Investigation of high spin states near N=50 shell closure in search for emergence of collectivity using INGA

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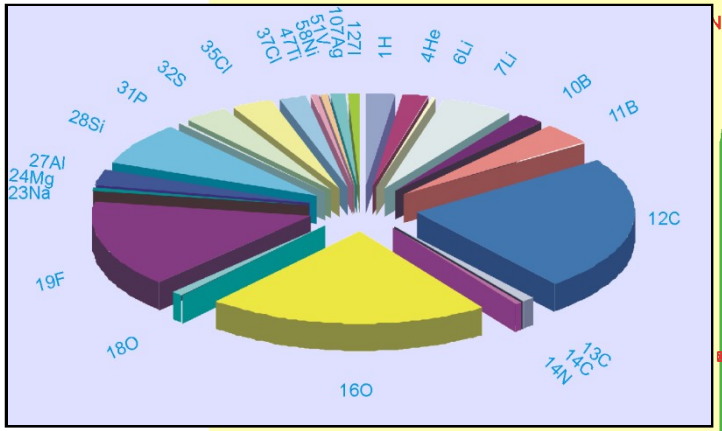
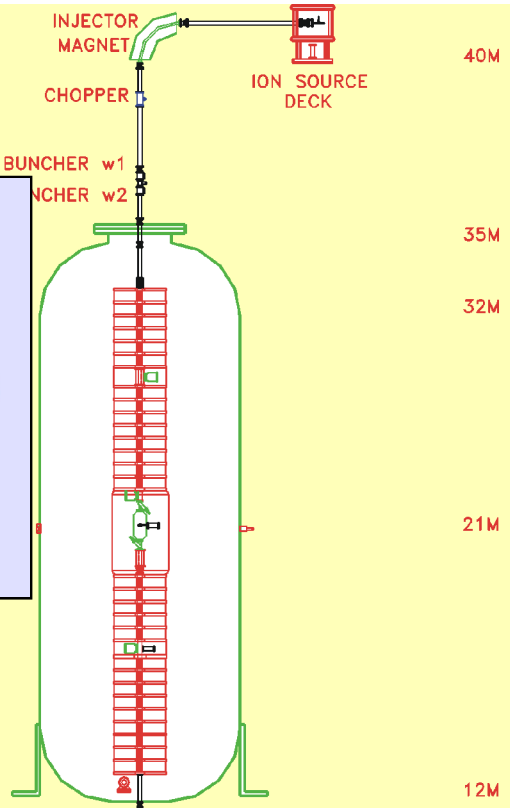
Outline:

- New features of INGA
- Recent results

TIFR-BARC Pelletron Linac Accelerator Facility at Mumbai





Research Programs

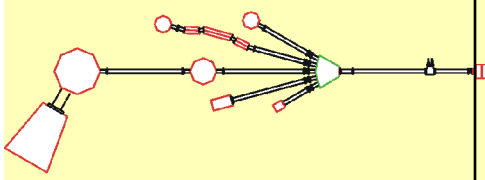
- Nuclear Physics
- Atomic Physics
- Condense Matter Physics
- Radiochemistry

Detector Facilities

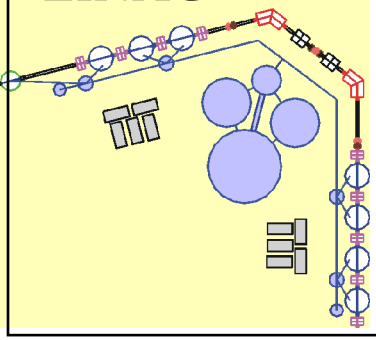
HPGe array & ancillary detectors
4π spin spectrometer
Large scattering chamber
CPDA for nuclear reaction
Neutron wall
High energy gamma array
LAMPS DAQ & software

