CNS Active Target Project

Takashi Hashimoto
CNS, University of Tokyo

Collaborators

CNS active target project core member

T. Hashimoto, S. Ota, H. Yamaguchi, S. Michimasa, T. Gunji, H. Tokieda,
T. Uesaka, H. Hamagaki, S. Kubono

GEM – MSTPC

S. Hayakawa, D. M. Kahl (CNS)
H. Ishiyama, Y. Hirayama, N.Imai, Y. Watanabe, S. C. Jeong,
H. Miyatake (KEK)
K. Yamaguchi, T. Komatsubara (Univ. of Tsukuba)
Y. Mizoi, T. Fukuda (Osaka Electro – Communication Univ.)
T. Yamada, N. Iwasa (Tohoku Univ.)
T. Teranishi (Kyushu Univ.)
S. Cherubini (INFN Catania)

CAT

H. Matsubara, M. Dozono, Y. Kikuchi (CNS)
T. Isobe, H. Otsu (RIKEN)
A. Ozawa, H. Suzuki, D. Nagae, T. Moriguchi, Y. Ito, Y. Ishibashi ,
H. Ohishi, T. Abe (Univ. of Tsukuba)
T. Kawabata (Kyoto Univ.)
Y. Maeda (Miyazaki Univ.)

Collaboration

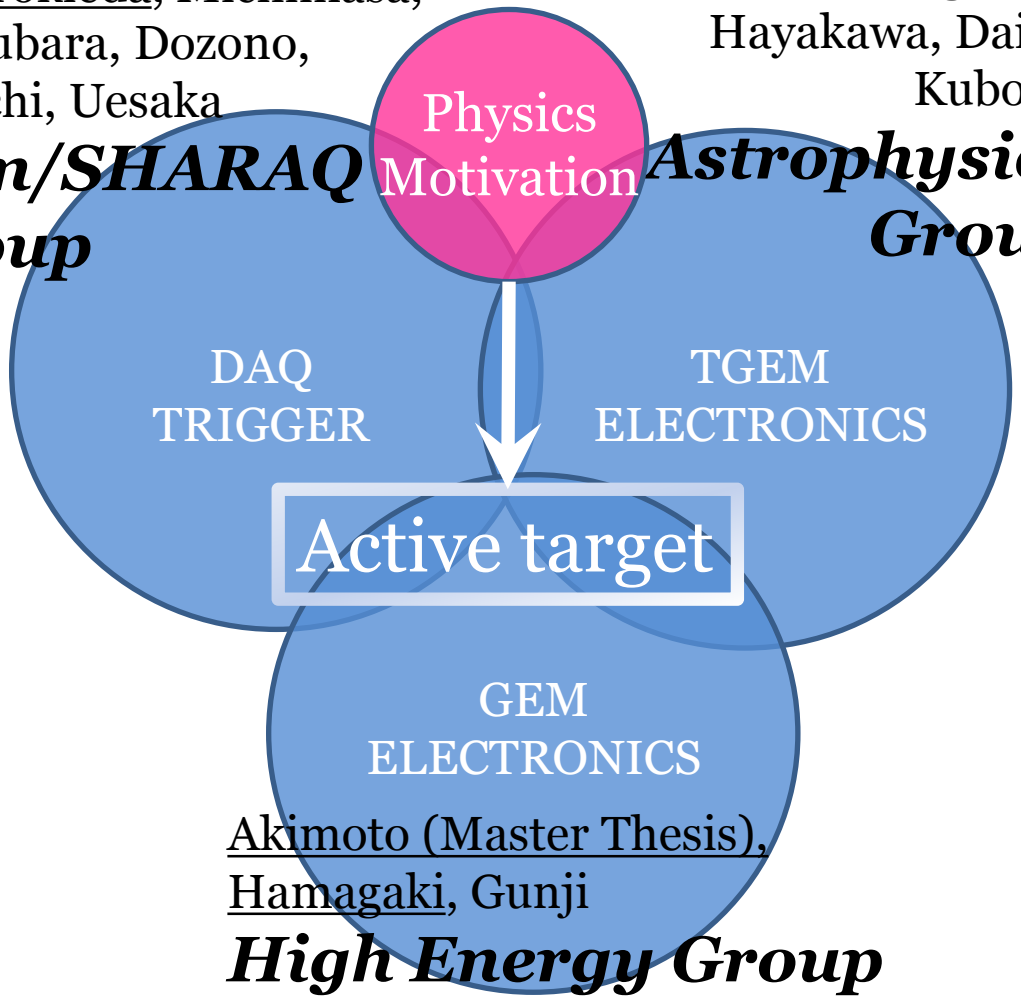
CNS, the University of Tokyo

Ota, Tokieda, Michimasa, Matsubara, Dozono, Kikuchi, Uesaka

Spin/SHARAQ Group

Hashimoto, Yamaguchi, Hayakawa, Daid, Kubono

Astrophysics Group



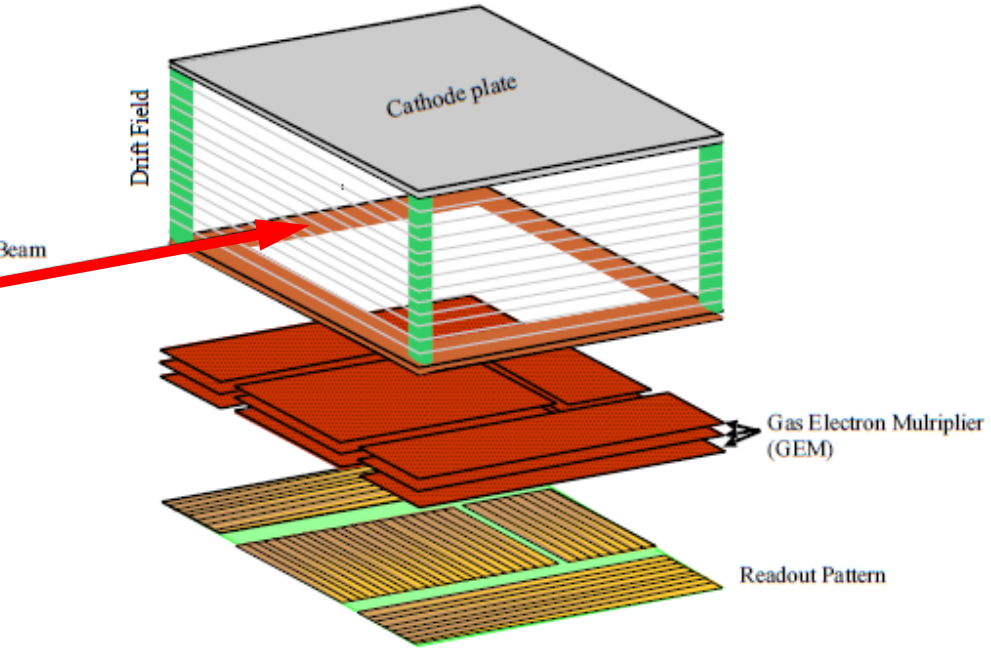
Akimoto (Master Thesis), Hamagaki, Gunji

