Performance studies of GEM or MWPC equipped MPI-TPC in magnetic fields

Katsumasa Ikematsu (DESY)

On behalf of the Asia/Europe TPC collaboration
(KEK - U. of Tsukuba - TUAT - Kogakuin U. - Kinki U. - Hiroshima U. - Saga U. - Mindanao State U. - Carleton U. - DESY - MPI)

The ECFA International Linear Collider Workshop 2005
16 November, 2005 @Vienna, Austria

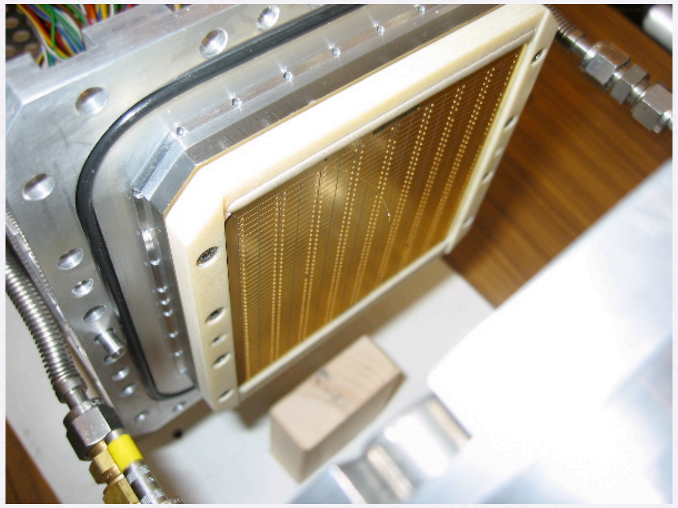
Overview

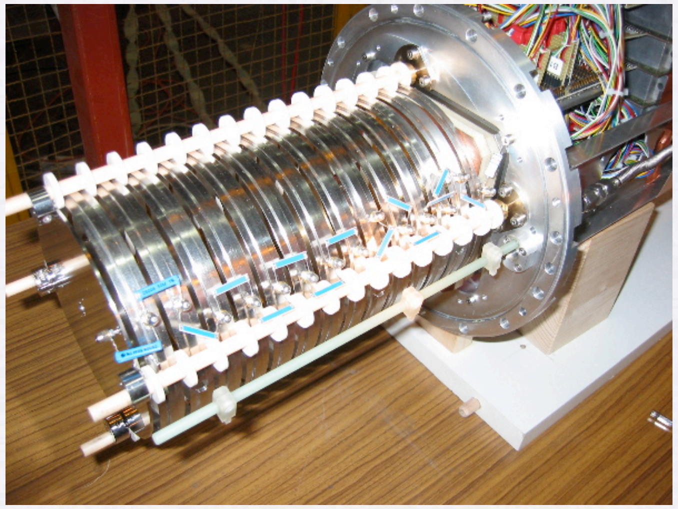
- MPI-TPC: Readout scheme and available data sets
  - Features, Pad geometry, B-field, Beam/Cosmic-ray & Gas
  - Facilities for Beam/Cosmic-ray tests
- Pad response studies
  - z-dependence of charge width

    -> width of pad response (@ 0 drift) & transverse diffusion constant
- Transverse spatial resolution studies
  - Goal: sigma_x ~ 170 μm @ 250 cm max. drift (4T, LDC)
  - Scale to real TPC -> transverse momentum resolution
- Longitudinal spatial resolution studies
  - Goal: sigma_z < 1 mm (for good track-cluster matching)
- Summary & outlook

Prototype TPC (MPI-TPC)

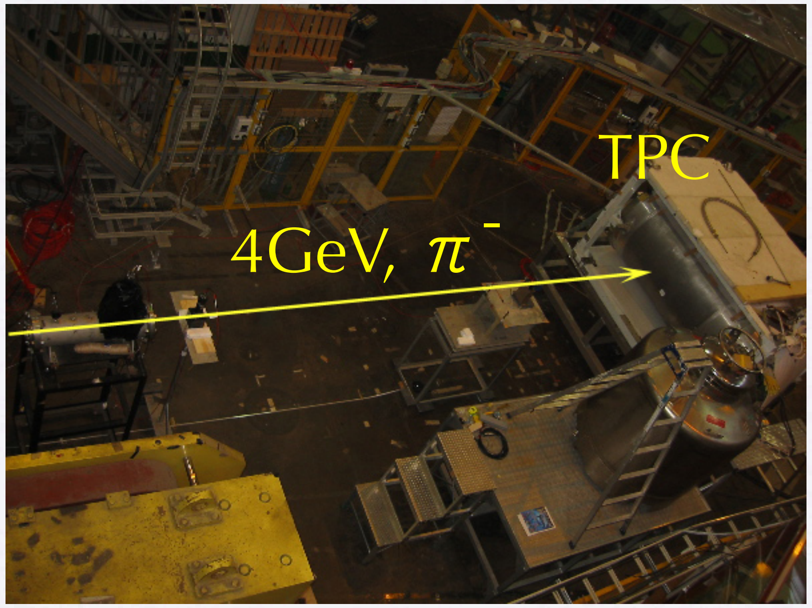
- Constructed at MPI (Max Plank Institute)
- Detachable endplate allows direct comparison of sensors
  - MPGD: GEM and MicroMEGAS
  - "Ultimate" MWPC
- 32 pads x 12 pad-rows = 384 readout ch (224 ch 7 pad-rows equipped)
- Maximum drift length: 26 cm (Eff. volume: 10 x 10 x 26 cm^3)
- 1 atm. Ar dominated Gas (Ar-CH_4-CO_2 (93-5-2): TDR Gas, Ar-CH_4 (95-5): P5 Gas)
- Charge sensitive pre-amplifier based on ALEPH readout electronics;
  FASTBUS FADC: 80ns time slice,
  Pre-amplifier: 500ns shaping time



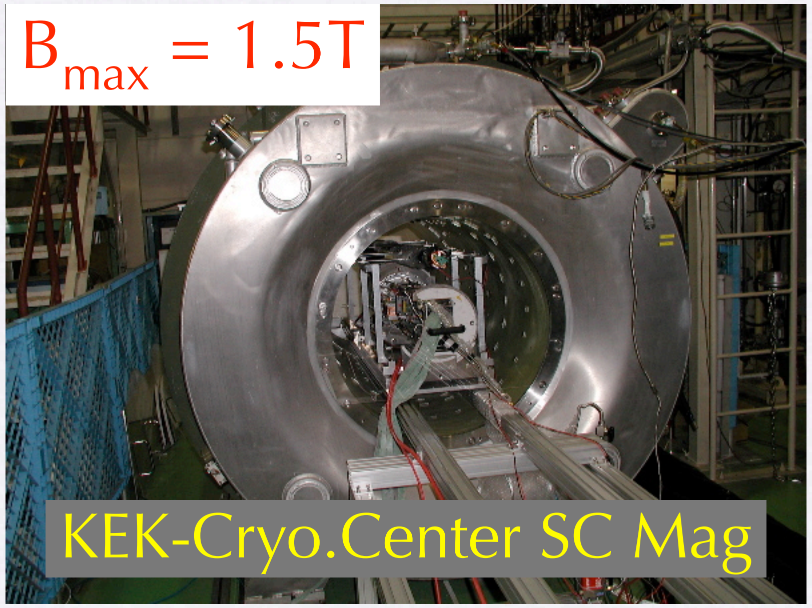


Facilities for Beam/CR test

- Superconducting solenoid & KEK-12GeV PS (π2) for beam test



- Superconducting solenoids at DESY and KEK-Cryogenic Center for cosmic-ray tests



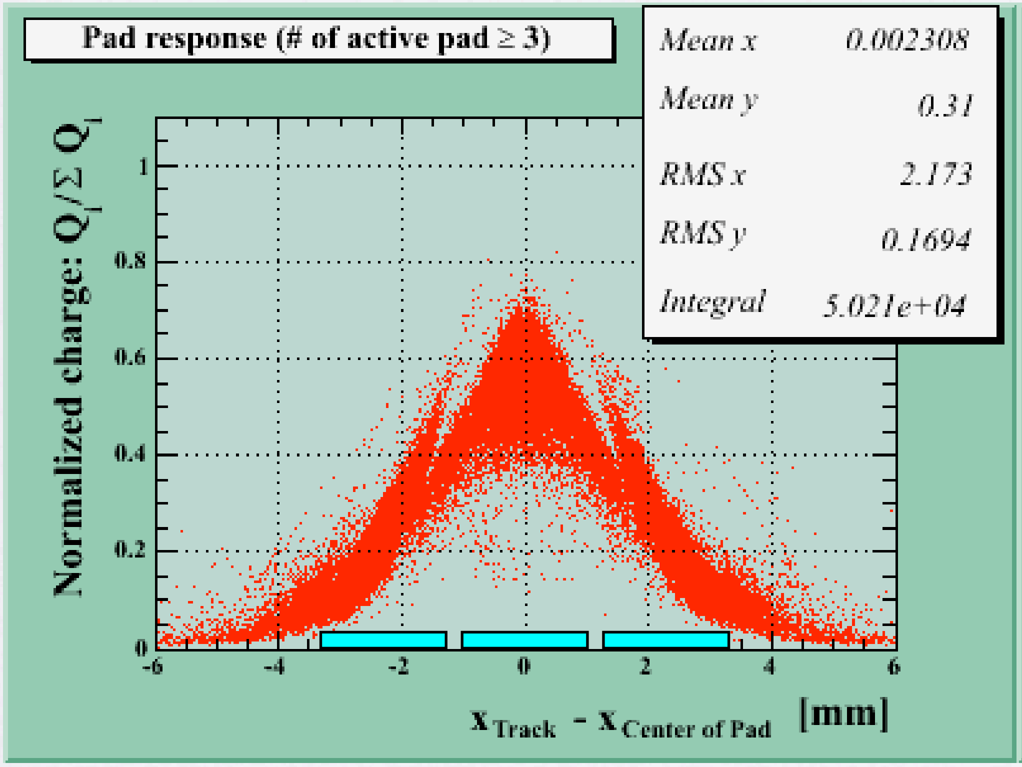
Readout scheme & data sets

Readout	GEM				MWPC				
Feature	Standard CERN GEM Triple GEM structure			+ resistive anode	1 mm anode-cathode thin gap 2 mm anode-wire spacing				
Pad geom. [mm] Width (pitch) x Length (pitch)	1.17 (1.27) x 6 (6.3)		2 (2.3) x 6 (6.3)	2 (2.3) x 6 (6.3)	2 (2.3) x 6 (6.3)				
B-field [T]	0T	1T	1T	1T	0T	1T	0 T	1 T	4 T
Beam/CR	Beam		CR	Beam	Beam		CR		
Gas	P5	P5, TDR	TDR	P5	TDR				

