CNS Active Target Project

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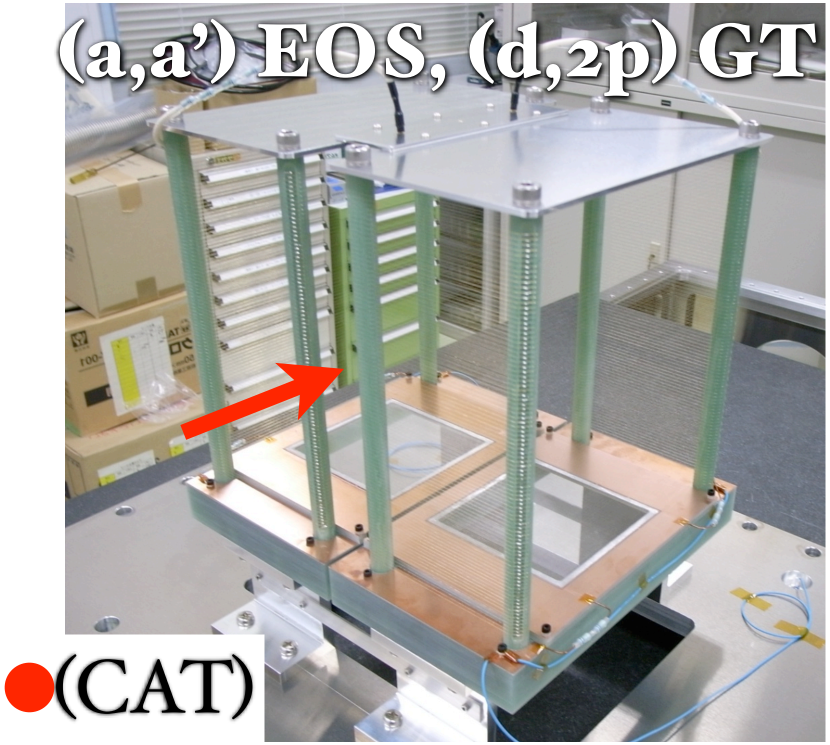
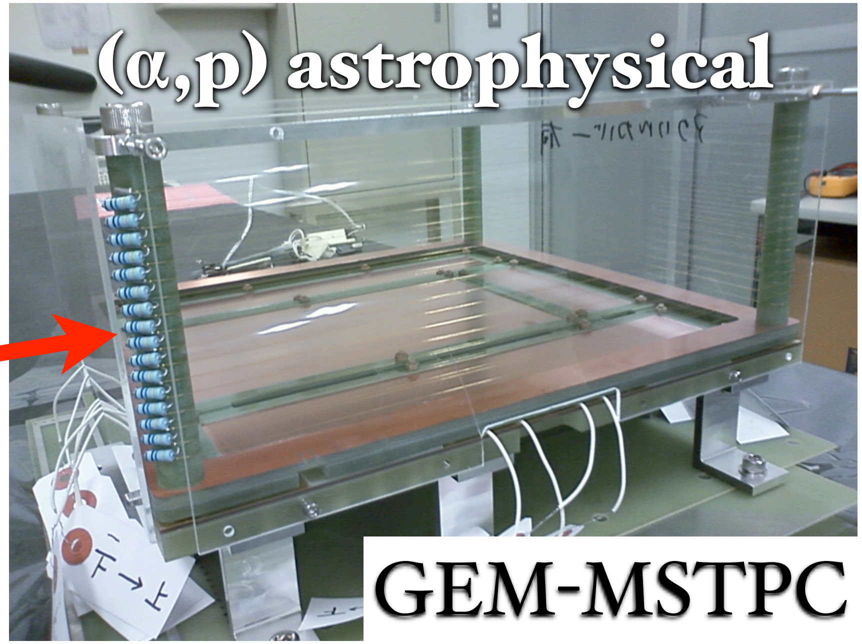




Two Types of "Active" Target

Beam inactive and active type

CNS Active Target Project

- 2009
    - Collaboration begins
    - Budget at the beginning of FY2009 in CNS (6M yen) + a part of Grant-in-aid for Scientific Research (~4M yen)
    - Construction of prototype was done in November
    - Test experiment in December, 2009 (CAT) and January and February in 2010 (GEM-MSTPC)
- 2010
    - Two (a,p) exp. in 2009 (GEM-MSTPC)
    - Test exp. w/ 250MeV/u ^{56}Fe @HIMAC (CAT)
- 2011...

Collaboration

Only Experimentalists

CNS, Univ. of Tokyo

High Energy
(GEM, Electronics)

SHARAQ
(Physics, Electronics, DAQ)

Astrophysics
(Physics, Construction)

RIKEN

Kyoto Univ.

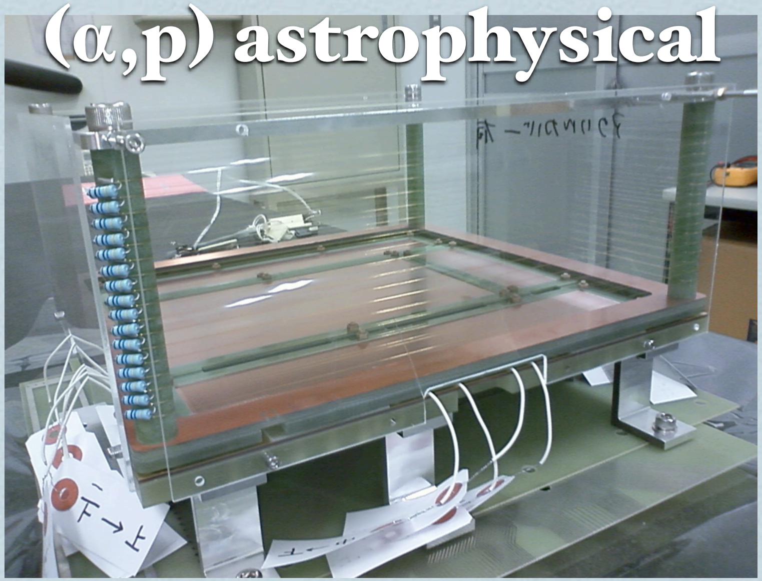
Univ. of Tsukuba

Miyazaki Univ.

(test experiment, potential users)

Collaborators

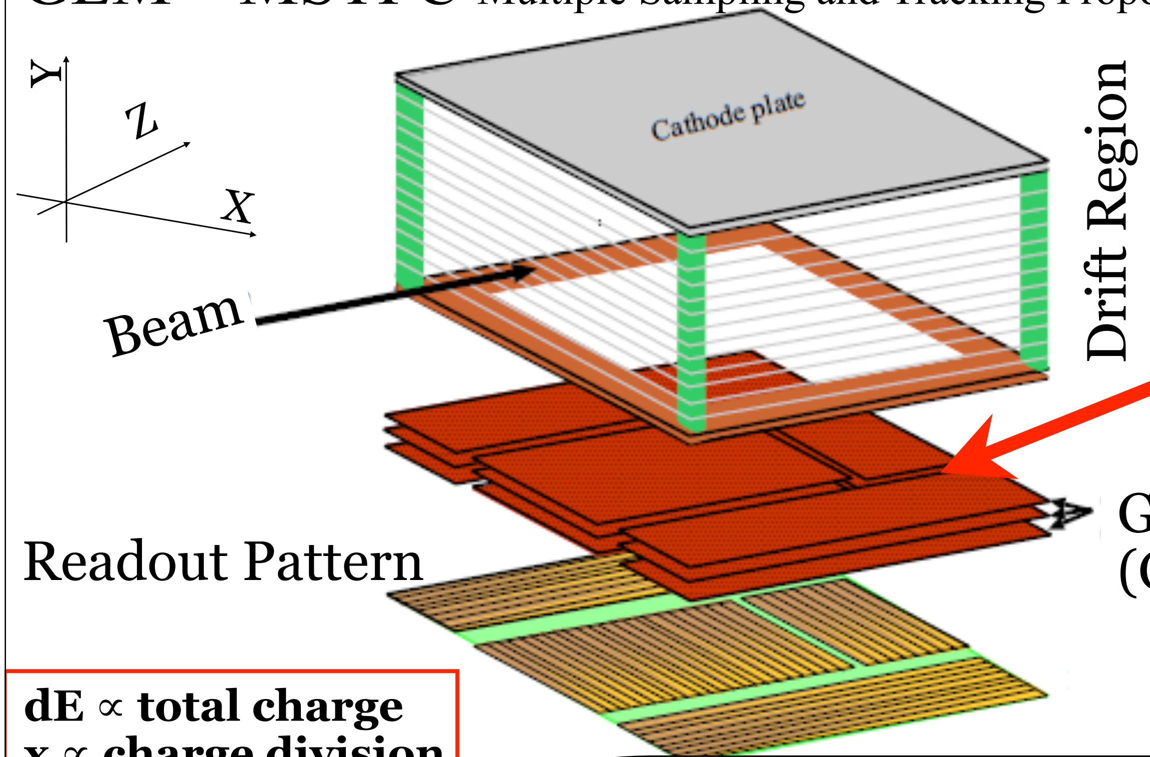
S. Ota, H. Tokieda (CAT), R. Akimoto (Master Thesis), M. Dozono, H. Matsubara, Y. Kikuchi,
T. Hashimoto (GEM-MSTPC), S. Michimasa, T. Gunji, H. Yamaguchi,
S. Kawase, T. Tsuji,
H. Hamagaki, T. Uesaka, S. Kubono (CNS),
T. Kawabata (Kyoto), H. Otsu, T. Isobe (Riken),
Y. Maeda (Miyazaki) A. Ozawa, H. Suzuki, D. Nagae, T. Morimoto, Y. Ito,
Y. Ishibashi, H. Oishi (Tsukuba)

