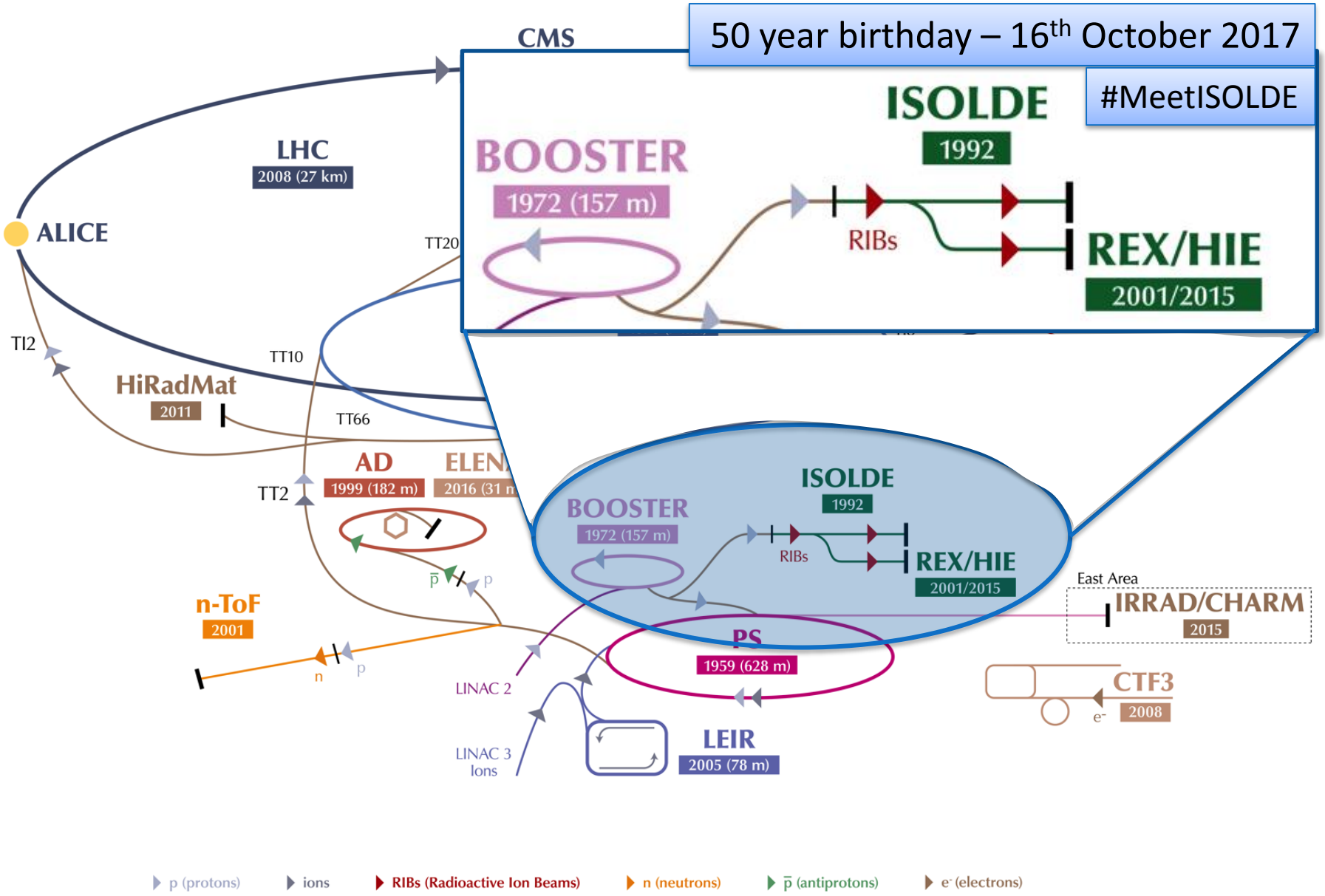
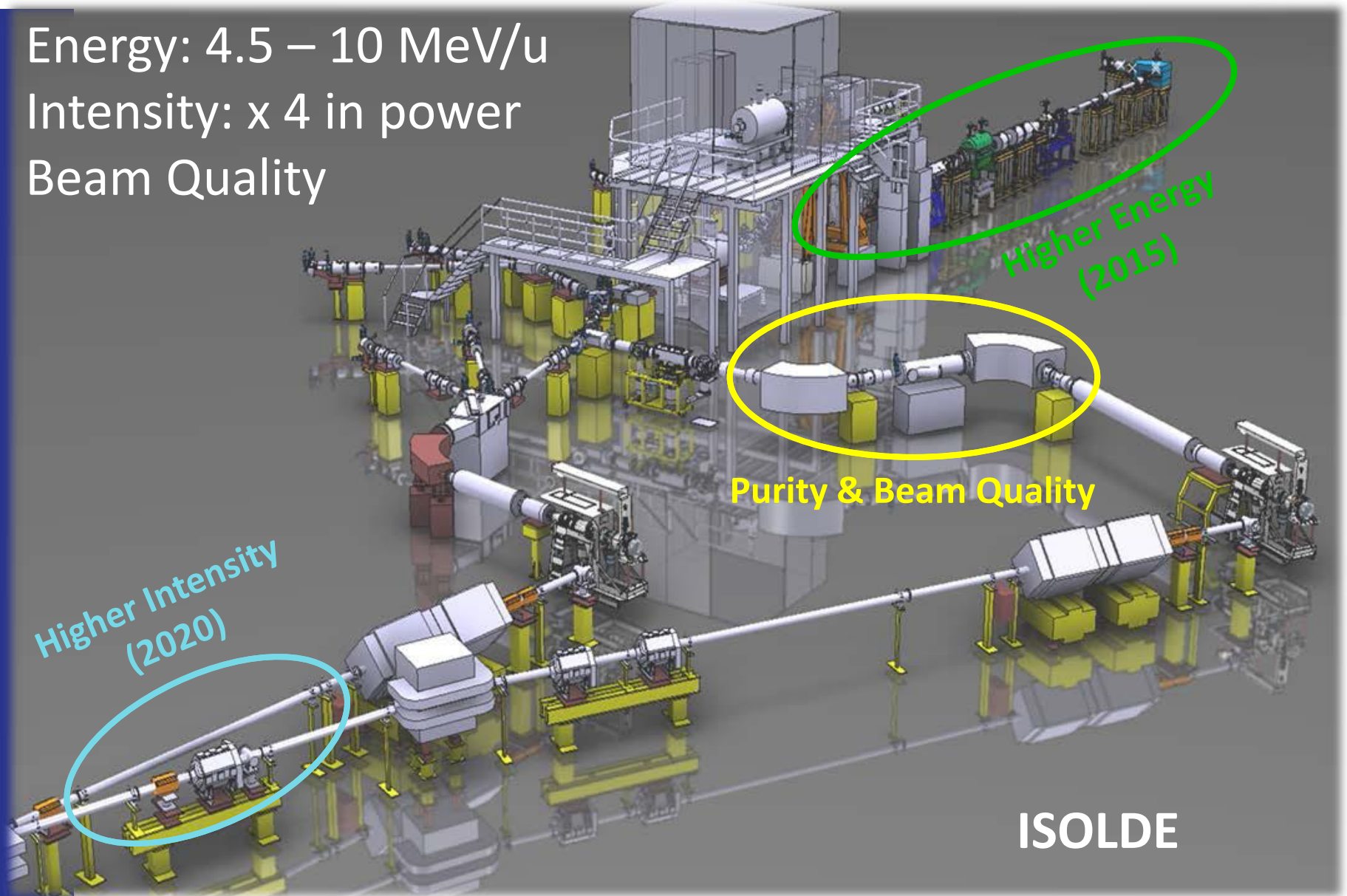
Exploiting post-accelerated RIBs at HIE-ISOLDE

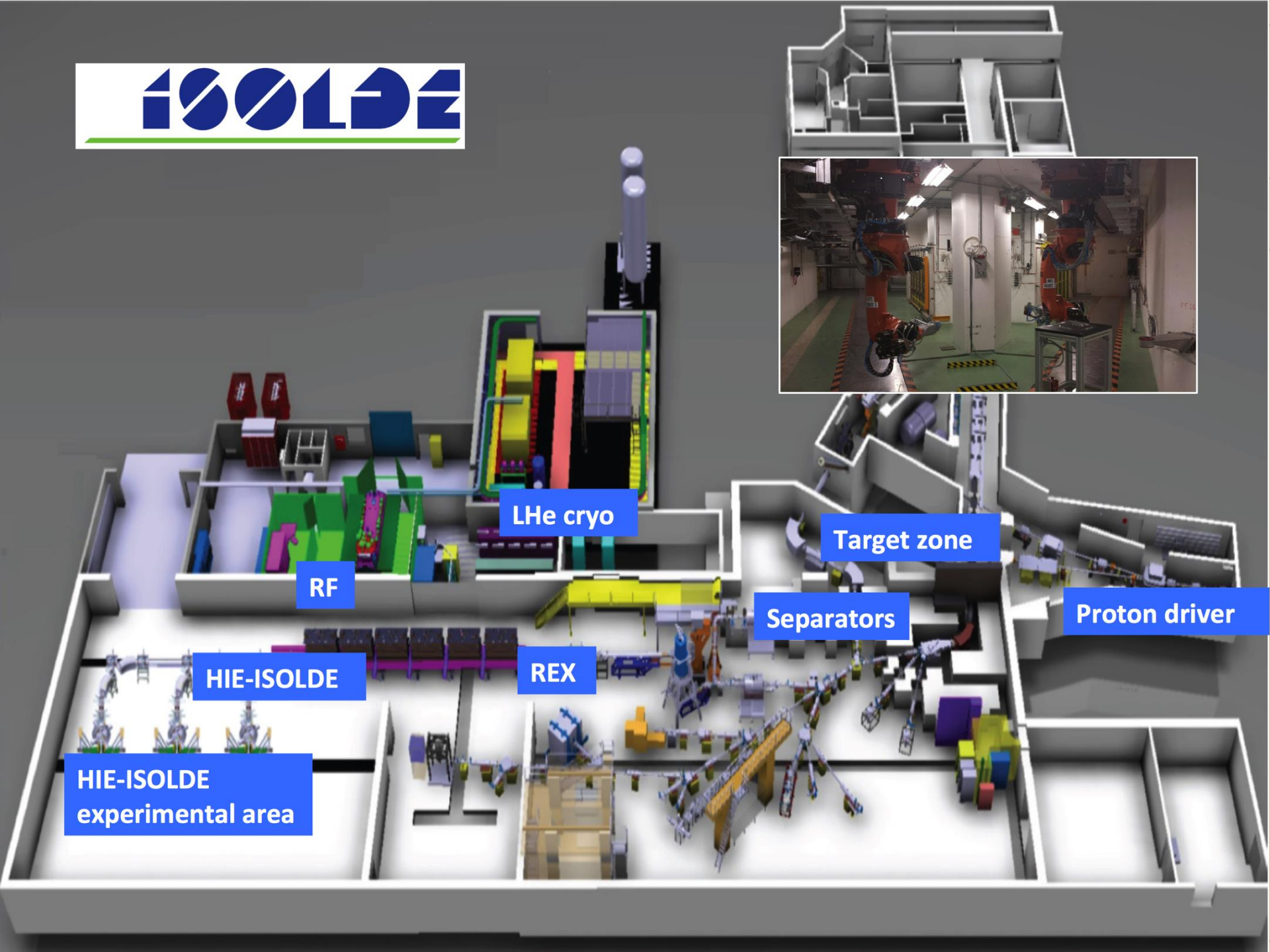
Liam Gaffney (CERN)

CERN accelerator complex

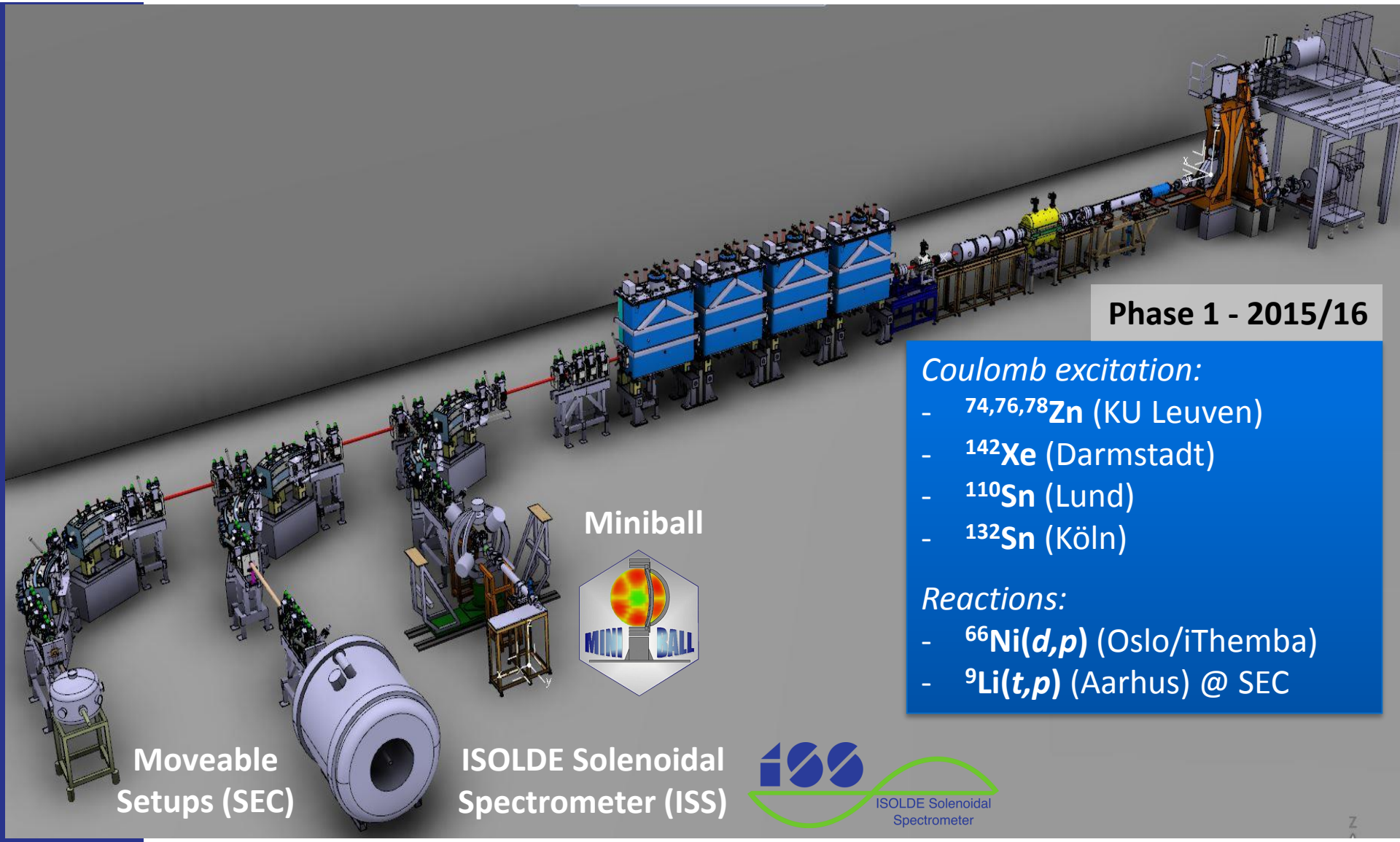


The HIE-ISOLDE project (2010 -)




