DIRC-like Time-of-flight Detector (DTOF) under the Offline Software of Super Tau-Charm Facility

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On behalf of the STCF DTOF-software working group

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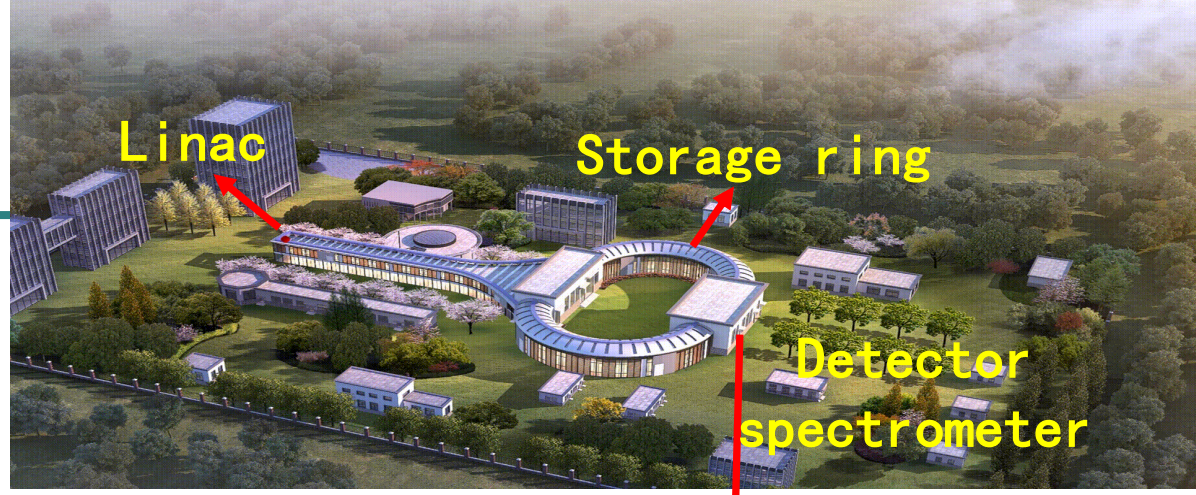
Super Tau-Charm Facility



Parameters of STCF:

- Center-of-mass energy: $2-7\mathrm{GeV}$
- Peak luminosity: $0.5\sim1\times10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Circumference: ~600m
- Crossing angle: 2×30mrad

Physical targets of STCF:

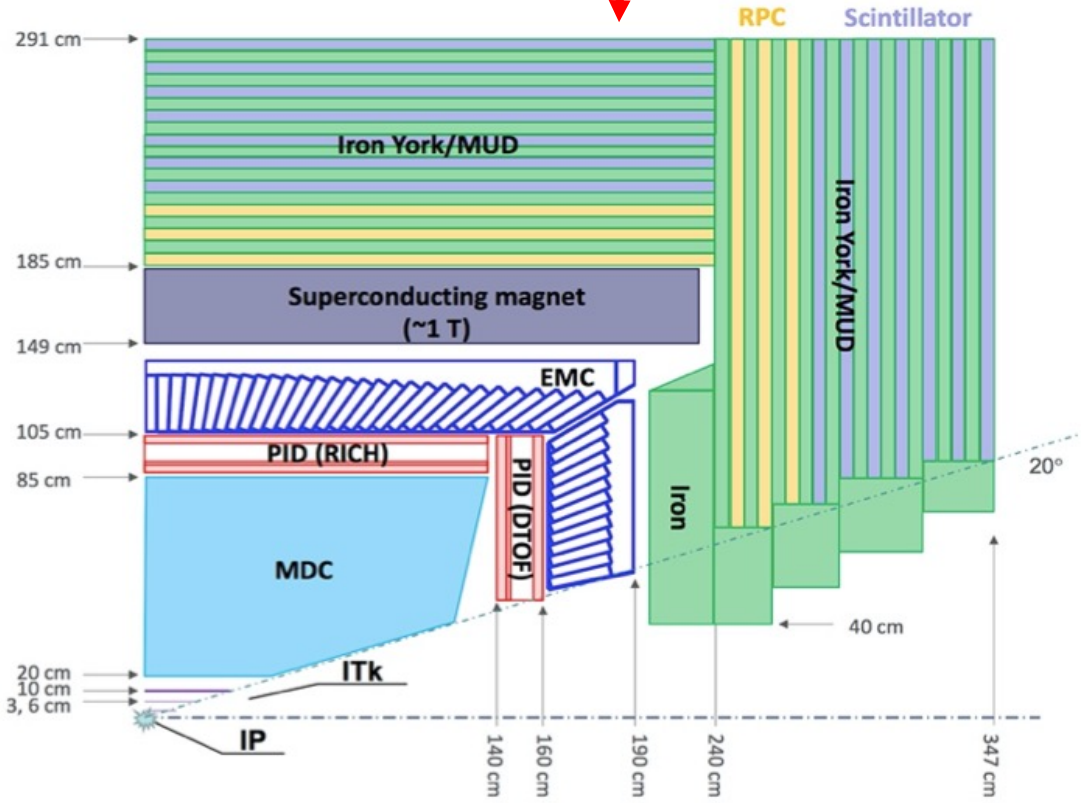
- Rich physics with c quark and τ leptons
- Non-perturbed strong interaction and hadron structure
- New physics searching

For PID system:

- π/K 4σ separation power up to 2 GeV/c

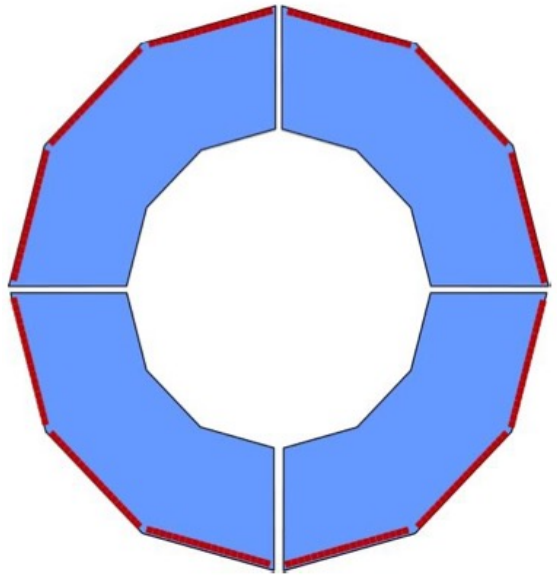
For DTOF :

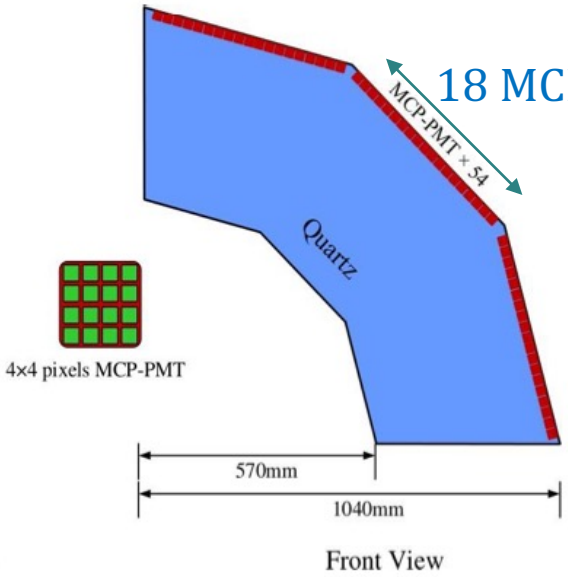
- > 4σ π/K separation at $p \leq 2$ GeV/c
- Time resolution ~ 46 ps

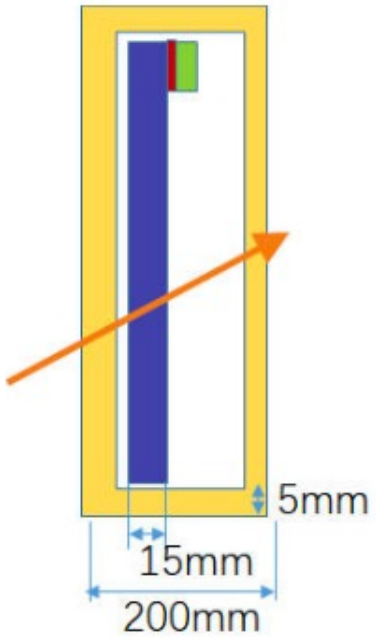


DTOF Geometry Configuration

- Two identical endcap discs, $\sim \pm 1400$ mm away from the collision point along the beam direction.
- Each disc: 4 sectors, $R_{min} = 570$ mm , $R_{max} = 1050$ mm.
- Covering polar angles $\theta \in (22° - 36°)$.

