Status report of LAMPS TPC

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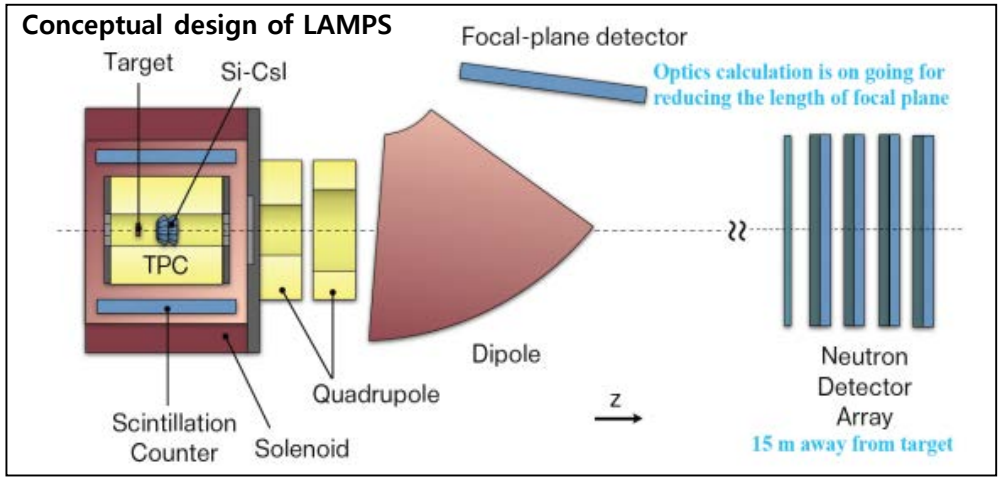
for LAMPS of RISP at IBS

Contents

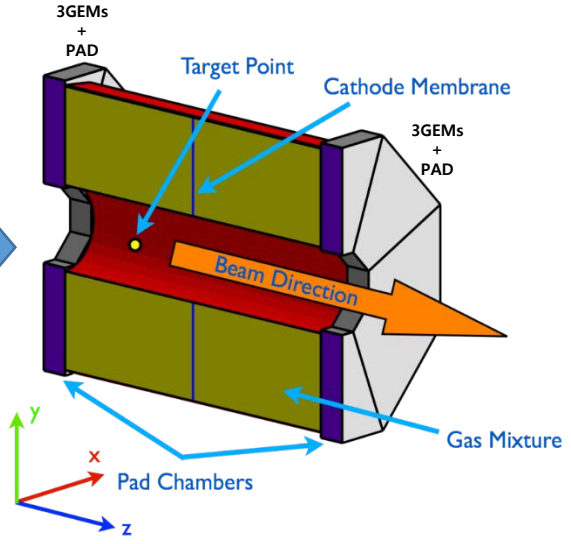
Time Projection Chamber for LAMPS

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
- Time Projection chamber (TPC): main charged particle tracker

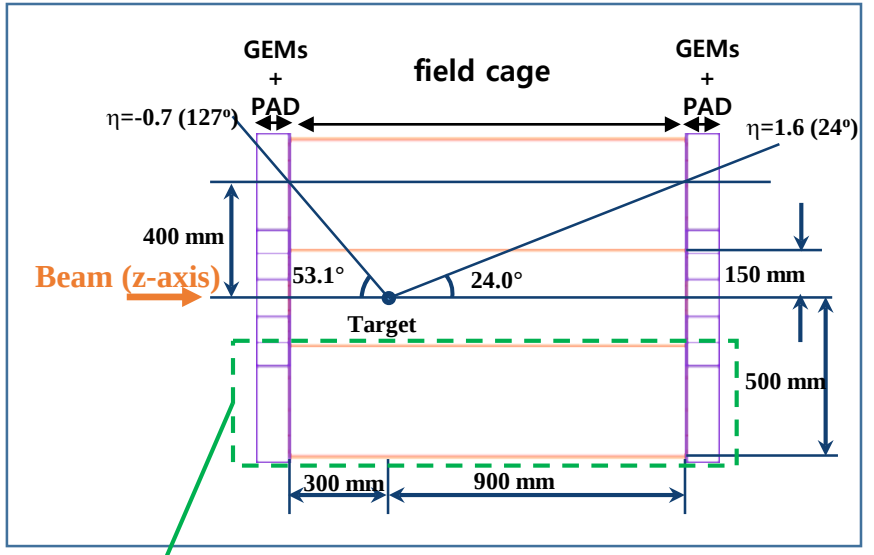


Conceptual design of LAMPS TPC



Initial design of LAMPS TPC
- 2 x 60 cm field cage (FC)
- 8 GEM sectors with triple-GEMs
- ~ 100,000 PADs

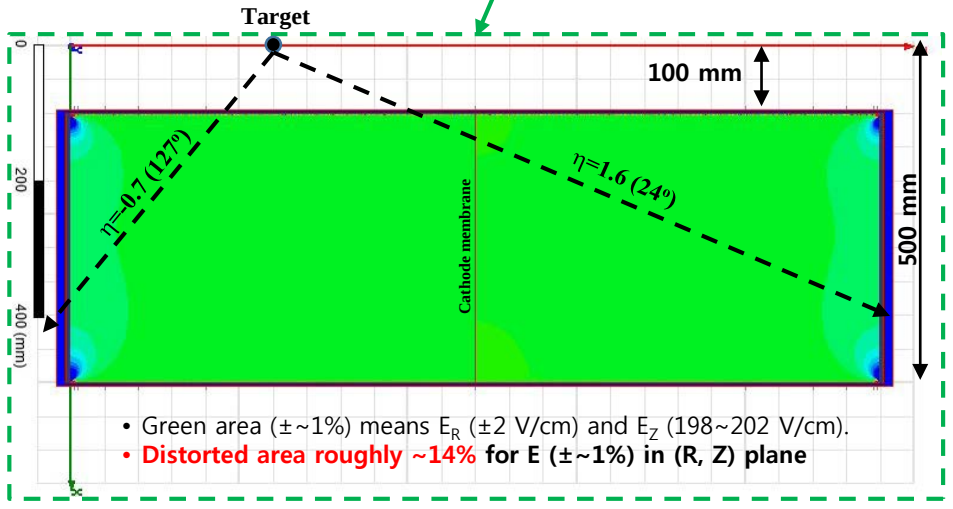
Cross-sectional view of LAMPS TPC

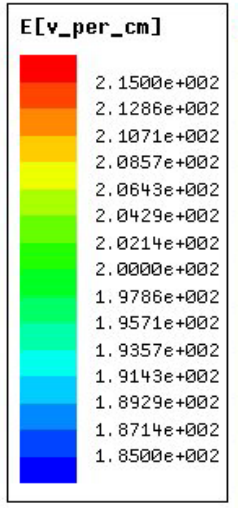


Requirements of LAMPS TPC
- large solid angle acceptance > 3π (24°<Θ<127°, 0°<Φ<360°)
- Good momentum resolution and particle identification (PID) of charge particles

