

# Probing intruder configurations in $^{186,188}\text{Pb}$ nuclei using Coulomb excitation

Following HIE-ISOLDE Letters of Intent I-107 and I-110

INTC meeting at CERN 27.6.2013

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UNIVERSITY OF JYVÄSKYLÄ

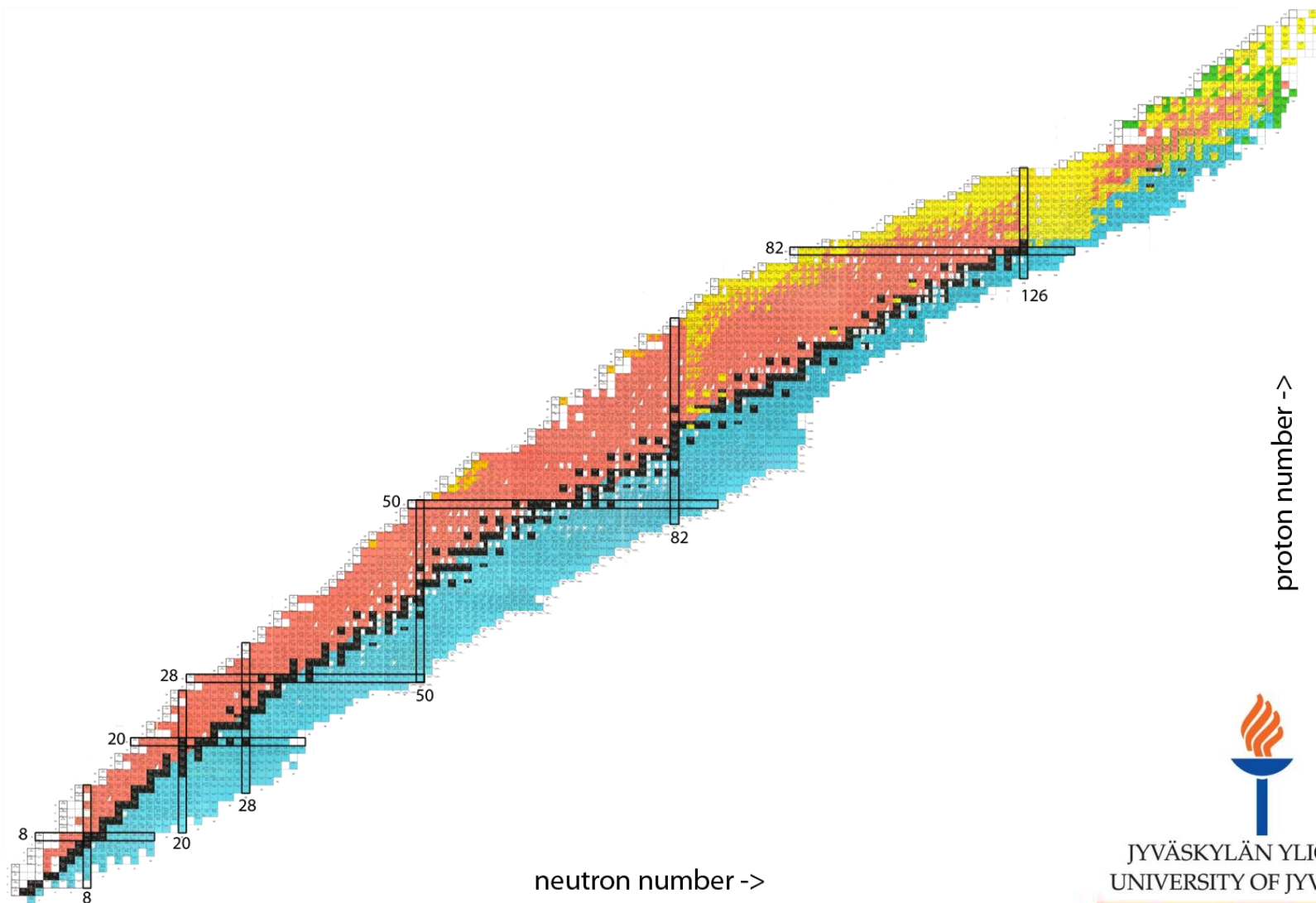


# Outline

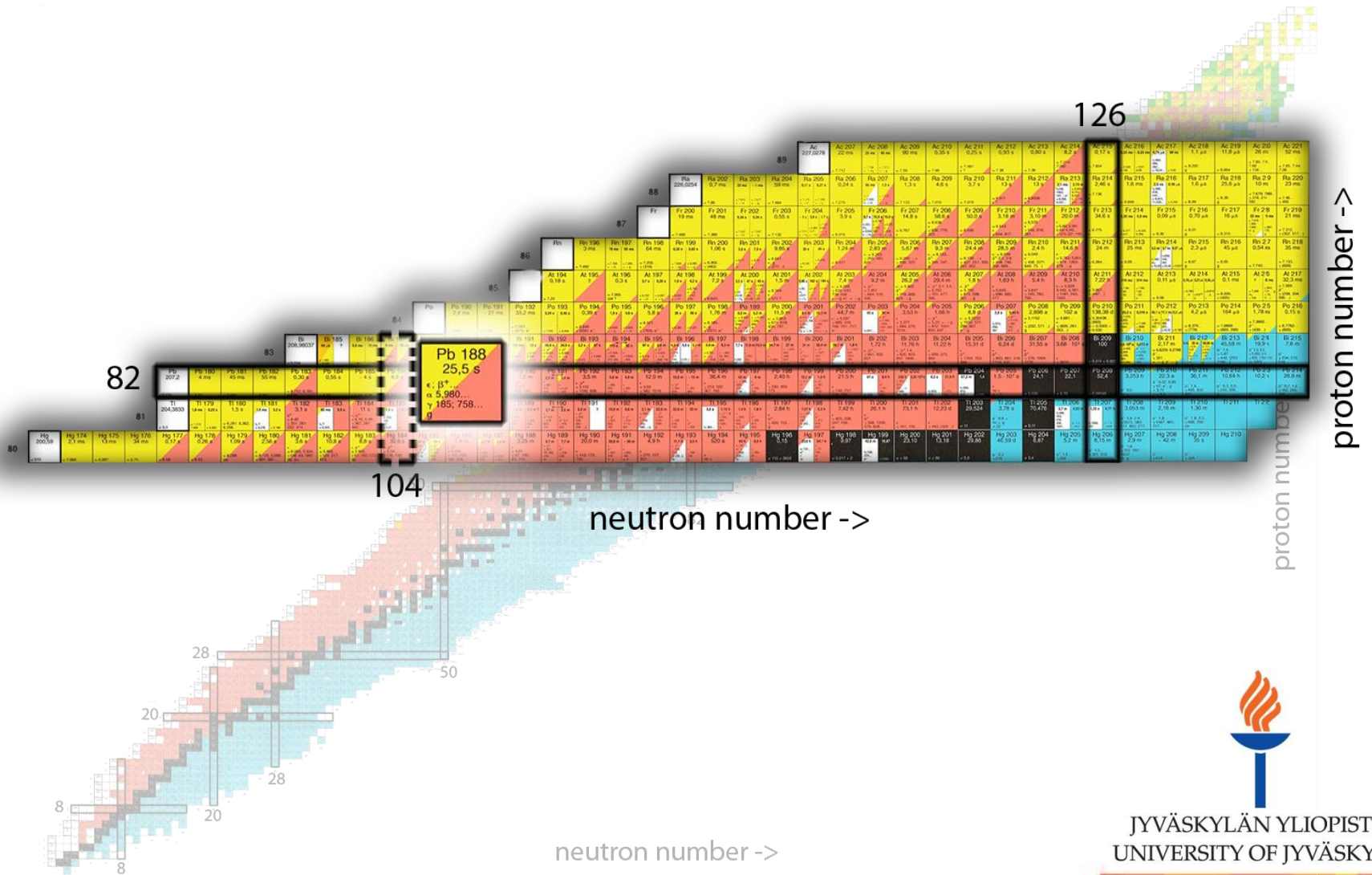
- 1) Physics background and motivation
- 2) Experiment description
- 3) Yield calculations and beam development



