Octupole collectivity: Coulomb excitation of ^{224}Ra

Liam Gaffney

REX-ISOLDE

Isotope
Separation
On-
Line
D ..?
E ..?

RIB
E-
Xperiment

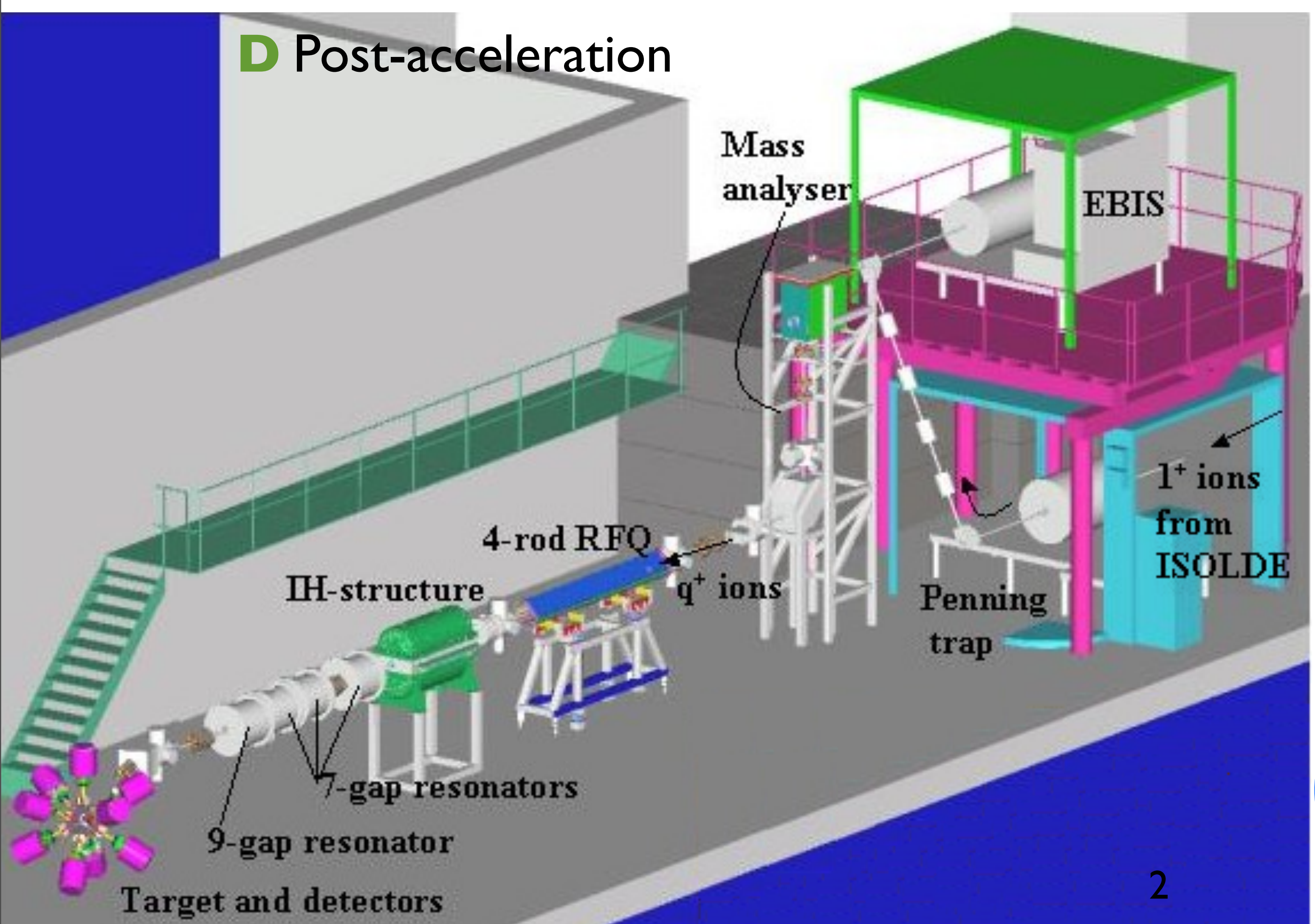
Radioactive
Ion
Beam

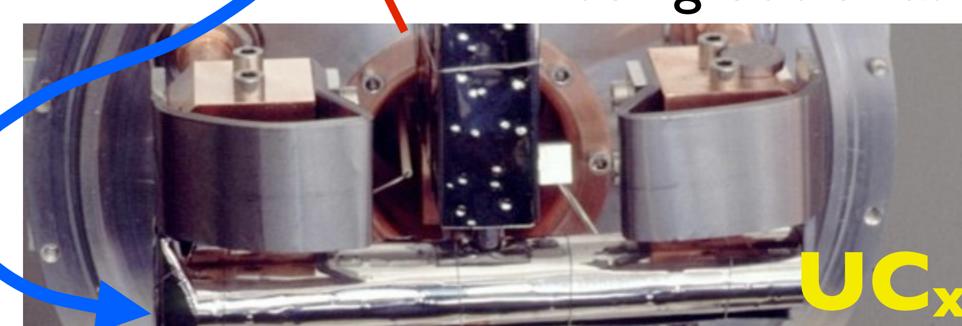
A 1.0 or 1.4GeV protons from PS Booster

B Heated tungsten line to ionise atoms diffusing out of target

C Mass separation in HRS

D Post-acceleration





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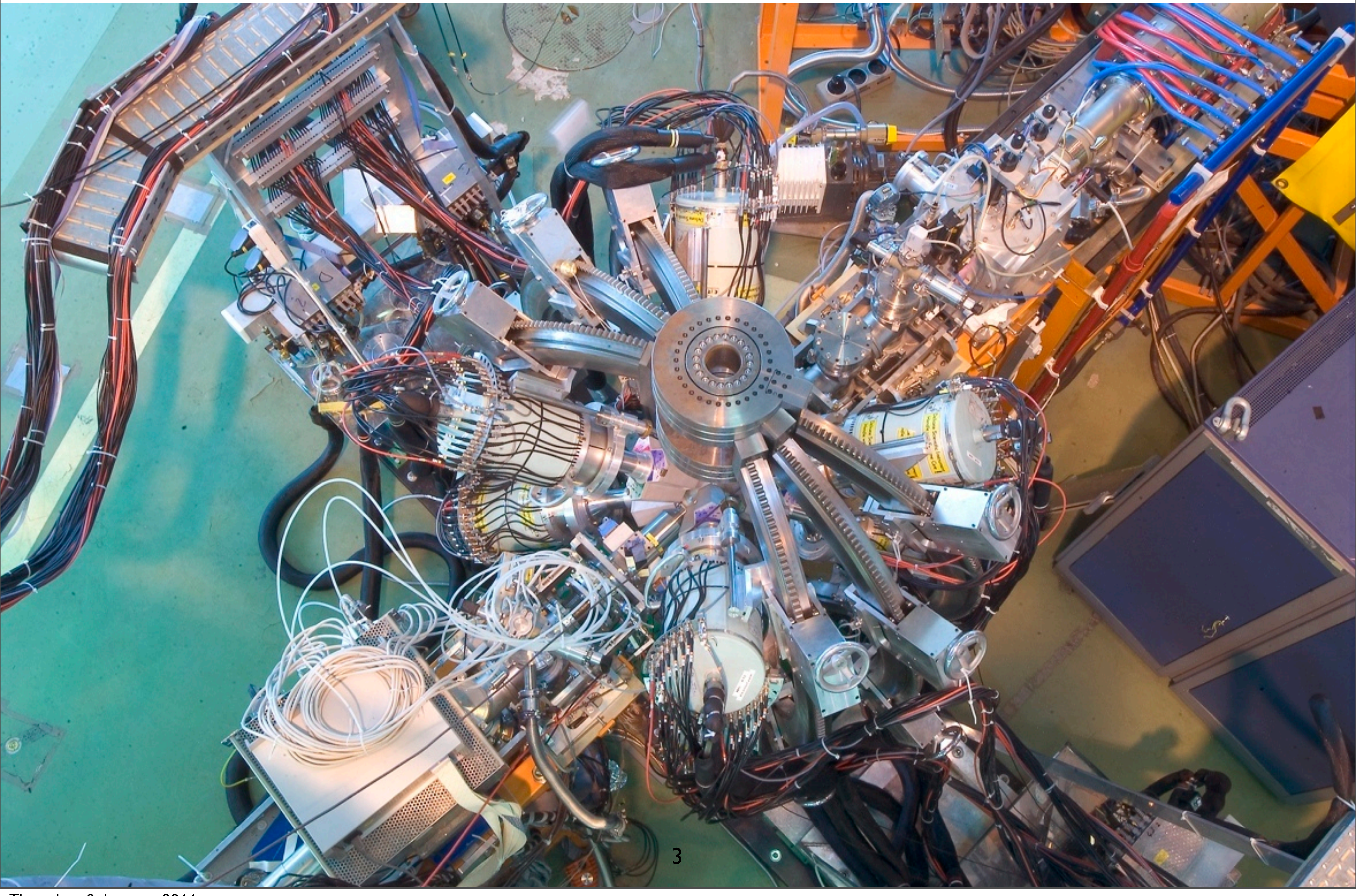

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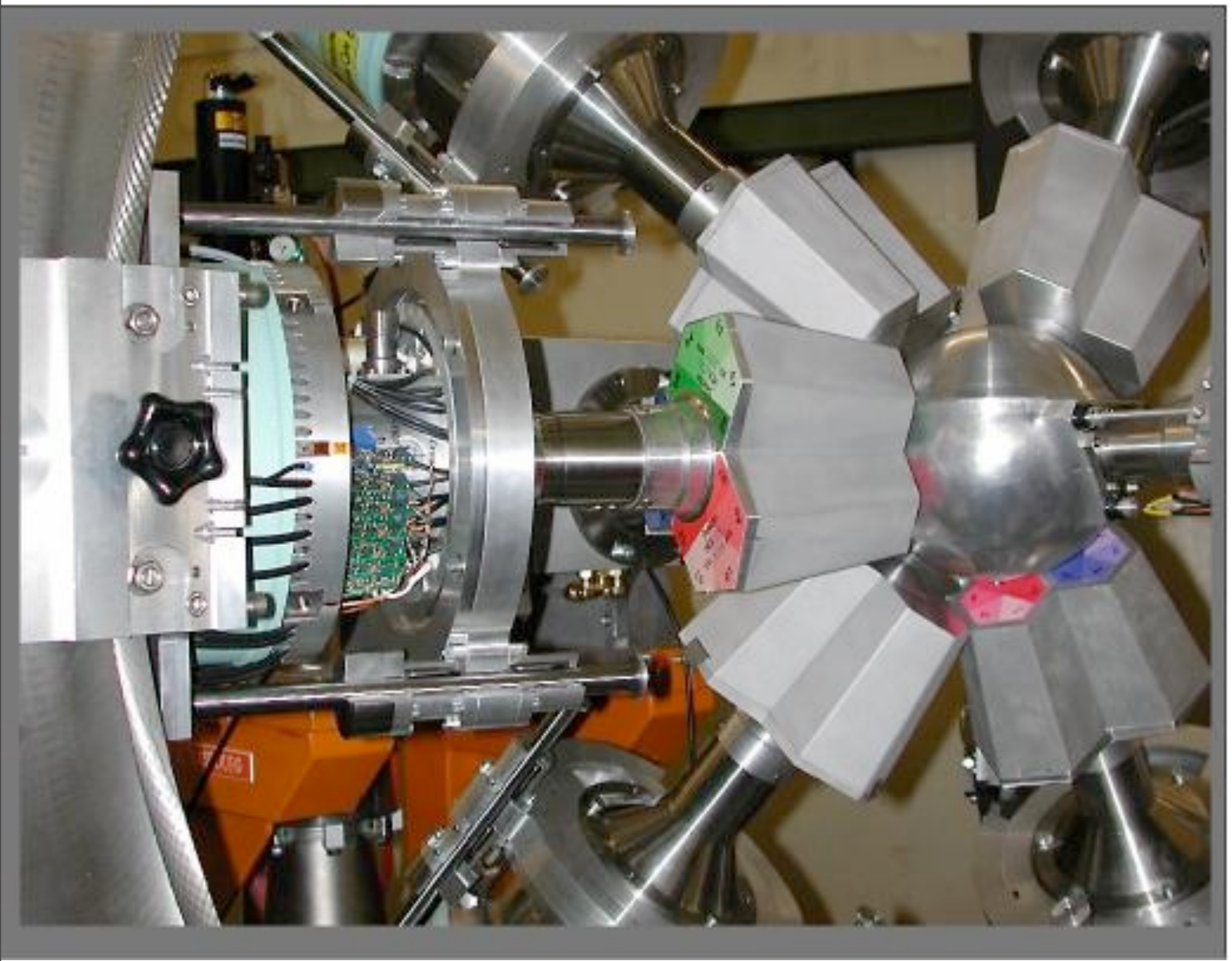
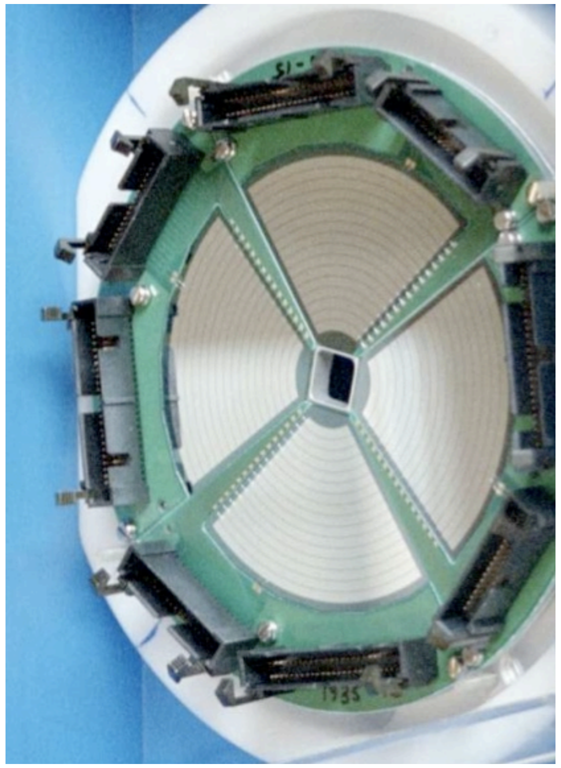
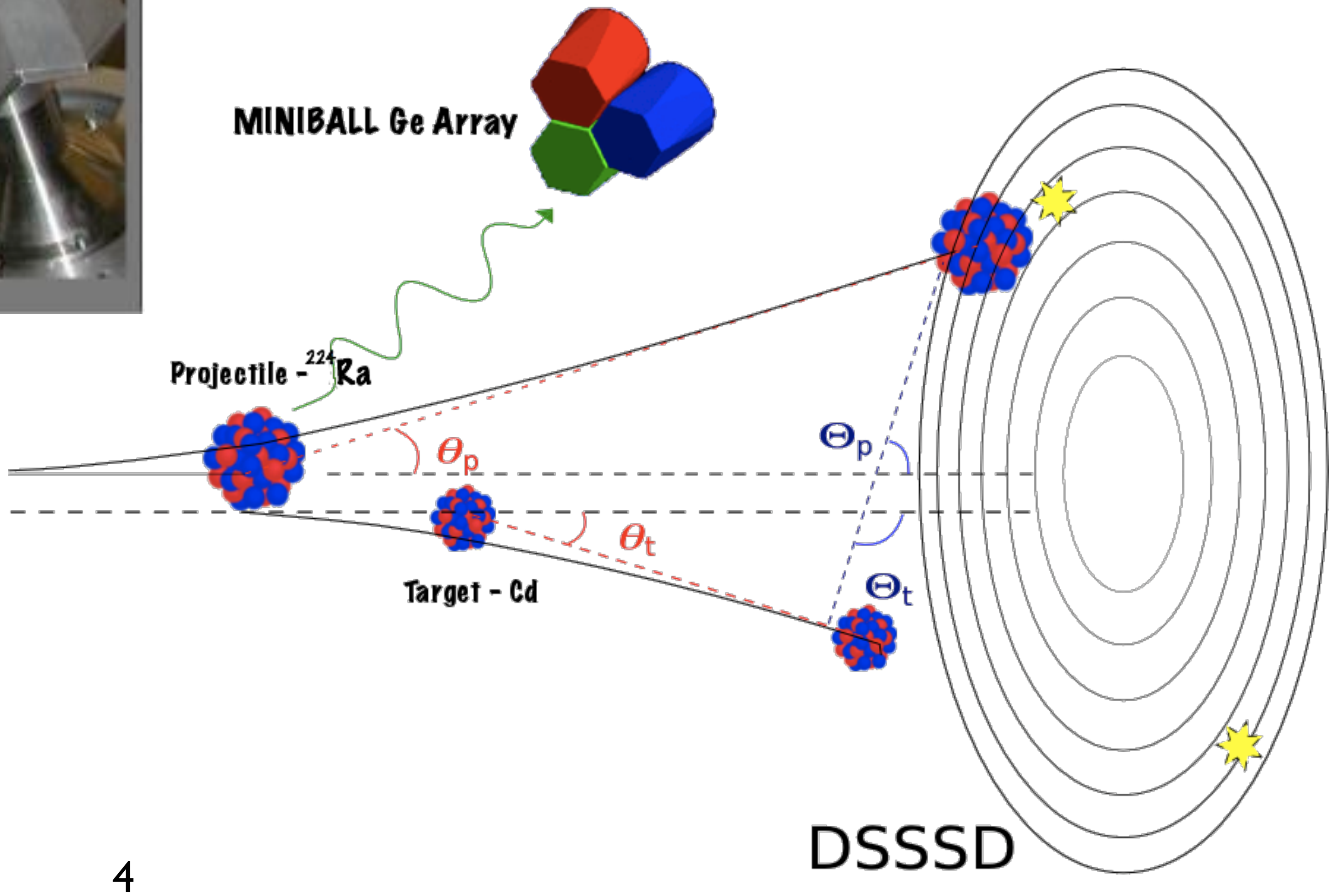


