Light, Large & Lustrous: The Many Accomplishments of Digital INGA @ VECC

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UGC-DAE CSR







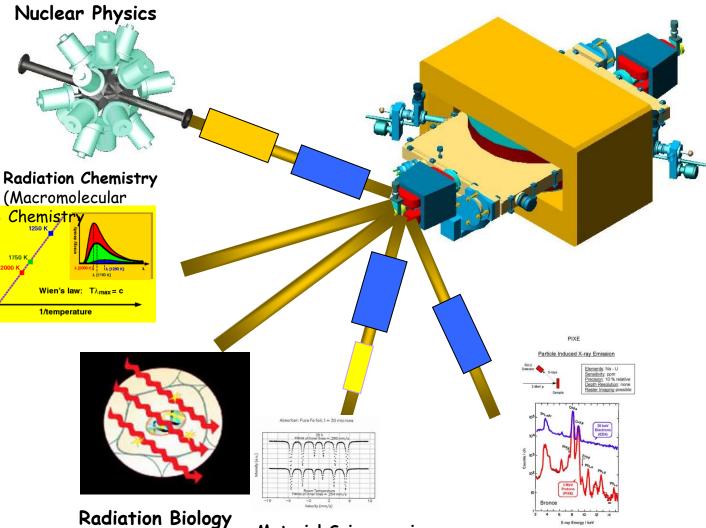


ELECTROMAGNETIC AND PARTICLE RADIATION FOR INVESTIGATING MATTER

(Stress Biology)



....Where the science come out from the depth of gammas....



Material Science using ion beams and radio-isotopes

Trace Element Sciences

Variable Energy Cyclotron Centre (DAE) @ Kolkata



K130 cyclotron at VECC operational since July, 1977

alpha, proton & heavy-ion beams @ 7-10 MeV/nucleon

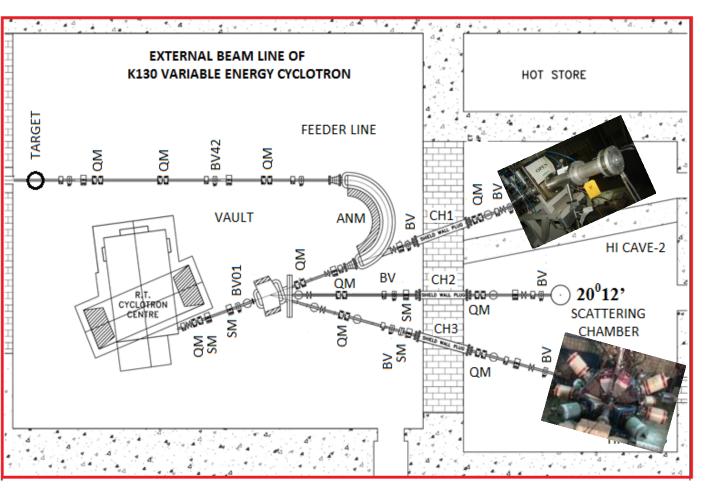
research in nuclear structure and dynamics, material science, radiation chemistry

spreading out, moving ahead



Experimental facilities at K-130 cyclotron

Light



Light-ion beams

Proton : 7 - 20 MeVDeuteron : 15 - 30 MeVAlpha : 28 - 60 MeV

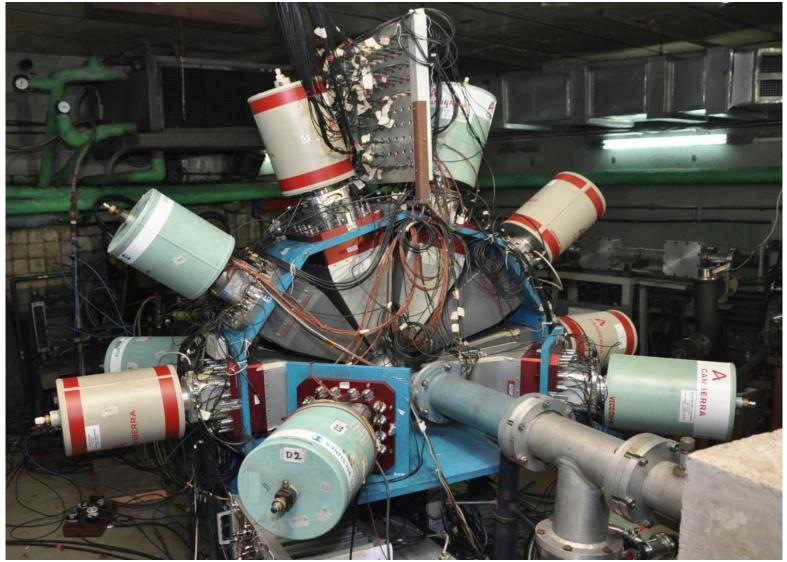
Heavy-ion beams

¹²C, ¹⁶O, ²⁰Ne, ⁴⁰Ar, etc Energy : 8 – 10 MeV/A

Unique in the Country:

The **high-energy alpha** beam The **Higher energy of heavyion** beams Beams of **inert gases**







Avatar of INGA





Available online at www.sciencedirect.com

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

VIER Nuclear Instruments and Methods in Physics Research A 526 (2004) 432–438

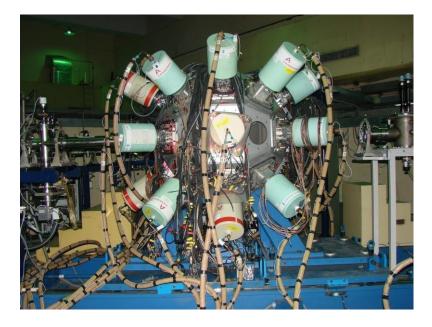
An automatic gain matching method for γ -ray spectra obtained with a multi-detector array