ISOLDE
LHe cryo
RF
Target zone
Separators
Proton driver
HIE-ISOLDE
REX
HIE-ISOLDE
experimental area

HIE-ISOLDE Phase 2 (2016-2018)



Phase 1 - 2015/16

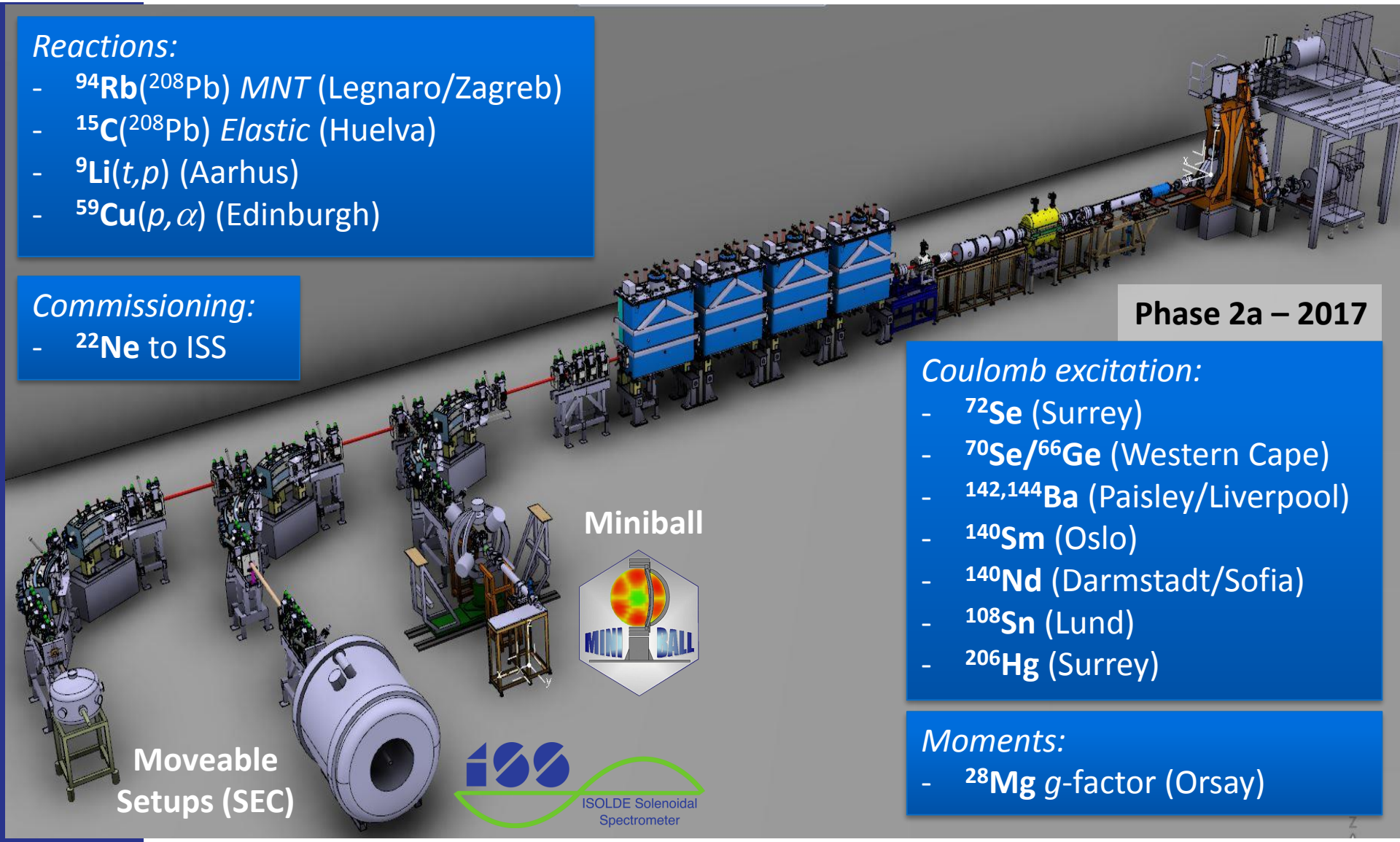
Coulomb excitation:

- ^{74,76,78}**Zn** (KU Leuven)
- ^{142}**Xe** (Darmstadt)
- ^{110}**Sn** (Lund)
- ^{132}**Sn** (Köln)

Reactions:

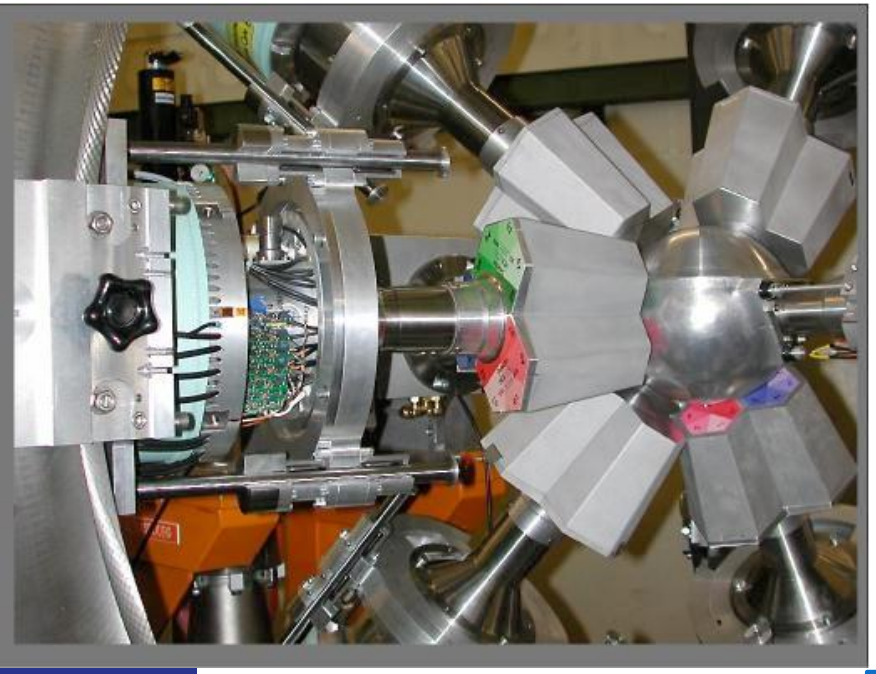
- ^{66}**Ni(*d*,*p*)** (Oslo/iThemba)
- ^{9}**Li(*t*,*p*)** (Aarhus) @ SEC

HIE-ISOLDE Phase 2 (2017-2018)



Miniball @ HIE-ISOLDE

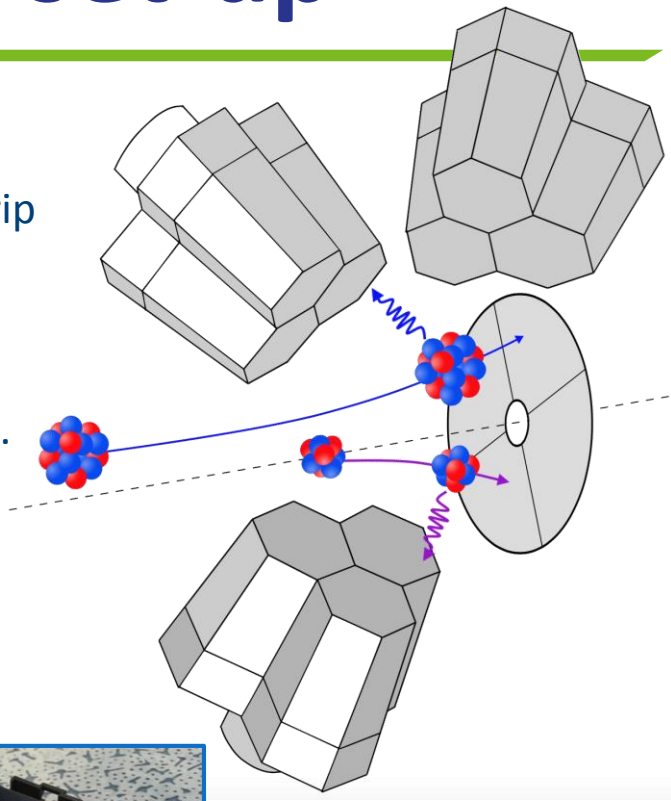
Miniball: Coulex set-up



Particle ID in a Double-Sided Si Strip Detector (DSSSD).

Event-by-event Doppler correction.

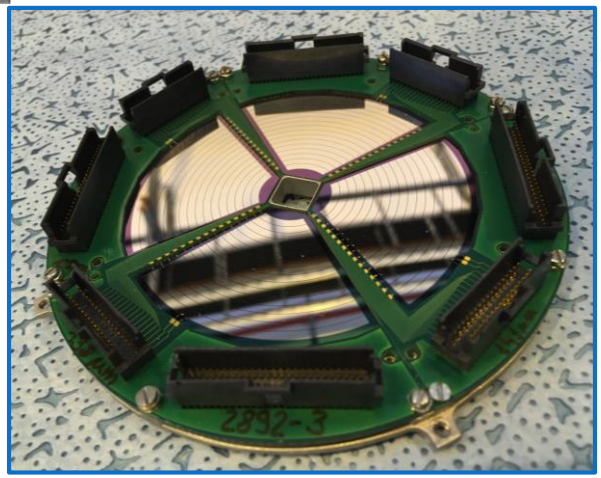
$17^\circ < \theta_{lab} < 54^\circ$



Array of HPGe of 8 triple clusters

6-fold electronic segmentation

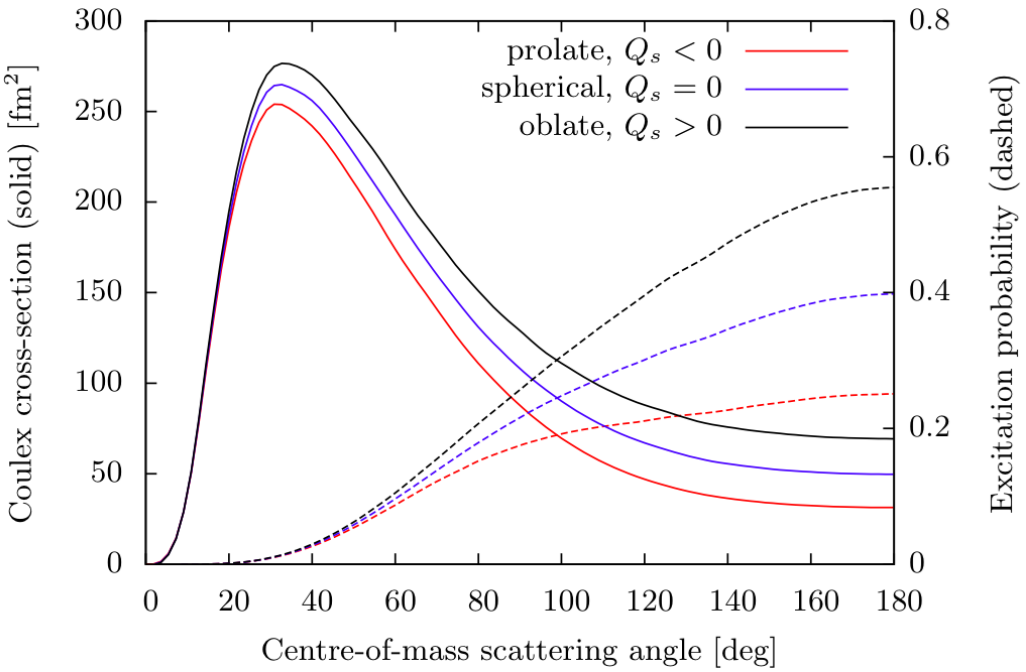
$\varepsilon > 7\%$ for 1.3MeV γ-rays



N. Warr et al., EPJ **49** (2013)

Why use Coulomb excitation?

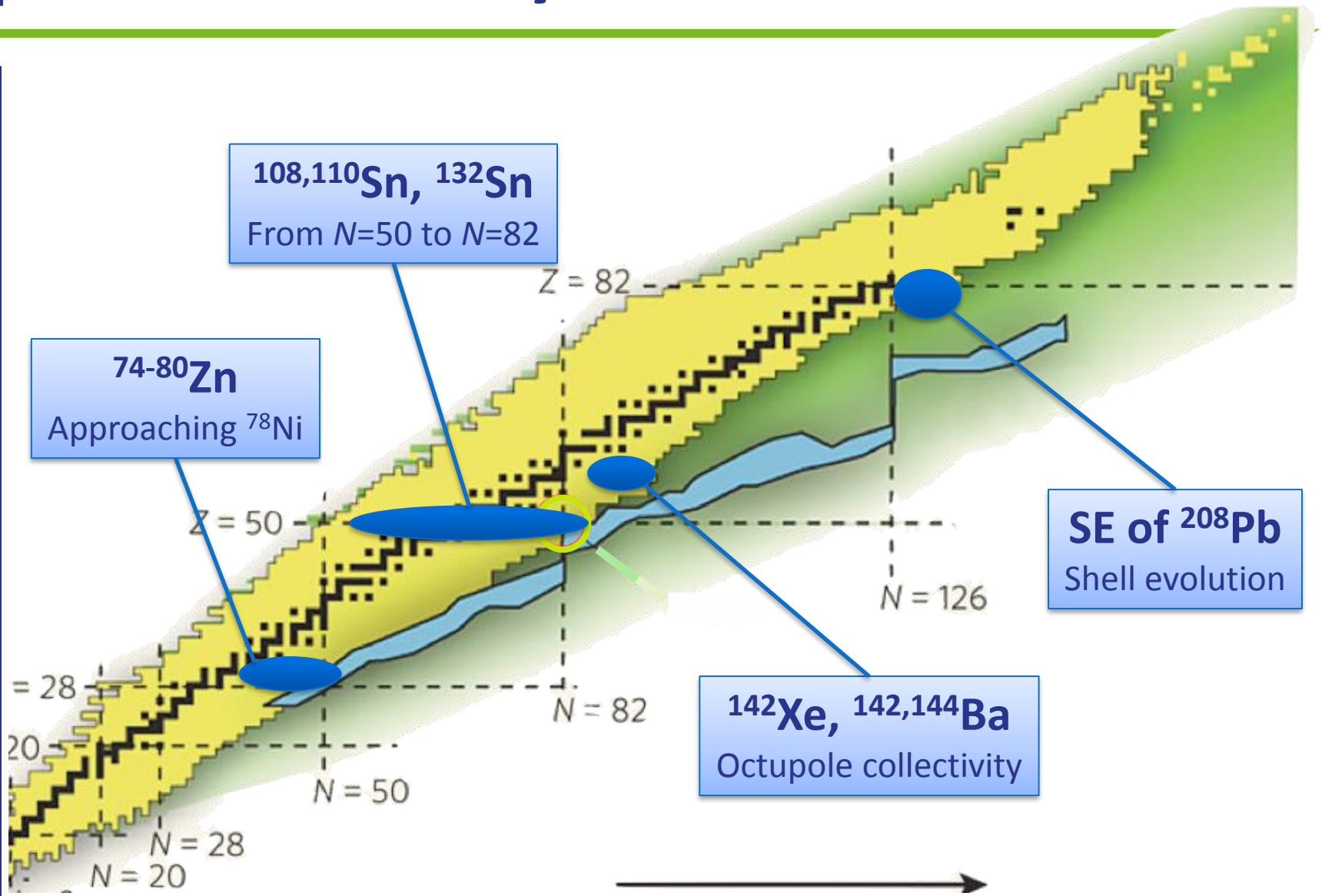
- Renaissance of “old” technique at new state-of-the-art RIB facilities.
- High cross sections (~barns)
- Ideal beam energies at ISOL facilities with post-acceleration – HIE-ISOLDE!
- Access to non-yrast states
- Complete sets of matrix elements accessible
- Sensitivity to spectroscopic quadrupole moments, Q_s.



