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N.C.S.R. "Demokritos"
Nuclear and Particle Physics Institute
Tandem Accelerator Laboratory
tandem.inp.demokritos.gr

Development of a Gas Ionisation Detector for the ToF-ERDA setup at N.C.S.R "Demokritos"

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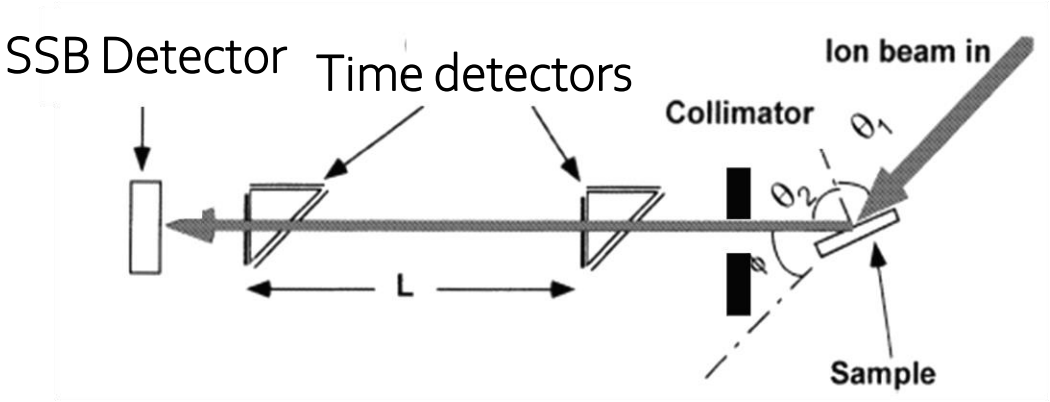
Motivation

Time of Flight – Elastic Recoil Detection Analysis (ToF – ERDA) experimental setup delivered by Ruđer Bošković Institute & installed at Tandem Laboratory of N.C.S.R "Demokritos"

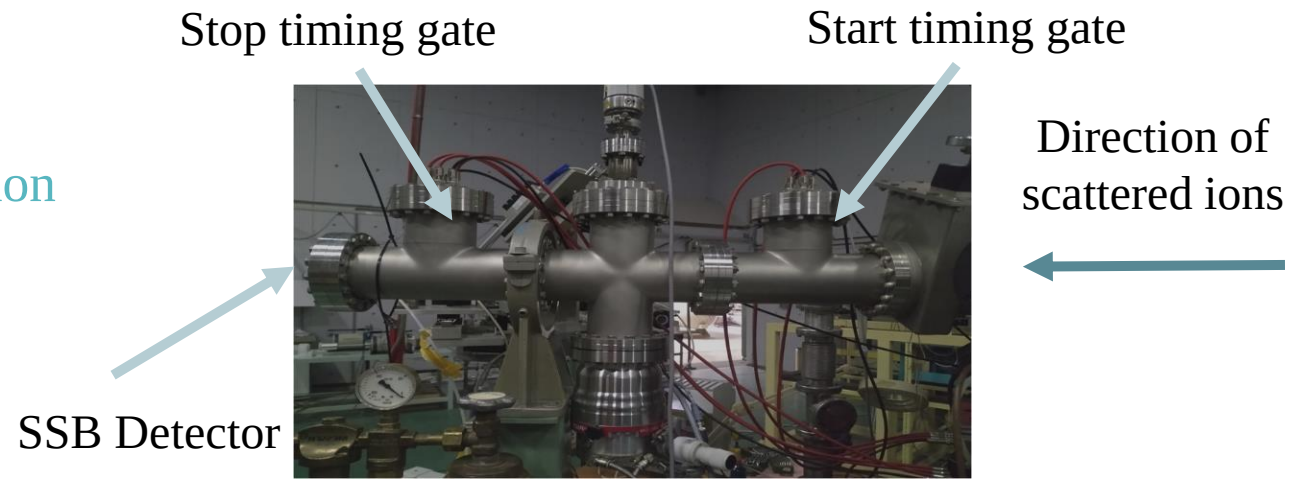


Detection of heavy ions:

