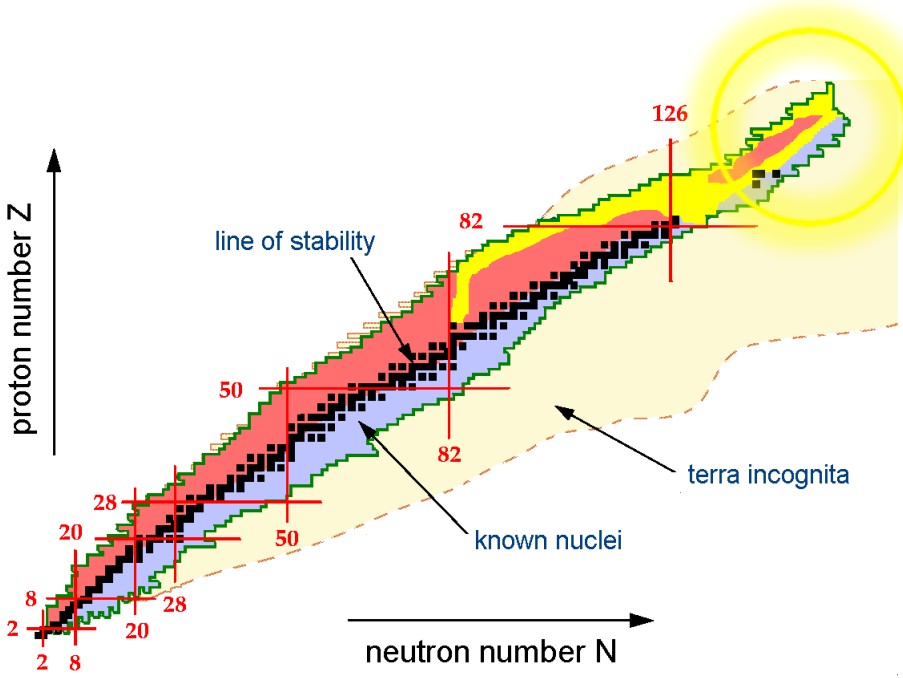
Fingerprinting Superheavy Elements with TASISpec

D. Rudolph, Lund University

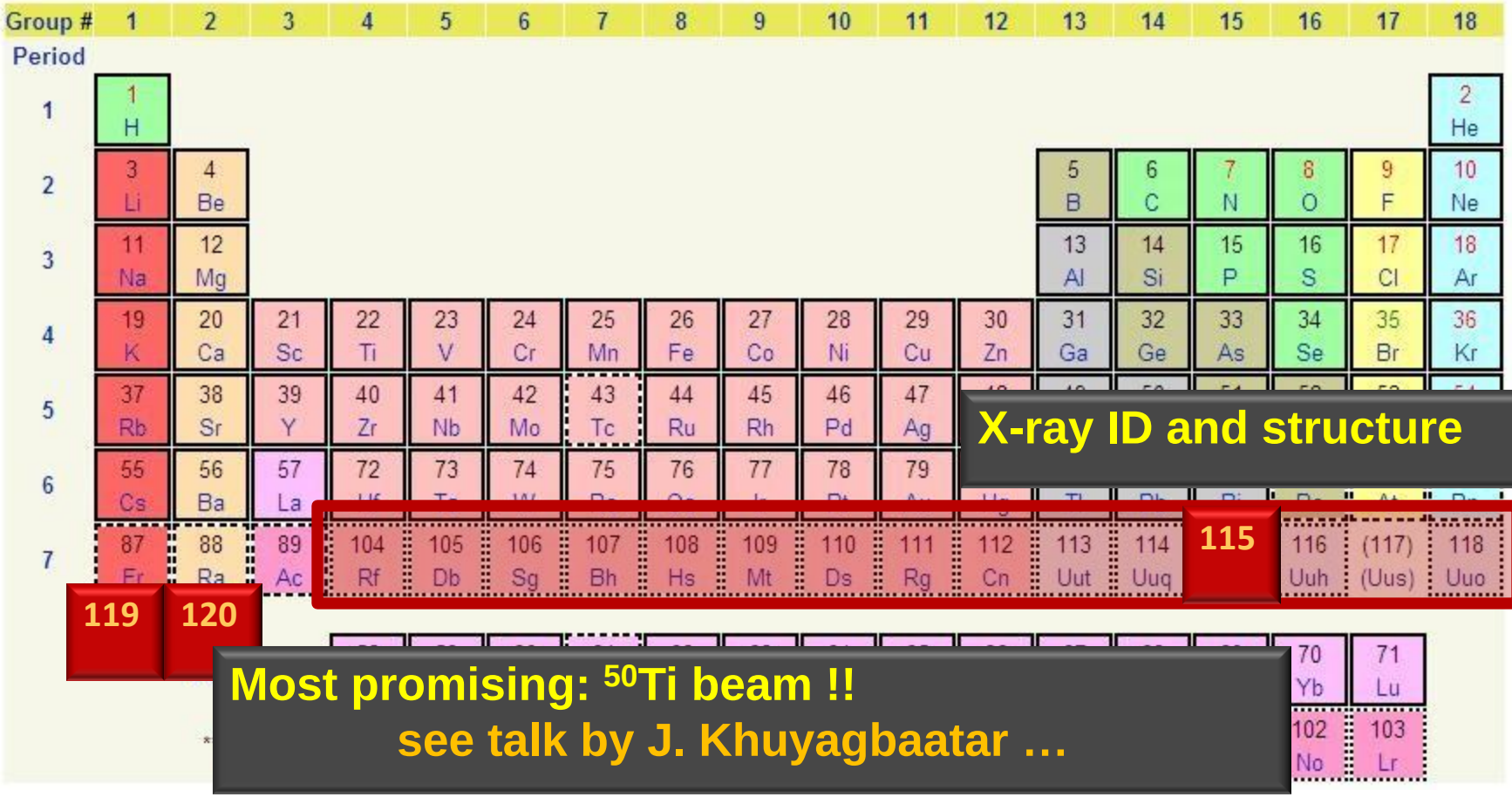
on behalf of TASISpec/TASCA collaborations

Fingerprinting Superheavy Elements

- Introduction & Status
- Fingerprinting with X-Rays – the Idea
- Results from the 2011 Preparatory Run
- Summary and Outlook



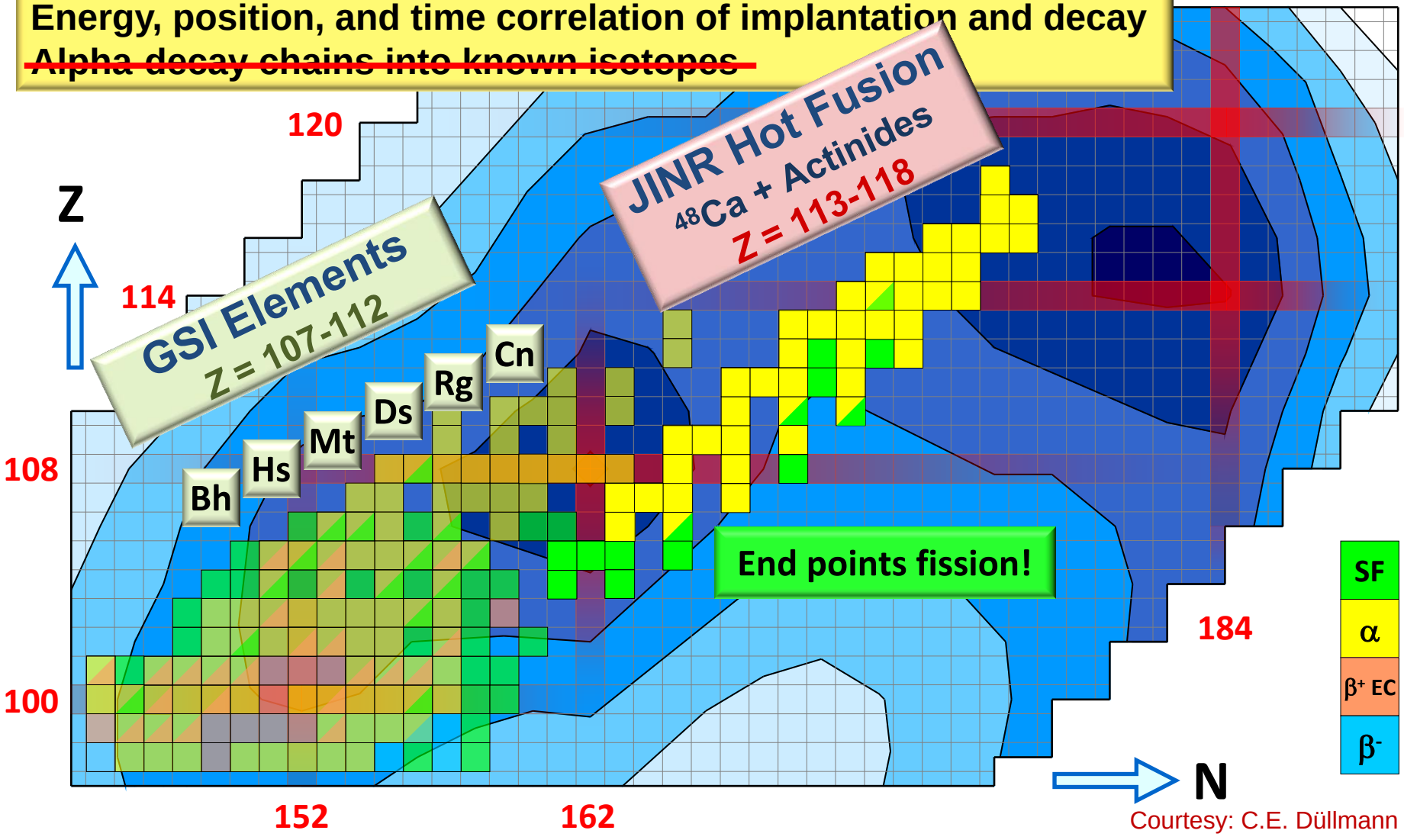
The Chemistry Perspective



The superheavy elements are the transactinides, $Z \geq 104$!

