

# Application of Time Projection Chamber in Nuclear Physics

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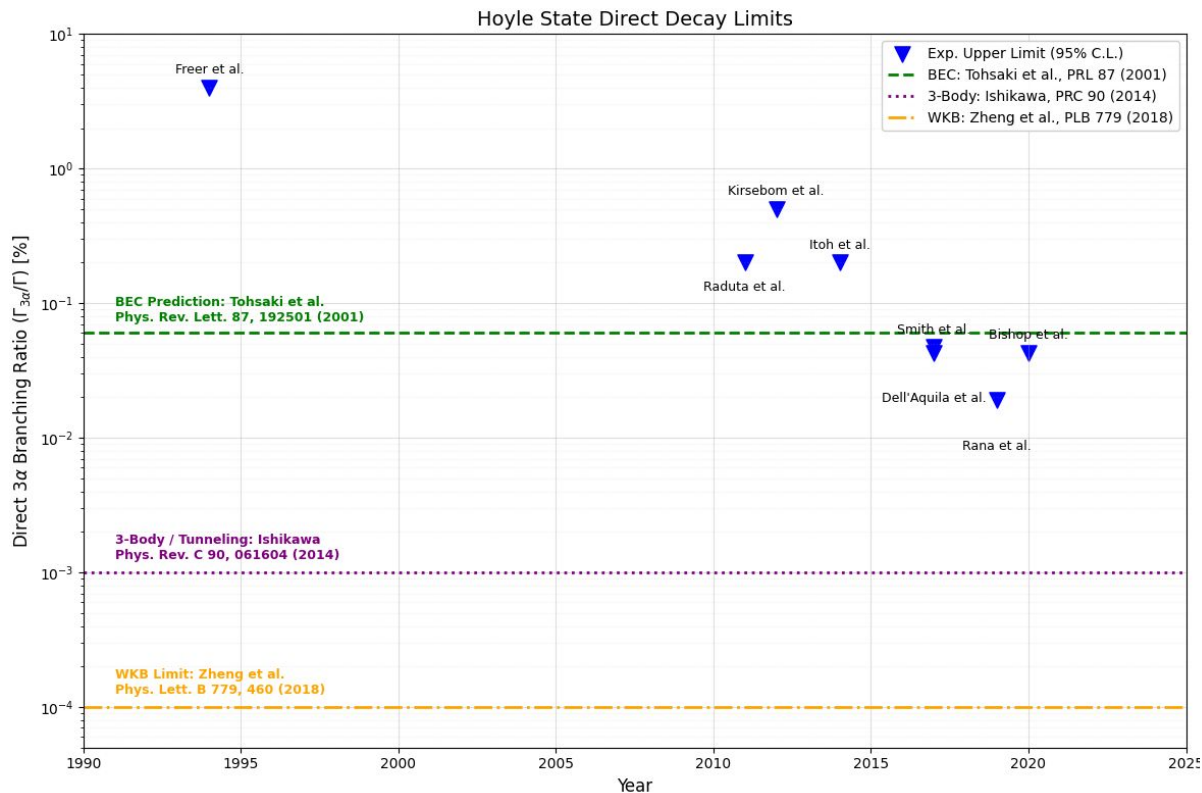


**2 February, 2026**

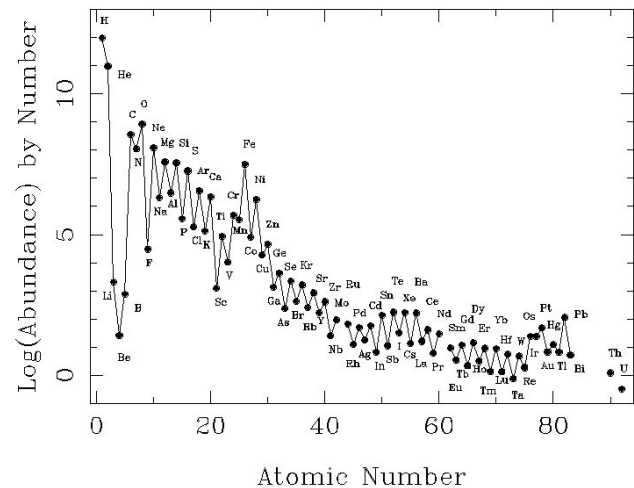
**7th Technology & Instrumentation in Particle Physics Conference**

