Development of a GEM-TPC for H-dibaryon Search Experiment at J-PARC

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for J-PARC E42/E45 Collaboration

Outline

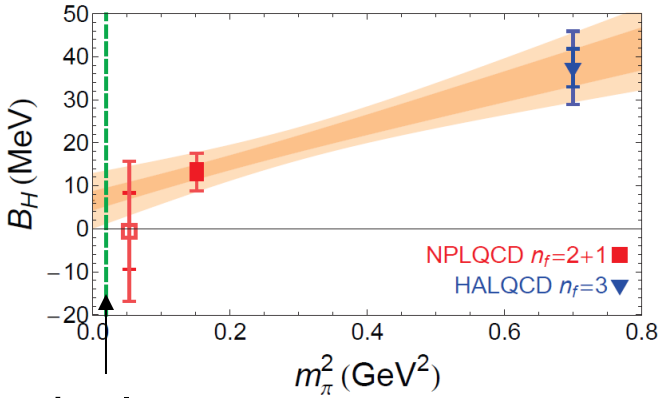
- Introduction
- HypTPC design
- Prototype tests
- Summary

Search for H-dibaryon

Most stable and compact 6-quark state (*uuddss*)

Lattice-QCD calculations

- Binding energy : -13 ~ +7 MeV
- H may be slightly bound or unbound



Physical π mass

Experimental search

- Peaks observed

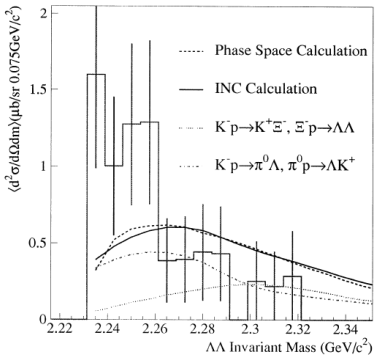
by KEK-E224, E522

around ΛΛ mass threshold

- Indication of H?
- Statistics not enough

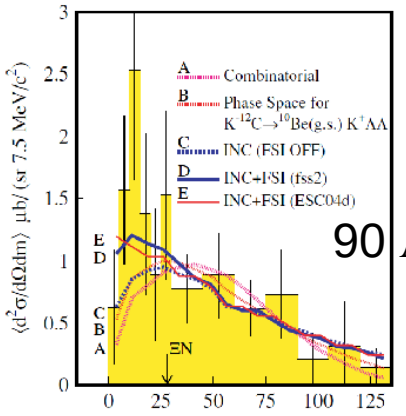
High statistics experiment at J-PARC

KEK-E224



m-2m$_\Lambda$(MeV/c^2)

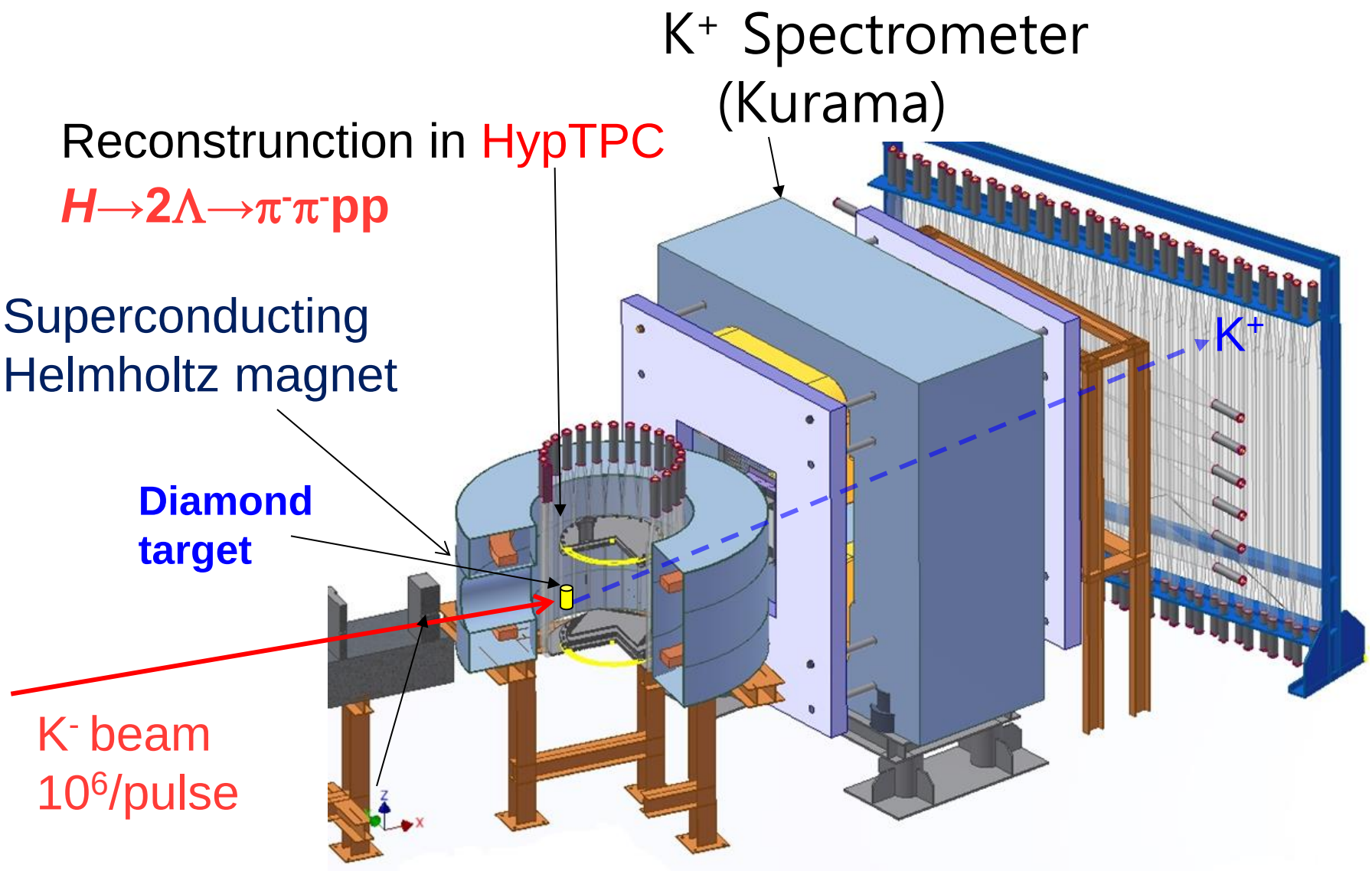
KEK-E522



m-2m$_\Lambda$(MeV/c^2)

J-PARC E42

Search for H-dibaryon in $^{12}C(K^-,K^+)X$ at 1.6 GeV/c



Required performance of HypTPC

- Maximize acceptance for H decay event
  - Target inside TPC
  - Inject 10^6 cps/cm^2 K^- beams directly into drift volume

  →Strong suppression of positive-ion feedback required

  GEM

  Gating grid

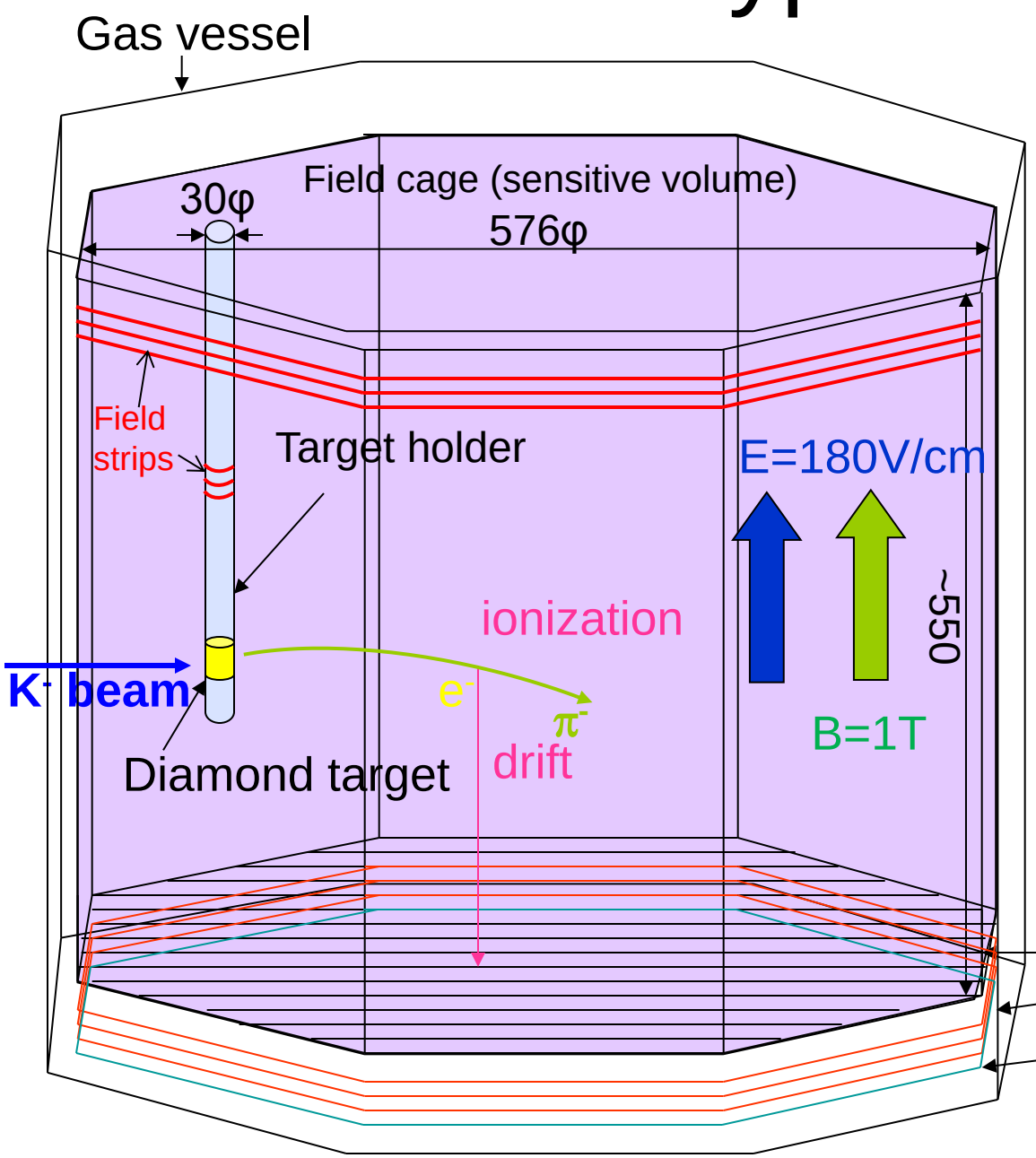
- High position resolutions
  - 1-2 MeV/c^2 $\Lambda\Lambda$ invariant mass resolutions