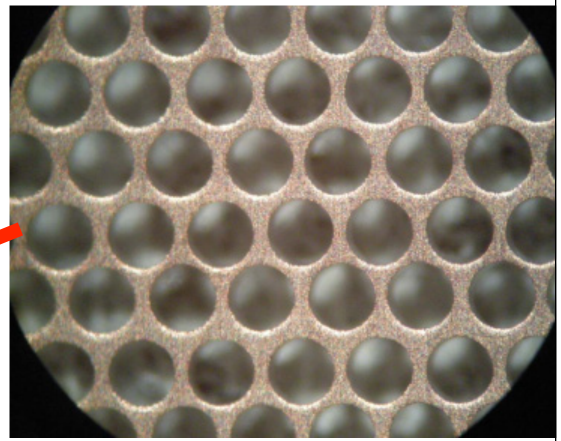


GEM-MSTPC

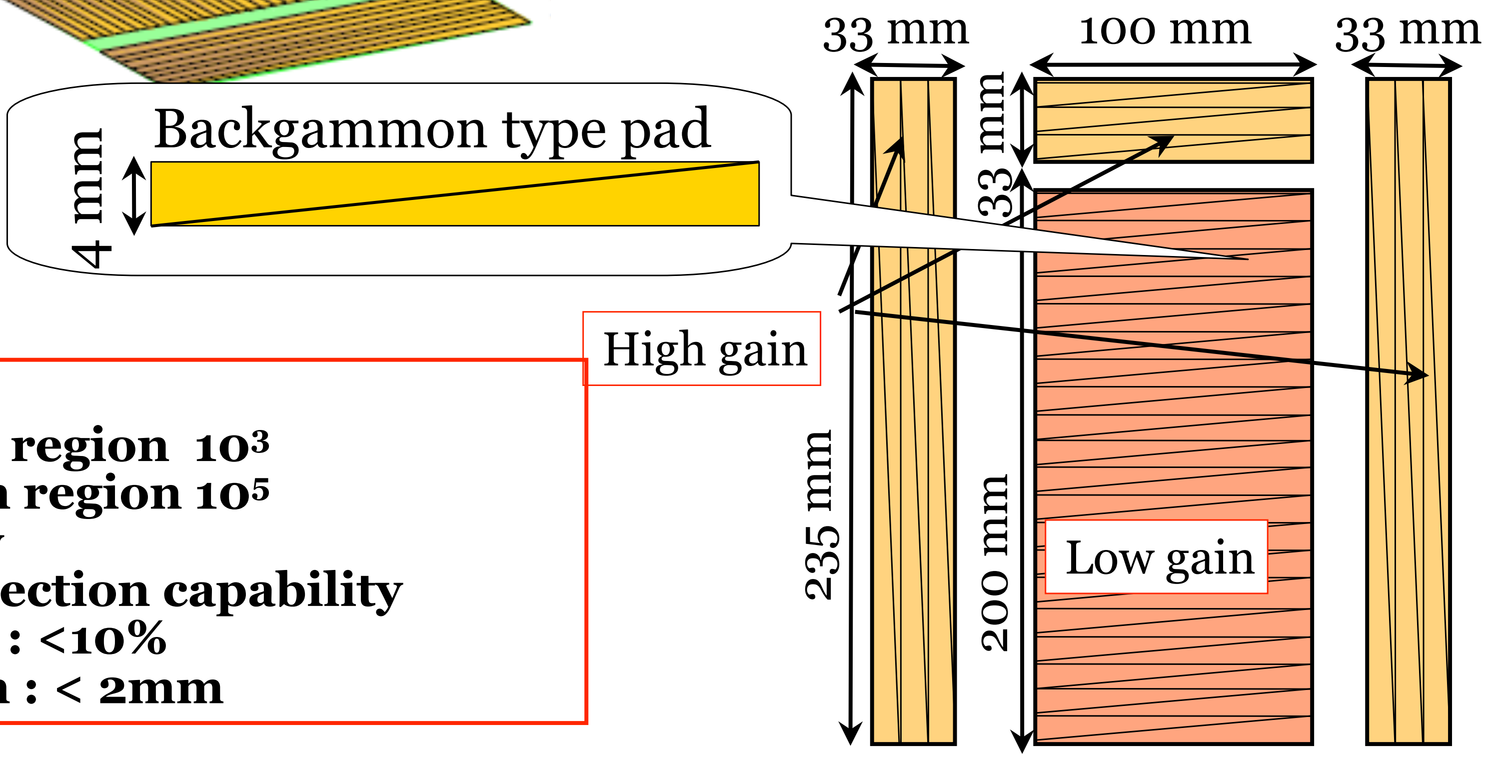
w/ low-energy, up to 100 kHz beam
(CRIB)

GEM – MSTPC Multiple Sampling and Tracking Proportional Chamber with Gas Electron Multiplier





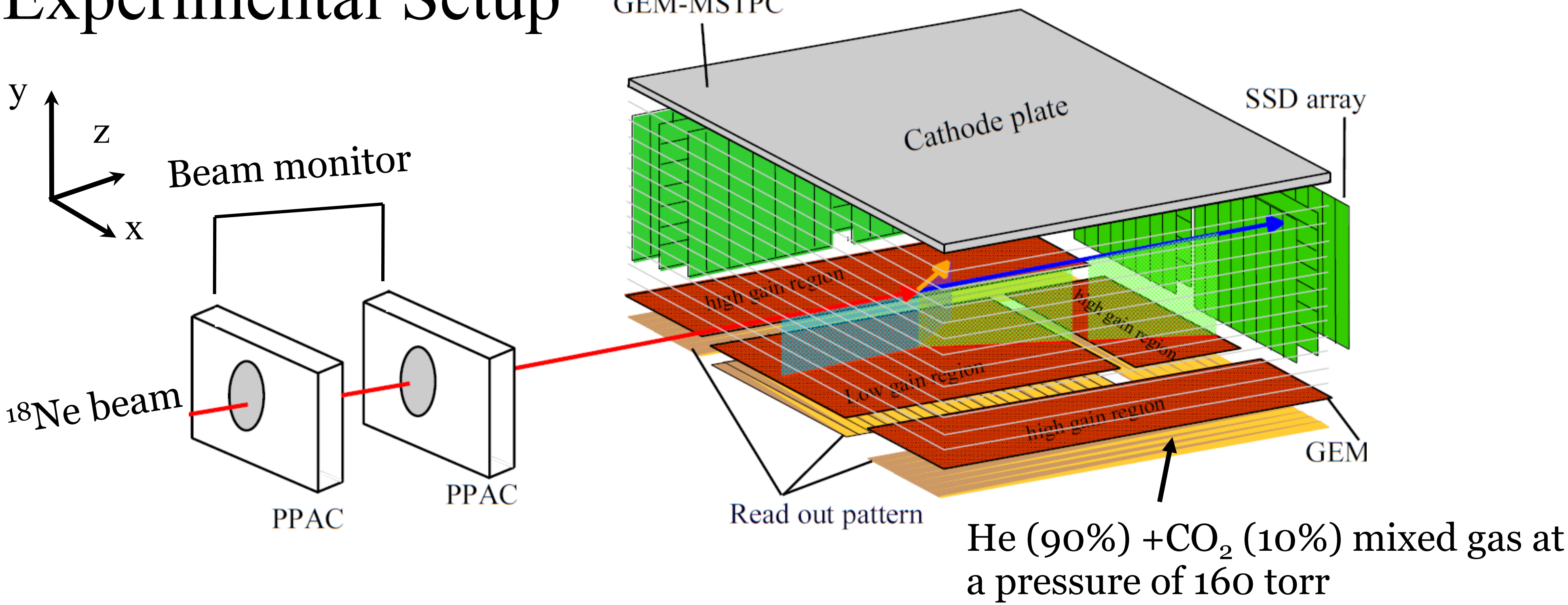
dE ∝ total charge
x ∝ charge division
y ∝ drift time
z ∝ pad number



Requirements

Gas gain : low gain region 10^3
high gain region 10^5
Long time stability
High rate beam injection capability
Energy resolution : <10%
position resolution : < 2mm

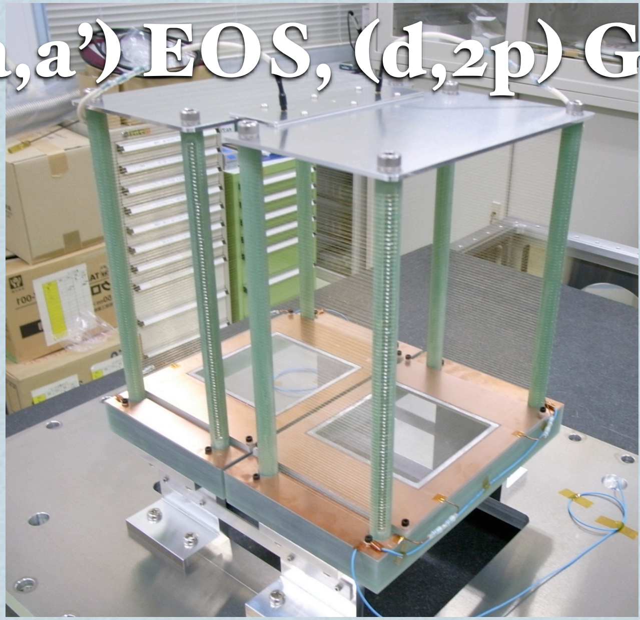
Experimental Setup



Advantages and merits

1. The gas in the chamber serves as an active target.
   -> The solid angle is 4π and detection efficiency is about 100%.
2. The MSTPC can measure 3D trajectories and dE/dx along their trajectrories.
   -> It serves a sufficient target thickness without losing any information.
   The identification of the reaction is clearly performed.