Design parameter of TPC components
- Triple-GEMs: ~8.7x10^3 gain in P-10 **[JKPS 68 (2016) 645 G. JHANG et al]**
- PAD: position resolution (σ_p) of 200-300 μm
- Field cage: drift velocity (v_D) of over 5 cm/μs

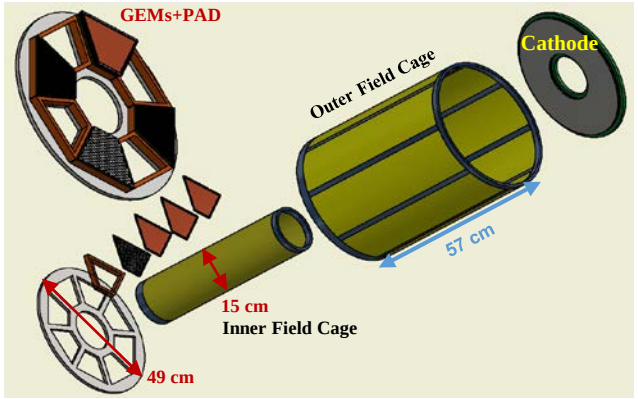
E field homogeneity in ±1%



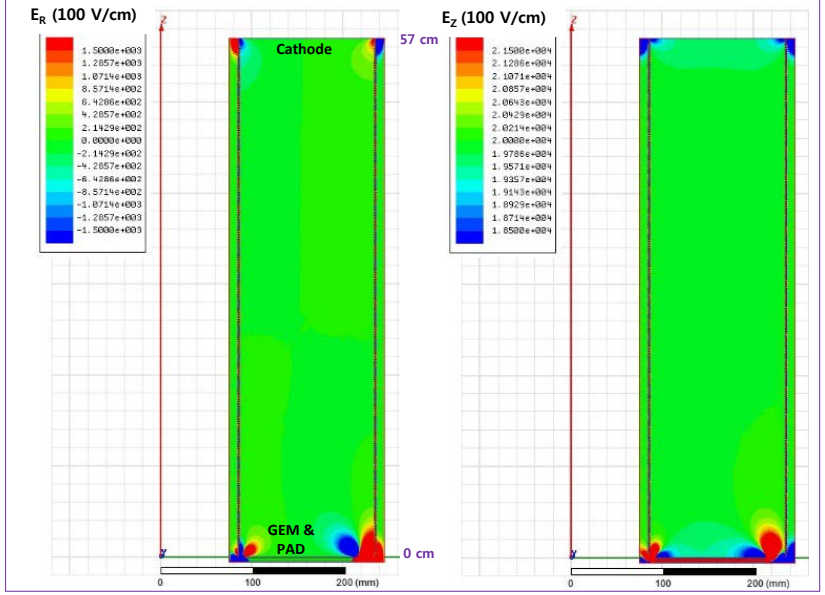


Performance of TPC prototype

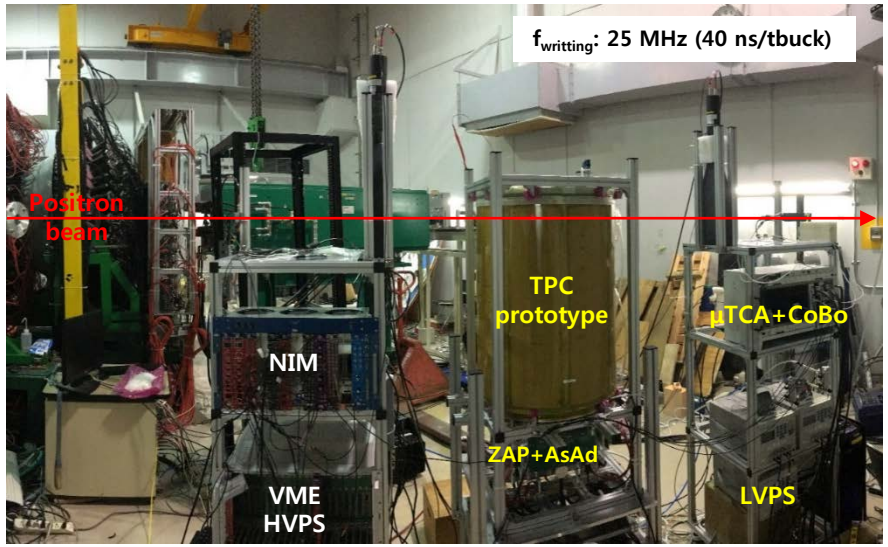
Specification of TPC prototype
- 1/8 volume of LAMPS TPC
- Drift length: 57 cm
- Triple-GEMs (2:2:2 mm)
- 4 PADs (3x10 and 4x15 mm^2)



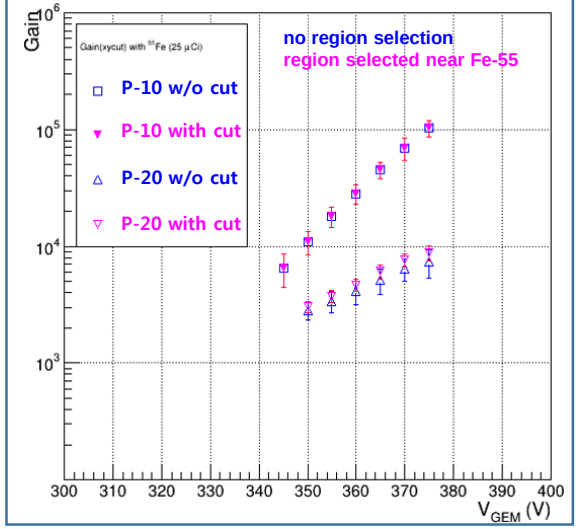
Electrical field distribution of field cage of TPC prototype
- Green area (±~1%) means E_R (±2 V/cm) and E_Z (198~202 V/cm).
- **Distorted area roughly ~15% for E (±~1%) in (R, Z) plane**



