CONSTRUCTION AND TESTS OF MPGD TPCs FOR ILC

Keisuke Fujii
On behalf of D_R&D_2 Team

May 20, 2009 in Tsukuba

I would like to dedicate this talk to Prof. Takayuki Matsui

Late Prof. Takayuki Matsui at home

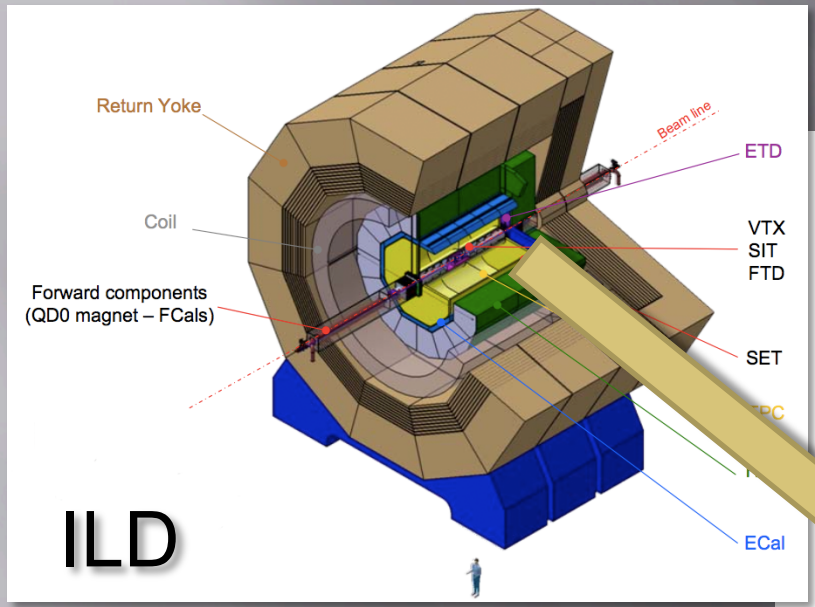
Prof. Takayuki Matsui died of cancer about a month ago.

As many of you know he made invaluable contributions to the community since the dawn of the linear collider projects in the late 1980's.

He was the organizer of the APPI series of winter institutes and was also a good skier.

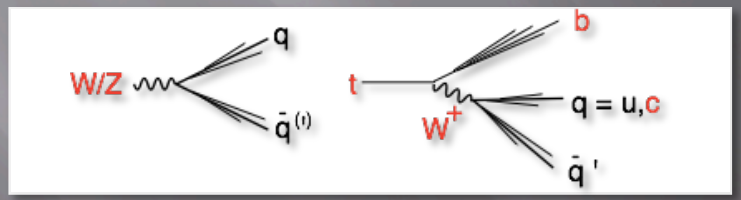
He was a great leader and it is really a great loss for all of us.

LC-TPC

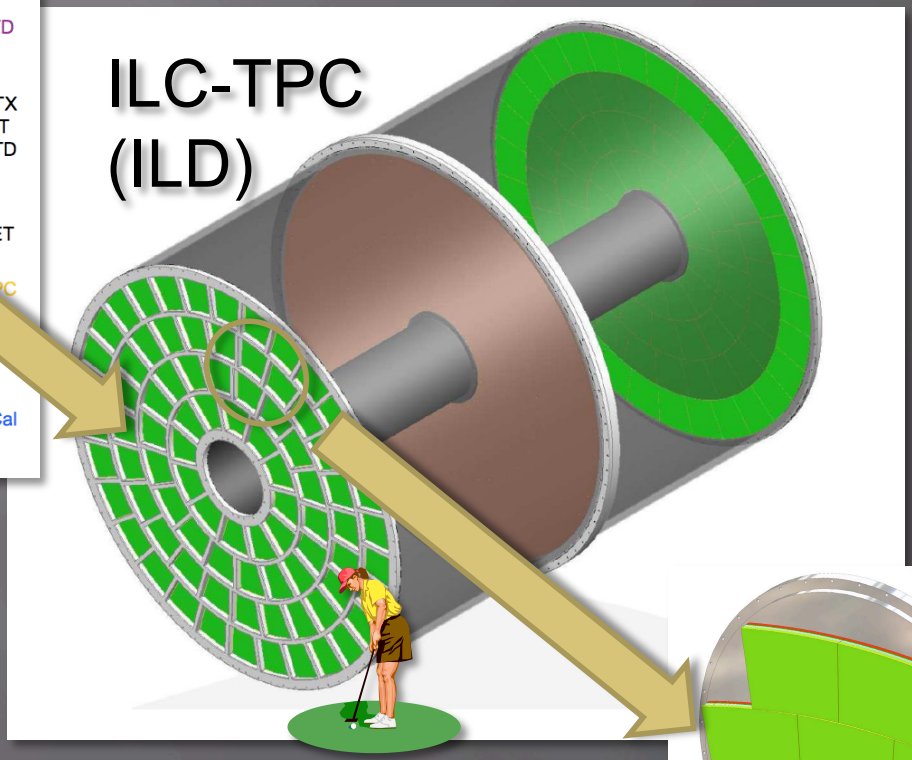


ILD LOI submitted on March 31, 2009

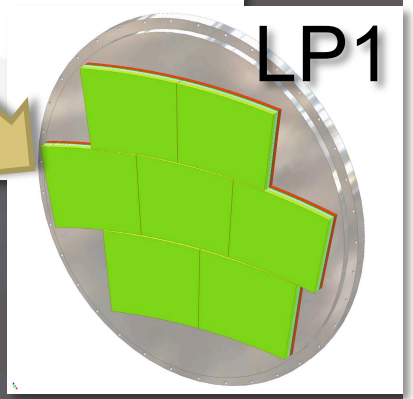
ILD : optimized for
Particle Flow Analysis



Highly efficient tracking in a jettey environment is an essential ingredient for PFA



Continuous 3D tracking in a large gaseous volume with ~200 space points.



Large prototype being tested at DESY

DETECTION TECHNOLOGIES

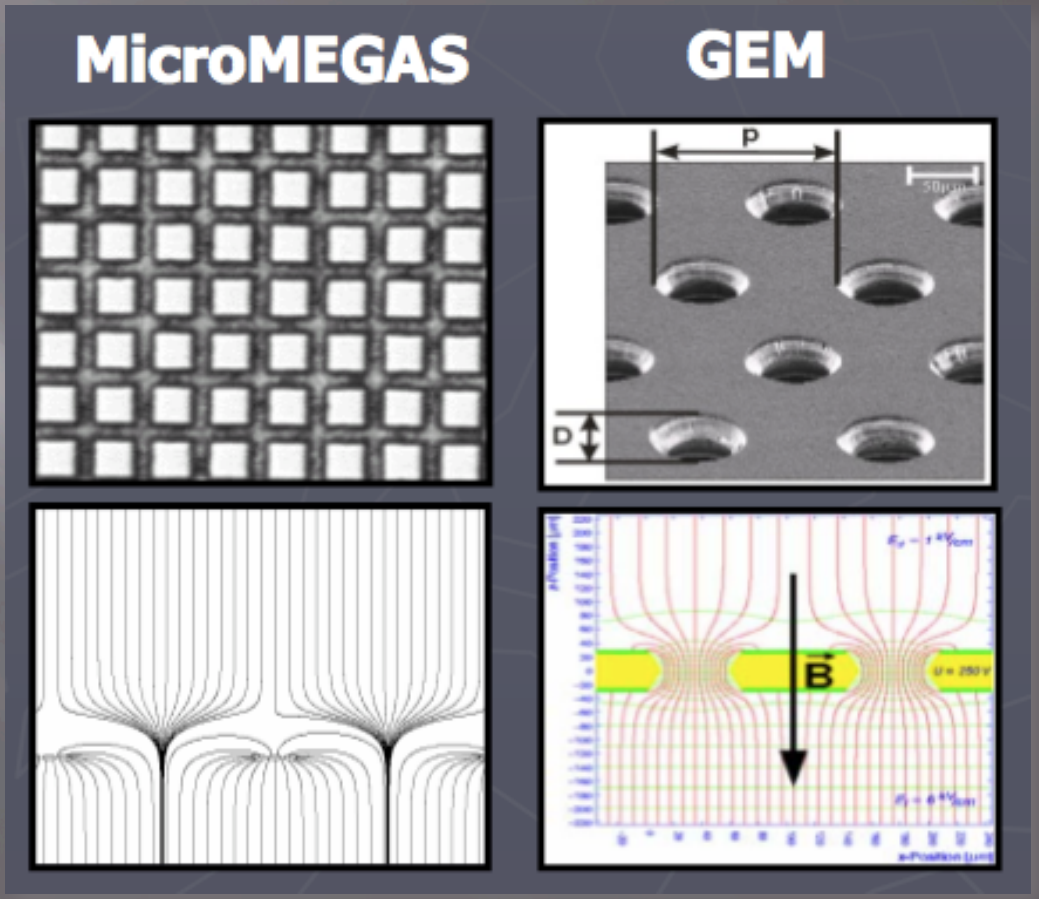
Micromegas and GEM

Performance Goals
for the LC-TPC

- >200 sampling points along a track with a spatial resolution better than ~100 microns in the XY plane over the full drift length of >200 cm
- 2-track separation better than ~2mm to assure essentially 100% tracking efficiency for jetty events
- High tracking efficiency also requires minimization of dead spaces near the boundaries of readout modules

Why MPGD readout?

- We need high (>3 T) B field to confine e+e- pair BG from beam-beam interactions, then ExB too big for conventional MWPC readout
- 2mm 2-track separation is difficult with MWPC readout
- Thick frames are unavoidable for MWPC readout



