Incident angle effect on the spatial resolution of an Asian GEM module

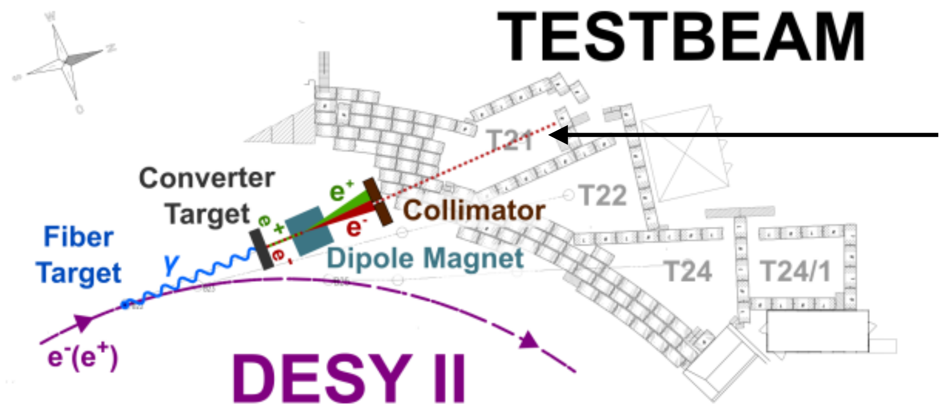
NAKAJIMA Jurina[A], FUJII Keisuke[B], YONAMINE Ryo[B], KOBAYASHI Makoto[B], MATSUDA Takeshi[B], OGAWA Tomohisa[B], AOKI Yumi[A], YUMINO Keita[A], NARITA Shinya[C], NEGISHI Kentaro[C], SHOJI Aiko[C], SUGIYAMA Akira[D], FUSAYASU Takahiro[E], TAKAHASHI Toru[F], WATANABE Takashi[G], KATO Yukihiro[H], IKEMATSU Katsumasa[I], SETTLES Ron[J], TIAN Junping[K], ARAI Daisuke[L], COLAS Paul[M], GANJOUR Serguei[M], DIENER Ralf[J], SCHÄFER Oliver[J], KAWADA Shin-ichi[J], MÜLLER Felix[J], JONSSON Leif[N], MJÖRNMARK Ulf[N], QI Huirong[O], KIHARA Daisuke[P]
and LCTPC collaboration

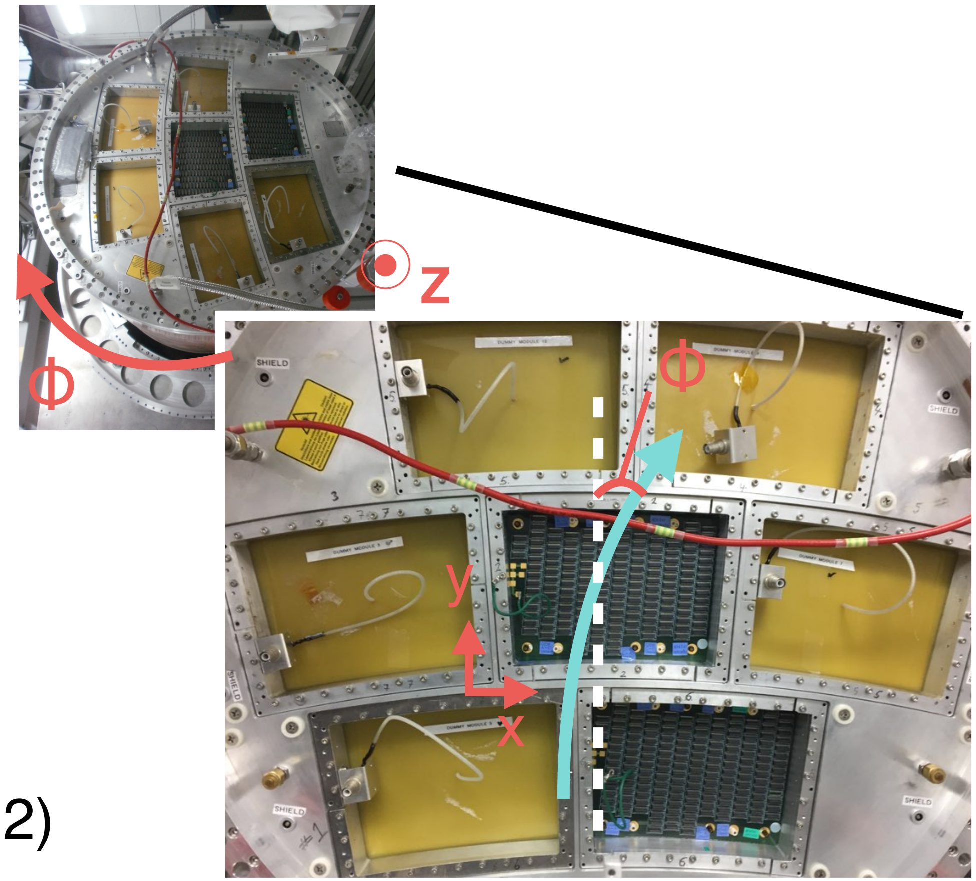
SOKENDAI[A], KEK[B], Iwate Univ.[C], Saga Univ.[D], Nagasaki Inst. of Applied Science[E], Hiroshima Univ.[F], Kogakuin Univ.[G], Kinki Univ.[H], Tohoku Univ.[I], DESY[J], Tokyo Univ[K], Fujikura Ltd[L], Université Paris-Saclay[M], Lund Univ.[N], Institute of High Energy Physics[O], Seigen Univ.[P]