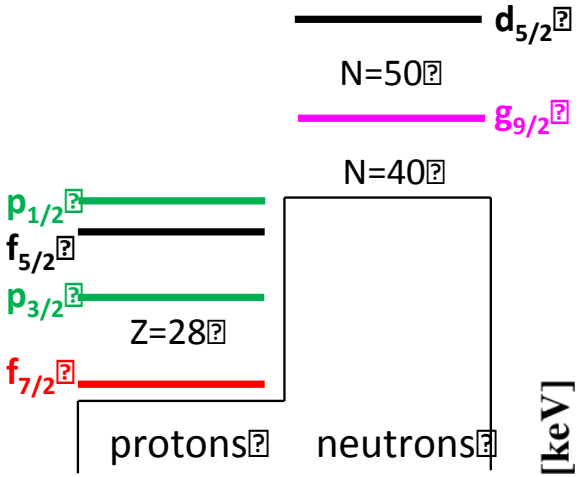
Additionally:

- useful in the search for new states
- sensitive to **sign** combinations

Physics cases

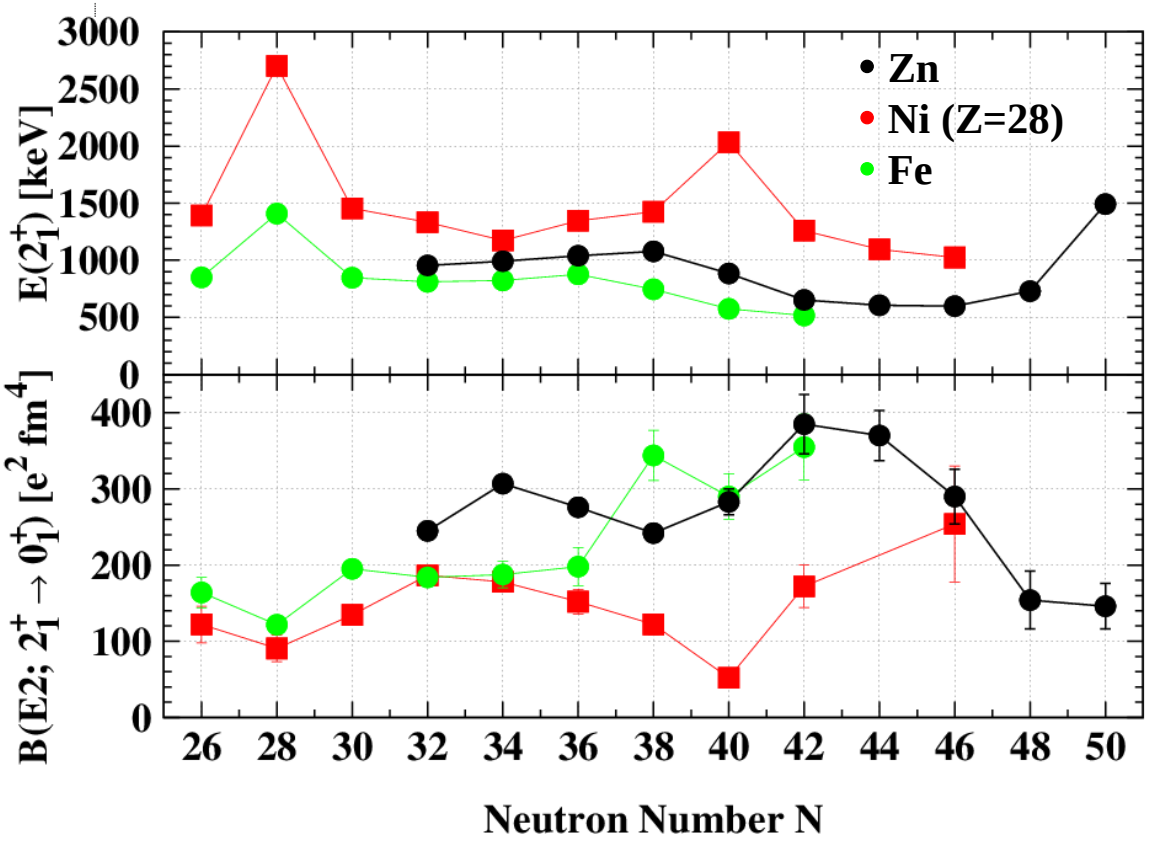


^{74,76,78}Zn – IS557

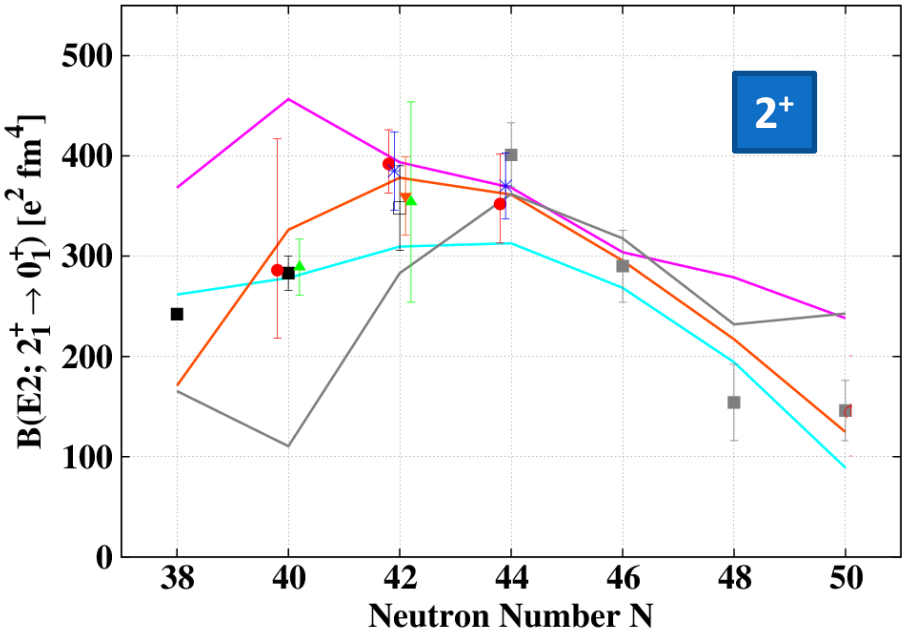


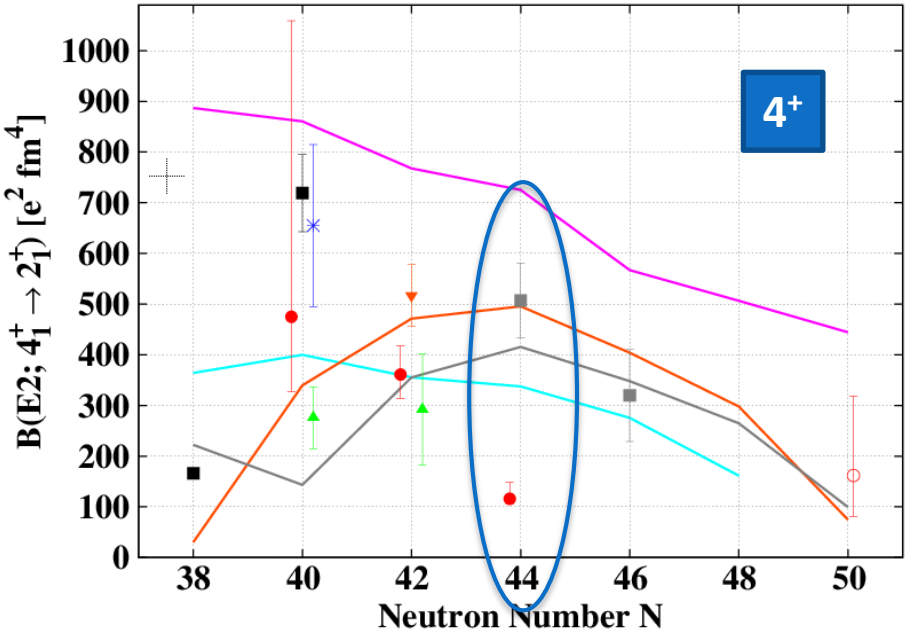
What happens when going towards *N*=50?

$^{74-80}$Zn: Coulomb excitation at REX-ISOLDE
(Van de Walle PRC (2009))



