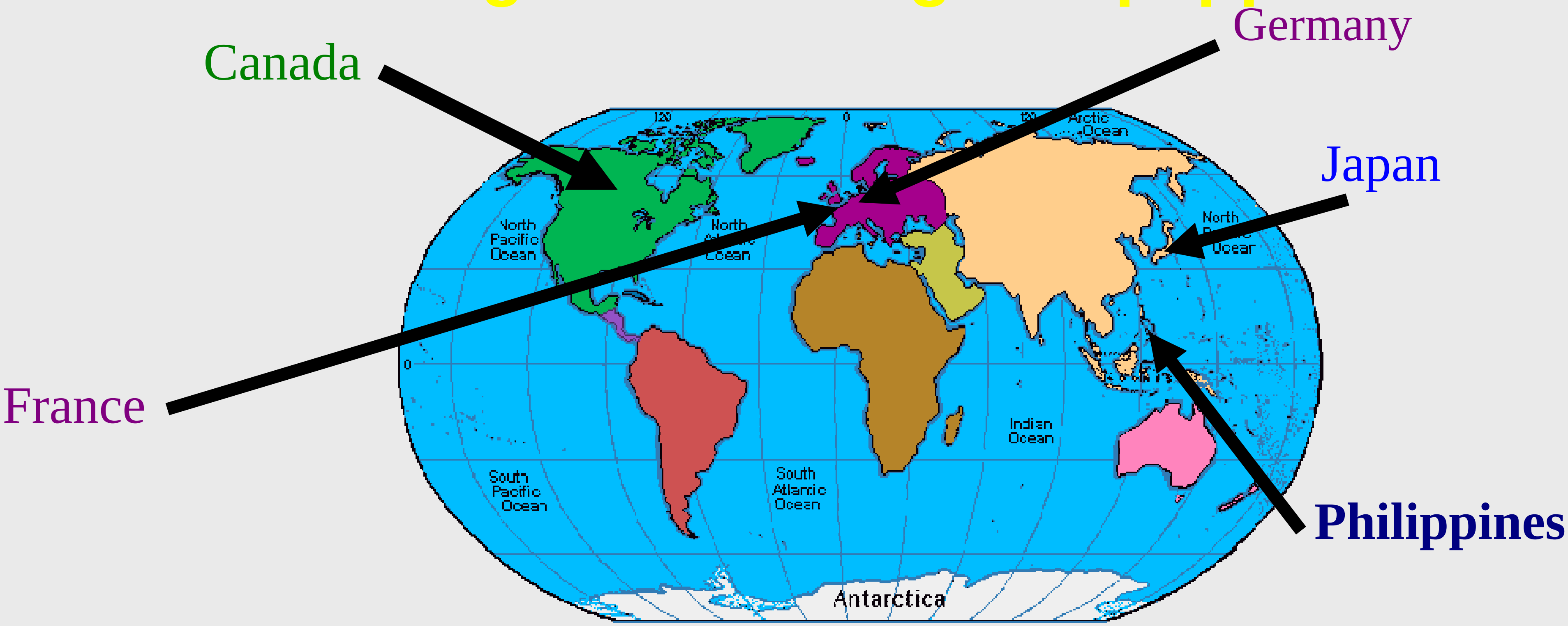
Studies on the Drift Properties and Spatial Resolution Using a Micromegas-equipped TPC



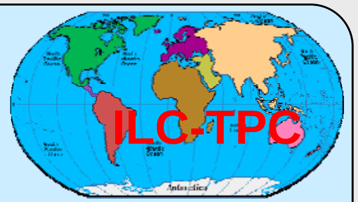
Collaborating Institutions:

Asia High Energy Accelerator Research Organization (KEK), TUAT, Kinki Univ., Hiroshima Univ, Saga Univ, Kogakuin Univ., Tsukuba Univ. (Japan) & Mindanao State University-IIT (Phil.)

Europe: MPI-Munich, DESY (Germany), DAPNIA/CEA/Saclay & LAL & IPN/Orsay (France)

Canada : Carleton University

Outline



1. Overview/Motivation

2. Experimental Set – up
   - Beam test facility@KEK

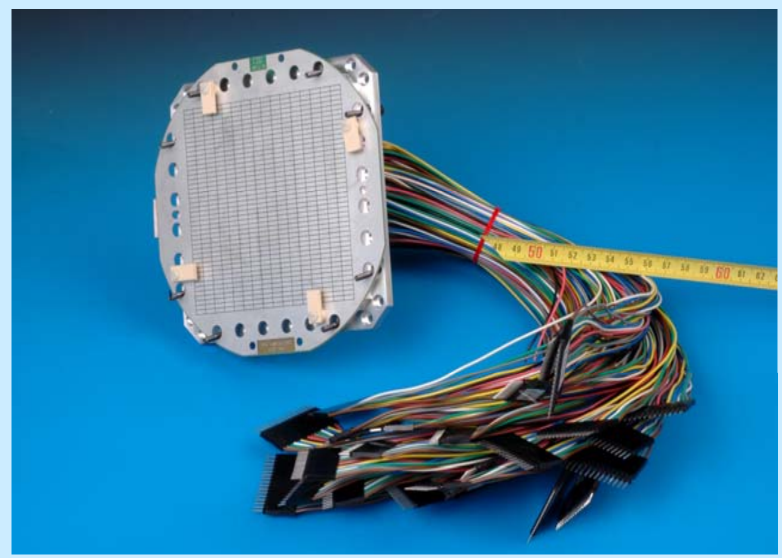
3. Some Preliminary Results
   - Electron drift velocity
   - Pad response studies
   - Transverse spatial resolution

4. Summary

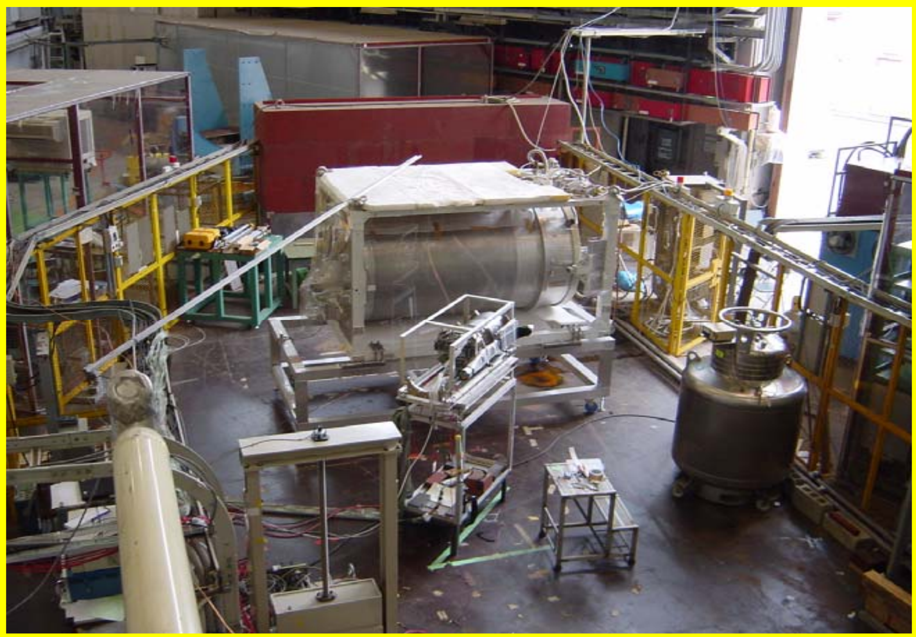
Motivation

Why Micromegas a possible option to TPC sensor ?

