Form No. BTR-1 for fresh proposals

BEAM TIME REQUEST
FOR THE UTILISATION OF IUAC PELLETRON

INTER-UNIVERSITY ACCELERATOR CENTRE
Accelerator Based Research Centre of UGC

INFORMATION ABOUT BTR - FORMS

BTR-1 Beam Time Request for Fresh Proposals
BTR-2 Beam Time Account (BTA) for Thesis Proposals
BTR-3 Request of Funds (along with Beam Time) for Fresh Proposals from Universities
BTR-4 Beam Time Request for Ongoing Proposals

Proposal No. **A U C** 1 **(to be filled by IUAC)**

Field (Please tick the relevant one)

Atomic Physics Materials Science **Nuclear Physics √** Radiation Biology AMS Others

1. **TITLE OF THE EXPERIMENT**: **Coulomb excitation of ^{120,122}Te isotopes**

2. (A) **PRINCIPAL INVESTIGATOR:**

Name ***Dr. Rakesh Kumar***

Designation Scientist-E
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Mailing Address GDA/INGA Group
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Mobile No. 9868207046
E-Mail Address rakuiuac@gmail.com Fax 011-26893666

2(B) **CO – PI** ***Dr. H. J. Wollersheim***
Designation Scientist
Affiliation GSI, Darmstadt, Germany
Tel. No. +49-(0)6159-71-2670

3. **COLLABORATORS** (including IUAC personnel, Research Scholars) *

S. No.	Name	Affiliation	Contact Phone No., Fax No. & E-mail Address
1.	Dr. H.J.Wollersheim	GSI	h.j.wollersheim@gsi.de
2.	Dr. R.K.Bhowmik	GGDU	ranjanbhowmik@gmail.com
3.	Dr Pieter Dornenbal	RIKEN	pieter@ribf.riken.jp
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9.	Mansi Saxena	DU	mansi.aqua@gmail.com
10.	Mr Somnath Nag	IIT kharagpur	somnanag@gmail.com
11.	Mr. Abhishek Yadav	AMU	abhishekyadav117@gmail.com
12.	Mr Vijay Raj sharma	AMU	phy.vijayraj@gmail.com
13.	Dr. Surjeet Mukherjee	MSU	smukherjee_msuphy@yahoo.co.in
14.	Prof N.L.Singh	MSU Baroda	singhnandlal@gmail.com
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16.	Dr. Tarkeshwer Trivedi	TIFR	ttrivedi1@gmail.com
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20.	Mr. R. K. Gujjar	IUAC	pritam.radhakishan@gmail.com

4A. DETAILS OF TA/DA SUPPORT NEEDED (SPECIFY NUMBERS)
[For university / college personnel only, maximum number four; (travel support is as per entitlement, but limited to AC 2 tier fare)]

Faculty **2** Student **2** Others

4B. BRIEF BIO-DATA OF P.I. (Please attach as per the format given in the Annexure**)**

5. TOTAL NUMBER OF SHIFTS REQUIRED FOR COMPLETION OF THE EXPERIMENT (1 SHIFT = 8 HRS.): (Justify the requirement in the annexures)

Note: Shift allotment will be done only for the first run if the proposal is accepted. For sanctioning of subsequent runs, form BTR-4 is to be submitted to AUC following the first run. Subsequent run sanction is subject to AUC review.

No. of runs proposed		No. of shifts proposed in each run	(I Run)	(II Run)	(III Run)
	1		**21**		

6. BEAM REQUIREMENTS (**Only for the first run** : Normally one type of ion in one run, but for more than one ion species in one run, requirement is to be given in order, changes are not possible later)

Ion species (with Mass no.)	Energy (MeV) Min.	Energy (MeV) Max.	Current (pnA) Min.	Current (pnA) Max.	DC/Pulsed	Charge state (if relevant)
^{58}Ni	**175**	**175**	**0.5**		**DC**	**13+**

7. (A) BEAM LINE TO BE USED (please tick the appropriate one) :
BIO LIBR HIRA MAT.SC. **GDA √** GPSC

7. (B) ACCESS-TIME NEEDED IN HOURS (with justification)

	Prior to run	After the run
For the Beam Line	**10**	**5**
For the Data Acquisition System		

8. TARGET / SAMPLE DETAILS

Material	Thickness (μg/cm^2)	Backing (if any) Material	Backing (if any) Thickness	Any special property e.g. hygroscopic, toxic etc.
^{120}Te, ^{122}Te	**500 μg/cm^2**	**Carbon**	**20-40 μg/cm^2**	

Note :

1) Users are requested to bring their targets properly mounted on standard target frames or on standard strip to be fixed on the ladder. Please make sure that no material is to be used which can outgas. Any residual radio-activity associated with the targets after irradiation should be thoroughly checked in consultation with the health physics group at IUAC.