Micro-Pattern Gas Detectors

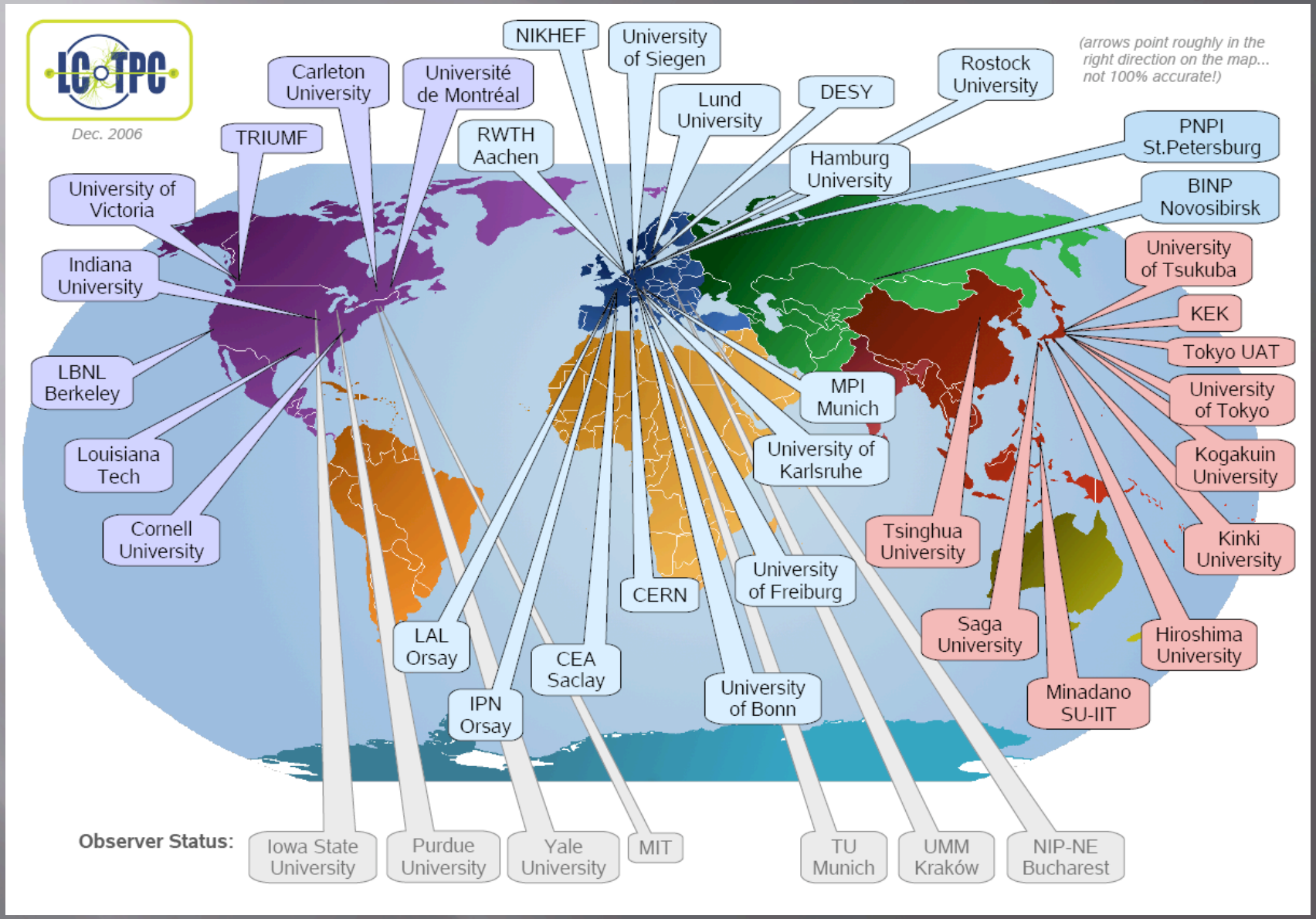
The Three R&D Phases for the ILC TPC

R&D Phase

1. **Demonstration Phase**: Provide a basic evaluation of the properties of an MPGD TPC and demonstrate that the requirements (at ILC) can be met using small prototypes.
2. **Consolidation Phase**: Design, build and operate a "Large Prototype" (of large number of measured points) at the EUDET facility in DESY.
3. **Design Phase**: Start working on an engineering design for aspects of the TPC at ILC.

We are mostly in the phase 2. However, there are still important studies of the phase 1 left, and the phase 3 is now starting together with the new ILD group.

LCTPC Collaboration



Activities

-- The past (about) one year --

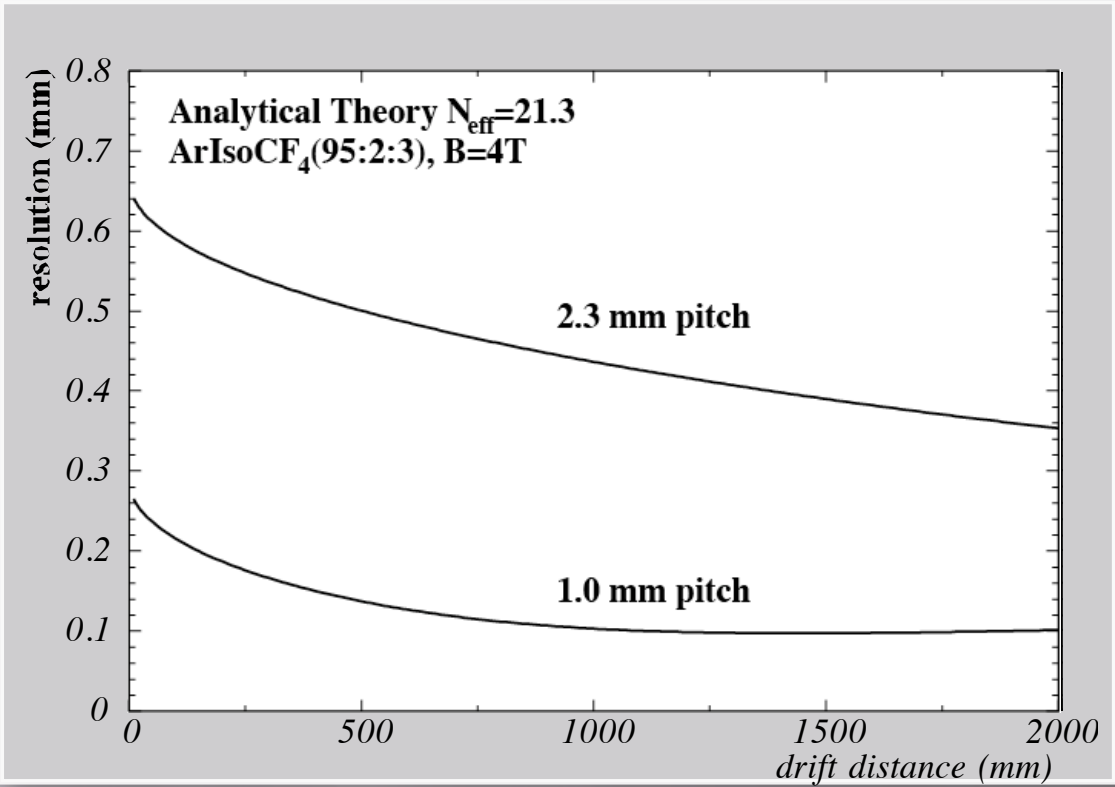
- T. Matsuda visited Saclay and summarized LC-TPC activity at DESY PRC in April 2008
- K. Fujii participated in FJPPL and did some work at Saclay in May 2008
- K. Fujii, K. Ikematsu, T. Matsuda, A. Sugiyama, H. Kuroiwa, P. Colas … participated in ILD Meeting and discussed LC-TPC for ILD and planning for LP1 tests in Sep. 2008
- T. Matsuda, R. Yonamine, P. Colas, D. Attie, … set up and carried out the 1st LP1 test with a Micromegas Panel test at DESY in Oct.-Dec. 2008
- P. Colas participated in TIPP09 and did some work at KEK in March 2009
- D .Attie, … participated in TILC09 and ILD Meeting here at Epochal in April 2009
- K. Fujii and R. Yonamine contributed to TPC Jamboree at Franciscan Monastery La Clarté-Dieu in Orsay in May 2009

Small Prototype Tests

-- Further demonstration continues --

Last year, I talked about an analytic formula that clarified fundamental limitations to spatial resolution and decided the R&D directions for the LC-TPC.

Extrapolation to LC TPC



- Need to reduce pad size relative to PRF
  - MM + resistive anode
  - MM + digital pixel readout, ideal to avoid effect of gain fluctuation if feasible
  - GEM with defocusing + narrow (~1mm) pads

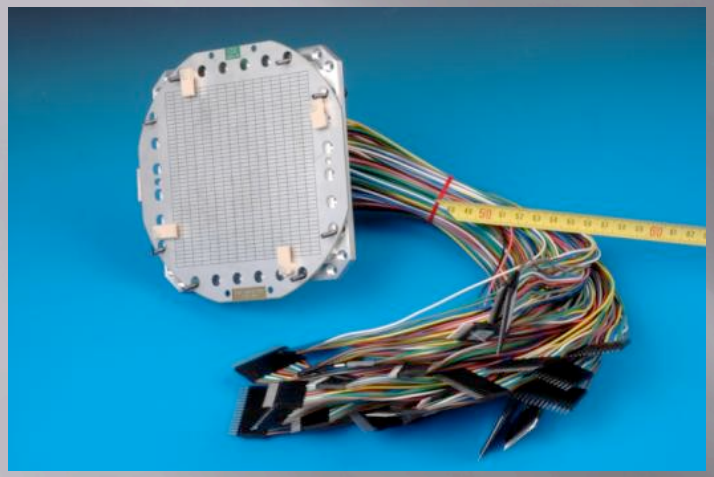
3 Solutions

The three solutions have been tested with small prototypes.
--> demonstration phase

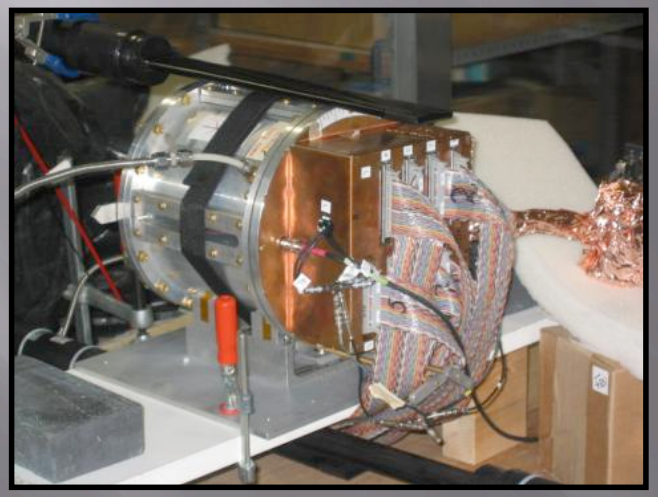
We are now tesitng them with a larger prototype.
--> consolidation phase

Small prototypes

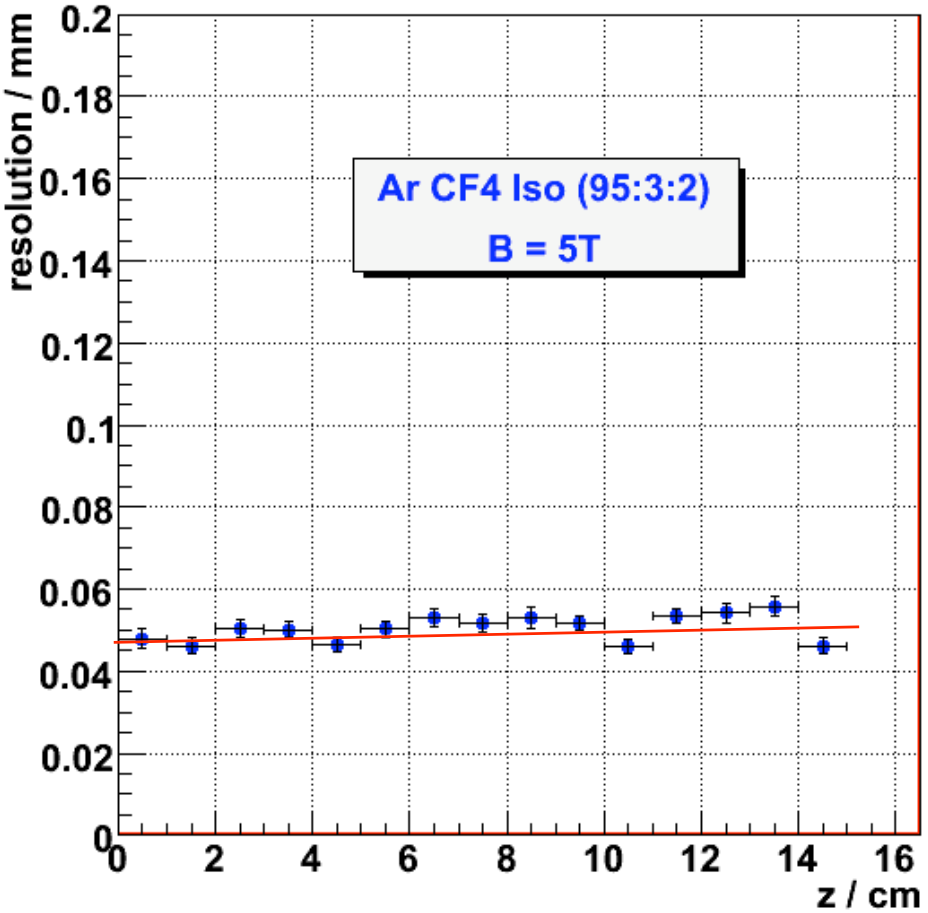
Micromegas



KEK beam test, MP-TPC (2005)