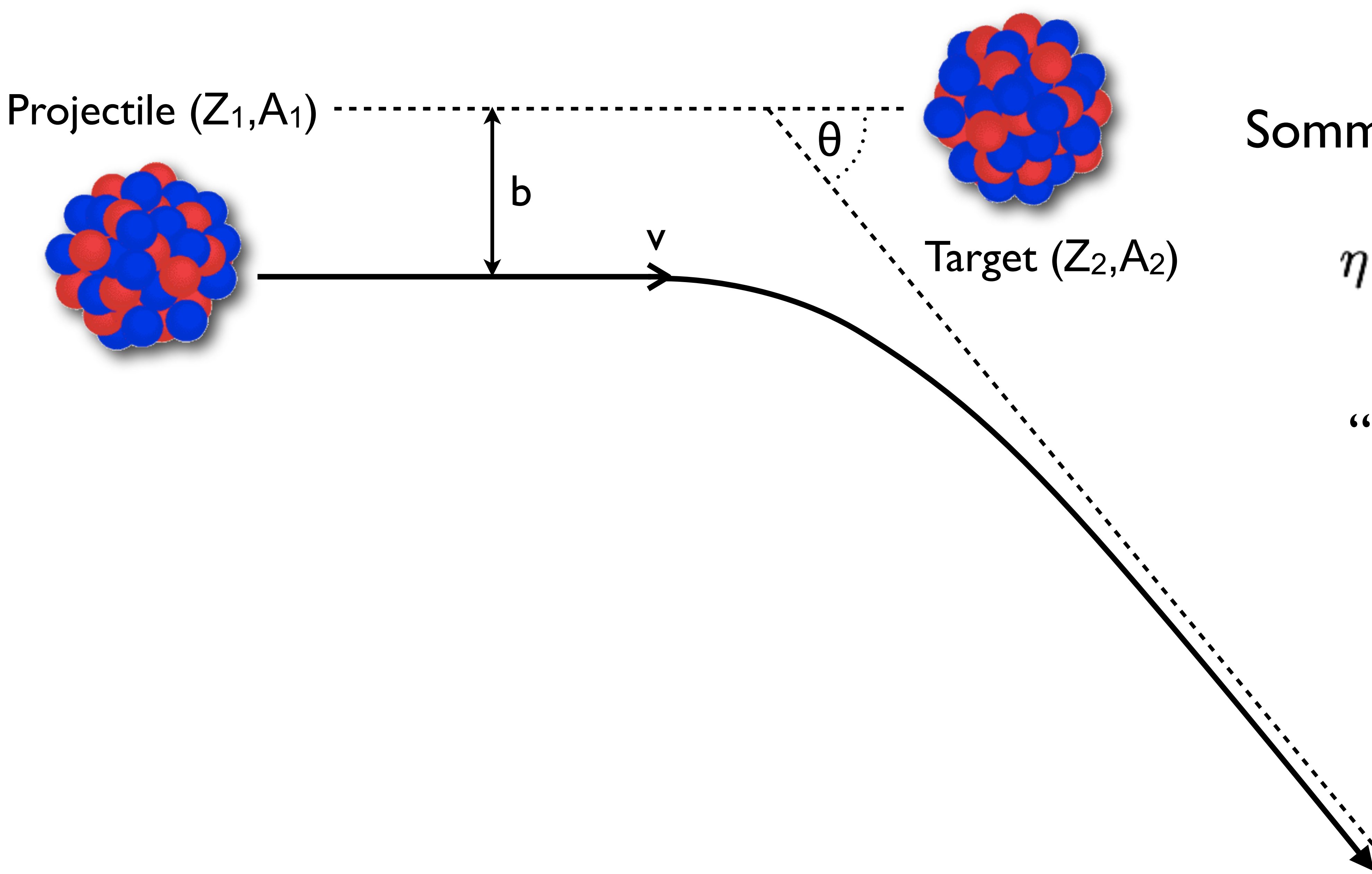
- Particle ID in a Double-Sided Si Strip Detector.
- Event by event Doppler correction.
- $17^{\circ} < \theta_{lab} < 54^{\circ}$





- Array of HPGe of 8 triple clusters
- 6-fold segmentation for positioning
- $\varepsilon > 7\%$ for 1.3MeV γ-rays

Coulomb Excitation



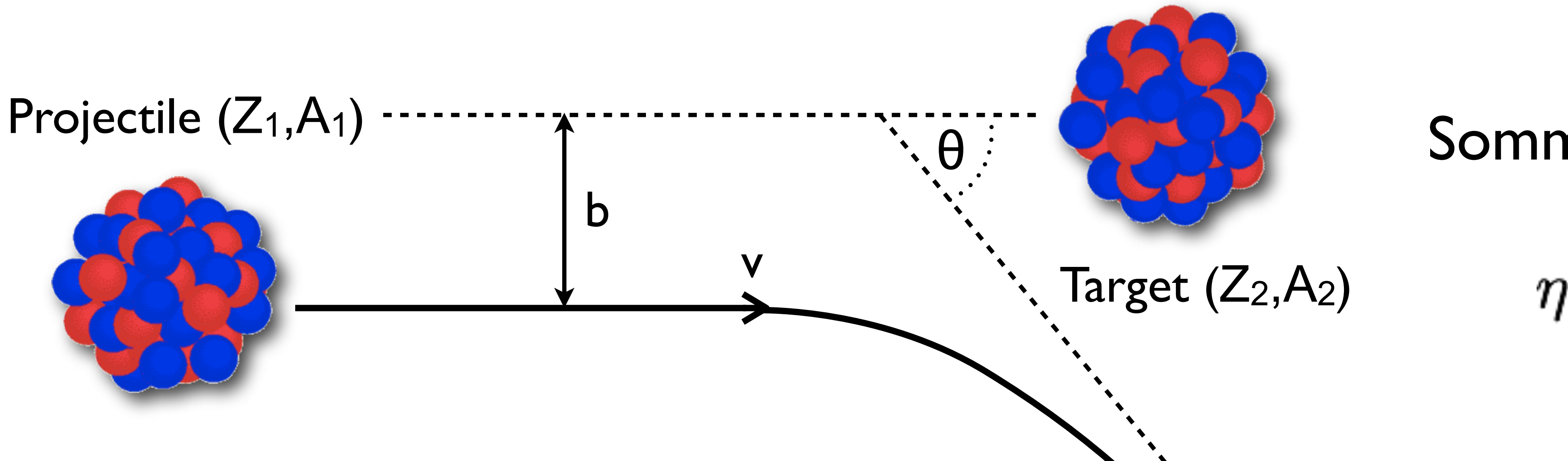
Sommerfeld parameter:

$$\eta = \frac{Z_1 Z_2 e^2}{\hbar v}$$

"Safe" Coulex:

$$\eta \gg 1$$

Coulomb Excitation



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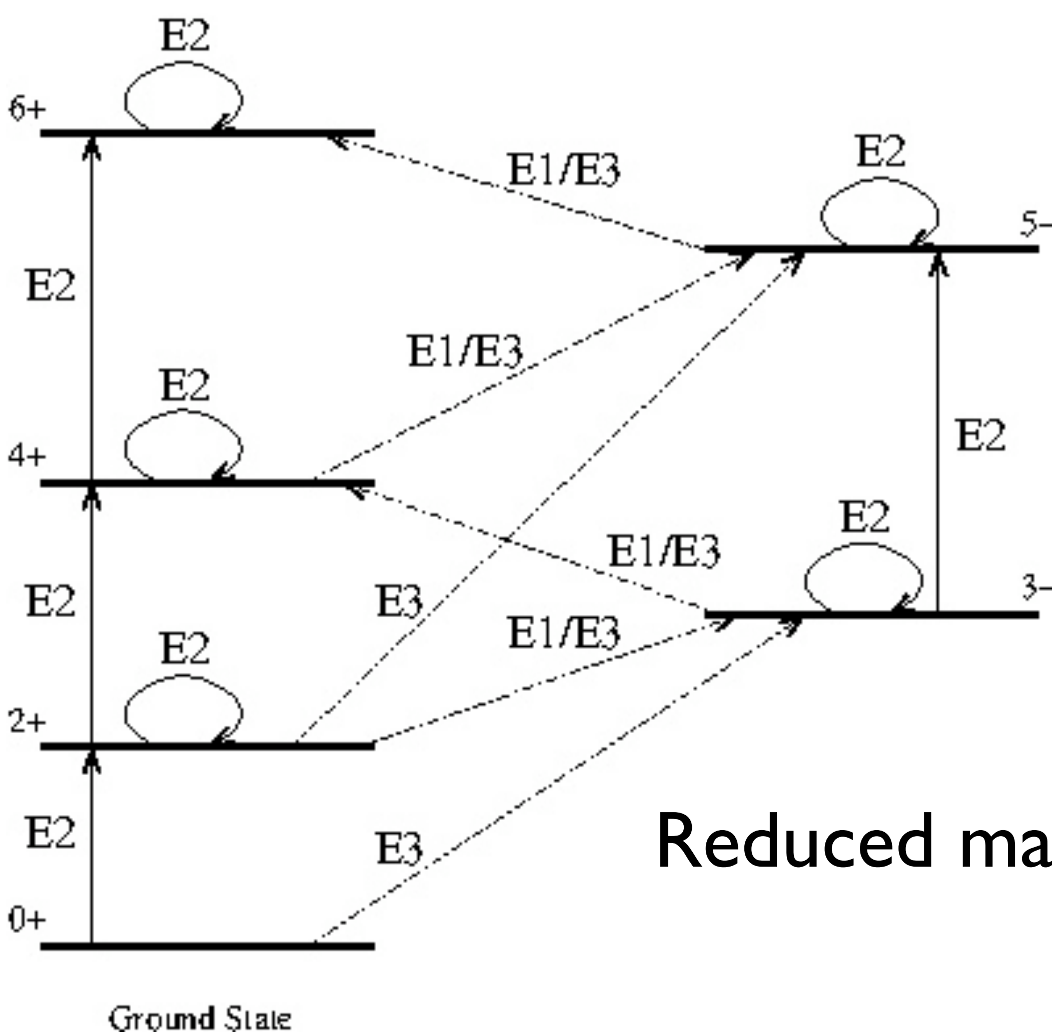

Reduced matrix elements: $< 0^+||E2||2^+ >$

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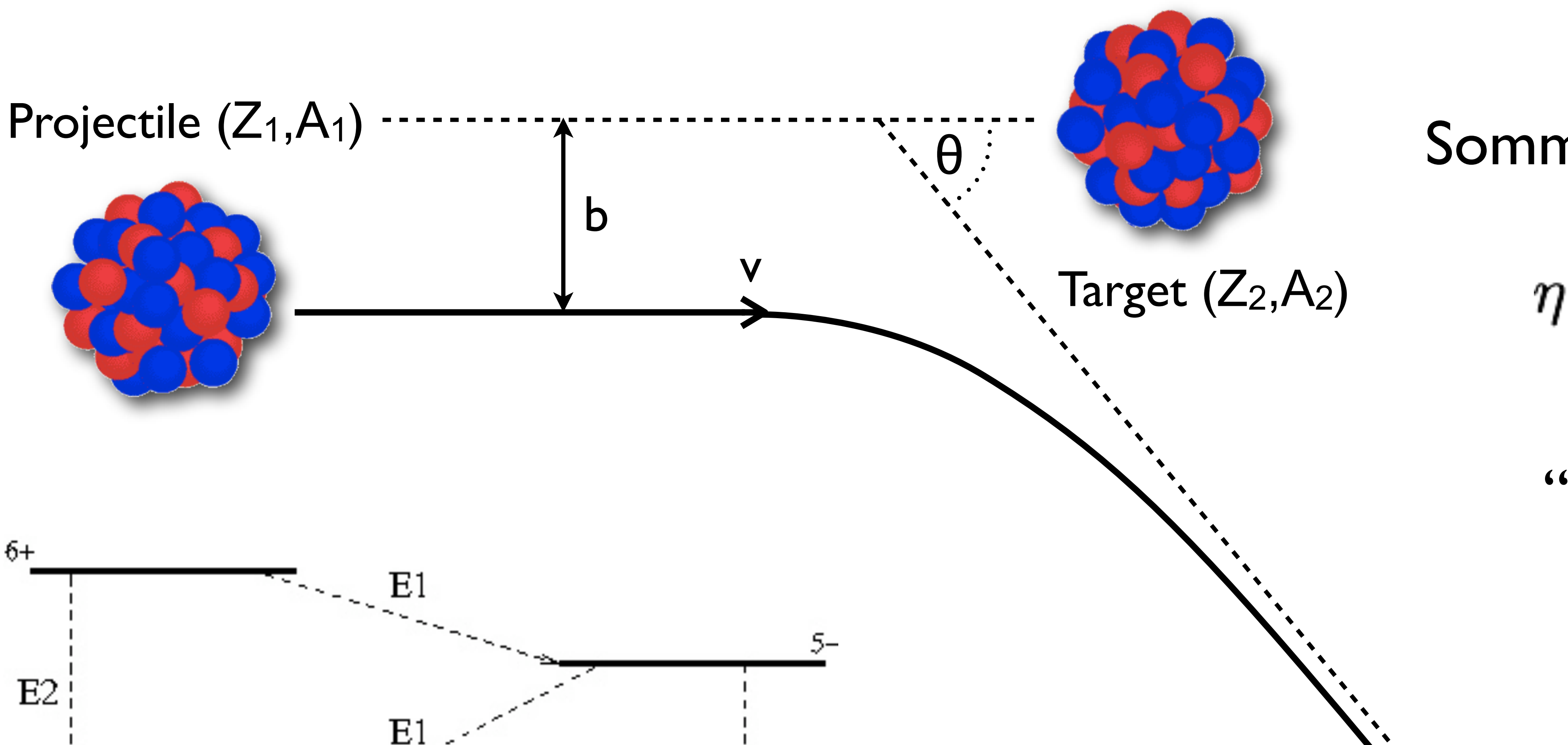

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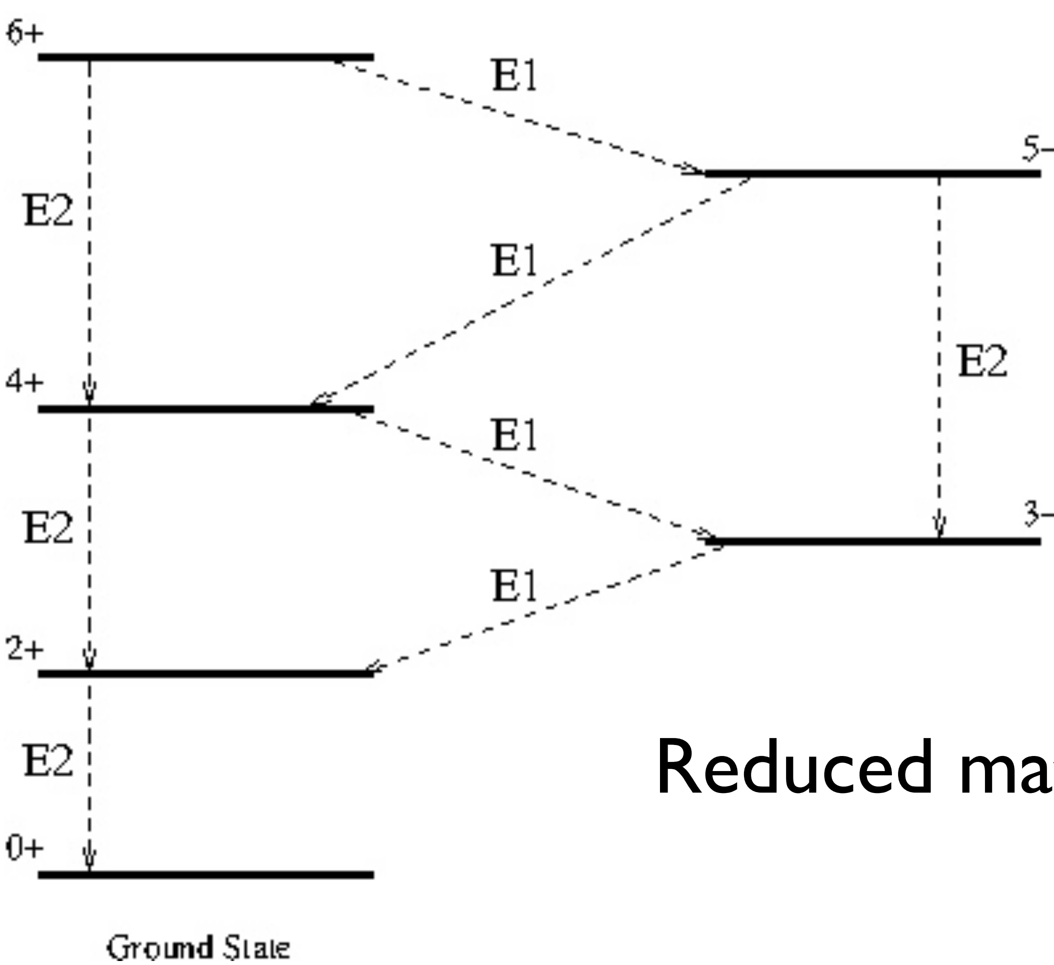


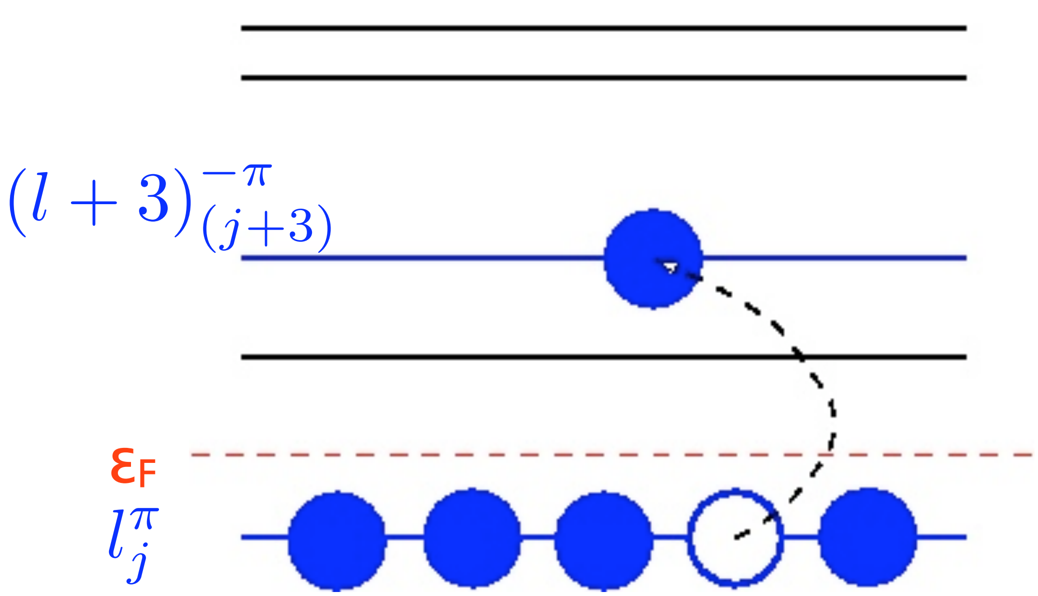
Reduced matrix elements: $< 0^+||E2||2^+ >$