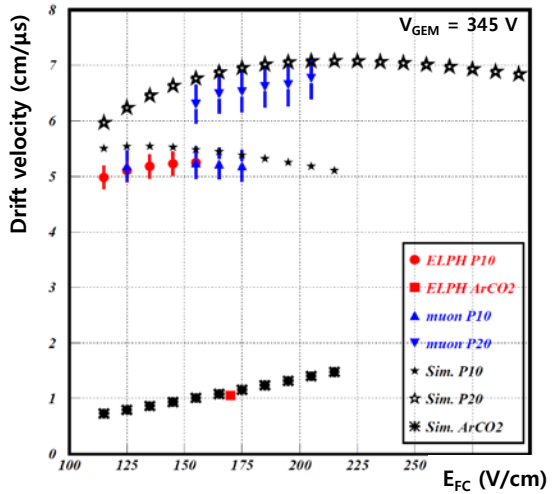
Test setup of TPC prototype at ELPH (Nov. 1-2 in 2016)



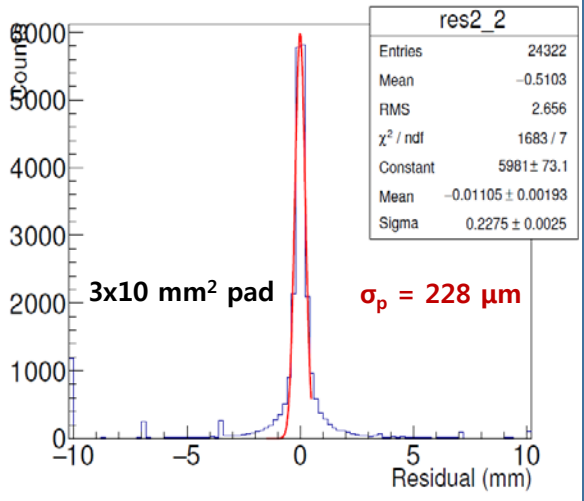
Gain of triple-GEMs with 5.9 keV X-ray



Drift velocity of TPC prototype



Position resolution



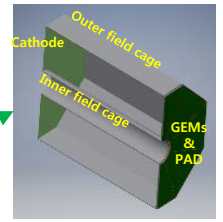
Test results of TPC prototype
- Max. gain: ~10^5 in P-10
  ~8*10^3 in P-20
- Max. drift velocity: ~5.25 cm/μs in P-10
  ~6.77 cm/μs in P-20
- Positon resolution: **~228 μm with 3x10 mm^2 PAD**
  ~513 μm with 4x15 mm^2 PAD
- Transverse diffusion: <600 μm/√cm in P-10
  <500 μm/√cm in P-20

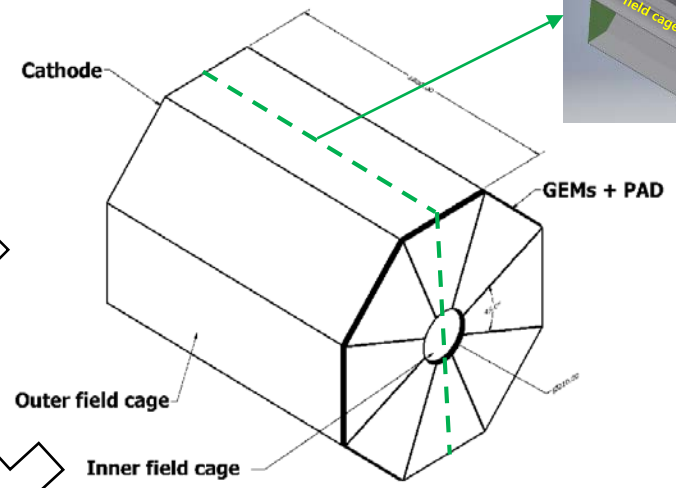
New design parameters for TPC
- **Gain of triple GEMs ~10^4 in P-20**
- **Drift velocity over 6 cm/μs for 120 cm drift length**
- **Position resolution (σ_p) ~230 μm with 3x10 mm^2**

Electric field distribution of LAMPS TPC

New design parameters for TPC

- Gain of GEMs ~10^4 in P-20
- Drift velocity over 6 cm/μs for 120 cm drift length
- Position resolution (σ_p) ~230 μm with 3x10 mm^2



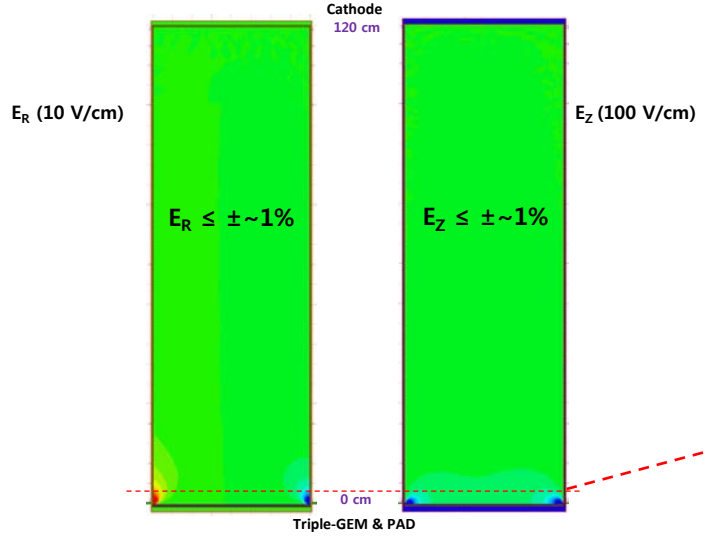


Specification of field cage (FC)

- 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

<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).
- **Distorted area roughly ~7% for E (±~1%) in (R, Z) plane**



<Field cage in 3D geometry>

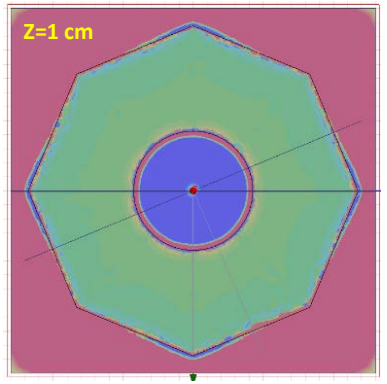
- Combination of cylindrical and octagonal structure
- **Distance between inner and outer FCs: Max. 7.5 cm**
- **Drift length: 30 cm**