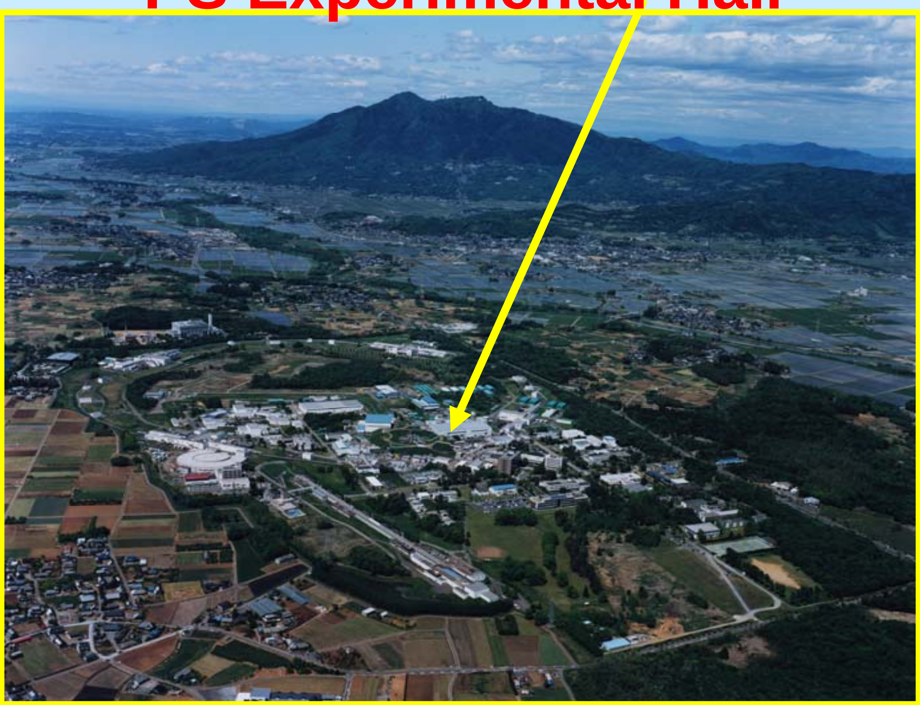
- **Small E×B effect**
- **Fast signals**
- **Self-suppression of positive ion feedback & the ions return to the grid**
- **Better spatial resolution**
- **No wire angular effect**



Beam Test on the Prototype Micromegas based TPC June 2005



PS Experimental Hall



Overview: KEK Complex

Conditions:

beam : 4GeV/c,π-

Gas Mixture: Ar+5% Isobutane

Maximum Drift Length =26 cm

E=220V/cm , B = 0. 0.5 & 1Tesla

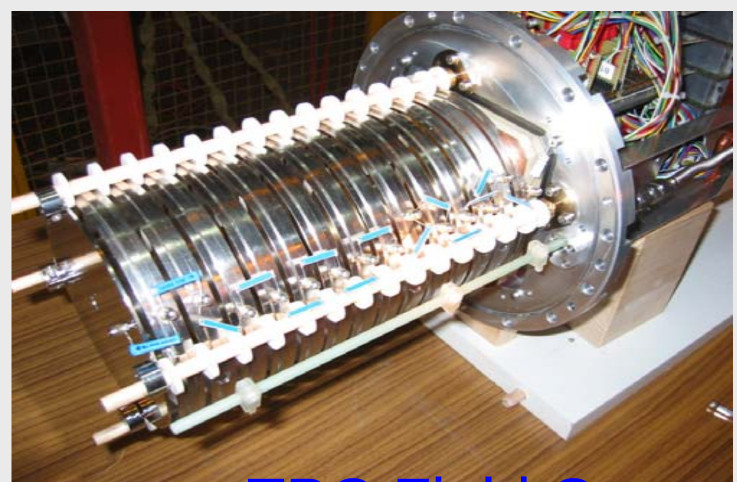
Gain = **10,000**

Pad Pitch width = 2.3 mm

Readout plane:

