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SPECTROMETER ELECTRON DETECTION

UNIVERSITY OF JYVÄSKYLÄ

The SPEDE spectrometer for Coulomb excitation experiments at HIE-ISOLDE

Philippos Papadakis

3rd GOSIA Workshop

Outline

- The SPEDE spectrometer
- Testing and commissioning
- GEANT4 simulations
- Approved experiments
- Physics case 1: Shape coexistence in $^{186,188}Pb$
- Physics case 2: Octupole collectivity in Rn and Ra nuclei
- Other applications of SPEDE
- Outlook

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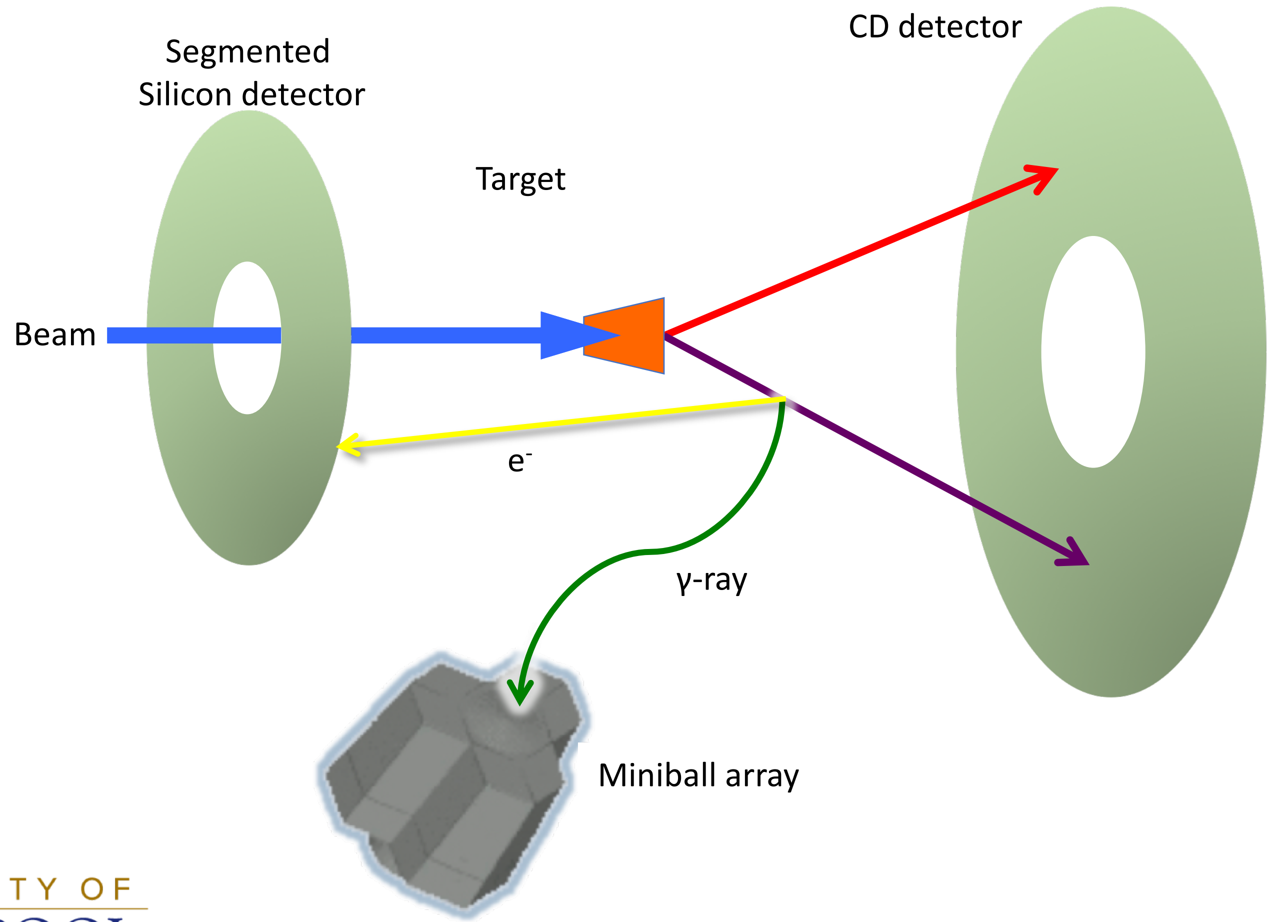
The SPEDE spectrometer

- The concept



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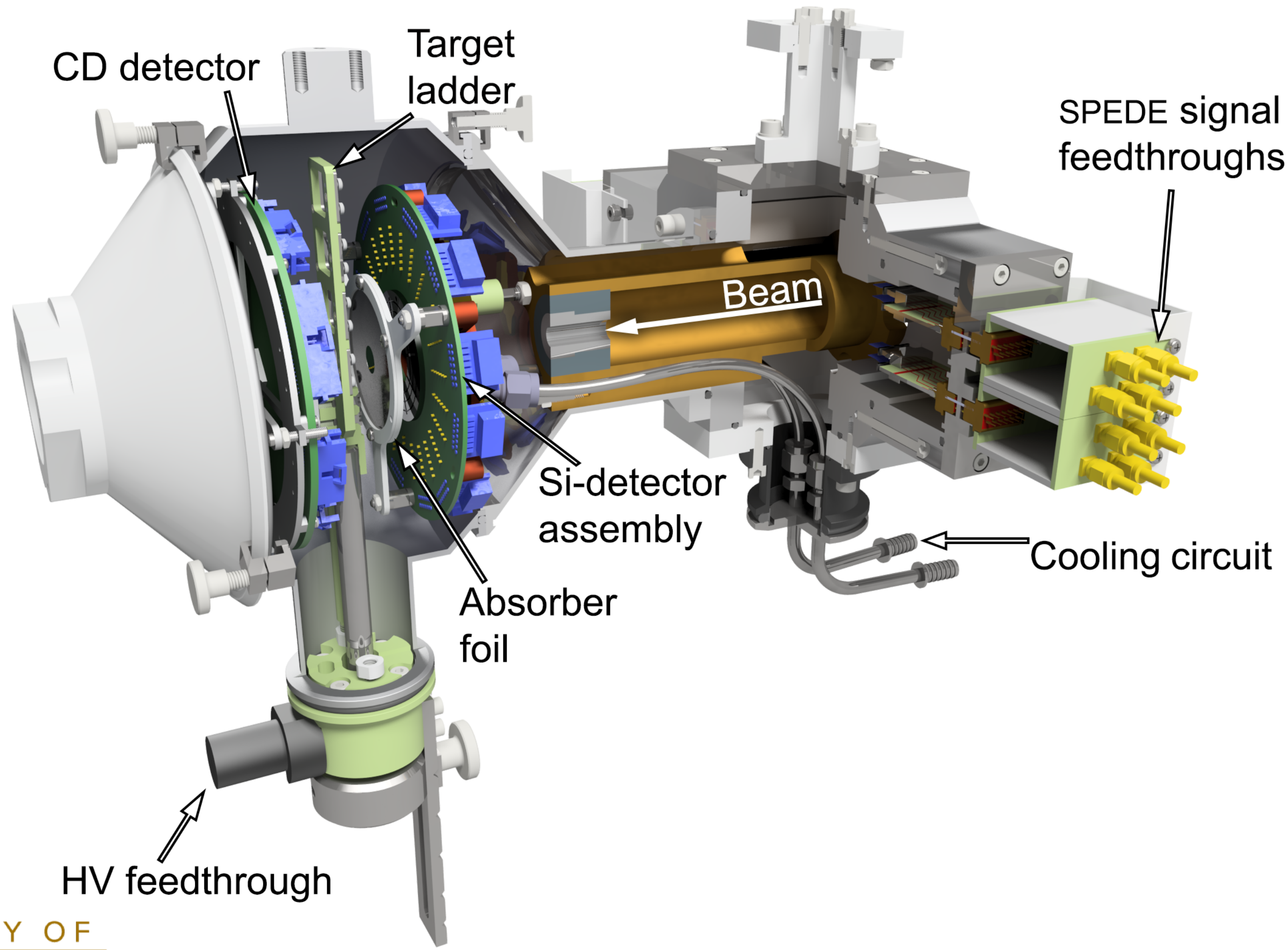
The SPEDE spectrometer

- Final design



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P. Papadakis *et al*. Eur. Phys. J. A (2018) 54: 42

The SPEDE spectrometer

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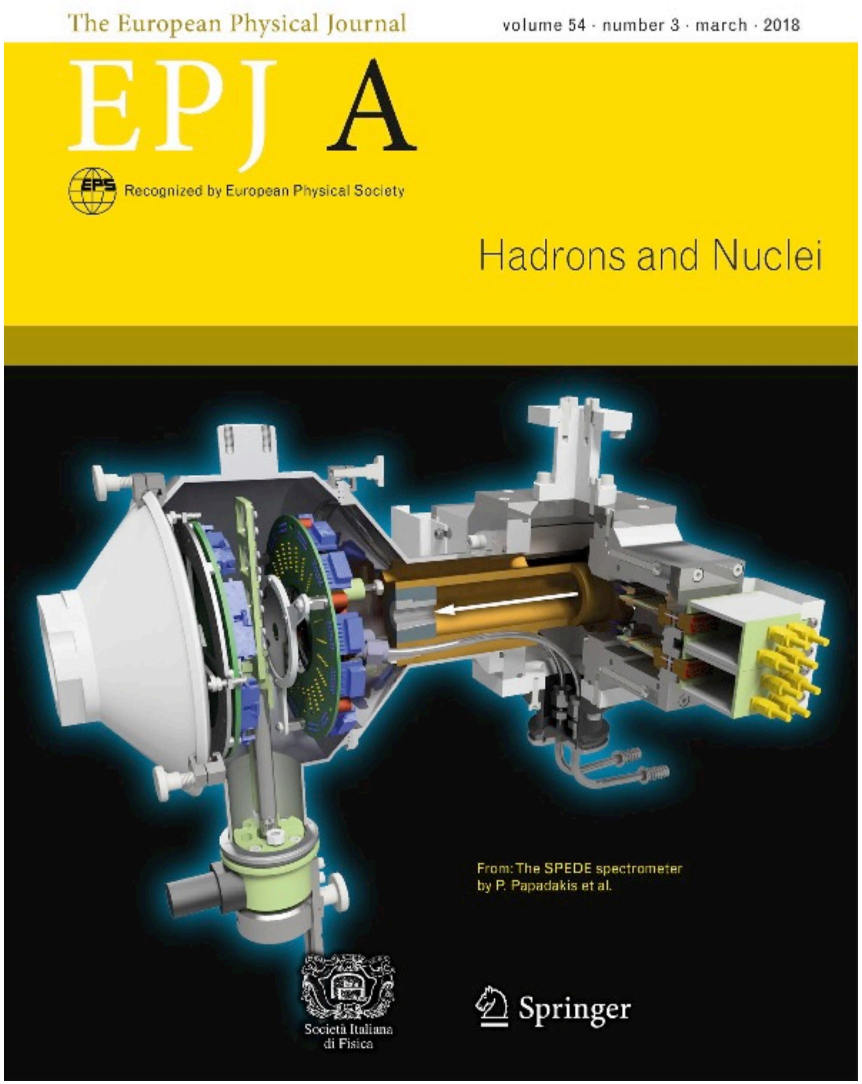
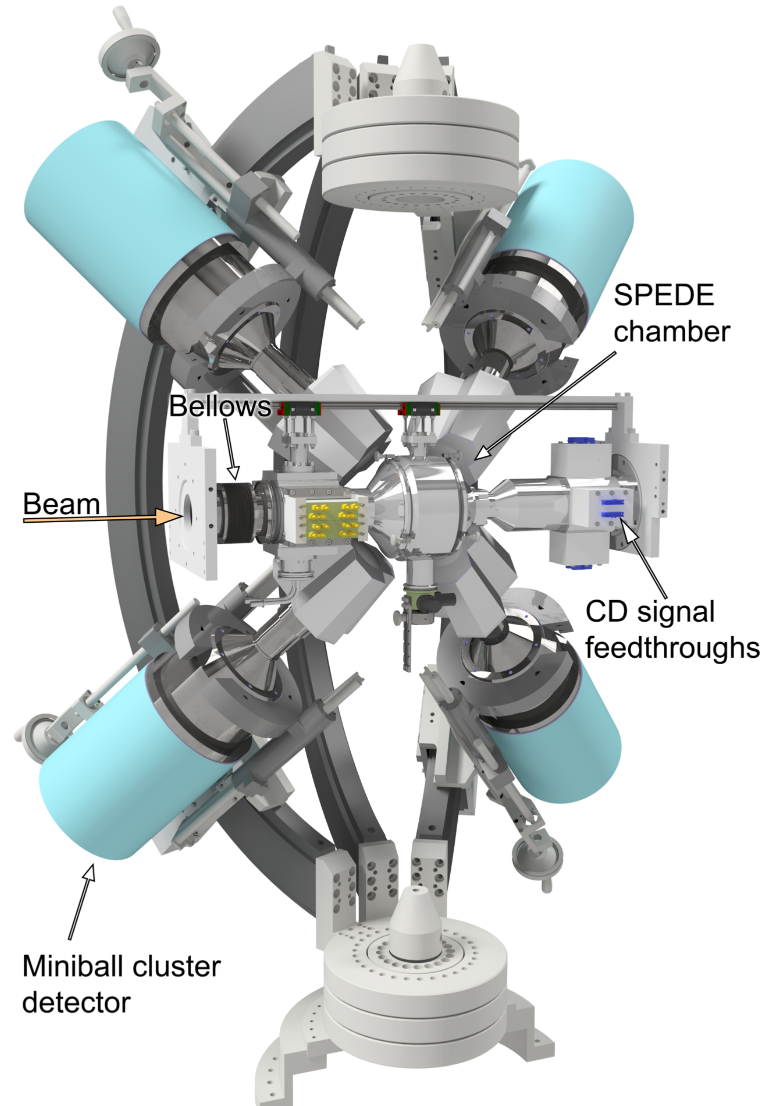


The SPEDE spectrometer

- Combined with Miniball



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The SPEDE spectrometer

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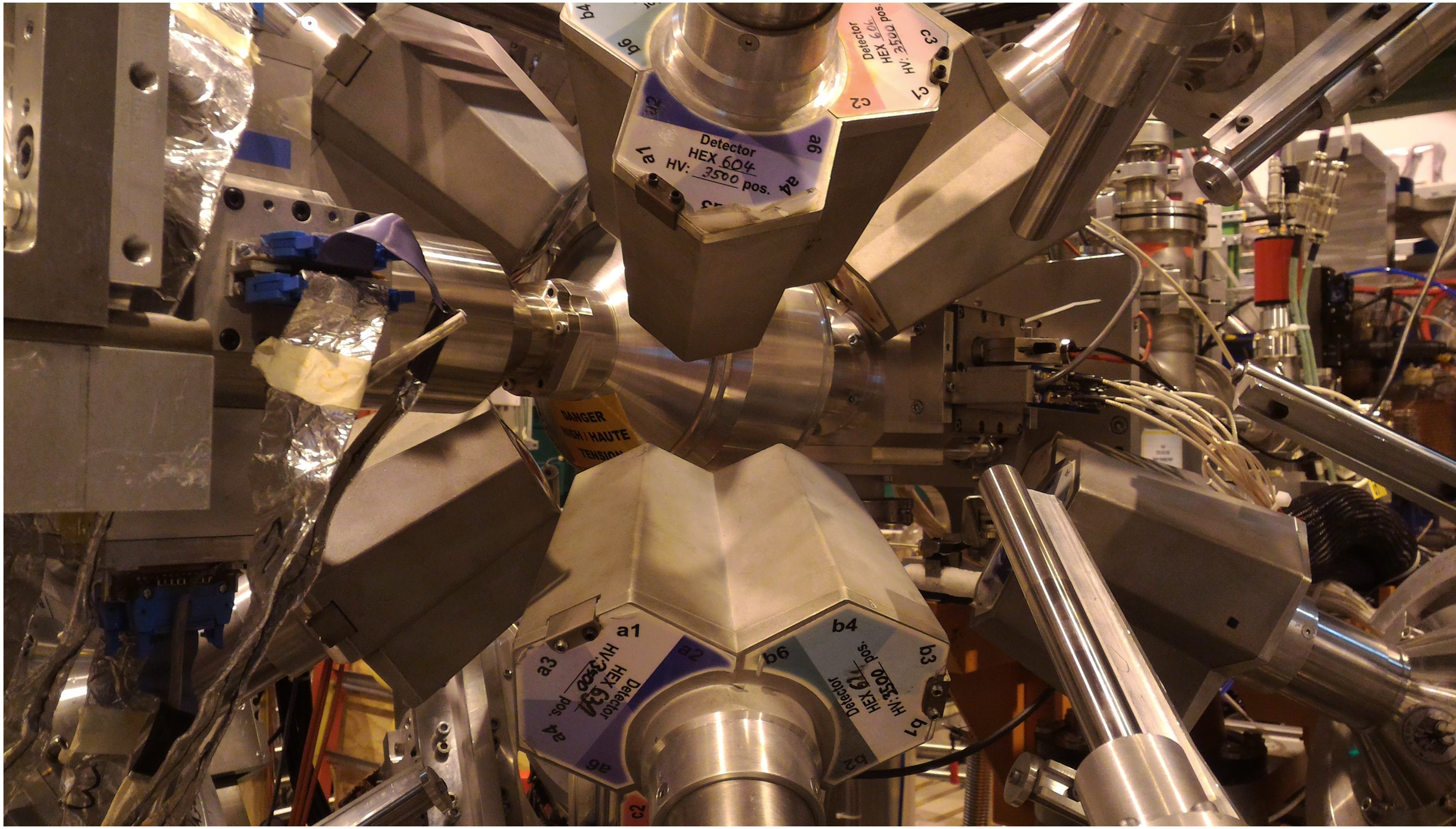

