Accelerator-based nuclear physics research at IUAC

Subir Nath

Nuclear Physics Group
Inter-University Accelerator Centre
New Delhi 110067, India

Plan of the talk

- About IUAC
- Accelerators at IUAC
- Nuclear physics facilities
- A few selected results
- Collaborative works

Major particle accelerator laboratories in India

IUAC, New Delhi

https://www.mapsofindia.com/states/

VECC, Kolkata

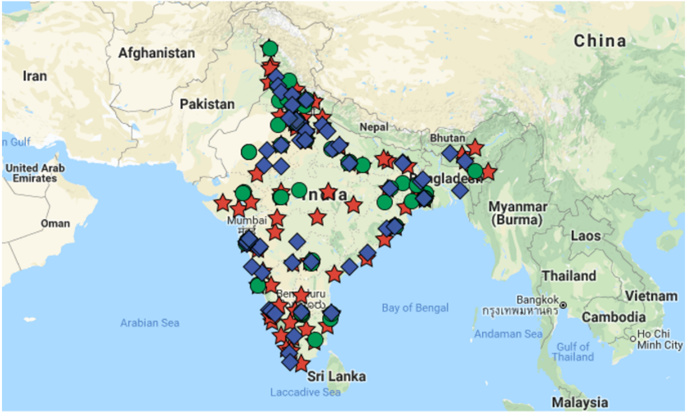
BARC / TIFR, Mumbai

IUAC: The first inter-university centre

- Established by the UGC in October, 1984
- Earlier known as the **Nuclear Science Centre** (NSC)
- Became a national user facility on July 8, 1991
- Primary **mandate** is to cater to the Indian universities

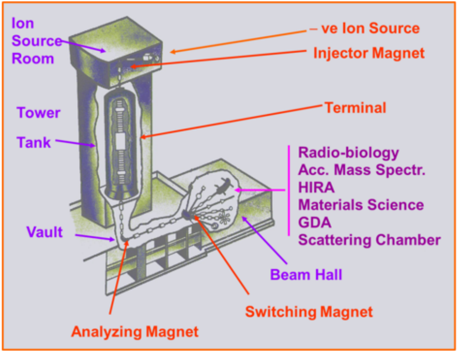
User footprints

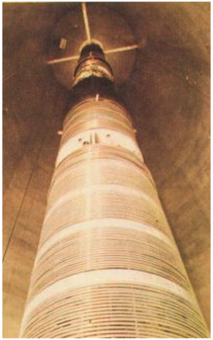
- Provide front-ranking **accelerator-based** research facilities within the university system



http://www.iuac.res.in/dash/

Accelerator: 15UD Pelletron

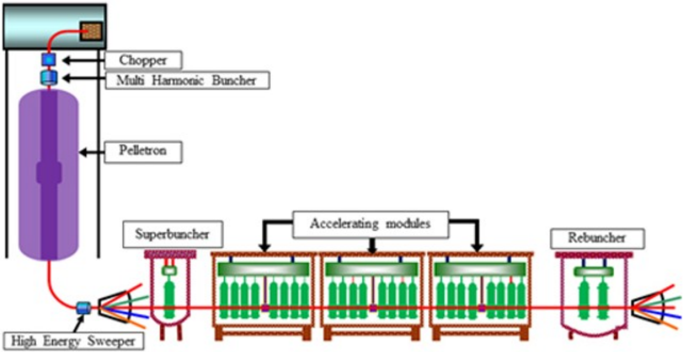




- All ion species (except inert elements)
- DC or pulsed (with TWD) operation
- Excellent terminal stability, $\Delta E \simeq 200$ keV

Nucl. Instrum. Methods A 268, 334 (1988)

Accelerator: Superconducting linac



- Consists of niobium quarter wave resonators
- Operating frequency 97 MHz
- Operating accelerating field 4 MV/m

Phys. Rev. ST Accel. Beams 12, 040101 (2009)

Small accelerators

1.7 MV RBS facility

500 kV XCAMS facility

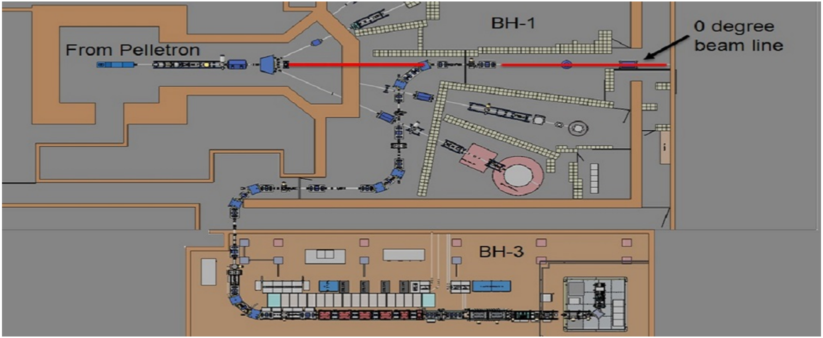
ECR-based positive ion facility

MC-SNICS-based negative ion facility

Table-top accelerator

http://www.iuac.res.in/en/accelerators

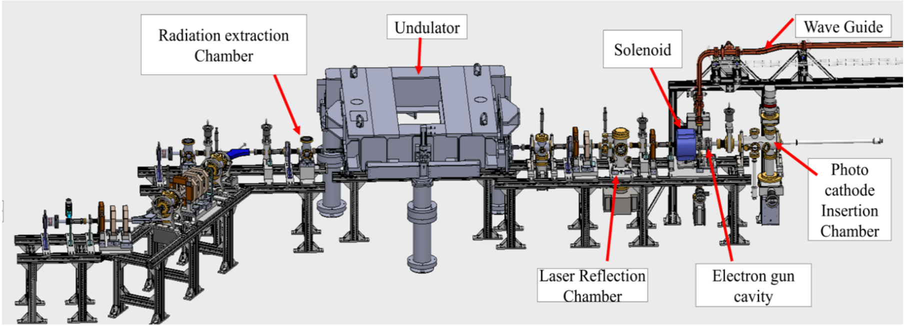
High current injector



- Substantial increase in beam current due to higher charge states
- Many new beam species to boost nuclear physics research

http://www.iuac.res.in/en/accelerators

Delhi Light Source



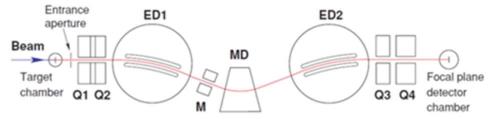
- A compact accelerator-based light source to produce THz radiation based on the principle of Free Electron Laser is currently being commissioned.