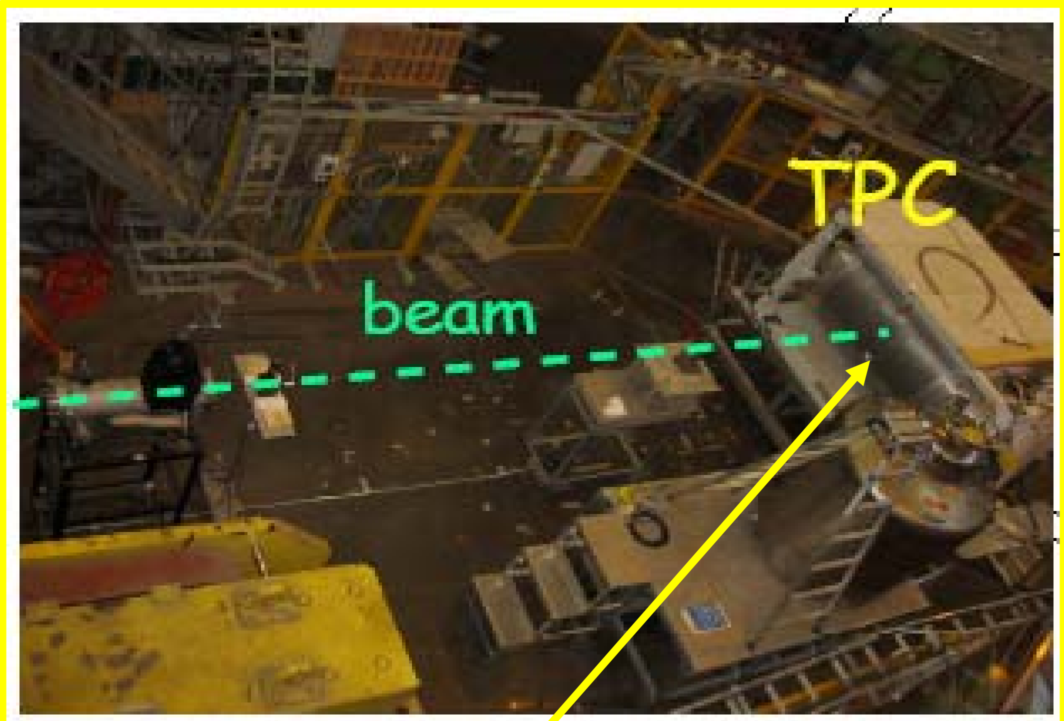
Effective area: 100 mm×100 mm

Field Cage: **cathode H.V.: = - 6 kV**



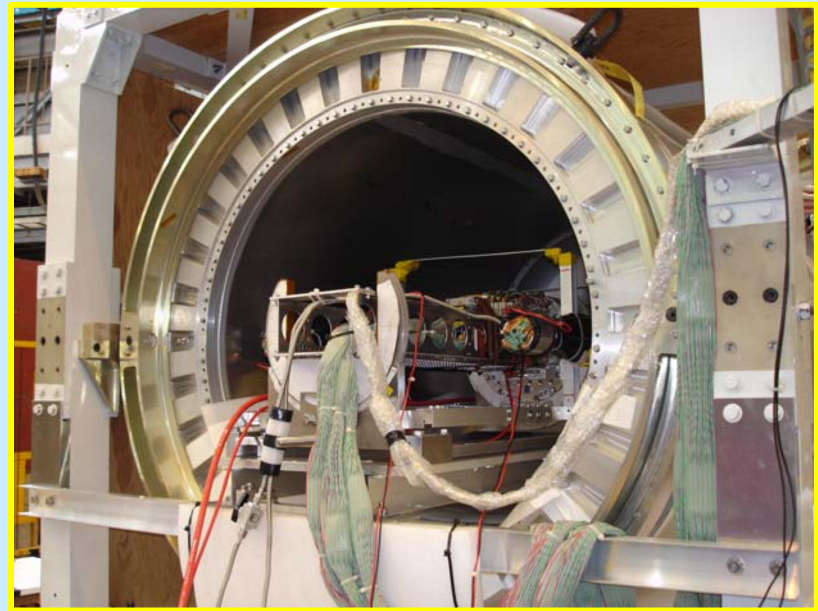
TPC Field Cage

Experimental set -up



Jacee Magnet

Inner diameter :
850 mm
Effective length:
1 m



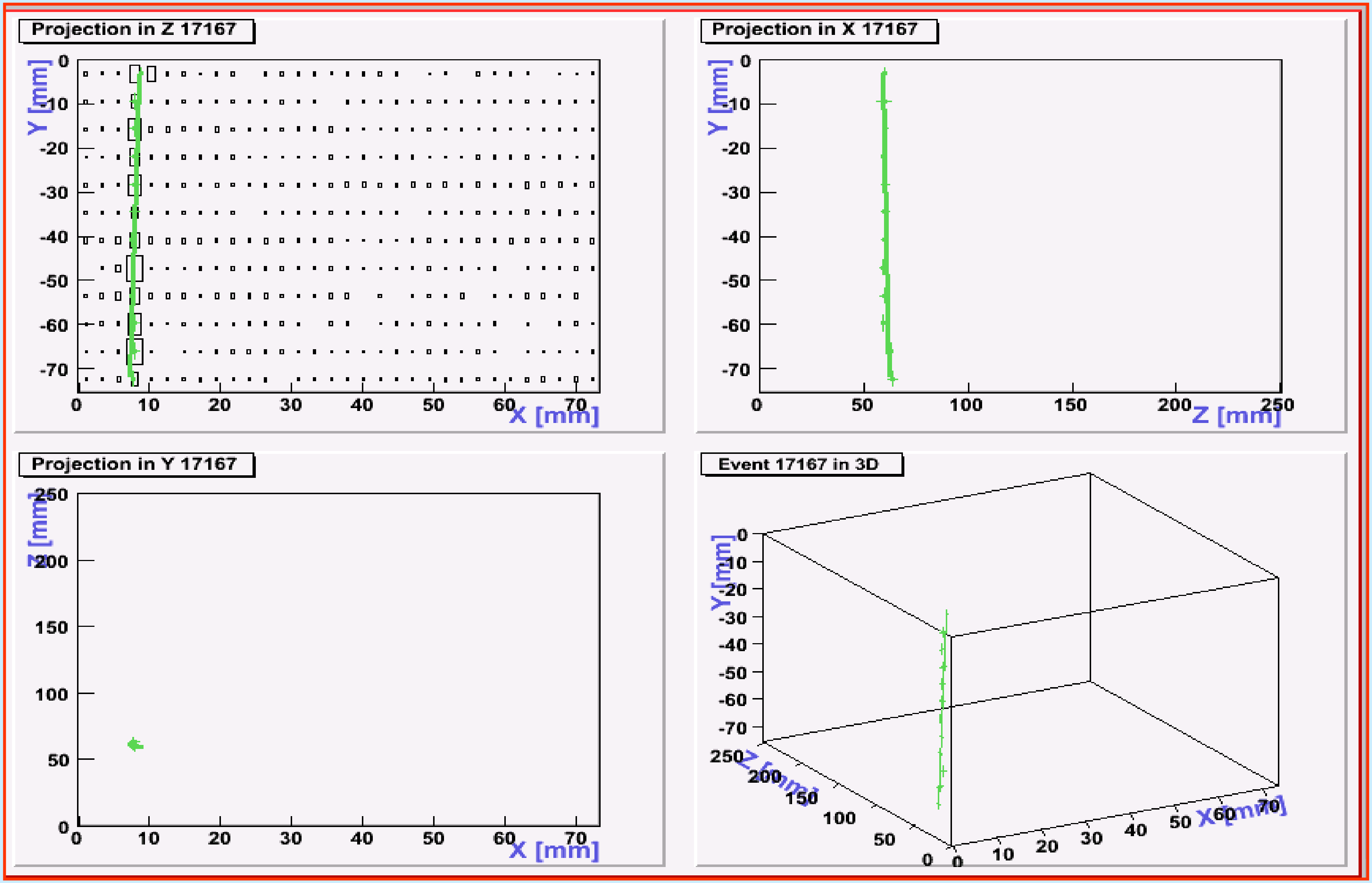
Readout-ALEPH TPC electronics:

24 amplifiers with 16 channels each digitized by 6 TPDs

FASTBUS FADC: 80ns time slice

Pre-amplifier: 500 ns shaping time

Some Preliminary Results



Event Display at B= 1Tesla

Drift Velocity Measurement

Method:

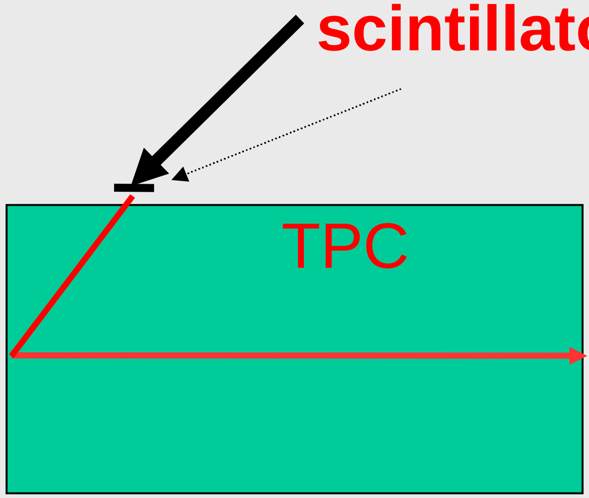
- determined from the maximum drift time bucket distribution on one pad

Average time Resolution for 4 central Padrows = 5.907 ± 30ns

Add:

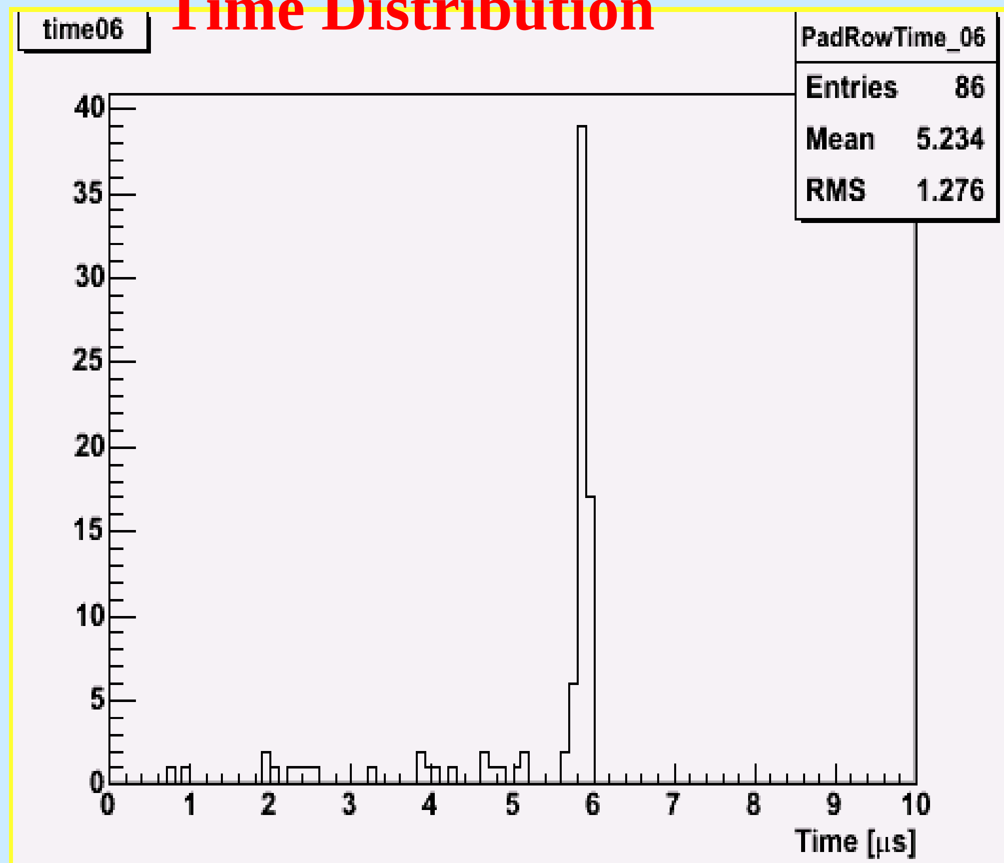
Trigger cable delay = 311±5ns
Trigger logic & TPD = 20ns
Total Time = 6.237 ±0.050 cm/μs
Total drift length=26.08 cm

