Status Update on DIRC Software for Misalignment Studies

DIRC Annual Meeting 2025

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On behalf of the ePIC at EIC

Outline:

1. **Misalignment implementation**
2. **Misalignment results**

Geometrical Reconstruction (GR)

- Event Selection Criteria
- Photon Yield Evaluation
- Kaon–Pion Separation Power

Time-Based Imaging (TM) within realistic configurations and constraints across various modes, using same and different PDF per nominal and misaligned detectors

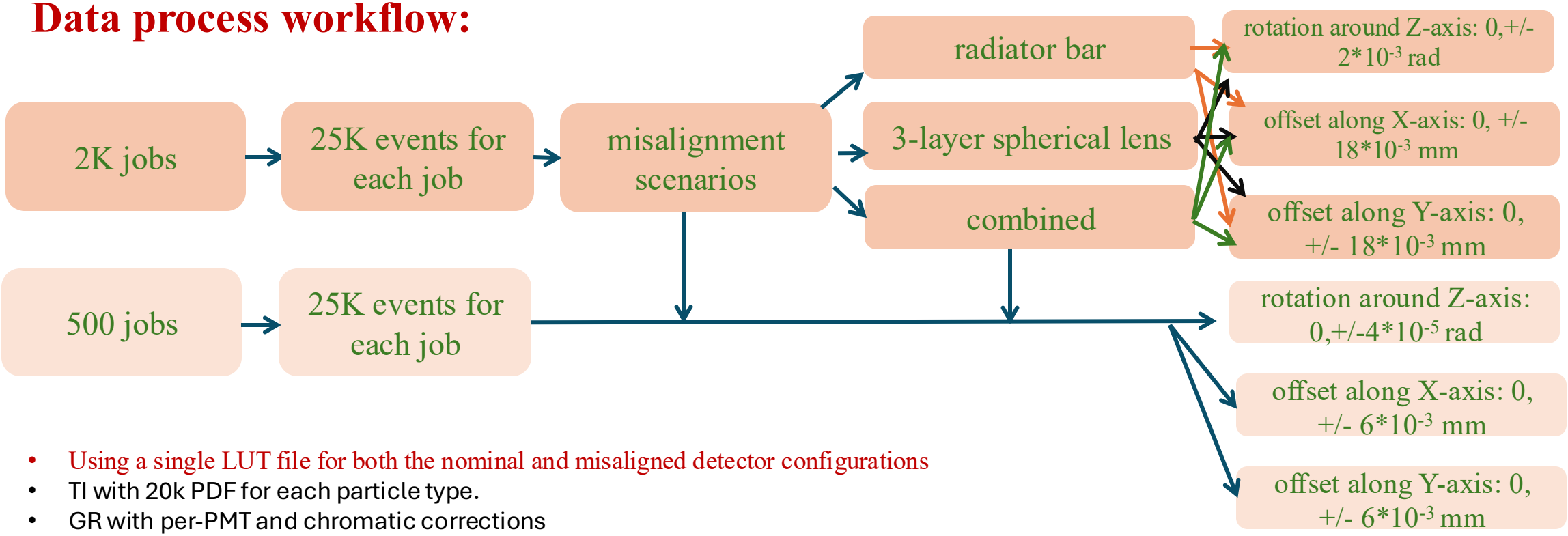
- Photon Yield Evaluation
- Kaon–Pion Separation Power

Misalignment Parameters:

Misalignment scenarios and modes in different detector components

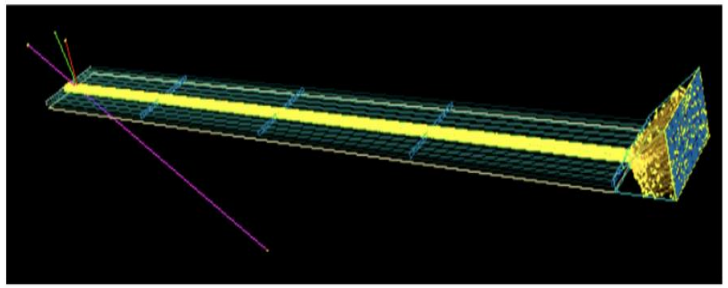
Misalignment Scenario	Misalignment Modes
Radiator Bar	Rotation, Shift
3-Layer Spherical Lens	Rotation, Shift
Combined (Radiator bar with 3-layer spherical lens)	Rotation, Shift

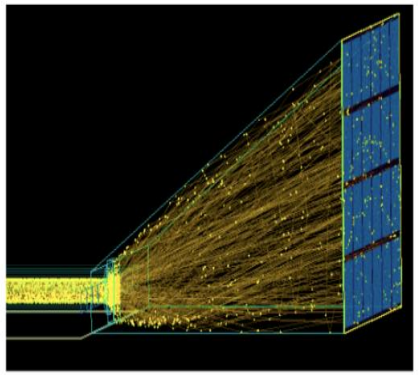
Data process workflow:

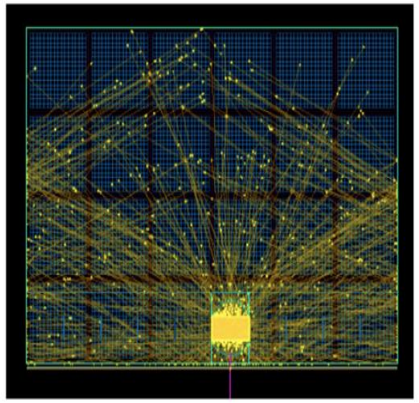


- Using a single LUT file for both the nominal and misaligned detector configurations
- TI with 20k PDF for each particle type.
- GR with per-PMT and chromatic corrections

Event Visualization for only One Event :

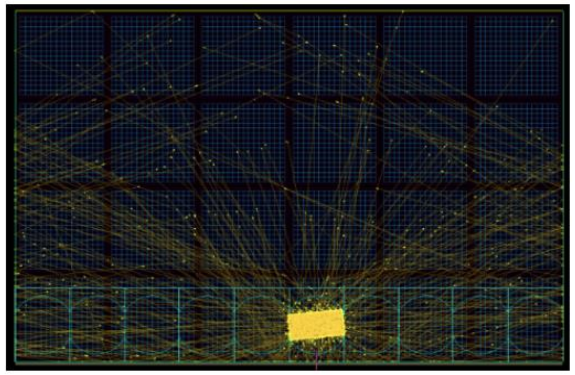


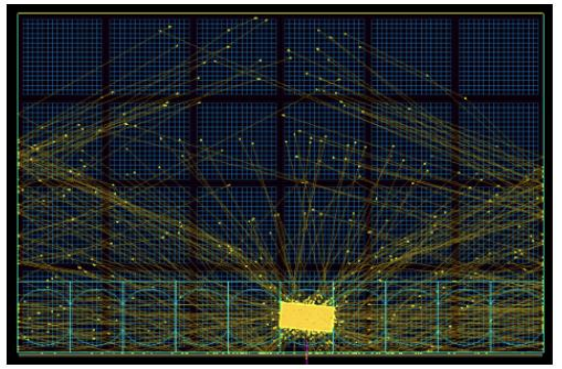




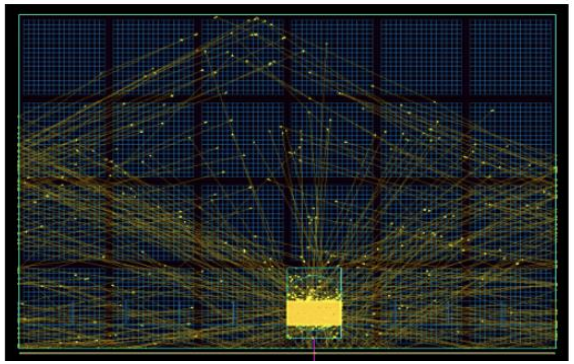
Event display from Geant4 showing one sector of the nominal DIRC detector. The sector includes 10 radiator bars, each comprising 4 segments, followed by spherical lenses, a prism, and sensor arrays.

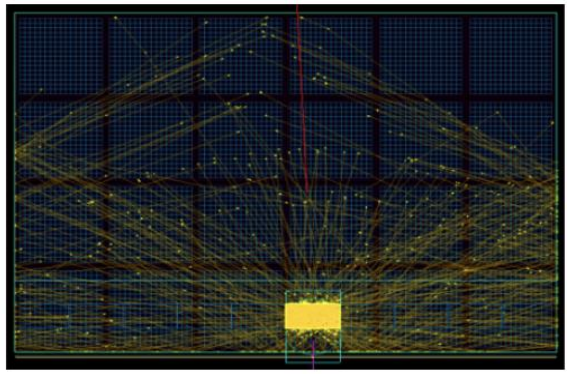
***Rotation** along the **Z-axis** ±0.040 rad*



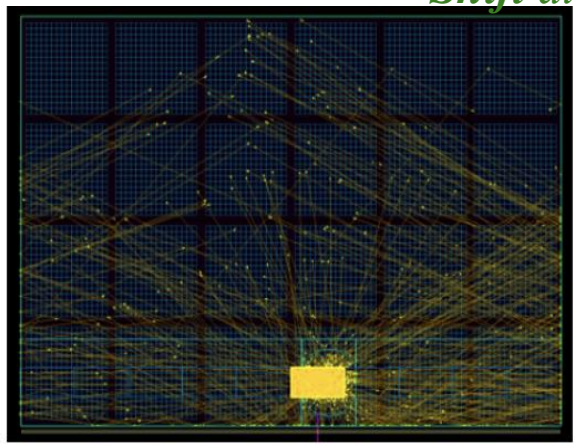


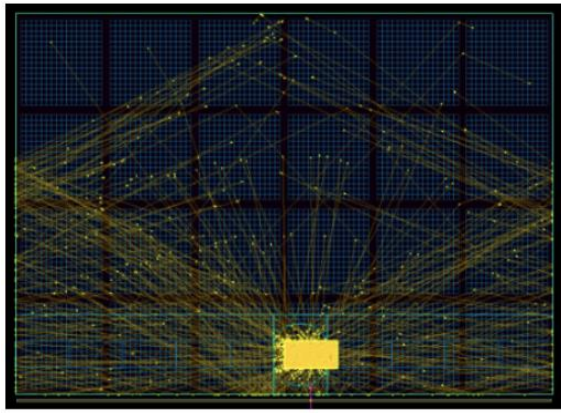
***Shift** along the **X-axis** ±7.2mm*





***Shift** along the **Y-axis** ±7.2mm*

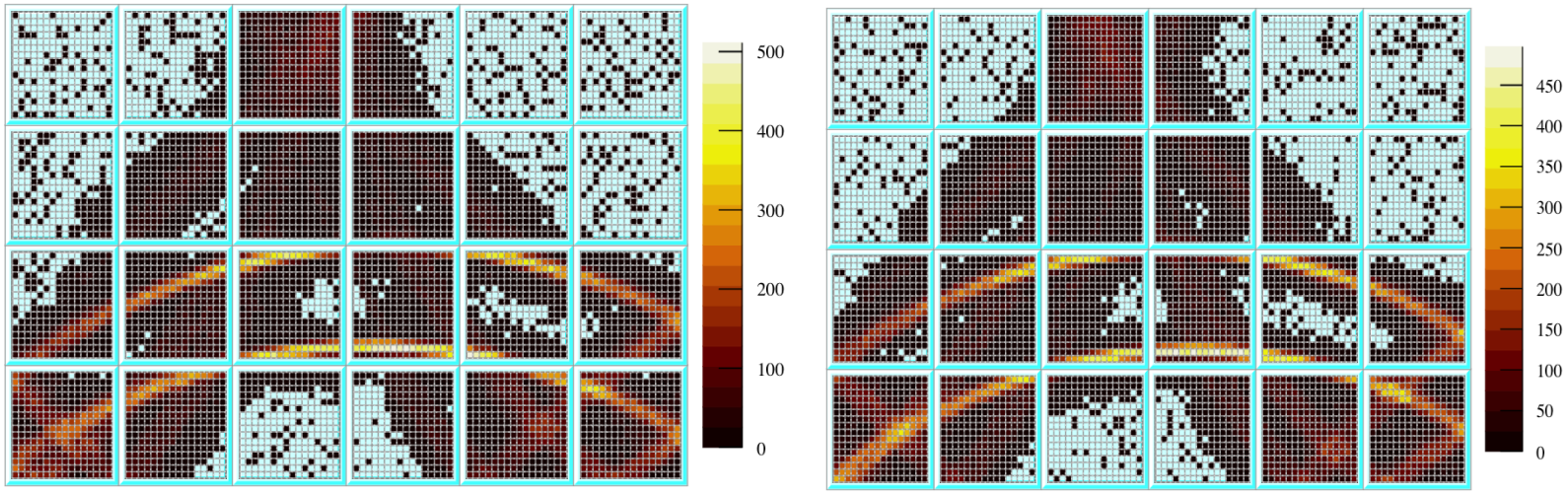




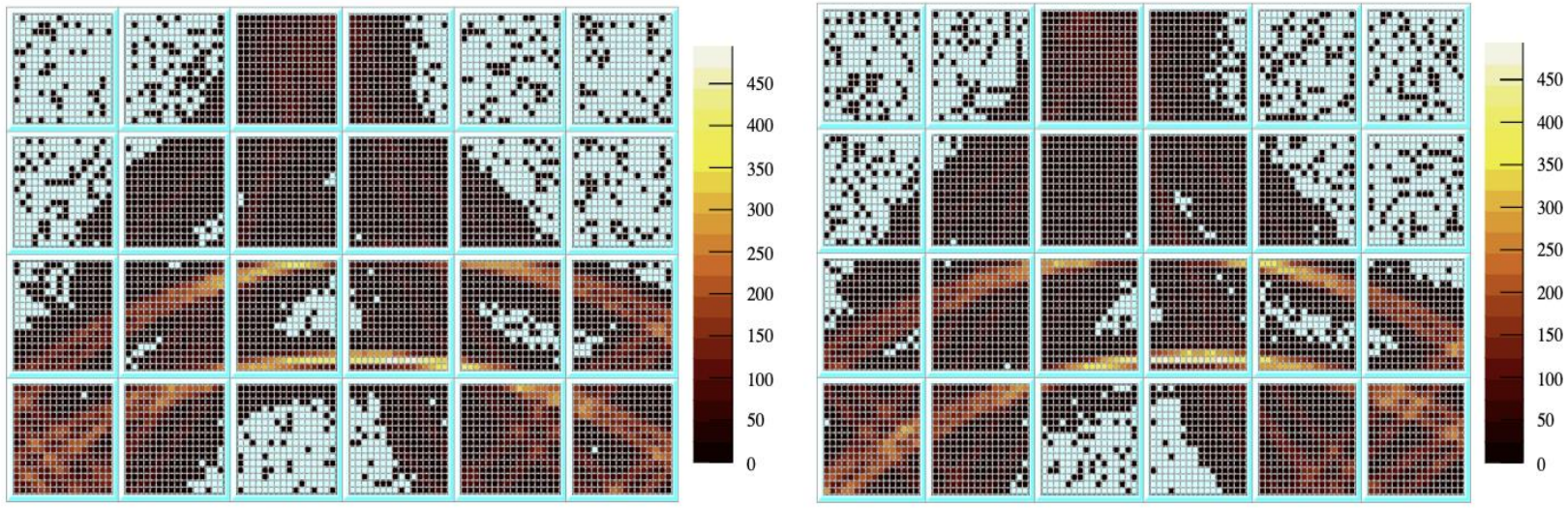
Hit Pattern for All Events per Different Misalignment Mode:

- **Misalignment Scenario**: *Radiator Bar*
- **Misalignment Mode:** *Rotation*

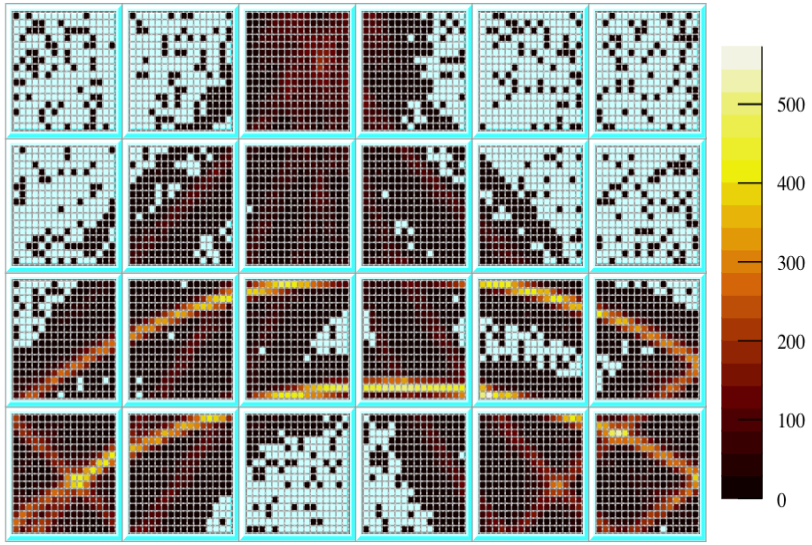
***Rotational bar** around the **z-axis** +/- 0.02 [rad]*

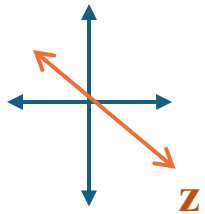


***Rotational bar** around the **z-axis** +/-0.04 [rad]*



Nominal Detector

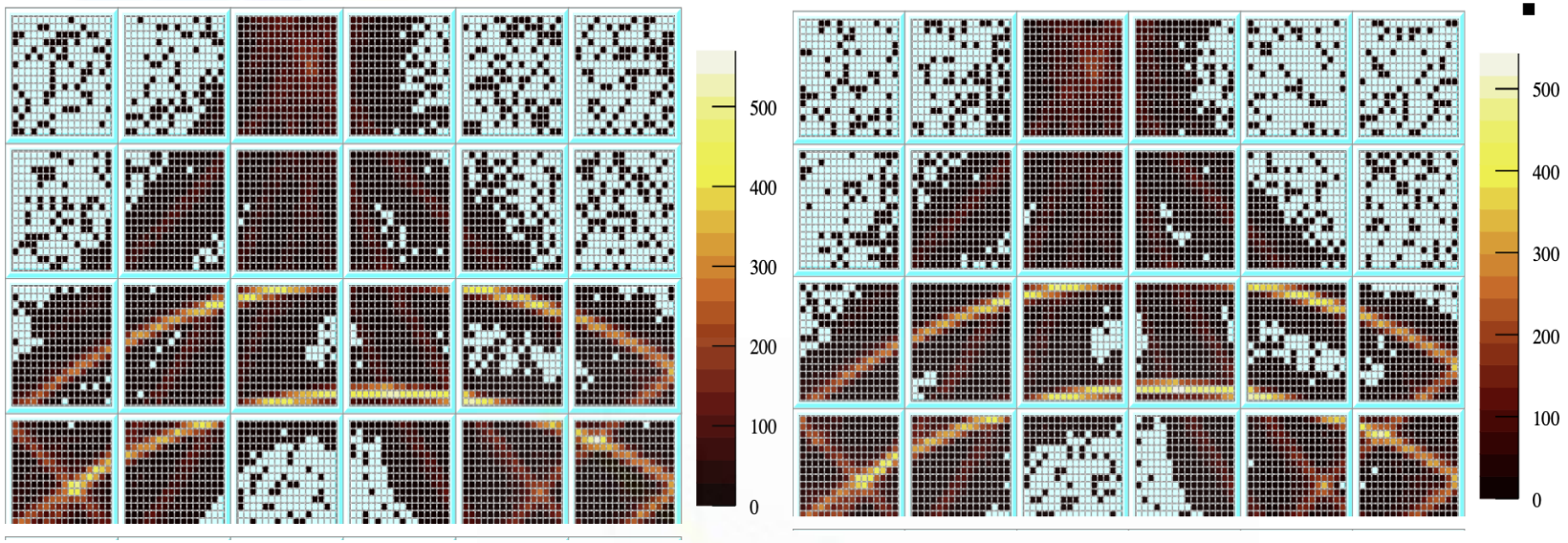




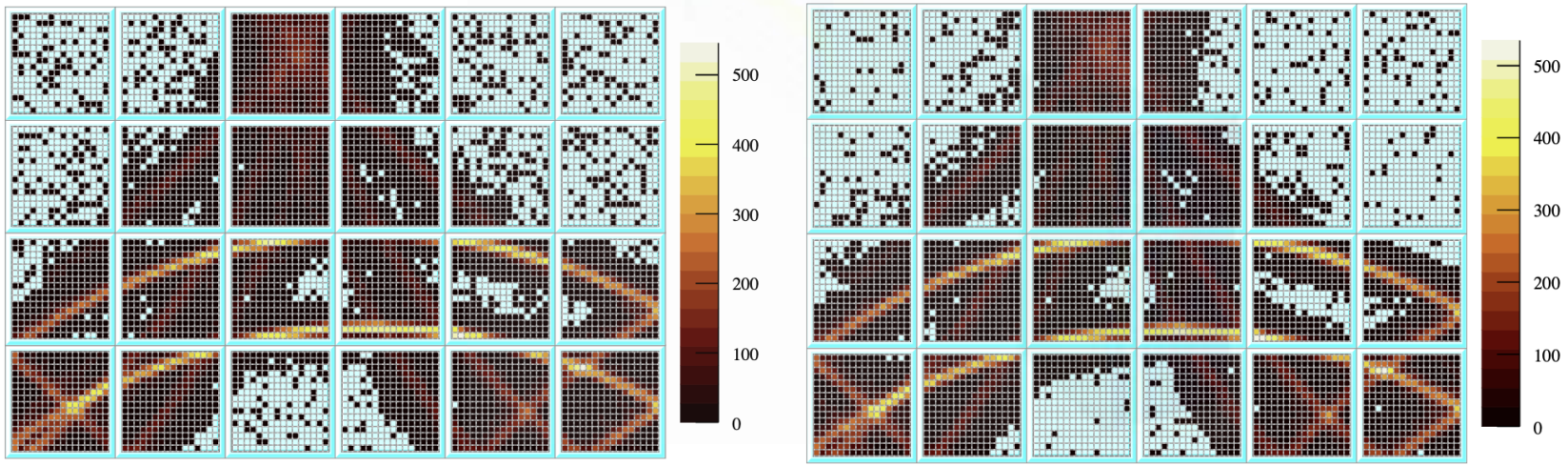
Hit Pattern for all Events per Different Misalignment Mode:

- **Misalignment Scenario:** *3-layer spherical lens*
- **Misalignment Mode:** *Rotation*

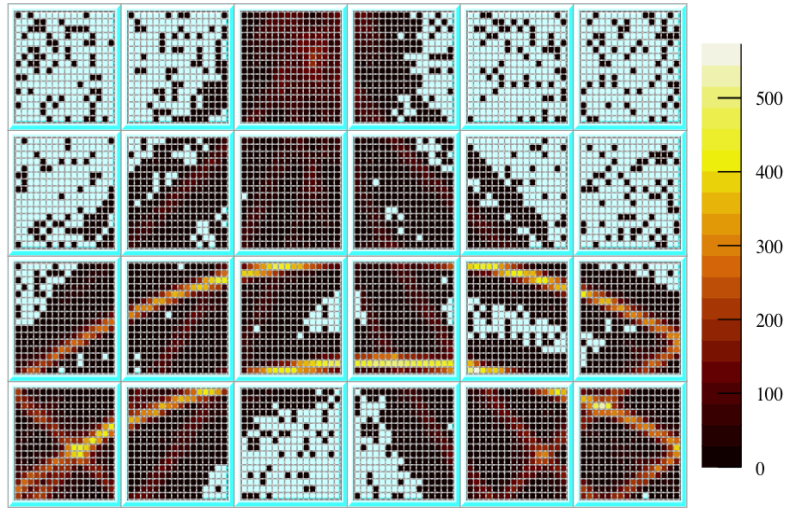
***Rotational lens** around the **z-axis** +/-0.02 [rad]*

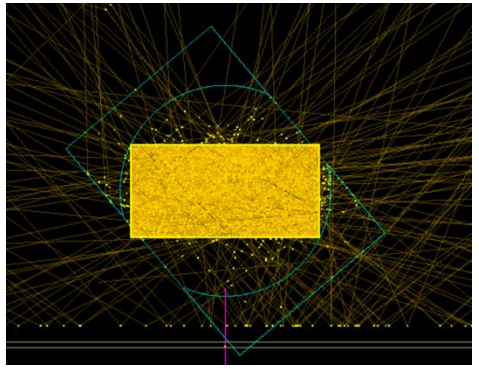


***Rotational lens** around the **Z-axis** +/-0.04 [rad]*



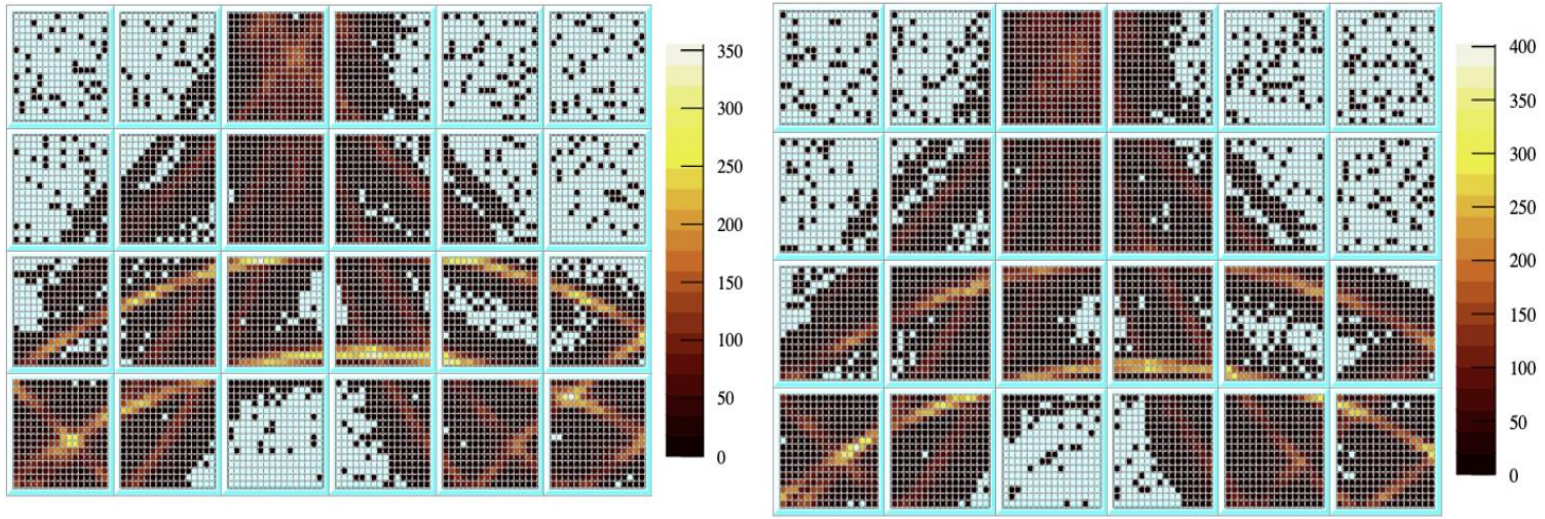
Nominal Detector



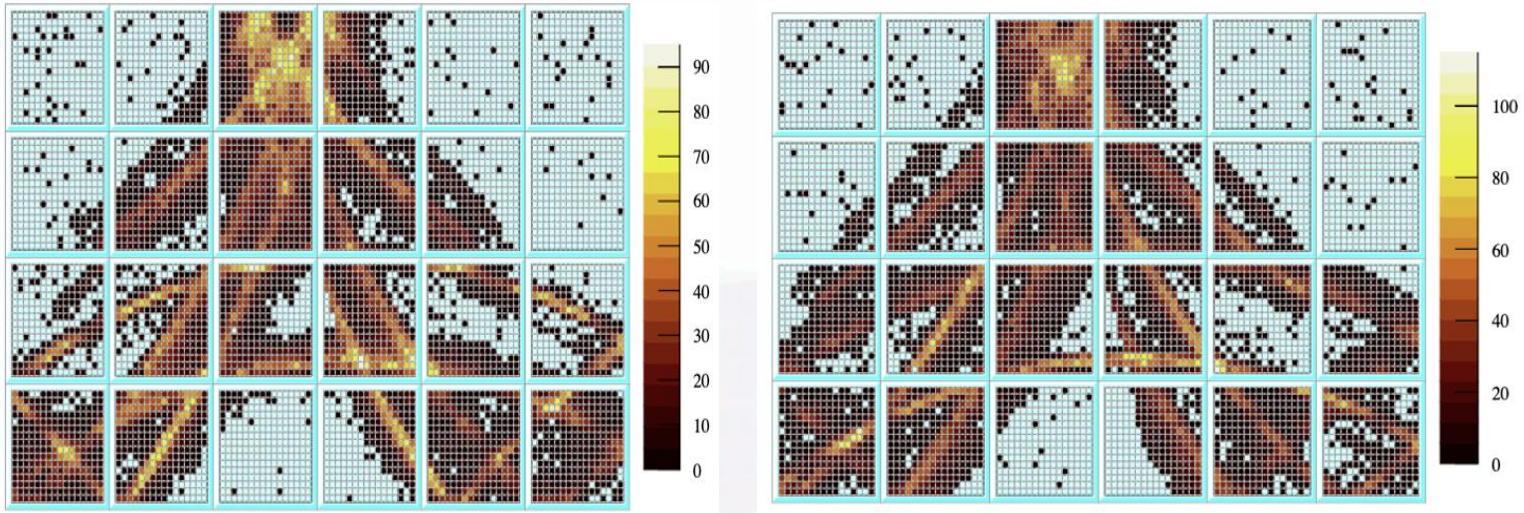


Hit Pattern for all Events per Different Misalignment Mode:

***Offset bar** around the **X-axis** +/- 7.2 mm*

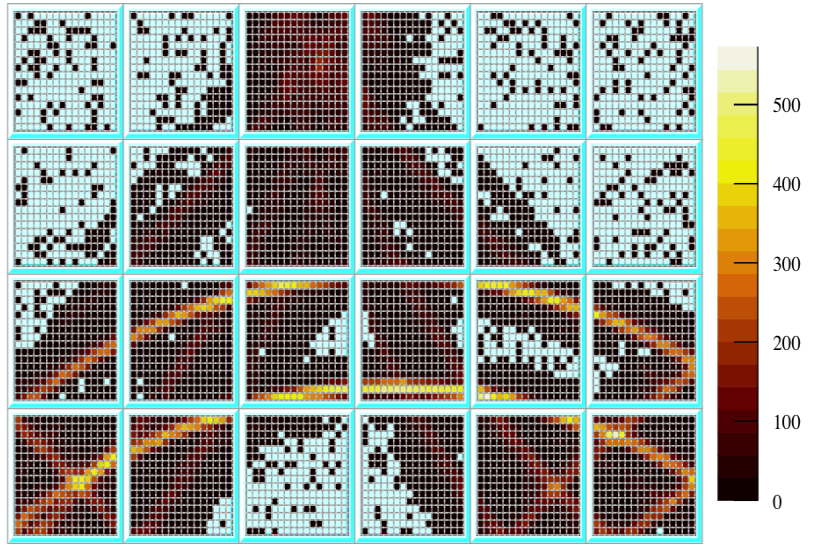


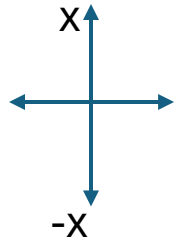
***Offset bar** around the **X-axis** +/- 14.4 mm*

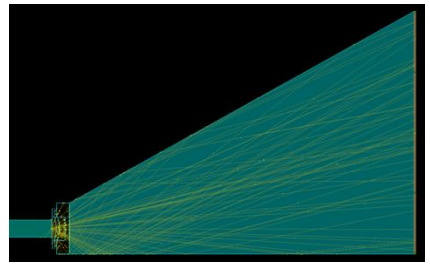


- **Misalignment Scenario:** *Radiator bar*
- **Misalignment Mode:** *Offset*

Nominal Detector

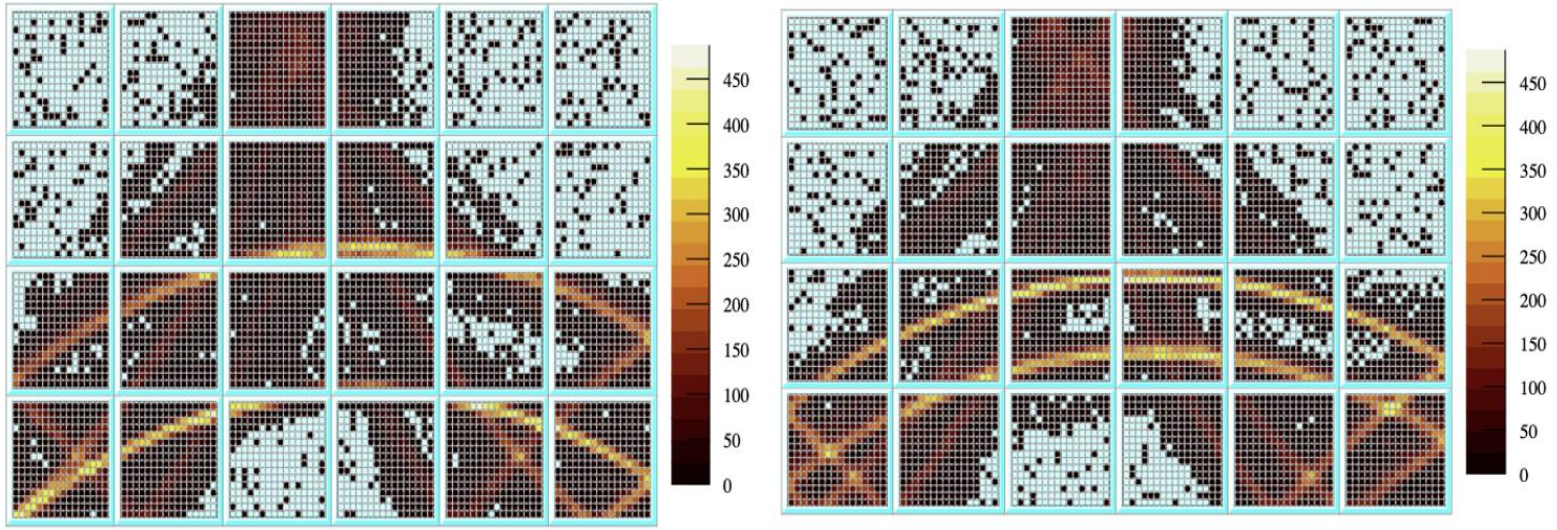




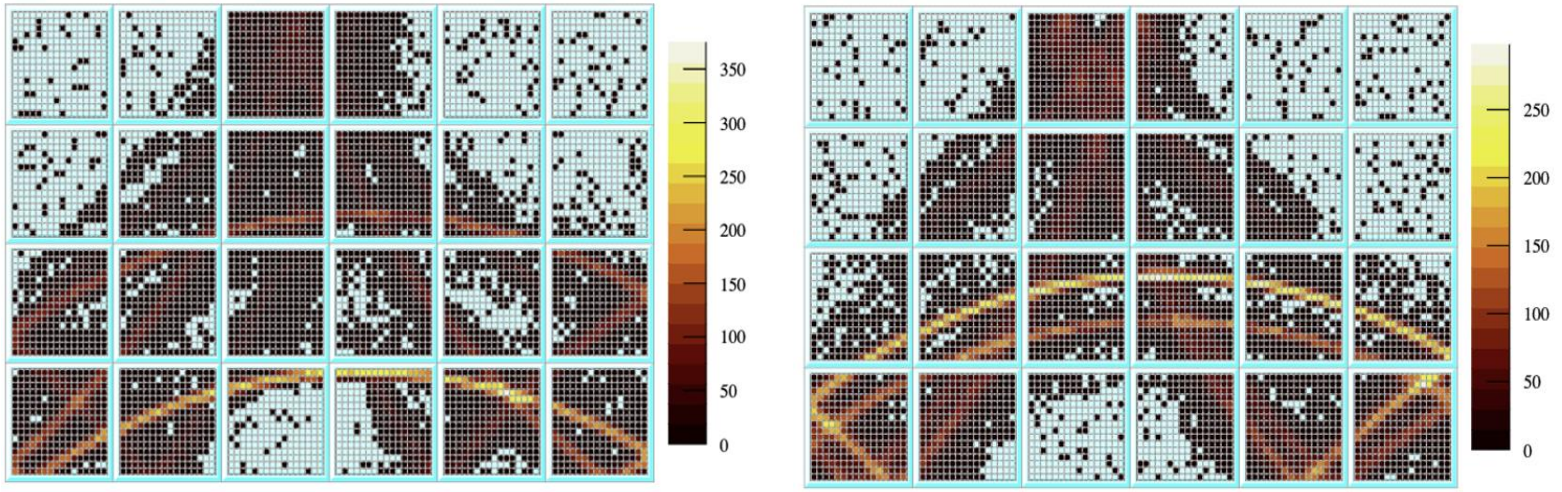


Hit Pattern for all Events per Different Misalignment Mode:

***Offset lens** around the **X-axis** +/- 7.2 mm*

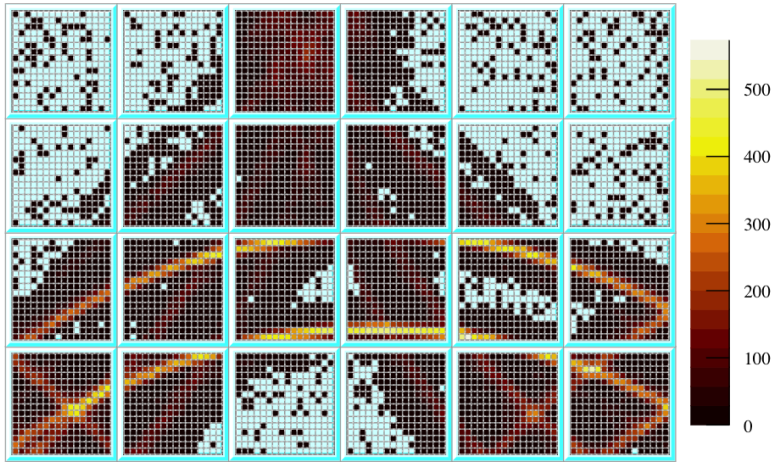


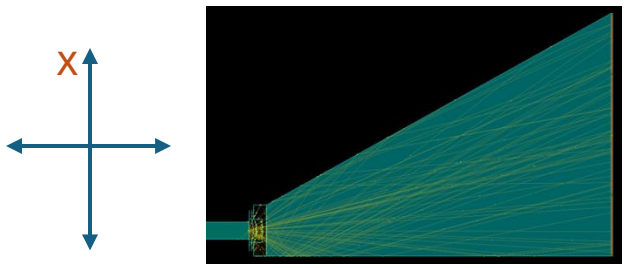
***Offset lens** around the **X-axis** +/- 14.4 mm*



- **Misalignment Scenario:** *3-layer spherical lens*
- **Misalignment Mode:** *offset*

Nominal Detector

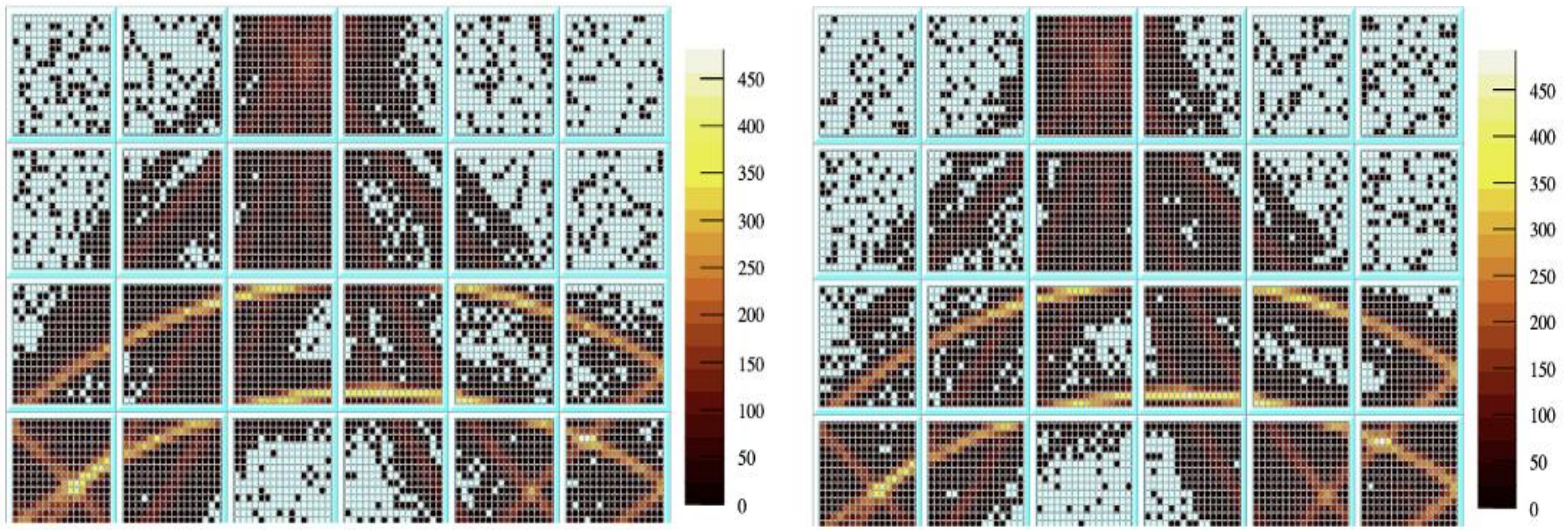




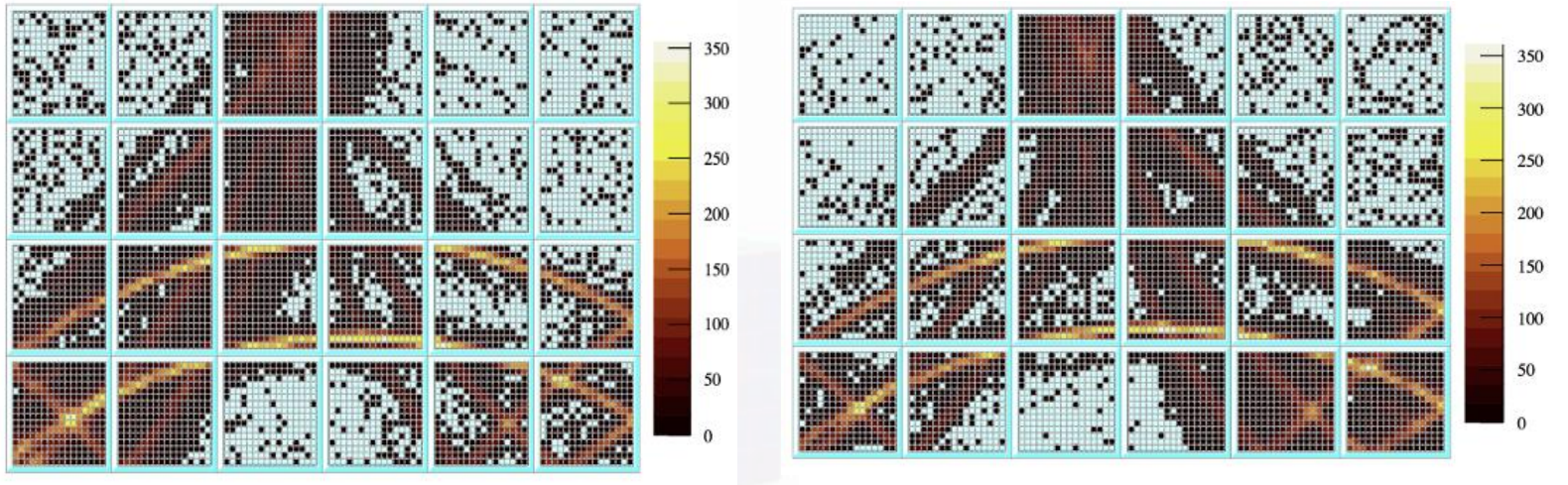
Hit Pattern for all Events per Different Misalignment Mode:

- **Misalignment Scenario:** *Radiator bar*
- **Misalignment Mode:** *Offset*

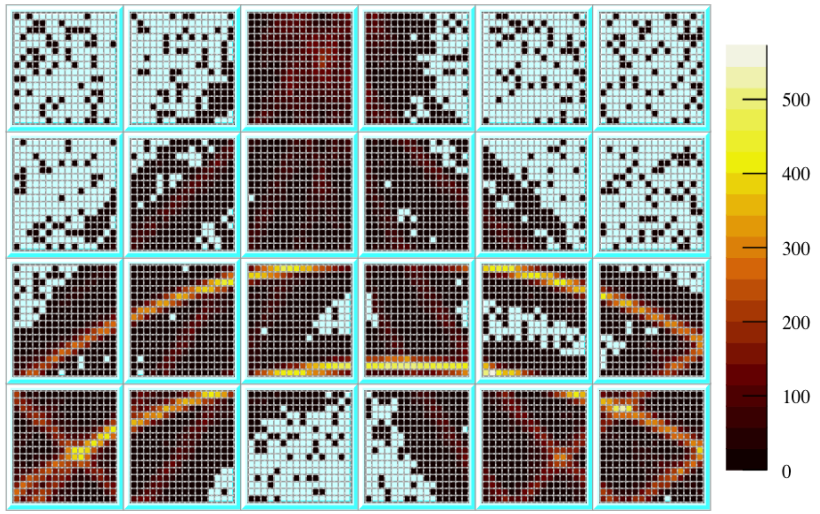
***Offset bar** around the **Y-axis** +/- 7.2 mm*

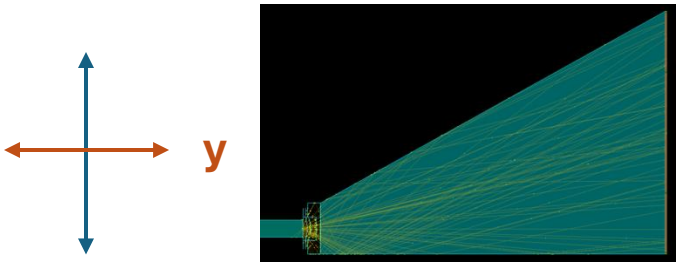


***Offset bar** around the **Y-axis** +/- 14.4 mm*



Nominal Detector

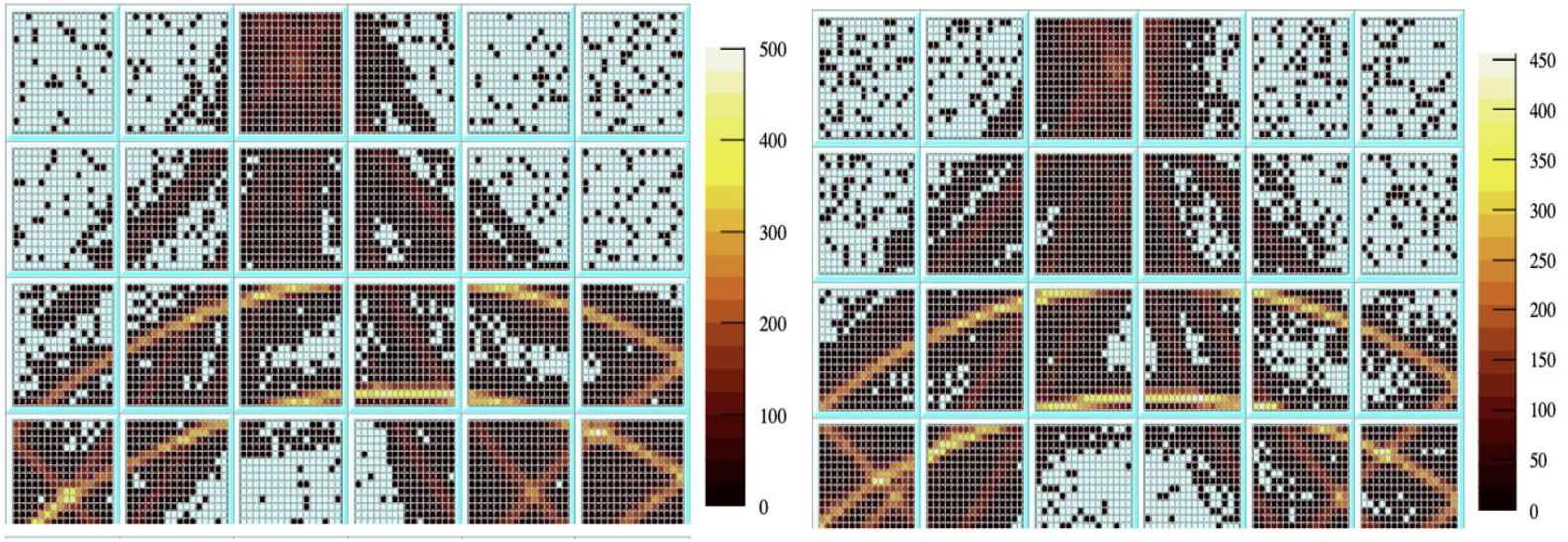




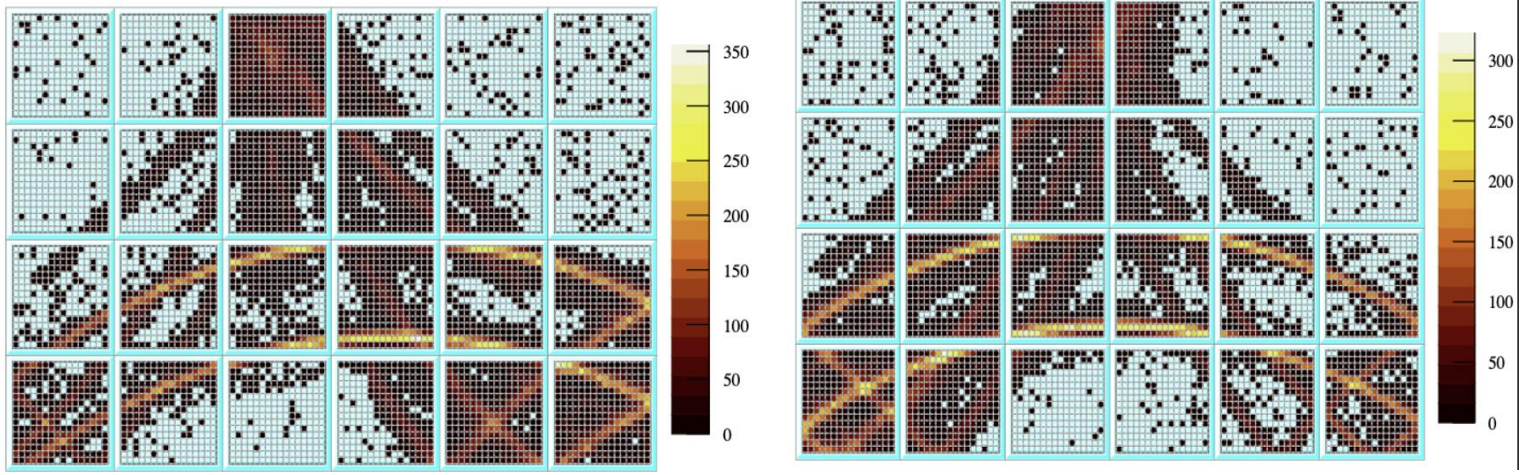
Hit Pattern for all Events per Different Misalignment Mode:

- **Misalignment Scenario:** *3-layer spherical lens*
- **Misalignment Mode:** *offset*

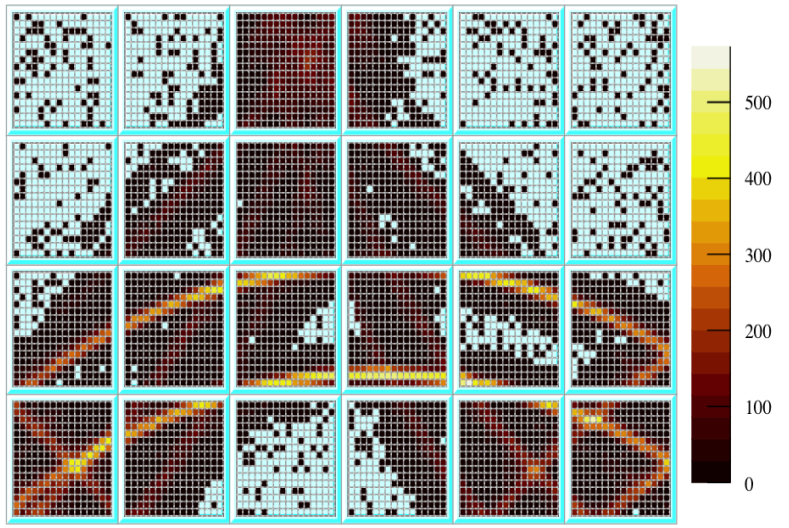
***Offset lenses** around the **Y axis** +/- 7.2 mm*

