Status report of LAMPS TPC

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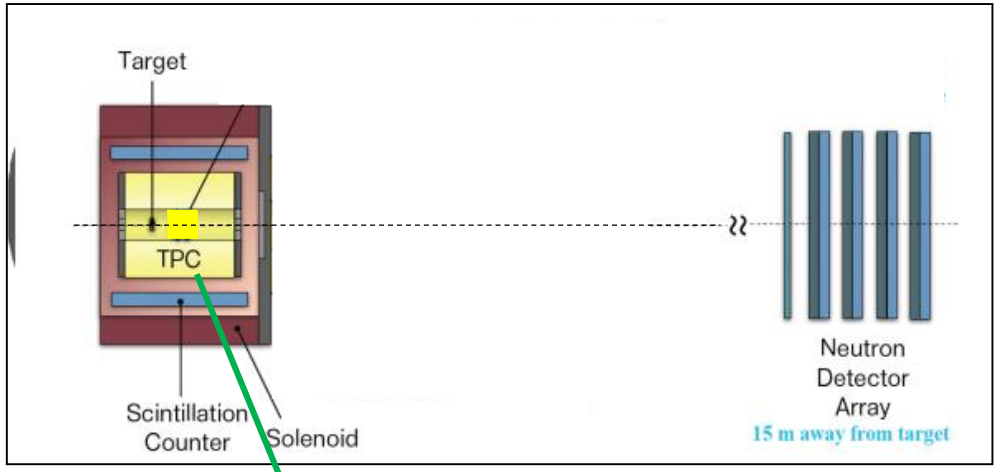
for LAMPS of RISP at IBS

Contents

Time Projection Chamber for LAMPS

RAON

Conceptual design of LAMPS



Goal of nuclear matter research

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

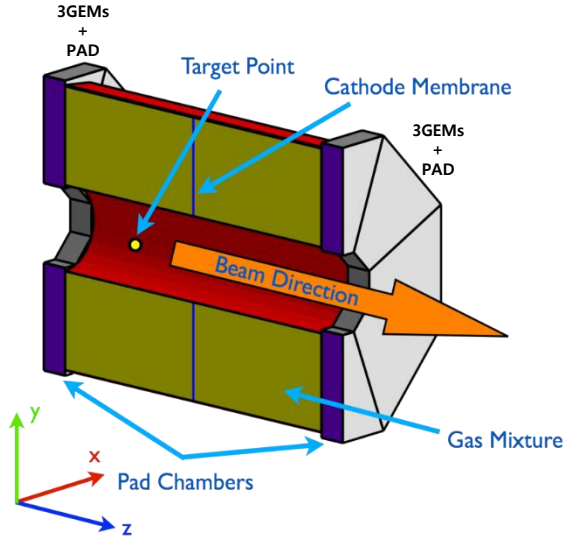
Detection systems of LAMPS

- Solenoid spectrometer and Neutron detector array
- TPC is the main charged particle tracker in the solenoid spectrometer.

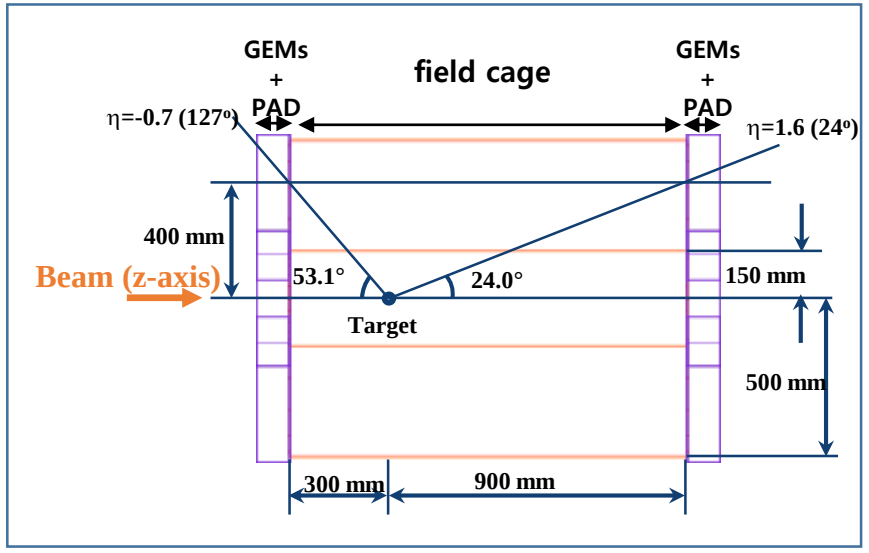
Requirements of LAMPS TPC

- large solid angle acceptance > 3π (24°<Θ<127°, 0°<Φ<360°)
- Good momentum resolution and particle identification (PID) of charge particles

Conceptual design of LAMPS TPC



Cross-sectional view of LAMPS TPC

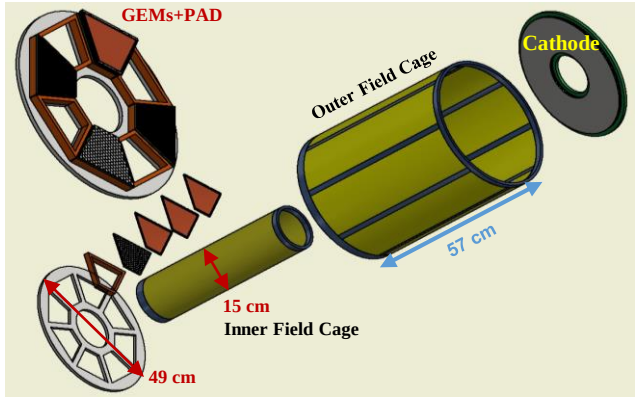


Original design of LAMPS TPC

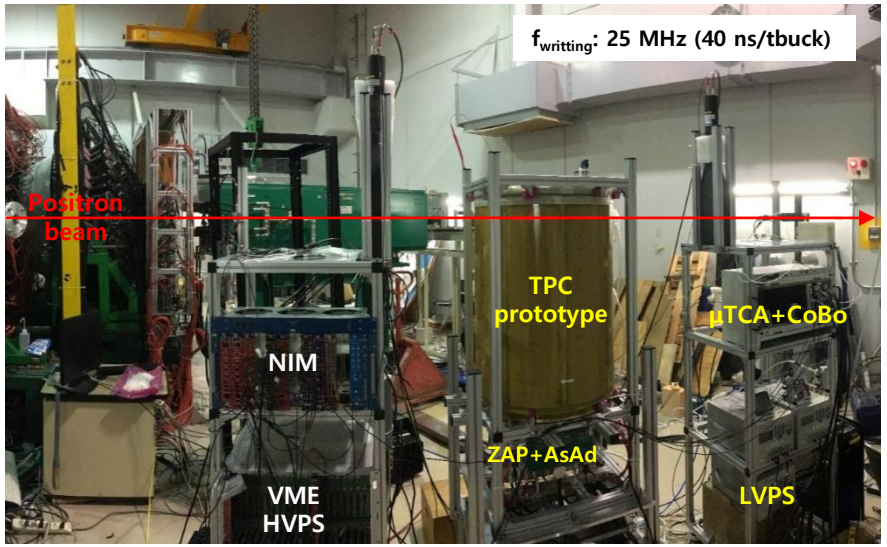
- 2 x 60 cm field cage (FC)
- 8 GEM sectors with triple-GEMs
- ~ 100,000 PADs
- GET system + NARVAL DAQ

