DIRC-like Time-of-flight Detector (DTOF)

under the **O**ffline **S**oftware of **S**uper Tau-**C**h**ar**m Facility (OSCAR)

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Super Tau-Charm Facility

Parameters of STCF:

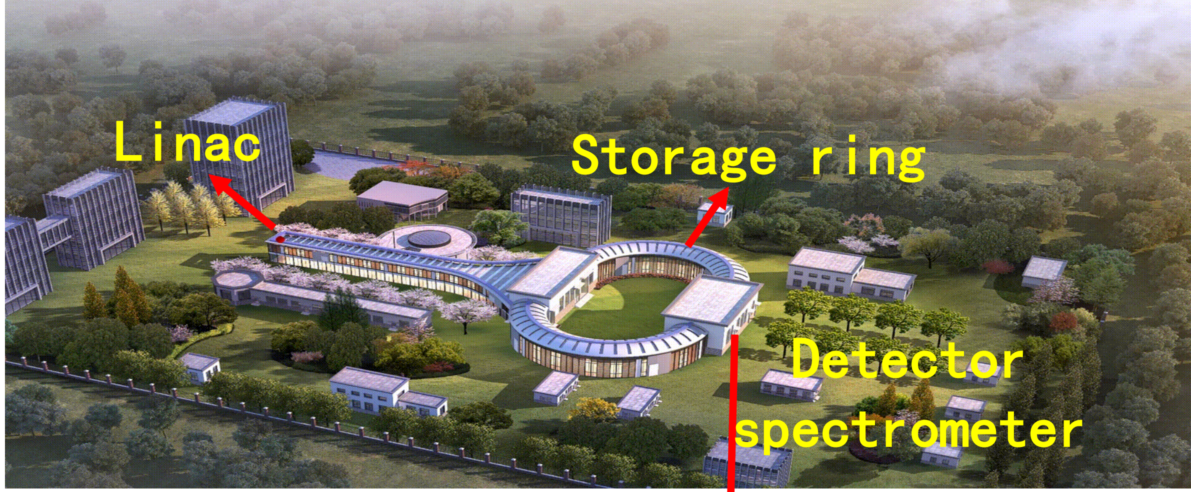
- Center-of-mass energy: $2-7\text{GeV}$
- Peak luminosity: $0.5\sim1\times10^{35}\text{cm}^{-2}\text{s}^{-1}$
- Circumference: ~600m
- Crossing angle: 2×30mrad

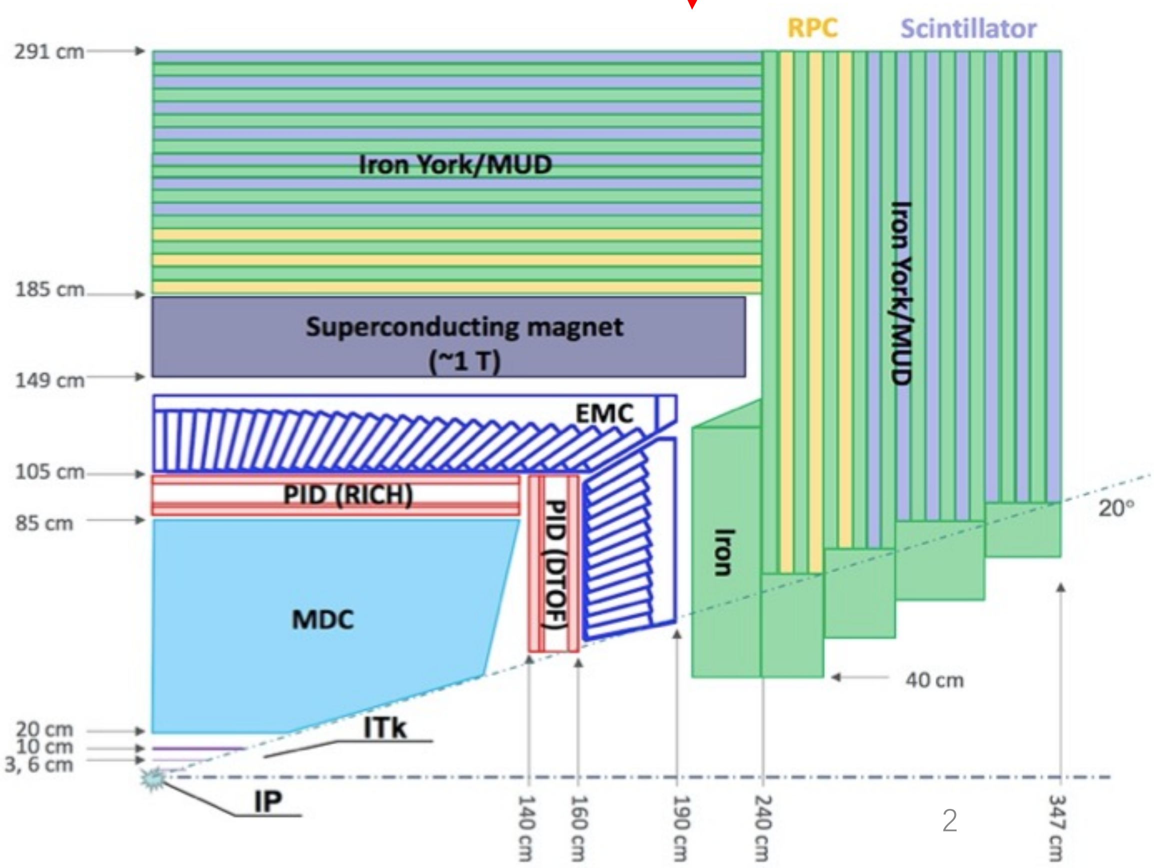
Physical targets of STCF:

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

For DTOF:

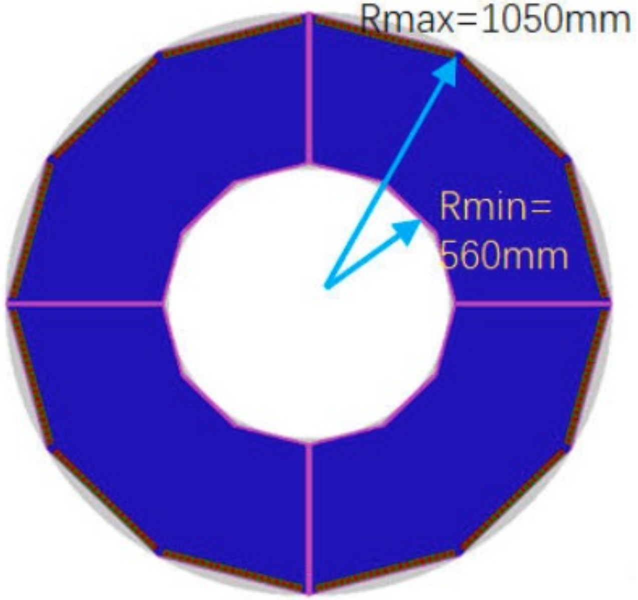
- $4\sigma\ \pi/K$ separation at $p = 2$ GeV/c
- Time resolution ~ 50 ps

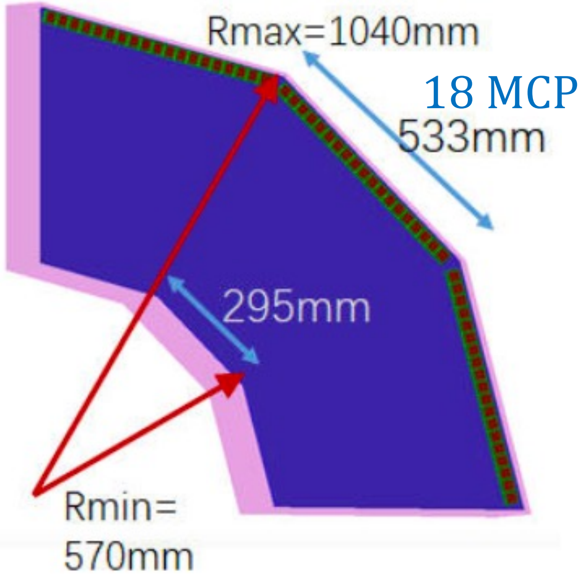




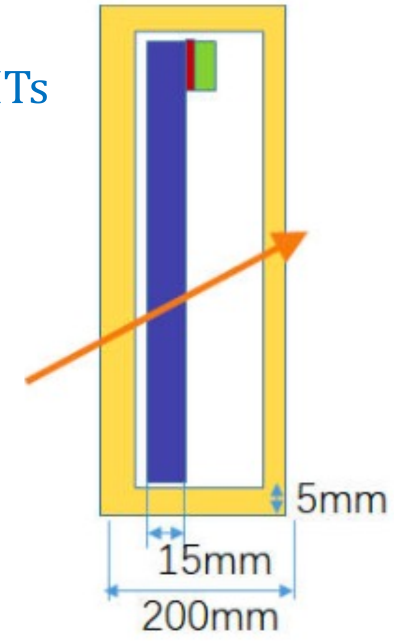
DTOF Geometry Configuration

- Two identical endcap discs at ~ ±1400 mm away from the collision point along the beam direction.
- Each disc is made up of 4 quadrantal sectors, with R_{min} = 560 mm , R_{max} = 1050 mm.
- Covering in polar angles of ~ 22° – 36°.