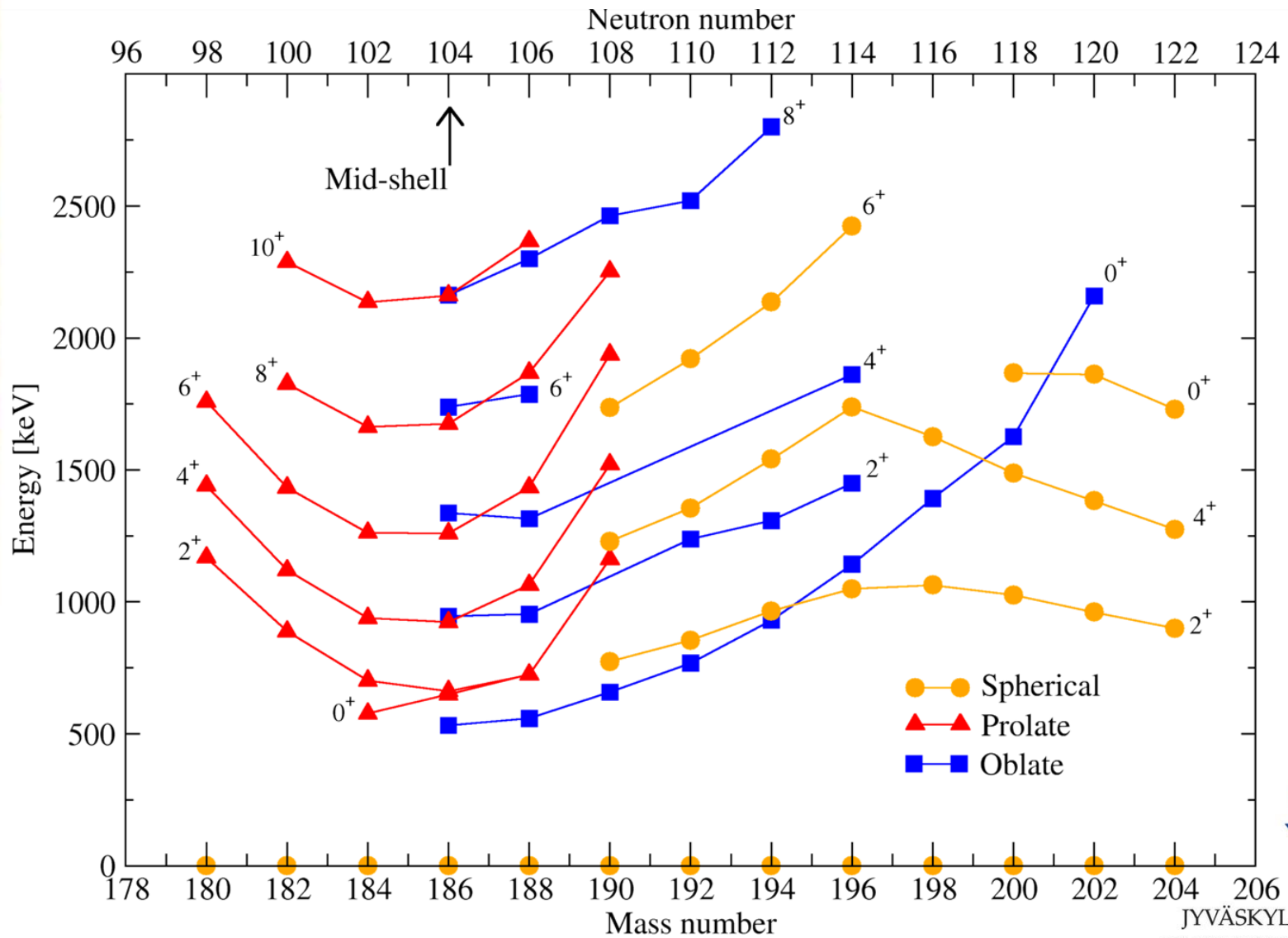
# Chart of Nuclei



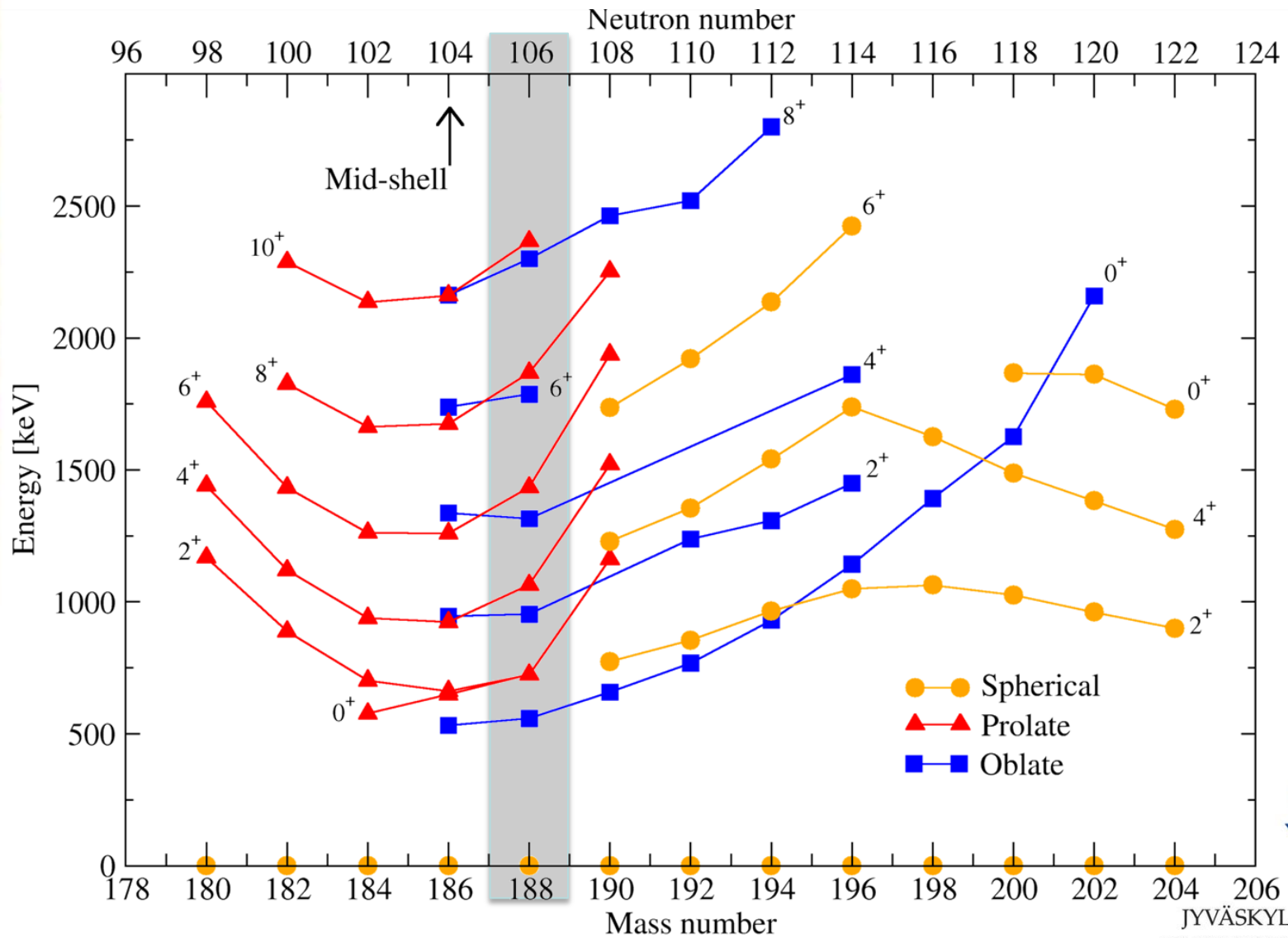
# Chart of Nuclei



# Level systematics of Pb isotopes

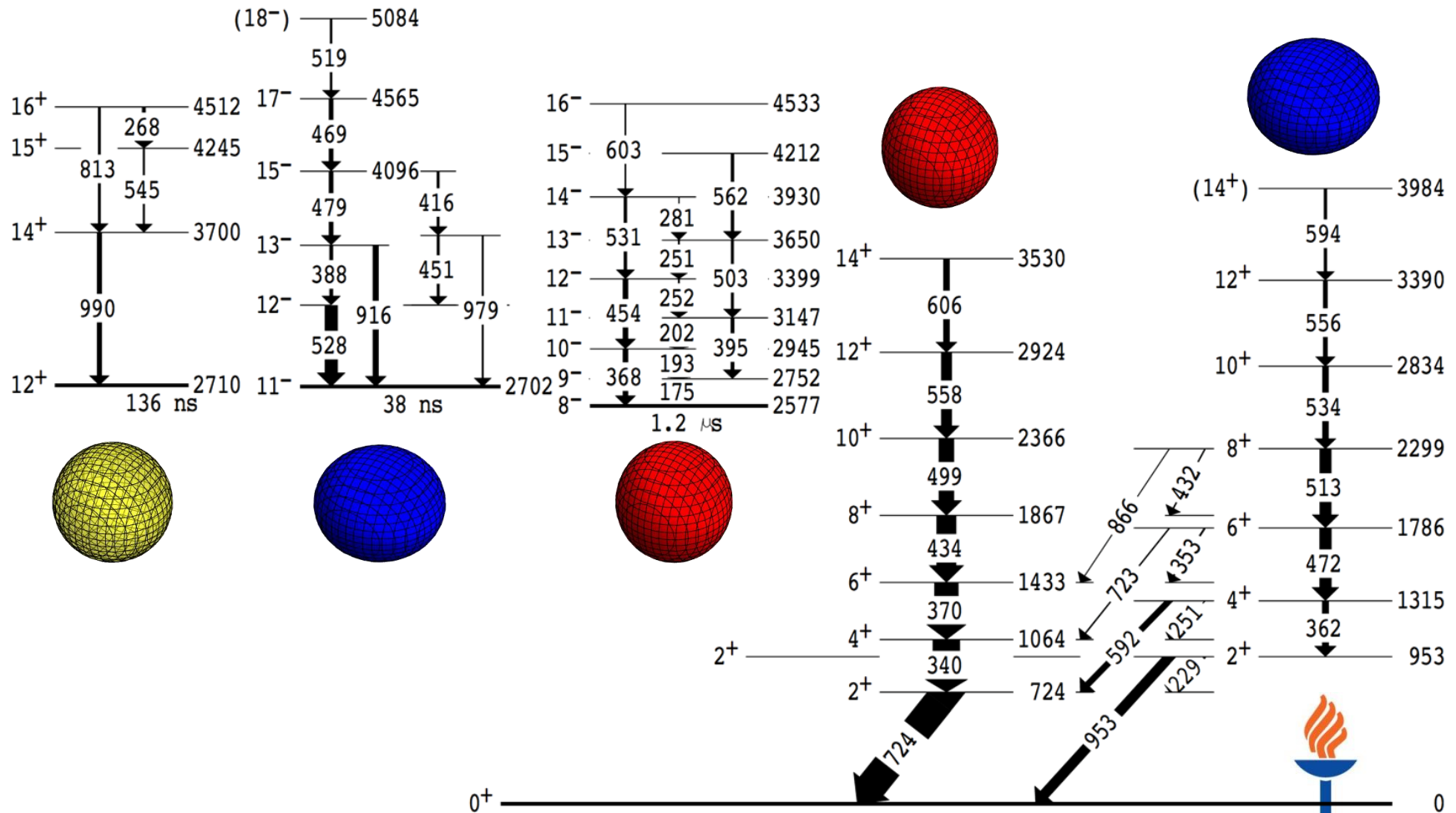


# Level systematics of Pb isotopes





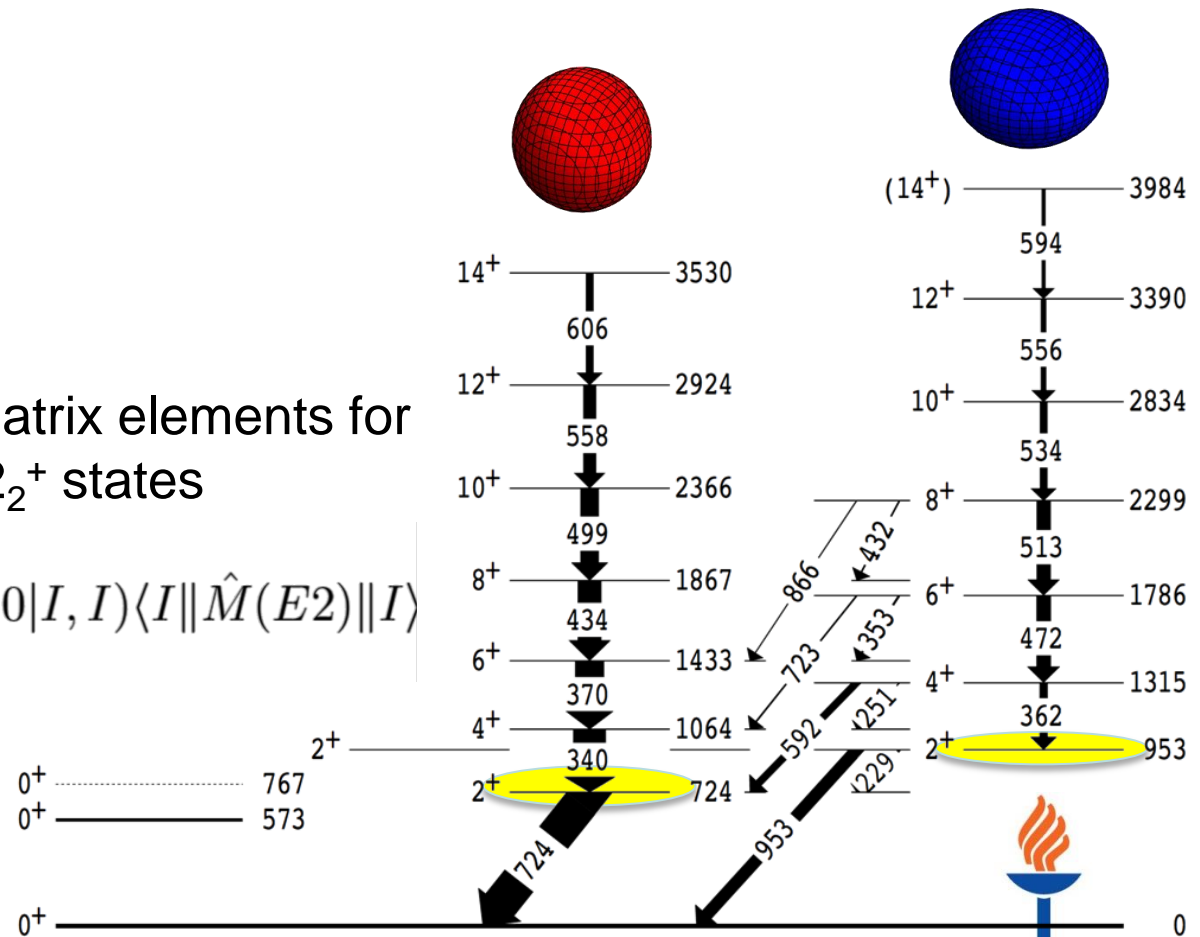
# $^{188}\text{Pb}$ level scheme



# Objectives of present work - 1 direct measurement of shapes

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

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



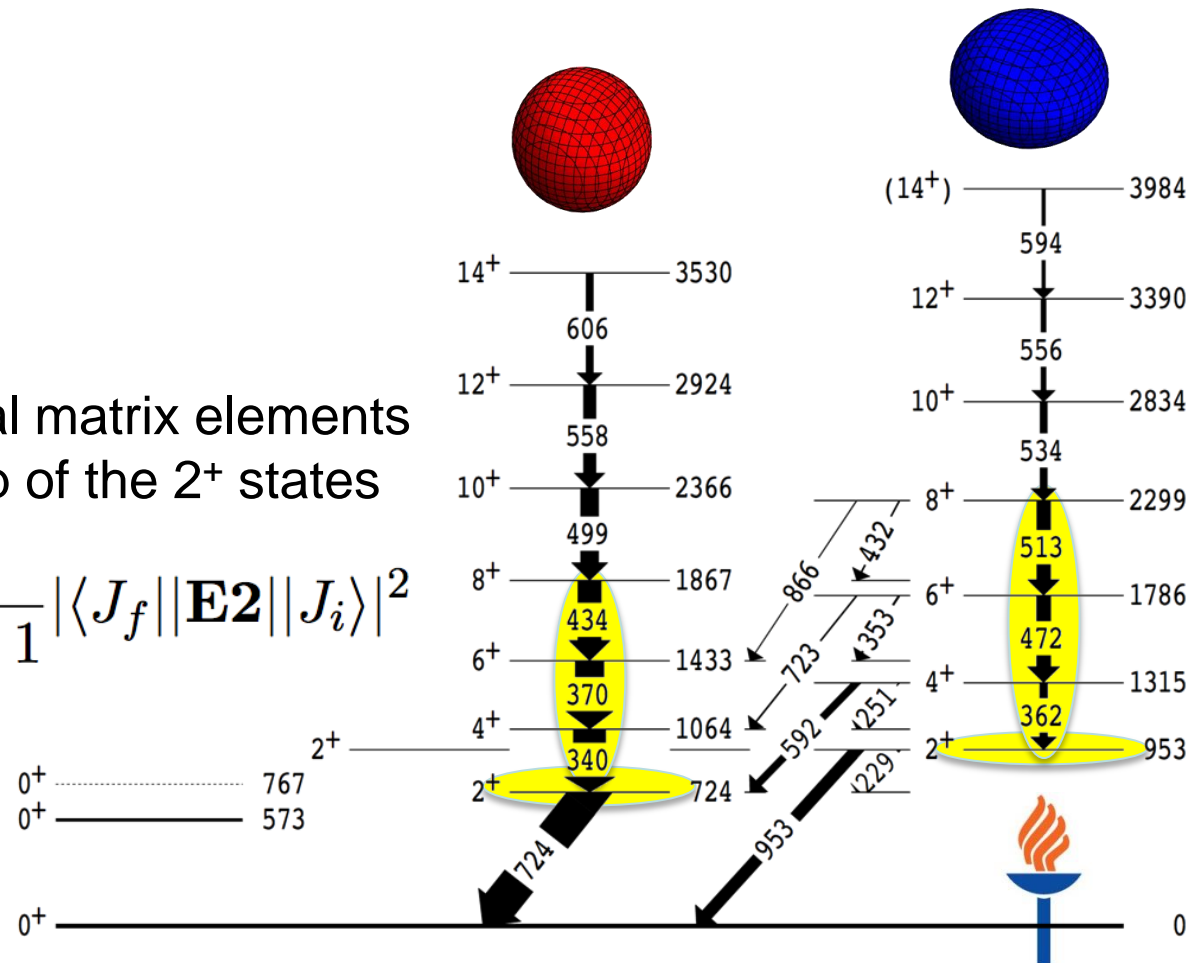


# Objectives of present work - 2

## collectivity of bands

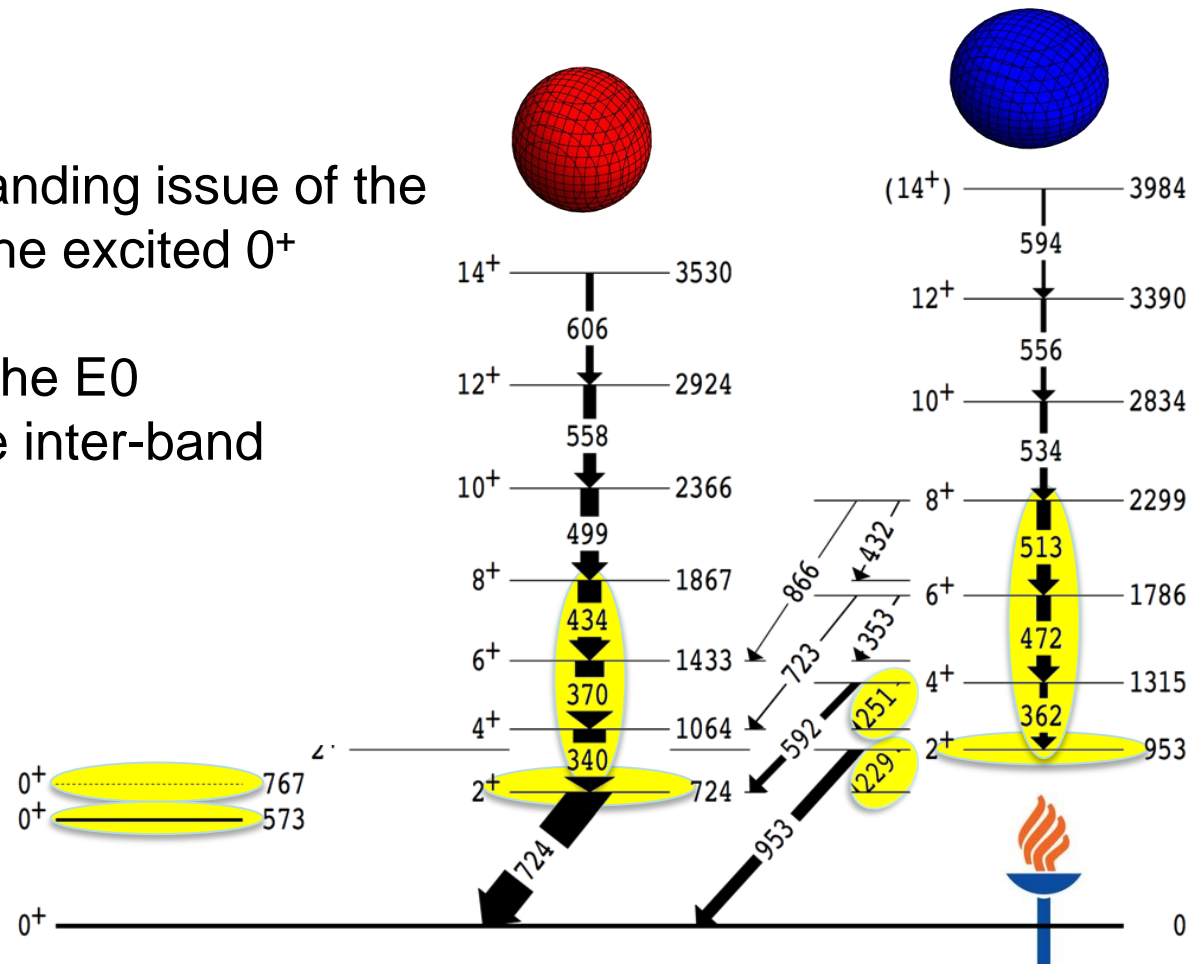
