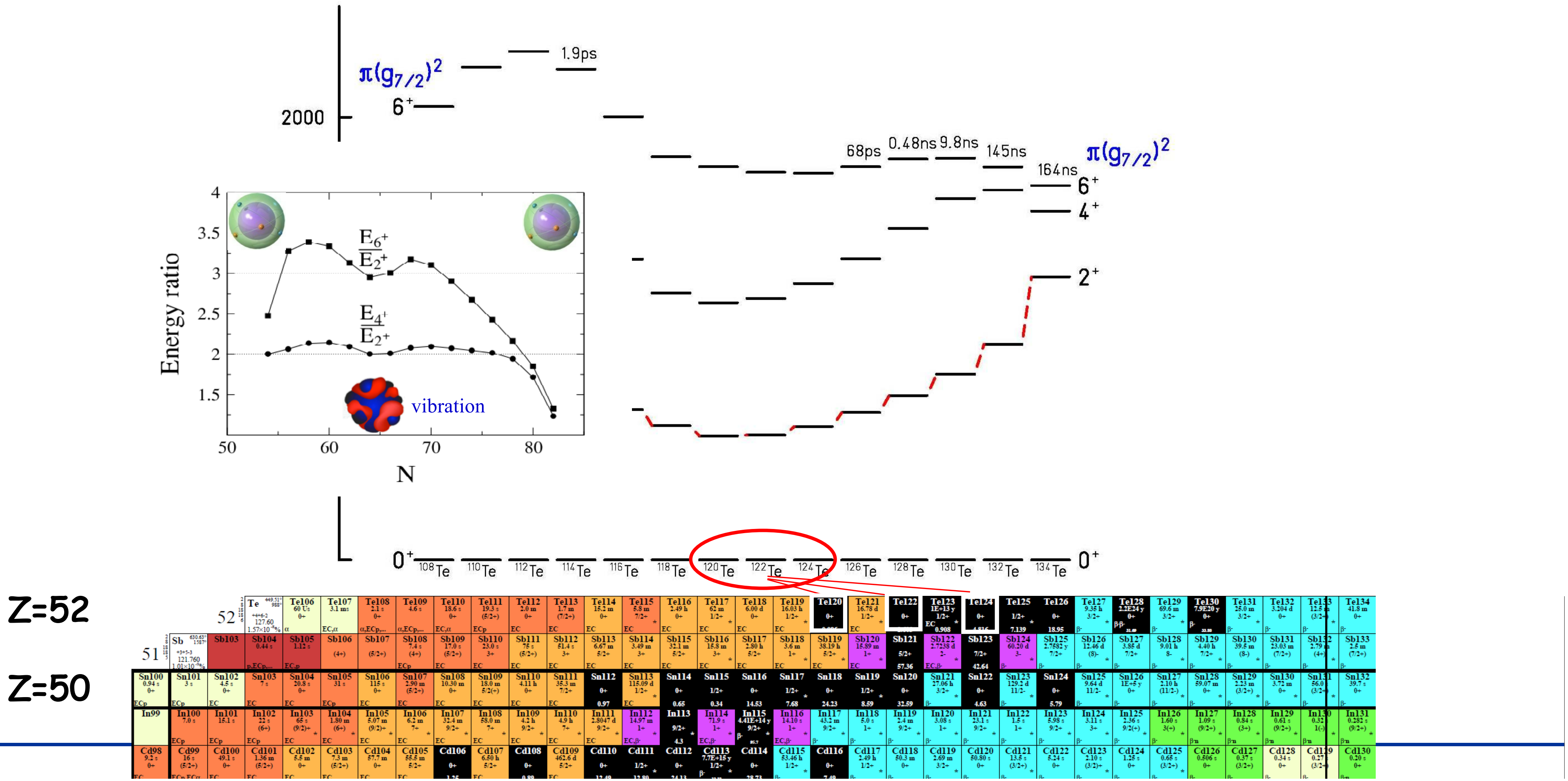
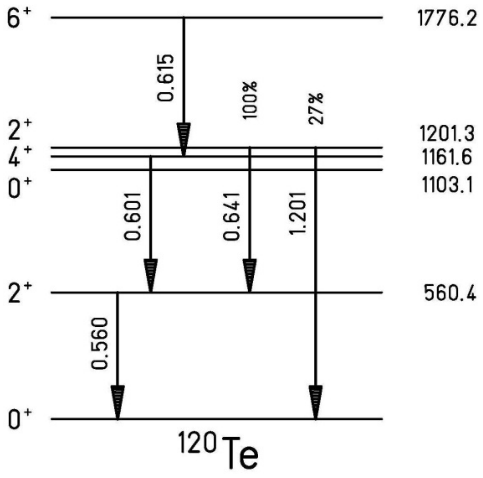
^{120}Te - Collapse of the vibrational picture

Mansi Saxena
Heavy Ion Laboratory, Warsaw

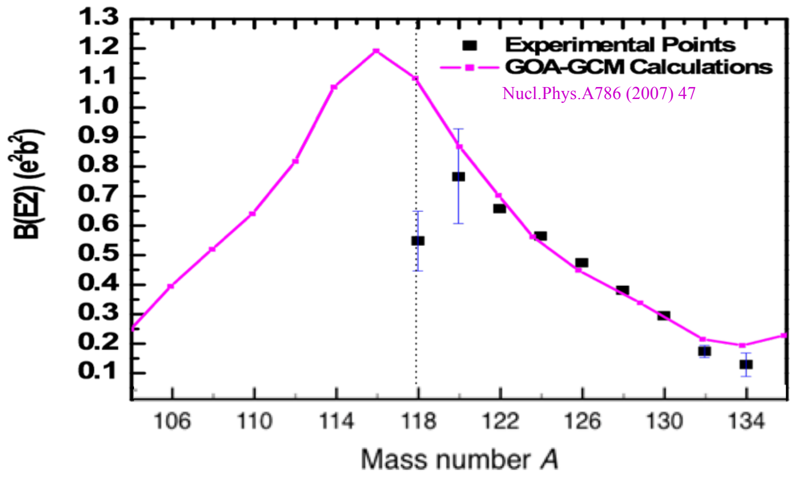
Systematics of Te isotopes (Z=52)

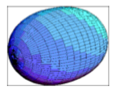


Collectivity of Te isotopes (Z=52)

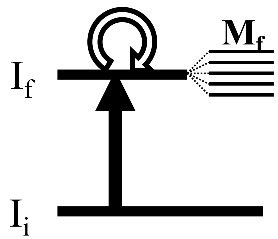


vibrational structure





Coulomb excitation / Re-orientation Effect



two unknowns:

- ➢ B(E2; $0^+ \rightarrow 2^+$)
- ➢ $Q_s(2^+)$ **= 0 !**

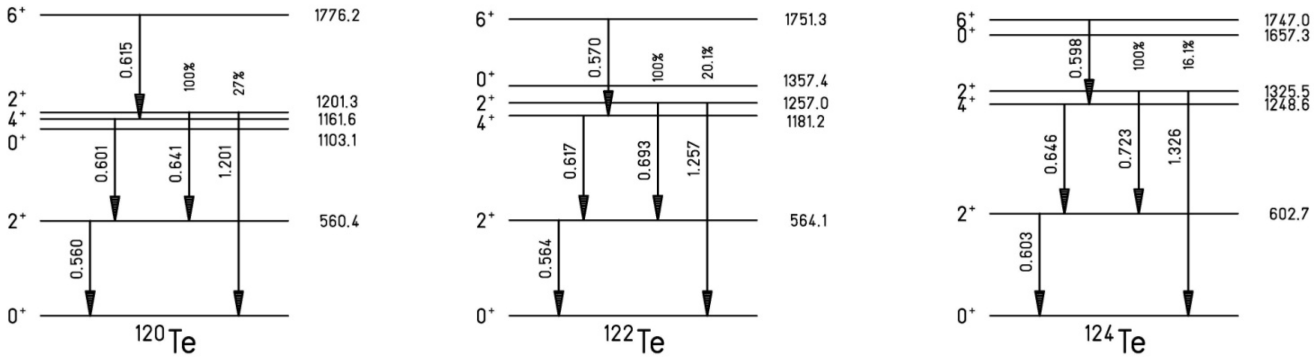
Isotope	Q_{2+}(eb)
^{120}Te	
^{122}Te	**-0.47±0.03**
^{124}Te	**-0.45±0.04**
^{126}Te	**-0.23±0.04**
^{128}Te	**-0.22±0.03**
^{130}Te	**-0.12±0.04**

large **quadrupole moments** compared to rotor with $\gamma = 0^0$

$$B(E2;0^+ \rightarrow 2^+) = \frac{5}{16\pi} Q_0^2$$

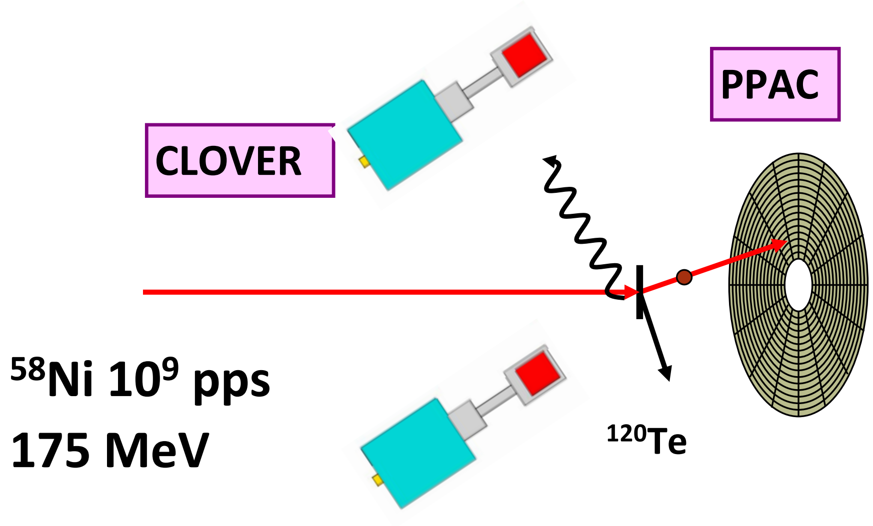
$$Q_{2^+} = -\frac{2}{7} \cdot Q_0$$

Motivation !!!!



- To study the nuclear structure of ^{120,122,124}Te nuclei
- To measure the B(E2; $0^+ \rightarrow 2^+$) value for ^{120}Te to a much higher precision !
- To measure the reduced transition probabilities of higher lying states !

Experimental Set up @ IUAC, New Delhi

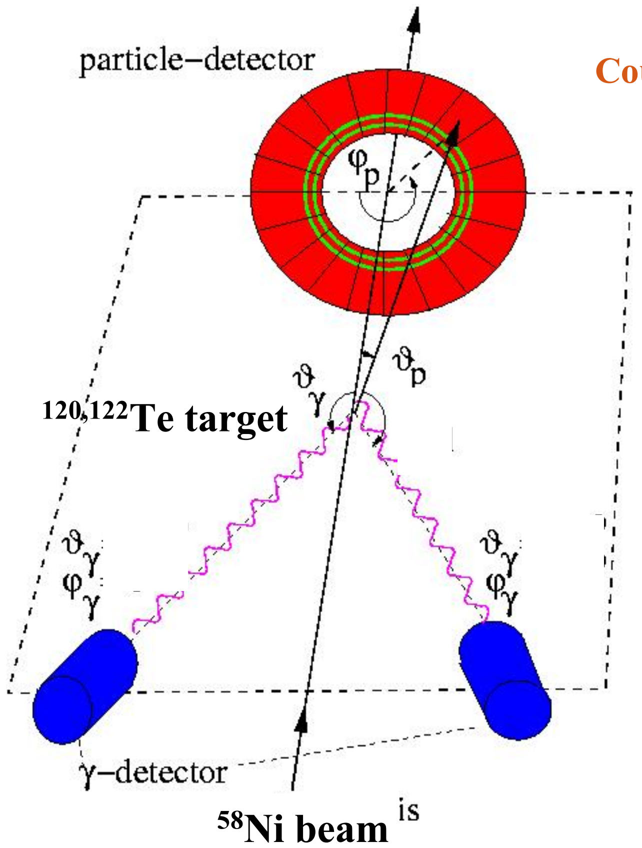


^{58}Ni $\rightarrow$ ^{120,122,124}Te (~ 0.15 mg/cm^2 thickness) @ 175MeV

Coulomb barrier ~ 240 MeV (lab frame)

IUAC, New Delhi

Experimental Set up @ IUAC, New Delhi



^{58}Ni → ^{120,122,124}Te (~ 0.15 mg/cm^2 thickness) @ 175MeV

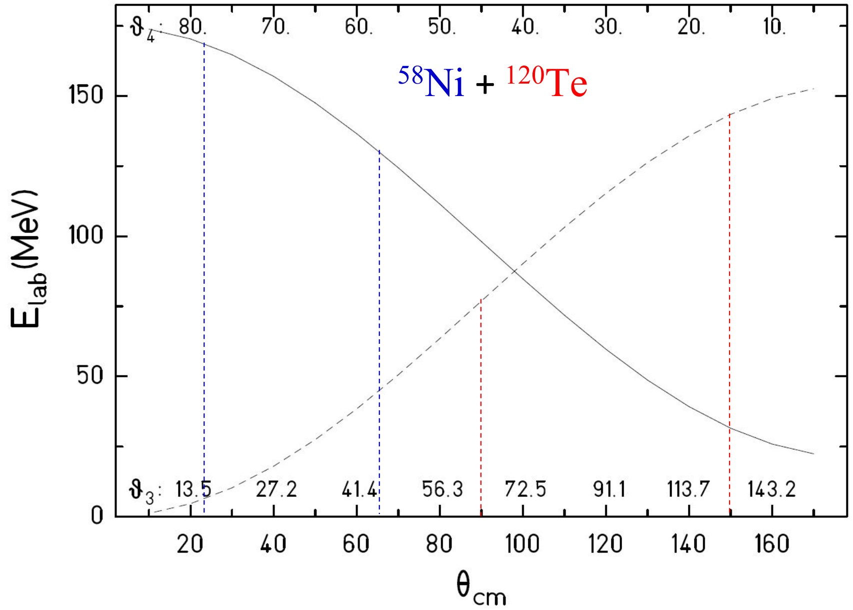
Coulomb barrier ~ 240 MeV (lab frame)