→ fast degradation of SSB detector performance

!! Replacement of the SSB detector with a Gas Ionisation Detector

- Long lasting performance – no defects
- Better energy resolution for heavy elements

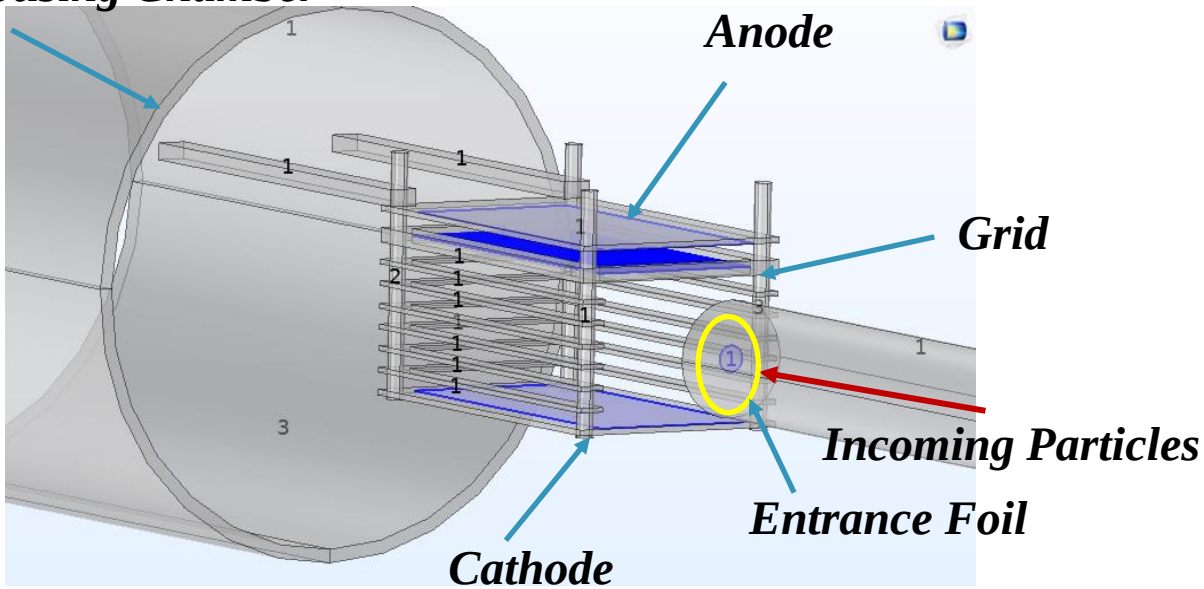


Design

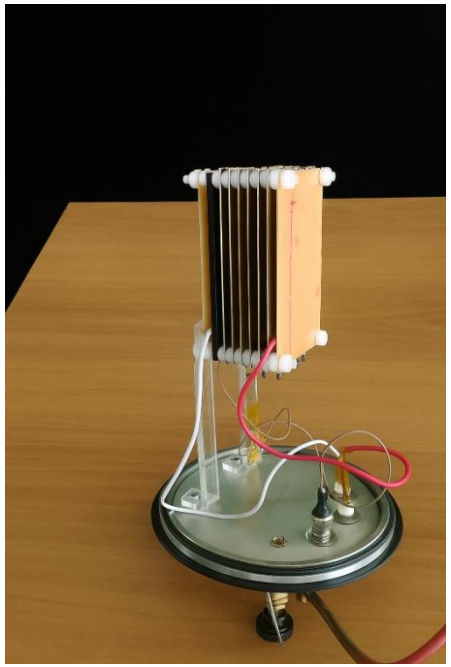
Pretty Simple & Low Cost

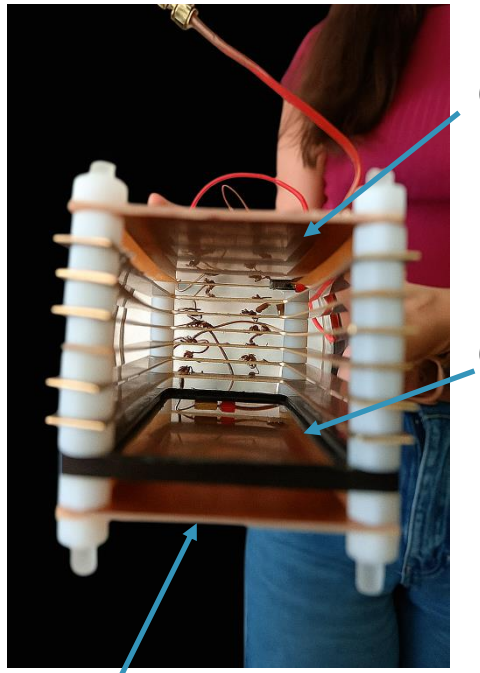
- 2 parallel Copper plates 110 x 60 mm → Anode & Cathode electrodes
- Tungsten Frisch grid 40 x 40 mesh → For the separation between drift and mesh region
- 6 metallic “shaping rings” → Ensure the homogeneity of the electric field in the drift area

Housing Chamber

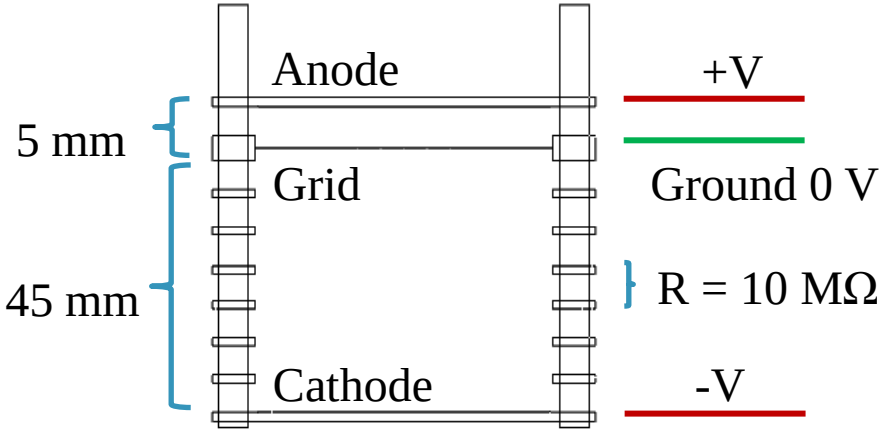


COMSOL Multiphysics 6.2





Schematic & Details



- Grid & Cathode are coupled via shaping rings and resistors (Voltage divider)
- Negative Voltage in Cathode
- Positive Voltage in Anode through Canberra 2003BT Charge Sensitive Preamplifier
  - Amplification (Canberra 2022)
  - DAQ

Technical Requirements:

✓ Thin entrance window for minimisation of the energy loss of the recoils
→ $Si_3N_4 \leq 50$ nm (imposes pressure limitations, 40 – 200 mbar)

✓ Gas with: - low w-value (mean energy required for the creation of electron-ion pair)
- high stopping power for fully stopping the ions in the active length of the detector
- low mass elements to avoid remarkable levels of scattering