High Energy Group

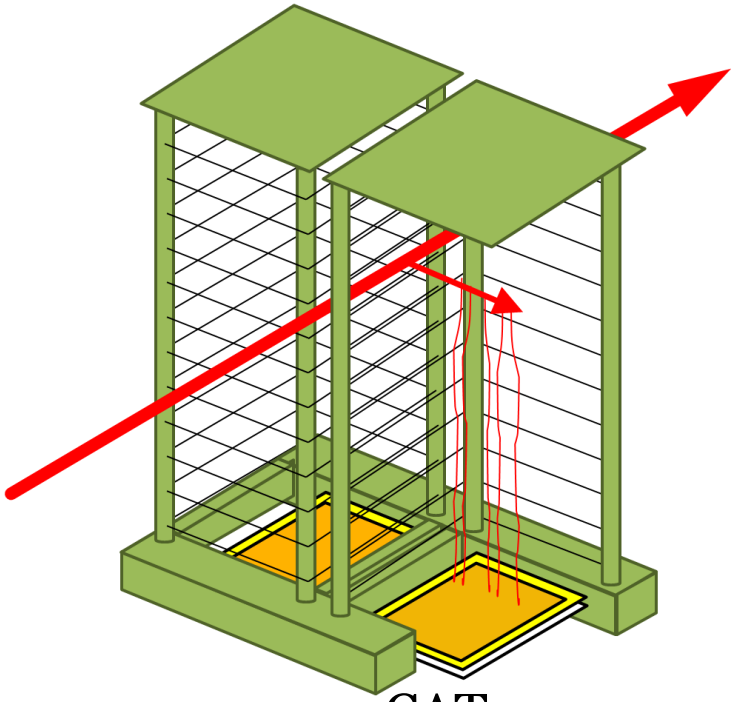
RIKEN
KEK
Kyoto Univ.
Univ. of Tsukuba
Miyazaki Univ.
Tohoku Univ.
Kyushu Univ.
INFN
(Test experiment, Potential users)
MSU
(Technical collaboration about a electron amplifier)

- Direct measurements of the (α, p), (α,n) reactions of astrophysical interest
- (In – beam) decay measurement

- α inelastic scattering for EOS, α cluster structure
- (d, ^{2}He) for GT



GEM – MSTPC



CAT

Two types of Active target are constructed

Left (GEM – MSTPC): A = 1 – 50, E ~ 10 MeV/u, I < 10^6 pps

Right (CAT): A = 50 – 80, E ~ 100 – 300 MeV/u, I = $10^{6\sim7}$ pps

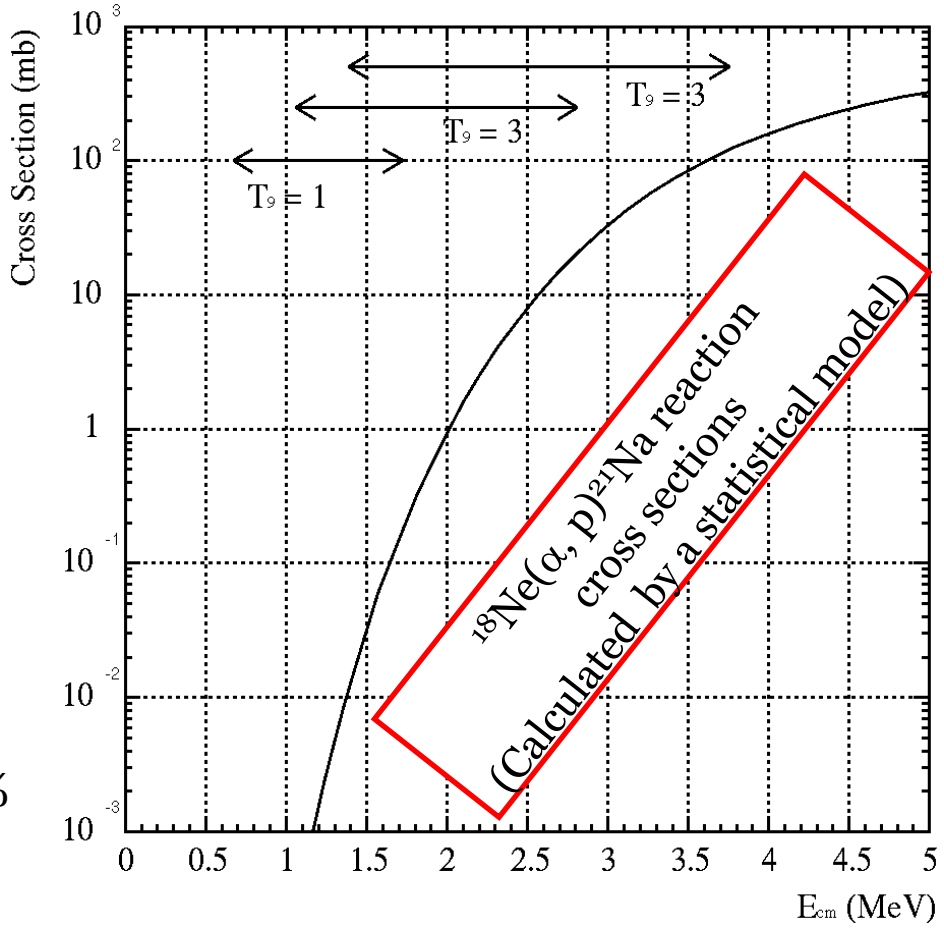
Both can be irradiated with high intensity HI beam

GEM – MSTPC

Multiple – Sampling and Tracking Proportional Chamber with Gas Electron Multiplier

Properties of (α, p) reactions

T = 1 – 3 GK
→ Ecm = 1 – 3 MeV
Estimated cross section
→ less than 1 mb
(in low energy region)



The purpose of experiment is
measurement of the reaction cross section
with a statistical uncertainty better than 20%