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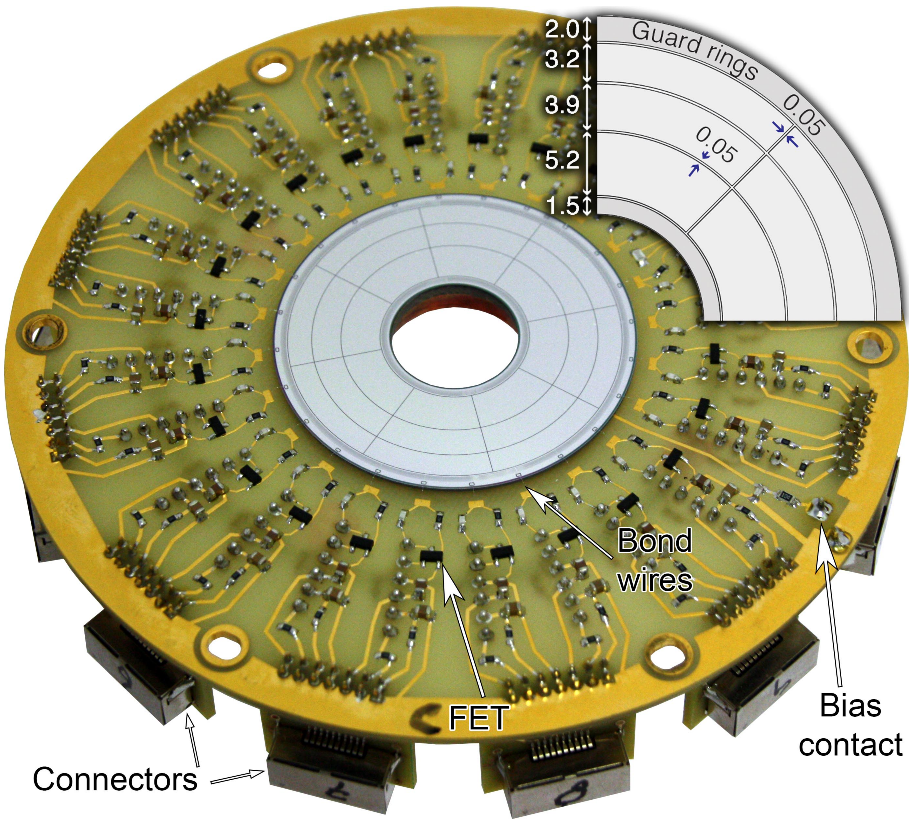
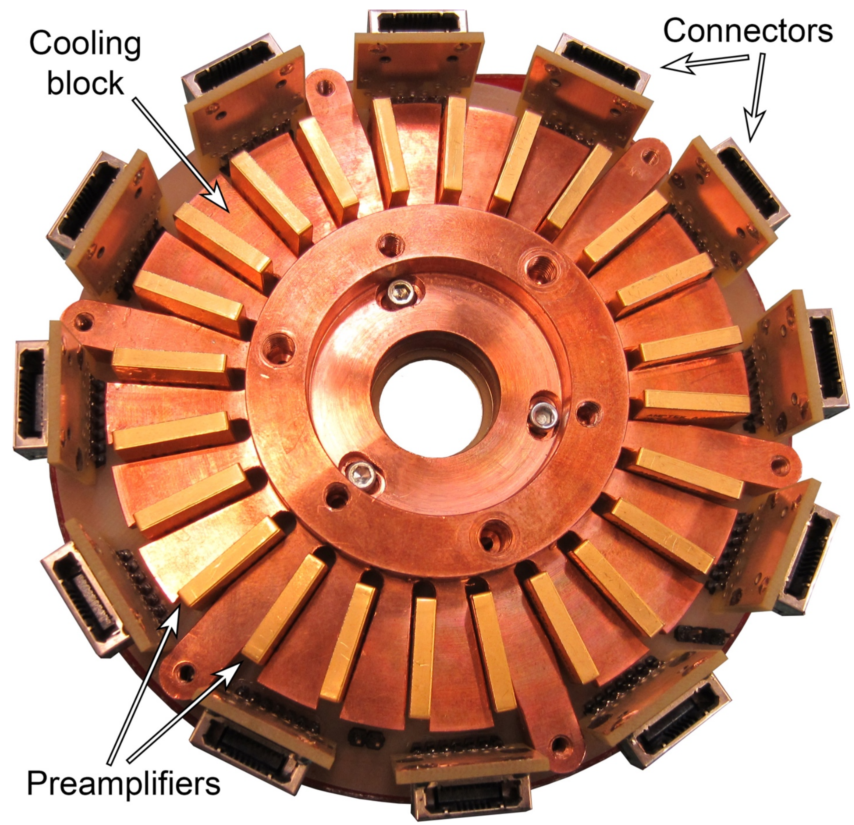
The SPEDE spectrometer

- The detector





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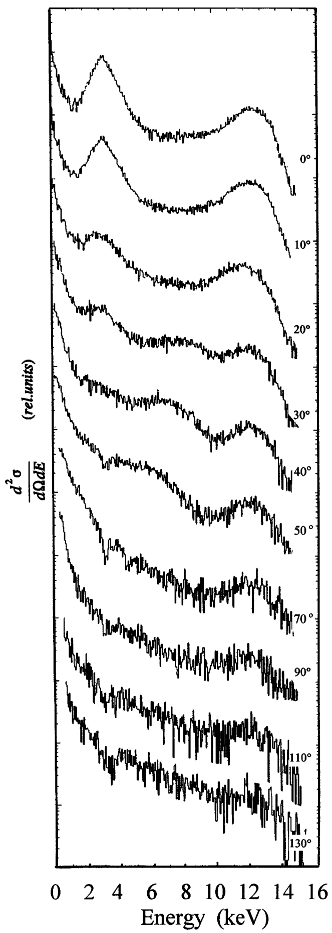
The SPEDE spectrometer

- δ electron suppression
  - Primarily low energy and forward focused



U. Bechthold *et al.*, Phys. Rev. Lett **79**, 2034 (1997)

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The SPEDE spectrometer

- δ electron suppression
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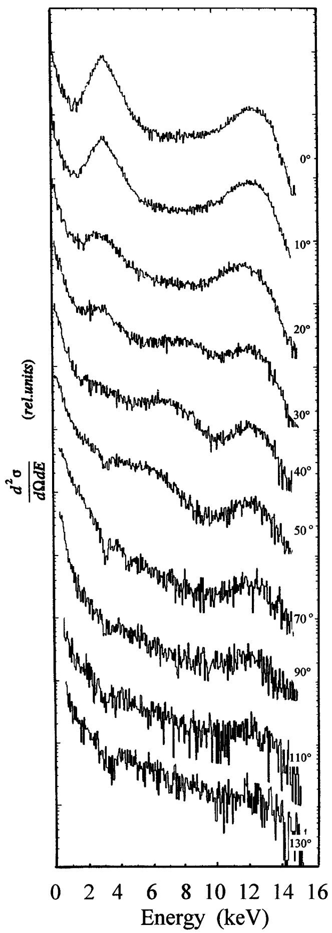
  - Detector at backwards angle
  - Absorber foil between target and detector
  - HV applied on target foil (up to +5kV)



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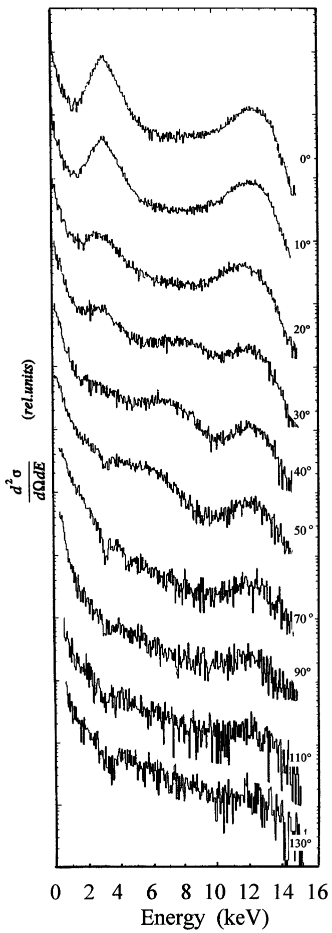

  - Primarily low energy and forward focused
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  - RIBs - Lower beam intensity

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  - Detector at backwards angle
  - Absorber foil between target and detector
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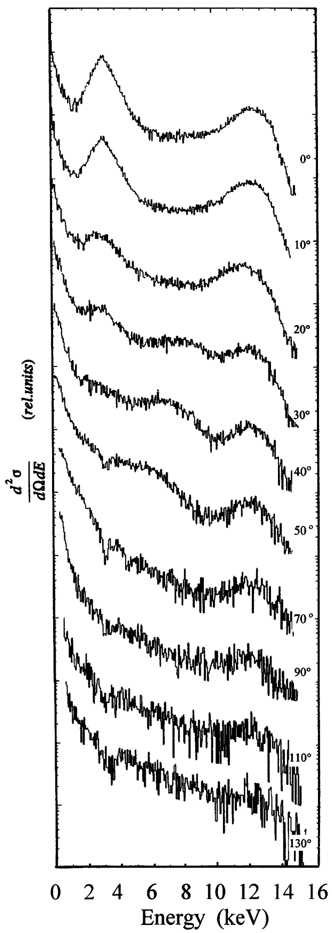
  - RIBs - Lower beam intensity
  - β-decay background supressed through coincidences with scattered particles



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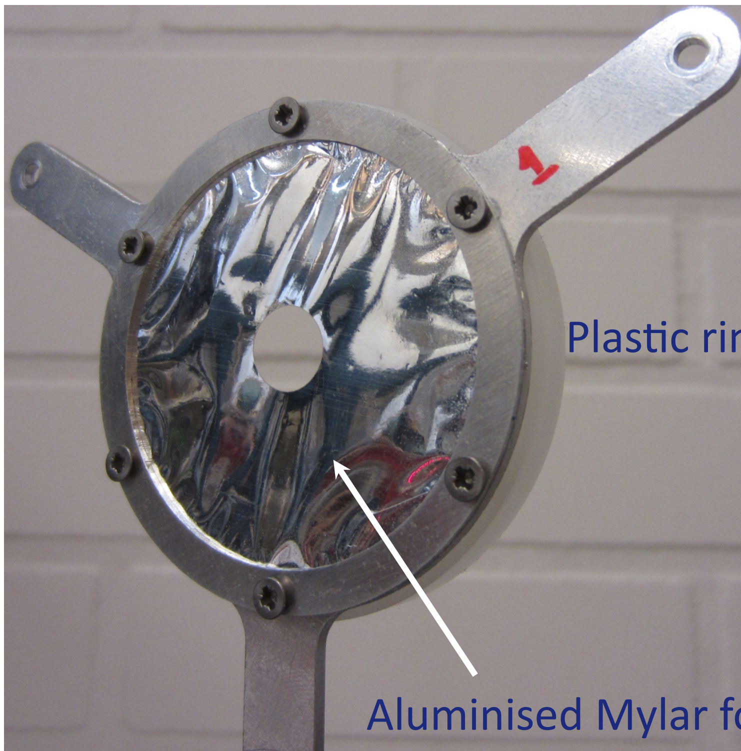
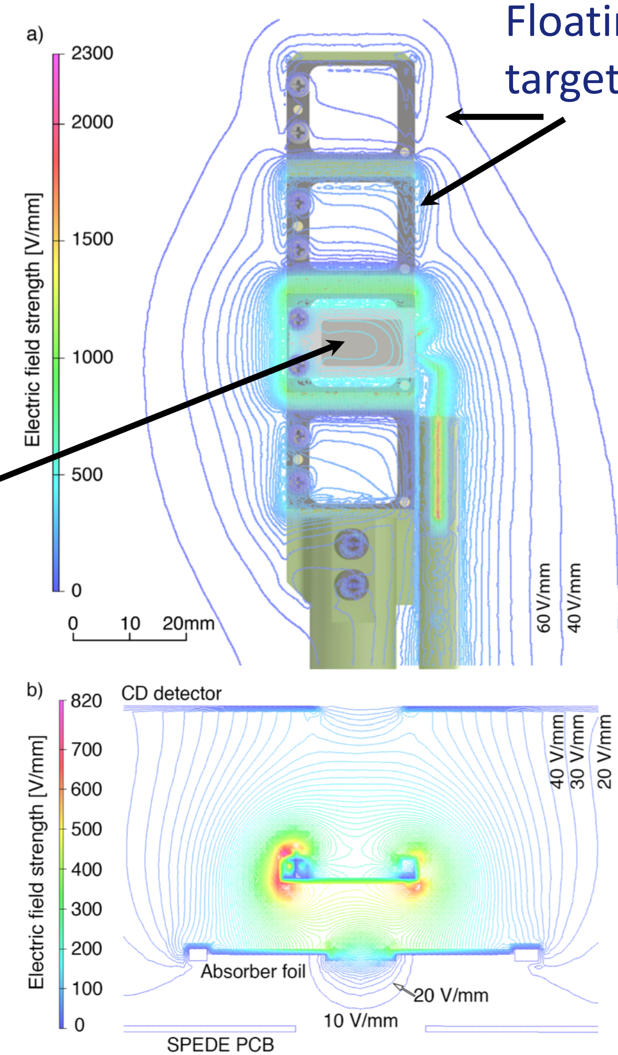


Plastic ring

Aluminised Mylar foil
- 12µm Mylar + 0.5µm Al
- Grounded

Biased target

Floating targets



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The SPEDE spectrometer

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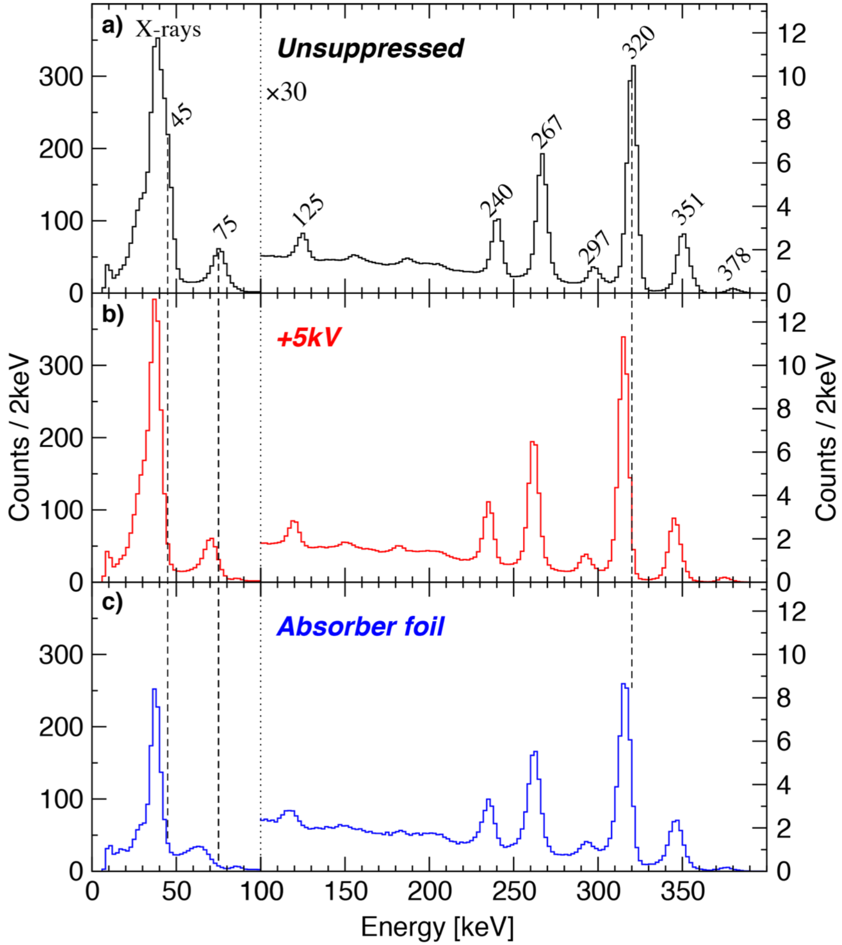

