Probing intruder configurations in ^{188}Pb nuclei using Coulomb excitation

Following Proposal to the ISOLDE and Neutron Time-of-Flight Committee
IS494 and HIE-ISOLDE Letters of Intent I-107 and I-110

INTC meeting at CERN 6.11.2019

Janne Pakarinen, JYFL, Finland

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Status of IS566 – relevant facts

- Physics case still valid
- HIE-ISOLDE still the only facility where this experiment can be conducted
- SPEDE commissioned in-beam and exploited at IDS
- Complementary ^{188}Pb SAGE data to be published
- ^{188}Pb Coulex data obtained in IS494 at REX-ISOLDE waiting for ^{188}Pb SAGE publication

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Outline

1) Physics background and motivation

2) Experiment description

Chart of Nuclei

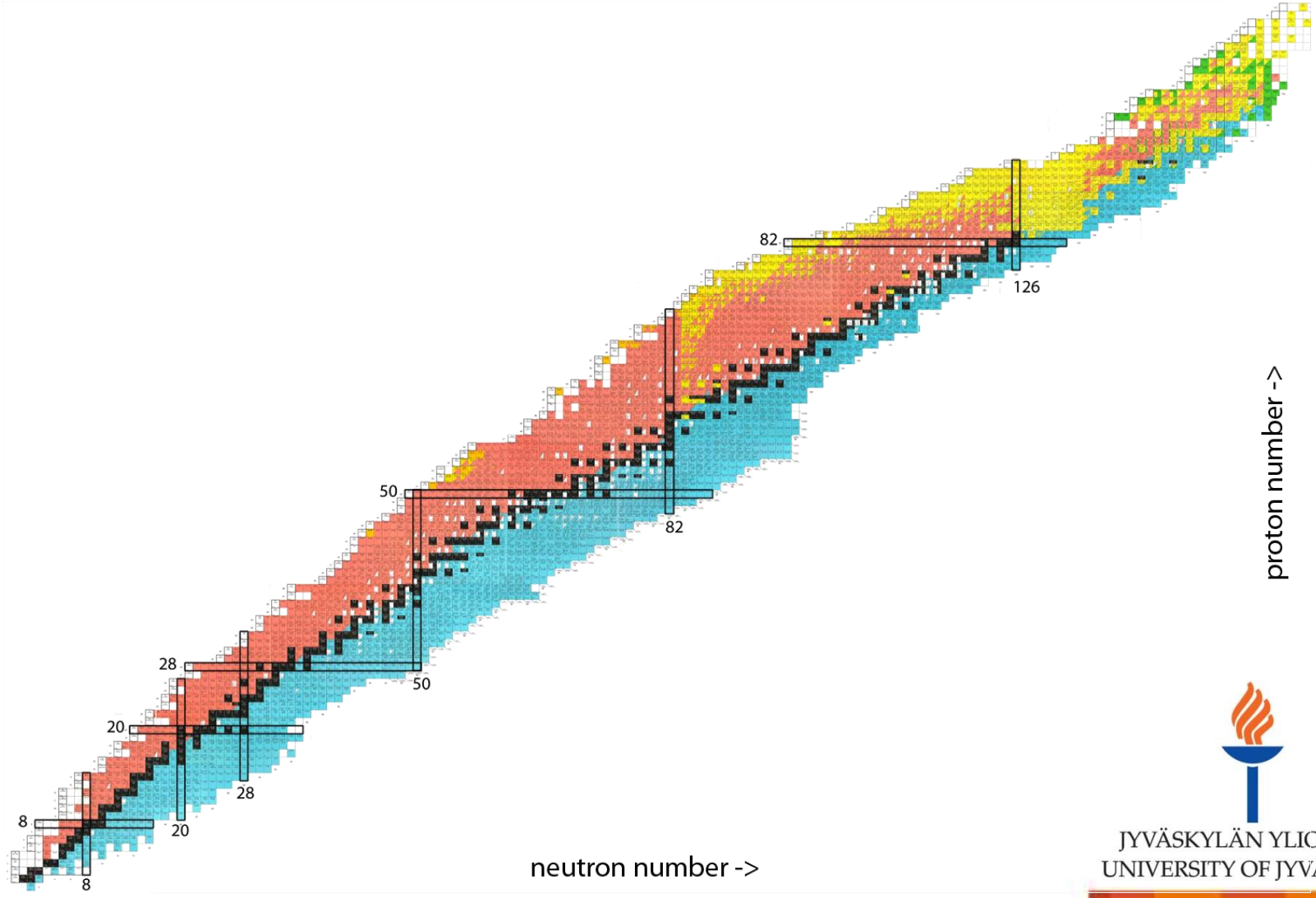

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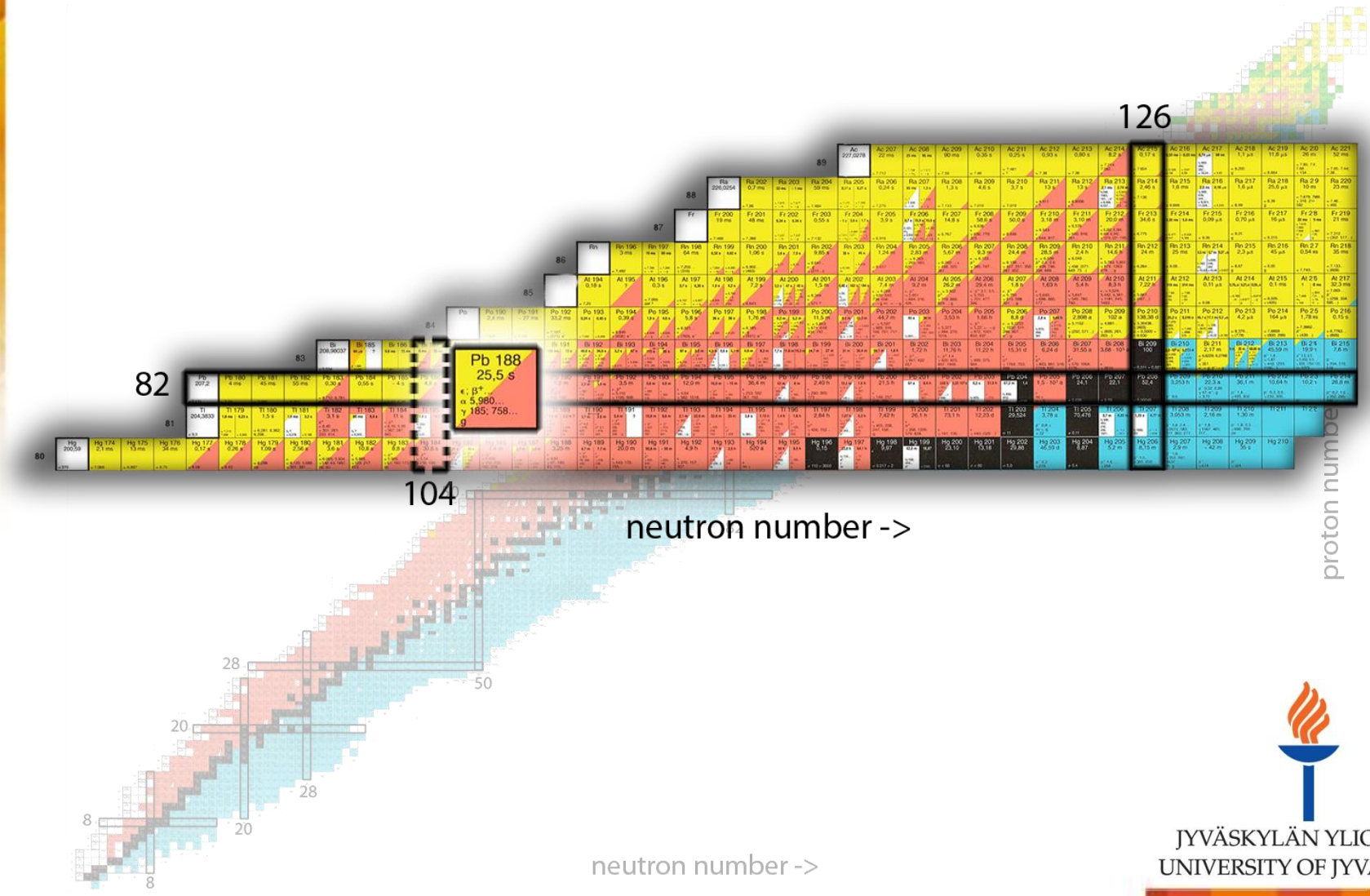
Chart of Nuclei