- ❖ **Development of prototype SAT-TPC for alpha particle tracking**
  - Characterization of the MicroMegas
  - Prototype SATTPC design and reconstructed tracks
  - Validation with simulation
- ❖ **Summary and future plan**

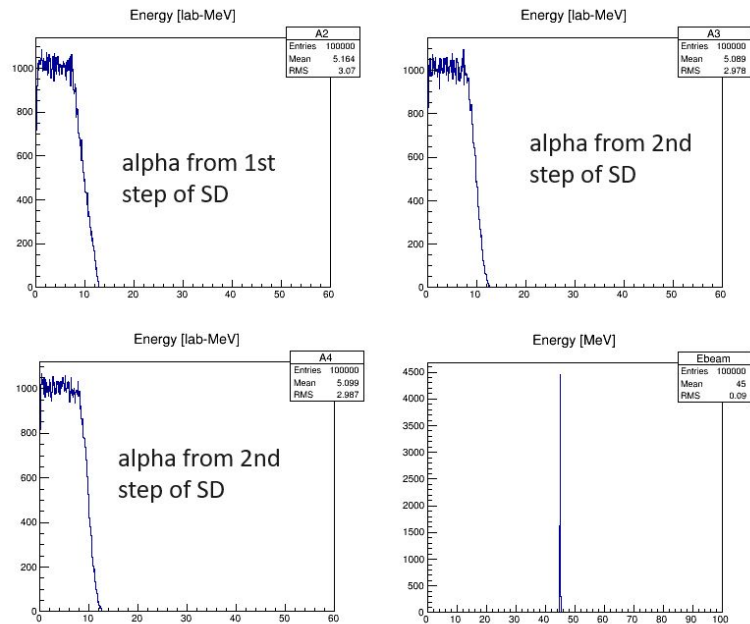
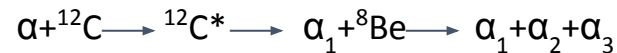
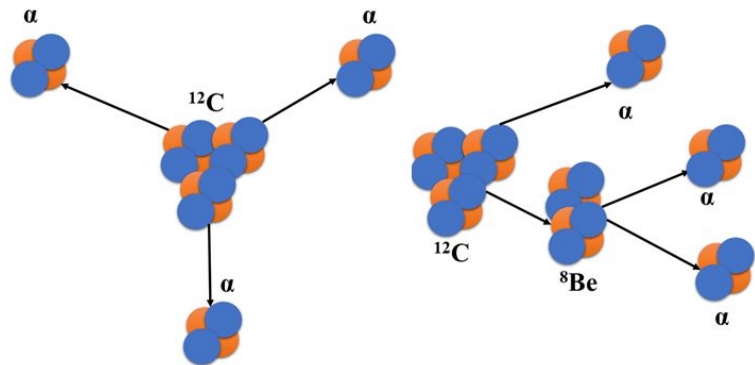
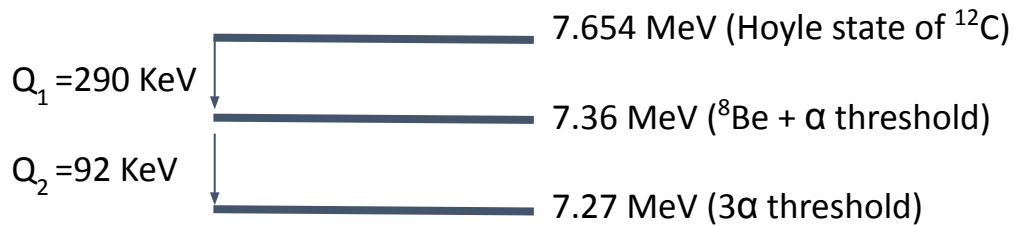
# Motivation



