LAMPS GEM based TPC R&D

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RI Experimental Systems Team

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- Nuclear collision experiment and LAMPS at RAON
- LAMPS TPC
- Characteristics of GEM for TPC
- TPC prototype with GEM
- Test setup of TPC prototype
- Test results with positron beam and cosmic ray muons
- New design of LAMPS TPC
- Summary

Large Acceptance Multi-Purpose Spectrometer (LAMPS)
Time Projection Chamber (TPC)
Gas Electron Multiplier (GEM)

RAON
Rare isotope Accelerator complex for ON-line experiments

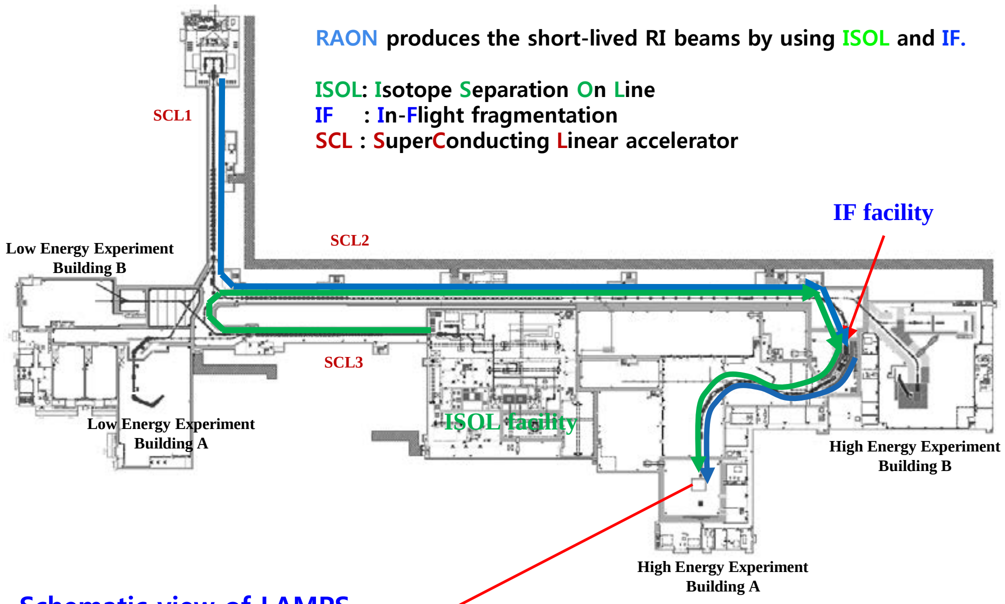
2018.Jan.29

AFAD2018 (Daejeon)

High energy nuclear collision experiment at RAON

RAON
Rare isotope Accelerator complex for ON-line experiments

Plenary talk "Status of RAON construction"
by Y.K.KWON at AFAD2018 in Jan 29 2018



Initial design concept of RAON facility

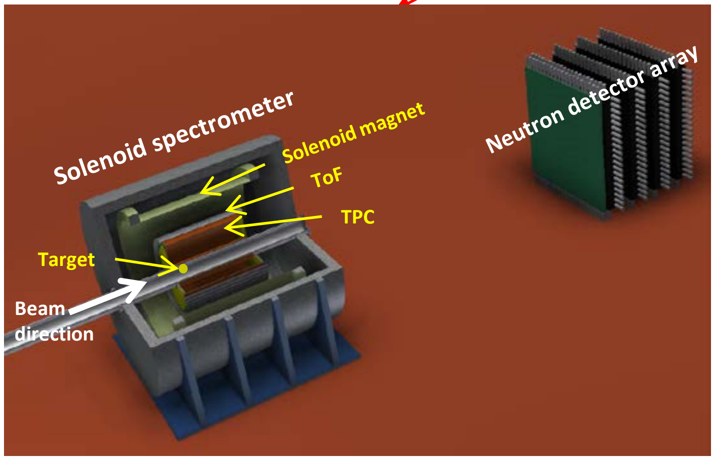
High intensity short-lived RI beams by ISOL & IF

- ISOL: direct fission of ^{238}U by 70 MeV proton
- IF: ^{238}U of 200 MeV/u (8.3 pμA)

More exotic RI beams by ISOL+IF

Stable heavy-ion beams

Schematic view of LAMPS



Goal of LAMPS

- Study of nuclear symmetry energy at supra-saturation density via heavy-ion collision experiment and nuclear reaction study

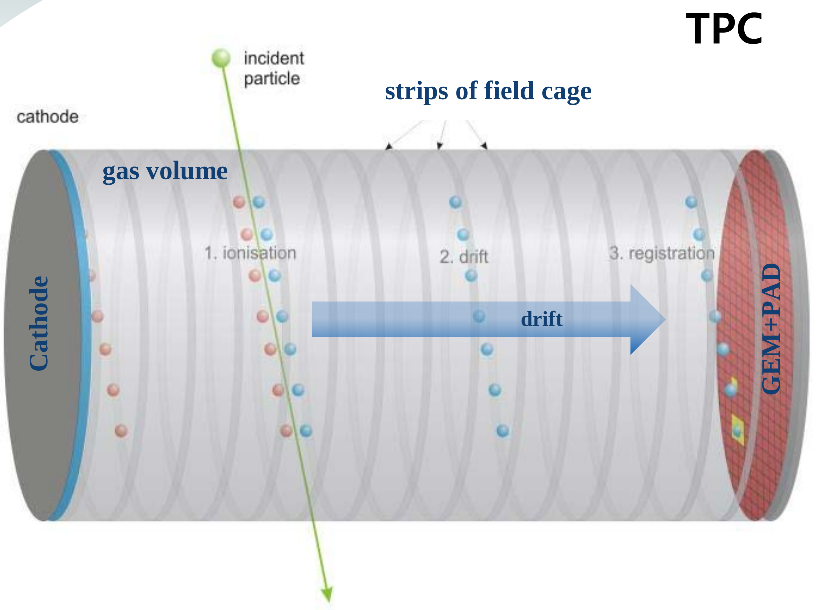
Requirements of LAMPS

- Magnetic strength (B): 0.5 T (B_{max} ~1 T)
- homogeneity of B field in TPC (ΔB/B) < ±1%
- more than 3π solid angle acceptance
- momentum (p) and particle identification (PID) of charged particles
- detection range of neutron energy: 10-300 MeV

Five institutes for LAMPS collaboration

- IBS, Korea Univ., Inha Univ., Chonnam National Univ., Chonbuk National Univ.