2) If targets are to be prepared at IUAC, user must write to Convenor AUC well in advance, to book target laboratory time and prepare the targets himself/herself at IUAC. Consultation will be provided.

Targets to be prepare at IUAC, New Delhi.

9. ONLINE/INSITU MEASUREMENTS PLANNED WITH JUSTIFICATION FOR THE BEAM SELECTION AND NO. OF SHIFTS ASKED (include also a brief description of any Offline studies planned and place of offline studies).
Limit your description to **maximum of 200 words** of text. (Annexure I)

***Kindly see Annexure 1*.**

10. SCIENTIFIC MOTIVATION:
Limit your description to **maximum of 200 words** of text only. (Annexure II)

Kindly see Annexure 2

11. IMPORTANCE OF THE PROPOSED EXPERIMENT IN THE CONTEXT OF THE INTERNATIONAL STATUS. Limit your description to **maximum of 200 words** only. A list of most recent publications in journal in the field relevant to the project must be submitted.
Kindly see Annexure 3

Note: Use annexure for figures/tables/references for items 9,10 & 11 above.

12A. Name and Affiliation of the theoretical physicist(s) associated with this proposal :

12B. Theoretical simulations / calculations in support of the experimental ideas :
(Limit to **maximum of 100 words** only)

Kindly see Annexure 4

13. Have you used the IUAC Pelletron before?
If yes, when? YES (2008 and 2009) Which beam(s)? ^{58}Ni and ^{14}N.
Publications, if any from the project :

1. **Enhanced 0+g.s.→2+1 transition strength in ^{112}Sn**
   R. Kumar, P. Doornenbal, A. Jhingan, R. K. Bhowmik, S.Muralithar, S. Appannababu, R.Garg, J. Gerl, M. Gorska, J. Kaur, I. Kojouharov, S. Mandal, S. Mukherjee, D. Siwal, A. Sharma, Pushpendra P. Singh, R. P. Singh and H. J. Wollersheim
   Phys. Rev. C 81, 024306 (2010)
2. **Enhanced E2 transition strength in ^{112,114}Sn**
   R. Kumar, P. Doornenbal, A. Jhingan, R.K. Bhowmik, S. Muralithar, P. Reiter, H. Grawe, S. Appannababu, P. Bednarczyk, L. Caceres, J. Cederk¨all, A. Ekstr¨om, R. Garg, J. Gerl, M.Grska, J. Kaur, I. Kojouharov, S. Mandal, S. Mukherjee, W. Prokopowicz, H. Schaffner, D.Siwal, A. Sharma, Pushpendra P. Singh, R.P. Singh, and H.J. Wollersheim
   Act. Phys. Pol. B No3-4 Vol. 42 (2011)
3. ^{14}N data to be published soon.

14. IF THERE IS A Ph.D STUDENT INVOLVED IN THE EXPERIMENT, PROVIDE THE FOLLOWING INFORMATION:

Note: Accelerator Users Committee (AUC) allocates highest priority to the Ph.D projects from universities and teaching institutions. Once a Ph.D. thesis proposal is accepted by AUC, a Beam Time Account (BTA) is opened for the project. The BTA takes care of the whole beam time requirement for the entire Ph.D work over a period of about 3 years. Use BTR-2 form for BTA. The actual scheduling of the beam time from the BTA can be made on a rapid scale through a simple process which just requires submission of duly completed form BTR-4 to the Convenor, AUC (at least six weeks in advance of the proposed run). There is no need to wait for an AUC meeting to get the request for a subsequent run sanctioned.