- Scattered projectiles and recoils are detected in an annular gas-filled parallel-plate avalanche counter (PPAC), subtending the angular range ϑ_{lab} = 15° - 45° in the forward direction.
  20 azimuthal segments with $\Delta\Phi=18^0$.

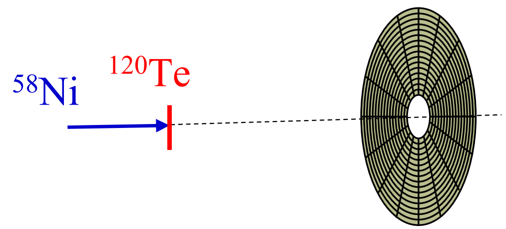
- De-excitation γ -rays are detected in four clover detectors mounted at ϑ_γ ~ 135° with respect to the beam direction.
- Data was collected in particle – γ coincidence AND.

⟶ Dr. R. Kumar – "facilities on COULEX" :-: Wednesday !

Analysis & Results of ^{58}Ni + ^{120}Te Experiment

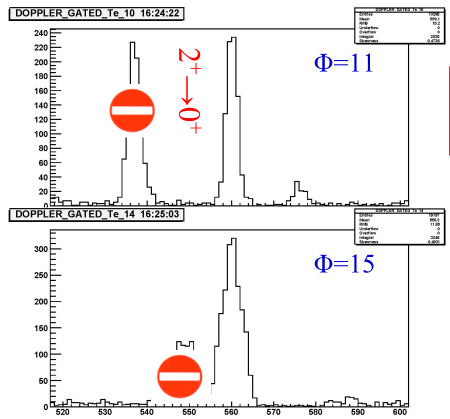


Φ segmentation



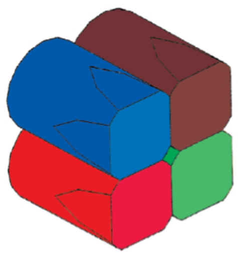
projectile and target nucleus are measured in PPAC

^{58}Ni in PPAC: distant collisions



γ-ray energy (keV)

2 γ-rays for same decay



clover Ge-detector

Results: ^{58}Ni + ^{120}Te Experiment

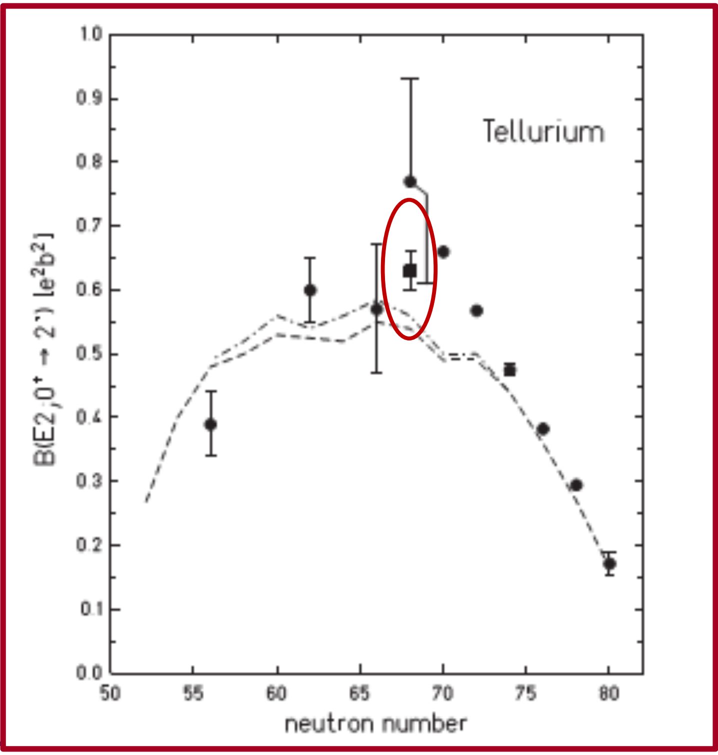
DOUBLE RATIO :

$$B\left(E2,\,^{120}Te\right) = B\left(E2,\,^{122}Te\right)\frac{\sigma_{^{122}Te}}{\sigma_{^{120}Te}}\left\{\frac{I_\gamma\left(^{120}Te\right)}{I_\gamma\left(^{58}Ni\right)}\right\}\left\{\frac{I_\gamma\left(^{58}Ni\right)}{I_\gamma\left(^{122}Te\right)}\right\}$$

