MRPC simulation

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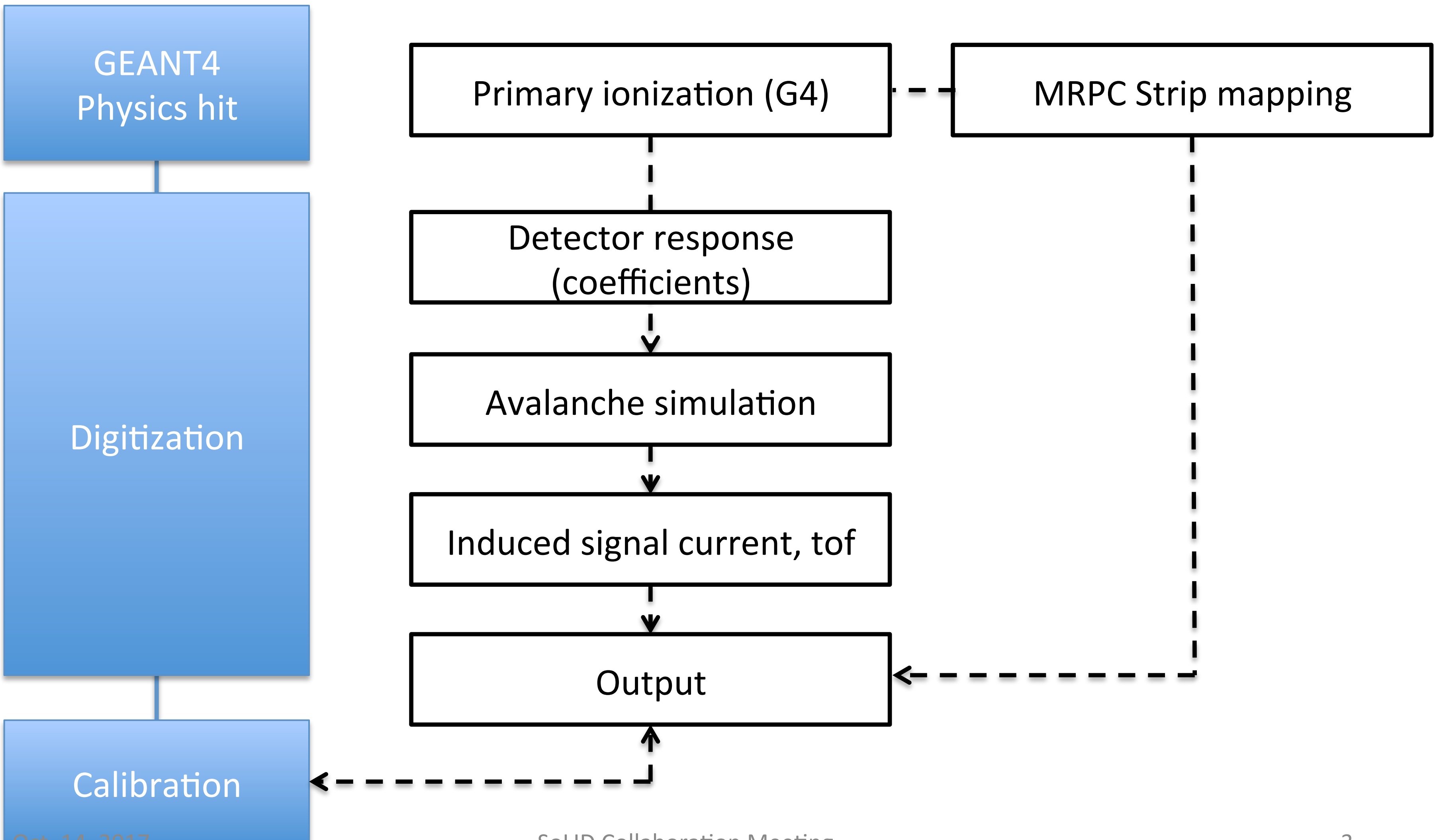
MRPC simulation

- Standalone digitization software developed for MRPC
- Based on the pCDR design
  - 10 gas gaps with a width of 0.25mm
  - Resistive plate with a width of 0.7 mm
  - gas mixture: $C_2F_4H_2$ (90%) : SF_6 (5%) : iso-C_4H_{10} (5%)
  - Strip readout at both ends

Basic scheme



Avalanche simulation

- Avalanche simulation based on the 1D model and the central limit theorem (Nucl. Instrum. Meth. A 500 (1-3) (2003) 144)
- Avalanche development can be characterized by two coefficient: Townsend coefficient (α) and attachment coefficient (η)
- P(n,x): probability for an avalanche started with a single electron to contain n electrons after distance x
- General solution is given as:

$$P(n,x)=\begin{cases} k\dfrac{\bar{n}(x)-1}{\bar{n}(x)-k}, & (n=0) \\ \bar{n}(x)\left(\dfrac{1-k}{\bar{n}(x)-k}\right)^2\left(\dfrac{\bar{n}(x)-1}{\bar{n}(x)-k}\right)^{n-1}, & (n>0) \end{cases}$$

$$\bar{n}(x)=e^{(\alpha-\eta)x}$$

(average number of electrons)

