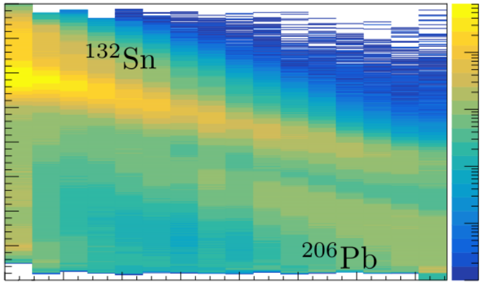
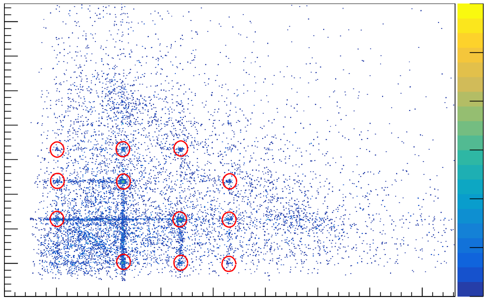
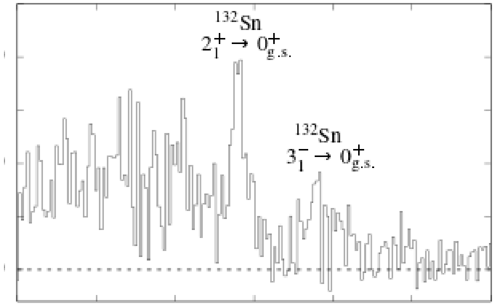
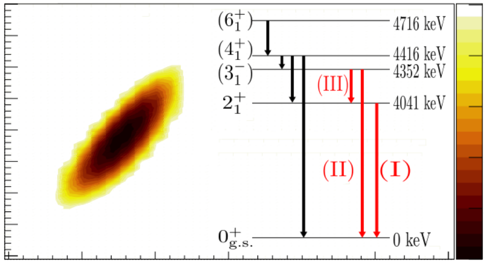
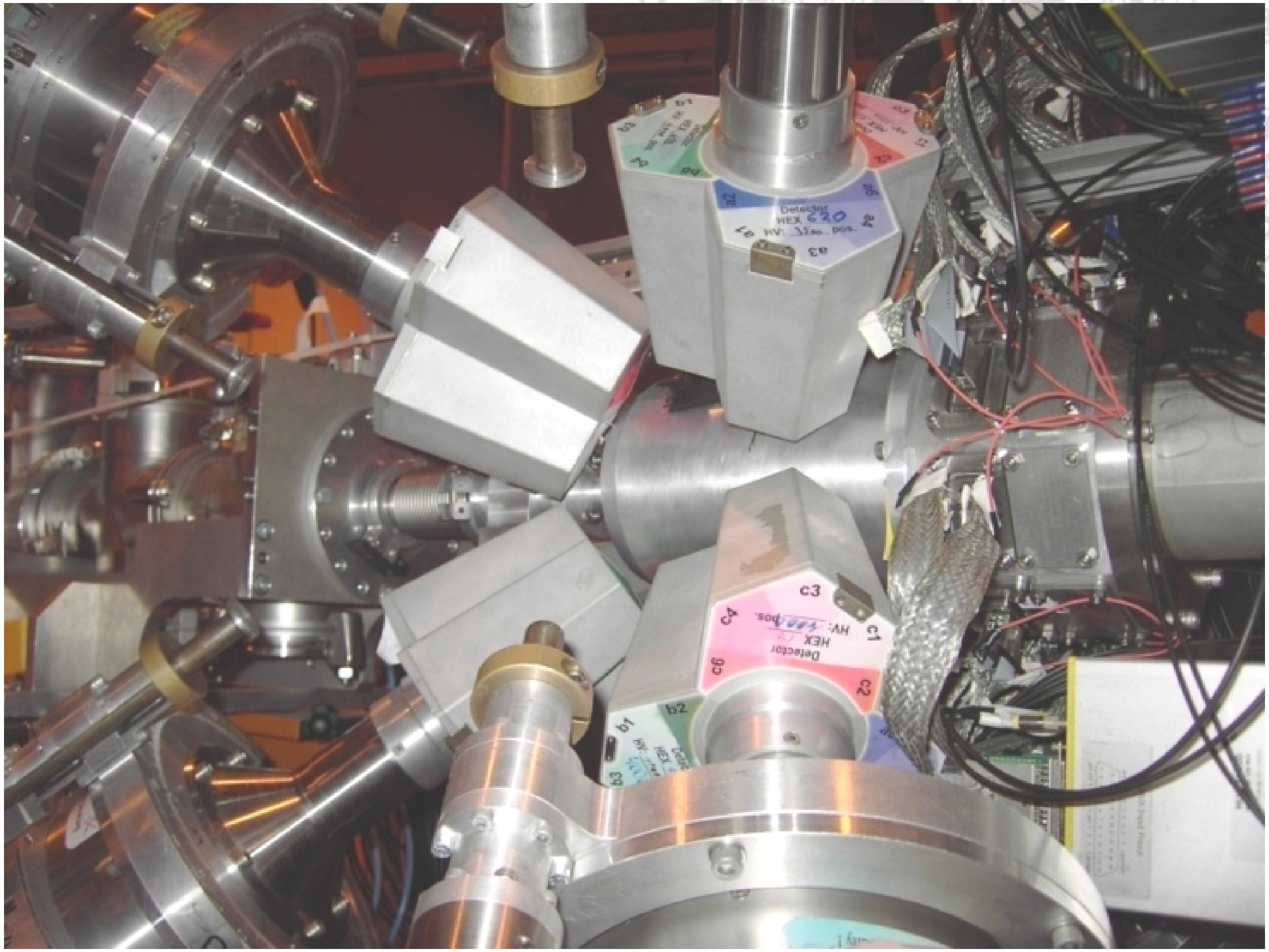
Coulomb excitation of doubly-magic ^{132}Sn at HIE-ISOLDE











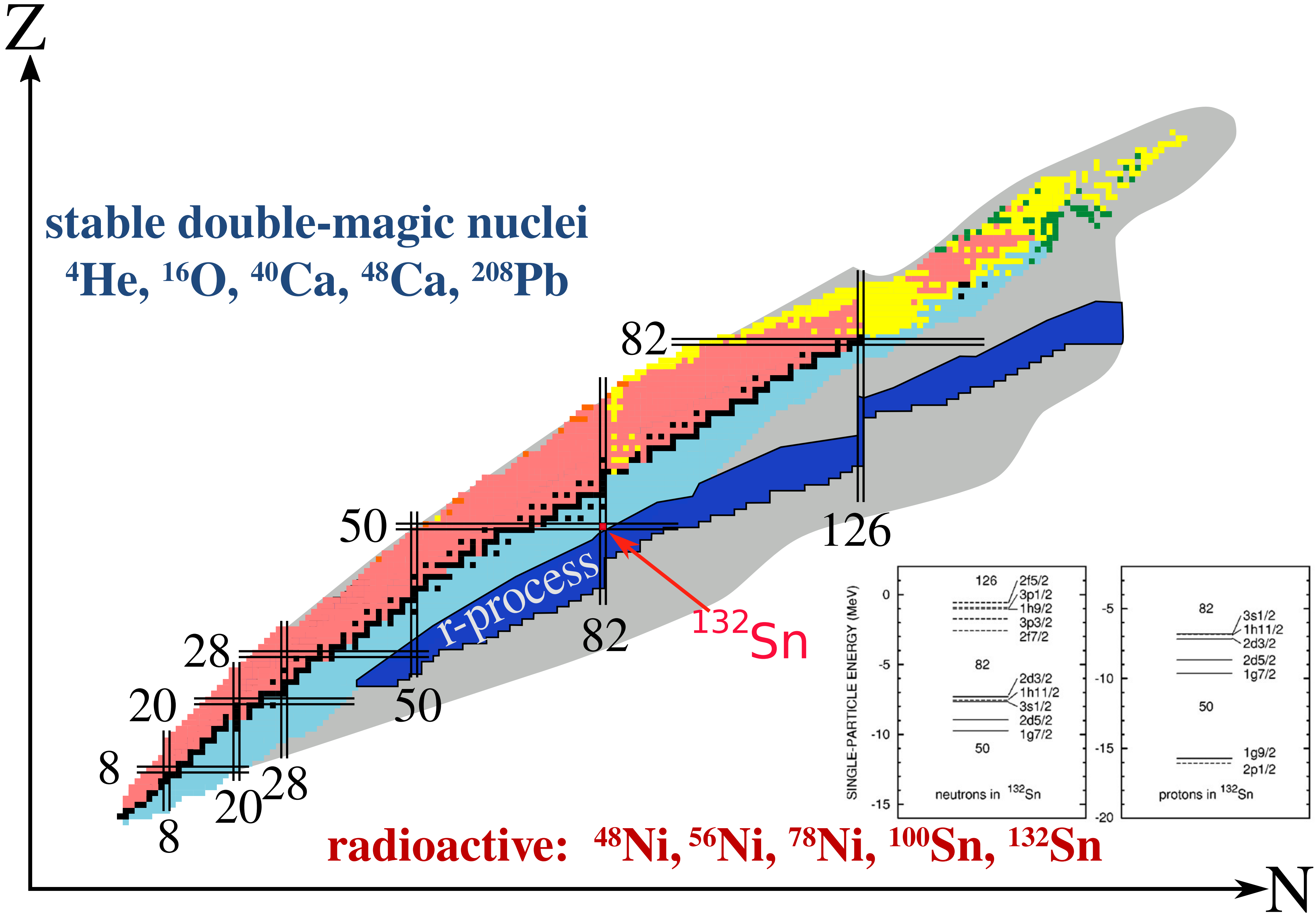
Universität zu Köln

Institute for Nuclear Physics
University of Cologne

Dawid Rosiak
04 December 2017

Motivation

stable double-magic nuclei
^{4}He, ^{16}O, ^{40}Ca, ^{48}Ca, ^{208}Pb



radioactive: ^{48}Ni, ^{56}Ni, ^{78}Ni, ^{100}Sn, ^{132}Sn

Motivation

^{131}I	^{132}I	^{133}I	^{134}I	^{135}I	^{136}I	^{137}I	^{138}I
^{130}Te	^{131}Te	^{132}Te	^{133}Te	^{134}Te	^{135}Te	^{136}Te	^{137}Te
^{129}Sb	^{130}Sb	^{131}Sb	^{132}Sb	^{133}Sb	^{134}Sb	^{135}Sb	^{136}Sb
^{128}Sn	^{129}Sn	^{130}Sn	^{131}Sn	^{132}Sn	^{133}Sn	^{134}Sn	^{135}Sn
^{127}In	^{128}In	^{129}In	^{130}In	^{131}In	^{132}In	^{133}In	^{134}In
^{126}Cd	^{127}Cd	^{128}Cd	^{129}Cd	^{130}Cd	^{131}Cd	^{132}Cd	^{133}Cd

Single-particle properties:

G. Bocchi *et al.*
PLB 760, 273-278 (2016)
Doi:10.1016/ j.physletb. 2016.06.065

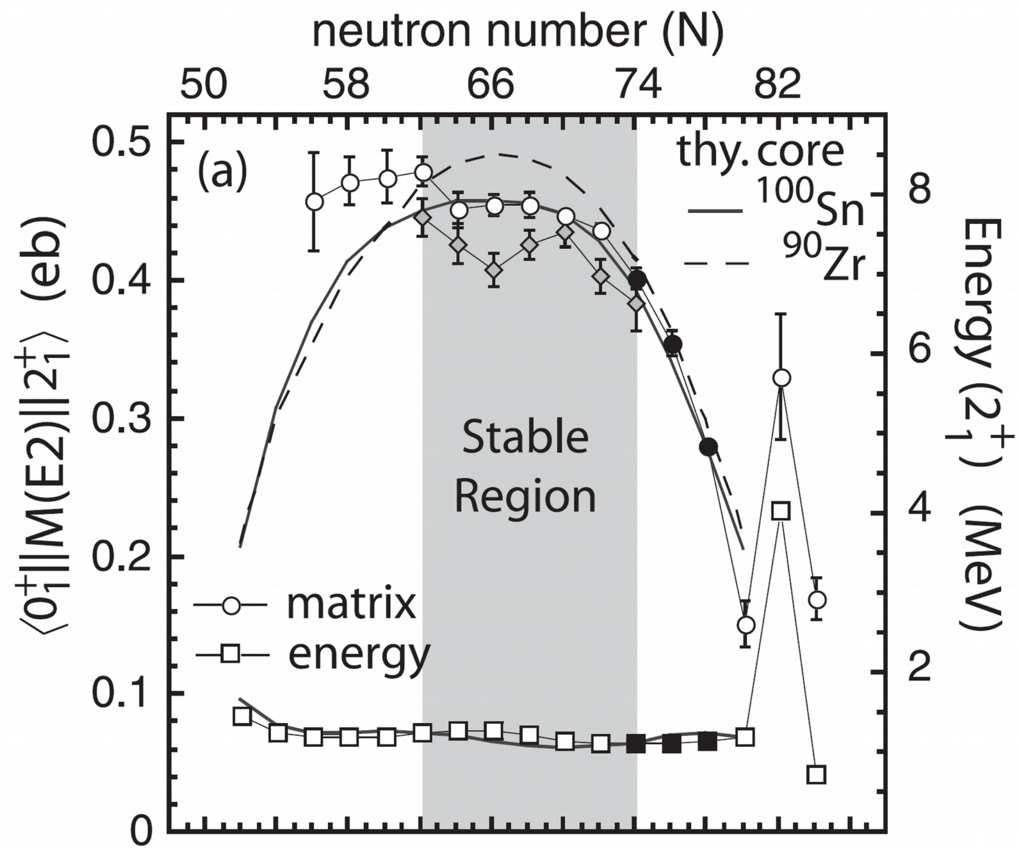
R. L. Kozub *et al.*
PRL, 109, 172-177 (October 2012)
doi:10.1103/ PhysRevLett. 109.172501

K. L. Jones *et al.*
Nature 465, 430–431 (27 May 2010)
doi:10.1038/465430a

M. Gorska *et al.*
PLB 672, 4, 313–316, (2009)
doi:0.1016/j.physletb. 2009.01.027

Coulomb excitation of ^{132}Sn:
Collective properties!

Coulomb excitation of ^{132}Sn



J.M. Allmond, et al., Phys. Rev. C 84 (2011) 061303(R)

shell-model calculations ^{100}Sn/^{90}Zr core (solid/dashed)
A.Banu, et al., Phys. Rev. C 72 (2005) 061305(R)

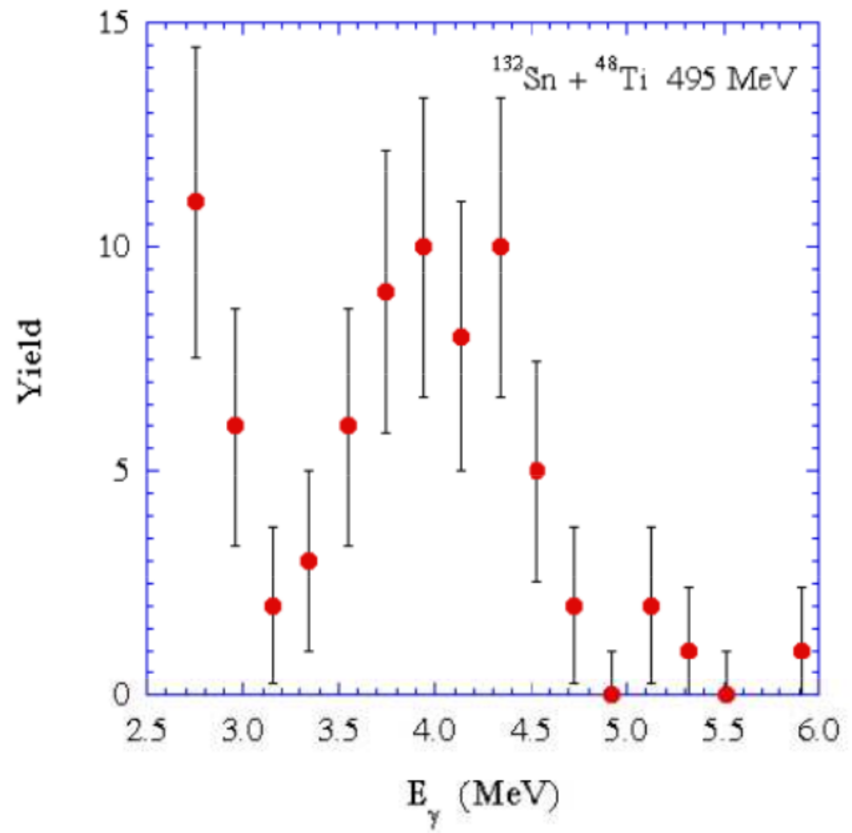
Lifetime measurement (gray-filled diamonds)
A.Jungclaus et al.; Phys. Lett. B 695 (2011) 110

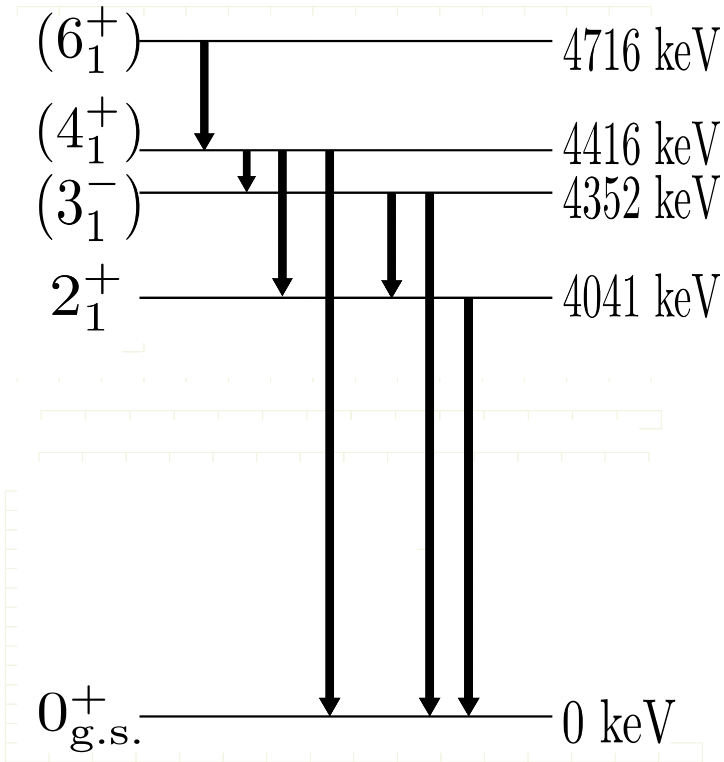
^{132}Sn:

B(E2; $0^+ \rightarrow 2^+$) = 0.11(3) e^2b^2
R.L. Varner et al.,
Eur. Phys. J. A 25, s01, 391 (2005),
4th International Conference on Exotic Nuclei and Atomic Masses.

B(E2; $0^+ \rightarrow 2^+$) = 0.14(6) e^2b^2
D.C. Radford et al.,
Nucl. Phys. A746, 83c (2004)

Coulomb excitation of ^{132}Sn





Experiment at Oak Ridge (HRIBF)

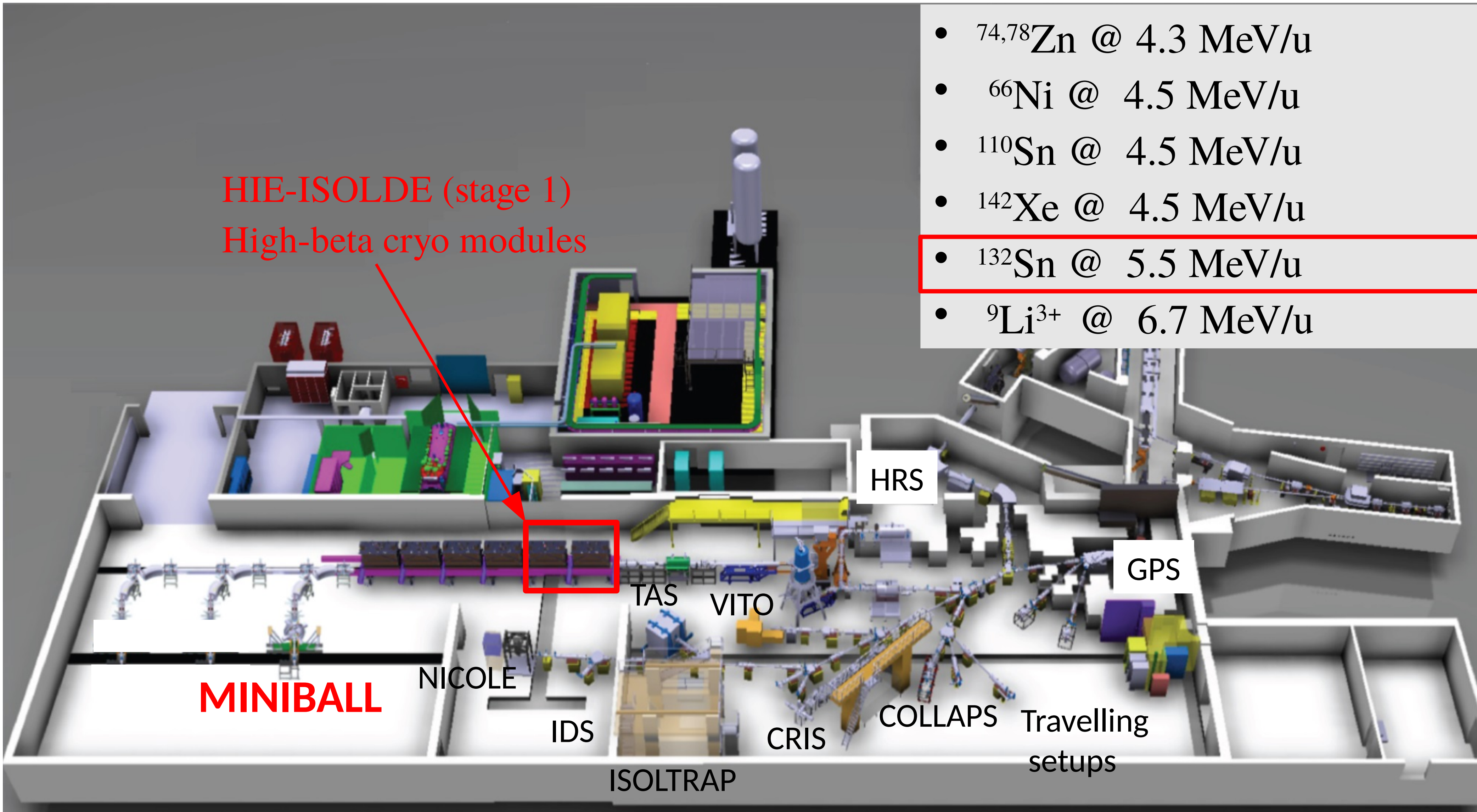
→ ^{132}Sn beam:
1.3 x 10^5 ions/s, 96% pure
3.75 MeV/u, 3.56 MeV/u
→ ^{48}Ti target, 1.3 mg/cm^2

→ BaF2 array
high efficiency ~30% @ 4 MeV
→ γ-particle coincidence measurement
→ inverse kinematics

ISOLDE facility

REX-ISOLDE: beam energies up to 3 MeV/u
HIE-ISOLDE (2016): two cryo modules, energy of 5.5 MeV/u for A/q≈4.5

- $^{74,78}Zn$ @ 4.3 MeV/u
- ^{66}Ni @ 4.5 MeV/u
- ^{110}Sn @ 4.5 MeV/u
- ^{142}Xe @ 4.5 MeV/u
- ^{132}Sn @ 5.5 MeV/u
- $^{9}Li^{3+}$ @ 6.7 MeV/u