National & International Collaboration

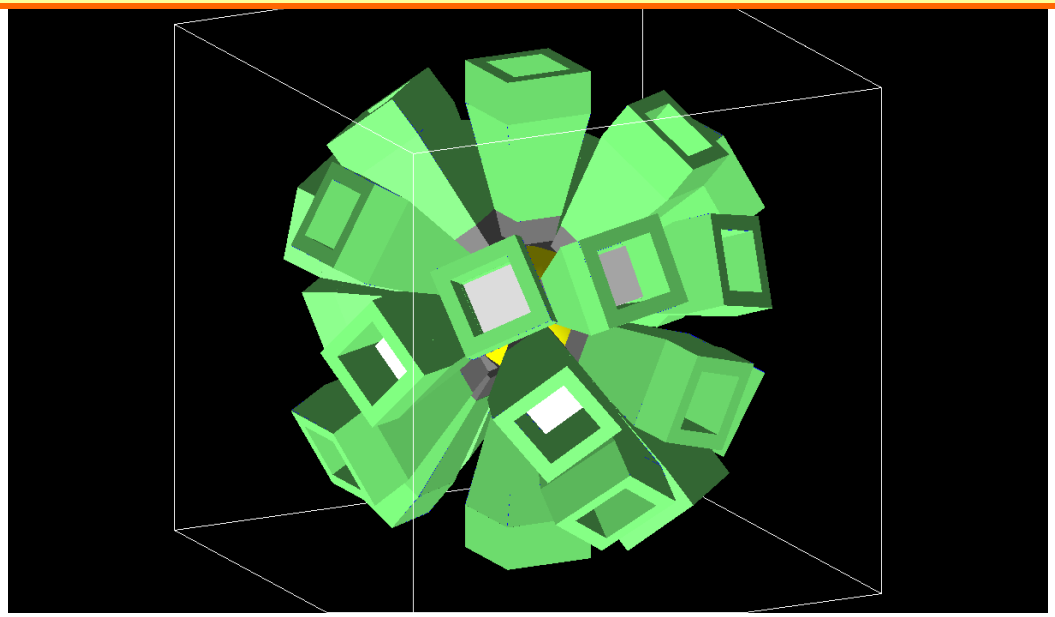
Experiment hall



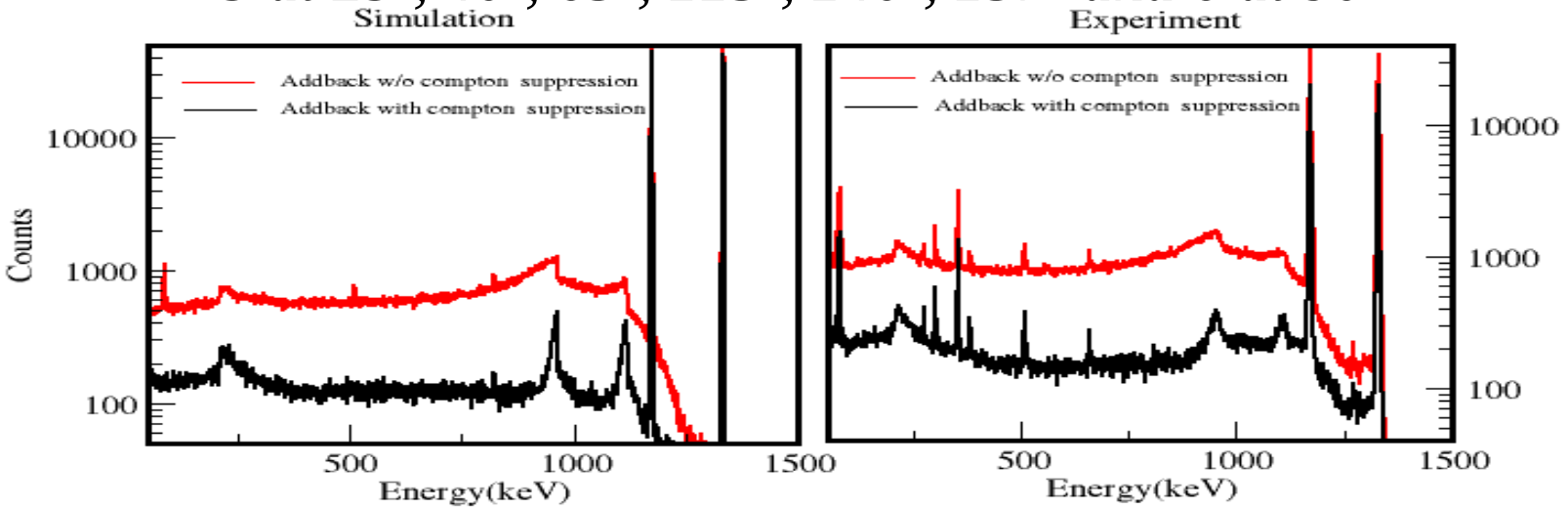
LINAC



Simulation for INGA



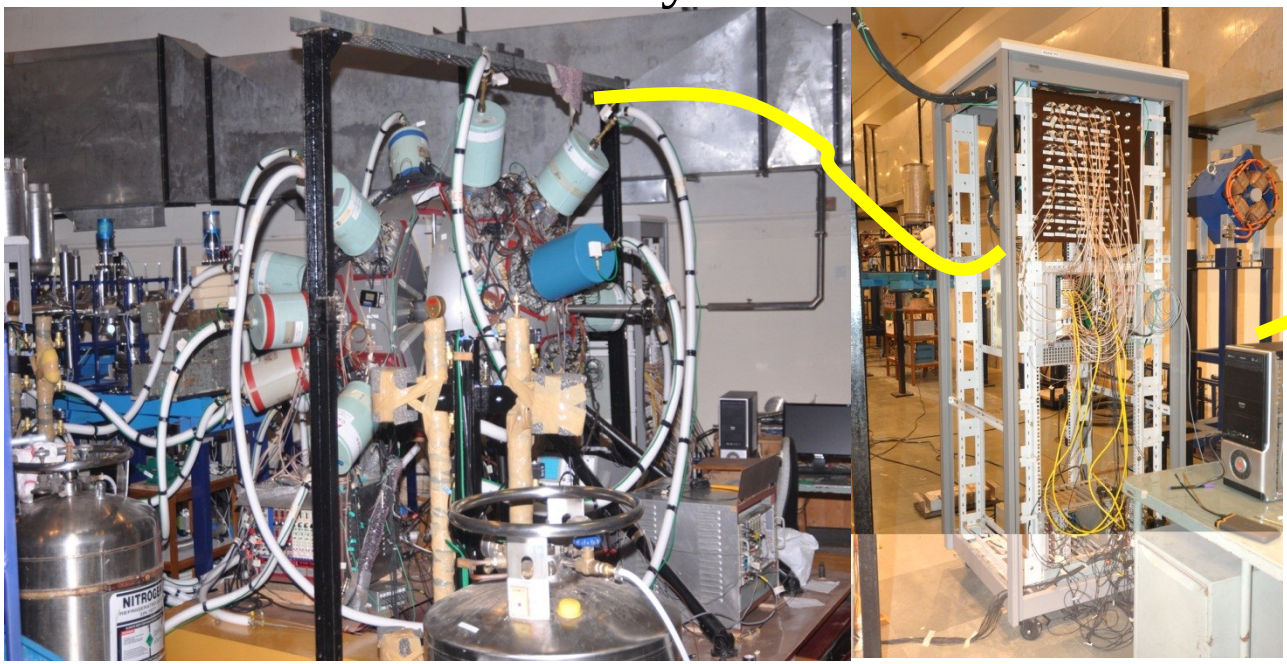
- Mounting position for 24 Clovers (ε_P ~5%)
- *3 at 23°, 40°, 65°, 115°, 140°, 157° and 6 at 90°*



DDAQ with INGA

Detector Array

DSP DAQ



Host PC

PC for Storage & Analysis

Detectors -> DSP cards -> PCI Bridge -> PC-> Gigabit -> PC

Indian National Gamma Array (INGA) is set up under a collaboration between TIFR, IUAC, BARC, SINP, IUC-DAE-CSR-UGC-KC, VECC and Universities

DSP based DAQ for 24 CS-Clovers and Ancillary detectors at TIFR

Technical specifications

- 100 MHz & 12-bit ADC's
- Data rate: 80 MB/sec
- Particle ID in CsI detectors using digital pulse shaping
- Trigger less system
- XIA based system

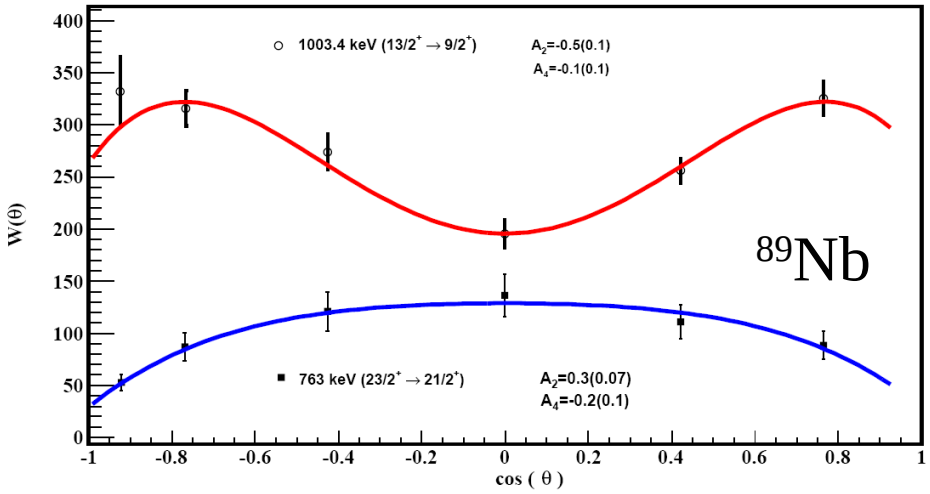
H. Tan et l., NSS 08, IEEE (2008) p 3196

Implementation for INGA

- Modular so easily expandable
- Versatile with complex trigger
- High count rate
- High stability
- Zero dead-time
- Long lived isomer measurements

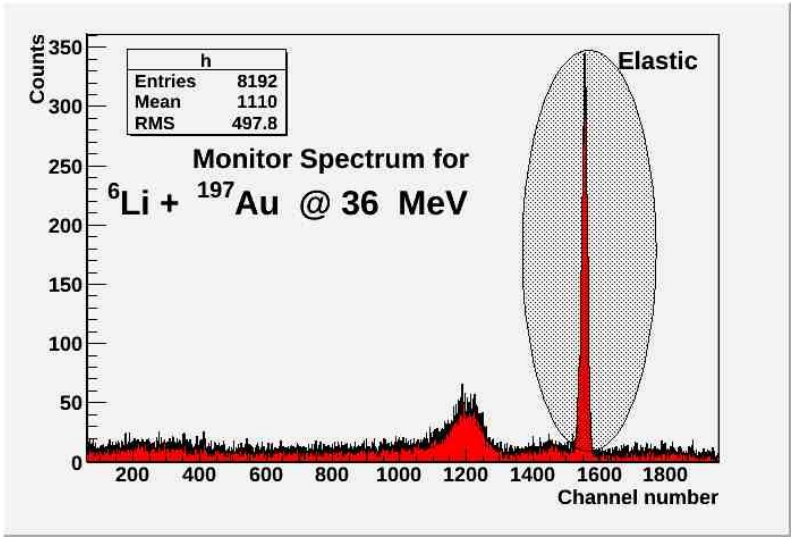
R. Palit AIP Conf Proc. 1336 (2011) 573
R. Palit, et al. NIMA 680 (2012) 90