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)

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

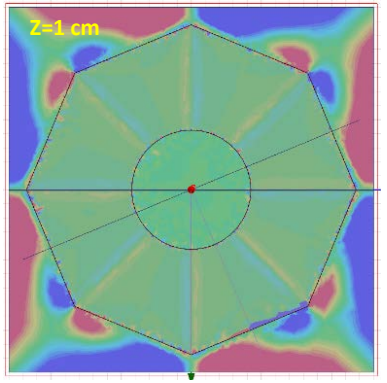
E_R



← 0 V/cm

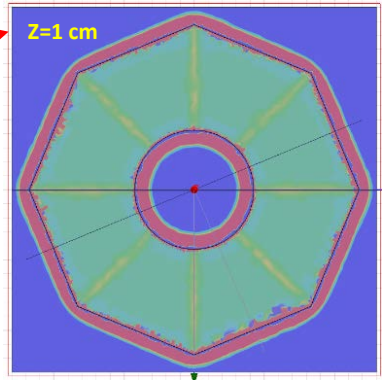
$\overrightarrow{E_\Phi} = -\overrightarrow{E_x}sin\varphi + \overrightarrow{E_y}cos\varphi$

E_Φ



← 0 V/cm

E_Z

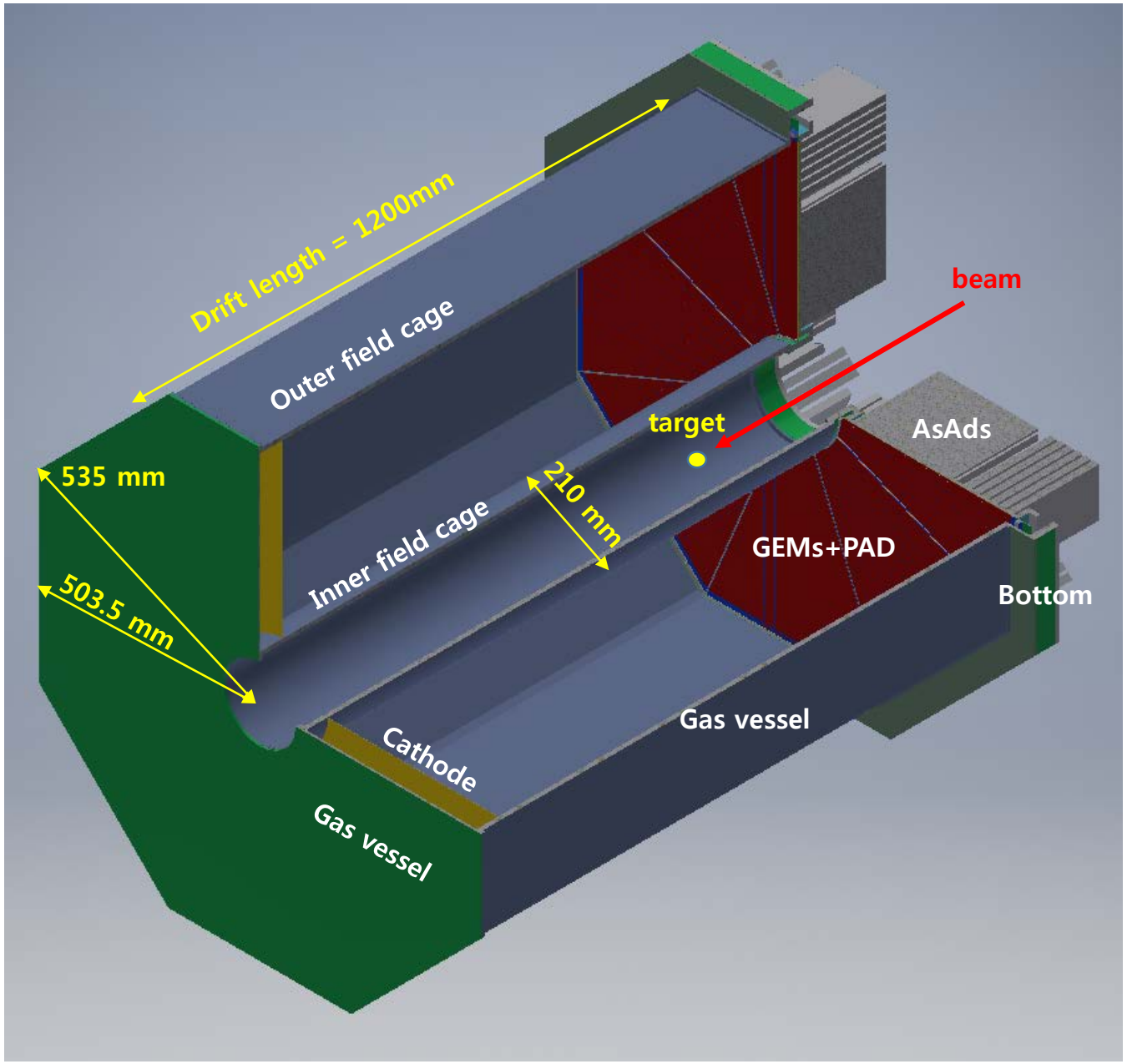


$\vec{Y}$

← 200 V/cm

$\vec{X}$

Design of LAMPS TPC



Field Cage

Cylindrical (inner) and octagonal (outer) structures
Size of field and mirror strips in Z-axis: 2mm Cu + 0.5mm spacing
Drift length: 1,200 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

PAD

PAD size: 3x10 mm^2
Total number of PAD in 8 GEM sectors (2,618ch/sector) = 20,944ch
Active area: R_{IN} = 105 mm
$R_{OUT}^{MIN.}$ 503.5 mm ~ $R_{OUT}^{MAX.}$ 535 mm

Cathode, Gas vessel, and Bottom

Φ_{IN} of gas vessel: 170 mm (Φ_{BEAM_PIPE}: 160 mm)
Gas & HV connection, Calibration system, Moving support

