Isomers close to the $^{170}Dy_{104}$ Valence Maximum: First Spectroscopy of $^{165,167,168}Tb$

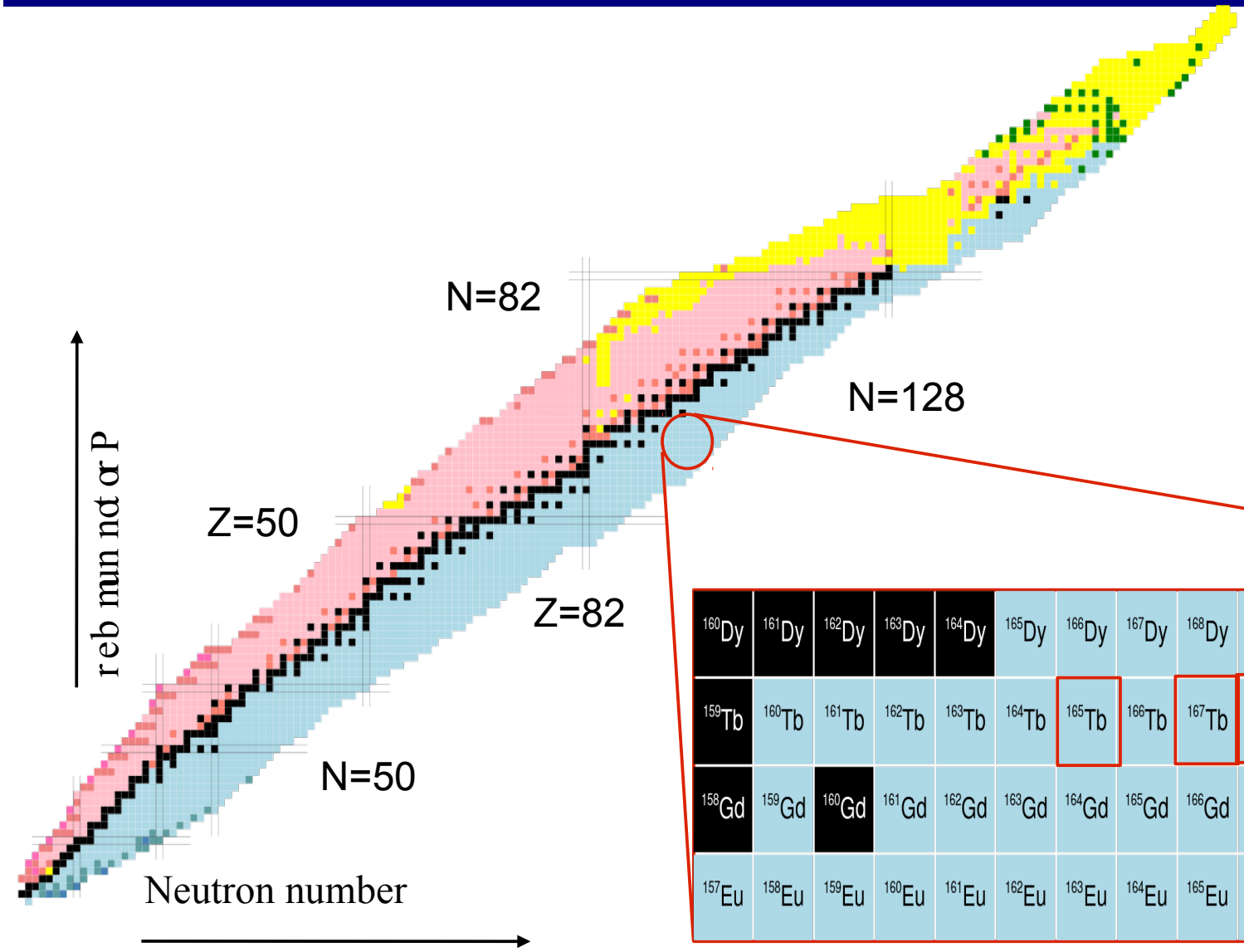
Laila.A Gurgi
Department of Physics
University of Surrey
Guildford, GU2 7XH, UK

l.a.gurgi@surrey.ac.uk

Outline

- Experimental details
- Range of nuclear species identified in the experiment
- Delayed gamma-ray spectroscopy of terbium (Z=65) isotopes
- Preliminary level schemes for ^{165,167,168}Tb.
- Suggested deformed single and multi-particle configurations for the observed isomeric states.
- Blocked BCS calculations
- Data analysis on-going .

The nuclear landscape



^{160}Dy	^{161}Dy	^{162}Dy	^{163}Dy	^{164}Dy	^{165}Dy	^{166}Dy	^{167}Dy	^{168}Dy	^{169}Dy	^{170}Dy	^{171}Dy	^{172}Dy	^{173}Dy	^{174}Dy	Dysprosium Z=66
^{159}Tb	^{160}Tb	^{161}Tb	^{162}Tb	^{163}Tb	^{164}Tb	^{165}Tb	^{166}Tb	^{167}Tb	^{168}Tb	^{169}Tb	^{170}Tb	^{171}Tb	^{172}Tb		Terbium Z=65
^{158}Gd	^{159}Gd	^{160}Gd	^{161}Gd	^{162}Gd	^{163}Gd	^{164}Gd	^{165}Gd	^{166}Gd	^{167}Gd	^{168}Gd	^{169}Gd	^{170}Gd			Gadolinium Z=64
^{157}Eu	^{158}Eu	^{159}Eu	^{160}Eu	^{161}Eu	^{162}Eu	^{163}Eu	^{164}Eu	^{165}Eu	^{166}Eu	^{167}Eu	^{168}Eu				Europium Z=63

Experiment

Where

RIKEN Nishina Center for Accelerator-Based Science, Japan .

Experiment Motivation

- Identify and explain the internal structure of (prolate deformed) neutron-rich Terbium isotopes.
- Identify isomeric decays (ns to μs lifetimes) in the Tb isotopes.
- Gamma-ray lines emitted following decays from metastable states

Experiment Method

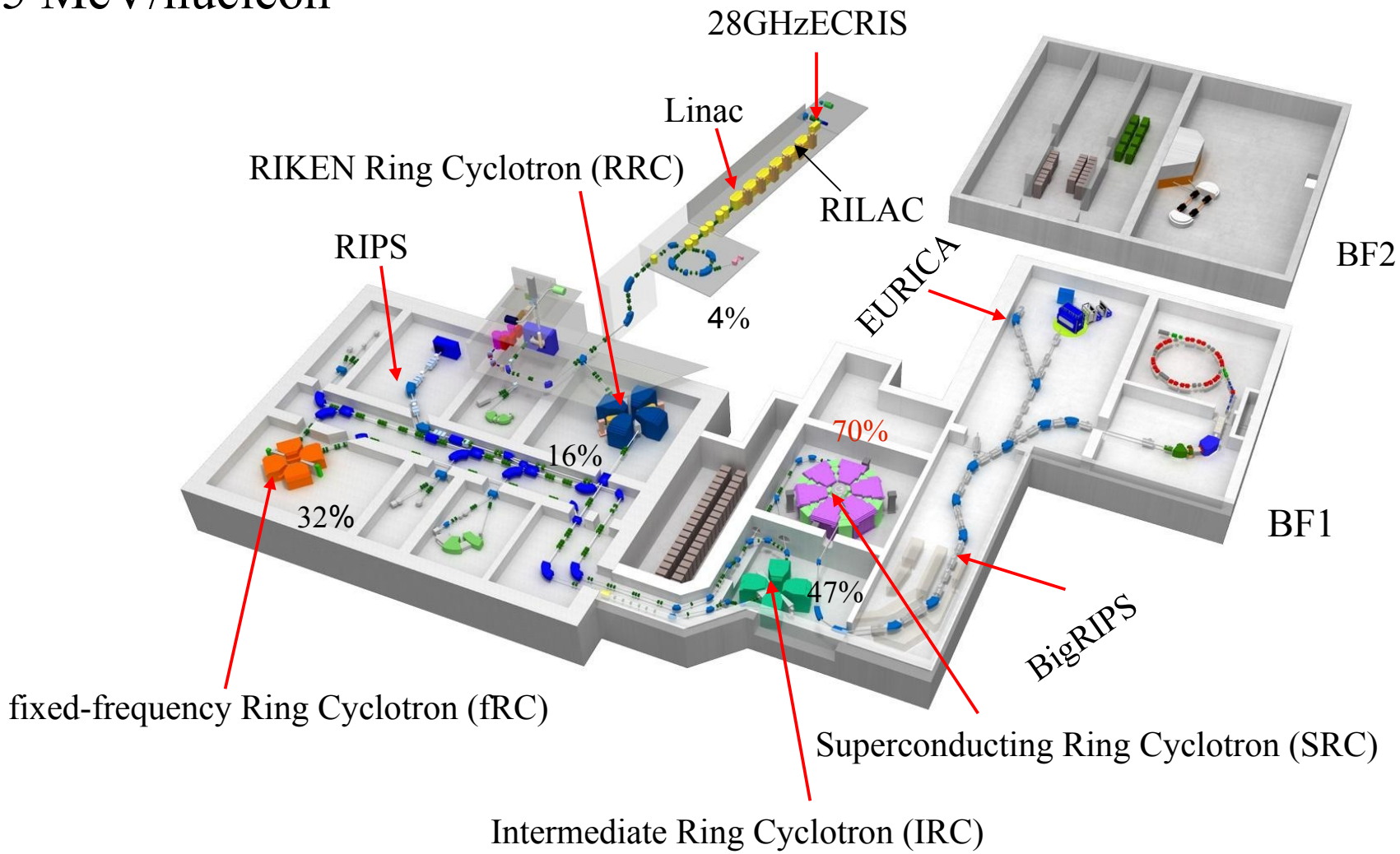
Nuclei created using projectile fission of ^{238}U primary beam.

- The Radioactive Isotope Beam Factory, RIBF.
- Nuclear species separated and identified using the BigRIPS;
- Measured decay in WAS3ABi and gamma rays in EURICA

Experimental Method.

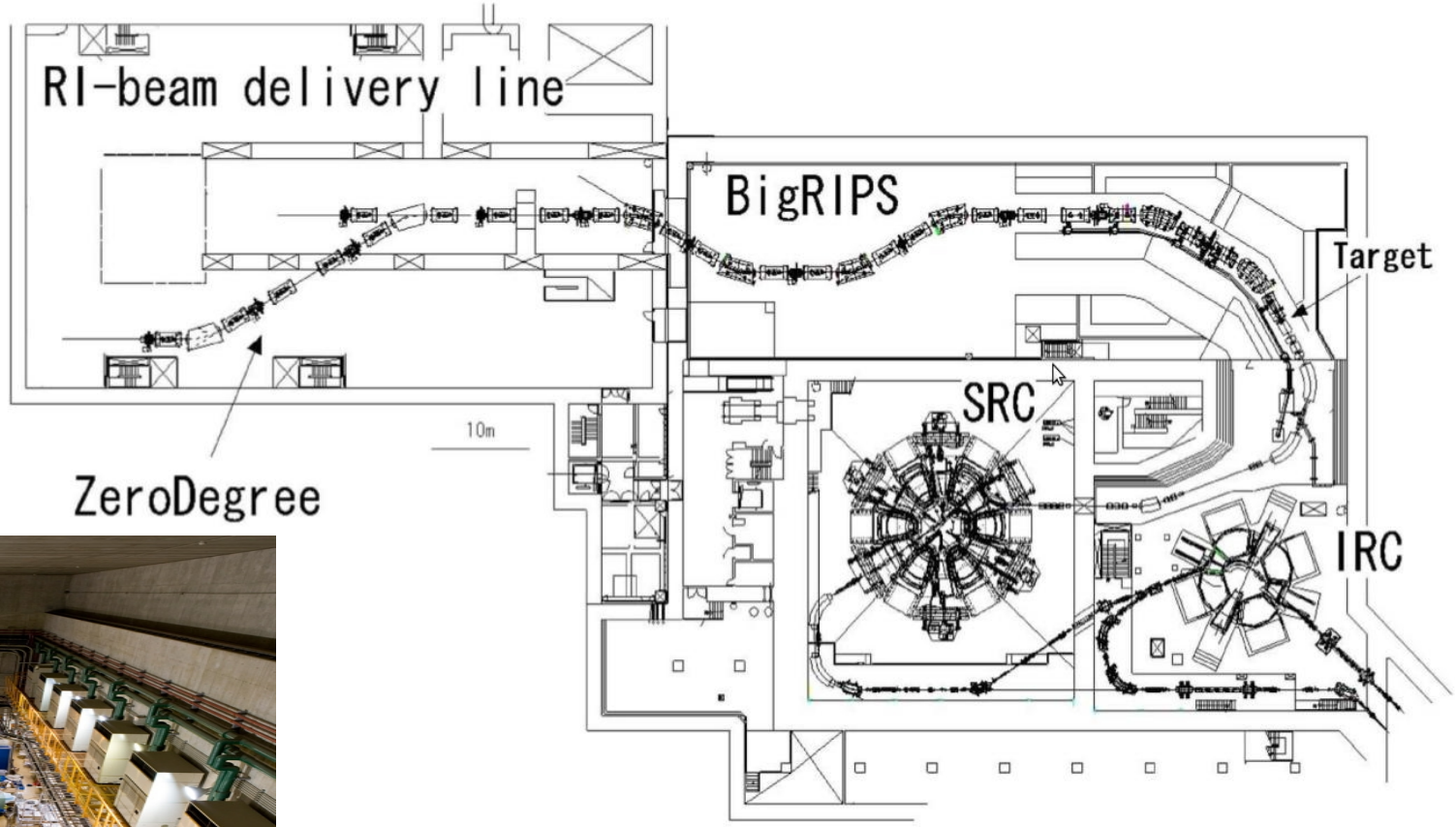
Radioactive Isotope Beam Factory (RIBF) RIKEN, Japan.

