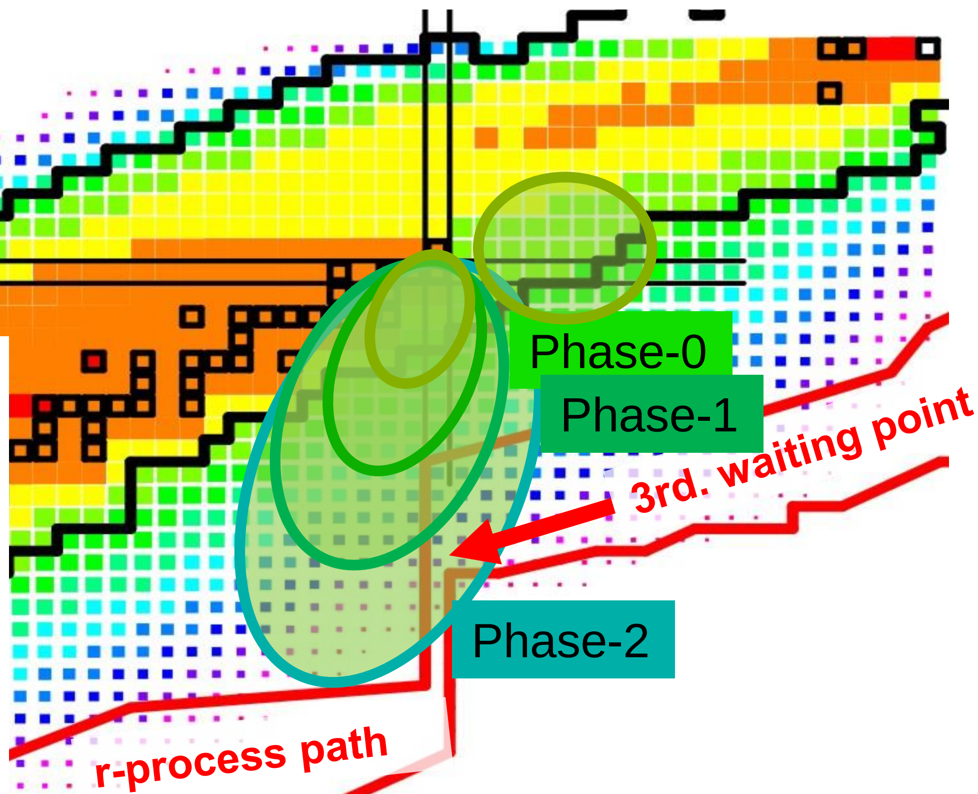
F. Schirru et al.,

J. of Instr. 7, P05005(2012)

DESPEC in 2018-2020 (phase 0)

Physics workshop held in September 2016
Focus on heavy neutron-rich nuclei
^{208}Pb and ^{238}U beams
Several detector systems ready:
DTAS, FATIMA, AIDA,
DEGAS, BELEN