LAMPS TPC (Time Projection Chamber)



Operation of TPC

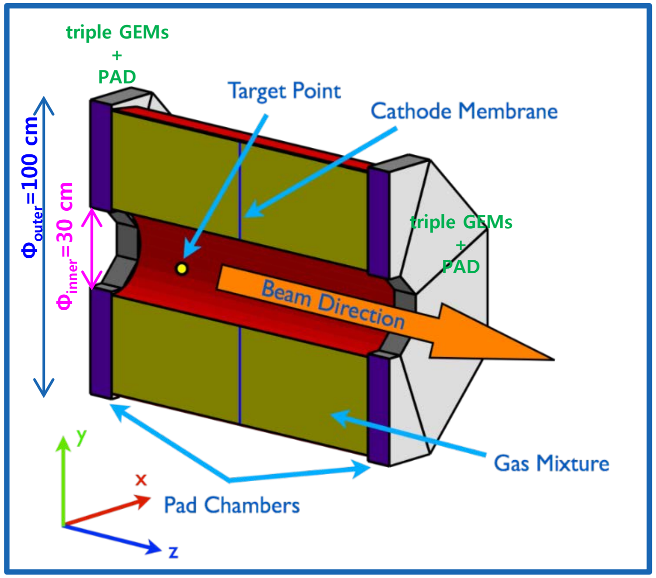
1. Incident particle ionizes gas molecular into an ion-electron pair ionization following the particle path in the gas volume.

2. Electrons drift toward triple GEMs and PAD readout.

3. Amplified electrons in GEMs are registered on PAD readout.

● **Requirements of LAMPS TPC**

- **Gain** of triple GEMs ~10^5 in P-10 ($Ar:CH_4$=90:10)
- **Position resolution (σ_p)** 200-300 μm
- Good **E** field homogeneity of field cage



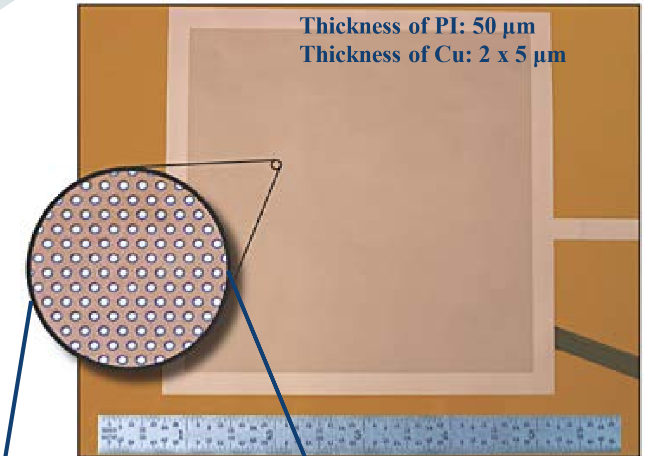
● **LAMPS TPC initial design**

- Field cage (2x60 cm)
- Length: 120 cm
- Inner and outer diameters: 30 and 100 cm
- Triple GEMs in each 8 sectors
- PAD readout
- GET system (~30k channels)

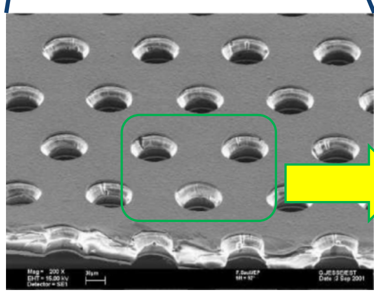
Characteristics of GEM for TPC

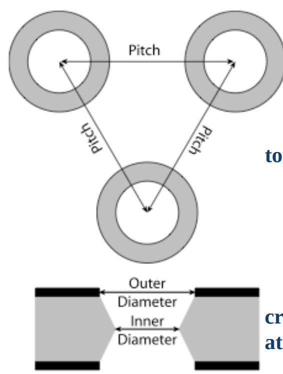
RAON

Gaseous Electron Multiplier (GEM)



Standard structure of GEM





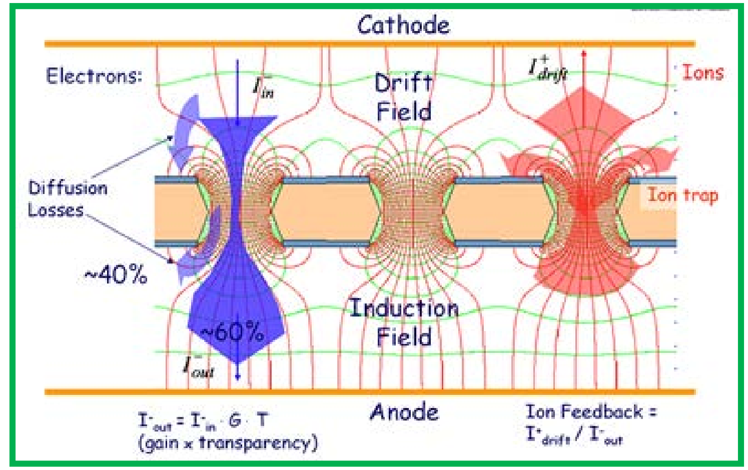
top view

cross-section at side view

Pitch: 140 µm
Outer (Cu) hole: 70 µm
Inner (PI) hole: 40 µm

Electron multiplication in the GEM

M. Hohlmann's presentation for CMS Upgrade Review, Feb. 2013



Disadvantages of wire method for TPC

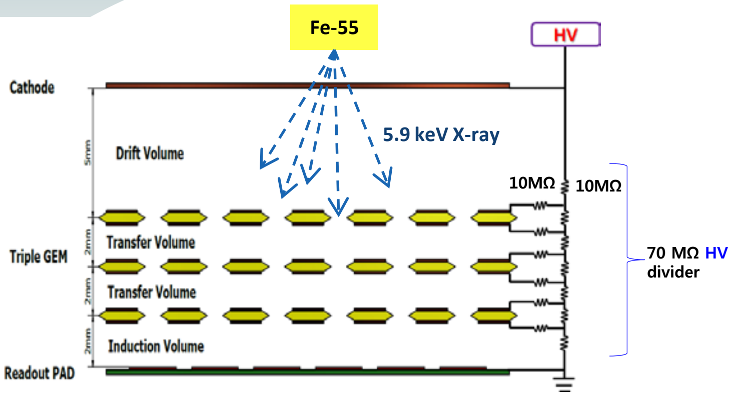
- Difficult to handle thin wires & limited spacing in between wires
- Dead time for data taking due to gating grid
- limited operation with continuous wave (CW) beam