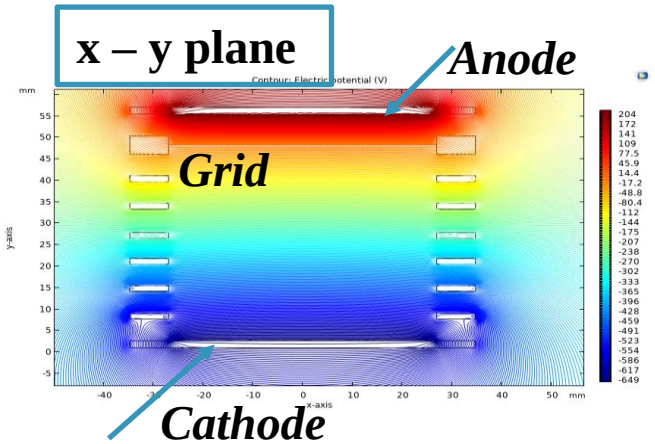
→ **Isobutane** – ideal choice

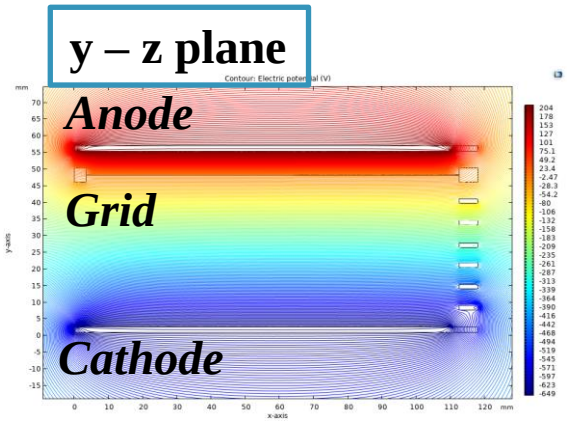
**Due to limitations, we used:*

- Argon Mixture 93% - CO_2 7%
- 230-700mbar
- Kapton & Mylar Foils

Voltage Determination & Noise

✓ ***Simulations*** using COMSOL Multiphysics 6.2 conducted for different voltage sets in order to ensure the homogeneity of the electric fields





COMSOL Multiphysics 6.2

✓ ***Experimentally***

For Anode:

1. Cathode → 0 V
2. Tried different Voltage values 0 – 700 V
3. For different pressures 230 – 500 mbar

$V_{anode,\ final}$ = 210 Volt ⟹ Electric field: ~ 42 V / mm

For Cathode:

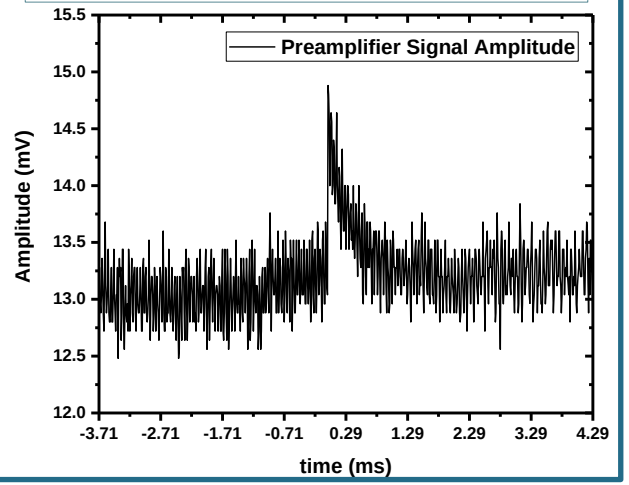
1. Fixed Anode → + 210 V
2. Tried different Voltage values -400 – -1200 V
3. For different pressures 230 – 500 mbar

$V_{cath,\ final}$ = -650 Volt ⟹ Electric field: ~ 14.5 V / mm

✓ ***Noise***

- Noise after preamplifier ~ 1 mV p-p
- Pulse rise time ~2 us
- After amplification – noise kept as low as possible

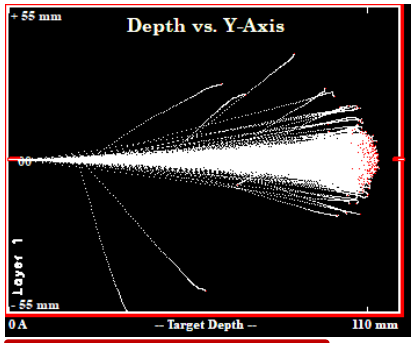
^{241}Am,α-source, E = 5.5 MeV



^{241}Am source test

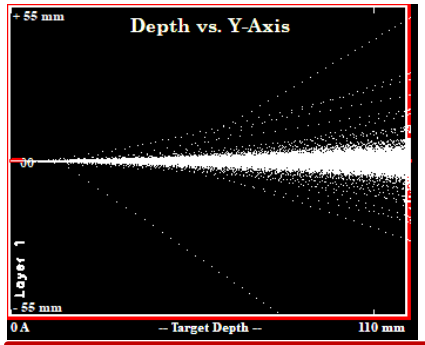
- ^{241}Am collimated source (d ~ 1 mm)
- Placed in front of the detector entrance
- Argon Mixture
- E_{alpha} = 5.5 MeV
- V_{anode} = 210 V, $V_{cathode}$ = -650 V