$$k=\frac{\eta}{\alpha}$$

Avalanche simulation

- Single gap avalanche simulation

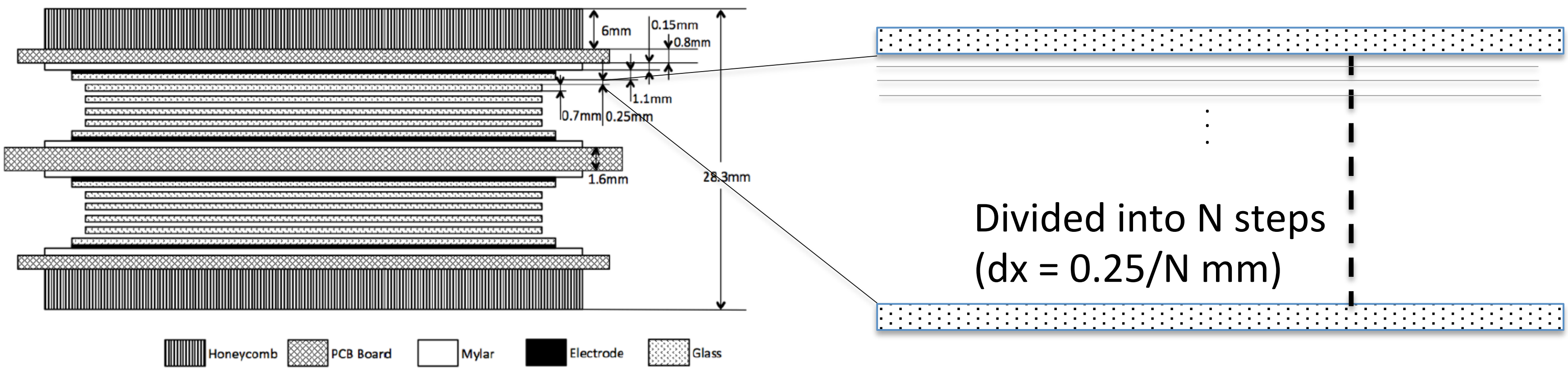


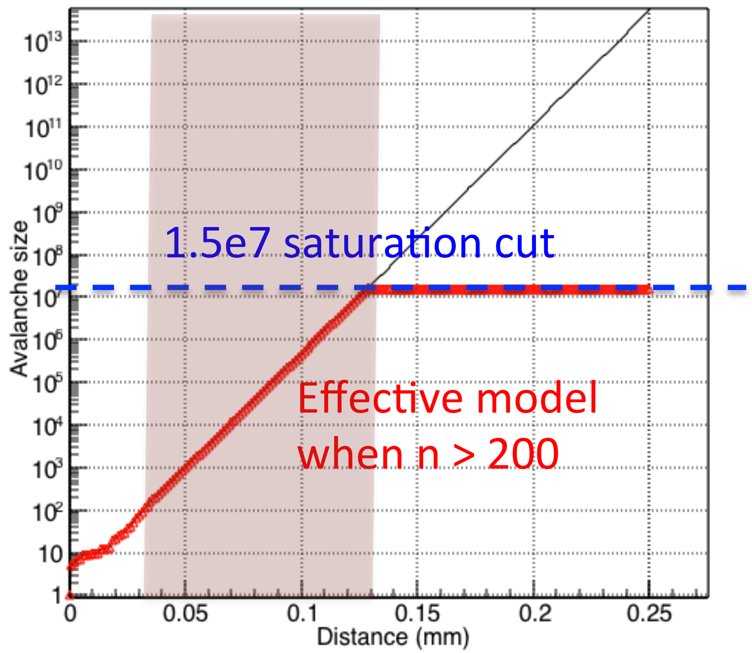
Figure 108: The structure of the MRPC prototype

- The positions of primary electrons are given by GEANT4 hit and Poisson distribution
- For each step, calculate the number of electrons with a probability for ionization/attachment (switches to the effective calculation from Gaussian distribution if $N_e > 200$)
- Simplified space charge effect: Number of electrons limited to 1.5e7

Avalanche simulation

- Single gap avalanche simulation

E = 108 kV/cm
Townsend coefficient (α) = 129/mm
Attachment coefficient (η) = 5.435/mm
Drift velocity = 0.201 mm/ns



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- For each step, calculate the number of electrons with a probability for ionization/attachment (switches to the effective calculation from Gaussian distribution if N_e > 200)
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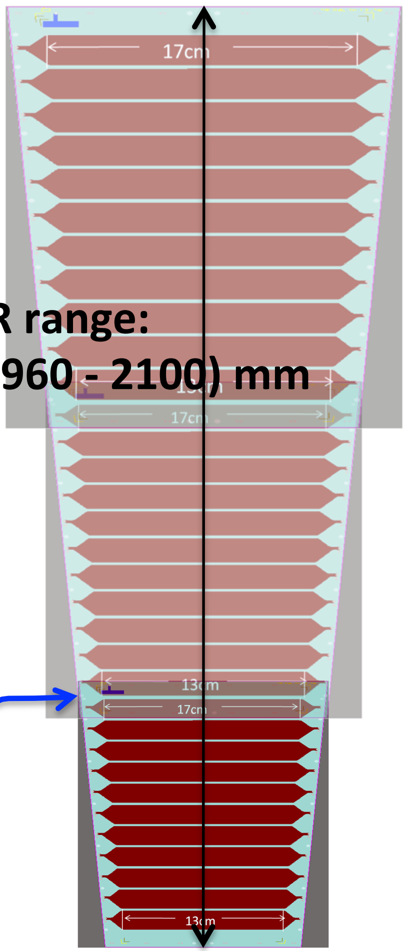
Strip mapping

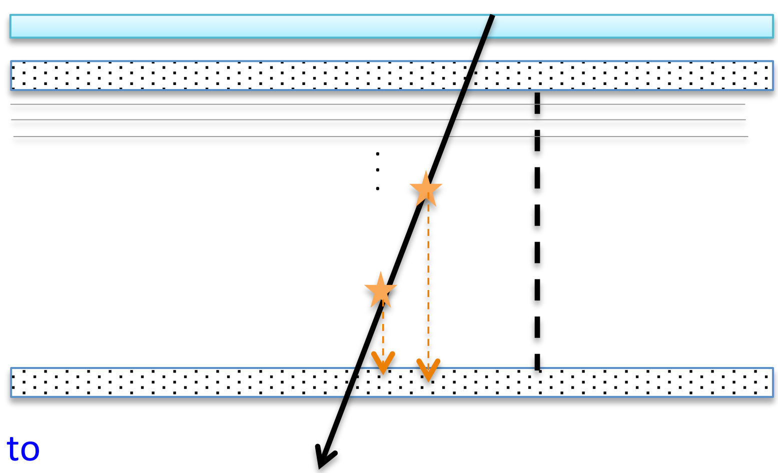


R range:
(960 - 2100) mm

Assume modules are overlapping to reduce blind region

- # supermodules: 50
  - each module has 7.2 of azimuthal angle coverage
- # strips: 33
  - Strip width: 25mm, gap: 3mm
- Minimum radial position of the first trip in order to set it to 130 mm:
  - R_{bottom}: 1033.15 mm (at least)

