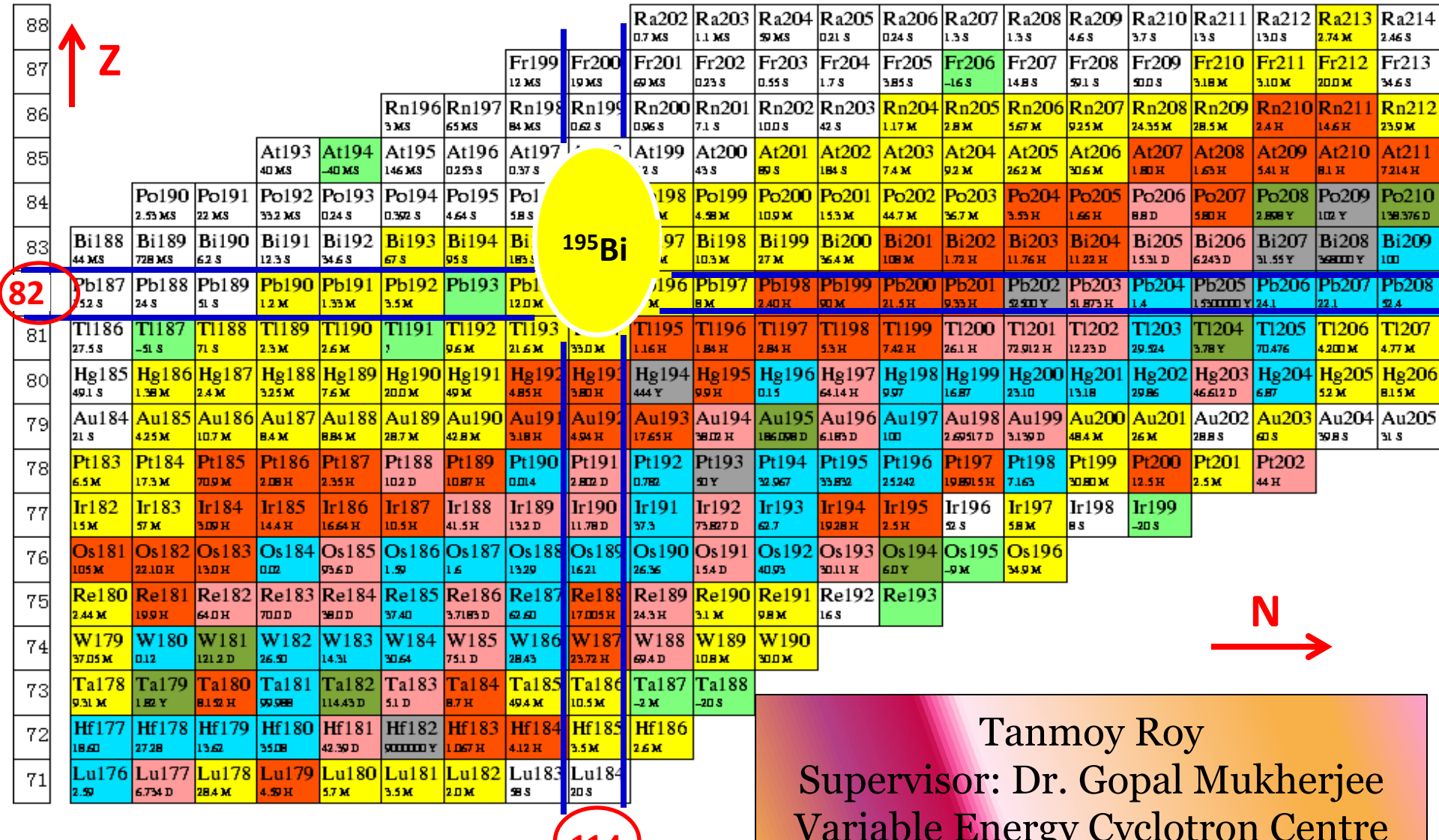
Study of high spin states and isomers in nuclei near Z=82



Tanmoy Roy
Supervisor: Dr. Gopal Mukherjee
Variable Energy Cyclotron Centre

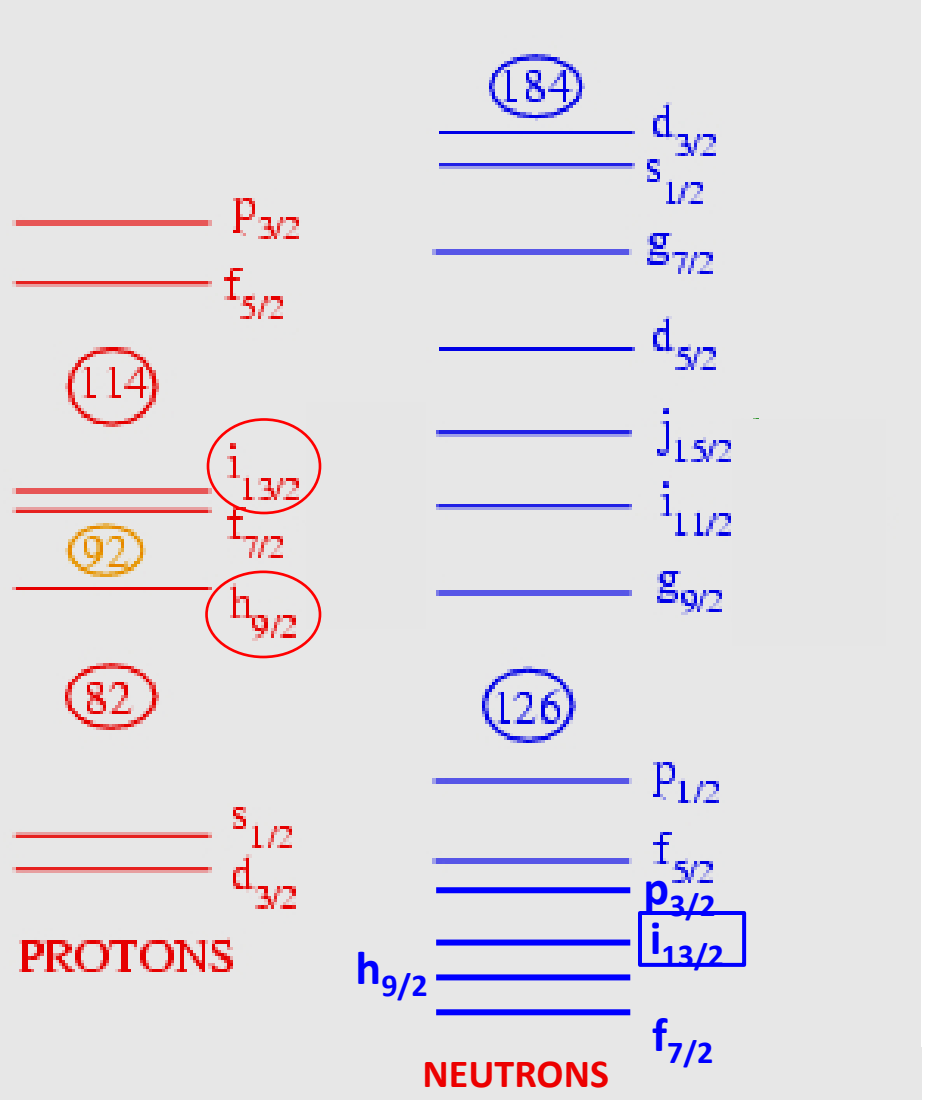
Plan of The Talk

Aim of the Study

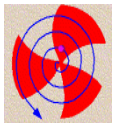
Experimental investigation of the effect of the effect and relative importance of these high- j proton and neutron orbitals on the high spin states in the nuclei near Z=82.

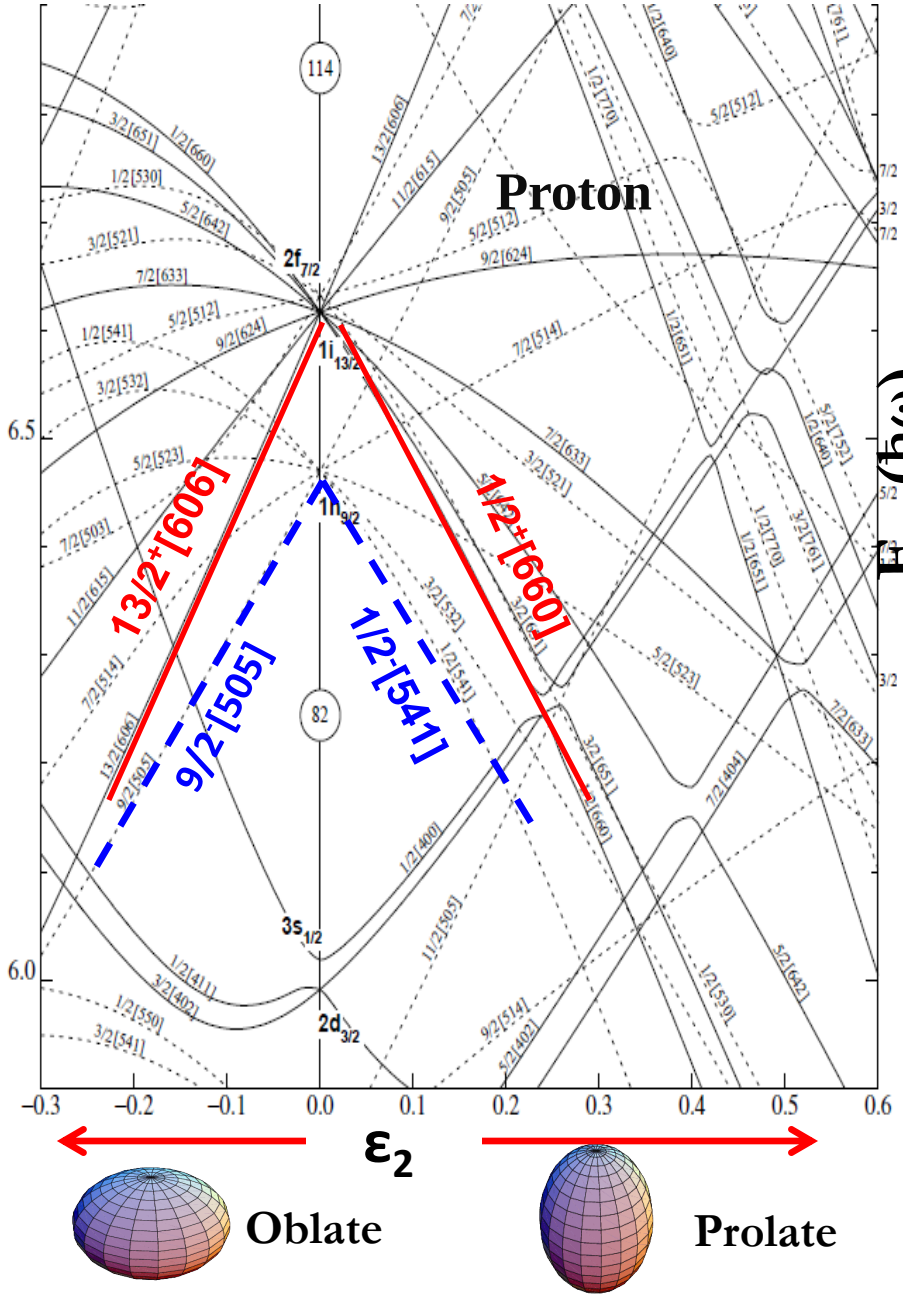
- Introduction
- Aim of the Study
- Experimental Details
- Data Analysis
- Conclusion

