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BESIII

STCF BTOF Simulation, Digitilization and Reconstruction

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OutLine

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- Digitilization
- Reconstruction
- Optimization
- Summary

Introduction

STCF Introduction

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STCF Future Performance :

- Center of Mass Energy : $2\sim7 GeV$
- Peak Luminosity : $0.5\sim1 \times 10^{35} cm^{-2} s^{-1}$
- Cross Angle : $2 \times 30 mrad$

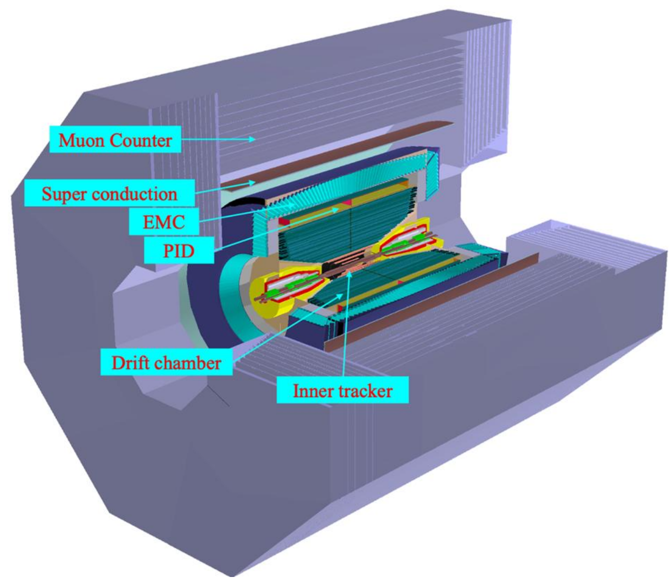
MUD
- μ/π suppression power >30 at $p < 2$ GeV/c

EMC
- Energy range: 25 MeV - 3.5 GeV
- $\sigma_E/E \sim 2.5\%$ at $E = 1$ GeV
- $\sigma_{pos} \sim 5$ mm, $\sigma_T \sim 300$ ps at $E = 1$ GeV

PID
- π/K (and K/p) efficiency >97% with mis-ID <2% up to 2 GeV/c

MDC
- $\sigma_{pos} = 130$ μm
- dE/dx ~ 6%, $\sigma_p/p = 0.5\%$ at 1 GeV/c
- Efficiency > 99% at $p_T > 0.3$ GeV/c and >90% at $p_T = 0.1$ GeV/c

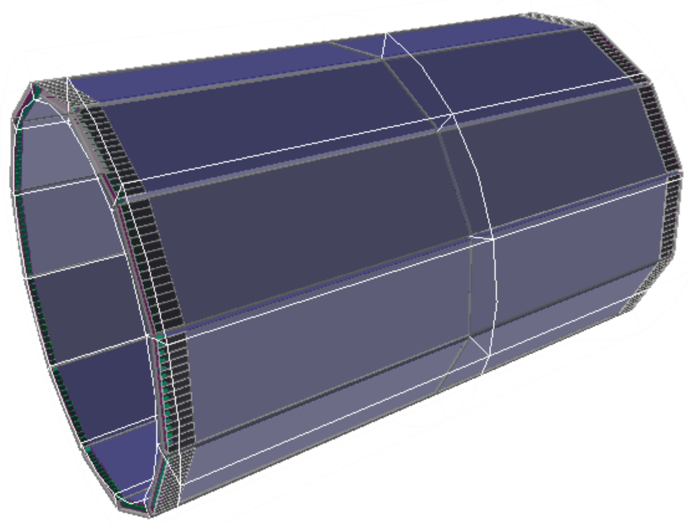
ITK
- ~0.25% X_0/layer
- $\sigma_{pos} = 100$ μm for single hit

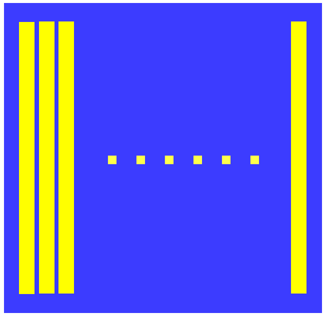


Simulation

BTOF Geometry

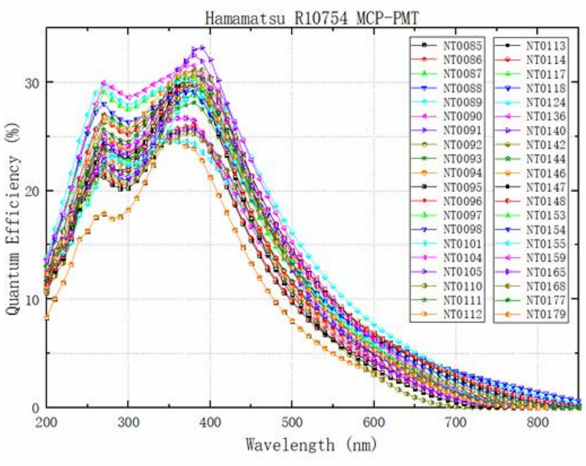
- 12 sectors, each corresponds with 30° azimuthal angle and has two silicon quartzs ($1350mm * 450mm * 20mm$), covered by a shield.
- Absorb coating on inner side and 15 MCP-PMTs (1×16 pixels) on outer side of quartz.
- Each PMT is connected with a front PCB and a FEE above

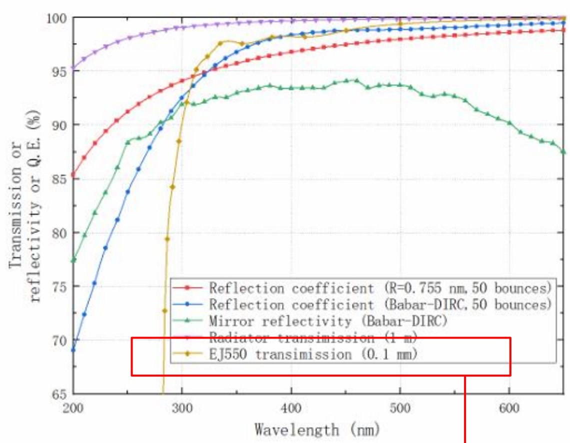


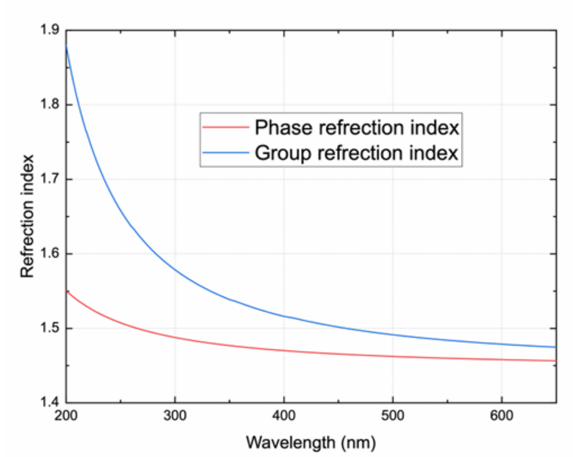


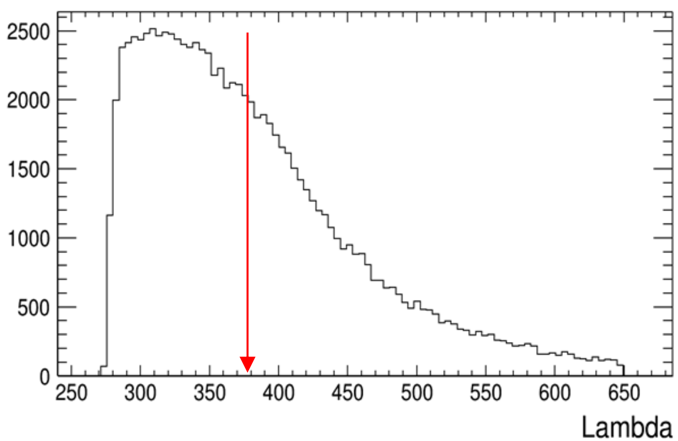
1×16 pixels

Simulation Parameter









- The cutting point of grease transmission (The yellow one) has been changed to about 375nm to reduce the dispersion and improve the time resolution.