ISOLDE facility

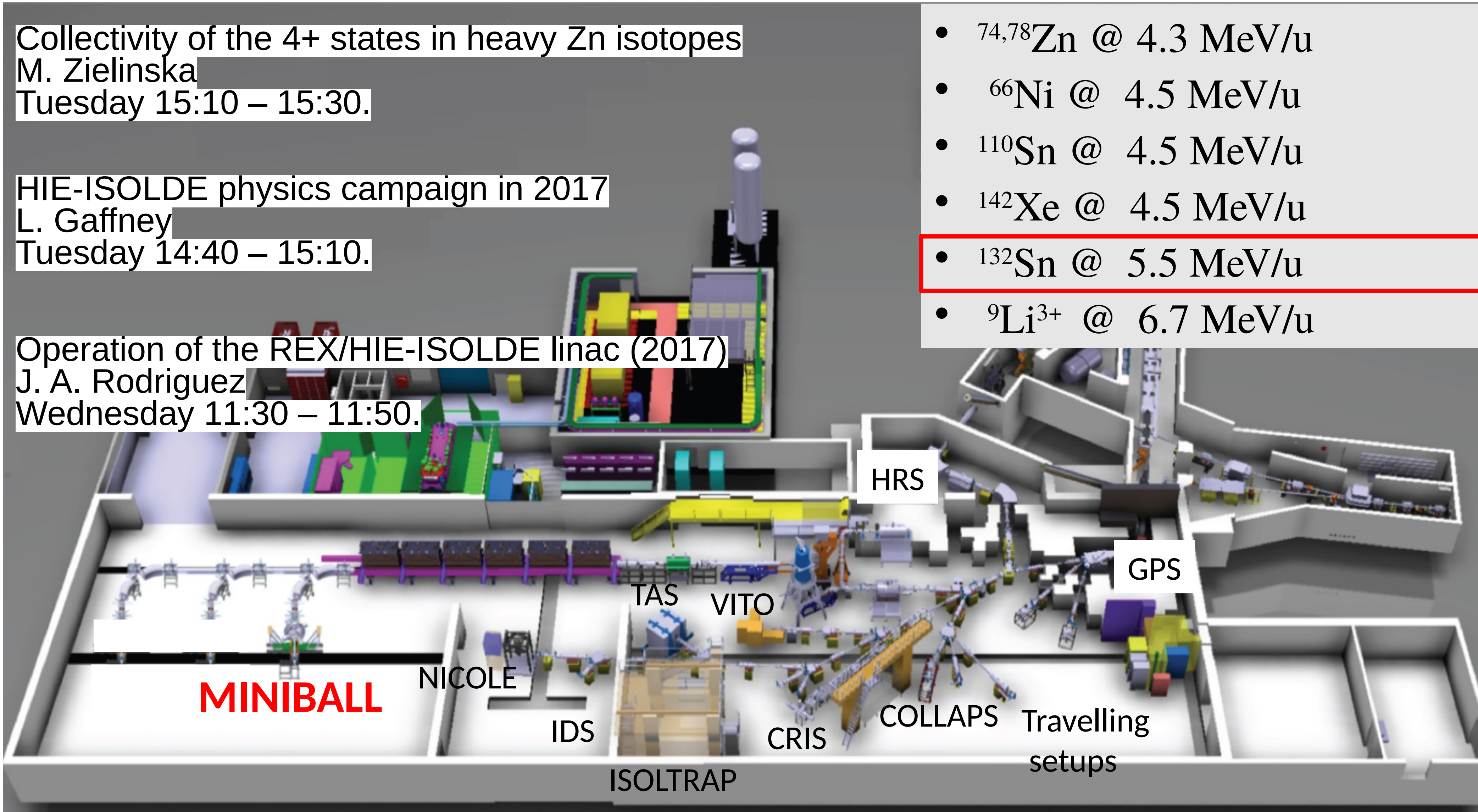
REX-ISOLDE: beam energies up to 3 MeV/u
HIE-ISOLDE (2016): two cryo modules, energy of 5.5 MeV/u for A/q≈4.5

Collectivity of the 4+ states in heavy Zn isotopes
M. Zielinska
Tuesday 15:10 – 15:30.

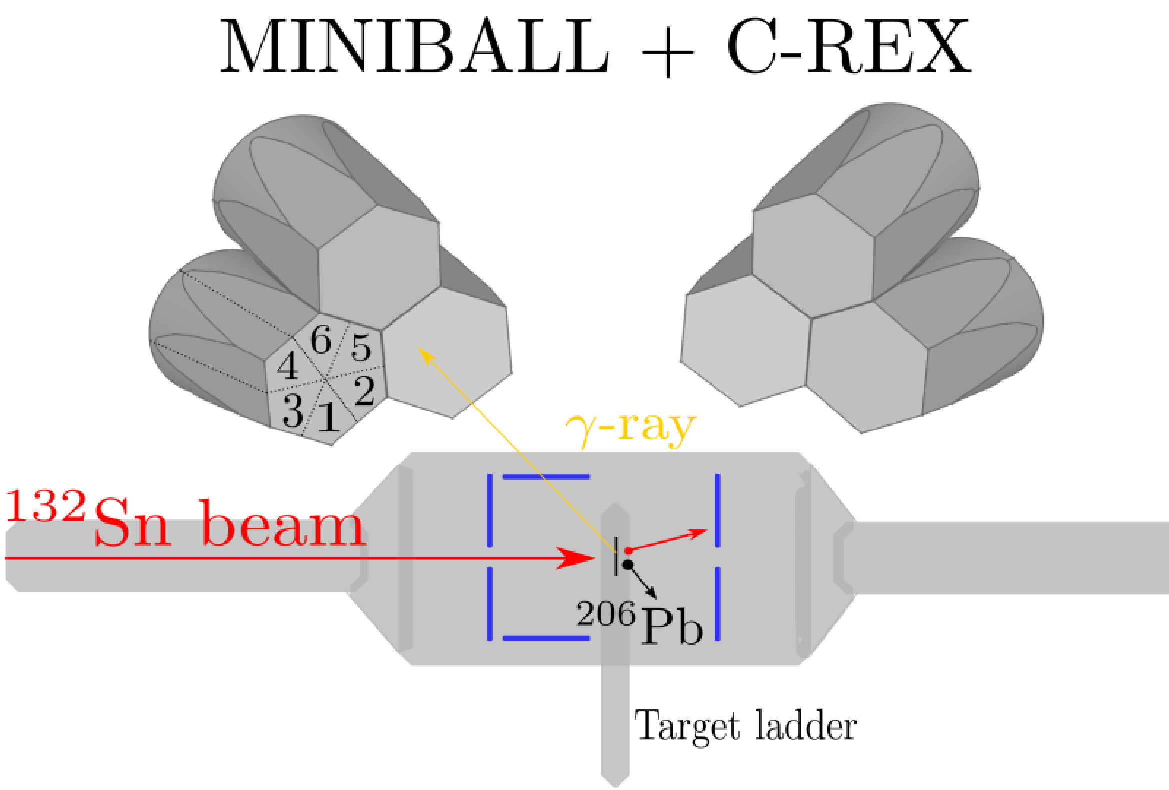
HIE-ISOLDE physics campaign in 2017
L. Gaffney
Tuesday 14:40 – 15:10.

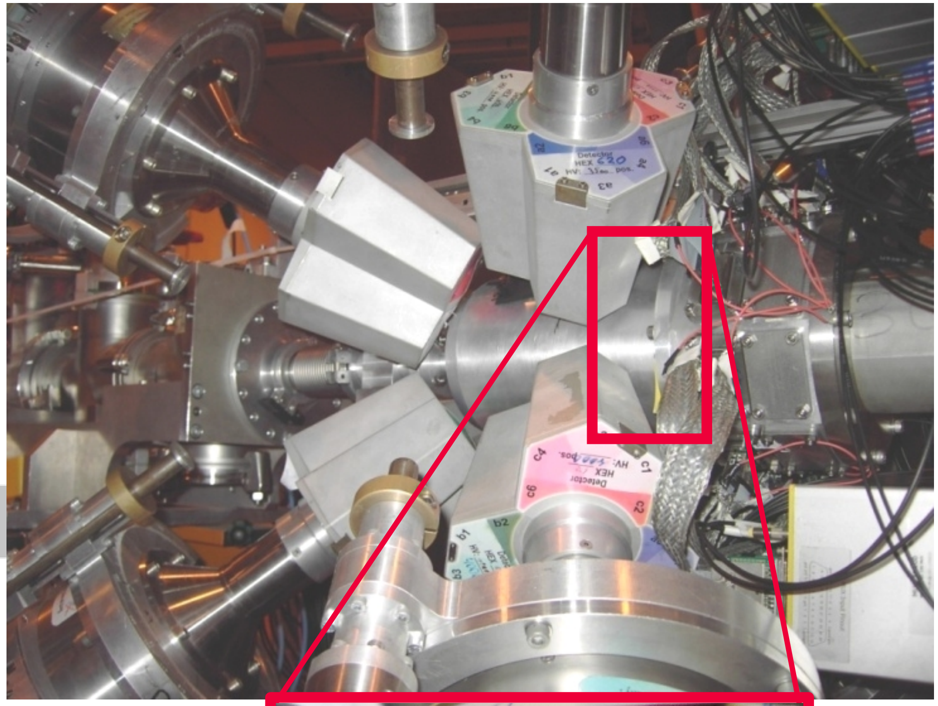
Operation of the REX/HIE-ISOLDE linac (2017)
J. A. Rodriguez
Wednesday 11:30 – 11:50.

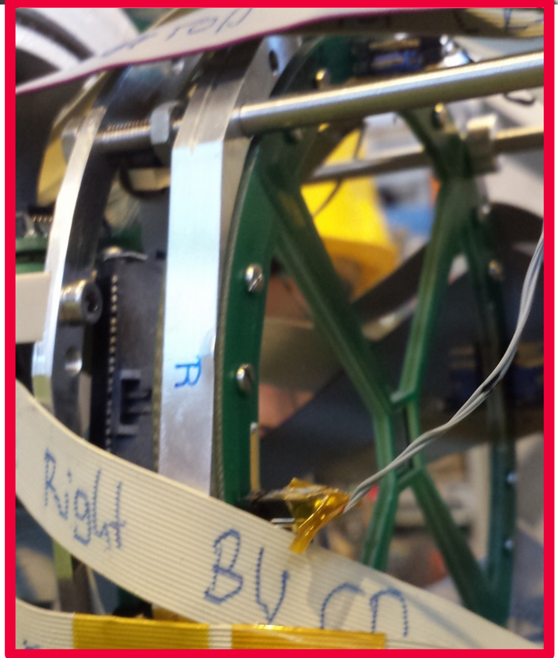
- ^{74,78}Zn @ 4.3 MeV/u
- ^{66}Ni @ 4.5 MeV/u
- ^{110}Sn @ 4.5 MeV/u
- ^{142}Xe @ 4.5 MeV/u
- ^{132}Sn @ 5.5 MeV/u
- ^{9}Li^{3+} @ 6.7 MeV/u



