Recent advances in Time Projection Chambers and implications for space-based gamma-ray detection

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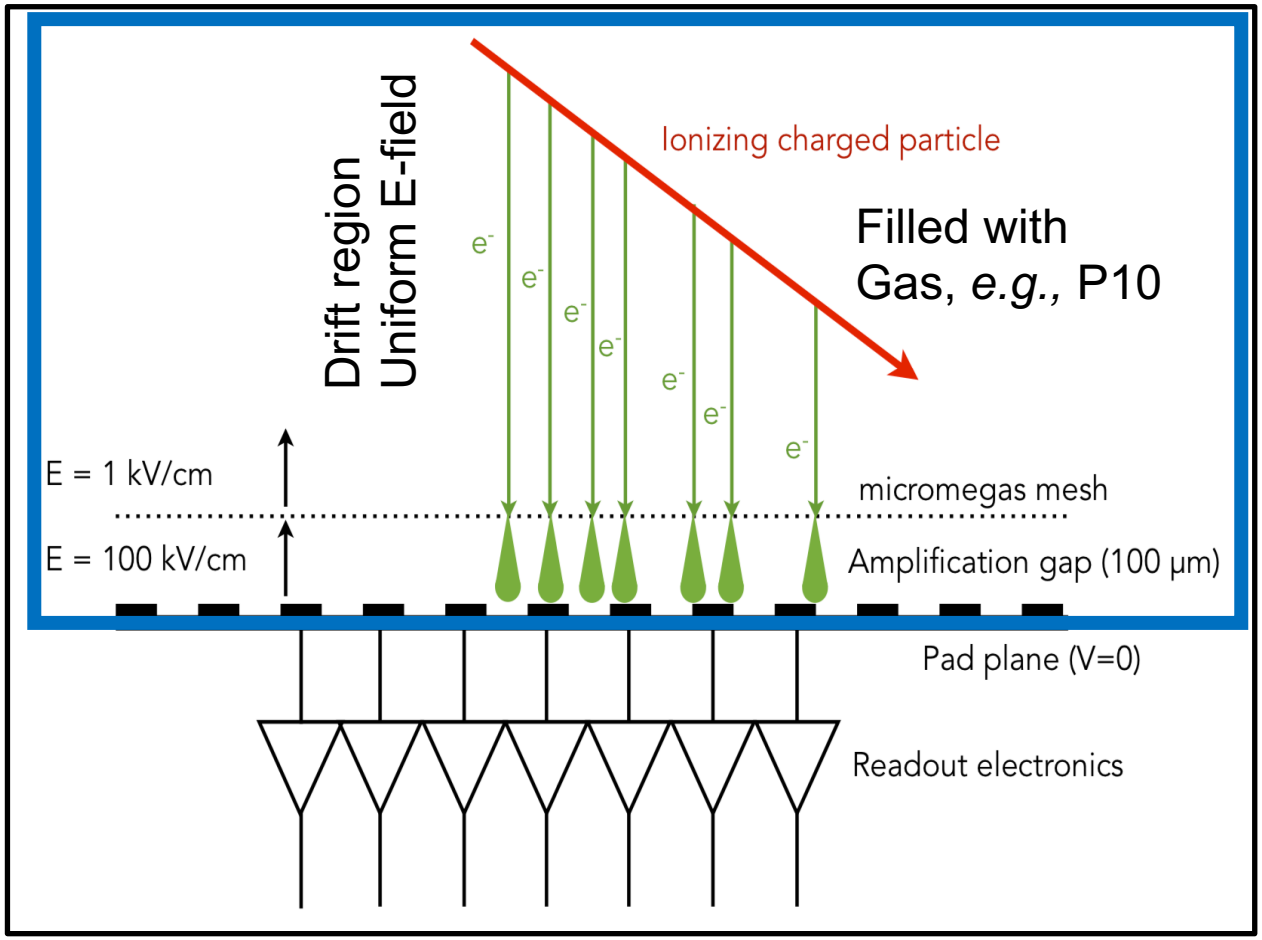
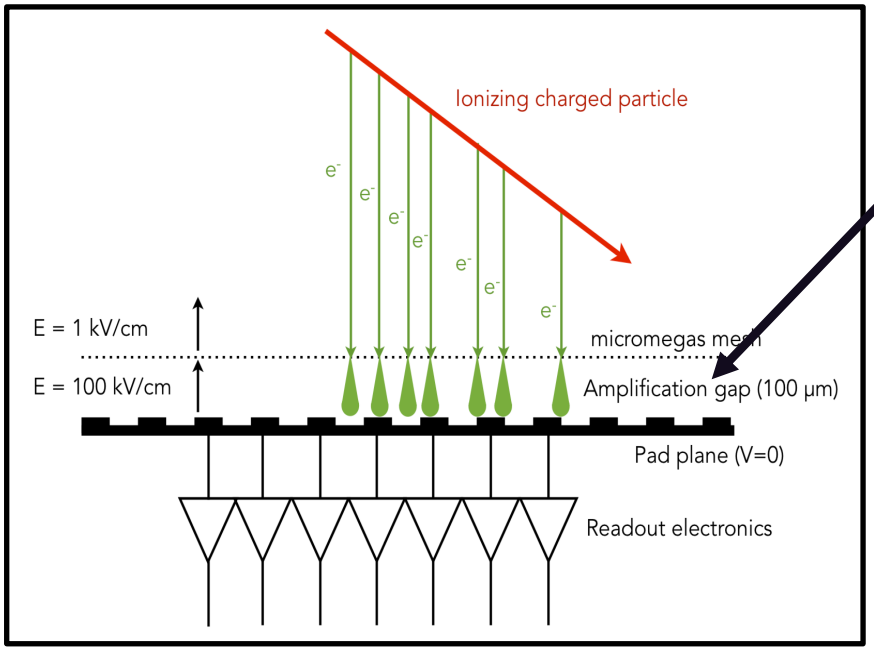
LA-UR-24-25142