beam at 45^0
scintillator counter



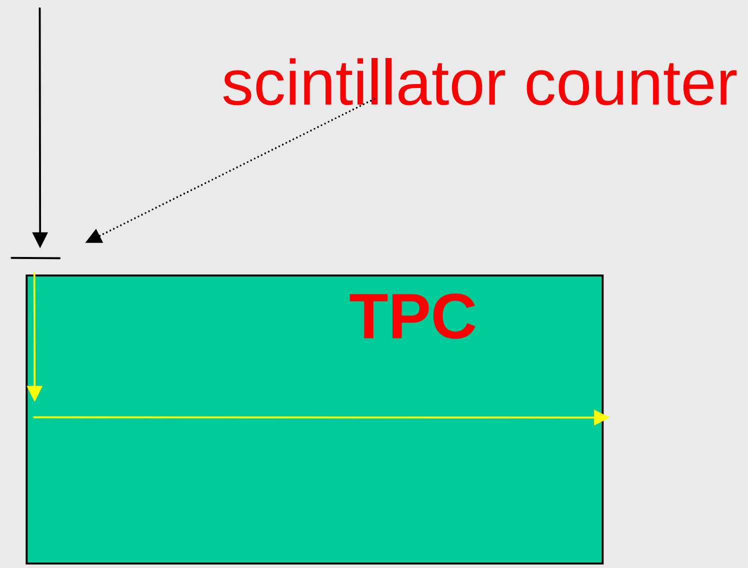
Ref: Paul Colas

Drift time (80 ns clock ticks

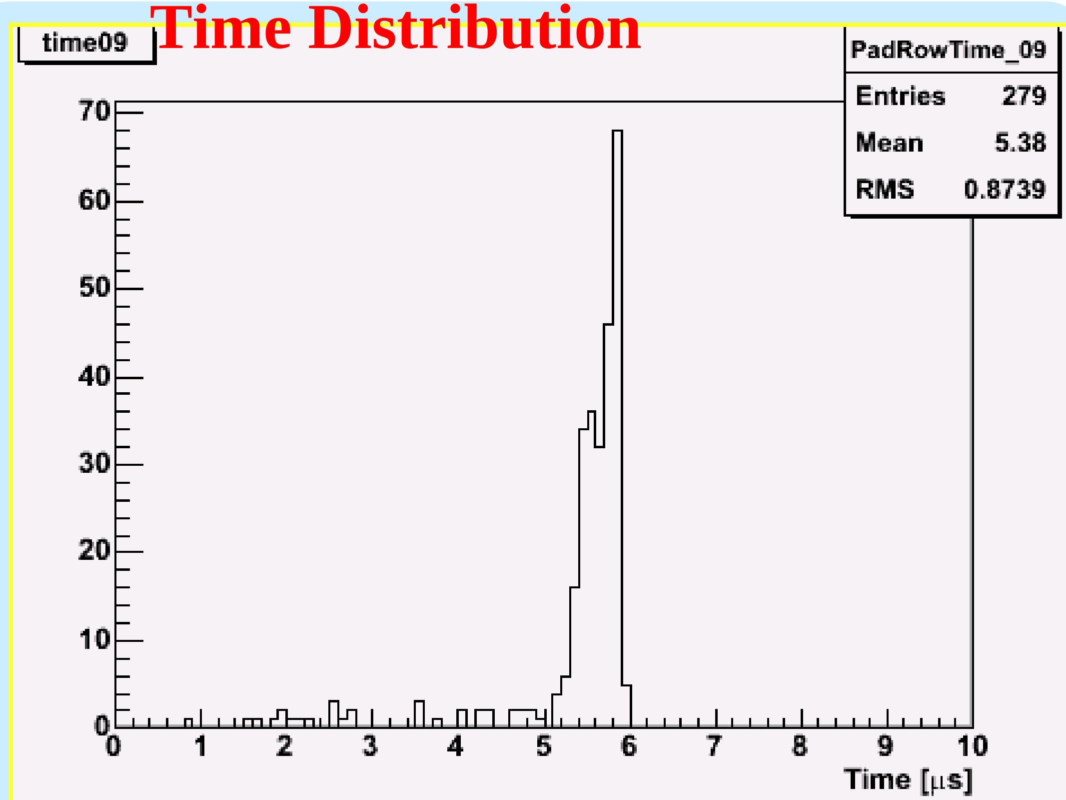


Drift Velocity (Ar+5% Iso) = 4.181 ±0.034cm/μs

(220V/cm,P=1002 hPa & Temp=27 ° C)



Time Distribution



Time Resolution @ **B= 0.5Tesla**

Padrow 6- 5.946ns

Padrow 7- 5.935ns

Padrow 8 -5.942ns

Padrow 9- 5.948ns

Total Ave Time =

6.273 ±0.050cm/µs

Total drift length=26.08 cm

Measured Drift Velocity (Ar+5% Iso)

