Probing the doubly-magic shell closure at ^{132}Sn by Coulomb excitation of neutron-rich ^{130}Sn

Maximilian Droste[1], Peter Reiter[1] and Thorsten Kröll[2] for the IS702 – collaboration

[1] Institute for Nuclear Physics, University of Cologne

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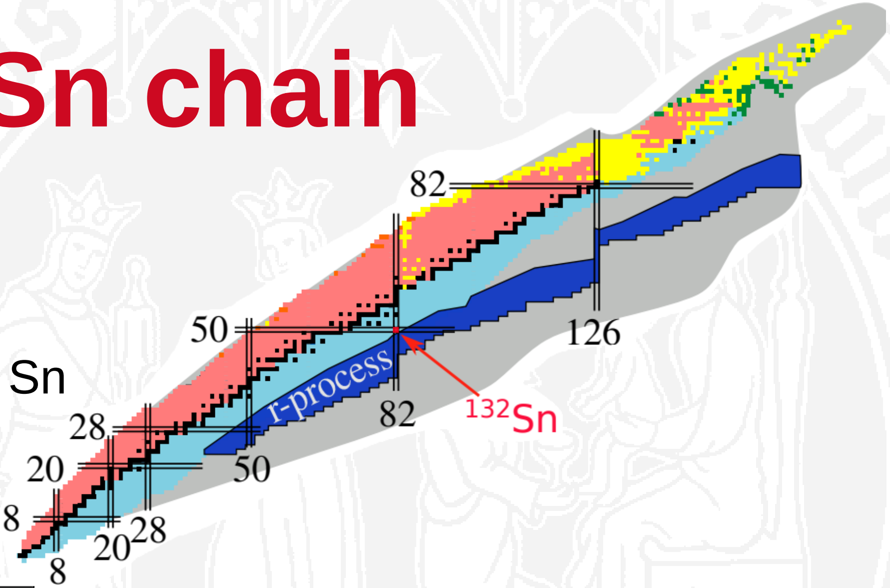
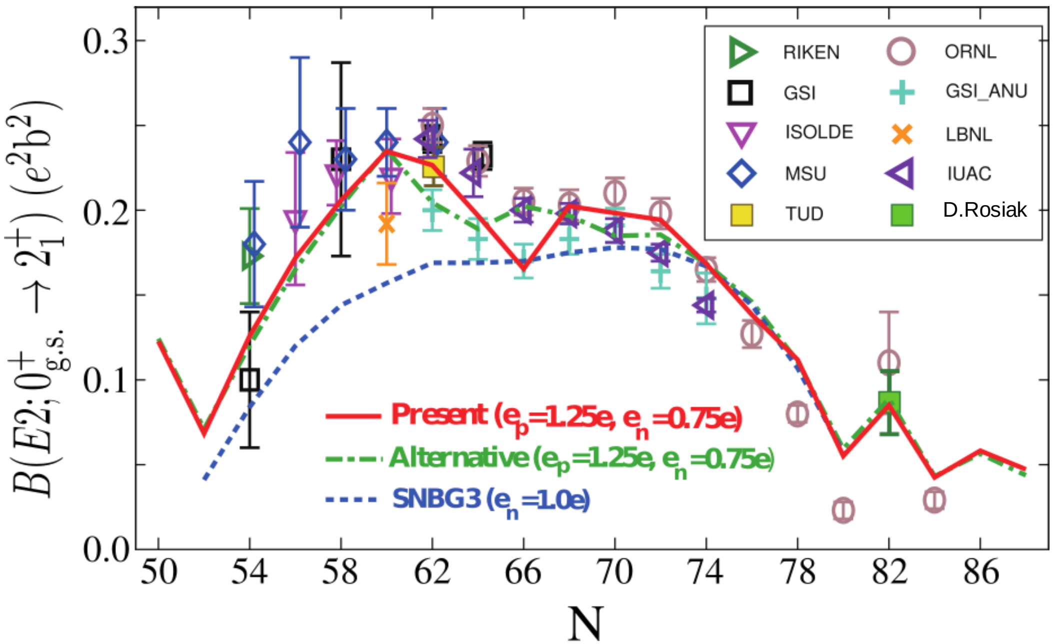
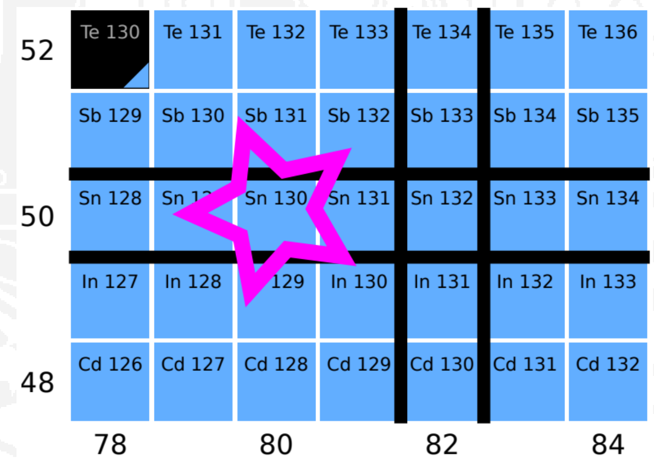
B(E2) values along Sn chain

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

MCSM calculations [1] able to describe whole Sn isotope chain using one Hamiltonian







$$B(E2; 0^+ \to 2^+)_{theo.} = 0.055\ e^2b^2\ [1]$$

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

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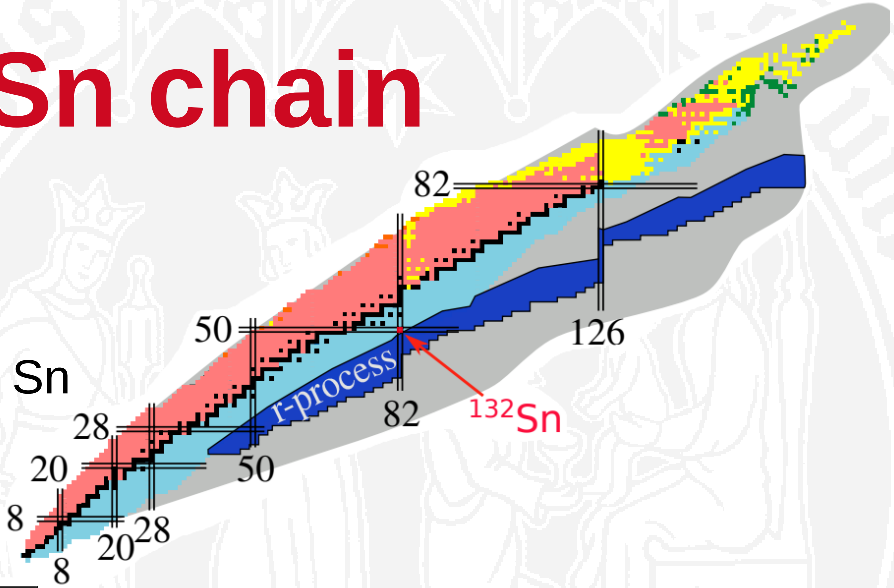

^{132}Sn region of interest for r-process

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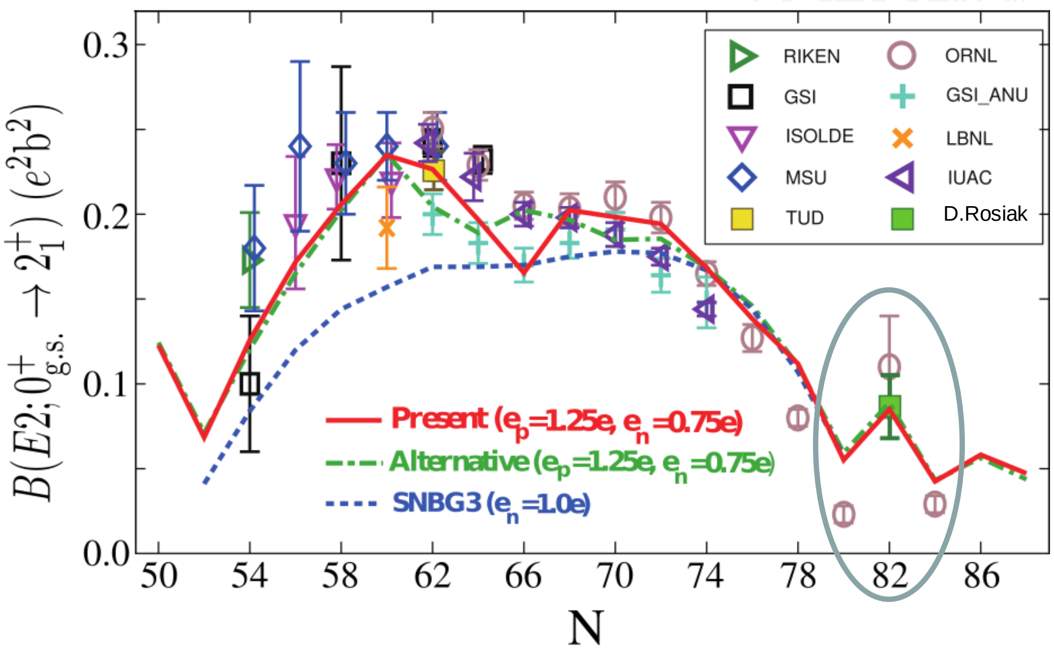

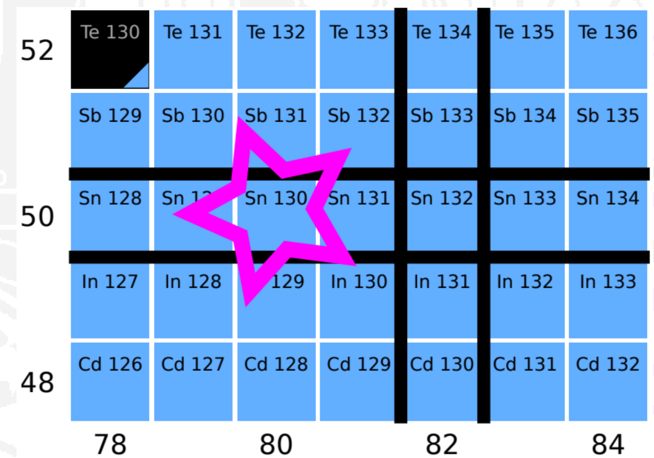

$B(E2; 0^+ \rightarrow 2^+)_{ORNL}$ = 0.023(5) e²b² [2]

$B(E2; 0^+ \rightarrow 2^+)_{*}$ = 0.054(10)$_{stat.}$ e²b²

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

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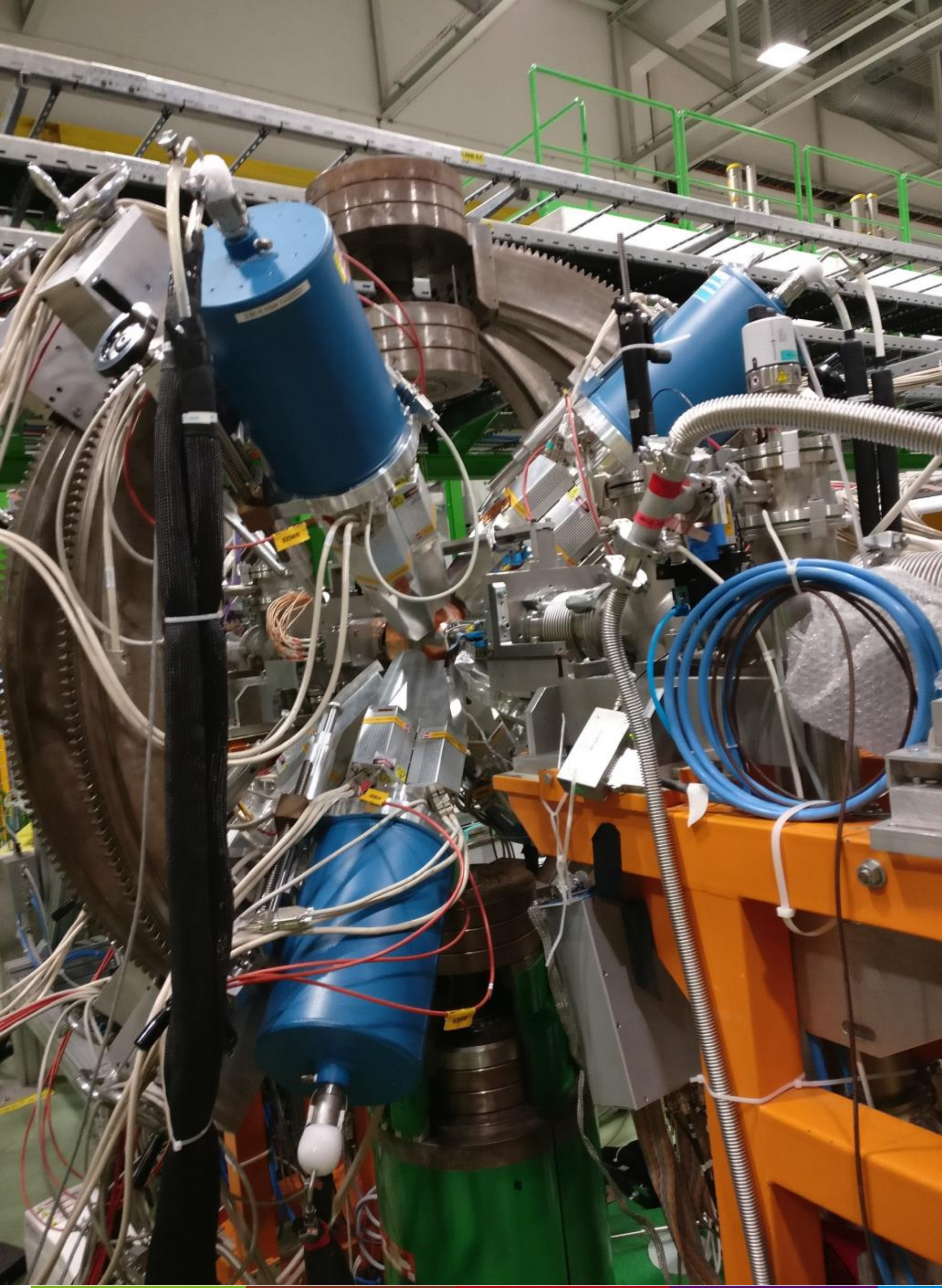
[2] D.C. Radford, *et al.* Nucl. Phys. A 752 (2005) 264c272c

*Miniball @ ISOLDE 2022

Miniball array

- 8 six-fold segmented triple HPGe-detectors
- All triples with new cryostat technology, updated preamplifier electronics
- FEBEX readout