Time Projection Chambers

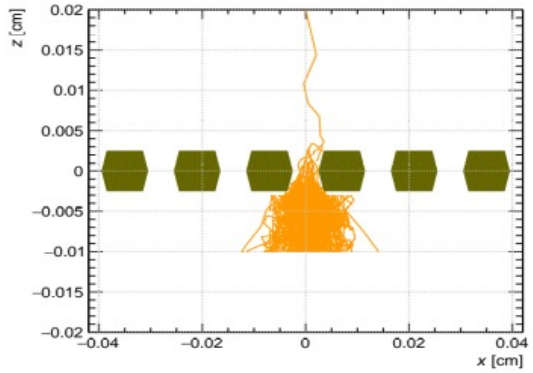


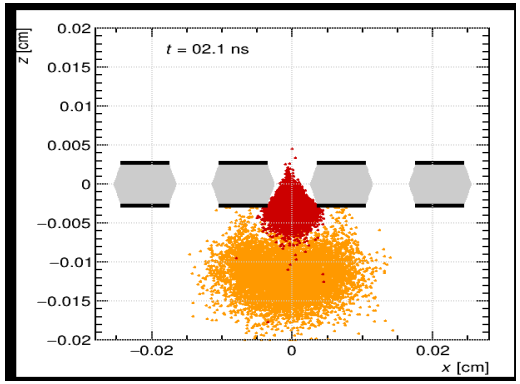
- x and y position of electrons (from primary ionization) provided by x-y position of pad →segmented anode
- Z-position from timing information, hence 3D tracks of charged particles
- Amplification of charge just above the pads

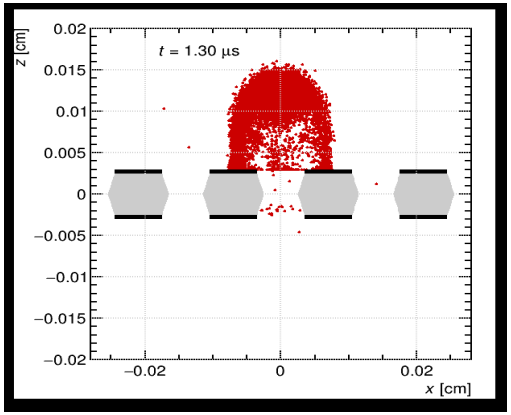
Time Projection Chambers



- For amplification, different micro-pattern gas detectors are used
- Micromegas
- Gas Electron Multipliers (GEMs)
- Thick Gas Electron Multipliers (Th-GEMs)
- OR combination of these