Measuring transitional matrix elements  
for transitions on top of the  $2^+$  states

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



# Objectives of present work - 3 measurement of the E0 transitions

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



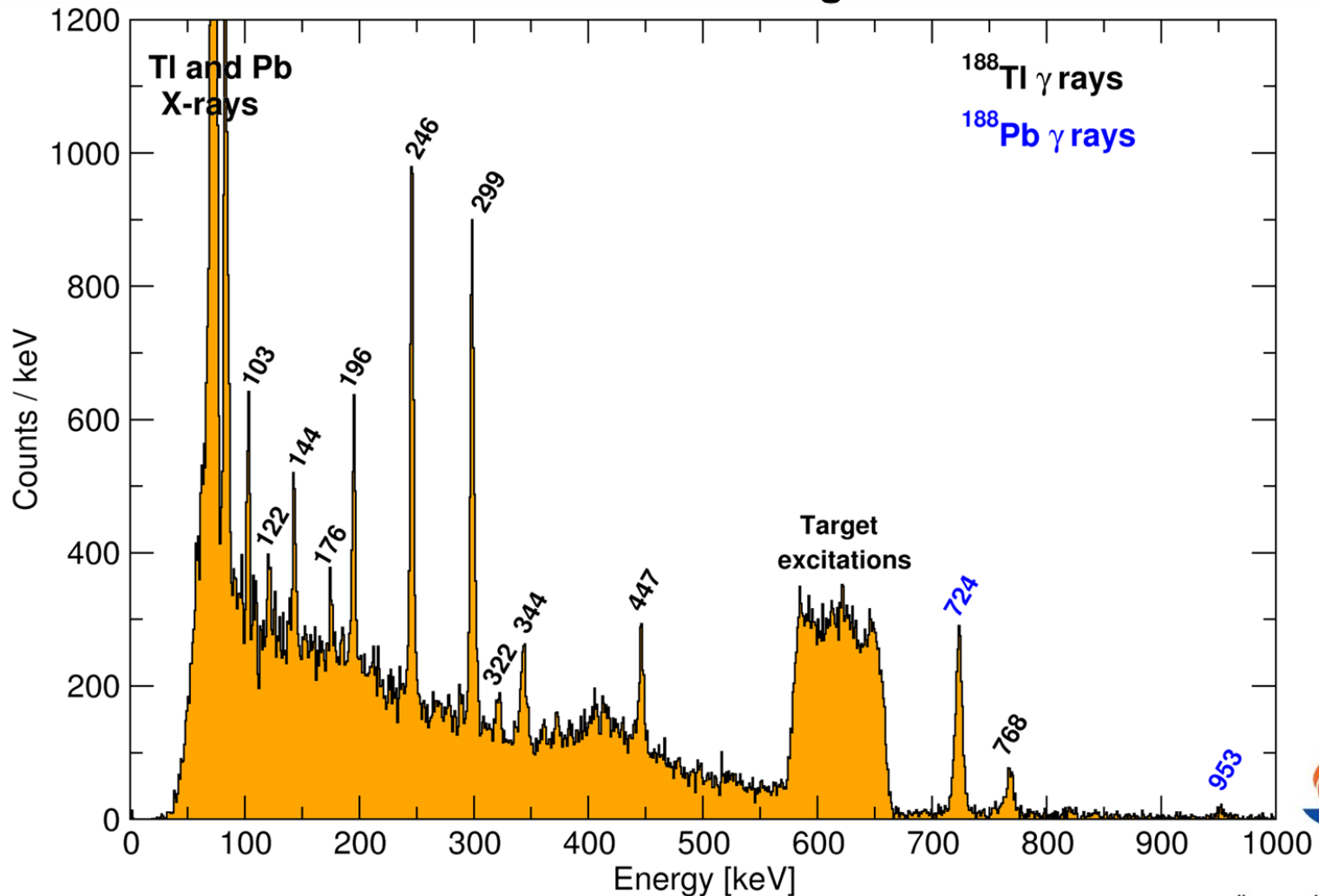
# Coulomb excitation of $(^{186}),^{188}\text{Pb}$

- UCx target + RILIS
- HIE-ISOLDE beam  $\sim 10^6$ pps @ MINIBALL
- Two energies: 3.5 and 4.1 MeV/u
- Two targets:  $^{112}\text{Cd}$  and  $^{48}\text{Ti}$
- Typical MINIBALL set-up + SPEDE
- Beam development for  $^{186}\text{Pb}$

