FABRICATION AND CHARACTERIZATION OF HIGH PURITY ^{93}Nb TARGET ON LEAD BACKING

ANAND PANDEY
Department of Physics and Astrophysics
University of Delhi

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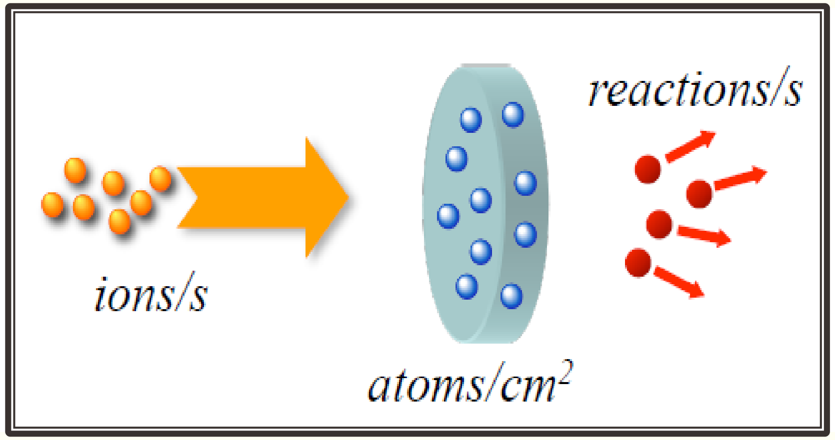
- Fabrication of the target
- Quality evaluation of target
  - SEM ………………….. surface uniformity
  - EDS, XRD …………. elemental purity check
  - XRF………………… elemental purity and thickness measurement
  - I-V characteristic ….. electrical conductivity
- Real testing of target in the experiment
- Summary
- Conclusion

Targets for Nuclear Physics Experiments



- ❖ Nuclear Reactions
- ❖ Nuclear Spectroscopy
- ❖ Nuclear Structure

<u>Quantities of interest</u>

- ❖ Angular distribution of reaction products ($dN/d\theta$)
- ❖ Reaction cross Section (σ or $d\sigma/d\Omega$)

$$\frac{reactions}{s} = \frac{ions}{s}\,\frac{atoms}{cm^2}\,\sigma$$

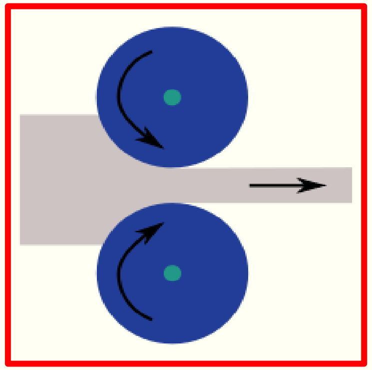
- ❖ Reaction rate (reactions /cm^3-s)
- ❖ Total Yield

The choice of material and thickness depend on physics case

…..often thin targets ~ < 2 mg/cm^2 are required

Methods of Target fabrication

* Thin (self-supporting) target foil …***Rolling Method***



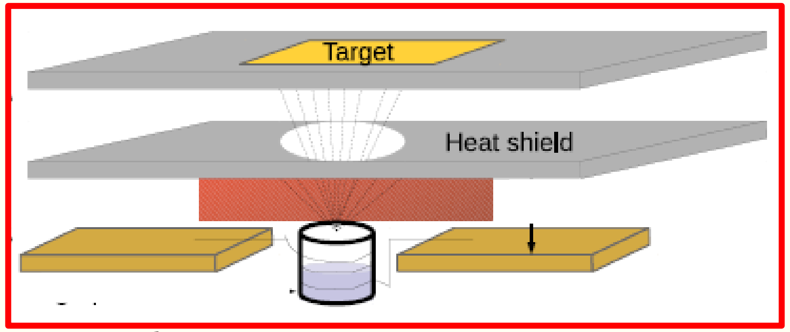
(e.g. gold, copper, silver,…)

Quality of foil depends upon :

- material, purity, chemical stability

Advantage : cost effective, mechanically strong foil

* Thin (backed) target foil …***Evaporation Method***



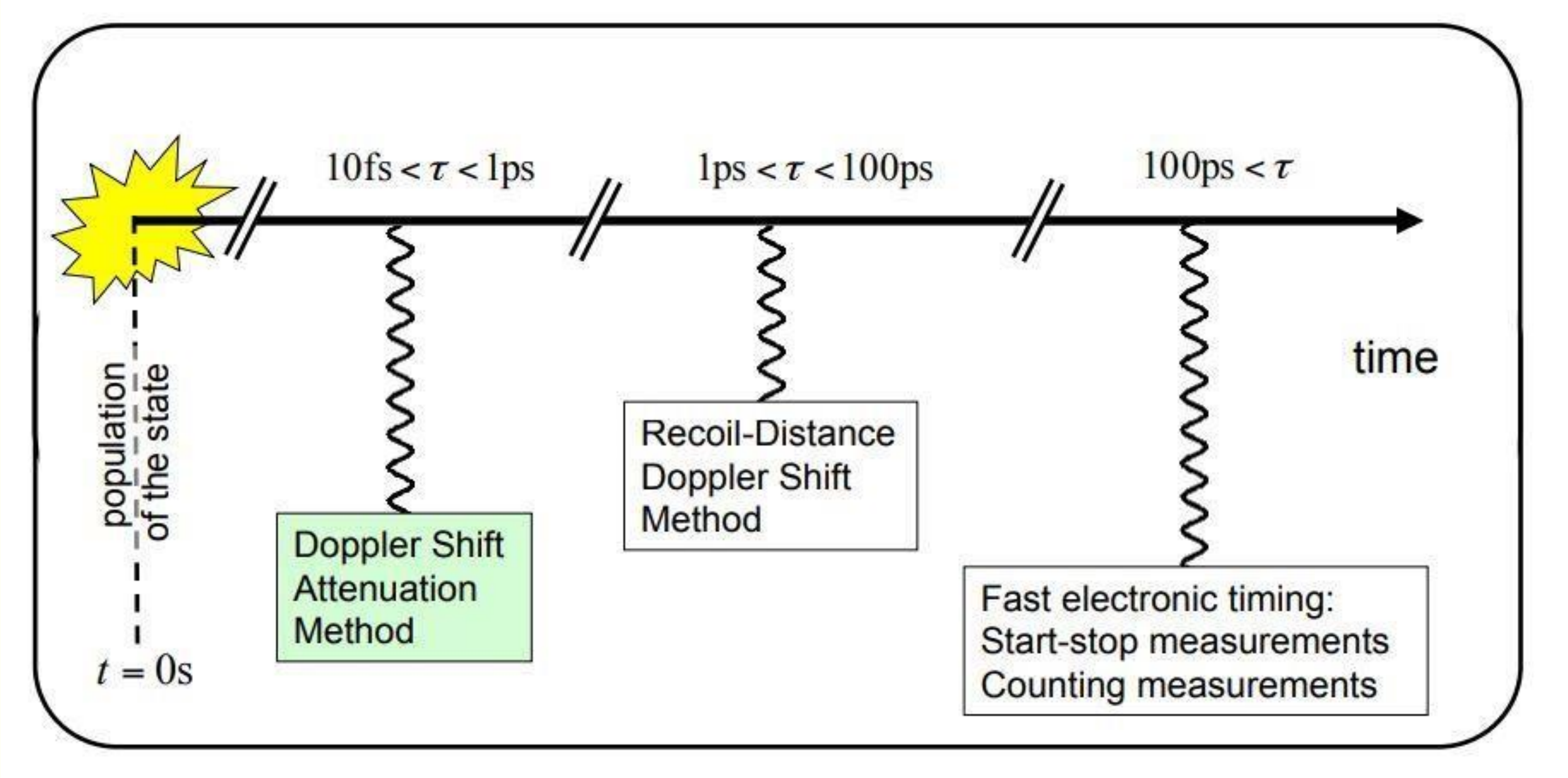
(for material in powder form)

Quality of foil depends upon :

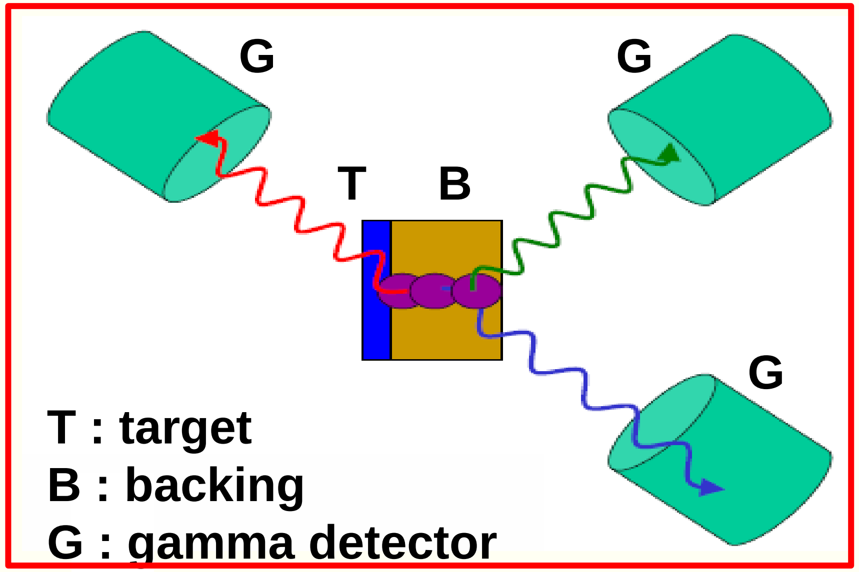
- choice of backing material, M.P. & B.P. of material