Digitization

BTOF Digitilization

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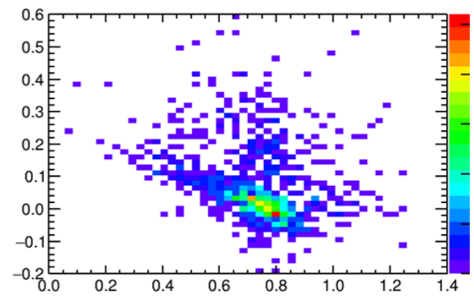
Digitilization processes:

- Simulate the performance of photon electron in MCP-PMT.
- Add Time-Amplitude Wandering Effect, T_0 uncertainty and dead time (5ns).
- Output channelID, TOA, TOT as input of reconstruction algorithm.

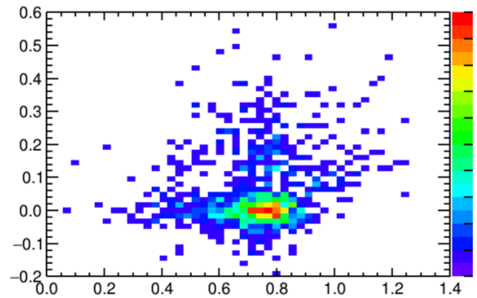
Digitilization parameters:

- TOT = TOTDis->GetRandom() (3 Gauss)
- TTS = TTSDis->GetRandom() (2 Gauss)
- TOTtru = TOT + Gaus(0, 10ps)
- TOTMEAN = 780ps   TOT_CALIPAR = 0.35
- TOA = time + TTS + (TOTtru - TOTMEAN)

  * TOTCALIPAR



TOA : TOT

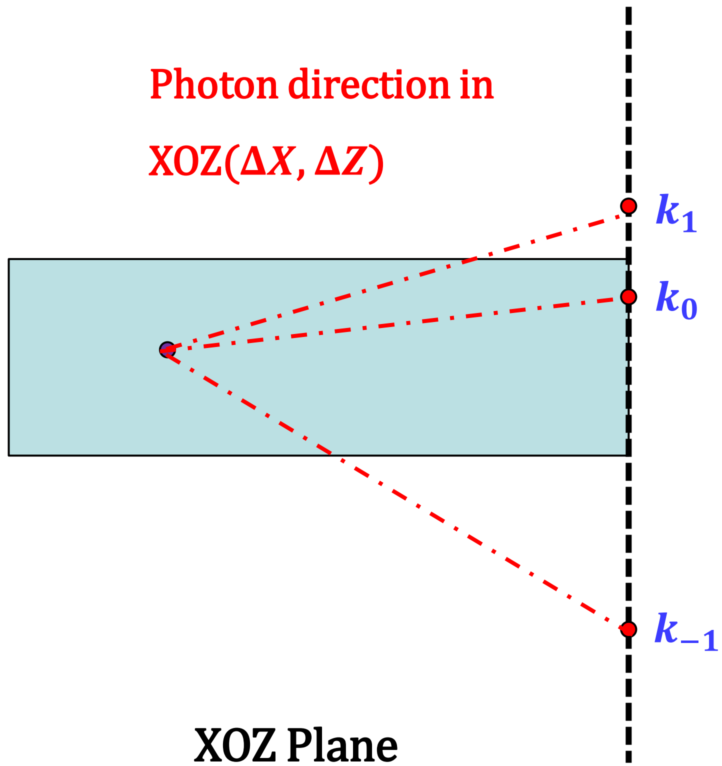


TOA : TOT

(after correction)

Reconstruction

Timing Method



Reconstruction Principle

- $\overrightarrow{v_t} = (t_x, t_y, t_z)$ $\overrightarrow{v_p} = (\Delta X, \Delta Y, \Delta Z)$
- $cos\theta_C = \frac{1}{n\beta} = \frac{\overrightarrow{v_t}\cdot\overrightarrow{v_p}}{|\overrightarrow{v_t}|\cdot|\overrightarrow{v_p}|}$
- $\Delta Z = Z_{hit} - Z_{ini}$
- $\Delta X = X_{hit}(k) - X_{ini}$
- For each k, we calculate ΔY and $LOP = \sqrt{\Delta_X^2 + \Delta_Y^2 + \Delta_Z^2}$
- The photon path with minimum $|TOF_{rec} - TOF_{hypo}|$ is selected
- $t_x\Delta X + t_y\Delta Y + t_z\Delta Z > 0$ (θ_C not $\pi - \theta_C$)

  $(\Delta X^2 + \Delta Z^2)/(\Delta X^2 + \Delta Y^2 + \Delta Z^2) \geq 1/n_p^2$ (TIR1)

  $(\Delta Y^2 + \Delta Z^2)/(\Delta X^2 + \Delta Y^2 + \Delta Z^2) \geq 1/n_p^2$ (TIR2)

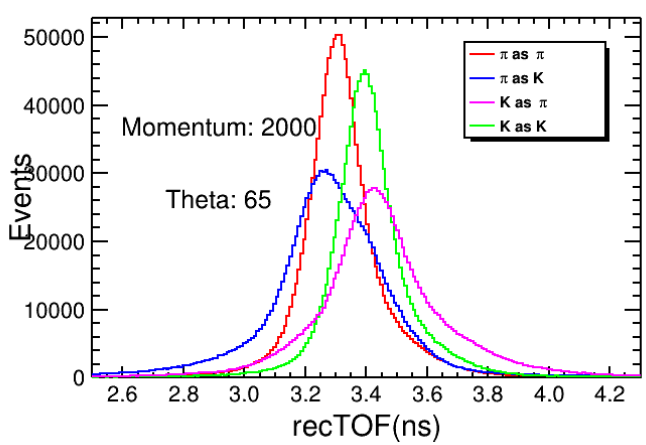
Timing Method

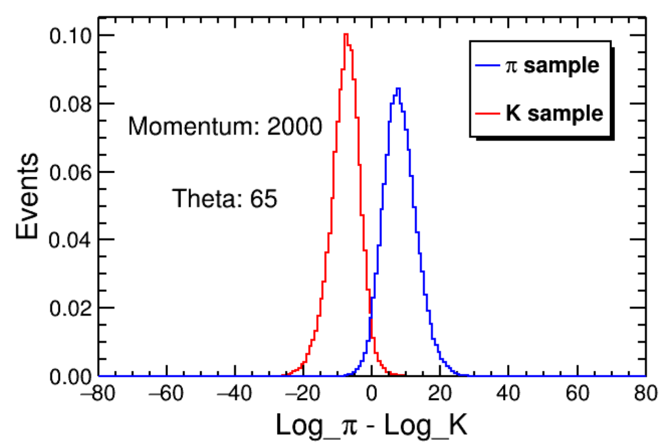
- ΔrecTOF ($TOF_{rec} - TOF_{hypo}$) distribution can be described with 3 Gauss model :

$$\Delta \mathrm{recTOF} = \mathrm{ratio1} * \mathrm{Gaus1}(0, \mathrm{resTOF}) + \frac{\mathrm{ratio1}}{2} * \mathrm{Gaus2}(0.135, \mathrm{sigma1}) + (1 - 1.5 * \mathrm{ratio1}) * \mathrm{Gaus3}(0.05, \mathrm{sigma2})$$

- Gaus1 is the main peak, Gaus2 represents the effect caused by TTS, Gaus3 represents the impact caused by multi-scattering.

