

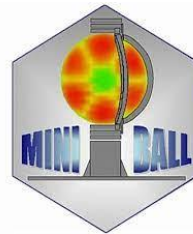
# Commissioning of Miniball@HIE-ISOLDE

## First results from Coulomb excitation for $^{130}\text{Sn}$

**Maximilian Droste**, Institute for Nuclear Physics, University of Cologne

Supported by BMBF Projects 05P18PKC11, 05P21PKC11

This project has received funding from the European Union's Horizon Research and Innovation programme under Grant Agreement No. 101057511



Bundesministerium  
für Bildung  
und Forschung



# New Miniball cryostats\*

## General structure:

- Eight triple cryostats
- Six-fold segmented HPGe crystals
- 168 high-resolution channels

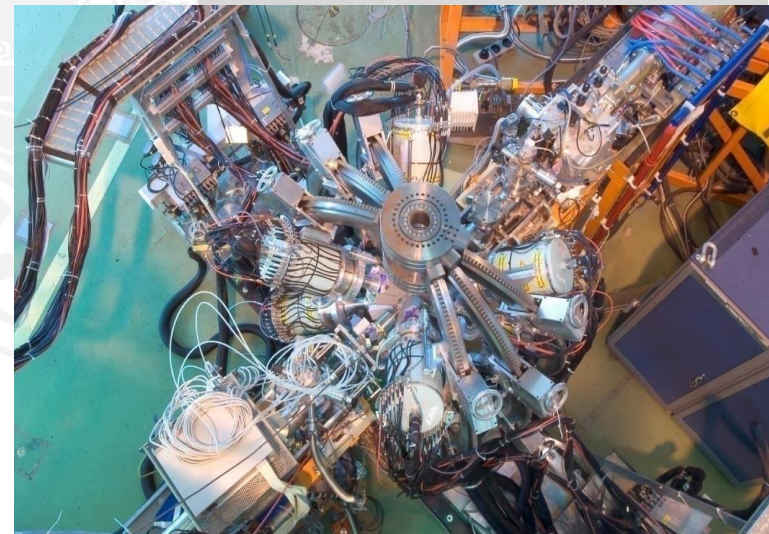
## After 20 years operation time

- Electronics out dated
- Mechanical problems

## Solution:

- Renewal of complete cryostat and capsule
- New analog electronics based on AGATA preamplifier

\*in cooperation with CTT, Montabaur



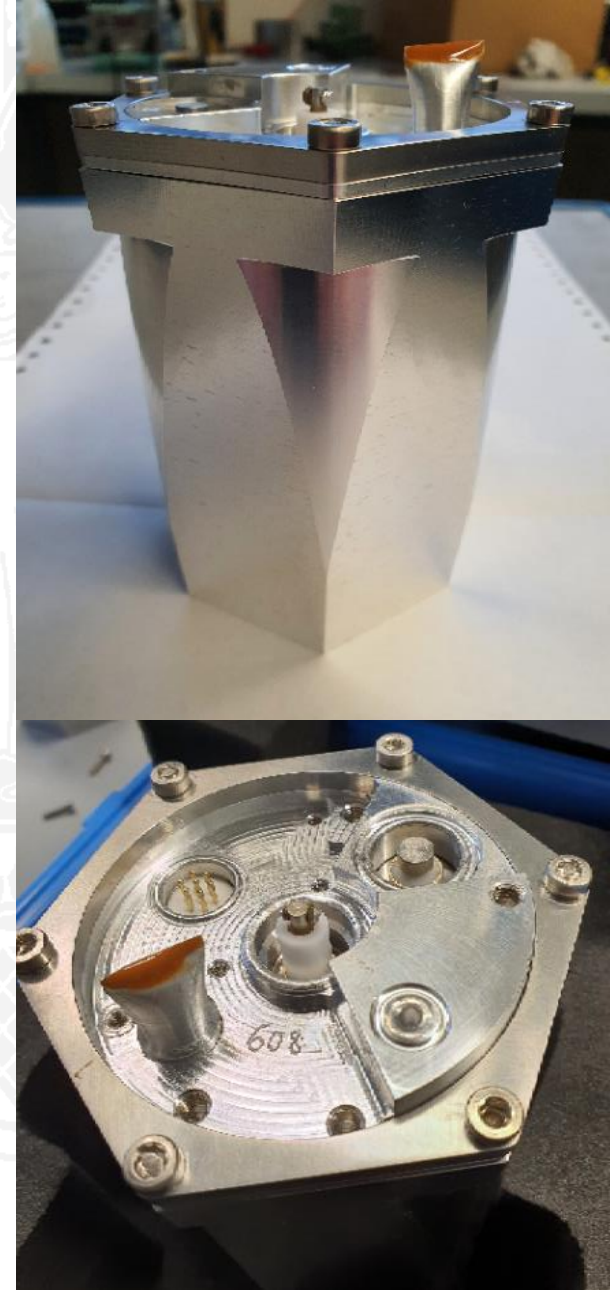
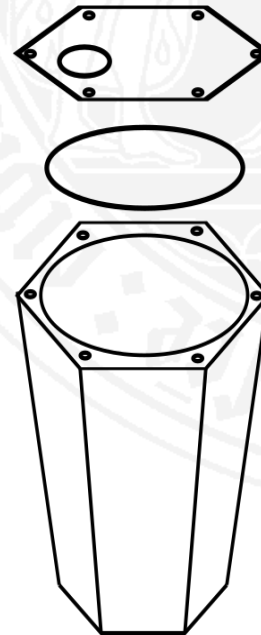
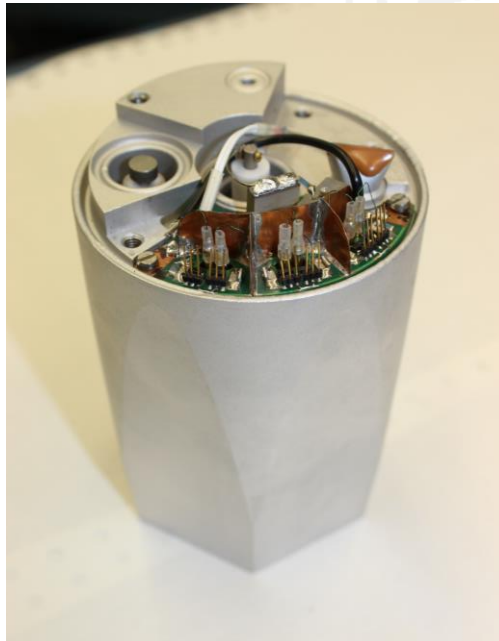
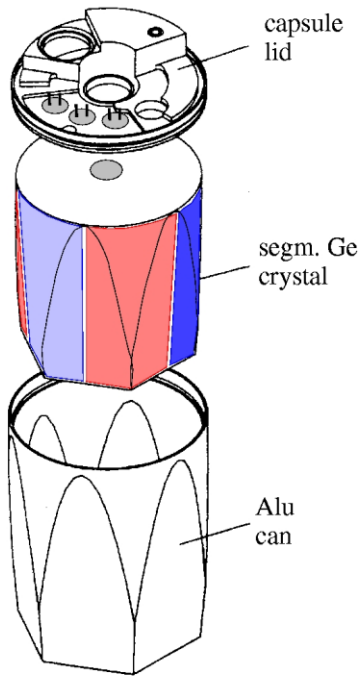
# New encapsulation

Old:

- Welded design
- Elaborate and expensive repairs

New:

- Lid fixed by screws
- Metal-elastic seal
- Highly temperature resistant
- UH vacuum
- Fast and cost effective repairs





# New cryostat design

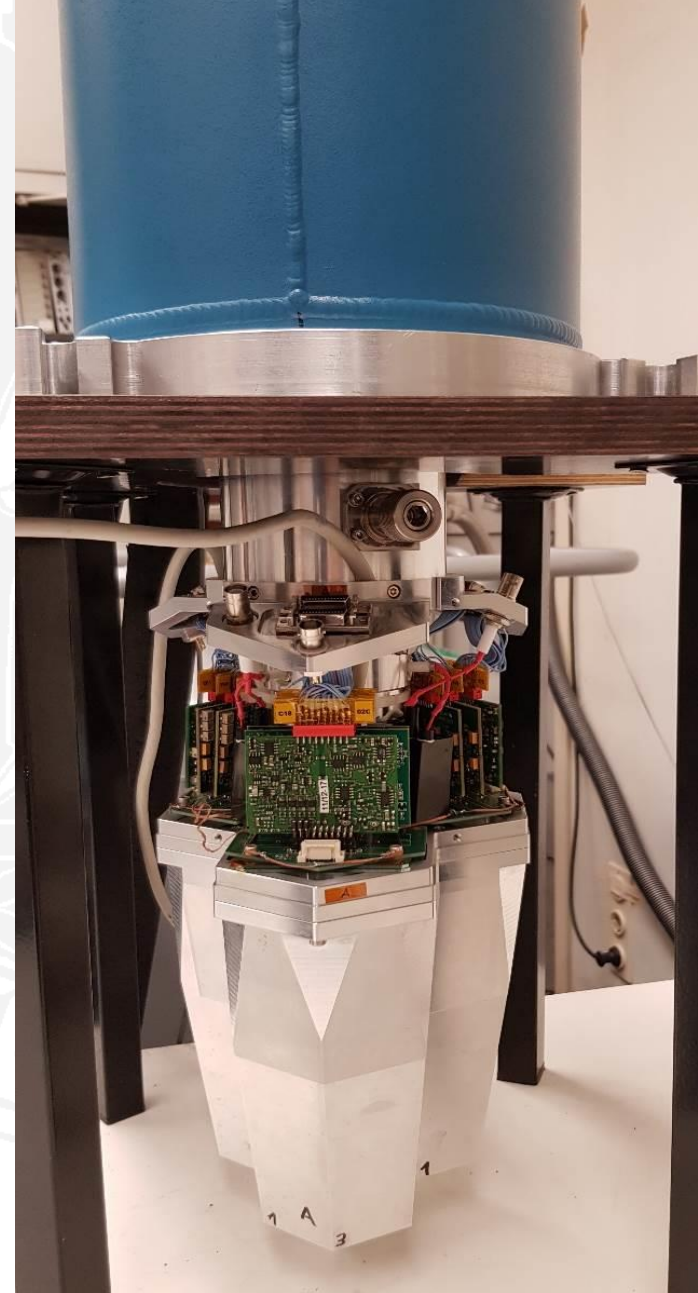
Old:

- Long neck for BGO backscattering
- Movable lid



New:

- No neck for BGO
- No moving parts
- Adjustment ring integrated into cryostat design



# New analog preamplifier electronics

Old:

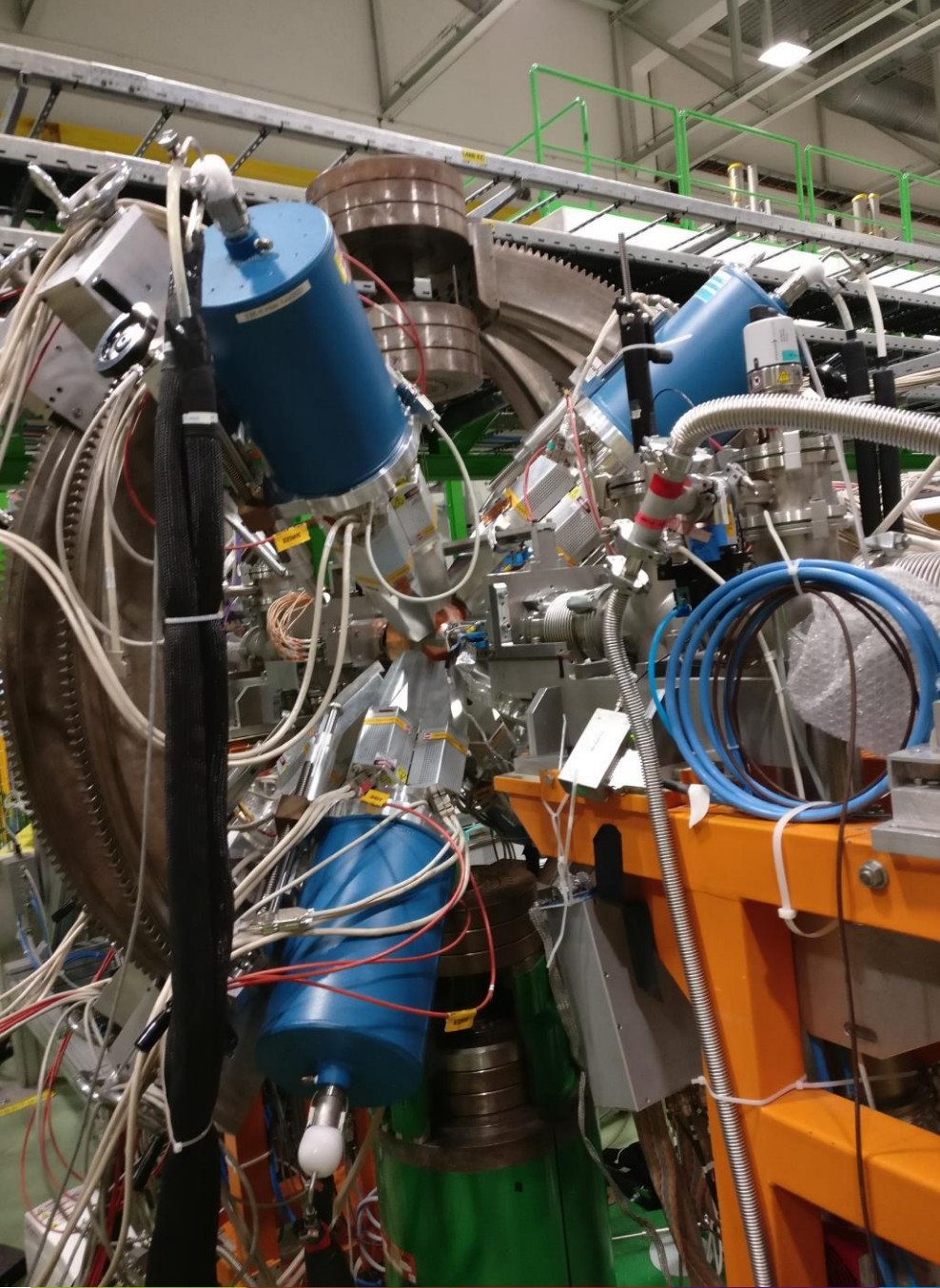
- Electronics soldered in place
- Glued feedthroughs
- Preamplifier board for every channel

New:

- Plug-in electronic parts
- Welded feedthroughs
- AGATA preamplifier
- Three preamplifier boards: One core, two segments



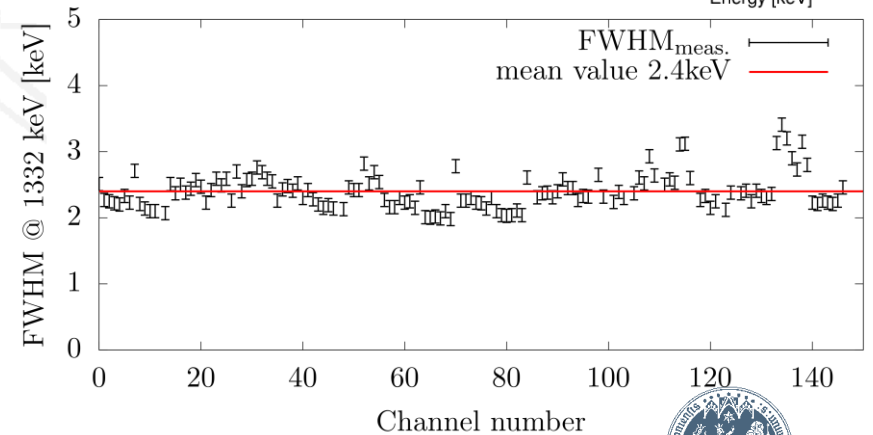
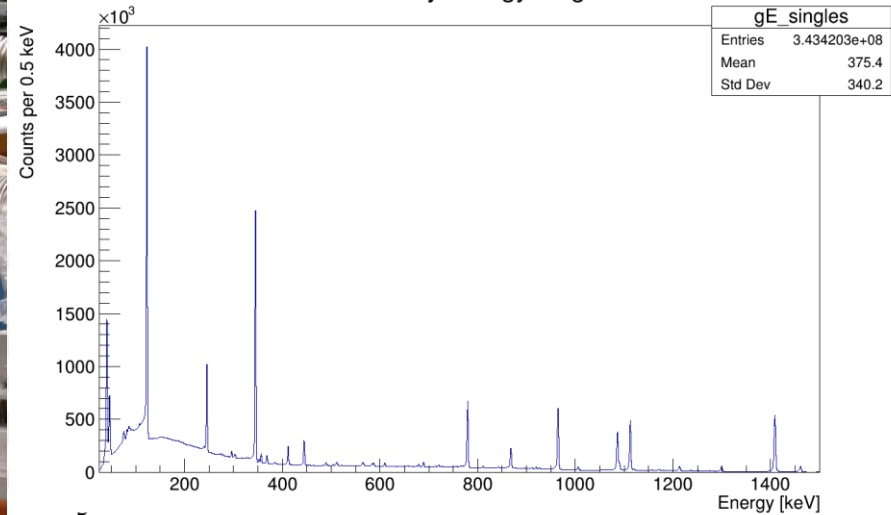




# Commissioning

- Seven new triple cryostats approved, mounted and operational
- 8<sup>th</sup> crystal will be transferred in June!

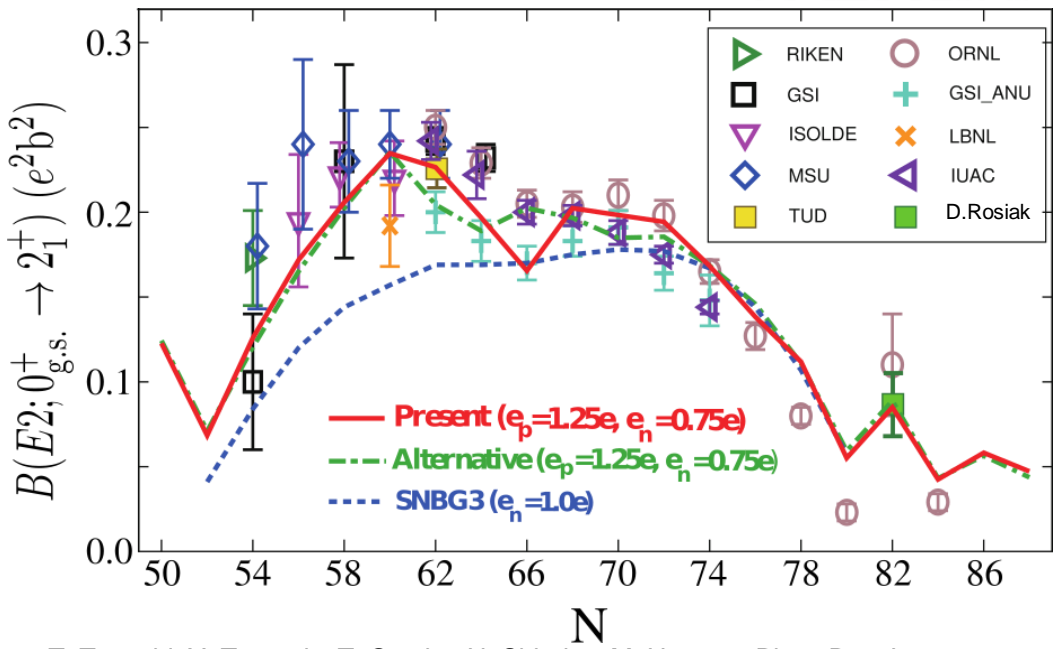
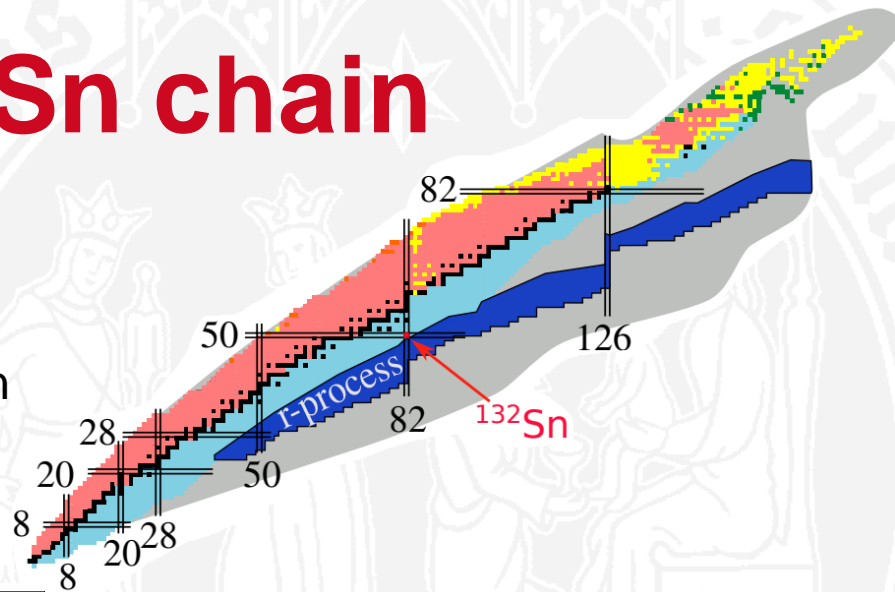
Gamma-ray energy singles