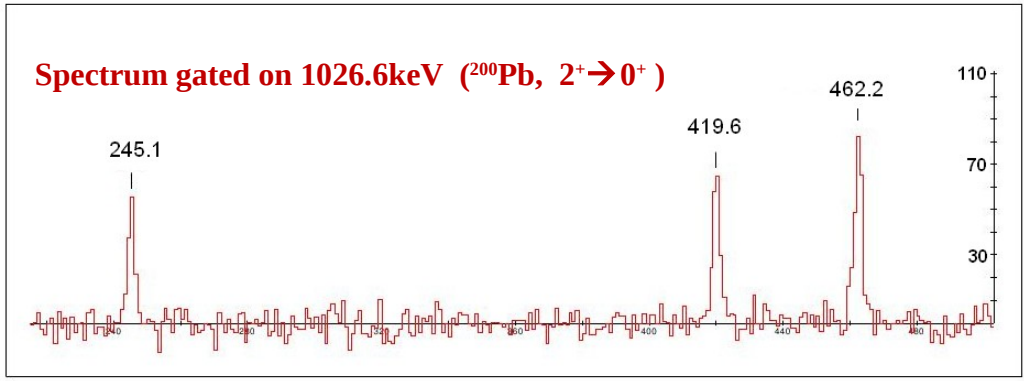
Angular Distribution & Cross section Measurements



- Singles measurement with 60 crystals each counting at 4- 5 kHz
- Total throughput is 260 kHz
- Data rate: 15 MB/sec
- Trigger less mode
- Cross section measurement

(Agreement between on-line and off-line experiments for 3n fusion channel in ^{6}Li + ^{197}Au reaction)



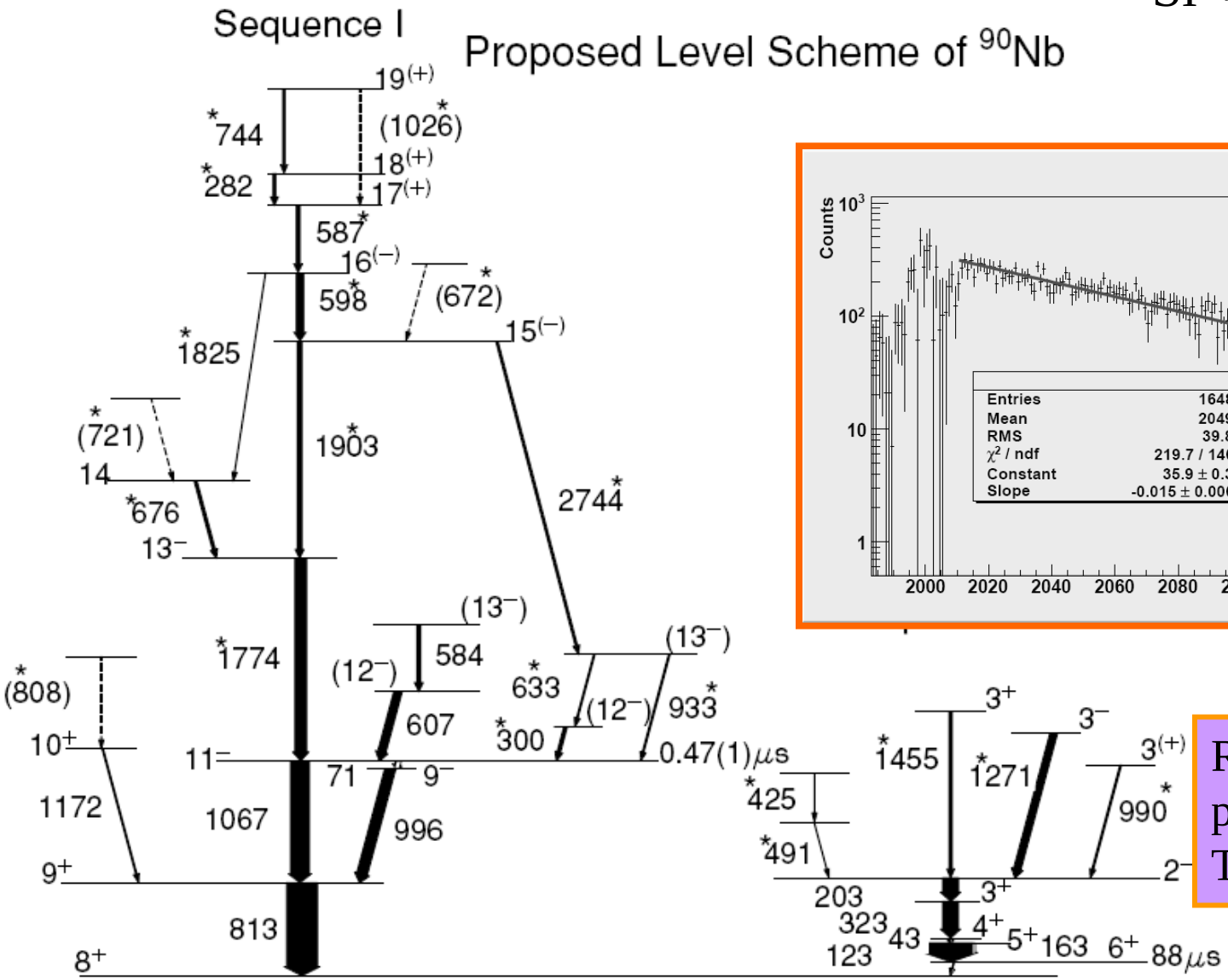


DDAQ has Increased the data throughput by 10 times for INGA

Long Lived Isomers near N=50

$^{28}Si + {}^{65}Cu$ @105 MeV

T-stamped data

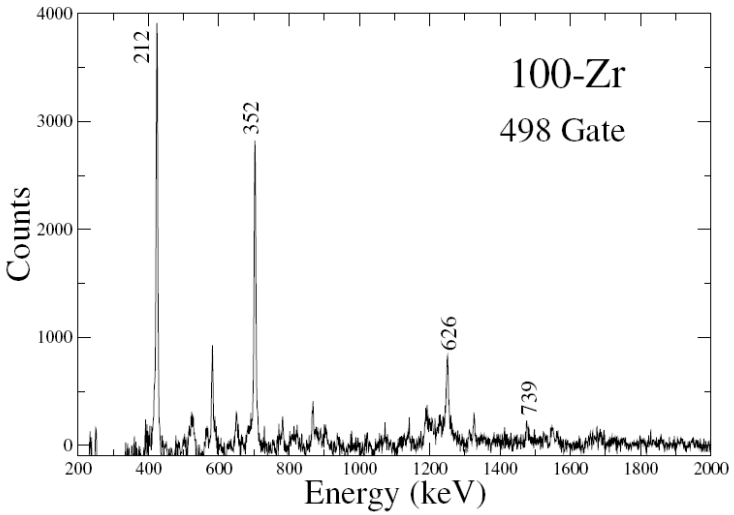


R. Palit, et al,

Reconfirmed the previous reported $T_{1/2} = 460\ (10)$ nsec

A. Chakrabarti, et al. PRC 72, 054309 (2005)

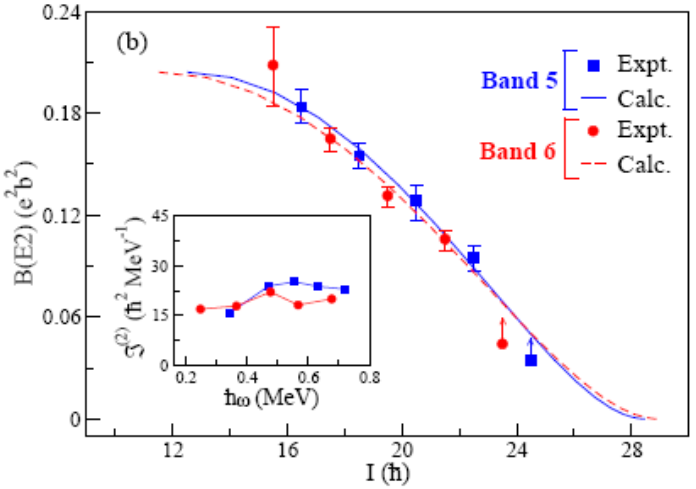
Recent results from current INGA campaign