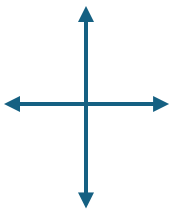


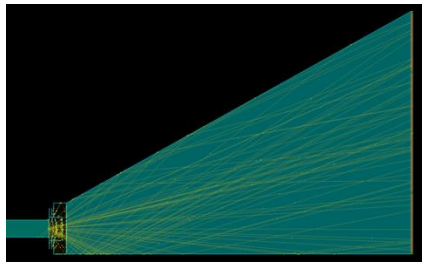
***Offset lenses** around the **Y axis** +/- 14.4 mm*



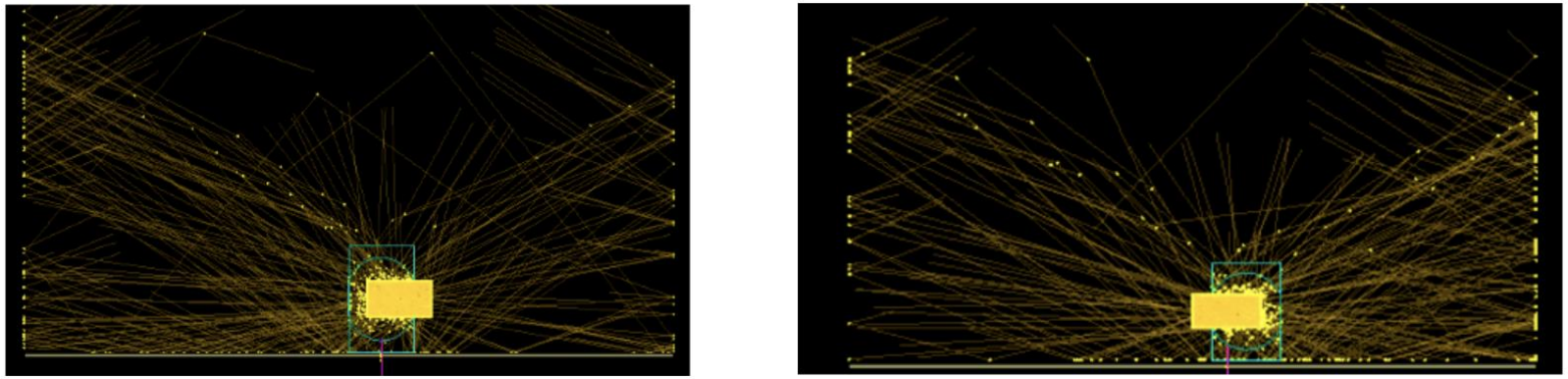
Nominal Detector





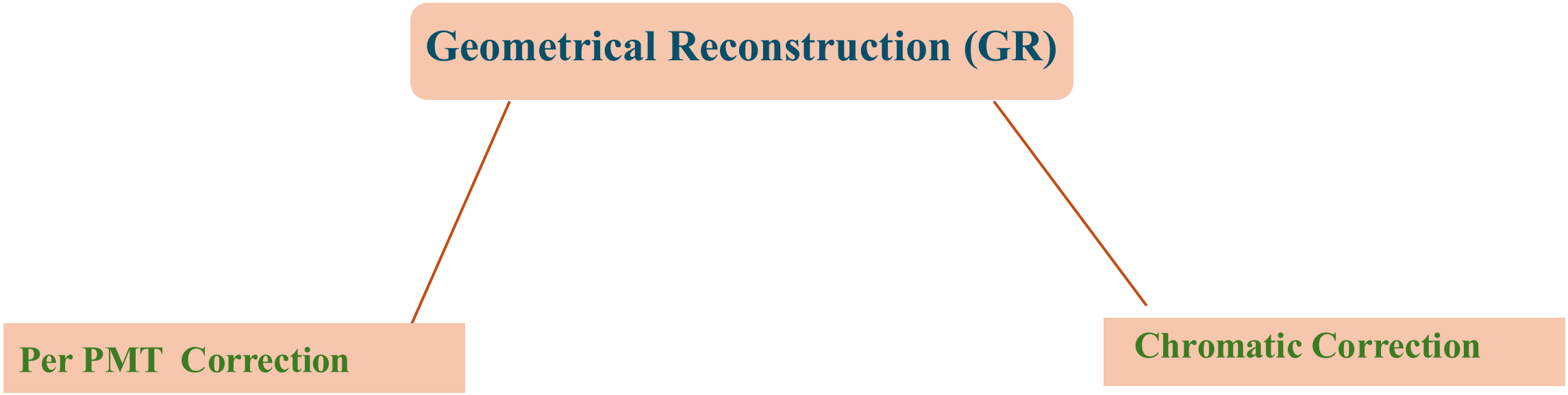


Event Display for Misalignment of the Bar and Lens Along the Positive Y-Direction (mirror-reflected)



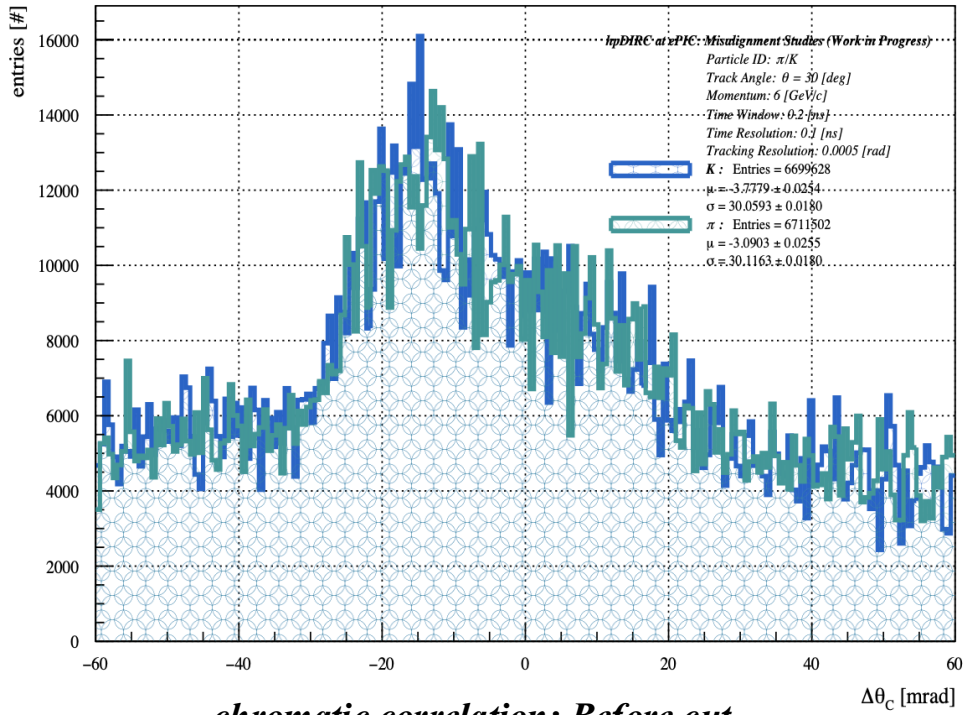
Event display comparing the photon hit patterns resulting from bar (left) and lens (right) misalignments along the positive Y-direction with an offset of +10 mm. This side-by-side layout highlights the reflected behavior and symmetry differences in hit patterns caused by each type of misalignment

The **main correction techniques** applied within **Geometrical Reconstruction (GR)**

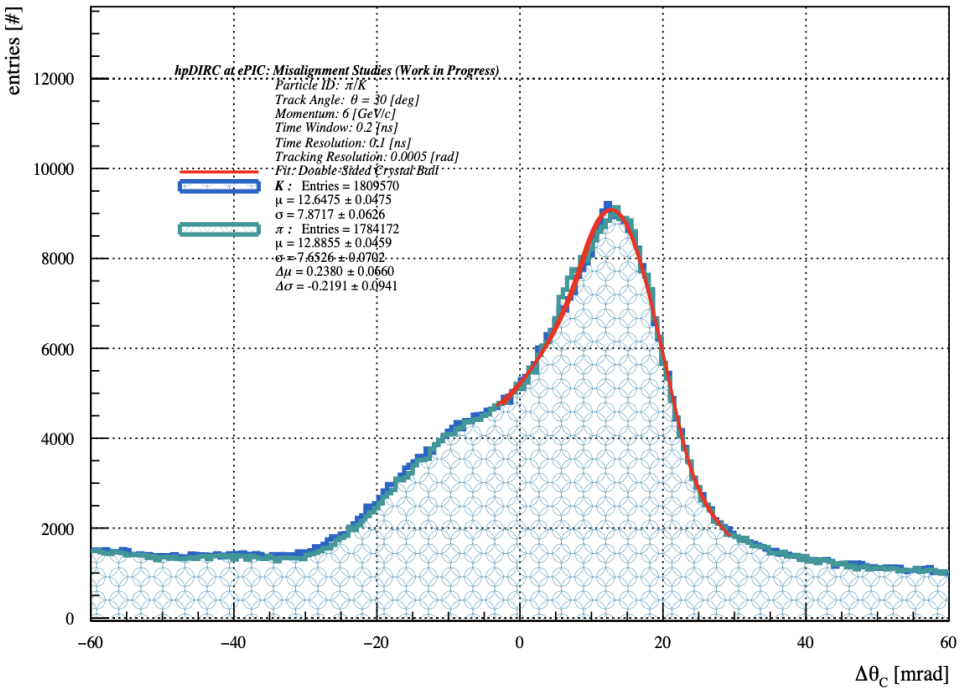


1. Chromatic Correction:

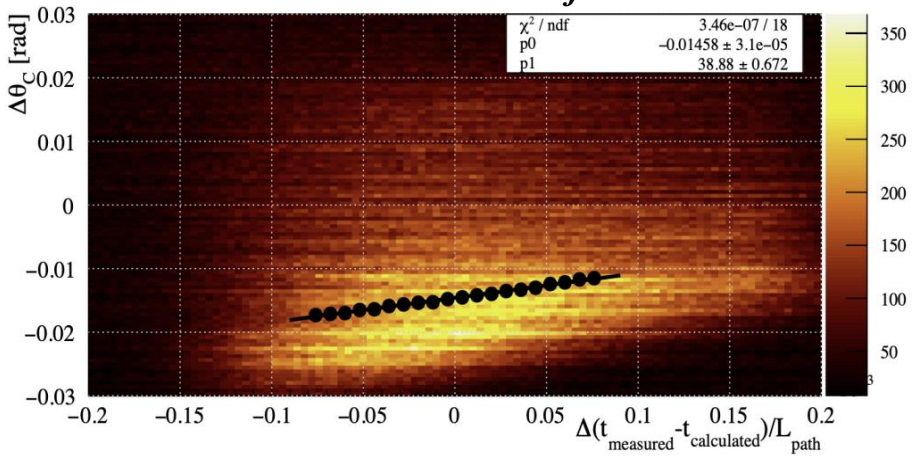
GR method; residual of Cherenkov angle: Before cut



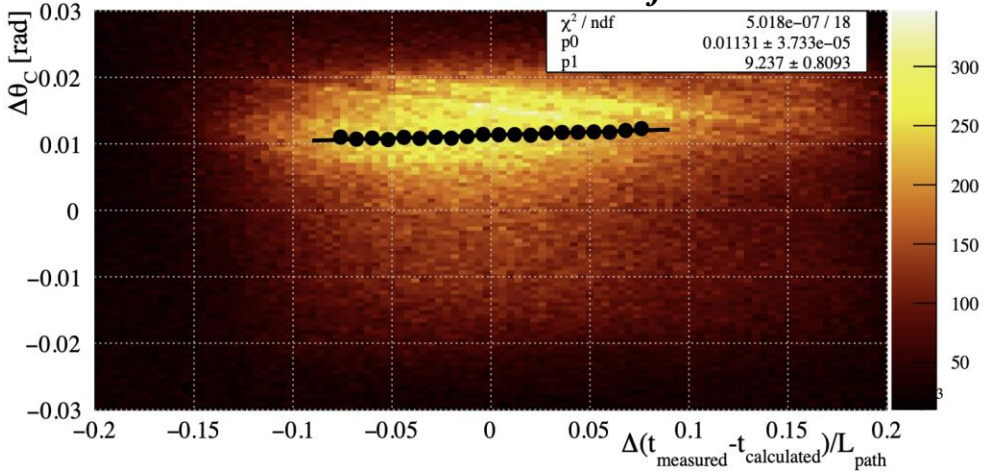
GR method; residual of Cherenkov angle: Before cut



chromatic correlation: Before cut



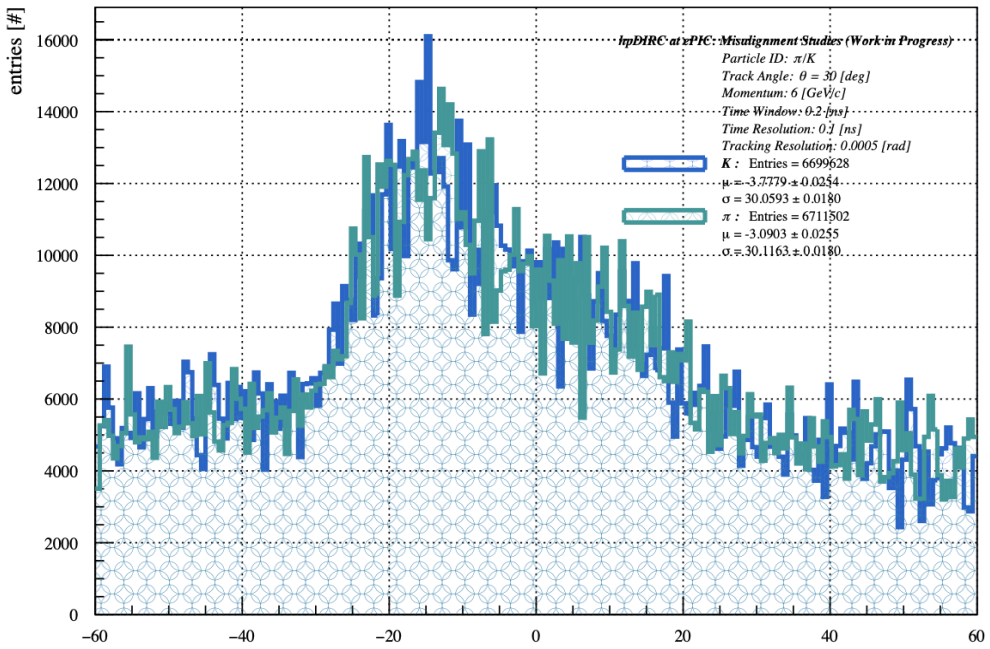
chromatic correlation: After cut



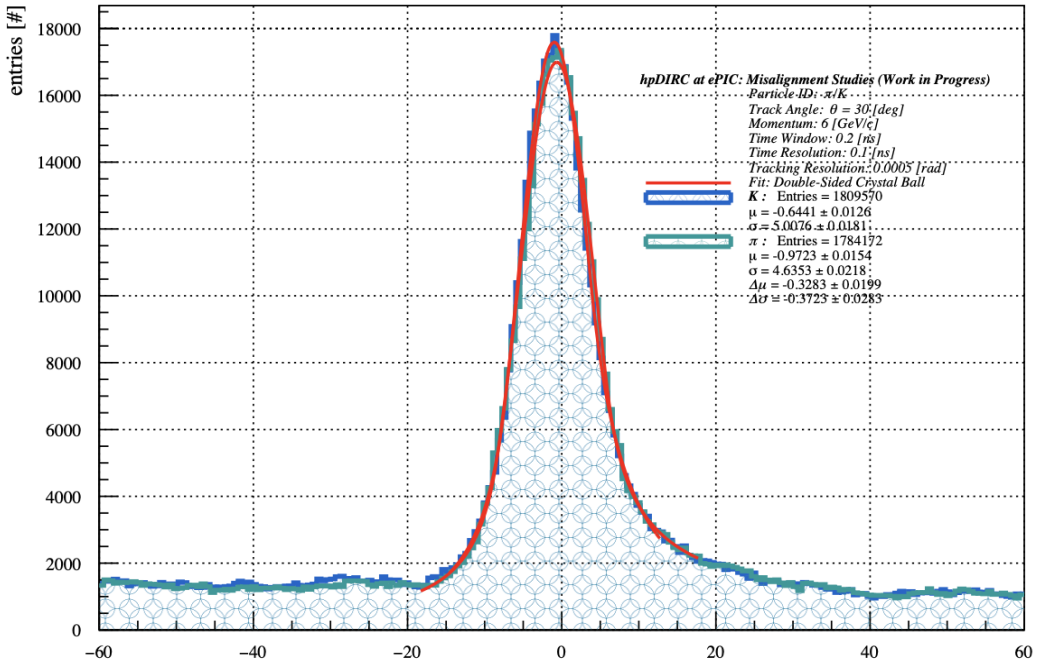
- ***Cutoff:*** *Applying wavelength cut (choosing PMT photocathode, inserting band filter) to reduce the chromatic dispersion effects on the Cherenkov angle and reduce the spreading.*

2. All Selection Cuts:

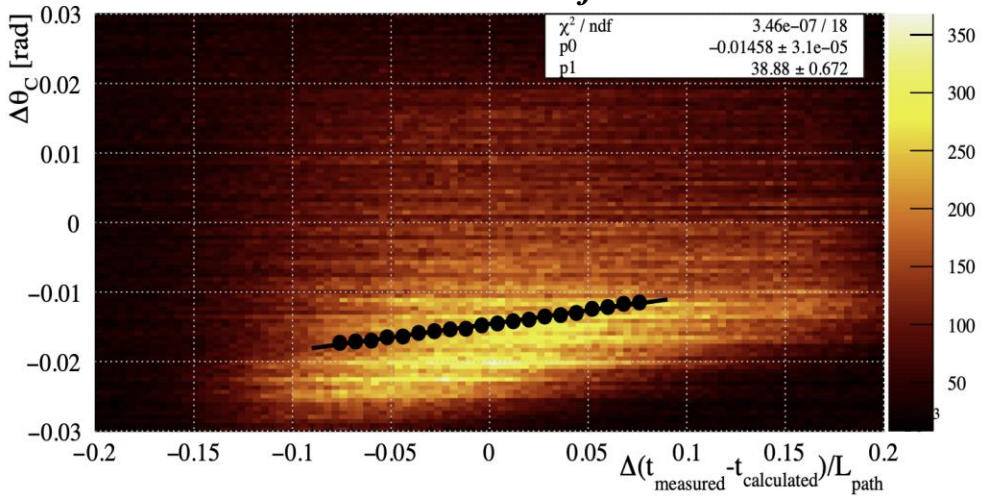
GR method; residual of Cherenkov angle: Before cut



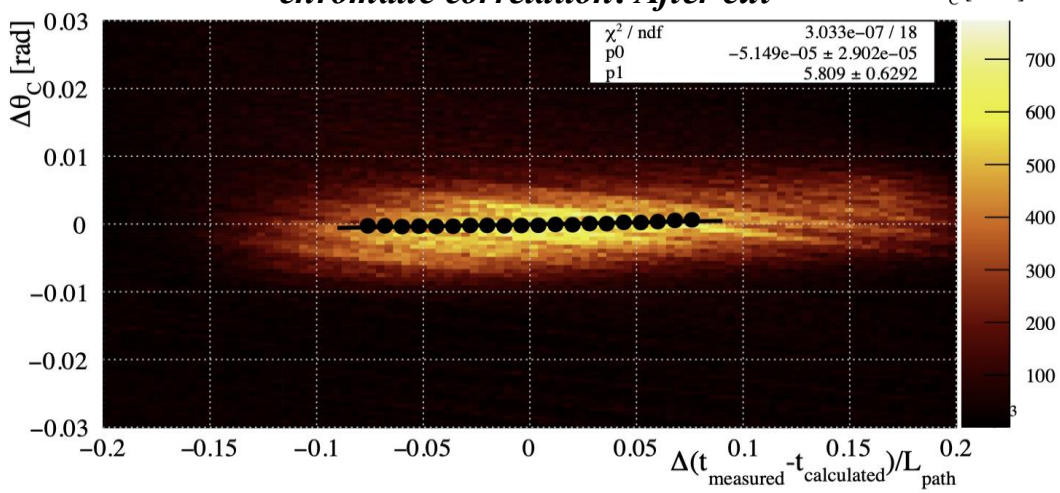
GR method; residual of Cherenkov angle: Before cut



chromatic correlation: Before cut

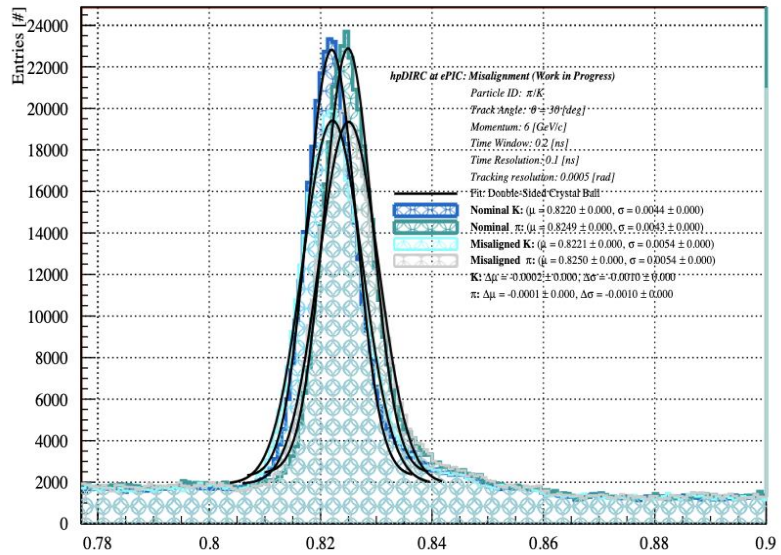


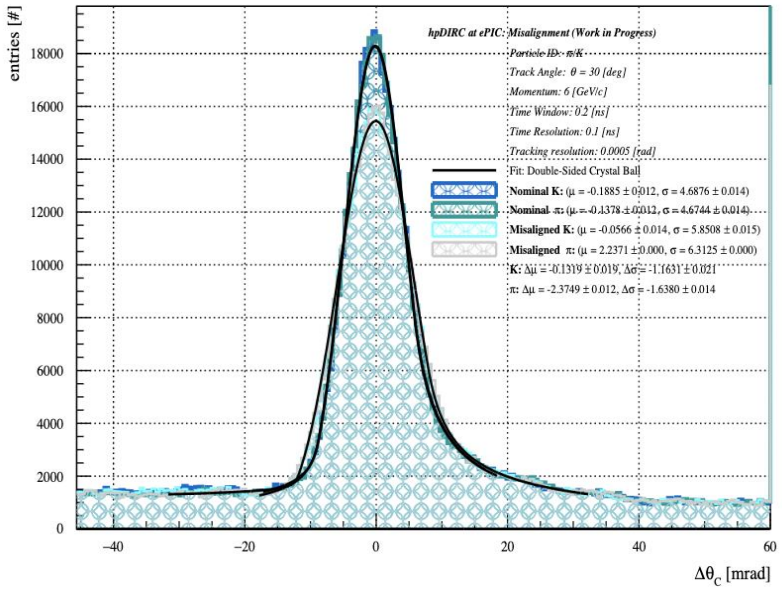
chromatic correlation: After cut



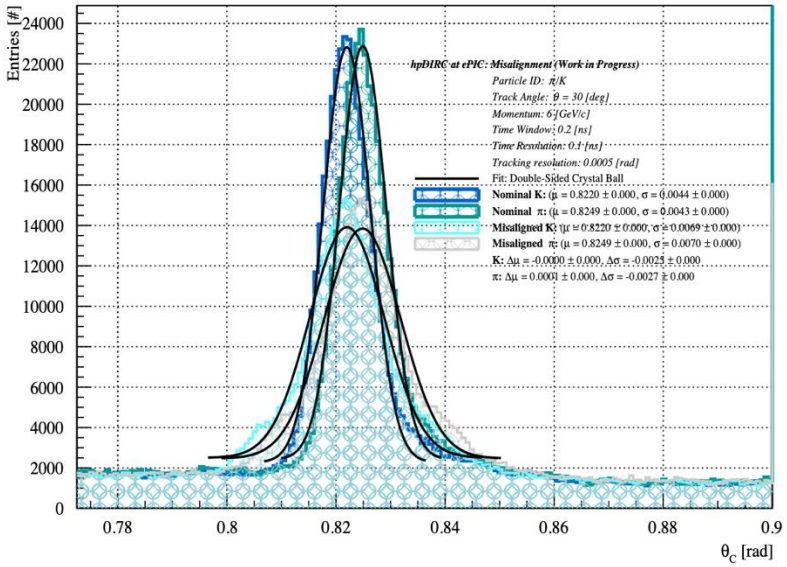
Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Pion and Kaon:

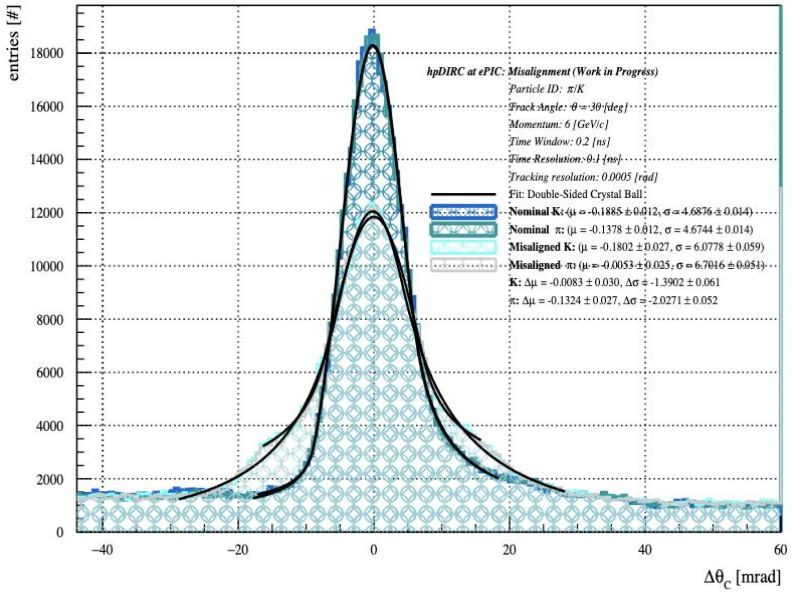
rotational bar around z with 0.006 rad



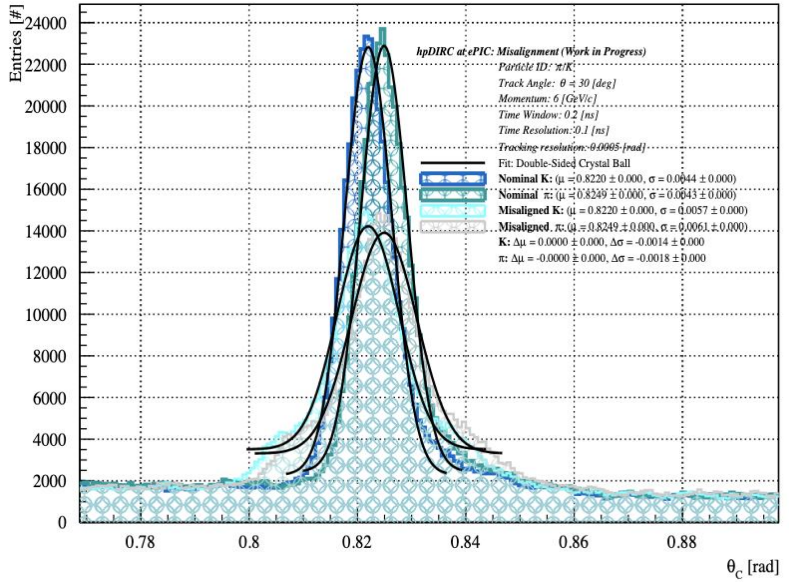


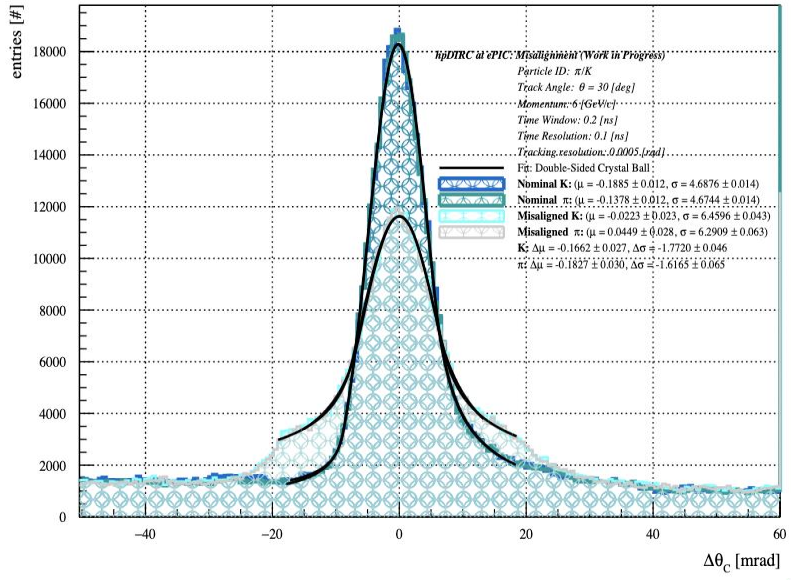
rotational bar around z with 0.016 rad



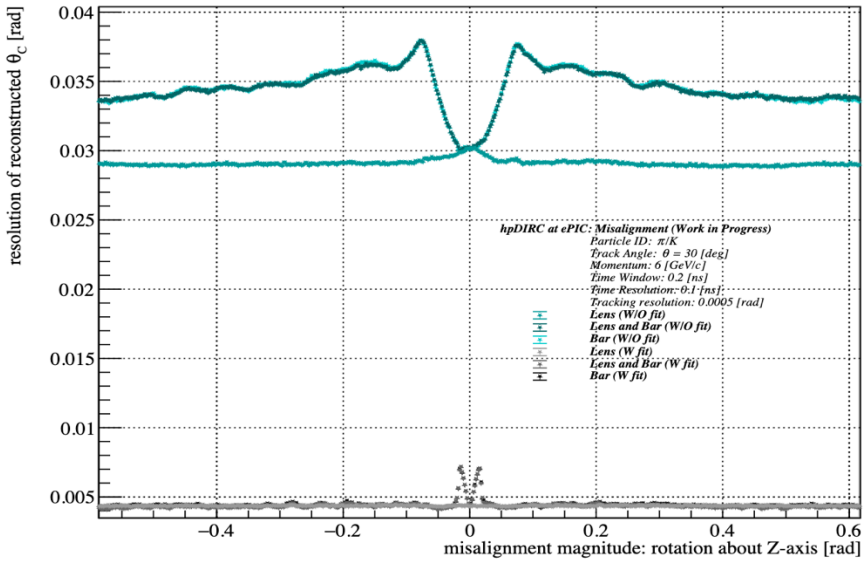


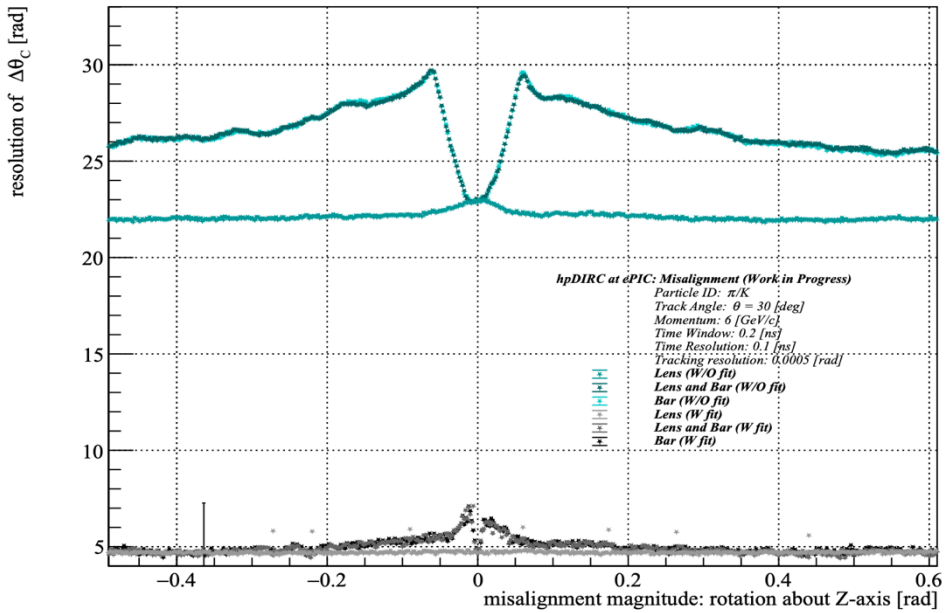
rotational bar around z with 0.018 rad

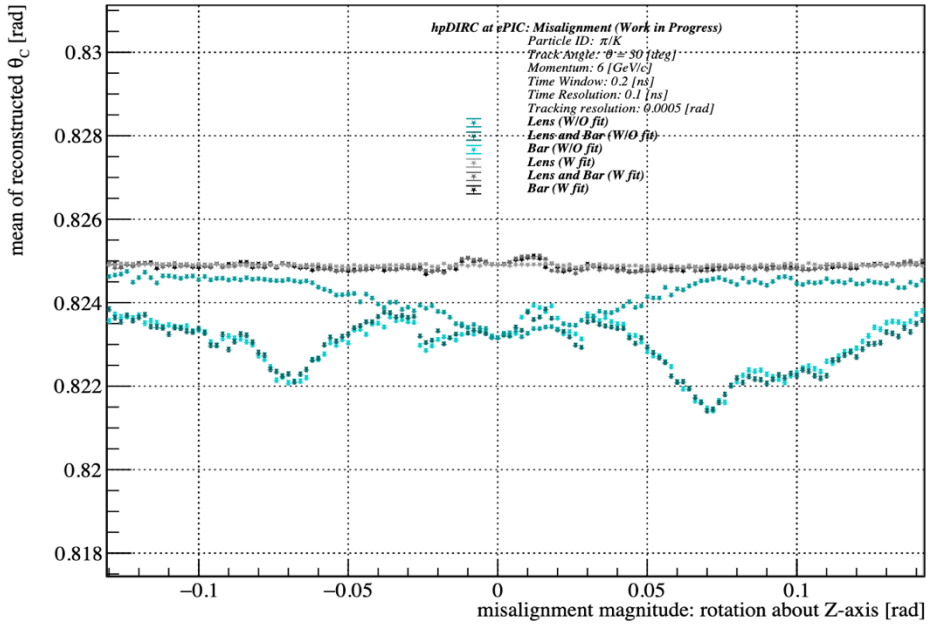


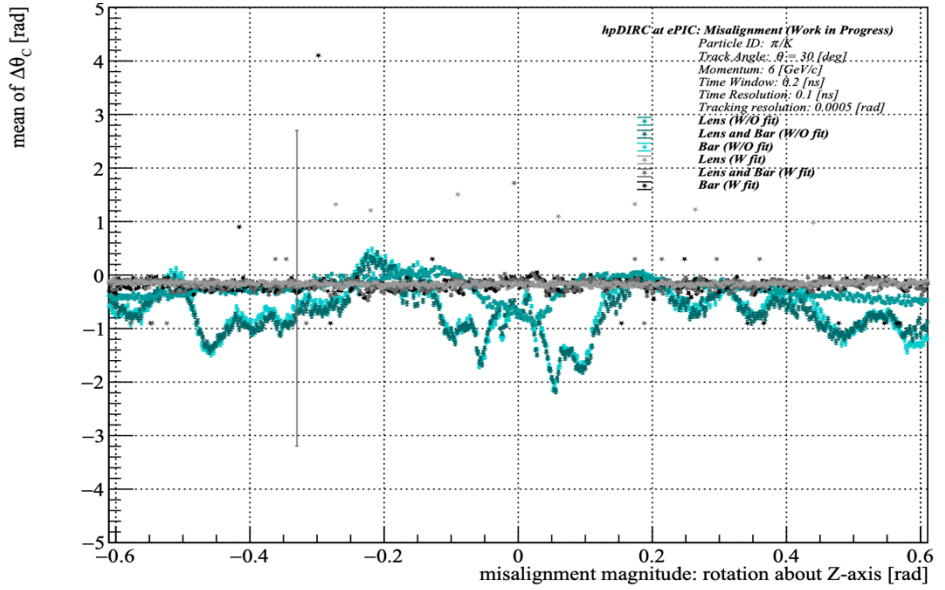


Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Pion only:

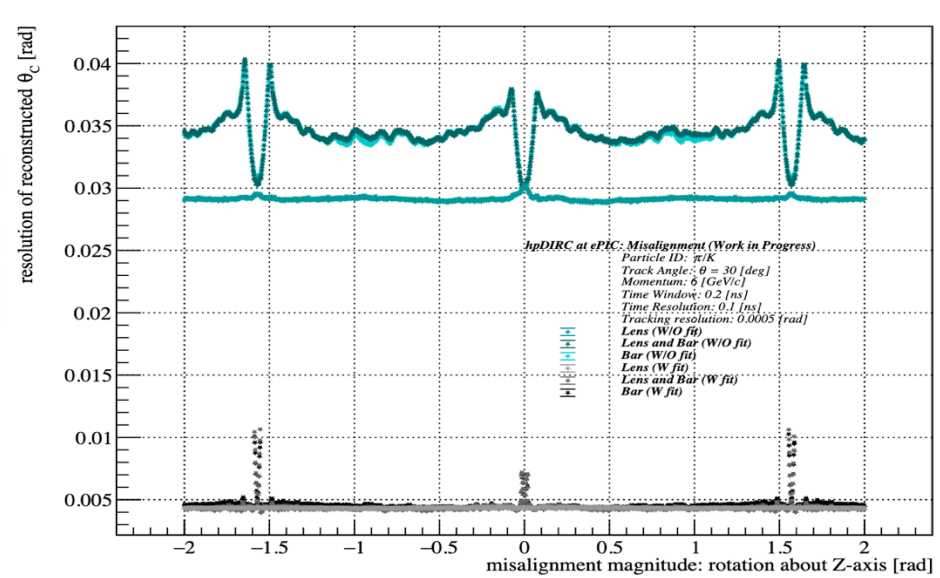


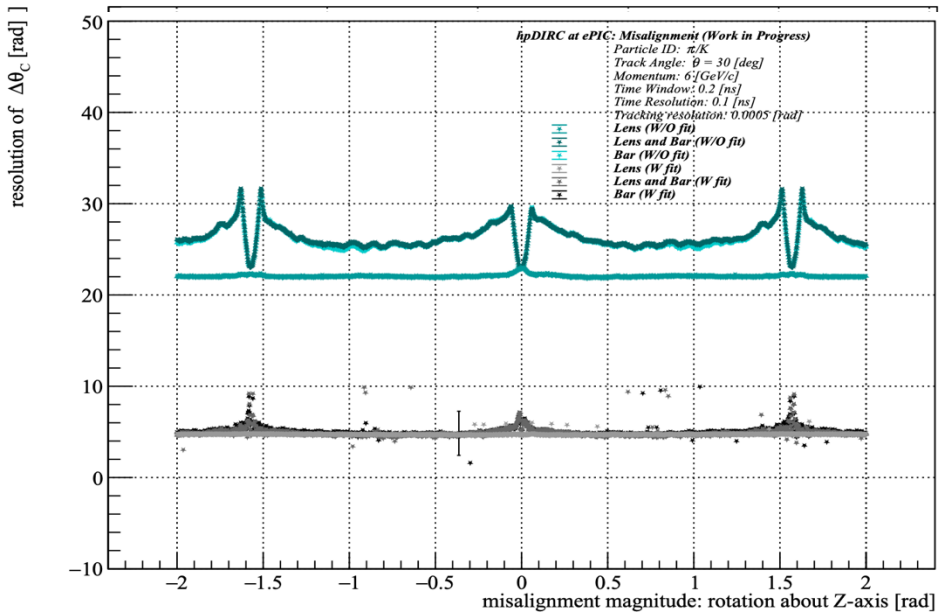


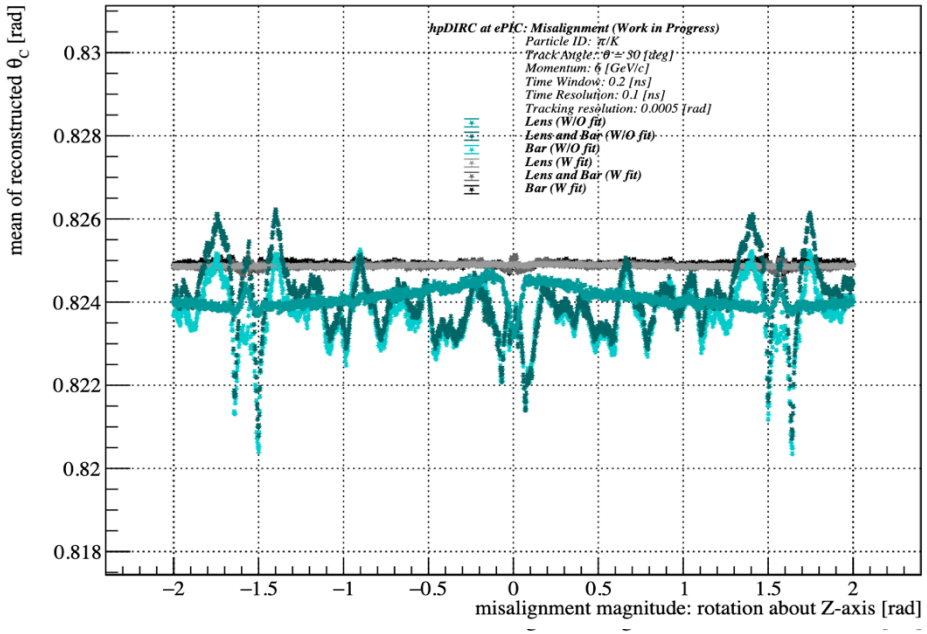


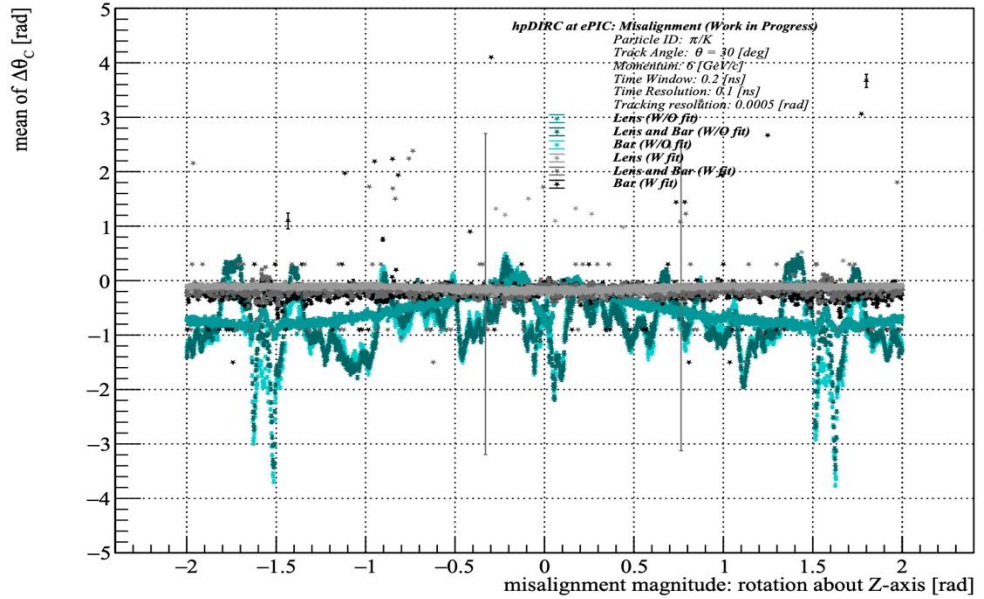


Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Pion only:



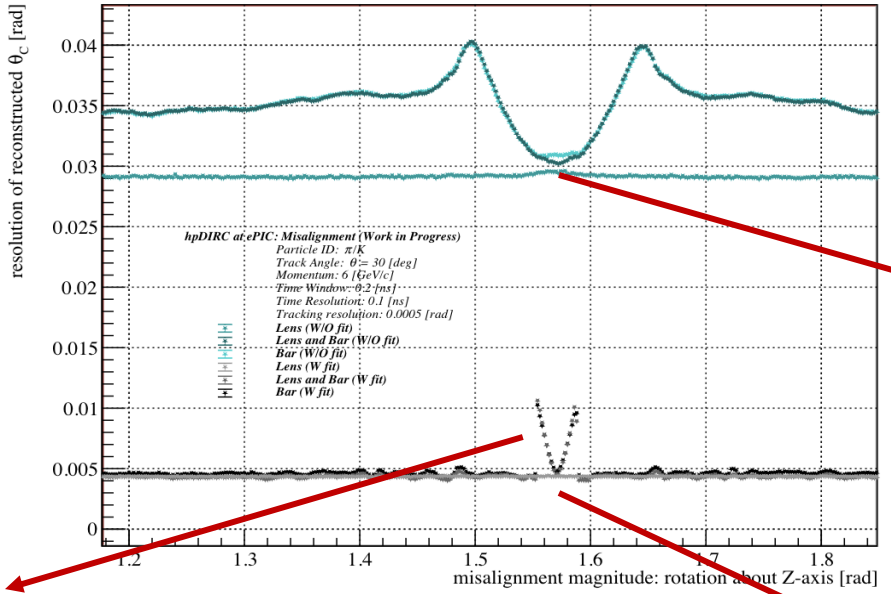


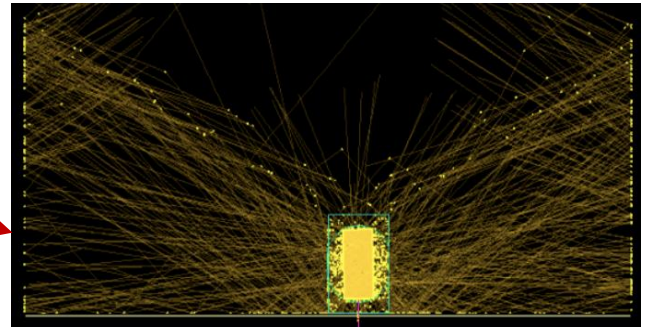




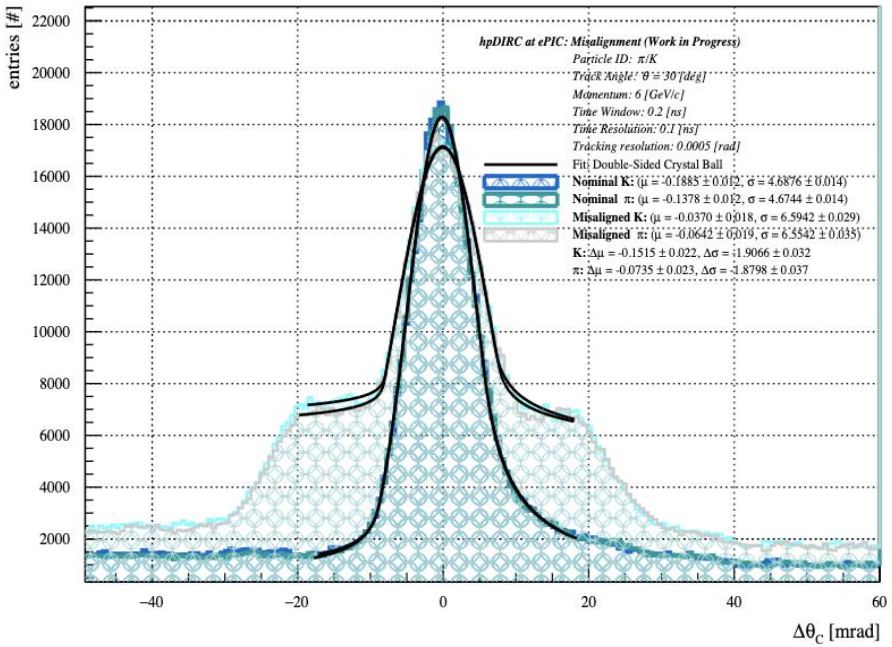
Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Pion only:

zoomed-in for the Positive direction:

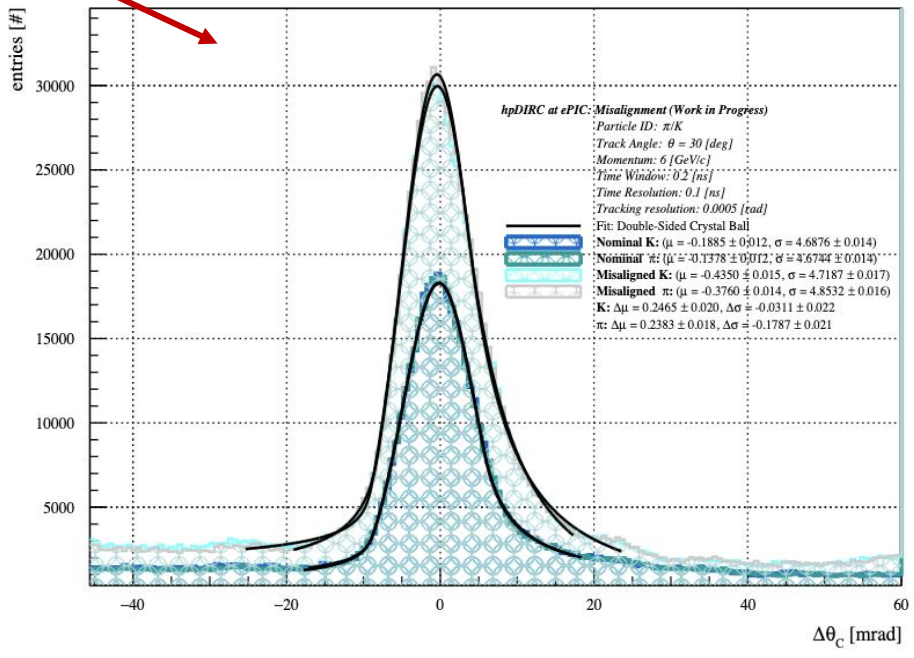




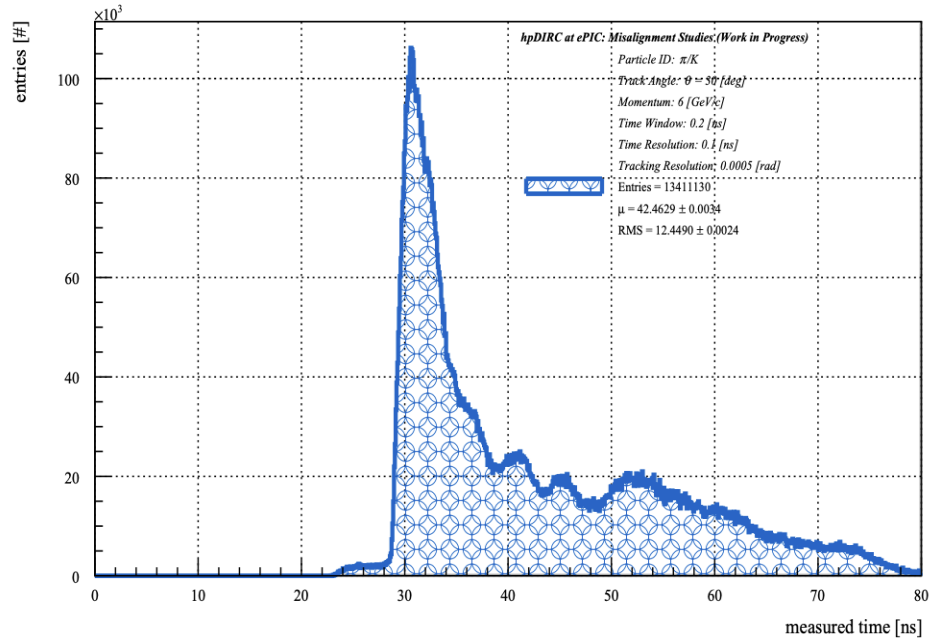
misaligned detector (rotation bar around z with 1.550 rad)

