

Piotr Bednarczyk

Instytut Fizyki Jądrowej
im. Henryka Niewodniczańskiego
Polskiej Akademii Nauk



From RISING to NUSTAR-

remarks on the Polish contribution

NUSTAR Week 2015
Warsaw Univ.

The two Capitals of Poland about XVII century



The two Capitals of Poland nowadays



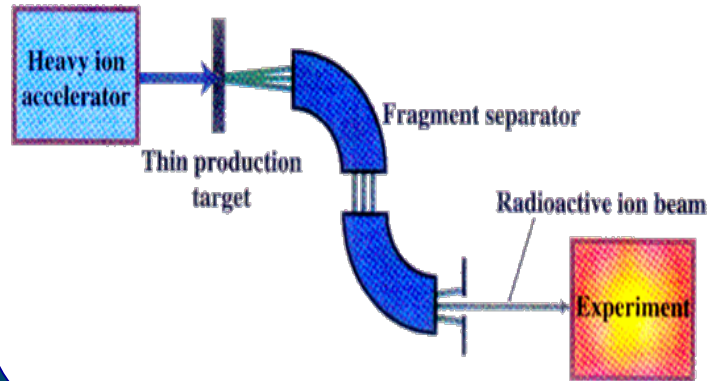
Successful campaign:

- > 100 Papers:
 - > 35 PRC
 - > 5 NIM
 - > 7 PRL
 - > 8 PLB
 - 1 Nature



Radioactive Ion Beams (reminder)

Projectile Fragmentation



from R.F. Casten, Nuclear Structure from a Simple Perspective

In flight facilities:
GANIL, RIKEN, MSU, **GSI-FAIR**

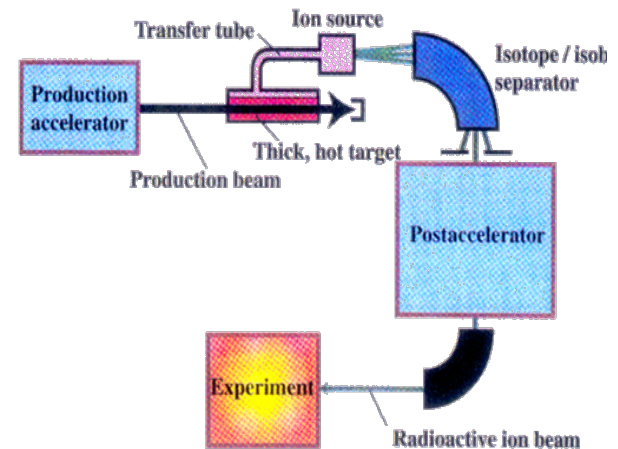
- o many exotic ions available ($T_{1/2}$: 100ns)
- o fast beams (100 A MeV, 0.5 c)

ISOL :

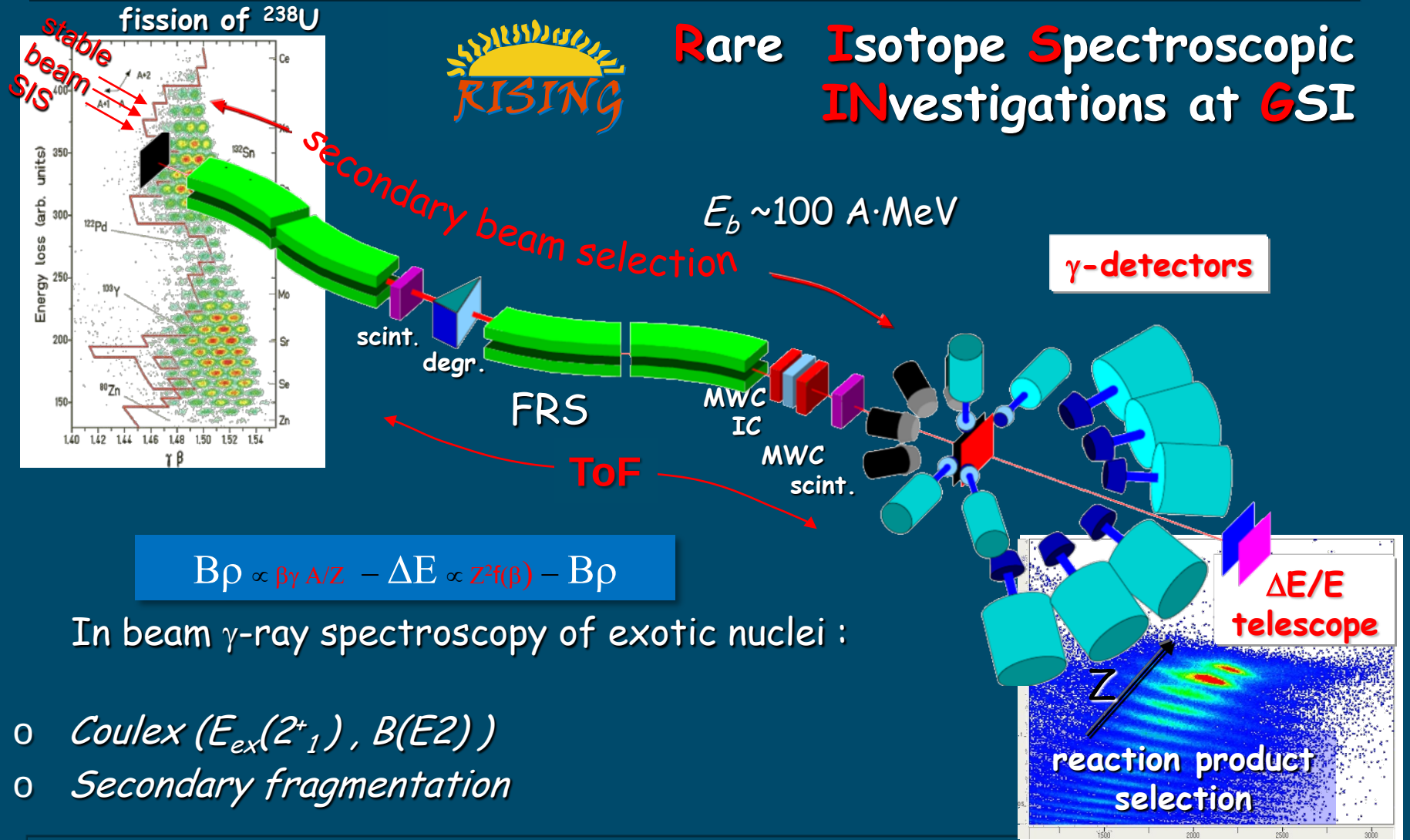
GANIL, CERN, TRIUMF

- o limited number of long living beams ($T_{1/2}$: ms-s)
- o better quality and higher intensities

ISOL



Gamma spectroscopy with fast beams

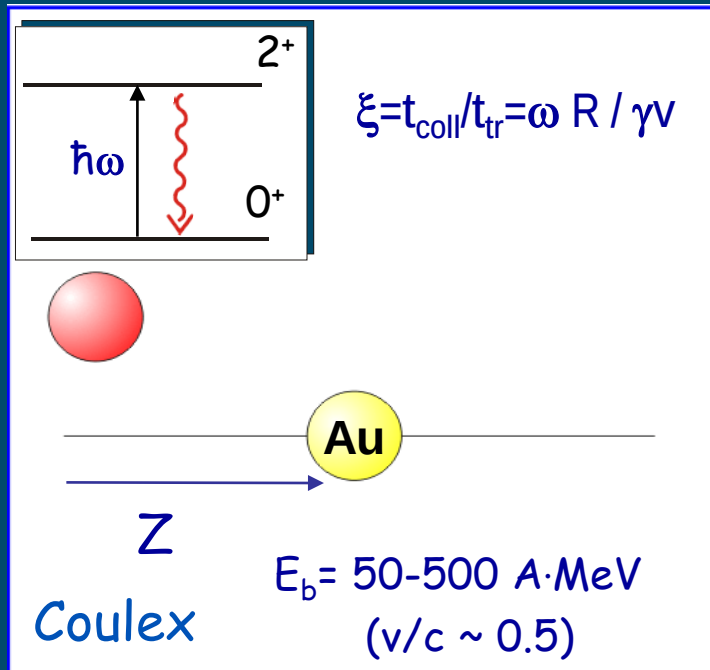


Intermediate energy Coulomb excitation

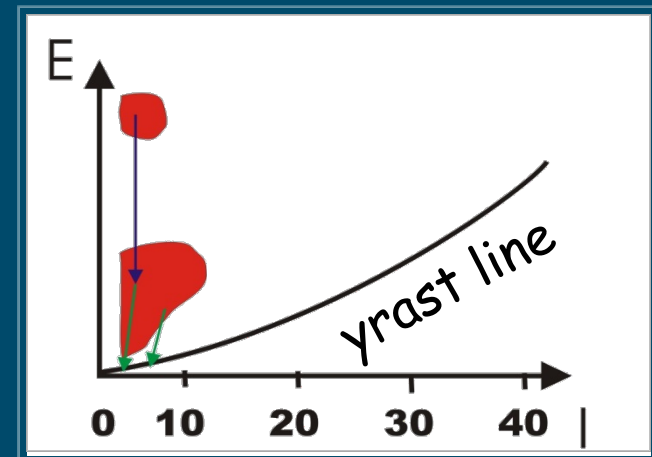
Semi-classical theory

A. Winther, K. Alder Nucl. Phys. A 319 (1979) 518

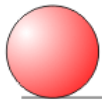
- o straight line trajectories
- o adiabacity condition $\xi \leq 1$
- one step excitation
- $E_{ex} \sim 10\text{-}20 \text{ MeV}$