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The SPEDE spectrometer

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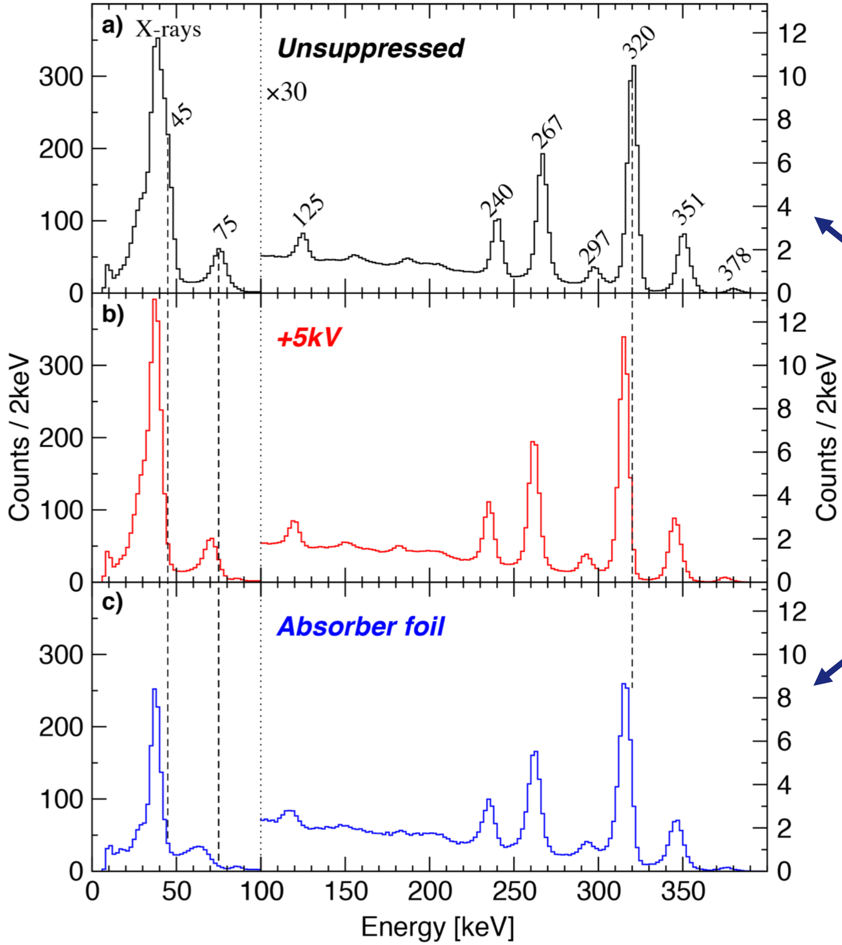
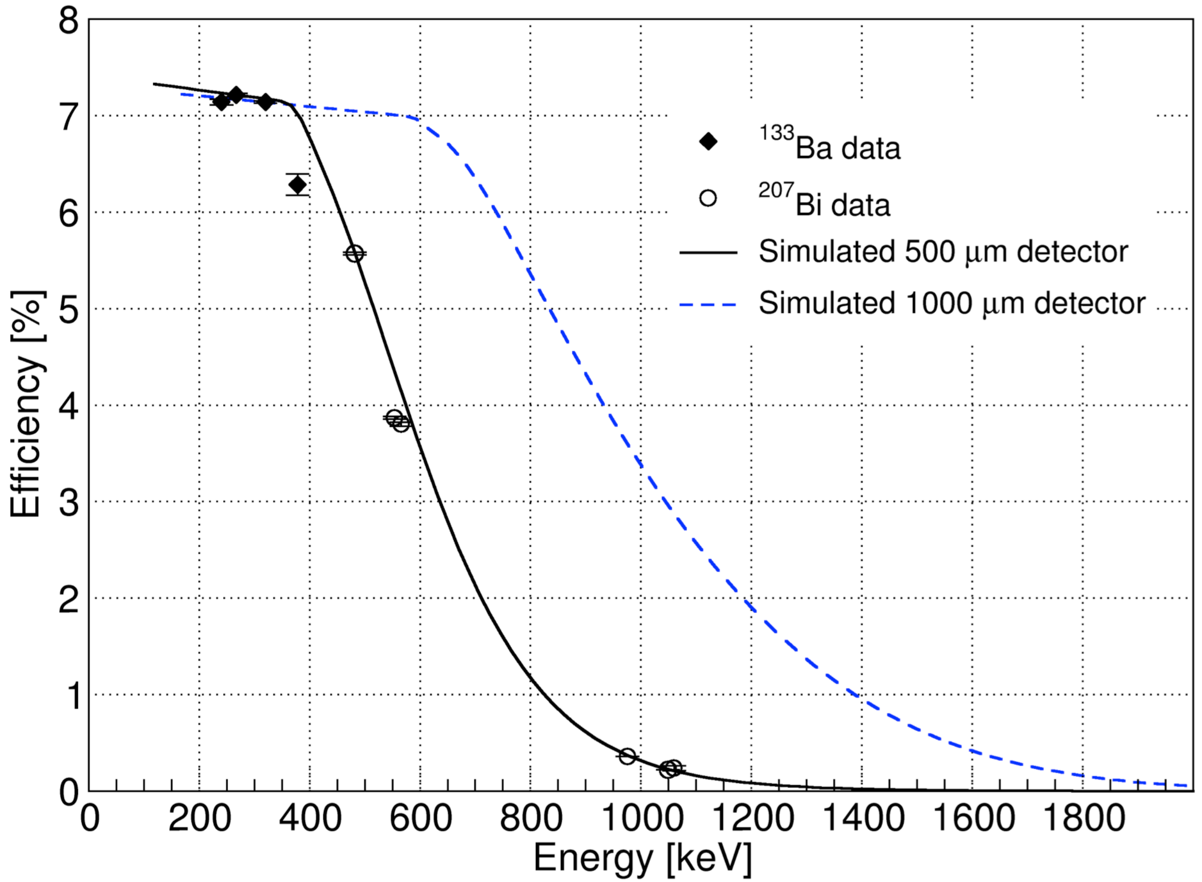


Table 1. Individual effects of the high voltage and aluminised Mylar absorber foil on the electron energy and full-width at half-maximum (FWHM) of the peaks from the ^{133}Ba decay [19].

	Energy [keV]	FWHM [keV]	Energy [keV]	FWHM [keV]
Literature	75.28(1)		320.03(1)	
This work				
Unsuppressed	75.4(1)	9.7(1)	320.2(1)	6.6(1)
+5 kV	70.0(1)	9.6(1)	315.2(1)	6.9(1)
Absorber foil	63.6(1)	12.9(1)	316.0(1)	7.7(1)

The SPEDE spectrometer

- Efficiency



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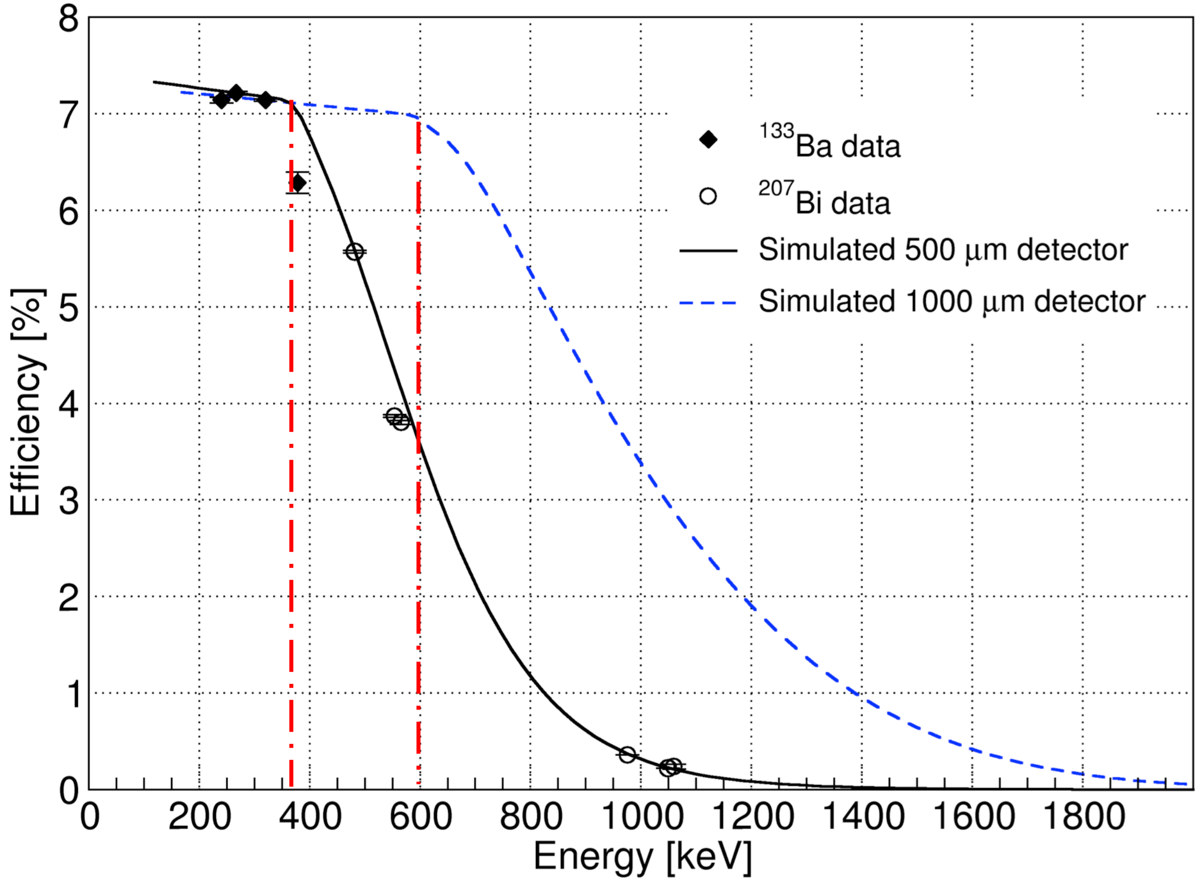
The SPEDE spectrometer

- Efficiency



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The SPEDE spectrometer

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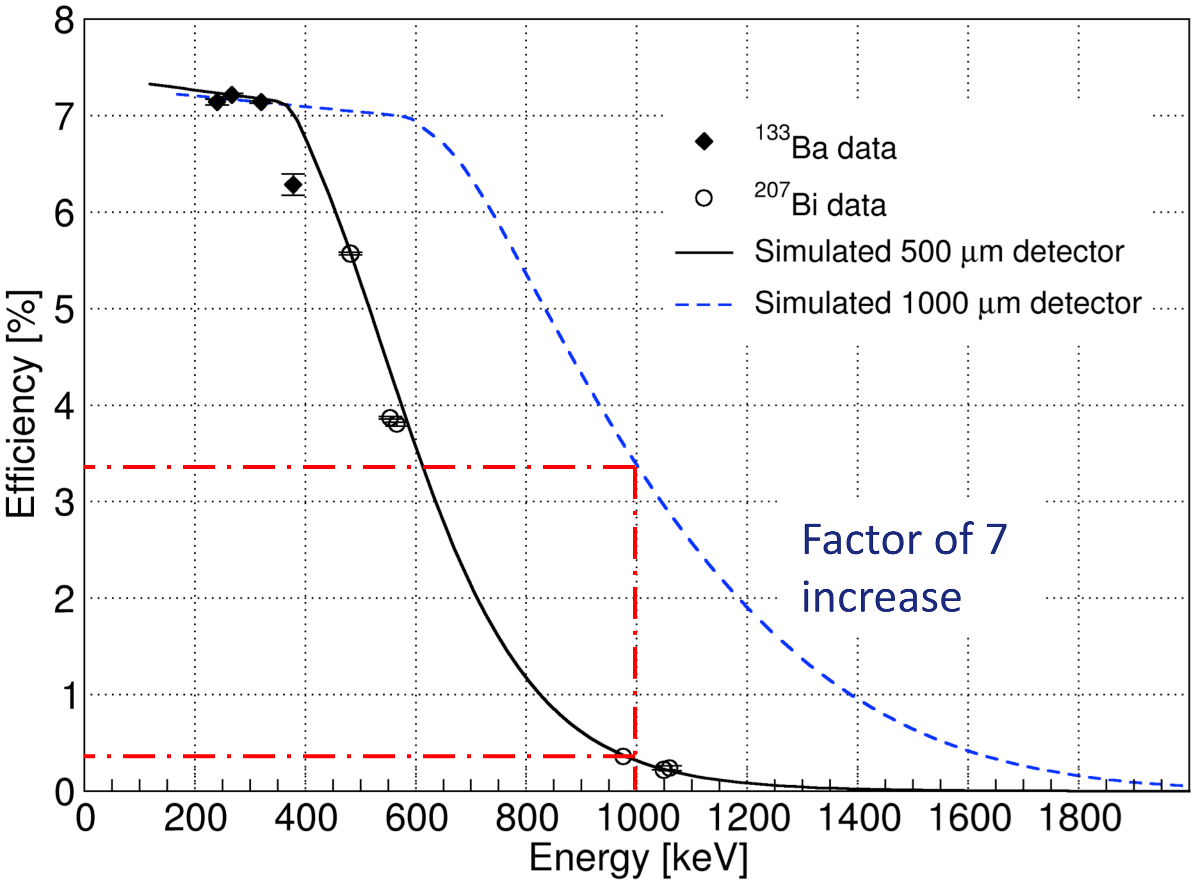

Testing and commissioning

- Source testing at HIE-ISOLDE
  - ^{191}Hg($t_{1/2}$ = 50 min) → ^{191}Au(3.2 h) → ^{191}Pt (2.8 d)

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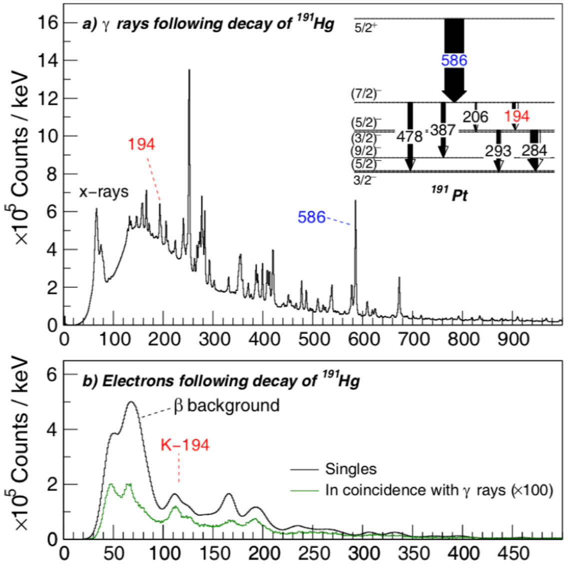
Total γ-ray spectrum

