Electrons from A 0.3s Isomer in ^{254}No

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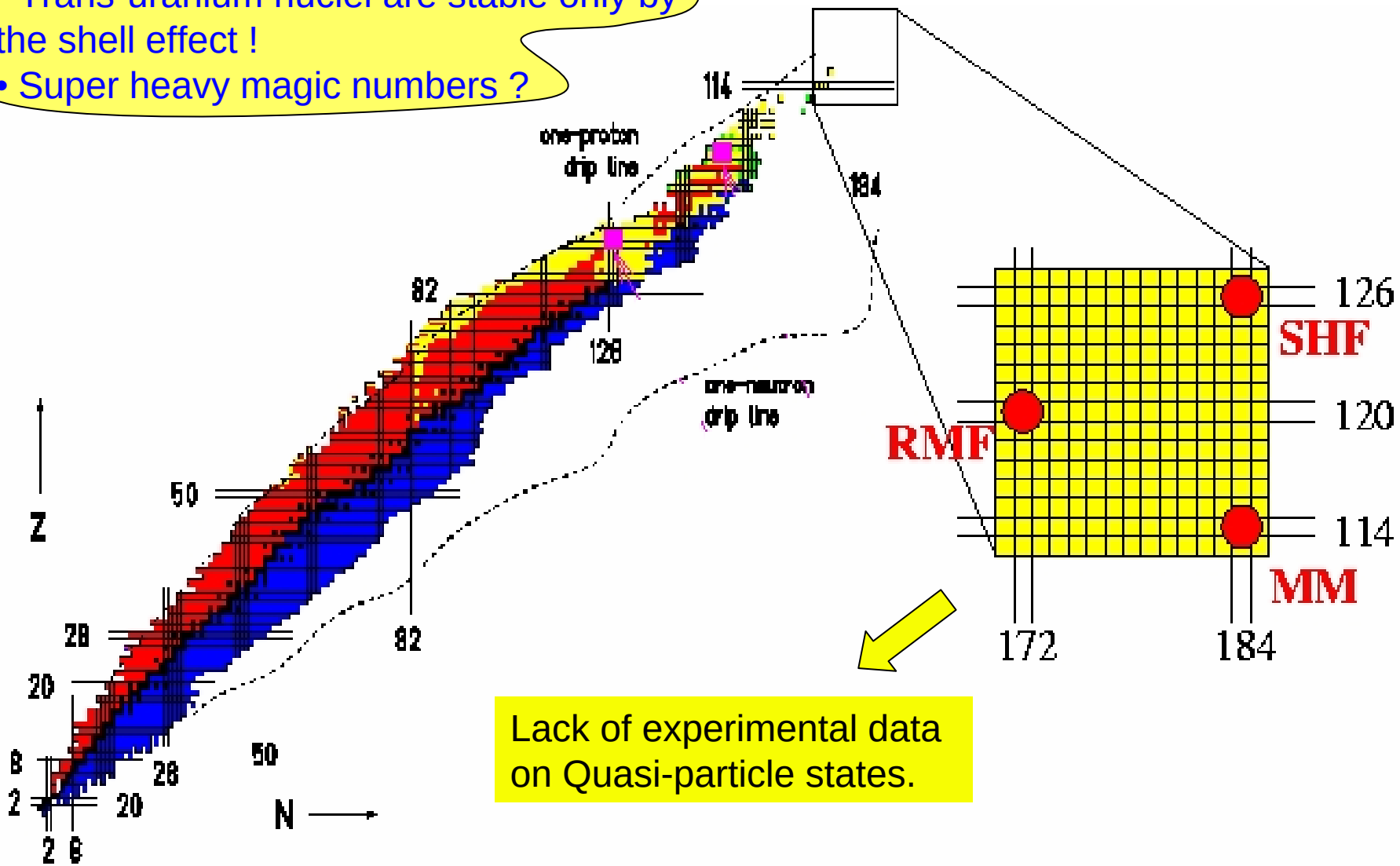
Plan of the talk:

- Introduction
- Challenges
- Experimental setup
- Results and discussion
- Conclusion

- Extra stability near the magic numbers.
- Trans-uranium nuclei are stable only by the shell effect !
- Super heavy magic numbers ?

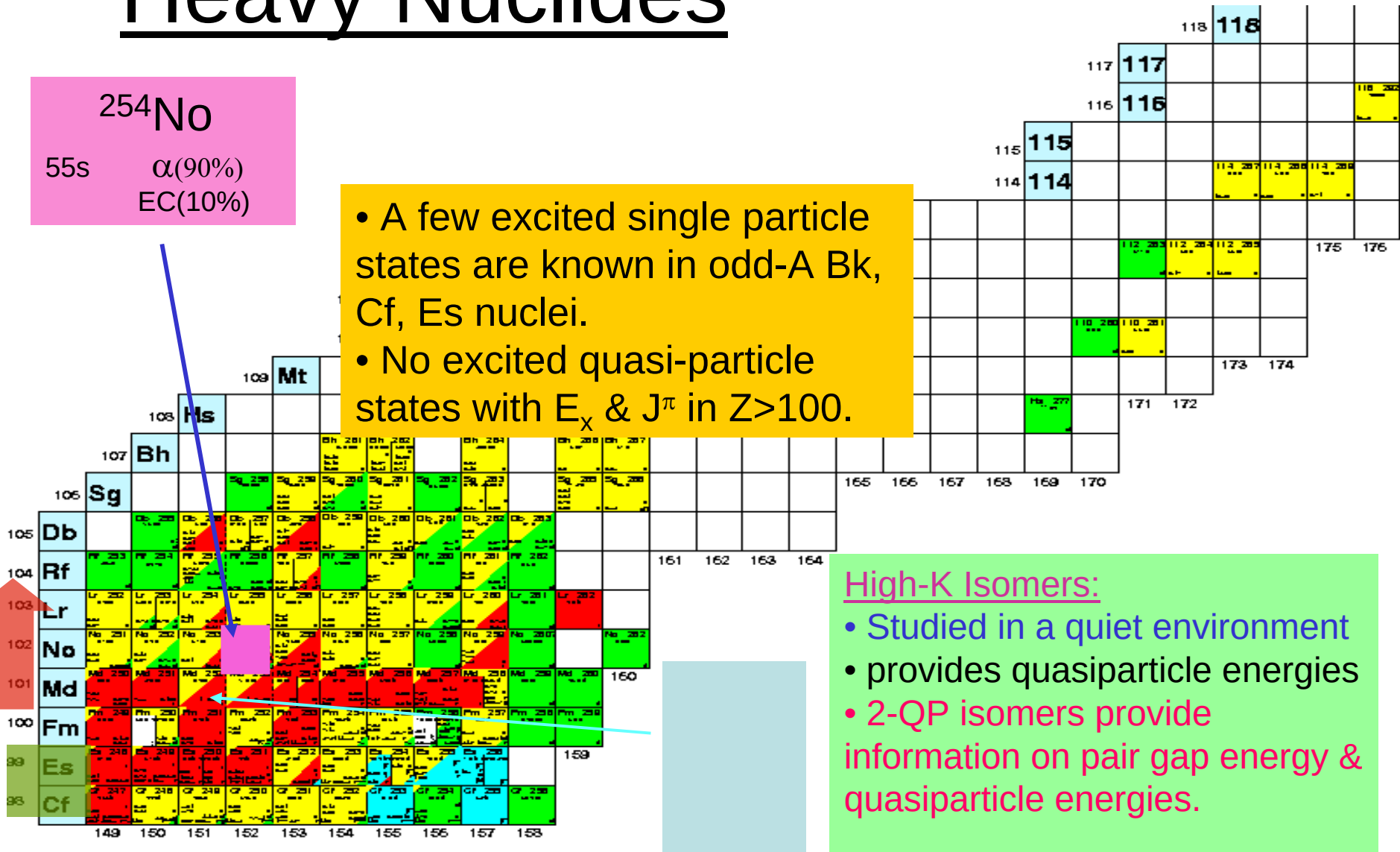


Lack of experimental data on Quasi-particle states.

Heavy Nuclides

^{254}No

55s α(90%)
EC(10%)



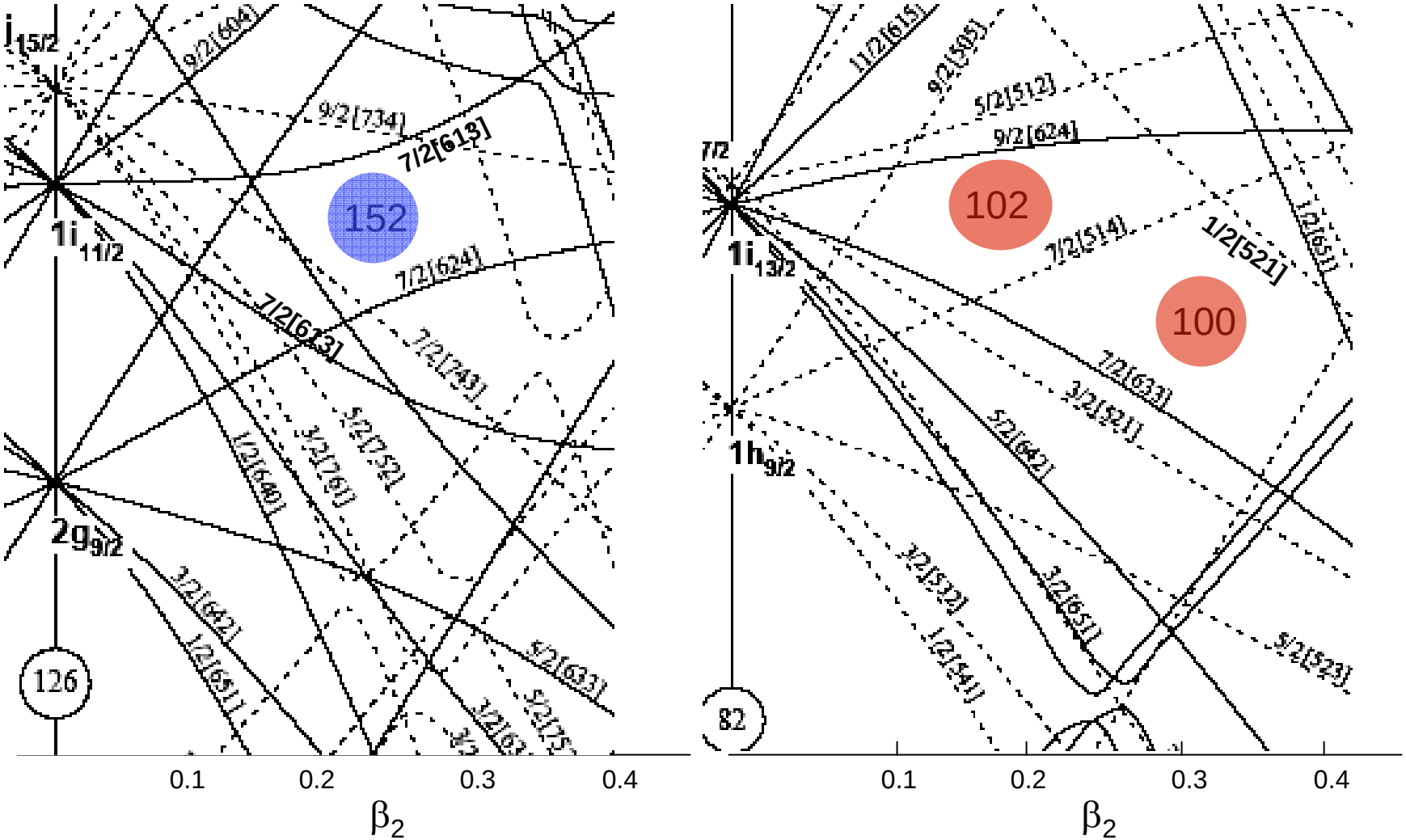
- A few excited single particle states are known in odd-A Bk, Cf, Es nuclei.
- No excited quasi-particle states with E_x & J^π in Z>100.

