Development of Micro-Pattern Gaseous Detectors for Nuclear Reaction Studies

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The fission fragment mass distributions can be used as an experimental probe to look for the presence or absence of shell effects in nuclei

Things We Need to Measure

(I) Z, A of emitted particles :

– tells us what the reaction was, what was made

Detection: by various means – dE/dx, time-of-flight

$$\frac{dE}{dx} = \frac{mZ^2}{E}$$

$$E = \frac{1}{2}mv^2$$

(II) Energy (E) and angles (θ) of emitted particles:

– excitation energies of the residual nuclei

– shapes of angular distributions can tell us about the reaction mechanism and properties of the residual nuclei

Detection: by direct energy measurement and position

(III) Cross sections :

σ, $\sigma(\theta)$ or $d\sigma/d\Omega$, $\sigma(E)$ or $d\sigma/dE$, $d^2\sigma/dEd\Omega$, etc.

– Magnitude of the cross section can inform us about a variety of properties.

Detection: by counting the scattered particles

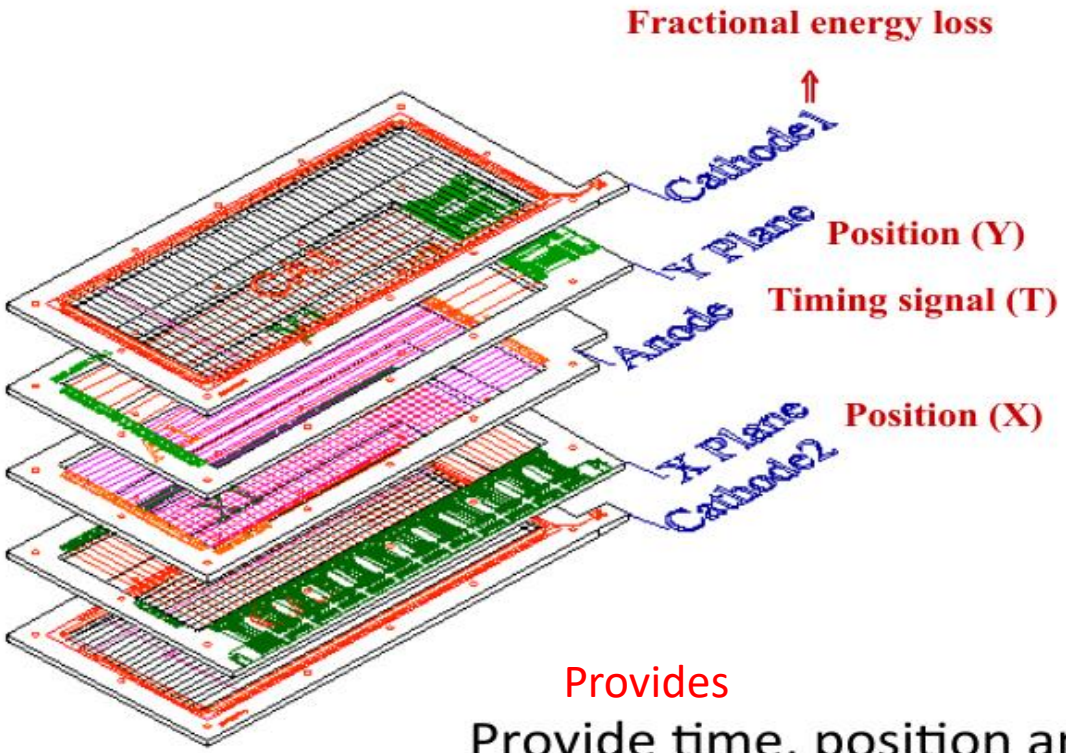
Energy, time, position and count

Multi-wire Proportional Counter (MWPC)

Effective area:

20 cm × 6 cm

24 cm × 10 cm



Low operational gas pressure

Thin walled window

Large surface area

Compact shape

High gain

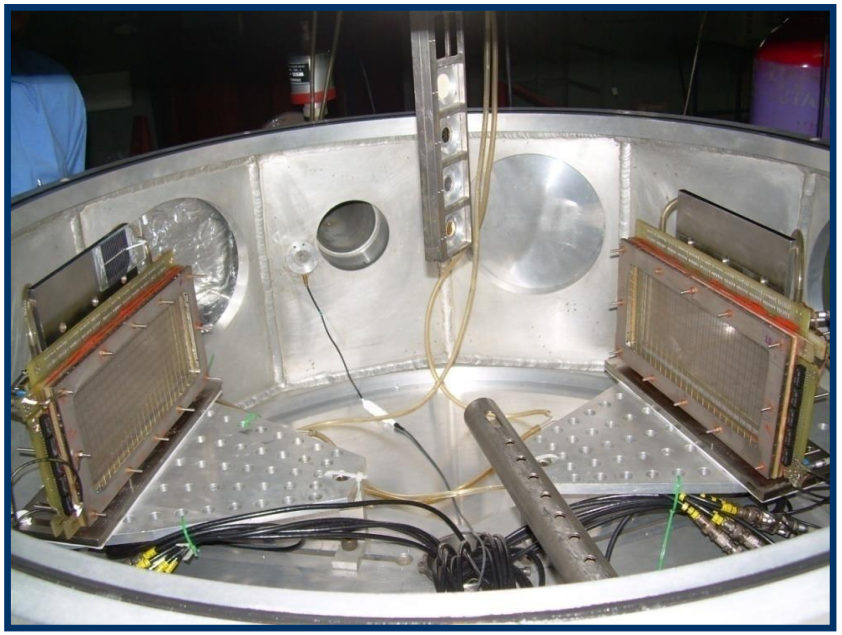
Breskin type detector

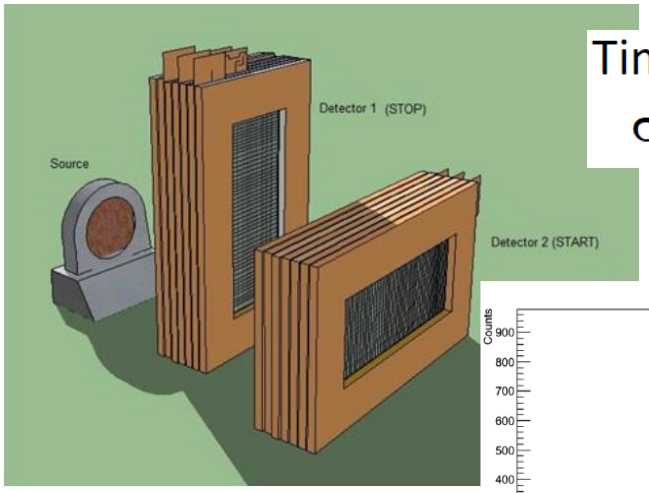
Provides

Provide time, position and energy loss info

- Produce secondary multiplication of primary electrons created in the region between Cathode and sense wires
- The very large electric field near the Anode wires causes a large localized avalanche of electrons and ions in the vicinity of the Anode
- Fast rising -ve pulse at the anode and +ve signals at the sense wires
- The position signals read by tapped delay lines (Rhombus industries, TZB-36/5 ns/tap)
- Designed and built at VECC

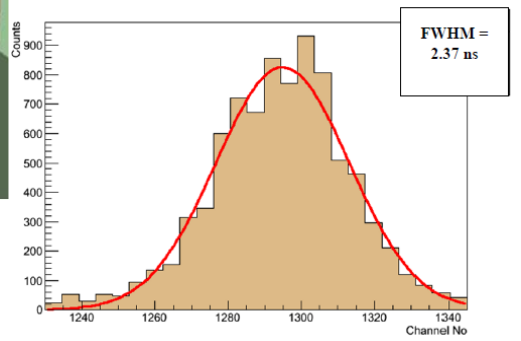
Reaction studied: ^{4}He + ^{232}Th; VECC beam : 26 – 70 MeV