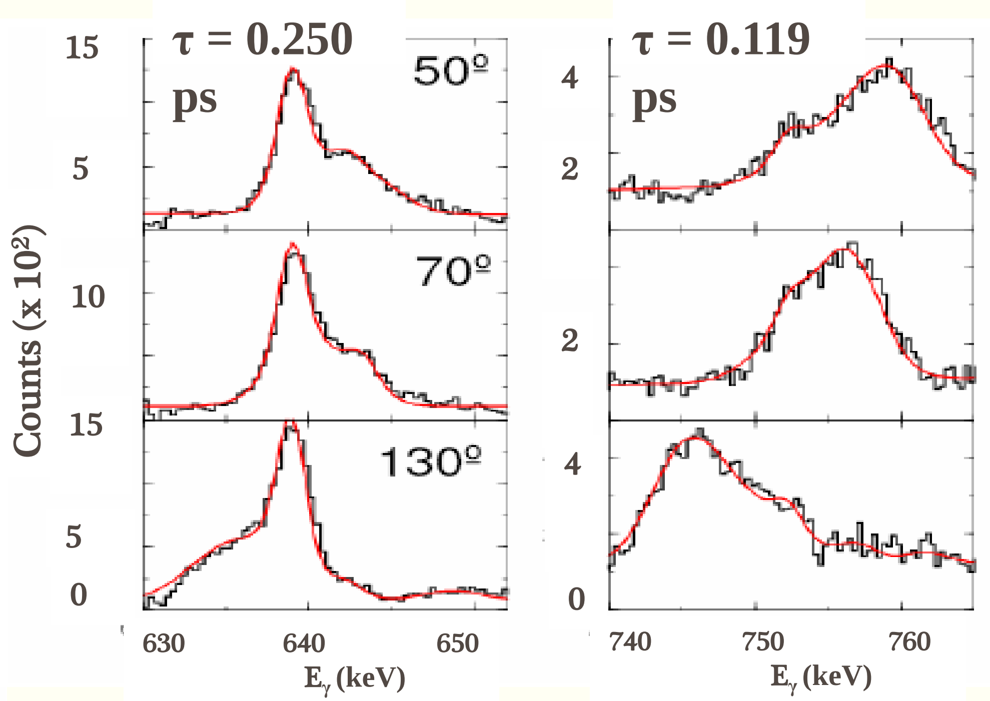
Advantage : Target foil of any thickness can be made

Motivation: Nuclear level lifetime measurement



Doppler Shift Attenuation Method (DSAM)





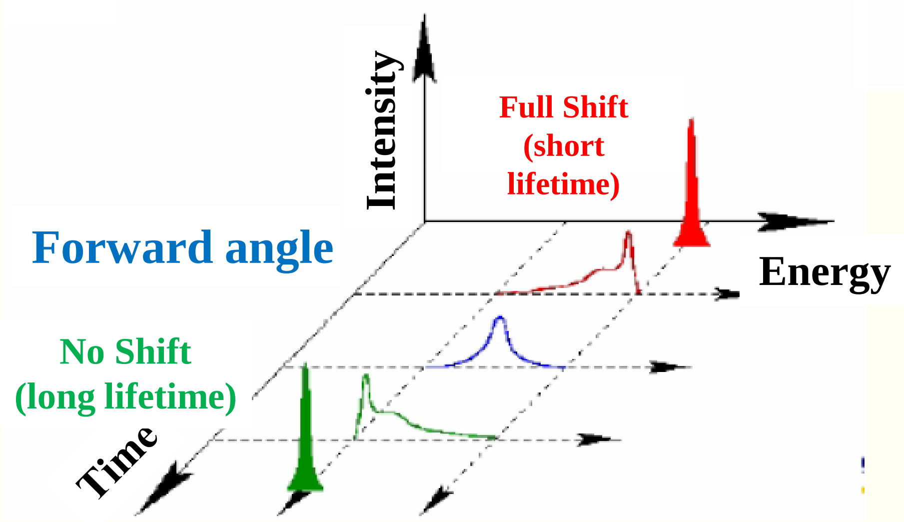
$E_s = E_0 [1 + \beta \cos(\theta)]$

$E_s \longrightarrow$ observed energy

$E_0 \longrightarrow$ actual energy

$\theta \longrightarrow$ angle between the recoiling nuclei and emitted γ - ray

$\beta = v/c$

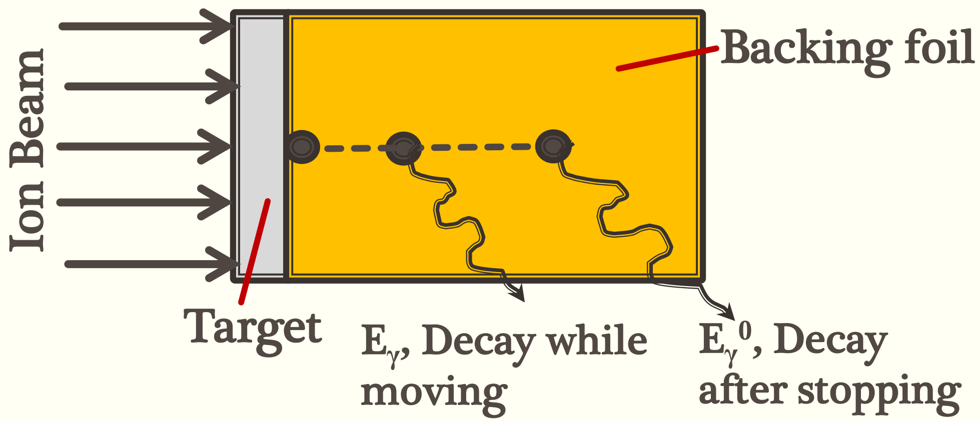


- Target with a thick backing is used
- γ-rays emitted from recoils pass through the backed material, slowed down and finally stopped, so lineshapes are observed
- Lineshapes depend on lifetime of states

Target properties for DSAM lifetime measurement

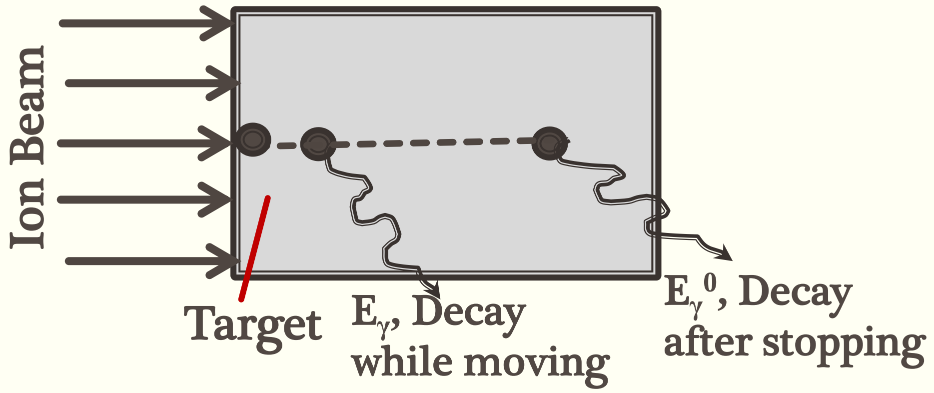
Target on backing

- Backing foil of high-Z material is suitable for the DSAM experiment
- Backing foil must be thick enough to stop all the recoils inside
- Preferably, Au ($Z \sim 79$) is chosen as backing material used due to better physical and chemical stability