Total electron spectrum



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Testing and commissioning

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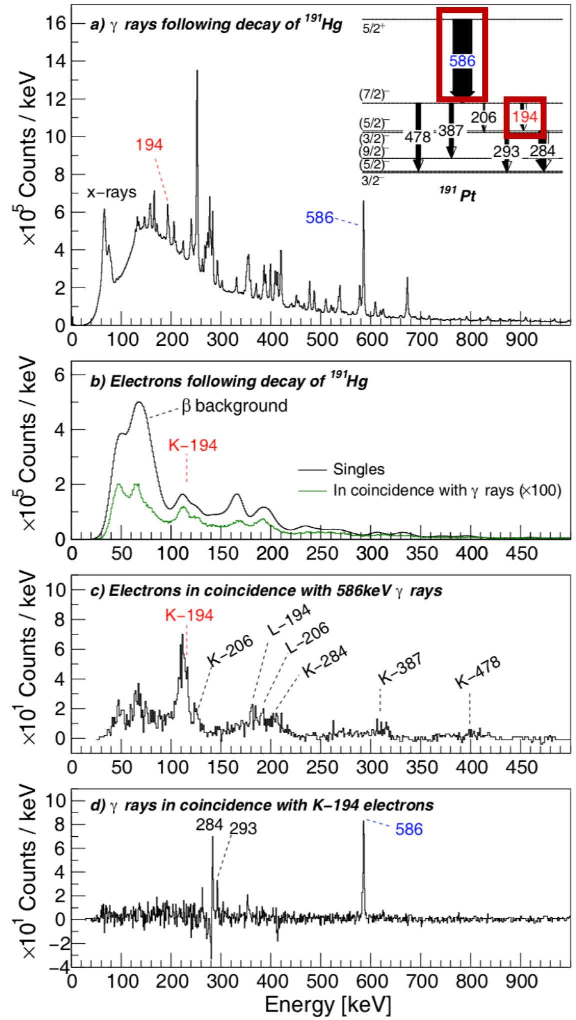
Total γ-ray spectrum

Total electron spectrum

Electrons in coincidence with 586keV γ rays

γ rays in coincidence with K-194 electrons



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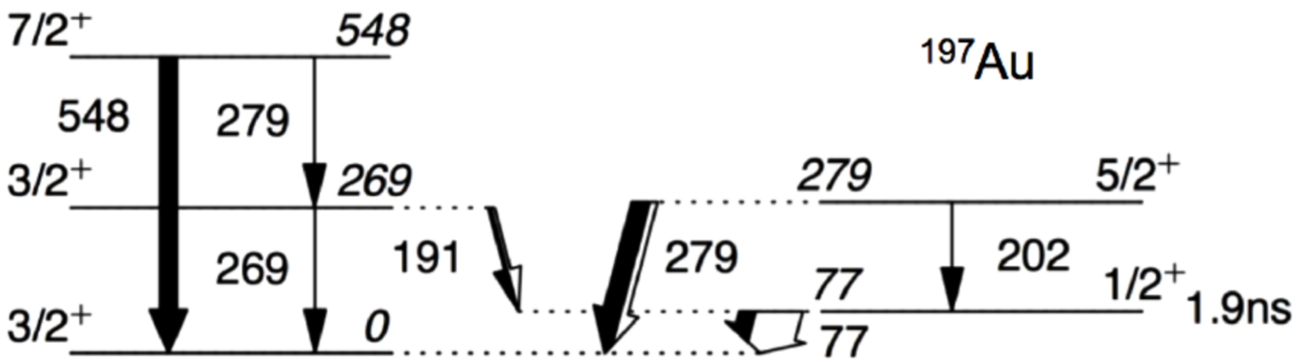
Testing and commissioning

- In-beam testing at Jyväskylä
  - ^{82}Kr(^{197}Au,^{197}Au*) at 4.26 MeV/u, 1200 μg/cm^2



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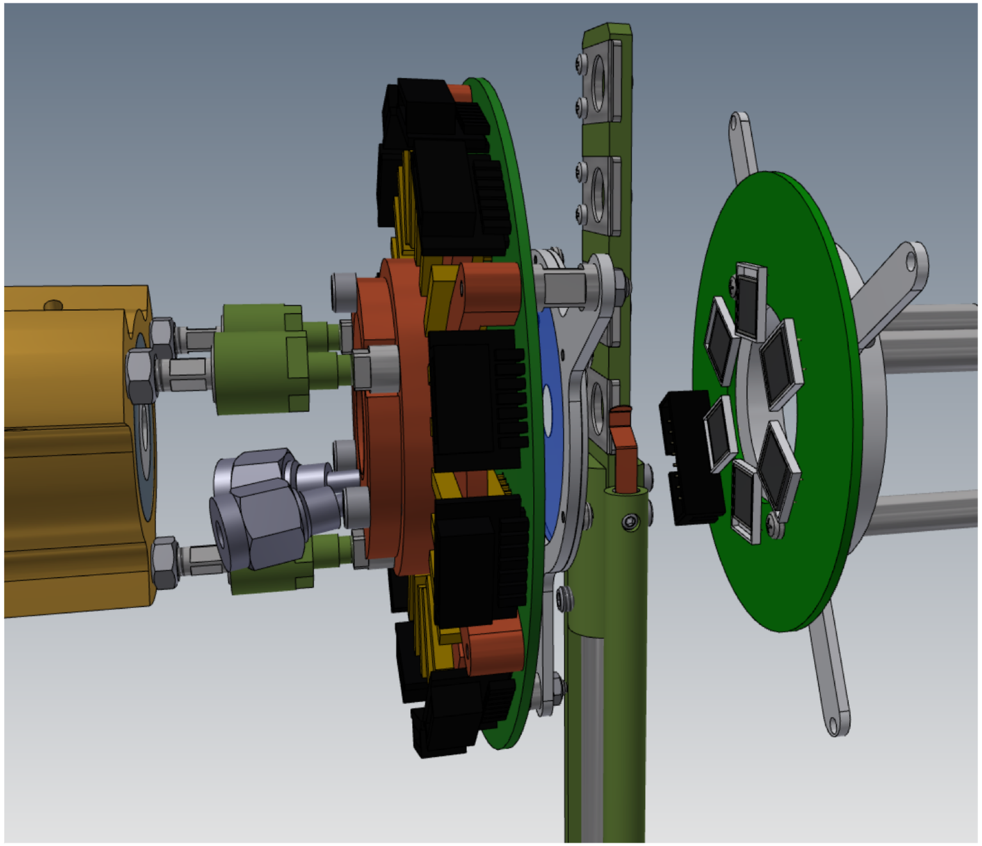

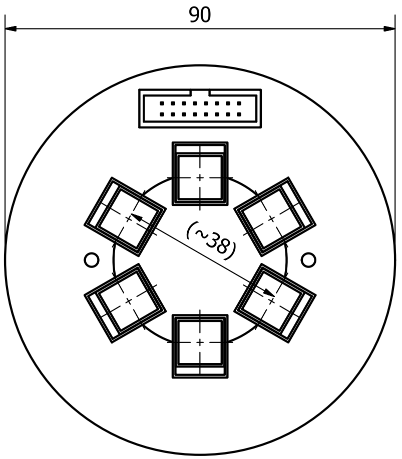

Hamamatsu S3590-09
Si PIN photodiodes
10x10 mm
300 μm thick
2% efficiency

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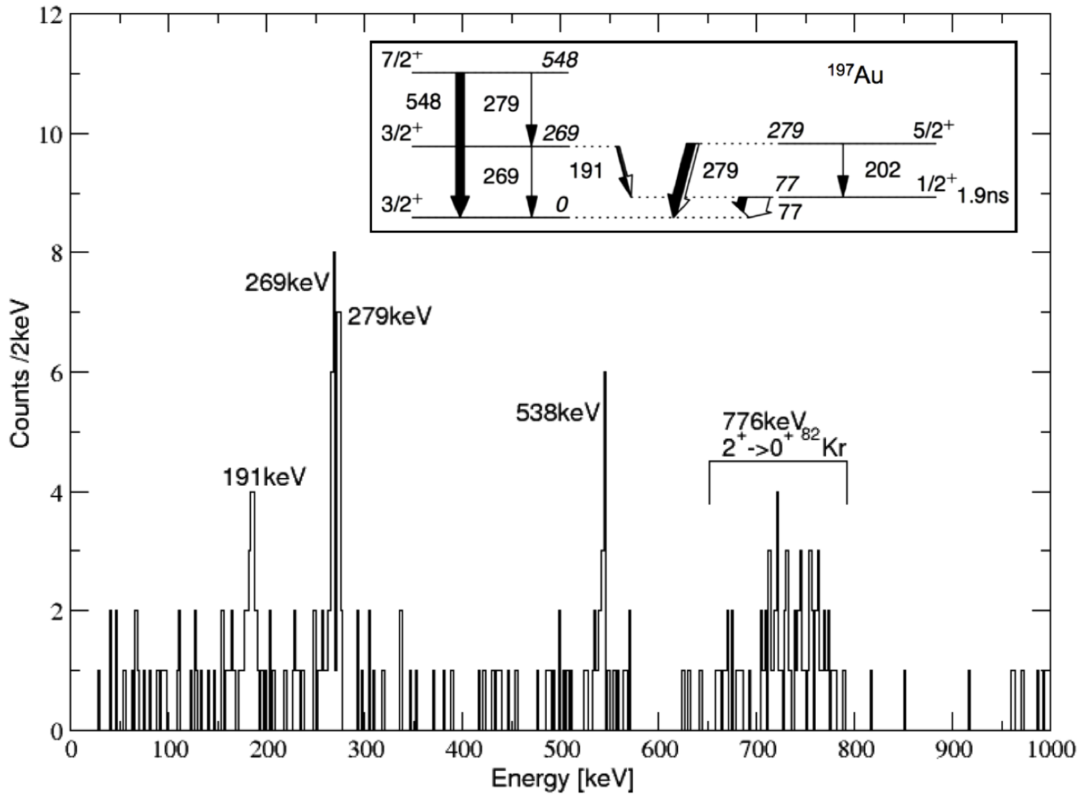
D.M. Cox *et al.*, Acta Phys. Pol. B 48 (2017) 3

Testing and commissioning

- In-beam testing at Jyväskylä
  - Particle gated, Doppler corrected γ-ray spectrum from single Phase I-type germanium detector



D.M. Cox *et al.*, Acta Phys. Pol. B 48 (2017) 3

Testing and commissioning

- In-beam testing at Jyväskylä

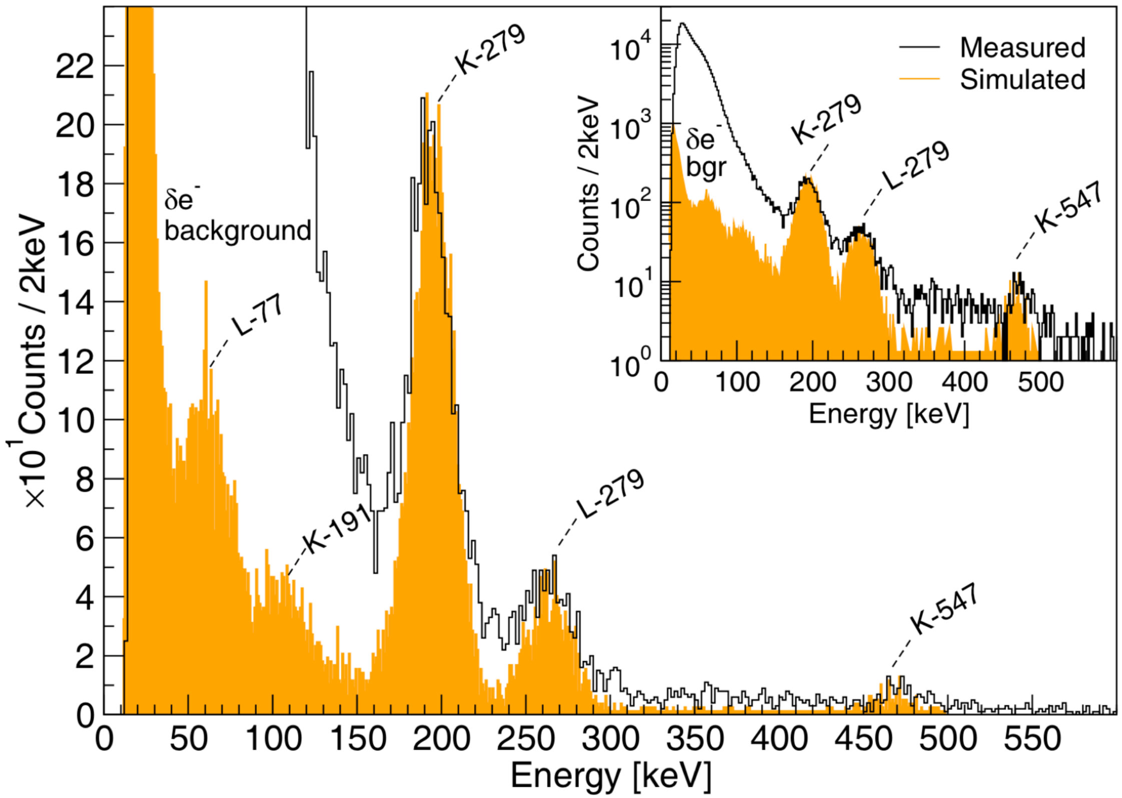


Table 2. Comparison of the K/L conversion ratio for the 279 keV $\frac{5}{2}^+ \rightarrow \frac{3}{2}^+$ transition in ^{197}Au obtained with SPEDE, to values calculated with BrIcc [24].

	$M1$	$E2$	$M1+E2$ $\delta = -0.39(2)$ [25]	This work
K/L ratio	6.05(12)	1.85(4)	5.63(13)	5.7(7)

Mixing ratio from:
A.E. Stuchbery *et al.*, Nucl. Phys. A 486, 374 (1988)

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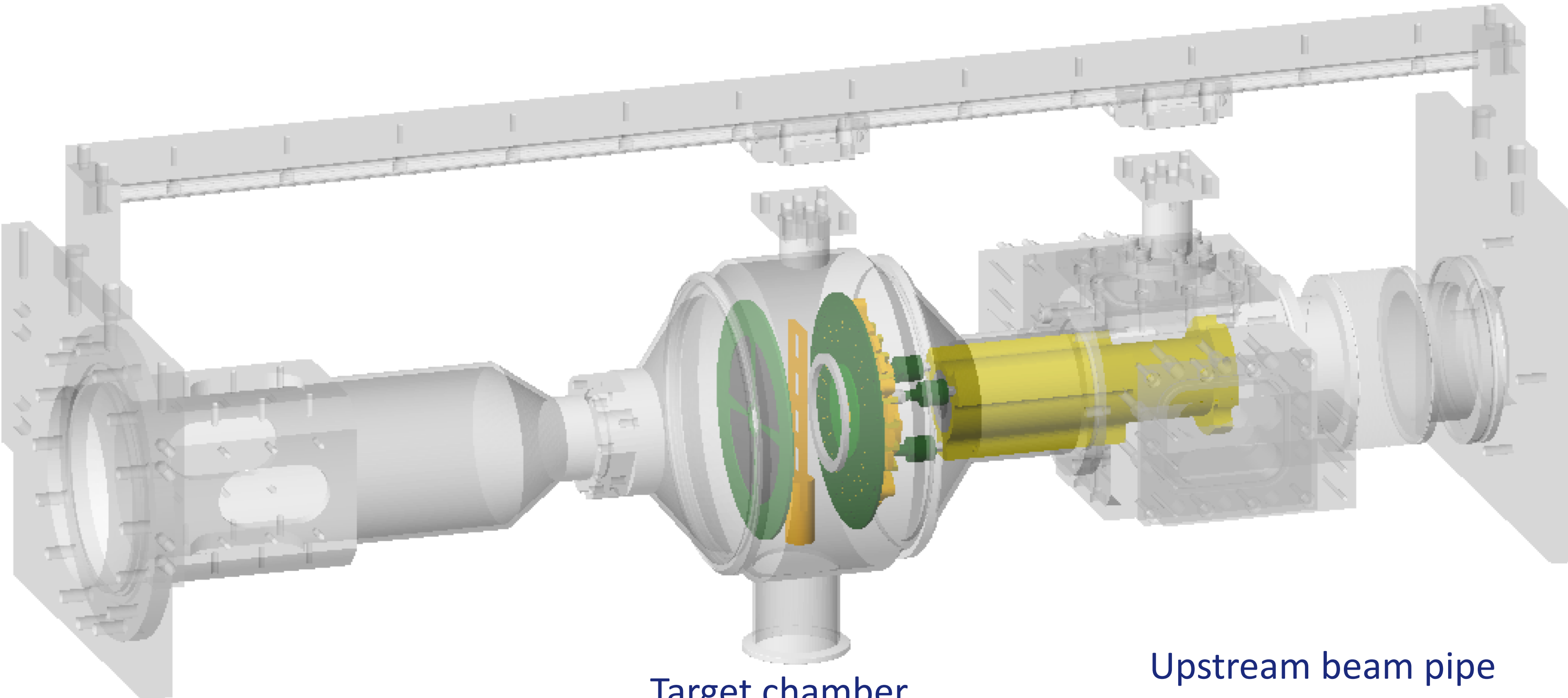
P. Papadakis *et al*. Eur. Phys. J. A (2018) 54: 42