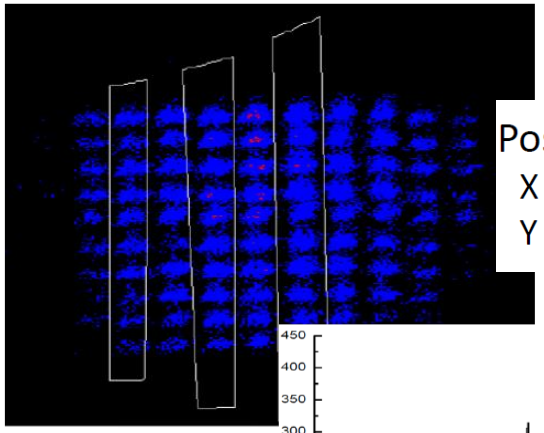




Time resolution

$\sigma_{det} = 0.7$ ns

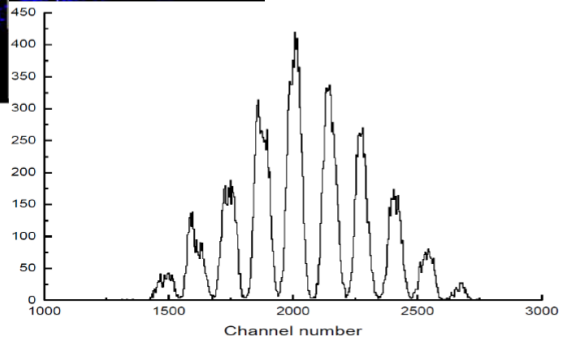




Position resolution:

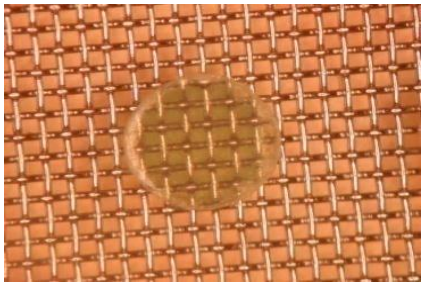
X (FWHM)= 1.2 mm

Y (FWHM)= 1.5 mm

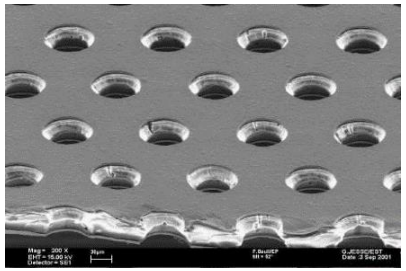


- Very good results obtained using MWPC.
- However, there are few drawbacks:
  - The central anode plane of MWPC is the main charge amplification region.
  - Since the gain ~(radius)-1, usage of 10 micron wire suits best for MWPCs
  - This makes the detector highly fragile and prone to tear
  - Replacement with other gaseous detectors can make the detector more robust.

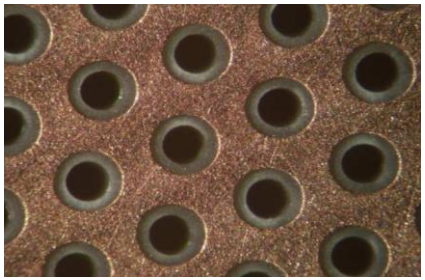
Recent Fundamental Innovations in Gas Detectors– Micro Pattern Gas Detectors