A)Name of the Student		
Research Field		
Has he/she cleared NET/GATE	Yes / No	**Year of clearing NET/Gate** **Score:**
Fellowship details	Yes / No	**Project & Amount**

B) Mailing Address

Fax: **Phone:** **e-mail:**

C) Ph.D. Registration Details

Date of Registration	
Department	
University	

D) Ph.D. Supervisor(s)

Name / Designation	
Department	
University / Institution	
Name / Designation	
Department	
University / Institution	

Date: **Signature (Principal Investigator)**

E-Mail to **:** dsen@iuac.res.in **//** academic@iuac.res.in
Send hard copy to **: The Convenor, AUC, Inter-University Accelerator Centre, Post Box No.10502, Aruna Asaf Ali Marg, New Delhi 110 067, India [Phone: 26893955 / 26892601, Fax (91-11)-26893666]**

Last date for submission : May 31 for July AUC // Nov. 10 for Dec. AUC

Bio-data of Principal Investigator

Name **Designation** **Affiliation:**	**Dr. Rakesh Kumar** **Scientist - E** **Inter University Accelerator Centre, New Delhi**
Past **Affiliation (s):**	**Same as above**
Date of Birth:	**6th January' 1975**

Category **General** **SC** **ST** **OBC**
others

General	SC	ST	OBC	others

Academic **Qualifications:**	**M.Sc., Ph.D.** (*Experimental Nuclear Physics*)

List of previous Projects/ Beam Times at IUAC (if any):

AUC No.	Sanctioned Year	Title	Status: completed or running
42112/NP	JULY 2007	**Study of absorptive break-up (incomplete fusion) dynamics in heavy-ion interactions at E/A=4-7 MeV**	**Completed:- Results are communicated to DAE 2010 symposium, a detailed paper will be submitted to Physical Review C shortly**

Brief Research Experiences :

I have been working at IUAC from 1998 onwards as a scientist in GDA and INGA Group. Over these years I have participated in almost all the experiments of Nuclear Physics in GDA/GPSC/INGA beam lines and have also performed measurements on my own. Recently two experiments were performed on Incomplete fusion using non alpha cluster beam to measure the Excitation Function and also a Coulomb Excitation experiment was performed to obtain the BE(2) vales of first excited 2+ state of Sn isotopes.

Signature of PI

Annexure – I

Proposed experiment with the justification of beam selection and no. of shifts asked

We propose to measure the B(E2↑) values of the first excited states ($0^+ \rightarrow 2^+$) of the stable Tellurium isotopes (^{120,122}Te) using Coulomb excitation of ^{58}Ni ($E_{lab} \approx 175$ MeV) on a highly enriched ≈500 μg/cm^2 Tellurium. This experiment is an extension of our recent measurements for the Tin (Sn) isotopes [1]. In the proposed experiment, we plan to make a double relative B(E2↑) measurement. The normalized intensity ratios of projectile (^{58}Ni) excitation to the Te excitation will be compared with the calibration run (i.e., ^{122}Te). From the statistical point of view, for an accurate B(E2↑) values, we aim for a peak integral of 10^4 counts per $2^+ \rightarrow 0^+$ transition in all projectile and target excitations.

The gamma-decays from the de-excitation of Te isotope(s) will be measured with the four Clover Ge-detectors. We intend to have a resolution of better than 1%. Assuming an intrinsic resolution of these detectors of 0.3% and a β of 0.05, the distance of the Ge-detectors from the target will be kept at ≈ 20cm, which results in a photo peak efficiency of 3% at 1.3 MeV.

The scattered projectile and target nuclei will be detected with a position sensitive annular Parallel Plate Avalanche Counter (PPAC) covering scattering angles of $\theta_{lab} = 15^0 - 45^0$ and $\Phi_{lab} = 0^0 - 360^0$. For the given configuration, the opening angle of the PPAC corresponds to an angular coverage of $22^0 \leq \theta_{cm} \leq 68^0$ and $90^0 \leq \theta_{cm} \leq 150^0$ in the center of mass system, respectively for projectile and target nuclei. In case of ^{58}Ni, the excitation of the 2^+ state at 0.560 MeV is clearly separated for both impact parameter regions and will not be disturbed by the target excitation (2^+ state at 1.454 MeV). For both impact parameter regions, at ~175 MeV beam energy and a beam current of 0.5 pnA, a cross section of 850 mb is calculated for ^{120}Te, but we have also to measure 35 mb of ^{58}Ni. The natural abundance of 120Te is 0.1%. The fact that, the enrichment of Te isotopes is much smaller than that of Sn isotopes, therefore, to achieve 10^4 counts per $2^+ \rightarrow 0^+$ transition in all projectile and target excitations, a beam time of 7 days *(including 1 day for the setup of the electronics and the calibration runs)* is required to complete this measurement.

References:

[1] R. Kumar *et al.,* Phy. Rev. C81, 024306 (2010).