High-K Isomers:

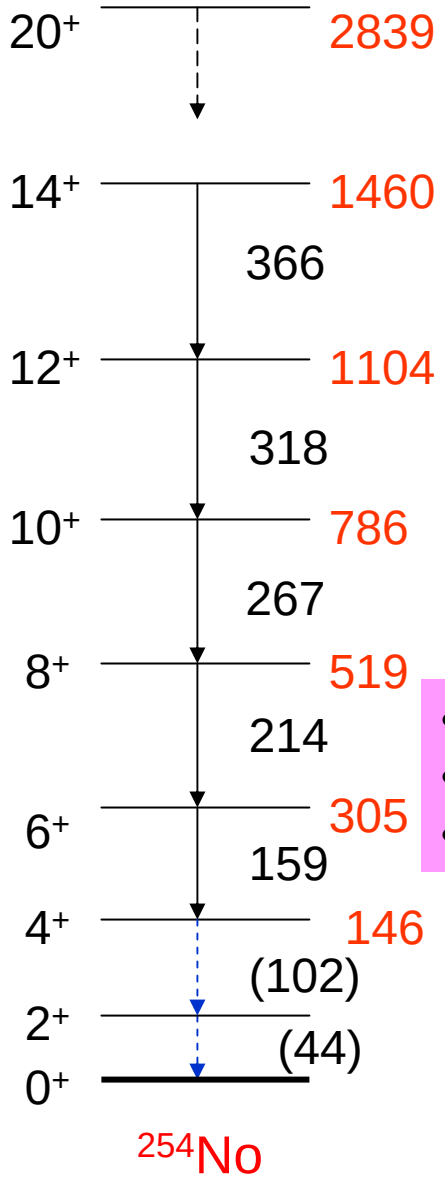
- Studied in a quiet environment
- provides quasiparticle energies
- 2-QP isomers provide information on pair gap energy & quasiparticle energies.

Neutrons

Protons



Possibility of high-K isomers near Z = 100, N = 150



P. Reiter et al. PRL **84** 3542 (2000)

Are there multiquasi-particle states (K-isomers) in ^{254}No (Z=102) ?

Evidence for a ~ 280 ms isomer… (Ghiorso et al. 1973)

~ 280 ms ?

- No E_x
- No J^π
- No decay path

Other known 2-QP isomers

- A 7^- isomer (70 ns) observed in ^{256}Fm at 1425 keV which decays to 8^+, 6^+, 6^- and 5^- states.
- A 1.8 s isomer observed in ^{250}Fm.
- Suggested configuration: $\pi\{[633]7/2^+ \times [514]7/2^-\}$

- In ^{270}Ds (Z=110) an isomeric state has longer α– decay half life (6 ms) than the ground state (100 μs).
- Suggested configuration: $\nu\{[724]11/2- \times [613]7/2+\}$ or $\nu\{[725]11/2- \times [615]9/2+\}$

Challenges

- Low cross-section : μb or less
- Highly converted transitions: electrons.
- Long half life: more randoms

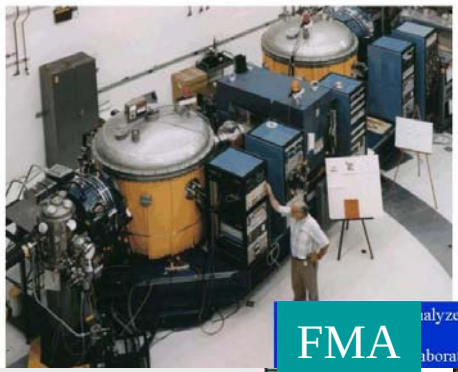
^{254}No

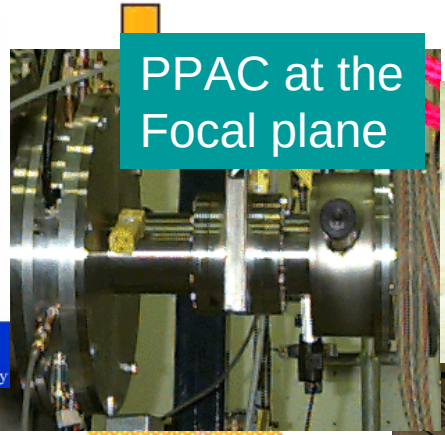
Transition energy	$J^{\pi}_{i} \rightarrow J^{\pi}_{f}$	α_{tot}
44 keV	$2^{+} \rightarrow 0^{+}$	1461
102 keV	$4^{+} \rightarrow 2^{+}$	27
159 keV	$6^{+} \rightarrow 4^{+}$	3.8
214 keV	$8^{+} \rightarrow 6^{+}$	1.2

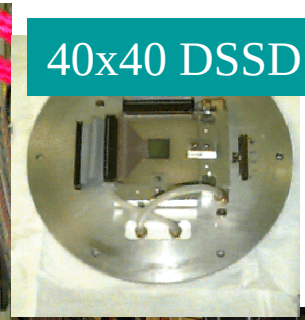
- Fragment Mass Analyzer for mass selection
- Measure Electrons: Double Sided Si Strip Detector

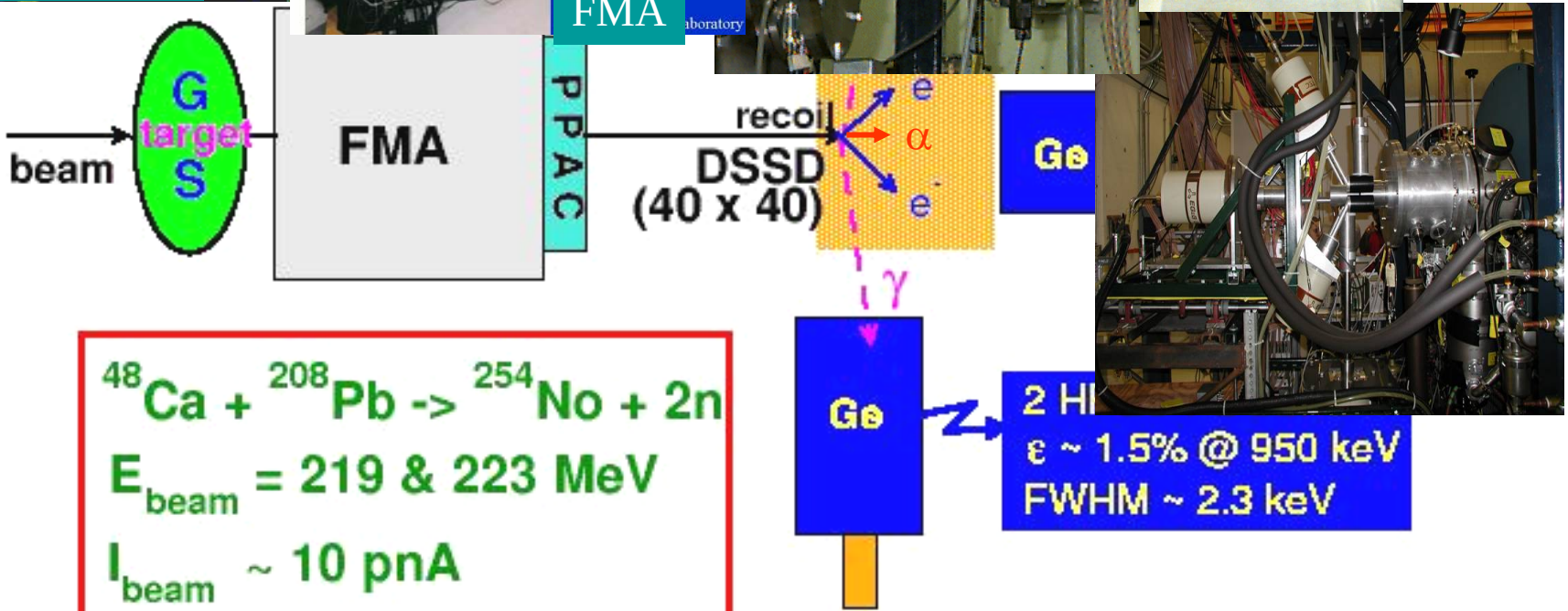
- Implant and decays in the same pixel
- Correlation of first and subsequent decays, e.g electron and α.

ATLAS at Argonne National Laboratory









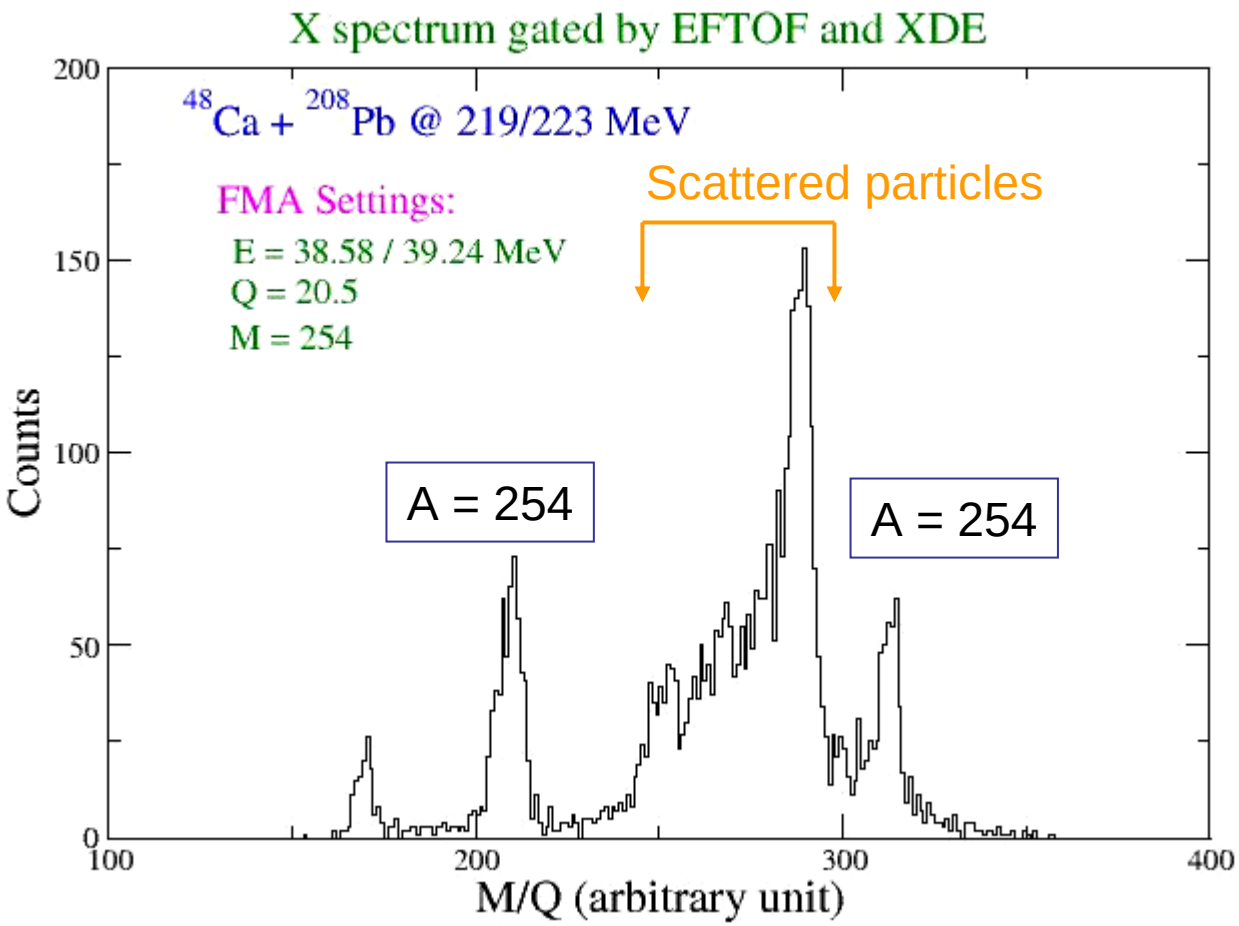
$^{48}Ca + {}^{208}Pb \rightarrow {}^{254}No + 2n$