Logarithmic SAD Abundances:  $\text{Log}(H) = 12.0$



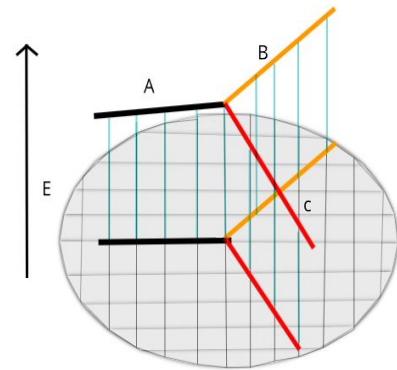
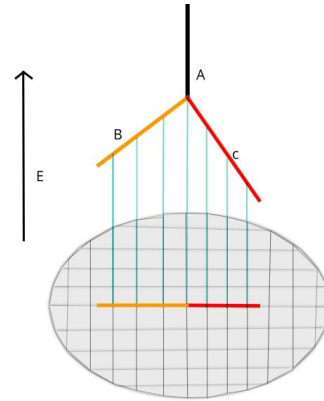
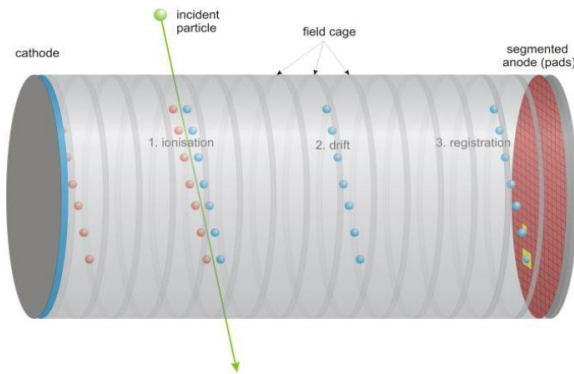
# Motivation of this work



4He beam energy (30-60 MeV) @  
 K130 cyclotron at Variable Energy Cyclotron Centre, Kolkata

# Time Projection Chamber in a nutshell

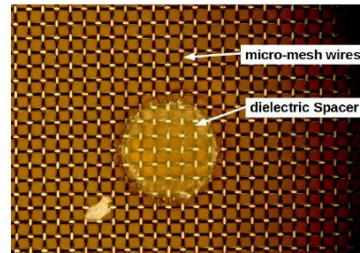
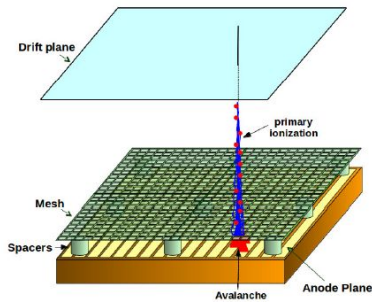
- ❖ TPC has an active gas volume with a good position-sensitive electron collection system inside an electric field and a charged particle will produce primary ionization along its track



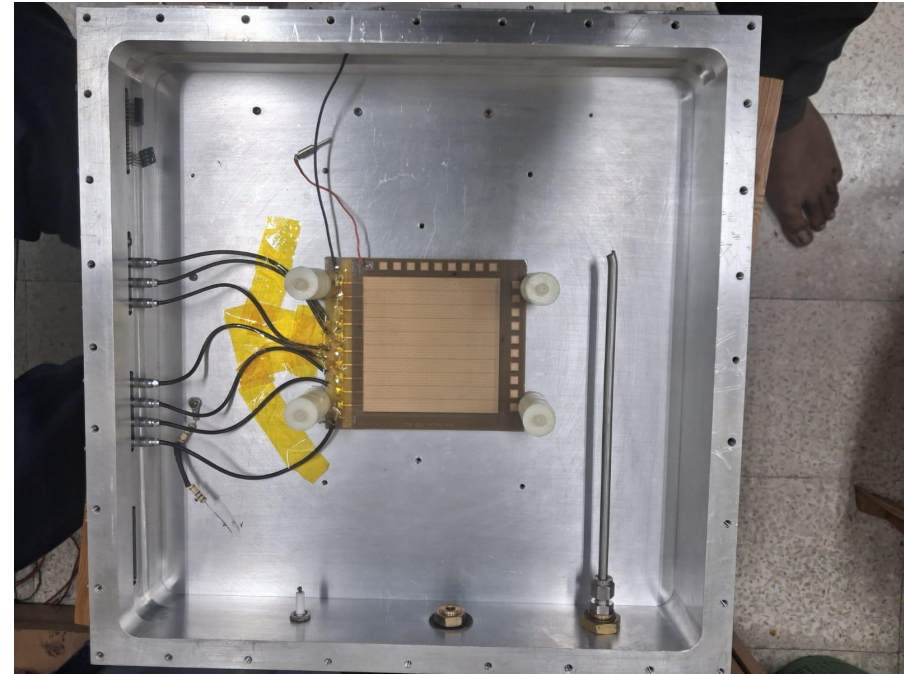
- ❖ The primary electrons drift under the action of the uniform electric field towards the end equipped with an electron multiplier for collecting signal producing a 2d image of the track
- ❖ 3rd dimension from the drift time of electrons
- ❖ Information
  - Angles, energy loss (from charge distribution over distance), particle identification