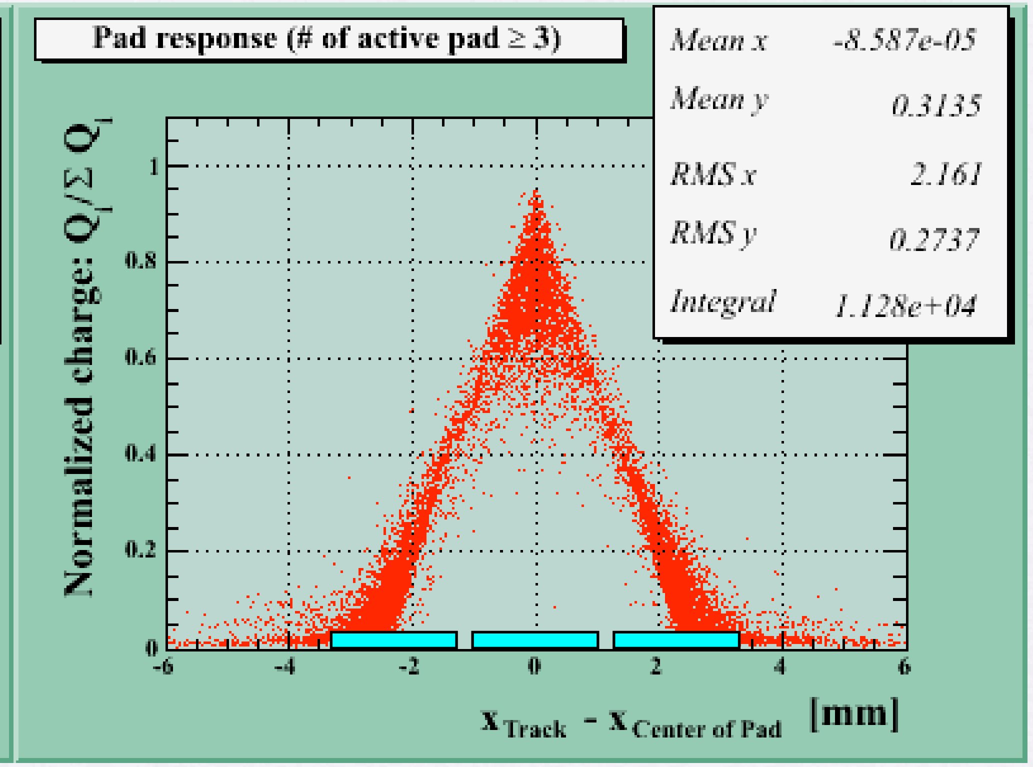
- GEM + resistive anode data -> to be analyzed soon
- MicroMEGAS data -> Paul's & Vincent's talks in detail

Pad response analysis

❖ Method: measurement of charge width from pad response



MWPC(1T) w/ 2mm-pad



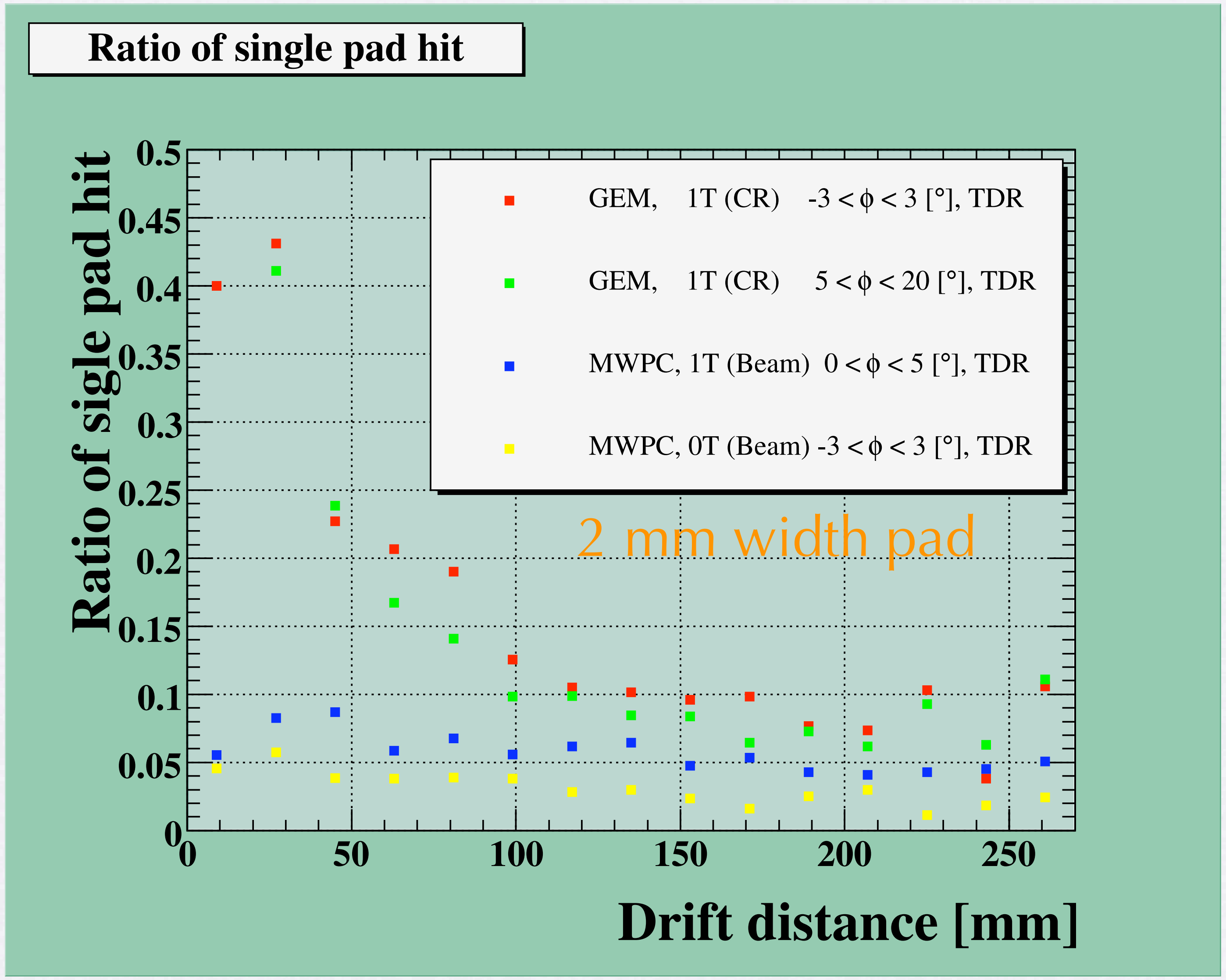
GEM(1T) w/ 2mm-pad

- Plot Q_i/Q_{tot} against $(X_{track} - X_{pad\text{-}center})$ for different drift region ($N_{zbins} = 15$)
- Reject single & double pad hits for pad response analysis
- Divide the plot into different X-Slices and fit each slice with a gaussian
- Plot the sigma as a function of drift length

Ratio of single pad hit

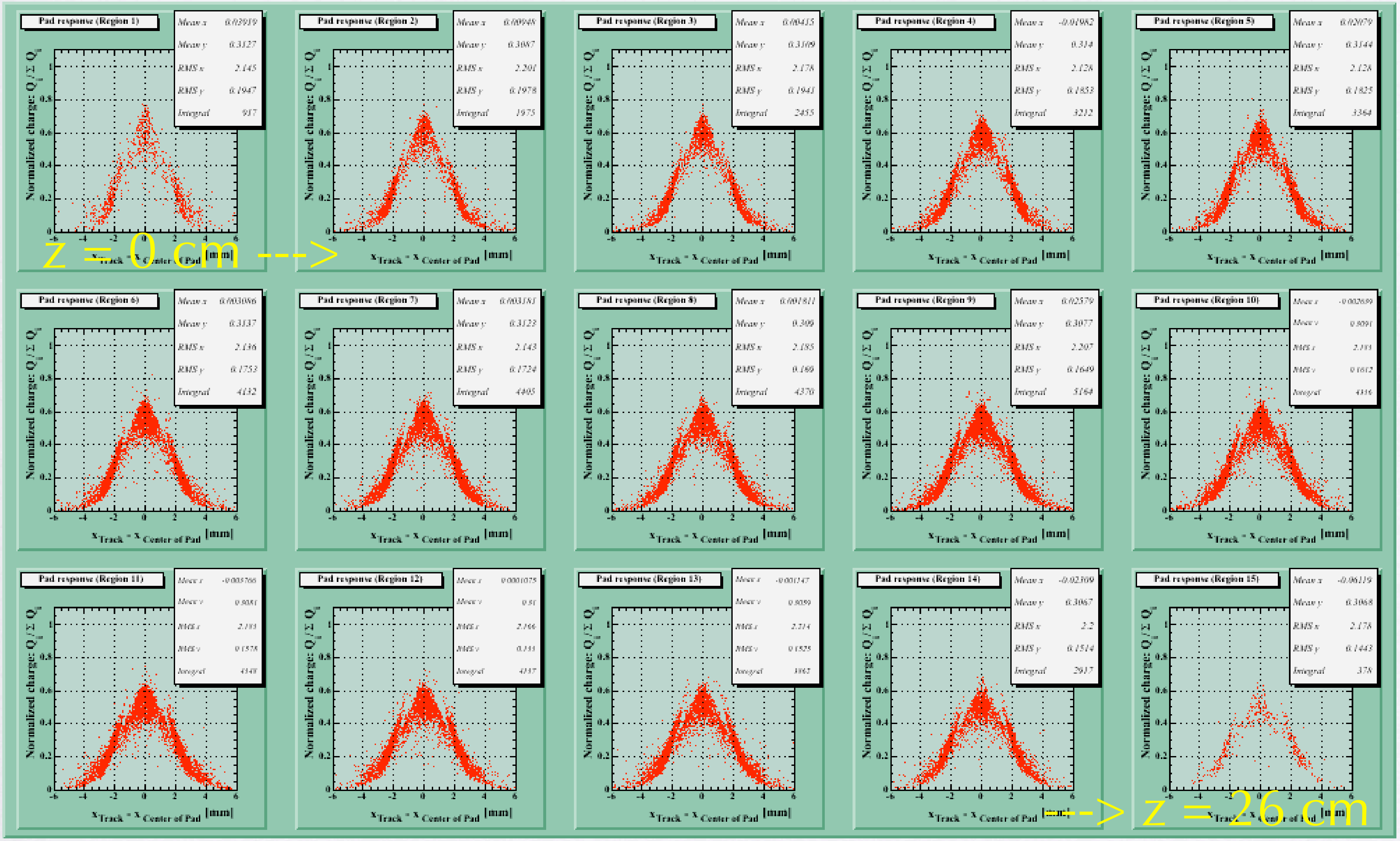
- For drift distance less than 15 cm, the # of hits w/ only single pad / row increase for the 2 mm pad.