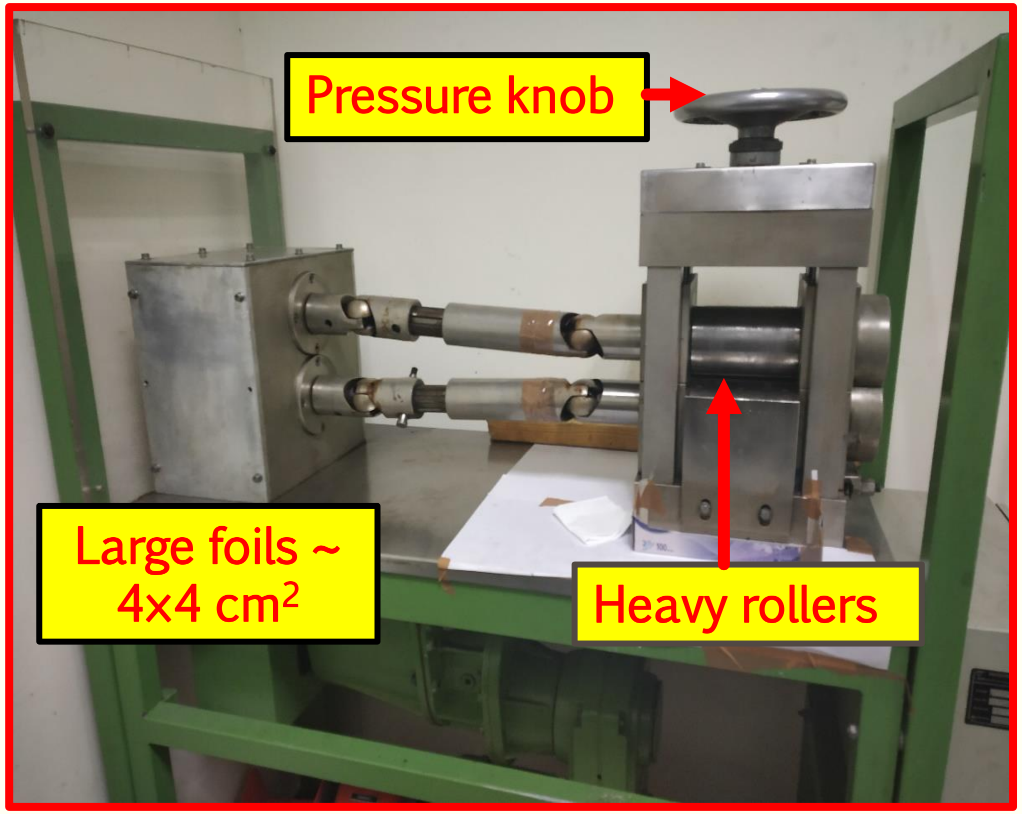


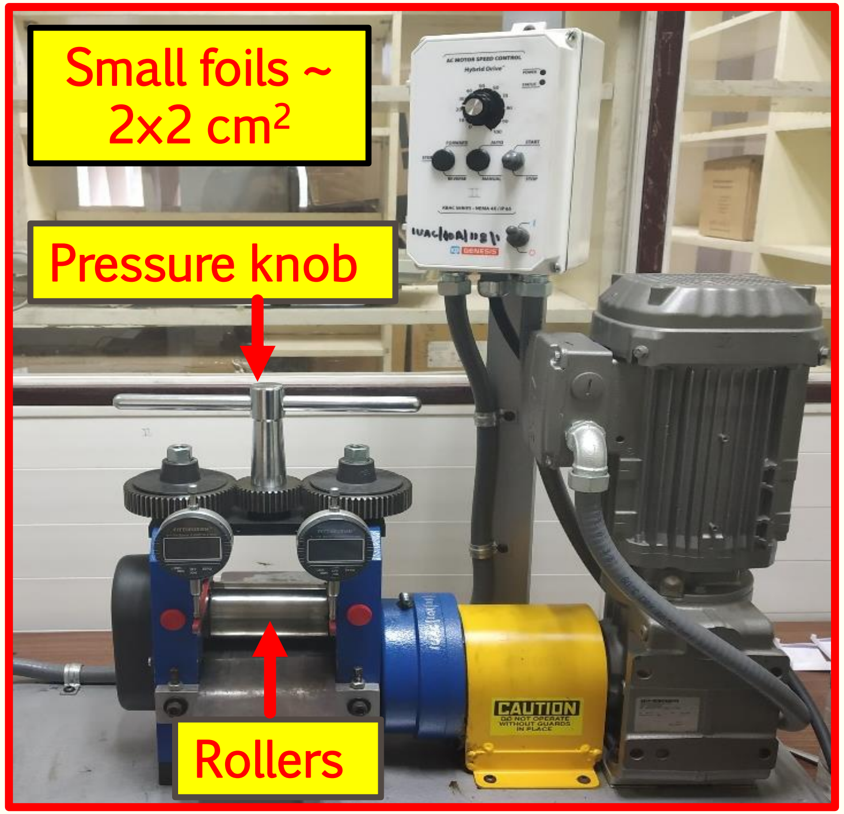
Self –supporting target

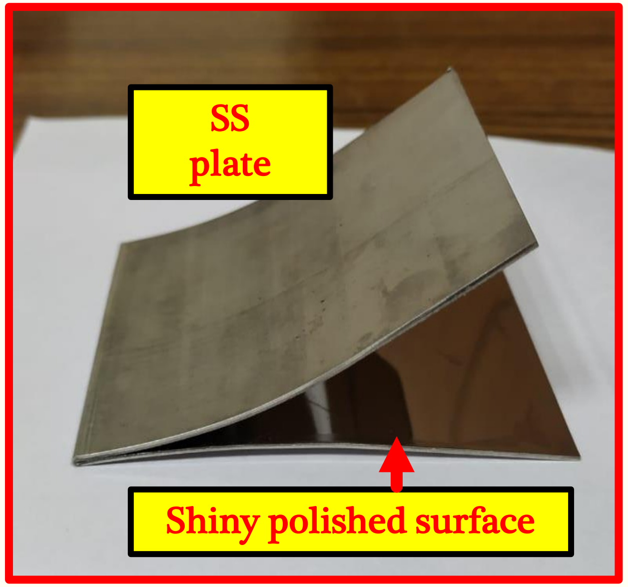
- Target foil must be thick enough to stop all the recoils inside
- Material Properties needed are :
  - cost effective, available and easy to roll
  - should have good mechanical strength
  - High M.P., B.P. and high thermal conductivity



Fabrication of the target foils: Rolling technique





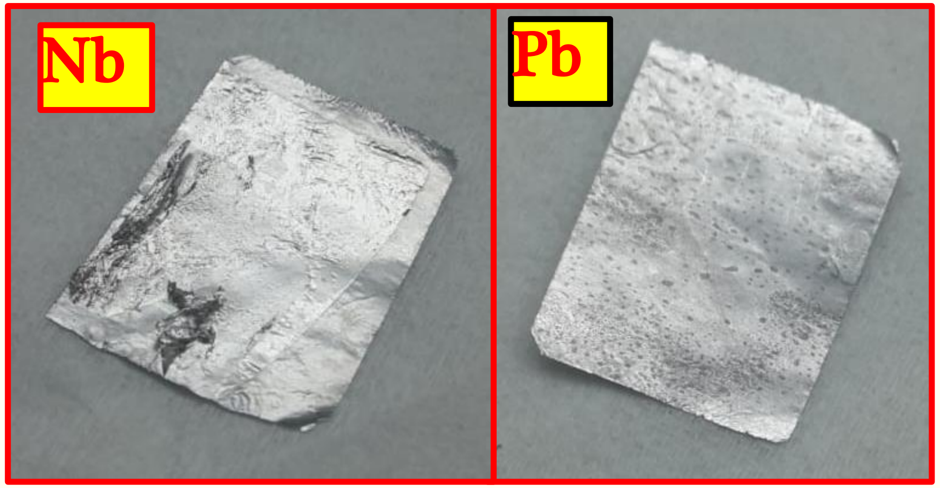


- ❖ Nb, Au and Pb foils were fabricated using mechanical rolling technique
- ❖ Materials were rolled keeping foils in between the stainless steel (SS) plate.
- ❖ Thickness of the foil is controlled using the pressure knob.

Fabrication of composite target

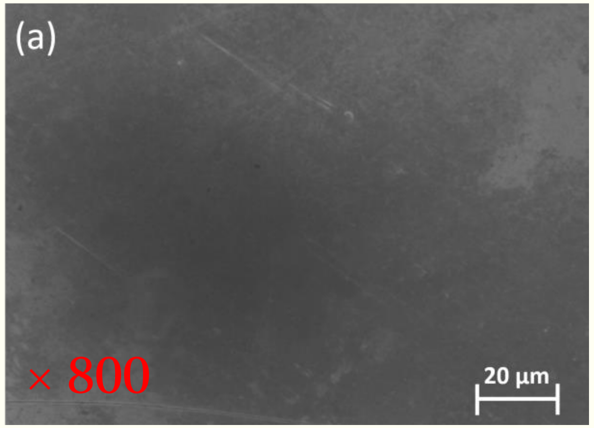
- Nb (~1 mg/cm^2), Au (~ 8mg/cm^2), Pb (~13 mg/cm^2) were fabricated
- Rolling was done in clean environment
- Thickness monitoring using geometrical thickness method was done regularly to obtain appropriate thickness
- Pb was found to be better backing material to form the composite target

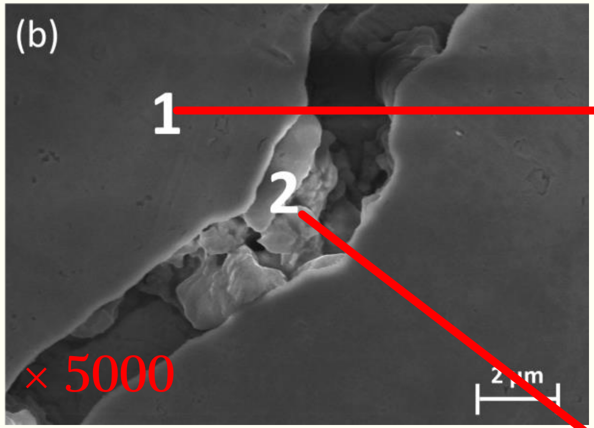
Composite target showing front(Nb) and back (Pb)