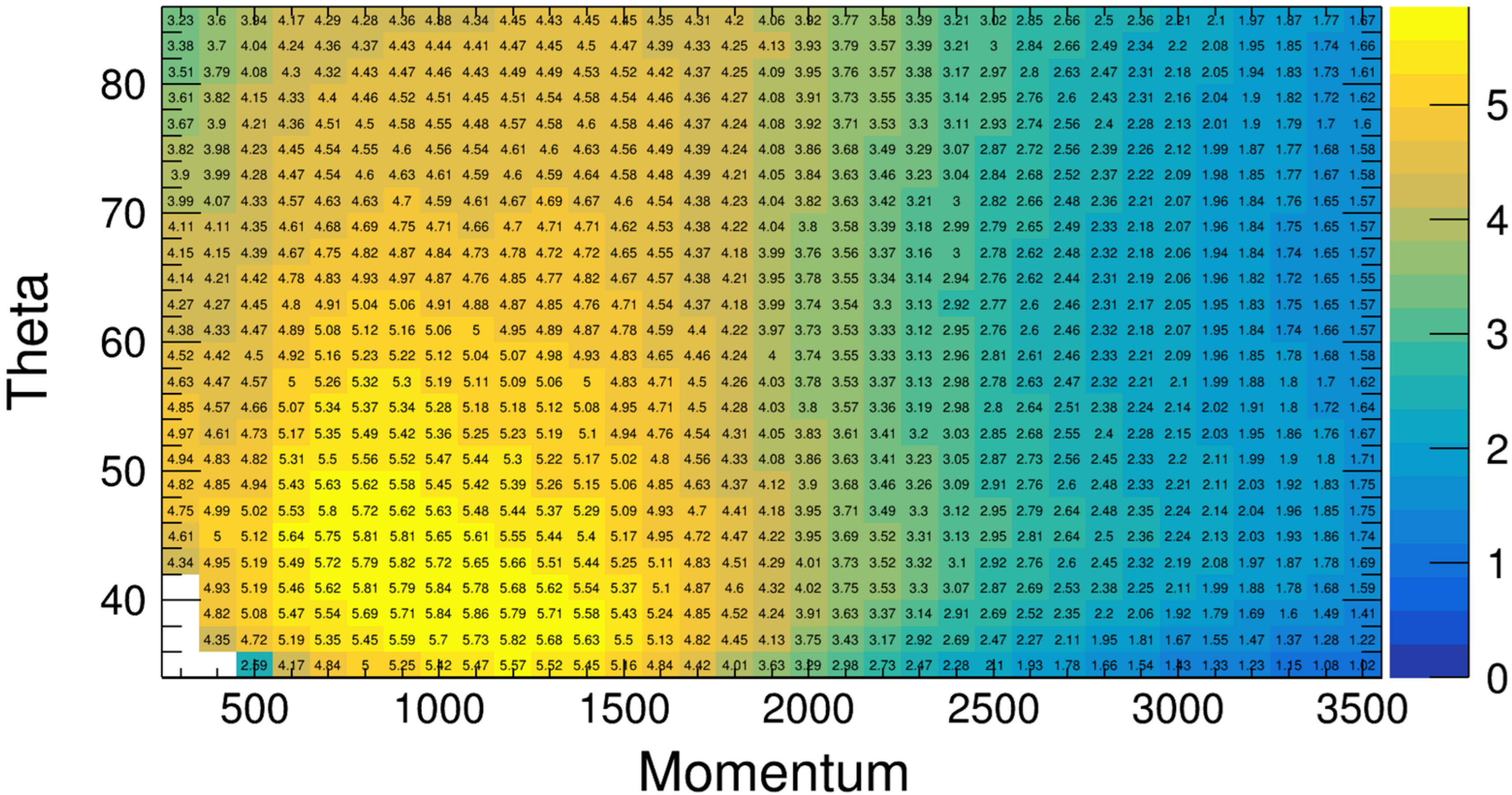
- $\mathcal{L}_h = e^{-\bar{N}_h} \prod_{i=1}^{N_{pe}} \bar{N}_h S_h \left(TOF_{rec} \middle| TOF_{hypo}\right) + B$





Timing Method

Separation between π/K (missid = 2%)



Timing Method

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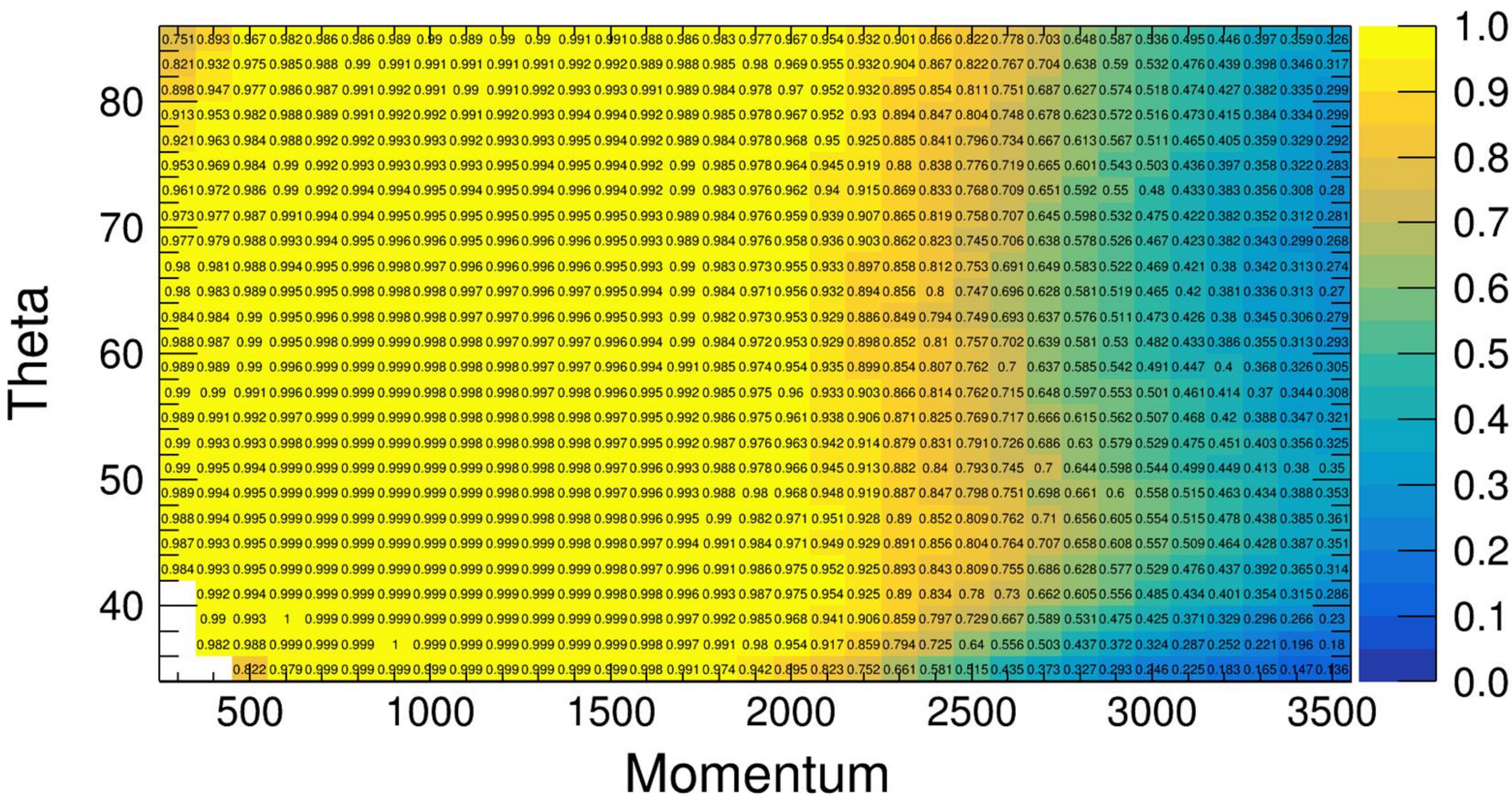
Efficiency of π (missid = 2%)