➤ $\sigma \sim B(E2\uparrow) Z^2$

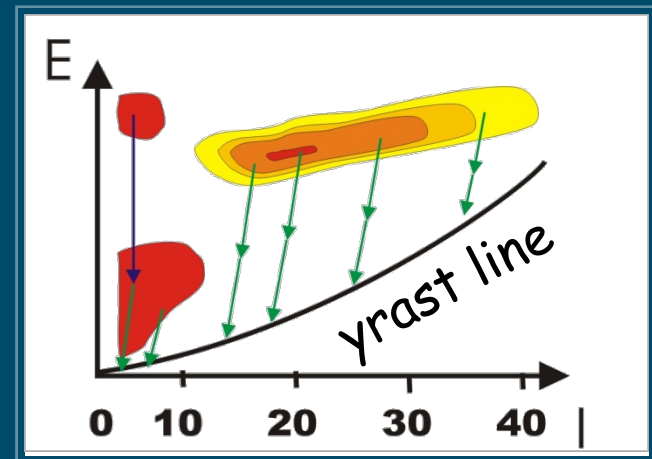


Secondary fragmentation



Heavy projectile on
Be target

- o Abrasion-Ablation
 - Access to higher spins



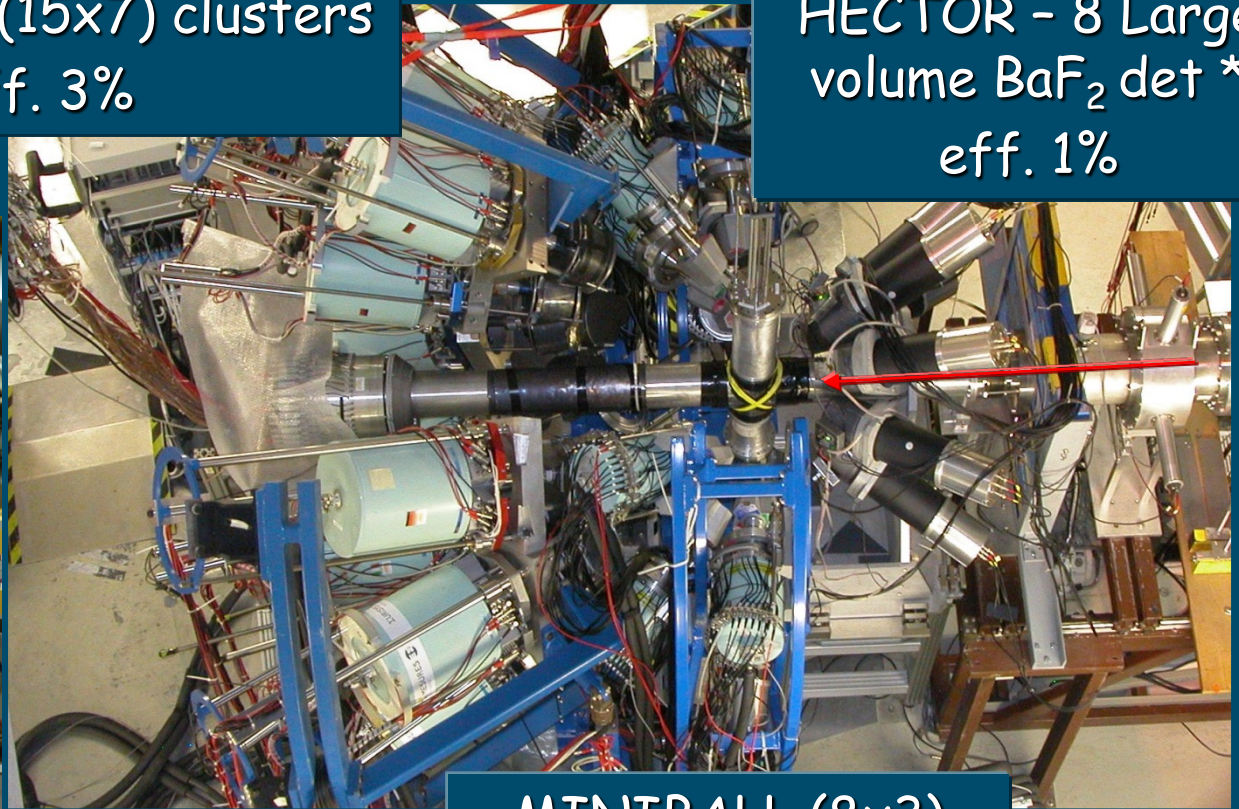
The RISING gamma detectors

EUROBALL (15x7) clusters
eff. 3%

HECTOR - 8 Large
volume BaF₂ det *
eff. 1%



**CATE position
sensitive Si-CsI
telescope**

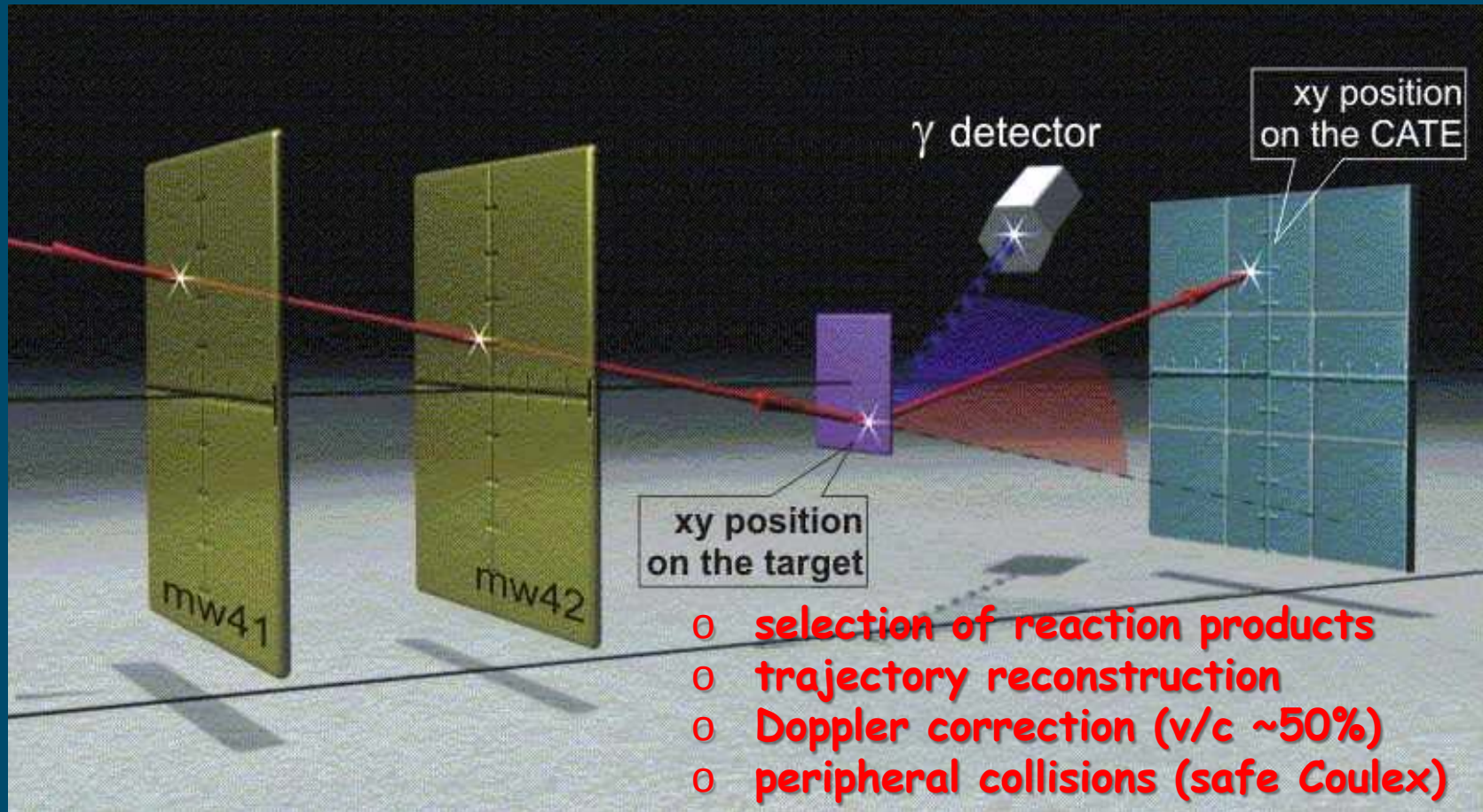


MINIBALL (8x3)
segmented clusters
eff. 1%

* HECTOR at present is in IFJ PAN, Kraków

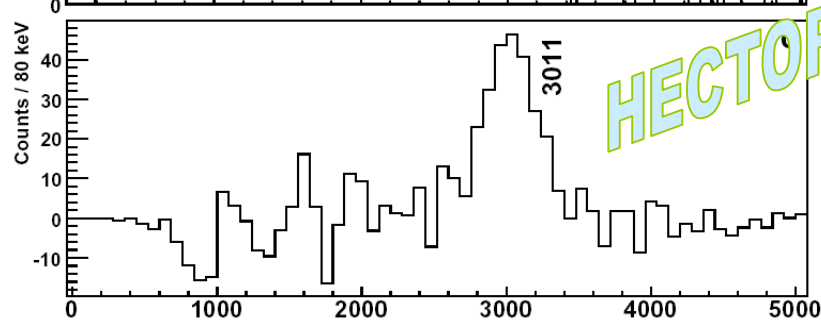
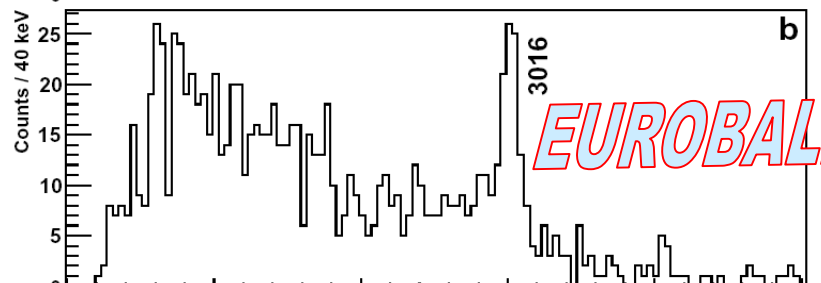
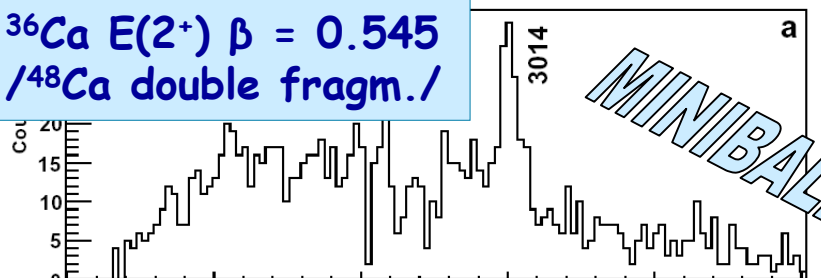
NUSTAR Week 2015
Warsaw Univ.

Projectile-reaction product tracking

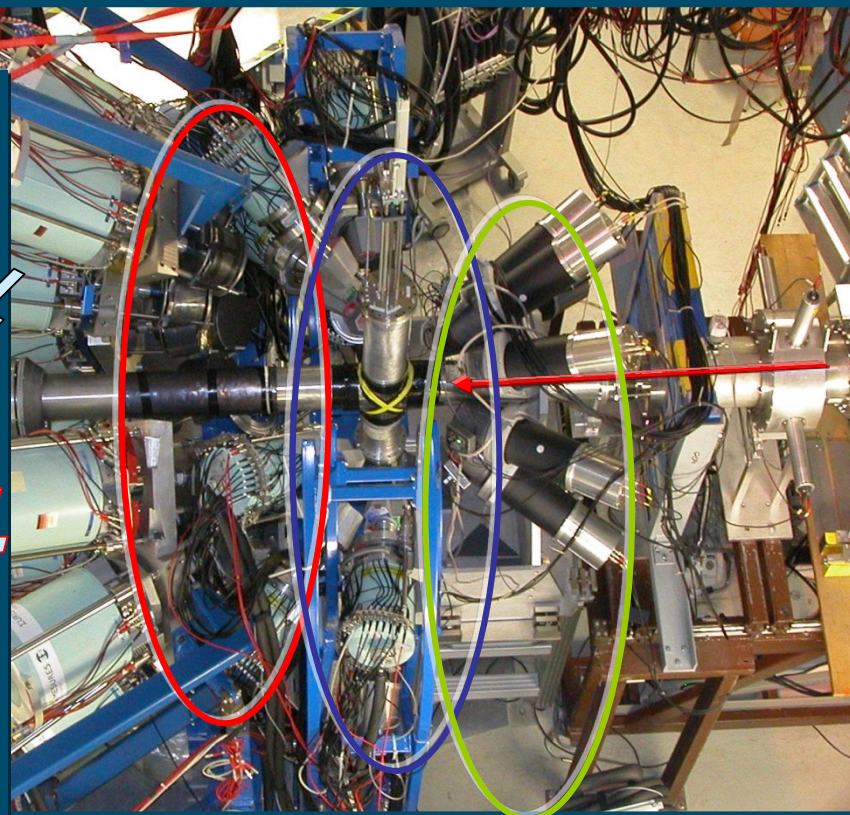


The RISING gamma detectors

^{36}Ca E(2⁺) $\beta = 0.545$
/ ^{48}Ca double fragm./



P.Doornenbal et al., Phys.Lett. B 647, 237 (2007)



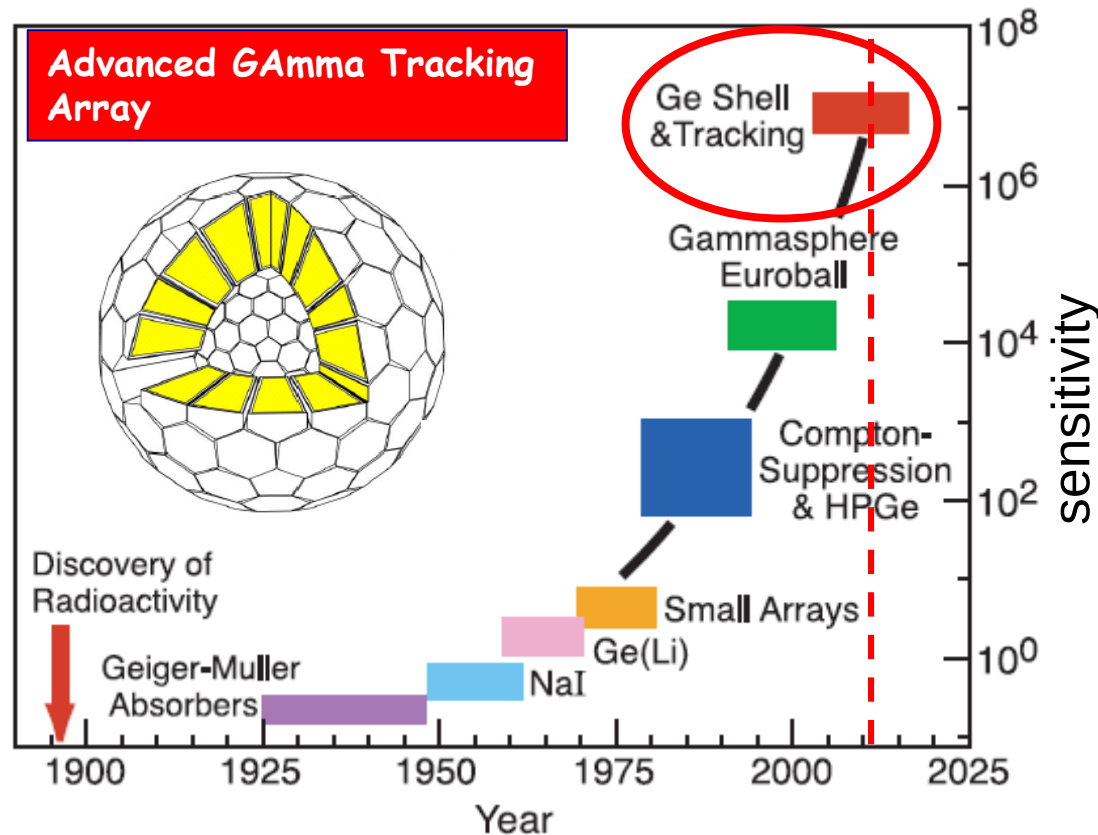
PreSPEC- the RISING upgrade



2014 National Nuclear
Physics Laboratories

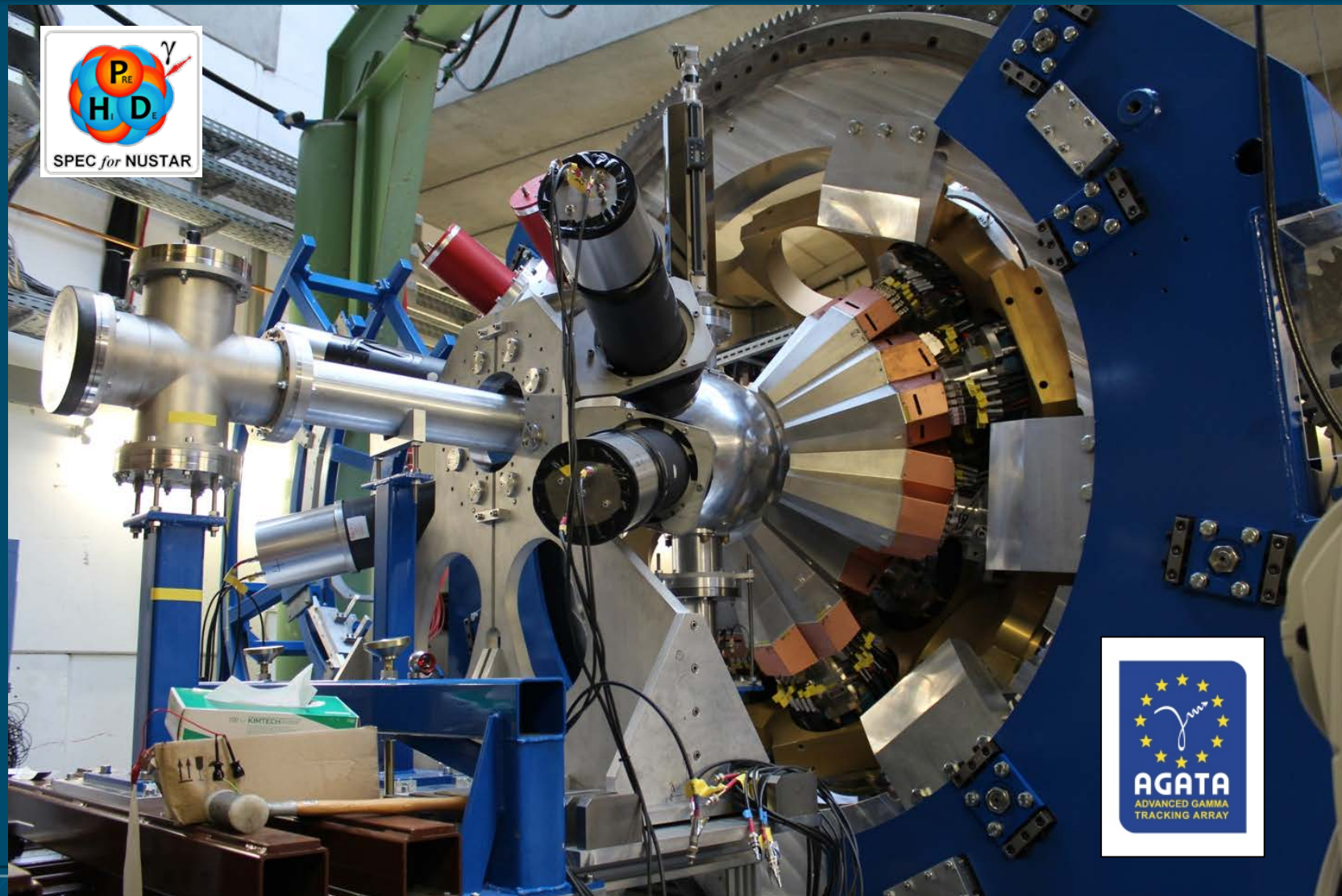


- o Gamma spectroscopy far from stability with radioactive beams (RIB)

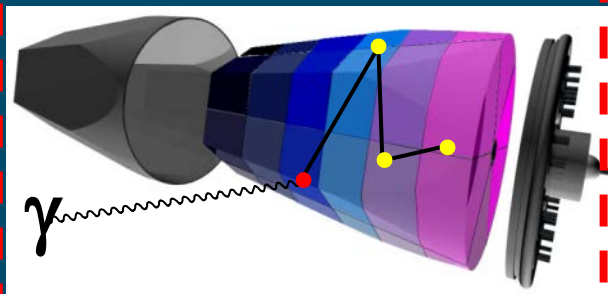


A. Machiavelli and I.Y.Lee et al. Rep.Prog.Phys. 66, 1095 (2003)

AGATA



Gamma tracking



Digitalization (14 bit,
100 MS/s) 37 segments

readout
(10 kB/evt/crystal)

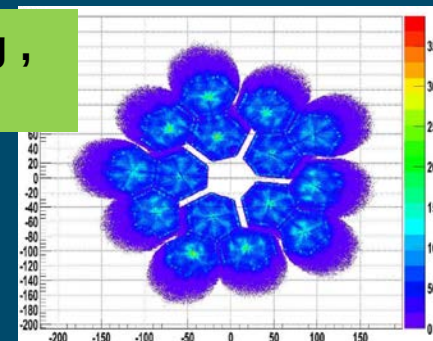
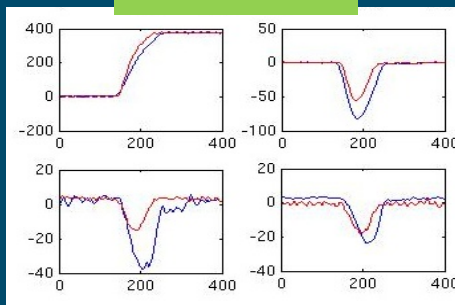
Global
Local

Event building ,
 $\Delta t = 10 \text{ ns}$

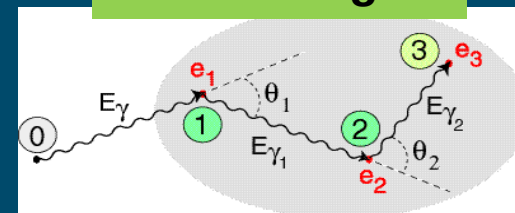
level
level

$(x, y, z, E, t)_i$

PSA



Tracking



Addback + Doppler
correction

HARDWARE

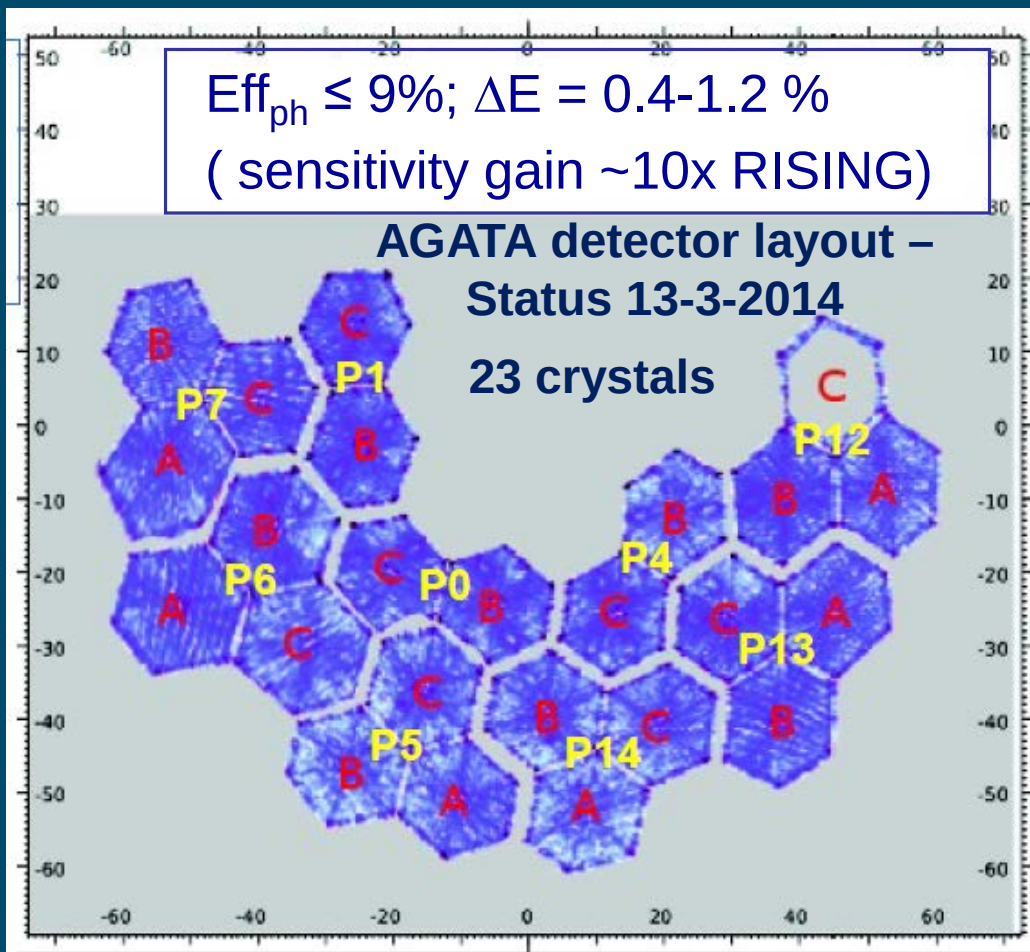
SOFTWARE

AGATA at PreSPEC - plans vs reality

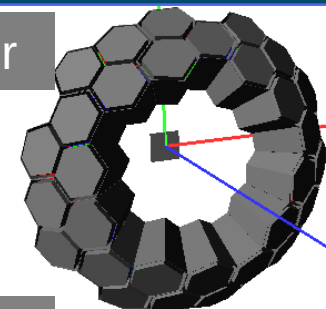
$\text{Eff}_{\text{ph}} \leq 9\%$; $\Delta E = 0.4\text{-}1.2\%$
(sensitivity gain $\sim 10\times$ RISING)