N.S. Pattabiraman, S.N. Chintalapudi, S.S. Ghugre* Inter University Consortium For DAE Facilities, Calcutta Center, Sector III LB-8, Bidhan Nagar, Kolkata 700 098, India

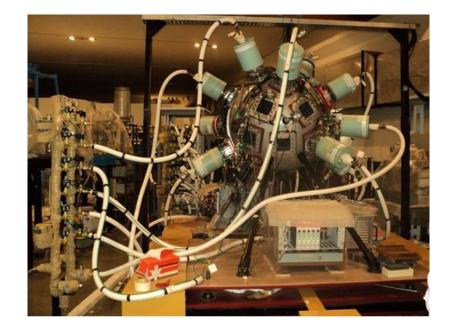




Modern Avatar









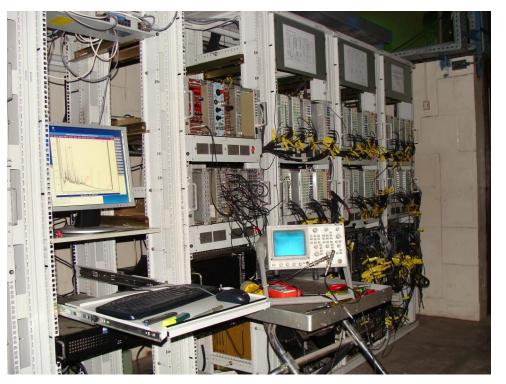
Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

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

A Compton suppressed detector multiplicity trigger based digital DAQ for gamma-ray spectroscopy

S. Das ^a, S. Samanta ^a, R. Banik ^{c,d}, R. Bhattacharjee ^a, K. Basu ^a, R. Raut ^{a,*}, S.S. Ghugre ^a, A.K. Sinha ^b, S. Bhattacharya ^{c,d}, S. Imran ^c, G. Mukherjee ^{c,d}, S. Bhattacharyya ^{c,d}, A. Goswami ^e, R. Palit ^f, H. Tan ^g



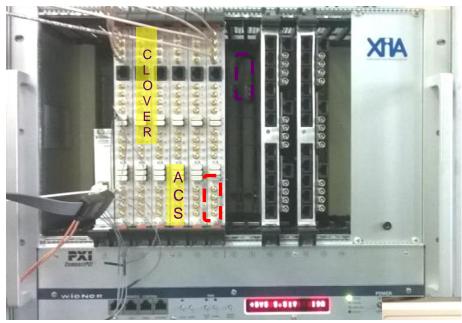
Conventional NIM Electronics @ IUAC Indigenous development both at the NIM & CAMAC level.

Digital DAQ of UGC-DAE CSR, KC

DSP based DAQ based on <u>recursive</u> <u>algorithms</u>, following the pioneering work by Knoll and co-workers :

compact, fast, efficient, improved throughput

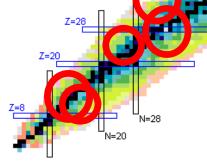
Lustrous



Physics with INGA @VECC Campaign









N=82

publications; theses; conf. presentations

N=126

N, number of neutrons

Digital DAQ of UGC-DAE CSR, Kolkata Centre

Pixie-16 (XIA LLC) modules with 12-bit 250 MHz ADC for digitization

16-channels to support 3 Compton suppressed Clover detectors. (Clovers: channels#0-11 & ACS:channels#12-14)

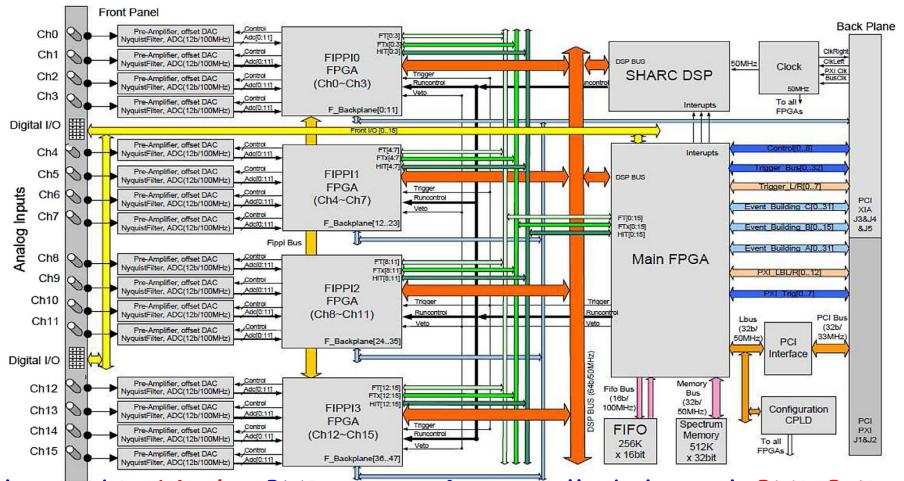
Firmware conceptualized by UGC-DAE CSR, Kolkata Centre & Implemented by XIA LLC (Dr. H. Tan et al.)

Successfully porting the knowledge of pulse processing in the analog domain to the digital real estate !!!