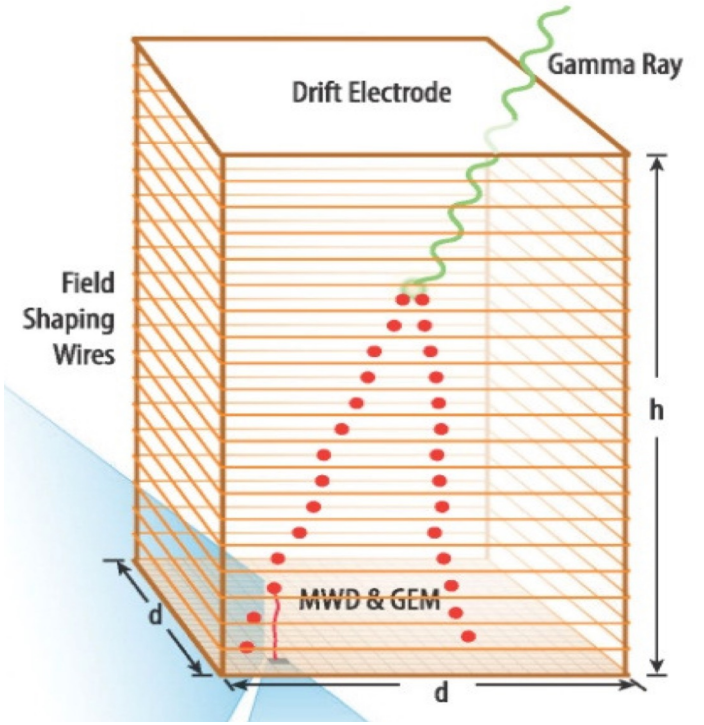




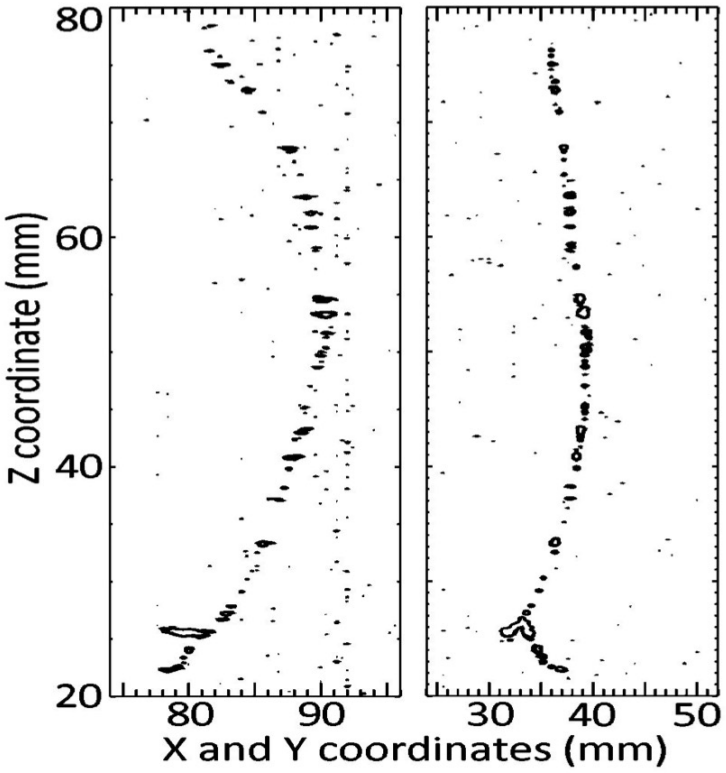


Simulated avalanche in GEMs

TPCs as pair production telescopes: AdEPT



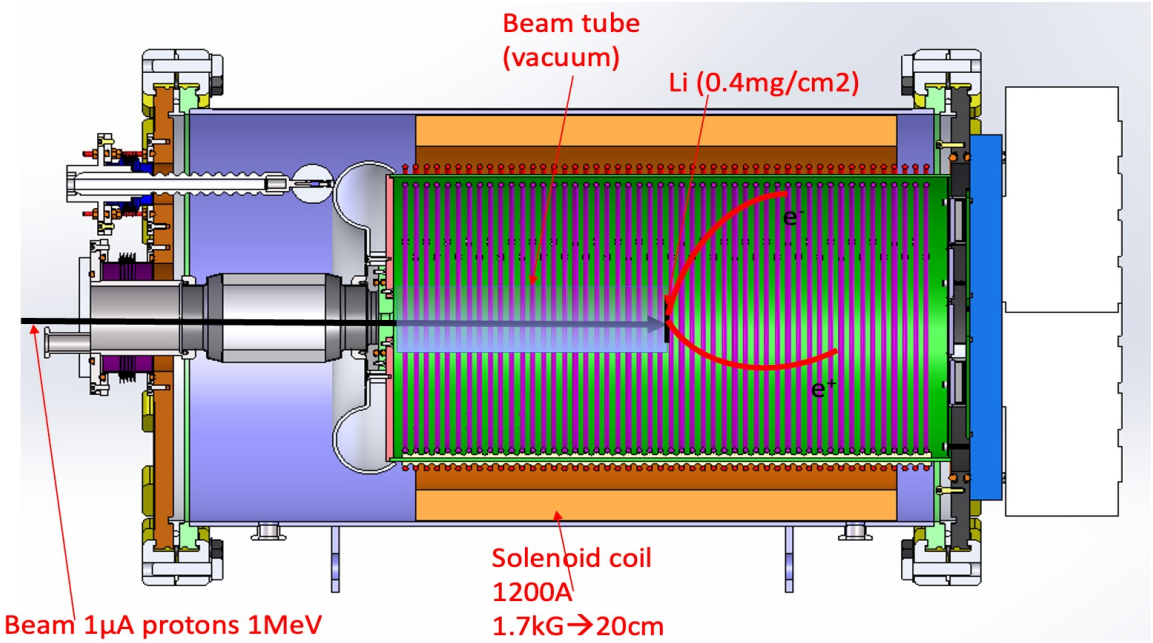
Negative ion drift → minimize diffusion



Low-energy β-particle tracks (from ^{90}Sr)

Hunter et al., Astroparticle Physics Volume 59, July–August 2014

18 MeV pair detection with TPC in laboratory