Nucl. Instrum. Methods B 402, 358 (2017)
Proc. IPAC'21 (Campinas, Brazil, 24–28 May 2021) 1633 (2021)

Research programmes at IUAC

- **Nuclear physics**
- Materials science
- Atomic and molecular physics
- Accelerator mass spectrometry and geochronology
- Radiation biology
- Nuclear instrumentation
- Computational physics
- . . .

Heavy Ion Reaction Analyzer (HIRA)



Heavy Ion Reaction Analyzer (HIRA)

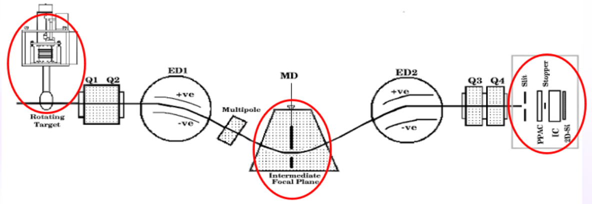
- A combination of EDs and MD allows energy/velocity dispersion matching
- m/q dispersion at the focal plane
- Triple focus at the focal plane

$$(x,\theta) = (y,\phi) = (x,\delta_E) = 0$$

- Suitable for complete fusion measurements
- Capable of QEL (transfer) measurements
- Had been used for secondary beam (^{7}Be) production

A. K. Sinha *et al.*, Nucl. Instrum. Methods A **339**, 543 (1994)
J. J. Das it et al., Nucl. Instrum. Methods B **241**, 953 (2005)
S. Nath, Nucl. Instrum. Methods A **576**, 403 (2007)

Radioactive ion beam facility



- Production reaction: p(^{7}Li, ^{7}Be)n
- In-flight separation of ^{7}Be by HIRA (with new optics and add-ons)
- Primary beam from 15UD Pelletron of IUAC
- Energy of ^{7}Be: 15-22 MeV (limited by HIRA deflectors)
- Intensity $\sim 10^4$ pps; purity $> 99\%$; Beam spot ~ 4 mm diameter
- Angular divergence: ± 30 mrad
- Energy spread: ± 500 keV

Nucl. Instrum. Methods B 241, 953 (2005)

RIB: Recent optimization for lower energies

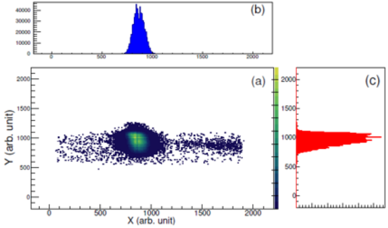
Optimization of low-energy ^{7}Be beam production in inverse kinematics using a recoil mass spectrometer

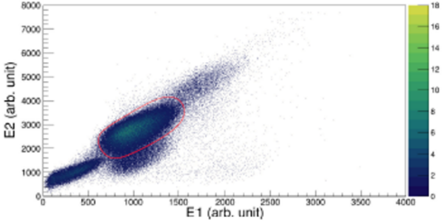
S. Nath[1],* J. Gehlot[1], Rishabh Kumar[1], Gonika[1], Chandra Kumar[1], Alankar Singh[1], Phurba Sherpa[2], N. Saneesh[1], T. Varughese[1], V. V. V. Satyanarayana[1], Rasna Baruah[3], Bhargab Boruah[3], Monuj Gogoi[3], Amritpal Singh[4], Ritankar Mitra[5], Niloy Ghosh[5], and S. Verma[2]
[1]*Nuclear Physics Group, Inter-University Accelerator Centre, New Delhi 110067, India*
[2]*Dept. of Physics & Astrophysics, University of Delhi, Delhi 110006, India*
[3]*Department of Physics, Cotton University, Panbazar, Guwahati 781001, India*
[4]*Dept. of Physical Sciences, I. K. Gujral Punjab Technical University, Kapurthala 144603, India and*
[5]*Department of Physical Sciences, Bose Institute, Bidhannagar, Kolkata 700091, India*

- Principal branch: $E_{\text{lab}} = 15$, 19 and 23 MeV
- Principal branch: Intensities in the range of 3 - 6 kHz
- Satellite branch: $E_{\text{lab}} = 5$, 10 and 15.5 MeV
- Satellite branch: Intensities in the range of 1 - 3 kHz

DAE Symp. 2025 (accepted for oral presentation)

RIB: Beam spot size and purity

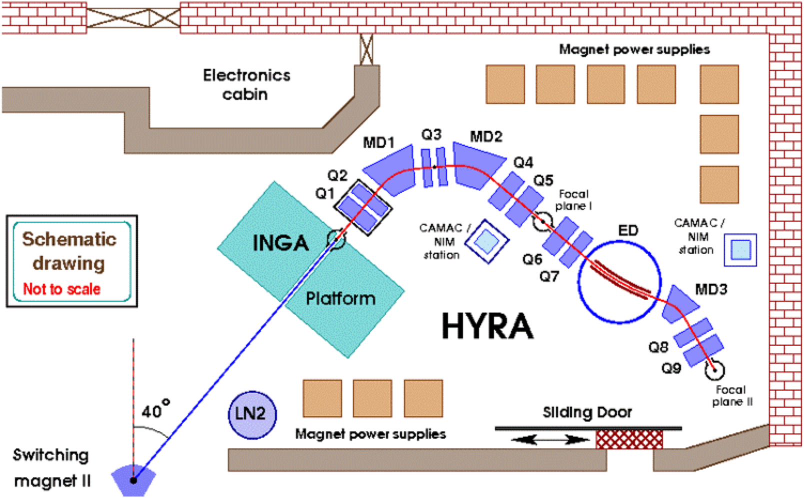




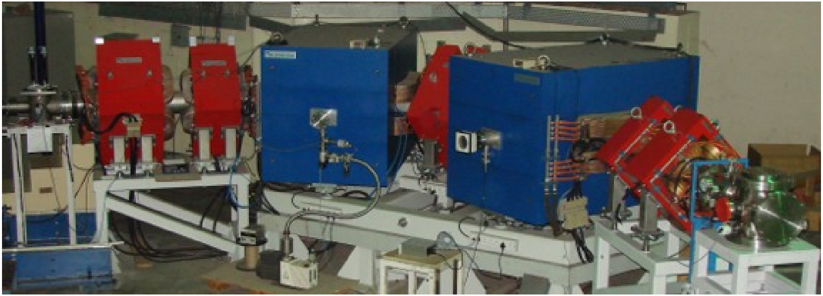
- DC beam of ^{7}Li (3 - 8 pnA) from the 15UD Pelletron
- E_{lab} (^{7}Li) range of 14 - 28 MeV
- 20 μm thick polypropylene foil (as the proton target)
- Size $\simeq$ 4 mm (FWHM) in x, $\simeq$ 6 mm (FWHM) in y
- Purity between 96 - 99%