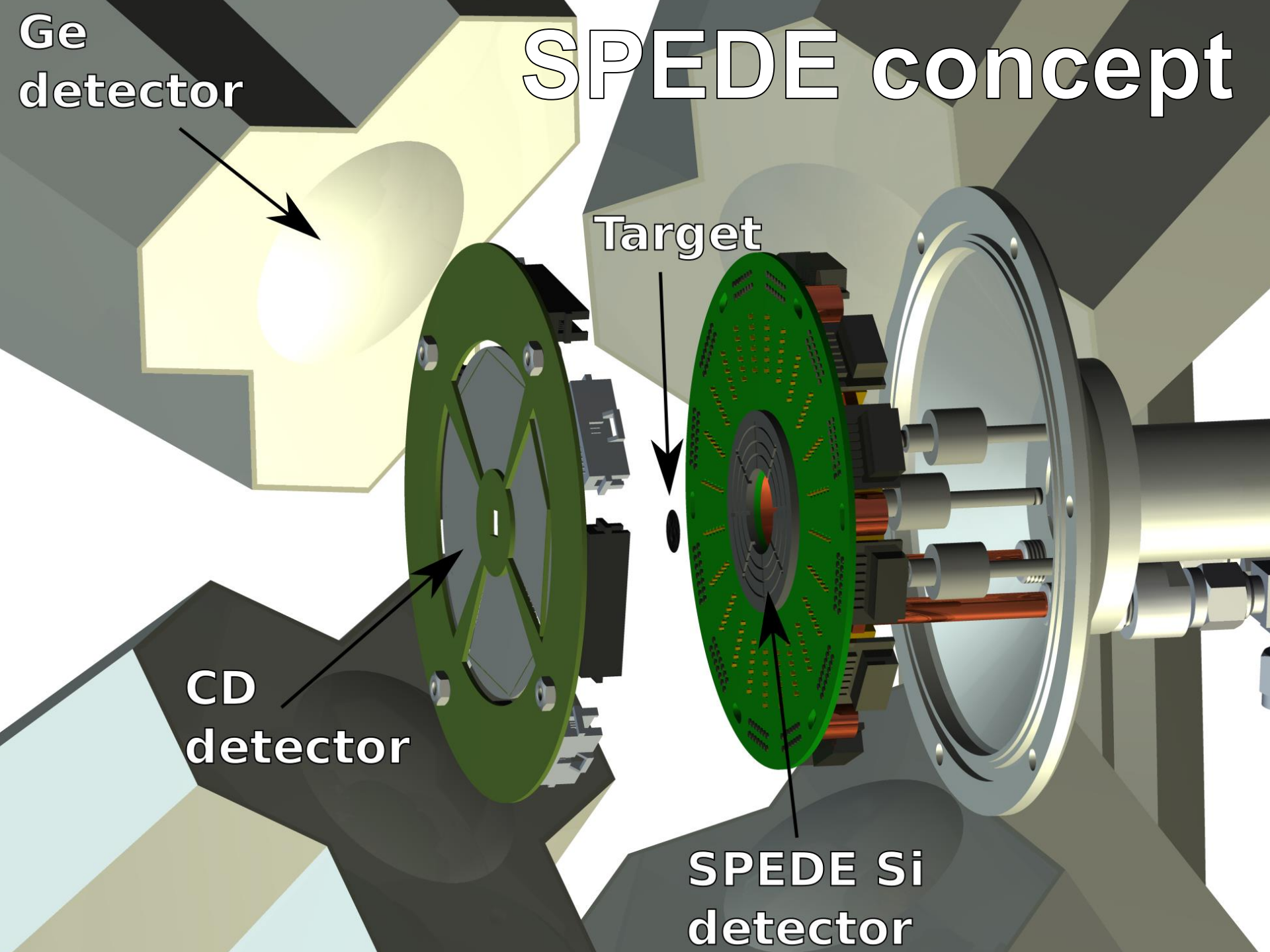


# DC bgr subtracted $\gamma$ -rays

Low CoM angles



# SPEDE concept



Ge  
detector

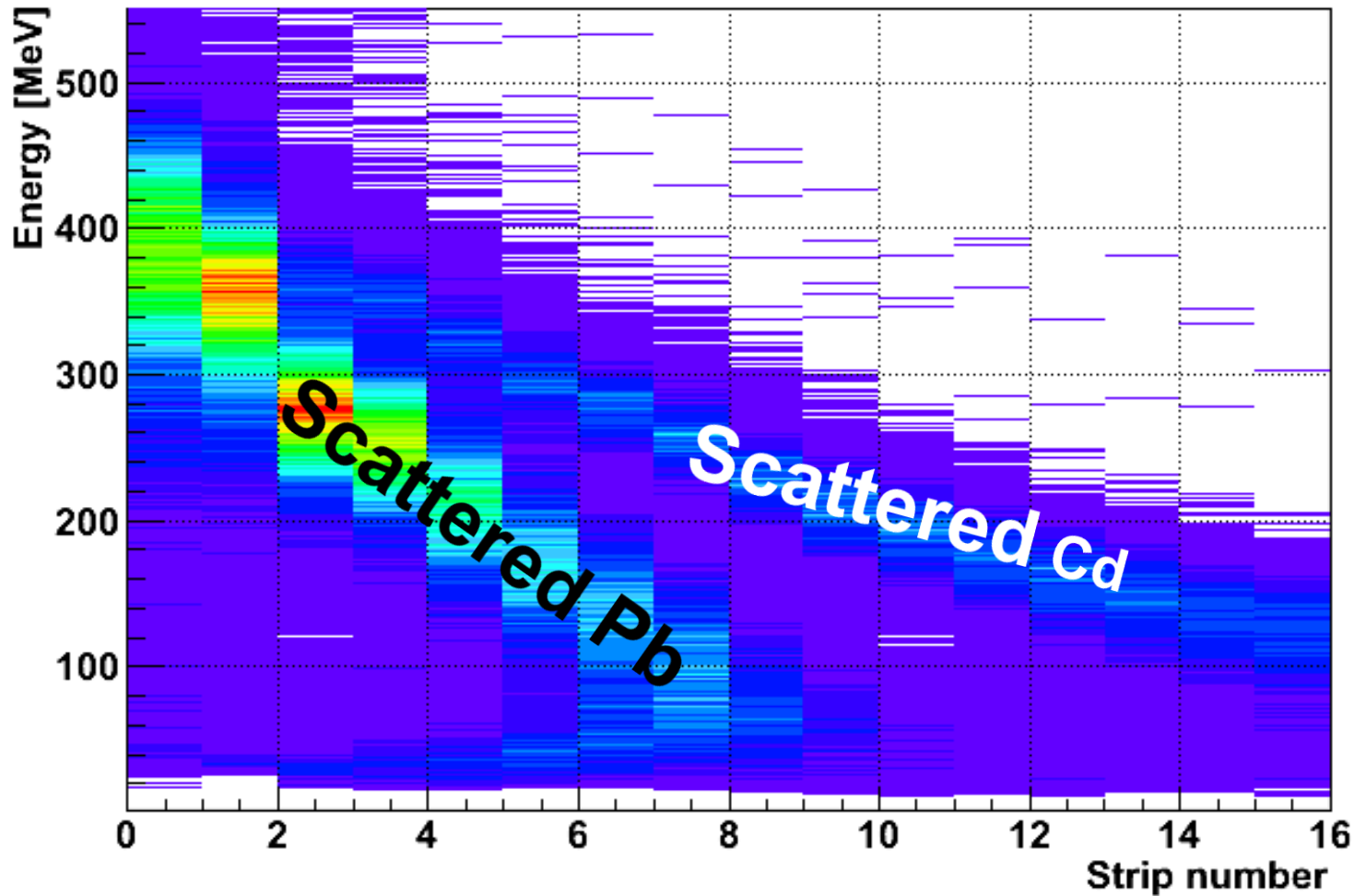
Target

CD  
detector

SPEDE Si  
detector

# Reaction kinematics

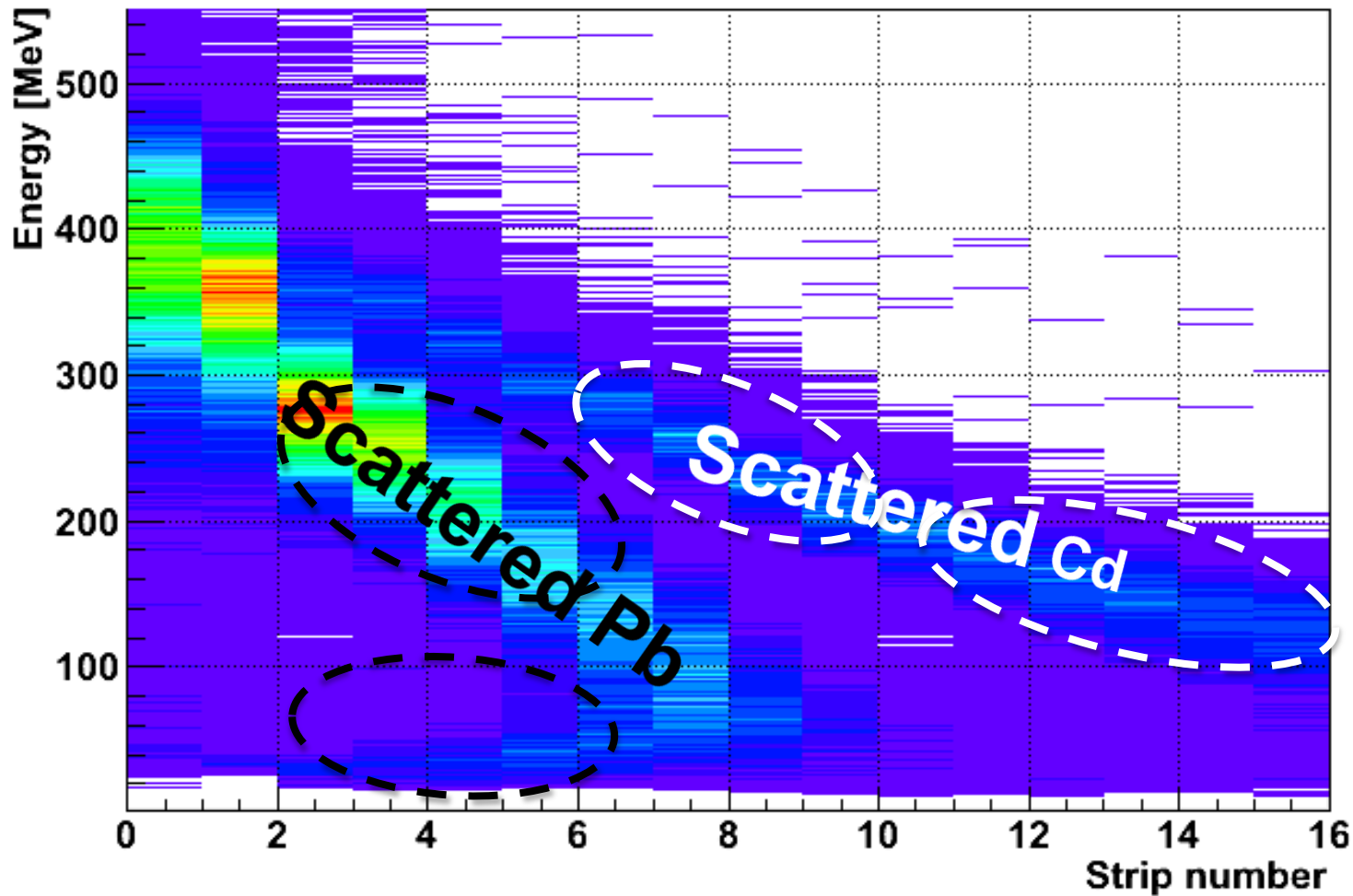
1-particle events in CD :: Pb-188 run



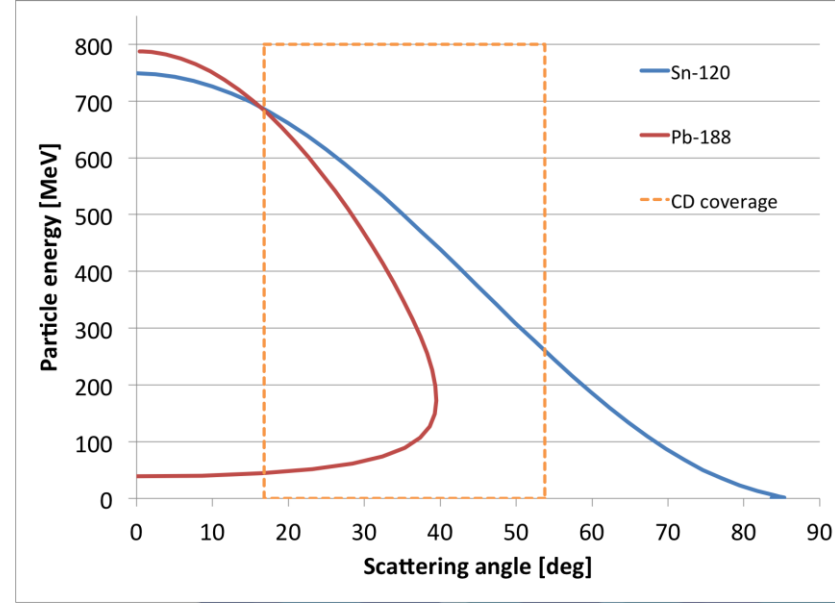
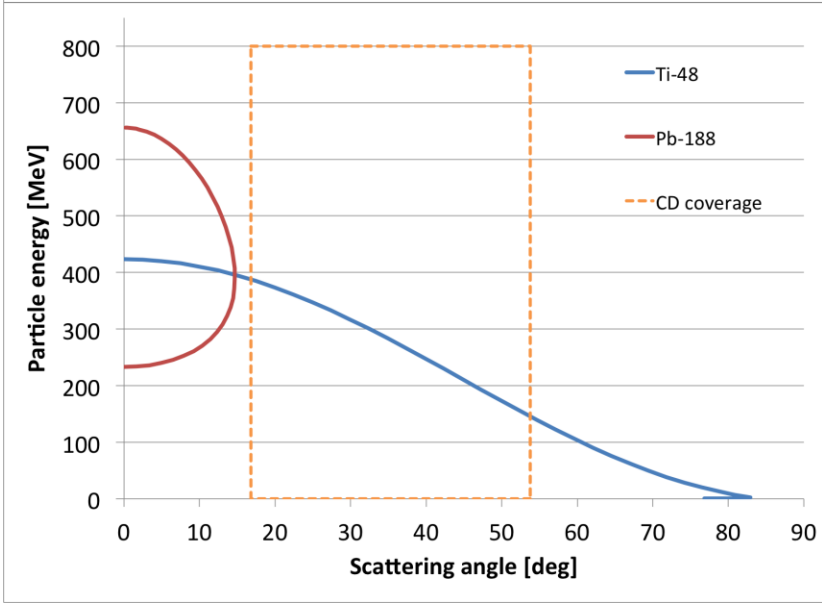
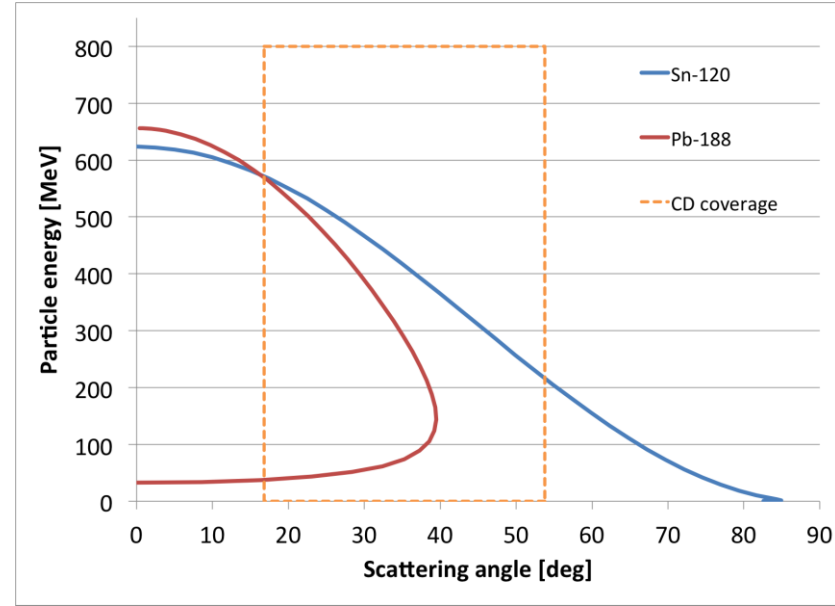
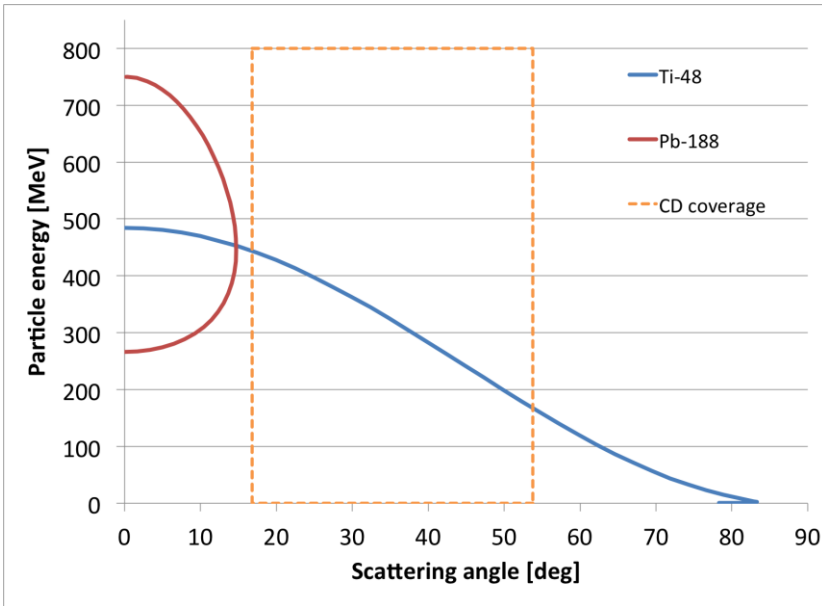


# Reaction kinematics

1-particle events in CD :: Pb-188 run



# Proposed reactions kinematics



# Yield estimates for $^{188}\text{Pb}$

– number of shifts as in proposal –

$I_i^\pi \rightarrow I_f^\pi$ Projectile	$E_{\text{transition}}$ [keV]	Det. Eff. [%]	4.3MeV/u $^{188}\text{Pb}+^{120}\text{Sn}$	3.5MeV/u $^{188}\text{Pb}+^{120}\text{Sn}$	4.0MeV/u $^{188}\text{Pb}+^{48}\text{Ti}$	3.5MeV/u $^{188}\text{Pb}+^{48}\text{Ti}$
$2_1^+ \rightarrow 0_1^+$	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 <sup>a)</sup>	8.0	1202	782	42	29
$0_2^+ \rightarrow 0_1^+$	502.5 <sup>a)</sup>	8.0	2294	1538	80	83
<b>Target</b>						