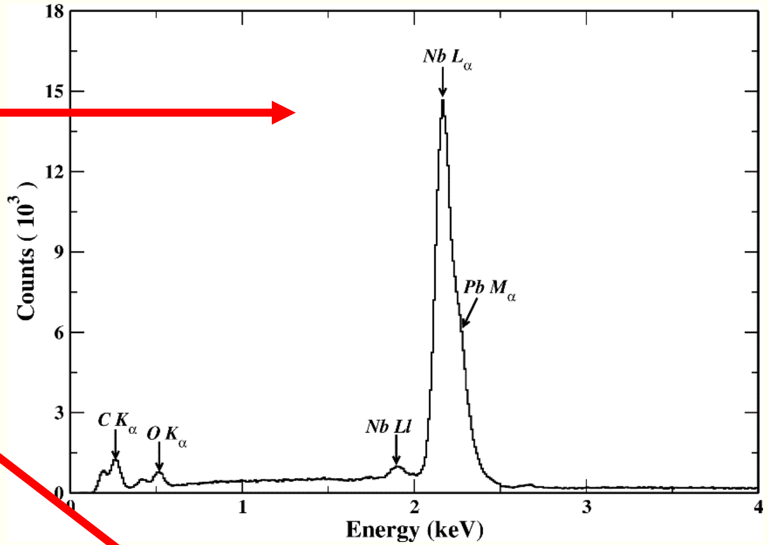


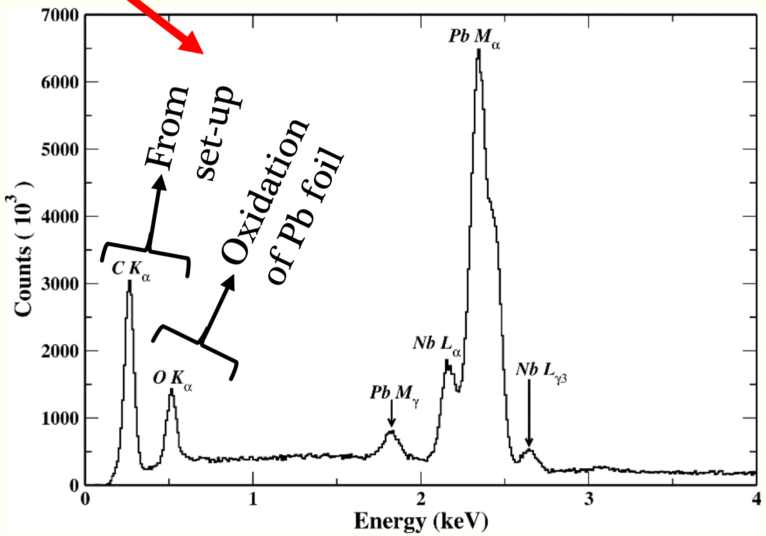
- Both Nb and Pb foils were kept over each other inside the SS plate and rolled to form composite target.
- One-way rolling at minimum possible pressure was done until both foils perfectly stick to each other.
- Finally, Nb target on Pb backing of required thickness was obtained

Surface Properties: Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDS)

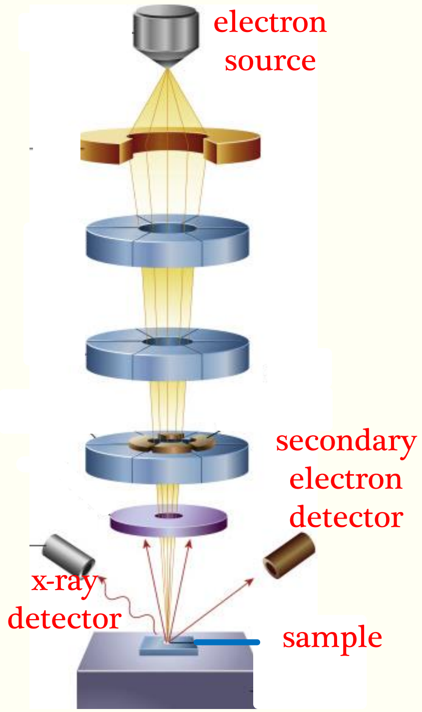






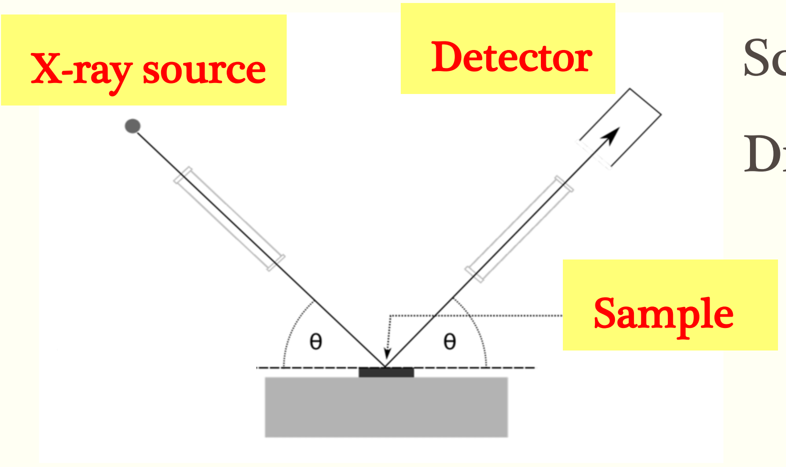


- ❖ SEM images suggests the uniform and smooth surface of the rolled target
- ❖ EDS spectra at two different regions (1 and 2) was taken to observe the elemental composition
- ❖ Observed O (K_α) due the oxidation of Pb surface

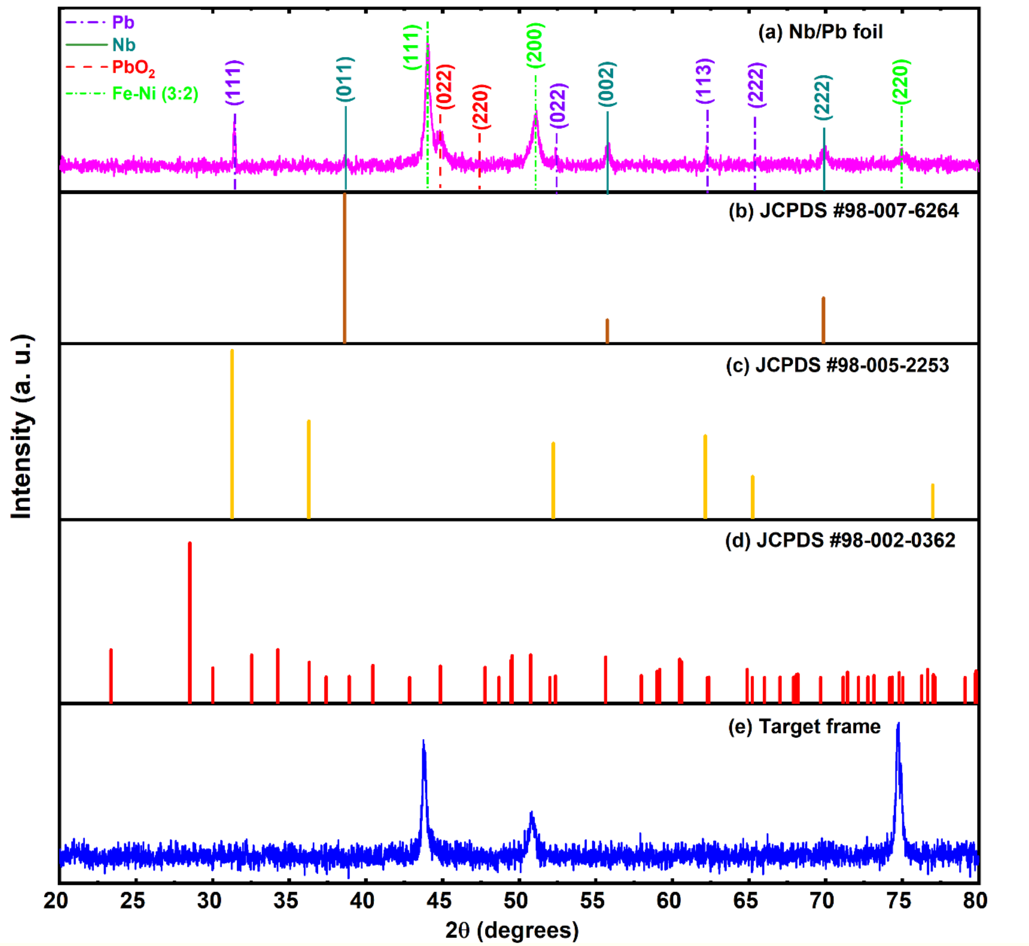


Schematics of SEM

Purity of the target: X-Ray Diffraction (XRD)