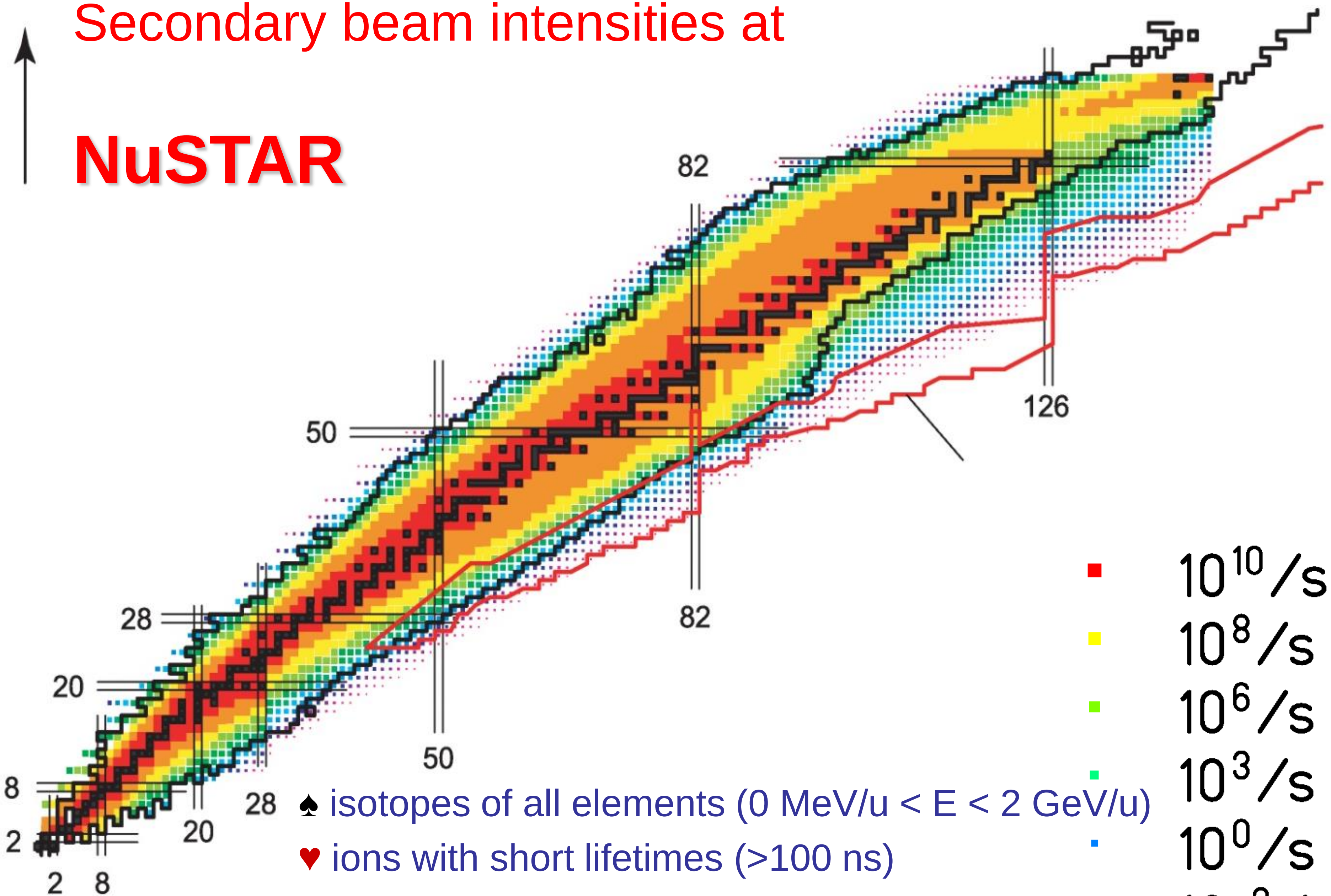


Mass abundances depend on the detailed structureof N=126 nuclei around the 3rd r-process waiting point

DESPEC will measure
-β-lifetimes
-neutron-branchings
-strength distributions
-level structure

Secondary beam intensities at

NuSTAR



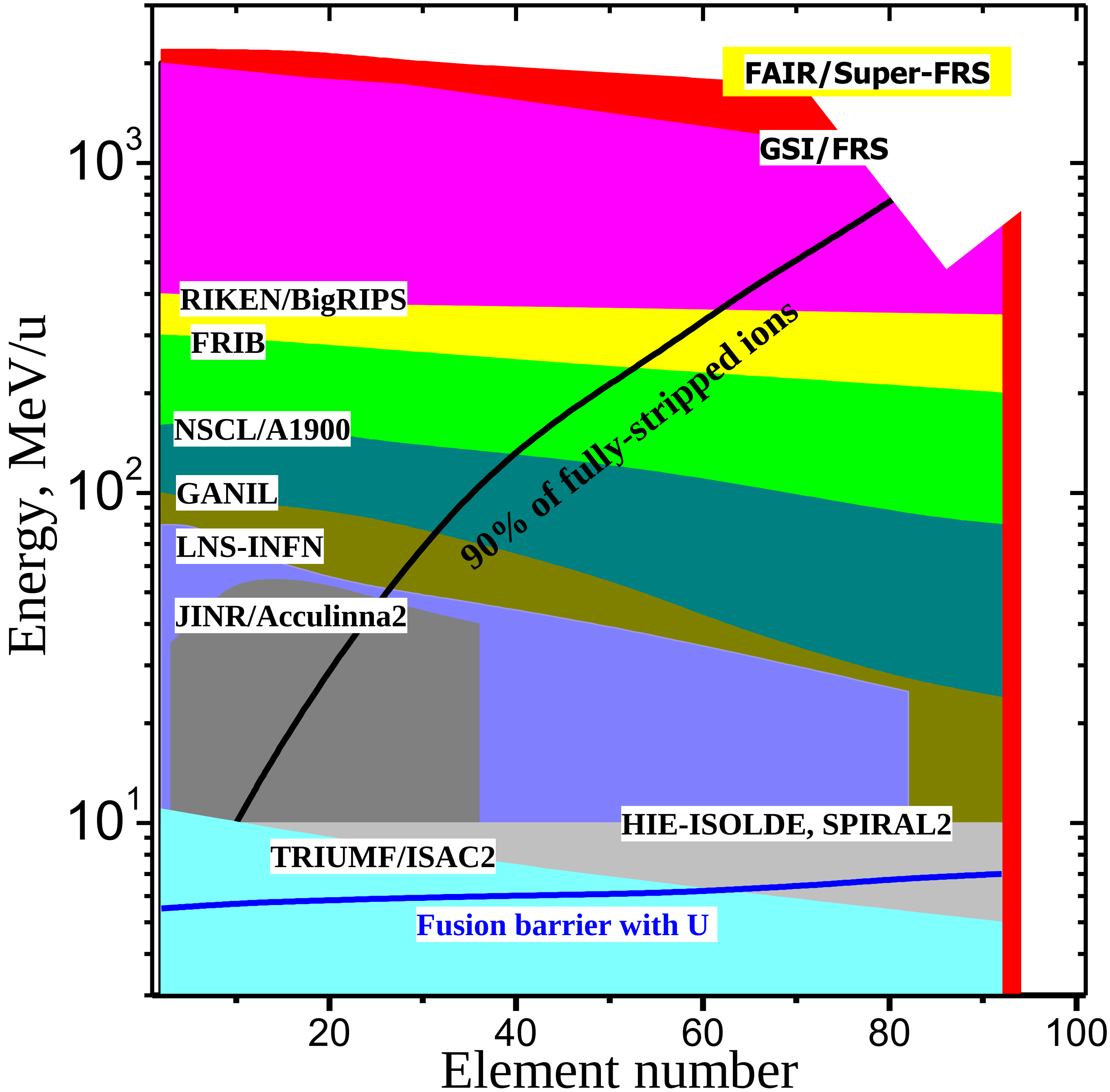
♠ isotopes of all elements (0 MeV/u < E < 2 GeV/u)

♥ ions with short lifetimes (>100 ns)

♣ isomeric beams

♦ storage rings

RARE-ISOTOPE BEAM FACILITIES



Experimental considerations

-fragmentation/spallation of ^{238}U, ^{208}Pb (^{209}Bi)

fragmentation: GSI/FAIR, (RIKEN)

spallation: ISOLDE

-multinucleon transfer on ^{208}Pb (^{198}Pt)

with particle identification (thin target)

without particle identification (thick target)