$2_1^+ \rightarrow 0_1^+$	$^{120}\text{Sn}$ : 1171 $^{48}\text{Ti}$ : 984	6.6 7.3	53153	26619	17241	17875
$4_1^+ \rightarrow 2_1^+$	$^{120}\text{Sn}$ : 1023 $^{48}\text{Ti}$ : 1312	7.2 6.1	10795	1640	63	16
$2_2^+ \rightarrow 0_1^+$	$^{120}\text{Sn}$ : 2097 $^{48}\text{Ti}$ : 2421	4.2 3.5	71	12	1	0

<sup>a)</sup> K-conversion electron energy



# Yield estimates for $^{186}\text{Pb}$

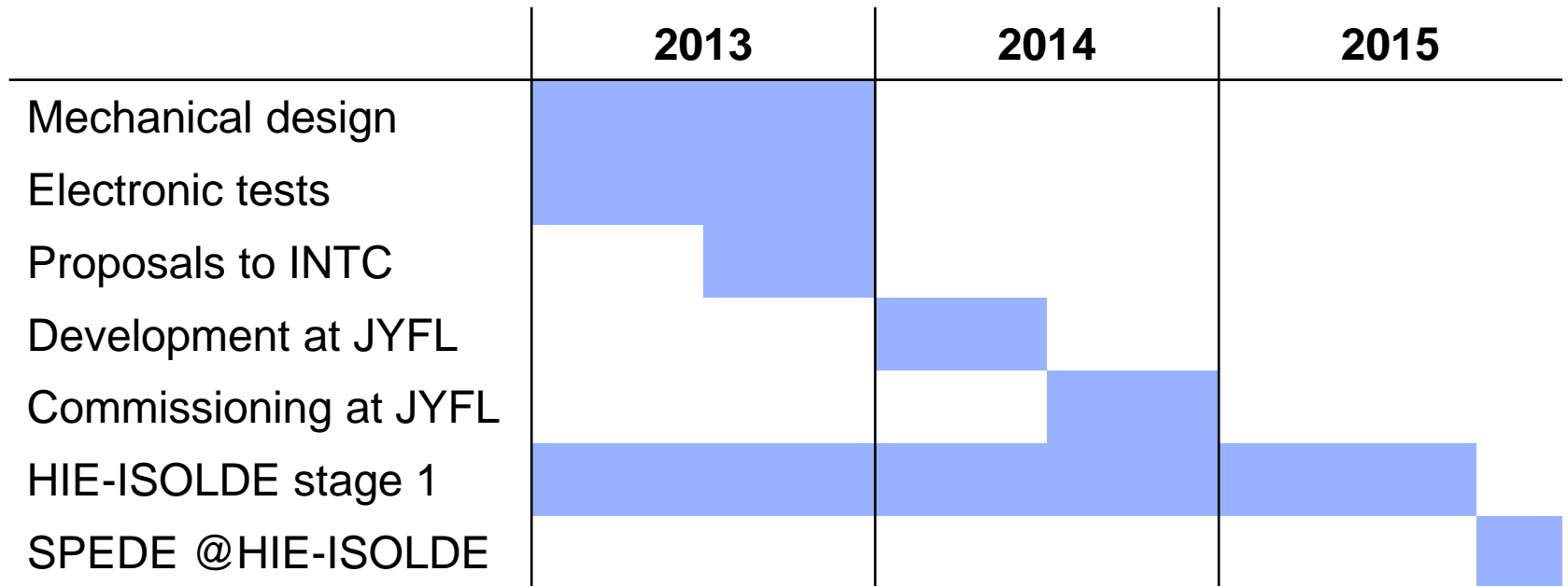
– 1 week of beam time –

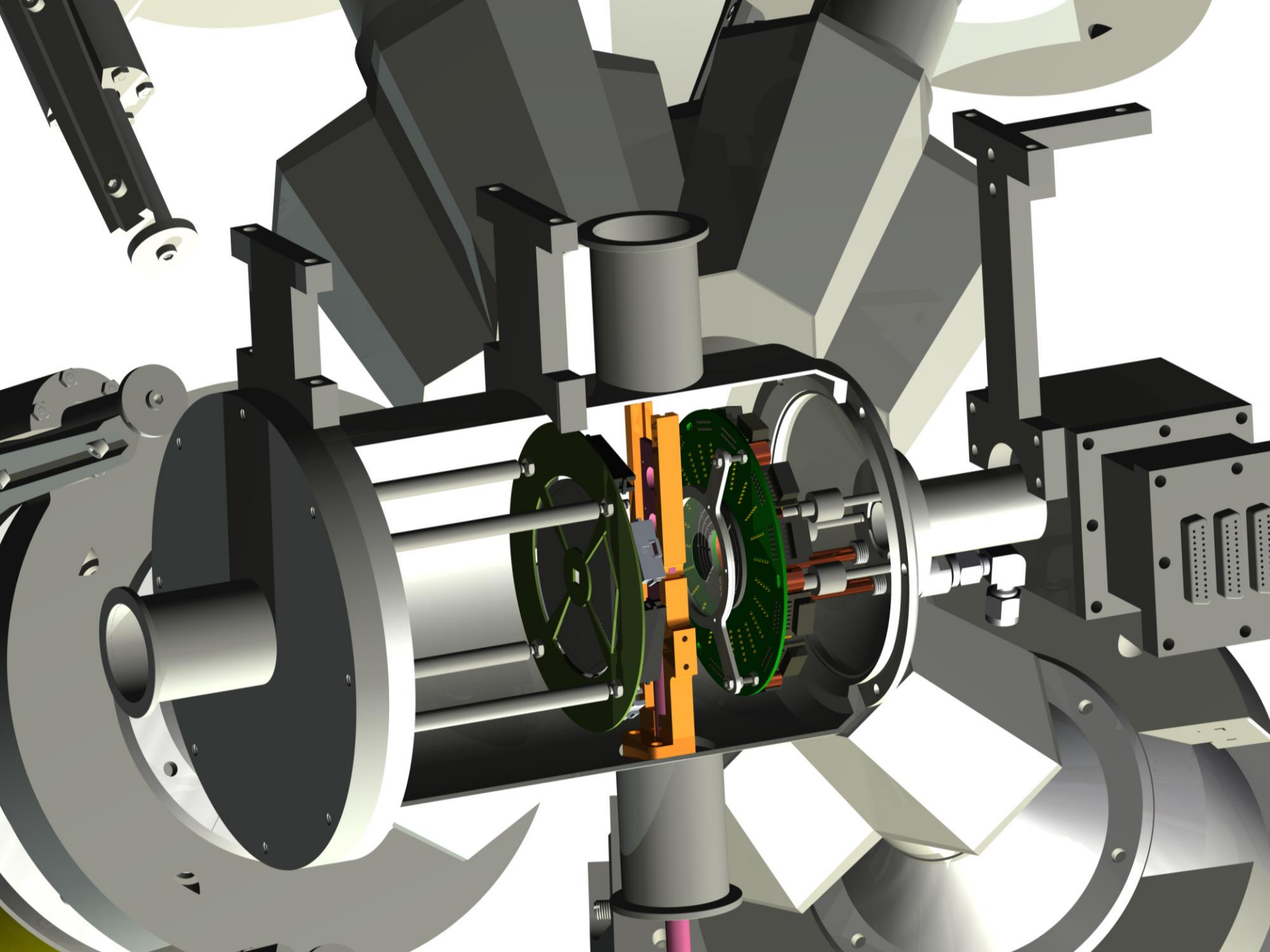
$I_i^\pi \rightarrow I_f^\pi$ Projectile	$E_{\text{transition}}$ [keV]	Det. Eff. [%]	4.2MeV/u $^{186}\text{Pb} + ^{120}\text{Sn}$
$2_1^+ \rightarrow 0_1^+$	662	9.3	678
$4_1^+ \rightarrow 2_1^+$	261	16.7	453
$6_1^+ \rightarrow 4_1^+$	337	14.2	149
$8_1^+ \rightarrow 6_1^+$	415	12.4	24
$2_1^+ \rightarrow 0_2^+$	130	22.2	7
$2_2^+ \rightarrow 0_1^+$	945	7.5	169
$4_2^+ \rightarrow 2_2^+$	392	12.9	86
$6_2^+ \rightarrow 4_2^+$	401	12.7	22
$8_2^+ \rightarrow 6_2^+$	424	12.2	4
$2_2^+ \rightarrow 0_2^+$	413	12.4	46
$2_2^+ \rightarrow 2_1^+$	295	15.5	3
$2_2^+ \rightarrow 2_1^+$	283 <sup>a)</sup>	15.9	5
$0_2^+ \rightarrow 0_1^+$	283 <sup>a)</sup>	8.0	32