# End Plate readout: Micromegas

## ❖ Micromegas

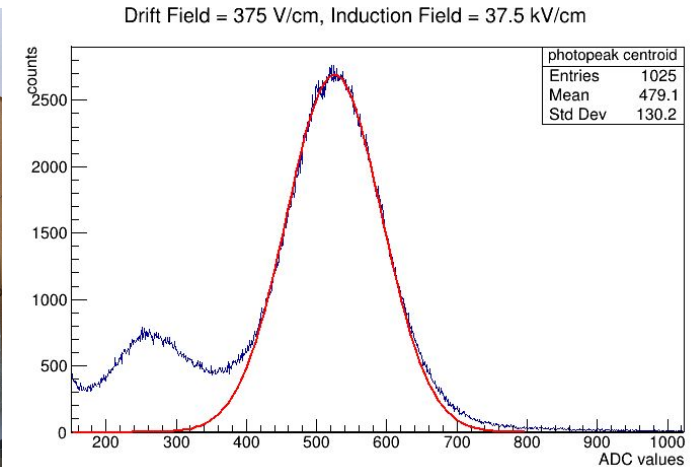
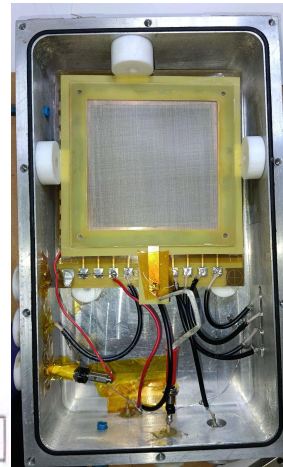
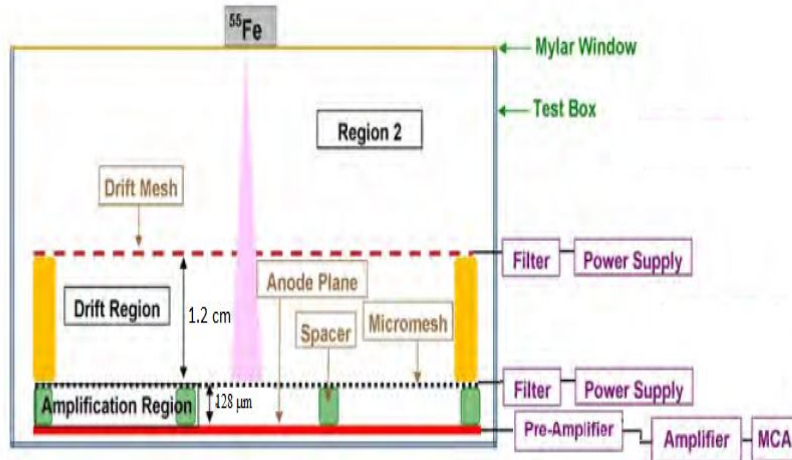


- ❖ The Micro Mesh Gaseous Structure (Micromegas) is a parallel-plate detector, composed of a very thin metallic wire-mesh which separates the low field drift region from the high field amplification region



