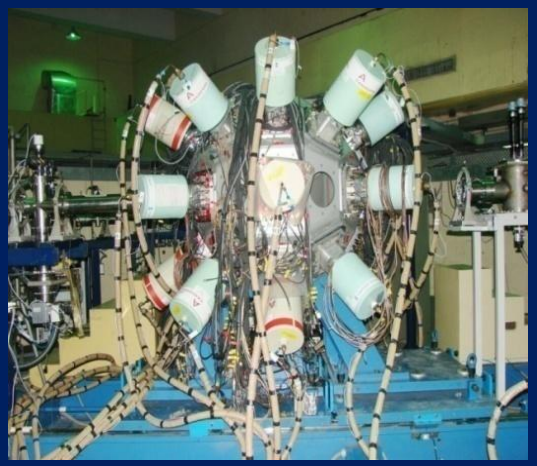
SIGNATURE OF CLUSTER STRUCTURE NEAR BETA-STABILITY AND FAR FROM STABILITY


Ushasi Datta

Saha Institute Of Nuclear Physics, Kolkata

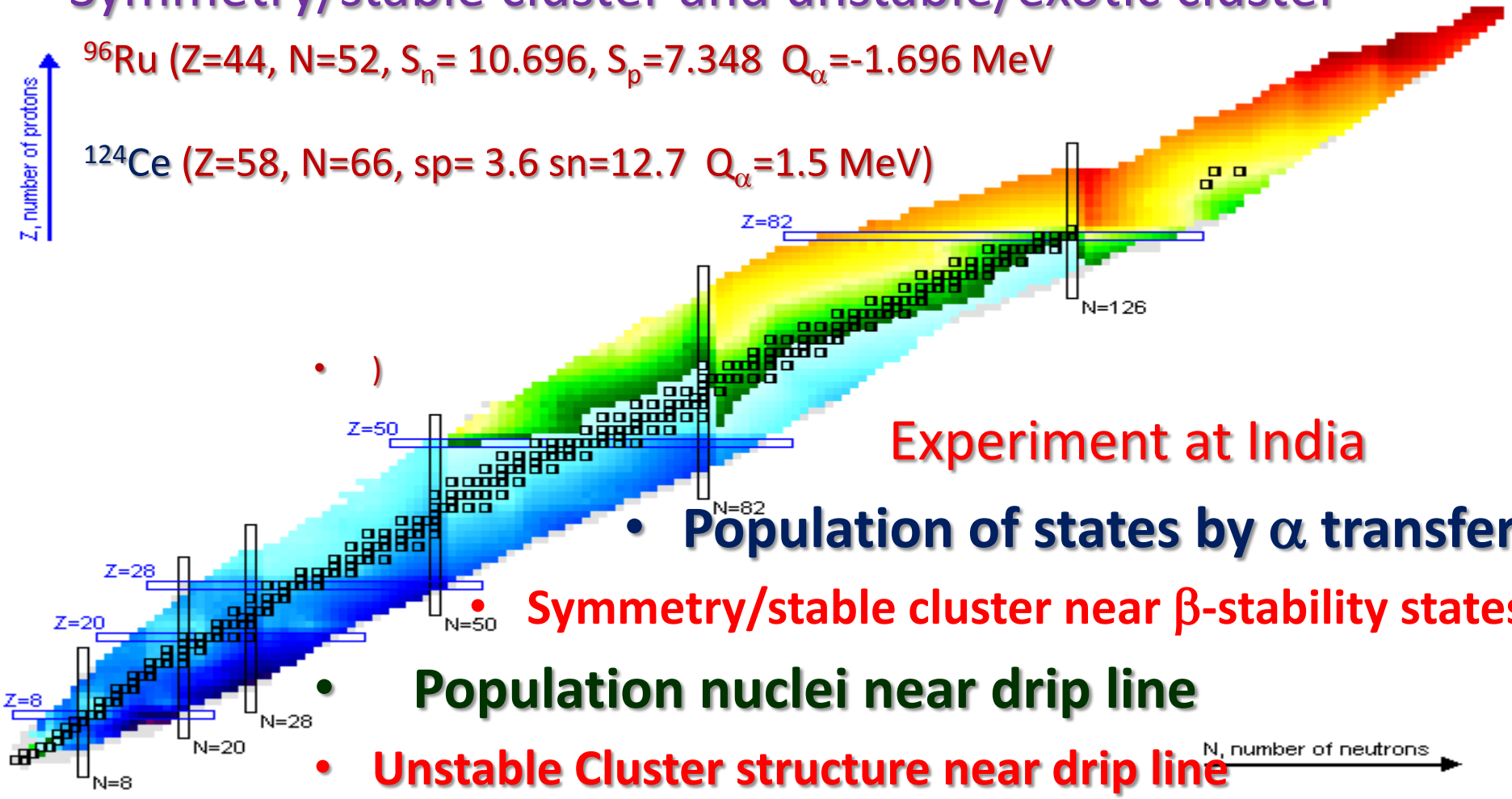
State of the Art in Nuclear Cluster Physics, SOTANCP4, Galveston, Texas, 15th May, 2018

Content of talk

- What we can learn from clusters in nuclei ??
- Symmetry/stable cluster and unstable/exotic cluster

^{96}Ru (Z=44, N=52, S_n= 10.696, S_p=7.348 Q_α=-1.696 MeV

^{124}Ce (Z=58, N=66, sp= 3.6 sn=12.7 Q_α=1.5 MeV)



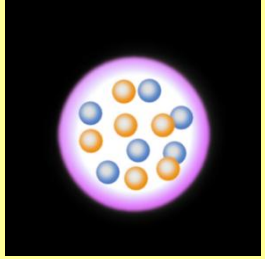
-)

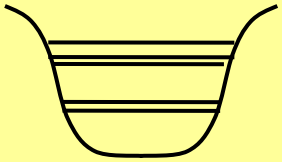
Experiment at India

- **Population of states by α transfer**
- **Symmetry/stable cluster near β-stability states**
- **Population nuclei near drip line**
- **Unstable Cluster structure near drip line**

Cluster & Mean field

A finite quantum many-body system of protons and neutrons

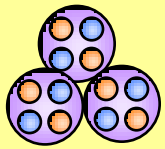




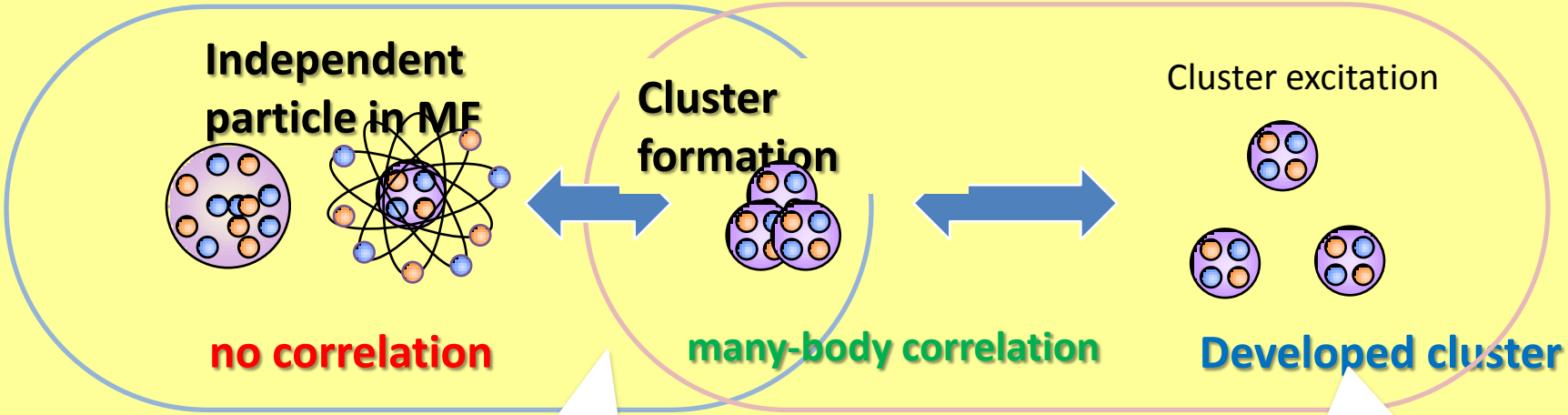
Cluster:
Many-body correlation

Mean field, shell structure
Independent single-particle

. Independent-particle feature in self-consistent mean-field
2. Strong nucleon-nucleon correlations

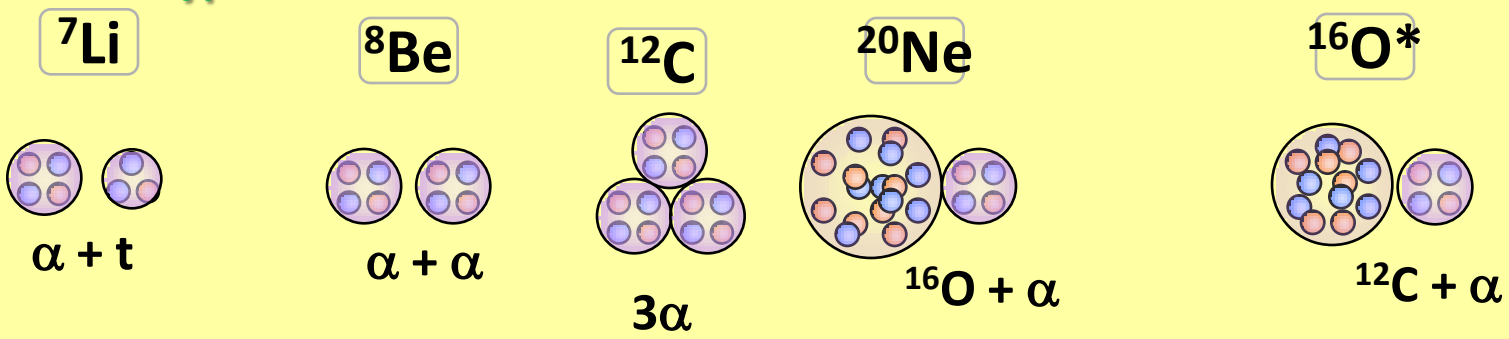


Shell structure・MF v.s. Cluster



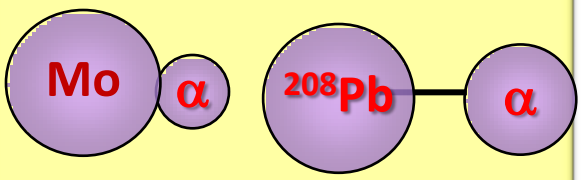
Cluster structures in stable and unstable nuclei

Typical cluster structures known in stable nuclei



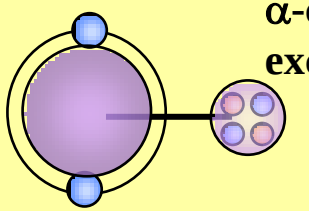
Heavier nuclei

Si-Si, Si-C, Pb-C, Mo-α

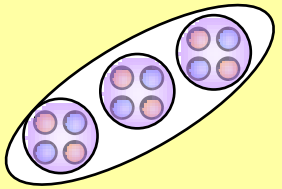


^{36}Ar-α, ^{24}Mg-a, ^{28}Si-a

Unstable nuclei

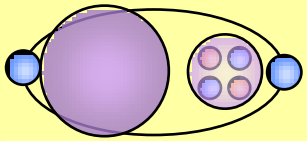


α-cluster excitation



3a linear chain

^{14}C*



Molecular orbital

Be, C, O, Ne, F

Cluster structure around proton drip line!!!!!

