Development of large GEM trackers

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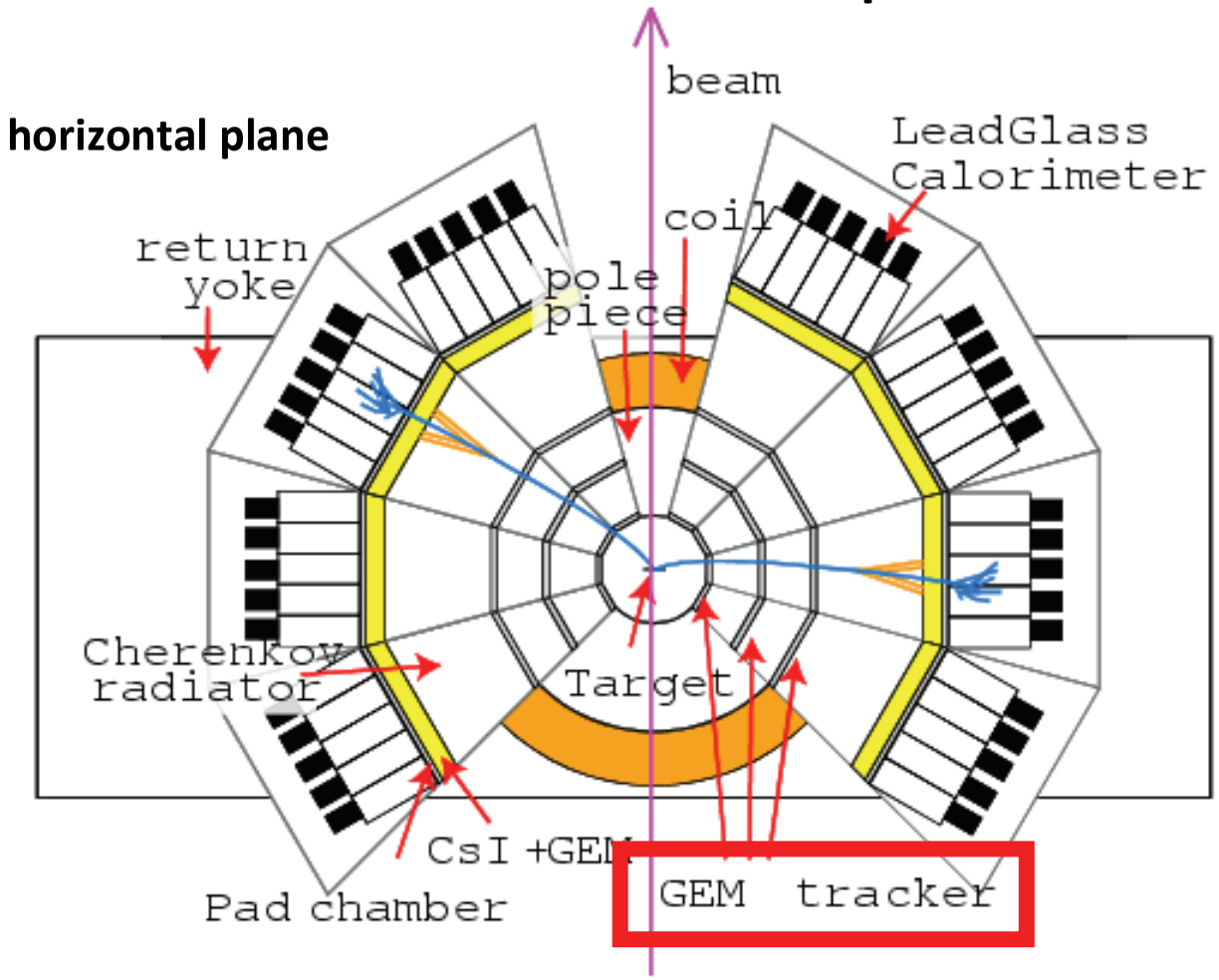
for J-PARC E16 collaboration

Outline

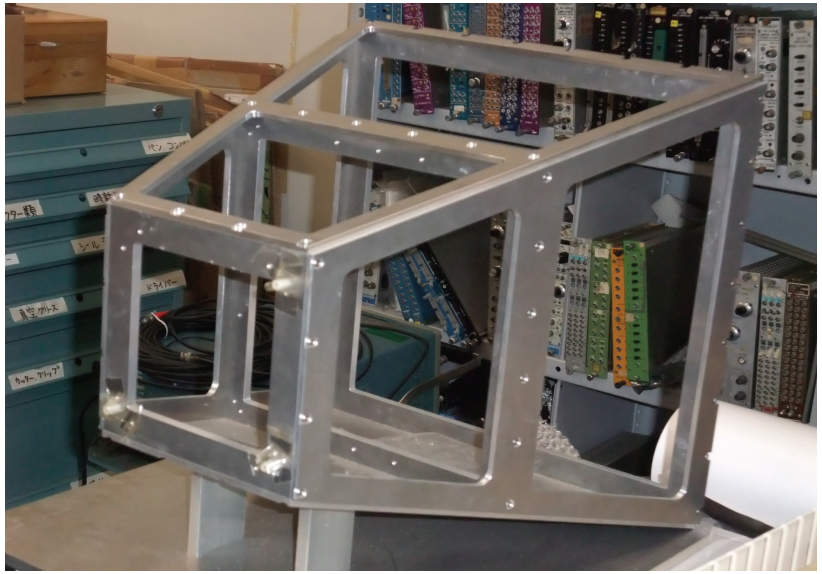
- GEM tracker for J-PARC E16 experiment
- Requirements
- Development of GEM
- Gain test
- Position resolution test
- Summary & Outlook

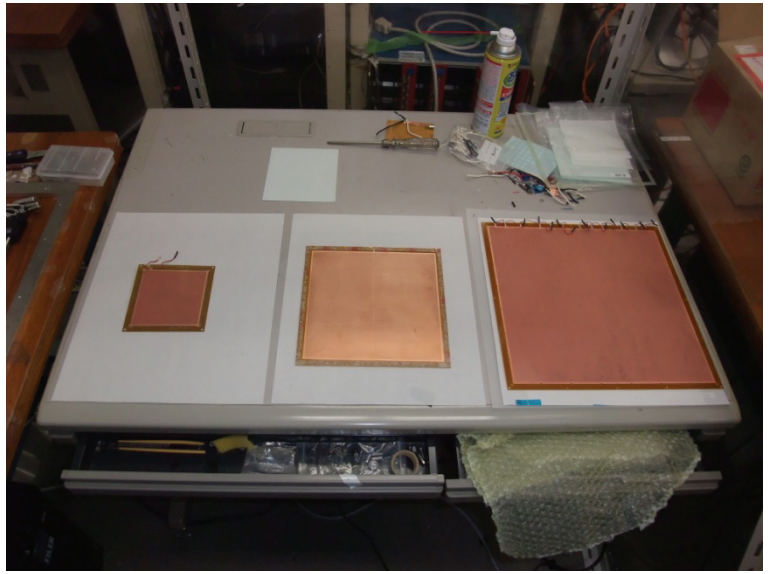
GEM tracker
for J-PARC E16 experiment



Measure 3 points of a track in magnetic field and reconstruct the momentum of charged particles.

GEM tracker





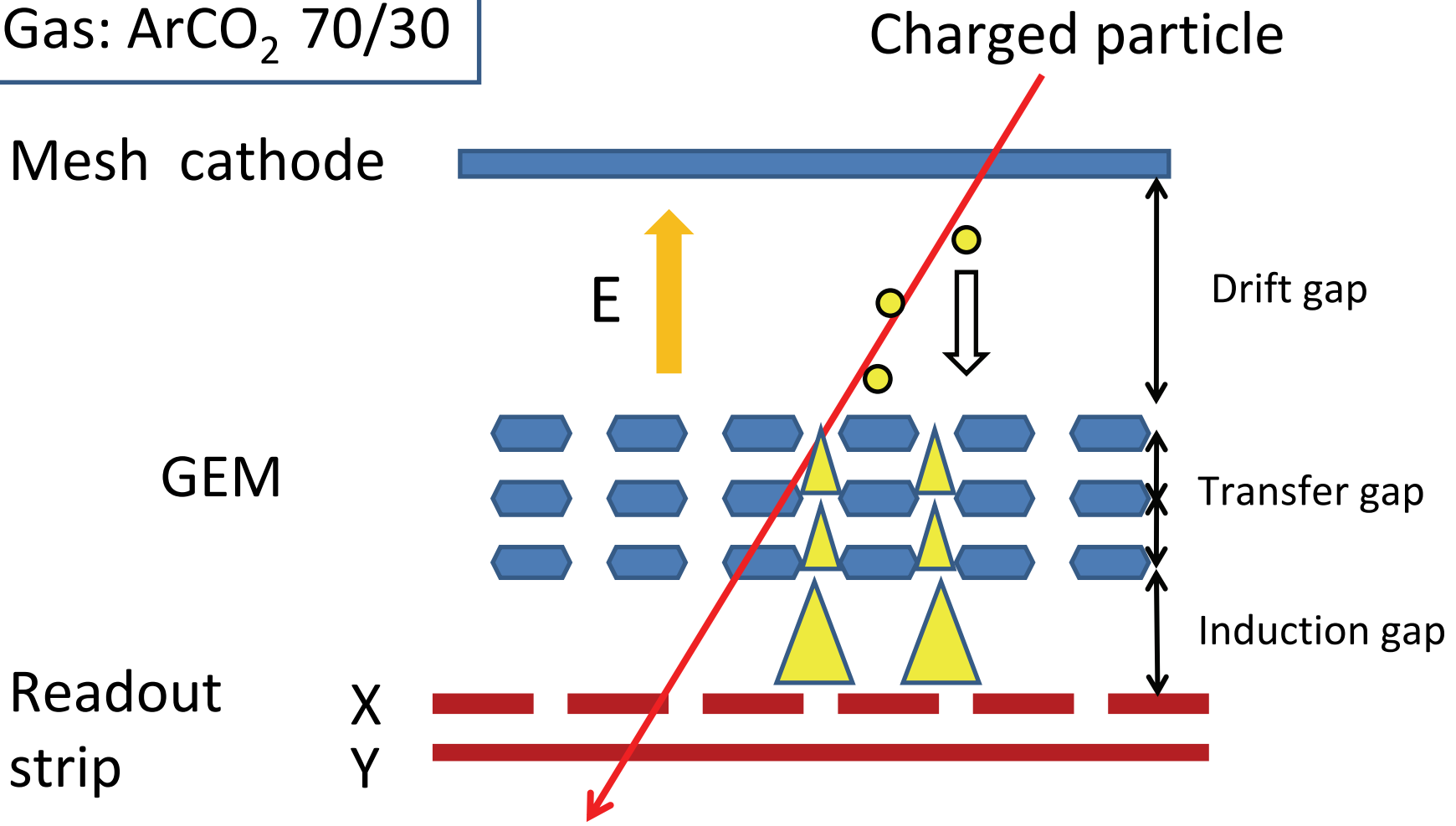
・GEM trackers are placed at 20, 40 and 60 cm away from the center of target.