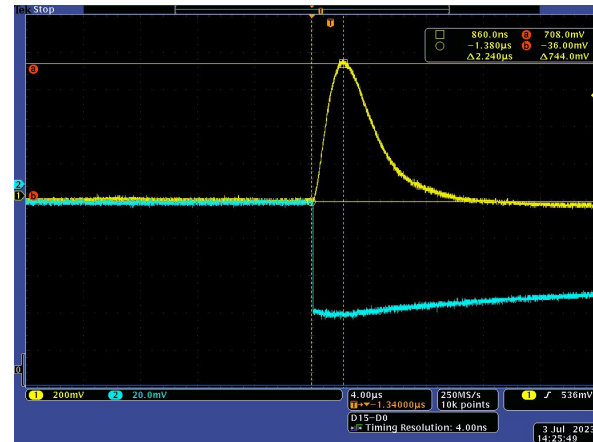
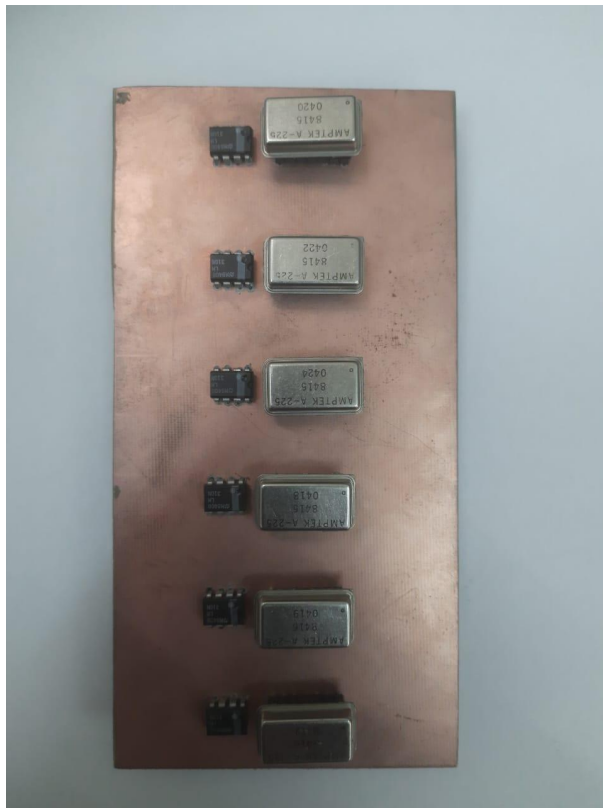
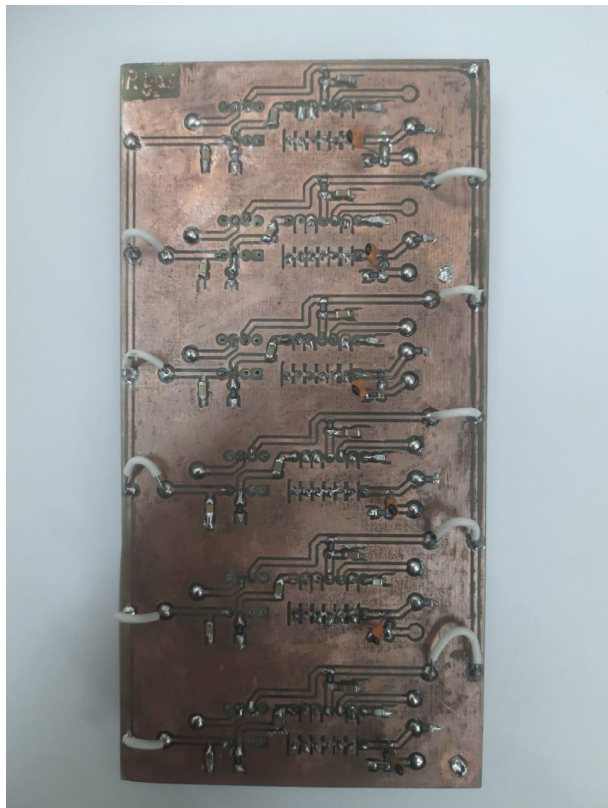
# Experimental Setup : Micromegas in test box

- ❖ The detector was placed inside a leak-proof chamber wherein a drift plane has been mounted above the detector
- ❖ Operated with Argon and CO<sub>2</sub> (90 : 10) gas mixture at atmospheric pressure.