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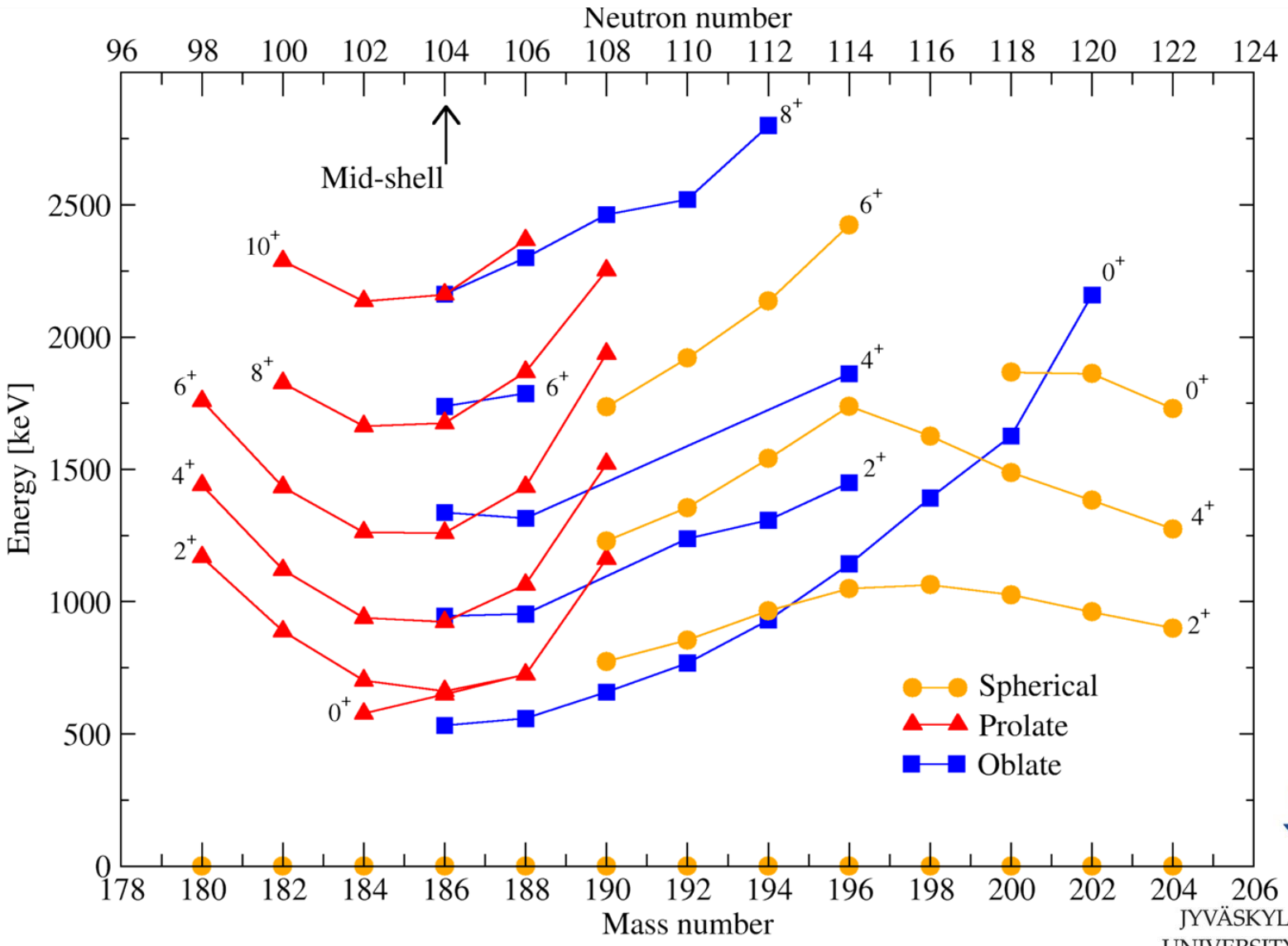
Level systematics of Pb isotopes