Compton suppressed Multiplicity based trigger

Discerningly triggerless !

PIXIE-16 Architecture

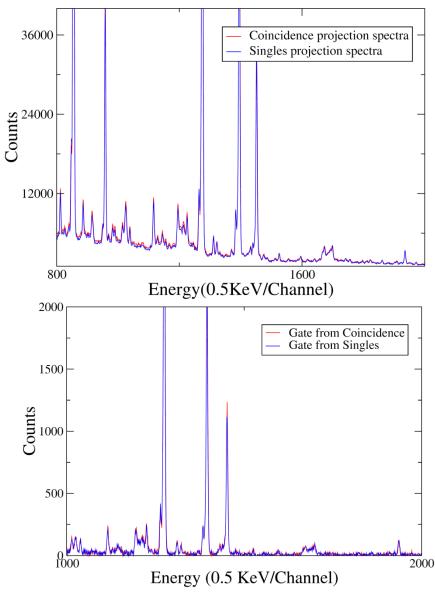


housed in 14-slot PXI crates & controlled through PXI-PCI controller bridged to the host computer through fiber optic cable

http://www.xia.com

Discerningly Triggerless !

Triggerless: Running the system in (Compton suppressed) singles mode. (Who needs those Compton events, anyway?) Surprise: γ - γ coincidence rate preserved. (The merit of graduating to a digital dag with Compton suppression enabled) Proof: Near identical matrix projection & gated spectra generated from coincidence and singles data.

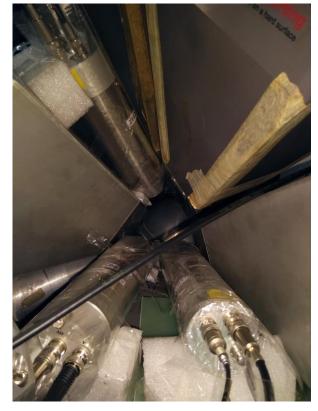


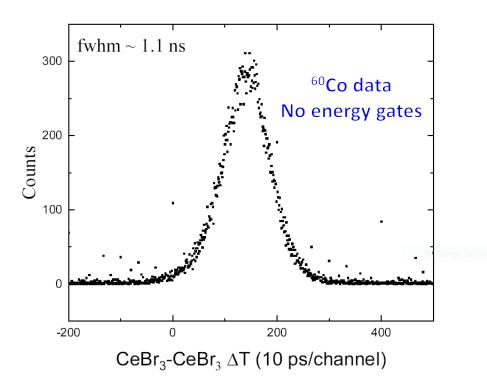
Impossible in the analog domain......

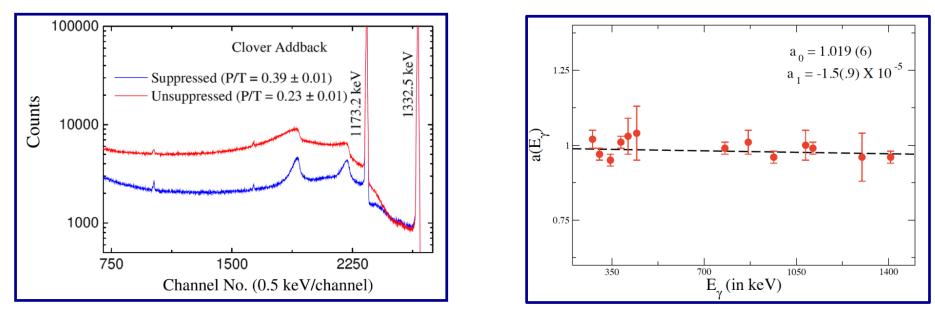
Provision for ancillary detectors ! Evolving Physics Objectives: Incorporation of ancillary detectors.

The ancillary detectors with varying trigger logic

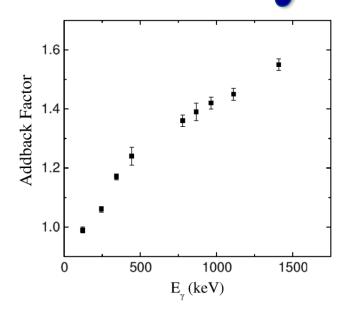
Fresh from the oven : with 250 MHz digitization

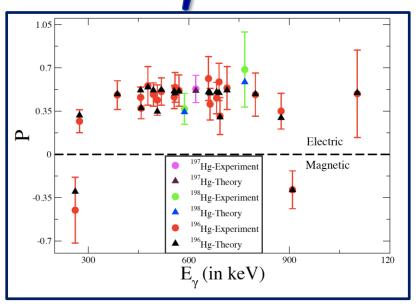












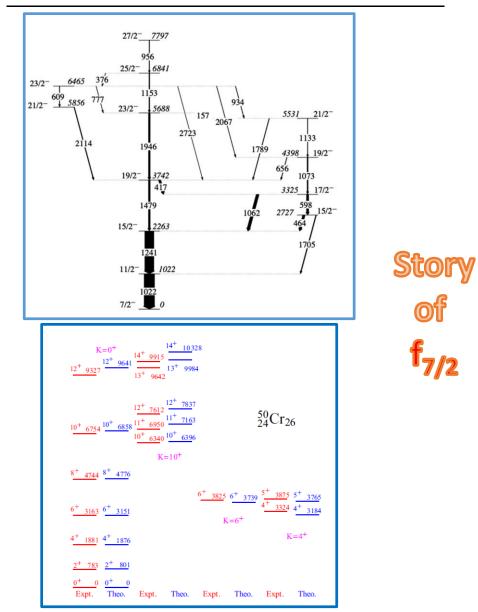
IUCPIX for data analysis of data from INGA@VECC