GEANT4 simulations

- Geometry



Downstream beam pipe

Target chamber
Including SPEDE detector,
target ladder,
Miniball CD detector

Upstream beam pipe
Including feedthroughs,
SPEDE support structure

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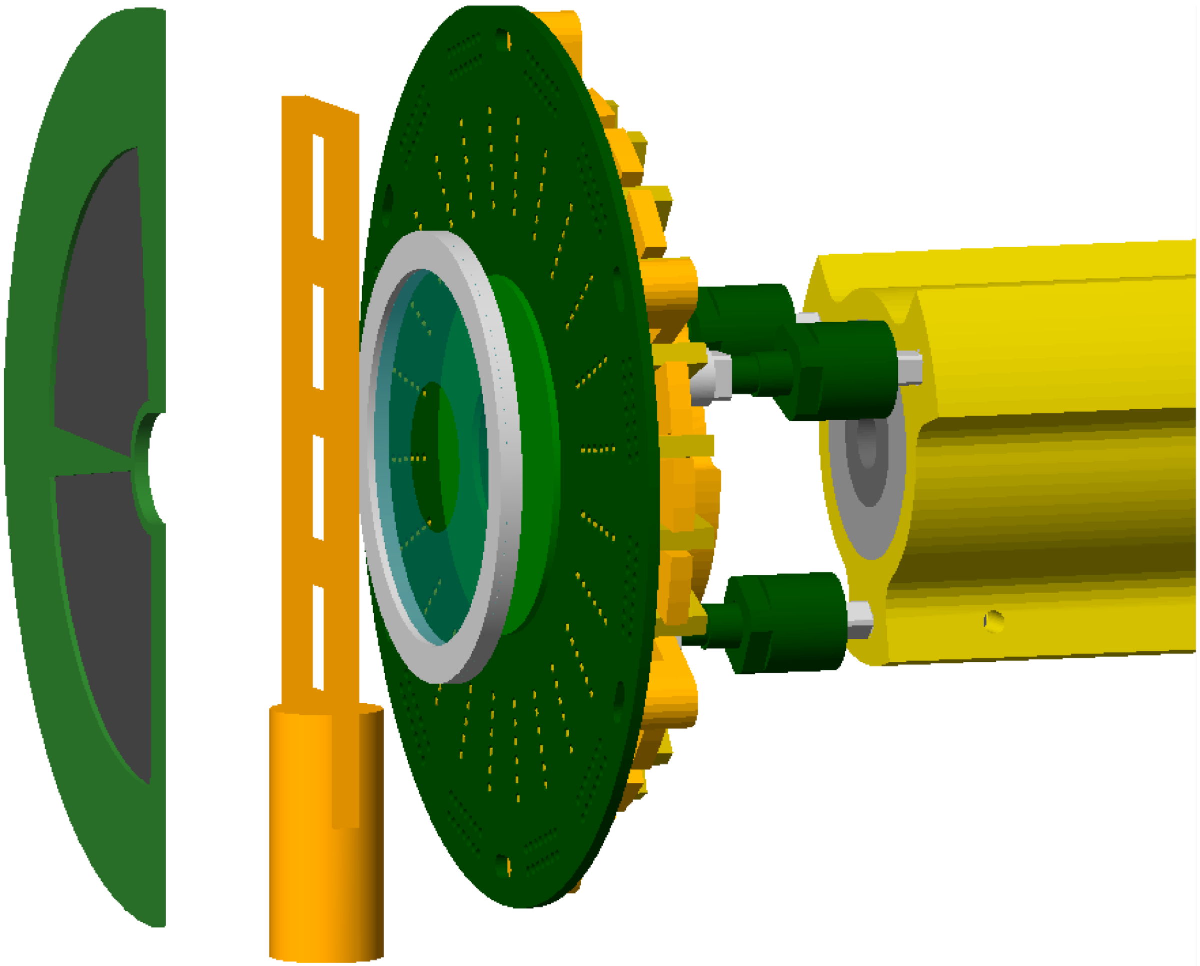
D.M. Cox *et al.*, to be published

GEANT4 simulations

- Geometry



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GEANT4 simulations

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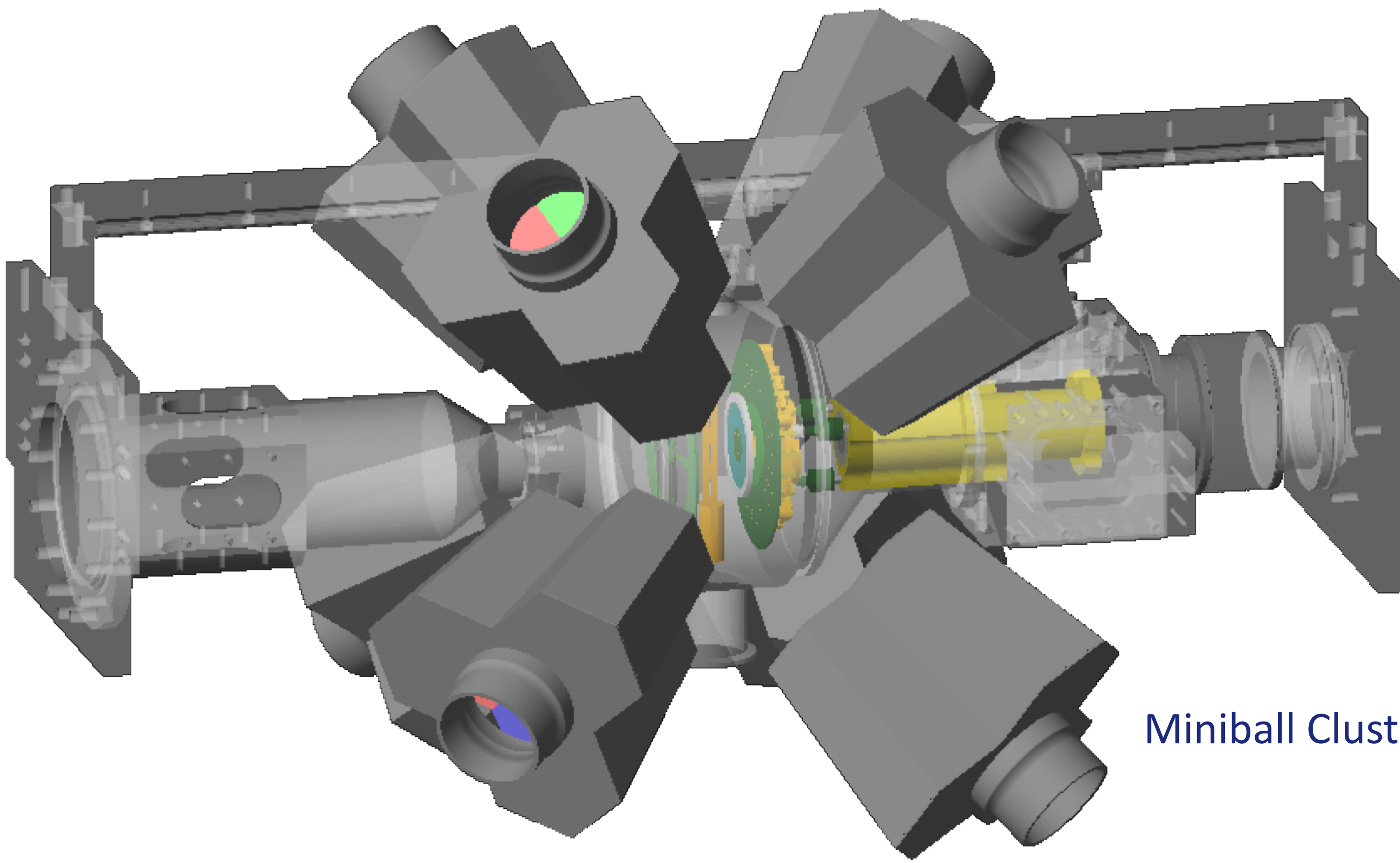

Miniball Cluster detectors

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GEANT4 simulations

- "The NPTool package aims to offer a unified framework for preparing and analysing complex experiments, making an efficient use of Geant4 and ROOT toolkits"
- TRex (CRex) & MINIBALL already simulated
- Simulate complete reaction
  - Beam
  - Reaction
  - Scattering (user defined cross section from e.g. Fresco)
  - De-excitation of the nucleus in the lab frame
  - Subsequent decay of products
  - Doppler correction algorithm same as in experiment analysis

A. Matta *et al.*, J. Phys. G. 43 (2016) 45113   nptool.org

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- Physics case 1: Shape coexistence in $^{186,188}Pb$
- Physics case 2: Octupole collectivity in Rn and Ra nuclei
- Other applications of SPEDE
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Approved experiments

- IS475 addendum - P.A. Butler, D.T. Joss et al.,

  Measurements of octupole collectivity in odd-mass Rn and Ra nuclei using Coulomb excitation
- IS552 (+ addendum) - P. Butler, D.T. Joss, M. Scheck et al.,

  Measurements of octupole collectivity in Rn and Ra nuclei using Coulomb excitation
- IS556 - J. Pakarinen et al.,

  Probing intruder configurations in ^{186,188}Pb using Coulomb excitation
- IS563 - K. Wrzosek-Lipska, D.T. Joss, D. Jenkins, J. Pakarinen et al.,

  Coulomb excitation of $^{182-184}$Hg: Shape coexistence in the neutron-deficient lead region

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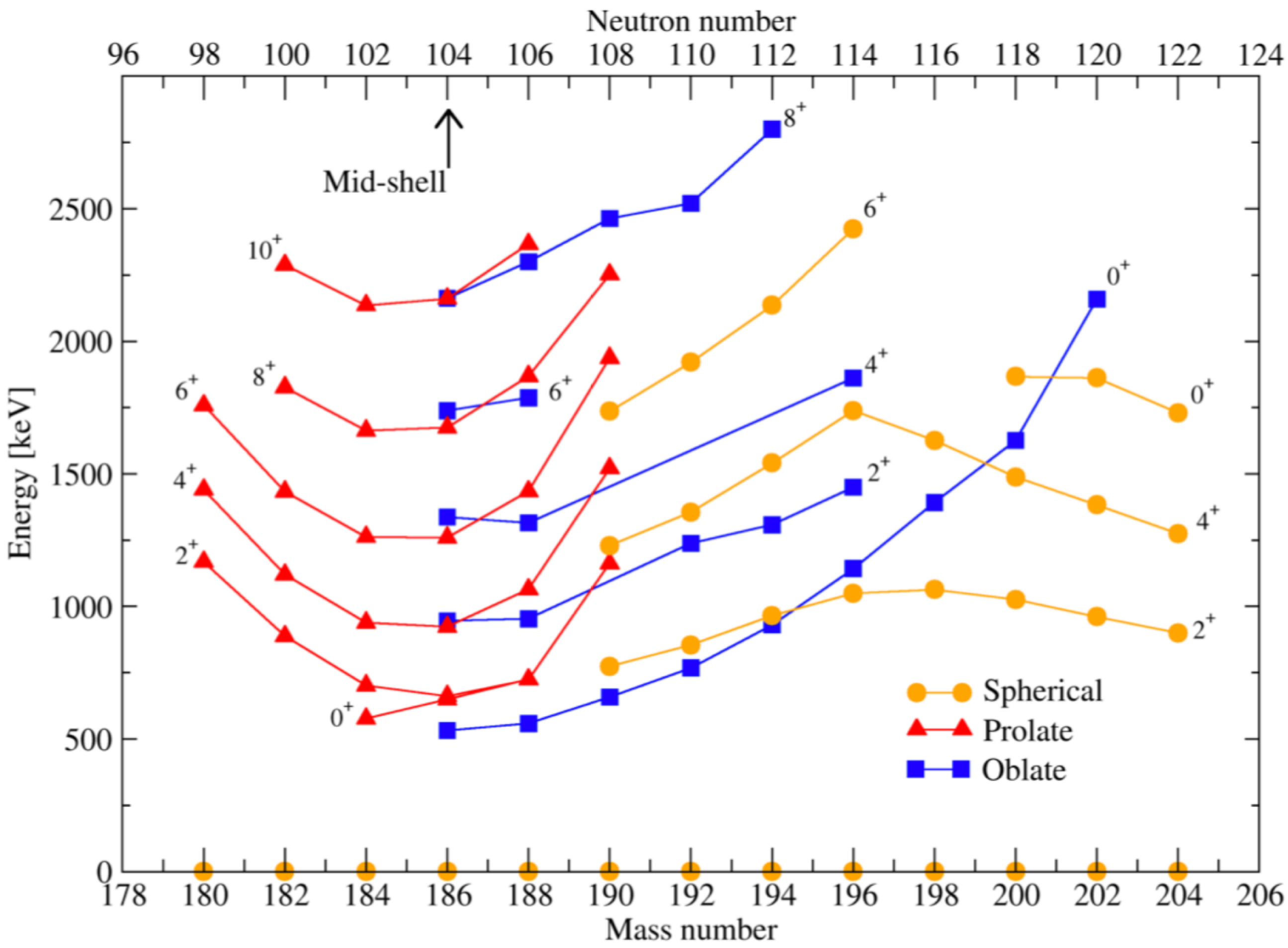
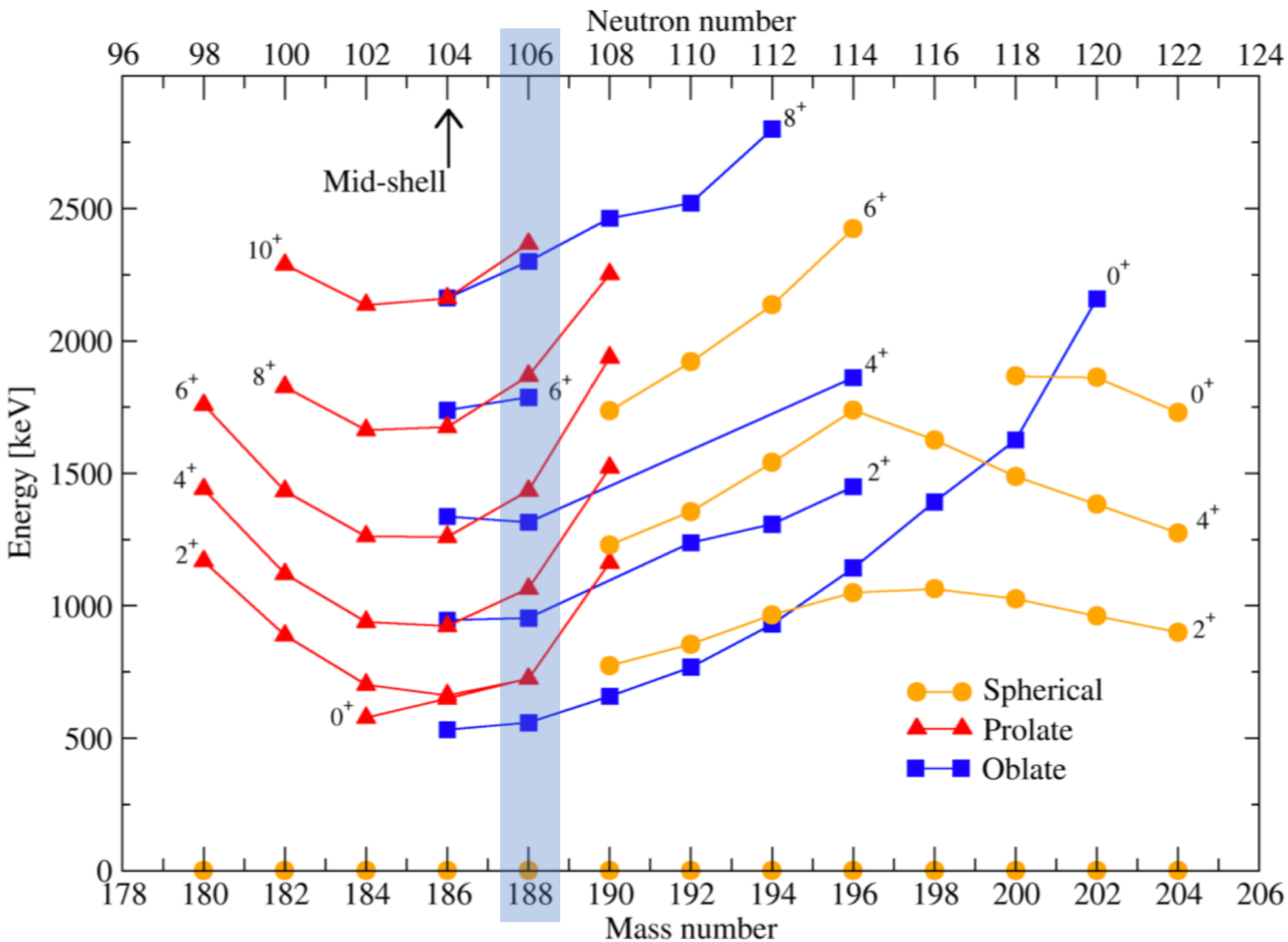
Physics case 1: Shape coexistence in $^{186,188}Pb$