Timing Method

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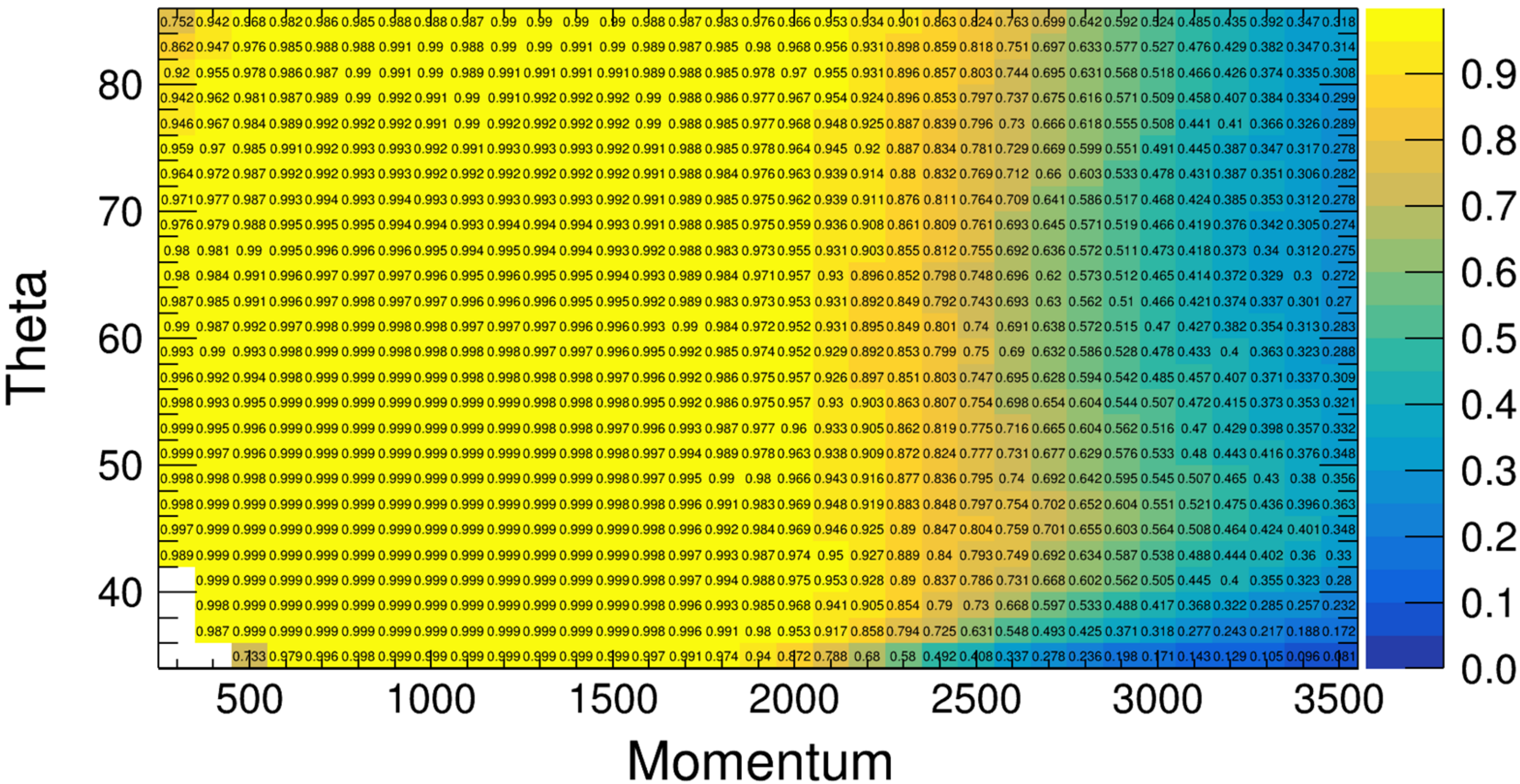
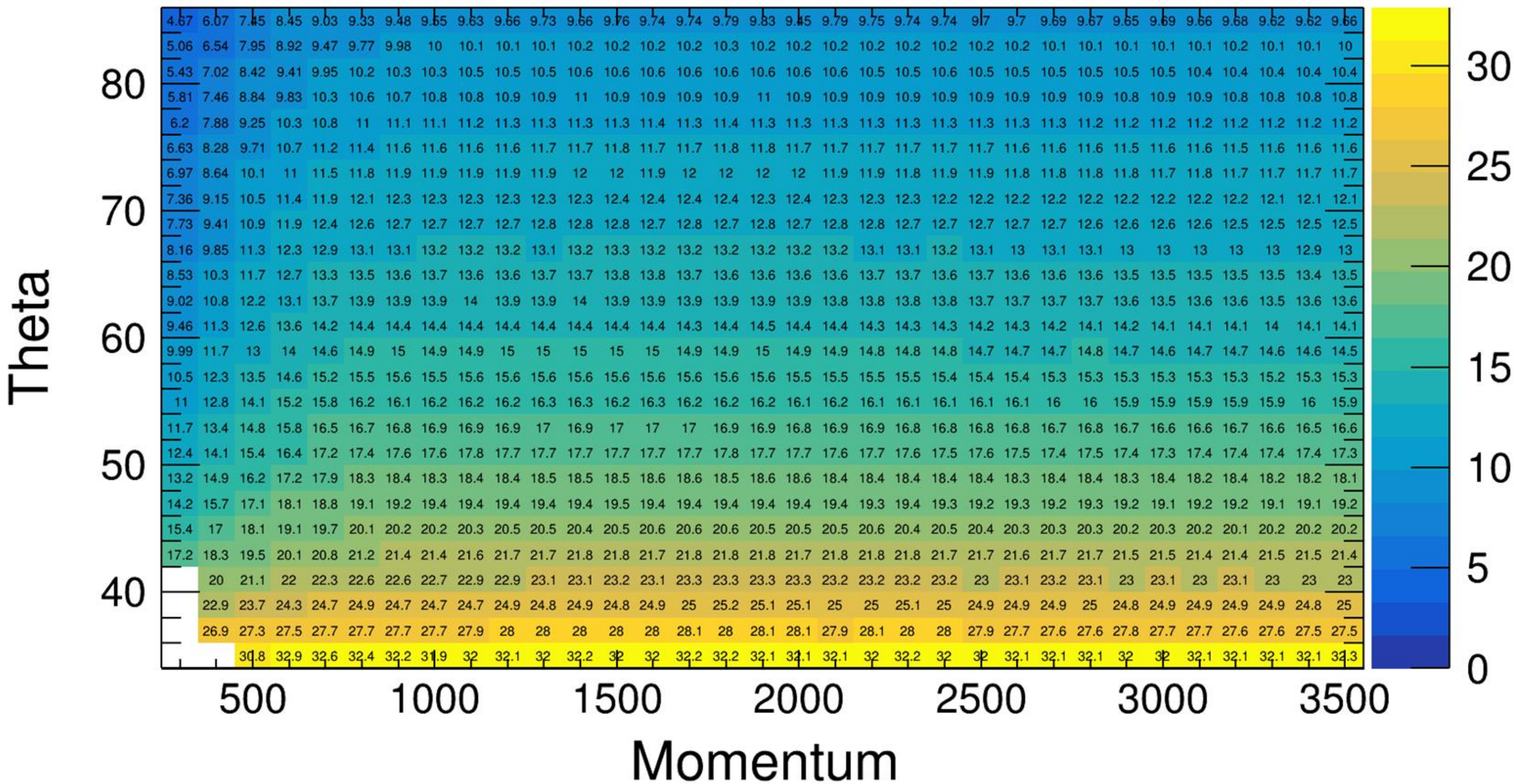
Efficiency of K (missid = 2%)