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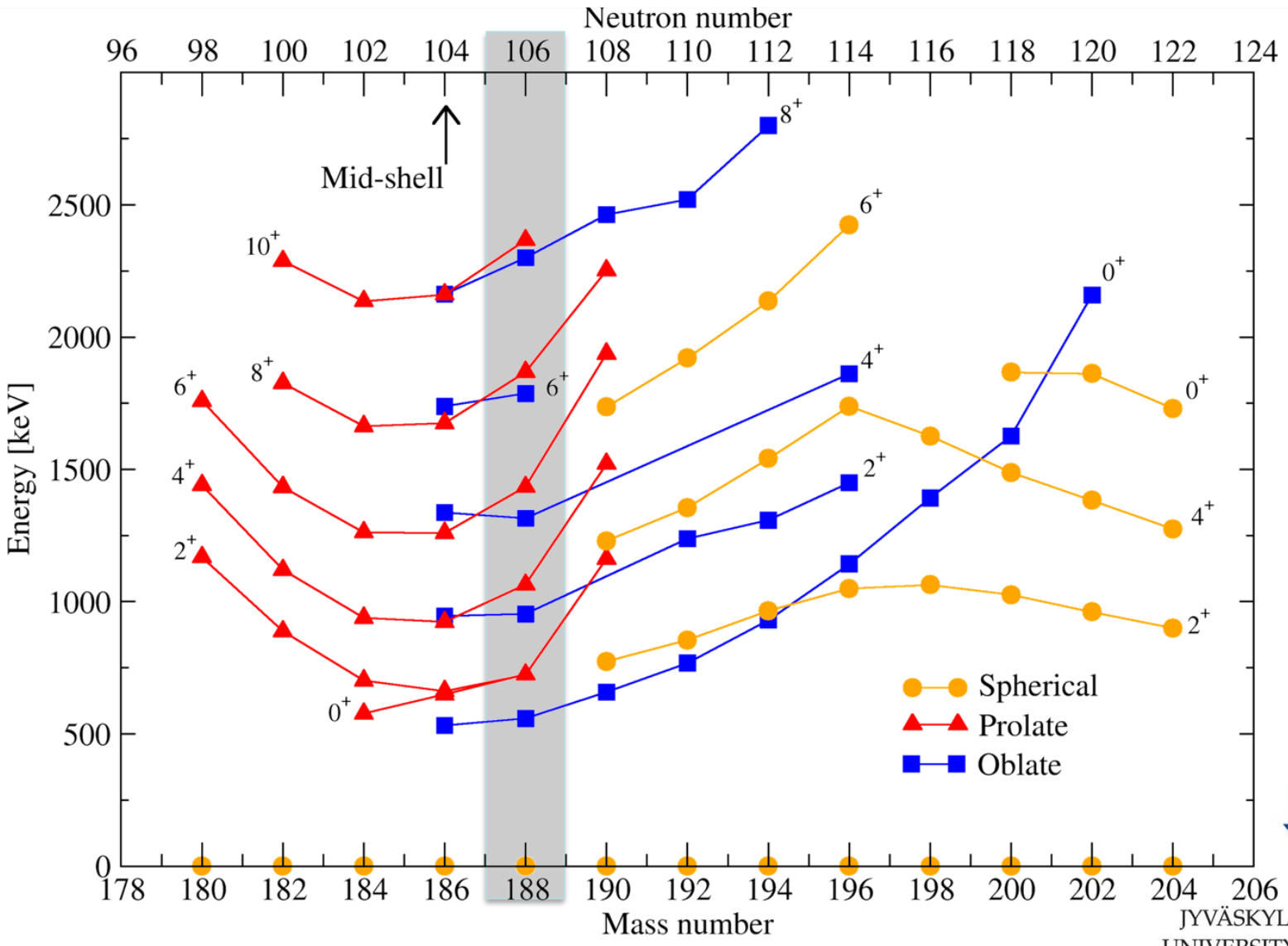
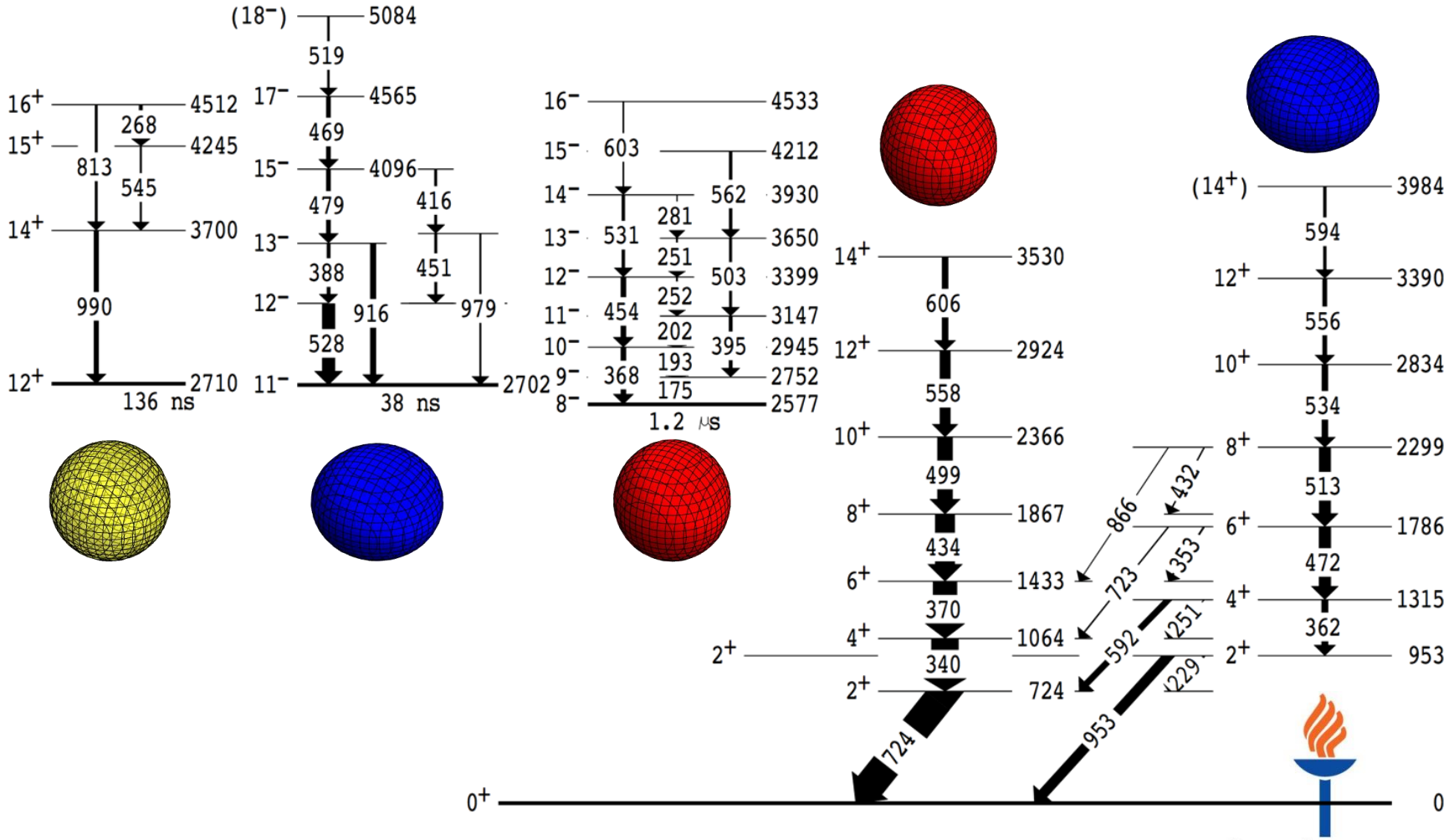


^{188}Pb level scheme



G.D. Dracoulis *et al.*, Phys. Rev C **67**, 051301(R) 2003

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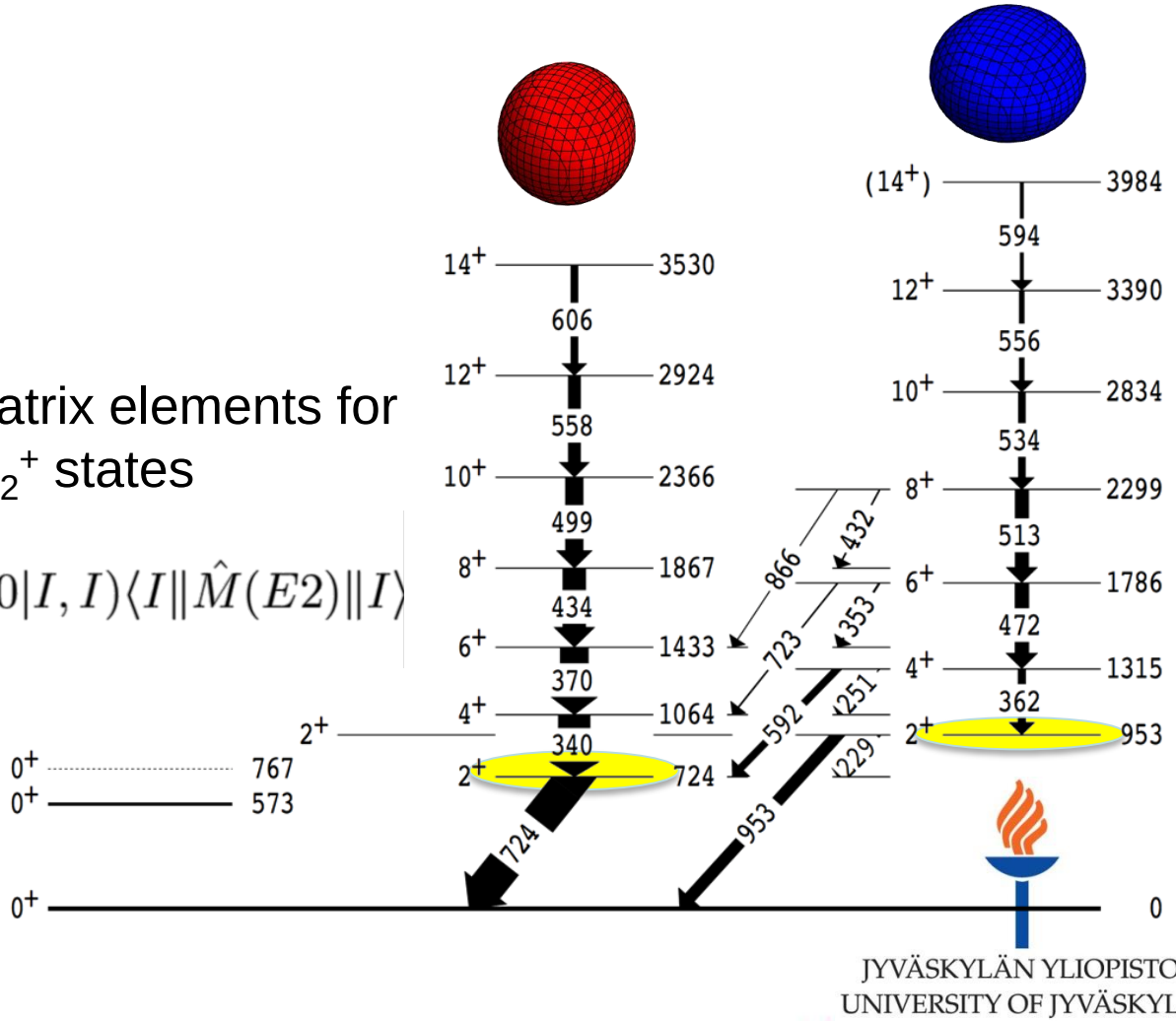
Objectives of present work - 1 direct measurement of shapes