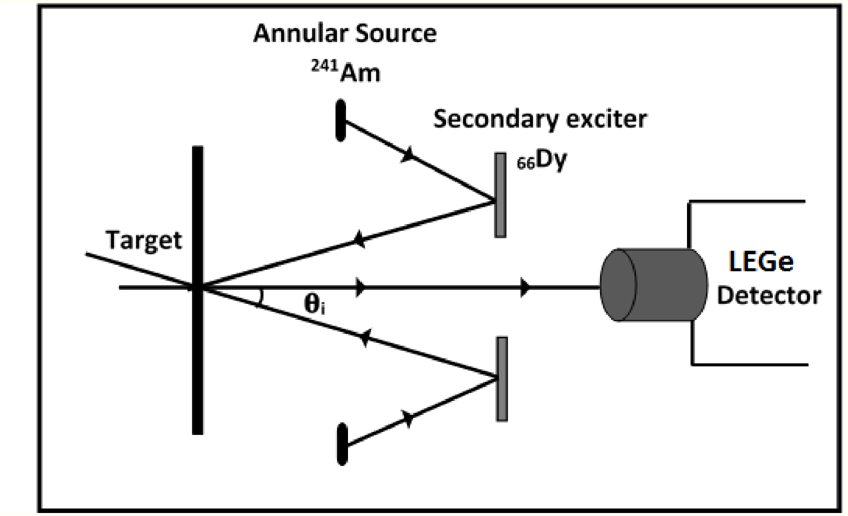


Schematics of X-ray Diffractometer



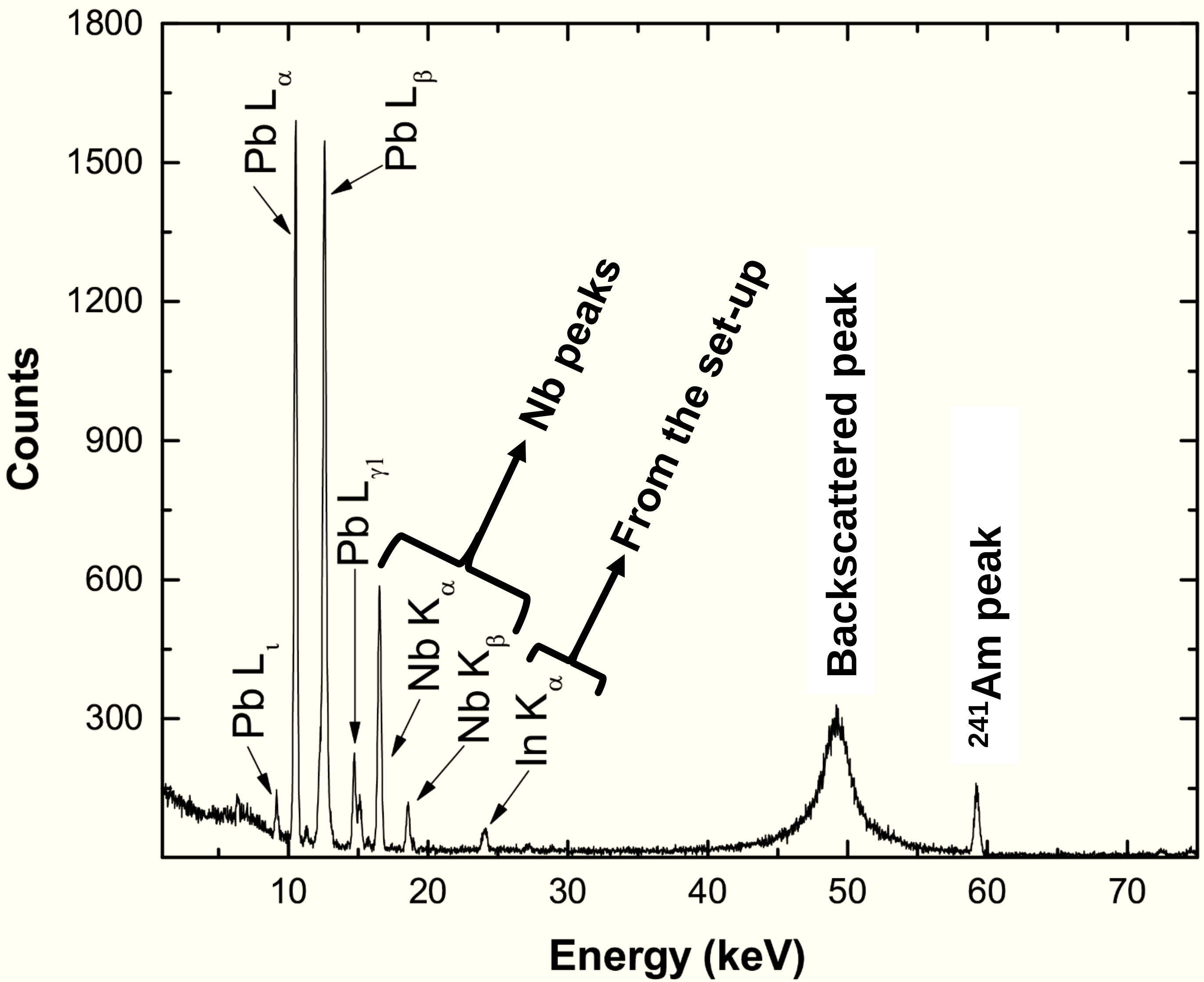
- XRD spectra taken for (a) Nb/Pb foil and (e) target frame is shown.
- The line patterns, (b), (c) and (d), representing the JCPDS file are used to determine the observed planes in the XRD spectra.
- The peaks corresponding to crystal planes in PbO_2 confirms the oxidation of Pb surface suggested from EDS spectra.

Thickness Measurement : X-Ray Fluorescence (XRF)



Schematics of the XRF set--up

- Energy spectrum obtained in XRF measurements for fabricated ^{93}Nb backed target
- No other major elemental impurity in the spectrum confirms purity of the fabricated target

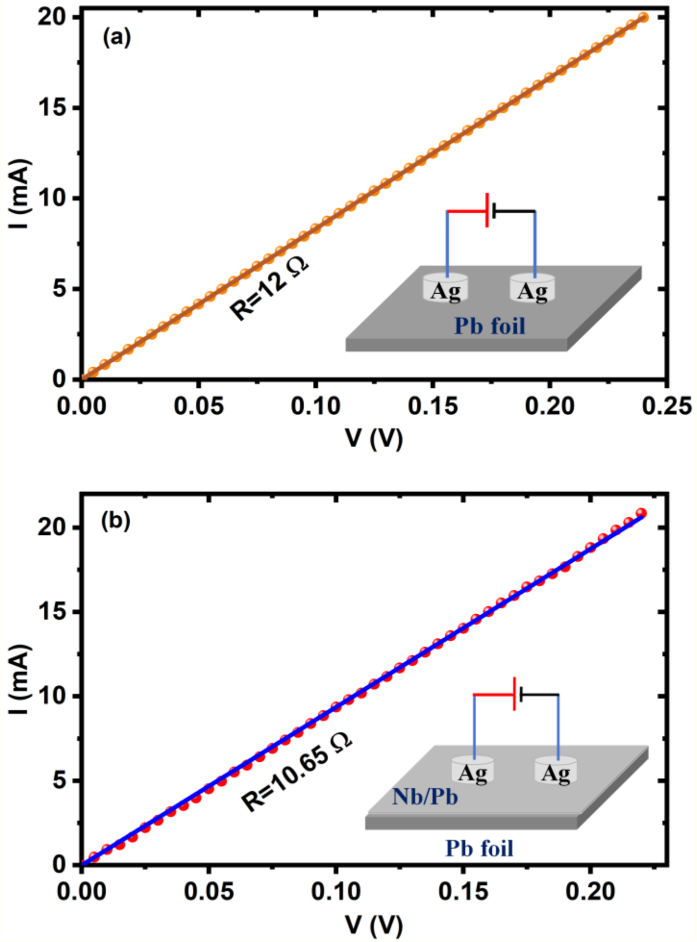


Thickness measurement

S. No.	Element	Geometrical Thickness mg/cm^2	Thickness from EDXRF Technique mg/cm^2
1)	Nb	0.98	0.9
2)	Pb	10.2	9.2

- Geometrical thickness: thickness obtained by dividing the measured weight of the foil by its geometrical area.
- Thickness from XRF measurement is in agreement with the estimated thickness

Electrical properties: Current-voltage (I-V) curve



- In nuclear experiments, when high energy heavy ion beam is incident on target, high amount of heat is generated. If this heat is trapped inside the target, it can damage the target (peel off)
- Good electrical and thermal conductivity is required

The parameters used to evaluate the electrical conductivity are mentioned in the table below

	d (cm)	A (cm^2)	l (cm)	R (Ω)	ρ $(m\Omega\, m)$	σ (S/m)
Pb	0.2	0.0314	0.65	12	5.79	172.7
Nb/Pb	0.15	0.018	0.45	10.65	4.26	234.7

- The electrical conductivity of the foil increases by ~36%

I-V characteristic plot at room temperature for (a) Pb foil and (b) Nb/Pb foil connected using lateral device structure configuration using the Ag top contacts. The schematics for the measurement is show in the respective inset

Experimental Details

Reaction used : ^{93}Nb (^{28}Si, p2n) ^{118}Xe @ 115 MeV @ 21 - 25 July 2019

Target: Nicely rolled, isotopically enriched **^{93}Nb (mono-isotopic)** foil of thickness ~ **1 mg/cm^2** on **thick Pb backing** (thickness ~ **10 mg/cm^2**) made by rolling method.