Experiment IS551







→ Molecular ISOLDE beam: **$^{132}Sn^{34}S$**

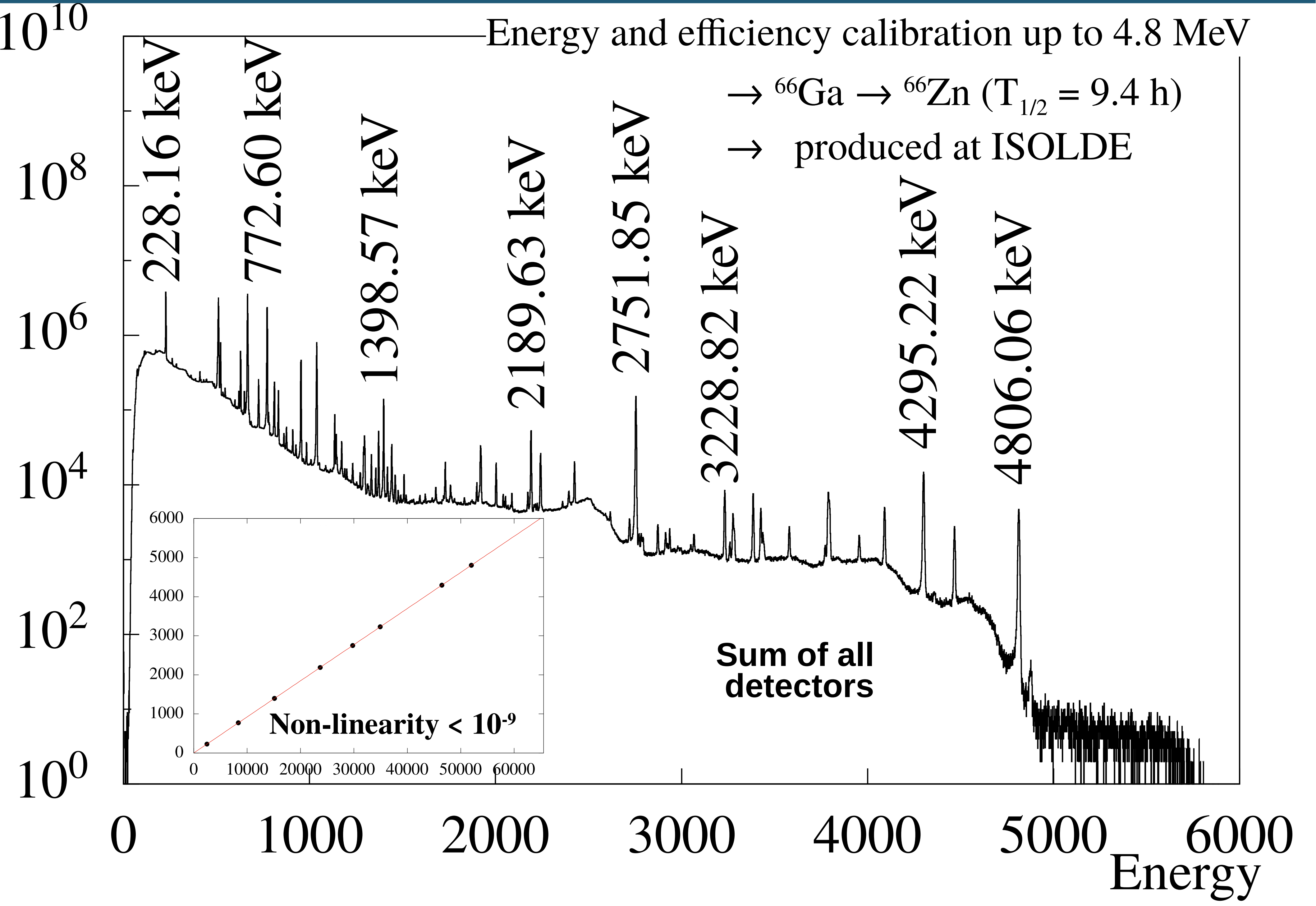
→ HIE-ISOLDE beam: $^{132}Sn^{31+}$ @ 5.49 MeV/u

→ Total RIB intensity: ~3 x 10^5 ions/s

→ 'safe' scattering angles: θ_{lab} = 17.8 - 41.5°

→ Beam composition: ^{132}Sn, ?

Experiment IS551

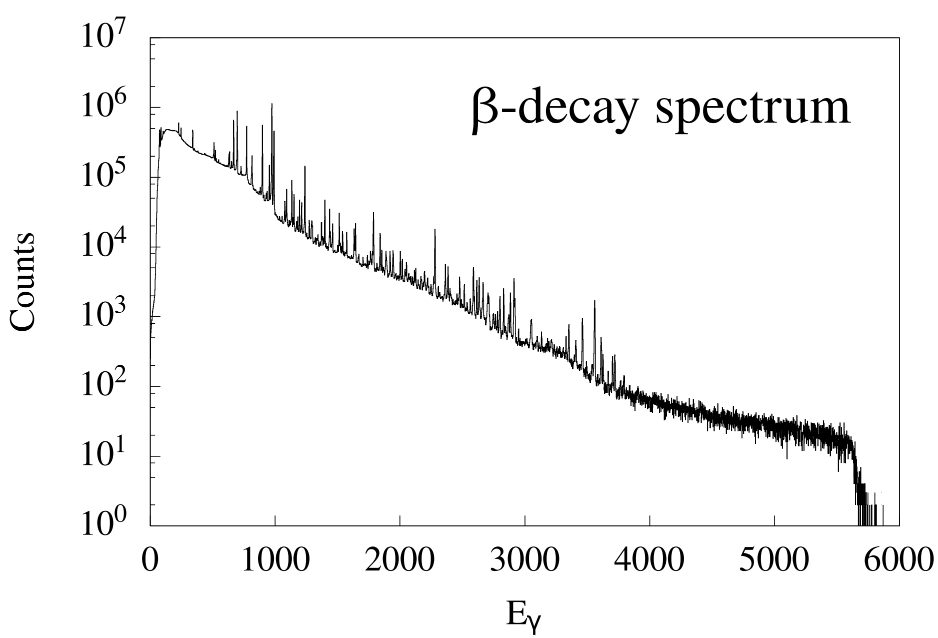


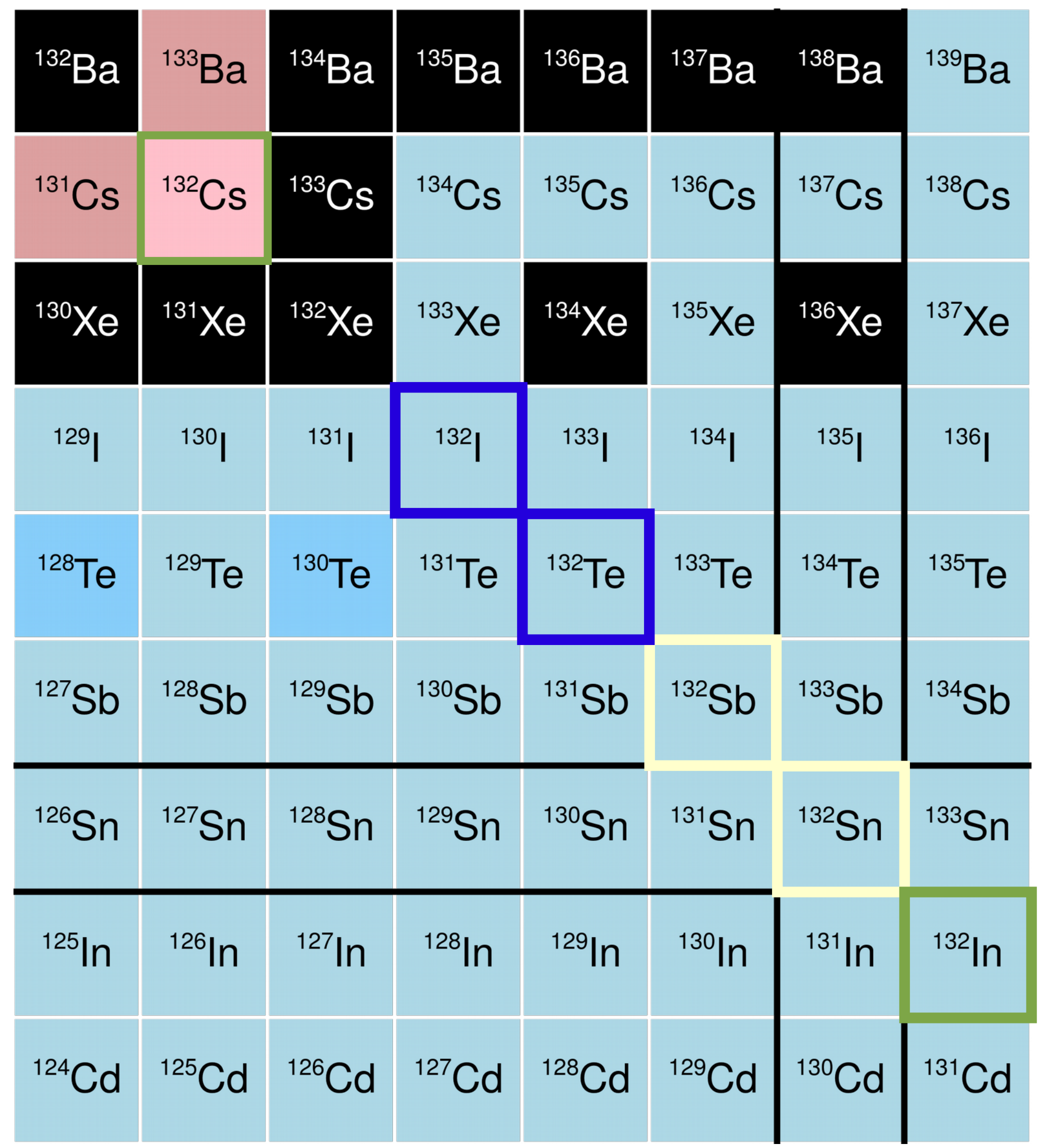
Experiment IS551

β-decay spectrum:
→ **no ^{132}In and ^{132}Cs**

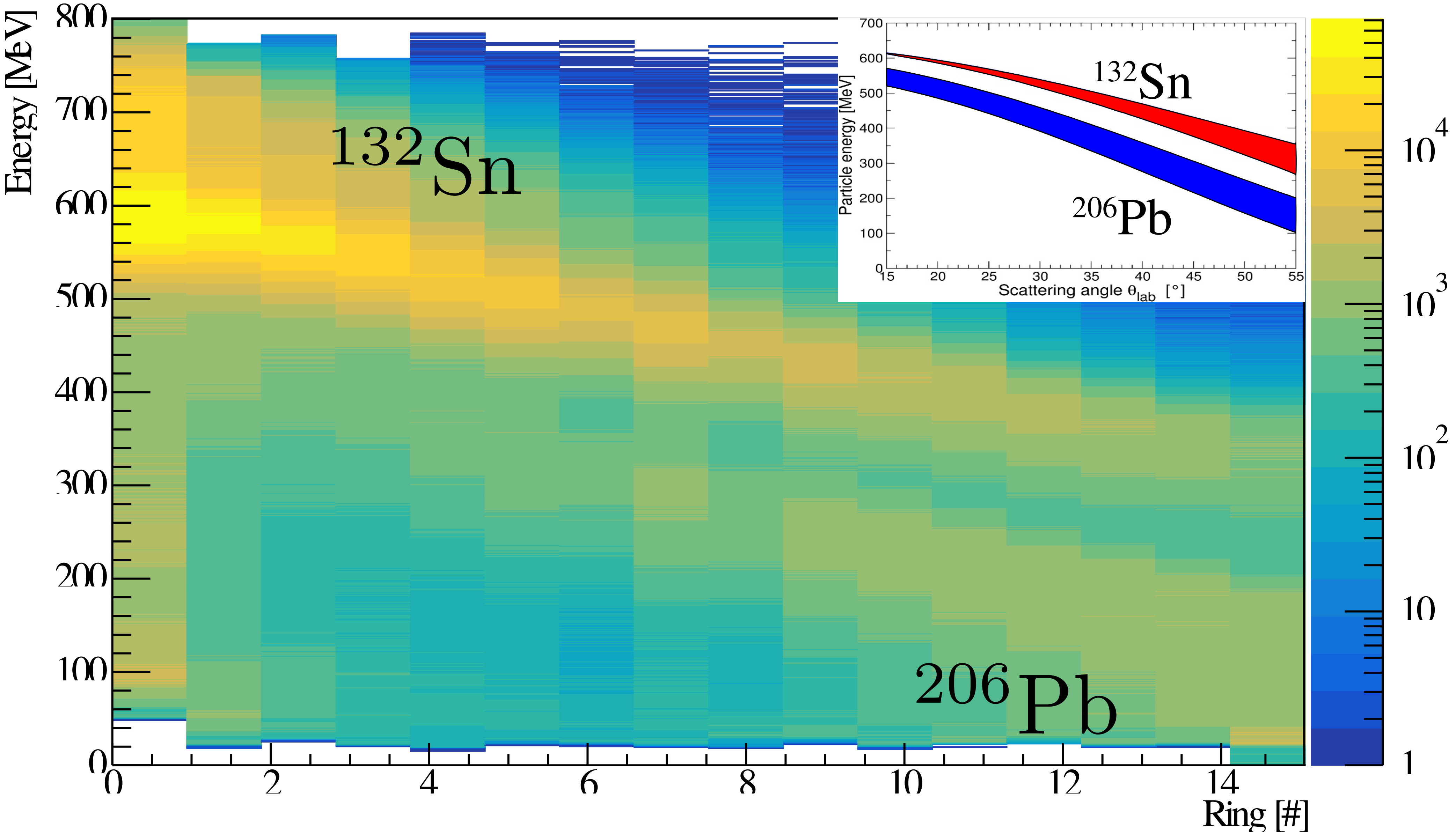
Evolution of β-decay ratios
→ **no ^{132}Te and ^{132}I**