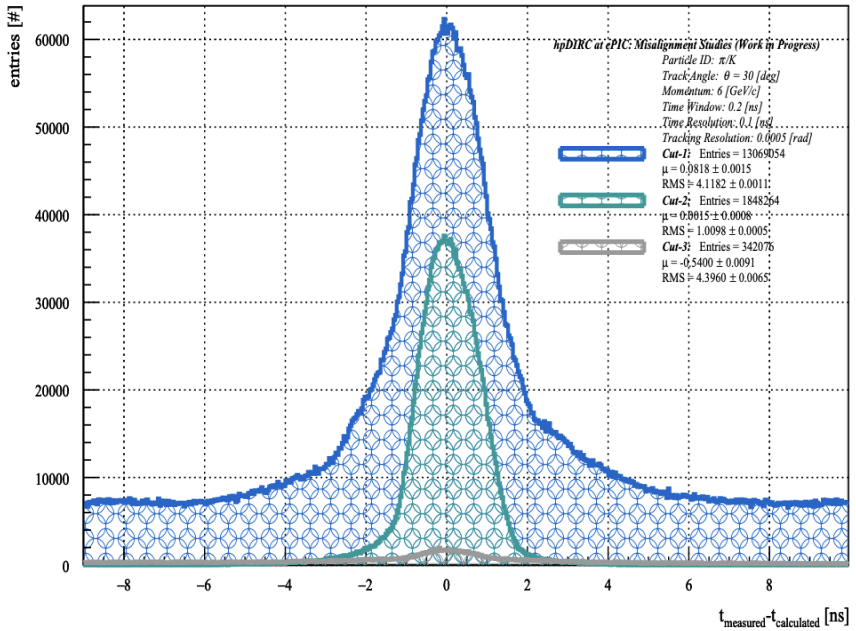


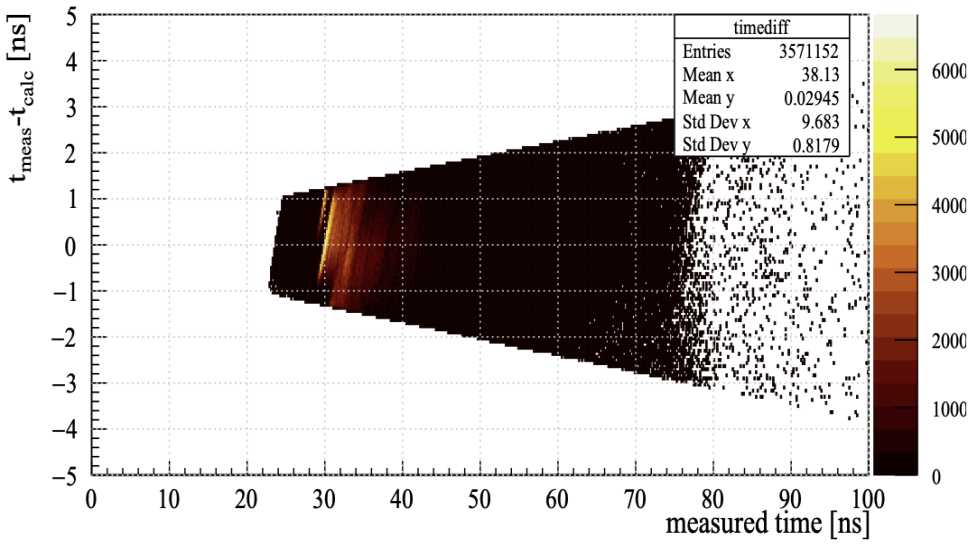
misaligned detector (rotation bar around z with 1.570 rad)

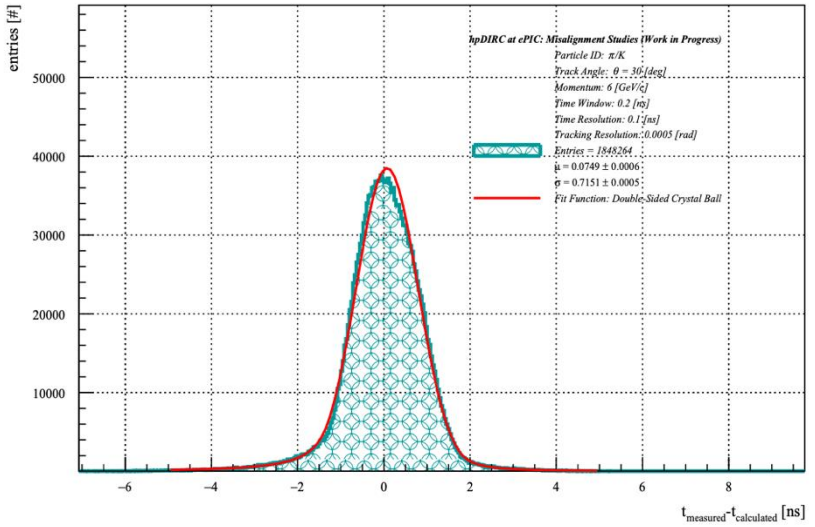


Timing-Imaging Method: Nominal Detector Configuration

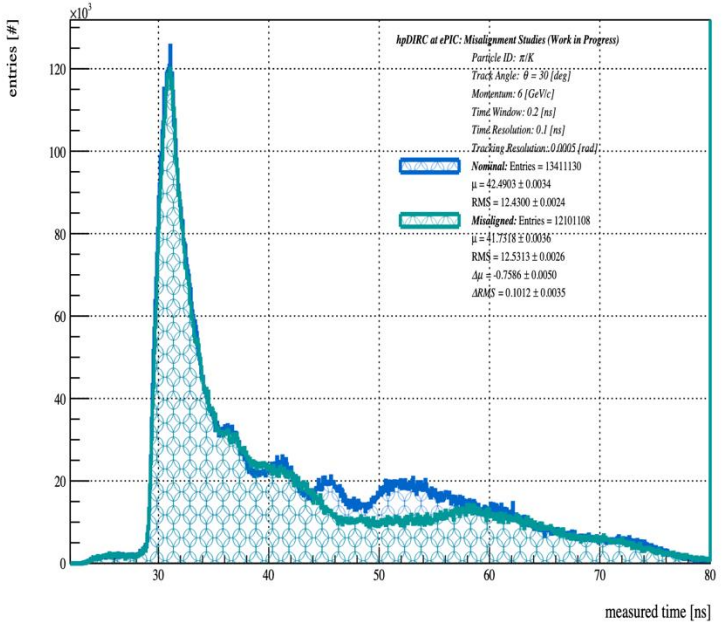


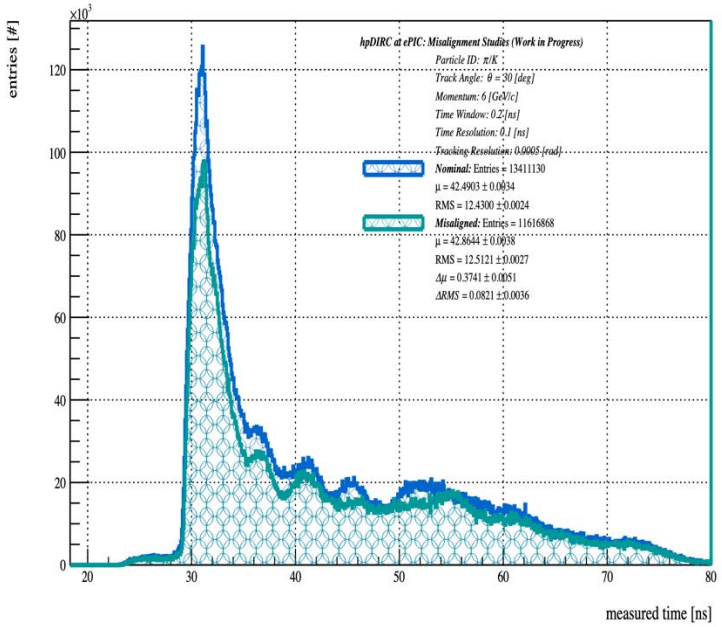


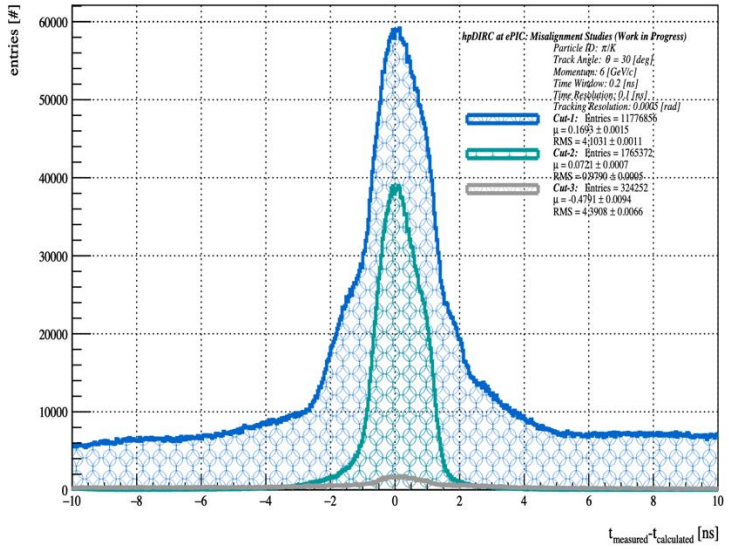


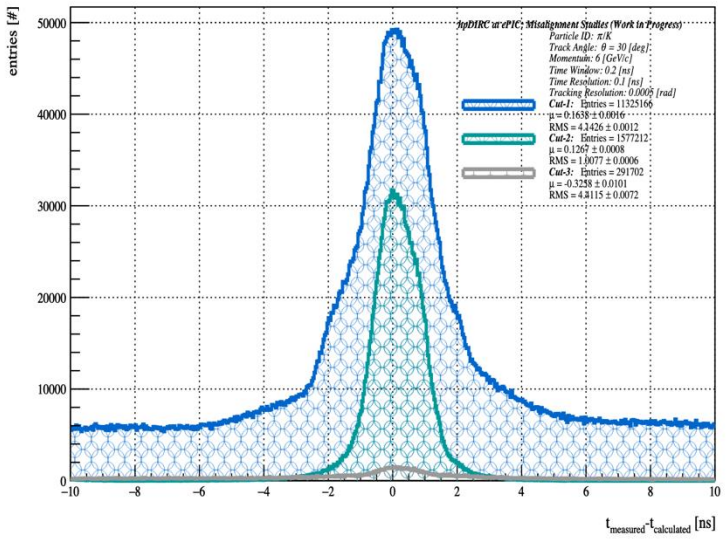


Timing-Imaging Method: Nominal and Misalignment Detector Configuration







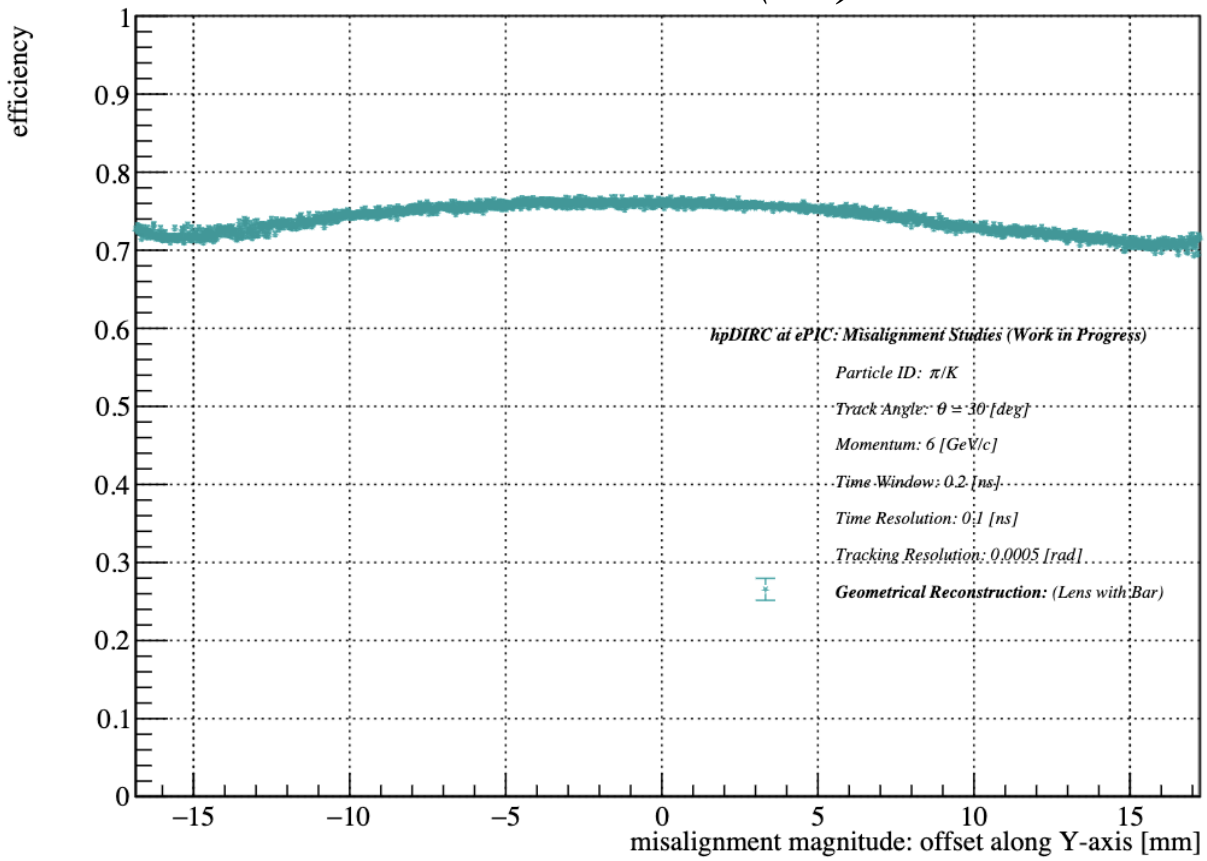


- *Top left: Photon arrival time for a detector with a 0.04 rad rotation of the bar around the z-axis.*
- *Top right: Time distribution for a detector with a 7.2 mm lens shift along the y-direction.*
- *Bottom left: Timing residual for the bar rotation misalignment.*
- *Bottom right: Timing residual for the lens offset along the y-direction.*

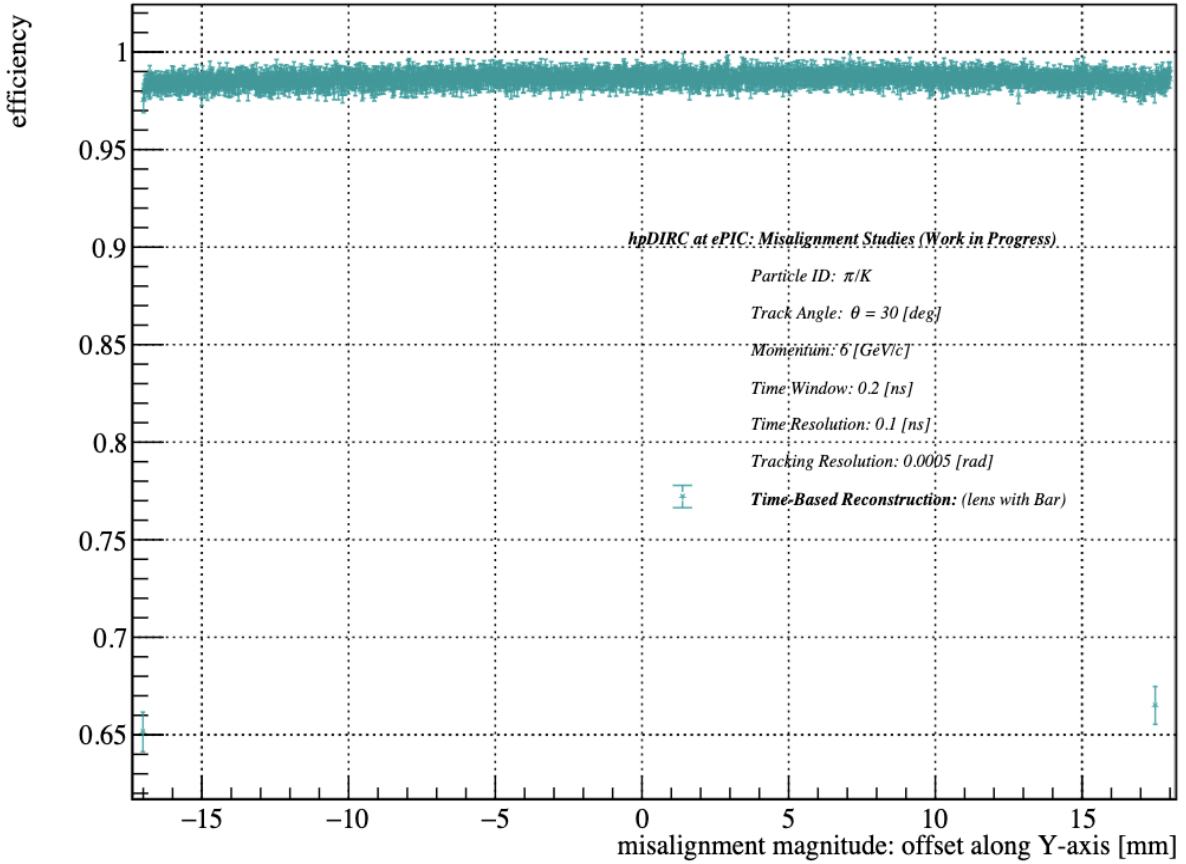
Photon Yield Efficiency:

Detected photon efficiency: $\epsilon = \frac{\langle N_{\text{Reco}} \rangle}{\langle N_{\text{Sim}} \rangle}$

Geometric Reconstruction (GR) method

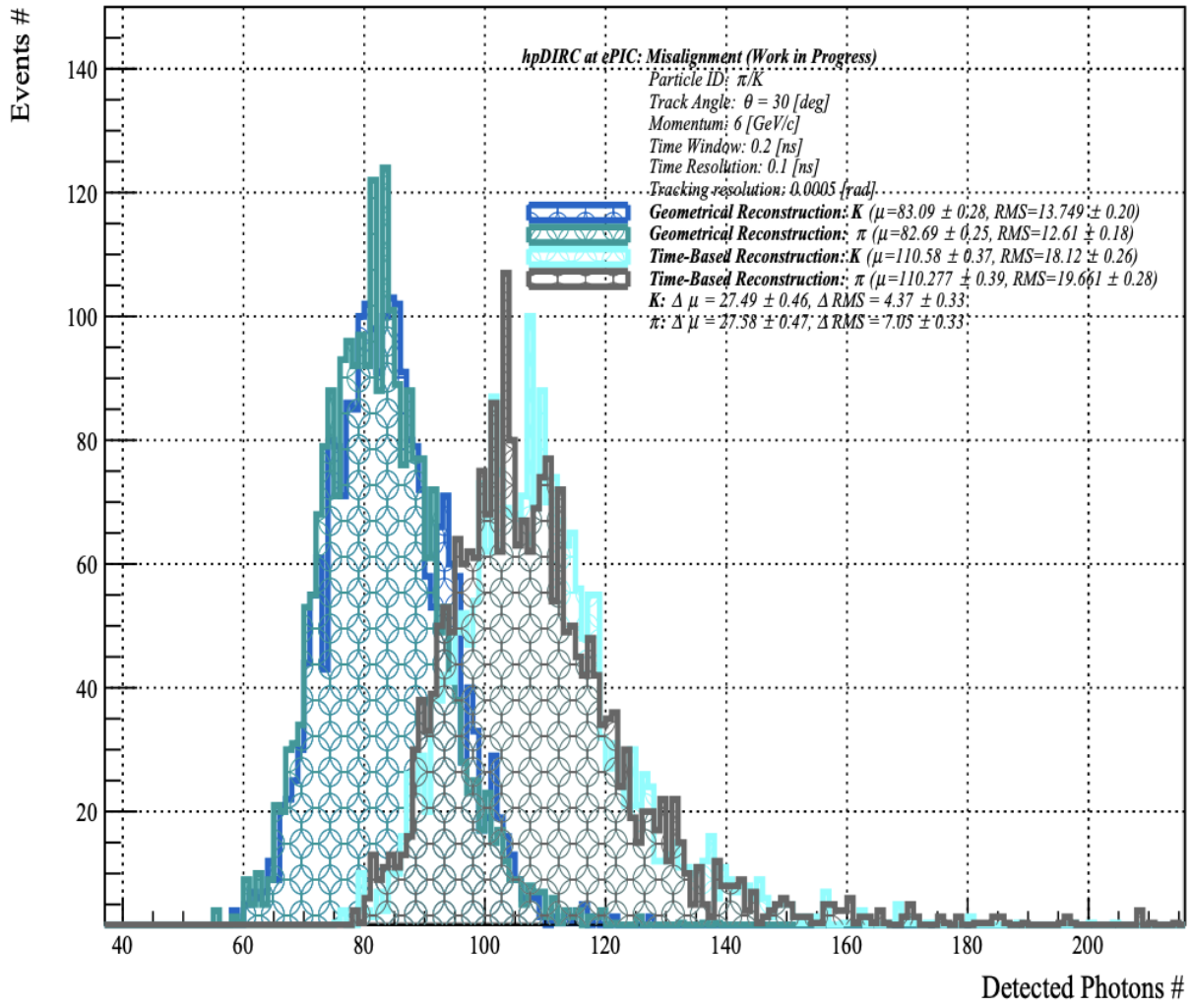


Timing imaging Reconstruction (TI) method

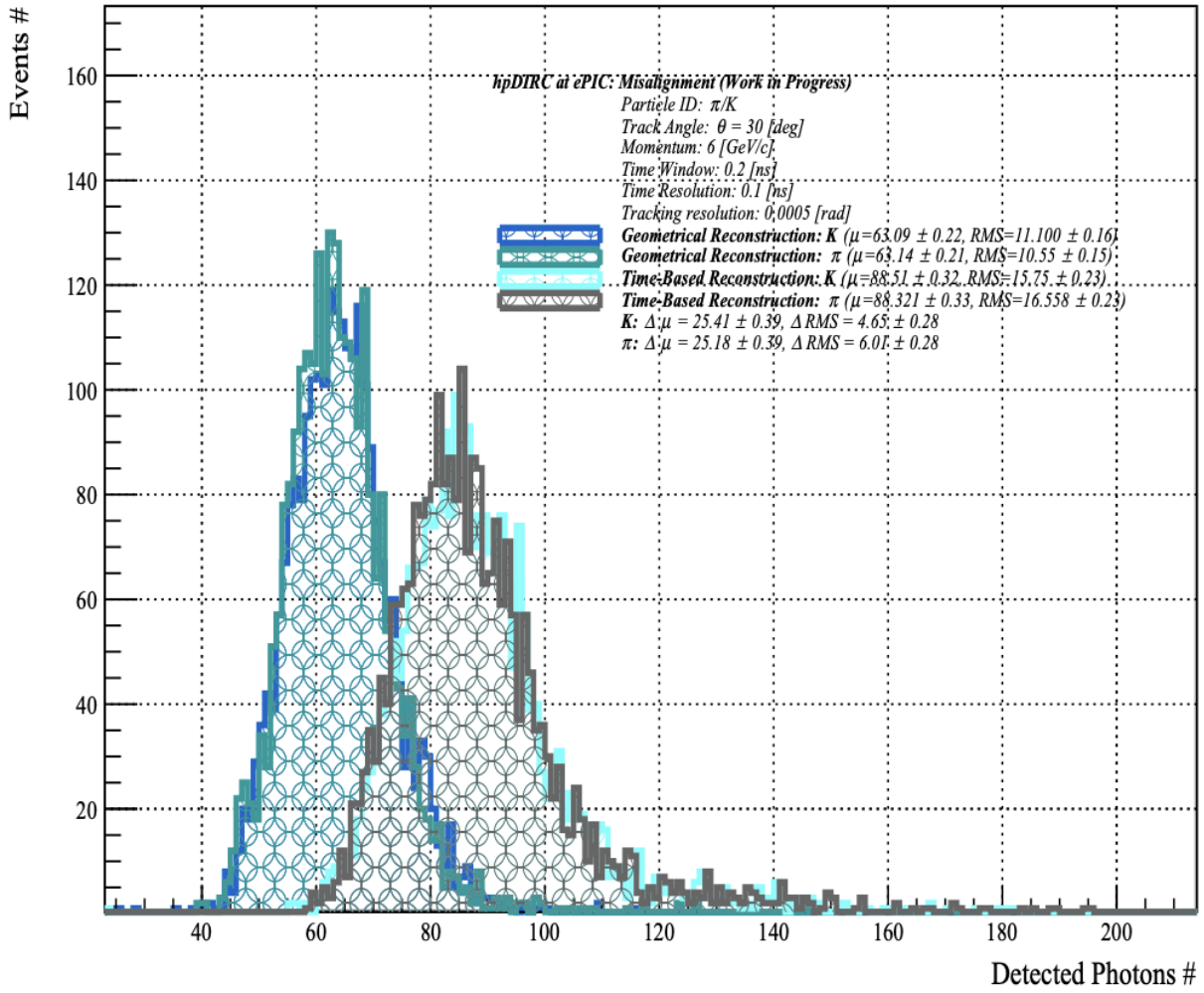


Reconstructed Photon Yield :

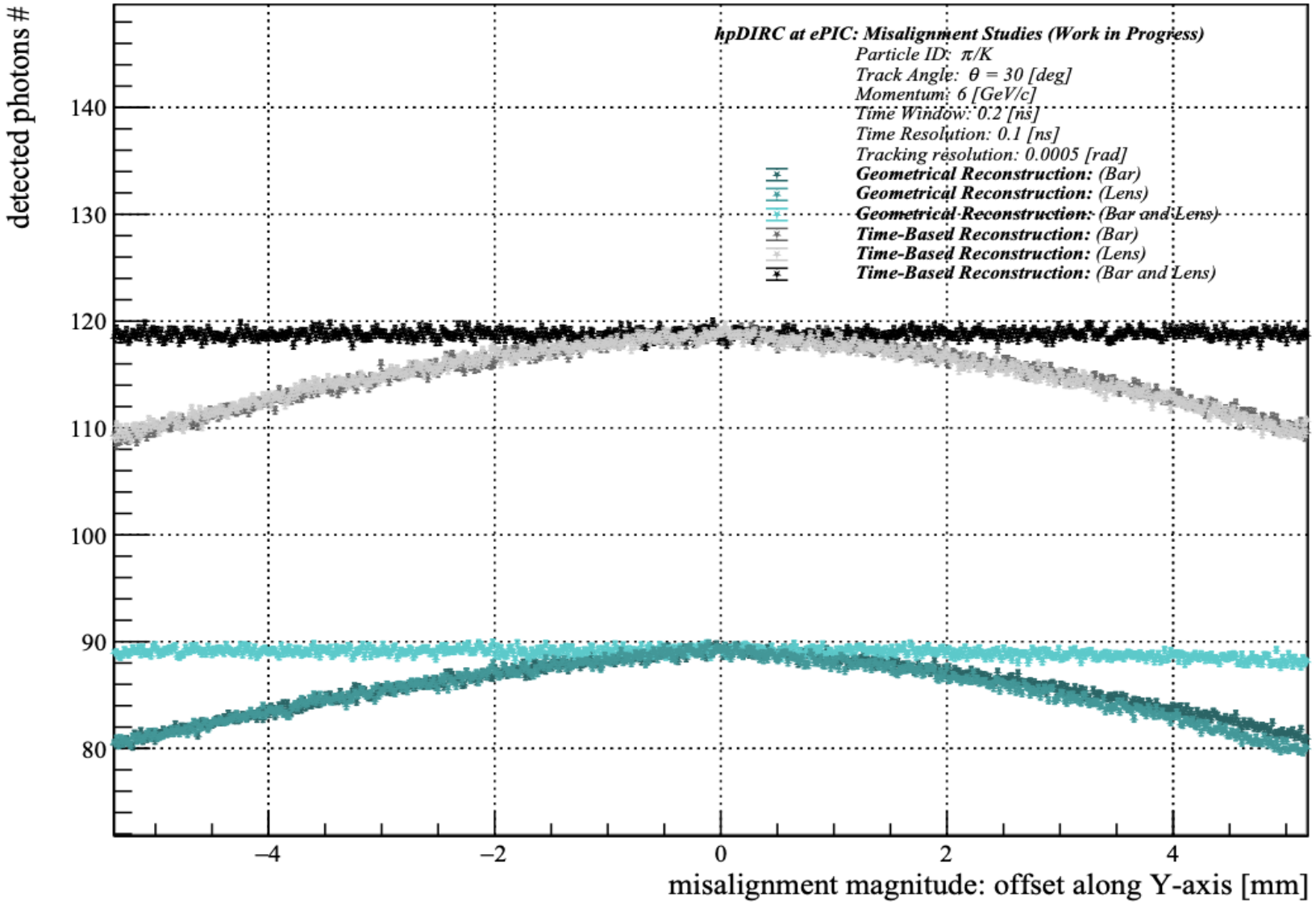
Nominal detector; GR and TI method



Misaligned detector; GR and TI method

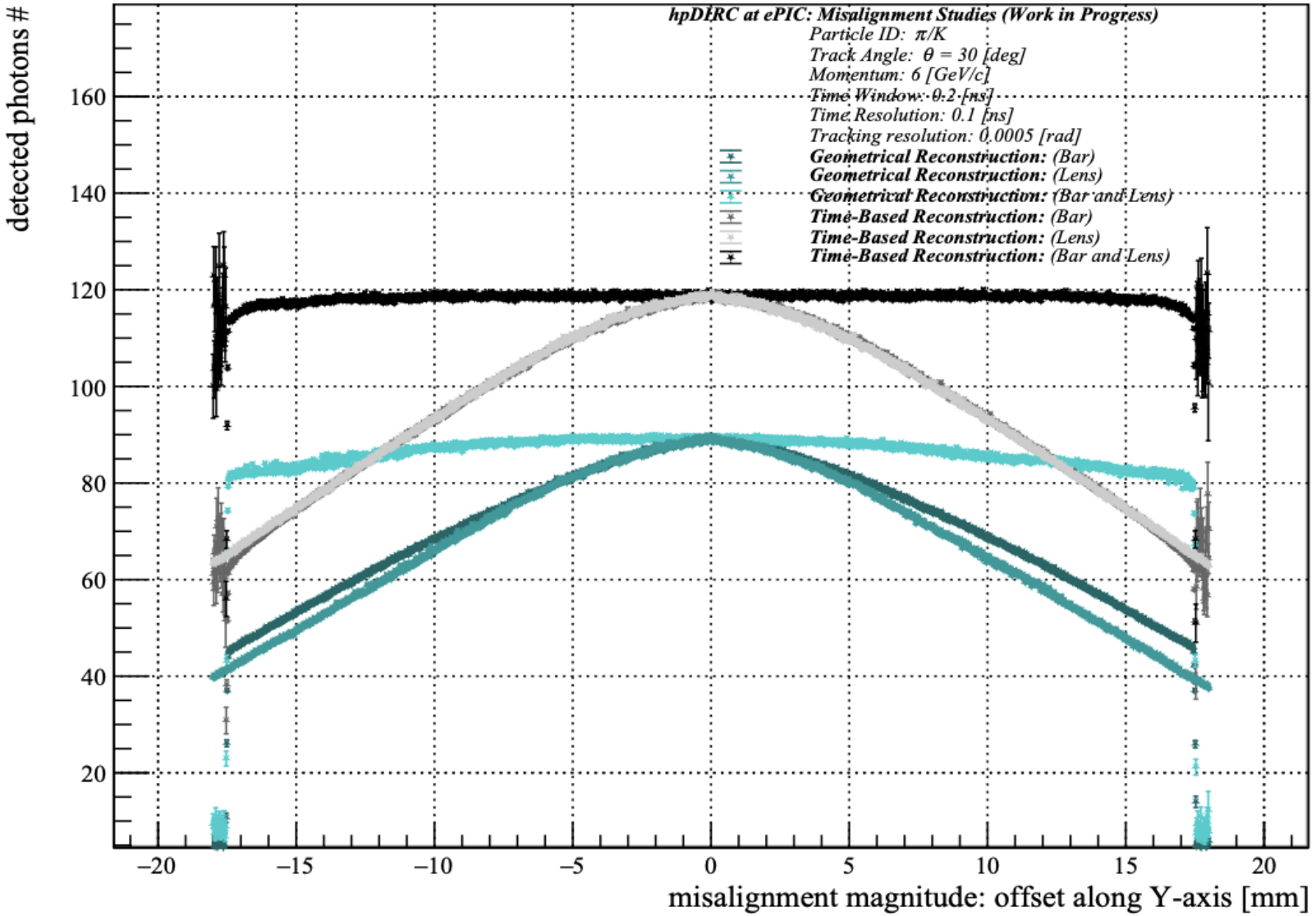


Reconstructed Photon Yield :



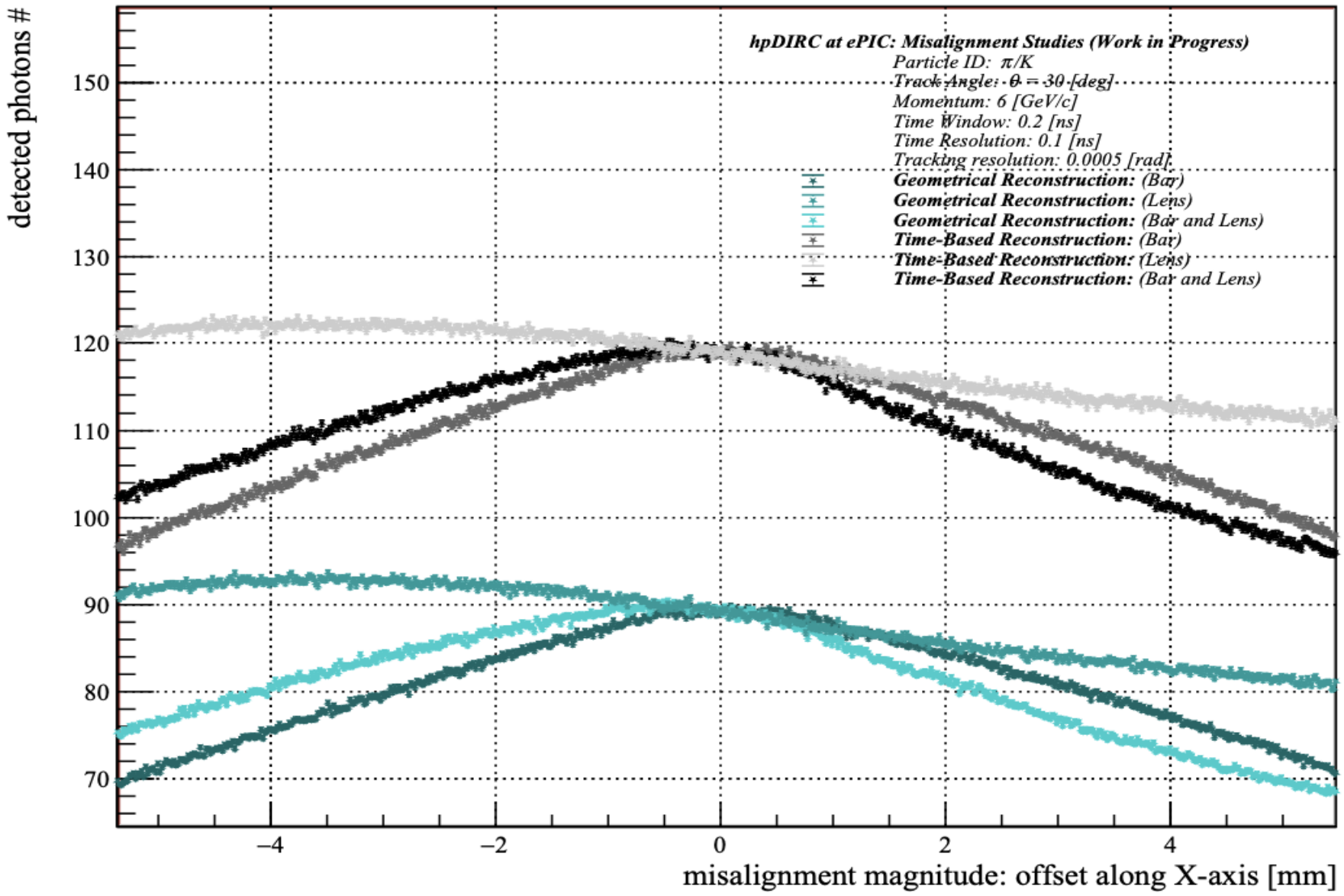
- *Checking all three misaligned scenarios in misaligned mode: which is offset along Y axis*
- *Detected photon # is decreased rapidly after 18 mm with increased the misalignment values specially for the bar and lenses while stable for the combined*
- *Photon # in the TI is better than GR method*

Reconstructed Photon Yield :



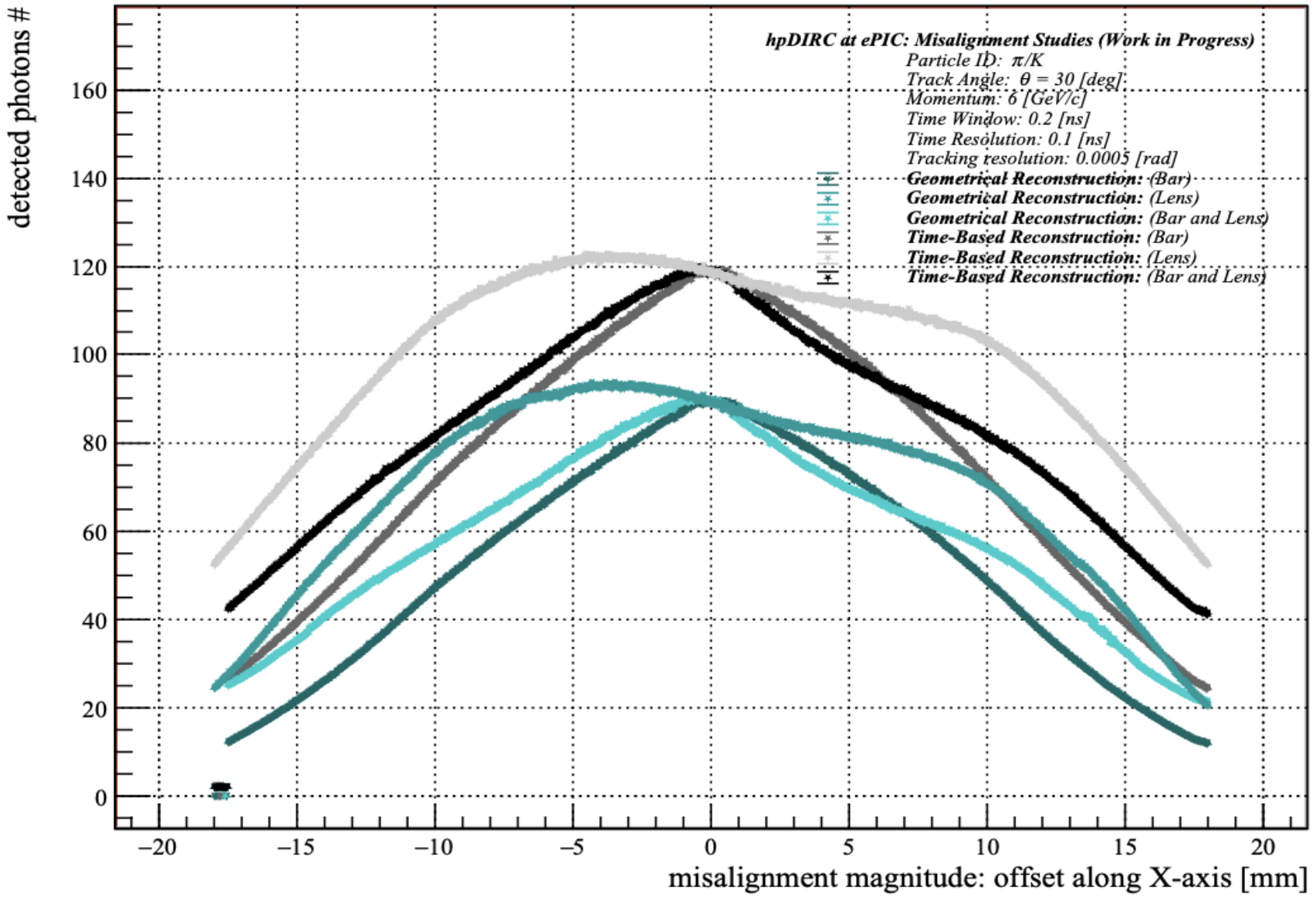
- *Checking all three misaligned scenarios in misaligned mode: which is offset along Y axis*
- *Detected photon # is decreased rapidly after 18 mm with increased the misalignment values specially for the bar and lenses while stable for the combined*
- *Photon # in the TI is better than GR method*

Reconstructed Photon Yield :



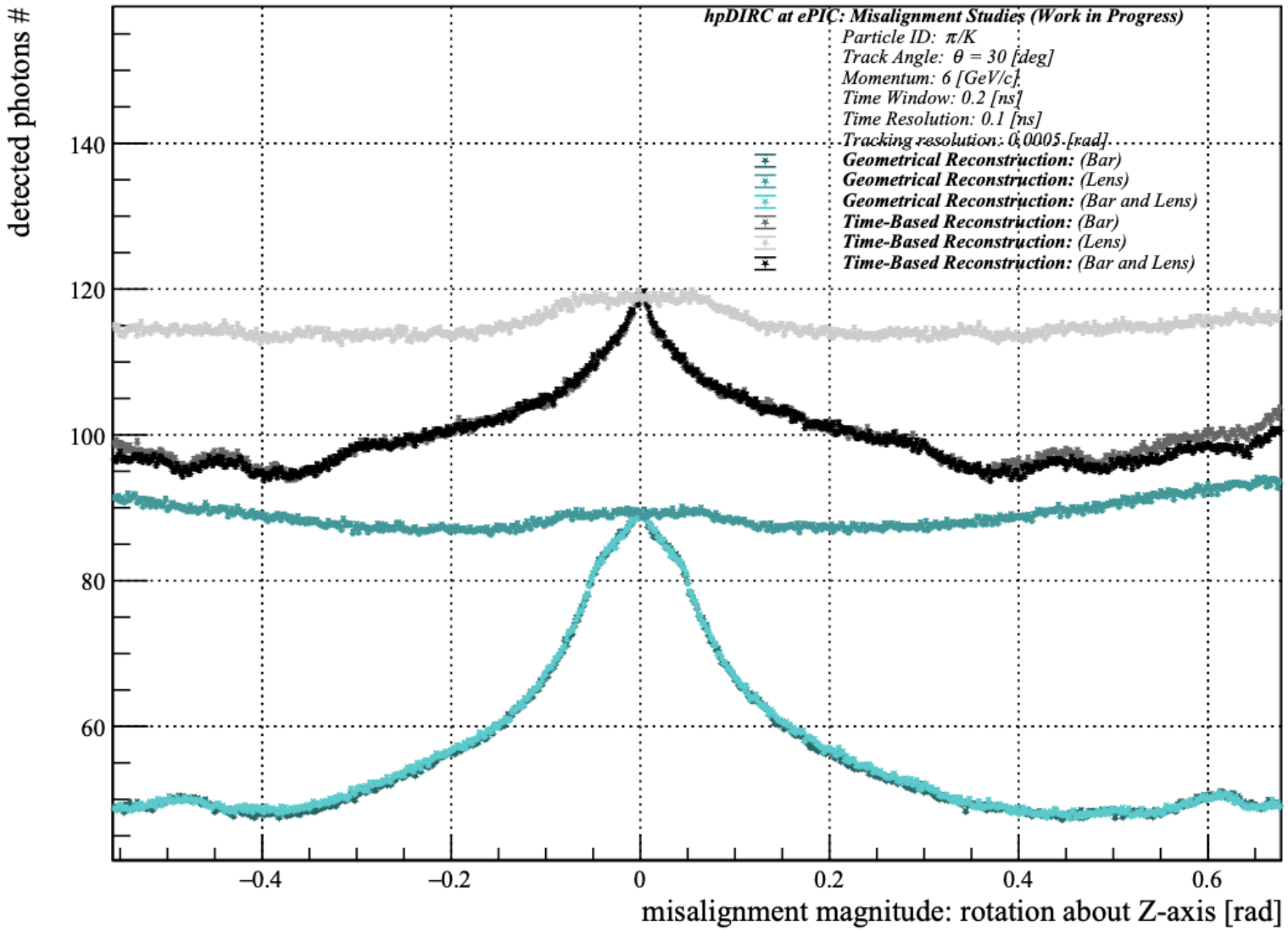
- *Checking all three misaligned scenarios in misaligned mode: which is offset along X axis*
- *Detected photon # is decreased rapidly after 18 mm with increased the misalignment values*
- *Photon # in the TI is better than GR method*

Reconstructed Photon Yield :

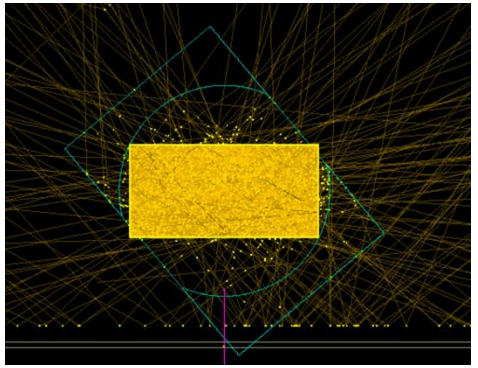


- *Checking all three misaligned scenarios in misaligned mode: which is offset along X axis*
- *Detected photon # is decreased rapidly after 18 mm with increased the misalignment values*
- *Photon # in the TI is better than GR method*

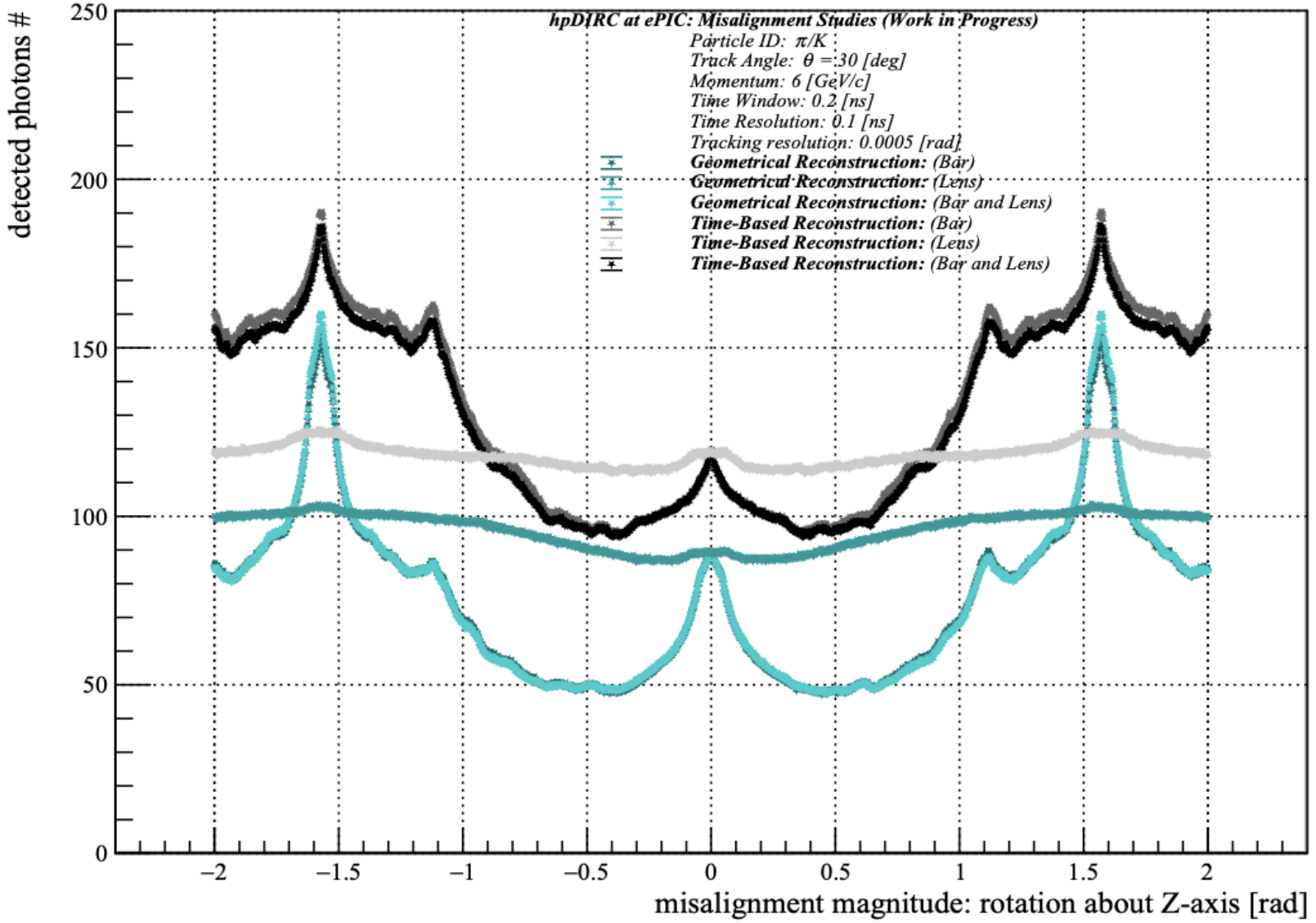
Reconstructed Photon Yield :



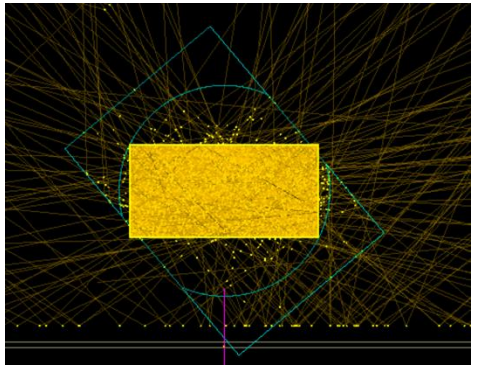
- *Checking all three misaligned scenarios in misaligned mode: which is rotation around Z axis*
- *Detected photon # is decreased quickly and back to increase while the rotation of lenses are stable*
- *Photon # in the TI is better than GR method*