Performance of TPC prototype

Specification of TPC prototype
- 1/8 volume of LAMPS TPC
- Drift length: 57 cm
- Triple-GEMs (2:2:2 mm)
- 4 PADs (3x10 and 4x15 mm^2)



Test setup of TPC prototype at ELPH (Nov. 1-2 in 2016)



Results of ELPH test
- Max. drift velocity: ~5.25 cm/µs in P-10
  ~6.77 cm/µs in P-20
- Positon resolution: **~228 µm with 3x10 mm^2 PAD**
  ~513 µm with 4x15 mm^2 PAD
- Transverse diffusion (sim.): <600 µm/√cm in P-10
  <500 µm/√cm in P-20

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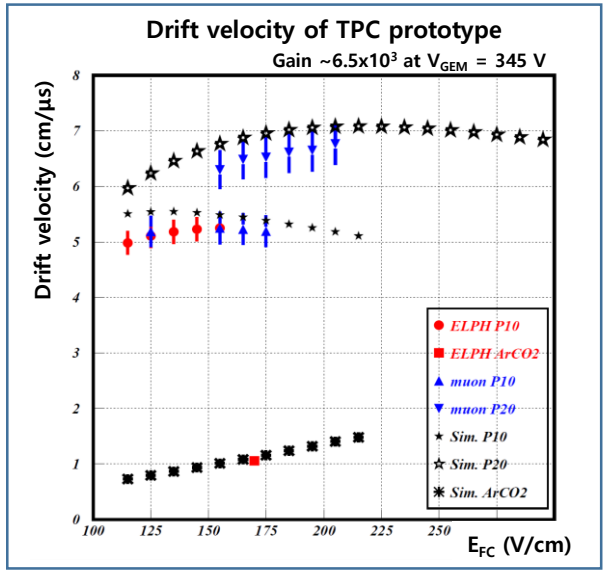
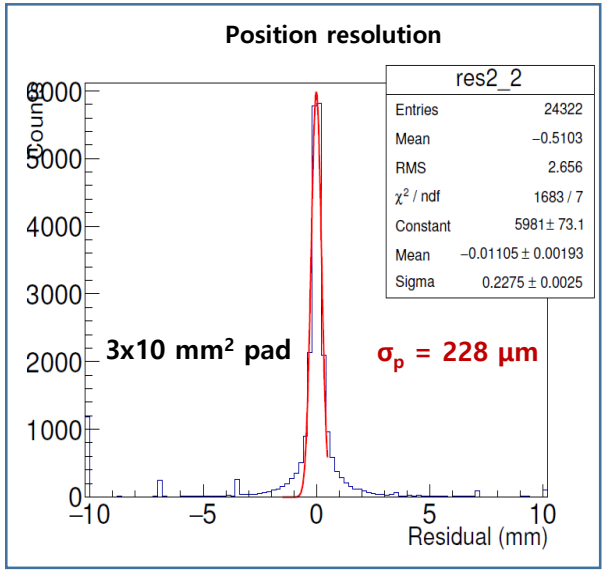
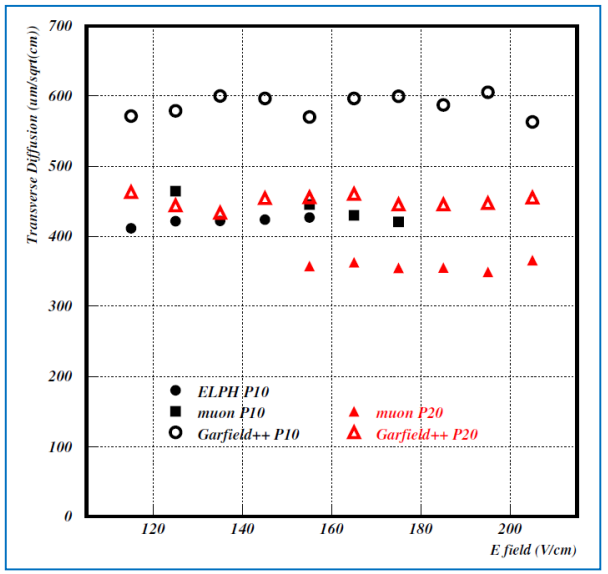
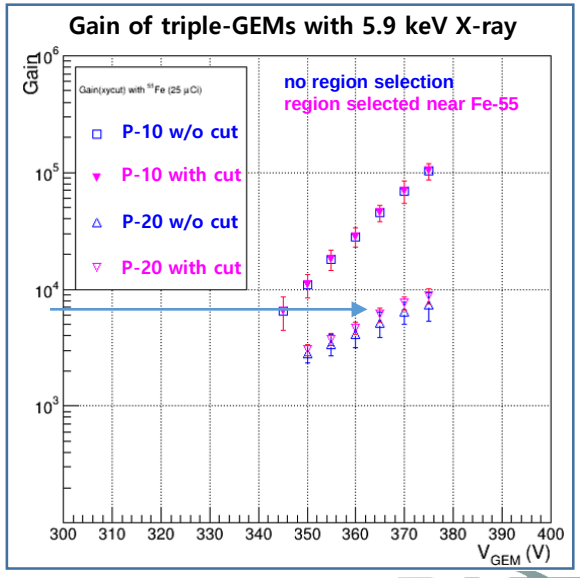
Results of gain test
- Max. gain: ~10^5 in P-10
  ~8*10^3 in P-20





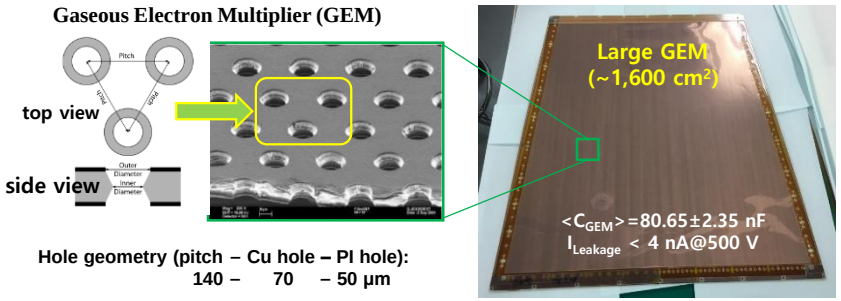


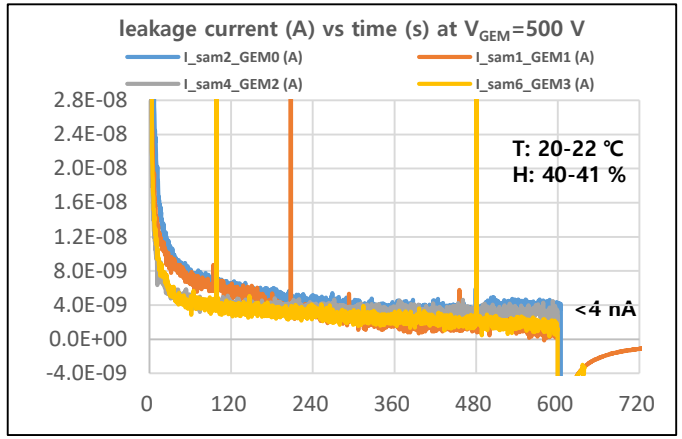


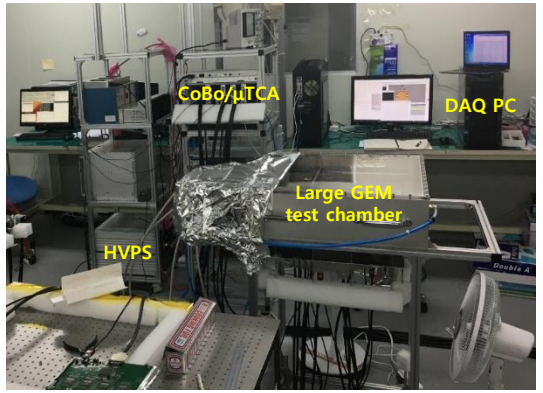
P-10 (exp): 420 $\mu m/\sqrt{cm}$ @ 155 V/cm