Implantation Measurement:
$N^{Sn}_{Beam}/N^{Sb}_{Beam} = 2.18$

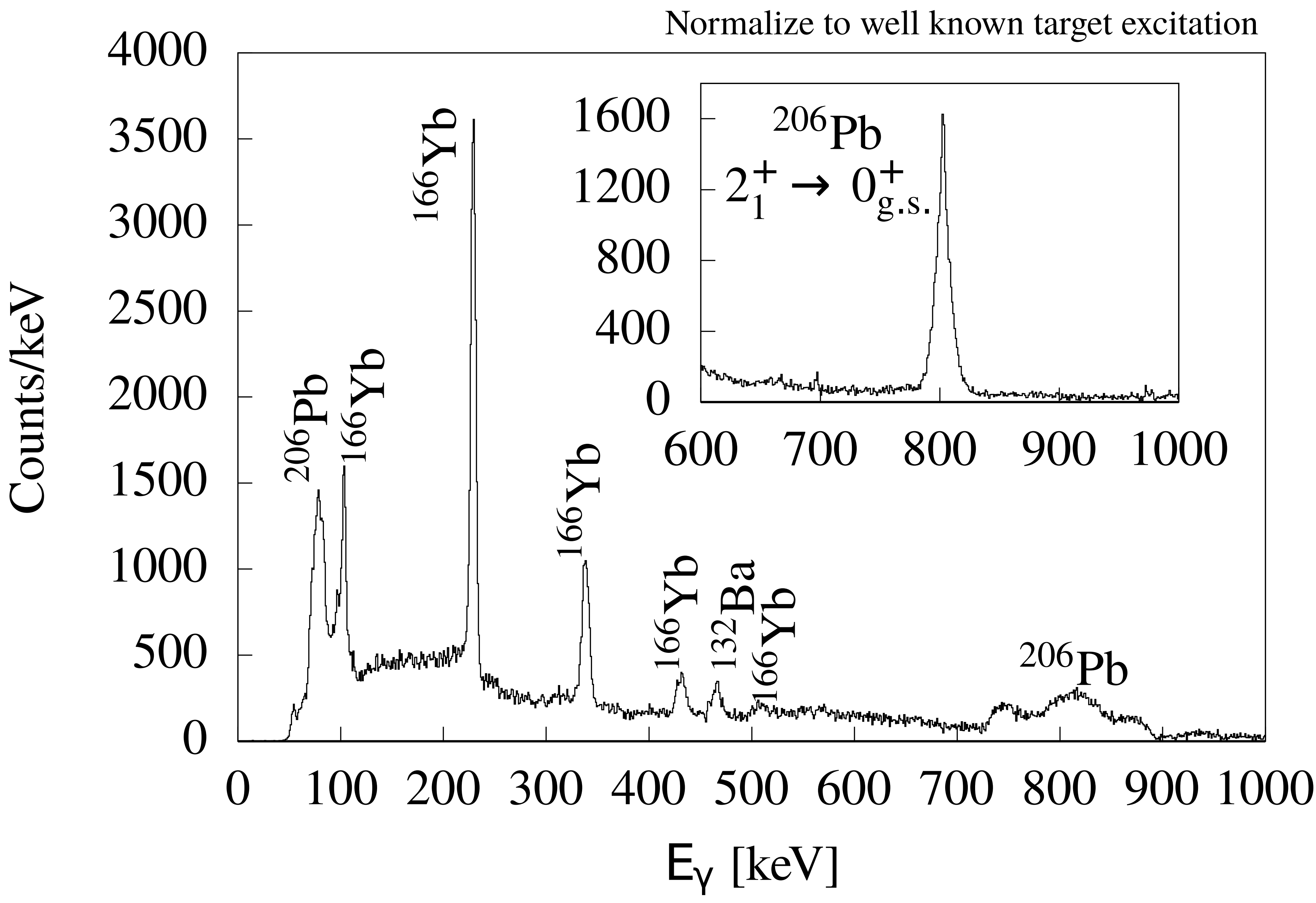




Experiment IS551

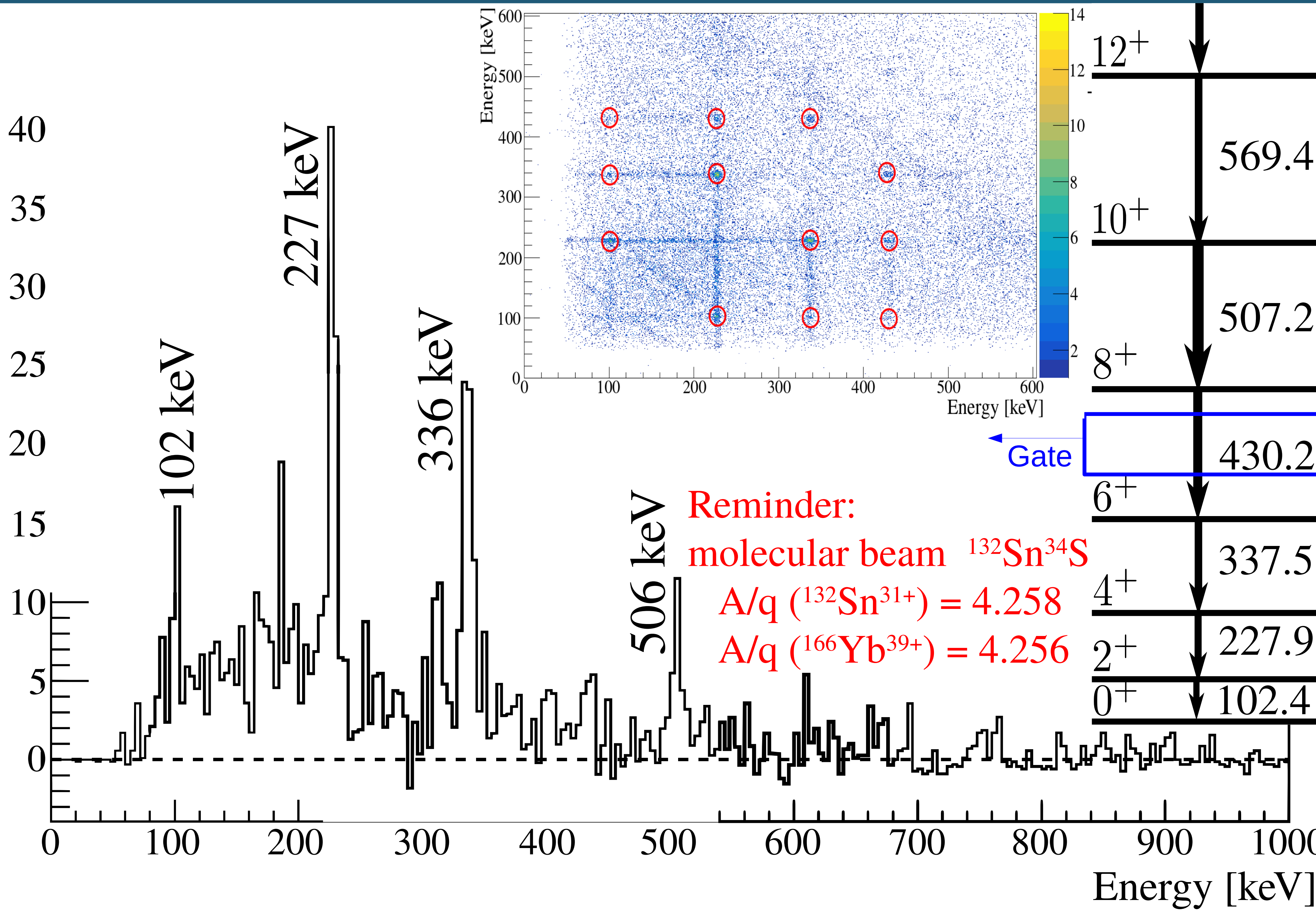


Experiment IS551



Experiment IS551

^{166}Yb



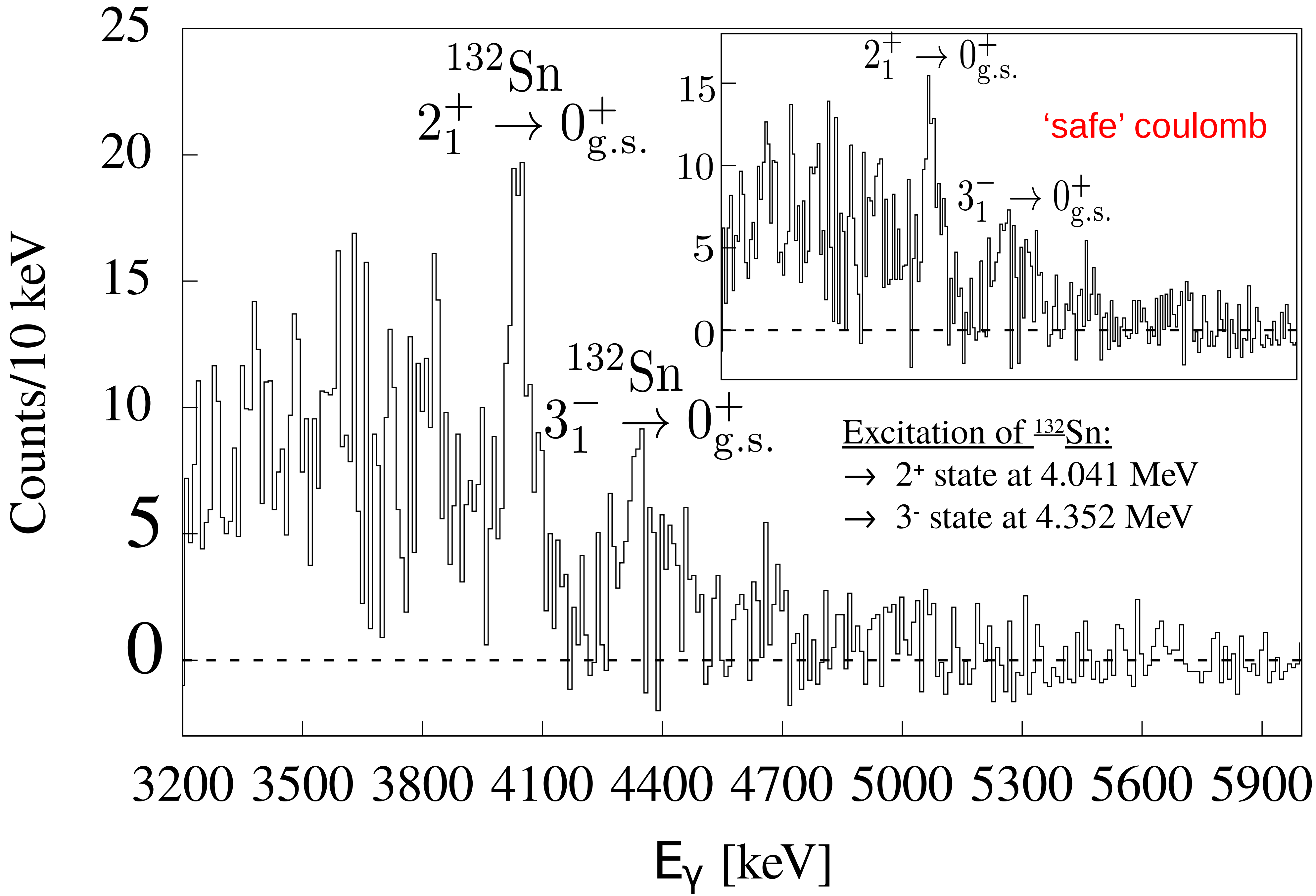
Reminder:

molecular beam $^{132}Sn^{34}S$

A/q ($^{132}Sn^{31+}$) = 4.258

A/q ($^{166}Yb^{39+}$) = 4.256

Experiment IS551



Excitation of ^{132}Sn:

→ 2^+ state at 4.041 MeV

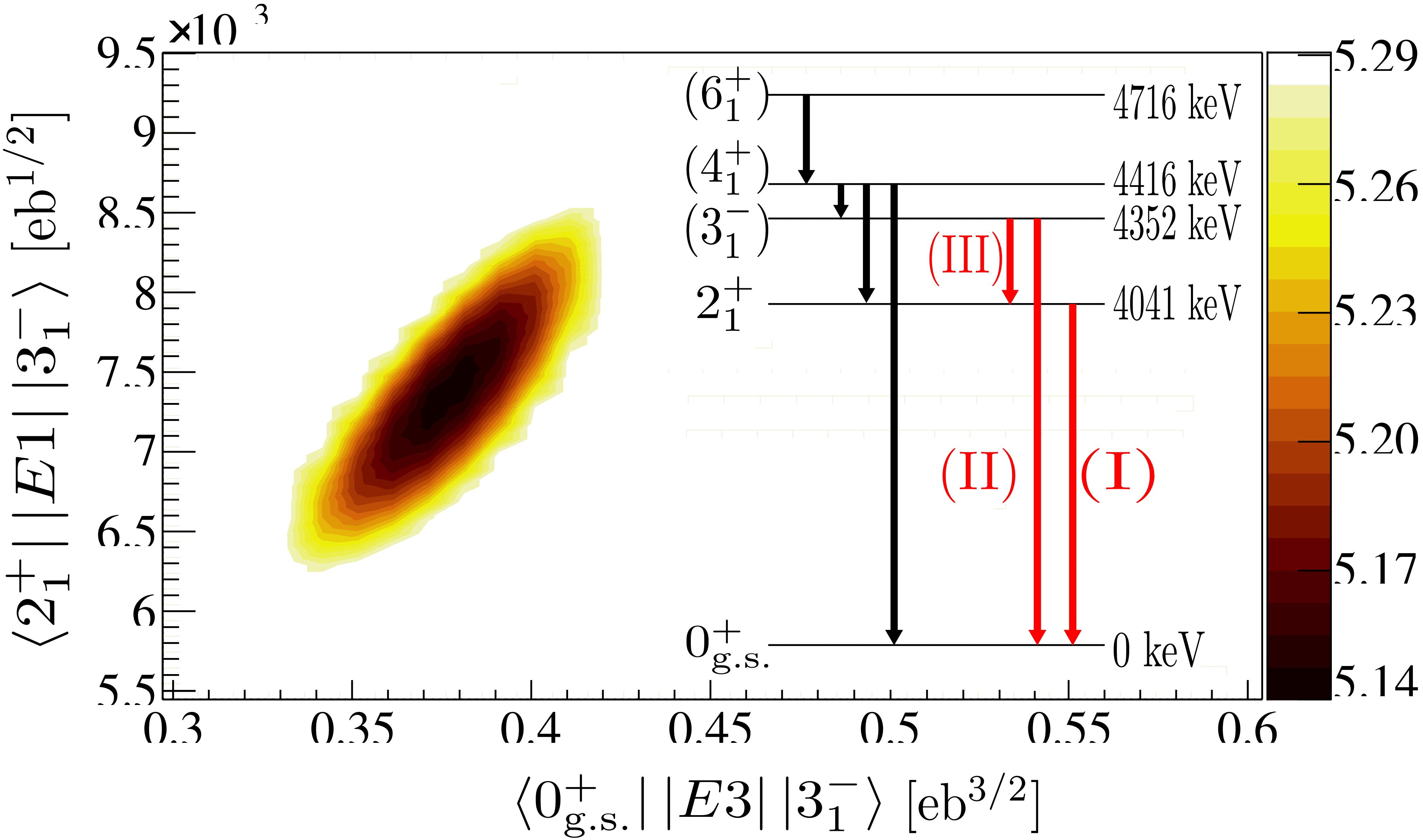
→ 3^- state at 4.352 MeV

GOSIA2 calculation

→ Intensities $2^+ \rightarrow 0^+$ and $3^- \rightarrow 0^+$ → Detector configuration → Level schemes of ^{132}Sn & ^{206}Pb

→ ^{206}Pb: E2 transition matrix element and Q quadrupole moment

→ ^{132}Sn: branching ratios $3^- \rightarrow 2^+$ / $3^- \rightarrow 0^+$ & $4^+ \rightarrow 3^+$ / $4^+ \rightarrow 2^+$ / $4^+ \rightarrow 0^+$

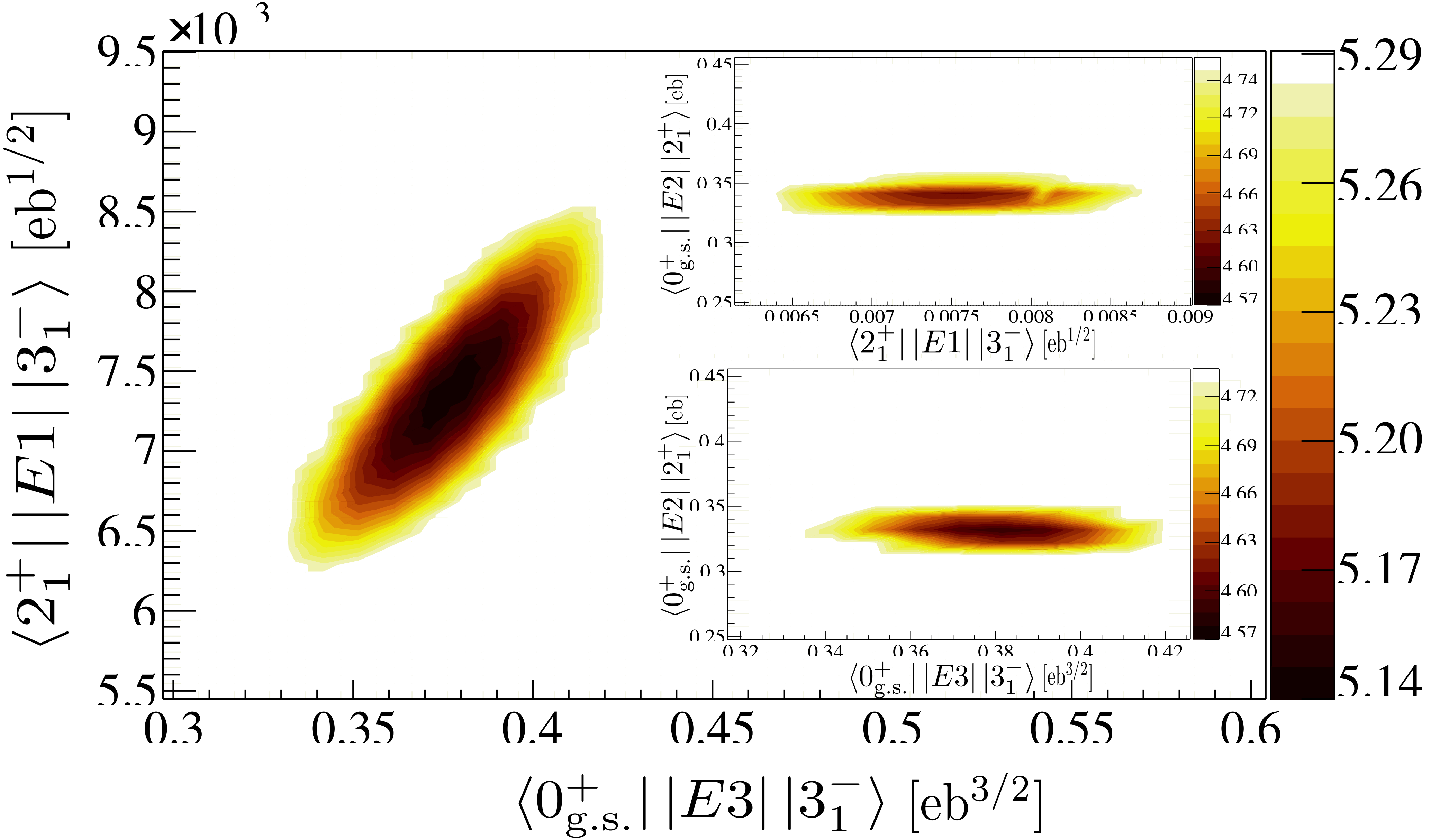


GOSIA2 calculation

→ Intensities $2^+ \rightarrow 0^+$ and $3^- \rightarrow 0^+$ → Detector configuration → Level schemes of ^{132}Sn & ^{206}Pb

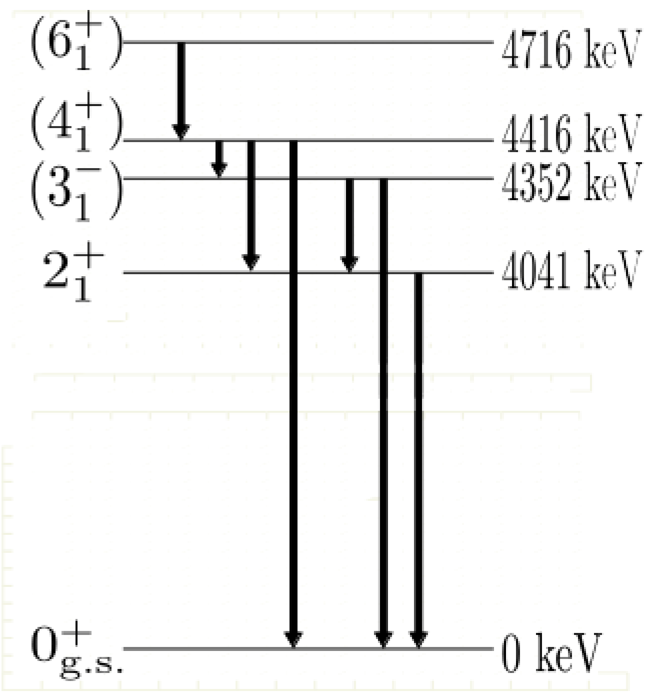
→ ^{206}Pb: E2 transition matrix element and Q quadrupole moment

→ ^{132}Sn: branching ratios $3^-\rightarrow2^+$ / $3^-\rightarrow0^+$ & $4^+\rightarrow3^+$ / $4^+\rightarrow2^+$ / $4^+\rightarrow0^+$