P = 500mbar



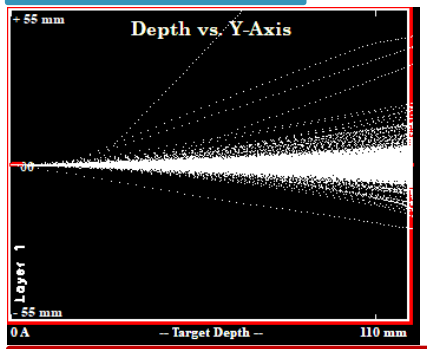
E_a = 5.5 MeV

P = 230mbar



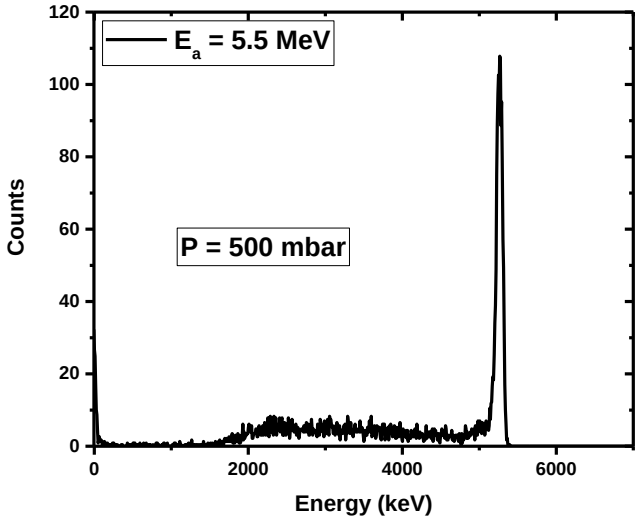
$E_{a,effective}$ = 2.3 MeV

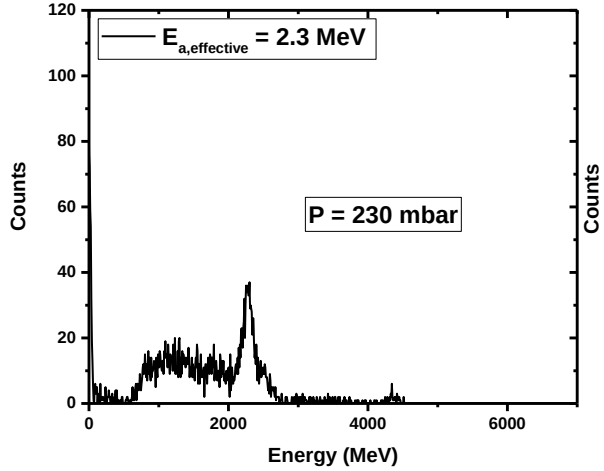
P = 305mbar

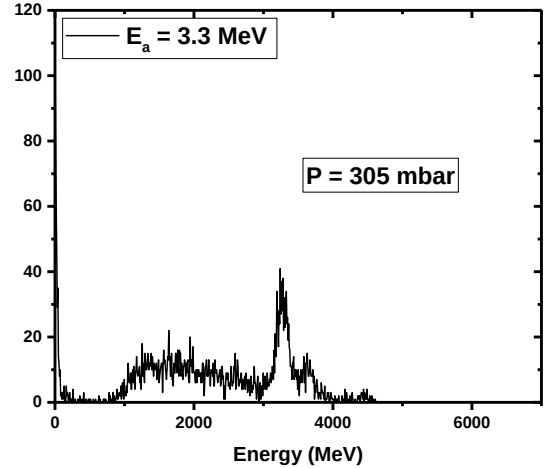


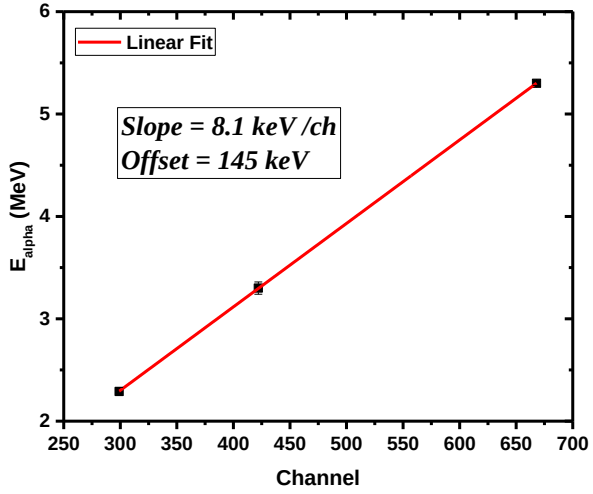
$E_{a,effective}$ = 3.3 MeV

SRIM 2013





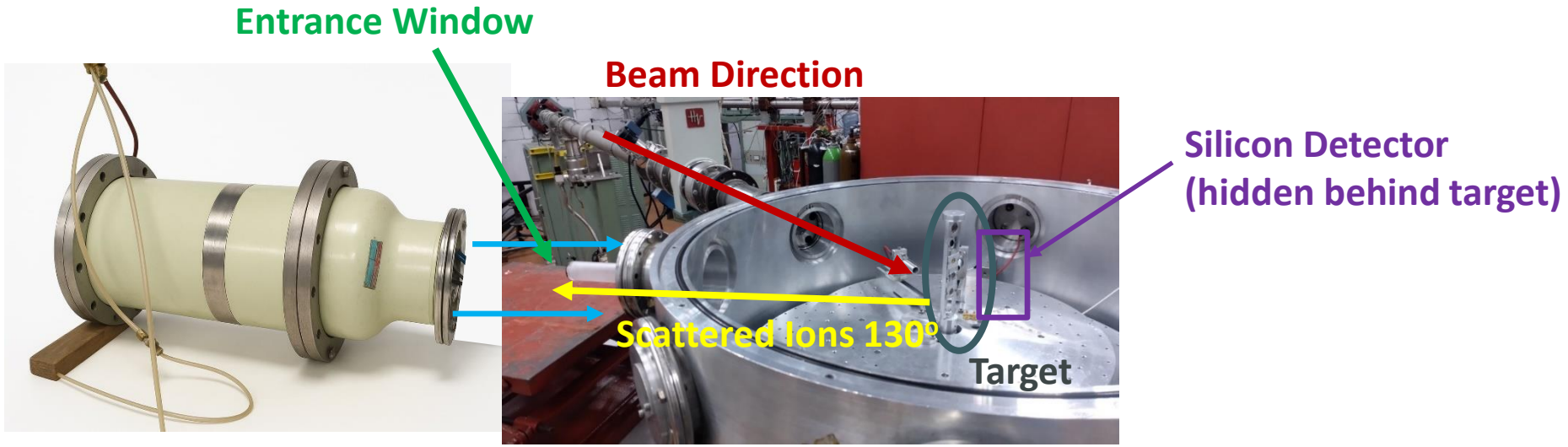




❖ In all cases the total counting rate was the same

Beam Tests

- Detector chamber mounted on the cylindrical goniometer chamber of Tandem Laboratory of N.C.S.R. “D” – 130^{o} exit angle
- Surface Silicon Detector in symmetrical angle
- Proton beam energies: 1000 – 1400 keV
- Oxygen beam 13 MeV
- A ^{197}Au thin target (140ug/cm^{2}) was used for the scattering of the beam
- Entrance window: Kapton foil 7.5 um OR Mylar foil 2.5 um