# B(E2) values along Sn chain

$^{132}\text{Sn}$  region of interest for r-process

MCSM calculations able to describe whole Sn isotope chain using one Hamiltonian



Theoretical value  $^{130}\text{Sn}$ :  
 $B(E2; 0^+ \rightarrow 2^+)_{\text{theo.}} = 0.055 e^2b^2$

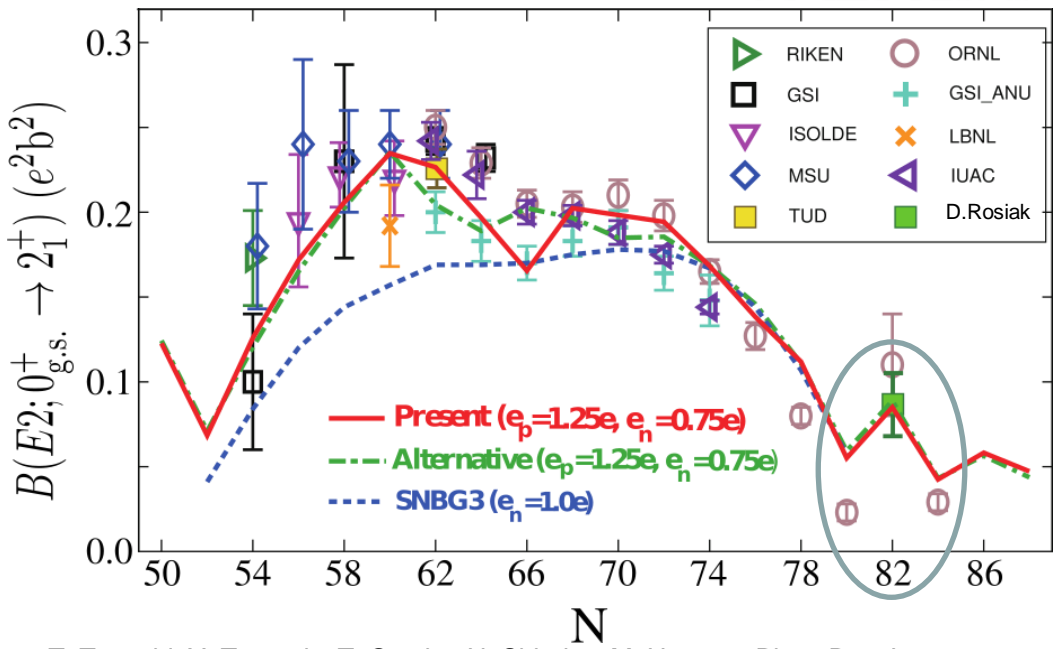
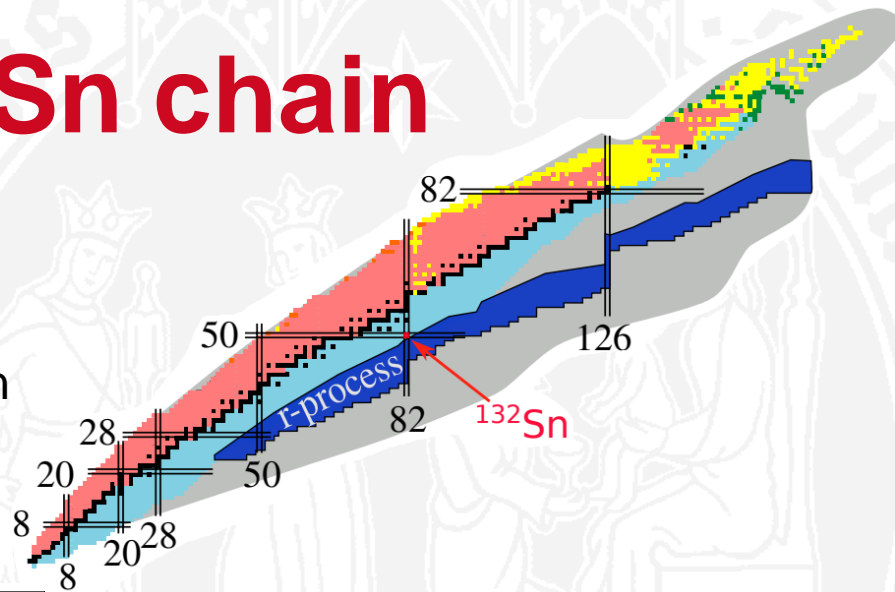
T. Togashi; Y. Tsunoda; T. Otsuka; N. Shimizu; M. Honma; Phys. Rev. Lett. 121, 062501 (2018)  
 $^{132}\text{Sn}$  value by D. Rosiak, et. al.; Phys. Rev. Lett. 121, 252501 (2018)



# B(E2) values along Sn chain

<sup>132</sup>Sn region of interest for r-process

MCSM calculations able to describe whole Sn isotope chain using one Hamiltonian?



52	Te 130	Te 131	Te 132	Te 133	Te 134	Te 135	Te 136
	Sb 129	Sb 130	Sb 131	Sb 132	Sb 133	Sb 134	Sb 135
50	Sn 128	Sn 129	Sn 130	Sn 131	Sn 132	Sn 133	Sn 134
	In 127	In 128	In 129	In 130	In 131	In 132	In 133
48	Cd 126	Cd 127	Cd 128	Cd 129	Cd 130	Cd 131	Cd 132
	78	80	82	84			

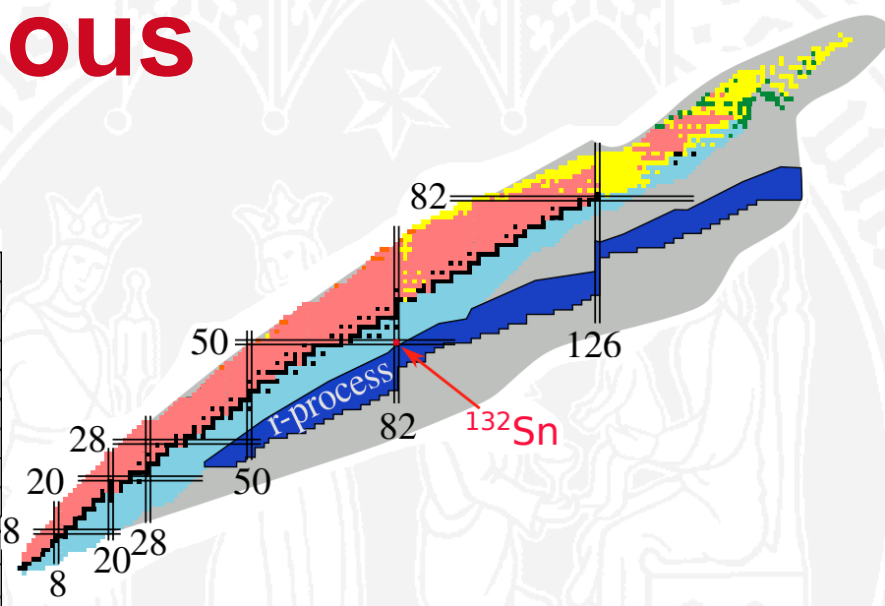
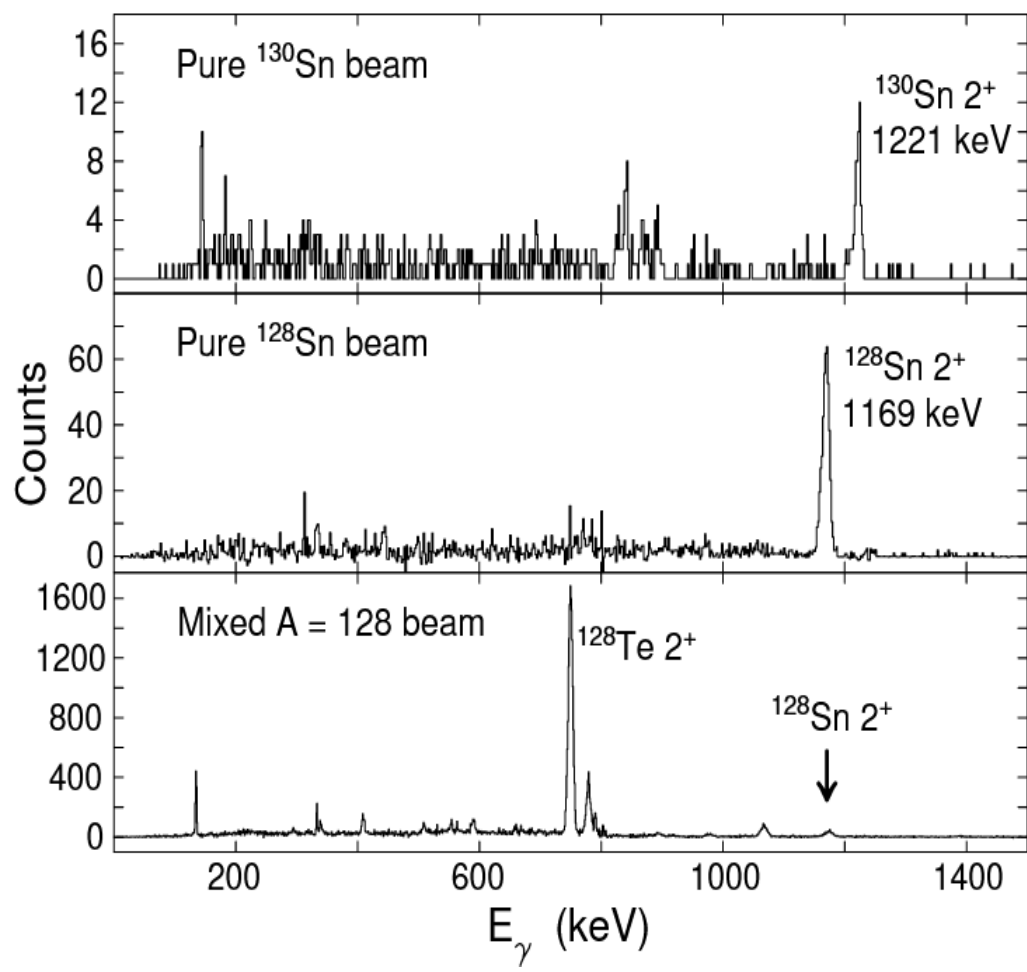
Theoretical value <sup>130</sup>Sn:  
 $B(E2; 0^+ \rightarrow 2^+)_{\text{theo.}} = 0.055 e^2b^2$

T. Togashi; Y. Tsunoda; T. Otsuka; N. Shimizu; M. Honma; Phys. Rev. Lett. 121, 062501 (2018)  
<sup>132</sup>Sn value by D. Rosiak, et. al.; Phys. Rev. Lett. 121, 252501 (2018)





# <sup>130</sup>Sn Coulex – previous experiment



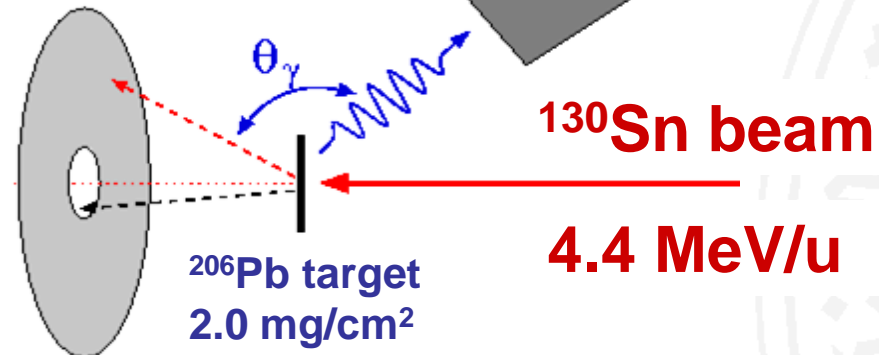
52	Te 130	Te 131	Te 132	Te 133	Te 134	Te 135	Te 136
	Sb 129	Sb 130	Sb 131	Sb 132	Sb 133	Sb 134	Sb 135
50	Sn 128	Sn 129	Sn 130	Sn 131	Sn 132	Sn 133	Sn 134
	In 127	In 128	In 129	In 130	In 131	In 132	In 133
48	Cd 126	Cd 127	Cd 128	Cd 129	Cd 130	Cd 131	Cd 132
	78	80	82	84			

Preliminary value <sup>130</sup>Sn:  
 $B(E2; 0^+ \rightarrow 2^+)_{\text{ORNL}} = 0.023(5) e^2 b^2$

D.C. Radford, *et al.* Nucl. Phys. A 752 (2005) 264c272c.



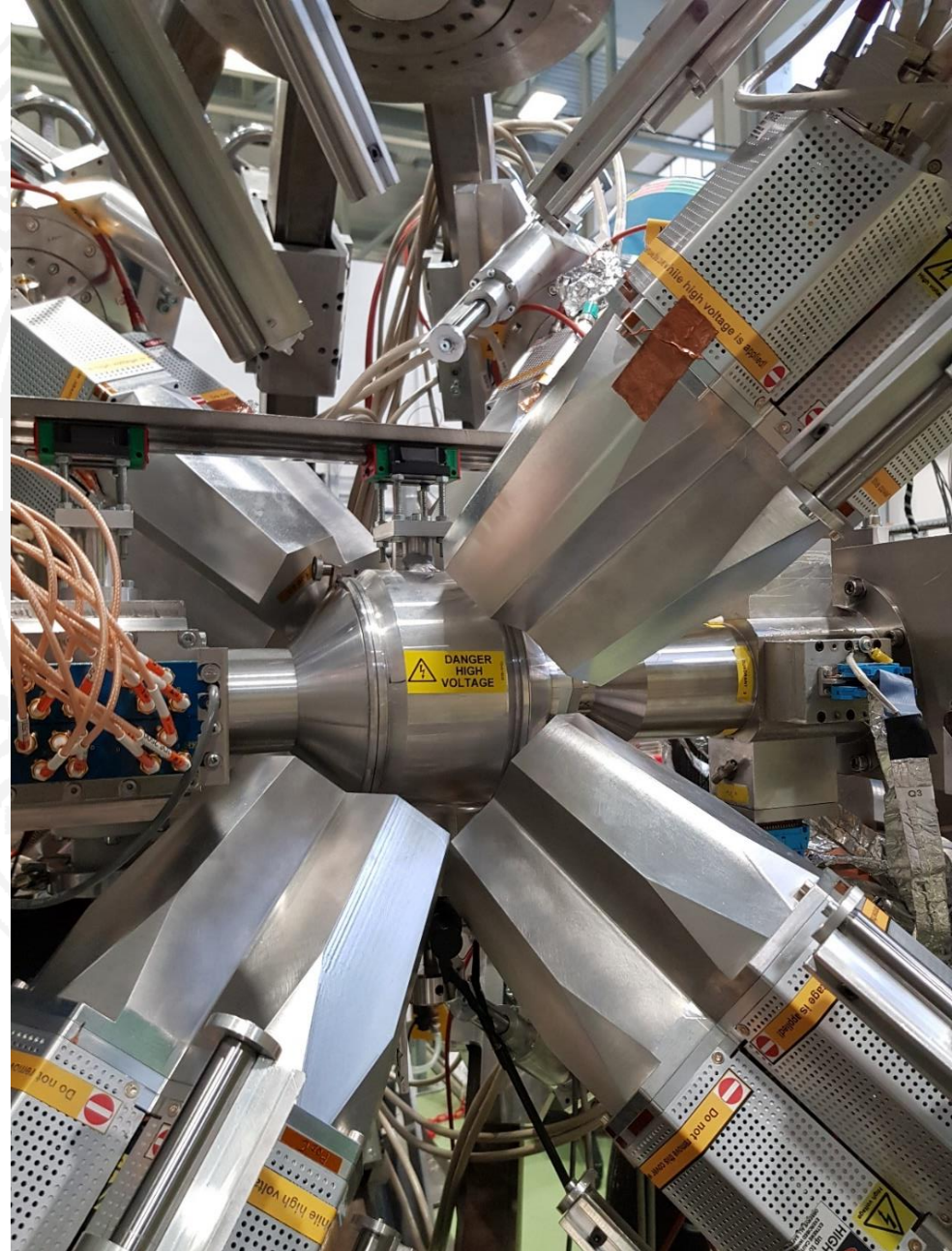
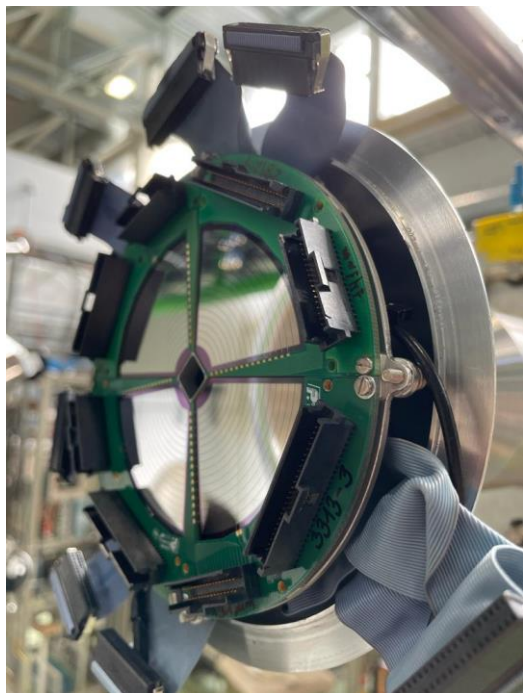
DSSSD