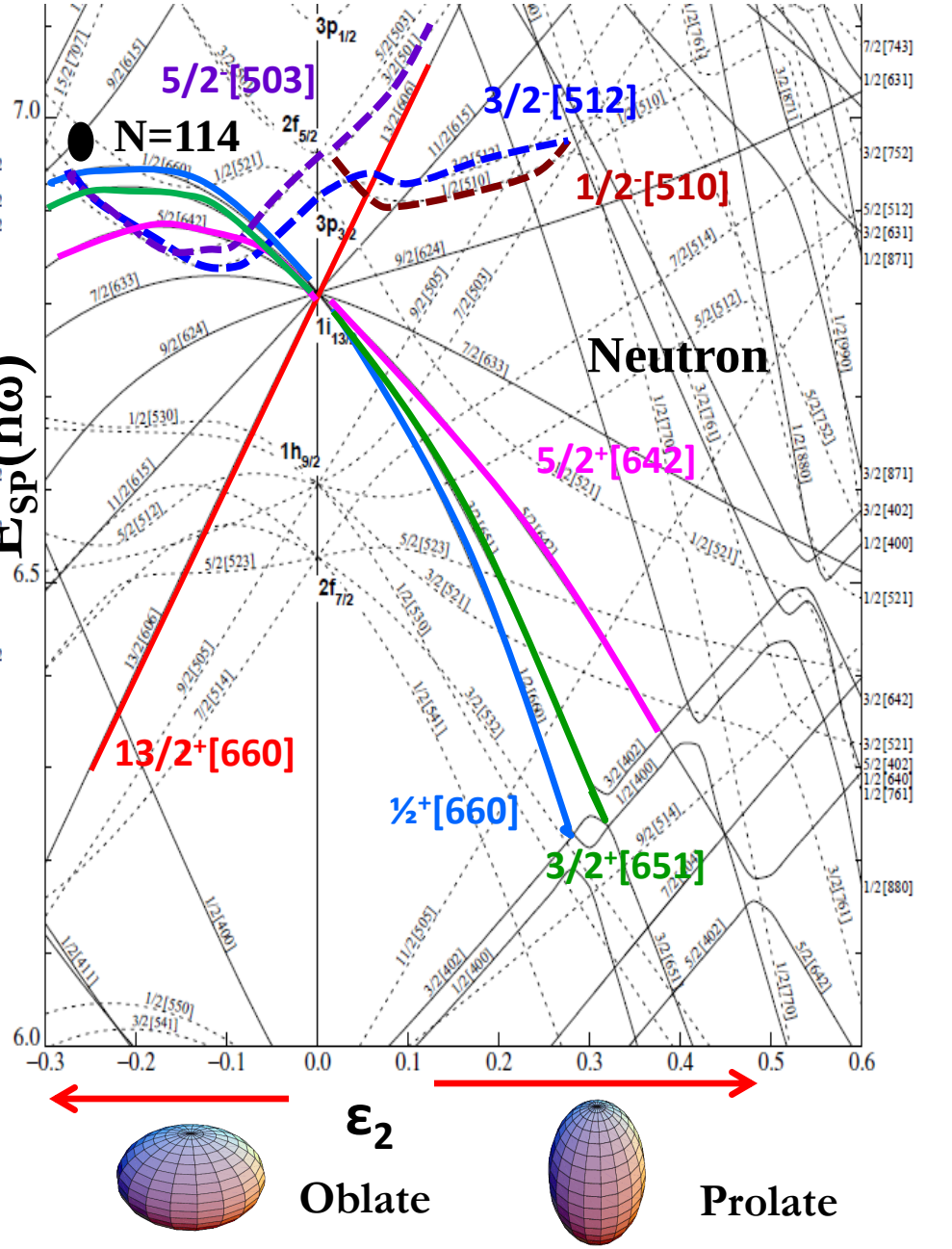
The relative position of high-j proton ($h_{9/2}$, $i_{13/2}$) and neutron ($i_{13/2}$) orbitals for nuclei in the mass region A~190 -200 with Z~82 according to the spherical shell model.



Nilsson Single Particle Diagram







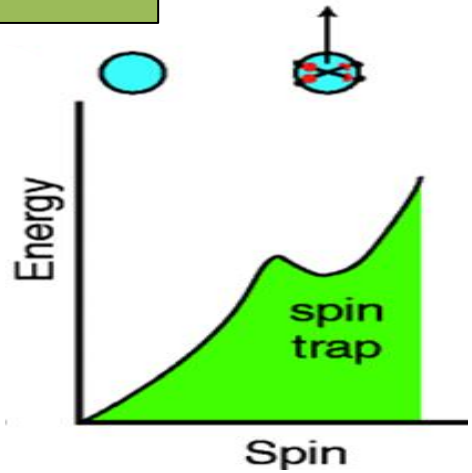
Various Phenomena

$9/2^-$ I_2 ; E_2 =483

$3/2^+$

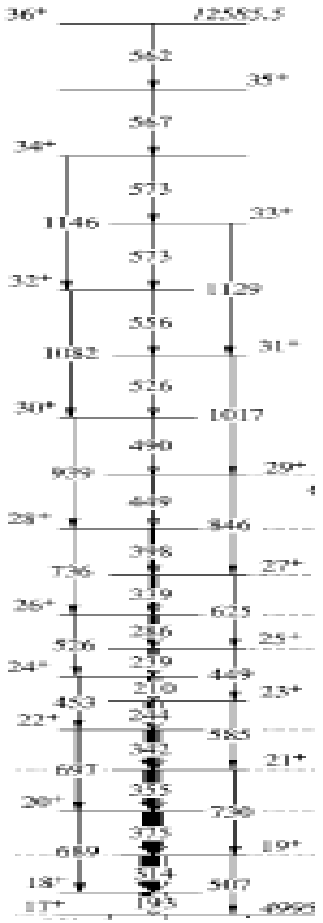
I_1 ; E_1 =384

$\Delta I=3$; $\Delta E=99$ keV

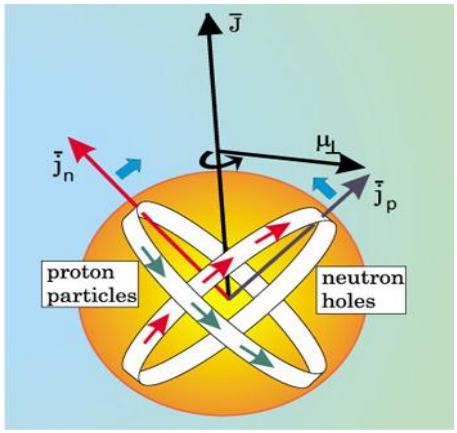


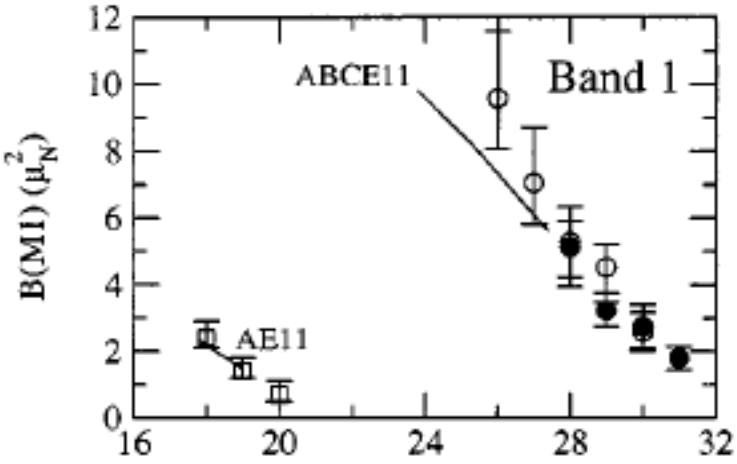
Large spin difference with small energy gap gives **Spin Isomer**