AGATA detector layout –
Status 13-3-2014

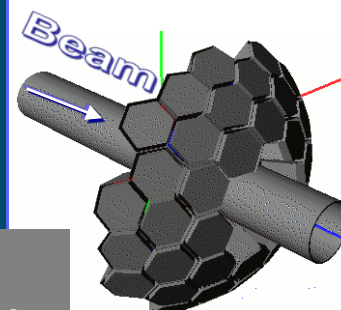
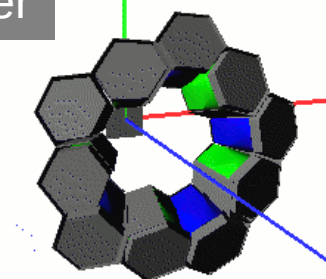
23 crystals



10 triple Cluster

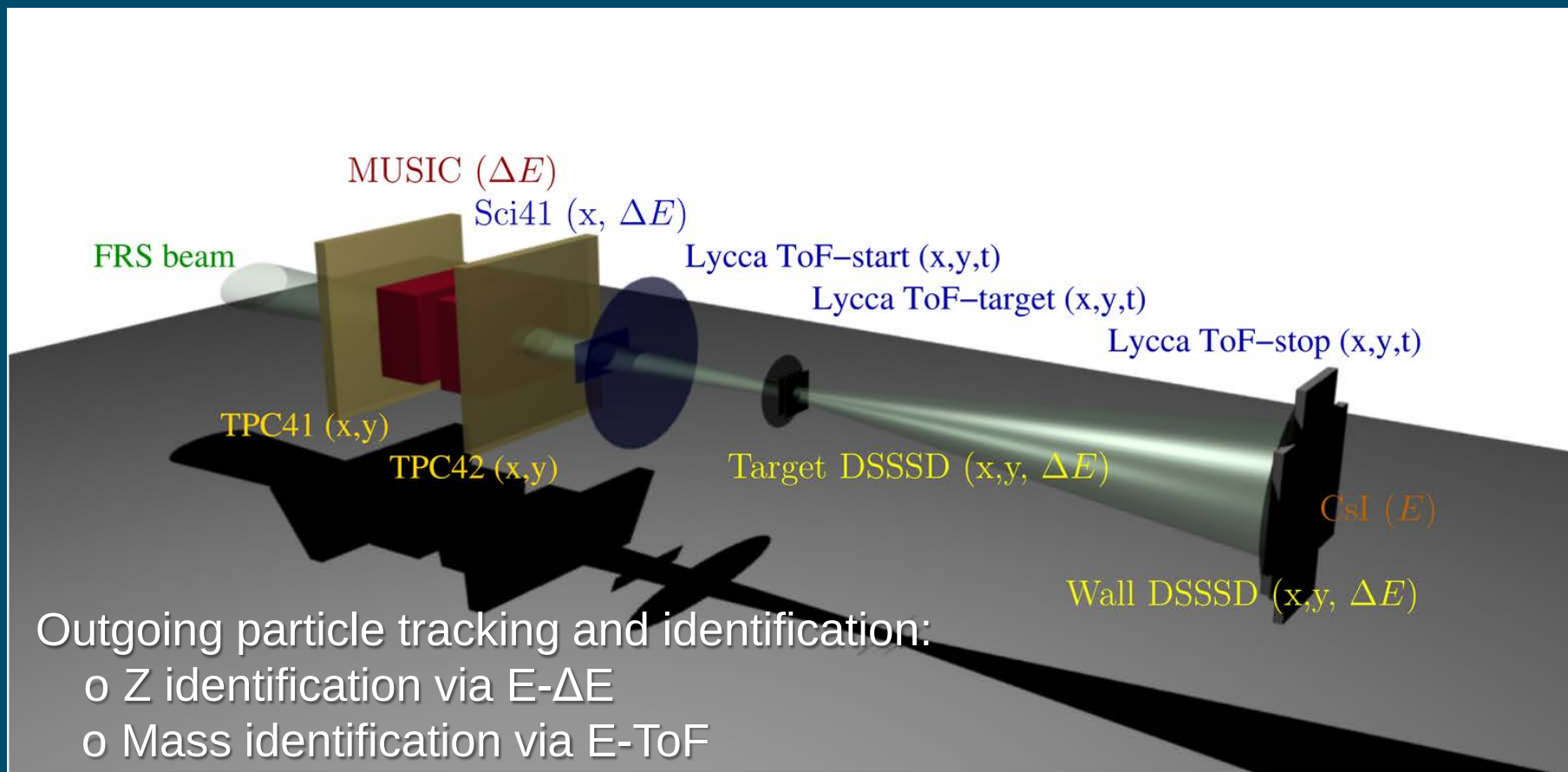


5 double Cluster

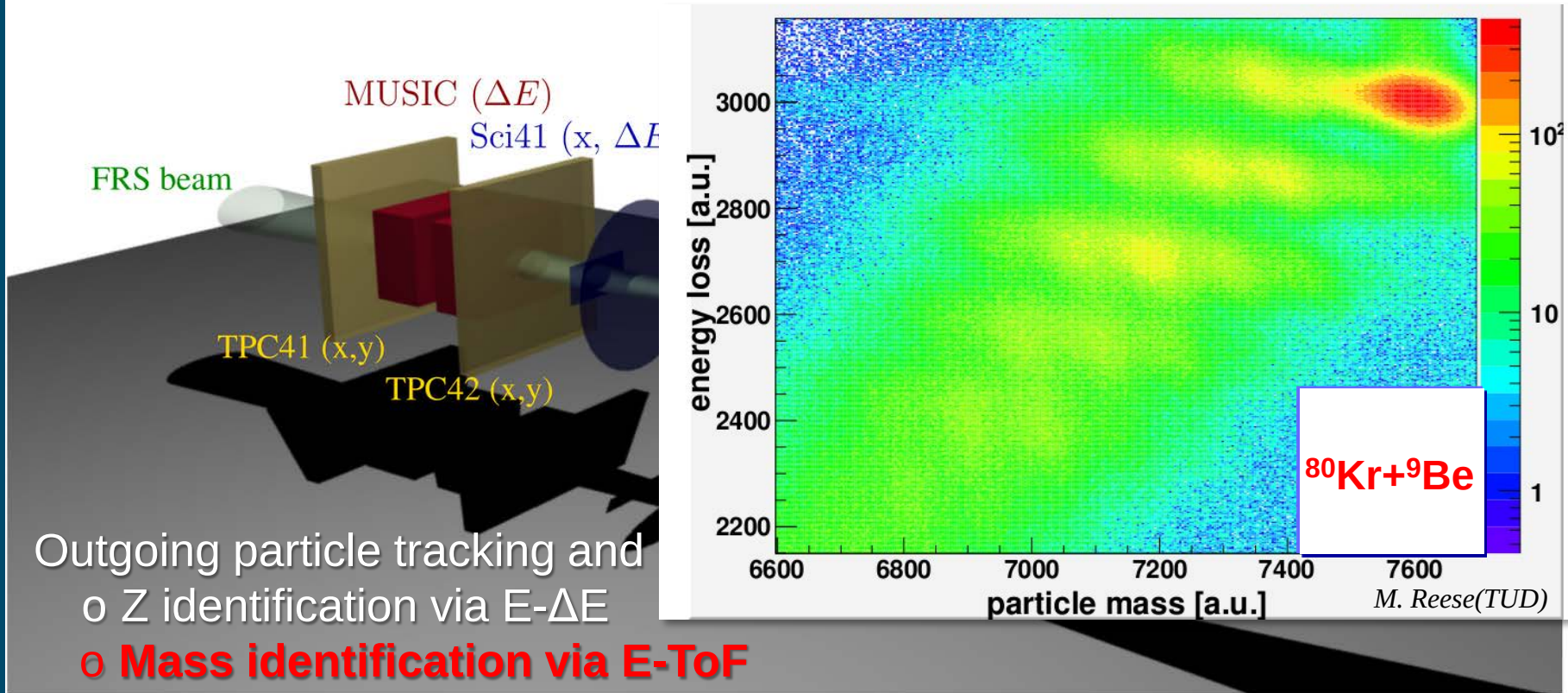


$\varepsilon_{\gamma} = 17.5$
 $\Delta E_{\gamma} = 0.4\%$

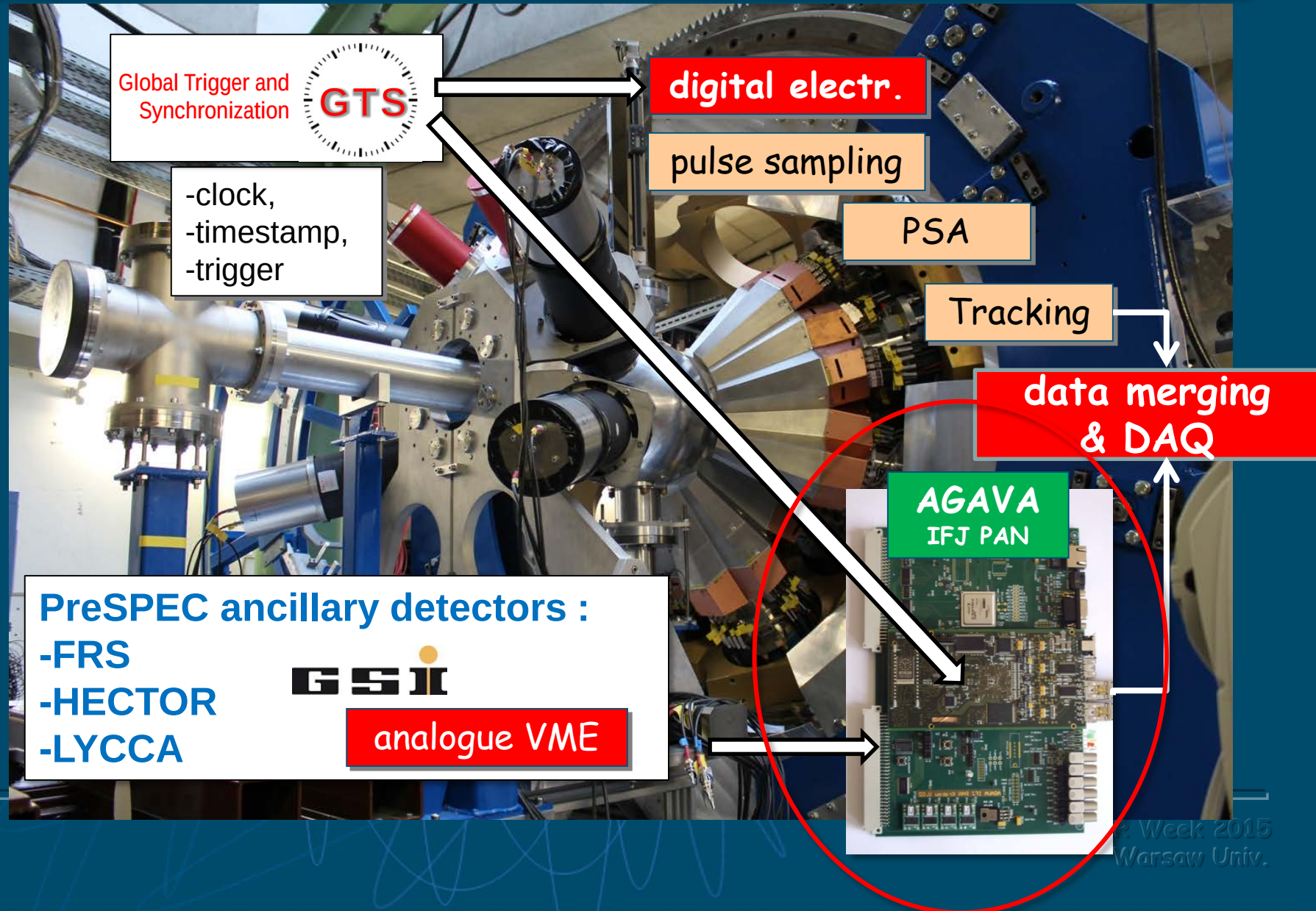
PreSPEC particle detectors



PreSPEC particle detectors

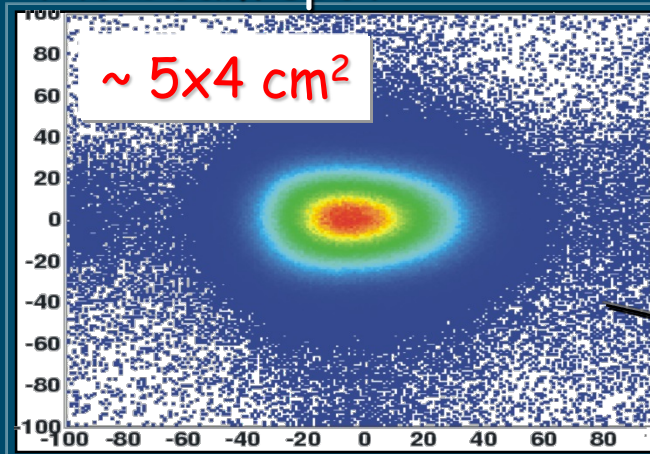


Interface for ancillary detectors - AGATA VME ADAPTOR

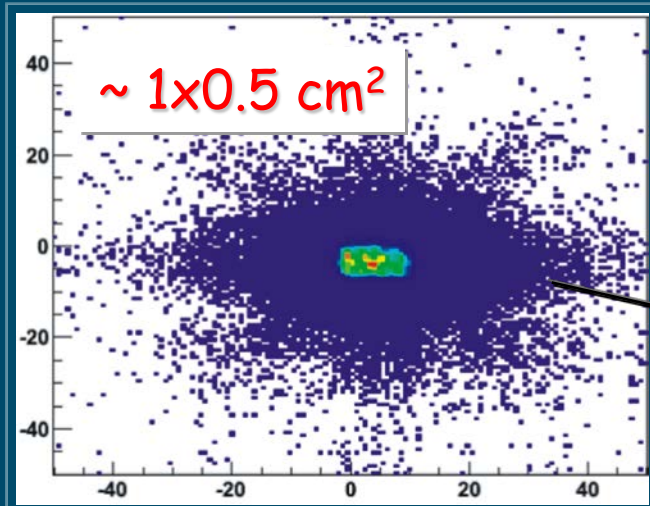


Low energy γ -background induced by primary and secondary beams

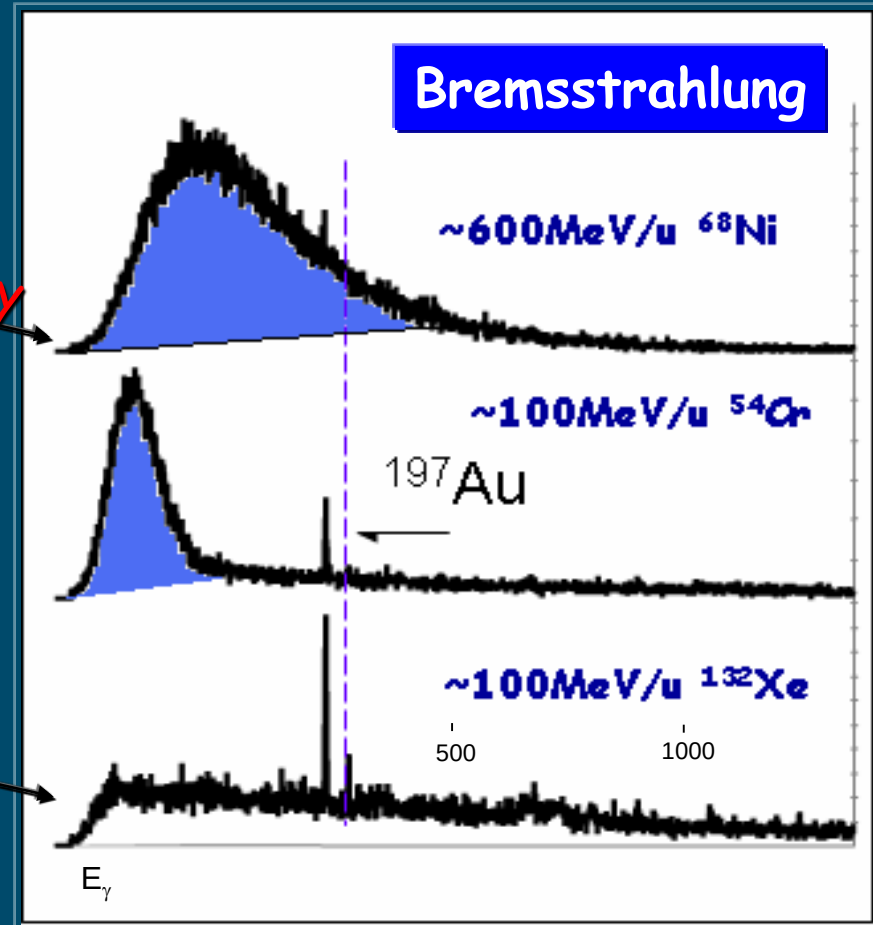
the beam spot:



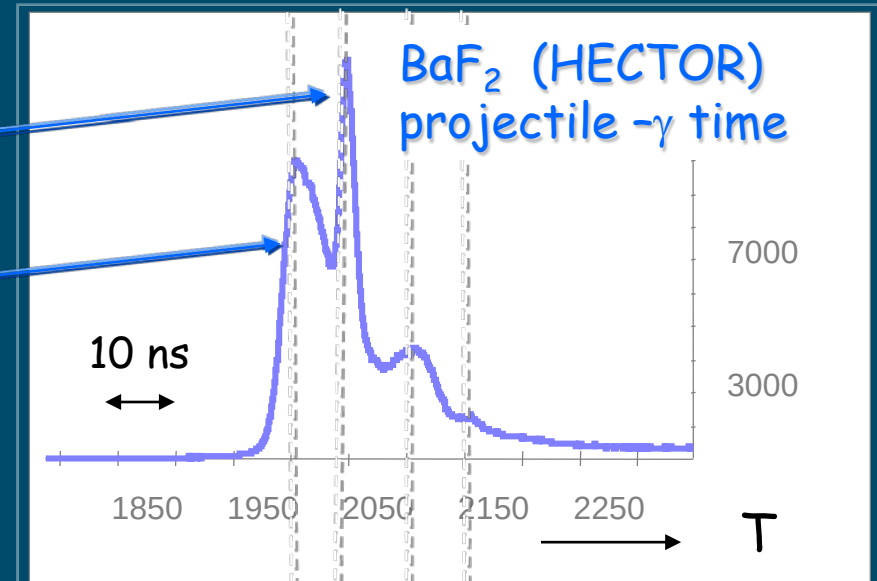
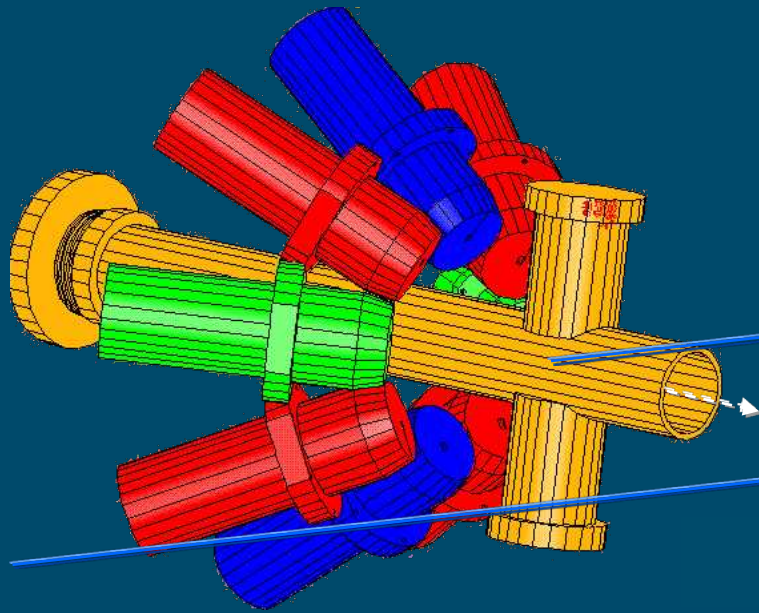
secondary
beams



primary
beam

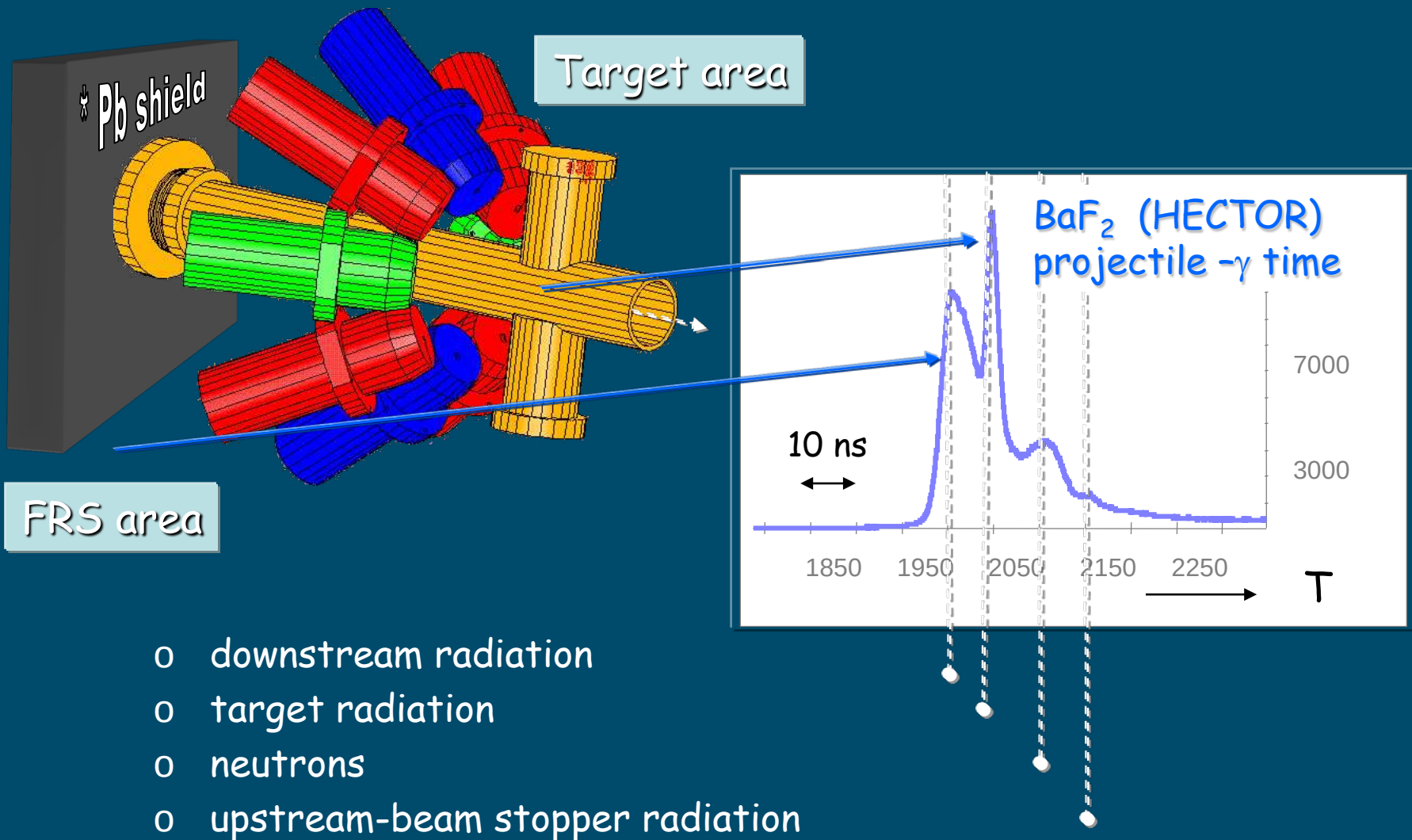


Origin of the background radiation determined with HECTOR

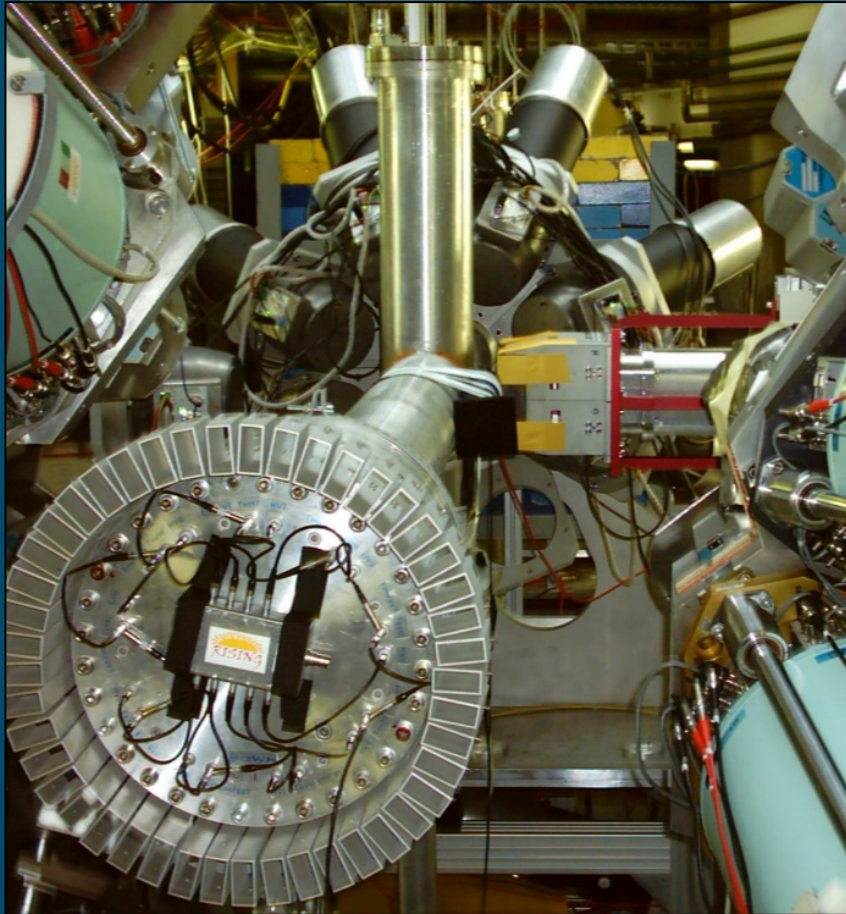


- o downstream radiation
- o target radiation
- o neutrons
- o upstream-beam stopper radiation

Origin of the background radiation determined with HECTOR

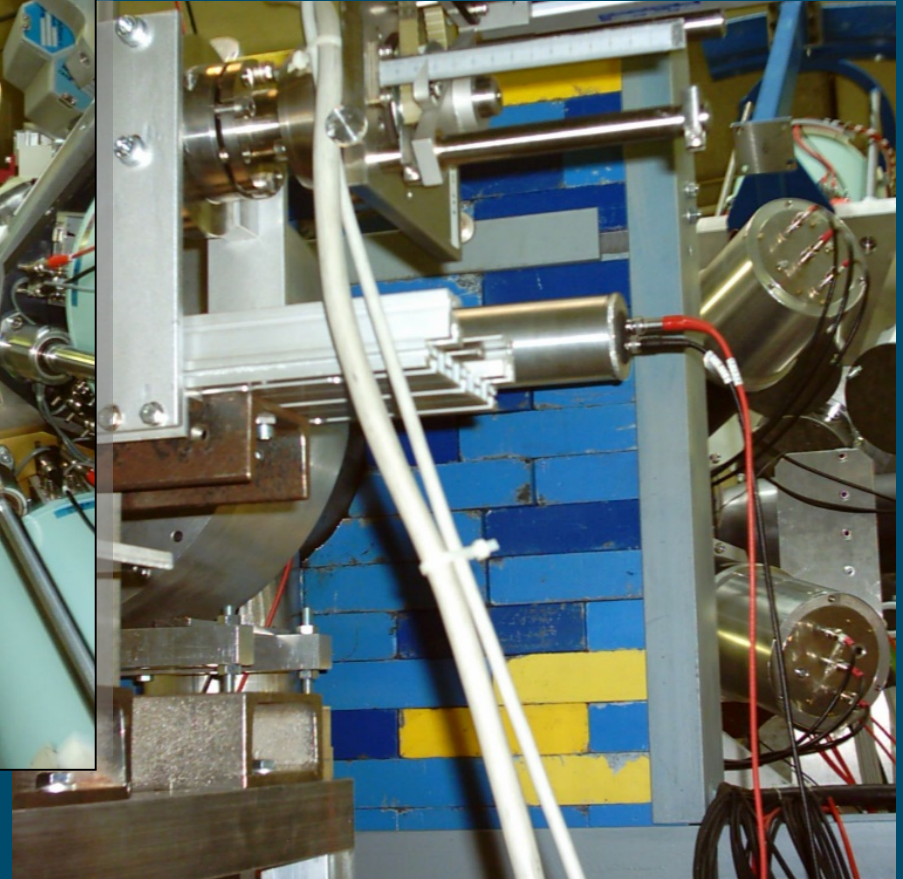


The Wall *



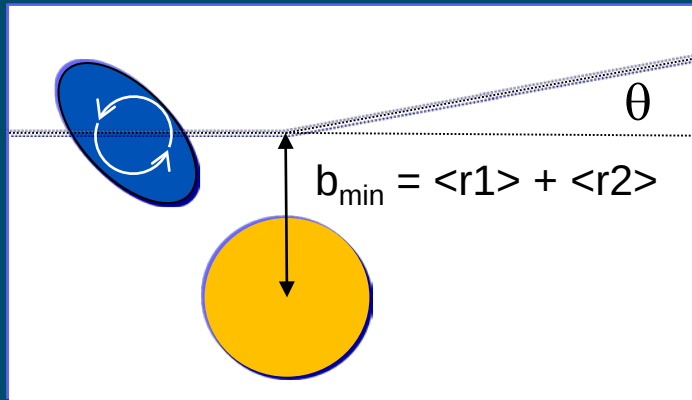
Target side

FRS side



Excitation cross sections and a nuclear deformation

*C.A.Bertulani et al., Comp. Phys. Comm.
152 (2003) 317*



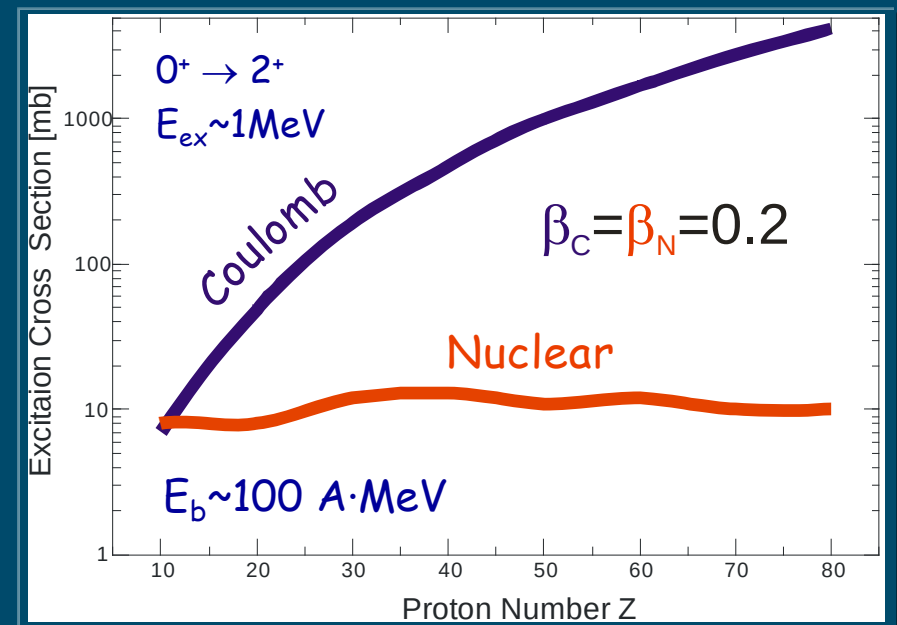
„Safe Coulex“:

- forward scattering $\theta \sim 2^\circ$

For light deformed projectiles
might not be sufficient to
suppress nuclear interaction

$$\sigma_N \sim \beta_N R$$

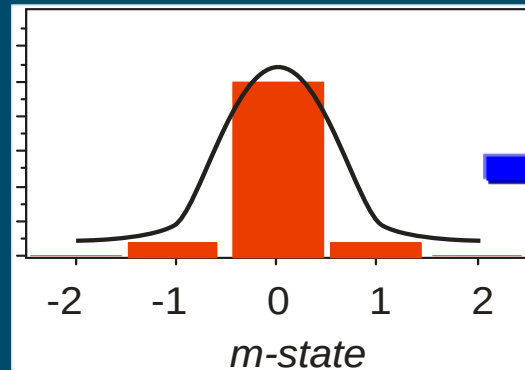
$$\sigma_C \sim B(E2\uparrow)Z^2 \rightarrow \beta_C$$



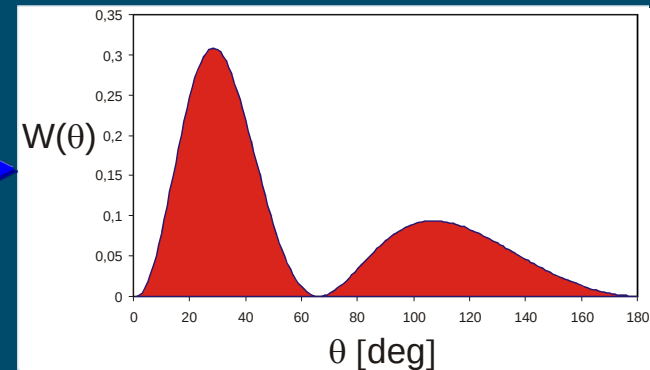
γ -ray angular distribution in nuclear and EM excitations in inelastic scattering of fast beams