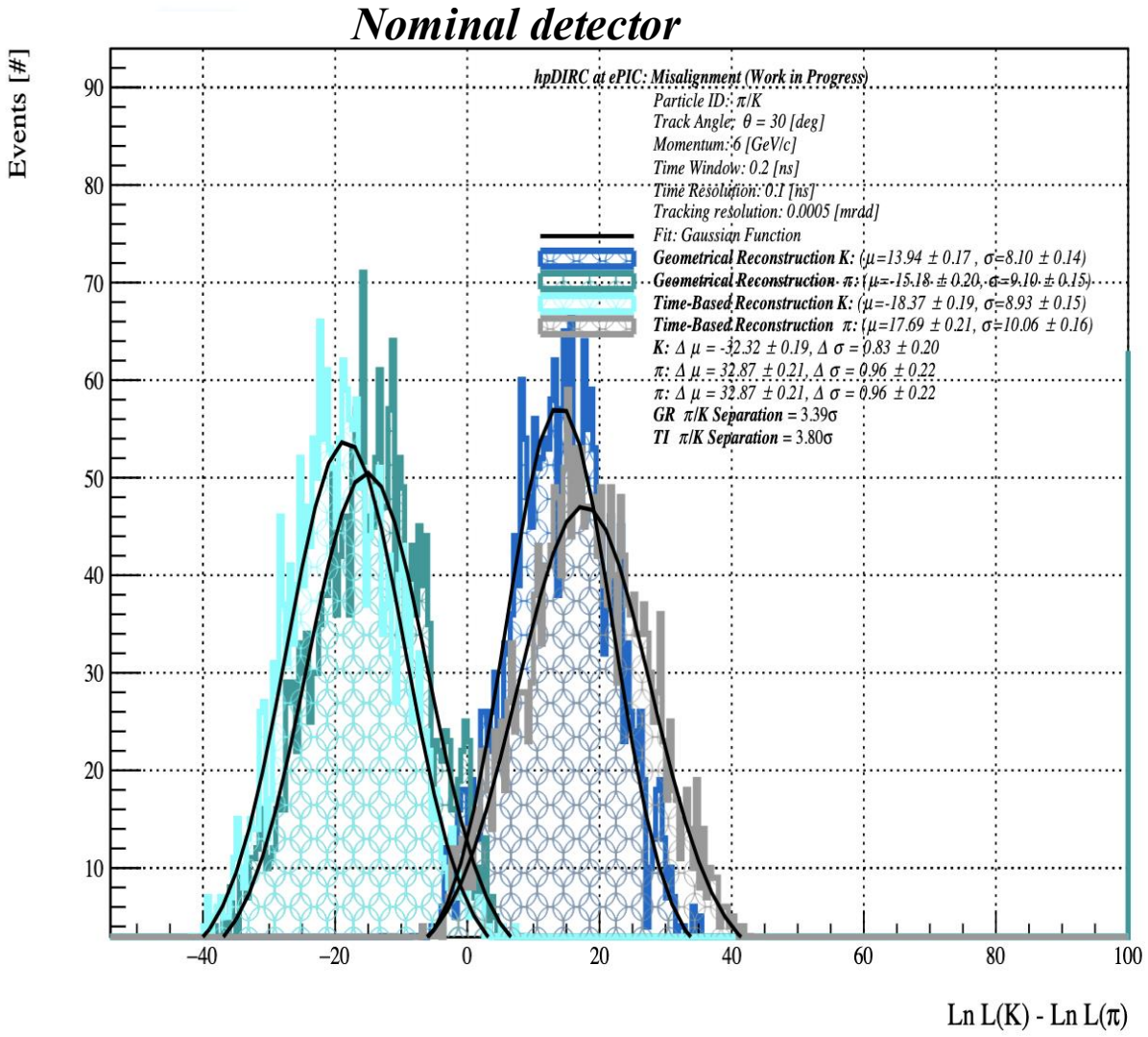
Reconstructed Photon Yield :

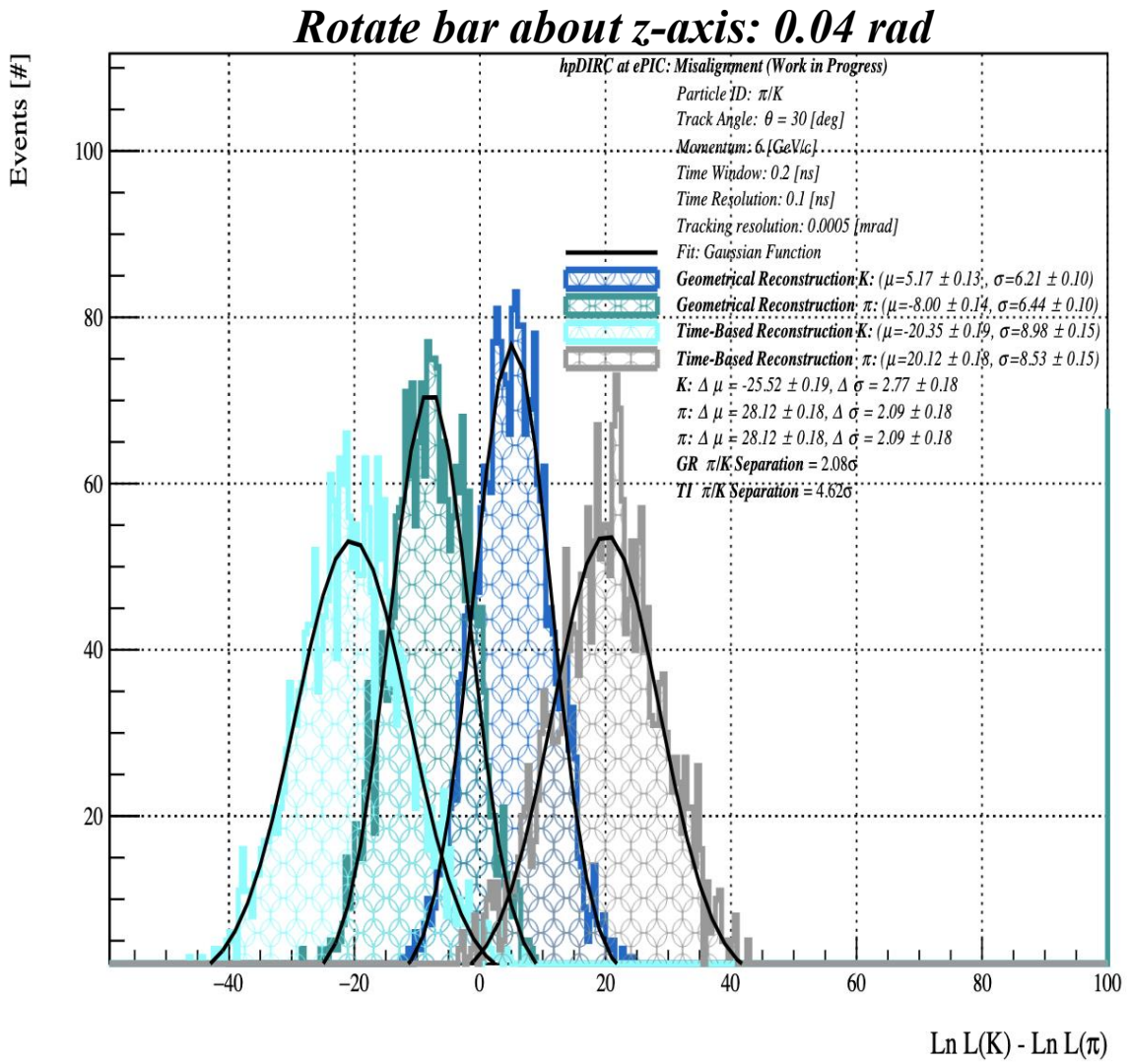


- *Checking all three misaligned scenarios in misaligned mode: which is rotation around Z axis*
- *Detected photon # is decreased quickly and back to increase while the rotation of lenses are stable*
- *Photon # in the TI is better than GR method*

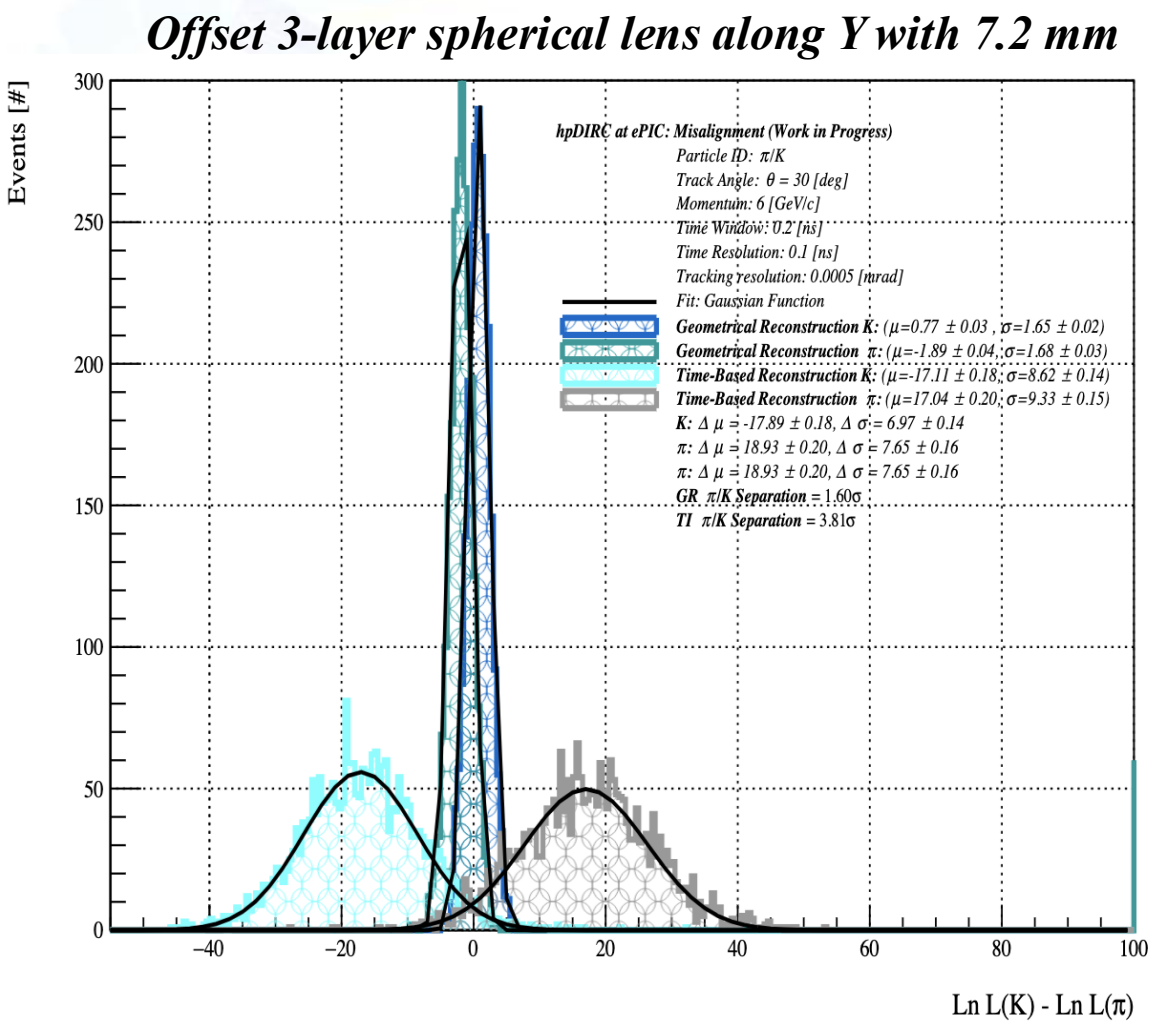


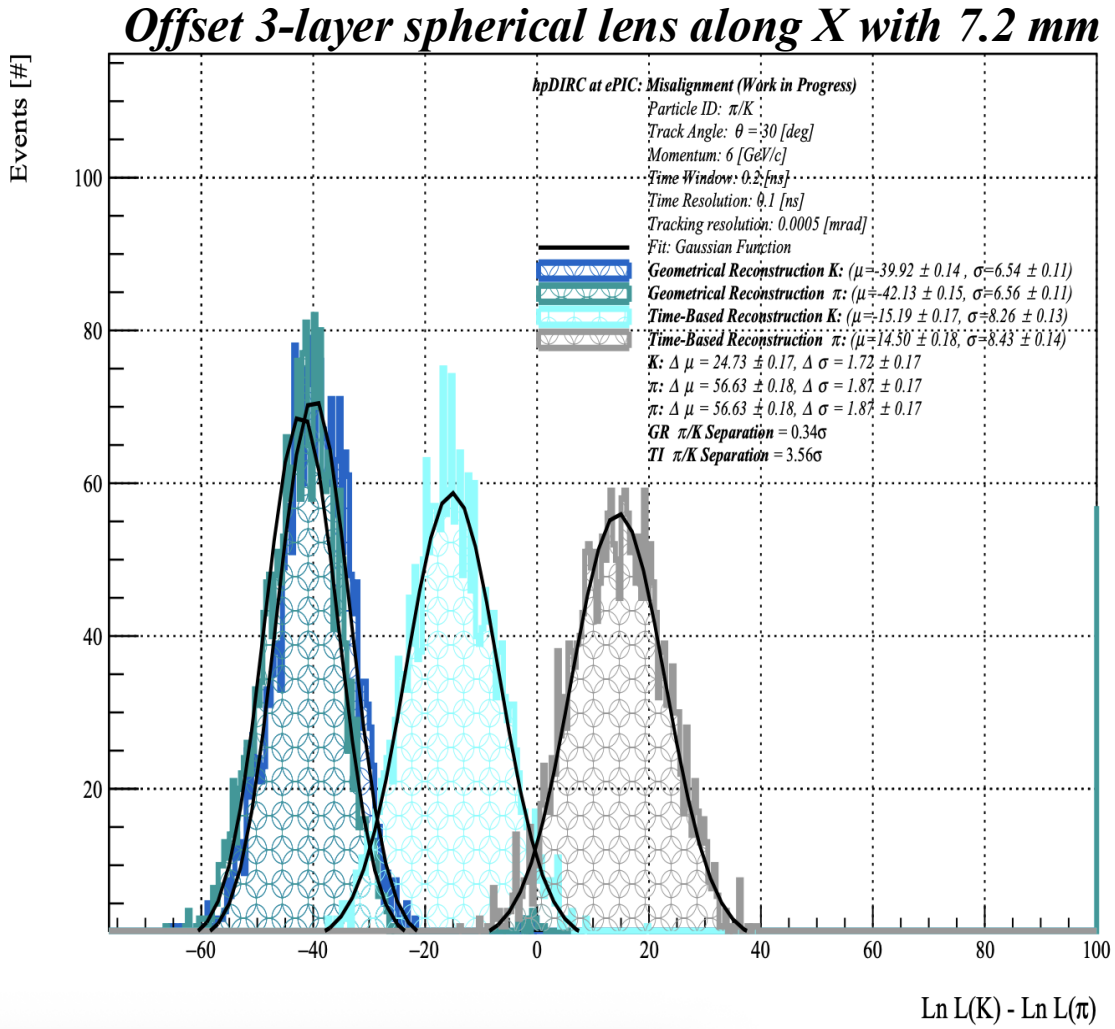
Separation Power between Kaon (K) and Pion (π):



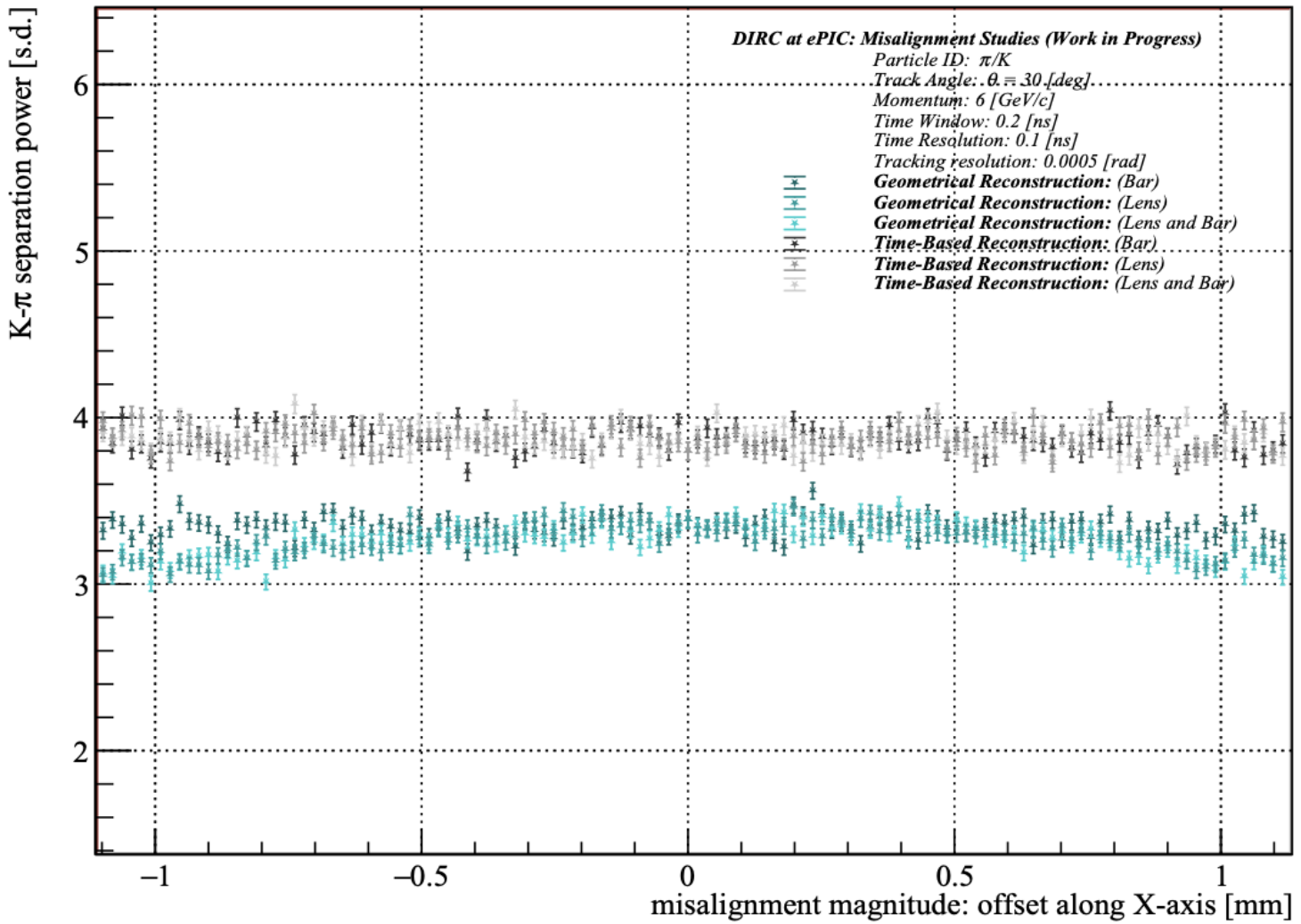


Separation Power between Kaon (K) and Pion (π):



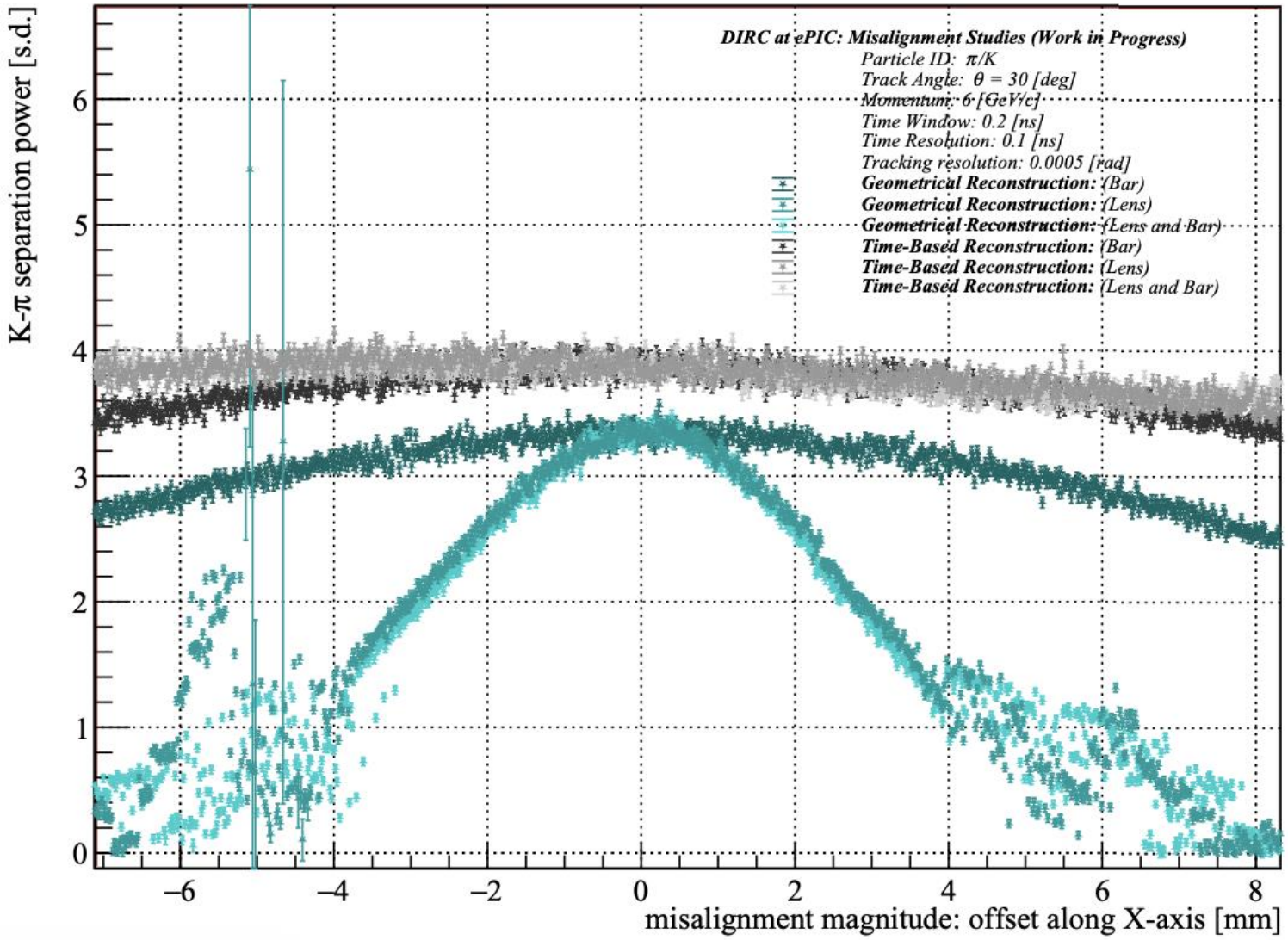


Separation Power between Kaon (K) and Pion (π):



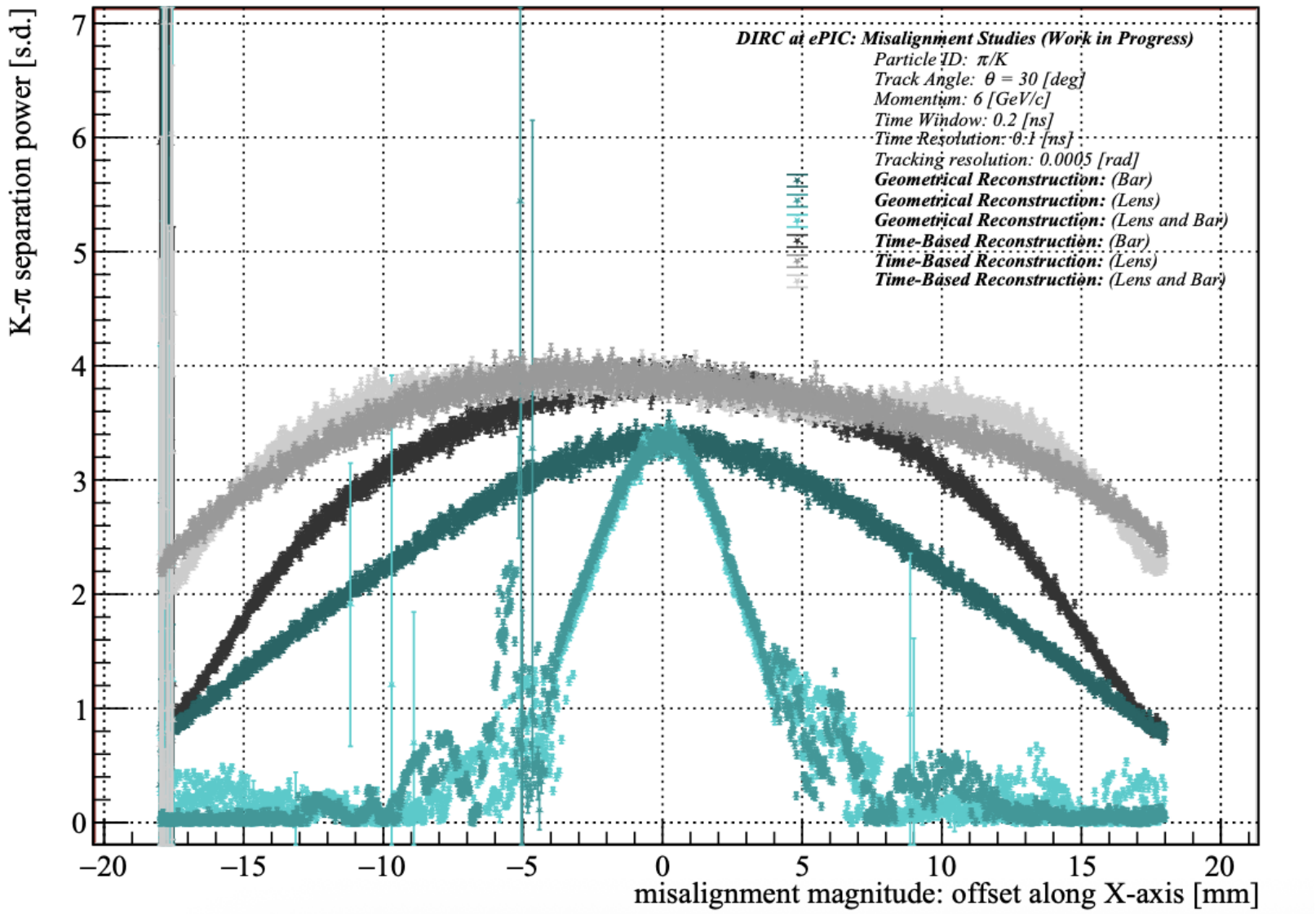
- *Checking all three misaligned scenarios in misaligned mode: which is offset along X axis*
- *SPR is decreased quickly specially with lenses and combined misalignment*
- *SPR is better for misalignment in TI method*
- *SPR for the nominal is not above 4 due to the idealized configuration (azimuthal angle)*

Separation Power between Kaon (K) and Pion (π):



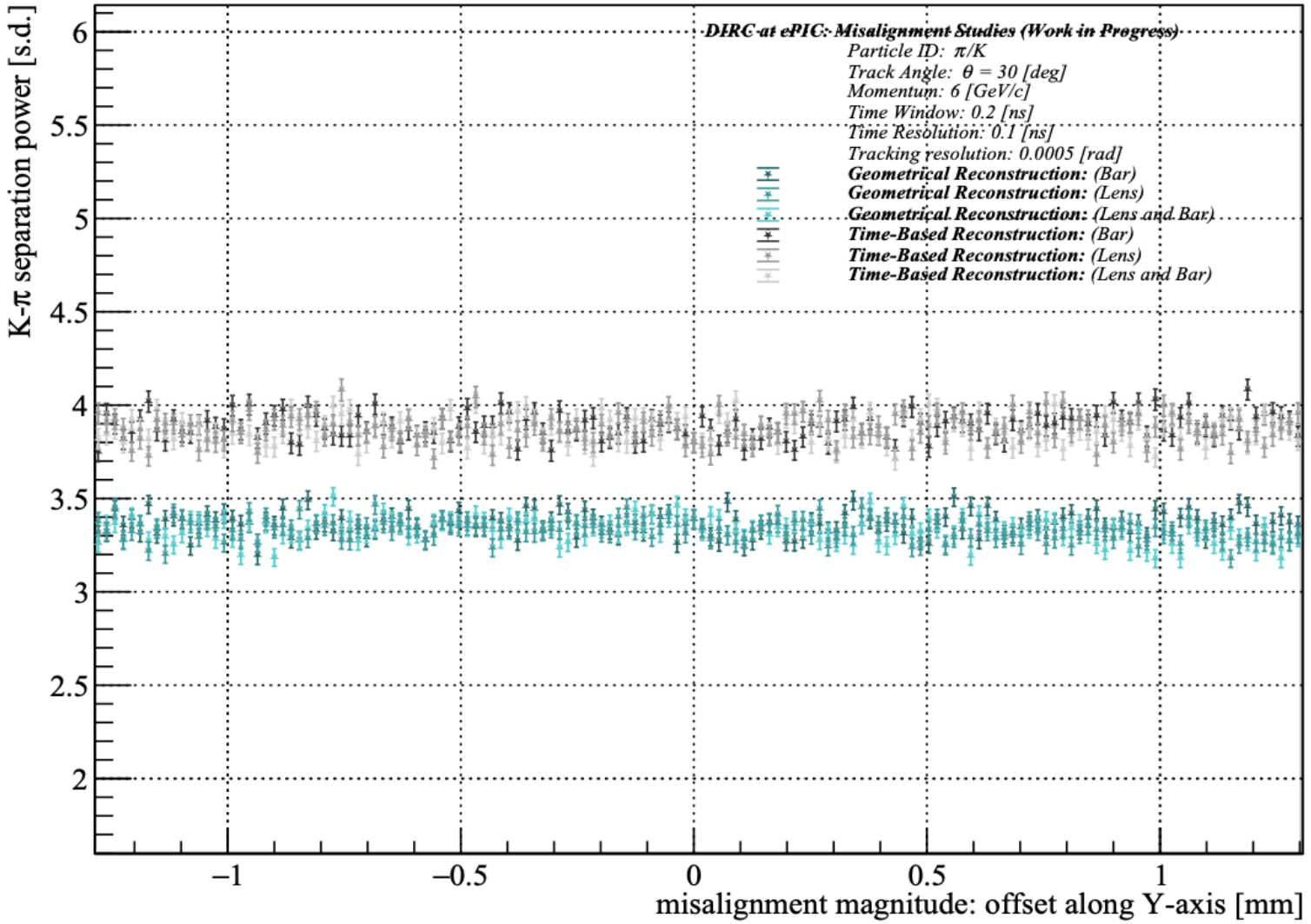
- *Checking all three misaligned scenarios in misaligned mode: which is offset along X axis*
- *SPR is decreased quickly specially with lenses and combined misalignment*
- *SPR is better for misalignment in TI method*

Separation Power between Kaon (K) and Pion (π):



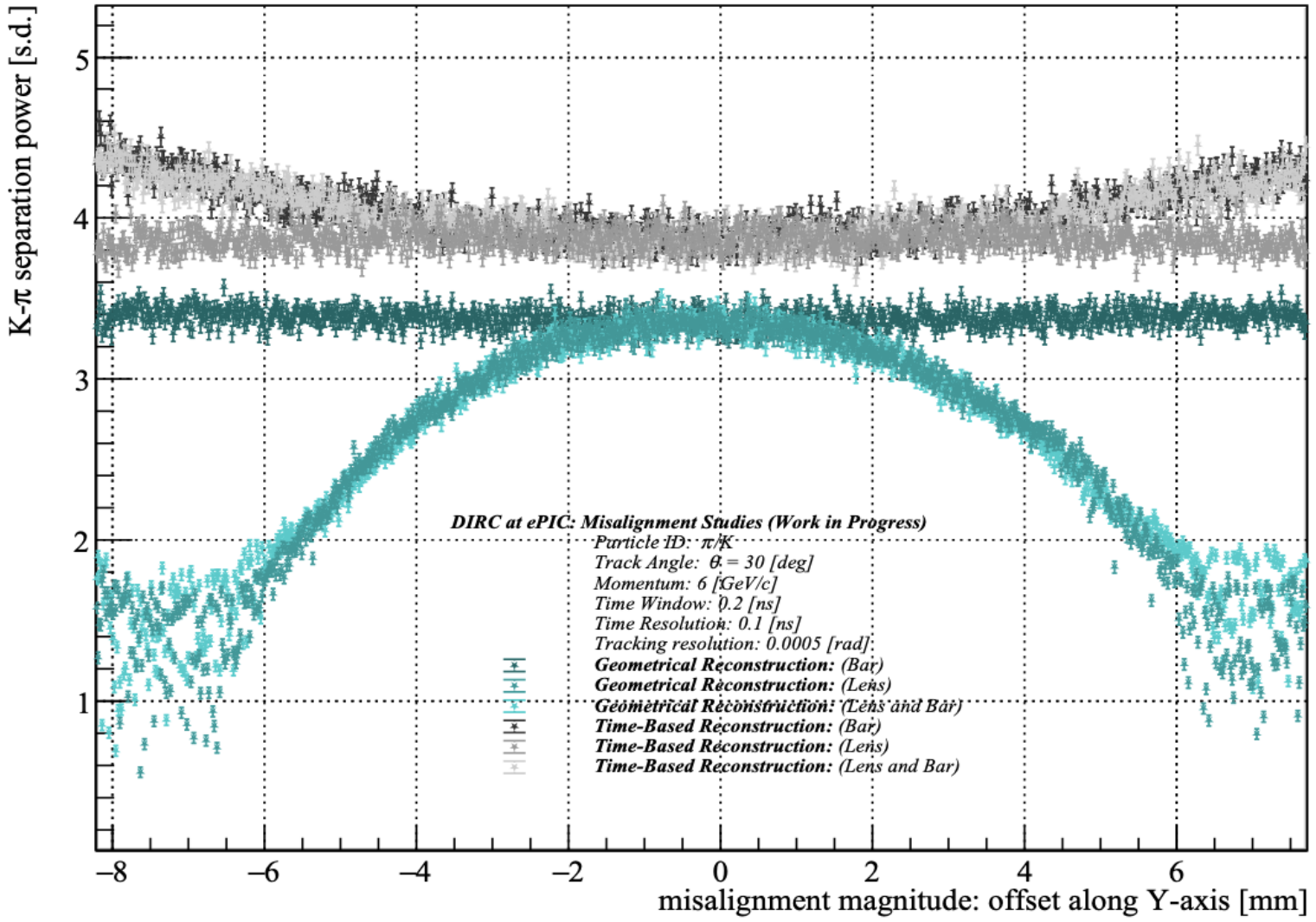
- *Checking all three misaligned scenarios in misaligned mode: which is offset along X axis*
- *SPR is decreased quickly specially with lenses and combined misalignment*
- *SPR is better for misalignment in TI method*

Separation Power between Kaon (K) and Pion (π):



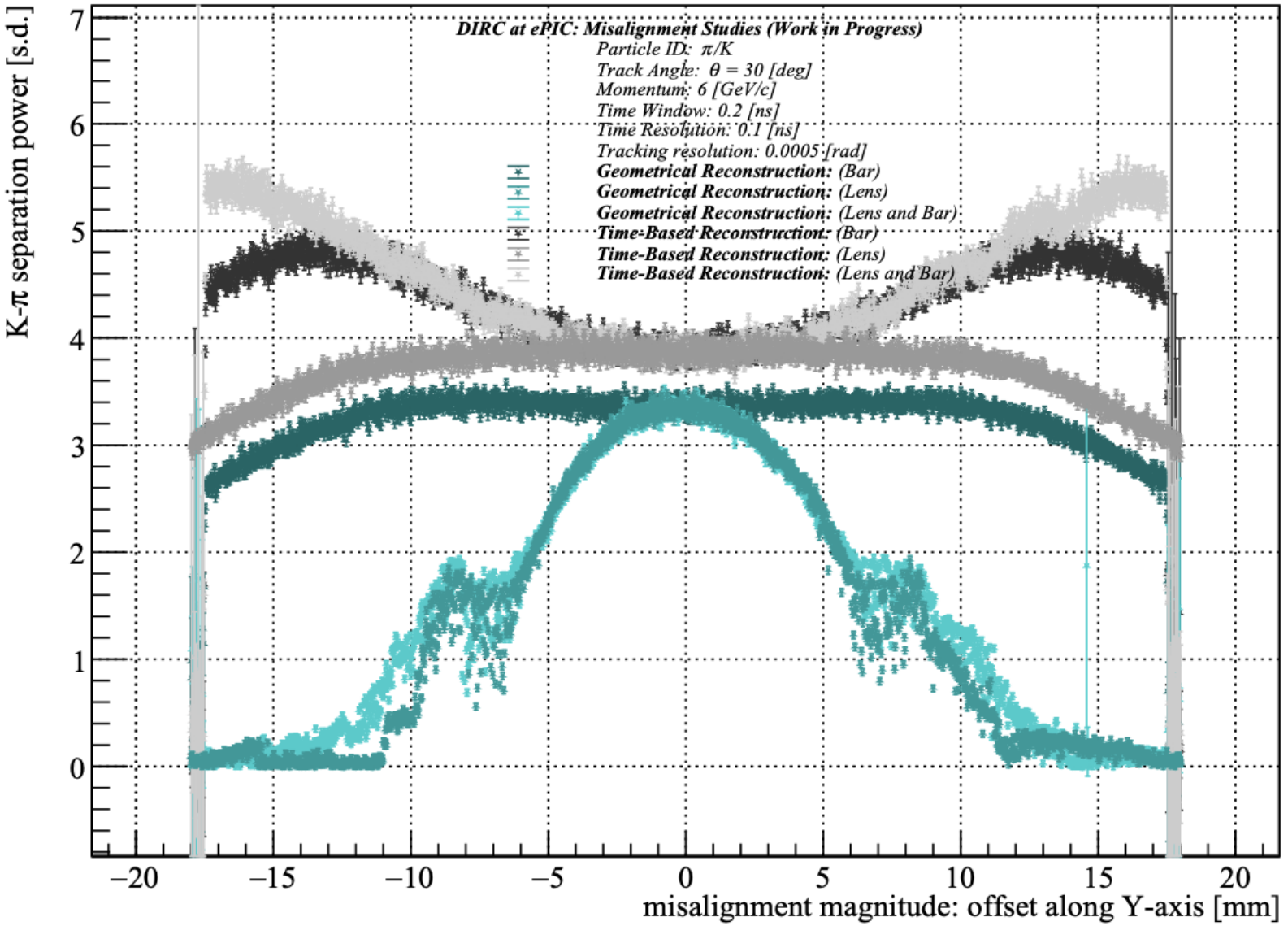
- *Checking all three misaligned scenarios in misaligned mode: which is offset along X axis*
- *SPR is decreased not quickly as X offset*
- *SPR is better for misalignment in TI method*

Separation Power between Kaon (K) and Pion (π):



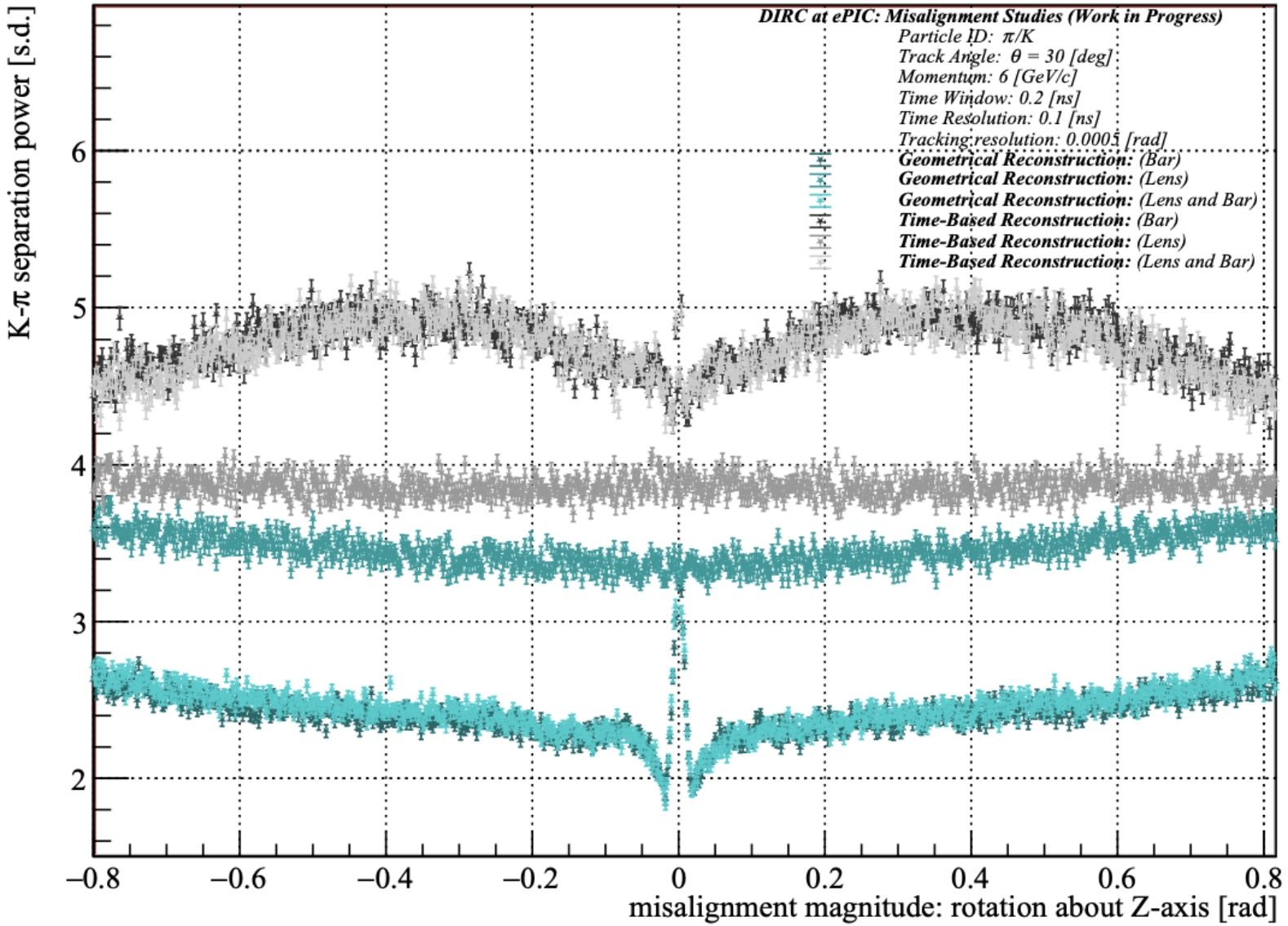
- *Checking all three misaligned scenarios in misaligned mode: which is offset along X axis*
- *SPR is decreased not quickly as X offset*
- *SPR is better for misalignment in TI method*

Separation Power between Kaon (K) and Pion (π):



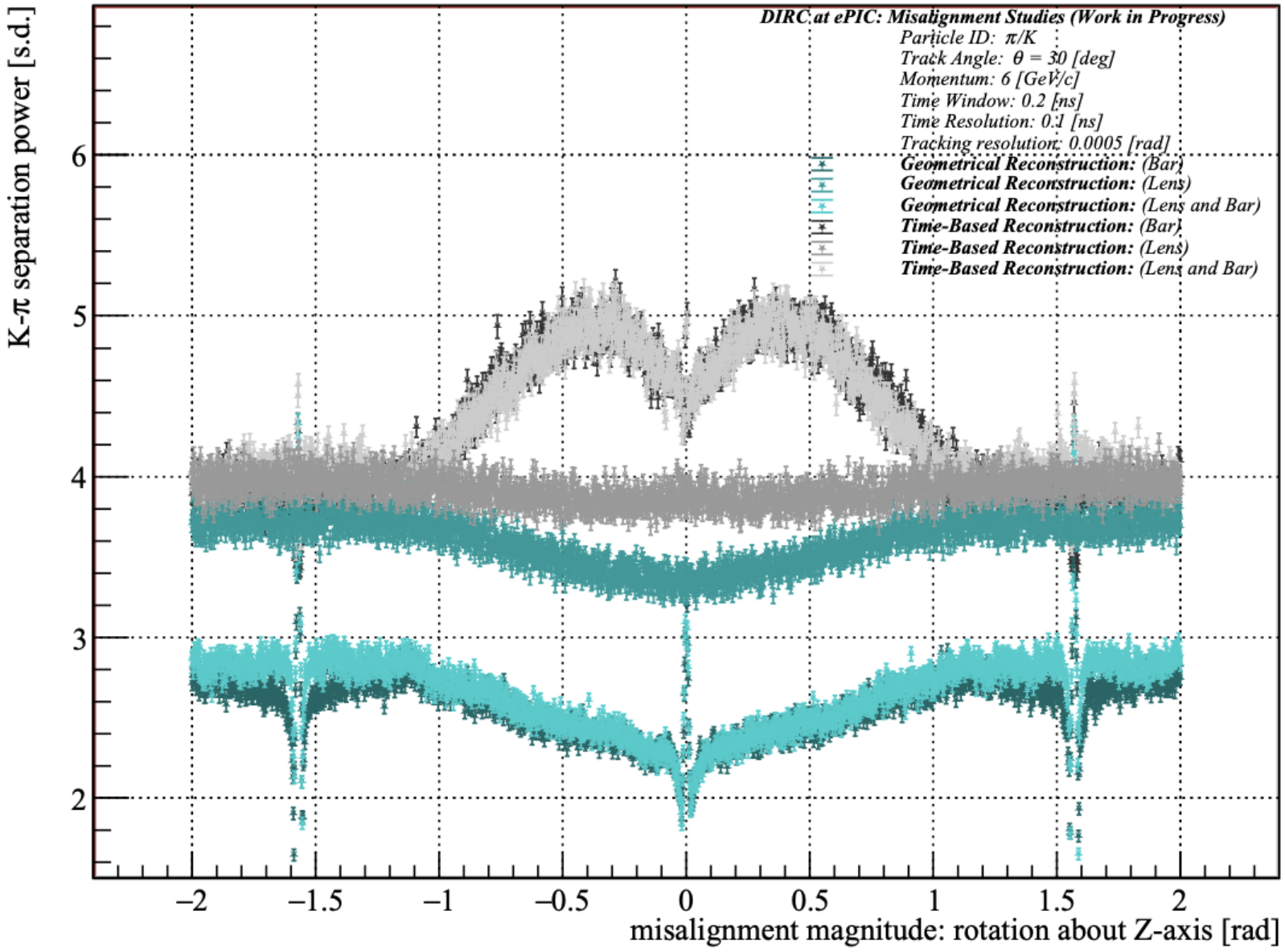
- *Checking all three misaligned scenarios in misaligned mode: which is offset along X axis*
- *SPR is decreased not quickly as X offset*
- *SPR is better for misalignment in TI method*

Separation Power between Kaon (K) and Pion (π):



- *Checking all three misaligned scenarios in misaligned mode: which is rotation the bar around Z axis*
- *SPR is decreased quickly specially with bar and combined misalignment*
- *SPR is better for misalignment in TI method*

Separation Power between Kaon (K) and Pion (π):



- *Checking all three misaligned scenarios in misaligned mode: which is rotation the bar around Z axis*
- *SPR is decreased quickly specially with bar and combined misalignment*
- *SPR is better for misalignment in TI method*

Summary Results on the Photon Yield, Reconstructed with Residual Cherenkov Angle and Separation Power:

Detected reconstructed photon number per one charged particle for realistic limitation:

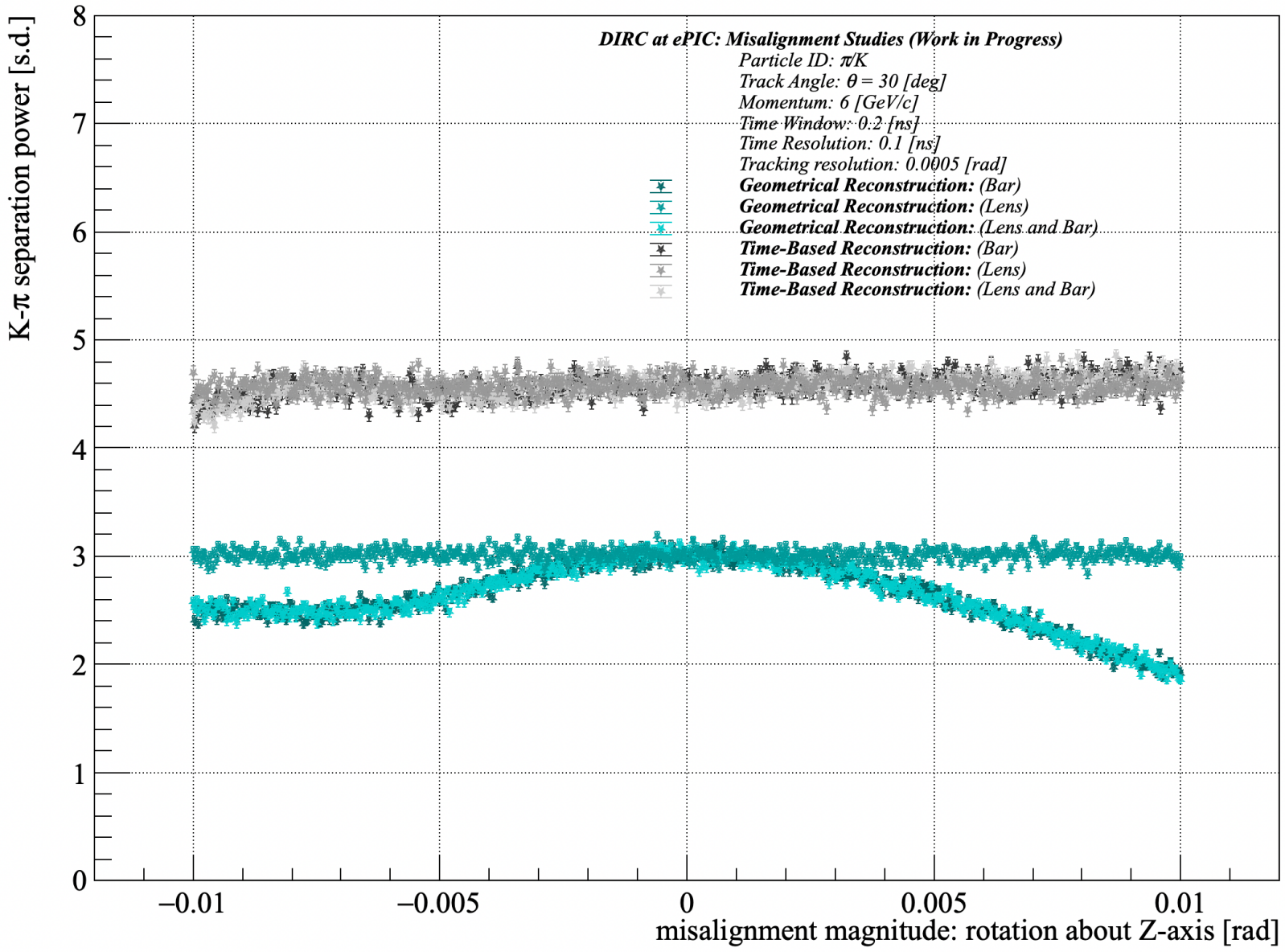
Misalignment	Direction	Component	GR Method	TI Method	Threshold
Offset	Y	3-layer spherical lens	<90	<110	±5 mm
		Bar	<120	<110	±5 mm
		Combined	stable	stable	> ±5 mm
	X	3-layer spherical lens	≤80	≤110	+5 mm
		3-layer spherical lens	≤90	≤120	-5 mm
		Bar and Combined	≤70	≤100	±5 mm
Rotation	Z	3-layer spherical lens	stable	stable	> ±0.2 rad
		Bar and Combined	≤50	≤100	±0.2 rad

Spatial resolution and separation power for realistic limitation:

Misalignment	Mode	Component	σ (rad)	SPR (σ)	Threshold
Offset	Y	3-layer spherical lens	4.5	3	±3 mm
		Combined	4.5	3	±3 mm
		Bar	stable	stable	±3 mm
	X	3-layer spherical lens	> 5	< 2	±3 mm
		Bar	stable	stable	± 3 mm
		Combined	> 5	< 2	±3 mm
Rotation	Z	3-layer spherical lens	stable	< 2	0.02 rad
		Bar and Combined	> 6	< 2	0.02 rad

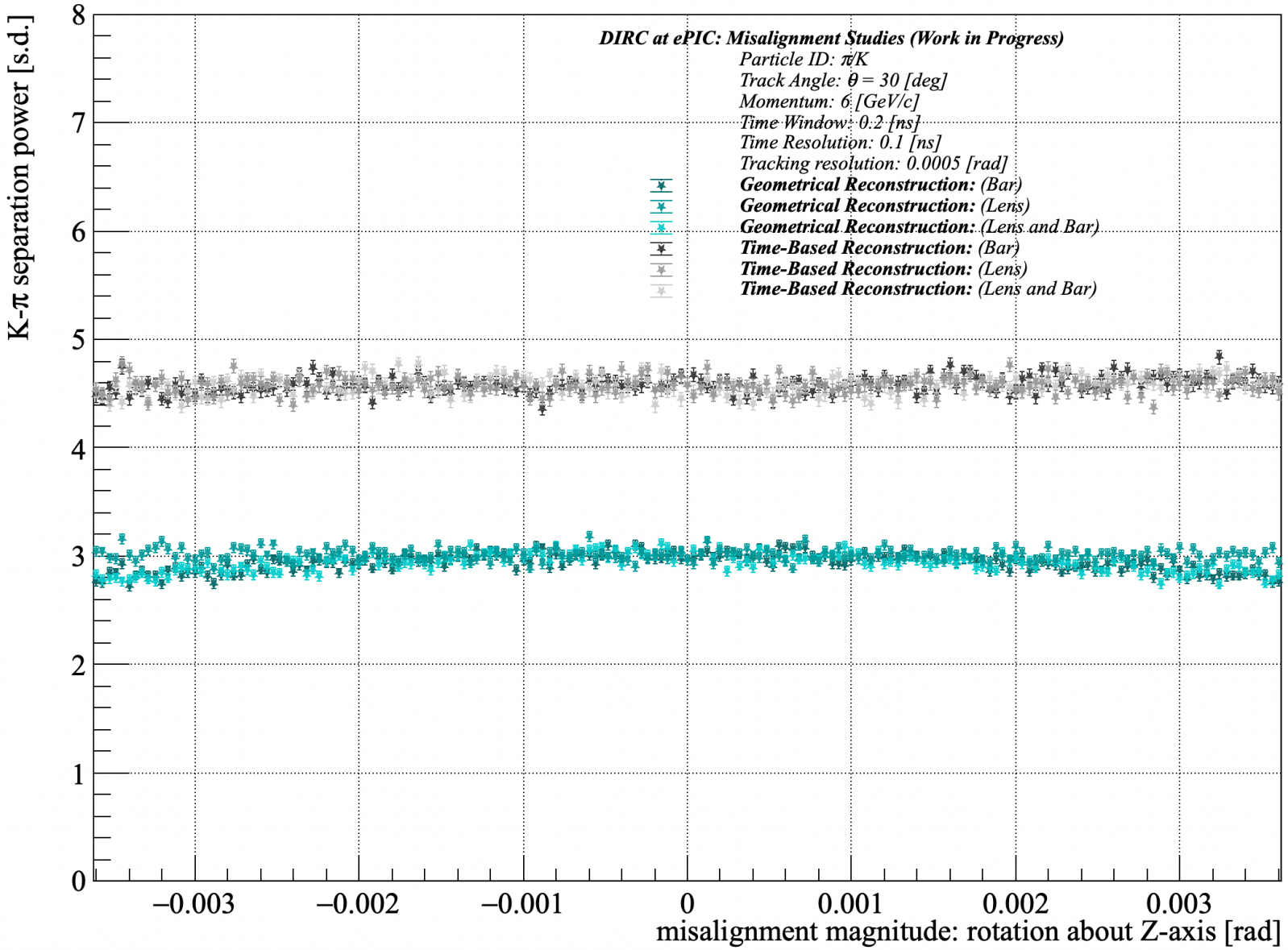
Misalignment studies conducted under realistic configurations and constraints across various modes, using different PDF per nominal and misaligned detectors.