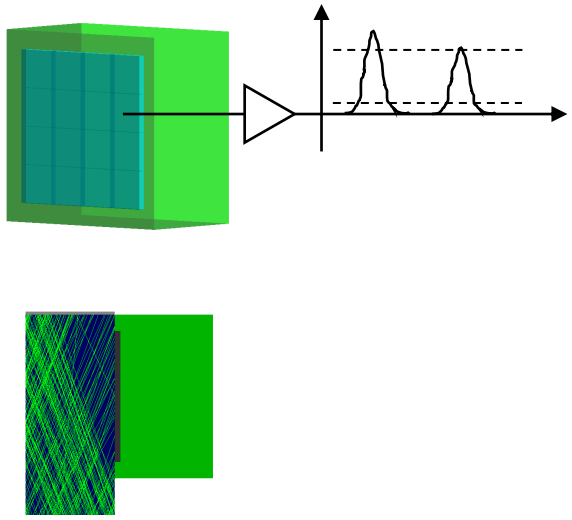






4×4 anodes

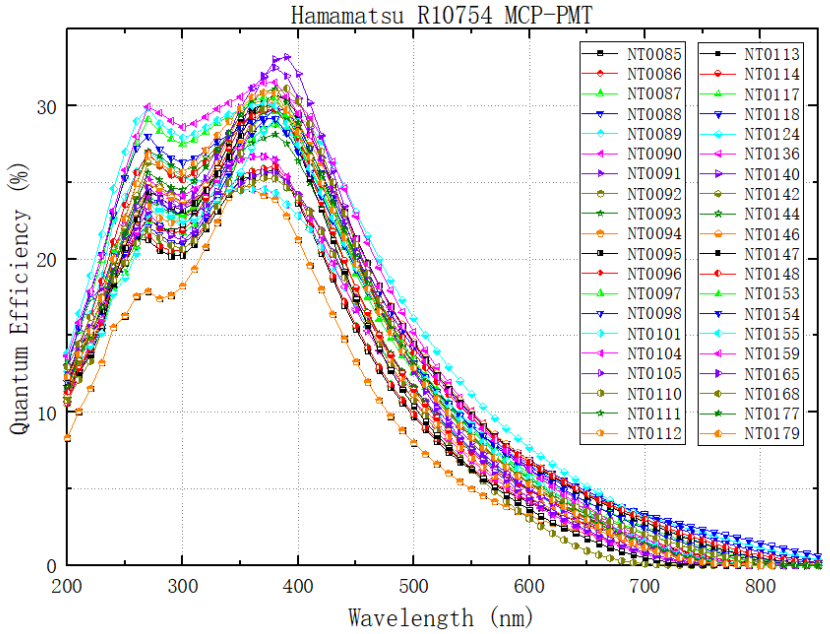
5.5×5.5 mm^2

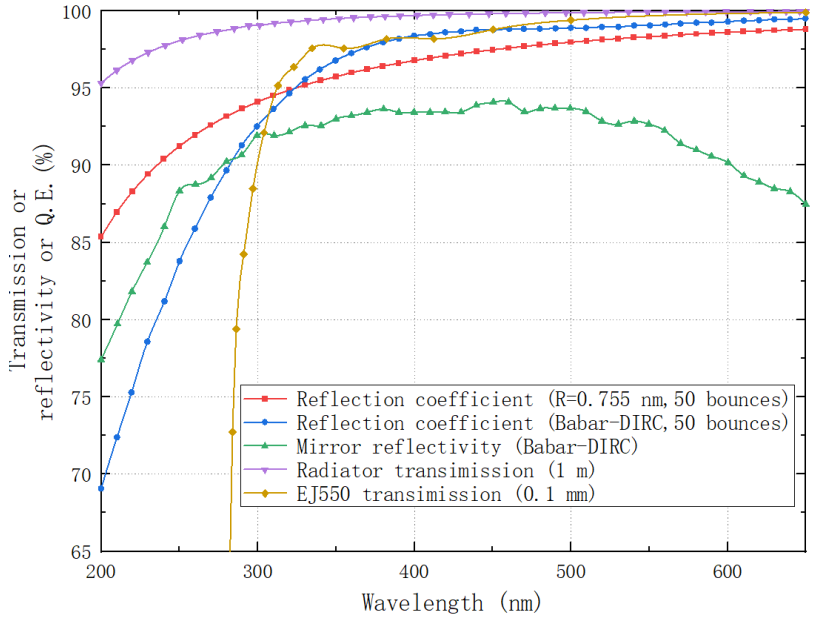


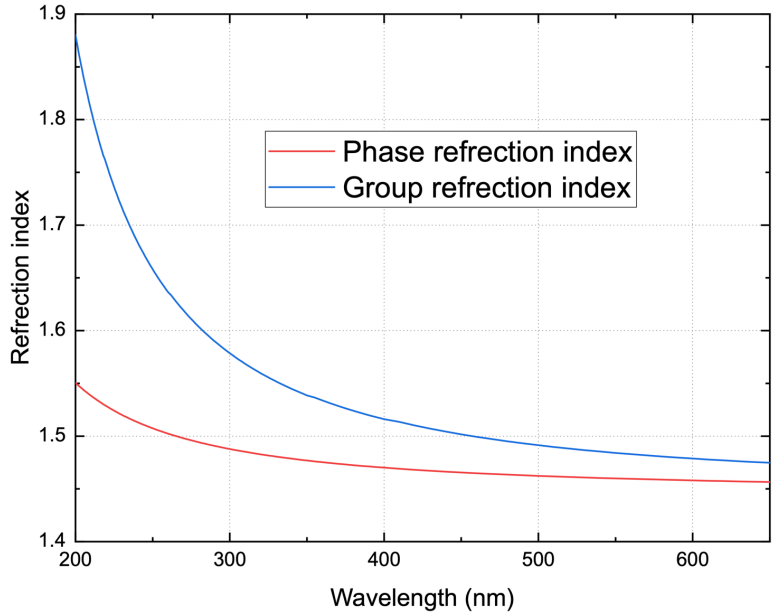
DTOF Simulation

Optical Parameters

- Optical parameters used in DTOF simulation.