RIKEN, GANIL, ANL

Neutron-rich nuclei from $^{136}Xe+^{198}Pt$

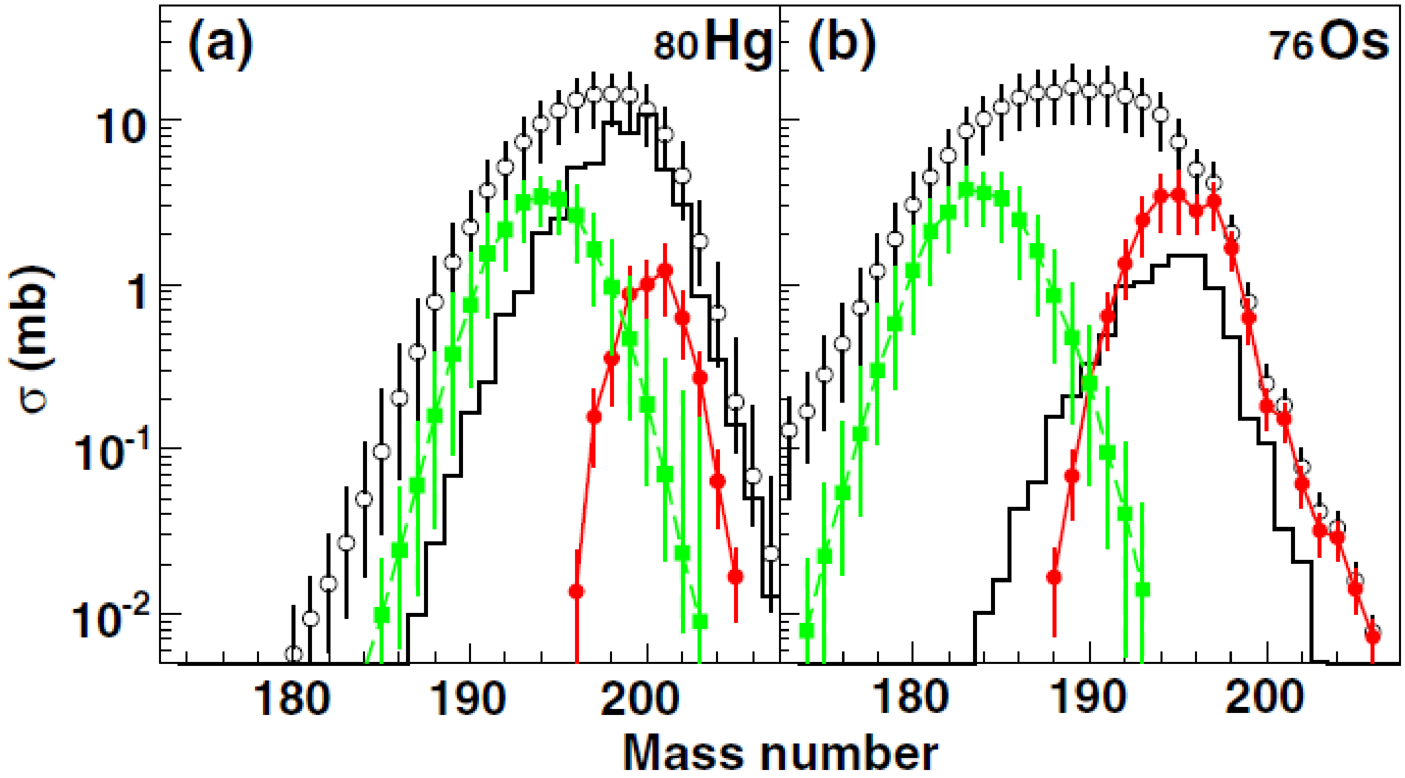
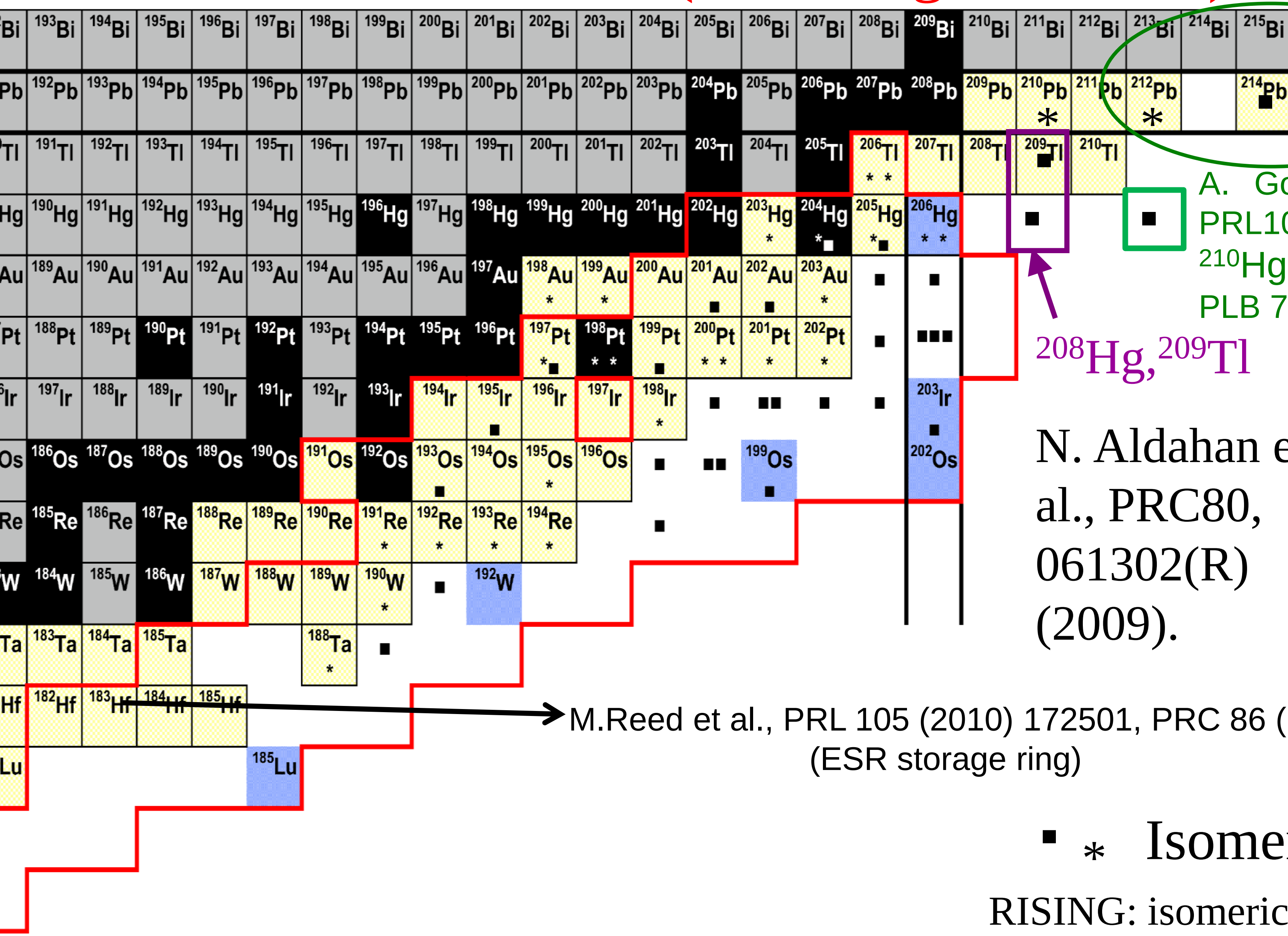