35 experiments

Z=82
N=126
Z=50
N=82
Z=28
N=50
Z=20
N=28
Z=8
N=20
N=8

^{107}Cd



PRC 87, 034304 (2013)

Nuclear Instruments and Methods in Physics Research A 680 (2012) 90–96

Contents lists available at SciVerse ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

A high speed digital data acquisition system for the Indian National Gamma Array at Tata Institute of Fundamental Research

R. Palit [a,*], S. Saha [a], J. Sethi [a], T. Trivedi [a], S. Sharma [a], B.S. Naidu [a], S. Jadhav [a], R. Donthi [a], P.B. Chavan [a], H. Tan [b], W. Hennig [b]

PHYSICAL REVIEW C **86**, 034315 (2012)

Experimental investigation of shell-model excitations of ^{89}Zr up to high spin

S. Saha,[1] R. Palit,[1,*] J. Sethi,[1] T. Trivedi,[1] P. C. Srivastava,[2] S. Kumar,[3] B. S. Naidu,[1] R. Donthi,[1] S. Jadhav,[1] D. C. Biswas,[4] U. Garg,[5] A. Goswami,[6] H. C. Jain,[1] P. K. Joshi,[1,†] G. Mukherjee,[7] Z. Naik,[8] S. Nag,[9] V. Nanal,[1] R. G. Pillay,[1] S. Saha,[6] and A. K. Singh[9]

PHYSICAL REVIEW C **87**, 034304 (2013)

Multiple antimagnetic rotation bands in odd-*A* ^{107}Cd

Deepika Choudhury,[1,*] A. K. Jain,[1] G. Anil Kumar,[1] Suresh Kumar,[2] Sukhjeet Singh,[3] P. Singh,[4] M. Sainath,[5] T. Trivedi,[6] J. Sethi,[6] S. Saha,[6] S. K. Jadav,[6] B. S. Naidu,[6] R. Palit,[6] H. C. Jain,[6] L. Chaturvedi,[7] and S. C. Pancholi[8]