Advantages of GEM for TPC

- Physical strength better than wire
- Prevent positive ions in ion back flow (IBF)
- High gain and good radiation hardness
- Enable to be operated at high event rate and under CW beam

Gain of triple-GEMs

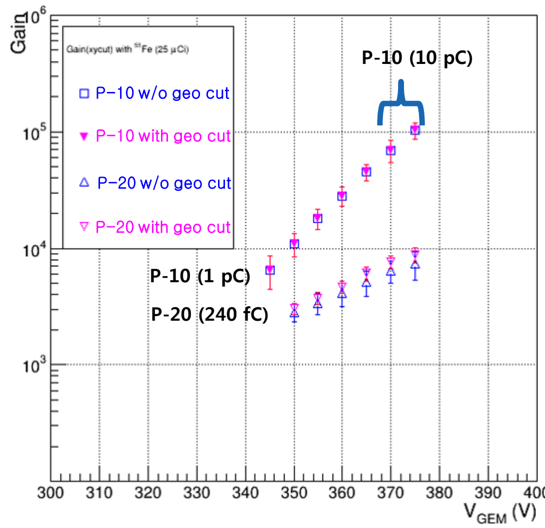
Schematic view of triple-GEM detector



$$\text{Gain} = \frac{\langle Q_{tot} \rangle}{N_0 Q_e} = \frac{\langle Q_{tot} \rangle}{220 \times 1.602 * 10^{-19}C}$$

$\langle Q_{tot} \rangle$: mean value of measured charge
N_0: initial number of p-e pairs
Q_e: electric charge of electron

Gain in mixed gases



Gap configuration: 5:2:2:2 mm

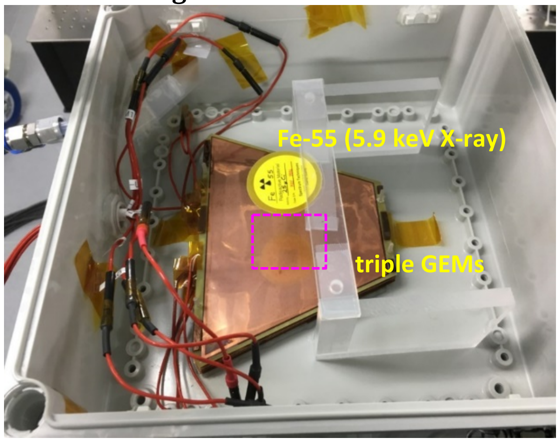
Mixed gases:
- P-10 ($Ar:CH_4$=90:10)
- P-20 ($Ar:CH_4$=80:20)

Input dynamic range:
- 1 and 10 pC in P-10
- 240 fC in p-20

Data Analysis:
- no region selection
- region selected near Fe-55

Gain at V_{GEM}=375 V:
~10^5 in P-10
~8×10^3 in P-20

Picture of gain measurement test



Comparison with gain in P-10 gas

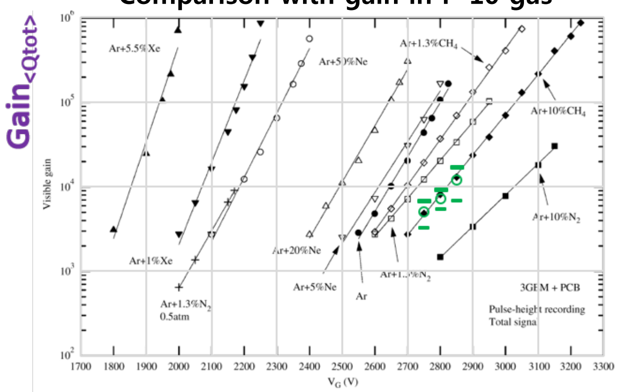


Fig. 7. Gain-voltage characteristics of a 3GEM + PCB photomultiplier in different gas mixtures for the total anode signal, detected with a charge amplifier, including both fast (primary) and slow (secondary scintillation-induced) components.

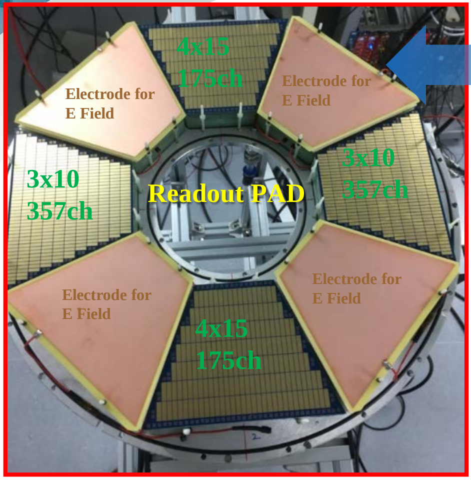
NIM A 443 (2000) 164 A. Buzulutskov, et. al.