Excitation Function: @ E_{lab} = 112, 115, 116, 120 MeV

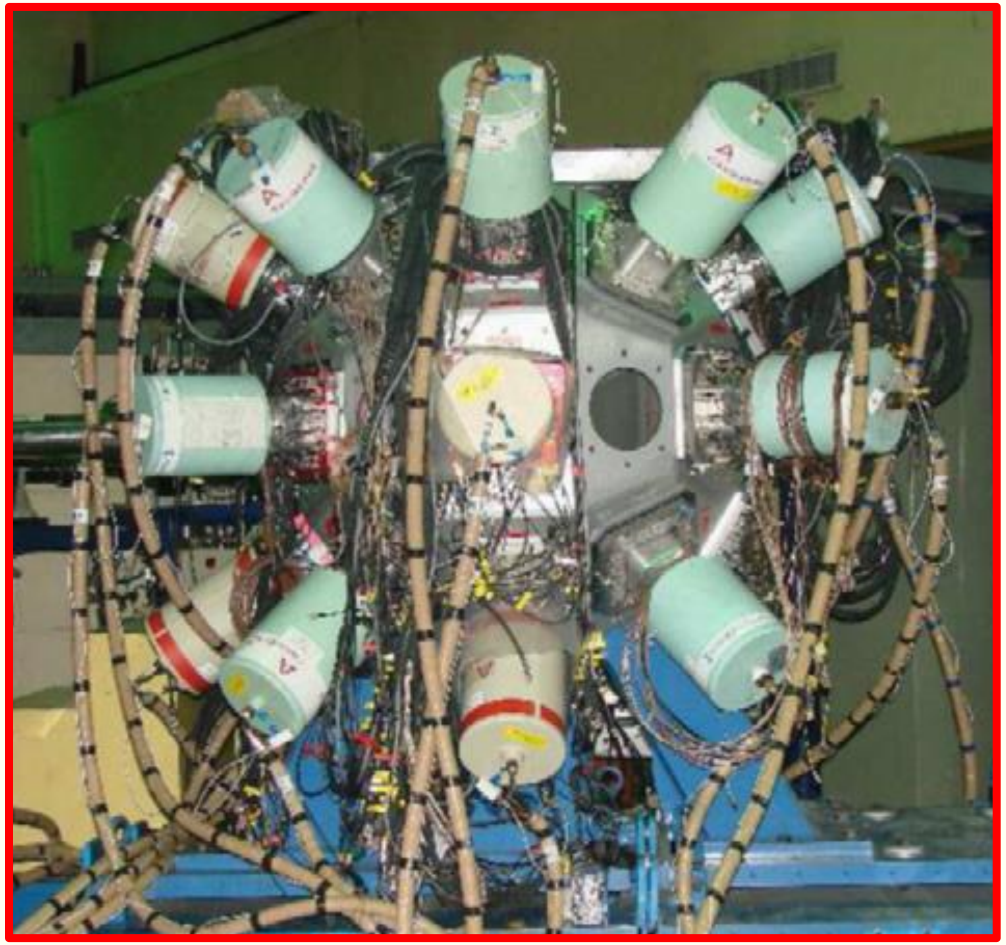
Detector in INGA set up: 16 Clovers detectors + 2 LEPS

@ 32°, 57°, 90°, 123°, 148° w.r.t. beam direction

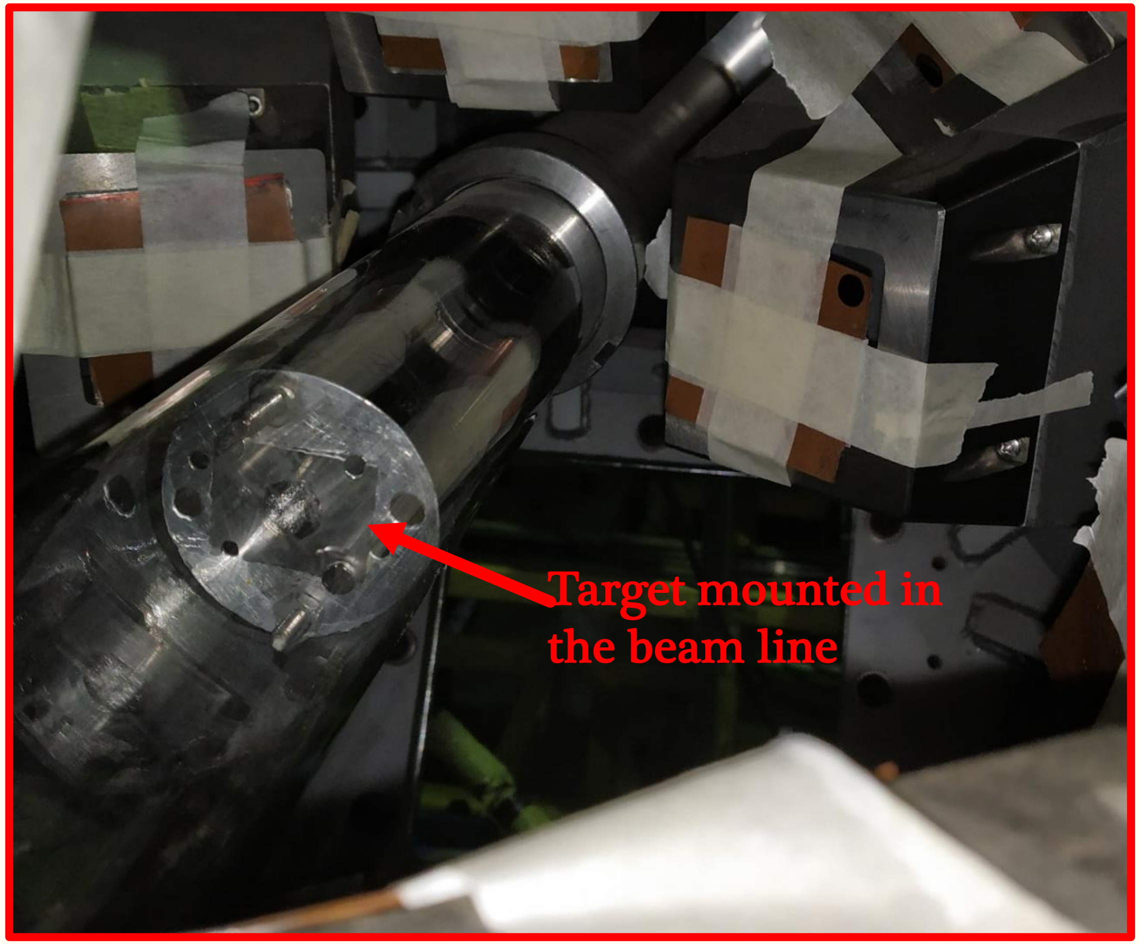
Beam used: **^{28}Si @ 115MeV** using charge state **9$^+$** and keeping terminal potential **@11.52 MeV** during the experiment.

No. of Shifts: **12** (1 Shift = 8 hours) **Data collected:** ~ **8*10^8** events in 2-fold

Experimental Details: Indian National Gamma Array(INGA)