Timing Method

N_{pe} of π (missid = 2%)



Timing Method

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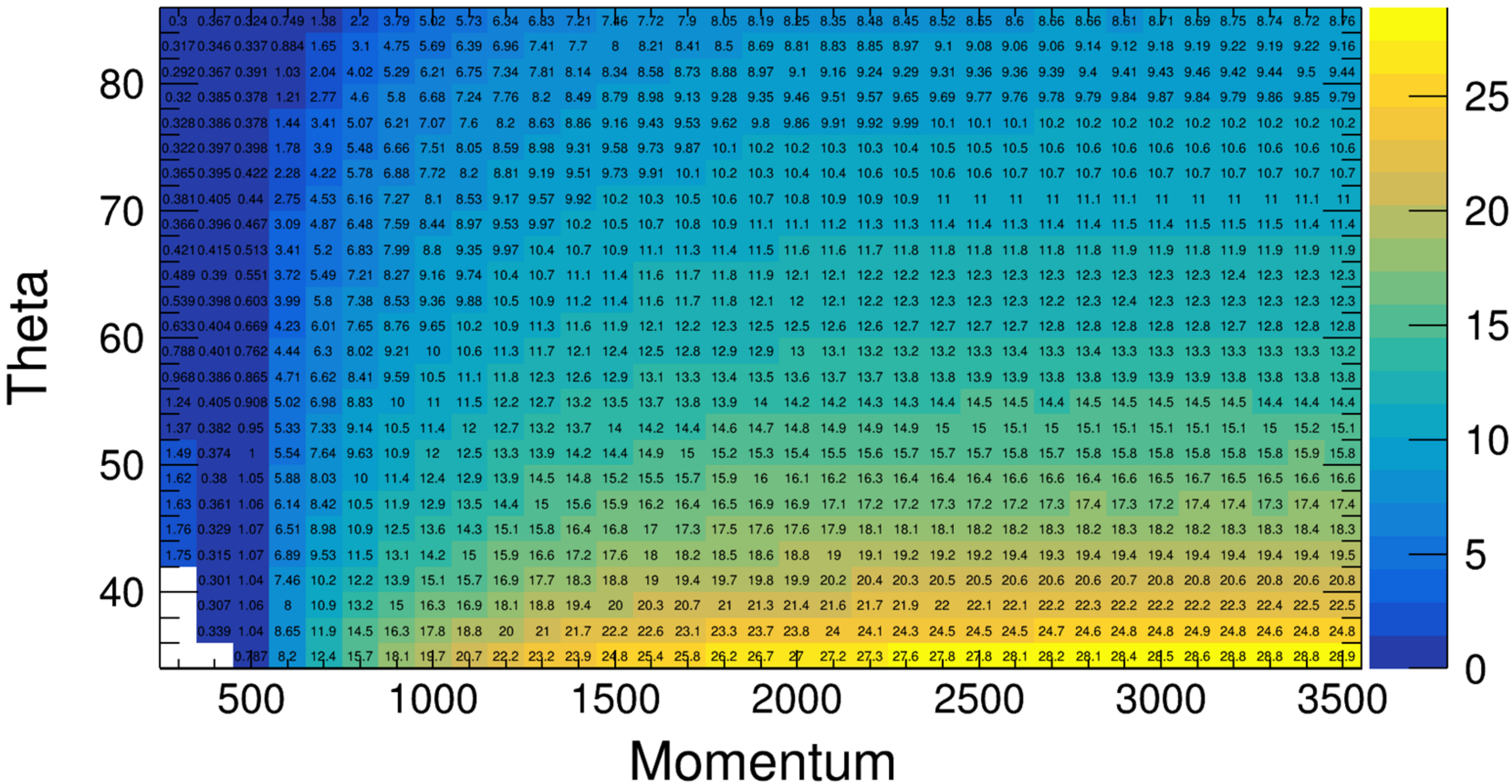
N_{pe} of K (missid = 2%)



2D rec Method

- $\overrightarrow{v_t} = (t_x, t_y, t_z)$ $\quad\quad$ $\overrightarrow{v_p} = (k_x, k_y, k_z)$
- θ and ϕ are polar and azimuthal angles of particle track
- θ_c and ϕ_c are polar and azimuthal angles of photon track relative to particle direction
- Then we have :

$$\begin{cases} k_x = \cos\phi\left(\cos\theta\sin\theta_c\cos\phi_c + \sin\theta\cos\theta_c\right) - \sin\phi\sin\theta_c\sin\phi_c, \\ k_y = \sin\phi\left(\cos\theta\sin\theta_c\cos\phi_c + \sin\theta\cos\theta_c\right) + \cos\phi\sin\theta_c\sin\phi_c, \\ k_z = \cos\theta\cos\theta_c - \sin\theta\sin\theta_c\cos\phi_c. \end{cases}$$

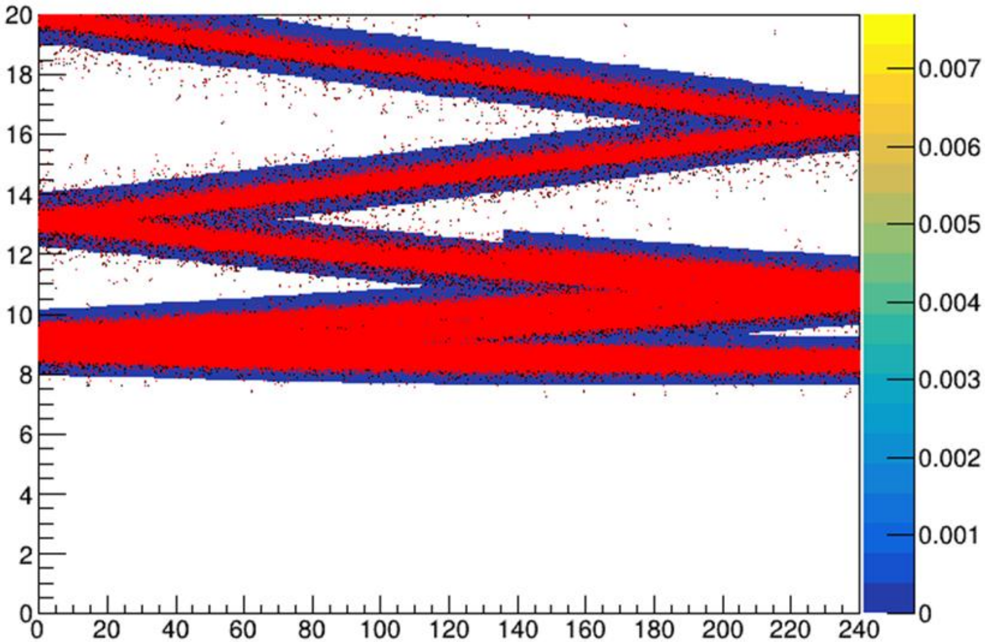
- $LOP = \sqrt{\Delta_X^2 + \Delta_Y^2 + \Delta_Z^2}$, Δ_z we already know, then by (k_x, k_y, k_z) we can also determine Δ_X and Δ_Y, Then we can get time information by $t = TOF + TOP$
- By folding the photon path, we can finally get the reaching channel of the photon.