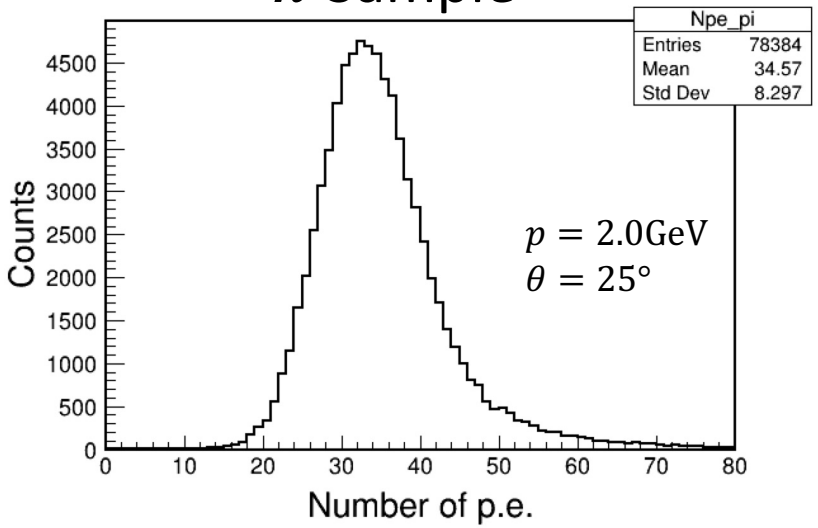


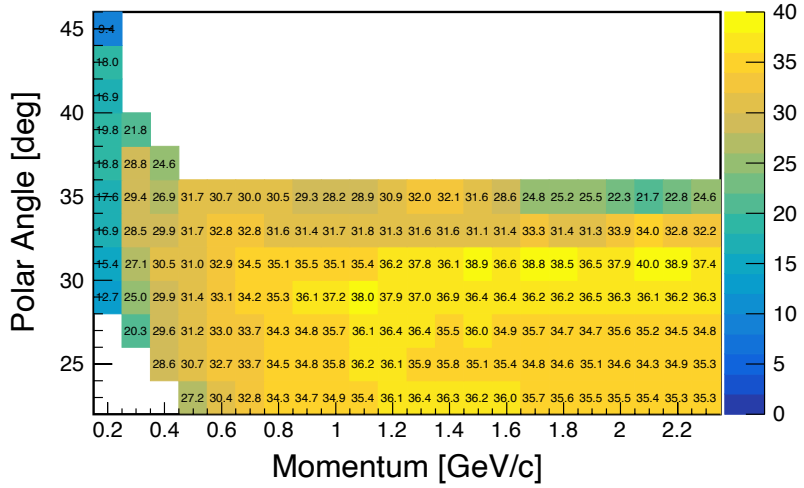


DTOF Simulation

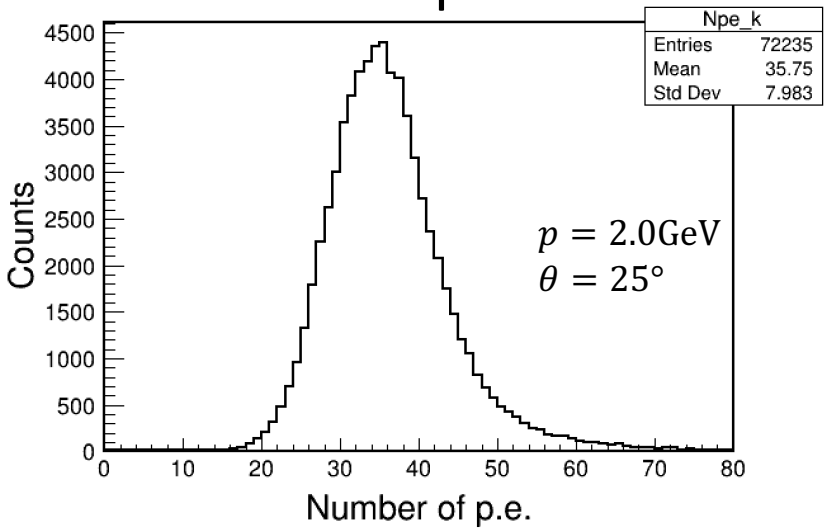
Photon Yield

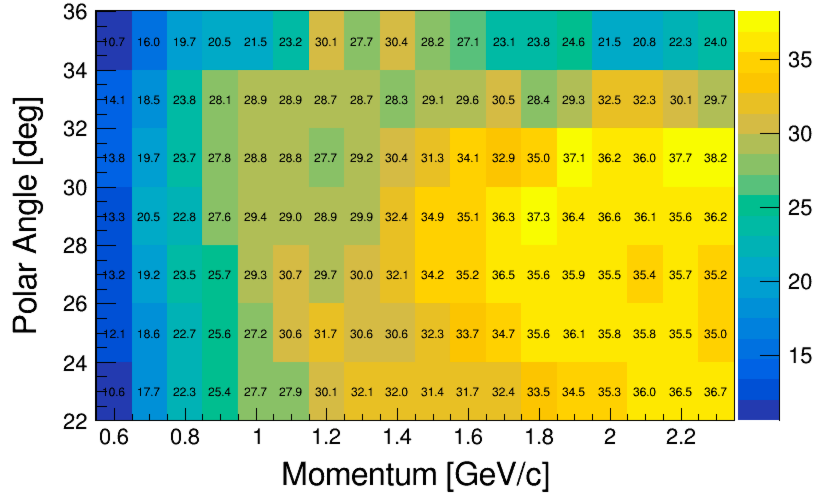
π Sample





K Sample





DTOF Reconstruction

Single Timing Uncertainties

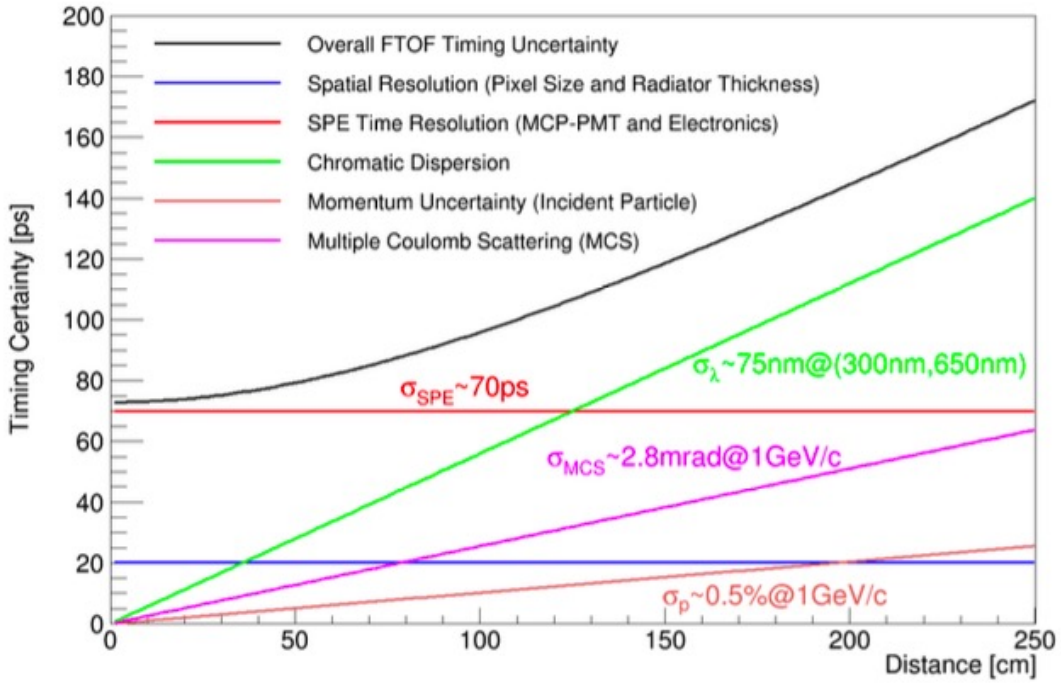
$$\sigma_t = \sigma_{T_0} \oplus \sigma_{t_{MCS}} \oplus \sigma_{TTS} \oplus \sigma_{t_\lambda} \oplus \sigma_{t_D} \oplus \sigma_{t_{ext(\vec{r},\vec{p})}}$$

OSCAR ~ 95.7 ps

π	/ps
$\sigma_{t_{MCS}}$	9.8
σ_{t_λ}	40.7
σ_{t_D}	14.36
$\sigma_{t_{ext}}$	16.5
σ_{T_0}	40
σ_{TTS}	70