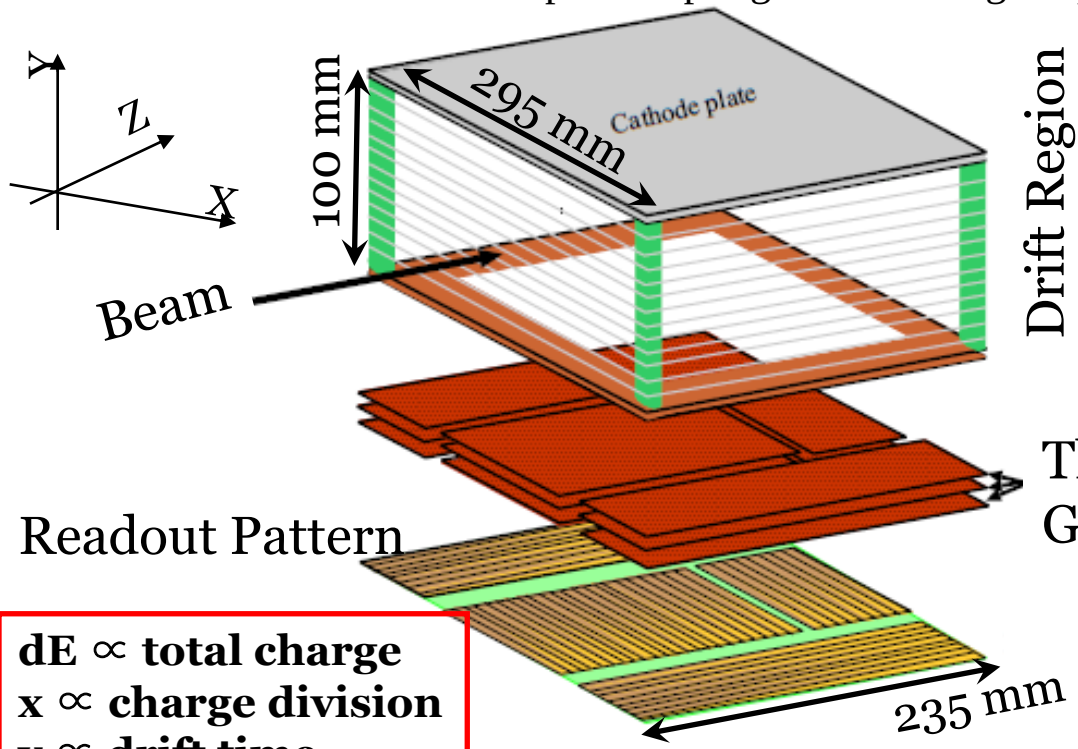
Required conditions for experiments

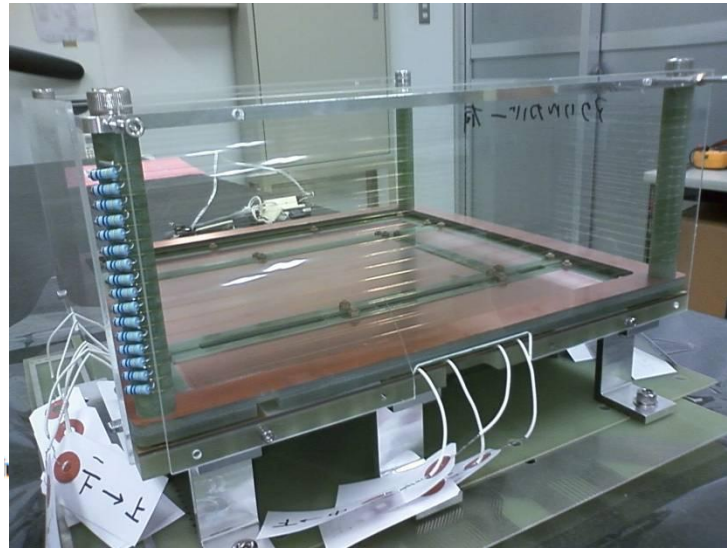
Low energy and high intensity RI beam
E < 4 MeV/u and I > 10^5 pps → RI beam is produced and separated by the CRIB facility

He gas target
Efficient detector system
detection efficiency is
higher than 15%
(including outer detectors)

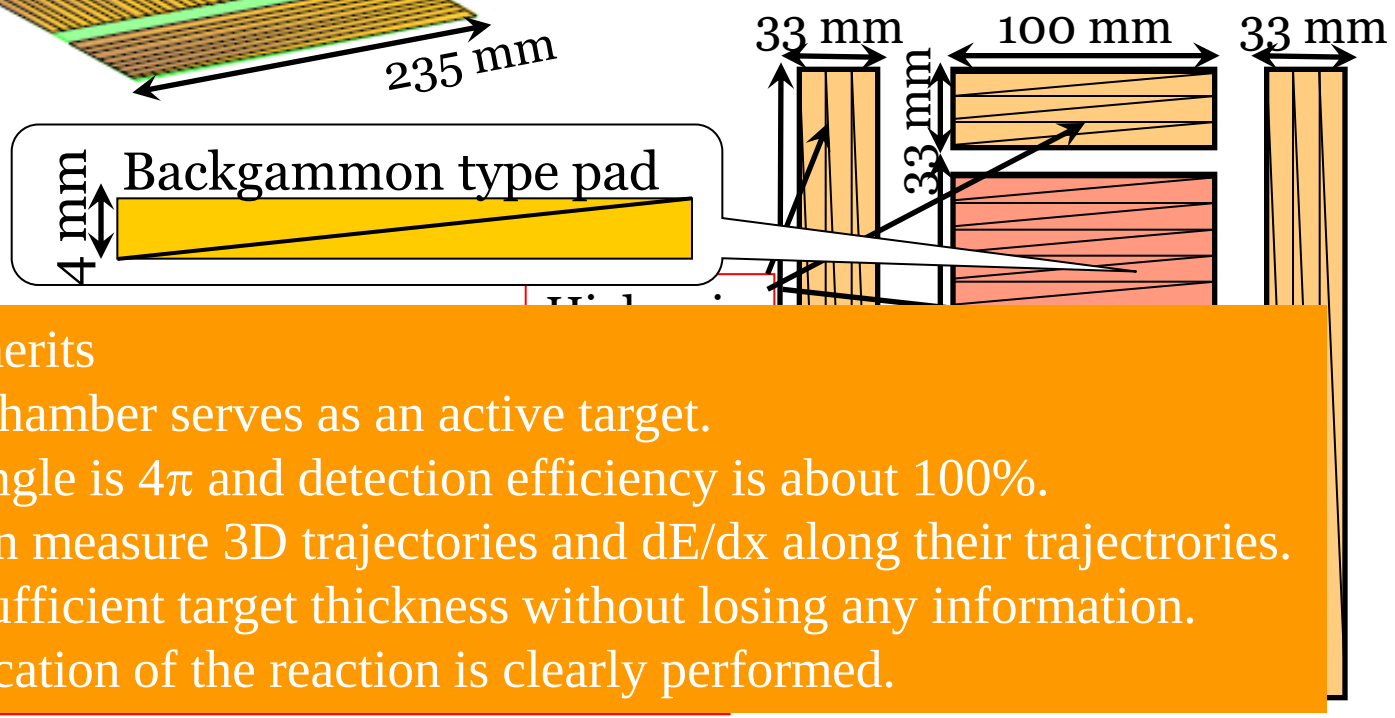
→ An active target detector system is a suitable detector!