Transition strengths in Zn

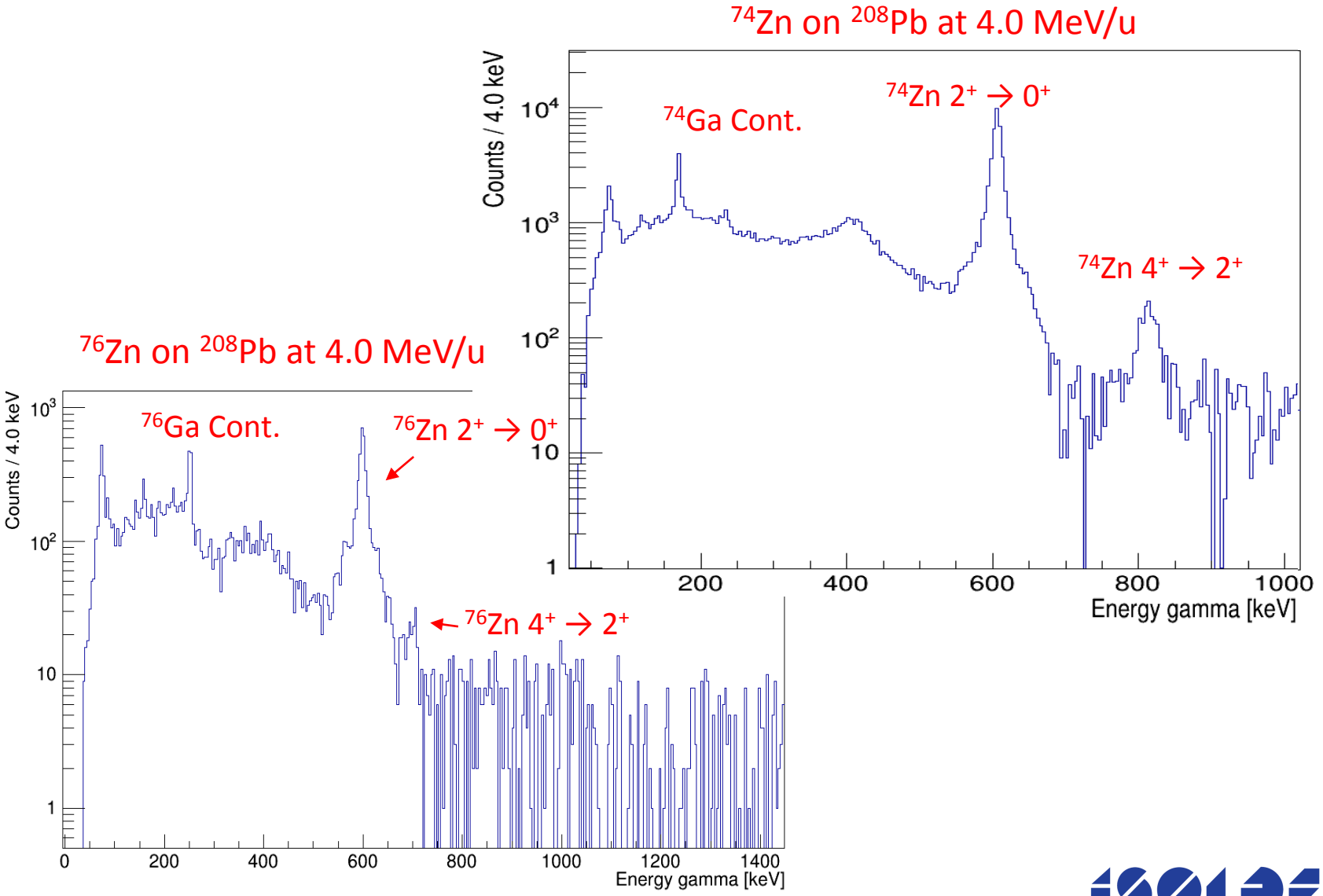




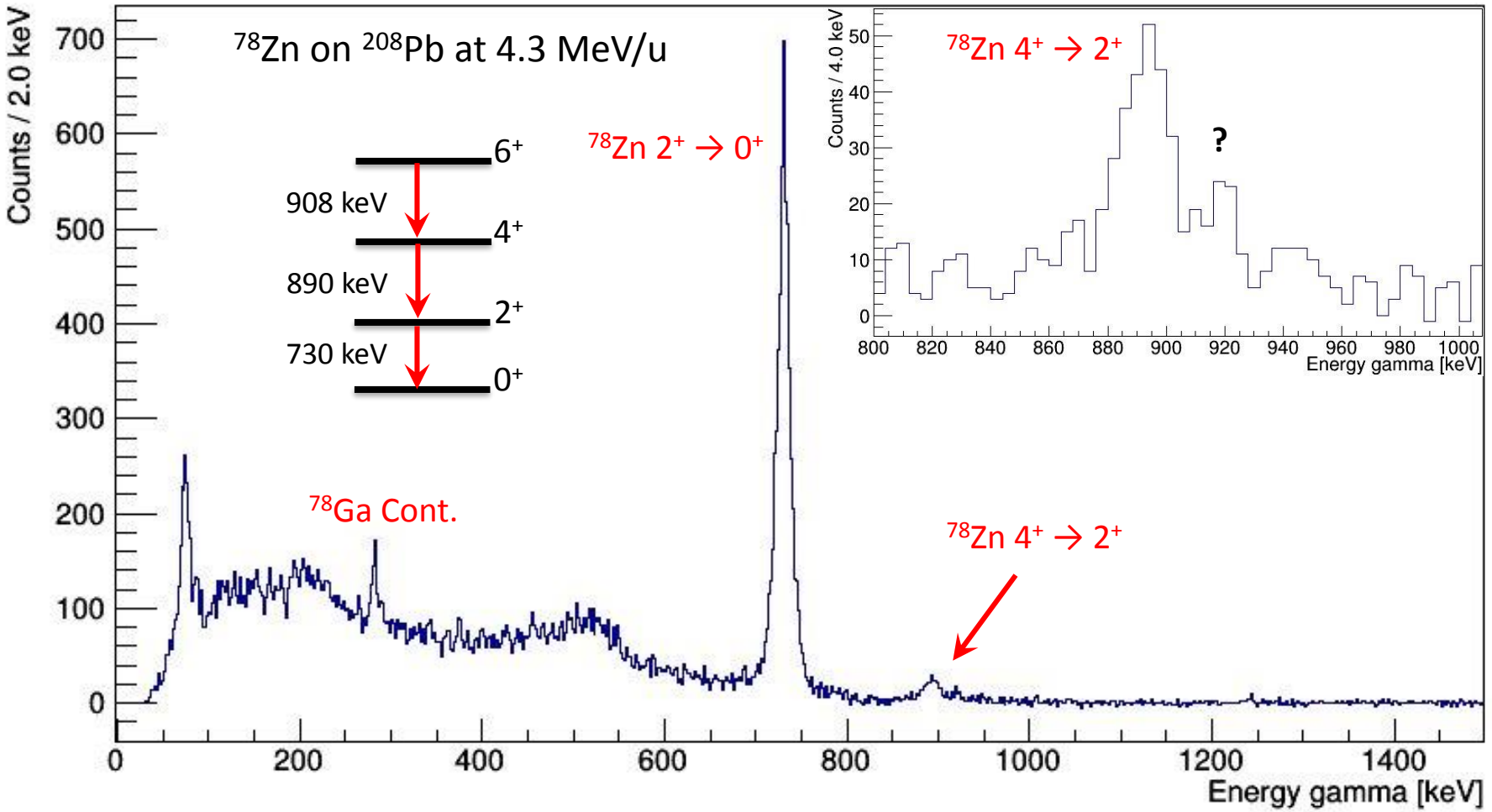
- Data:
  - Coulomb excitation
    - Van de Walle PRC (2009)
    - ▼ Hellgartner, TU Munich (2015)
  - Doppler shift
    - ● Louchart PRC (2013)
    - ▲ Čeliković Act. Phys. Pol. (2013)
    - ■ National Nuclear Data Center (NNDC)
    - ○ Shiga PRC (2016)

- Theory:
  - Shell model calculations
    - JUN45 (^{56}Ni core: $pf_{5/2}g_{9/2}$) Honma PRC (2009)
    - ... LNPS (48Ca: $pfg_{9/2}d_{5/2}$) Lenzi PRC (2010)
    - MCSM Otsuka *Priv. comm.* (2016), Shimizu Phys. Scr. (2017)
  - HFB – Gogny D1S force
    - Delaroche PRC (2010)

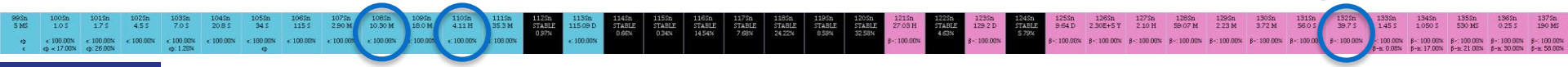
γ-ray spectra ^{74,76}Zn



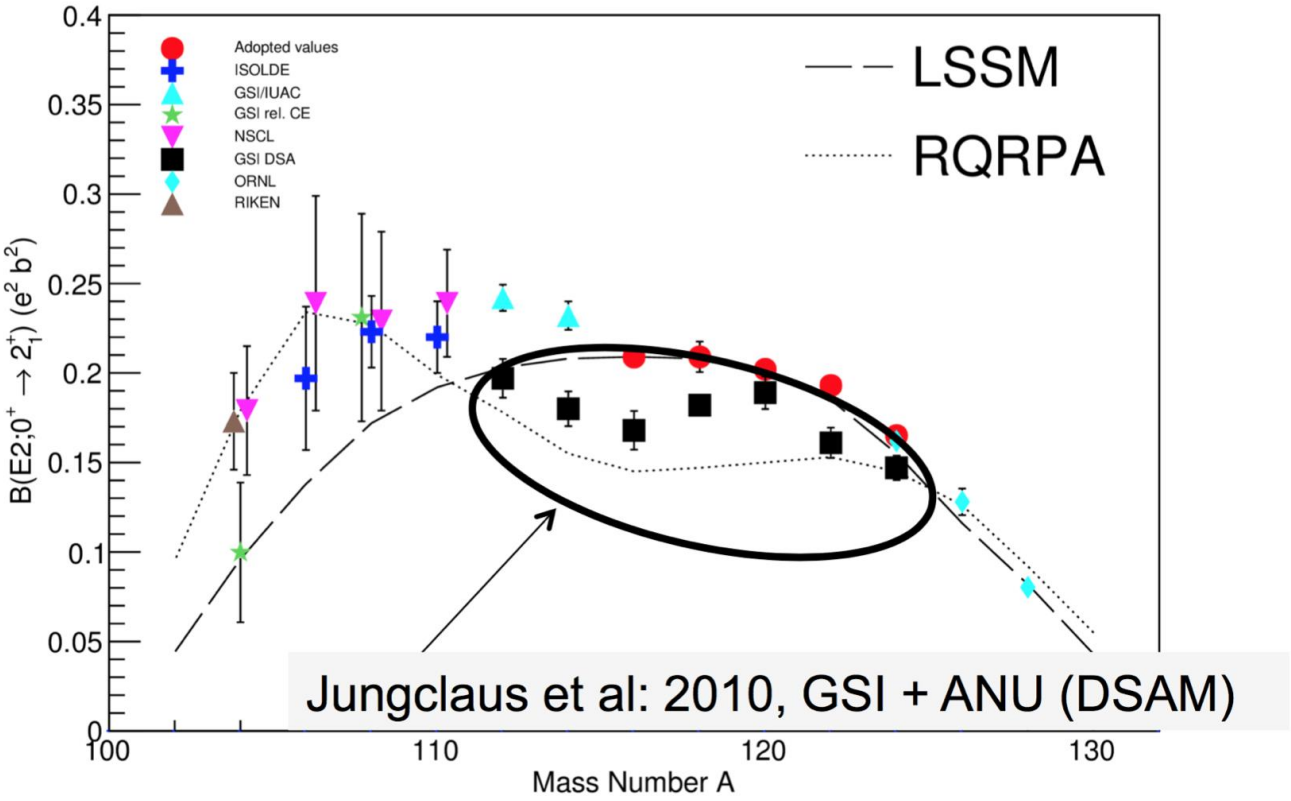
γ-ray spectra ^{78}Zn (2016)



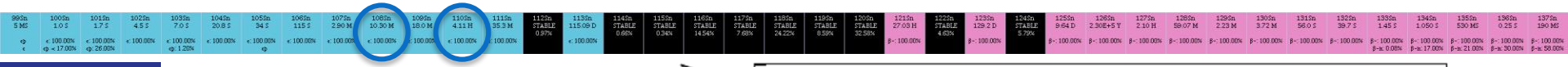
$^{108,110\ldots132}$Sn – Extreme isotopes



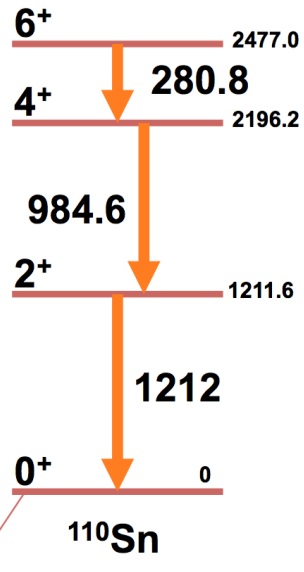
- Both ends of the Sn isotopic chain, towards N=50 and N=82.
- Discrepancies exist even in the middle of the chain…
- Large uncertainties on the neutron-deficient side

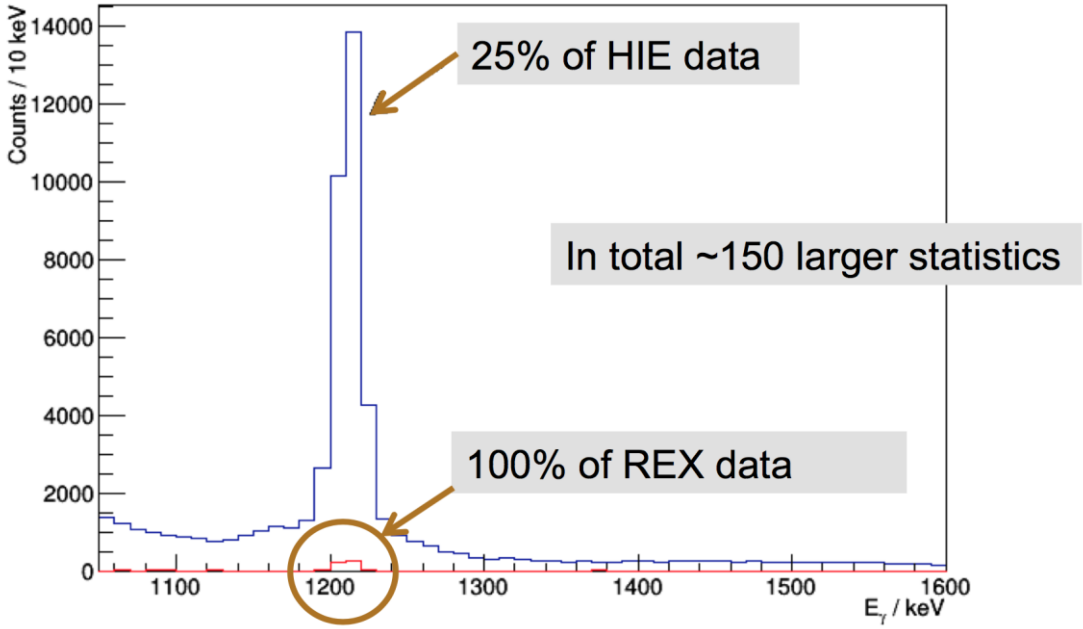


Neutron-deficient – IS562



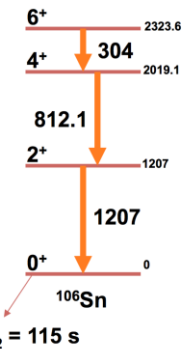
$T_{1/2}$ = 5.6 ns





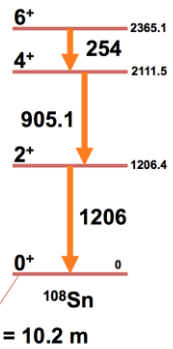
$T_{1/2}$ = 4 h

$T_{1/2}$ = 2.8 ns



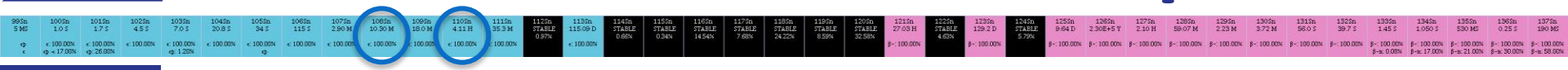
$T_{1/2}$ = 115 s

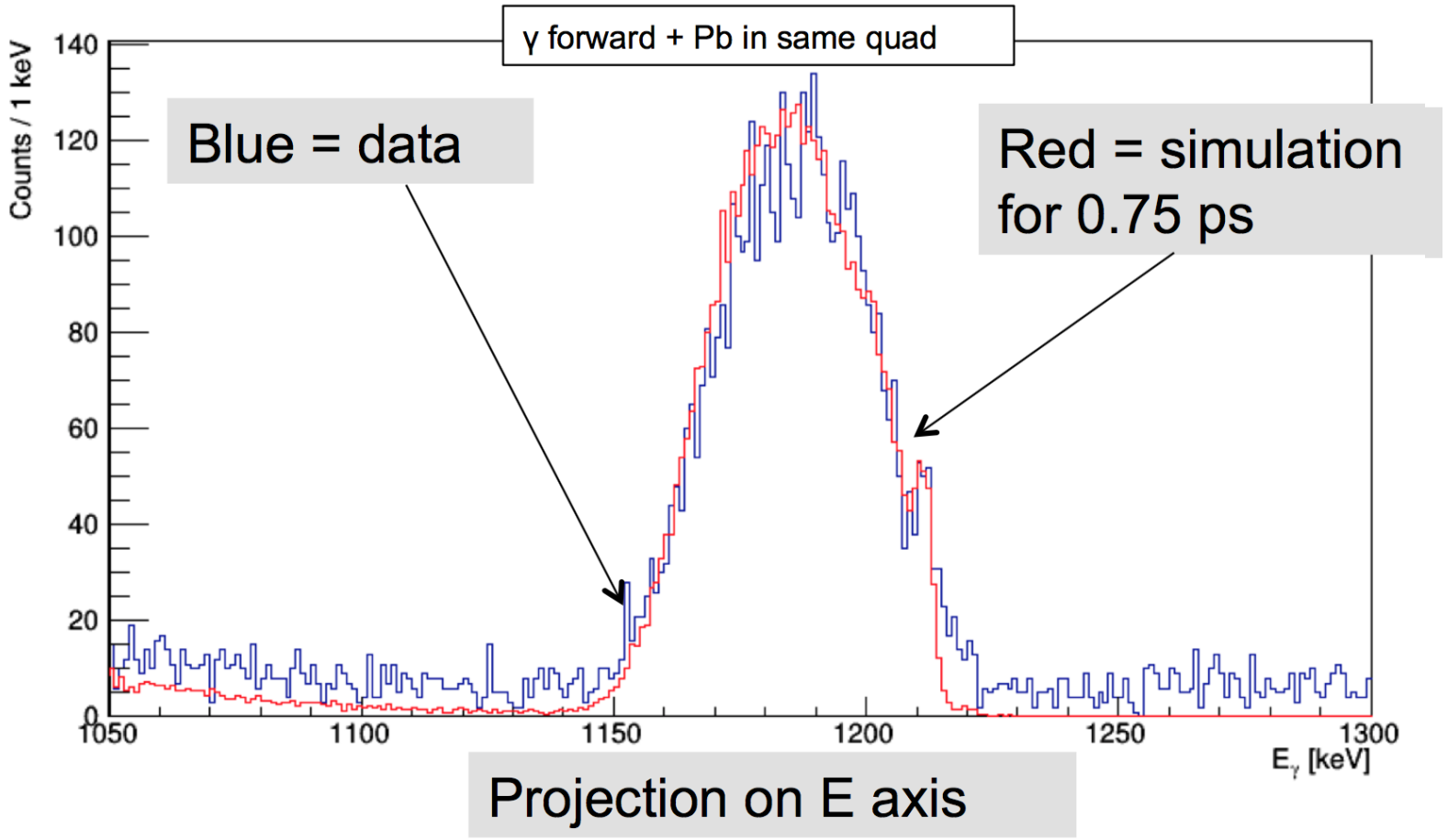
$T_{1/2}$ = 7.4 ns



$T_{1/2}$ = 10.2 m

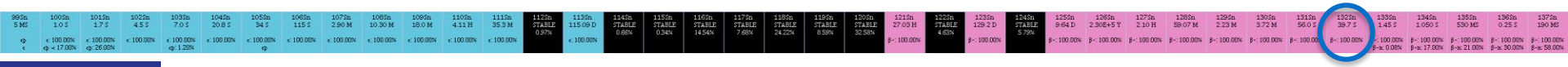
DSAM from line shape?