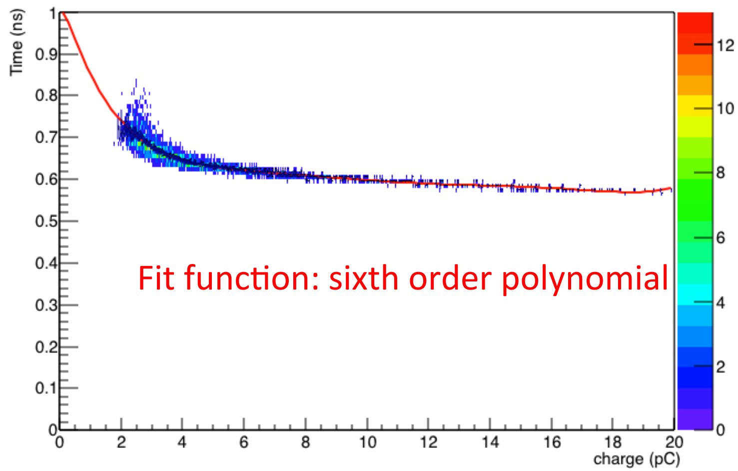
Virtual front plane



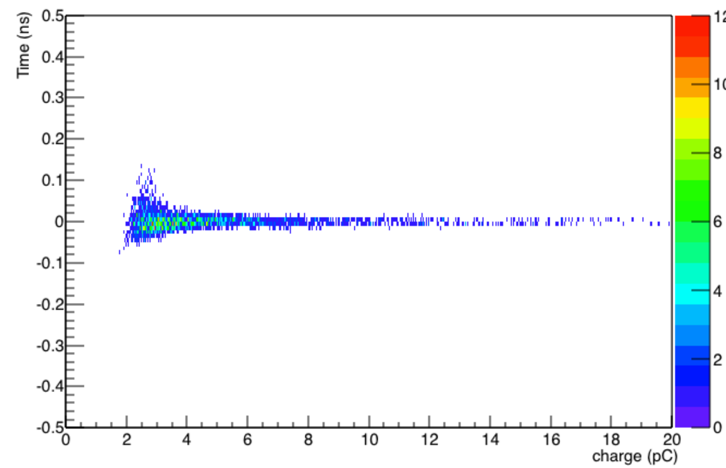
- Line equation: hit position at the virtual front plane and average position inside the gap
- X, Y positions of primary ions

