Decay scheme studies using radiochemical methods

R. Tripathi, P. K. Pujari
Radiochemistry Division

A. K. Mohanty
Nuclear Physics Division

Bhabha Atomic Research Centre, Mumbai, India

Non-compound compound nucleus fission

❖Fission fragment angular distribution
❖Role of entrance channel mass asymmetry and target deformation

Incomplete fusion reactions

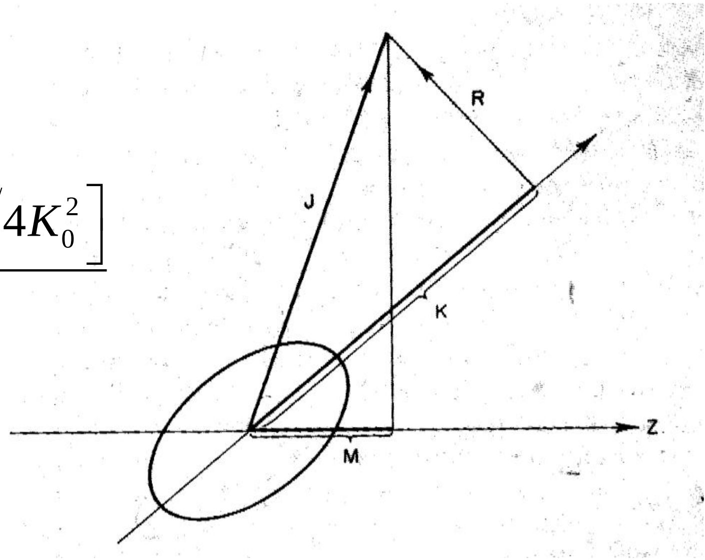
❖Measurement of cross sections of projectile like fragments
❖Threshold behaviour for massive transfer reactions

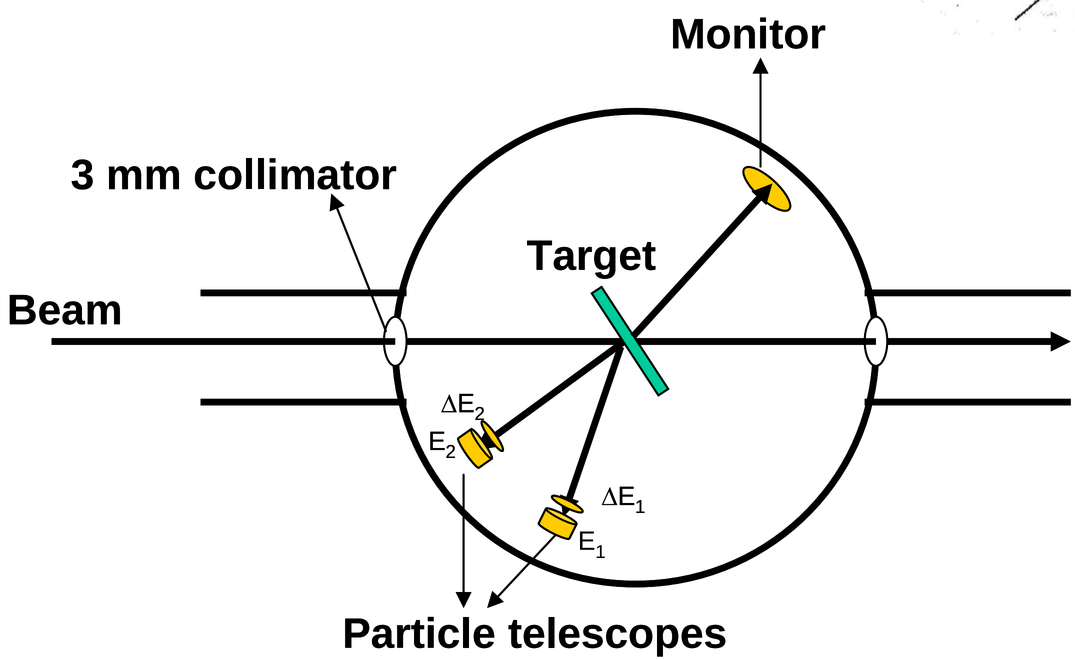
Decay Scheme studies

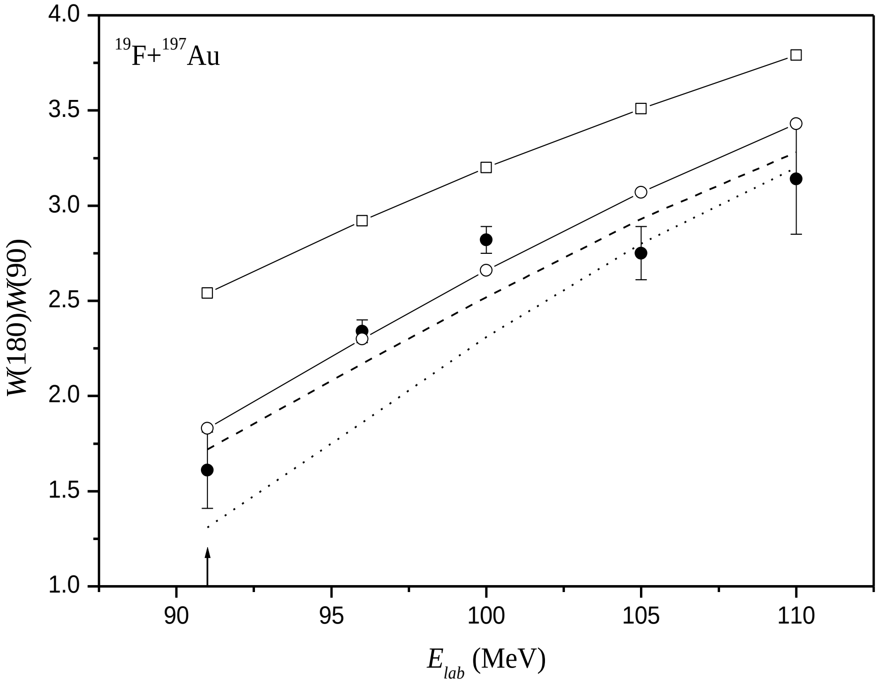
❖Irradiation followed by off-line gamma-ray spectrometry
❖Nuclear data of absolute gamma-ray intensities, level scheme, branching fractions

Fission fragment angular distribution: Study of non-compound nucleus fission

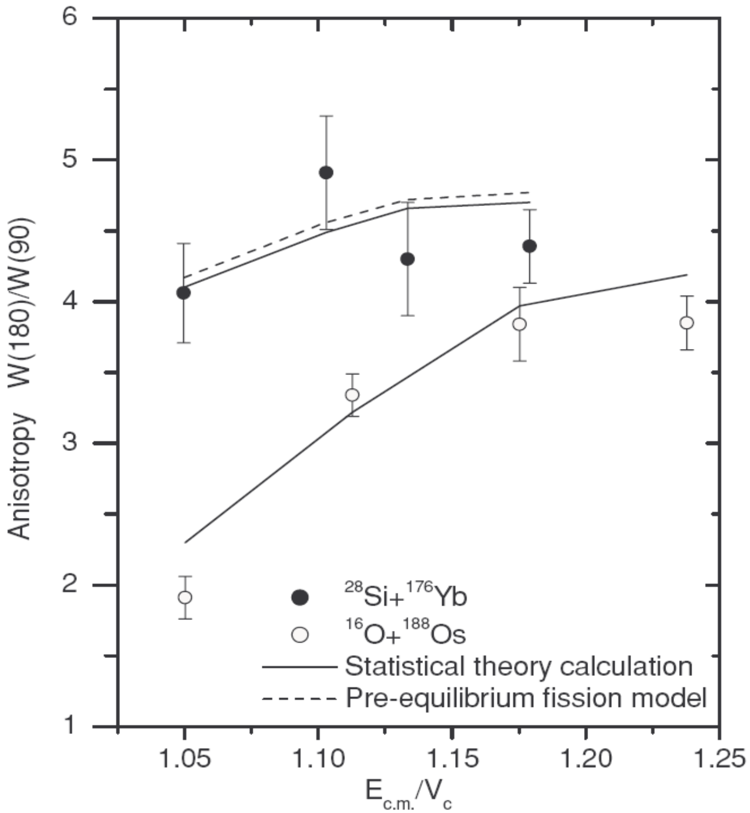
$$W(\theta_{cm}) = C\sum_{l=0}^{\infty} \frac{(2l+1)^2 T_l e^{-\frac{(l+1/2)^2 \sin^2(\theta_{cm})}{4K_0^2}} J_0\left[i(l+1/2)^2 \sin^2(\theta_{cm})/4K_0^2\right]}{\sqrt{2K_0^2}\, erf\left[(l+1/2)/\sqrt{2K_0^2}\right]}$$