Annexure – II
Scientific Motivation

Numerous experimental and theoretical studies are currently focused on nuclear shell structure far from the line of stability [1]. In particular, the evaluation of nuclear properties, e.g., the energy of the first excited 2^+ - state and the reduced transition probabilities across closed shell Z = 50 are the area of great interest. Nuclei near the closed *proton* or *neutron* shells exhibit a rich variety of phenomena. In this region of nuclear chart, a small change in the number of constituent nucleons can introduce dramatic changes in the structure. The Te nuclei with 52 *protons* lie in the transitional region between the spherical nuclei, and deformed Xe and Ba nuclei. Fig.1a illustrates the observed level energies and B(E2↑) values in Te isotopes. The energies of the first excited 2^+ and 4^+ states reveal vibrational patterns almost throughout the isotopic chain except in the vicinity of A = 134.

The evolution of B(E2↑) values in Te isotopes are shown in Fig2b. The B(E2↑) values for the $2^+ \rightarrow 0^+$ transitions are predicted to follow a parabolic behavior around the neutron mid shell, reaching their maximum at ^{118}Te. Fig.2b shows an indication of lower B(E2) values in case of ^{120}Te (two neutrons more than the mid shell ^{118}Te nucleus) with an error bar of 20% [2]. Therefore, it is needed to measure much accurate B(E2↑) values for Te isotopes than that existing in the literature.

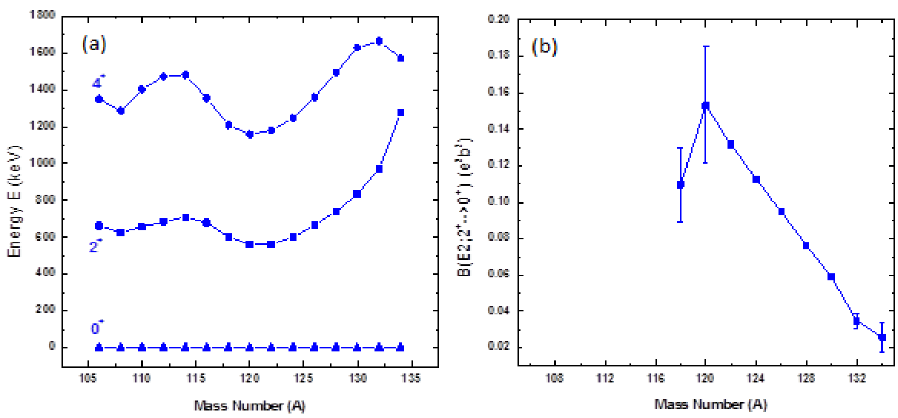


Figure-1: *(a)* Observed level energies and B(E2↑), and *(b)* the evaluation of B(E2↑) values values for Te isotopes.

We aim to measure transition probability of the $0^+ \rightarrow 2^+$ transitions by means of Coulomb excitation. The proposed study aims to probe systematics of B(E2↑) values in stable ^{120}Te. The B(E2↑) values of ^{122}Te will be used as a reference point.

References:

[1] H.Grawe and M.Lewitowicz, Nucl. Phys. A693, 116 (2001), and references contained therein

[2] G. M. Temmer and N. P. Heydenburg Phys. Rev. 104, 967–980 (1956)

Annexure – III

Importance of the proposed experiment in the context of the international status

Theoretically, the nuclei lying between two shell closures, the B(E2↑) values should follow a parabolic nature attaining maximum at around mid shell. The Large Scale Shell Model (LSSM) calculations yield quite satisfactory agreement for Sn isotopes (refer to Fig.1) [1, 2]. However, for Te isotopes, one has to use Generator Coordinate Method (GCM) to describe the vibrational character. As shown in Fig.2, the GCM calculations under Gaussian Overlap Approximation (GOA) show parabolic behavior for Te isotopes [3].

As shown in Fig.1, the experimental observations show deviations from such a parabolic behavior in neutron deficient Sn isotopes. The B(E2; $2^+ \rightarrow 0^+$) values for Sn isotopes do not follow the parabolic behavior from the neutron mid shell towards the doubly-magic ^{100}Sn (refer to Fig.1). This indicates the weakening of the N = Z = 50 shell closure [4, 5].

