二重増幅率制御型多層THGEMの高強度重イオンビームに対する性能評価

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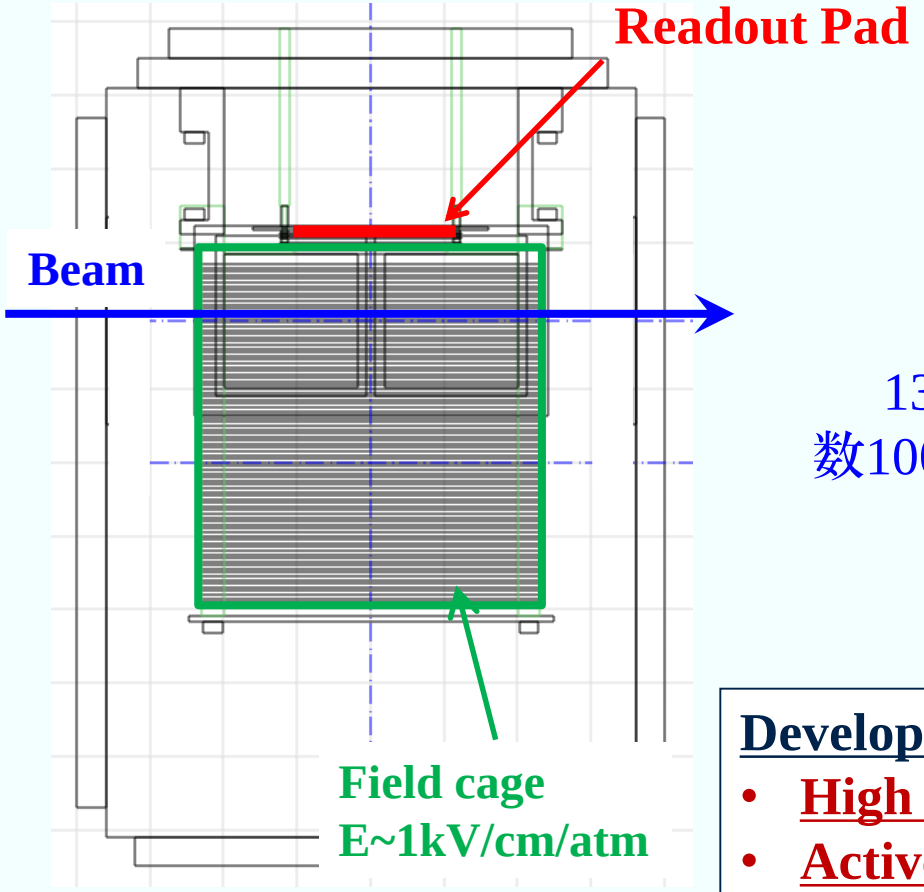
Outline

1. Introduction
    1. CNS Active target
    2. “Dual Gain control” & “Multi-layer structure” of THGEM
2. Performance evaluation for the THGEM
    1. Gain curve and resolutions with the high intensity beam
    2. Bending deflection
3. Summary

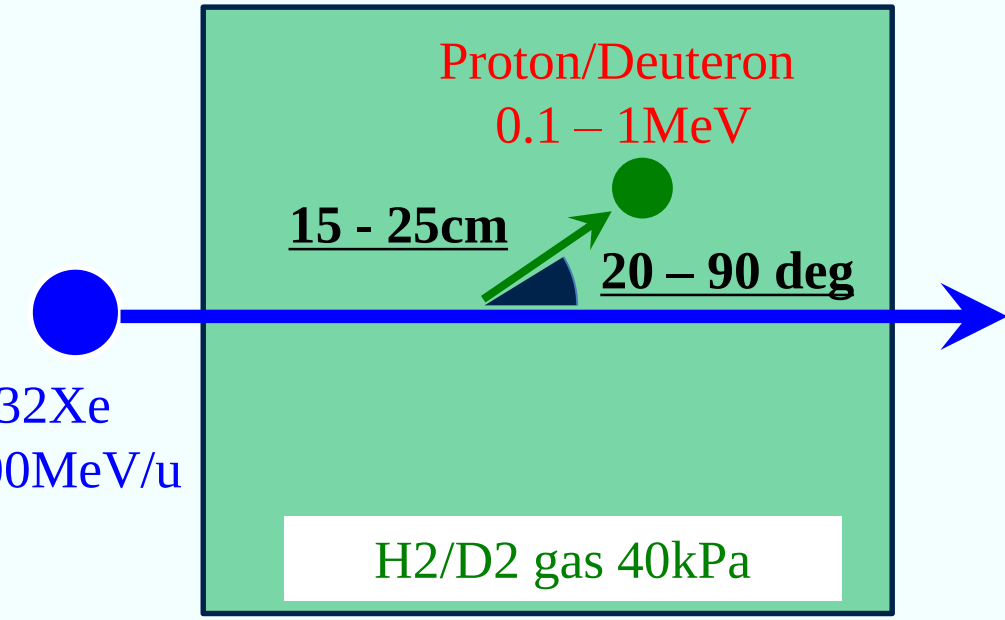
CNS Active target “CAT”

Gas Active Target with Box type GEM-TPC

Side View of CAT-S



逆運動学陽子/重陽子非弾性散乱測定



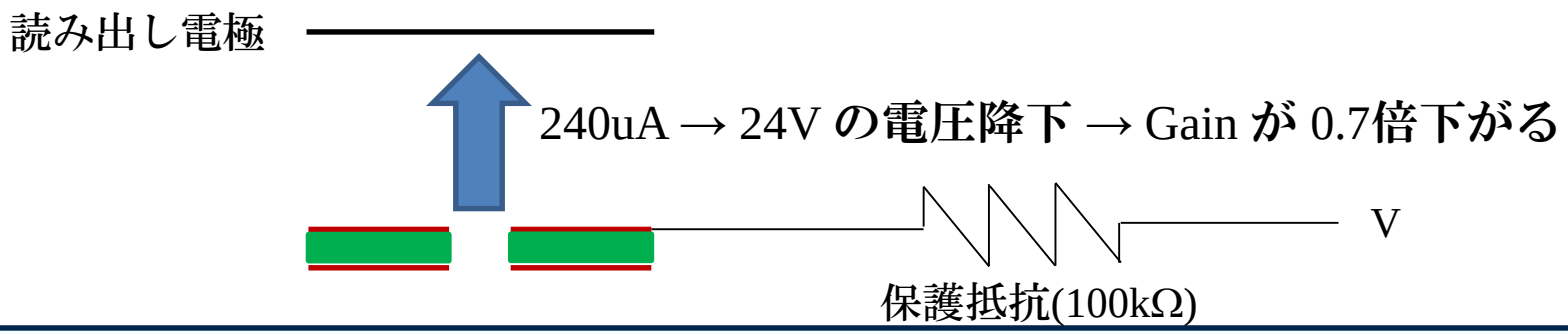
Development to increase luminosity and statistics

- **High intensity beam: 1MHz**
- **Active region of TPC: 30 cm × 30 cm**

Point of the development for GEM

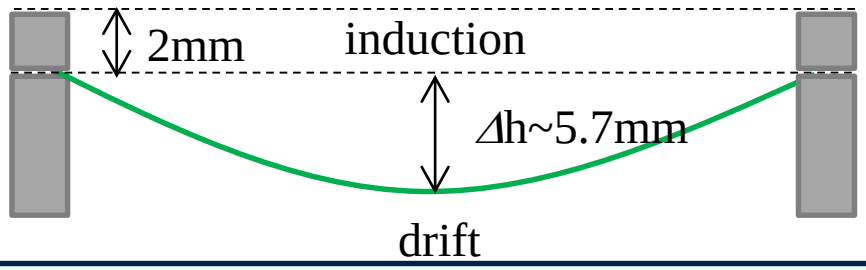
- **大強度重イオンビームの照射 → 電離電子数の増加**
  - **~120fC / 300mm with 1MHz** of 132Xe beam 185MeV/u in H2 gas 40kPa
    - Induction region における大電流