Carleton TPC with res. anode

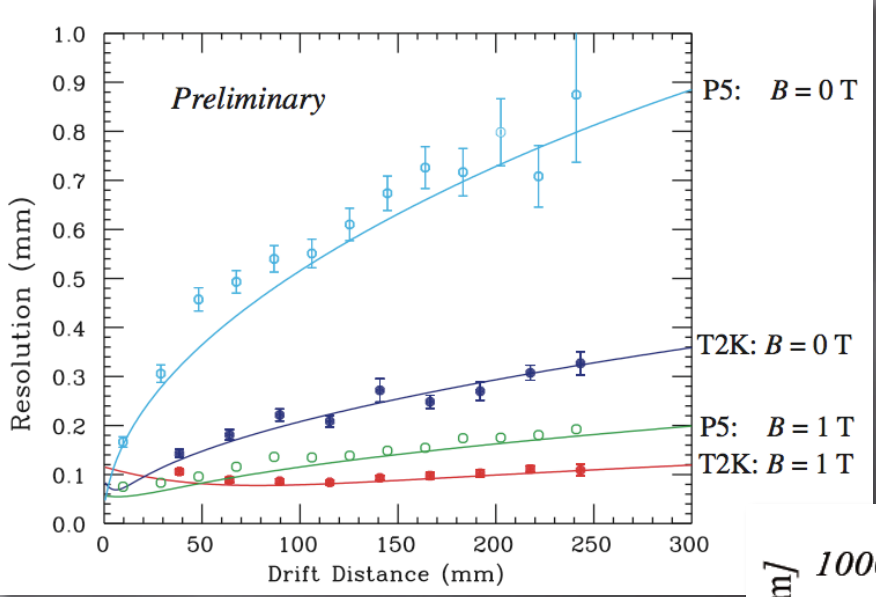


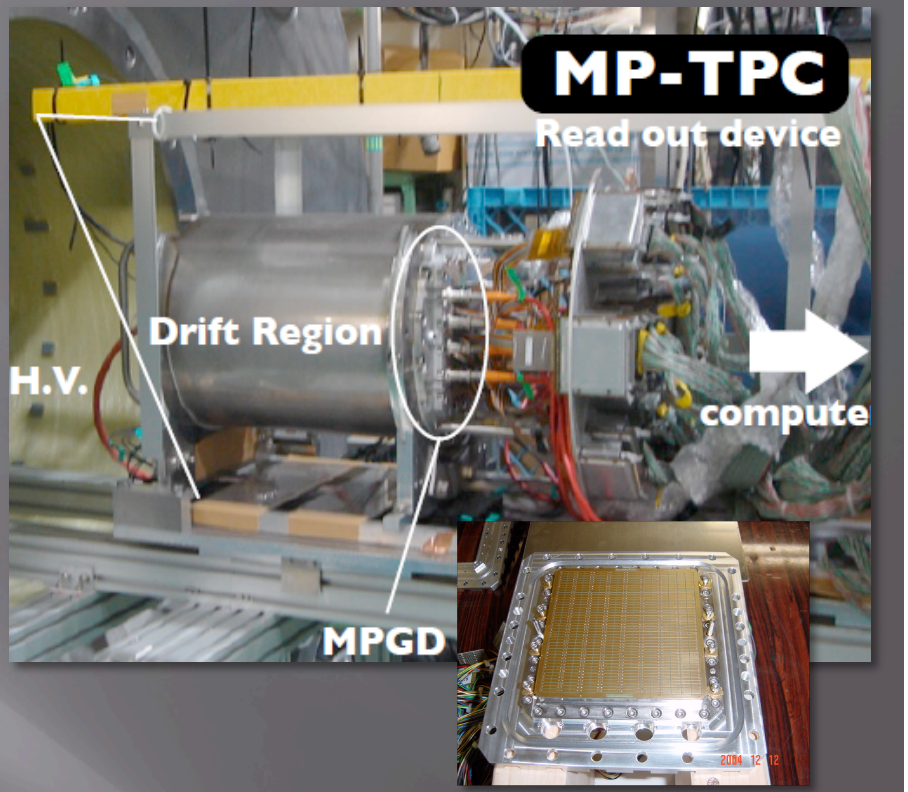
DESY 5T cosmic test, 2007

50 µm resolution with 2mm pads

Small prototypes

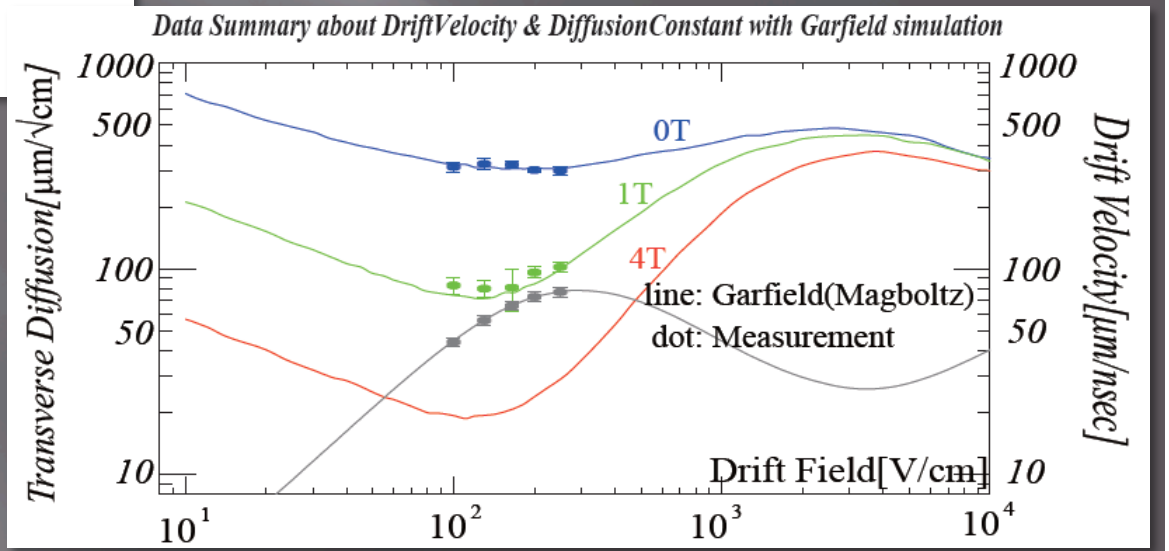
GEM



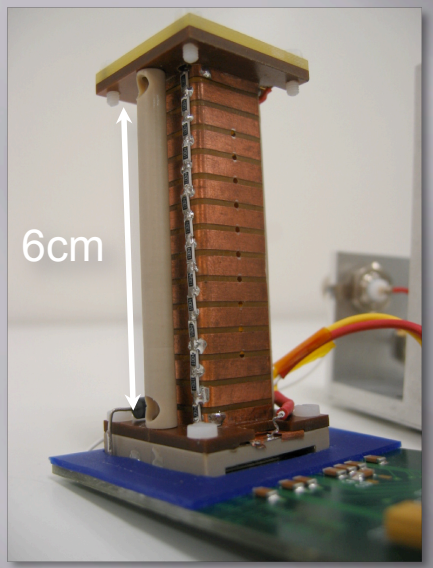


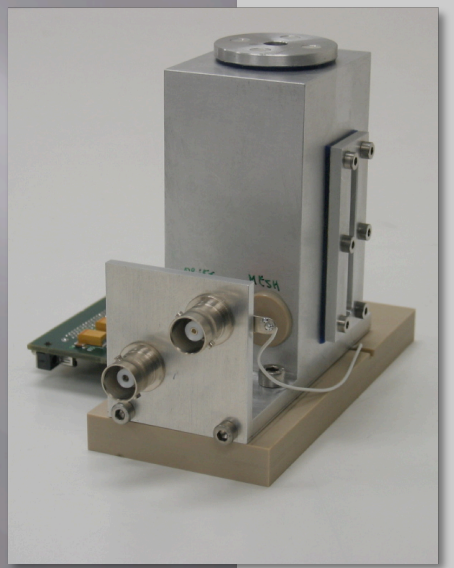
MP-TPC cosmic-ray test in 2008 at KEK.

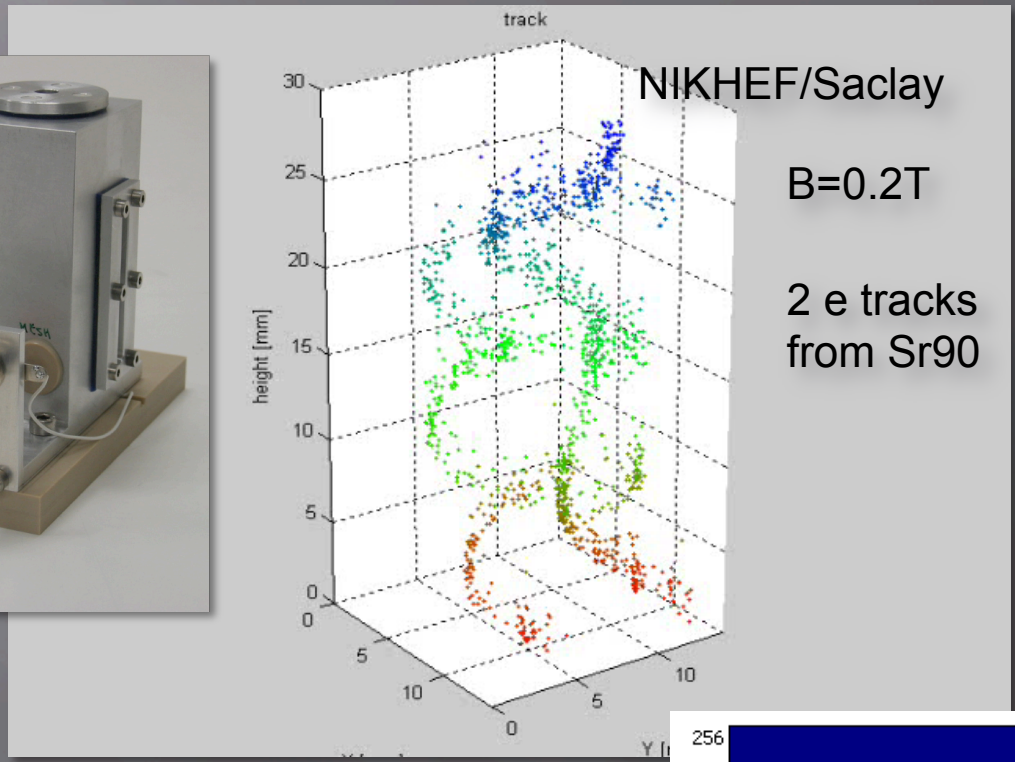
Good operation with Ar-CF4-isobutane.