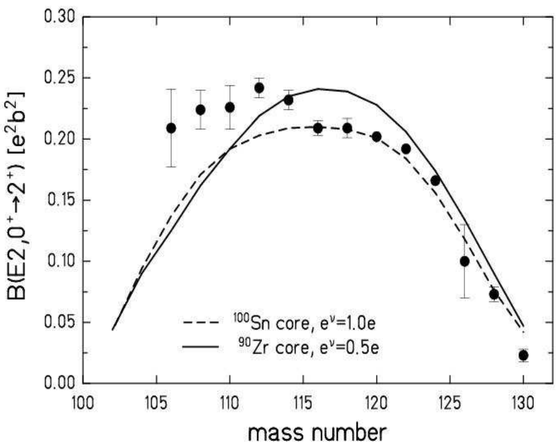


Fig.1:- Experimental data on B(E2;0^+g.s $\rightarrow 2^+_1$) values in the Sn isotope chain from the current results for ^{112,114}Sn and from [6, 7, 8, 9, 10]. The dotted and the full lines show the predictions of the large-scale shell model calculations [7] performed with a ^{110}Sn core and a ^{90}Zr core, respectively.

Further, as shown in Fig.2, the information on B(E2↑) values in Te nuclei below N = 66 is lacking. The proposed study will shed light on the role of the residual proton-neutron interactions in the development of collectivity when approaching the N = Z line. ***It may be pointed out that the stable beam facility of IUAC is perfect to settle the agreement or disagreement.***

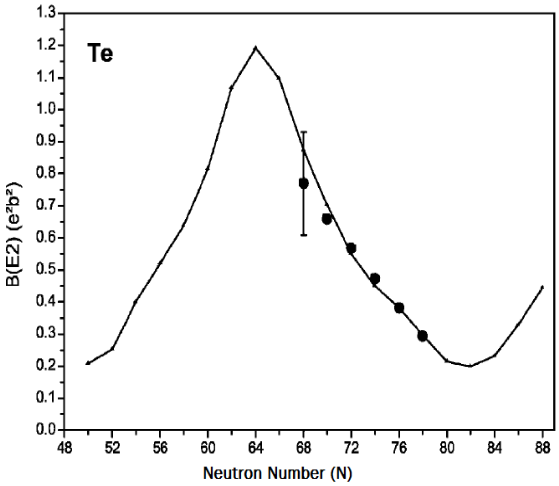


Fig.2 :- GCM–GOA calculated quantities (full lines and triangles) are compared with experimental values (full dots with error bars for *B(E2)* values) in Te isotopes. This comparison is displayed for transition probabilities *B(*E2; $0^+ \rightarrow 2^+$). The experimental data have been taken from Refs. [11,12].

References:

[1] M. Hjorth-Jensen et al., Phys. Rep. 261 (1995), 124.

[2] R. Machleidt, F. Sammarruca and Y. Song Phys. Rev. C **53**, 1483 (1996).

[3] J. Libert, B. Roussi`re and J. Sauvage, Nucl. Phys. A 786, 47 (2007).

[4] J. Cederk˙ll et al., Phys. Rev. Lett. 98, 172501 (2007).

[5] A. Ekstr¨m et al., Phys. Rev. Lett. 101, 012502 (2008).

[6] S. Raman, C. W. Nestor and P. Tikkanen, At. Data and Nucl. Data Tables 78, (2001) 1.

[7] A. Banu et al., Phys. Rev. C 72, 061305(R) (2005).

[8] D.C.Radford et al., Nucl.Phys. A 752, 264c (2005)

[9] J.Cederk¨all et al., Phys.Rev.Lett. 98, 172501, (2007)

[10] A.Ekstr¨om et al., Phys.Rev.Lett. 101, 012502 (2008)

[11] S. Raman, C.W. Nestor, P. Tikkanen, At. Data Nucl. Data Tables 78 (2001) 64.

[12] http://www.nndc.bnl.gov/ensdf/za_form.jsp.