a) K-conversion electron energy

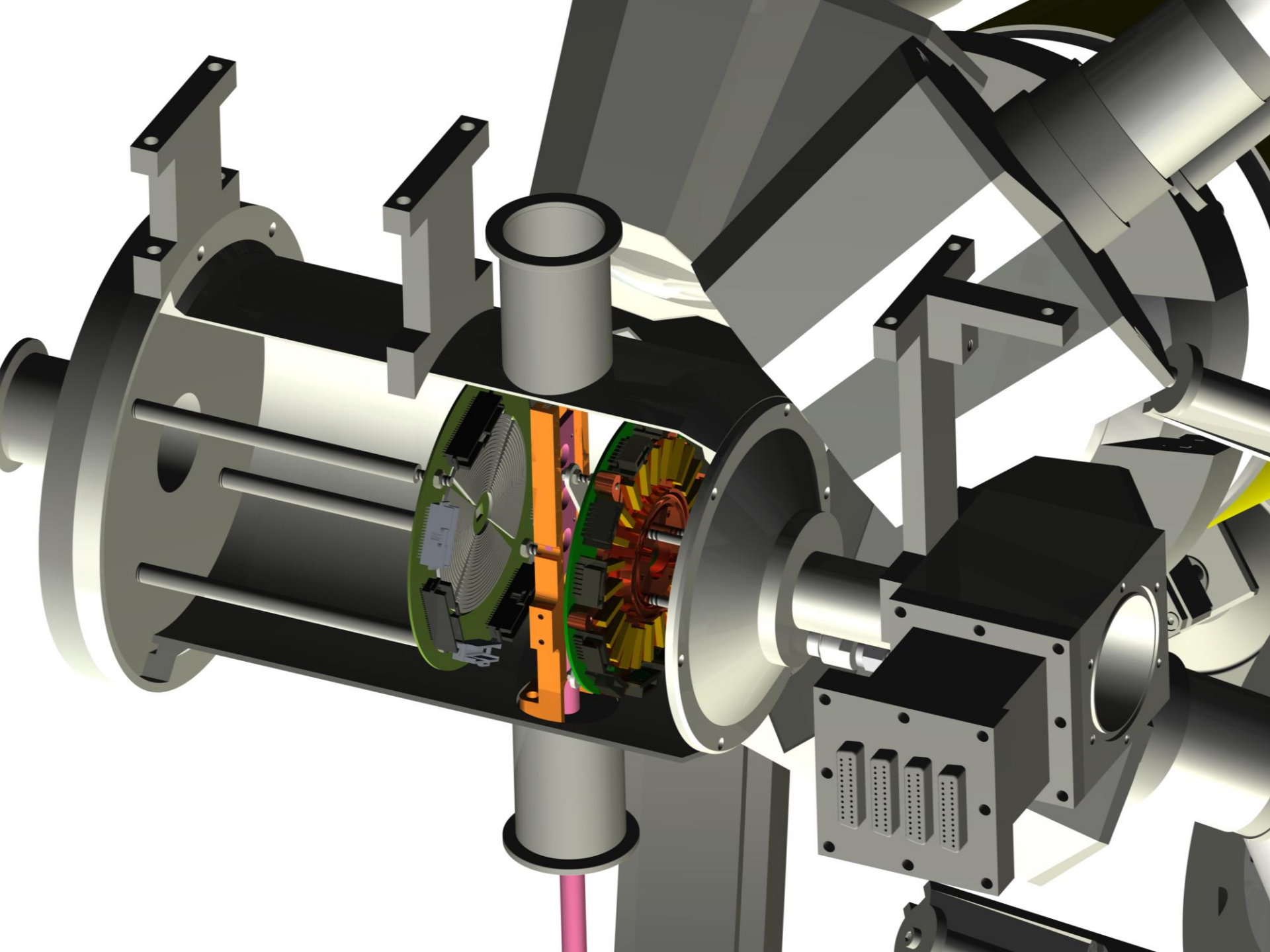


# SPEDE timeline

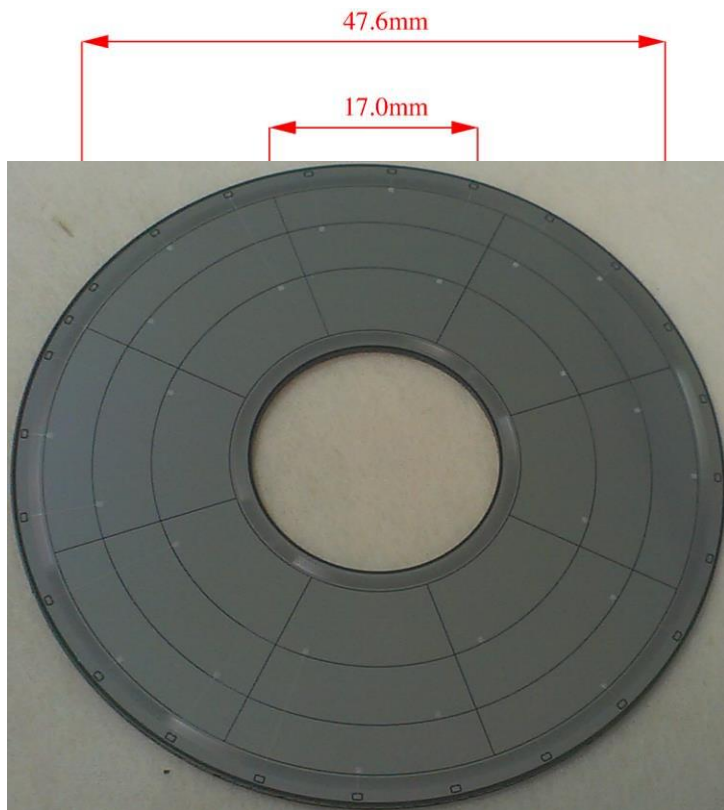




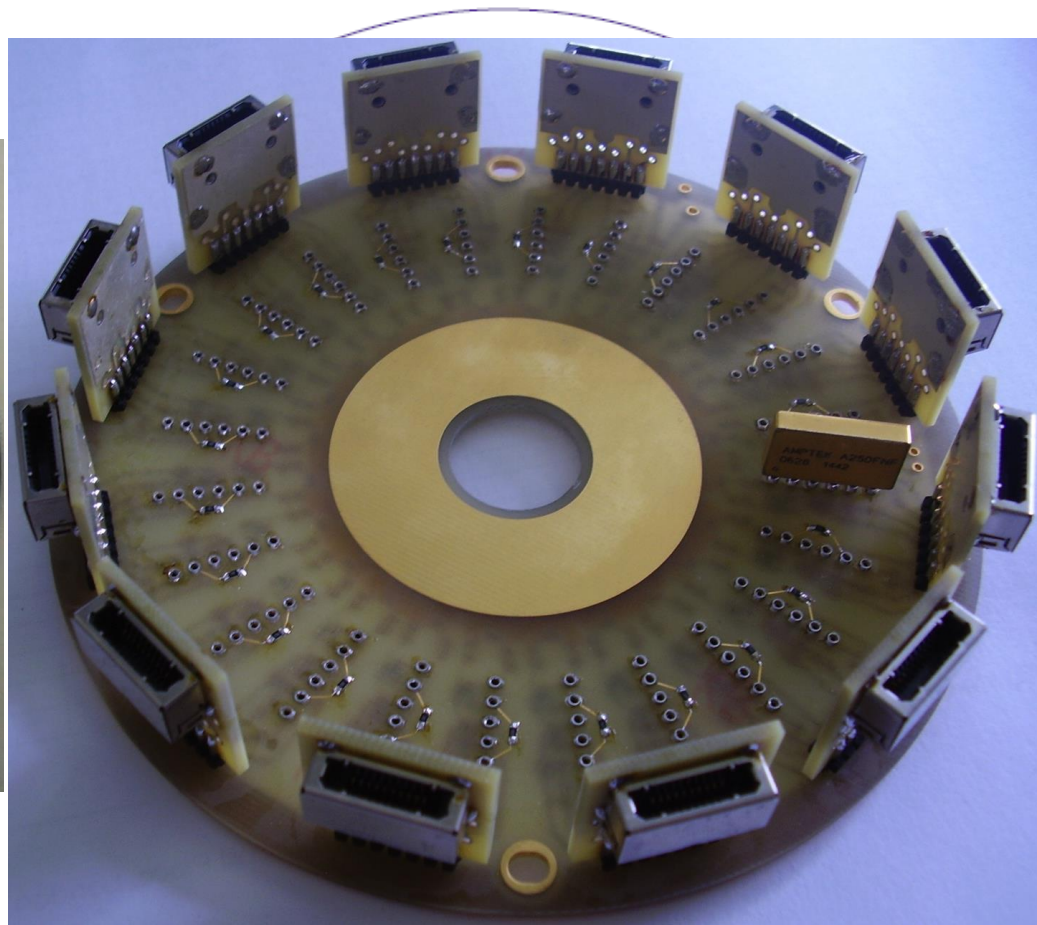




# Silicon detector and PCB layout



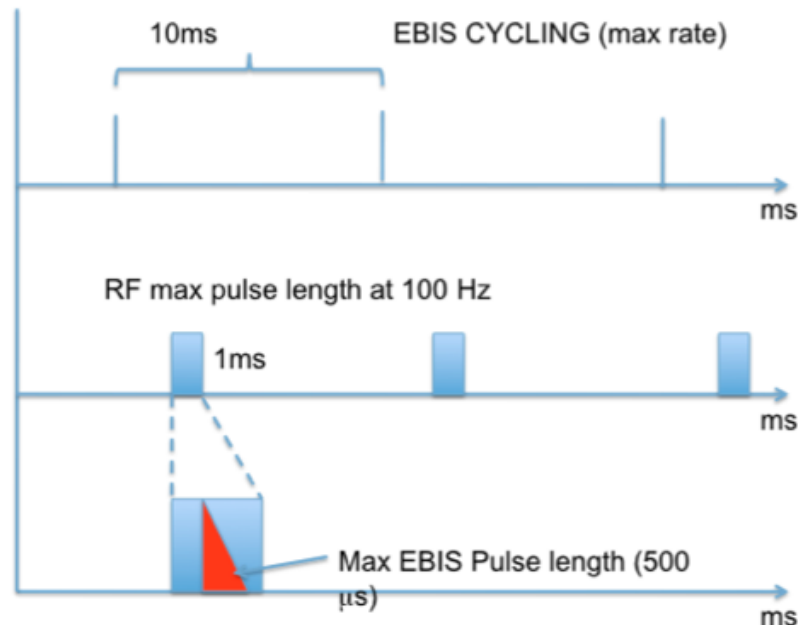
500 $\mu$ m



# In-beam tests at JYFL

## Development (2014)

- Investigation of  $\delta$ -electron suppression
- Cocktail beam: N, Ne, Si, Ar, Fe, Kr and Xe
- Beam intensity and time profile as HIE-ISOLDE





# Summary

## SPEDE status:

- Detector designed and ordered after Geant4 simulations
- On-going tests of electronics
- Mechanical design being finalised
- Development and commissioning proposal accepted by JYFL PAC

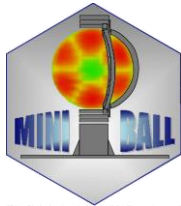
## Request:

- 1) We request 12 shifts for  $^{188}\text{Pb}$  experiment
- 2) Development of  $^{186}\text{Pb}$  beam