^{96}Ru

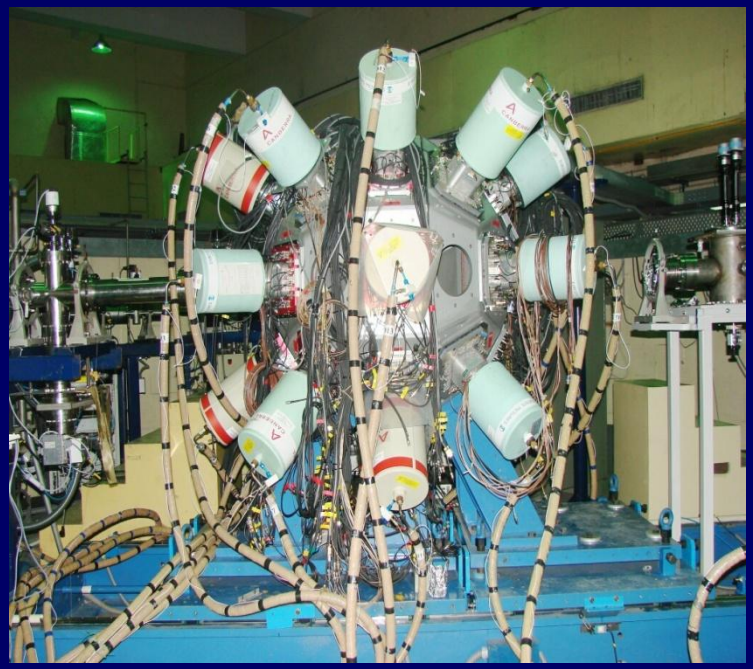
Population of ^{96}Ru cluster states
by alpha transfer to ^{92}Mo
Asymmetry molecular cluster structure

^{124}Ce

Populated by fusion evaporation ^{92}Mo+^{32}S
Is it a indirect evidence exotic cluster emission?

^{92}Mo+^{32}S

The Experiment at IUAC, New Delhi, 14 UD Pelletron machine)



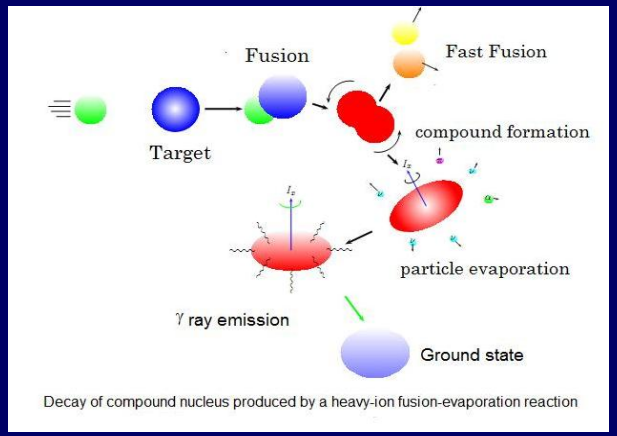
Indian National Gamma Array(INGA)

♣ ^{32}S (150 MeV) + ^{92}Mo
$\Rightarrow$ ^{124}Ce (compound nuclei)

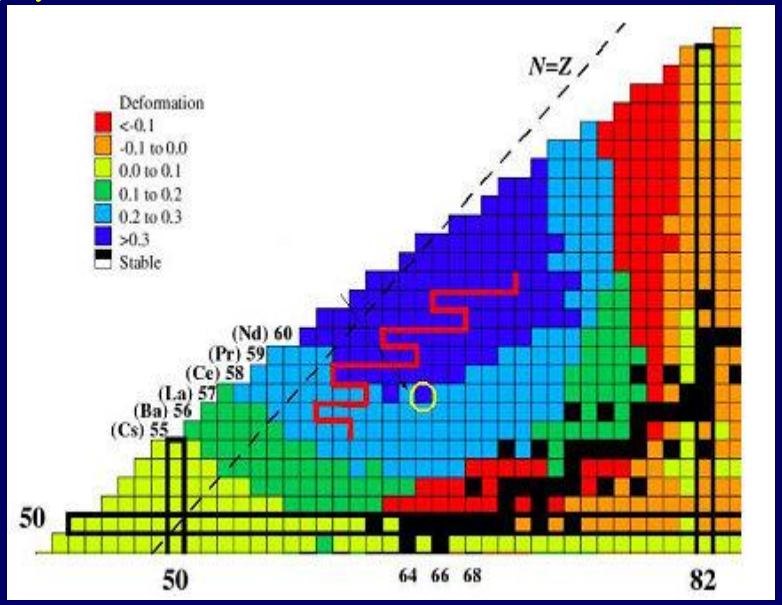
^{92}Mo target self-supporting,
Au backing

♣Measured γ-rays in coincidence mode
♣ INGA (14 CLOVER array)

♣ γ-γ mode



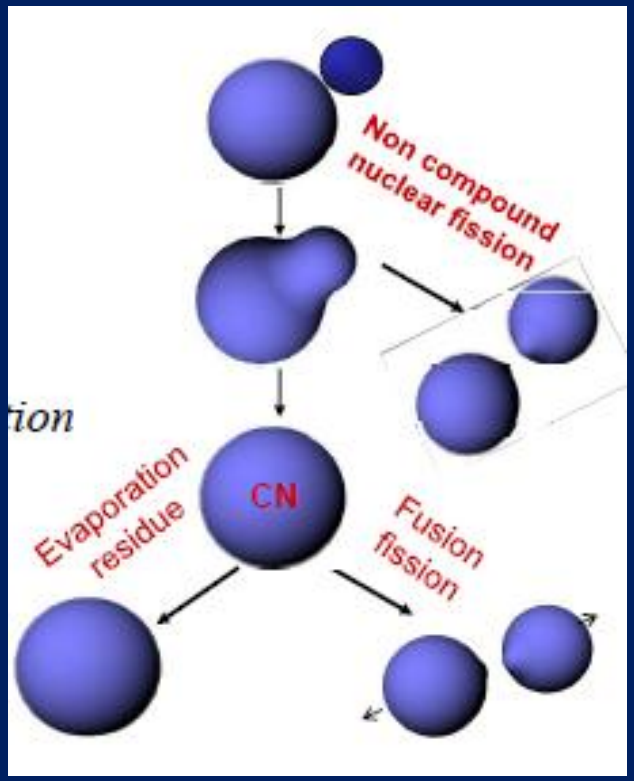
Decay of compound nucleus produced by a heavy-ion fusion-evaporation reaction

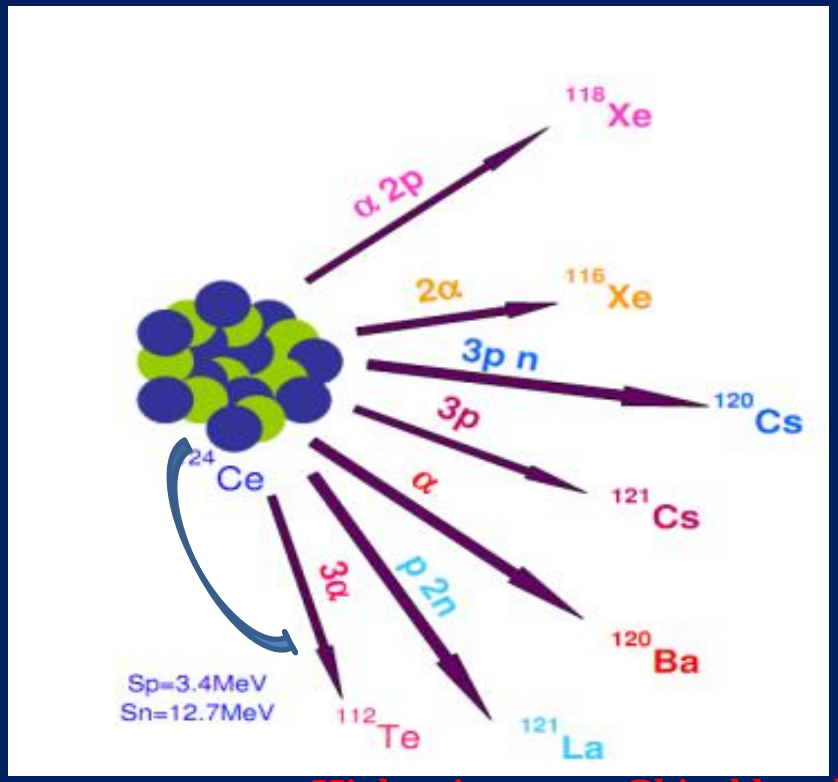


STRUCTURE AND REACTION STUDIES USING $^{32}S+^{92}Mo$ REACTION

Nuclear structure near drip line

Reaction dynamics





High spin states, Chiral band, octupole-corelation, multi quasiparticle band

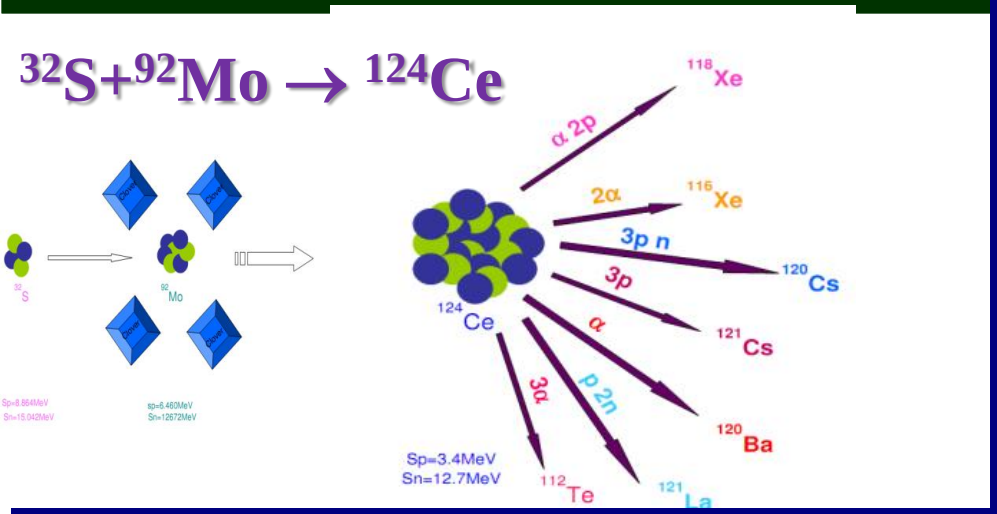
CN process, nCN process, transfer etc.