^{196}Pb: Band 1



Magnetic Rotational (MR) Band





ABC: quasi ν $i_{13/2}$ origin

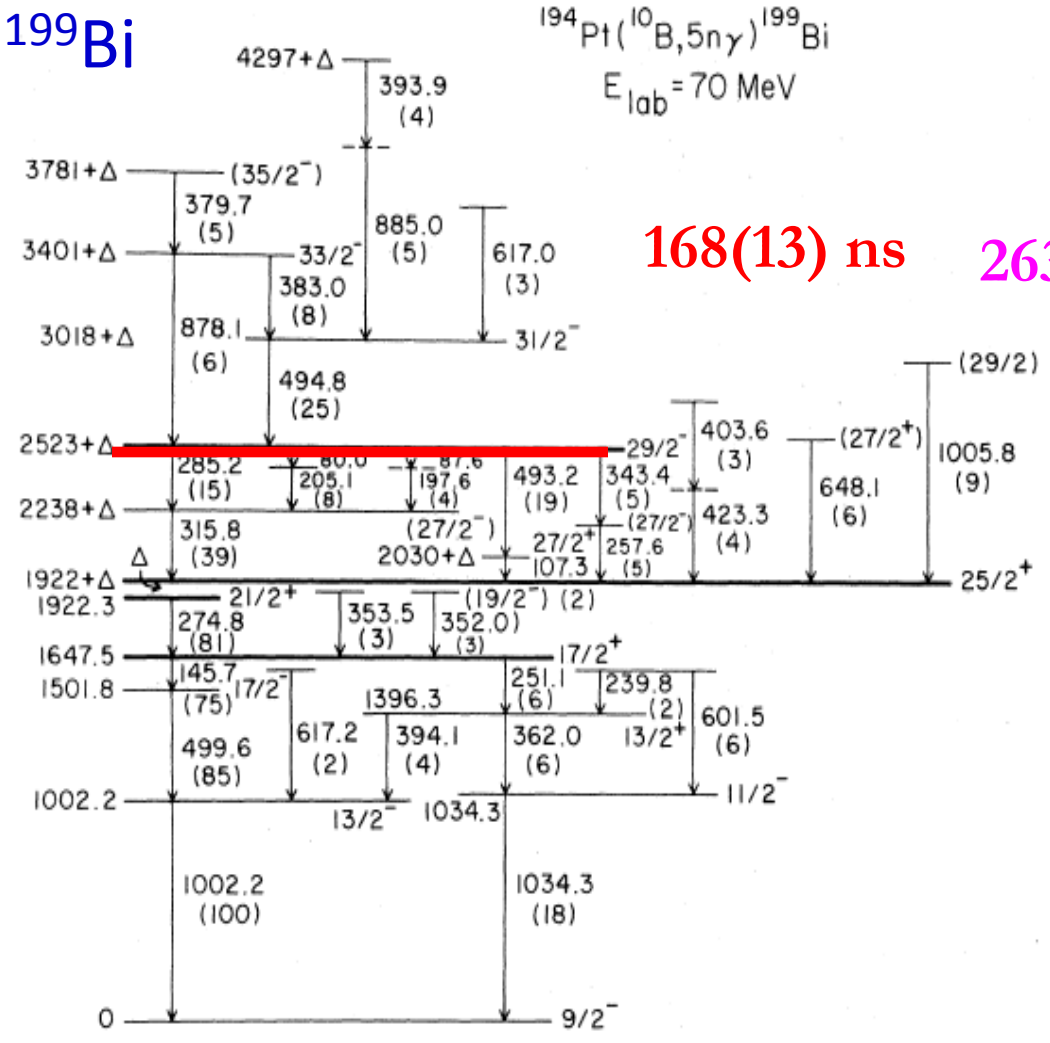
E: quasi ν $p_{3/2}$, $f_{5/2}$ origin

$\pi(h_{9/2}, i_{13/2})$ 11^-

A. K. Singh et. al., NP**A 707**, 3 (2002).

A. K. Singh et. al., PR**C 66**, 064314 (2002).

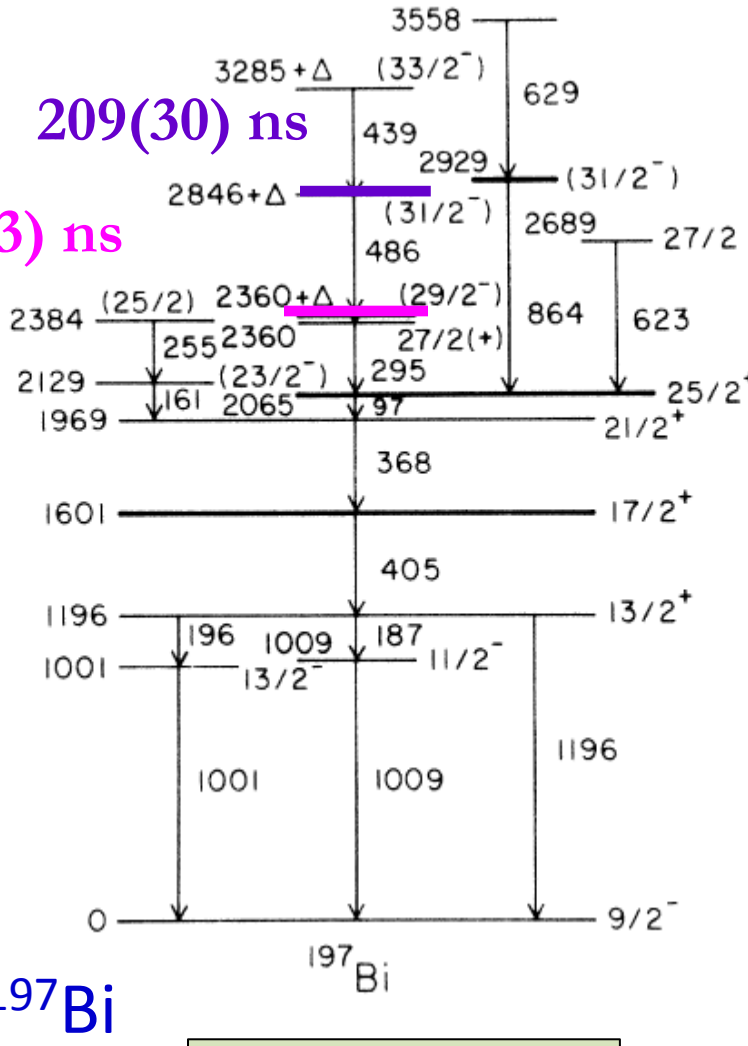
Band structures in odd-A Bi nuclei



168(13) ns

263(13) ns

209(30) ns



197Bi

W. F. Piel et al.,
PRC **31**, 2807(1985).

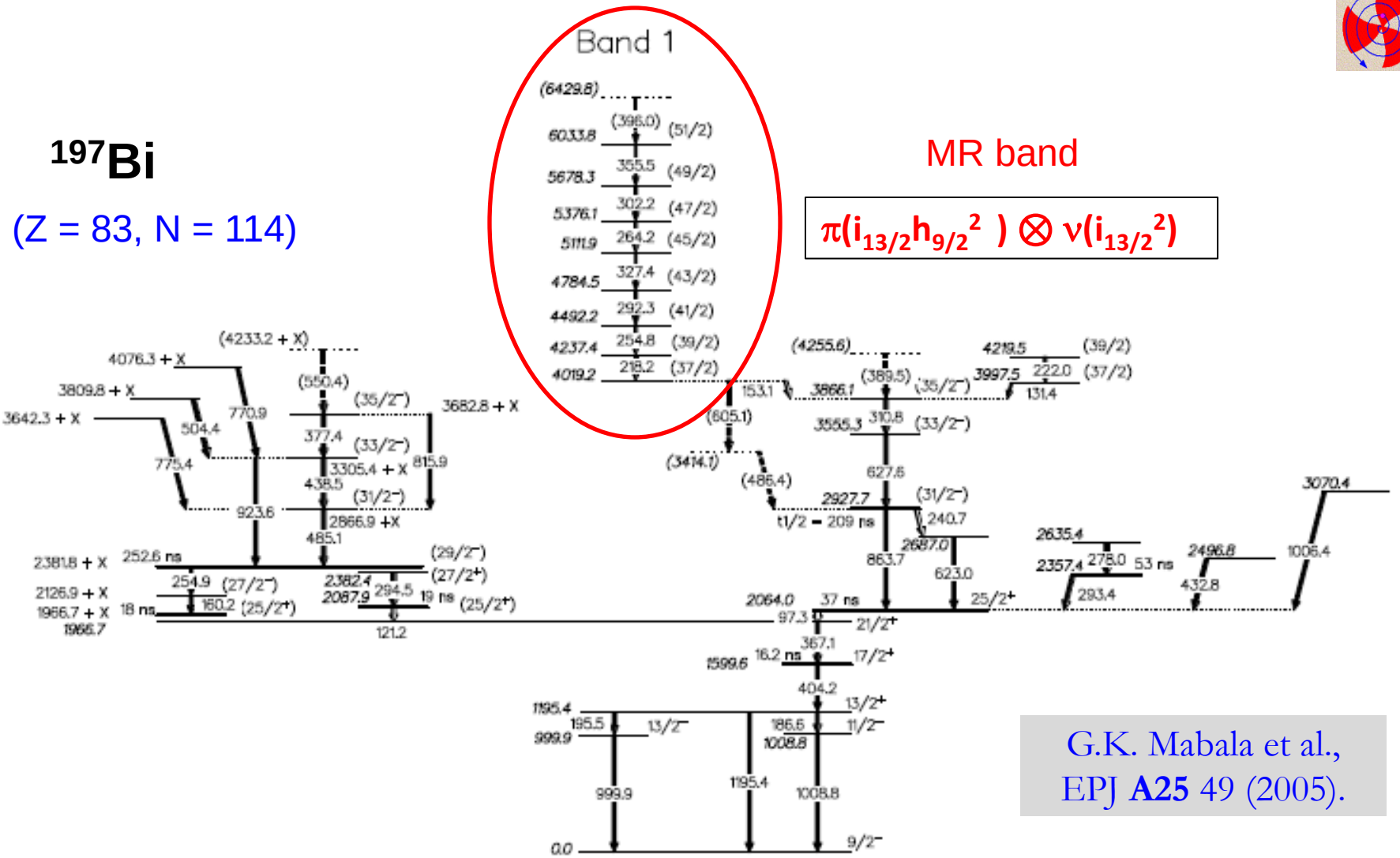
T. Chapuran et al.,
PRC **33**,130(1985).

^{197}Bi

(Z = 83, N = 114)

MR band

$\pi(i_{13/2}h_{9/2}^{2}) \otimes \nu(i_{13/2}^{2})$

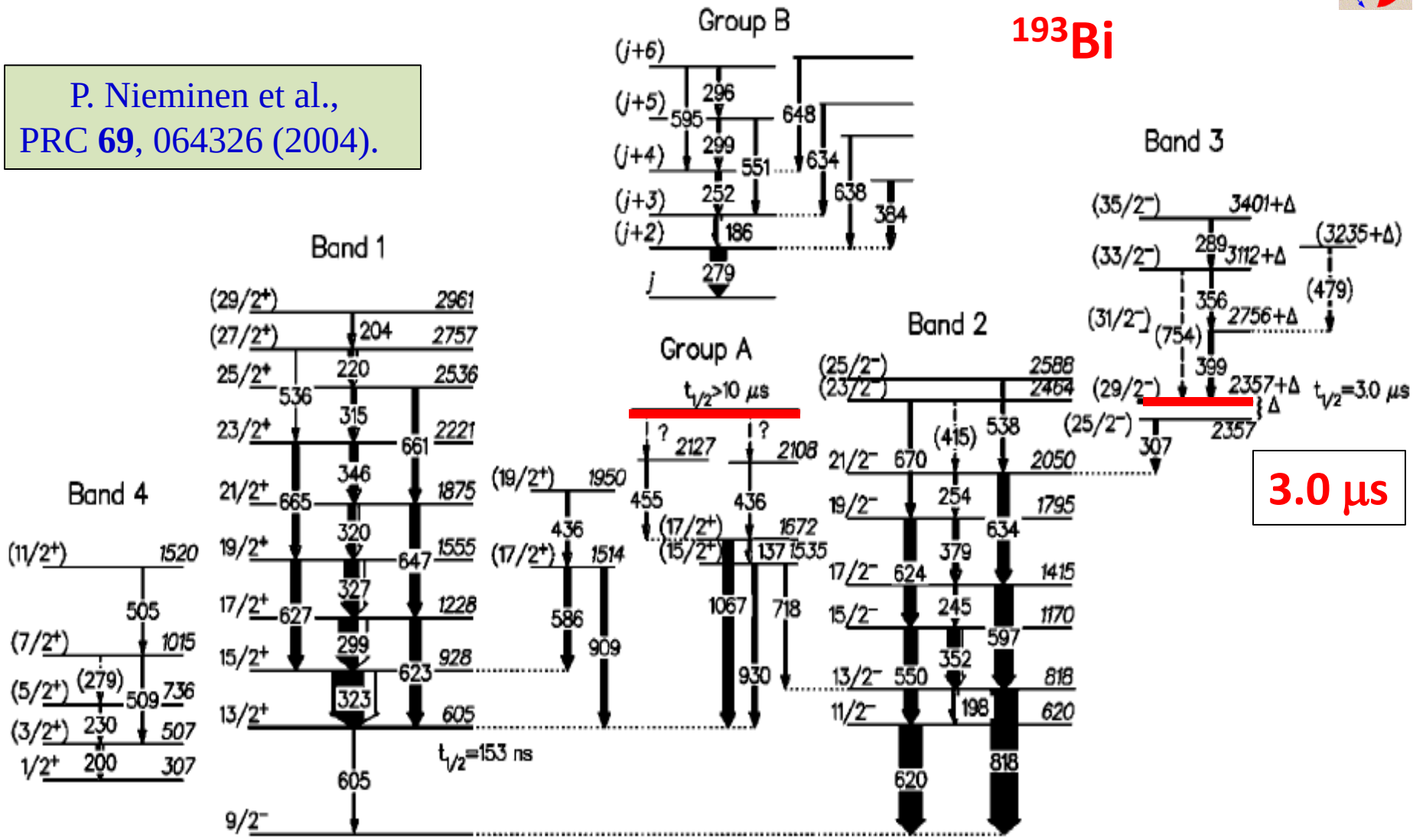


G.K. Mabala et al.,
EPJ **A25** 49 (2005).

- **Low lying excited states correspond to spherical shape**
- **Magnetic rotational bands observed at excitation energy above 4MeV**

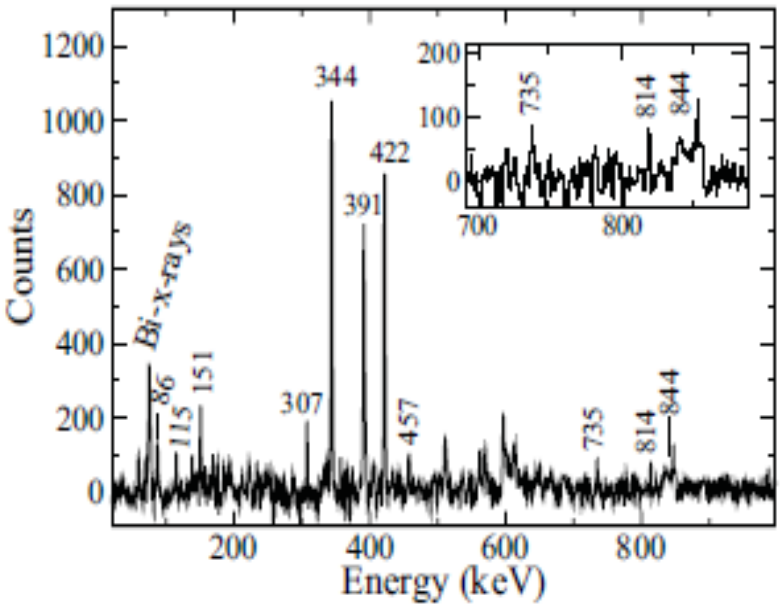
- **Well developed band structures correspond to deformation**