TPC from FRIB, experiment at U. of Notre Dame

$p + {}^{7}Li \rightarrow {}^{8}Be^{*} (\sim 18\ MeV) \rightarrow e^{+}e^{-}$

W. Mittig (FRIB, P.I.)

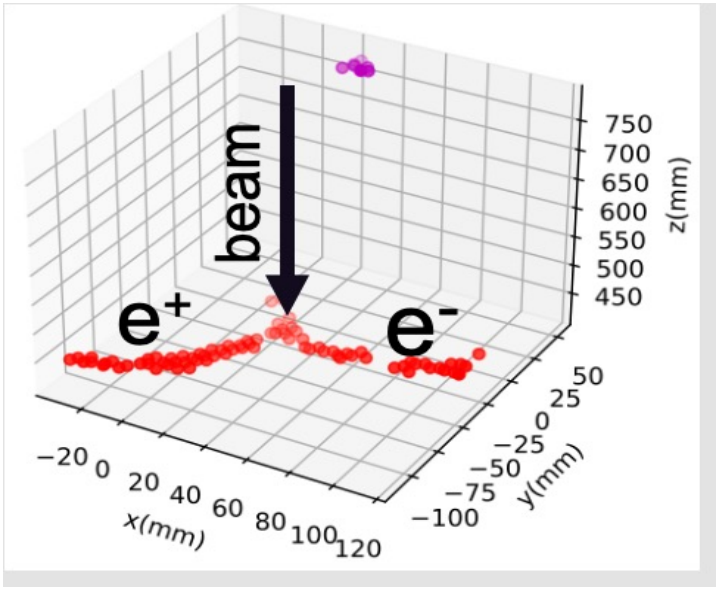
Experiment at Notre Dame
Ep~1.1MeV
LiOH (enriched, 04.mg/cm2+10μg/cm2 LiF) on 250μ Be

Gas P10 1atm
Pad-plane 2048 channels

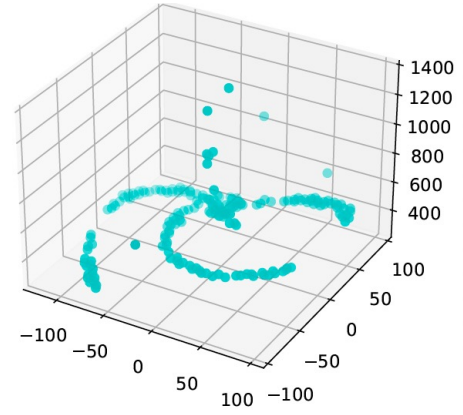
3-GEMs +micromegas
Trigger: mesh of μ-megas signal