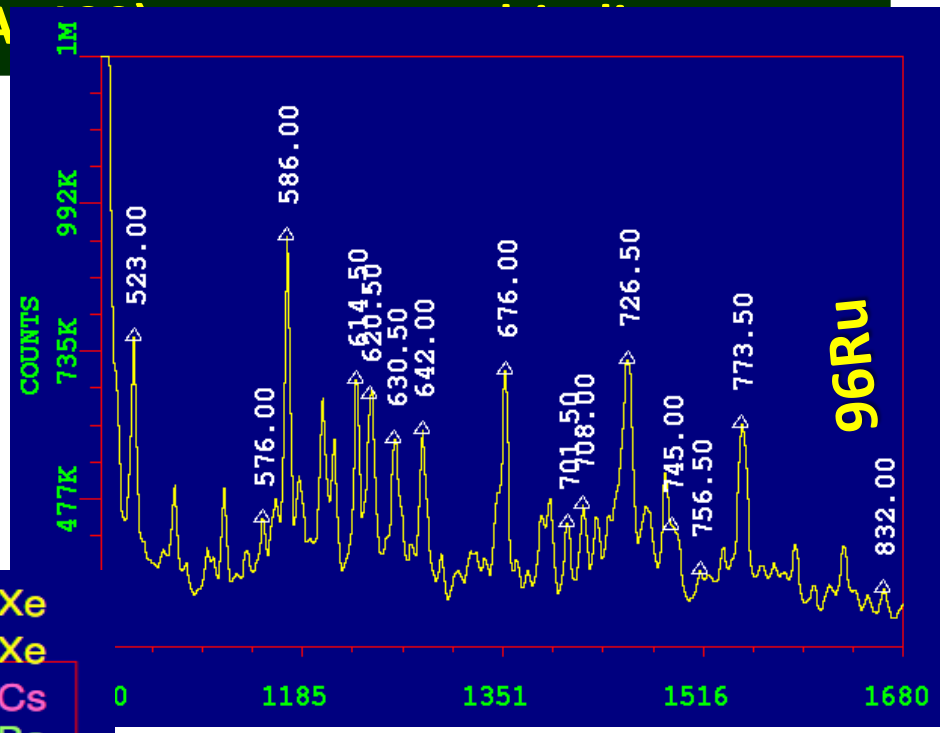
Pre-equilibrium cluster emission, Evaporation of CN

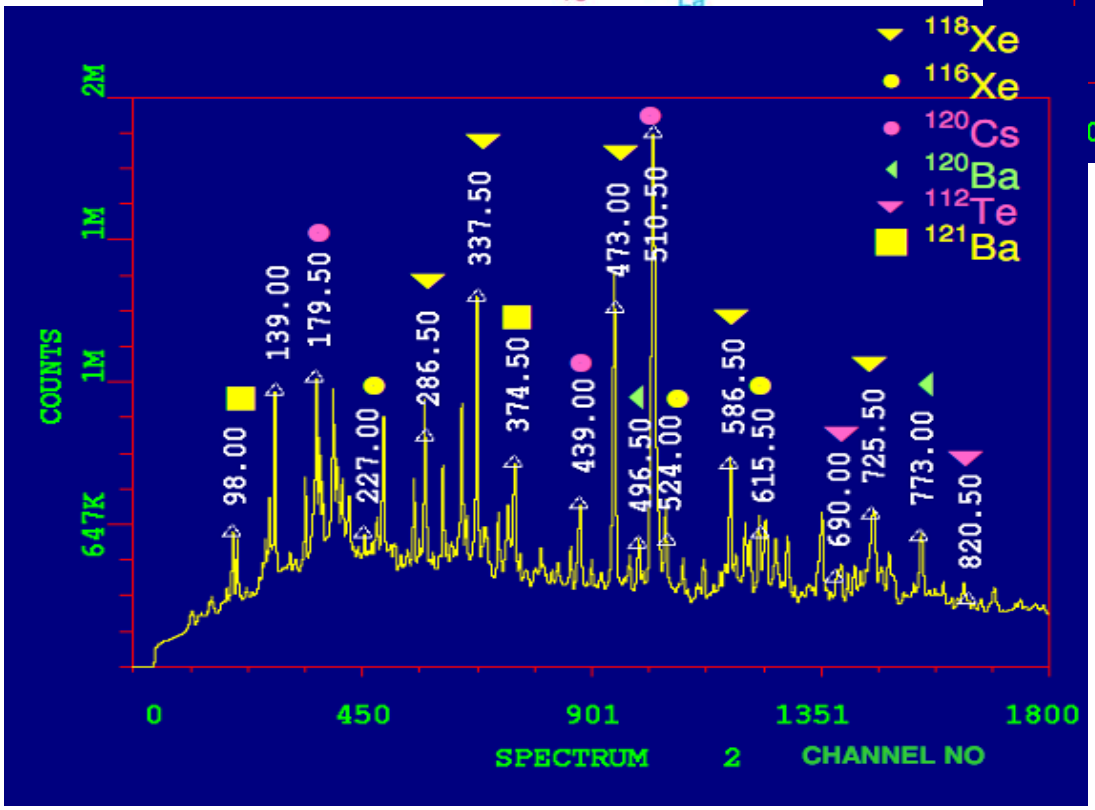
$^{119-121}$Cs, ^{121,122}La, $^{120-122}$Ba $^{116-120}$Xe, ^{119,117,115}I, ^{110,114}Te, etc

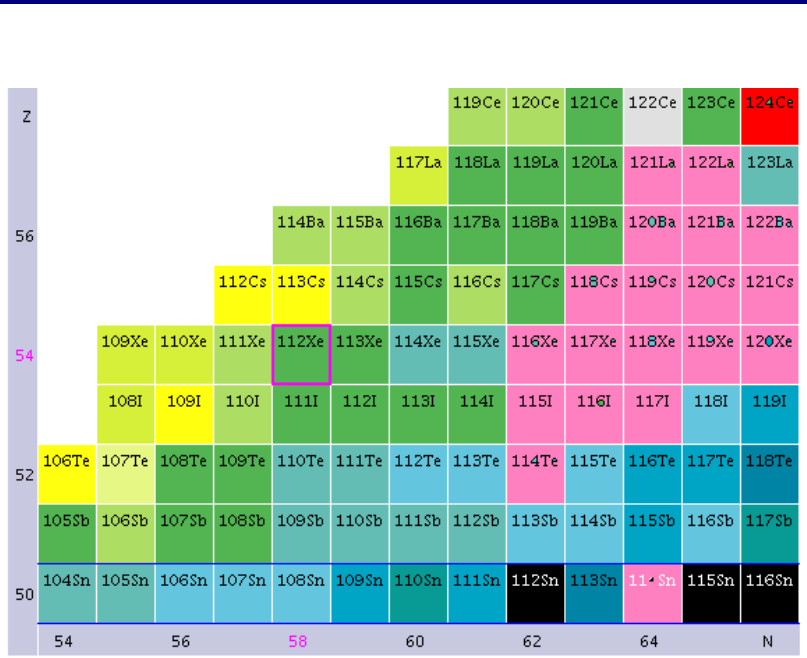
^{93}Tc, $^{94-96}$Ru

High spin states of transitional nuclei (A









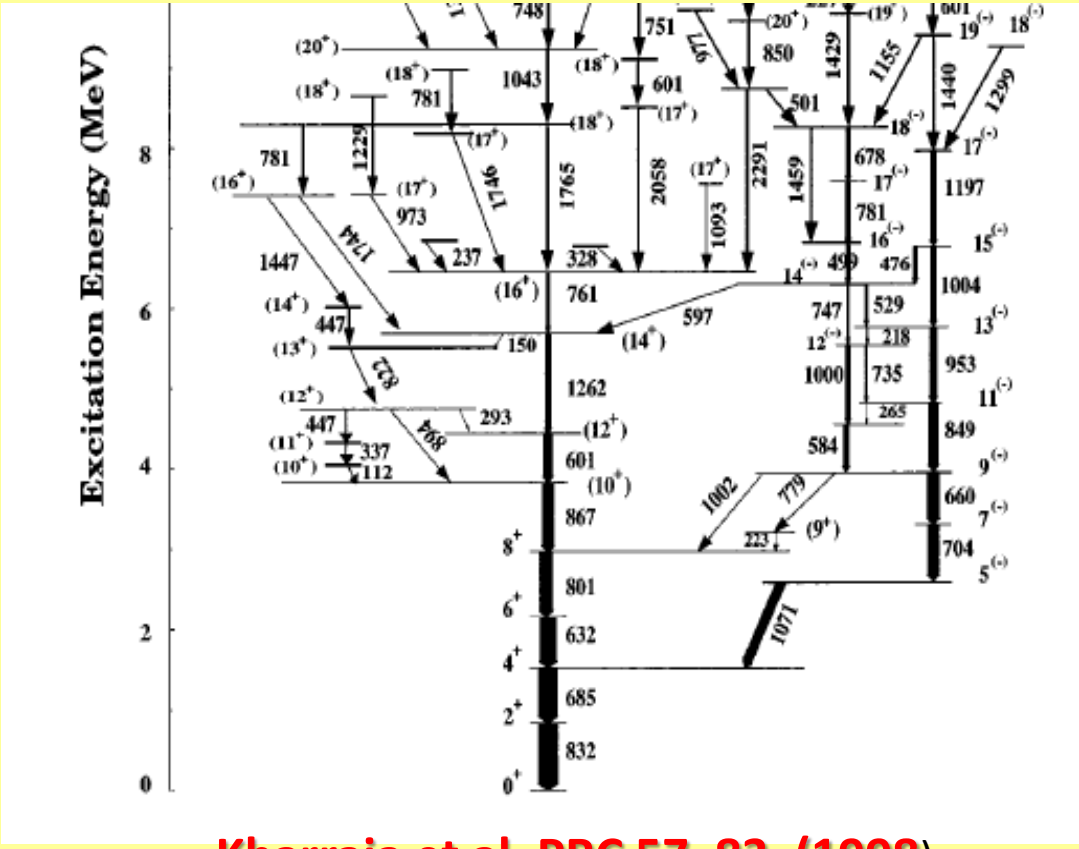
^{96}Ru

^{96,98}Ru can only be produced efficiently via the *v p*-process. Furthermore, the production of Ru in the *vp*-process heavily depends on the presence of very proton-rich material in the ejecta.