・Sizes of GEM trackers are 10×10 cm^2 , 20×20 cm^2 and 30×30 cm^2.

・Hit position is detected by 2-D strips.
(top side:X strips, bottom side:Y strips)

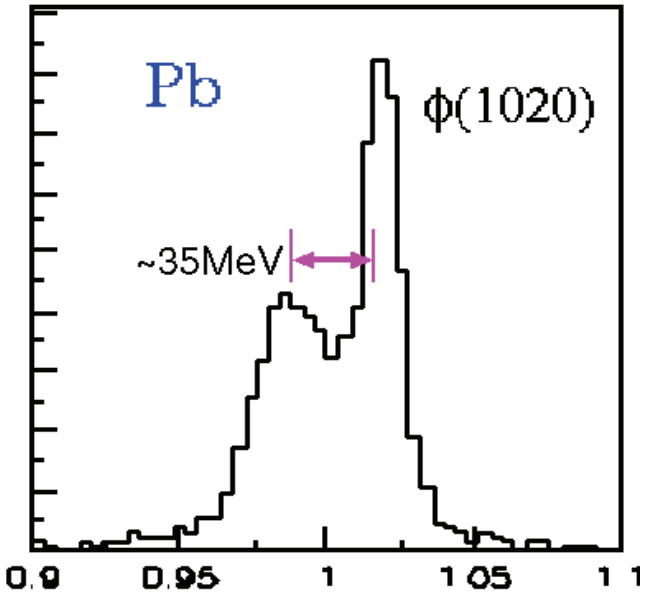
GEM Tracker

Gas: $ArCO_2$ 70/30



Requirements

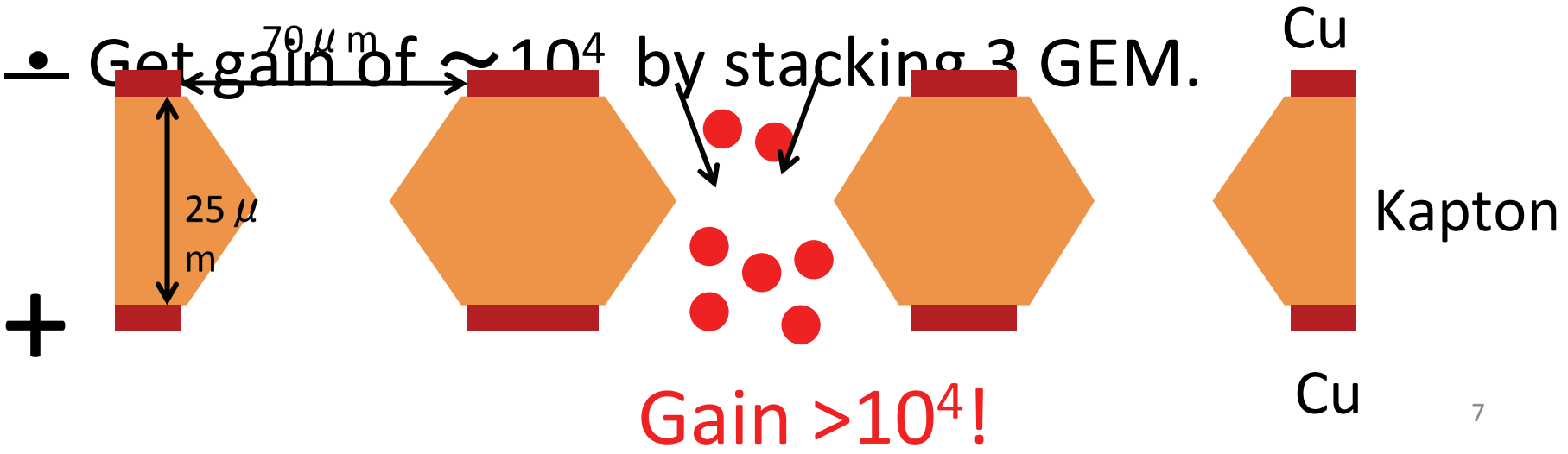
- Tolerability for high rate environment. (~5kHz/mm^2)
  GEM worked under 25 kHz/mm^2 in CERN COMPASS experiment.
- Gain of >10^4
  To achieve good S/N ratio and efficiency.
- Position resolution of 100 μ m in horizontal plane.
  To achieve mass resolution of 5 MeV/c^2 and observe mass shift clearly.



σ_M=5MeV, $\beta\gamma$<0.5
simulation result

Development of GEM

- 4 μ m Cu is coated on both sides of 50 μ m insulator.
- Holes of ϕ 70 μ m are made with 140 μ m pitch.
  Electron avalanche is caused by adding 370～400 V between Cu electrodes.
- Get gain of ～10^4 by stacking 3 GEM.



Development of large GEM

- Large size of holes and flabbiness are the problems in development of 30×30 cm^2 GEM.

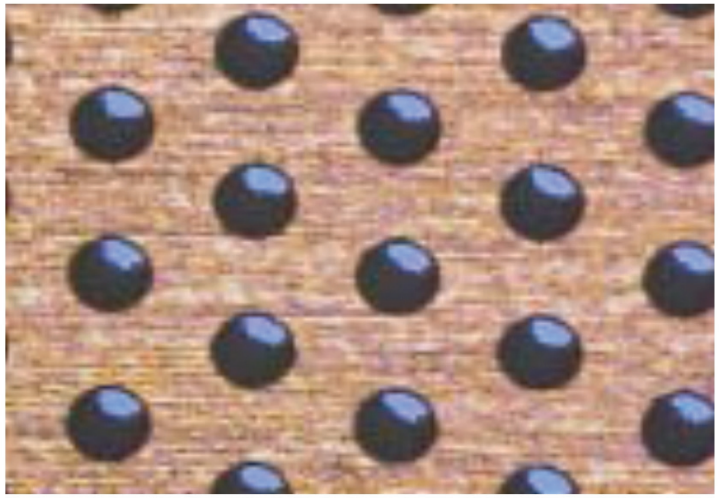
- Large size of holes
  Large size of holes is due to a miss alignment between top and bottom masks which is used in etching of Cu holes. Alignment of masks was difficult for large GEM.

- Flabbiness
  A gap between two GEM foils becomes too small due to their flabbiness.

  Extension of hole size and gap between GEM lead to lower gain.

Alignment of GEM masks

- The shape of holes became like cat's-eye due to miss alignment of masks.
- As a result, hole size became larger and gain decreased.



Cat's -eye shape of holes

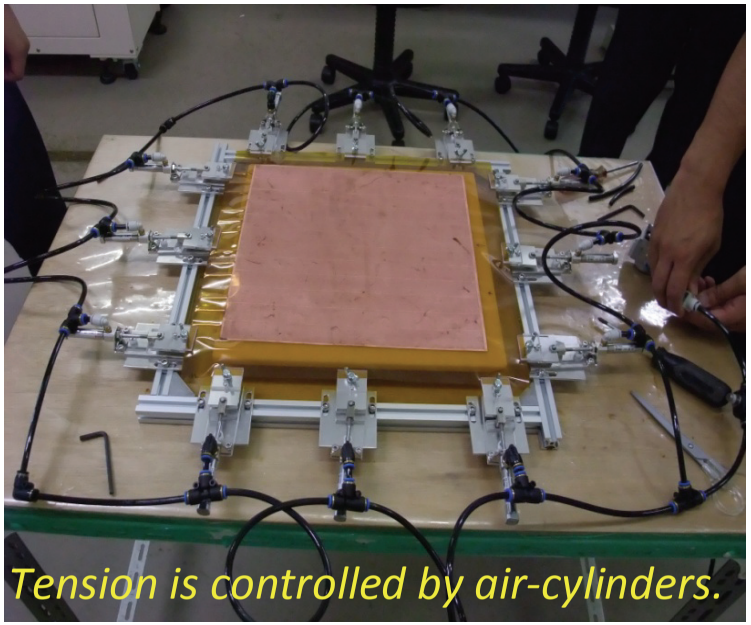
Improvement of masks!

	Cu [μ m]	PI [μ m]
before	84	55
after	77	51

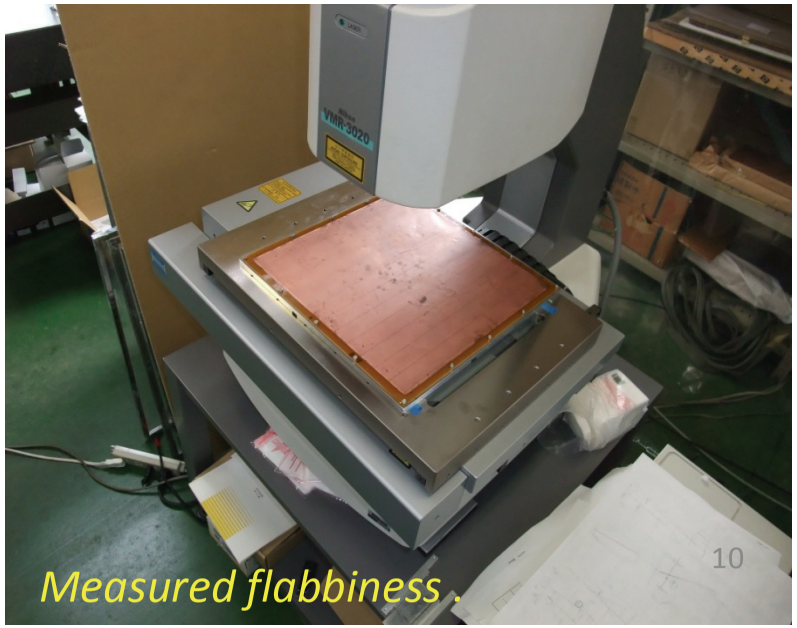
Success to suppress the hole size!

