Recent Results from INGA on Excitations of Transitional Nuclei

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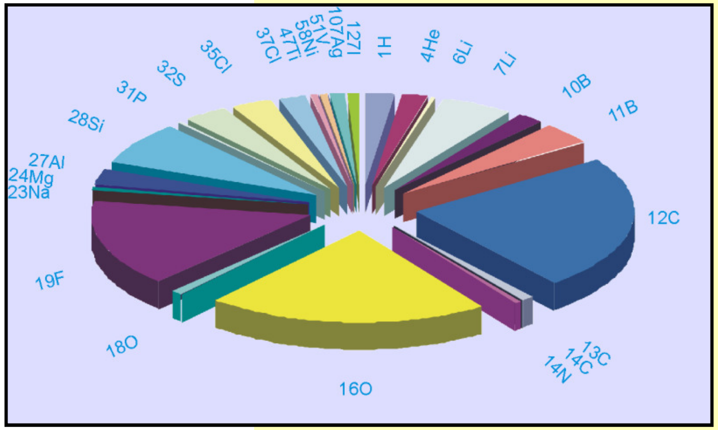
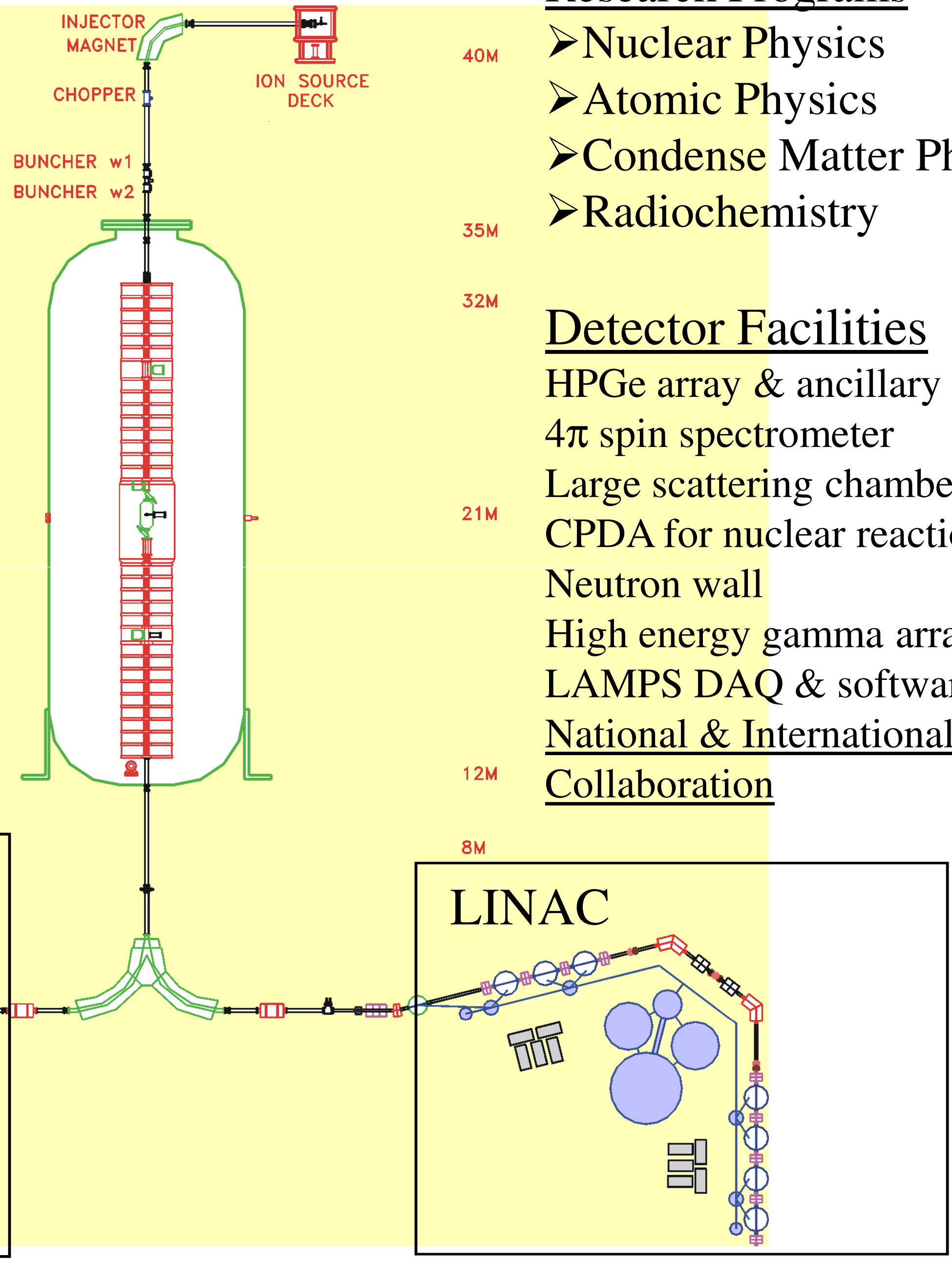
TIFR

Outline:

- New features of the array at TIFR
- Recent results
  - Excitation modes of transitional nuclei
  (Magnetic, Chiral, Wobbling)
- Future possibilities

TIFR-BARC Pelletron Linac Accelerator Facility at Mumbai





Specifications

Heavy ions upto A~80
E/A~5-12 MeV

Energy gain 14MV/q
Module 7 nos
Resonators 28 nos

Bunch width ~200 ps
Beam Intensity 0.1-10 pnA

Research Programs

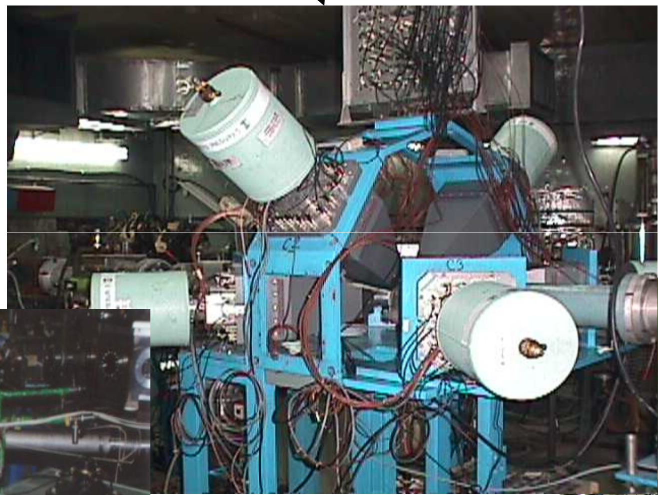
- Nuclear Physics
- Atomic Physics
- Condense Matter Physics
- Radiochemistry