Thanks to Jacob Snall and Joakim Cederkall (Lund)

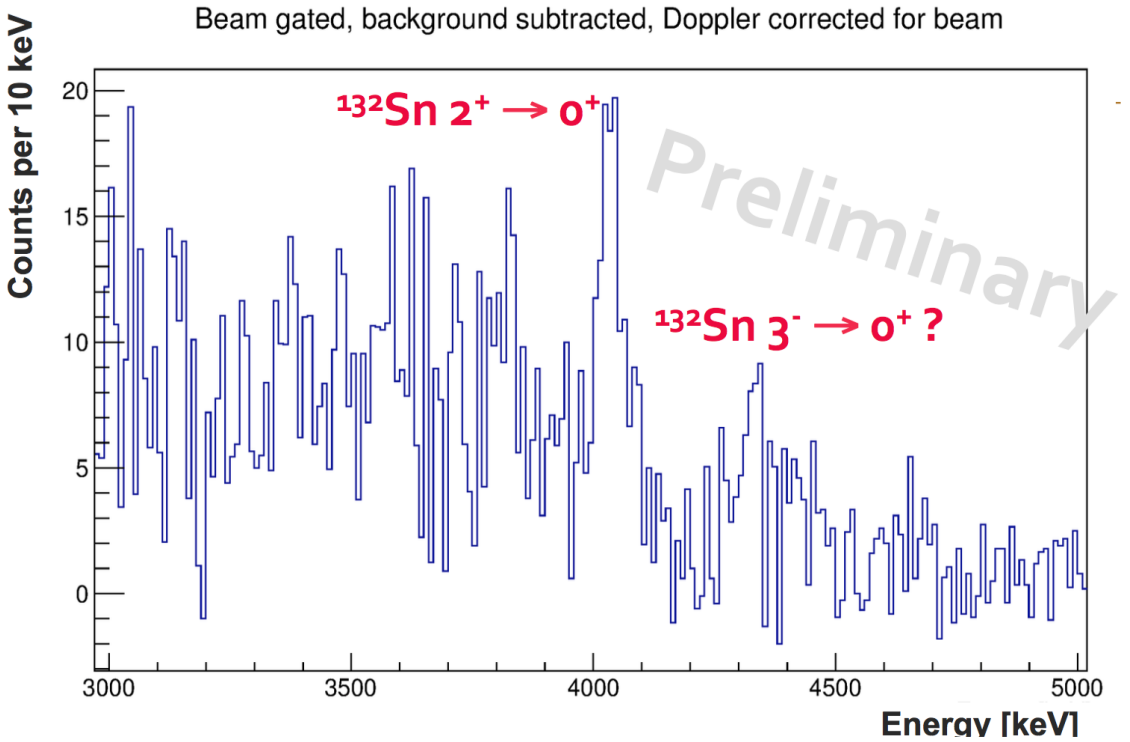
Doubly magic ^{132}Sn – IS551



- First 2^+ at 4.041 MeV; coupled with low B(E2) → Very low cross-section!
- Preliminary result, analysis of single- and double-escape peaks.
- Hints of 3^- excitation also observed.

Previous measurements:

B(E2; $0^+ \rightarrow 2^+$) = 0.14(6) e^2b^2
D.C. Radford et al., Nucl. Phys. A746, 83c (2004)
B(E2; $0^+ \rightarrow 2^+$) = 0.11(3) e^2b^2
R.L. Varner et al., Eur. Phys. J. A 25, s01, 391 (2005)

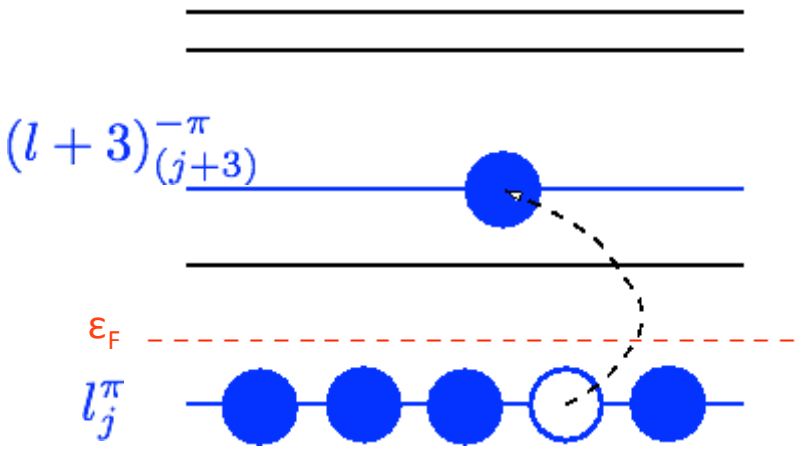


Thanks to Dawid Rosiak and Peter Reiter (Köln)

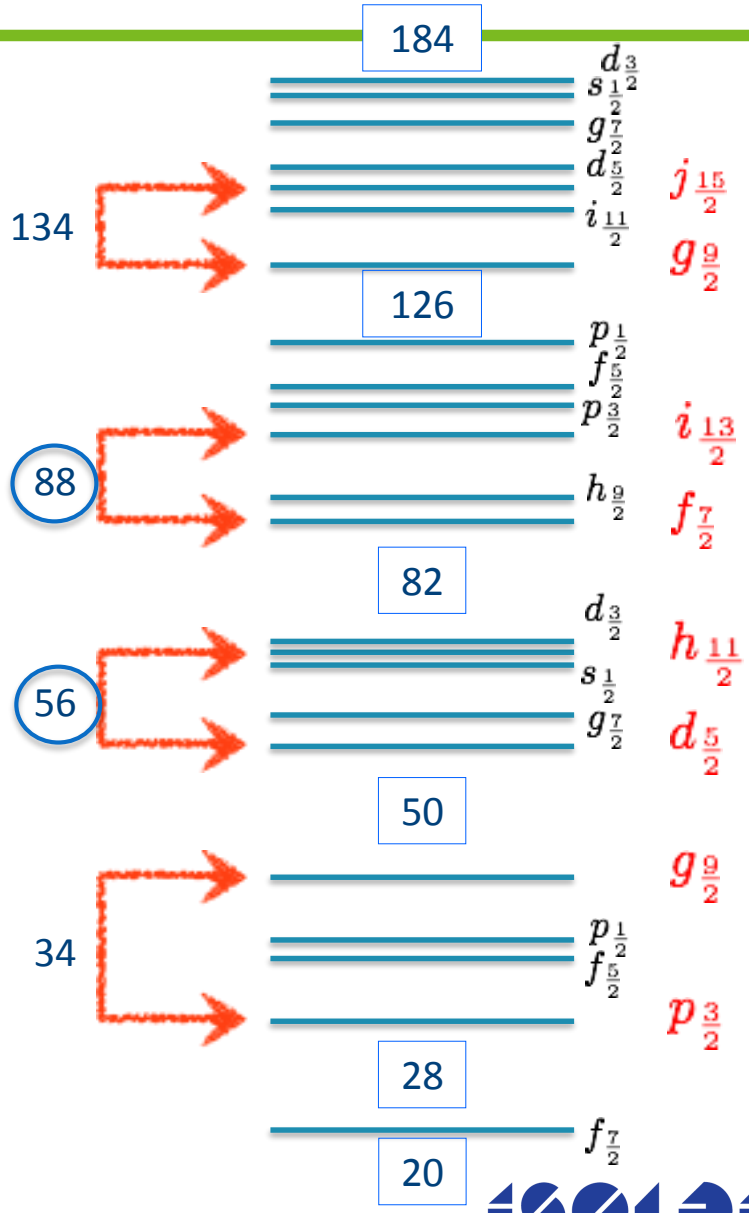
Octupole Collectivity

Microscopically driven...

Intruder orbitals of opposite parity and ΔJ, ΔL = 3 close to the Fermi level

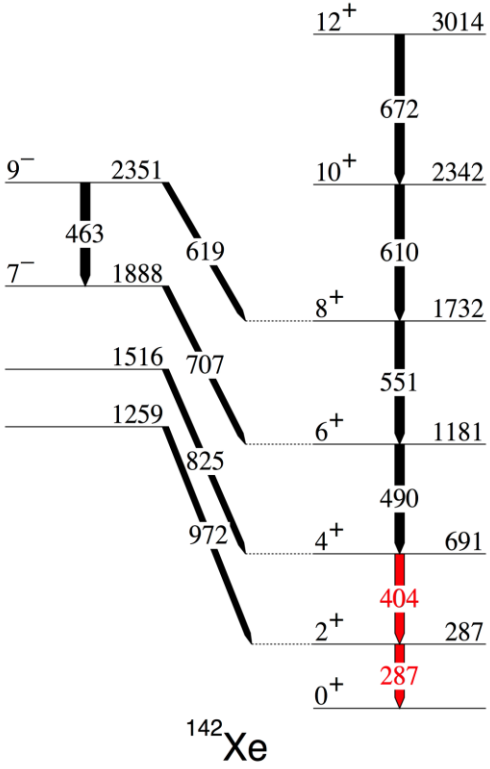


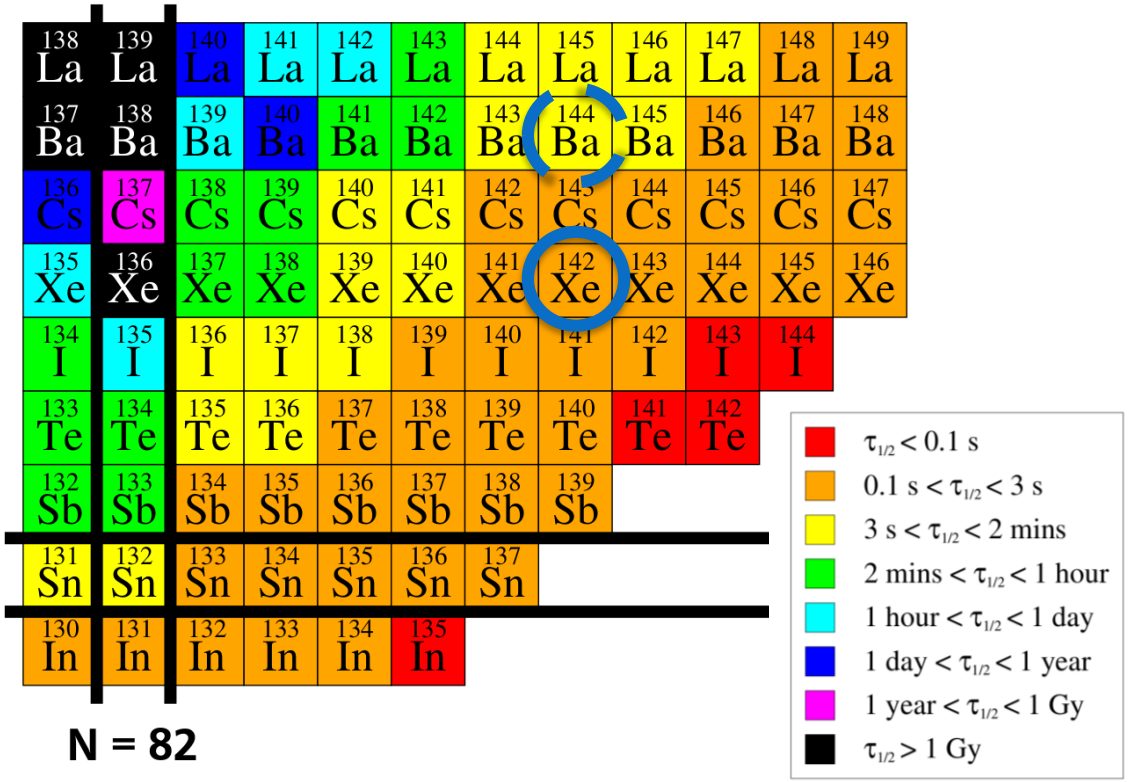
^{144}Ba is centre of the Z = 56, N = 88 region



North-east of ^{132}Sn: ^{142}Xe & ^{144}Ba

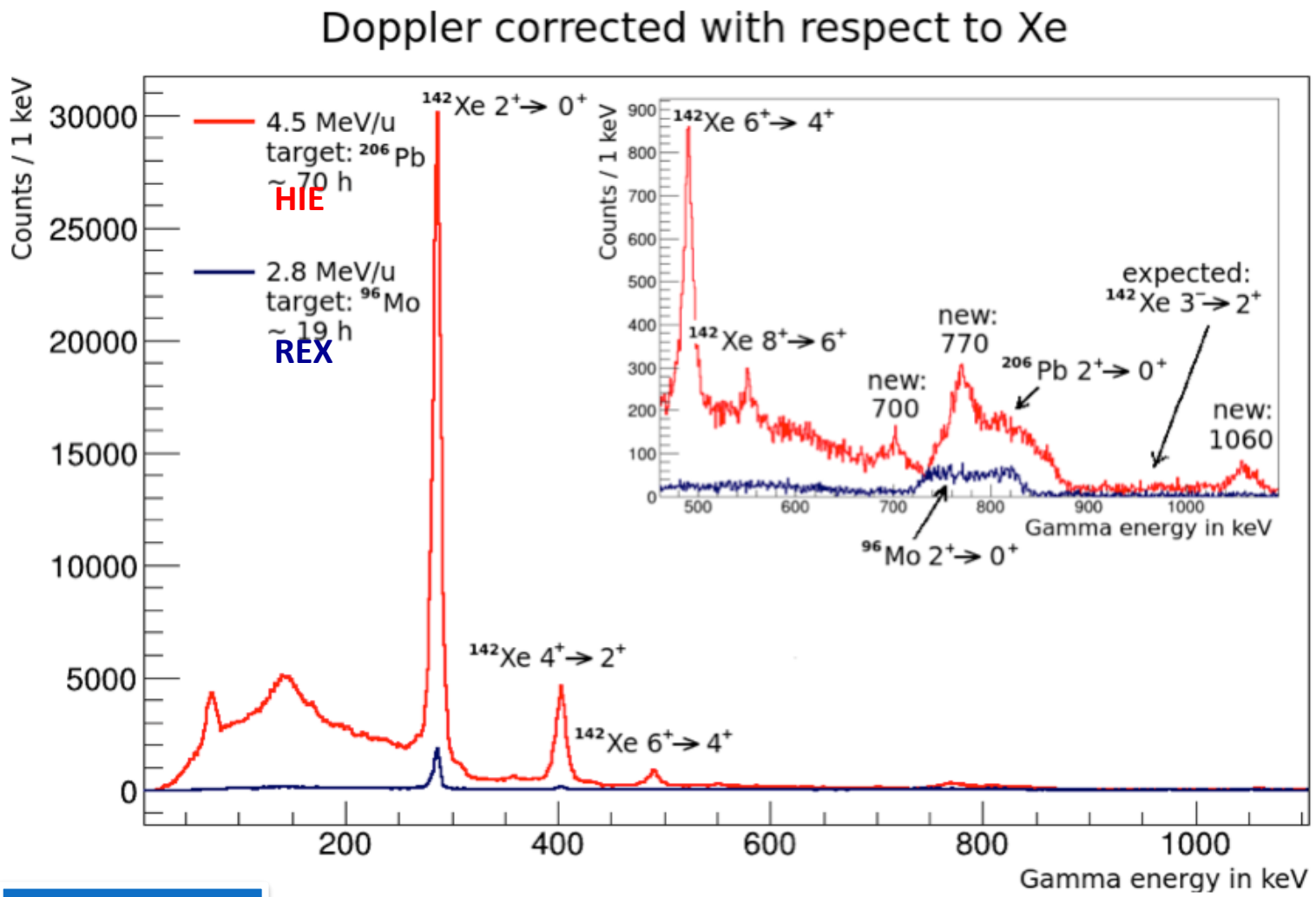
- Regions to the north-east of doubly-magic shell closures, good candidates for octupole deformation.
- B(E3) known to be good measure; CARIBU@ANL[1] – ^{144}Ba = 48^{+25}_{-34} W.u.