$^{19}F+^{197}Au$



$^{16}O+^{188}Os$, $^{28}Si+^{176}Yb$

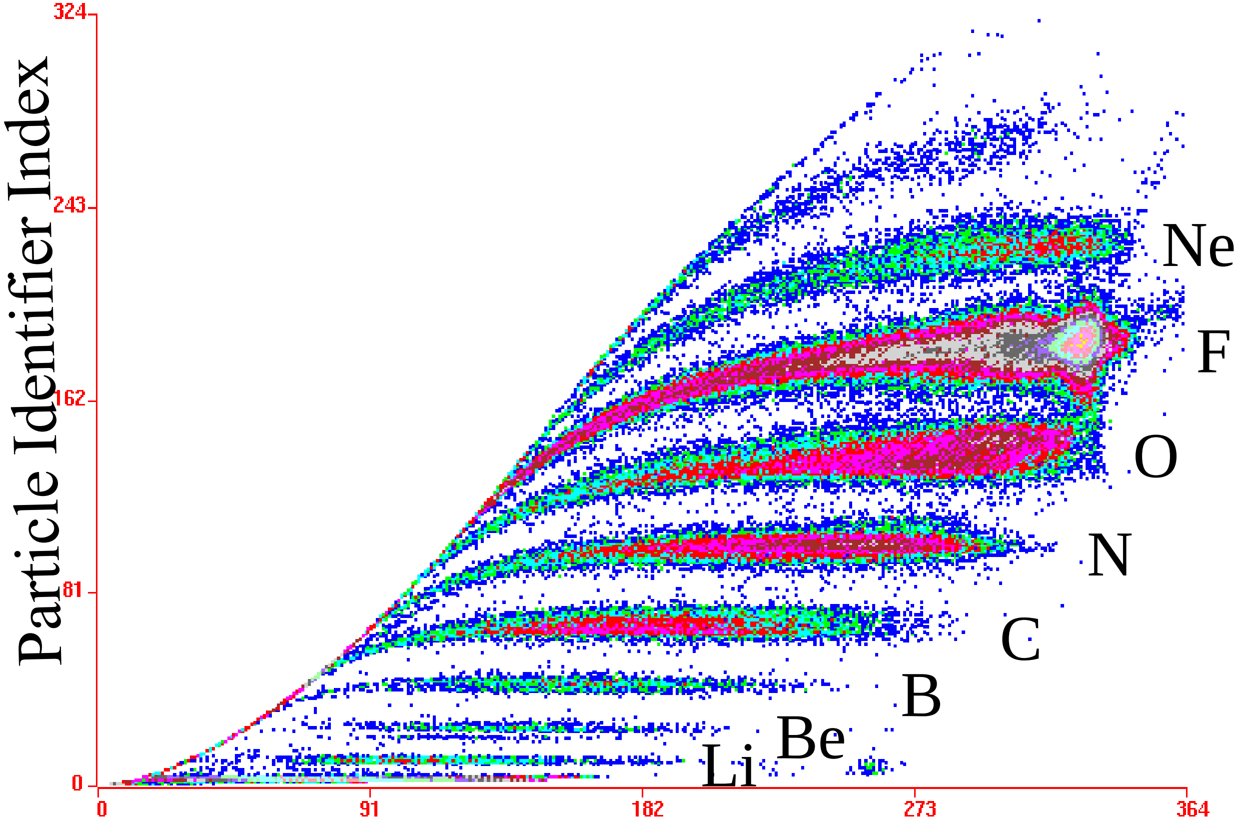
No significant contribution from non-compound nucleus fission in pre-actinide region for systems with Z_PZ_T<~1000

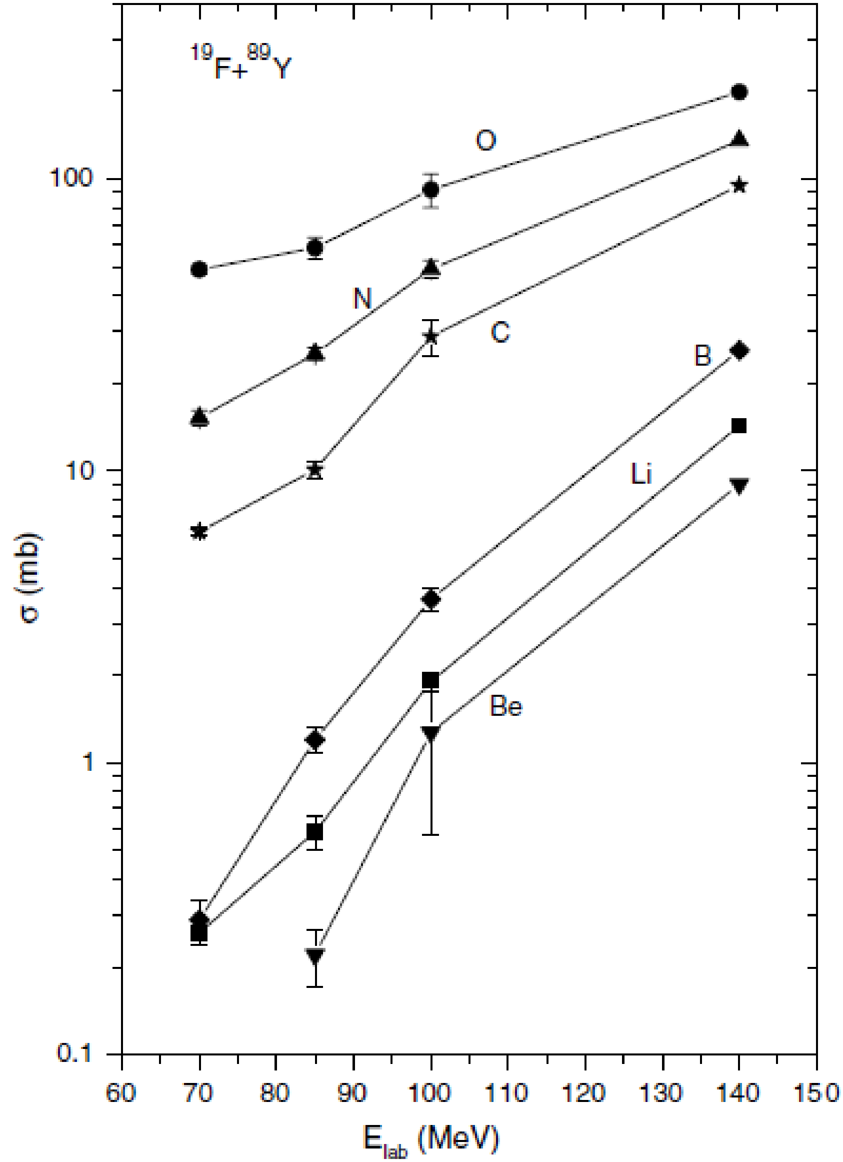
R. Tripathi et al., Phys. Rev. C **71**, 044616 (2005), Phys. Rev. C **79**, 064607 (2009)
Int. J. Mod. Phys. E **17**, 419 (2008)