Micro-TPC: MM+TimePix





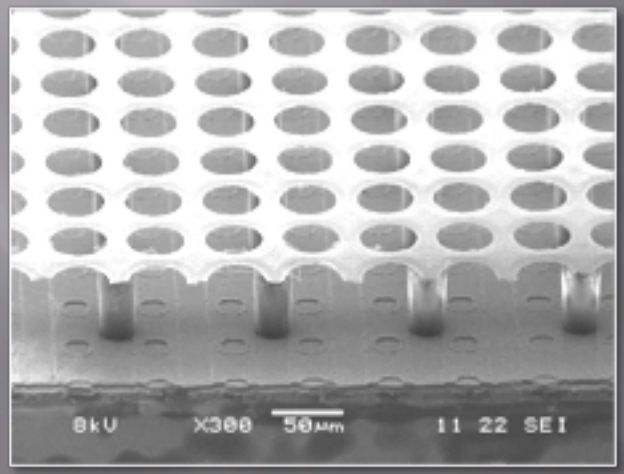


NIKHEF/Saclay

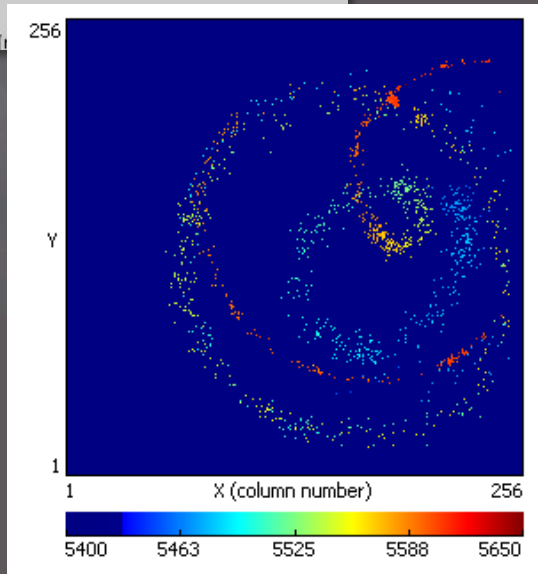
B=0.2T

2 e tracks from Sr90

J. Timmermans



Si protection against discharge

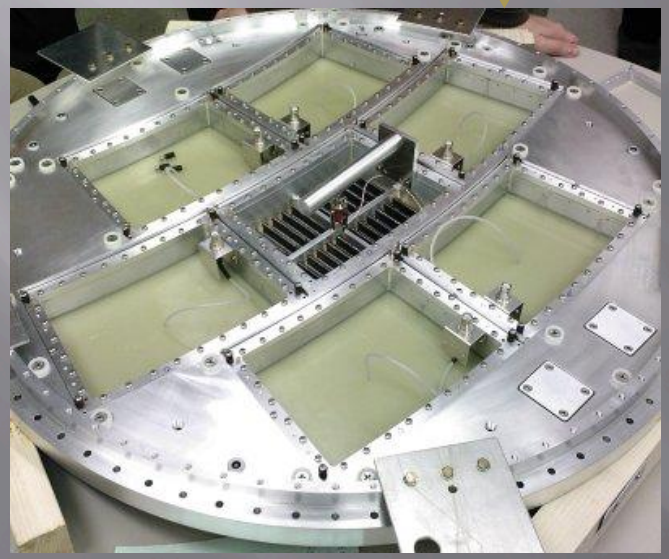


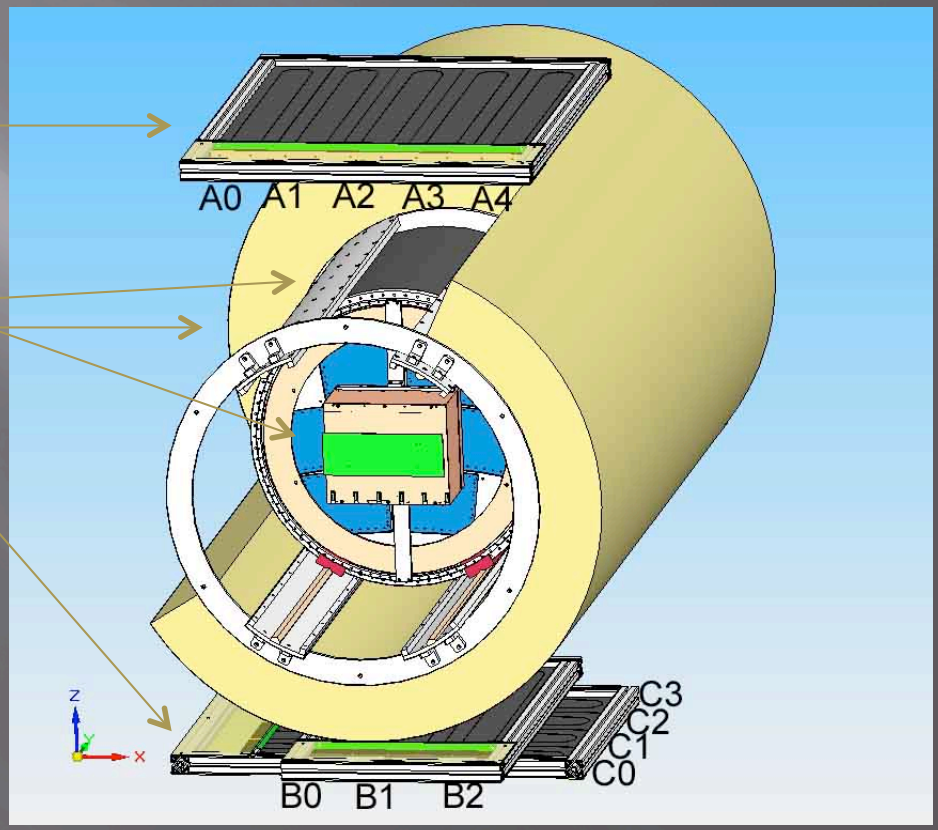
THE LARGE PROTOTYPE

LC-TPC project using the
EUDET test facility at DESY

The EUDET setup at DESY

PCMag magnet from KEK
Cosmic trigger hodoscope from Saclay-KEK-INR
Beam trigger from Nikhef
Dummy modules from Bonn
Field cage, gas from DESY
Endplate from Cornell





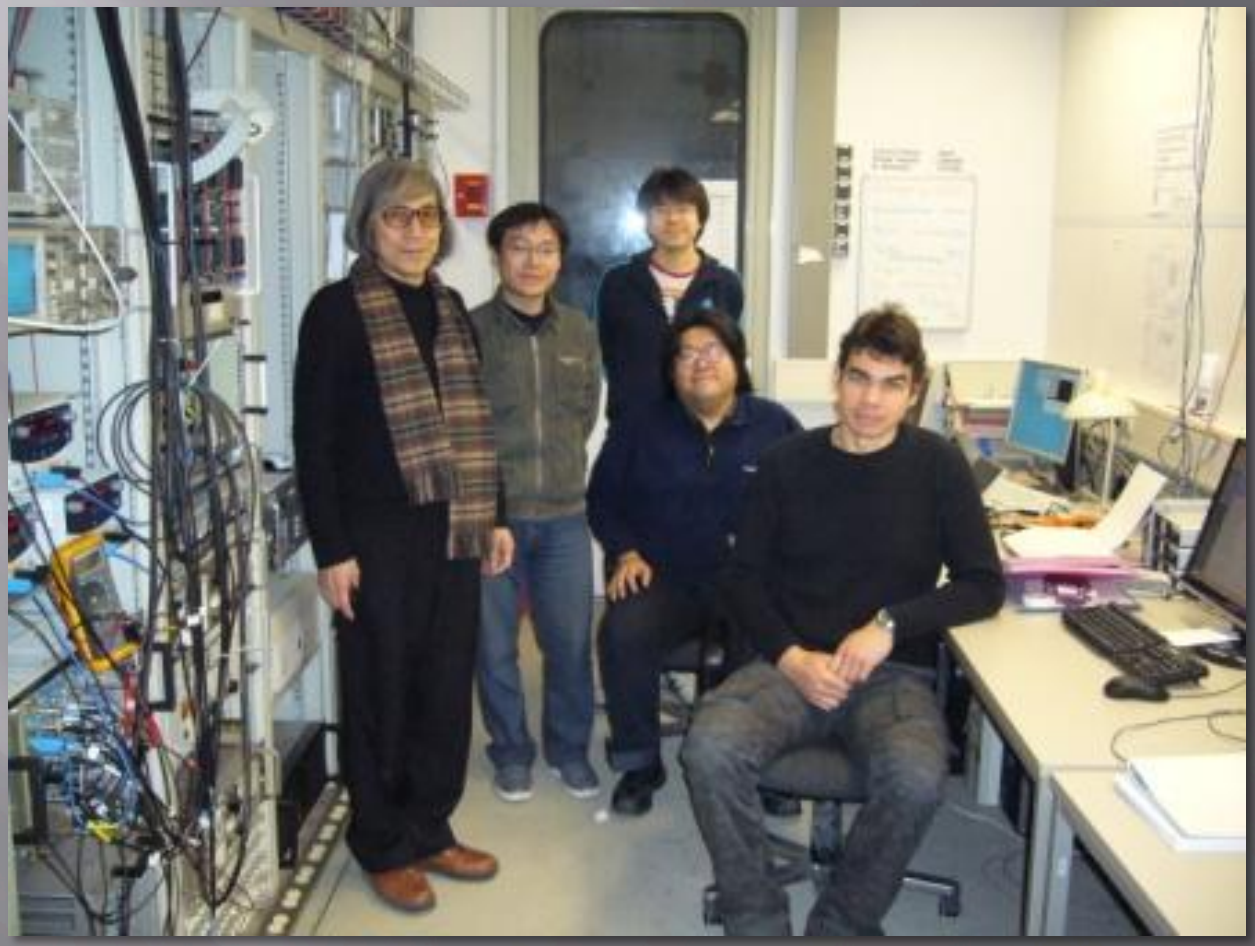
Micromegas modules from France
GEM modules from Asia