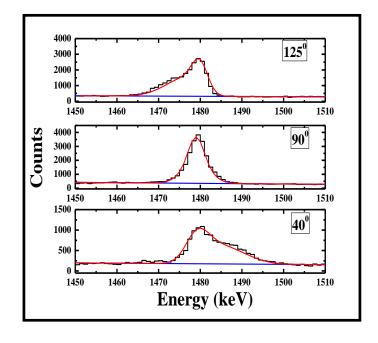
IUCPIX is the software package developed by the Nuclear Physics Group at the Kolkata Centre for processing the data acquired with the digital DAQ system of the Centre. It has several component codes for data simplification, time sequencing and data reduction.

- 1. Matrix of increased dimensions (resolution): 8192×8192
- 2. Prompt-delayed γ - γ matrix: isomer identification
- 3. LEPS gated γ - γ matrix: clean channel

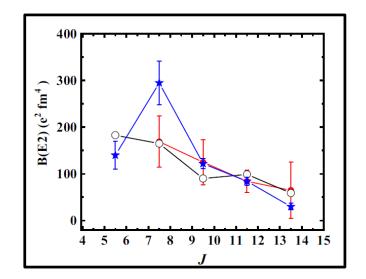


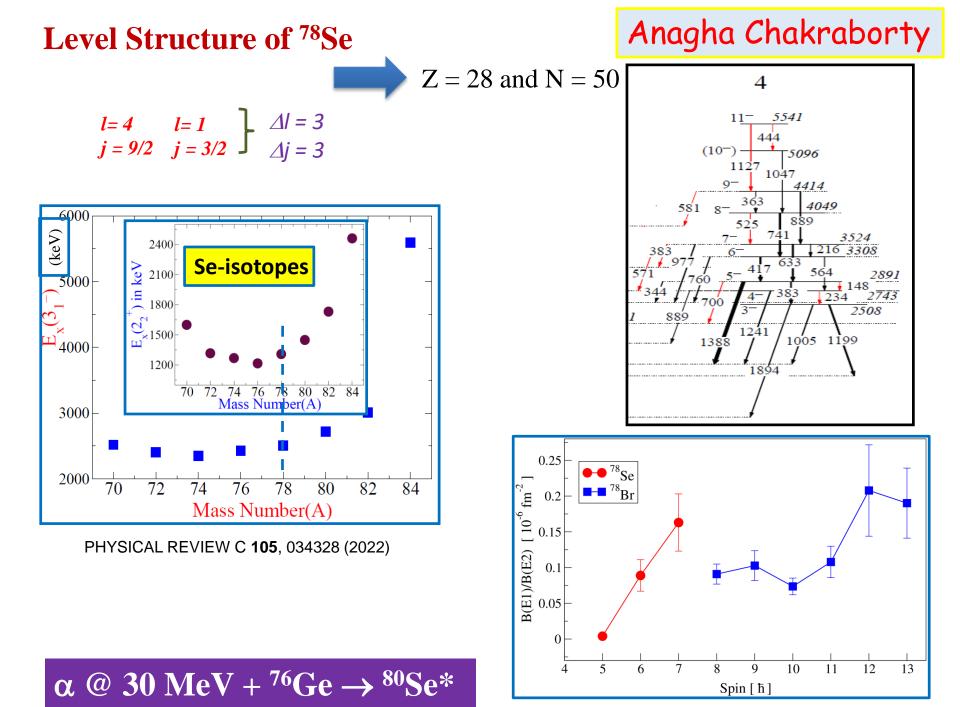
PHYSICAL REVIEW C 105, 044304 (2022)