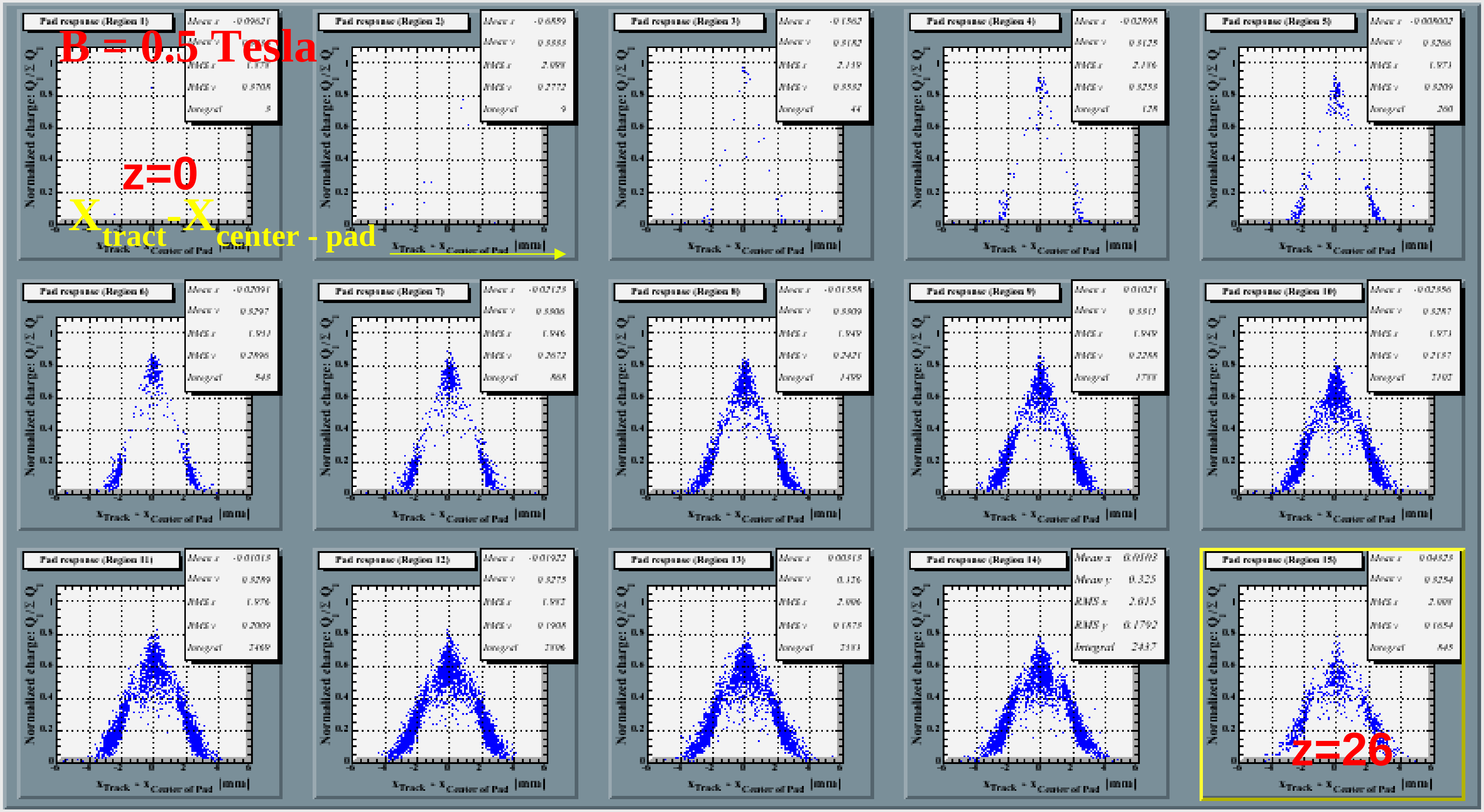
Beam at normal incidence

V_d = 4.157 ±0.036cm/µs

...... in excellent agreement with

Magboltz Simulation:
V_d= 4.173 ± 0.016 cm/µs

Charge Width Measurement for different drift regions



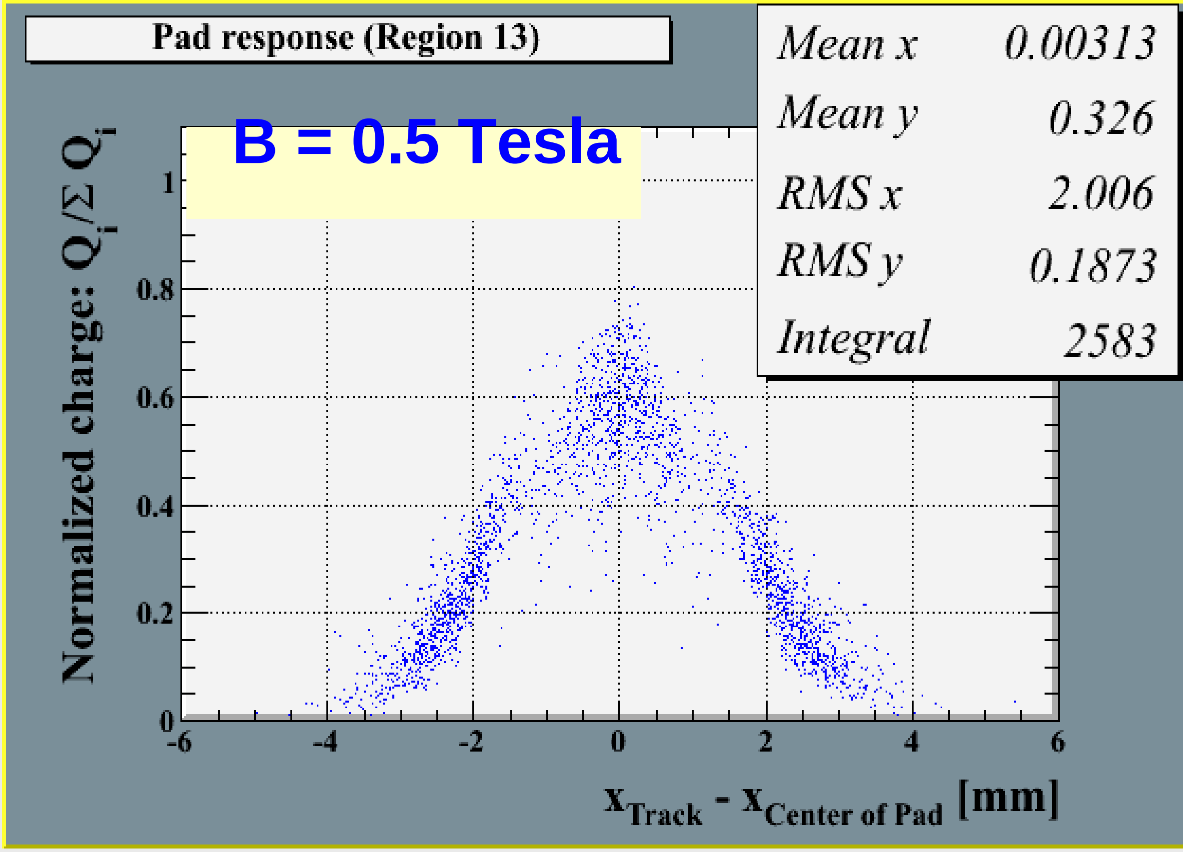
■Most Tracks are found out to cross in the middle padrows

■Charge distribution becomes wider at longer drift distance due to diffusion

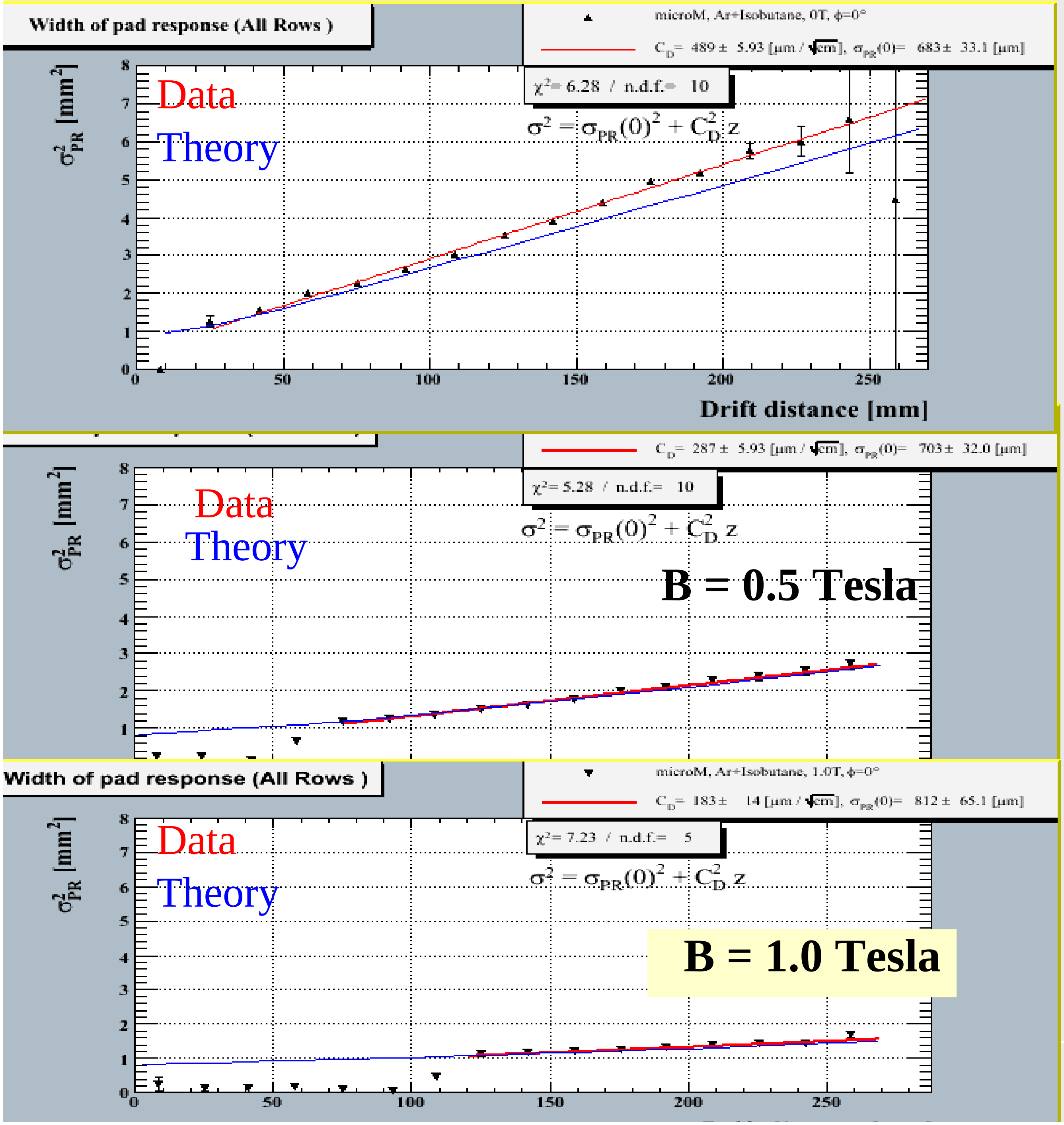
Charge Width Measurement from Pad Response

Method:

- **Plotted Qi/Q_{tot} against X_{tract} - $X_{pad\text{-}center}$ for different drift regions (N zbins = 15)**
- **Reject single & double pad hits**
- **Divide the plot into different X-slices**
- **Fit each slice with Gaussian function**
- **Plotted sigma vs drift length.**
- **The slope of the fitted track spread is used to measure the transverse diffusion.**