Obtaining diagonal matrix elements for the 2_1^+ and 2_2^+ states

$$eQ_{sp} = \sqrt{\frac{16\pi}{5}} \frac{1}{\sqrt{2I+1}} (I, I, 2, 0|I, I) \langle I \| \hat{M}(E2) \| I \rangle$$



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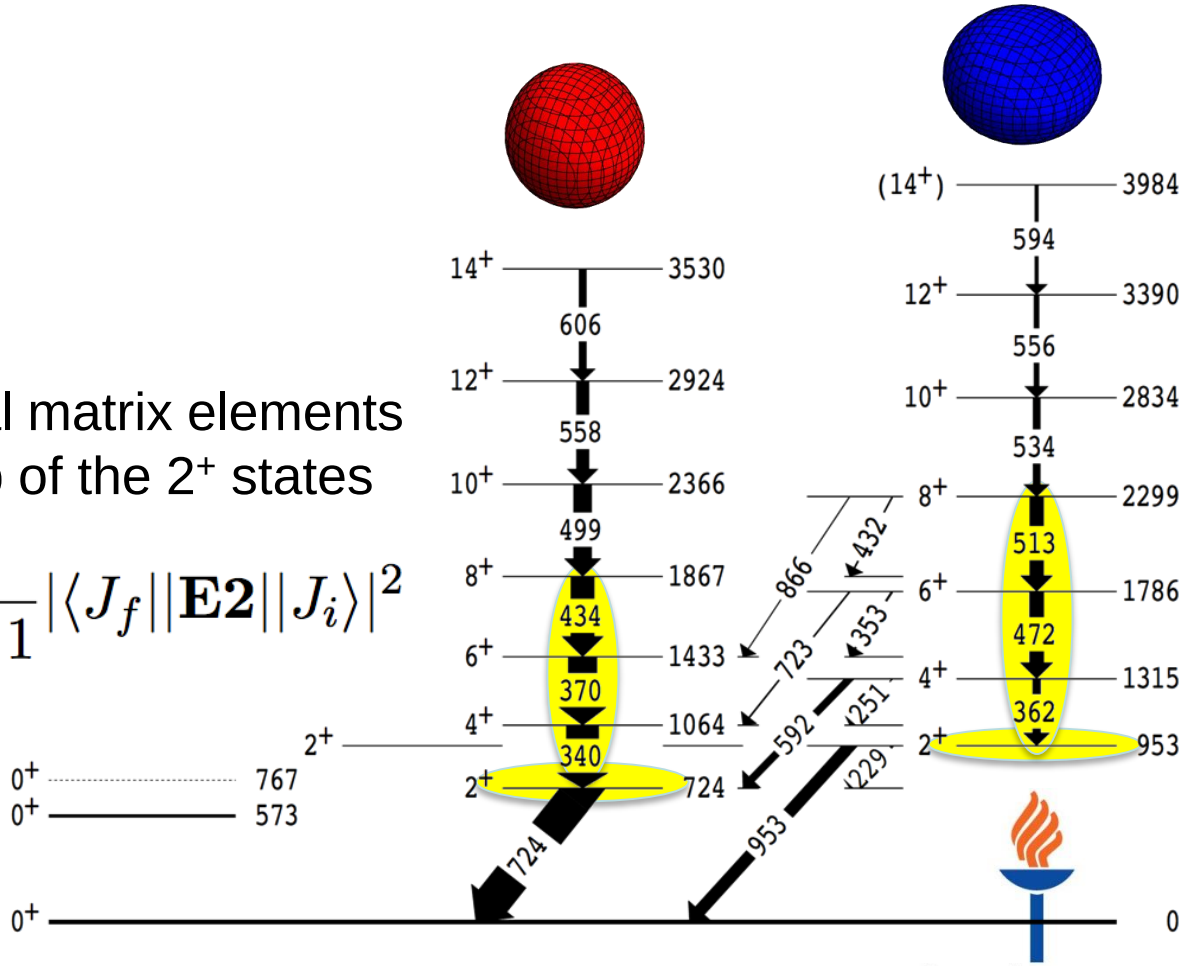
G.D. Dracoulis *et al.*, Phys. Rev C **67**, 051301(R) 2003

Objectives of present work - 2 collectivity of bands

Measuring transitional matrix elements for transitions on top of the 2^+ states

$$B(E2, J_i \rightarrow J_f) = \frac{1}{2J_i + 1} |\langle J_f || \mathbf{E2} || J_i \rangle|^2$$



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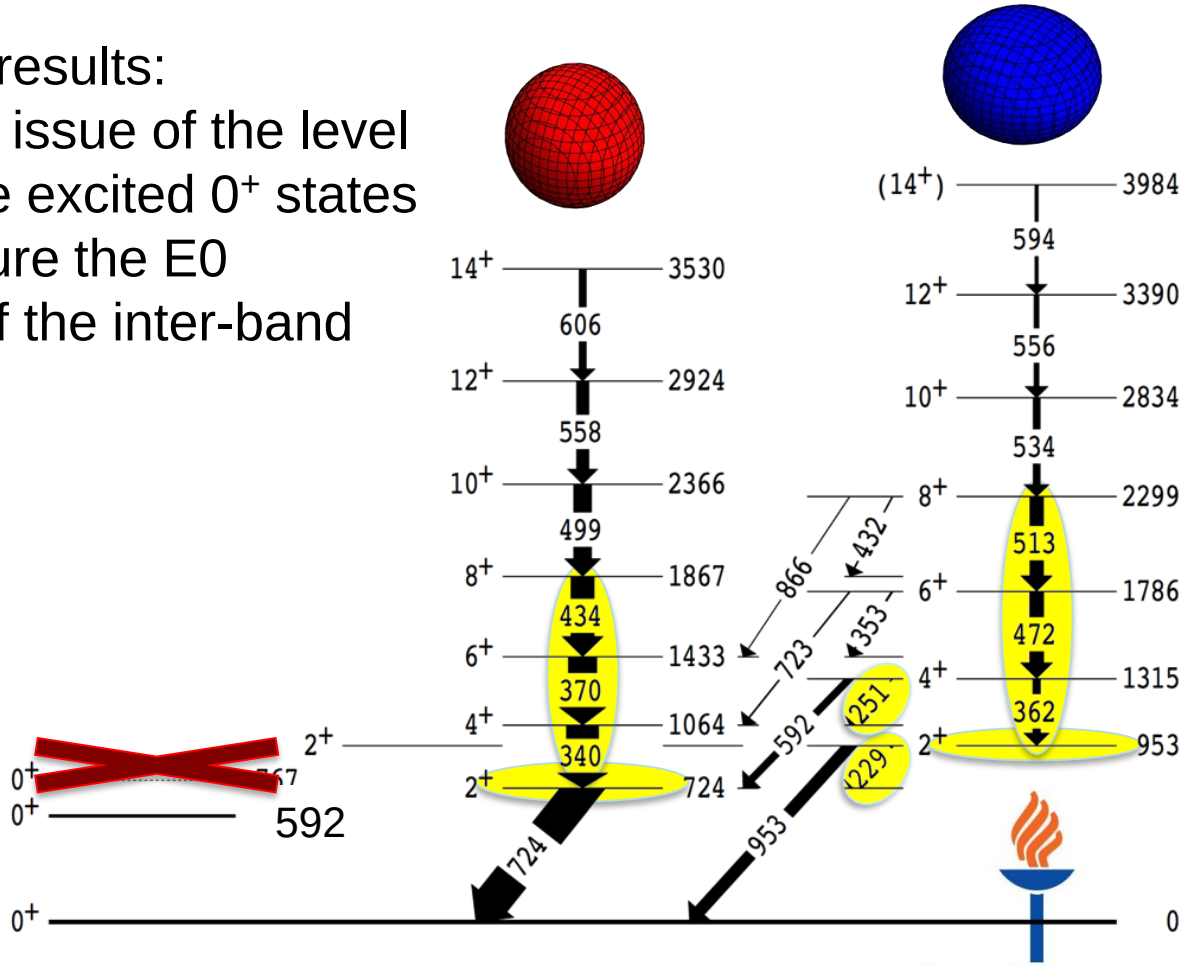
G.D. Dracoulis *et al.*, Phys. Rev C **67**, 051301(R) 2003