  → 300μm position resolutions

  →Dipole magnetic field (~1T) parallel to the drift field

  Small pad size (a few mm)

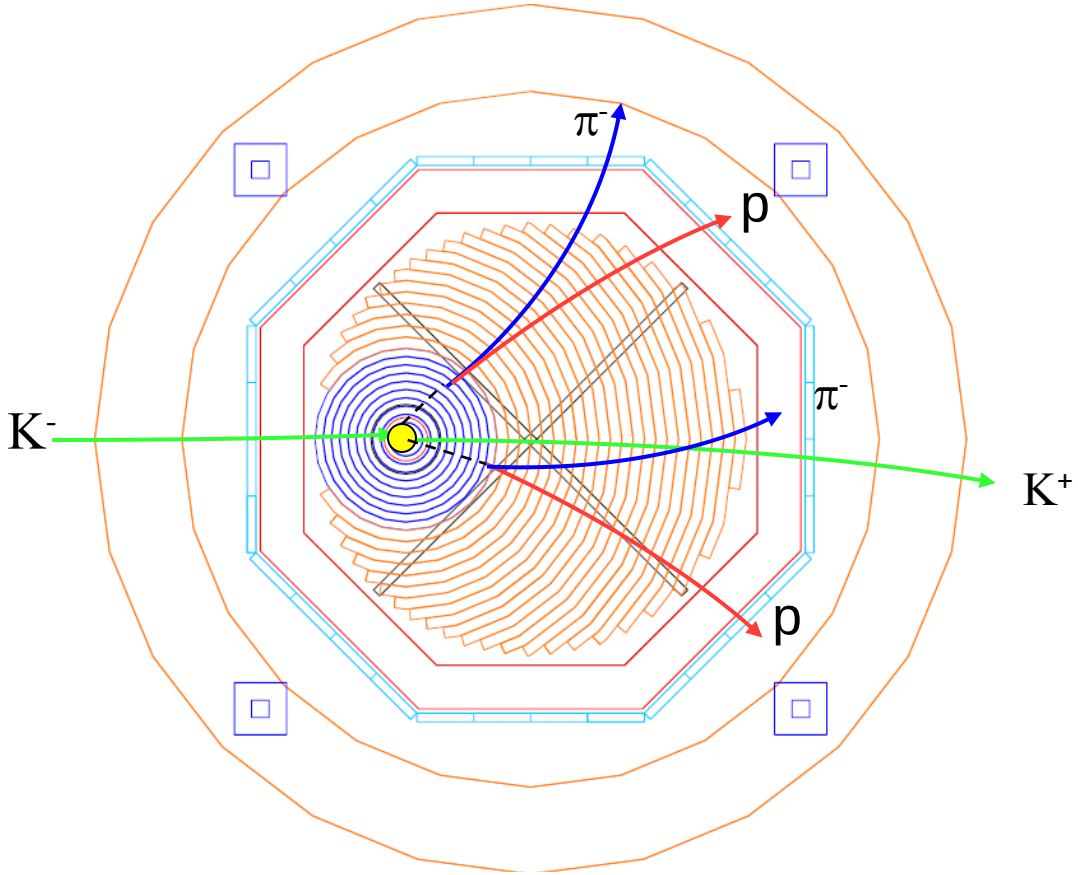
HypTPC



- Octagonal prism shape field cage
  576(ϕ) x550(h)
- Cylindrical target holder with field strips
- Gas
  P-10 (Ar-CH_4(90:10))
- Vertical magnetic and drift field
- Gating grid + GEM + pad plane in the bottom

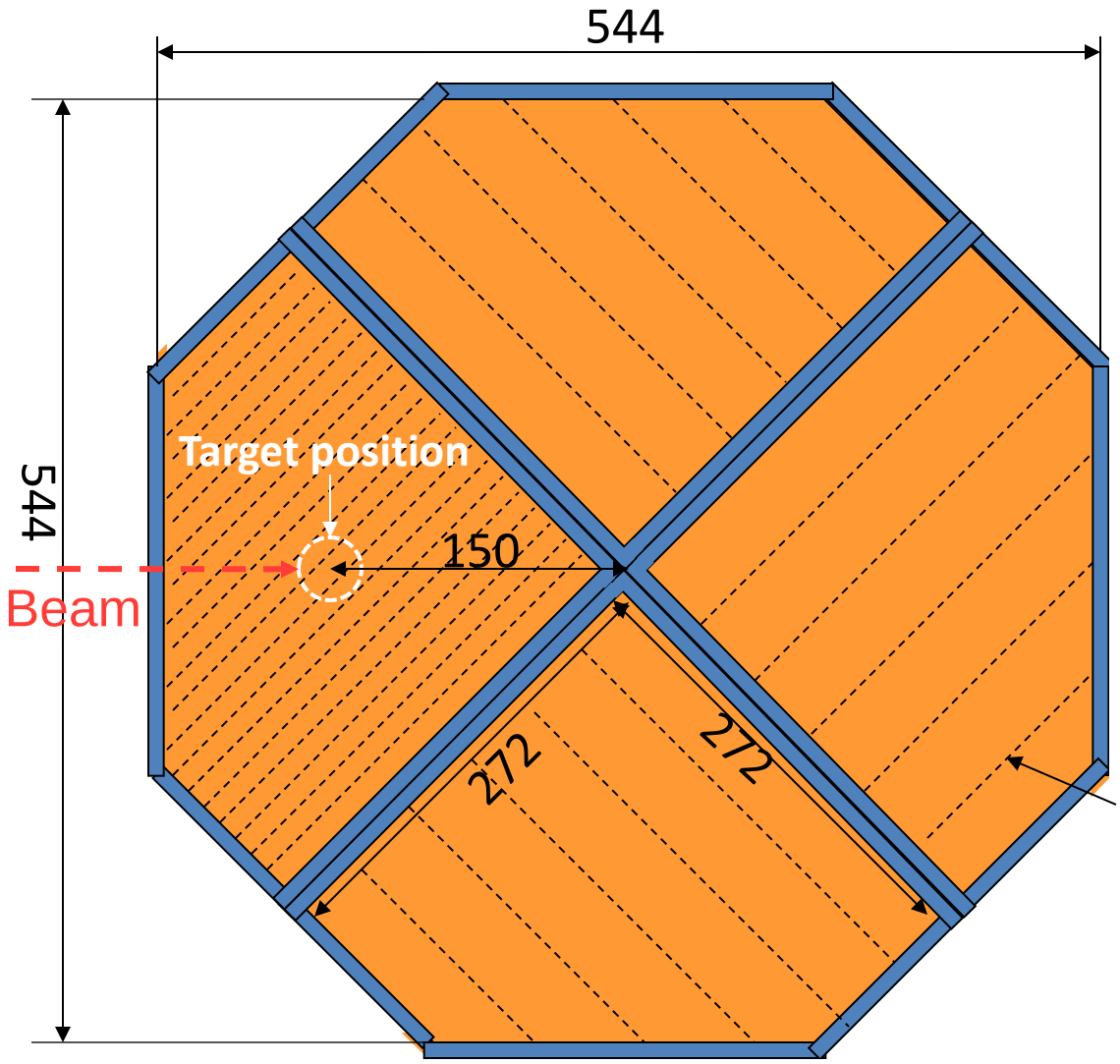
H-dibaryon decay event

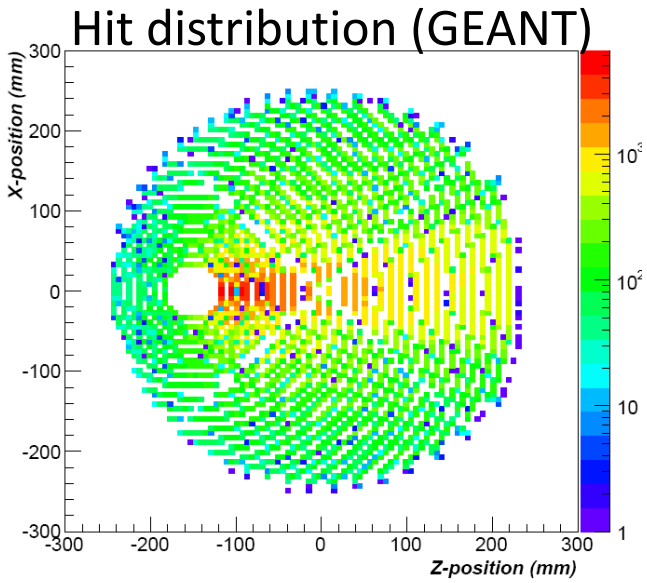
Top view of TPC



GEM configuration

- 4 GEMs (277x277mm^2)
- 3-layer GEM (50μm+50μm+100μm)