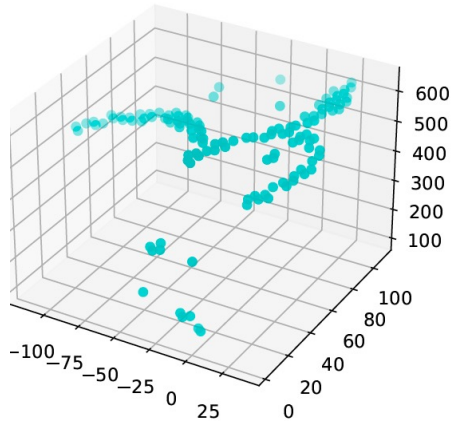
e^-e^+ pair tracks from recent experiment

Tracks of interest

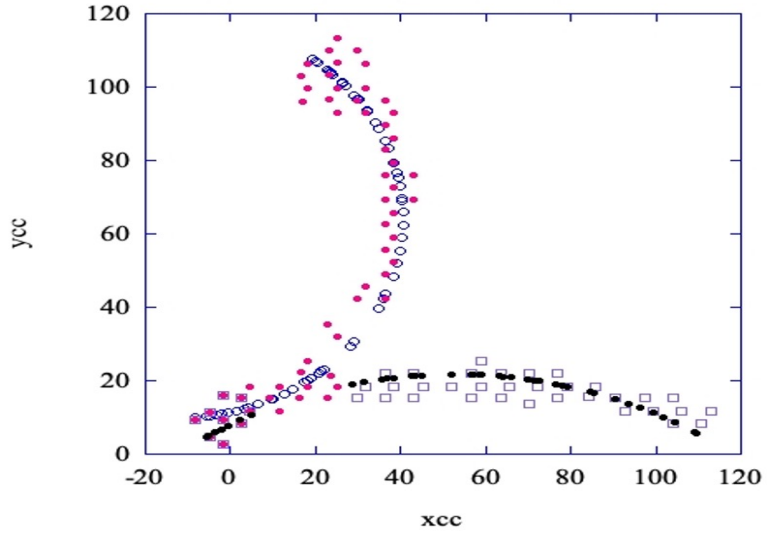


Nearly 20% events
→ re-scattering OR triplets

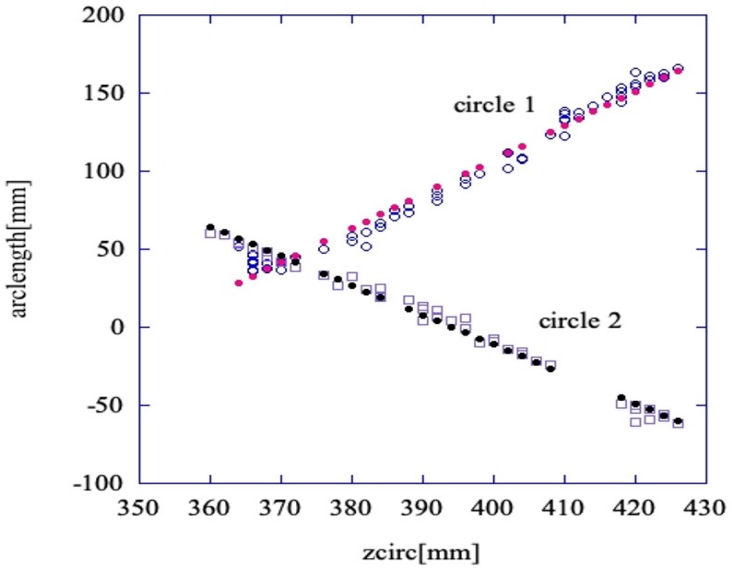




e^-e^+ pair tracks from recent experiment



RANSAC fit provide radius of curvature → Energy



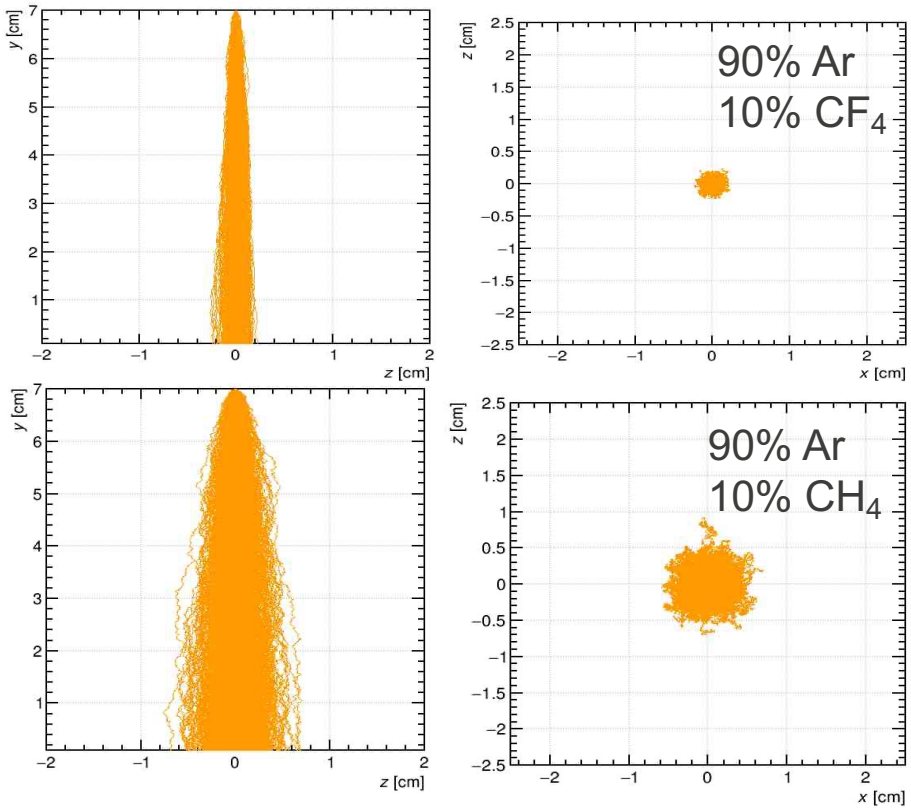
Provides angle