E_{beam} = 219 & 223 MeV

I_{beam} ~ 10 pnA

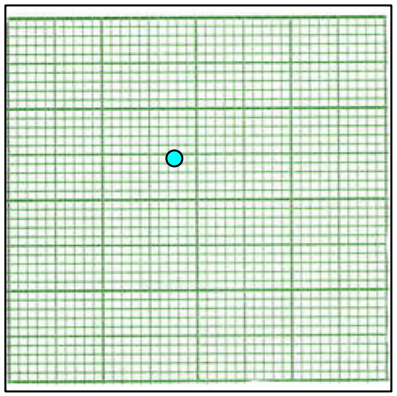
Target : ~ 0.5 mg/cm^2

Mass spectrum

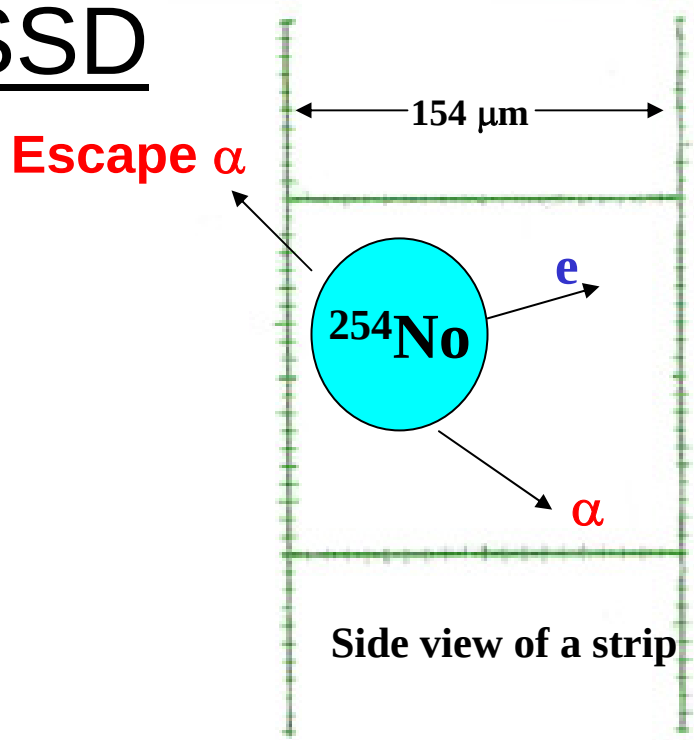


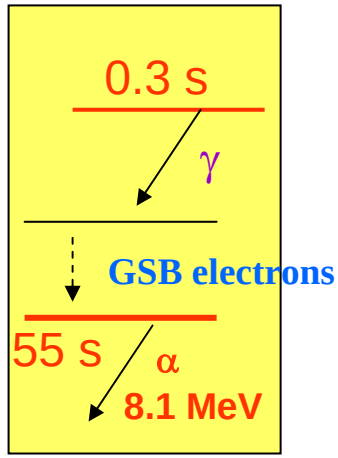
DSSD

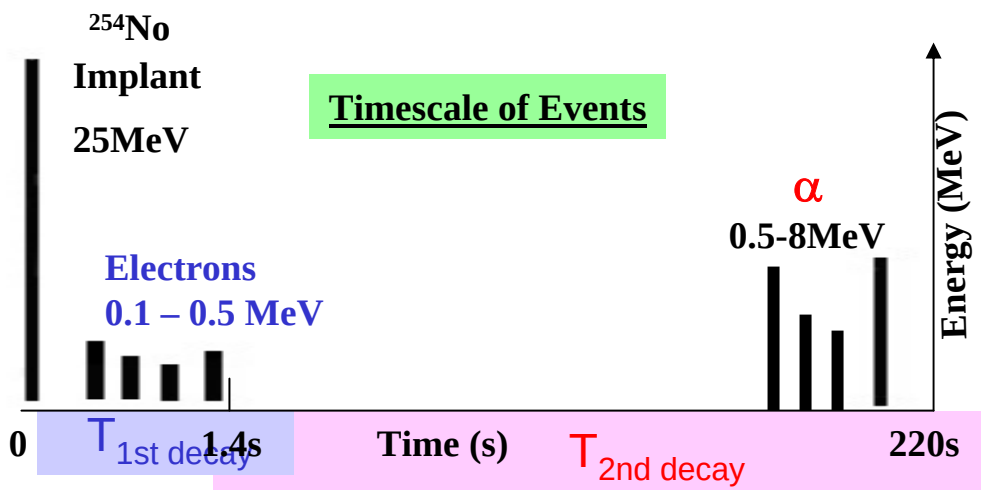
40mm X 40mm



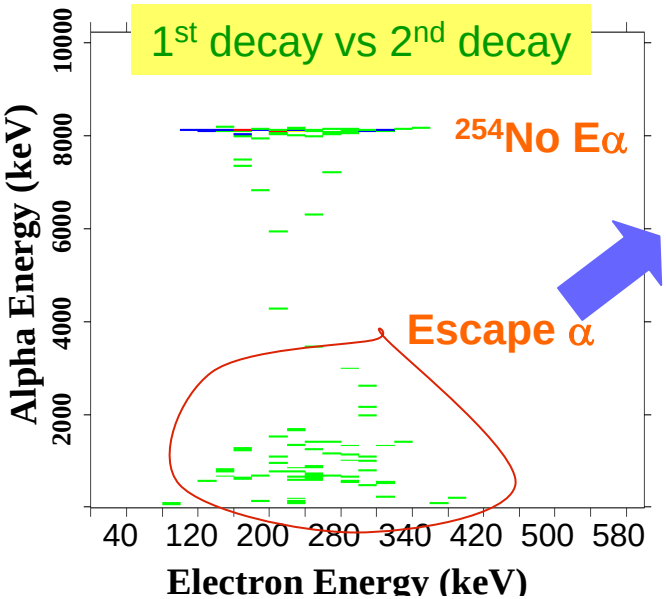
Front View of DSSD



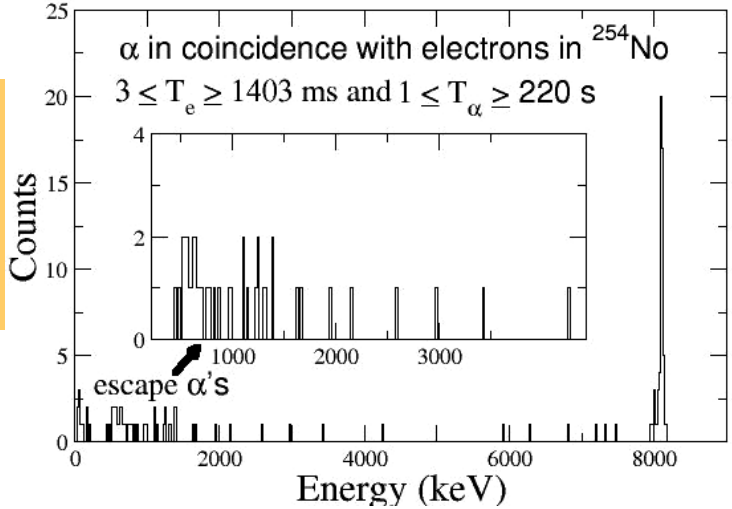




Electron-alpha correlation

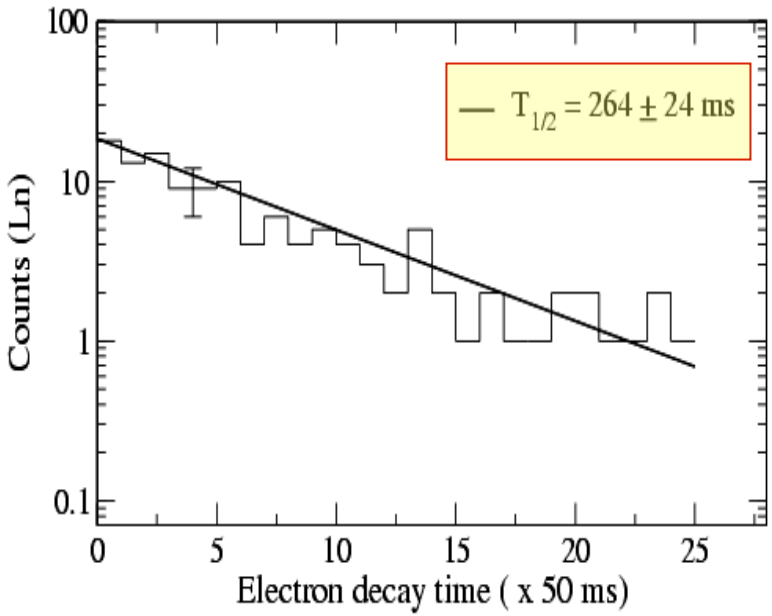


^{254}No implantation depth ~ 4.5 μm
→Energy of escape α > 470 keV



- No. of ^{254}No at the DSSD: 1125 (112)
- No. of e - α coincidences: ~ 125

Isomer ratio ~ 11 %

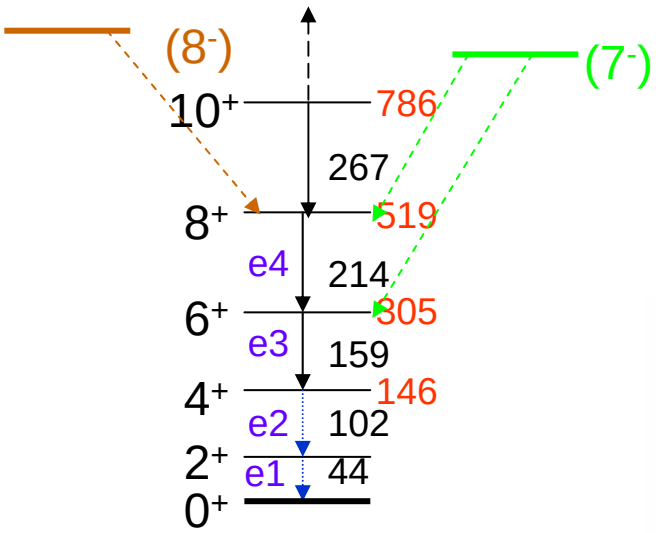


Most intense γ-ray has 2 counts at 967 keV !!