$^{130}\text{Sn}$  beam

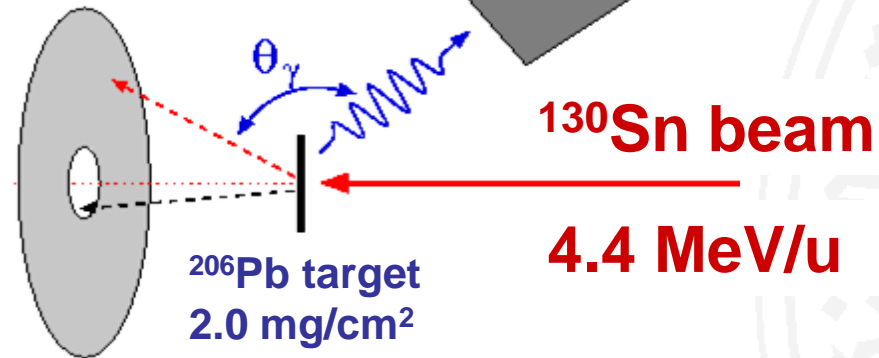
4.4 MeV/u

$^{206}\text{Pb}$  target  
2.0 mg/cm<sup>2</sup>





DSSSD

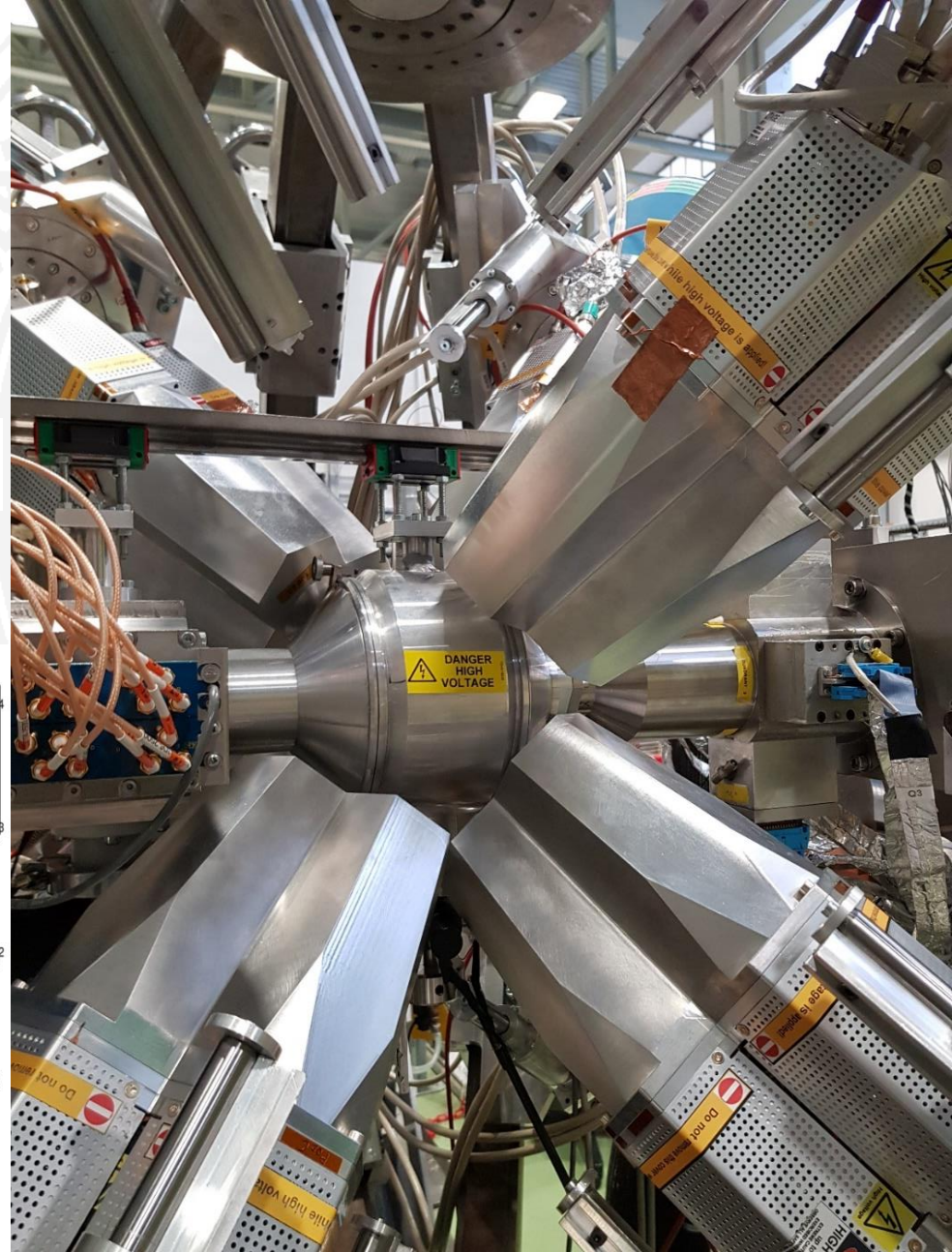
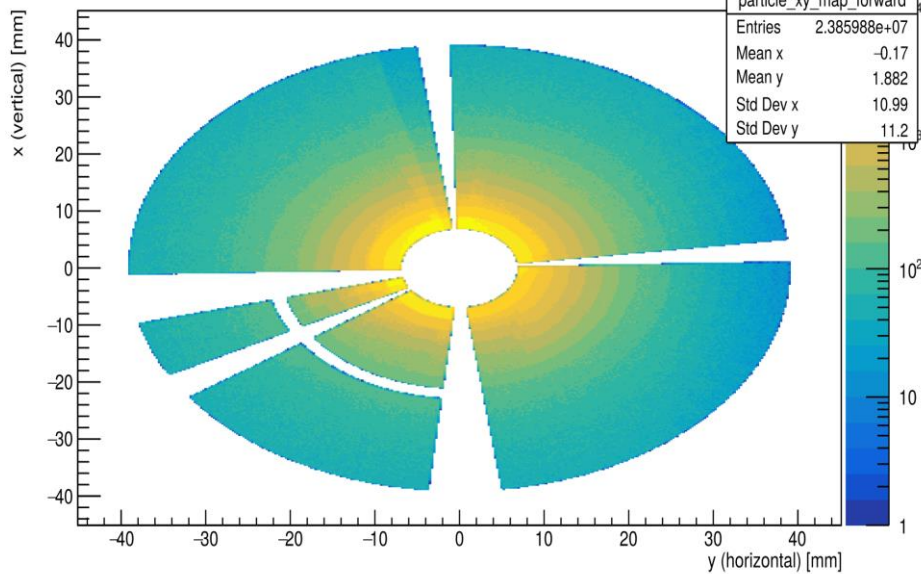


$^{130}\text{Sn}$  beam

4.4 MeV/u

$^{206}\text{Pb}$  target  
2.0 mg/cm<sup>2</sup>

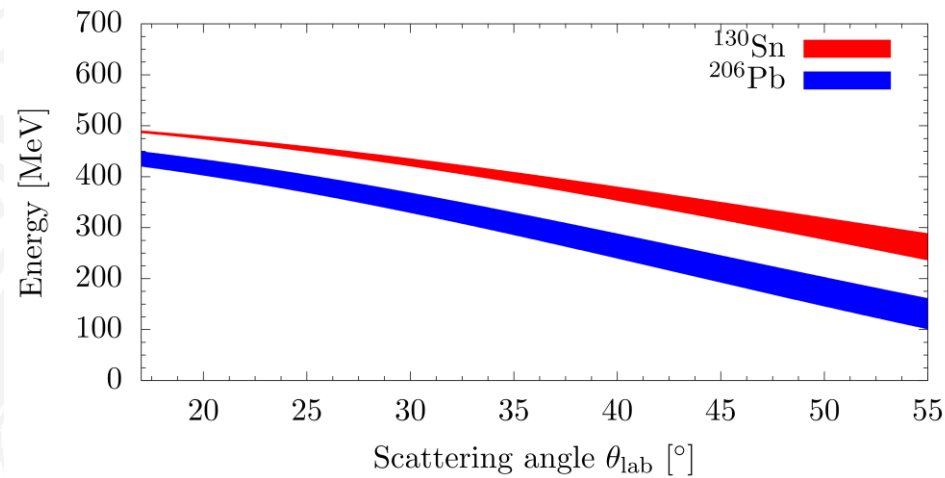
Particle X-Y hit map ( $\theta < 90^\circ$ )



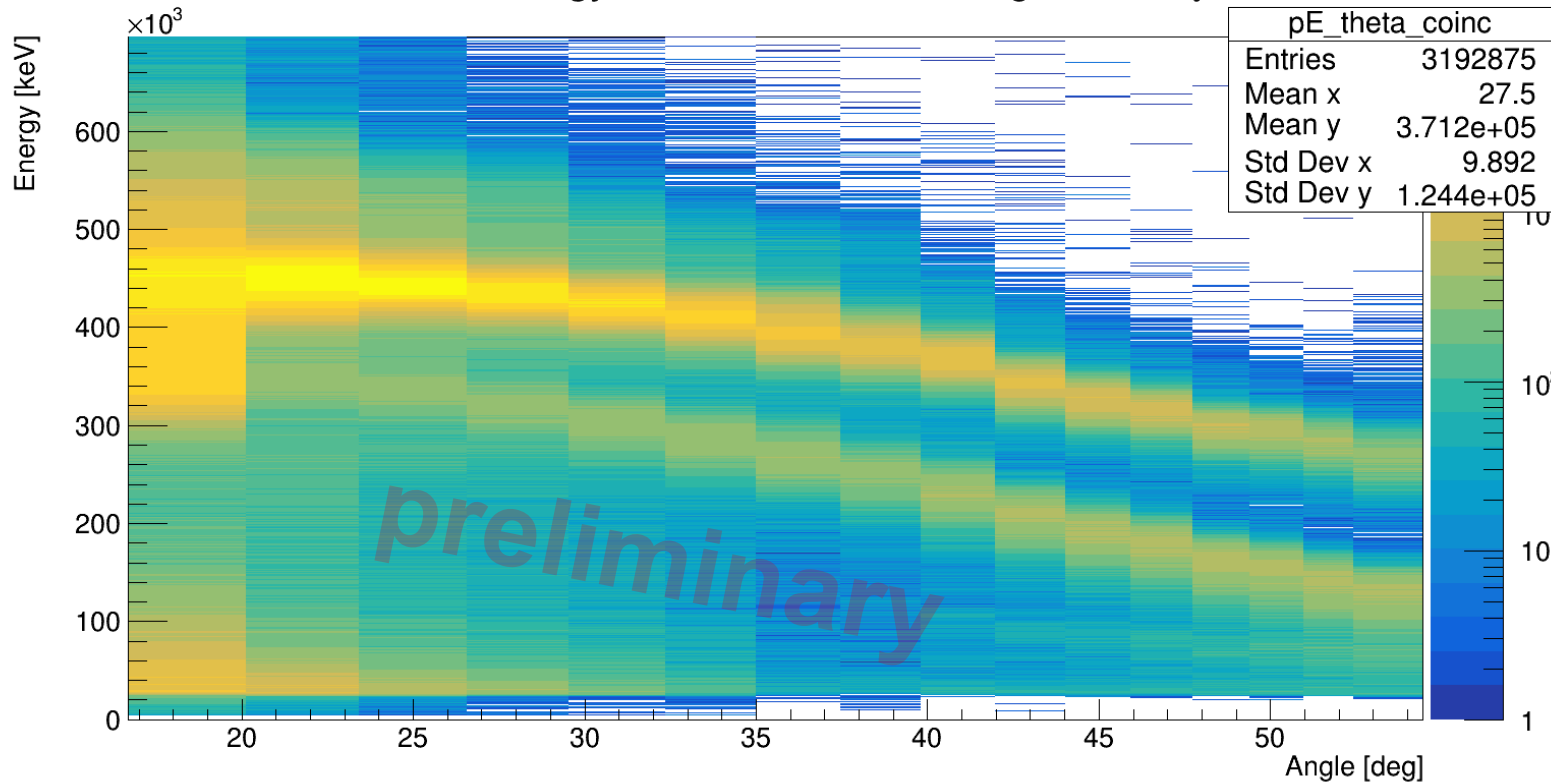


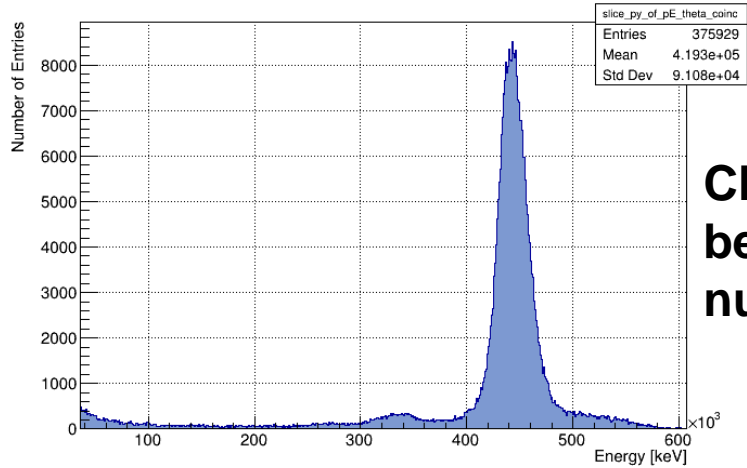
# Kinematics

- $^{130}\text{Sn}$  beam, 4.4 MeV/u  
( $^{130}\text{Sn}^{34}\text{S}^{+1}$  molecular ion)
- $^{206}\text{Pb}$  target, 2.0 mg/cm<sup>2</sup>
- 75 hours beamtime
- $5 \times 10^5$  ions per second

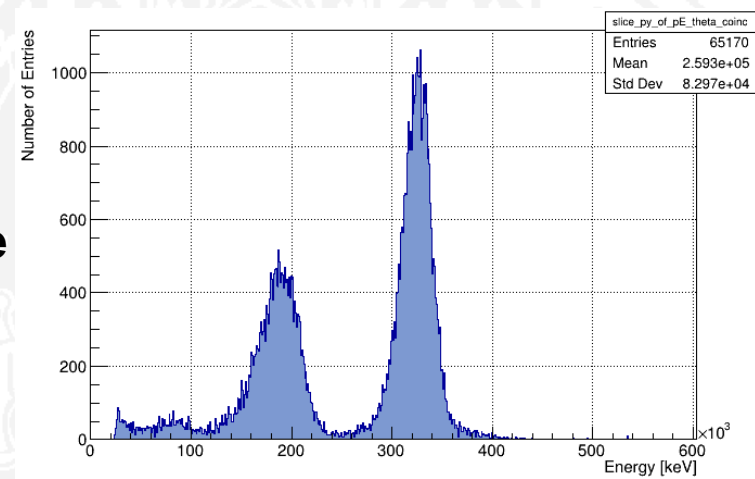


Particle energy in coincidence with a gamma ray

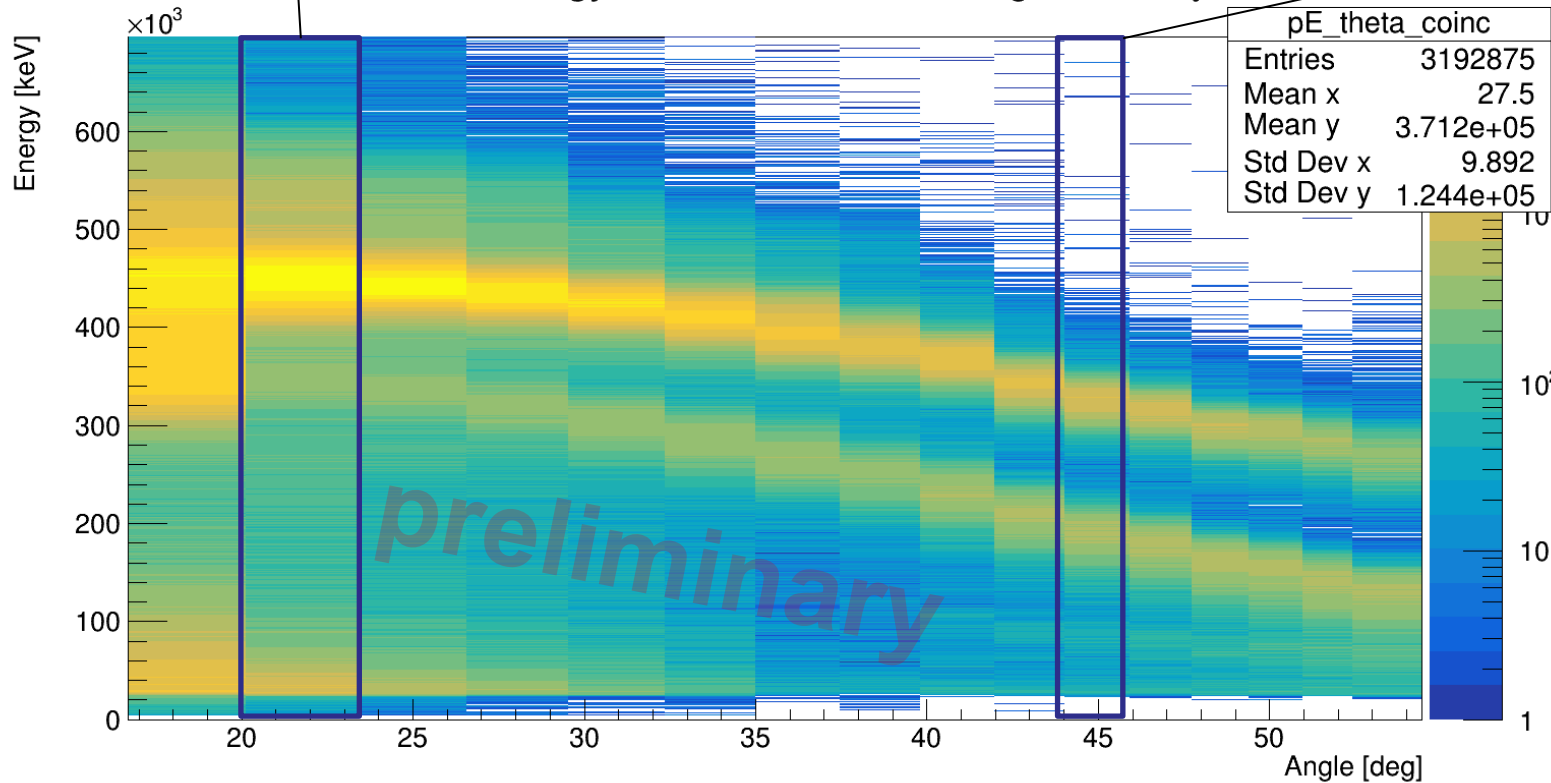




**Clear separation of beam and target like nuclei**



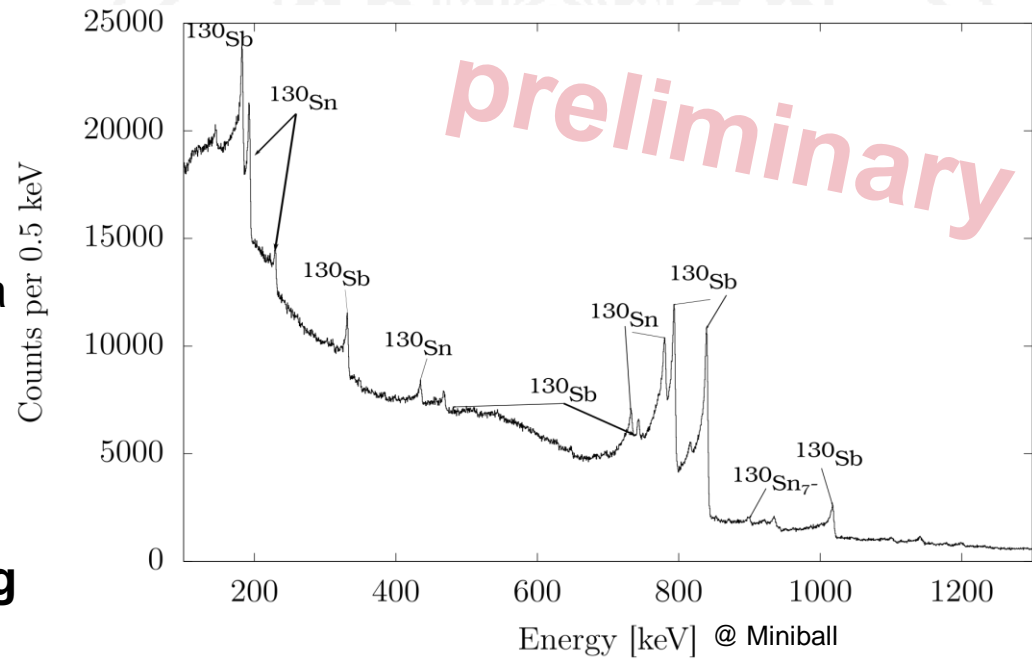
Particle energy in coincidence with a gamma ray



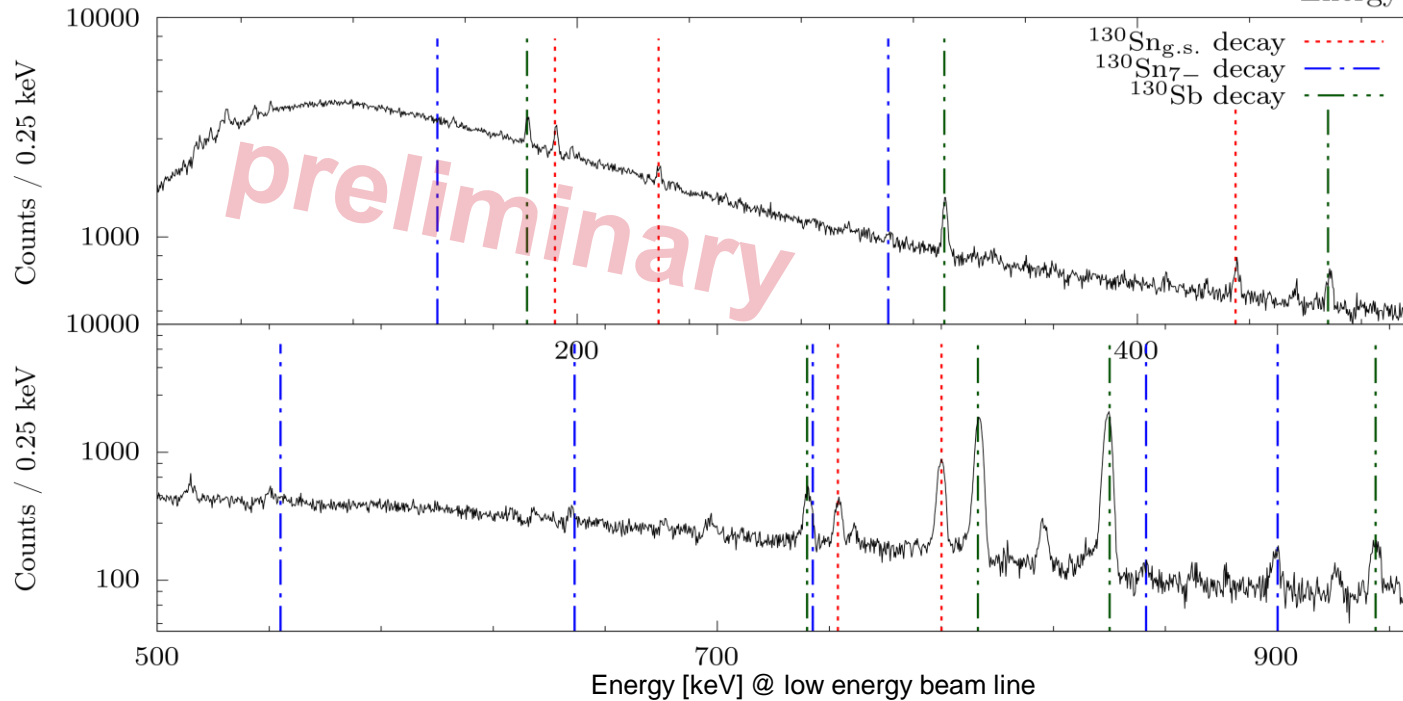
# Beam purity

## Dominating $^{130}\text{Sn}$

- No  $\gamma$ 's from A=164 isobars in spectra
- Only  $^{130}\text{Sn}$  and  $^{130}\text{Sb}$
- $^{130}\text{Sn}_{\text{g.s.}}$  ( $T_{1/2} = 3.7$  min)
- $^{130}\text{Sb}_{\text{g.s.}}$  ( $T_{1/2} = 39.5$  min)