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





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



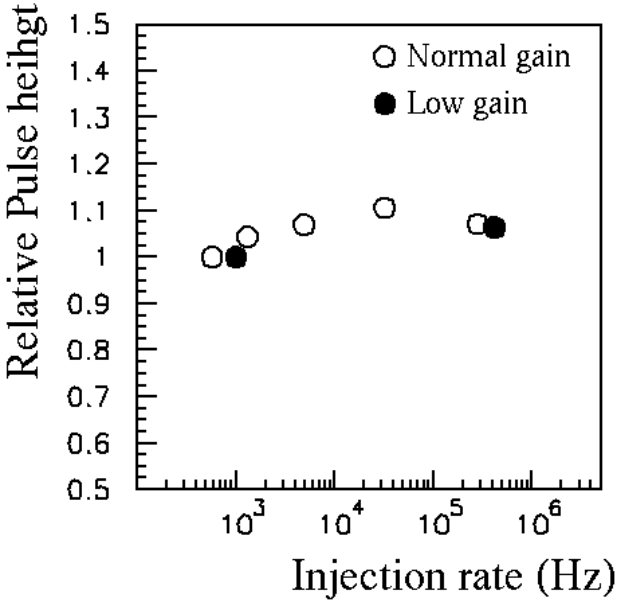
Advantages and merits
1. The gas in the chamber serves as an active target.
-> The solid angle is 4π and detection efficiency is about 100%.
2. The MSTPC can measure 3D trajectories and dE/dx along their trajectrories.
-> It serves a sufficient target thickness without losing any information.
The identification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

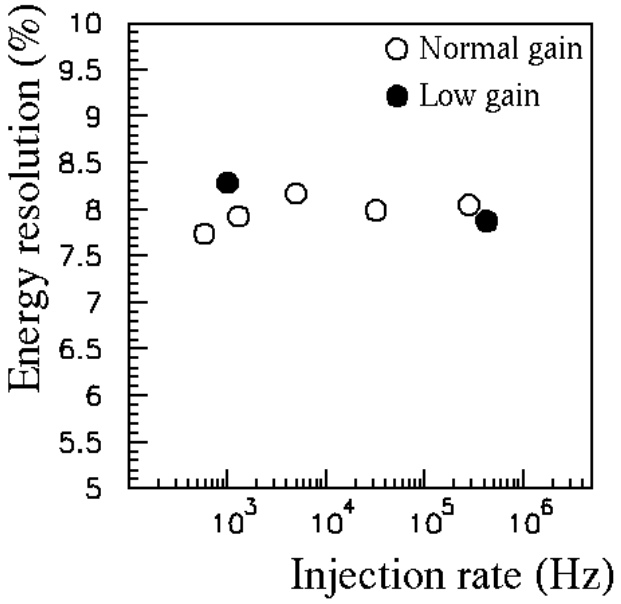
High beam injection rate capability

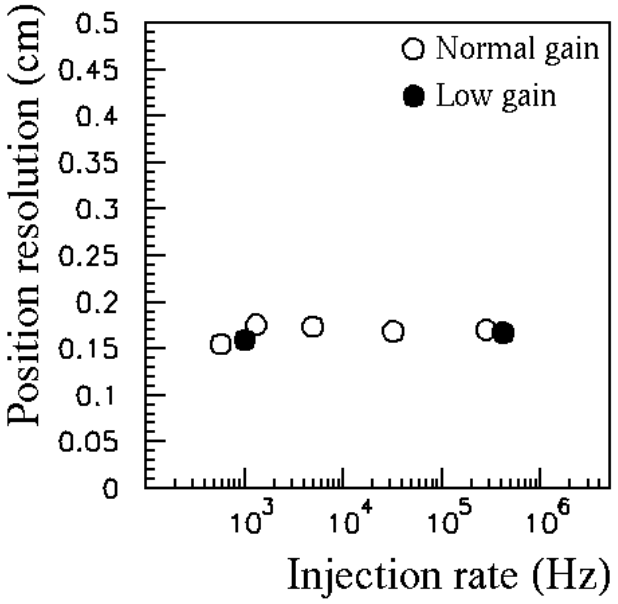
Measurement of the injection beam rate dependence of the detector response

beam : ^{11}B, 6 MeV, 500 pps – 420 kpps、diameter: 1mmφ

Gas: He + CO_2 (10%), 120 torr







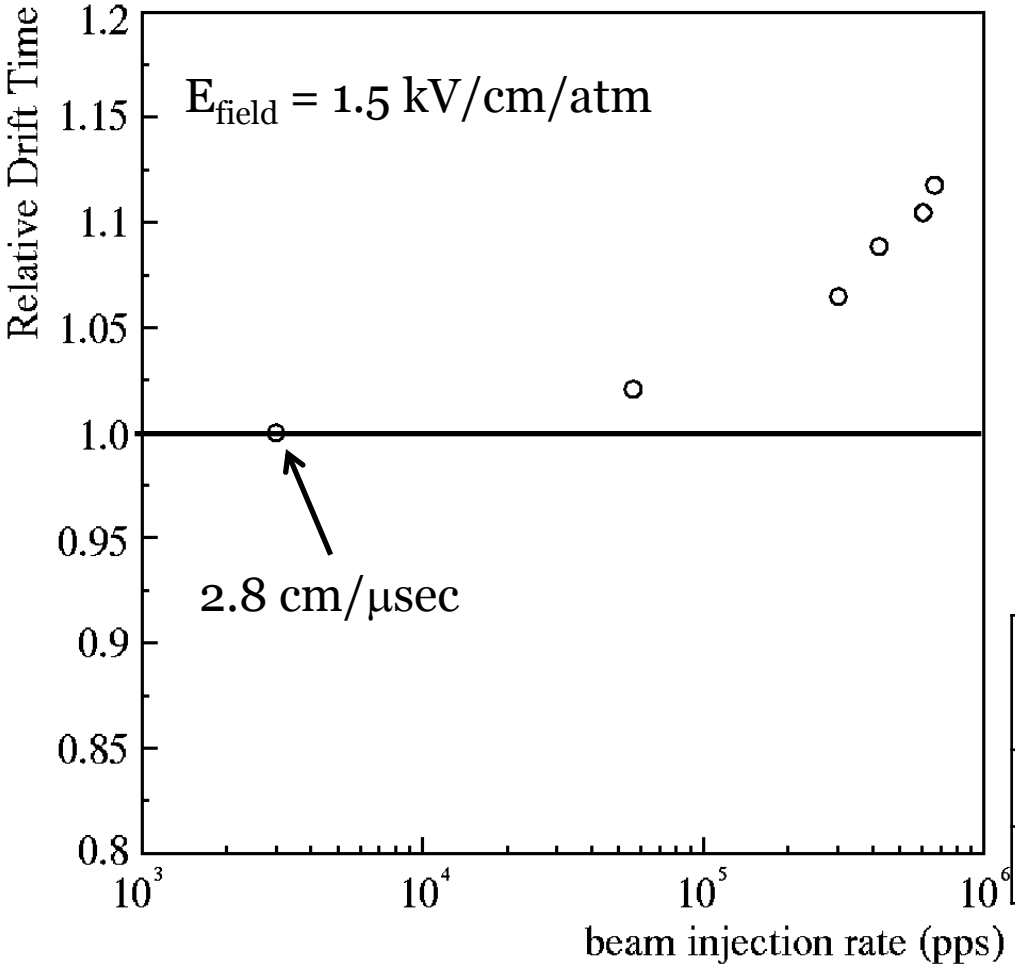
Energy resolution : 8%

position resolution : 1.7 mm

The energy and position resolution do not depend on beam injection rate.