11, March 2021

Beam test LP1 in 2016 and Data

Checking performance of Asian module with the gating foil and the field shaper

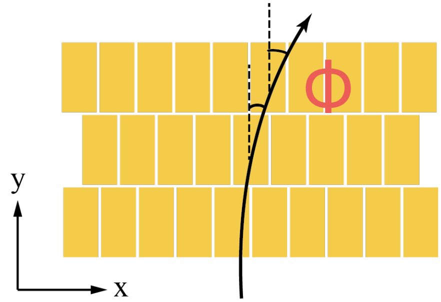




Set up

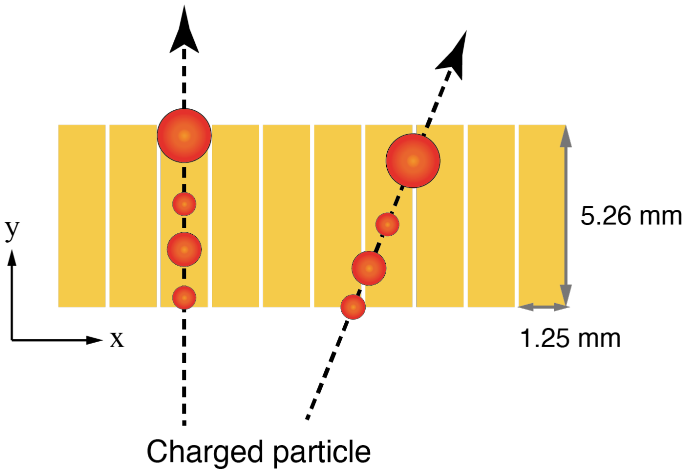
- Electron Beam [GeV] = 5
- B [T] = 1
- T2K gas (Ar:CF4:iso-C4H10 = 95:3:2)
- Frame work : Marlin TPC
- 20000evt / 1 run

→ Using FS data



Incident angle effect on the spatial resolution

$$\sigma_x^2(Z; w, L\tan\phi, C_d, N_{eff}, \hat{N}_{eff}, [f]) = [A] + \frac{1}{N_{eff}}[B] + [C] + \frac{1}{\hat{N}_{eff}}[D]$$



Systematic error of the charge centroid method

[A] is Purely geometric effect

$$[A] = \int_{-1/2}^{1/2} d\left(\frac{\tilde{x}}{w}\right) \sum_{N=1}^{\infty} P_{PI}(N;\bar{N}) \prod_{i=1}^{N} \left[\sum_{k_i=0}^{\infty} \bar{\bar{P}}_{SI}(k_i)\right] \times \left\{\left(\sum_a (aw) \sum_{i=1}^{N} \langle\langle F_a \rangle_{\Delta x}^{y}\rangle_y^{k_i} \left\langle \frac{\sum_{j=1}^{k_i} G_{ij}}{\sum_{i=1}^{N}\sum_{j=1}^{k_i} G_{ij}} \right\rangle_G^{k_i, \sum_{i=1}^{N} k_i} - \tilde{x}\right)^2\right\}$$

The diffusion term(Gas gain fluctuation & finite pad pitch)

$$[B] = \int_{-1/2}^{1/2} d\left(\frac{\tilde{x}}{w}\right) \left\langle \left(\sum_a (aw) F_a(\tilde{x}+\Delta x) - \sum_a (aw)\langle F_a(\tilde{x}+\Delta x)\rangle_{\Delta x}\right)^2 \right\rangle_{\Delta x}$$

Electric noise $\quad [C] = \left(\frac{\sigma_E}{\bar{G}}\right)^2 \left\langle \frac{1}{N^2} \right\rangle_N \sum_a (aw)^2$

Angular Pad effect $\quad [D] = \frac{L^2 \tan^2\phi}{12\hat{N}_{eff}}$

$$\longrightarrow \quad [D] = \tan^2\phi\, \sigma_d \left\langle \frac{1}{\sum_{i=1}^{N} k_i} \right\rangle_{N,k} \left\langle \left(\frac{G}{\bar{G}}\right)^2 \right\rangle_G$$

(Long drift limit: $\sigma_d \gg L$)