Diffusion Constant Measurements



Track segment width as function of Z

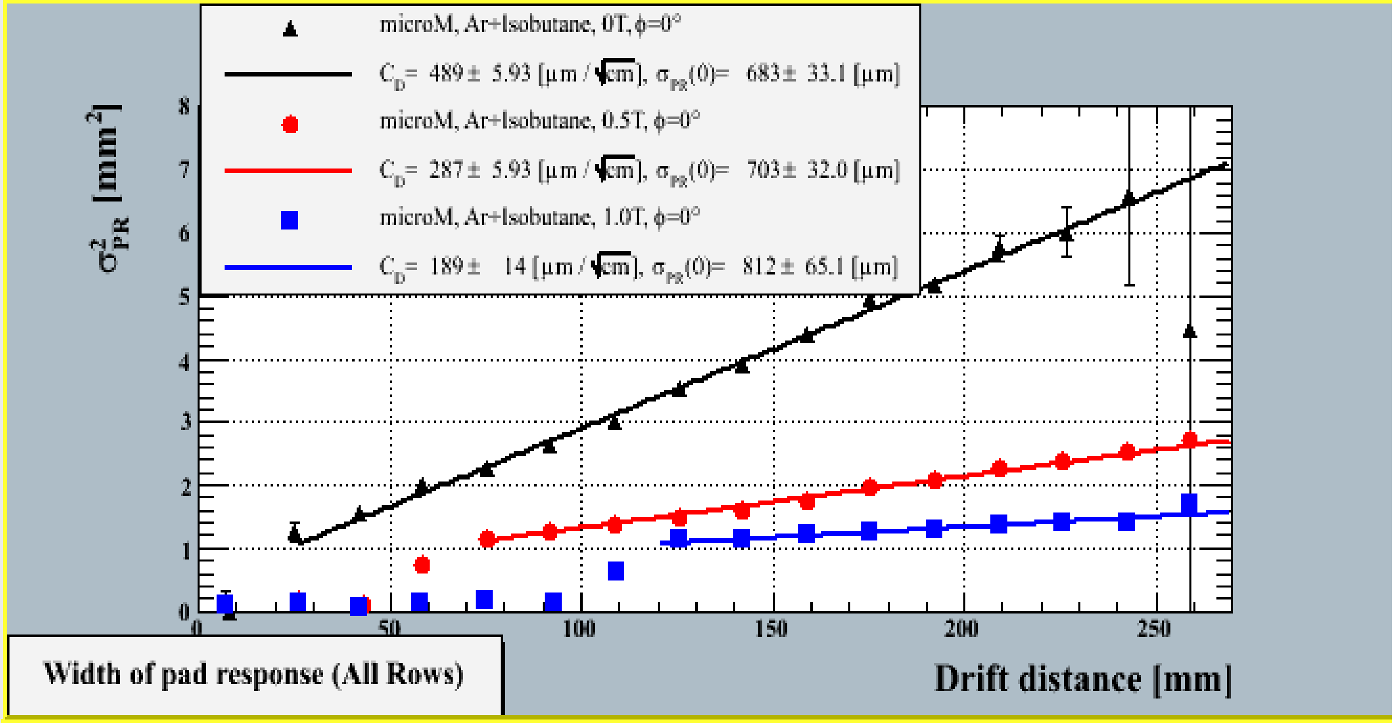
$$\sigma^2_{PR} = \sigma^2_{PR\,0} \quad C^2_D Z$$

with

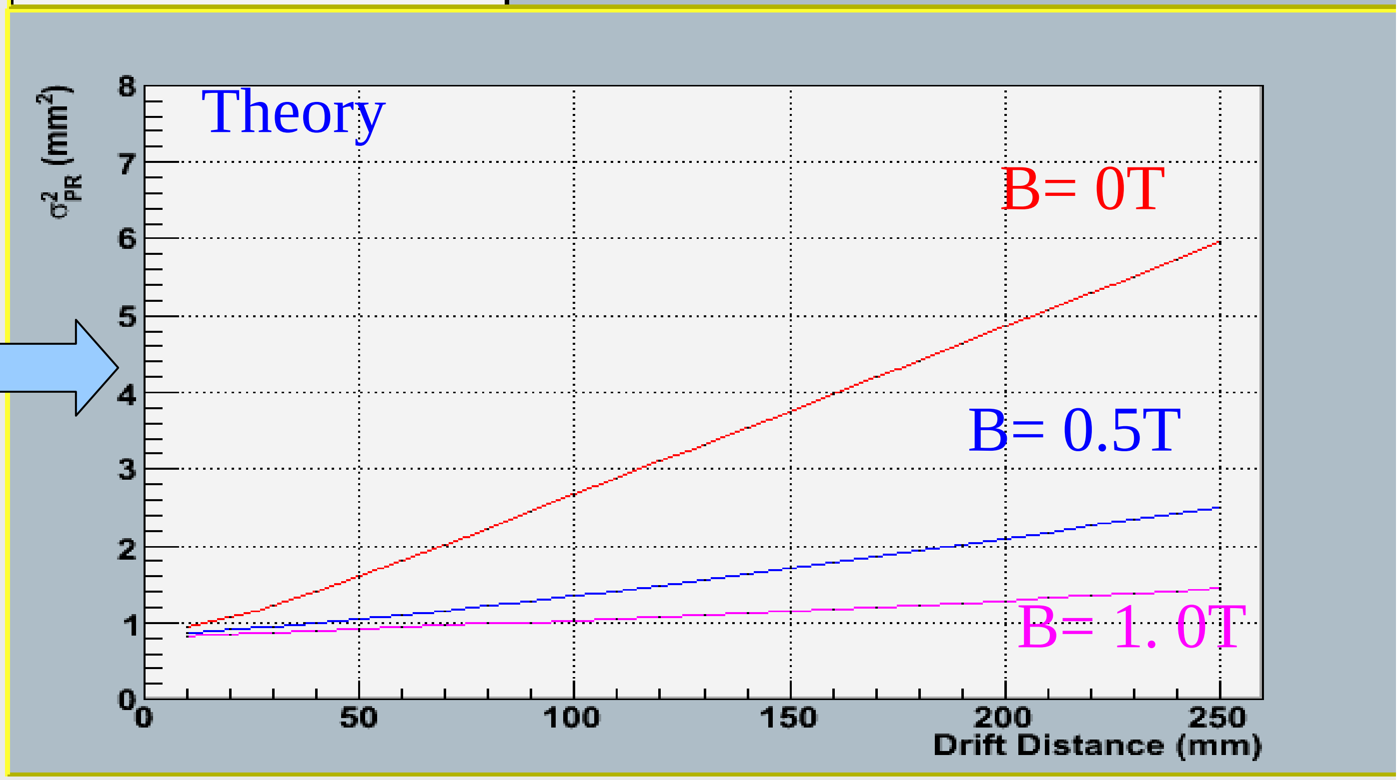
$$^2_{PR\,0} = \frac{w^2}{12} \quad ^2_{PRF}$$

B	C_D Magboltz	C_D measured
0T	469	489
0.5T	285	287
1T	193	189

The fit of the slope for large z gives a good measurement of C_D



Analytical calculation for Ar+5%isobutane with Magboltz diffusion coeff. for B=0, 0.5 and 1 T, <1/N>=1/46 and Polya fluctuations with ❑=0.5, pad pitch = 2.3 mm (Program coded by Keisuke Fujii)