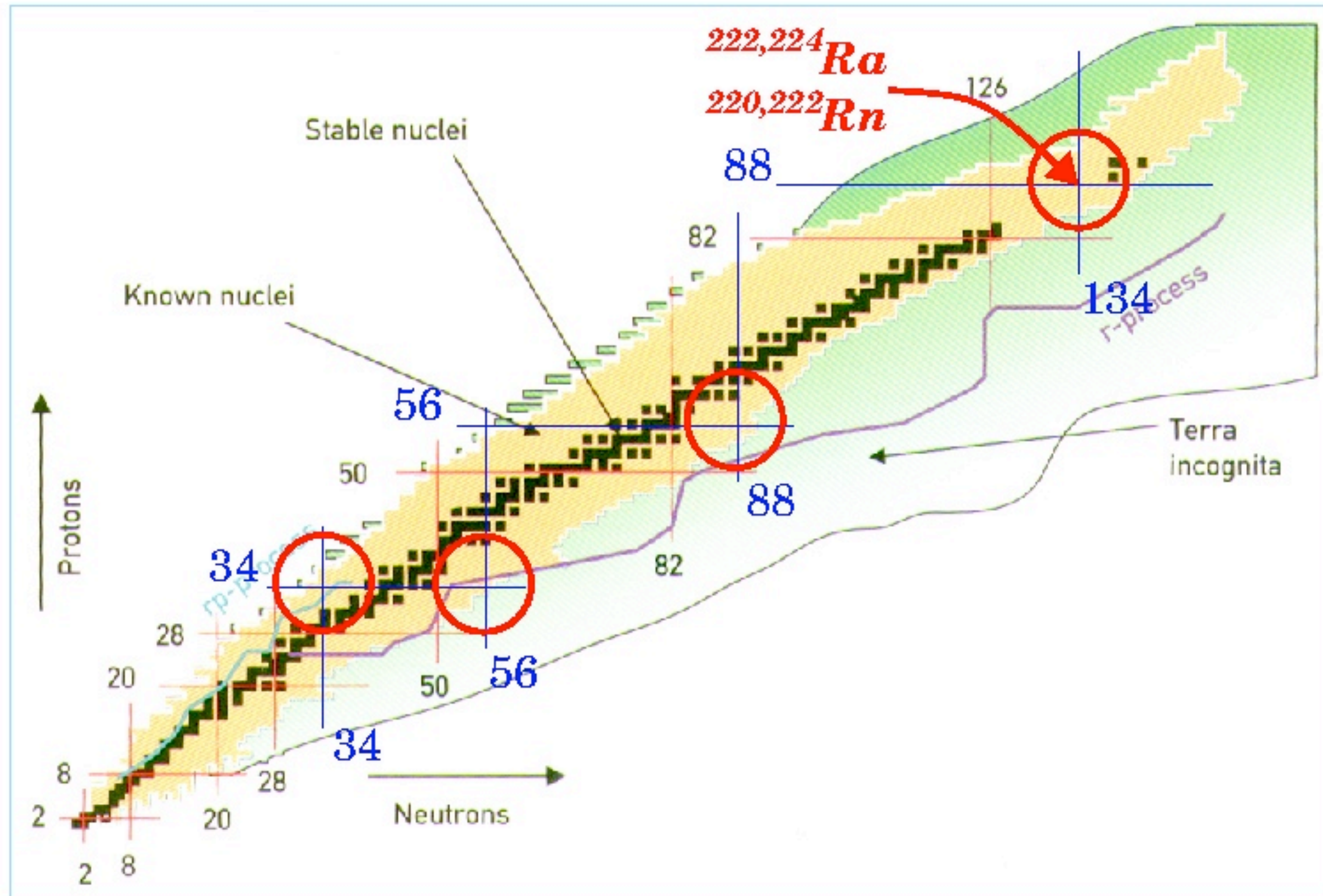
Octupole Collectivity

Octupole correlations enhanced at the magic numbers: **34, 56, 88, 134**

Microscopically...

Intruder orbitals of opposite parity and **ΔJ, ΔL = 3** close to the Fermi level





^{220,222}Rn and ^{222,224}Ra lie near Z=88, N=134

$$\pi\left(f_{7/2} \rightarrow i_{13/2}\right) \quad \nu\left(g_{9/2} \rightarrow j_{15/2}\right)$$

Octupole Collectivity

Macroscopically...

Nuclei take on a "pear" shape

Reflection asymmetric

- β_3-vibration
- β_2-deformation + β_3-softness
- β_2-deformation + β_3-deformation
- Static β_3-deformation?

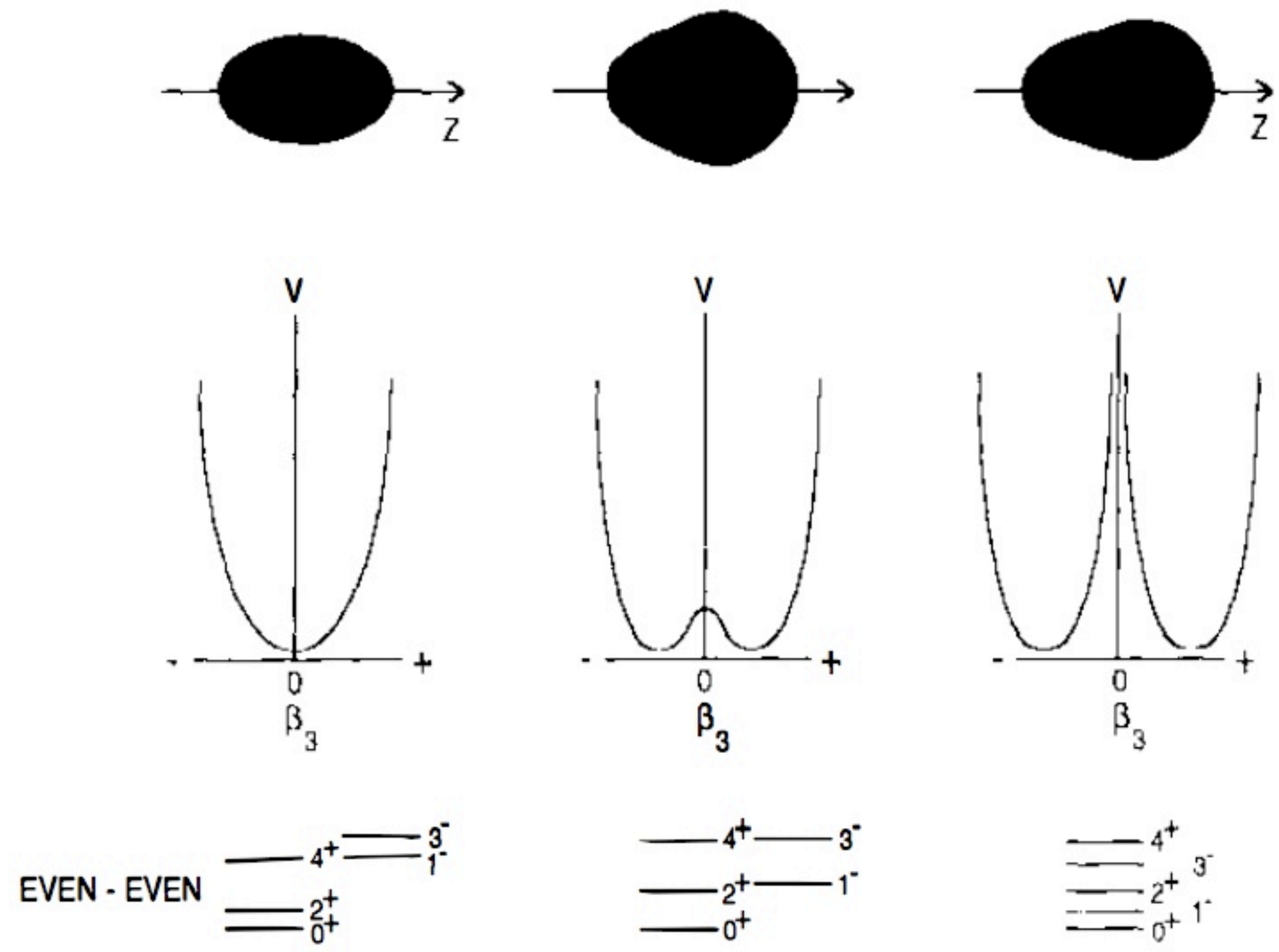


Image: I. Ahmed and P.A. Butler, Ann. Rev. Nucl. Part. Sci (1993) **43**

2^L deformation -- β_L
L=2: Quadrupole, oblate/prolate shapes
L=3: Octupole, reflection asymmetry

Signatures...

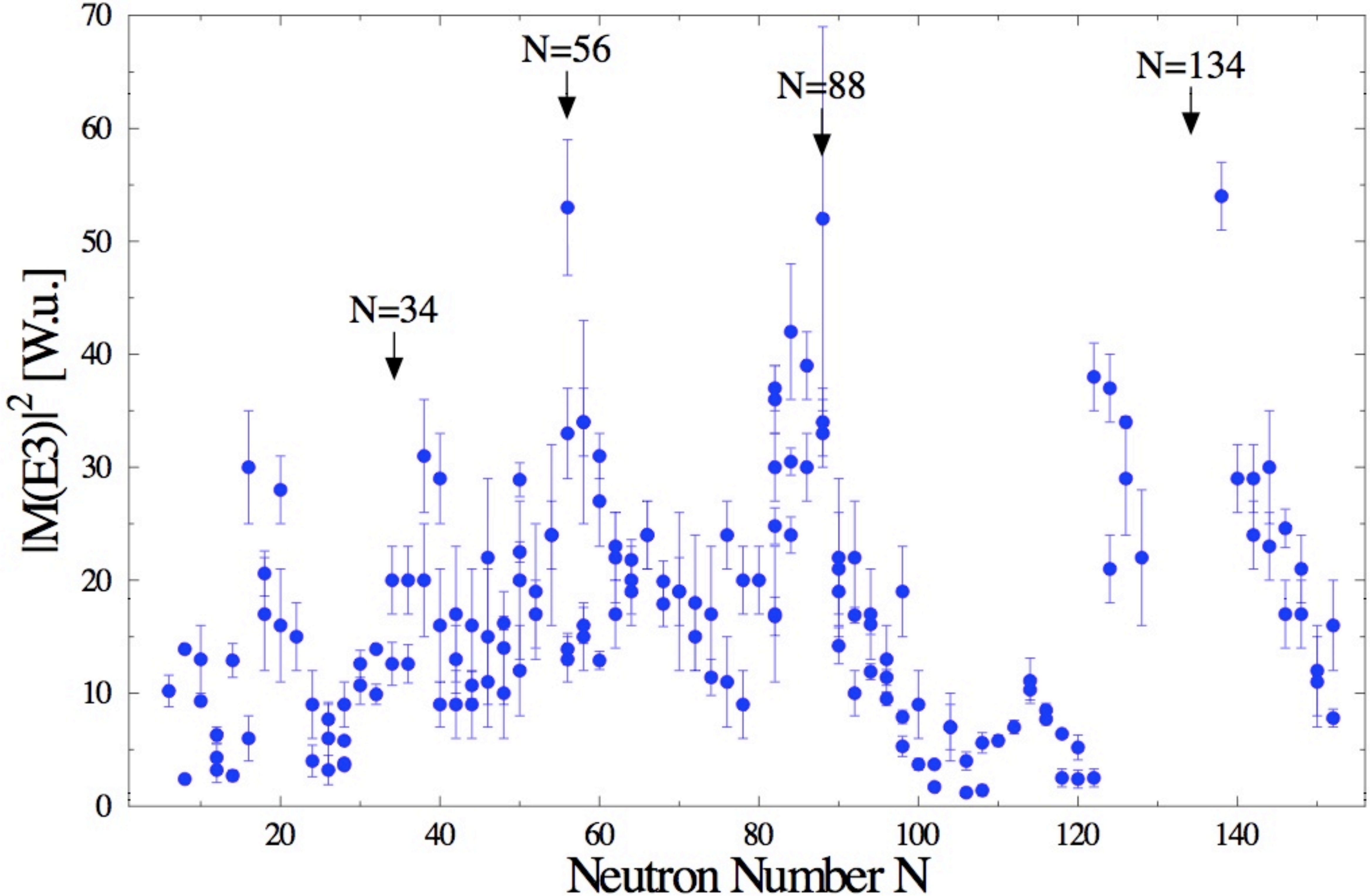
Odd-even staggering, negative parity

Parity doublets in odd-A nuclei

Enhanced E1 transitions

Large E3 strength → $B(E3; 0^+ \rightarrow 3^-)$ = $< 0^+ || E3 || 3^- >^2$

Octupole Collectivity



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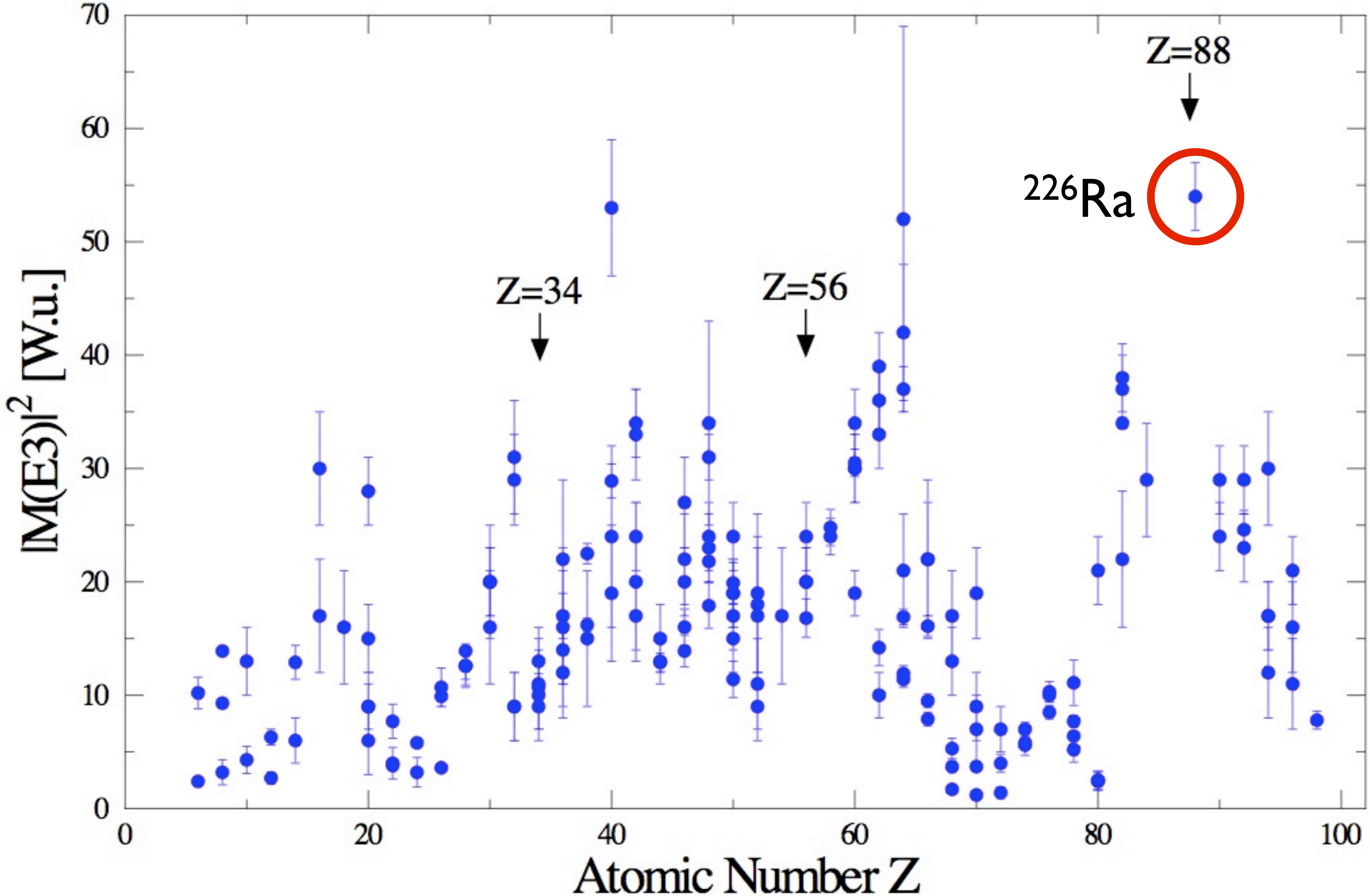
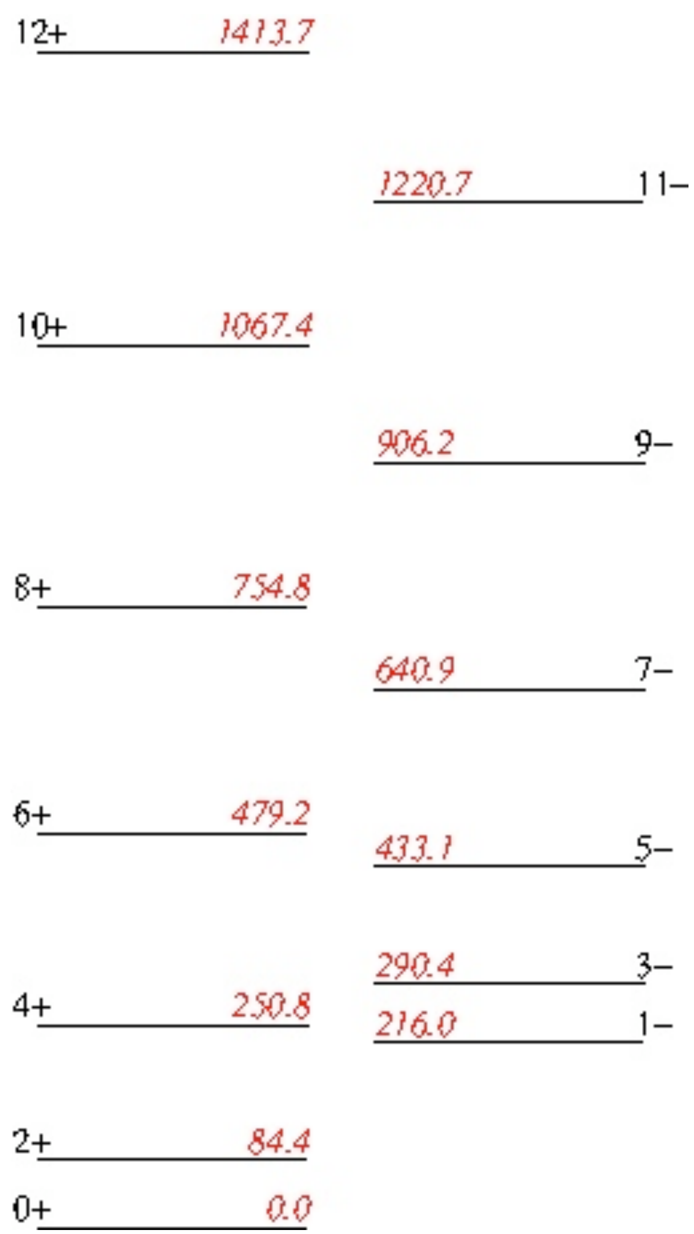