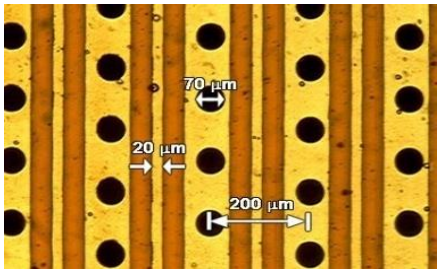
Micromegas



GEM



THGEM



MHSP

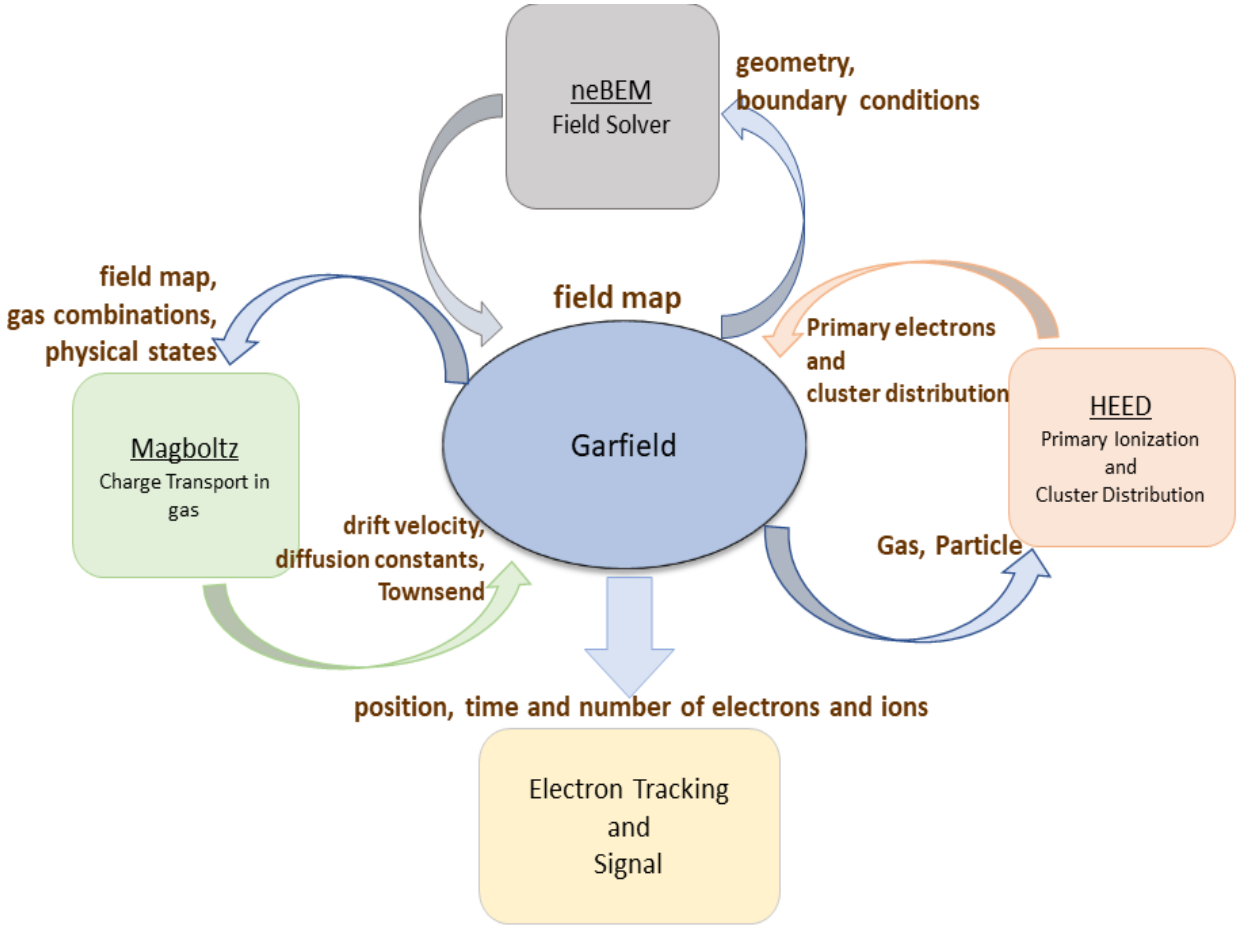
Design goals:

• Time of arrival of the fission fragment => Quick rise time of the anode signal.