In previous experiments: angular resolution ~ 0.5 deg. , with similar data-analysis approach

Improvements being considered for e-e+ pair detection:

- **Better electron diffusion→ Sharper tracks**
- **Higher gain → different MPGD?**

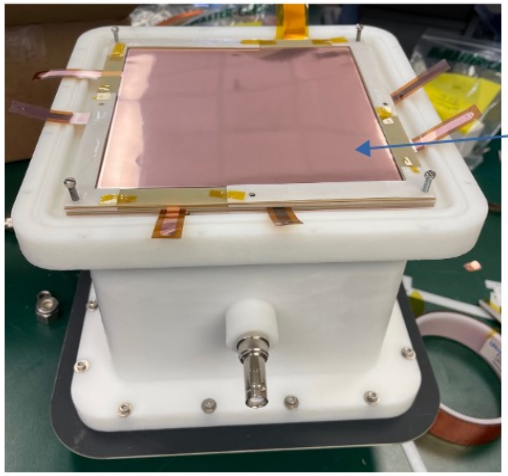
Electron diffusion: $Ar:CH_4$ v/s $Ar:CF_4$

Simulated electron-drift



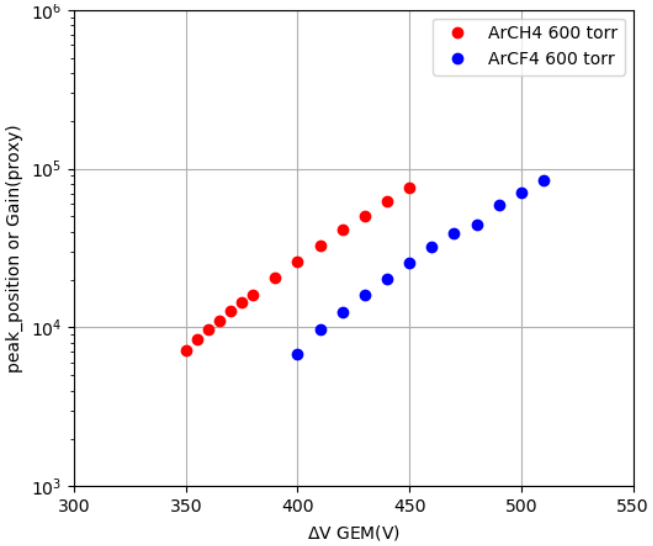
$Ar:CF_4$ is a better alternative compared to P10 to reduce electron diffusion