P. Nieminen et al.,
PRC **69**, 064326 (2004).

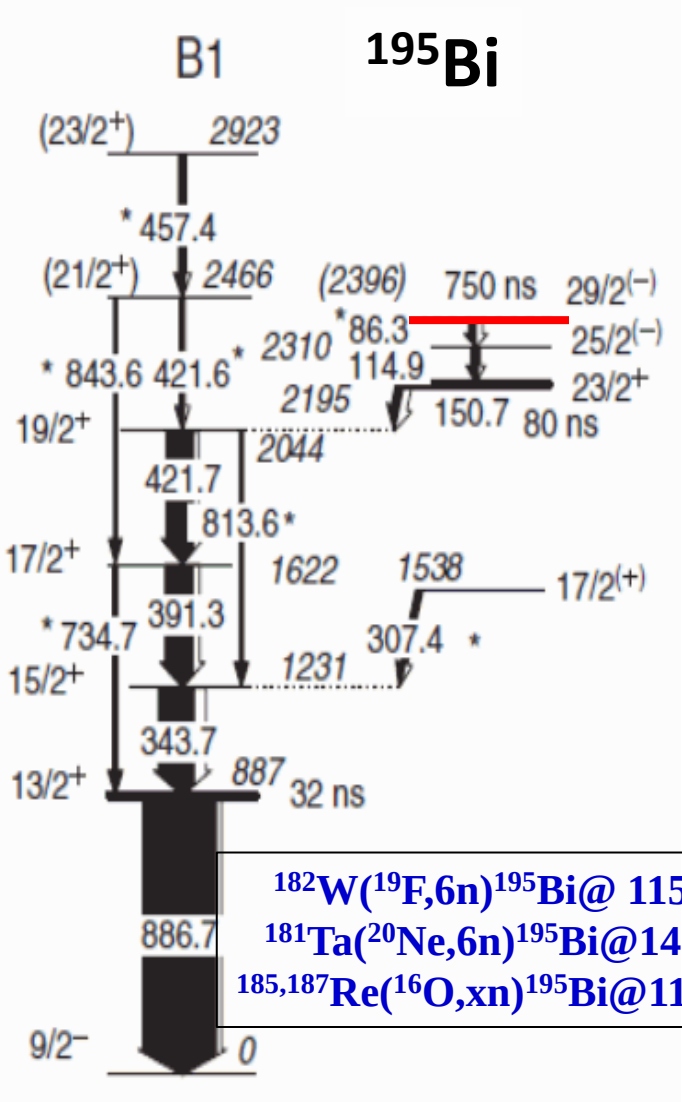


Much improved level scheme
A. Herz´aˇn et al.,
PRC **92**, 044310 (2015).

- Onset of deformation at N=112.
- 750 (50) ns at $29/2^{(-)}$ is the highest spin isomer known in this nucleus.
- No state above 2923 keV is known even using heavy-ion induced reaction.
- Intensity of 457-keV is very weak in the prompt coincidence spectrum ➔ indicates the presence of higher spin isomer.



Coincidence spectra gated by 886 keV γ ray



^{182}W(^{19}F,6n)^{195}Bi@ 115MeV
^{181}Ta(^{20}Ne,6n)^{195}Bi@145MeV
^{185,187}Re(^{16}O,xn)^{195}Bi@112.5MeV

H. Pai et al., PRC **85**, 064317(2012)
T. Lonnroth et al., PRC **33**,1641(1986)

Isomers in Bi, Po and At nuclei

Nucleus	States	Isomers ($T_{1/2}$)
^{193}Bi	$29/2^-$	3(1) μs
^{193}Bi	$29/2^+$	85(3) μs
^{195}Bi	$29/2^-$	750(50) ns
^{197}Bi	$29/2^-$	263(13) ns
^{197}Bi	$31/2^-$	209(30) ns
^{199}Bi	$29/2^-$	168(13) ns
^{201}Bi	$29/2^-$	124(4) ns

Nucleus	States	Isomers ($T_{1/2}$)
^{192}Po	11^-	0.58(10) μs
^{194}Po	11^-	15(2) μs
^{196}Po	11^-	856(17) ns
^{198}Po	11^-	200(20) ns
^{200}Po	12^+	0.75(5) μs
^{200}Po	11^-	100(10) ns

Nucleus	States	Isomers ($T_{1/2}$)
^{196}At	5^+	11(2) μs
^{199}At	$13/2^+$	0.58(13) μs
^{205}At	$29/2^+$	7.76(14) μs

$11^- \rightarrow \pi i_{13/2} \otimes \pi h_{9/2}$

$12^+ \rightarrow \nu i_{13/2}{}^{-2}$

$13/2^+ \rightarrow \nu i_{13/2}$

$29/2^- \rightarrow \pi h_{9/2} \otimes \nu 12^+$

$29/2^+ \rightarrow ((\pi h_{9/2})^{+2}{}_{8+}(\pi\, i_{13/2})^{+1}(\nu\, f_{5/2})^{-2}{}_{0+})$

$31/2^- \rightarrow \pi h_{9/2} \otimes \nu 12^+$

The proton and neutron excitations to $h_{9/2}$ and $i_{13/2}$ high-j orbitals give rise to isomers in these nuclei.

High spin isomer study in ^{195}Bi

HYbrid Recoil mass Analyzer (HYRA)

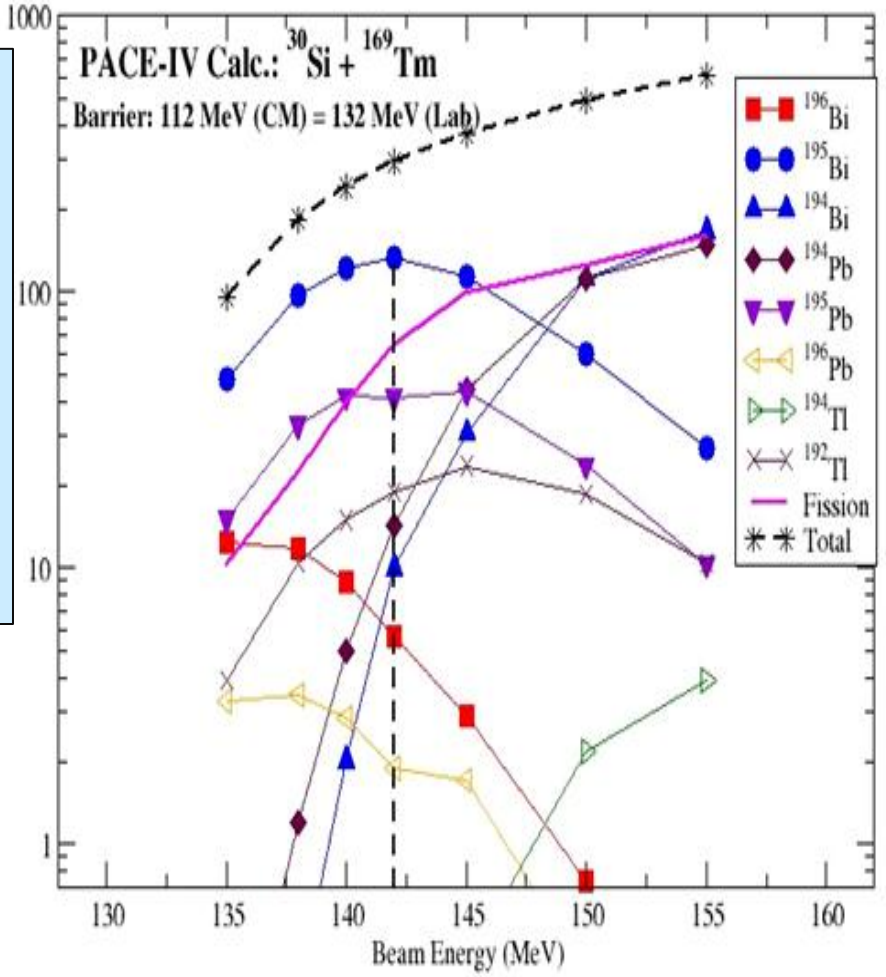
^{30}Si+ ^{169}Tm → ^{199}Bi → ^{195}Bi + 4n @ 145 MeV
→ ^{193}Bi + 6n @ 168 MeV

Charge State: 12^+ **Beam current: 0.25 pna**

Beam Time: 48 hours

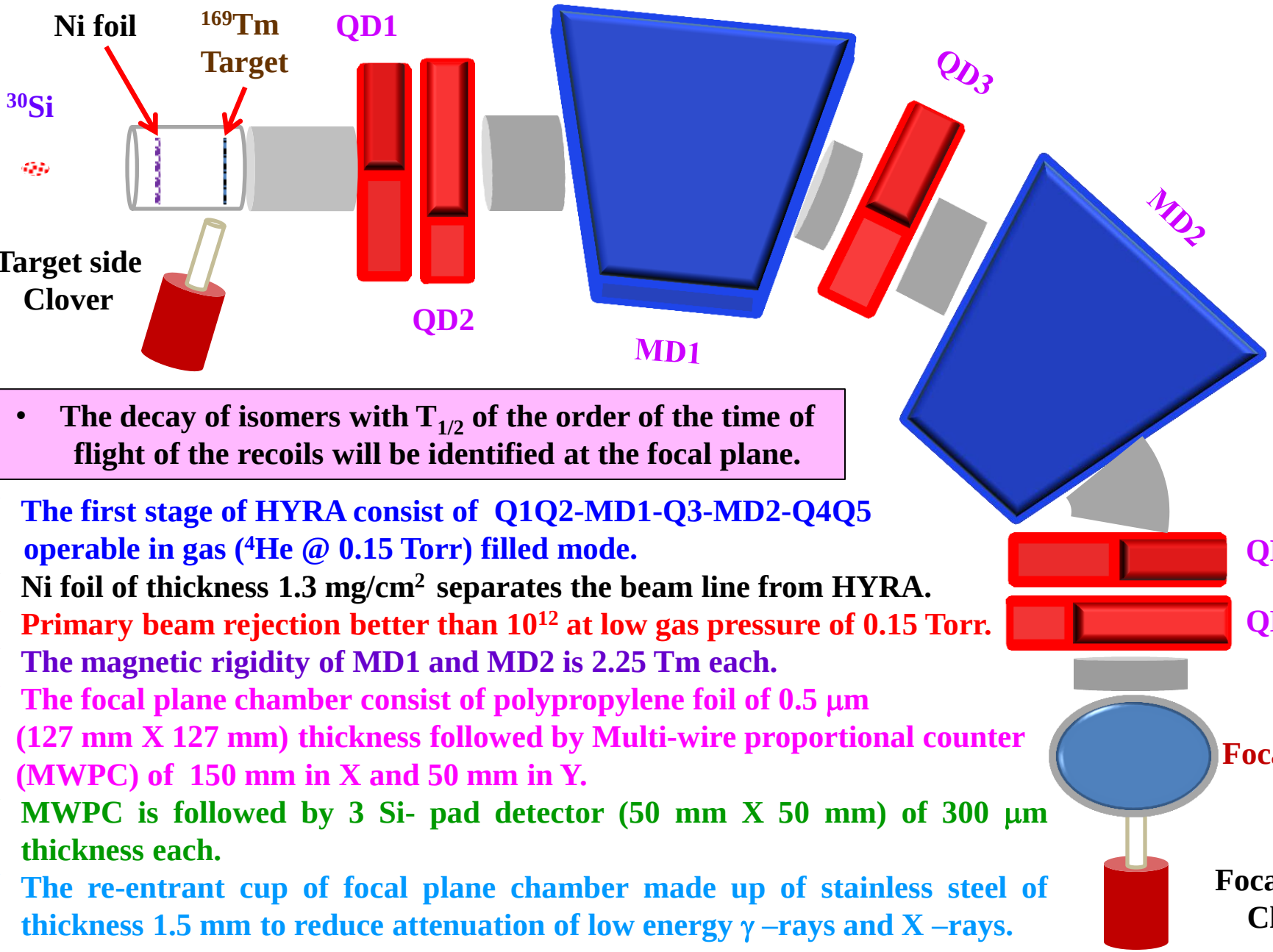
Target: ^{169}Tm(Z=69) @ 0.78mg/cm^2

Detectors: 1 MWPC, 3-Si pad detectors,
1 clover each at Focal plane and Target side.