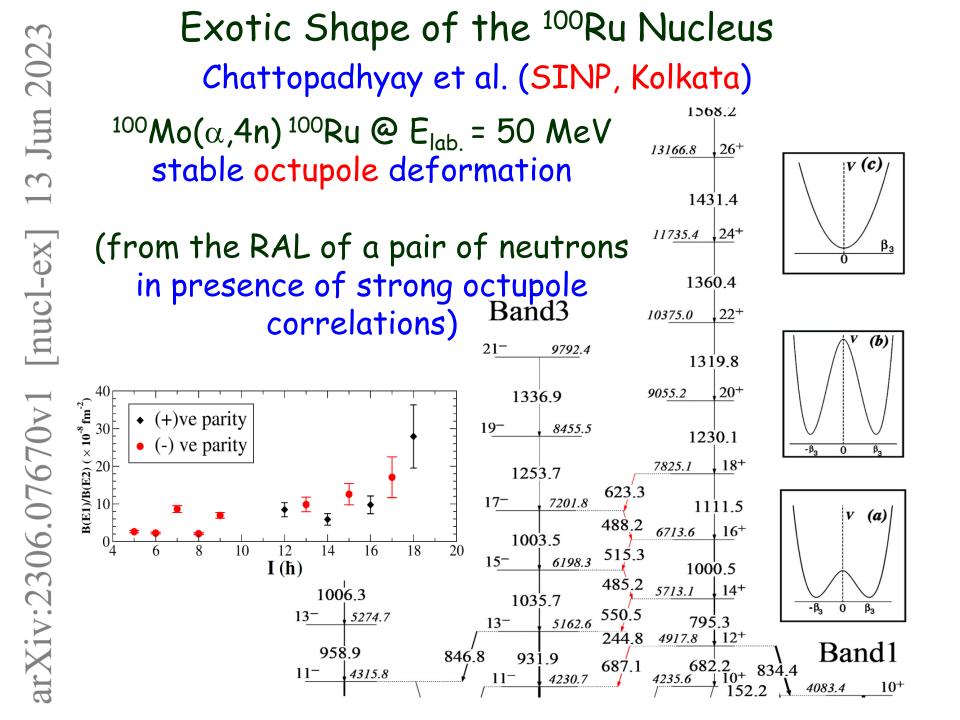




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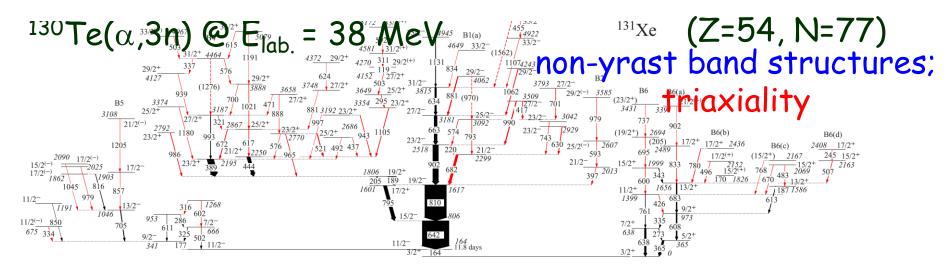






Deformation & Collectivity in the Z~50 Nuclei Bhattacharyya et al. (VECC, Kolkata)

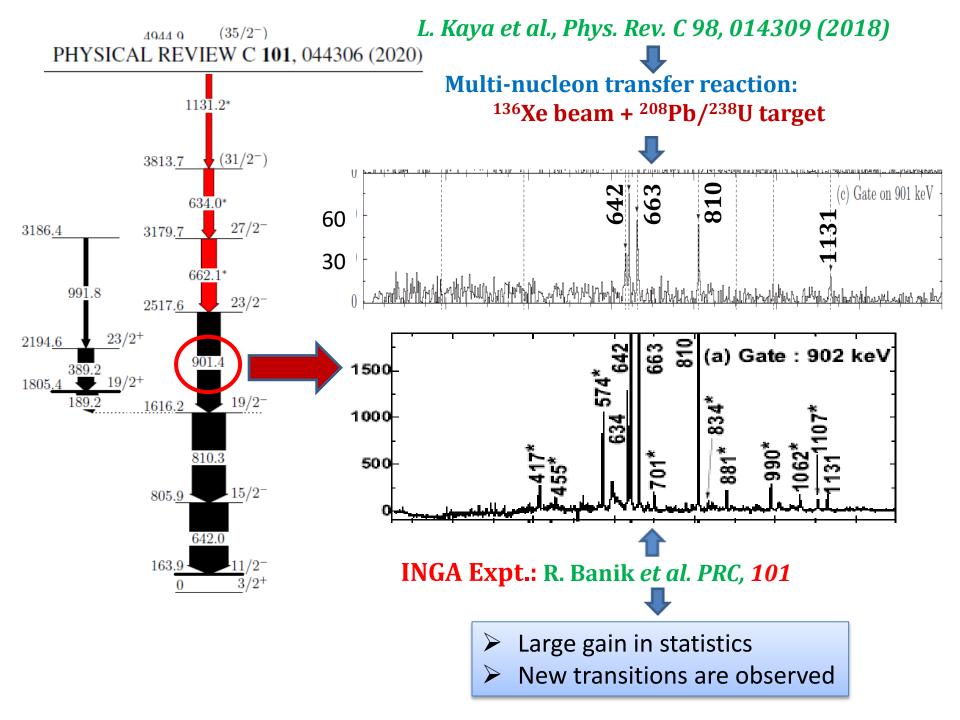
PHYSICAL REVIEW C 101, 044306 (2020)



PHYSICAL REVIEW C 101, 014322 (2020)

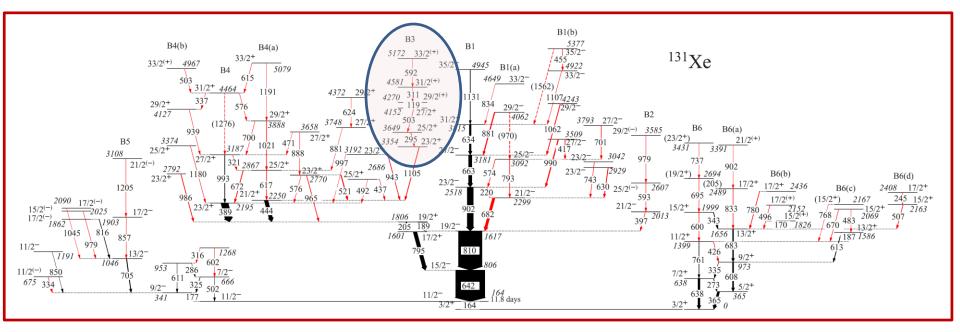
Observation of signature partner bands in ¹¹⁷Sb additional work (using test setup for INGA) (Z=51, N=66)

along with single particle excitations in the low energy regime



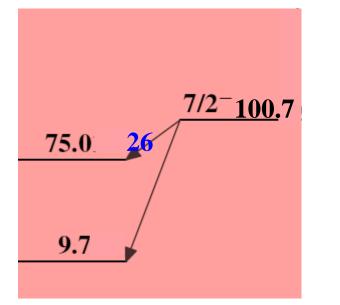
PHYSICAL REVIEW C 101, 044306 (2020)