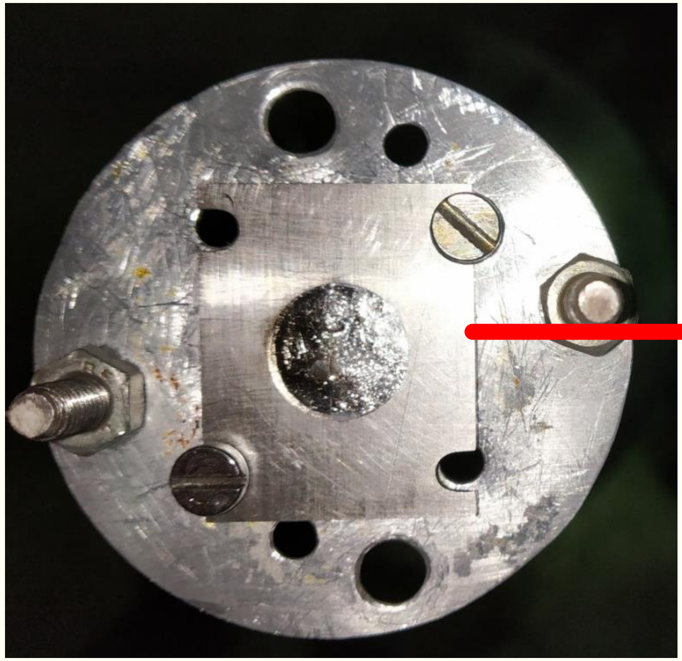


INGA facility @IUAC, Delhi was used

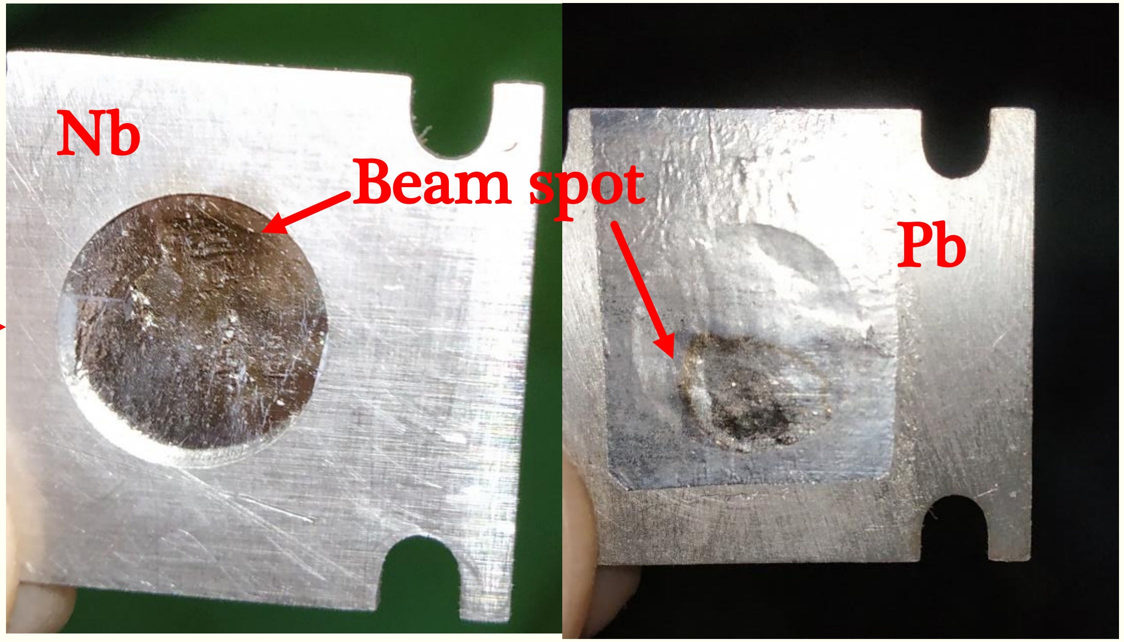


Inside view showing mounted target

Quality of the target: after experiment

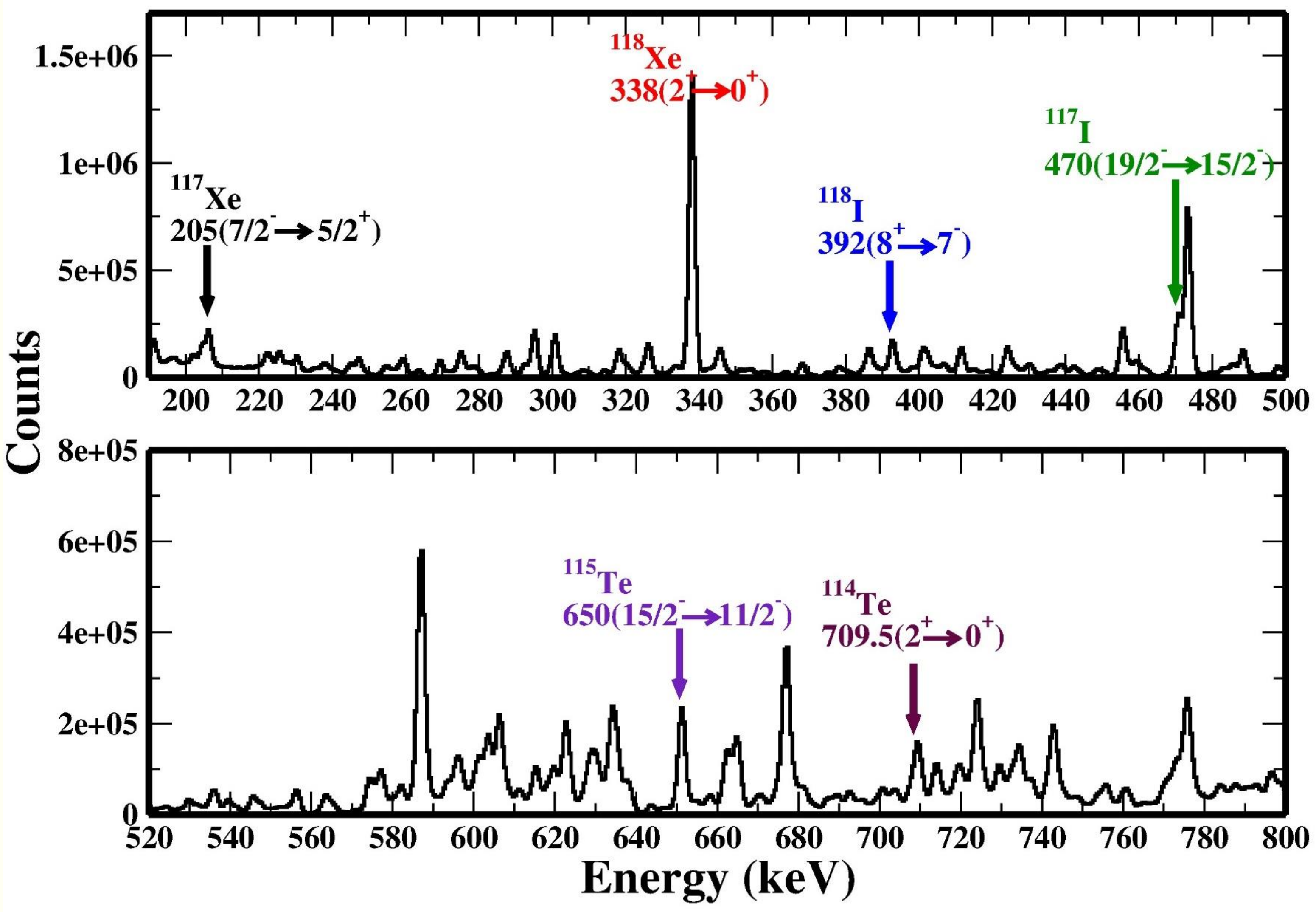


Target holder removed from the beamline after experiment.

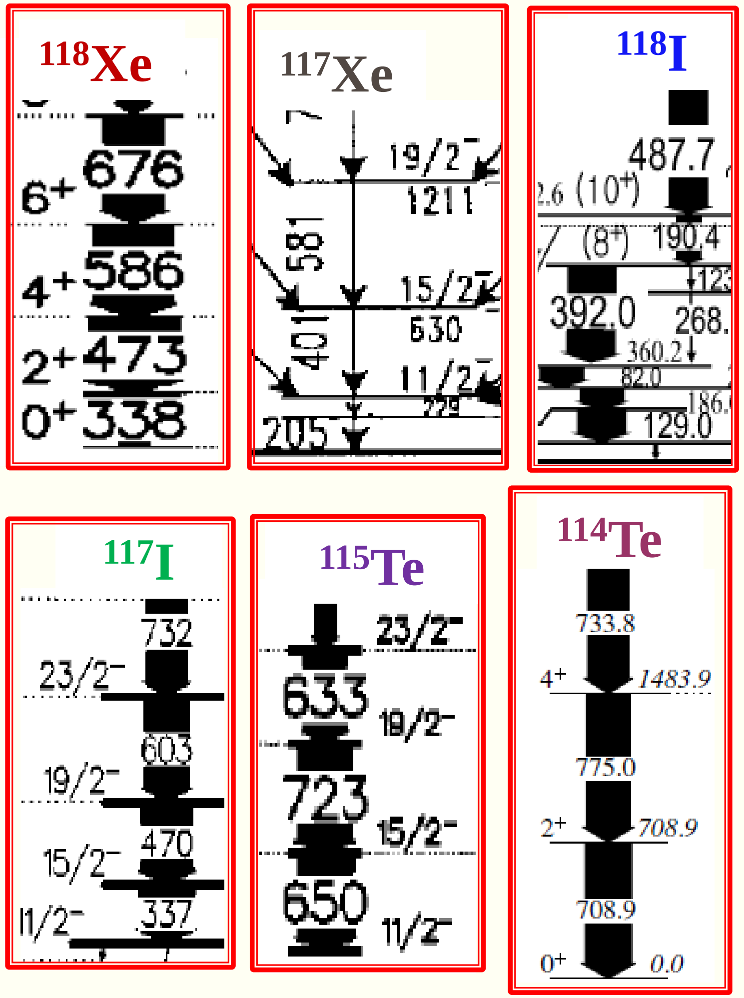


Picture showing condition of the target after experiment was carried out successfully.