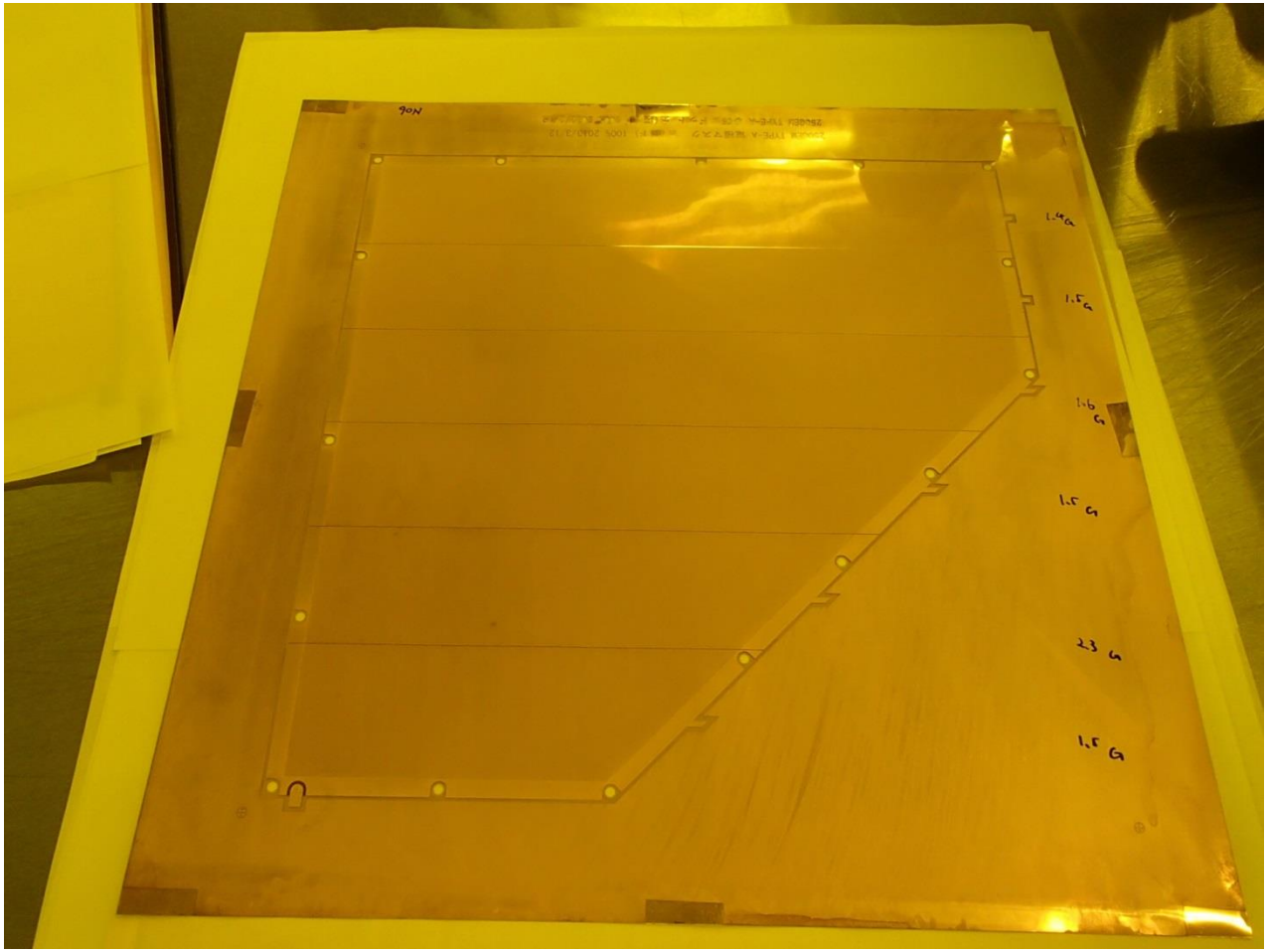


Electrode division

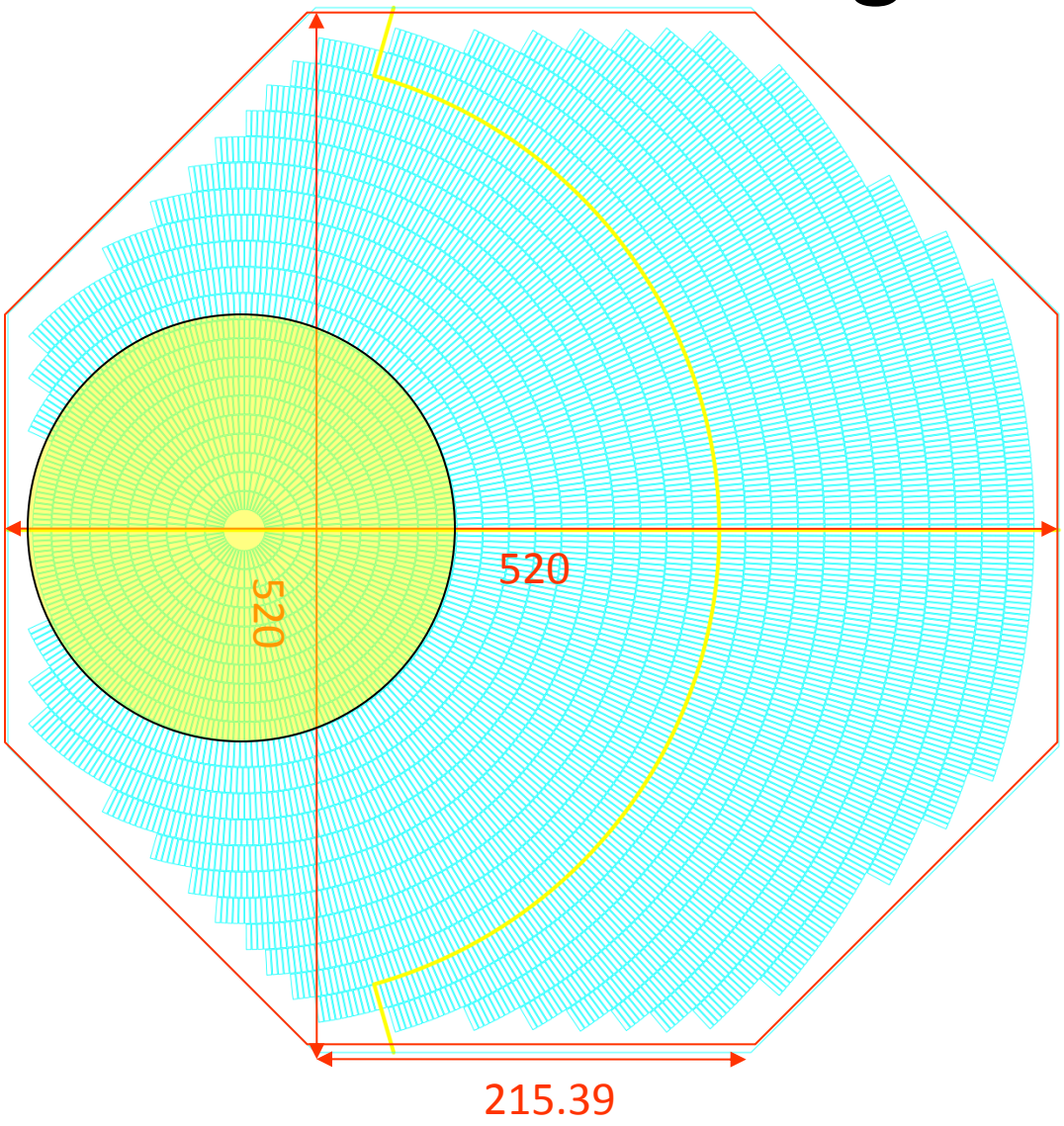
- 12.5 mm width (20 div.) 1 sheet
- 41mm width (6 div.) 3 sheets

- Suppress discharge rate
- Minimize acceptance reduction in case an electrode is broken

GEM



Pad configuration



- Inner planes (rings)

2.1~2.7x9mm^2

#plane=10

- Outer planes (rings)