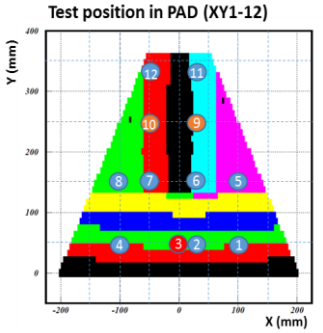
Test results of Large GEM

<Detector setup>
Gas volume: ~56 liters
Gap configuration: triple- and quadruple-GEMs
Pre-mixed gas: P-10 (Ar:CH_4=90:10) and P-20
Test source: Fe-55 (25 μCi, 2014)
Number of pad: 2559 ch (3x10 mm²/pad)



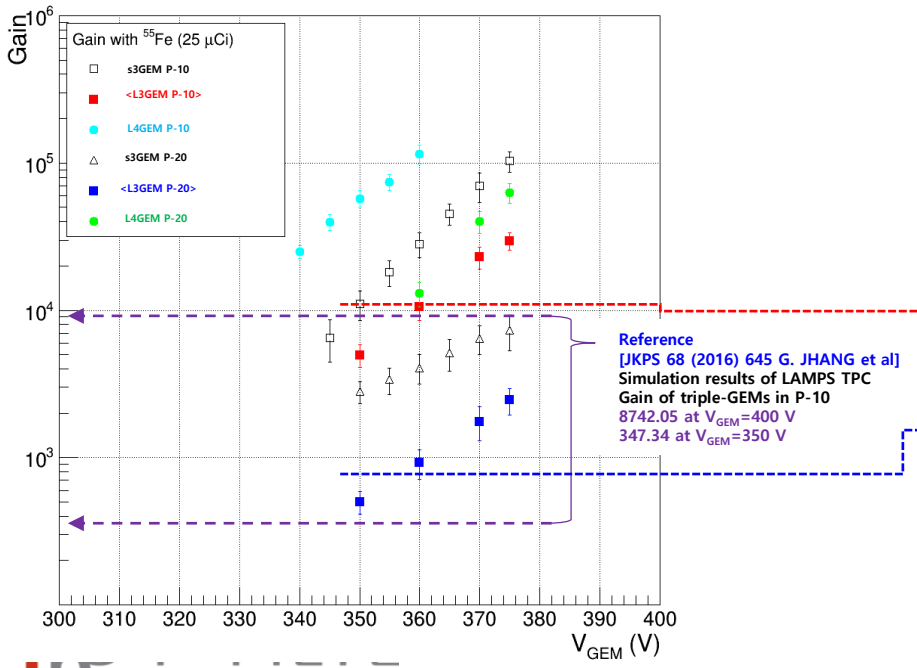






GEM structure	Gas	V_{GEM} (V)	V_{GEM} (V) for discharge event	Test position (XY#)
3LGEM	P-10	350, 360, 370, 375	380, 385, 390	XY1-12
3LGEM	P-20	350, 360, 370, 375		XY3, XY9, XY10
4LGEM	P-10	340, 345, 350, 355, 360	365, 370 V	XY3
4LGEM	P-20	360, 370, 375		XY3

Gain of GEM

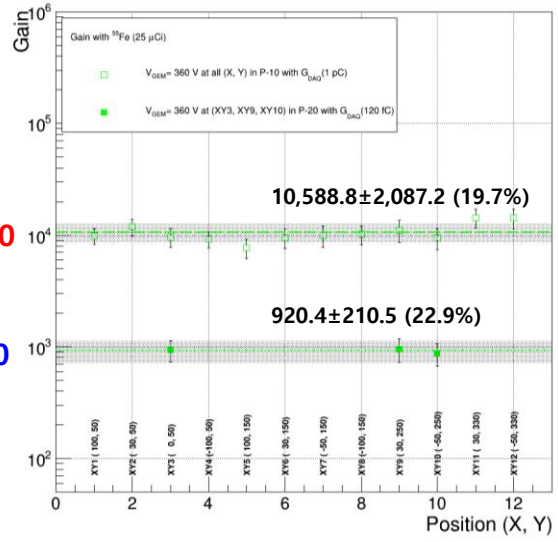


Reference
[JKPS 68 (2016) 645 G. JHANG et al]
Simulation results of LAMPS TPC
Gain of triple-GEMs in P-10
8742.05 at V_{GEM}=400 V
347.34 at V_{GEM}=350 V

L3 P-10

L3 P-20

Gain uniformity at V_{GEM} = 360 V

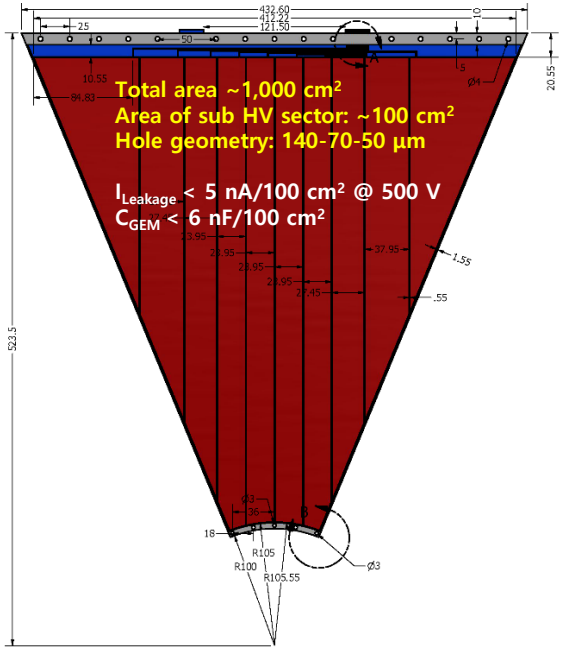


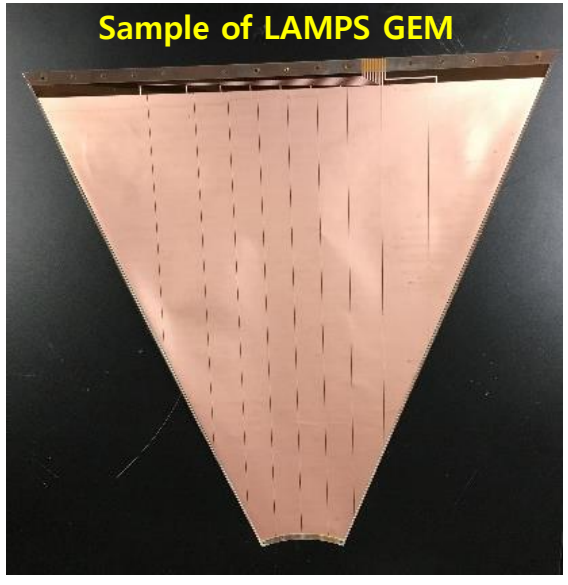
Status of LAMPS GEM

Production status of LAMPS GEM
- Facility at MECARO will be ready by end of July.
- GEM sample will be delivered and tested in Aug. – Sep.
- Final production design will be decided in Oct.
- Then, mass production is going on.