345 MeV/nucleon

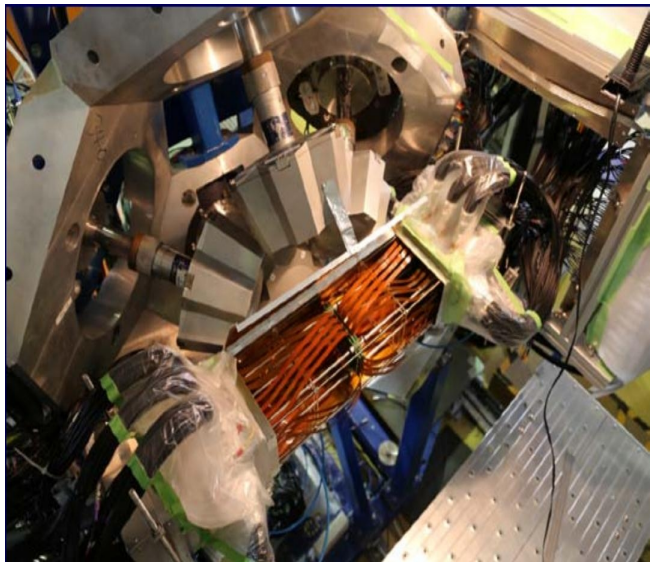


BigRIPS: particle separation and identification

^{9}Be target

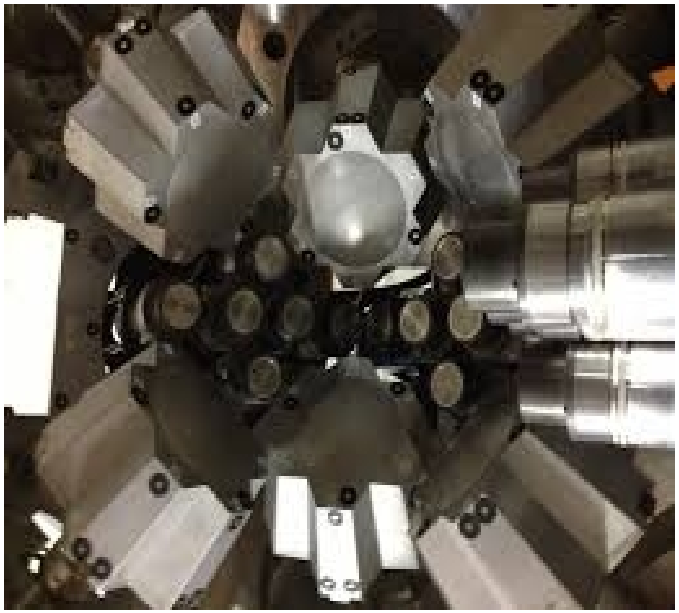


WAS3ABI & EURICA



WAS3ABI: Wide-range Active Silicon-Strip Stopper Array for Beta and Ion detection

Double-sided Silicon Strip Detectors
60 x 1 mm strips in x direction
40 x 1 mm strips in y direction

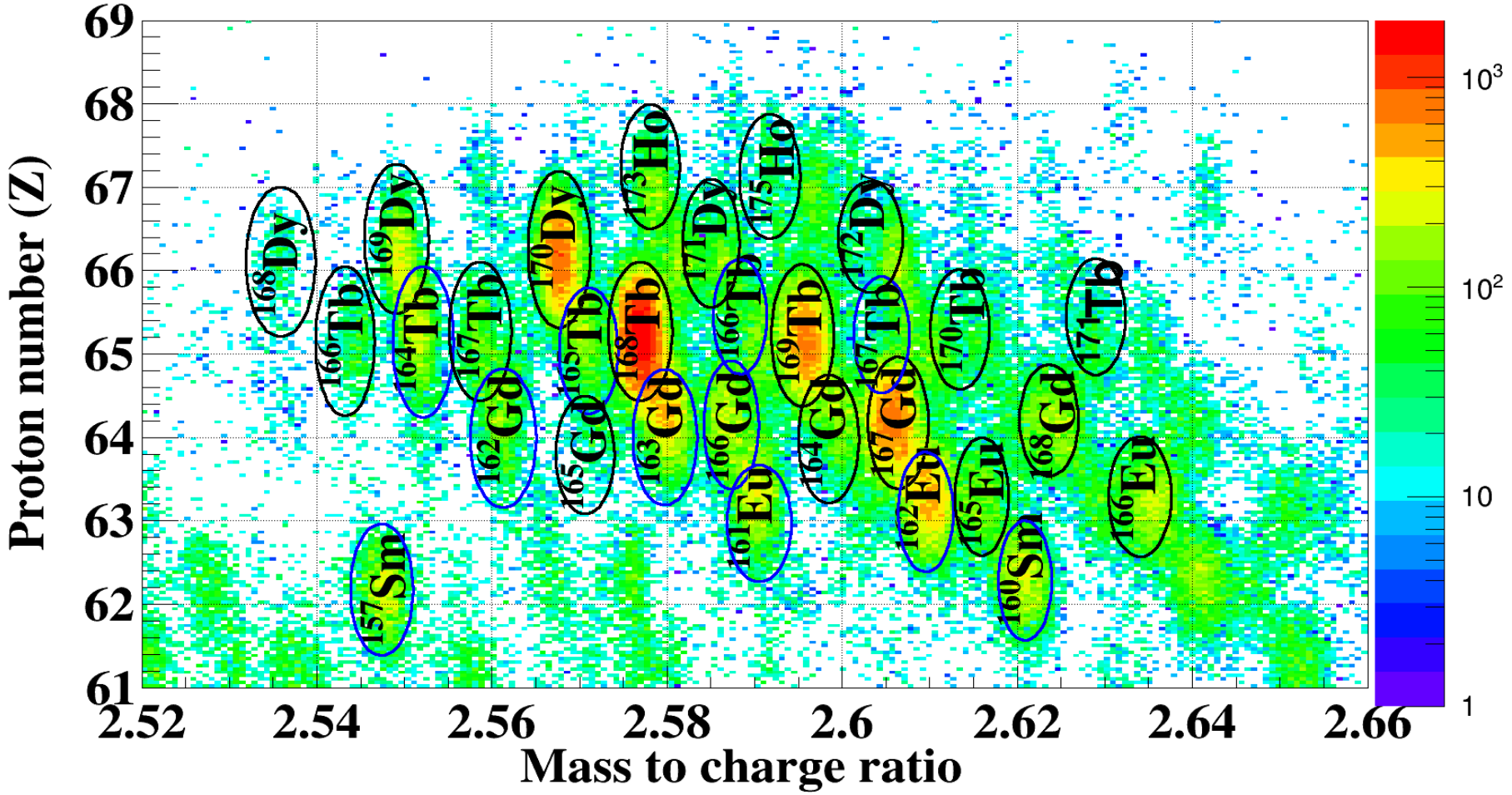


EURICA: Euroball RIKEN Cluster Array for (ion correlated) gamma-ray measurements.

- 84 HPGe in 12 x 7 element CLUSTER dets.
- 18 LaBr3(Ce).

Data Analysis.

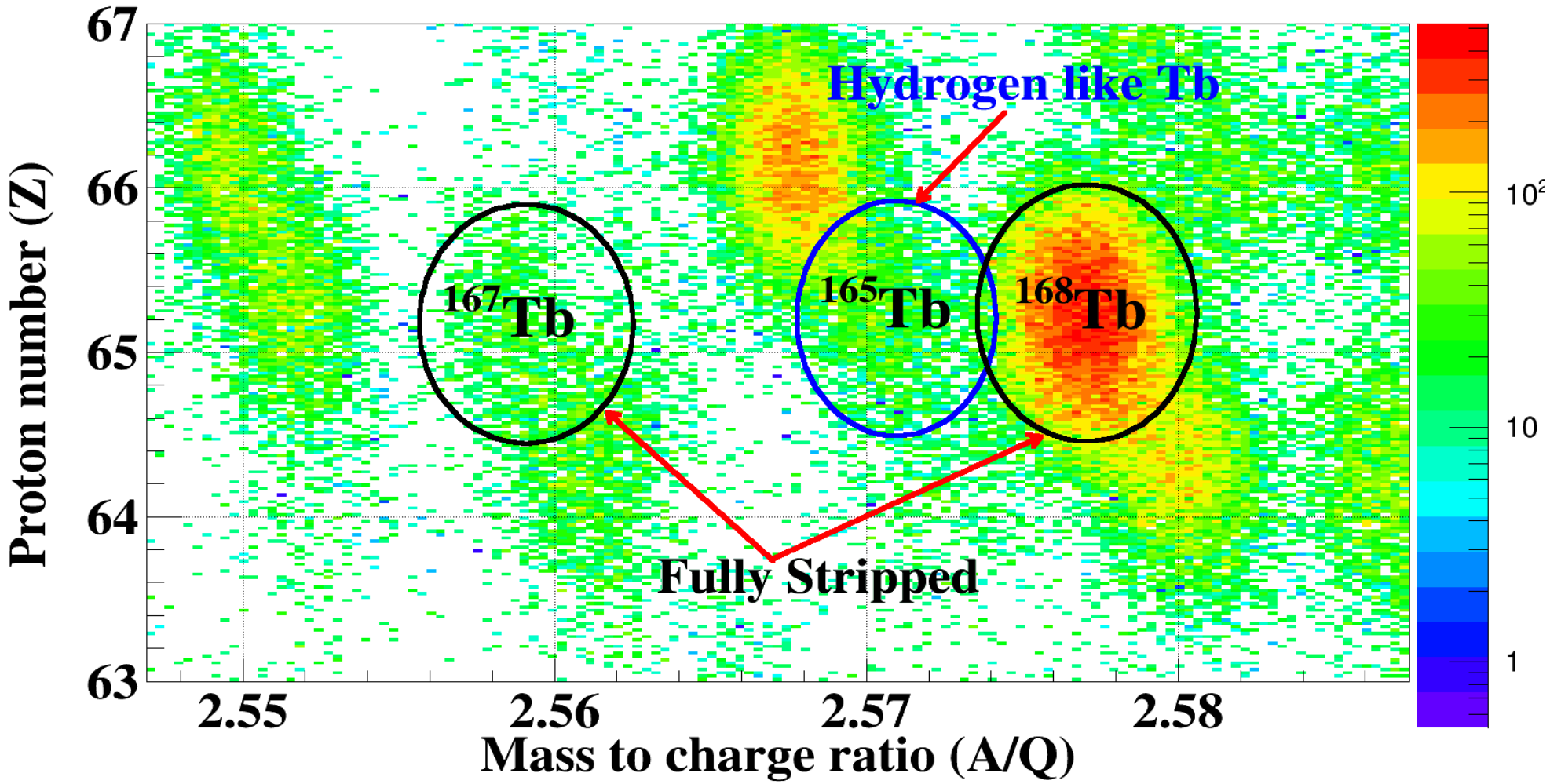
Particle identification(PID)