On-going measurements with LANL-TPC



Gas Electron Multipliers(GEMs) for charge amplification)

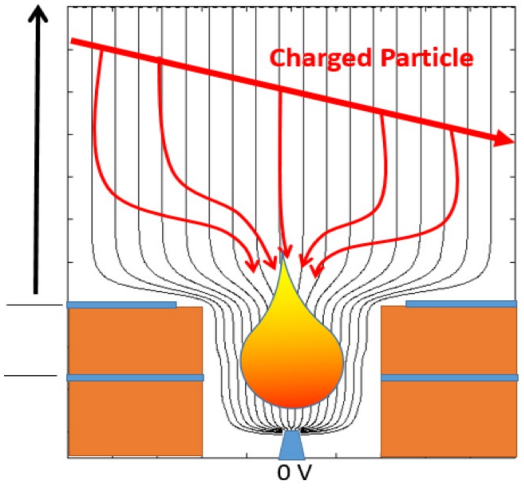
SREFT-TPC
(C. Prokop and J .S. Randhawa)

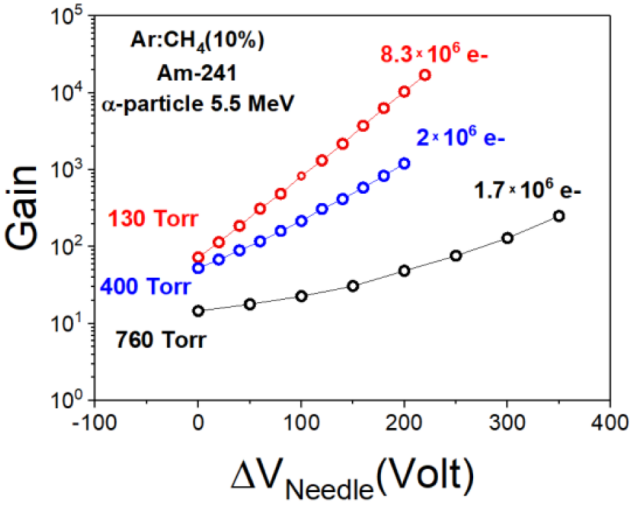


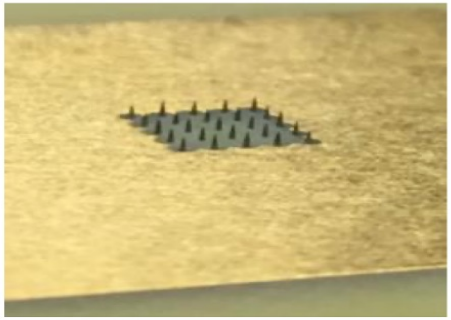
Gain is Ar:CF_4 is comparable to P10

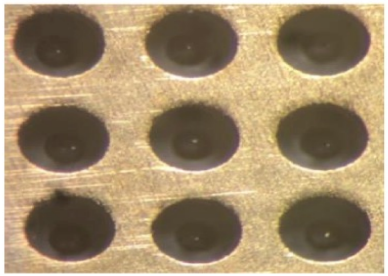
Higher Gain:
Towards a novel micro-pattern gas detector

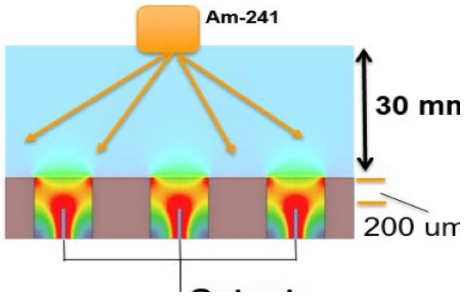
Idea: Combine Thick GEMs and needles for more amplification











Next steps:

- Development of full scale tip-hole detector using 3D printing of needles

J. S. Randhawa *et al.* 2020
J. Phys.: Conf. Ser. 1498 012004

Summary

- Direct detection of 18 MeV e^-e^+ pair using Time Projection Chamber
- TPC filled with Ar:CH_4(90:10) 1 atm pressure
- 3-GEMs+Micromegas → Gain barely enough
- e^--drift → Electron diffusion is high
- Nearly 10%-20% events → re-scattering/triplets

Next possible developments:

- Ar:CF_4 (90:10) to reduce diffusion
- Gain measurements in Ar:CF_4 → comparable to Ar:CH_4
- Development of a new MPGD for higher gain at higher pressures