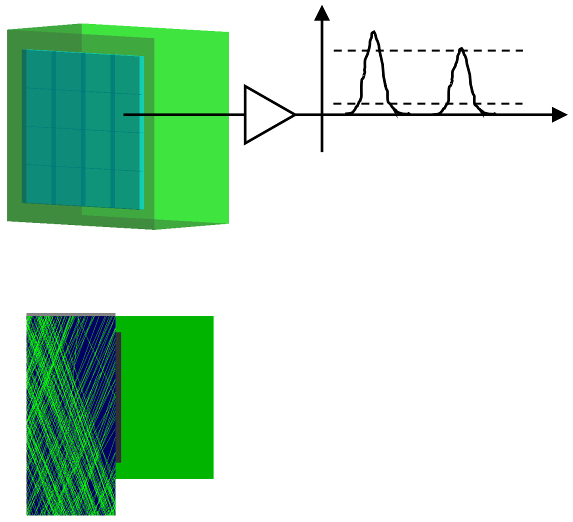


18 MCP – PMTs



4×4 anodes

5.5×5.5 mm^2



Single Timing uncertainty

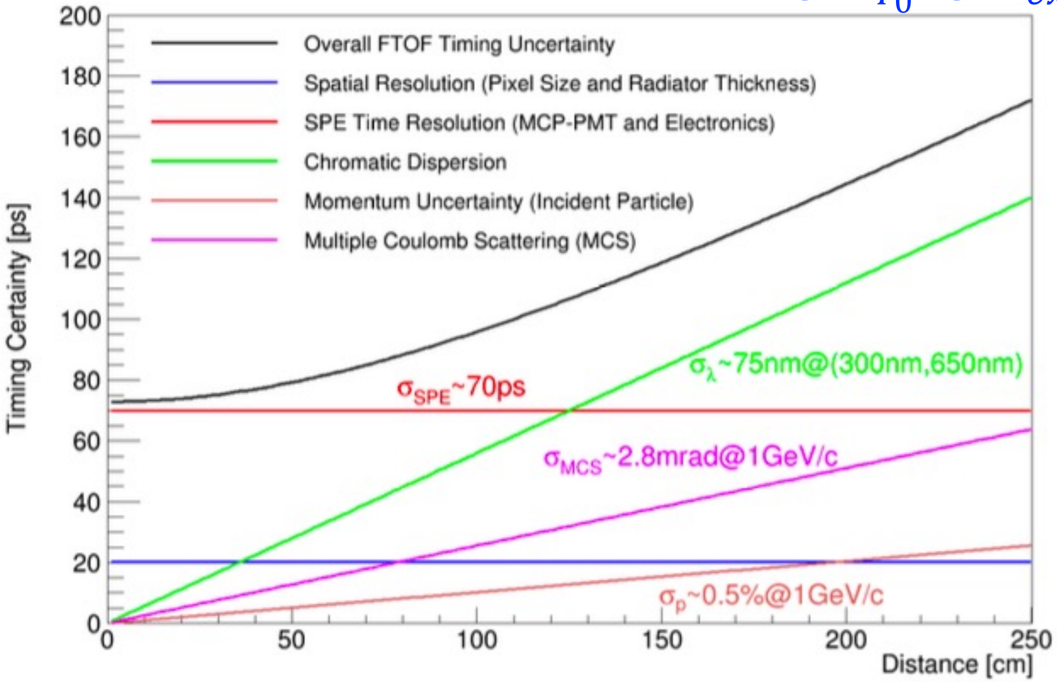
$$\sigma_t = \sigma_{T_0} \oplus \sigma_{t_{MCS}} \oplus \sigma_{TTS} \oplus \sigma_{t_\lambda} \oplus \sigma_{t_D} \oplus \sigma_{t_{ext(\vec{r},\vec{p})}}$$