Identification Problem *Z* > 112

Separation and implantation of fusion-evaporation products
Energy, position, and time correlation of implantation and decay
~~**Alpha decay chains into known isotopes**~~



Courtesy: C.E. Düllmann

IUPAC/IUPAP 2011: 114 and 116 Approved!

News: Discovery of the Elements with Atomic Number 114 and 116

Priority for the discovery of the elements with atomic number 114 and 116 has been assigned, in accordance w **Dubna-Livermore Collaboration** n scientists from the Joint Institute for Nuclear Research in Dubna, Russia and from Lawrence Livermore, California, USA …

The IUPAC/IUPAP Joint Working Party (JWP) on the priority of claims to the discovery of new elements has reviewed the relevant literature pertaining to several claims. In accordance with the criteria for the discovery of elements … it was concluded that "the establishment of the ident **anchor nuclide ^{283}Cn (Z = 112)** caying chains, originating from a variety of production pathways essentially triangulating its A,Z character enables that nuclide's use in unequivocally recognizing higher-Z isotopes that are observed to decay through it."

From 2004 Dubna-Livermore collaborations th **cross-bombardment** and extend decay chain sequence for identification of Z = ^{287}114 from ^{48}Ca + ^{242}Pu fusion …; and (ii) tha suppo

Review conclu

Main (scientific) problem:

Neither direct Z nor mass identification!

doi:10.1351/PAC-REP-10-05-01 or see **R.C. Barber *et al.*, Pure Appl. Chem. 83, 1485 (2011)**

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Review conclu

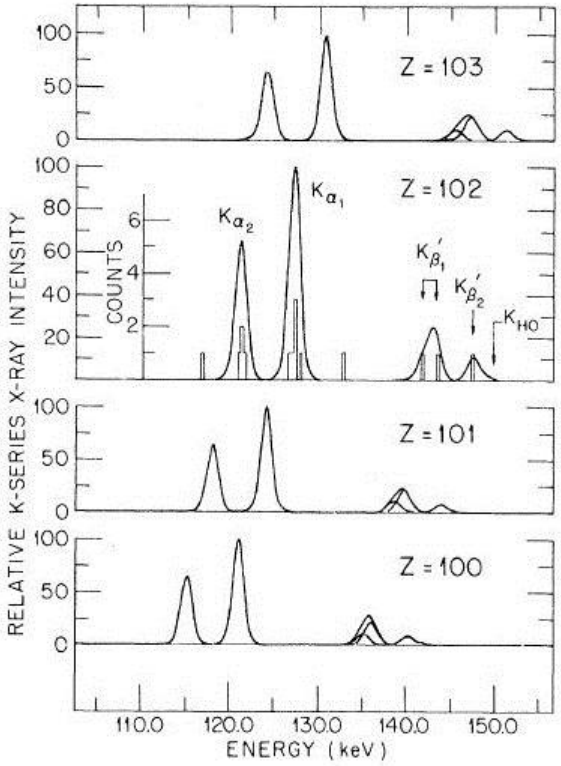
Opportunity:
"… overlap with prior results or *fully characterizing the identity of a descendent* in a chain are among the types of co-participation that would need to be carefully taken into account"

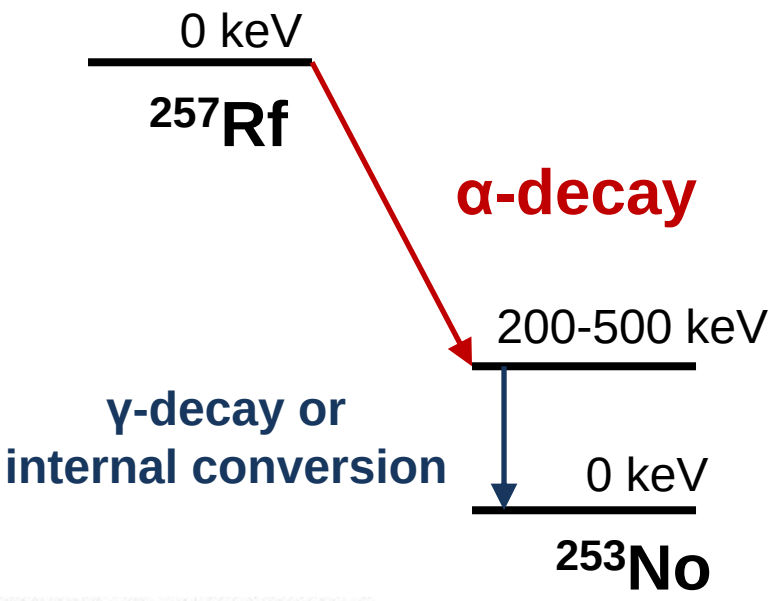
doi:10.1351/PAC-REP-10-05-01 or see **R.C. Barber *et al.*, Pure Appl. Chem. 83, 1485 (2011)**

TASISpec: X-ray Fingerprinting of E115

in the spirit of

R. Bemis *et al*., PRL31, 647 (1973)





K X rays!

15 alpha-photon coincidences consistent with No (*Z* = 102) *K* X rays

Identification of Rf (*Z* = 104)

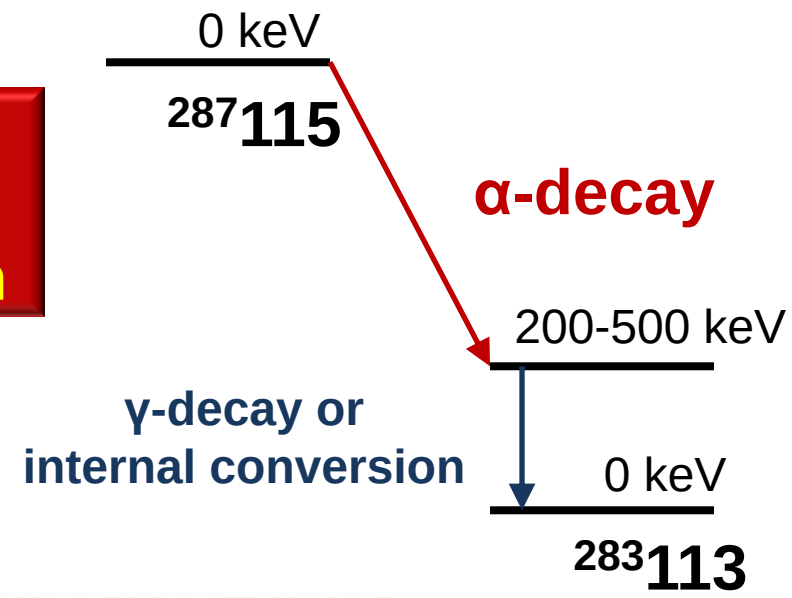
TASISpec: X-ray Fingerprinting of E115

- long odd-mass decay chains
- reasonable production cross section

Z **- Identification of E115 chain**

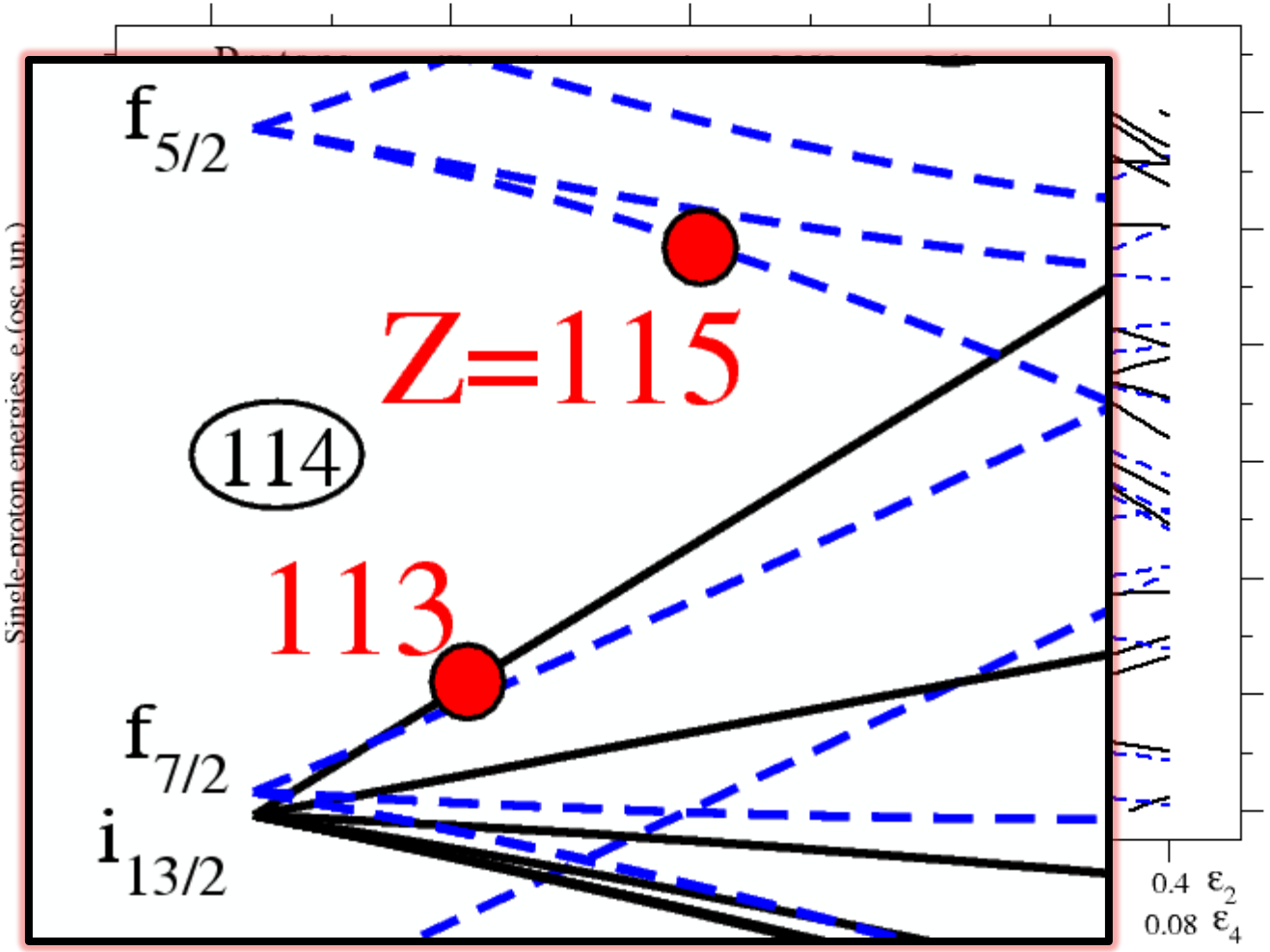
8 weeks approved at GSI
(including ENSAR funds!)