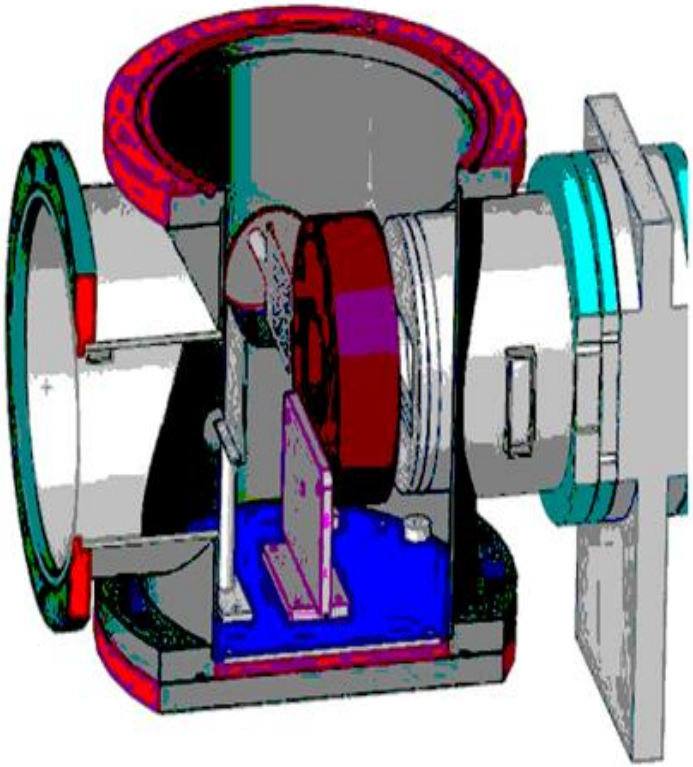
IUAC – New Delhi

HYbrid Recoil mass Analyzer (HYRA)

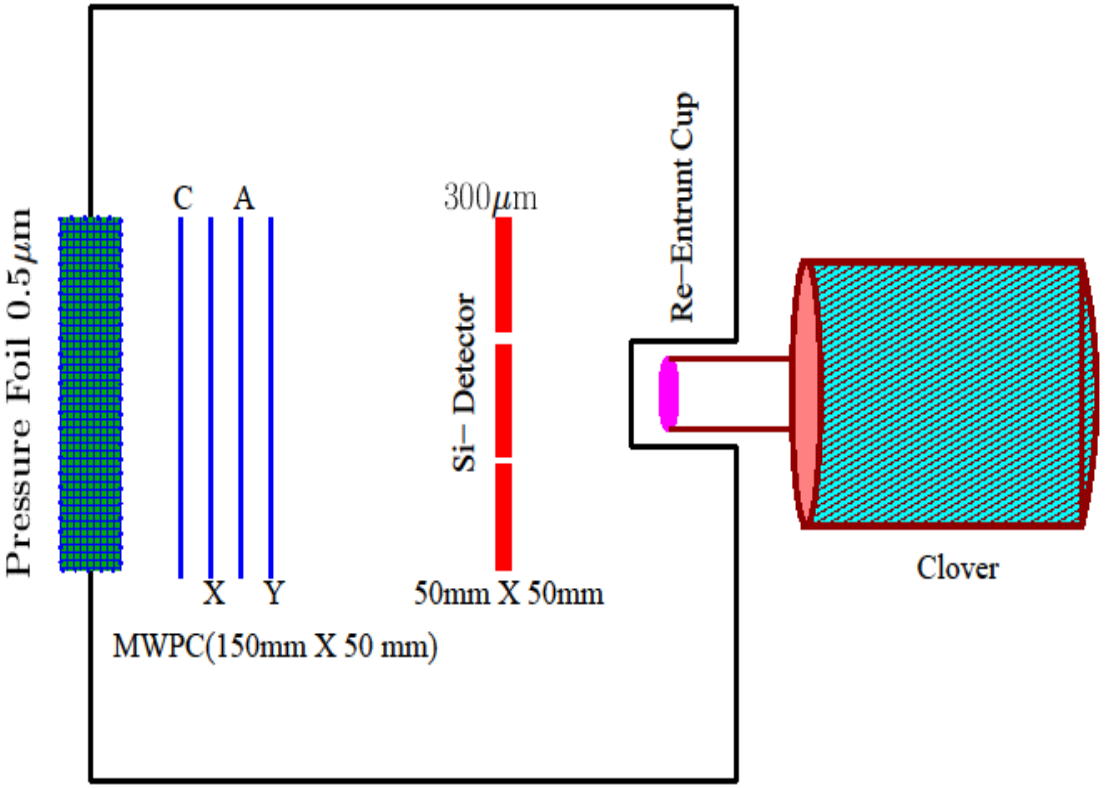


- The decay of isomers with $T_{1/2}$ of the order of the time of flight of the recoils will be identified at the focal plane.

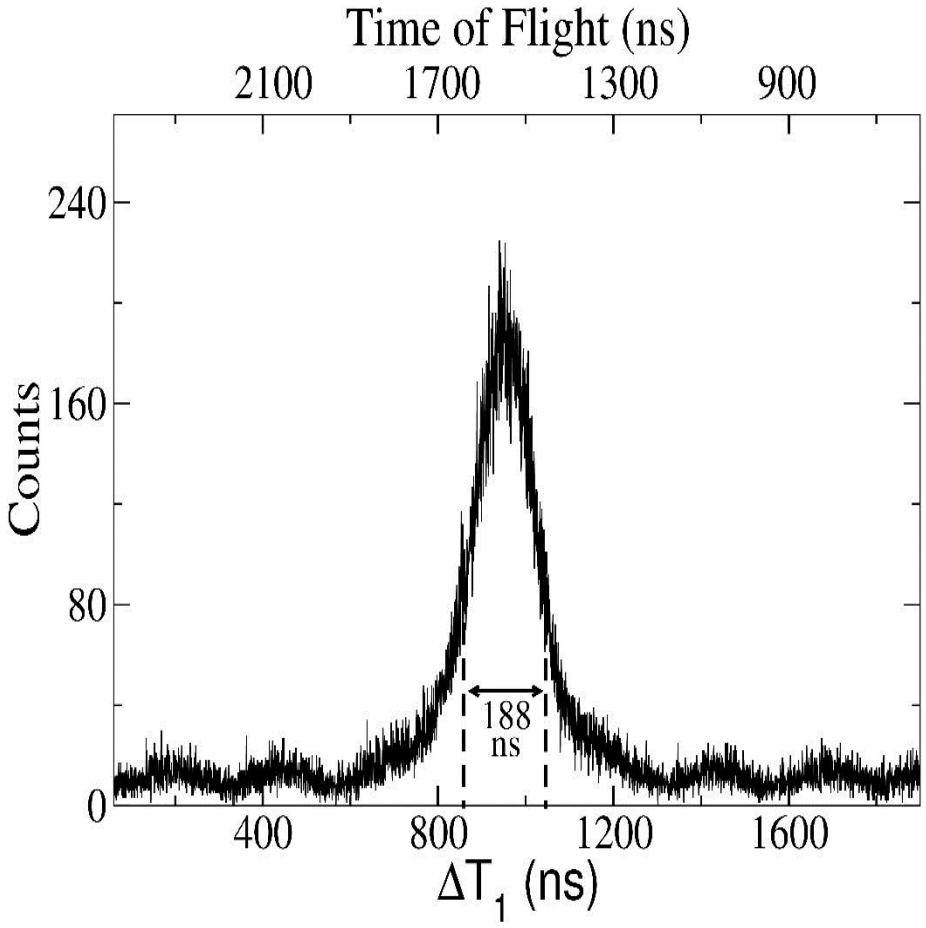
- ✓ The first stage of HYRA consist of Q1Q2-MD1-Q3-MD2-Q4Q5 operable in gas (^{4}He @ 0.15 Torr) filled mode.
- ✓ Ni foil of thickness 1.3 mg/cm^2 separates the beam line from HYRA.
- ✓ Primary beam rejection better than 10^{12} at low gas pressure of 0.15 Torr.
- ✓ The magnetic rigidity of MD1 and MD2 is 2.25 Tm each.
- ✓ The focal plane chamber consist of polypropylene foil of 0.5 μm (127 mm X 127 mm) thickness followed by Multi-wire proportional counter (MWPC) of 150 mm in X and 50 mm in Y.
- ✓ MWPC is followed by 3 Si- pad detector (50 mm X 50 mm) of 300 μm thickness each.
- ✓ The re-entrant cup of focal plane chamber made up of stainless steel of thickness 1.5 mm to reduce attenuation of low energy γ –rays and X –rays.

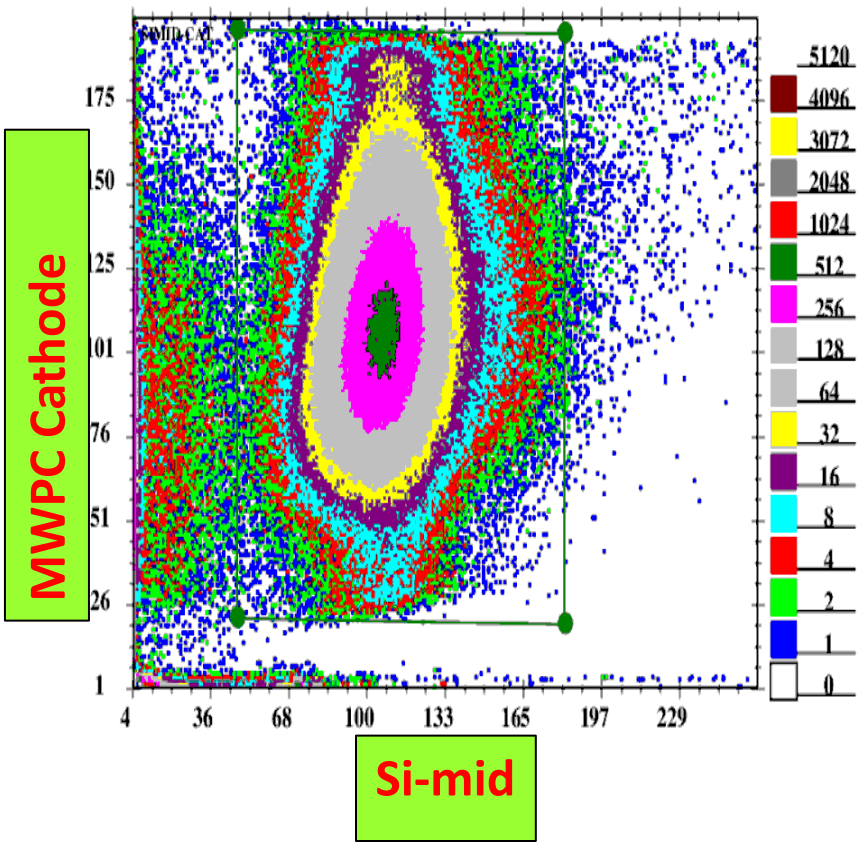


Schematic representation of
Focal plane chamber.



Schematic representation of
Focal plane detector system consisting of Multi-wire proportional counter (MWPC), 3 Si-pad detectors and one clover detector outside the focal plane chamber.