The experiment - ^{224}Ra



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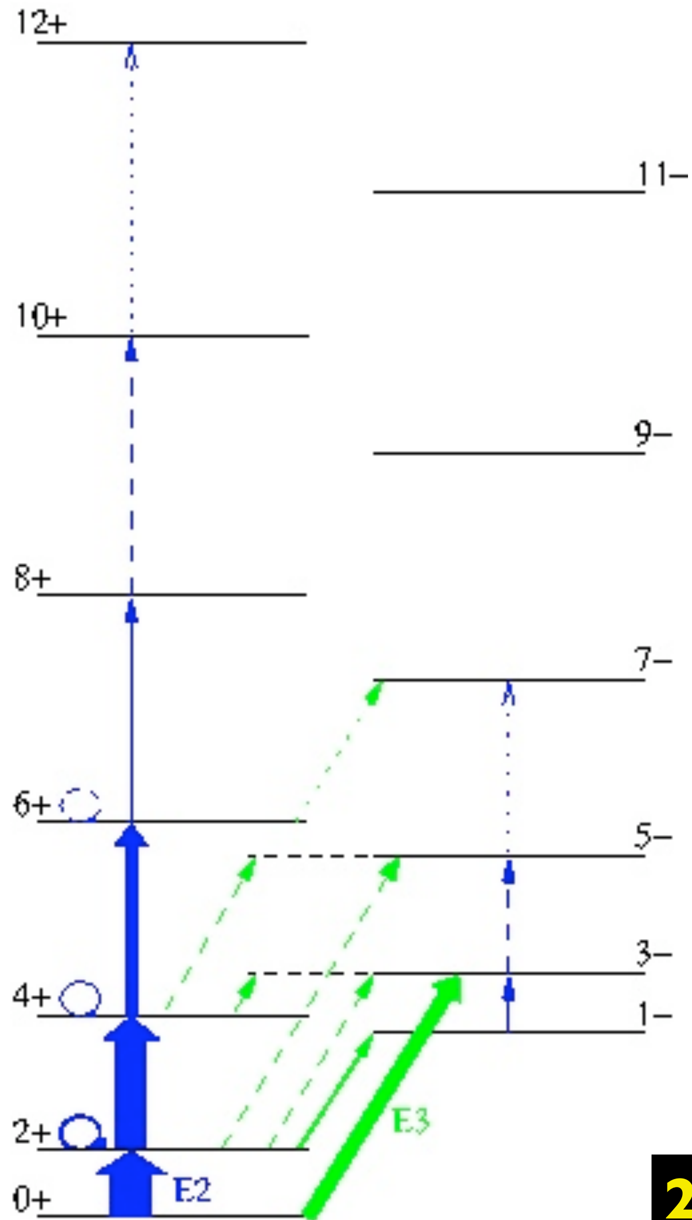

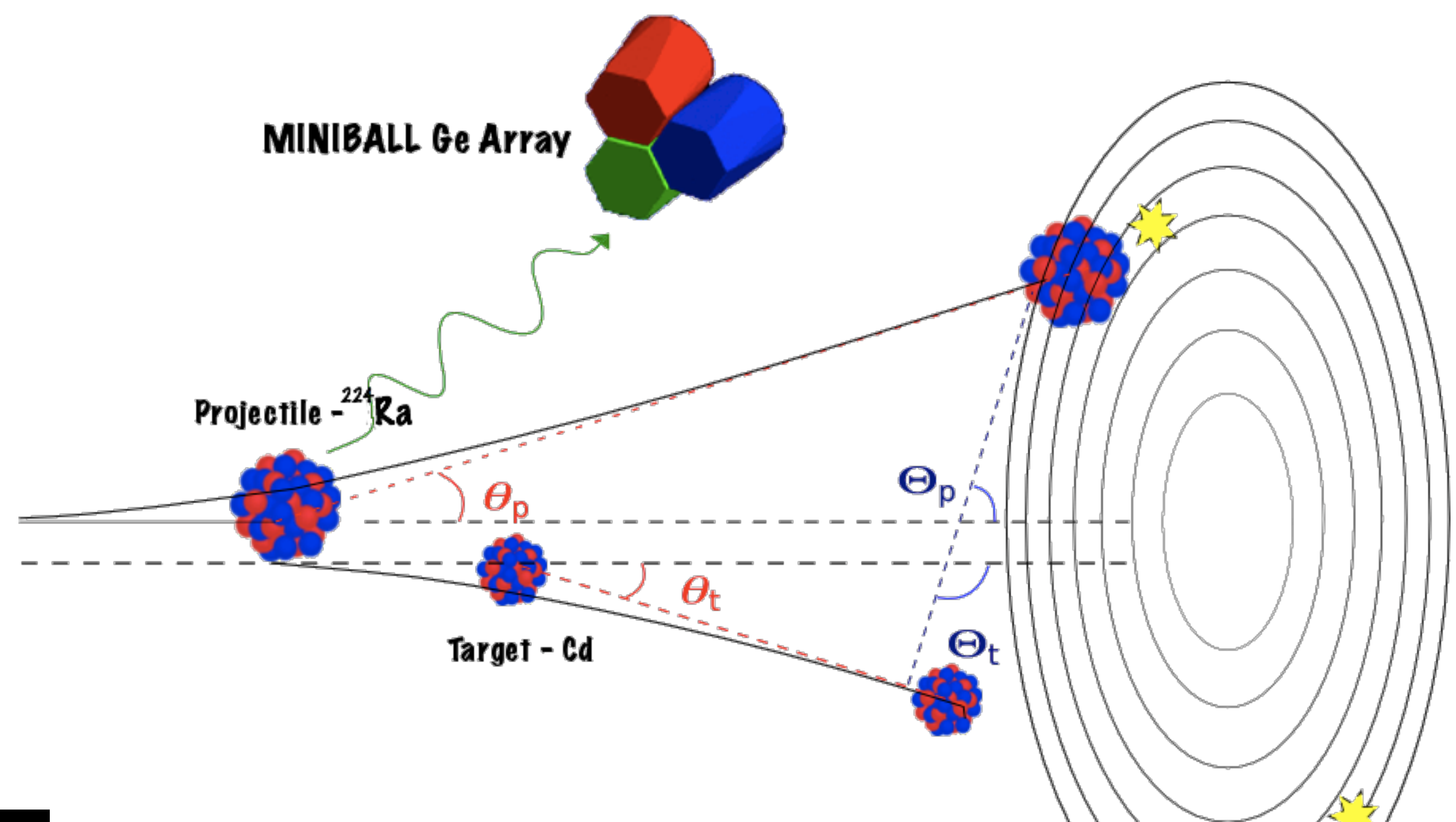

2.83 A.MeV
634MeV

2.0 mg/cm^2

^{224}Ra → ^{112}Cd / ^{120}Sn

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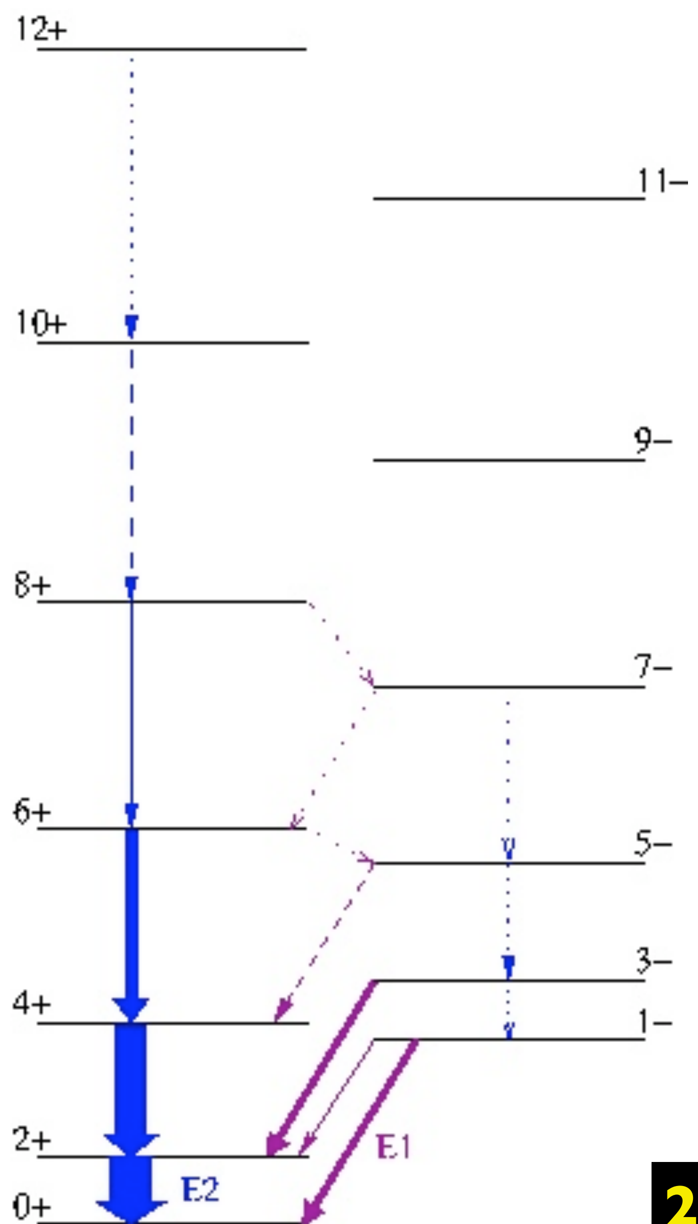

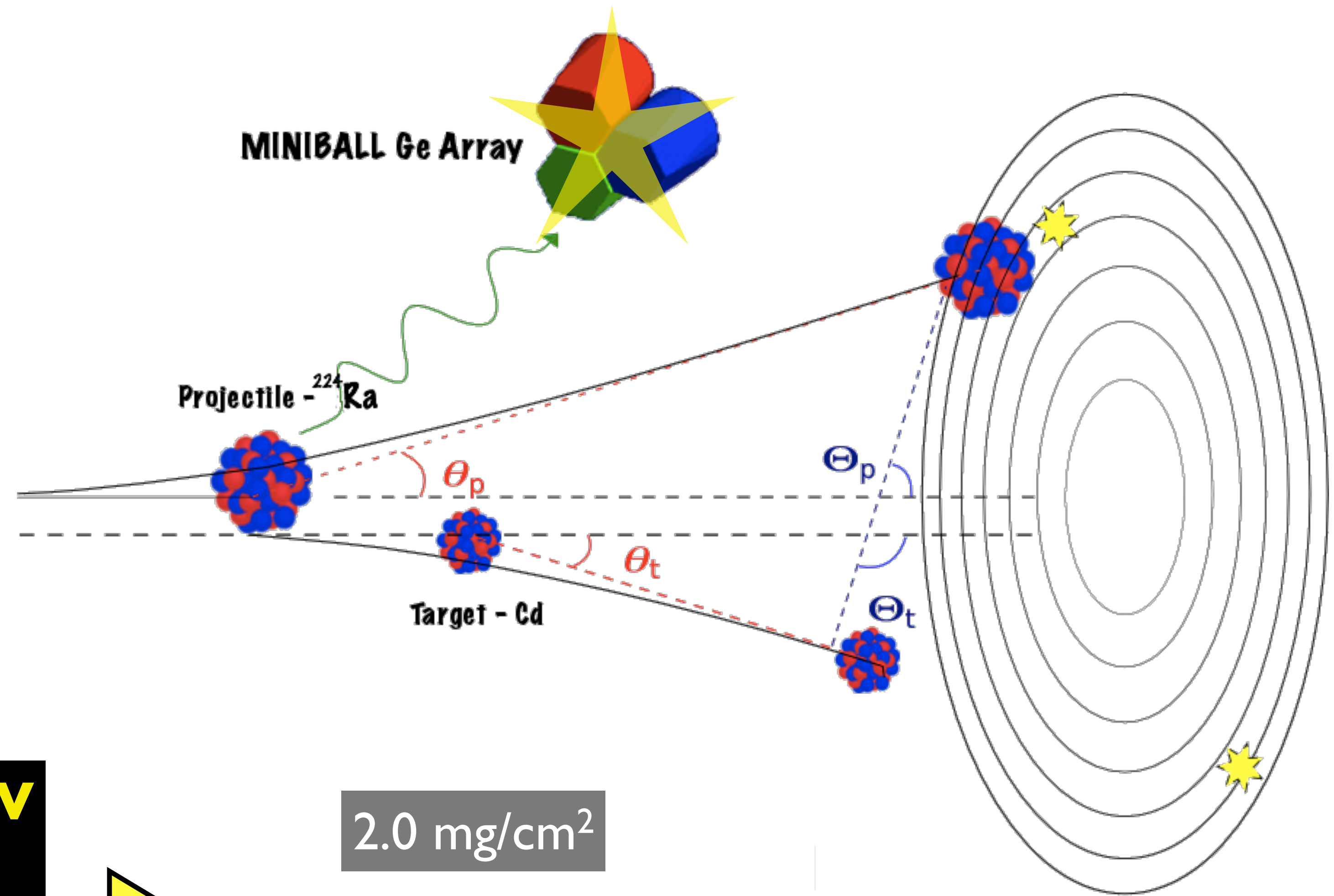

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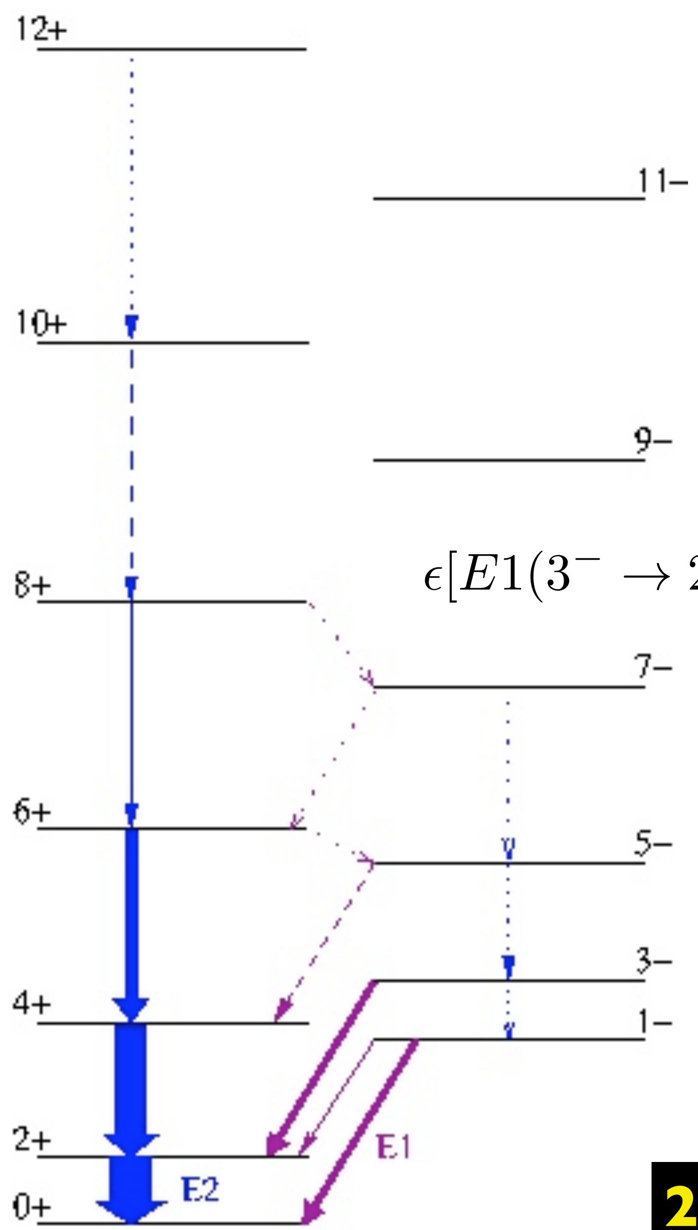
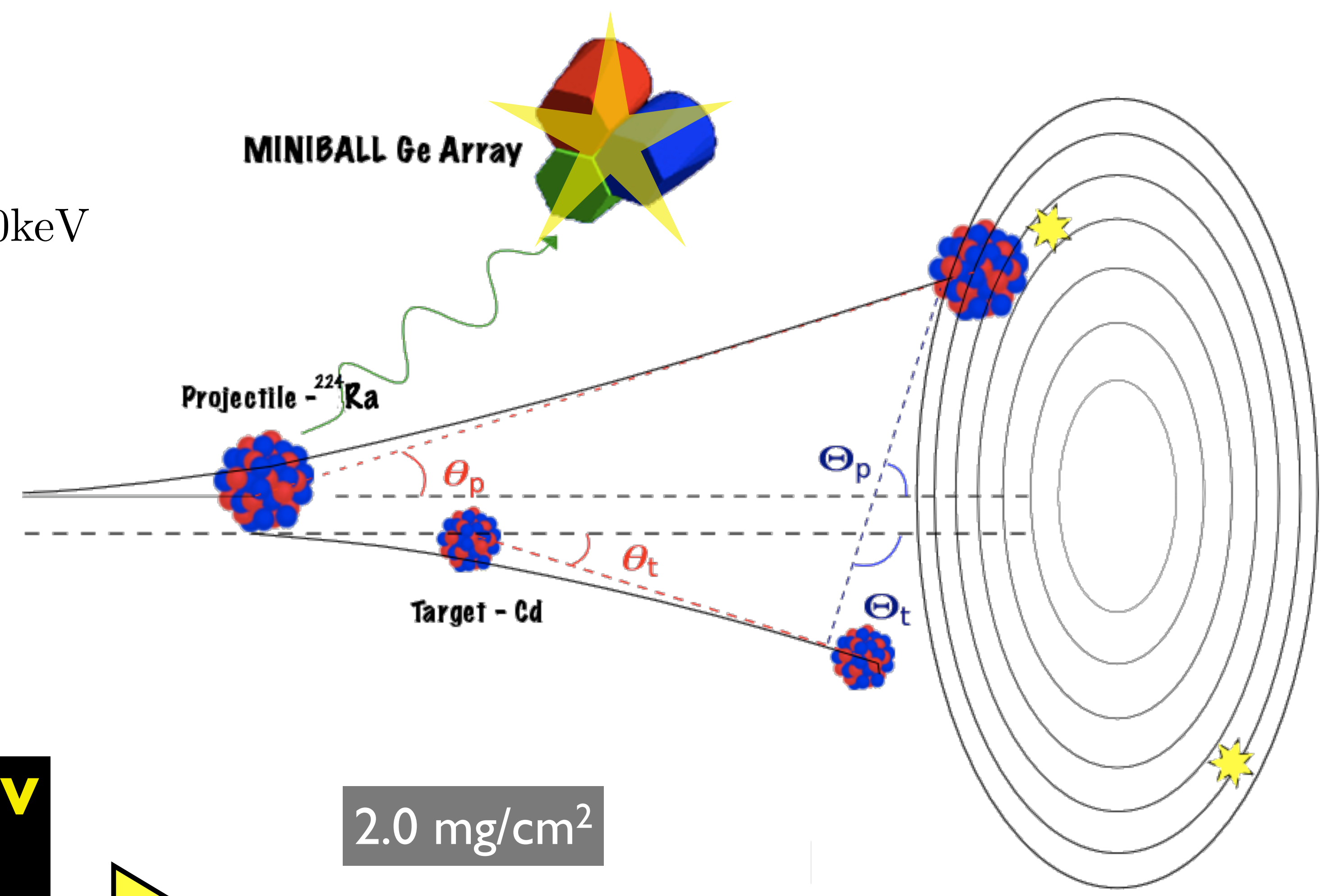
$$N[^{224}\mathrm{Ra}(3^-)] \propto Y[E1(3^- \to 2^+)]$$
$$\propto B(E3\uparrow; 0^+ \to 3^-)$$
$$\propto \beta_3$$



$$\epsilon[E1(3^- \to 2^+)] = 206.0\mathrm{keV}$$



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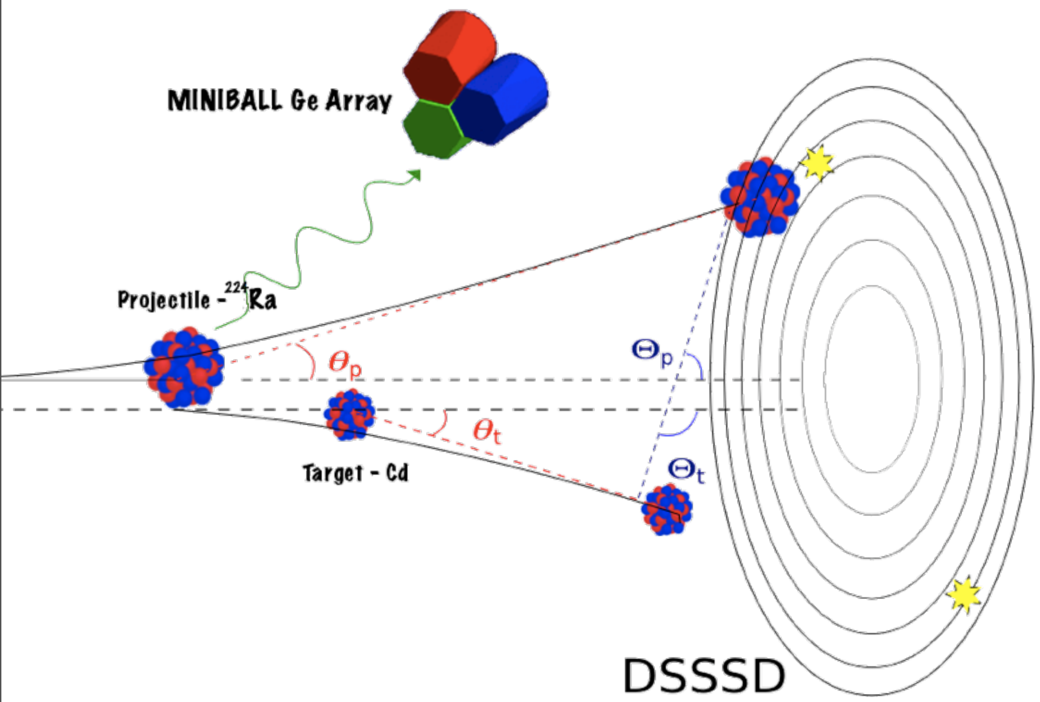