Expected number: ~ 2

Electron spectrum

$$E_{sum} = \sum_{i=1}^{4} e_i$$

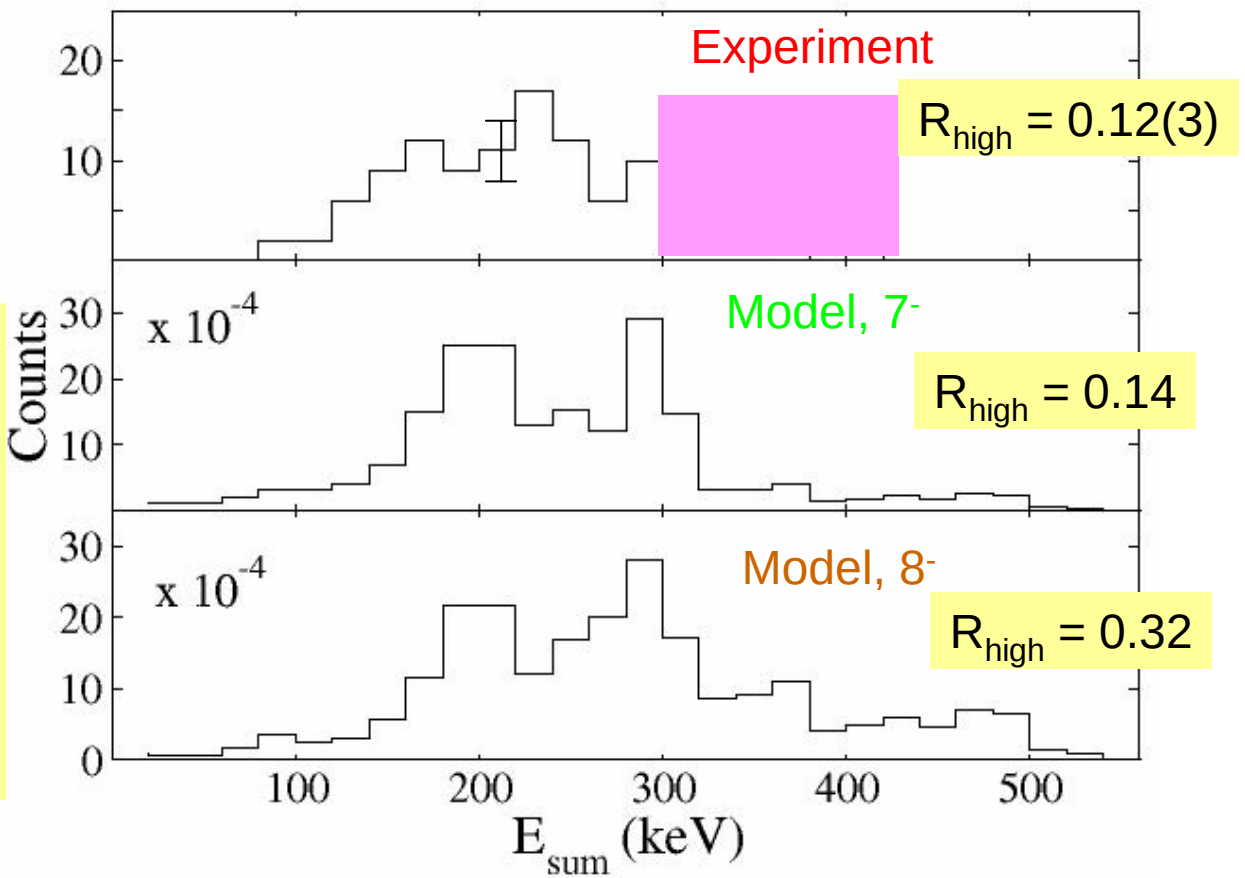


e_i = energy deposited in the DSSD by the electrons for each transition.

$$R_{high} = \frac{N_{high}}{N_{tot}}$$

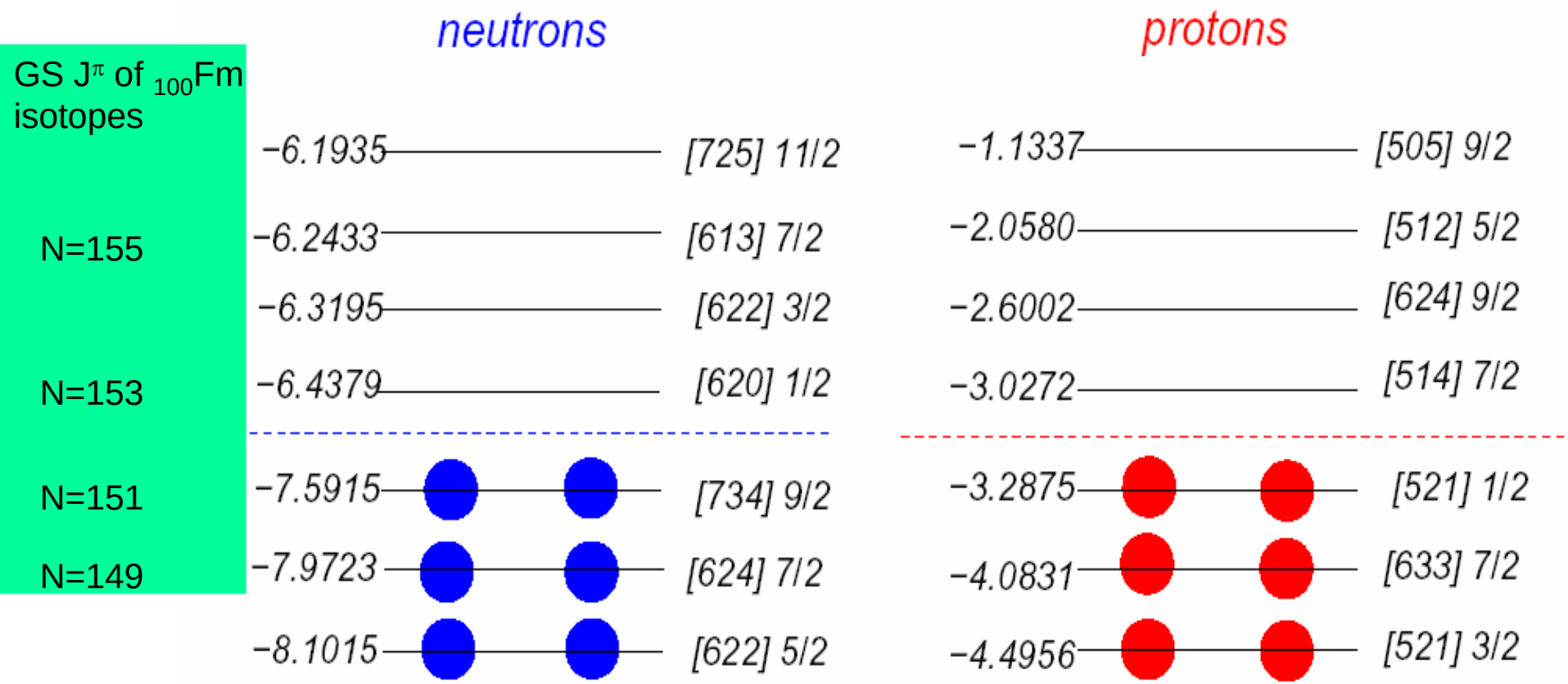
N_{high} = No. of electrons with energy > 305 keV

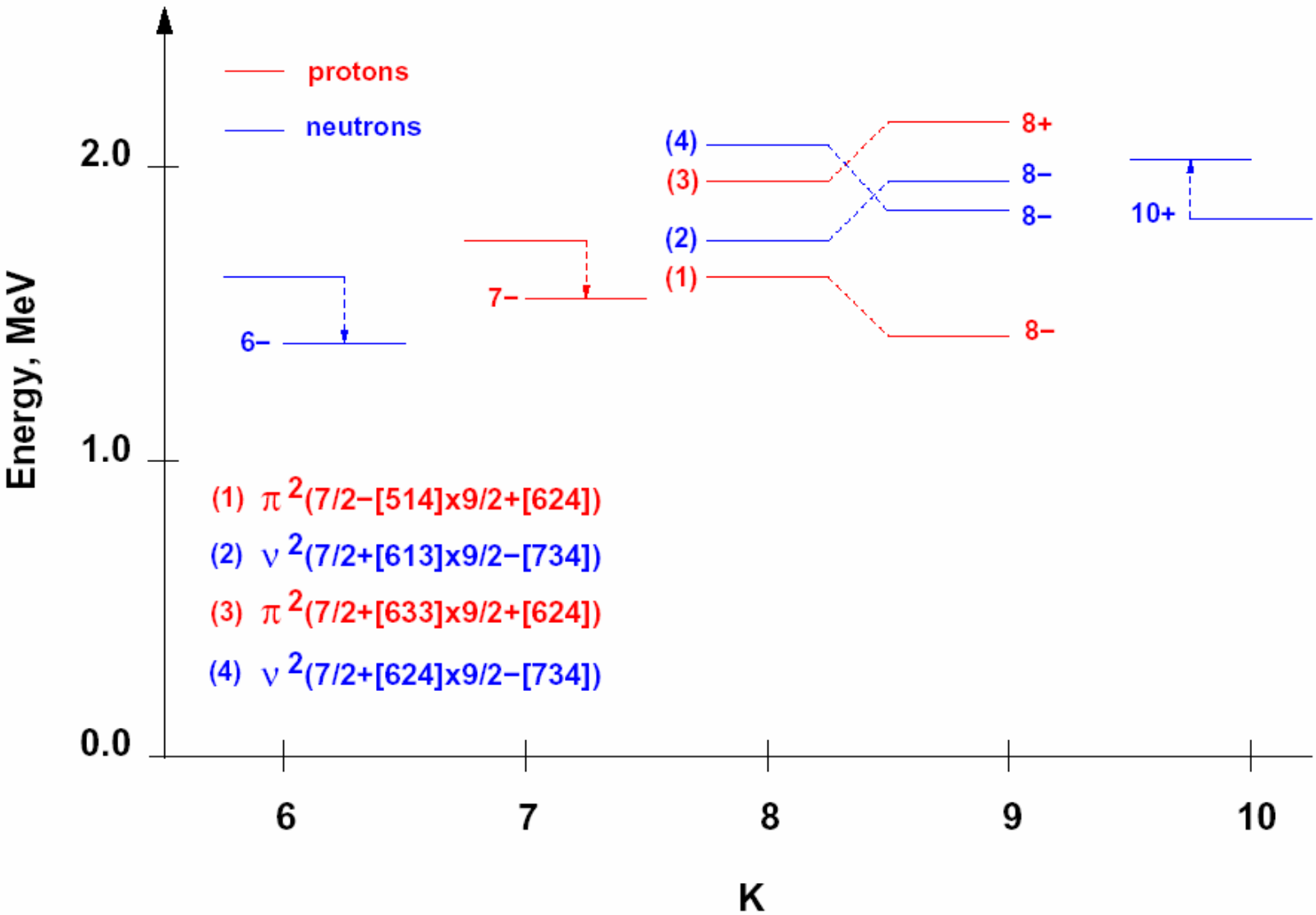
N_{tot} = Total no. of electrons in the spectrum.