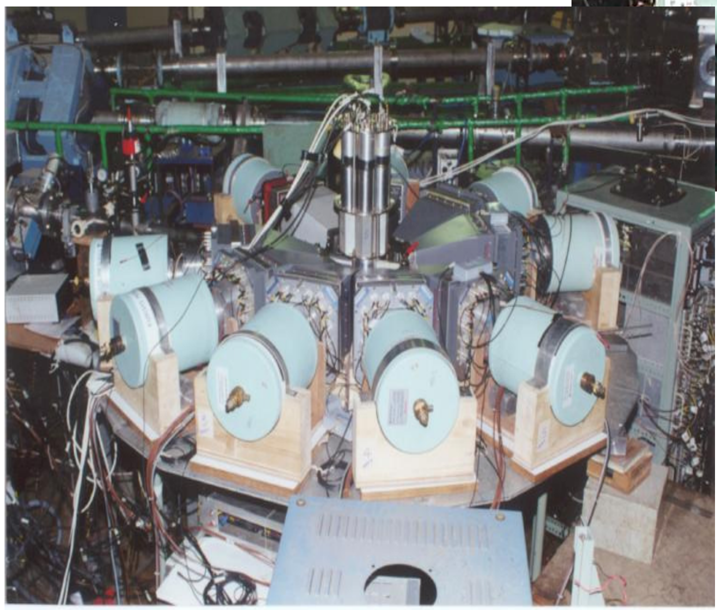
Detector Facilities

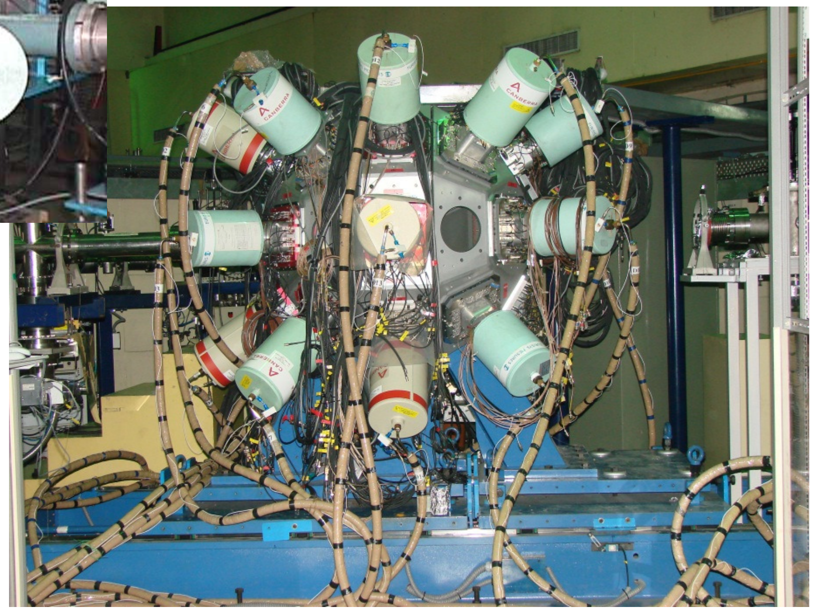
HPGe array & ancillary detectors
4π spin spectrometer
Large scattering chamber
CPDA for nuclear reaction
Neutron wall
High energy gamma array
LAMPS DAQ & software
National & International Collaboration

INGA campaigns at different accelerator facilities

INGA01	INGA03	INGA05	sINGA07-8	INGA08-9	INGA11-12
TIFR	NSC	VECC	TIFR	IUAC	TIFR



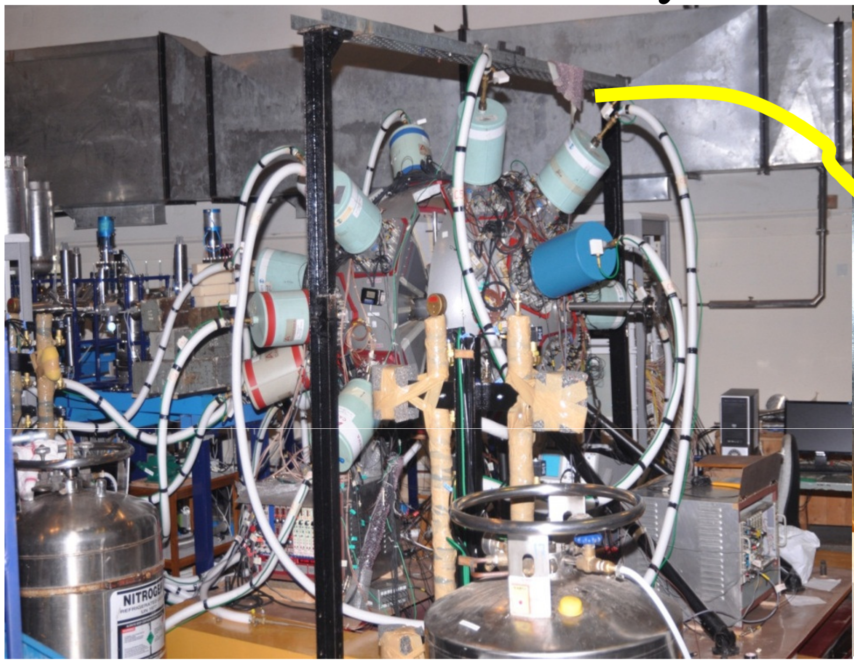


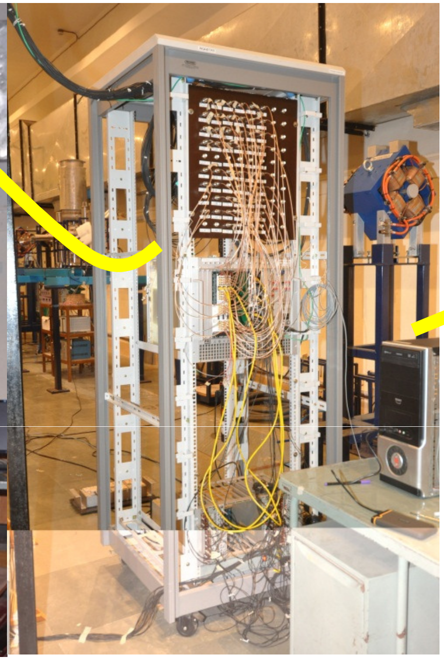


DDAQ with INGA

Detector Array

DSP DAQ





Host PC

PC for Storage & Analysis

- Mounting position for 24 Clovers (ε_P ~5%)
- *3 at 23^o, 40^o, 65^o, 115^o, 140^o, 157^o and 6 at 90^o*
- Detectors -> DSP cards -> PCI Bridge -> PC-> Gigabit -> PC

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

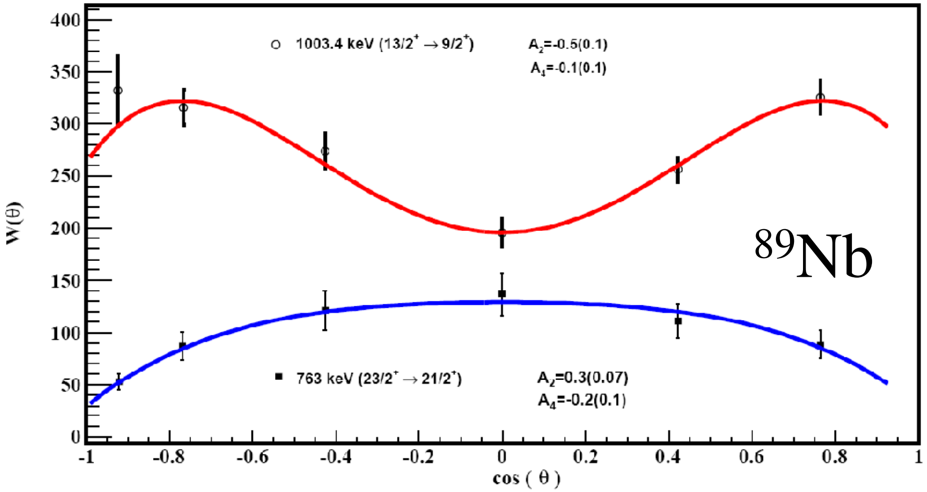
H. Tan et l., NSS 08, IEEE (2008) p 3196