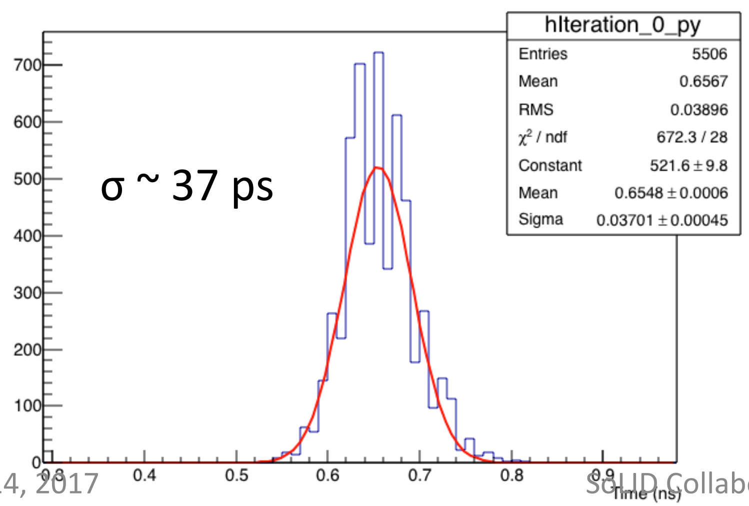
Slewing correction

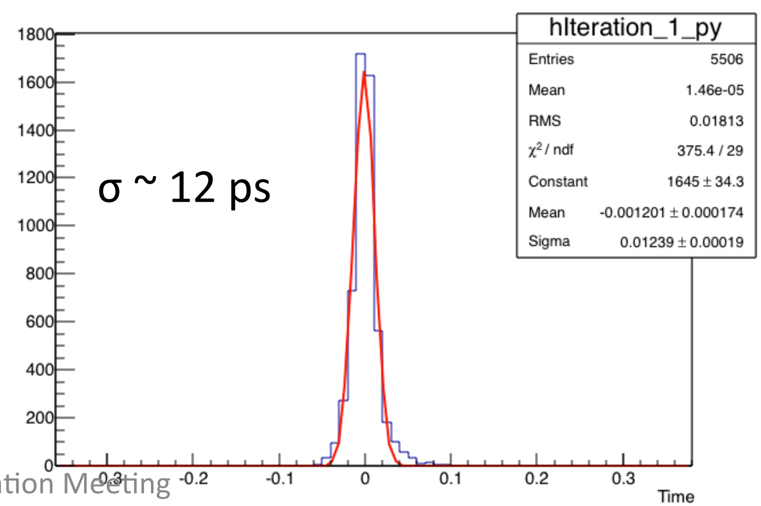
Before slewing correction



After slewing correction

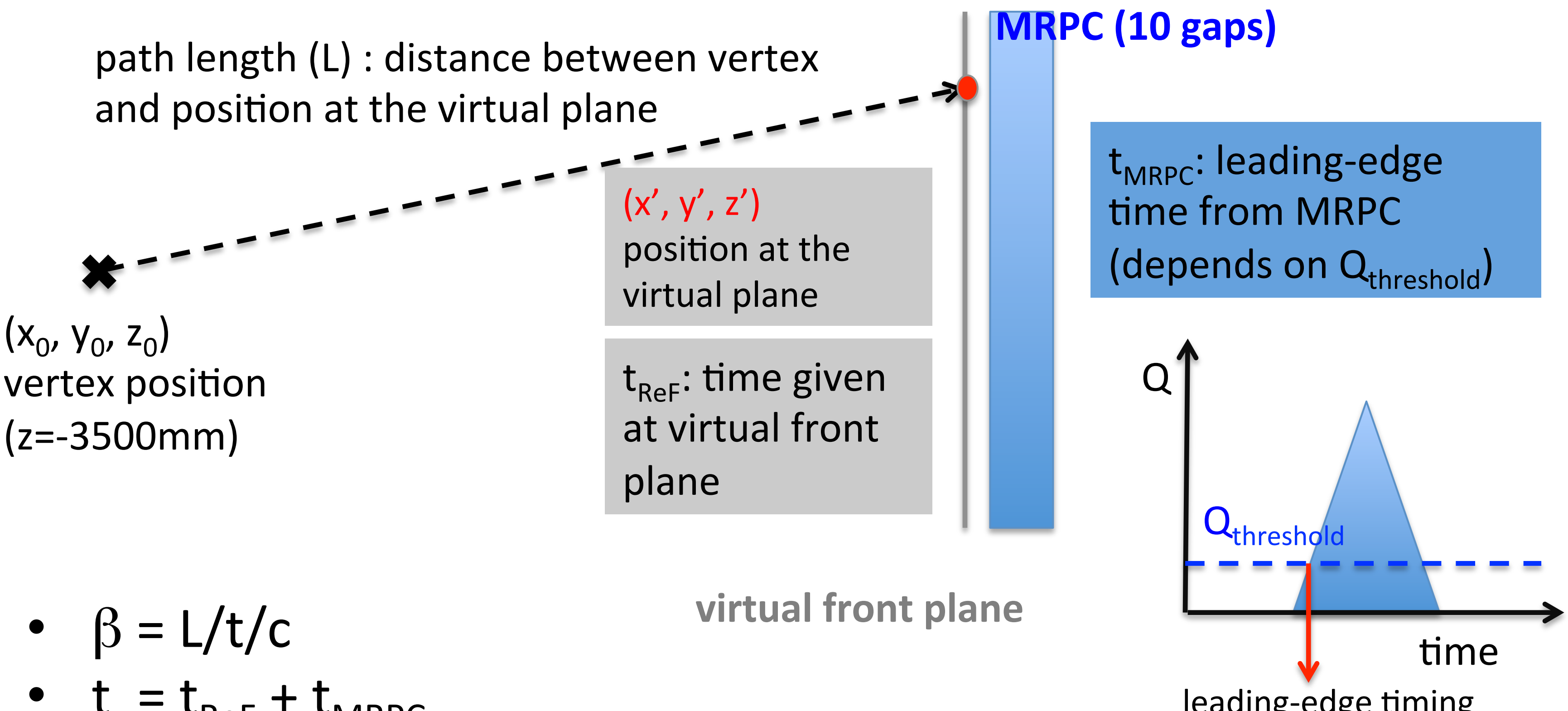






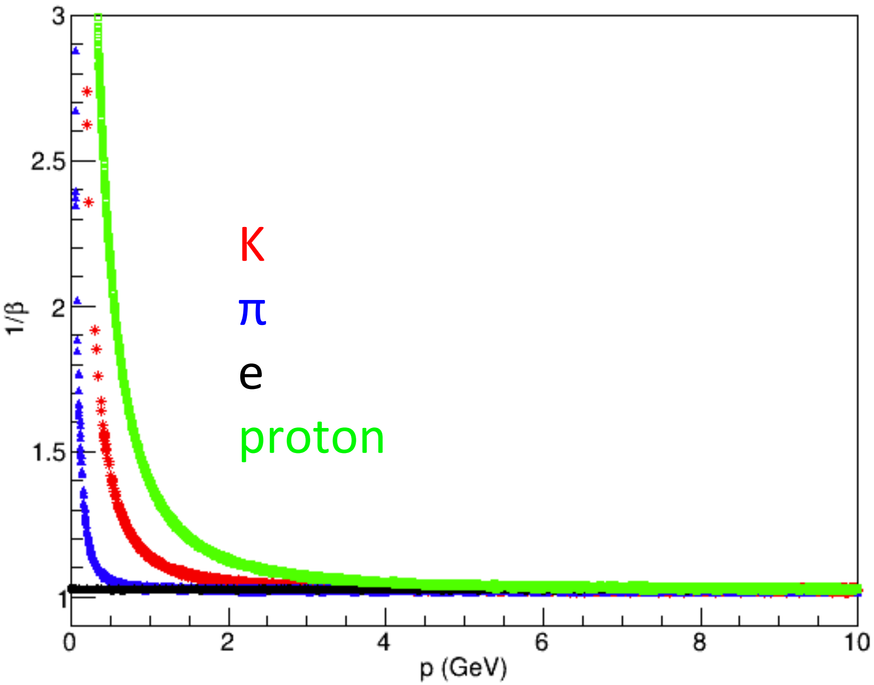
Single particle simulation

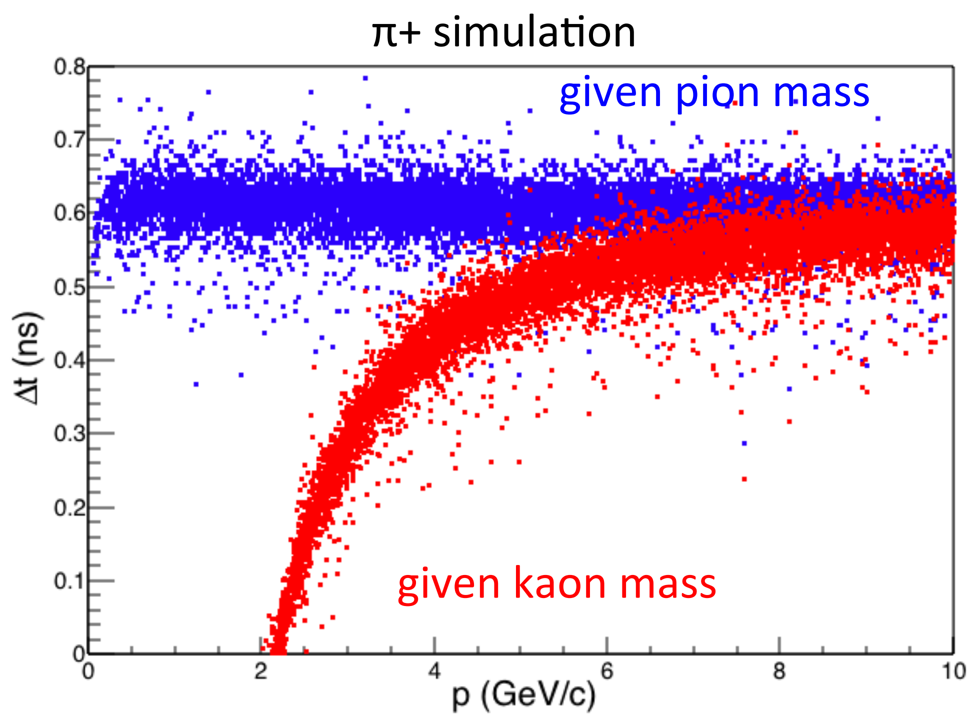
- $K^{\pm}$, $\pi^{\pm}$, p, e
- Single particle generation at the target position (z = -3500 mm)
- Initial momentum range of [0, 10] GeV, flat p
- Select only prompt hadrons/electrons by checking the track information