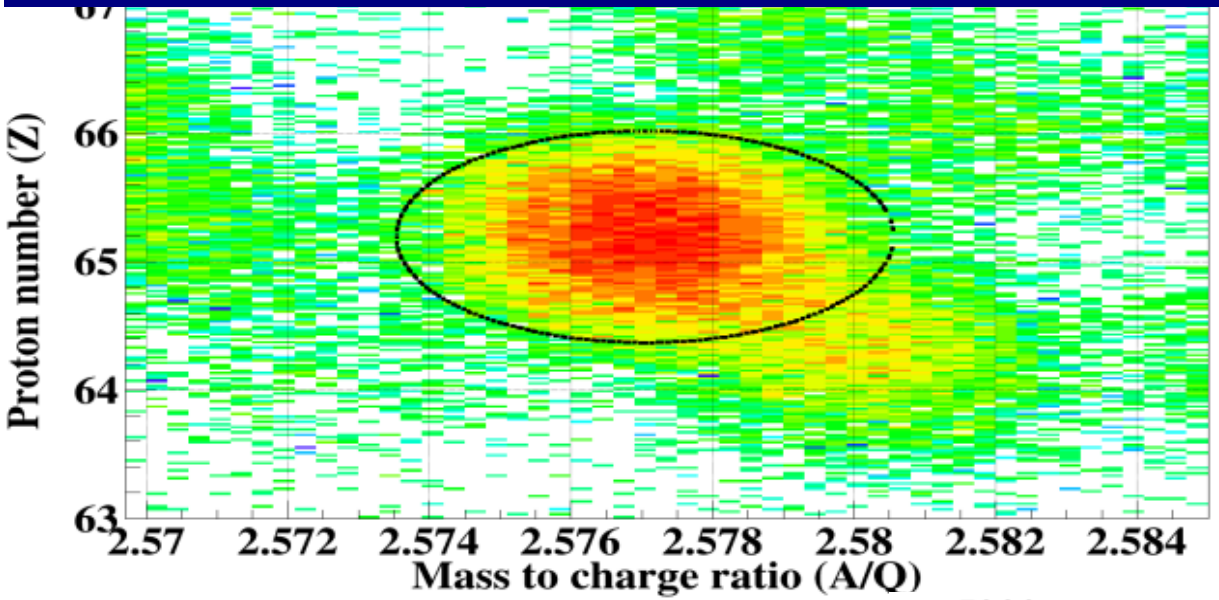
Hydrogen Like → Mass number/(Z-1)

Fully stripped → Mass number/(Z)

Particle identification(PID)



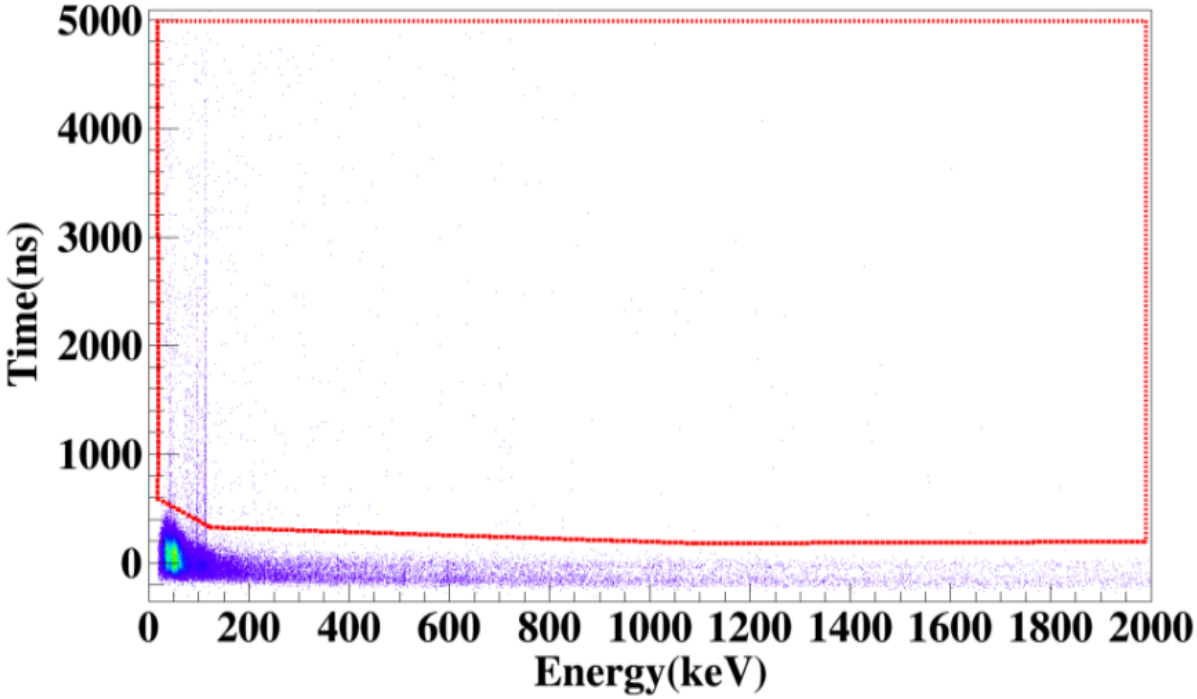
^{168}Tb



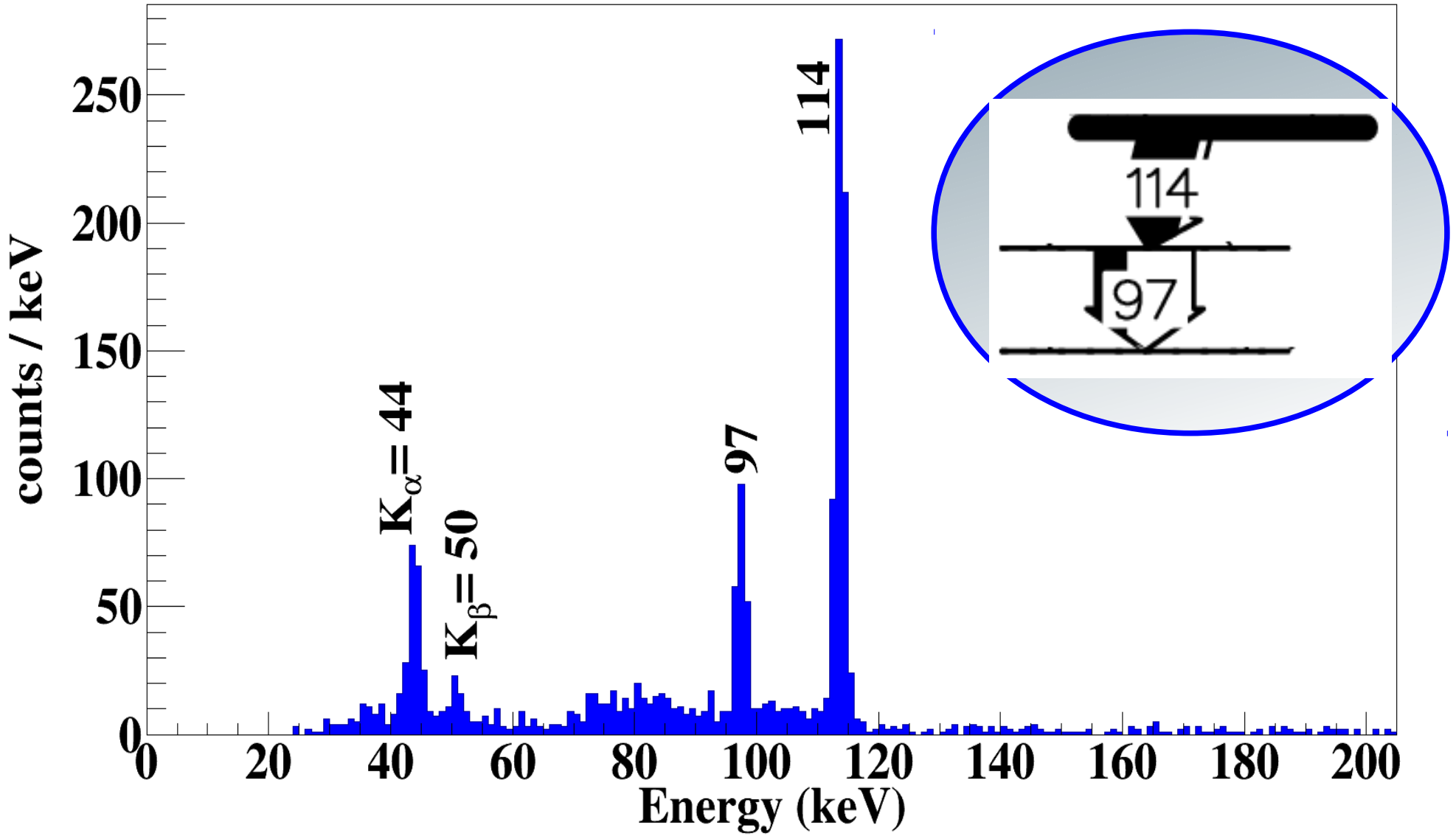
Gate placed around ^{168}Tb in PID

Energy-time matrix associated with ^{168}Tb

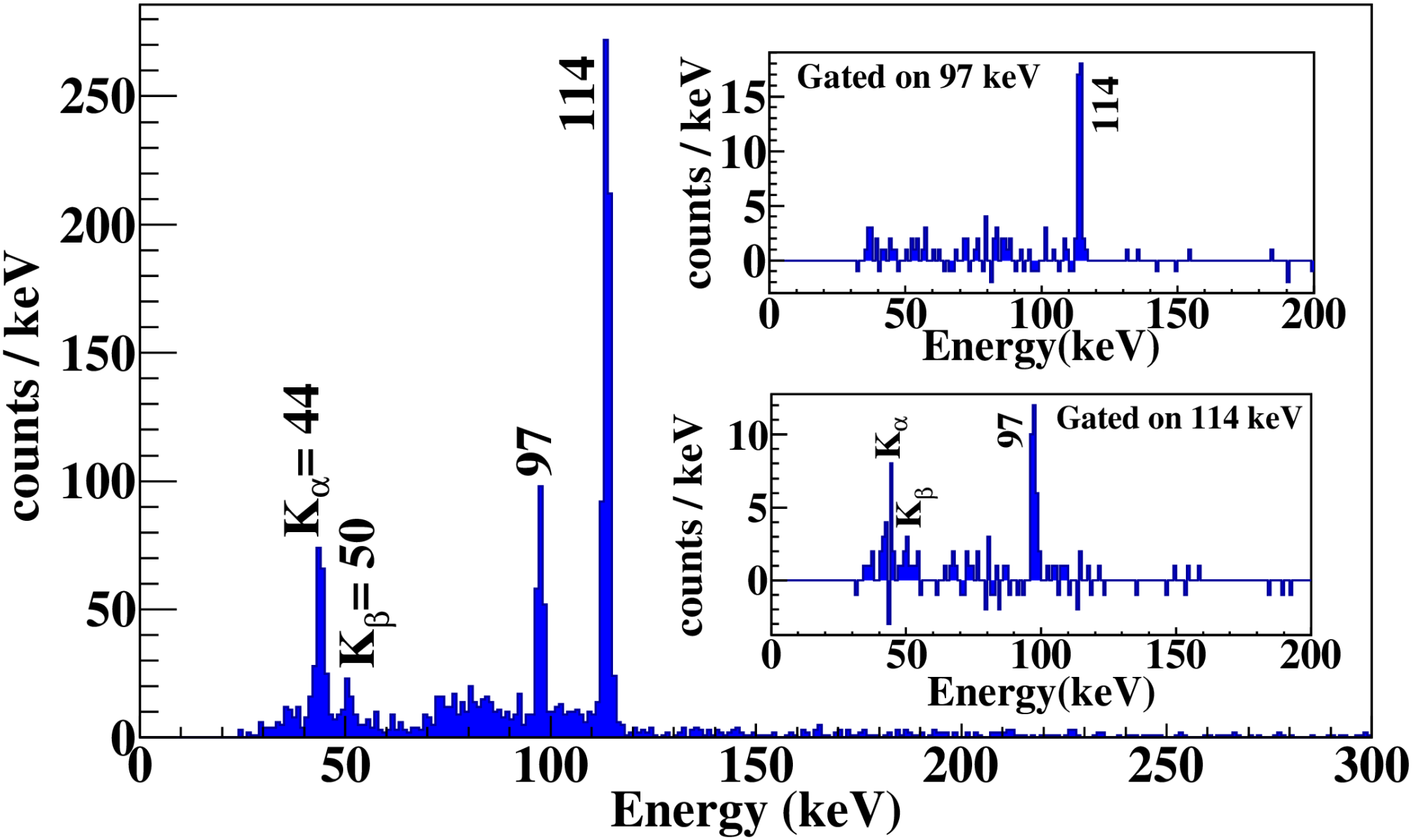
Time window 3μs to 5μs has made in the energy-time matrix to reduce the prompt flash .