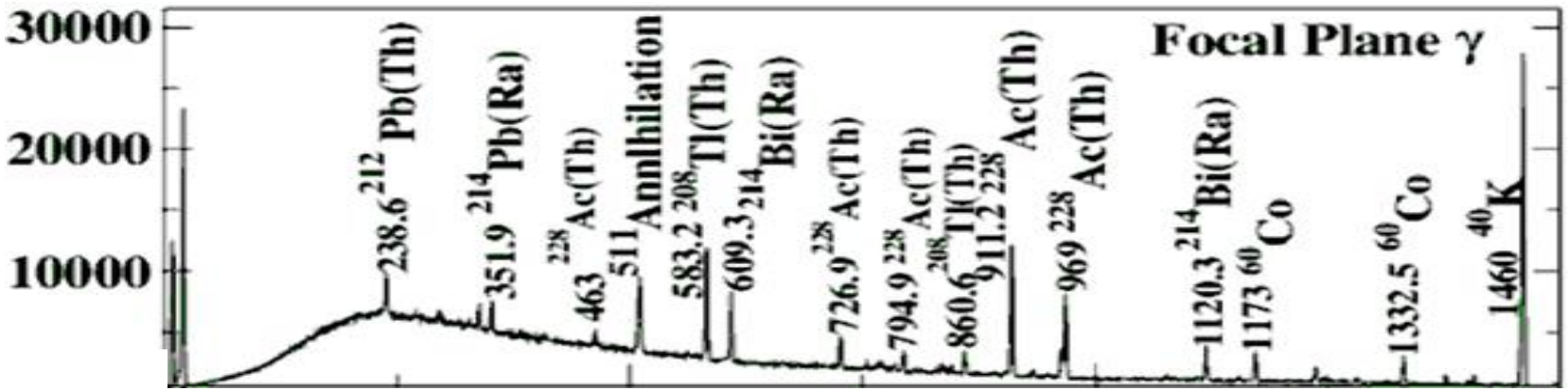




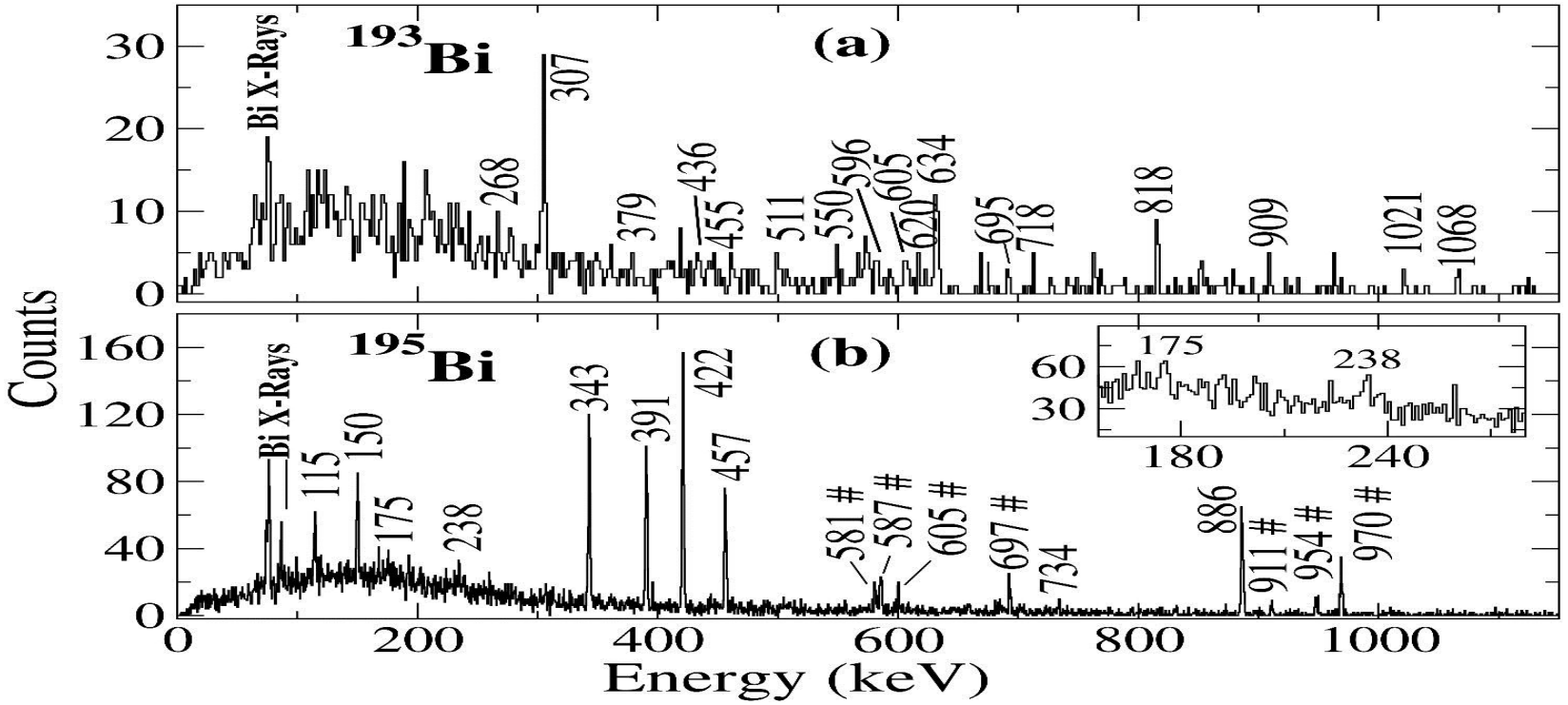
ΔT_1: Time (TAC) between target Clover and MWPC ➔ Start form MWPC and stopped by Target clover :Time of flight of ER

2D of MWPC (cathode) vs Si- identifies Evaporation Residue (ER)

Trigger: (MWPC .and. Si) .or. Clover

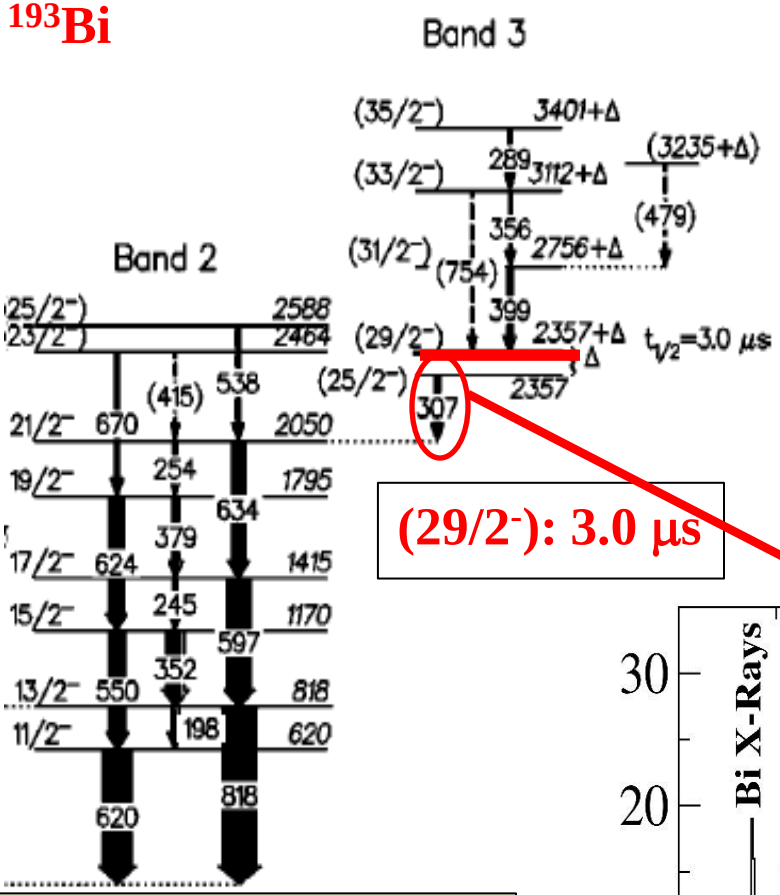


Raw γ-ray spectrum at the focal plane



ER gated γ-ray spectra at the focal plane

^{193}Bi

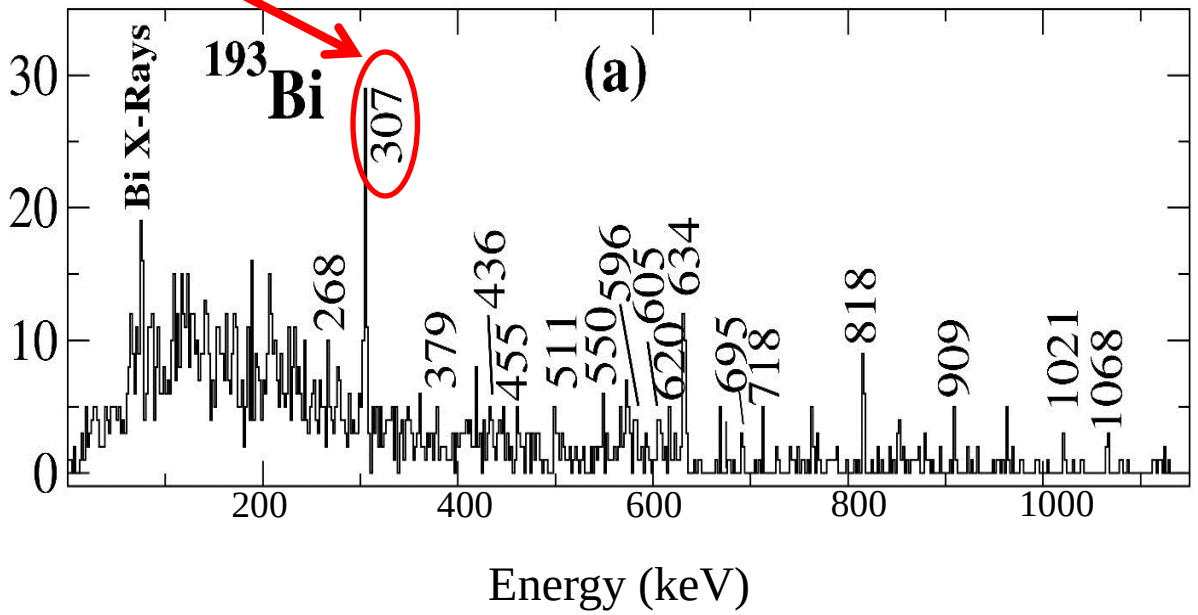


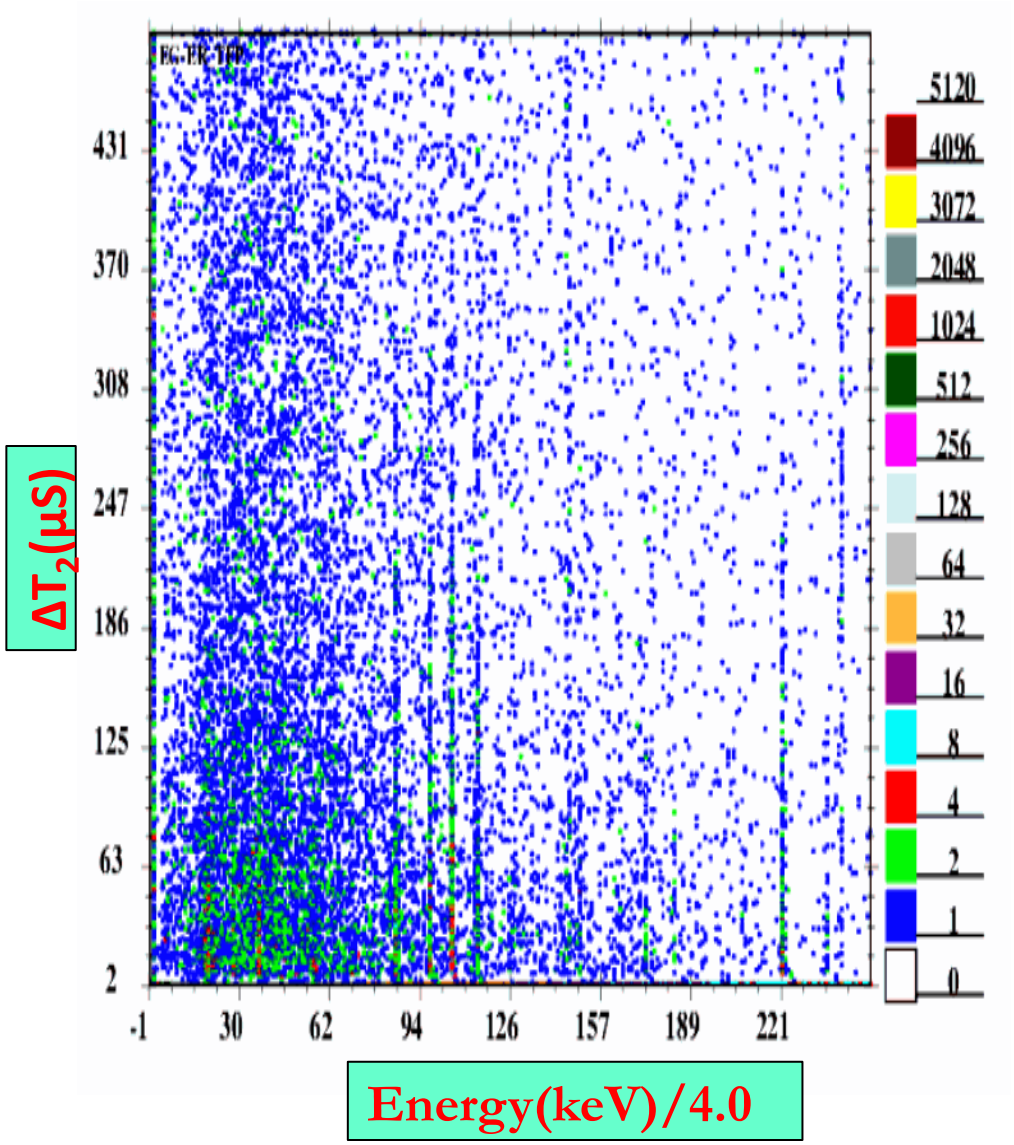
P. Nieminen et al.,
PRC **69**, 064326 (2004).