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

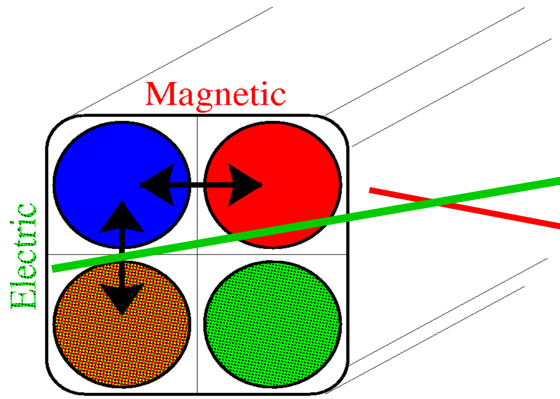
R. Palit AIP Conf Proc. 1336 (2011) 573

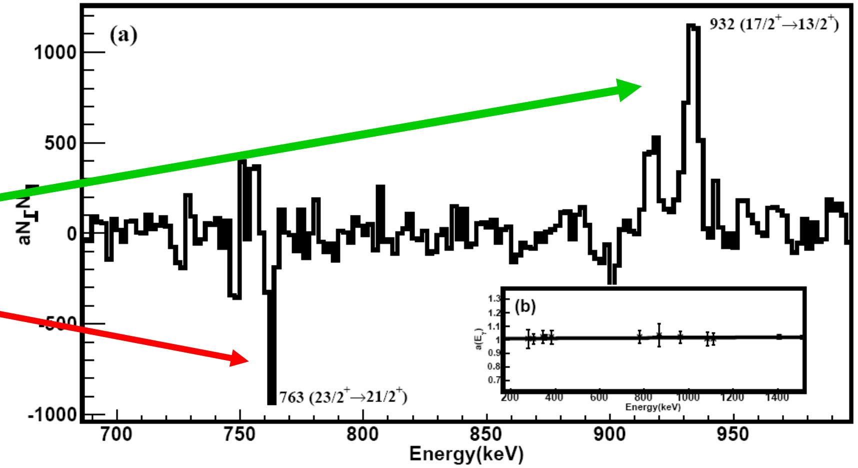
R. Palit, et al. NIMA 680 (2012) 90

Angular Distribution & Polarization



- 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

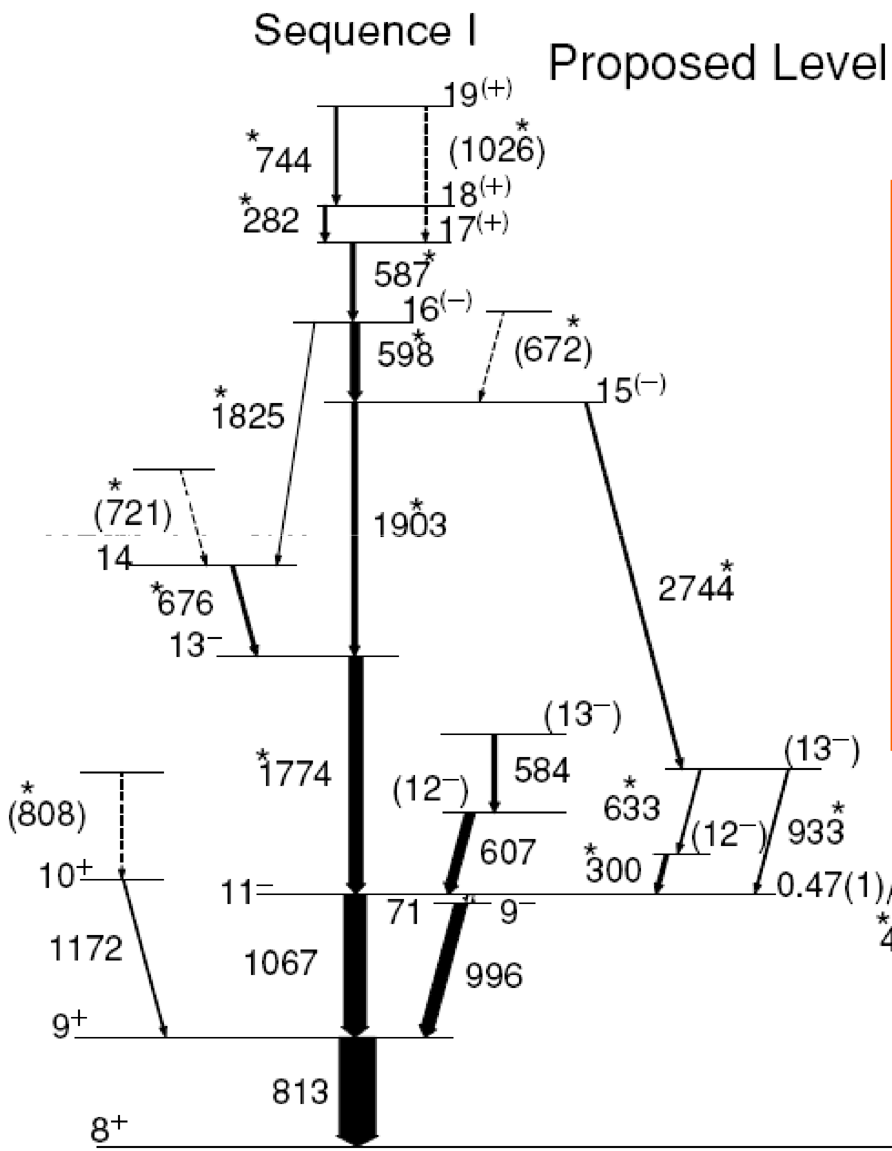


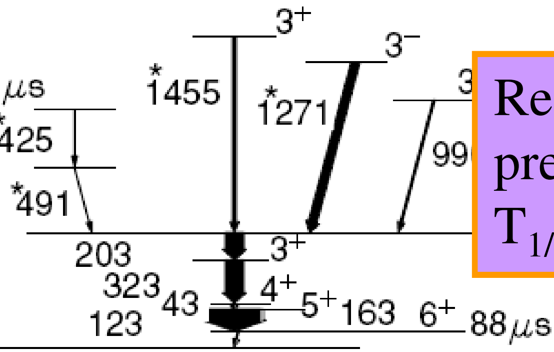


DDAQ has Increased the data throughput by 10 times for INGA

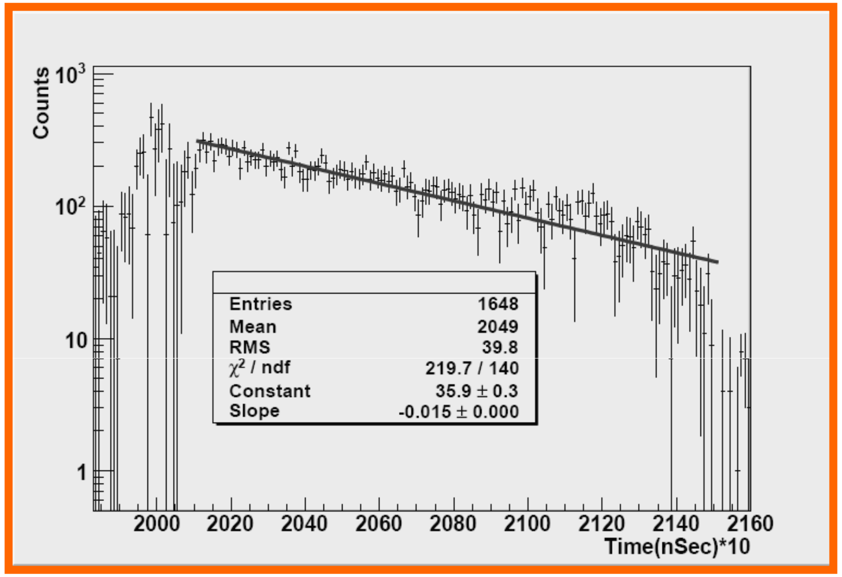
Long Lived Isomers near N=50

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





T-stamped data



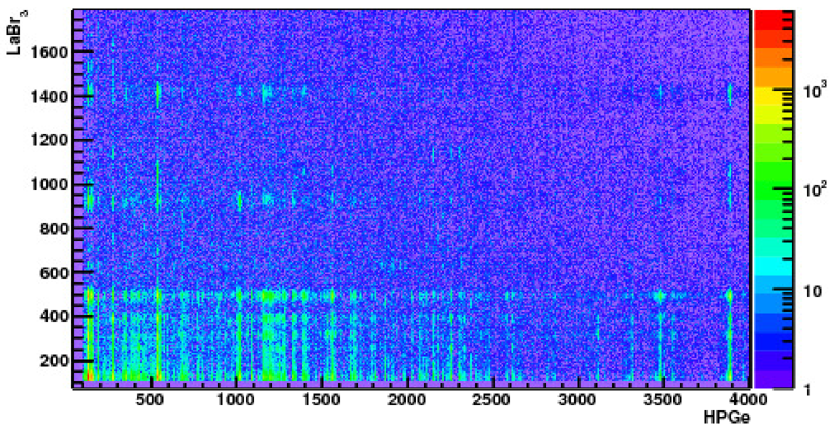
R. Palit, et al,

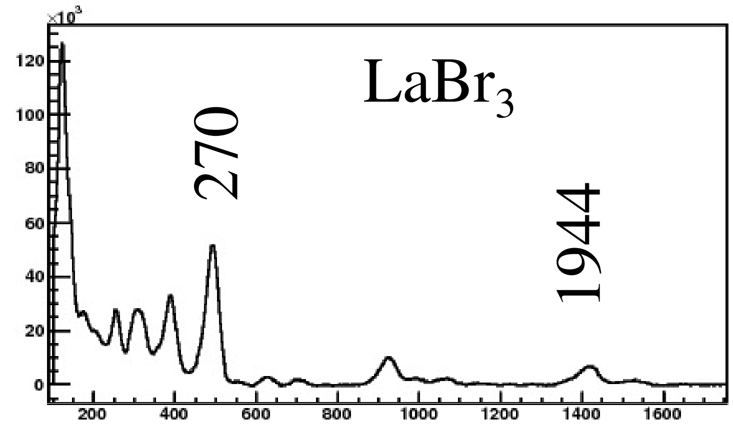
Reconfirmed the previous reported $T_{1/2} =$ 460 (10) nsec