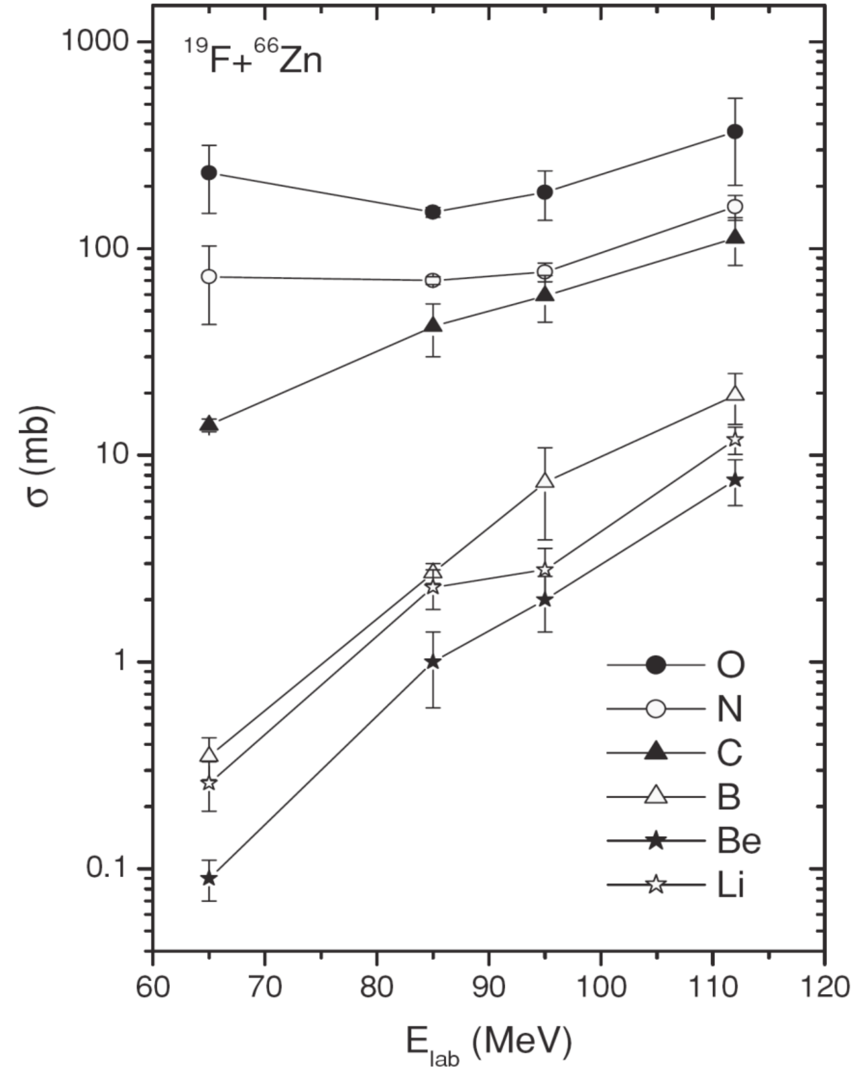
Studies on incomplete fusion: Beam energy dependence of PLF cross sections

- **$^{19}F+^{66}Zn$, ^{89}Y reactions**
- **Dependence of mass transfer (incomplete fusion) on beam energy**

Measurement of PLFs using Si E-ΔE telescopes







Threshold behaviour for massive transfer reactions

J. Phys. G **35**, 025101 (2008)

Phys. Rev. C **79**, 064604 (2009)

Decay scheme studies using radiochemical method

Study of decay of Bk isotopes

$^{11}B + ^{238}U \rightarrow ^{249}Bk^* \rightarrow ^{249-xn}Bk$ (243, **244**, 245,246)

Target: ^{238}U (Thickness ~30 mg/cm^2)

Irradiation: 6 M position (Three irradiations of about 18-24 h each), Reaction induced by $^{11}B(4+, 5+)$, $V_{c,lab}$ =57.2 MeV
TV=10.7 MV E=52.5, 64.2 (I~ 190 nA)

Measurement: Off-line singles and coincidence measurements using three HPGe detectors

Due to the large background from the fission products and U, chemical separation is must

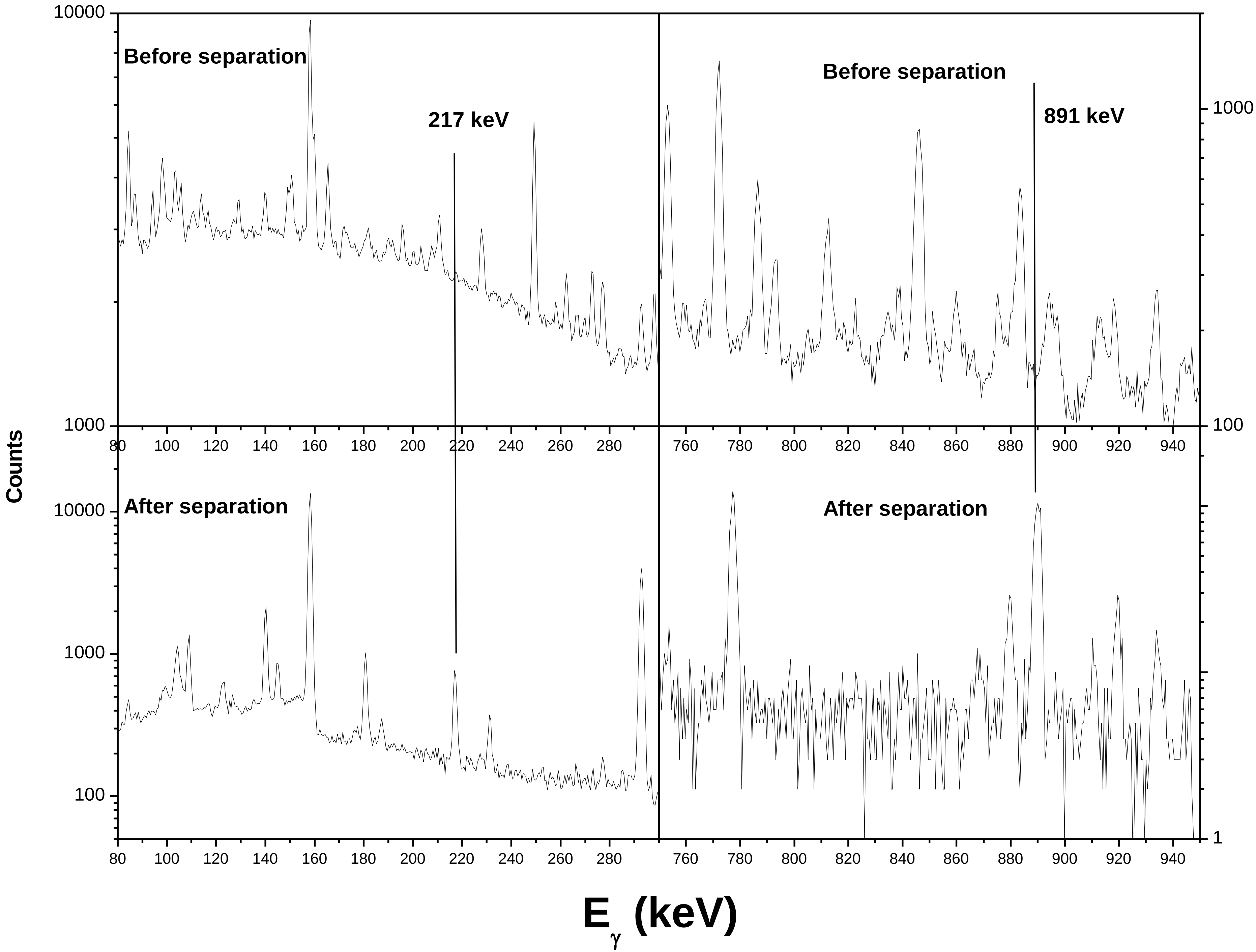
Separation through ion-exchange column (Removal of U)