Annexure – IV

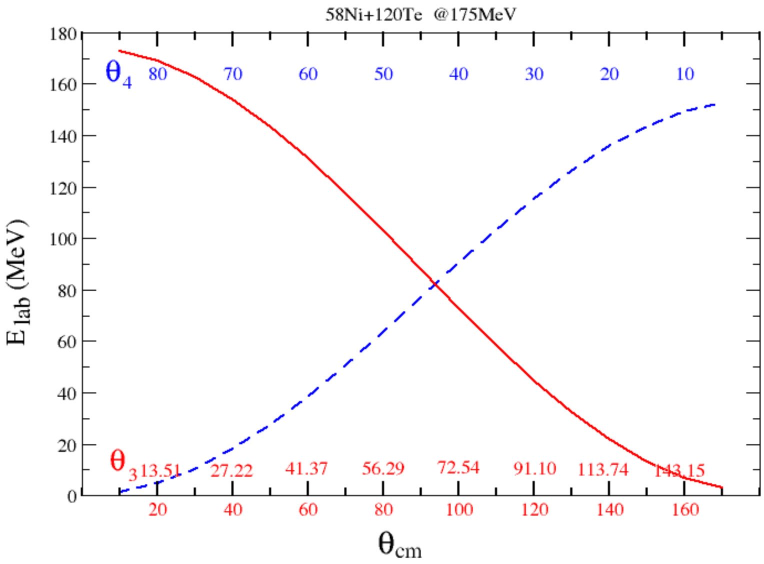
1. Kinematics

- Calculations are performed with FORTRAN program: ***kinemat.f***

^{58}Ni projectile (A1=A3=58) on ^{120}Te target nucleus (A2=A4=120) at E_{lab}=175MeV

TH-CM cm(degree)	TH-3 lab(degree)	E-3 (MeV)	E-4 (MeV)	TH-4 lab(degree)
10	6.745	173.832	1.168	85
20	13.515	170.363	4.637	80
30	20.332	164.699	10.301	75
40	27.225	157.013	17.987	70
50	34.226	147.536	27.464	65
60	41.370	136.558	38.442	60
70	48.70	124.412	50.588	55
80	56.292	111.467	63.533	50
90	64.204	98.116	76.884	45
100	72.544	84.765	90.235	40
110	81.448	71.820	103.180	35
120	91.103	59.674	115.326	30
130	101.758	48.696	126.304	25
140	113.741	39.219	135.781	20
150	127.430	31.532	143.468	15
160	143.150	25.868	149.132	10
170	160.900	22.400	152.600	5

Kinematics of 58Ni on 120Te @175 MeV



Coulomb excitation cross section

- Coulomb excitation calculations were performed with the Winther-de Boer Coulex code [1].
- Coulomb excitation calculations are performed with FORTRAN program: lell30e1.f
- Cross sections are integrated with FORTRAN program: anggro.f

In a first step the Coulomb excitation cross-section (lell30e1.f) is calculated. Then we can distinguish 3 cases for the particle-γ angular correlation (anggro.f):

(i) calculation in the rest-frame
(I24=1, Q0=1, Q2=0, Q4=0),

(ii) calculation in the laboratory frame
(only Lorentz-boost: I24=0, Q0=1, Q2=0, Q4=0),

(iii) calculation in the laboratory frame with γ-ray angular correlation
(I24=0, Q0=Q2=Q4=1).

The results from anggro.f have to be multiplied by 4π to obtain the cross sections in [barn].

Table-1: Cross-section for the ^{58}Ni+^{120}Te system at 175 MeV

θ_γ Φ_γ	θ_{cm}	S. No.	^{120}Te : σ_2 (mb) ^{58}Ni $\rightarrow$ ^{120}Te 175MeV	^{58}Ni : σ_2 (mb) ^{58}Ni $\rightarrow$ ^{120}Te 175MeV	Ratio ^{120}Te/^{58}Ni
135^0, 55^0	$22.2^0 - 65.0^0$	(i)	848.1	34.78	24.33
		(ii)	838.1	31.88	26.29
		(iii)	805.1	33.43	24.08

Table-2: Cross-section for the $^{58}Ni+^{122}Te$ system at 175 MeV

$\theta_\gamma\ \Phi_\gamma$	θ_{cm}	S. No.	$^{122}Te : \sigma_2$ (mb) $^{58}Ni \rightarrow {}^{122}Te$ 175MeV	$^{58}Ni : \sigma_2$ (mb) $^{58}Ni \rightarrow {}^{122}Te$ 175MeV	Ratio $^{122}Te/^{58}Ni$
$135^0, 55^0$	$22.1^0 - 66.6^0$	(i)	770.8	38.43	20.06
		(ii)	754.2	35.61	21.20
		(iii)	794.6	36.96	21.50

Table-3: Double ratio of 120Te/122Te as determined from the above two tables

$\theta_\gamma\ \Phi_\gamma$	θ_{lb}	S. No.	Ratio $^{120}Te/^{122}Te$
$135^0, 55^0$	$15^0 - 45^0$	(i)	1.215
		(ii)	1.240
		(iii)	1.120

References :-

1. A.Winther and J. De Boer, A computer program for multiple Coulomb excitation,1965, in K. Alder and A. Winther, Coulomb Excitation, Academic Press, NewYork-London (1966).