M.Eichler et al., J.Phys. G 45 , (2018)

Mixed symmetry states

A.Henning et al,
Phys.Rev. C 92, 064317 (2015)

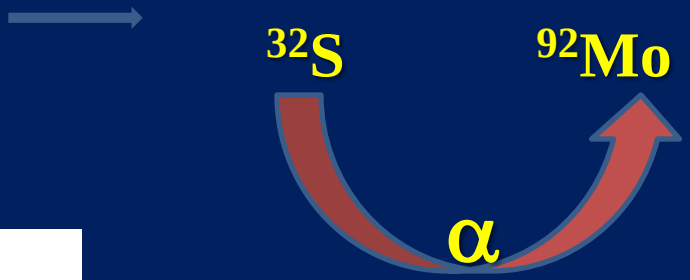


Kharraja et al, PRC 57, 83, (1998)

Total nucleus	$\langle r^2 \rangle_T^{1/2}$ (fm)	$\langle r^2 \rangle_T^{1/2} / \langle r^2 \rangle_{T\,\mathrm{exp}}^{1/2}$
^{90}Sr	4.220	0.990
^{92}Zr	4.254	0.988
^{94}Mo	4.322	0.993
^{96}Ru	4.363	0.993

α-cluster in Mo, Ru
M.A.Souza, H.Miyake
Phys.Rev. C 91, 034320 (2015)

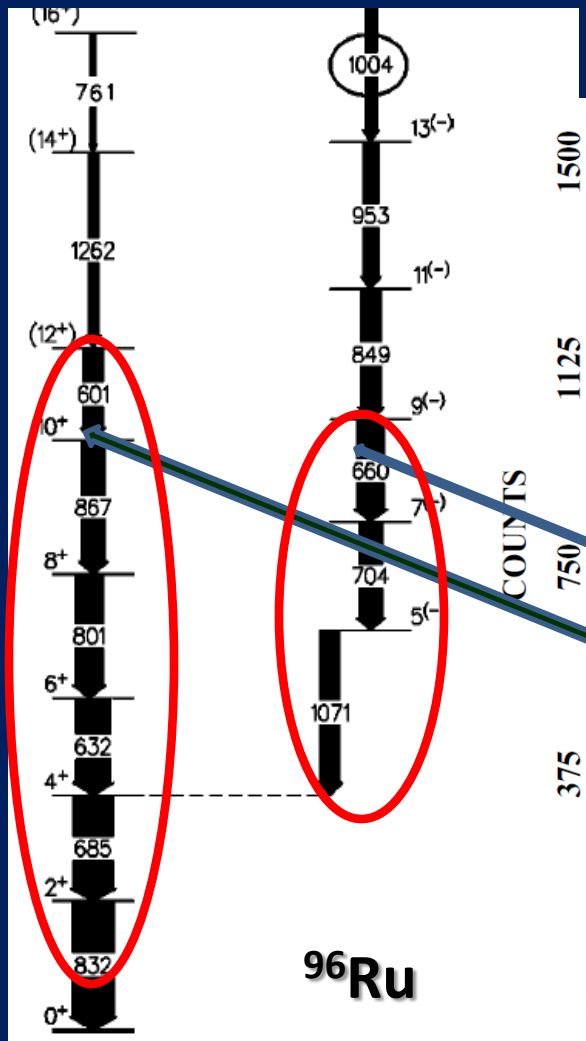
Alpha cluster transfer

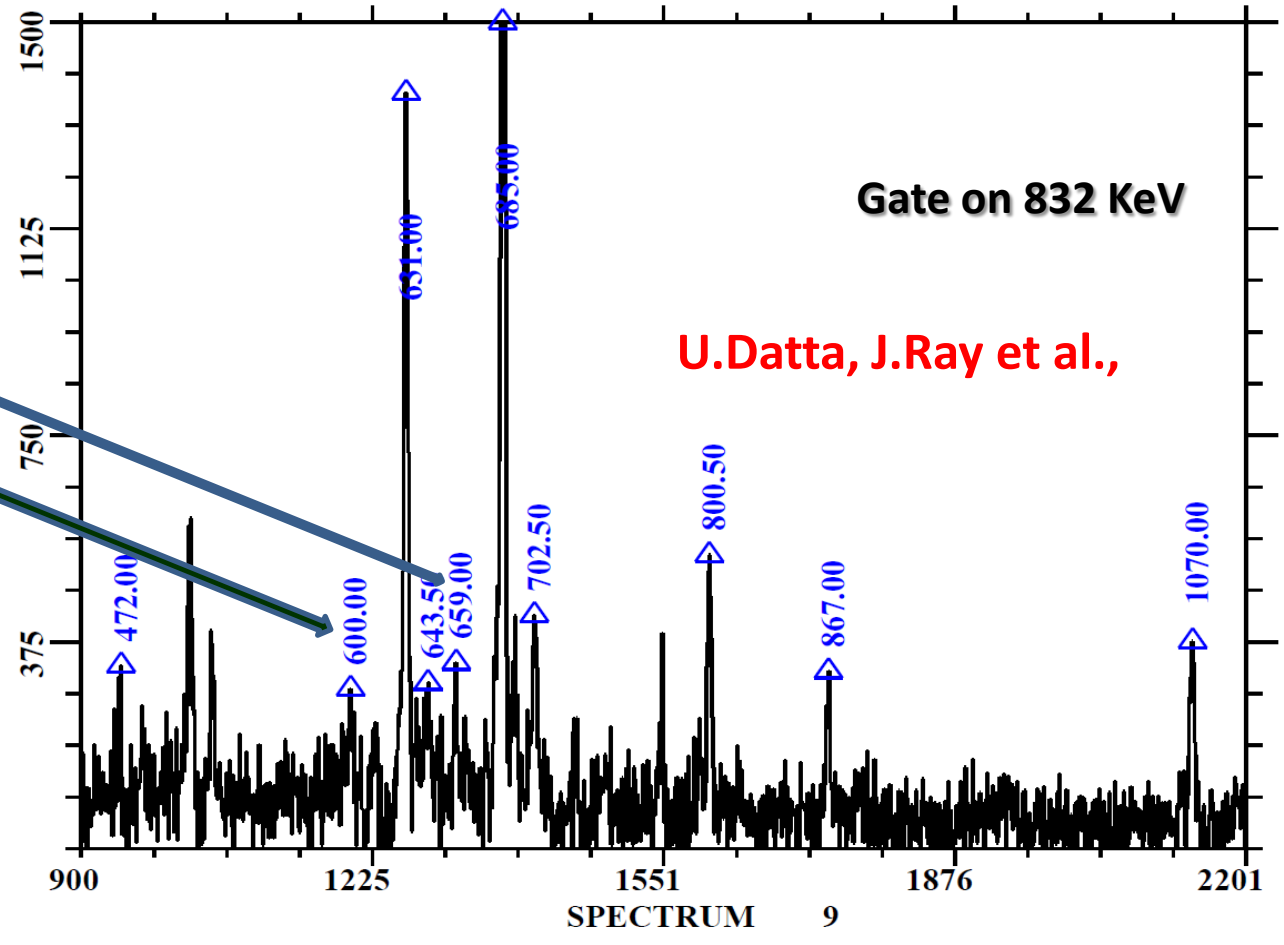


^{96}Ru (Z=44, N=52)