[1] B. Bucher et al. Phys. Rev. Lett. 116, 112503 (2016)

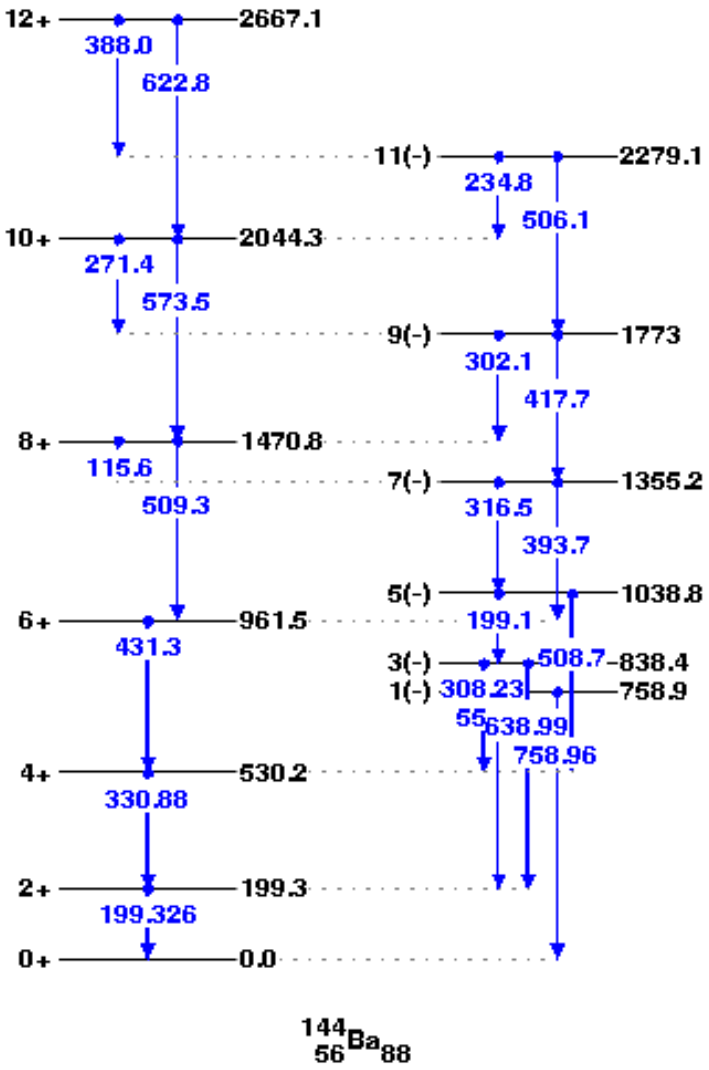
Comparison of REX/HIE – ^{142}Xe



2016 data

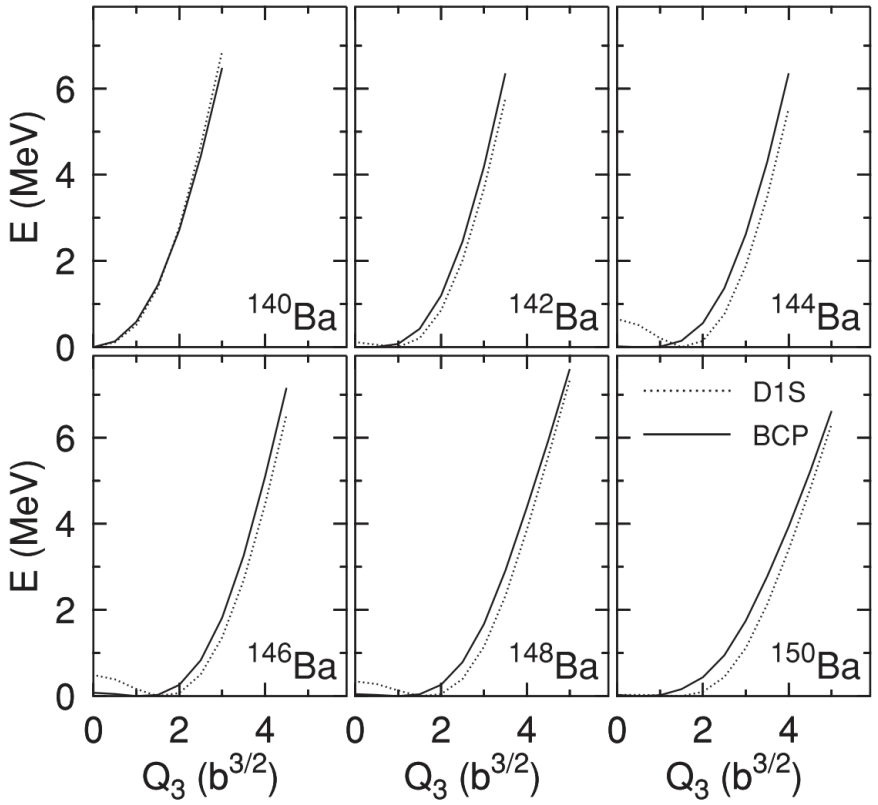
Thanks to Corinna Henrich and Thorsten Kröll (Darmstadt)

Lanthanides: ^{142,144}Ba – IS553



- Predicted by mean-field approaches to be most likely candidate for β_3 deformation in lanthanide region.

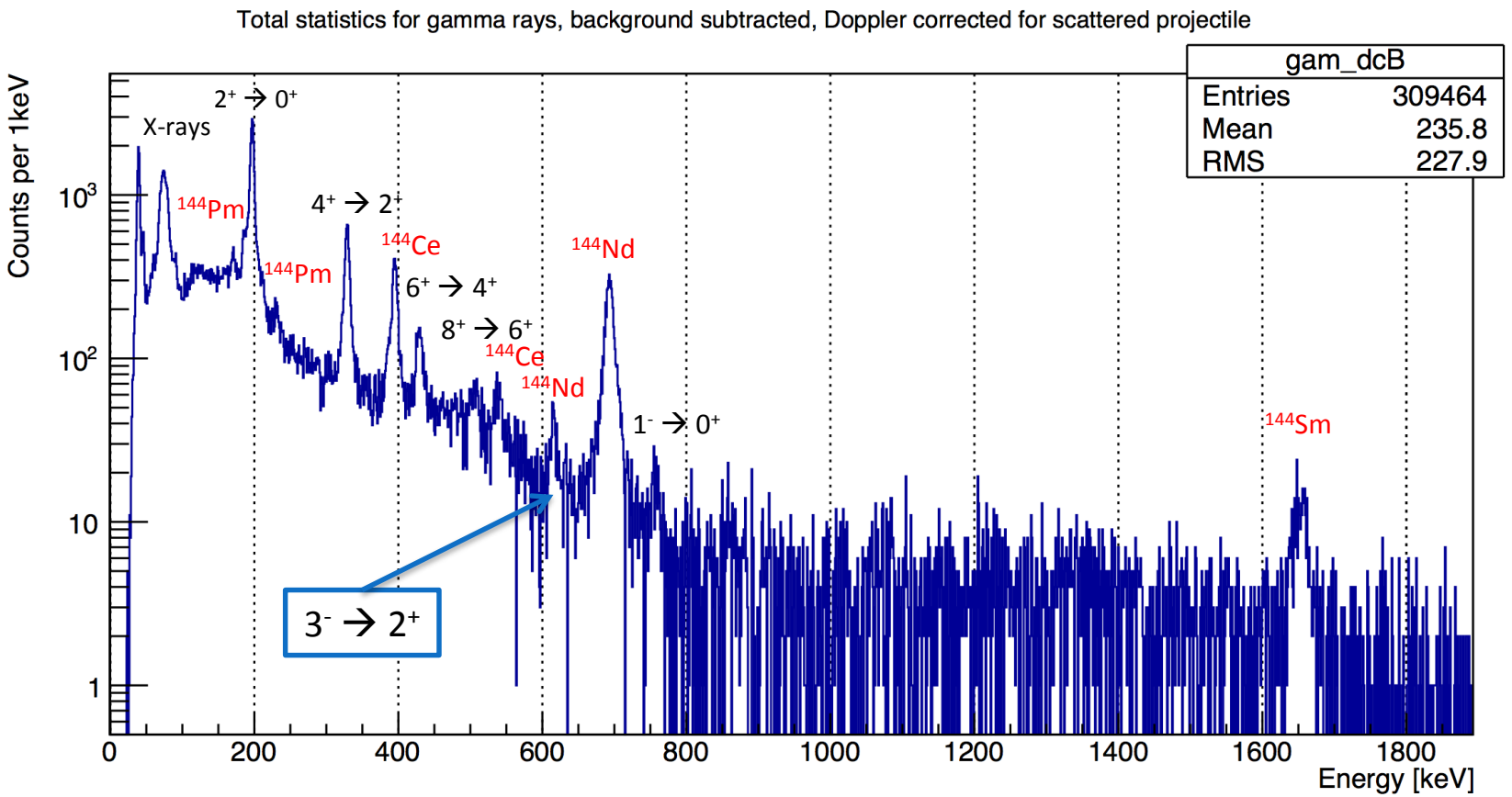
L. M. Robledo, M. Baldo, P. Schuck, and X. Viñas, Phys. Rev. C **81**, 34315 (2010).



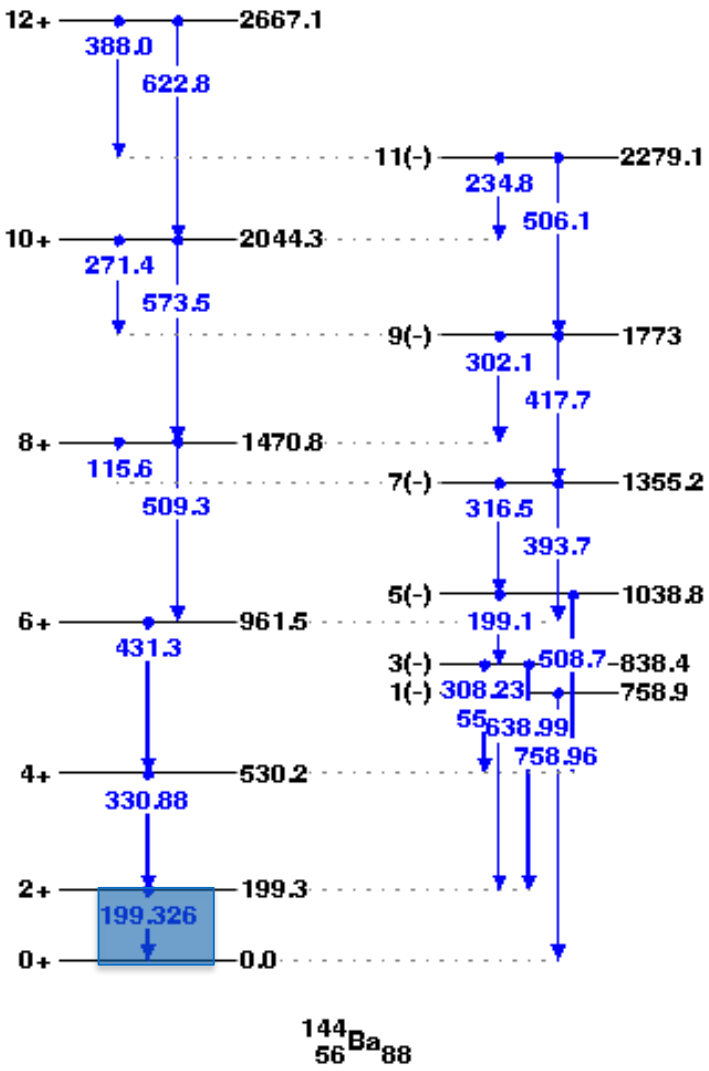
^{144}Ba on ^{208}Pb

2017 data

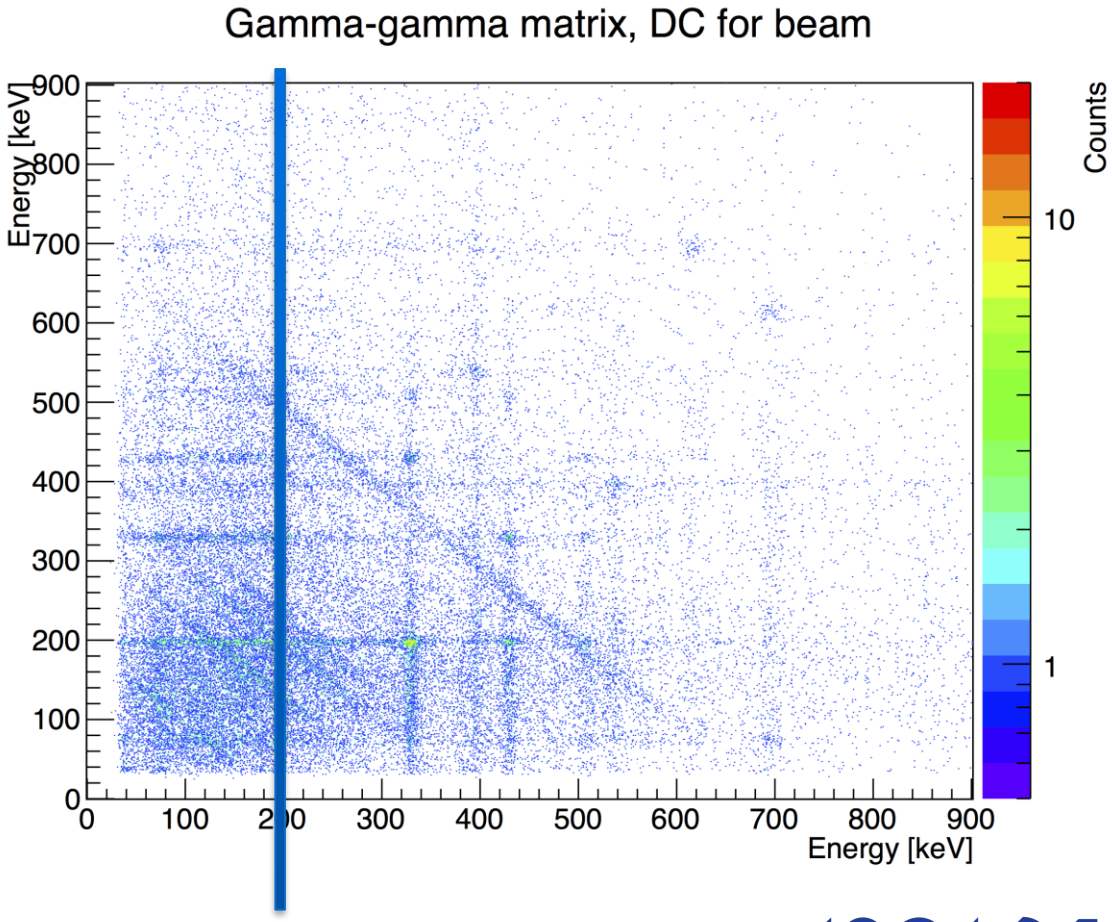
- ~50% of the total statistics shown.
- Doppler correction/gating/background subtraction to be improved