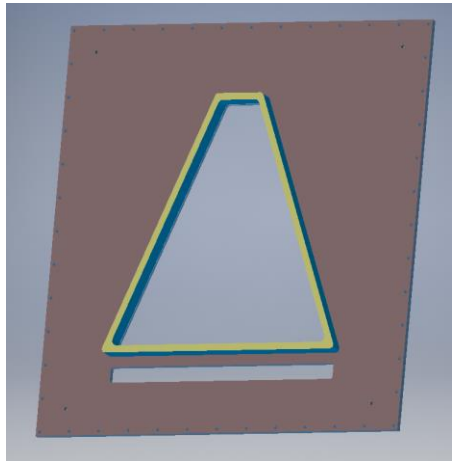
Readiness of LAMPS GEM test
- GEM Test chamber will be installed before TEST (Aug).
- Leakage current measurement system is ready.
- PAD assembly support is ready.

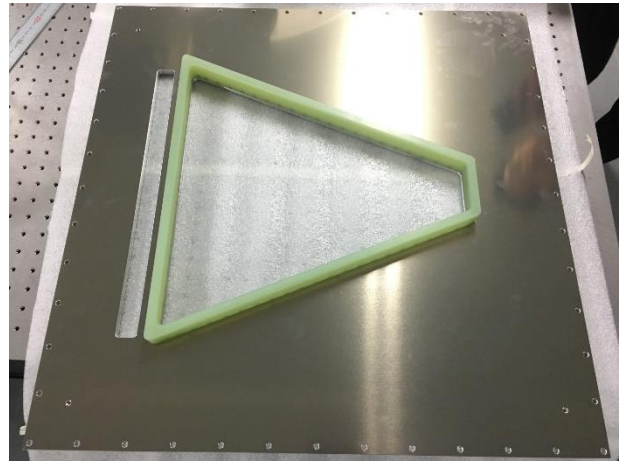
Design of LAMPS GEM (under production)



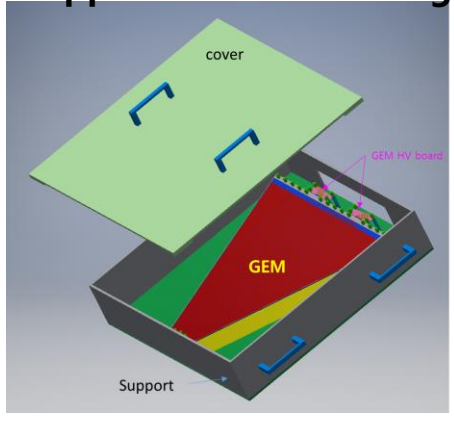


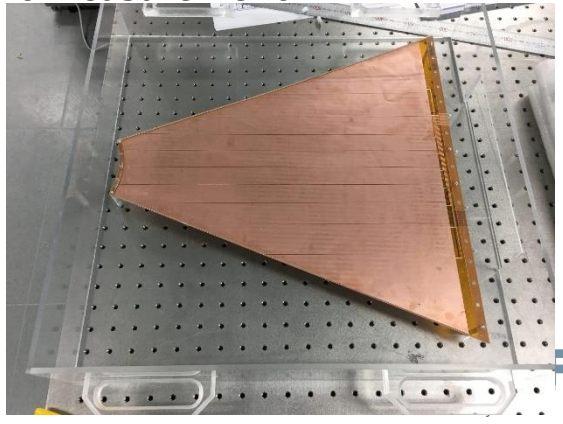
GEM test chamber





Support for GEM leakage current measurement

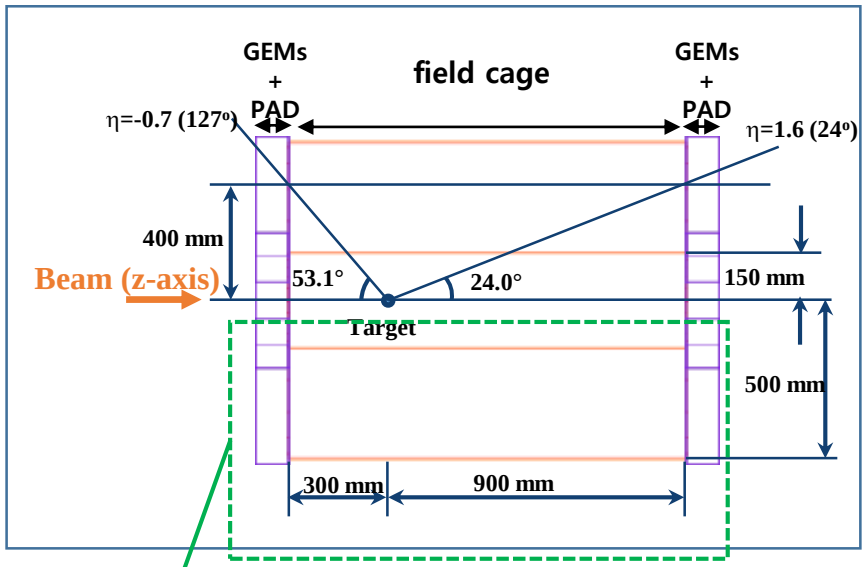




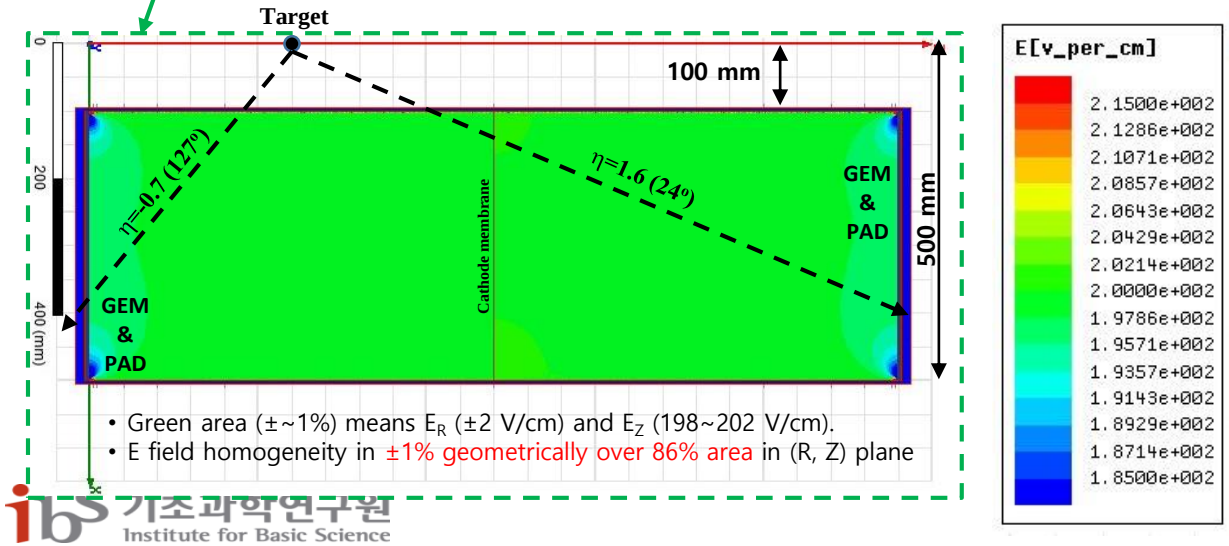
Electric field distribution of prototype TPC for LAMPS