Final results

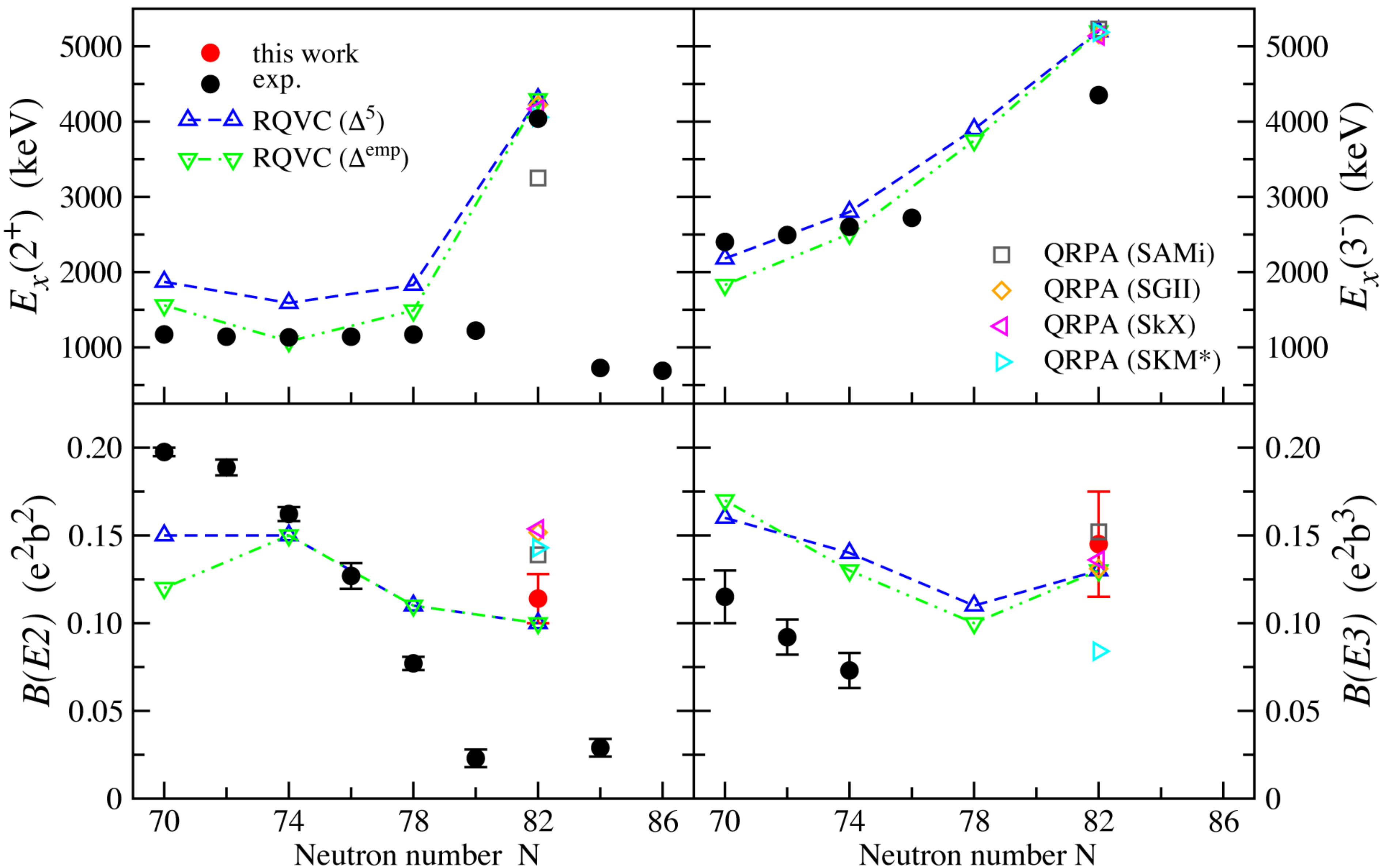
	This work	ORNL Conf. Proc.
B(E2; $2^+ \rightarrow 0^+$)	**0.114(14) e^2b^2**	**0.11(3)/0.14(6) e^2b^2**
B(E3; $3^- \rightarrow 0^+$)	**0.145(31) e^2b^3**	**-**
B(E1; $3^- \rightarrow 2^+$)	**1.1(4) x 10^{-5} e^2b**	**-**



R.L. Varner et al., Eur. Phys. J. A 25, s01, 391 (2005), 4th International Conference on Exotic Nuclei and Atomic Masses.

D.C. Radford et al., Nucl. Phys. A746, 83c (2004)

New theoretical results for ^{132}Sn



A. V. Afanasjev and E. Litvinova, Phys. Rev. C **92**, 044317 (2015). RQVC results.

G. Colo, P. F. Bortignon, and G. Bocchi, Phys. Rev C **95**, 034303 and private communication (2017) QRPA results.

Summary

→ Successful experiment at HIE-ISOLDE and max. energy of 5.5 MeV/u (2016).

→ Determined beam composition.

→ 132Sn: $2^+ \rightarrow 0^+$ and $3^- \rightarrow 0^+$ transitions identified.

→ Final B(E2), B(E1) and B(E3) values.

→ Comparison with theoretical models.

Outlook:

→ State of the art shell-model calculation.
Strasbourg and Tokyo groups.

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

D. Rosiak[1], M. Seidlitz[1], P. Reiter[1], K. Arnswald[1], T. Berry[2], A. Blazhev[1], M.J.G. Borge[3], J. Cederkäll[4], L. Gaffney[3], C. Henrich[5], R. Hirsch[1], A. Illana Sisón[6], K. Johnston[3], Y. Kadi[3], L. Kaya[1], Th. Kröll[5], M.L. Lozano Benito[7], M. Queiser[1], G. Rainovski[8], J.A. Rodriguez[7], E. Siesling[7], J. Snäll[4,3], P. van Duppen[6], A. Vogt[1], M. von Schmid[5], N. Warr[1], F. Wenander[7], and K.O. Zell[1]

[1] *Institut für Kernphysik, Universität zu Köln, 50937 Köln, Germany*

[2] *Department of Physics, University of Surrey, Guildford, GU2 7XH, United Kingdom*

[3] *Physics Department, ISOLDE, CERN, 1211 Geneva 23, Switzerland*

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[6] *Institute for Nuclear and Radiation Physics, K.U. Leuven, 3001 Leuven, Belgium*

[7] *ISOLDE, CERN, 1211 Geneva 23, Switzerland*

[8] *Department of Atomic Physics, University of Sofia, 1164 Sofia, Bulgaria*

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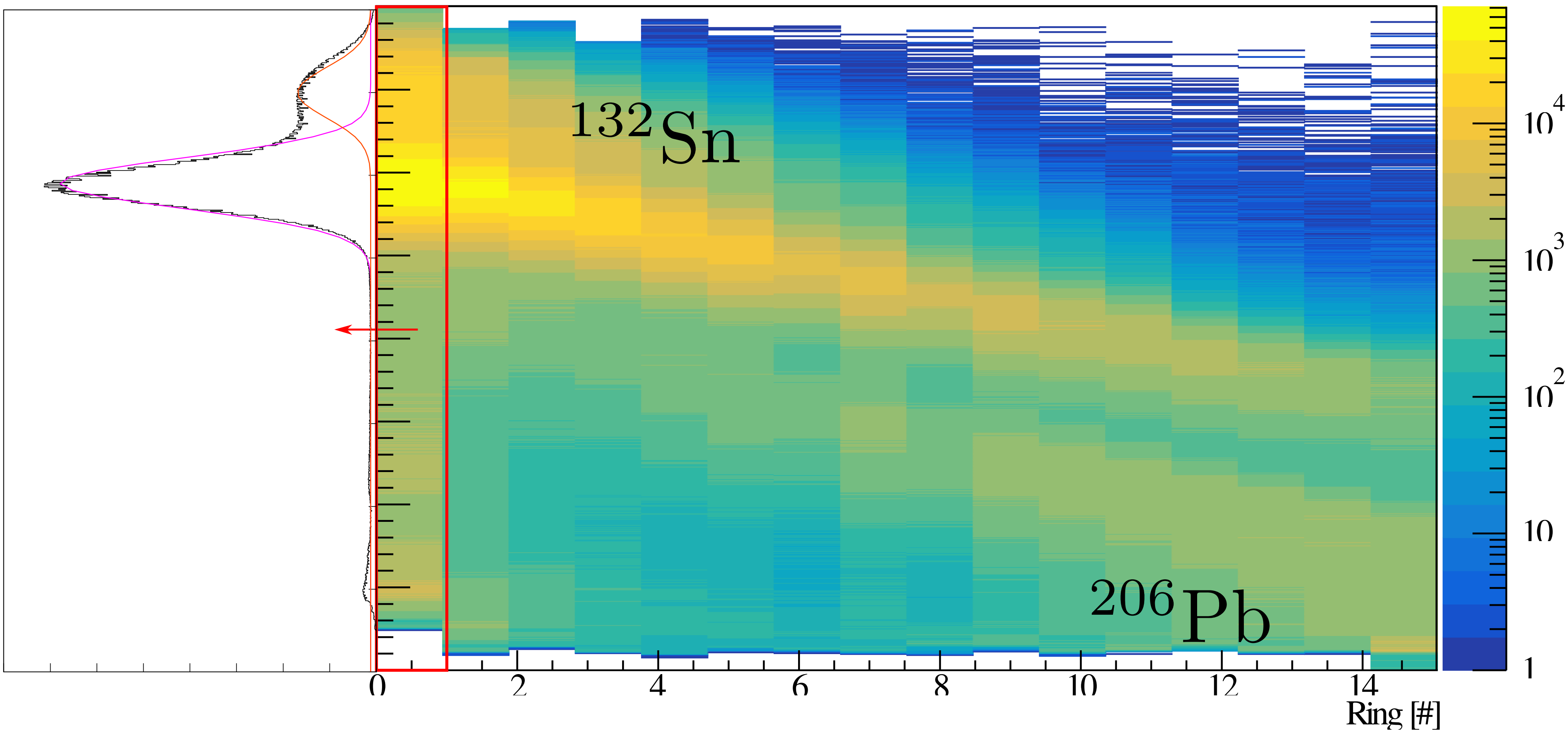
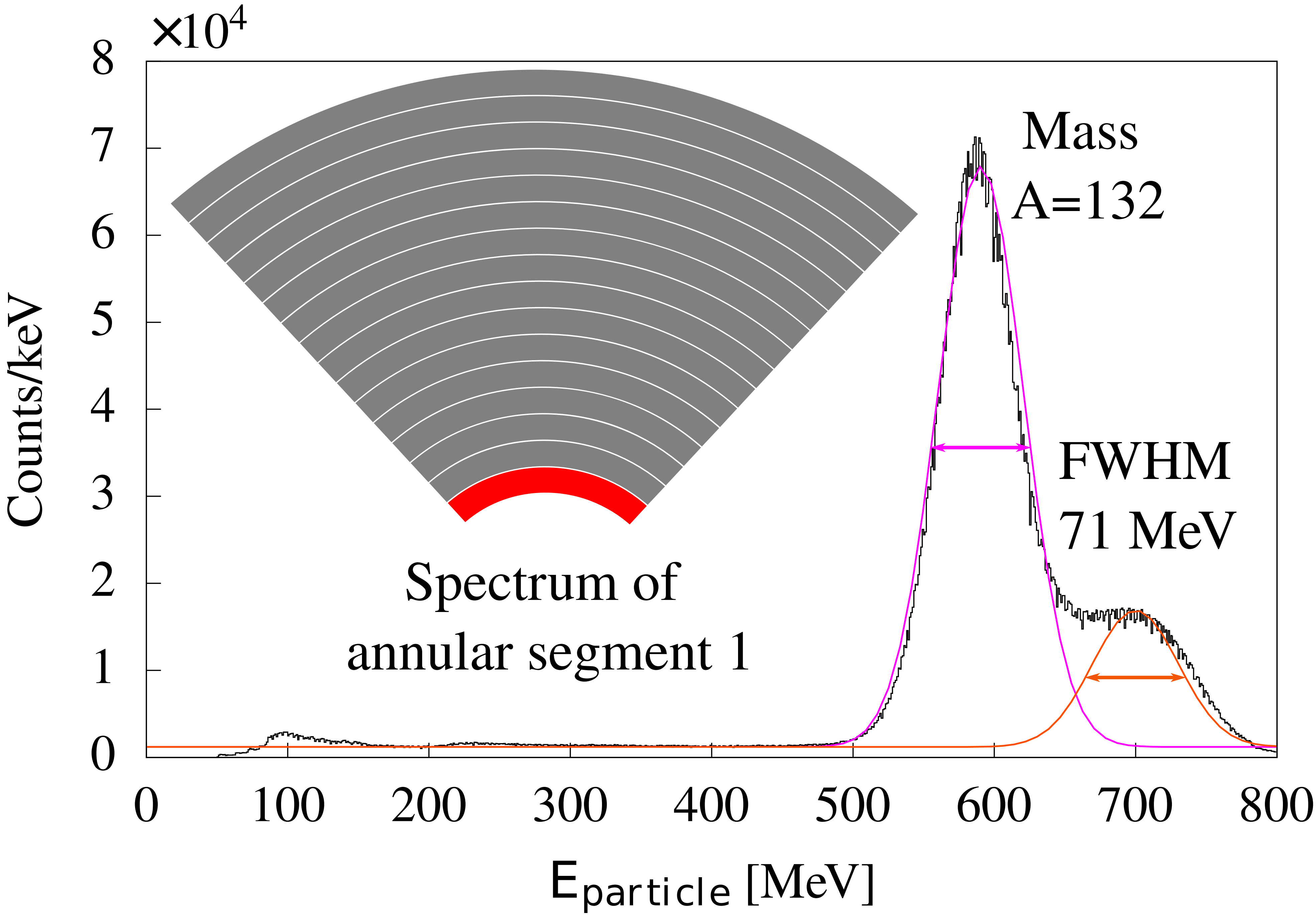
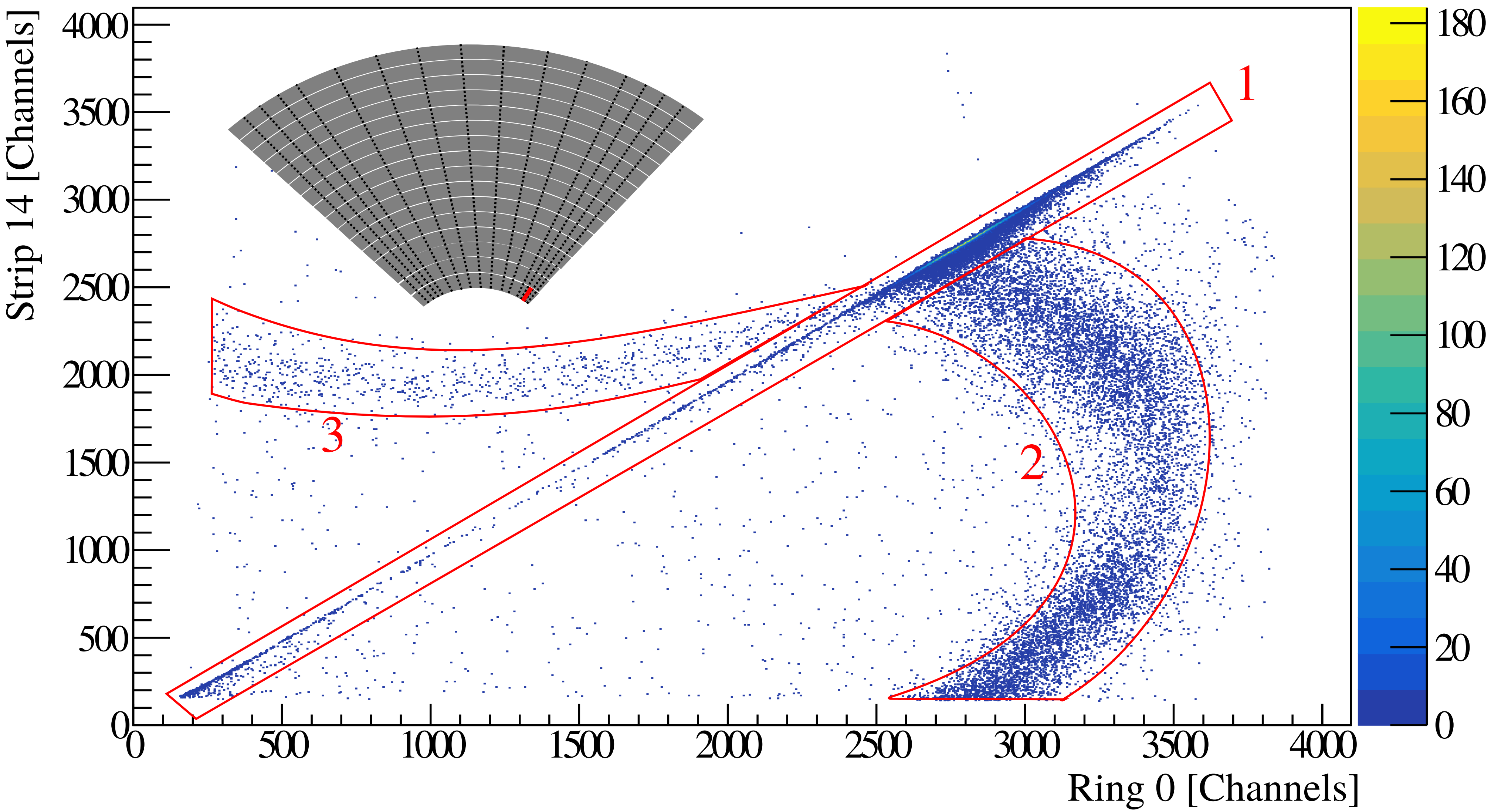
Backup