GET Electronics

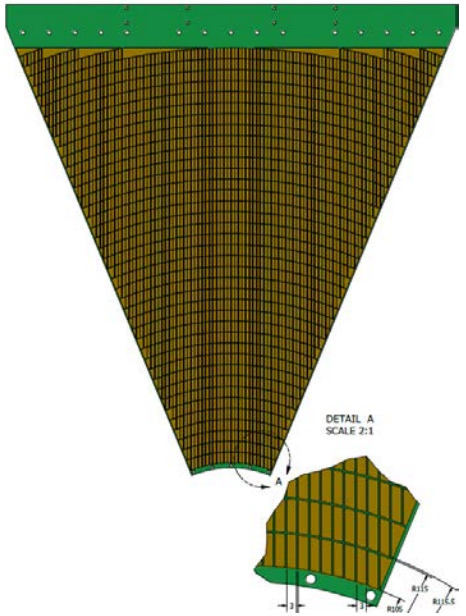
Total number of AsAd (11 EA/GEM sector) = 88 EA

Design of TPC parts

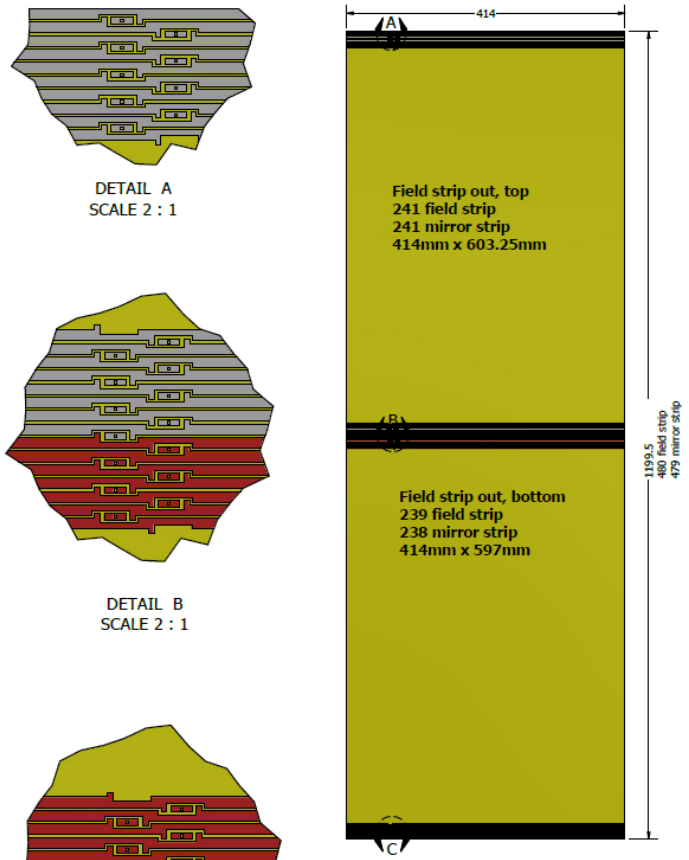
Field Cage
Size of field and mirror strips in Z-axis: 2mm Cu + 0.5mm spacing
480 field strips and 479 mirror strips for 1200 mm drift length

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)

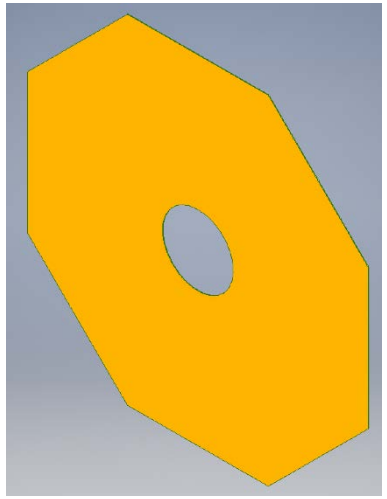
PAD
PAD size: 3x10 mm^2
Number of PAD per GEM sector: 2,618
Total number of PAD= 20,944ch
Active area: R_{IN} = 105 mm
$R_{OUT}^{MIN.}$ 503.5 mm ~ $R_{OUT}^{MAX.}$ 535 mm



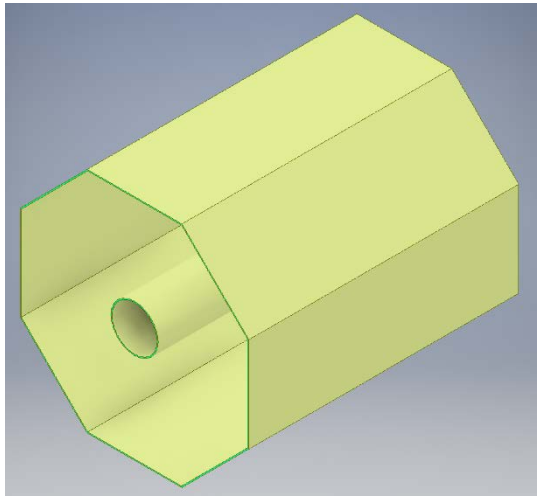
Field strip out



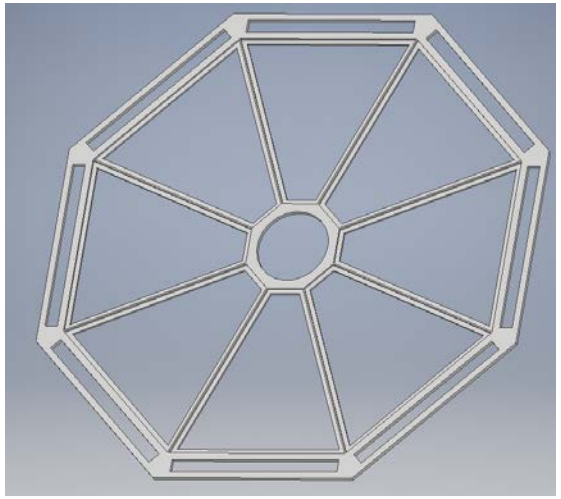
Cathode



Gas vessel



Bottom

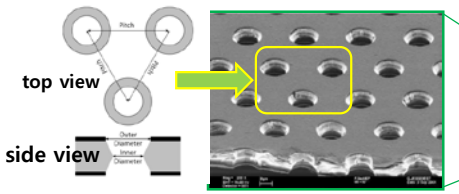


Update the drawing of Cathode, Gas vessel, Bottom, Gas & HV connection, Calibration system, moving support