Flabbiness of GEM

- When GEM foils are stacked for the operation, a gap between GEM foils can become small due to its flabbiness. Such small gap can cause a discharge.
- Operation voltage becomes higher when make the gap longer to avoid short.
- A special jig is developed to add tension to GEM when the foil is glued to a frame.



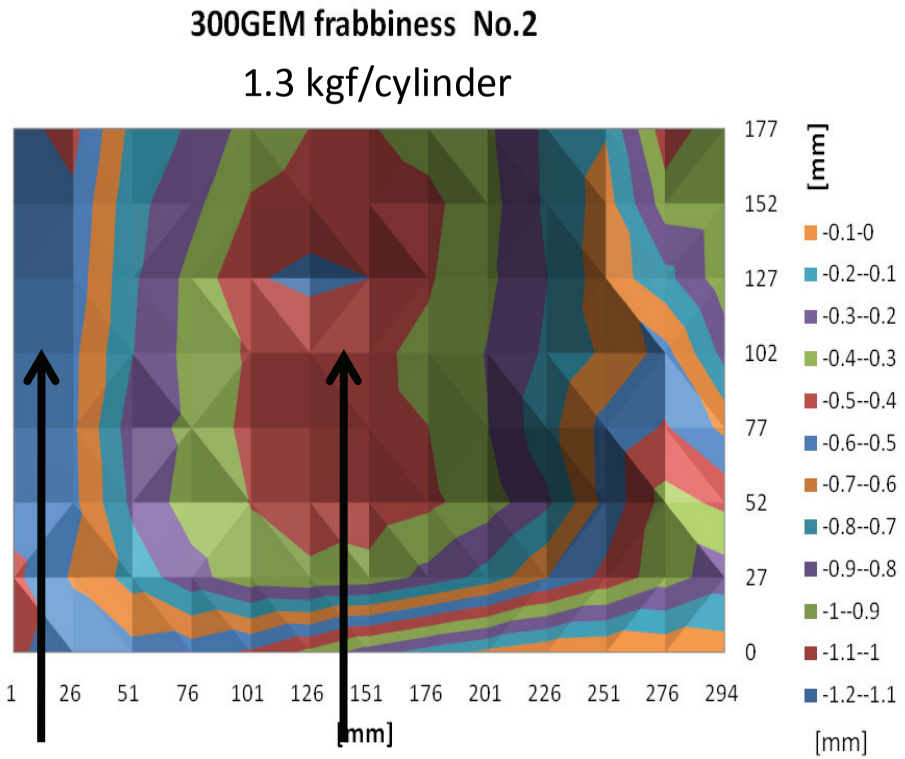
Tension is controlled by air-cylinders.



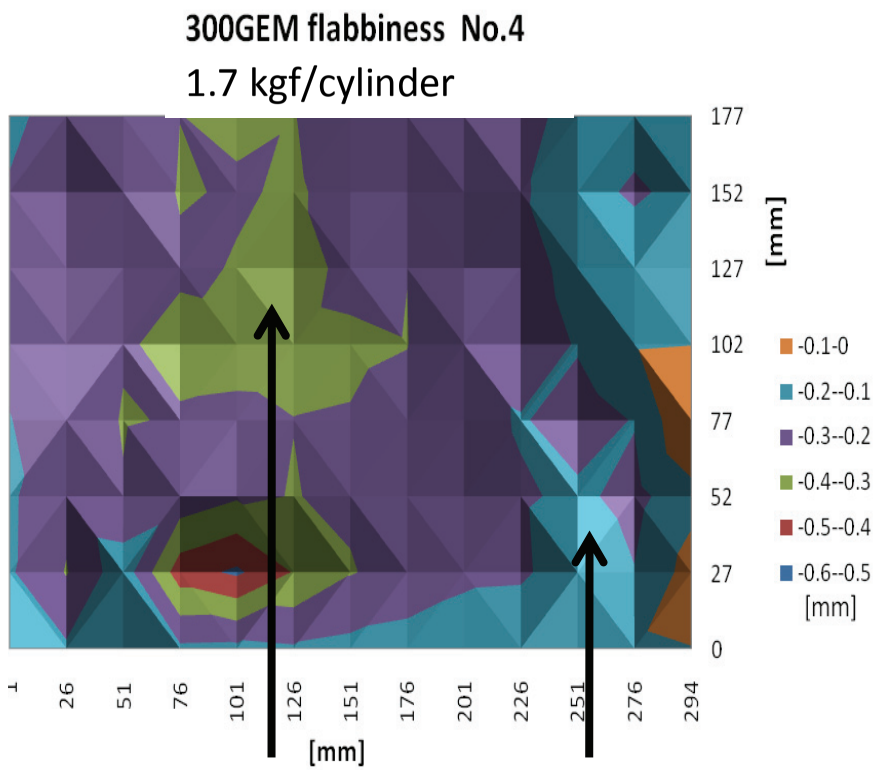
Measured flabbiness .

solution to flabbiness

Flabbiness of 30 × 30 cm^2 GEM pulled with 1.3 kgf/cylinder and 1.7 kgf/cylinder



~500 μ m

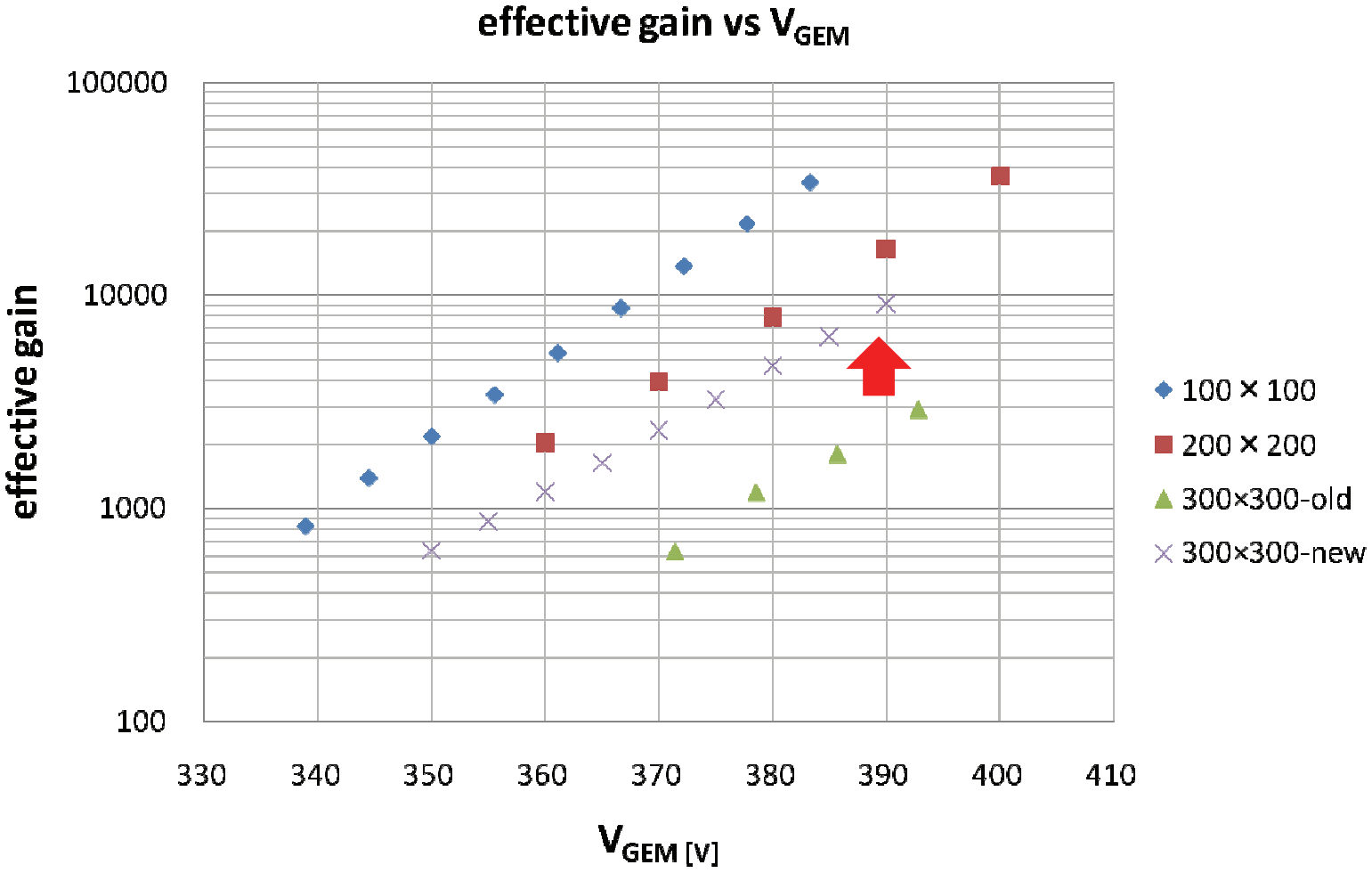


~200 μ m

Achieved uniformity of 200 μ m with 1.7kgf /cylinder.

Gain measurement

- Measured gain of each size GEM with Fe^{55} 5.9 keV X-ray.