## Beam composition analysis on going





# Preliminary results

**Total intensity:**

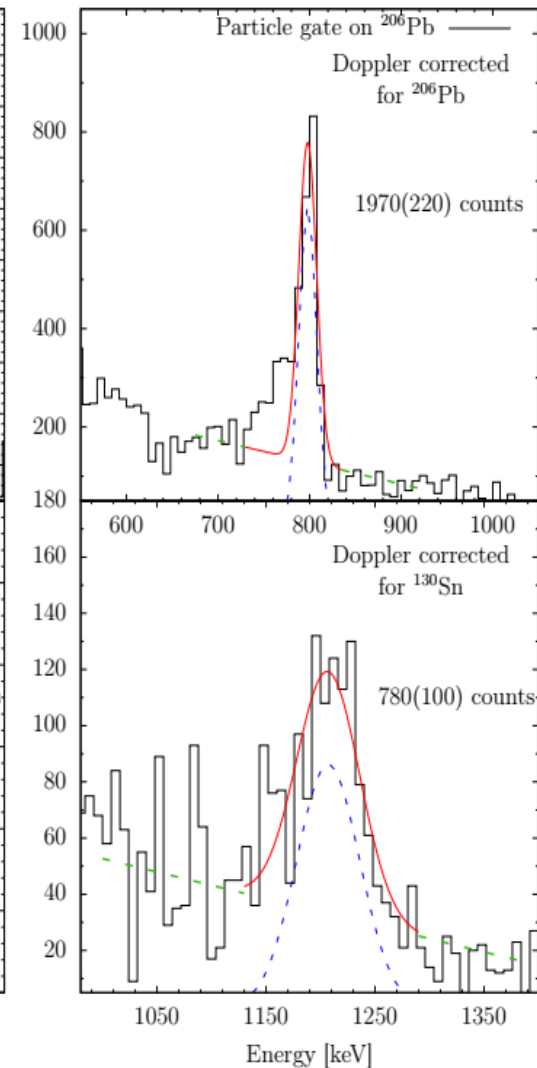
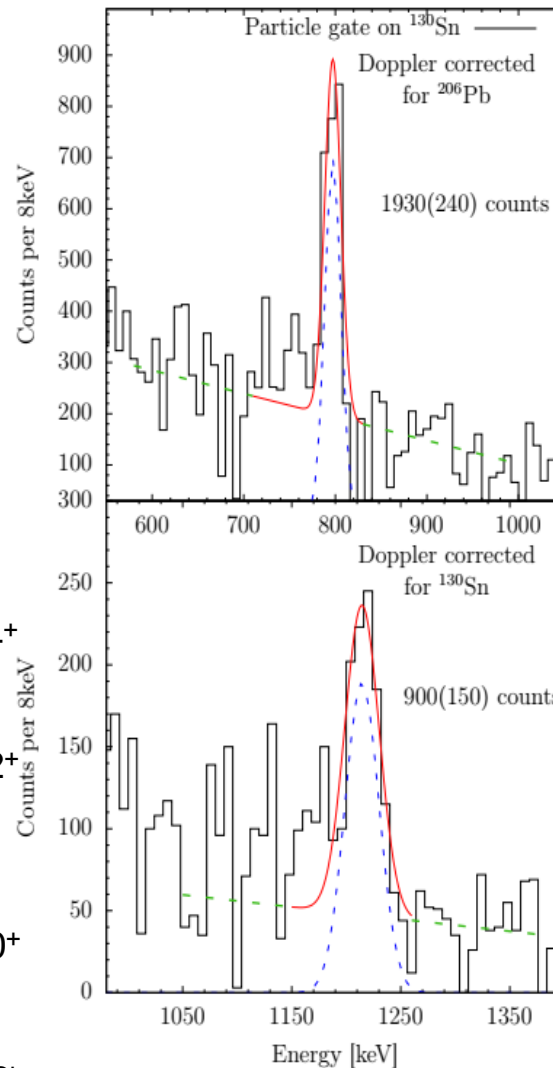
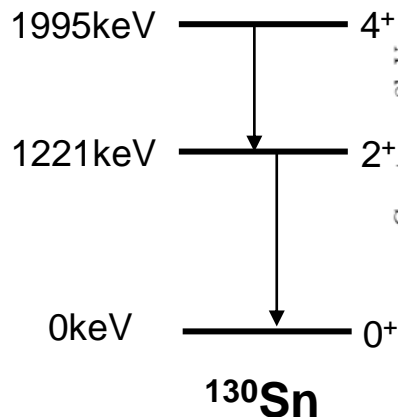
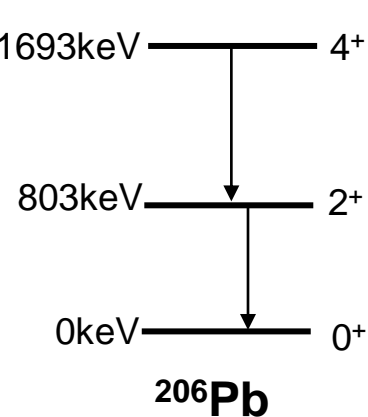
$$I_{206\text{Pb}}(2^+ \rightarrow 0^+) = 3900(350)$$

$$I_{130\text{Sn}}(2^+ \rightarrow 0^+) = 1700(200)$$

**Beam purity:**  $^{130}\text{Sn} \sim 75\%$

**Matrix element  $^{206}\text{Pb}$  for normalization:**

$$M(E2; 2^+ \rightarrow 0^+) = 0.3178(47) \text{ eb [1]}$$



[1] F. G. Kondev. "Nuclear Data Sheets for A = 206." In: Nucl. Data Sheets 109.6 (2008), pp. 1527–1654



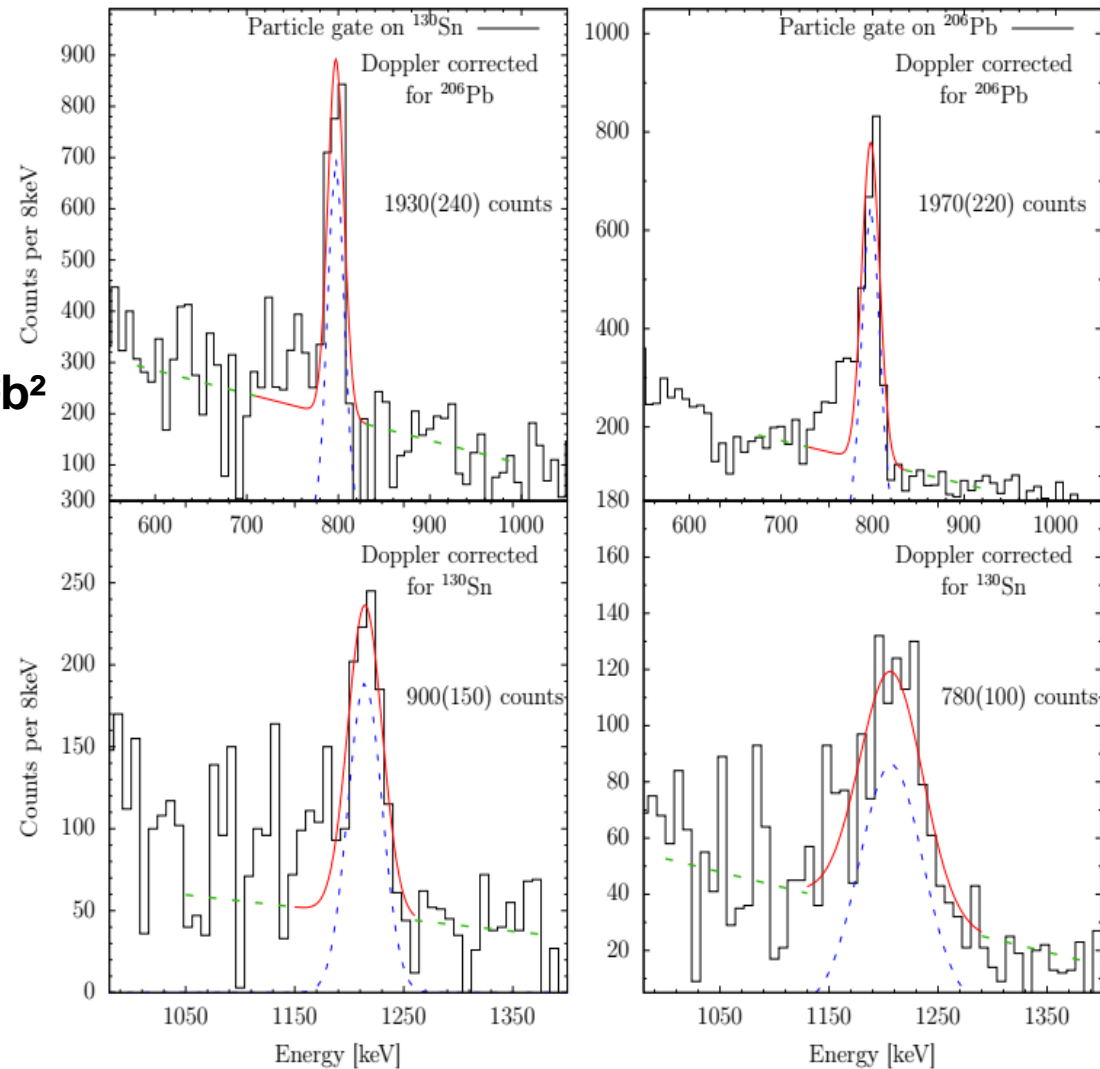
# Preliminary GOSIA2 analysis

## PRELIMINARY RESULT:

$$B(E2; 0^+ \rightarrow 2^+)_{\text{this work}} = 0.056^{+10}_{-14} \text{ stat. } e^2b^2$$

$$B(E2; 0^+ \rightarrow 2^+)_{\text{ORNL}} = 0.023(5) e^2b^2 [1]$$

$$B(E2; 0^+ \rightarrow 2^+)_{\text{theo.}} = 0.055 e^2b^2 [2]$$



[1] D.C. Radford, *et al* Nucl. Phys. A 752 (2005) 264c272c.

[2] T. Togashi; Y. Tsunoda; T. Otsuka; N. Shimizu; M. Honma; Phys. Rev. Lett. 121, 062501 (2018)

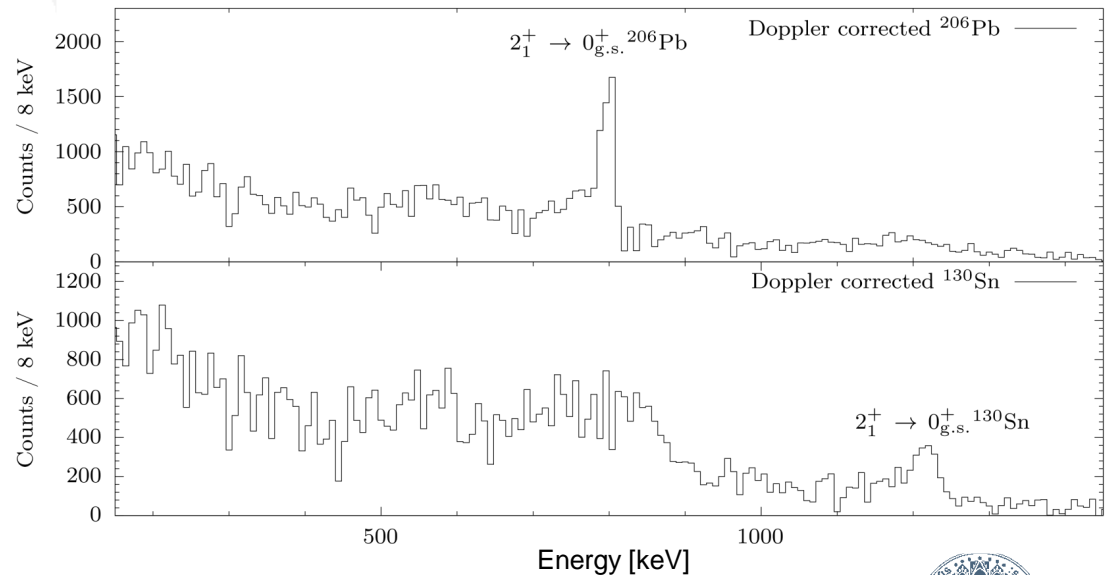


# Summary

New Miniball triple cluster detector developed in Cologne

First campaign after LS2 @HIE-ISOLDE

Preliminary results in  $^{130}\text{Sn}$





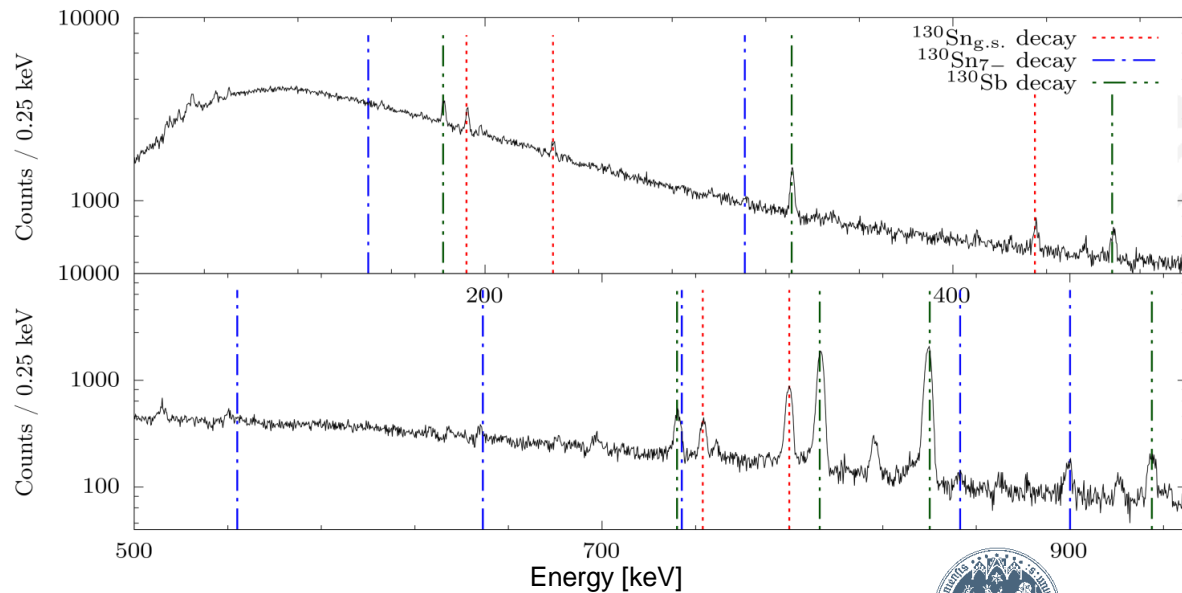
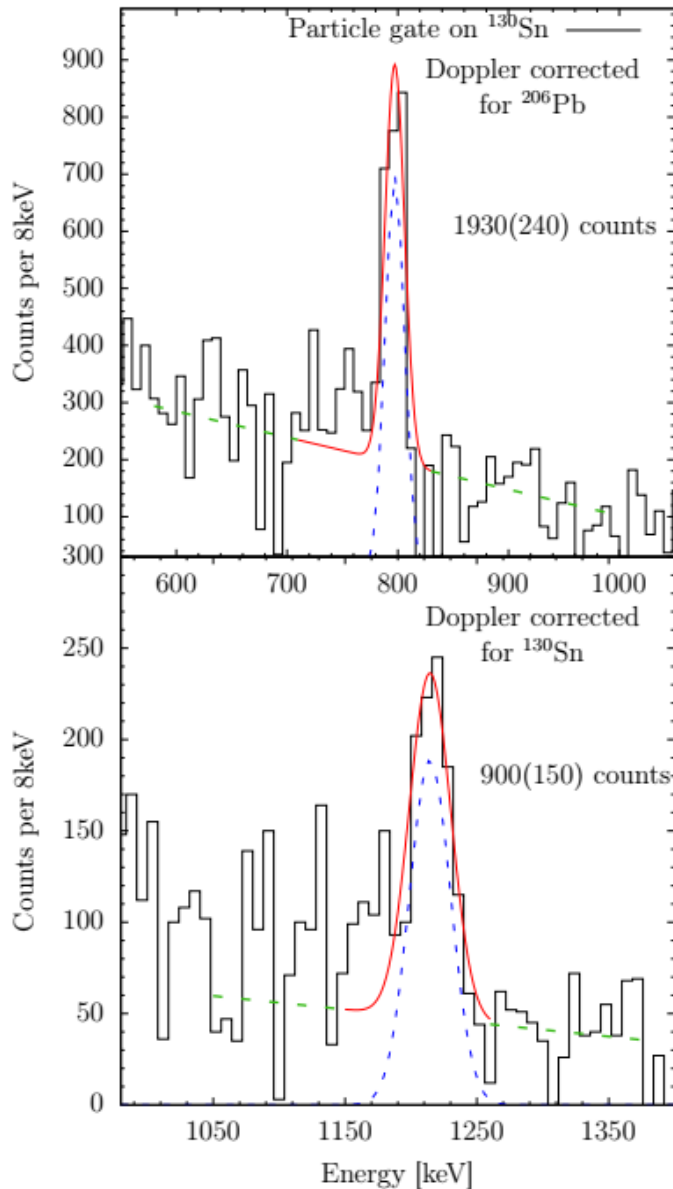
# Outlook

8<sup>th</sup> crystal ready for transfer to ISOLDE

Detailed investigation of beam composition

Investigate peak form in Doppler corrected spectra

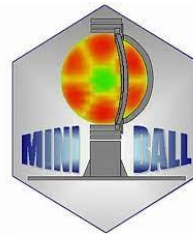
Remeasuring  $^{130}\text{Sn}$  @ ISOLDE with increased intensity (and new DAQ firmware)



# Thank you for your attention and thanks to the IS702 Collaboration

Supported by BMBF Projects 05P18PKC11, 05P21PKC11

This project has received funding from the European Unions Horizon Research and Innovation programme under Grant Agreement No. 101057511