(a,a’) EOS, (d,2p) GT



CAT

w/ high-energy, up to 1 MHz beam

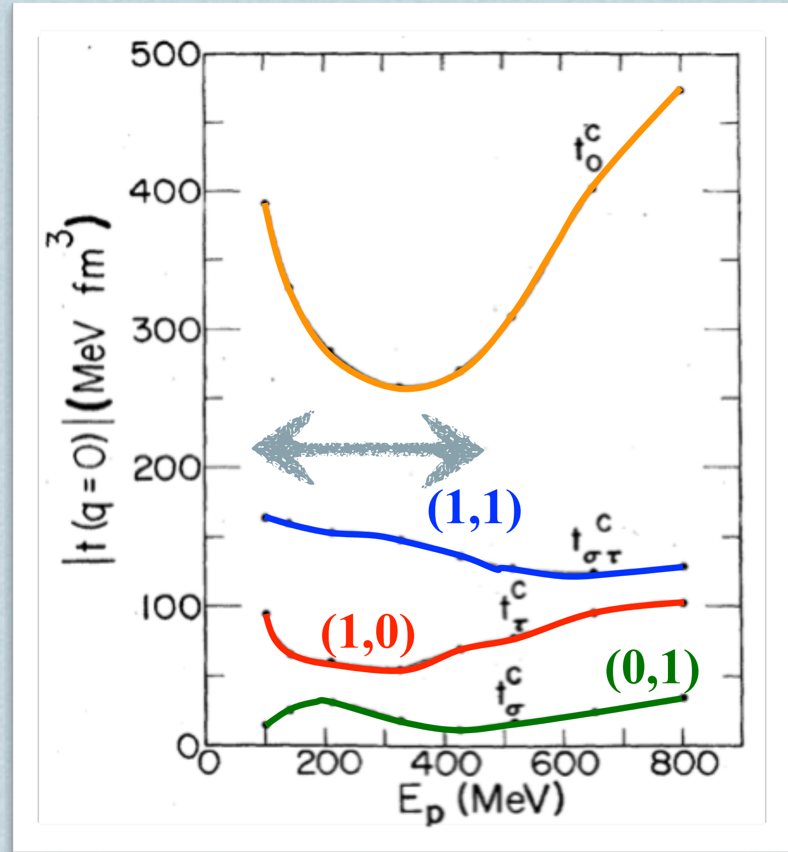
(SHARAQ, ZDS, RI-Ring ...)

Missing Mass Spectroscopy for (medium-) heavy RI

- Structure of unstable nuclei
  - Inelastic scattering, Gamow-Teller, Transfer...
- Giant resonances : incompressibility
  - Isoscalar/Isovector Monopole
- *via* Traditional reactions in inverse kinematics
  - (a,a'), (d,d'), (d,^{2}He), (^{3}He,t), (d,p), (p,d), (^{3}He,a),...

Spin(S)-Isospin(T) Selectivities

- Gamow-Teller
  - **ΔL=0**, **ΔT=1, ΔS=1**
- Fermi
  - **ΔL=0**, **ΔT=1, ΔS=0**
- Isoscalar monopole
  - **ΔL=0**, **ΔT=0, ΔS=0**



Incident beam energy: 100-300 MeV/u => RIBF

Spin-Isospin Selectivities

	ΔS=0	ΔS=1
ΔT=0	(p,p'), (d,d'), **(α,α')**	(p,p') (d,d')
ΔT=1	(p,p') (p,n) (^{3}He,t')	(p,p'), (p,n), (^{3}He,t') **(d,^{2}He)**

Gamow-Teller: (d,^{2}He)

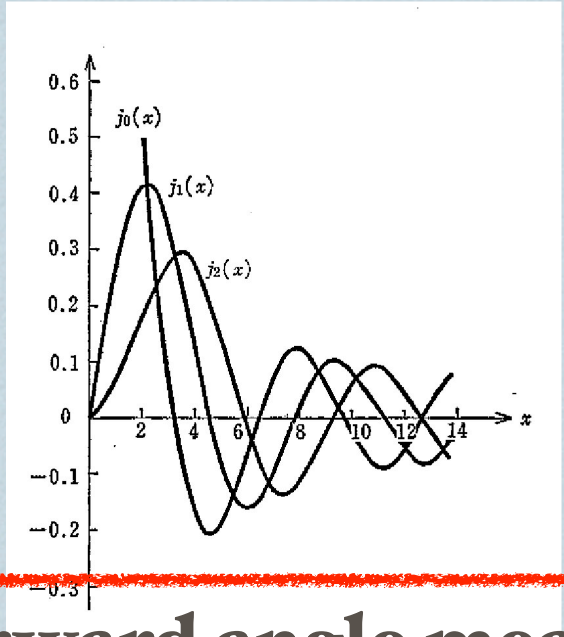
Isoscalar monopole: (α,α')

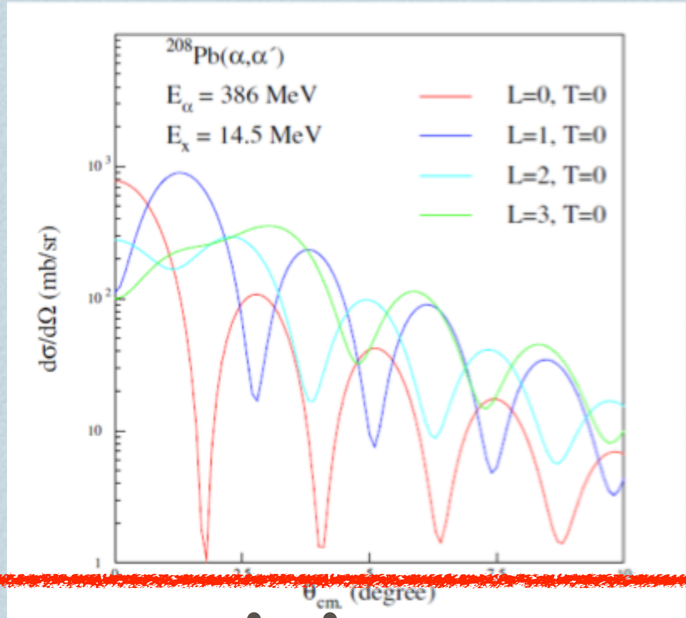
D_2 and ^{4}He gas

Momentum Transfer

- If the reaction occurs in the vicinity of nuclear surface,

$$\frac{d\sigma}{d\Omega} \sim |j_l(qR)|^2$$



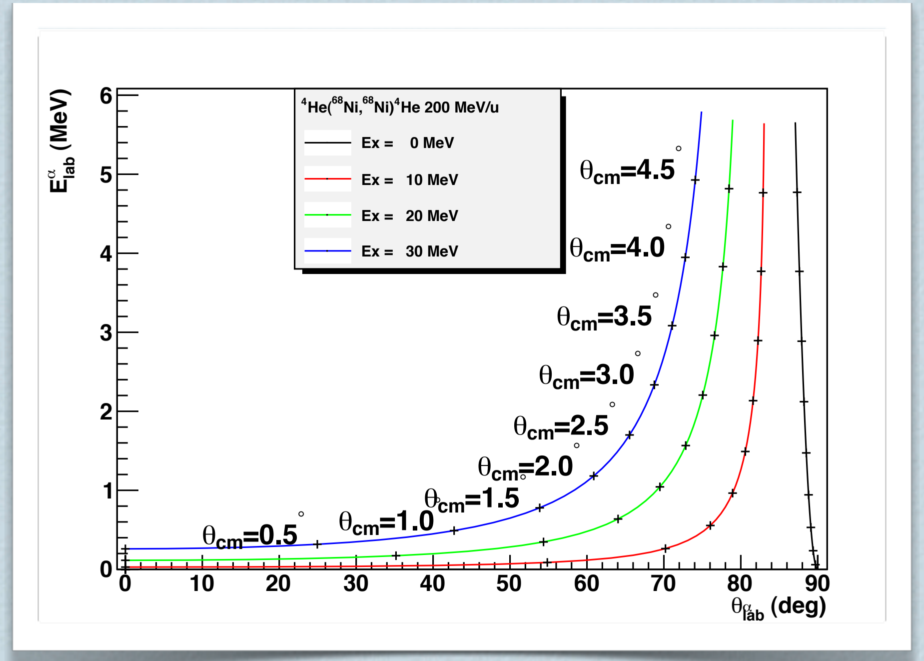


M. Itoh

Forward angle measurement is important

Inverse kinematics

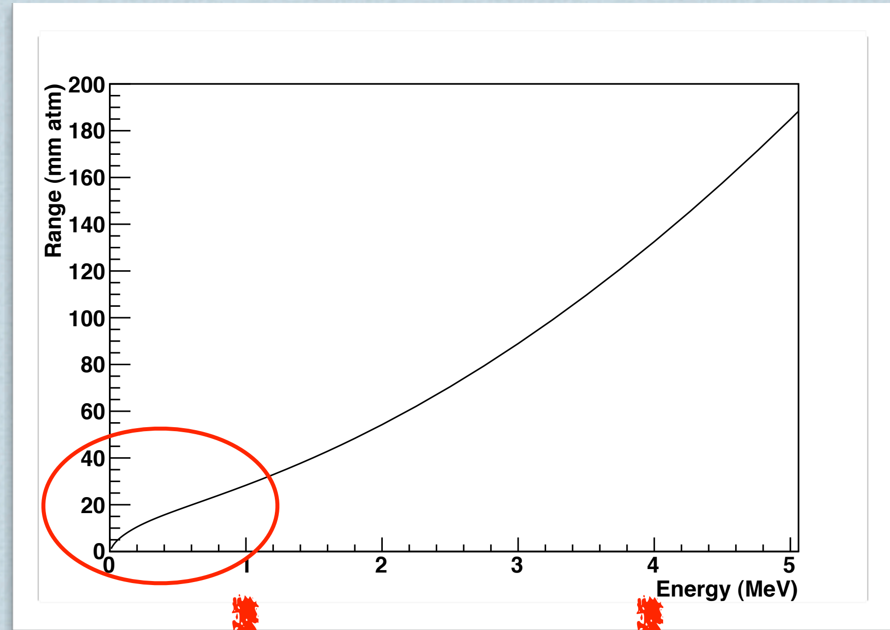
- $^4He(^{68}Ni,^{68}Ni)^4He$ @200MeV/u
- Recoil angle is large enough to measure
- Recoil energy is very small, less than 1 MeV for forward angle (<2 deg in c.m.) scattering



Recoil energy at forward scattering is very small

Range in He gas

- $\rho(^4He)$ = 0.2 mg/cm^3
- 0.1 MeV : 6.9 mm atm
- 0.5 MeV : 17.8 mm atm
- 1.0 MeV : 28.3 mm atm