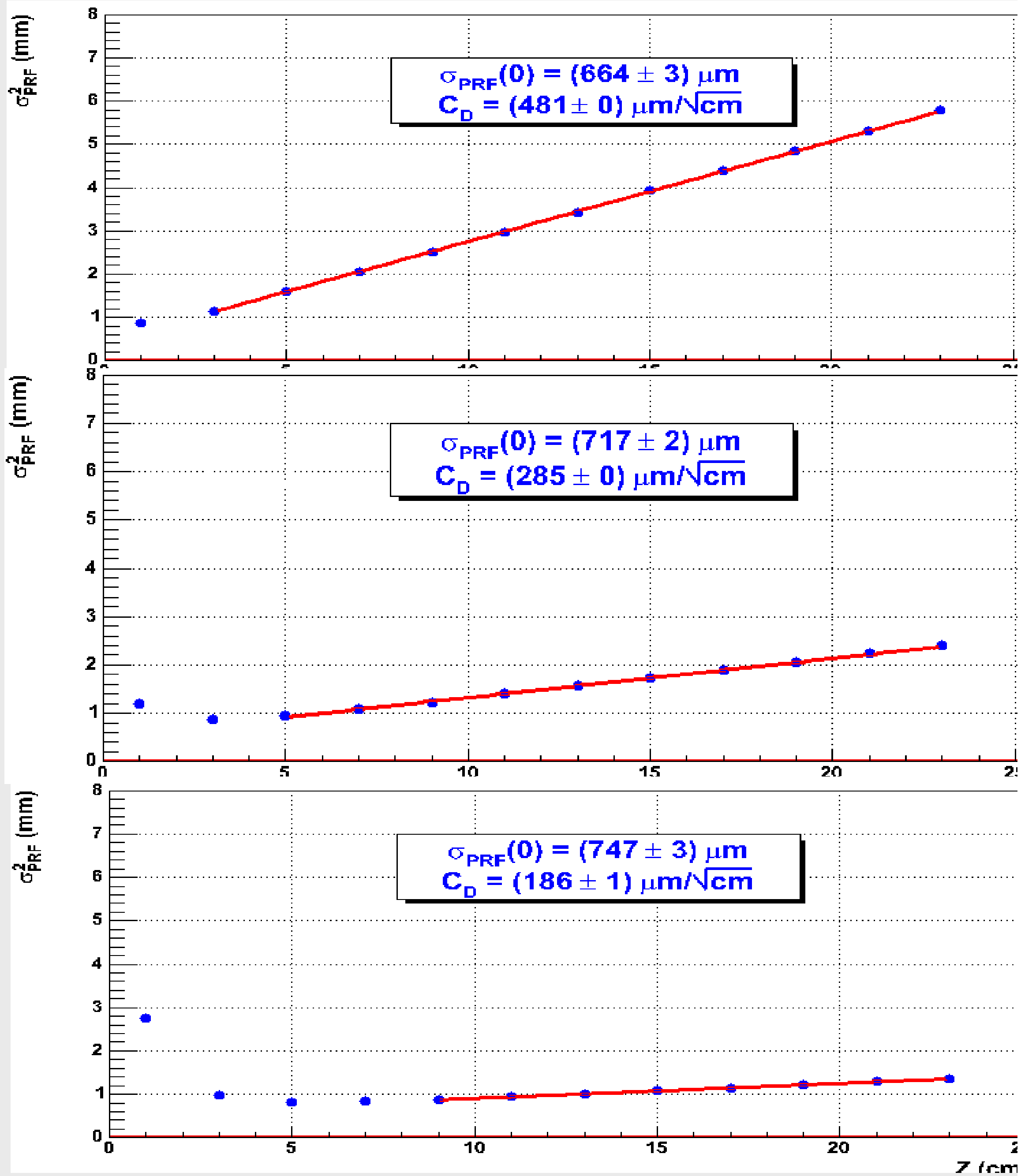


Track Segment Width vs Z –Simulation Studies

$$\sigma_{trk-segment^2} = \sigma_{0trk-segment^2} + C_{D^2}\, Z$$

The fit of the slope for large z gives a good measurement of C_D

B	C_D input	C_D fit
0T	469	481
0.5T	285	285
1T	193	186

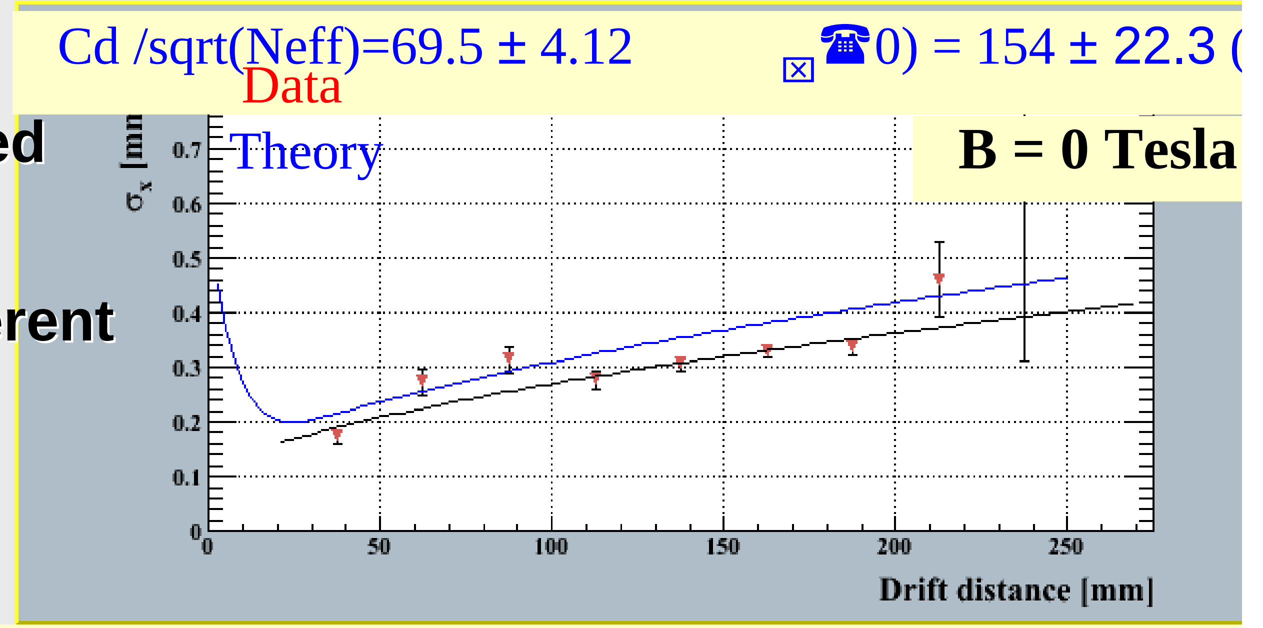


by K. Boudjemline

Spatial Point Resolution-Two Padrow Measurement

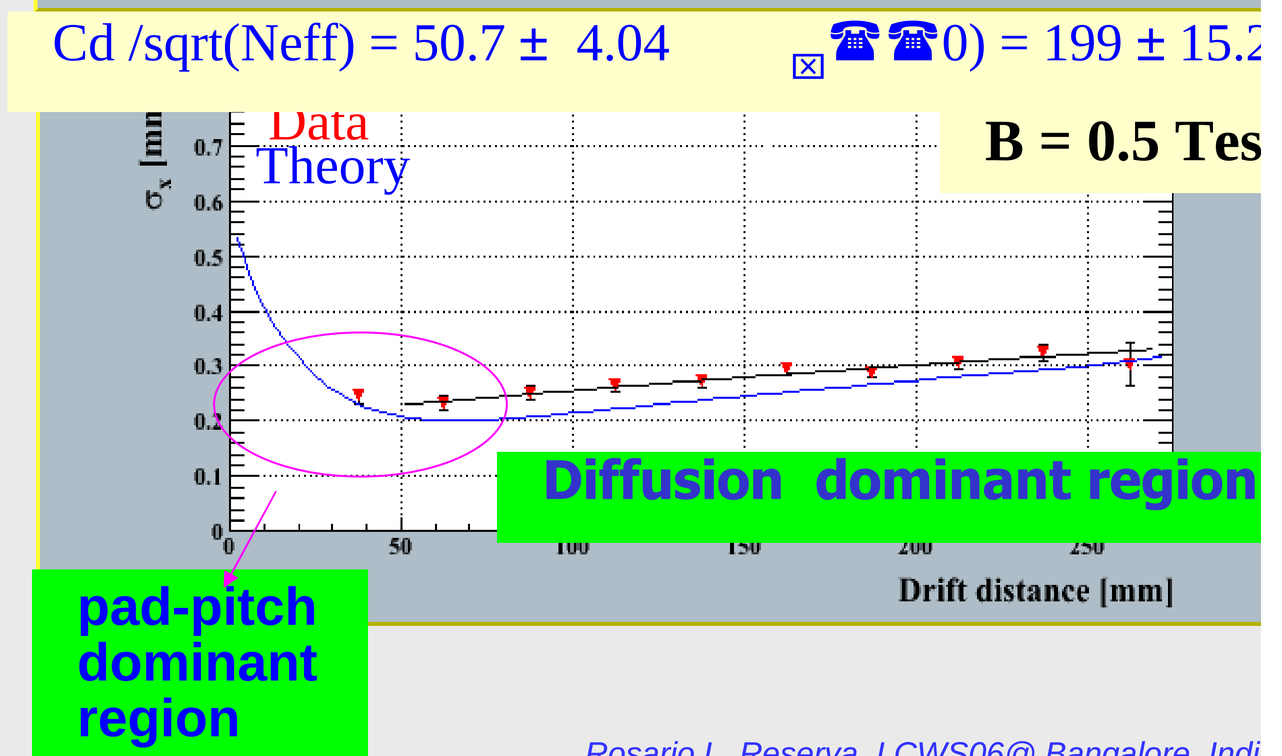
Method:

- The residual is calculated & fitted by gaussian func
- Sigma is plotted for different drift regions