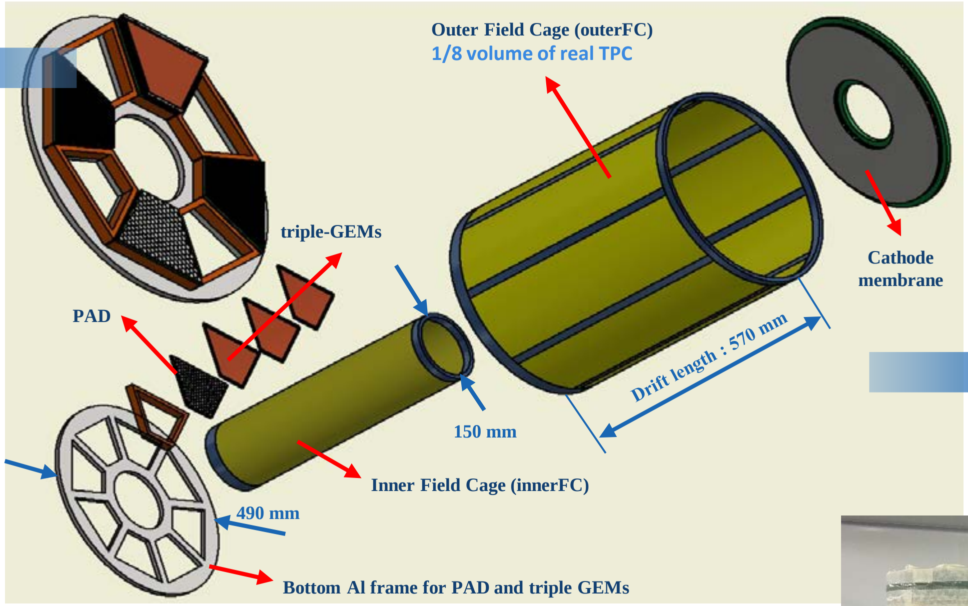
Gap configuration: 1.9:1.8:2.0:1.9 mm

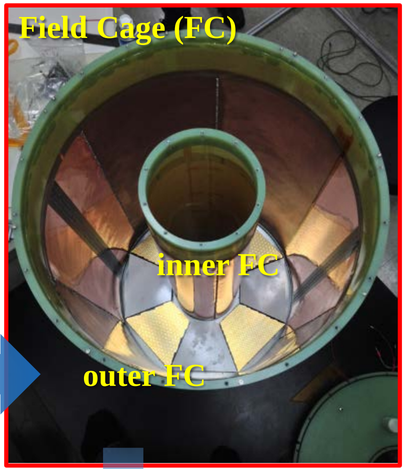
Same V_{GEM} and V_{GAP} configuration

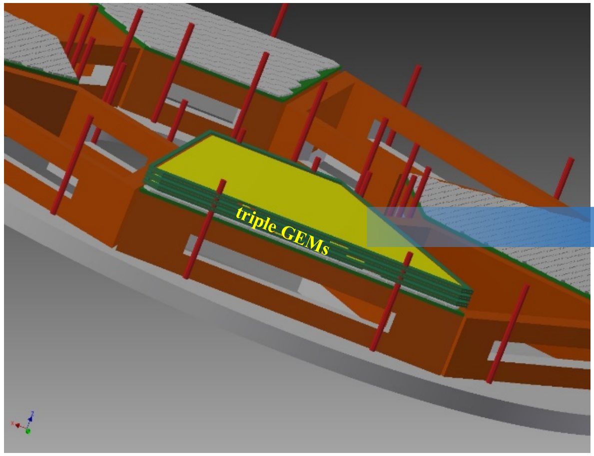
Gain at V_G = 2850 V:
>10^4 in P-10

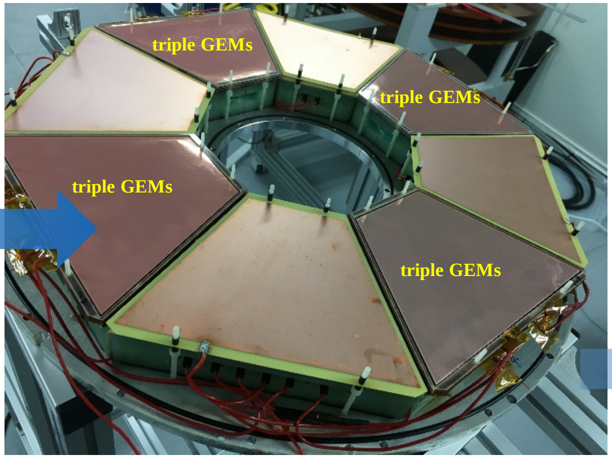
TPC prototype with triple GEMs

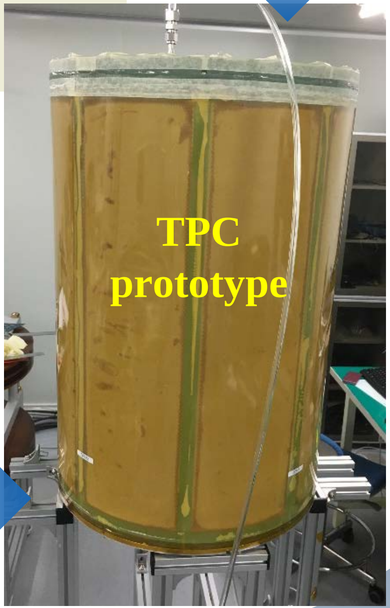




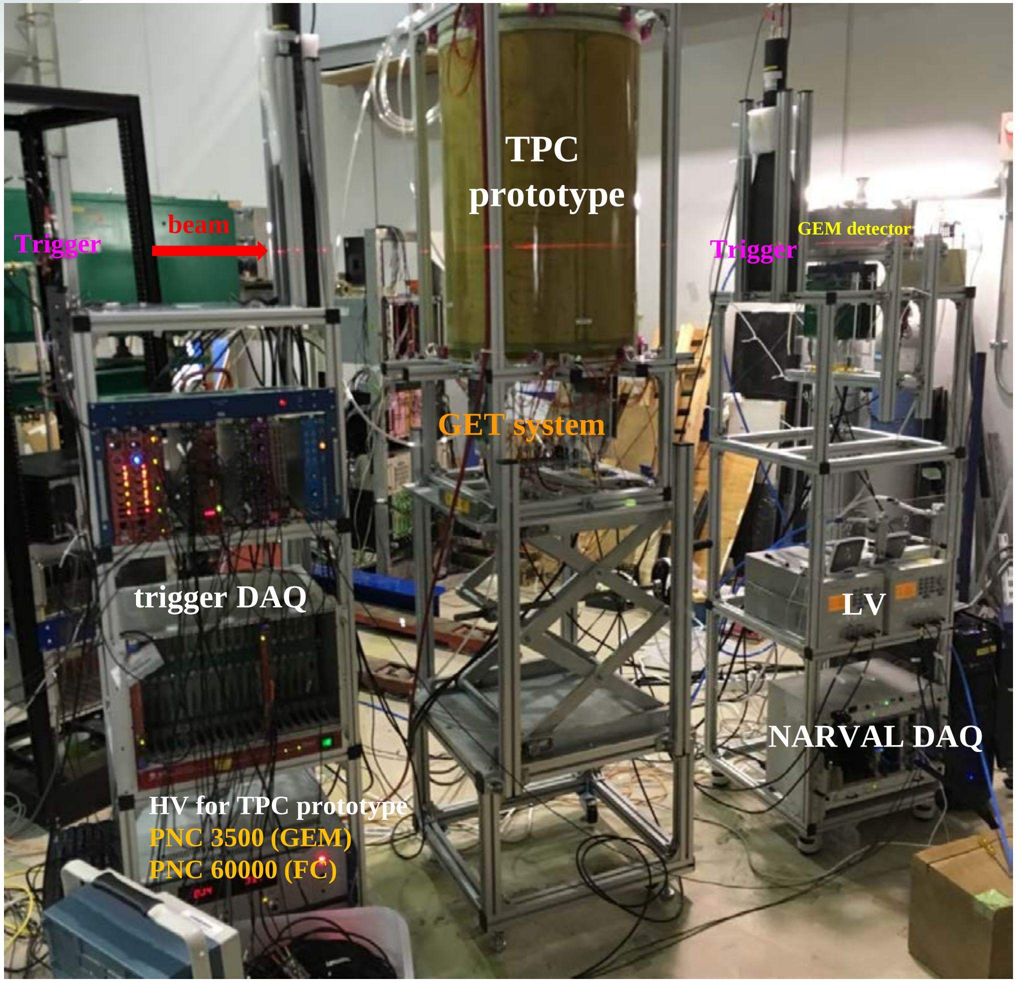








Test setups of TPC prototype at ELPH in Tohoku University



Run summary

Beam time: 2 days (12h+12h) in Nov 1-2 2016
Beam: positron

Mixed gases:
- P-10 (Ar/CH_4=90/10)
- Ar-CO2 (Ar/CO_2=90/10)

PAD sizes:
- 4x15 mm^2 for TPC prototype
- 3x10 mm^2 for GEM detector

Electric field on field cage (FC):
- E_{FC} = 115, 125, 135, 145, 155 V/cm in P-10
- E_{FC} = 170 V/cm in Ar-CO2

Applied voltage on a GEM, gap, and GEM1top:
- $V_{GEM} = V_{GAP}$ = -345 V
- $V_{GEM1top}$ = -2,070 V ($3V_{GEM} + 3V_{GAP}$)

Beam height (or drift length, L_d) at TPC prototype:
- L_d^{MAX} = 57 cm
- L_d = 20.24, 35.24, 50.24 cm

Data analysis and event display

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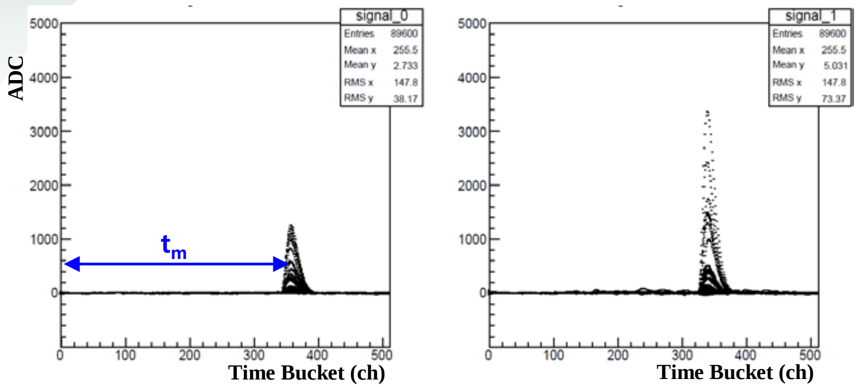
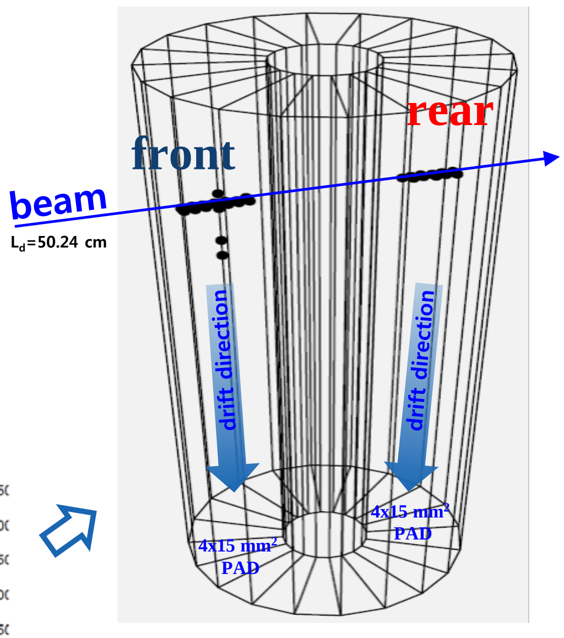
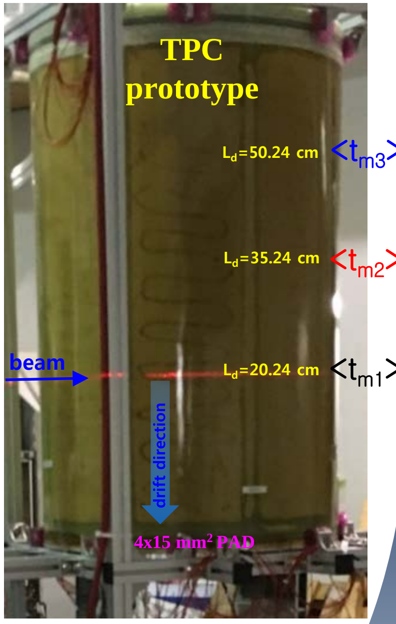
Distribution of raw signal