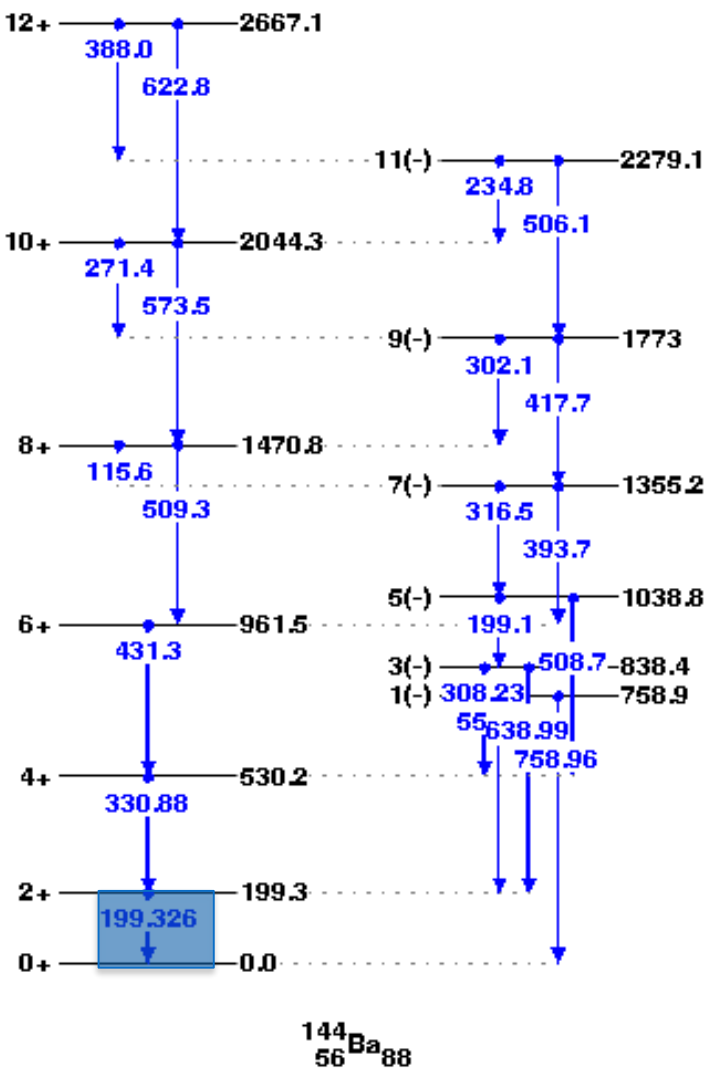
γγ matrix: ^{144}Ba on ^{208}Pb



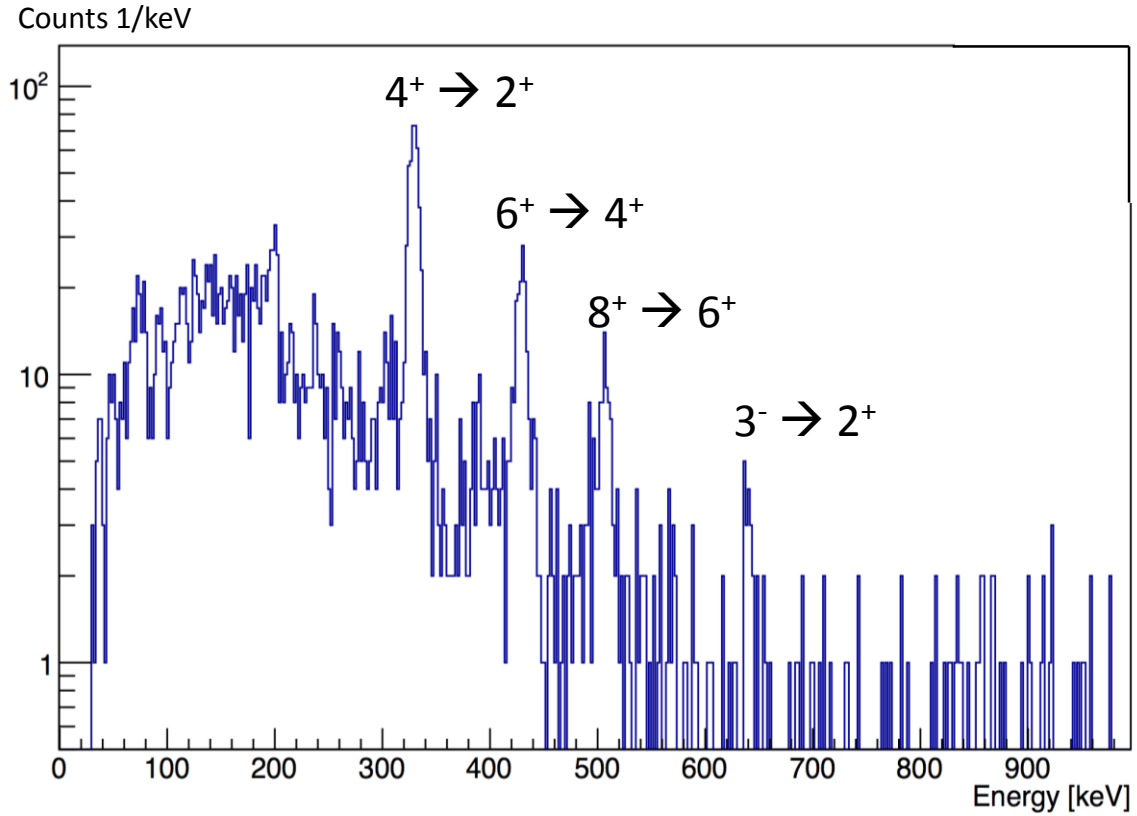
- Particle-gamma-gamma spectrum.
- Doppler-corrected for ^{144}Ba (to be improved)



γγ matrix: ^{144}Ba on ^{208}Pb

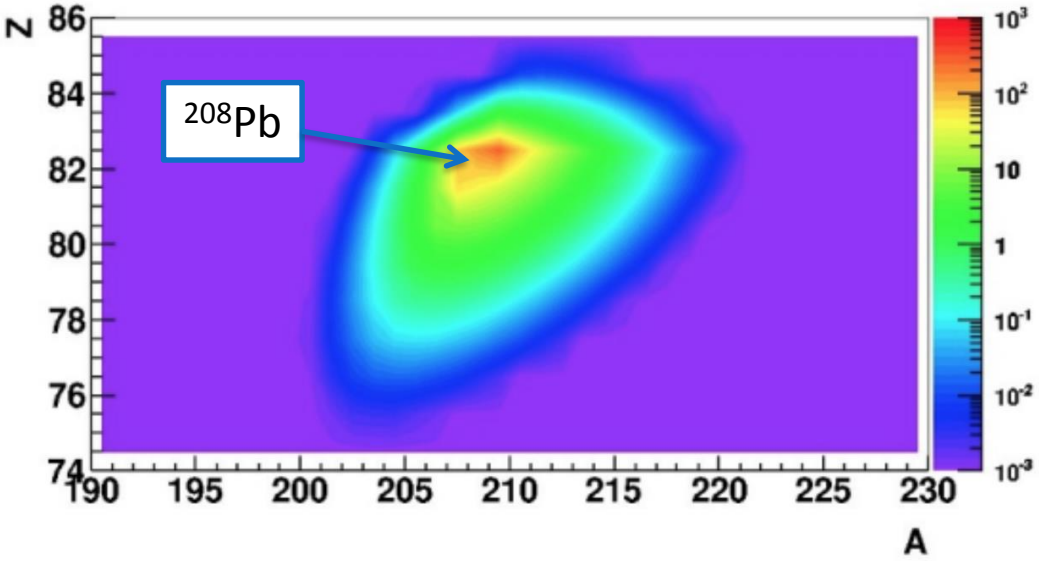


- Particle-gamma-gamma spectrum.
- Doppler-corrected for ^{144}Ba (to be improved)
- 17 counts in $3^- \rightarrow 2^+$ peak.

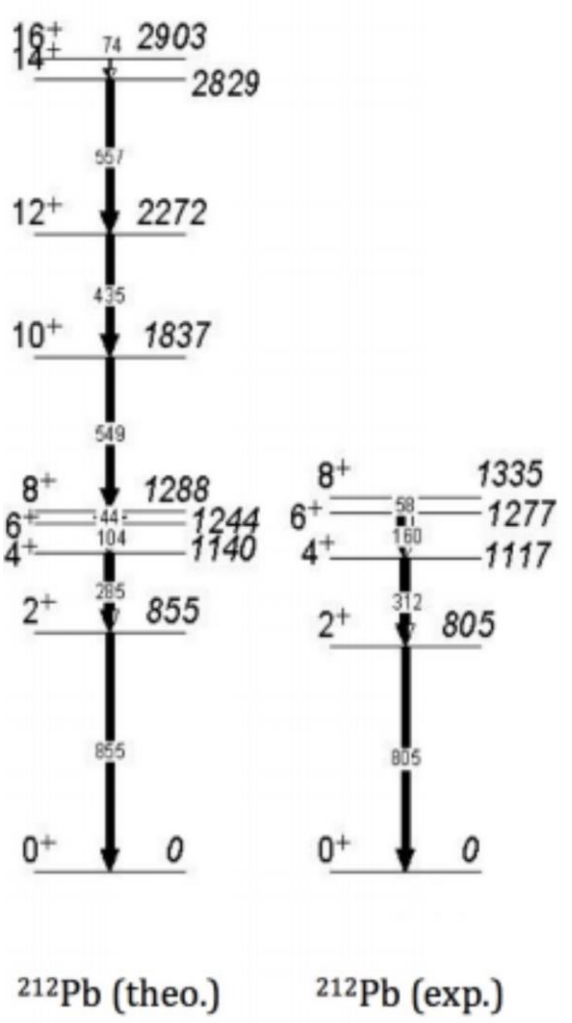


Multi-nucleon transfer – IS572

- Neutron-rich ^{94}Rb beam above Coulomb barrier.
- Populate nuclei south-east of ^{208}Pb.