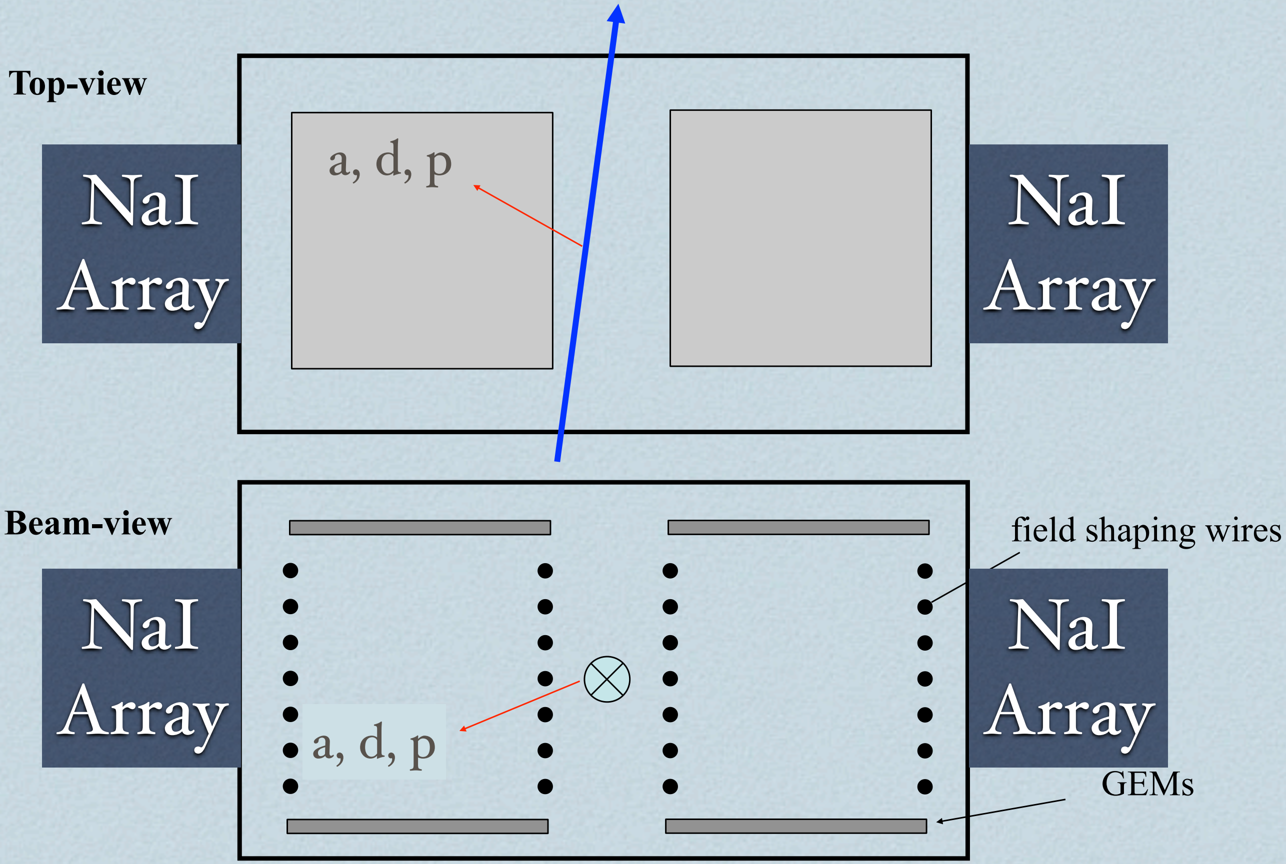
θ_{cm}~1 deg θ_{cm}~4 deg

To measure forward angle scattering, an “active” target is needed

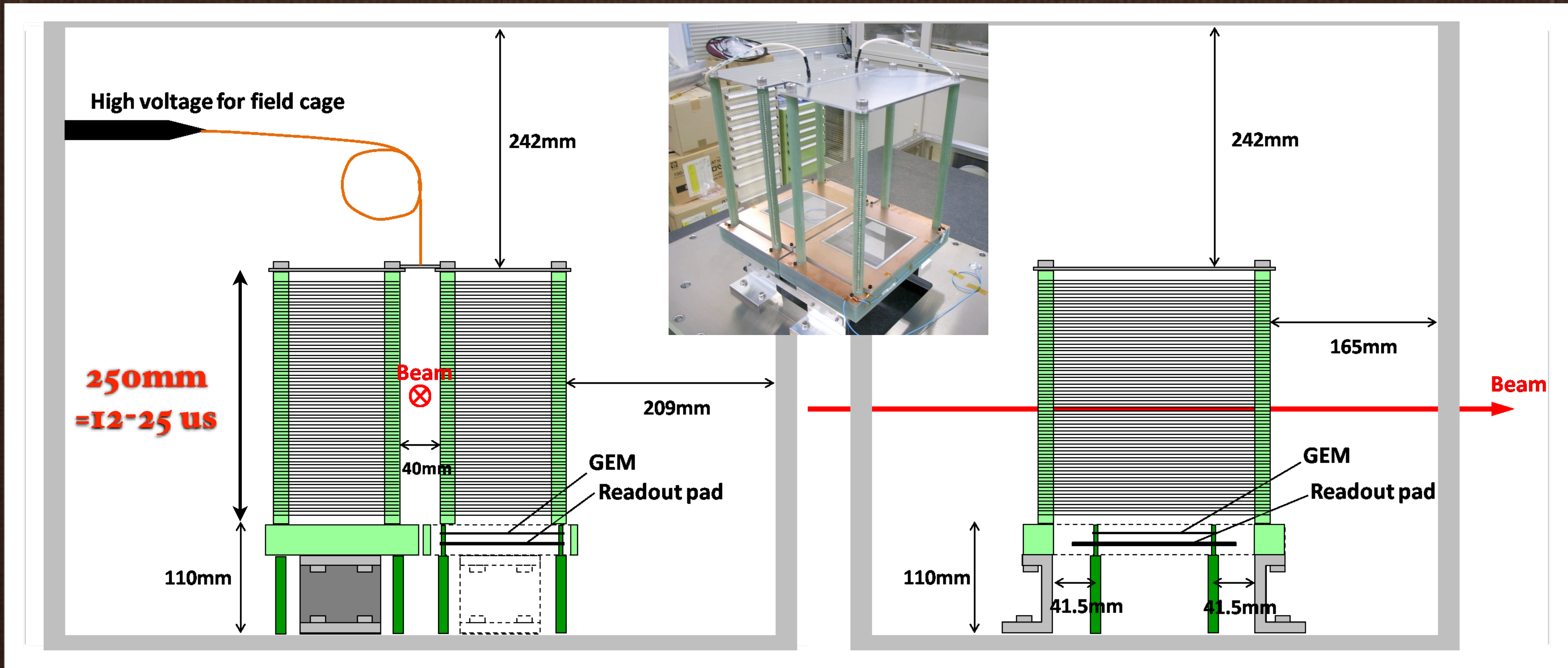
Effect on Electric Field by Intense Heavy Ion Beam

- Required beam intensity for 300 events / day
  - Target : 3 x 10^{20} particle/cm^2 (= 100 mm atm)
  - Cross section: 0.1 mb (assumed)
  - then, **100-kHz beam** is needed
- => considerable space charge effect, delta ray, ...

Concept of CAT

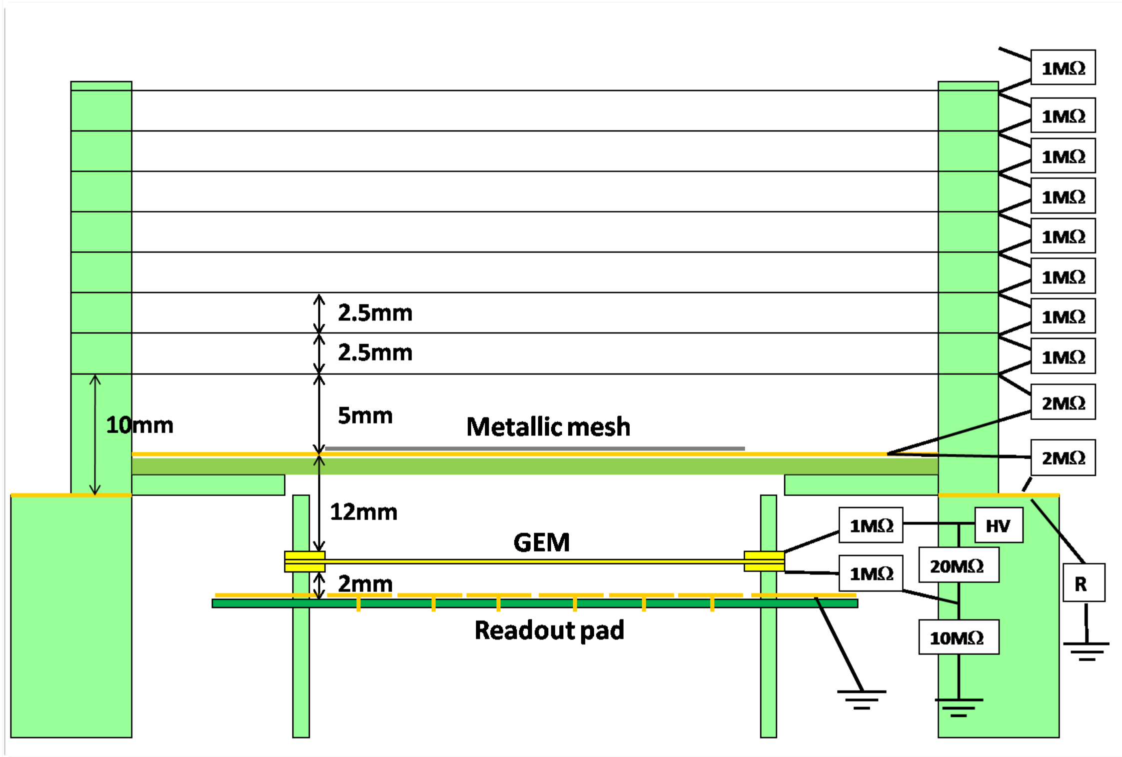


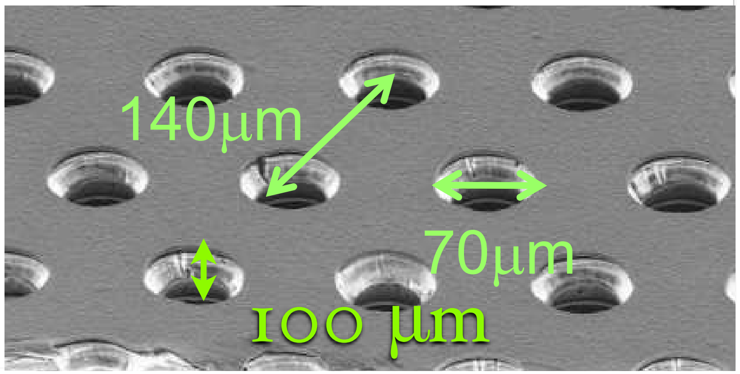
needs external monitor of beam-like particles
but, space charge effect is small enough (by simulation).