- Design parameters of prototype TPC for LAMPS
- Drift length: 57 cm
- Triple-GEMs and PAD
- Strip pitch: 2.5 mm (2 mm strip width + 0.5 mm spacing)
- Spacing between GEM and Field strip: 7.4 and 22.5 mm to inner and outer field cage, respectively, in R axis

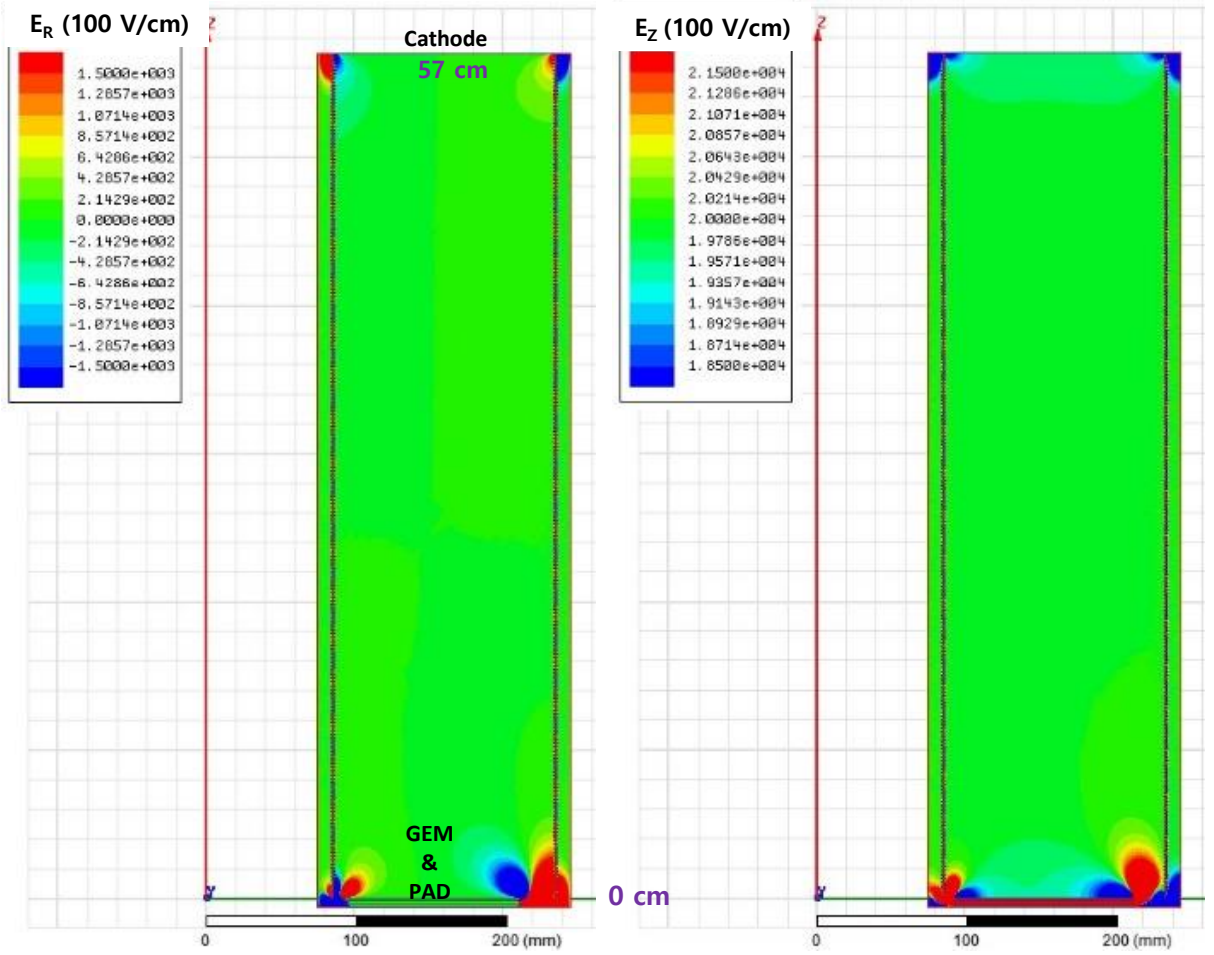
Cross-sectional view of LAMPS TPC



TPC without spacing between GEM and Field strip in R axis



- Green area (±~1%) means E_R (±2 V/cm) and E_Z (198~202 V/cm).
- E field homogeneity in ±1% geometrically over 86% area in (R, Z) plane

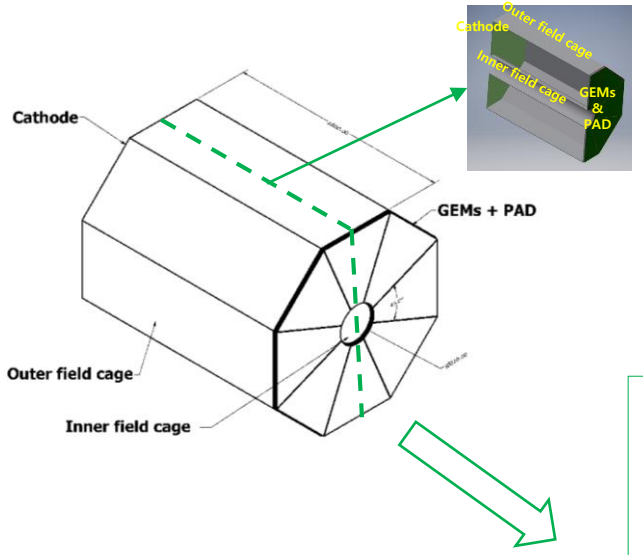


- Green area (±~1%) means E_R (±2 V/cm) and E_Z (198~202 V/cm).
- E field homogeneity in ±1% geometrically over 85% area in (R, Z) plane

Electric field distribution of LAMPS TPC

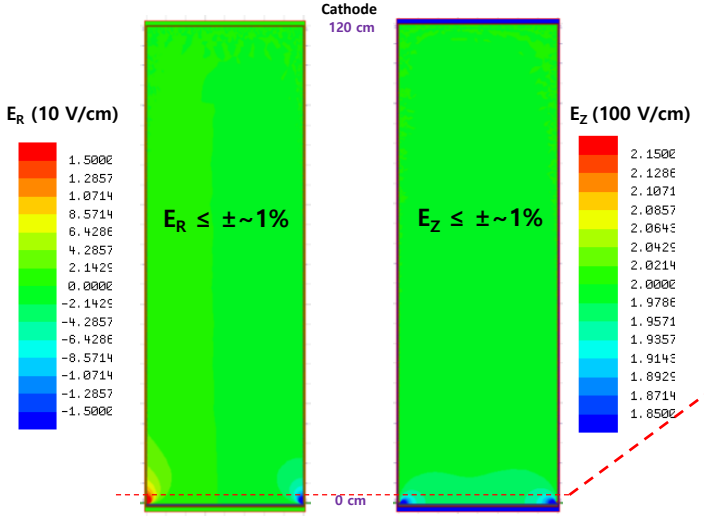
Electrical field distribution of field cage
- **Calculation error** for E_X, E_Y, and E_Z: **12.4%**
- E field at Z=1 cm from GEM
- **Green area (±~2%)** means: E_R (±4 V/cm)
  E_Φ (±4 V/cm)
  E_Z (196~204 V/cm)