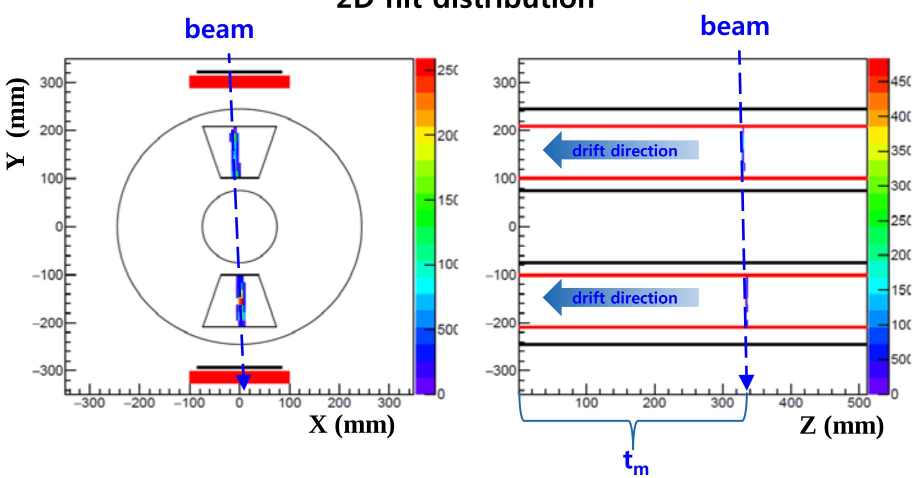


3D hit distribution



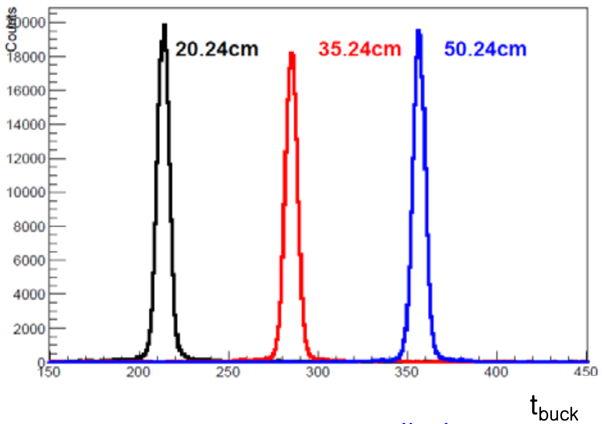


2D hit distribution

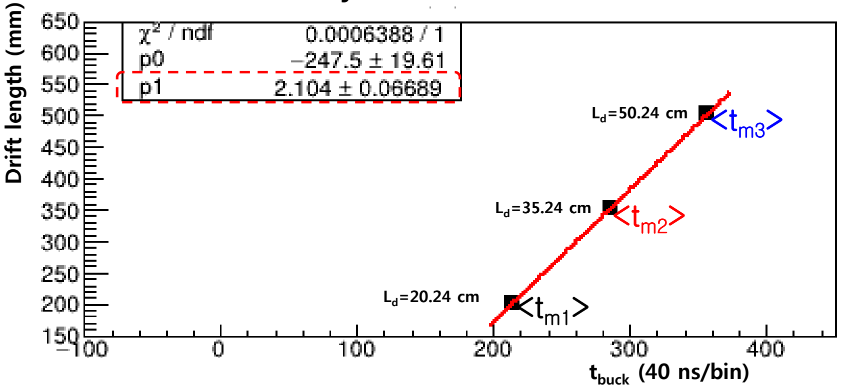


Test result: drift velocity

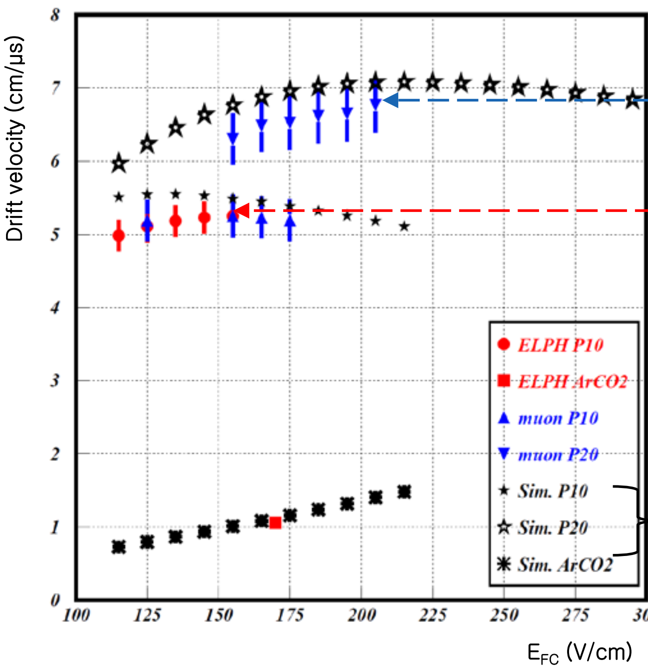
Time distribution for each beam height



Drift velocity at E = 155 V/cm in P-10



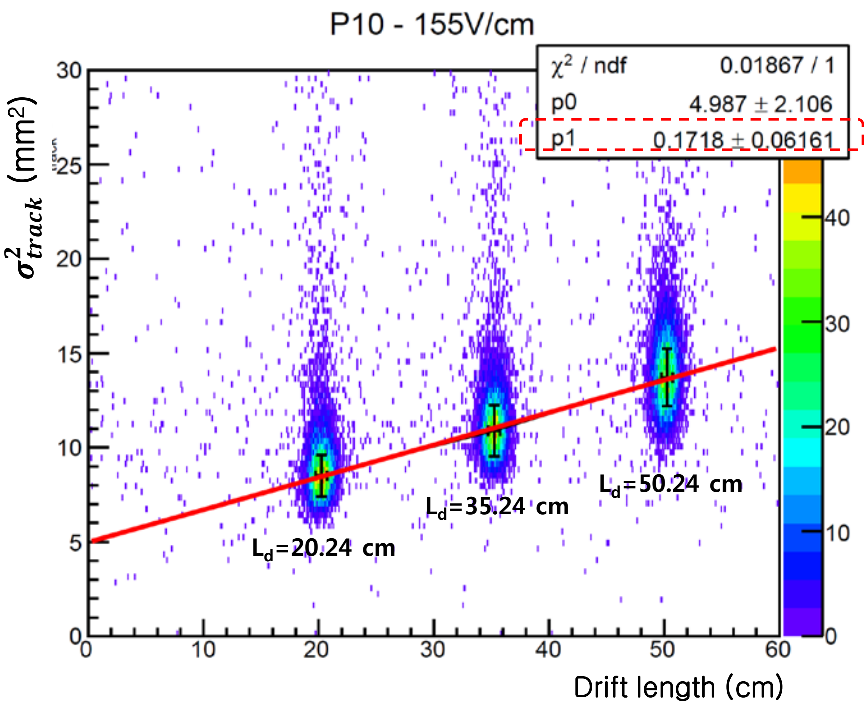
v_d = 2.104 (±0.167) mm/t_{buck}
= 5.26 (±0.167) cm/μs