^{120}Te + ^{58}Ni : ⟶

$$\langle 2^+ \| M(E2) \| 0^+ \rangle = 0.816(5)$$

$$B(E2; 0^+ \rightarrow 2^+) = 0.666(20) e^2 b^2$$



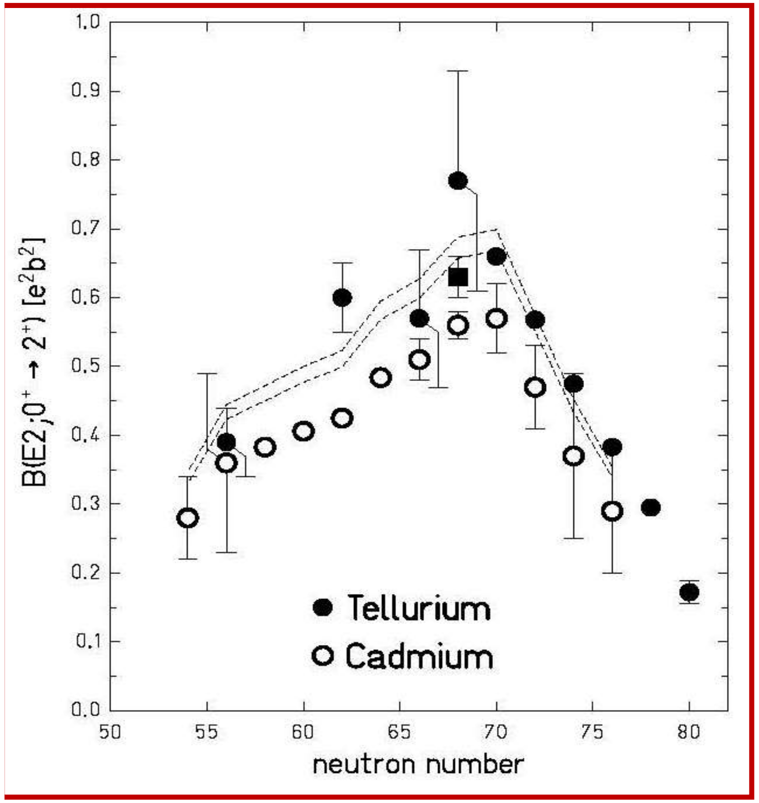
Comparison with LSSM calculations

✓ Effective charge used were $e_\nu = 0.8e$, $e_\pi = 1.5e$
✓ SM calculation bottom dashed line with $d_{5/2}\, g_{7/2}$ inverted
✓ Model space ($g_{7/2}$, $d_{5/2}$, $d_{3/2}$, s, $h_{11/2}$) was used.
✓The model space was limited for midshell nuclei allowing excitation of four neutrons in the $h_{11/2}$ sub shell

T. Back et.al, Phys.Rev.C 84 (2011)041306

Results: ^{58}Ni + ^{120}Te Experiment

Comparison with Cd isotopes

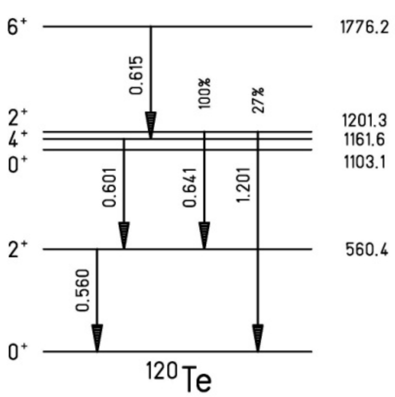


✓The dashed curve is calculated from the exp. Cd data scaled by a factor of $(52/48)^2$

✓The 2 proton particle states (Te) are identical to the 2 proton hole states (Cd)

Z=52	114Te	115Te	116Te	117Te	118Te	119Te	120Te	121Te	122Te	123Te	124Te	125Te	126Te	127Te	128Te
	113Sb	114Sb	115Sb	116Sb	117Sb	118Sb	119Sb	120Sb	121Sb	122Sb	123Sb	124Sb	125Sb	126Sb	127Sb
	112Sn	113Sn	114Sn	115Sn	116Sn	117Sn	118Sn	119Sn	120Sn	121Sn	122Sn	123Sn	124Sn	125Sn	126Sn
	111In	112In	113In	114In	115In	116In	117In	118In	119In	120In	121In	122In	123In	124In	125In
Z=48	110Cd	111Cd	112Cd	113Cd	114Cd	115Cd	116Cd	117Cd	118Cd	119Cd	120Cd	121Cd	122Cd	123Cd	124Cd
	62		64		66		68		70		72		74		76

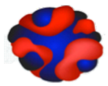
Experimental Results of ^{120,122,124}Te

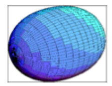


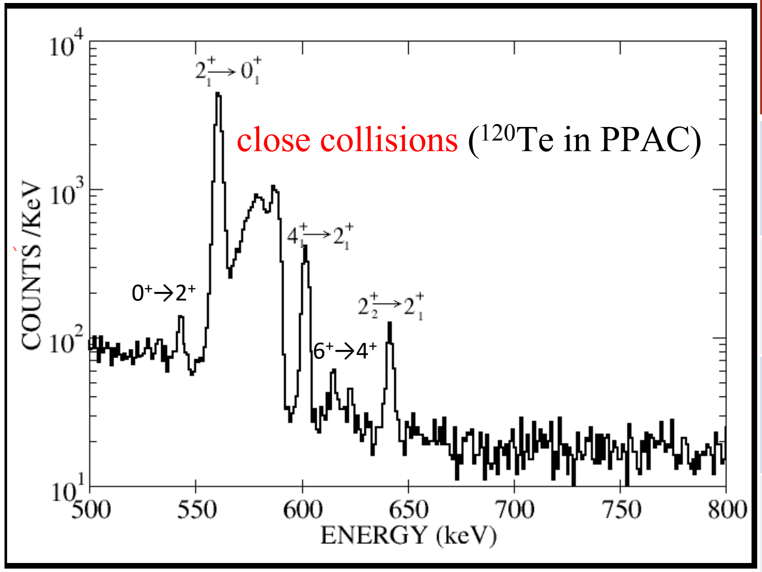
PHYSICAL REVIEW C **90**, 024316 (2014)

Rotational behavior of ^{120,122,124}Te

M. Saxena,[1] R. Kumar,[2] A. Jhingan,[2] S. Mandal,[1] A. Stolarz,[3] A. Banerjee,[1] R. K. Bhowmik,[2] S. Dutt,[4] J. Kaur,[5] V. Kumar,[6] M. Modou Mbaye,[7] V. R. Sharma,[8] and H.-J. Wollersheim[9]







	Experiment	Vibrator	Asymmetric Rotor (γ = 27.5)	IBA-2
$\frac{B(E2;4^+ \to 2^+)}{B(E2;2^+ \to 0^+)}$	1.640(33)	2.0	1.426	1.514
$\frac{B(E2;6^+ \to 4^+)}{B(E2;2^+ \to 0^+)}$	2.37(58)	3.0	1.781	1.82
$\frac{B(E2;2_2^+ \to 2^+)}{B(E2;2^+ \to 0^+)}$	1.215(50)	2.0	0.906	1.560
$\frac{B(E2;2_2^+ \to 2^+)}{B(E2;2_2^+ \to 0^+)}$	82.9(47)		20.42	105

Conclusions of the Experiment

PHYSICAL REVIEW C **90**, 024316 (2014)

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- **B(E2; $0^+ \rightarrow 2^+$) well described by the shell model**
  - **quadrupole deformation $\beta = 0.18$**

- **Experimental excitation energies and transition probabilities can be described by triaxial rotor model.**

Study of static quadrupole moments in ^{120}Te

Heavy Ion Laboratory

- For ^{120}Te the quadrupole moments (Q_{2+}) are not known experimentally.