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und Forschung



# Results $^{130}\text{Sn}$

**Beam current:**  $^{130}\text{Sn}$  beam current  $\sim 5 \cdot 10^5$  ions/second (reduced proton current)

**Beam purity: dominating  $^{130}\text{Sn}$  ( $^{130}\text{Sb}$  ?)**

- Doppler correction: no  $\gamma$ 's from stable or instable

**A=130, 164 isobars**

- No  $\gamma$ 's from A=164 isobars in spectra

-  $^{130}\text{Sb} \sim 10\%$

**Isomeric to ground state ratio:  $\sim 15\%$  isomeric component**

**Statistics** with uncertainties due to random background

**Total beam time: 75 hours vs. 120 hours requested**

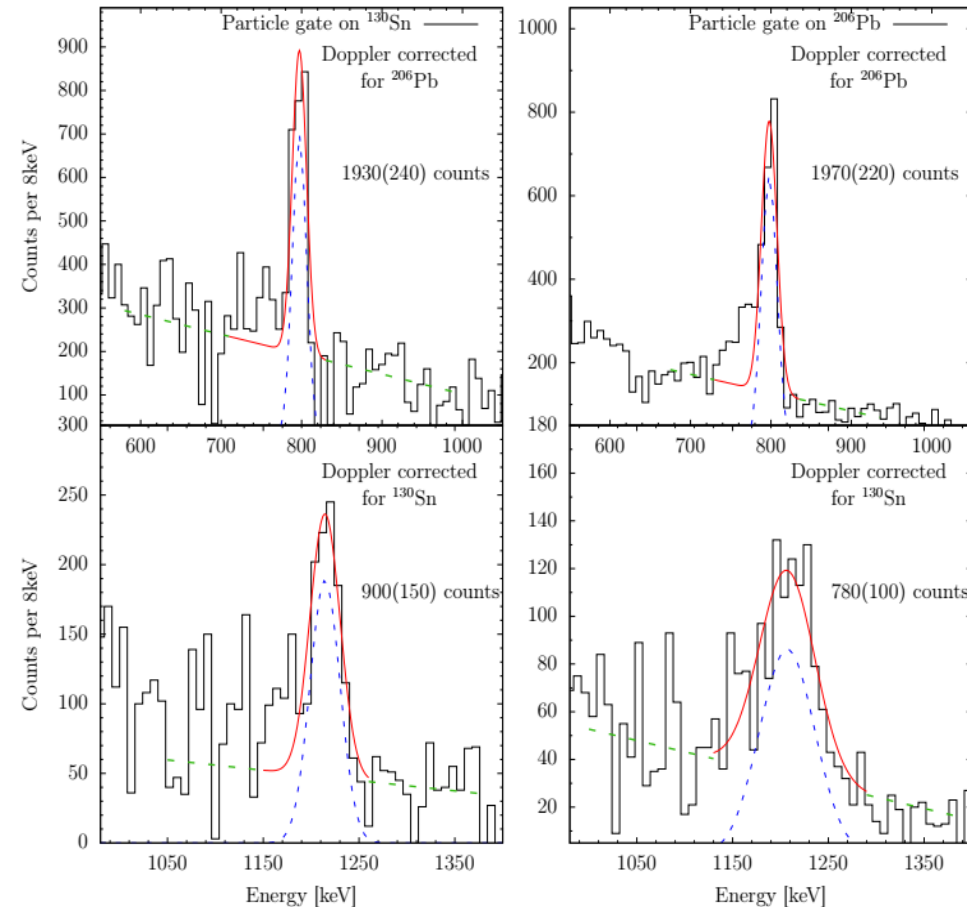
**High instantaneous Miniball count rate**

- reduced proton current, replace collimator by 5mm aperture

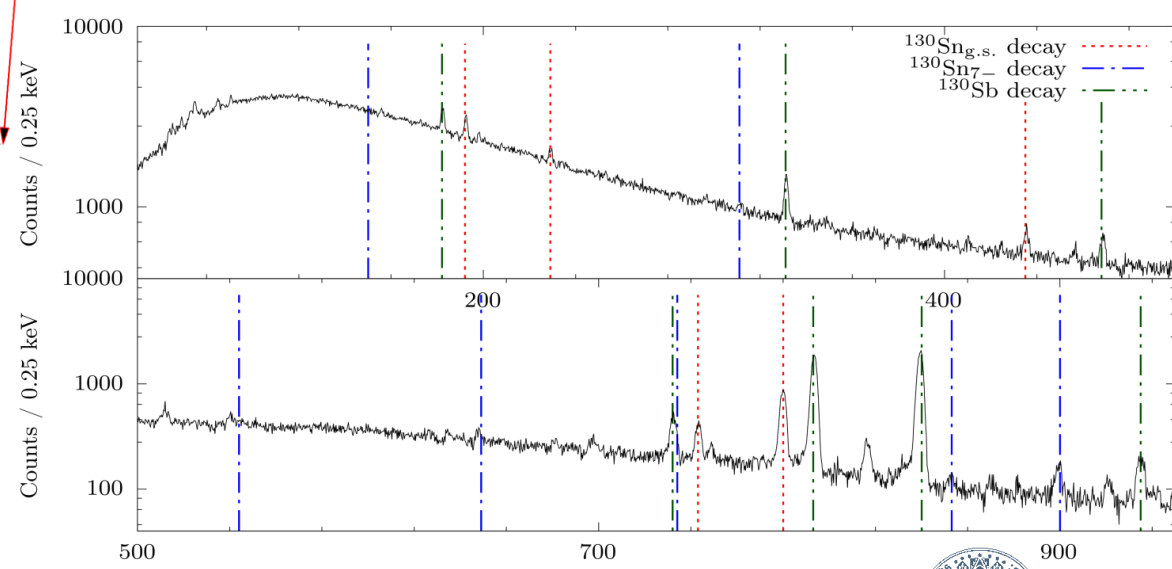
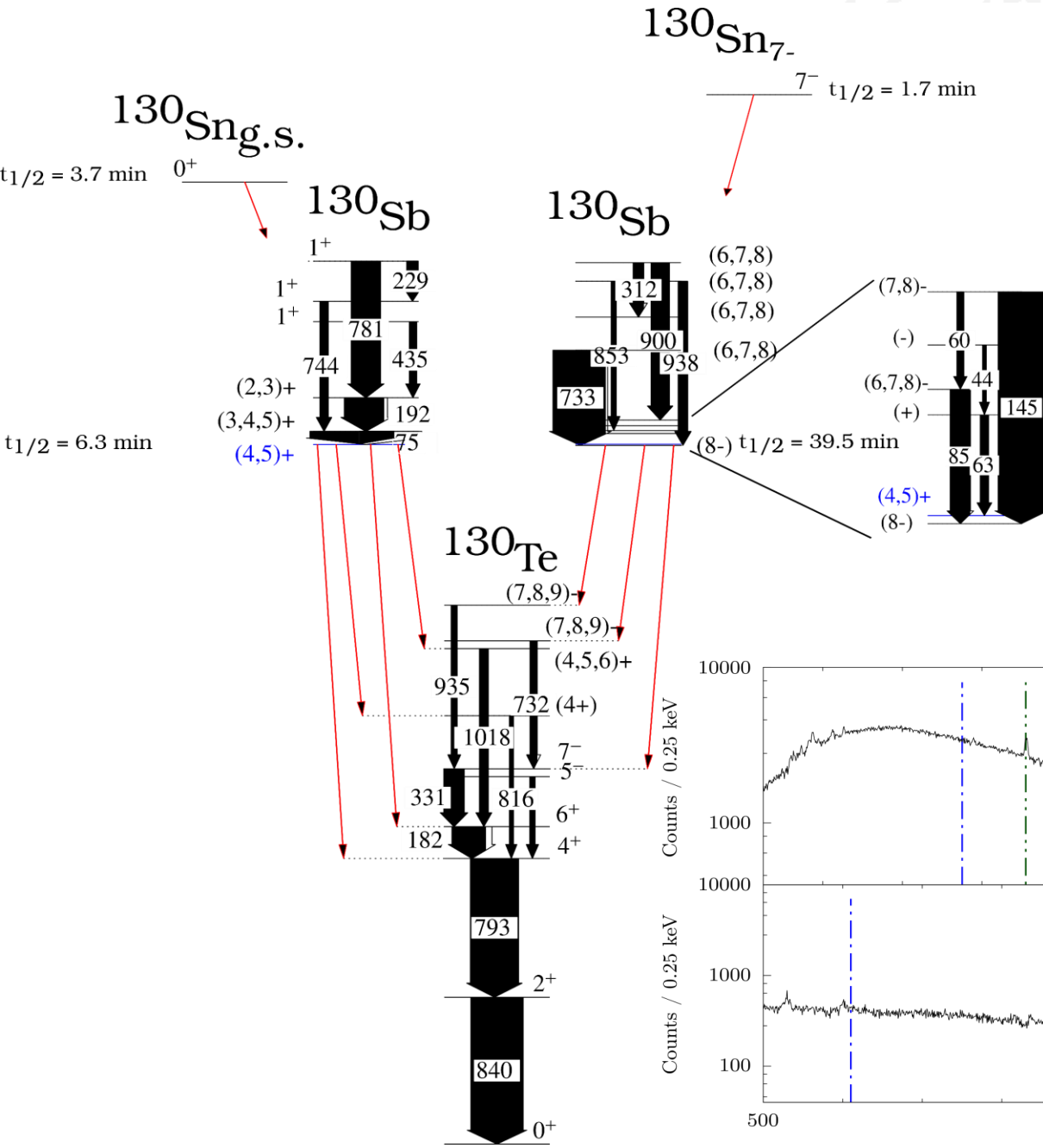
**Preliminary FEBEX DAQ**

- No particle gamma trigger, single event read-out, no dedicated FPGA software, high 39% dead time,...

**→ Follow up experiment!**

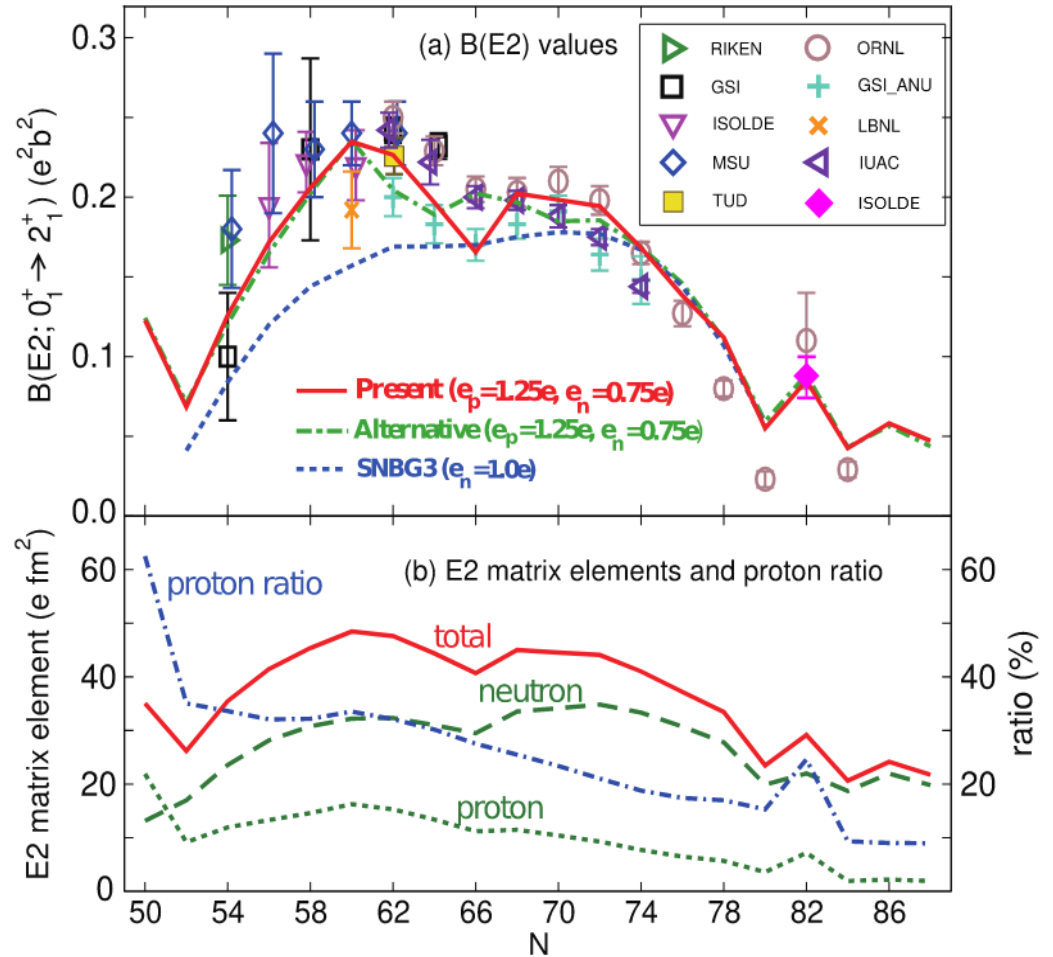
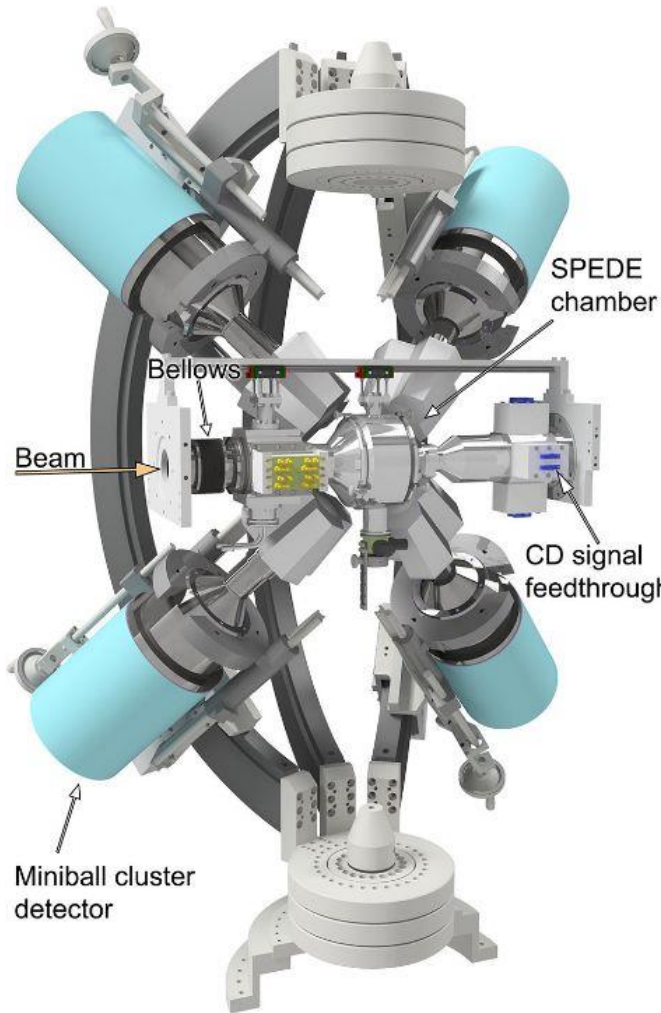






# Outlook

## Follow-up experiment with improved DAQ



# Summary

Successful campaigns Miniball@PSI and @RIKEN

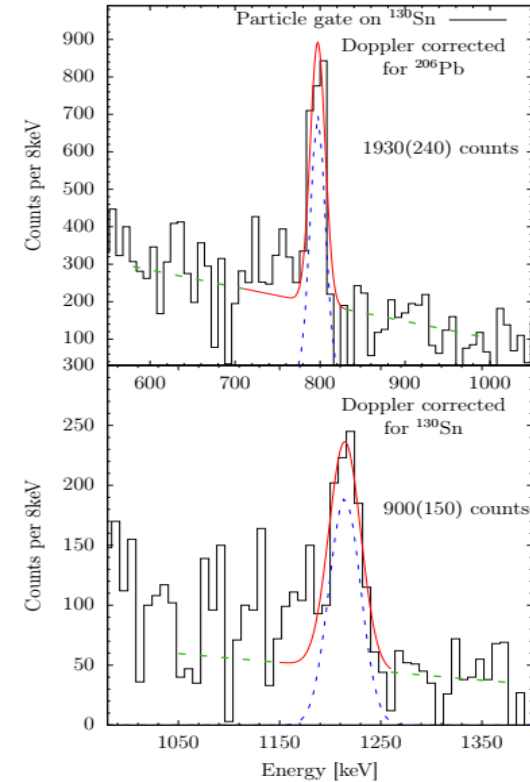
New Miniball triple cluster detector

First campaign after LS2

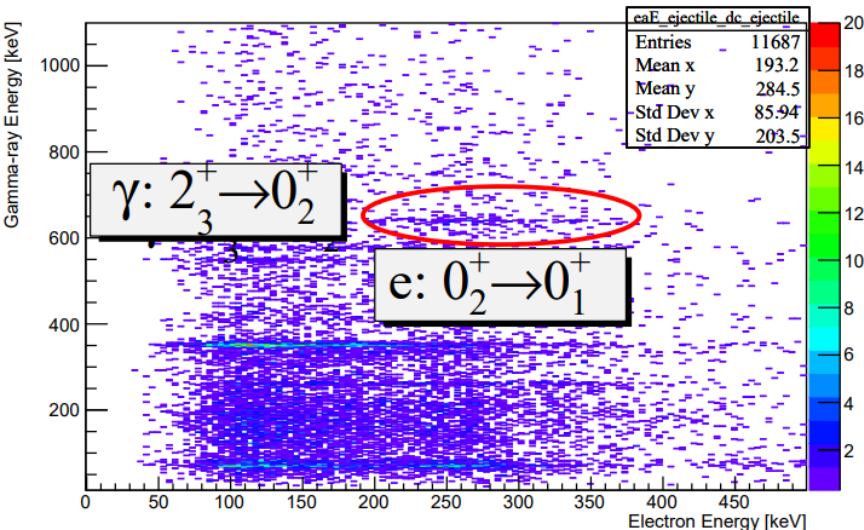
Preliminary results in  $^{130}\text{Sn}$

New electron spectrometer SPEDE installed

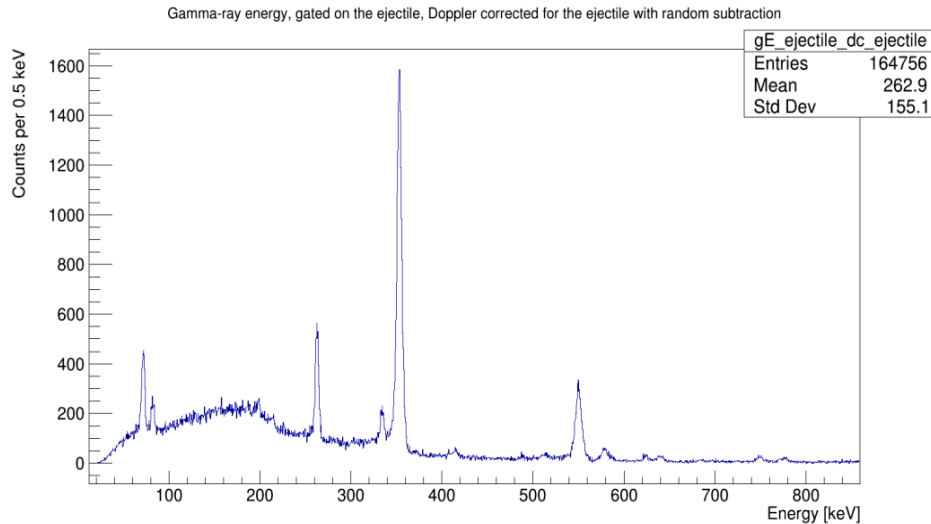
Preliminary results of  $^{182}\text{Hg}$  electron-gamma coincidences



Electron-gamma matrix with addback, gated on the ejectile, Doppler corrected for the ejectile with random subtraction