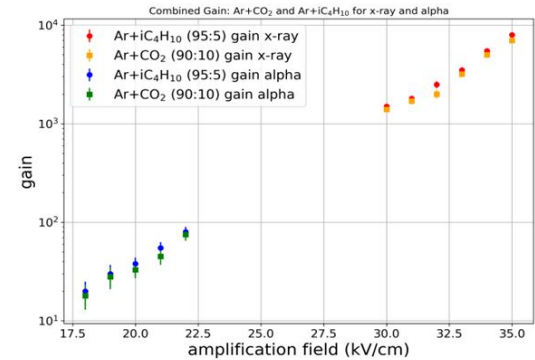
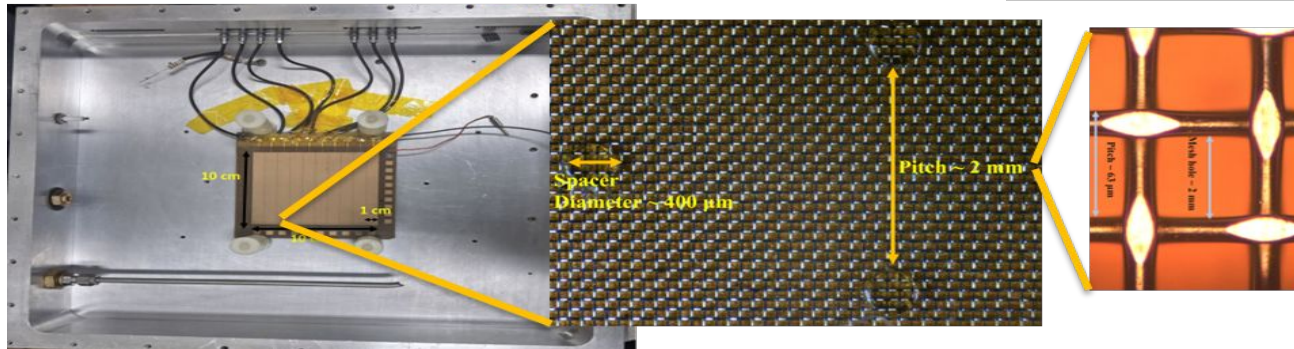
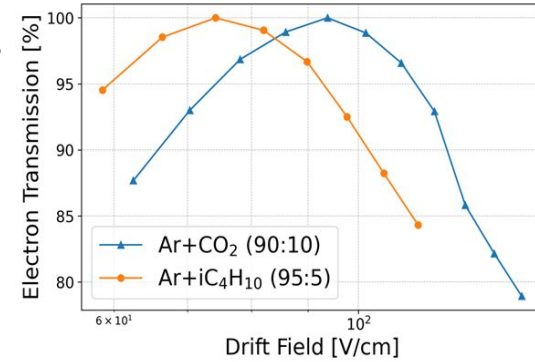
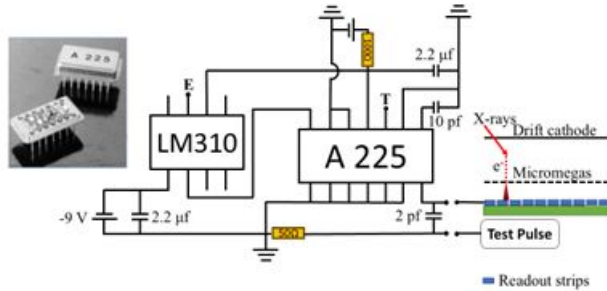
- ❖ Fe55 Used as a soft X-Ray source
- ❖ Conversion gap and amplification gap of the Micromegas is 1.2 cm and 128 μm respectively

# 6 channel DAQ for Micromegas



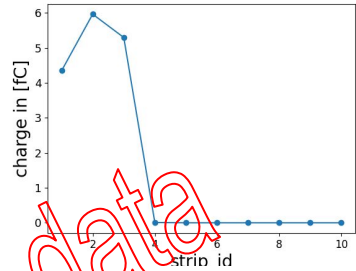
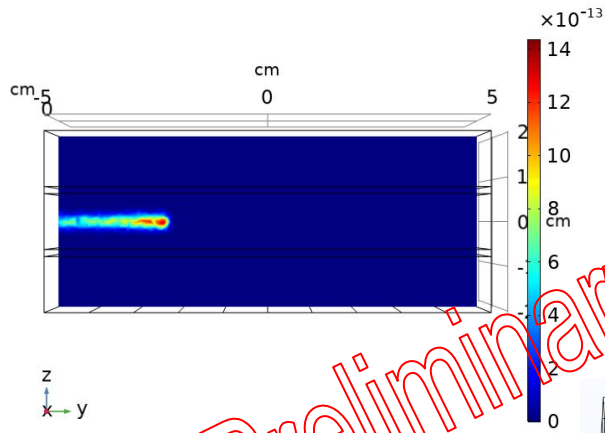
# Development of Time Projection Chamber

- Characterized Micromegas gain, energy resolution and electron transparency in Ar-CO<sub>2</sub> and Ar-iC<sub>4</sub>H<sub>10</sub> mixtures using <sup>55</sup>Fe X-rays and <sup>241</sup>Am α-sources to establish optimal operating fields.