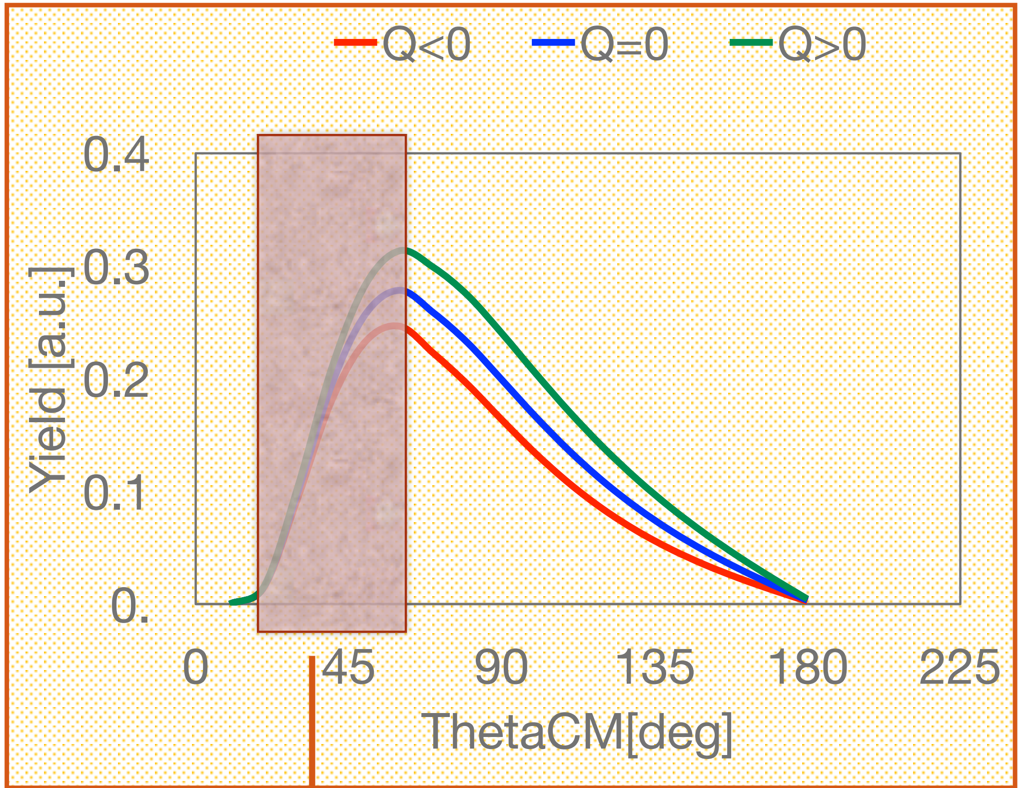
- Quadrupole moments (Q_{2+}) for ^{120}Te will further give us information about the deformation in this nuclei.

Sensitivity of Q(2+)

- Excitation probability depends on:
  - projectile scattering angle interaction strength,
  - size and sign of quadrupole moment
- Gamma yields are experimental observable

$$P^{(2)}_{0\to 2}(\theta,\xi) = P^{(1)}_{0\to 2}(\theta,\xi)\cdot\left[1+\sqrt{\frac{7}{2\pi}\frac{5}{4}}\cdot\frac{A_p}{Z_p}\cdot\frac{\Delta E}{1+{A_p}/{A_t}}\cdot Q_2\cdot K(\theta,\xi)\right]$$

$$Q(2^+) = -\sqrt{\frac{2\pi}{7}\frac{4}{5}}\cdot\langle 2\|M(E2)\|2\rangle$$



I.U.A.C, Delhi

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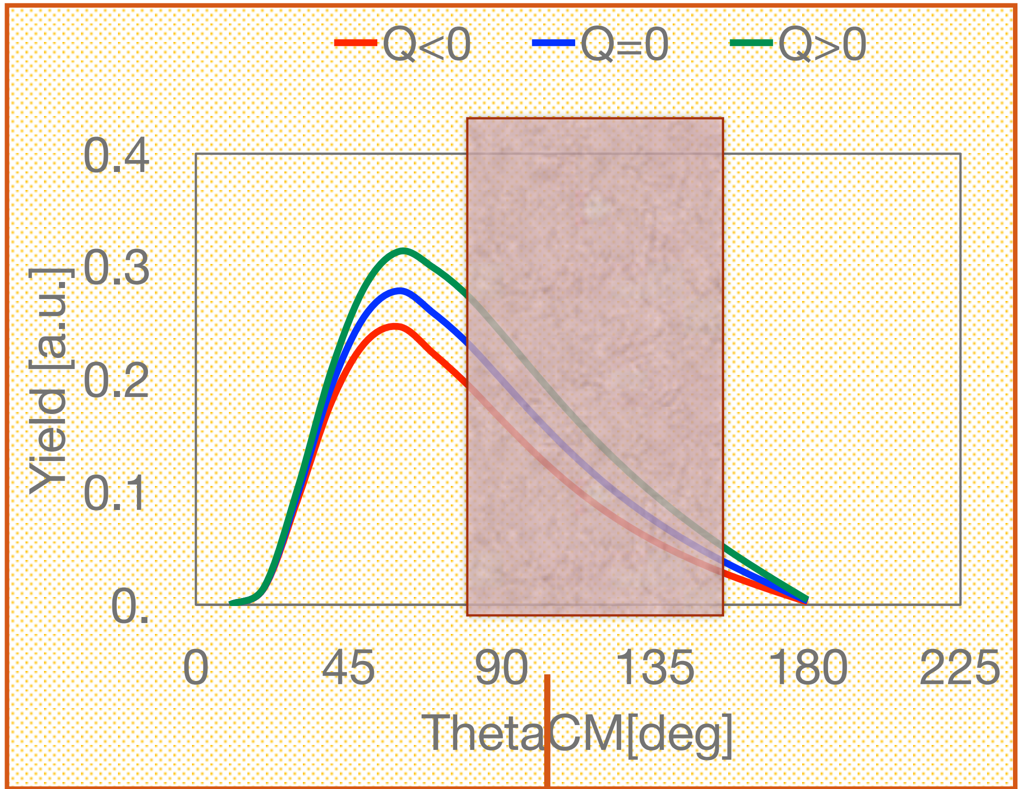


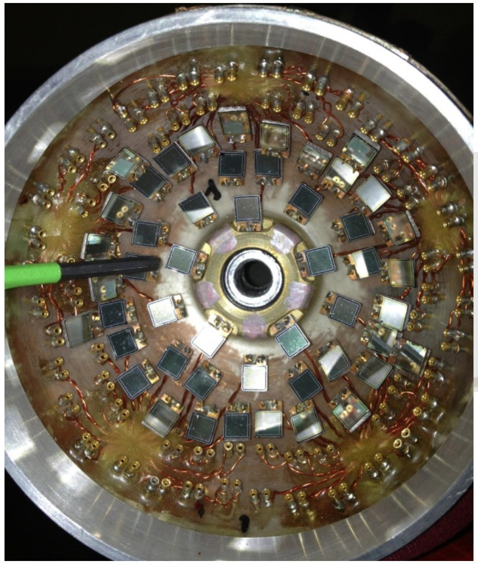
Complementary measurements at Delhi & Warsaw !!