- $\beta = L/t/c$
- $t = t_{ReF} + t_{MRPC}$

TOF PID

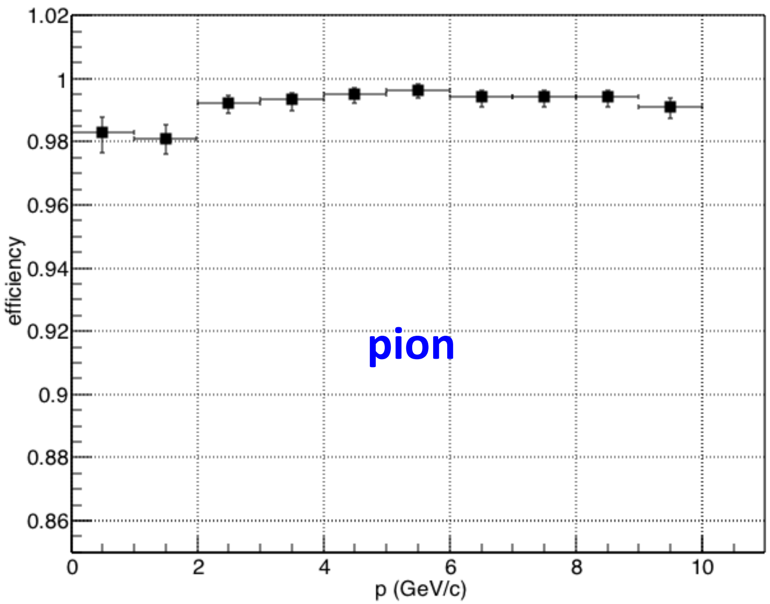


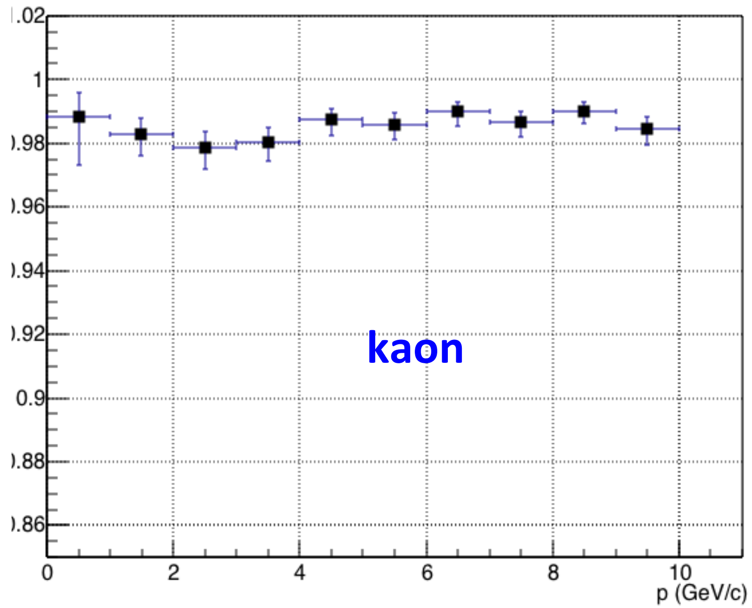


Δt = time_measured ($t_{Ref} + t_{Leading}$) - time_expected

Performance in simulation

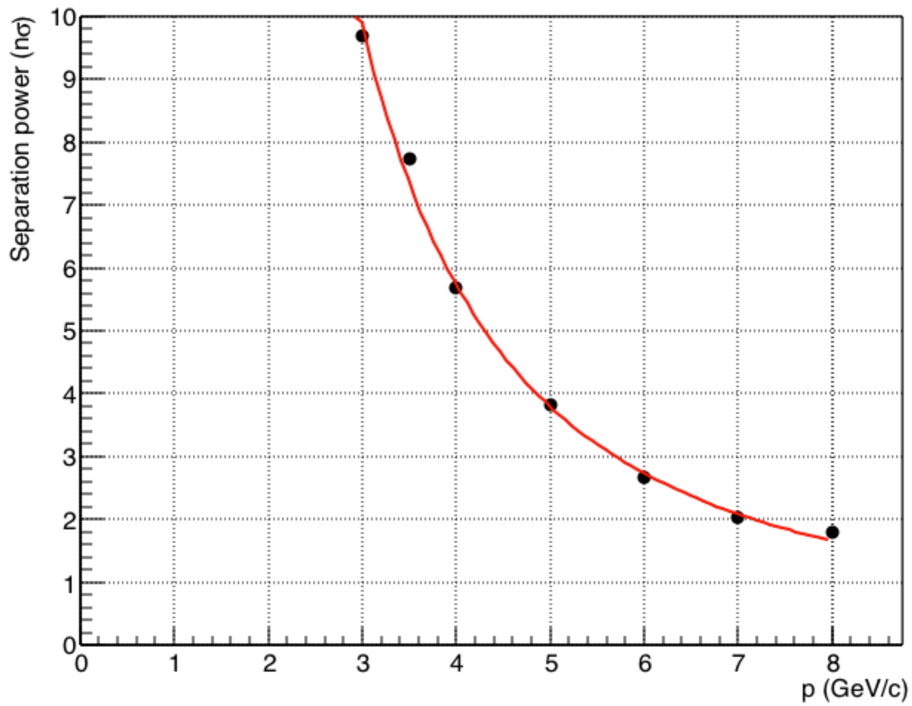
- Detection efficiency: (#MRPC signal)/(#VFP track)
- Average efficiency > ~98%





p/K separation

$$\text{Separation power} = \frac{\left|(t_{meas} - t_p) - (t_{meas} - t_K)\right|}{\sqrt{\sigma_K^2 + \sigma_\pi^2}}$$