Q_α=-1.56 MeV

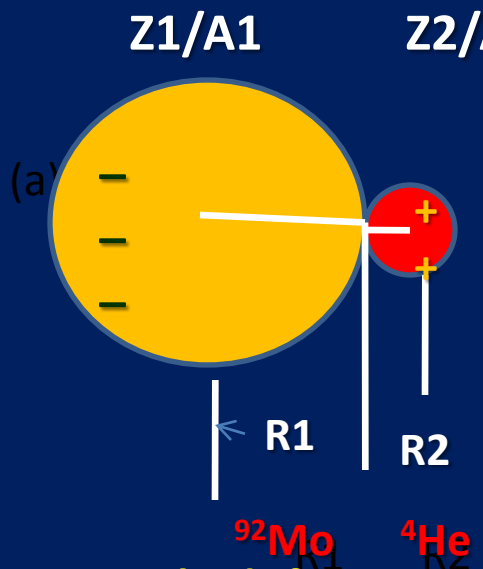
S_n= 10.696, S_p=7.348



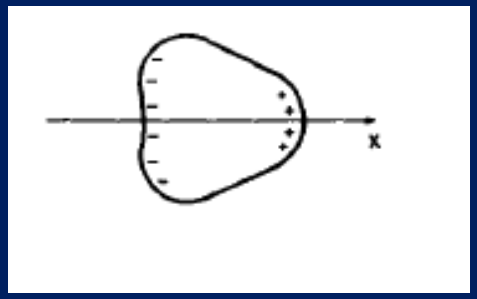


Origin of negative parity states in ^{96}Ru populated in α cluster transfer

A. **Cluster structure**



B. **Octupole deformation**



F. Iachello, PLB , 1981

Dipole moment (C M)= 1.27 e fm

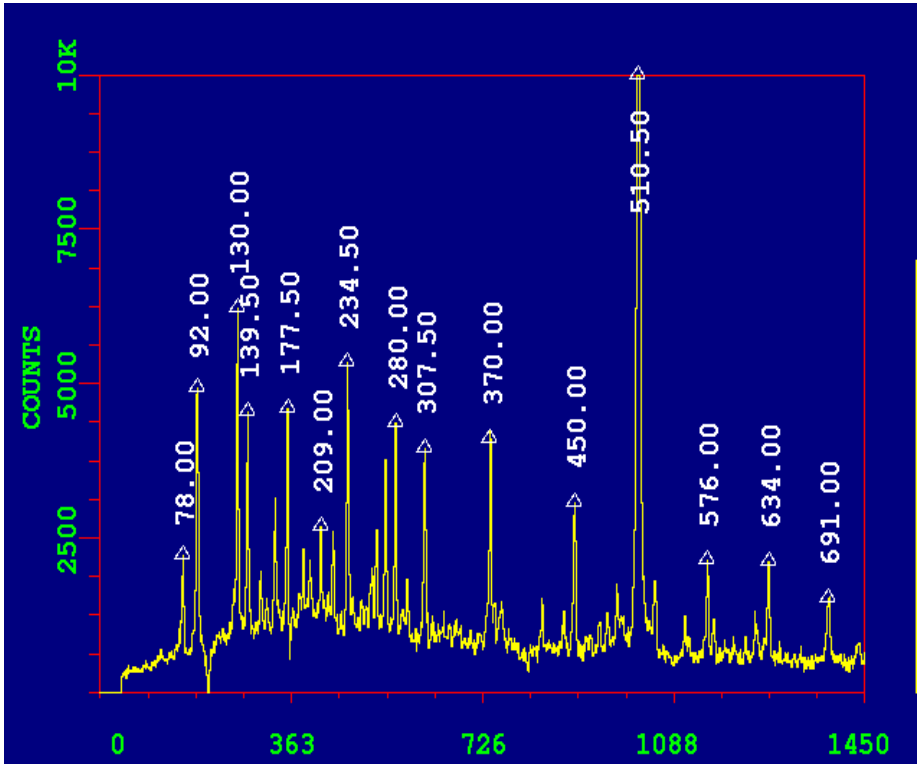
B(E1) (CM) = 1.1 e^2fm^2

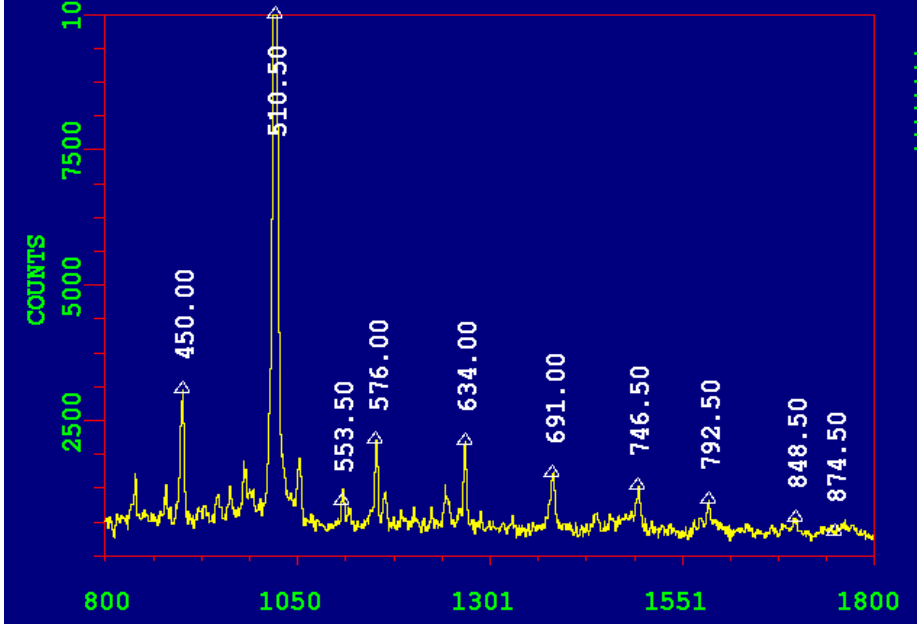
Dipole moment (Oct. Def.)= 0.058 fm

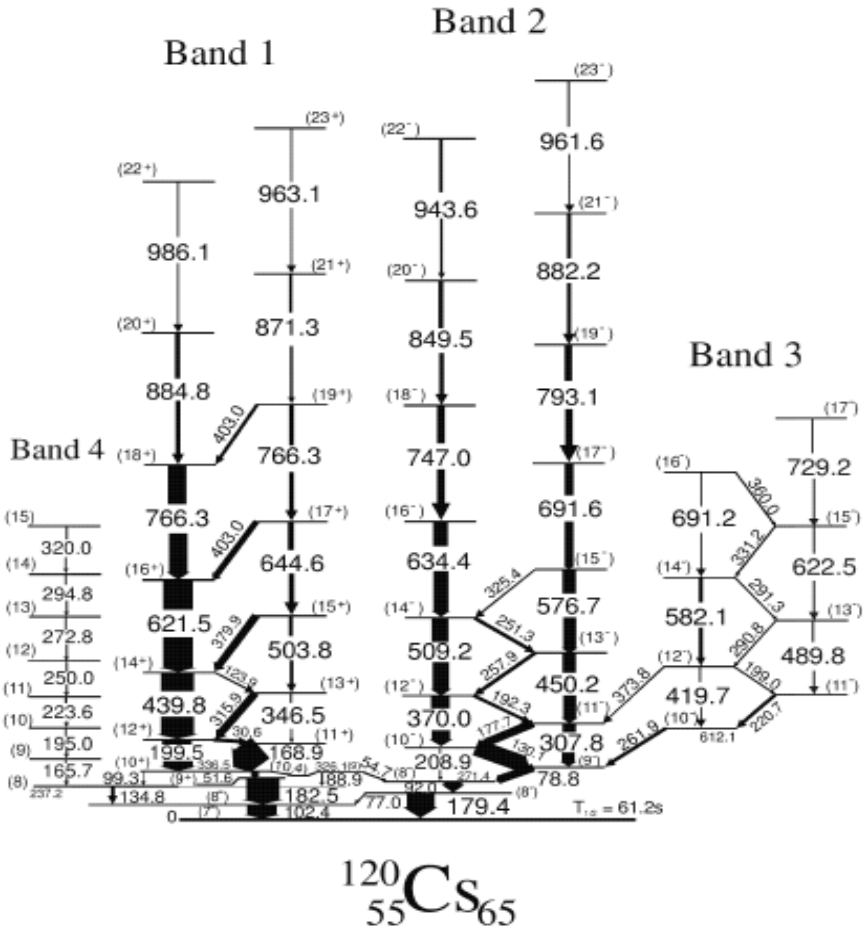
B(E1) (CM) = 2.4 x 10^{-4} e^2fm^2

Preliminary Expt. Life time (5-) ~ 5 ps
U.Datta, J.Ray , I.Ray, et al,

Dual character !!!!