➤ Nuclear interaction

oblate spin alignment

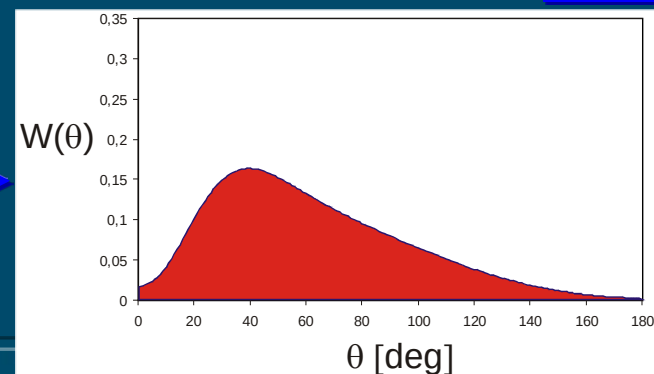
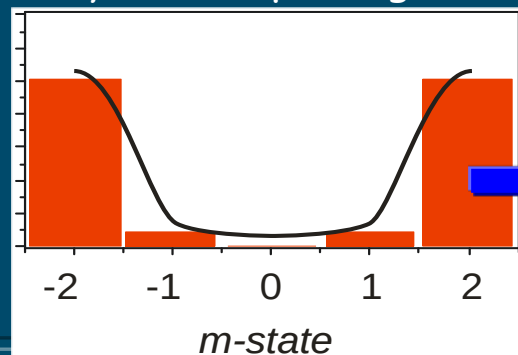


In the Lab. system $v/c=0.4$



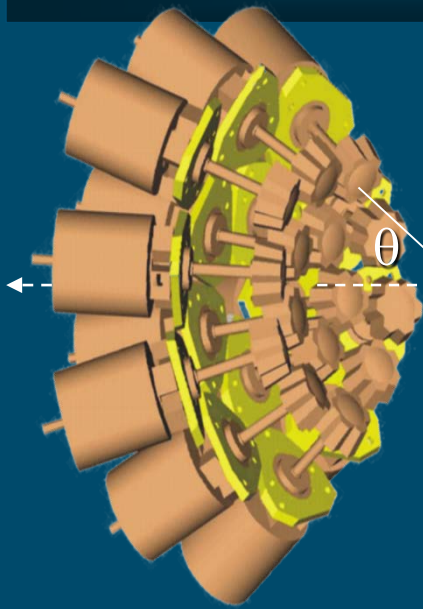
➤ EM interaction

prolate spin alignment



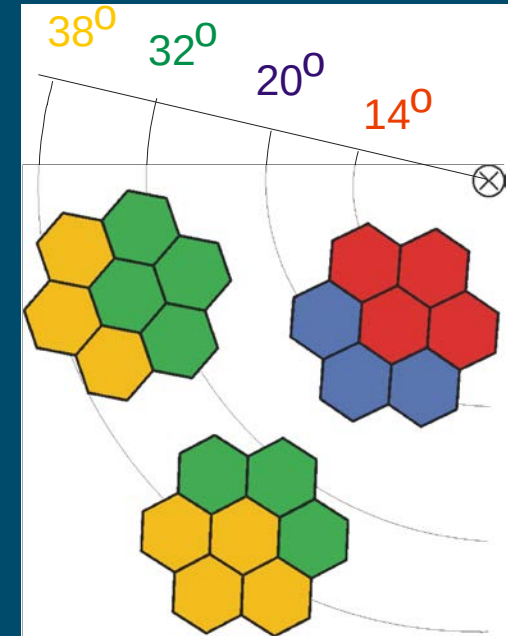
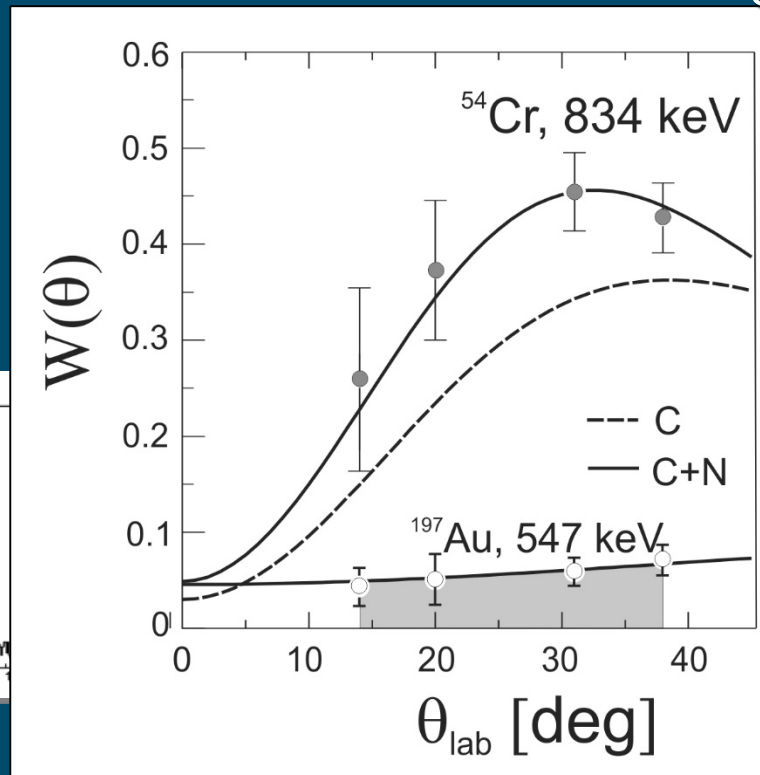
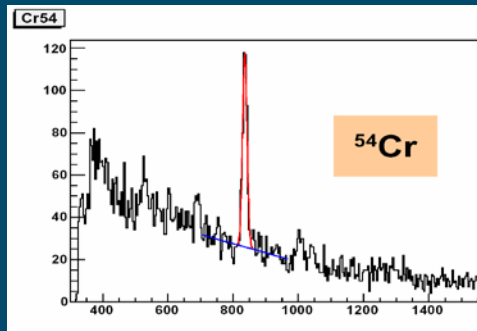
$0^+ \rightarrow 2^+$
 $E_\gamma < 1\text{ MeV}$
 $v/c=0.4$

Angular sensitivity of the RISING EB cluster array

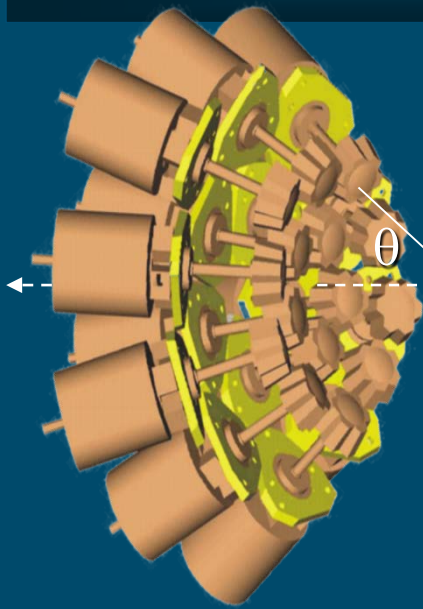


- o 3 cluster rings:
too much overlap, not sensitive

- o 4 single Ge shells

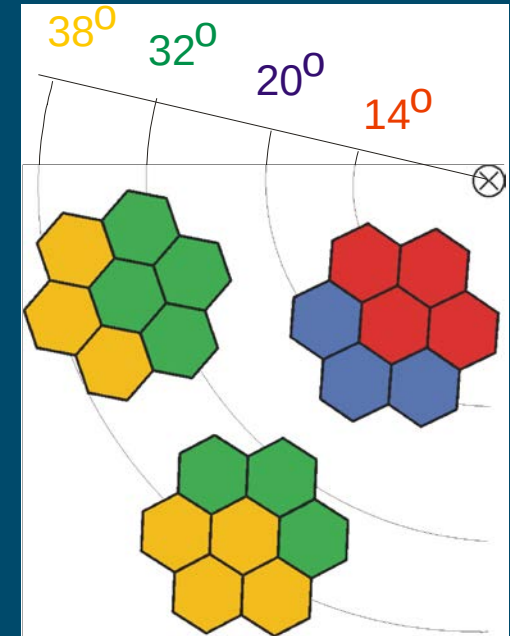
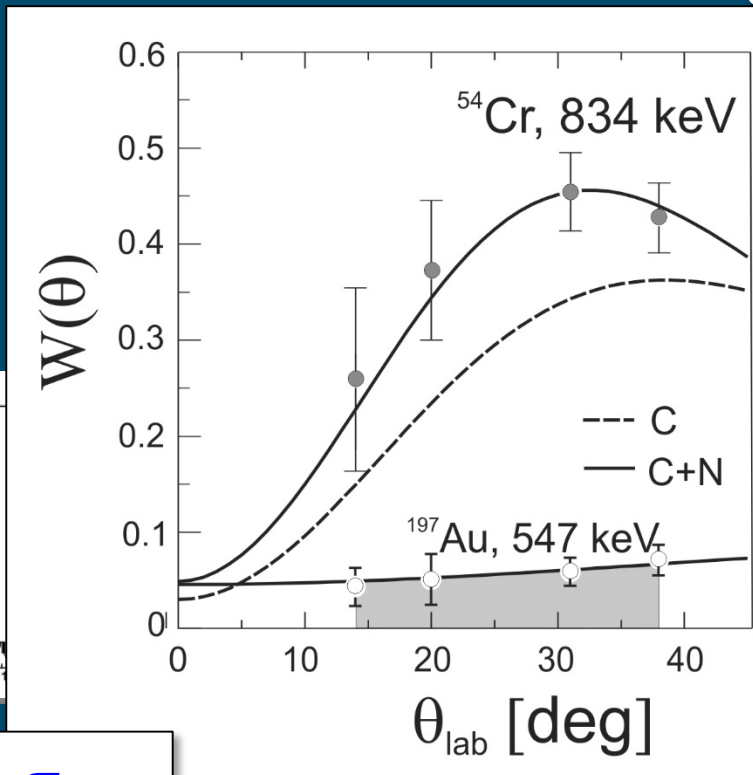
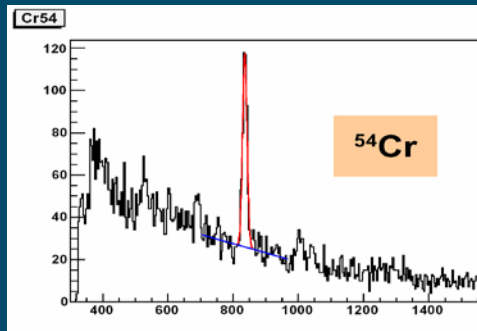


Angular sensitivity of the RISING EB cluster array



- o 3 cluster rings:
too much overlap, not sensitive

- o 4 single Ge shells

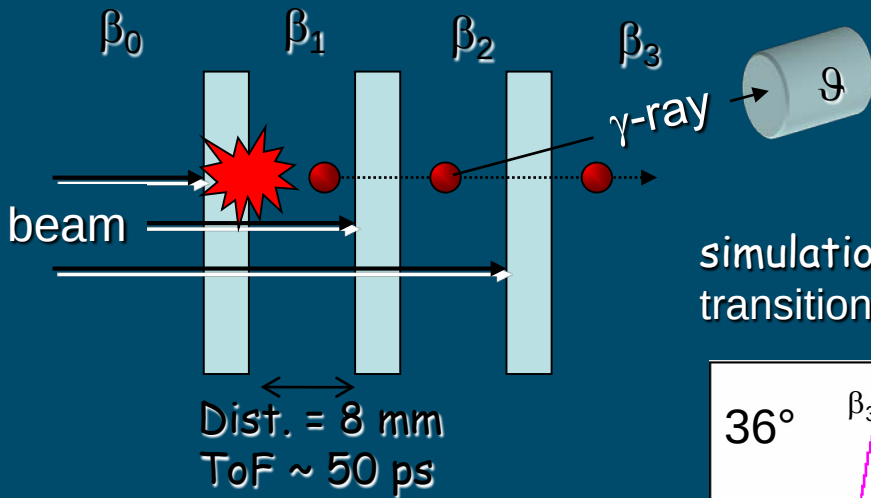


$$\sigma_N \approx 10\% \sigma_{Tot}$$

Recoil Distance Doppler Shift at RISING

The RISING "plunger"

three Fe 1mm targets at variable distances

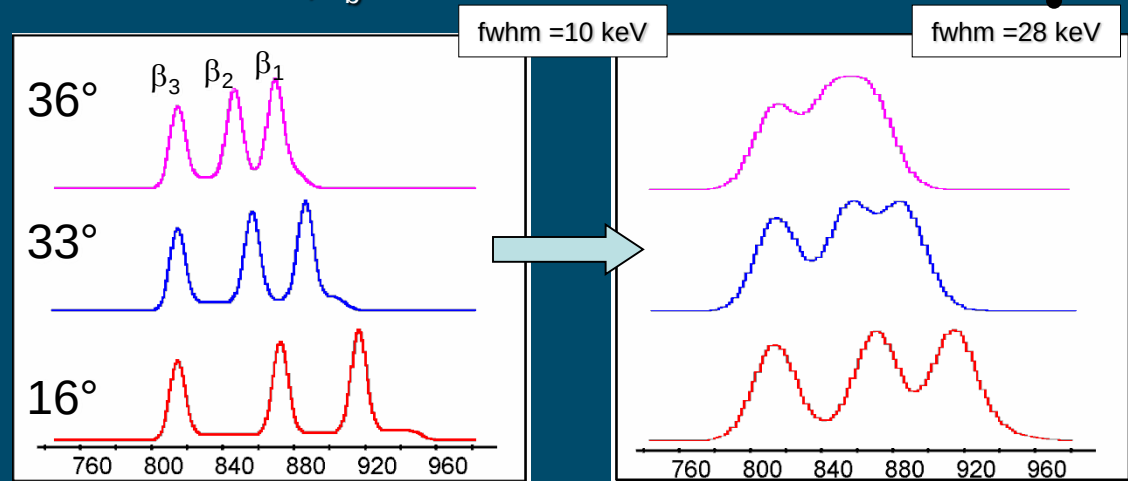


intensity distribution :

- o lifetime
- o Lorentz boost

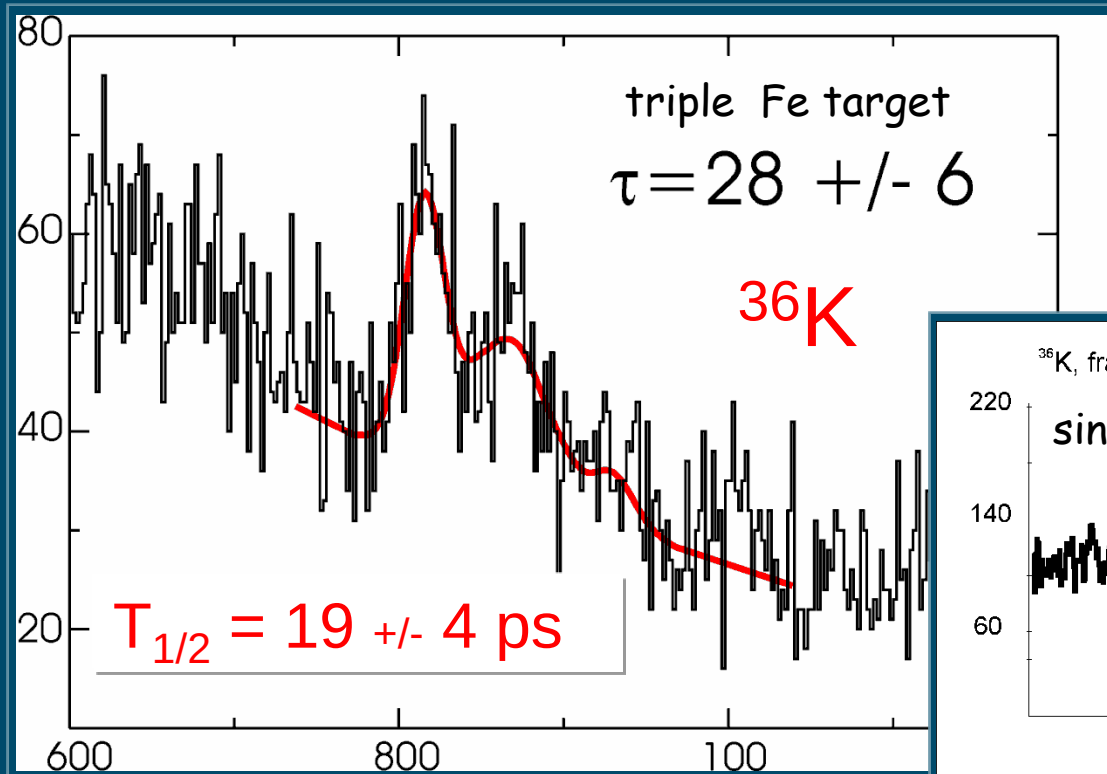
$$B(E2; 0^+_1 \rightarrow 2^+_1) \propto 1/E_\gamma^5 \tau$$