Gain = 2000 (反跳粒子用設定)のとき



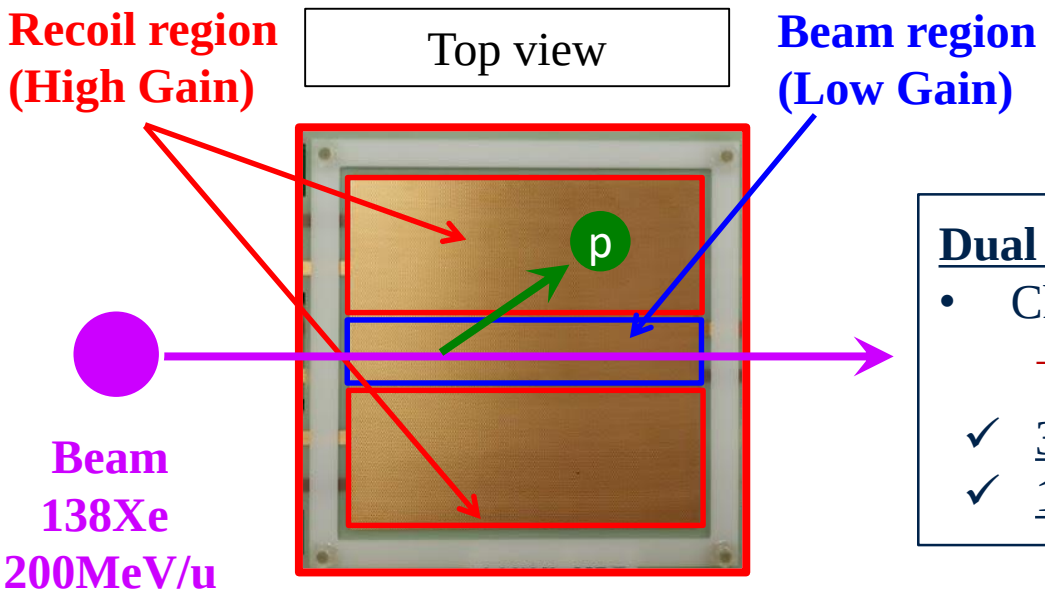
- **GEMの面積の拡張 → 自重によるたわみが心配**

300mm x 300mm x 0.4mmt, FR4 両端支持等分布荷重一次元計算



Ex: induction region の電場強度が変化
→ GEMの中央と端でGain が20%程度変わる

二重増幅率制御型 THGEM (Dual Gain THGEM)



Dual Gain control structure

- Change gain between beam and recoil region
  → **measurement of high intensity beam**

✓ 300kHz in RIBF113@RIBF (S. Ota et al.)
✓ 1Mppp in H307-6 @ HIMAC (S. Ota et al.)

S.Ota et al., ,J. Radioanal. Nucl. Chem.305, 907-911 (2015).

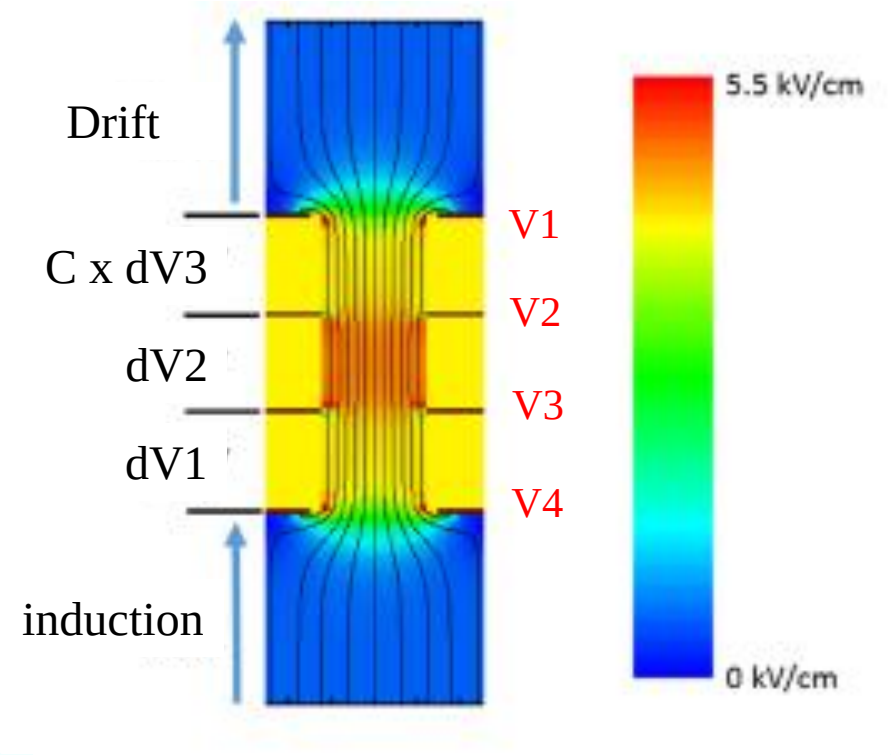
Requirement (with H_2 gas 40kPa)

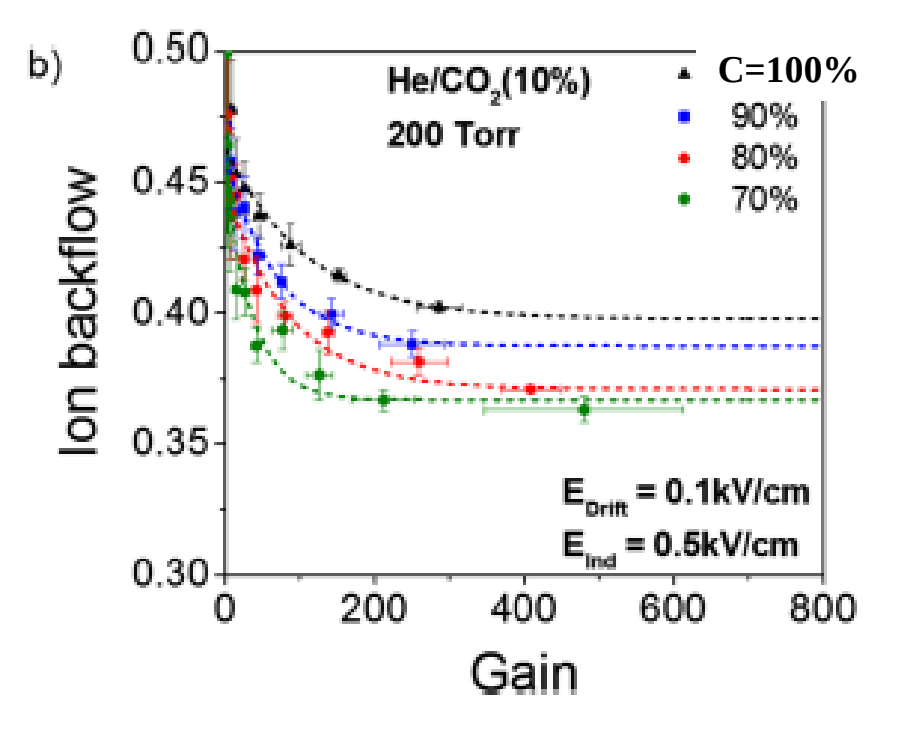
- Gain

Gain	ΔV_{GEM} [V]	電流 @ Induction [uA]	GEM の電圧降下 [V]
2000	~ 600	240	24
100	~ 500	12	1.2

- Charge resolution
  - **Less than 10%** ($\delta\theta_{LAB}$ ~ 10mrad)

多層 THGEM (Multi-layer THGEM)





Multi-layer Thick GEM (M-THGEM)

- 厚いので自重でたわみにくい(はず)
- Transfer region がないのでGain を稼げる
- GEM電圧比を変えてion backflow を制御するなどの幅が増える