FIG. 2 (color online). Experimentally deduced (open circles) and calculated by GRAZING (histograms) cross sections for Hg (left) and Os (right) isotopes. Isotopic distributions for different windows of total kinetic energy loss from −25 to 25 MeV and from 175 to 225 MeV are indicated by different filled symbols of circles and squares, respectively.

Y.X. Watanabe et al., Phys. Rev. Lett. 115, 172503 (2015)

GANIL exp.

Isomeric states (from fragmentation)



A. Gottardo et al.
PRL109(2012)1625
^{210}Hg:
PLB 725 (2013)292

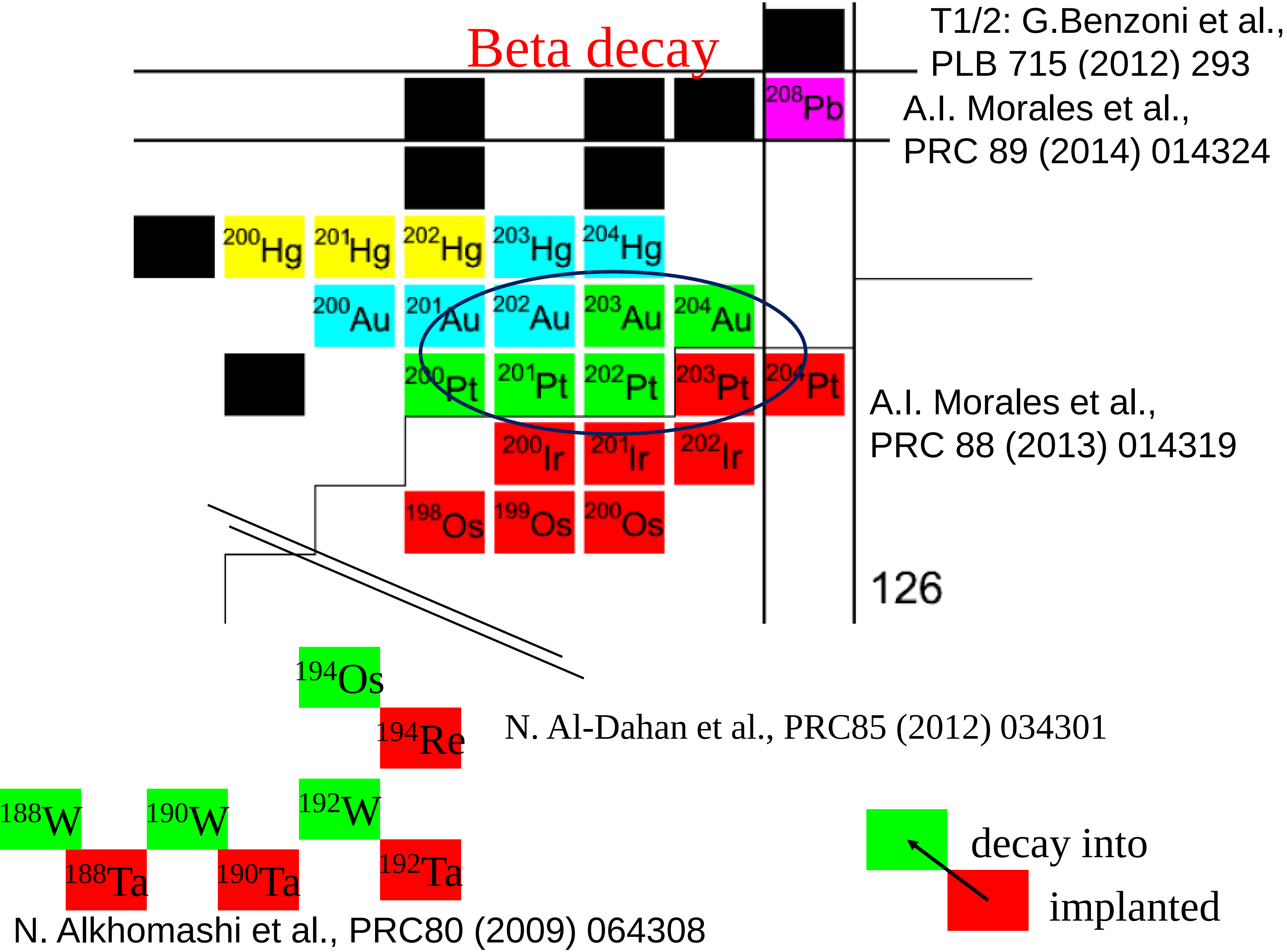
N. Aldahan et al., PRC80, 061302(R) (2009).