Design parameter for Electric field study in TPC
- Strip pitch
- Shape of field cage (cylindrical and octagonal)



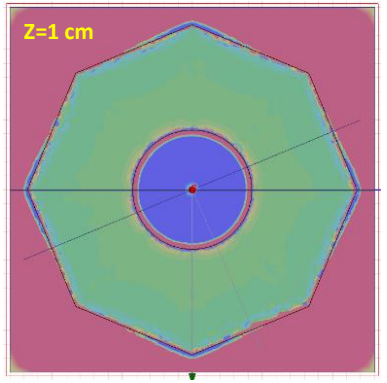
<Field cage in 3D geometry>
- Combination of **cylindrical and octagon** shapes
- **Distance between inner and outer FCs: Max. 7.5 cm**
- **Drift length: 30 cm**

<Field cage in 2D geometry>
- Calculation error: <0.01%
- Green area (±~1%) means E_R (±2 V/cm) and E_Z (198~202 V/cm).
- E field homogeneity in ±1% geometrically over 93% area in (R, Z) plane

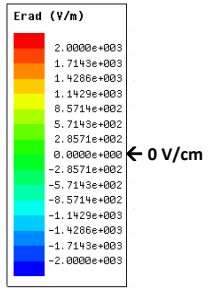


Specification of field cage (FC)
- Strip pitch: 2.5 mm (2+0.5)
- Electric field strength: E_Z = 200 V/cm
- Position of cathode: middle of last strip in Z-axis

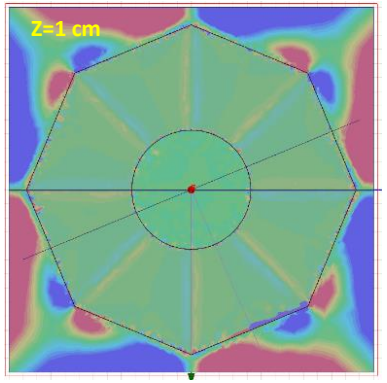
E_R



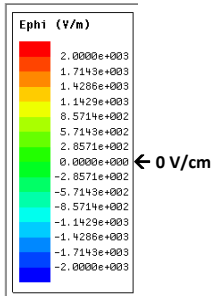
$\overrightarrow{E_R} = \overrightarrow{E_x}cos\varphi + \overrightarrow{E_y}sin\varphi$



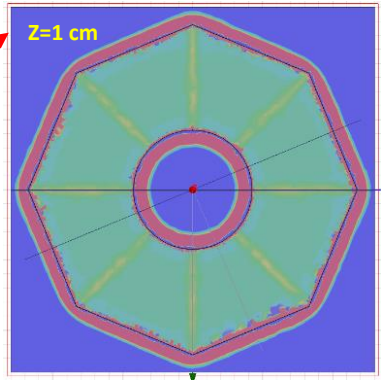
E_Φ



$\overrightarrow{E_\Phi} = -\overrightarrow{E_x}sin\varphi + \overrightarrow{E_y}cos\varphi$

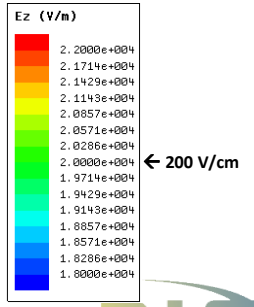


E_Z

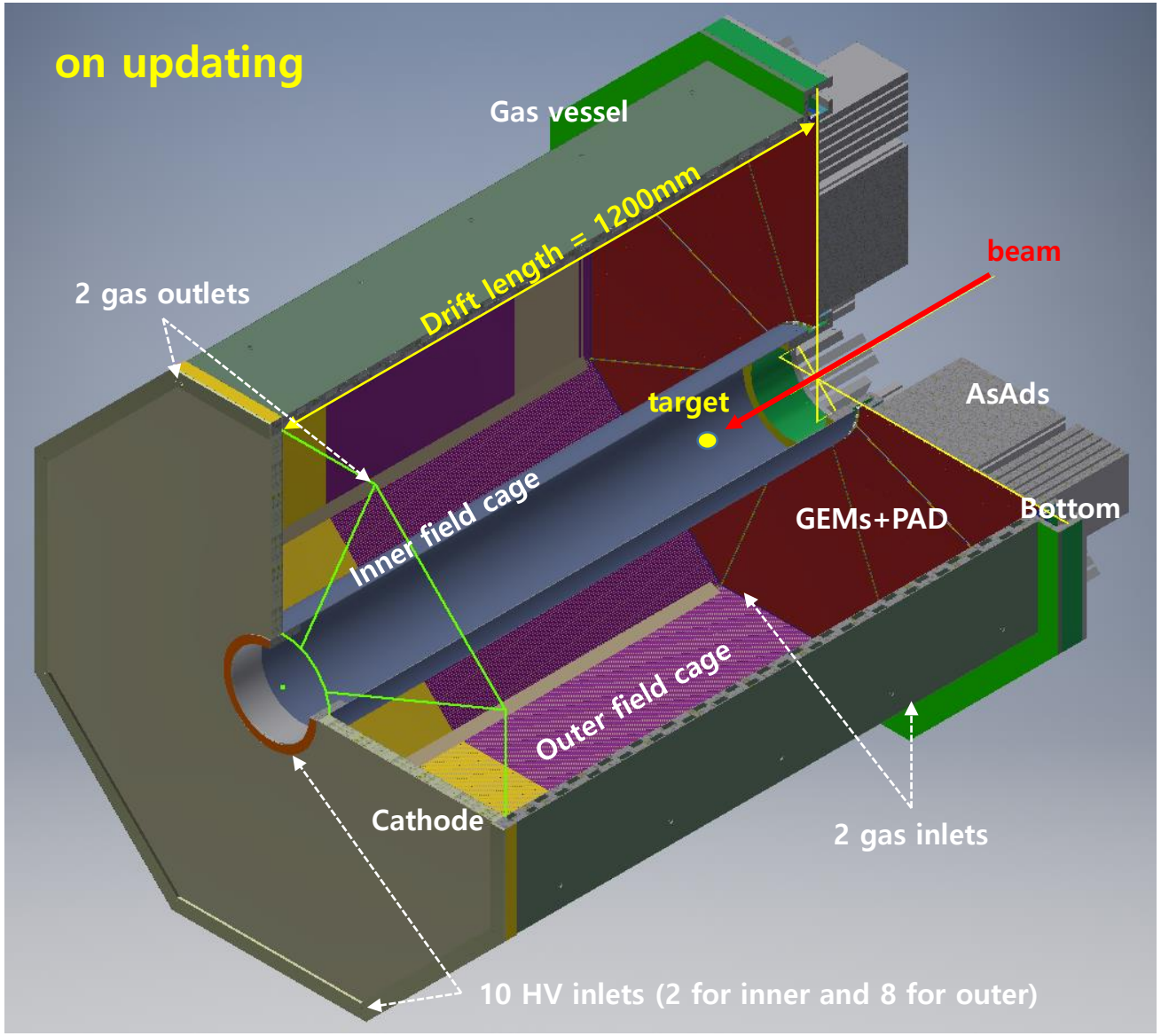


$\vec{Y}$

$\vec{X}$



Design of LAMPS TPC (2019.07)