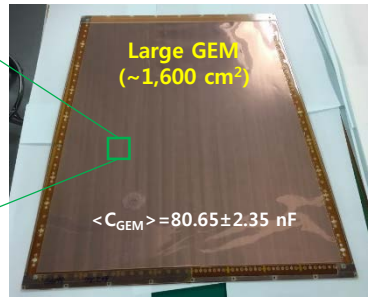
Large GEM to LAMPS GEM

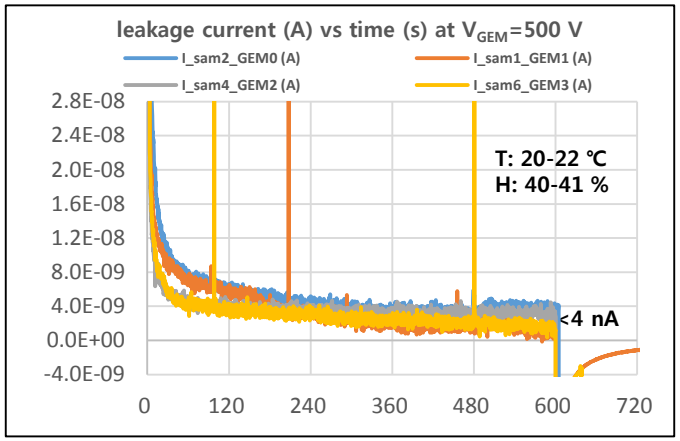
<Detector setup>
Gas volume: ~56 liters
Gap configuration: triple- and quadruple-GEMs
Pre-mixed gas: P-10 (Ar:CH_4=90:10) and P-20
Test source: Fe-55 (25 μCi, 2014)
Number of pad: 2559 ch (3x10 mm²/pad)

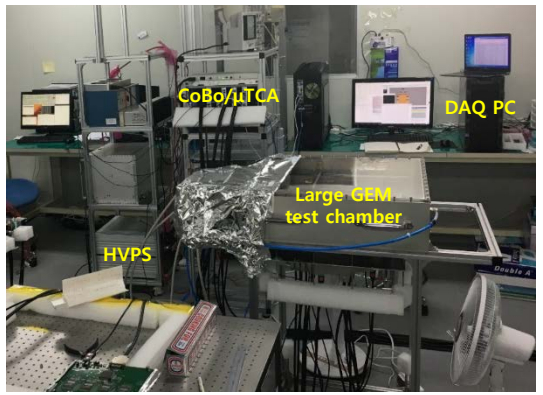
Gaseous Electron Multiplier (GEM)

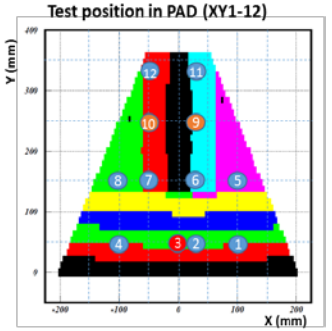


Hole geometry (pitch – Cu hole – PI hole):
140 – 70 – 50 μm



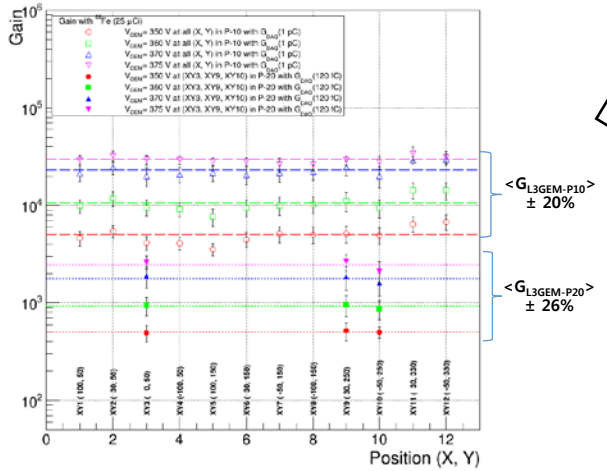




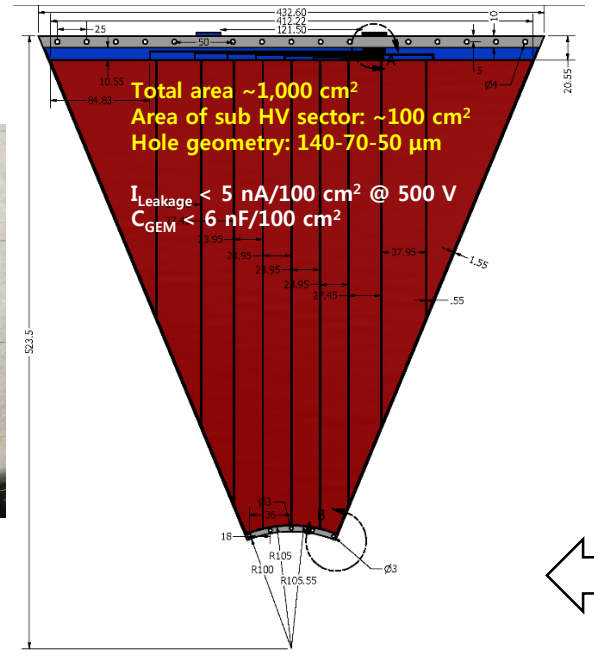


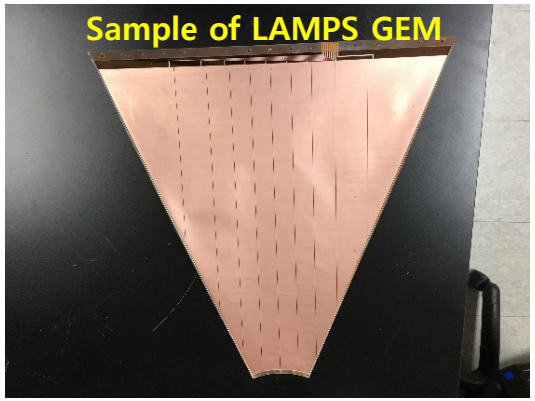
GEM structure	Gas	V_{GEM} (V)	V_{GEM} (V) for discharge event	Test position (XY#)
3LGEM	P-10	350, 360, 370, 375	380, 385, 390	XY1-12
3LGEM	P-20	350, 360, 370, 375		XY3, XY9, XY10
4LGEM	P-10	340, 345, 350, 355, 360	365, 370 V	XY3
4LGEM	P-20	360, 370, 375		XY3