2.3~2.4x12.5mm^2

#plane=22

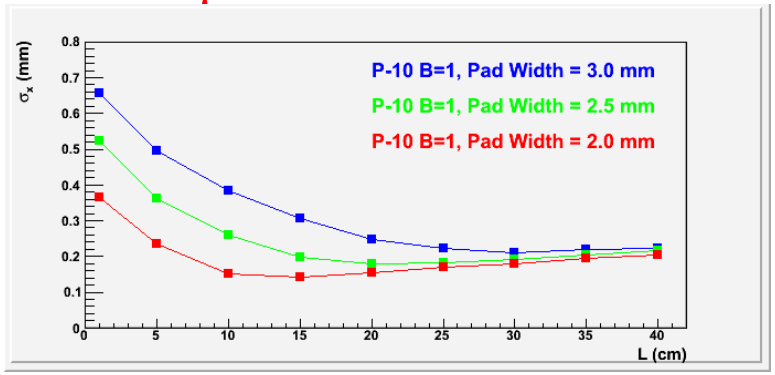
Total #pad 5768

Average charge sharing

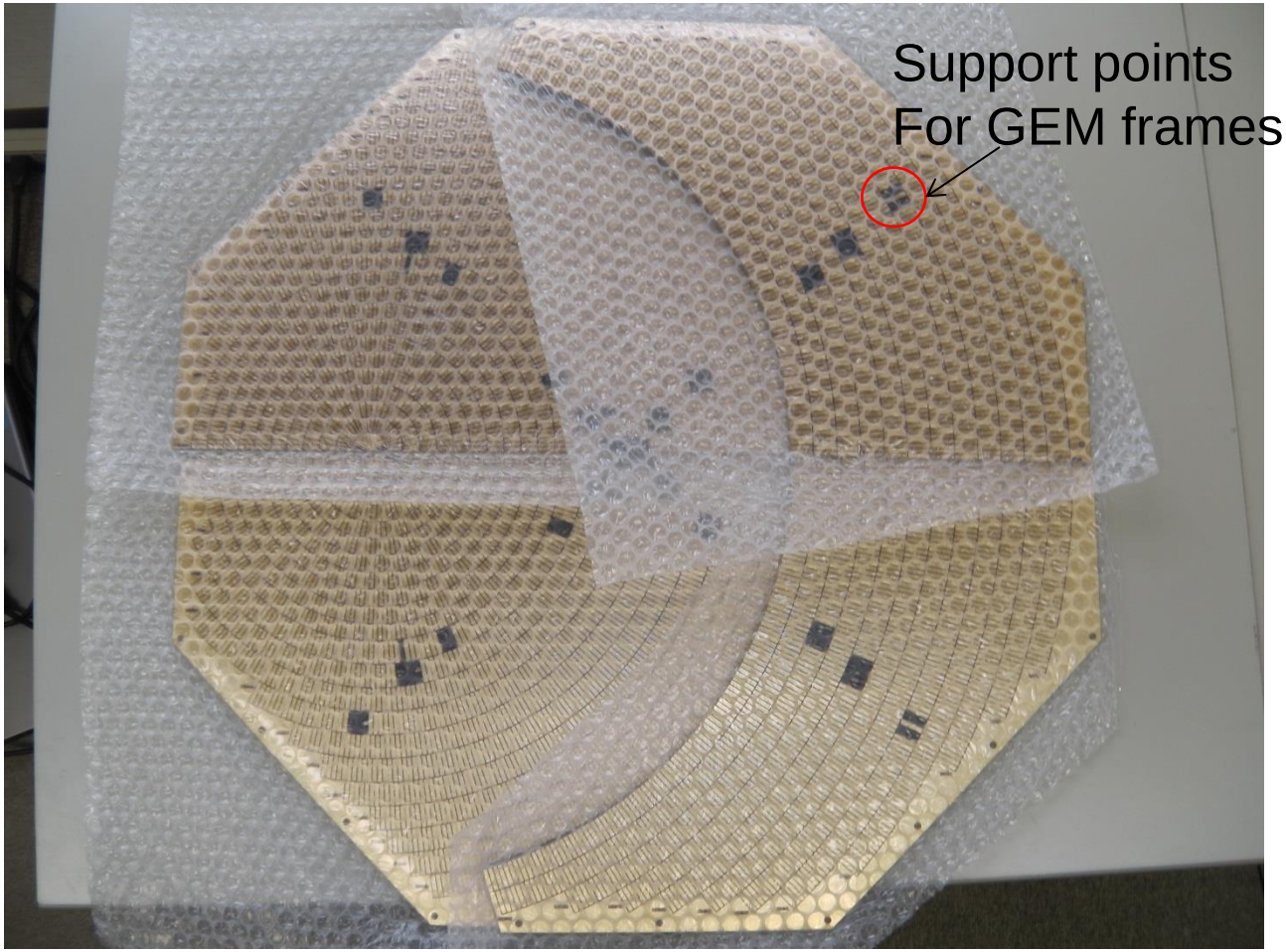
~ 3 pads / hit

Horizontal position resolution at B=1T

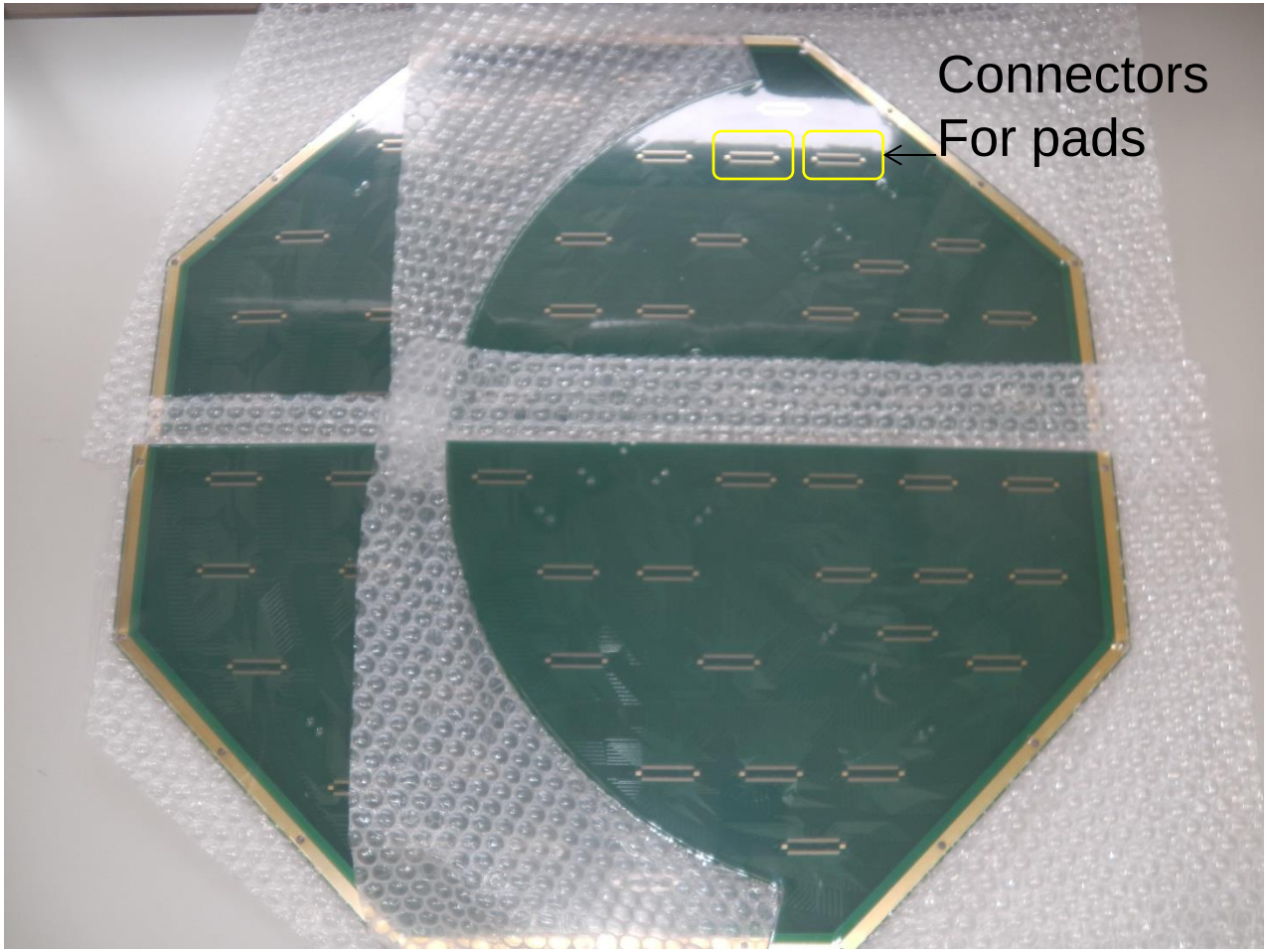
< 300μm



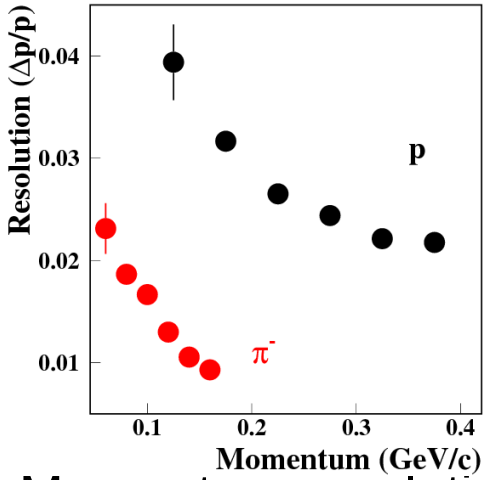
Pad plane



Pad plane (back side)