M.Reed et al., PRL 105 (2010) 172501, PRC 86 (2012) 054321
(ESR storage ring)

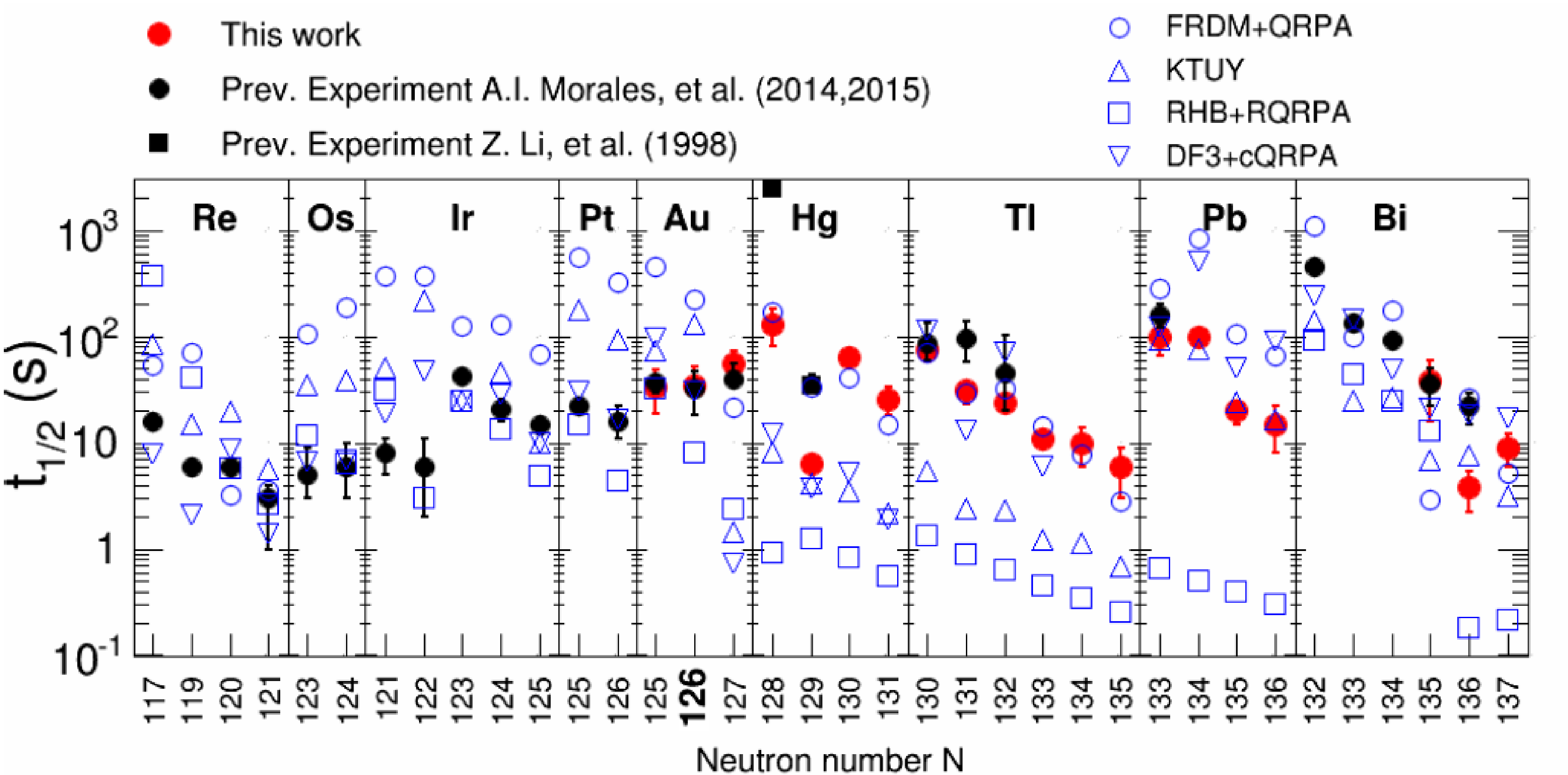
▪ * Isomeric state

RISING: isomeric decays

S. Steer et al., Phys. Rev. C 84 (2011) 044313


Beta decay
T1/2: G.Benzoni et al.,
PLB 715 (2012) 293
208Pb
A.I. Morales et al.,
PRC 89 (2014) 014324
200Hg
201Hg
202Hg
203Hg
204Hg
200Au
201Au
202Au
203Au
204Au
200Pt
201Pt
202Pt
203Pt
204Pt
A.I. Morales et al.,
PRC 88 (2013) 014319
200Ir
201Ir
202Ir
198Os
199Os
200Os
126
194Os
194Re
N. Al-Dahan et al., PRC85 (2012) 034301
188W
190W
192W
188Ta
190Ta
192Ta
decay into
implanted
N. Alkhomashi et al., PRC80 (2009) 064308