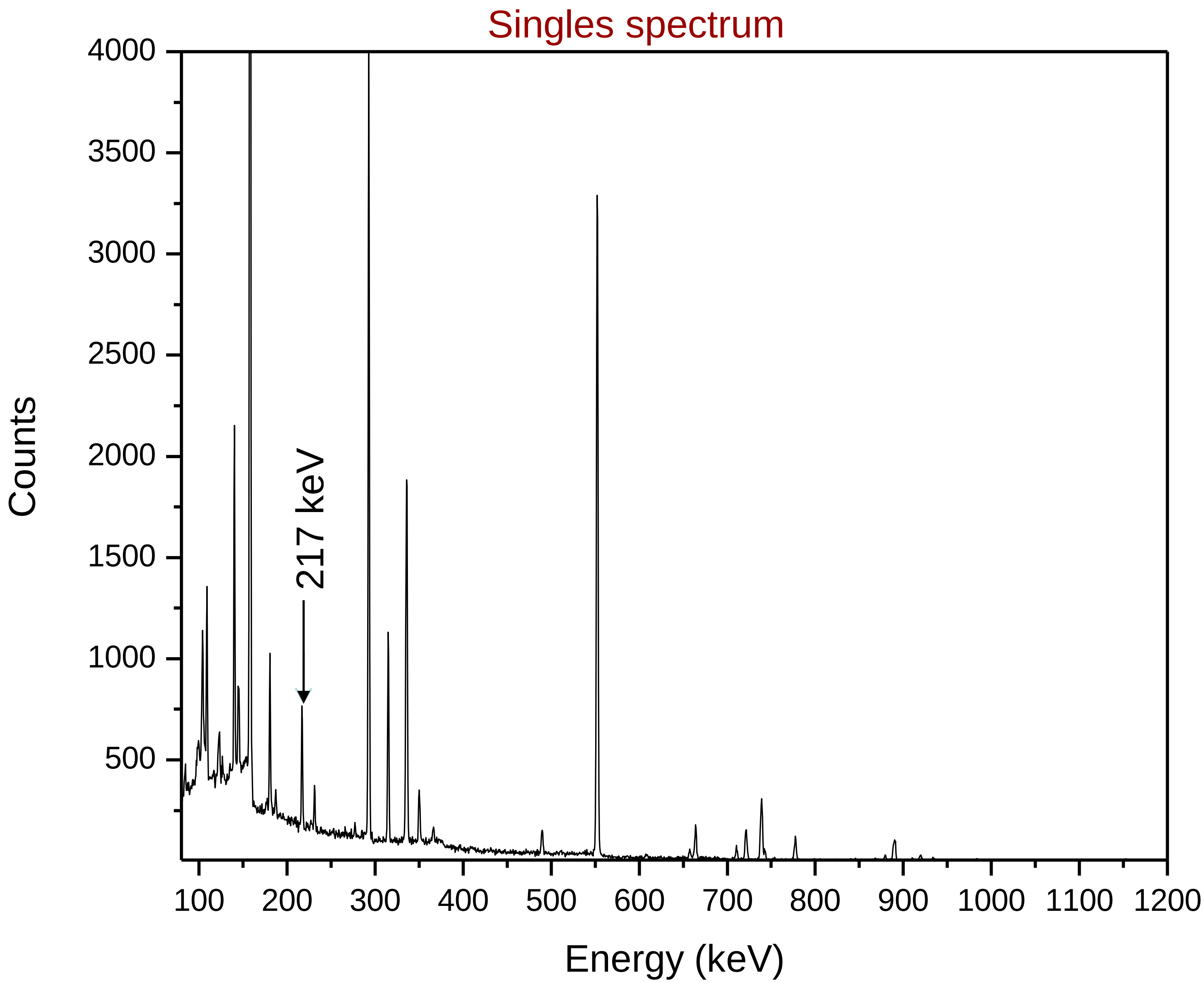
↓

Extraction into 0.15 M HDEHP solun (Separation from bulk fission products)

↓

Extraction Ce+Bk into H_2O_2+HNO_3 solution

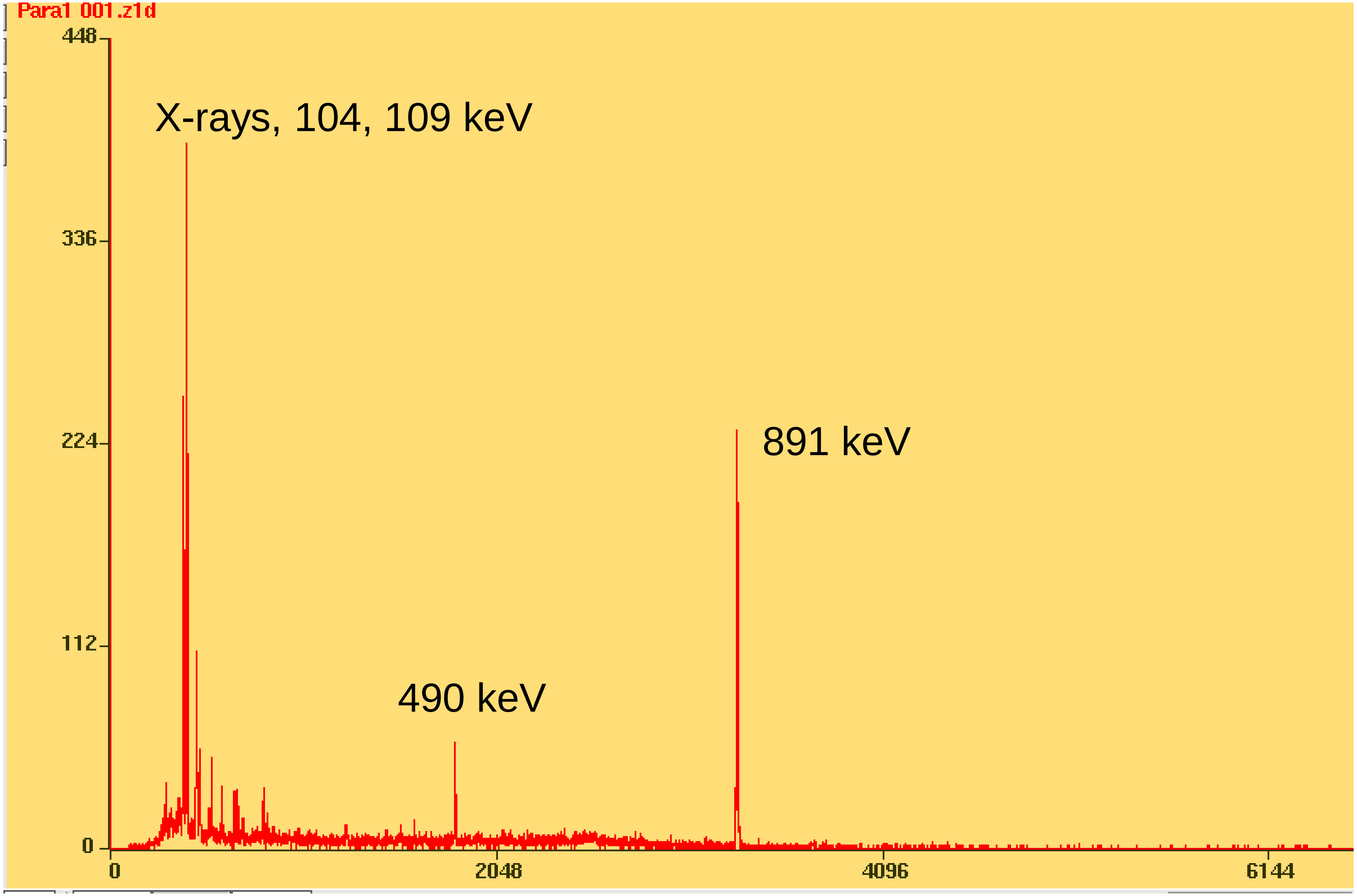

Before separation
217 keV
Before separation
891 keV
After separation
After separation
Counts
Eγ (keV)
10000
1000
100
1
80
100
120
140
160
180
200
220
240
260
280
760
780
800
820
840
860
880
900
920
940



Singles spectrum
Counts
Energy (keV)
217 keV
4000
3500
3000
2500
2000
1500
1000
500
100
200
300
400
500
600
700
800
900
1000
1100
1200

Coincidence spectrum

Gamma-ray spectra gated with 217 keV



Decay scheme studies around ~190

❖Isomeric states for several isotopes in the mass region ~190

❖Most of the isomers decay by EC/β+, many common gamma-lines

❖In many cases half-lives are also very close

❖Heavy ion reactions mainly produce high spin isomer

❖Difficult to study low spin isomer: Determination of absolute gamma-ray intensities, branching fractions, decay scheme

Ex:

$^{194}Tl^{m}$ (7^{+}) $T_{1/2}$ = 32.8 m

$^{194}Tl^{g}$ (2^{-}) $T_{1/2}$ = 33.0 m

Study of decay of $^{194}Tl^{g}$

$^{181}Ta(^{19}F,6n)^{194}Pb \rightarrow {}^{194}Tl^{g}$

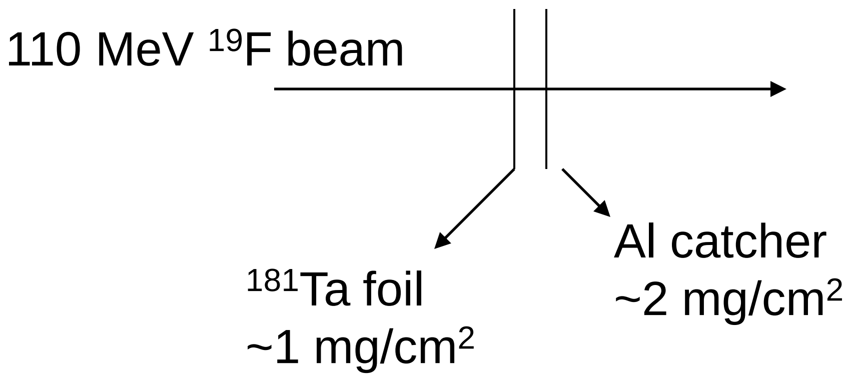
Dissolution of catcher foil in dil. NaOH solution