2DPDF Calculation

- To get 2D time-channel PDF to calculate likelihood conveniently, we divide wavelength(λ), particle track in the radiator and ϕ_c into many pieces
- In each λ interval, we have certain N_p, N_g and θ_c
- Then we divide particle track, in each interval we have the emission position and track momentum.
- After the binning above, we divide ϕ_c, then we can reconstruct the photon path and get time and channel information.
- Photon transmission efficiency $\epsilon = R_{lateral}^{Nx} * R_{bottom}^{Ny} * e^{-\frac{LOP}{\Lambda}} * \epsilon_{QE} * \epsilon_{Tgrease}$
- Total reflection should also be satisfied. ($\sin\theta_p \geq 1/N_p^{max}$)
- Then we can calculate $N_h = \sum_{i=0}^{Bin\lambda} \sum_{j=0}^{Bint} \sum_{k=0}^{Bin\lambda} \frac{2\pi z^2}{137} sin^2\theta_c(\frac{1}{\lambda_{min}} - \frac{1}{\lambda_{max}})\ dL * \epsilon$
- $\mathcal{L}_h = e^{-\bar{N}_h} \prod_{i=1}^{N_{pe}} \bar{N}_h S_h\,(ch_i, t_i) + B$

Comparision

BTOF PDF Npe=17.65



Comparison of calculated PDF and simulation

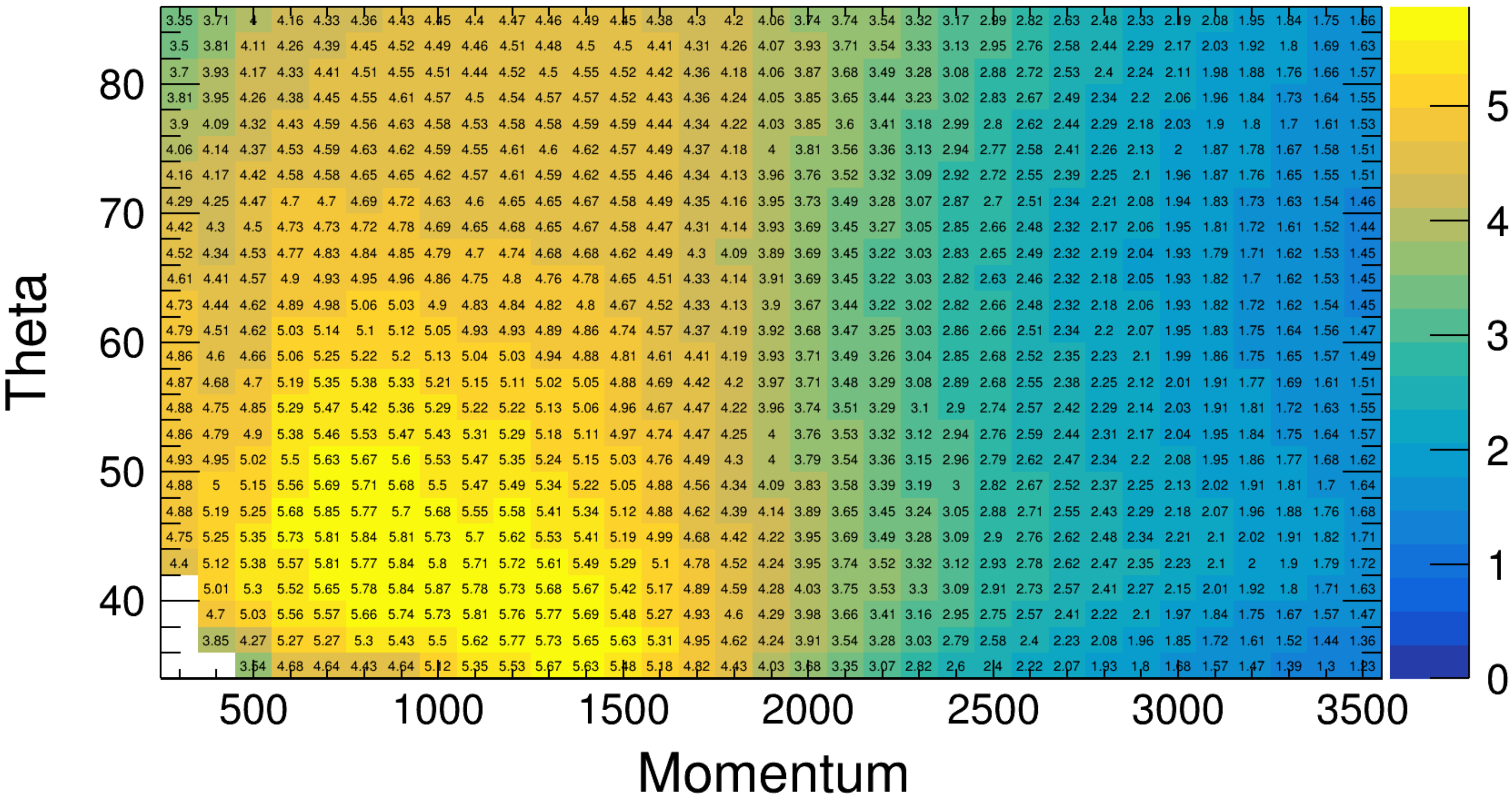
Npe (t < 20)	16.36
NPDHit(t < 20)	2314375
NPDHit(t > 20)	151836
Npe	17.43

Simulation $N_{pe} = N_{pe}(t < 20) \times (1 + \frac{NPDHit(t>20)}{NPDHit(t<20)})$

Both appearance and N_{pe} between PDF and simulation are in good agreement !