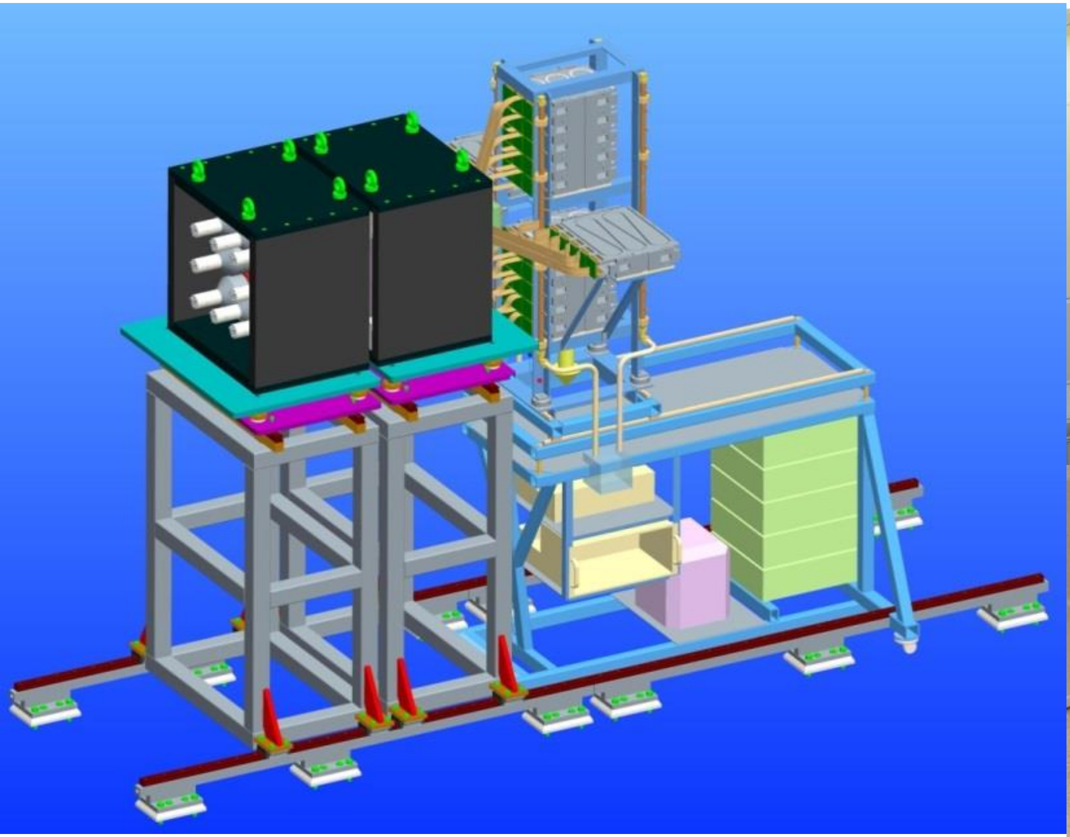
Lifetime measurements

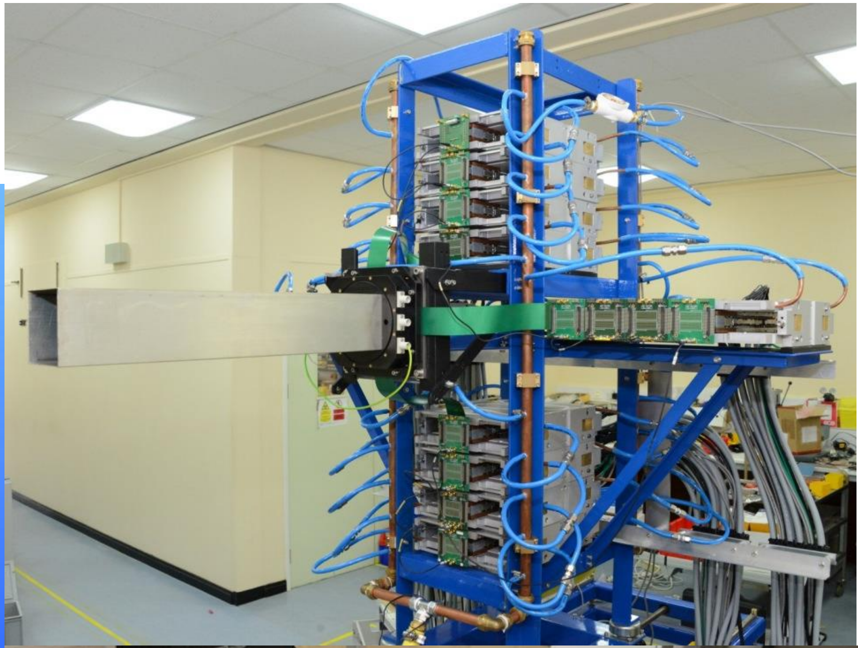


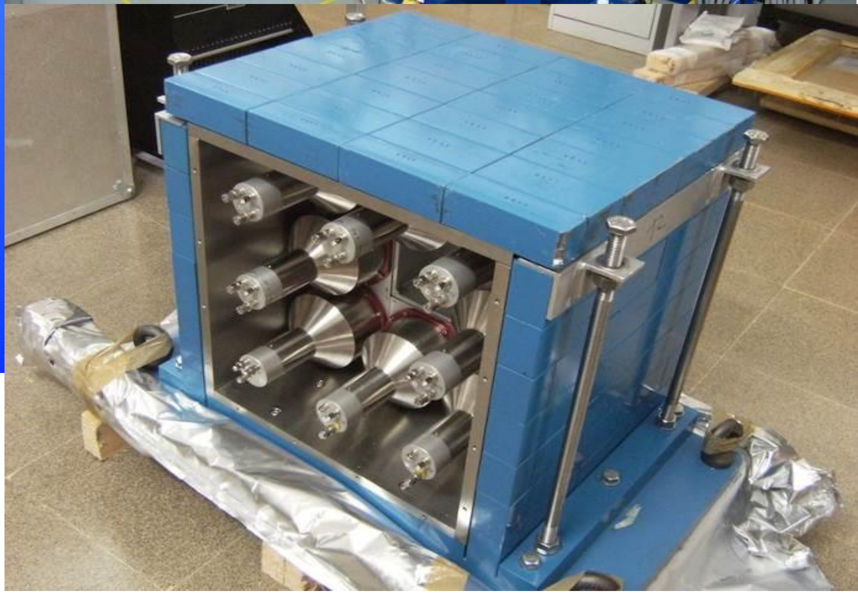
⇒ The most neutron-rich N=126 for which lifetime was measured is ^{204}Pt