Geometrical Design

The region along beam path is masked.

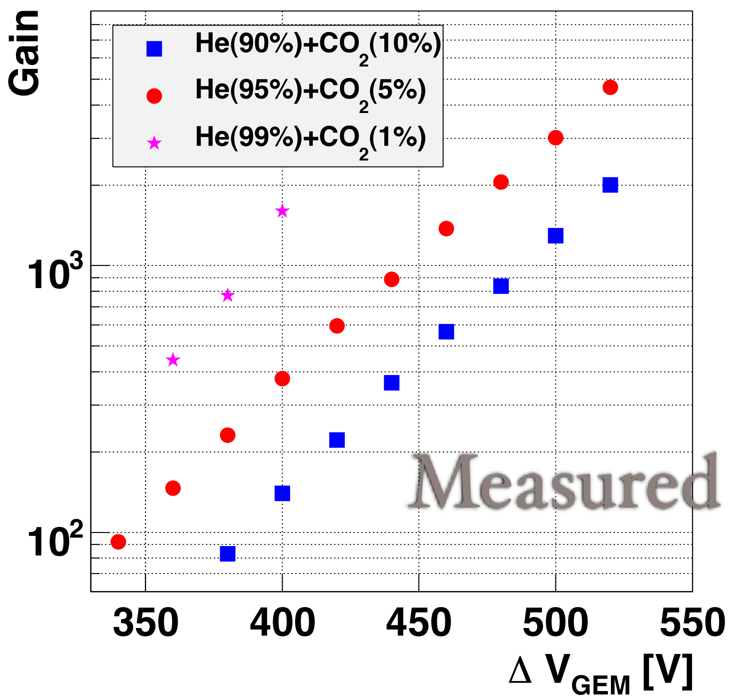


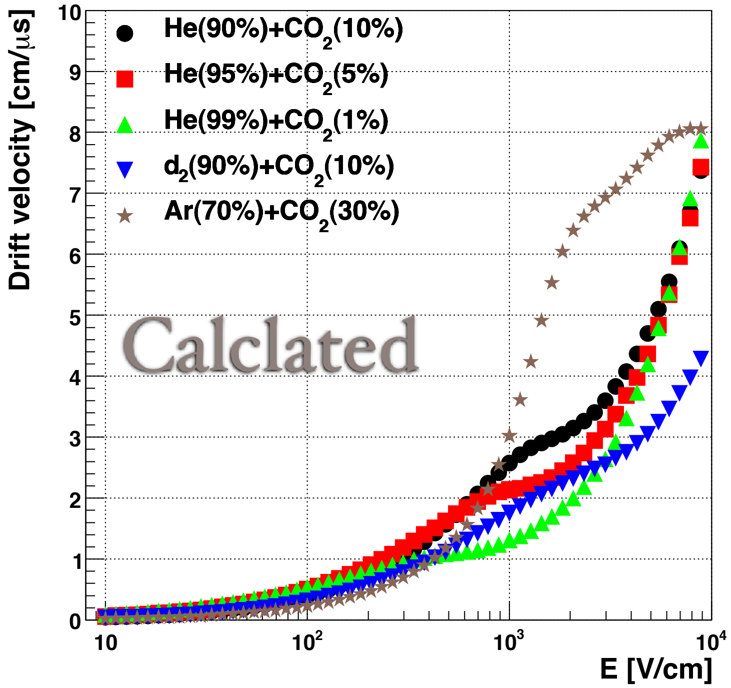



Electron Amplifier (GEM)

CNS-type

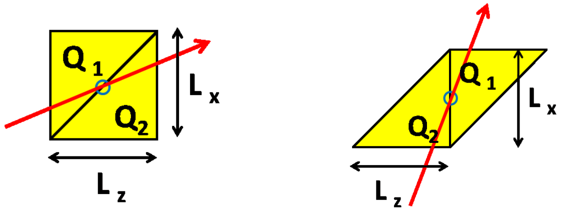
vender: scienergy





Property of He+CO_2 Gas

Position = Charge ratio

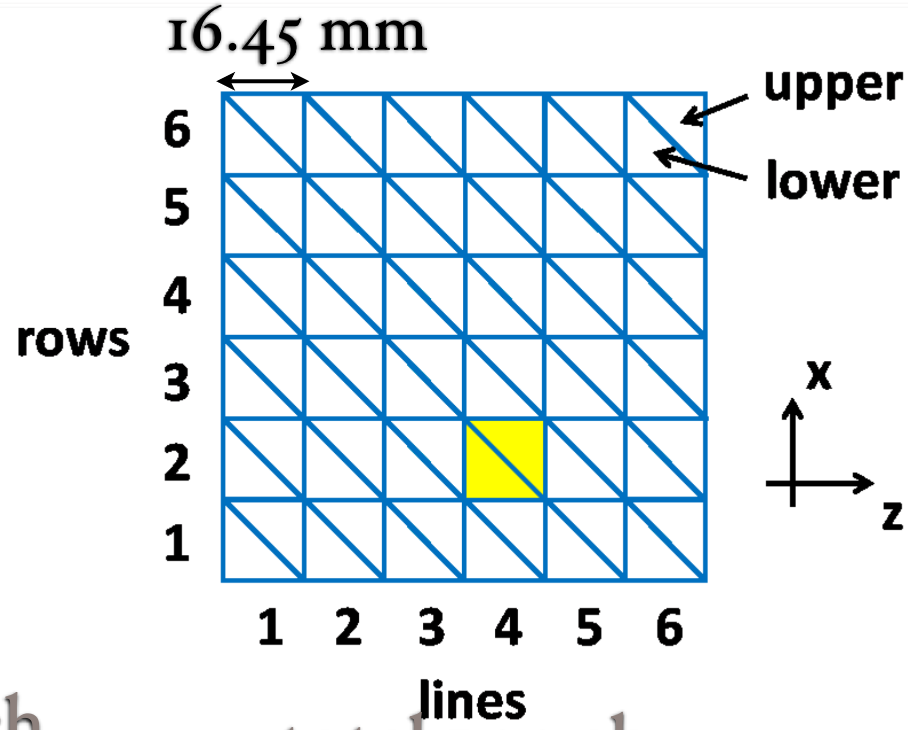


Designed Resolutions

0.3 mm(RMS)

~5 mrad (RMS)

Optimized: res. and # of ch.



total 144 ch

Readout Pad

Backgammon shape is chosen to optimize the resolutions and the number of readout channels

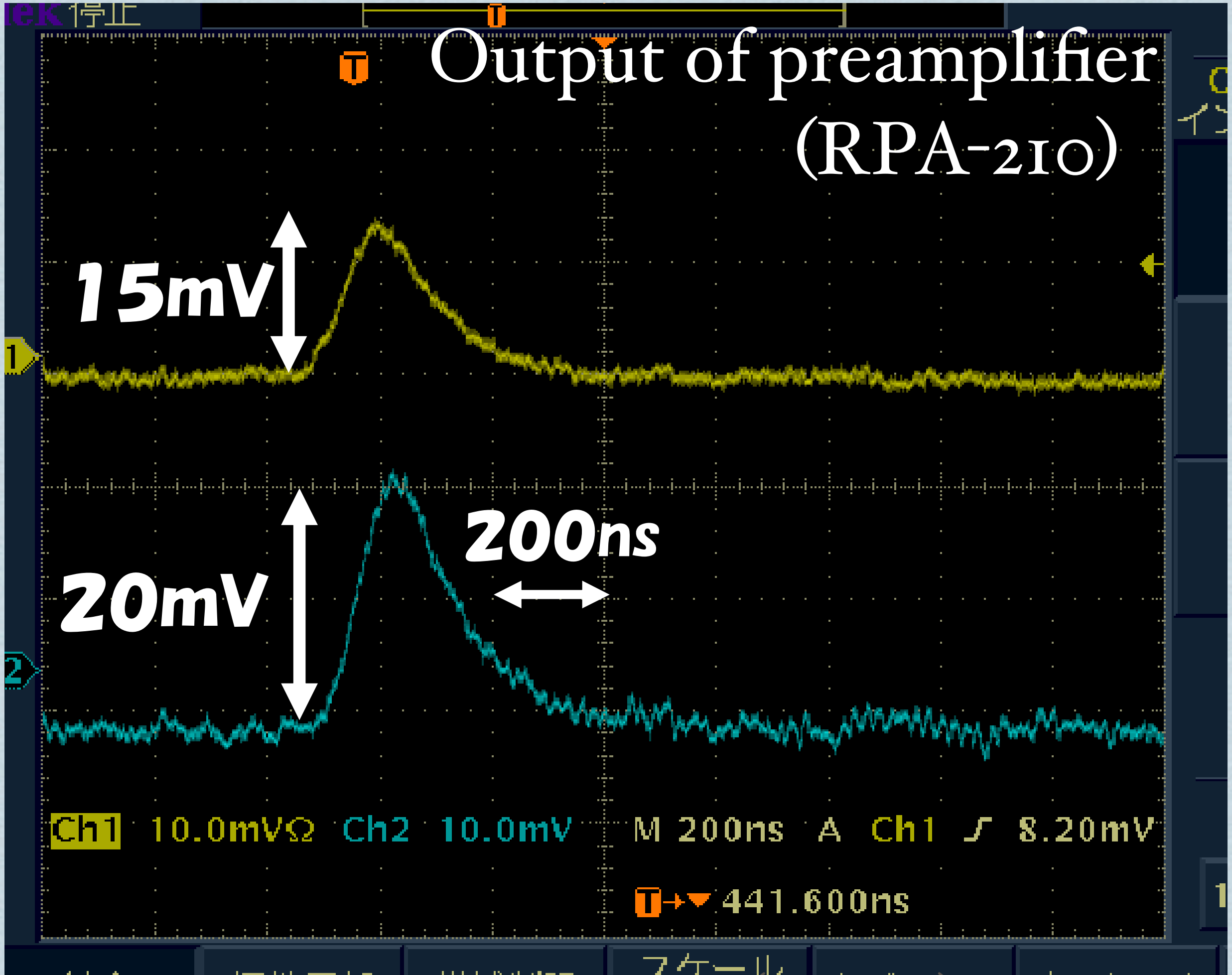
Electronics and DAQ software

- 3 x 6 x 2 pads (144ch) readout (for now)
- preamp
- FADCs
- Trigger
- DAQ (babirl: Baba-san's talk)