- This is the sign we cannot obtain charge width in the case of 2 mm pad.
- Narrower pad size is necessary!
- We replaced pad-plane from 2 mm non-stagg. (2 mm width + 0.3 mm gap) to 1 mm staggered (1.17 mm width + 0.1 mm gap).



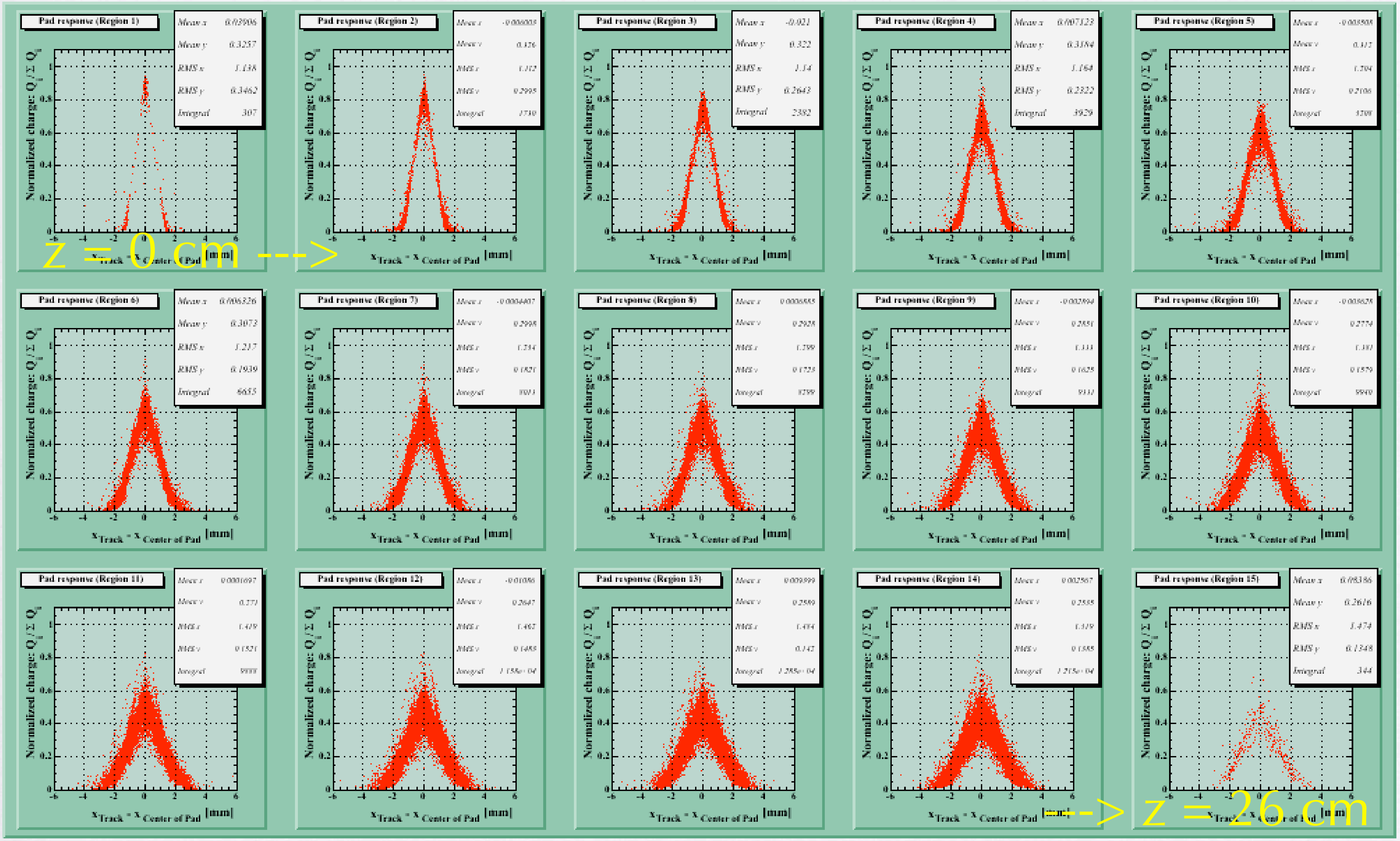
Z-dep of charge width (MWPC)

- Charge width for different drift region (MWPC, 1T, TDR)

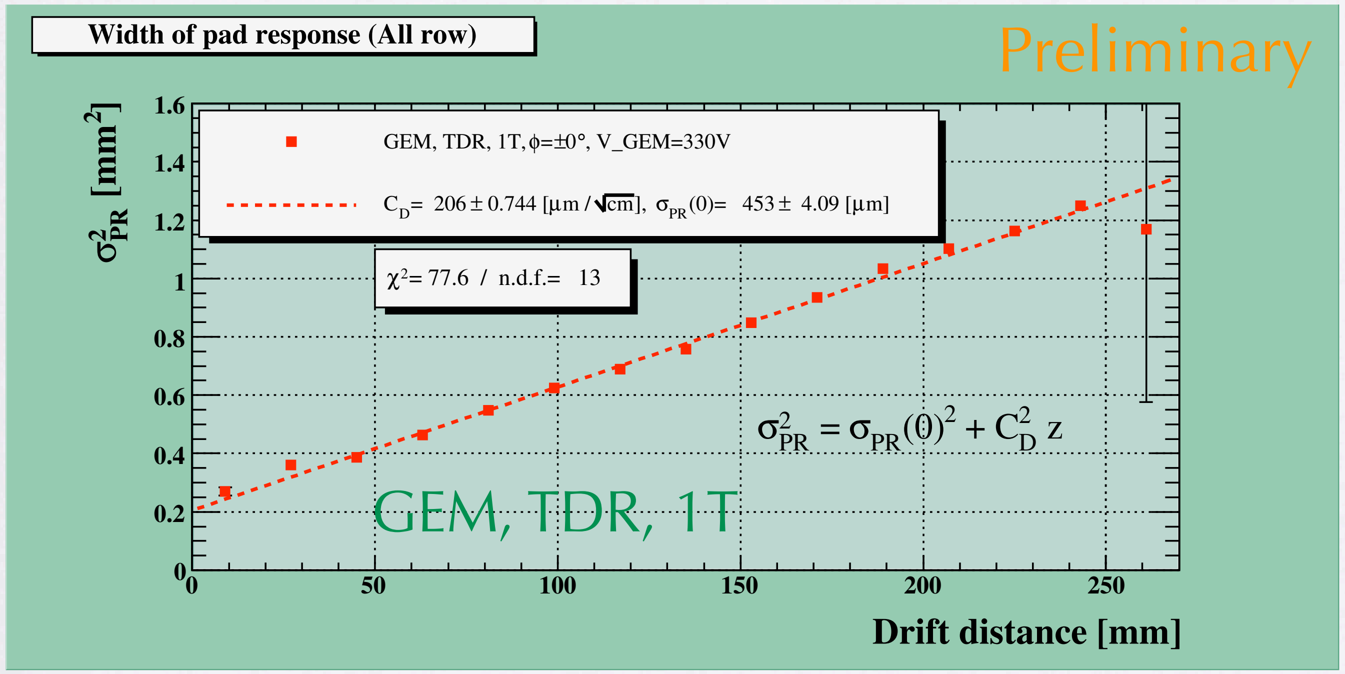


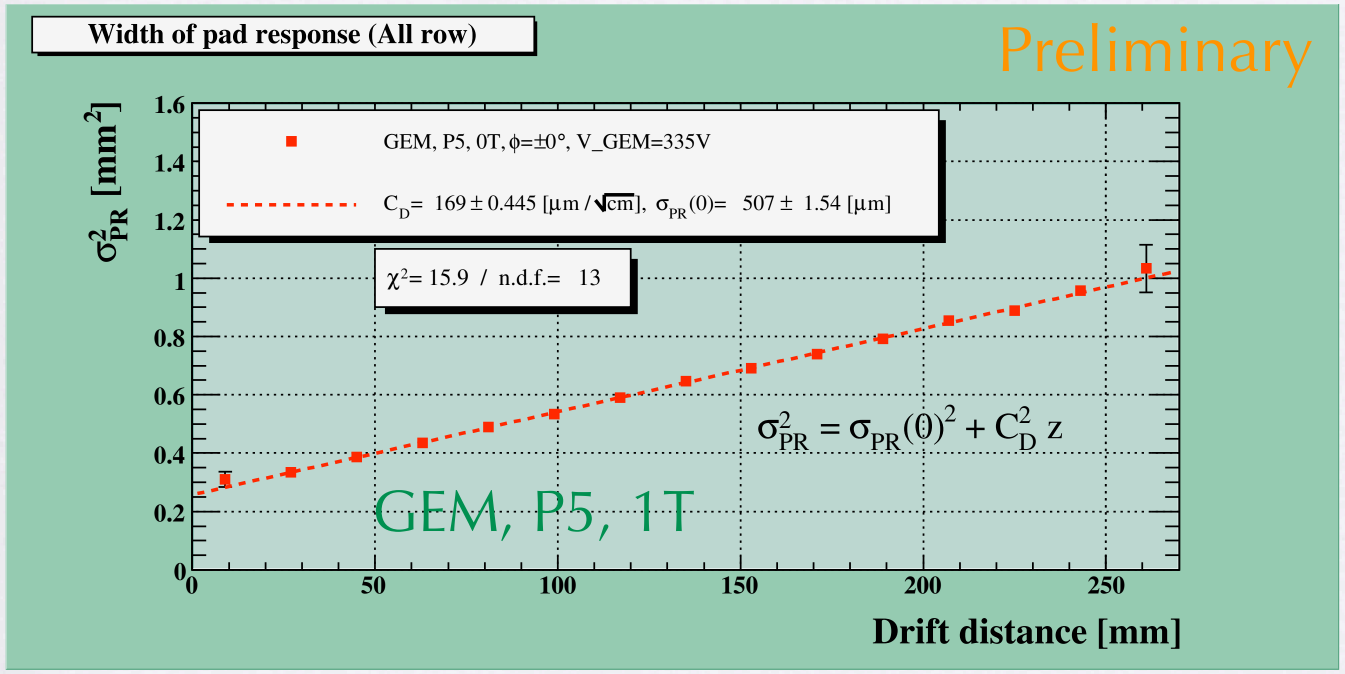
Z-dep of charge width (GEM)