# Transport of primary electron in drift region of TPC (Ar:CO<sub>2</sub> 90:10)

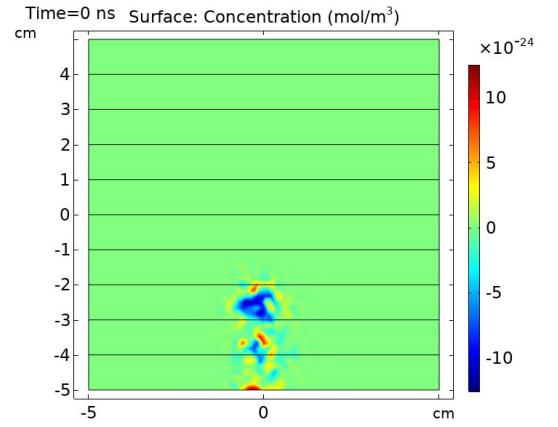
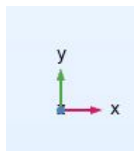
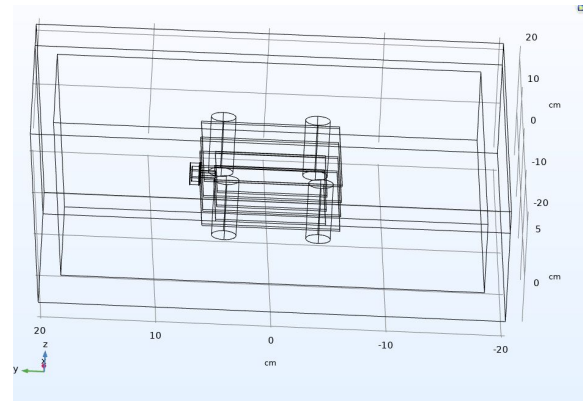
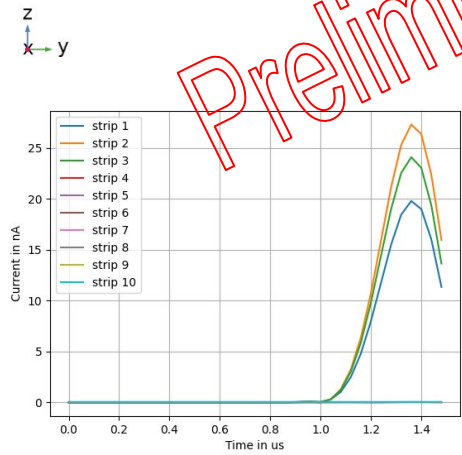
Time=0 ns Electron Concentration (mol/m<sup>3</sup>)



- ❖ The detector plane was segmented into 10 one dimensional strips with 1 cm width
- ❖ The simulation was performed with 325 V/cm drift field and in atmospheric pressure