Common data taking at DESY

FCPPL

Li Bo

David Attié



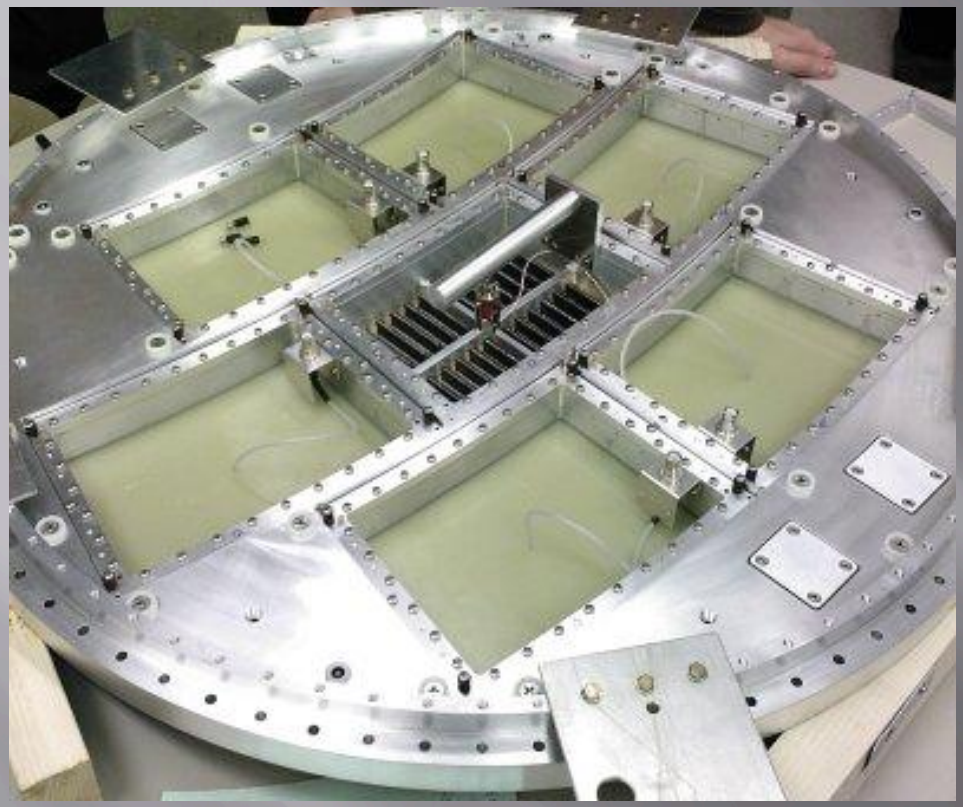
FJPPL

T. Matsuda

R. Yonamine

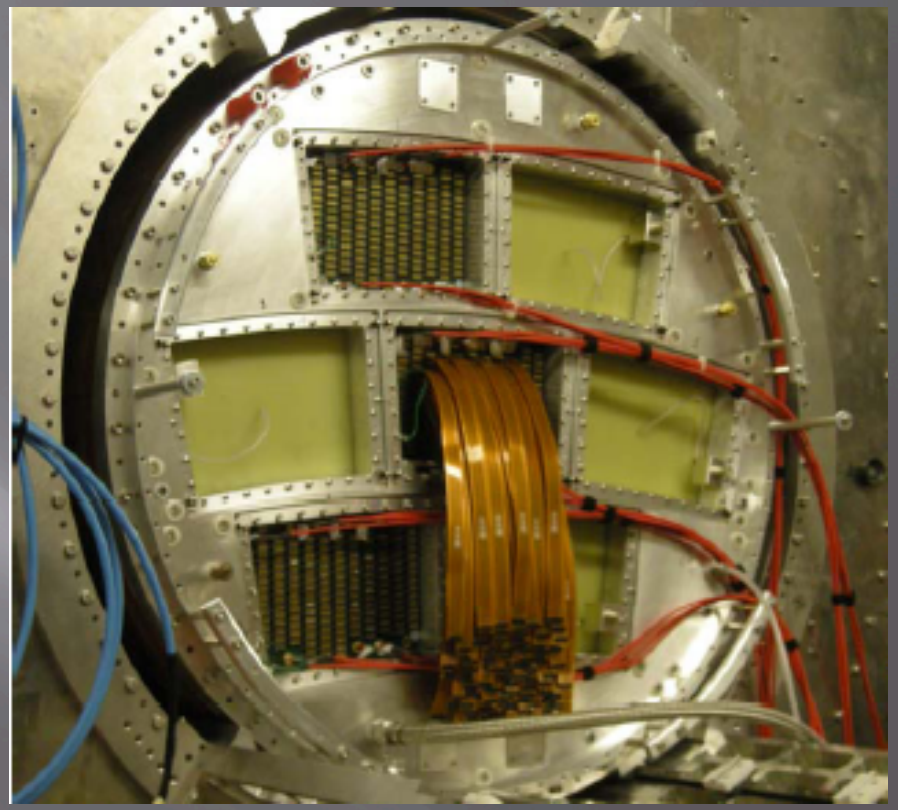
H. Kuroiwa

Micromegas



About 2000 readout channels
AFTER-based electronics
(made in Saclay)

GEM



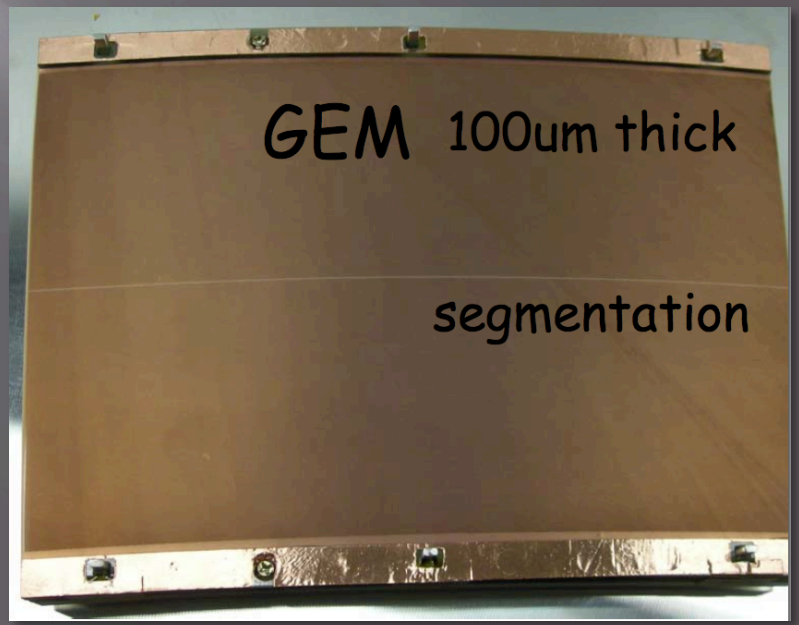
About 3200 readout channels
ALTRO-based electronics
(made at CERN)

Micromegas

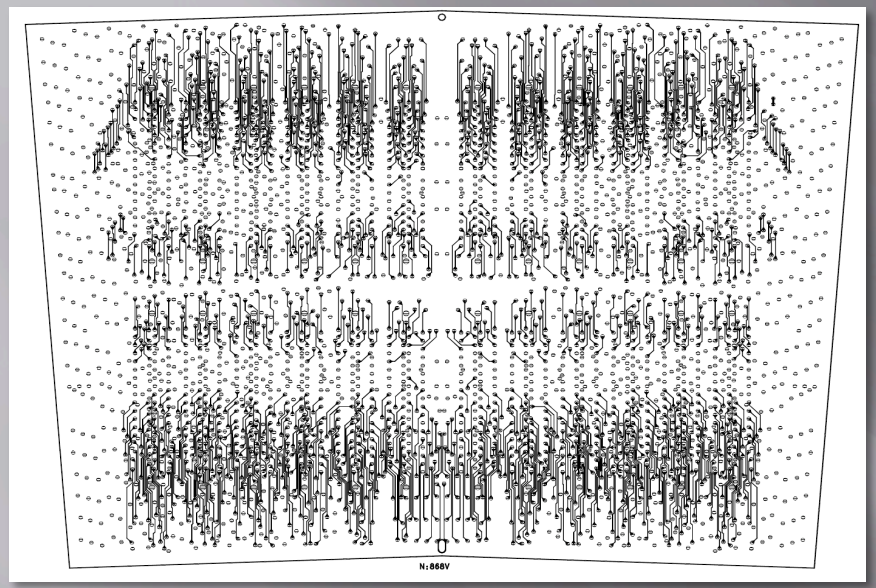
‘Bulk’ technology (CERN-Saclay)
with resistive anode (Carleton)

New 100 micron GEM (plasma-etched in Japan) streched from 2 sides.

DOUBLE GEM

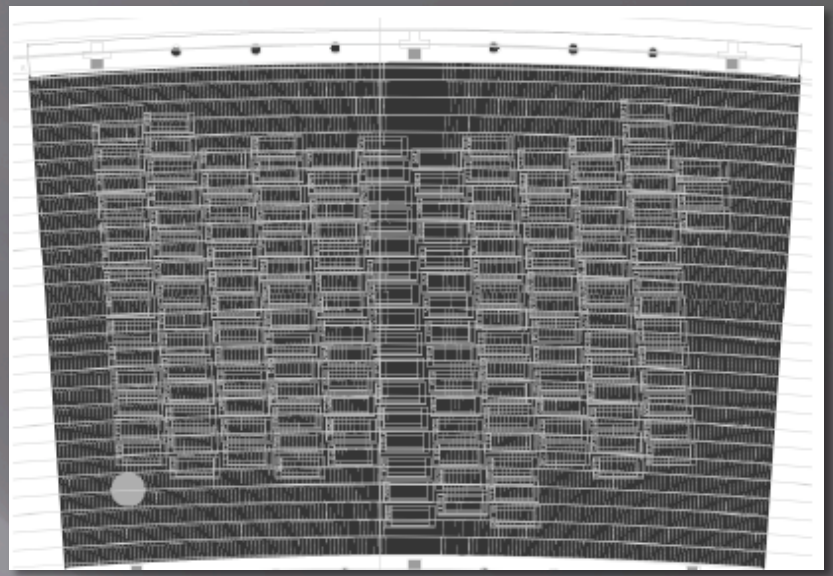


Micromegas

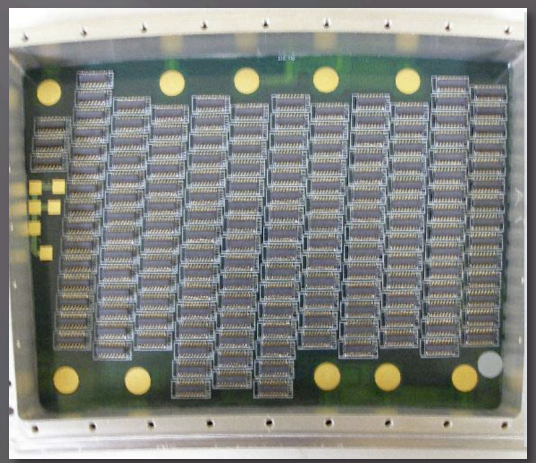


4-layer routing (CERN) and 6-layer routing (Saclay)
24x72 pads, 2.7-3.2 mm x 7 mm

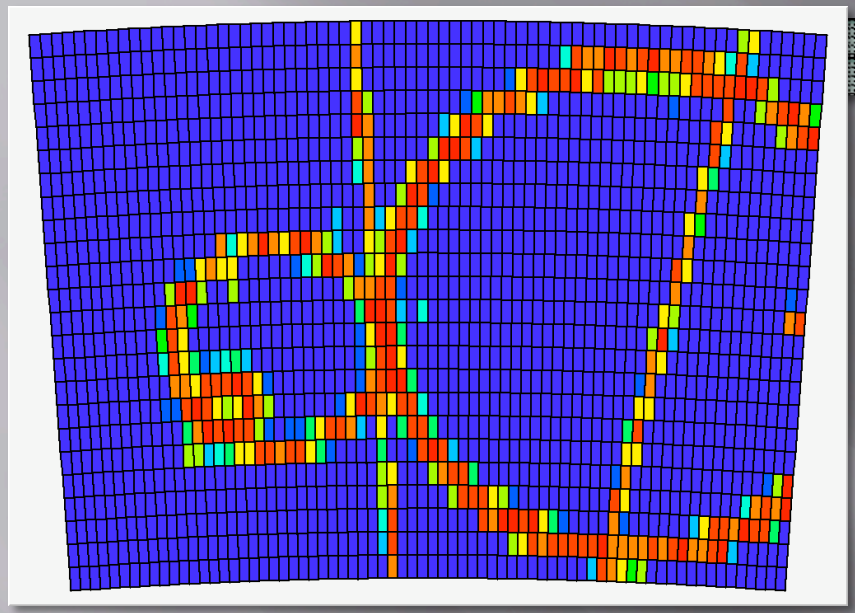
DOUBLE GEM



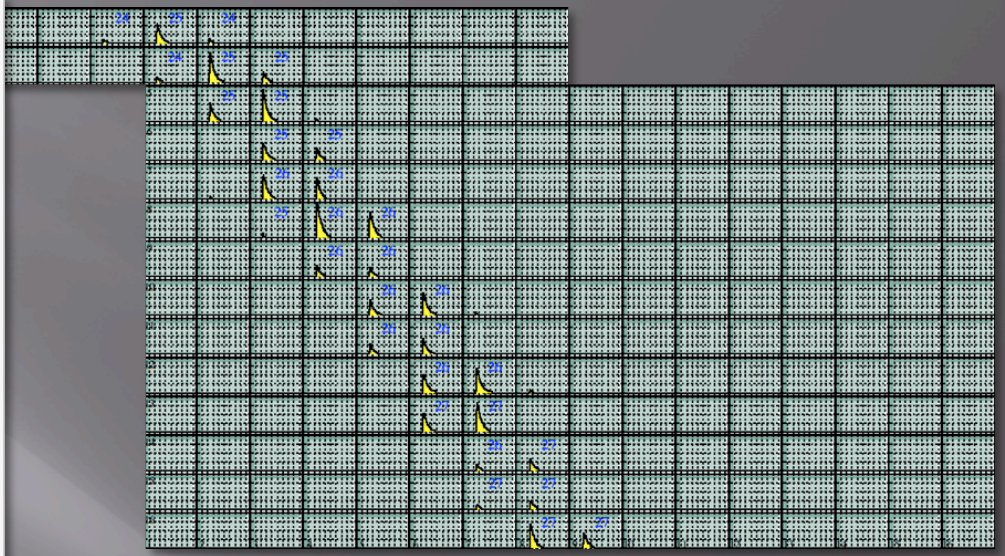
8-layer routing done at Tsinghua
28x176-192 pads, 1.1 mm x 5.6 mm