厚さ [mm]	自重によるたわみ [mm]
0.40	5.7
1.2	0.63

M. Cortesi et al., Review of Scientific Instruments 88,013303 (2017).

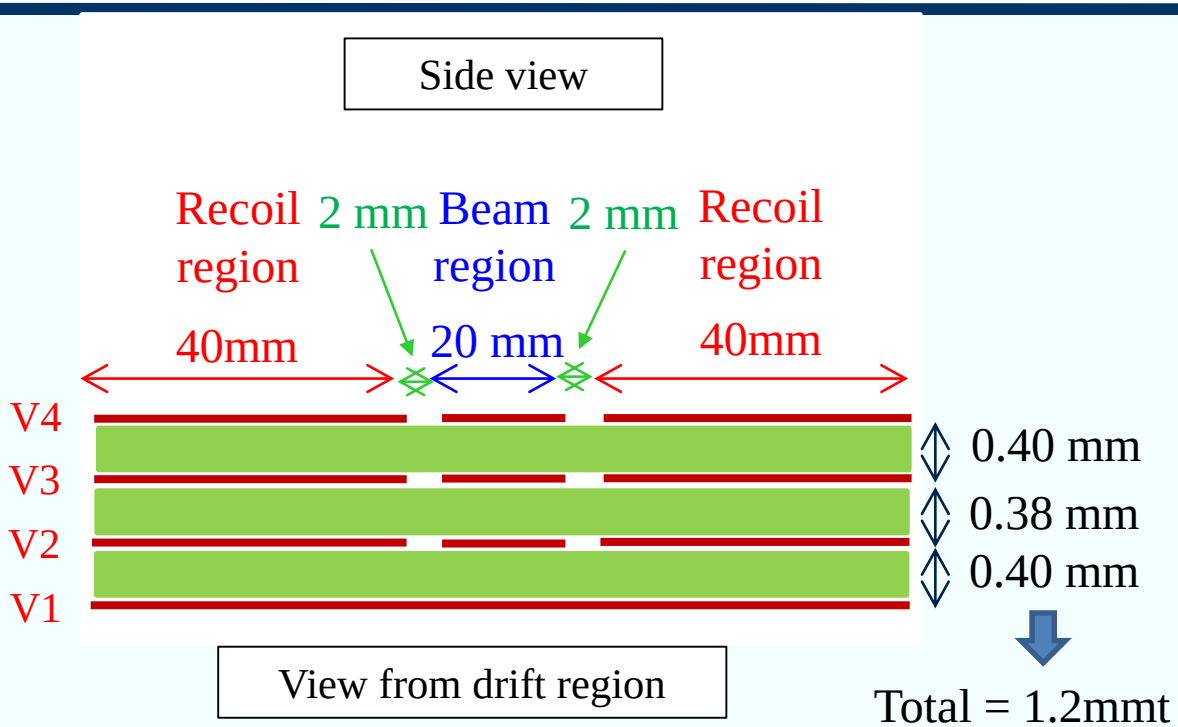
目的

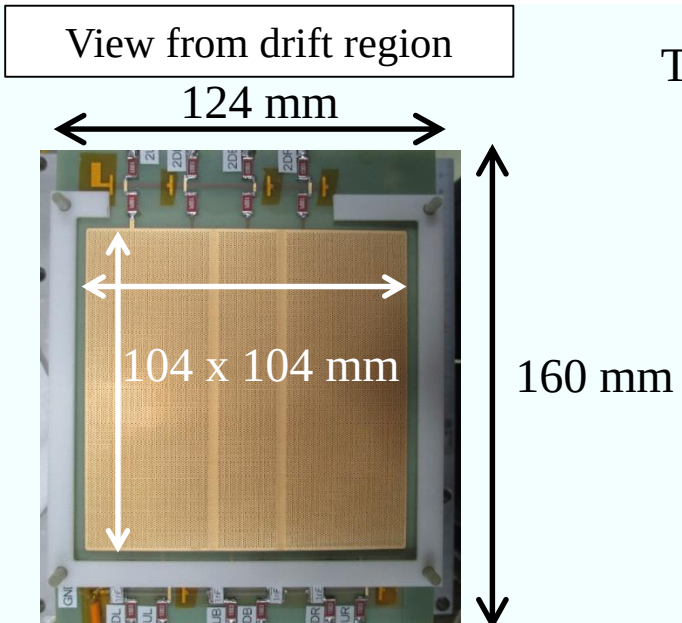
二重増幅率制御構造 + 多層構造のGEMを作成し性能を評価する

- **大強度重イオンビームに対する性能評価**
  - プロトタイプ(10cm x 10cm)を作ってテストした
    - Gain と Charge Resolution の要請を達成できるか？
    - Beam 強度を上げた時にも要請を維持できるか？

- **GEMの面積拡張に対する性能評価**
  - 30cm x 30cm GEMを実際に作成してテストする
    - (ラフな)たわみ測定
    - (ゲインの一様性測定 (in progress))

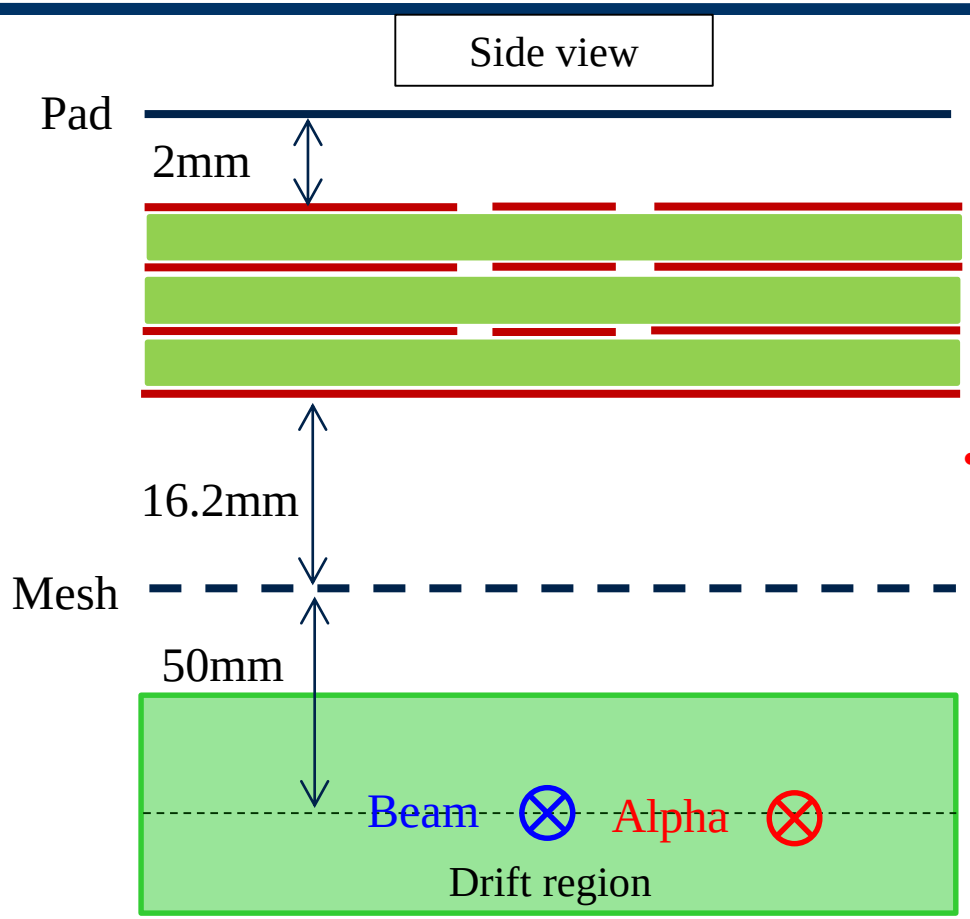
プロトタイプ二重増幅率制御型 THGEM





- 製作
  - 林栄精器(株)
- 材質
  - 基盤: FR4
  - 電極: Cu 0.33mm^t
- Hole size
  - Pitch
    - Z: 0.35 mm
    - X: 0.6062 mm
  - Diameter: 0.3 mm

プロトタイプ二重増幅率制御型 THGEM の性能評価



ΔV_B(for Beam) = $R_B \times \Delta V_{GEM}$

ΔV_M(for Beam) = $R_M \times \Delta V_{GEM}$

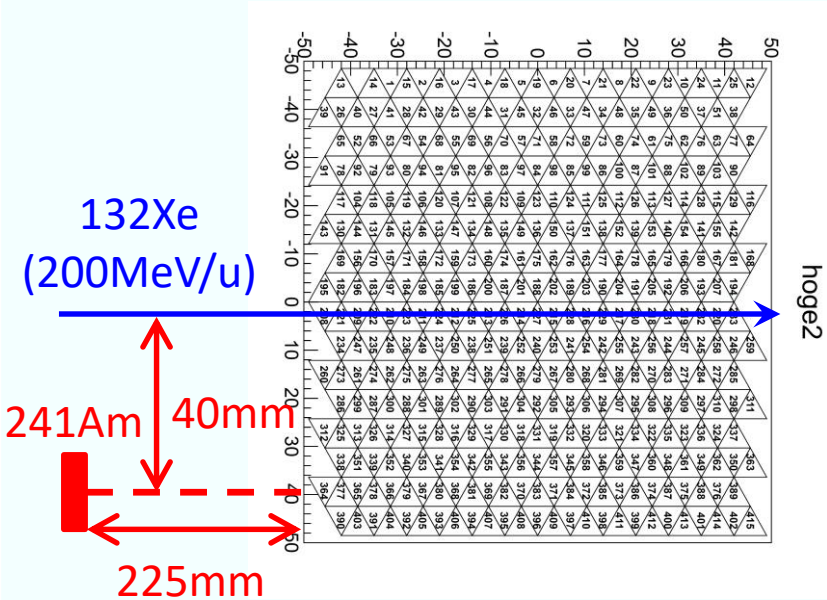
ΔV_T(for Beam) = $R_T \times \Delta V_{GEM}$

Total V is kept same.