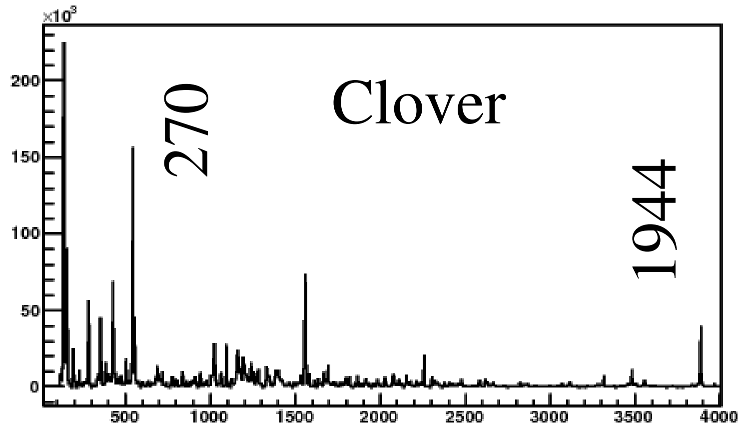
A. Chakrabarti, et al. PRC 72, 054309 (2005)

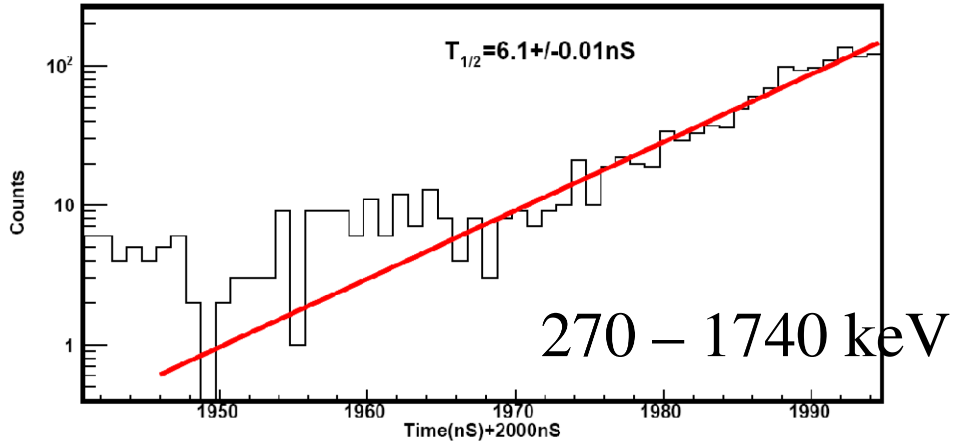
High spin Isomers with two $LaBr_3$(Ce) coupled to INGA

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



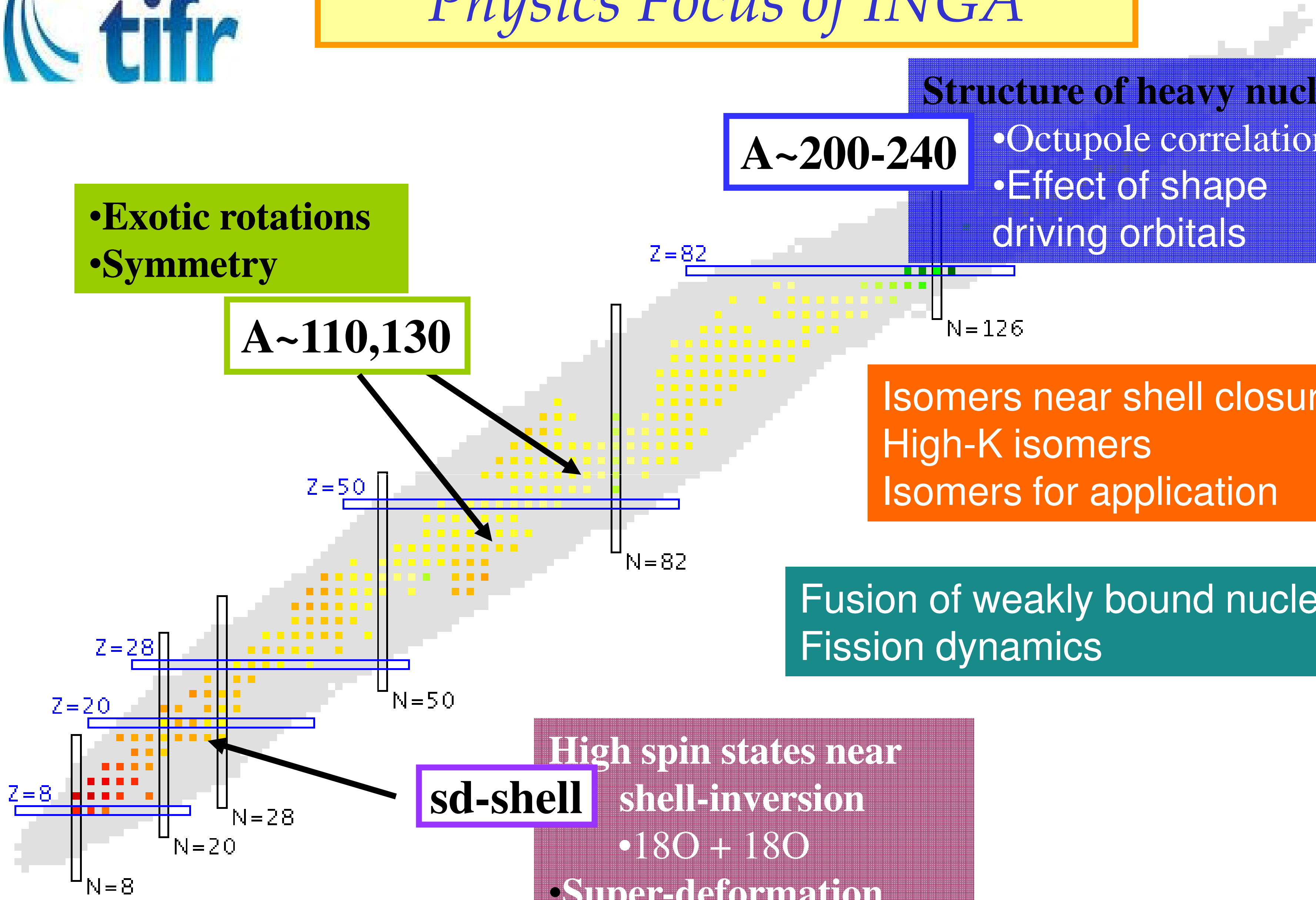






Sudipta et al.