Physics Focus of INGA

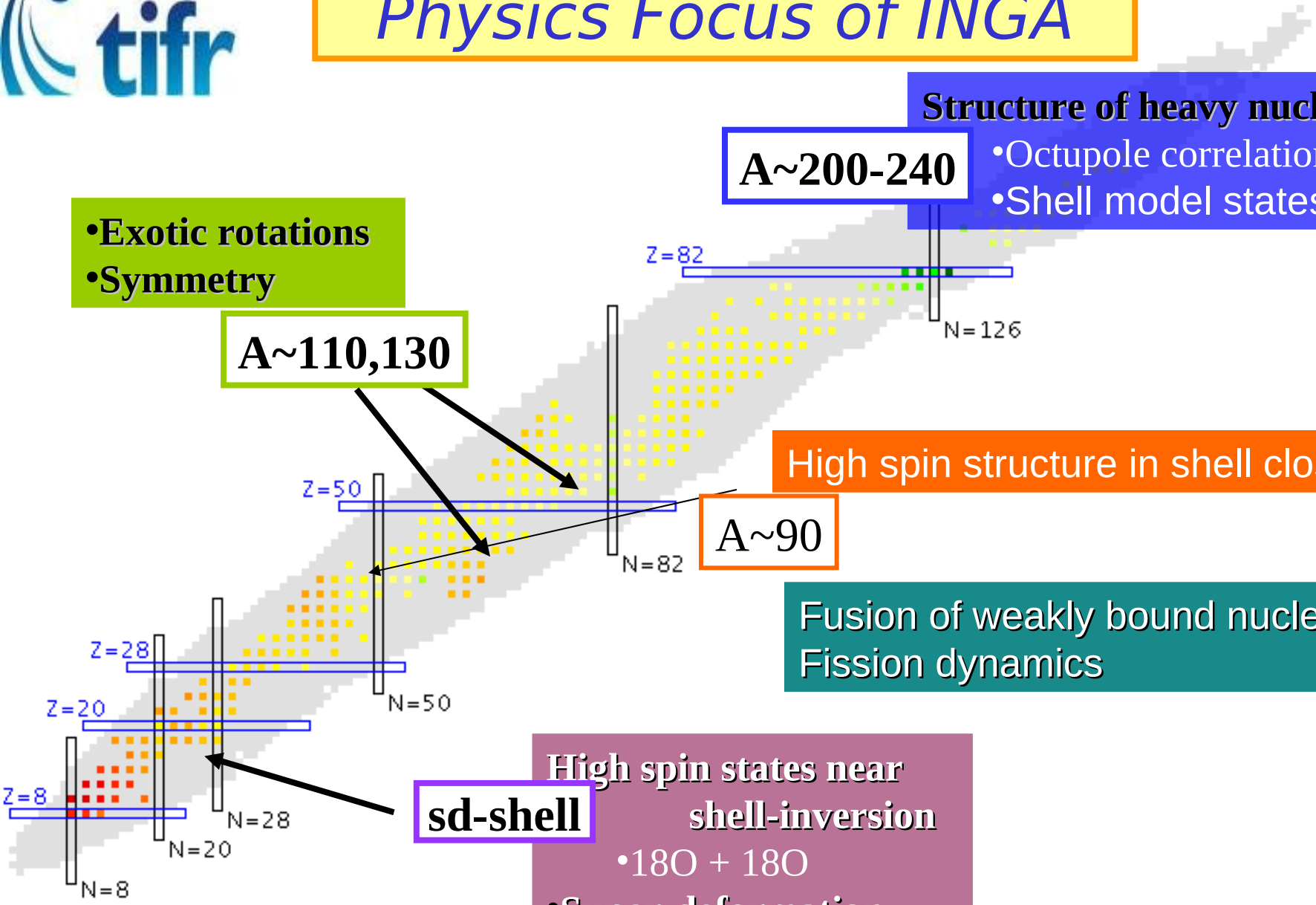
Structure of heavy nuclei

A~200-240

- Octupole correlations
- Shell model states

- **Exotic rotations**
- **Symmetry**

A~110,130



High spin structure in shell closure

A~90

Fusion of weakly bound nuclei
Fission dynamics

sd-shell

High spin states near shell-inversion

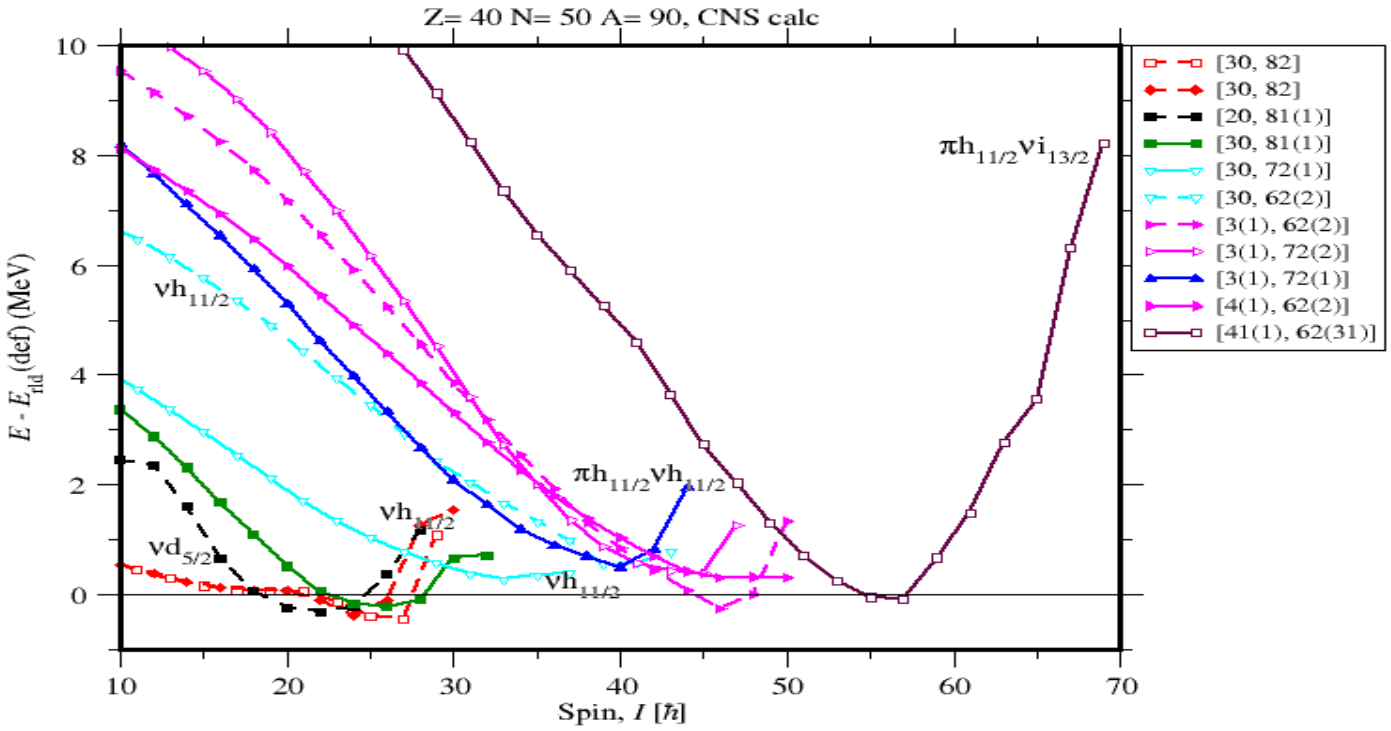
- 18O + 18O
- **Super-deformation**

Interest in high spins states of nuclei near A~90

Test of large scale shell model calculation.

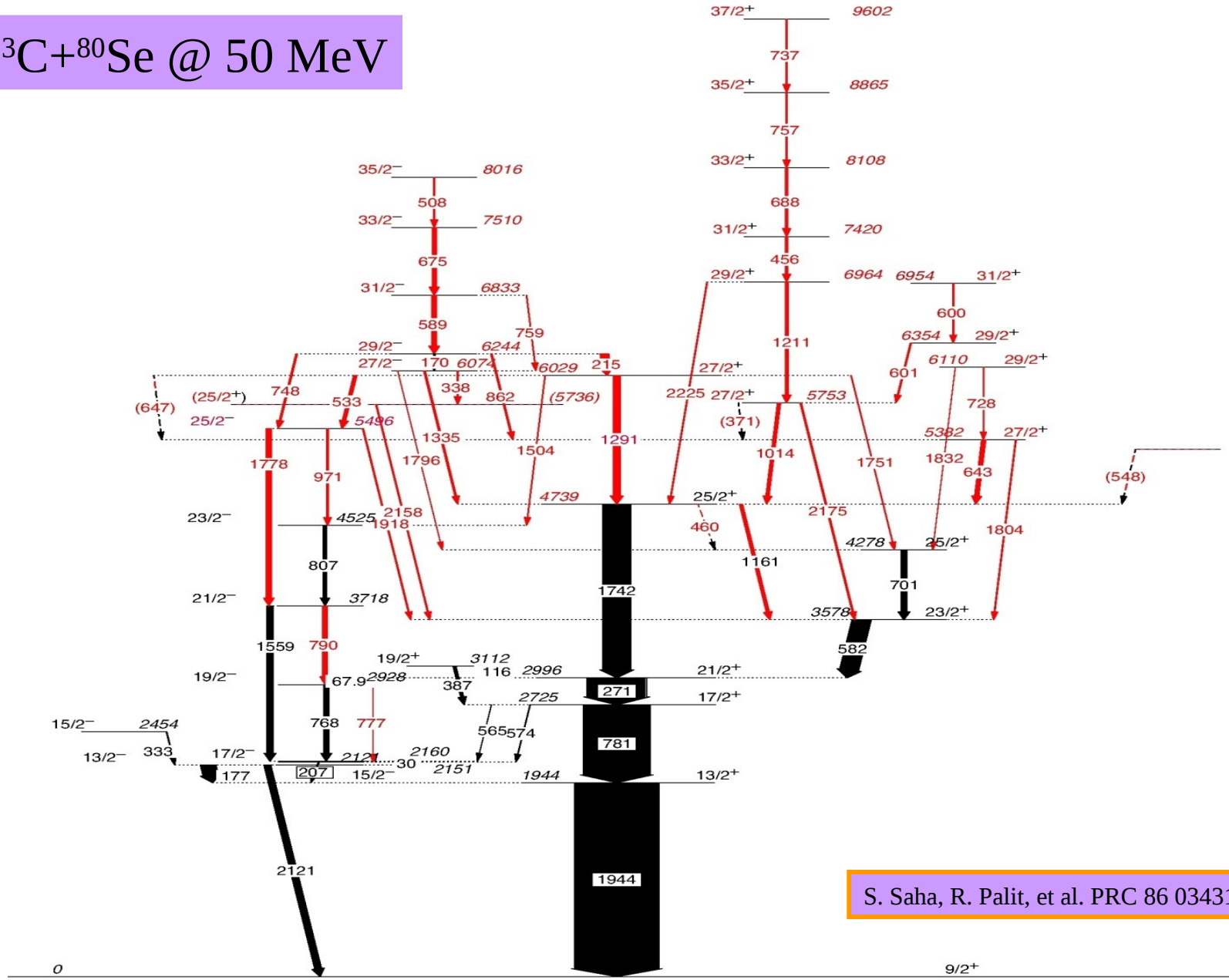
Onset of collectivity at higher spins.

High spin isomer.