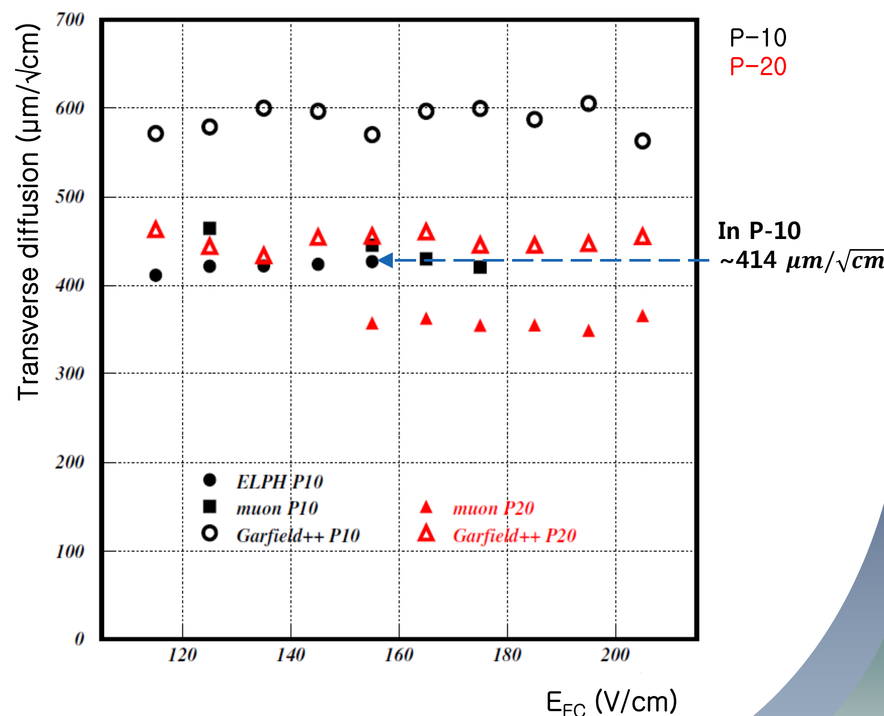


Test result: diffusion

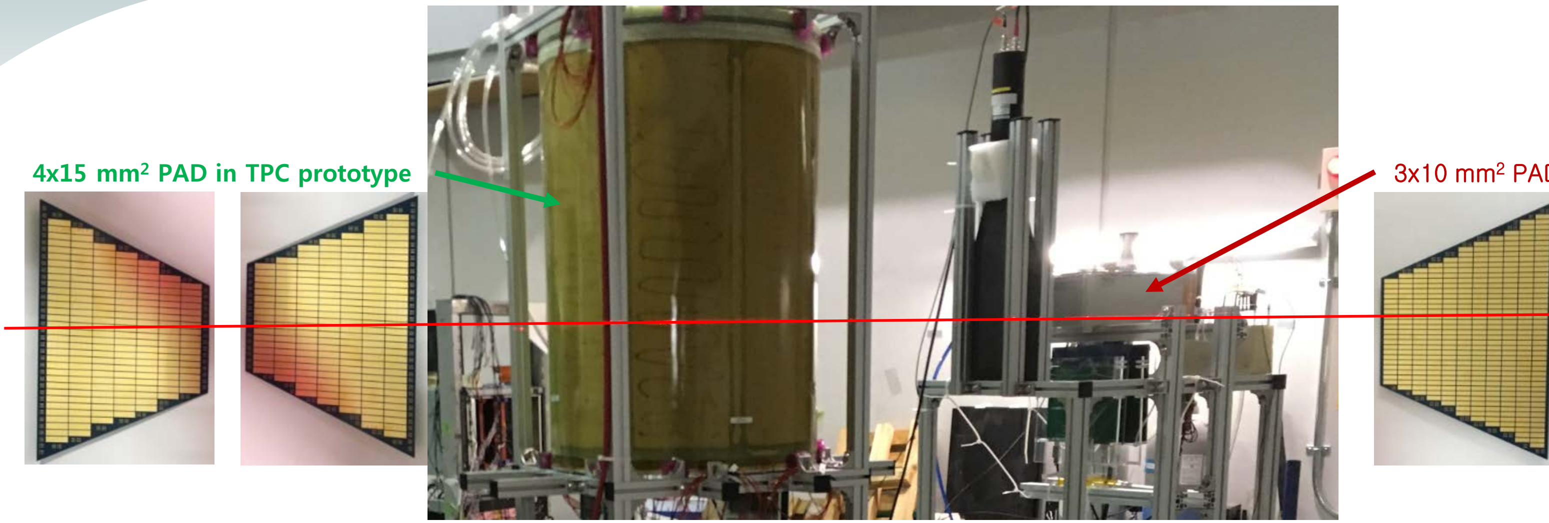
$$\sigma_{track}^2 = C_D^2 \cdot Z + \sigma_0^2$$