Physics Focus of INGA



Structure of heavy nuclei

A~200-240

- Octupole correlations
- Effect of shape driving orbitals

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

A~110,130

Isomers near shell closure
High-K isomers
Isomers for application

Fusion of weakly bound nuclei
Fission dynamics

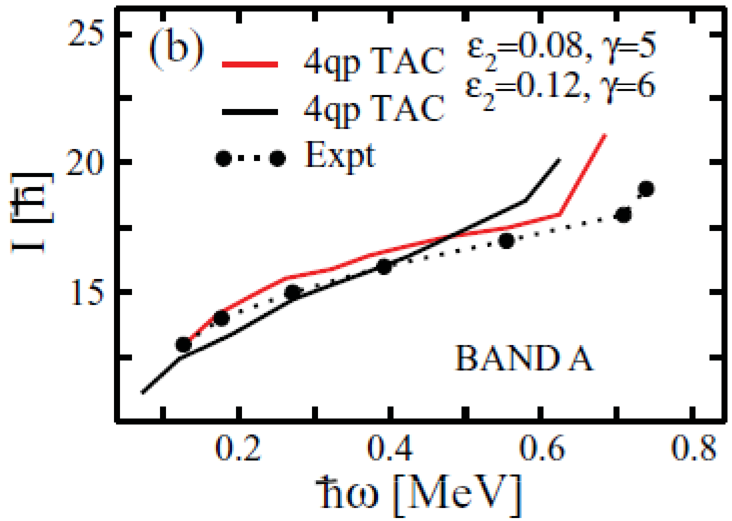
sd-shell

High spin states near shell-inversion

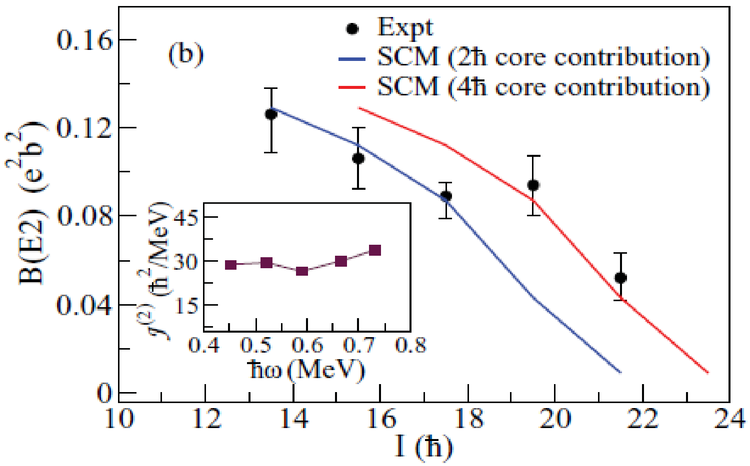
- 18O + 18O

- **Super-deformation**

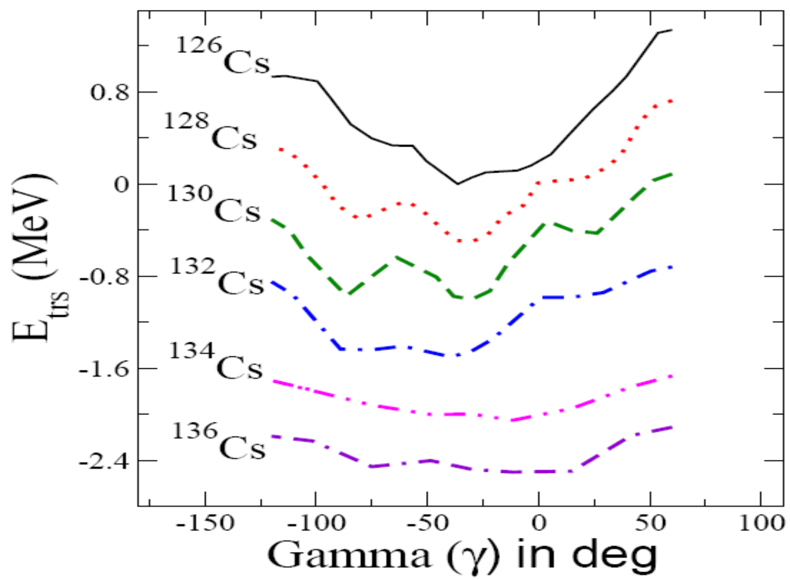
Recent results from INGA



Search for multiple chiral bands
T. Trivedi, et al PRC 85 (2012)



Axial asymmetry In Cs isotopes
H. Pai, et al PRC 84 (2011)



Anti-magnetic rotation in ^{105}Cd
D. Chaudhury, et al. PRC82(2010)

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **82**, 061308(R) (2010)

Evidence of antimagnetic rotation in odd-A ^{105}Cd

Deepika Choudhury,[1,*] A. K. Jain,[1] M. Patial,[1] N. Gupta,[1] P. Arumugam,[1] A. Dhal,[2,6] R. K. Sinha,[2] L. Chaturvedi,[3] P. K. Joshi,[4] T. Trivedi,[4] R. Palit,[4] S. Kumar,[5] R. Garg,[5] S. Mandal,[5] D. Negi,[6] G. Mohanto,[6] S. Muralithar,[6] R. P. Singh,[6] N. Madhavan,[6] R. K. Bhowmik,[6] and S. C. Pancholi[6]

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **84**, 041301(R) (2011)

Structural change of the unique-parity $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration in ^{134}Cs

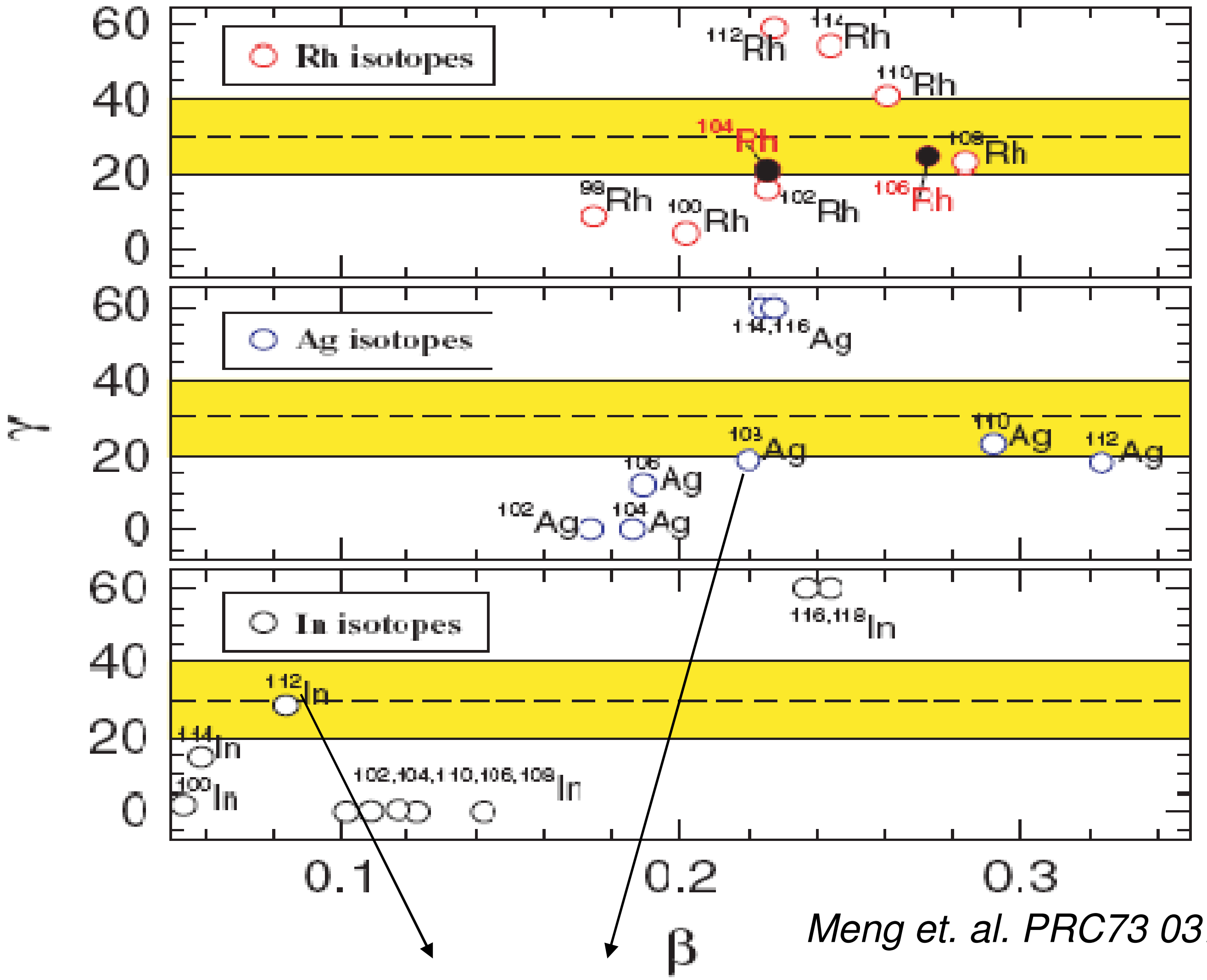
H. Pai,[1] G. Mukherjee,[1,*] A. Raghav,[2] R. Palit,[2] C. Bhattacharya,[1] S. Chanda,[3] T. Bhattacharjee,[1] S. Bhattacharyya,[1] S. K. Basu,[1] A. Goswami,[4] P. K. Joshi,[2] B. S. Naidu,[2] Sushil K. Sharma,[2] A. Y. Deo,[2,†] Z. Naik,[2,‡] R. K. Bhowmik,[5] S. Muralithar,[5] R. P. Singh,[5] S. Kumar,[6] S. Sihotra,[7] and D. Mehta[8]

PHYSICAL REVIEW C **85**, 014327 (2012)

Small quadrupole deformation for the dipole bands in ^{112}In

T. Trivedi,[1] R. Palit,[1,*] J. Sethi,[1] S. Saha,[1] S. Kumar,[2] Z. Naik,[1] V. V. Parkar,[1,†] B. S. Naidu,[1] A. Y. Deo,[1] A. Raghav,[1] P. K. Joshi,[1] H. C. Jain,[1] S. Sihotra,[3] D. Mehta,[3] A. K. Jain,[4] D. Choudhury,[4] D. Negi,[5] S. Roy,[6] S. Chattopadhyay,[6] A. K. Singh,[7] P. Singh,[7] D. C. Biswas,[8] R. K. Bhowmik,[5] S. Muralithar,[5] R. P. Singh,[5] R. Kumar,[5] and K. Rani[5]