DAE Symp. 2025 (accepted for oral presentation)

HYbrid Recoil mass Analyzer (HYRA)



HYRA: Gas-filled mode



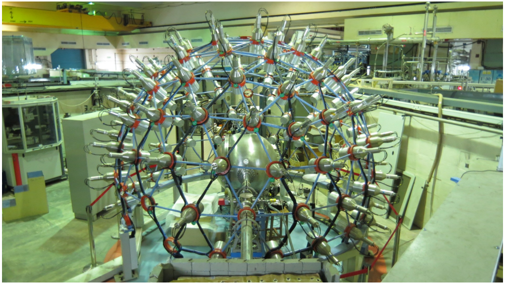
- Magnetic field region filled with dilute helium
- Excellent beam rejection
- Higher efficiency due to charge state and velocity focusing
- Fusion dynamics studies in $A > 200$ nuclei

Pramana – J. Phys. 75, 317 (2010)

General purpose scattering chamber

- Installed at the 45^o beam line in Beam Hall I
- Rotating arms for mounting detectors
- Equipped with a pair of multi-wire proportional counters
- In-vacuum target transfer system

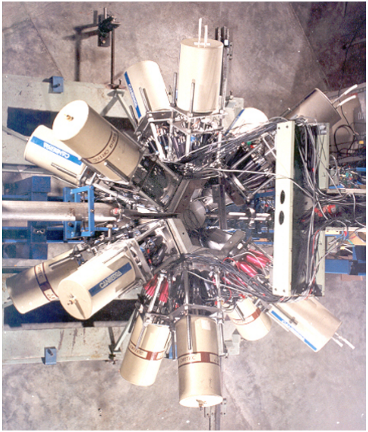
National Array of Neutron Detectors (NAND)



- Started as a national collaboration between institutes and universities
- Array of 100 liquid scintillators of 5" $\times$ 5", commissioned in 2016
- Flight path of 1.75 m for TOF set up; thin-walled spherical chamber
- Provision to use light charged particle and fission detectors

Talk by **N. Saneesh**

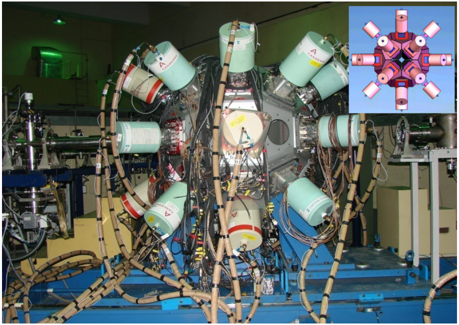
Gamma Detector Array (GDA)



- A modest array of 12 Compton-suppressed HPGe detectors
- Precursor to the Indian National Gamma Array (INGA)

Indian J. Pure Appl. Phys. 27, 660 (1989)

Indian National Gamma Array (INGA)

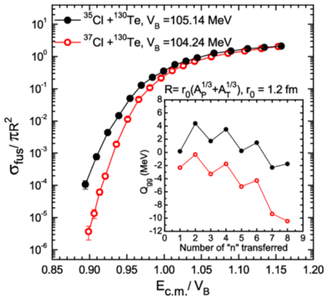


- An array of Compton-supressed Clover detectors
- Maximum 24 Clovers can be accommodated in the array
- Total photopeak efficiency of INGA $\sim 5\%$
- Optimized for γ-γ-γ and higher fold data
- Can be coupled with auxiliary detectors and add-ons

Nucl. Instrum. Methods A 622, 281 (2010)

A few selected results

Role of PQNT channels in fusion: Open questions



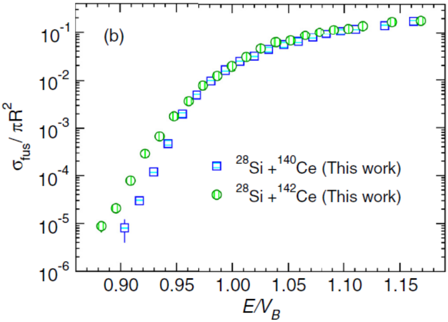
Phys. Rev. C 102, 024615 (2020)

- Do PQNT channels always lead to fusion enhancement?
- Does enhancement depend on magnitude of transfer Q-values?
- Do PQNT channels beyond 4n transfer play a role?
- What is the role of deformation in intermediate partition?
- What is the relative importance of deformation and PQNT?
- How does PQNT effect play out in presence of shell closure?

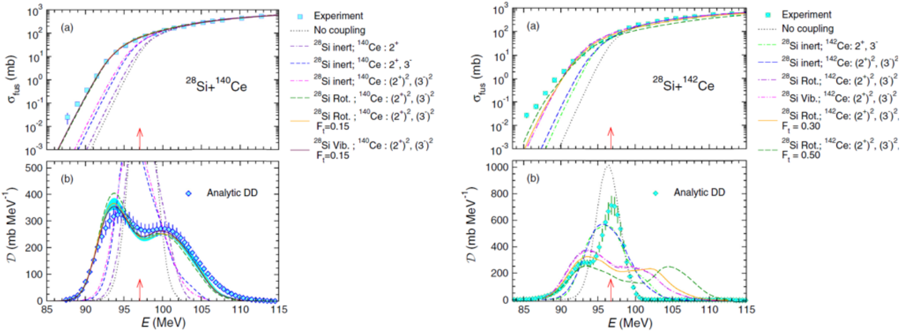
Role of PQNT channels in Si+Ce systems

TABLE I. The ground-state (g.s.) to g.s. Q-values for neutron pickup channels for ^{28}Si + ^{140,142}Ce.

Systems	Q value (MeV)					
	$+1n$	$+2n$	$+3n$	$+4n$	$+5n$	$+6n$
^{28}Si + ^{140}Ce	−0.72	+2.43	−0.70	+1.01	−4.43	−4.78
^{28}Si + ^{142}Ce	+1.30	+6.483	+3.871	+5.623	+0.40	+0.439

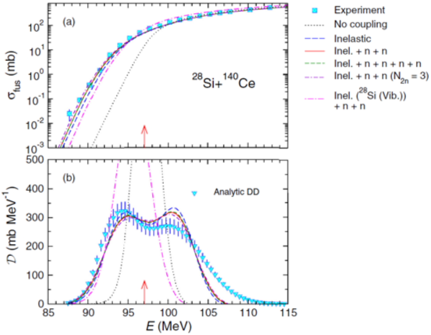


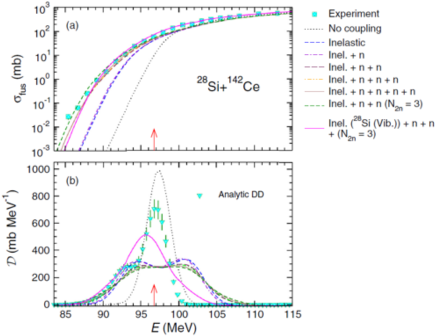
Role of PQNT channels in Si+Ce systems



- Comparison of data with microscopic coupled-channels calculations.