- Charge width for different drift region (GEM, 1T, TDR)



Width of PR (TDR & P5, 1T)





- z-dependence of charge width

$\sigma_{PR}{}^2 = \sigma_{PR}(0)^2 + C_D{}^2\, z$

$\sigma_{PR}(0)$: Width of pad response (@ 0 drift)

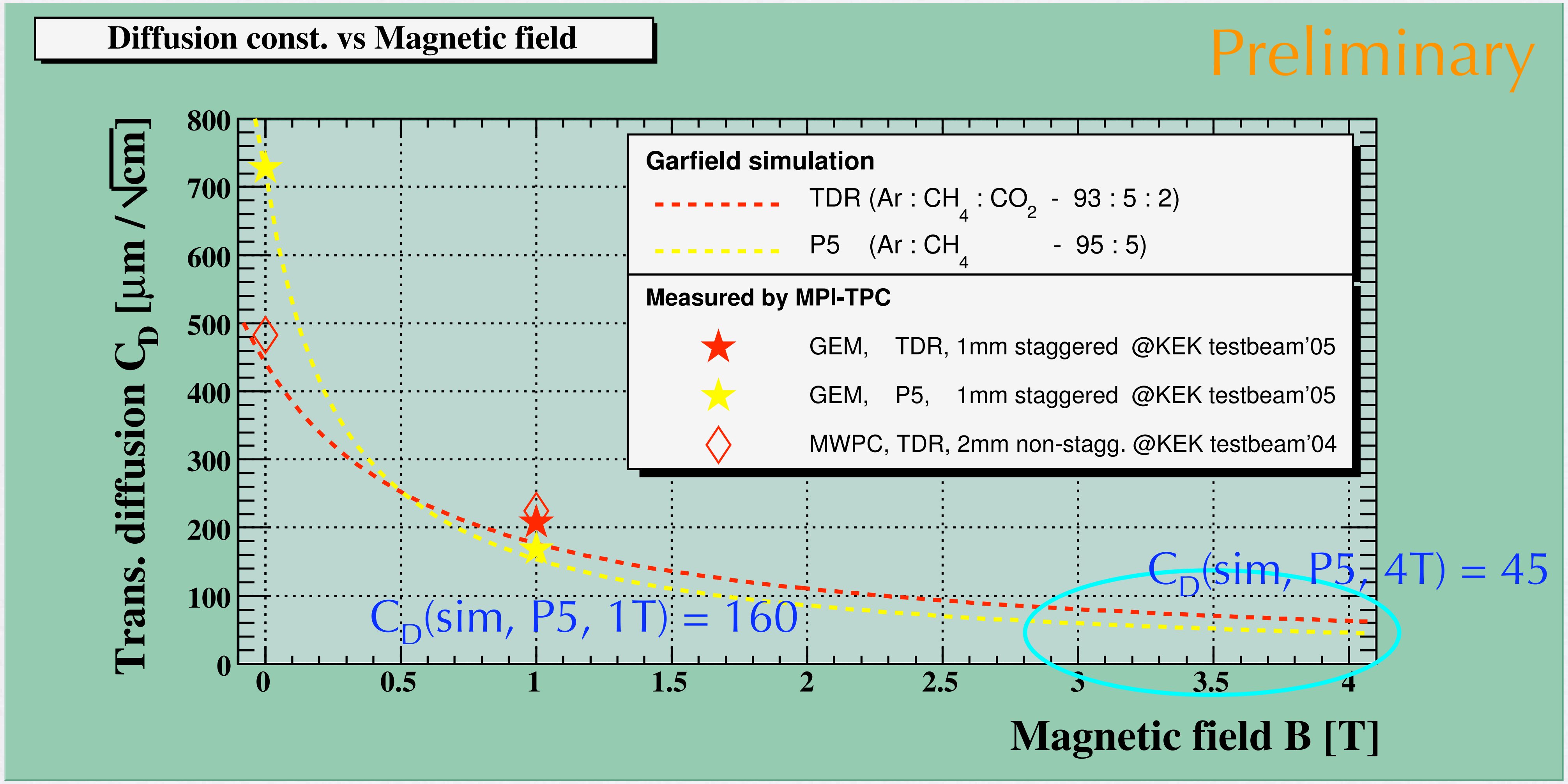
- TDR(1T): 453 μm (GEM)
- P5(1T): 507 μm (GEM)
- TDR(1T): 1390 μm (MWPC)

GEM has big advantage over MWPC as to the 2 track separation

$\sigma_{PR}(0)^2 = \sigma_{PRF}{}^2 + w^2/12$

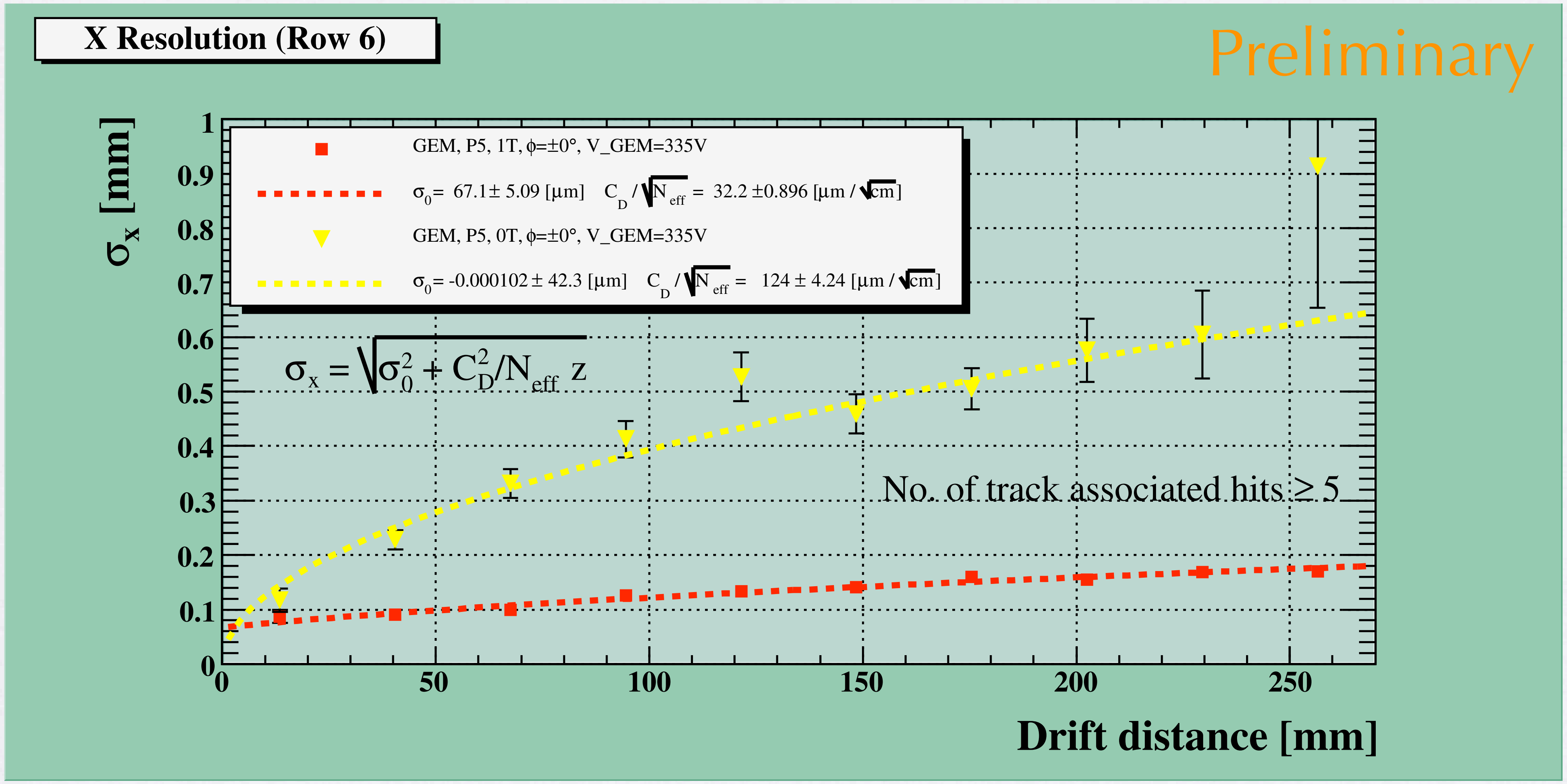
- w/√12: 367 μm (GEM)
- w/√12: 663 μm (MWPC)

Comparison between sim & meas.