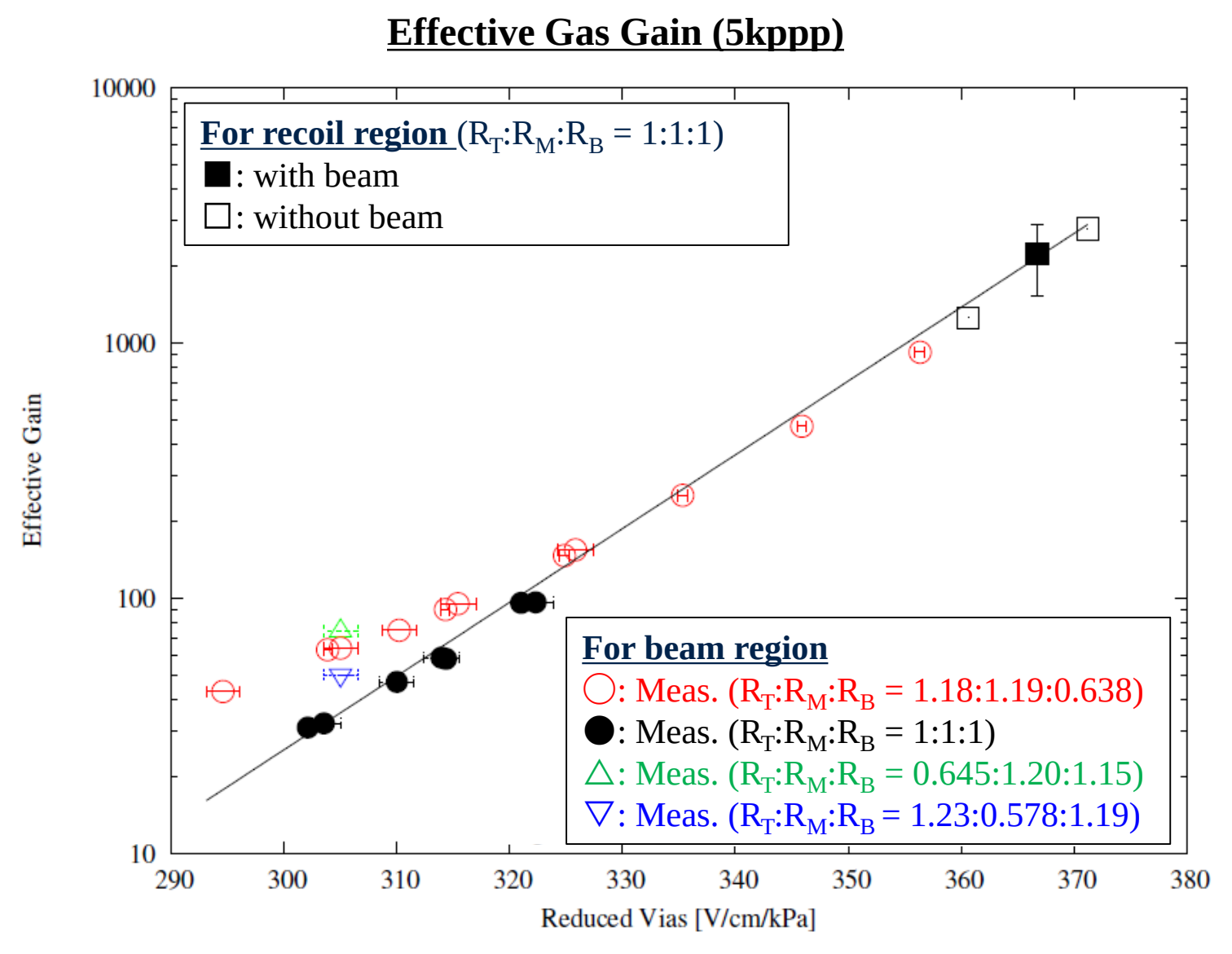
- Keep gain of about 2000 in the recoil region

PH2 Beam Line @ 放射線医学総合研究所 HIMAC

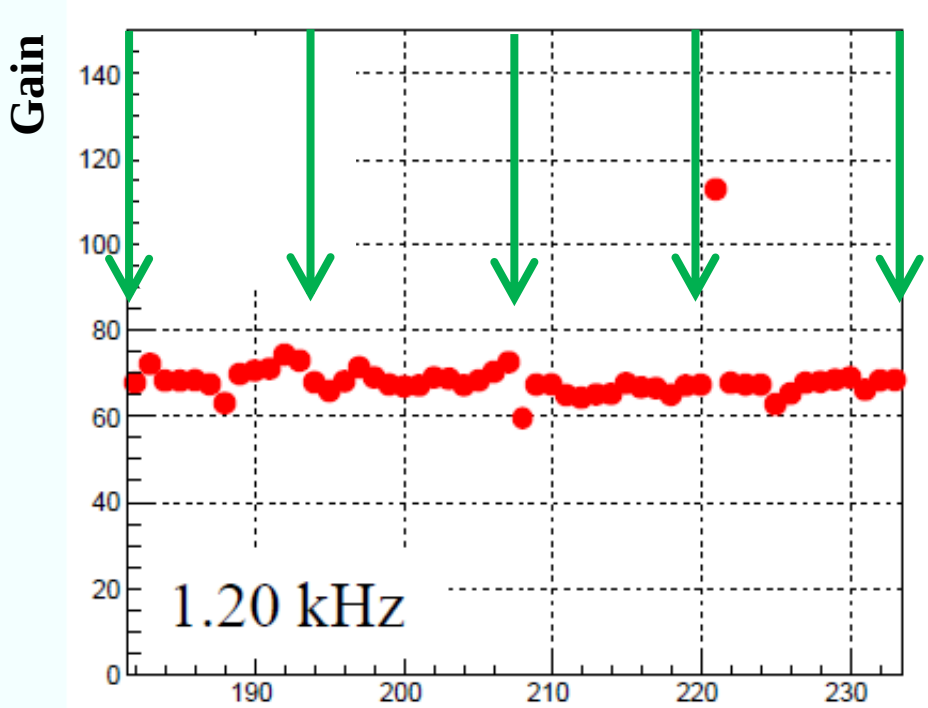
- Beam: 200MeV/u 132Xe, 5kppp or 1Mppp
  - Beam energy at entrance of CAT: ~185MeV
- Alpha 5.49 MeV from 241Am source
- Gas: H2 gas 40kPa