simulation for the 814 keV transition in ^{36}K , $E_b = 196 \text{ MeV/u}$

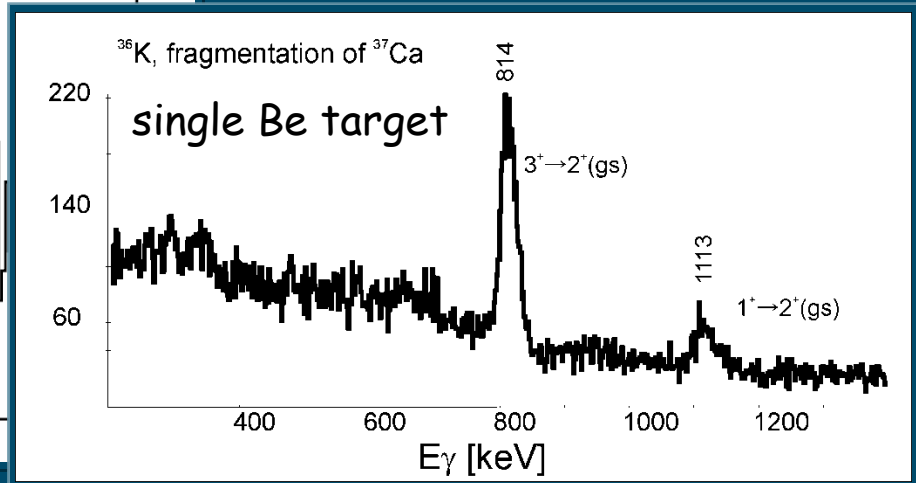


$$0.53 < \beta < 0.43$$

Lifetime of the 3^+ level in ^{36}K

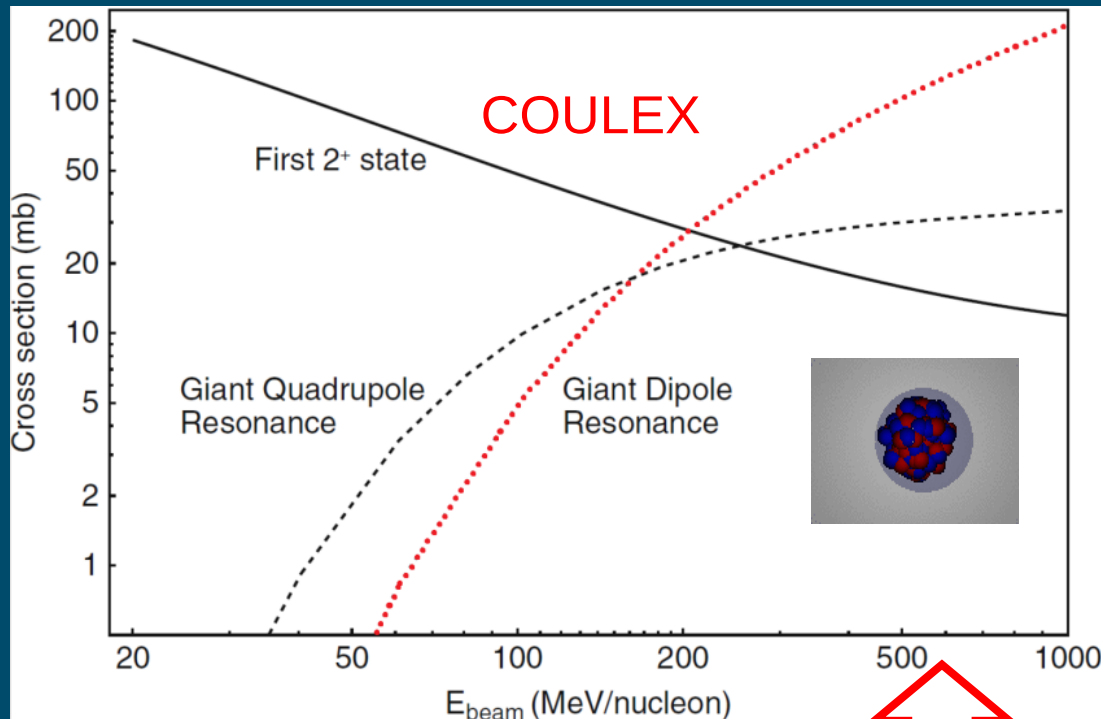


- o θ integrated spectrum
- o line-shape fit

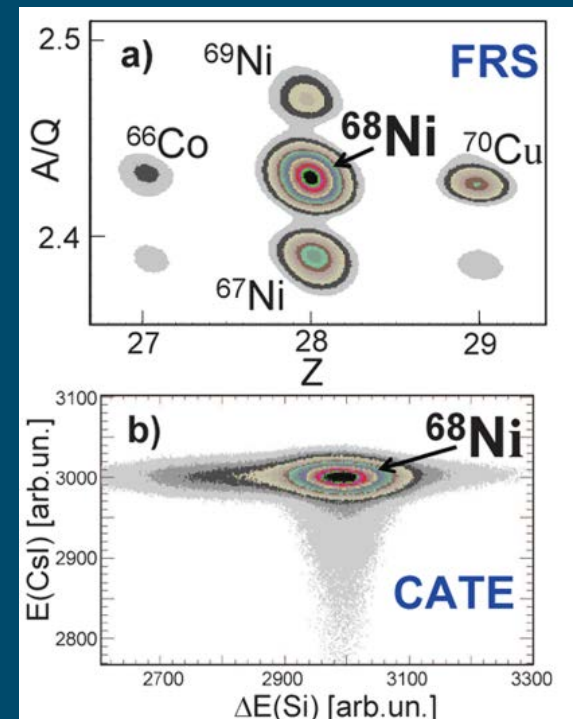


First lifetime measurement in p-rich ^{36}K with the triple plunger with RIB

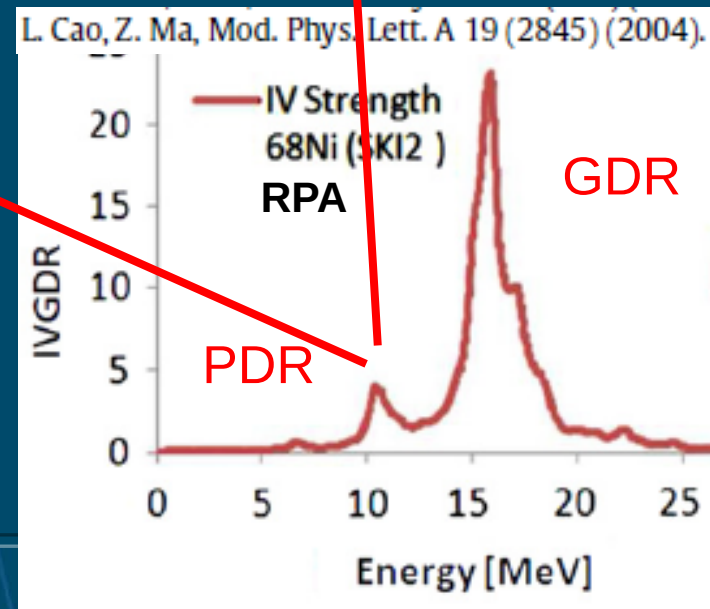
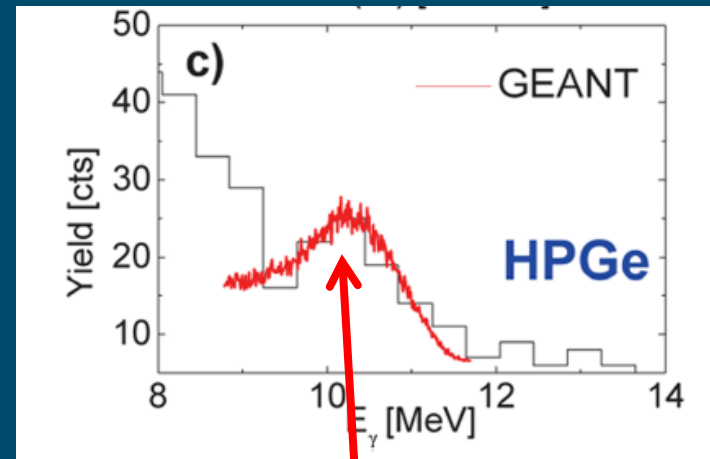
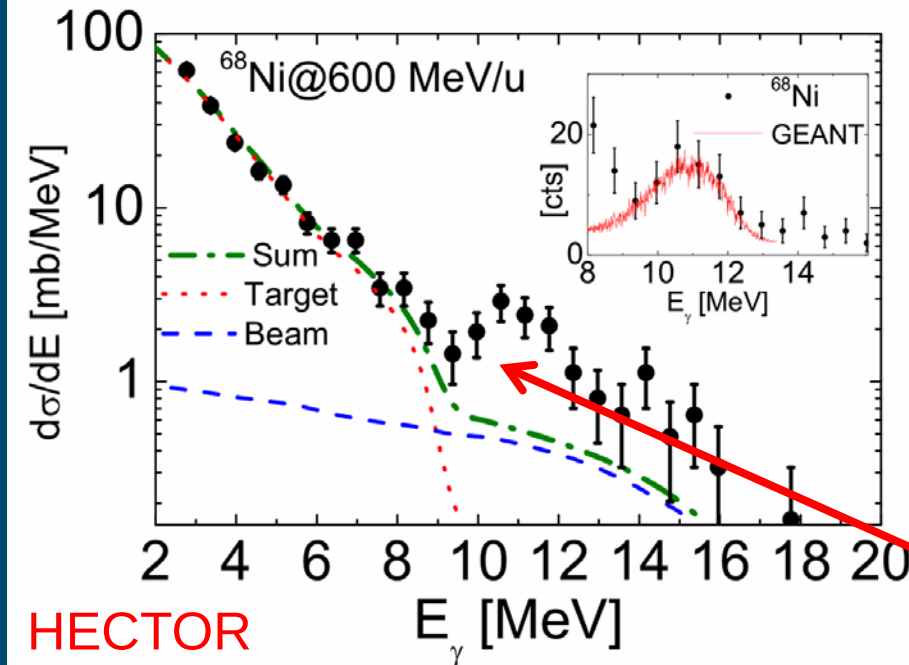
Pygmy Dipole Resonance in ^{68}Ni



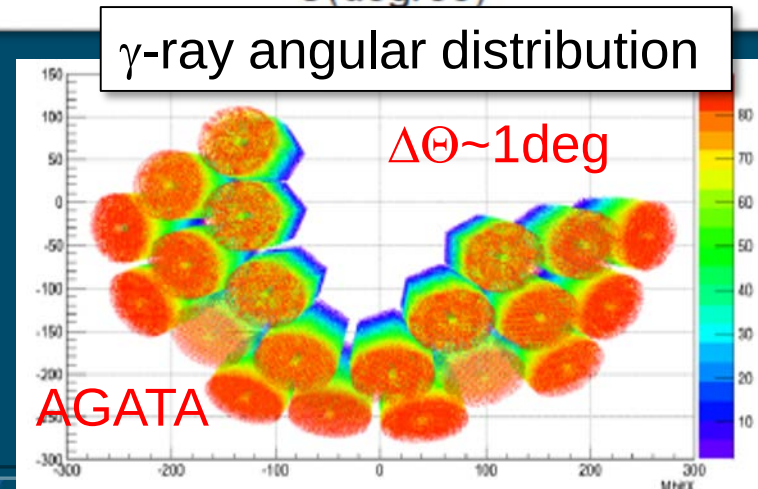
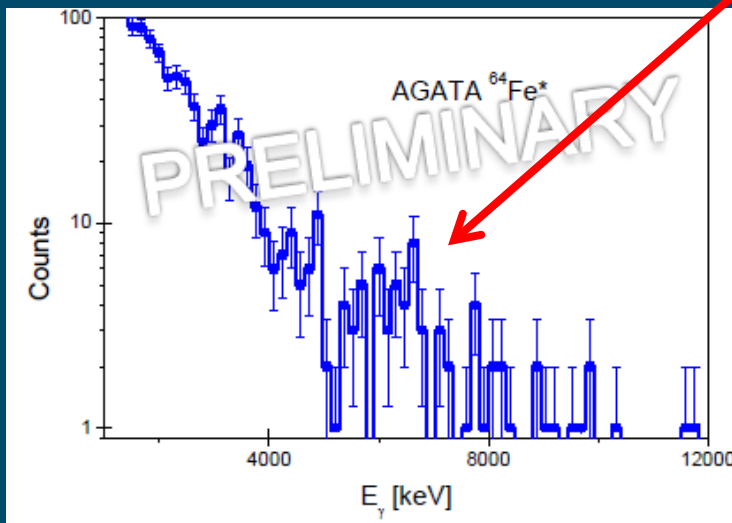
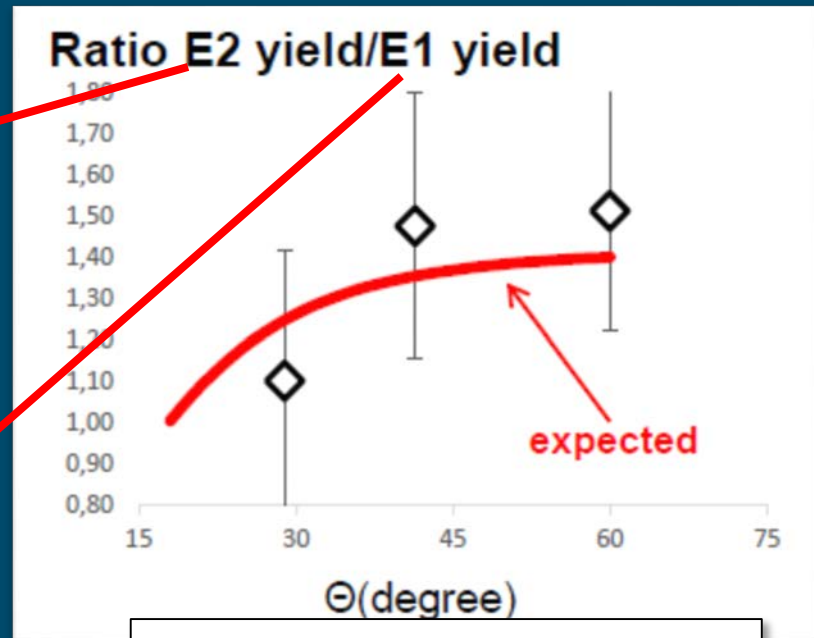
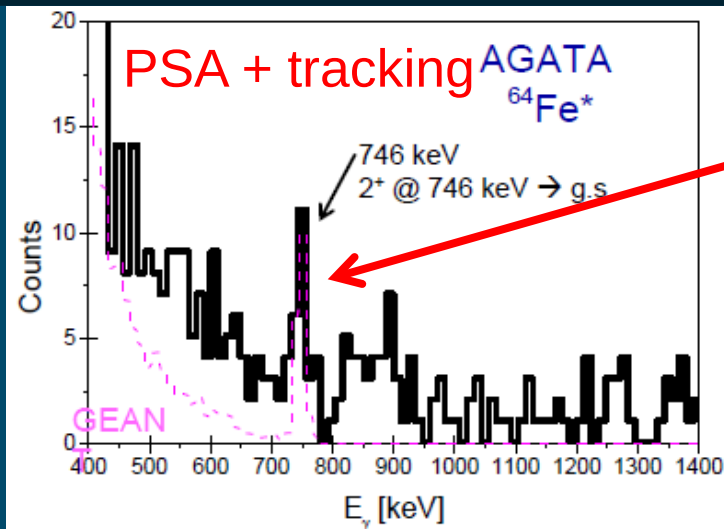
^{68}Ni at 600 A MeV
on Au target



Pygmy Dipole Resonance in ^{68}Ni



PDR in $^{62,64}\text{Fe}$



γ -decay spectroscopy at FRS- the early stage

17 December 1998

PHYSICS LETTERS B

ELSEVIER

Physics Letters B 444 (1998) 32–37

New isotopes and isomers produced by the fragmentation of ^{238}U at 1000 MeV/nucleon

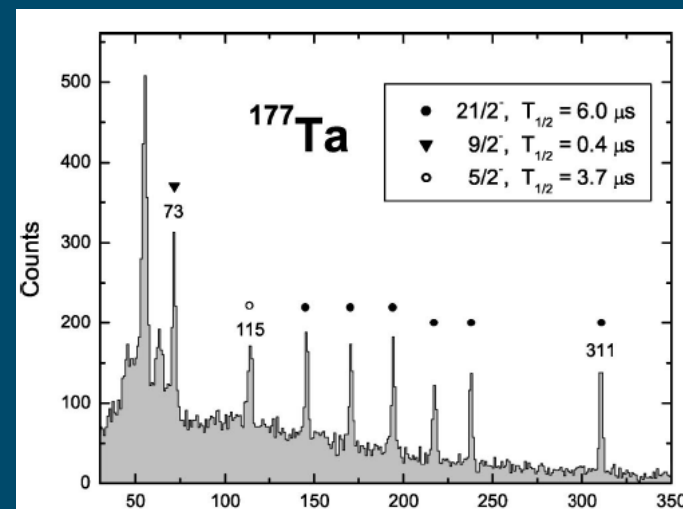
M. Pfützner ^{a,b}, P. Armbruster ^b, T. Baumann ^b, J. Benlliure ^b, M. Bernas ^c, W.N. Catford ^d, D. Cortina-Gil ^b, J.M. Daugas ^e, H. Geissel ^b, M. Górski ^{a,b}, H. Grawe ^b, R. Grzywacz ^a, M. Hellström ^b, N. Iwasa ^b, Z. Janas ^a, A.R. Junghans ^b, M. Karny ^a, S. Leenhardt ^c, M. Lewitowicz ^e, A.C. Mueller ^c, F. de Oliveira ^e, P.H. Regan ^d, M. Rejmund ^{a,b}, K. Rykaczewski ^{a,f}, K. Sümmerer ^b