$\oplus \sigma_{T_0} \oplus \sigma_{ext}$ ~ 94 ps

$\text{Distance} = \sqrt{\Delta X^2 + \Delta Y^2} = 63.5$ cm ~ 83 ps



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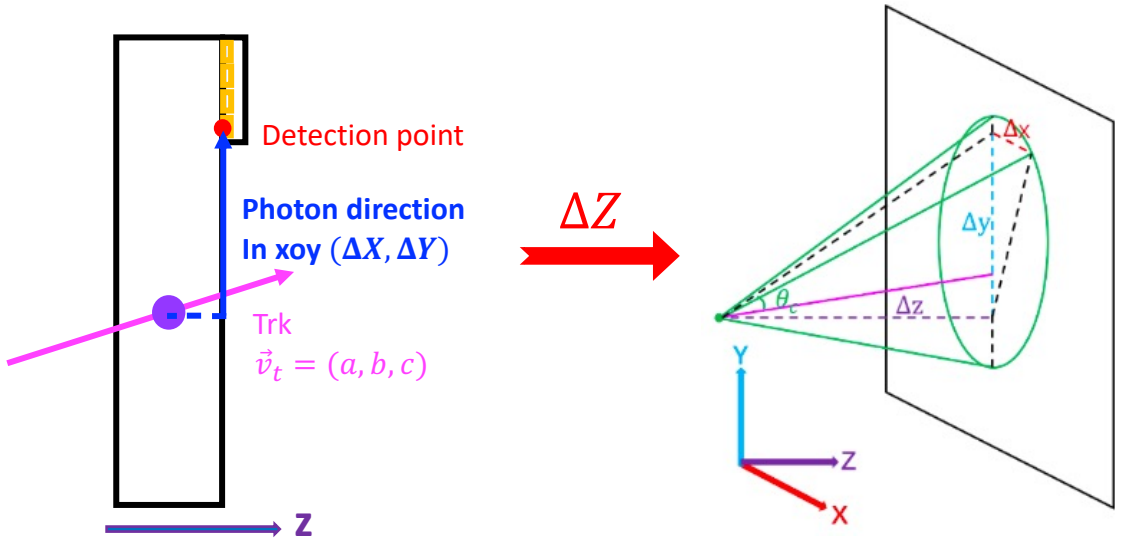
DTOF Reconstruction

Likelihood Method for PID – Timing Method

- **TOF Reconstruction**

$$cos\theta_c = \frac{1}{n\beta} = \frac{\vec{v}_t \cdot \vec{v}_p}{|\vec{v}_t| \cdot |\vec{v}_p|} \qquad \begin{cases} \vec{v}_t = (a, b, c) \\ \vec{v}_p = (\Delta X, \Delta Y, \Delta Z) \end{cases}$$

$$LOP = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2} \implies TOF_{rec} = T - \frac{LOP \cdot \overline{n_g}}{c} - T_0$$