Role of PQNT channels in Si+Ce systems





- Comparison of data with empirical coupled-channels calculations.

Role of PQNT channels in Si+Ce systems

PHYSICAL REVIEW C **111**, 034621 (2025)

Probing the influence of weak channels on fusion dynamics in ^{28}Si + ^{140,142}Ce

Chandra Kumar,[1] Gonika,[1] J. Gehlot,[1] Phurba Sherpa,[2] A. Parihari,[3] K. Kundalia,[4] Ashna B.,[5] Amar Das,[6] Rajesh K. Sahoo,[7] Rayees Ahmad Yatoo,[8] Md. Moin Shaikh,[9] Sunil Kalkal,[8] N. Madhavan,[1] and S. Nath[1,*]
[1]*Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India*
[2]*Department of Physics & Astrophysics, University of Delhi, Delhi 110007, India*
[3]*Department of Physics, Rajdhani College, University of Delhi, Delhi 110015, India*
[4]*Department of Physical Sciences, Bose Institute, Bidhannagar, Kolkata 700091, India*
[5]*Department of Physics, Central University of Kerala, Kasargod 671320, India*
[6]*Department of Physics, Suren Das College, Hajo 781102, Assam, India*
[7]*Department of Physics, Central University of Jharkhand, Ranchi 835222, Jharkhand, India*
[8]*Department of Physics & Material Science, Thapar Institute of Engineering & Technology, Patiala 147004, India*
[9]*Department of Physics, Chanchal College, Malda 732123, West Bengal, India*

- A much stronger influence of neutron transfer channels is inferred in ^{28}Si+^{142}Ce compared to ^{28}Si+^{140}Ce.
- Mismatch between experimental results and theoretical predictions in case of ^{28}Si+^{142}Ce points to the limitations of existing coupled-channels approaches to interpret the influence of neutron transfer channels on fusion dynamics comprehensively.

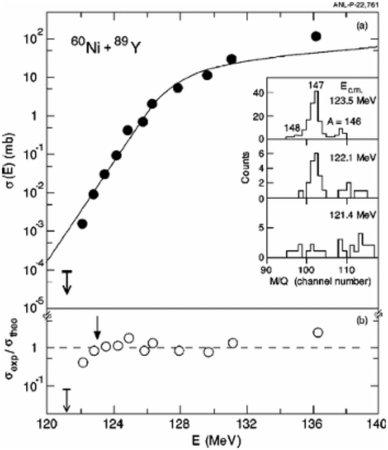
Deep sub-barrier fusion hindrance

Deep Sub-barrier
Fusion hindrance

Theoretical approaches:

- Sudden model
- Adiabatic model
- Quantum decoherence
- Pauli principle
- ...

The debate continues.



C. L. Jiang et al., Eur. Phys. J. A **57**, 235 (2021)
B. B. Back et al., Rev. Mod. Phys. **86**, 317 (2014)

C. L. Jiang et al.,
Phys. Rev. Lett. **89**, 052701 (2002)

Online

Direct detection of ERs by recoil separators
Direct and elegant method
Focal plane detector at background-free region
Demands higher recoil energies for efficient detection

Offline

Off-beam characteristic γ-ray counting

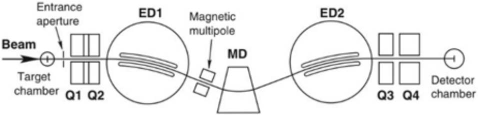
A. Shrivastava *et al.*, Phys. Lett. B **755**, 332 (2016).

IOP Publishing — Journal of Physics G: Nuclear and Particle Physics
J. Phys. G: Nucl. Part. Phys. **45** (2018) 095103 (11pp) https://doi.org/10.1088/1361-6471/aad5c7

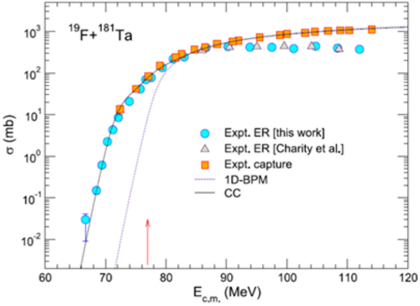
Investigation of fusion hindrance in a soft asymmetric system deep below the barrier

Md Moin Shaikh[1,8], S Nath[1], J Gehlot[1], Tathagata Banerjee[1,9], Ish Mukul[1,10], R Dubey[1,11], A Shamlath[2], P V Laveen[2], M Shareef[2], A Jhingan[1], N Madhavan[1], Tapan Rajbongshi[3,12], P Jisha[4], G Naga Jyothi[5], A Tejaswi[5], Rudra N Sahoo[6] and Anjali Rani[7]

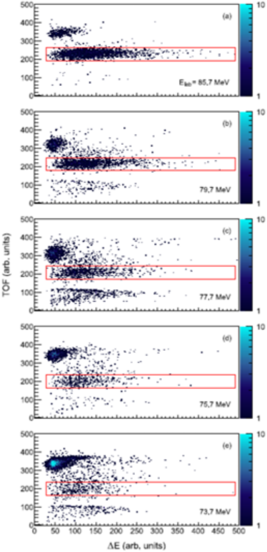
Fusion measurement in F+Ta system



A. K. Sinha *et al.*, Nucl. Instrum. Methods A **339**, 543 (1994)



Md. Moin Shaikh *et al.*, J. Phys. G: Nucl. Part. Phys. **45**, 095103 (2018)