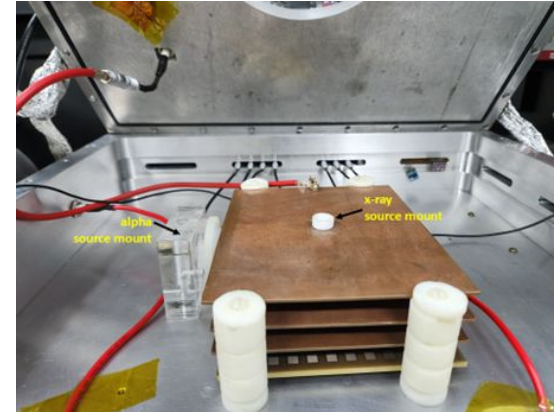
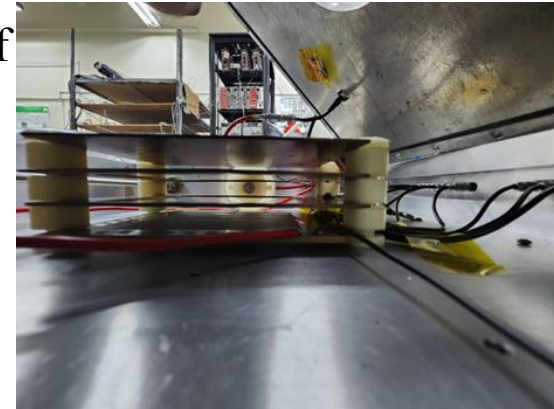
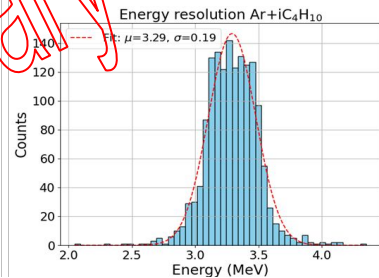
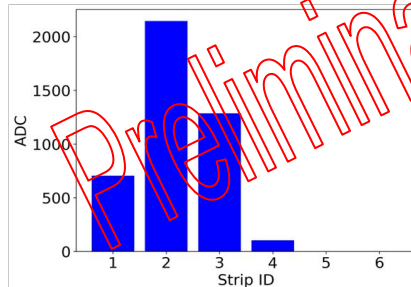
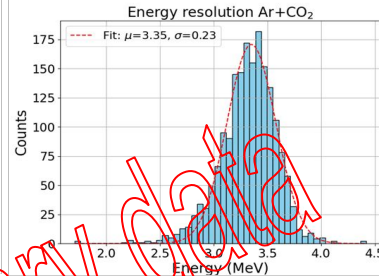
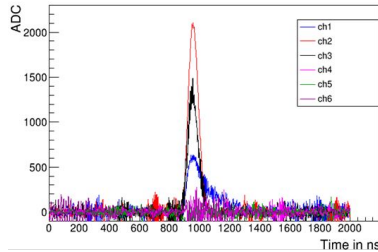
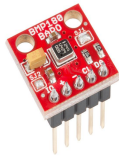
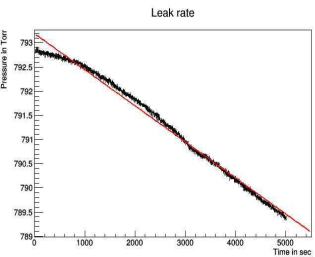
$$\frac{dE}{dx} = 2\pi N_a r_e^2 c^2 \rho \frac{Z}{A} \frac{q^2}{\beta^2} \left[ \ln\left(\frac{2m_e \gamma^2 \nu^2 W_{max}}{I^2}\right) - 2\beta^2 - \delta - 2\frac{C}{Z} \right]$$

Preliminary data



# Development of Time Projection Chamber

- The prototype SAT-TPC achieves  $\alpha$ -particle energy resolutions of  $\sigma = 6.9\%$  (FWHM  $\approx 16.1\%$ ) in Ar-CO<sub>2</sub> (90:10) and  $\sigma = 5.7\%$  (FWHM  $\approx 13.6\%$ ) in Ar-iC<sub>4</sub>H<sub>10</sub> (95:5) for an effective deposited energy of  $\sim 3.4$  MeV from 5.48 MeV <sup>241</sup>Am  $\alpha$ 's.



# Summary and Future plan

- ❖ Stable gain over 100 observed with Argon CO<sub>2</sub> and Argon + iC<sub>4</sub>H<sub>10</sub> gas mixtures.
- ❖ Energy resolution of 5.7% and 6.9% of alpha particle from <sup>241</sup>Am source obtained from prototype SATTPC data
- ❖ Adequate energy resolution for alpha particles, charge-profile analysis, suitable for particle identification and kinematic reconstruction of Hoyle state decay events in AT-TPCs.
- ❖ Future Work will include tests with other gas mixtures such as hydrogen and helium, expanding the versatility of AT-TPCs.
- ❖ Future Work will also include measurement of track length and energy of alpha particles in reduced pressure
- ❖ These results validate the Micromegas detector as a strong candidate for electron amplification in the present prototype and future upgrades to a full-scale Saha Active Target TPC

Thank you for your kind attention