↓

Precipitation of Pb as $PbSO_4$

↓

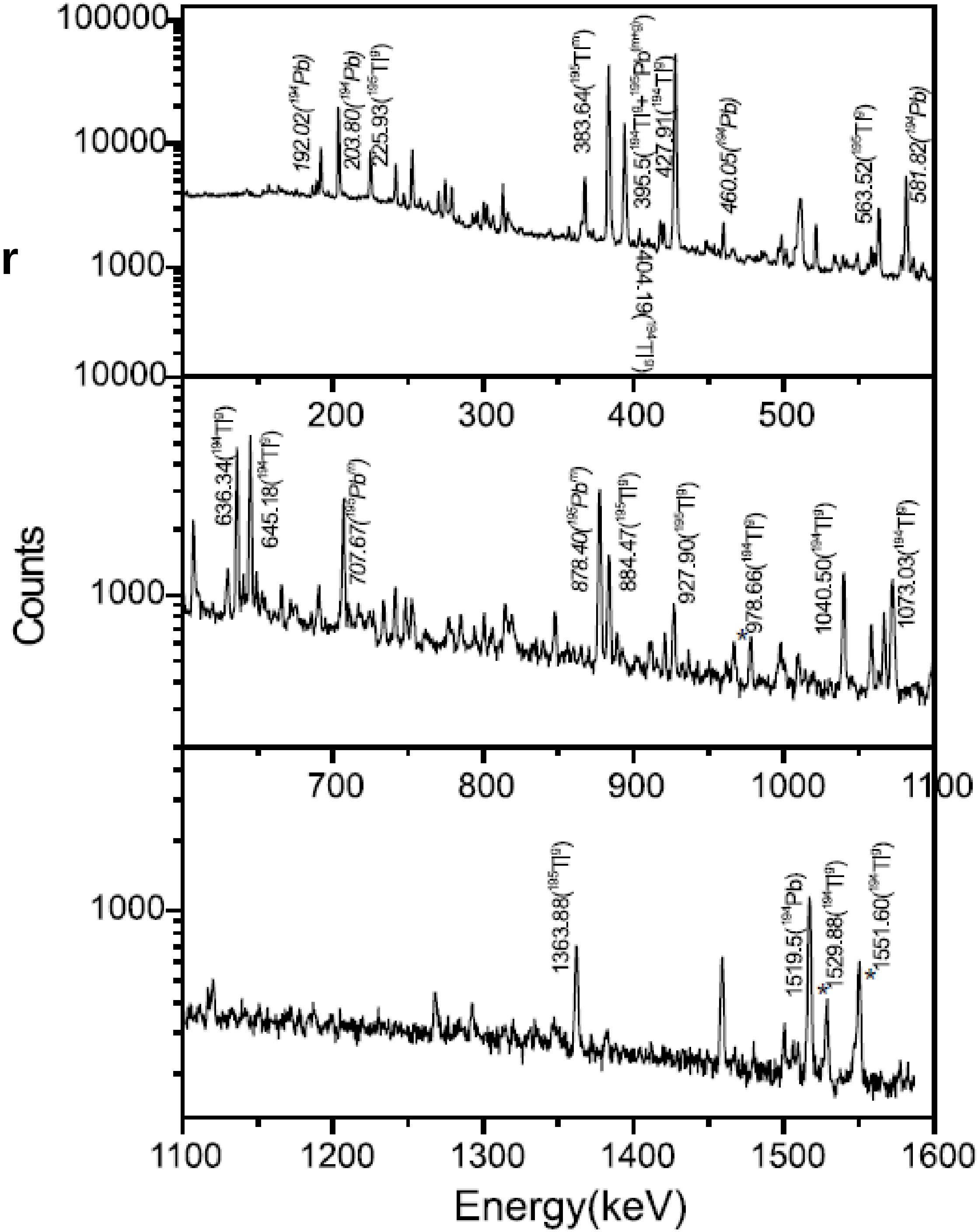
Gamma-ray spectrometry



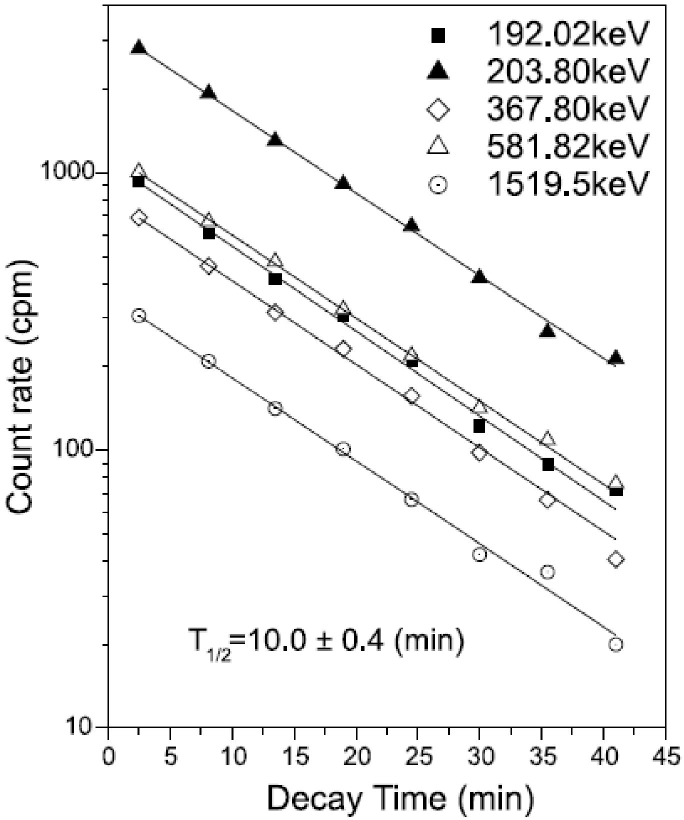
Schematic of irradiation setup

Singles and coincidence measurements

Gamma-ray spectra after separation of Pb



Decay curves of ^{194}Pb



Earlier lit. values

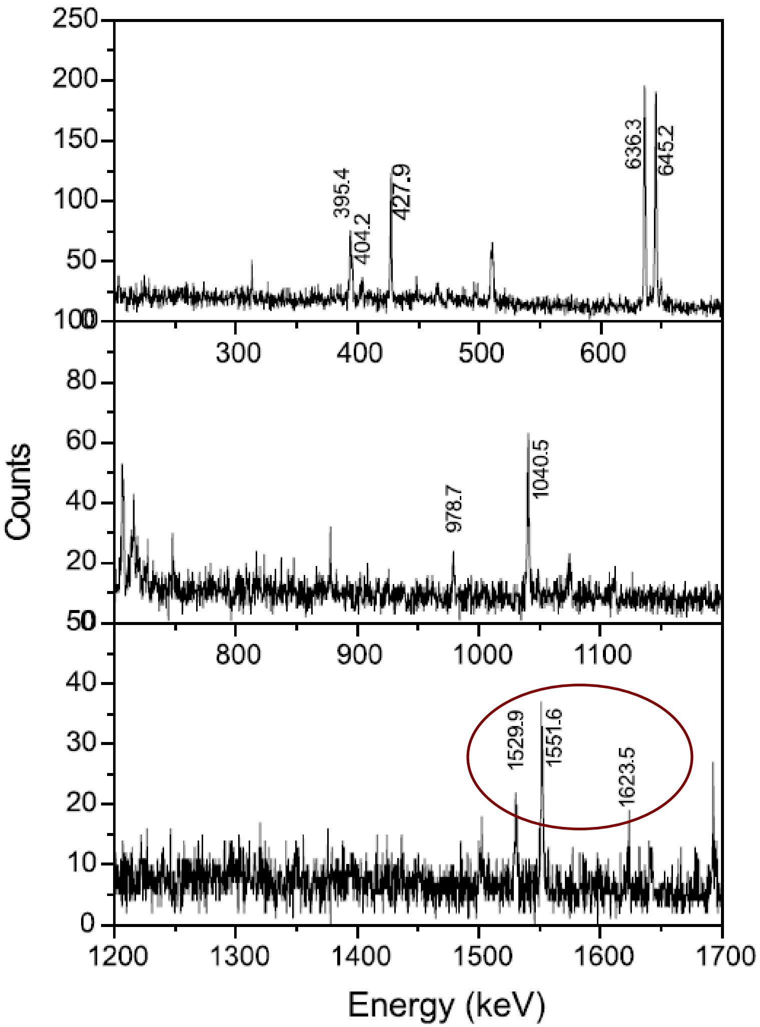
12.0±0.5 m [Y. A. Ellis-Akovali et al., Phys. Rev. C **36**, 1529 (1987)]

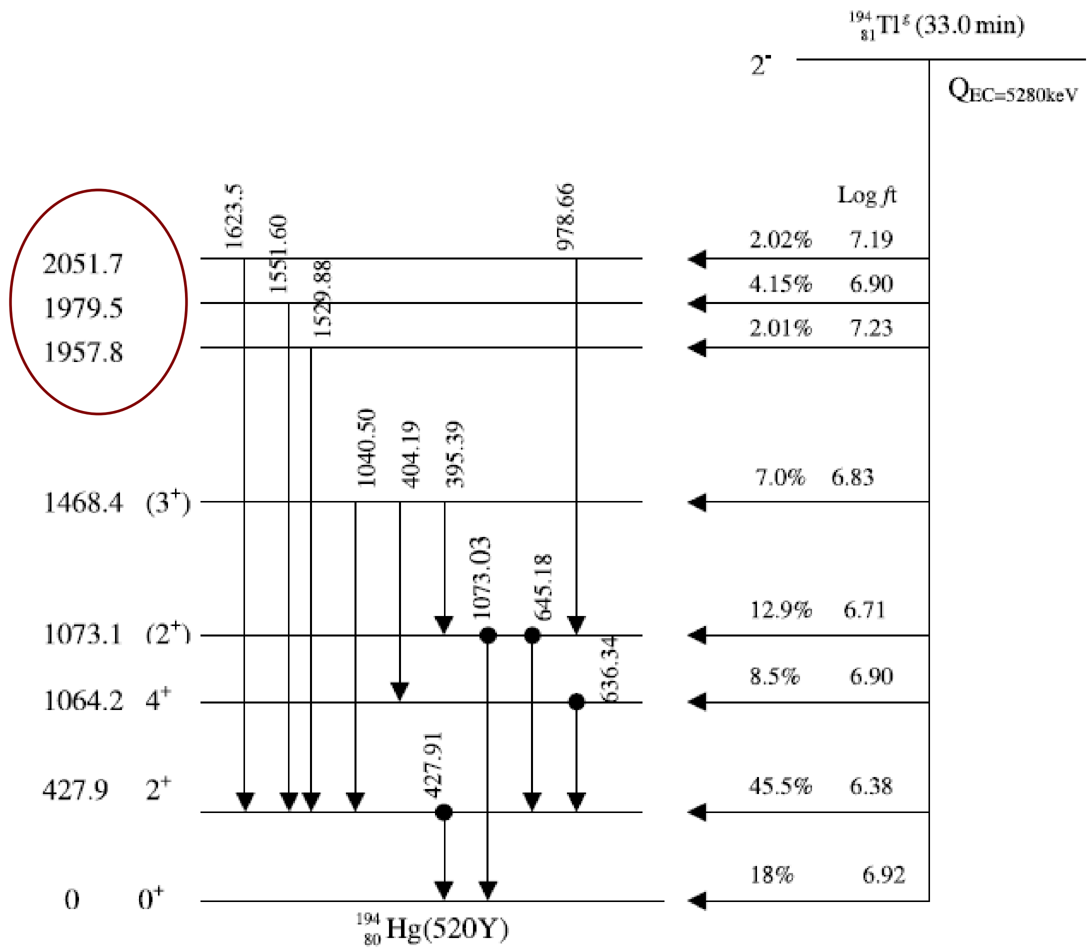
9.1±1.1 m [(K. H. Hicks, Phys. Rev. C **25**, 2710 (1982)]

From the peak areas of ^{194}Tl^{g} gamma-rays, their absolute emission intensities were determined

$$\mathrm{PA}(t) = A_0 \varepsilon_\gamma a_\gamma \left(\frac{\lambda_{\mathrm{Tl}}}{\lambda_{\mathrm{Tl}} - \lambda_{\mathrm{Pb}}} \right) \times \left\{ \mathrm{e}^{-\lambda_{\mathrm{Pb}} t} \left(\frac{1 - \mathrm{e}^{-\lambda_{\mathrm{Pb}} \Delta T}}{\lambda_{\mathrm{Pb}}} \right) - \mathrm{e}^{-\lambda_{\mathrm{Tl}} t} \left(\frac{1 - \mathrm{e}^{-\lambda_{\mathrm{Tl}} \Delta T}}{\lambda_{\mathrm{Tl}}} \right) \right\} + A_1 \cdot \mathrm{e}^{-\lambda_{\mathrm{Tl}} t} \left(\frac{1 - \mathrm{e}^{-\lambda_{\mathrm{Tl}} \Delta T}}{\lambda_{\mathrm{Tl}}} \right),$$