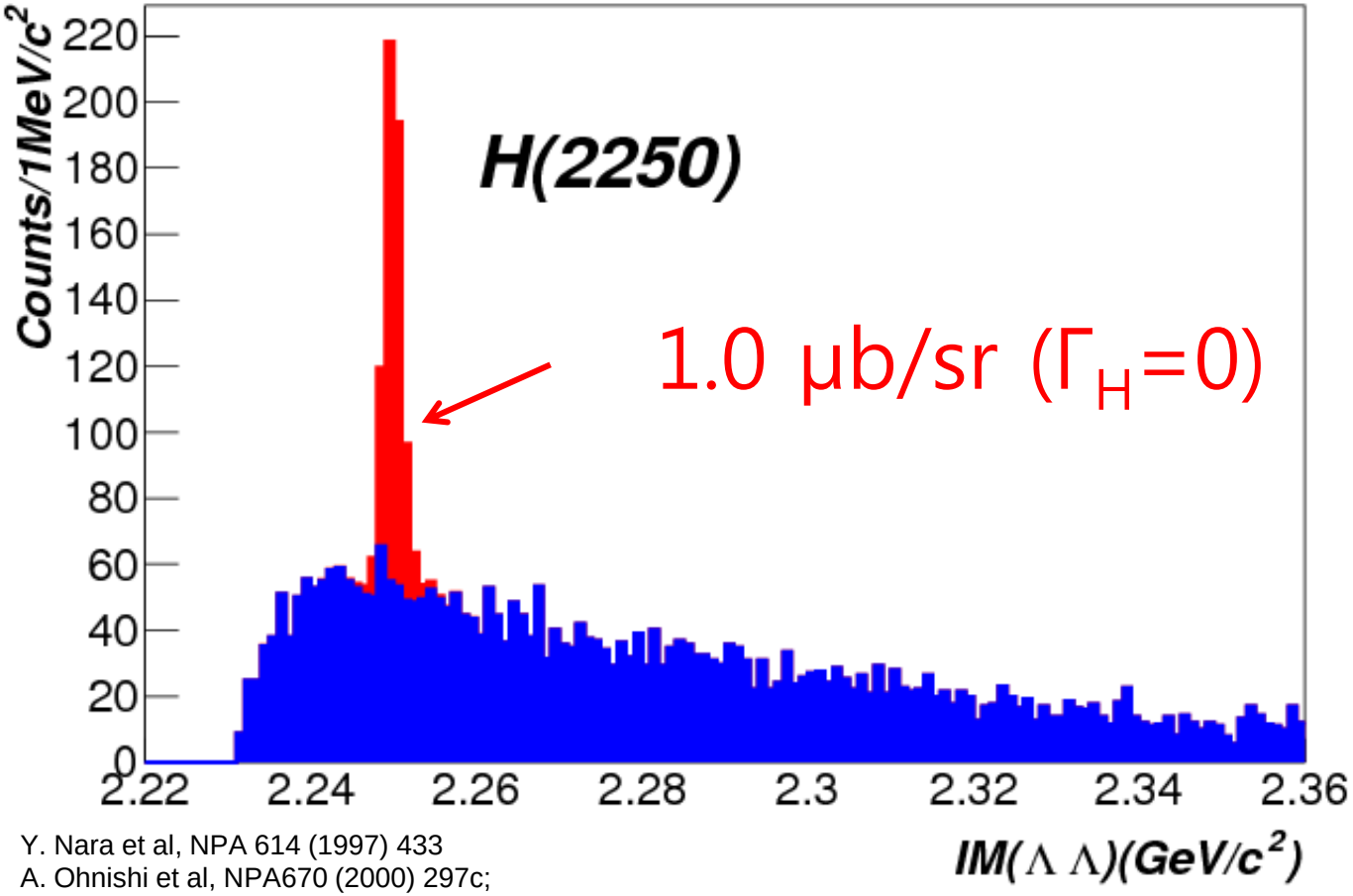
Simulated H-dibaryon mass spectrum



Momentum resolution
π : 0.8-2.3%
p : 2.2-4.0%

Invariant mass resolution
~1.5 MeV/c^2

11000 ΛΛ events
and 1440 H-dibaryons
in 33-day experiment



Y. Nara et al, NPA 614 (1997) 433
A. Ohnishi et al, NPA670 (2000) 297c;
Few-body Syst. Suppl. 12 (2000) 367;
NPA684(2001),595;NPA691(2001) 242c.

J.K. Ahn PAC meeting, Jul. 2012

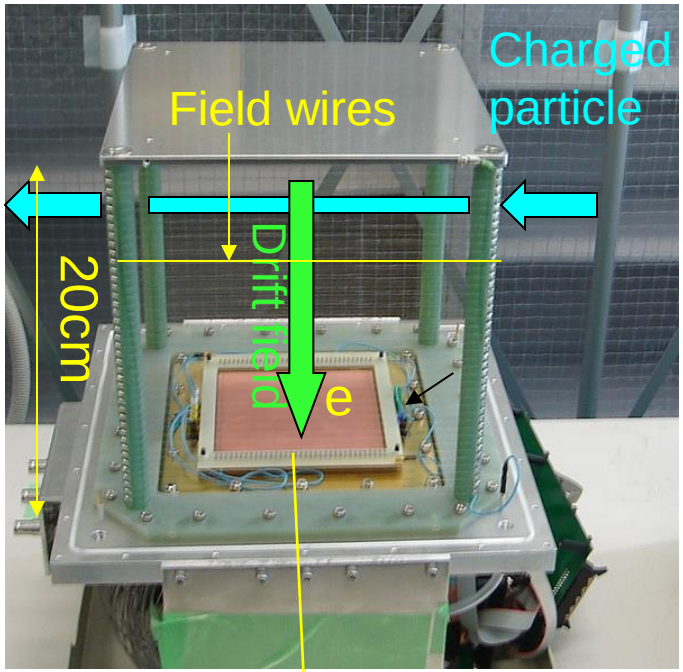
TPC prototype

Small TPC

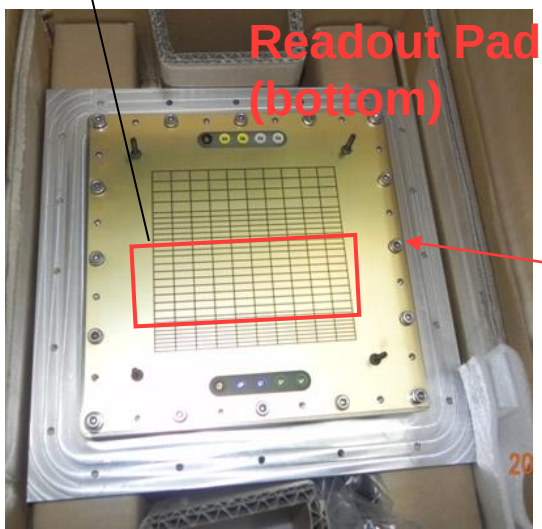
- 100mmx100mm GEM
- 200mm drift length

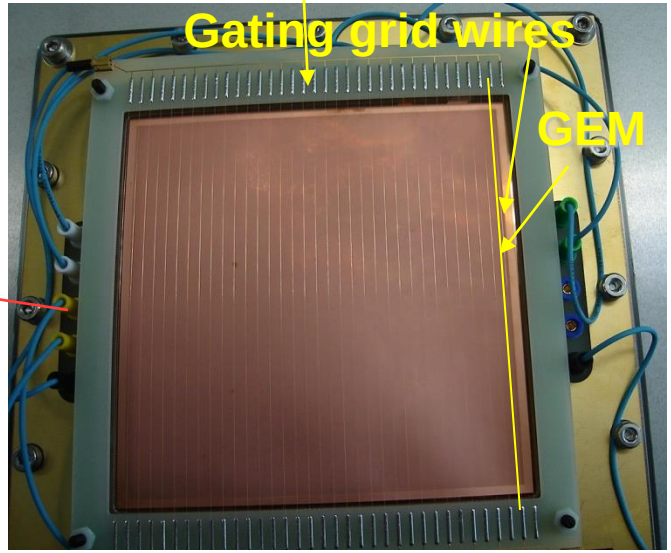
- Gating grid wires
- 3-layer GEM
- Readout pads (4mmx10mm)
- Gas