Preamp. (RPA-210) REPIC

- RPA-210 (REPIC) (CXA3653Q chip)
  - 24ch -1.0pC - 1.0pC
  - 0.8 V/pC
  - τ=80 ns
  - GEM-Preamp: 80cm flat cable

Typical signal ($He+CO_2(5\%)$)



very low noise (~1mV)

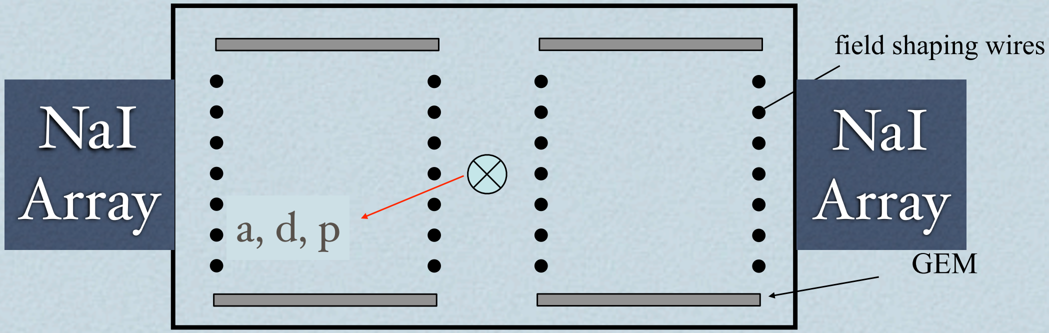
FADCs

FADC	resolution sampling rate	cost	zero suppression	threshold	architecture	production	dead time	availability
COPPER II	12bit 65MHz (max)	1.3MJPY/32ch	software	software	1cpu/ 32ch	KEK	readout	144 ch*
SIS3301	14bit 105 MHz (max)	1MJPY / 8ch	hardware	each ch	VME	SIS	no	40 ch
V1740	12bit 65MHz (max)	1MJPY / 64ch	hardware	every 8ch	VME	CAEN	no	64 ch
GET		cheap?	hardware?	each ch?				

*most part is property of KEK

Event and Sampling Trigger

- Event trigger
  - delayed Beam AND NaI (for high momentum recoils)
  - GEM (itself not pad)

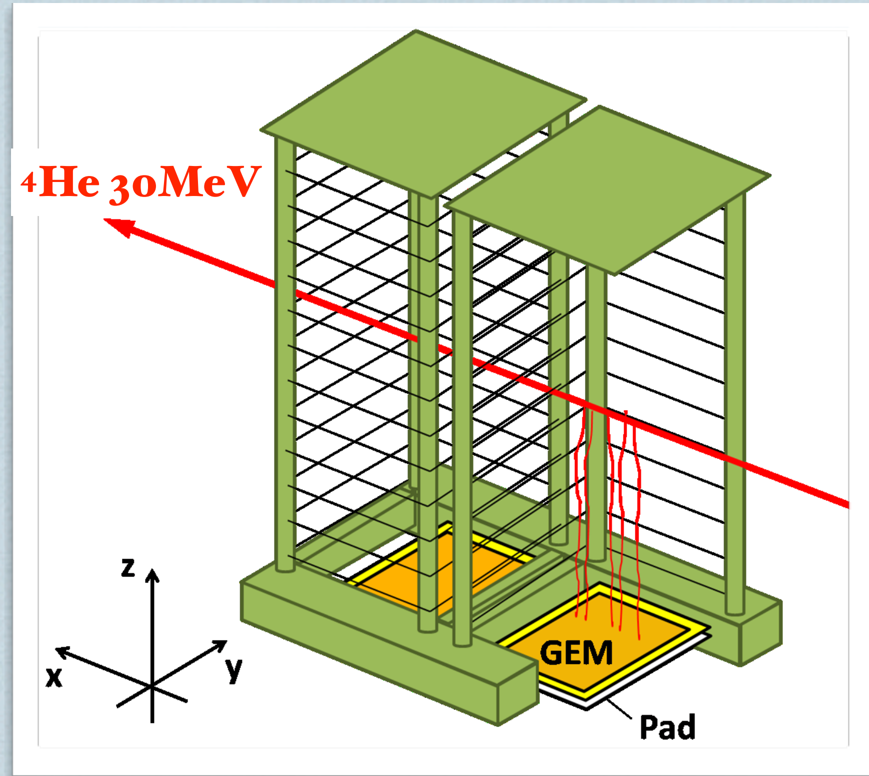


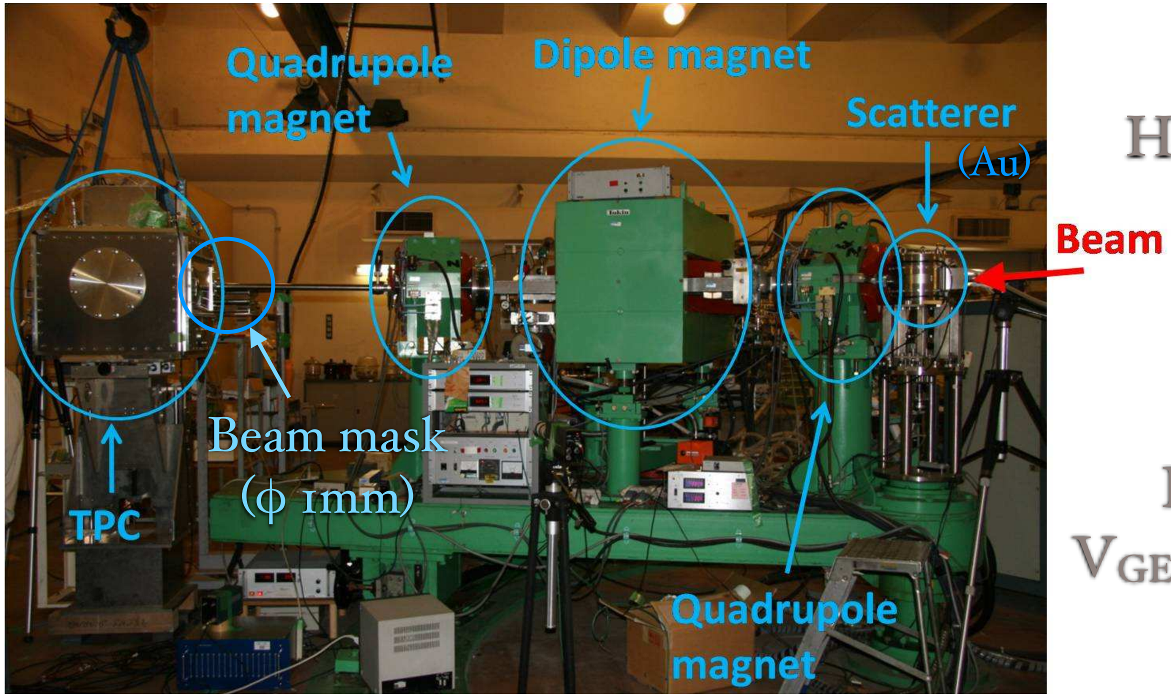
- Sampling trigger (in SIS3301, V1740)
  - self-trigger is generated under or below threshold
  - clock synchronized => time-stamp track identification
- Gate for COPPER II is open when the previous event was finished

Test Experiment in Tsukuba (Dec. 2009)

- Position and angular resolution
  - Incident position
  - Iincident angle
  - Gas gain
- Alpha particle at 30 MeV
- 100-10kHz

R. Akimoto Master Thesis





He 30 MeV, ~10^2 Hz (~200 electrons/mm)

He+CO_2(5%) 1 atm.