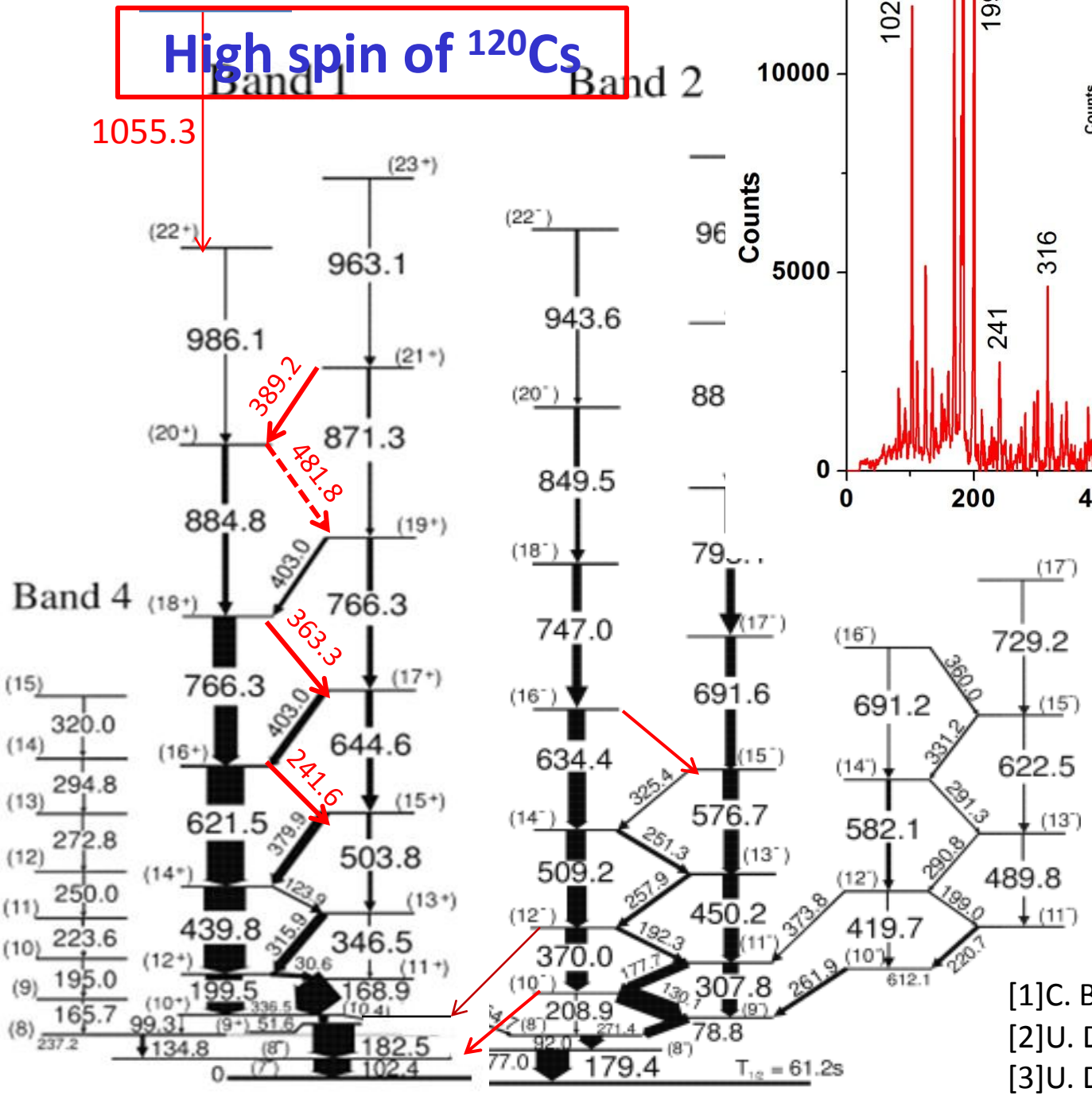


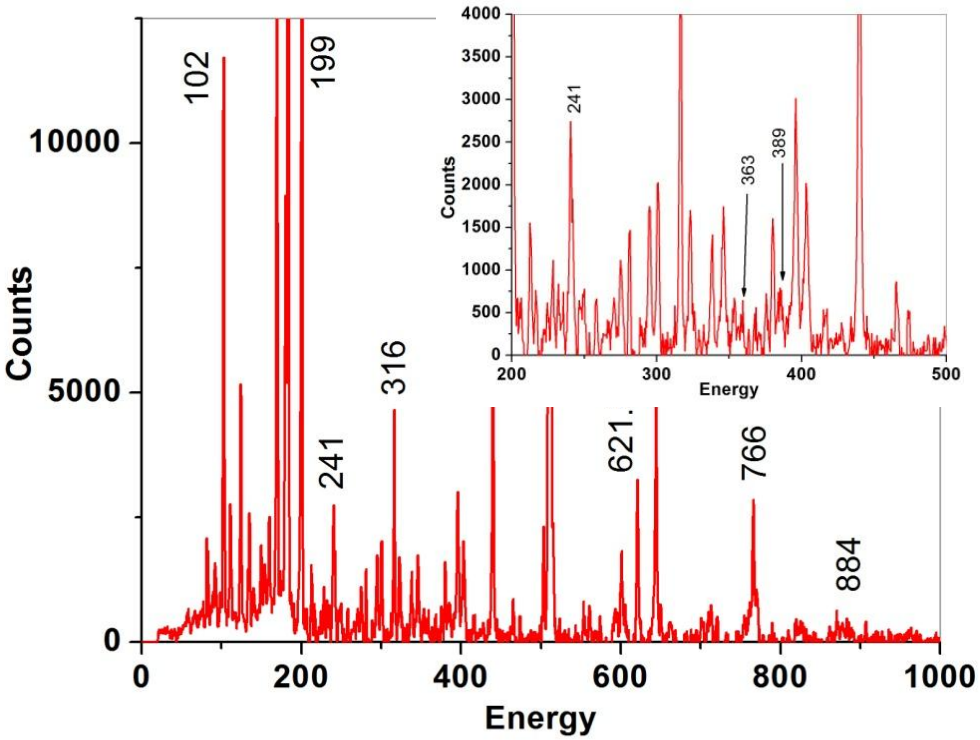




C.B.Moon et al, Nucl. Phys A 2001

High spin of ^{120}Cs

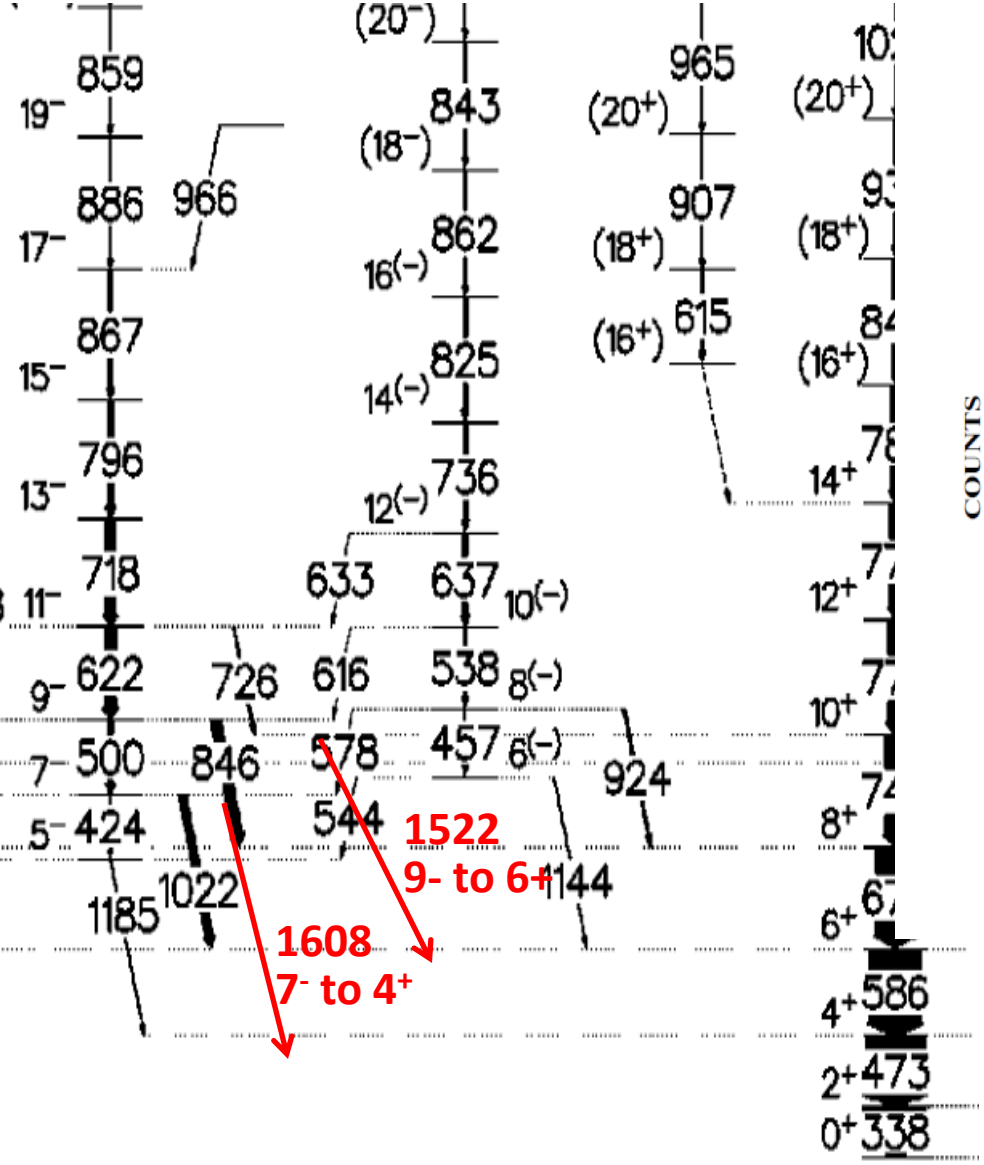


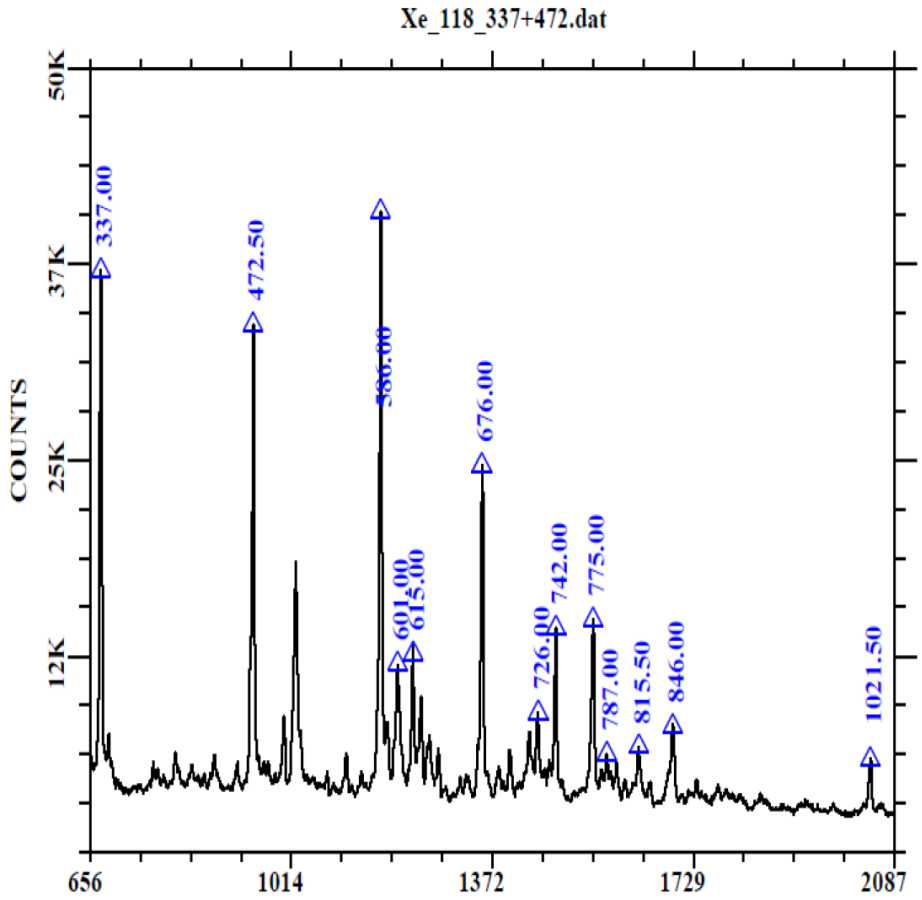


Shape co existence observed in La, Isotopes near this region [2,3]

[1]C. B. Moon *et al*. NPA 696 (2001)
[2]U. D. Pramanik et al. PRC 52, 117
[3]U. D. Pramanik et al. PRC 54, 1221