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

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

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



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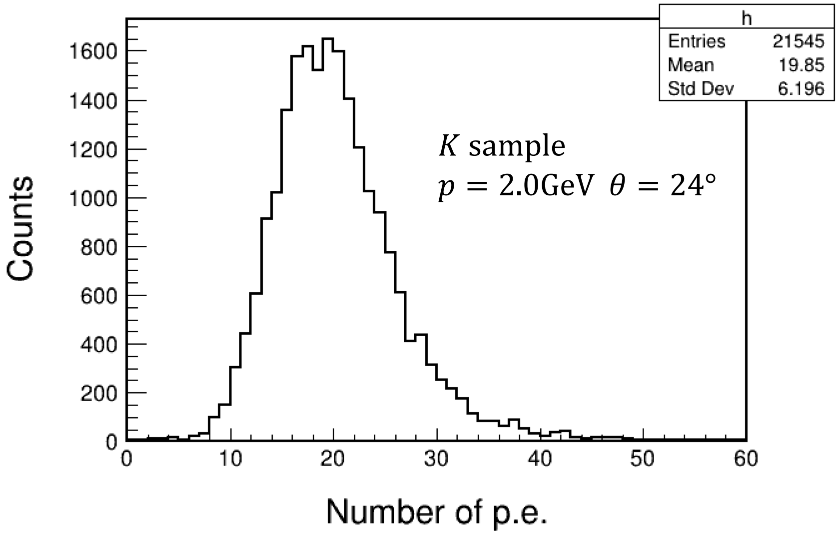
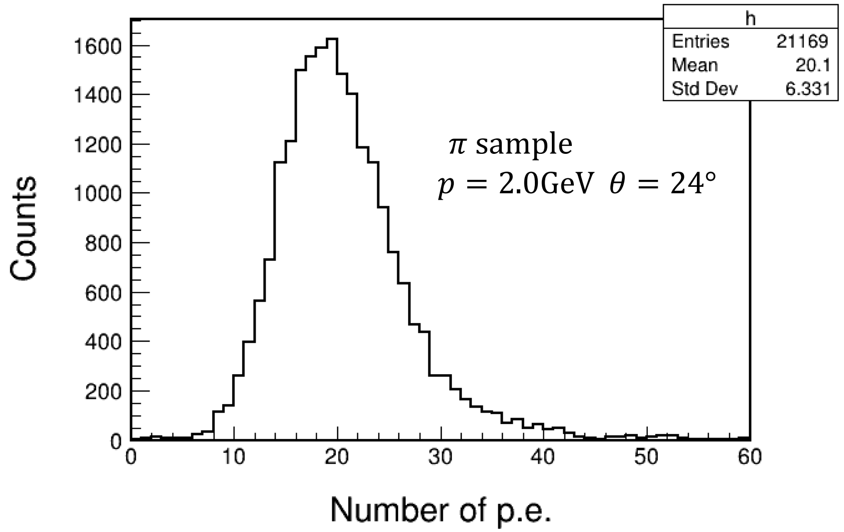
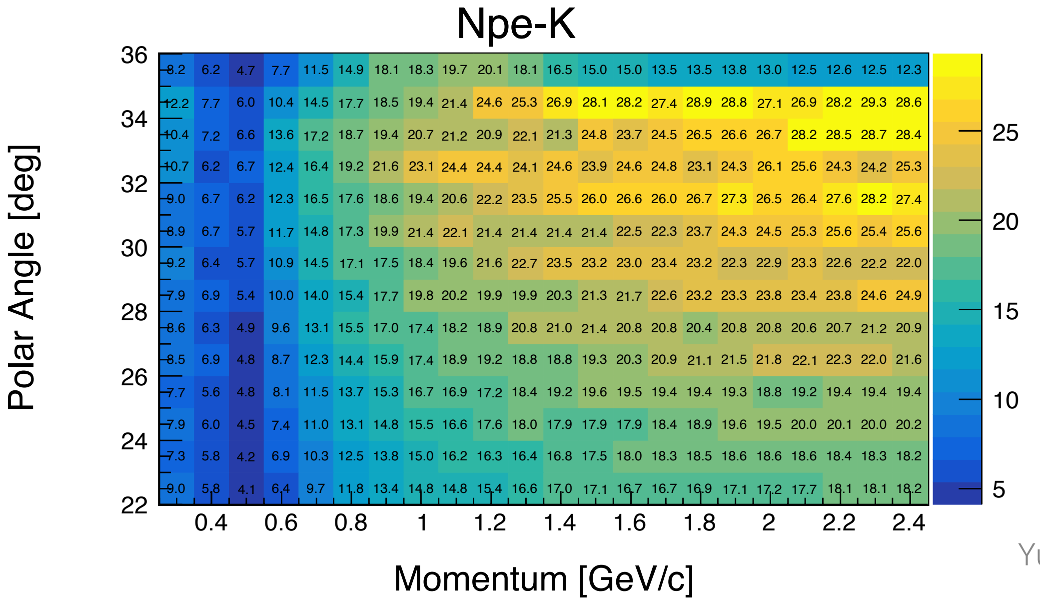
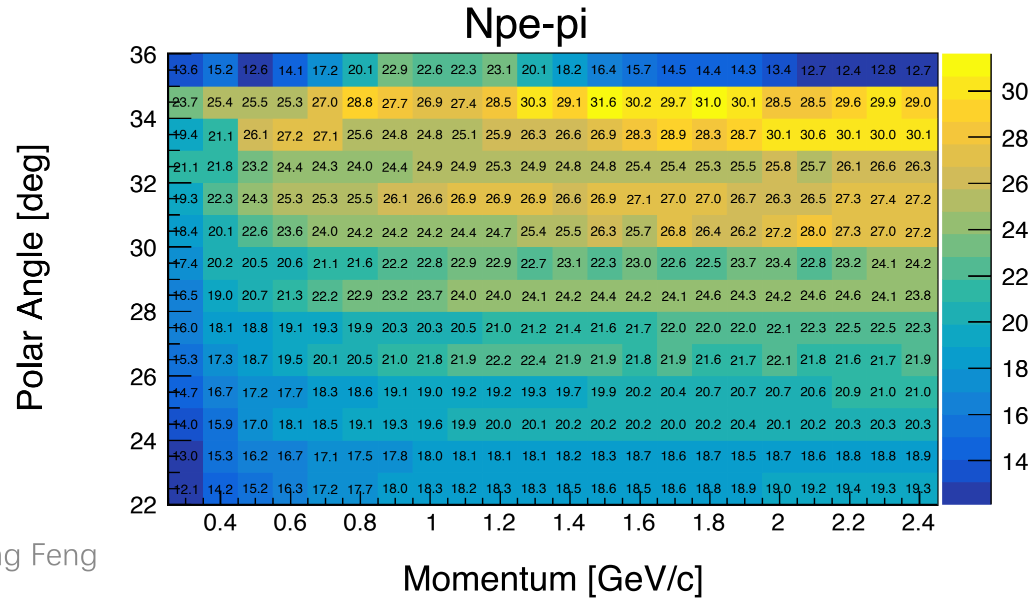
Photoelectron Yield