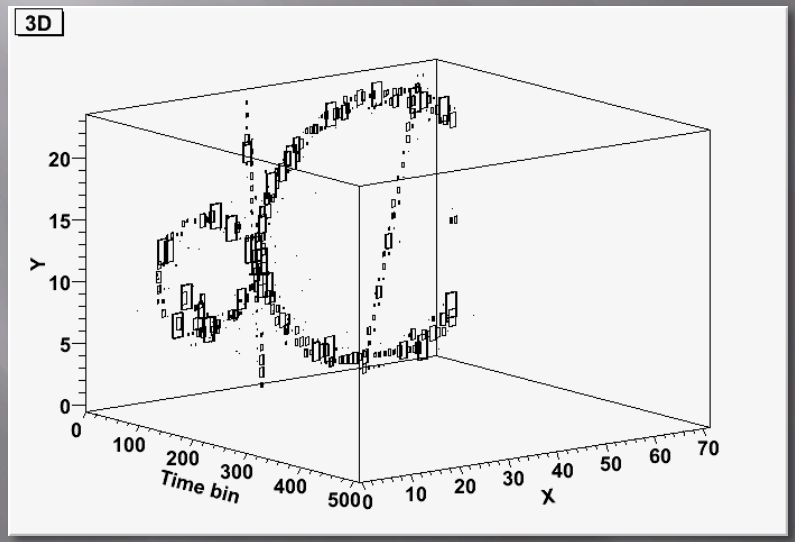


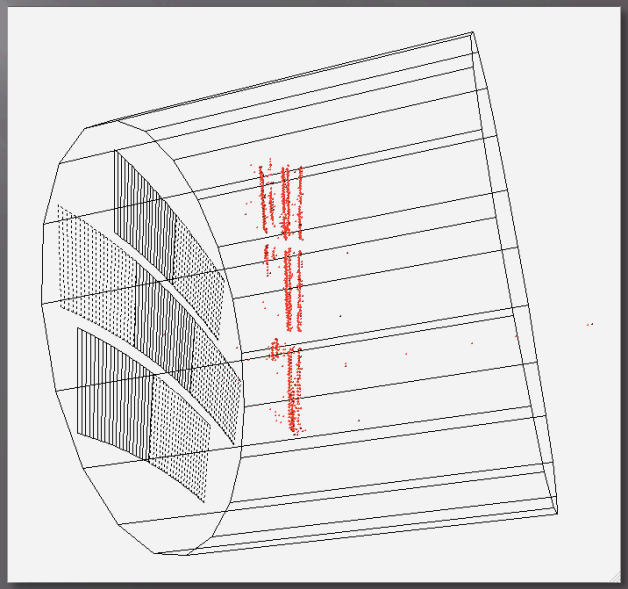
Micromegas



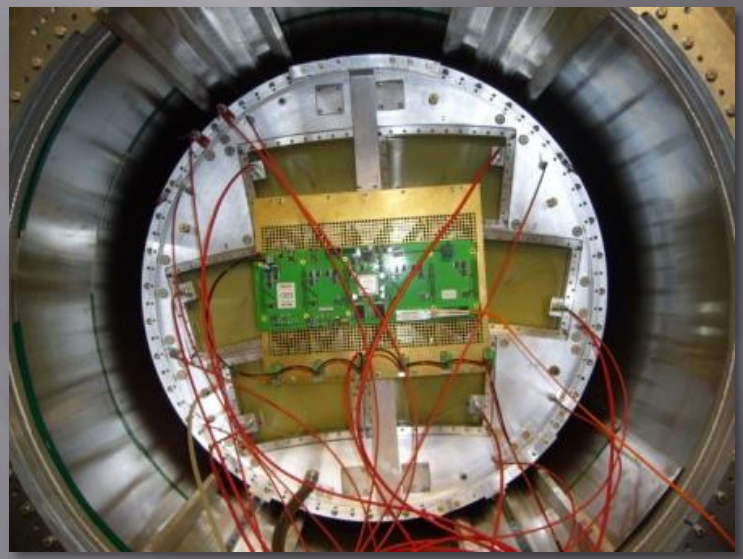
Double GEM







FIRST MICROMEGAS RESULTS

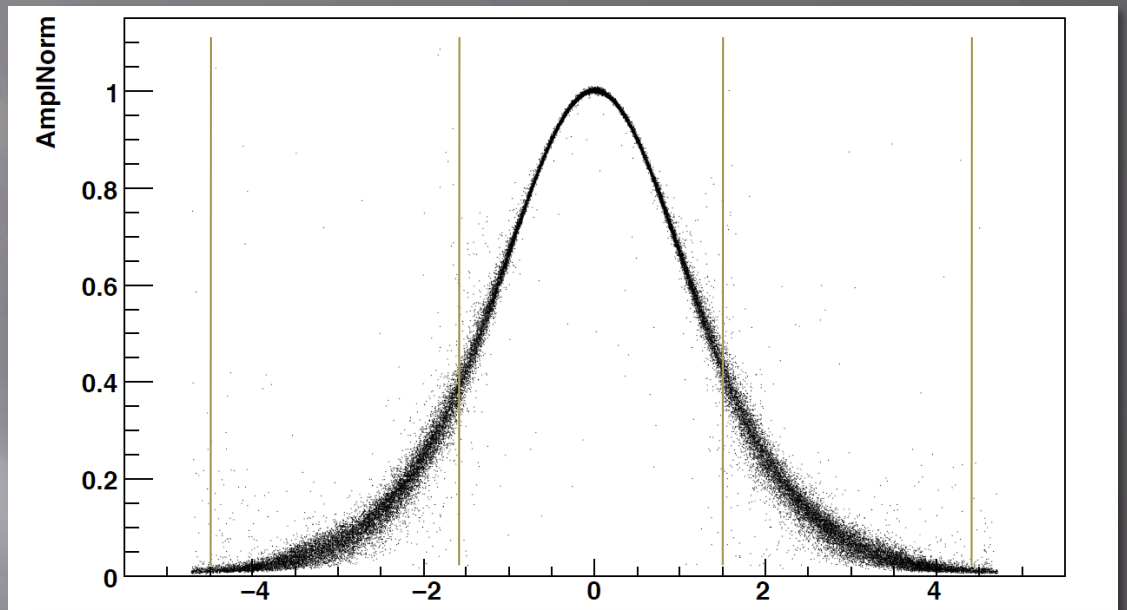


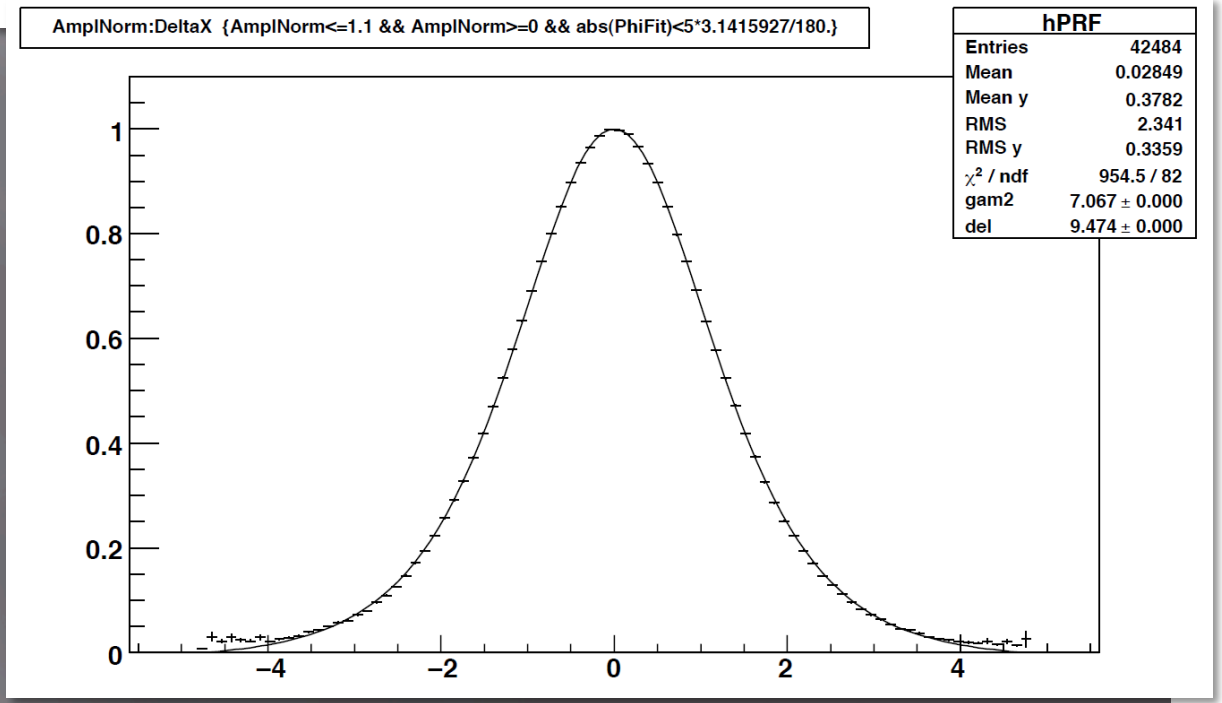
Determination of the Pad Response Function (B=1T beam data)