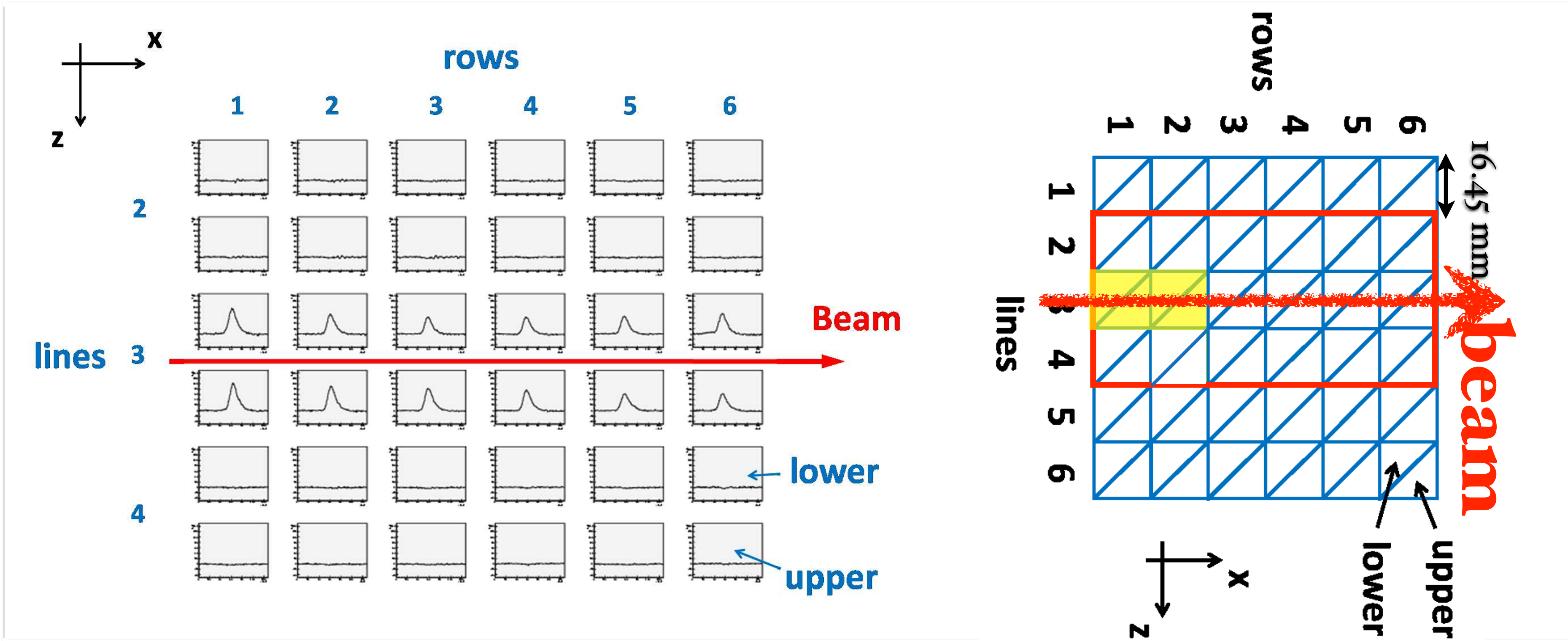
E_{drift} 700 [V/cm]

V_{drift} : 2 [cm/μs]

Diffusion : 250 [μm/cm]

V_{GEM}: 390-450 V (gain: 10^2-10^3)