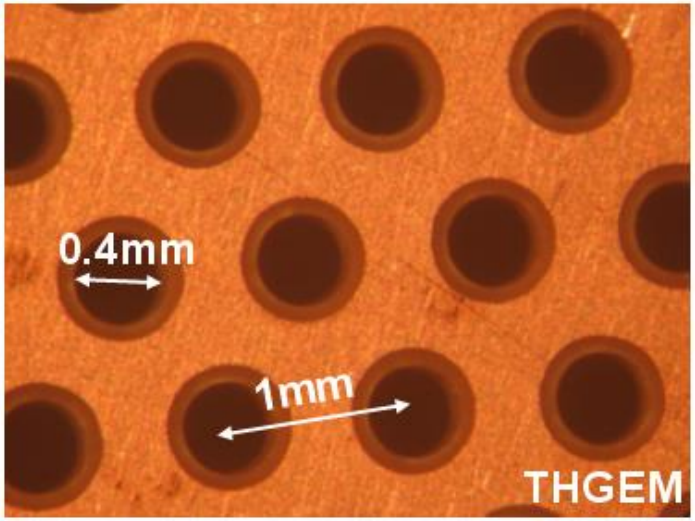
• Position signals (X and Y co ordinates) of the point of impact of the fission fragment => Induced wired planes for the position signals

• Energy loss of the fission fragment in the gas volume => readout from the pre amplifier.

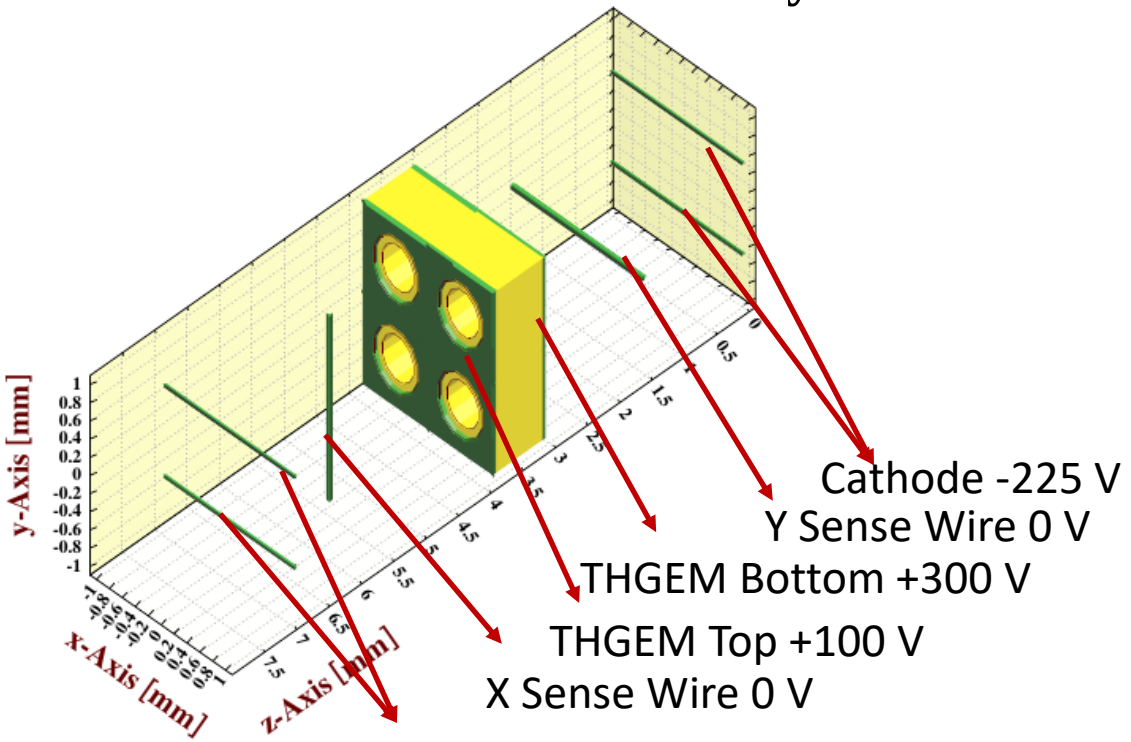
Tools to study detector response:



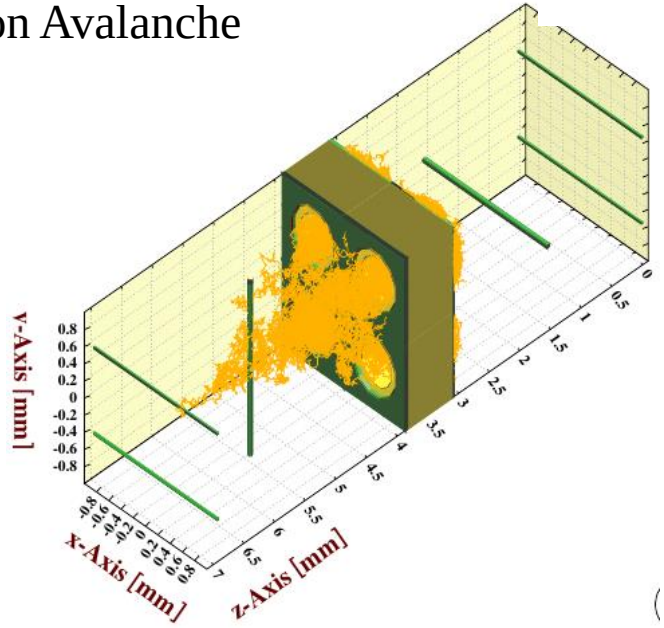
THGEM Detector



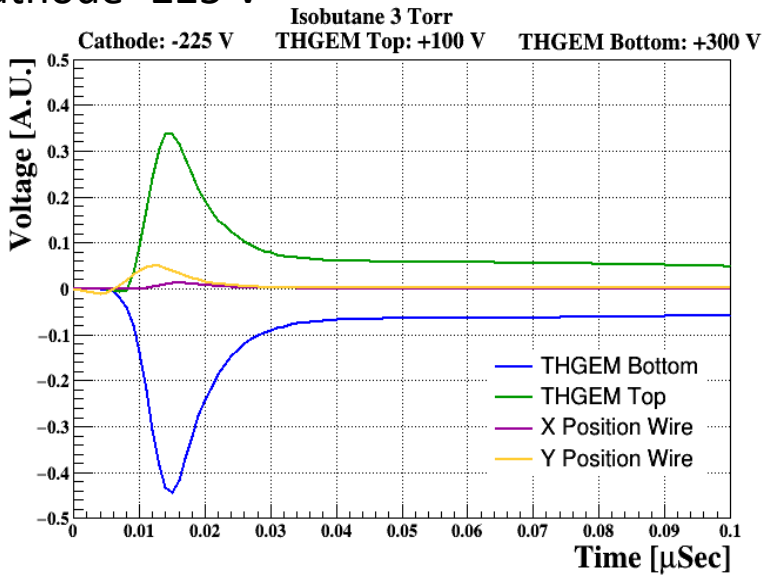
THGEM Multi-Wire Hybrid Detector



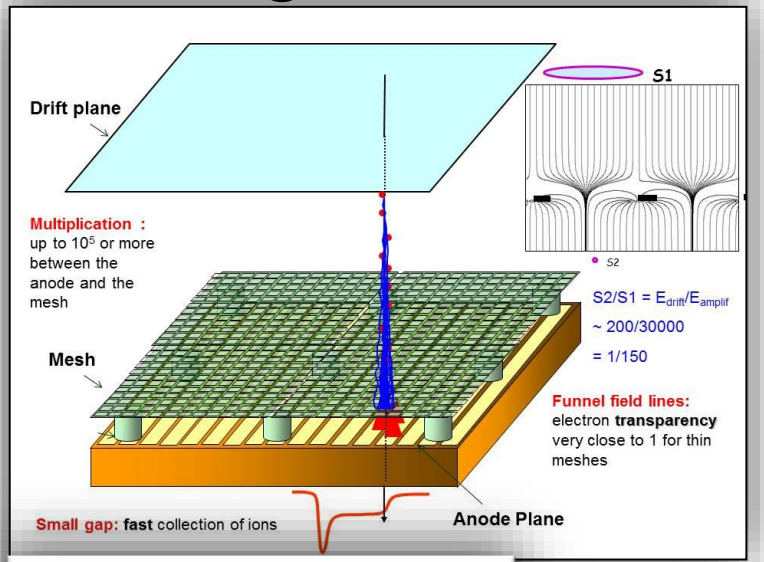
Electron Avalanche

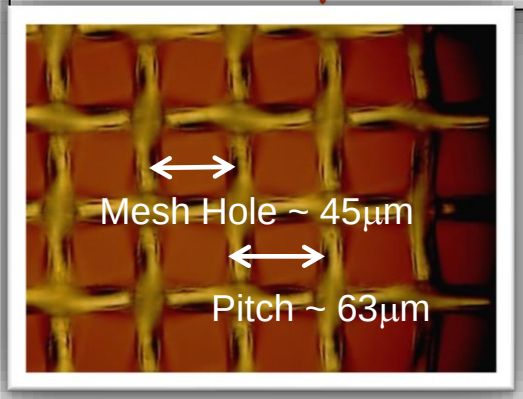


Cathode -225 V

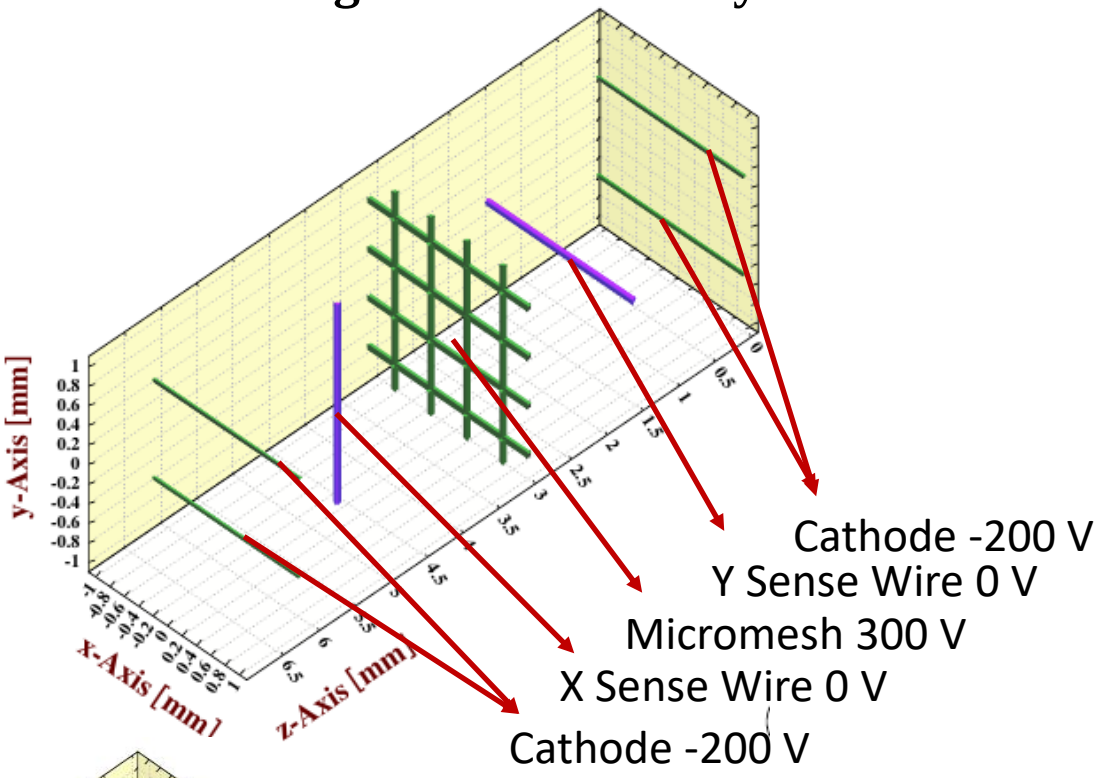


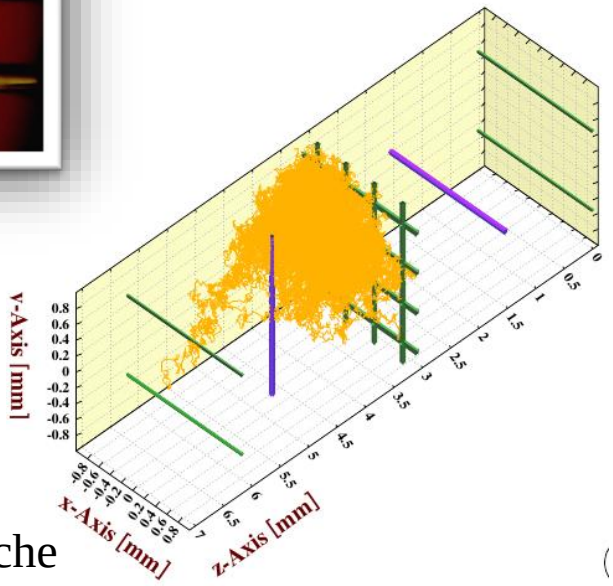
Micromegas Detector



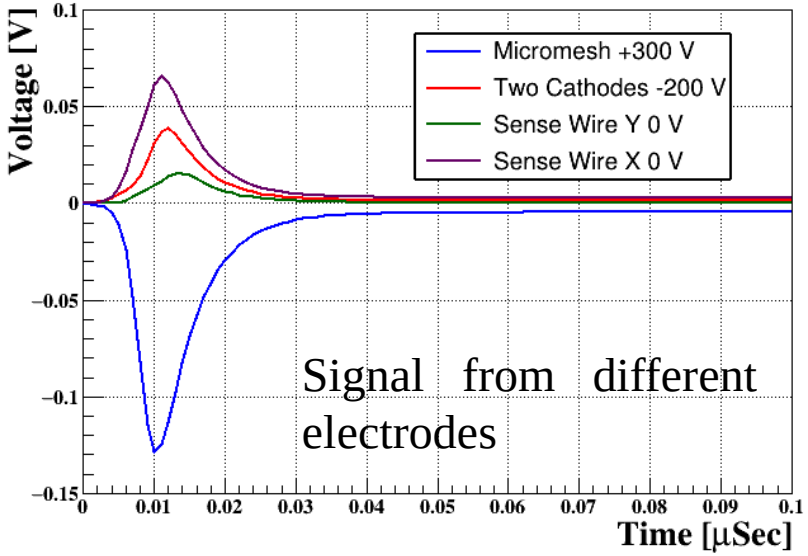


Micromegas Multi-Wire Hybrid Detector





Electron Avalanche



Conclusion and Future Plan:

a) The aim of this study is to build a MPGD-based device in low pressure environment for the measurement of charged particles and fission fragments.

b) Simulation toolkit has been validated at first by the good agreement reached between the simulation and experimental data for MWPC-based Breskin type detector.

c) Fabrication, experiment and simulation of THGEM-based detector is ongoing. Initial focus is to find suitable electrical and geometrical configuration for sufficiently strong signals from all the electrodes.

d) Simulation of the detector response of several new detector configurations is ongoing. This will be carried out to help the design optimization and data interpretation of the prototypes and understanding detector physics. Intrinsic detector properties will be investigated and related physics issues, such as discharge studies, ageing properties will be carried out. Atmospheric pressure characterization for locally fabricated THGEMs and Micromegas is ongoing.

e) Use of the new detector in different Indian accelerator facilities

References

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2. Sauli F, https://doi.org/10.1142/11882
3. Bhattacharya P et al., 2022 Jour. Phys.: Conf. Series 2349 012017

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THANK YOU