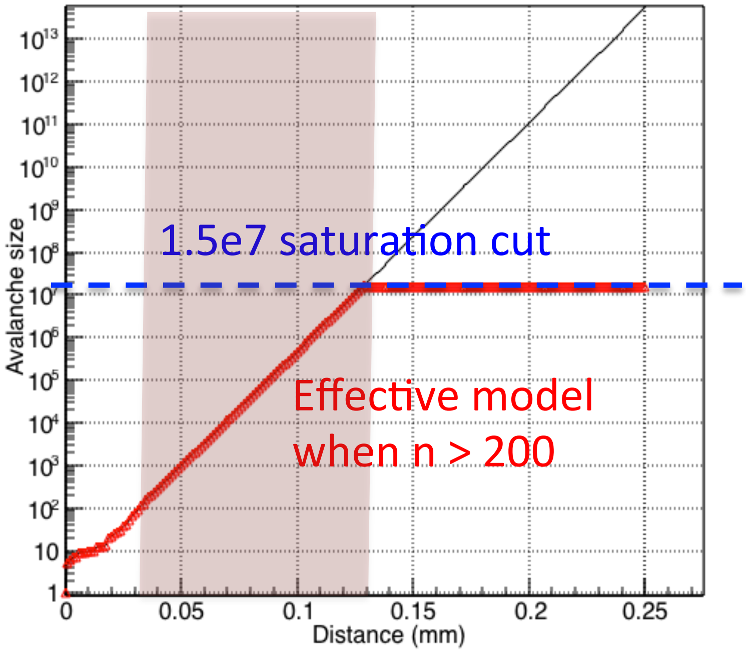
Summary and outlook

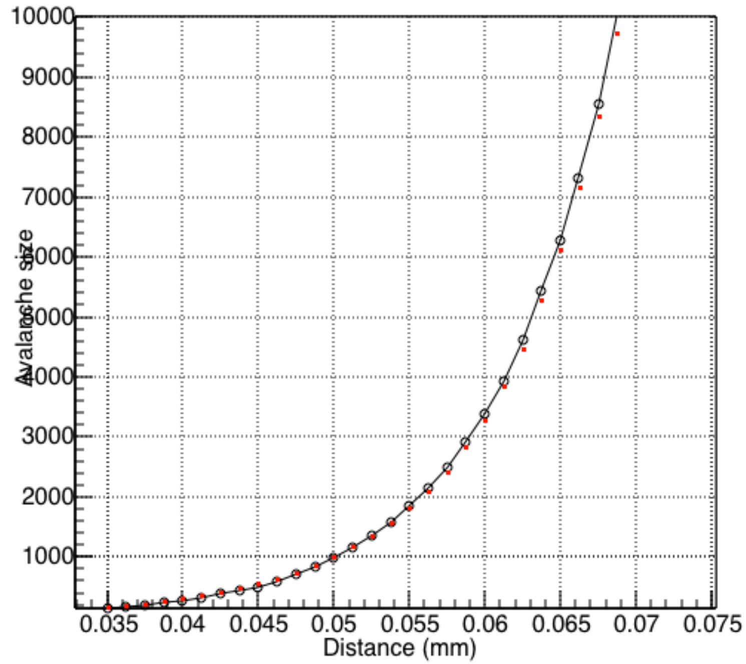
- Initial study with the MRPC simulation
- Further implementation of other uncertainty sources for more realistic time resolution
- Finishing up the tech note
- First version of codes on github:
  - https://github.com/sanghwapark/SolMRPC

  (instruction will be up soon)

Backup

Avalanche simulation

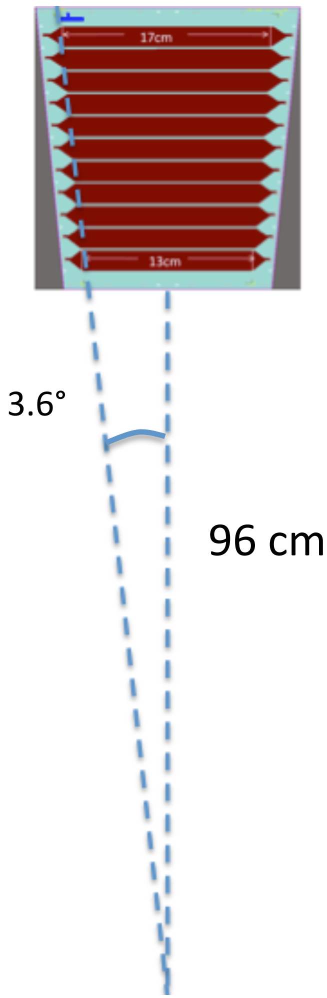




E = 108 kV/cm
Townsend coefficient (α) = 129/mm
Attachment coefficient (η) = 5.435/mm
Drift velocity = 0.201 mm/ns

- Used the same random seed for the comparison.
- Only minor difference in the avalanche size between the general solution and the effective model.