Objectives of present work - 3 measurement of the E0 transitions

Confirm recent SAGE results:

1) Long-standing issue of the level energies of the excited 0^+ states
2) Directly measure the E0 components of the inter-band transitions



G.D. Dracoulis *et al.*, Phys. Rev C **67**, 051301(R) 2003

Outline

1) Physics background and motivation

2) Experiment description

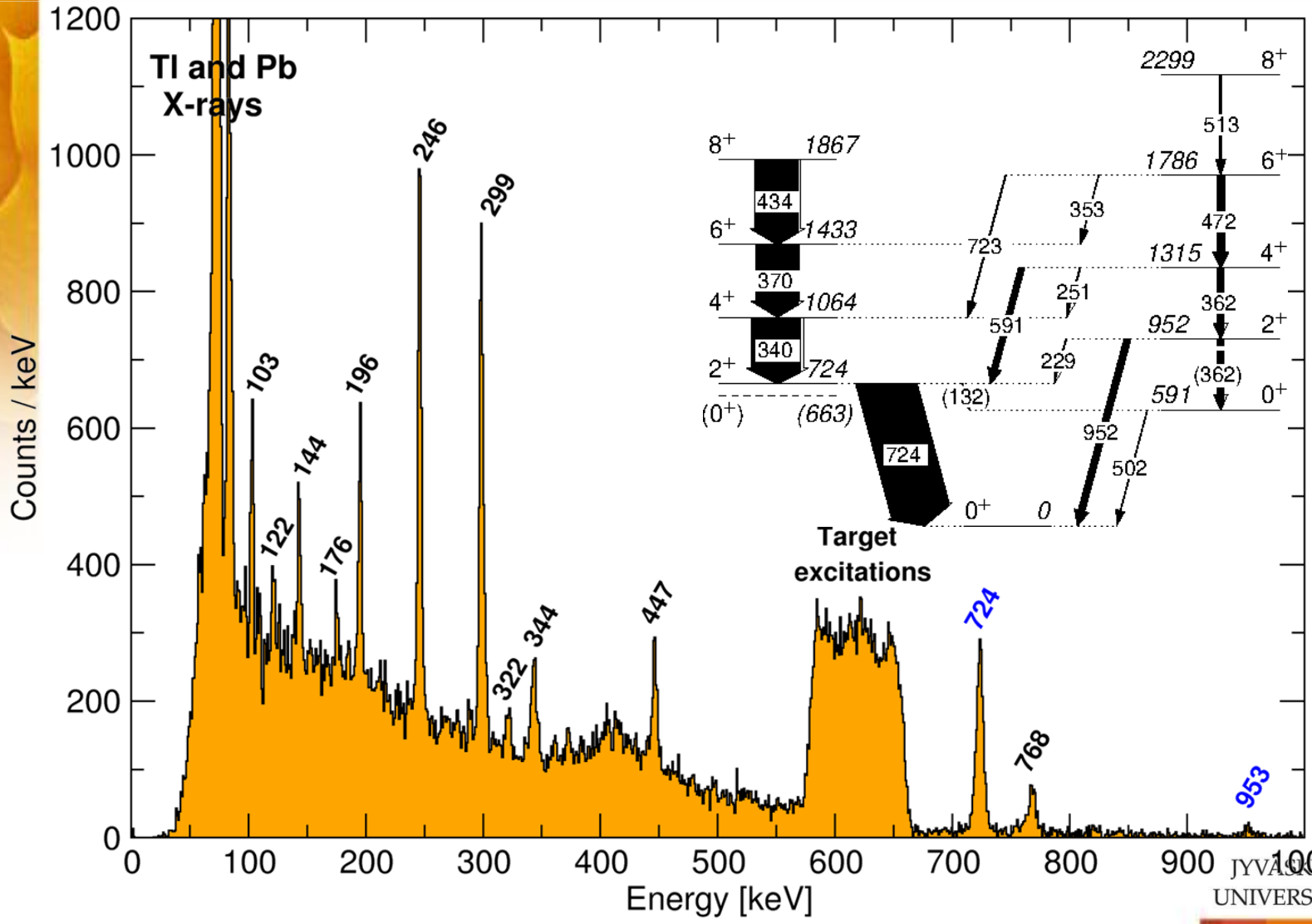
Coulomb excitation of ^{188}Pb

- UCx target + LIST/VADLIS
- HIE-ISOLDE beam ~10^6pps @ MINIBALL
- Two energies: 3.5 and 4.1MeV/u
- Two targets: ^{112}Cd and ^{48}Ti
- Typical MINIBALL set-up + SPEDE

Number of shifts		
^{188}Pb on ^{120}Sn @ 4.2MeV/u	2	Lasers off runs 30% of beam time
^{188}Pb on ^{120}Sn @ 3.5MeV/u	3	--- " ---
^{188}Pb on ^{48}Ti @ 4.0MeV/u	2	--- " ---
^{188}Pb on ^{48}Ti @ 3.5MeV/u	3	--- " ---

DC bgr subtracted γ-rays from IS494

Low CoM angles



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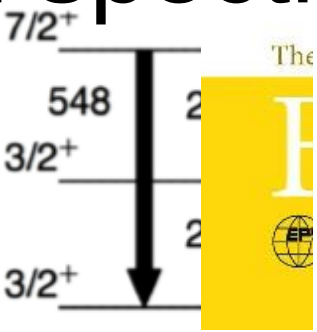
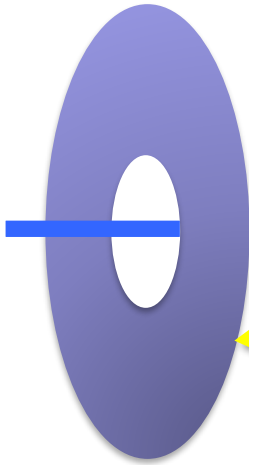
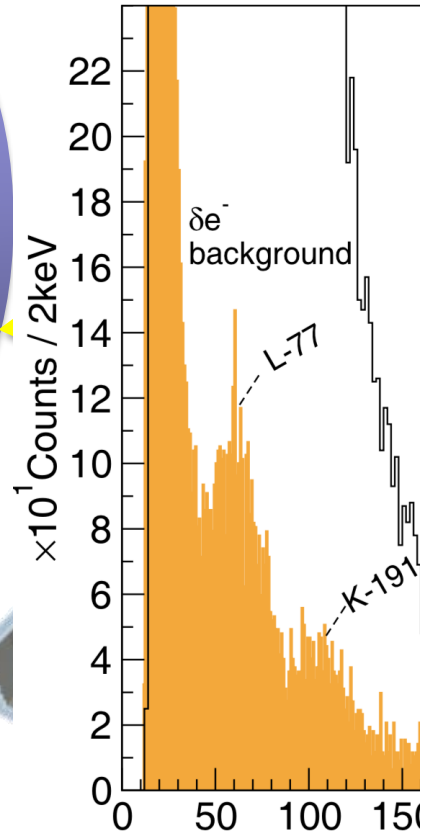
The SPEDE spectrometer



Segmented Silicon detector

Beam





ISOLDE — Beta-decay studies

As can be seen in Fig. 2, a better algorithm to clean the spectrum in the region of interest is needed. So far we can only set an experimental upper limit for the branching to this state of 4.4×10^{-6}.