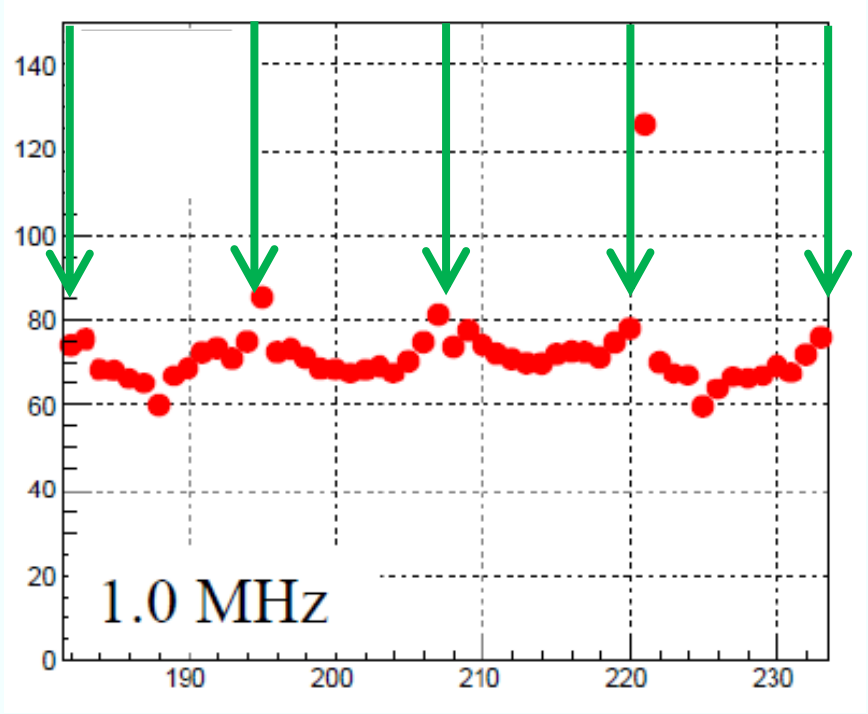


Gain Curve in the beam region with the low intensity beam

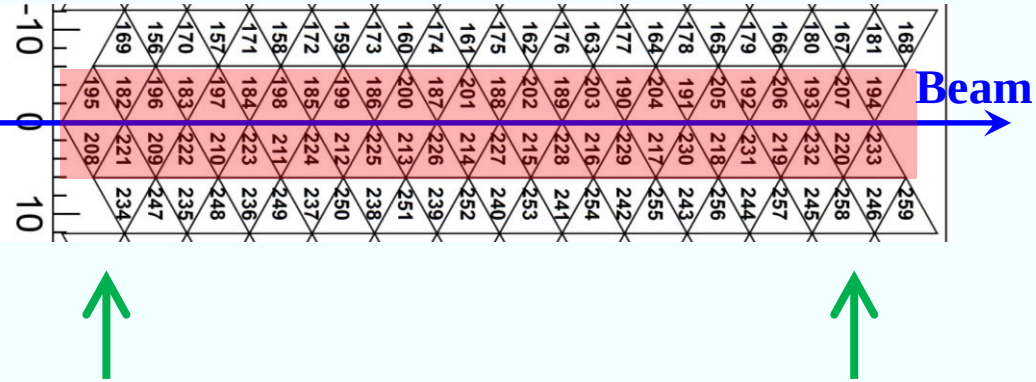


Gain with the high intensity beam



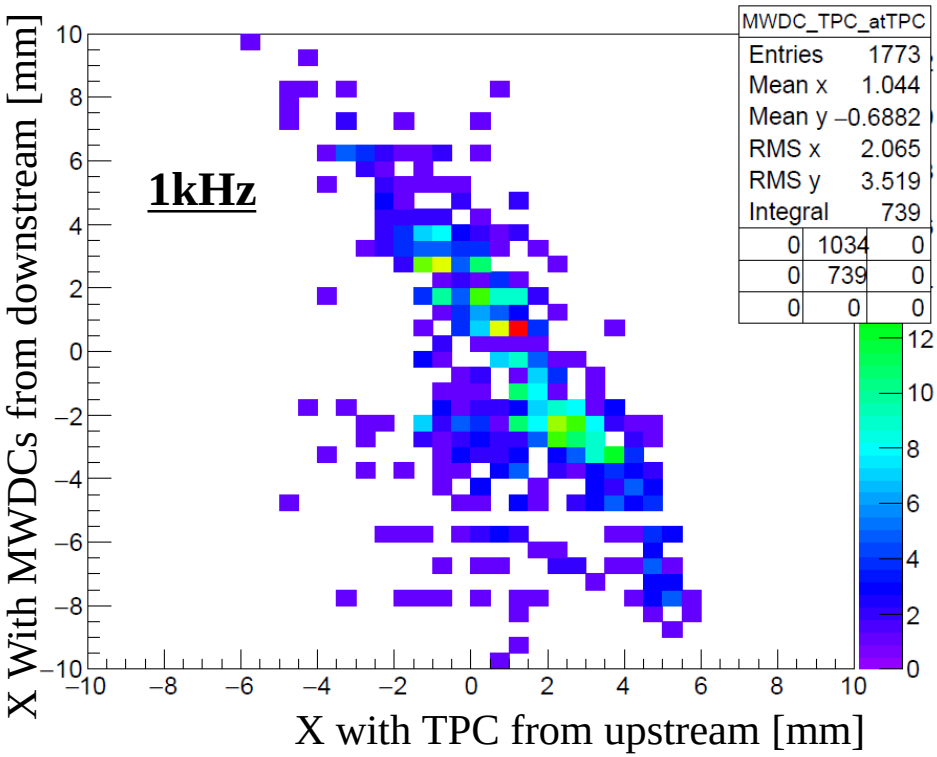


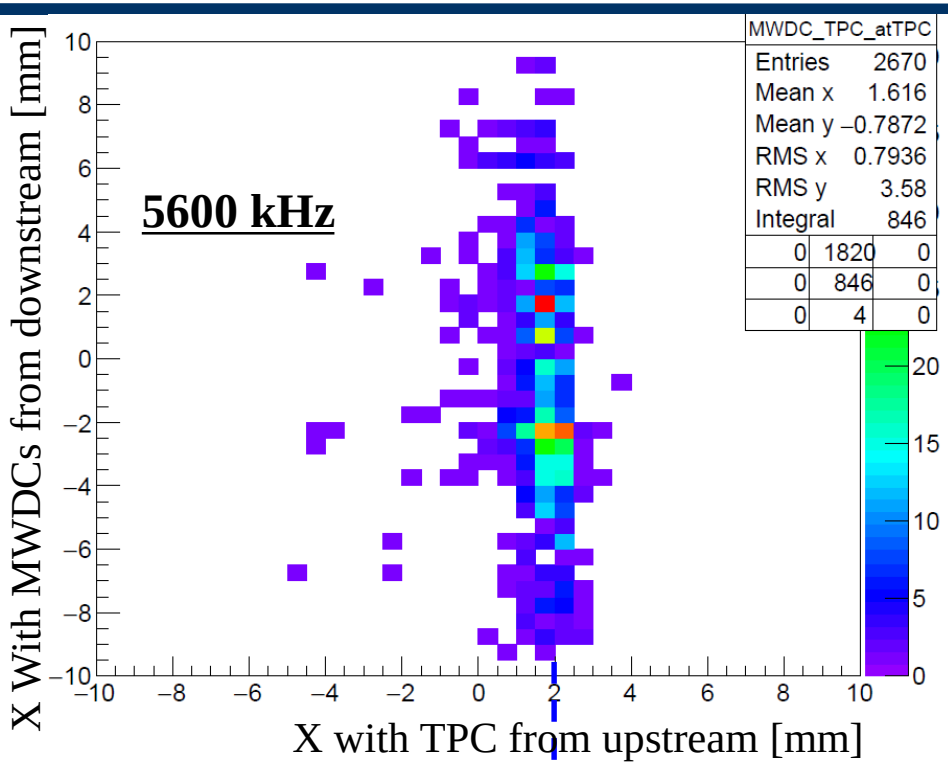
Pad ID of readout pad

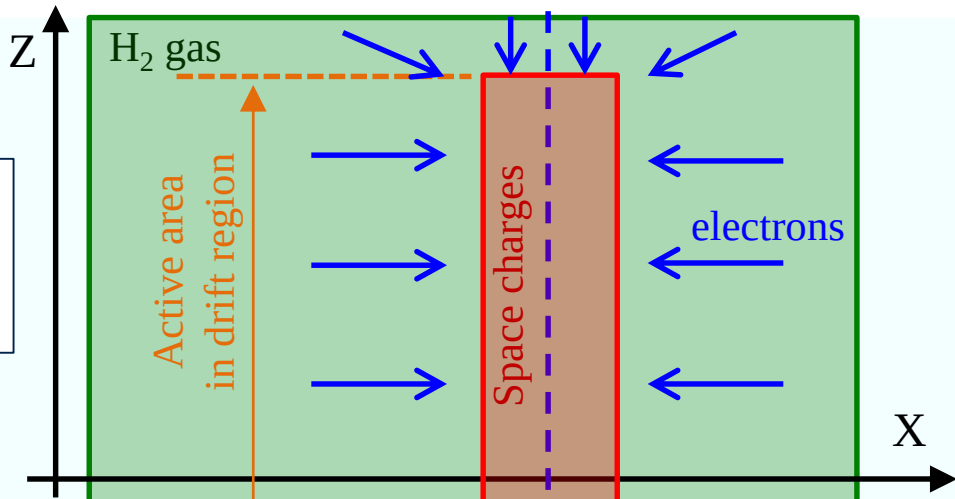


- Not so change from the low intensity beam around the center of the GEM
- ~15% larger than the low intensity beam, at around the edge of beam axis direction on the GEM