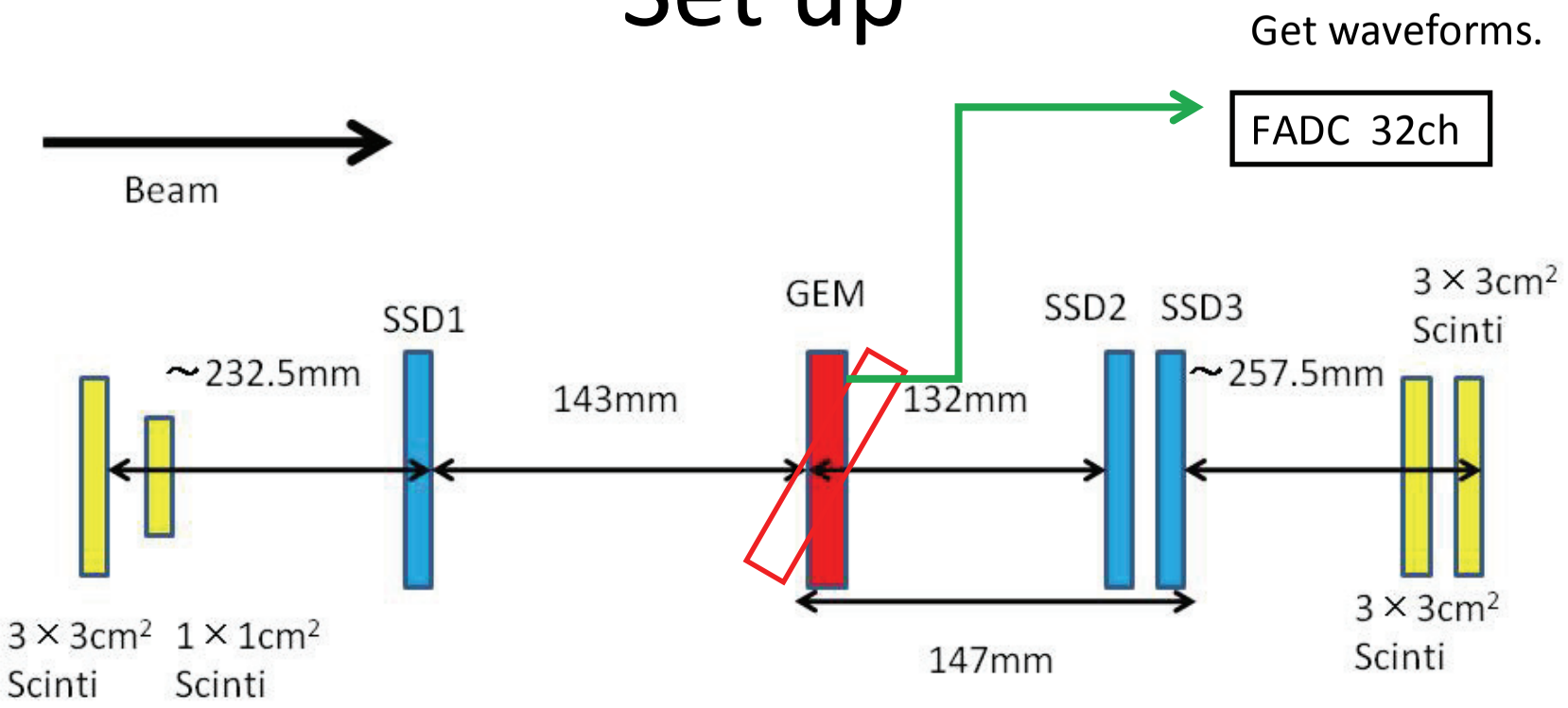
Gain of ~10000 is achieved by improvements of hole size and flabbiness.

Beam test of GEM tracker

- Evaluate the position resolution of GEM tracker at GeV-γ beam line of Tohoku Univ.
- Positron beam, which has a momentum of 750 MeV/c.
- Detector gas is $ArCO_2$ 70/30.
- $10 \times 10 cm^2$ GEM with 350 μm pitch read out.
- $20 \times 20 cm^2$ and $30 \times 30 cm^2$ GEM with 700 μm pitch readout.

Position resolution and efficiency are evaluated.

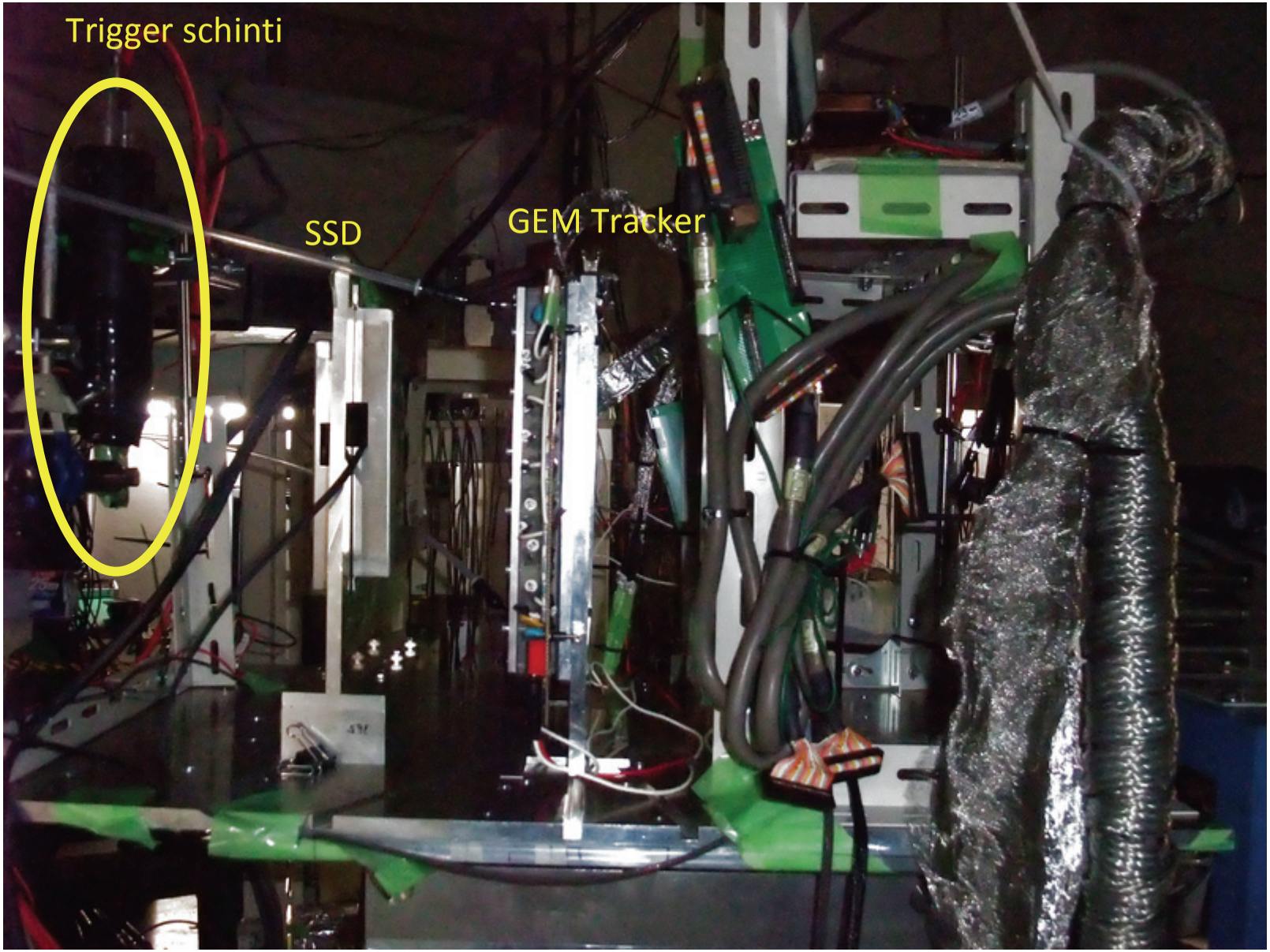
Set up



・The reference hit position at GEM tracker is obtained by interpolating the hit positions of Silicon Strip Detector (SSD) 1 & 2.

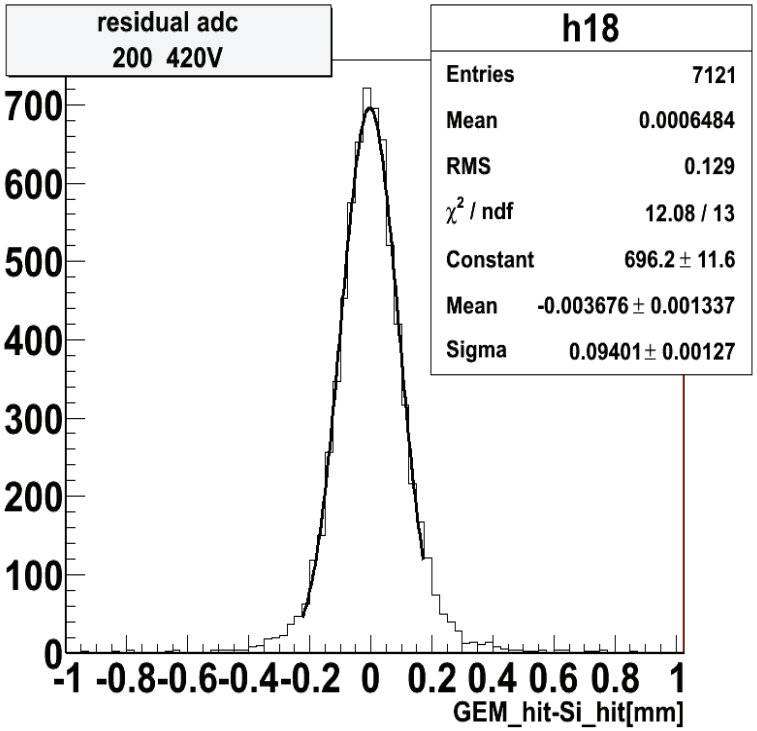
・Position resolution is evaluated as the difference between the hit position by GEM tracker and the reference hit position.