OSCAR









Likelihood Method for PID

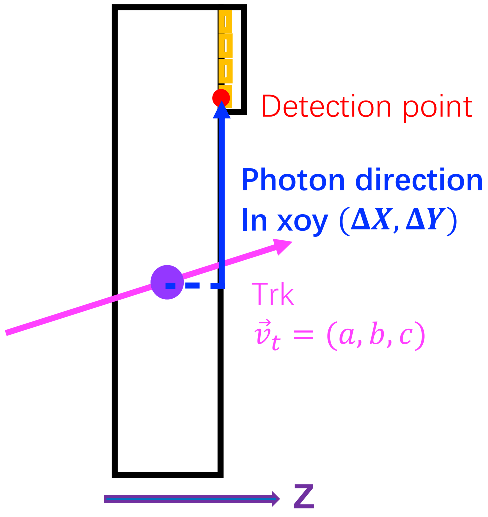
● Timing Method B. Qi *et al* 2021 *JINST* **16** P08021

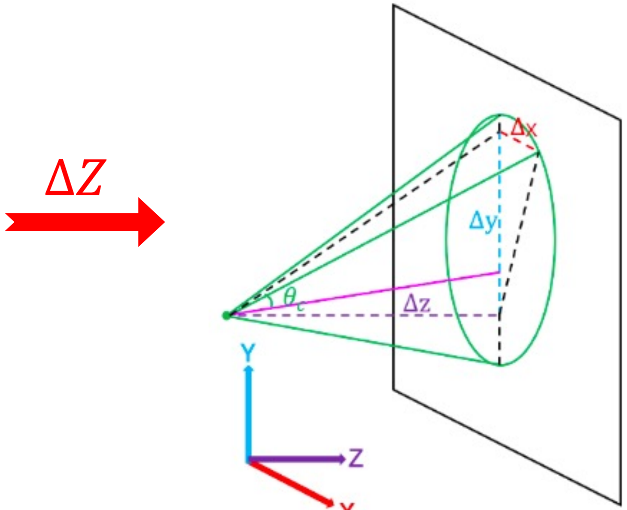
➢ TOF Reconstruction

$$cos\theta_c = \frac{1}{n\beta} = \frac{\vec{v}_t \cdot \vec{v}_p}{|\vec{v}_t| \cdot |\vec{v}_p|}$$

$$\begin{cases} \vec{v}_t = (a, b, c) \\ \vec{v}_p = (\Delta X, \Delta Y, \Delta Z) \end{cases}$$

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





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

Likelihood Method for PID

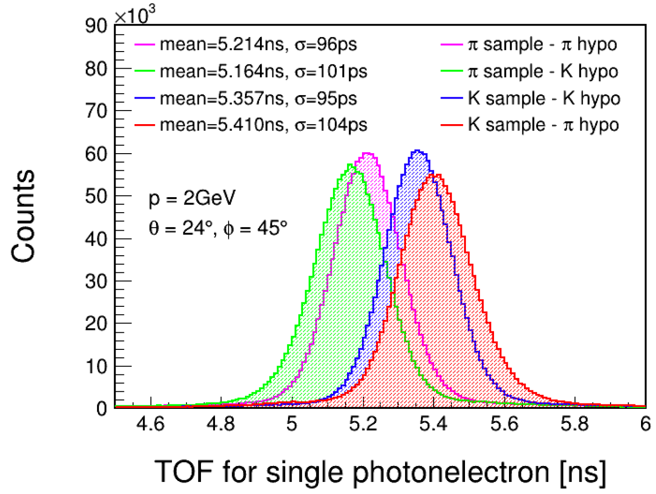
- **Timing Method**

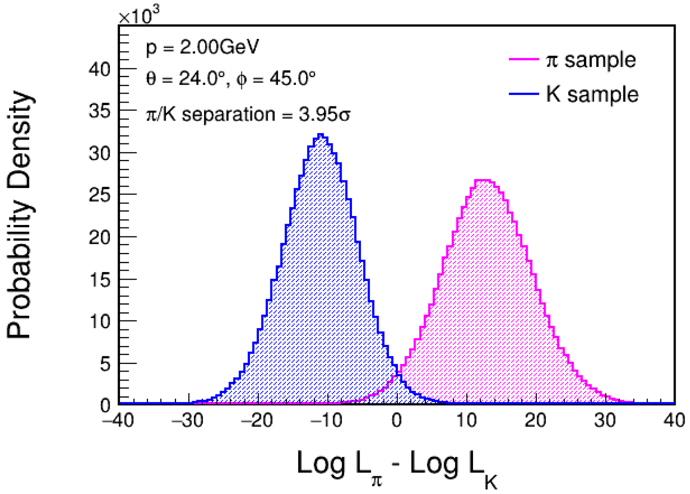
$$\mathcal{L}_h = \prod_{i=0}^{N_{p.e.}} f_h(TOF_i)$$