Module design

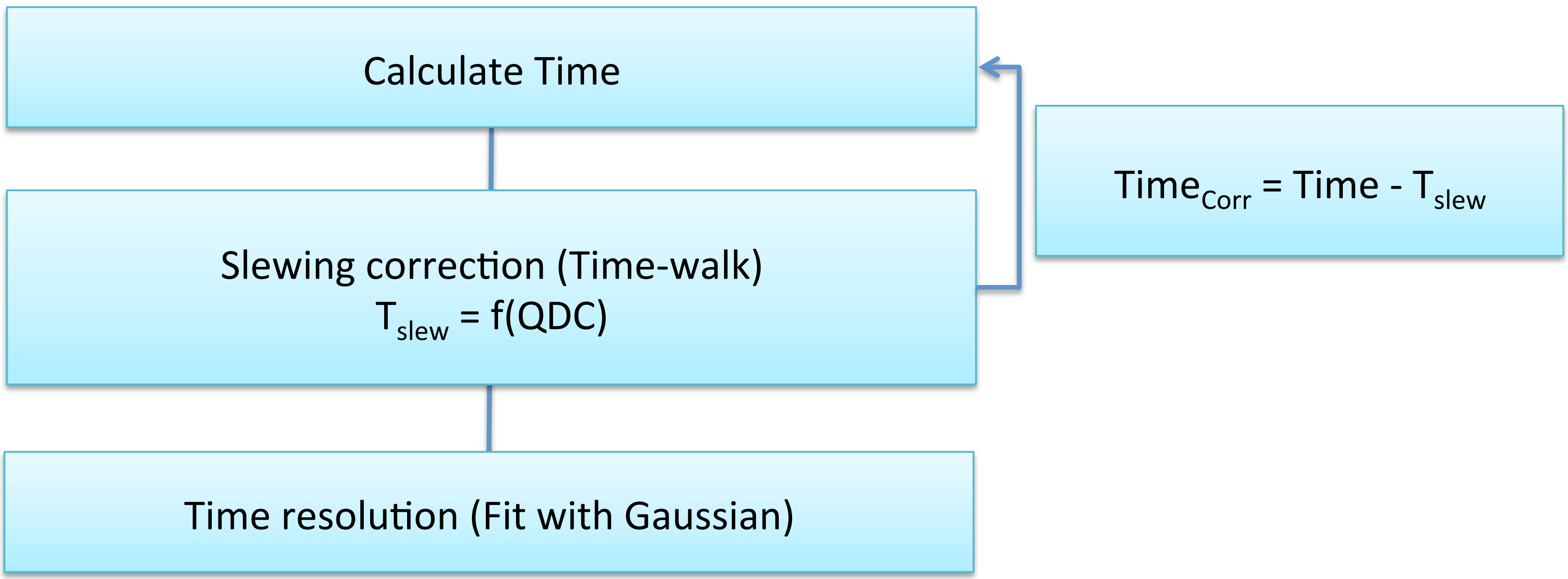


- Assum 50 supermodules: each module has 7.2 of azimuthal angle coverage
- 3.6 degree is ~ 6.28e-2 rad
- Minimum radial position of the first trip in order to set it to 130 mm:
  - R_{bottom}: 1033.15 mm (at least)
- 11th strip is supposed to have a strip length of 170 mm according to the pCDR
- With this initial condition, 11th strip would be located at R_{bottom} of 1033.15 + 250 + 30 ≅ 1313
- To follow the pCDR design: 25 mm strip width, 3mm interval → the length of 11th strip would be limited to 165.2 mm instead of 170 mm.
  - In order to have the 11th strip with a length of 170 mm, the bottom of the first strip should be located at least at 1071 mm from the center.
- At R = 960 mm, the maximum strip length is ~ 120.8 mm
- The bottom/top edge design would depend on physics?

Calibration

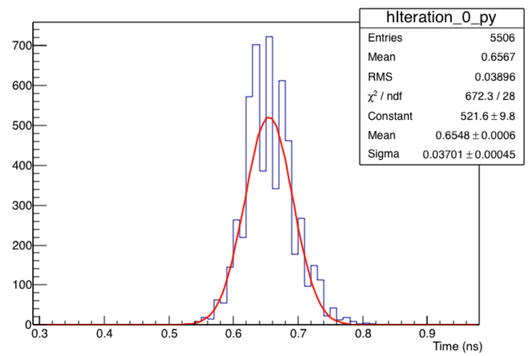
Average from both strip ends — Reference time — Shifted to be centered around 0