Fusion measurement in F+Ta system

Systematics for asymmetric systems

System	$Z_p Z_t$	ζ	V_B (MeV)	E_s (MeV)	E_{min} (MeV)	Q_{CN} (MeV)	Q_n (MeV)	Q_{2n} (MeV)	Q_p (MeV)	Q_{2p} (MeV)	$Q_{^2H}$ (MeV)	$Q_{^3H}$ (MeV)	$Q_{^3He}$ (MeV)	$Q_{^4He}$ (MeV)
$^{19}F+^{181}Ta$	657	2724	77.9	69.4	66.7	−23.67	−0.98	0.48	6.90	1.32	6.27	10.53	5.59	11.99
$^{16}O+^{208}Pb$	656	2529	77.0	66.1	68.7	−46.48	−3.22	−1.92	−7.40	−10.86	−5.11	−1.18	−5.95	5.25
$^{16}O+^{204}Pb$	656	2527	77.3	66.0	68.7	−44.52	−4.25	−3.12	−6.04	−7.82	−4.74	−1.18	−3.94	6.70
$^{12}C+^{198}Pt$	468	1574	56.0	48.2	47.0	−13.95	−2.61	−0.28	−6.99	−9.63	−3.33	1.69	−3.25	7.27
$^{11}B+^{197}Au$	395	1275	47.4	41.9	37.9	5.00	−4.70	−6.47	10.17	3.87	7.20	9.27	7.20	11.96
$^{7}Li+^{198}Pt$	234	608	28.5	25.6	19.3	8.82	−5.52	−7.31	8.33	0.86	3.09	4.09	2.46	8.77
$^{6}Li+^{198}Pt$	234	565	28.9	24.3	19.6	8.53	−0.30	−4.12	−3.32	−10.46	8.68	4.53	1.28	4.57

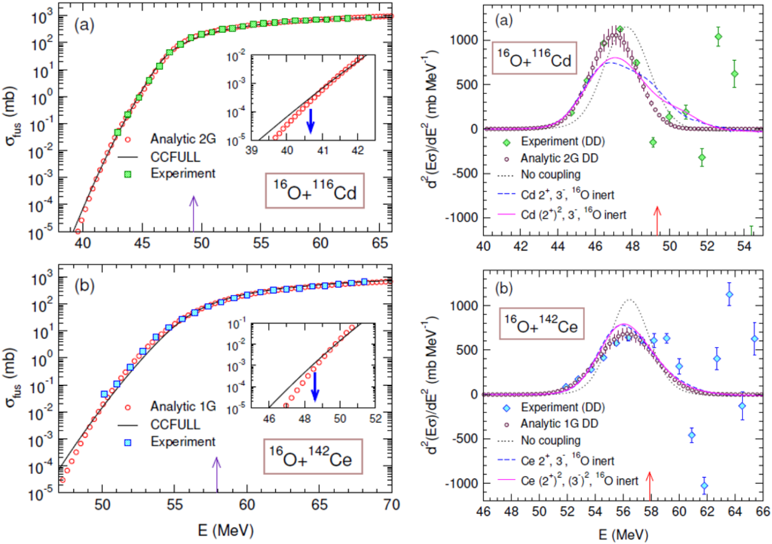
α-particle break-up threshold

^{6}Li: 1.474 MeV | ^{7}Li: 2.468 MeV | ^{19}F: 4.013 MeV | *No hindrance observed*

^{11}B: 8.665 MeV | ^{12}C: 7.366 MeV | ^{16}O: 7.162 MeV | *Hindrance observed*

Systems showing no hindrance: more particle transfer channels with +ve Q-values

Fusion measurement in O+Cd,Ce systems



Fusion measurement in O+Cd,Ce systems

TABLE V. Comparison between experimentally determined threshold energy (E_s) and logarithmic slope at the threshold energy (L_s) with their empirical counterparts E_s^{emp} and L_s^{emp}, which are functions of the ζ-parameter, for asymmetric and symmetric systems with similar values of ζ.

System	ζ	E_s (MeV)	E_s^{emp} (MeV)	$E_s^{4\sigma}$ (MeV)	L_s (MeV^{-1})	L_s^{emp} (MeV^{-1})
$^{16}O+^{116}Cd$	1440	41.34	40.85	40.29	2.68	2.73
$^{32}S+^{48}Ca$	1402	32.55	40.03		3.74	2.74
$^{36}S+^{48}Ca$	1451	36.71	41.06		3.23	2.73
$^{16}O+^{142}Ce$	1760	48.89	47.41	48.67	2.55	2.66
$^{28}Si+^{64}Ni$	1730	45.60	46.97		2.78	2.66
$^{40}Ca+^{40}Ca$	1789	49.03	48.16		2.58	2.65

- Fusion hindrance is inferred by extrapolation in both the systems.
- The Gaussian analytic recipe for $\mathcal{D}$ can be used for determining the threshold energy for fusion hindrance.
- Fusion hindrance is a generic feature of all systems, independent of entrance channel mass asymmetry.

R. Biswas *et al.* (under review)

Stabilizing effect of $Z = 82$ shell closure

PHYSICAL REVIEW C **99**, 061601(R) (2019)

Rapid Communications

Search for stabilizing effects of the $Z = 82$ shell closure against fission

J. Gehlot,[1] S. Nath,[1,*] Tathagata Banerjee,[1,†] Ish Mukul,[1,‡] R. Dubey,[1,§] A. Shamlath,[2] P. V. Laveen,[2] M. Shareef,[2] Md. Moin Shaikh,[1,∥] A. Jhingan,[1] N. Madhavan,[1] Tapan Rajbongshi,[3,¶] P. Jisha,[4] and Santanu Pal[1,#]

[1]*Nuclear Physics Group, Inter-University Accelerator Centre, Aruna Asaf Ali Marg, Post Box 10502, New Delhi 110067, India*

[2]*Department of Physics, School of Mathematical and Physical Sciences, Central University of Kerala, Kasaragod 671314, India*

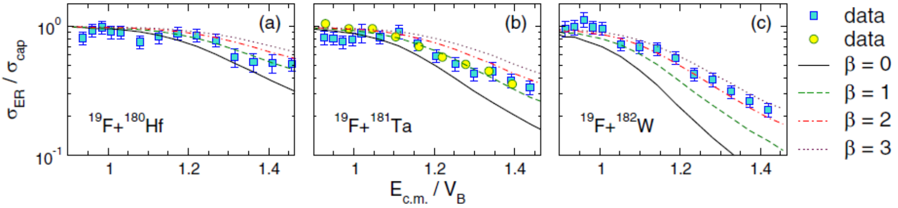
[3]*Department of Physics, Gauhati University, Guwahati 781014, India*

[4]*Department of Physics, University of Calicut, Calicut 673635, India*

TABLE I. Details of the nuclear reactions studied in this Rapid Communication. β_2, V_B, Q_{CN}, χ_{CN}, and η_{BG} are the quadrupole deformation, the Coulomb barrier, Q value of the reaction, CN fissility, and the Businaro-Gallone critical mass asymmetry, respectively. Z_pZ_t and $\eta = \frac{|A_p - A_t|}{(A_p + A_t)}$ are entrance channel charge product and mass asymmetry, respectively. Here Z_p (Z_t) and $A_p(A_t)$ respectively denote atomic number and mass number of projectile (target).