1 week used to define optimum running scheme
(June 2011)



TASISpec: X-ray Fingerprinting of E115

Proton single-particle energies



I. Ragnarsson, B.G. Carlsson, Lund

^{287}115 has $f_{5/2}$ –based ground state

Known $T_{1/2}$ indicates favoured alpha decay
(Yu.T. Oganessian et al.)

This implies either
$f_{5/2} \rightarrow f_{5/2}$ (sph)
5/2[503] → 5/2[503] (obl)
1/2[521] → 1/2[521] (prol)
The latter are lowest in energy *at these shapes* in the daughter ^{283}113 …

… but are expected at ~500 keV excitation energy with respect to the $f_{7/2}$ –based ground state of ^{283}113!

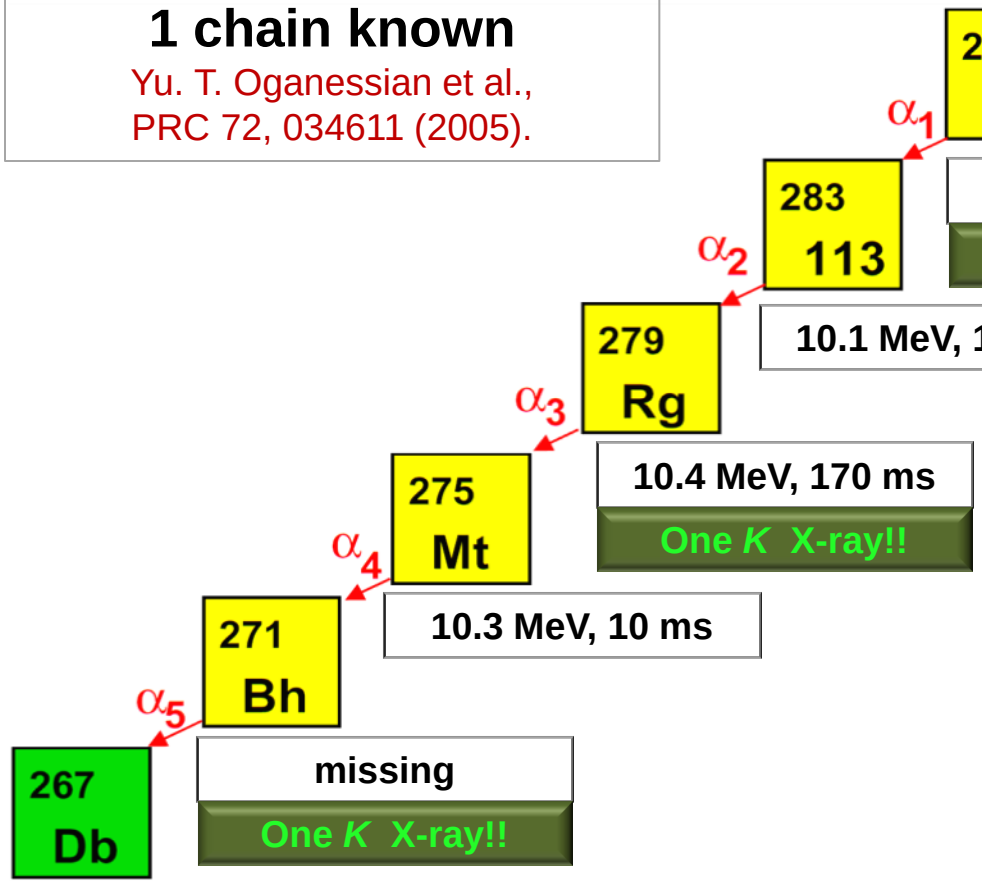
TASISpec: X-ray Fingerprinting of E115

$^{243}Am(^{48}Ca,4n)^{287}115$

~10 chains expected in 8 weeks

1 chain known

Yu. T. Oganessian et al.,
PRC 72, 034611 (2005).



Total appearing @ TASISpec:
3 · 10 = 30 α-*K* X-ray coincidences

Total (to be) observed:
30 · 80% · 40% = 10 α-*K* X-ray coincidences

Bonus track: ≥ 20 $^{288}115$ chains

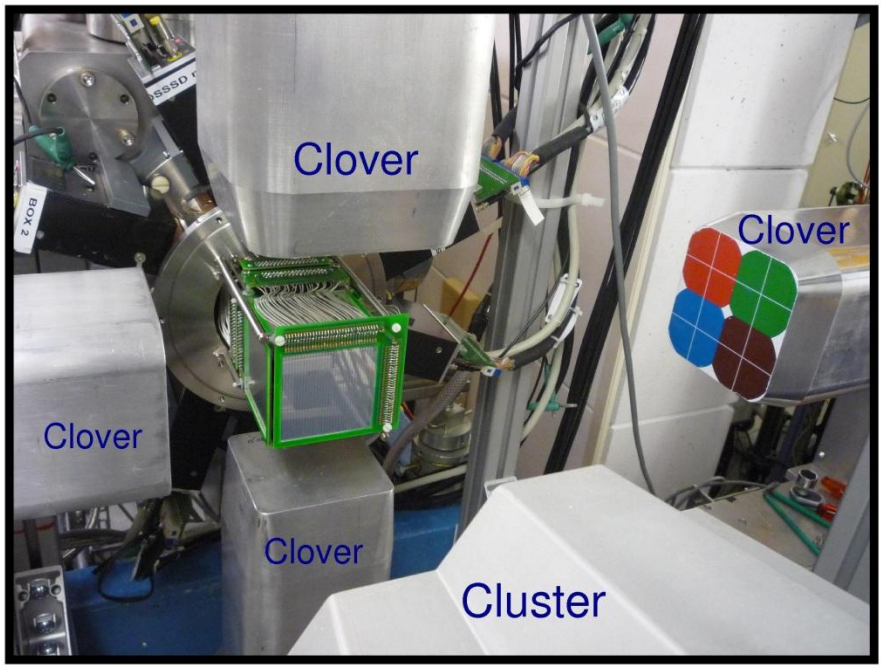
cf. F.P. Heβberger et al., EPJA 43, 175 (2010),
observed two α-K_α coincidences $^{261}Bh \rightarrow {}^{257}Db$

TASISpec

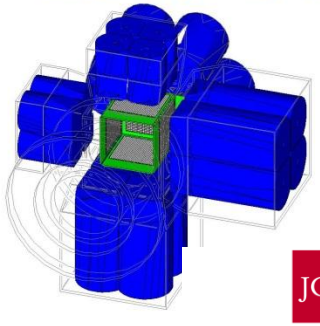
Highly efficient multi–coincidence spectroscopy set–up for TASCA's very compact focal plane image

1 Implantation DSSSD (1024 pixels)
4 box–DSSSDs (1024 pixels)
=> ~80% α–detection efficiency

4 Ge Clover (4*4 crystals)
1 Ge Cluster (7 crystals)
=> ~40% γ–detection eff. at 150 keV



L–L Andersson et al., NIM A 622, 164 (2010)
L.G. Sarmiento et al., NIM A 667, 26 (2011)



Virtually constructed with GEANT4 simulation package

LUND UNIVERSITY
UNIVERSITY OF LIVERPOOL
HELMHOLTZ ASSOCIATION
Helmholtz Institute Mainz
GSI
UNIVERSIDAD NACIONAL DE COLOMBIA
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

E115

OAK RIDGE NATIONAL LABORATORY
Managed by UT-Battelle for the Department of Energy

^{243}Am target material

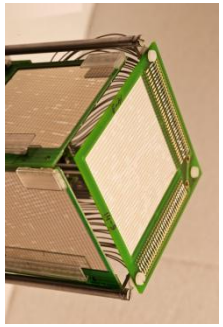
TASISpec E115: The Schematic Setup

beam | target wheel | separator | detectors

^{48}Ca, 2·10^{13}/s
in pulse
ECR + UNILAC

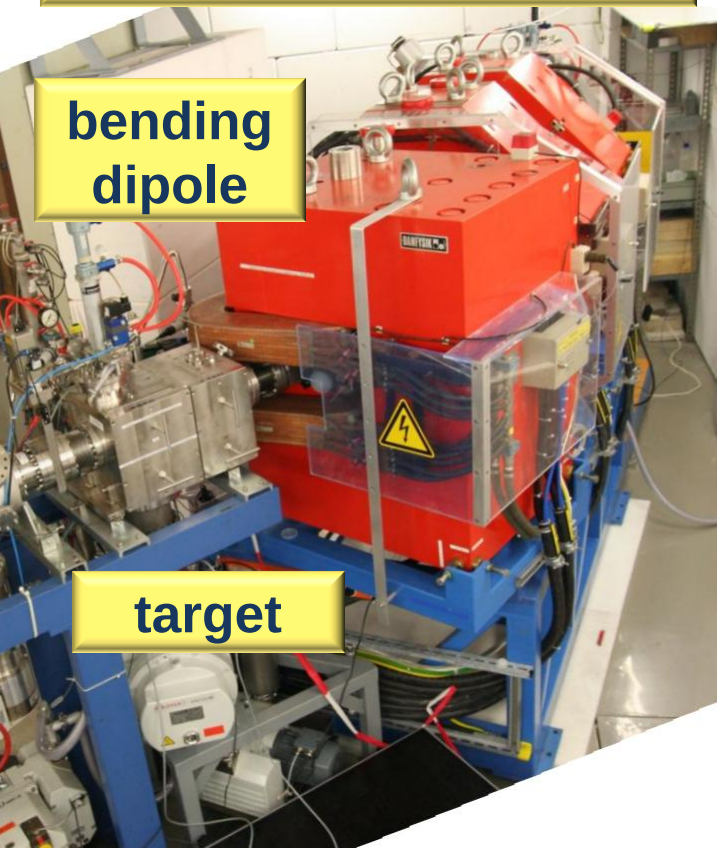
2x ^{243}Am
≥0.5 mg/cm^2

High Transmission Mode
or
Small Image Mode ?