P-10



Pad size 4mm x 10mm

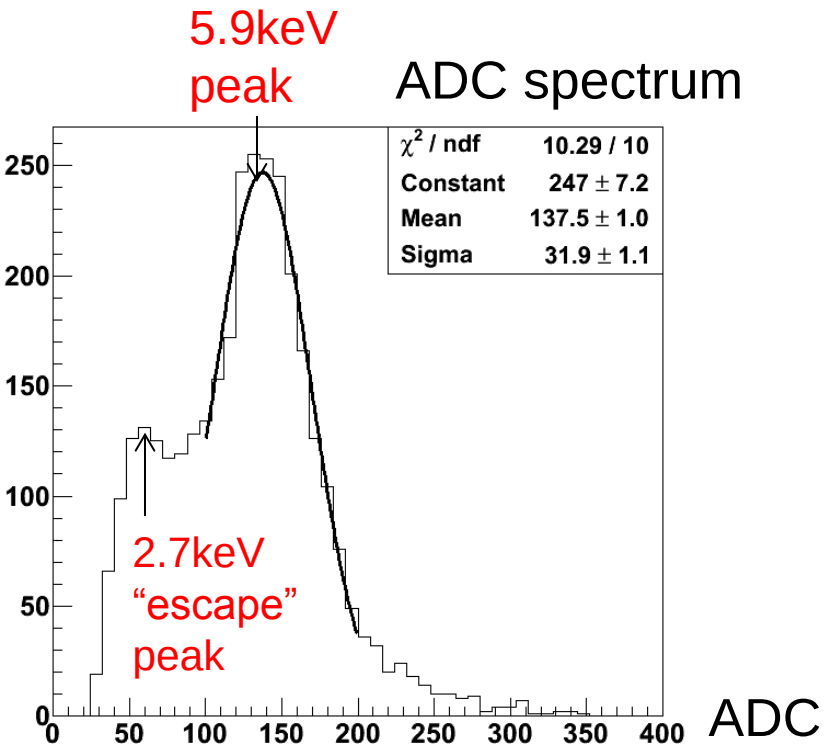




Source tests in Lab

^{55}Fe Test

Ar-CF_4(95:5)
V_{GEM}(50μm)=350V

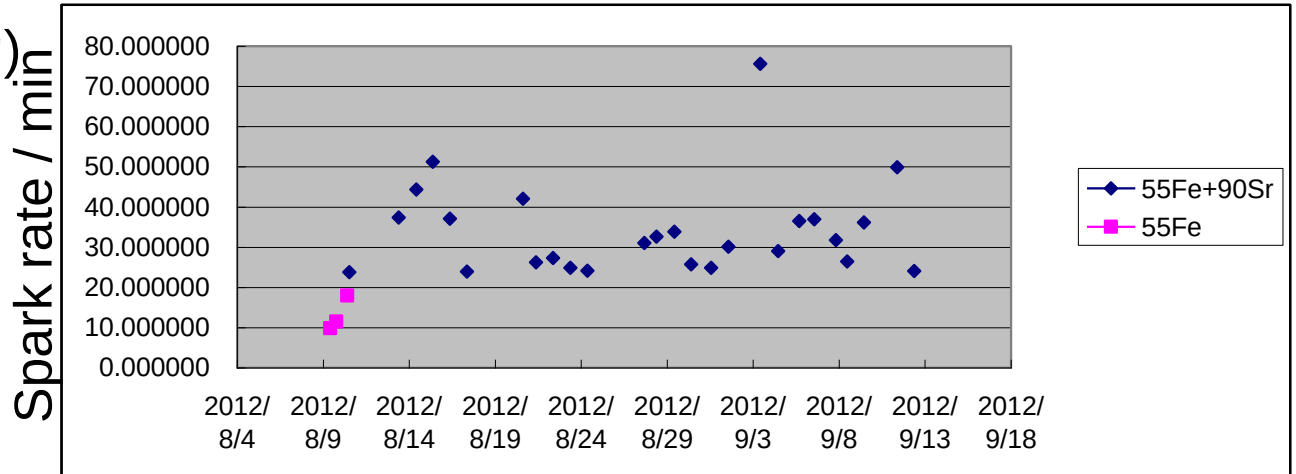


Long-term HV test of GEMs

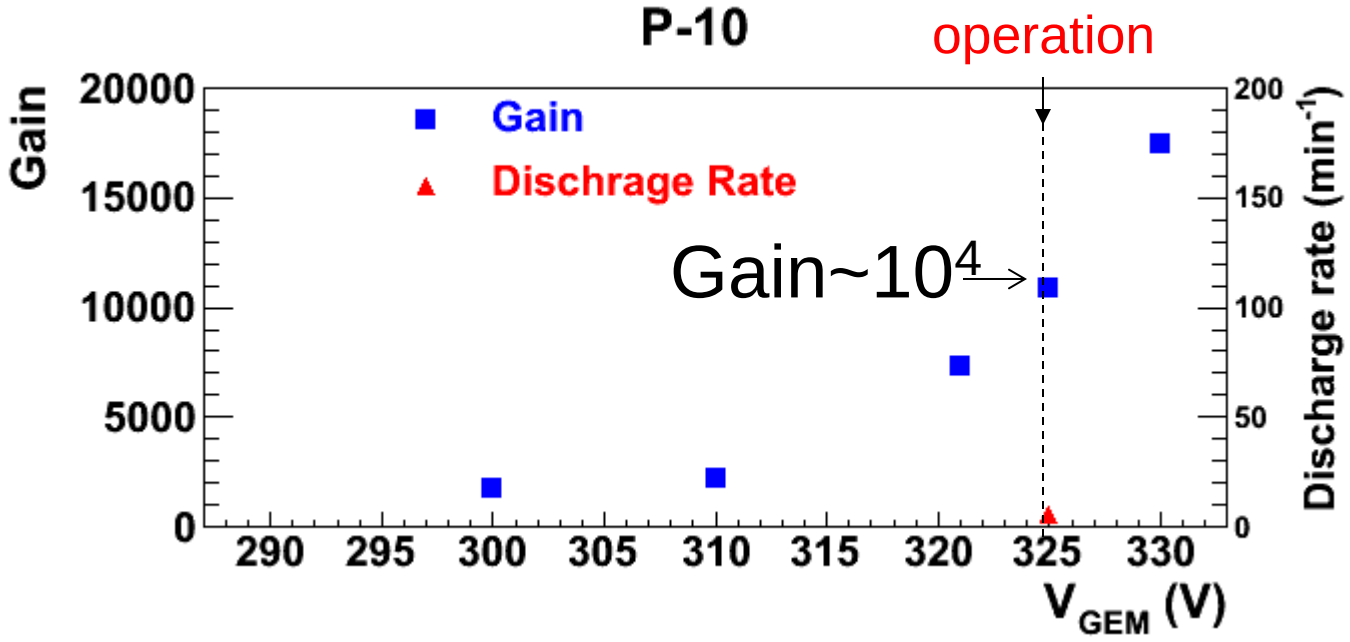
^{90}Sr(1MBq)+^{55}Fe(0.9MBq)

Stable operation
No GEM broken

P-10
V_{GEM}(50μm)=325V



GEM gain


P-10
operation
Gain
Dischrage Rate
Gain~10^4
Gain
Discharge rate (min^-1)
V_GEM (V)
20000
15000
10000
5000
0
200
150
100
50
0
290
295
300
305
310
315
320
325
330

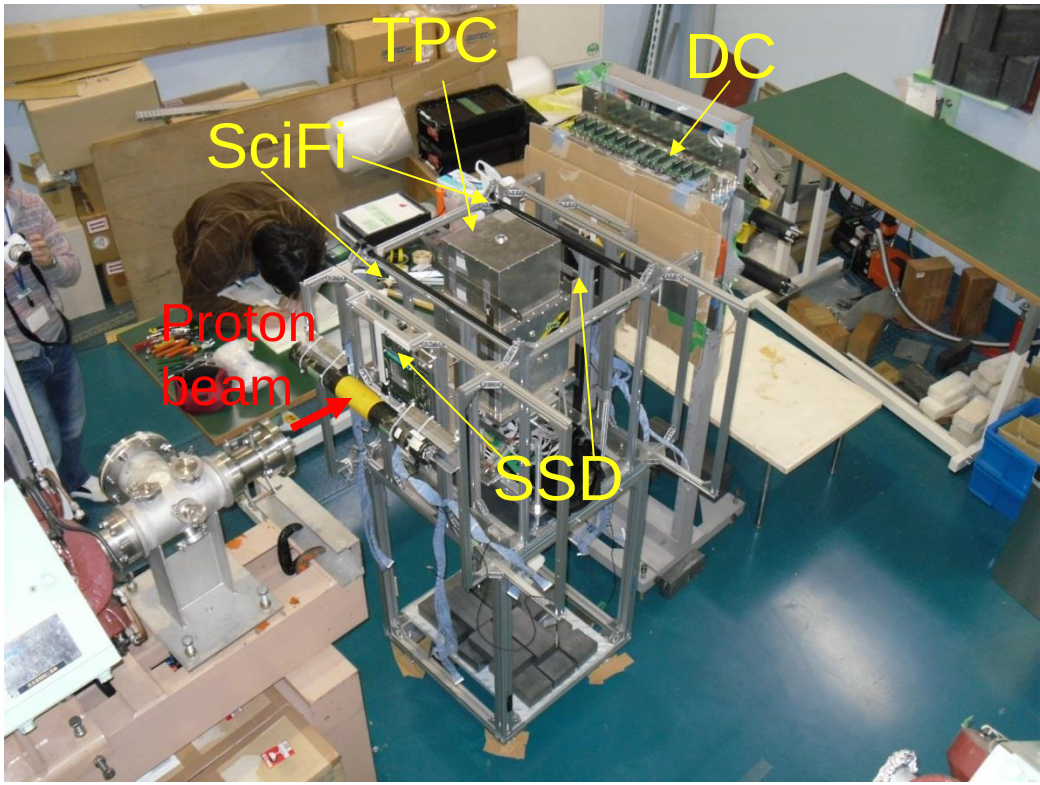
High rate beam test at RCNP(Nov 2011)