- Measurement is more or less consistent with simulation
- Extrapolation to 3T - 4T maybe justified

X-resol (GEM, B-dep, P5)

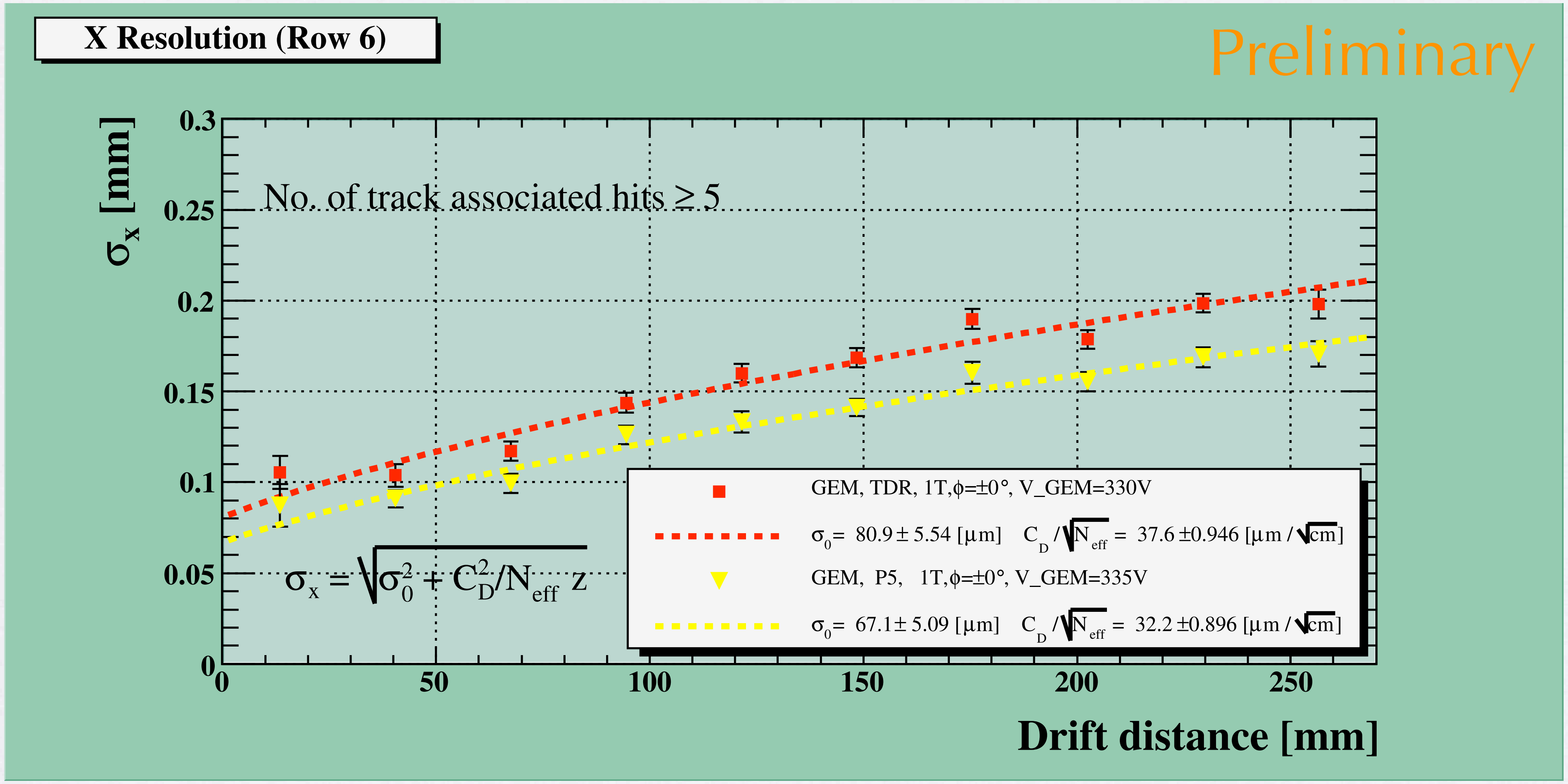


- $\sigma_{r\phi}^2 = \sigma_{r\phi}^2(z;\ldots) = \sigma_{r\phi}^2(z=0) + \left(\frac{\partial \sigma_{r\phi}^2}{\partial z}\right)_{z=0} z + \ldots$ All z-dependence comes from diffusion
- $\sigma_{r\phi} = \sqrt{{\sigma_0}^2 + \left(\frac{\partial \sigma_{r\phi}^2}{\partial z}\right) z} = \sqrt{{\sigma_0}^2 + \frac{C_D^2}{N_{eff}} z}$

  C_D : Transverse diffusion (per $1e^-$)

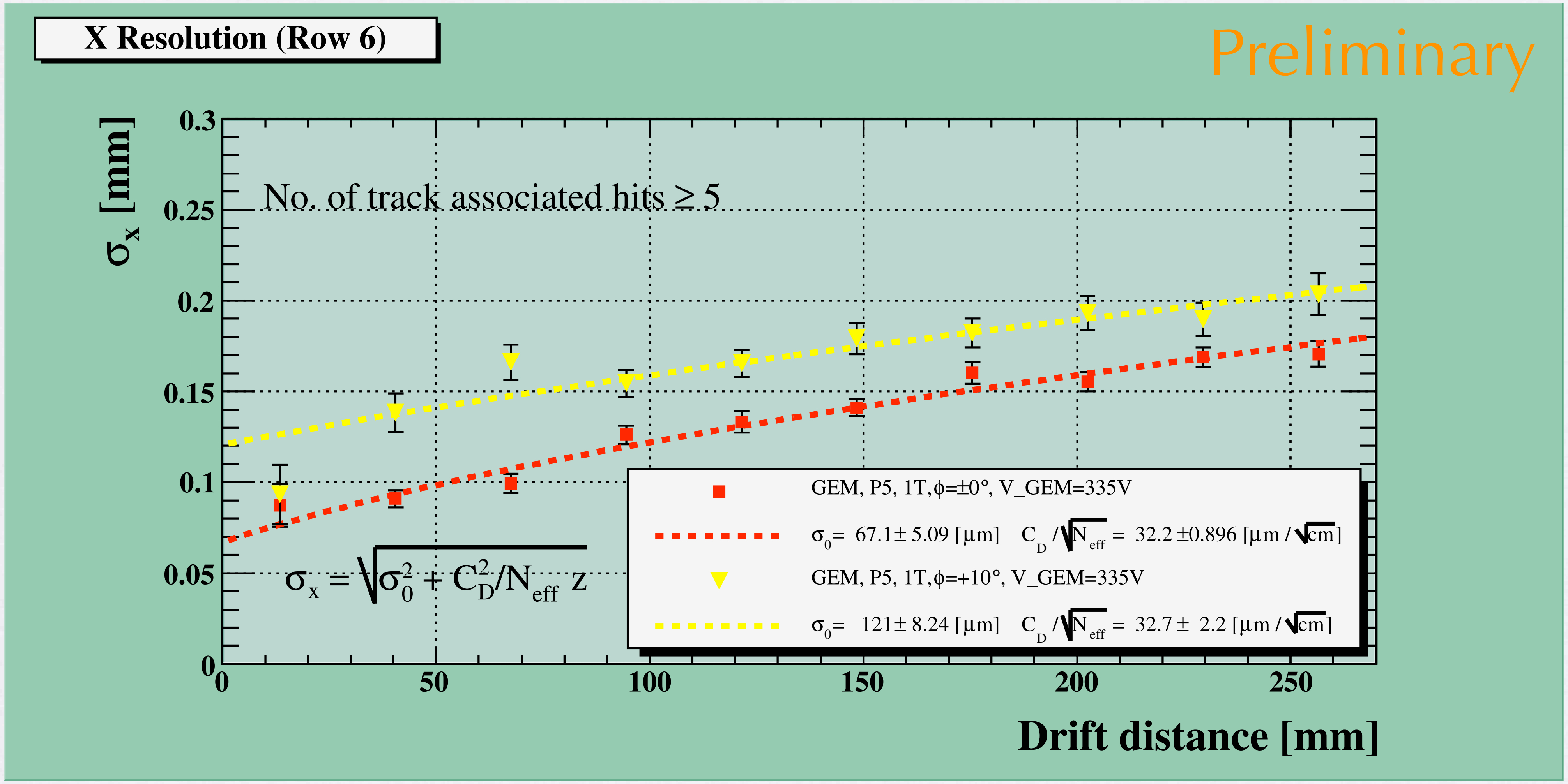
  N_{eff} : Effective # of e^-(per 1pad)
- Neff = 28 (for 1T), Neff = 33 (for 0T)

X-resol (TDR & P5, 1T)



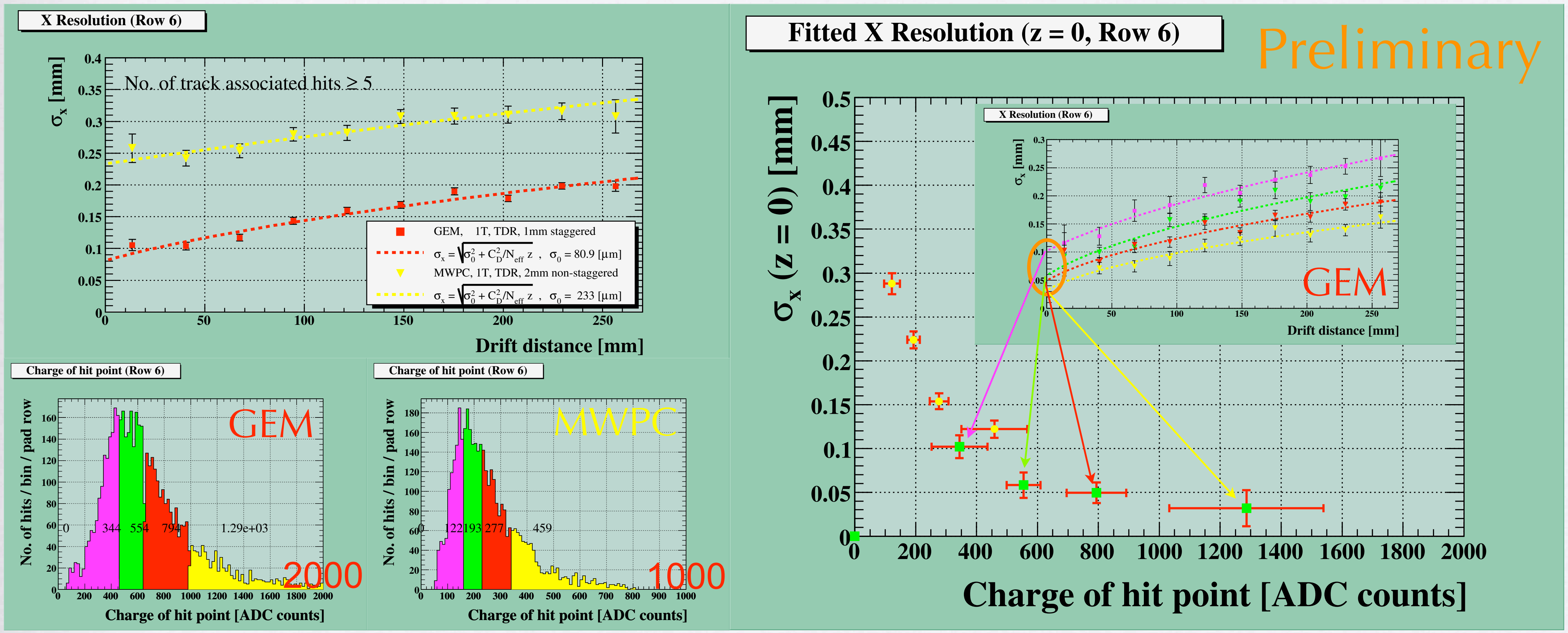
- GEM voltage was adjusted to get same pulse height
- sigma_0 = 65 ~ 80 micron (P5 & TDR)
- P5 gas provides better x-resolution
- sigma_x ~ 175 micron (@ 26 cm drift, P5)