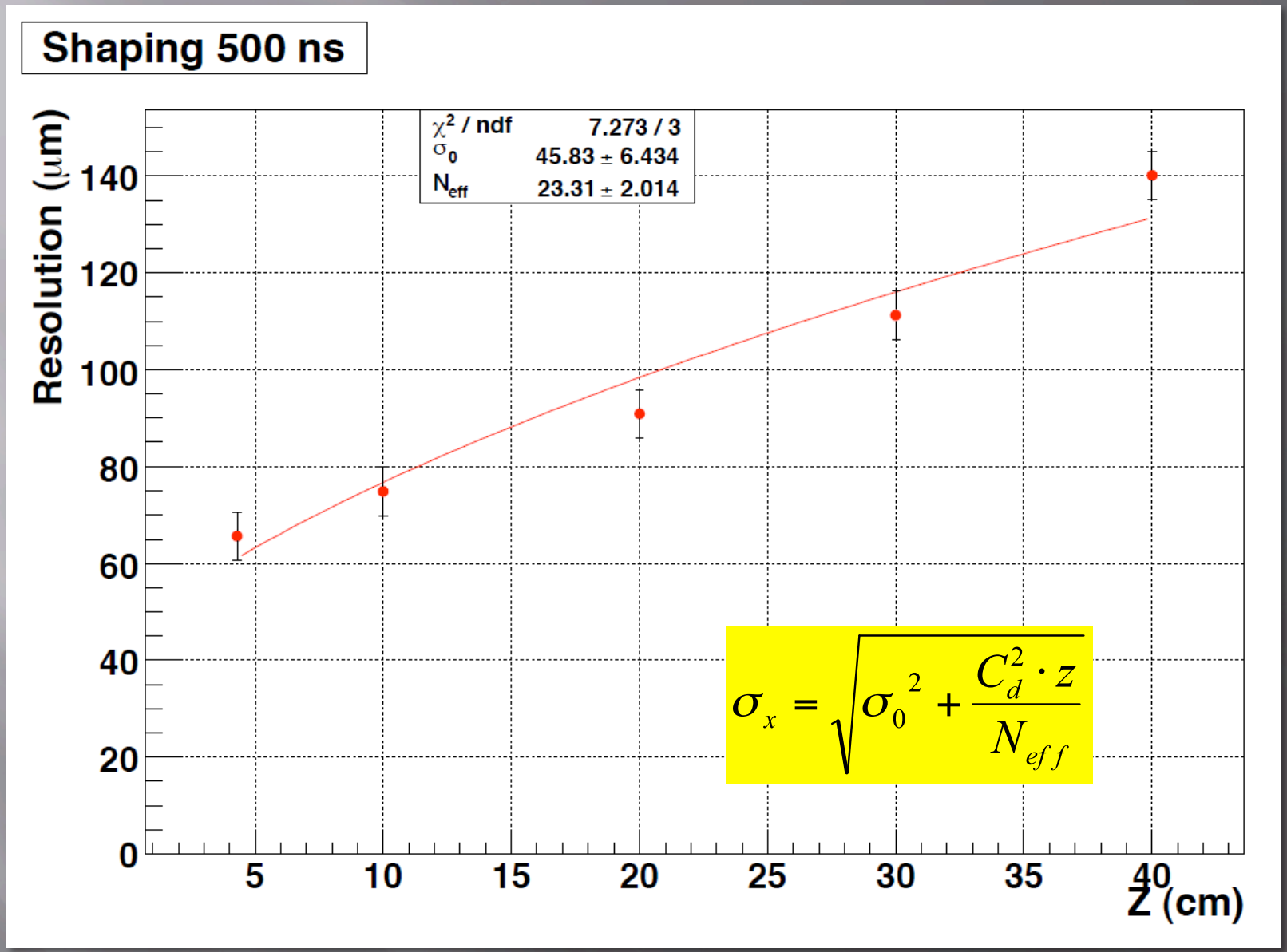
Fraction of the row charge on a pad vs $x_{pad} - x_{track}$ (normalized to central pad charge)

Clearly shows charge spreading over 2-3 pads (use data with 500 ns shaping)

Then fit x(cluster) using this shape with a χ^2 fit, and fit simultaneously all rows to a circle in the xy plane

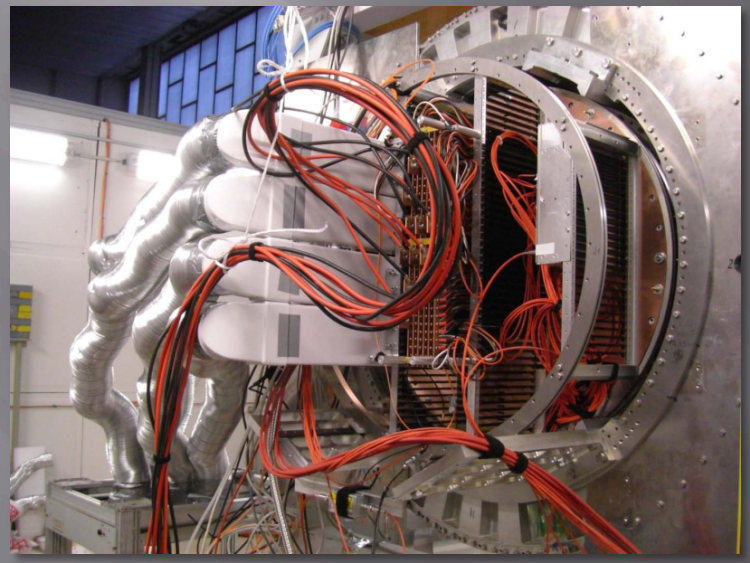






Resolution 46±6 microns with 2.7-3.2 mm pads
Effective number of electrons 23.3±2.0 consistent with expectations

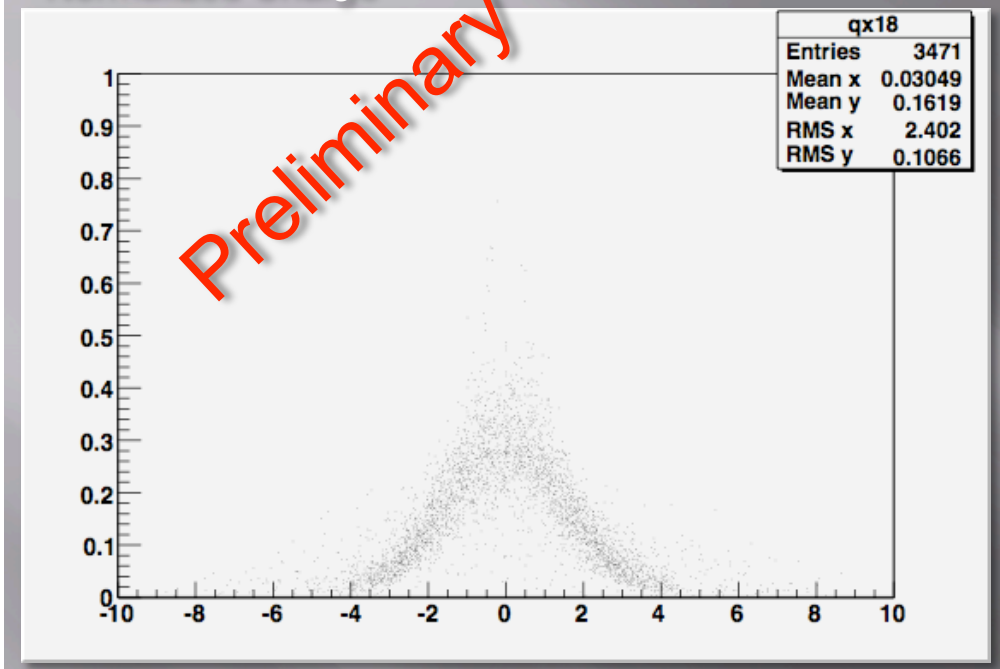
FIRST GEM RESULTS

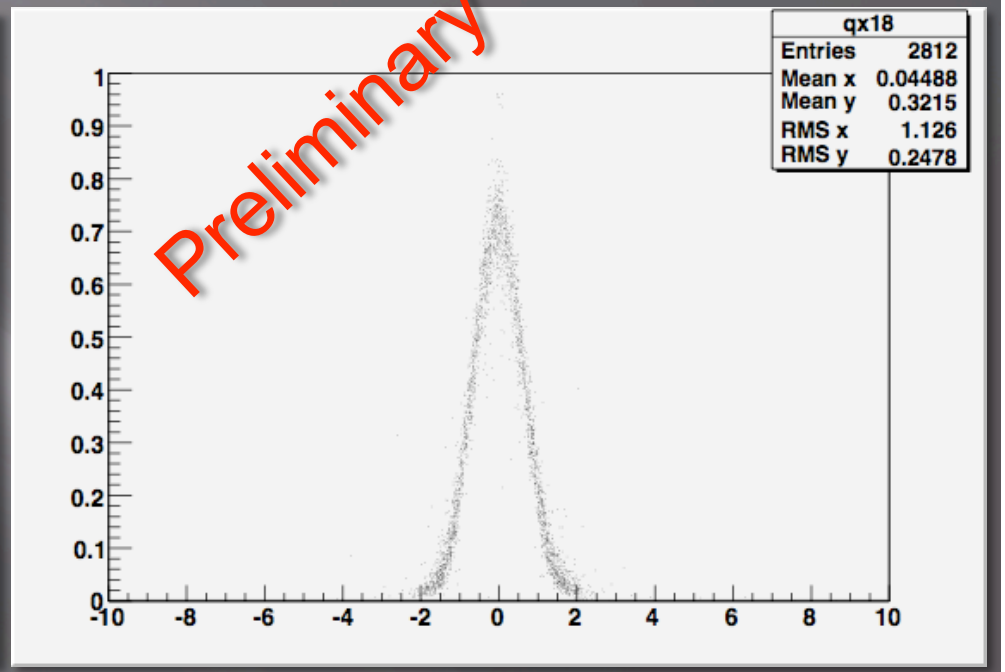


Pad Response

Z=250mm, Row18

Normalized Charge



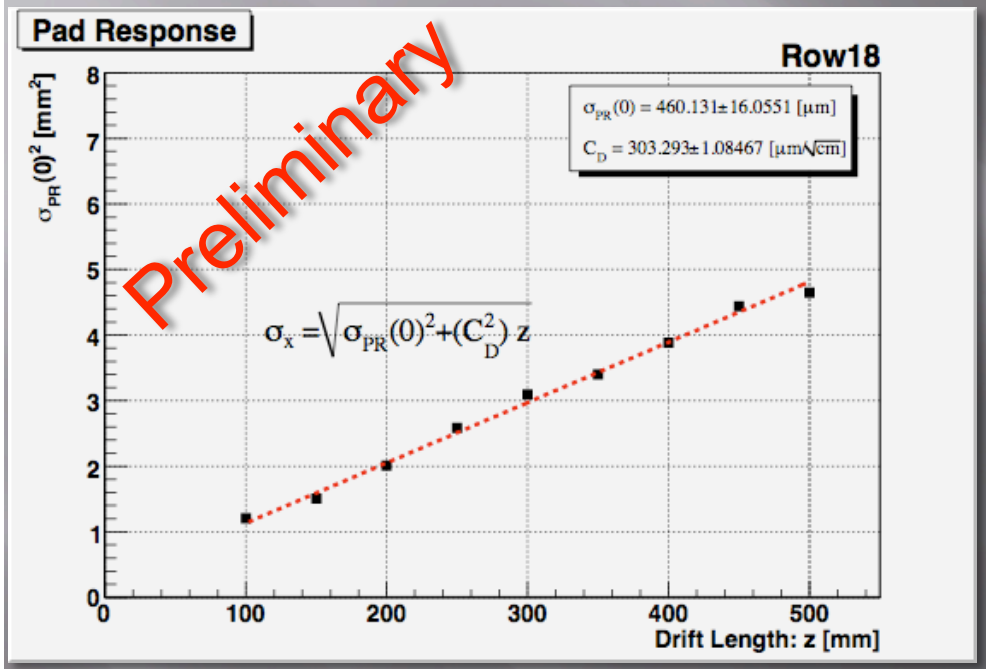


x[mm]