Sarmistha Bhattacharyya

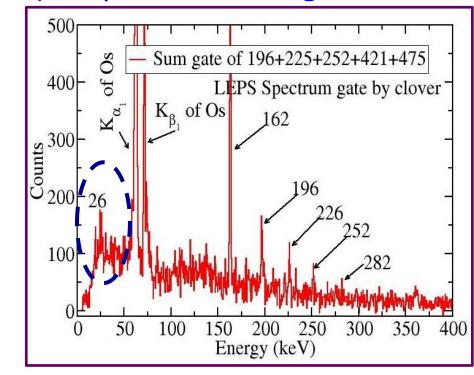


Observation of 72 new transitions !! Structural evolution from gamma soft to triaxial Effect of N=110 Deformed Shell Gap on Nuclear Shape : Story of ¹⁸⁷Os ¹⁸⁴W(α ,3n)¹⁸⁷Os @ E_{α} = 36 MeV

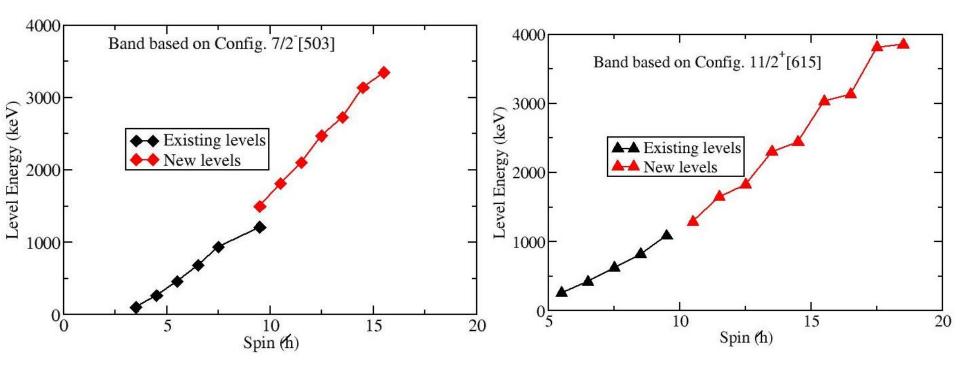
Os positioned between prolate deformed rare earths & spherical Pb nuclei. Odd-A Os isotopes exhibit rotational bands based on different multi-quasiparticle configurations.



H. Sodan et al., Nucl. Phys. A237 (1975) 333



- More than 90 new transitions are placed in the level scheme.
- Bands based on $\nu h_{9/2}$ and $\nu i_{13/2}$ have been extended beyond first particle alignment.
- These two bands are built on high Ω orbital but show energy staggering at higher angular momentum \rightarrow Triaxiality ?
- Gamma bands with 1-phonon and 2-phonon excitations have been identified for the first time in this nucleus.



Twin Bands (Pseudo – Nilsson doublet)

3000

2500

2000

1500

1000

500

evel Energy (keV)

20

Pseudo spin symmetry between two rotational bands arises when the configurations differs by

 $\Delta\Omega$ =1; $\Delta\Lambda$ =2

3000

2500

2000

1500

1000

500

Level Energy (keV)

Band based on Config. 1/2 [510]

5

Can be explained by considering Pseudo Nilsson quantum no.: N'=N -1, Λ '= Λ -1, Ω '= Ω

 Expt. Observation: Nearly degenerate bands with different configurations (as above)

The known twin Nilsson doublet bands in ¹⁸⁷Os are extended to $27/2^{-1}$ state. Pseudo spin symmetry seems to breakdown at higher spins \rightarrow Change in structure

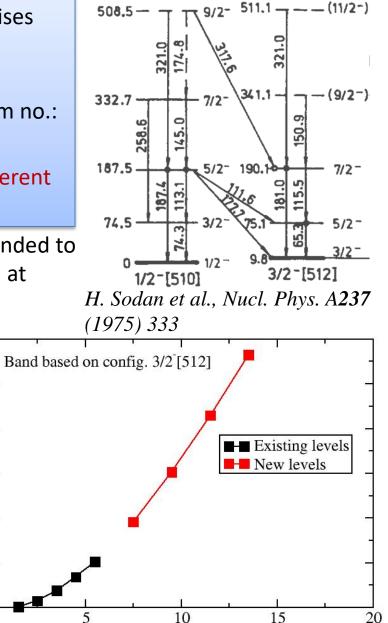
• Existing levels

15

10

Spin (h)