X-resol (Phi-dep, P5, 1T)



- sigma_0 of phi = 10 deg data is significantly larger because of angular pad effect.
- diffusion term is comprable -> effect of phi-dependence is negligible for x-resolution at long drift distances

Comparison between GEM & MWPC



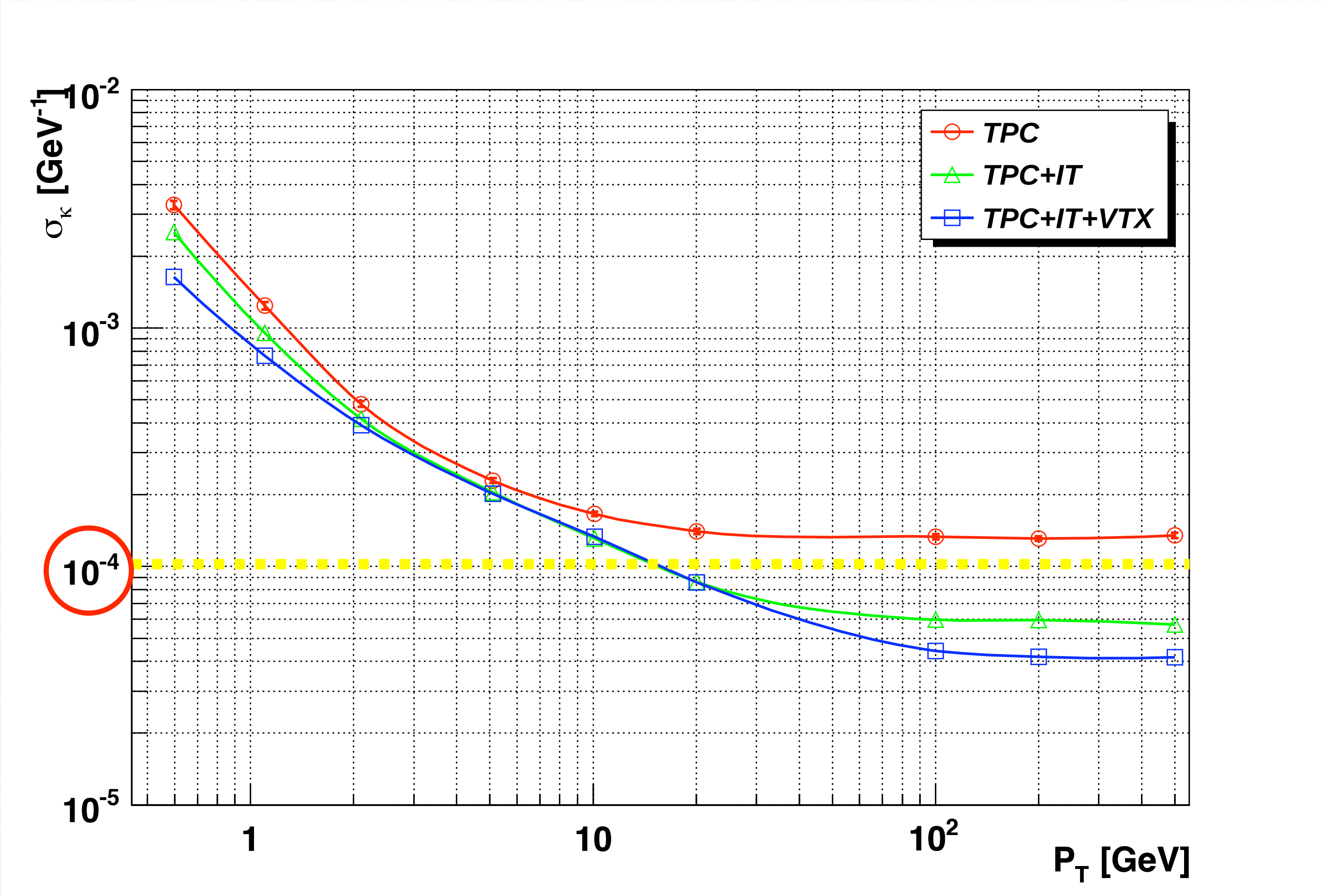
Pulse hight dist.

sigma_0 as a function of pulse hight

- GEM: 1 mm staggered, MWPC: 2 mm non-stagg. pad (1T, TDR)
- S/N ratio was small in the case of MWPC readout -> large sigma_0

Scale to real TPC

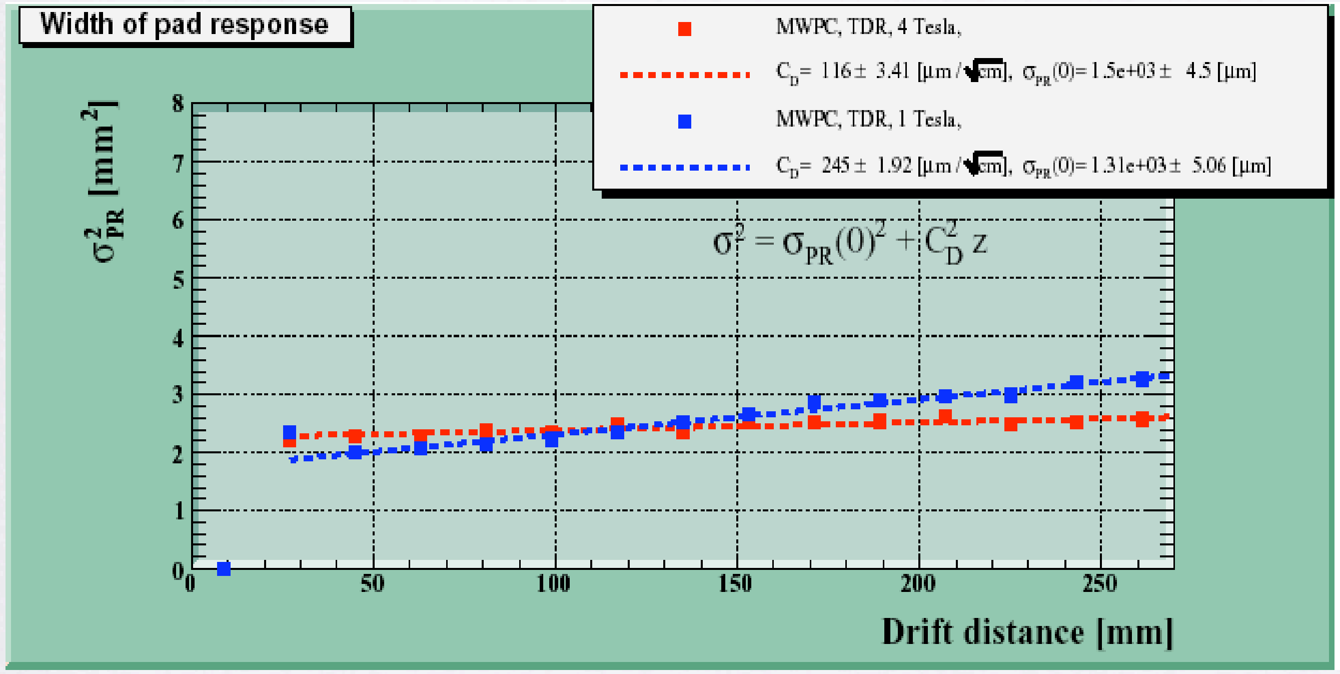
- According to the Magboltz simulation, C_D is reduced by a factor of 160(1T) / 45(4T) in the case of P5, giving sigma ~ 160 um at the max. drift distance of 250 cm.
  - Resultant momentum resolution (for the GLD, 3T w/ Jupiter full MC simulation) had been calculated by A. Yamaguchi.
    (http://chep.knu.ac.kr/ACFA8/program2.php?sub=Simulation)