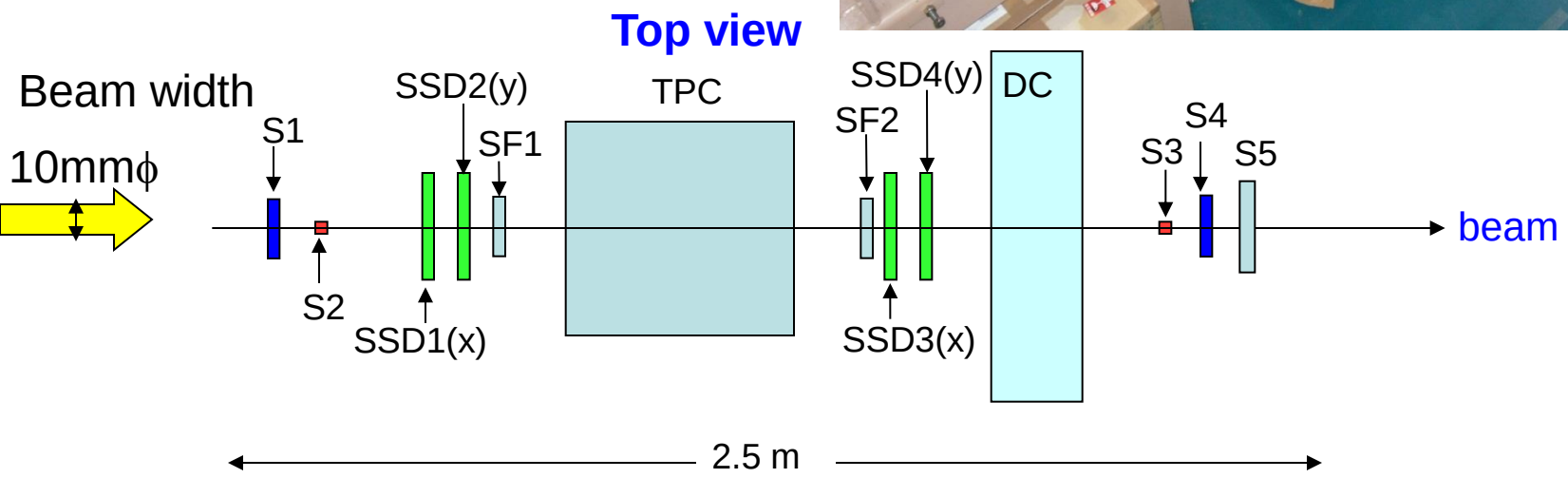
400 MeV proton beam

with 10^3-10^7 cps / cm^2

– Measure hit position shifts

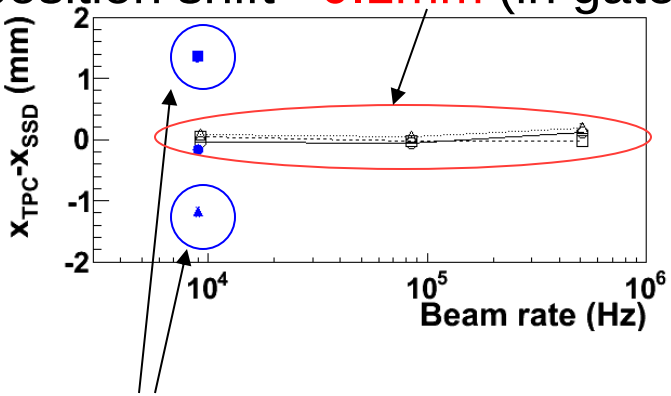
- Silicon Strip Detectors as track position reference



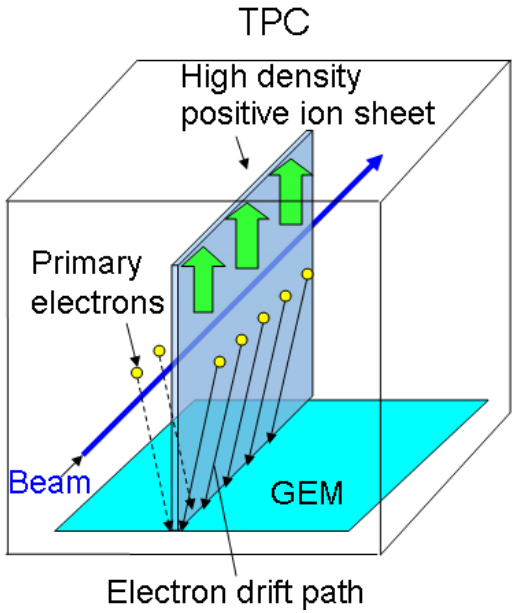


Results

Hit position shift <0.1mm (in gate operation)

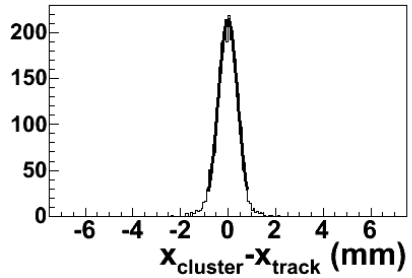


with gate open

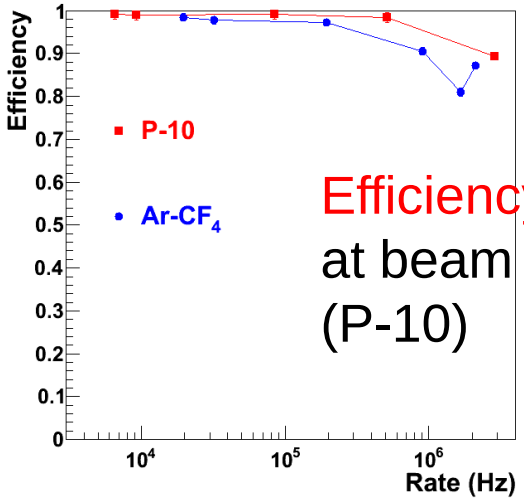


Horizontal position resolution
with 4mm pad (B=0)

σ_x=0.40mm

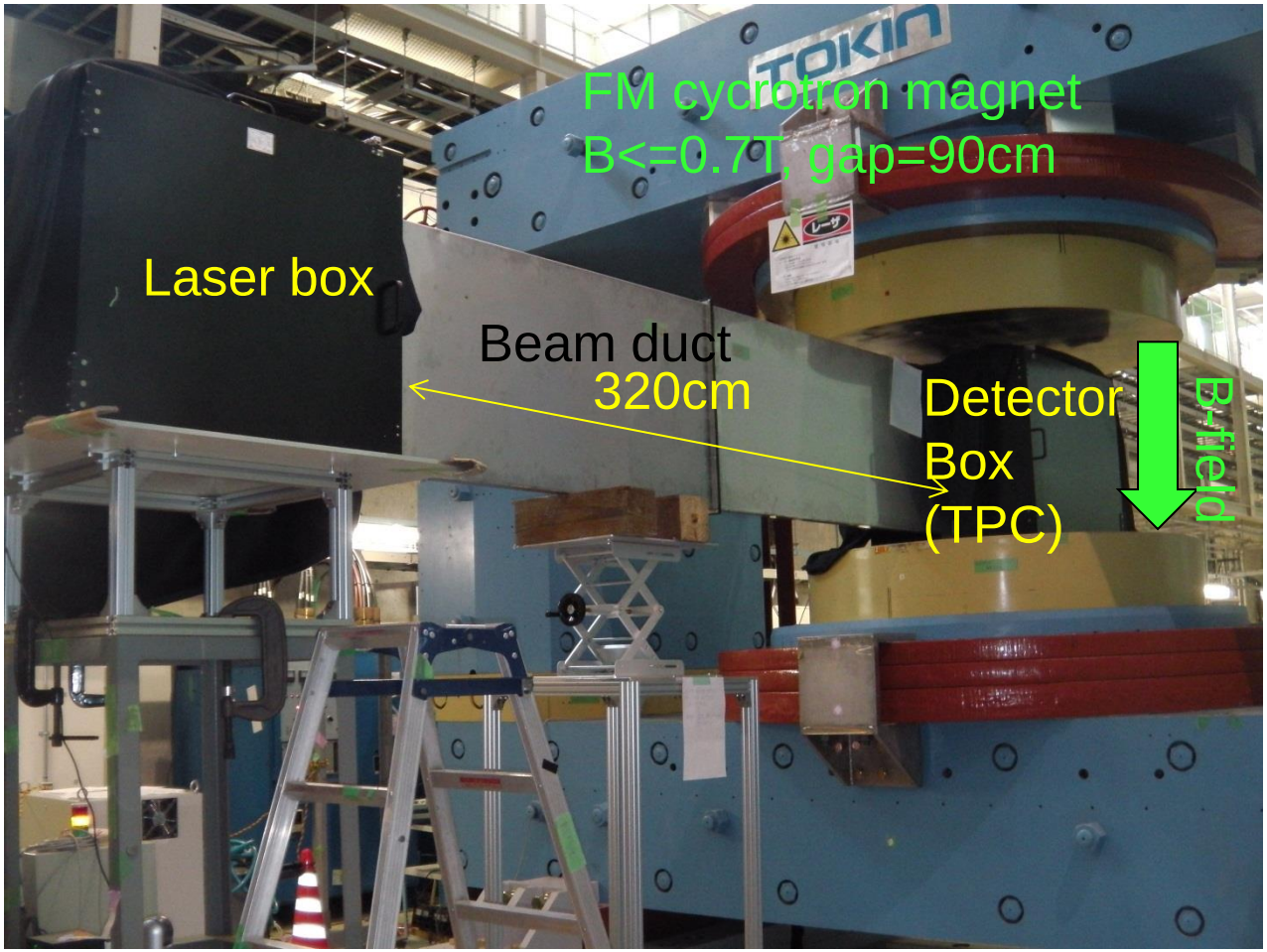


Efficiency vs beam rate



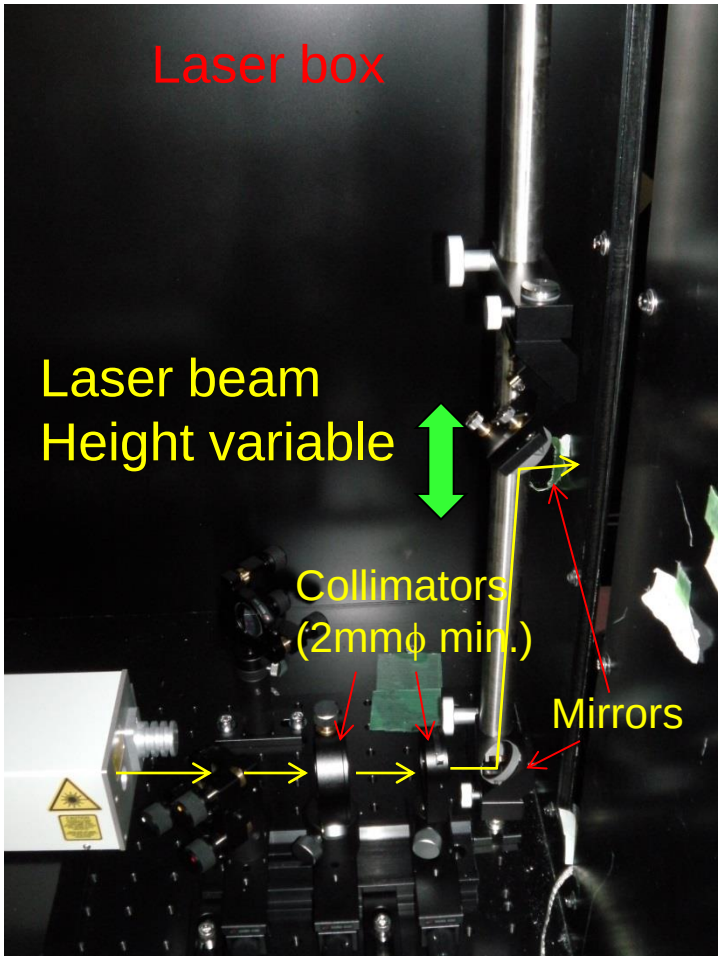
Efficiency>95%
at beam rate<10^6
(P-10)