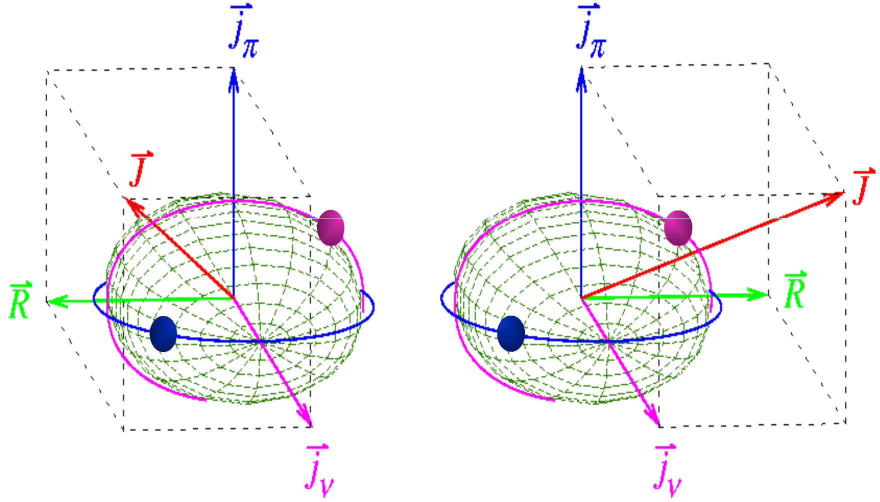
Odd-odd Isotopes near A ~ 110

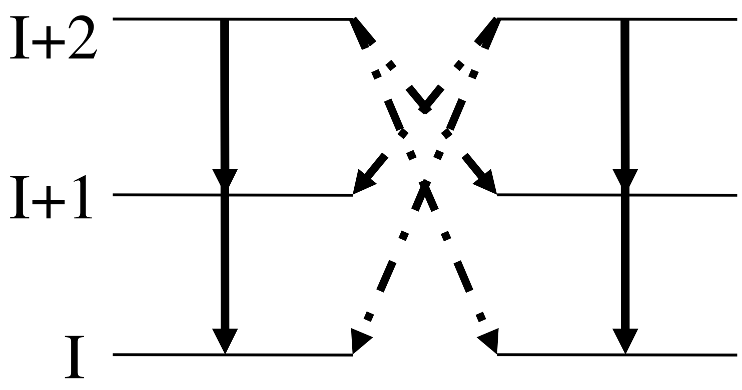


Meng et. al. PRC73 037303 (2006)