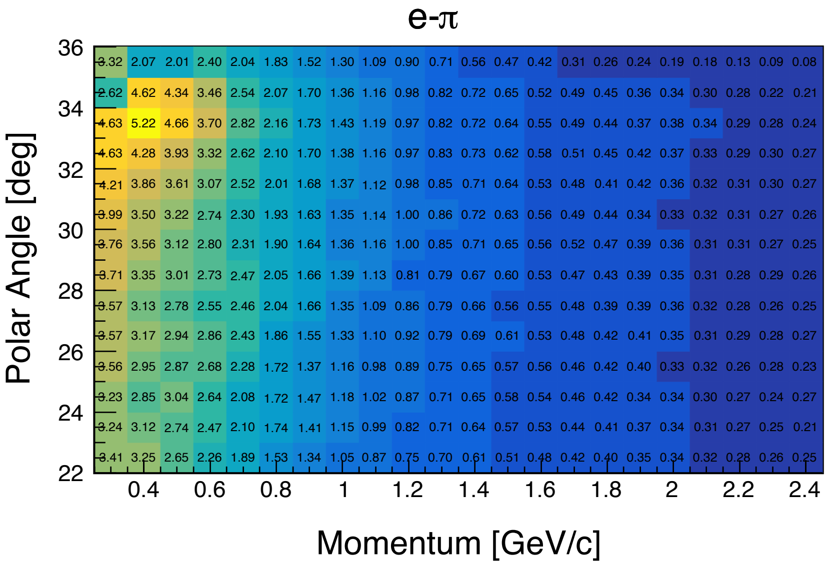
$$f_h(t) = Gaus(TOF_{rec} | TOF_{hypo}, \sigma) + 0.05_{bkg}$$

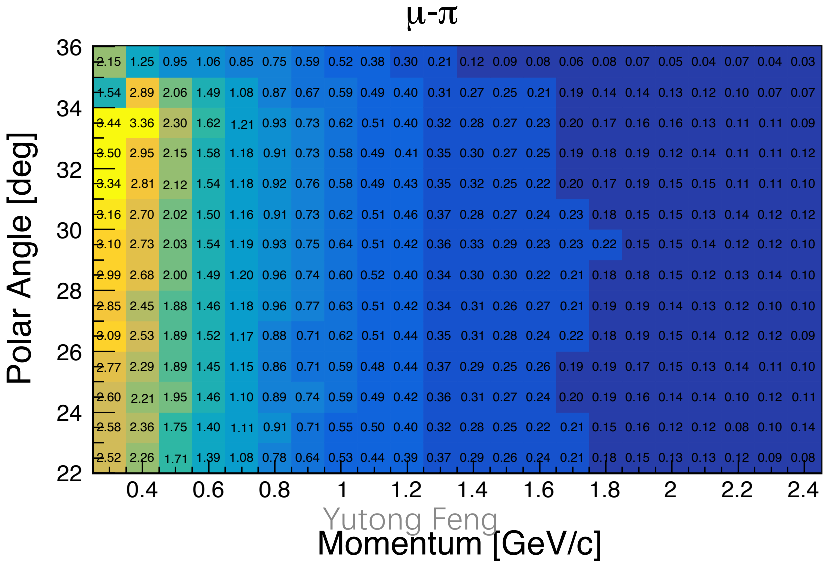
- $\sigma_t \sim 95\ ps$ by single photon-electron
- $\sigma_t \sim 50\ ps$ by multi-photon-electrons
- $3.95\sigma\ \pi/K$ separation at $p = 2.0$ GeV/c