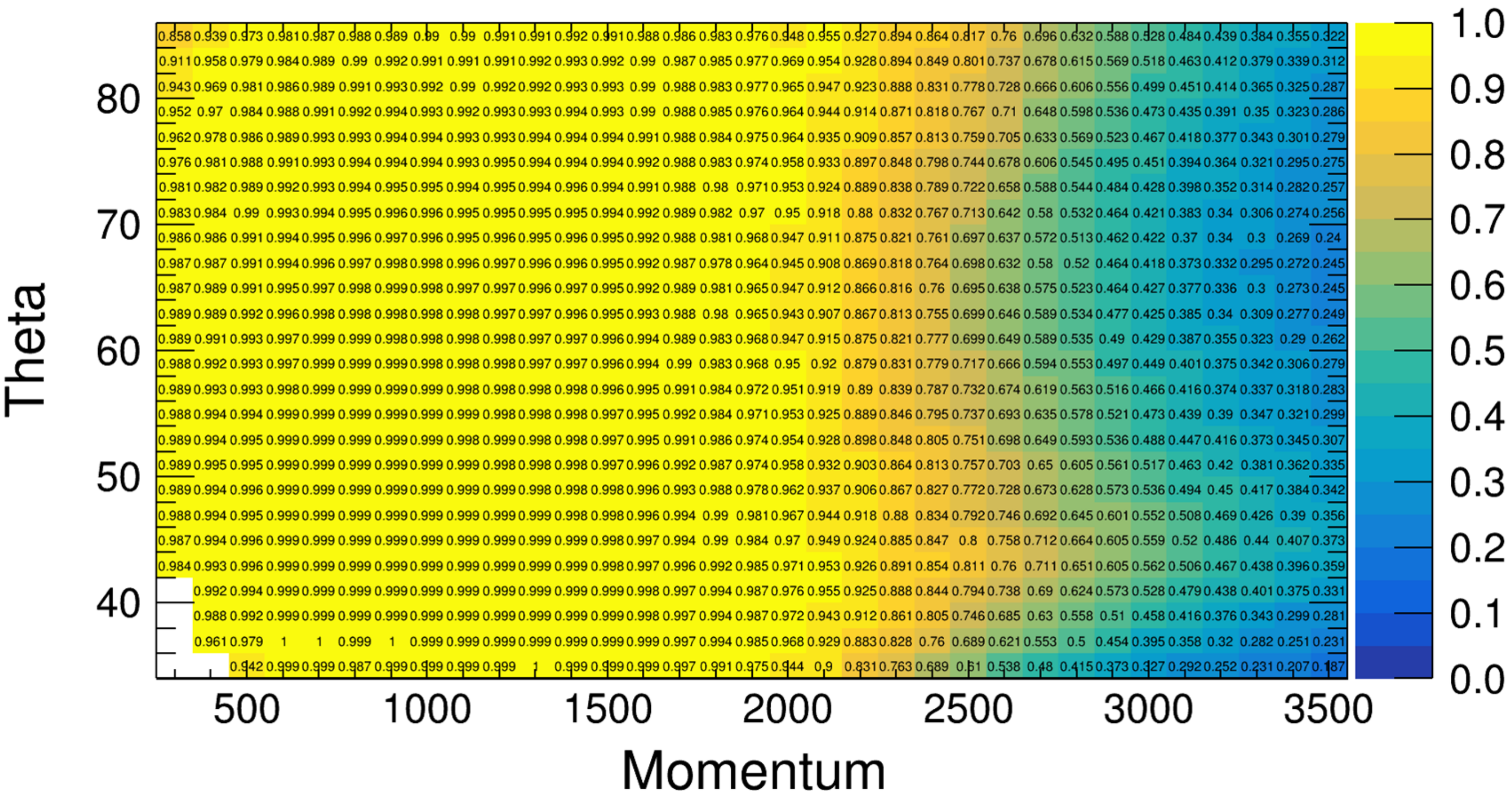
Imaging Method

Separation between π/K (missid = 2%)



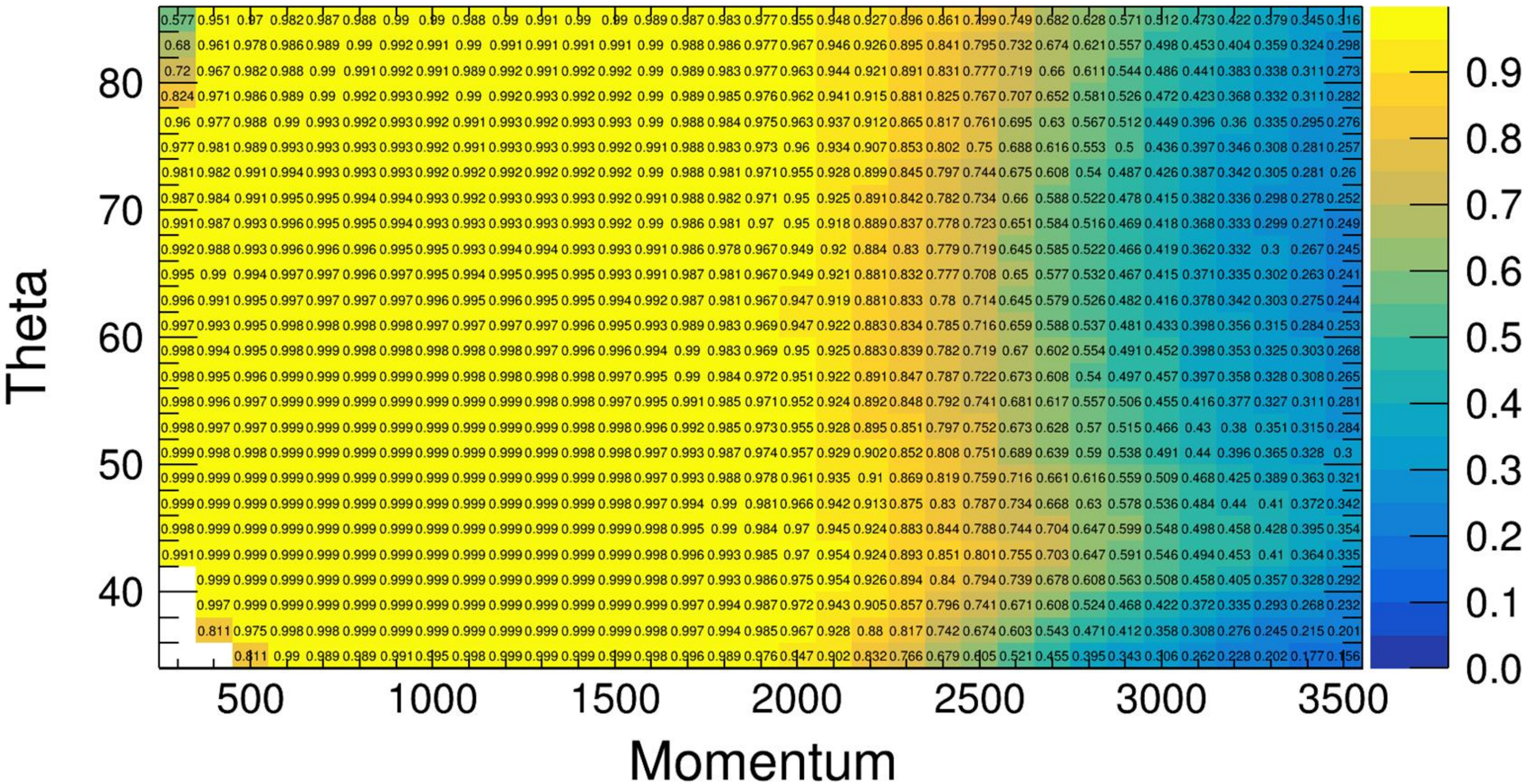
Imaging Method

Efficiency of π (missid = 2%)



Imaging Method

Efficiency of K (missid = 2%)



Optimization

Pixels change

1*16 Pixels

```
Momentum: 2000
Theta:    85
π/ K separation = 4.15σ
πPID Efficiency = 0.981
K PID Efficiency = 0.981
```

```
Momentum: 2000
Theta:    65
π/ K separation = 3.78σ
πPID Efficiency = 0.956
K PID Efficiency = 0.956
```

```
Momentum: 2000
Theta:    55
π/ K separation = 3.7σ
πPID Efficiency = 0.949
K PID Efficiency = 0.948
```

```
Momentum: 2000
Theta:    37
π/ K separation = 3.89σ
πPID Efficiency = 0.967
K PID Efficiency = 0.967
```

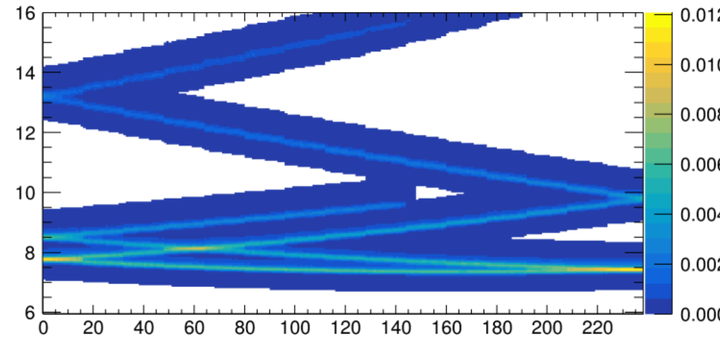
4*4 Pixels

```
Momentum: 2000
Theta:    85
π/ K separation = 4.3σ
πPID Efficiency = 0.987
K PID Efficiency = 0.987
```