Convergence of X position because of ion backflow

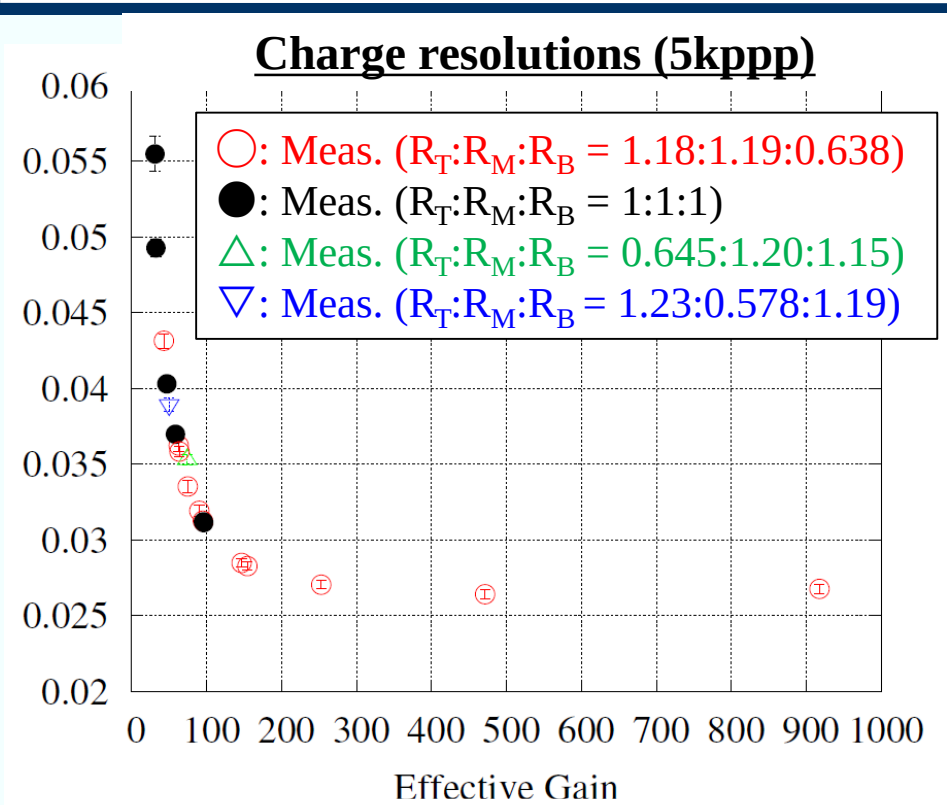


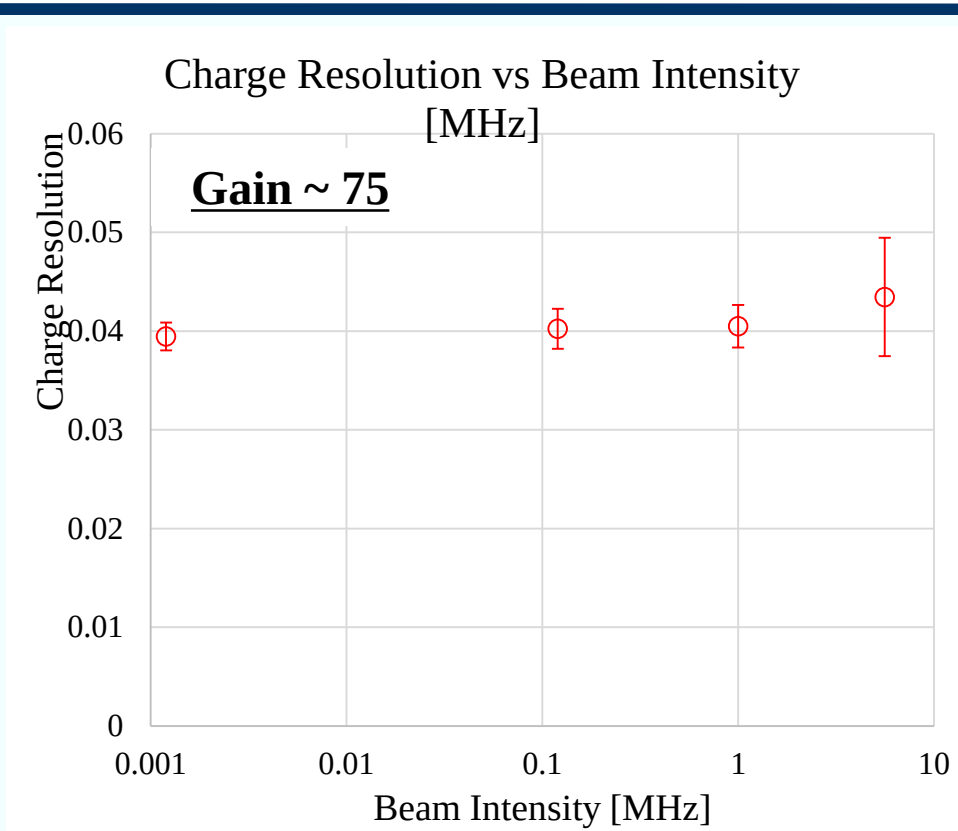


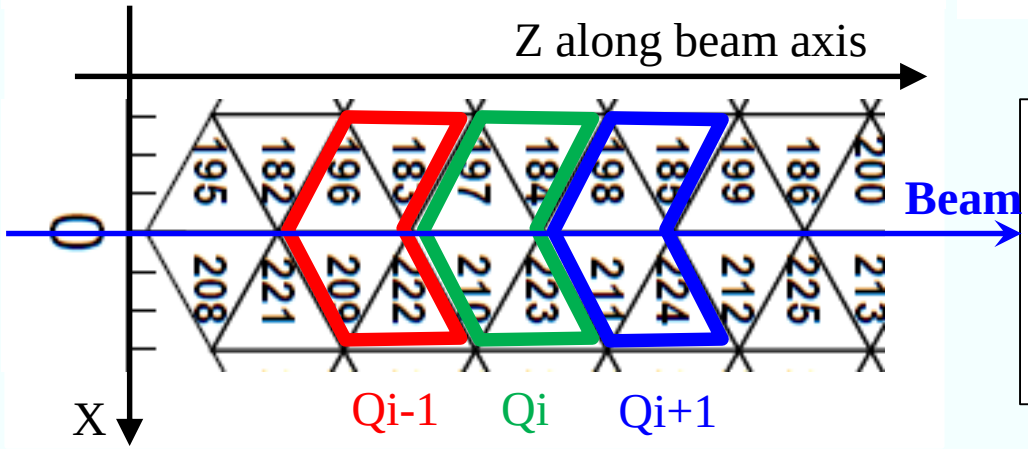


- **Space charges by ion backflow converge ionized electrons to beam axis.**
  → **Sigma of X with TPC become small.**