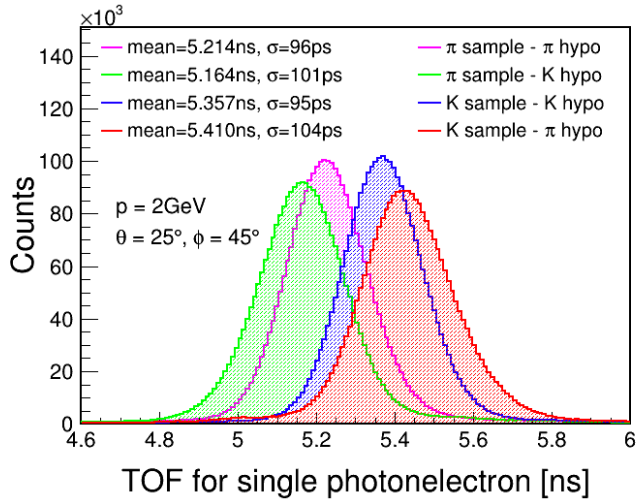
- **Likelihood construction**

$$\mathcal{L}_h = \prod_{i=0}^{N_{p.e.}} f_h(TOF_i)$$

signal bkg

$$f_h(t) = Gaus\left(TOF_{rec} | TOF_{hypo}, \sigma\right) + 0.05$$

where $TOF_{hypo} = \frac{LOF}{c\beta_{hypo}}$



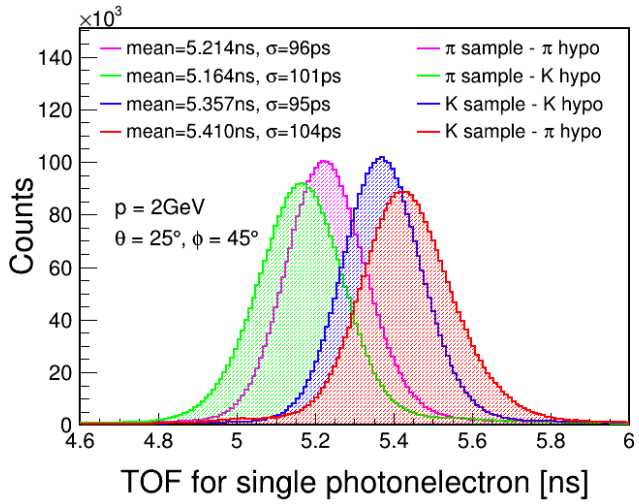
DTOF Reconstruction

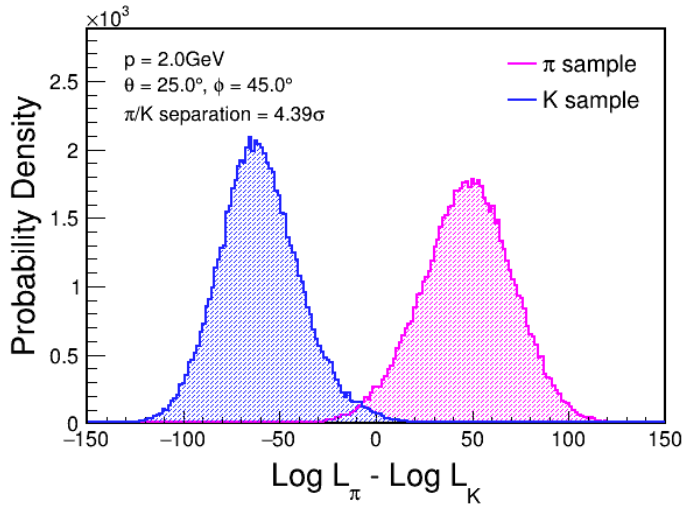
Likelihood Method for PID – Timing Method

- **Performance**

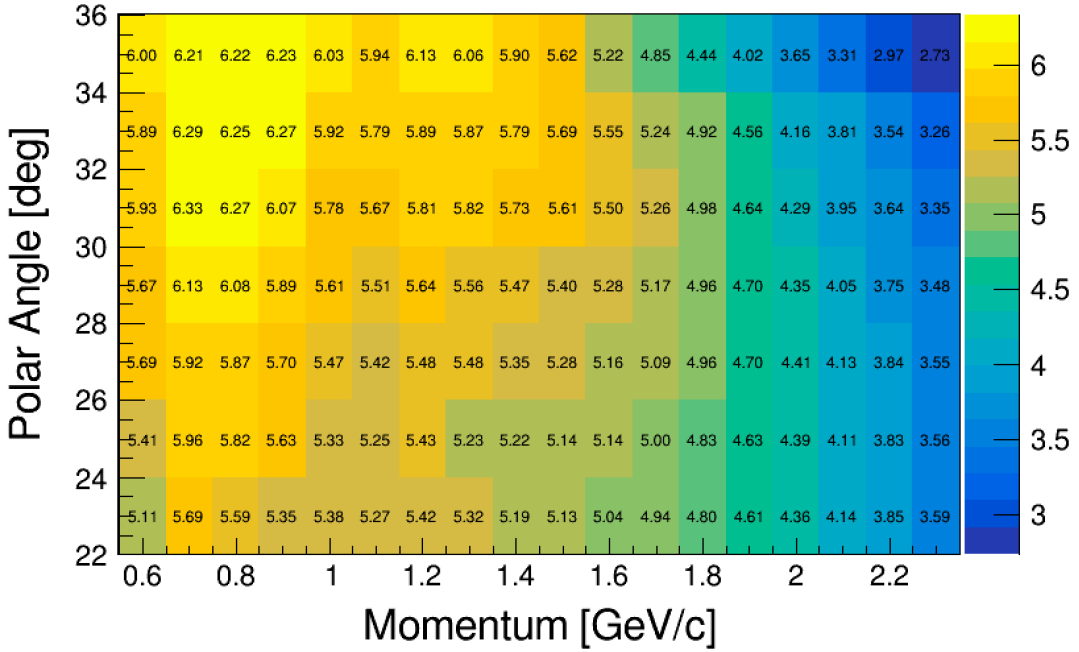
$$\mathcal{L}_h = \prod_{i=0}^{N_{p.e.}} f_h(TOF_i)$$