These results satisfied our requirements

Beam injection rate dependence of drift velocity



Drift time becomes longer with beam injection rate.

The field distortion from ionized gas : 1.1 % at 10^6 pps

The reason of this effect is ion feed back.

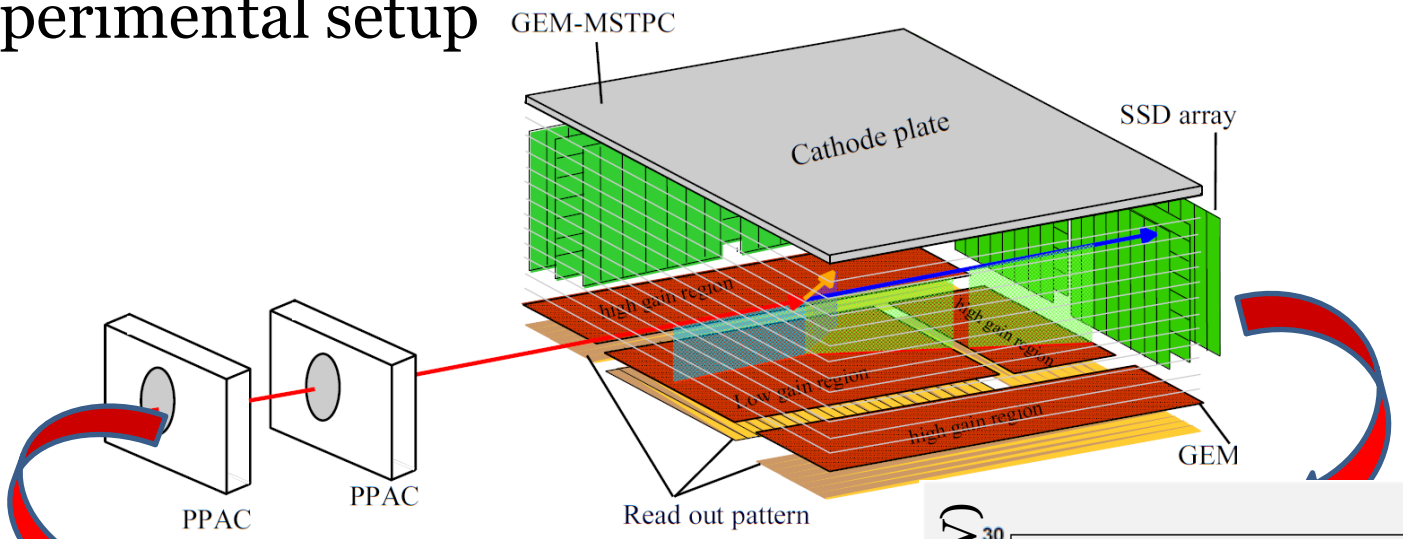
Injection rate (kpps)	Position distortion (mm)
200	2.2
400	3.6

The position distortion of drift direction can be corrected by the beam line detectors

The GEM – MSTPC can be used to our experiment with the satisfied performances

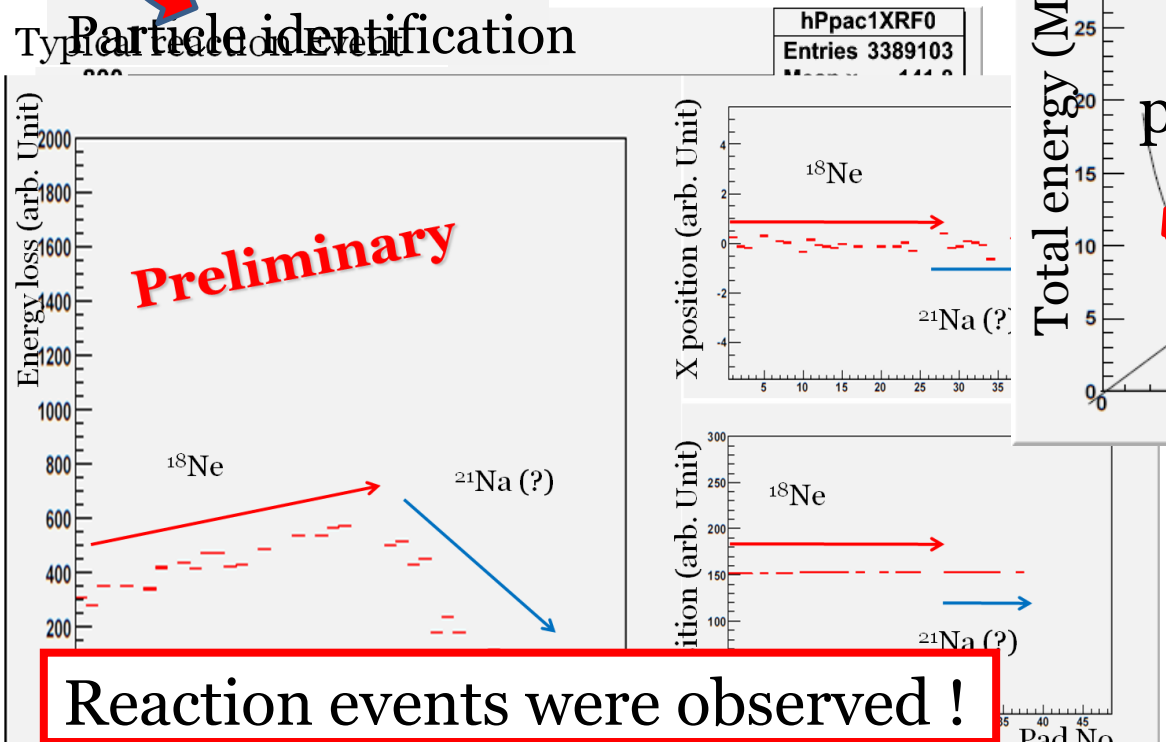
Preliminary results of $^{18}Ne(\alpha, p)^{21}Na$