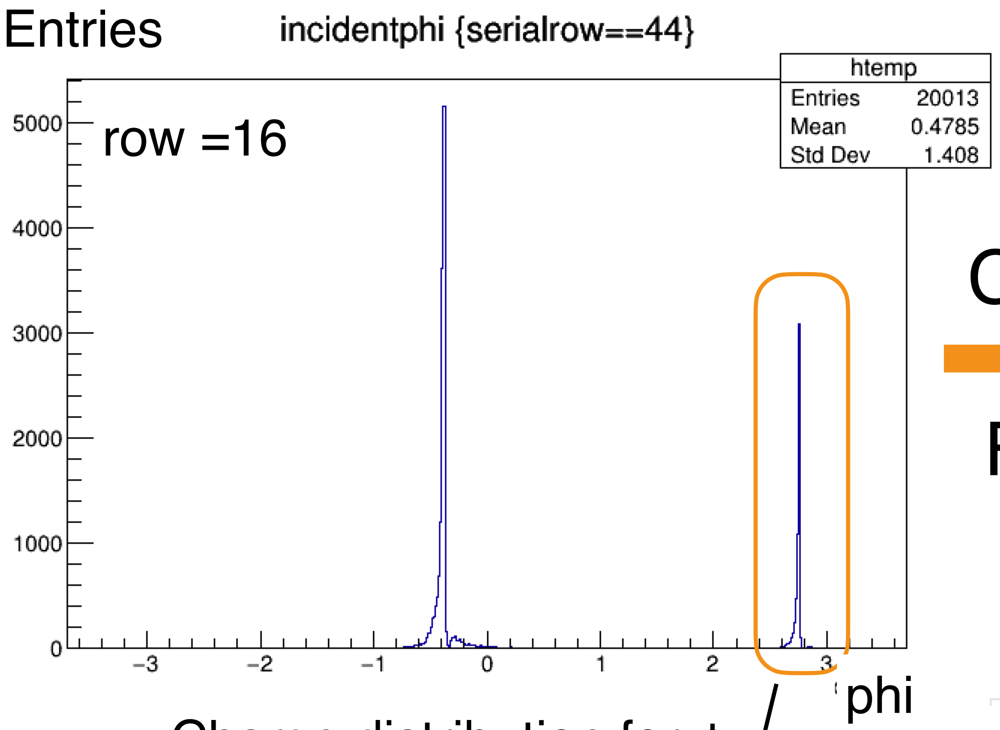
$$N_{eff} = \left[\left\langle \sum_{i=1}^{N}\sum_{j=1}^{k_i} \left\langle \left(\frac{\sum_{j=1}^{k_i} G_{ij}}{\sum_{i=1}^{N}\sum_{j=1}^{k_i} G_{ij}}\right) \right\rangle_G^{k_i, \sum_{i=1}^{N} k_i} \right\rangle_{N,k}\right]^{-1}$$

$$\hat{N}_{eff} \approx \left[\left\langle \sum_{i=1}^{N} \left\langle \left(\frac{\sum_{j=1}^{k_i} G_{ij}}{\sum_{i=1}^{N}\sum_{j=1}^{k_i} G_{ij}}\right) \right\rangle_G^{k_i, \sum_{i=1}^{N} k_i} \right\rangle_{N,k}\right]^{-1}$$

R.Yonamine,K.Fujii [https://doi.org/10.1088/1748-0221/9/03/C03002]

How to decide ϕ

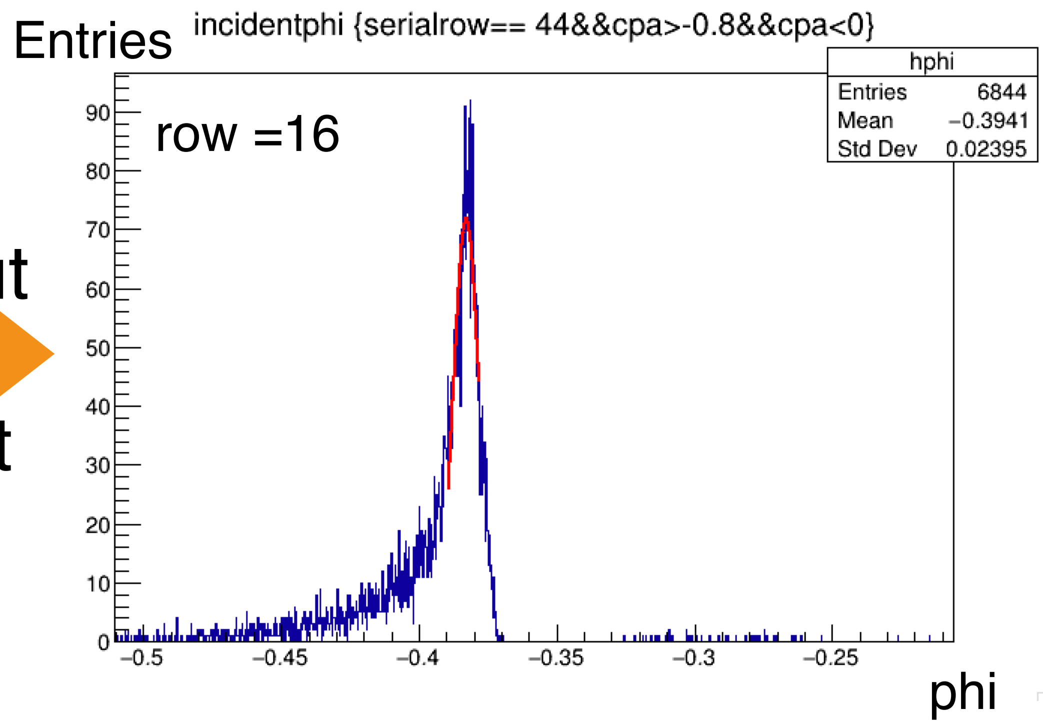
#20156, w/FS(Shaper time 120s), ϕ=20°, B=1T