- $\sigma_t \sim 96\ ps$ by single photon-electron
- $\sigma_t \sim 46.3\ ps$ by multi-photon-electrons
- 4.39σ π/K separation at $p = 2.0$ GeV/c





π/K separation power in different $(|\vec{p}|, \theta)$:



DTOF Reconstruction

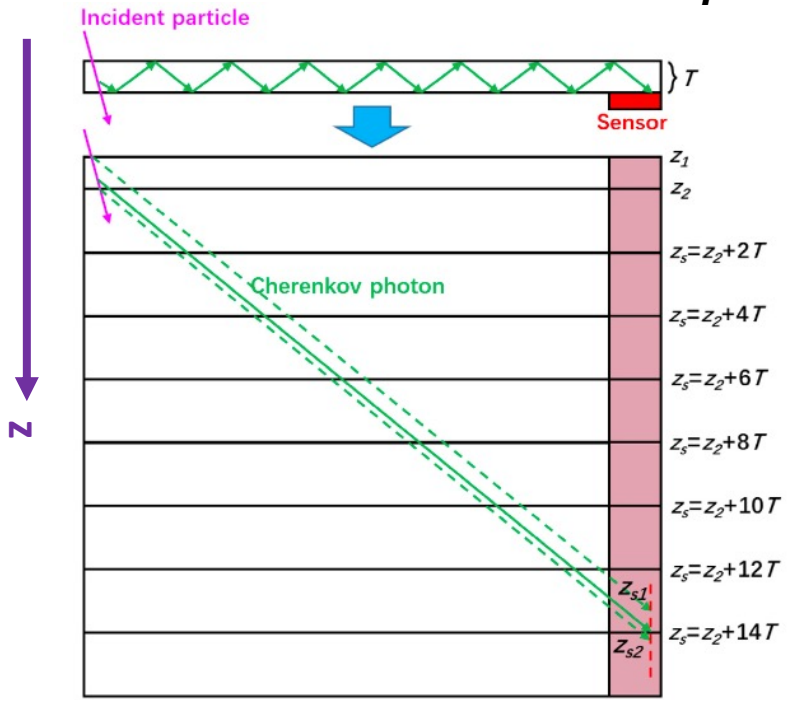
Likelihood Method for PID – Imaging Method

- **Photon TOA v.s. (x_s, y_s) Reconstruction**

$$cos\theta_c = \frac{1}{n\beta} = \frac{\vec{v}_t \cdot \vec{v}_p}{|\vec{v}_t| \cdot |\vec{v}_p|} \qquad \begin{cases} \vec{v}_t = (a, b, c) \\ \vec{v}_p = (x_s - x_0, y_s - y_0, z_s - z_0) \end{cases}$$

$$z_s = z_2 + 2mT$$

$$\boldsymbol{(x_s, y_s) \Rightarrow z_e, \phi_c \Rightarrow TOA = TOF + \frac{\Delta LOF_e}{\beta c} + TOP}$$