B=0T

B=1T

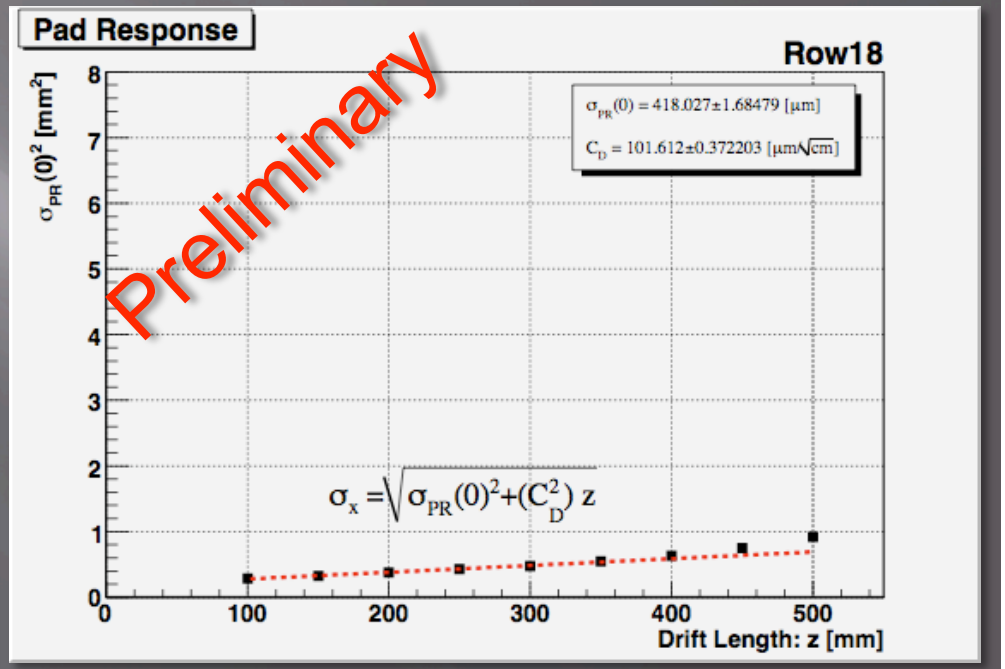
Width of Pad Response as a Function of Drift Length



B=0T

fitting result

Diffusion Coefficient = 303±1[μm/√cm]

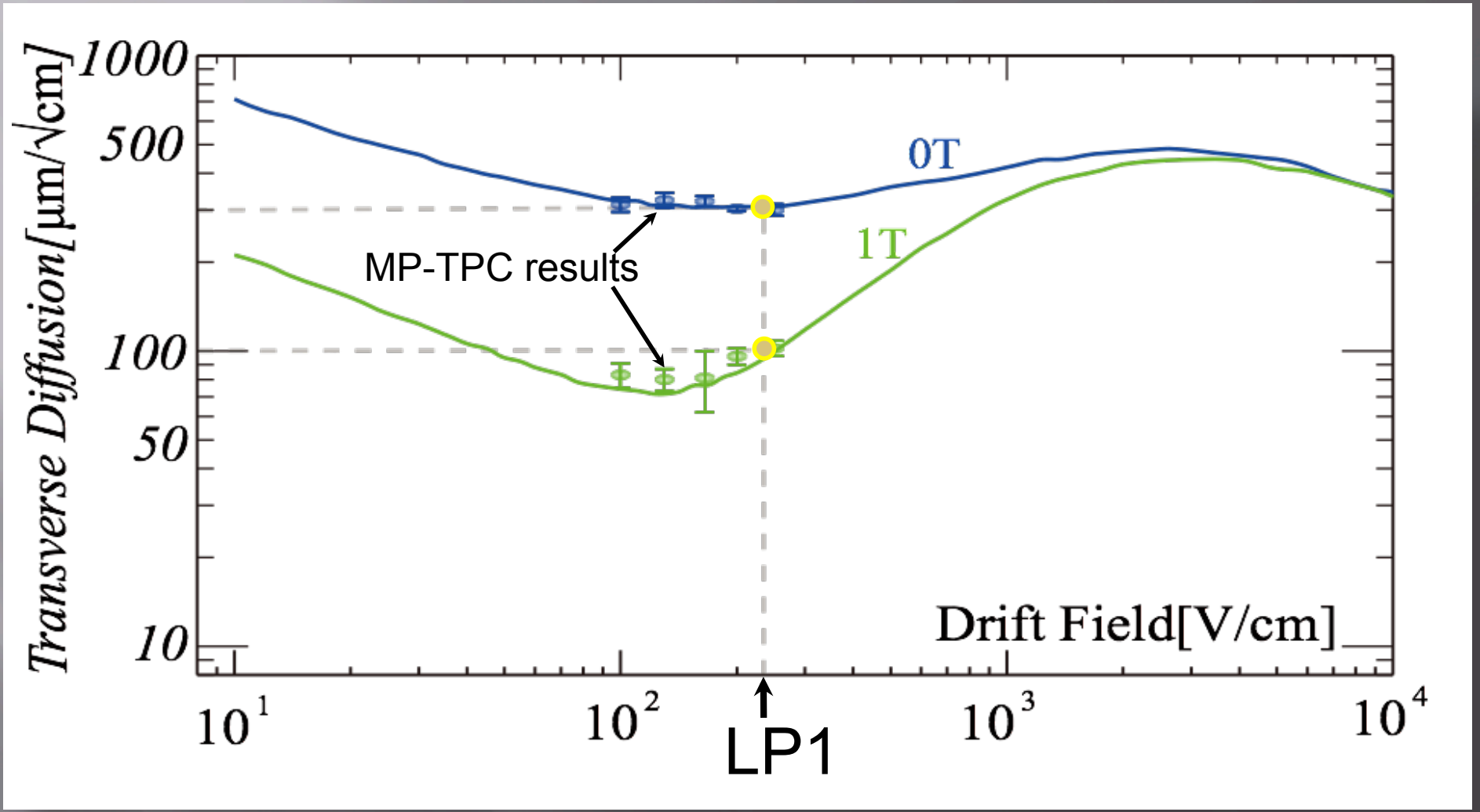


B=1T

fitting result

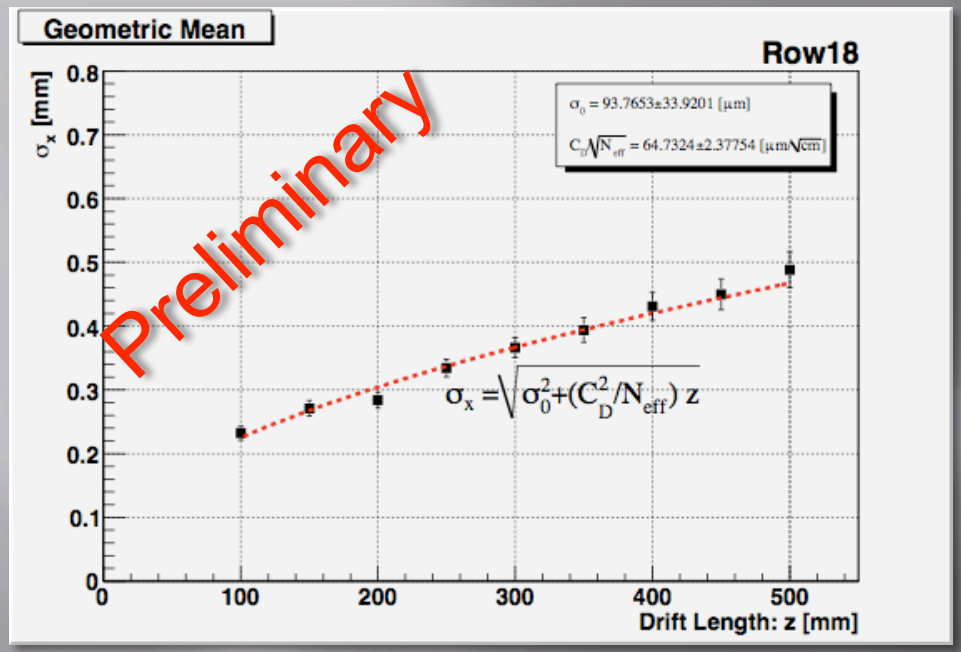
Diffusion Coefficient = 101.6±0.4[μm/√cm]

Comparison with Small Prototype (MP-TPC) And GARFIELD/Magboltz Simulation

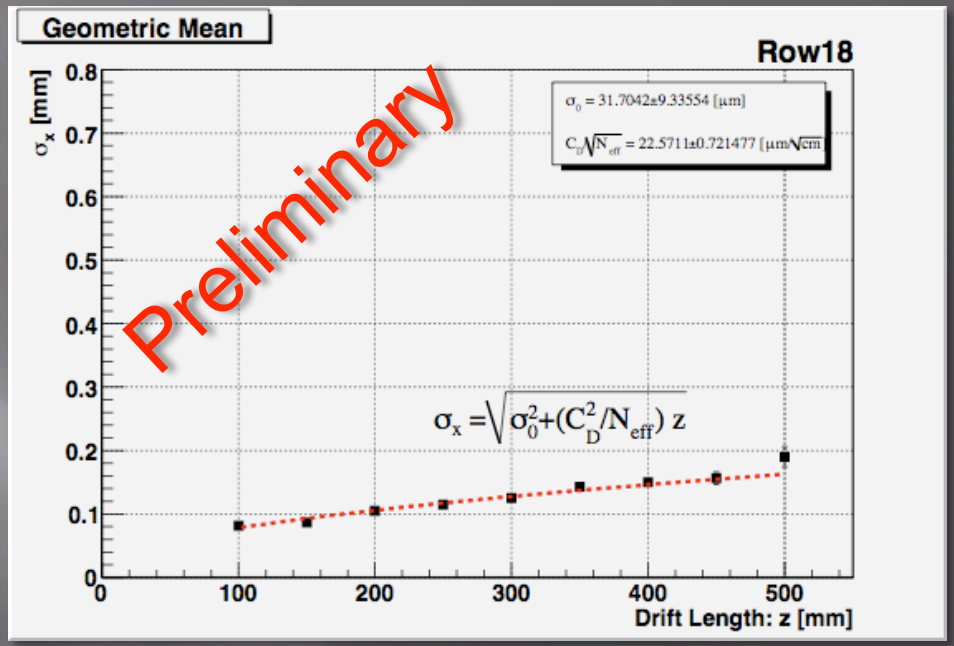


LP1 data are consistent with GARFIED/Maboltz simulation for diffusion coefficient.

GM resolution as a function of drift length



B=0T



B=1T

fitting result

$$\frac{C_D}{\sqrt{N_{eff}}} = 65 \pm 2[\mu m/\sqrt{cm}]$$

fitting result

$$\frac{C_D}{\sqrt{N_{eff}}} = 22.6 \pm 0.7[\mu m/\sqrt{cm}]$$

Effective number of electrons 21±2 consistent with the small prototype result

Summary

- Harvest time has come! We are busy analyzing the 1st large prototype (LP1) beam test data at DESY starting late 2008.
- More preparation for the 2nd LP1 test in FY2009.
  - More modules, more readout electronics, Gating GEM, …
- The LP1 data will be invaluable to prepare ourselves for the design phase.
- Hope we can show multi-module analysis results at the next FJPPL WS.
- We continue small prototype tests for
  - understanding of gas multiplication processes
  - optimization of gas mixtures
  - Gating GEM optimization
- We continue more R&D for MM+TimePix since it is theoretically the best choice.