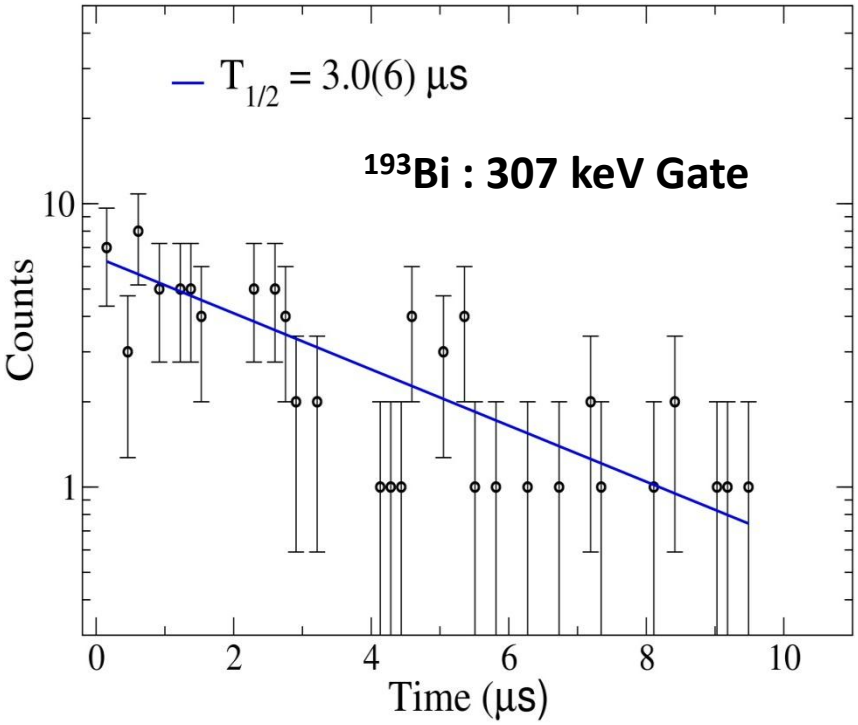
^{30}Si + ^{169}Tm → ^{199}Bi → ^{193}Bi + 6n @ 168 MeV

Observances of **307, 620, 818, 550, 634** keV γ transitions @ Focal plane ensures population of known 3.0 μs isomer.

(29/2⁻): 3.0 μs

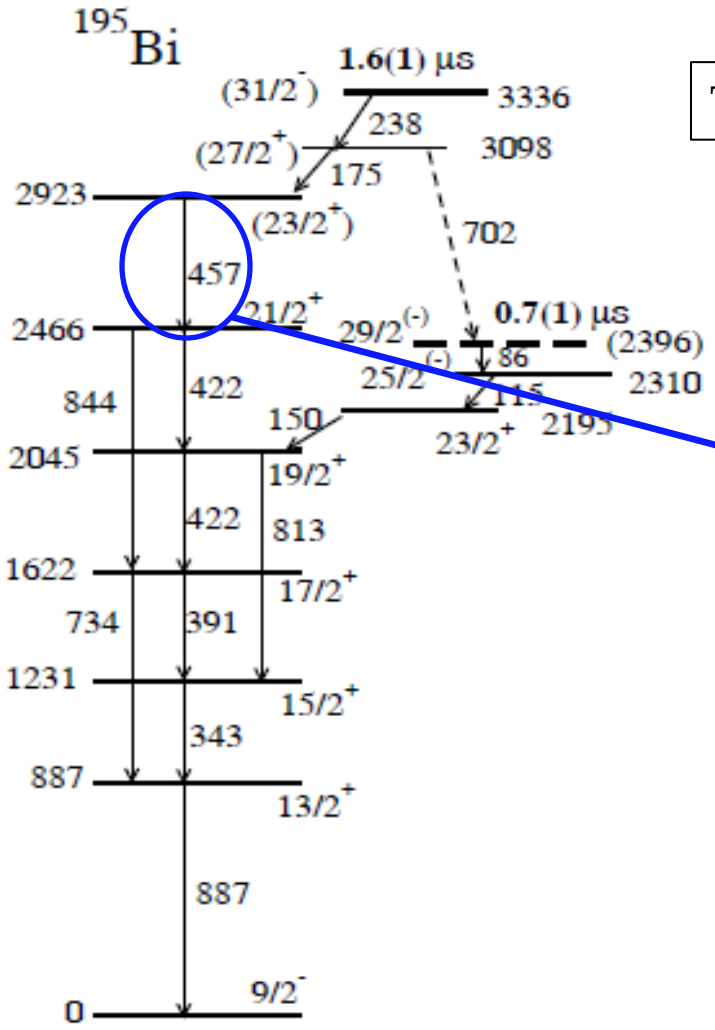




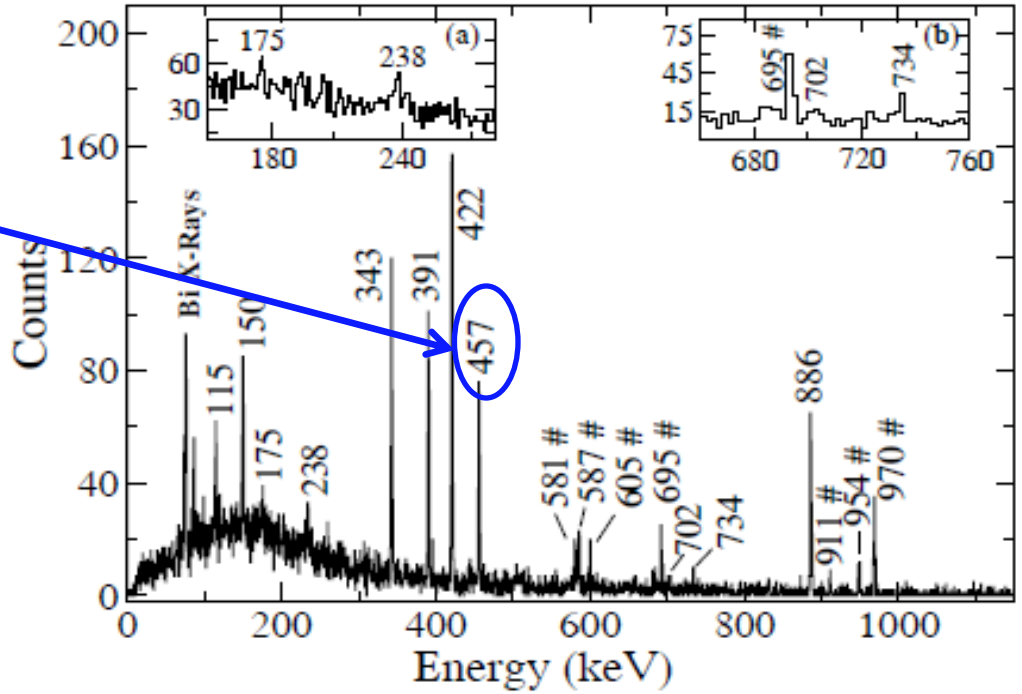


ΔT_2: Time (TAC) between MWPC and Focal plane Clover ➔ Isomer decay half-life

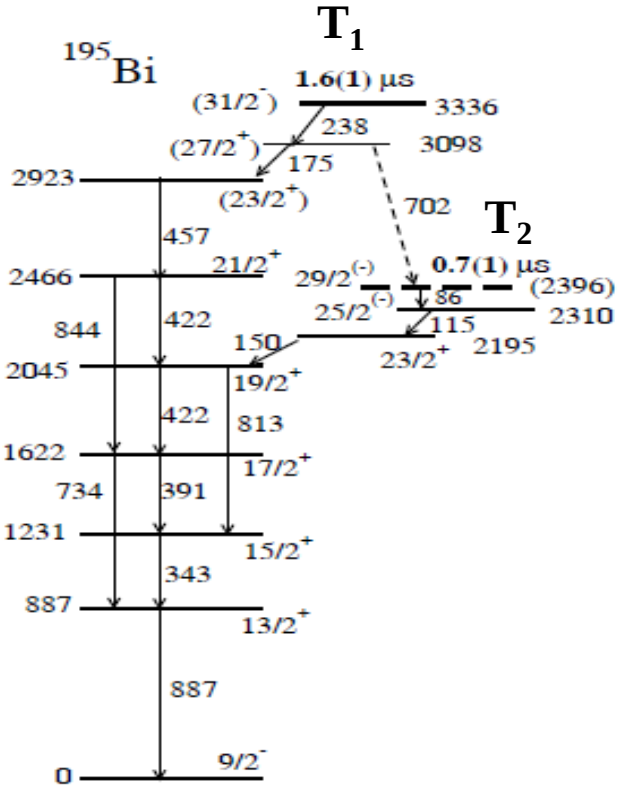
A 2D between ΔT_2 & γ energies of focal plane clover detector is used to determine the life time of the states by putting a gate on specific γ ray and projecting its counts on time axis.

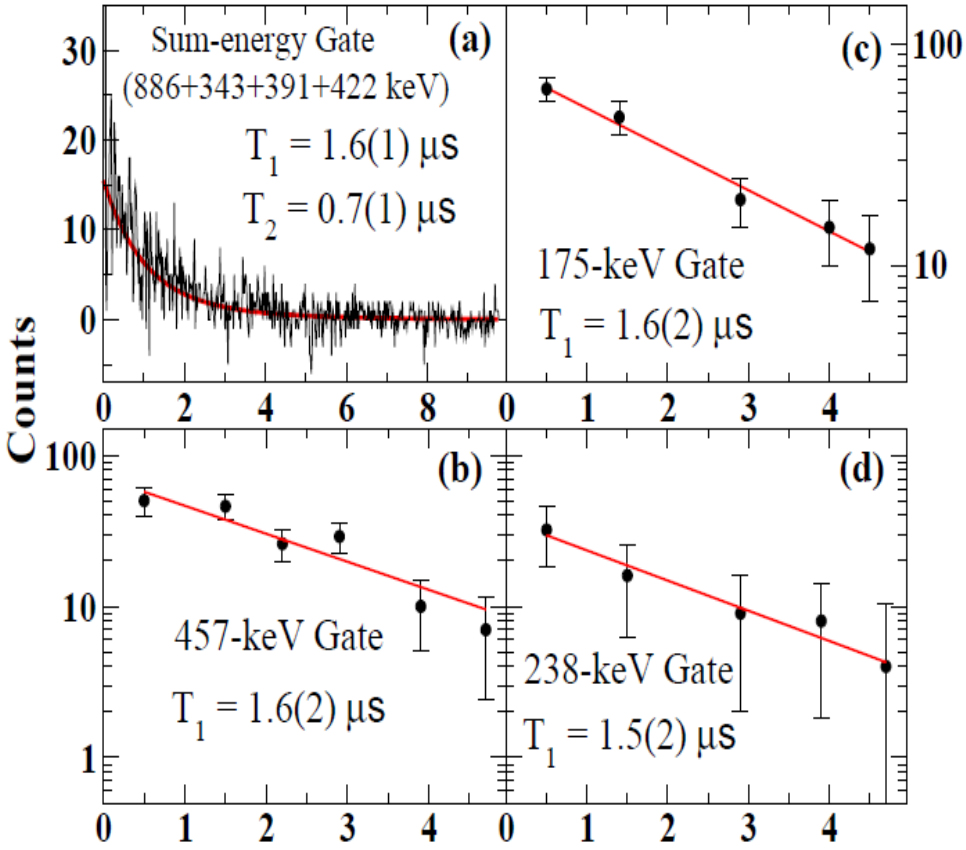


Typical measured time of flight for ER ~ 1.53(9) μs



Observance of 457 keV γ transition at the focal plane even after two half life ($T_{1/2}$) of the known $29/2^{(-)}$ [750(50) ns] isomeric state ensures the presence of another high spin isomer in ^{195}Bi.