Calculations

Woods-Saxon potential : standard parameters

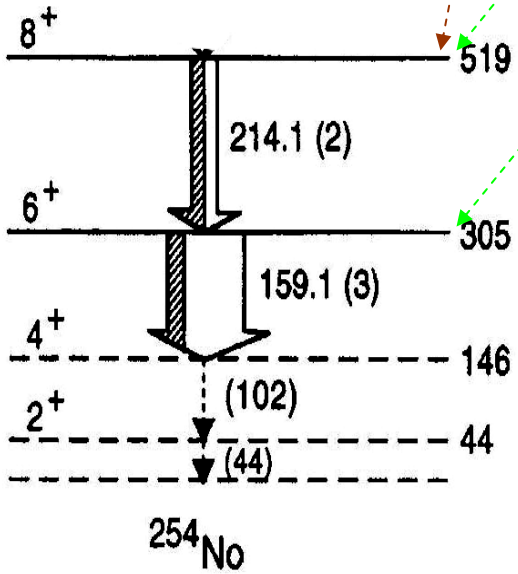



protons
neutrons
2.0
1.0
0.0
Energy, MeV
6−
7−
(4)
(3)
(2)
(1)
8+
8−
8−
8−
10+
(1) π 2(7/2−[514]x9/2+[624])
(2) ν 2(7/2+[613]x9/2−[734])
(3) π 2(7/2+[633]x9/2+[624])
(4) ν 2(7/2+[624]x9/2−[734])
6
7
8
9
10
K

Configuration: $\pi\{[624]9/2^+ \times [514]7/2^-\}$ $\pi\{[633]7/2^+ \times [514]7/2^-\}$

$K^\pi =$ 8^- OR 7^- $T_{1/2} = 264(24)$ ms

$f_\nu = 138$ 297 378



Summary and conclusions:

- Isomer decay in ^{254}No has been studied at the focal plane of the FMA using DSSD.
- The electron-alpha correlation confirmed the existence of the isomer. The half life of the isomer has been measured to be 264(24) ms.
- The electron spectrum suggests decays to the 6^+ and 8^+ states in the GSB and, hence, $K^\pi = 7^-$ for the isomer.

Collaborators

T. L. Khoo, D. Seweryniak, R. Blinstrup, I. Ahmad, M. P. Carpenter, C. N. Davids, S. Freeman, J. Greene, N. Hammond, R. V. F. Janssens, F. Kondev, T. Lauritsen, C. J. Lister, E. F. Moore and S. Sinha
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Yale University
P. T. Greenlees, R. Julin, M. Leino, J. Uusitalo
University of Jyväskylä, Finland

THANK YOU

Single particle levels in odd-A nuclei in mass 250 region

Bk (Z = 97)

1/2⁻ 569

1/2⁻ 411

7/2⁺ 36

(3/2⁻) 8

7/2⁺ ?

(3/2⁻)	(3/2⁻)	3/2⁻	(3/2⁻)	7/2⁺	(3/2⁻)
N= 144	146	148	150	152	154

Es (Z = 99)

1/2⁻ 411

(3/2⁻)106

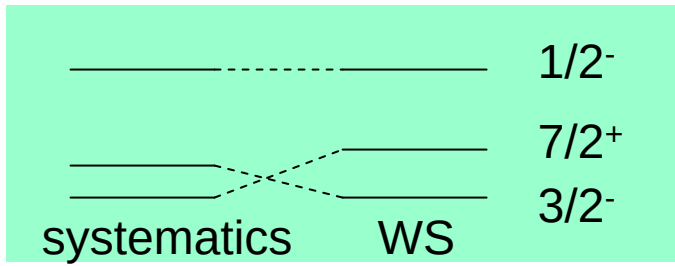
7/2⁺ 8

3/2⁻	(7/2⁺)	7/2⁺	(3/2⁻)	7/2⁺	(7/2⁺)
N= 146	148	150	152	154	156

Md (Z = 101)

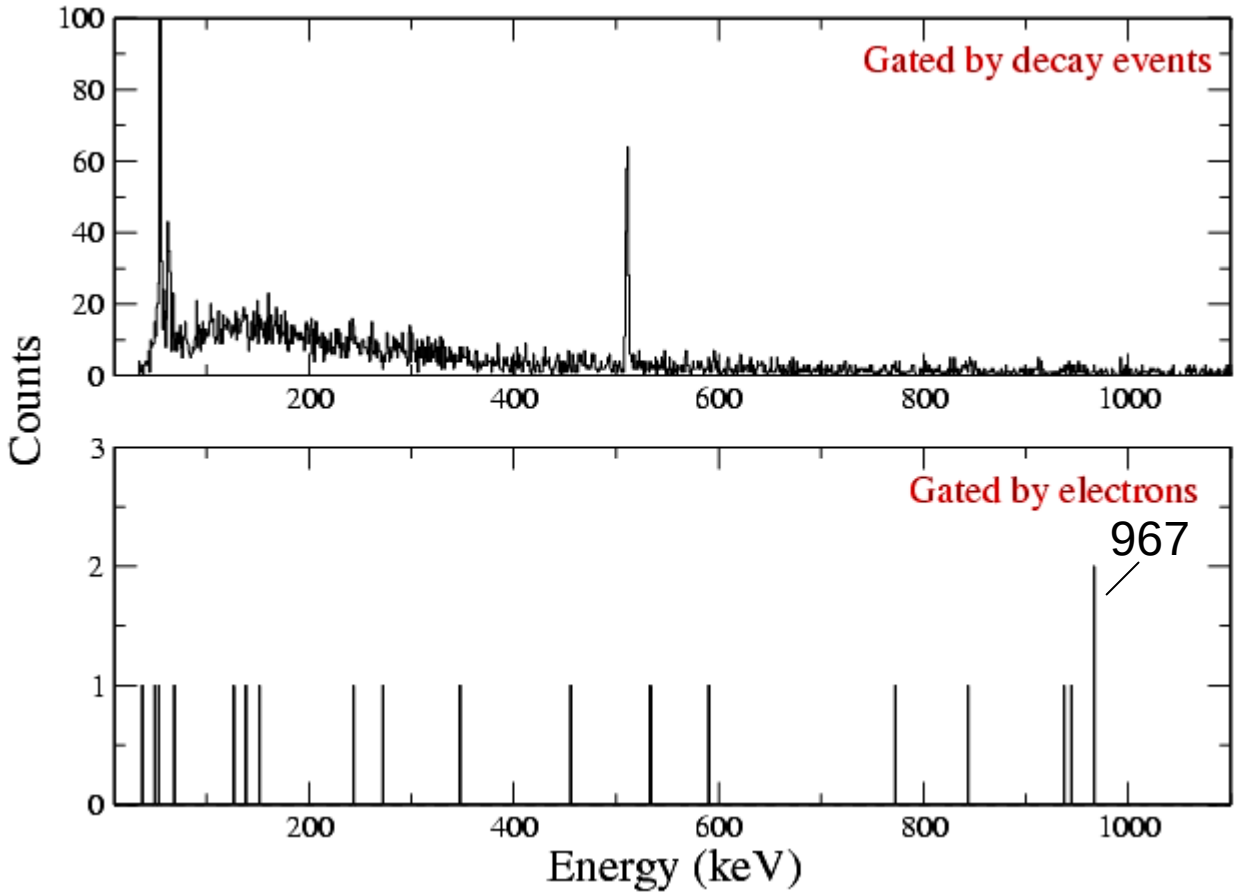
(1/2⁻)	(1/2⁻)	7/2⁻	7/2⁻
N= 144	152	154	156