Courtesy: J. Pakarinen

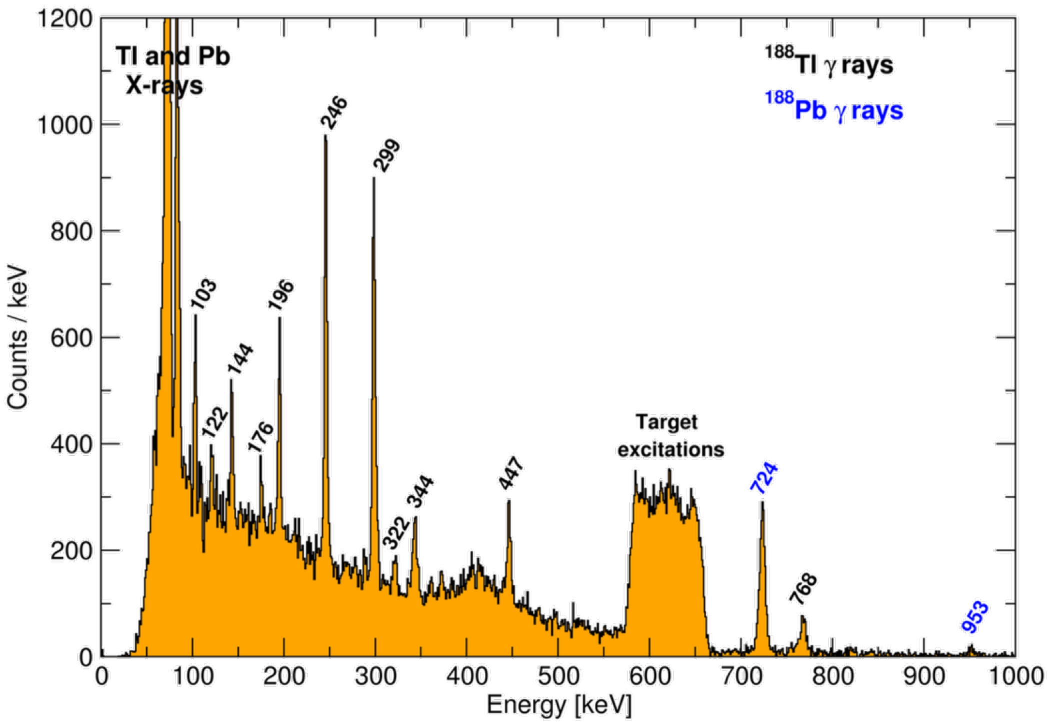
Physics case 1: Shape coexistence in ^{186,188}Pb



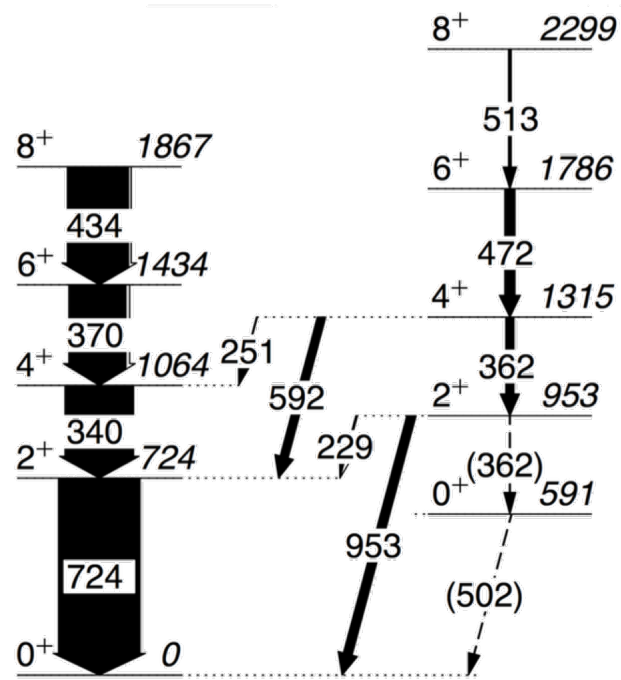
Courtesy: J. Pakarinen

Physics case 1: Shape coexistence in ^{186,188}Pb

γ-ray spectrum from IS494



Detail from ^{188}Pb level scheme



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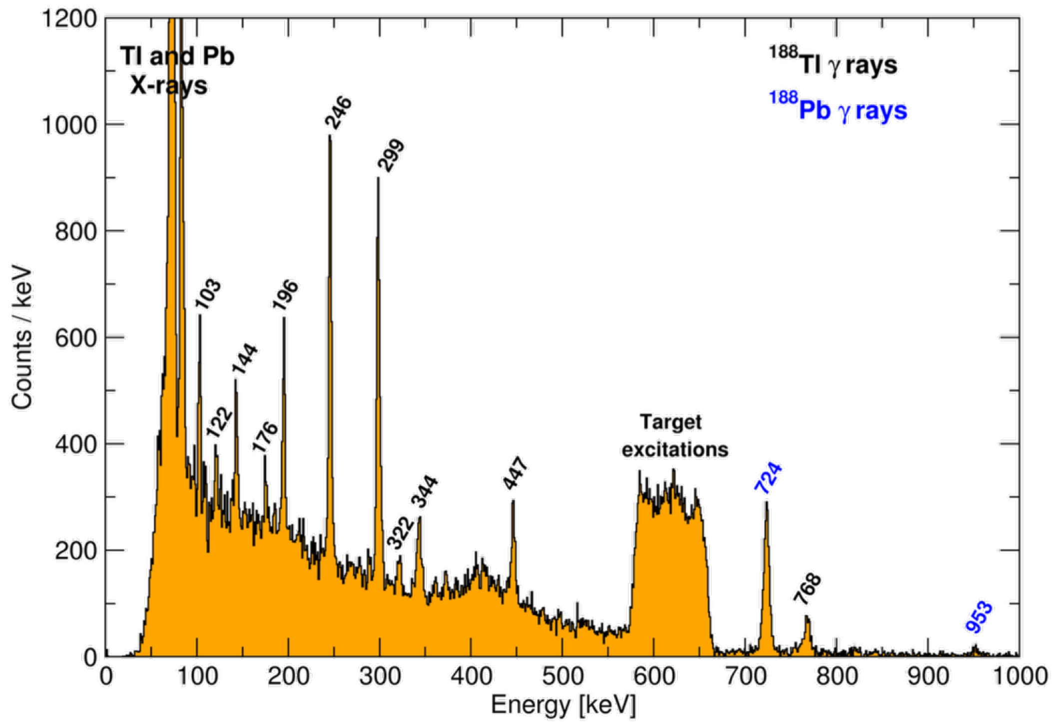
Physics case 1: Shape coexistence in $^{186,188}Pb$

γ-ray spectrum from IS494



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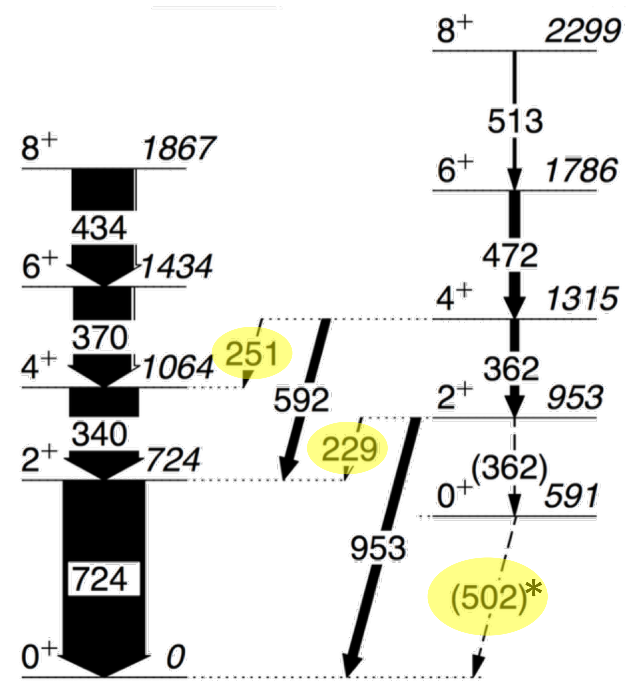

*K-electron energy

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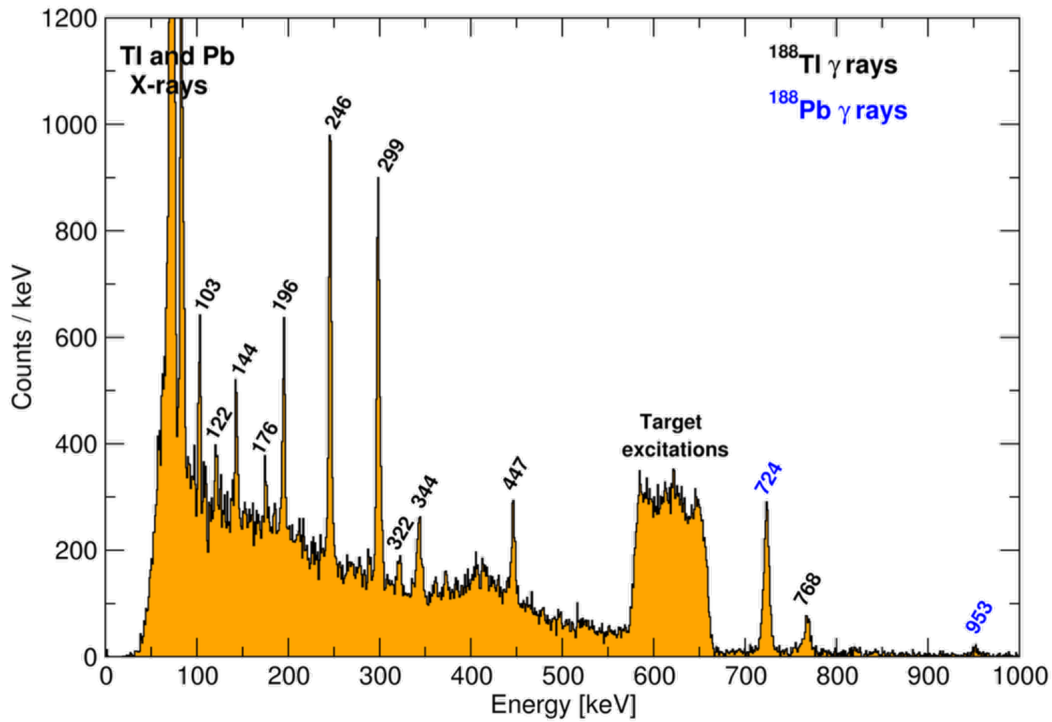
γ-ray spectrum from IS494



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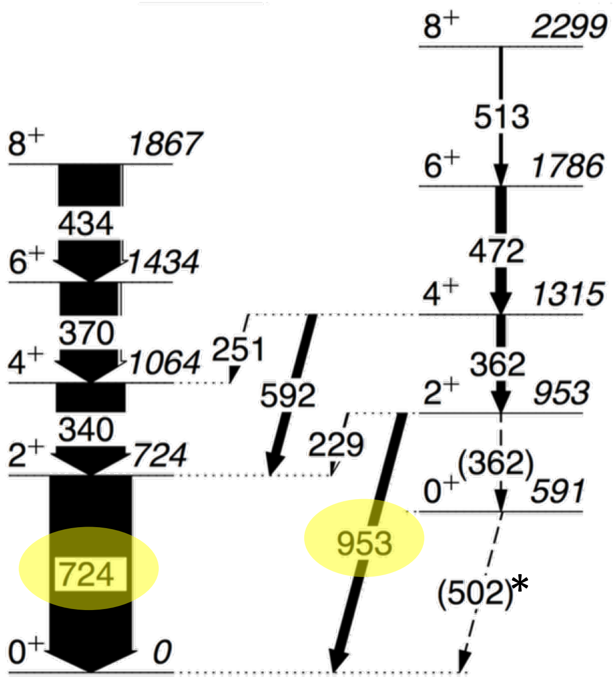

*K-electron energy

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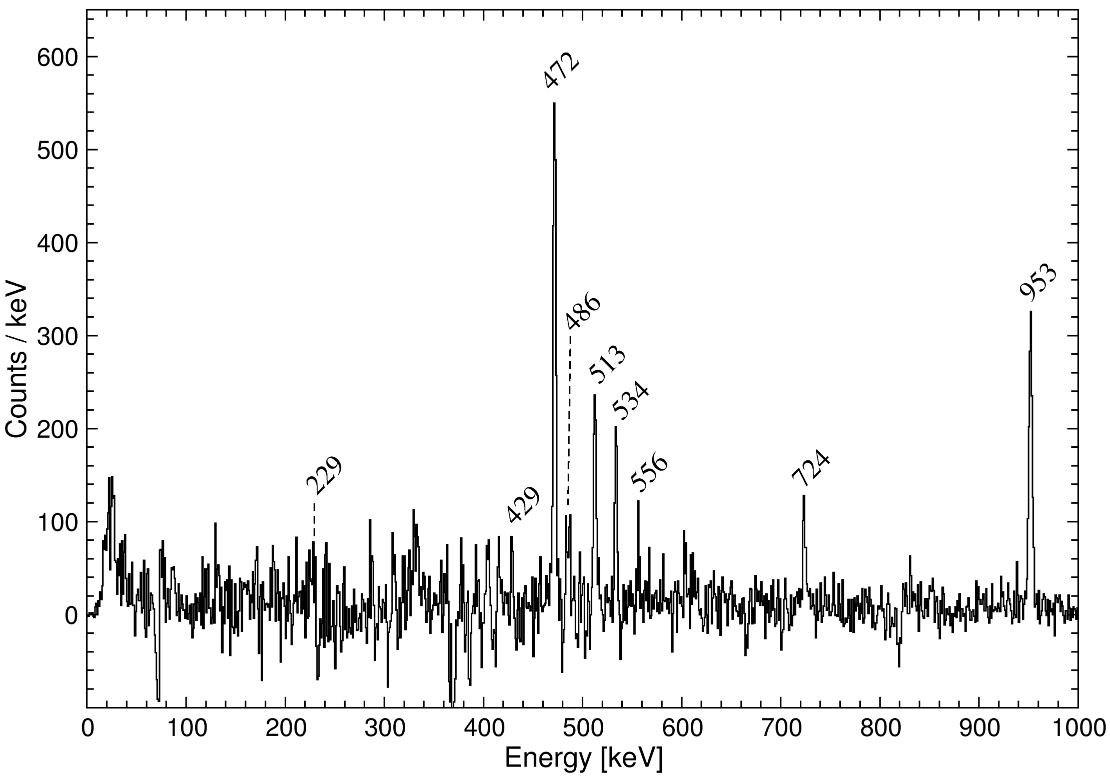
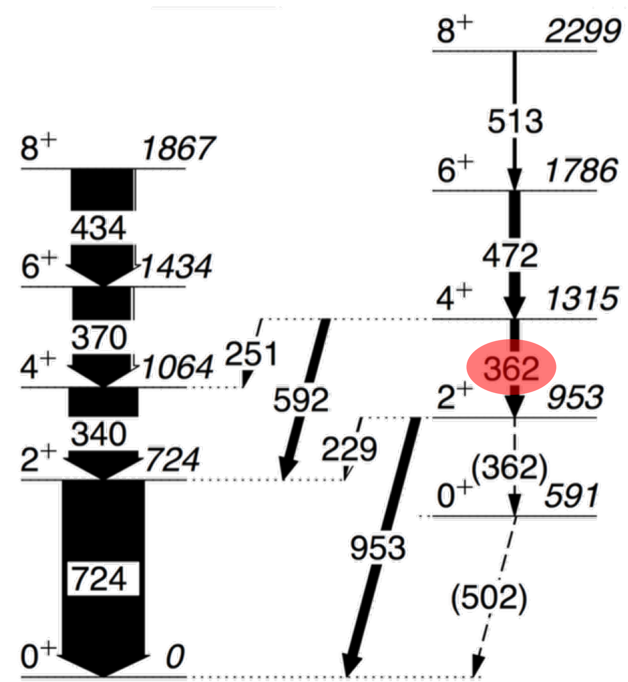
Physics case 1: Shape coexistence in ^{186,188}Pb