Charge distribution for ϕ

Electron lost energy by Bremsstrahlung before inject in TPC

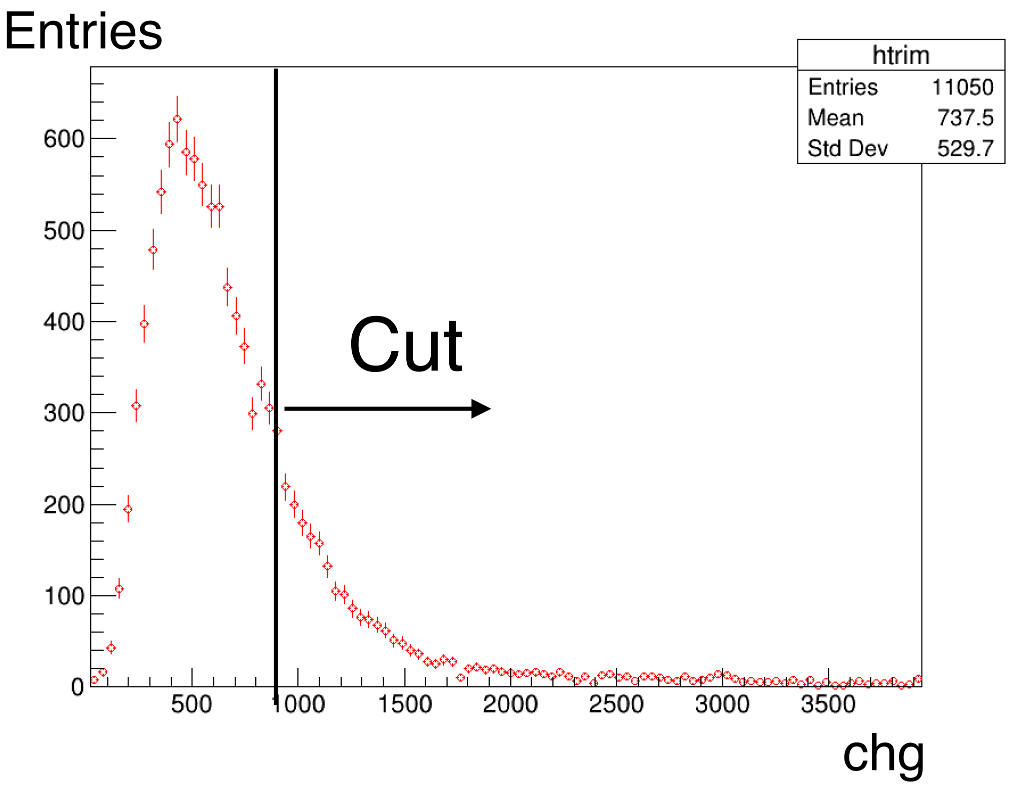
Cut → Fit

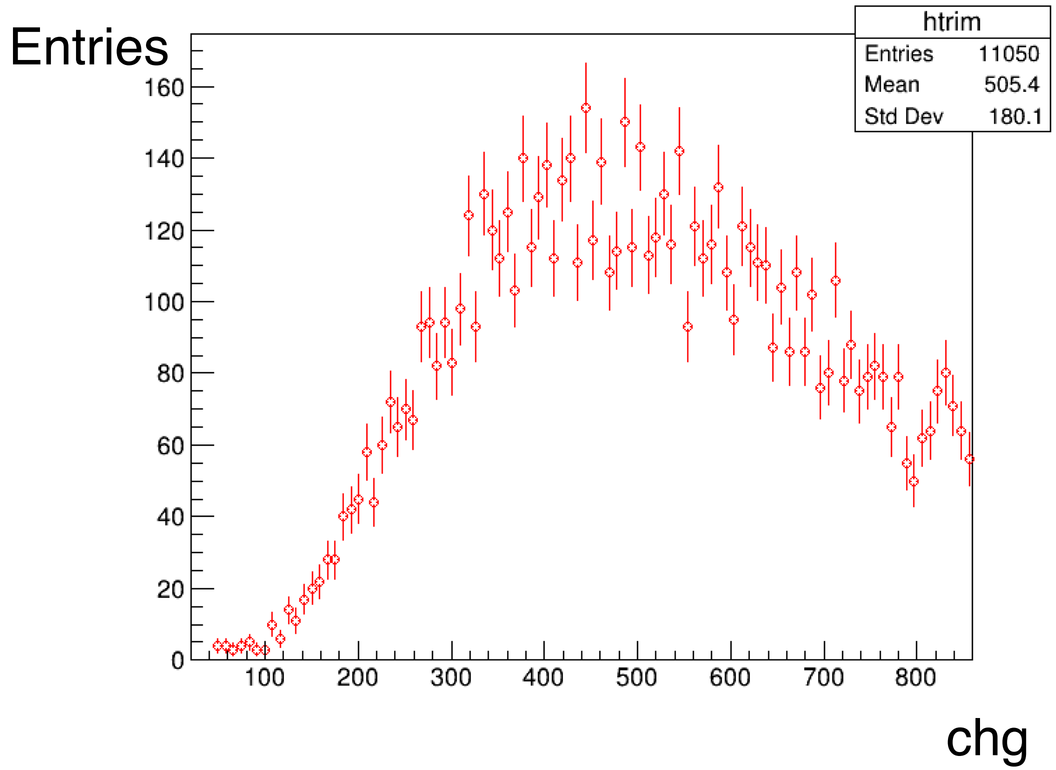


- Binning 10000
- Electron momentum(cpa) -0.8< cpa <0