R. Caballero-Folch et al., PRL17, 012501 (2016)

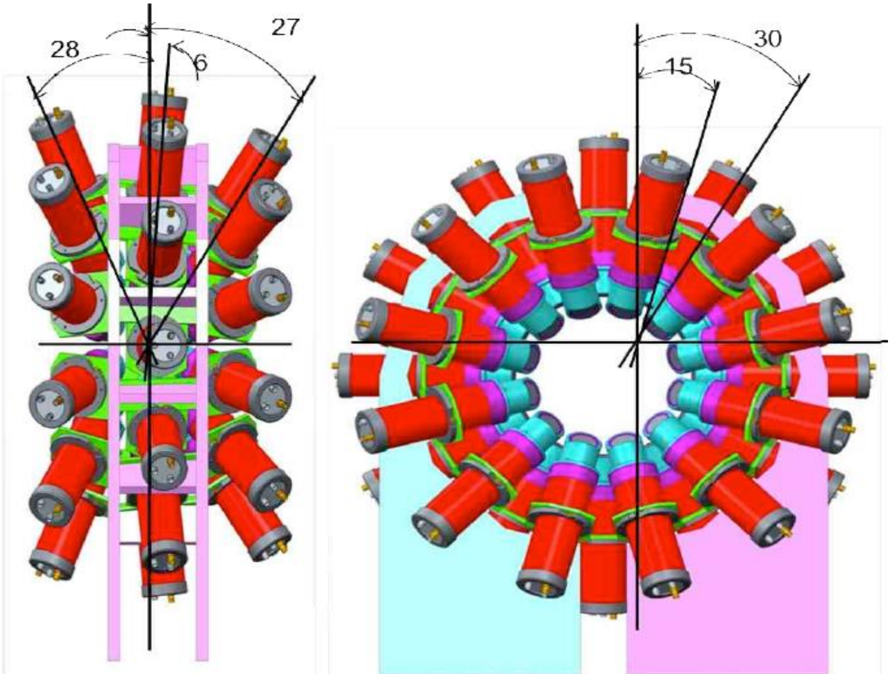
At the beginning (2018) lower beam intensity
⇒ start with equipment never used at GSI:
DTAS+AIDA