Separation Power between Kaon (K) and Pion (π):



- **Misalignment Mode:** *Rotation*

Separation Power between Kaon (K) and Pion (π):

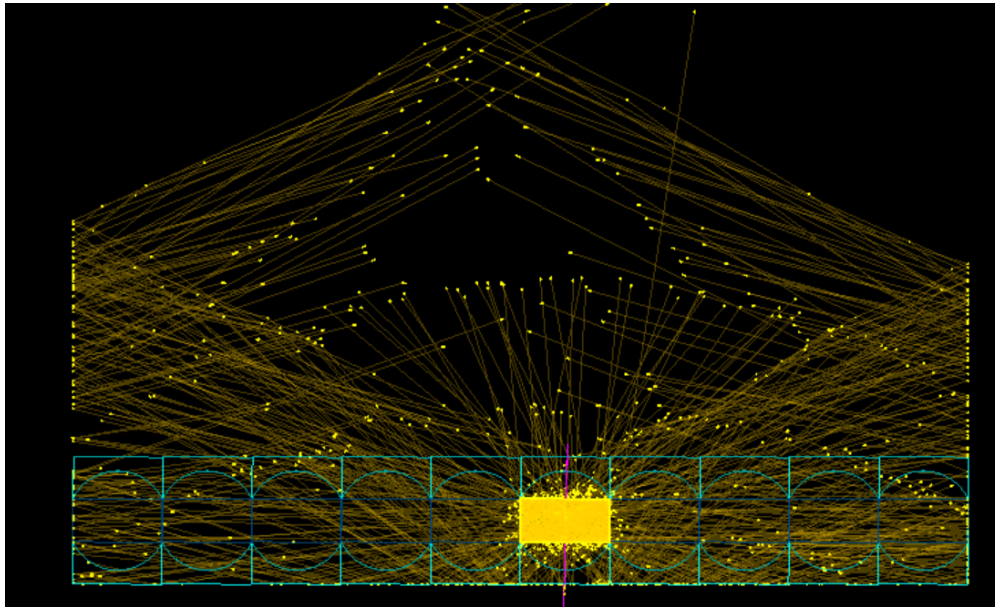


- **Misalignment Mode:** *Rotation*

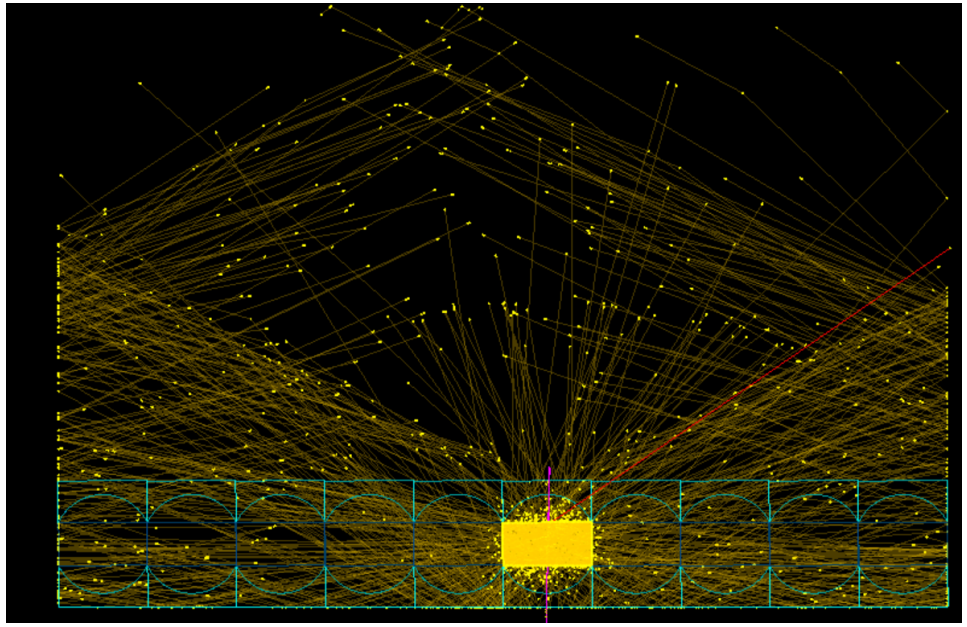
Event Visualization for only One Event :

- **Misalignment Scenario**: *Radiator Bar*
- **Misalignment Mode:** *Rotation*

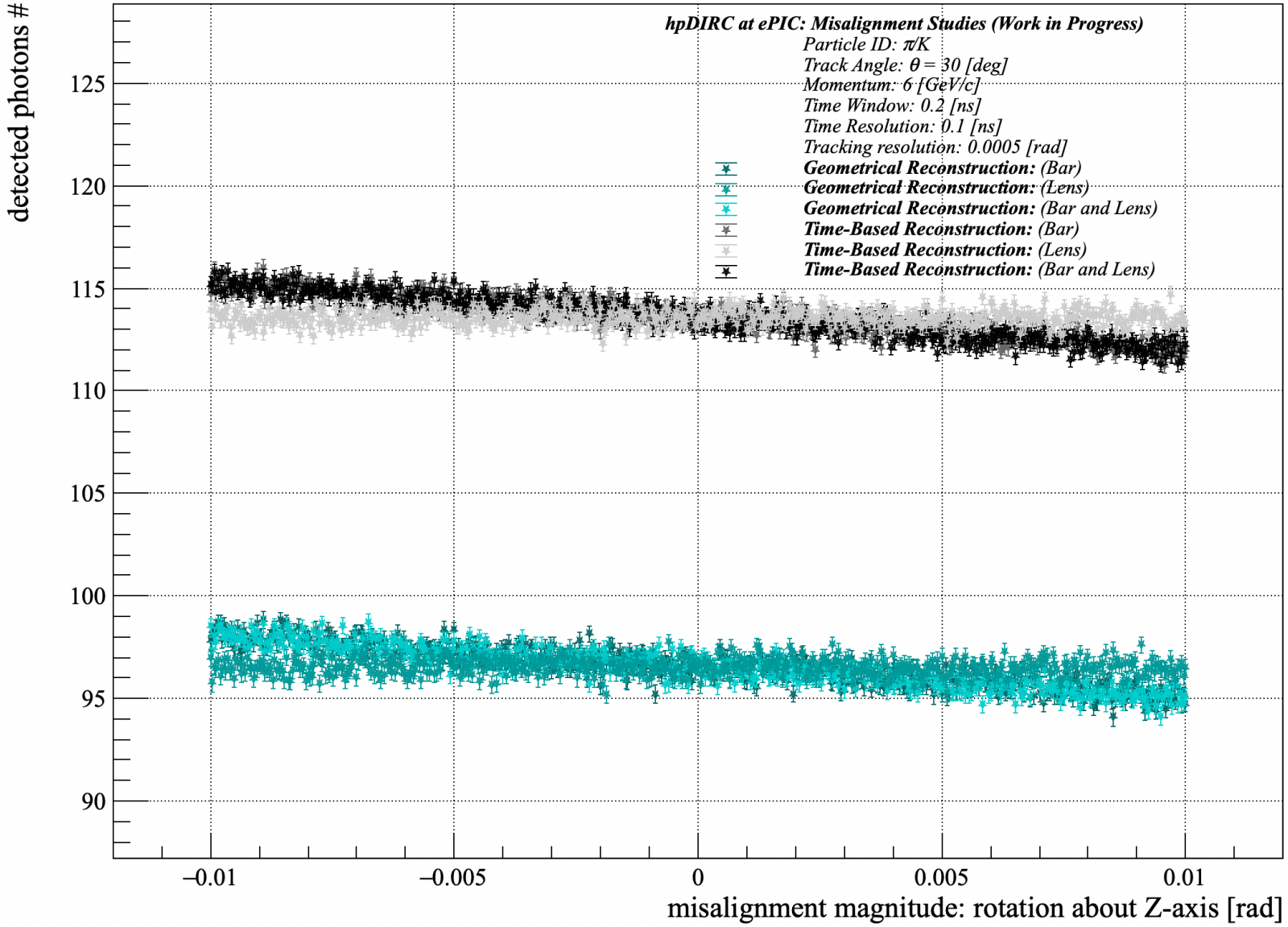
Rotational Angle: -0.01 rad : photon #:120



Rotational Angle: +0.01 rad : photon #118



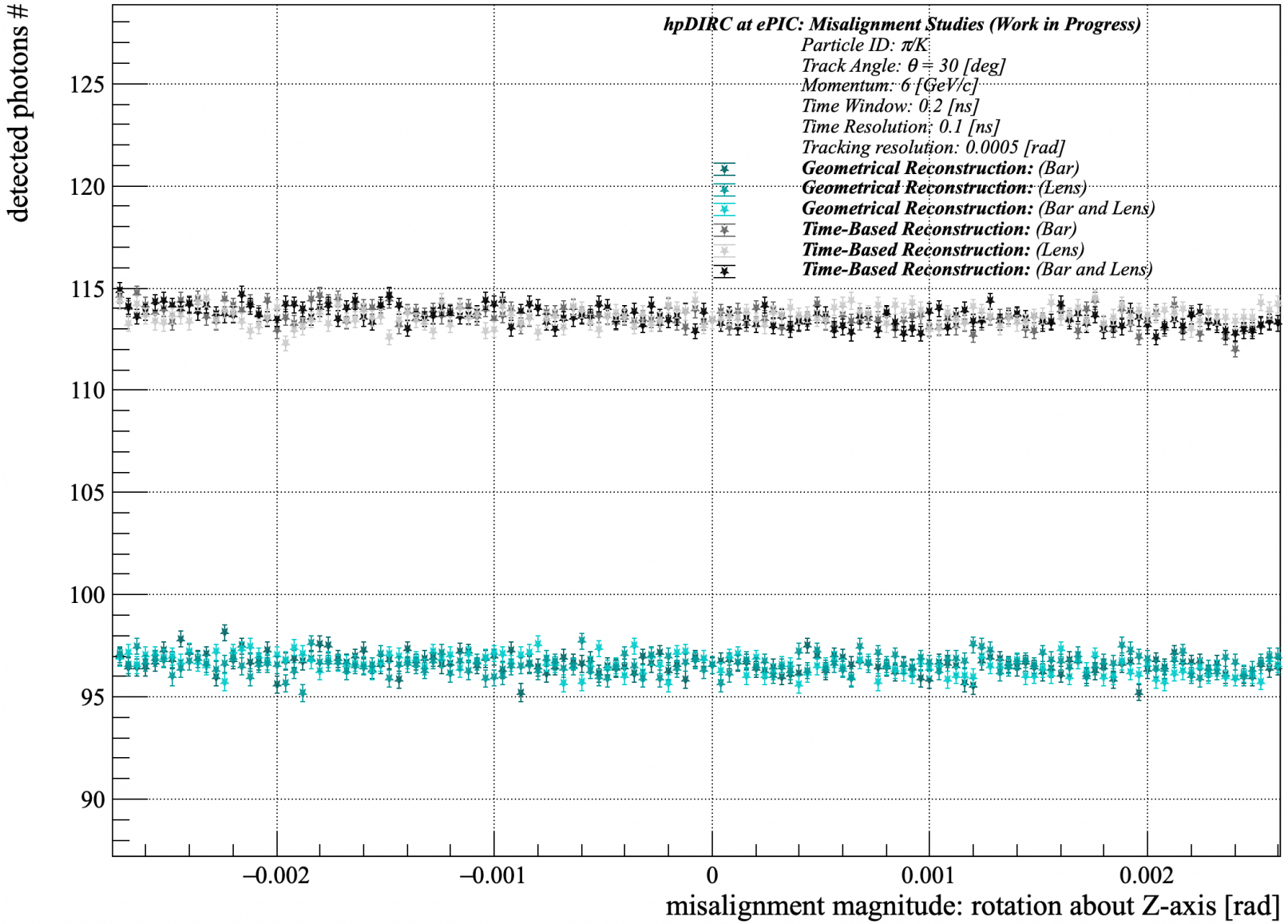
Reconstructed Photon Yield :



- **Misalignment Mode:**

  Rotation

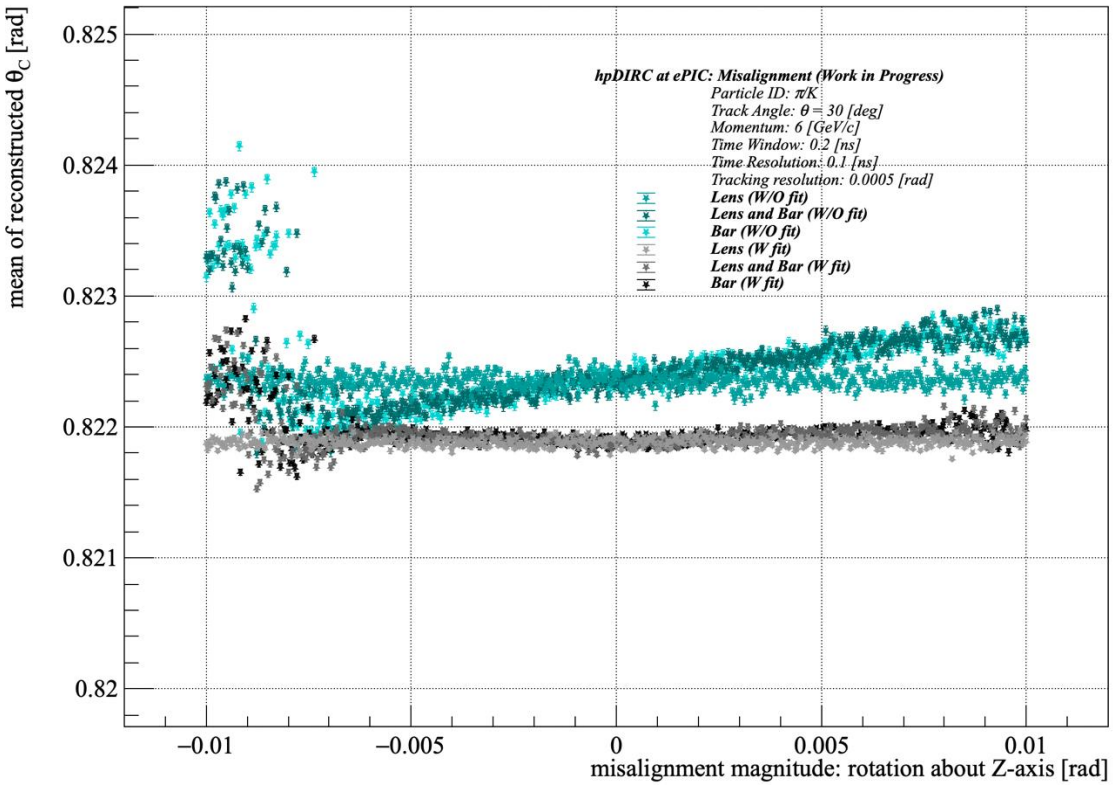
Reconstructed Photon Yield :

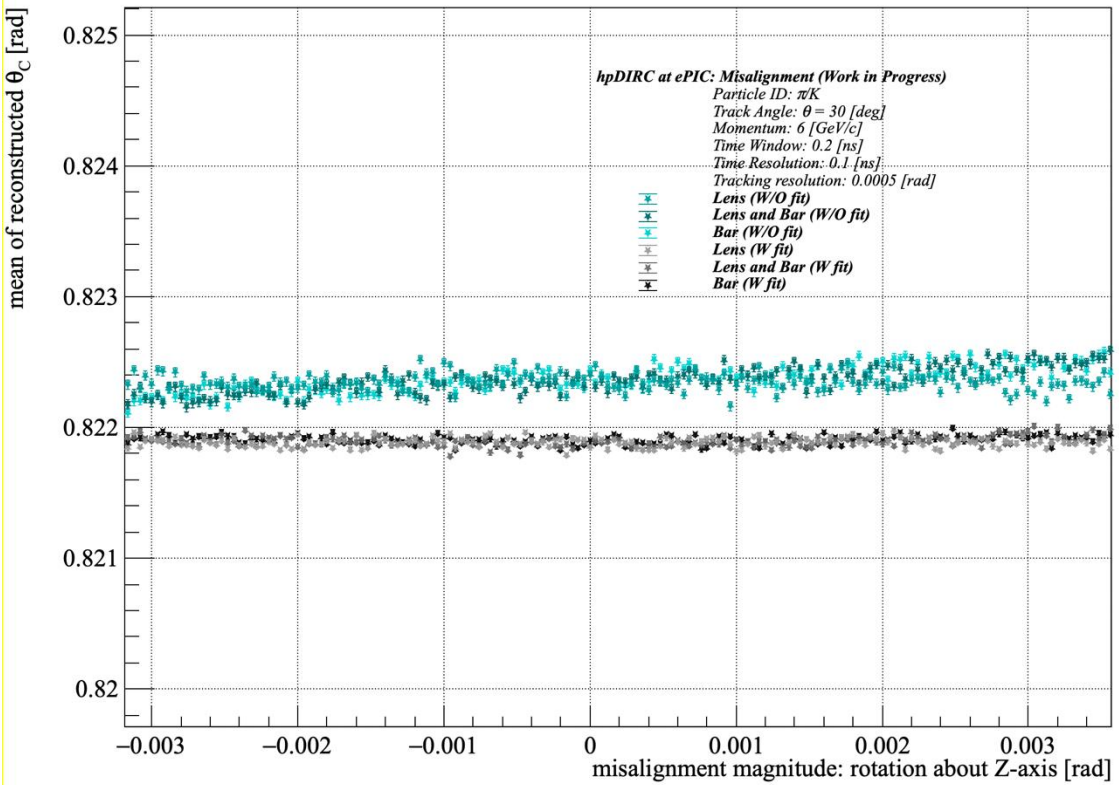


- **Misalignment Mode:**

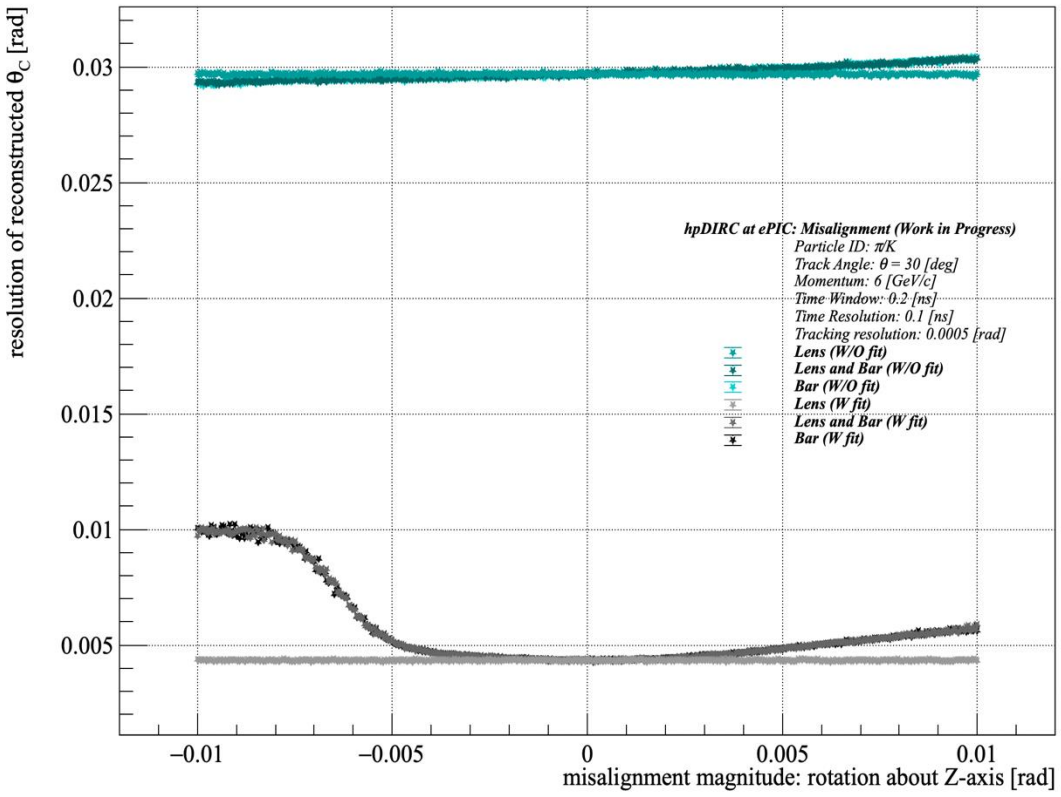
  Rotation

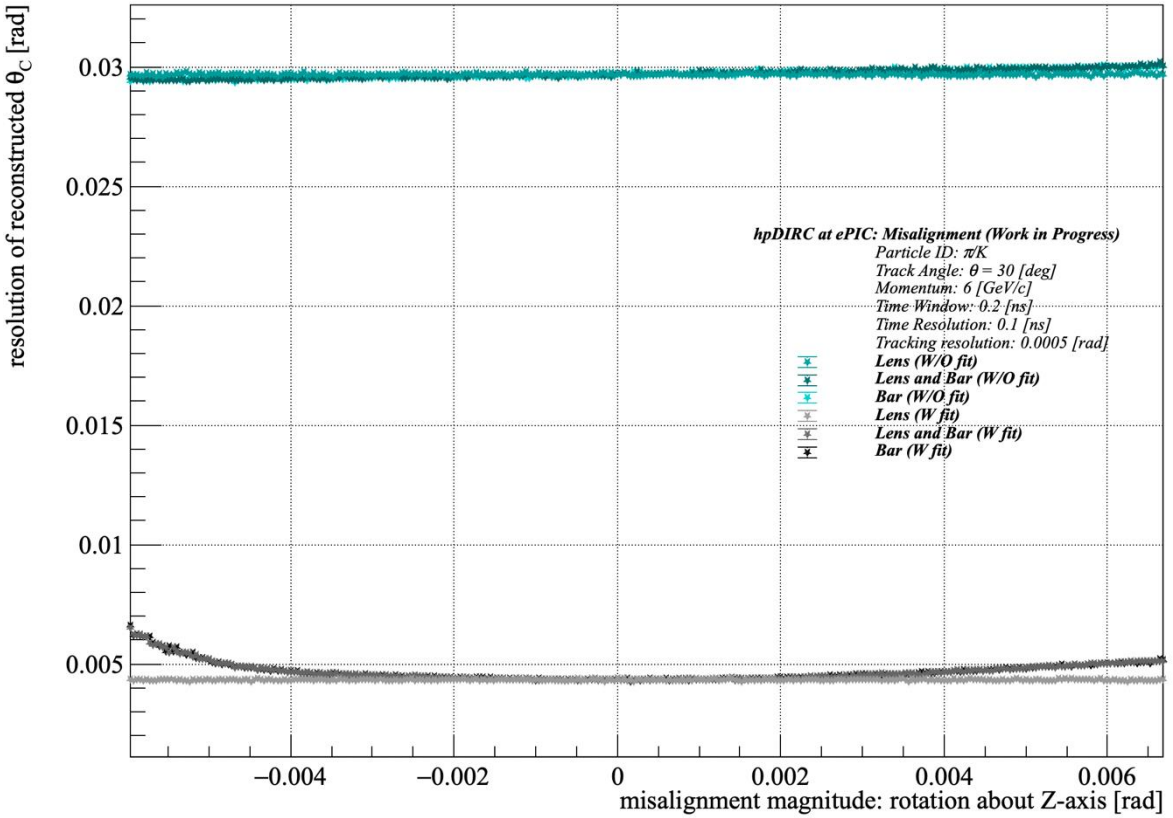
Reconstructed Cherenkov Angle for Nominal and Misaligned :



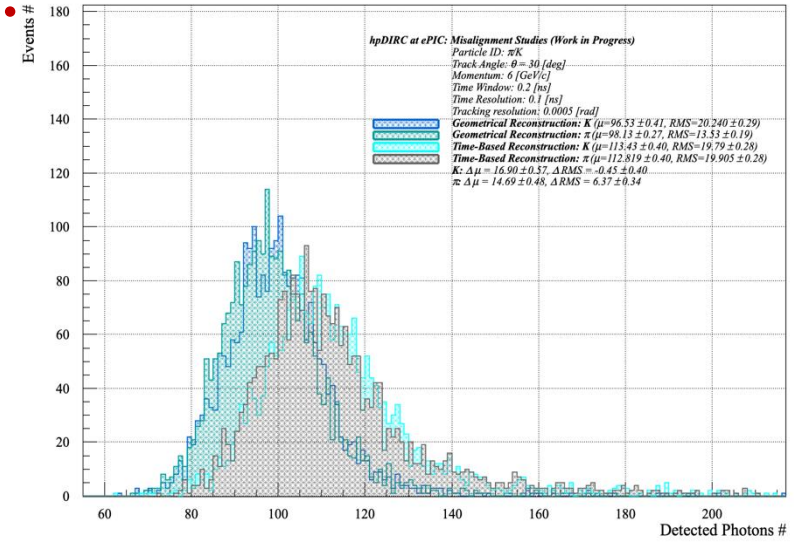


Reconstructed Cherenkov Angle for Nominal and Misaligned :



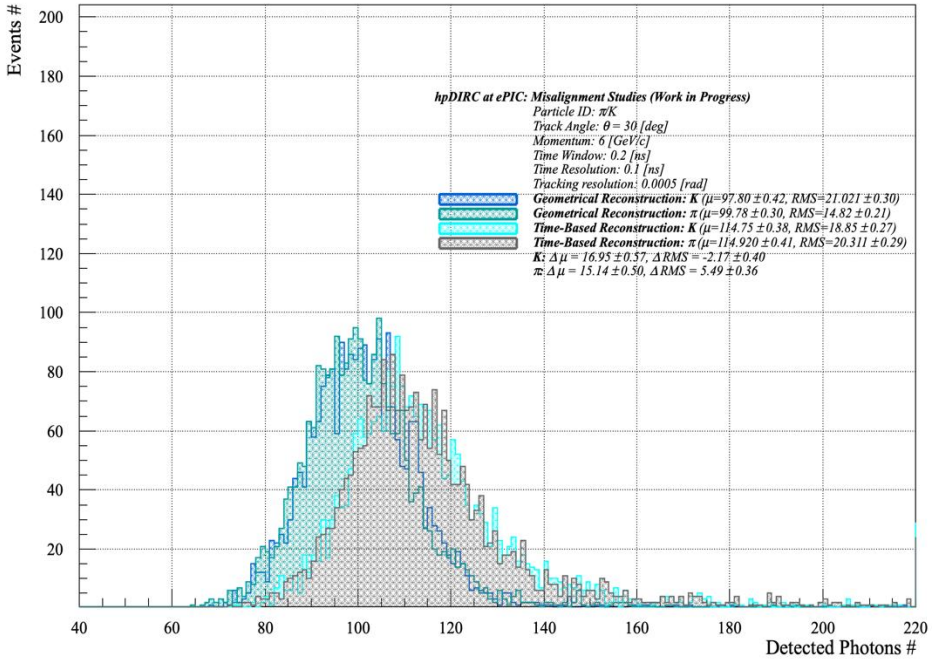


Reconstructed Photon Yield :

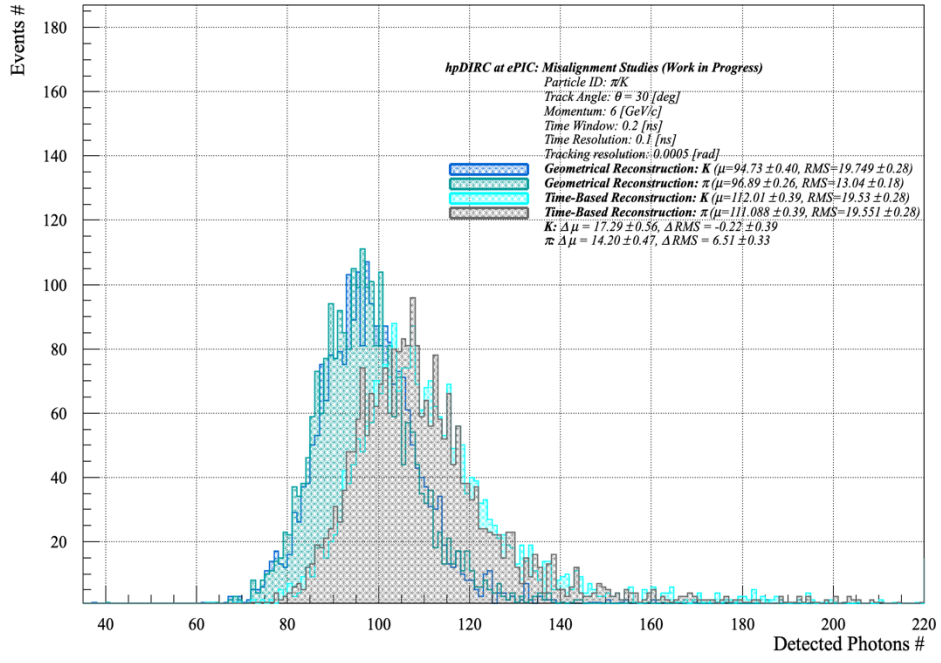


Nominal detector; GR and TI method

Misaligned detector; GR and TI method: rotational bar around Z with -0.01 rad

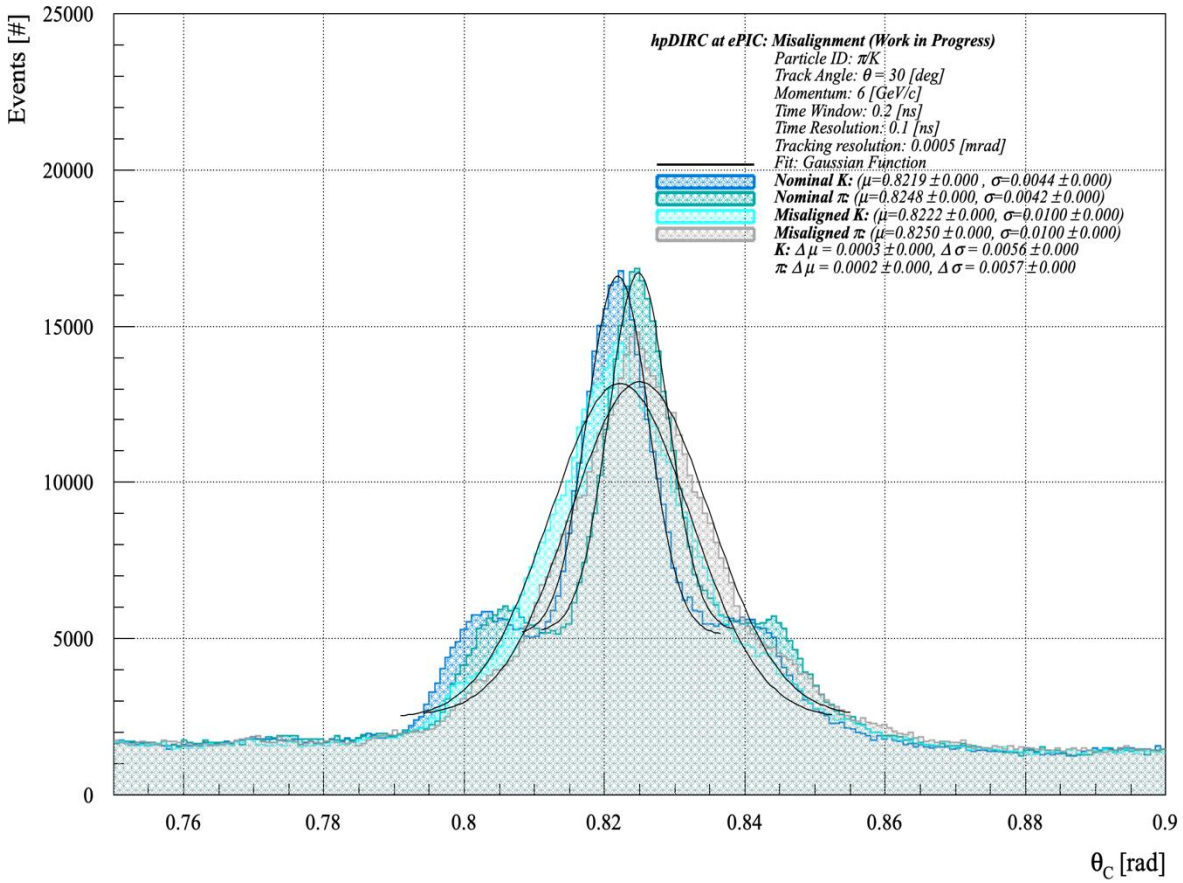


Misaligned detector; GR and TI method: rotational bar around Z with +0.01 rad

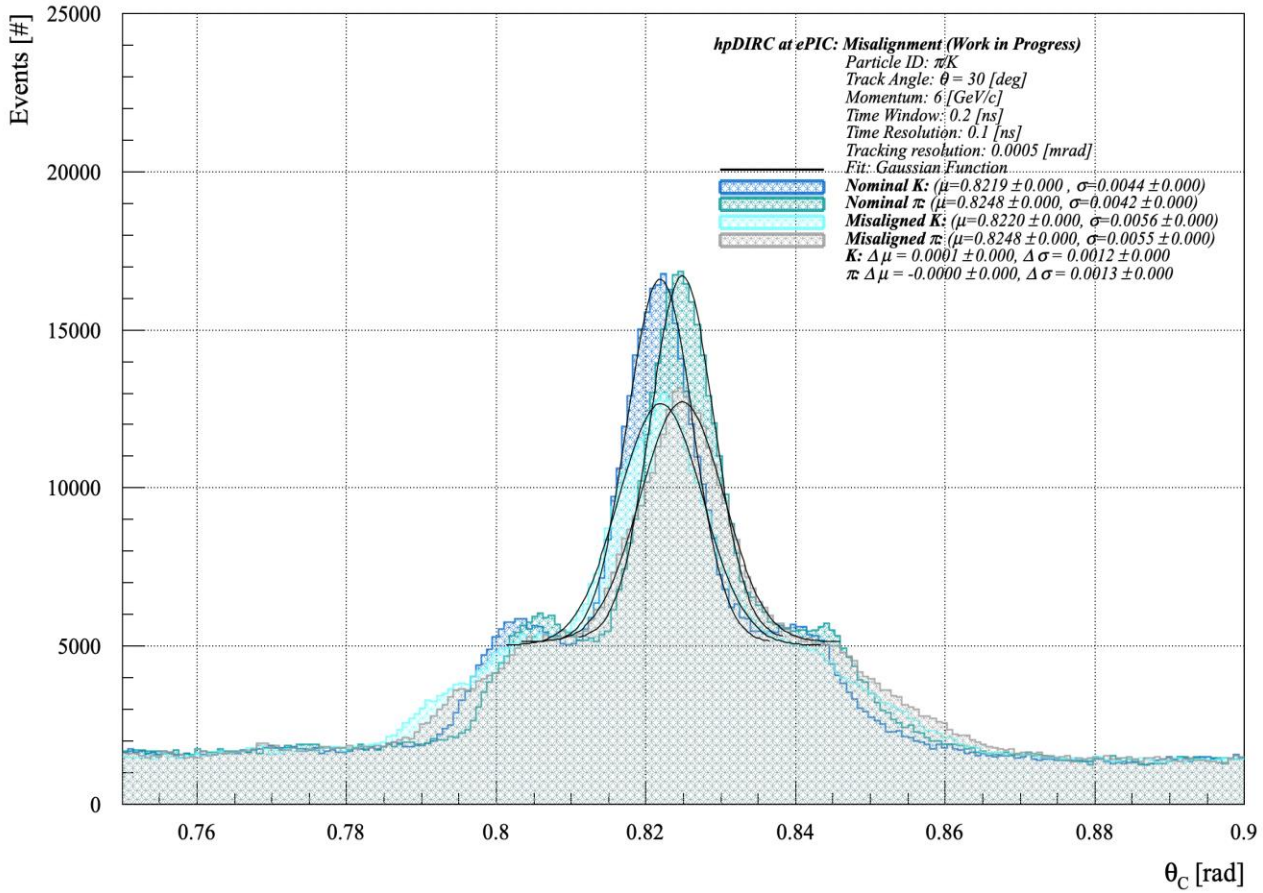


Reconstructed Cherenkov Angle for Nominal and Misaligned :

rotational bar around z with -0.01 rad

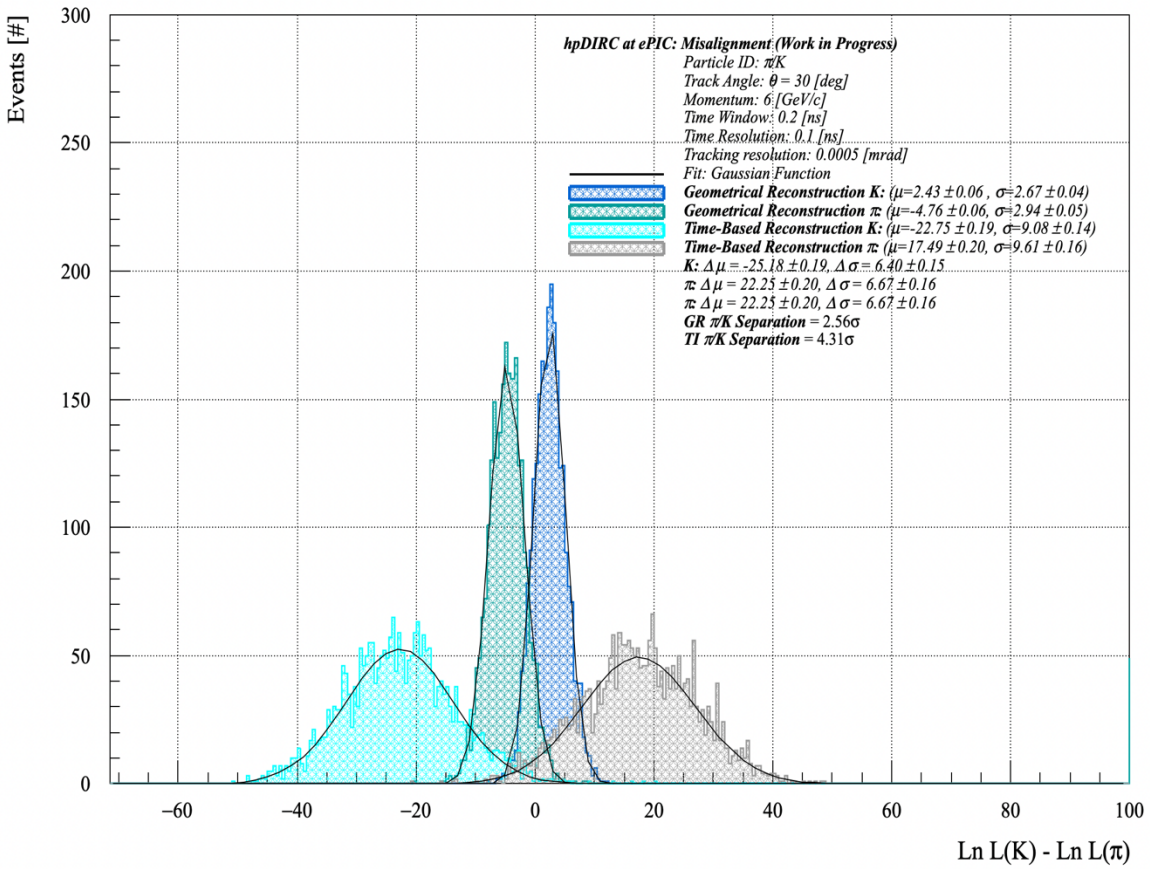


rotational bar around z with +0.01 rad

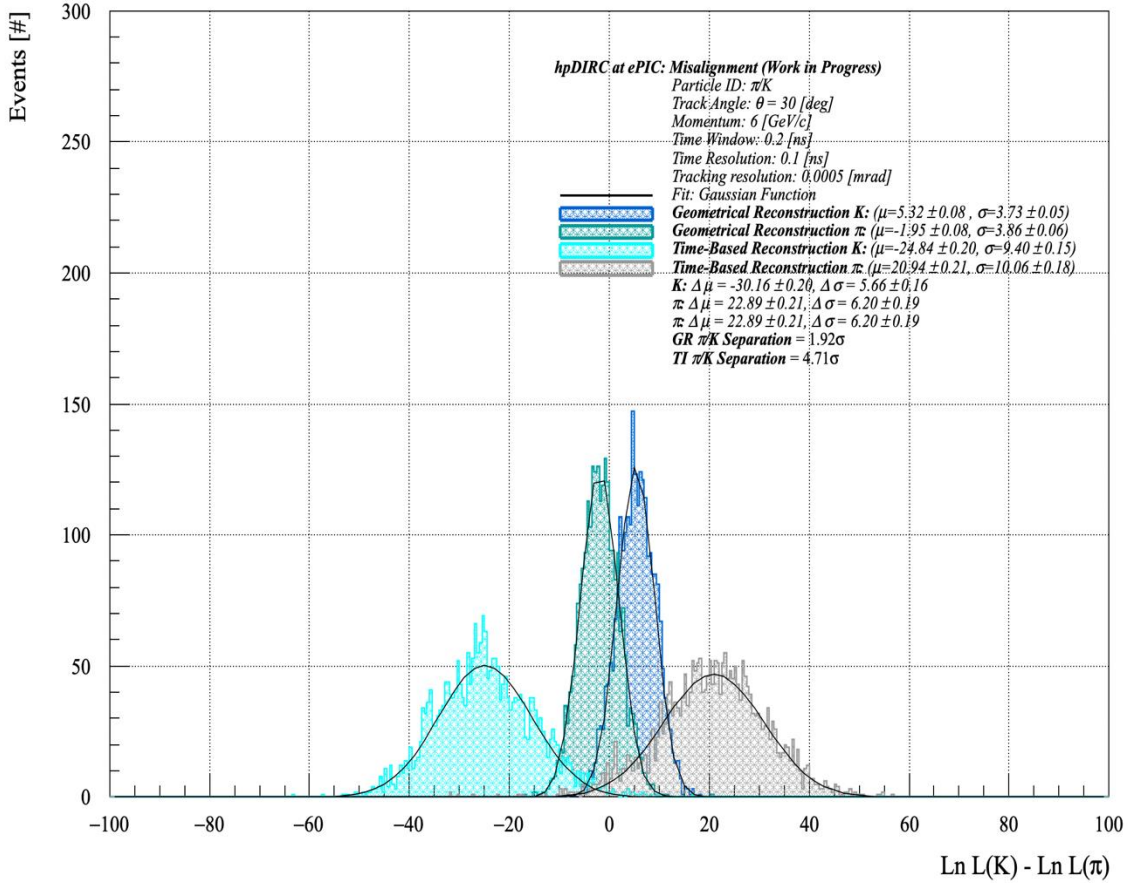


Separation Power between Kaon (K) and Pion (π):

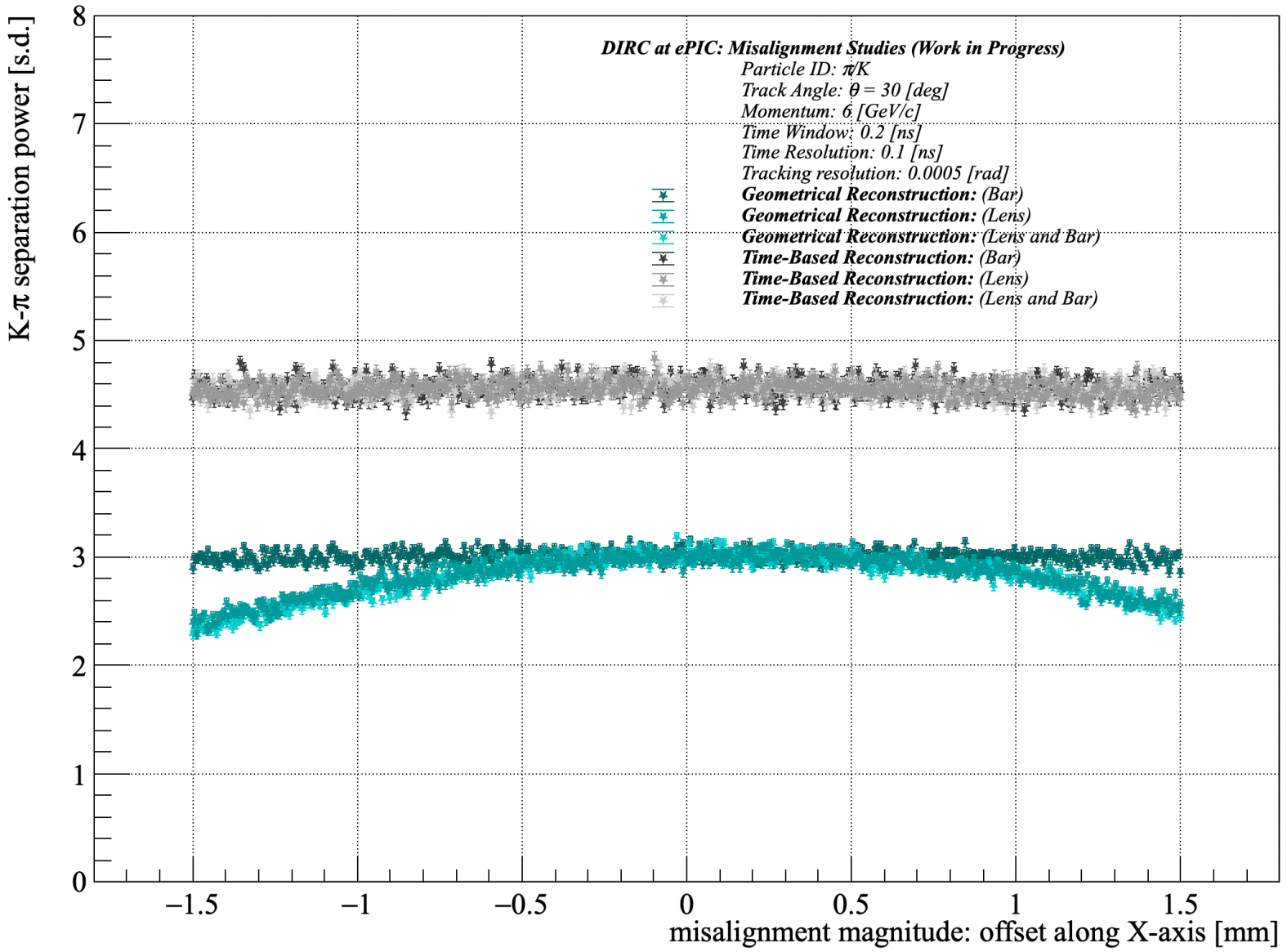
Rotate bar about z-axis: -0.01 rad



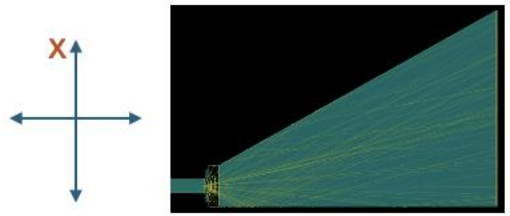
Rotate bar about z-axis: +0.01 rad



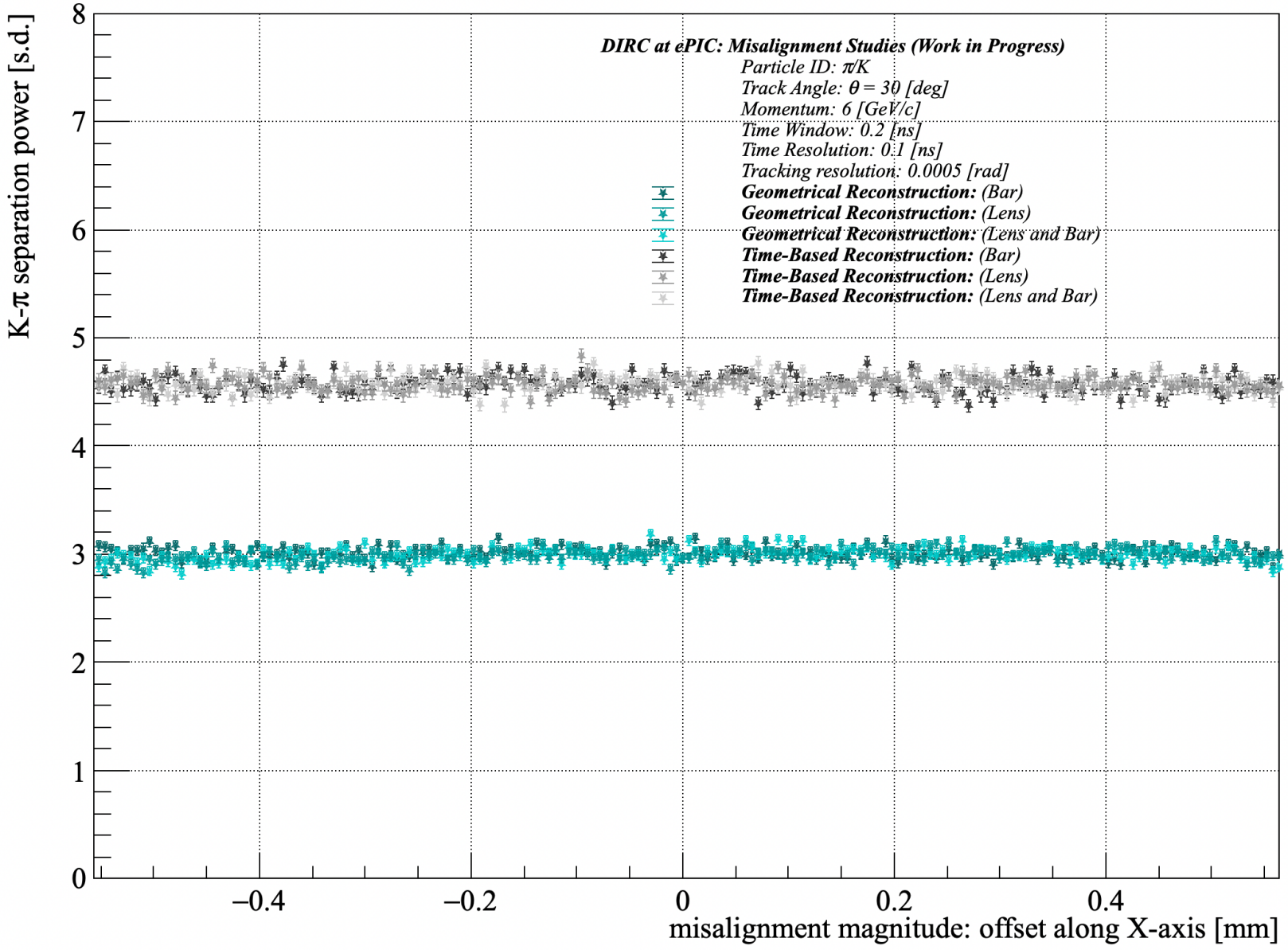
Separation Power between Kaon (K) and Pion (π):