Identification of 20 isomeric states in A~180 rare earth nuclei

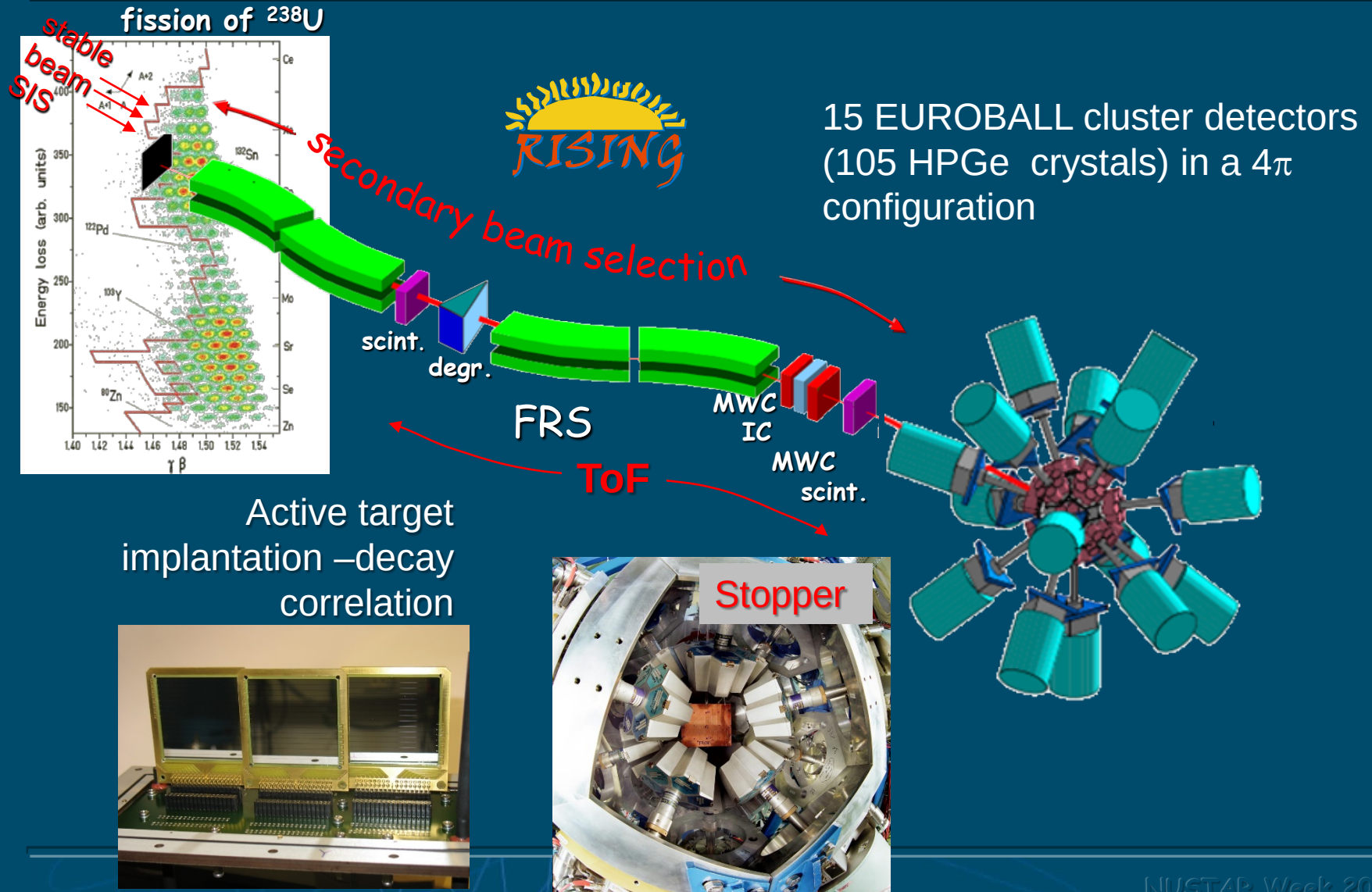
PHYSICAL REVIEW C, VOLUME 65, 064604

Angular momentum population in the fragmentation of ^{208}Pb at 1 GeV/nucleon

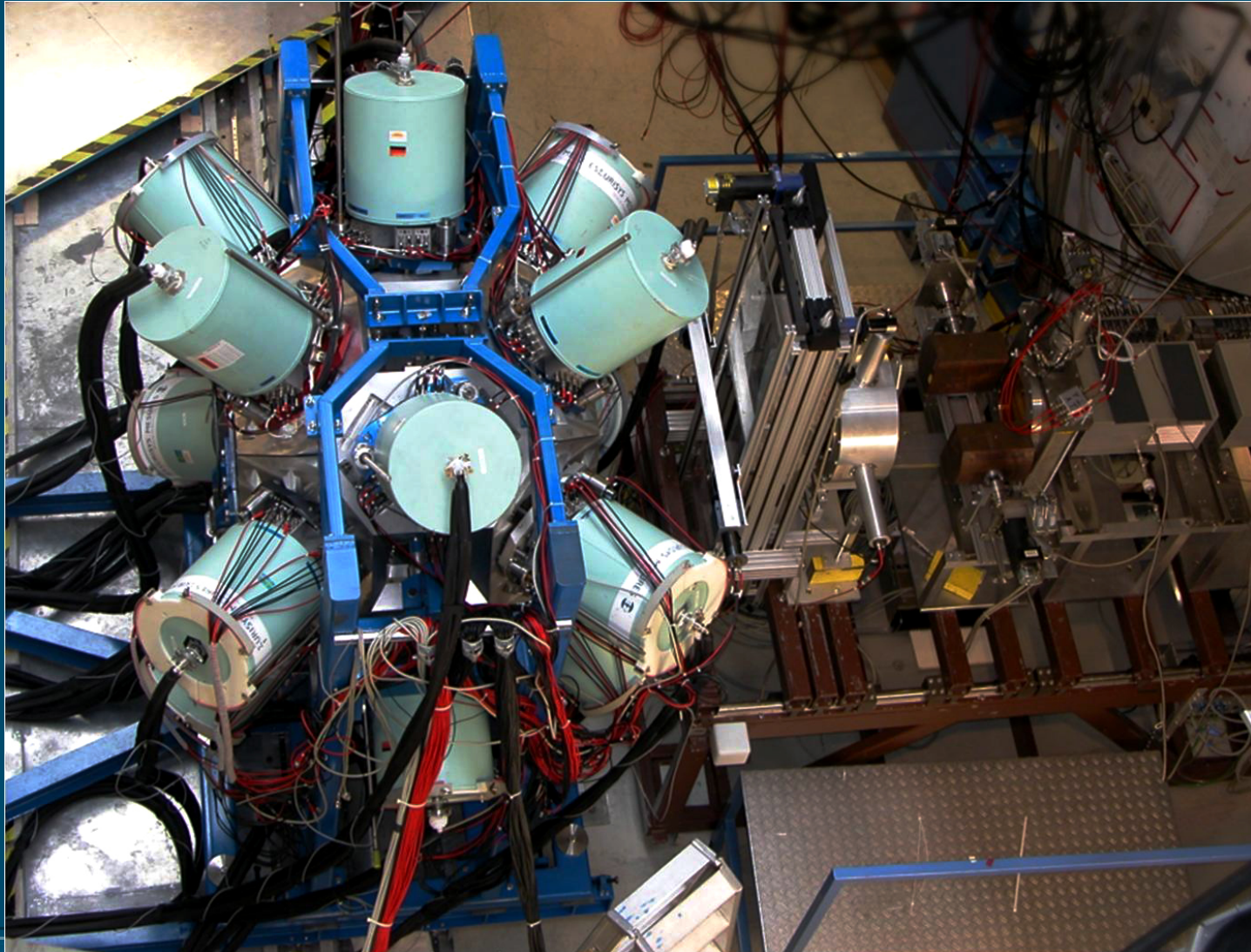
M. PFÜTZNER *et al.* (2002)



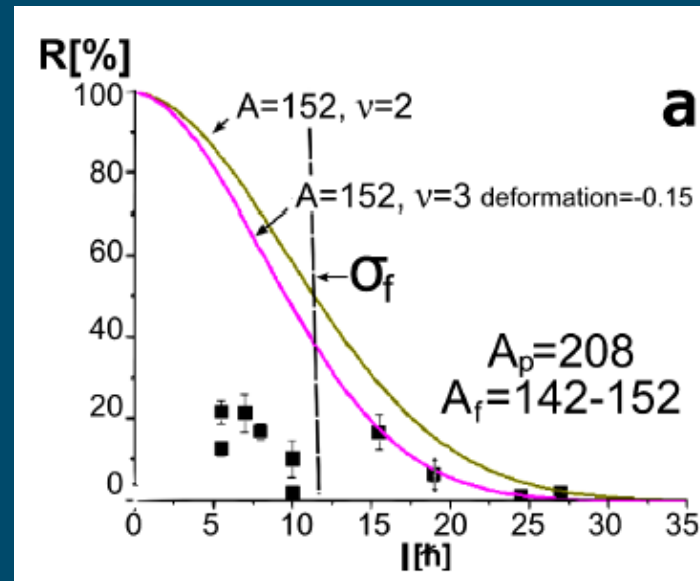
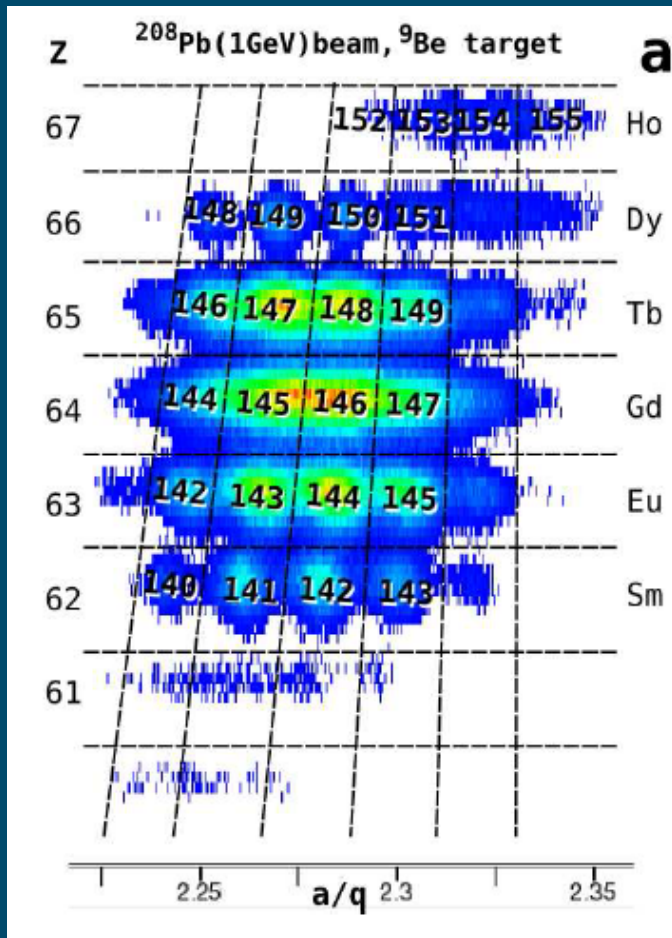
Followed by RISING with stopped beams



RISING with stopped beams



Isomer production rates



- o Study of isomer production in fragmentation of a relativistic ^{208}Pb beam - test of nuclear fragmentation models

g-RISING setup

8 EB Clusters

beam

Al degrader

slits

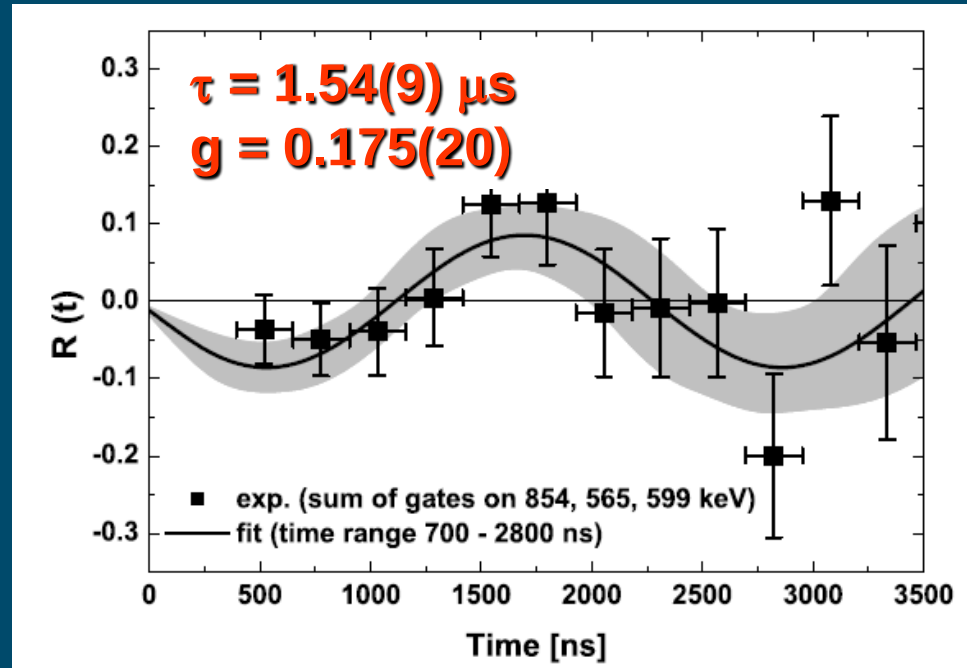
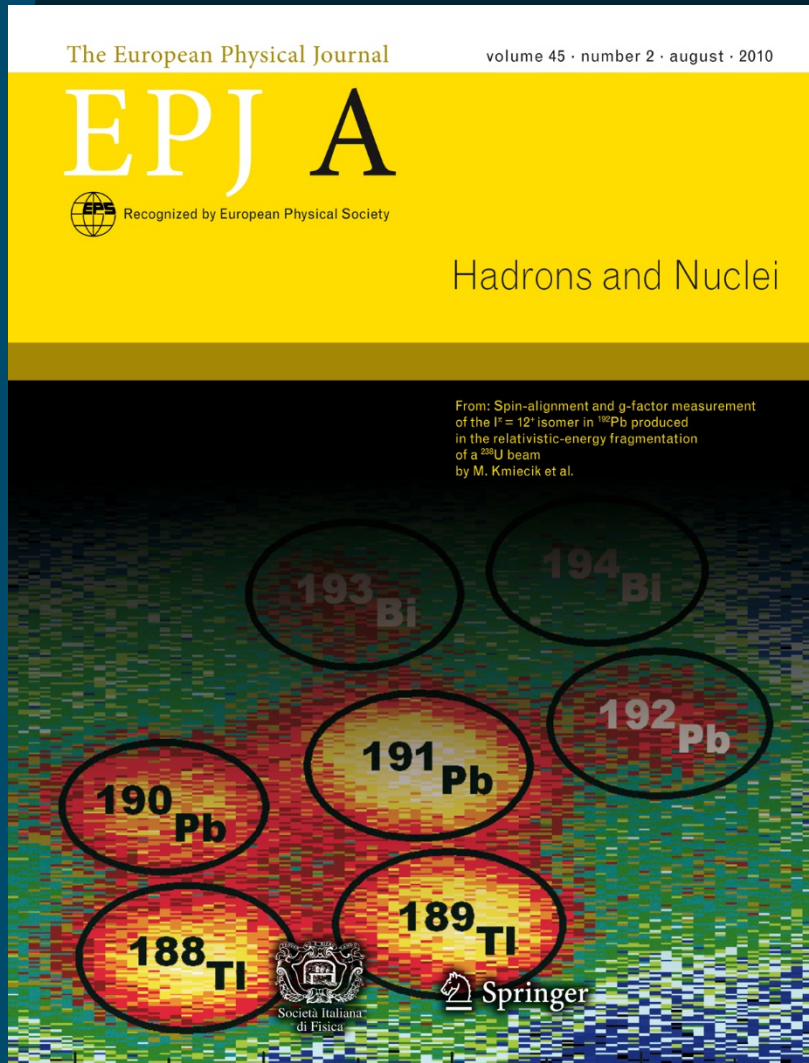
SC41