Octupole deformation in ^{118}Xe

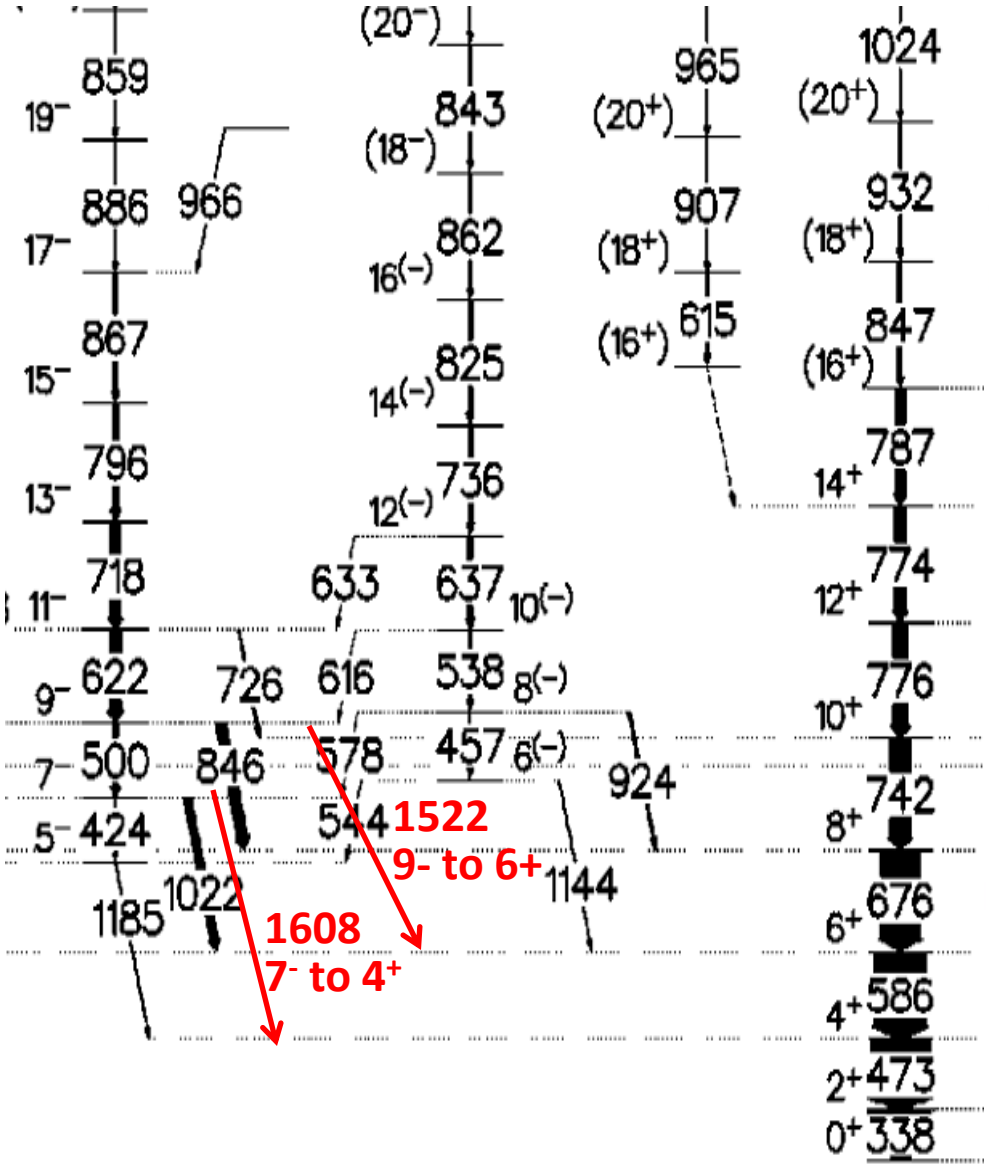


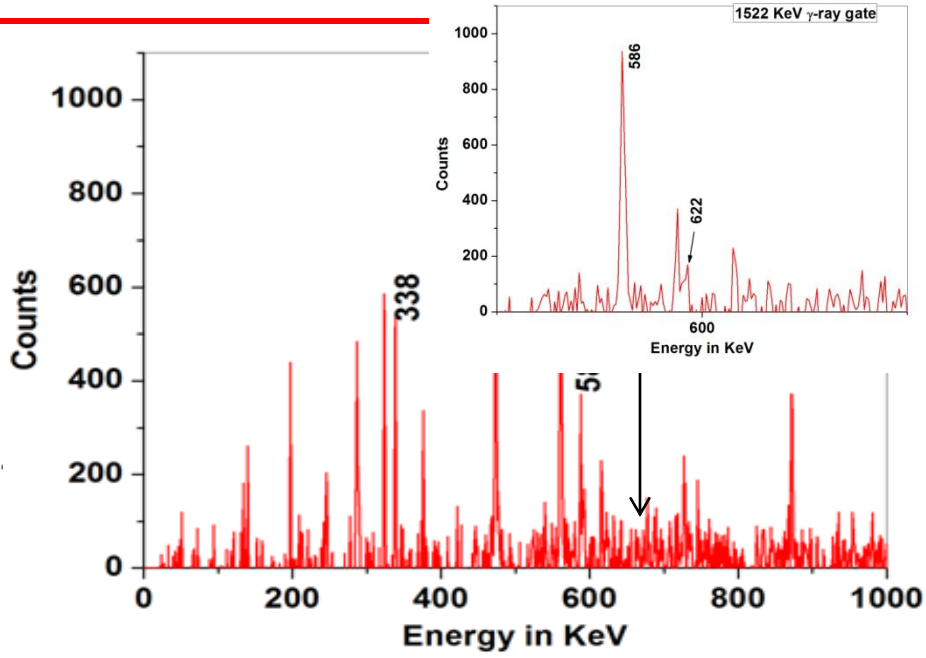


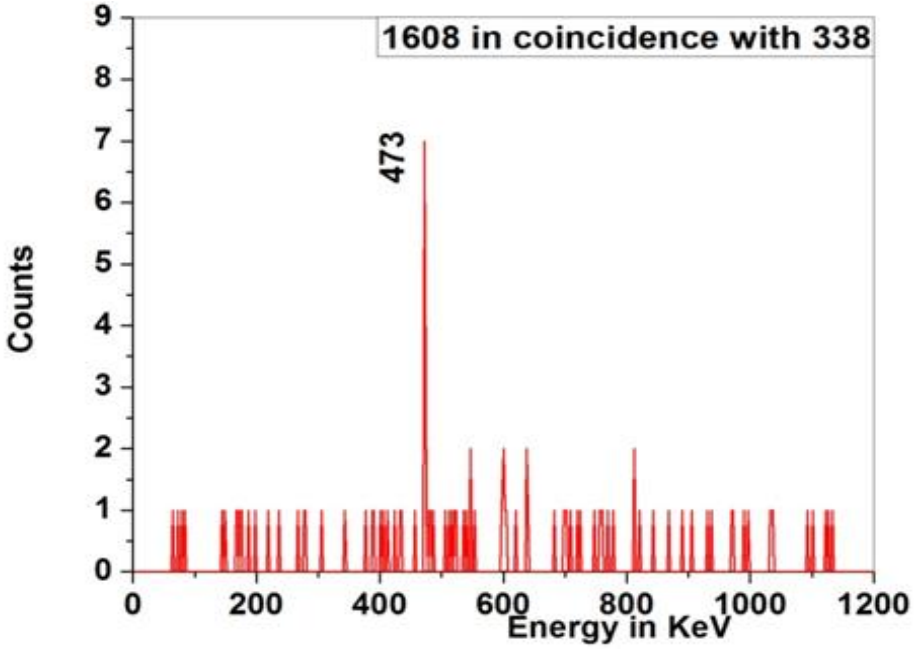
J. M .Sears *et al.* PRC 57 (1998)

Manuscript under preparation

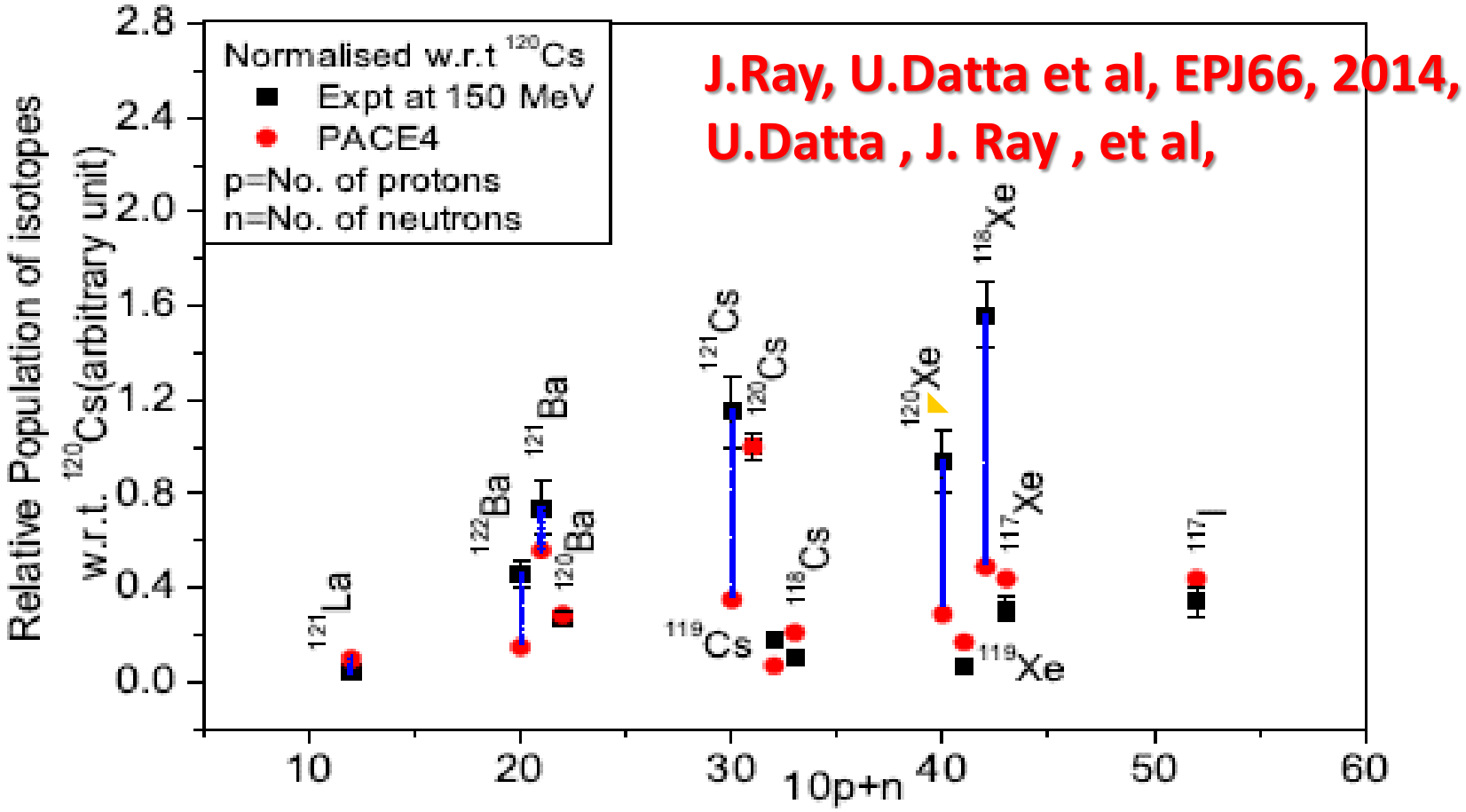
octupole deformation in ^{118}Xe







J. M .Sears *et al.* PRC 57 (1998)



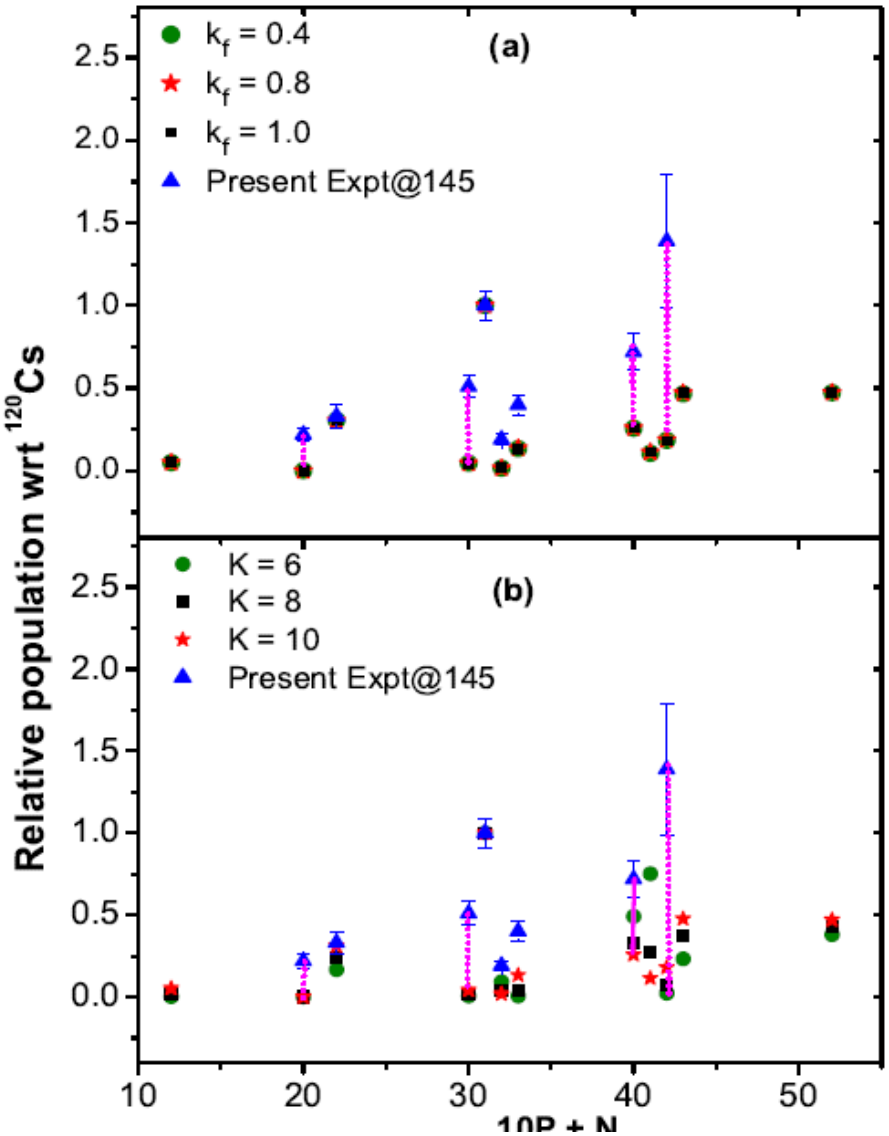
J.Ray, U.Datta et al, EPJ66, 2014,
U.Datta , J. Ray , et al,

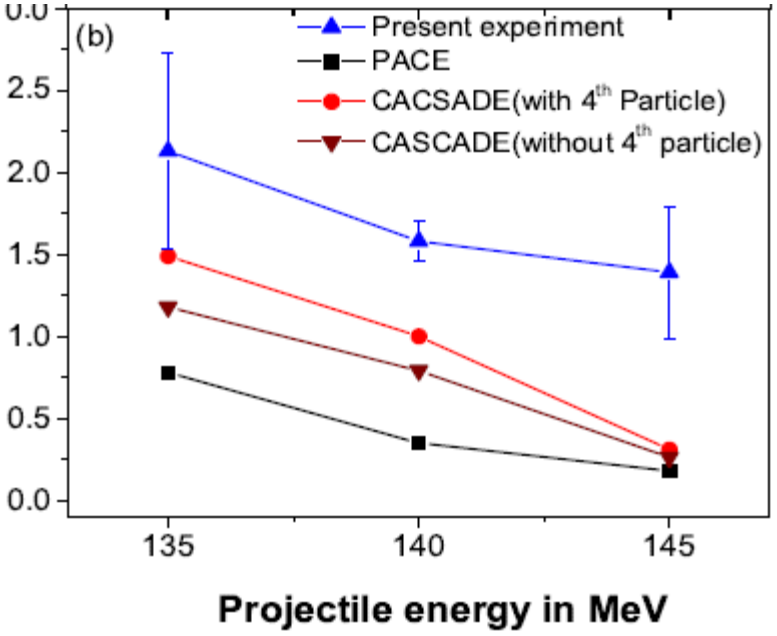
2p, 2pn, α, 3p, α2p, 3pn

- Enhancement of α2p , 3p, 4p
- 2 α2p compared to Pace

(statistical model calculation)