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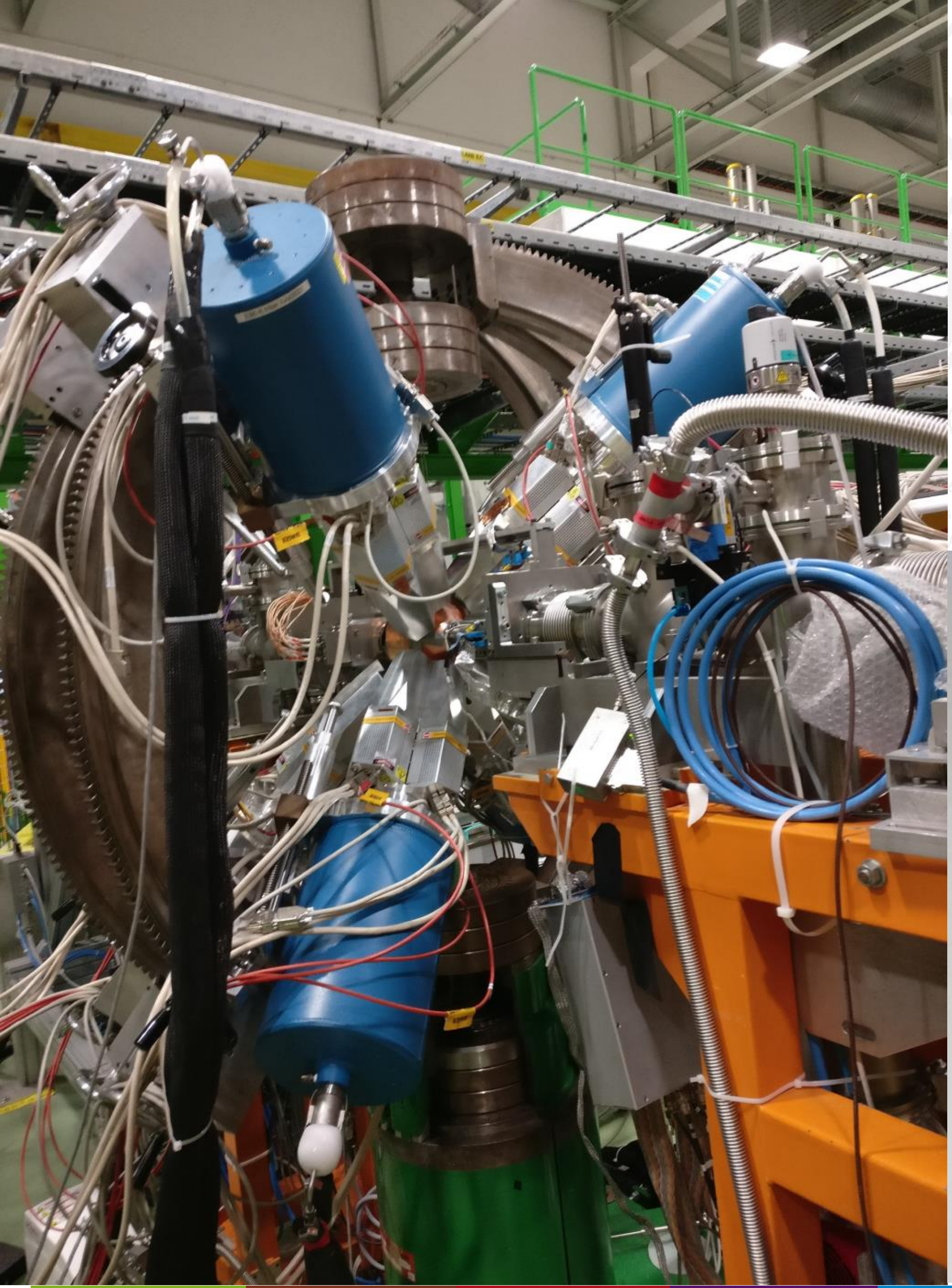
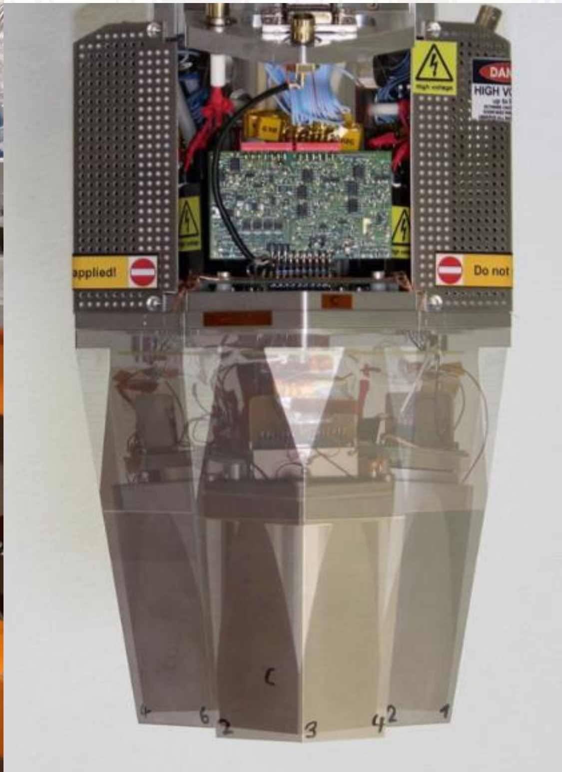
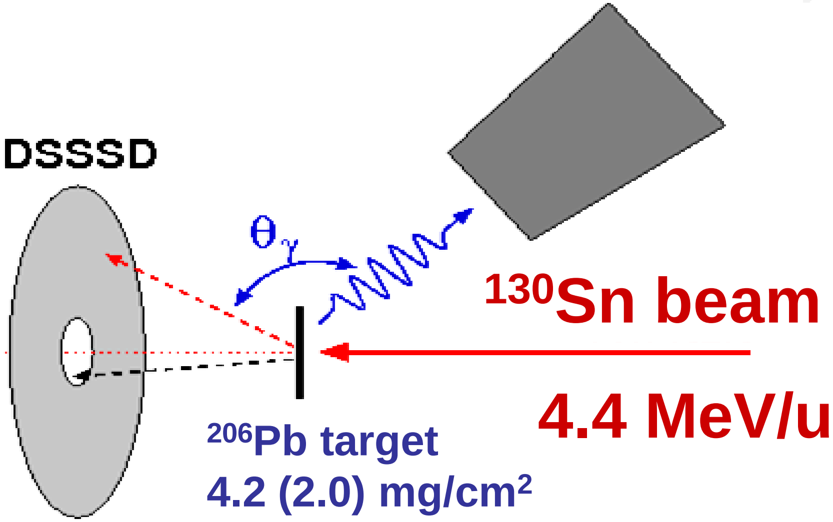
Talk by Frank Browne

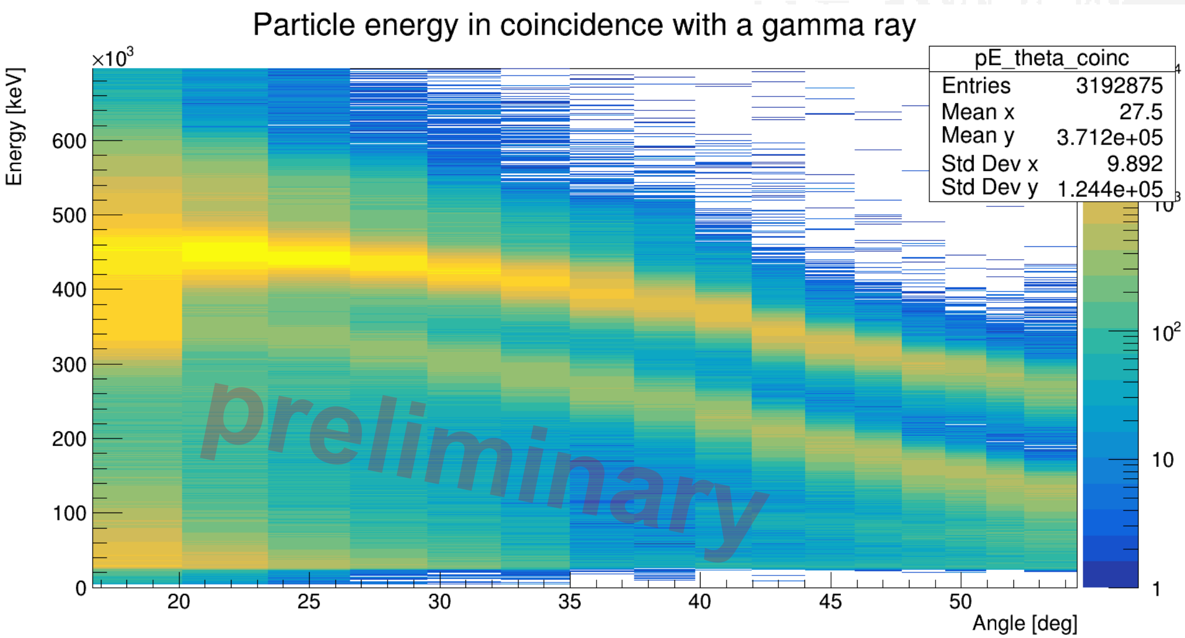


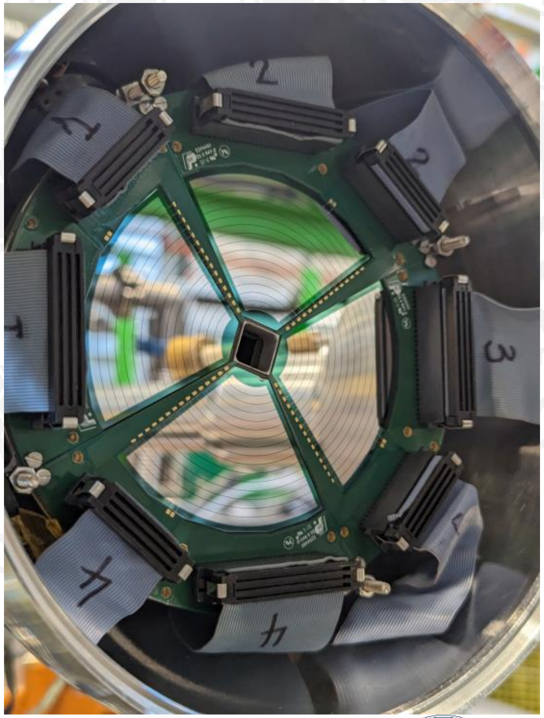


Kinematics

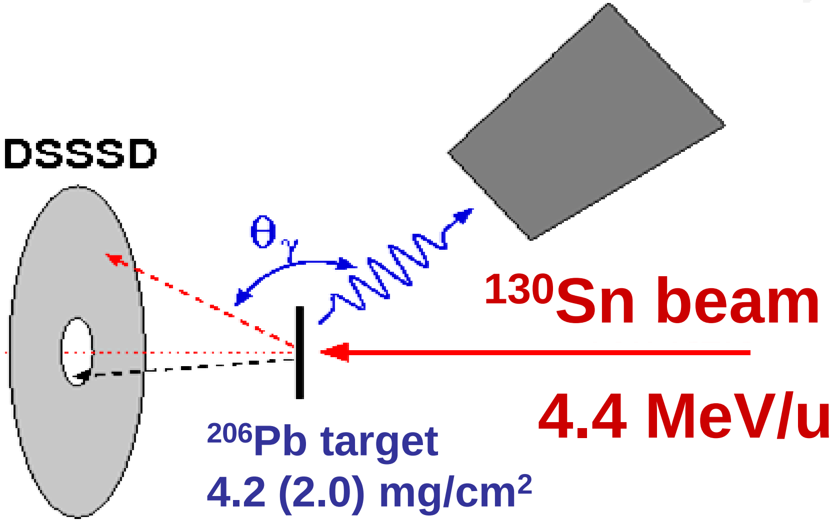
- ^{130}Sn beam, 4.4 MeV/u ($^{130}Sn^{34}S^{+}$)
- November 2022:
  - ^{206}Pb target, 2.0 mg/cm^2
  - 75 hours beamtime
  - ~5x10^5 ions/s @ target
- October 2023:
  - ^{206}Pb target, 4.2 mg/cm^2
  - 110 hours beamtime
  - ~5x10^5 ions/s @ target





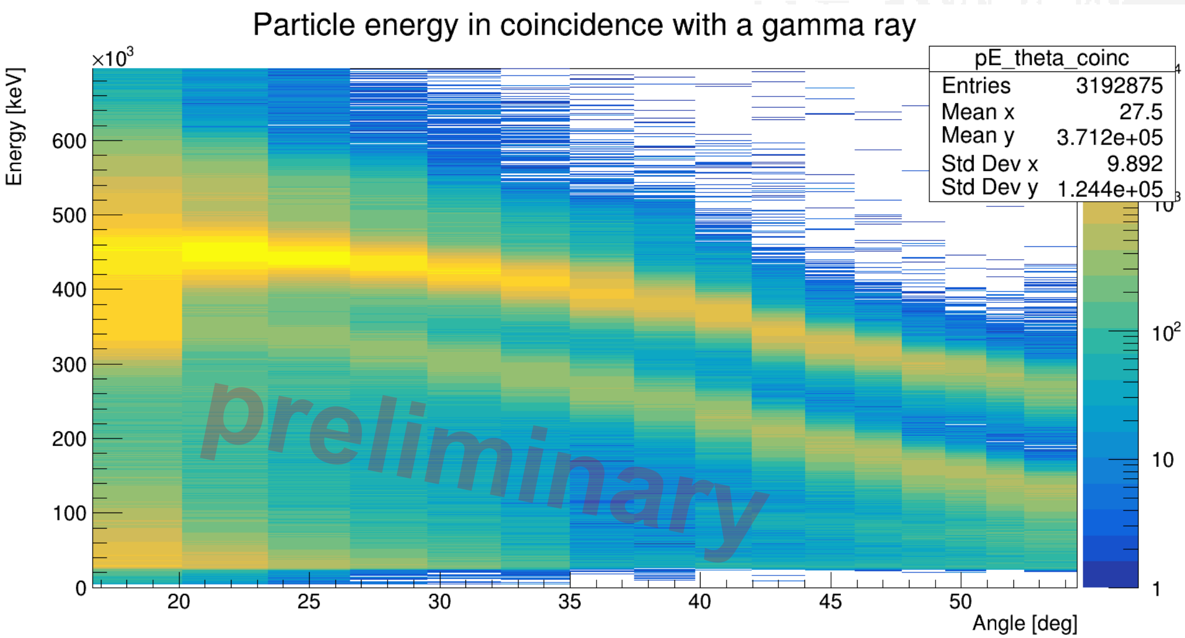


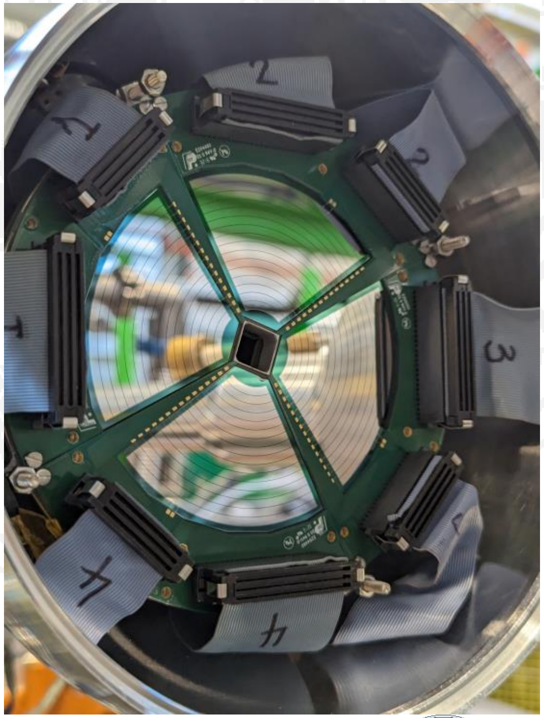
Kinematics



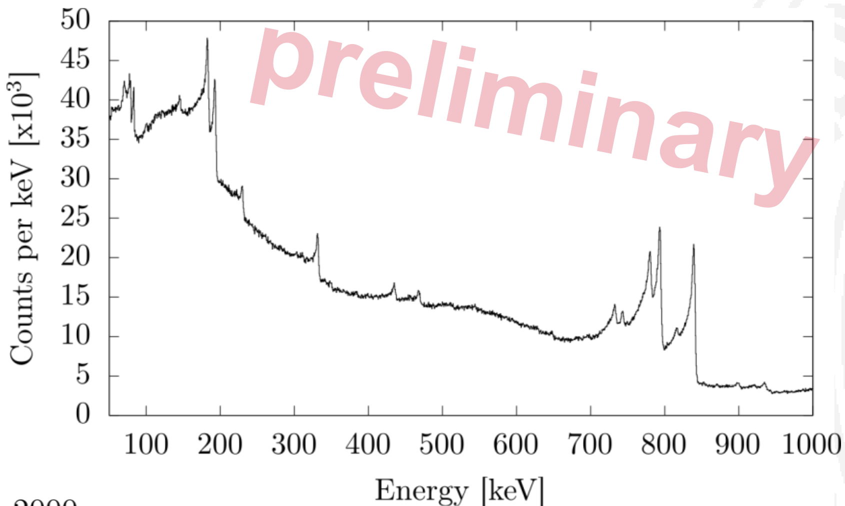
- 130S… MeV/u ($^{130}Sn^{34}S^{+}$)
- No…
  - …
  - 7…
  - ~5x10^{5} ions/s @…
- October 2023:
  - ^{206}Pb target, 4.2 mg/cm^{2}
  - 110 hours beamtime
  - ~5x10^{5} ions/s @ target