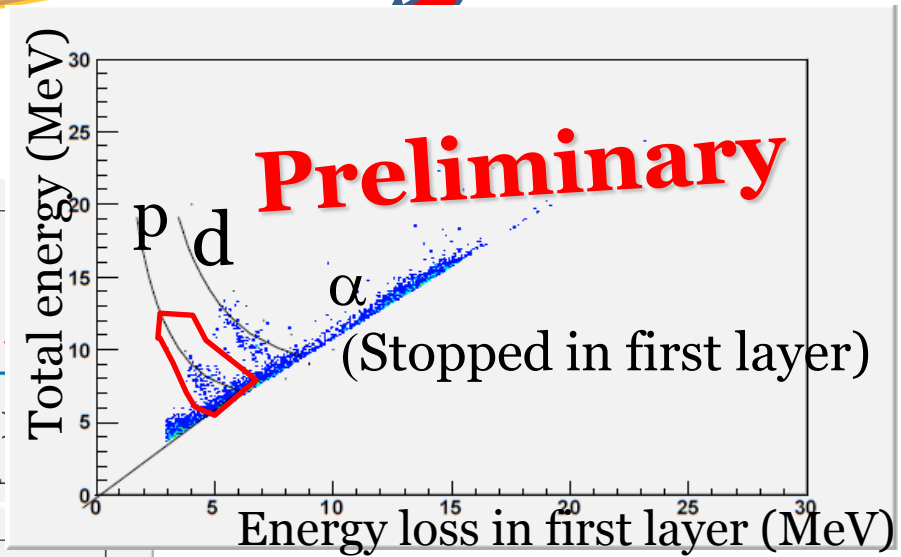
Experimental setup



Particle identification

Typical reaction event





Not all events

Reaction events were observed !

CAT

CNS Active Target

Missing Mass Spectroscopy with RI beams

Nuclear structure
  Inelastic scattering, Gamow – Teller, Transfer …
Giant resonance: Incompressibility
  Isoscaler/Isovector monopole

Spin (S) –Isospin (T) selectivities

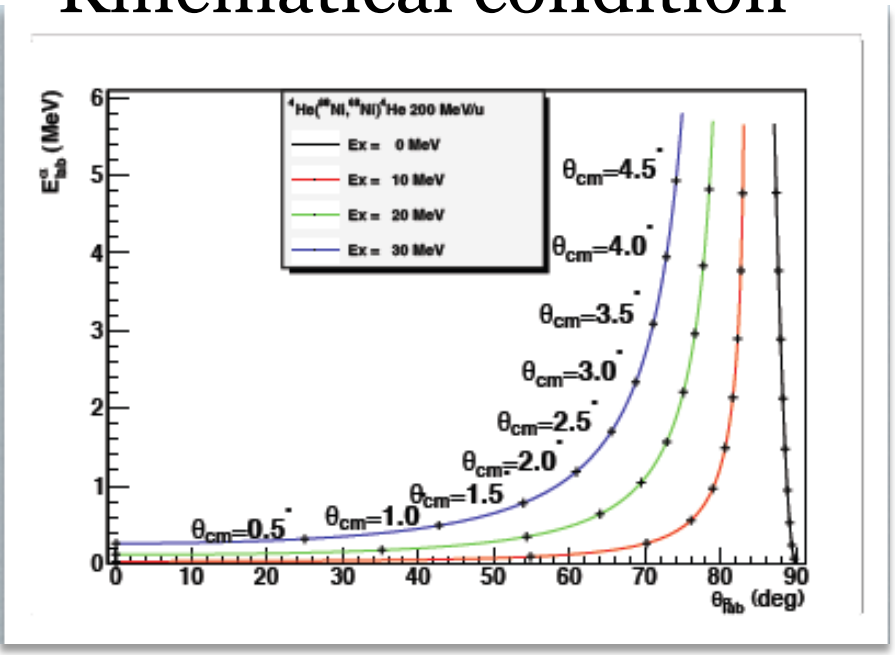
Gamow – Teller: $\Delta L = 0, \Delta S = 1, \Delta T = 1$
Fermi : $\Delta L = 0, \Delta S = 0, \Delta T = 1$
Isoscaler monopole: $\Delta L = 0, \Delta S = 0, \Delta T = 0$

	$\Delta S = 0$	**$\Delta S = 1$**
$\Delta T = 0$	(p,p'), (d,d'), **(α,α')**	(p,p'), (d,d')
$\Delta T = 1$	(p,p'), (p,n), $(^3\mathrm{He},t)$,	(p,p'), (p,n), $(^3\mathrm{He},\mathrm{t})$, **$(d,^2\mathrm{He})$**

(d, ^{2}He) reaction to extract β^+ strength in the pf – shell region
α inelastic scattering to pin down monopole strengths

in *inverse kinematics*

Kinematical condition



^{4}He(^{56}Ni, ^{56}Ni)^{4}He @ 200 MeV/u

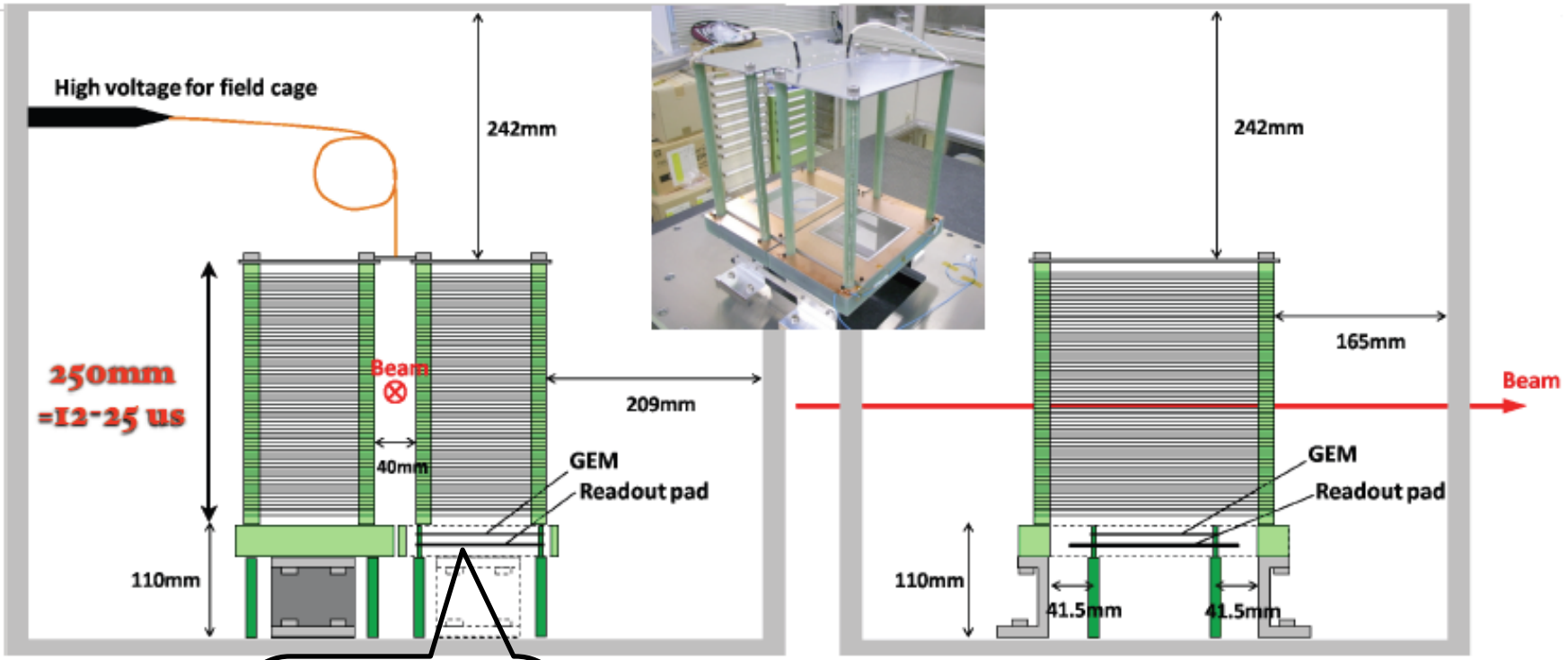
- Recoil angle is large enough to measure.
- Recoil energy is very low, less than 1 MeV for forward angle scattering