γ-ray spectrum from S07

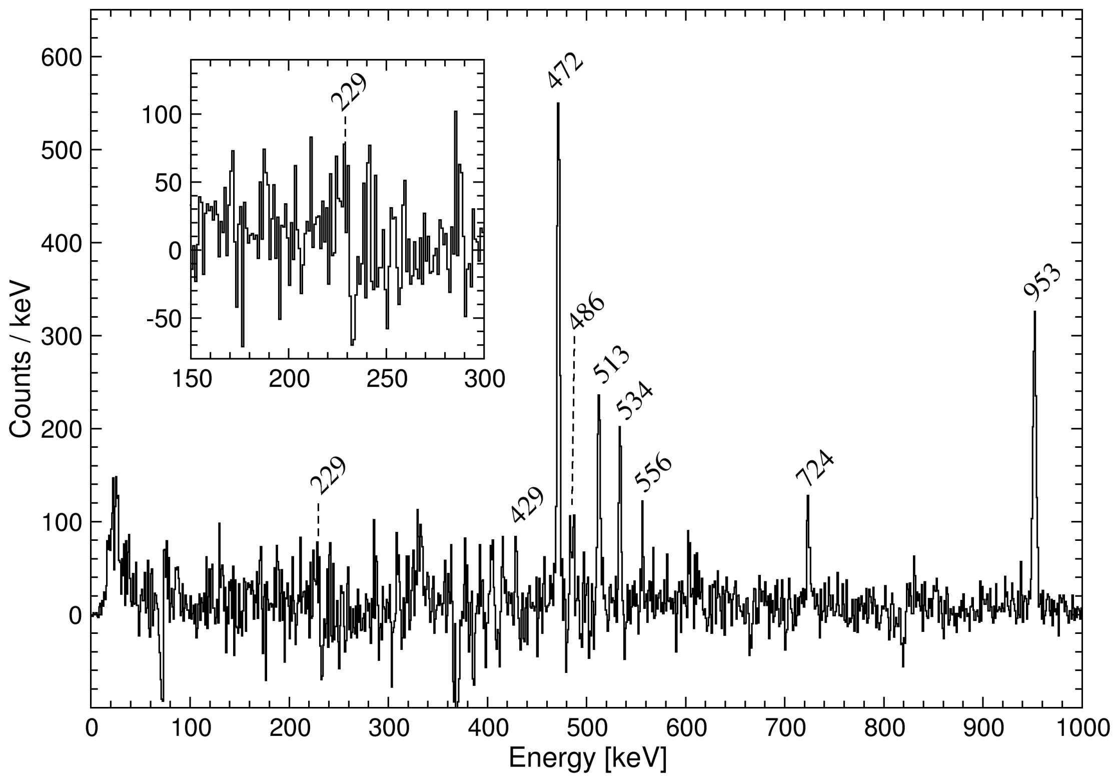


Detail from ^{188}Pb level scheme

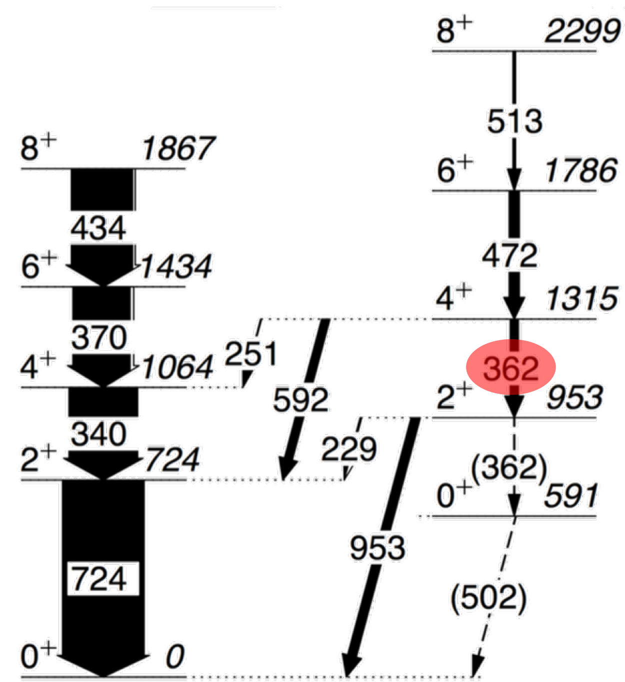


Physics case 1: Shape coexistence in $^{186,188}Pb$

γ-ray spectrum from S07



Detail from ^{188}Pb level scheme



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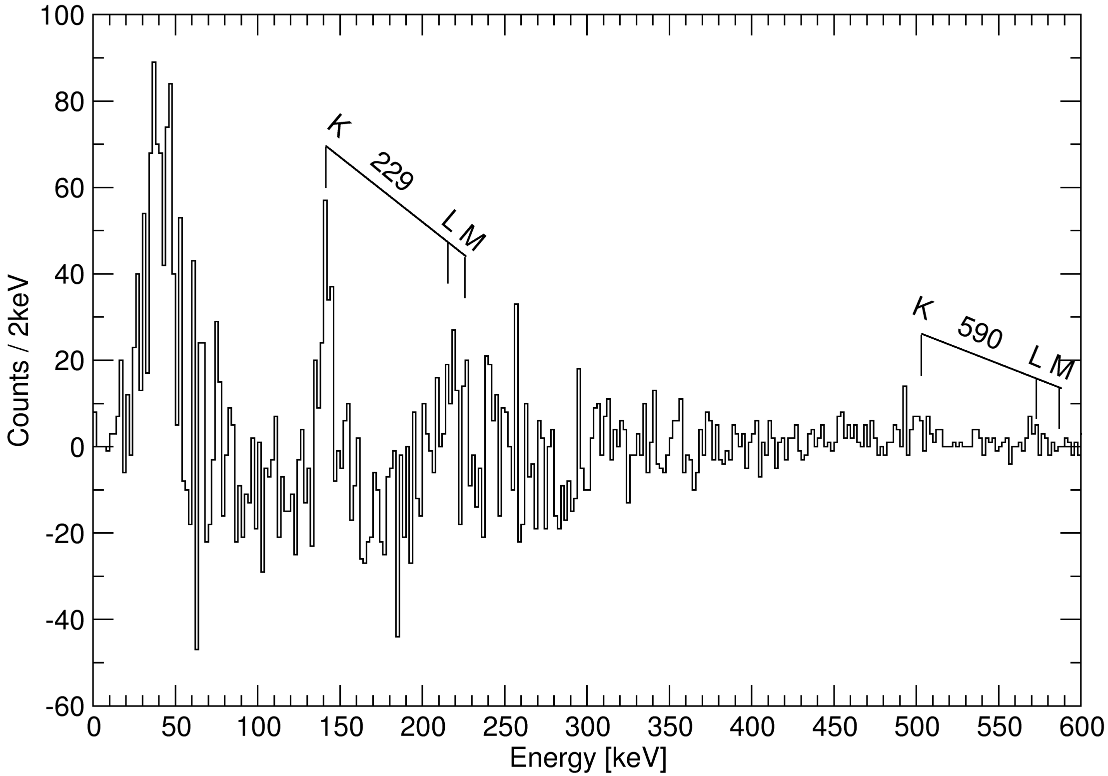
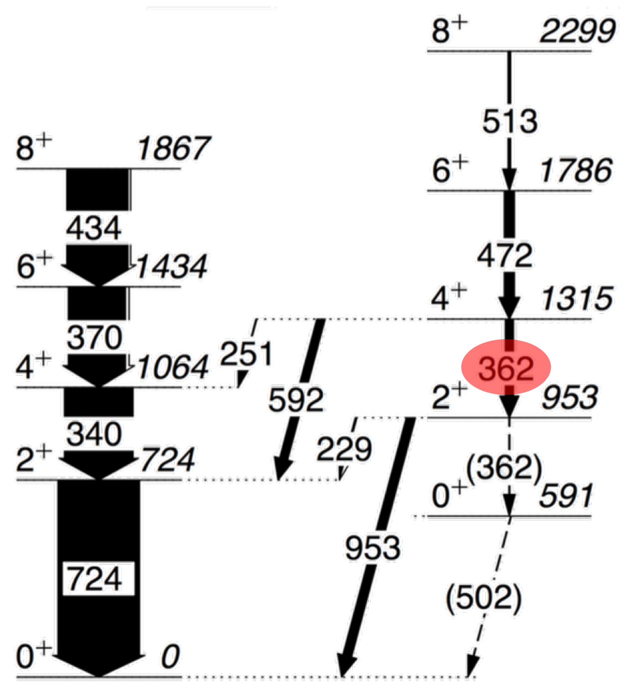
Physics case 1: Shape coexistence in ^{186,188}Pb

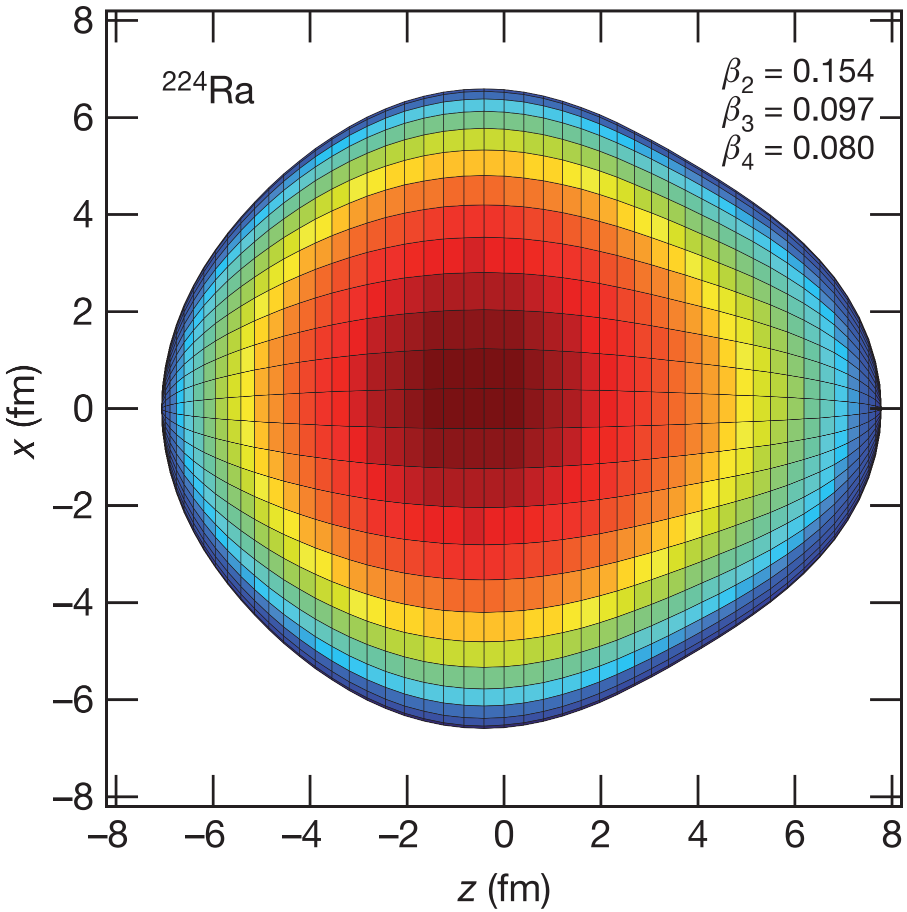
electron spectrum from S07



Detail from ^{188}Pb level scheme



Physics case 2: Octupole collectivity of Rn and Ra



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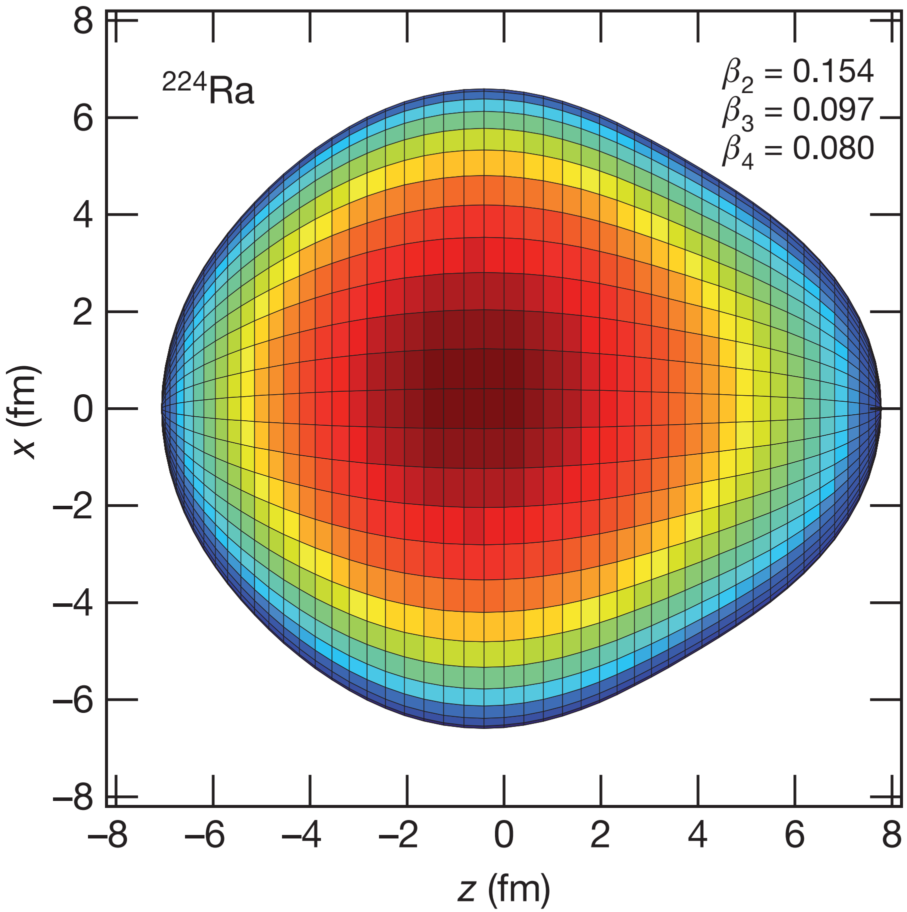
L.P. Gaffney et al., Nature (London) 497, 199 (2013).