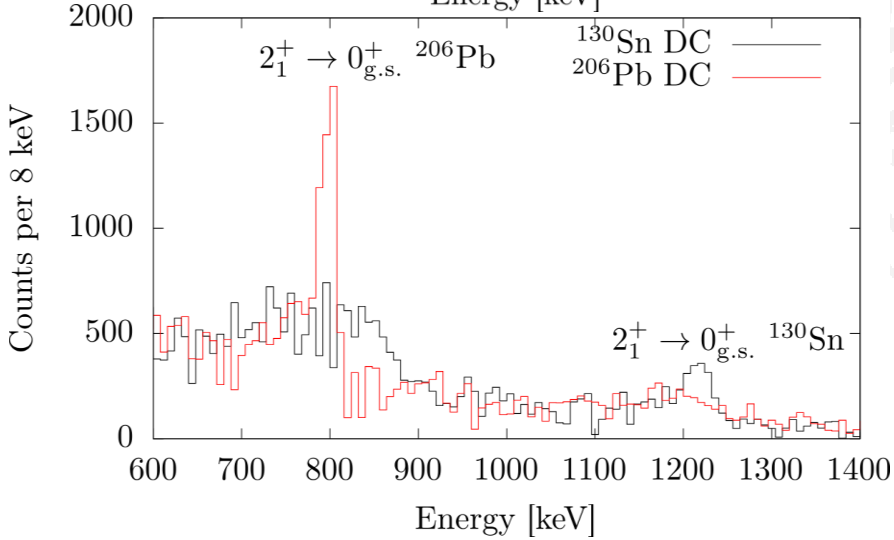
Thanks to the IS595 collaboration for extra day!





2022 data

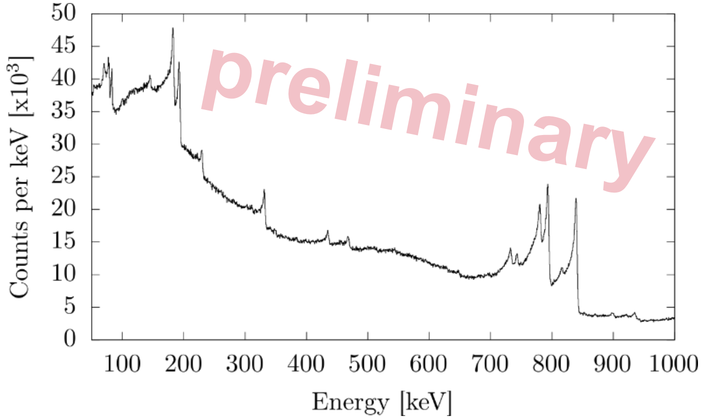


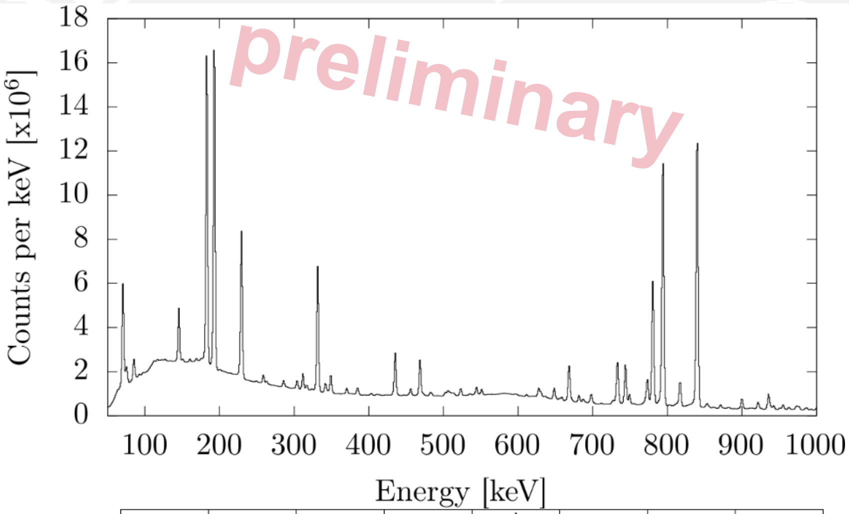


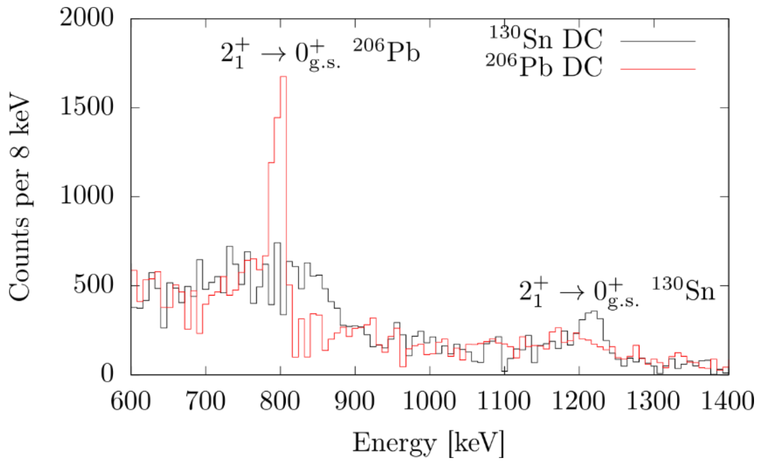
I(206Pb; 2+->0+)=3900 (400) **FWHM (803keV) = 35 keV**

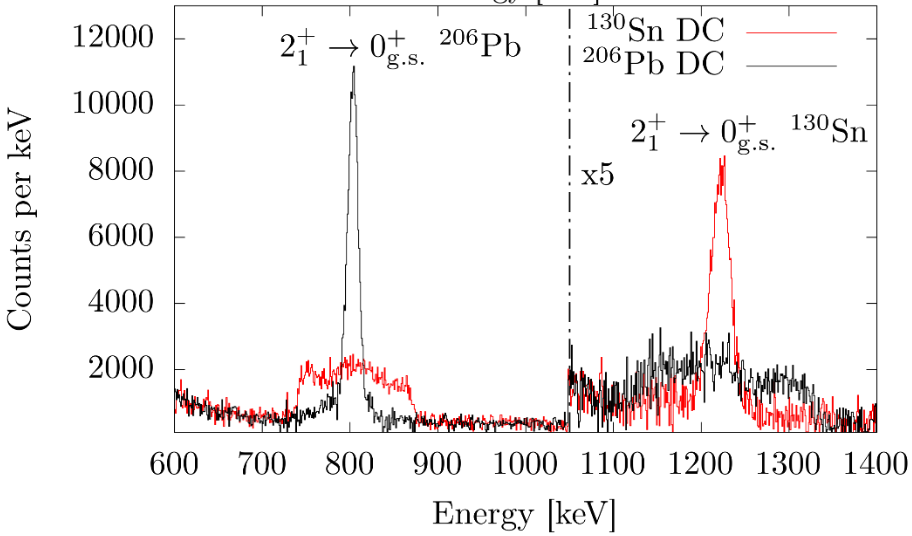
I(130Sn; 2+->0+) =1500 (300)

2022 data vs. 2023 data









I(206Pb; 2+->0+)=3.900 (400) FWHM (803keV) = 35 keV

I(130Sn; 2+->0+) =1.500 (300)

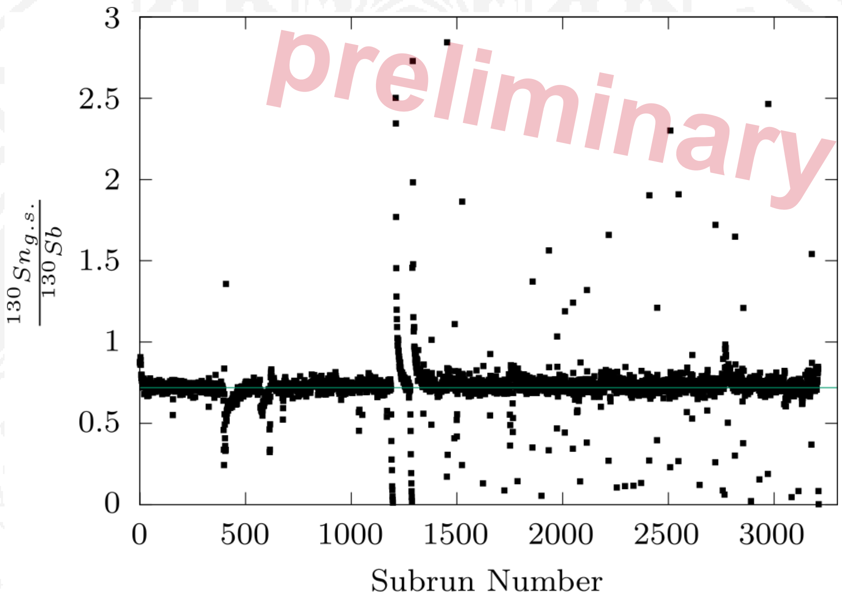
I(206Pb; 2+->0+) =162.100 (2.000) FWHM (803keV) = 14.4 keV

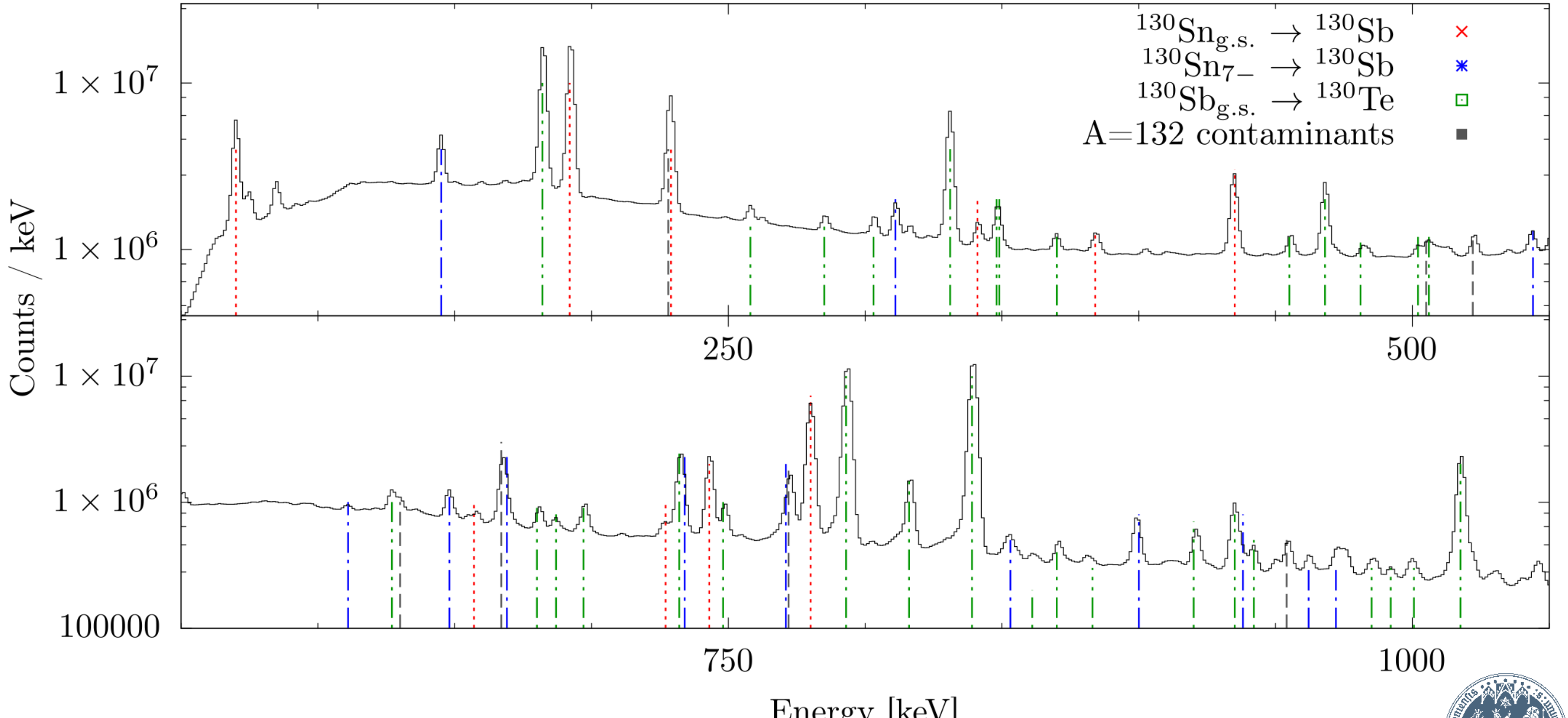
I(130Sn; 2+->0+) =40.000 (1.000)