- $\text{Time} = (T_{MRPC(left)} + T_{MRPC(right)})/2 - (T1+T2+T3+T4)/4 - 1085$



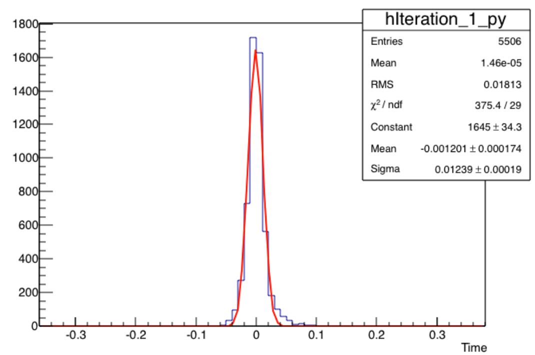
Slewing correction for MC

iteration: 0



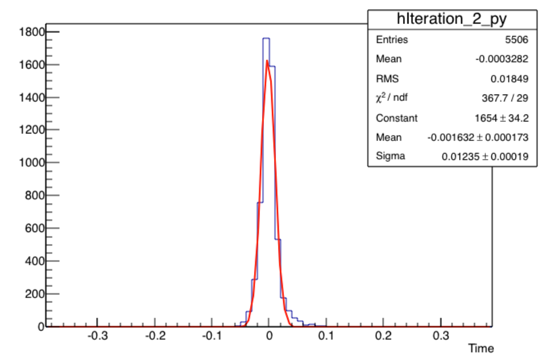
σ ~ 37 ps

iteration: 1



σ ~ 12 ps

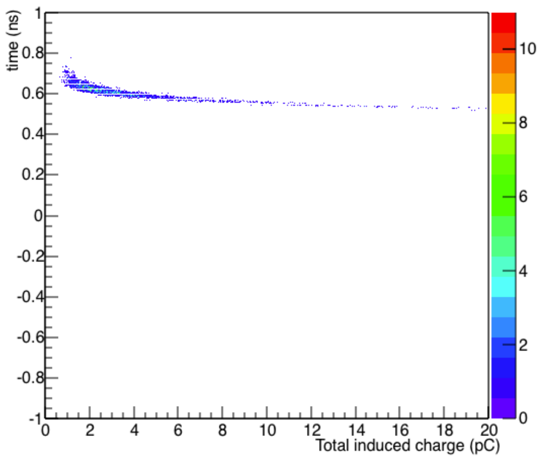
iteration: 2

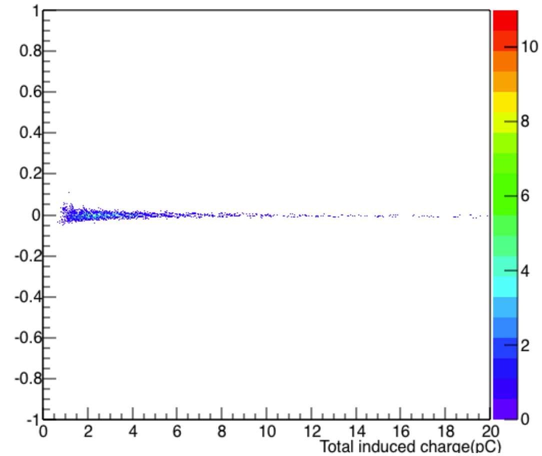


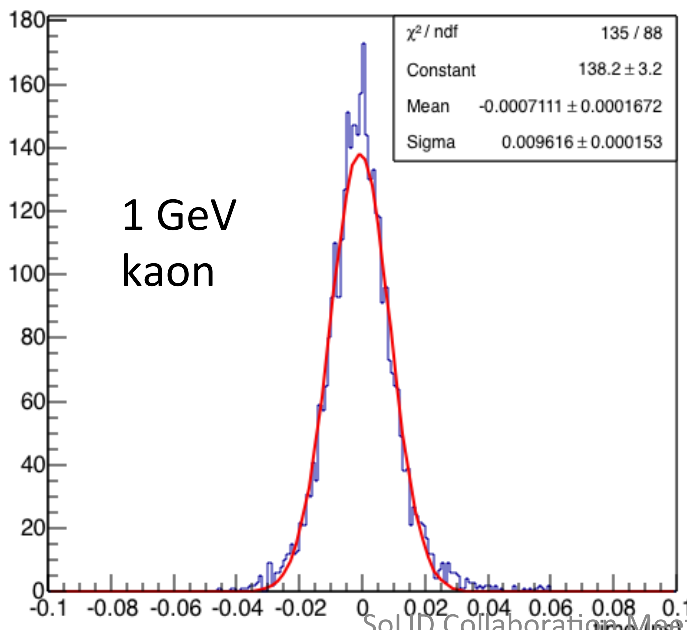
σ ~ 12 ps

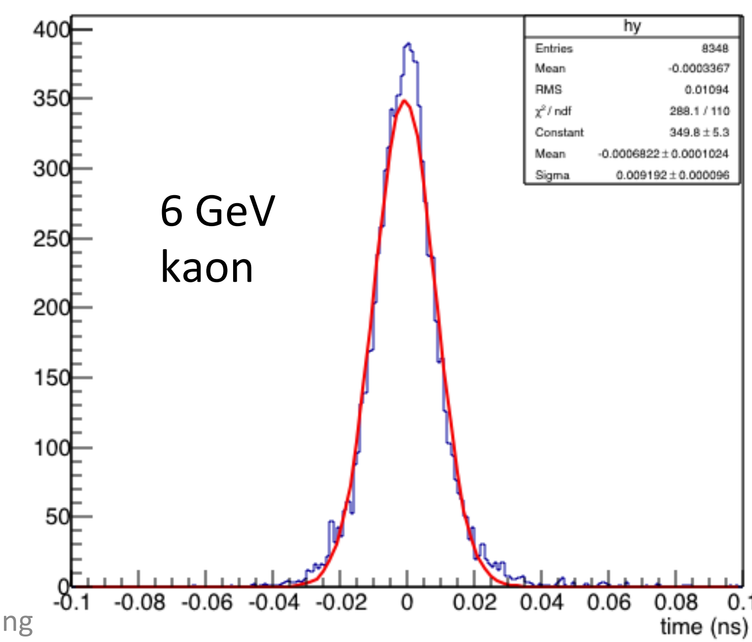
- Further iteration doesn't make much difference

Slewing correction

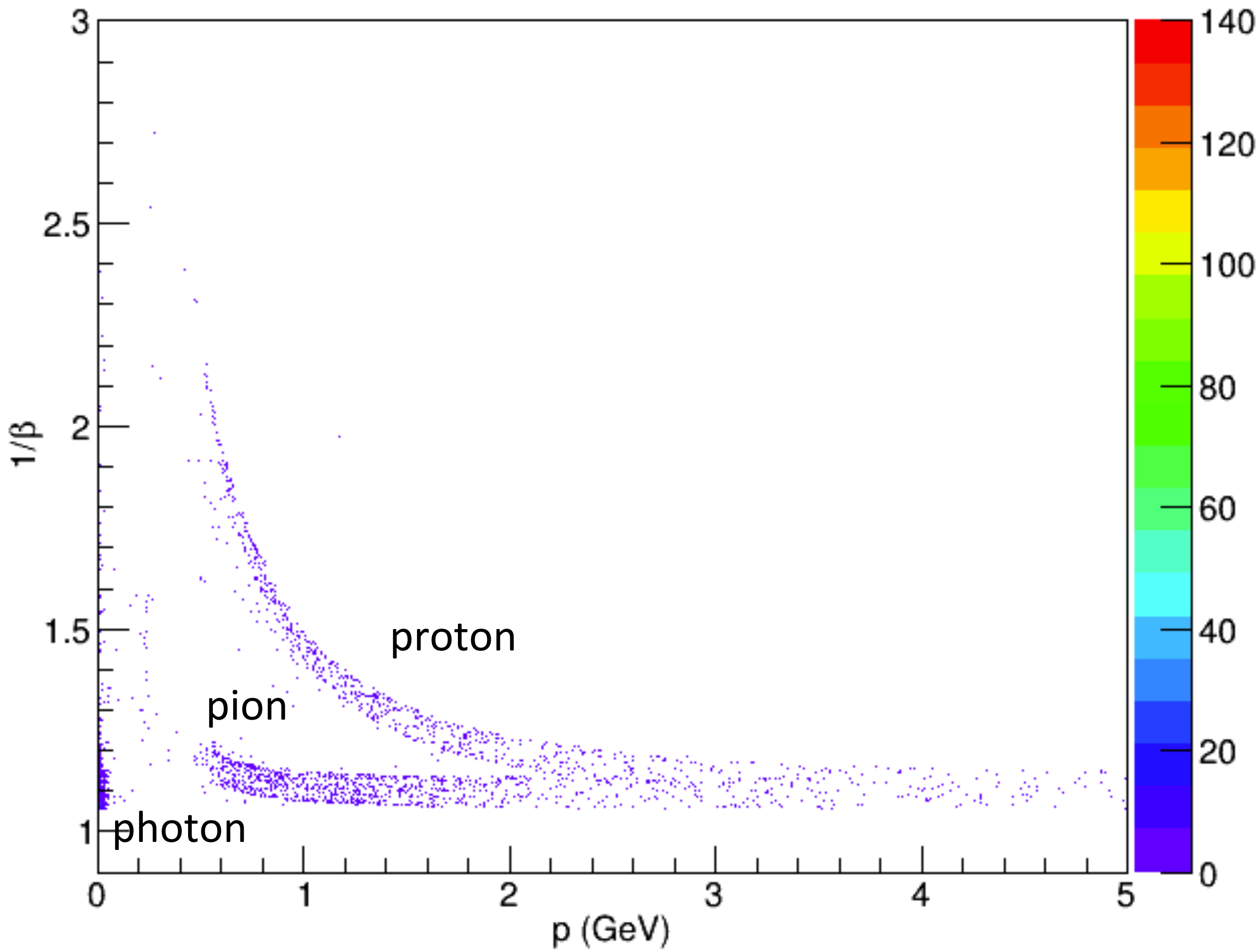








BeamOnTarget



Slewing correction