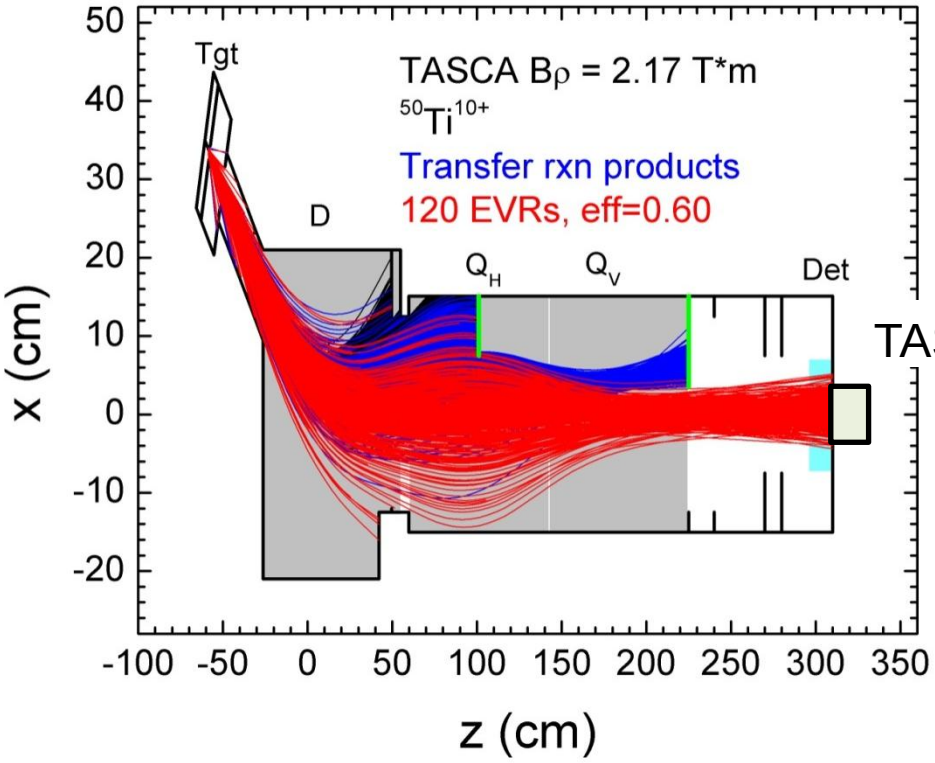
TASISpec

TASCA Background Reduction



Gas-filled separator
TASCA

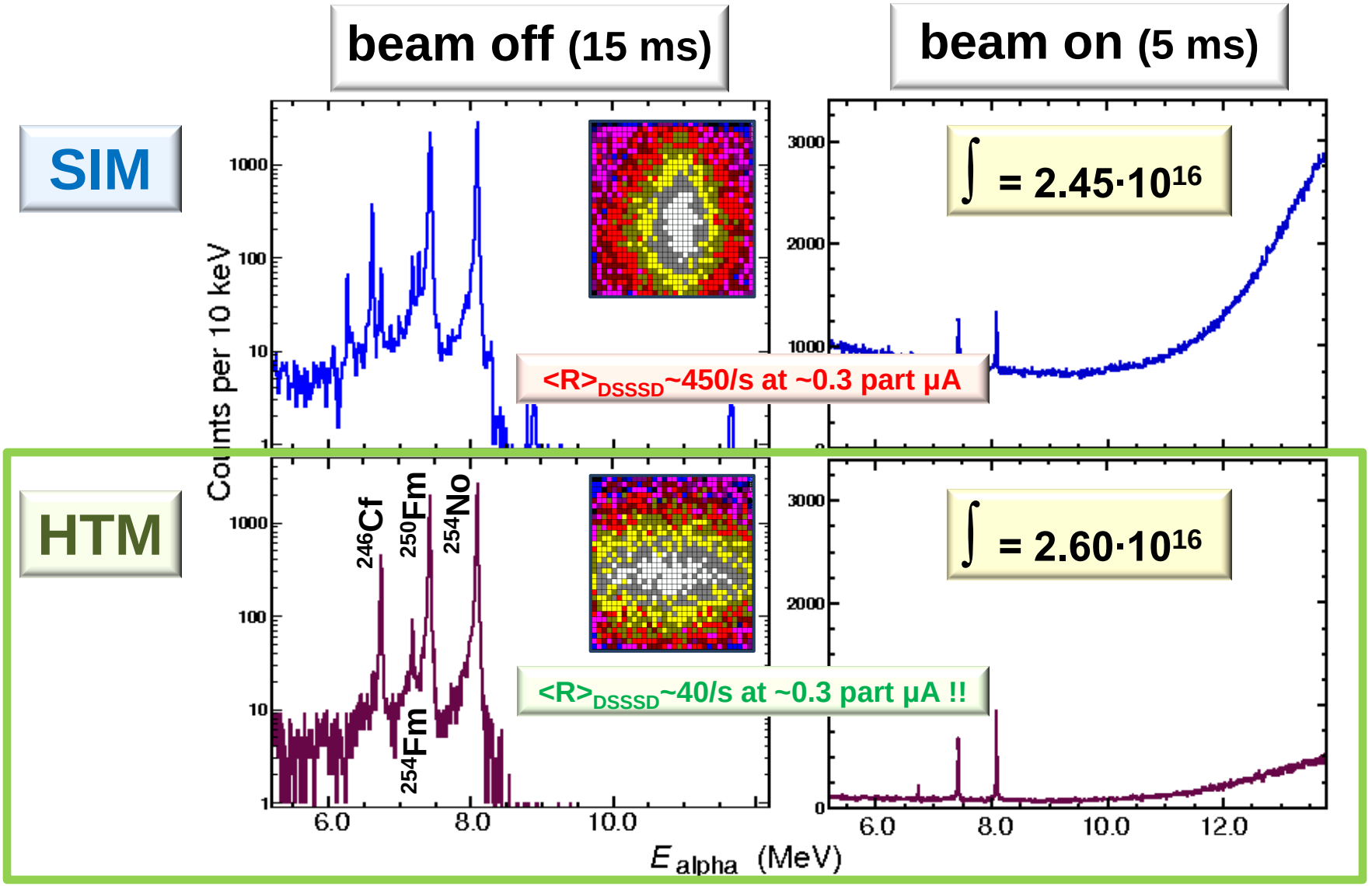
Background reduction successful by introducing two slits; concluding tests during E115 week.



J.M. Gates *et al.*: use SLITS !!

Simulations E115: U. Forsberg

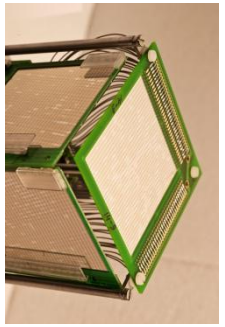
TASISpec Background: $^{208}Pb(^{48}Ca,2n)^{254}No$