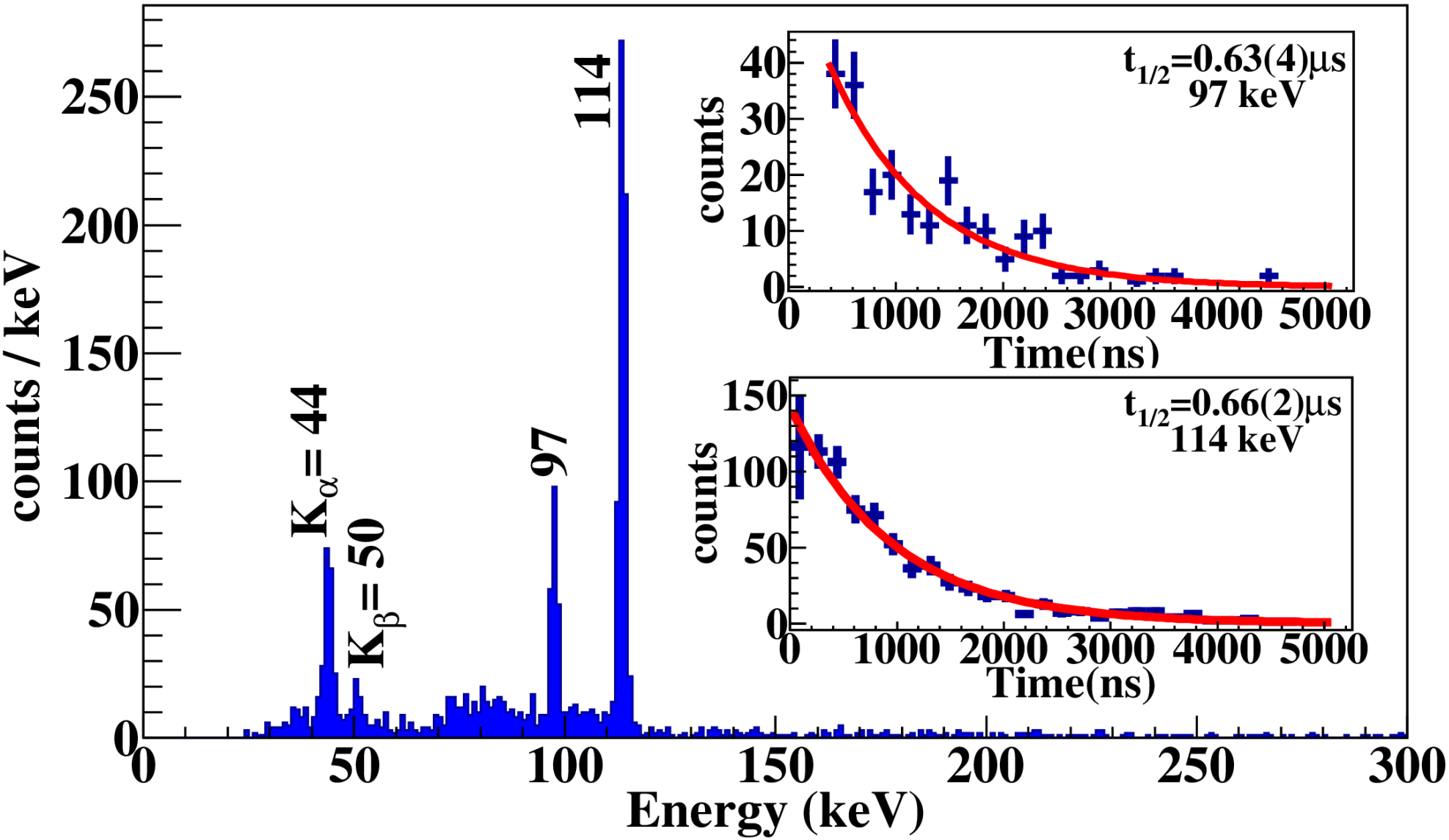
^{168}Tb:Gamma Spectroscopy



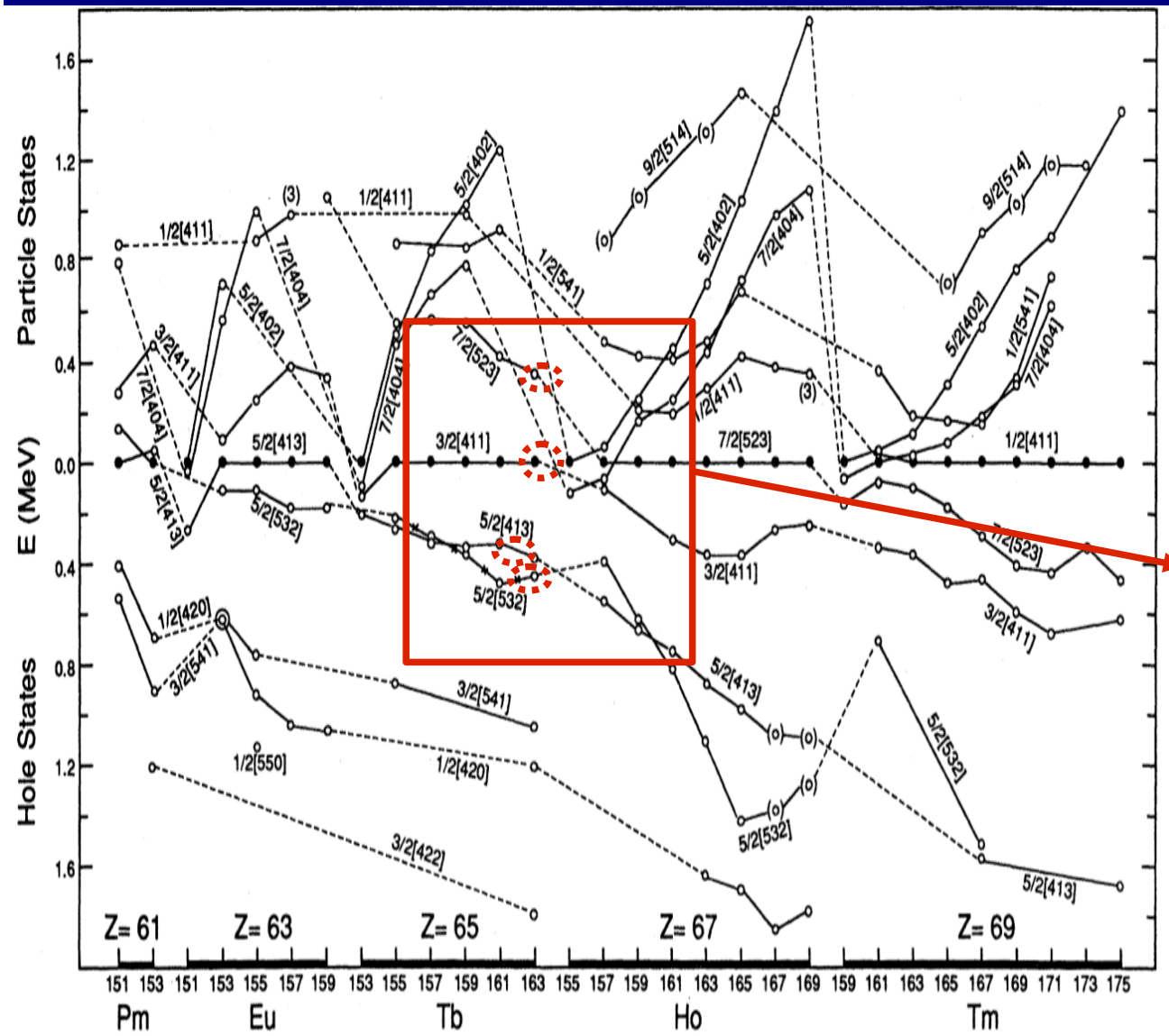
^{168}Tb:Gamma Spectroscopy



^{168}Tb:Gamma Spectroscopy

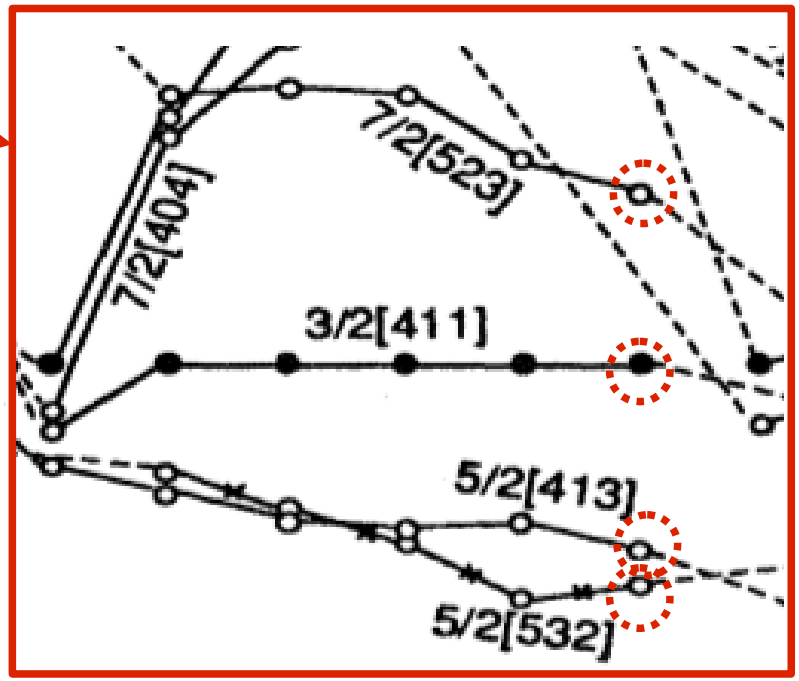


Possible deformed single and multi-particle configurations



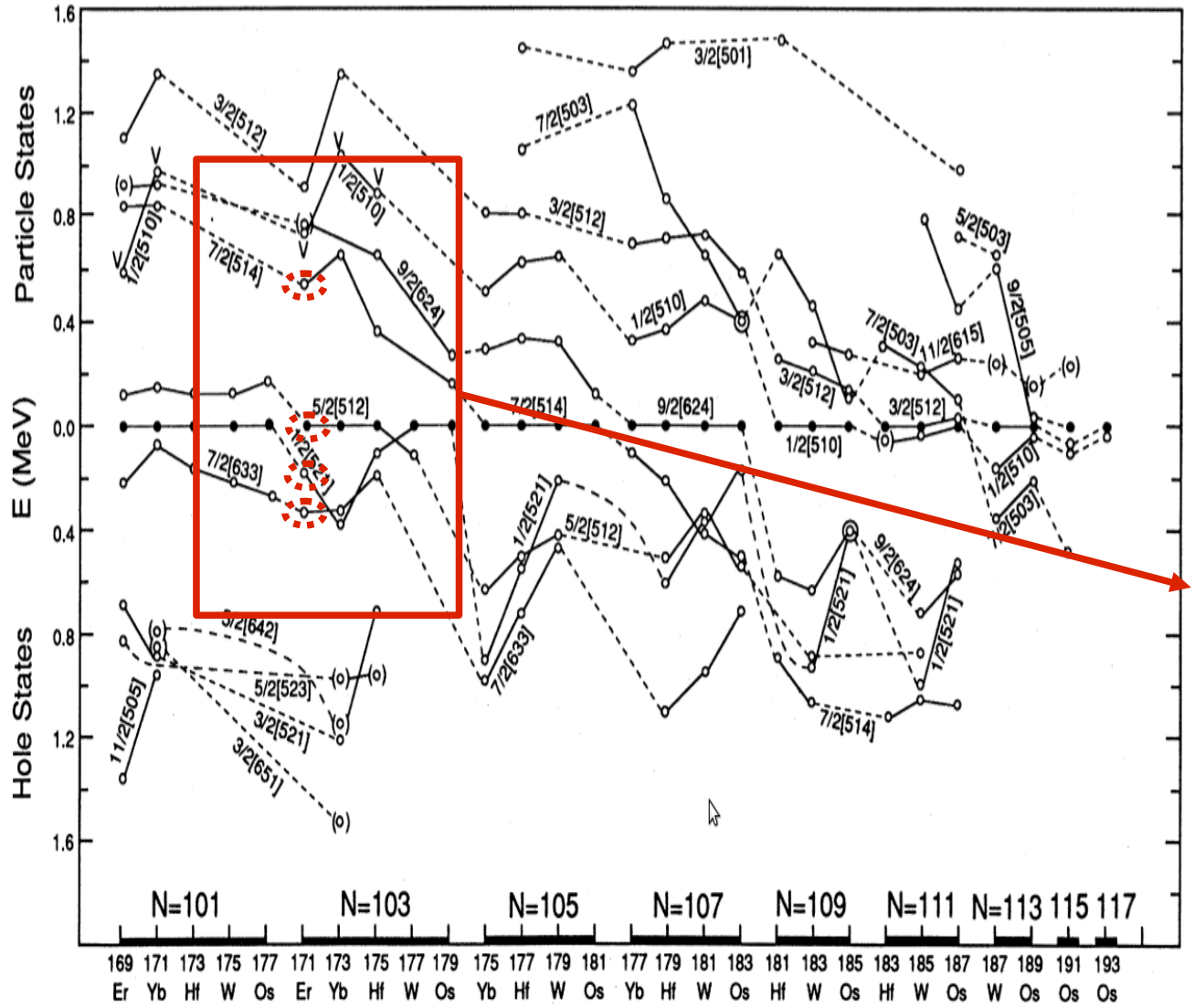
Nilson proton configuration for Z= 65

3/2[411], 7/2[523], 5/2[413] and 5/2[532]