System	β_2 (target)	V_B (MeV)	Z_pZ_t	η	CN	Q_{CN} (MeV)	χ_{CN}	η_{BG}
${}^{19}_{9}F_{10} + {}^{180}_{72}Hf_{108}$	0.274	76.8	648	0.809	${}^{199}_{81}Tl_{118}$	−23.210	0.691	0.831
${}^{19}_{9}F_{10} + {}^{181}_{73}Ta_{108}$	0.269	77.9	657	0.810	${}^{200}_{82}Pb_{118}$	−23.678	0.701	0.838
${}^{19}_{9}F_{10} + {}^{182}_{74}W_{108}$	0.259	79.0	666	0.811	${}^{201}_{83}Bi_{118}$	−28.314	0.712	0.844

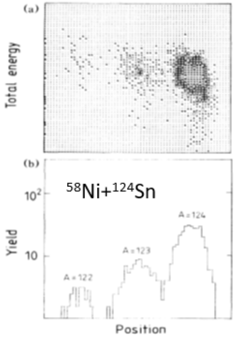
Stabilizing effect of $Z = 82$ shell closure



- No abrupt enhancement of ER cross sections observed with $Z = 82$
- Enhanced stabilizing effects of $Z = 82$ shell against fission not found experimentally.
- This is in contrast with the role of shell closure in the SHE region.

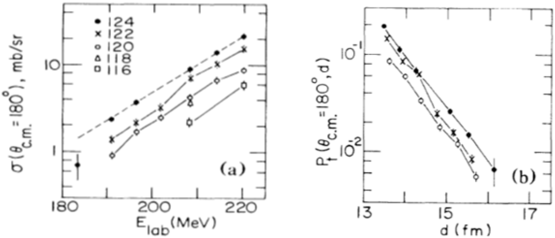
Detection of target-like events in a recoil separator

- Experiment was performed in RMS at Daresbury Laboratory Nuclear Structure Facility.
- Aim was to study sub-barrier transfer reactions on ^{58}Ni + ^{A}Sn using an RMS.



The differential cross-sections and absolute cross-sections are calculated with the *assumption* that yields of

Elastic + Inelastic + Transfer = Rutherford

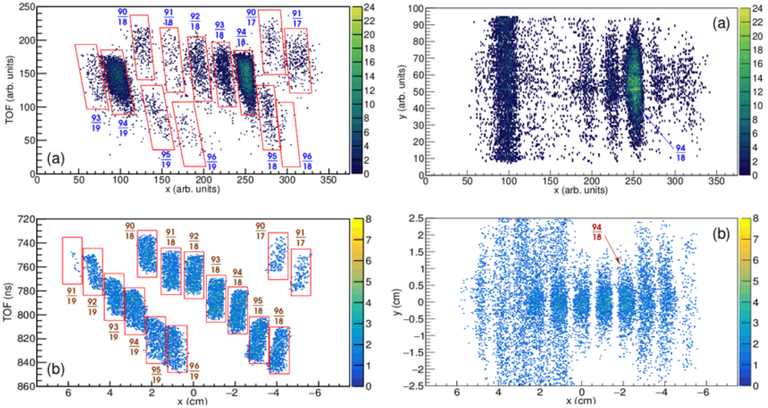


Differential cross-section for 1n pickup channel

R. R. Betts et al., Phys. Rev. Lett. 59, 978 (1987)
C. N. Pass et al., Nucl. Phys. A 499, 173 (1989)

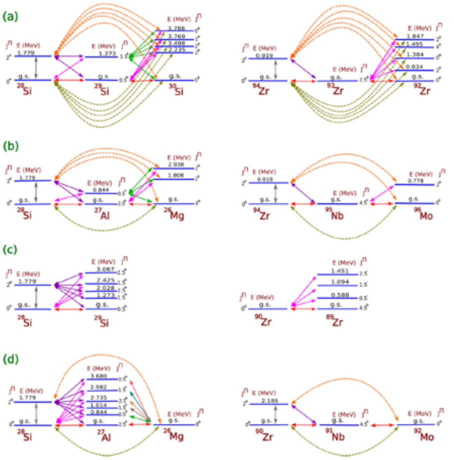
Measurement of MNT channels in HIRA

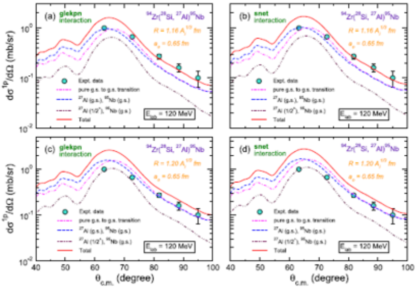
- Focal plane spectra for ^{28}Si+^{94}Zr; $E_{\text{lab}} = 94$ MeV, HIRA @6^o

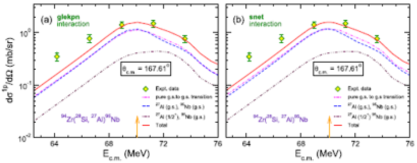


S. Kalkal et al., Phys. Rev. C 83, 054607 (2011)
Rohan Biswas et al., Eur. Phys. J A 56, 1 (2020)
Rohan Biswas et al., Eur. Phys. J A 57, 9 (2021)

CRC results for Si+Zr system



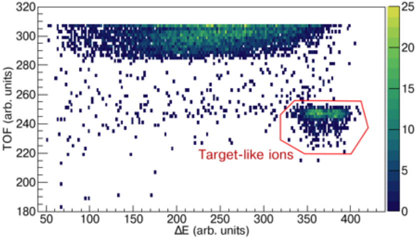




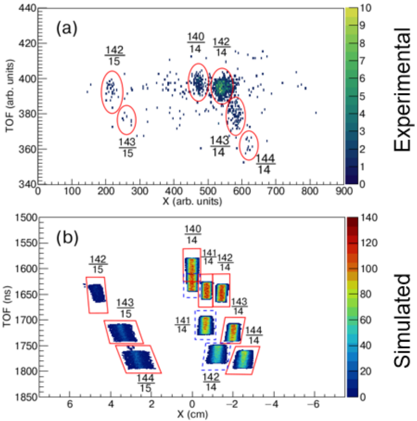
Chandra Kumar *et al.*, Eur. Phys. J. A 59, 277 (2023)