Detailed Spectroscopy of ^{112}In & ^{108}Ag isotopes using INGA

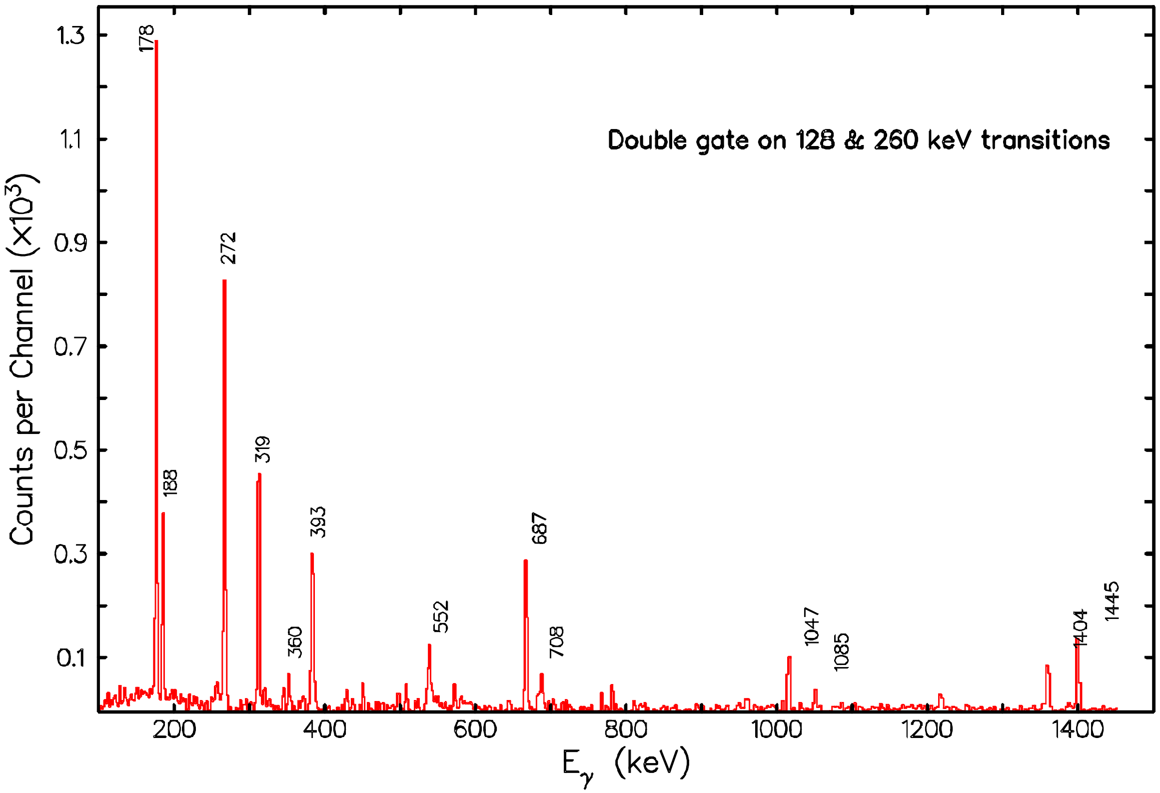
Chiral doublets



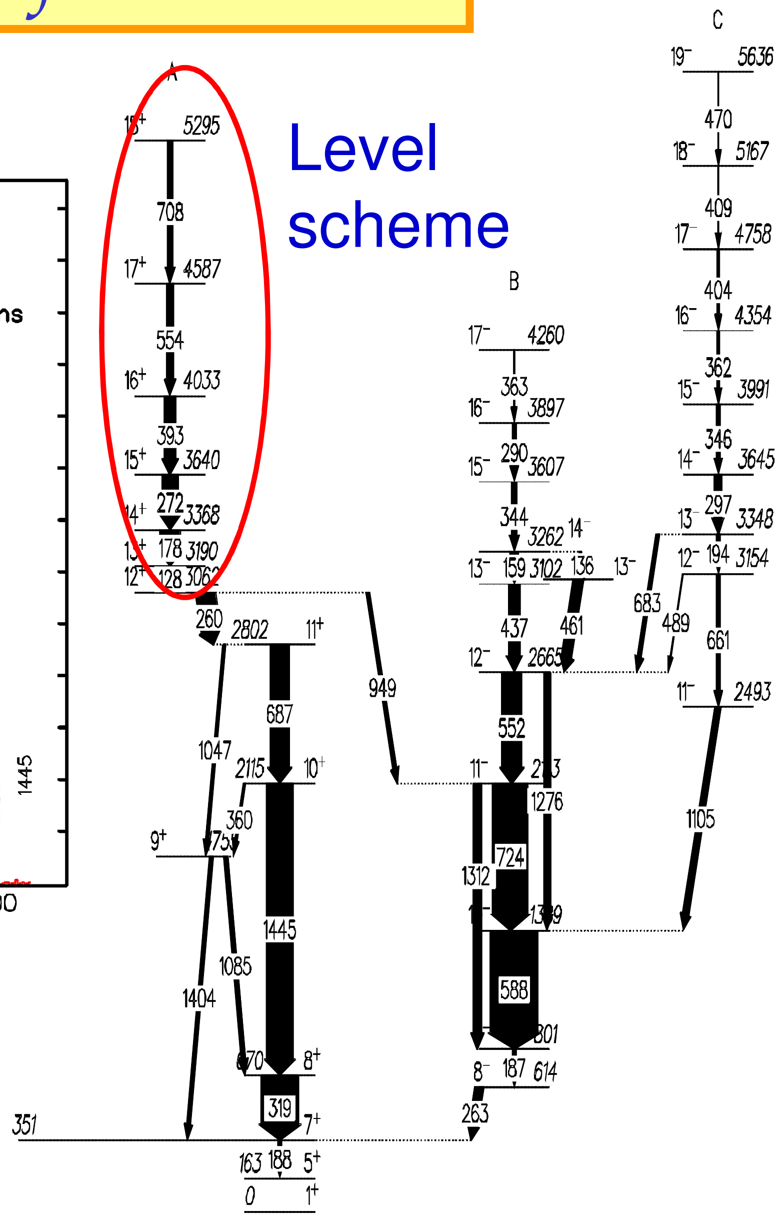


S. Frauendorf   Rev. Mod Phys 73, 463(2001)
K. Starosta, et. al., PRL 86, 971 (2001)

High spin structure of ^{112}In

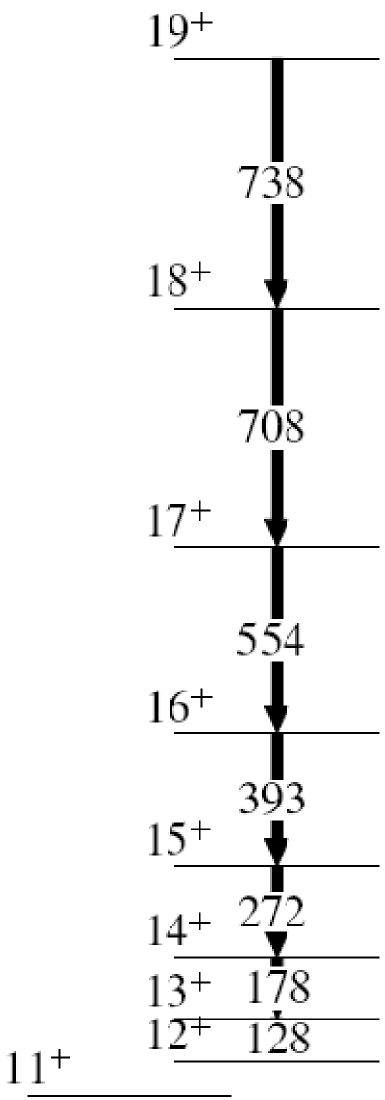


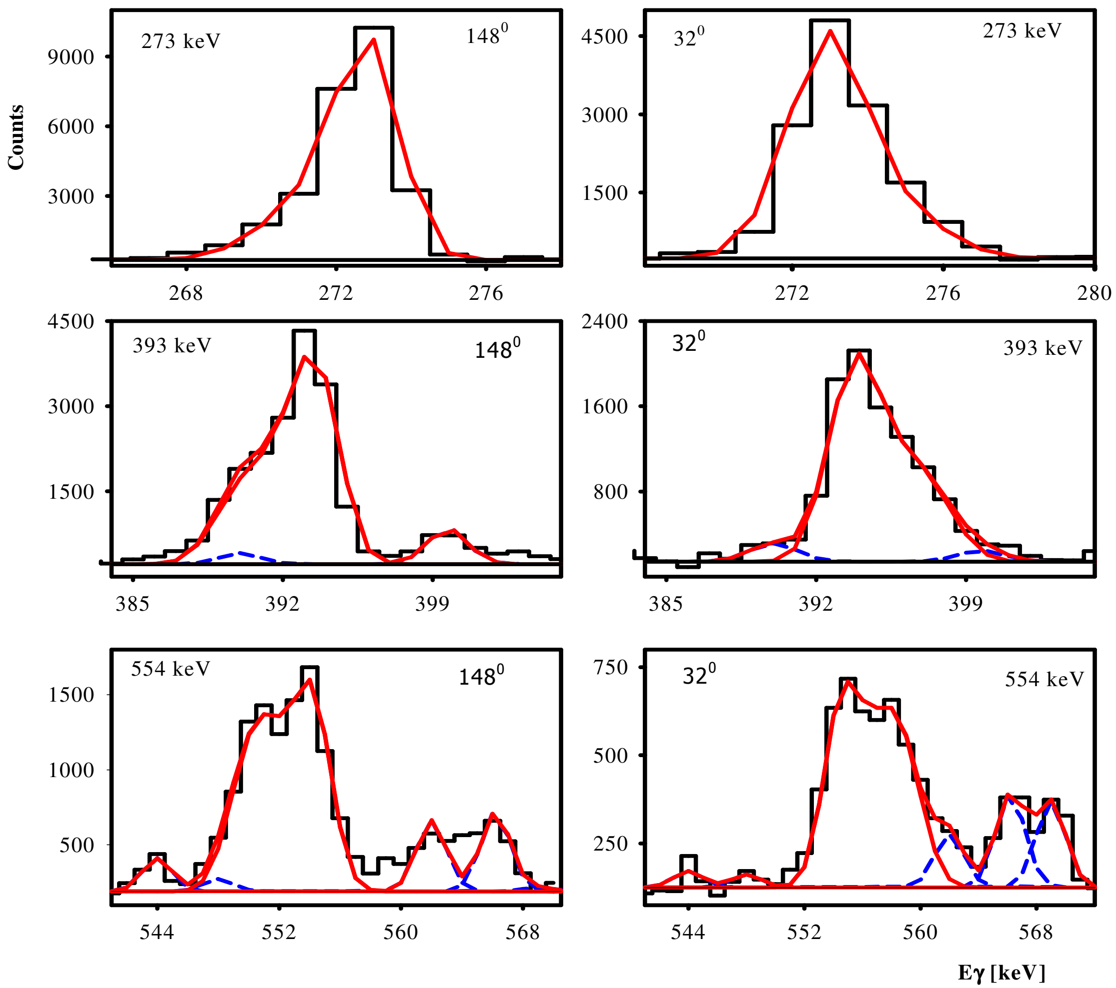
Level scheme



C.Y. He et al., PRC83, 024309, (2010)

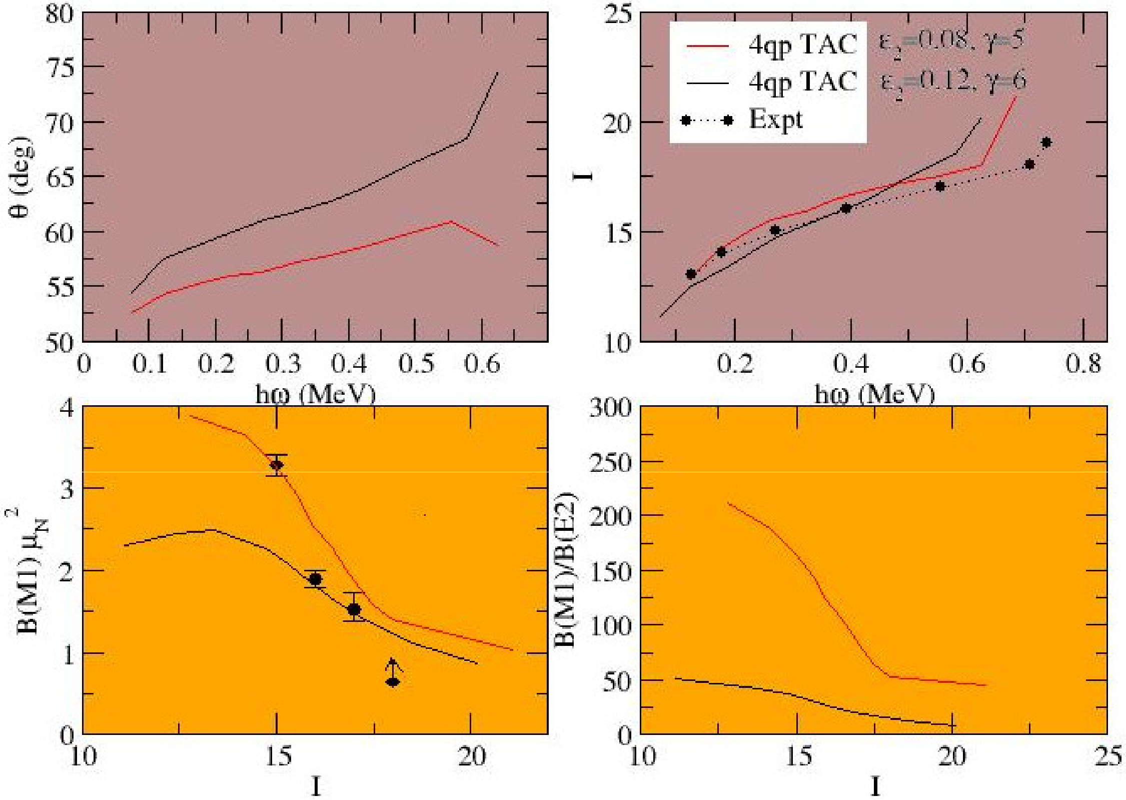
Lifetime measurement for dipole band in ^{112}In