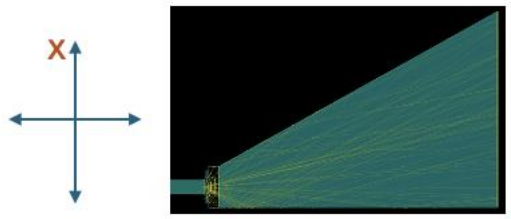
- **Misalignment Mode:** *Offset*



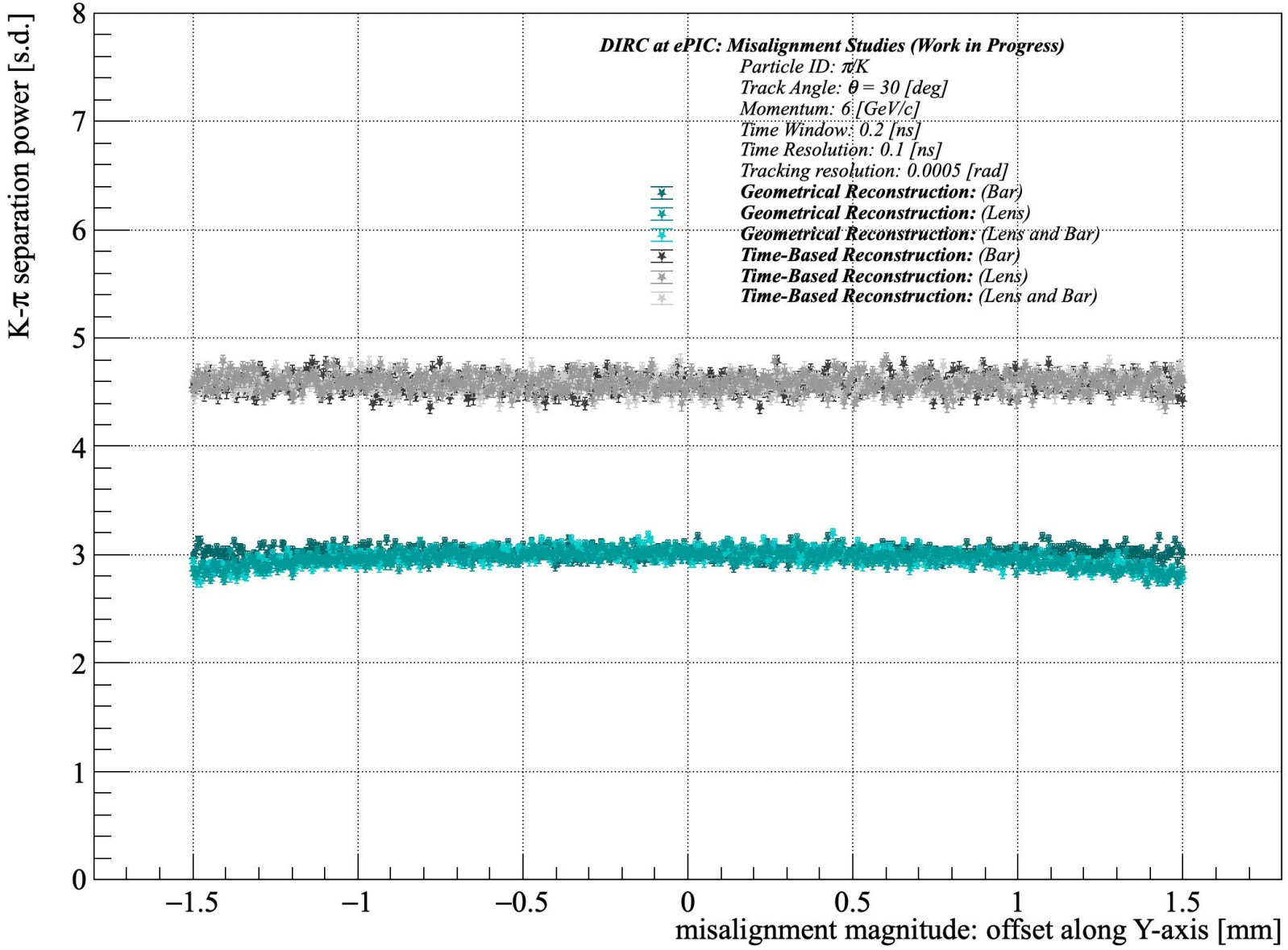
Separation Power between Kaon (K) and Pion (π):



- **Misalignment Mode:** *Offset*

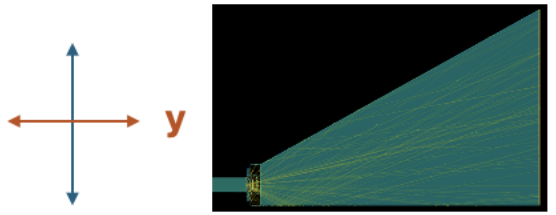


Separation Power between Kaon (K) and Pion (π):

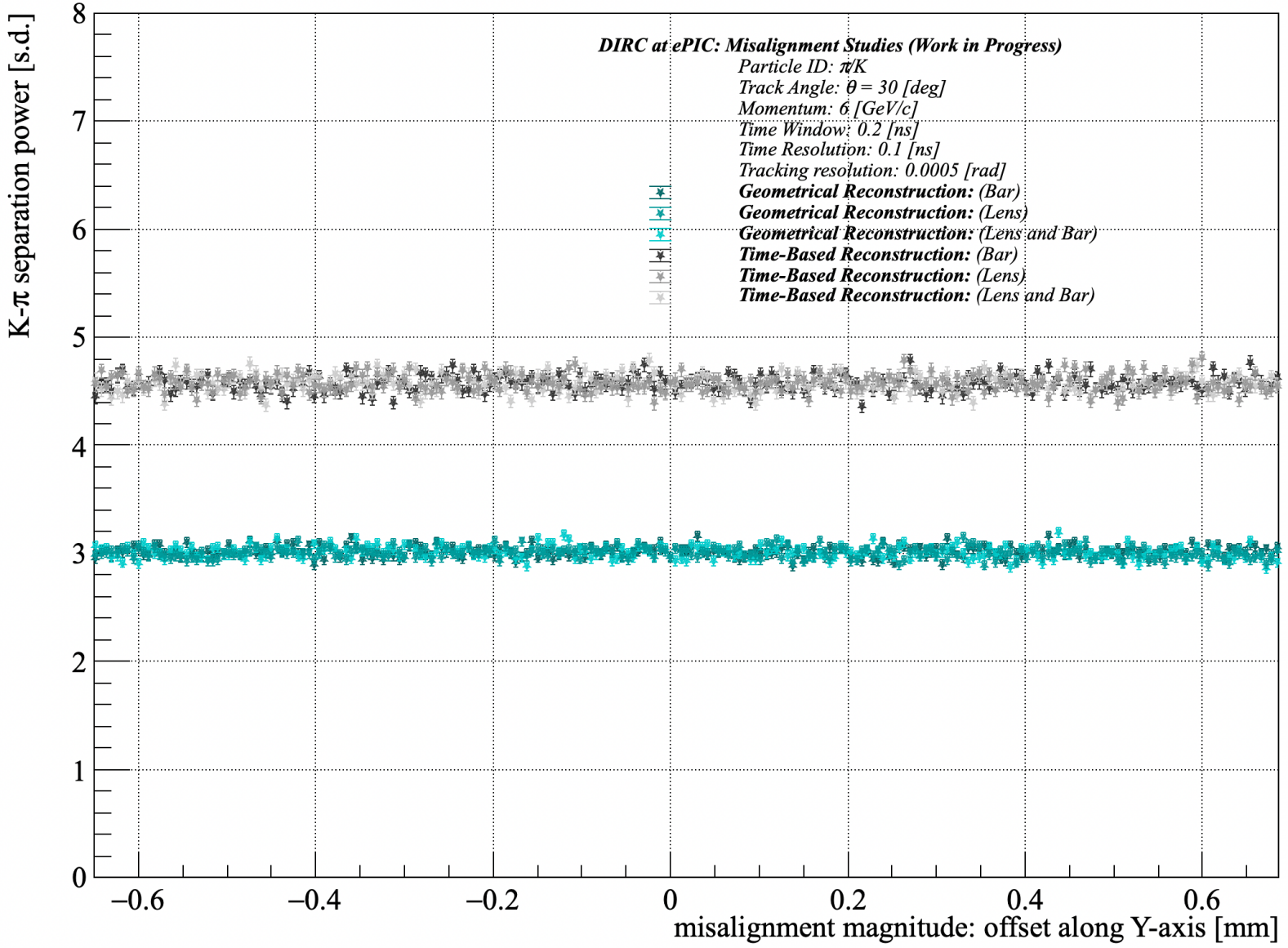


- **Misalignment Mode:**

  Offset

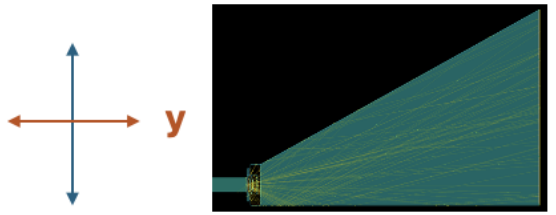


Separation Power between Kaon (K) and Pion (π):

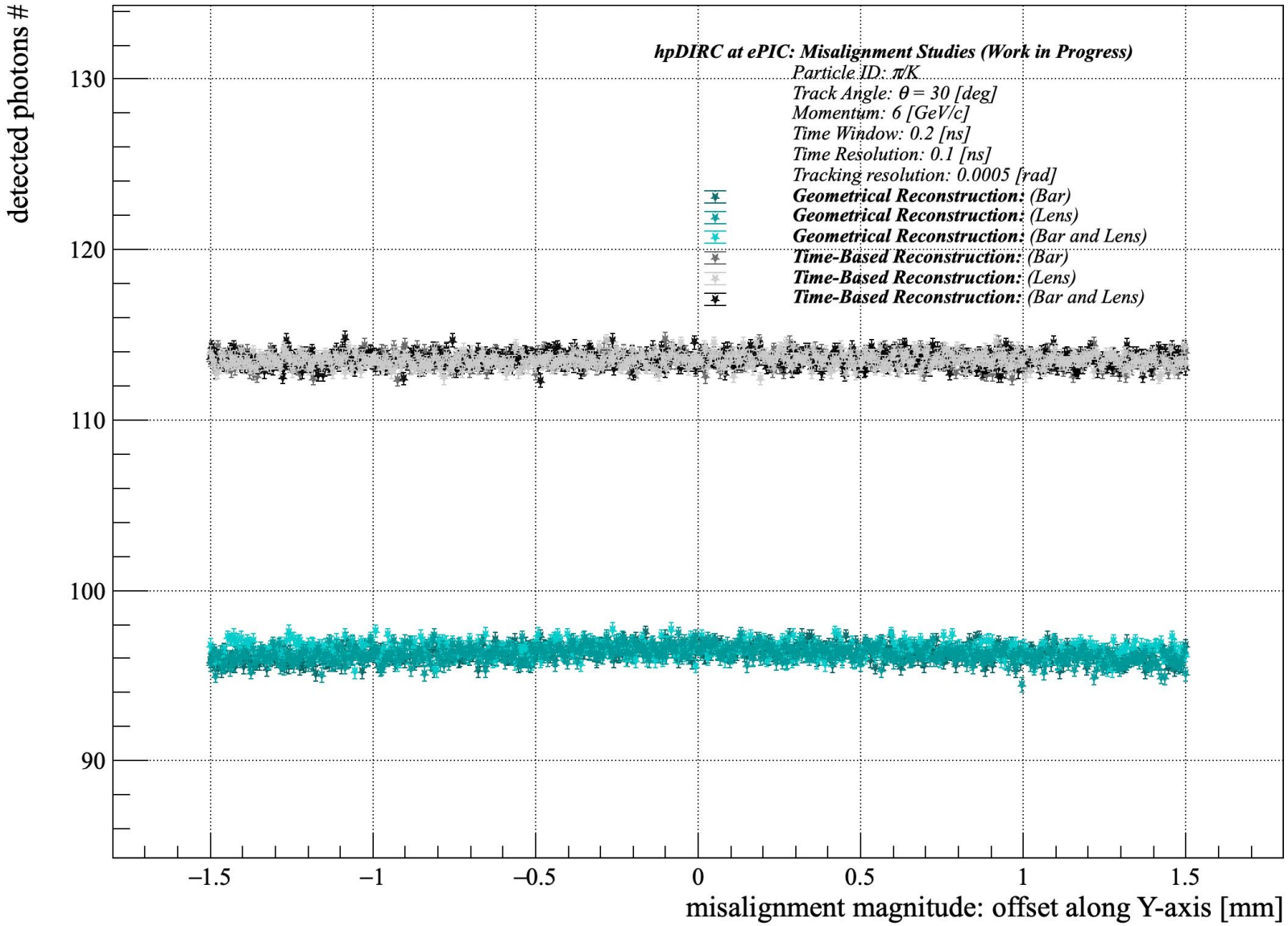


- **Misalignment Mode:**

  Offset

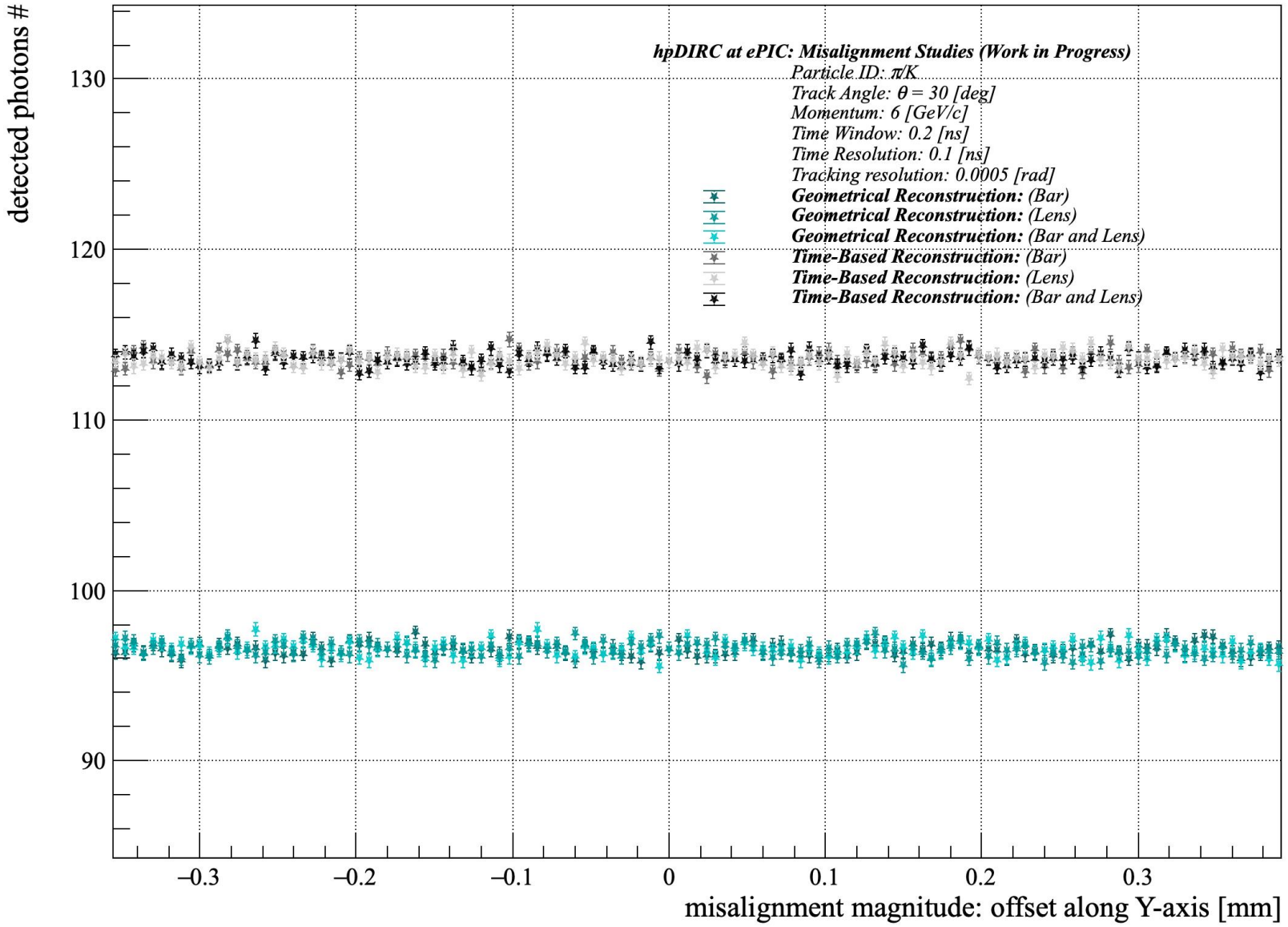


Reconstructed Photon Yield :



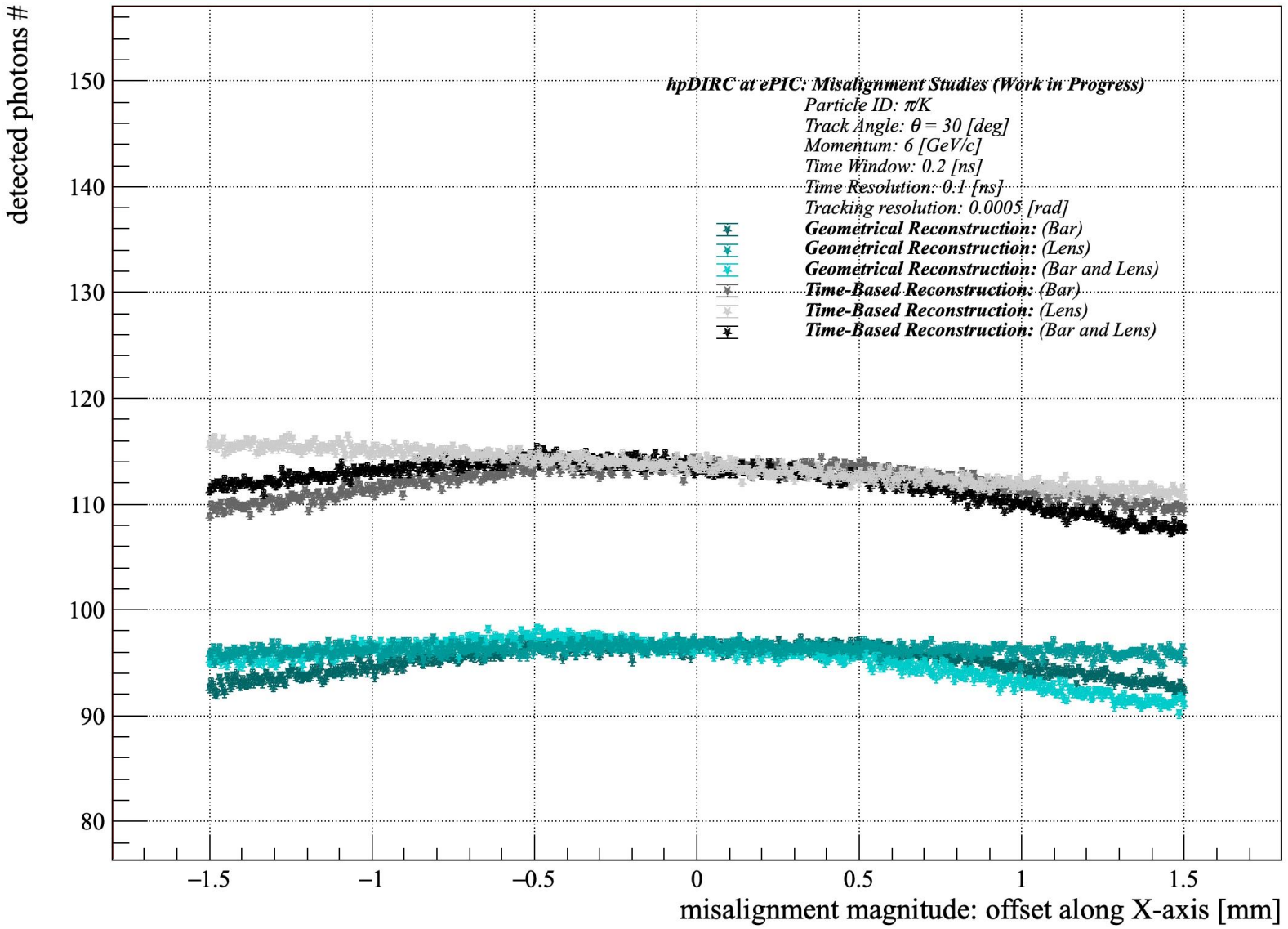
- **Misalignment Mode:** *Offset*

Reconstructed Photon Yield :



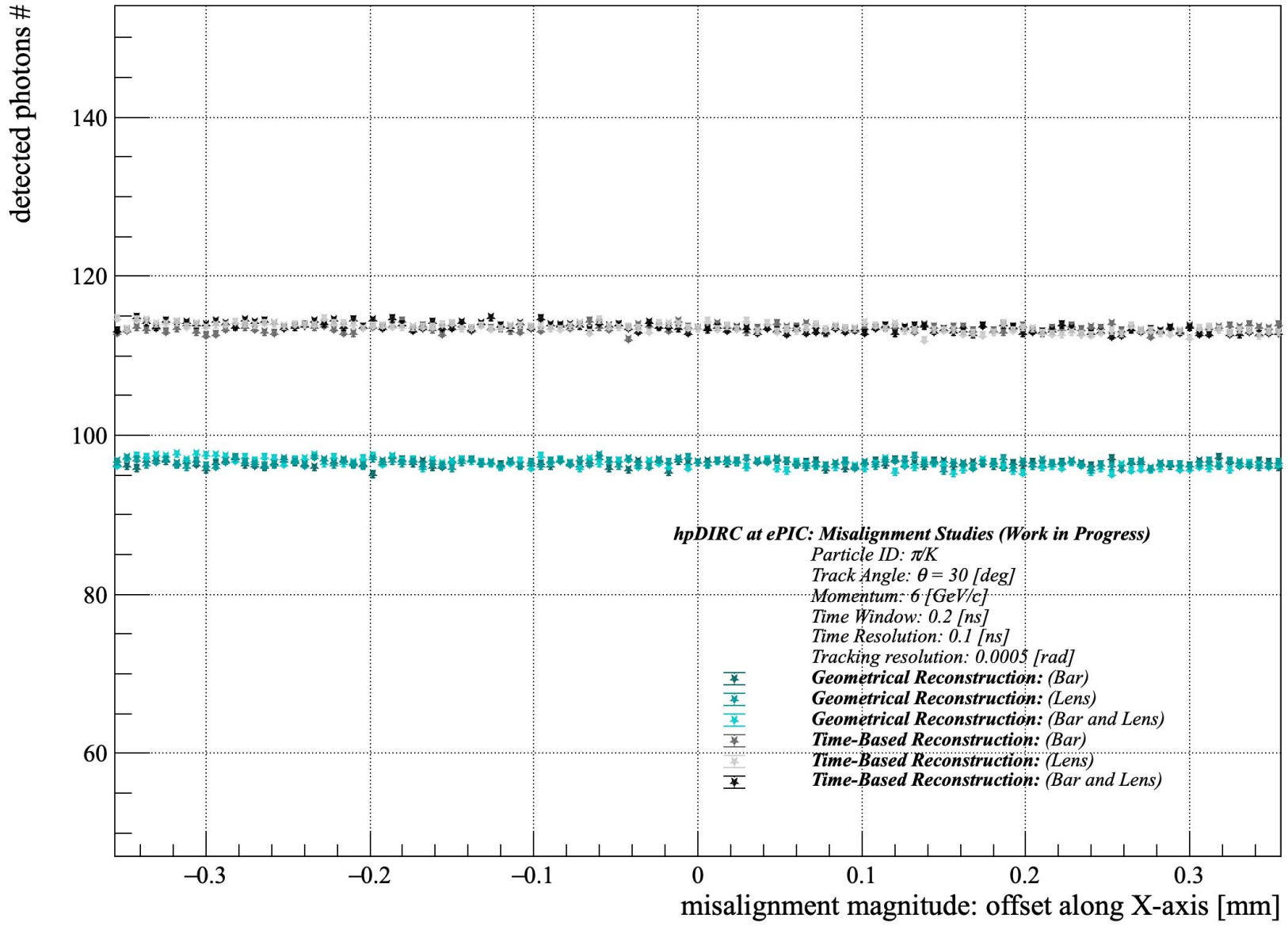
- **Misalignment Mode:** *Offset*

Reconstructed Photon Yield :



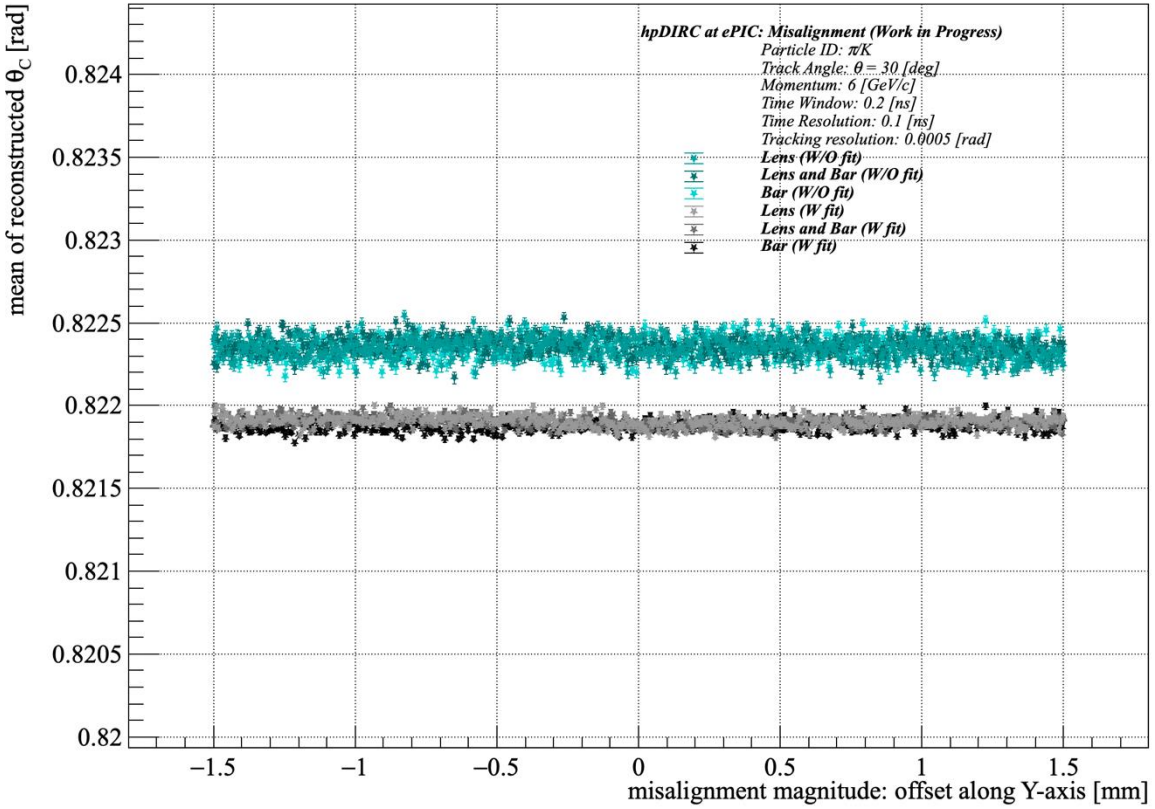
- **Misalignment Mode:** *Offset*

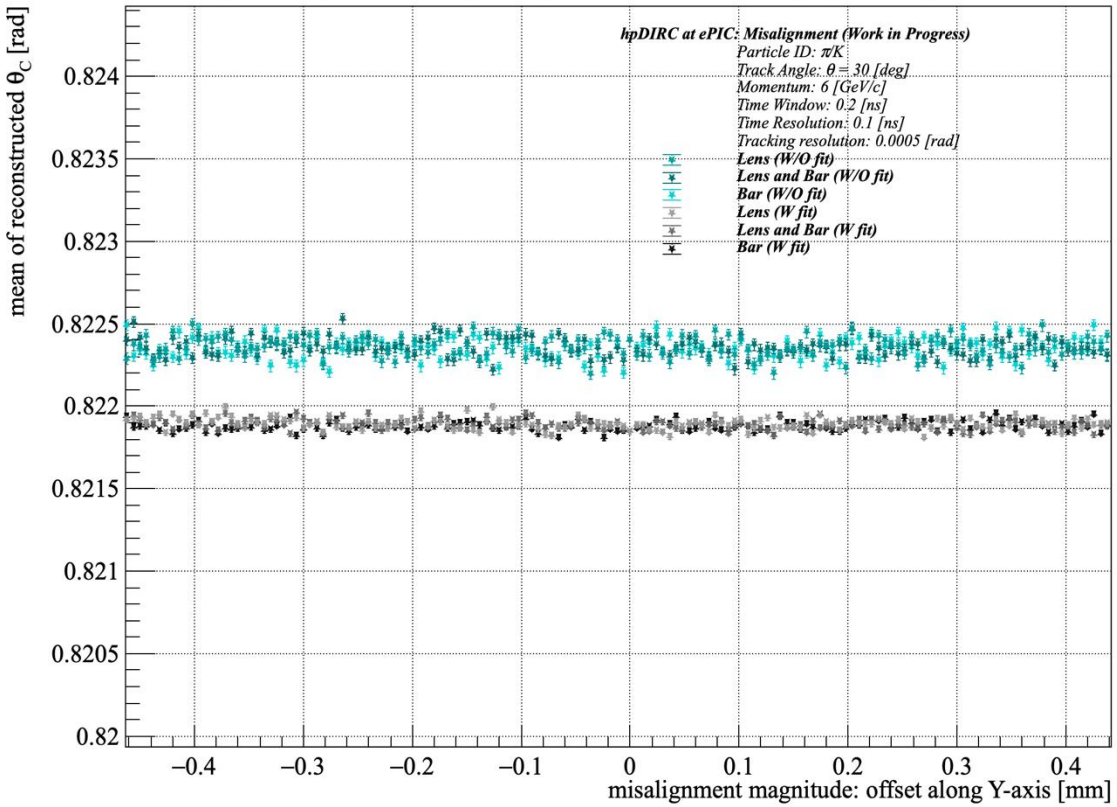
Reconstructed Photon Yield :



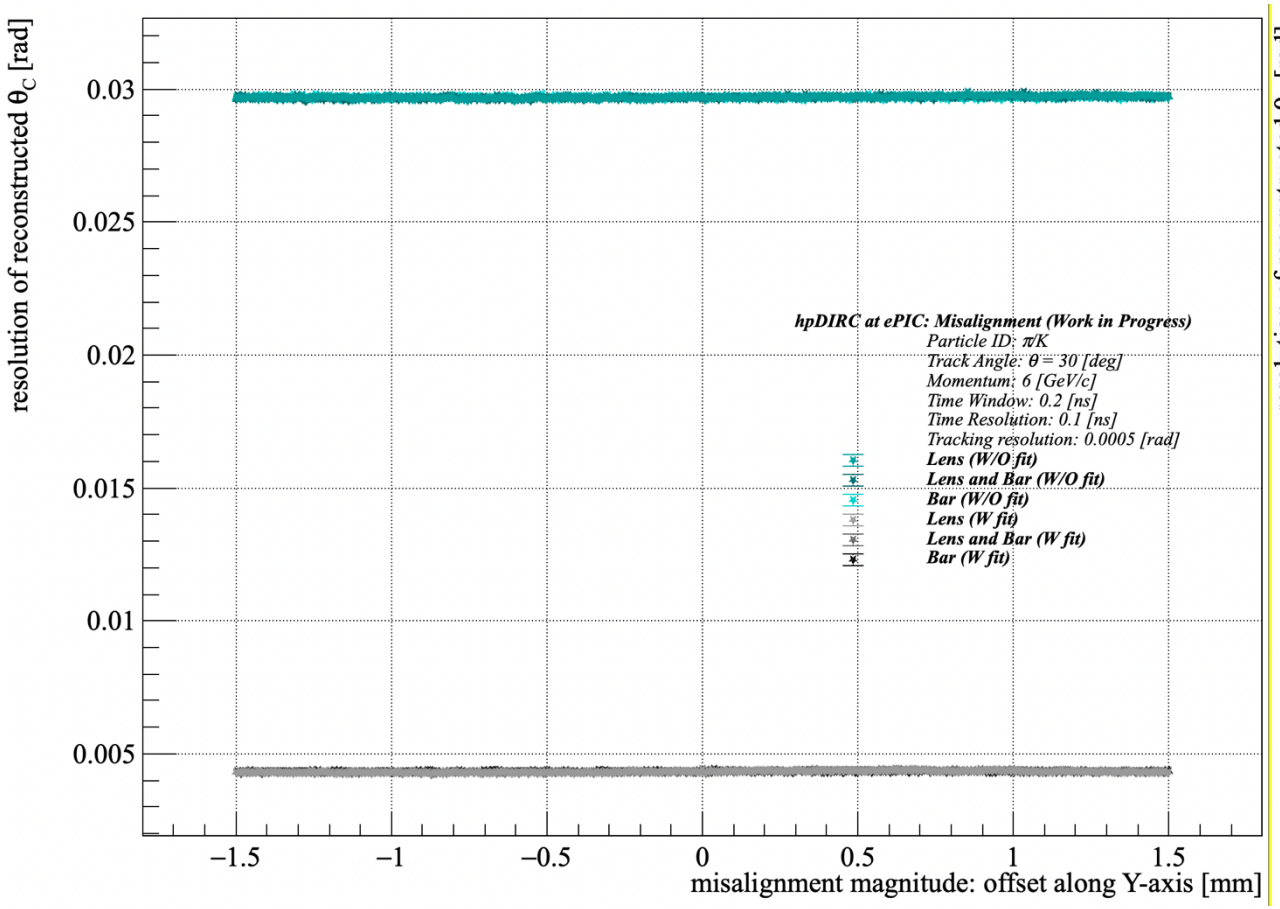
- **Misalignment Mode:** *Offset*

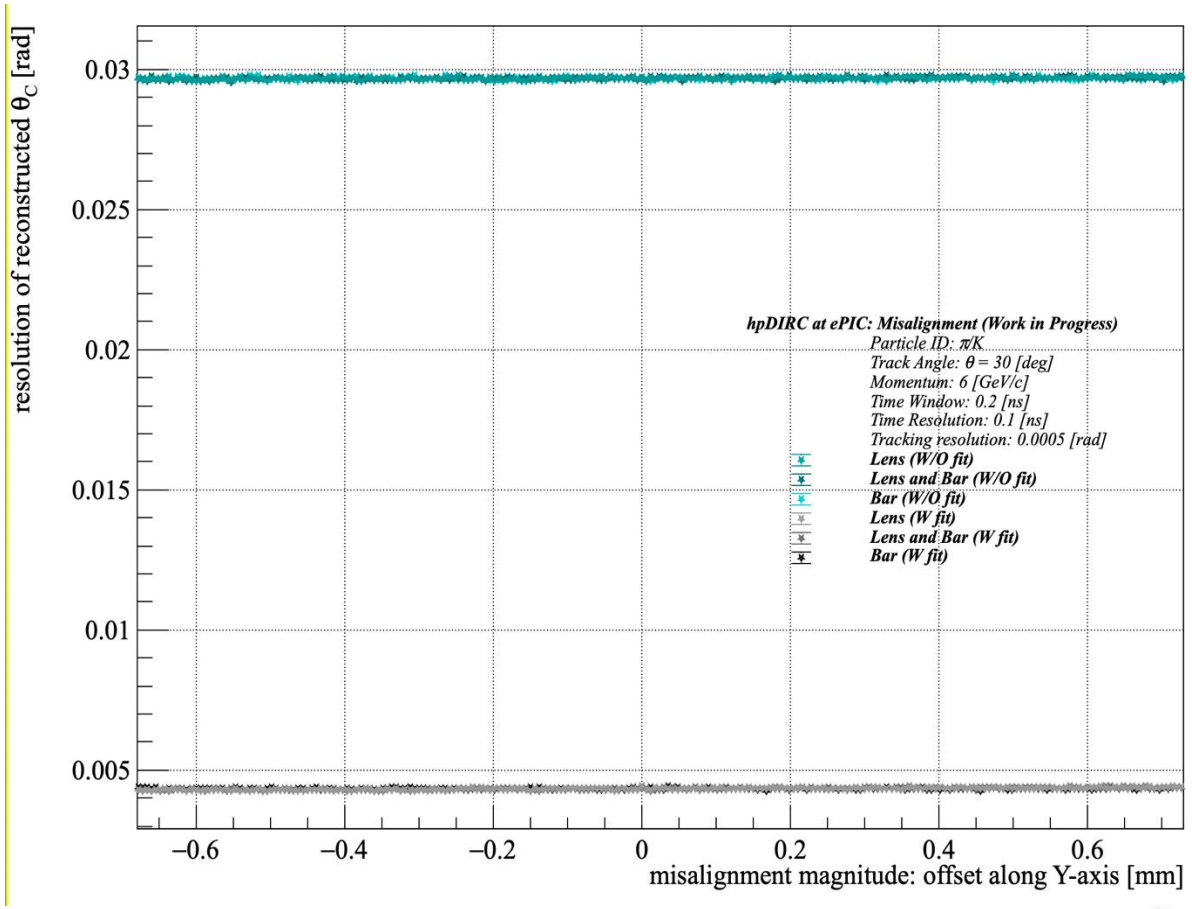
Reconstructed Cherenkov Angle for Nominal and Misaligned :



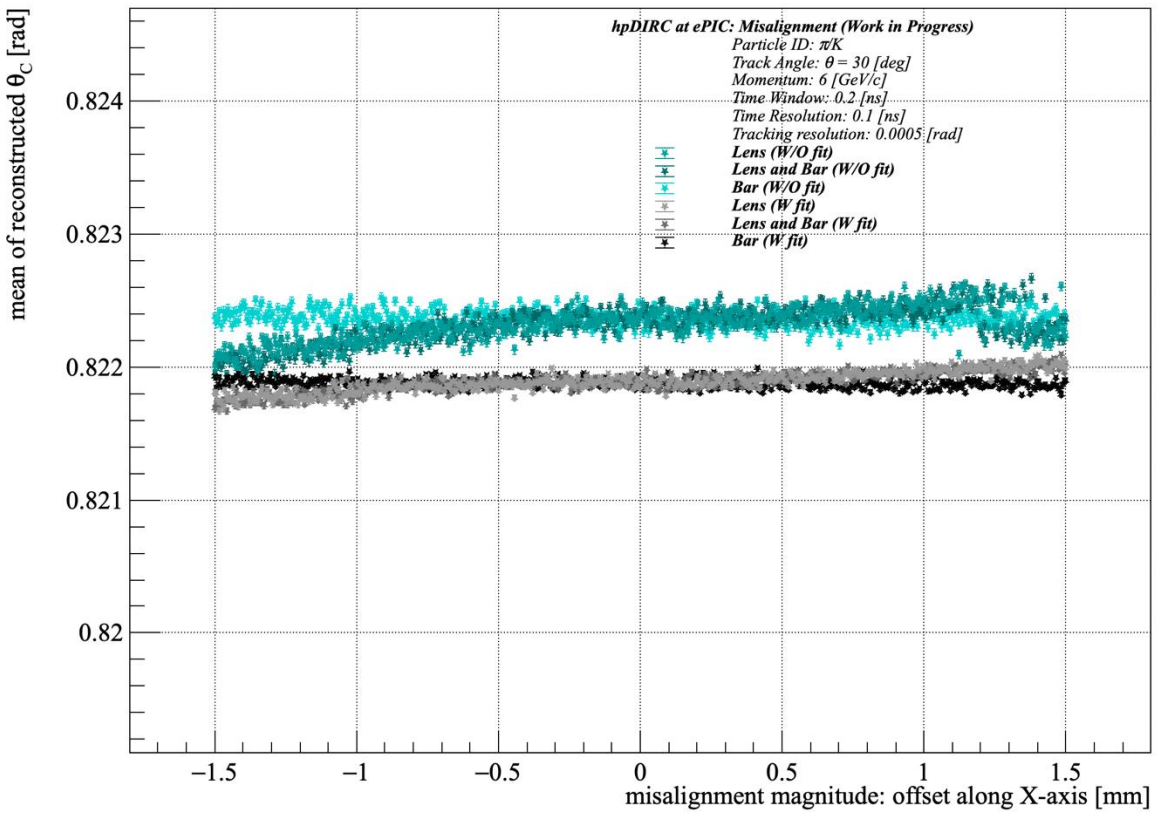


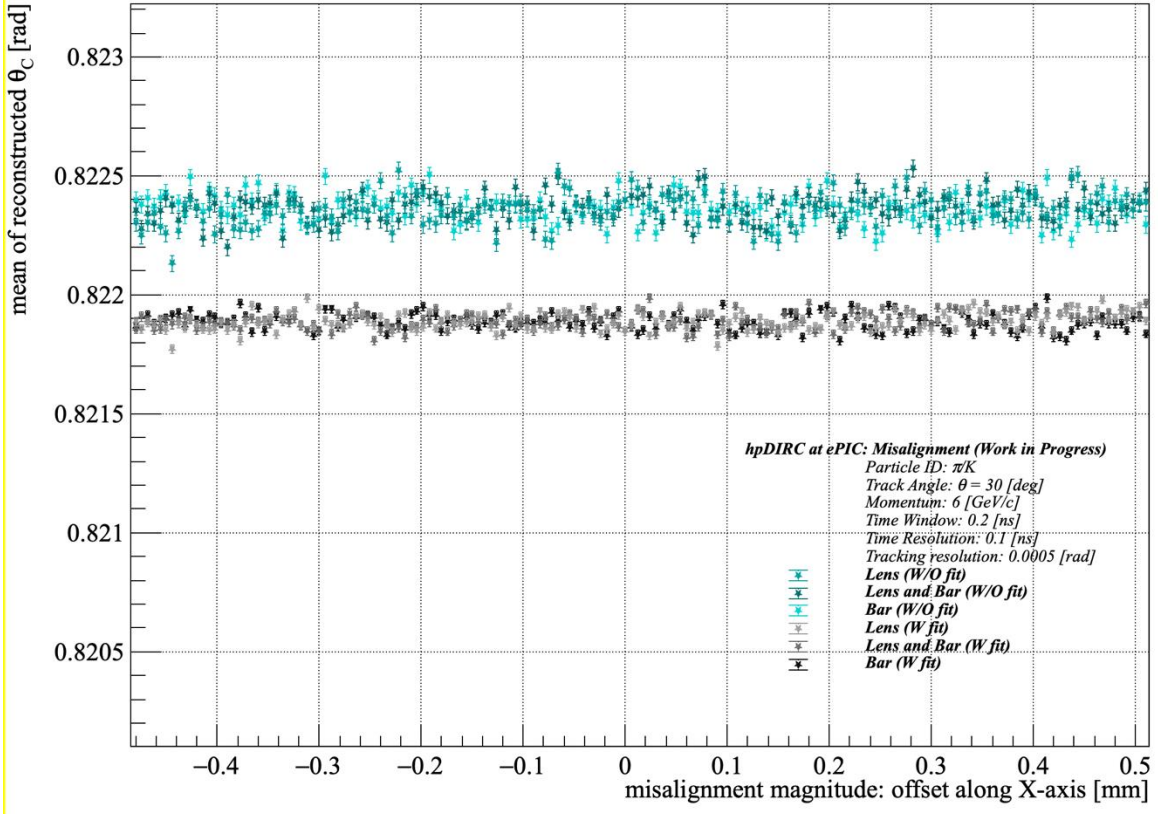
Reconstructed Cherenkov Angle for Nominal and Misaligned :



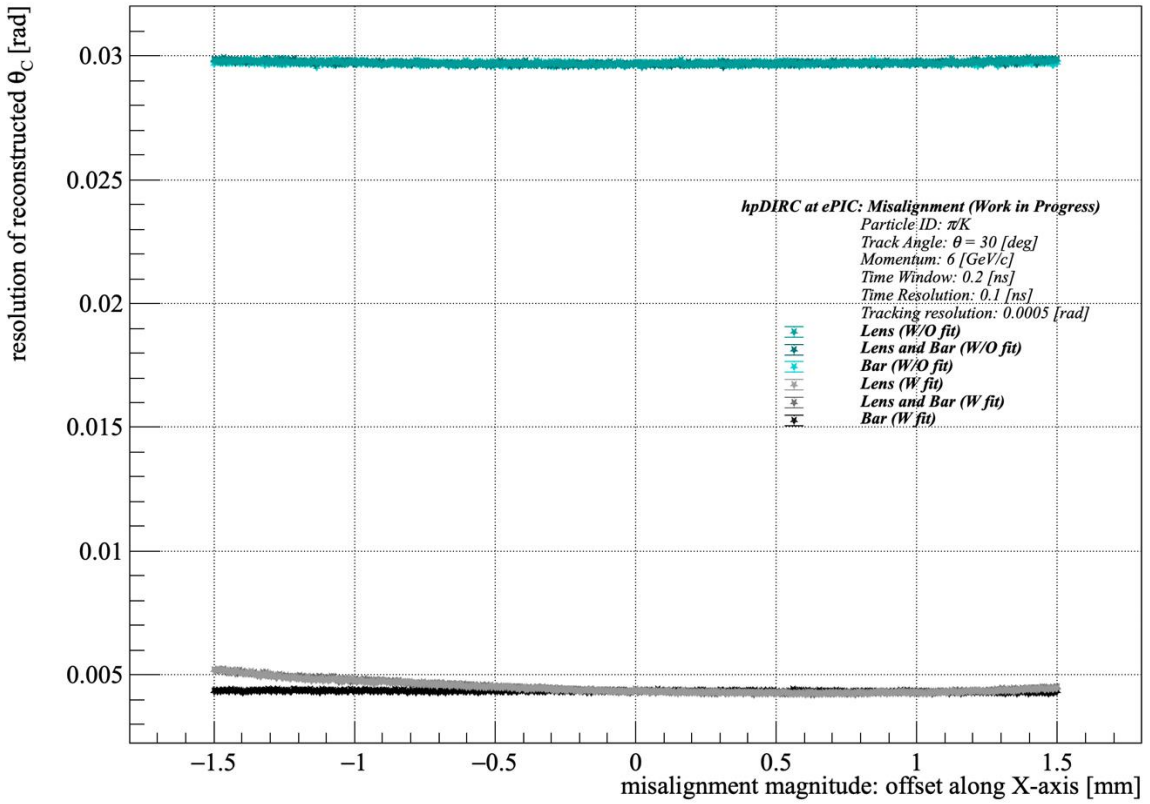


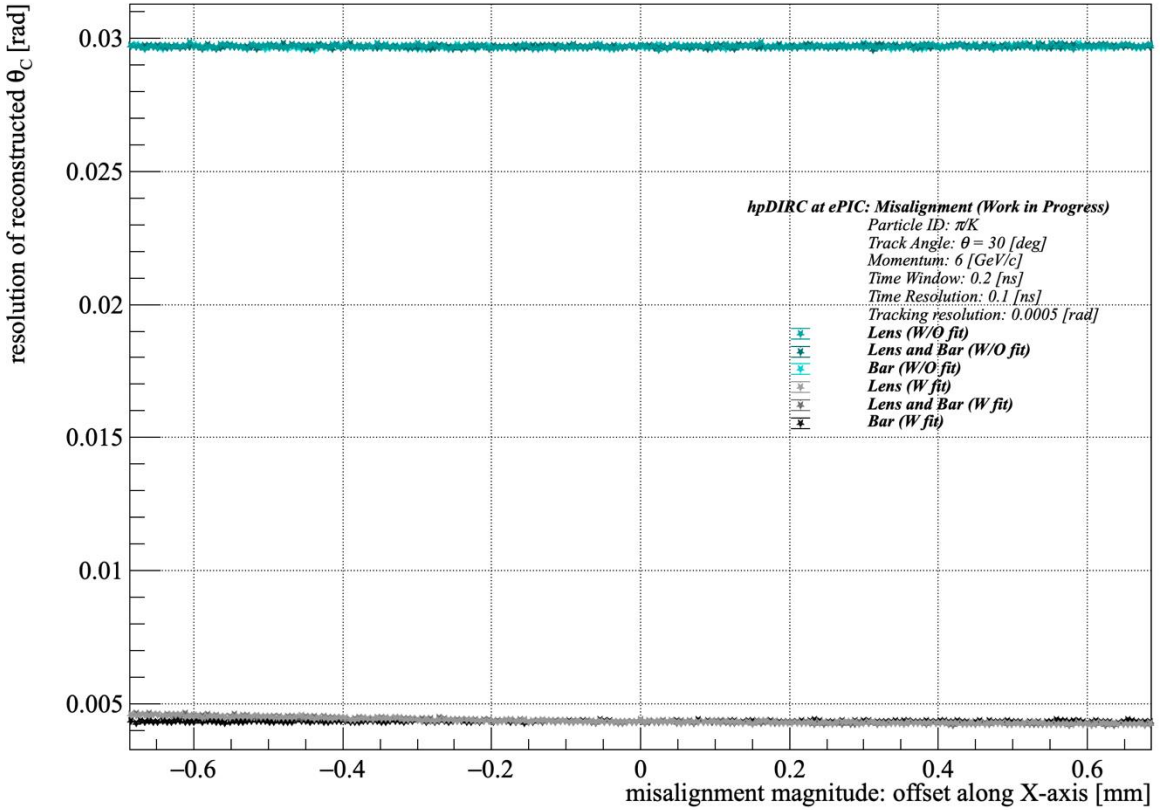
Reconstructed Cherenkov Angle for Nominal and Misaligned Detector :





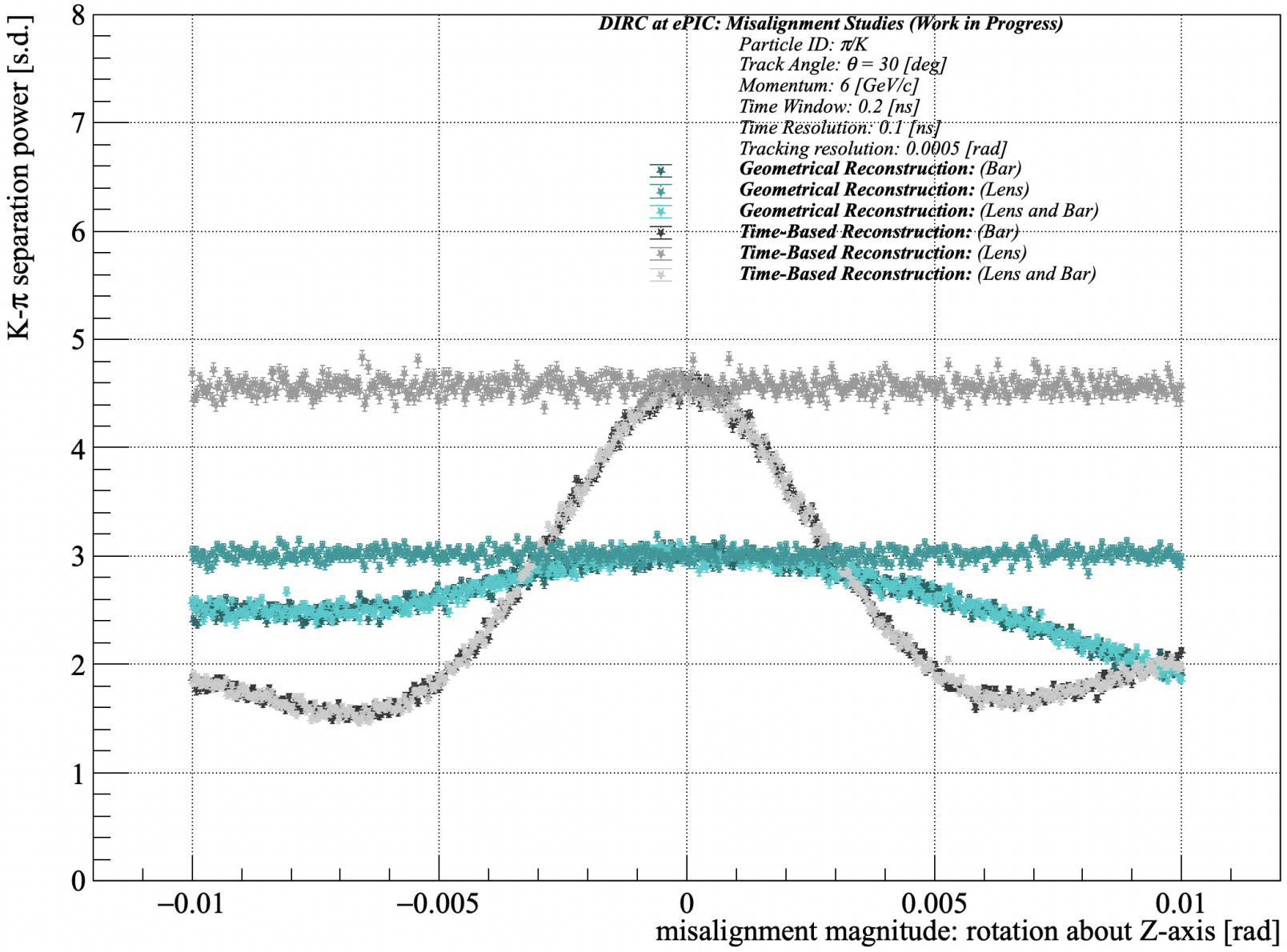
Reconstructed Cherenkov Angle for Nominal and Misaligned :





Misalignment studies conducted under realistic configurations and constraints across various modes, using same PDF for both the nominal and misaligned detectors.