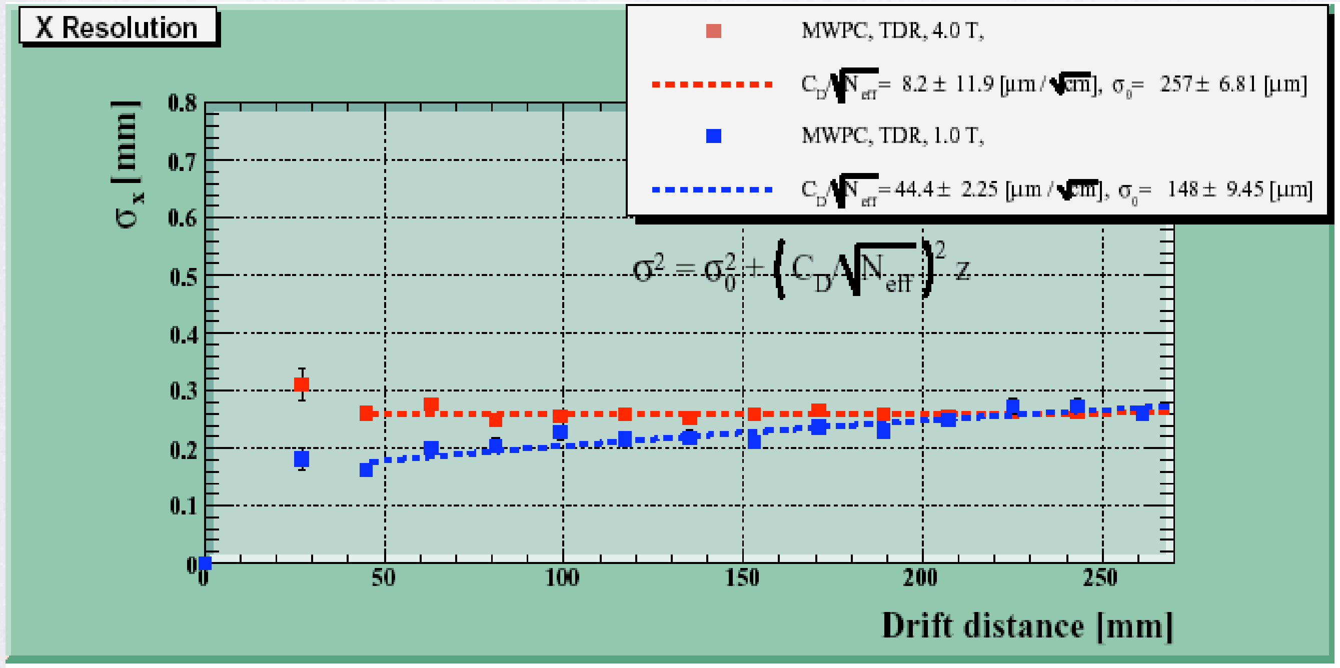


Momentum resolution vs transverse momentum (|cos| < 0.7)

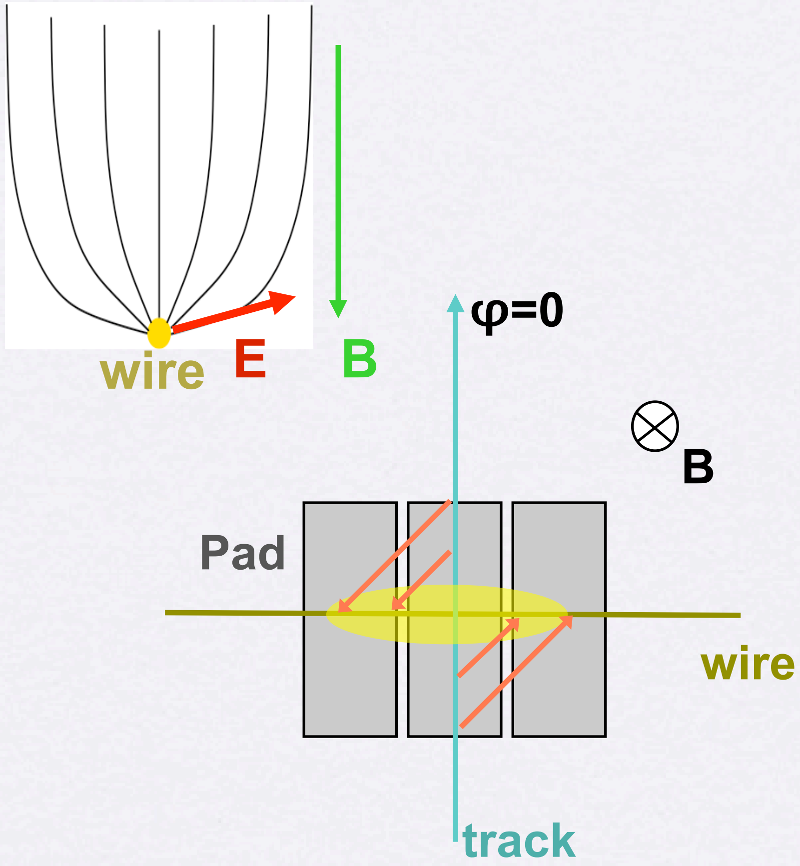
A. Yamaguchi (U. Tsukuba)

Width of PR & x-resol (MWPC, 4T, TDR)

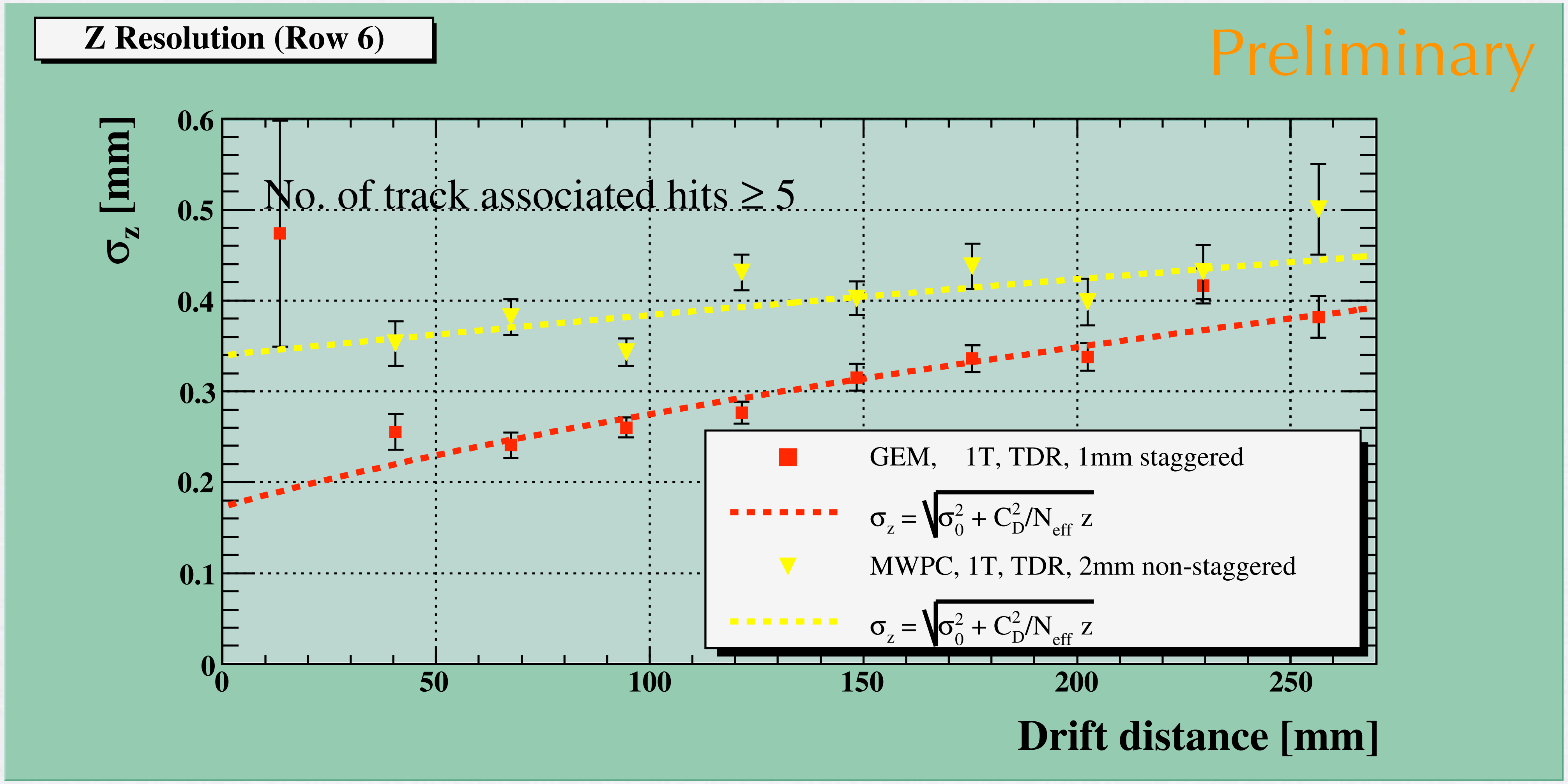




- In case of MWPC, width of PR (@ 0 drift) & sigma_0 get worth due to ExB effect at higher magnetic field.



Z-resol (GEM & MWPC, 1T)



- sigma_z < 500 micron (@ 26 cm drift, GEM & MWPC)
- Obtained z-resolution satisfies the requirement
- No problem for Track-Cluster matching

Summary & outlook

- Performance studies of MPI-TPC w/ triple GEM or MWPC were performed using test beam and cosmic ray.
- Transverse diffusion and spatial resolution were measured as a function of drift distance up to 26 cm.
- Diffusion constants were found to be consistent with those given by Magboltz simulation.
- Extrapolation of the obtained spatial resolution to 4T gives 160 micron at the maximum drift length (250 cm) of the LDC-TPC.
- Obtained z-resolution satisfies the requirement.
- "Ultimate" MWPC readout may also work, but with poorer granularity and larger ExB effect.
- MPI-TPC w/ & w/o a resistive anode combined with GEM were also tested using test beam at KEK at the end of October (To be analyzed soon).
- Fair comparison between GEM and MicroMEGAS w/ same environment.