References

[1] T. Nilsson, *Hyperfine Interact.* **129**, 67 (2000).
[2] S. Vinals, *ISOLDE Newsletter* p. 22 (2018).
[3] M. Munch, *IEEE TNS* **66**, 575 (2019).

Shape coexistence in proton-rich ^{182,184,186}Hg isotopes studied through β decay

Results of experiment IS641

Marek Stryjczyk for the IDS collaboration

The proton-rich mercury isotopes represent one of the most prominent example of shape coexistence [1]. The experimental γ- and electron spectroscopy studies point to the coexistence of two classes of states in the even-mass mercury isotopes with strong mixing between the low-lying states in ^{182,184}Hg [1, 2, 3]. In particular, the presence of strong $E0$ components in the $2_2^+ \rightarrow 2_1^+$ transitions are interpreted as a fingerprint for mixing between two states with different deformation [1, 3].

The spectroscopic quadrupole moments (Q_s) and monopole transition strengths ($\rho^2(E0)$), which allow states exhibiting different deformations to be distinguished unambiguously, will be measured in the Coulomb excitation (Coulex) experiment at HIE-ISOLDE [4]. However, additional spectroscopic information (branching ratios and internal conversion electron (ICE) coefficients) is needed for the data analysis [5]. Although these values have been provided by a previous thallium β-decay experiment [3], the uncertainties of the conversion coefficient and the γ-ray branching ratios for the $2_2^+ \rightarrow 2_1^+$ transition of interest are of the order of 20 – 30%. The main goal of the experiment was to reduce these uncertainties and, consequently, to increase the precision of Q_s and $\rho^2(E0)$ values in the future Coulex experiment.

The beams of ^{182,184,186}Tl were produced in proton-induced-fission of a UC_x target, selectively ionized by RILIS, mass separated by HRS and, finally, implanted on the movable tape station at the ISOLDE Decay Station (IDS). The measured yield of ^{182}Tl, $1.3 \times 10^5 \frac{ions}{\mu C}$, was about an order of magnitude higher than reported in the Yield Database. The detection setup consisted of four standard IDS HPGe clovers, combined with an additional HPGe clover and the SPEDE spectrometer recently developed for ICE measurements [6]. A FWHM-resolution of 7 keV for 300-keV electrons was achieved, allowing the separation of neighboring peaks.

Examples of the γ-ray and electron energy spectra gated on the 1837 keV γ-ray transition in ^{182}Hg are presented in Fig. 1. Prominent peaks at 261 keV and 351 keV are associated with the $4_1^+ \rightarrow 2_1^+$ and $2_1^+ \rightarrow 0_1^+$ transitions, respectively. Preliminary results show an agreement with the known decay scheme, however, the final data analysis is currently ongoing.

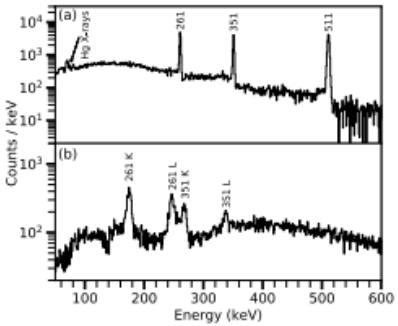


Figure 1: Portions of the background-subtracted (a) γ- and (b) electron energy spectra gated on the 1837 keV transition in ^{182}Hg. The transition energies are given in keV.

http://isolde-ids.web.cern.ch/isolde-ids/

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

Yield estimates for ^{188}Pb

– number of shifts as in proposal –

$I_i^\pi \rightarrow I_f^\pi$ Projectile	$E_{transition}$ [keV]	Det. Eff. [%]	4.3MeV/u ^{188}Pb+^{120}Sn	3.5MeV/u ^{188}Pb+^{120}Sn	4.0MeV/u ^{188}Pb+^{48}Ti	3.5MeV/u ^{188}Pb+^{48}Ti
$2_1^+ \rightarrow 0_1^+$	723.5	8.8	126375	107093	3695	4749
$4_1^+ \rightarrow 2_1^+$	340.2	14.1	61877	36737	1890	1607
$6_1^+ \rightarrow 4_1^+$	369.7	13.3	28827	10907	666	359
$8_1^+ \rightarrow 6_1^+$	433.8	12.0	8725	1752	115	35
$2_1^+ \rightarrow 0_2^+$	133.9	7.0	170	455	16	20
$2_2^+ \rightarrow 0_1^+$	952.5	7.5	37970	24846	1341	1380
$4_2^+ \rightarrow 2_2^+$	362.5	13.5	19402	7680	533	345
$6_2^+ \rightarrow 4_2^+$	471.5	11.4	4570	890	70	26
$8_2^+ \rightarrow 6_2^+$	513.0	10.8	812	73	6	1
$2_2^+ \rightarrow 0_2^+$	361.5	13.5	3542	2317	125	129
$2_2^+ \rightarrow 2_1^+$	228.7	18.0	1352	879	47	48
$2_2^+ \rightarrow 2_1^+$	140.2[a)]	8.0	1202	782	42	29
$0_2^+ \rightarrow 0_1^+$	502.5[a)]	8.0	2294	1538	80	83
Target						
$2_1^+ \rightarrow 0_1^+$	^{120}Sn: 1171 ^{48}Ti: 984	6.6 7.3	53153	26619	17241	17875
$4_1^+ \rightarrow 2_1^+$	^{120}Sn: 1023 ^{48}Ti: 1312	7.2 6.1	10795	1640	63	16
$2_2^+ \rightarrow 0_1^+$	^{120}Sn: 2097 ^{48}Ti: 2421	4.2 3.5	71	12	1	0

[a)] K-conversion electron energy

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Summary

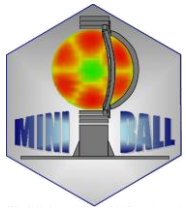
Instrumentation:

- ✓ Standard MINIBALL configuration + SPEDE
- ✓ SPEDE ready (plans for further developments)
- ✓ Complementary data obtained

Request:

1) We request 10 shifts for ^{188}Pb experiment
2) Yield tests (and Tl suppression) employing VADLIS