Proton stripping in O+Ce system

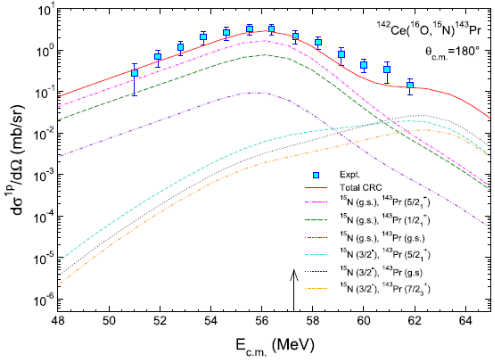
^{16}O+^{142}Ce @E_{lab} = 63 MeV



$$\left(\frac{d\sigma}{d\Omega}\right)^{1p(2p)}_{180^\circ} = \frac{Y_{143(144)}}{Y^{Ruth}_{norm}} \frac{\Omega_{norm}}{\Omega^{eff}_{HIRA}} \frac{1}{\epsilon_{HIRA}} \left(\frac{d\sigma}{d\Omega}\right)^{Ruth}_{\theta_{norm}}$$



CRC results for O+Ce system



Eur. Phys. J. A (2023) 59:60
https://doi.org/10.1140/epja/s10050-023-00975-z

THE EUROPEAN PHYSICAL JOURNAL A

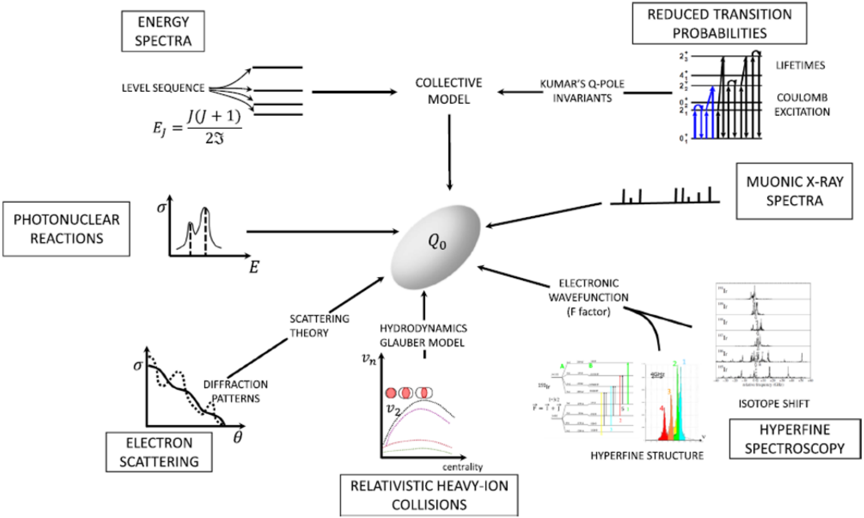
Check for updates

Regular Article - Experimental Physics

Determination of 1p- and 2p-stripping excitation functions for ^{16}O+^{142}Ce using a recoil mass spectrometer

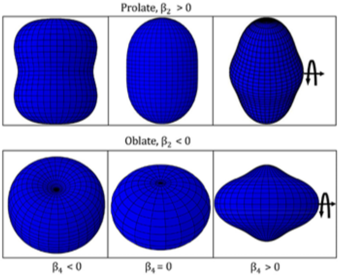
Rohan Biswas[1,8], S. Nath[1,a], J. Gehlot[1], Gonika[1], Chandra Kumar[1], A. Parihari[2], N. Madhavan[1], A. Vinayak[3], Amritraj Mahato[4], Shoaib Noor[5], Phurba Sherpa[2], Kazuyuki Sekizawa[6,7,b]

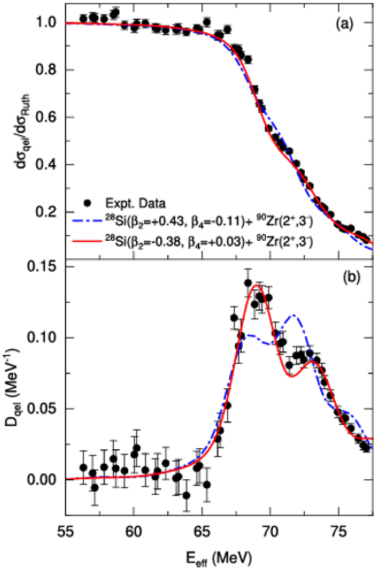
Determining shapes of nuclei



David Verney, Eur. Phys. J. A 61, 82 (2025)

Deformation extracted from QEL scattering



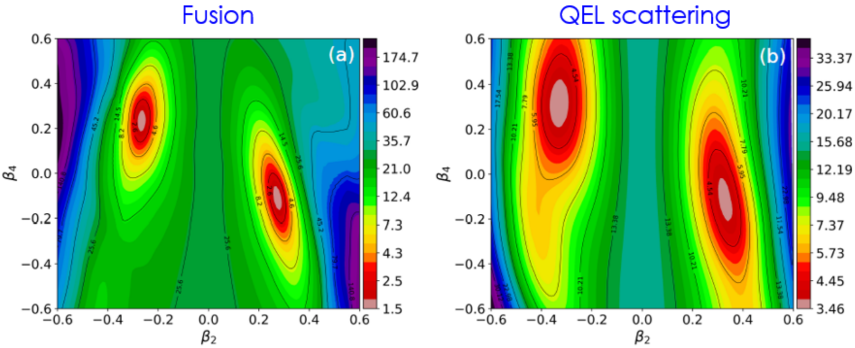


- ✓ ^{28}Si is determined to be an oblate-shaped
- ✓ $\beta_2 = -0.38 \pm 0.01$ and $\beta_4 = +0.03 \pm 0.01$
- ✓ Good agreement with results from electromagnetic probes and SHF theory
- ✓ *Potential route to investigate the g.s. structure of exotic nuclei using RIBs*

Y. K. Gupta et al., Phys. Lett. B 845, 138120 (2023)

χ^2-distribution for β_2 and β_4 of ^{28}Si

^{28}Si+^{144}Sm

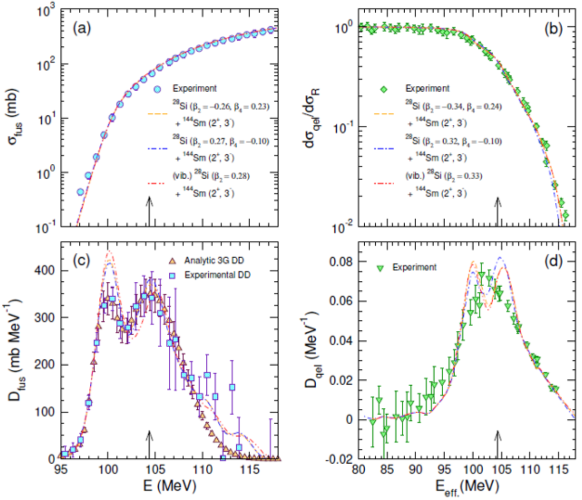


- ✓ χ^2-minimization performed with respect to the *barrier distribution*
- ✓ Both data sets reveal *two* minima (prolate and oblate)