Pb-wall

**SC43
veto**

Magnet coil

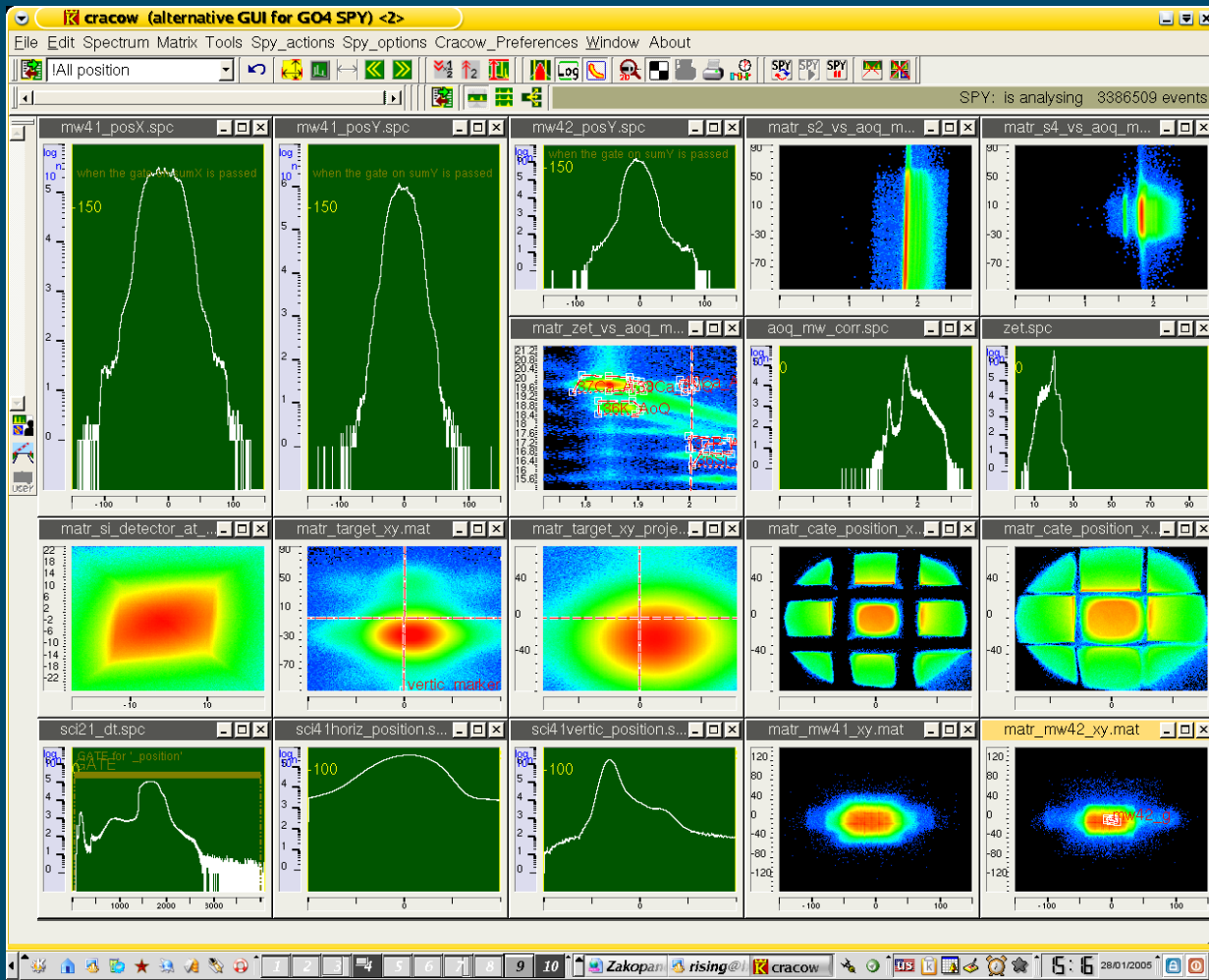
g -factor of the $I^\pi = 12^+$ isomer in ^{192}Pb (RIB)



- o first proof of a large spin alignment in heavy products of fragmentation reactions with relativistic projectiles (1 AGeV ^{238}U)

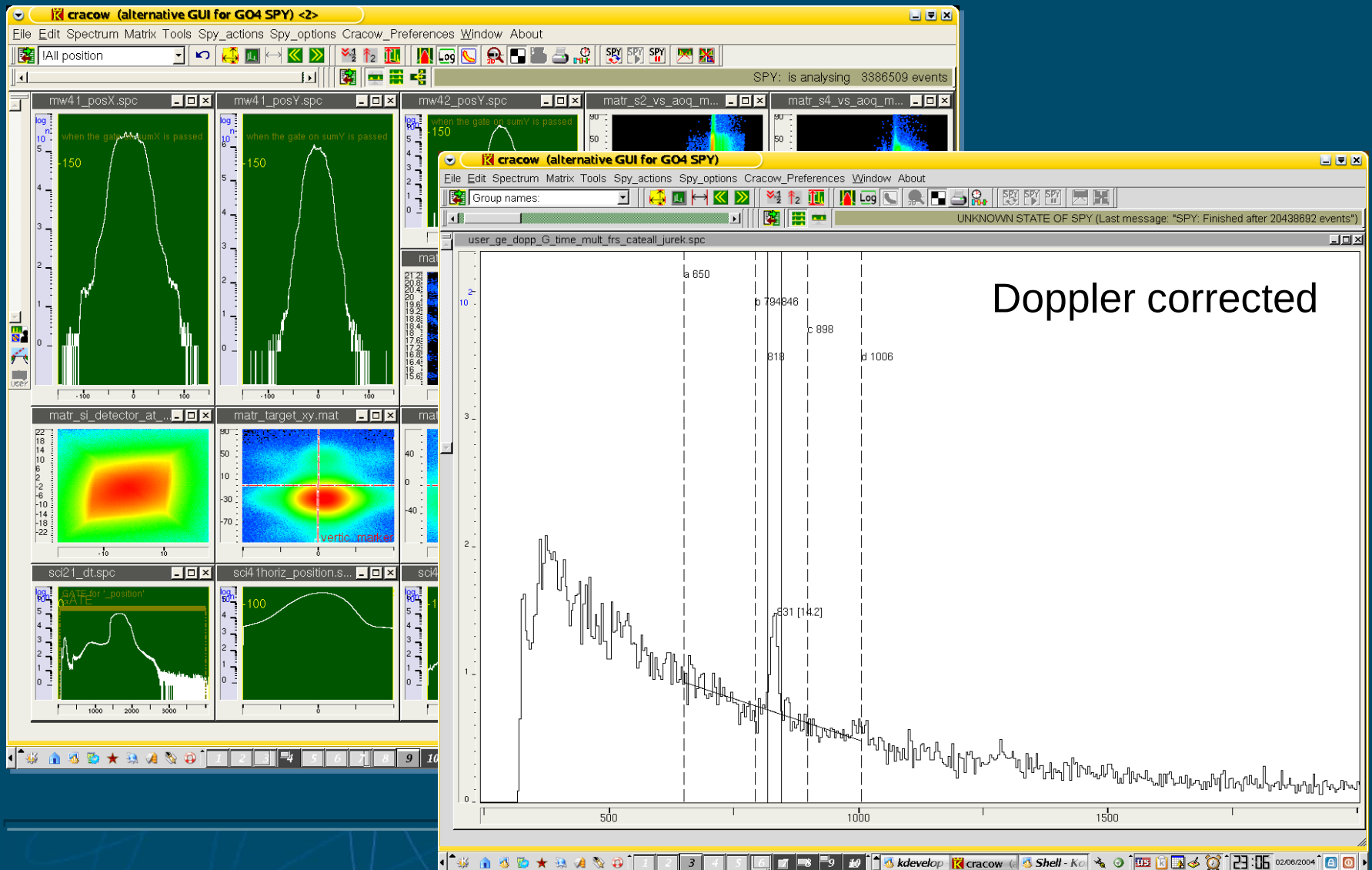
Alignment: $\eta \approx 30\%$

The Cracow code - an interactive method of sophisticated online



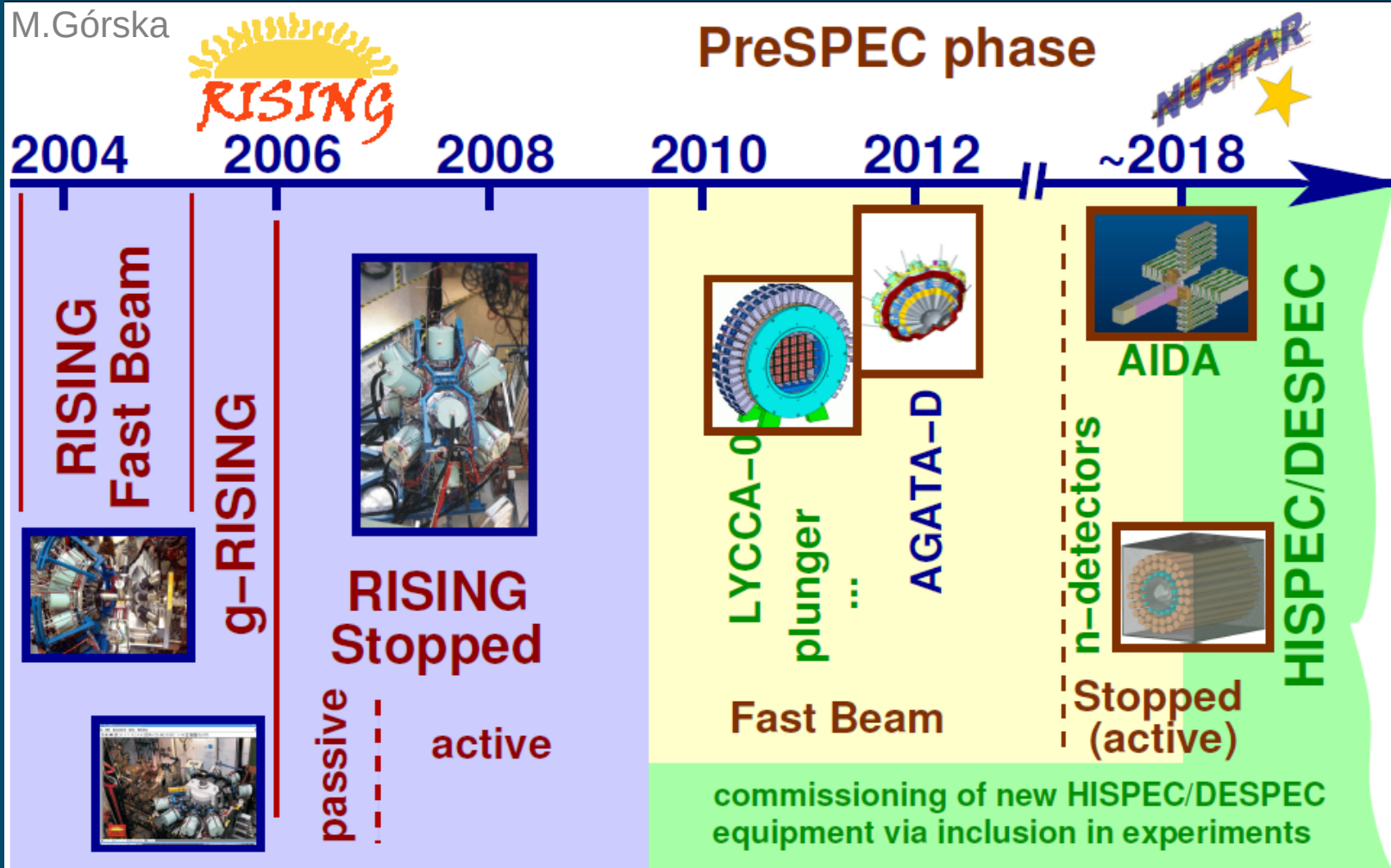
- o 1d, 2d gates
- o Conditions (&, |, !)
- o User defined spectra

The Cracow code - an interactive method of sophisticated online



Evolution of γ -spectroscopy with RIB

M.Górska



U [ions/s]

10^7

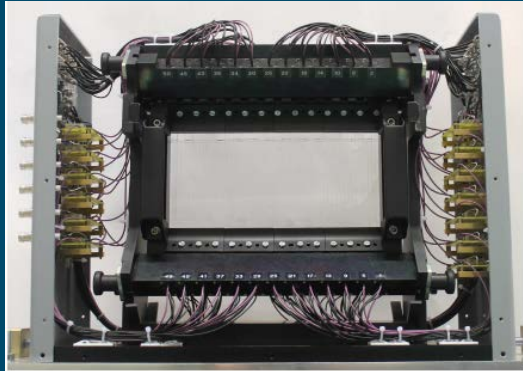
10^8

$>10^9$

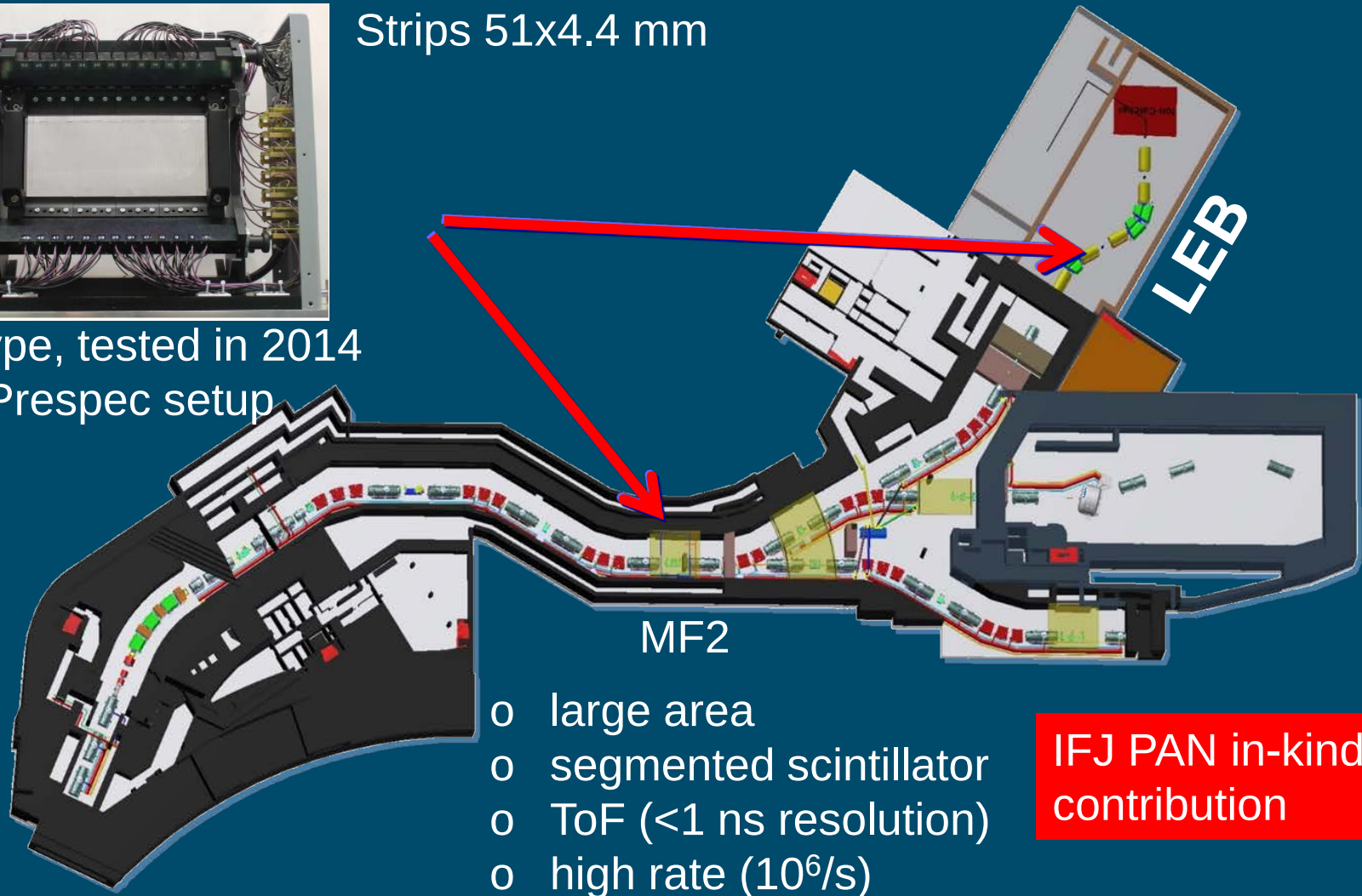
NUSTAR Week 2015
Warsaw Univ.

FINGER detector for NUSTAR

Strips 51x4.4 mm



Prototype, tested in 2014
at the Prespec setup



Polish participants in NUSTAR/HISPEC-DESPEC

NUSTAR 2022 perspective

IFJ PAN, Kraków	12
Warsaw University	15

Star Trek



Credit to RISING,
PreSPEC PMs
and their teams

Rising Team

H.J. Wollersheim, D.E. Appelbe, A. Banu, R. Bassini, T. Beck, F. Becker, **P. Bednarczyk**, K.-H. Behr, M.A. Bentley, G. Benzoni, C. Boiano, U. Bonnes, A. Bracco, S. Brambilla, A. Brunle, A. Burgerh, K. Burkard, P.A. Butler, F. Camera, **M.Ciemala**, D. Curien, J. Devin, P. Doornenbal, C. Fahlander, K. Fayz, H. Geissel, J. Gerl, M. Gorska, H. Grawe, **J. Grebosz**, R. Griffiths, G. Hammond, M. Hellstrom, J. Hoffmann, H. Hubel, J. Jolie, J.V. Kalben, **M. Kmiecik**, I. Kojouharov, **R. Kulesa**, N. Kurz, I. Lazarus, J. Lin, J. Leske, R. Lozeva, **A. Maj**, S. Mandal, **W. Meczynski**, B. Million, G. Munzenberg, S. Muralithar, M. Mutterer, **S.Myalski**, P.J. Nolan, G. Neyens, J. Nyberg, **W. Prokopowicz**, V.F.E. Pucknell, P. Reiter, D. Rudolph, N. Saito, T.R. Saito, D. Seddon, H. Schaffner, J. Simpson, K.-H. Speidel, **J. Styczen**, K. Summerer, N. Warr, H. Weick, C. Wheldon, O. Wieland, M. Winkler, M. **Zieblinski**, A.B. Garnsworthy, P.H. Regan, L. Cáceres, S. Pietri, Y. Sune, Zs. Podolyák, P.Regan, S.J. Steer, R. Hoischen, A. Heinz, A. Kelic, F. Montes, S. Tachenov, **E. Werner-Malento**, B.B. Blank, C. Brandau, W.N. Catford, I.J. Cullen, Zs. Dombrádi m, E. Estevez, W. Gelletly, G. Ilieo, G.A. Jones a, A. Jungclaus, F.G. Kondev q, T. Kurtukian-Nieto, S. Lalkovski l,r, Z. Liua, **S. Myalski** , **M. Pfützner**, S. Schwertel, T. Shizuma, A.J. Simons, P.M. Walker a, F.R. Xuv,