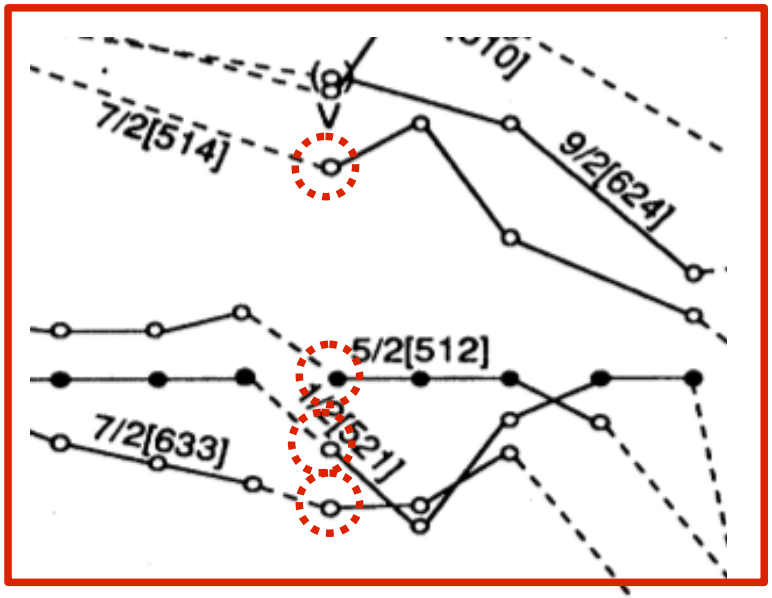
A. K. Jain et al;Rev. Mod. Phys. , Vol. 62, No. 2, April 1990

Possible deformed single and multi-particle configurations



Nilson neutron configuration for N=103

5/2[512], 7/2[514], 1/2[521] and 7/2[633]



A. K. Jain et al;Rev. Mod. Phys. , Vol. 62, No. 2, April 1990

^{168}Tb-Blocked BCS calculations (Bardeen-Cooper-Schrieffer)

K^{π}	configuration	E_x(keV)
^{168}Tb		
4^-	$\nu\frac{5}{2}^-[512] \otimes \nu\frac{3}{2}^+[411]$	0
6^+	$\nu\frac{5}{2}^-[512] \otimes \nu\frac{7}{2}^-[523]$	274
5^-	$\nu\frac{5}{2}^-[512] \otimes \nu\frac{5}{2}^+[413]$	285
5^+	$\nu\frac{5}{2}^-[512] \otimes \nu\frac{5}{2}^-[532]$	324
2^-	$\nu\frac{1}{2}^-[521] \otimes \nu\frac{3}{2}^+[411]$	428
5^-	$\nu\frac{7}{2}^-[514] \otimes \nu\frac{3}{2}^+[411]$	445
7^+	$\nu\frac{7}{2}^-[514] \otimes \nu\frac{7}{2}^-[523]$	719
6^-	$\nu\frac{7}{2}^-[514] \otimes \nu\frac{5}{2}^+[413]$	730
6^+	$\nu\frac{7}{2}^-[514] \otimes \nu\frac{5}{2}^-[532]$	769
5^+	$\nu\frac{7}{2}^+[633] \otimes \nu\frac{3}{2}^+[411]$	538
7^-	$\nu\frac{7}{2}^+[633] \otimes \nu\frac{7}{2}^-[523]$	812
6^+	$\nu\frac{7}{2}^+[633] \otimes \nu\frac{5}{2}^+[413]$	824
6^+	$\nu\frac{9}{2}^+[624] \otimes \nu\frac{3}{2}^+[411]$	573
8^-	$\nu\frac{9}{2}^+[624] \otimes \nu\frac{7}{2}^-[523]$	847
7^+	$\nu\frac{9}{2}^+[624] \otimes \nu\frac{5}{2}^+[413]$	859
7^-	$\nu\frac{9}{2}^+[624] \otimes \nu\frac{5}{2}^-[532]$	898

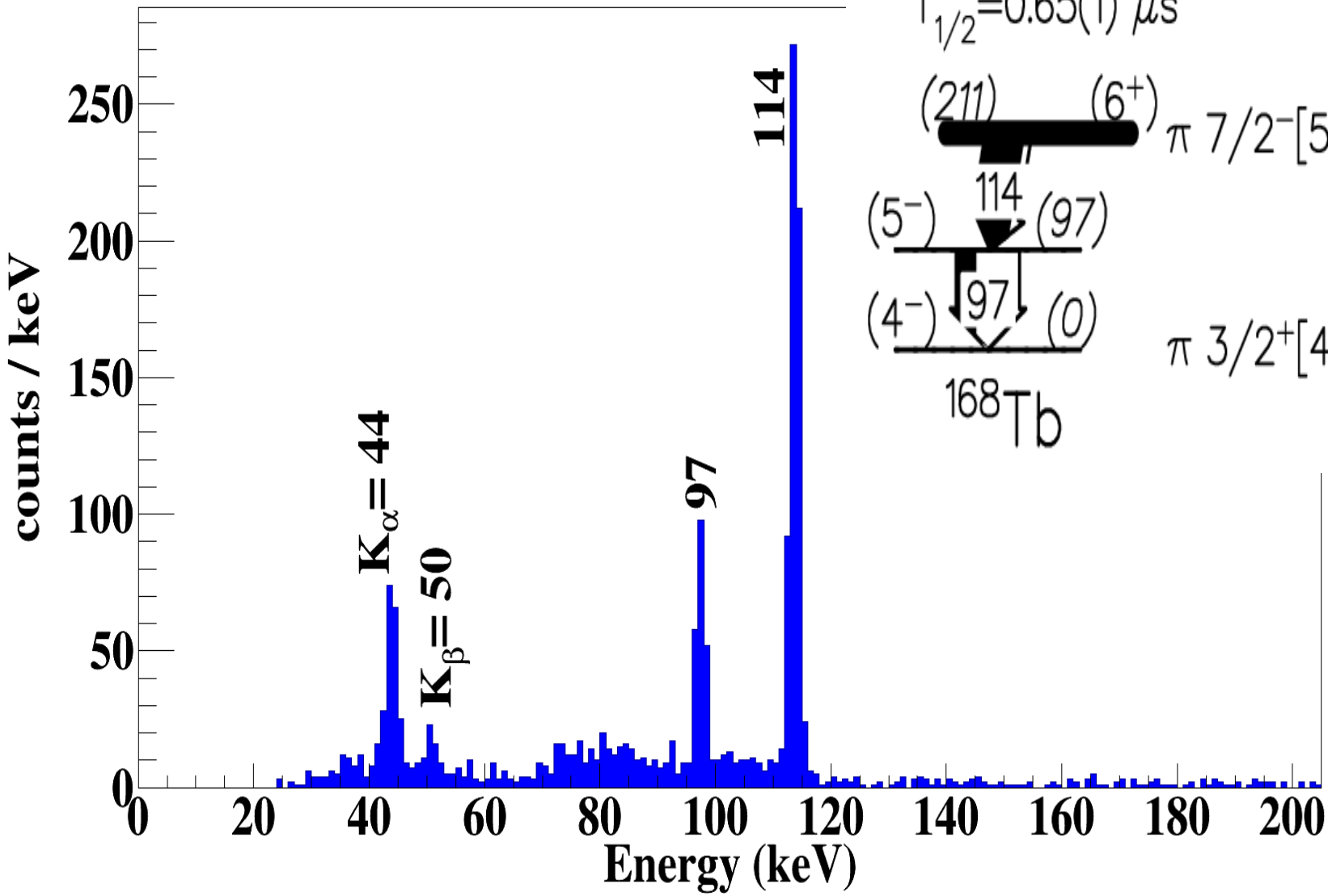
Two Quasiparticle States: with one neutron and one proton .

<u>Input parameters:</u>

Deformation parameters ϵ_2 =0.275 and ϵ_4=0.040, taken from (P. Möller et al).

Monopole pairing strengths $G_{\nu(n)}$=20 A.MeV and $G_{\pi(p)}$ =21A.Mev, in accordance with (Jain et al)

^{168}Tb:Gamma Spectroscopy



Missing intensity calculation-^{168}Tb

	97 keV	114 keV
α_{E1}	0.326	0.211
α_{E2}	2.92	1.617
α_{M1}	2.40	1.51
I_{γ}	196.29	587.35
ε_{Abs}	25.14	24.51
$I_{\gamma}/\varepsilon_{Abs}$	7.81	23.96
$1+\alpha_{E1}$	1.326	1.211
$1+\alpha_{E2}$	3.92	2.617
$1+\alpha_{M1}$	3.40	2.51

$$\frac{I_{\gamma 97}}{I_{\gamma 114}} = \frac{7.80\left(1+\alpha_{97}\right)}{23.96\left(1+\alpha_{114}\right)} \approx 1$$