- Gauss fit(2 times) 1σ

Charge correction

Take 70% trim average for upper bound

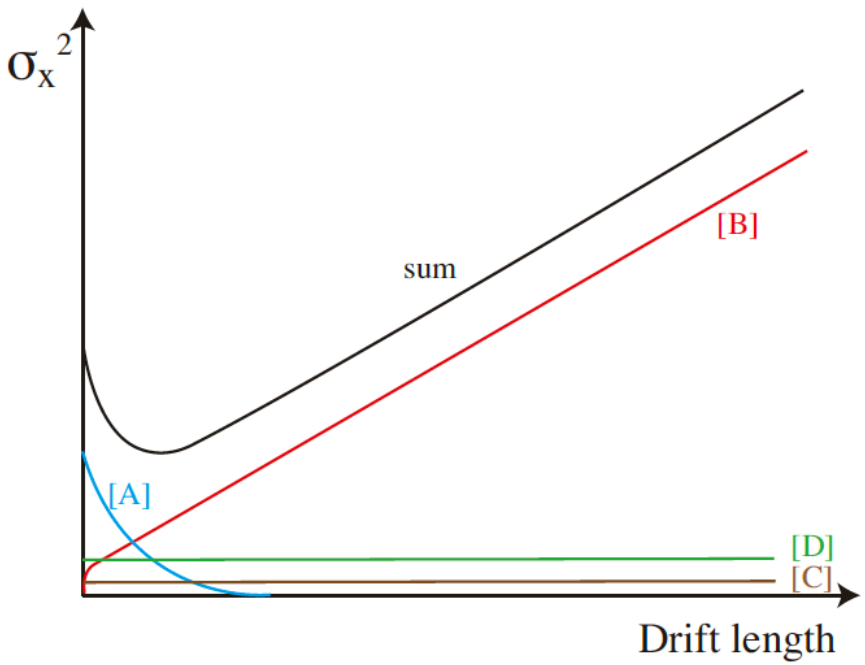




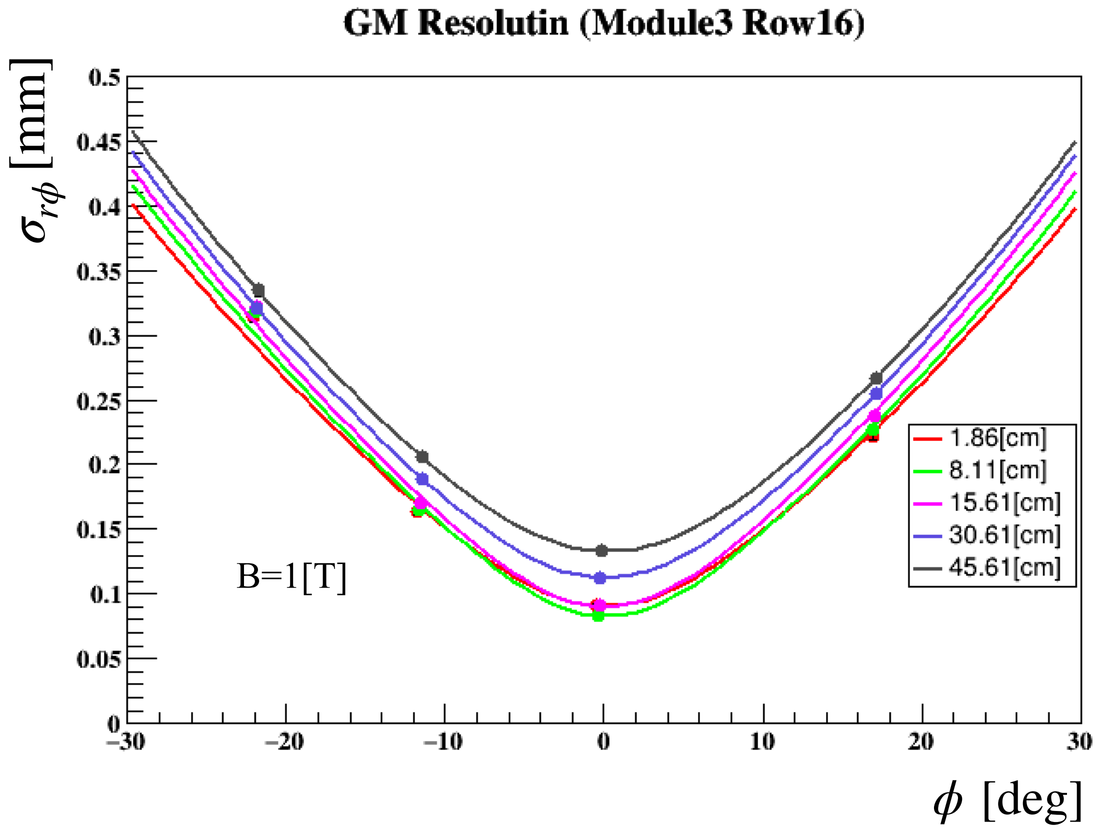
Ignore the contribution from the tail