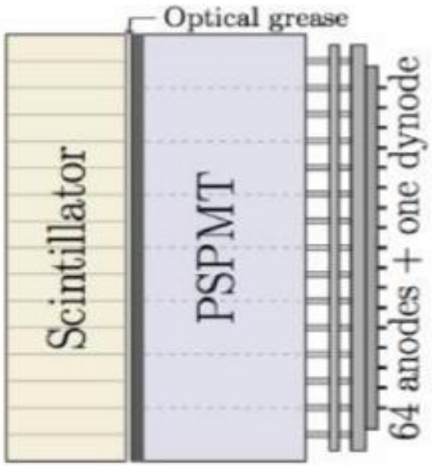






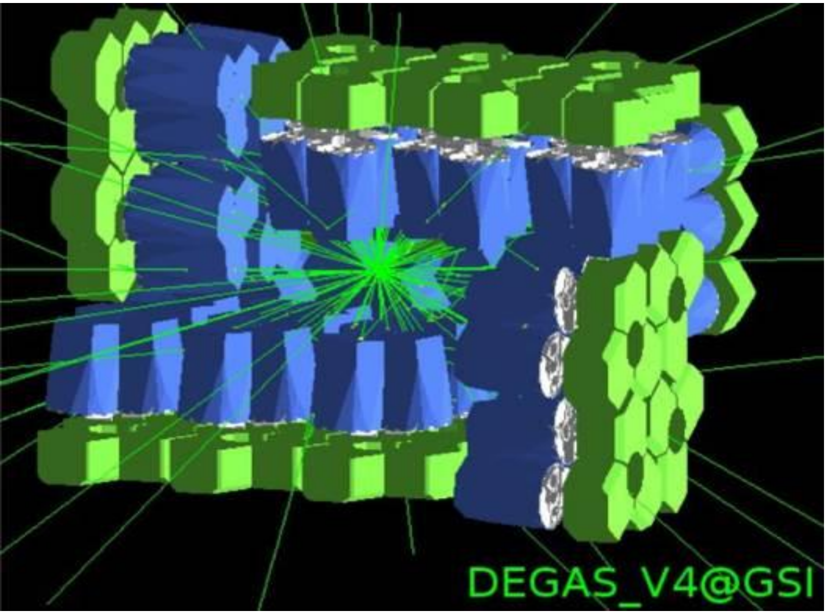
and FATIMA+AIDA

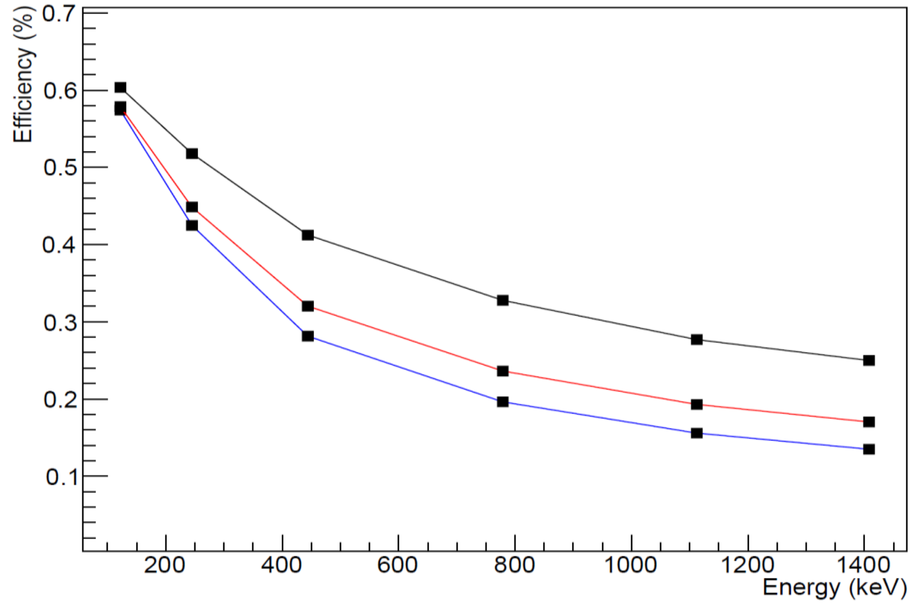


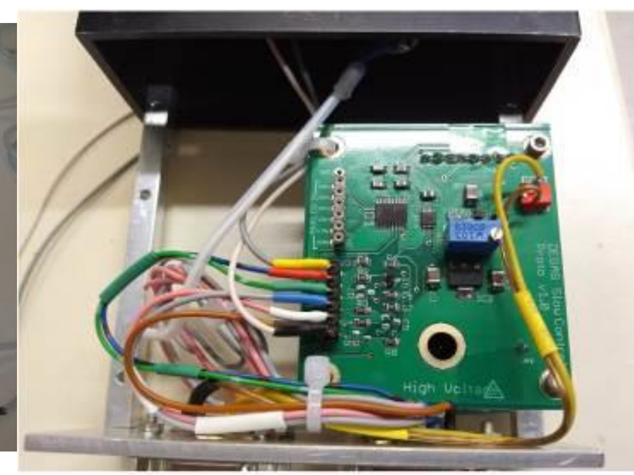


Active Si stopper used at RIKEN, where 2-mm thick 65 x 45 mm2 plastic detectors were sandwiching 5 Si DSSSDs, with an estimated efficiency of 30%. On the right hand side a sketch of the implantation segmented fast plastic is shown.

And later (with higher beam intensities): DEGAS +AIDA + (FATIMA)







Detector capsule, cooling engine and high-voltage control board

DESPEC in 2018-2020 (phase 0)

Physics workshop held in September 2016

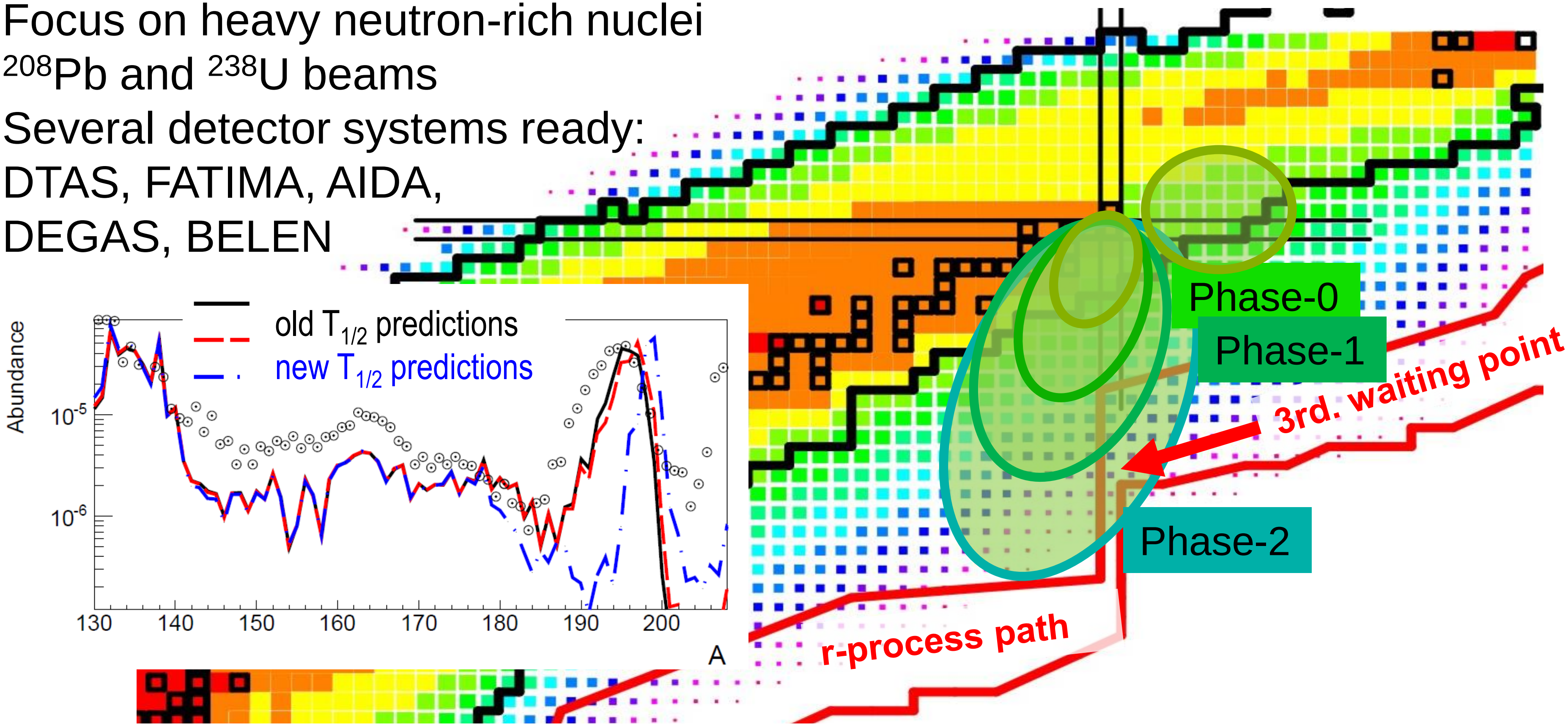
Focus on heavy neutron-rich nuclei

^{208}Pb and ^{238}U beams

Several detector systems ready:

DTAS, FATIMA, AIDA,

DEGAS, BELEN



9 (+1) proposals

241 shifts requested

parasitic beam during beam development (months before exps.)

GPAC on 19-21 Sept. 2017