U. Forsberg, PhD thesis, Lund University

TASISpec E115: Ready to Run at Any Time

beam | target wheel | separator | detectors



^{48}Ca, 2·10^{13}/s
in pulse
ECR + UNILAC

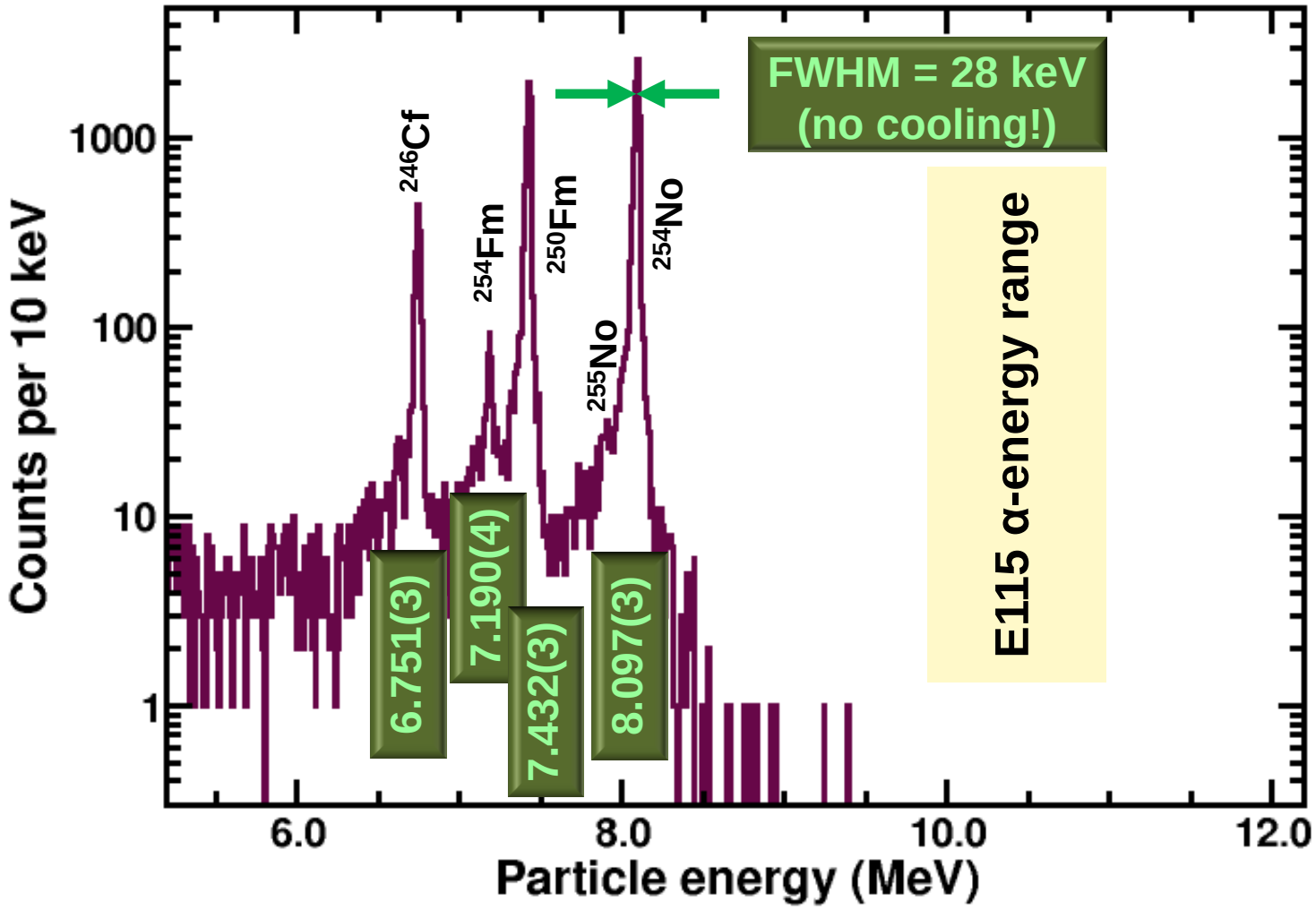
2x ^{243}Am
≥0.5 mg/cm^2

TASISpec

TASISpec: $^{208}Pb(^{48}Ca,2n)^{254}No$

HTM

beam off (15 ms)

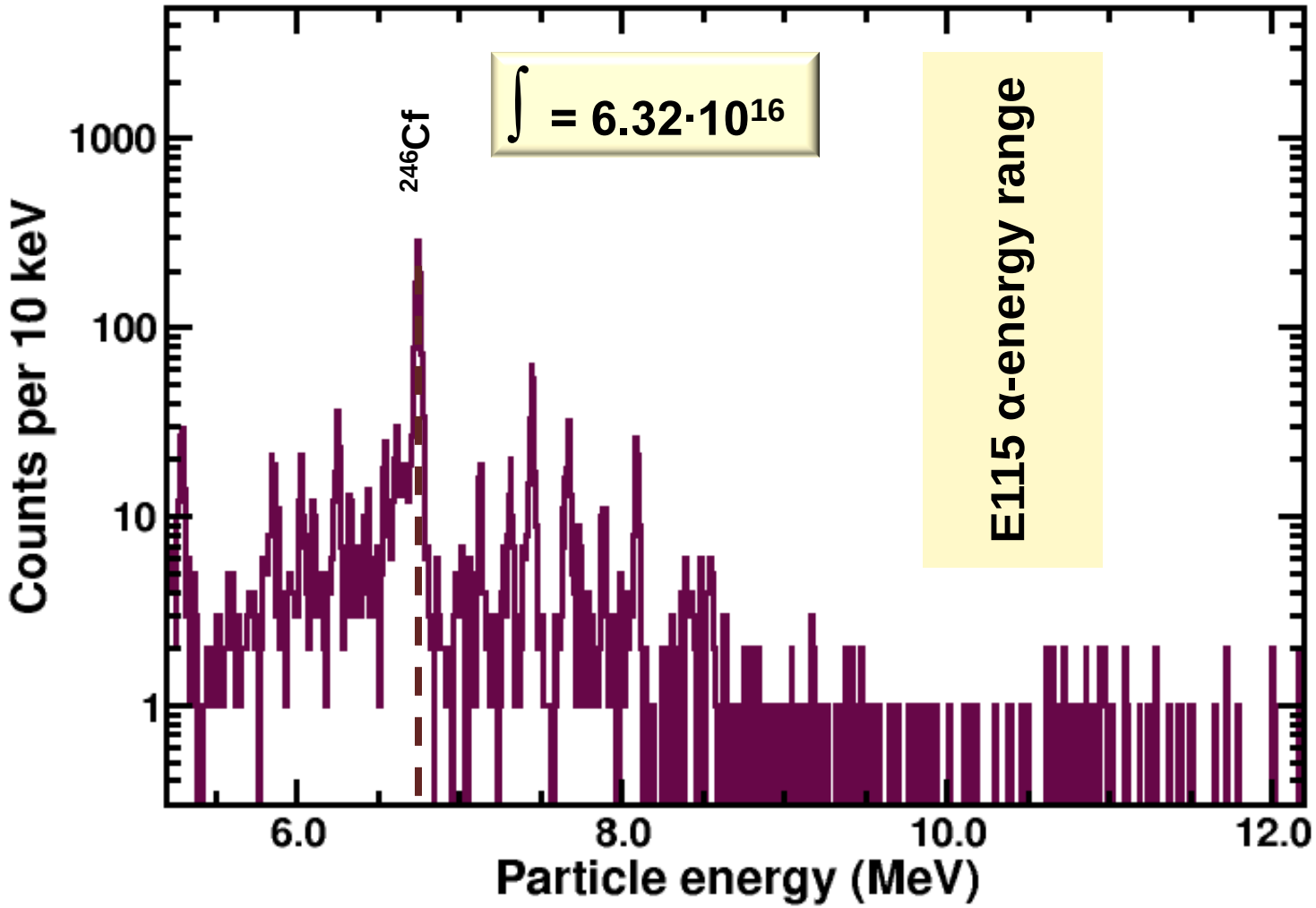


TASISpec: ^{243}Am(^{50}Ti,x*n*)$^{293-x}$117

HTM

beam off (15 ms)

<R>$_{DSSSD}$~30/s at ~0.6 part μA



TASISpec: ^{243}Am(^{50}Ti,x*n*)$^{293-x}$117

HTM

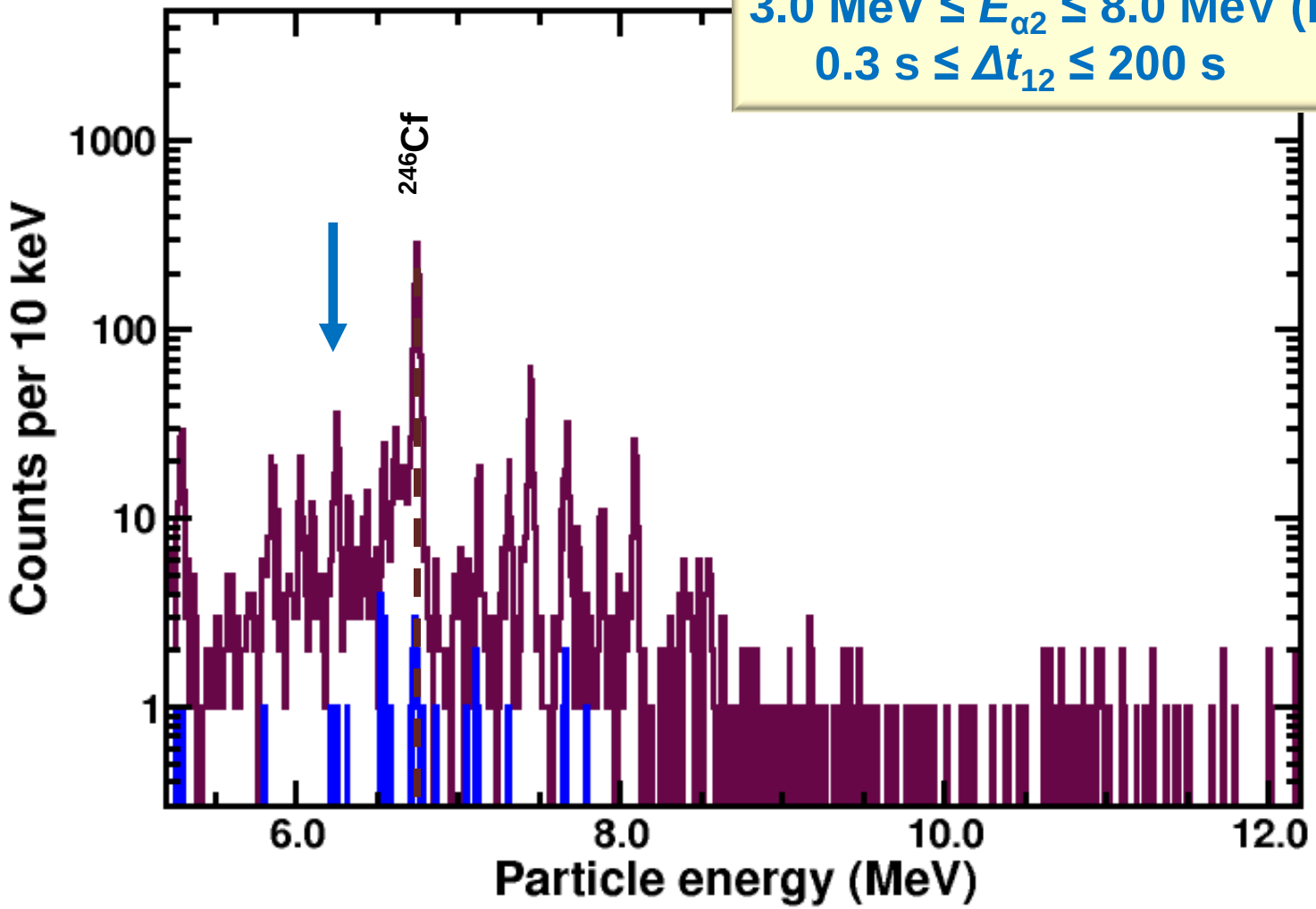
beam off (15 ms)

α-α correlations #1:

6.2 MeV ≤ $E_{\alpha 1}$ ≤ 6.4 MeV (beam off)

3.0 MeV ≤ $E_{\alpha 2}$ ≤ 8.0 MeV (beam off)

0.3 s ≤ Δt_{12} ≤ 200 s



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HTM

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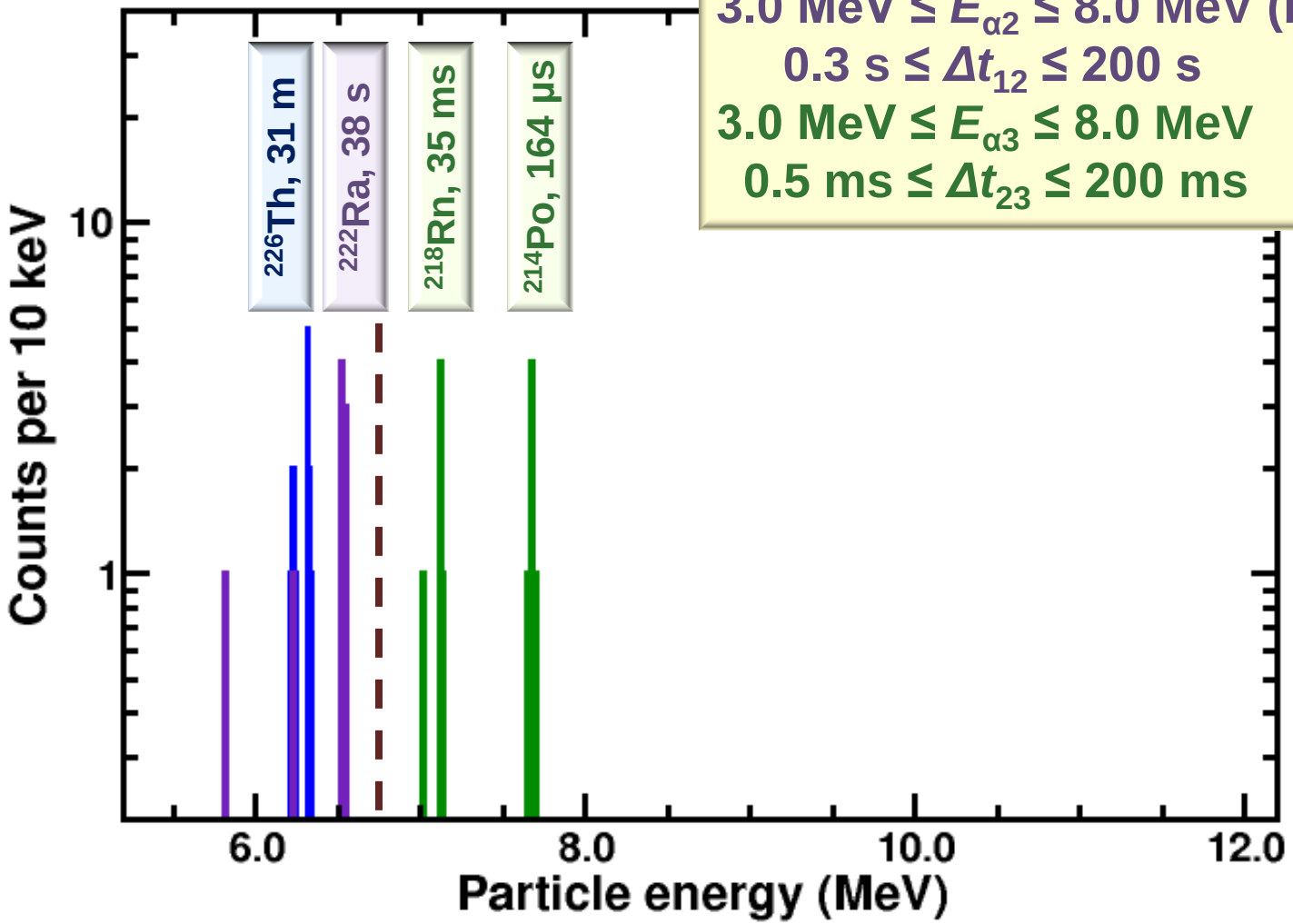
3.0 MeV ≤ $E_{\alpha 2}$ ≤ 8.0 MeV (beam off)

0.3 s ≤ Δt_{12} ≤ 200 s

3.0 MeV ≤ $E_{\alpha 3}$ ≤ 8.0 MeV (off/on)

0.5 ms ≤ Δt_{23} ≤ 200 ms



TASISpec: ^{243}Am(^{50}Ti,x*n*)$^{293-x}$117

HTM

α-α-α correlations #2:

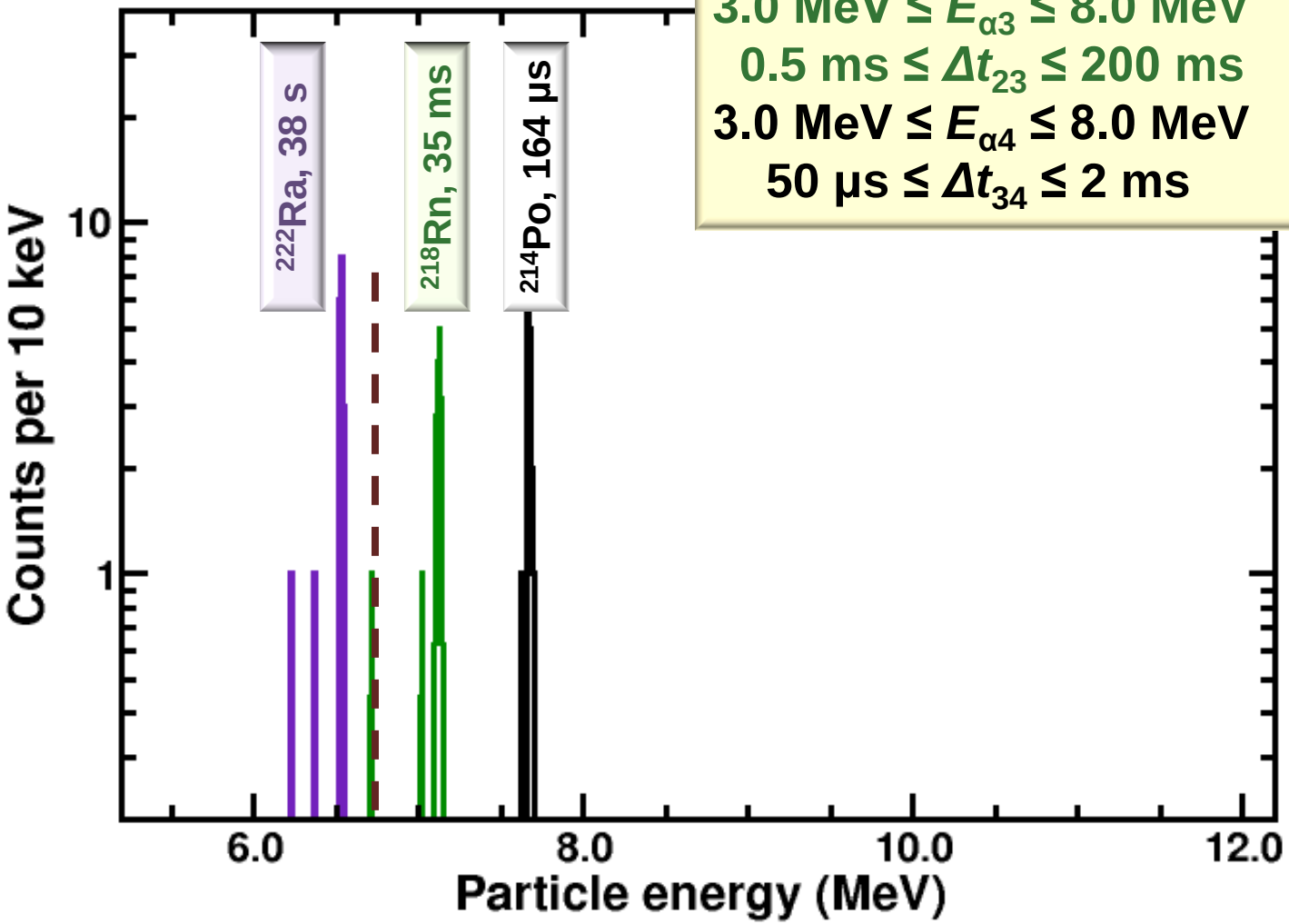
6.2 MeV ≤ $E_{\alpha 2}$ ≤ 6.6 MeV (off/on)