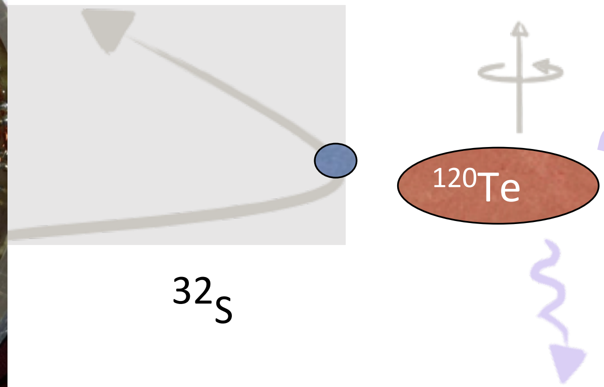
HIL, WARSAW

Experimental Set Up at HIL, Warsaw

$^{32}S \rightarrow {}^{120}Te$ (~ 0.15 mg/cm^2 thickness) @ 91 MeV

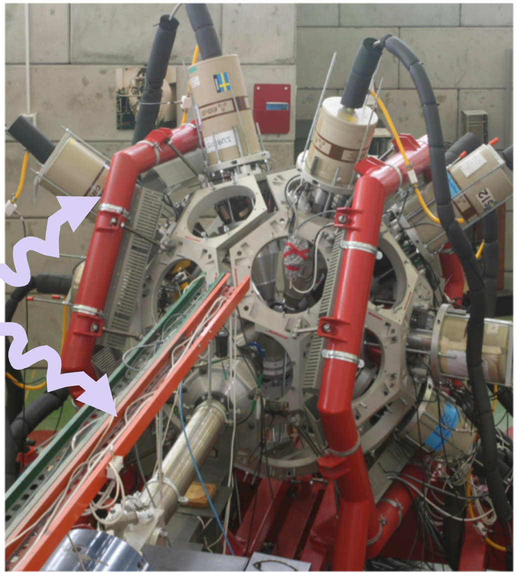
Coulomb barrier ~ 125 MeV (lab frame)