# Outlook

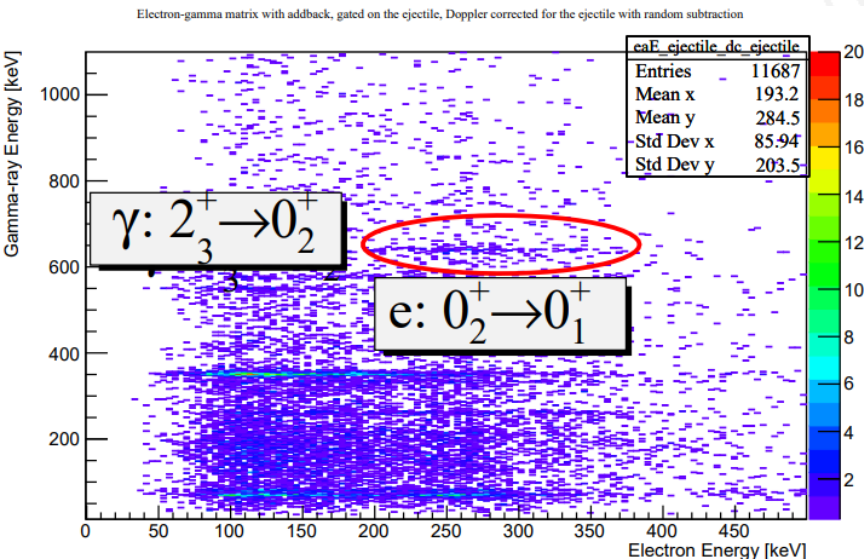


**New electron spectrometer SPEDE installed**

**Reduced background in  $^{182}\text{Hg}$**

**Reperforming Coulex  $^{130}\text{Sn}$  with improved DAQ**

**Two further triple cryostats approved by BMBF**



**Preliminary results of  $^{182}\text{Hg}$  electron-gamma coincidences**



# New Data Acquisition

## FEBEX:

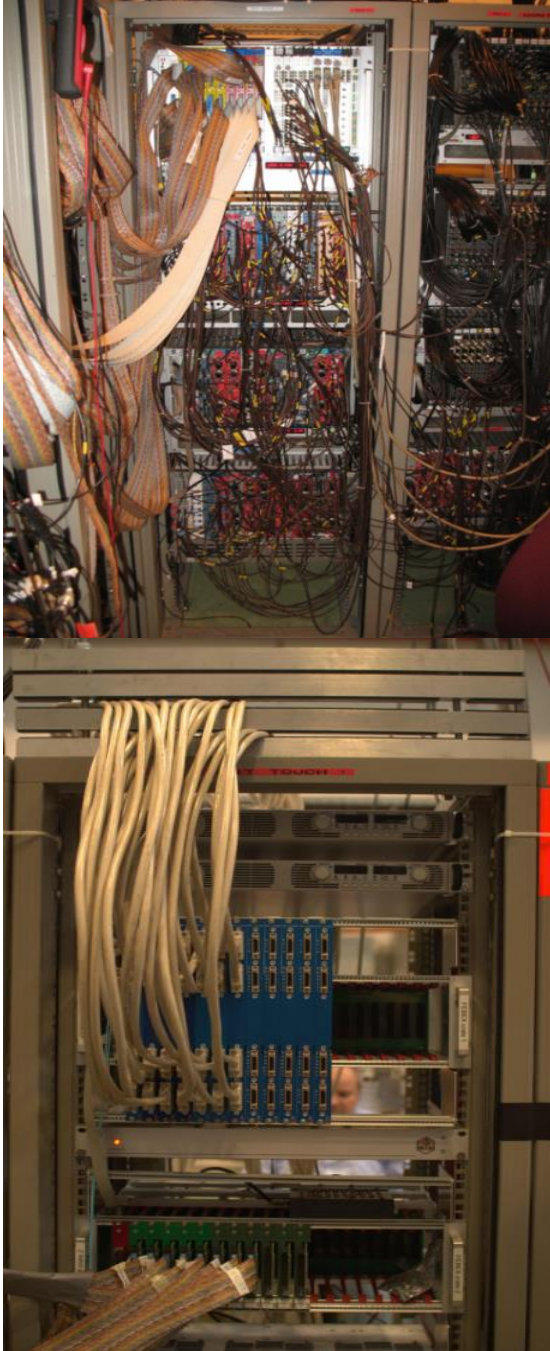
- 16-channel ADCs
- Highly compact design
- 310 channels in <2 racks
- Customizable firmware

## Event mode readout

- Triggered Particle AND/OR Gamma
- All cards readout → Common deadtime

## Future plans:

- Continuous readout
- Real-time control of digital filter parameters

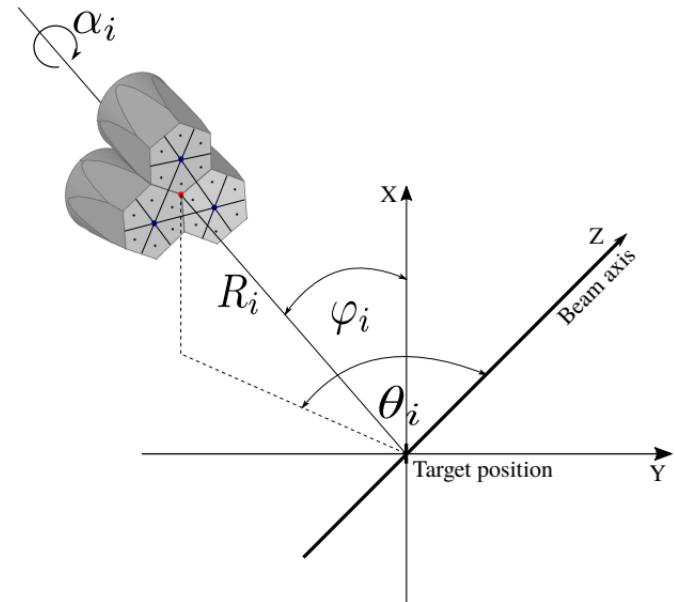
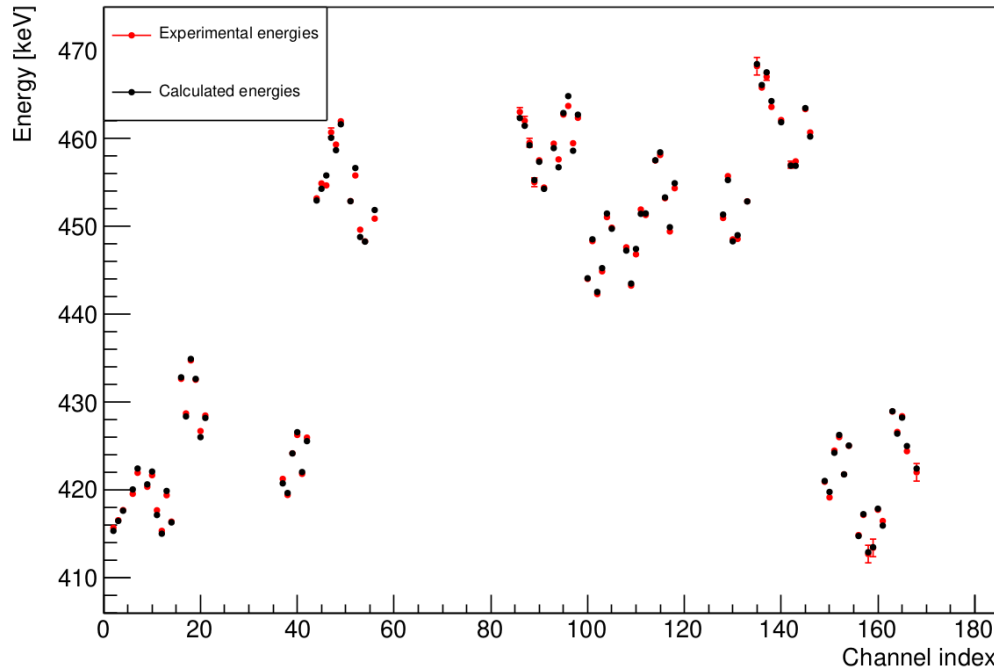
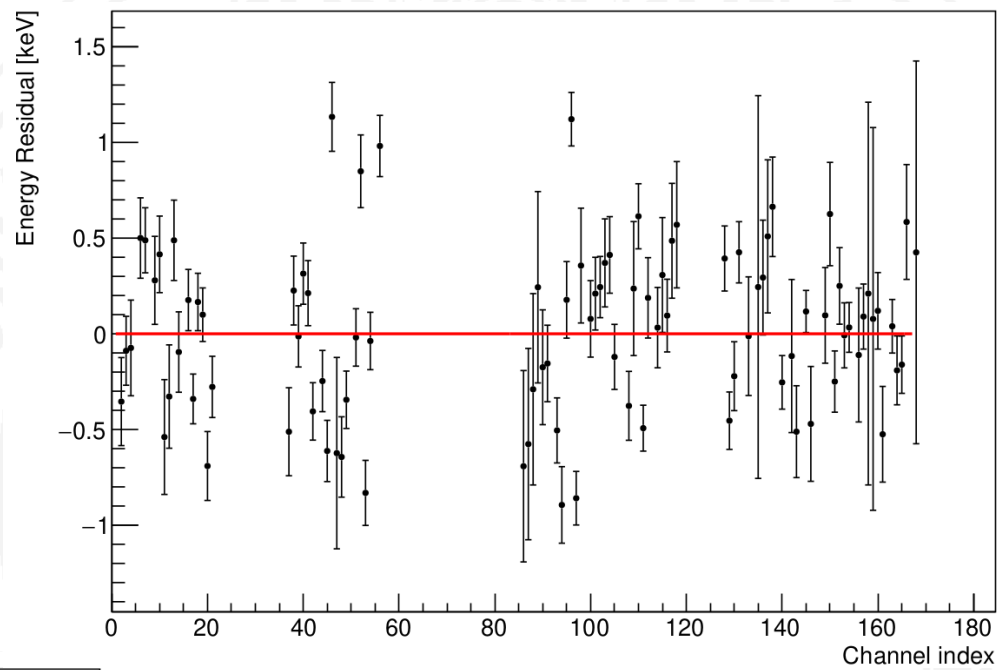


Doppler correction using stable beam experiment

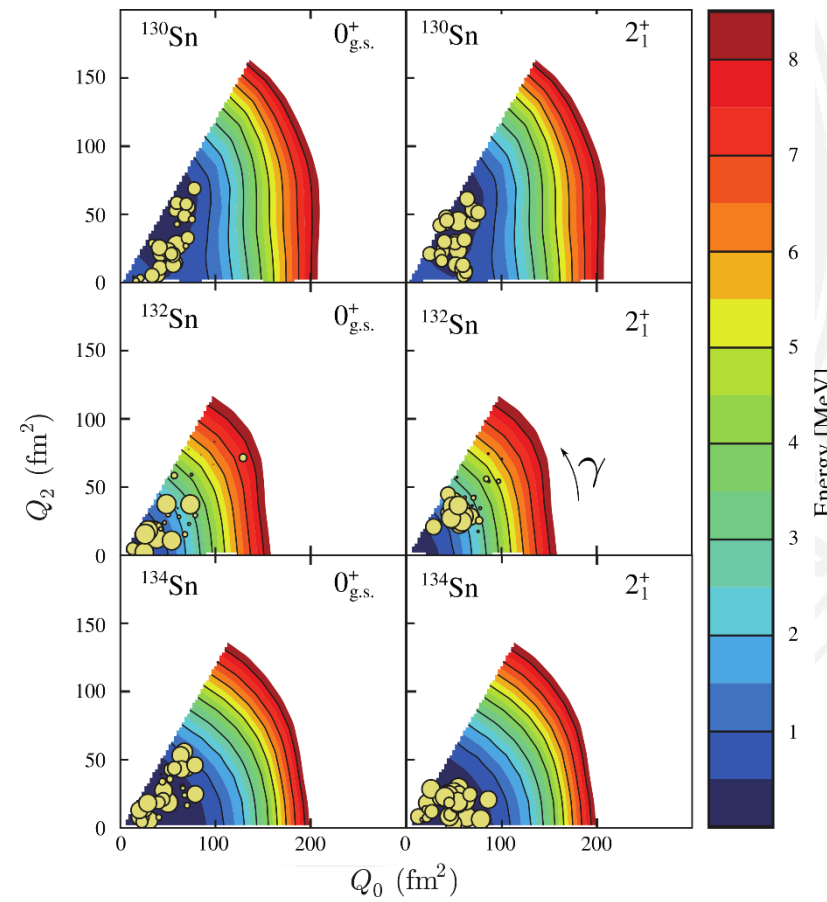
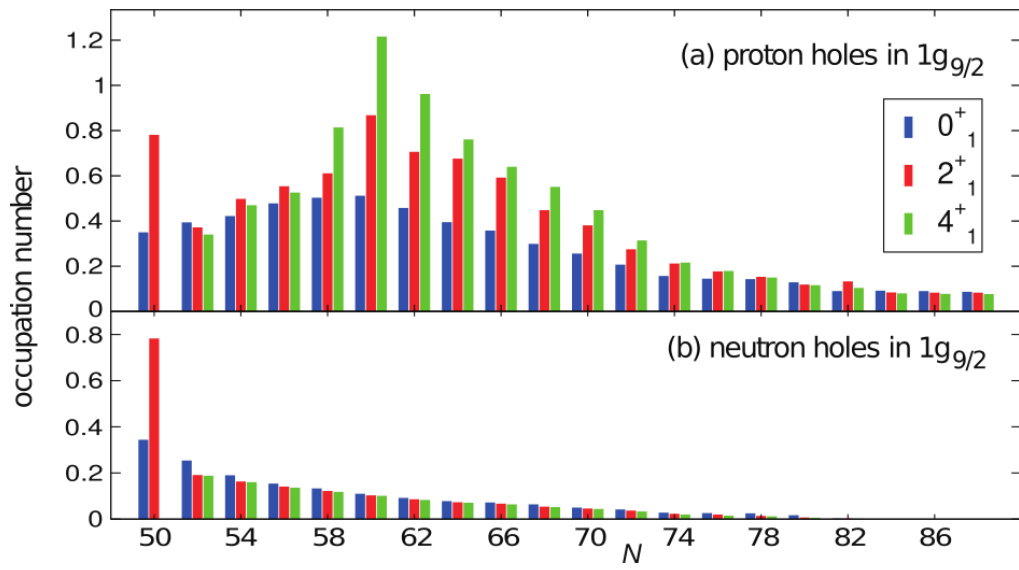
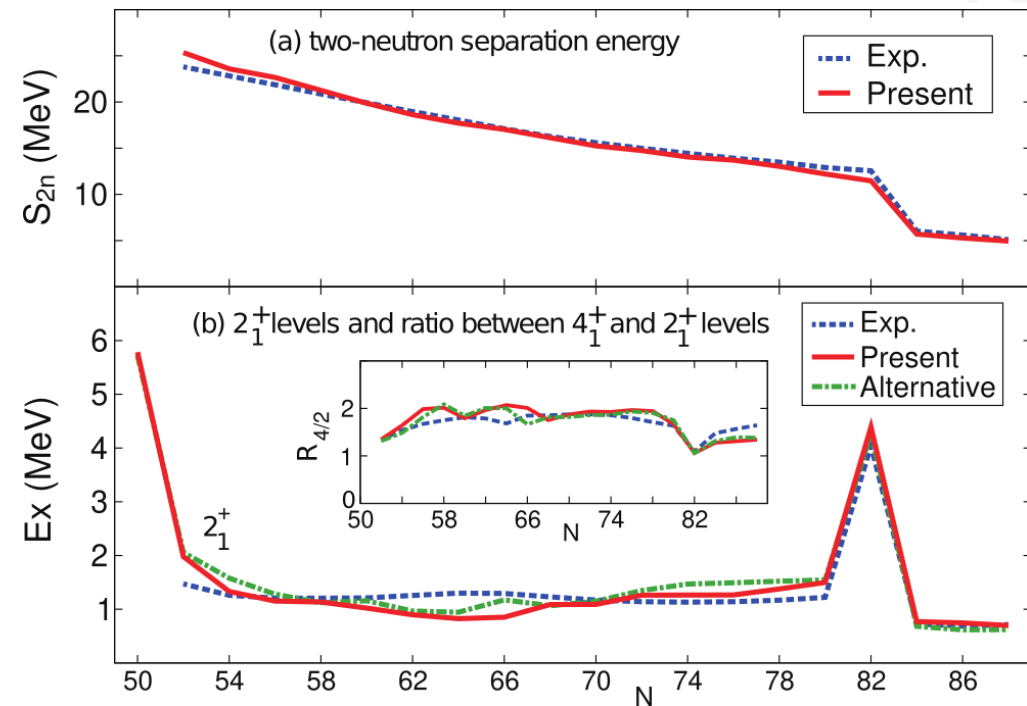
Zeigen? Schönes Spektrum raussuchen

Rechtes Bild rauszoomen.  
Linkes Bild: Positionen der Detektoren zeigen

Background Zeit Spektrum zeigen



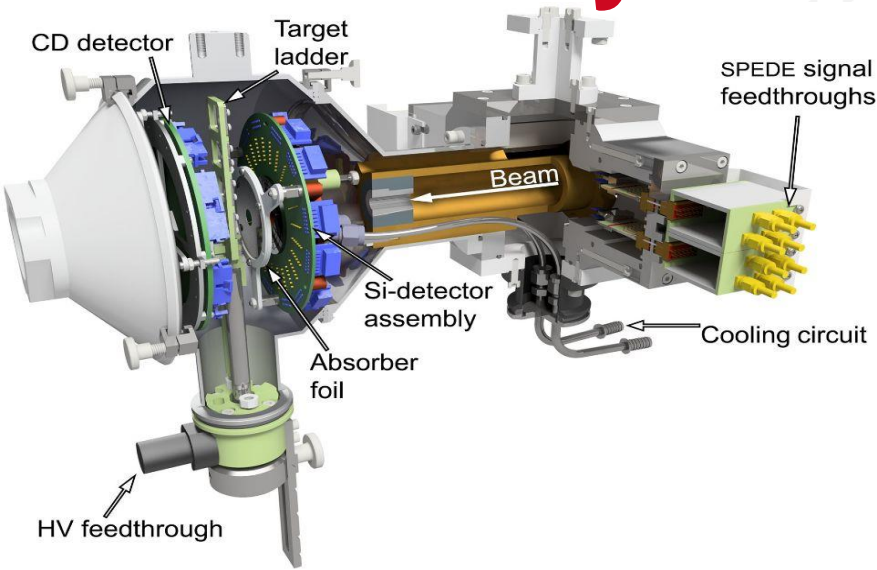
# Case of $^{130}\text{Sn}$



T. Togashi; Y. Tsunoda; T. Otsuka; N. Shimizu; M. Honma; Phys. Rev. Lett. 121, 062501 (2018)



# Summary & Outlook Miniball

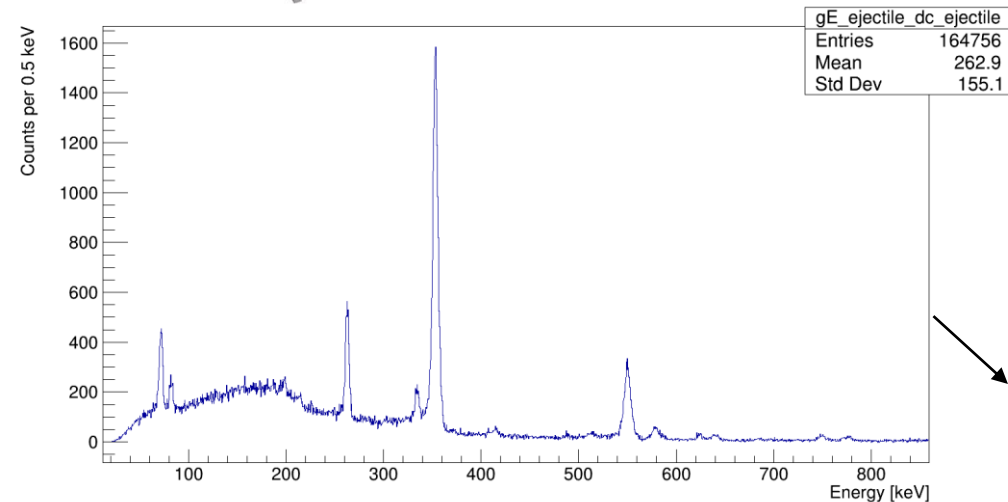


**Miniball back in business @ISOLDE!**

Mounting two more upgraded triple cryostats (1 triple plus prototype)

Testing new FEBEX firmware

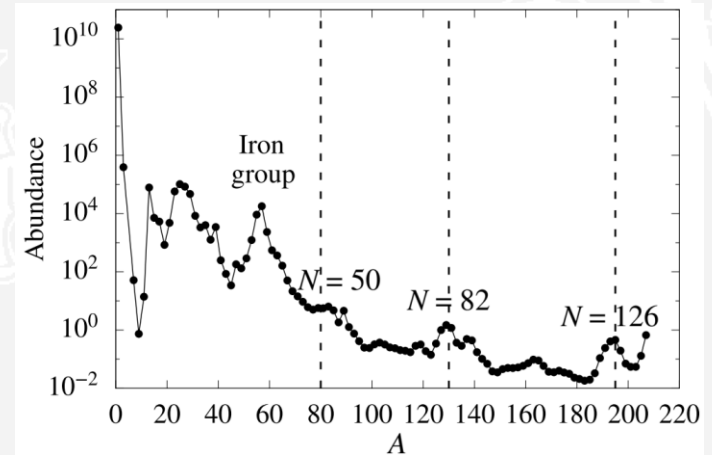
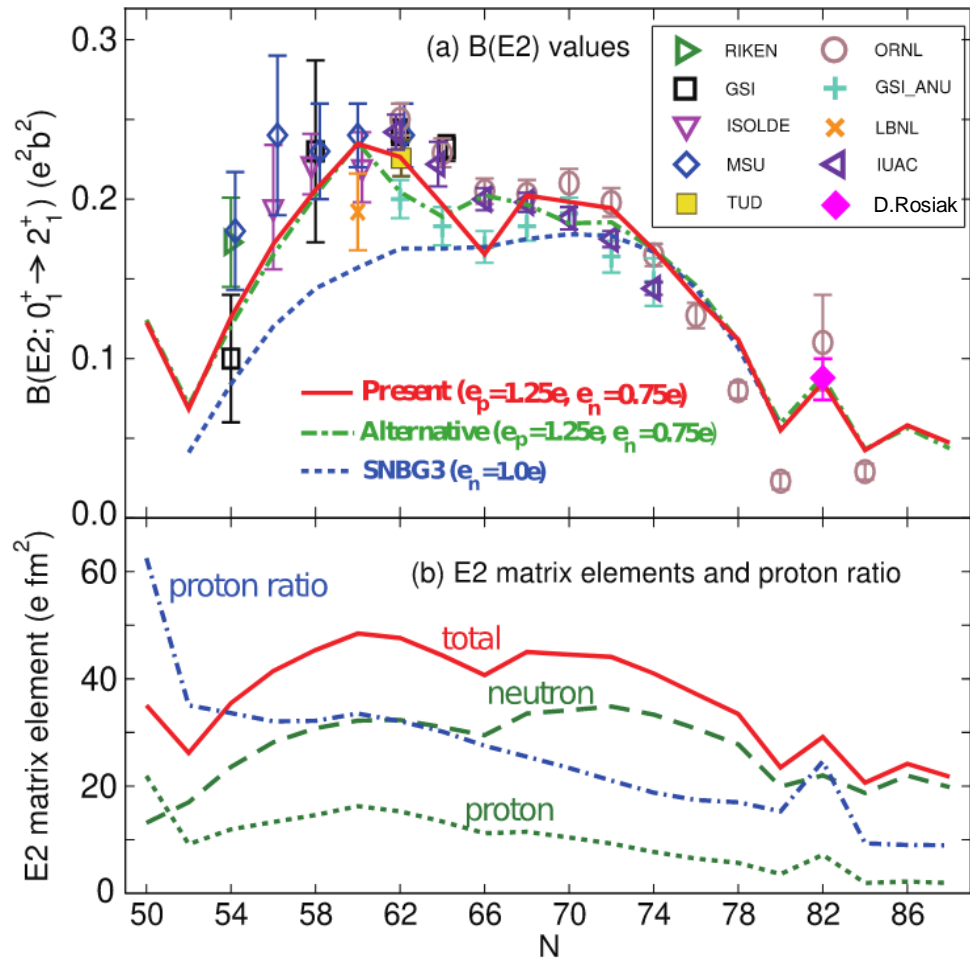
Many more experiments to go!