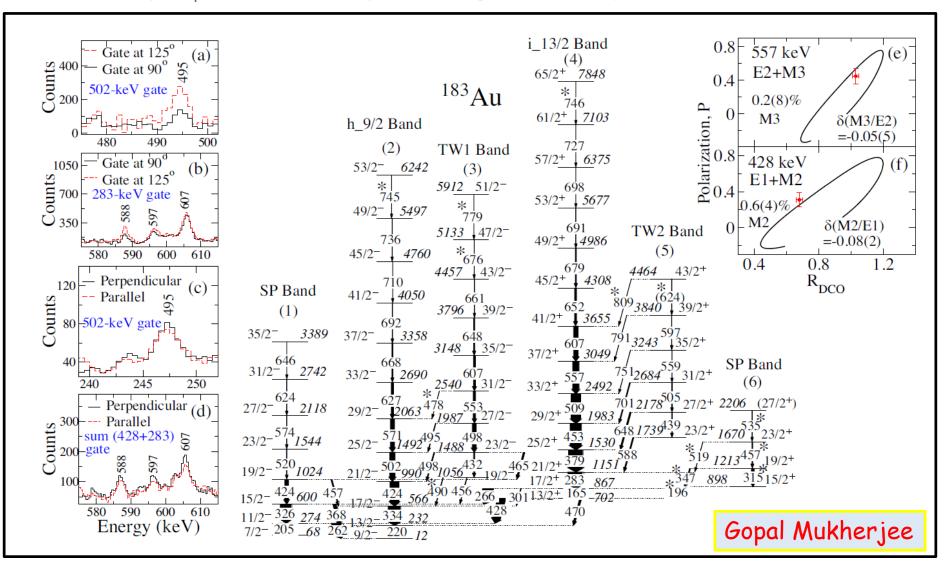
New levels



Spin (h)

First Observation of Multiple Transverse Wobbling Bands of Different Kinds in ¹⁸³Au

S. Nandi[©],^{1,2} G. Mukherjee[©],^{1,2,†} Q. B. Chen[©],³ S. Frauendorf[©],⁴ R. Banik[©],^{1,2,‡} Soumik Bhattacharya,^{1,2} Shabir Dar[©],^{1,2} S. Bhattacharya,^{1,2} C. Bhattacharya,^{1,2} S. Chatterjee,⁵ S. Das,⁵ S. Samanta,⁵ R. Raut,⁵ S. S. Ghugre,⁵ S. Rajbanshi,⁶ Sajad Ali,⁷ H. Pai[©],⁸ Md. A. Asgar,⁹ S. Das Gupta,¹⁰ P. Chowdhury,¹¹ and A. Goswami^{8,*}





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Physics Letters B

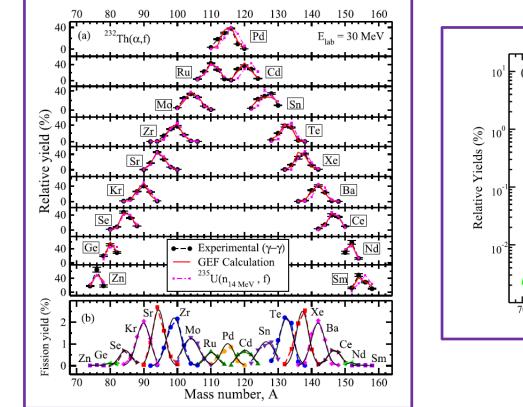


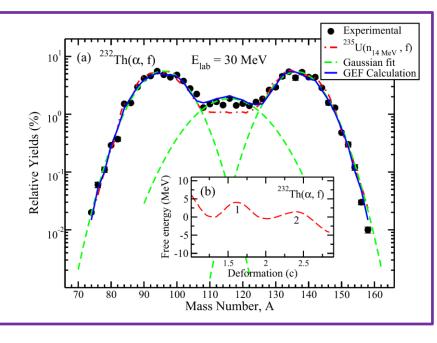
www.elsevier.com/locate/physletb

Evidence for competing bi-faceted compound nucleus fission modes in 232 Th(α ,f) reaction



Aniruddha Dey ^{a,b}, D.C. Biswas ^{a,c}, A. Chakraborty ^{b,*}, S. Mukhopadhyay ^a, A.K. Mondal ^{b,1}, K. Mandal ^{b,2}, B. Mukherjee ^b, R. Chakrabarti ^d, B.N. Joshi ^a, L.A. Kinage ^a, S. Chatterjee ^e, S. Samanta ^e, S. Das ^e, Soumik Bhattacharya ^{c,f}, R. Banik ^g, S. Nandi ^{c,f}, Shabir Dar ^{c,f}, R. Raut ^e, G. Mukherjee ^{c,f}, S. Bhattacharyya ^{c,f}, S.S. Ghugre ^e, A. Goswami ^{h,3}





Physics Letters B 825 (2022) 136848

The 1 TB (!) Experiment with Digital INGA @ VECC quest for tetrahedral symmetry, T. Bhattacharjee et al.

PHYSICAL REVIEW C 97, 021302(R) (2018)

Rapid Communications

Spectroscopic criteria for identification of nuclear tetrahedral and octahedral symmetries: Illustration on a rare earth nucleus

J. Dudek,^{1,2} D. Curien,¹ I. Dedes,² K. Mazurek,³ S. Tagami,⁴ Y. R. Shimizu,⁴ and T. Bhattacharjee⁵

search in ¹⁵²Sm experimental signature: E3 transitions (from TD -> GSB)

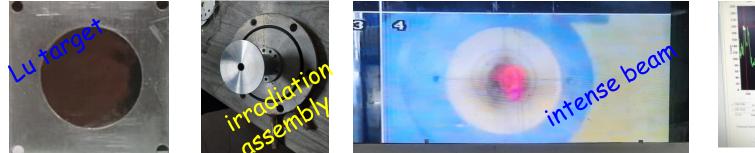
E3 transitions expected to appear predominantly in singles with no coincident gamma

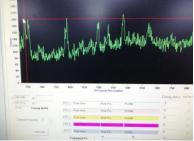
gamma-gamma trigger would exclude them from acquisition entire data acquired in SINGLES mode (setup of 12 CS HPGe clovers)

DATA VOLUME ~ 1 TB (did the DAQ perform as per expectations!!!!!!) Experiment using Digital INGA @ VECC [Probing Ground State Spin-Parity of ¹⁷⁸Ta (SSSIHL)] $^{175}Lu(\alpha,n) @ E_{lab.} \sim 21 \text{ MeV}$ (minimum α -beam energy at VECC $\sim 28 \text{ MeV}$ use of Al degraders....)