^{32}S

91 MeV



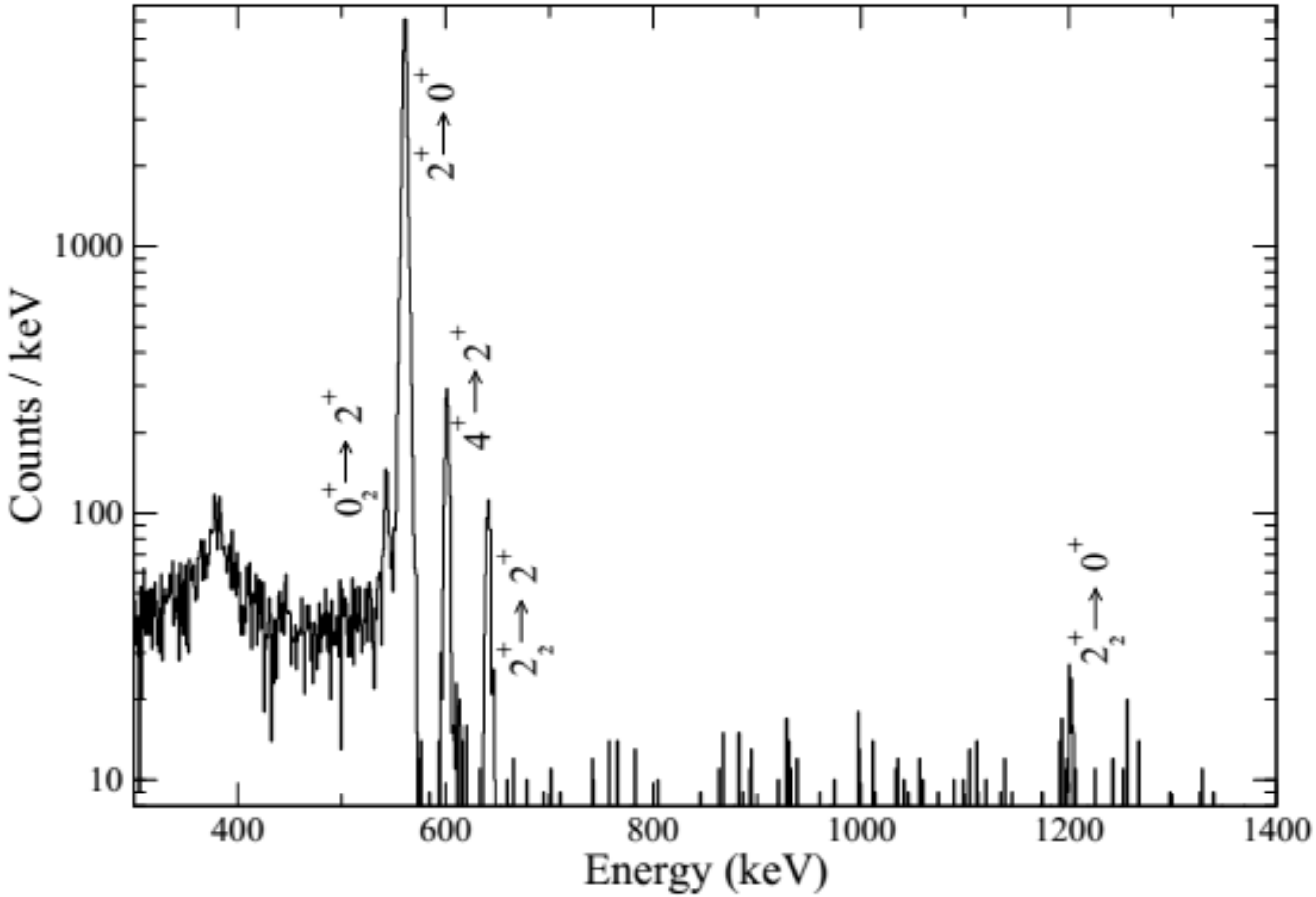
48 PiN-Diode HI Detectors

θ_{LAB}: 110÷170 deg

15 HPGe & ACS

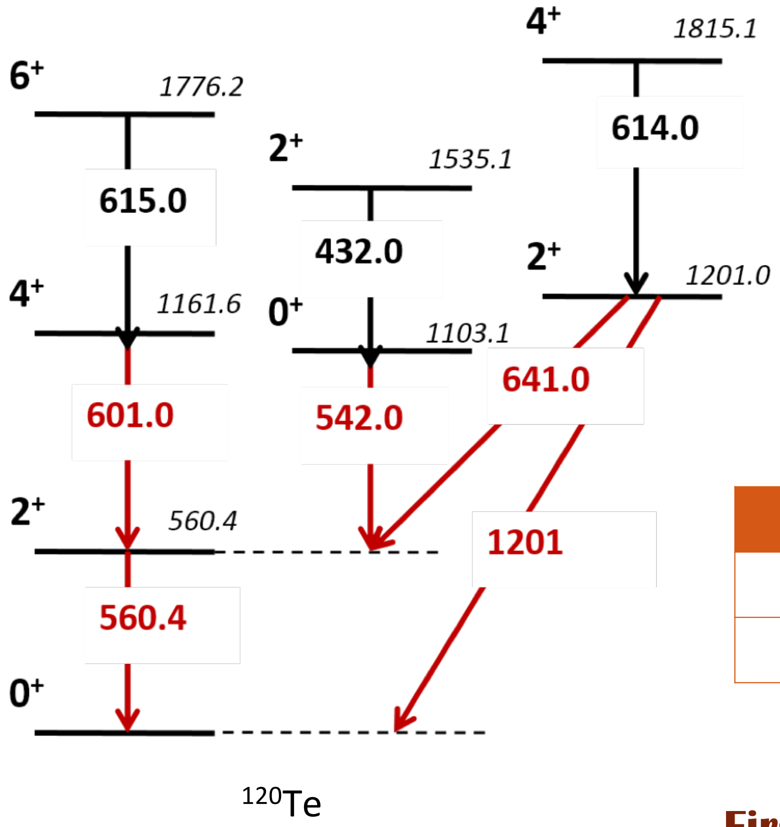
Efficiency@1.3MeV: 0.5%

Doppler Corrected γ-ray Spectrum



Experimental Results

GOSIA – Coulomb Excitation least squares search code



Transition $I_i \rightarrow I_f$	$\|\langle I_f\|\|E2\|\|I_i\rangle\|$ (Exp)	$B(E2)\downarrow$ (e^2b^2)
$2_1^+ \rightarrow 0_1^+$	0.778±0.014	0.121±0.004
$4^+ \rightarrow 2_1^+$	1.342±0.019	0.200±0.006
$2_2^+ \rightarrow 2_1^+$	0.955±0.020	0.183±0.009
$2_2^+ \rightarrow 0_1^+$	0.161±0.011	0.0052±0.0008

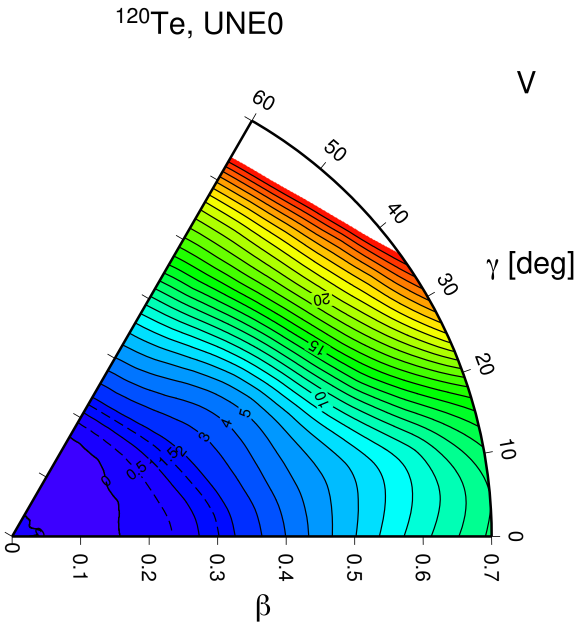
State (I)	$\langle I\|\|E2\|\|I\rangle$ (Exp)	Qs (eb)
2_1^+	-0.55±0.04	-0.41±0.03
4_1^+	-1.02±0.25	-0.77±0.19

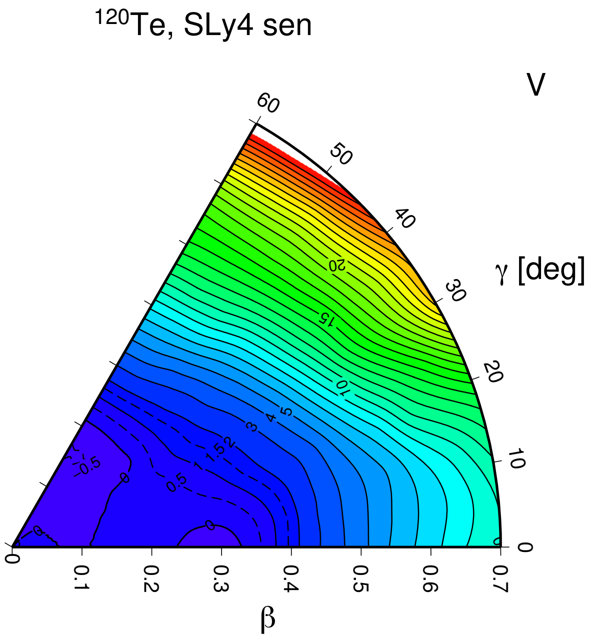
First experimental proof of deformation in ^{120}Te nucleus!!

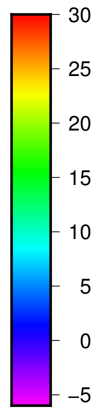
- Acta Physica Polonica B Vol 49 (2018)

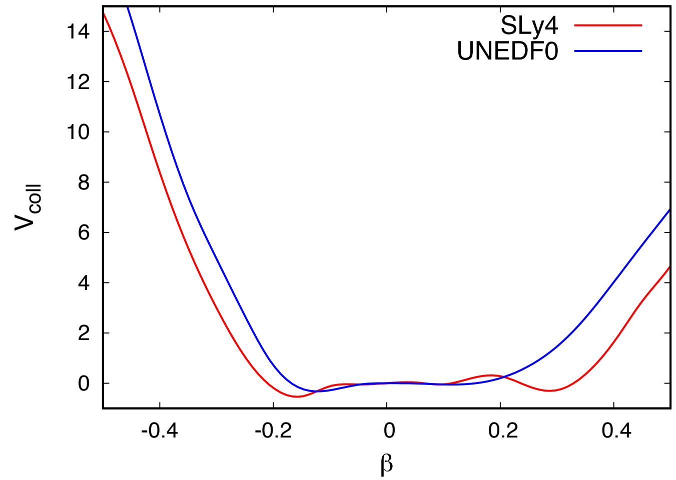
Collective Potential Energy

- ✓ General Bohr Hamiltonian based on microscopic mean field theory
- ✓ Two variants of Skyrme interaction – SLy4 & UNEDF0