Acknowledgements



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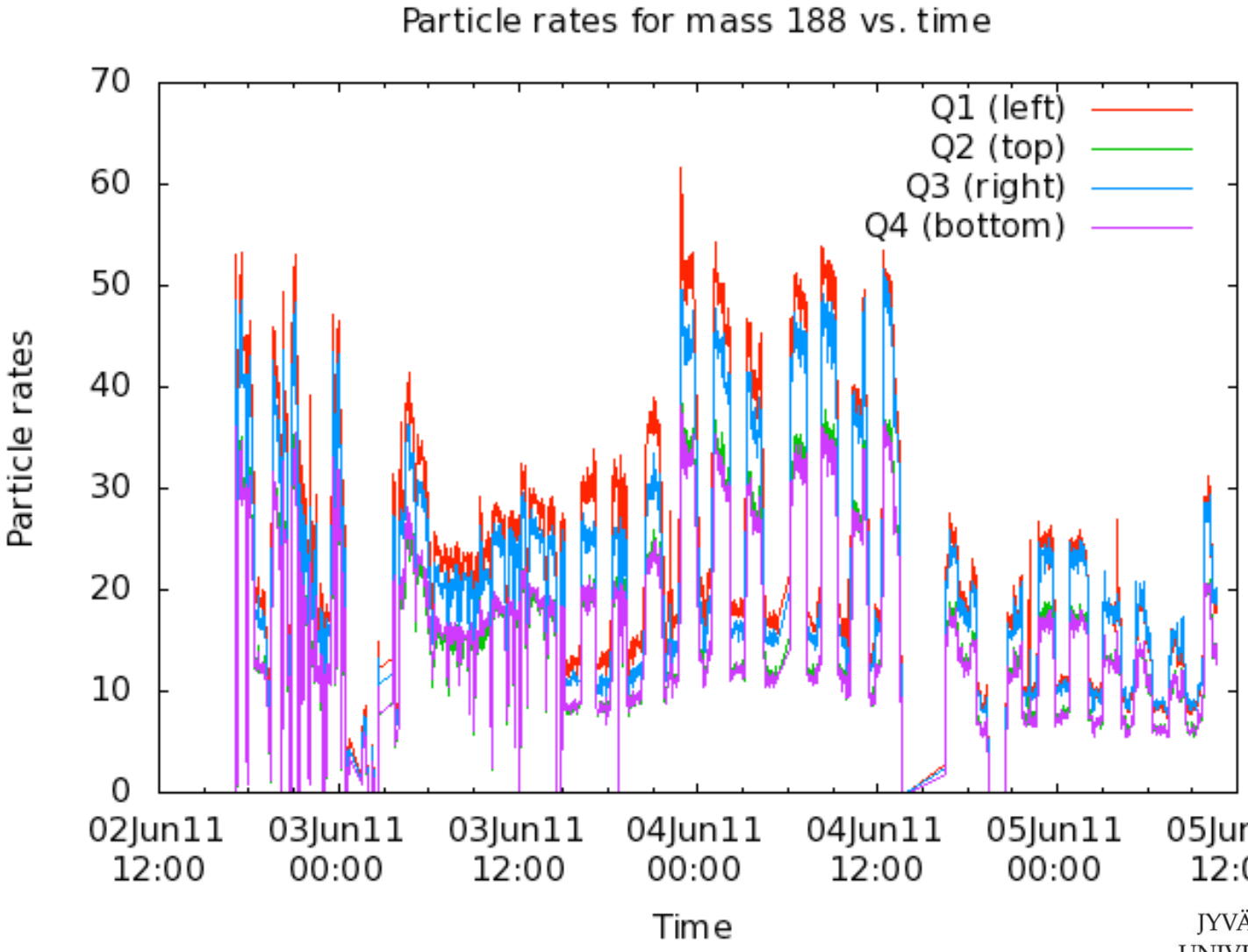
Laser on/off



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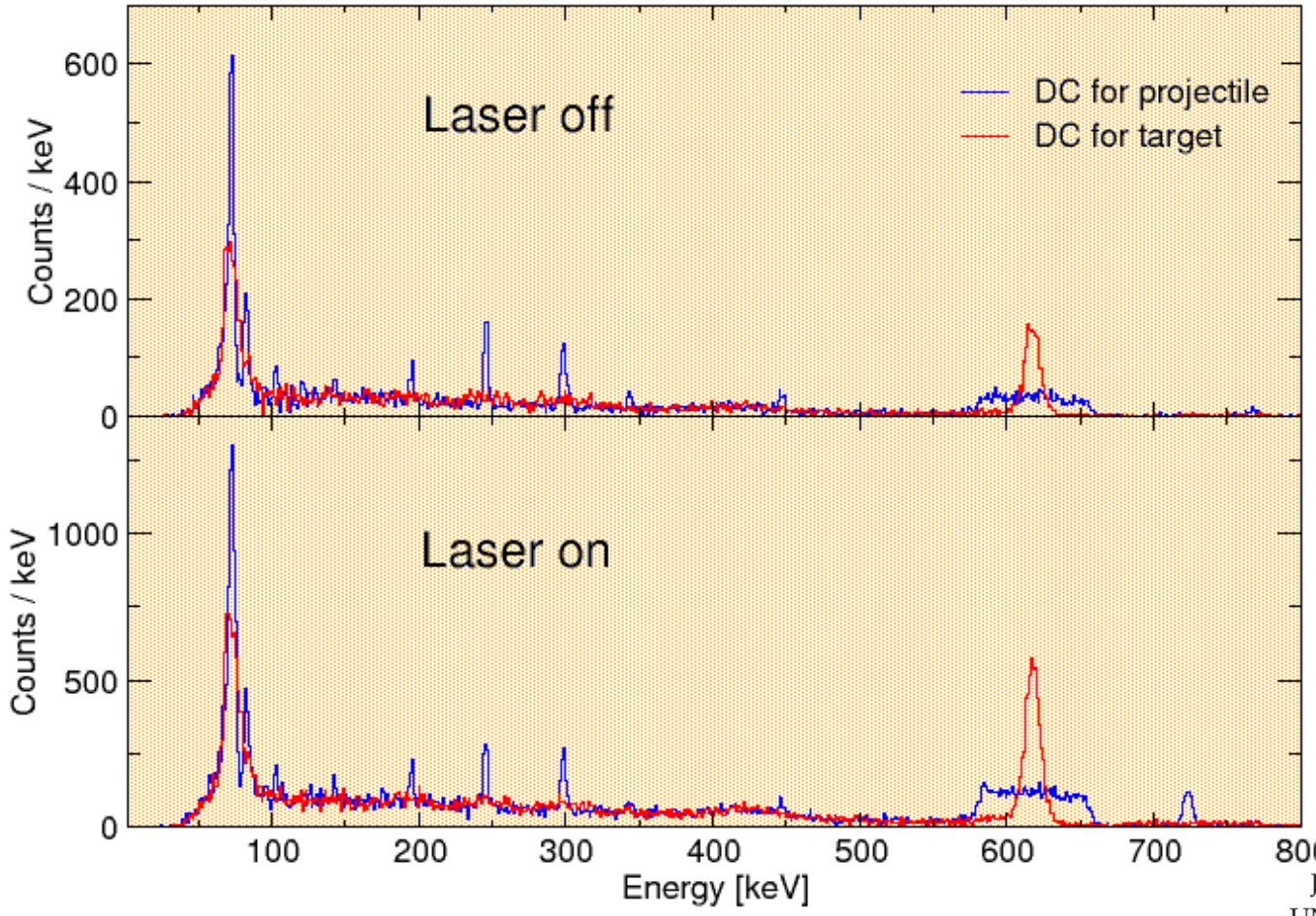
Laser on/off