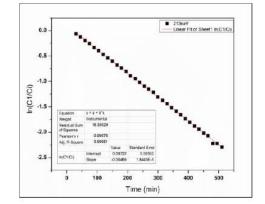
un-optimized optics of degraded beam in channel # 3...low statistics of production

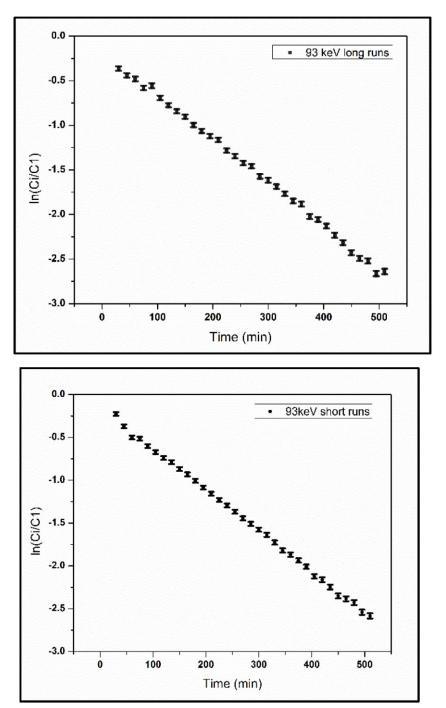
migration to channel #1 (current ~ 500 nA) for irradiation

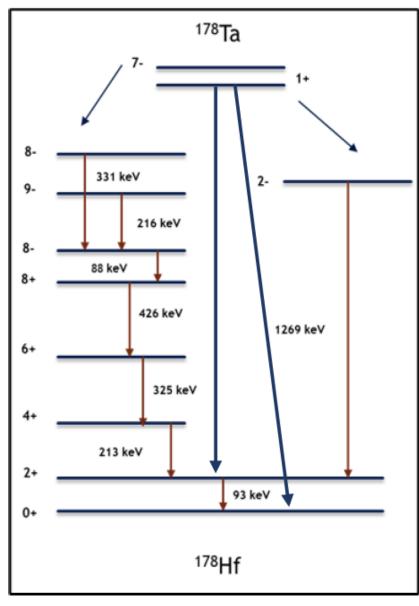




decay of 1⁺ ($t_{1/2} \sim 9.3 \text{ minutes}$) and 7⁻ ($t_{1/2} \sim 2.4 \text{ hrs.}$) tracked (code for time slicing the data developed)

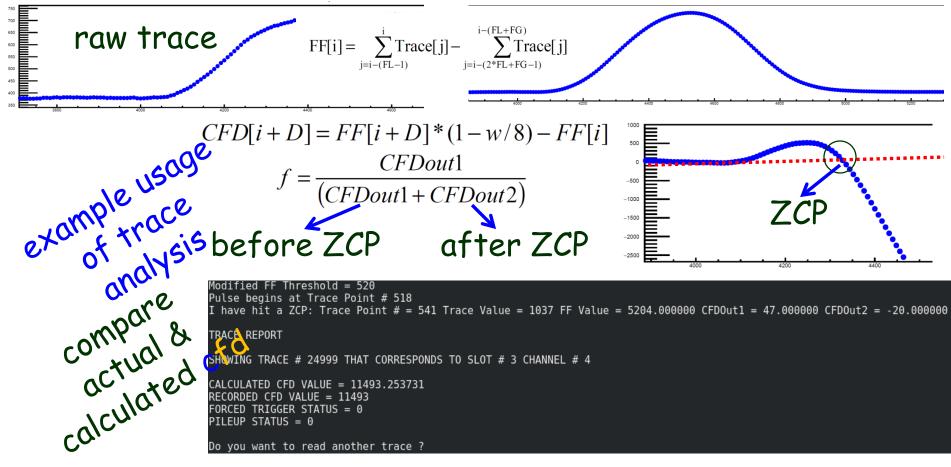






Extended Use of the Digital DAQ trace acquisition & analysis

merit of digital DAQ: acquisition of trace for detector pulse understanding/optimization of pulse processing algorithms



ROOT based code developed by NP Group @ UGC-DAE CSR, KC

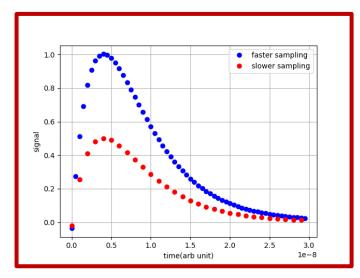


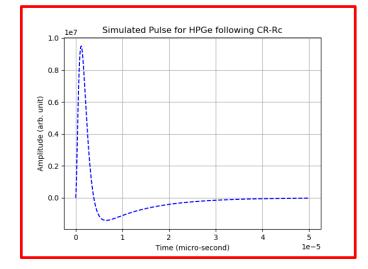
Looking ahead to a DIGITAL INGA campaign with heavy-ions (²⁰Ne, ¹⁶O.....) at VECC





Learning To Be Discrete !!!!!





Codes developed in Python