Beam purity

Dominating ^{130}Sn

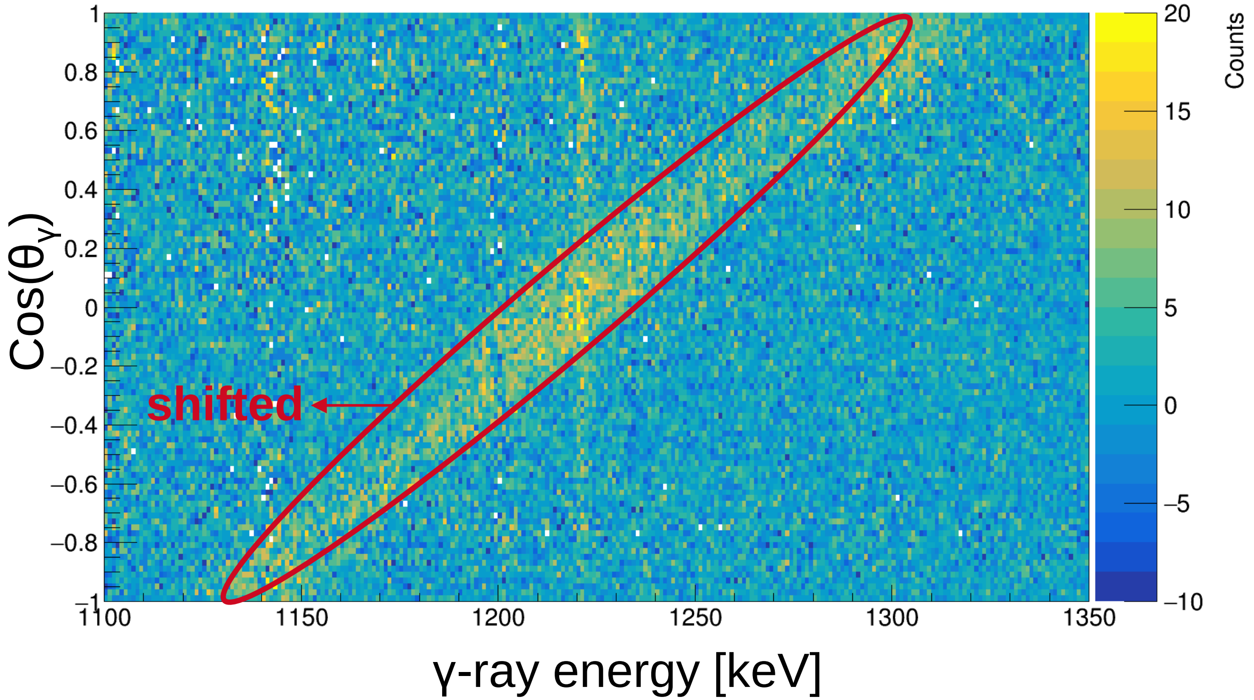
- No γ's from A=164 isobars in spectra
- Only ^{130}Sn and ^{130}Sb (and long-lived ^{132}Sn daughter nuclei from IS595)
- 70% $^{130}Sn_{g.s.}$
- 30% $^{130}Sn_{7-}$





7^- Isomer

Time of flight
Target → CD ~ 3ns.
Why do we see a stopped component?



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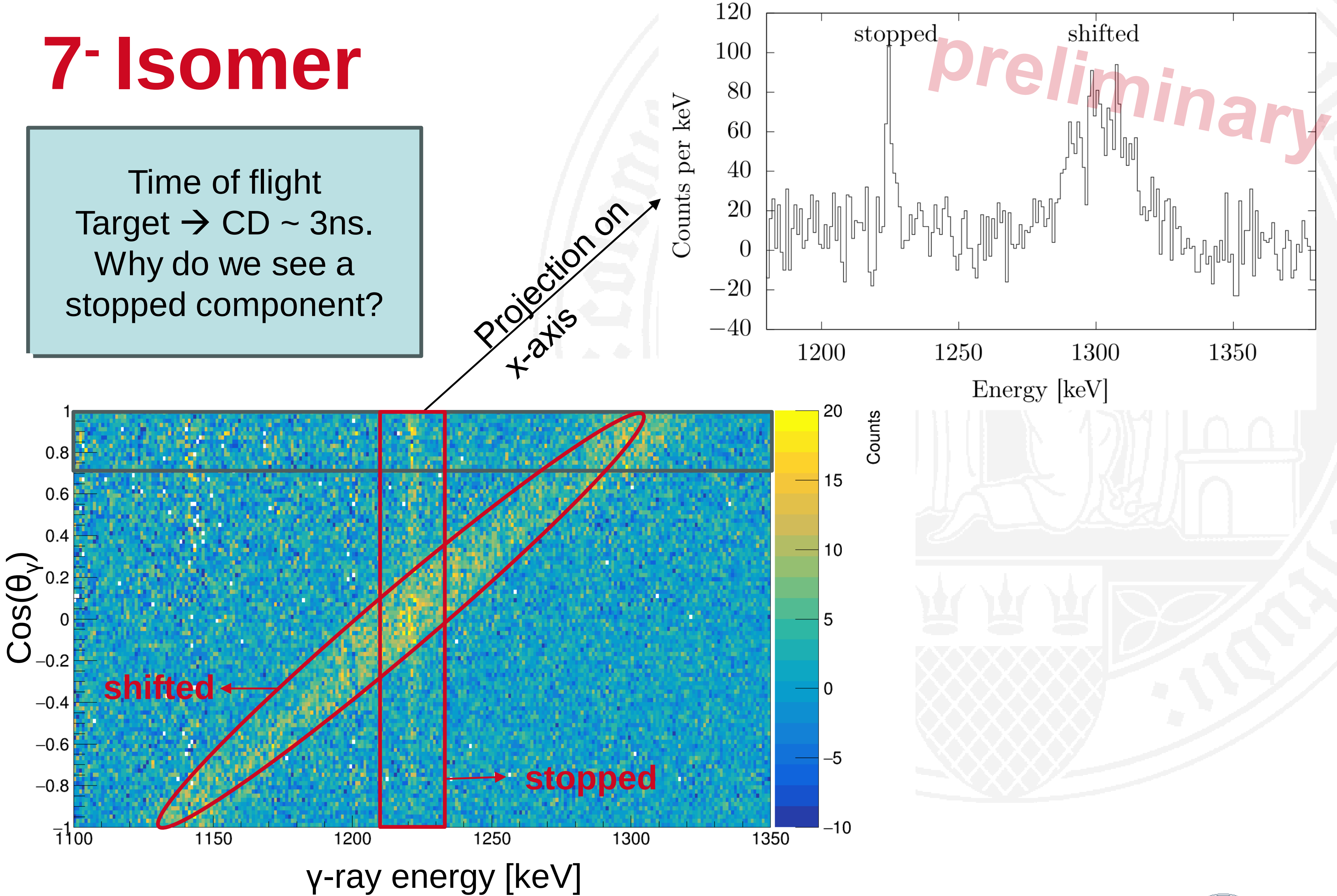
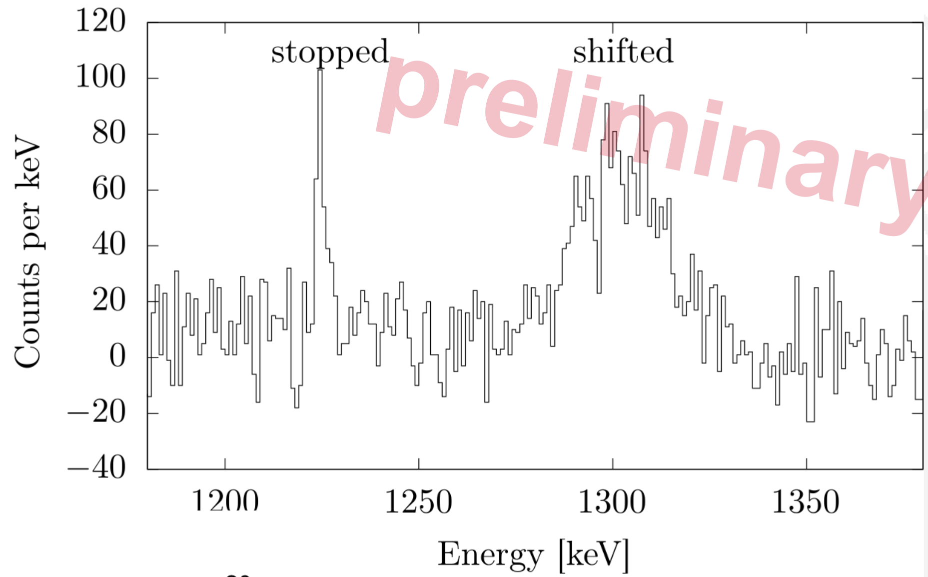
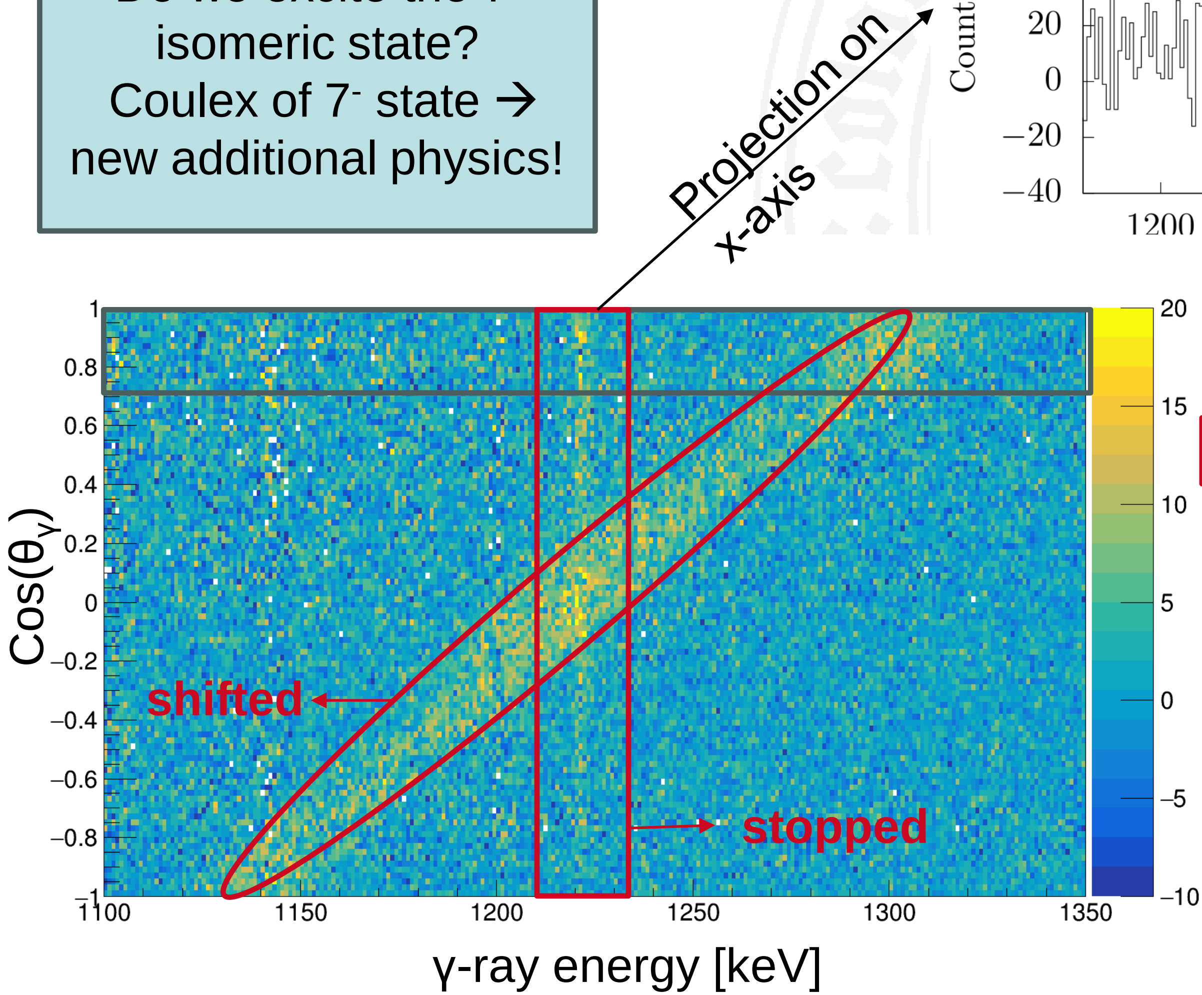
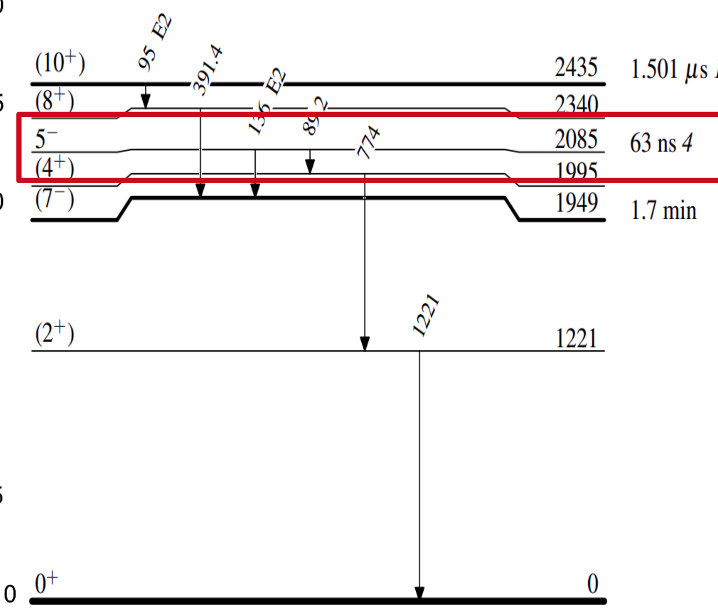


7⁻ Isomer

Do we excite the 7⁻ isomeric state?
Coulex of 7⁻ state → new additional physics!