Gain uniformity

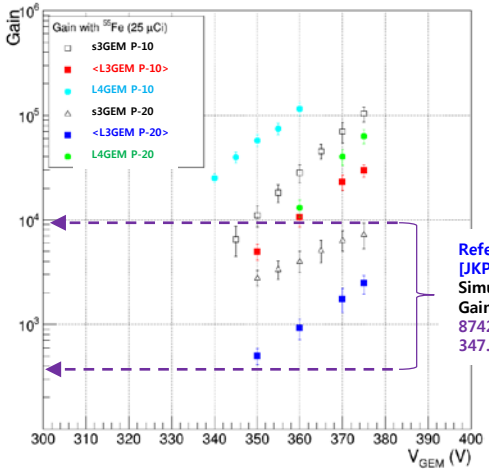


Design of LAMPS GEM (under production)





Gain of GEM



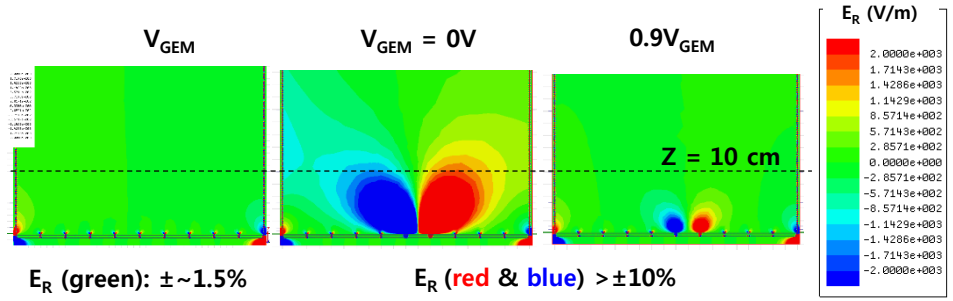
Reference
[JKPS 68 (2016) 645 G. JHANG et al]
Simulation results of LAMPS TPC
Gain of triple-GEMs in P-10
8742.05 at V_{GEM}=400 V
347.34 at V_{GEM}=350 V

New design parameter of TPC

- **Gain of triple GEMs ~10^4 in P-20**
- Drift velocity over 6 cm/μs for 120 cm drift length
- Position resolution (σ_p) ~230 μm with 3x10 mm²

High voltage supply system for TPC

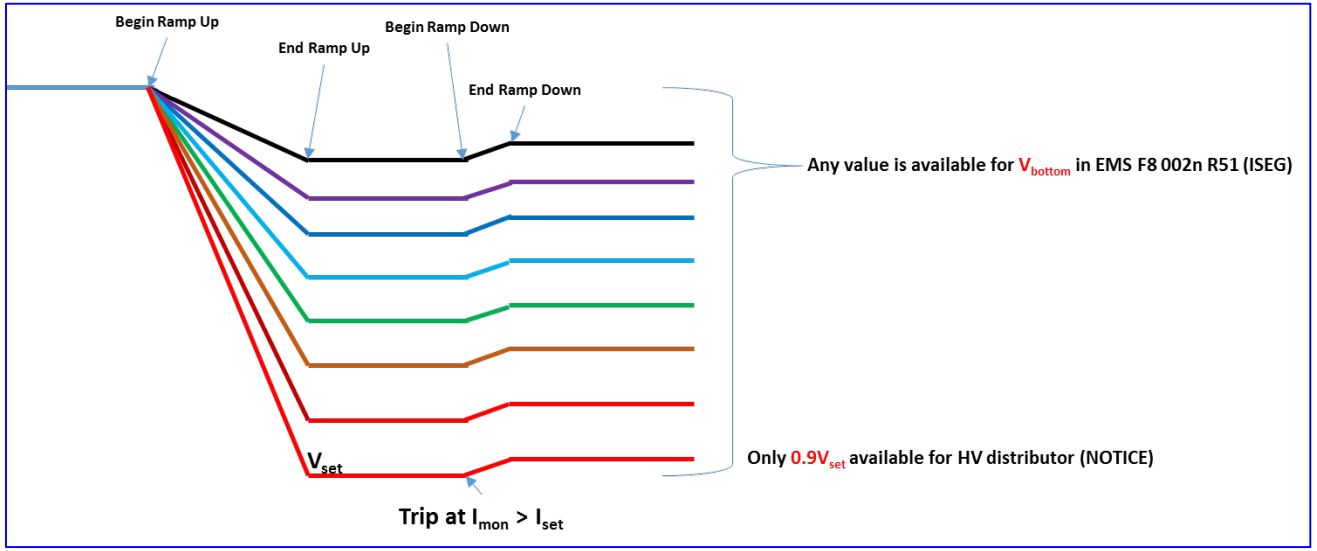
When the discharge occurs, V_{GEM} becomes 0 V due to trip function in HVPS.
→ Then, E field in FC is distorted.

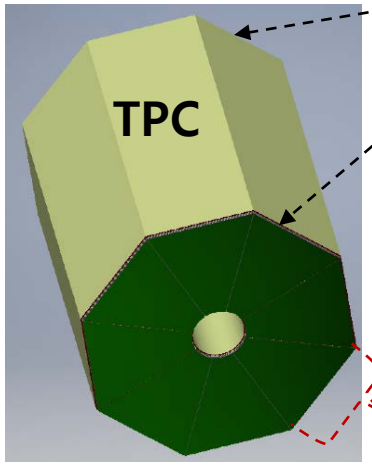


E_R (green): ±~1.5% E_R (red & blue) >±10%

High voltage system for TPC

- **High voltage power supply (HVPS)**
  GEM mode
  programmable bottom voltage (V_{bottom}) → to minimize the E field distortion in FC
- **High voltage distribution system (HVDS)**
  GEM mode
  V_{bottom} can be set for a certain sub-HV sector → to minimize the E field distortion in FC