# Acknowledgements



Technische Universität München

Comenius University  
Bratislava  
Slovakia



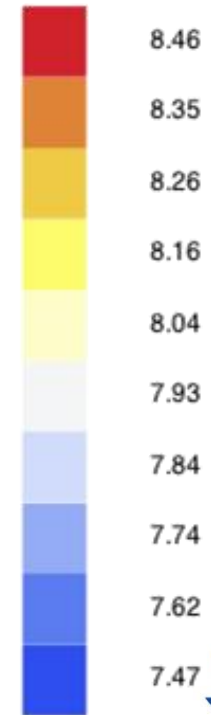
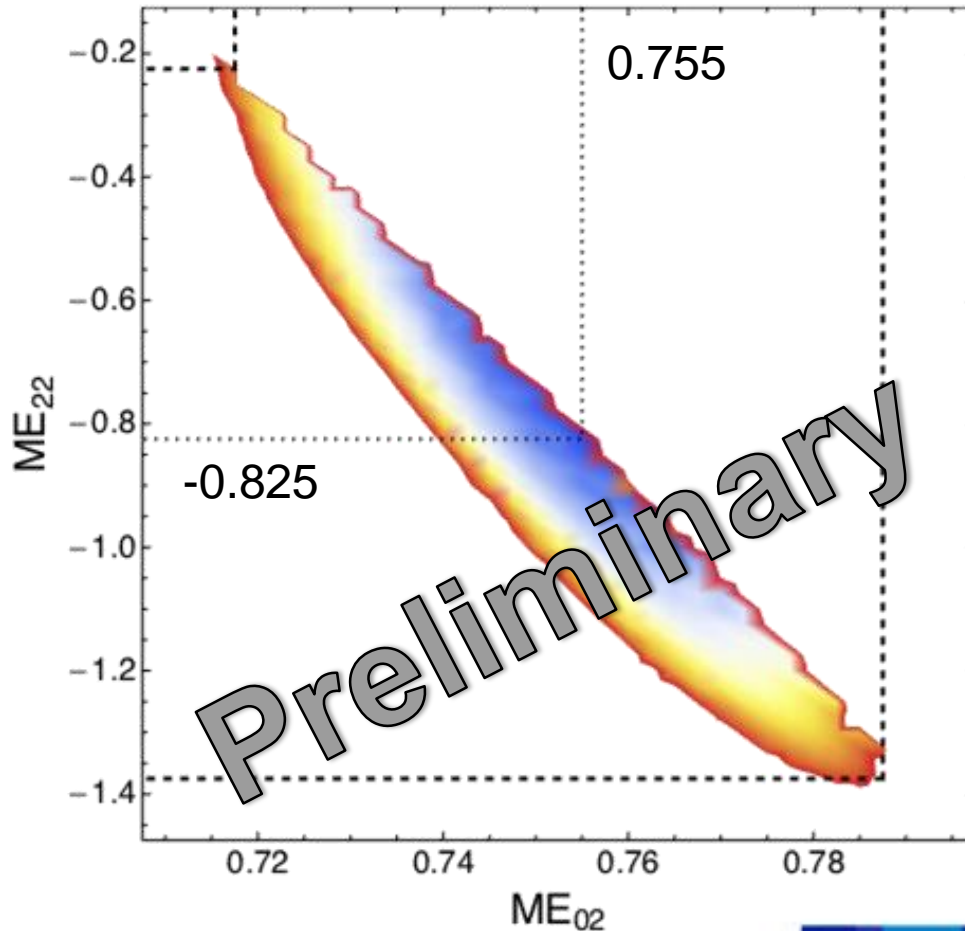