GM Resolution for the inclined tracks

R.Yonamine,
https://doi.org/10.1088/1748-0221/9/03/C03002



$$\sigma_x^2 = [A] + \frac{1}{N_{eff}}[B] + [C] + \frac{1}{\hat{N}_{eff}}[D]$$



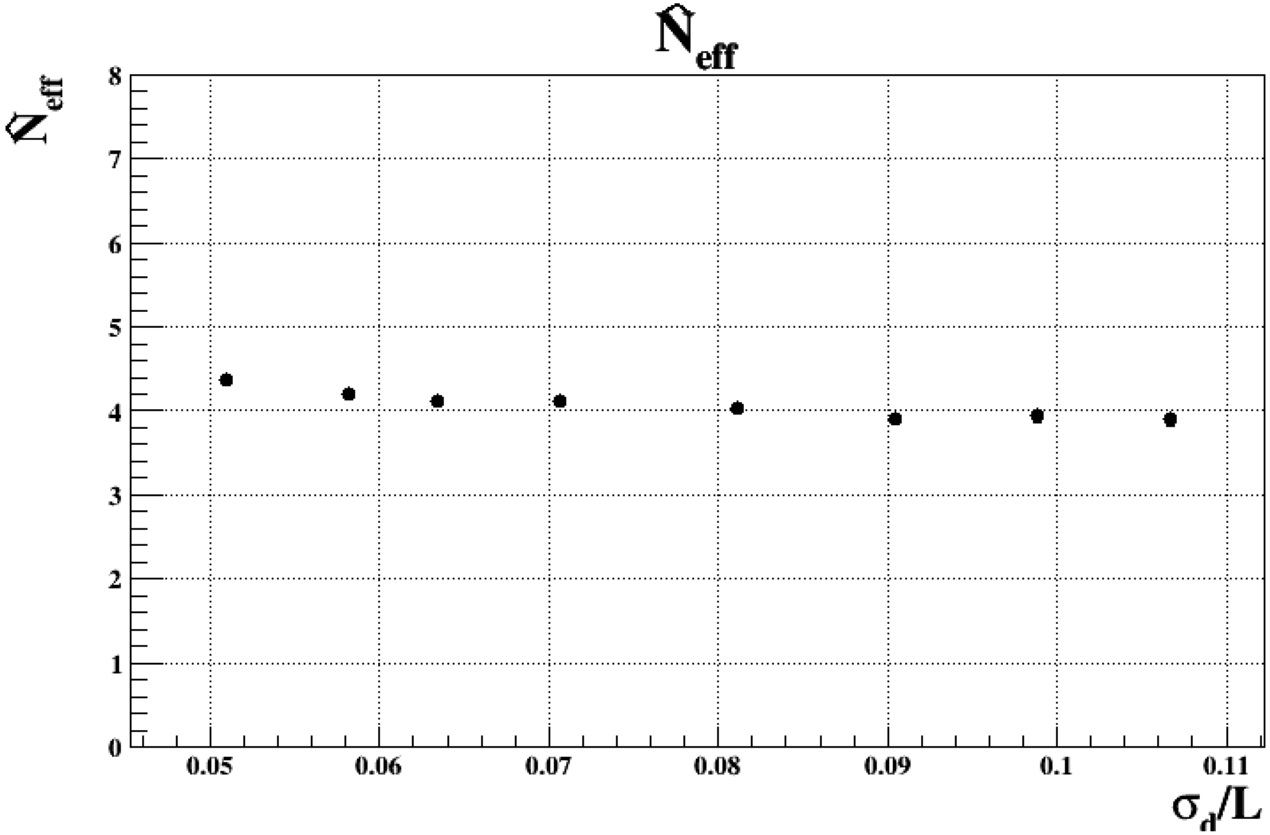
How about $\hat{N}_{eff}$?