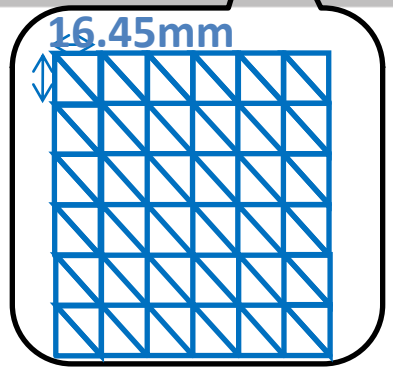
An " active" target is needed to measure the forward angle scattering!

Requirements
High beam injection capability: >10^6 pps
Angler resolution : < 7.5 mrad
→ Position resolution: < 1 mm
Energy resolution : <10%

In order to achieve these requirements, space charge effect has to be removed **as possible**

CAT CNS Active Target





Beam area is inactive region

→ No gas multiplication

→ No ion feed back

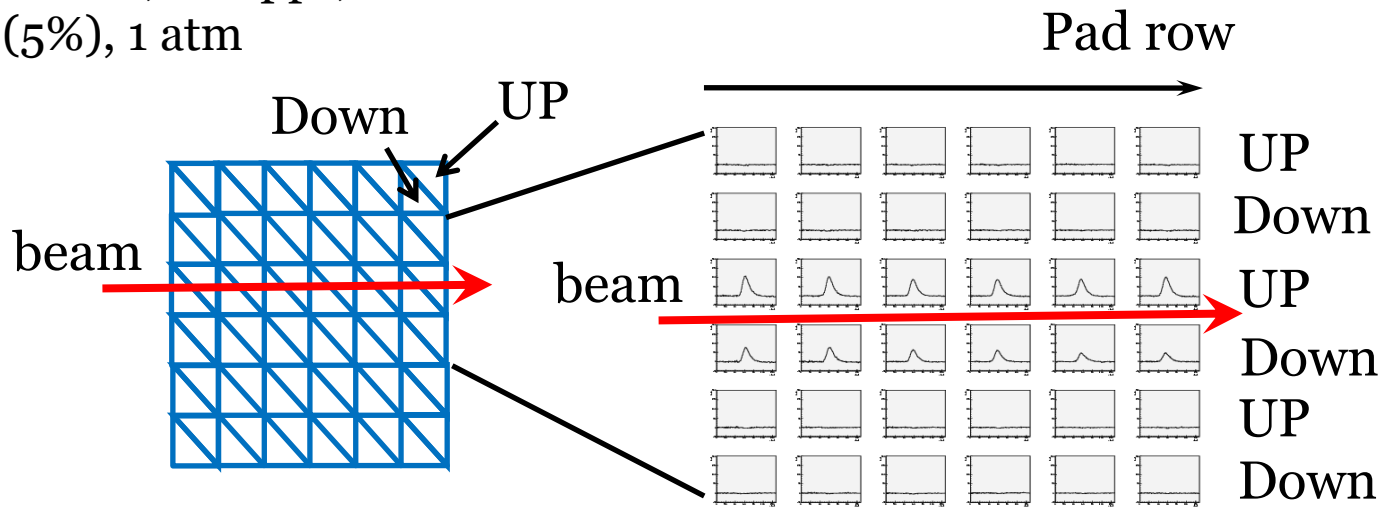
→ The drift field uniformity is kept

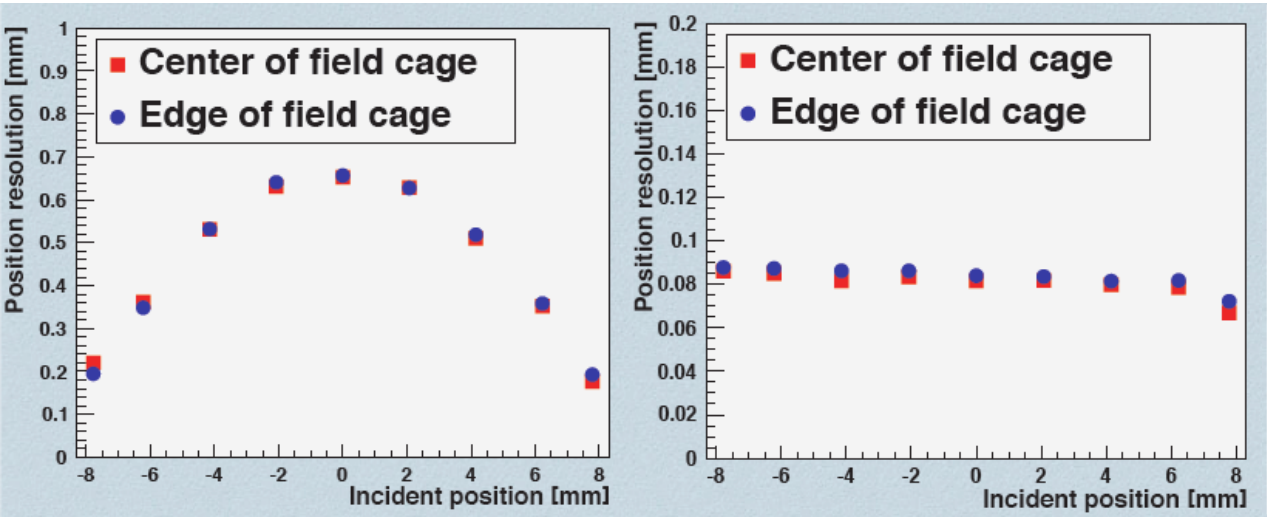
dE ∝ total charge
Horizontal position ∝ charge division
Vertical position ∝ drift time