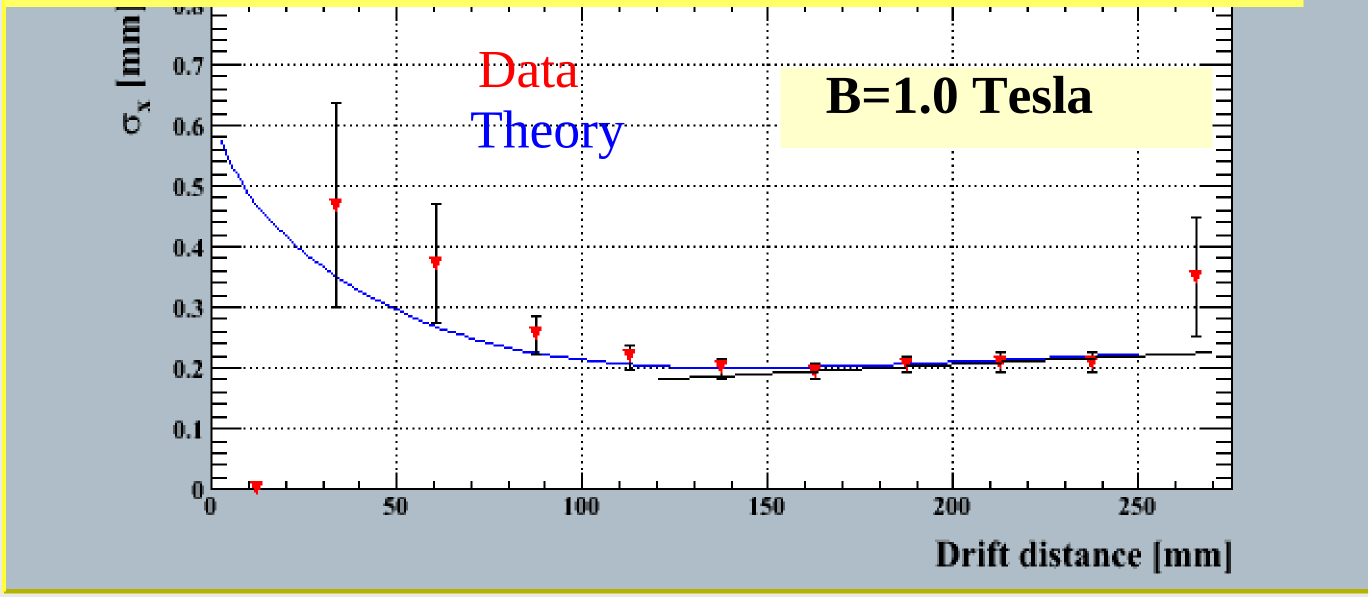
The Z-dependence of Spatial Resolution

$$\sigma_x = \sqrt{\sigma_{0}^{2} \quad C_{D^2}/N_{eff} \quad Z}$$



At lower z, the spread due to diffusion is small compared to pad-pitch.

Cd /sqrt(Neff)=40.7± 3.64 $\sigma_x(0)$ = 134 ±76.2 (um)



- At low drift distances, the resolution tends to pitch/√12

Analytical Calculation for spatial resolution (adapted from K. Fujii)
Pad : 2.3 mm
Diffusion Constant :
469, 285 and 193 (um/sqrt cm)
for *B* = 0, 0.5 and 1.0 T

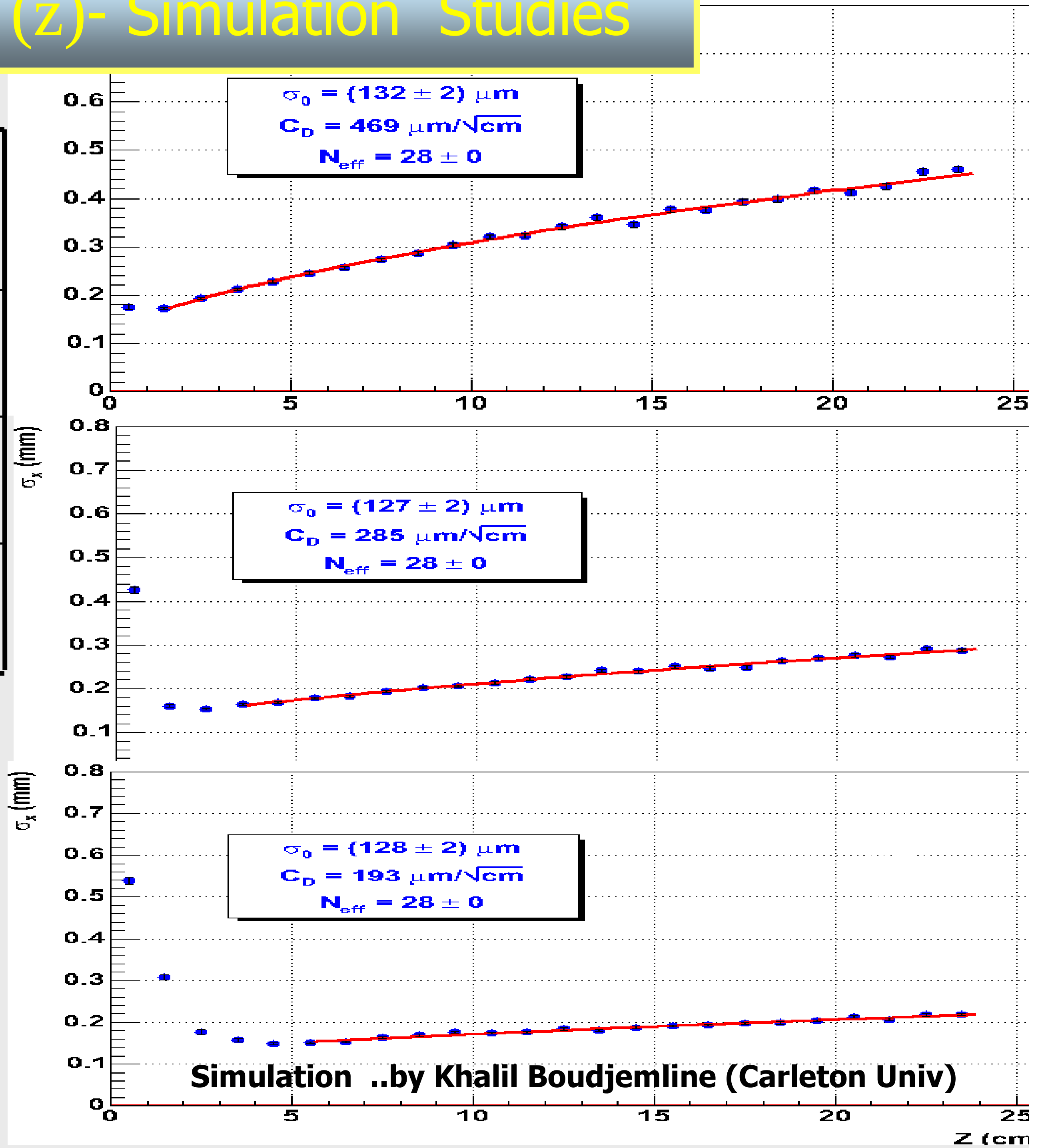
Detailed talks on analytical formulation of resolution limit to be given by K. Makoto

Spatial Resolution σ_x (z)- Simulation Studies

B	$\sigma_x(0)$ measured	$\sigma_x(0)$ fit
0T	154 ± 22.3	132 ± 2
0.5T	199 ± 15.2	127 ± 2
1T	134 ± 76.2	128 ± 2

Good agreement with analytical calculation

$$\sigma_0 = 2.3 \text{ mm} / \sqrt{(12\text{x}28)} = 126\ \mu\text{m}$$



Summary of Preliminary Results

T572 Beam Test : Micromegas TPC Beam Test @ KEK

June 22-July 1, 2005

(With 3-Pad Cluster in PR Analysis and & with Pedestal Correction)

	Cd (μm/√cm)	$Sigma_{PR}(0)$ (μm)	Cd/ sqrt $\{N_{eff}\}$	Spatial Resolution σ_x (0)
B=0 T	489 ± 5.93	683 ± 33.1	69.5 ± 4.12	154 ± 22.3
B=0.5 T	287 ± 5.93	703 ± 32.0	50.7 ± 4.04	199 ± 15.2
B=1.0 T	189 ± 14.0	812 ± 65.1	40.7 ± 3.64	134 ± 76.2

	Magboltz Prediction Diffusion Constant (Cd)	Montecarlo Simulation Diffusion Constant (Cd)
B=0 T	469	481 ± 0
B=0.5 T	285	285 ±0
B=1.0 T	193	186 ± 1

SUMMARY

- **Prototype Micromegas - TPC had been successfully operated at KEK, Japan.**
- **Measured drift velocity is in excellent agreement with Magboltz prediction.**
- **At large Z, track segment can be approximated by gaussian fit. C_d is calculated from the asymptotic slope of the sqrt(Z) dependence.**
- **Measured spatial resolution as a function of drift distance, i.e, $\sigma_x(0)$” ơ(100)μm to few 100 μm with variation in Z due to diffusion and pad pitch contribution.**

Acknowlegment

ILC- ASIA/ EUROPE/ CANADA
TPC Collaboration
KEK, Tsukuba, Japan
ACFA
LCWS06 Organizers
MSU-IIT, Phil