Test Result - Effective cluster number $\hat{N}_{eff}$

$$\hat{N}_{eff}(\phi = 0) = \frac{L^2 \tan^2 \phi \cos \phi}{12\sigma_{ang}^2}$$

- L(Pad height) = 0.526 [cm]
- σ_{ang} = 0.0749 [cm]
- $\sigma_d = C_d\sqrt{Drift\ length}[\mathrm{cm}]$

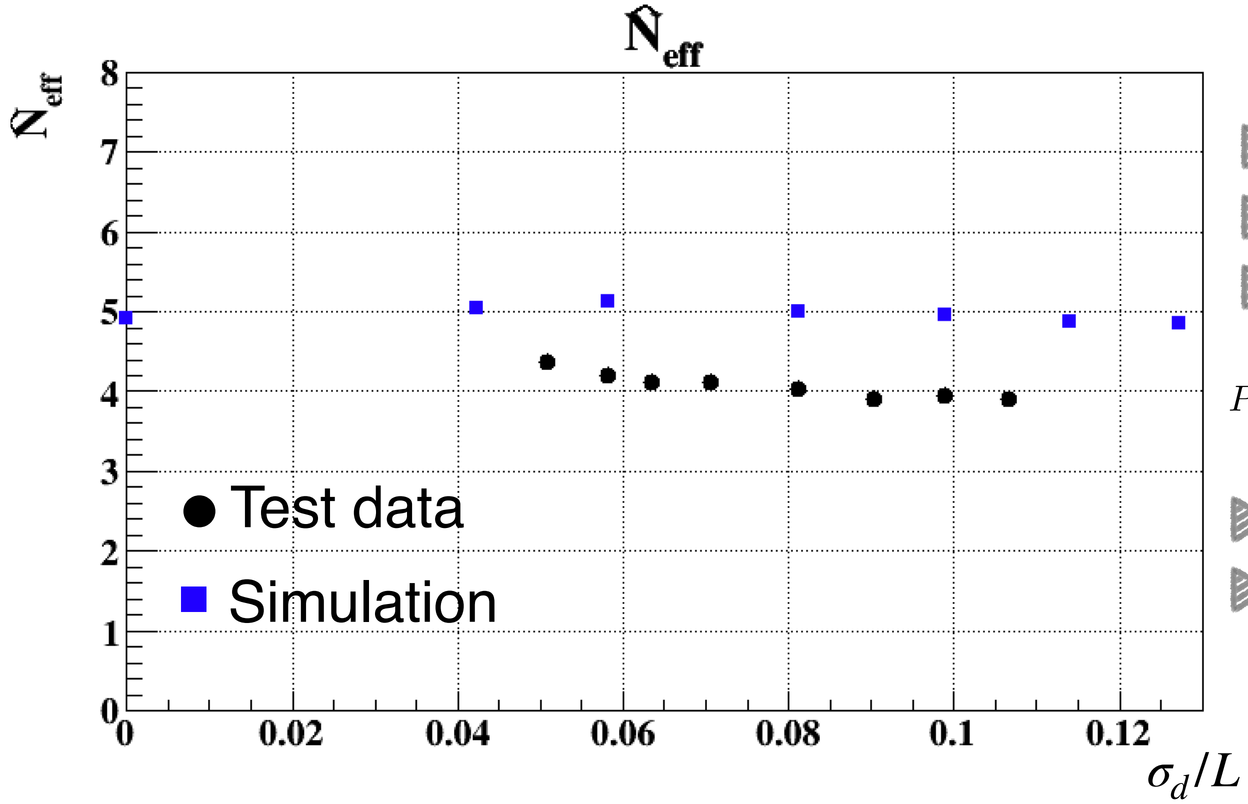
$\hat{N}_{eff}$ is the effective number of **primary clusters**