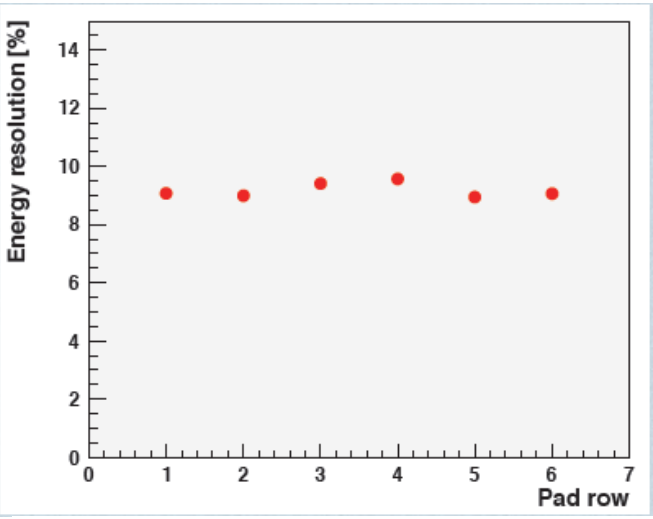
The CAT needs external monitor to measure the beam like particles

Basic performances of CAT

At 12UD Tandem accelerator of Univ. of Tsukuba
Beam : ^{4}He, 30 MeV, 100 pps, diameter: 1mmφ
Gas: He +CO_2 (5%), 1 atm







Less than 700 μm

Less than 100 μm

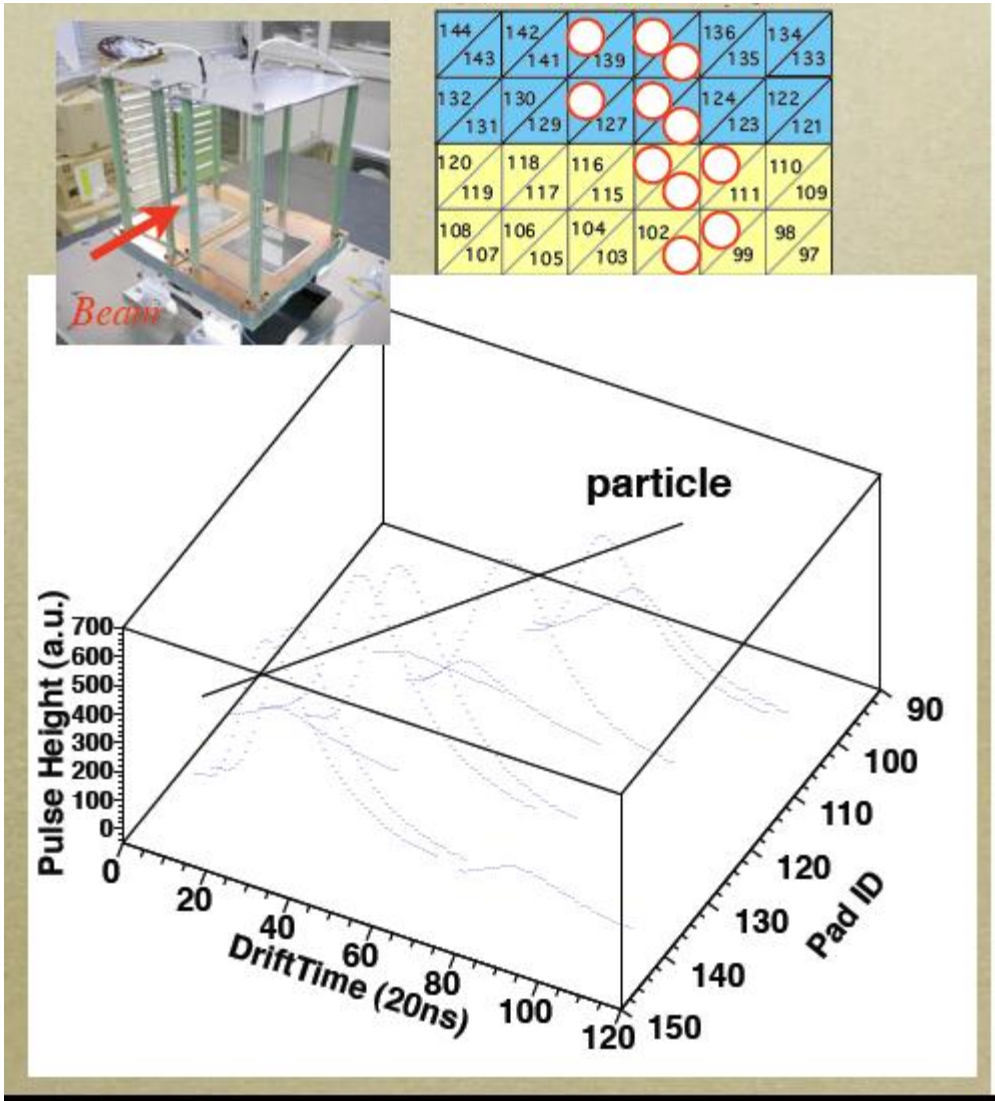
Energy resolution 9%

Beam test w/ d_2 + CO_2 (5%) at HIMAC

Heavy **I**on **M**edical **A**ccelerator in **C**hiba

Beam: ^{56}Fe, 250 MeV/u
Gas: d_2 + CO_2 (5%), 1 atm

- GEMs were operated online w/ d_2 gas for the first time
- CAT worked with 10^6 pps HI beam irradiated between the cages
- Particle tracks were observed successfully (even though the particle may not be light particle)



Summary

We constructed two types active target detectors.

Basic performances

	GEM - MSTPC	CAT
Beam	active	inactive
Electron amplifier	TGEM	GEM
Position resolution (mm)	1.7 mm (x), 2.2 mm (y, distortion), 4.2 mm (z, pad size)	0.7 mm (x, z. 16.45 mm step), 0.1 mm (y)
Energy resolution (%)	8%	9%
beam injection capability (pps)	$< 10^6$	$>10^6$
Merit and demerit	All charged particles can be measured The position resolutions are worse than the CAT	Good position resolutions It needs external monitor to measure beam like particles

Both can be irradiated with high intensity HI beam

Present status

GEM – MSTPC

The measurement of $^{18}Ne(\alpha, p)^{21}Na$ reaction have been performed.
The experiment have been finished successfully.
→Reaction events are observed.

CAT

It worked with 10^6 pps HI beam irradiated between the cages.

Precise analysis of these experiments is in progress.

In the next FY

GEM – MSTPC

Measurement of the β – delayed α decay of ^{16}N will be performed.
(after a gating grid system installation.)

CAT

Measurement of the $d(^{56}Ni, ^{56}Co)^2He$ reaction will be performed.
It is first physics run of the CAT