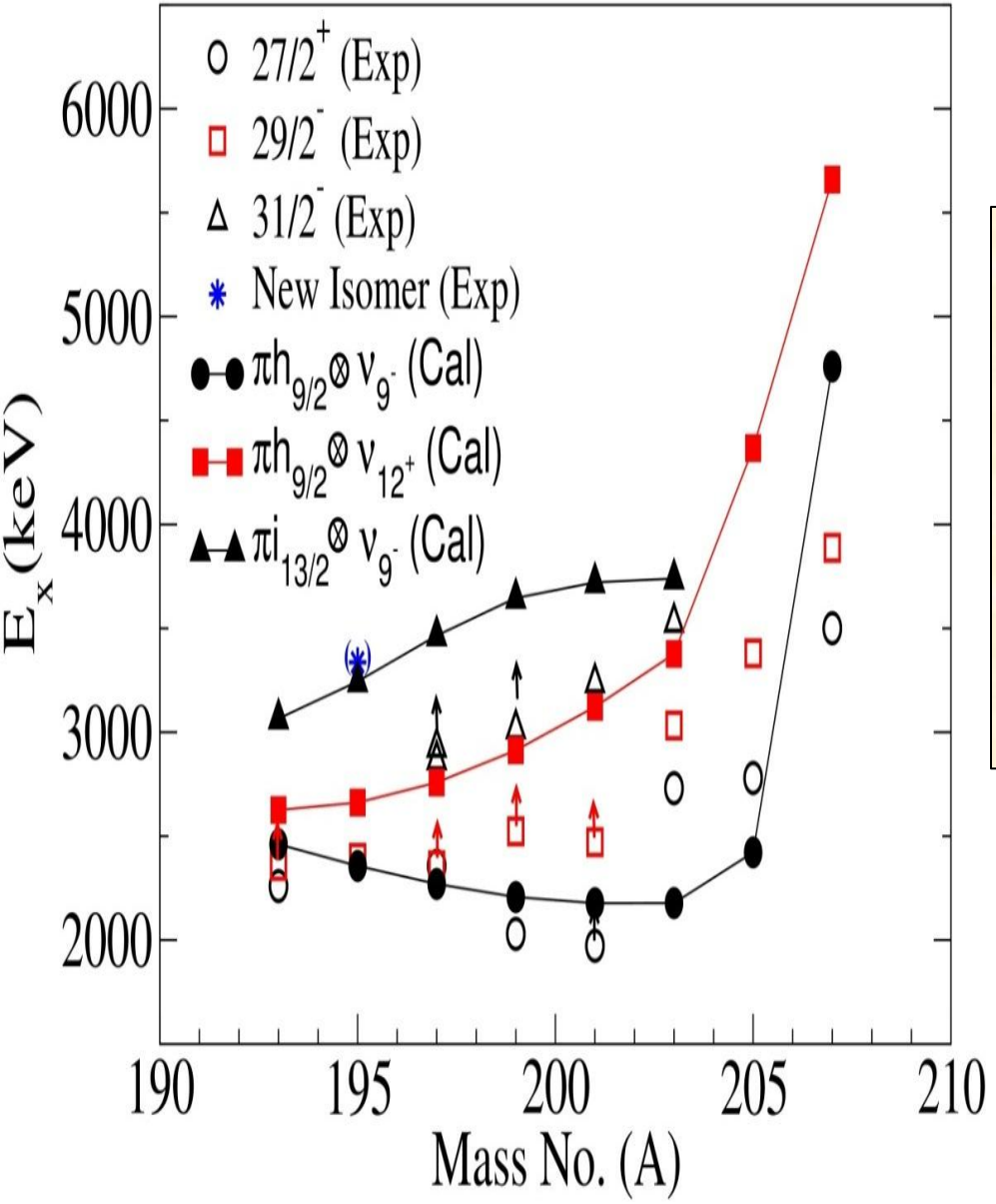
(a) $$Y = \frac{A0 * T_2}{T_1 - T_2} * \{exp(-\frac{0.693 * t}{T_1}) - exp(-\frac{0.693 * t}{T_2})\}$$

$$+A1 * exp(-\frac{0.693 * t}{T_1}) + A2 * exp(-\frac{0.693 * t}{T_2}), \quad (1)$$

(b) $$Y = B0 * exp(-\frac{0.693 * t}{T_1}),$$

In the sum energy gate life time of the two isomeric states are measured by fitting the data points using Eq. (1) considering the new isomer decaying through 457, 422 keV γ transitions as well as through115 and 150 keV γ transitions.

Systematic of Isomers



$$E^{A}_{3qp} = E^{A}_{1qp} + \frac{E^{A-1}_{2qp} + E^{A+1}_{2qp}}{2}$$

$\pi h_{9/2} \otimes \nu_{9}$- isomer in ^{199}Bi

Excitation Energy: 9^- State of Pb core

^{198}Pb -2231 keV **^{200}Pb**- 2183 keV

^{199}Bi=0 keV for **$\pi h_{9/2}$**

$E^{A}_{3qp} = 0 + (2231+2183)/2 = 2207$ keV

$27/2^+ : 2030 + \Delta$ keV

Configuration of the new isomer:

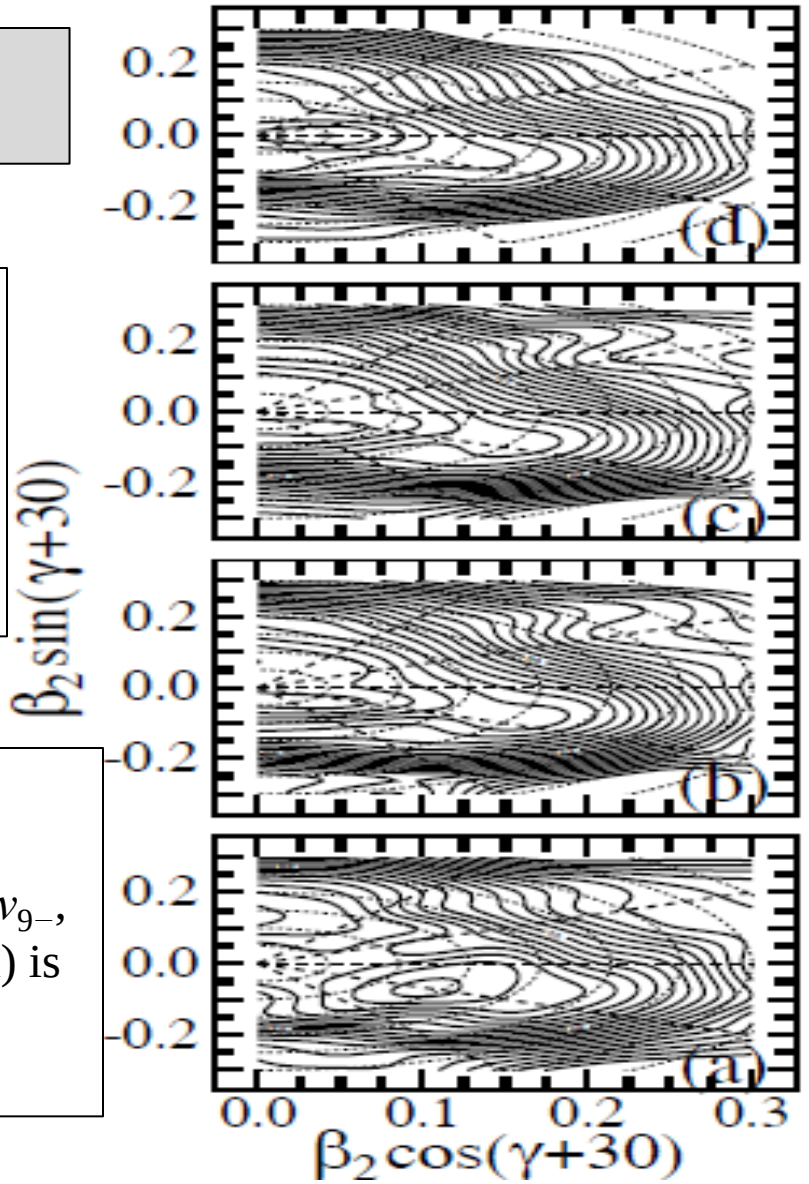
$\pi i_{13/2} \otimes \nu_{9}^-$

TRS: Oblate Deformation

W. Nazarewicz *et al.*, Nucl. Phys. A **435**, 397 (1985).
W. Nazarewicz *et al.*, Nucl. Phys. A **512**, 61 (1990).

Total Routhian Surface (TRS) calculations. A deformed Woods-Saxon potential and BCS pairing was used to calculate the single-particle energies and the total energy of the system was obtained by employing the Strutinsky shell correction method.

Total Routhian Surface (TRS) for different configurations of the ^{195}Bi and ^{194}Pb.
The panels (a), (b), (c) are for $\pi i_{13/2} \otimes \nu_{9-}$, $\pi h_{9/2} \otimes \nu_{9-}$, $\pi h_{9/2} \otimes \nu_{12+}$ configurations in ^{195}Bi and the panel (d) is for the two-neutron $i^{-2}{}_{13/2}$ configuration in ^{194}Pb. The contours are 300 keV apart.



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DOI 10.1140/epja/i2015-15153-5

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

The result has been published to
T. Roy et. al., **EPJA 51,** 153 (2015).

A new high-spin isomer in ^{195}Bi

T. Roy[1], G. Mukherjee[1,a], N. Madhavan[2], T.K. Rana[1], Soumik Bhattacharya[1], Md.A. Asgar[1], I. Bala[2], K. Basu[3], S.S. Bhattacharjee[3], C. Bhattacharya[1], S. Bhattacharya[1,b], S. Bhattacharyya[1], J. Gehlot[2], S.S. Ghugre[3], R.K. Gurjar[2], A. Jhingan[2], R. Kumar[2], S. Muralithar[2], S. Nath[2], H. Pai[1,c], R. Palit[4], R. Raut[3], R.P. Singh[2], A.K. Sinha[3], and T. Varughese[2]

[1] Variable Energy Cyclotron Centre, Kolkata 700064, India
[2] Inter University Acclerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India
[3] UGC-DAE-CSR Kolkata Centre, SectorIII/LB-8 Bidhan Nagar, Kolkata 700098, India
[4] Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai 400005, India

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Conclusion

- Isomeric decay study has been carried out first time at focal plane of Hybrid Recoil mass Analyzer (HYRA) using fusion evaporation reaction of ^{30}Si beam on ^{169}Tm target at the beam energy of 168 and 145 MeV respectively.
- The decay of the known 3ms isomer in ^{193}Bi has been measured and the present half life agrees well with the earlier reported value.
- A new high spin isomer **$(31/2^-)$** of half-life **1.6(1)ms** has been identified in ^{195}Bi. This new isomer's configuration has been assigned as $\pi i_{13/2} \otimes \nu_9^-$ with oblate deformation bassed on Total Routhian Surface (TRS) calculation.
- Present calculation suggests a strong shape driving effect of $i_{13/2}$ orbital over $h_{9/2}$ orbital. It will be interesting to see whether any rotational band structure builds on this state in future experimental studies.

Collaborators

VECC
G. Mukherjee (Supervisor)
H. Pai
Md. A. Asgar
S. Bhattacharyya
M. R. Ghoil
T. K. Rana
C. Bhattacharya
S. Bhattacharya
Soumik Bhattacharya
T. Bhattacharjee

TIFR
R. Palit
S. Saha
J. Sethi
T. Trivedi
B. S. Nauidu
Shital Thakur
S. V. Jadav
R. Dhonti

IUAC
N. Madhavan
S. Nath
R. P. Singh
S. Murlithar
R. Kumar
J. Ghelot
T. Varughese
I.Bala
R. K. Gurjar

UGC-DAE-CSR (Kolkata)
A. K. Sinha
S. S. Ghugre
R. Raut
S. S. Bhattachrjee
K. Basu

SINP
A. Goswami

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