Very preliminary results of  $^{182}\text{Hg}$   
Doppler-corrected spectra



# B(E2) values along Sn chain

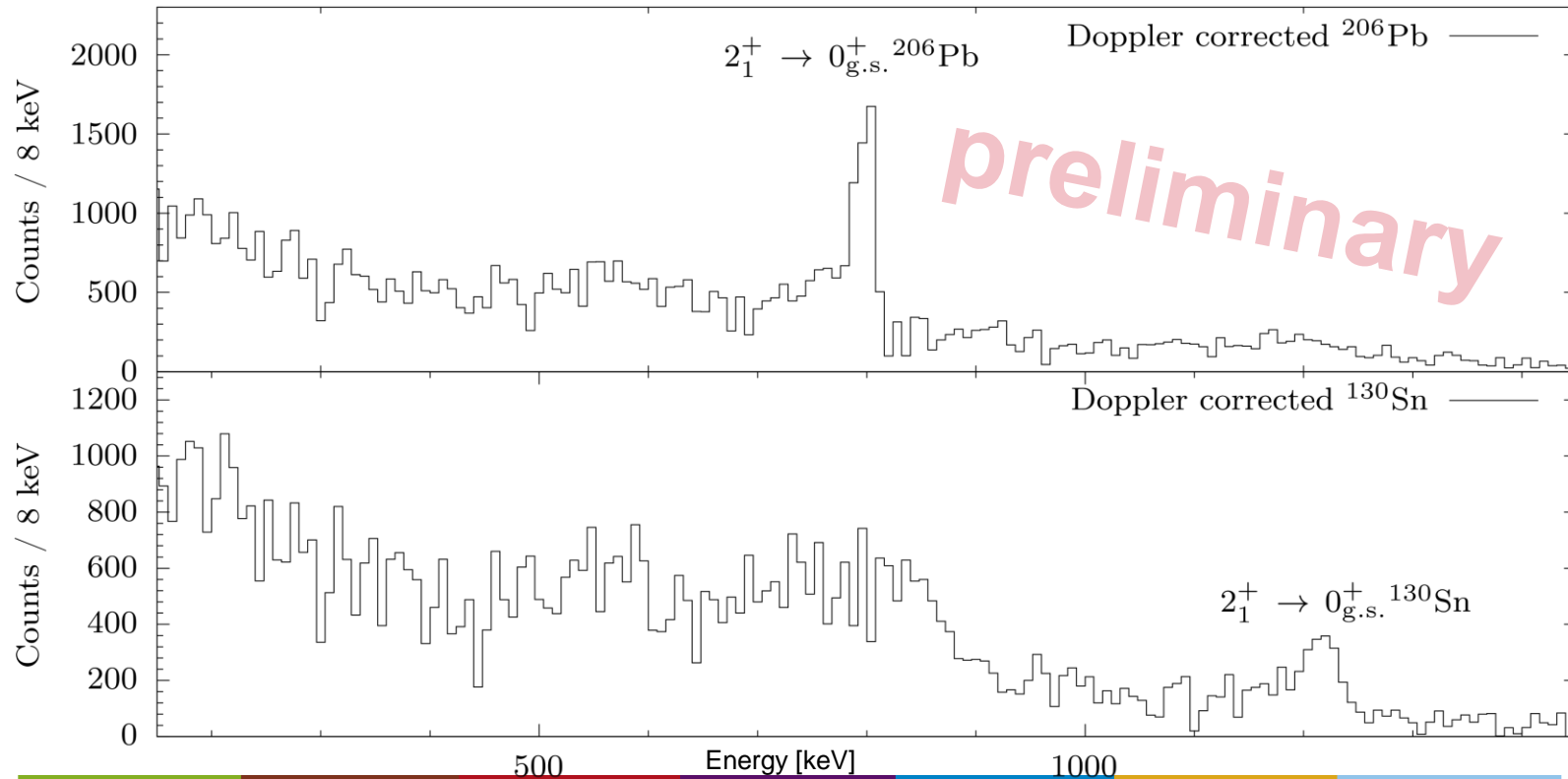
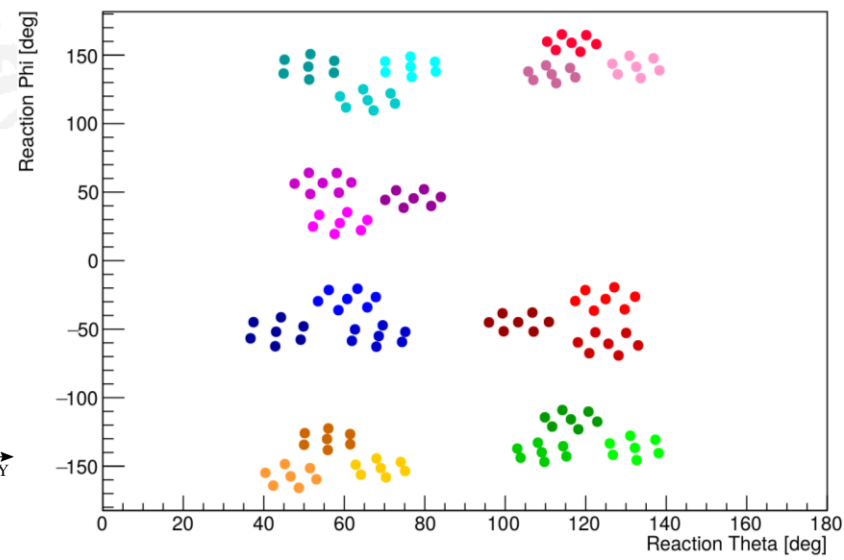
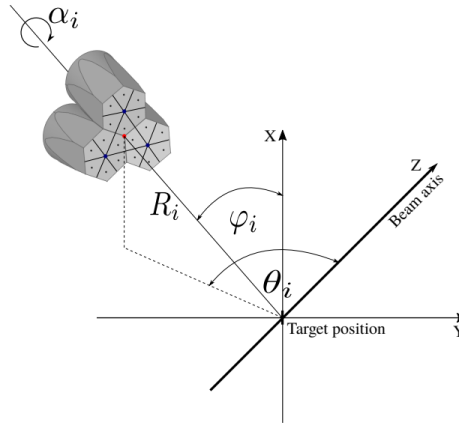


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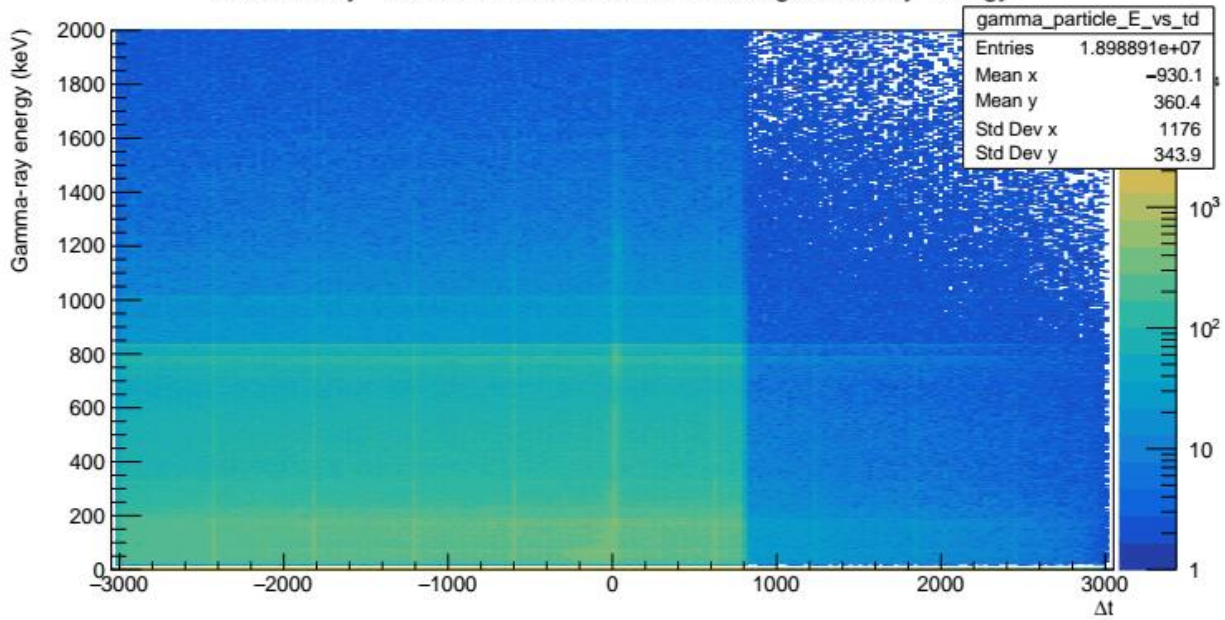
T. Togashi; et al.; Phys. Rev. Lett. 121, 062501 (2018)  
 $^{132}\text{Sn}$  value by D. Rosiak, et. al.; Phys. Rev. Lett. 121, 252501 (2018)



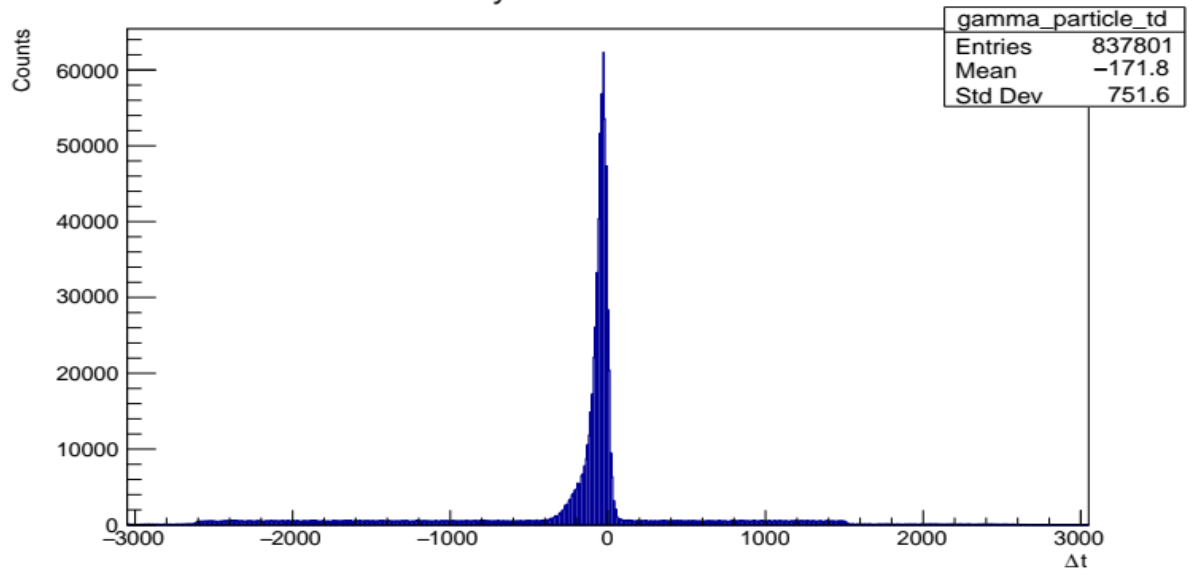
# Doppler-corrected spectra



# Gamma-ray - Particle time difference versus gamma-ray energy

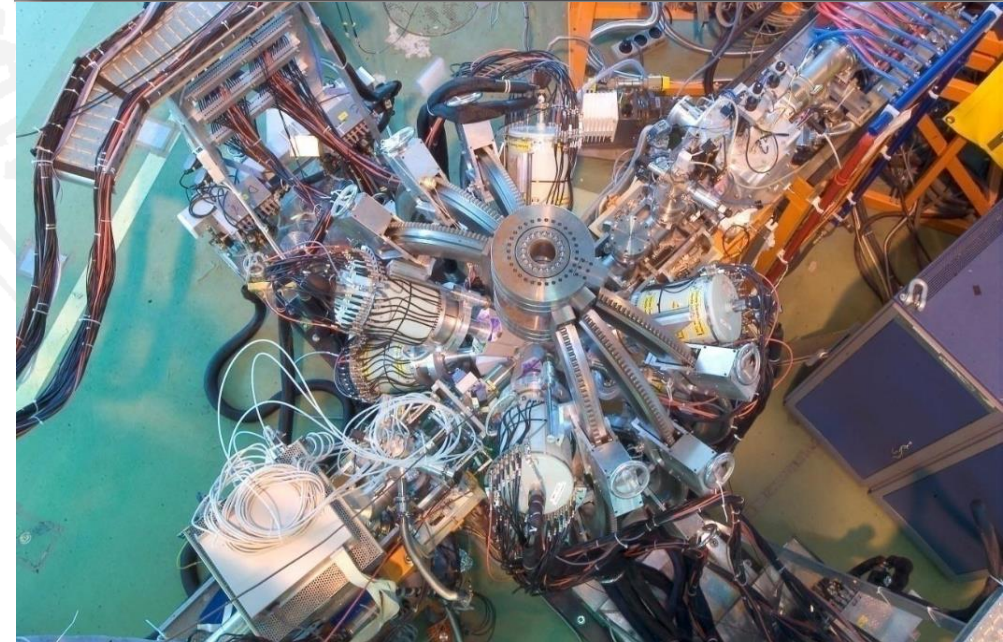
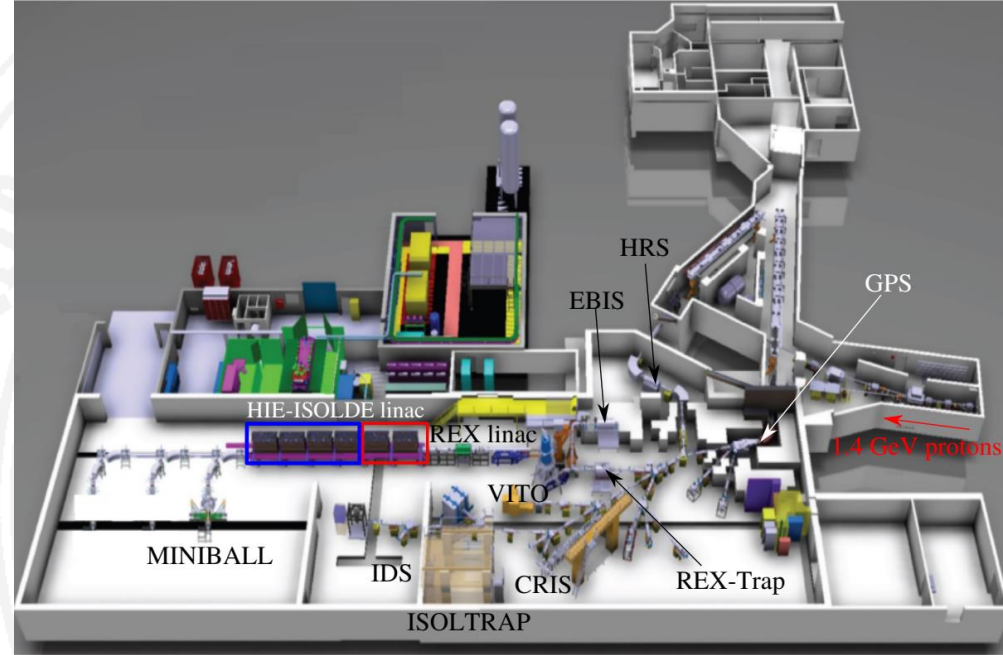


# Gamma-ray - Particle time difference



# Miniball@ISOLDE

- In-Beam  $\gamma$ -ray spectroscopy experiments @ISOL (Isotope Separation On-Line) facility
- Exotic nuclei @ISOLDE, CERN
  - Coulomb excitation
  - Transfer reactions
  - Deep-inelastic scattering
- 2001: Start @REX-ISOLDE
  - Beam energies  $< 2.8\text{MeV/u}$
- 2015: Upgraded to HIE-ISOLDE
  - Beam energies  $< 10\text{MeV/u}$
- 2019: Long Shutdown 2
- 2022: Restart of Miniball@ISOLDE



Reiter, P.; Warr, N. in *Prog. Part. Nucl. Phys.* (2020). **113** 103767

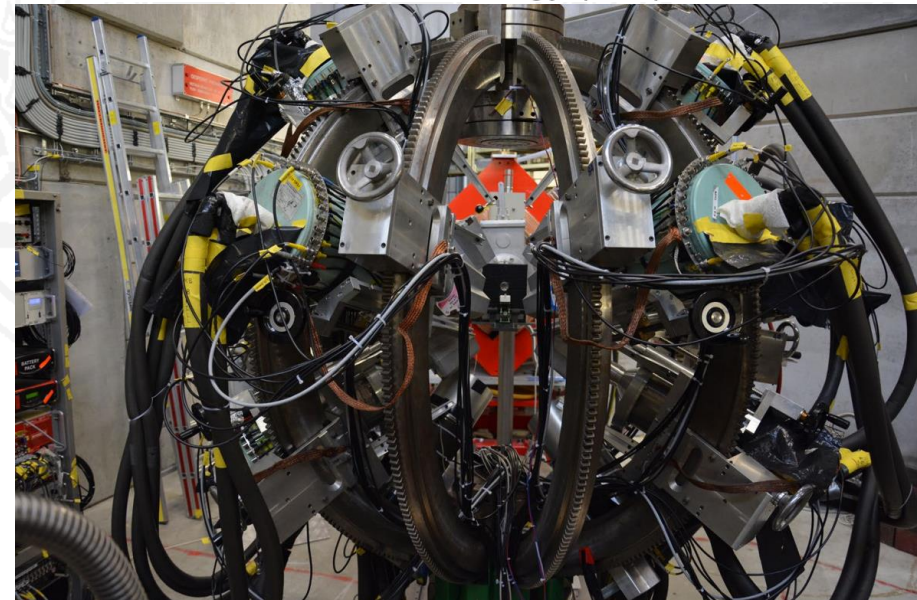
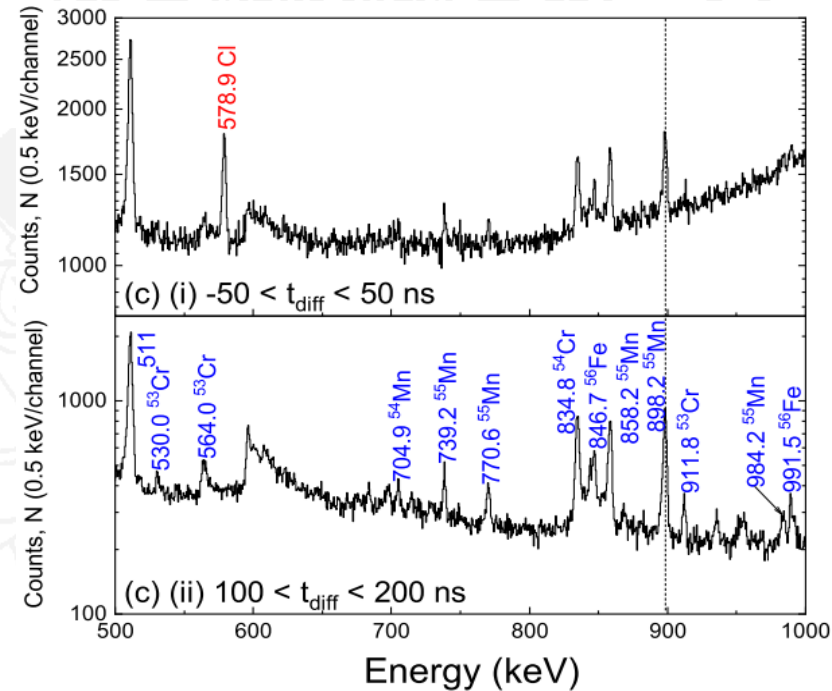
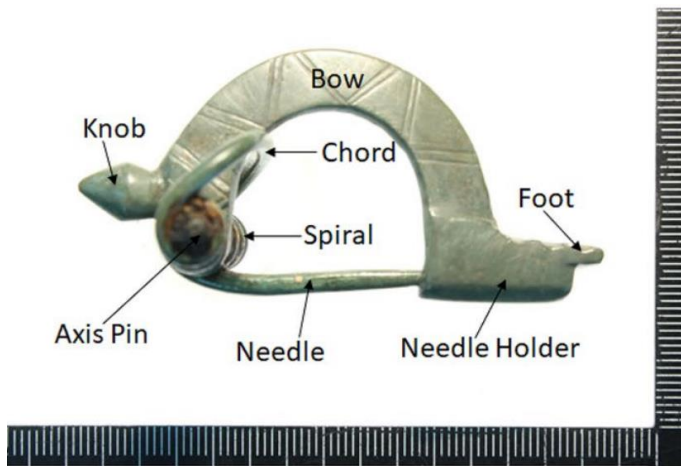