Backup slides

Requirement for transverse single point resolution

- Required point resolution: $\sigma_{r\phi}$ & # of samples: n

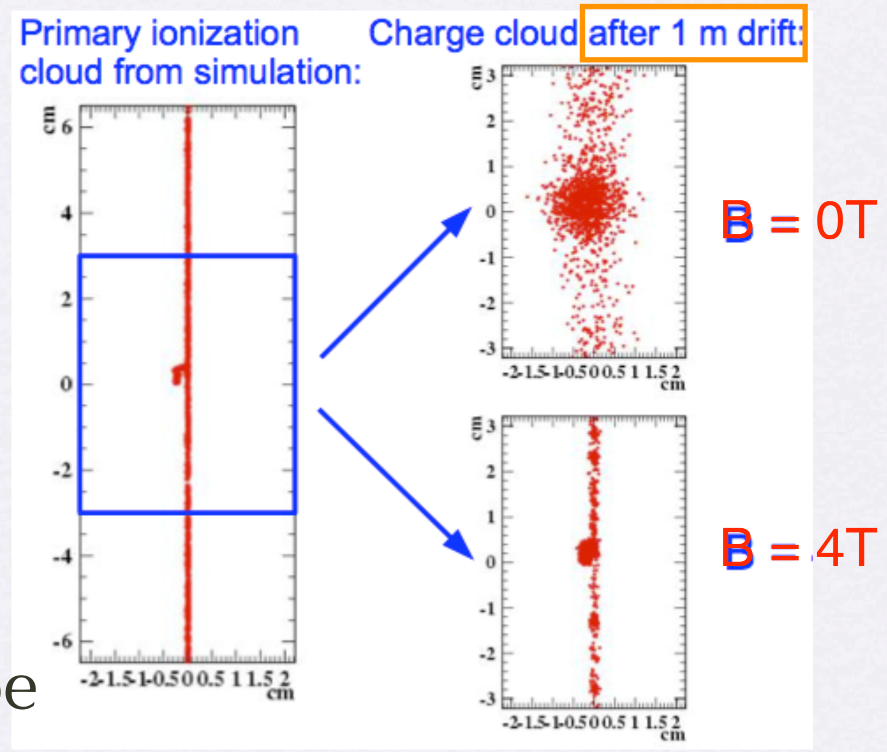
$$\frac{\sigma_{p_T}}{p_T} \simeq \sqrt{\left(\frac{\alpha' \sigma_{r\phi}}{Bl^2}\right)^2 \left(\frac{720}{n+4}\right) {p_T}^2 + \left(\frac{\alpha' C}{Bl}\right)^2 \left(\frac{10}{7}\left(\frac{X}{X_0}\right)\right)}$$

measurements | multiple scattering

  - LDC: (B, l) = (4 T, 120 cm)
  - GLD: (B, l) = (3 T, 165 cm)

$n : 200 \sim 250 \rightarrow \sigma_{r\phi} \lesssim 150\ \mu\mathrm{m}$

- R&D item: Good $\sigma_{r\phi}$ for long drift distance (z ~ 2.5 m)?
  - Ionized primary electrons drift to readout pad curling up B-field
    - Dispersion of charge cloud strongly depends on B-fields & drift distance
    - B-fields dependence of $\sigma_{r\phi}$



- Understand performance of prototype TPCs in higher B-fields
  - "Proof of Principle" -> Large prototype

Possible sensors for LC-TPC

❖ There are 3 readout schemes for LC-TPC in the market

◆ "Ultimate" MWPC (Well established -> should be fall back option)

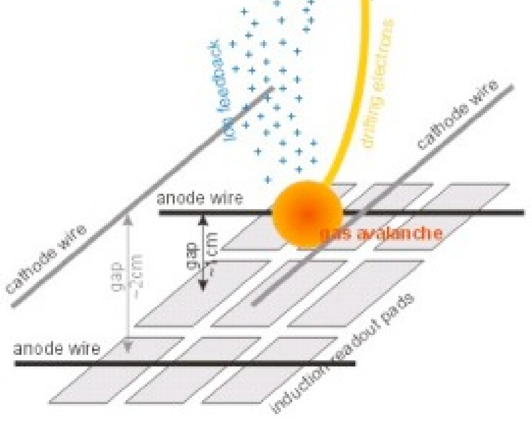
✦ 1 mm thin gap between anode-wires to cathode-pad

Localize induced charge dist. on pads; Narrow PRF ~ 1.5 mm

✦ 2 mm small pitched anode-wires

Small wire-angular and ExB effect

KEK test beam in Jun '04



◆ Gas Electron Multiplier (GEM)

✦ Narrow PRF & Fast signal (Δt ~ 20 ns, no ion tail)

(only electrons are collected by the readout structure)

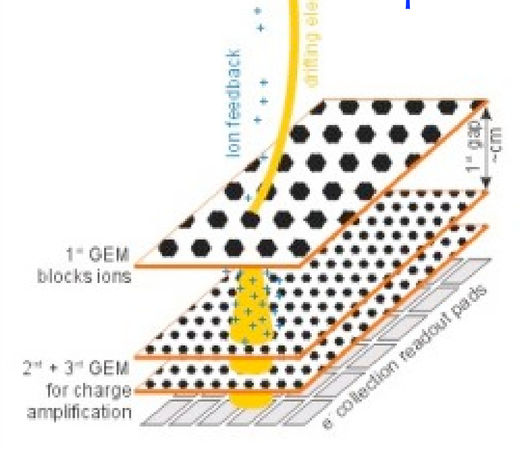
-> Very good multi-track resolution: ΔV ~ 1 mm^3

✦ Intrinsic ion feedback suppression: I^+/I^- ~ 0.1 %

✦ Comparably small distortions due to ExB effects

✦ High flexibility in the geometry of the readout pads

KEK test beam in Apr '05



◆ Micro Mesh Gaseous Structure (MicroMEGAS)

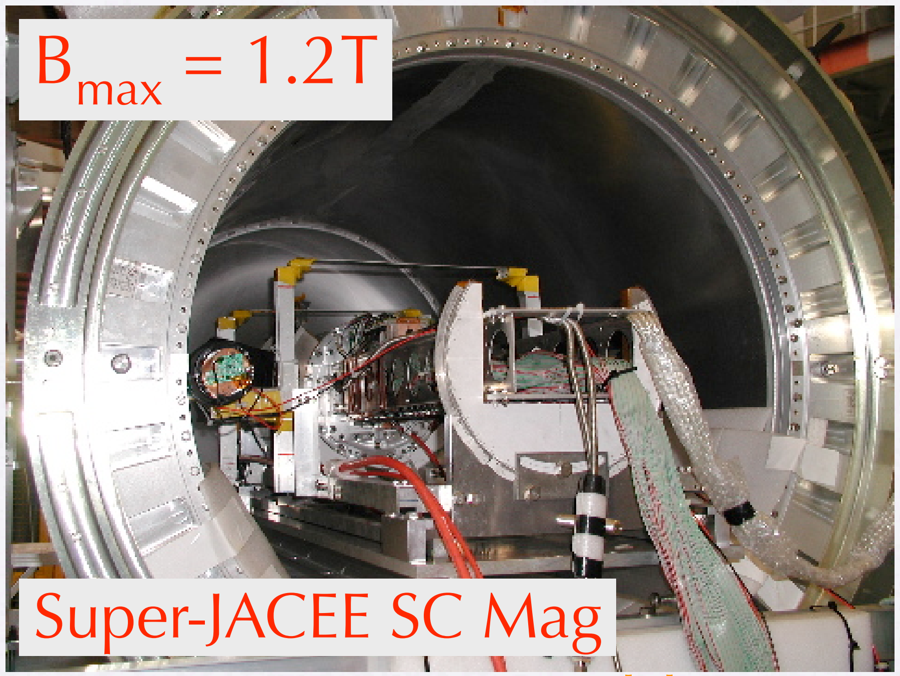
✦ Next talk in details

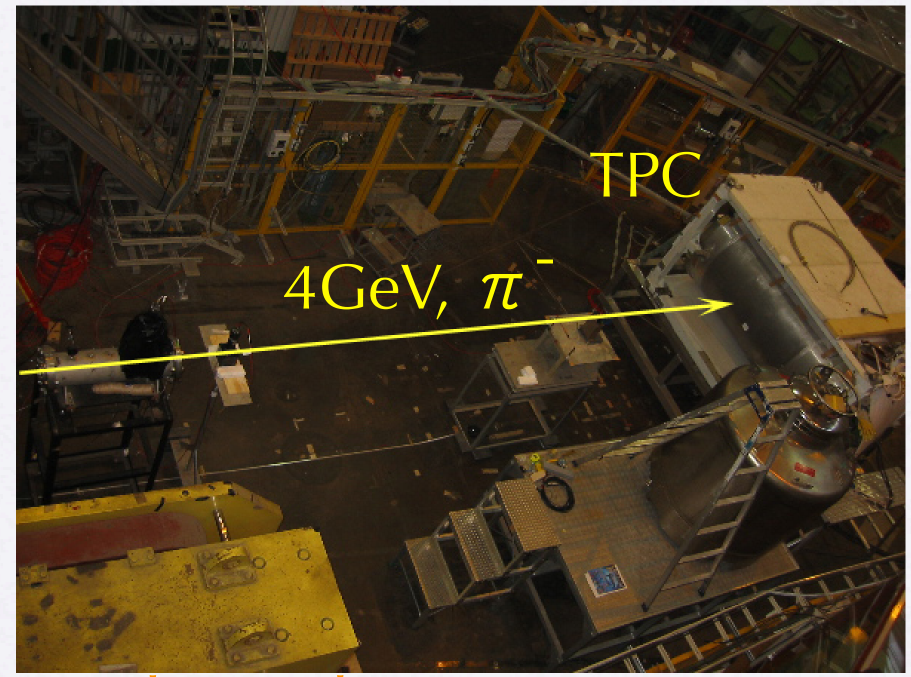
KEK test beam in Jun '05

❖ Comparison w/ same field cage, electronics and analysis

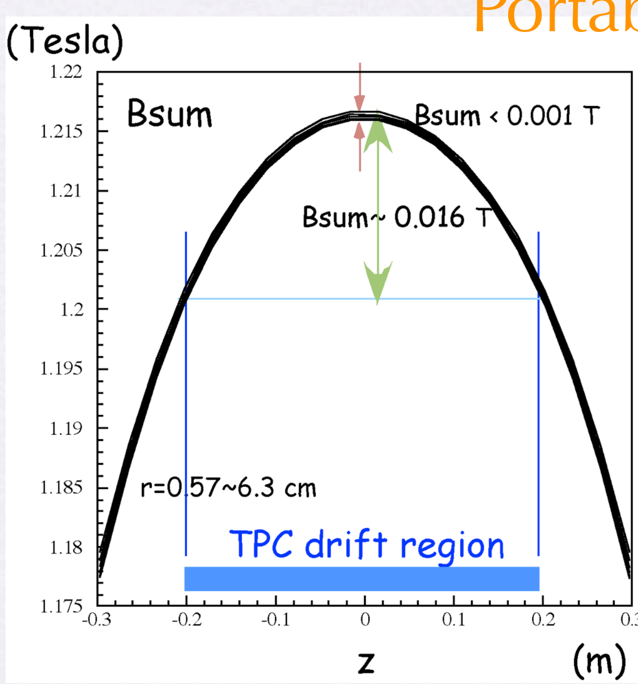
JACEE Magnet (PCMAG)

- Superconducting solenoid & “π2 beam line” at KEK-12GeV PS





Portable magnet on beam line



B = 1.216T
at z=0, r=0
dB ~ 1.3%
(at z=20cm,
r=0~6cm)