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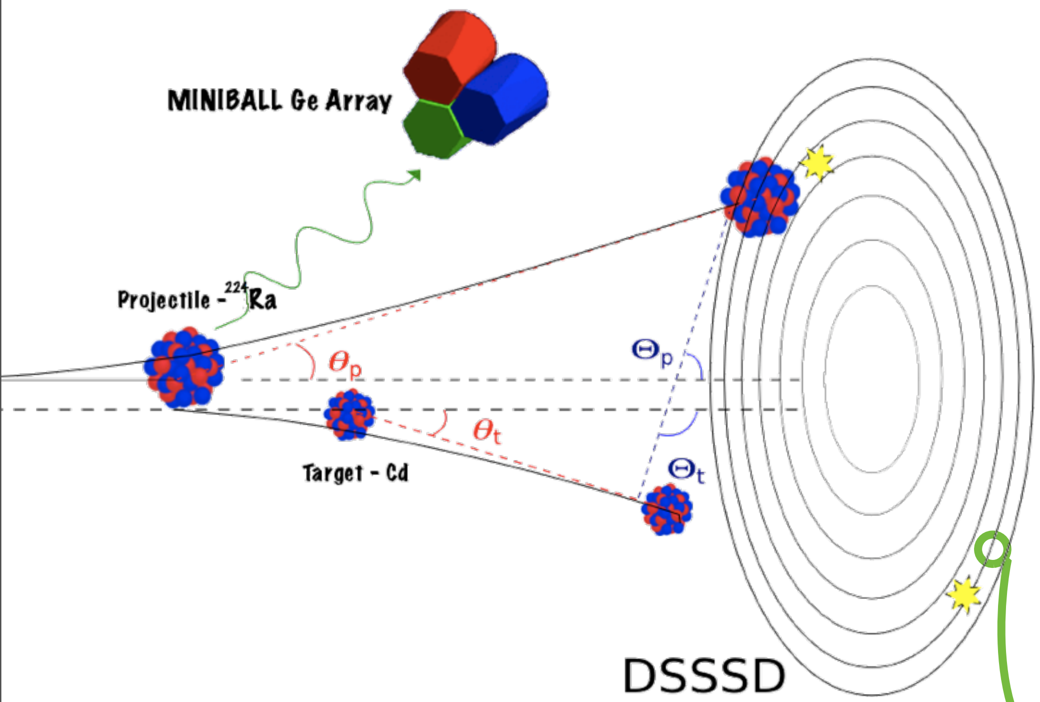

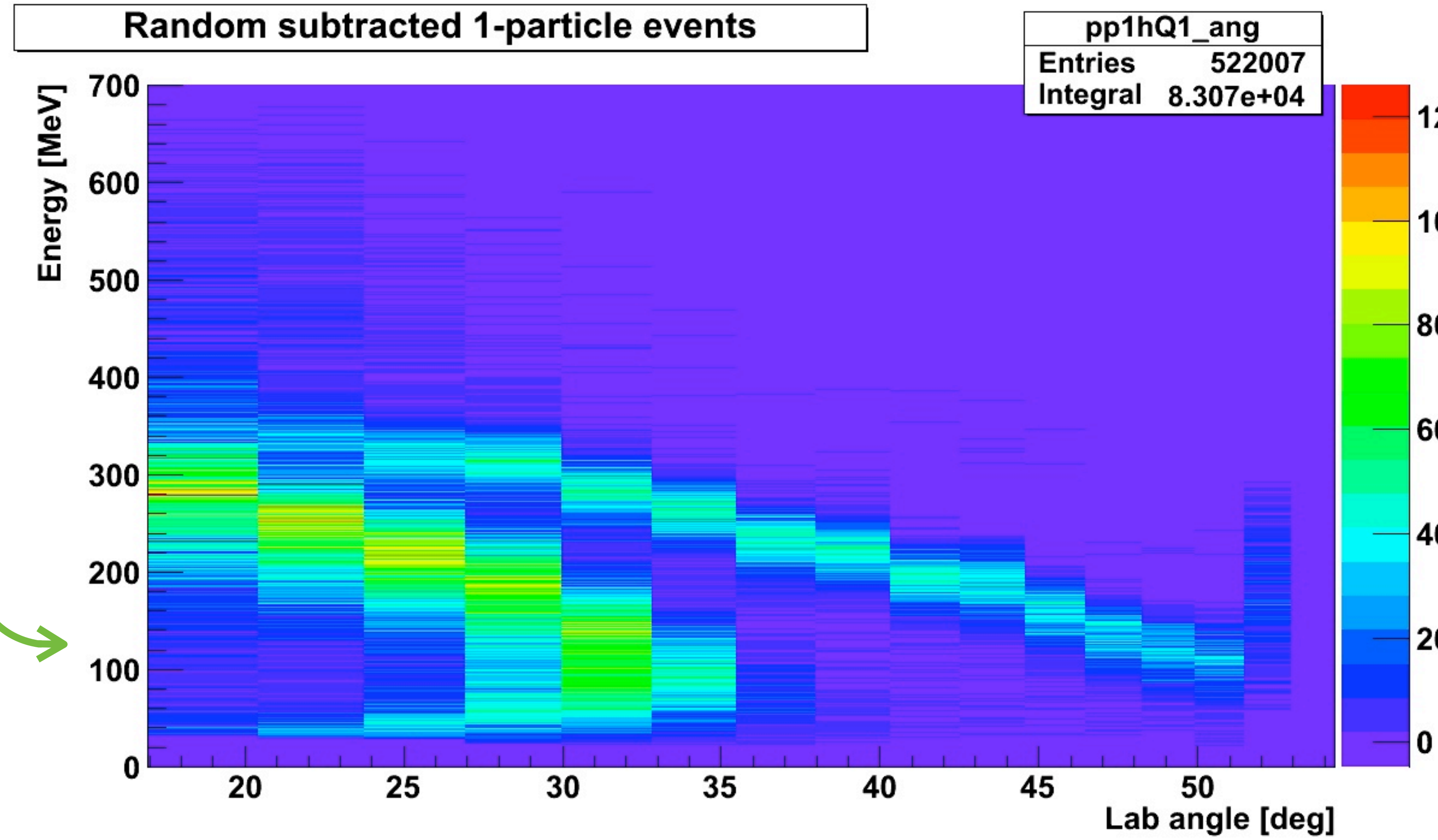

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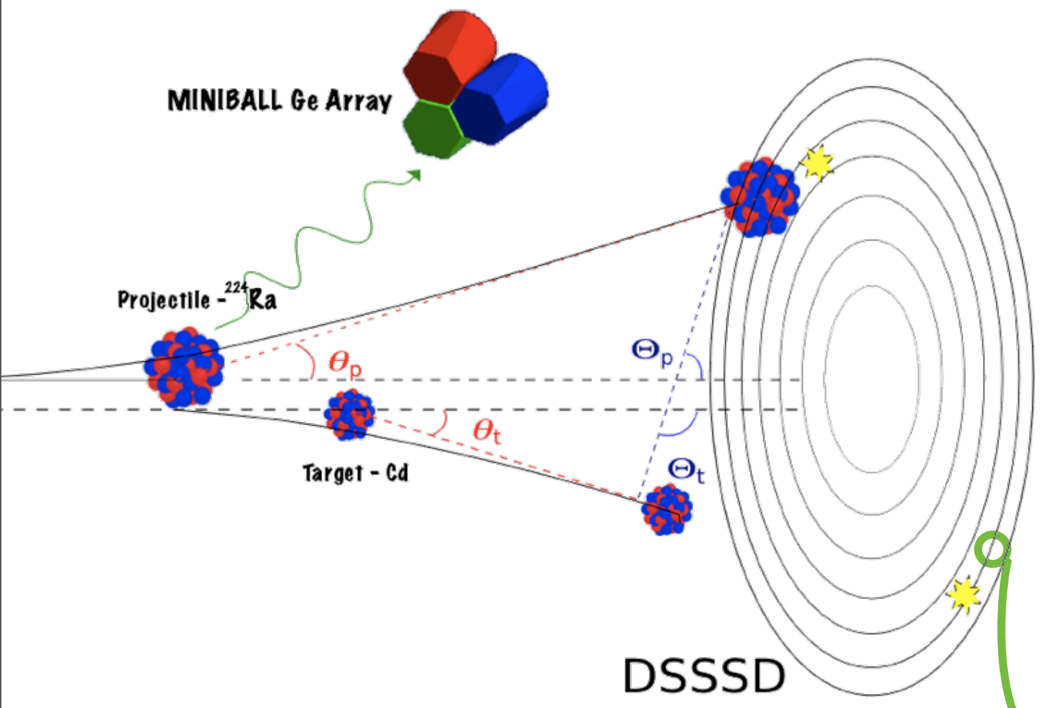

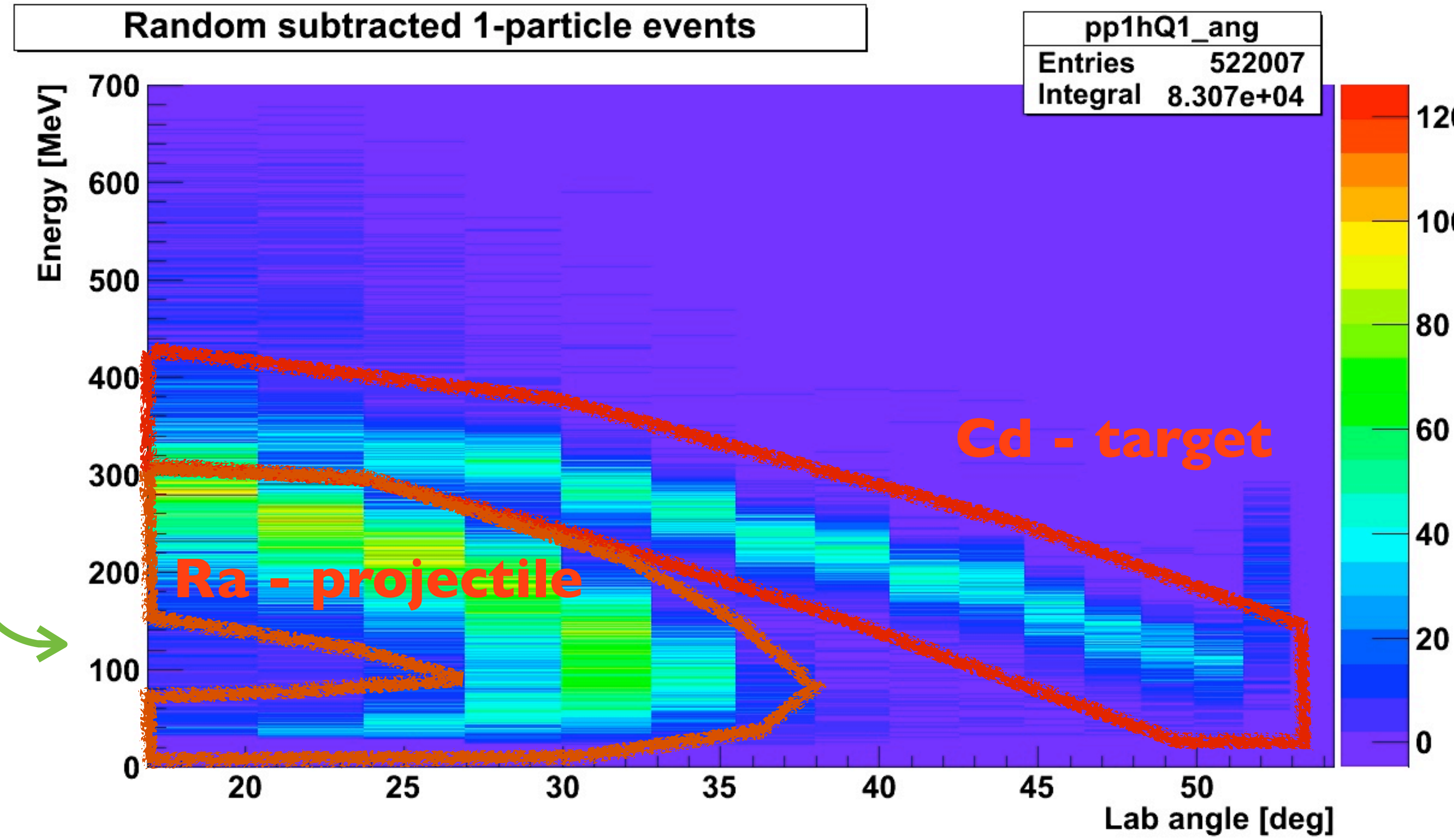

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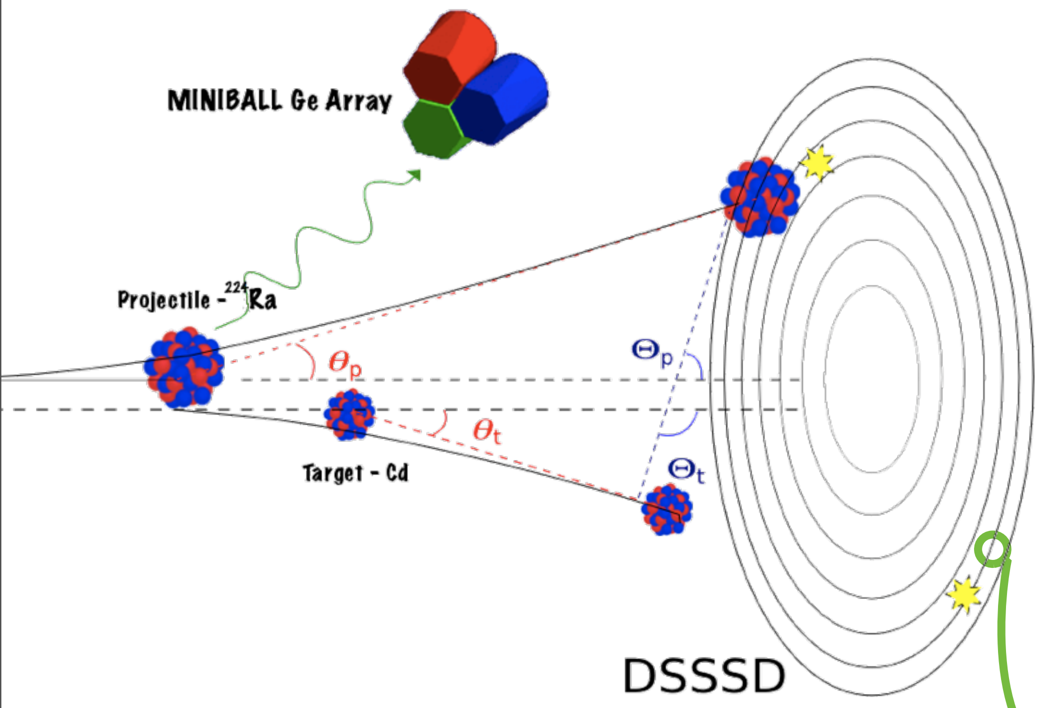