Cathode, Gas vessel, and Bottom

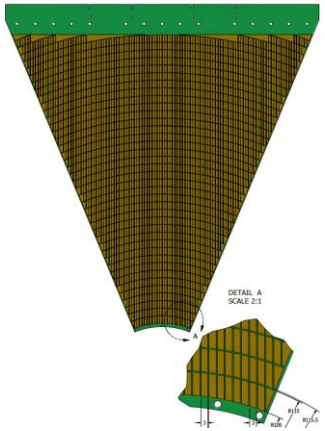
Asymmetry shape of field cage: cylindrical and octagon shapes

Field Cage

Size of field and mirror strips in Z-axis: 2mm Cu + 0.5mm spacing
Drift length : 1200 mm

PAD

PAD size: 3x10 mm^2
Total number of PAD in 8 GEM sectors
Channel: 2,712ch/sector → 21,696 ch/total
Active area: R_{IN} = 105 mm
$R_{OUT}^{MIN.}$ 503.5 mm ~ $R_{OUT}^{MAX.}$ 535 mm



GEM

Total area ~1,000 cm^2
GEM sector: 8 EA
Sub HV sector in a GEM: 10 EA (~100 cm^2/sub HV sector)
Hole geometry (Cu pitch - Cu hole - PI hole): 140-70-50 μm

GET Electronics

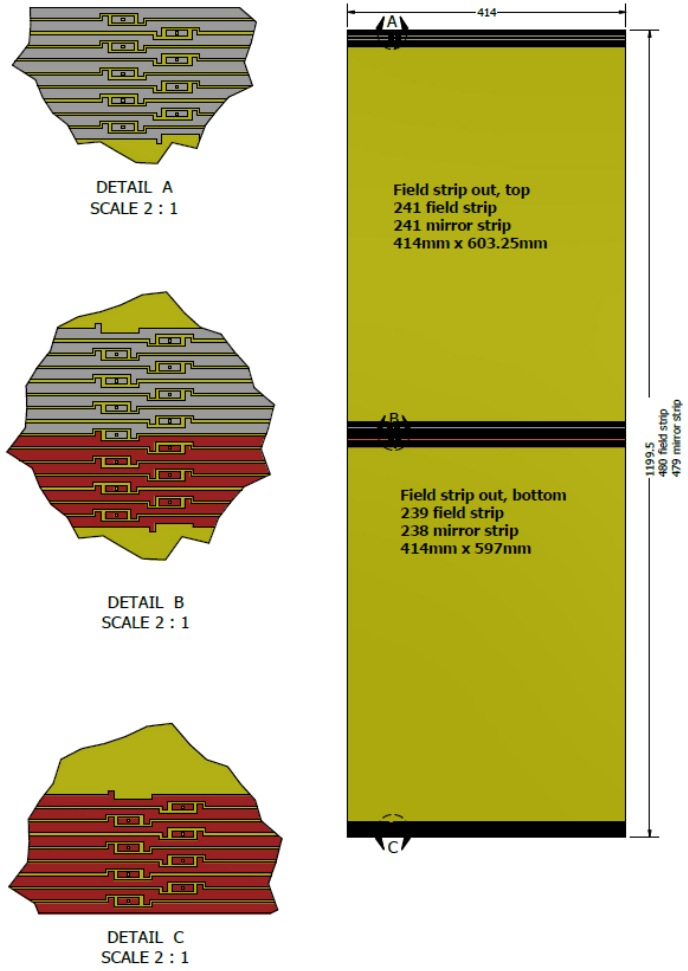
Total number of AsAd board (11EA/GEM sector) = 88EA

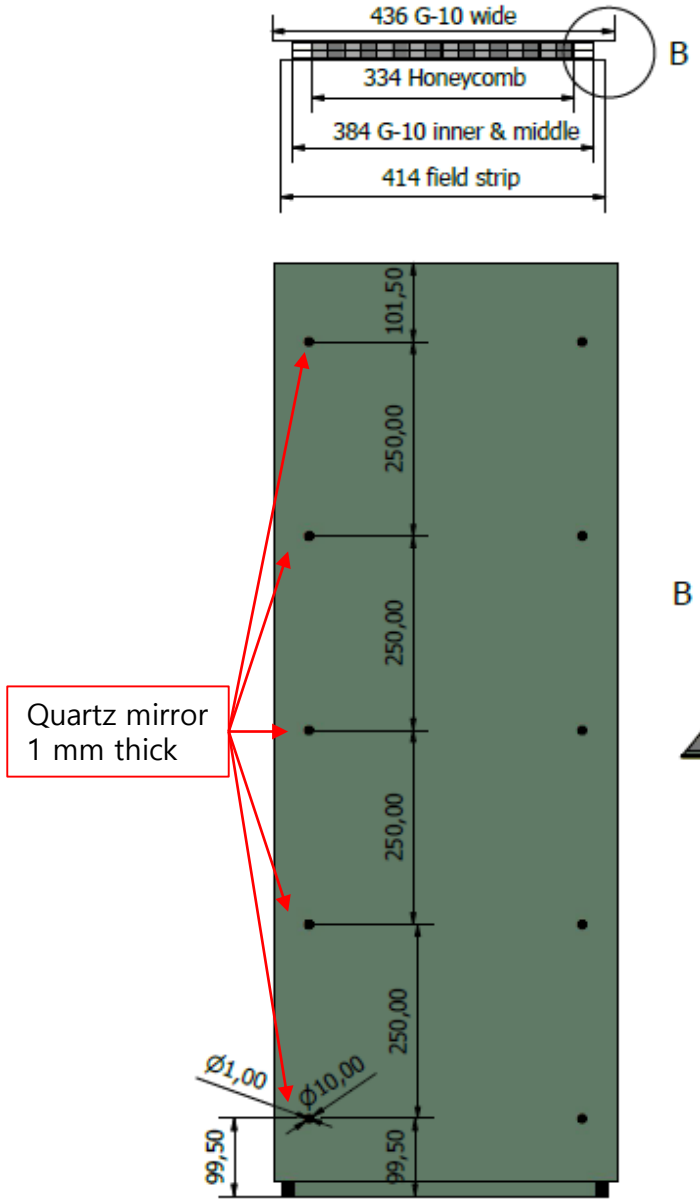
Design of field cage

Field Cage
Size of field and mirror strips in Z-axis: 2mm Cu + 0.5mm spacing
480 field strips and 479 mirror strips for 1200 mm drift length

Inner field strip board: 1EA strip board (660*1199.5 mm^2)
Outer field strip board: 8 EA strip board (414*1199.5 mm^2)