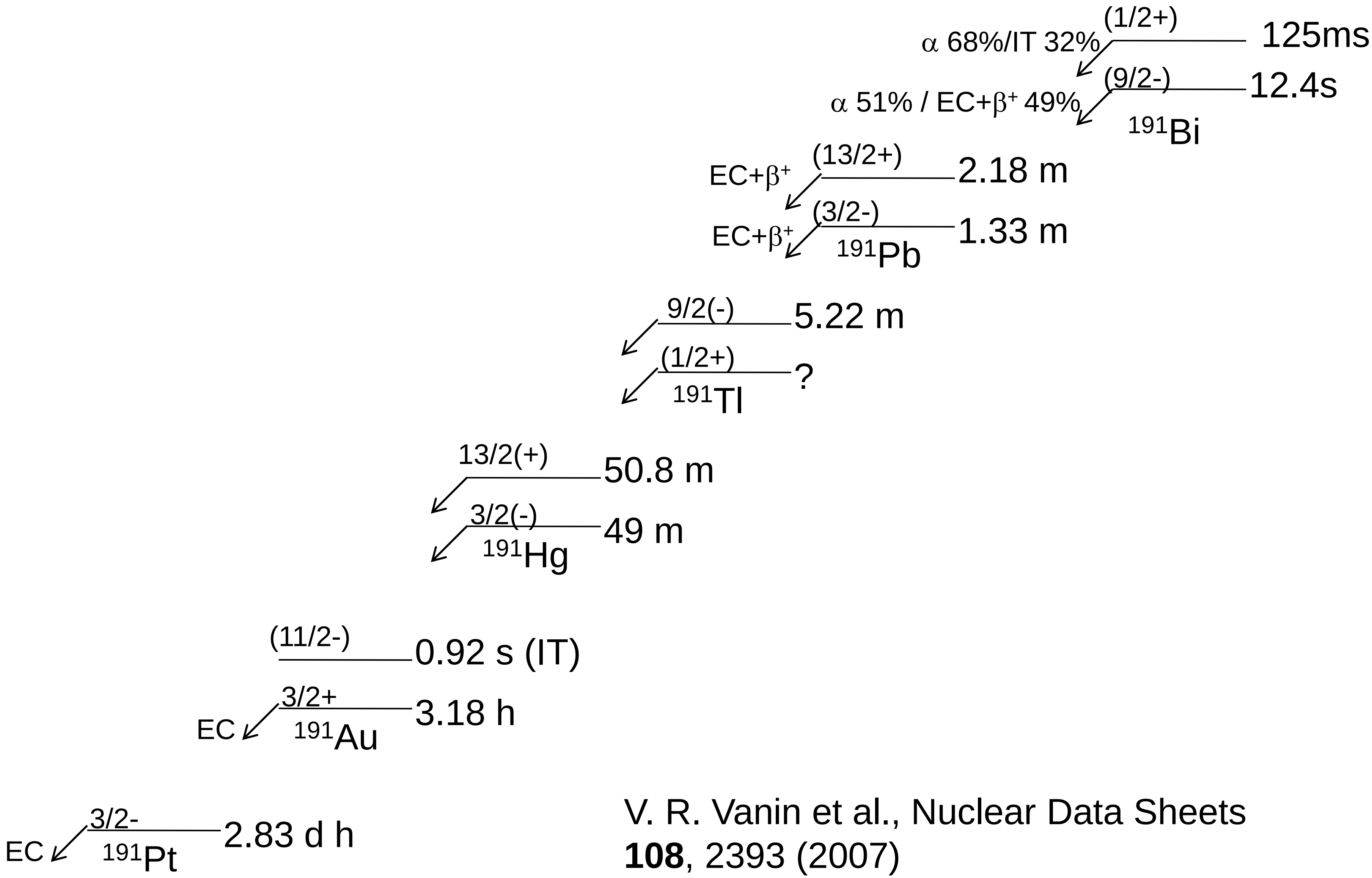
Decay scheme of $^{194}Tl^{g}$





Radiochim. Acta **91**, 1 (2003)

Proposed decay scheme studies at ISOLDE



V. R. Vanin et al., Nuclear Data Sheets **108**, 2393 (2007)

ISOLDE-RILIS facility with the capability of isomer separation is an ideal choice

Eur. Phys. J. A **39**, 33–48 (2009)
DOI 10.1140/epja/i2008-10693-3

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

Nuclear structure of ^{189}Tl states studied via β^+/EC decay and laser spectroscopy of $^{189m+g}$Pb

J. Sauvage[1,a], J. Genevey[2], B. Roussière[1], S. Franchoo[1,3,4], A.N. Andreyev[5,6,7], N. Barré[1], J.-F. Clavelin[1], H. De Witte[5], D.V. Fedorov[8], V.N. Fedoseyev[4], L.M. Fraile[4,b], X. Grave[1], G. Huber[3], M. Huyse[5], H.B. Jeppesen[4,c], U. Köster[4,9], P. Kunz[3], S.R. Lesher[5,d], B.A. Marsh[4], I. Mukha[5,e], J. Oms[1], M. Seliverstov[3,8], I. Stefanescu[5,f], K. Van de Vel[5,g], J. Van de Walle[4], P. Van Duppen[5], and Yu.M. Volkov[8]

[1] Institut de Physique Nucléaire, IN2P3-CNRS/Université Paris-Sud, F-91406 Orsay Cedex, France
[2] Laboratoire de Physique Subatomique et de Cosmologie, IN2P3-CNRS/Université Joseph Fourier, F-38026 Grenoble Cedex, France
[3] Institut für Physik, Johannes Gutenberg Universität, D-55099 Mainz, Germany
[4] ISOLDE, CERN, CH-1211 Genève 23, Switzerland
[5] Instituut voor Kern- en Stralingsfysica, K.U. Leuven, B-3001 Leuven, Belgium
[6] Oliver Lodge Laboratory, University of Liverpool, Liverpool, L69 7ZE, UK
[7] TRIUMF, Vancouver BC, V6T 2A3, Canada
[8] Petersburg Nuclear Physics Institute, 188350, Gatchina, Russia
[9] Institut Laue-Langevin, 38042 Grenoble cedex 9, France

Proposed candidates for decay scheme studies

^{191}Bi (9/2^{-} ; $T_{1/2}$=12.4 s)
No information about the decay scheme for the EC/β^{+} decay of ^{191}Bi to ^{191}Pb

^{191}Pb(3/2^{-} ; $T_{1/2}$=1.33 m)
Only relative gamma-ray intensities are known

^{191}Pb(13/2^{+}; $T_{1/2}$=2.18 m)
Only relative gamma-ray intensities are known

^{191}Tl(1/2^{+})
No information about the decay mode and half-life

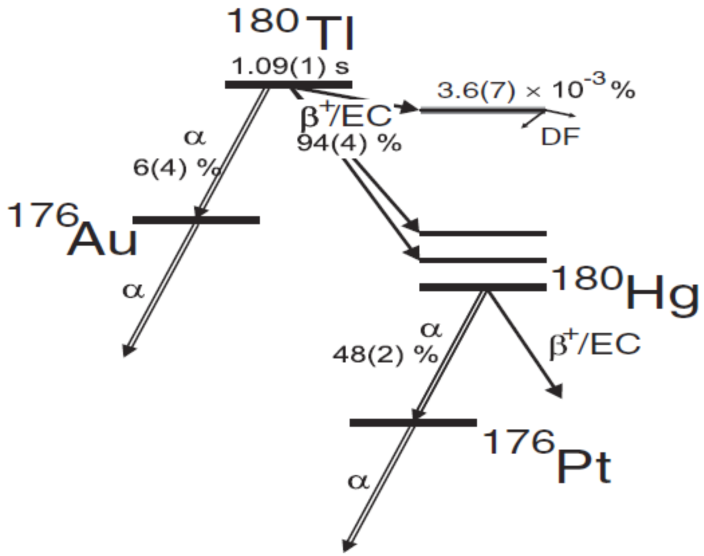
^{191}Hg(3/2^{-}; $T_{1/2}$=49 m)
Only relative gamma-ray intensities are known

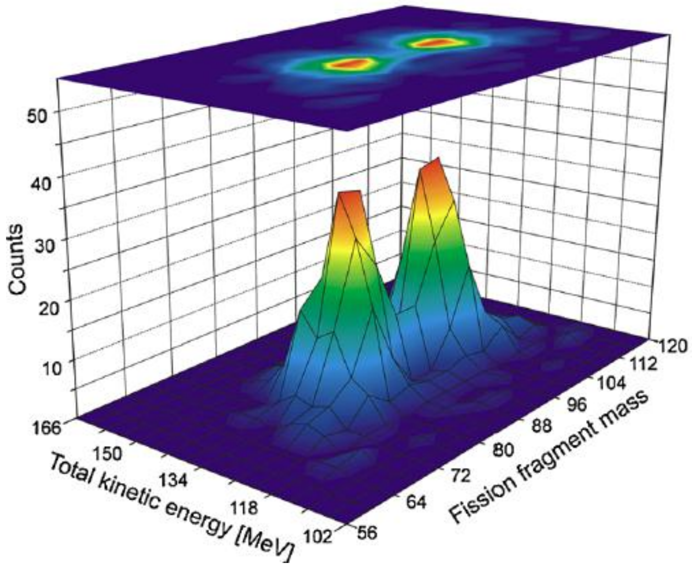
^{191}Au (3/2^{+}; $T_{1/2}$=3.18 h)
Gamma-ray intensities are approximate

Studies on less neutron deficient isotopes can be carried out at our accelerator facilities