No data for Lr (Z=103) and above

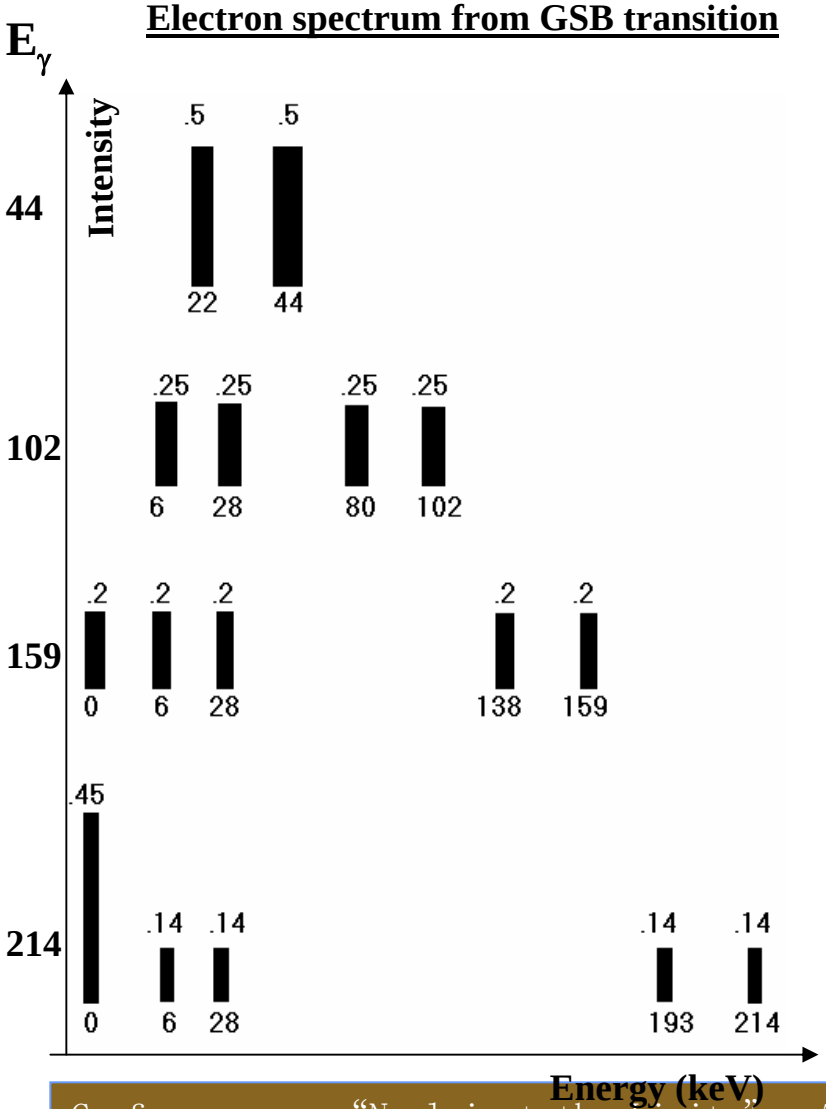


Proton levels near the Fermi surface

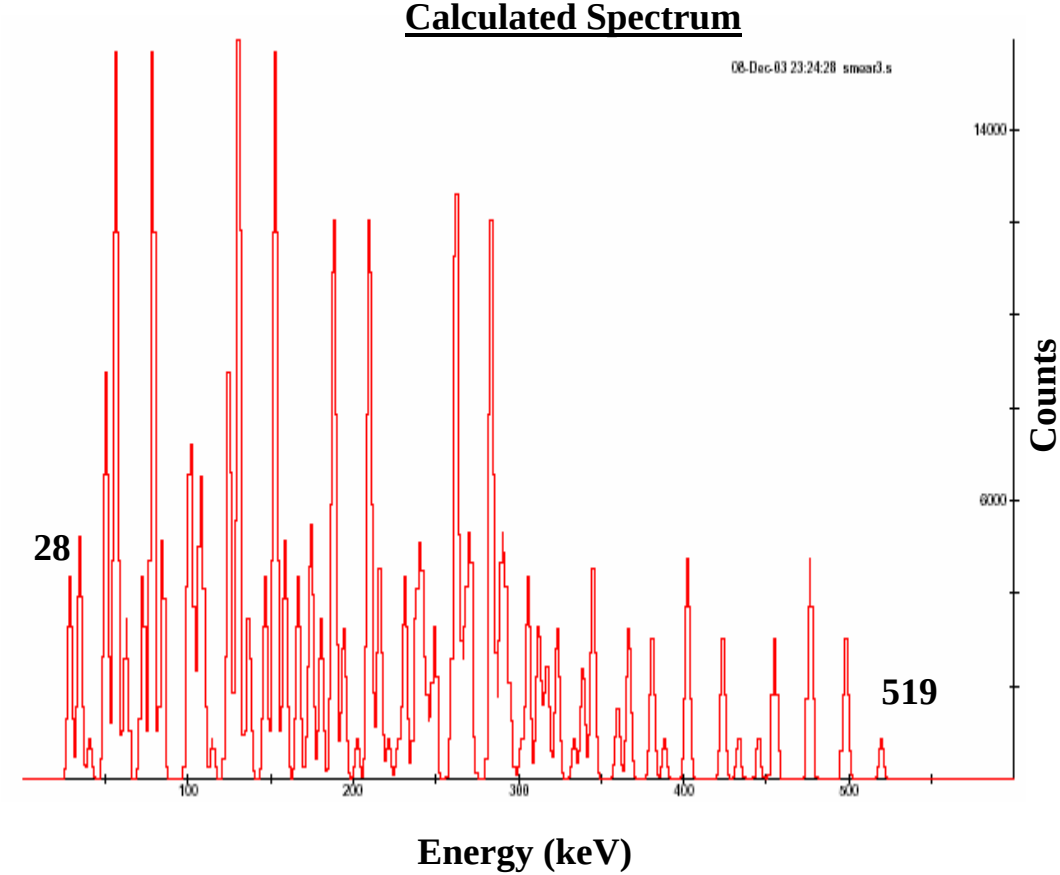
γ-ray spectra

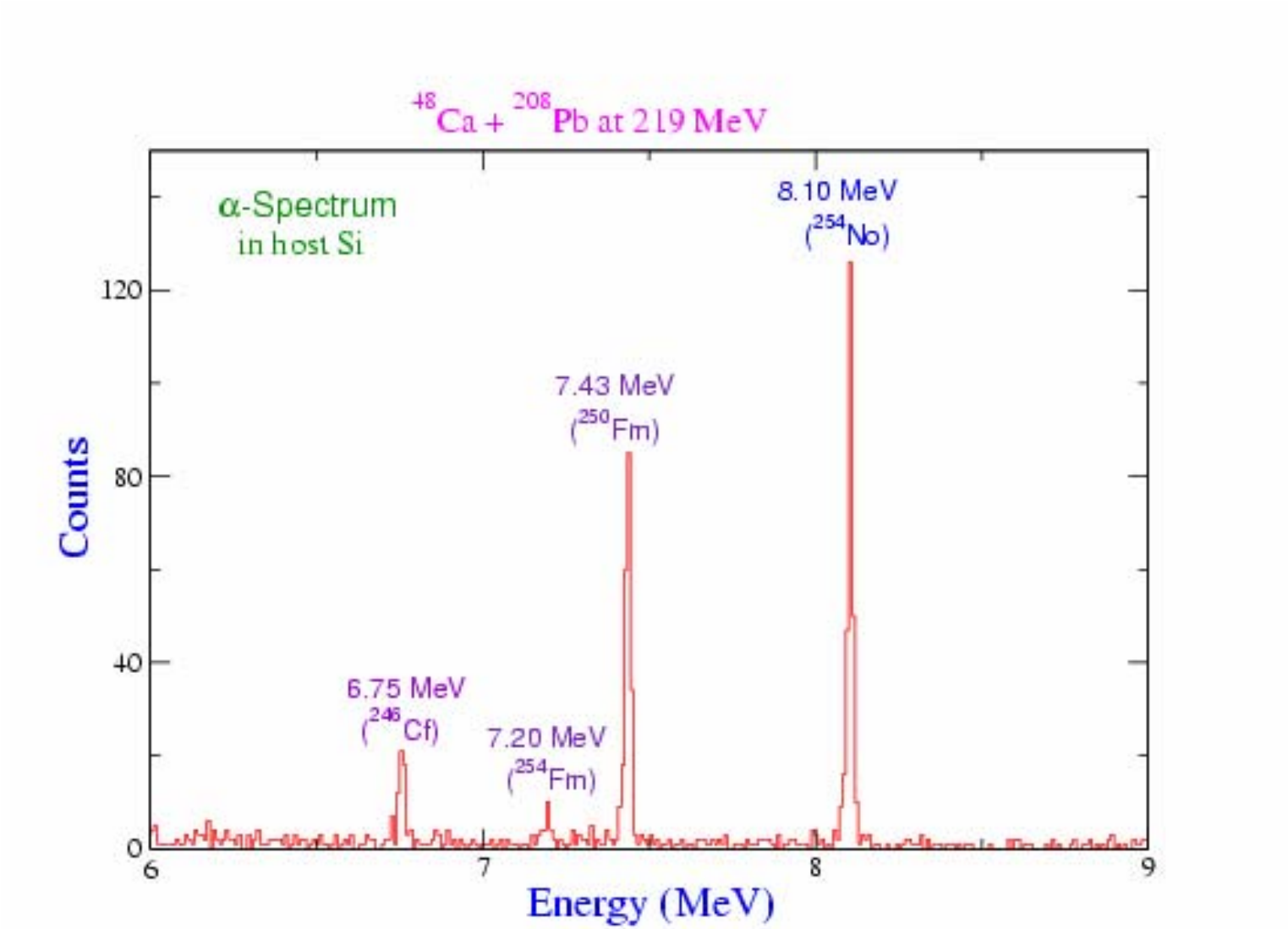


Electron spectrum from GSB transition

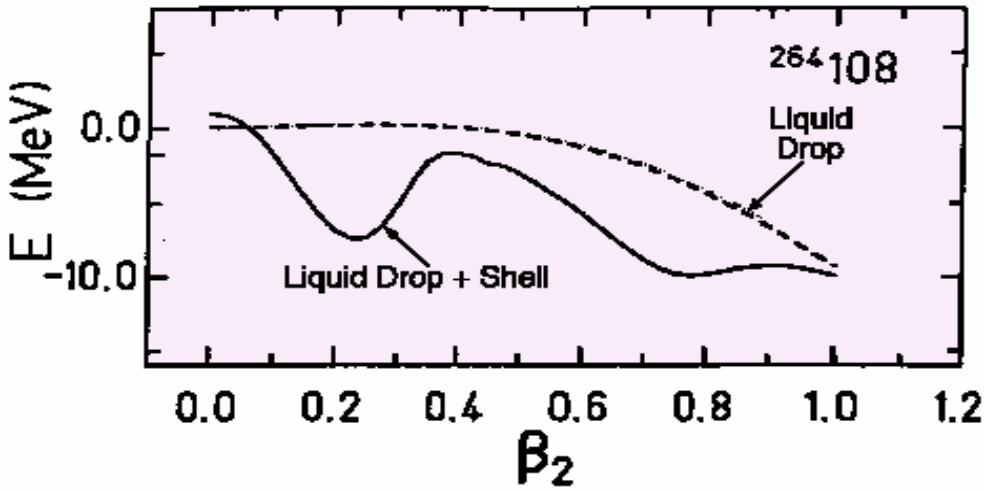


Calculated Spectrum




^{48}Ca + ^{208}Pb at 219 MeV
α-Spectrum
in host Si
8.10 MeV
(^{254}No)
7.43 MeV
(^{250}Fm)
6.75 MeV
(^{246}Cf)
7.20 MeV
(^{254}Fm)
Counts
Energy (MeV)
0
40
80
120
6
7
8
9

Shell-Stabilized Nuclei at the Limits of Charge, Spin and Excitation Energy



Heaviest nuclei

are at the *limits of Coulomb Stability*;
would fission instantaneously, but are stabilized by shell-effects.

They may be *different from ordinary nuclei* since

they are bound by predominantly the *shell-correction energy.*

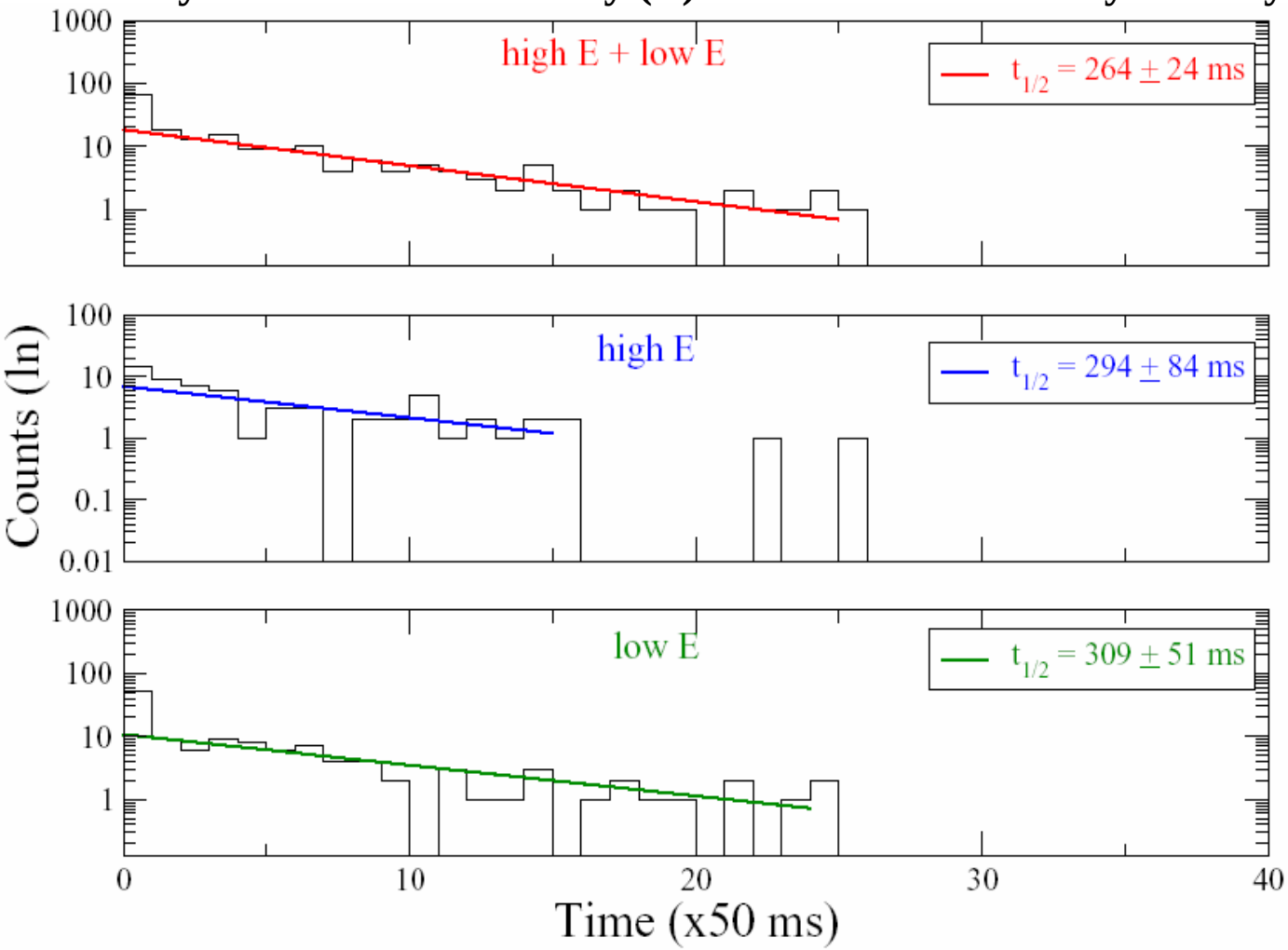
(Lighter nuclei are bound by the *liquid-drop barrier.*)