$$\frac{\left(1+\alpha_{97}\right)}{\left(1+\alpha_{114}\right)} = 3.07$$

$$\frac{\left(1+\alpha_{97E1}\right)}{\left(1+\alpha_{114E1}\right)} = 1.09$$

$$\frac{\left(1+\alpha_{97E2}\right)}{\left(1+\alpha_{114E1}\right)} = 3.23$$

$$\frac{\left(1+\alpha_{97M1}\right)}{\left(1+\alpha_{114E1}\right)} = 2.80$$

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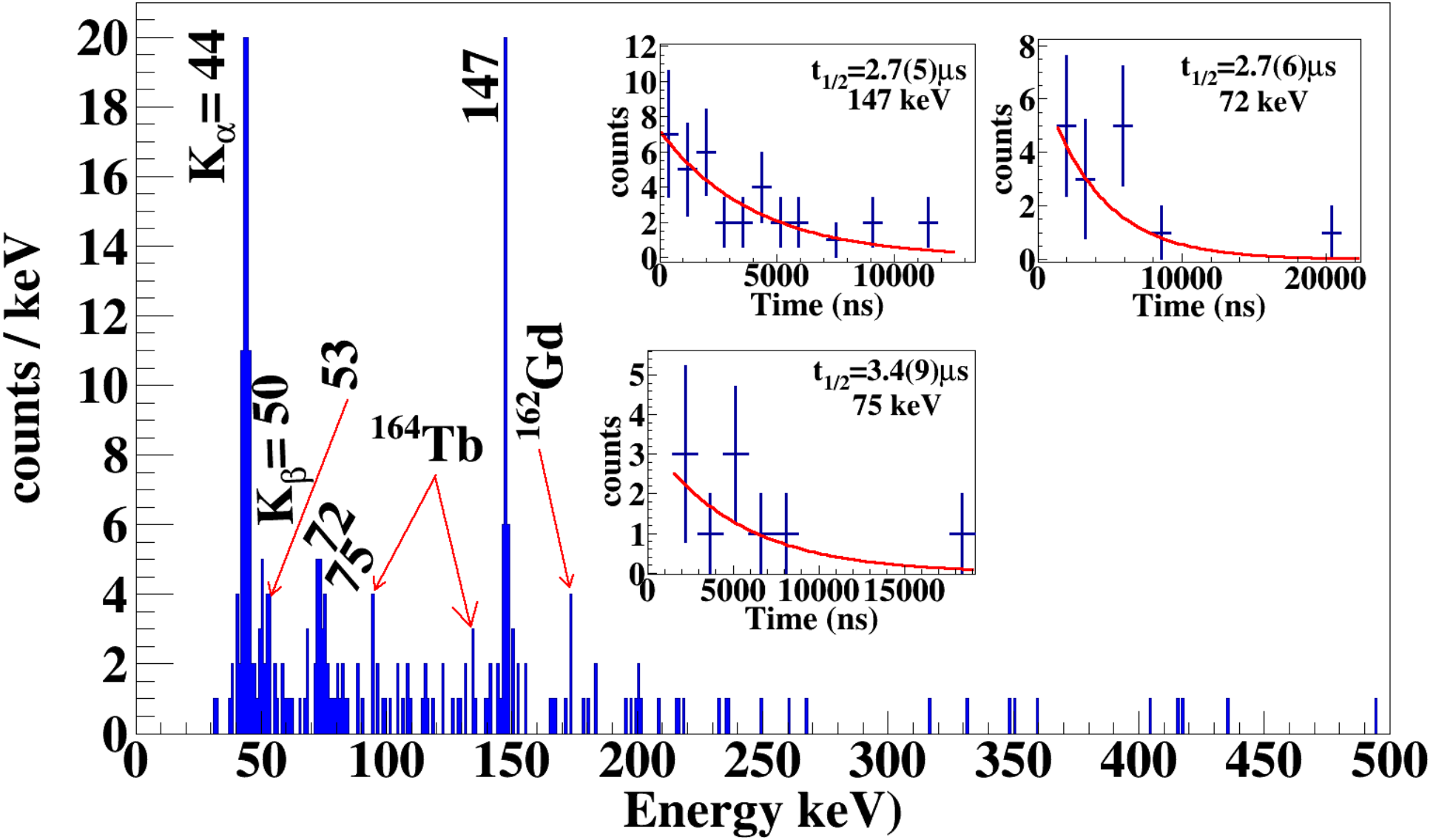
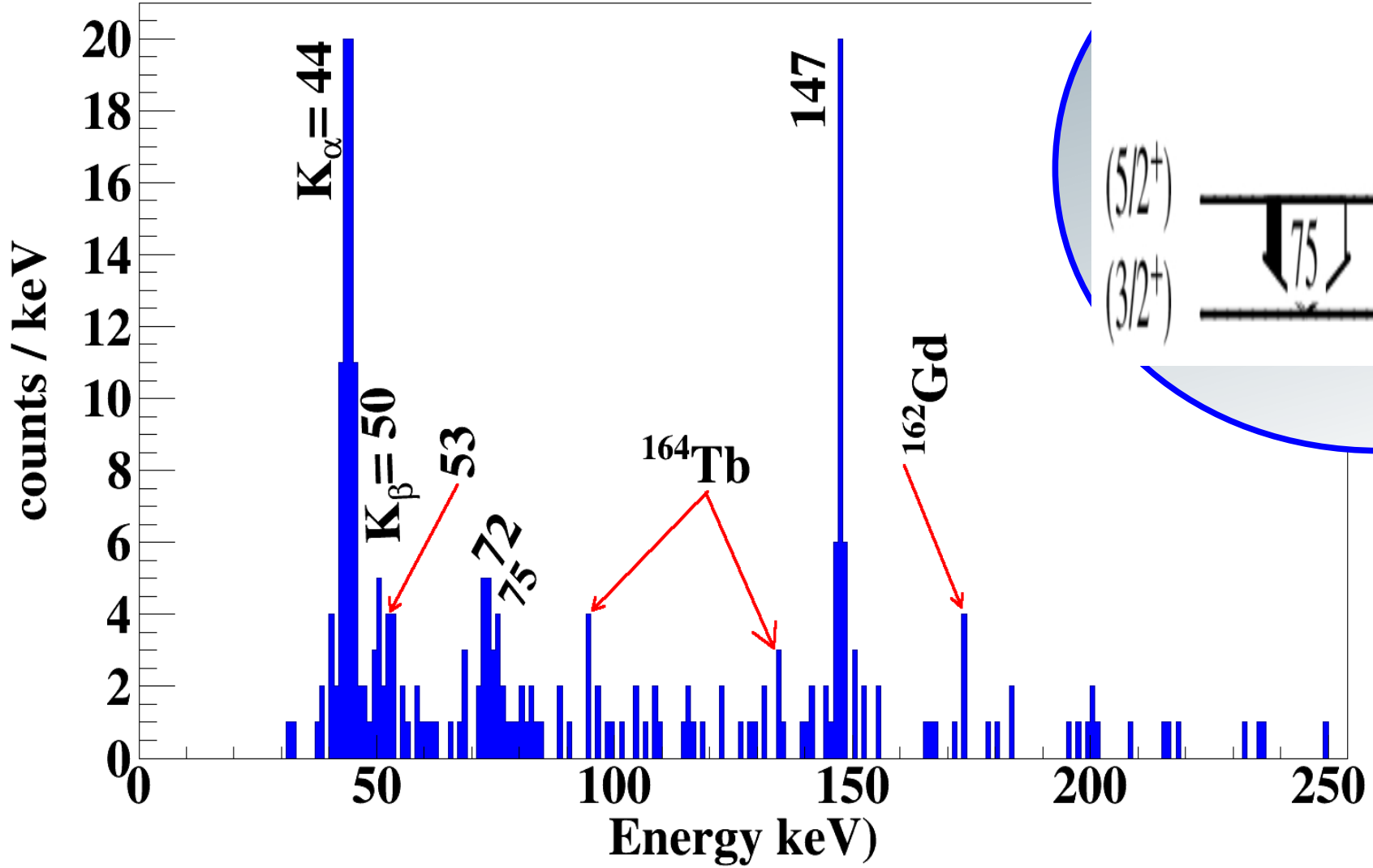
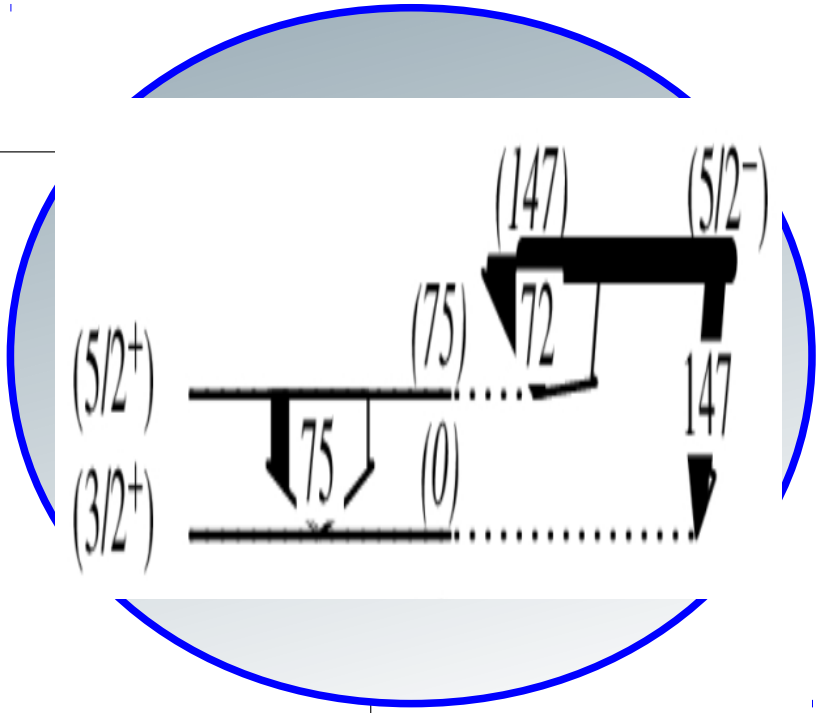
Data analysis on-going.