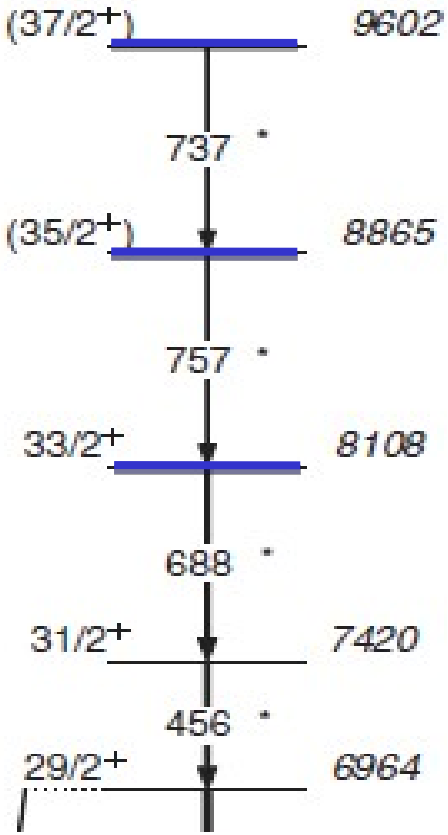


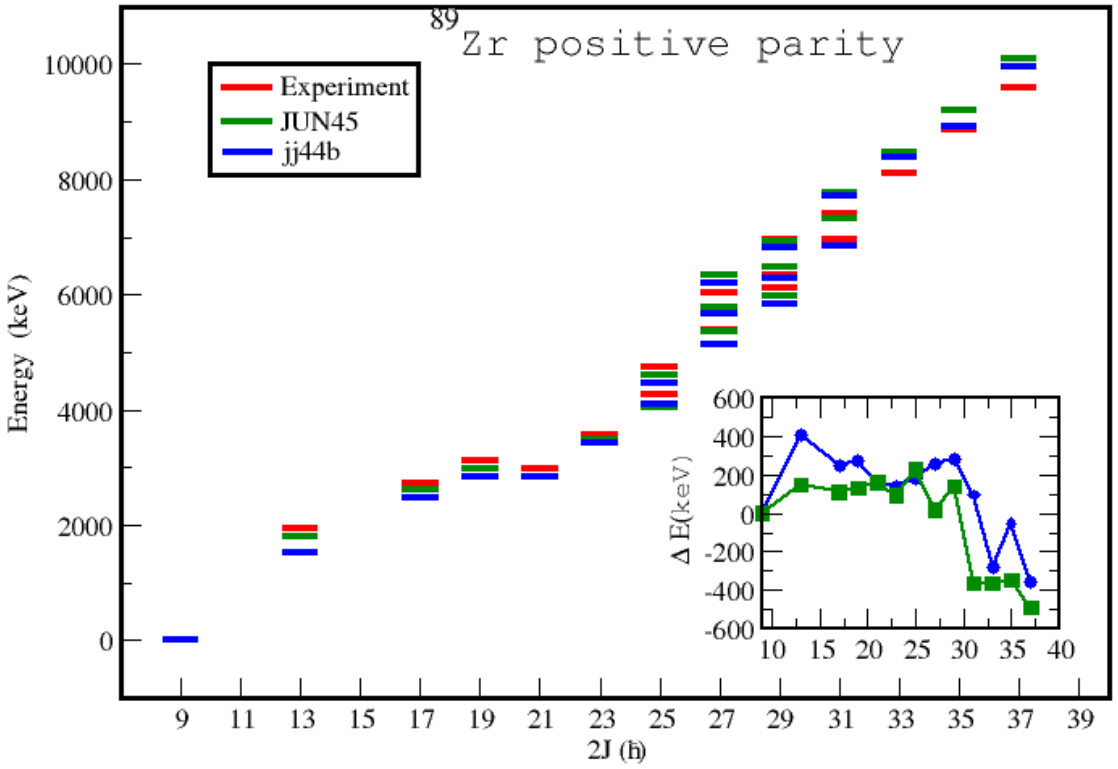
High spin states of ^{89}Zr

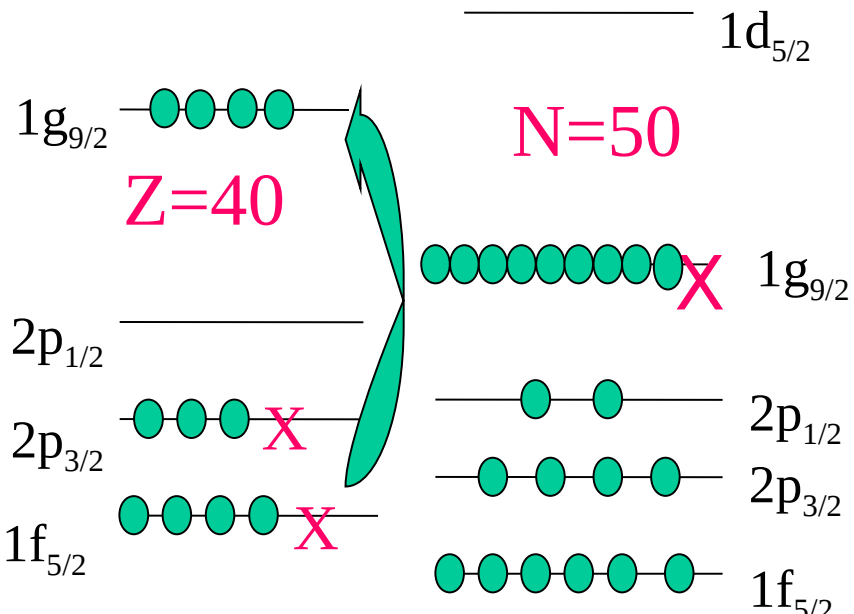
$^{13}C+^{80}Se$ @ 50 MeV

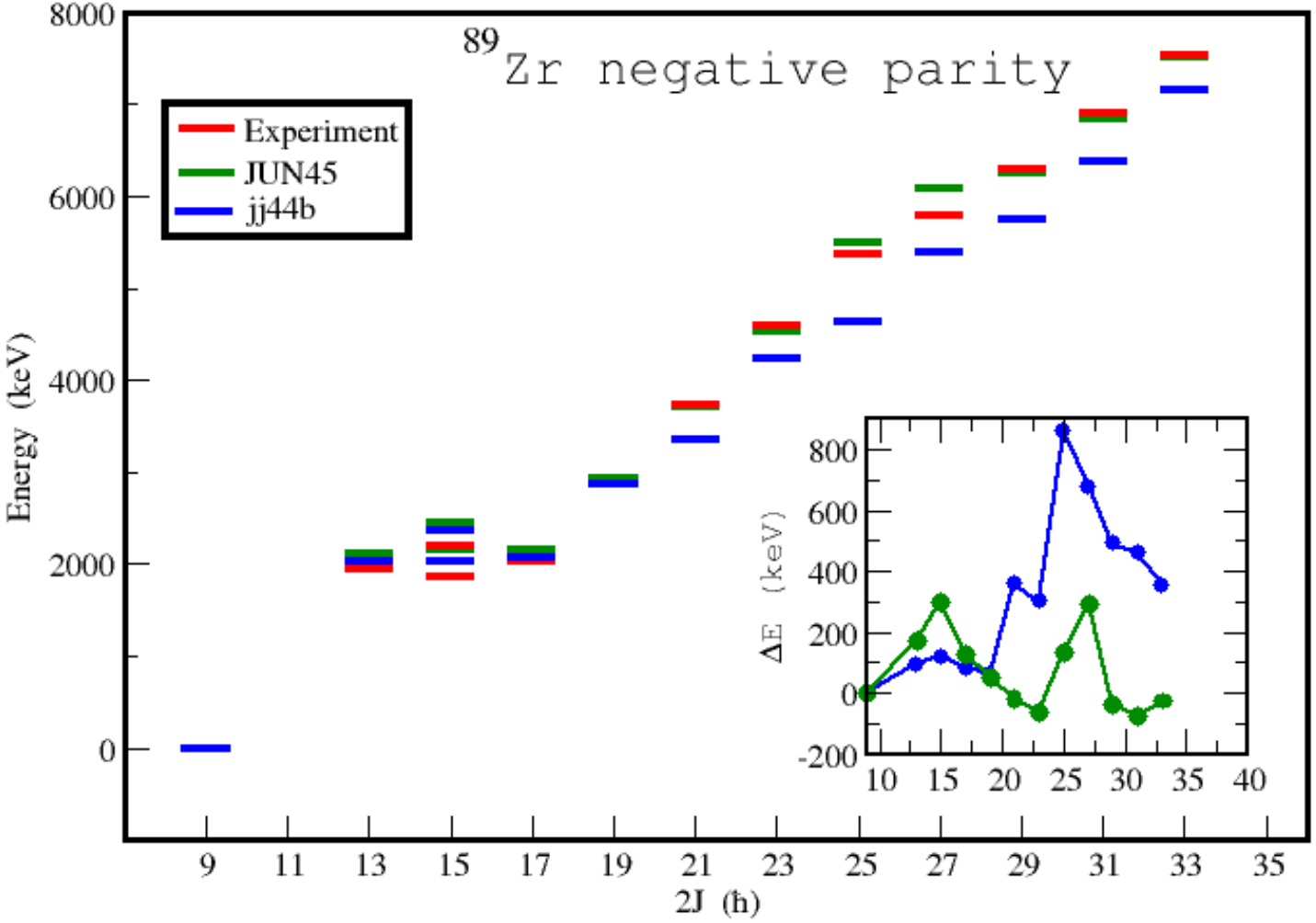


S. Saha, R. Palit, et al. PRC 86 034315 (2012).


(37/2+)
9602
737
(35/2+)
8865
757
33/2+
8108
688
31/2+
7420
456
29/2+
6964

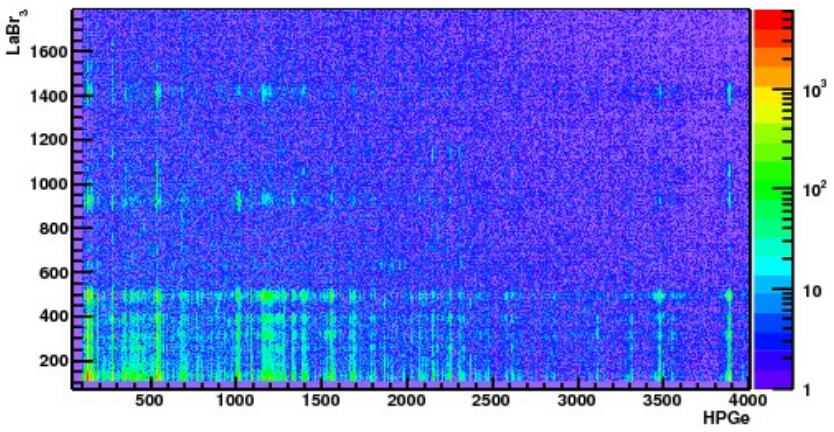

89Zr positive parity
Experiment
JUN45
jj44b
Energy (keV)
2J (ħ)
ΔE(keV)