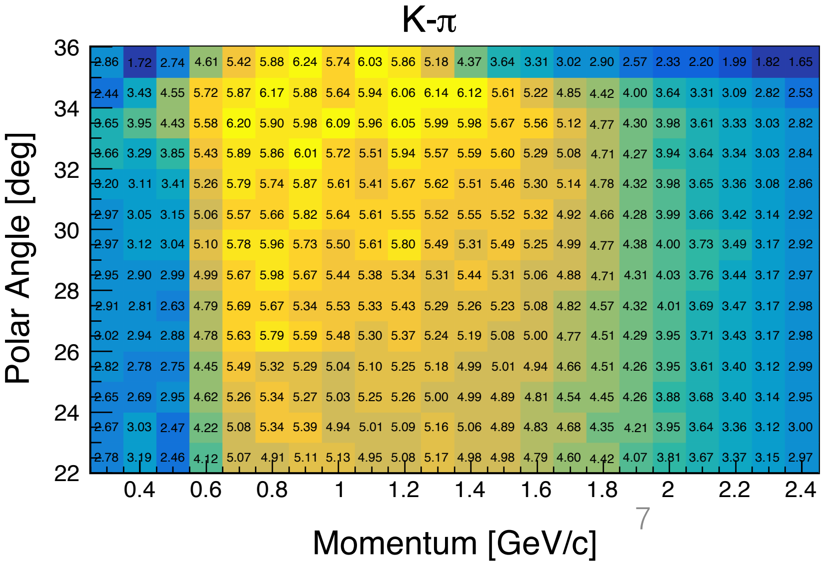
OSCAR











Likelihood Method for PID

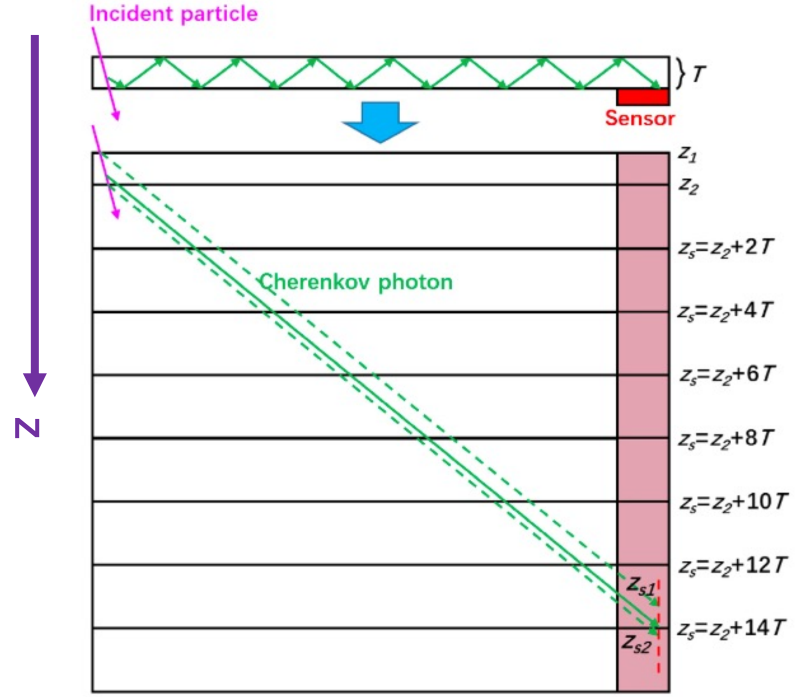
- **Imaging Method** Nucl.Instrum.Meth.A 1049 (2023)

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

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

$$z_s = z_2 + 2mT$$

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



➢ **Likelihood construction**

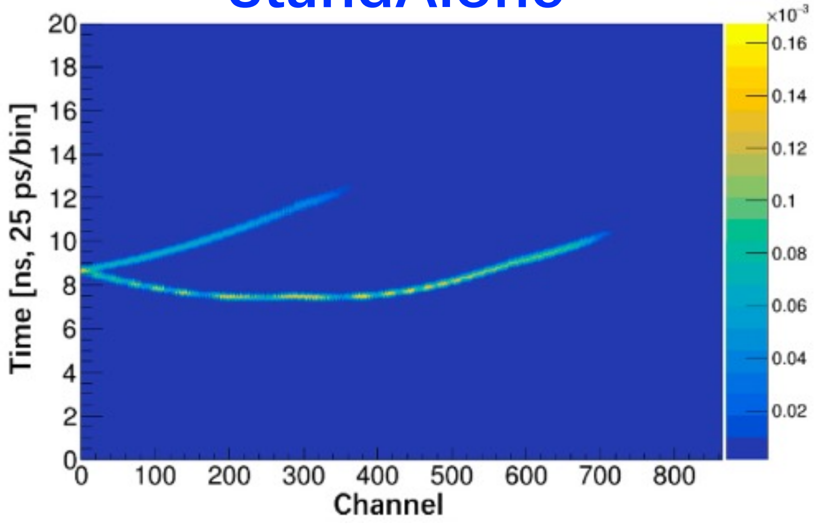
$$\mathcal{L}_h = p_h(N_{p.e.}) \prod_{i=0}^{N_{p.e.}} f_h(x_i, t_i)$$