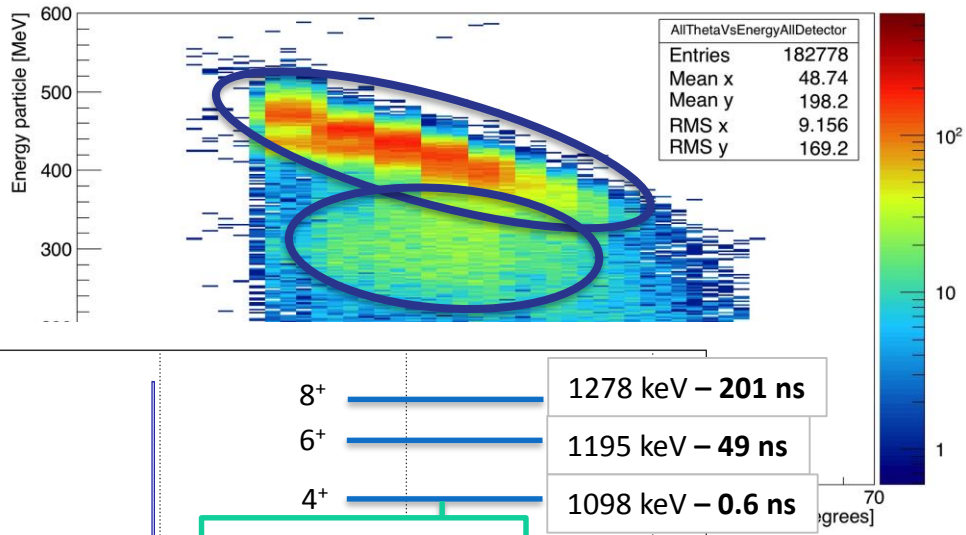


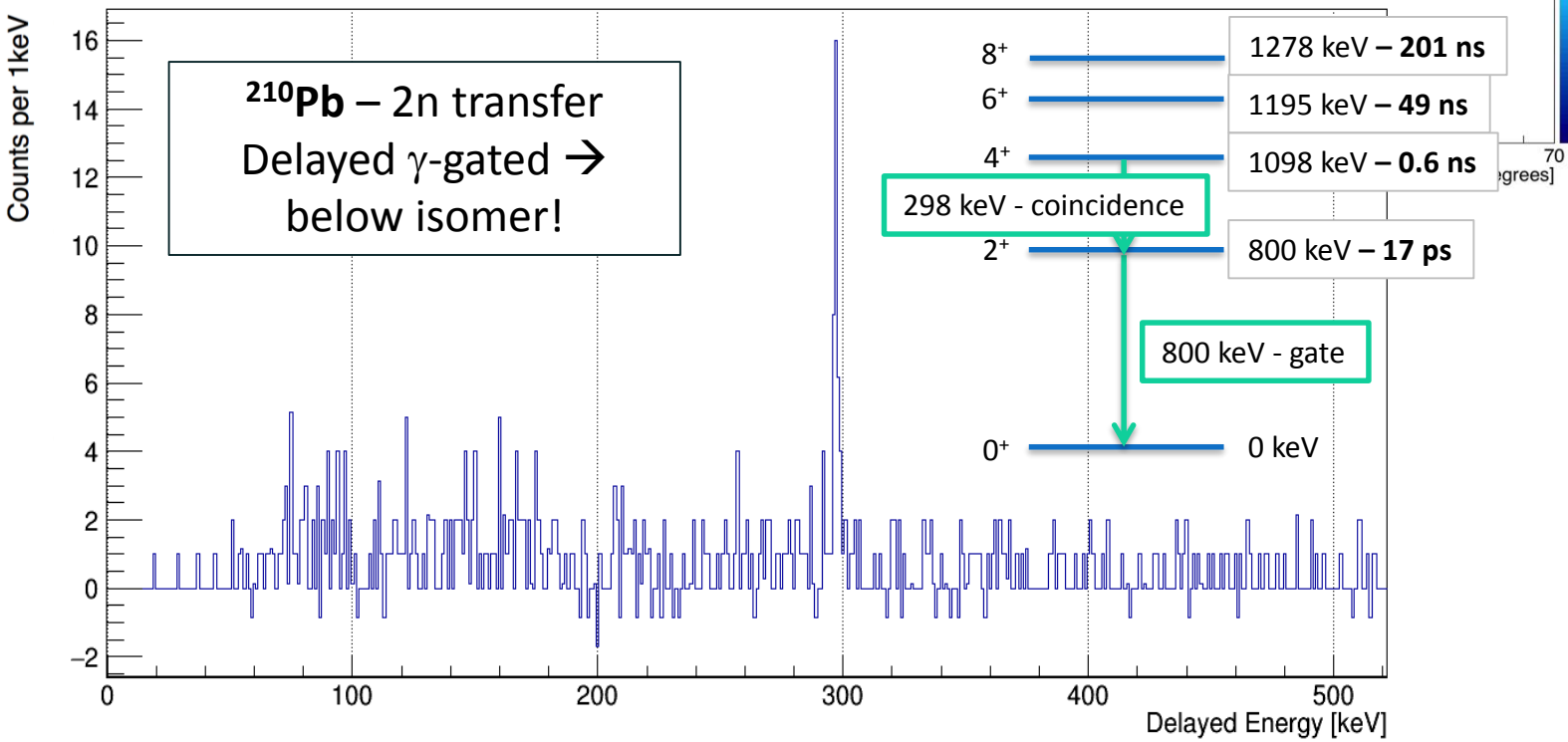
- Technical challenges of high-rates:
  - Slow extraction of EBIS → 1.6 ms.
  - Trigger selection of Miniball implemented.



Preliminary γ-ray spectra

- Particle-gated
- Prompt coincidence
- Doppler-corrected
- Background-subtracted





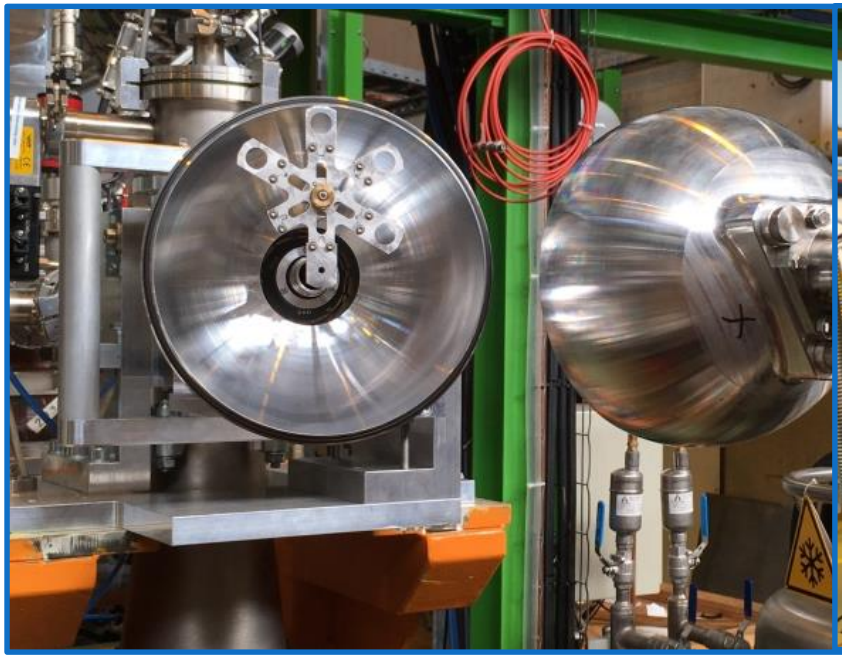
Few hours of data

Thanks to Jose Javier Valiente-Dobon, Susana Sziler, Petra Colovic, Andrés Illana Sison.

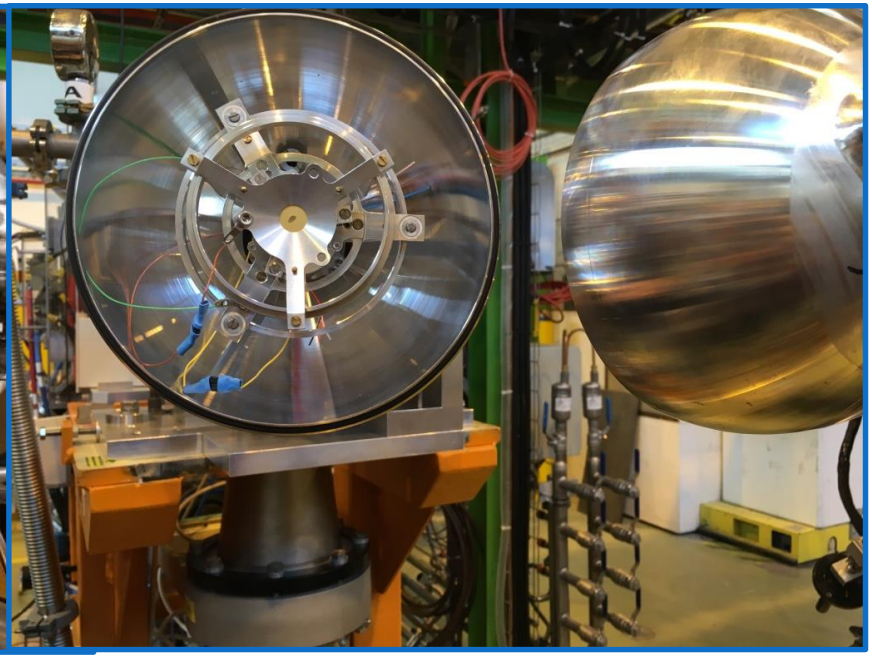
New developments: Plunger

- New plunger chamber installed for 2017.
- Developed at IKP Köln.
- Excited-state lifetime measurements, g-factors, etc.

Coulex target wheel



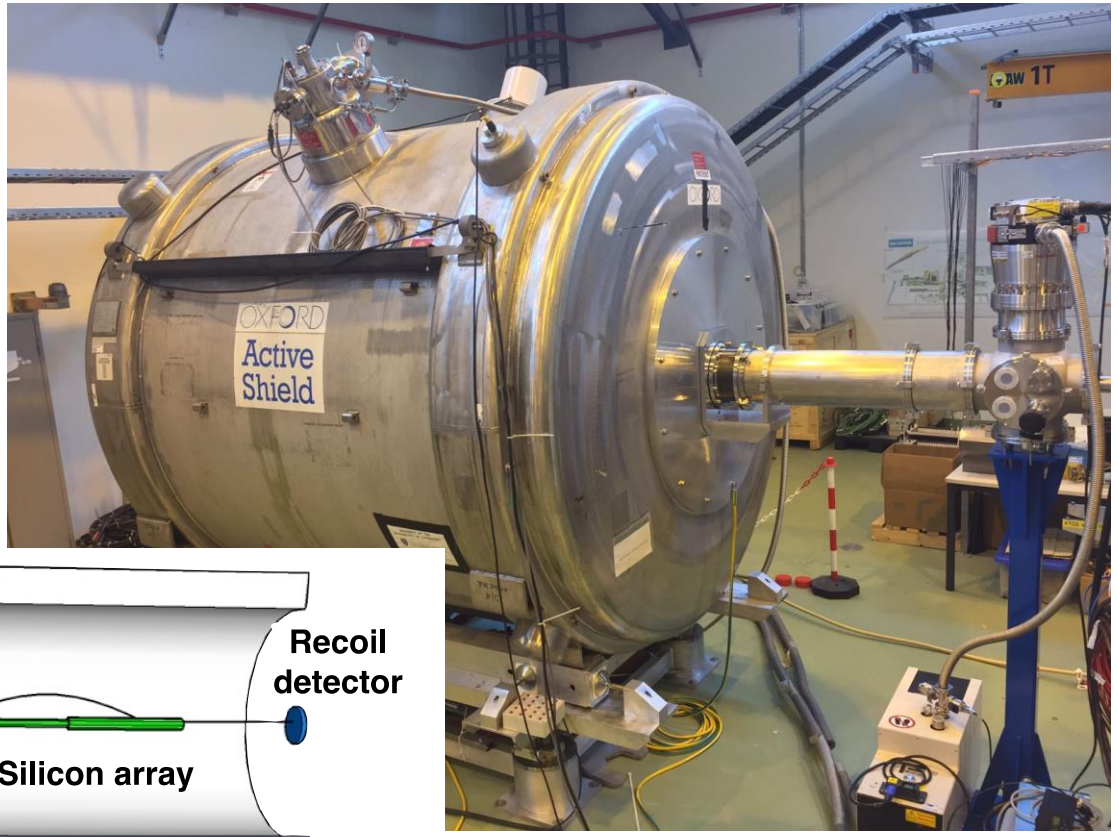
Plunger

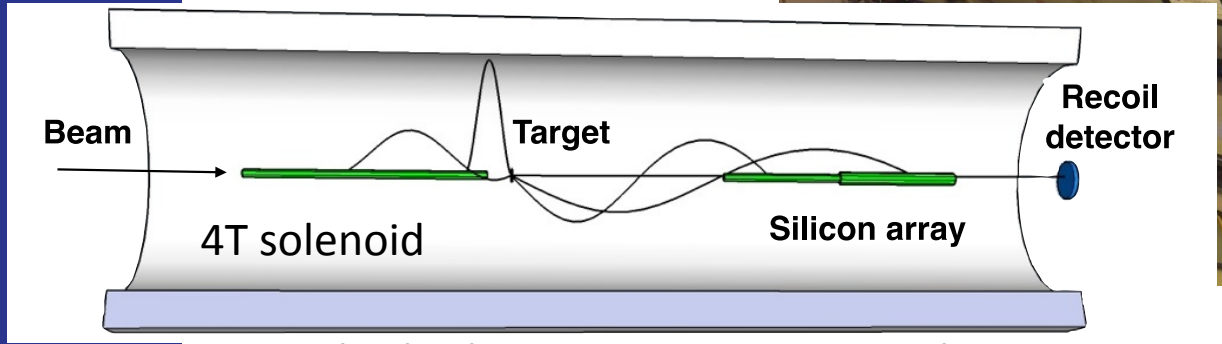


ISOLDE Solenoidal Spectrometer

- Cold and tested up to 2.75 T.
- Connected to beam line and bore holds vacuum.
- Stable beam next month
- **RIB in 2018!!**
  - ^{206}Hg(*d*,*p*)
  - ^{28}Mg(*d*,*p*)

ISOLDE Solenoidal Spectrometer



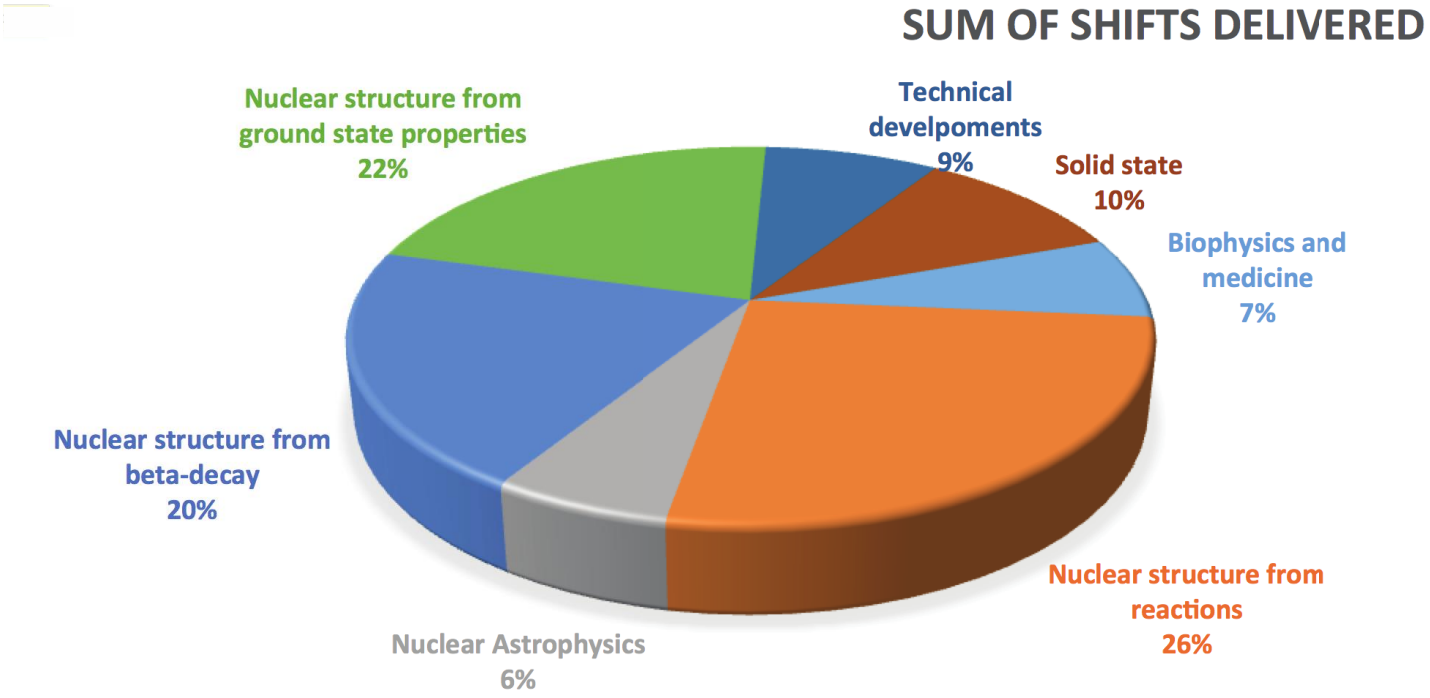


Helical orbit spectrometer principle

Conclusions

The HIE-ISOLDE facility

- HIE-ISOLDE is operating as a reliable and exciting new facility.
  - Three beam lines are now in use, Miniball, ISS and SEC.
- Last year (2016) saw 6 RIB experiments, 5 of them at Miniball
- This year (2017) we've seen a full campaign of 12 RIB experiments.



Thank you – Merci