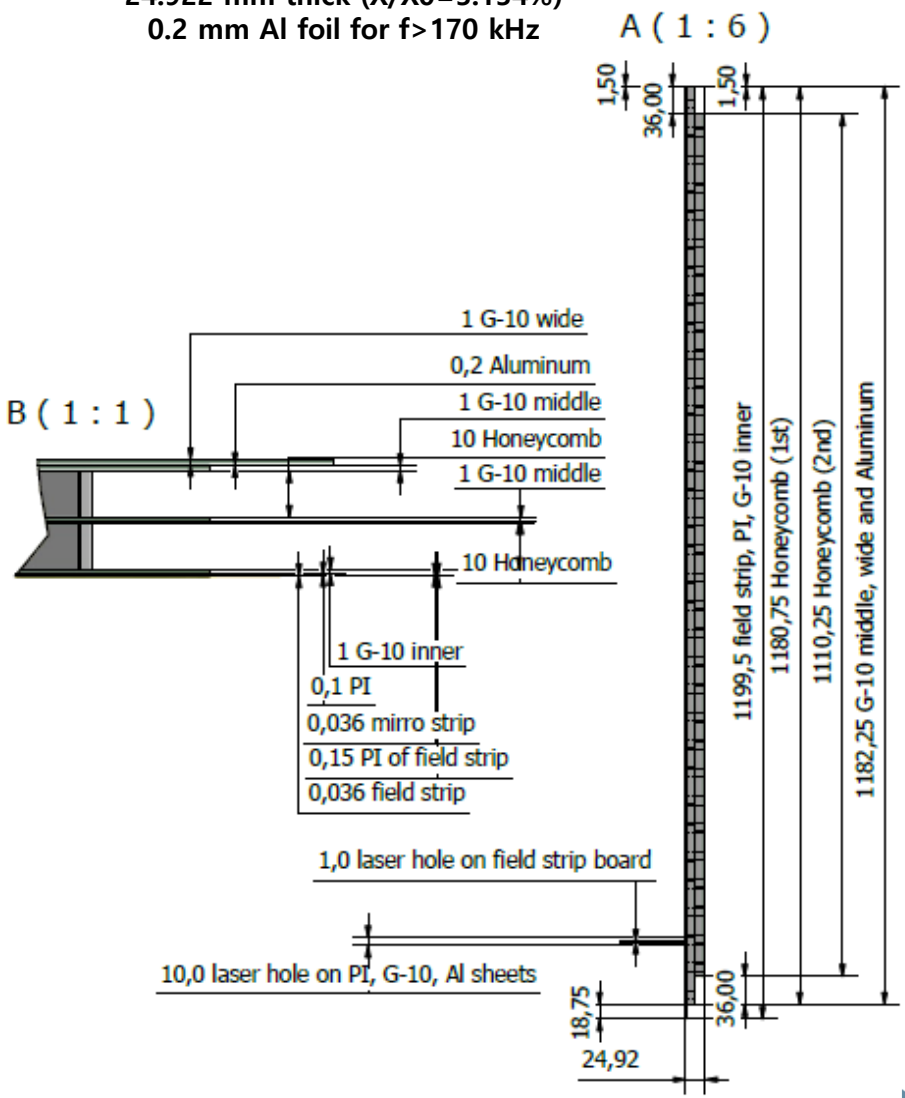
Field strip out





Outer field cage

24.922 mm thick (X/X0=3.134%)
0.2 mm Al foil for f>170 kHz



What we have done and have to do:

What we have done:

◆ **TPC prototype test**
- ELPH positron beam test in P-10 (Ar:CH_4=90:10) and Ar:CO_2=90:10
- Cosmic ray muon test in P-10 and P-20 (Ar:CH_4=80:20)
- Drift velocity and electric field distortion

◆ **Gas electron multiplier (GEM)**
- Quality test of GEM foil (140 and 1600 cm^2): optical and electrical properties
- Performance test of GEMs: V_{GEM}, gain, # of hits, discharge rate, and so on

What we have got:

- Gain (L3GEM): ~$2x10^4$ at P-10 and ~$2x10^3$ at P-20
  (L4GEM): ~$2x10^5$ at P-10 and ~$6x10^4$ at P-20
  (Sim., 3GEM): $8.7x10^3$ in P-10 [JKPS 68 (2016) 645 G. JHANG et al]
- Drift velocity (v_D) of over 6 cm/μs in P-20 for 120 cm drift length
- E field homogeneity in ±1% geometrically over 93% area
- Position resolution (σ_p): ~230 μm with 3x10 mm^2 PADs in P-10
- Transverse diffusion (exp.): 420 $\mu m/\sqrt{cm}$ @ 155 V/cm in P-10

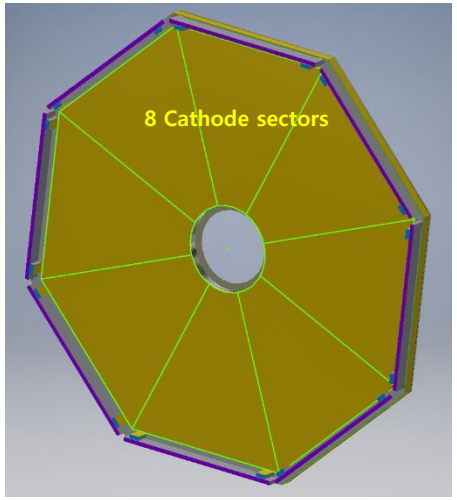
What we have to do:

◆ **Fabrication of LAMPS TPC**
- Design of gas vessel and field cage by July
- Fabrication by Dec.

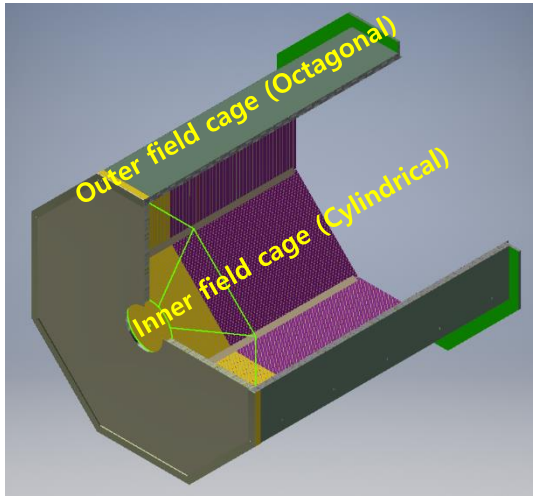
◆ **Gas electron multiplier (GEM)**
- Sample test of GEM (Aug – Sep)
- Final design of LAMPS GEM (Oct)

◆ **Operational system for TPC**
- High voltage supply system (HVPS delivered in July)
- Gas supply system
- Laser calibration system

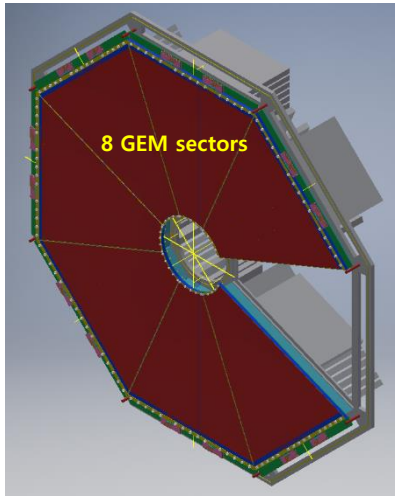
Cathode



Gas vessel



Bottom



Thank you for your attentions!