# Miniball 2019 - PSI

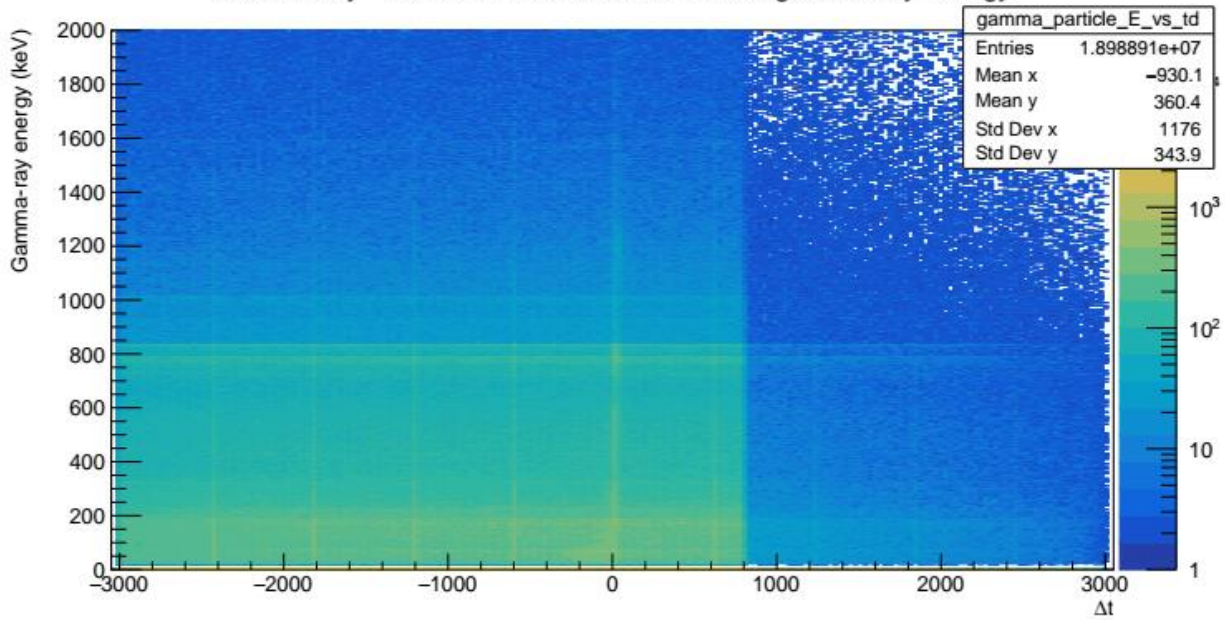
- Muonic atom spectroscopy [1]
- New method for Non-Destructive Depth-Selective elemental composition analysis by muon induced x-rays and  $\gamma$ -rays [2]

→ Elemental composition of *knob bow fibula* (Kaiseraugst, Switzerland) investigated [3]

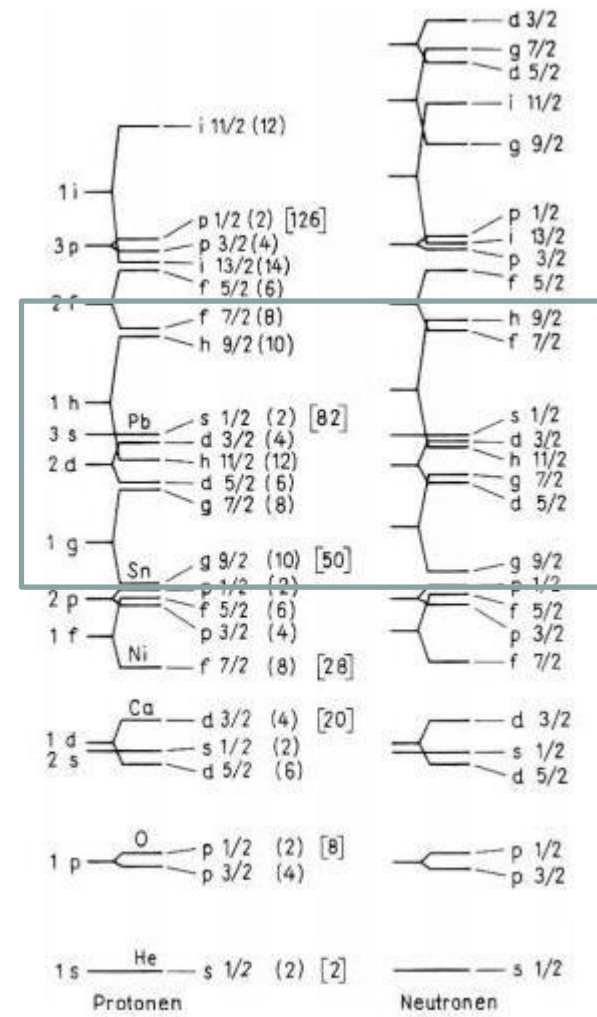
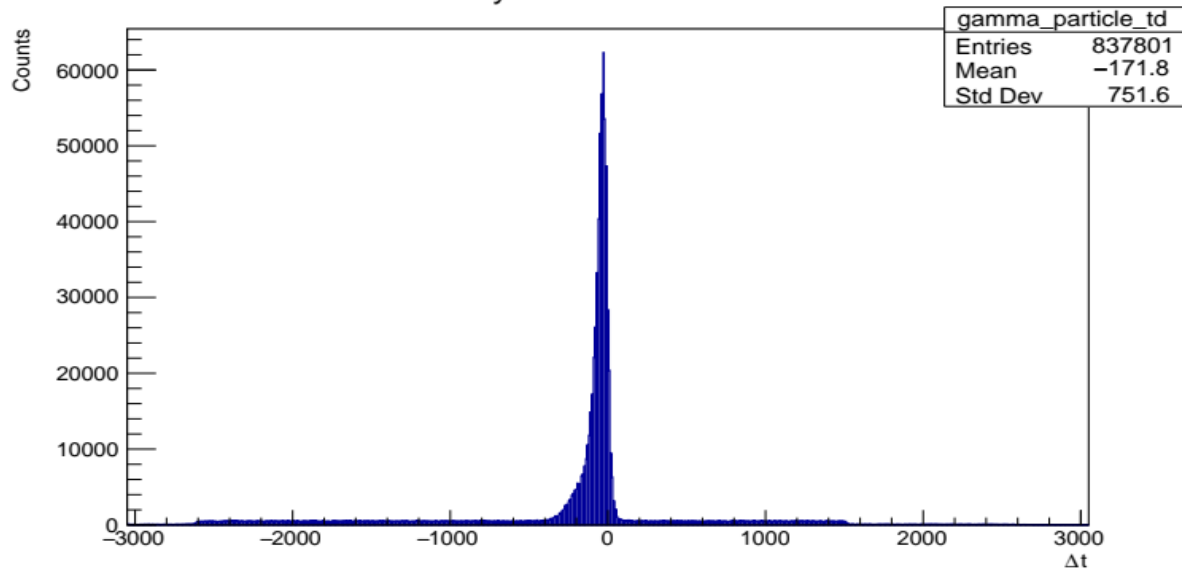


- [1] A. Knecht, et al. *Europ. Phys. Journ. A* 59(2) (2023)
- [2] S. Biswas, et al. *Nucl. Heritage Science* 11 43 (2023)
- [3] S. Biswas, et al. *Applied Sciences* 12(5) (2022) 2541

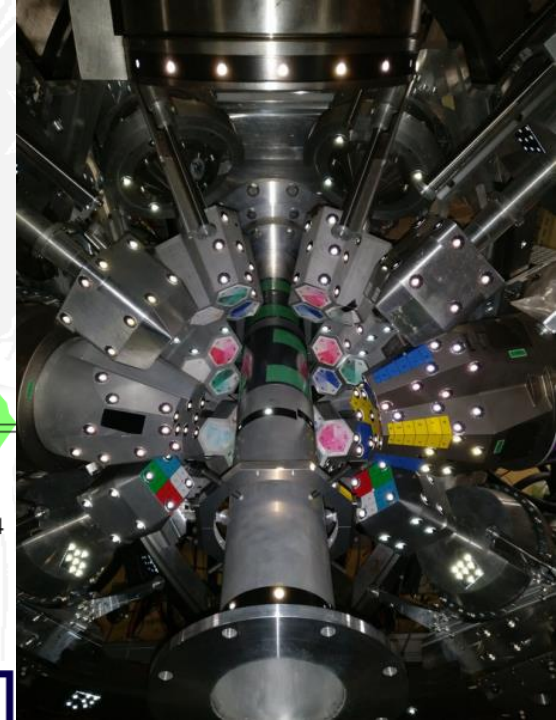
# Gamma-ray - Particle time difference versus gamma-ray energy



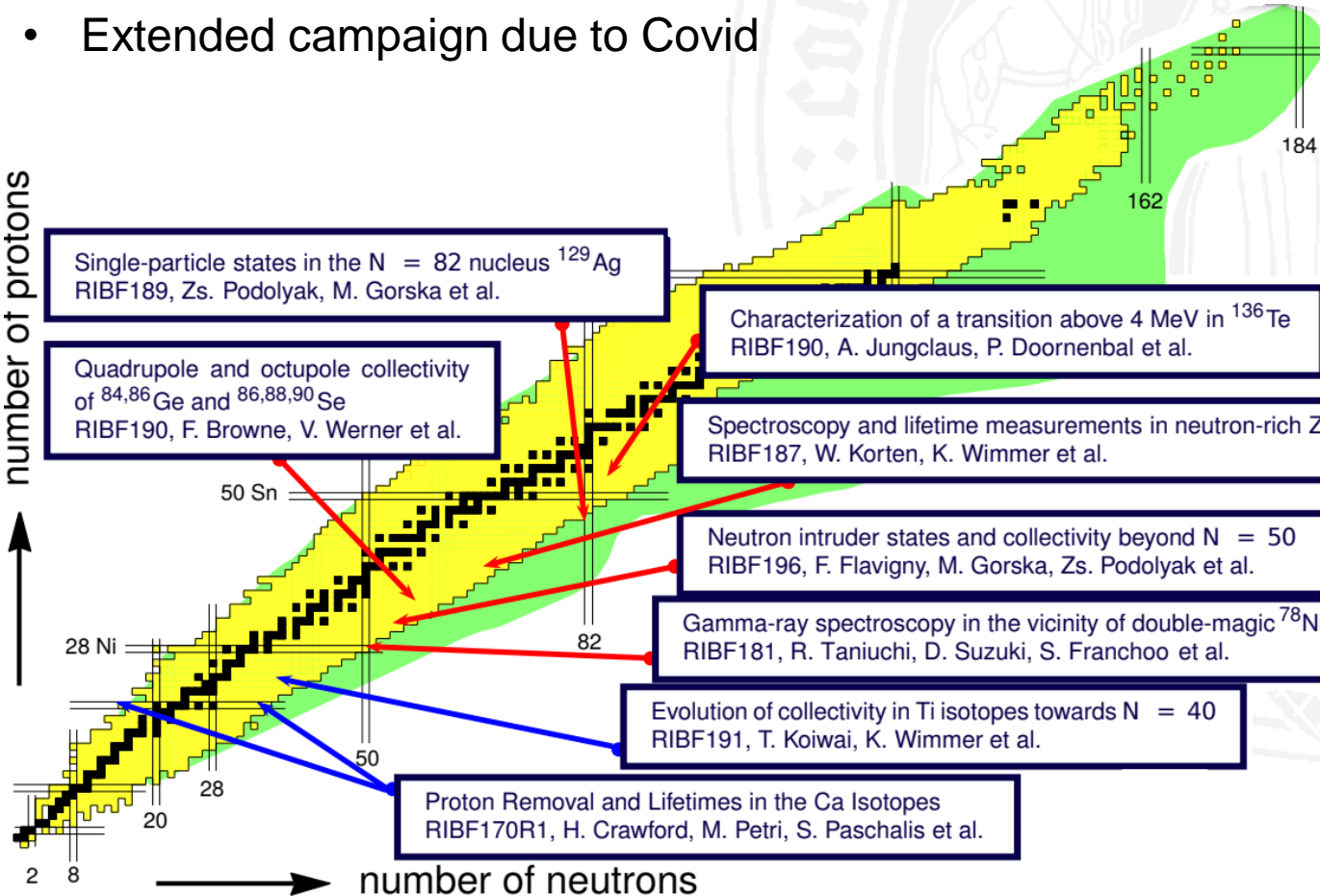
# Gamma-ray - Particle time difference



# Miniball 2020/21 - RIKEN



- Miniball + BGRIPS
- Extended campaign due to Covid





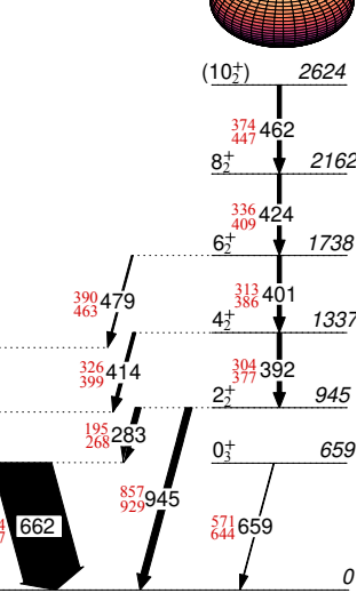
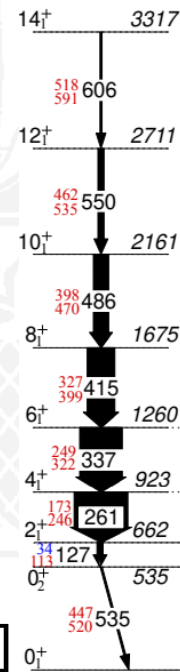
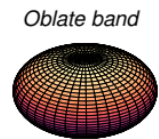
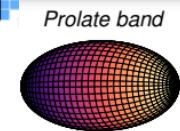
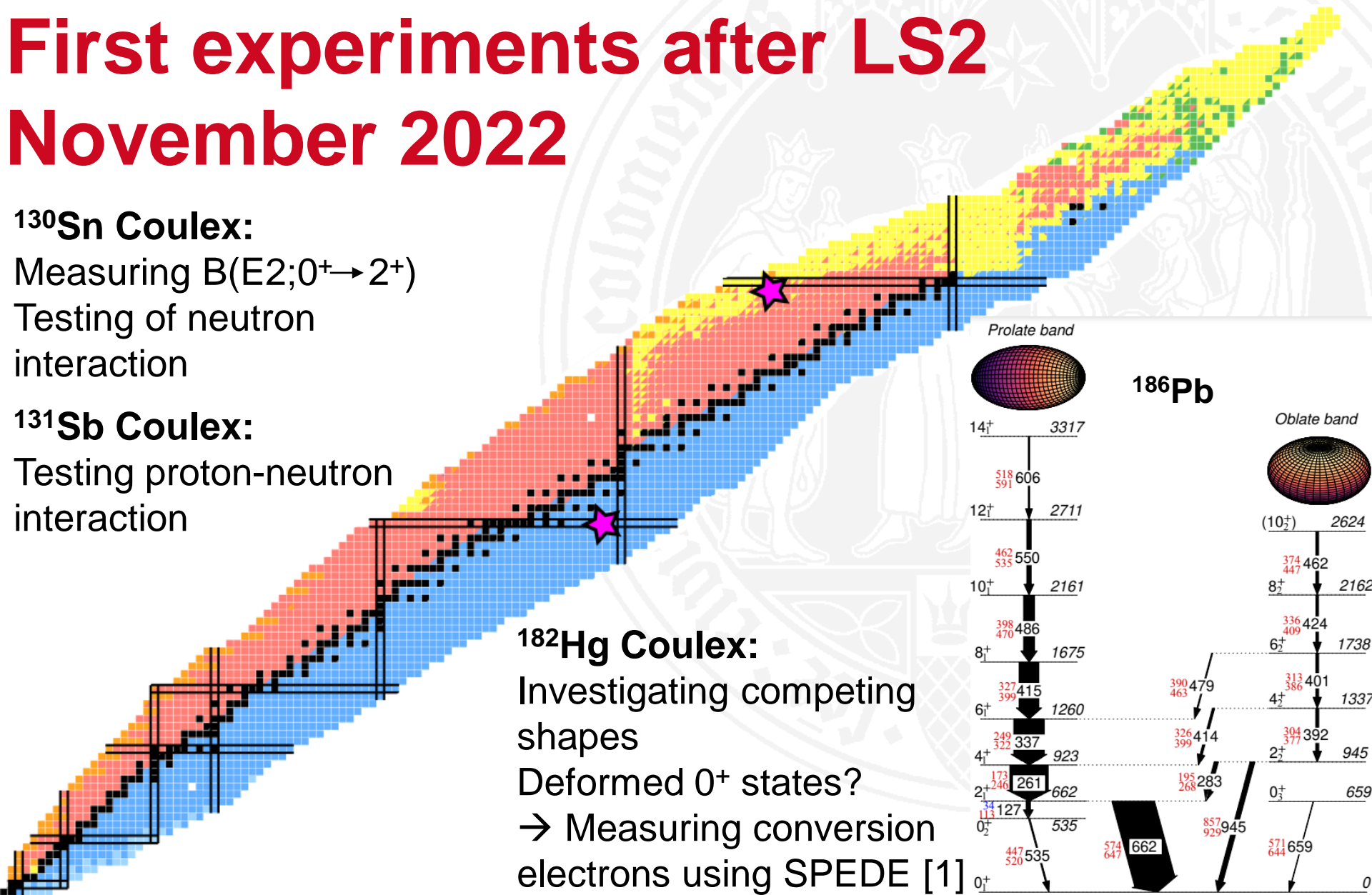
# First experiments after LS2

## November 2022

**$^{130}\text{Sn}$  Coulex:**  
 Measuring  $B(E2; 0^+ \rightarrow 2^+)$   
 Testing of neutron interaction

**$^{131}\text{Sb}$  Coulex:**  
 Testing proton-neutron interaction

**$^{182}\text{Hg}$  Coulex:**  
 Investigating competing shapes  
 Deformed  $0^+$  states?  
 → Measuring conversion electrons using SPEDE [1]



[1] Papadakis, P., Cox, D.M., O'Neill, G.G. *et al.* The SPEDE spectrometer. *Eur. Phys. J. A* **54**, 42 (2018)