Coupled-channels results for Si+Sm system

$^{28}Si+^{144}Sm$

- ✓ CC calculations reproduce both fusion and quasielastic data quite well
- ✓ Barrier distributions are more *sensitive* to subtle changes in couplings
- ✓ Fusion appears to be a *superior* avenue to extract g.s. deformation parameters



Summary of the results for ^{28}Si

	Collectivity of ^{28}Si	β_2	β_4	$\chi^2(\beta_2,\beta_4)$ / $\chi^2(\beta_2)$
Fusion	Oblate	$-0.26^{+0.03}_{-0.03}$	$+0.23^{+0.09}_{-0.10}$	1.5162
	Prolate	$0.27^{+0.03}_{-0.04}$	$-0.11^{+0.11}_{-0.11}$	1.5052
	Vibrational	$0.28^{+0.06}_{-0.06}$		1.9091
Quasi-elastic	Oblate	$-0.34^{+0.08}_{-0.07}$	$+0.24^{+0.21}_{-0.35}$	3.6070
	Prolate	$0.32^{+0.07}_{-0.07}$	$-0.10^{+0.27}_{-0.25}$	3.5779
	Vibrational	$0.33^{+0.06}_{-0.07}$		3.6864

Phys. Lett. B 862 (2025) 139319

ELSEVIER

Contents lists available at ScienceDirect

Physics Letters B

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

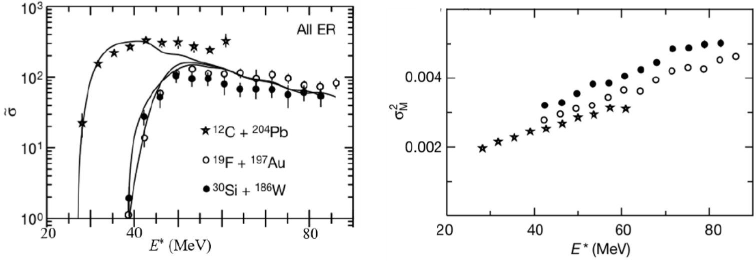
Letter

On extraction of ground state deformation parameters from quasielastic and fusion excitation functions

Chandra Kumar, S. Nath *

Nuclear Physics Group, Inter-University Accelerator Centre, Aruna Asaf Ali Marg, New Delhi 110067, India

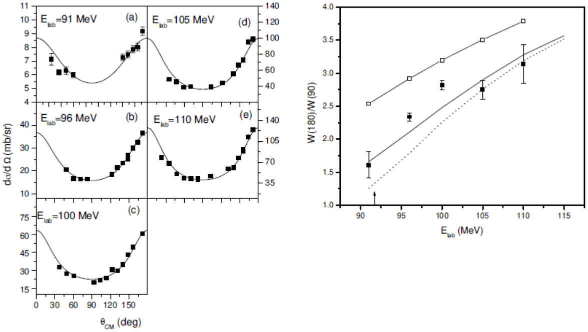
Fusion inhibition in less fissile system



- Reactions induced by lighter projectiles ($A_p \leq 20$) assumed to exclusively lead to CN formation
- An asymmetric system (^{19}F+^{197}Au) revealed presence of quasifission
- Different outcomes linked to initial mass asymmetry

A. C. Berriman et al., Nature (London) 413, 144 (2001)

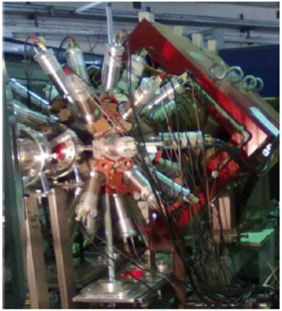
No clear signature of quasifission in F+Au system

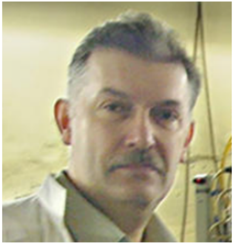


- Fission fragment angular distribution in $^{19}F+^{197}Au$ could be explained within the statistical saddle point model (SSPM)
- No clear signature of quasifission was found

R. Tripathi et al., Phys. Rev. C 71, 044616 (2005)

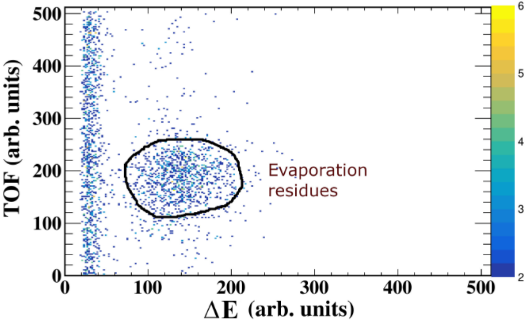
A collaborative experiment





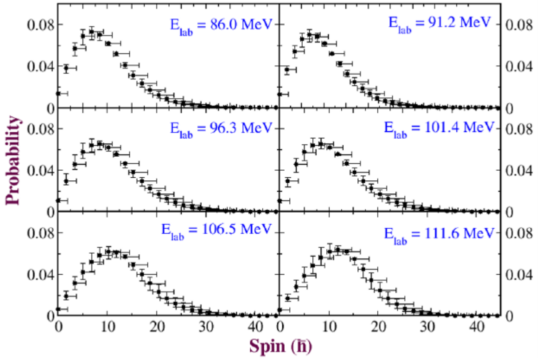
Details of experiment

- HYbrid Recoil mass Analyzer (in gas-filled mode)
- TIFR 4π spin spectrometer (29 NaI detectors)
- Beam: ^{19}F (pulsed)
- Target: ^{197}Au (250 μg/cm^2)
- E_{lab} : 86 – 112 MeV



R. Tripathi et al., Phys. Rev. C 71, 044616 (2005)

Measured angular momentum distribution



Generalized relation between $\langle M_\gamma \rangle$ and $\langle \ell_{\rm CN} \rangle$:

$$\langle \ell_{\rm CN} \rangle = \Delta I_{\rm ns} \left(\langle M_\gamma \rangle - M_{\gamma s} \right) + \sum_i \Delta I_i M_i + I_0$$

- Langevin dynamical calculations are in progress.

Gonika et al., Proc. DAE Symp. Nucl. Phys. 68, 357 (2024)

Overlapping interests with FLNR, JINR

Physics with recoil separators

- Fusion-fission dynamics by measurement of ER cross sections
- Multi-nucleon transfer by detection of target-like events
- Determination of fusion barrier from quasi-elastic measurements

Thanks for your attention