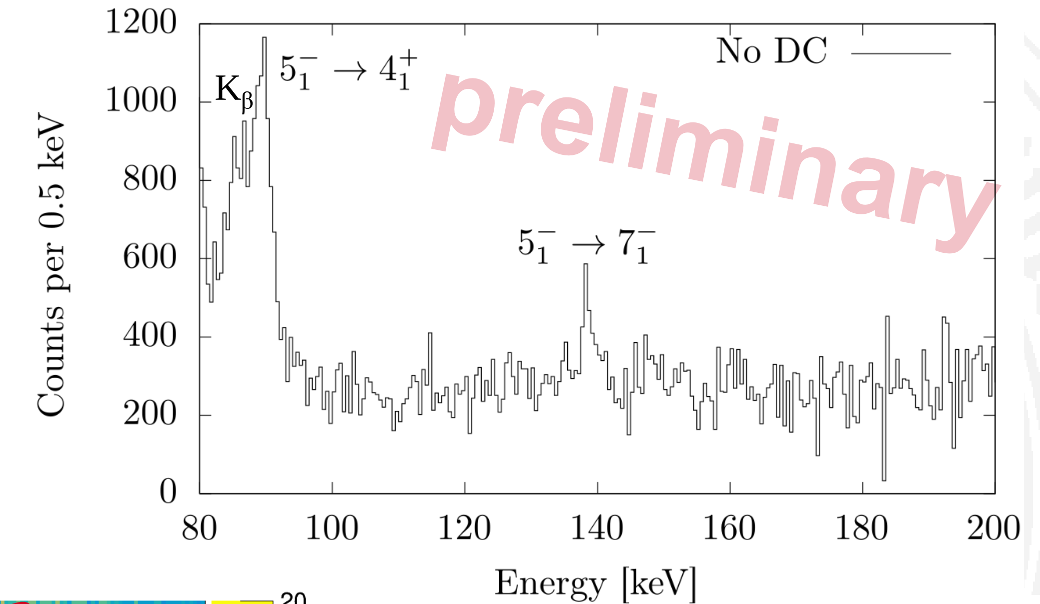


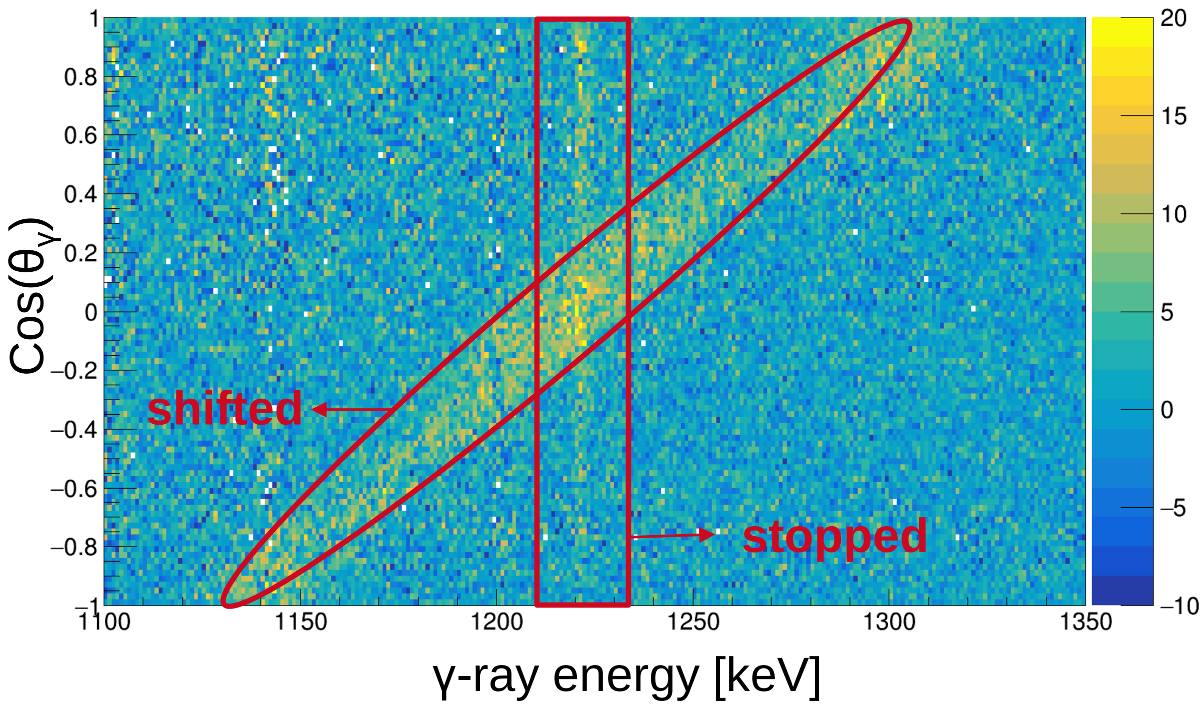


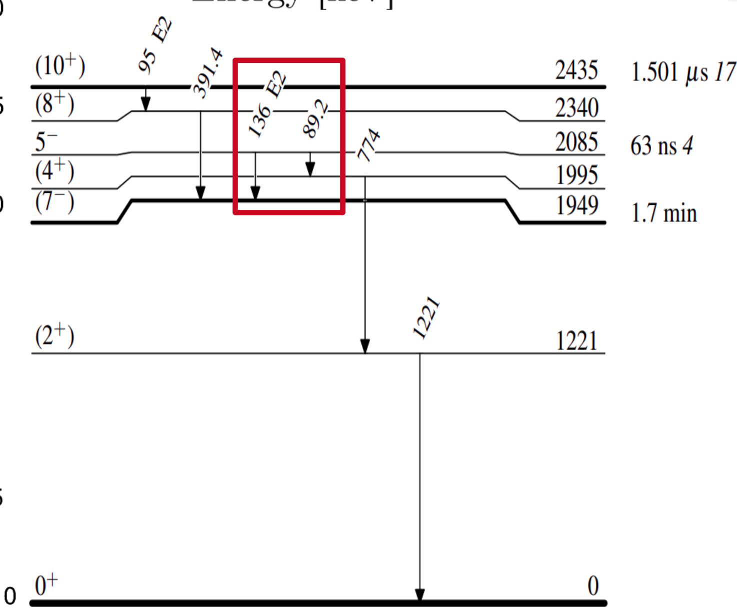


7^- Isomer

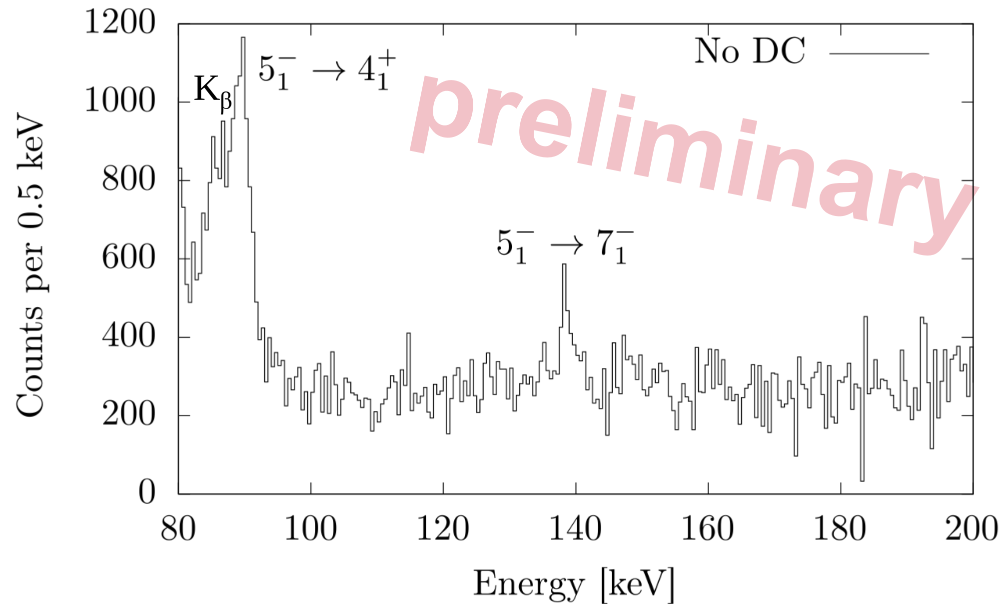
Coulex of 7^- state
Two other decay lines
from 5^- state



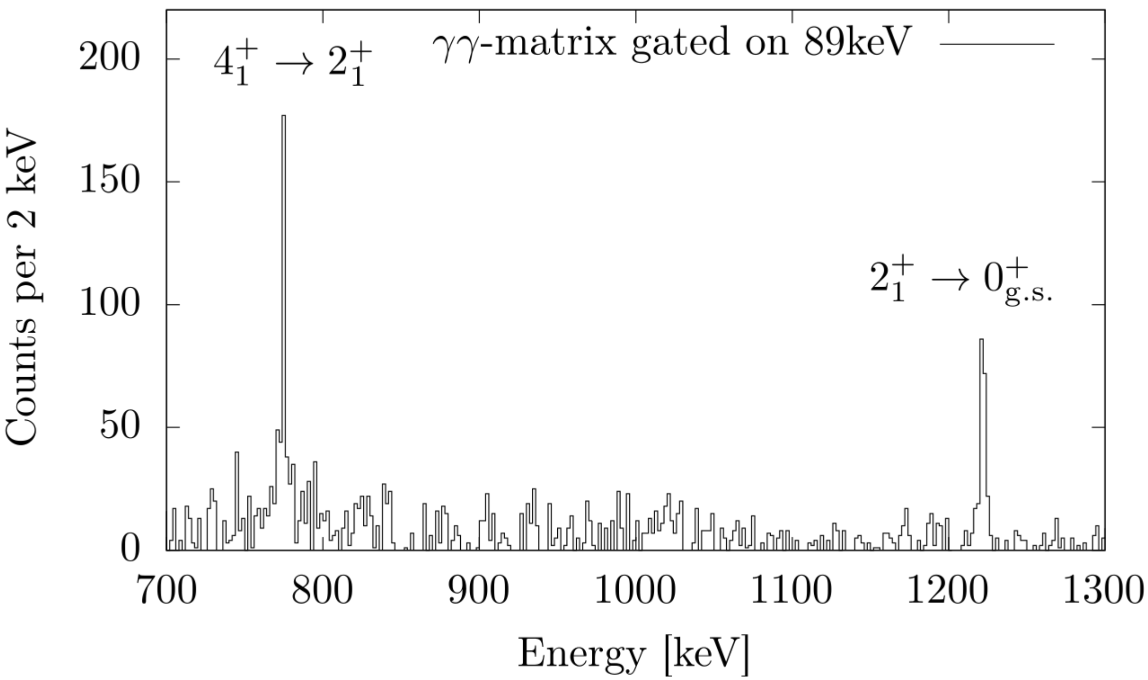


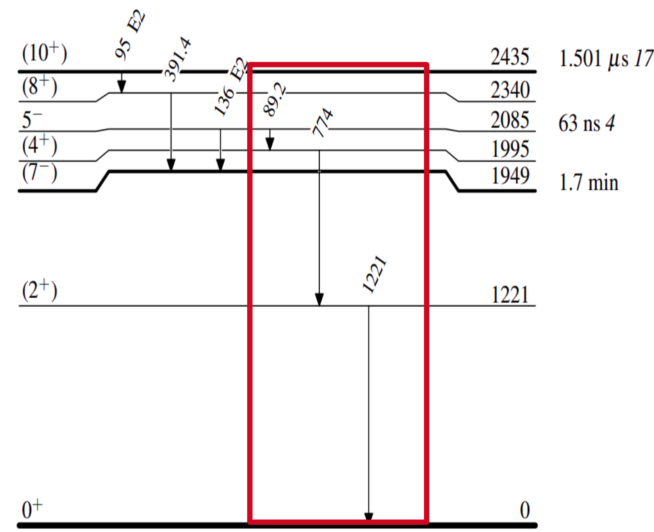


7^- Isomer



Coulex of 7^- state
Coincidence gate on $5^- \rightarrow 4^+$
Cascade $4^+ \rightarrow 2^+ \rightarrow 0^+$





Summary & Outlook

Two Coulomb excitation experiments performed with Miniball @ ISOLDE

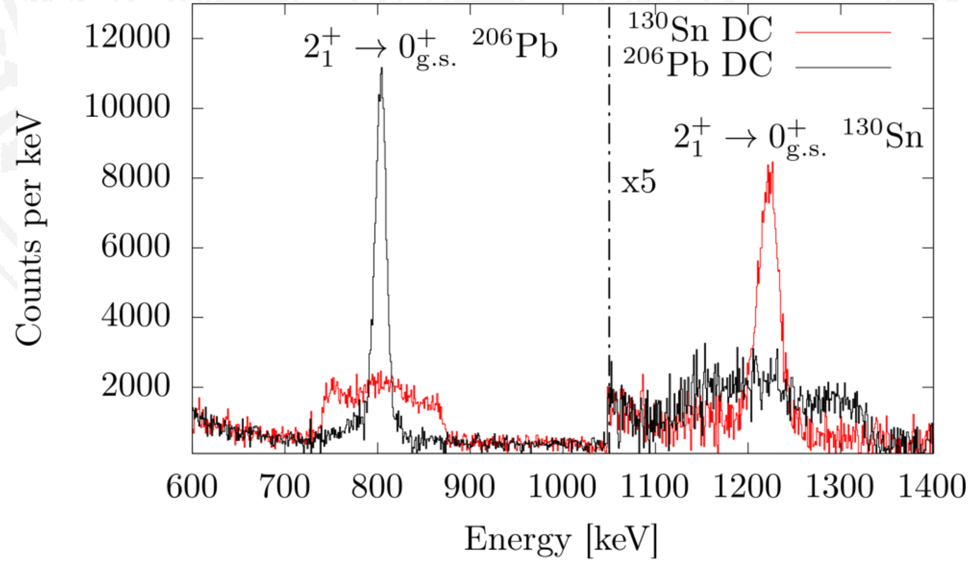
Previous result of GOSIA analysis of B(E2)-value in excellent agreement with theory, but with large stat. uncertainties

→ Remeasured B(E2) value in 2023
→ 110 hours stable beamtime; 5×10^5 ions/s
→ Improved DAQ and beam focus
→ High statistics run
→ Reducing B(E2; $2^+ \rightarrow 0^+_{g.s.}$) uncertainty
→ Nuclear structure information of 7^- isomer and 5^- excited state will be obtained

Beam composition

Two-step excitation? 4^+ state?