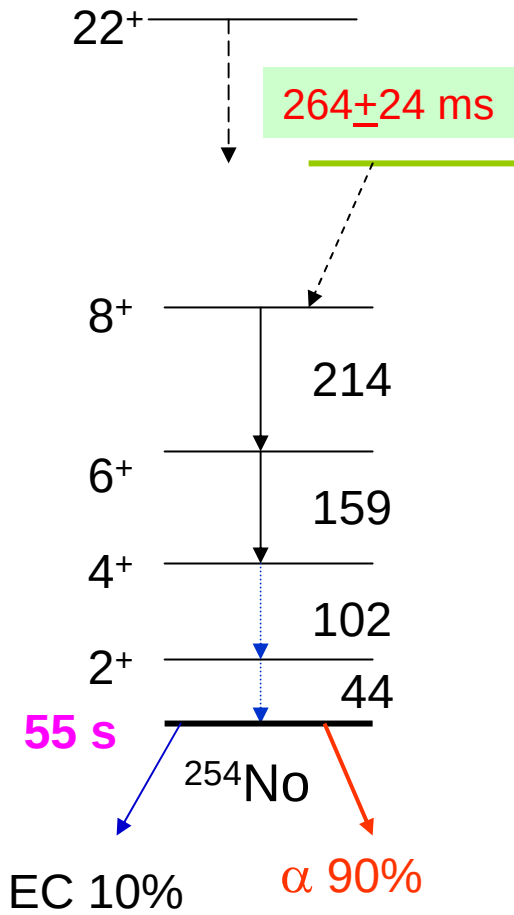
T.L. Khoo, Argonne

Low Energy Program Review, 8 Sep., 2001

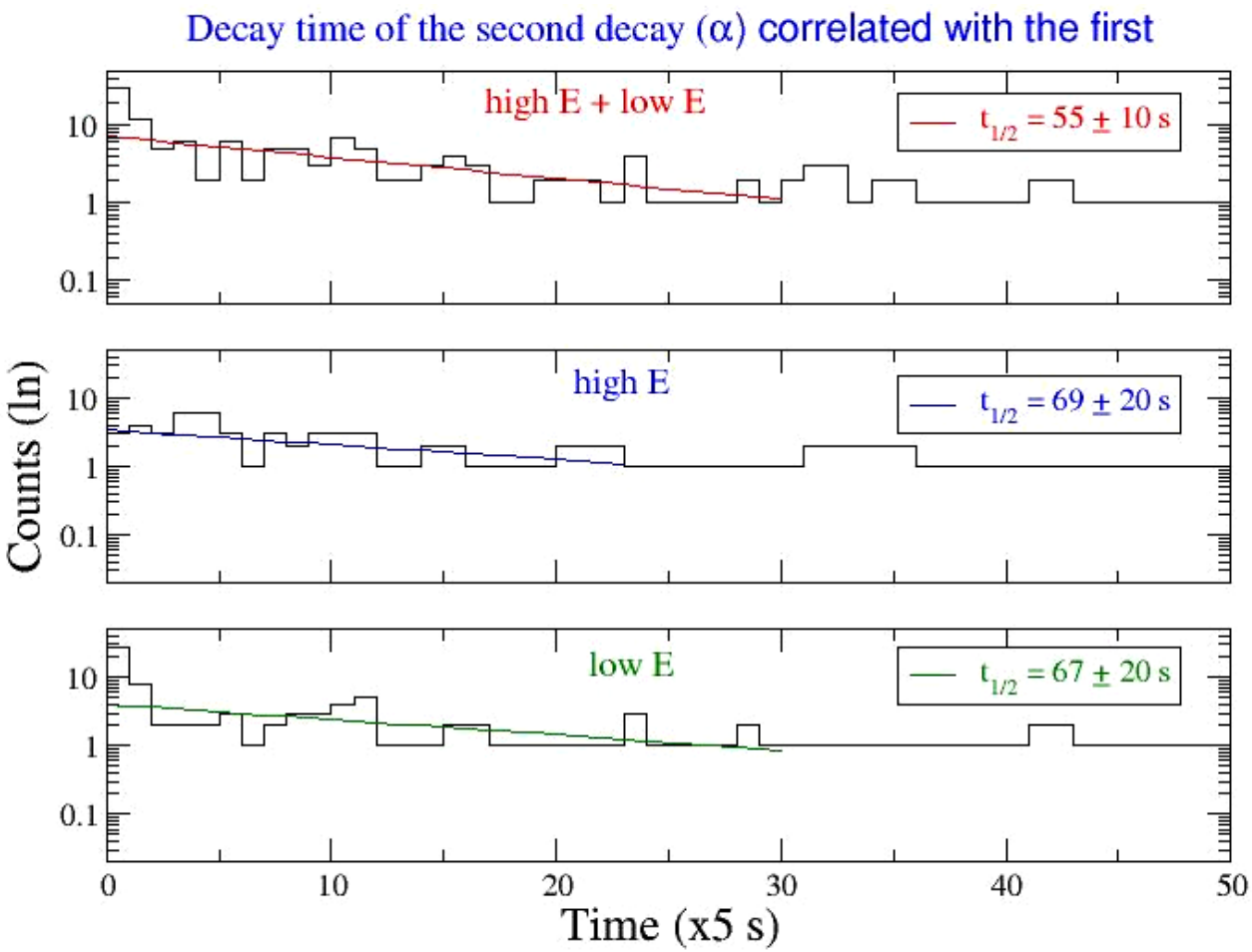
Results

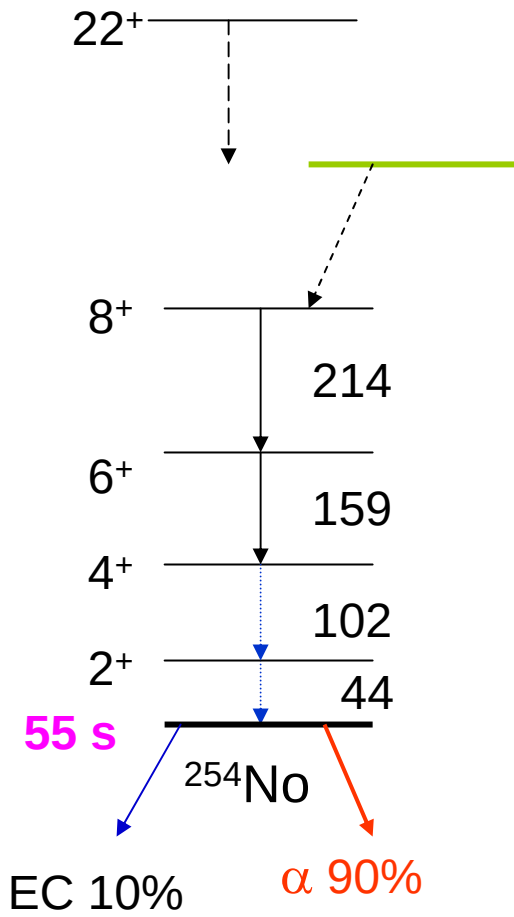
Decay time of the first decay (e^-) which are followed by α decay



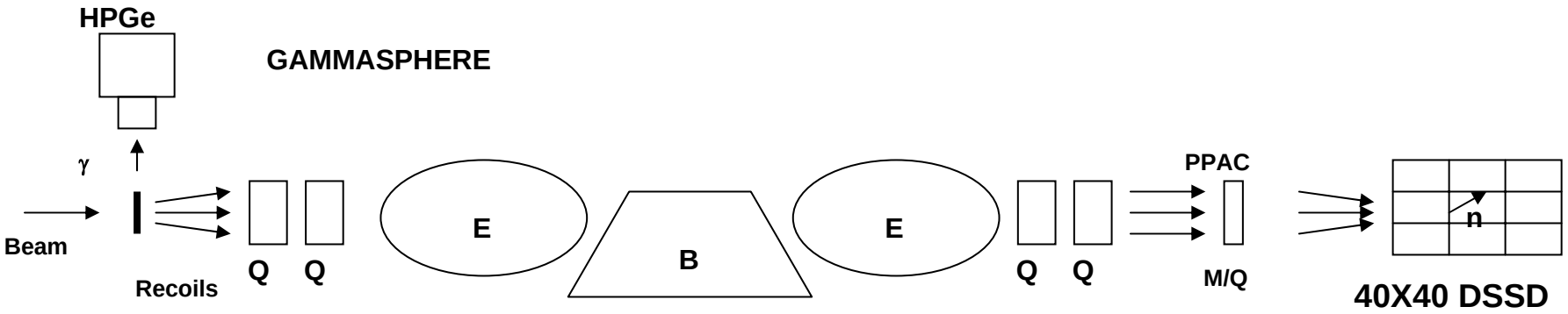


Results


Decay time of the second decay (α) correlated with the first
high E + low E
$t_{1/2}$ = 55 ± 10 s
high E
$t_{1/2}$ = 69 ± 20 s
low E
$t_{1/2}$ = 67 ± 20 s
Counts (ln)
Time (x5 s)


22+
8+
214
6+
159
4+
102
2+
44
55 s
254No
EC 10%
α 90%

$^{208}Pb(^{48}Ca,2n)$ Reaction

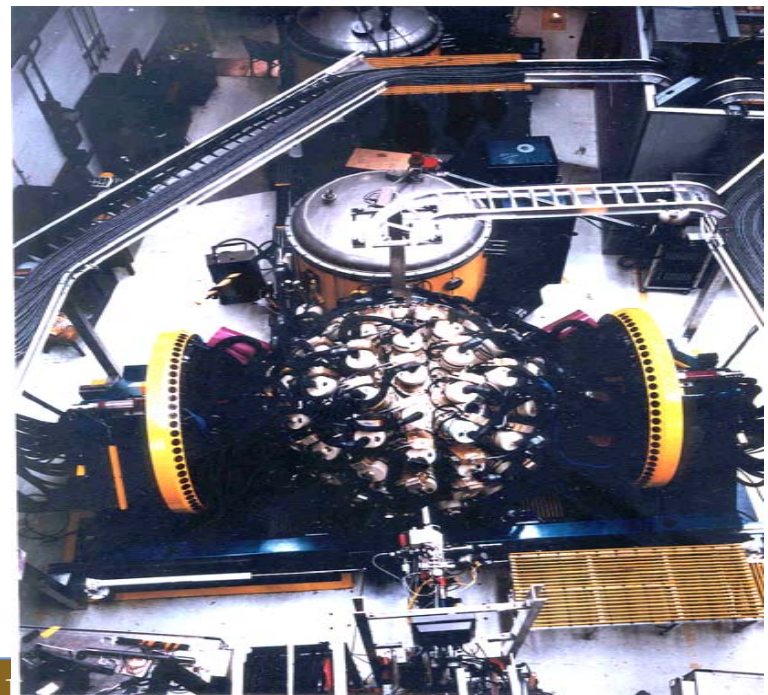


-Argonne Tandem Linac Accelerator System (ATLAS)