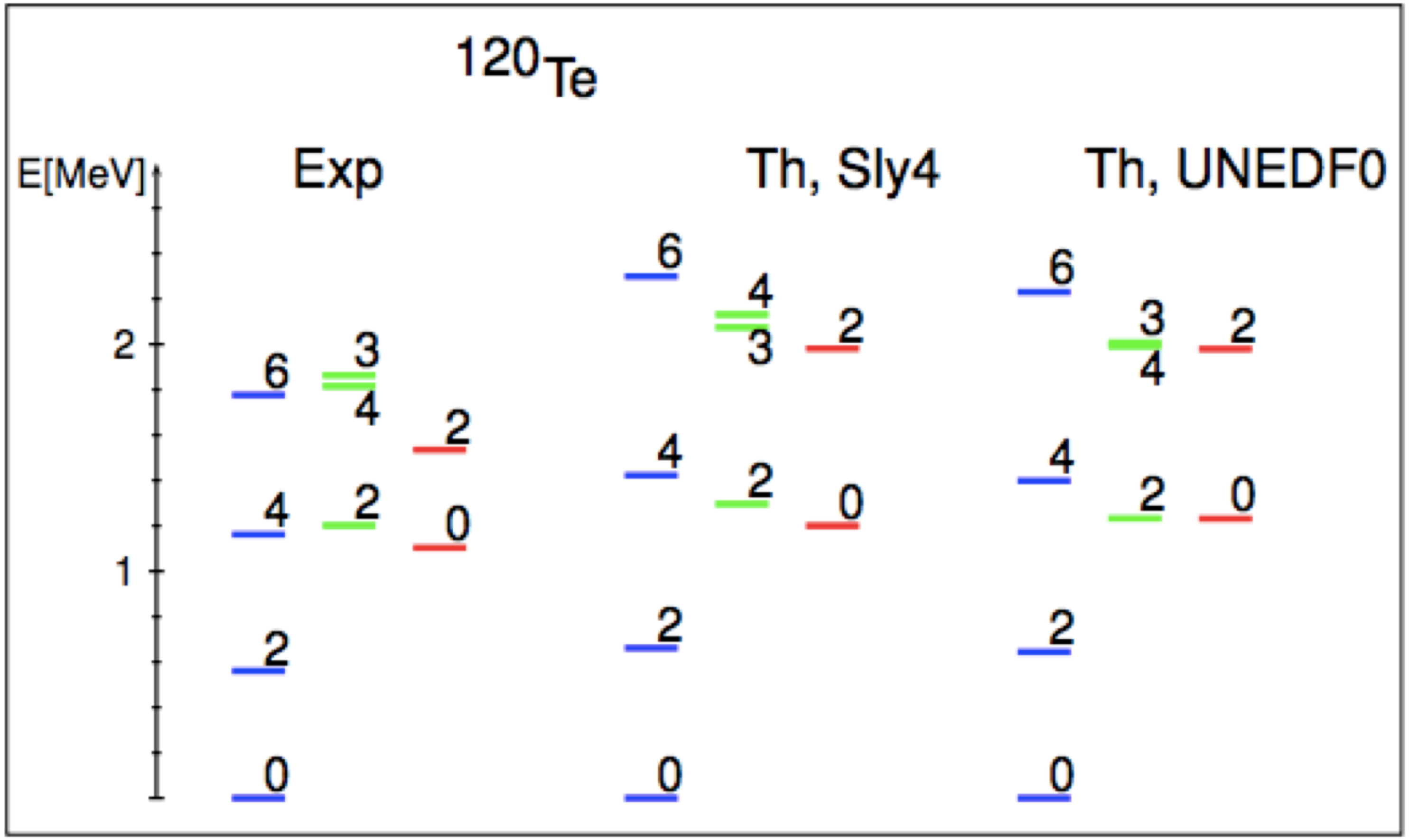




- ❖ Weak dependence on the γ parameter
- ❖ Flat minima in the β axis (UNEDF0)

L. Próchniak et. al , HIL Annual Report 2017

Energy levels



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E2 Matrix Elements

Table 1: Experimental and theoretical matrix elements of the $E2$ operator (in [eb])

I_1	I_2	$\langle I_1 \| E2 \| I_2 \rangle$ Exp	Th, SLy4	Th, UNEDF0
Non-diagonal				
2_1	0_1	0.778 ± 0.014	0.850	0.698
4_1	2_1	1.342 ± 0.019	1.598	1.298
2_2	2_1	0.955 ± 0.020	1.119	0.955
2_2	0_1	0.161 ± 0.011	0.054	−0.019
Diagonal				
2_1	2_1	-0.55 ± 0.04	−0.421	−0.140
4_1	4_1	-1.02 ± 0.25	−0.982	−0.419

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Summary

- ✓ Two experiments were performed – different scattering ranges

  IUAC, Delhi ⟶ $\vartheta_{lab} = 15° - 45°$ (Forward)

  HIL, Warsaw ⟶ $\vartheta_{lab} = 110° - 170°$ (Backward)

- ✓ Magnitudes and relative signs of the transitional matrix elements of the low-lying states in ^{120}Te were determined using GOSIA.

- ✓ Non-zero value of the diagonal matrix elements of the 2^+ and 4^+ states.

- ✓ Theoretical calculations performed using the GBH based on the microscopic mean field theory (SLy4 and UNEDF0)

List of collaborators

P. J. Napiorkowski, M. Komorowska, M. M.-Minda, M. Palacz, W. Piątek, L. Próchniak, J. Srebrny, A. Stolarz, K. Wrzosek-Lipska

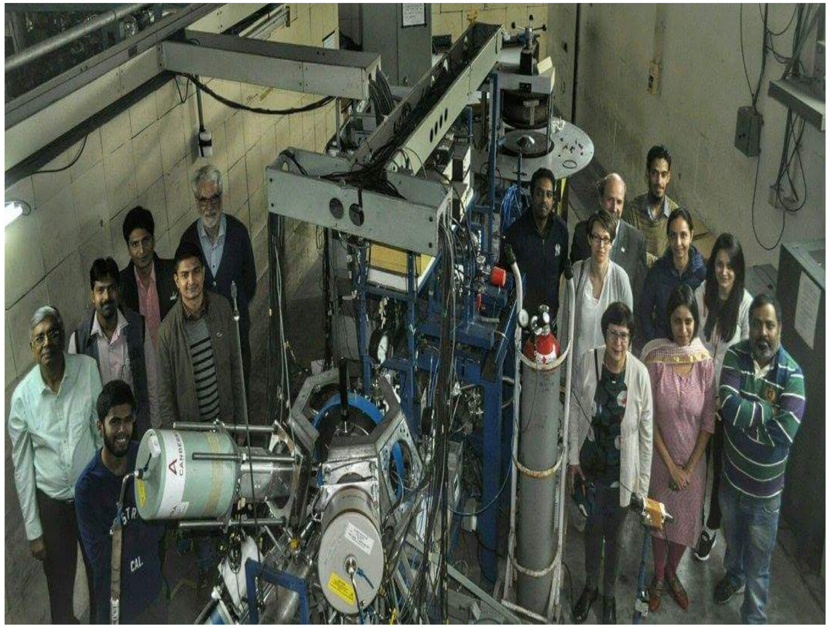
HIL, University of Warsaw, Warsaw, Poland

M. Kicinska-Habior, A. Korgul

Faculty of Physics, University of Warsaw, Warsaw, Poland

C. Henrich,

Institut für Kernphysik, T.U.Darmstadt, Germany



R. Kumar, A. Jhingan

I.U.A.C., New Delhi India

H. J. Wollersheim

GSI ,Darmstadt, Germany

P. Doornenbal

RIKEN, Japan

S. Dutt

Department of Physics, AMU, ALigarh, India