Physics case 2: Octupole collectivity of Rn and Ra



Octupole nuclei

↓

Enhanced Schiff moment

↓

Atomic Electric-Dipole Moment

↓

Indications of CP-violation

↓

Constrains on extension of SM

Significant increase in sensitivity over non-octupole deformed nuclei

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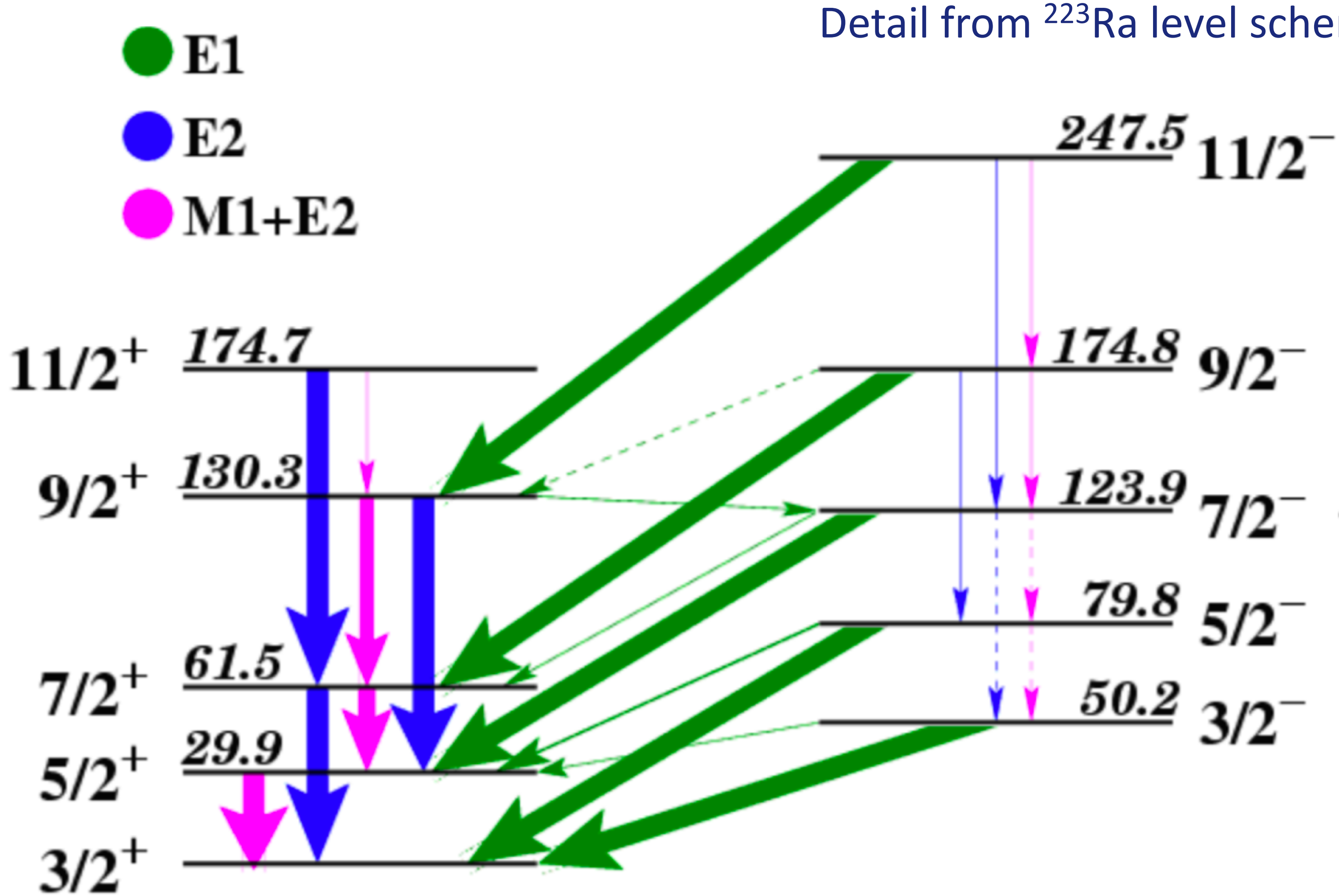
L.P. Gaffney et al., Nature (London) 497, 199 (2013).

Physics case 2: Octupole collectivity of Rn and Ra

Detail from ^{223}Ra level scheme



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Physics case 2: Octupole collectivity of Rn and Ra

nucleus	initial	final	γ energy	counts (γ)	counts (e^-)	Mλ, shell
^{221}Rn	9/2+	7/2+	*70*	**1850**	**20300**	M1, L
	11/2+	9/2+	*70*	**450**	**5000**	M1, L
	13/2+	11/2+	*160*	**140**	**380**	M1, K
	7/2-	7/2+	*110*	**200**	12	E1, L
	9/2-	7/2-	*70*	10	**110**	M1, L
^{223}Ra	5/2+	3/2+	29.9	**145**	**5650**	M1, M
	7/2+	3/2+	61.5	40	**5970**	E2, L
	7/2+	5/2+	31.6	**85**	**2880**	M1,M
	9/2+	5/2+	100.4	**170**	**1170**	E2, L
	9/2+	7/2+	68.8	**125**	**1730**	M1, L
	11/2+	7/2+	113.2	**140**	**540**	E2, L
	11/2+	9/2+	44.1	12	**150**	M1,M
	3/2-	3/2+	50.2	**90**	**90**	E1, L
	7/2-	5/2+	94.0	**70**	14	E1, L
	9/2-	7/2+	113.3	**100**	6	E1,L

Table 2. Estimated counts (γ-ray and conversion electron) for various transitions in ^{221}Rn and ^{223}Ra, assuming 9 shifts with beam intensity of 5 x 10^4 pps on a 2 mg/cm^2 Cd target. The ^{221}Rn level scheme is schematic. Intensities in bold are considered significant for observation. The last column gives the parameters for the e^- conversion line; K, L, M binding energies are respectively 98, 18, 4 keV for Rn, and 104, 19, 5 keV for Ra.

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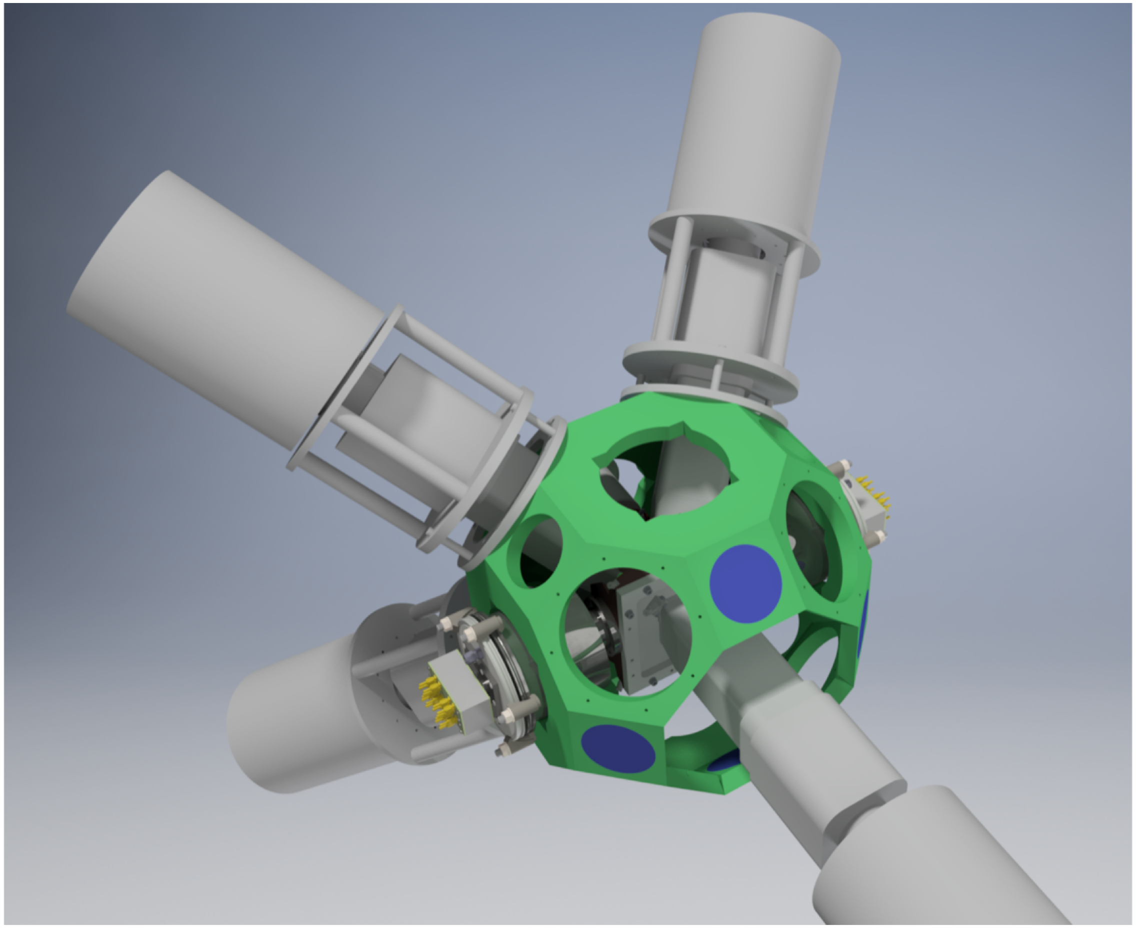
Outline

- The SPEDE spectrometer
- Testing and commissioning
- GEANT4 simulations
- Approved experiments
- Physics case 1: Shape coexistence in ^{186,188}Pb
- Physics case 2: Octupole collectivity in Rn and Ra nuclei
- Other applications of SPEDE
- Outlook

Other applications of SPEDE

- SPEDE at IDS



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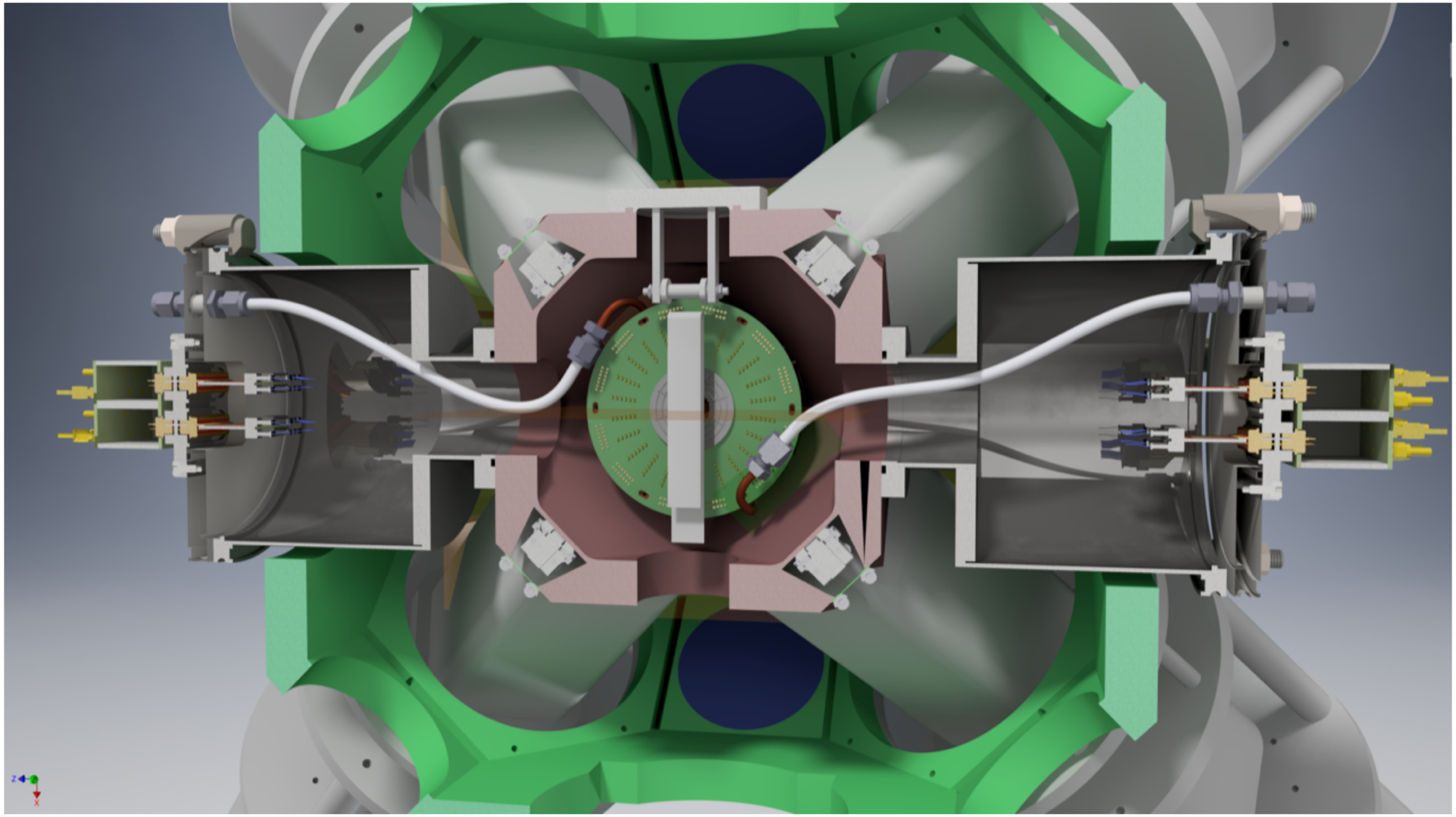
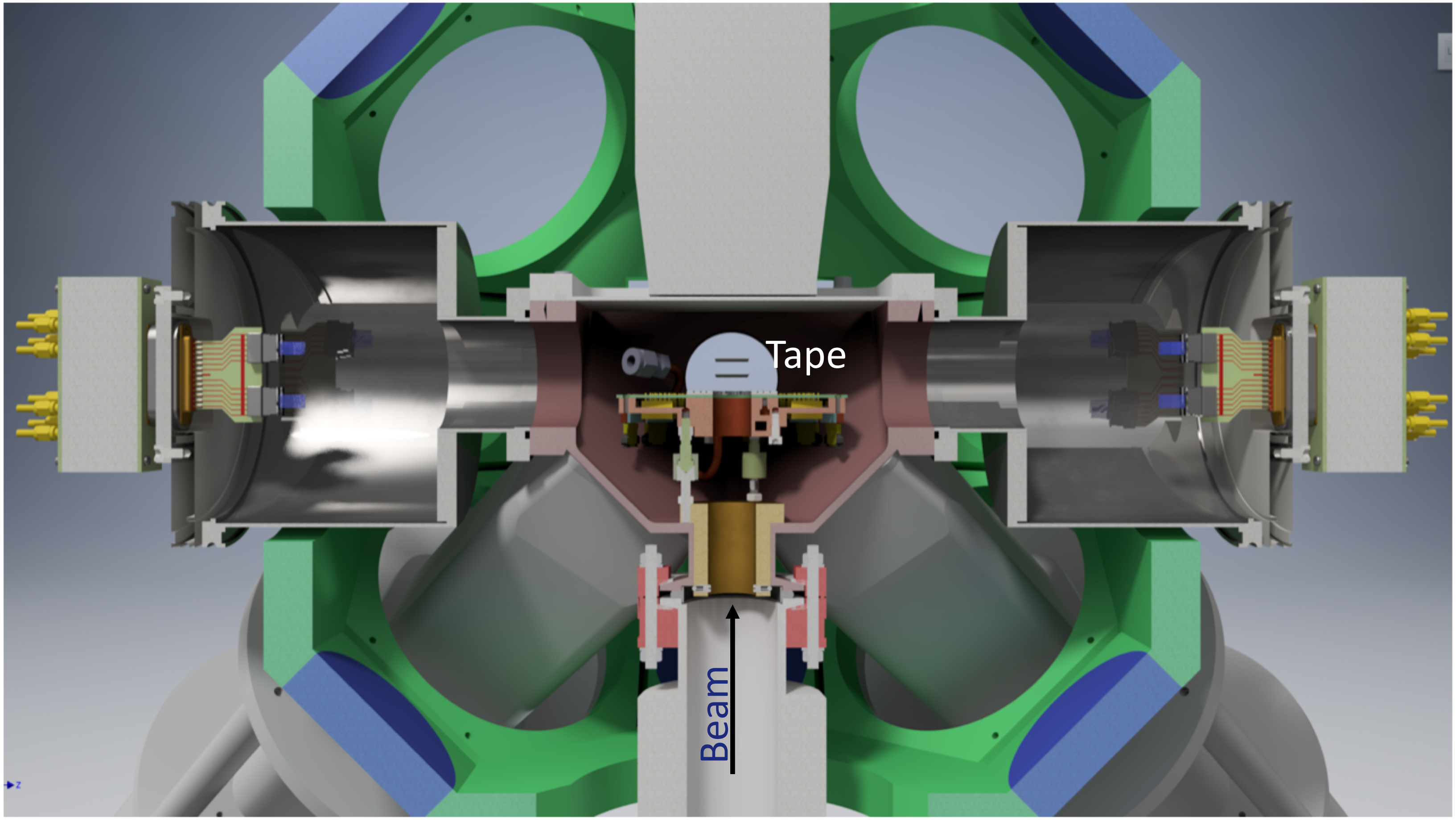
Other applications of SPEDE

- SPEDE at IDS



Other applications of SPEDE

- SPEDE at IDS



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Other applications of SPEDE

- SPEDE at IDS

- Example experiment:
- IS641 "The structure of the low-lying excited states in $^{182;184;186}$Hg studied through +/EC decay of $^{182;184;186}$Tl at IDS"
- Spokesperson: Kseniia Rezynkina

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Outlook

- The SPEDE spectrometer was constructed in JYFL and tested both in JYFL and at ISOLDE
- Electron efficiency around 7% up to ~400keV with a 0.5mm thick detector
- 1mm detector on order from Micron
- 4 approved proposals
- SPEDE will be used at IDS first and after the long shutdown will be ready for use at Miniball

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