・Angle between GEM tracker and beam is changed to 0°, 15° and 30°.


Trigger schinti
SSD
GEM Tracker

Position resolution with large GEM (0° beam)

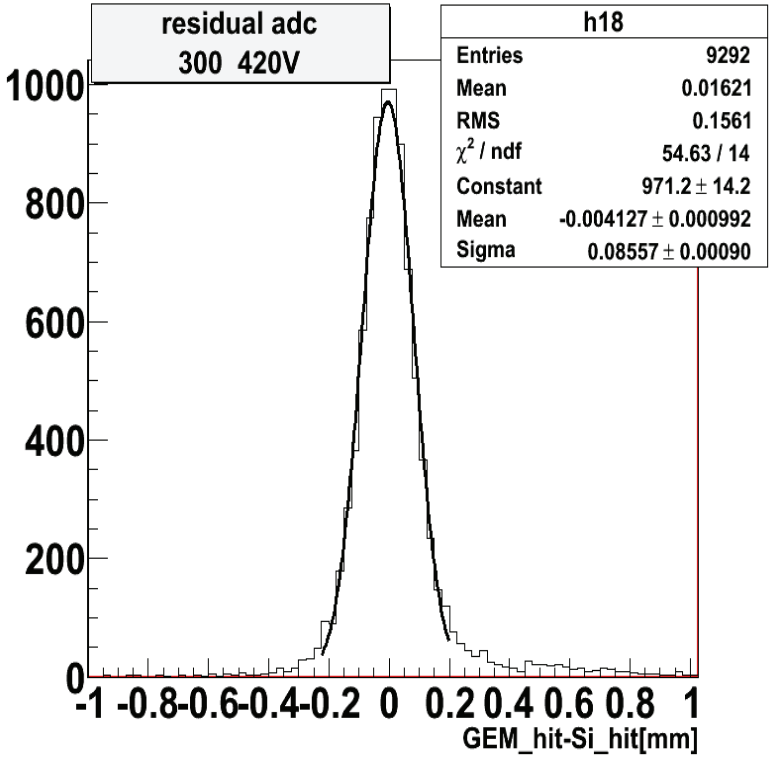
$20 \times 20 cm^2$ GEM



Residual σ 94 μ m

Efficiency 96%

$30 \times 30 cm^2$ GEM

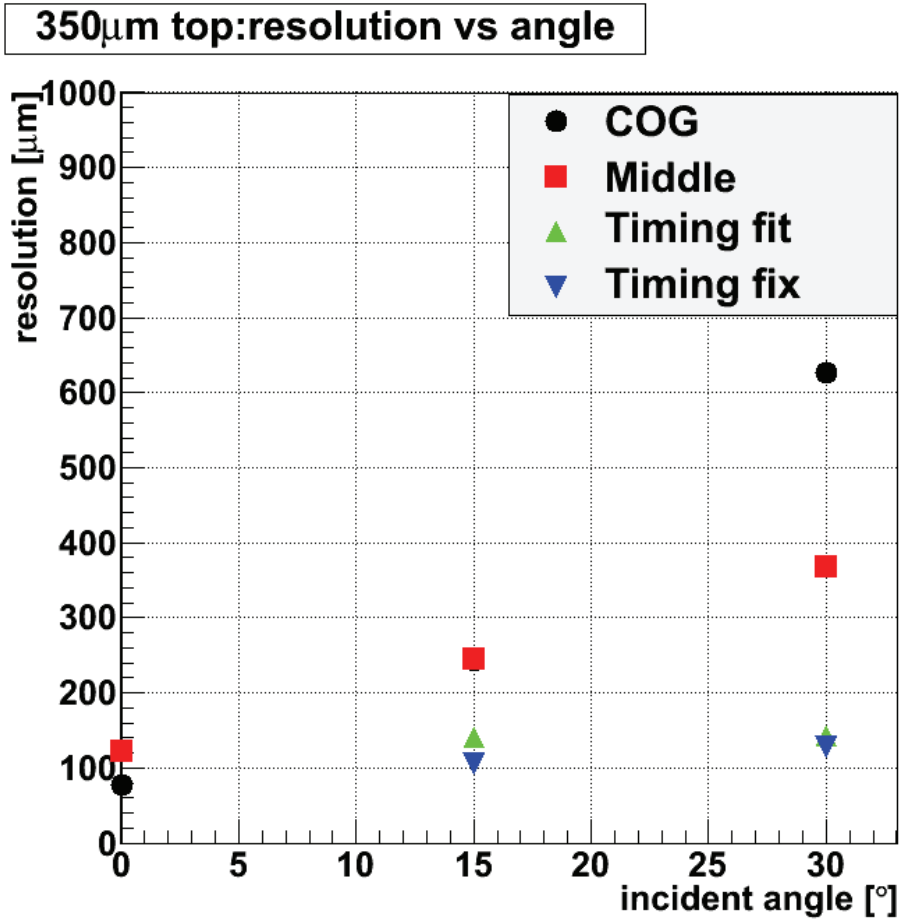


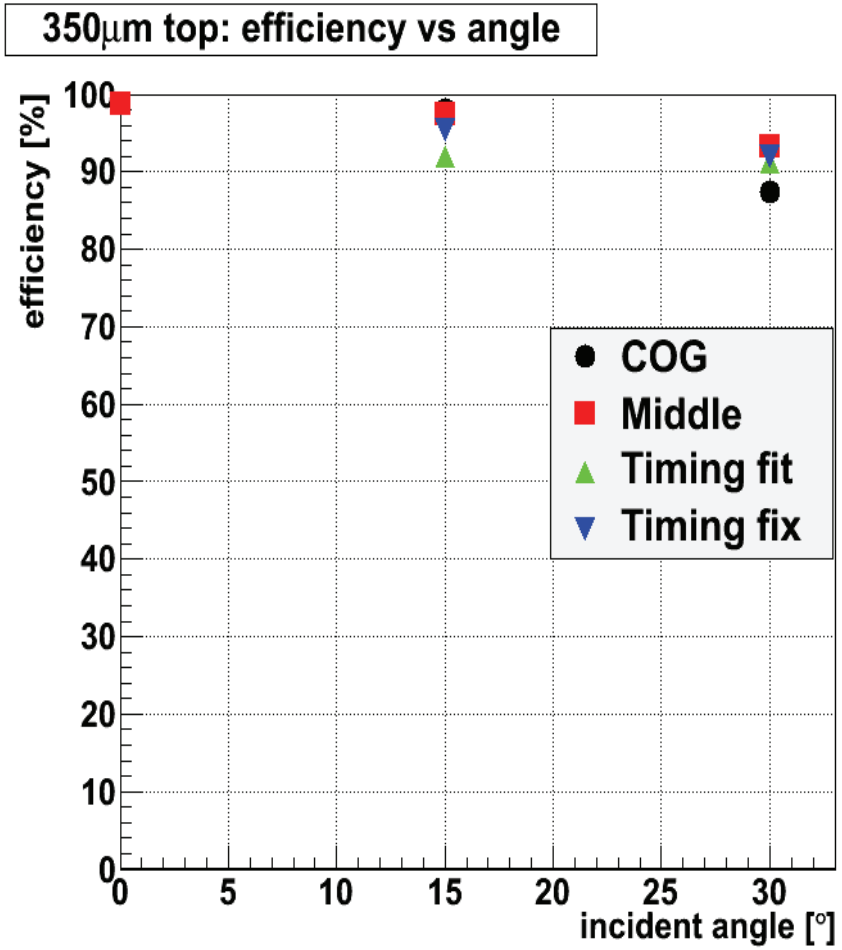
Residual σ 86 μ m

Efficiency 95%

Position resolution of 100 μ m is achieved with large GEM!

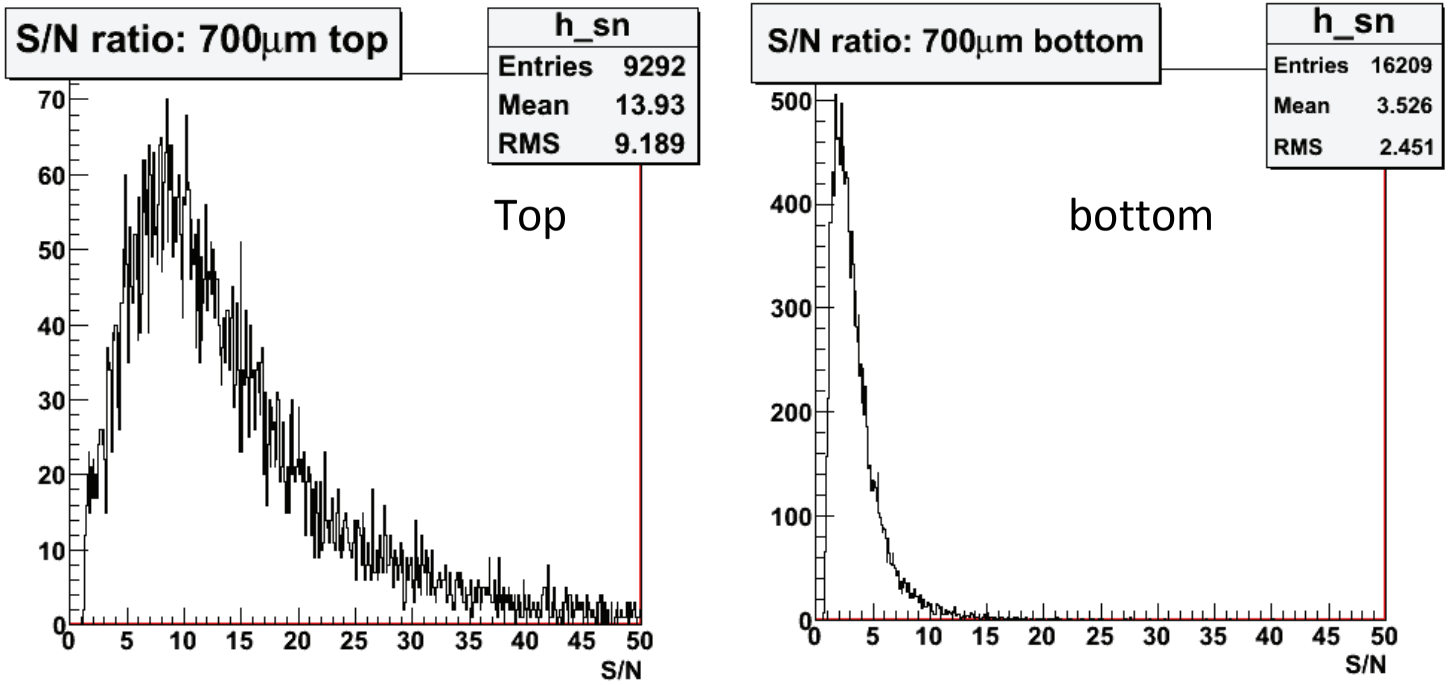
350 μ m strip pitch (drift gap 6mm, horizontal)





Position resolution ~100 μ m and efficiency 95% up to 15° inclined beam.