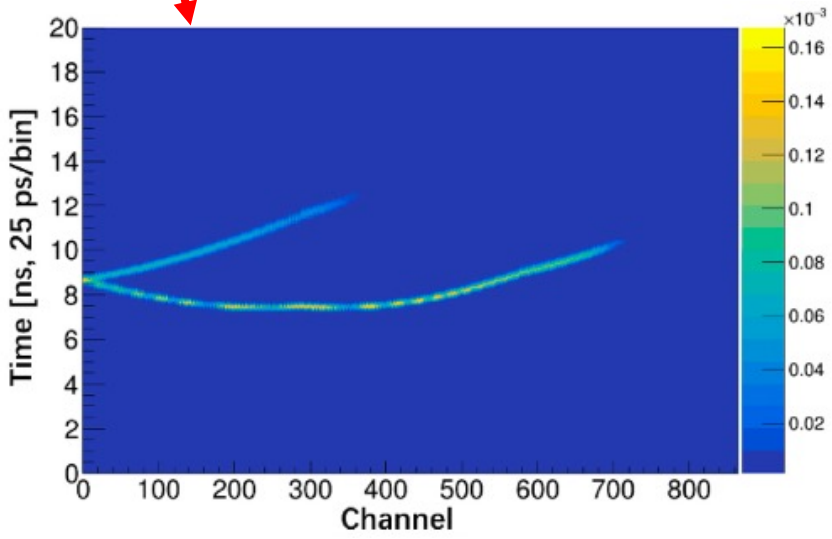
- **Likelihood construction**

$$\mathcal{L}_h = p_h(N_{p.e.}) \prod_{i=0}^{N_{p.e.}} f_h(x_i, t_i)$$

$$p_h(N_{p.e.}) = \sum_{n=0}^{N} Poisson_h(n, N_e) \times F_{bkg}(N - n)$$

$$f_h(x, t) = S_h(x, t) + const_{bkg}$$

$S_h(x, t)$ is the signal P.D.F. with a weight of $N_{p.e.}$



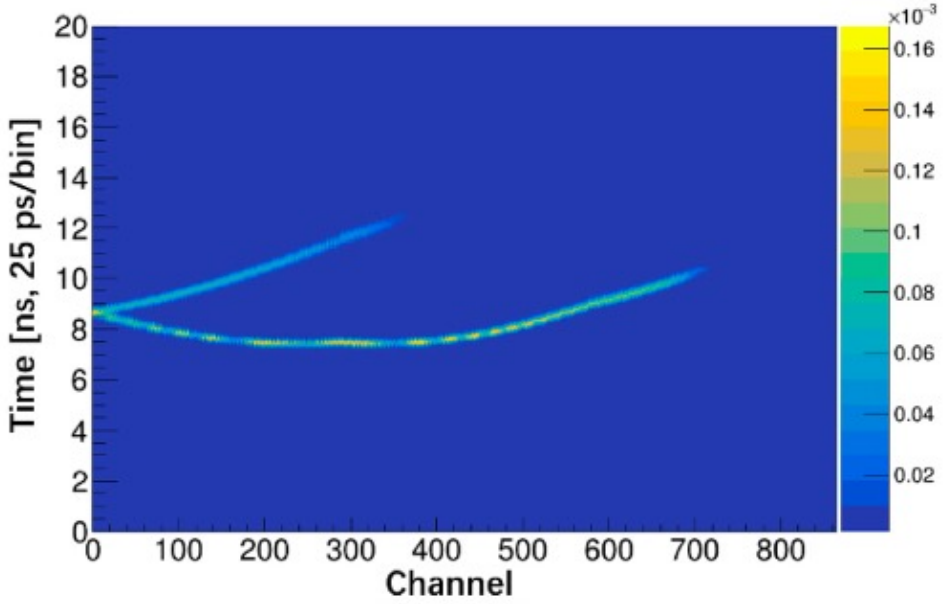
DTOF Reconstruction

Likelihood Method for PID – Imaging Method

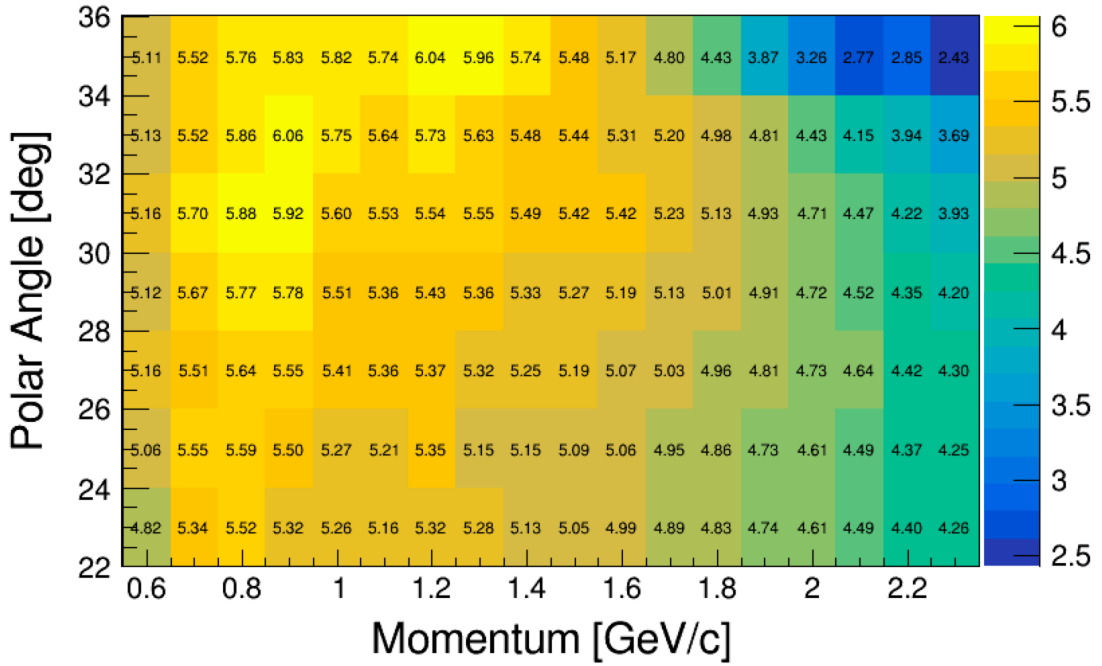
- **Performance**

$$\mathcal{L}_h = p_h(N_{p.e.}) \prod_{i=0}^{N_{p.e.}} f_h(x_i, t_i)$$

- Improve π/K separation ~**4.61σ**, at $p = 2.0$ GeV/c
- Imaging method performed better at $p > 2$ GeV/c



Preliminary result (need to be optimized):
π/K separation power in different $(|\vec{p}|, \theta)$:



Summary

The Simulation & Reconstruction software of DTOF has been established based on OSCAR:

Simulation

- Geometry simulation has been constructed.

Reconstruction

✓ Both two Algorithm can satisfy 4σ π/K separation power at $\mathrm{p} \leq 2.0\ \mathrm{GeV/c}$

Timing method

- π/K separation $\sim 4.39\sigma$, at $\mathrm{p} = 2.0\ \mathrm{GeV/c}$.
- Overall reconstructed TOF time resolution $\sim 46\ \mathrm{ps}$.

Imaging method

- π/K separation $\sim 4.61\sigma$, at $p = 2.0\ \mathrm{GeV/c}$.

Improve the efficiency of Global PID. $\theta \in (22°, 36°)$, $\mathrm{p} \in (0.2, 2.4)\ \mathrm{GeV/c}$.

Thank you!

BackUp

BackUp

$@\ \theta = 41°, p = 0.2\ \text{GeV},\ \pi$ Sample