Charge Resolution in the beam region





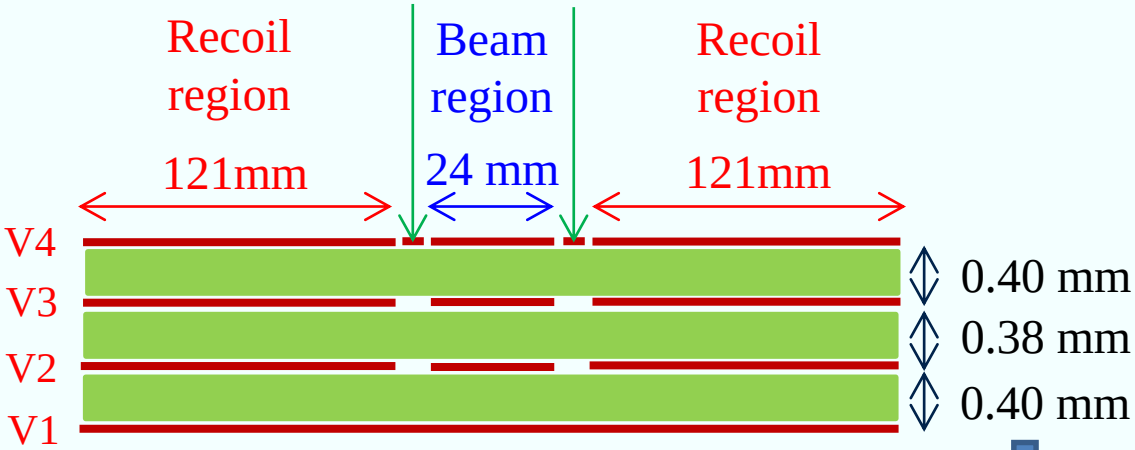


- Resolution of Q_i = sigma of dQ
  where, $dQ = Q_i - \frac{Q_{i-1}+Q_{i+1}}{2}$
- Deposit energy ~ 0.65 keV
  → # of electrons ~ 18000 個

Dual Gain Multi-Layer THGEM (DG M-THGEM) for CAT-M

製作: 林栄精器(株)

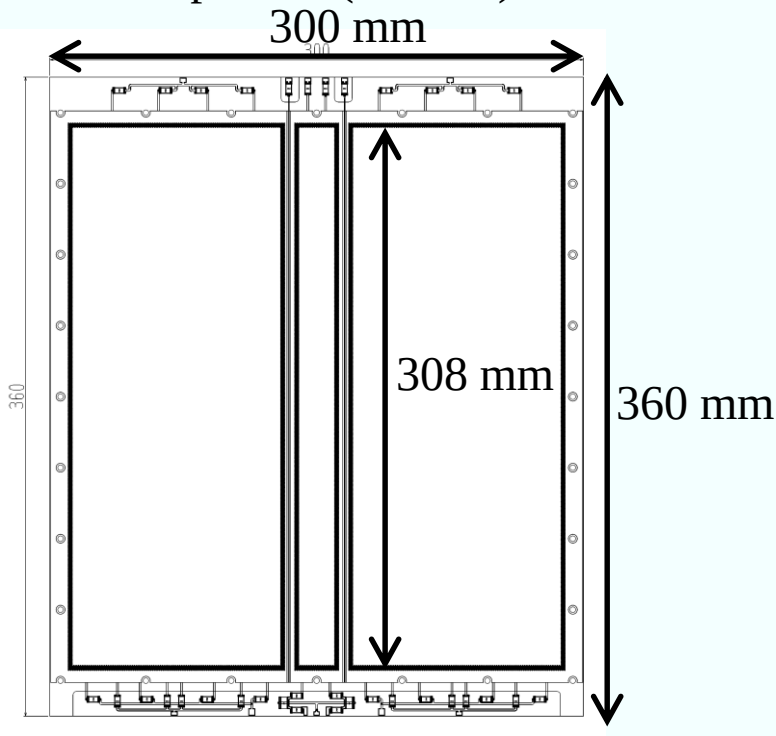
Buffer Region (6 mm)
and
Medium Electrode (0.4 mm on V4)



Drift region

Total = 1.2mmt

Top View (透視図)



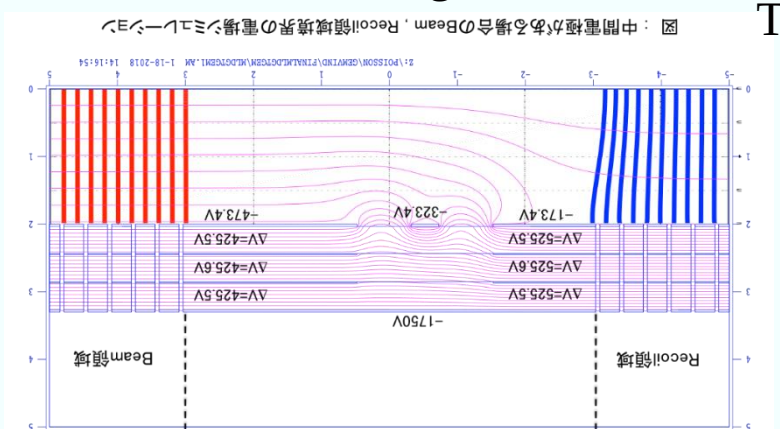
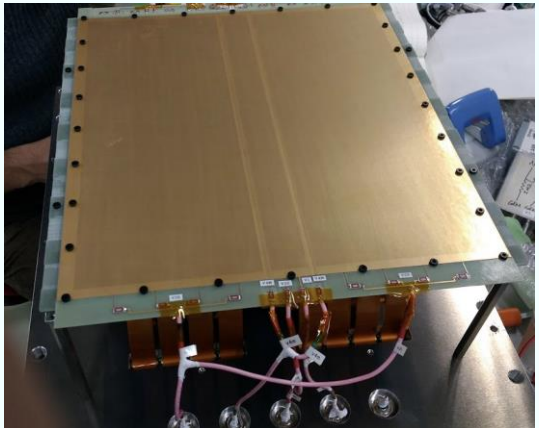
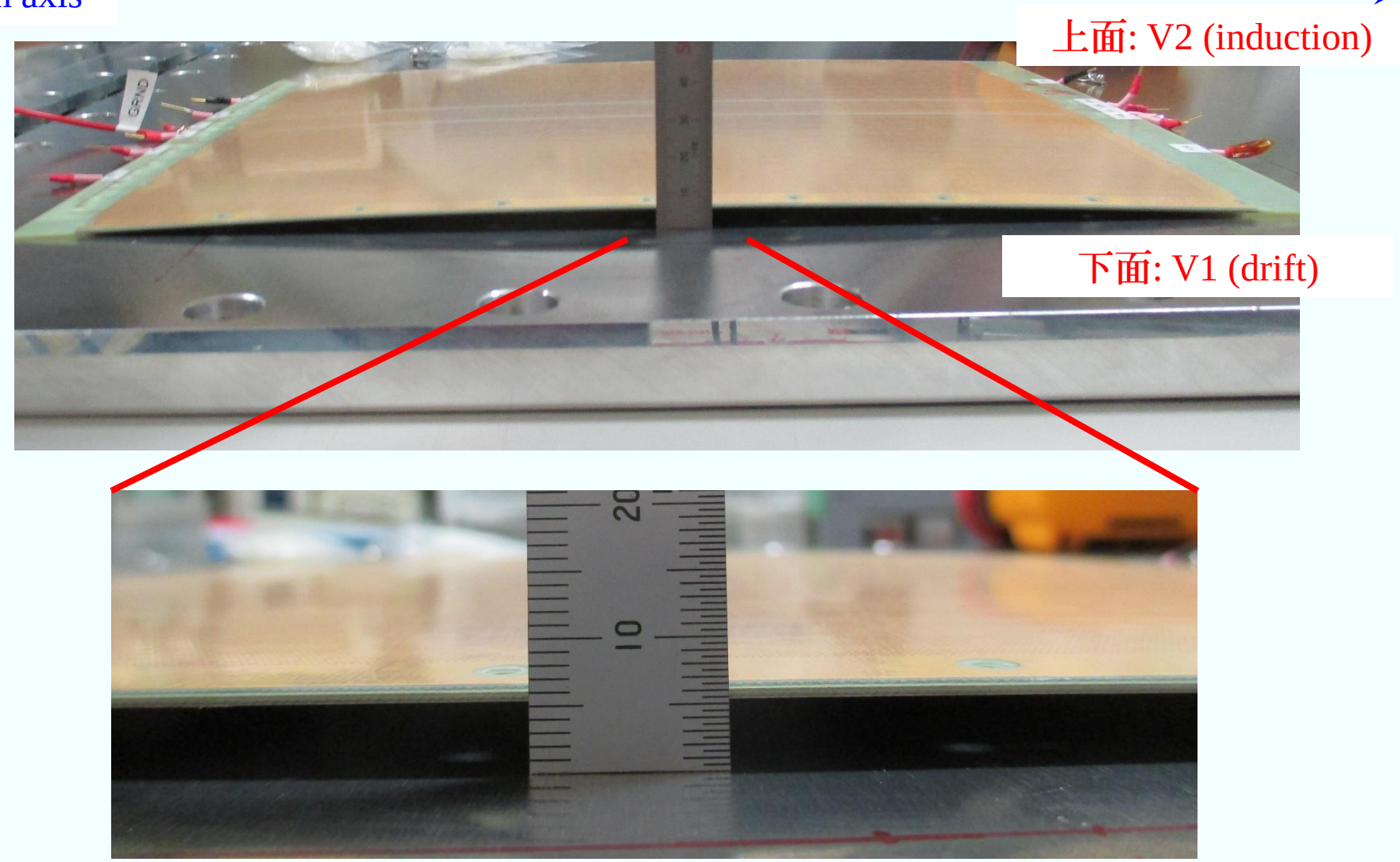