Study of beta delayed fission

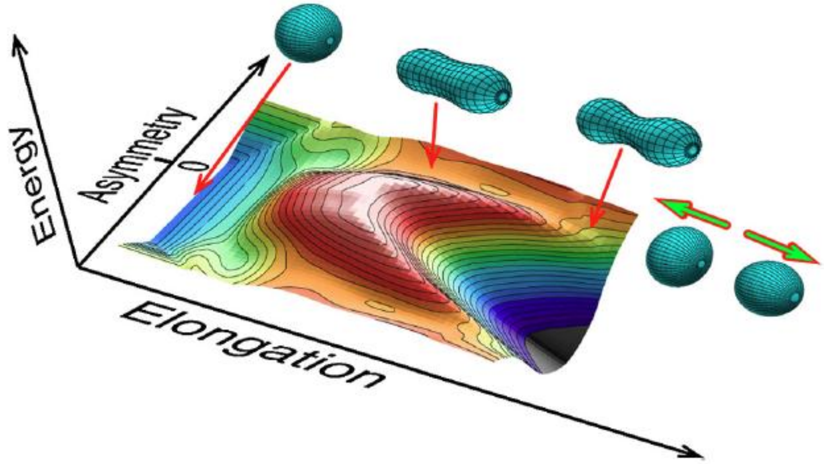
A. N. Andreyev et al., Phys. Rev. Lett. **105**, 252502 (2010)





❖^{188}Bi → ^{188}Pb (Another system for beta delayed fission)

❖Complementary studies can be carried out through heavy ion reactions



Summary

- Detailed decay studies mass chains around ~190 are proposed at ISOLDE facility
- This mass region is also important for the study of beta delayed fission
- Complementary studies can be carried out at our facilities in India

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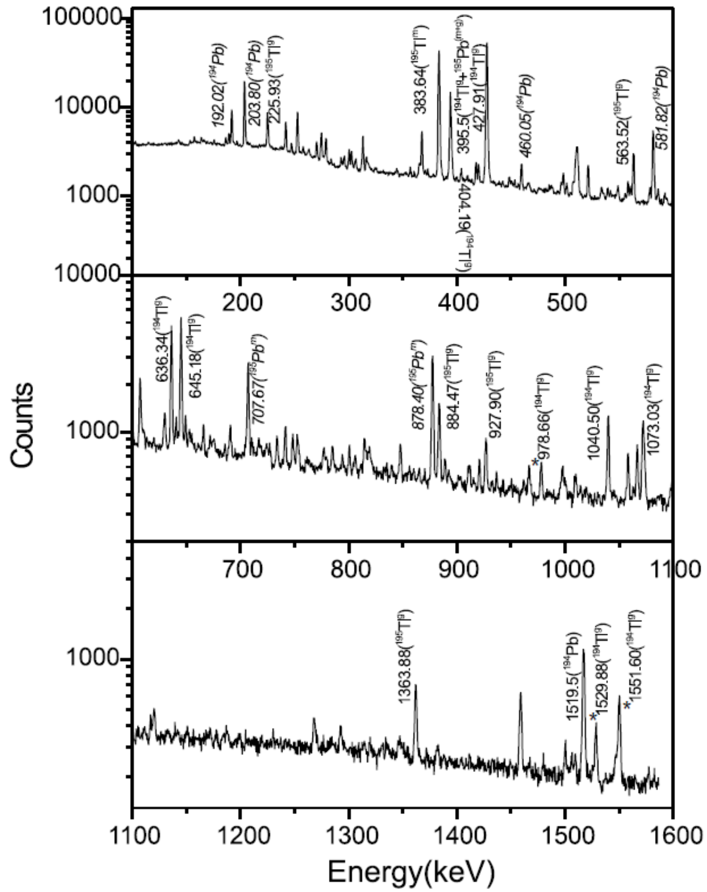
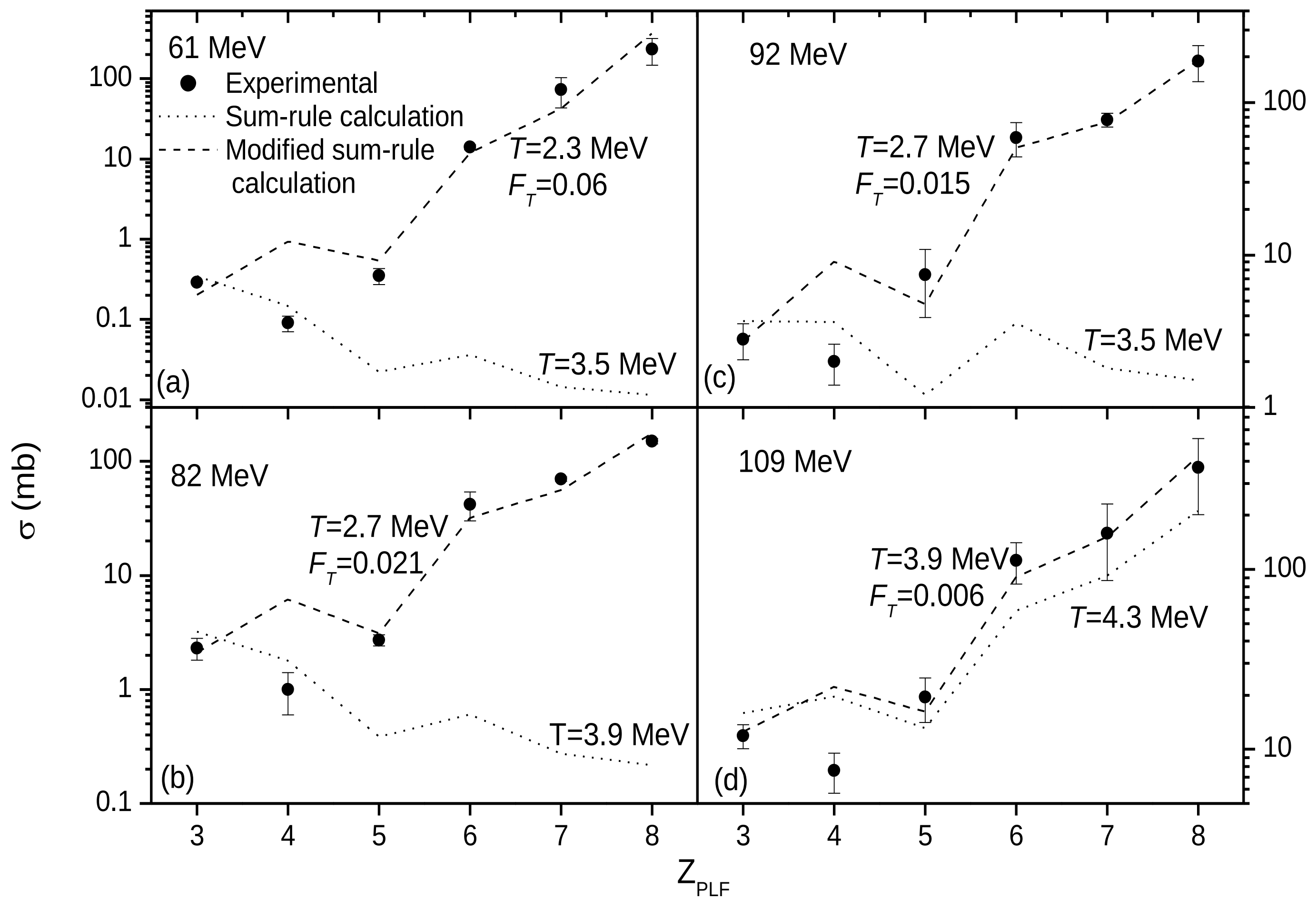
K. Mahata
B. K. Nayak

Thank You


Counts
Energy(keV)
100000
10000
1000
10000
1000
1000
200
300
400
500
700
800
900
1000
1100
1100
1200
1300
1400
1500
1600
192.02(194Pb)
203.80(194Pb)
225.93(195Tlg)
383.64(195Tlm)
395.5(194Tlg+195Pbm+g)
427.91(194Tlg)
404.19(194Tlg)
460.05(194Pb)
563.52(195Tlg)
581.82(194Pb)
636.34(194Tlg)
645.18(194Tlg)
707.67(195Pbm)
878.40(195Pbm)
884.47(195Tlg)
927.90(195Tlg)
*978.66(194Tlg)
1040.50(194Tlg)
1073.03(194Tlg)
1363.88(195Tlg)
1519.5(194Pb)
*1529.88(194Tlg)
*1551.60(194Tlg)

Modification of sum-rule model

Incorporation of effective competition from ICF for low *l*-waves



$^{19}F+^{66}Zn$