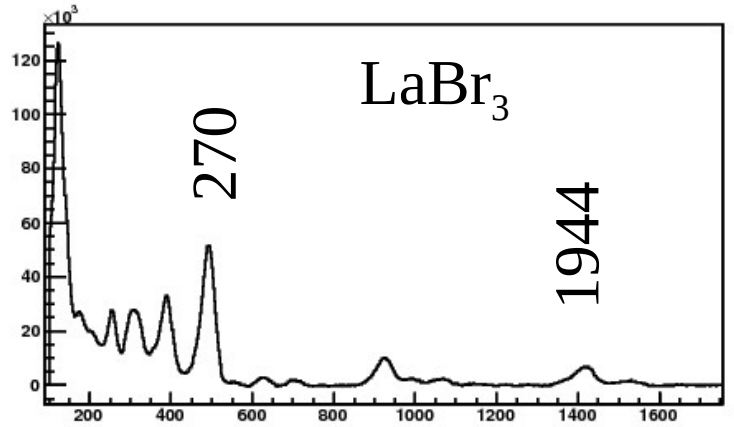

1d5/2
1g9/2
N=50
Z=40
2p1/2
2p3/2
1f5/2
X
1g9/2
2p1/2
2p3/2
1f5/2

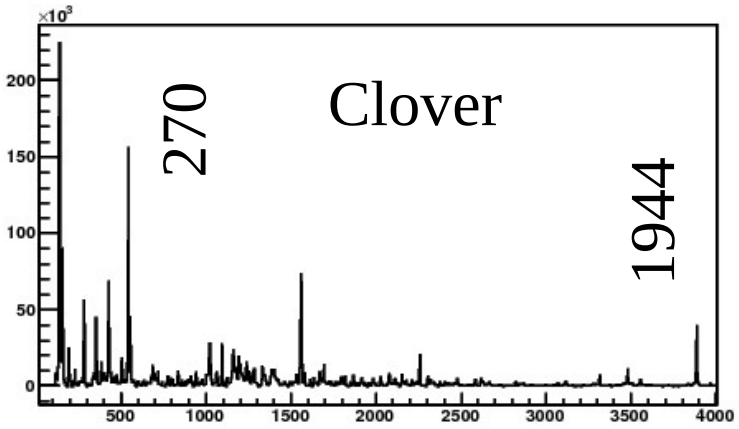

^{89}Zr negative parity
Experiment
JUN45
jj44b
Energy (keV)
2J (ħ)
ΔE (keV)

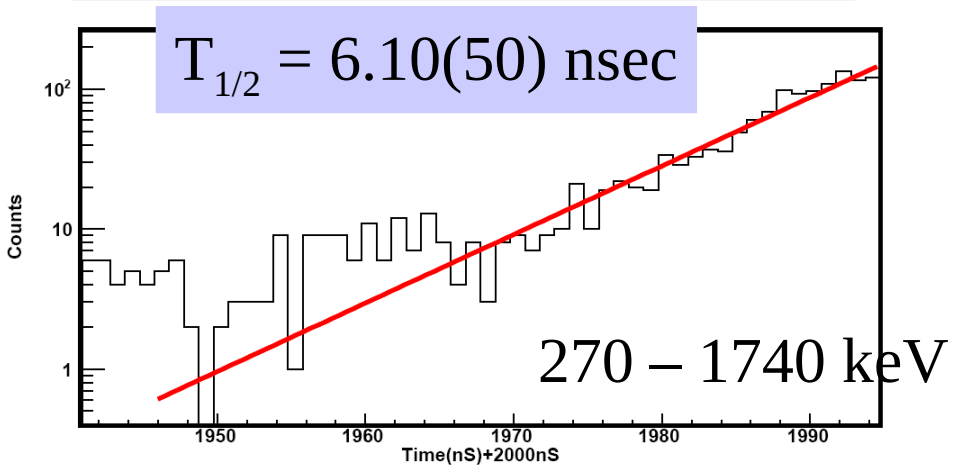
High spin Isomers with two $LaBr_3(Ce)$ coupled to INGA

^{89}Zr: 1944 – 780 – 270 – 1740 cascade extending the level scheme to $25/2^+$









Sudipta et al.

Large-scale shell model Calculations

Model space: $p_{3/2}$, $f_{5/2}$, $p_{1/2}$ and $g_{9/2}$ orbitals.

(133 – two-body matrix elements)
Effective interactions: JUN45 and jj44b.
Shell model calculations with ANTOINE (Strasbourg).

P.C. Srivastava (IITR)

Role of proton excitations from $p_{3/2}$ and $f_{5/2}$ to $g_{9/2}$ orbital for higher spin states is important.

Both predict $\nu(g_{9/2}^{-1})$ configuration for the $9/2^+$ ground state.

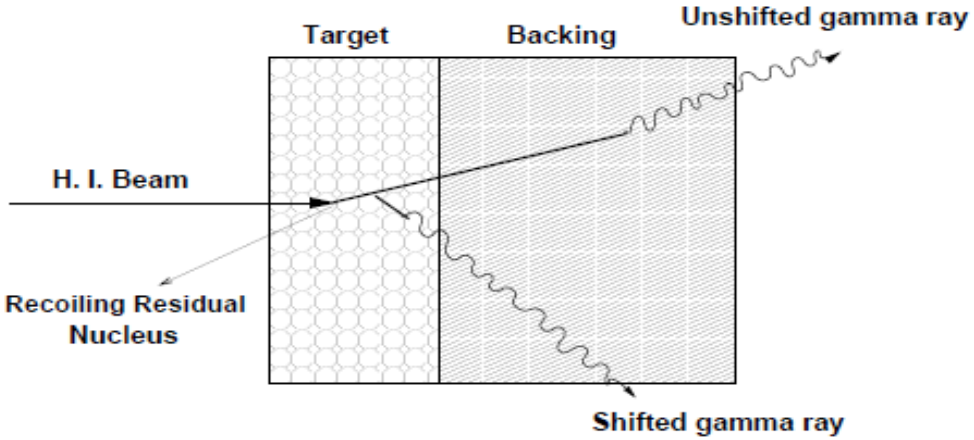
The low-lying yrast states up to $25/2^+$ are well reproduced with $\pi(f_{5/2}^{6}p_{3/2}^{4}(p_{1/2}g_{9/2})^{2}) \otimes \nu\,((p_{1/2}g_{9/2})^{11})$ configurations contributing maximally.

The non-yrast $25/2^+$ and three $27/2^+$ states observed in experiment have dominant contribution from seniority 3 states involving proton excitations from $p_{3/2}$ and $f_{5/2}$to $p_{1/2}$.