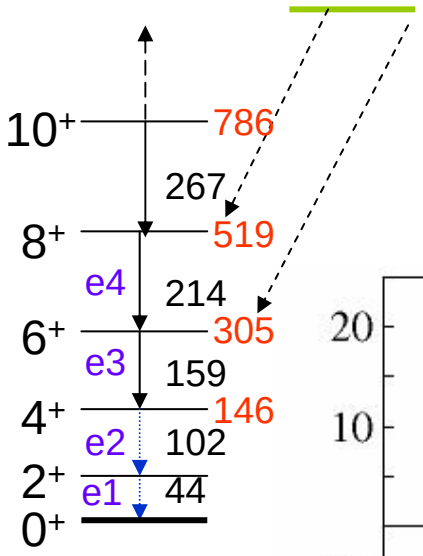
-Gammasphere

-Fragment Mass Analyzer (FMA)

-Double-Sided Silicon Strip Detector (DSSD)



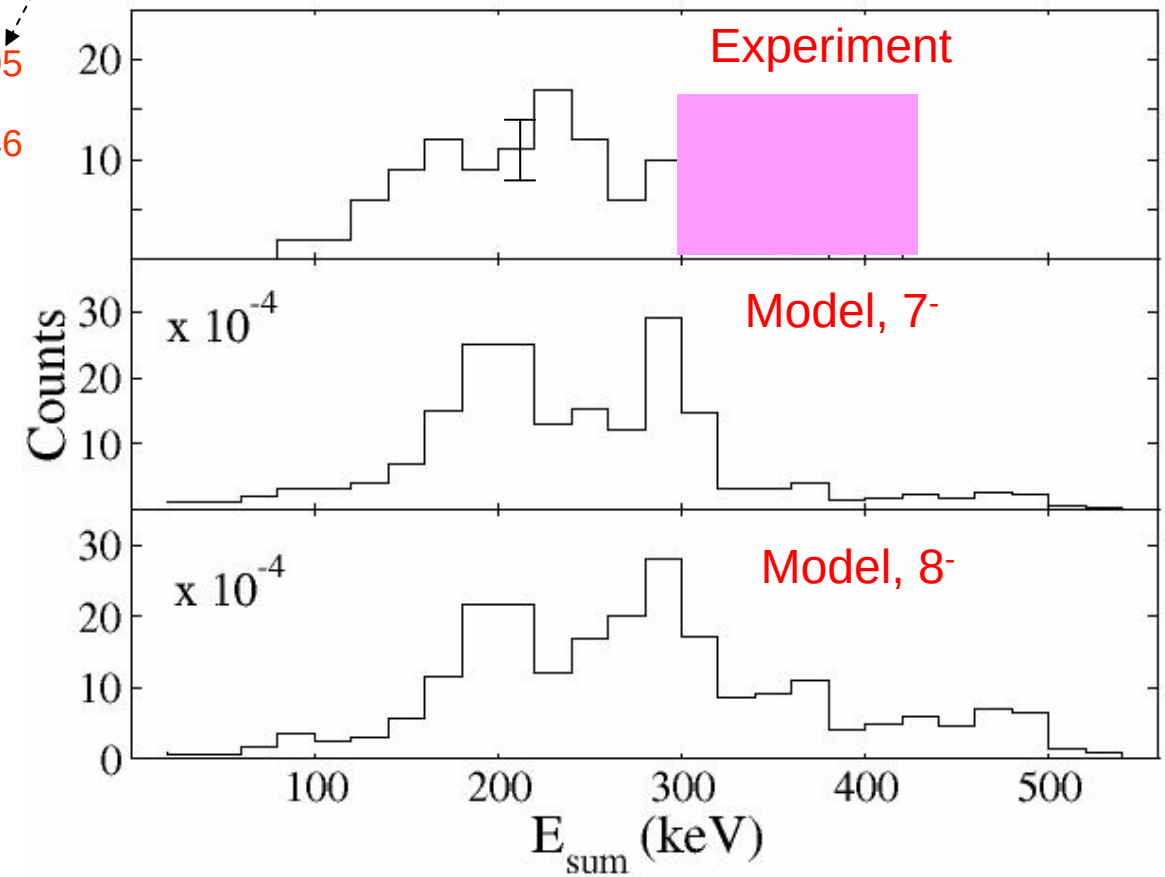
Electron spectrum



If Auger

$$E_{sum} = E_{tot} - \sum_{i=1}^{n} e_i + \Delta e_i + B.E - \cancel{E_{X\text{-}ray}} \quad n=1,2,3,4$$

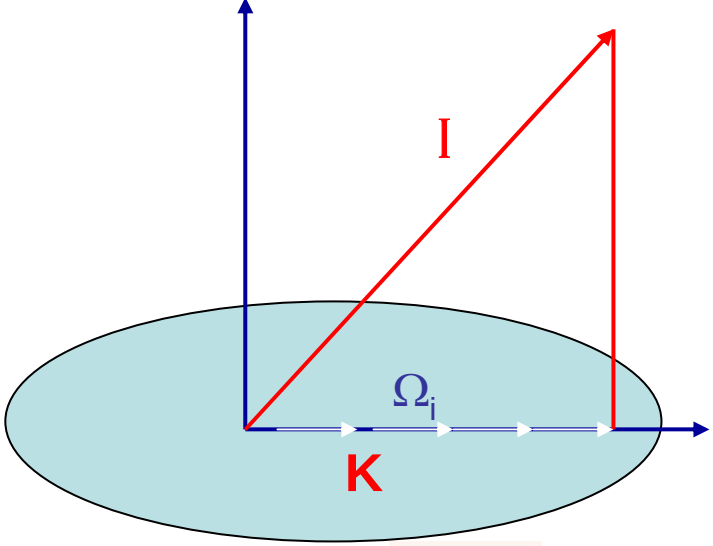
E_{tot} = Excitation energy, Δe = energy loss of electron in 4.5 μm,
B.E= Binding energy of electron and $E_{X\text{-}ray}$ = escape X-ray energy.



$$R_{hit} = \frac{N}{N_{tot}}$$

N = number of electrons with energy > 315 keV

N_{tot} = Total number of electrons in the spectrum.



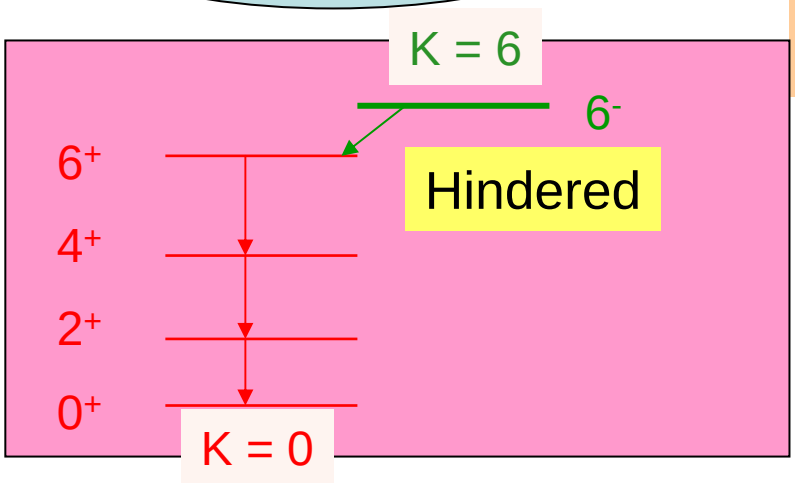
K is a "good" quantum number

K selection rule:

$\Delta K \leq \lambda$ (λ = transition multipolarity)

K-forbidden transition with $\Delta k > \lambda$ are hindered

➡ High K isomers



Larger Δk ➡ more hindrance ➡ more isomeric

Hindrance factor:

$$F_W = \frac{\text{Partial } \gamma\text{-ray halflife}}{\text{Weisskopf single particle estimate}}$$

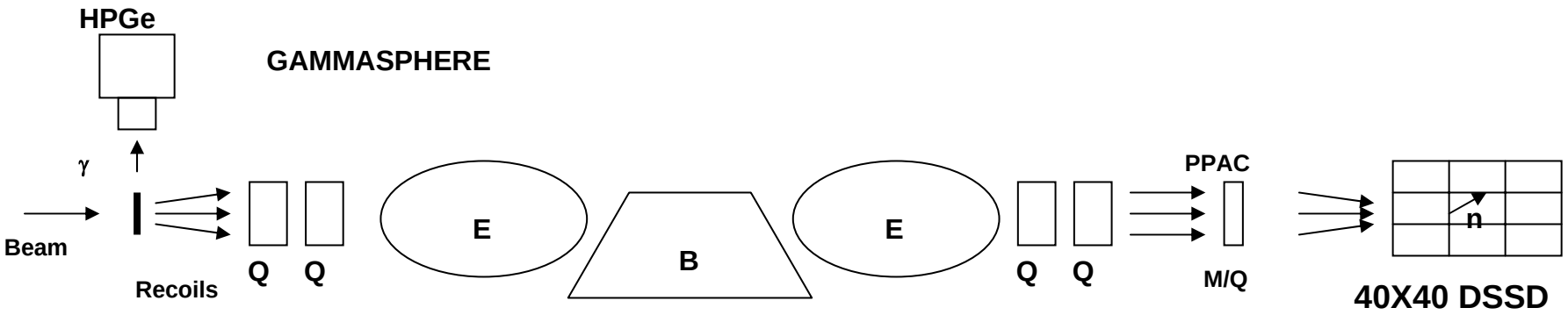
Reduced hindrance factor per Degree of K-forbiddenness:

$f_\nu = (F_W)^{1/\nu}$

ν = degree of forbiddenness = $\Delta k - \lambda$

Measure of the "goodness" of the K quantum number

$^{208}Pb(^{48}Ca,2n)$ Reaction



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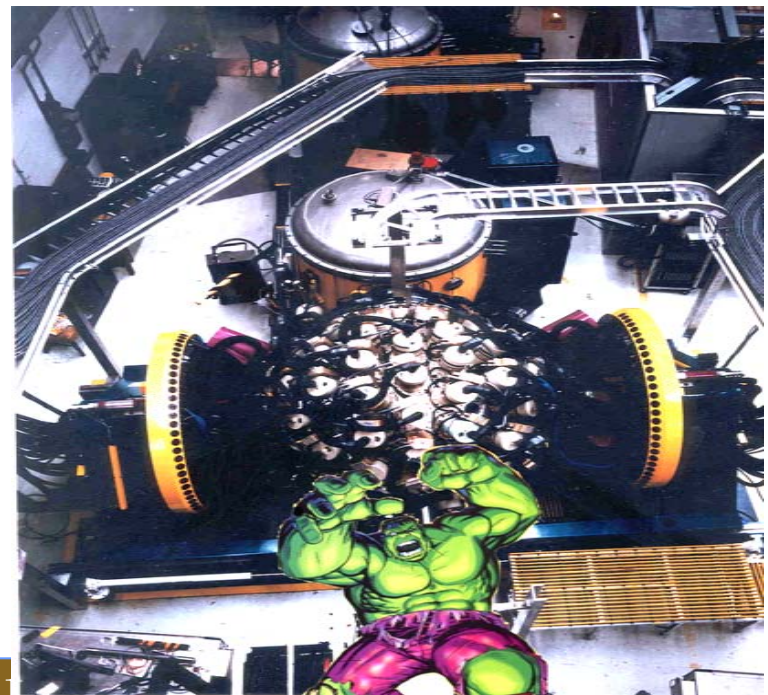

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