^{132}Sn
^{206}Pb
0
2
4
6
8
10
12
14
Ring [#]
1
10
10^2
10^3
10^4

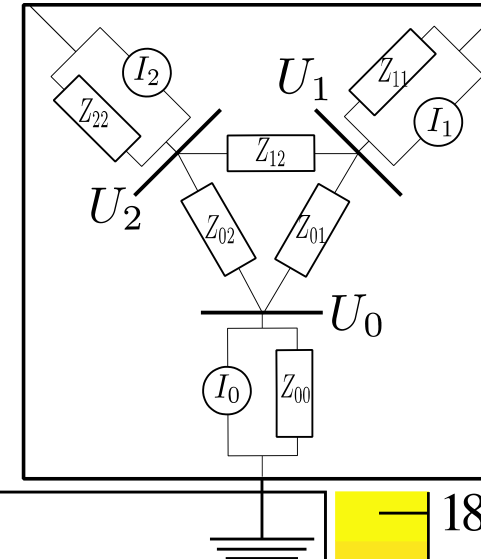


×10^4
8
7
6
5
4
3
2
1
0
Counts/keV
Mass
A=132
FWHM
71 MeV
Spectrum of
annular segment 1
0
100
200
300
400
500
600
700
800
E_particle [MeV]



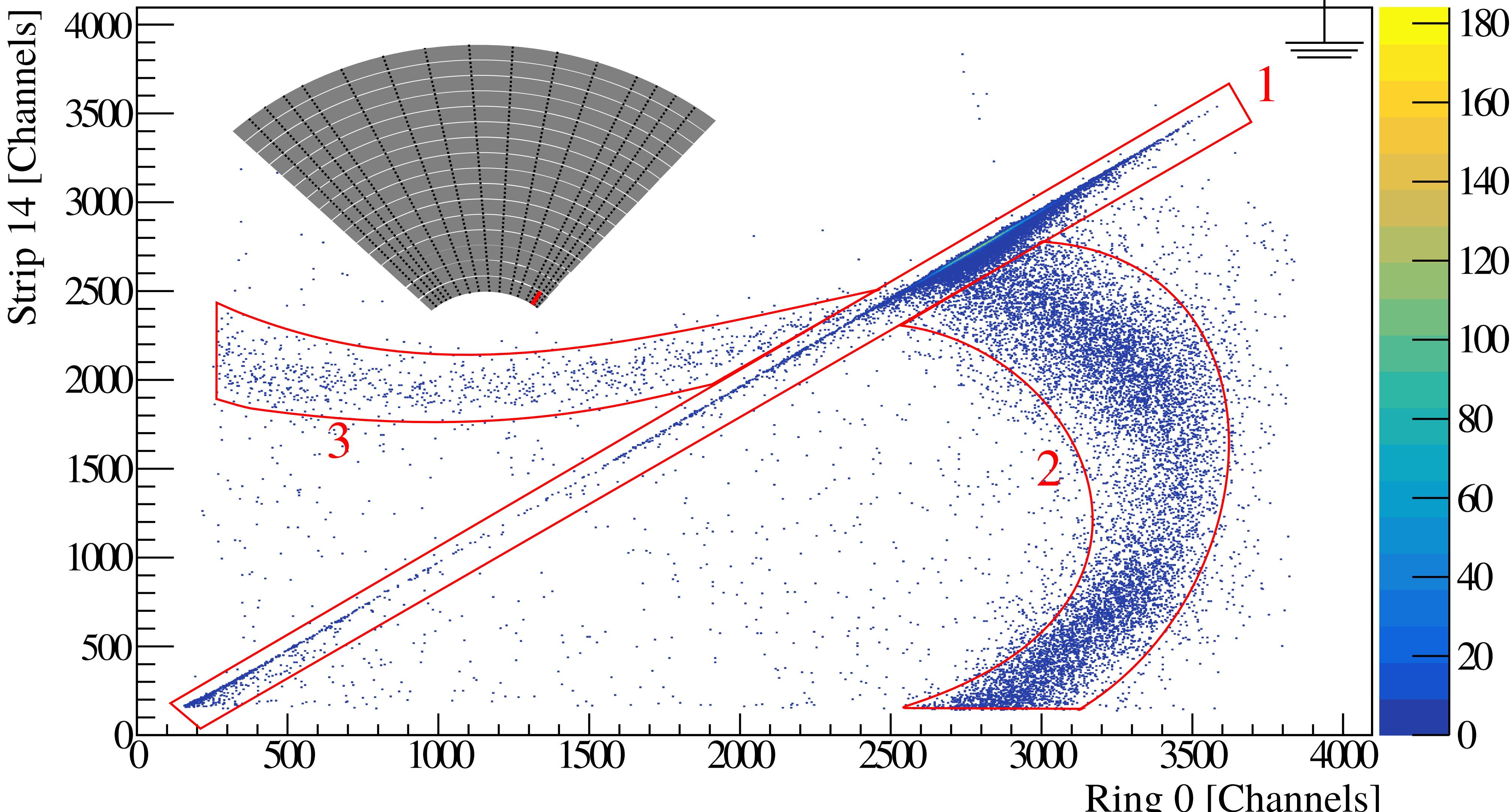
Strip 14 [Channels]
Ring 0 [Channels]
0
500
1000
1500
2000
2500
3000
3500
4000
0
20
40
60
80
100
120
140
160
180
1
2
3

$$\vec{i} = \begin{pmatrix} i_0 \\ i_1 \\ i_2 \end{pmatrix} = \begin{pmatrix} \sum_i Z_{0i}^{-1} & -Z_{01}^{-1} & -Z_{02}^{-1} \\ -Z_{01}^{-1} & \sum_i Z_{1i}^{-1} & -Z_{12}^{-1} \\ -Z_{02}^{-1} & -Z_{12}^{-1} & \sum_i Z_{2i}^{-1} \end{pmatrix} \cdot \begin{pmatrix} v_0 \\ v_1 \\ v_2 \end{pmatrix} = \mathbf{Z^{-1}} \cdot \vec{v}$$

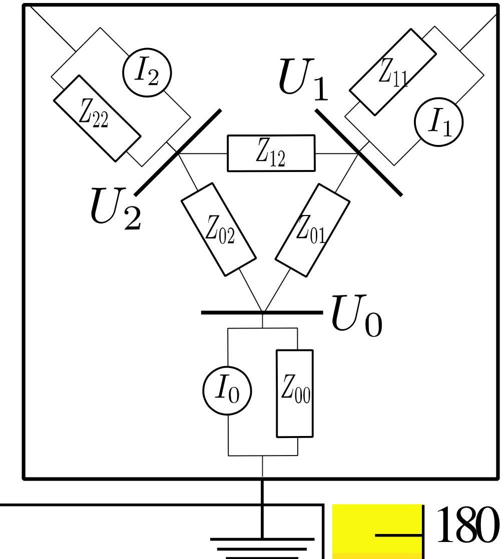


Characterization of Large Volume HPGe Detectors. Part I & Part II: Experimental Results

Nucl. Instr. and Meth. A (2006) 569, Issue 3, 764-789



$$\vec{i} = \begin{pmatrix} i_0 \\ i_1 \\ i_2 \end{pmatrix} = \begin{pmatrix} \sum_i Z_{0i}^{-1} & -Z_{01}^{-1} & -Z_{02}^{-1} \\ -Z_{01}^{-1} & \sum_i Z_{1i}^{-1} & -Z_{12}^{-1} \\ -Z_{02}^{-1} & -Z_{12}^{-1} & \sum_i Z_{2i}^{-1} \end{pmatrix} \cdot \begin{pmatrix} v_0 \\ v_1 \\ v_2 \end{pmatrix} = \mathbf{Z^{-1}} \cdot \vec{v}$$



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