図 : 中間電極がある場合のBeam , Recoil領域境界の電場シミュレーション



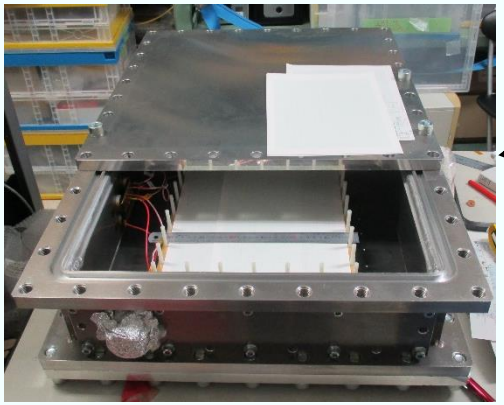
Bending of the GEM

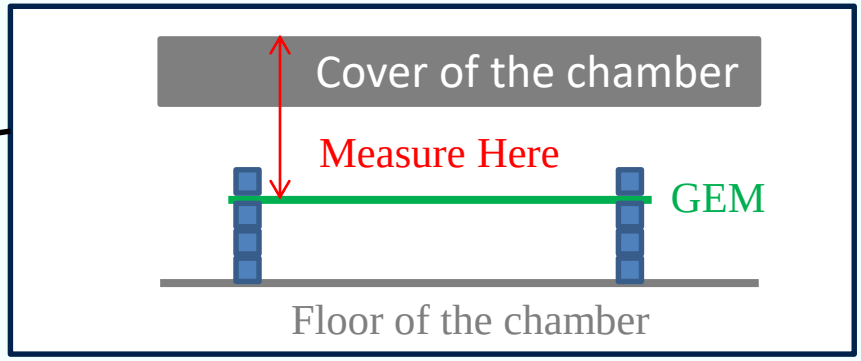
Beam axis

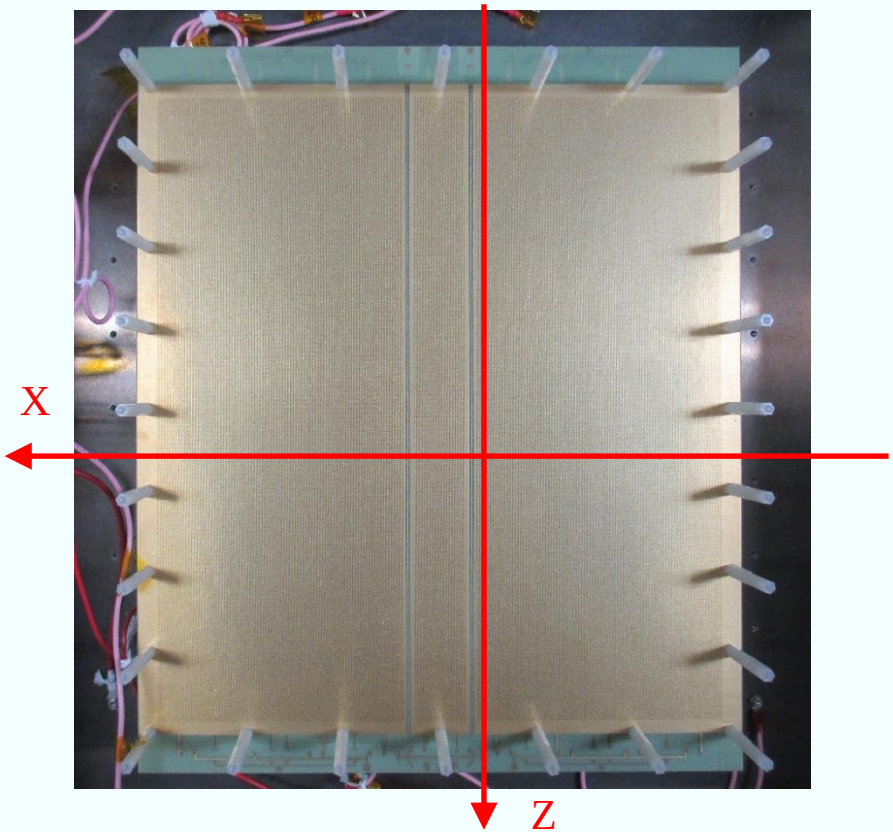


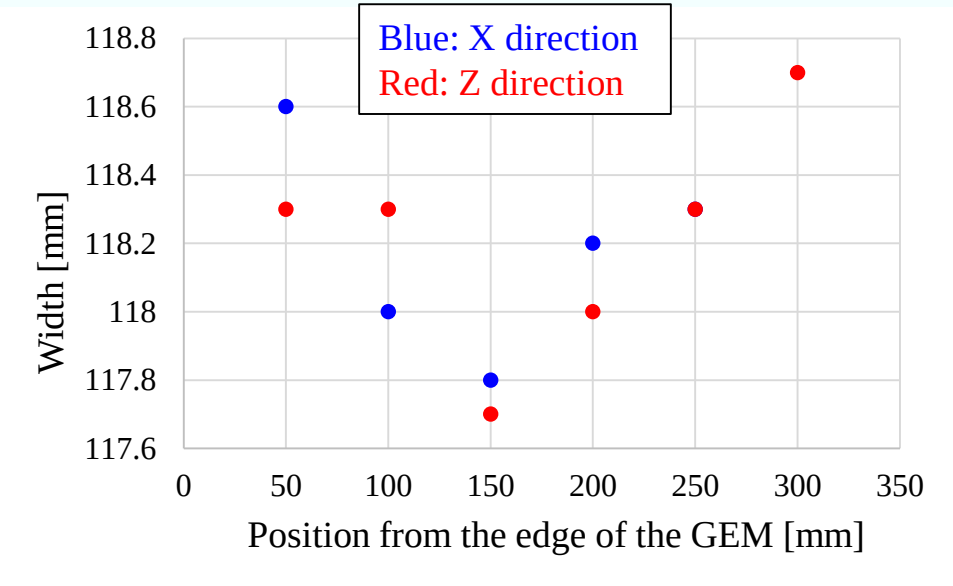
Maximum bending deflection is about 5 mm if the GEM is not mounted (convex upwards)

Bending of the mounted GEM









最大で1mm 程度induction region 側にたわむ
→ Gain 変化 ~ 20% @ induction ~ 2mm

Summary

- **Point of development of GEM for Active target "CAT"**
  - Heavy-ion high intensity beam of 1MHz
  - TPC Active region: 30cm x 30cm
- **Double Gain Multi-layer THGEM (DG M-THGEM) for CAT-M**
  - Dual Gain control system: operating deferent gain for each region independently
  - Multi-layer THGEM: stack of several THGEM
- **Performance of DG M-THGEM with a high intensity beam of 132Xe 200MeV/u**
  - Can we achieve previous performance for the beam region?

    → **OK.**

    ✓ Gain < 100

    ✓ Charge Resolution < 6%
  - Can we correctly perform track reconstruction with the high intensity beam?

    → **X position converge to beam axis and charge resolution become wrong above 100kHz**

    ☐ Need to reduce ion-backflow
- **Bending deflection of Large DG M-THGEM**
  - How about the bending deflection ?

    → Maximum bending deflection is about 1mm

    ☐ Check gain uniformity of Large DG M-THGEM : in progress