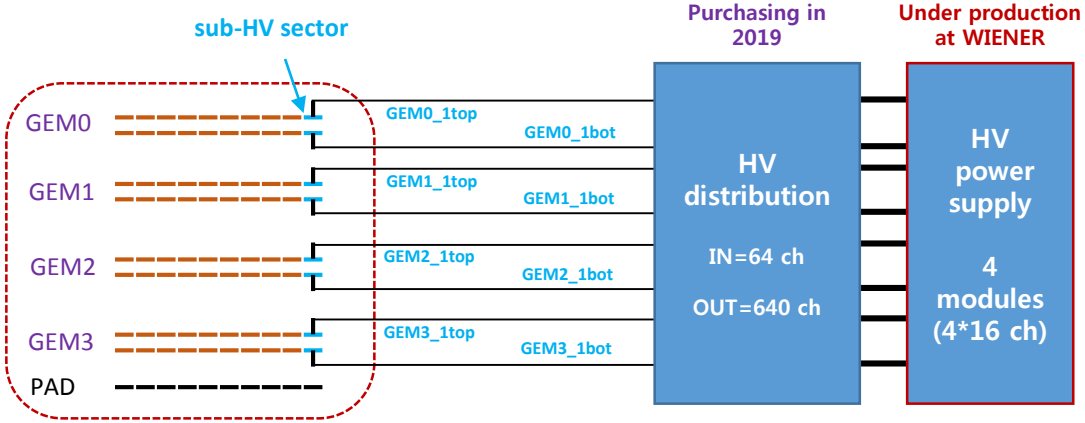




Inner_Strip_End
Outer_Strip_End
Cathode
→ Heizinger PNC60000-3

Inner_Strip1
Outer_Strip1
→ Heizinger PNC3500-20

640 channels of HV system
- 8 GEM sectors
- 10 sub HV sectors in a GEM
- Max. 4 GEM layers
- 2 electrodes for a GEM



HV power supply for GEM
1.16 channel → 8 channels * 2 groups
2.Floating ground (FG)
3.GEM mode
4.Max. floating voltage (V_{CHmax}): floating 1 kV
5.V_{max} = floating 5 kV in a group
6.Current monitor resolution (σ_{Imon}):
  20 μA (0.1 nA)
  1 mA (5 nA) – automatically range selection
7.Possible to set V_{bottom}

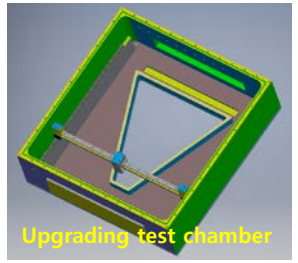
WIENER EMS series (Redel 51 pin HV connectors)

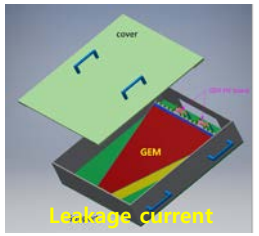
Working plan for LAMPS in 2019~2021

2019 ~ 2020 → **2021**

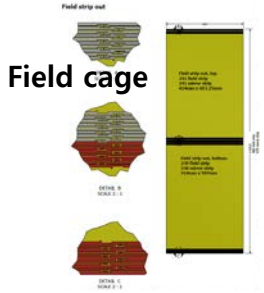
QA of LAMPS GEMs

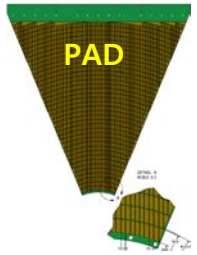
Test of LAMPS GEMs

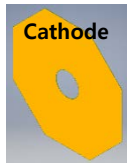


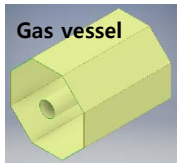


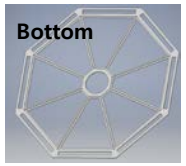
Fabrication



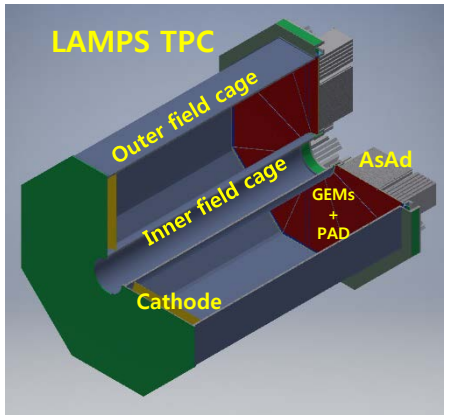




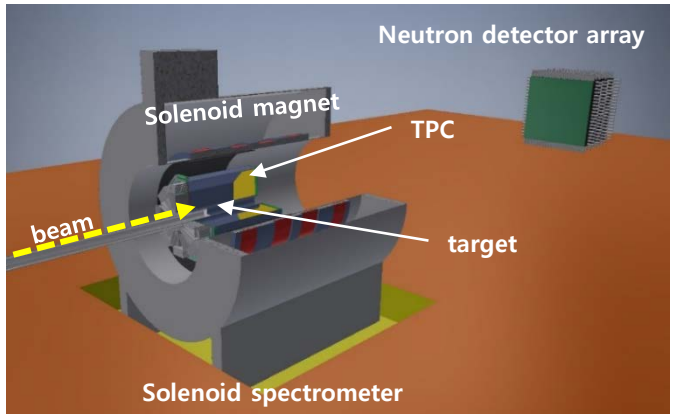


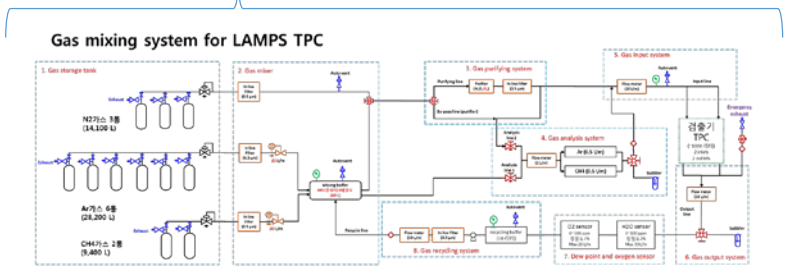


Assembly & Test



Installation & Trial run





◆ Gas electron multiplier (GEM)
- Production facility (㈜MECARO) will be re-constructed by early of July.
- Quality test of GEM foil (1,000 cm^2): optical and electrical properties by early of 2020
- Performance test of GEMs: V_{GEM}, gain, # of hits, discharge rate and etc by 2020

◆ LAMPS TPC
- Update drawing of TPC and moving support
- Fabrication and assembly by Oct in 2019
- Operation test by 2020

◆ Operation system for TPC
- High voltage supply system in 2019
- Gas supply system by early of 2021

◆ Installation and trial run of LAMPS in 2021

What we have to do for LAMPS TPC now?
- Need better performance of triple-GEMs in P-20
- Update drawing of cathode, gas vessel, bottom, gas & HV connection, calibration system and beam line alignment on moving support
- Installation of HV supply and gas supply systems

Thank you for your attentions!