3.0 MeV ≤ $E_{\alpha 3}$ ≤ 8.0 MeV (off/on)

0.5 ms ≤ Δt_{23} ≤ 200 ms

3.0 MeV ≤ $E_{\alpha 4}$ ≤ 8.0 MeV (off/on)

50 µs ≤ Δt_{34} ≤ 2 ms



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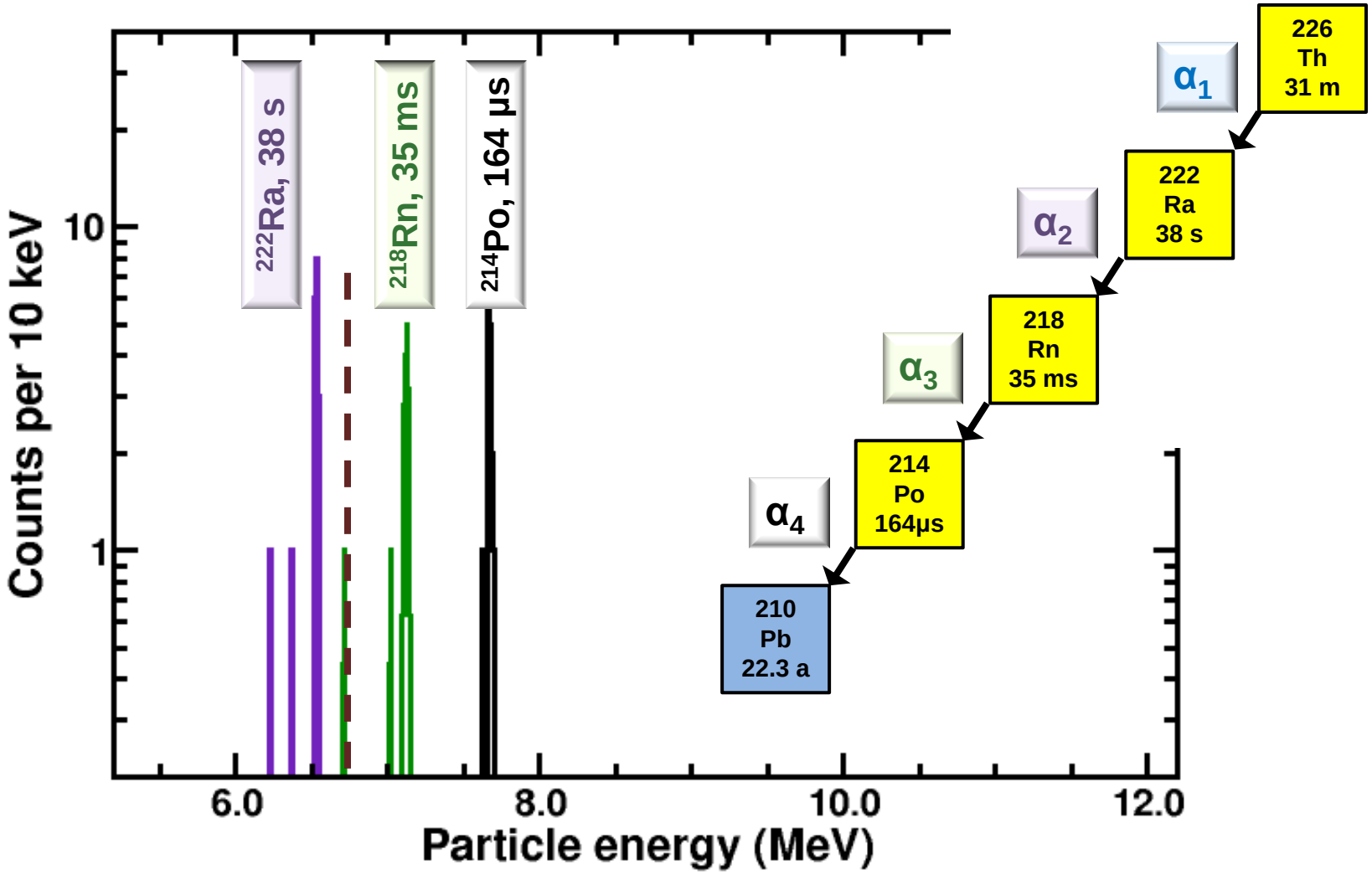
HTM



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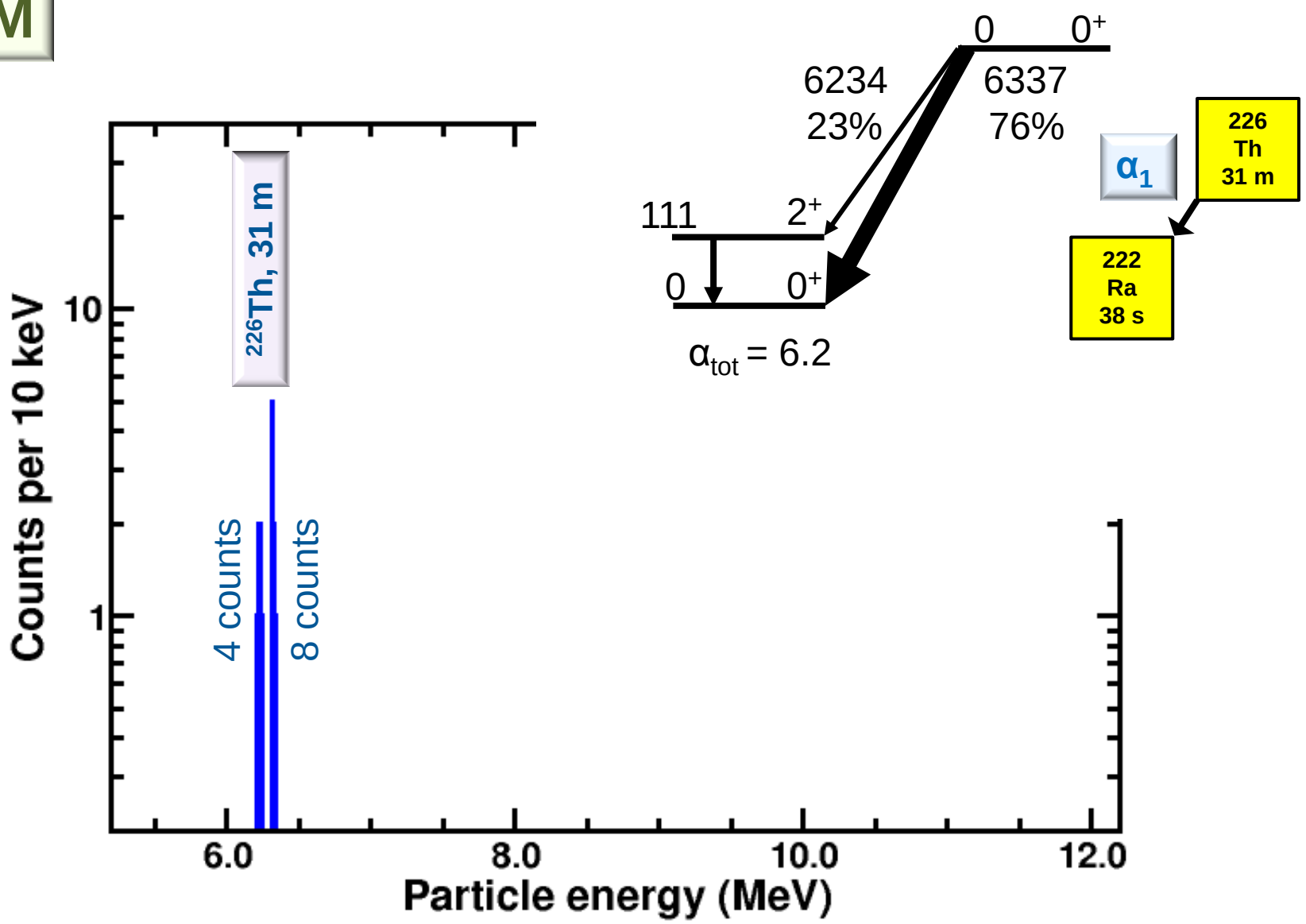
HTM



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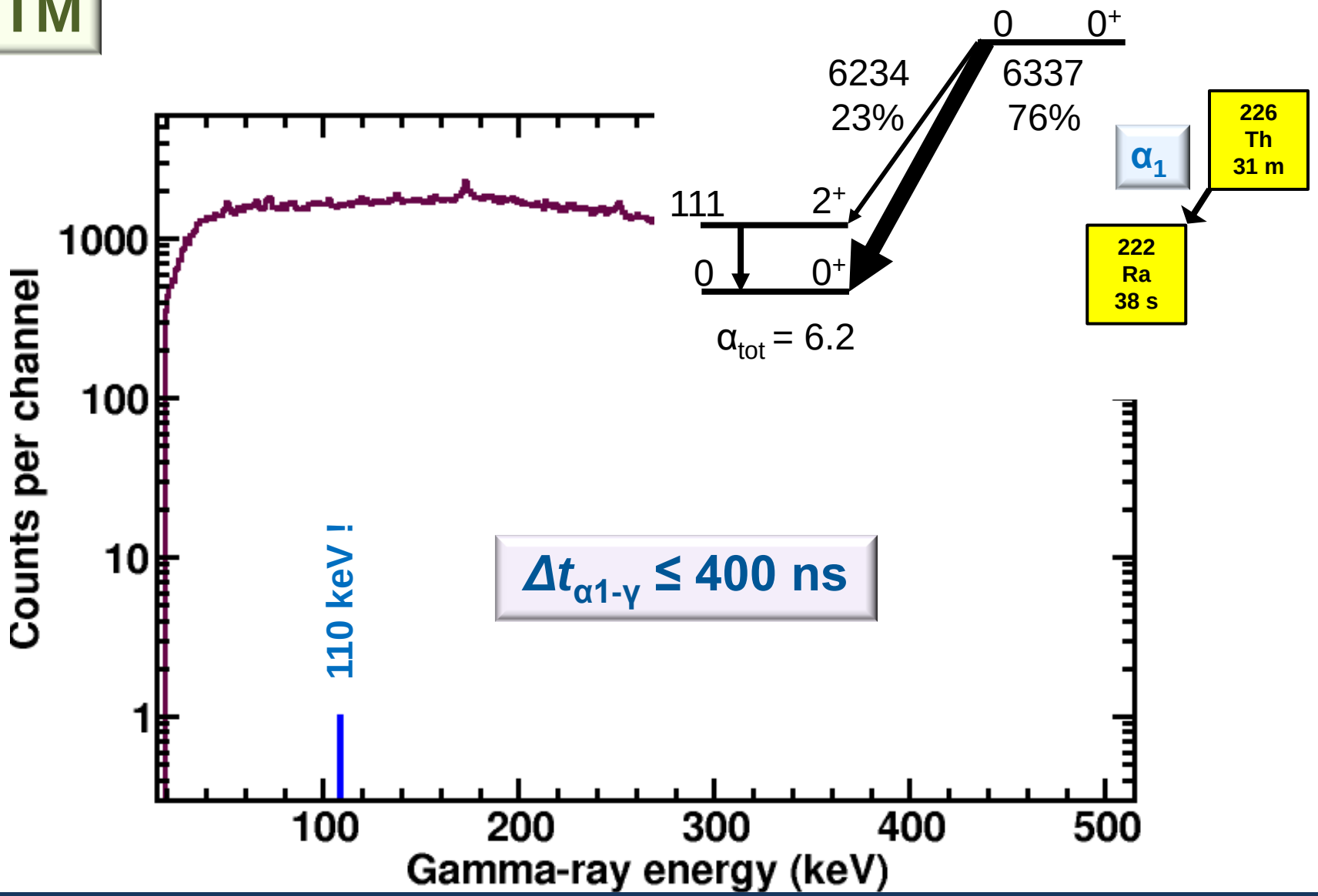