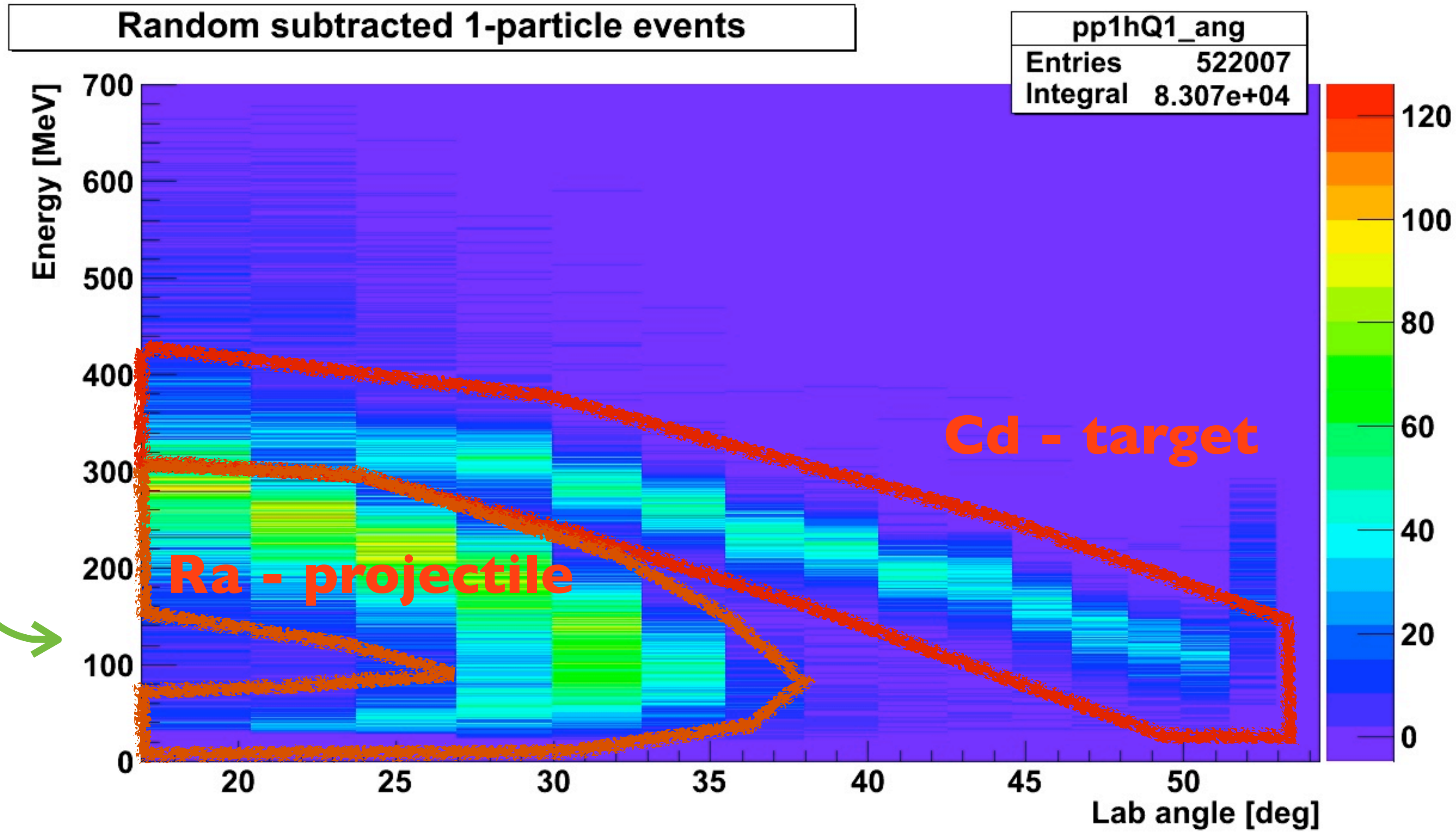

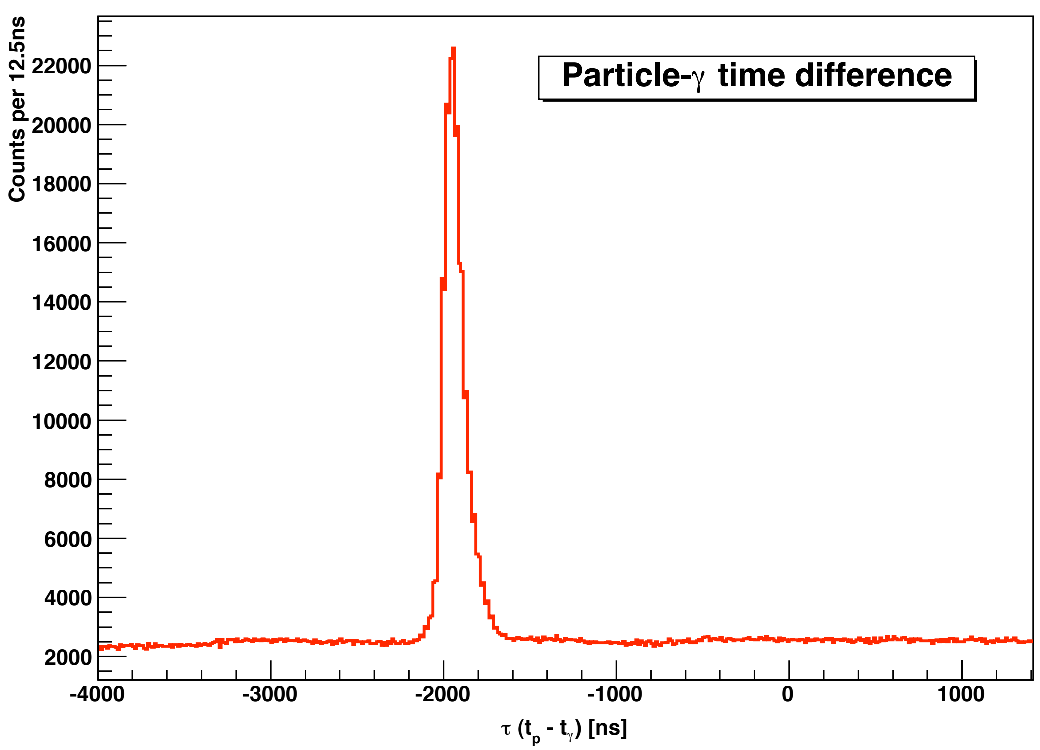

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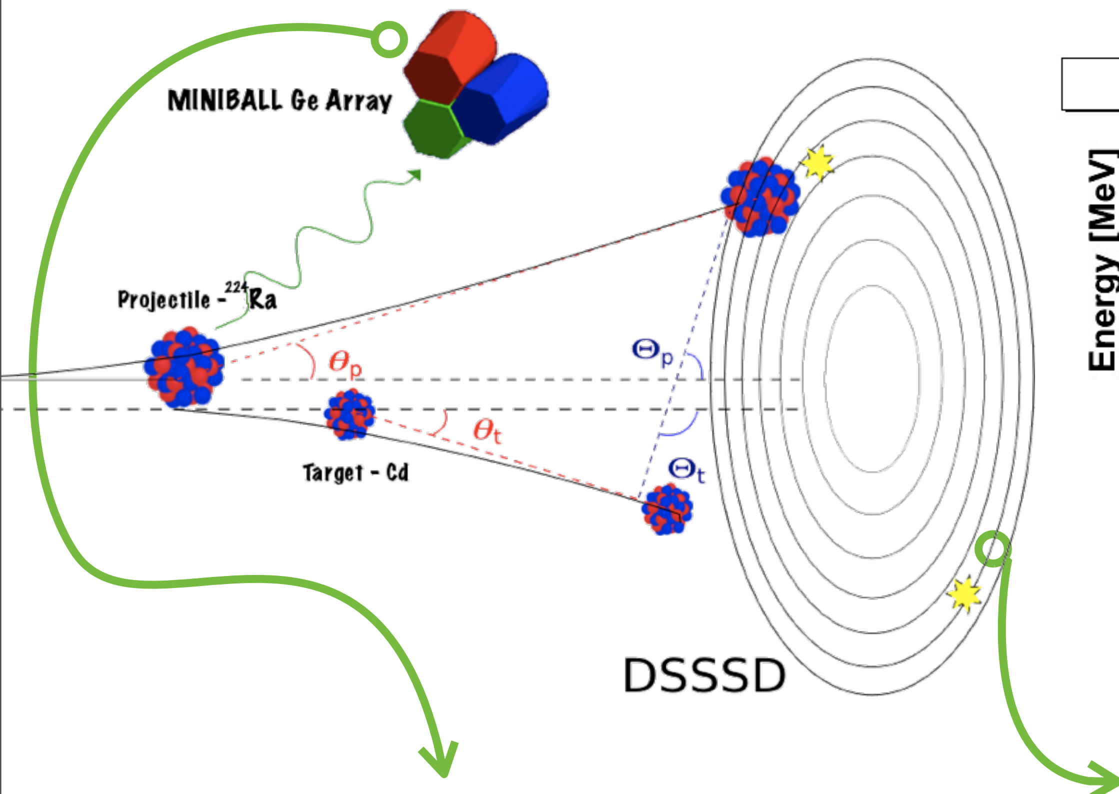

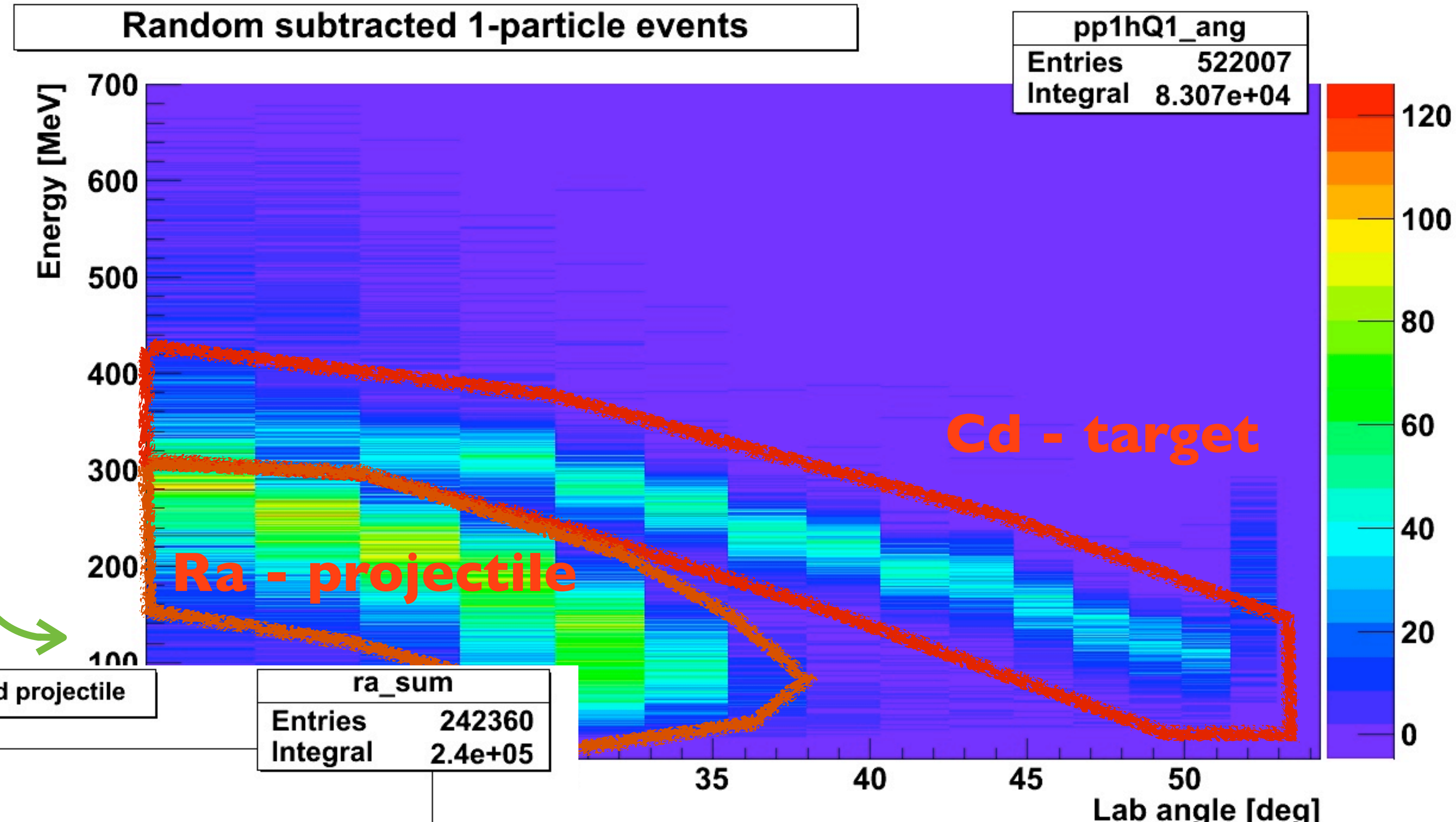

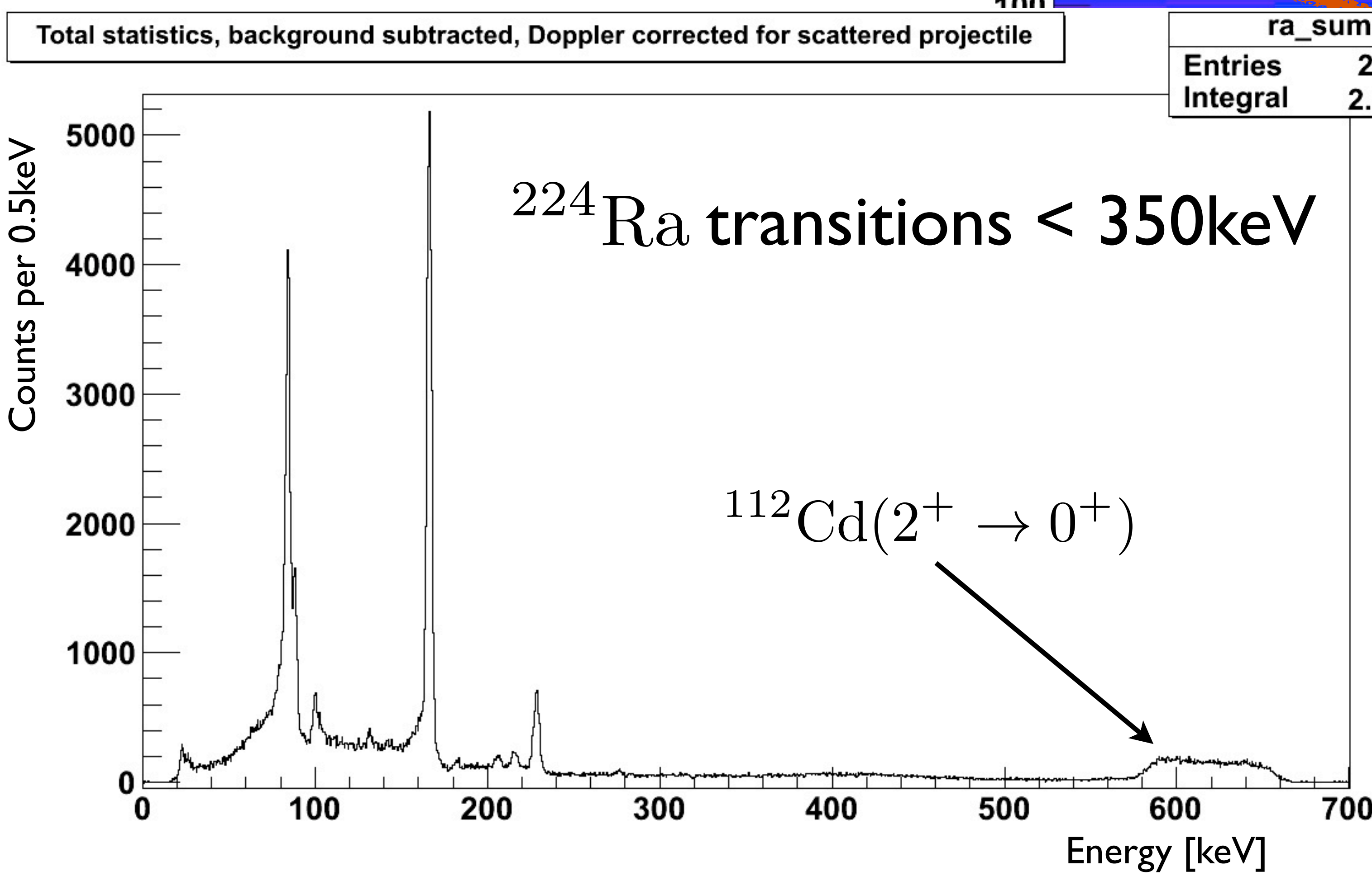

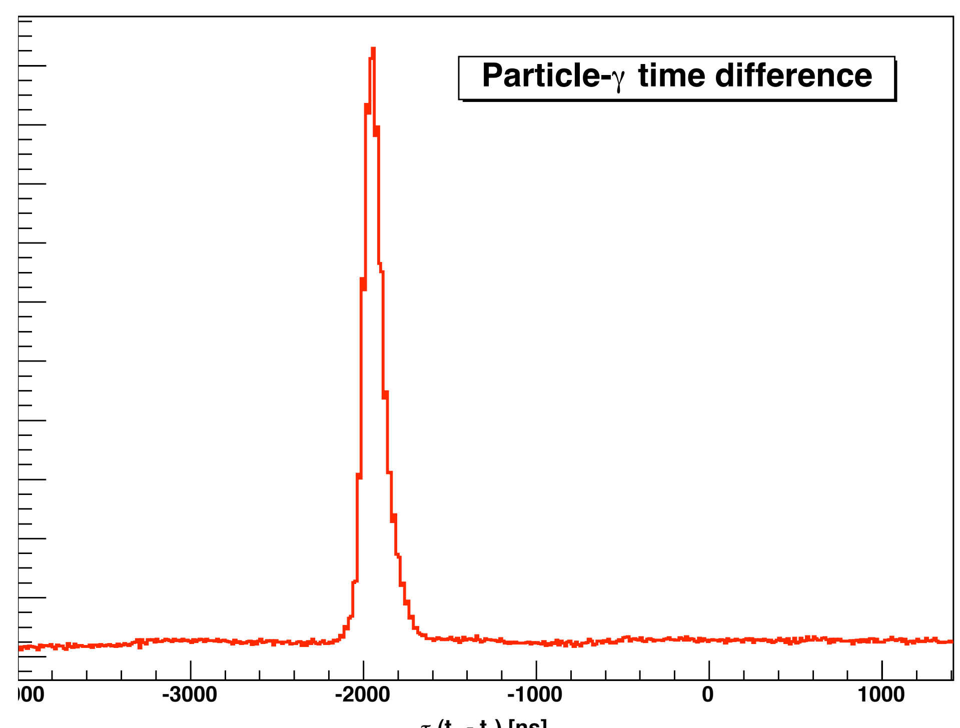

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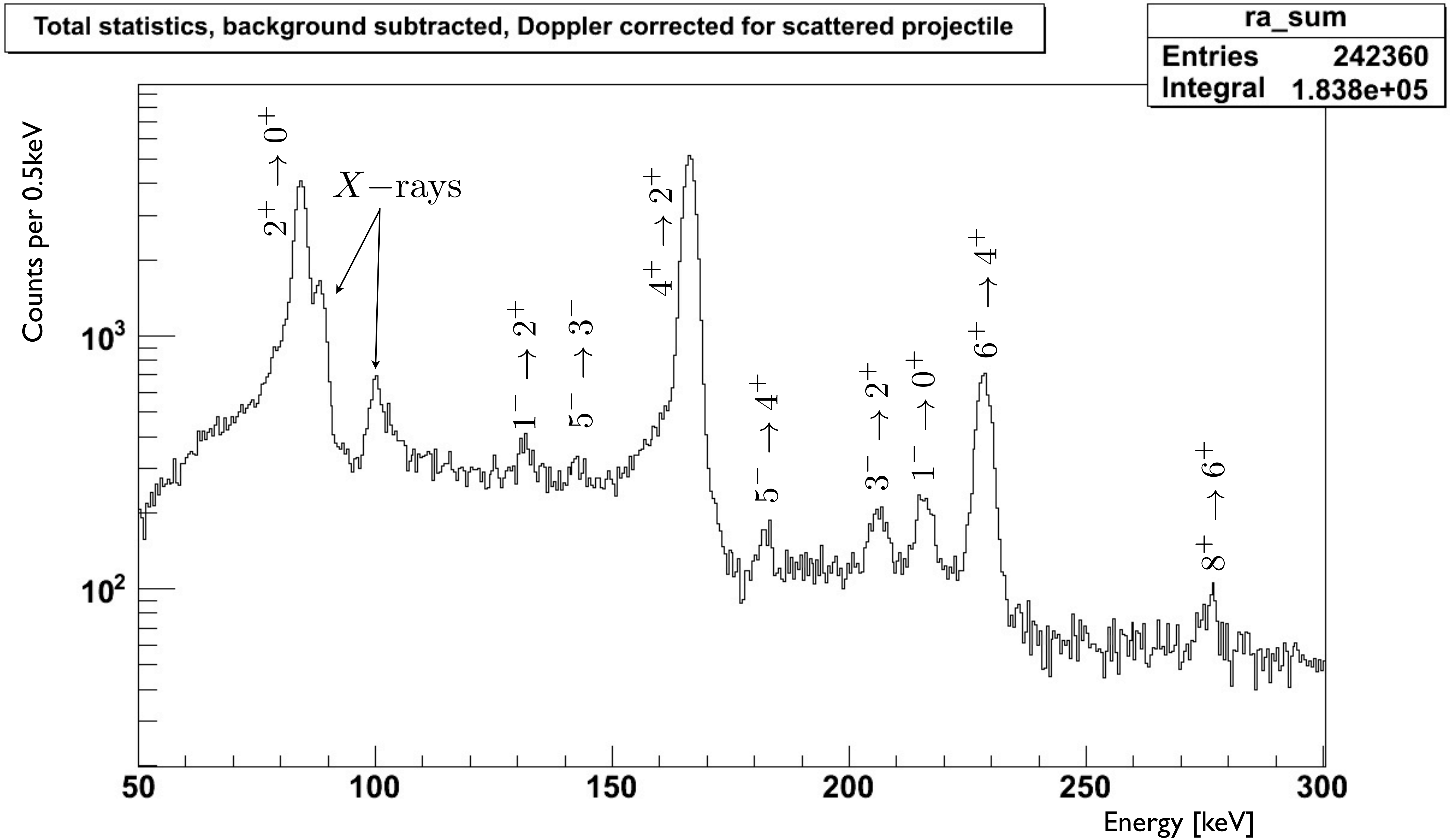