^{167}Tb:Gamma Spectroscopy

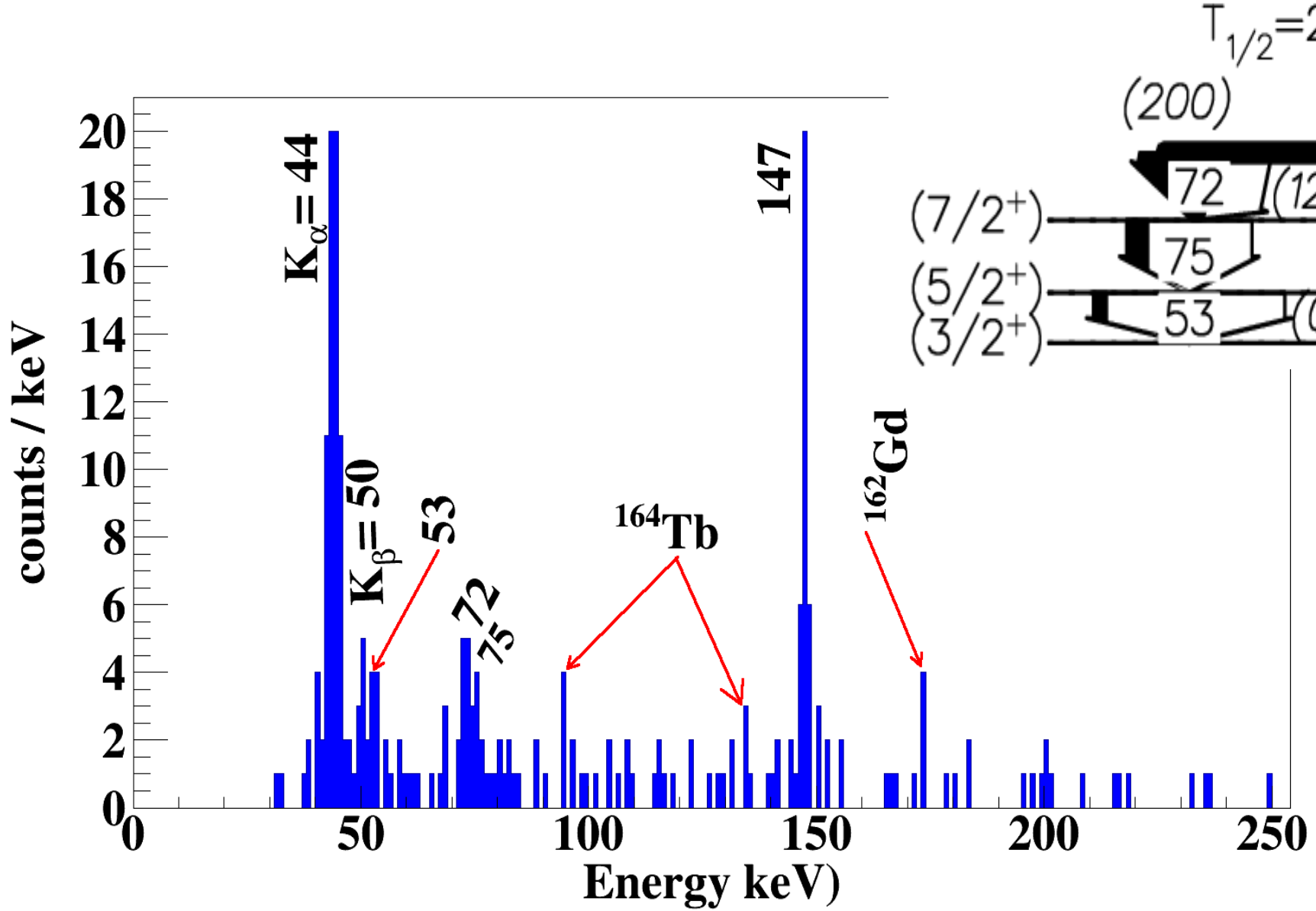


^{167}Tb:Gamma Spectroscopy

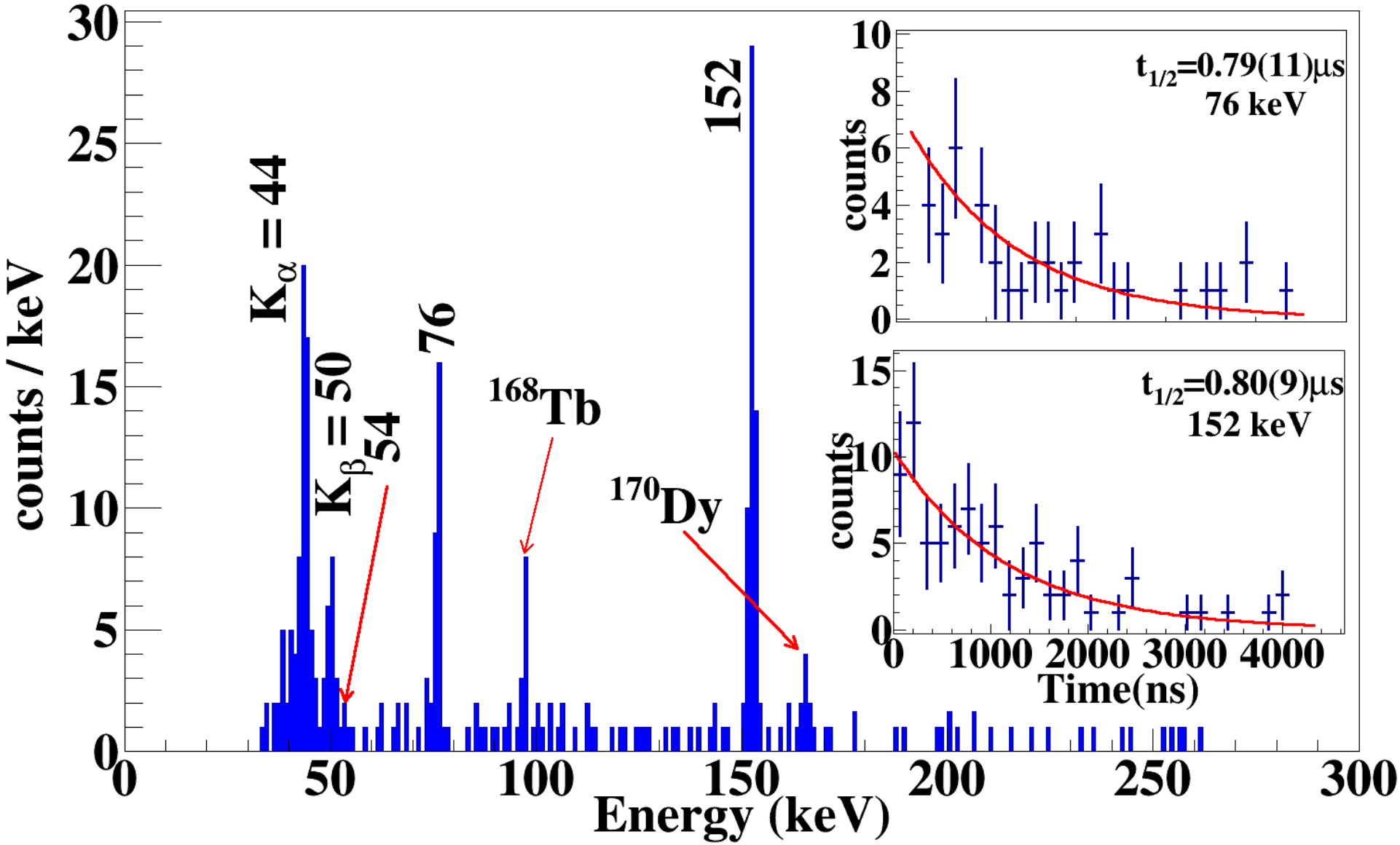




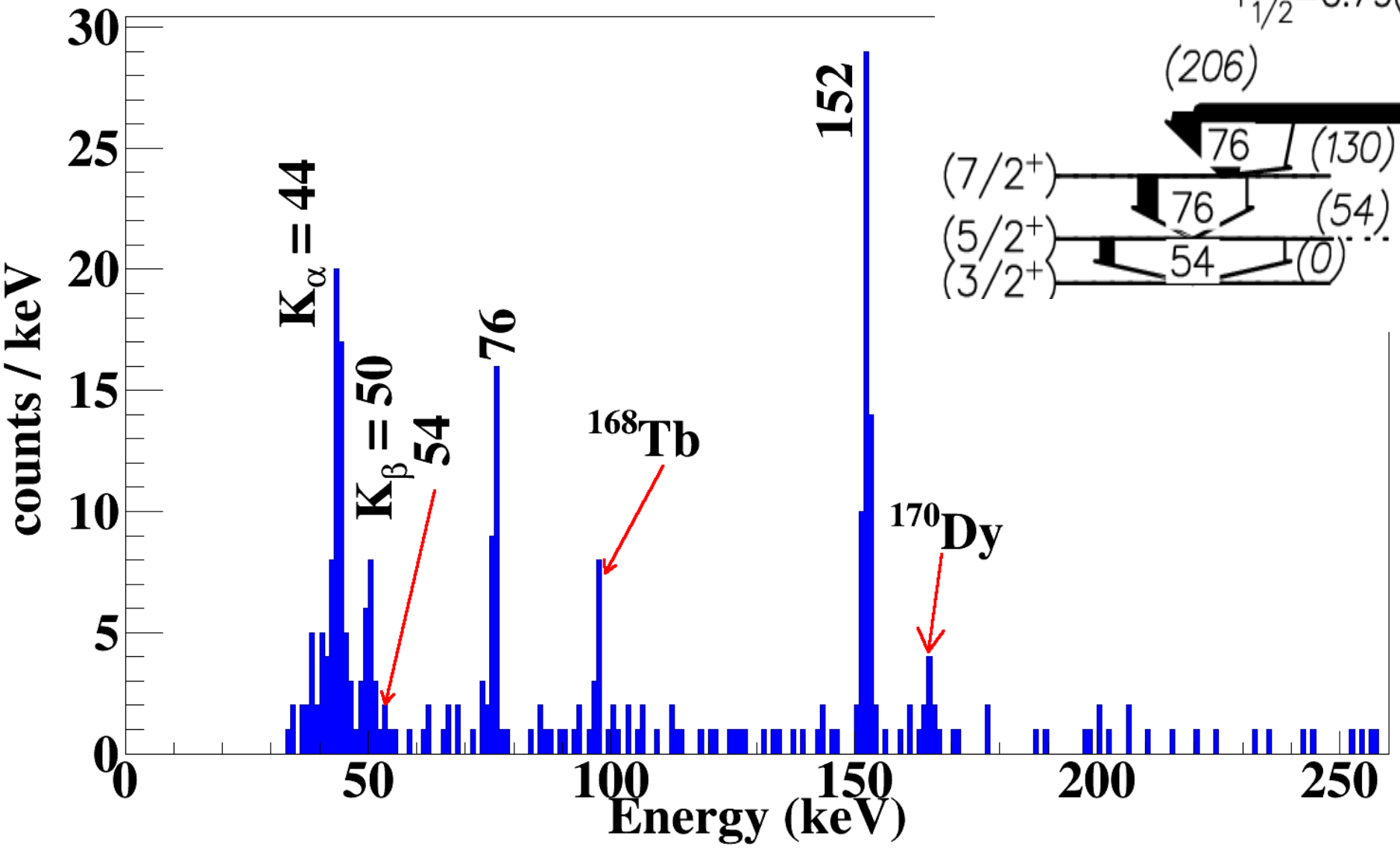
^{167}Tb:Gamma Spectroscopy



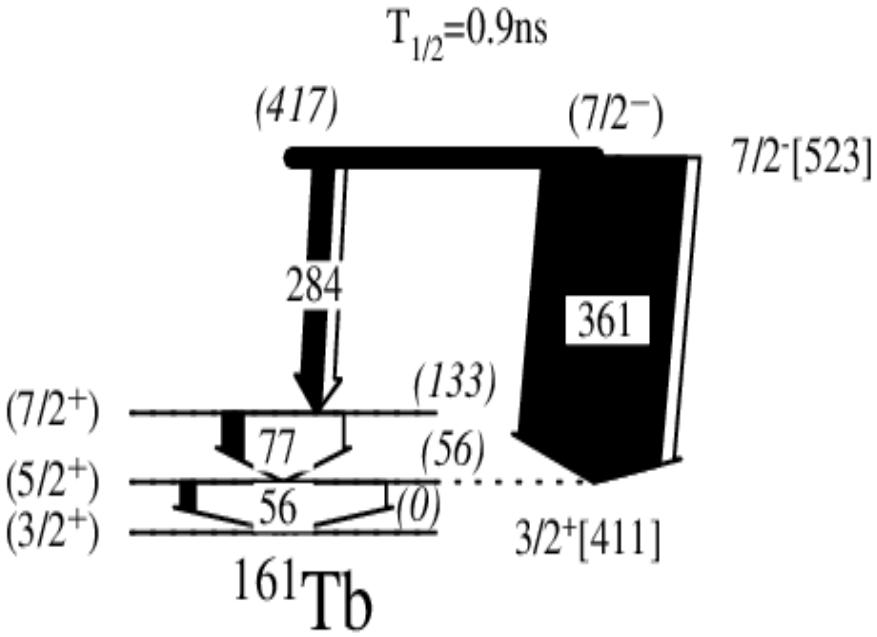
^{165}Tb:Gamma Spectroscopy

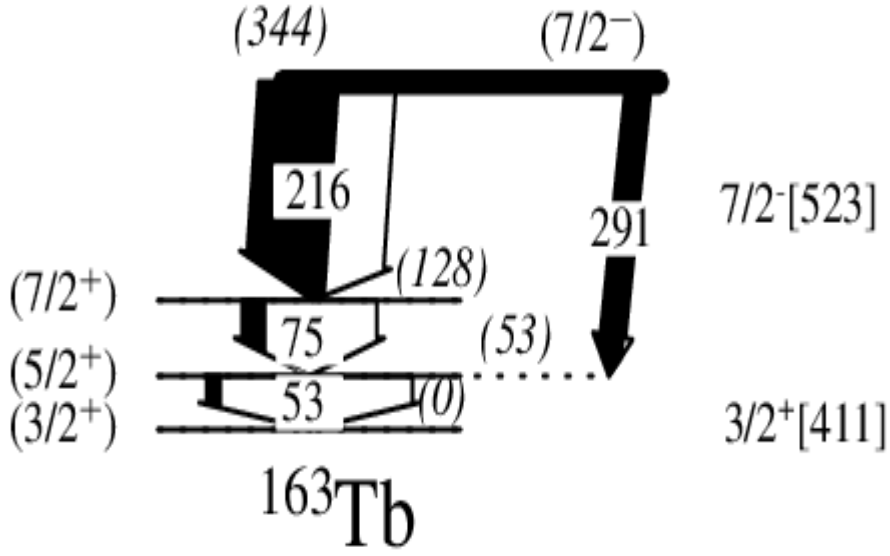


^{165}Tb:Gamma Spectroscopy



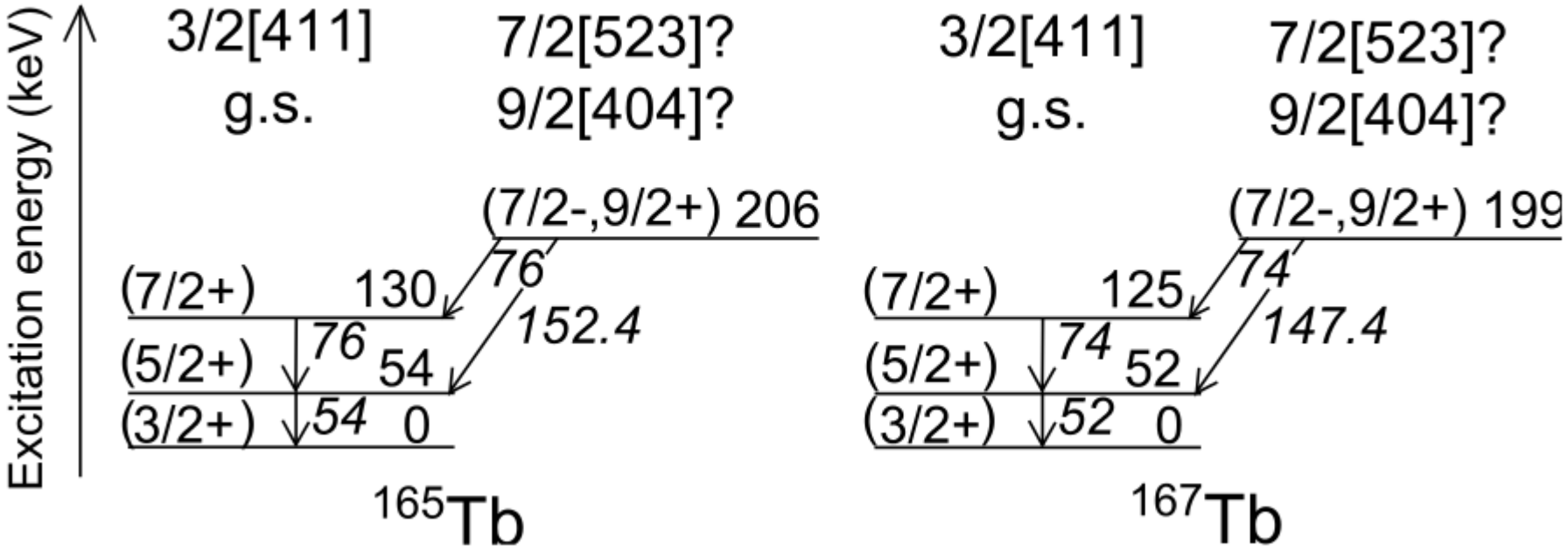
^{161}Tb and ^{163}Tb level schemes





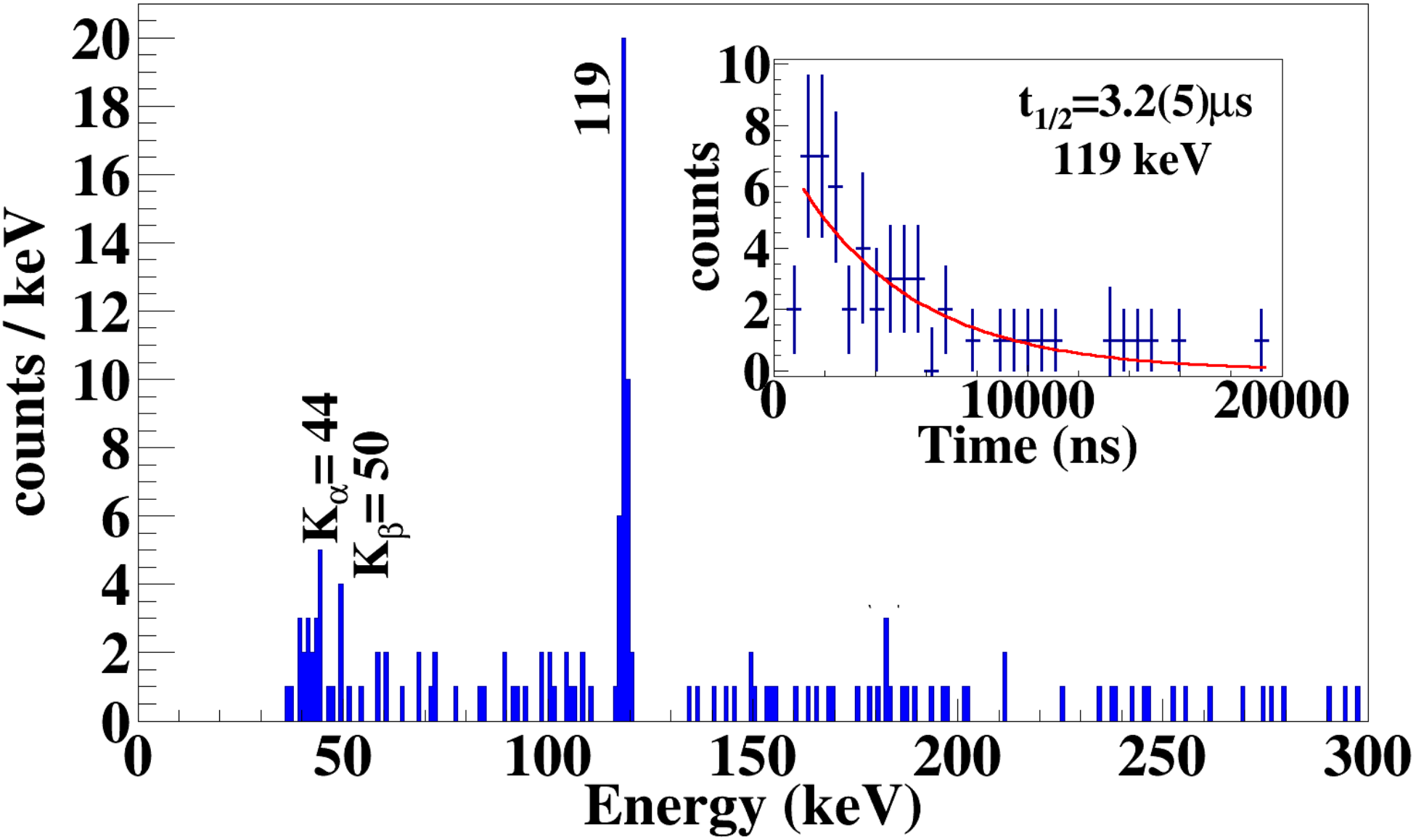
national nuclear data center
http://www.nndc.bnl.gov/useroutput/AR_9039884DD11748B72920744FDE7FE806_1.html

^{165}Tb and ^{167}Tb level schemes



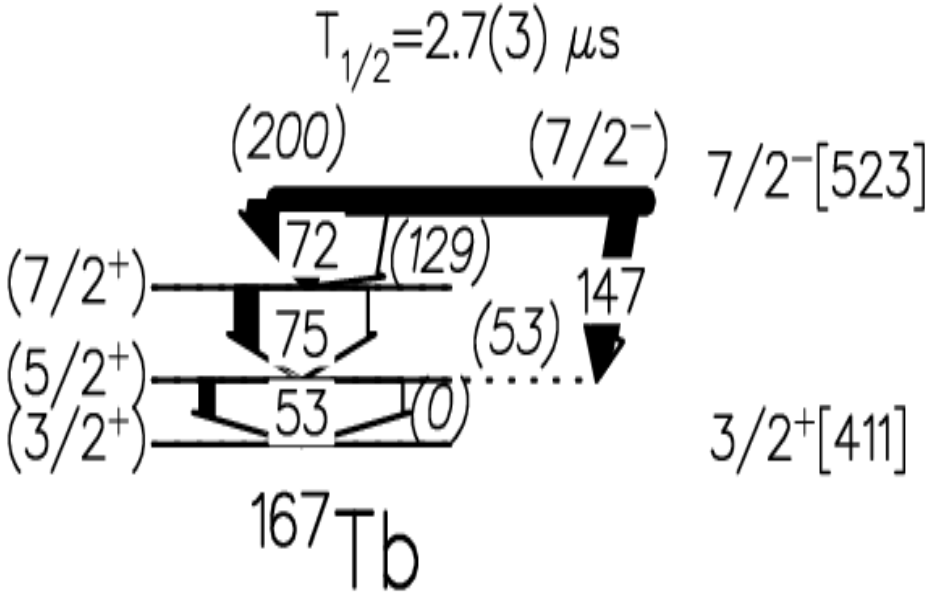
internal report on isomers in Tb isotopes from CNS report: R.Yokoyama,al,et. CNS-REP-92, p.11 (2014)

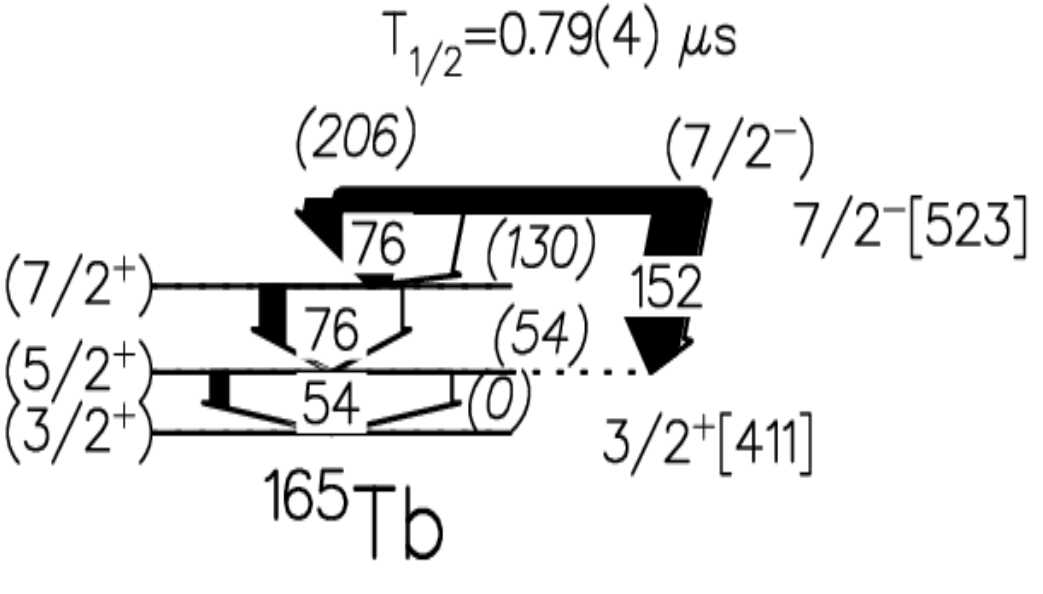
Preliminary ^{166}Tb Gamma Spectroscopy

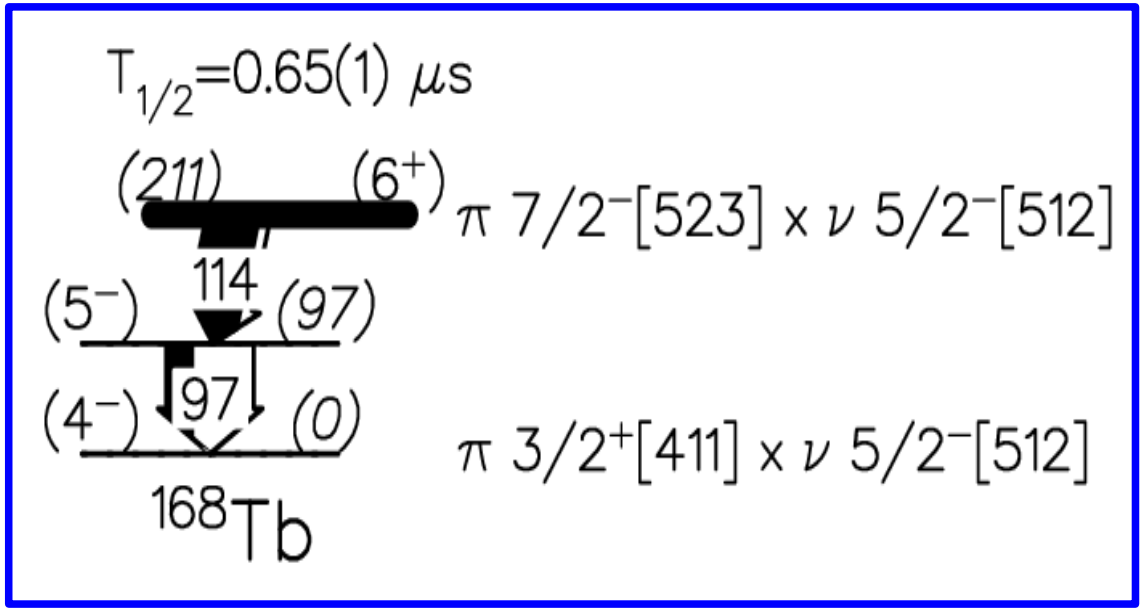


Summary

Single proton isomers in ^{165}Tb, ^{167}Tb and odd-odd nuclei ^{168}Tb







Collaborators

P.H.Regan[1,2], H.Watanabe[4,5], P.-A.Söderström[3], P.M.Walker[1], Zs.Podolyák1, S.Nishimura[3],T.A.Berry[1], P.Doornenbal[3], G.Lorusso[1,2,3], T.Isobe[3], H.Baba[3], Z.Y.Xu6,[7], H.Sakurai[3,8], T.Sumikama[3,9],W.N.Catford[1], A.M.Bruce10, F.Browne[10], G.J.Lane[11], F.G.Kondev[12], A.Odahara[13], J.Wu[3,14], H.L.Liu[15], F.R.Xu[14], Z.Korkulu[3,16], P.Lee[17], J.J.Liu[6,] V.H.Phong[3,18], A.Yagi[13], G.X.Zhang[5], T.Alharbi[19], R.J.Carroll[1], K.Y.Chae[20], Zs.Dombradi[16], A.Estrade[7,21], N.Fukuda[3], C.Griffin[21], E.Ideguchi[13,23], N.Inabe[3], H.Kanaoka[13], I.Kojouharov[24], T. Kubo[3], S.Kubono[3], N.Kurz[24], I.Kuti[16], S.Lalkovski[1], E.J.Lee[20], C.S.Lee[17], G.Lotay[1], C.-B.Moon[25], I.Nishizuka[9], C.R.Nita[10.26], Z.Patel[1], O.J. Roberts[27], H.Schaffner[24], C.M.Shand[1], H.Suzuki[3], H.Takeda[3], S.Terashima[5], Zs.Vajta[16], S.Yoshida[13] & J.J. Valiente-Dòbon[28]

[1]University of Surrey, [2]National Physical Laboratory, [3]RIKEN Nishina Center, [4]International Research Center for Nuclei and Particles in the Cosmos, [5]School of Physics and Nuclear Energy Engineering, [6]University of Hong Kong, [7]KU Leuven, Instituut voor Kern- en Stralings fysica, [8]University of [9]Tohoku, [10]University of Brighton, [11]Australian National University, [12]Argonne National Laboratory, [13]Osaka University, [14]Peking University, [15]Xi'an Jiaotong University, [16]Institute for Nuclear Research, [17]Chung-Ang University, [18]NU Hanoi University of Science, [19] Almajmaah University, [20]Sungkyunkwan University, [21]University of Edinburgh, [22]Central Michigan University, [23]Research Center for Nuclear Physics (RCNP), Osaka University, [24]GSI Helmholtzzentrum für Schwerionenforschung GmbH, [25]Hoseo University, [6](IFIN-HH), RO-077125, [27]University College [28]Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro.

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Thank you
for your attention.