Simulation - Effective cluster number $\hat{N}_{eff}$

Calculate the $\hat{N}_{eff}$ in the same set up as the beam test

$$\hat{N}_{eff}(\phi = 0) = \frac{L^2 \tan^2\phi \cos\phi}{12\sigma_{ang}^2}$$



- Heed in Garfield++
- L(Pad height) = 5.26 [mm]
- Gas gain fluctuation : θ=0.6

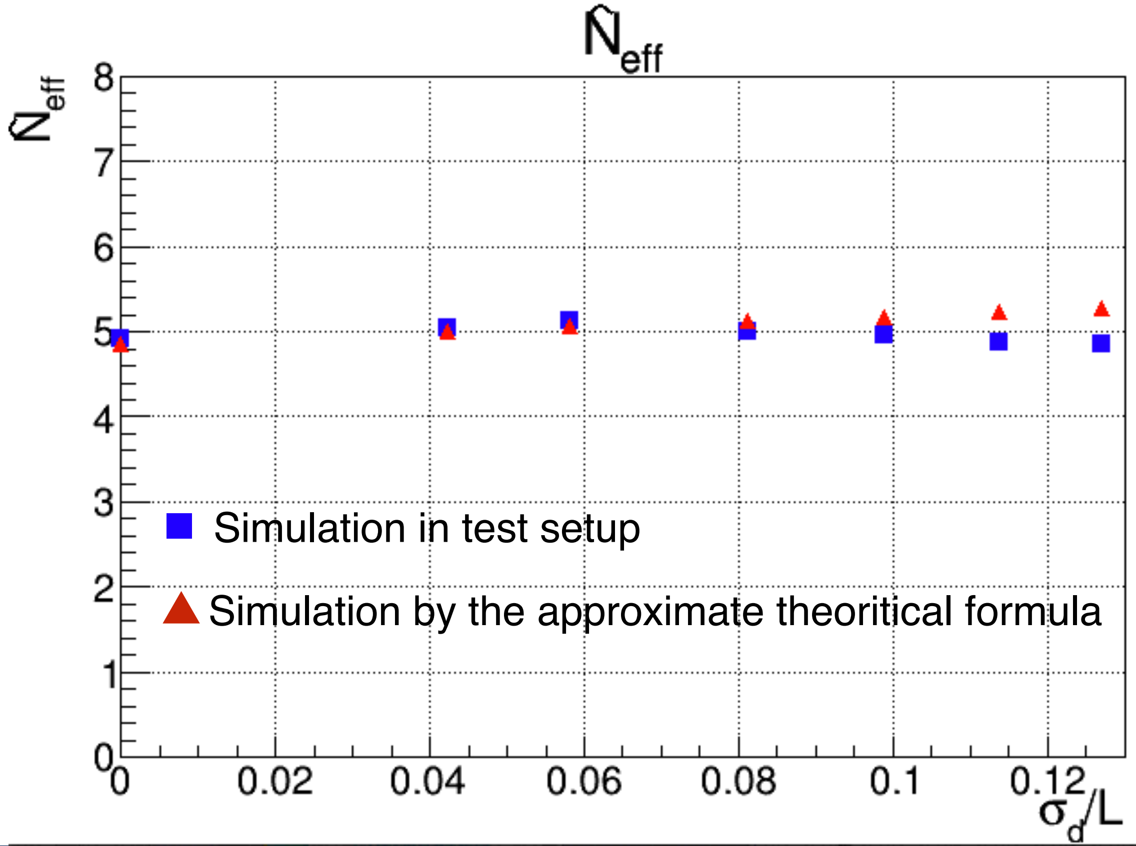
$$P_G(G/\bar{G};\theta) = \frac{(\theta+1)^{\theta+1}}{\Gamma(\theta+1)}\left(\frac{G}{\bar{G}}\right)^{\theta}\exp\left(-(\theta+1)\left(\frac{G}{\bar{G}}\right)\right)$$

- Ignore finite pad effect
- Ignore the magnetic field effect

Effective cluster number $\hat{N}_{eff}$

Evaluate the approximate theoretical formula

$$\hat{N}_{eff} \approx \left[\left\langle \sum_{i=1}^{N} \left\langle \left(\frac{\sum_{j=1}^{k_i} G_{ij}}{\sum_{i=1}^{N} \sum_{j=1}^{k_i} G_{ij}} \right) \right\rangle_G^{k_i, \sum_{i=1}^{N} k_i} \right\rangle_{N,k} \right]^{-1}$$



- Heed in Garfield++
- L(Pad height) = 5.26 [mm]
- Gas gain fluctuation : θ=0.6

$$P_G(G/\bar{G};\theta) = \frac{(\theta+1)^{\theta+1}}{\Gamma(\theta+1)} \left(\frac{G}{\bar{G}}\right)^{\theta} \exp\left(-(\theta+1)\left(\frac{G}{\bar{G}}\right)\right)$$

- Ignore finite pad effect
- Ignore the magnetic field effect

Summary

- Analyze the beam test data for the inclined track
→Confirm the inclined angular effect as expected

- How about $\hat{N}_{eff}$?
→Need to more improvements in our simulation

- Evaluate the approximate theoretical formula of $\hat{N}_{eff}$
→Two our simulation match.