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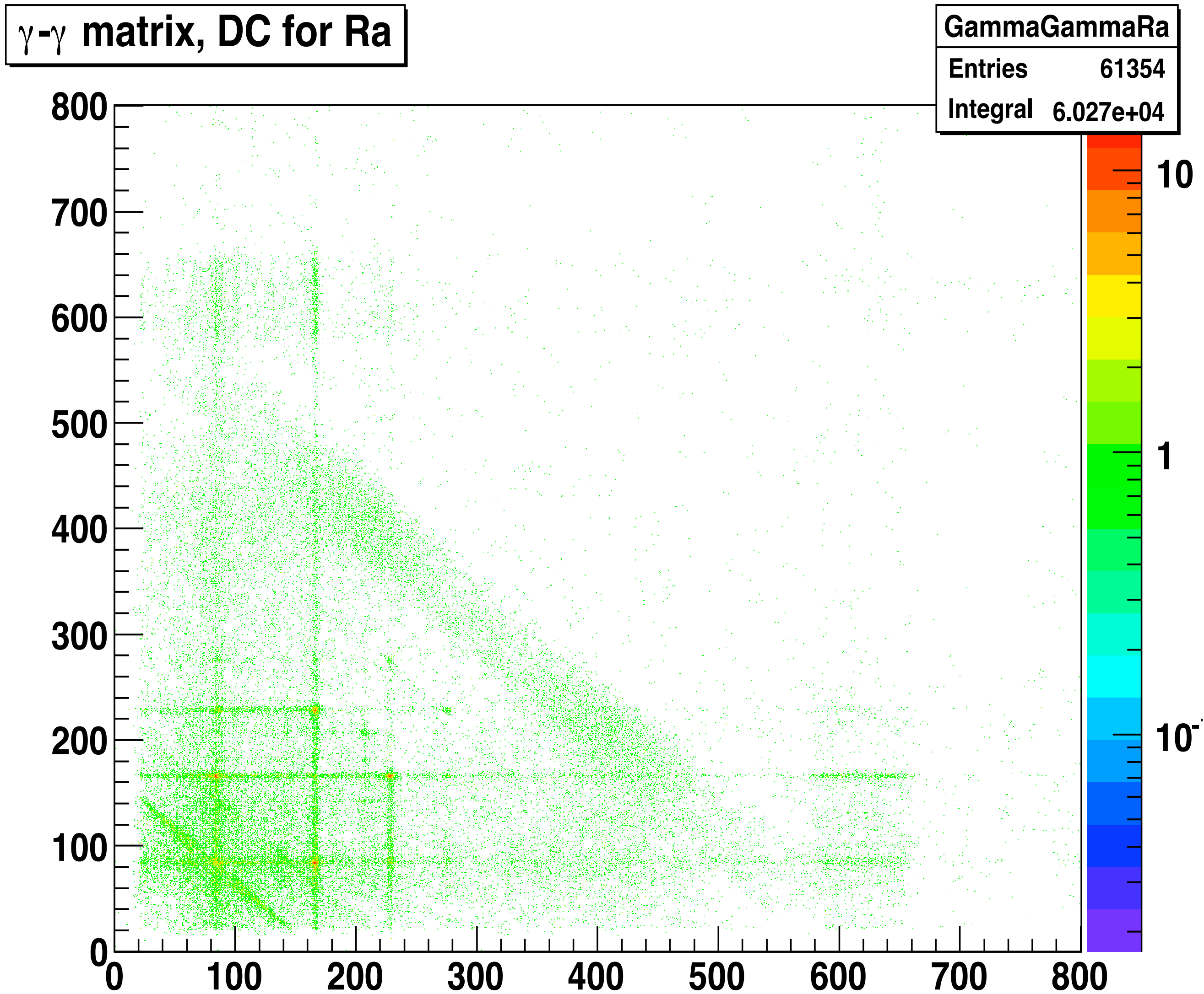

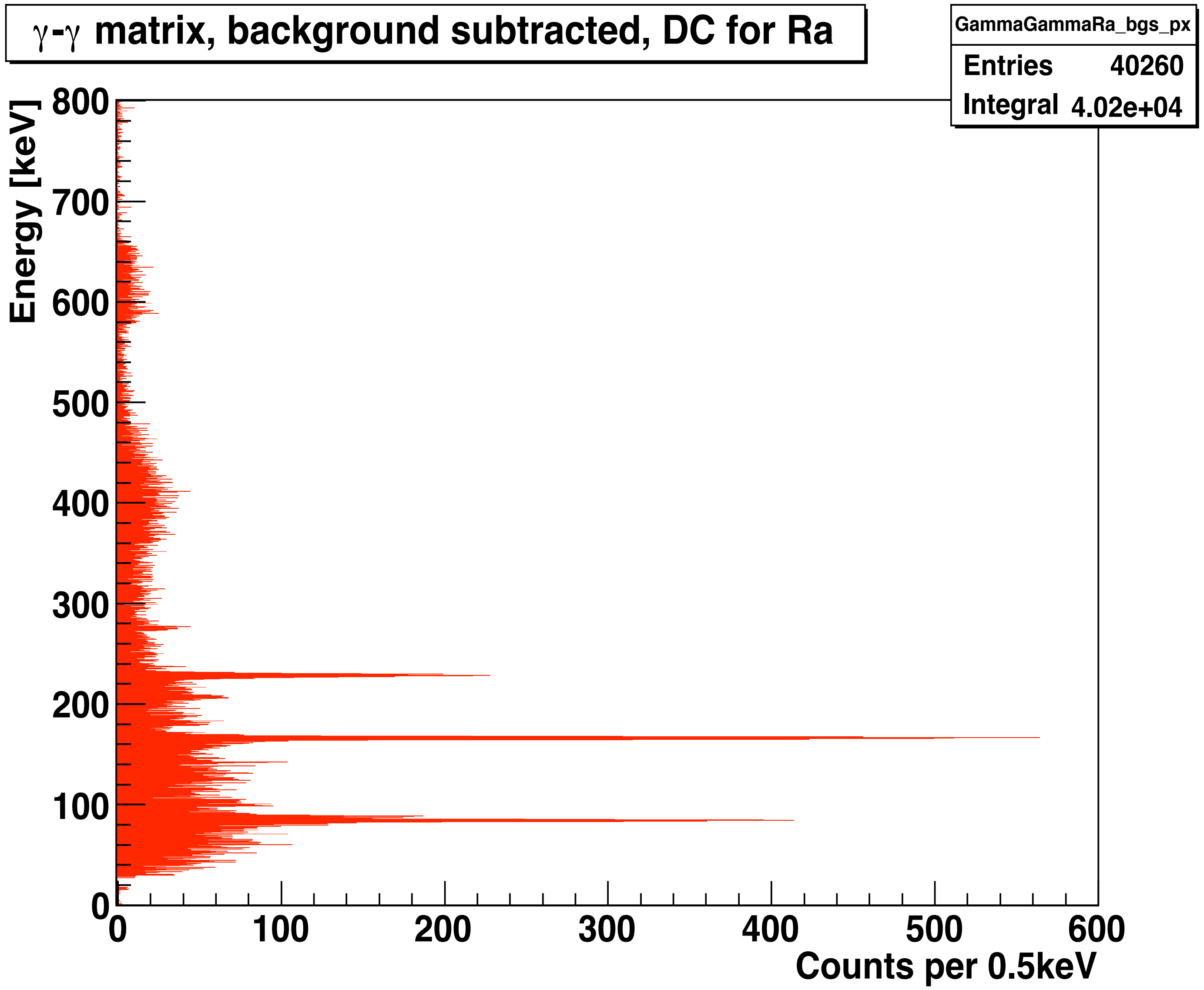

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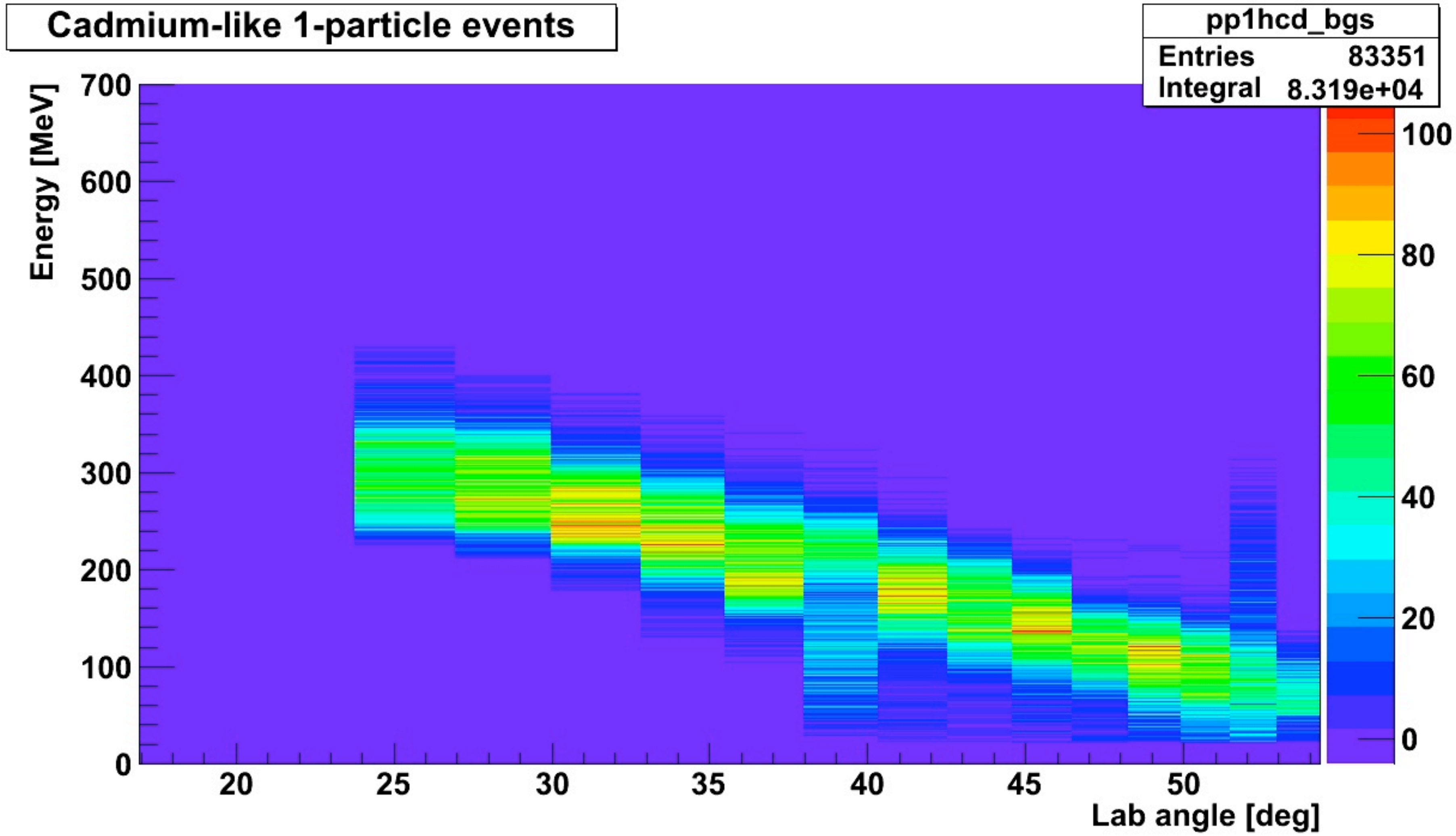

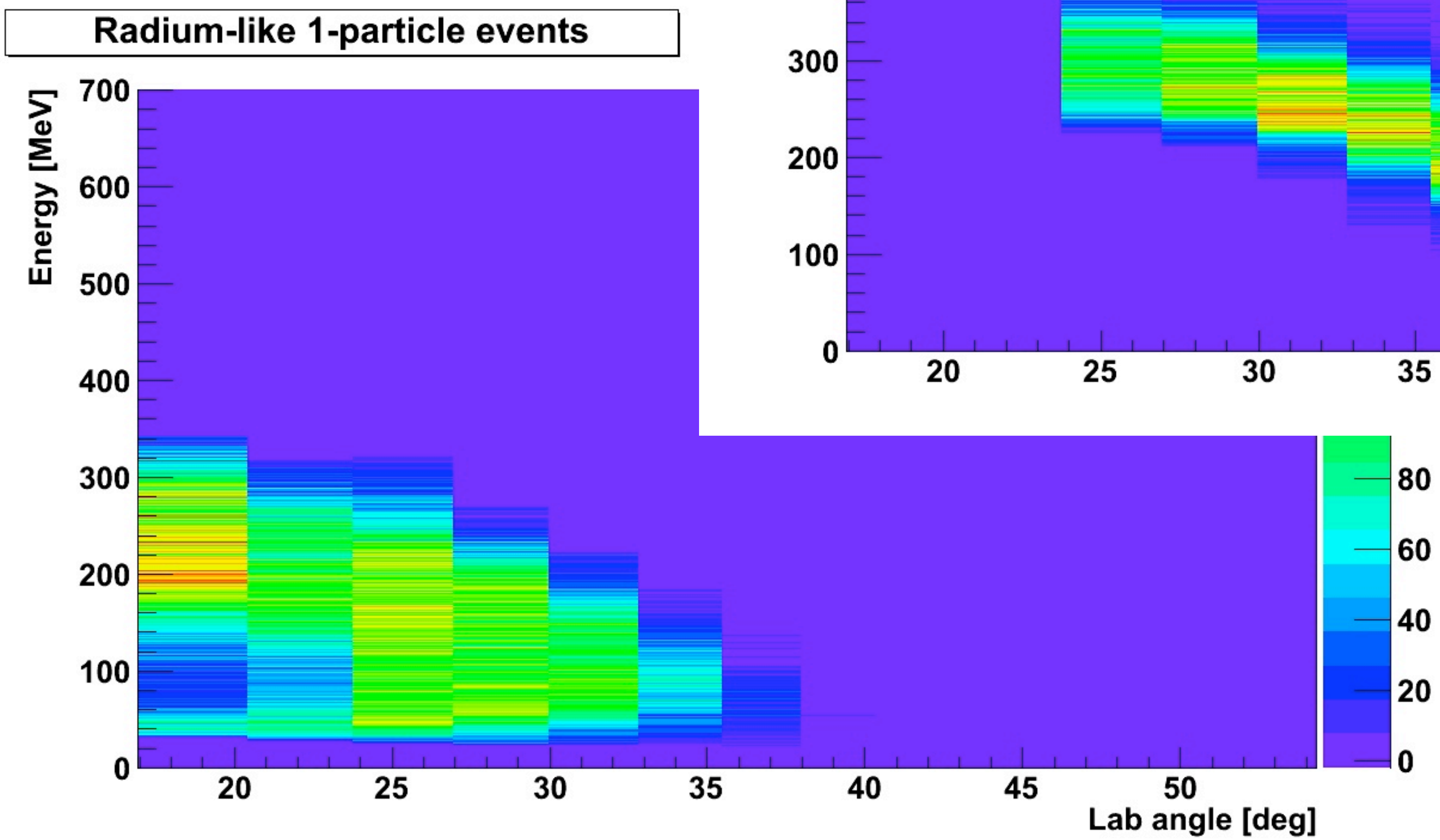

Gosia Analysis

72 Matrix elements -- 34 experimental data points

"Experiment"	Number and type of data
Multi-nucleon transfer[1,2] $^{226}Ra(^{58}Ni,^{60}Ni)^{224}Ra$ $^{232}Th(^{136}Xe,^{128}Te)^{224}Ra$ Alpha, alpha-prime[3] $^{226}Ra(\alpha,\alpha'2n)^{224}Ra$ Alpha-decay[4] $^{228}Th \rightarrow \alpha$	Branching ratios (1^-, 3^-, 5^-) -- **3** (+3 limits)
Delayed-coincidence[5,6]	Lifetimes (2^+, 4^+) -- **2**
Cd only detection $23.9^\circ < \theta_{lab} < 54.3^\circ$	γ-ray yield -- **9**
Ra, high CoM branch $22.2^\circ < \theta_{lab} < 29.9^\circ$	γ-ray yield -- **6**
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2-particle events $17.1^\circ < \theta_{lab} < 54.3^\circ$	γ-ray yield -- **8**
Total	34

[1] Poynter *et al.,* Phys. Lett. B **232**, 447 (1989)
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Huge parameter space - Reduce number of matrix elements by using rigid rotor

$$< I||E\lambda||I' >= (2I+1)^{\frac{1}{2}}(I0\lambda0|I'0)Q_\lambda a_\lambda$$

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- All E4 matrix elements fixed -- 17 MEs
- Q_2 coupled for states $I_i > 6\hbar$ -- 12 MEs
- Q_1 coupled for states $I_i > 6\hbar$ -- 6 MEs
- Q_3 coupled for states $I_i > 6\hbar$ -- 11 MEs
- 26 matrix elements + 4 normalisation constants = **30** parameters in fit