Beam Tests – proton beam

-Proton beam of E = 1000, 1200, 1300 & 1400 keV

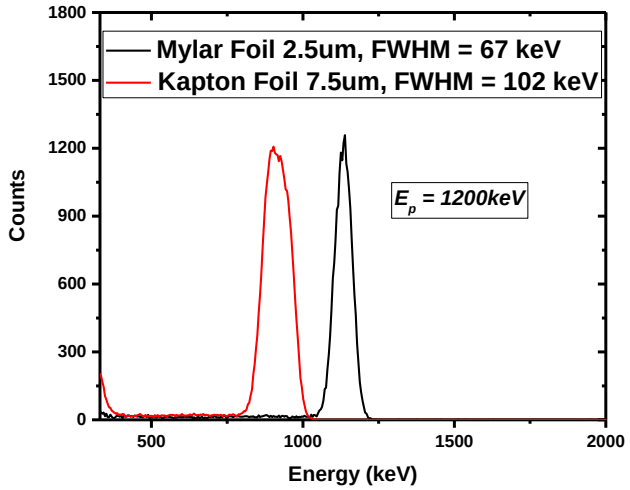
-^{197}Au thin target

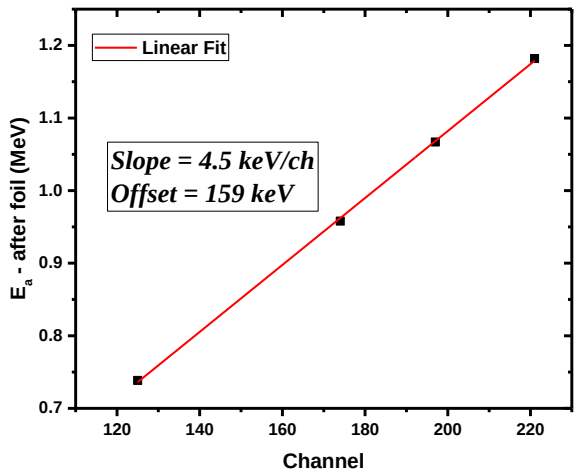
-Energy loss in entrance foils ranges between 32 – 26 keV/um { Kapton: 240 – 195 keV; Mylar: 80 – 65 keV

-Range in the Detector ~ 55 – 105 mm

-Gas Pressure = 400mbar

-V_{anode} = 210 V, $V_{cathode}$ = -850 V

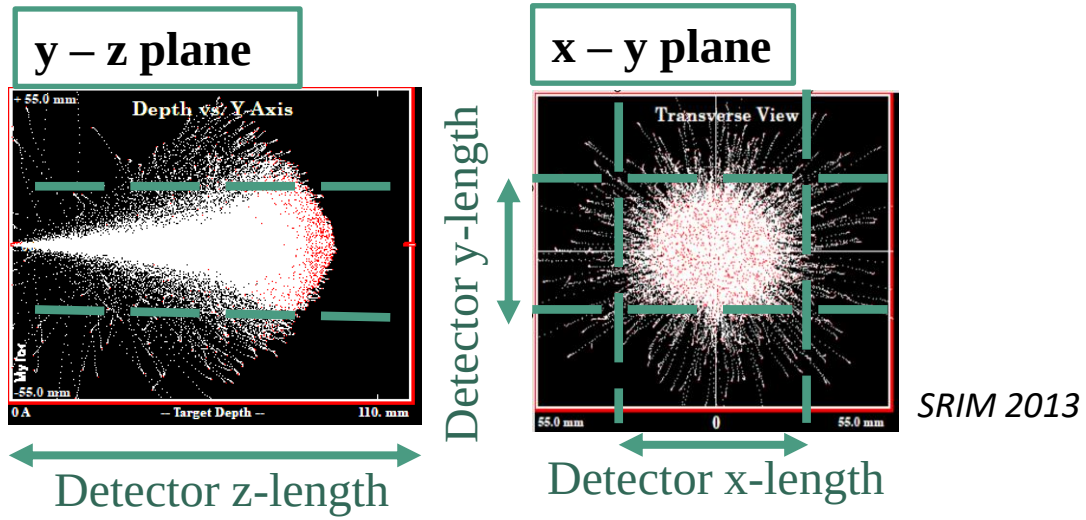




Beam Tests – proton beam

- The ratio between the geometrical solid angles of the windows of the 2 detectors $\frac{\Delta\Omega_{Si}}{\Delta\Omega_{Gas}} = 14.9$
- The yield ratio of the main peak → $\frac{Y_{Si}}{Y_{Gas}} = 19.8$

→ Particles exceed the physical dimensions of the detector due to lateral straggling

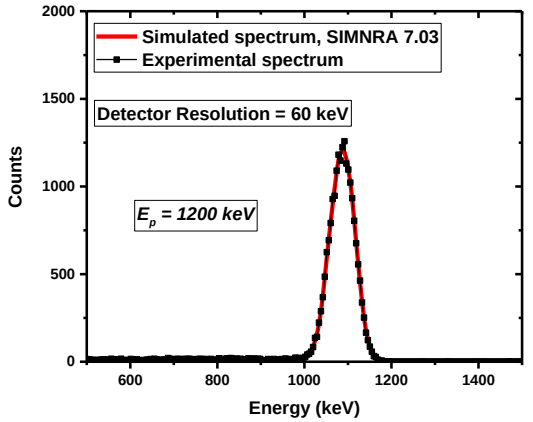


E_p = 1200 keV, 400mbar

Rough estimation of the resolution:

- Calibration
- Ratio between the geometrical solid angles
- Simulated Silicon detector spectrum, SIMNRA 7.03

Gas Detector spectra



Under the specific conditions

- *Detector resolution = 60 keV*
  - not affected by the existence of the entrance foil
- *Silicon resolution = 23 keV*

Needs improvement!

Beam Tests – Oxygen beam

-Oxygen beam 13 MeV

-^{197}Au thin target

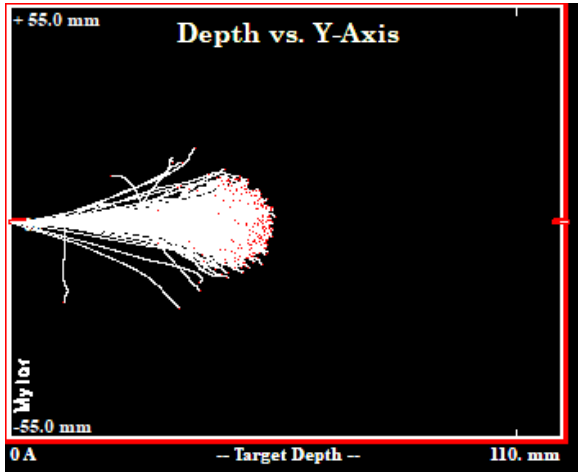
-Mylar entrance foil

-Reaches the gas with energy ~6 MeV, similar to ERDA expected

-Gas Pressure ~230mbar

-V_{anode} = 210 V, $V_{cathode}$ = -650 V

-Range in the Detector ~ 50mm



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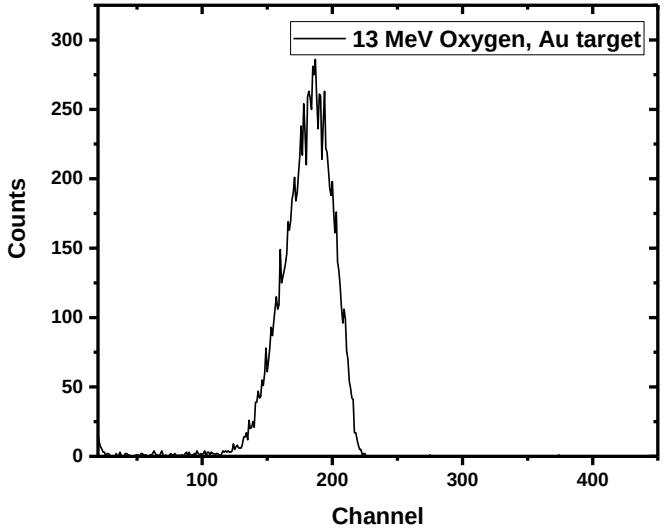

❖ *Comparing with Silicon detector*

Ratio between detectors solid angles → $\frac{\Delta\Omega_{Si}}{\Delta\Omega_{Gas}} = 14.9$

Yield ratios of the Oxygen peaks → $\frac{Y_{Si}}{Y_{Gas}} = 15.6$

Good Agreement !

Future Perspectives

- Replace the entrance window with thin Si_3N_4 for the minimisation of energy loss of detected particles
- Replace argon gas with isobutane
- Characterise the detector behaviour in lower pressures and lower energies, more suitable for ToF - ERDA technique
- Substitute selected insulator-based components with metallic alternatives to enhance the performance
- Replace the single-plated anode to more complex patterns:
  - ❖ trapezoidal-shaped to achieve lower capacitance and higher resolution
  - ❖ divided in pieces to function as ΔE-E detector for application in different IBA techniques
- !!! Mount the chamber on TOF-ERDA spectrometer and evaluate the overall performance

Thank you for your attention!