Bottom side S/N



・S/N ratio of the bottom side is about 1/3 of the top side and efficiency is bad.

(Top:95%　　Bottom:87%)

New readouts are now developed for higher pulse height of the bottom side. (carbon coating, thinner polyimide and through holes)

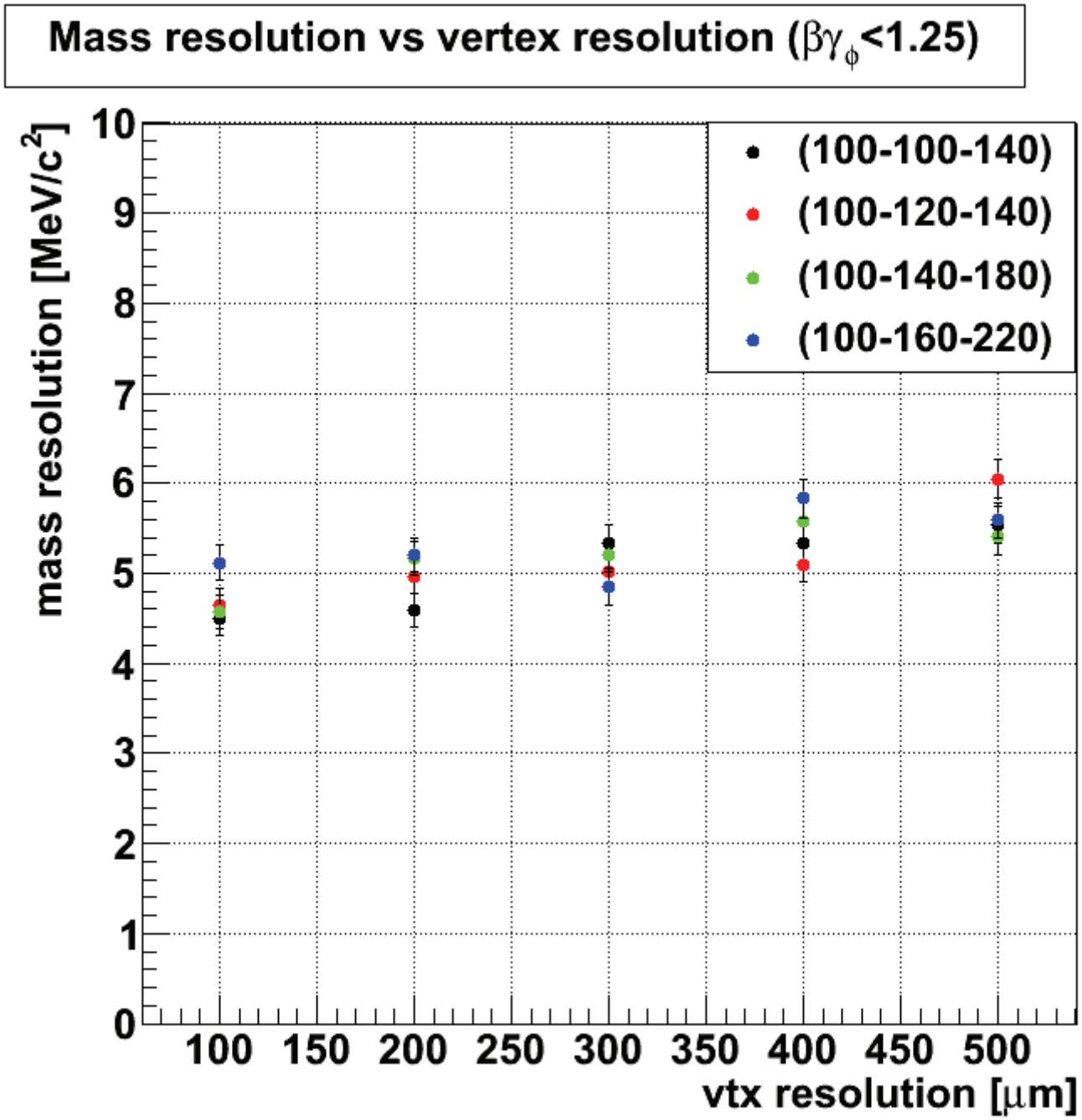
GEM tracker beam test

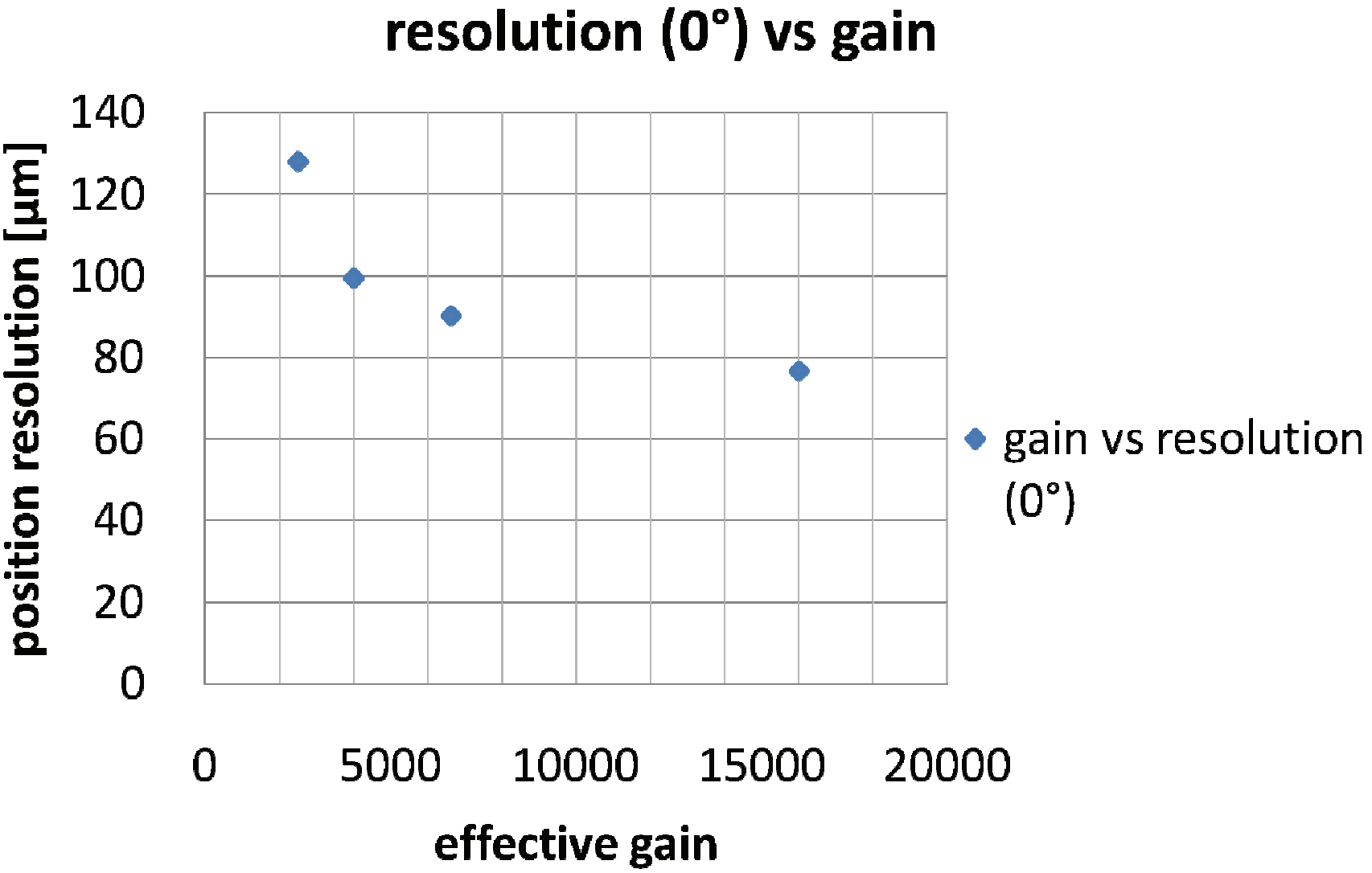
- Position resolution of 100 μ m is achieved with large GEM for 0° .
- 350 μ m pitch readout is adopted for the top side.
- Timing information is effective for the inclined beam.
- Need to develop the bottom side to improve pulse height and efficiency.