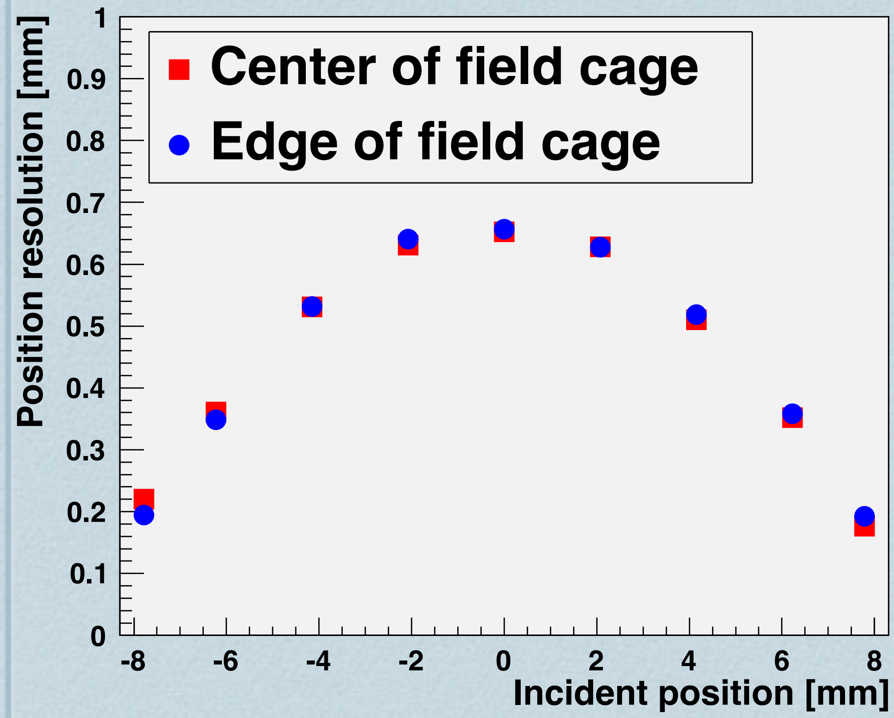
Setup



Typical Events

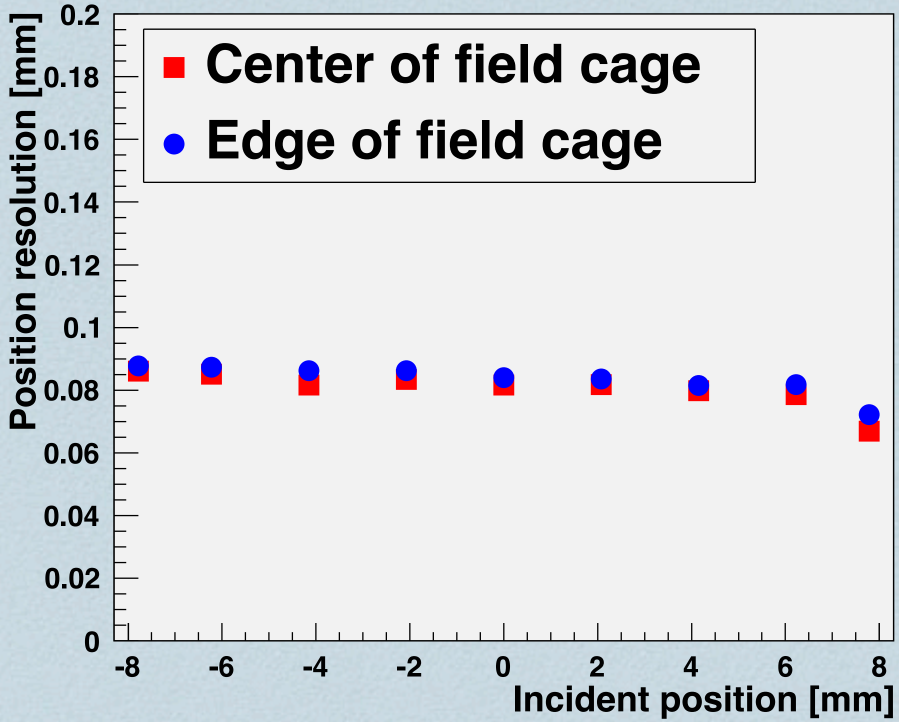
Position resolutions

Perpendicular to drift direction



less than 700um from charge division

Drift direction

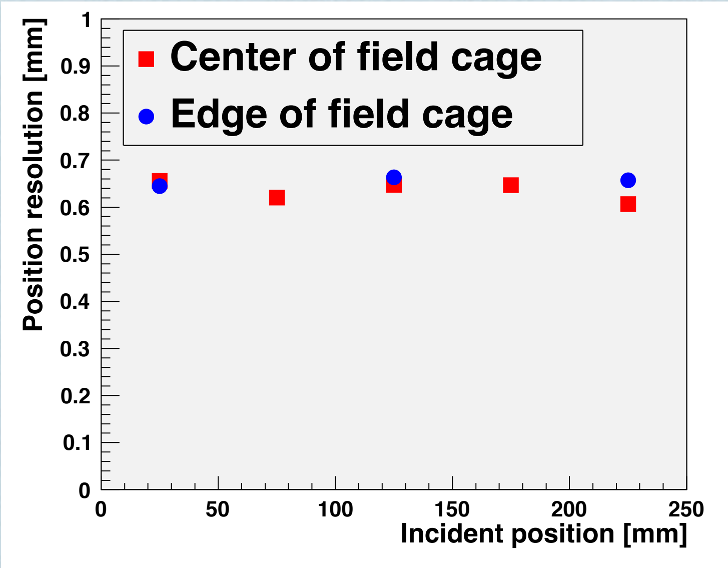


less than 100 um from time projection

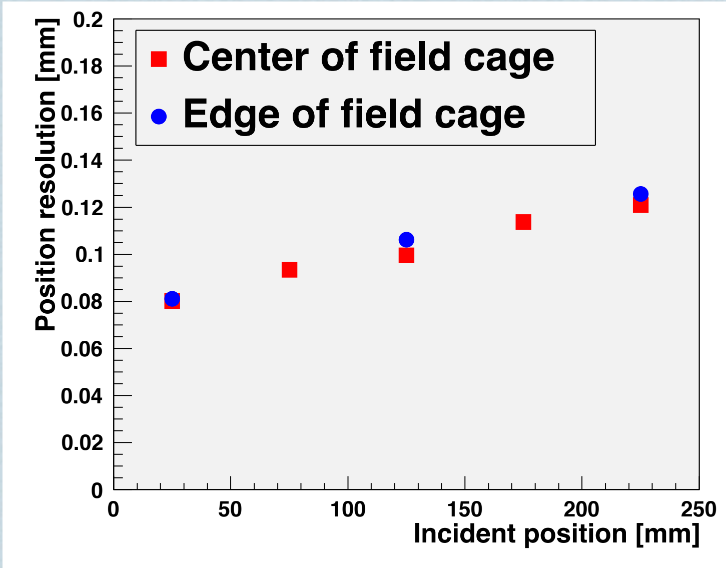
Effect of diffusion

dependency on the drift length

Perpendicular to drift direction



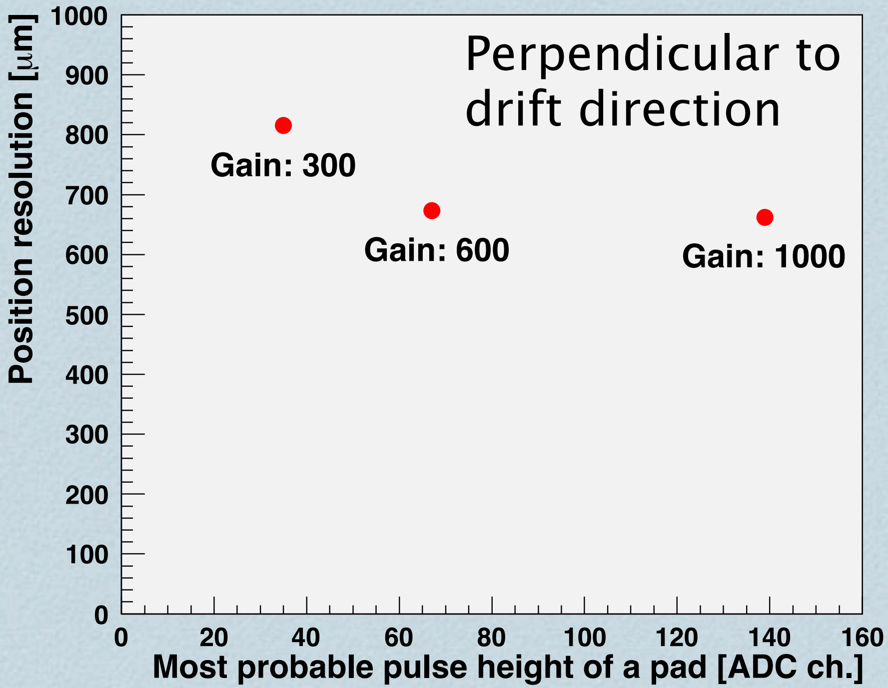
Drift direction

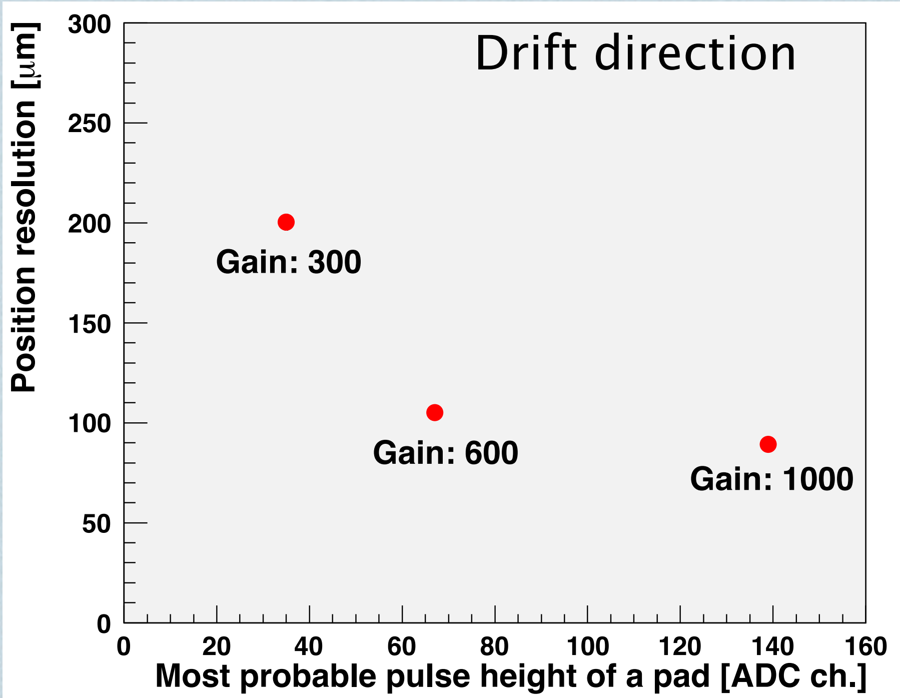


almost constant (within 100um) resolution

=> diffusion does not largely affect

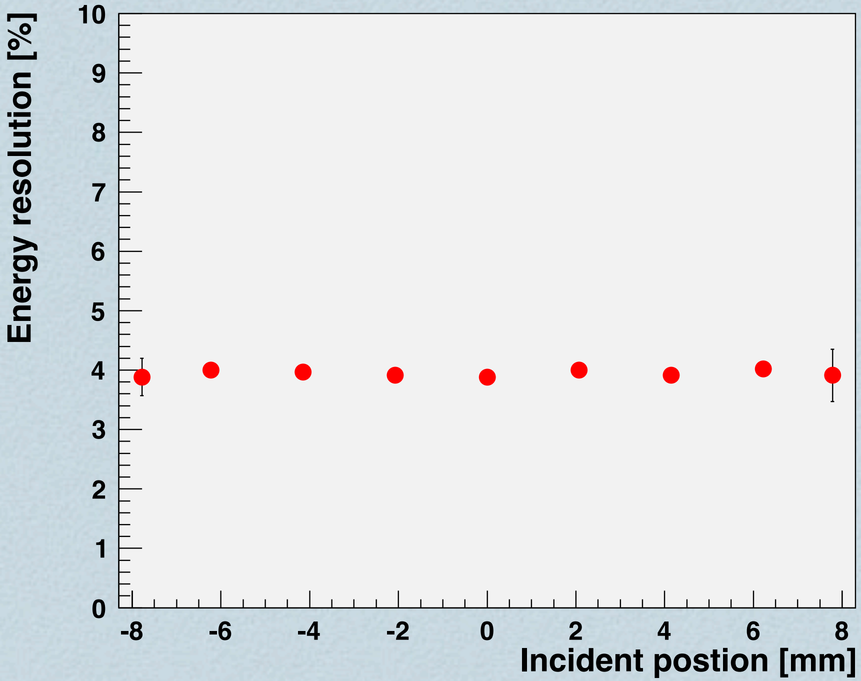
Dependence on Gas Gain

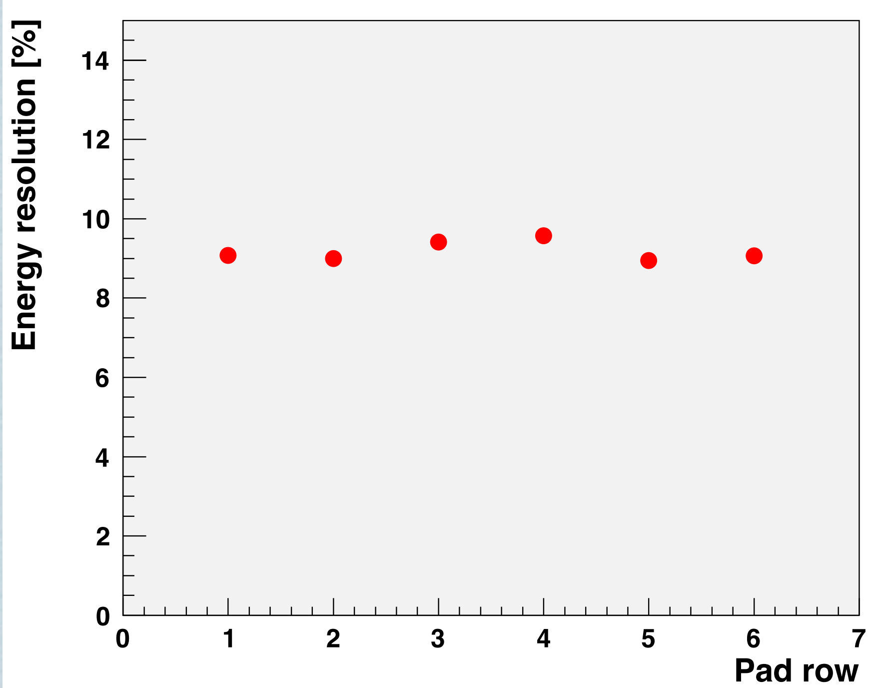




gas gain was varied by changing high voltage supply to GEM
As expected, larger gain (up to 10^3), better resolution.

Energy resolution



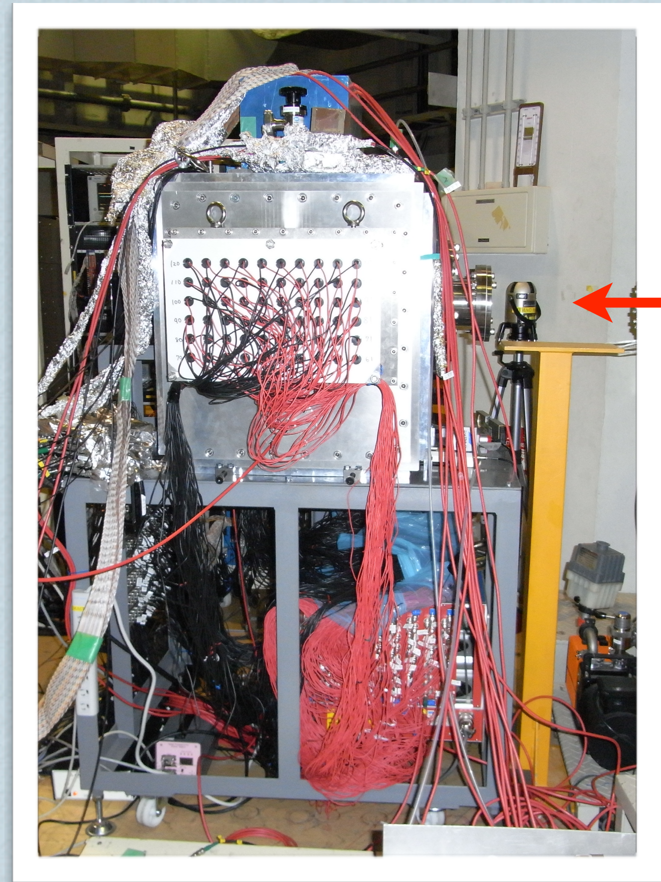


energy resolution ~ 10% (σ) for one row

3.3% (σ) for total (6) rows

Test Exp. in HIMAC (Dec. 2010)

- 56Fe 250MeV/u
- D2+CO2(5%) 1 atm
- double GEM
  - test of whole the system include NaI, trigger, electronics
  - Evaluate delta-ray effect w/ high-Z and high-intensity (1 MHz) beam
  - light ion tracking w/ D2 gas



^{56}Fe

analysis in progress

Outlook

- D_2 (+CO_2) property w/ GEM, especially spark probability
- Optimize pad size/shape and upgrade electronics (V1740+optical readout?)
- Reaction measurement ^{56}Fe, ^{56}Ni(d,d' or 2p) w/ D_2 (HIMAC)
  - Giant monopole and Gamow-Teller strength