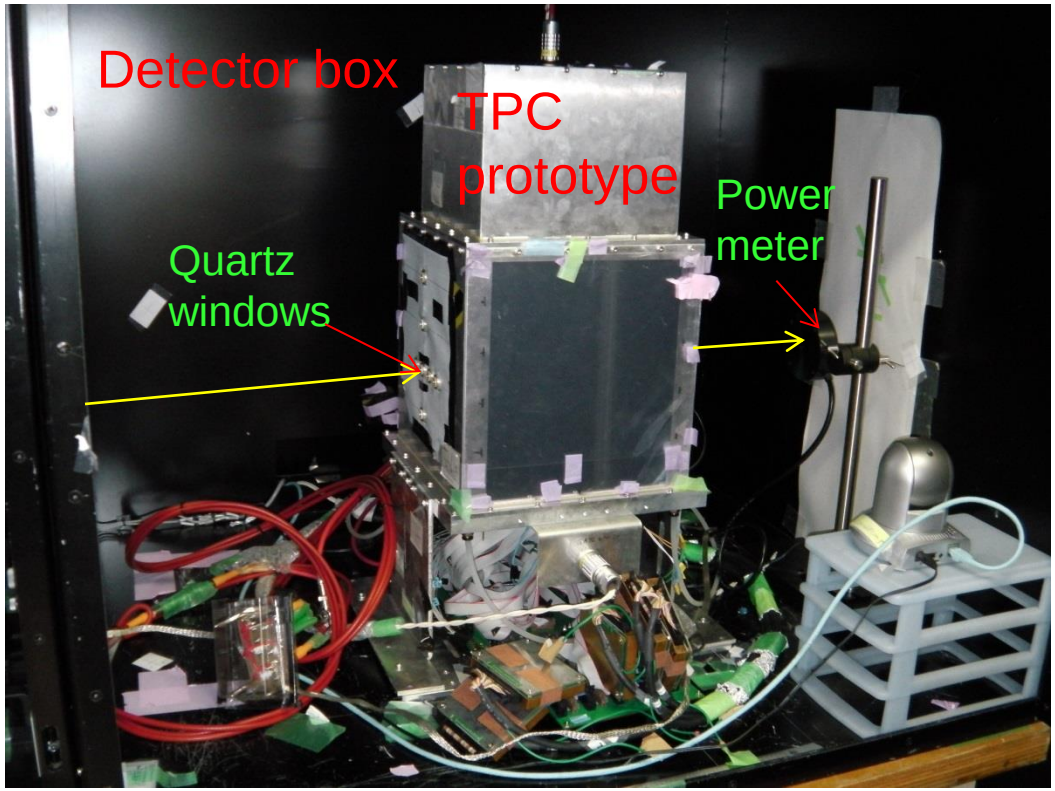
Test with UV laser with B-field (J-PARC, Apr 2013)



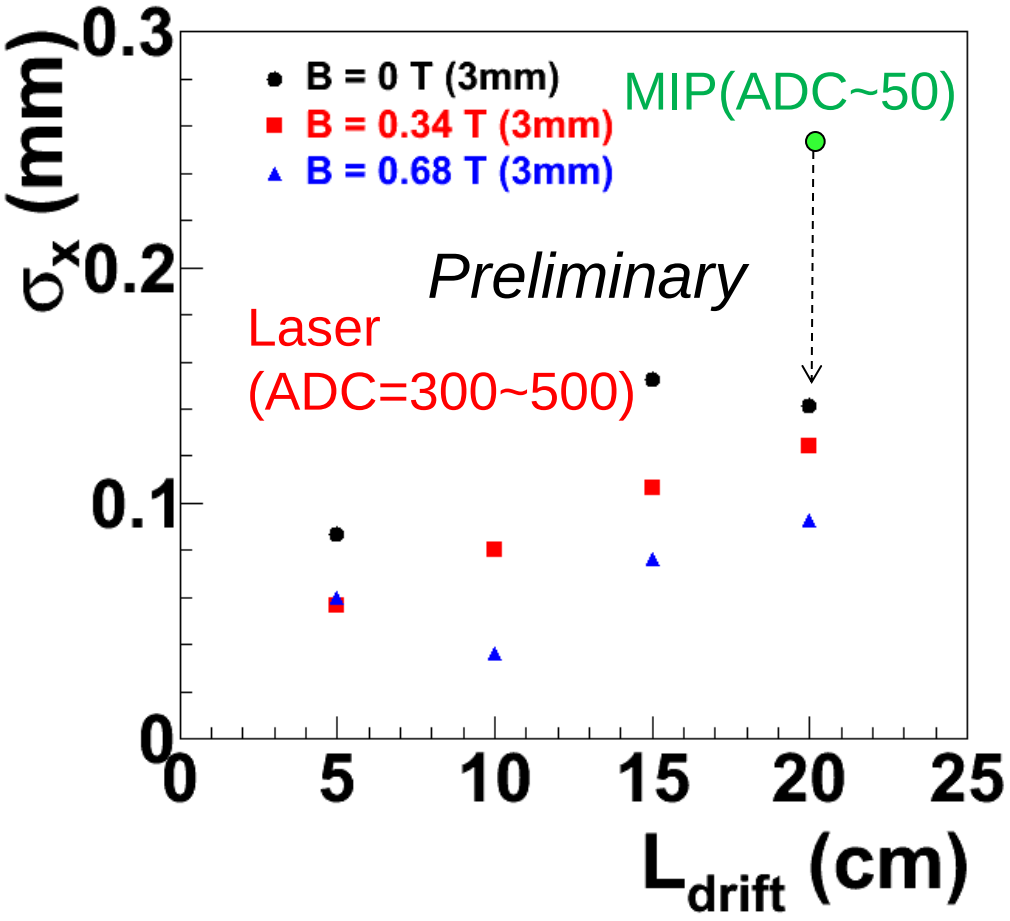
Laser optics

- YAG laser 266nm
- Energy 0-15mJ/pulse, 10Hz



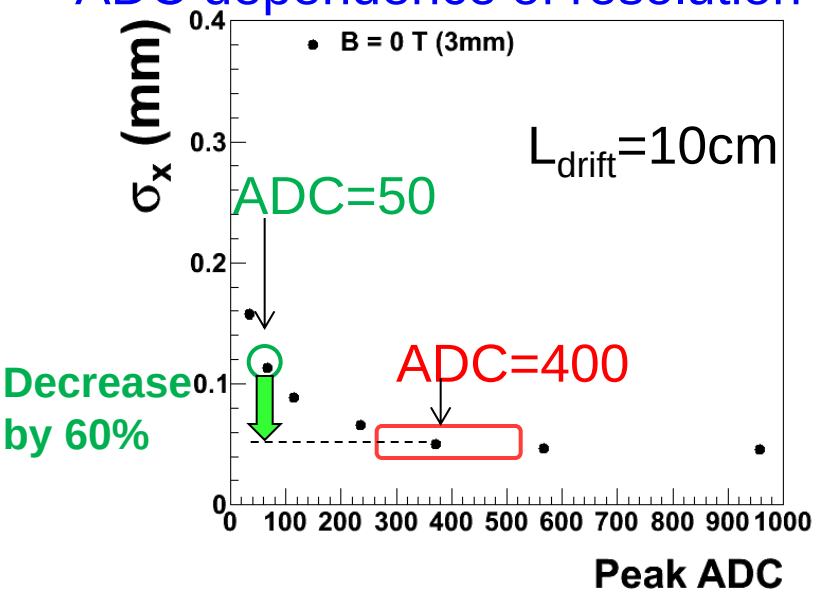


Horizontal resolutions with B-field



- Resolutions improve by 40-50% B=0 → 0.7 T
- Resolutions are 60% smaller than expected for MIP
  may be due to higher energy deposit (no. of electrons)

ADC dependence of resolution



Summary

- We have been developing HypTPC for J-PARC E42
  - High rate operation:
    - GEM and gating grid wires
  - Large H decay event acceptance:
    - A cylindrical target holder inside TPC drift volume
- Tests of a prototpe TPC successful
  - Low ion-feedback and good efficiency at beam rate of 10^6 cps/cm^2
  - GEMs worked stably for 1 month
- Resolutions improved by 40% at 0.7 T in the laser test

Prospects

Sep 2013-	Test of TPC2 (final TPC) GEM gain and stability against discharge
Nov 2013	Field cage and target holder
Apr 2014-	Full system tests with electronics (GET)
Dec 2014	Goal completion

The E42 Collaboration

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