TASISpec: ^{243}Am(^{50}Ti,x*n*)$^{293-x}$117

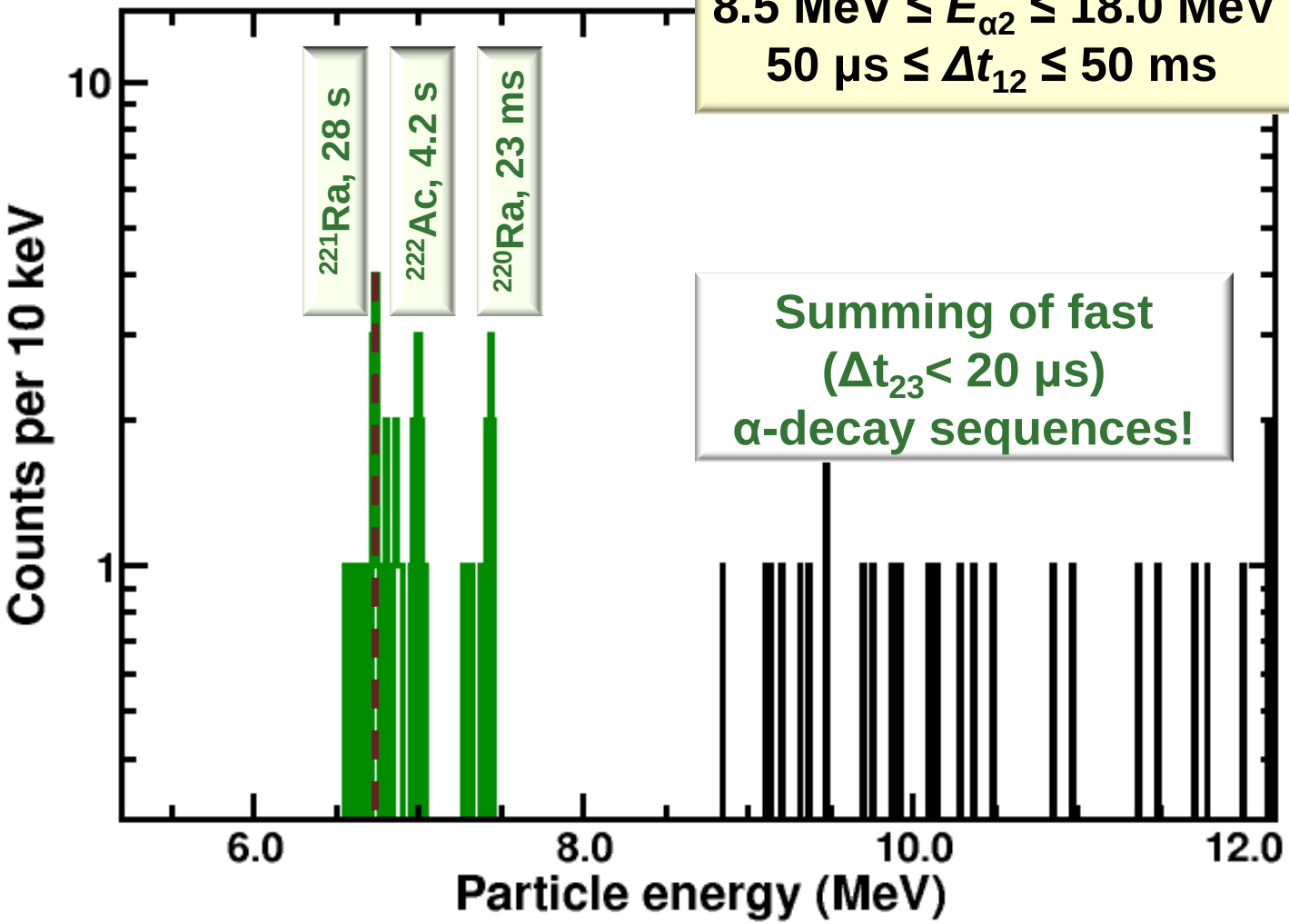
HTM

α-α correlations #2:

6.5 MeV ≤ $E_{α1}$ ≤ 7.6 MeV (beam off)

8.5 MeV ≤ $E_{α2}$ ≤ 18.0 MeV (beam off)

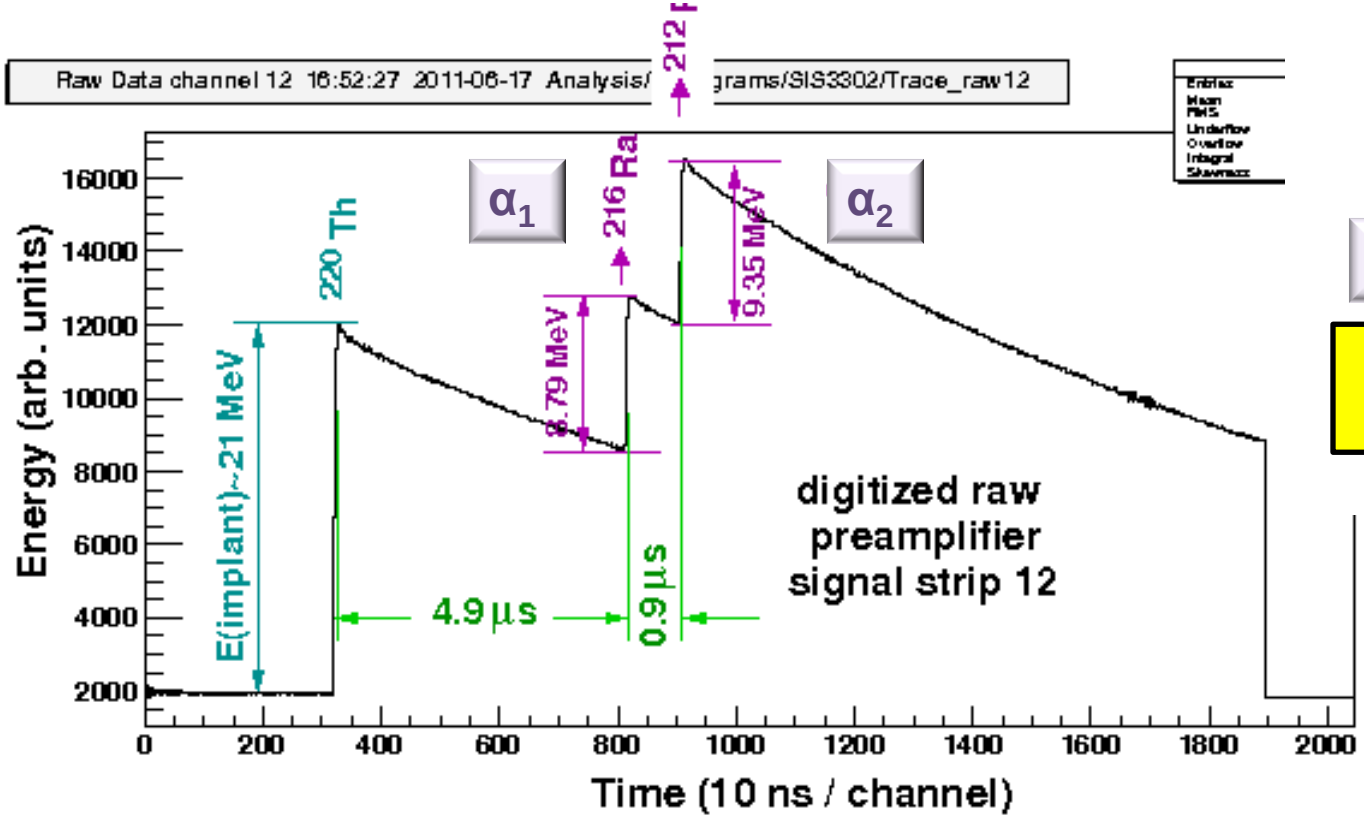
50 μs ≤ Δt_{12} ≤ 50 ms

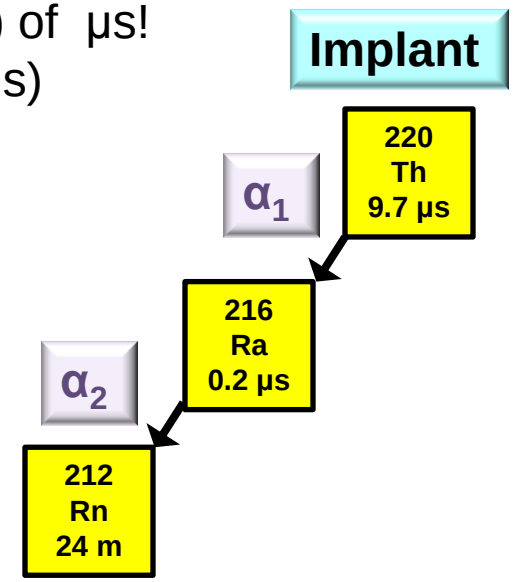


Summing of fast (Δt_{23}< 20 μs) α-decay sequences!

Fast Alpha Decays – Sampling Electronics

Electronics and data acquisition, dead time several (tens) of μs!
(eventually misses implantation-decay correlations)





The 2011 *Z*=120 *TASCA* experiment was performed with dead-time free sampling ADC cards developed at GSI-EE N. Kurz *et al*.

Outlook

June 2011, week 1 of U261:
X-ray Fingerprinting of E115 decay chains
IUPAC: *"… fully characterizing the identity of a descendent in a chain …"*

- **1st 3rd: no beam!**
- **2nd 3rd: established E11[illegible] …odest) ^{48}Ca beam**
  - ✓ **upgra[illegible]**
  - ✓ **TASC[illegible] …transmission, …**
  - ✓ **basic [illegible] beam shut-off function**
  - ➢ **(may) upgrade to GSI-EE FEBEX digital electronics (Lund)**
  - ➢ **(may) include NaI anti-Compton cubes (Liverpool)**
- **3rd 3rd: final readiness tests for TASCA E120 (summer 2011)**
  - ✓ **more s[illegible]**
  - ✓ **the ^{50}Ti[illegible]**
  - ✓ **digital [illegible]**

READY to run at any time (spring 2013 !?)

For more details:
see talk by J. Khuyagbaatar …