Fusion evaporation channel of $^{32}S+^{92}Mo$

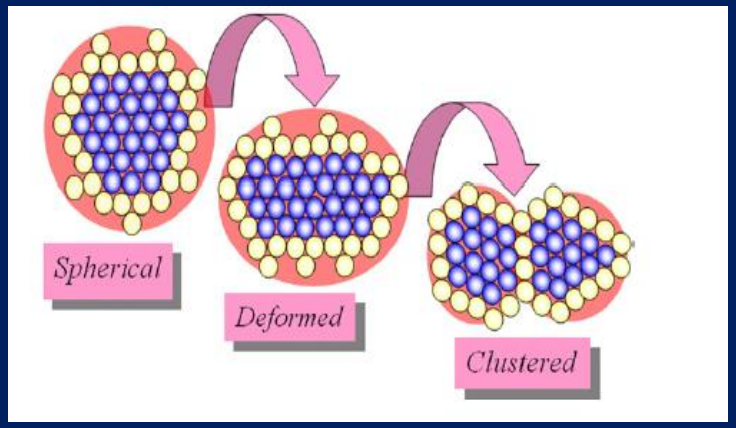




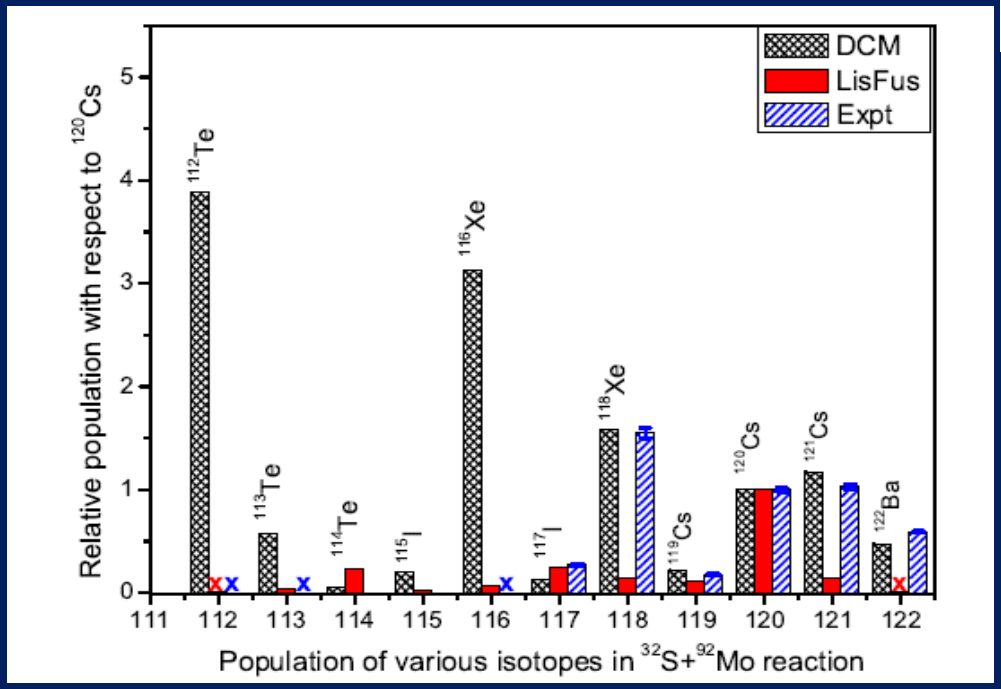
J.Ray, U.Datta et al,

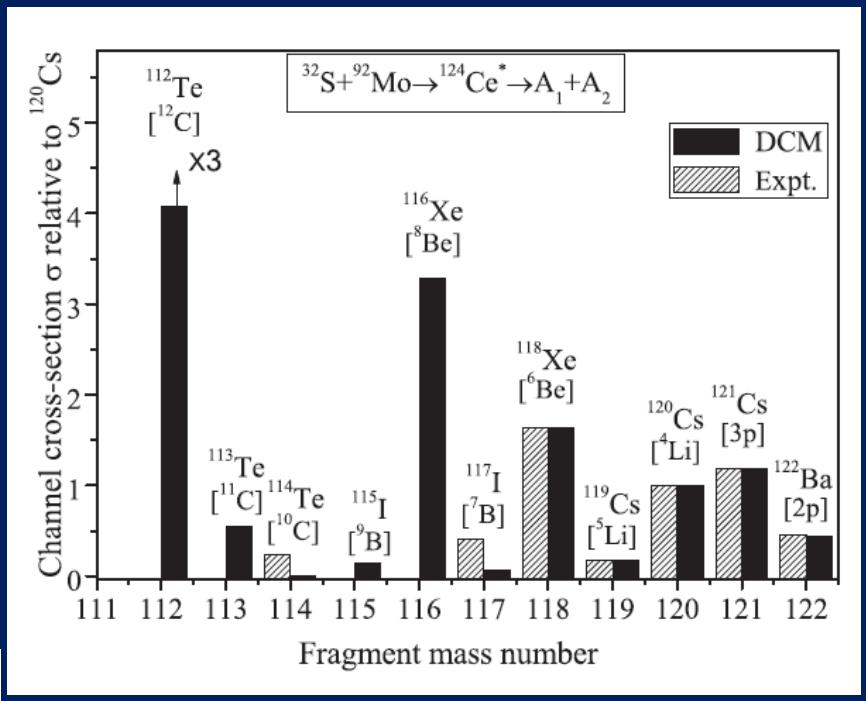
FIG. 5: Comparison of experimental result with PACE4 calculation of $^{32}S + ^{92}Mo$ at 145 MeV using different values of (a) fission barrier scaling factor, K_f= 0.4, 0.8, 1.0; (b) level density parameter constant, K = 6, 8 and 10.

Evaporation of "hot" and rotating ^{124}Ce



U.Datta , J. Ray et al,





Dynamical Cluster model ,
A.Kaur PRC2014, 2015

Lee Sobotka talk

pre-equilibrium cluster emission
Schuetrumpf & Nazarewicz PRC96, 2017 ,

Collaboration

U.Datta[1], J.Ray[1] , I. Ray[1] , G.Mondal, R. K. Bhowmik[2], A.Chakraborty[3], S. Chakraborty[1,4], S.Ganguly[5], R.Garg[6], S.Goel[6], S. Mandal[6], B. Mukherjee[3], P. Mukherjee[7], S.Muralithar[2], D. Negi[2], M. Saxena[5], A. Rahaman[1,8], I. Ray[1], Purnima Singh[9], A. K. Singh[9], R. P. Singh[2] and INGA collaboration

[1]Saha Institute of Nuclear Physics,Kolkata

[2]Inter University Accelerator Centre (IUAC), New Delhi

[3]Viswa Bharati University, Bolpur, WB, India

[4] Camelia Institute of Technology, Kolkata

[5]Chandannagar College, Chandannagar

[6]University of New delhi, New Delhi

[7]St. Xaviers College, Kolkata

[8]Jalpaiguri Govt. Engg. College, Jalpaiguri, WB

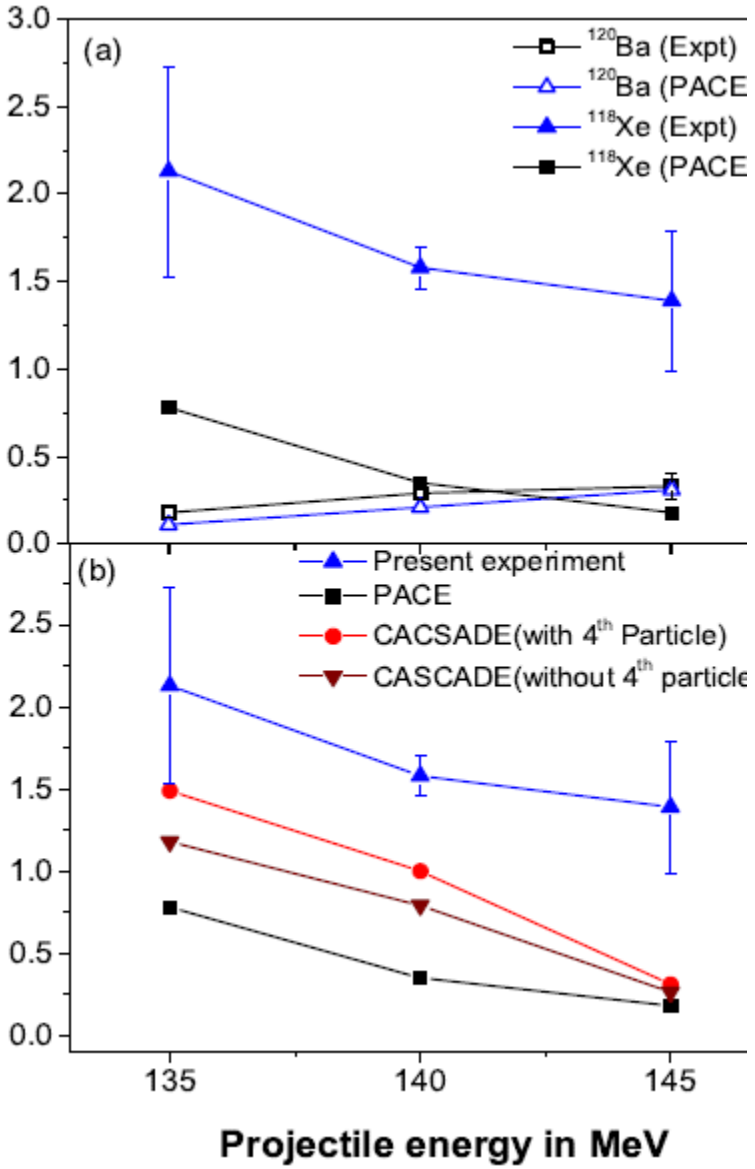
[9]Indian Institute of Technology, Kharagpur


INSTITUTE OF NUCLEAR PHYSICS
THANK YOU

- What we can learn from cluster??
- Why we want to study clusters in nuclei??
- Symmetry cluster and asymmetry cluster
- ^{96}Ru (Z=44, N=52, S_n= 10.696, S_p=7.348 Q_α=1.696 MeV)
- Description of simple experiment at India
- Population of states by alpha transfer
- Symmetry cluster near beta stability states
- Population nuclei near drip line
- Cluster structure near drip line

TABLE I:

	Q value in M
$^{124}Ce \xrightarrow{-4p2n} {}^{118}Xe$	-32.04
$^{124}Ce \xrightarrow{-\alpha 2p} {}^{118}Xe$	-3.74
$^{124}Ce \xrightarrow{-^{6}Be} {}^{118}Xe$	-5.12



Collaboration

Ushasi Datta[1], J.Ray[1], G. Mondal, R. K. Bhowmik[2], S. Chakraborty[1], R. Garg[3], S. Goyal[3], S. Ganguly[5], S. Kumar[3], S. Mandal[3], B. Mukherjee[4], S.Muralithar[2], A.Rahaman [1,6] , D.Negi[2], M. Saxena[4], and R. P. Singh[2] and INGA collaboration

[1] Saha Institute of Nuclear Physics, Kolkata, India , [2] Inter University Accelerator Centre (IUAC), New Delhi, India , [3] University of New Delhi, New Delhi, India [4] Viswa Bharati University, Santiniketan, India, [5] Chandannagar College, Chandannagar, India , [6] Jalpaiguri Govt. Engg. College