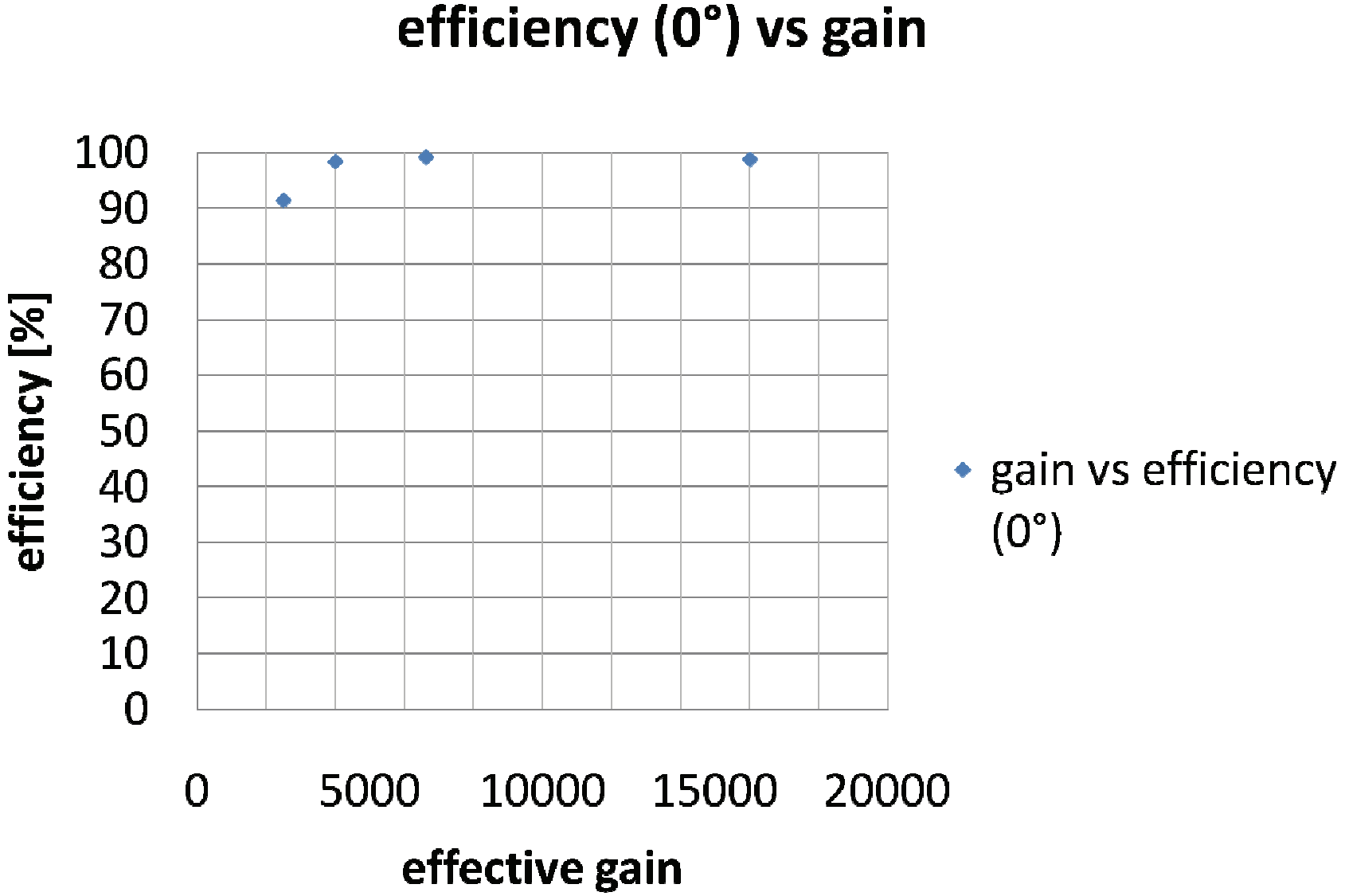
Summary & Outlook

- Large GEM tracker is developed for J-PARC E16 experiment.
- $10 \times 10 cm^2$, $20 \times 20 cm^2$ and $30 \times 30 cm^2$ GEM are manufactured and achieved enough gain.
- Position resolution and efficiency are evaluated in the beam test.
- Resolution of 100 μ m and efficiency of 95% are achieved in the top side readout.
- New readouts are developed for the efficiency of the bottom side.

backup

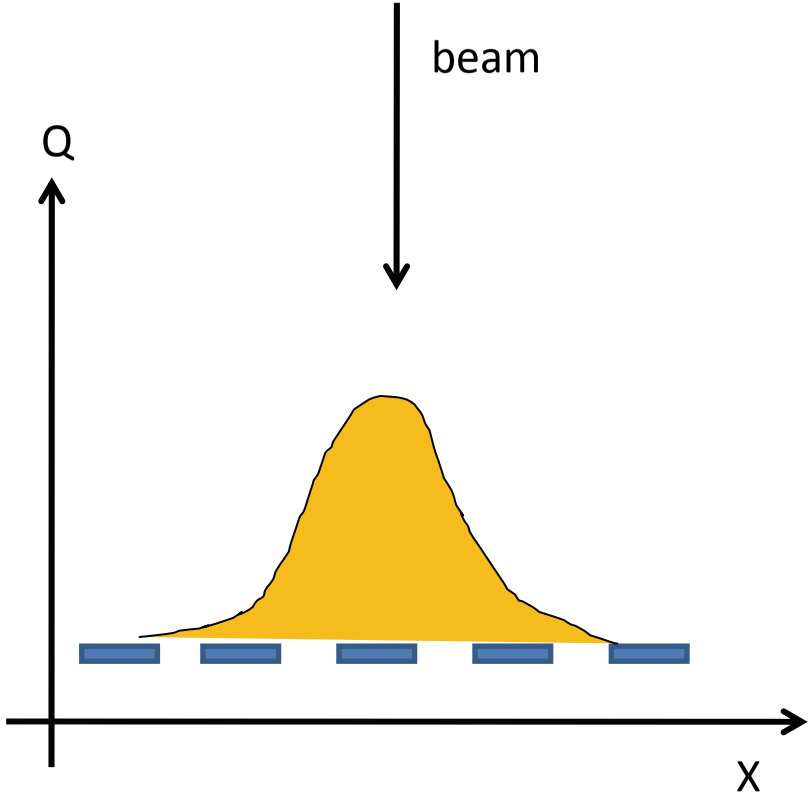

Mass resolution vs vertex resolution ($\beta\gamma_\phi$<1.25)
mass resolution [MeV/c^2]
vtx resolution [μm]
(100-100-140)
(100-120-140)
(100-140-180)
(100-160-220)
0
1
2
3
4
5
6
7
8
9
10
100
150
200
250
300
350
400
450
500


resolution (0°) vs gain
position resolution [µm]
140
120
100
80
60
40
20
0
0
5000
10000
15000
20000
effective gain
gain vs resolution (0°)


efficiency (0°) vs gain
efficiency [%]
100
90
80
70
60
50
40
30
20
10
0
0
5000
10000
15000
20000
effective gain
gain vs efficiency (0°)