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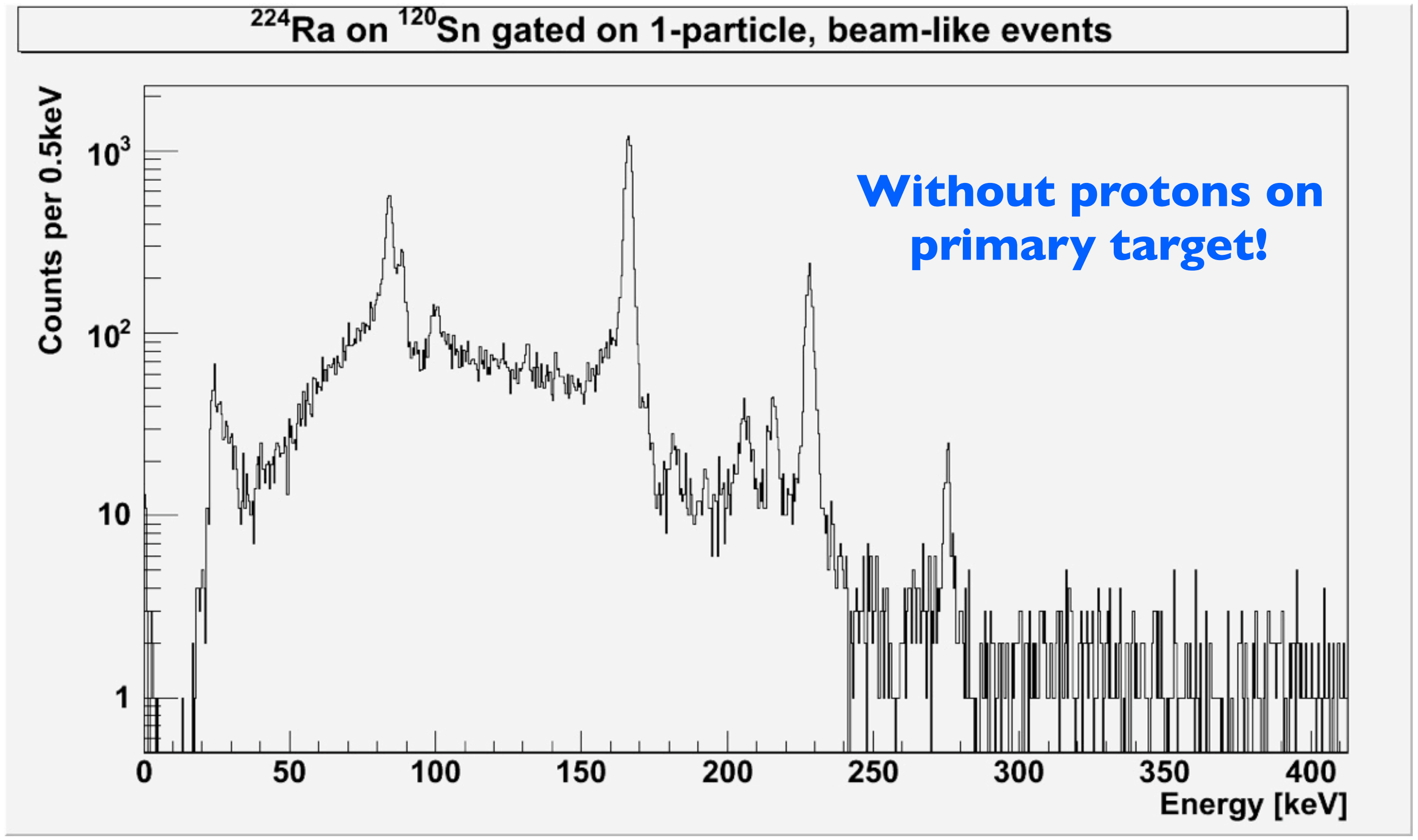
Outlook and "to do"s

$T_{1/2}(^{228}Th)$ = 1.913 years

$T_{1/2}(^{224}Ra)$ = 3.66 days

Z(Cd) = 48

Z(Sn) = 50



~25 more data points in the fit from yield information

+ 4 normalisation constants

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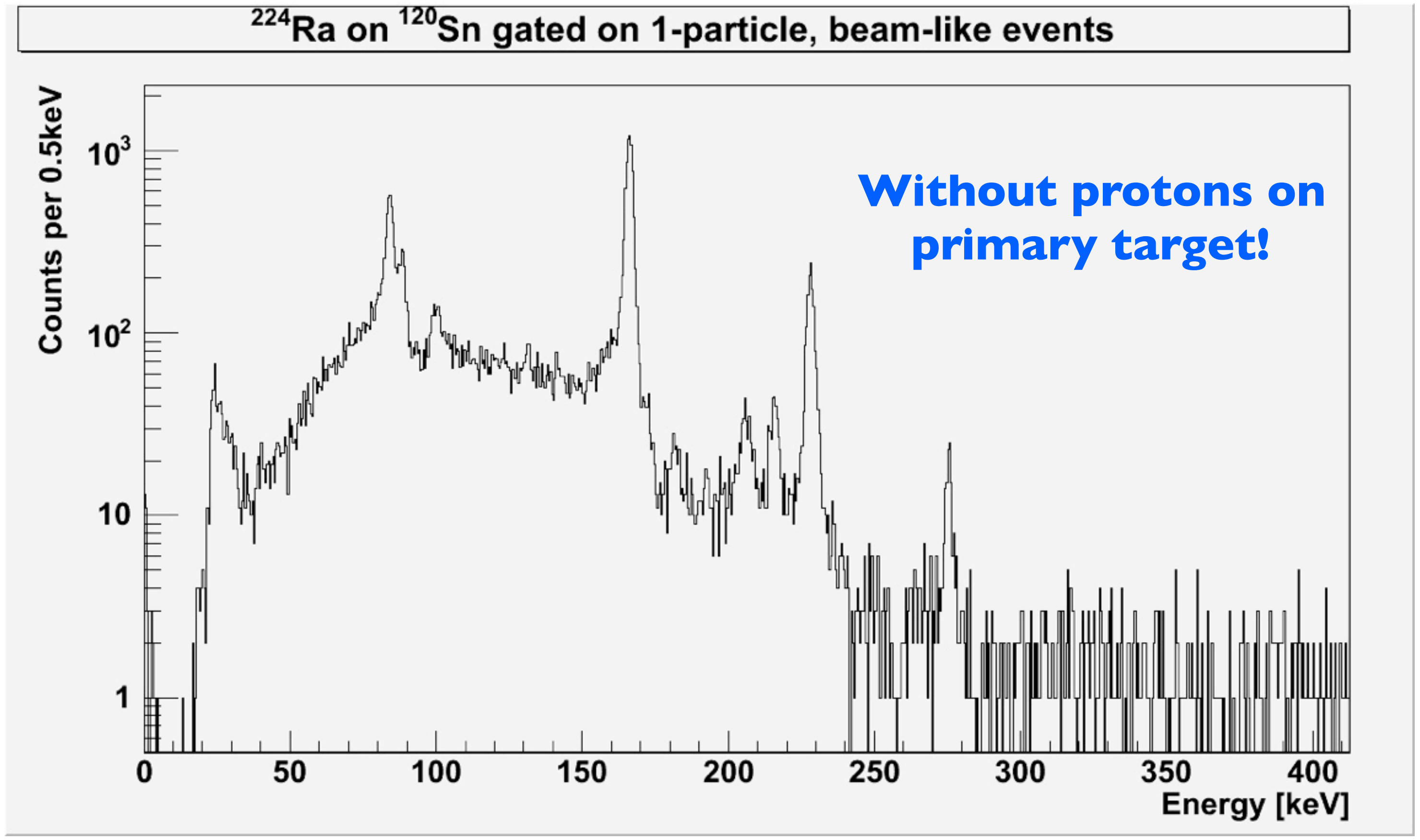

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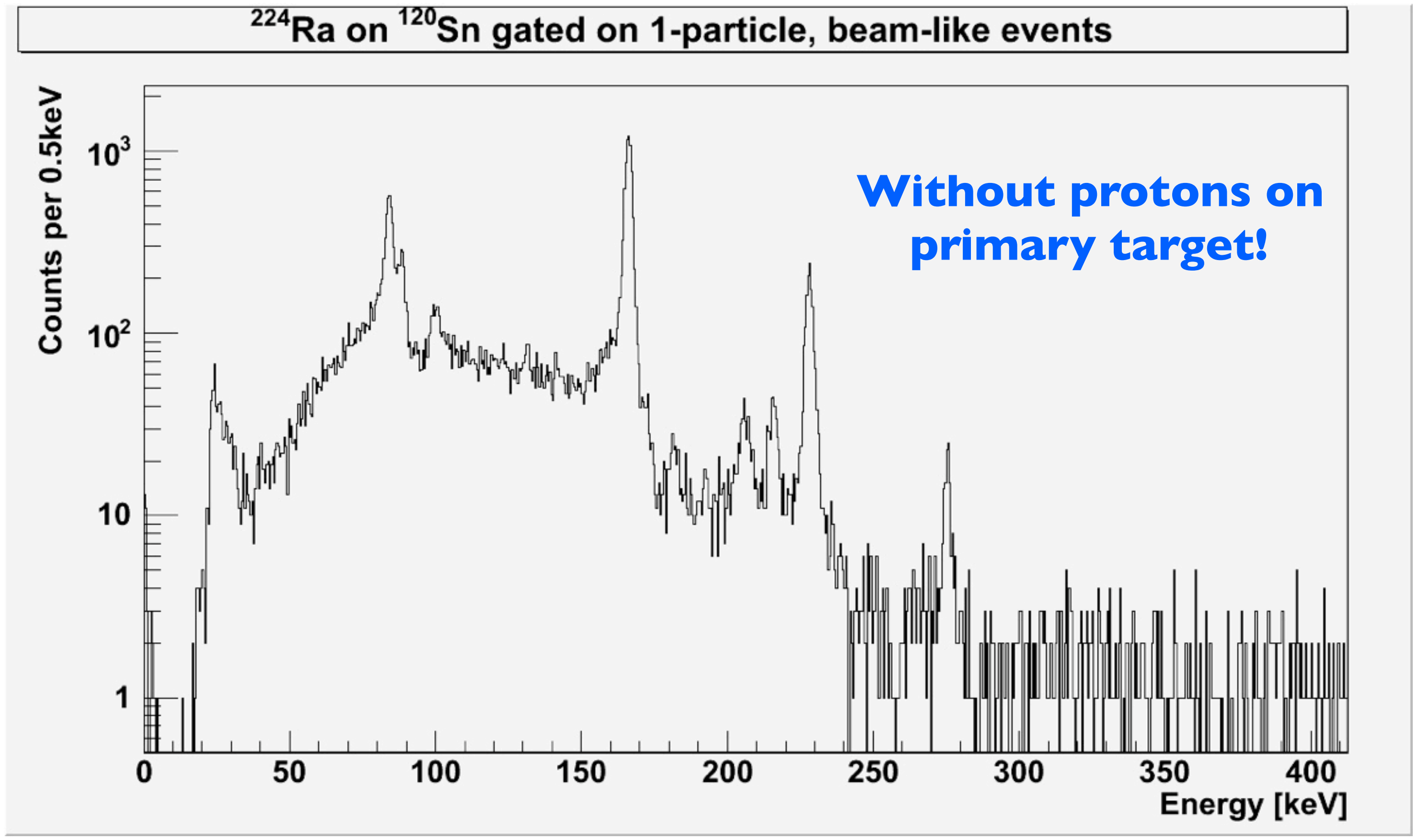

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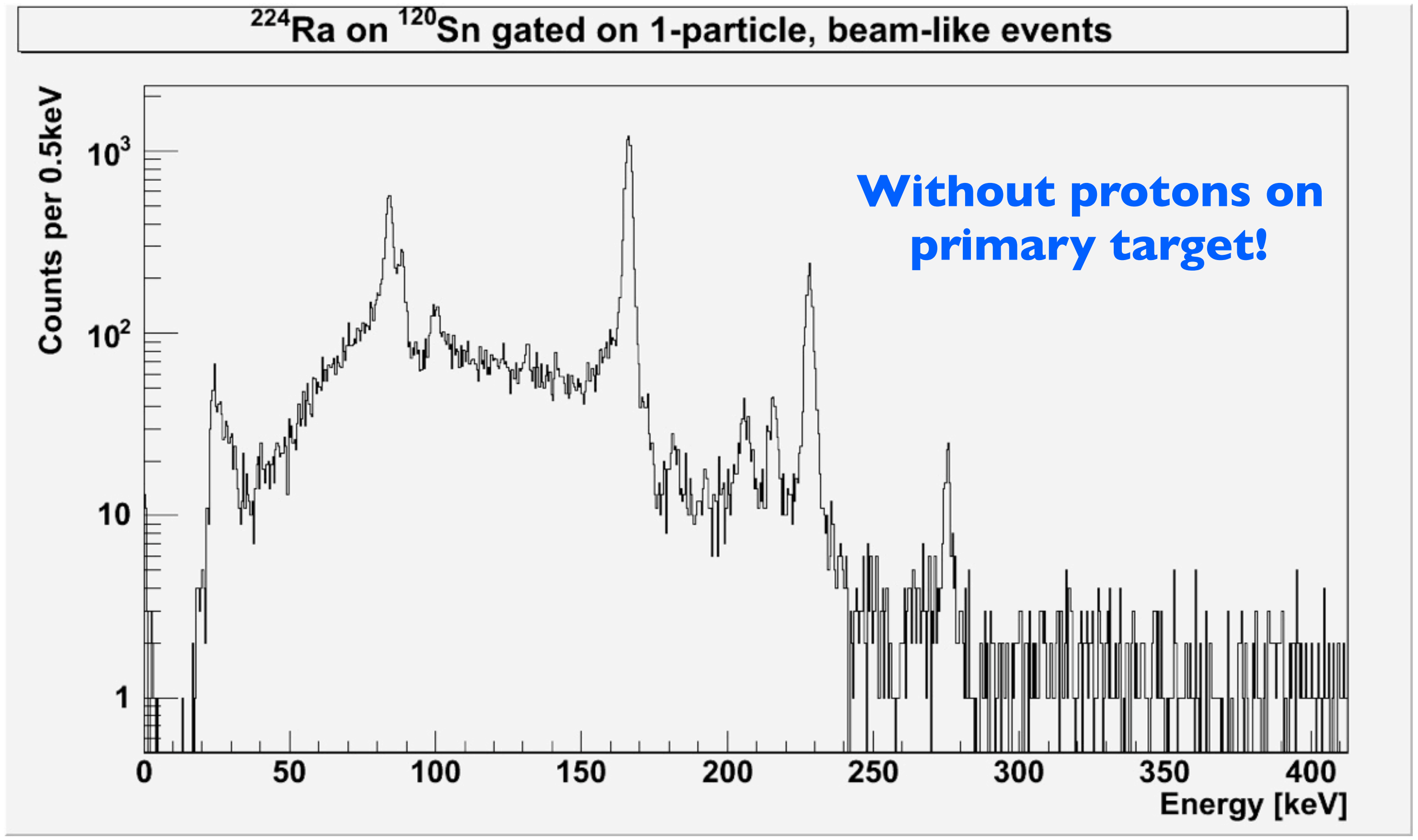

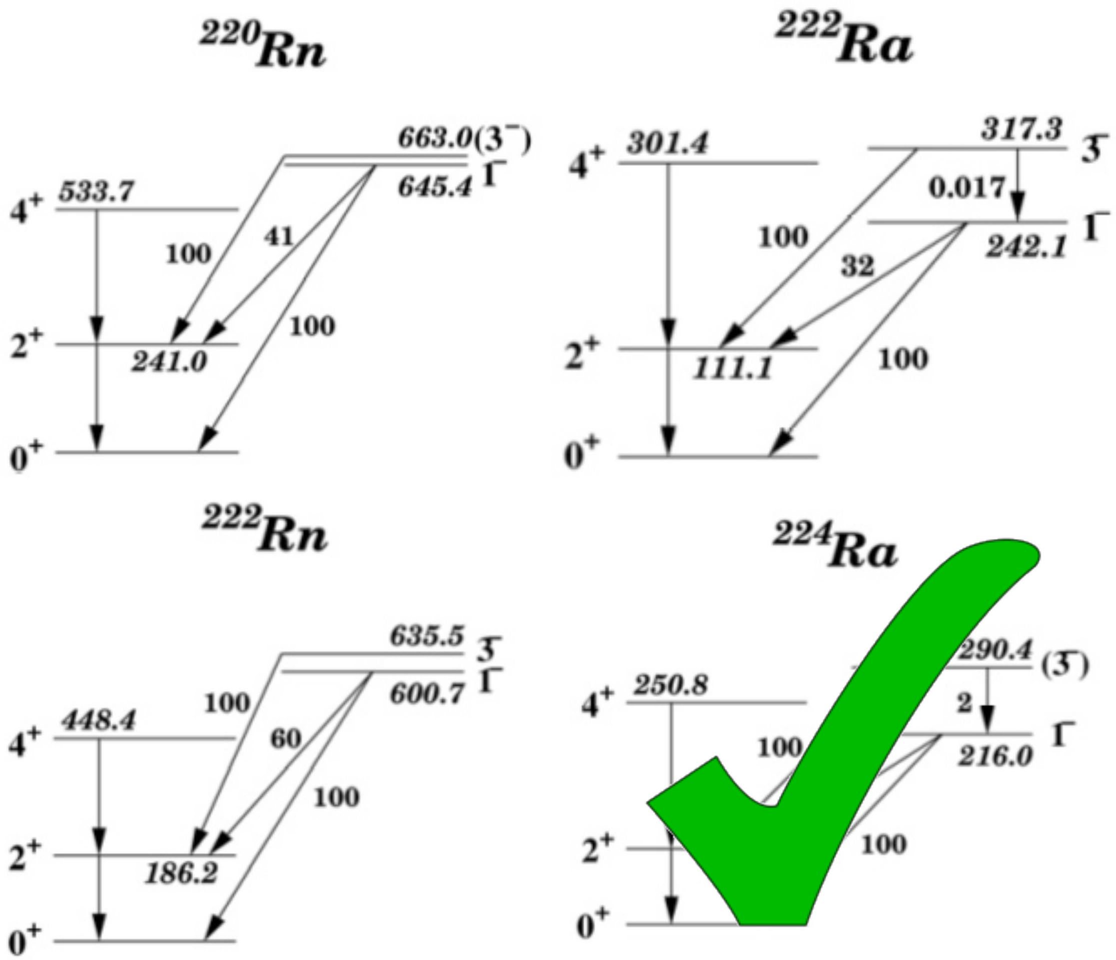

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Collaborators

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T. Grahn	**University of Jyväskylä, Finland**
K. Hadynska, J. Iwanicki, P. Napiorkowski, M. Zielinska	**HIL University of Warsaw, Poland**

Thank you!