GOSIA analysis for B(E2; $2^+ \rightarrow 0^+_{g.s.}$) and B(E2; $5^- \rightarrow 7^-$) values



Thank you for your attention and thanks to the IS702 Collaboration

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IKP

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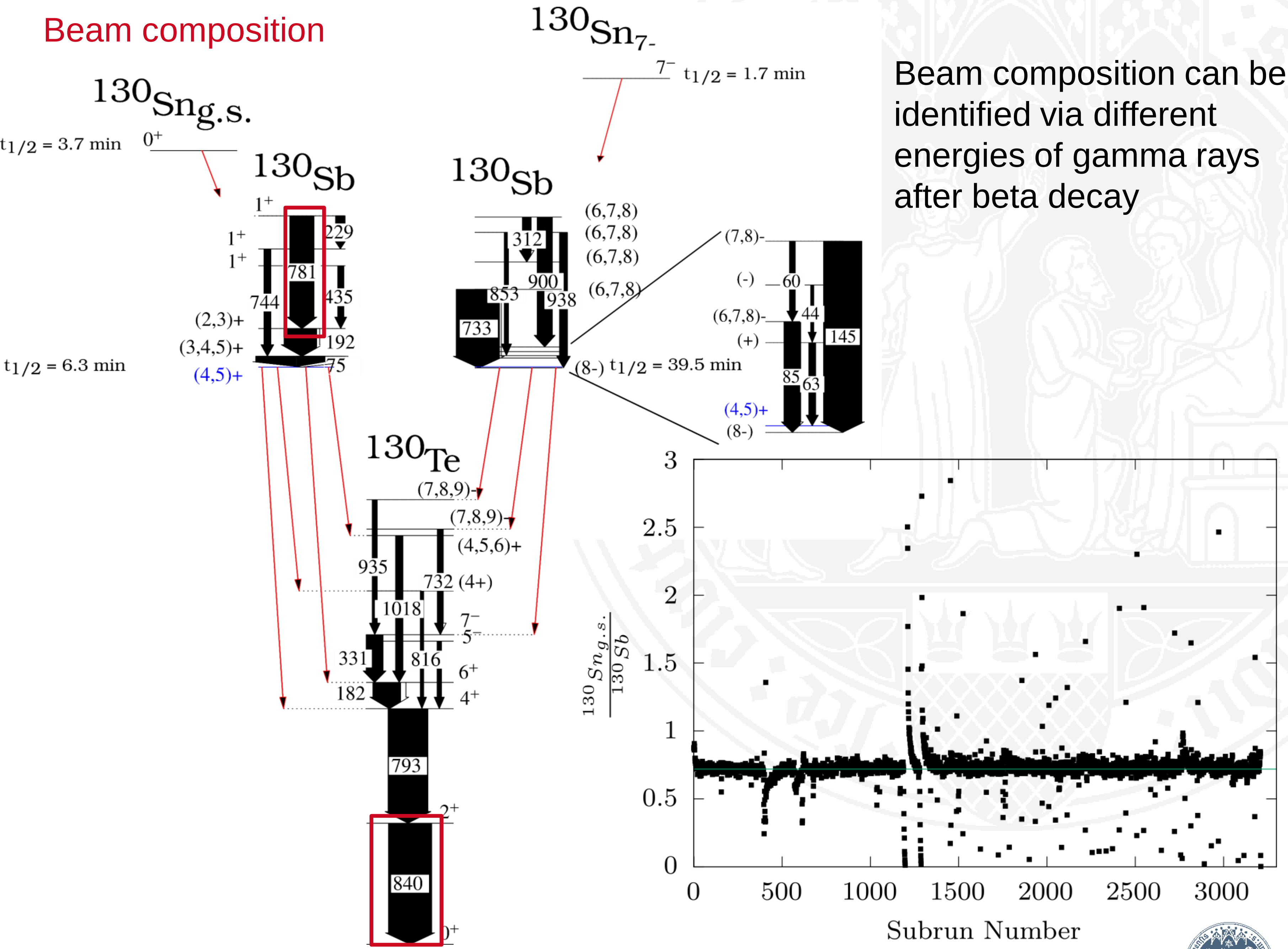
MINIBALL

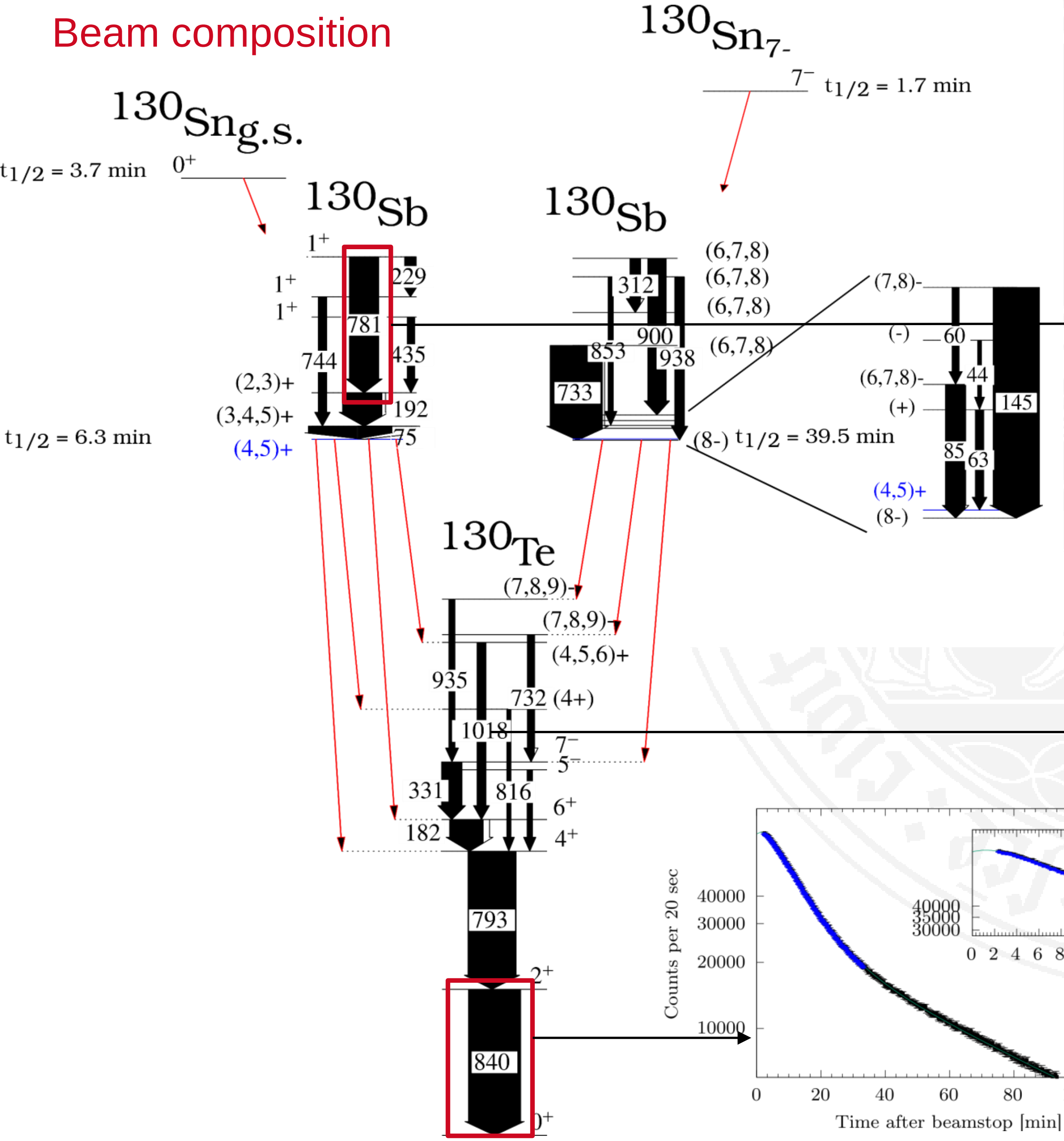
Bundesministerium für Bildung und Forschung

Beam composition



Beam composition can be identified via different energies of gamma rays after beta decay

Beam composition



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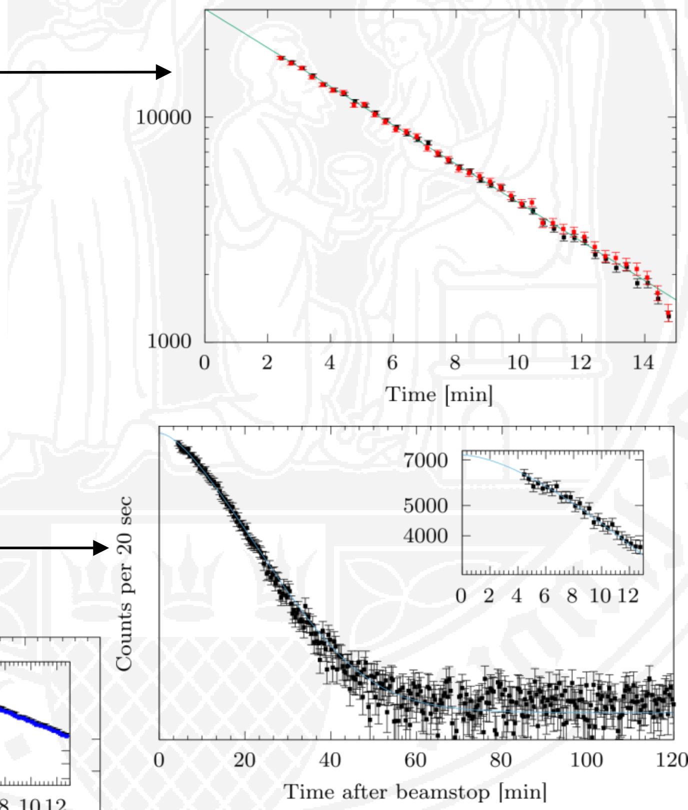


New Miniball cryostats*

General structure:

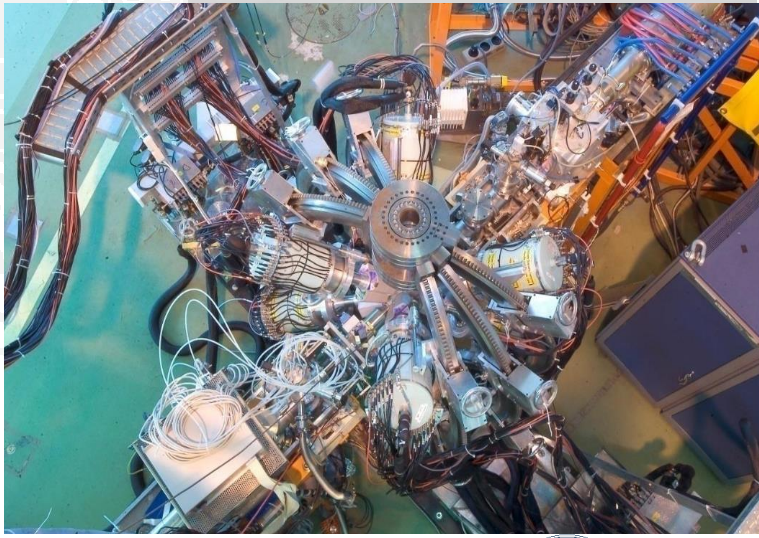
- Eight triple cryostats
- Six-fold segmented HPGe crystals
- 168 high-resolution channels

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

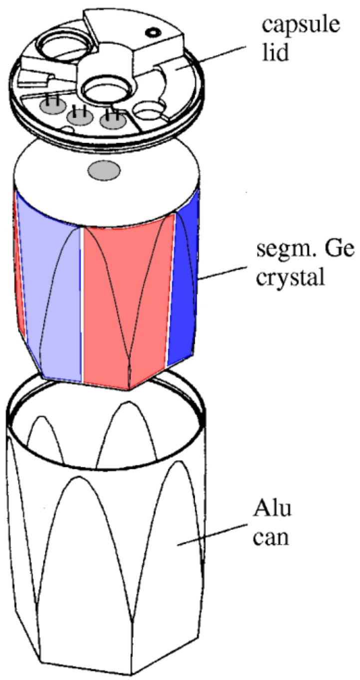
Old:

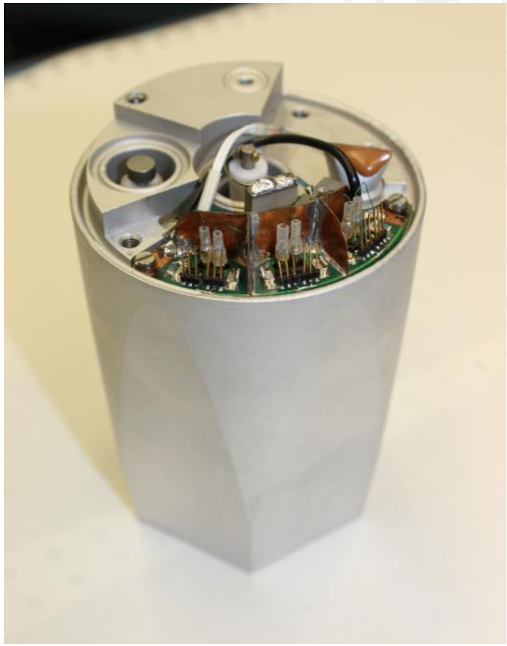
- Welded design

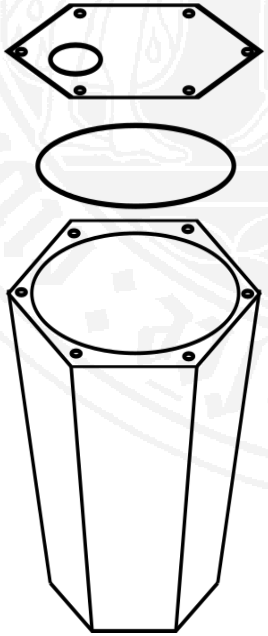
→ Elaborate and expensive repairs

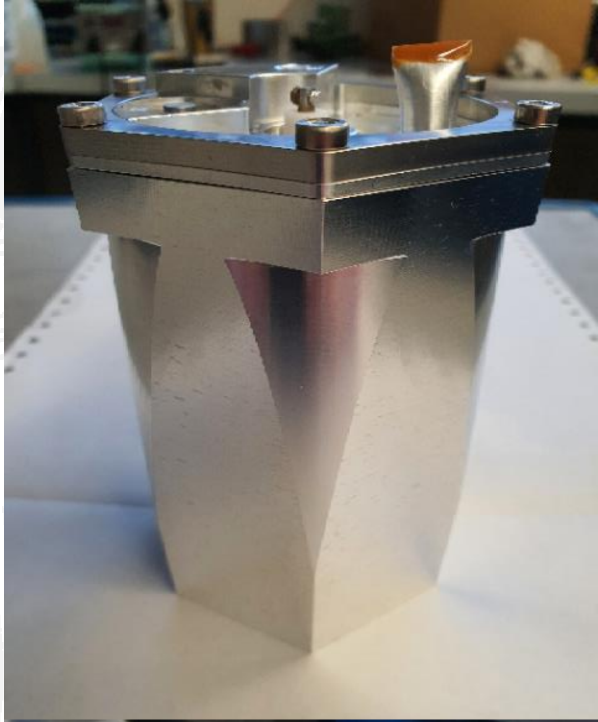
New:

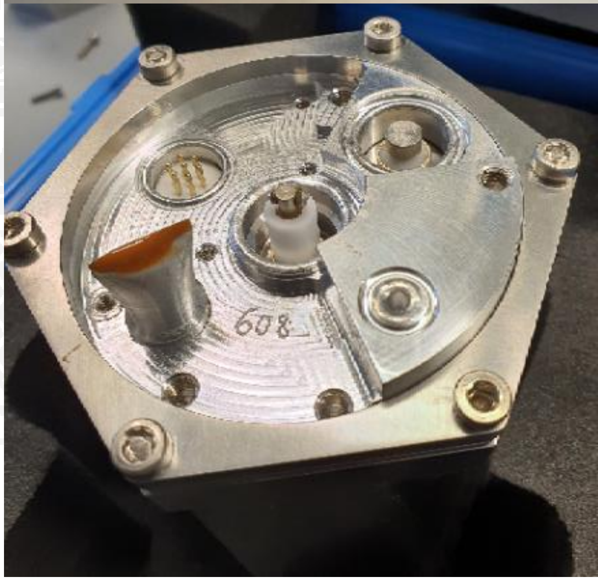
- Lid fixed by screws
- Metal-elastic seal
- Highly temperature resistant
- UH vacuum
- Fast and cost effective repairs











New cryostat design

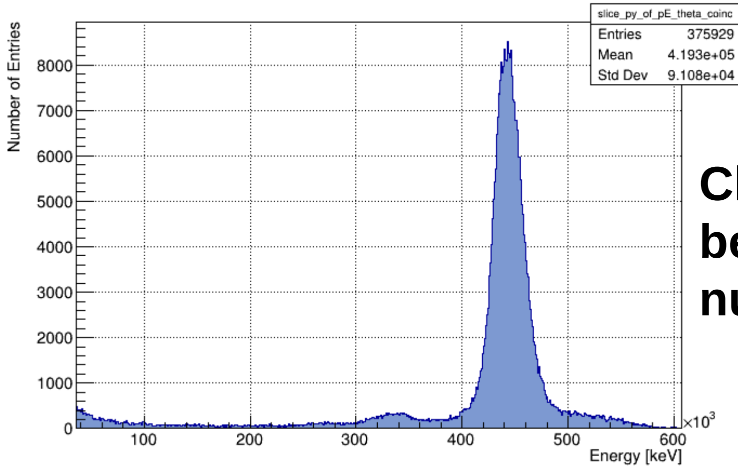
Old:
- Long neck for BGO backscattering
- Movable lid