γ-rays in coincidence with ^{188}Pb detected in low CoM angles



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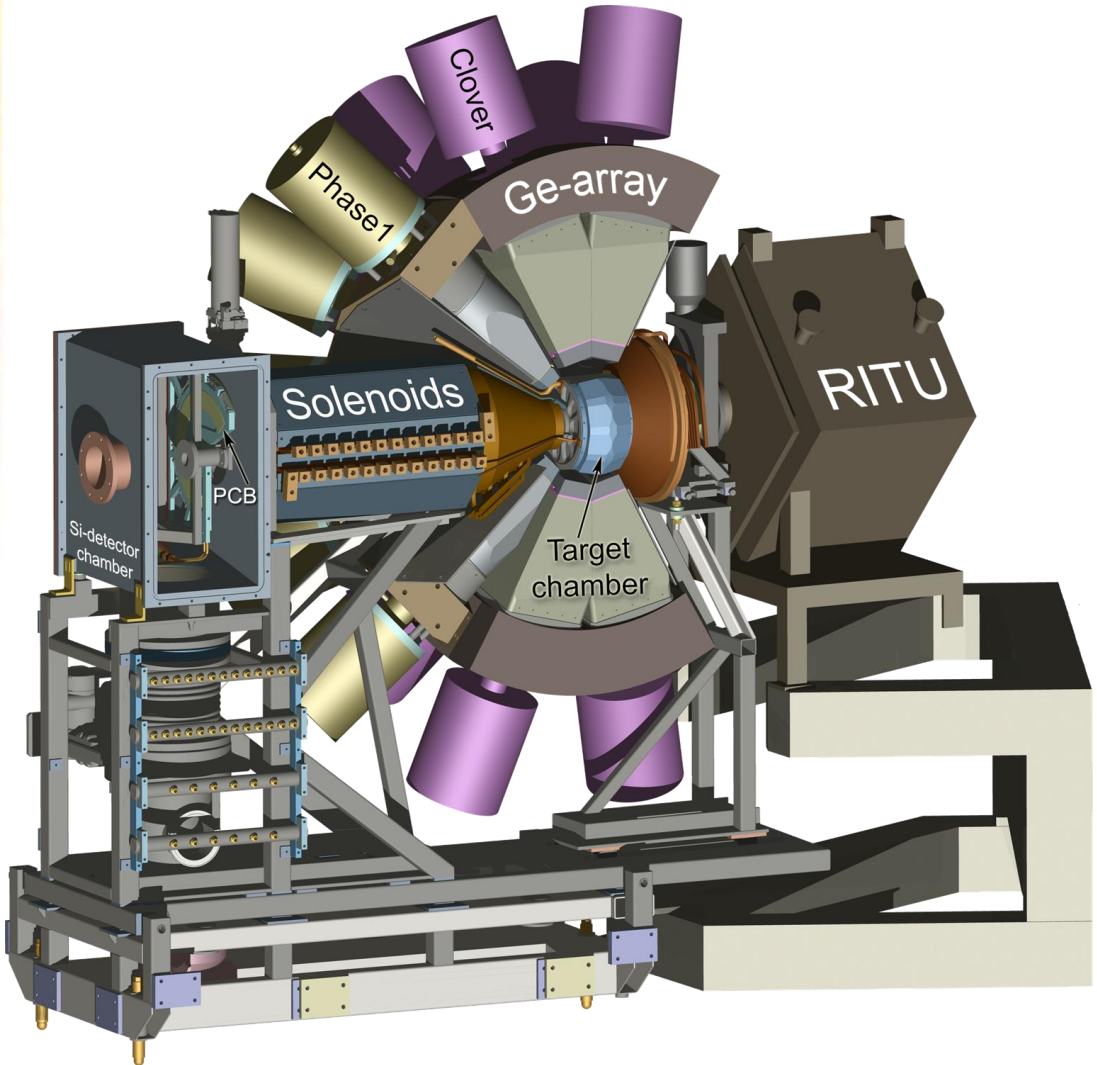
Probing conversion electrons in ^{188}Pb using the SAGE spectrometer



- ^{160}Dy(^{32}S,4n)^{188}Pb
- E_{beam}=165MeV
- $\sigma \sim 1100\mu b$
- $I_{beam} \approx$ 18pnA
- 7 days of beam time
- SAGE+RITU+GREAT
- Fully digital DAQ

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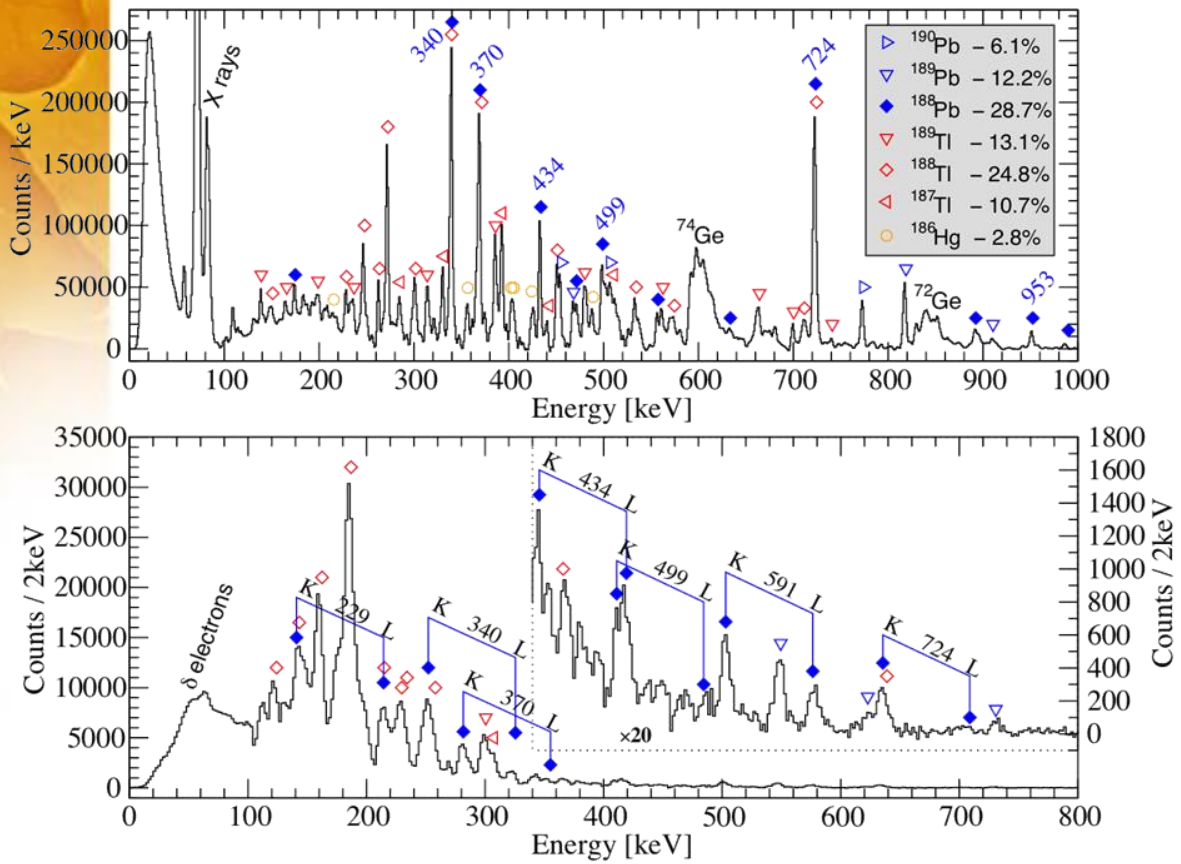
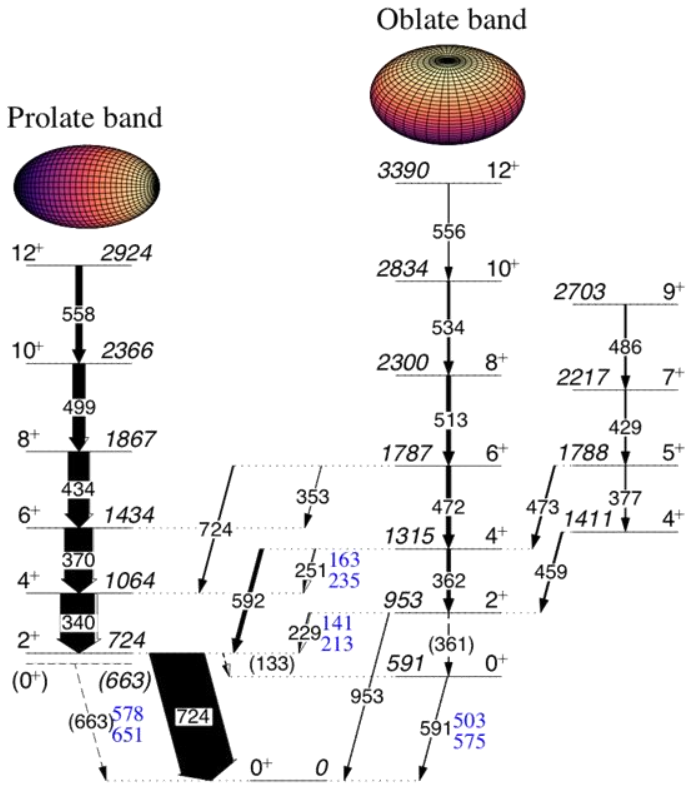
Direct measurement of conversion electrons in ^{188}Pb





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