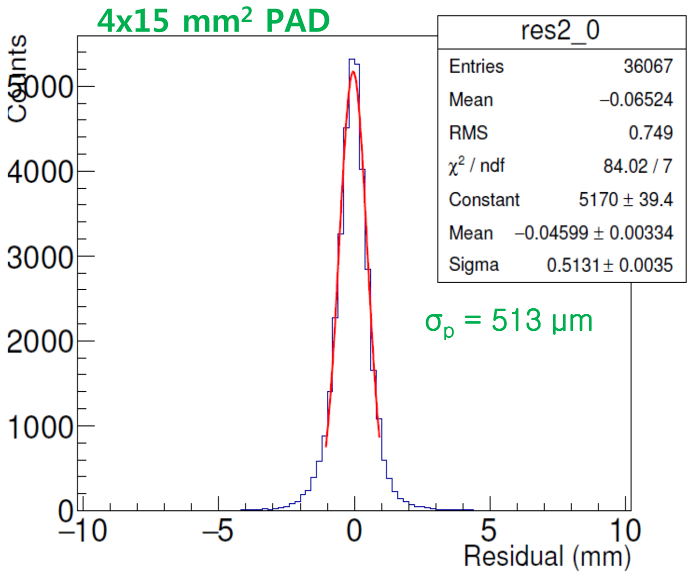
σ_{track}: standard deviation of charge cloud
C_D: transverse diffusion
Z : drift length
σ_0: from readout system

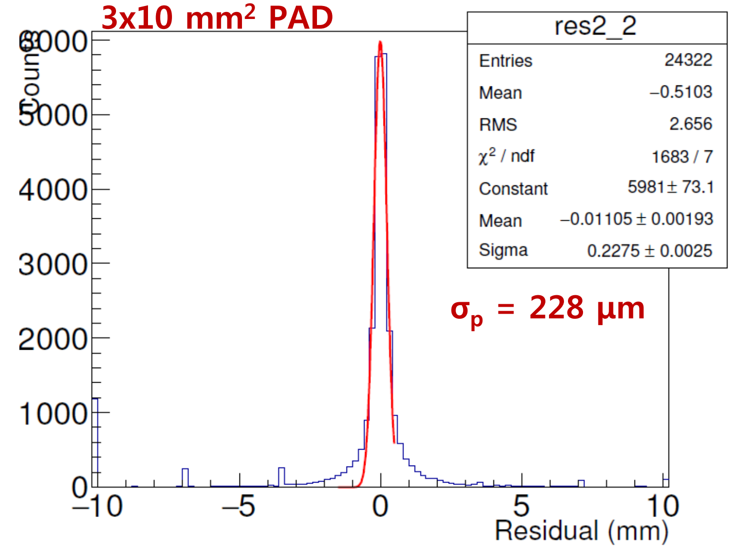




Test result: position resolution



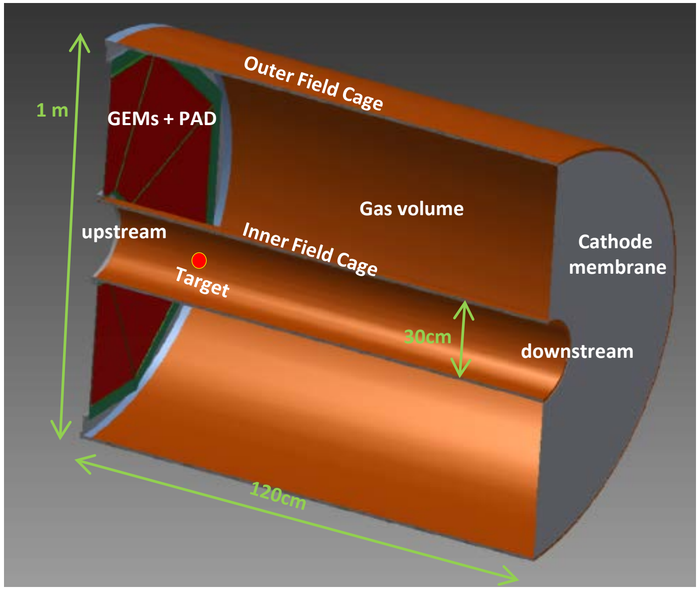




New design for LAMPS TPC

- **Why TPC re-designing?**
  - **Need to improve momentum resolution (Δp/p)** of TPC initially designed (v_D > 5 cm/μs, L_d = 60 cm)
  - **Limited electronics channels** of GET system for readout on both sides of TPC
  - Expect **more radiation damage** on the electronics at downstream than upstream

- **Test results of TPC prototype**
  - **Gain** of triple GEMs at V_{GEM} = 375 V: **~8x10³ in P-20 gas**
  - **Drift velocity** (v_D): over 6 cm/μs in E_{FC}=155-205 V/cm in P-20 gas
  - **Transverse diffusion** (C_D): ~ 400-500 $\mu m/\sqrt{cm}$ in P-20 gas
  - **Position resolution** (σ_P): ~228 μm with 3x10 mm² PAD



- **New design for LAMPS TPC**
  - **Field cage of 120 cm long with v_D over 6 cm/μs**
  - Length: 120 cm
  - Inner and outer diameters: 30 and 100 cm
  - GEMs+PAD in each 8 sectors
  - **PAD readout only in upstream for better position resolution**
  - GET system (Max. 30,720 channels)

Summary

RAON

- **Experimental facilities for various science topics** with stable and short-lived RI beams has been developing and constructing **at RAON.**

- **Large Acceptance Multi-Purpose Spectrometer (LAMPS)** for symmetry energy study in nuclear physics experiment has been developing**.**

- **TPC prototype**

  Field cage (drift length of 57 cm and strip pitch of 2.5 mm)

  2 mm gap triple GEMs (effective area ~140 cm^2)

  PAD readout: 175 channels for 4x15 mm^2

  357 channels for 3x10 mm^2

  GET system

- **Test results of TPC prototype with positron beam and cosmic ray muon**

  Gain of triple GEMs at V_{GEM} = 375 V: **~10^5 in P-10** and **~8×10^3 in P-20**

  Drift velocity (v_D): ~5.25 cm/μs at E_{FC} = 155 V/cm in P-10 gas

  ~6.77 cm/μs at E_{FC} = 205 V/cm in P-20 gas

  Diffusion (C_D): ~ 400-500 $\mu m/\sqrt{cm}$ in P-10 and P-20 gases

  Position resolution (σ_P): ~228 μm with 3x10 mm^2 PAD

  ~513 μm with 4x15 mm^2 PAD

- **Outlook**

  Large GEM test chamber (effective GEM area ~1,650 cm^2)

  Specific design of main component for LAMPS TPC

Thank you for your attention!
감사합니다 !

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