# Matrix elements for the $2_1^+$ state

$1\sigma$  contour of the  $\chi^2$  surface

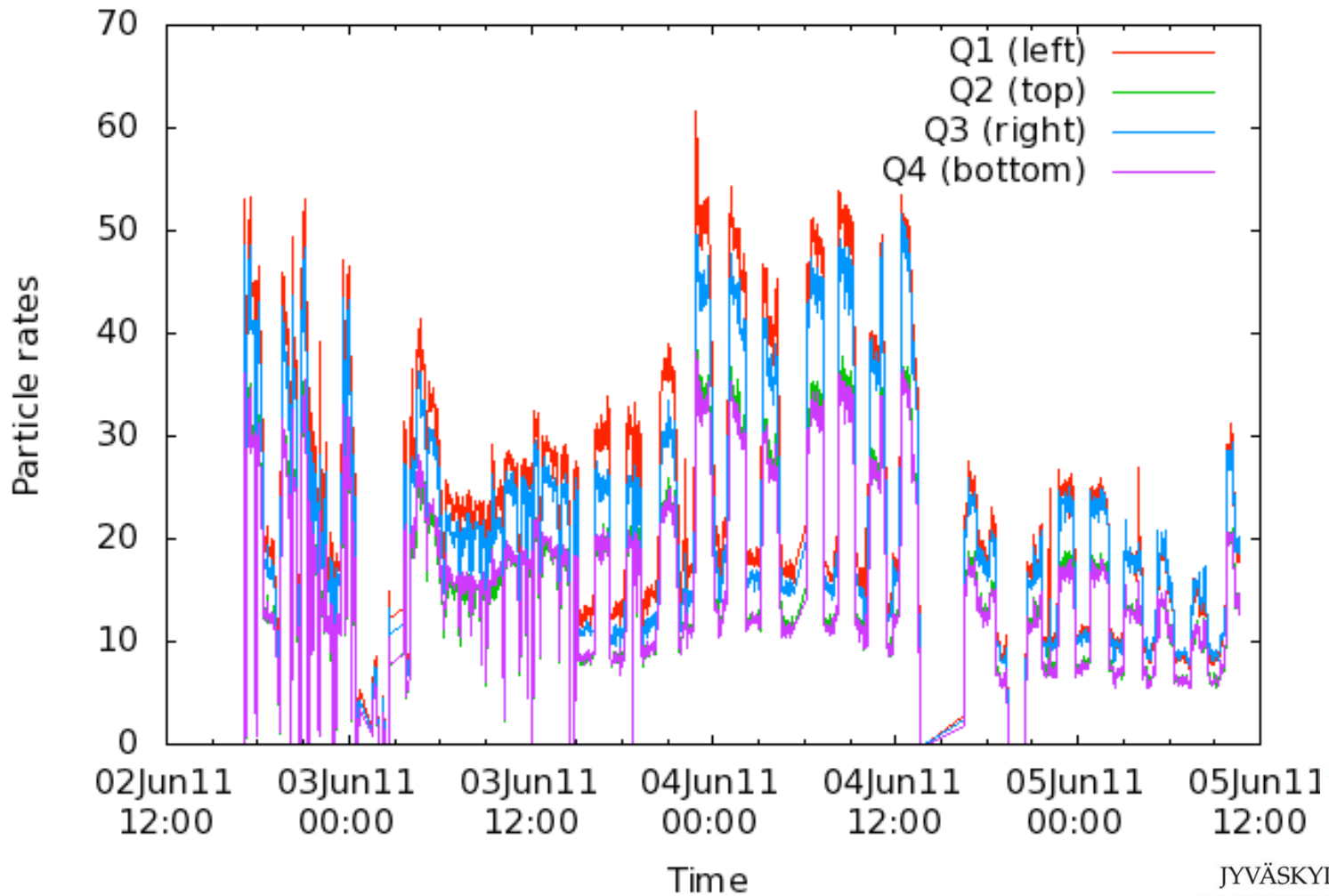
$B(E2) \sim 18(2)$  W.u

$Q_{sp}$   
 $\sim -0.6(5)$  eb



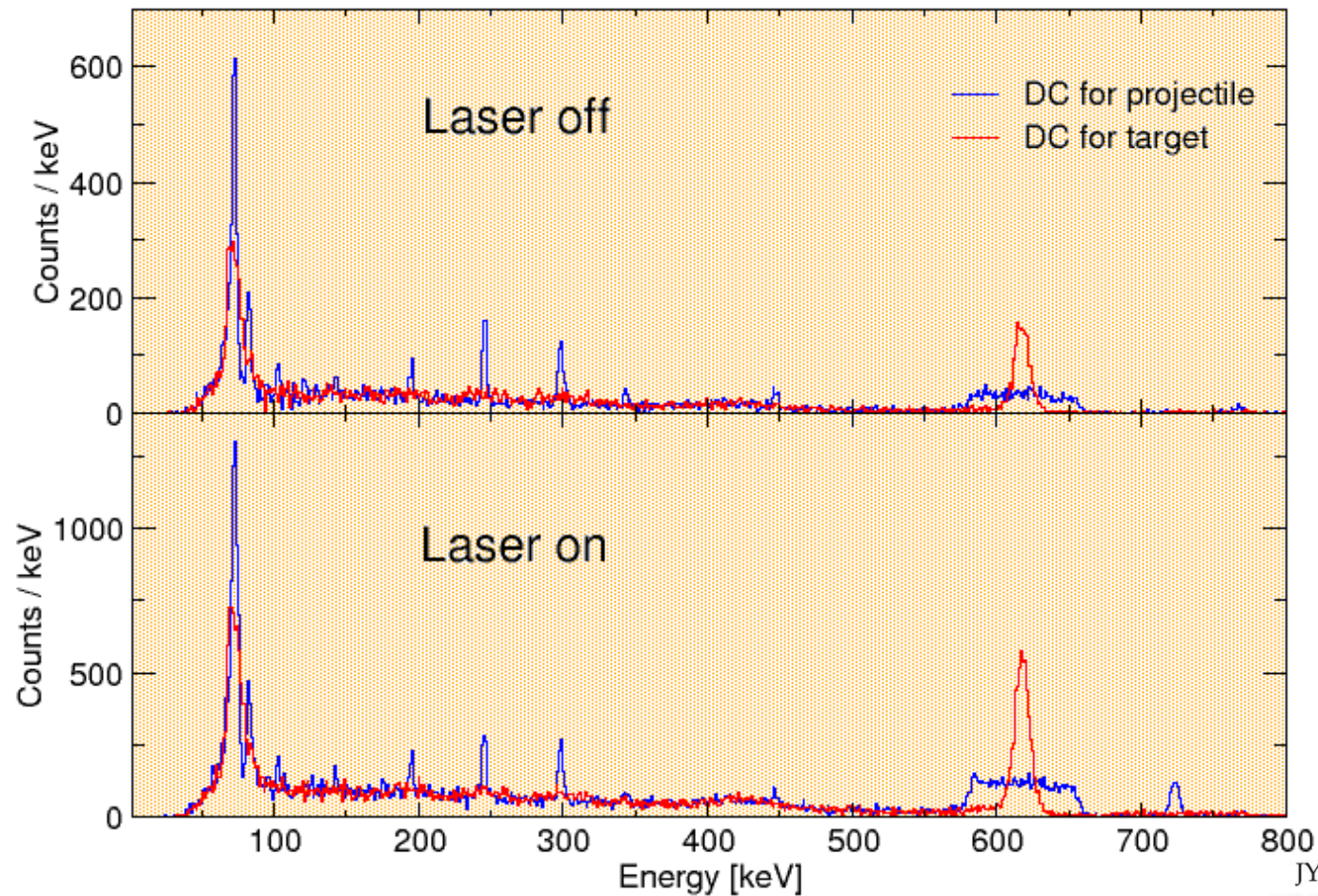
# Laser on/off

Particle rates for mass 188 vs. time

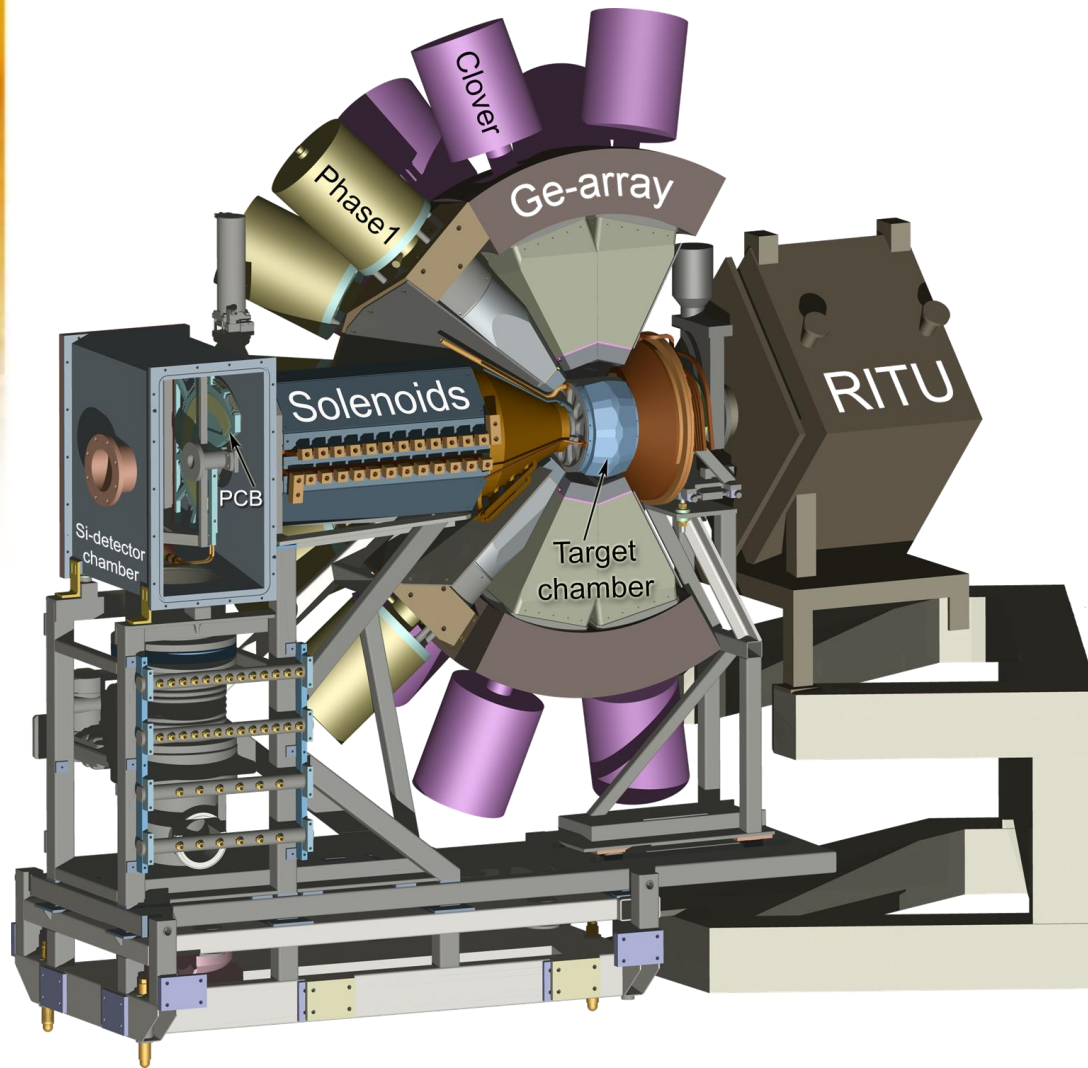


# Laser on/off

$\gamma$ -rays in coincidence with  $^{188}\text{Pb}$  detected in low CoM angles



# Probing conversion electrons in $^{188}\text{Pb}$ using the SAGE spectrometer

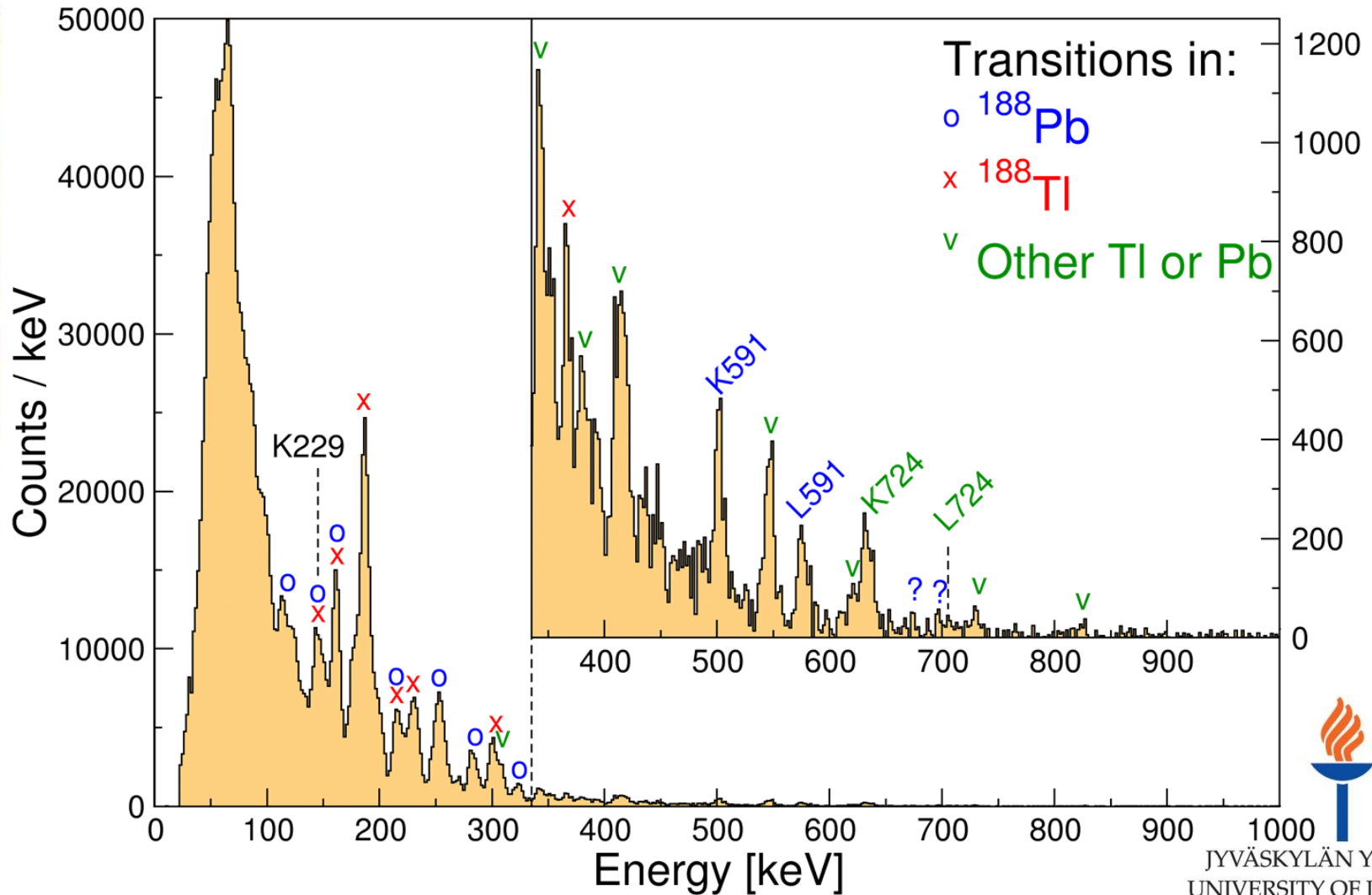


- $^{160}\text{Dy}(^{32}\text{S},4n)^{188}\text{Pb}$
- $E_{\text{beam}} = 165\text{MeV}$
- $\sigma \sim 1100\mu\text{b}$
- $I_{\text{beam}} \approx 18\text{pA}$
- 7 days of beam time
- SAGE+RITU+GREAT
- Fully digital DAQ

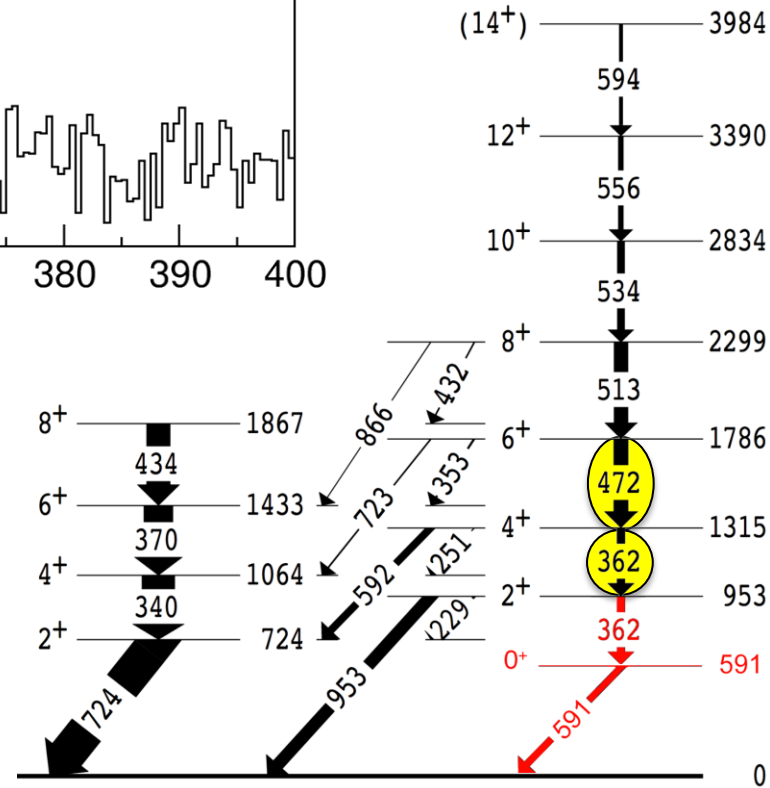
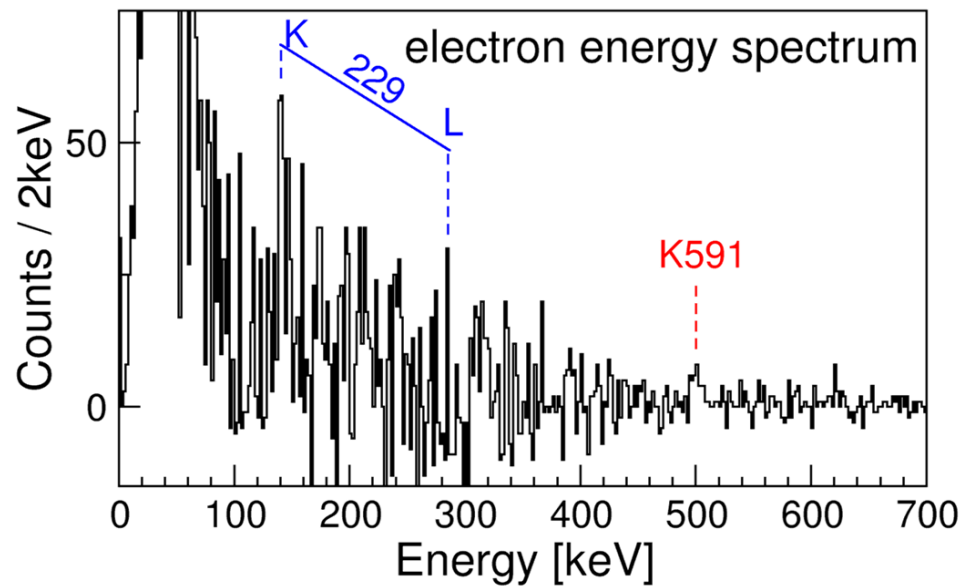
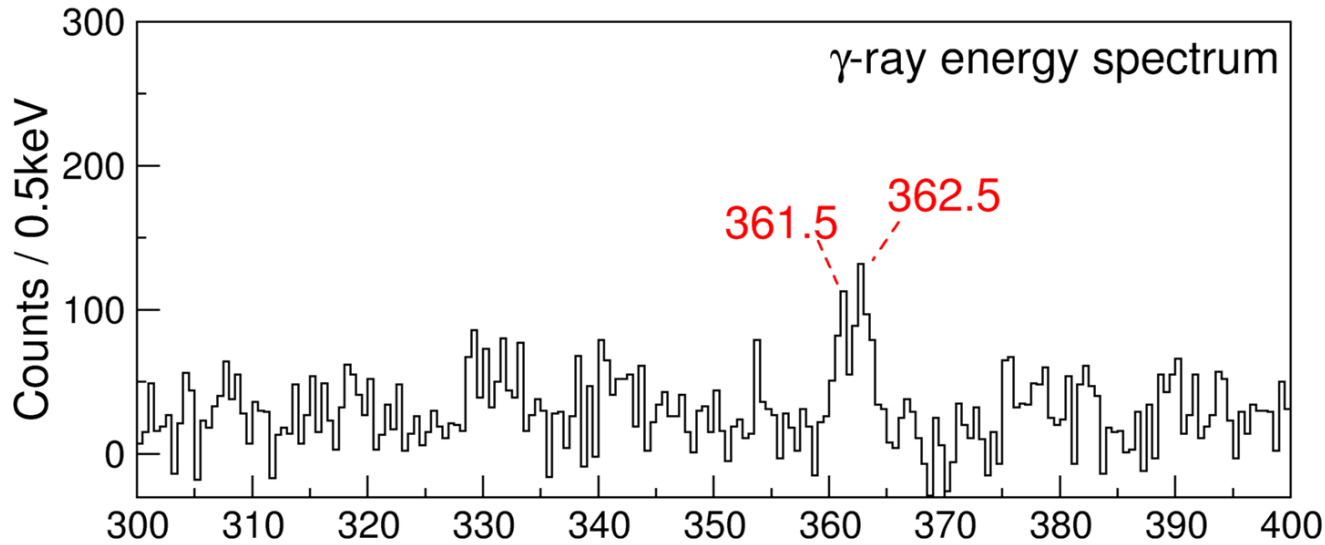




# Recoil gated electron singles



# Gate on 472 and 362keV $\gamma$ -rays





$^{188}\text{Tl}$

vs.

$^{188}\text{Pb}$