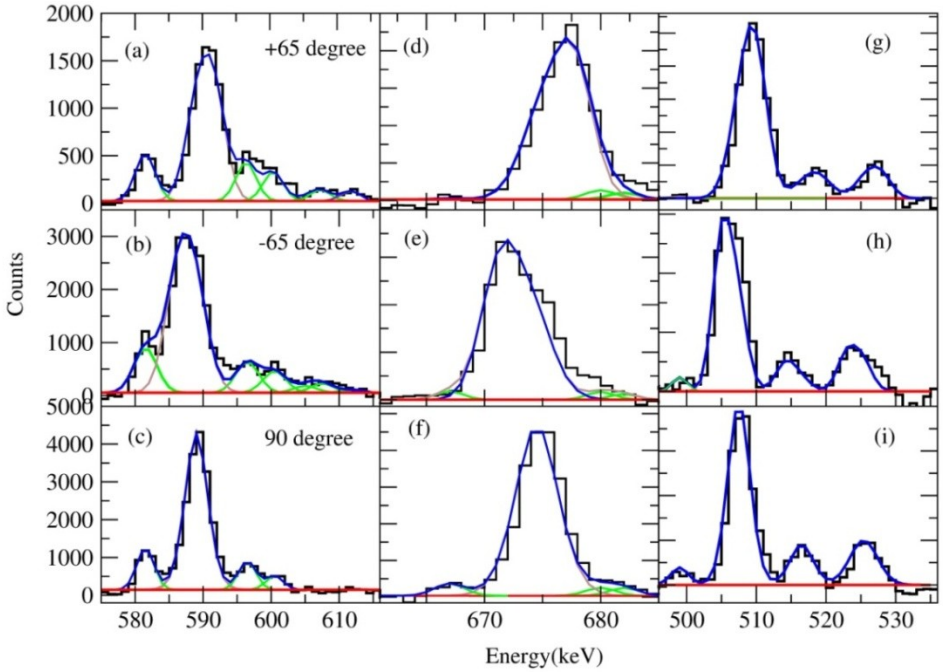
From $21/2^-$ onwards up to $35/2^-$ the states have dominant contribution from proton excitation from $f_{5/2}$ to $g_{9/2}$ and quite well explained by shell model calculations.

B(E2; 21/2->17/2) 64.9(1.5) e2fm4 JUN45 36.35 & jj44b 51.76

Lifetime measurements



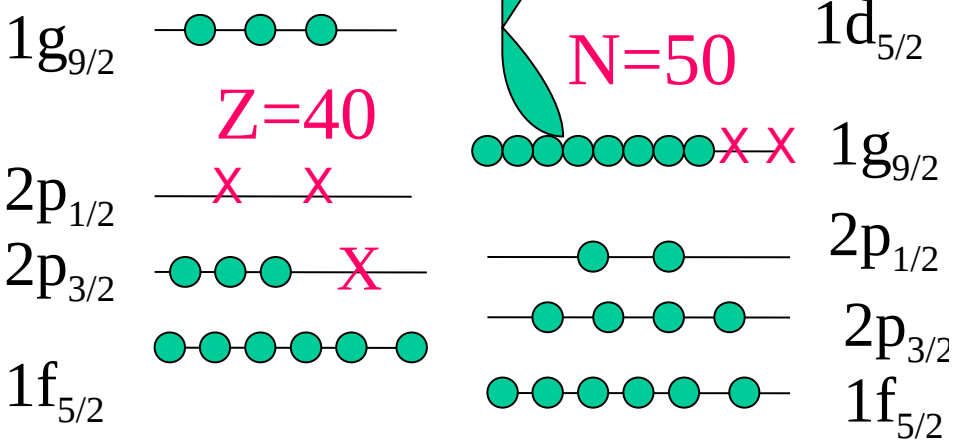
DSAM Measurement

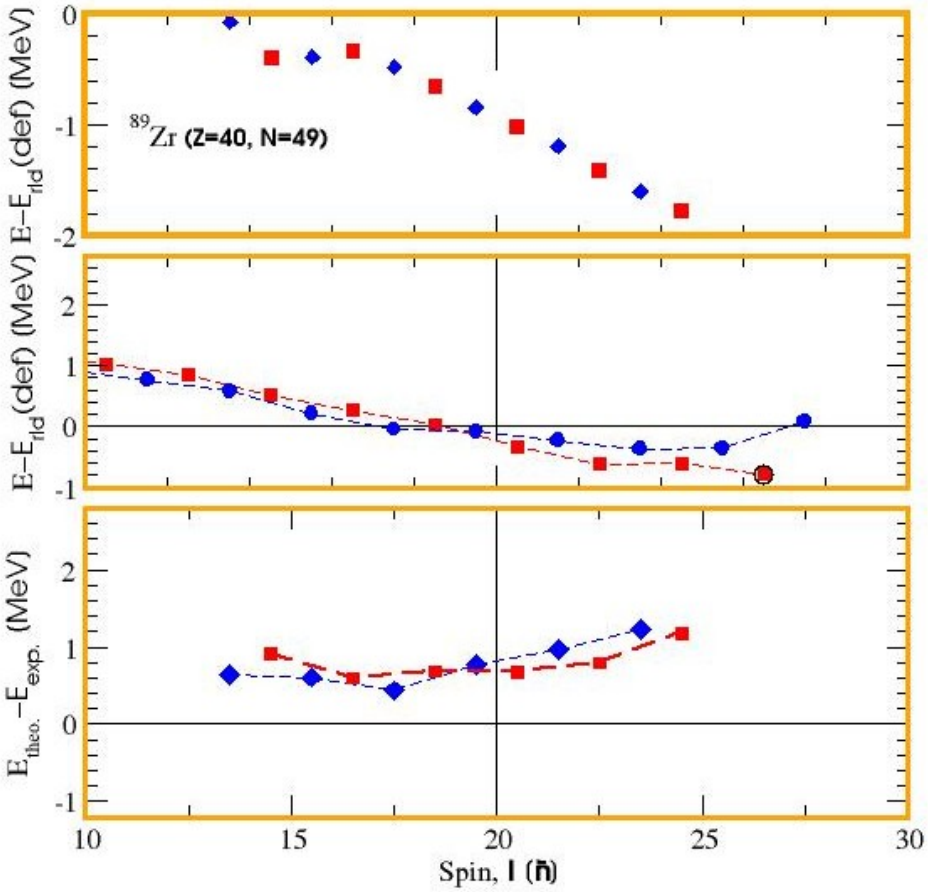


Fast M1 transitions with
$B(M1) \sim 1 - 2\ \mu_N^2$

Cranking calculations using Multi-quasi-particle configurations

$^{13}C + ^{80}Se$ @ 60 MeV





Summary

Discussed the new features of INGA coupled to a DDAQ
(incresaed data throughput (~10 times) compared to our previous analogue readout scheme)

High spin states in ^{89}Zr up to 49/2.

Comparison of the measured levels of ^{89}Zr with that of the shell model calculations for positive and negative parity states.

A regular band has been observed in medium spin.
Its structure has been explained using multi-quasi-particle configuration in Cranking calculation .

Addition of ancillary detectors and different reactions will be explored for further investigation of emergence of collective structure at high spin in nuclei near ^{90}Zr.

Collaboration & Acknowledgements

S. Saha, J. Sethi, T. Trivedi, S. Biswas, P. Singh, D. Choudhury,

B.S. Naidu, P.B. Chavan, S. Jadhav, R. Donthi

S. Sharma ,Z. Naik, S. Tandel, S. Kumar, G. Mukherjee, S.Sihotra,

S. Tandel, D. Mehta, A.K. Jain, L.S. Danu, S. Mukhopadhya

P.K. Joshi, P. Verma, S. Sinha

And INGA Collaboration

H.C.Jain, R.K. Bhowmik, S. Bhattacharya, S.Kailas, A.K. Jain, A.K. Sinha, S.K. Basu, S. Muralithar, R.P. Singh, R. Kumar, A. Goswami,, S. Bhattacharyya, S. Ghugre, D.C. Biswas, A. Chatterjee

R.G. Pillay, V. Nanal, I. Mazumdar

S.K. Sarkar

Pelletron-Linac staff members, Central Workshop & LTF of TIFR

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INGA Collaboration Meeting at TIFR in March 2013