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

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

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

StandAlone



Likelihood Method for PID

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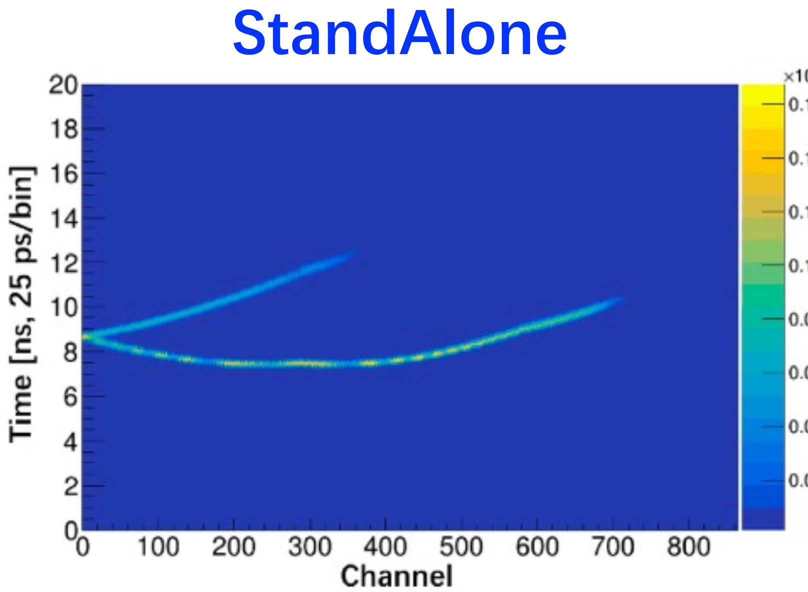
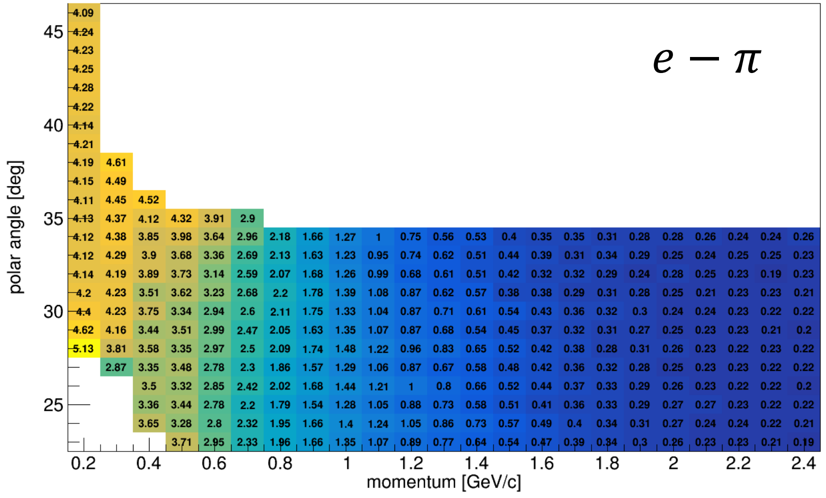
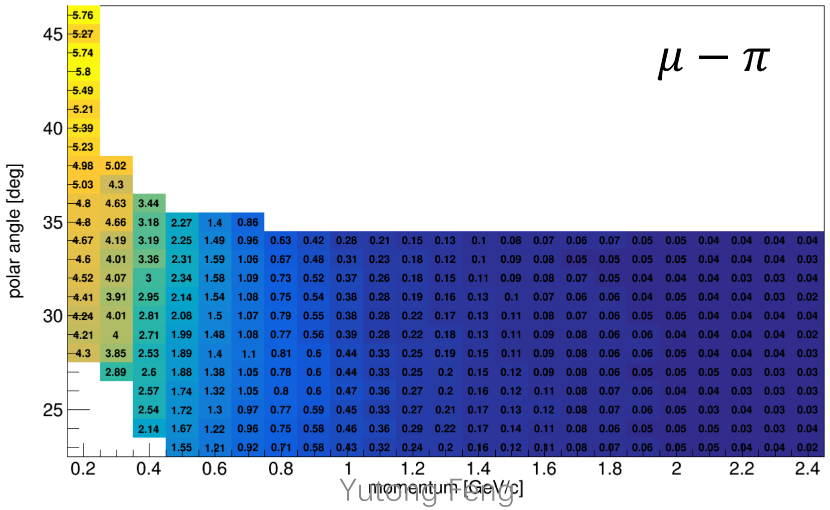
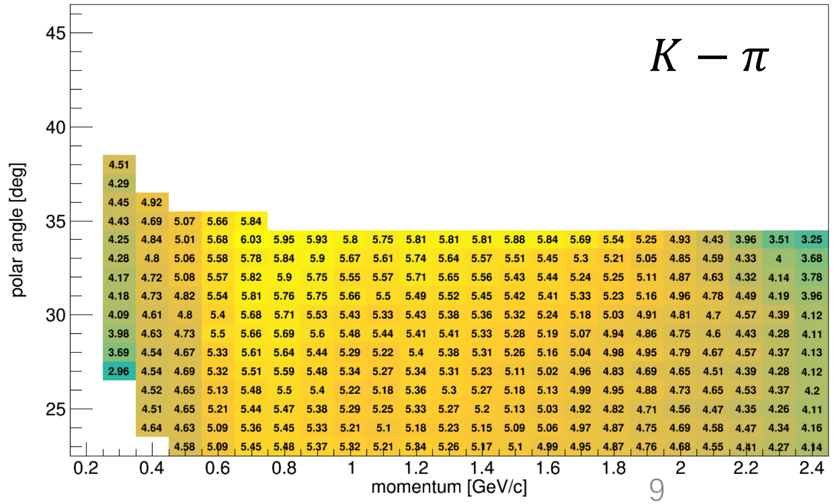
Improve π/K separation ~4.7σ, at p = 2.0 GeV/c









Summary

DTOF Software:

- **Timing method (OSCAR):**
  - π/K separation $\sim 4\sigma$, at $p = 2.0$ GeV/c
  - Overall reconstructed TOF time resolution ~50 ps
  - Improve the efficiency of Global PID. $\theta \in (22°, 36°)$, $p \in (0.2, 2.4)$ GeV/c
- **Imaging method (StandAlone):**
  - π/K separation $\sim 5\sigma$, at $p = 2.0$ GeV/c

Thank you !