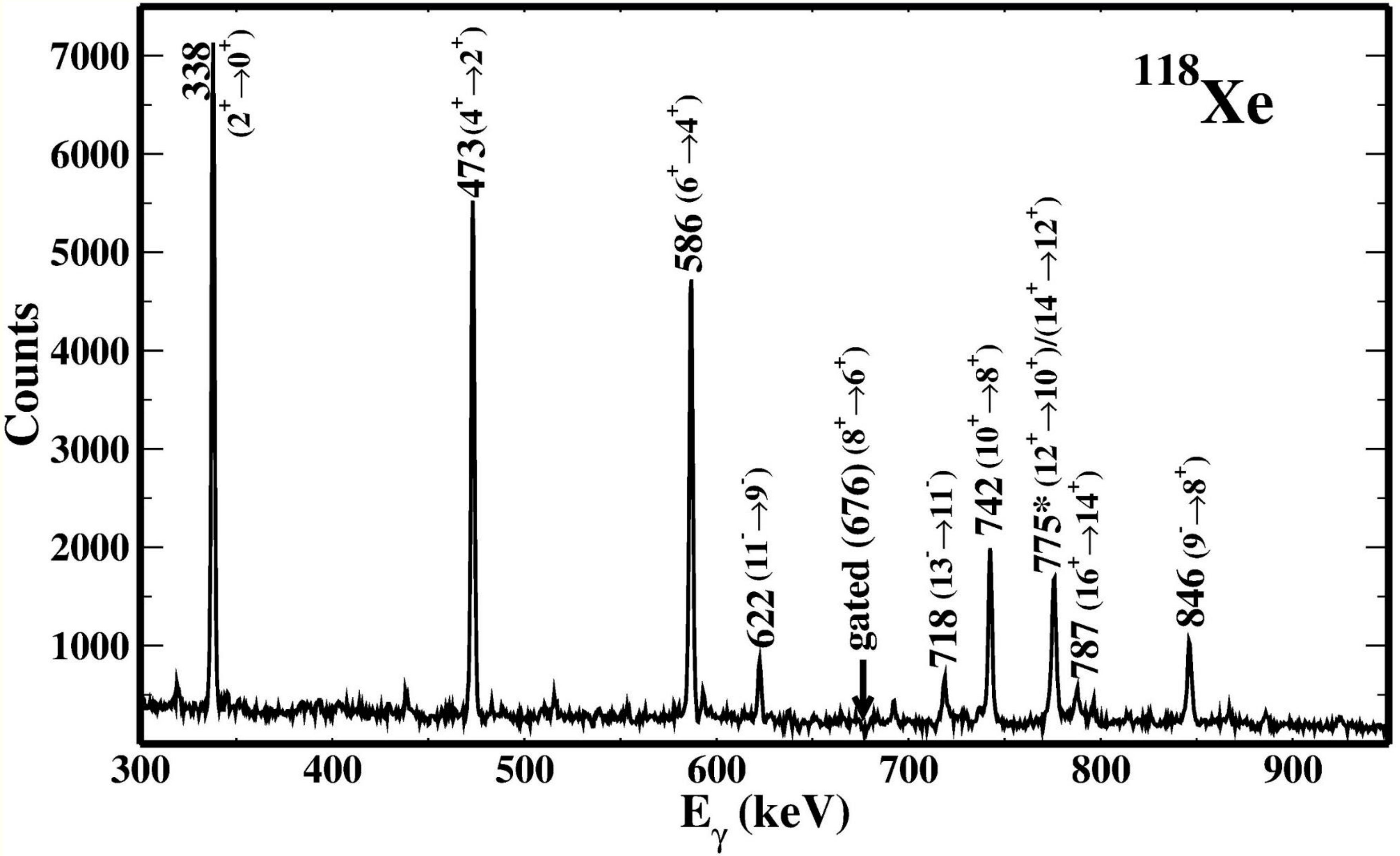
Real testing of target

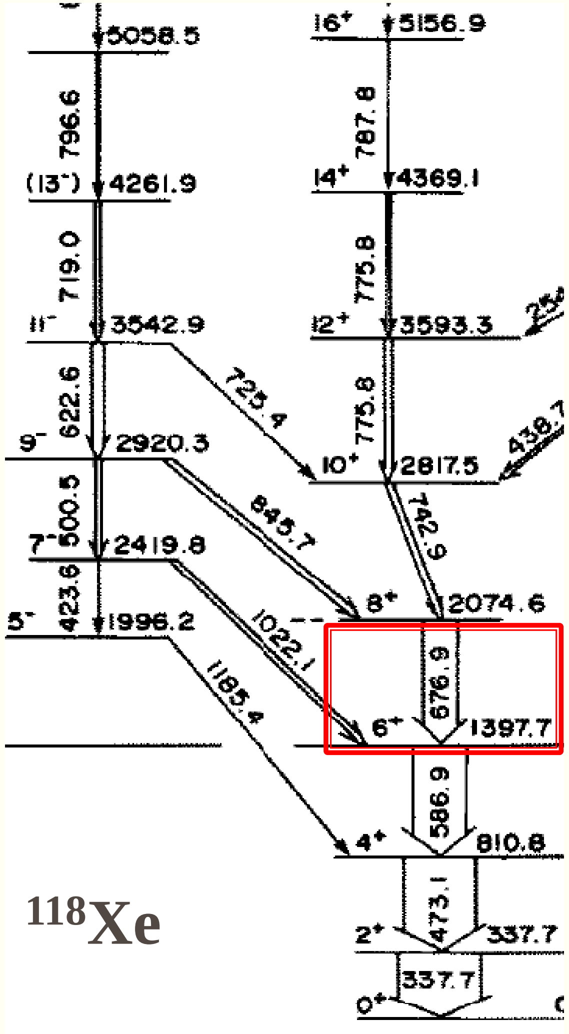


yrast band in



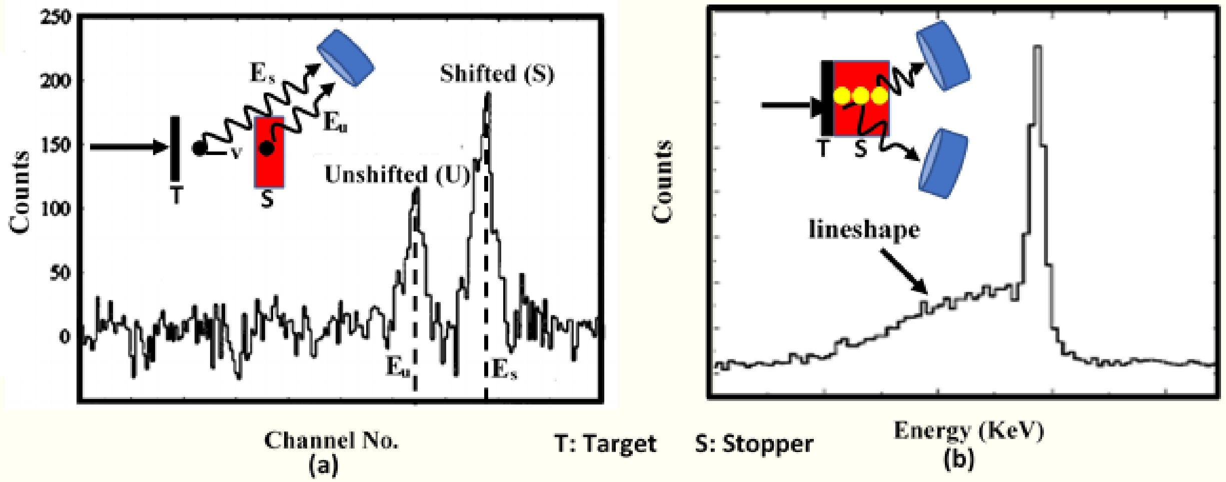
Real testing of target



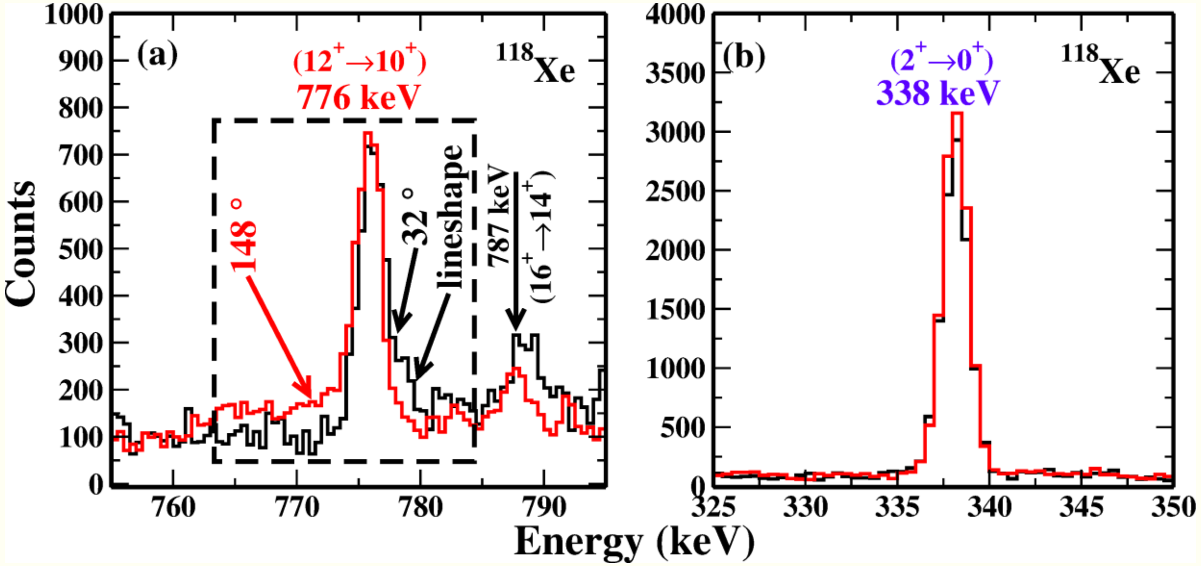


Real testing of target

- In DSAM experiment, target and backing foils must stick perfectly to each other, leaving no vacuum gap b/w the foils



Picture showing (a) two distinct gamma energy corresponding to a given gamma-ray (shifted and unshifted) obtained in a typical RDM lifetime measurement experiment (b) a gamma energy peak with lineshape in the leading edge, obtained in a typical DSAM lifetime measurement experiment.



Portion of energy spectrum obtained in the DSAM lifetime measurement experiment showing the quality of the target: (a) lineshape observed for 776 keV transition in forward and backward detector having lifetime in DSAM range; (b) No lineshape observed for 338keV transition, having long lifetime.

- Two foils (target and backing) do not lose contact during the experiment.

Summary

- ❖ Thin Nb target foil was fabricated using mechanical rolling
- ❖ Pb was used as backing material as Au and Nb do not stick to each other
- ❖ Thickness and elemental purity of the target foil was confirmed using XRF, EDS and XRD techniques
- ❖ Uniformity and smoothness of surface was confirmed from SEM images
- ❖ Electrical conductivity of the foil was found to be increased by 36%

continued

Conclusion

- ❖ Thin Nb target with Pb backing was fabricated using rolling method
- ❖ Good quality target fabricated in the present work is successfully employed in the nuclear lifetime experiment
- ❖ Target and backing foil stick perfectly to each other
- ❖ Targets fabricated using rolling method exhibit great mechanical strength and also loss of material is minimal.
- ❖ The target is in good condition even after experiment and can be used again for nuclear experiment if required

Thank You