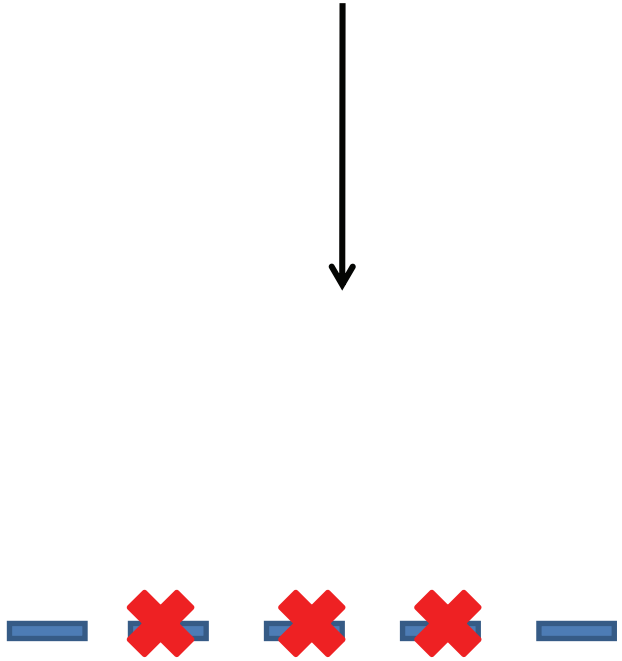
0° 入射に対して

重心法
電荷の重心を取る



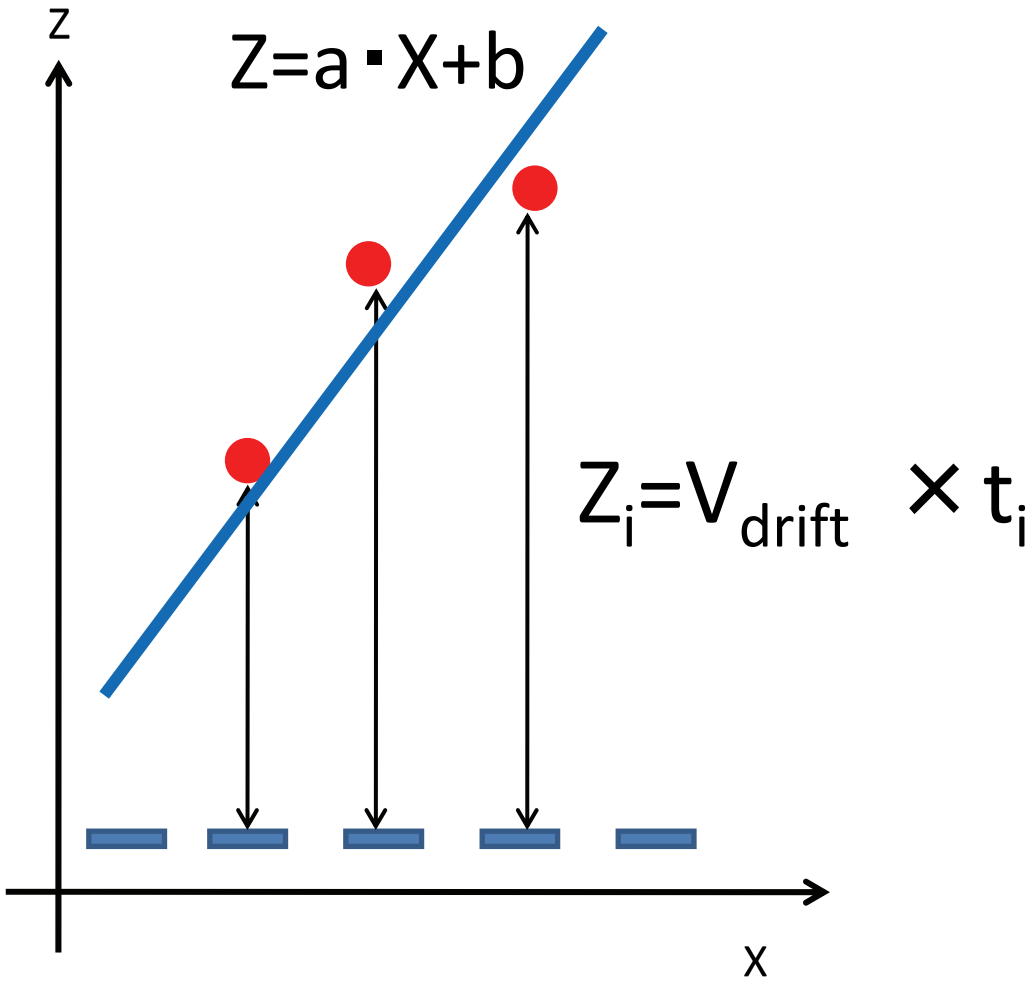
$$Xgem = \Sigma X_i \, Q_i / Q_{sum}$$

中点法
hit stripの真中を取る



$$Xgem = \Sigma (X_{left} + X_{right}) / 2$$

15°，30° 入射に対して



$Z_i = V_{drift} \times t_i$

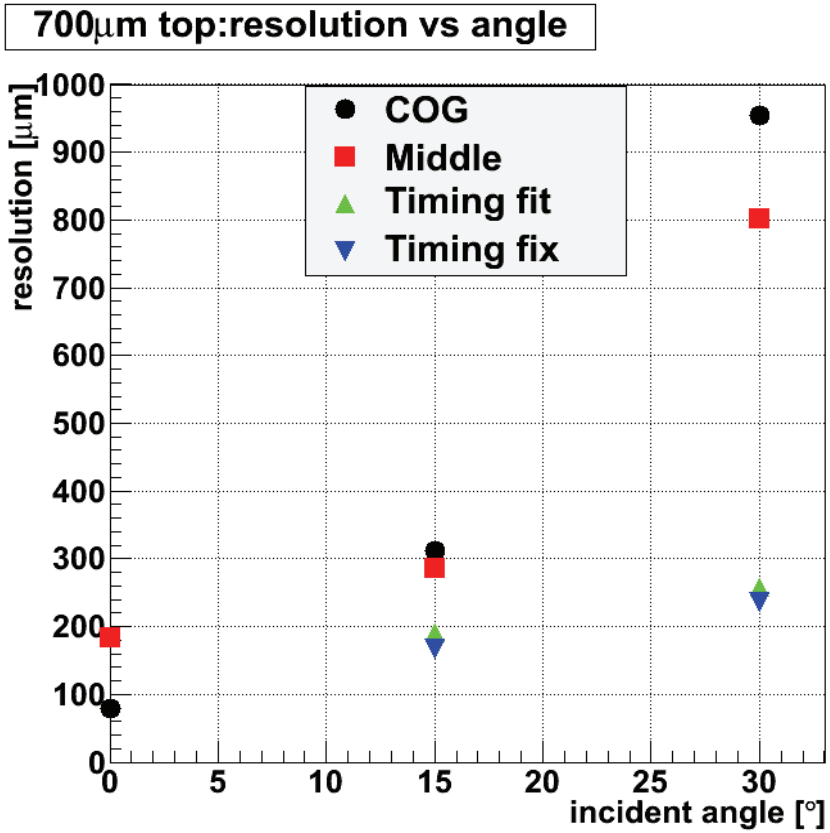
・電離が起きた点をドリフト速度とドリフト時間で計算する。

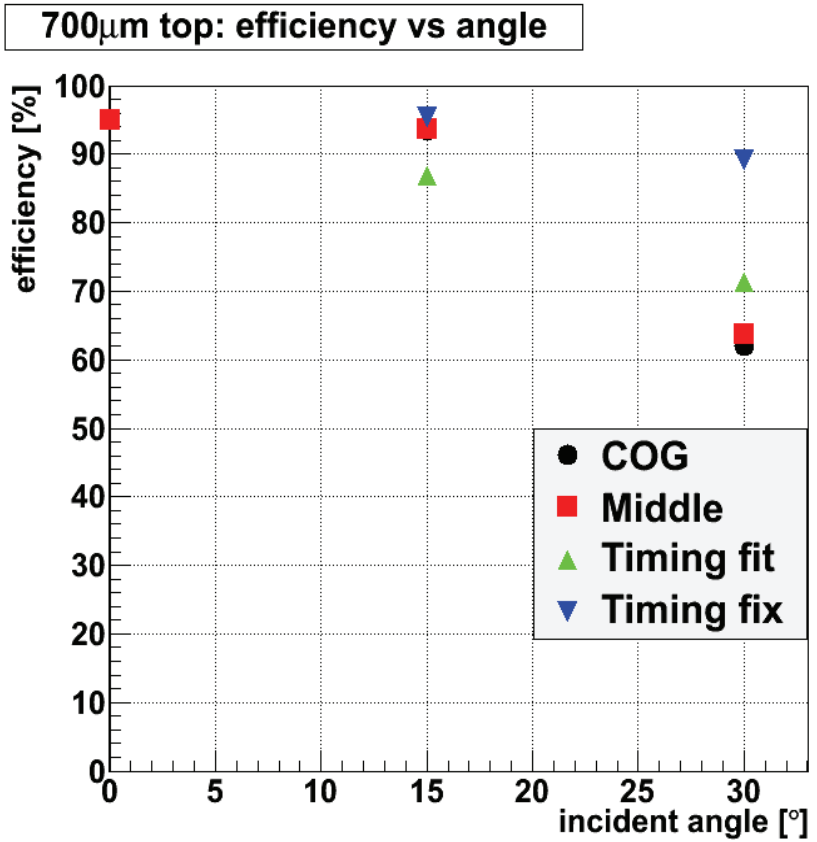
・求めた点を一次の式でフィットする。

・傾きと切片　2つのパラメータでfitする。
→timing fit 法

・傾きは15°または30°に固定してfitする。
→timing fixed angle 法

700 μm pitch (drift gap 6mm, horizontal)



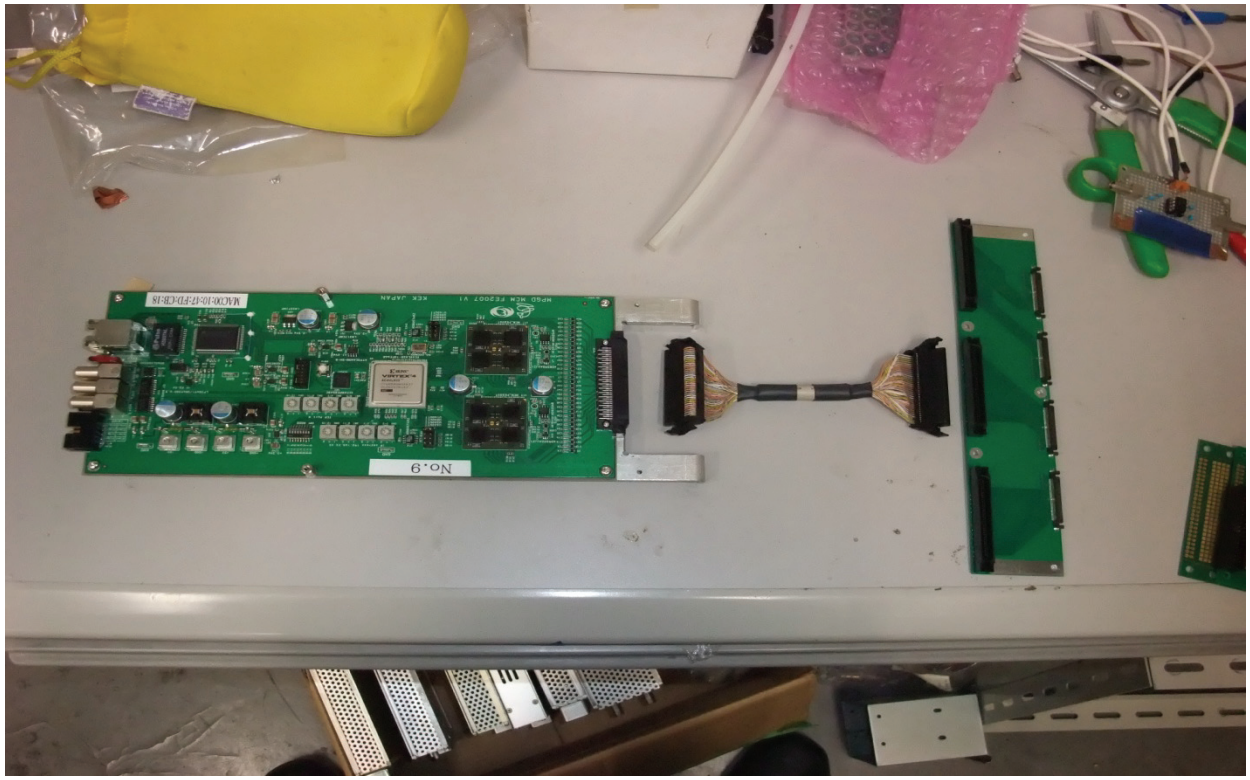


15°で170 μm程度。

700 μmで15°までで位置分解能 100 μm を達成することは困難である。→horizontal 方向は350 μm pitchの使用。

horizontal						vertical		
0°		15°		30°				
COC	middle	tdc fit	tdc fix	tdc fit	tdc fix	middle	ΔM [MeV/c2]	ΔM ($\beta\gamma$<1.25) [MeV/c2]
77			105		127	255	5.9	4.8
77		140		143		255	6.4	4.9
	122	140		143		255	7.4	5
	122	245 (middle)		368 (middle)		255	9.3	6.3

読み出し回路



GEMFE 2007

- 64ch /board
- 各chに対してコンパレータが実装されている。
- 100 MHz clock.
- GEMのhit　stripをthresholdによって割り出し、hit位置を計算する。
- thresholdを変えて位置分解能を測定する。各角度につき5点測定。