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

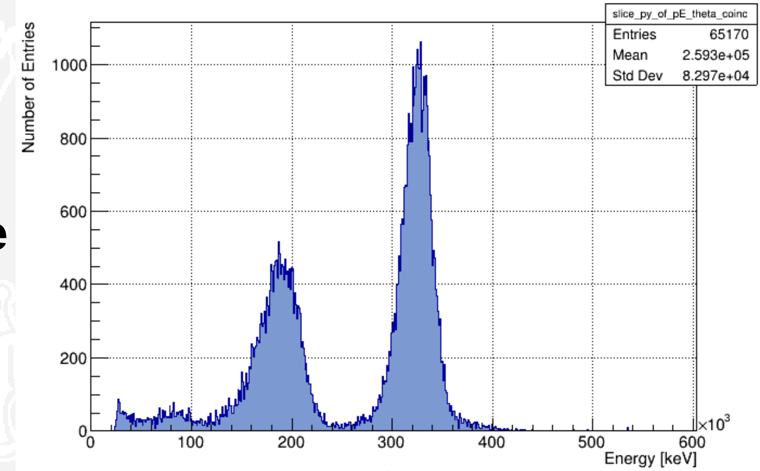
New analog preamplifier electronics

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

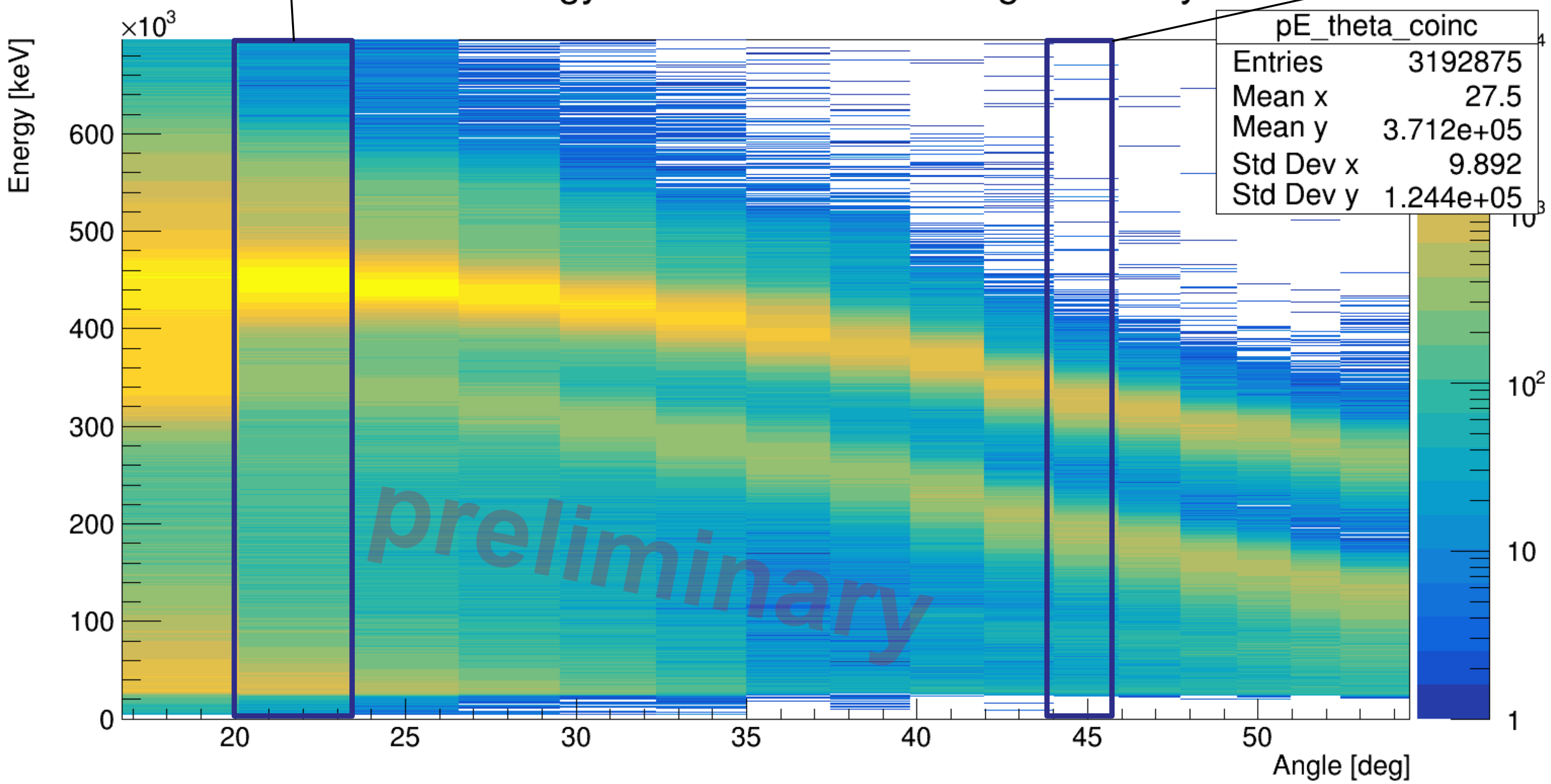
New:
- Plug-in electronic parts
- Welded feedthroughs
- AGATA preamplifier
- Three preamplifier boards: One core, two segments



Clear separation of beam and target like nuclei



Particle energy in coincidence with a gamma ray



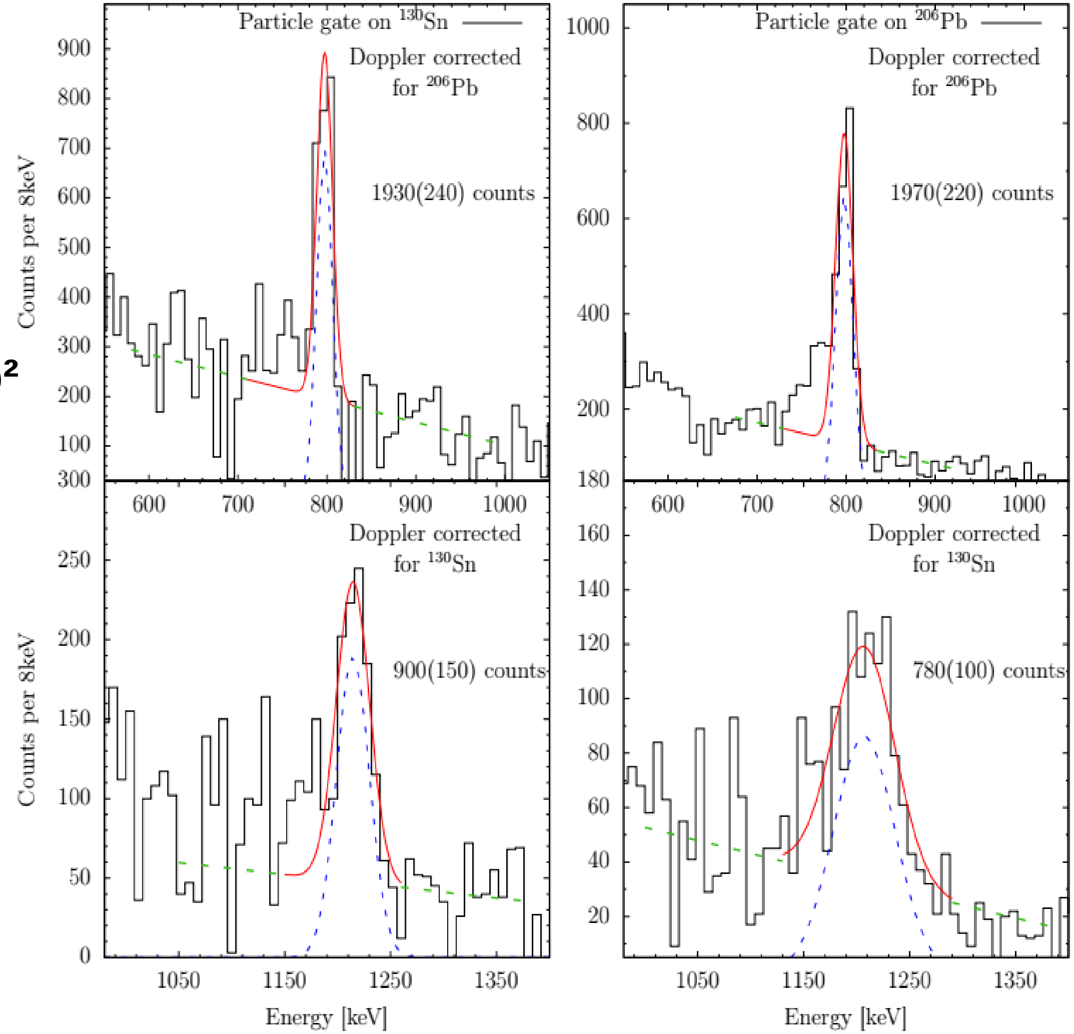
Preliminary GOSIA2 analysis

PRELIMINARY RESULT:

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

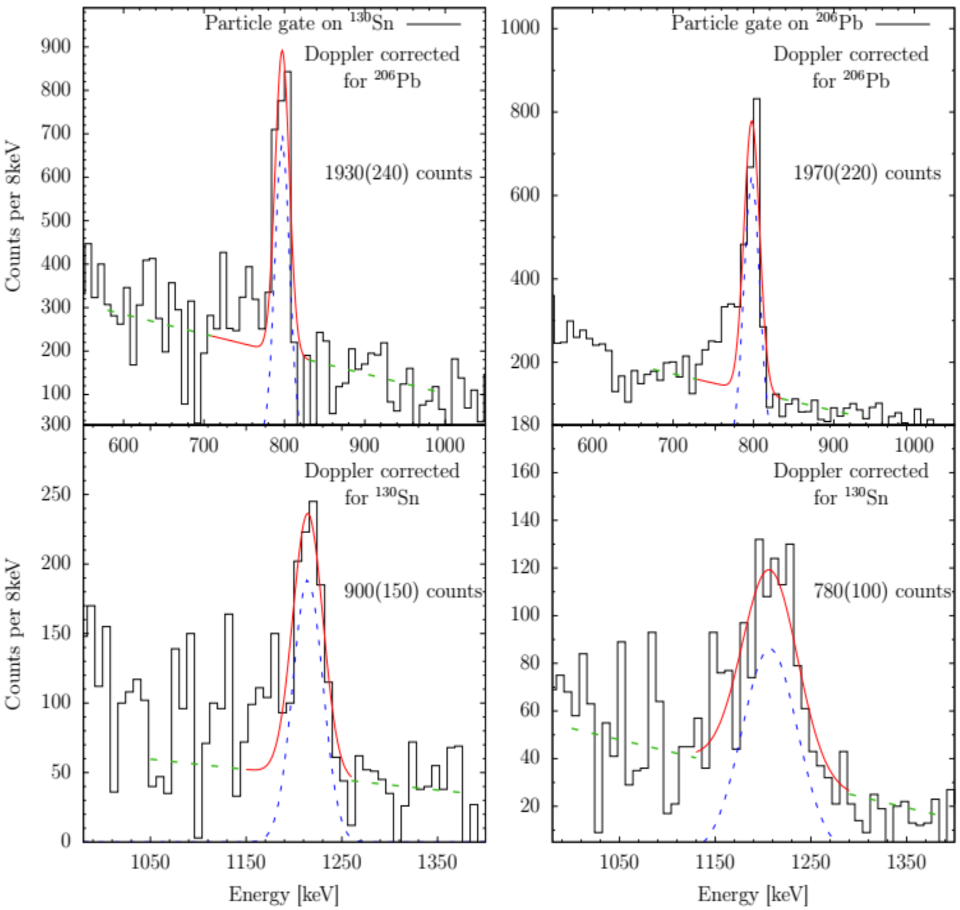
$B(E2; 0^+ \rightarrow 2^+)_{\text{ORNL}} = 0.023(5)\ e^2b^2$ [1]

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

Results ^{130}Sn



Beam current: ^{130}Sn beam current ~ **5*10⁵ ions/second** (reduced proton current)

Beam purity: dominating ^{130}Sn (^{130}Sb ?)
- Doppler correction: no γ's from stable or instable A=130, 164 isobars
  - No γ's from A=164 isobars in spectra
  - ^{130}Sb ~10%

Isomeric to ground state ratio: ~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!

Preliminary results

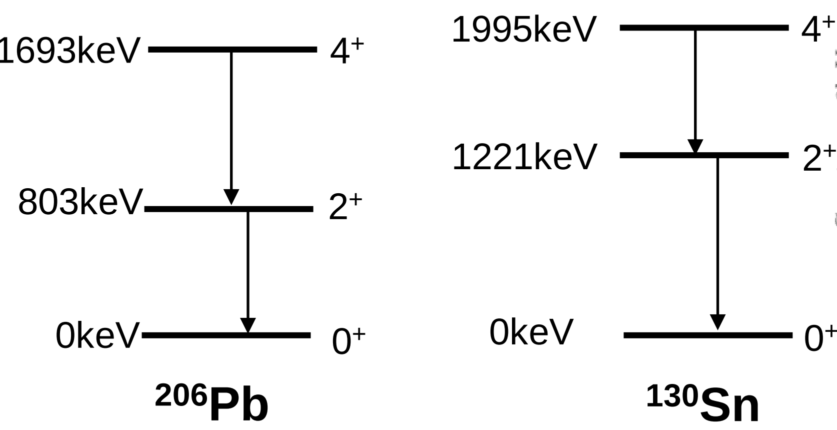
Total intensity:

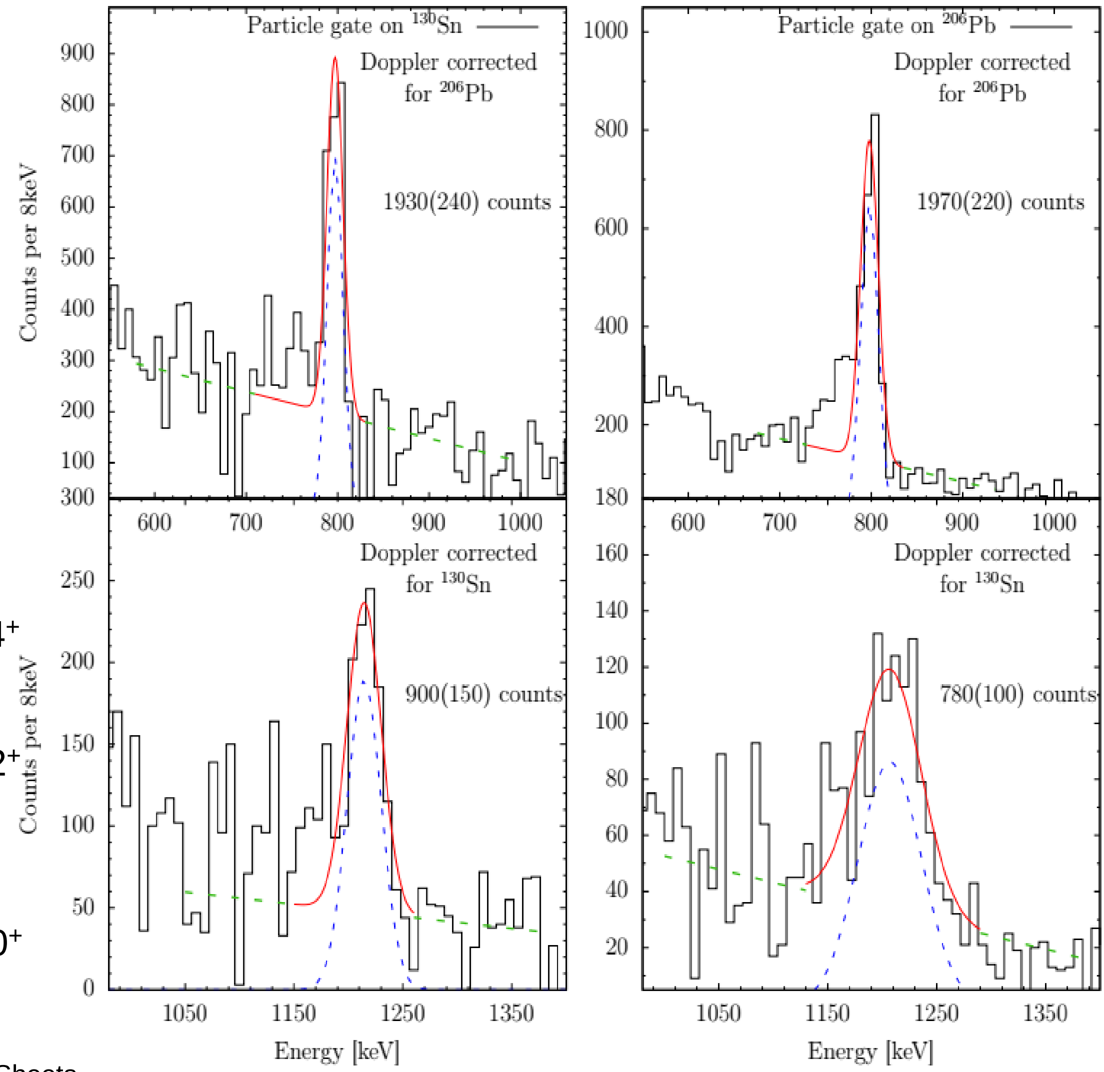
$I_{206Pb}(2^+ \rightarrow 0^+) = 3900(350)$

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

Beam purity: ^{130}Sn ~75%

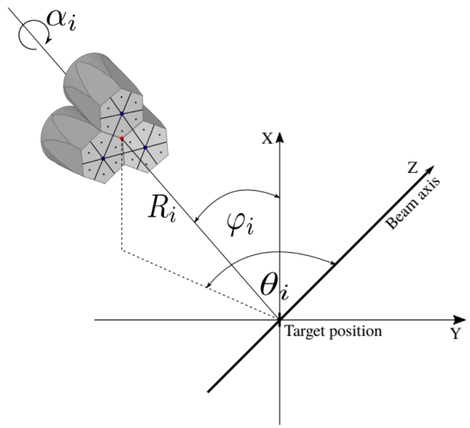
Matrix element ^{206}Pb for normalization:
$M(E2; 2^+ \rightarrow 0^+) = 0.3178(47)$ eb [1]

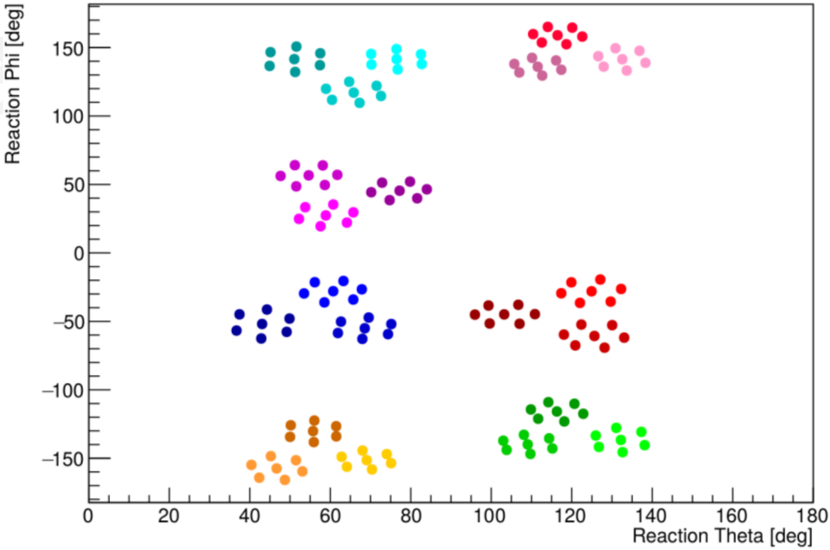


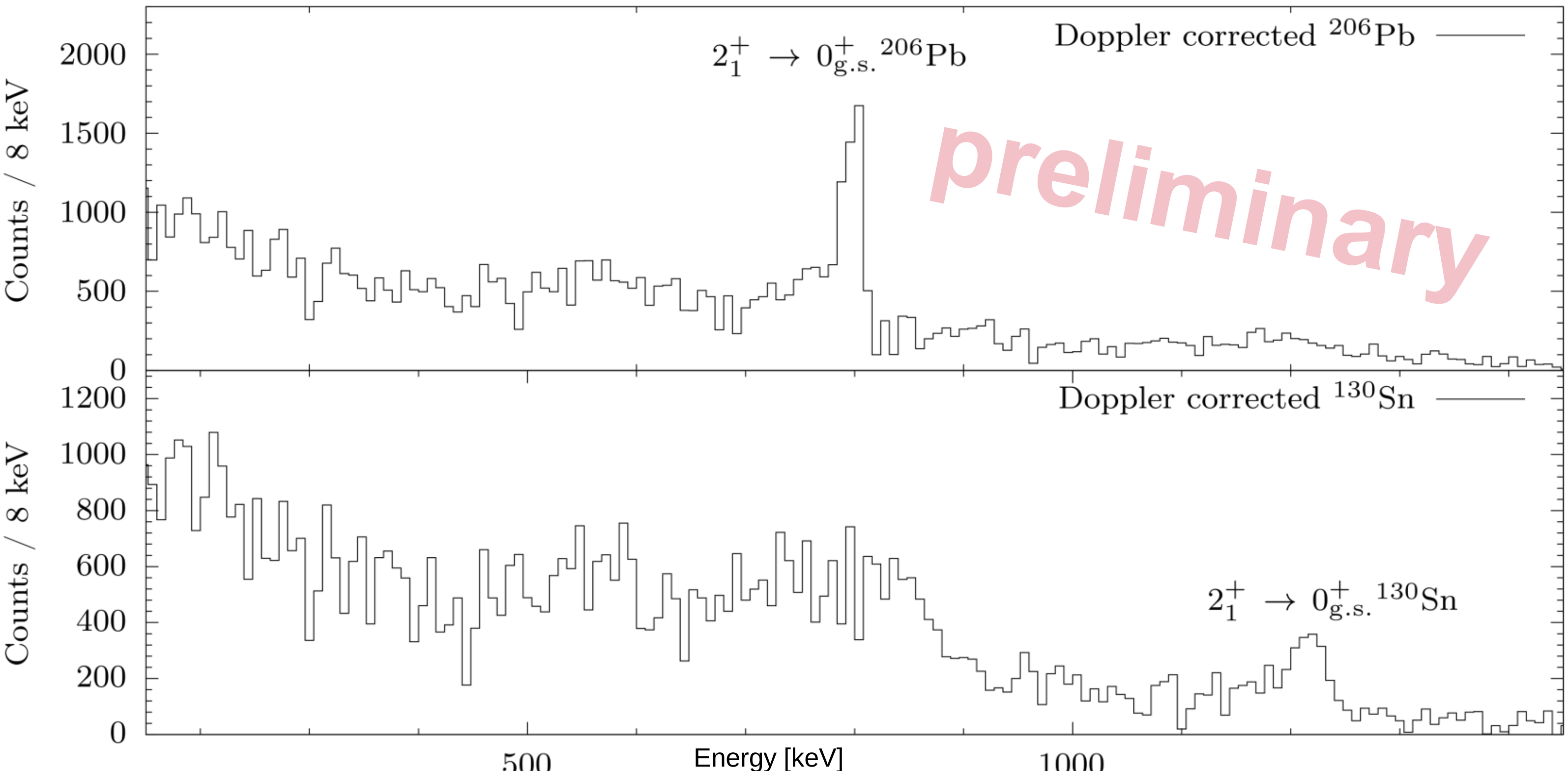


[1] F. G. Kondev. "Nuclear Data Sheets for A = 206." In: Nucl. Data Sheets 109.6 (2008), pp. 1527–1654

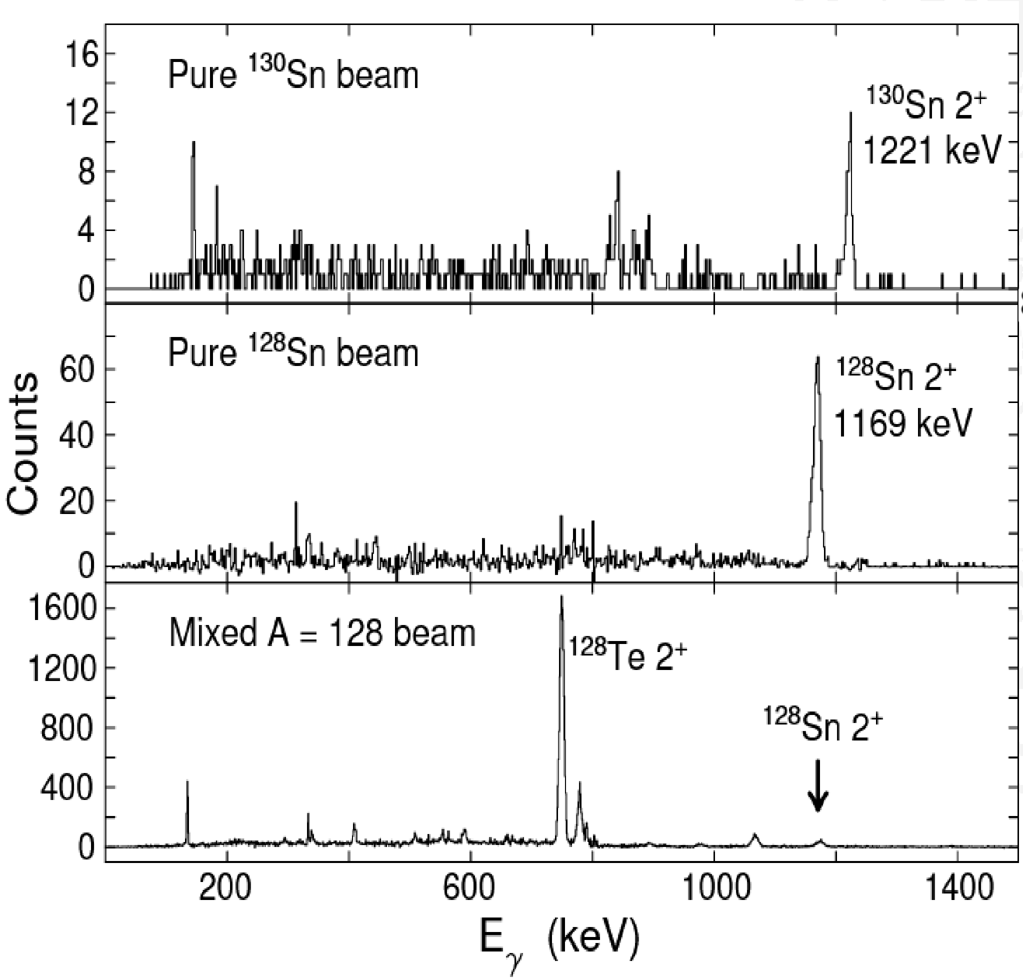
Doppler-corrected spectra

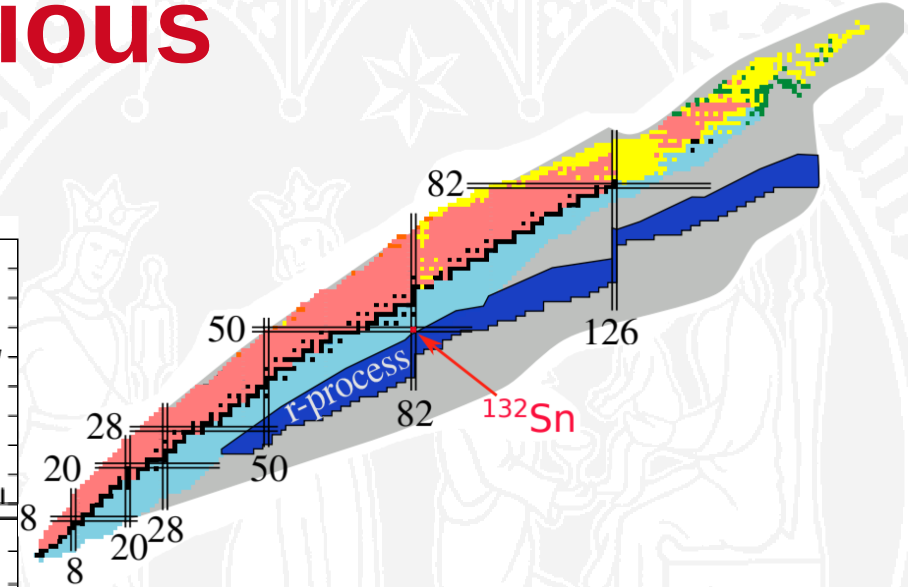


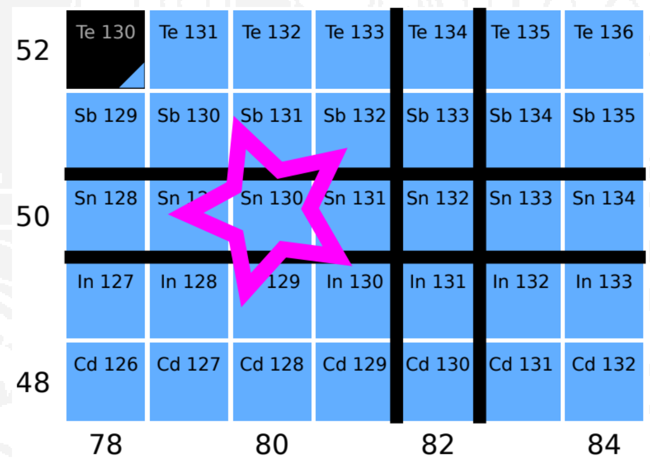




^{130}Sn Coulex – previous experiment







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

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