Doppler Shift Attenuation study for sub-pico sec $T_{1/2}$ levels decaying by 272, 393, 554, and 708 keV transitions

Comparison of B(M1) values with TAC calculations

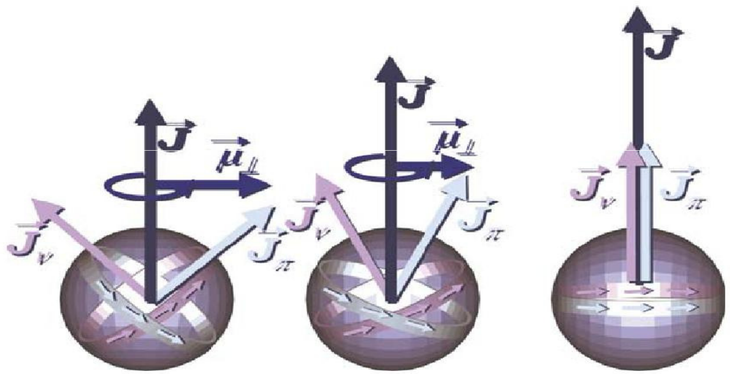


TAC configuration

$\pi g_{9/2}$ - $\nu((h_{11/2})^2 d_{5/2}/g_{7/2})$

ε_2 = 0.12 and $\gamma = 6^0$

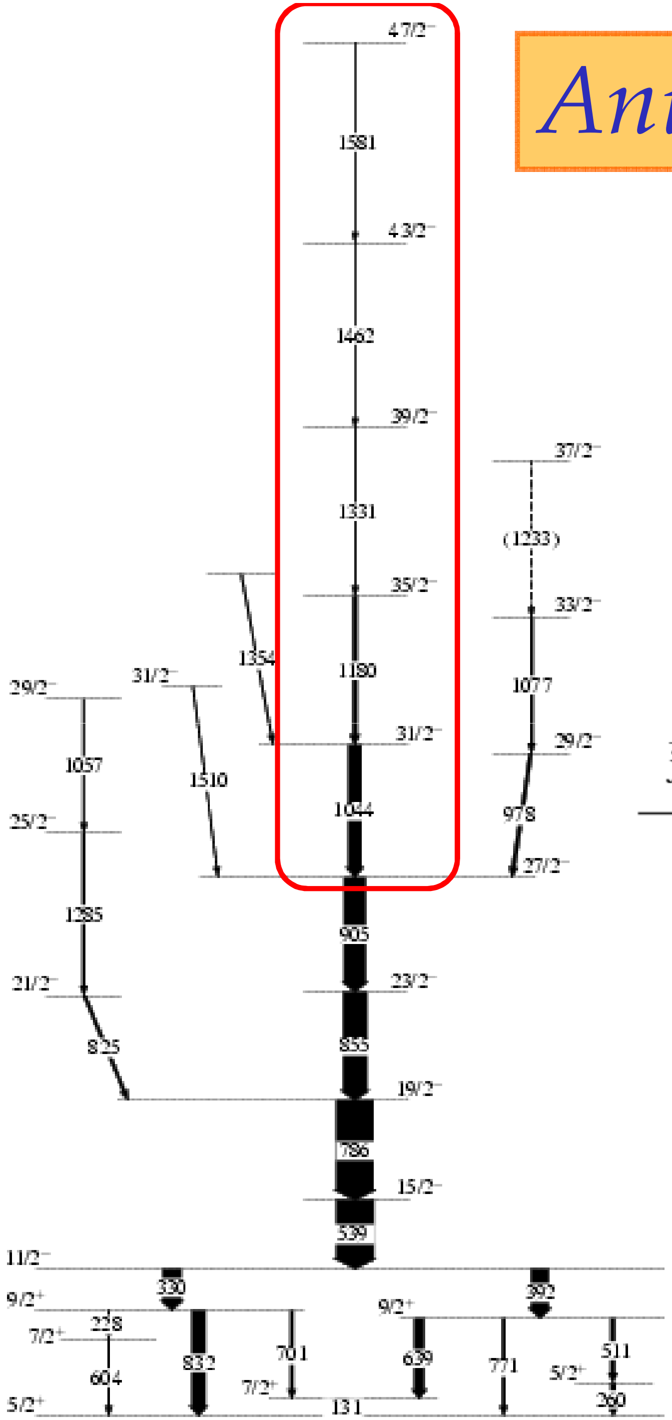
ε_2 = 0.08 and $\gamma = 5^0$

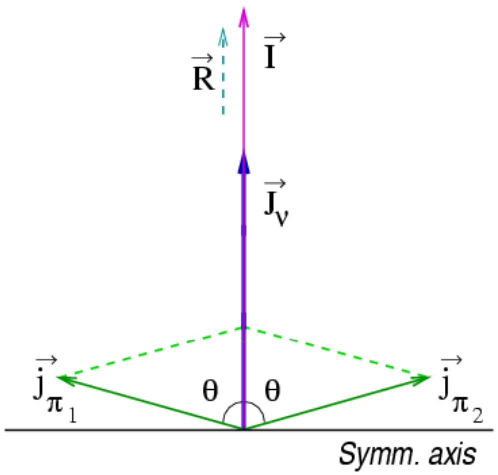


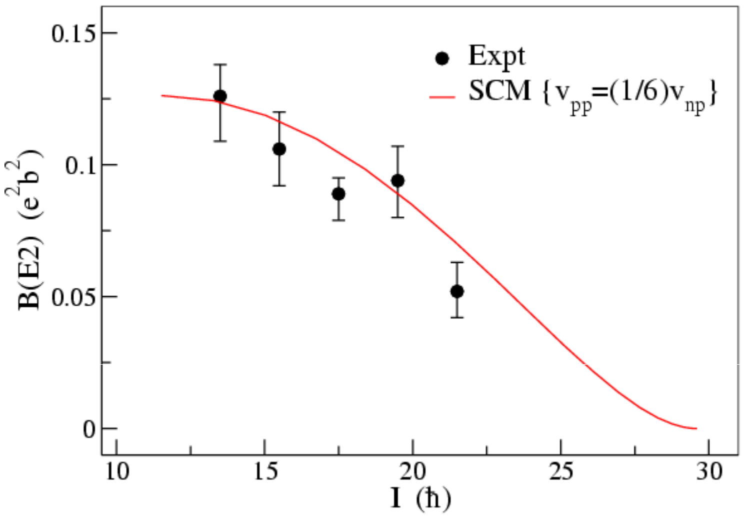
1. Regular sequences of M1 transitions
2. Weak or absent E2 transitions
3. B(M1) decreases with angular momentum

T. Trivedi, et al., PRC85 (2012)

Anti Magnetic Rotation in ^{105}Cd







$$B(E2) = \frac{15}{32\pi}(eQ)^2_{eff}\sin^4\theta$$

$$\nu(g^2_{7/2}h_{11/2})\otimes\pi(g^{-2}_{9/2})$$

1st evidence of AMR to be operative in an odd-A nucleus

Future experiments with INGA coupled to ancillary detectors and Spectrometer

- Structure of high spin isomers
- Structure of heavy nuclei with A > 200
- Heavy nuclei spectroscopy with tagging on fast particle emission
- Identify candidates for prompt proton emission outside of Z~28, N~28
  - Possibly neutron-deficient Te isotopes?
- Study of important nuclei around N=Z line
- Investigation of proton rich nuclei in light mass region
- Investigation of quasi-continuum to look for nuclear shape evolution and dynamics

Summary

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

Results of search for chiral bands in ^{108}Ag & ^{112}In
Anti-magnetic rotation in $^{105,107}Cd$

Addition of ancillary detectors, HYRA spectrometer at IUAC and over all efficiency will enhance its capability for the investigation of
Nuclear structure with varying J & T(N-Z) for probing

- Different phases, their coexistence & transitions
- Insight for shell structure and residual interactions

Collaboration & Acknowledgements

S. Saha, J. Sethi, T. Trivedi,

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

D. Choudhury, S. Sharma ,Z. Naik, V. Parkar, A.Y. Deo, H. Pai, S. Kumar, G. Mukherjee, S.Sihotra,

D. Mehta, A.K. Jain

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, A. Goswami,, S. Bhattacharyya, S. Ghugre, D.C. Biswas, A. Chatterjee
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S.K. Sarkar
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