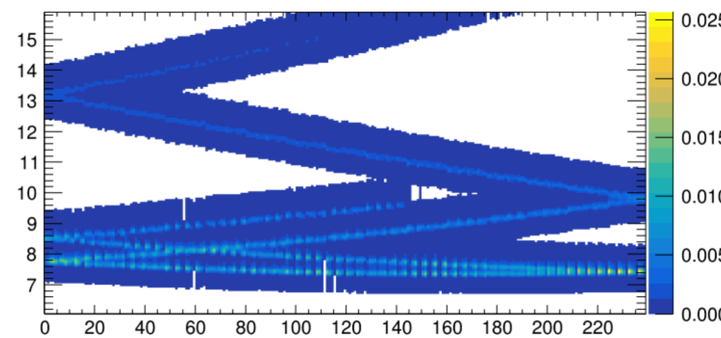
```
Momentum: 2000
Theta:    65
π/ K separation = 3.97σ
πPID Efficiency = 0.971
K PID Efficiency = 0.972
```

```
Momentum: 2000
Theta:    55
π/ K separation = 4.04σ
πPID Efficiency = 0.976
K PID Efficiency = 0.976
```

```
Momentum: 2000
Theta:    37
π/ K separation = 3.96σ
πPID Efficiency = 0.97
K PID Efficiency = 0.971
```



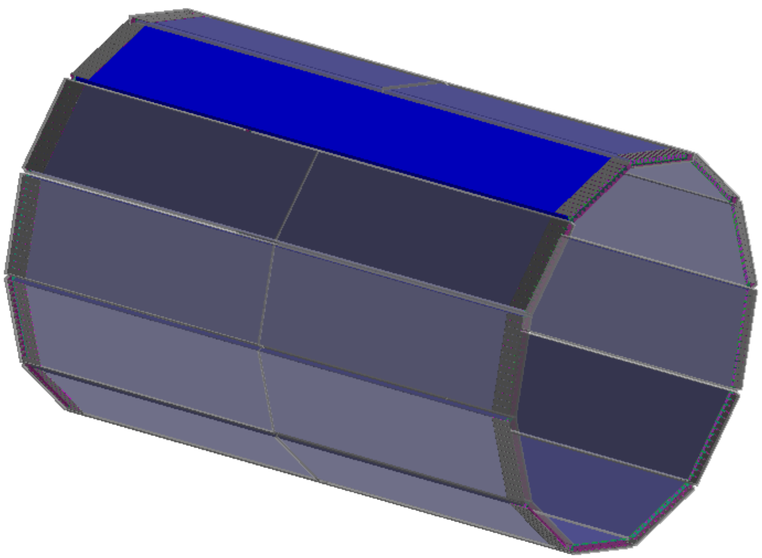
1*16 Pixels

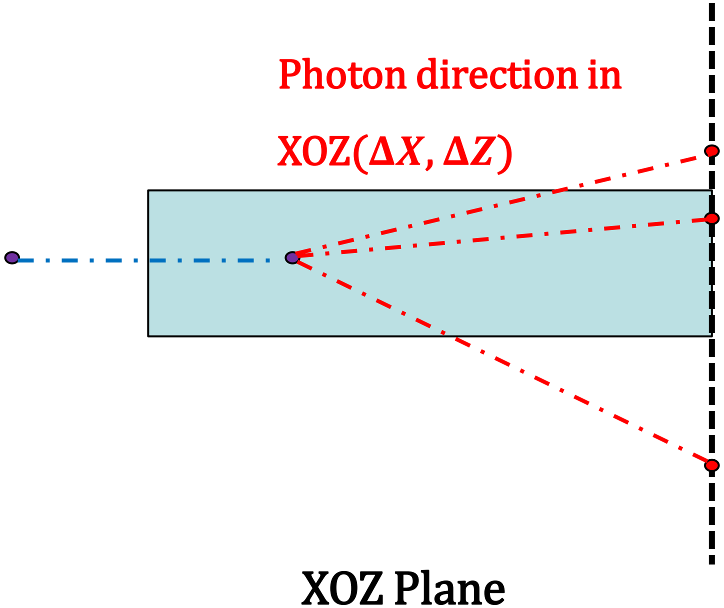


4*4 Pixels

Geometry change

- In each sector, two silicon quartzs are connected with grease instead of absorbing coat on inner side.
- Performance when large polar angle is hoped to be improved.





Geometry change

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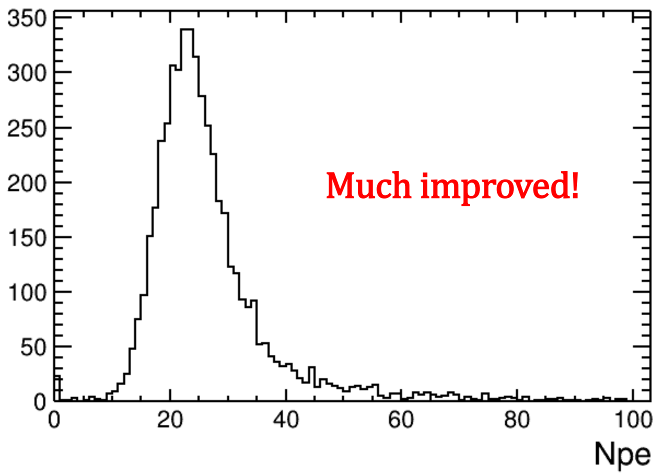
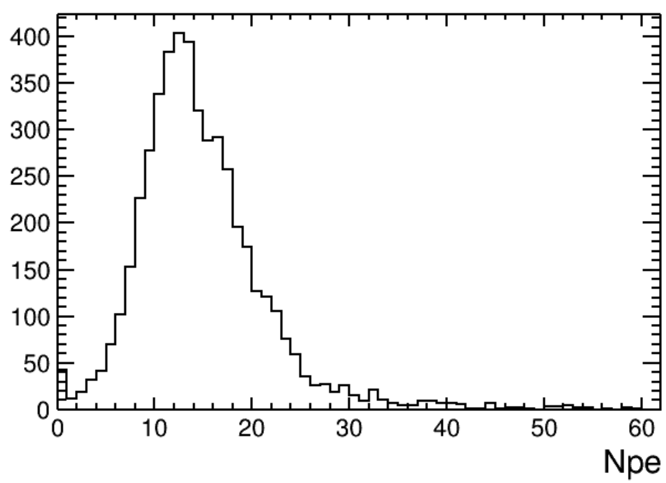


New Geometry (85° polar angle)



Old Geometry (85° polar angle)

New Geometry (Imaging)	Old Geometry (Imaging)
Momentum: 2000 Theta: 85 π/ K separation = 4.6σ πPID Efficiency = 0.993 K PID Efficiency = 0.993	Momentum: 2000 Theta: 85 π/ K separation = 4.3σ πPID Efficiency = 0.987 K PID Efficiency = 0.987
Momentum: 2000 Theta: 65 π/ K separation = 3.98σ πPID Efficiency = 0.972 K PID Efficiency = 0.972	Momentum: 2000 Theta: 65 π/ K separation = 3.97σ πPID Efficiency = 0.971 K PID Efficiency = 0.972
Momentum: 2000 Theta: 55 π/ K separation = 4.09σ πPID Efficiency = 0.979 K PID Efficiency = 0.978	Momentum: 2000 Theta: 55 π/ K separation = 4.04σ πPID Efficiency = 0.976 K PID Efficiency = 0.976
Momentum: 2000 Theta: 37 π/ K separation = 4σ πPID Efficiency = 0.972 K PID Efficiency = 0.973	Momentum: 2000 Theta: 37 π/ K separation = 3.96σ πPID Efficiency = 0.97 K PID Efficiency = 0.971

Summary

Summary

- BTOF simulation, digitalization and reconstruction have been completed.
- TOF and 2D algorithm have all reached the requirement of STCF CDR.
- New optimization of geometry change can improve PID performance.