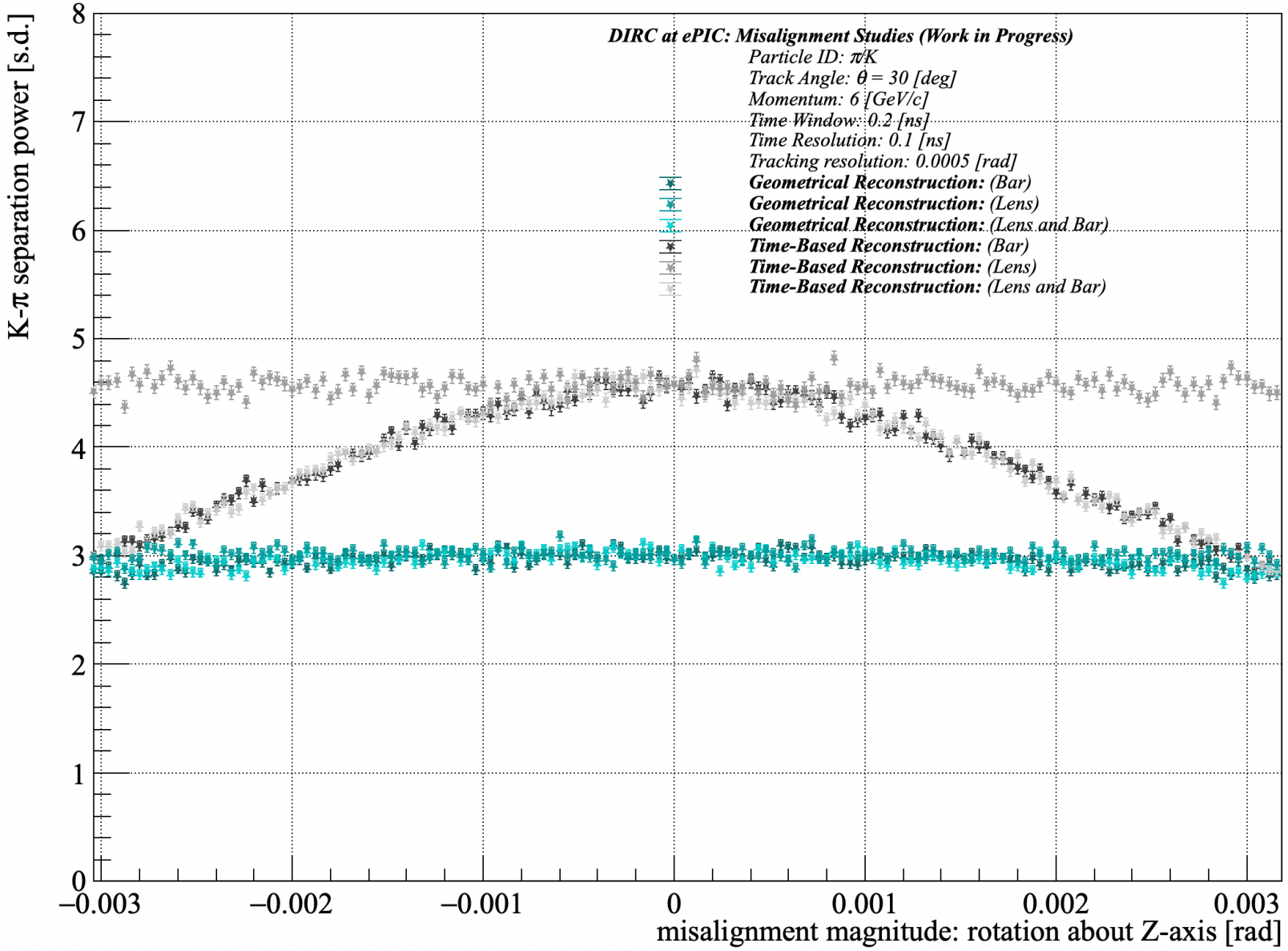
Separation Power between Kaon (K) and Pion (π):



- **Misalignment Mode:**

  Rotation

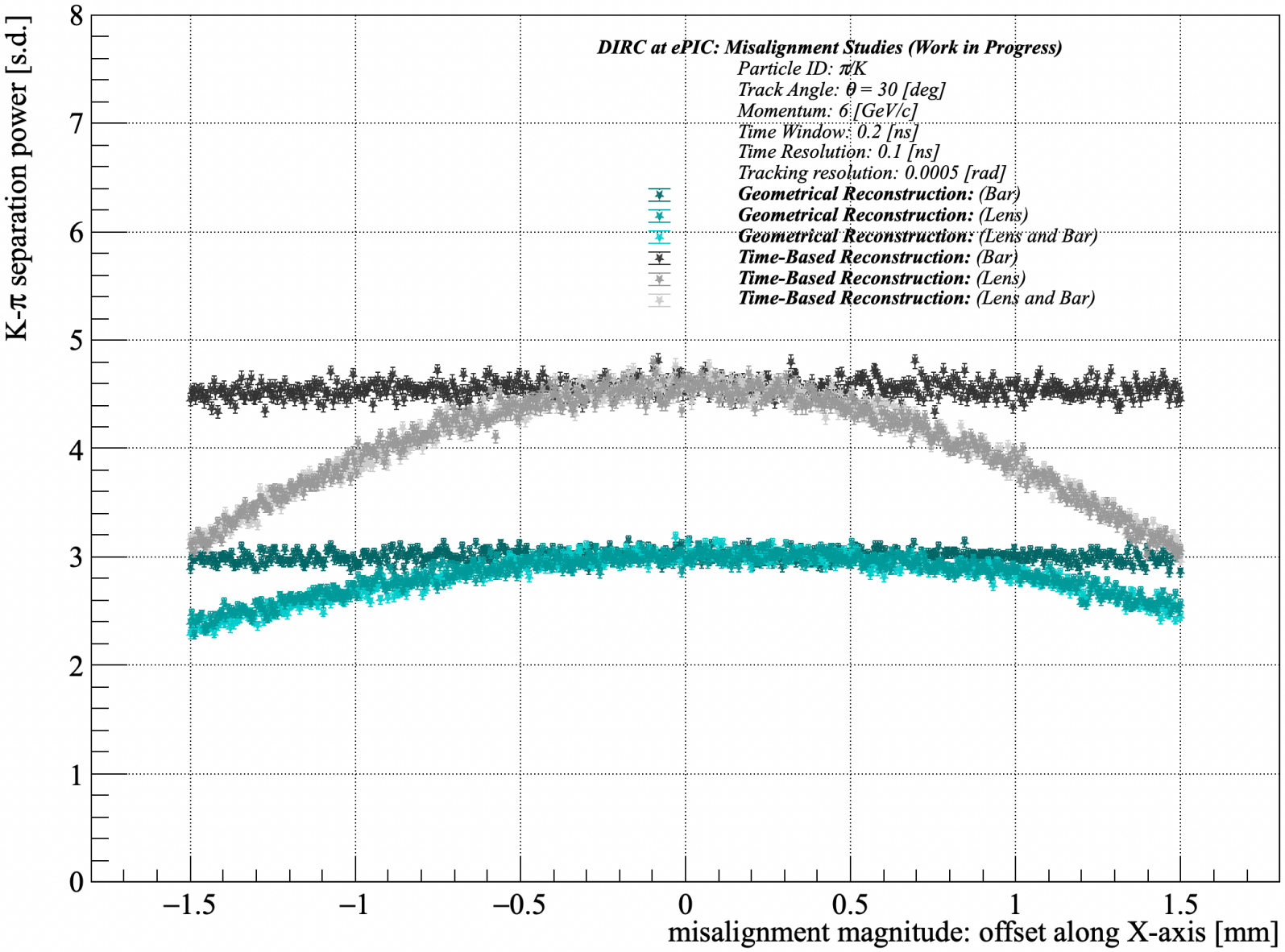
Separation Power between Kaon (K) and Pion (π):



- **Misalignment Mode:**

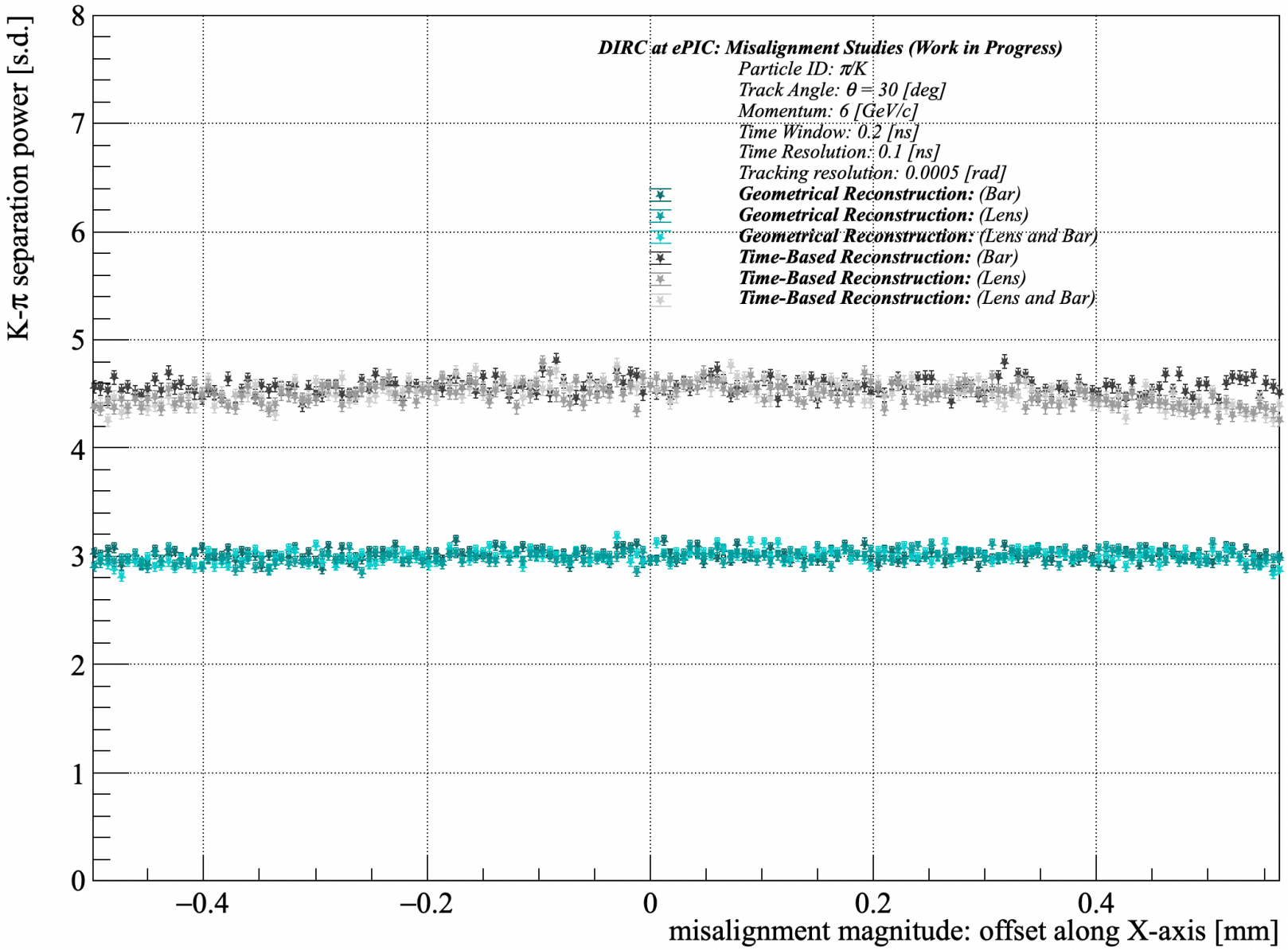
  Rotation about Z-axis

Separation Power between Kaon (K) and Pion (π):



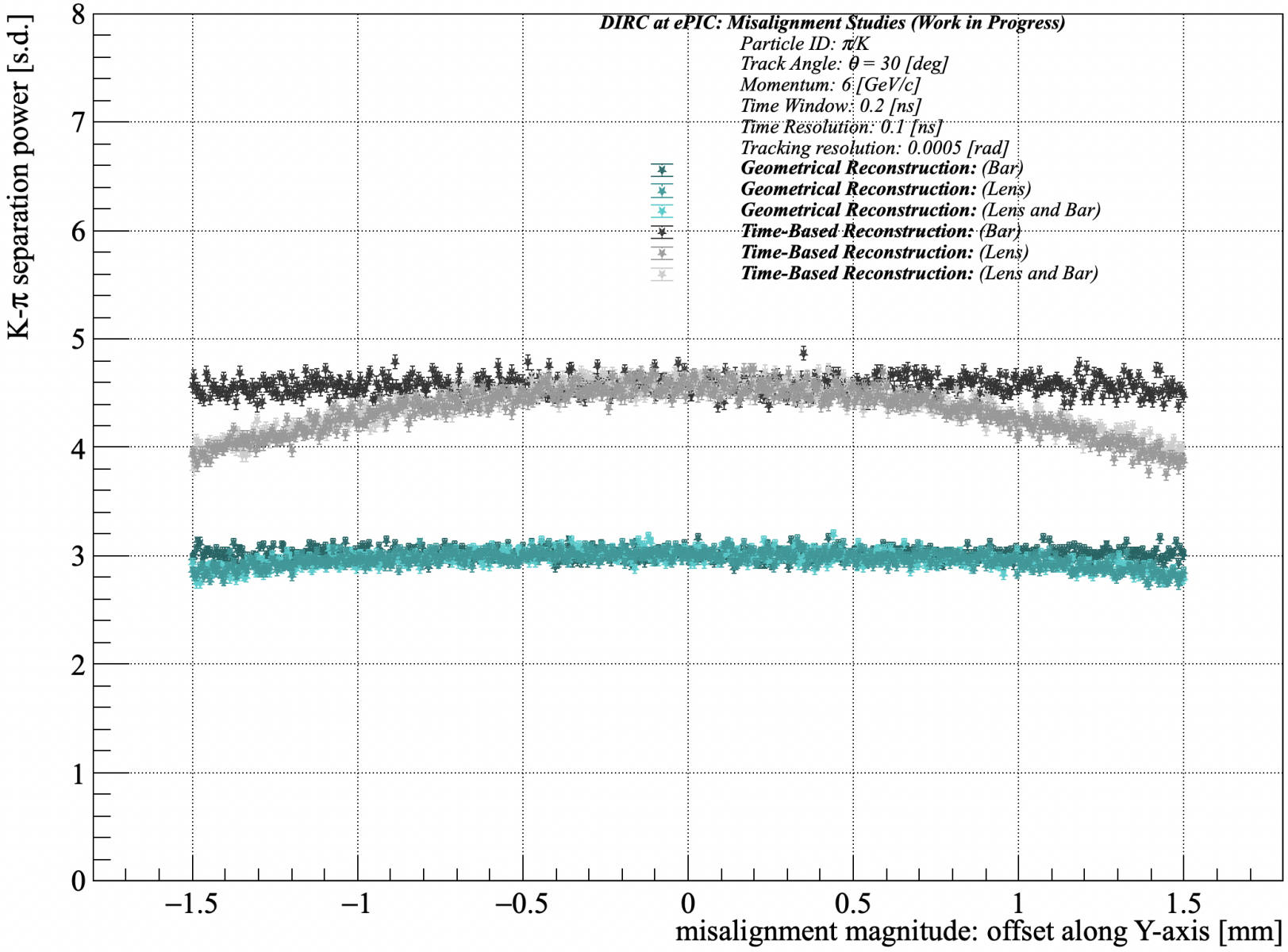
- **Misalignment Mode:** *Offset along X-axis*

Separation Power between Kaon (K) and Pion (π):



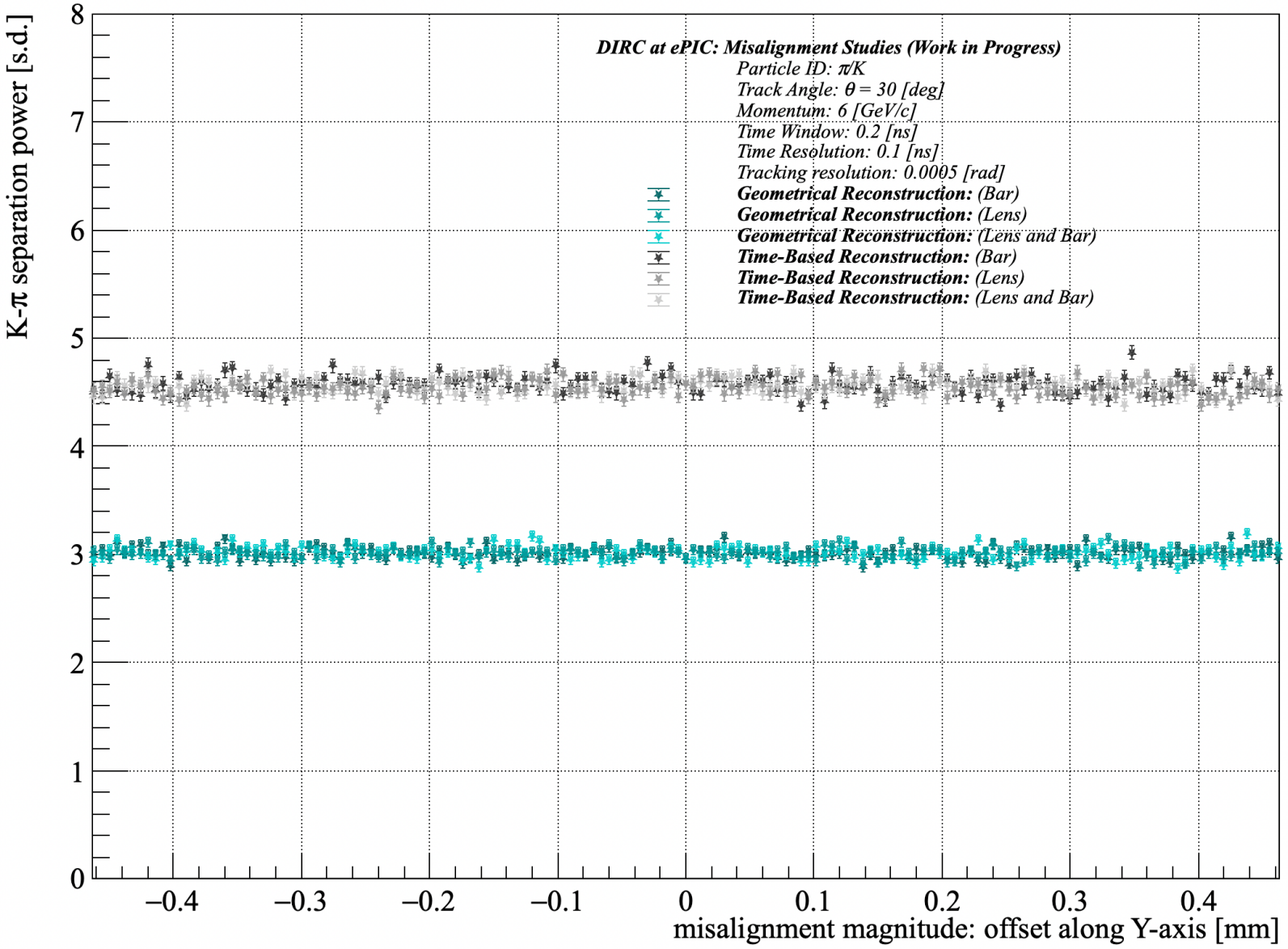
- **Misalignment Mode:** *Offset along X-axis*

Separation Power between Kaon (K) and Pion (π):



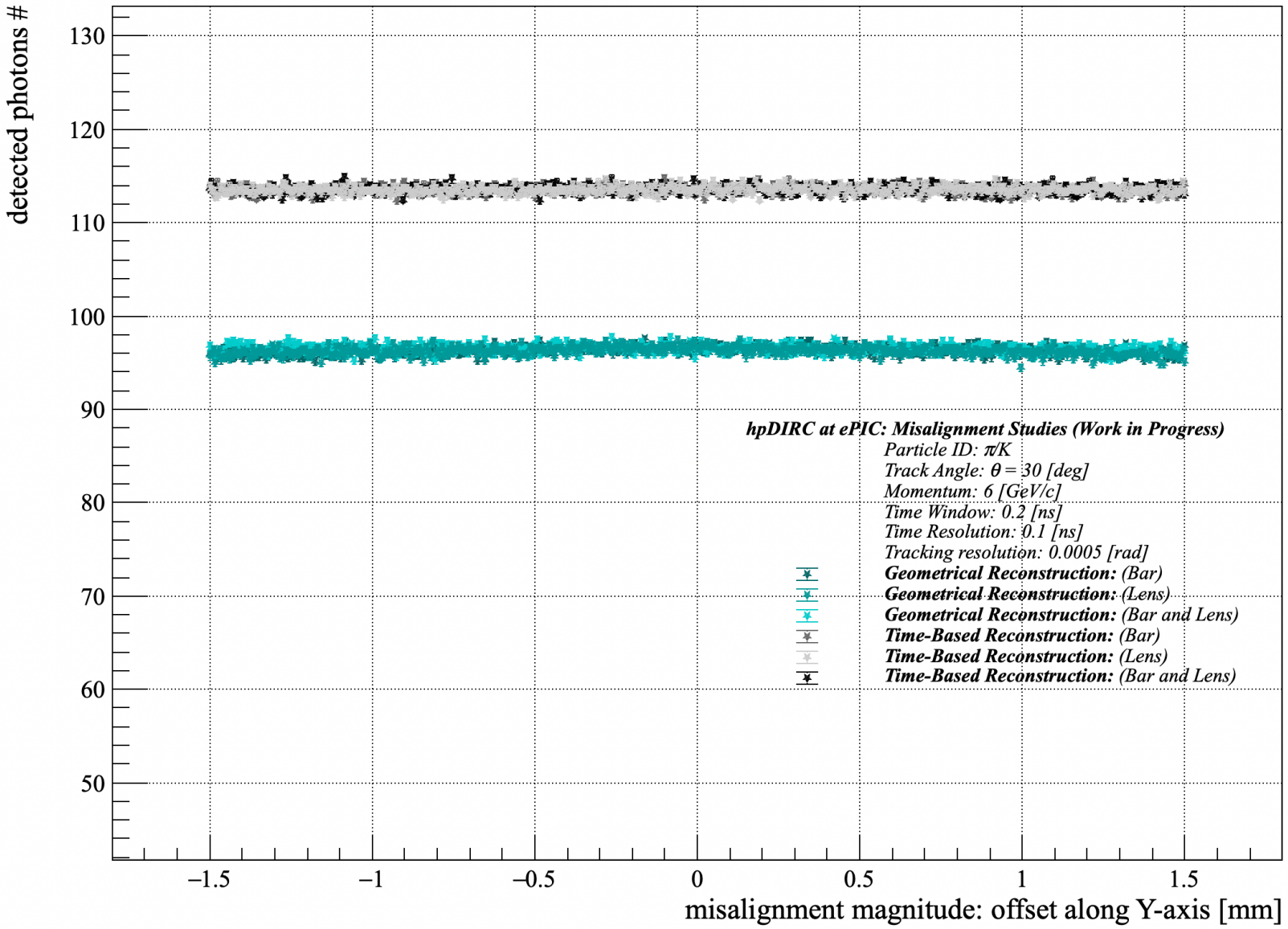
- **Misalignment Mode:** *Offset along Y-axis*

Separation Power between Kaon (K) and Pion (π):

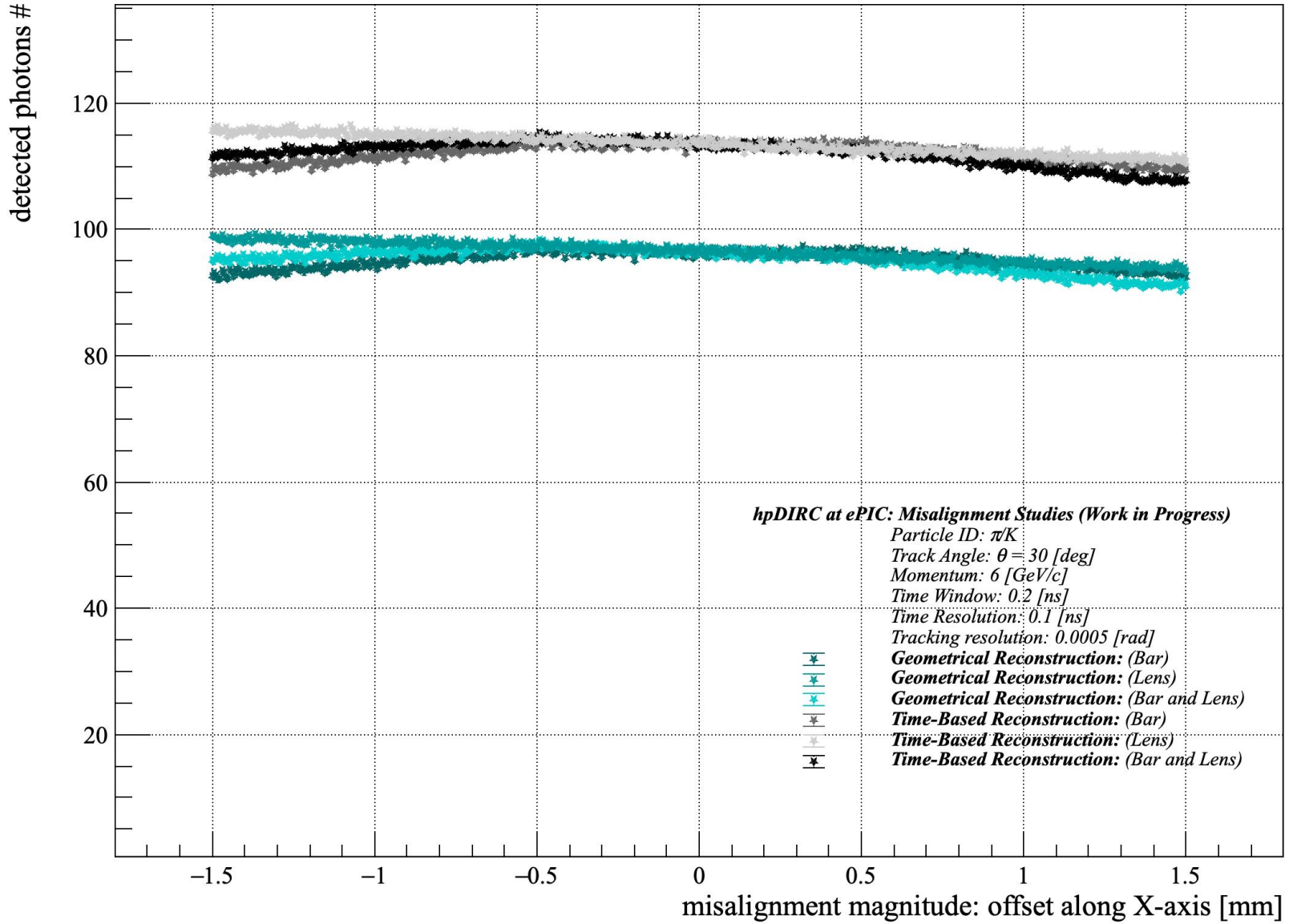


- **Misalignment Mode:** *Offset along Y-axis*

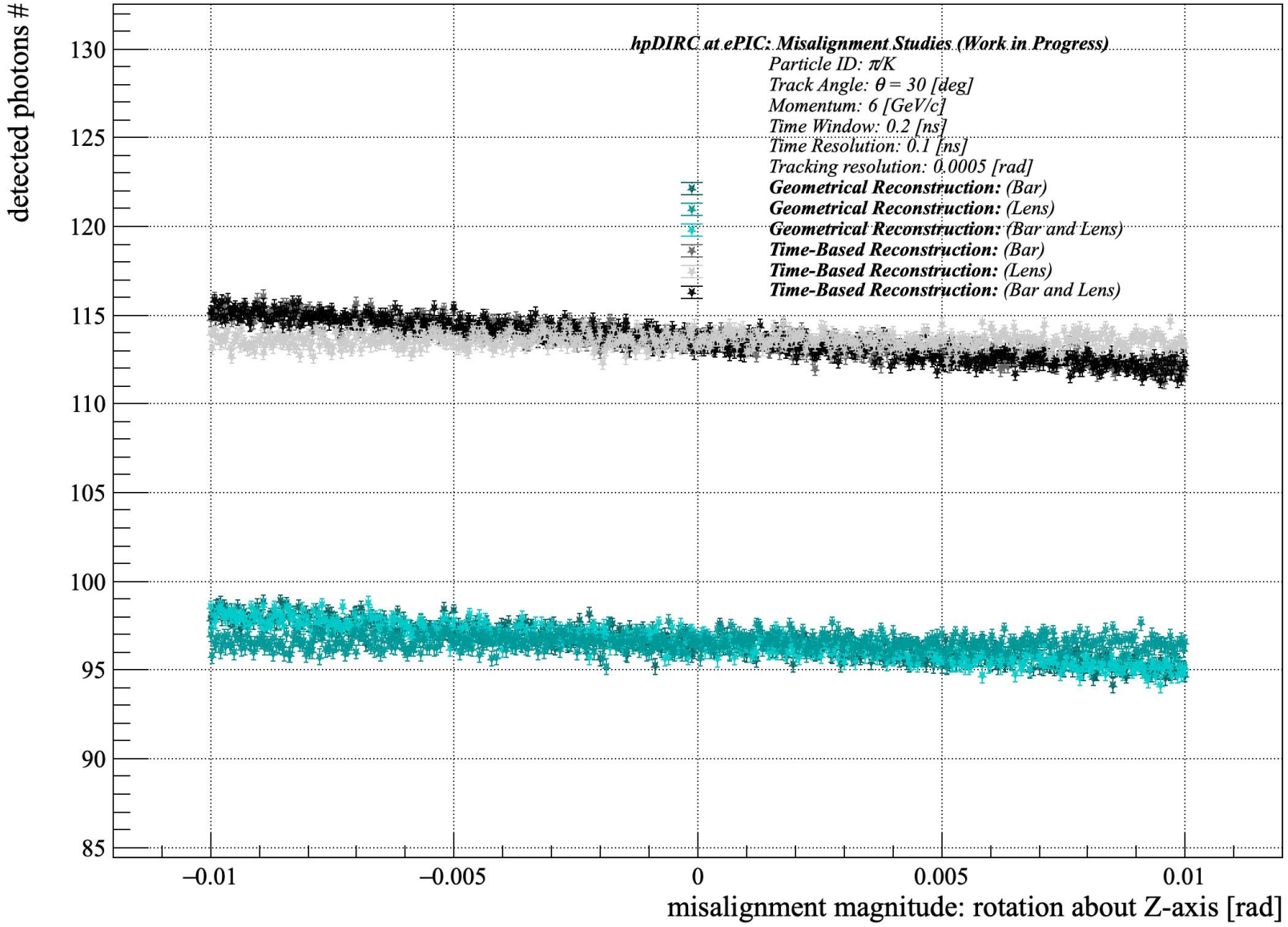
Backup ….


detected photons #
130
120
110
100
90
80
70
60
50
−1.5
−1
−0.5
0
0.5
1
1.5
misalignment magnitude: offset along Y-axis [mm]
hpDIRC at ePIC: Misalignment Studies (Work in Progress)
Particle ID: π/K
Track Angle: θ = 30 [deg]
Momentum: 6 [GeV/c]
Time Window: 0.2 [ns]
Time Resolution: 0.1 [ns]
Tracking resolution: 0.0005 [rad]
Geometrical Reconstruction: (Bar)
Geometrical Reconstruction: (Lens)
Geometrical Reconstruction: (Bar and Lens)
Time-Based Reconstruction: (Bar)
Time-Based Reconstruction: (Lens)
Time-Based Reconstruction: (Bar and Lens)

same pdf


detected photons #
120
100
80
60
40
20
−1.5
−1
−0.5
0
0.5
1
1.5
misalignment magnitude: offset along X-axis [mm]
hpDIRC at ePIC: Misalignment Studies (Work in Progress)
Particle ID: π/K
Track Angle: θ = 30 [deg]
Momentum: 6 [GeV/c]
Time Window: 0.2 [ns]
Time Resolution: 0.1 [ns]
Tracking resolution: 0.0005 [rad]
Geometrical Reconstruction: (Bar)
Geometrical Reconstruction: (Lens)
Geometrical Reconstruction: (Bar and Lens)
Time-Based Reconstruction: (Bar)
Time-Based Reconstruction: (Lens)
Time-Based Reconstruction: (Bar and Lens)

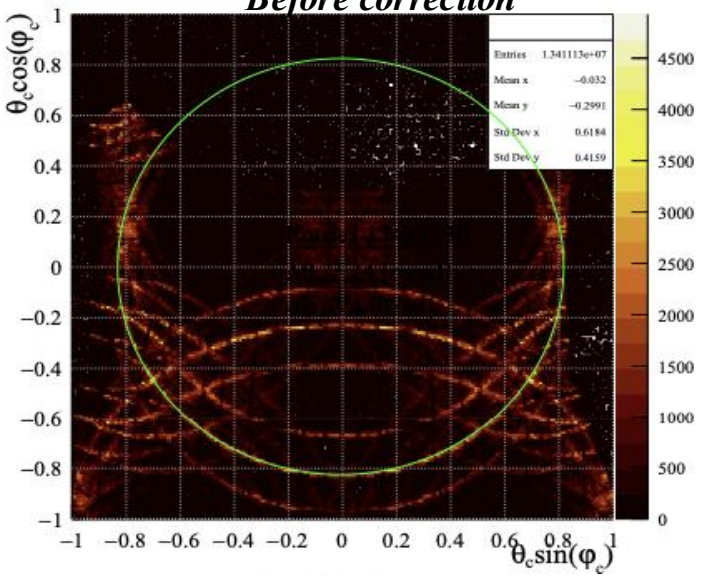
same pdf


hpDIRC at ePIC: Misalignment Studies (Work in Progress)
Particle ID: π/K
Track Angle: θ = 30 [deg]
Momentum: 6 [GeV/c]
Time Window: 0.2 [ns]
Time Resolution: 0.1 [ns]
Tracking resolution: 0.0005 [rad]
Geometrical Reconstruction: (Bar)
Geometrical Reconstruction: (Lens)
Geometrical Reconstruction: (Bar and Lens)
Time-Based Reconstruction: (Bar)
Time-Based Reconstruction: (Lens)
Time-Based Reconstruction: (Bar and Lens)
detected photons #
130
125
120
115
110
105
100
95
90
85
–0.01
–0.005
0
0.005
0.01
misalignment magnitude: rotation about Z-axis [rad]

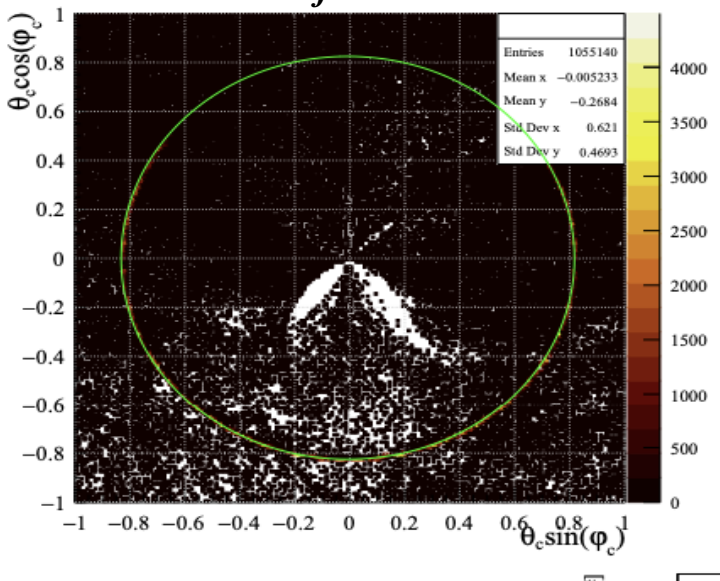
Same pdf

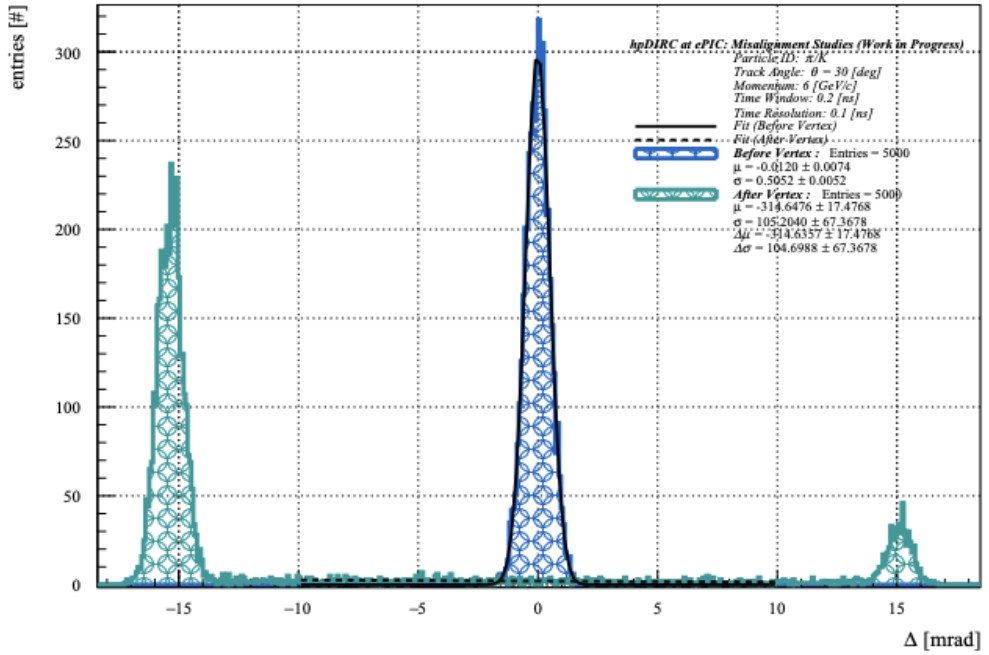
1. Cherenkov Ring Fit Correction:

Before correction

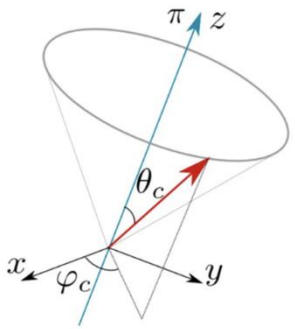


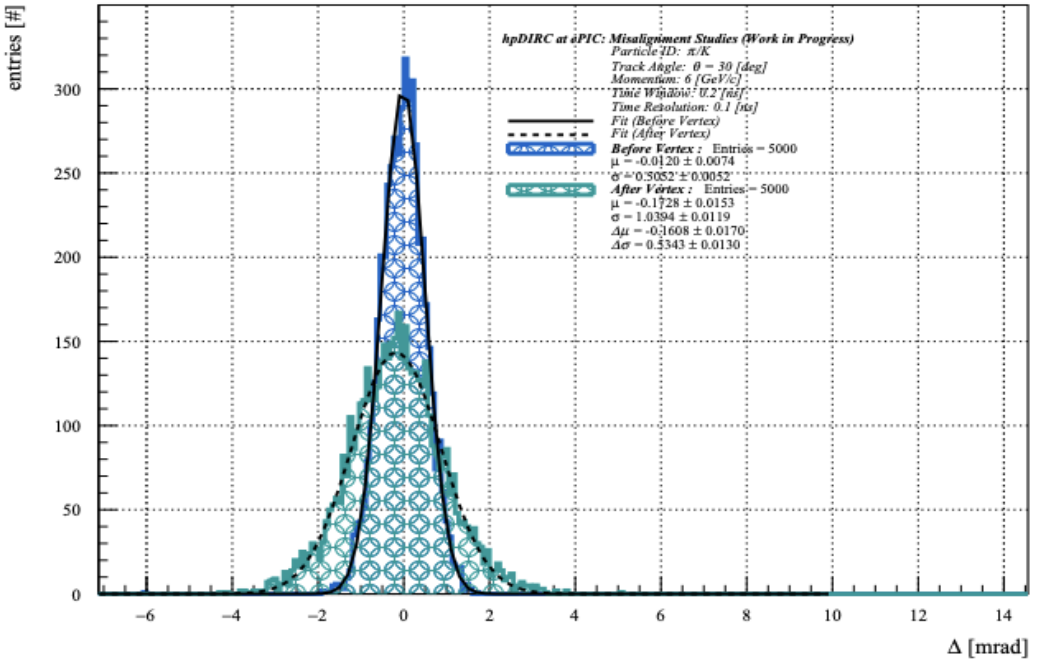
After correction





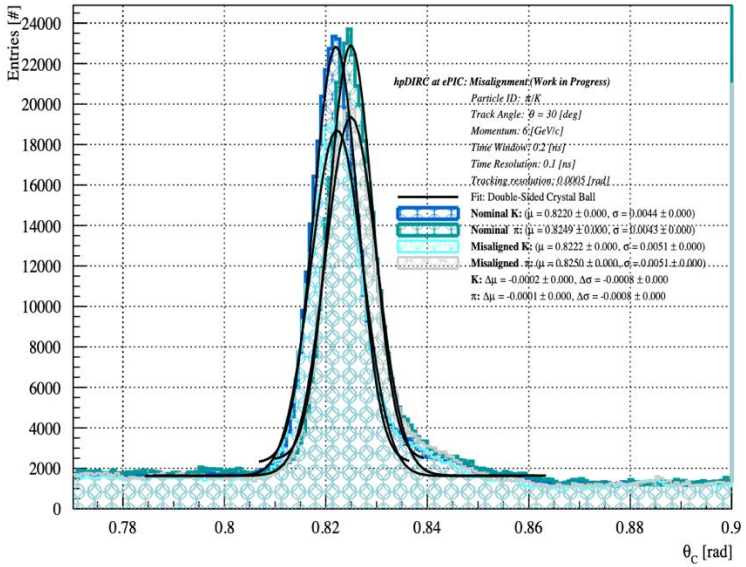
Fitting Stage	**Before Correction** (σ [mrad])	**After Correction** (σ [mrad])
Before Vertex Fit	0.5052 ± 0.0052	0.5052 ± 0.0052
After Vertex Fit	–	1.0394 ± 0.0119

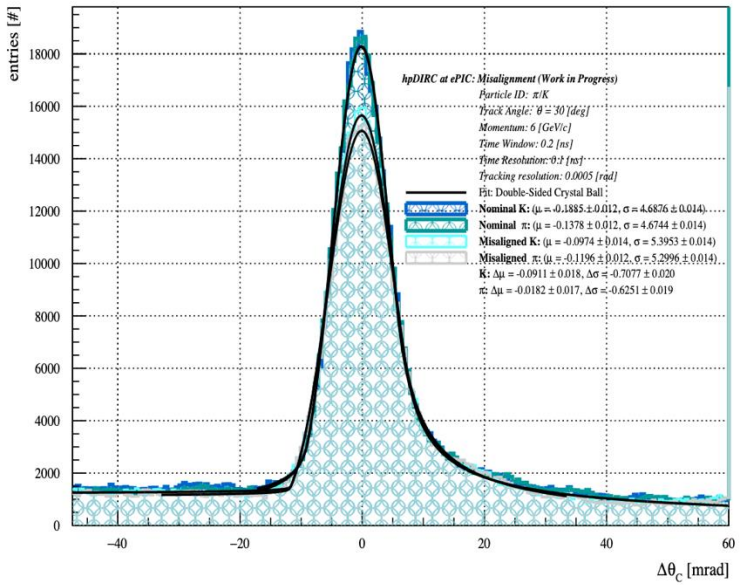




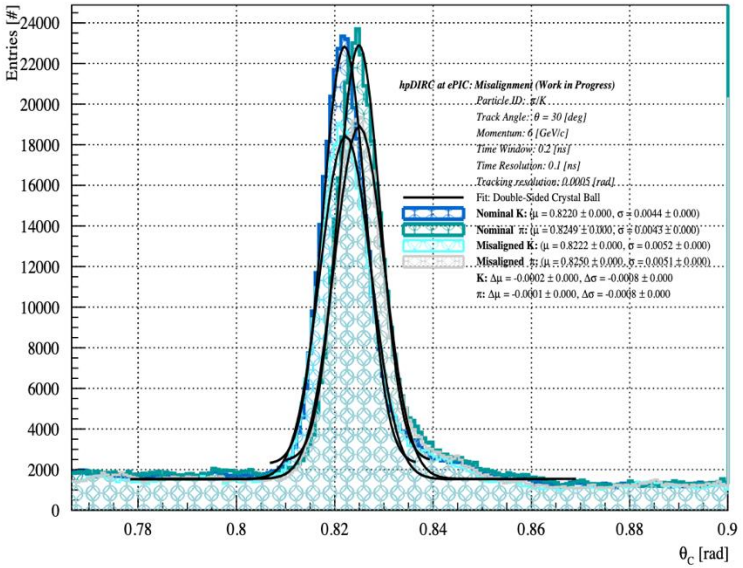
Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Pion and Kaon:

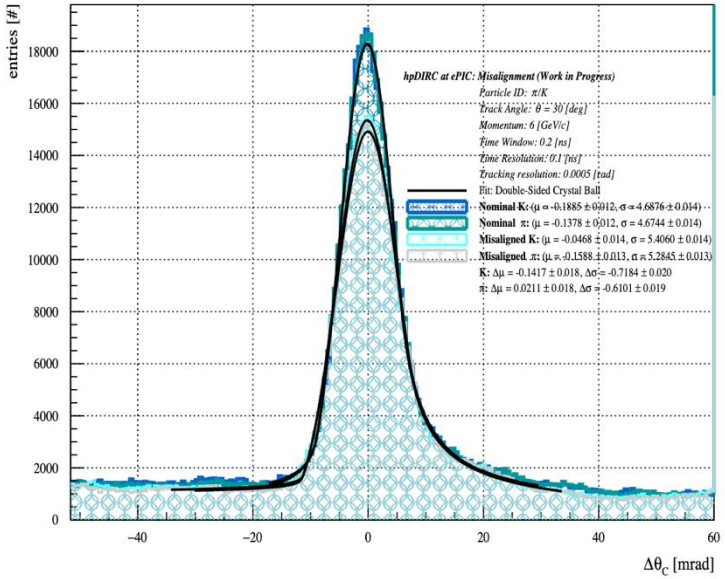
offset lens along Y with 4.986 mm



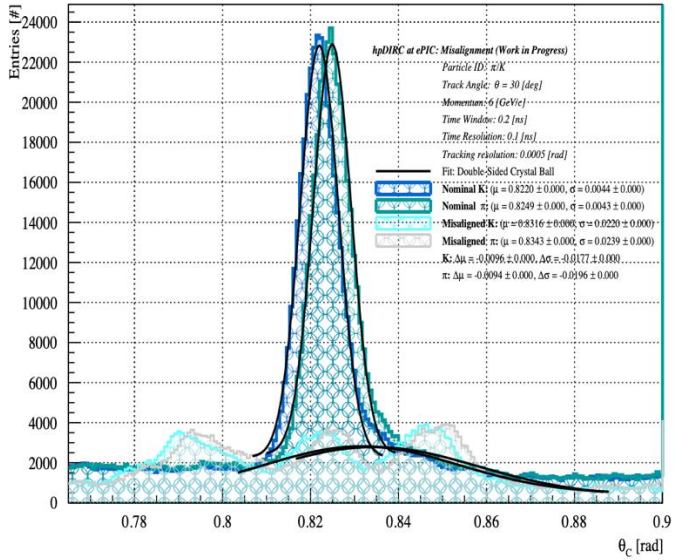


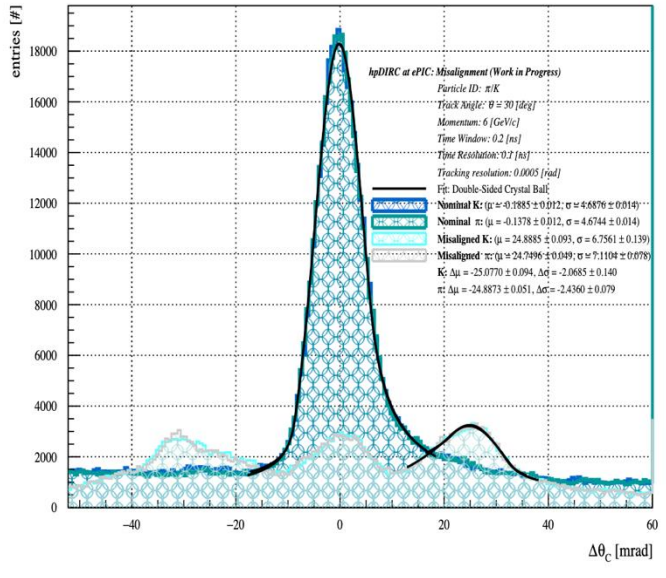
offset lens along Y with 5.400 mm



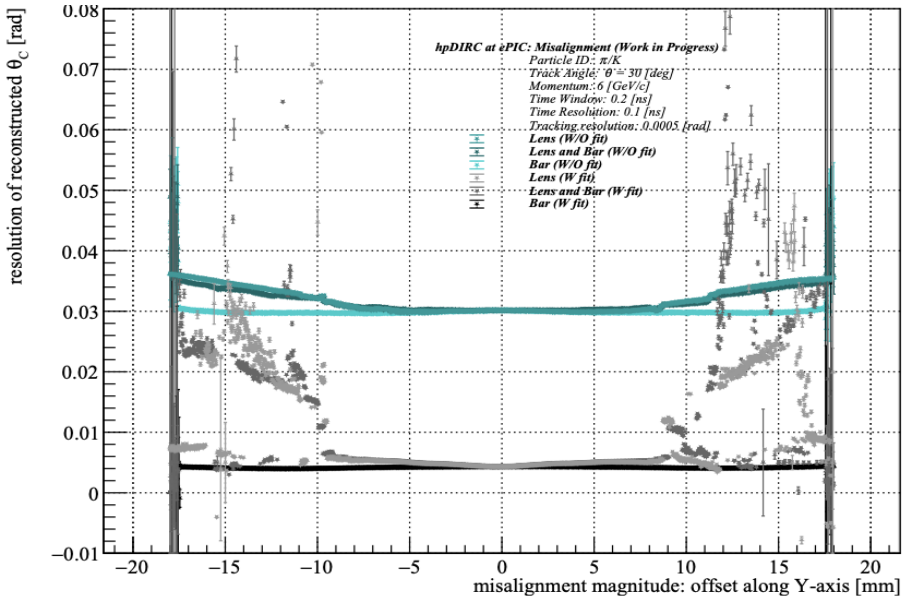


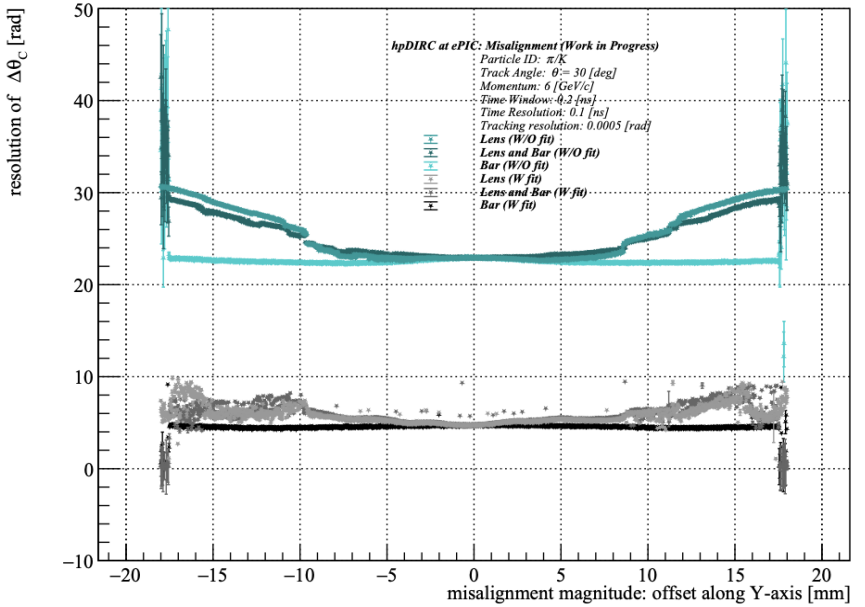
offset lens along Y with 14.382 mm

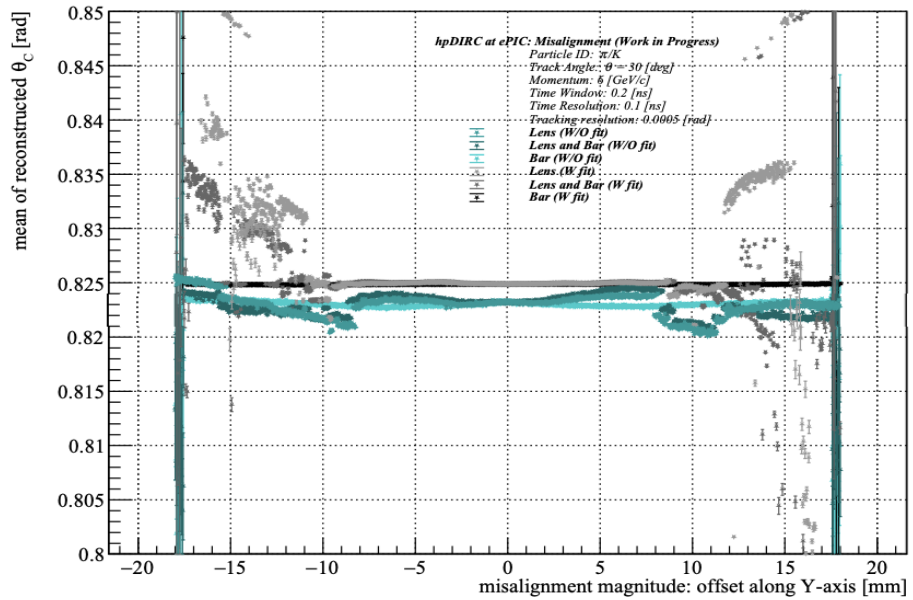


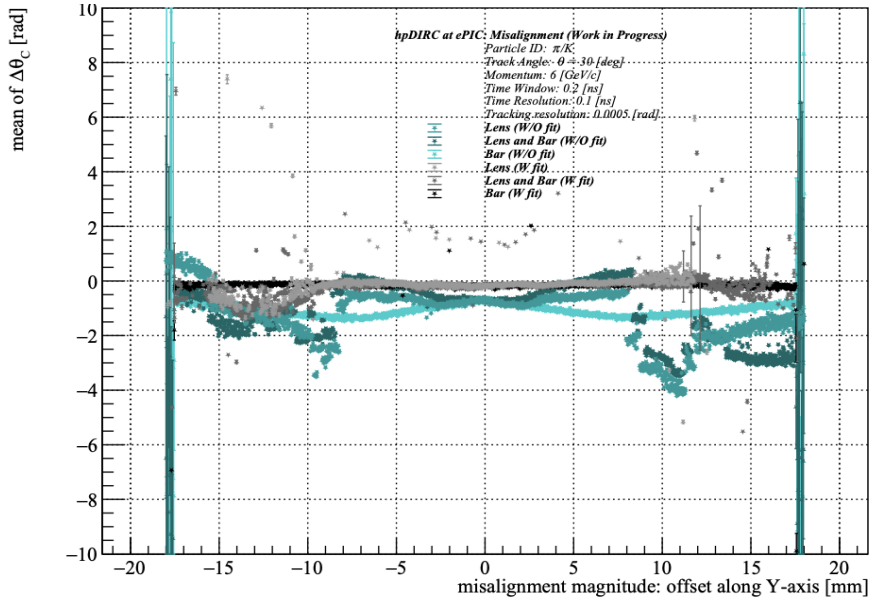


Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Pion only:

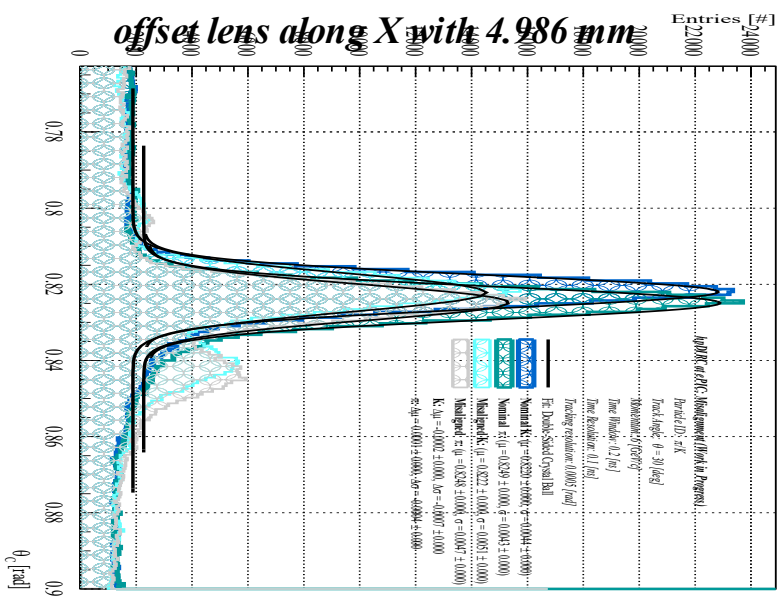


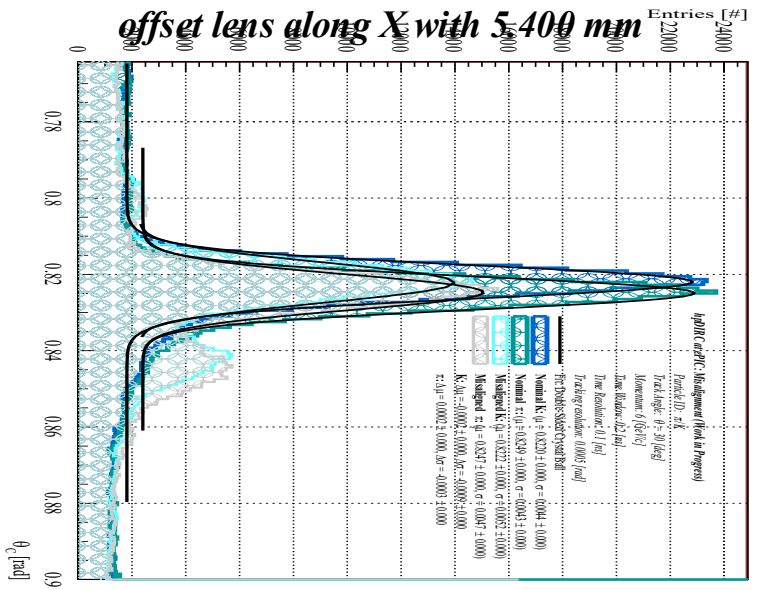


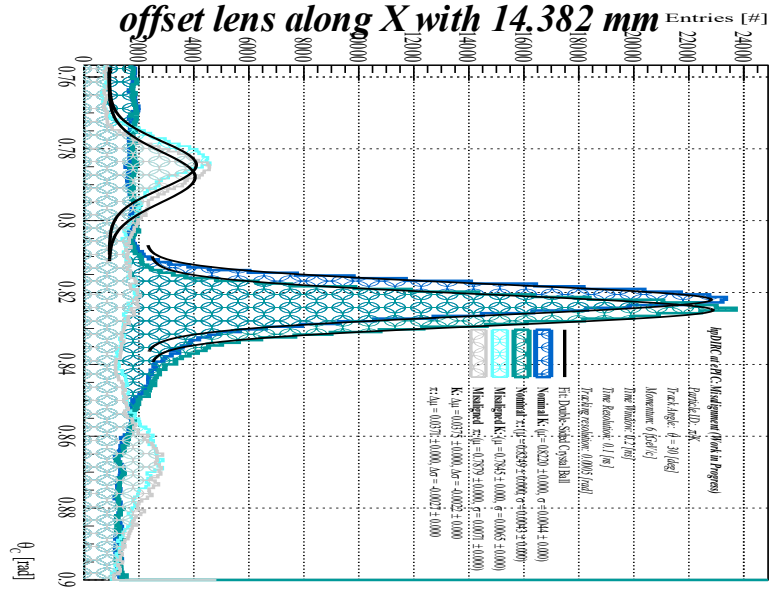


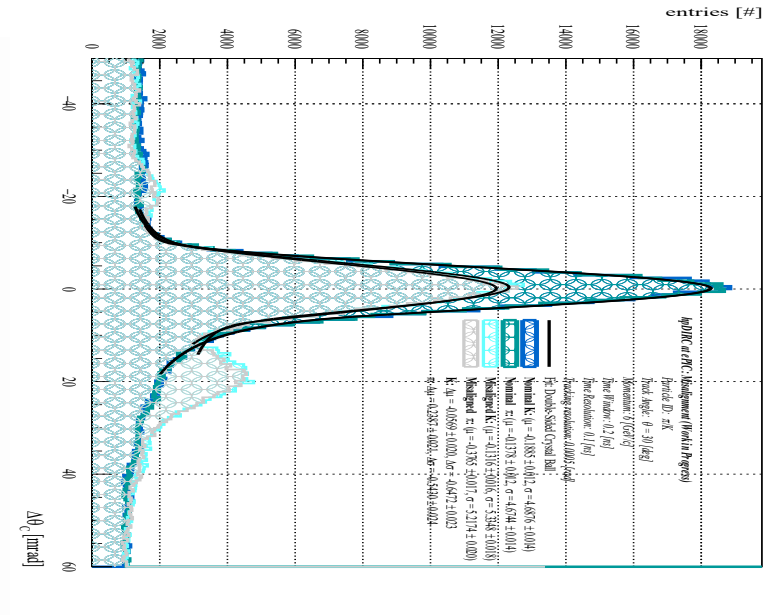


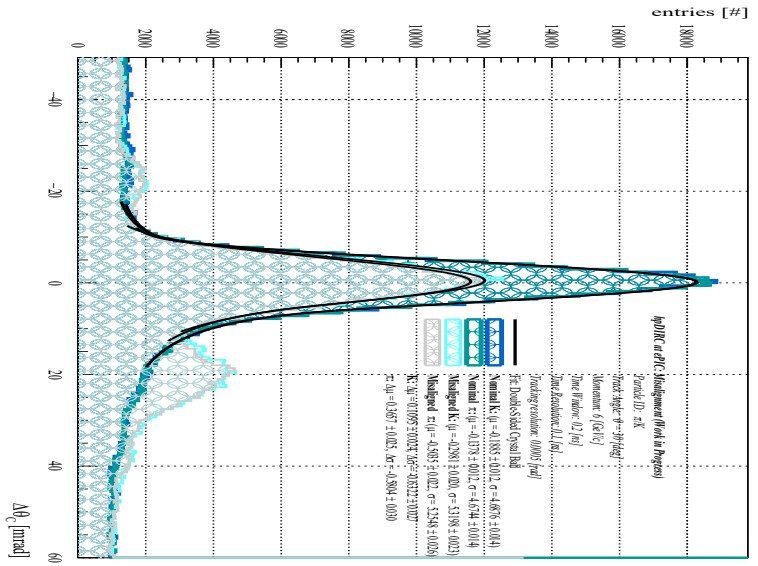
Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Pion and Kaon:

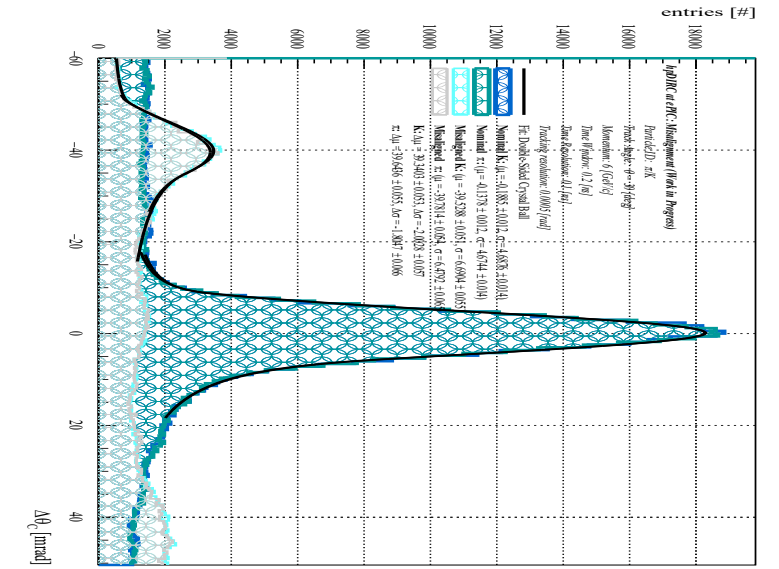




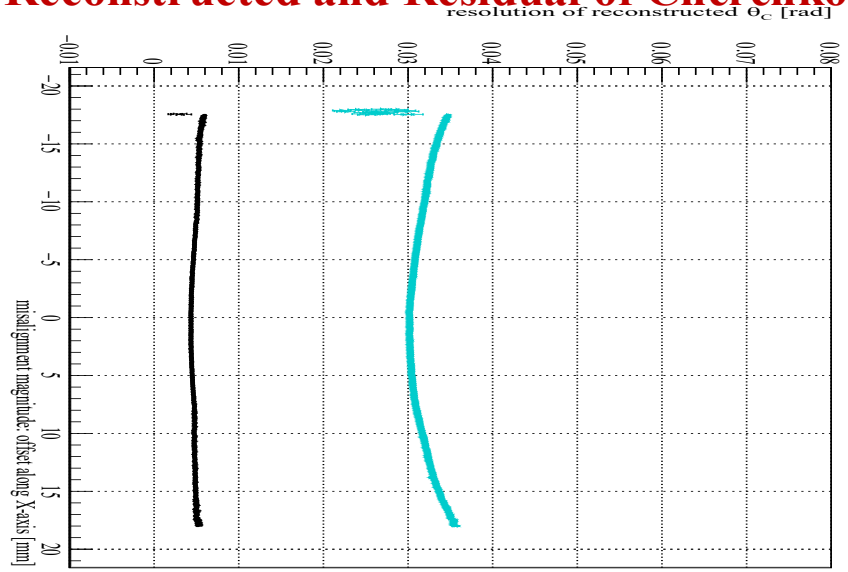


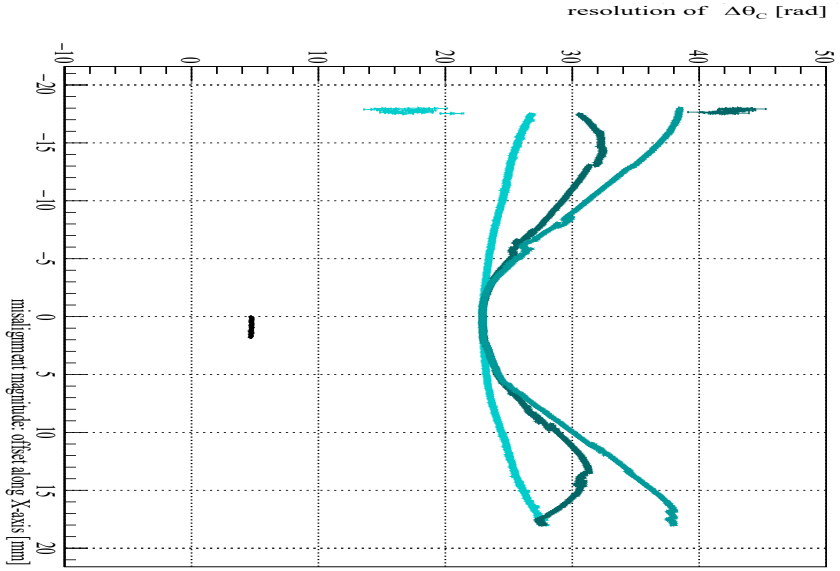


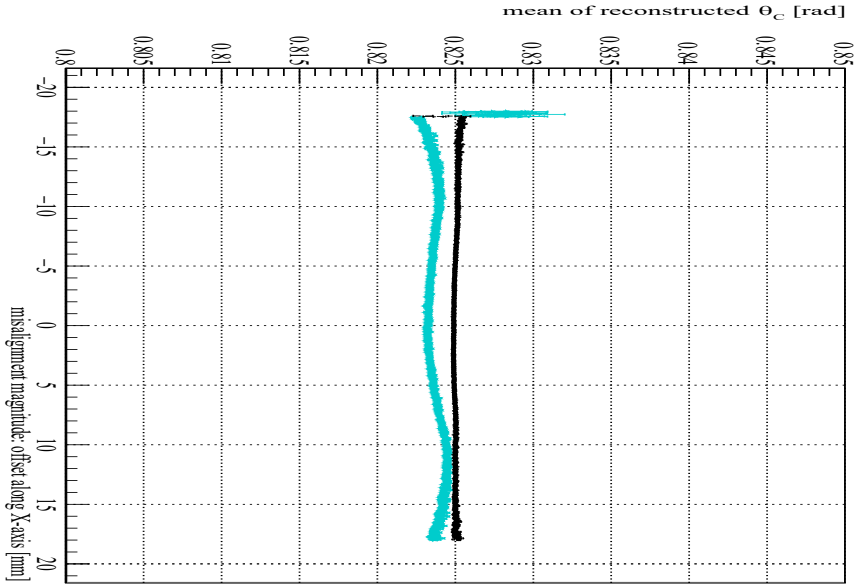


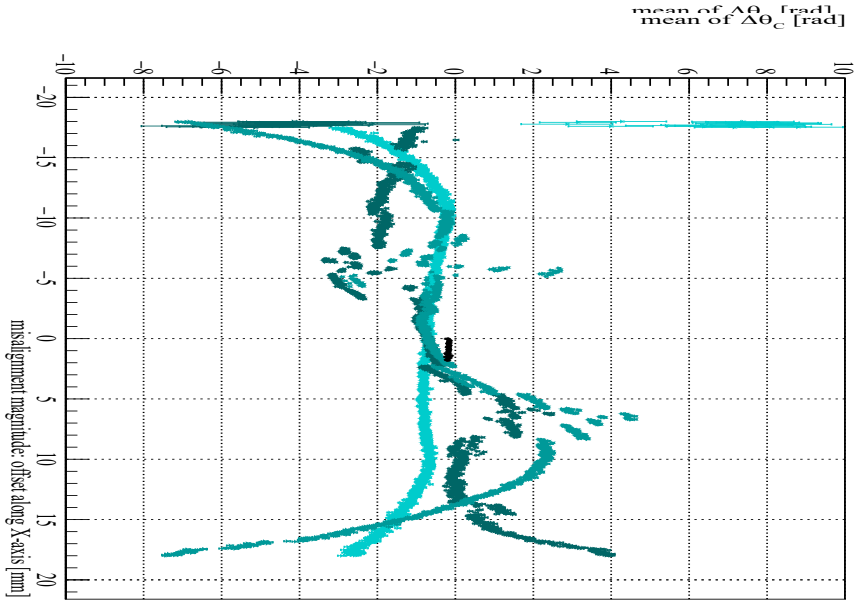


Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Pion only:

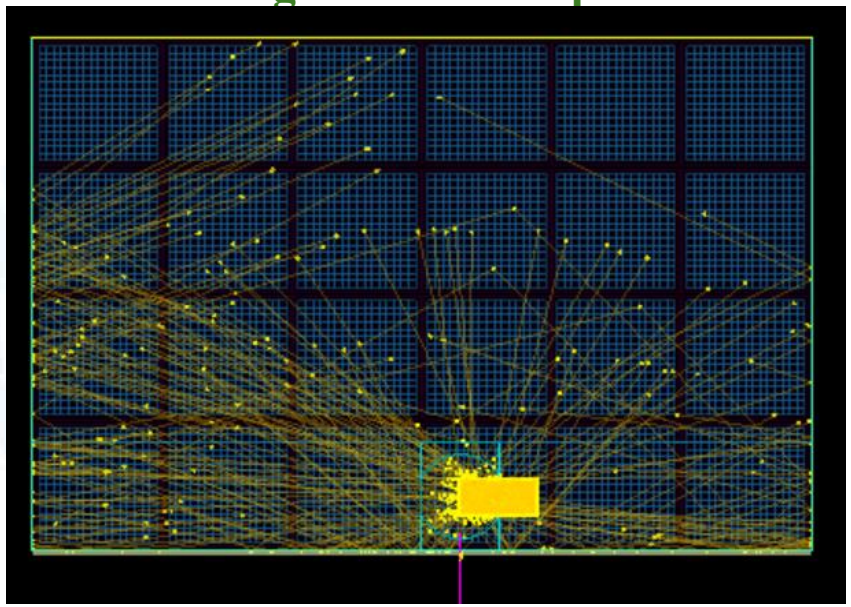




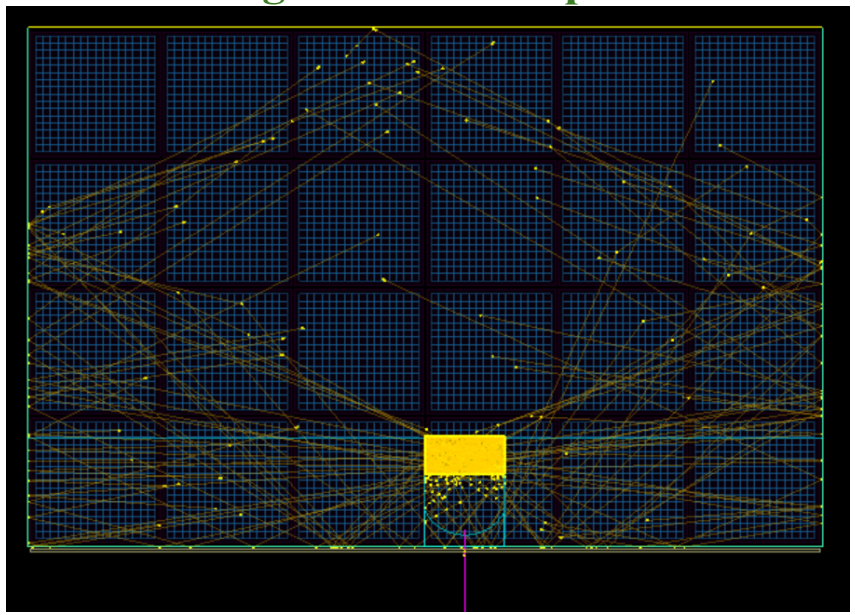




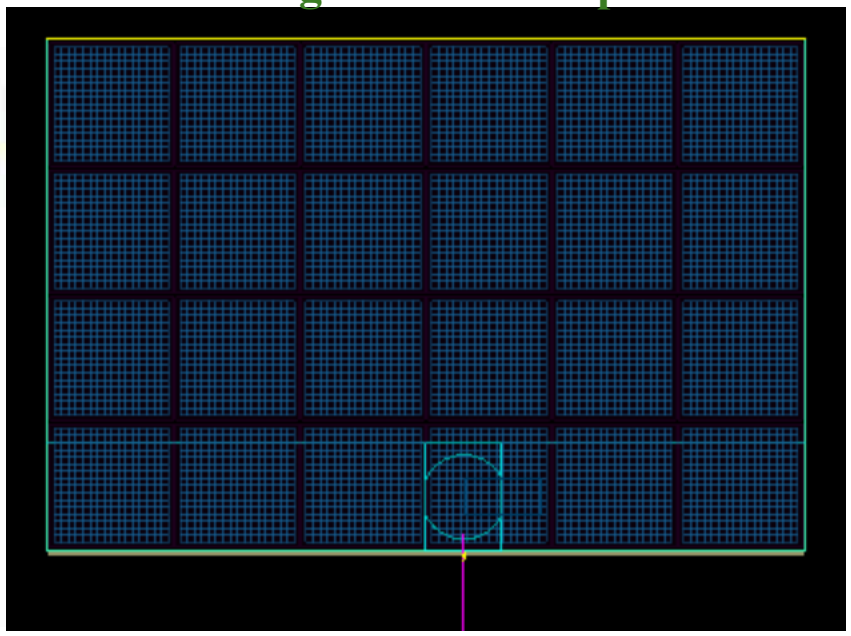
shift bar along Y at 17 mm: photons #: 93



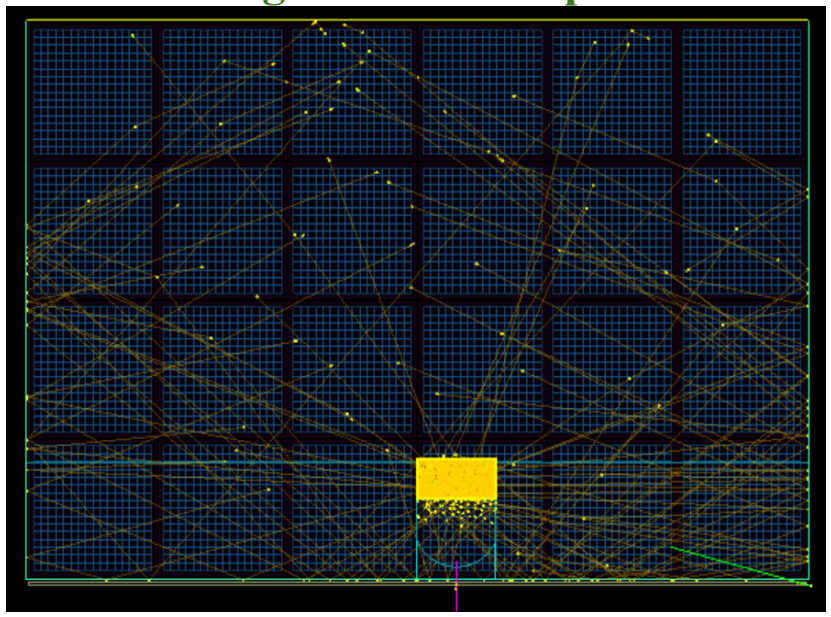
shift bar along X at 17 mm: photons #: 38



shift bar along Y at 18 mm: photons #: 0

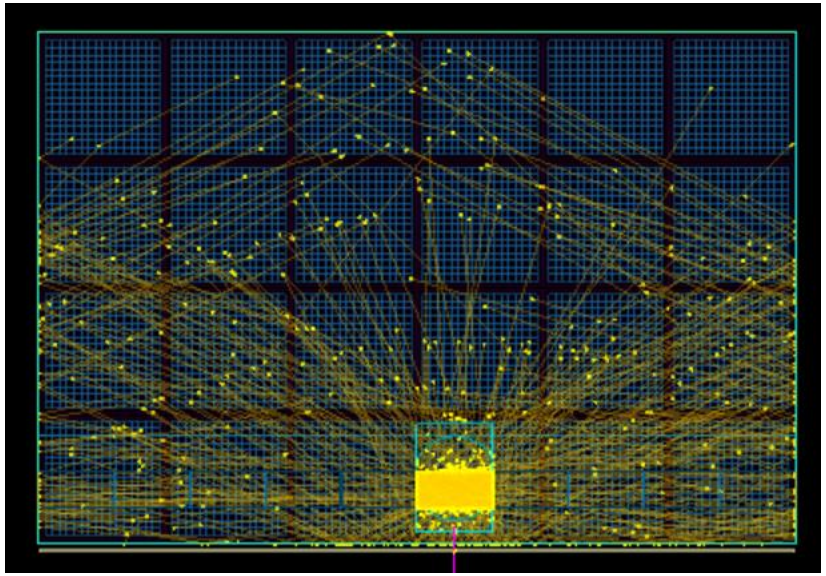


shift bar along X at 18 mm: photons #: 34

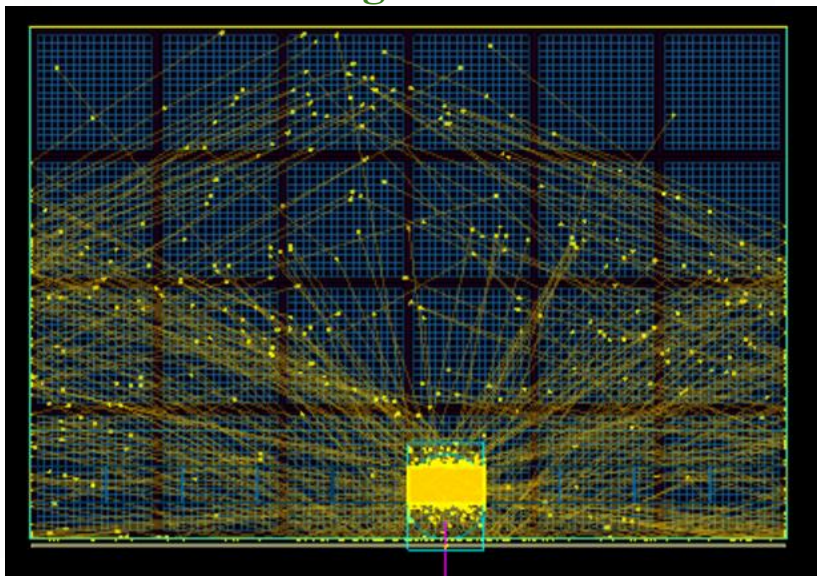


Why there is smooth dropped in the photons number in X not in the Y: the position of the charged track

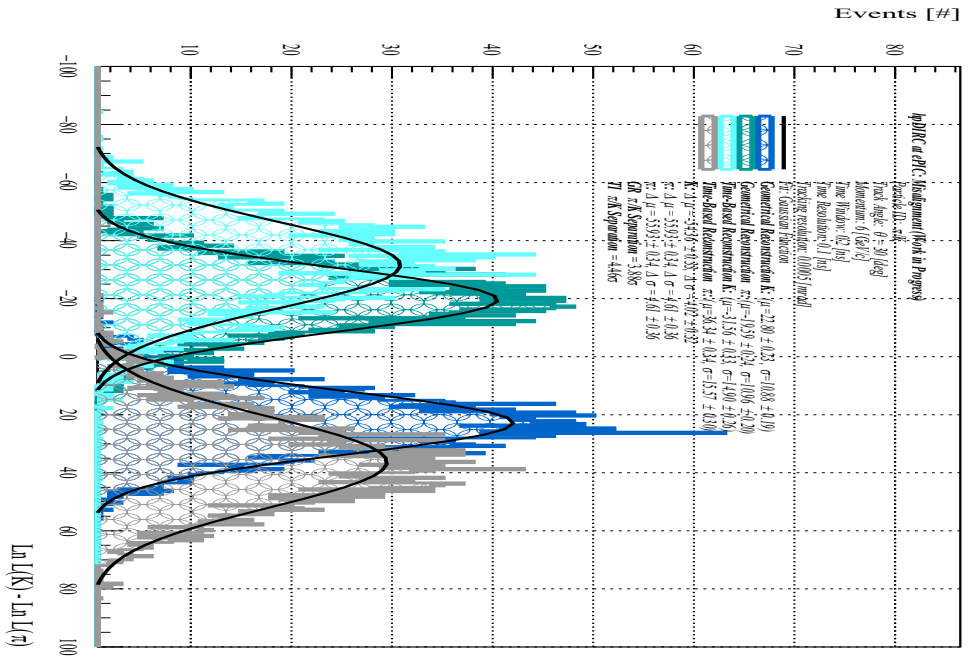
Offset lens along X at 5.4 mm: 164



Offset lens along -X at 5.4 mm: 139



Why the photons number in the offset along X is not same in the +/- direction

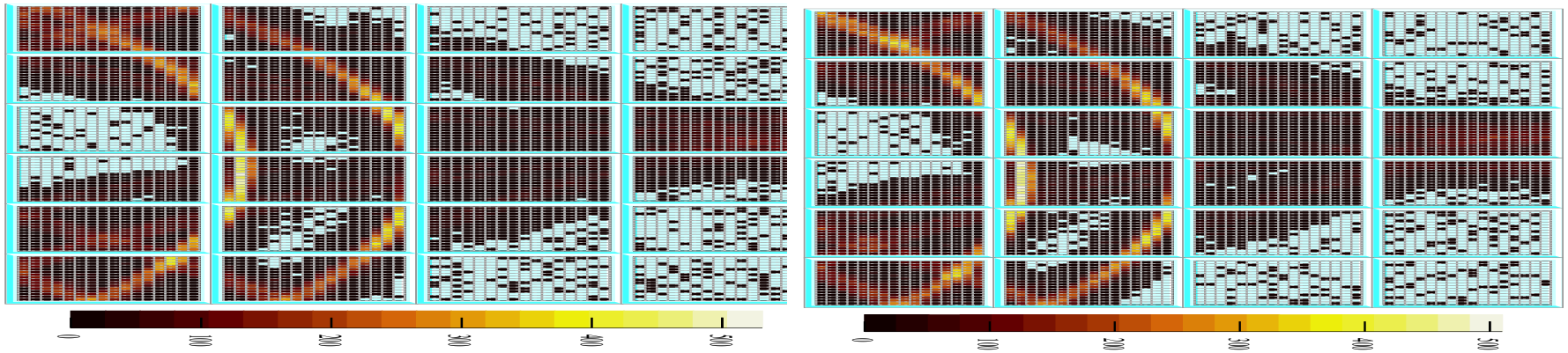


Photon hit distribution when the radiator bar is rotated vertically by 1.57 rad, showing enhanced particle separation performance better than nominal detector showing in the Bottom.

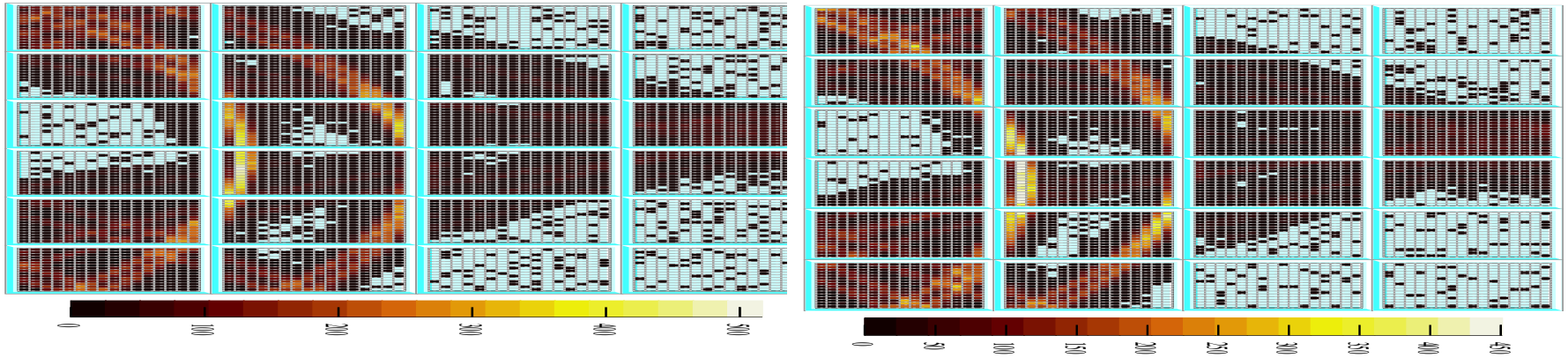
Hit Pattern for All Events per Different Misalignment Mode:

- **Misalignment Scenario**: *Combined*
- **Misalignment Mode:** *Rotation*

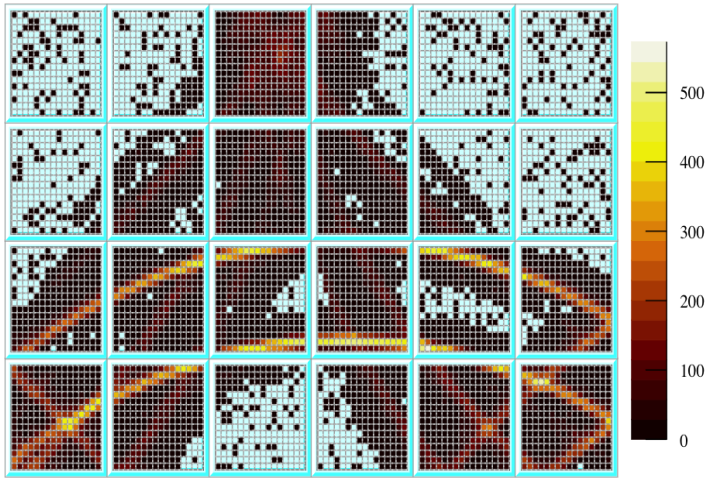
***Rotational combined** around the **Z-axis** +/-0.02 [mrad]*



***Rotational combined** around the **Z-axis** +/-0.04 [mrad]*



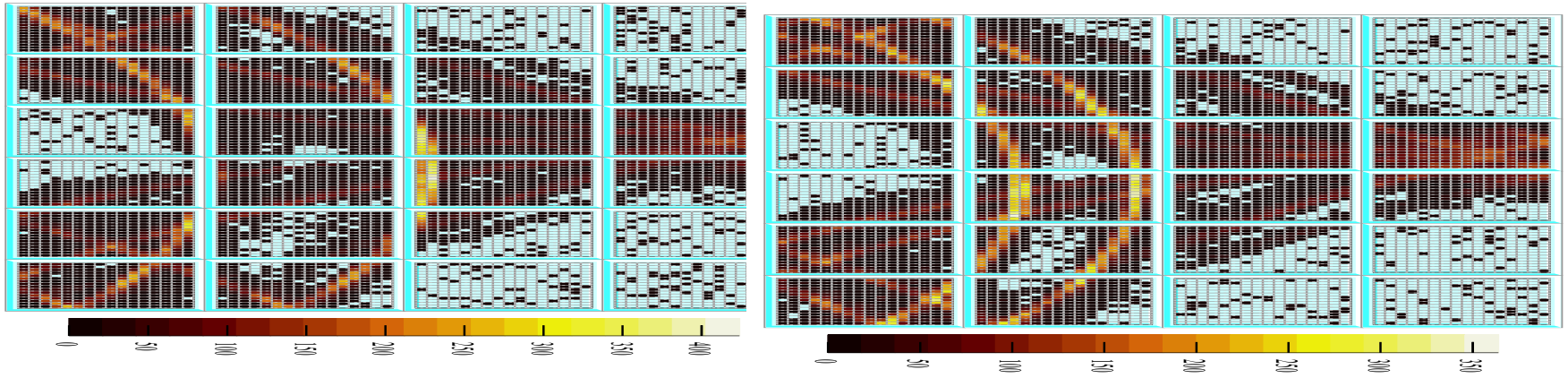
Nominal detector



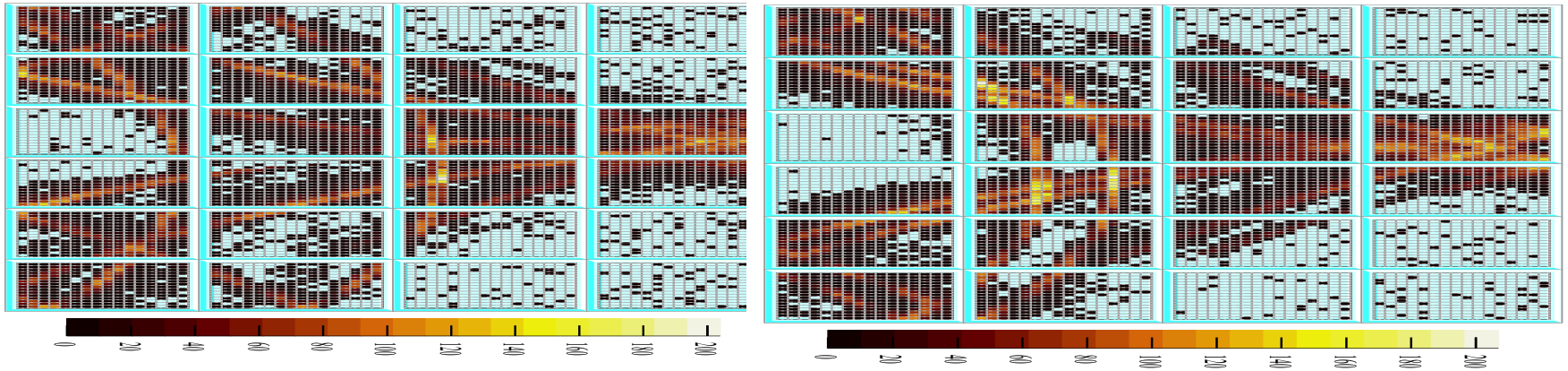
Hit Pattern for All Events per Different Misalignment Mode:

- **Misalignment Scenario**: *Combined*
- **Misalignment Mode:** *Offset*

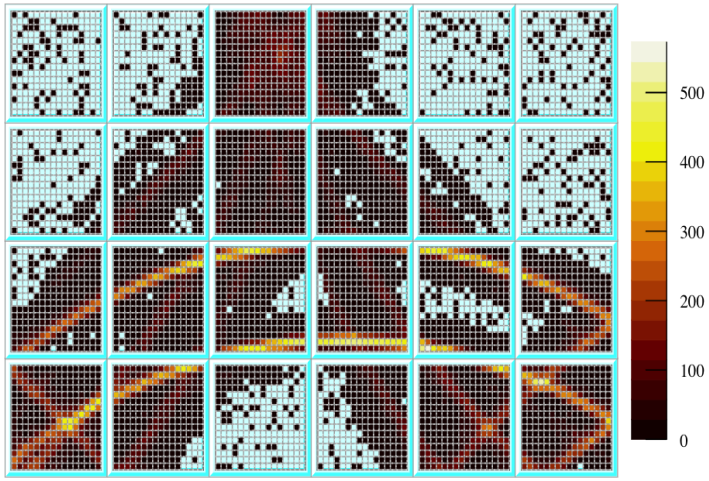
***Offset combined** around the **X-axis** +/- 7.2 mm*



***Offset combined** around the **X-axis** +/- 14.4 mm*



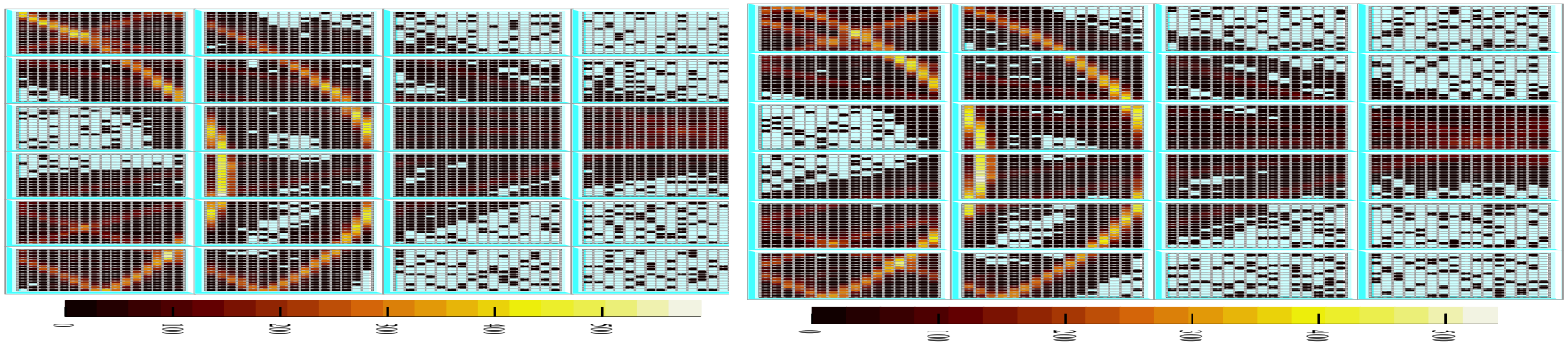
Nominal detector



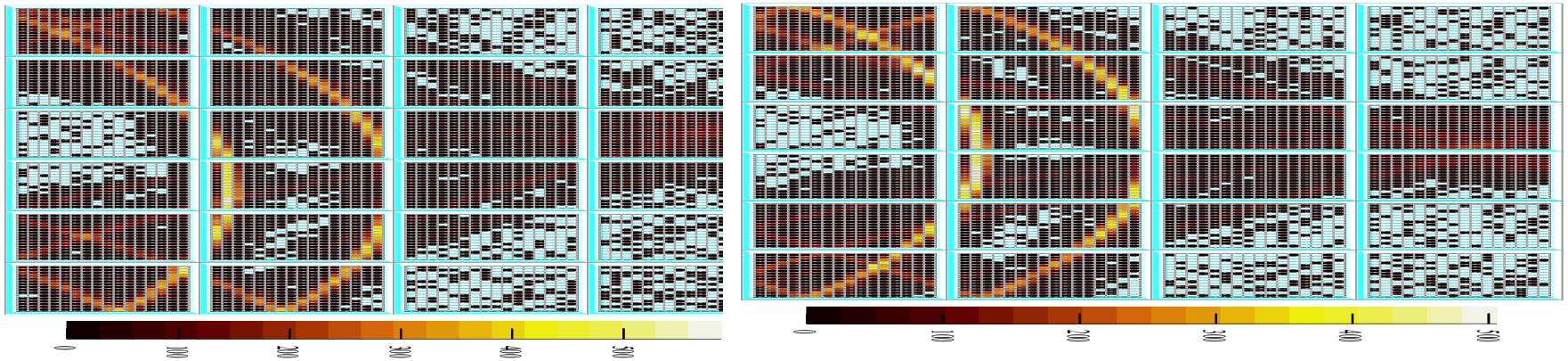
Hit Pattern for All Events per Different Misalignment Mode:

- **Misalignment Scenario**: *Combined*
- **Misalignment Mode:** *Offset*

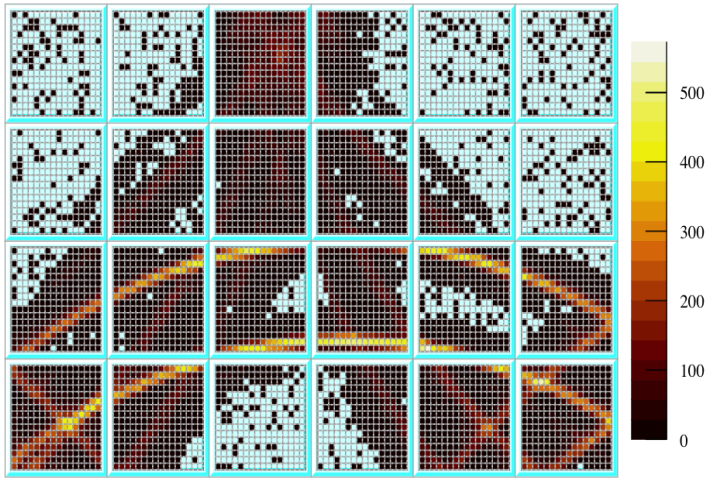
***Offset combined** around the **Y-axis** +/- 7.2 mm*



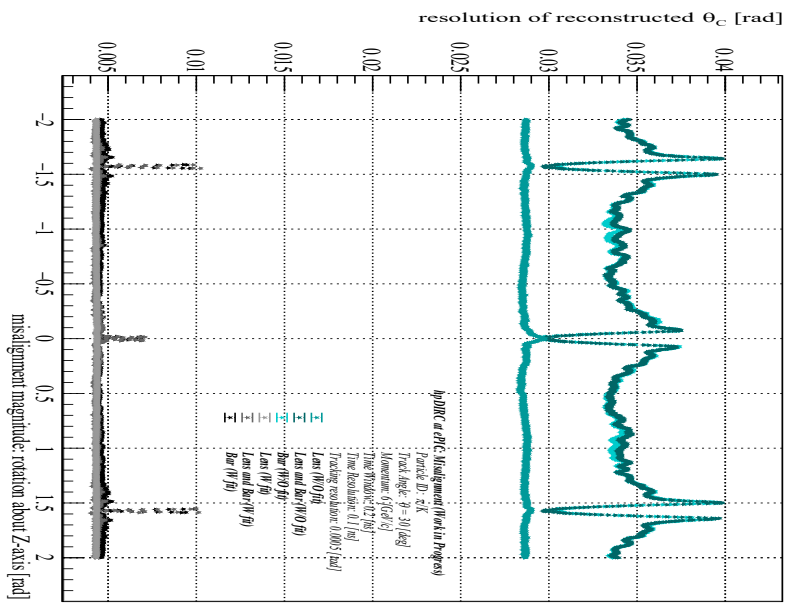
***Offset combined** around the **Y-axis** +/- 14.4 mm*

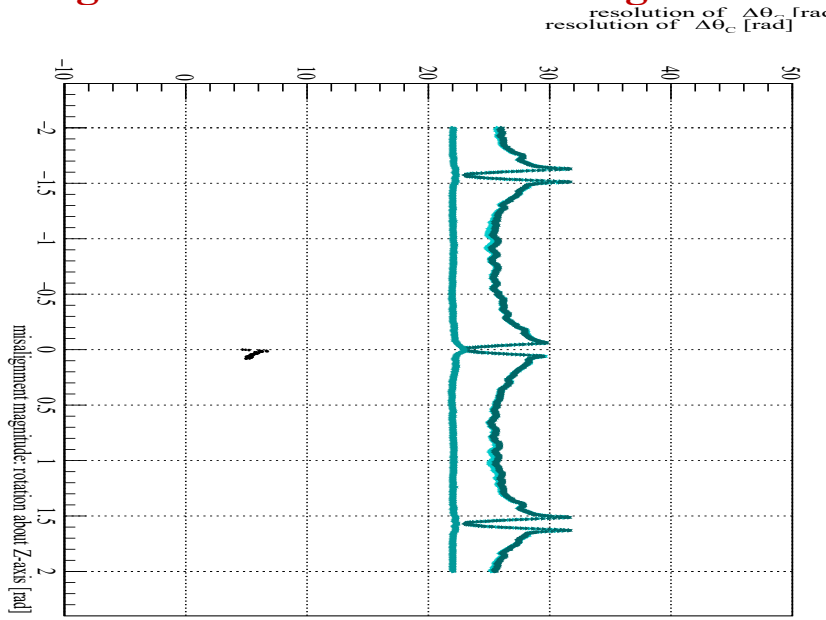


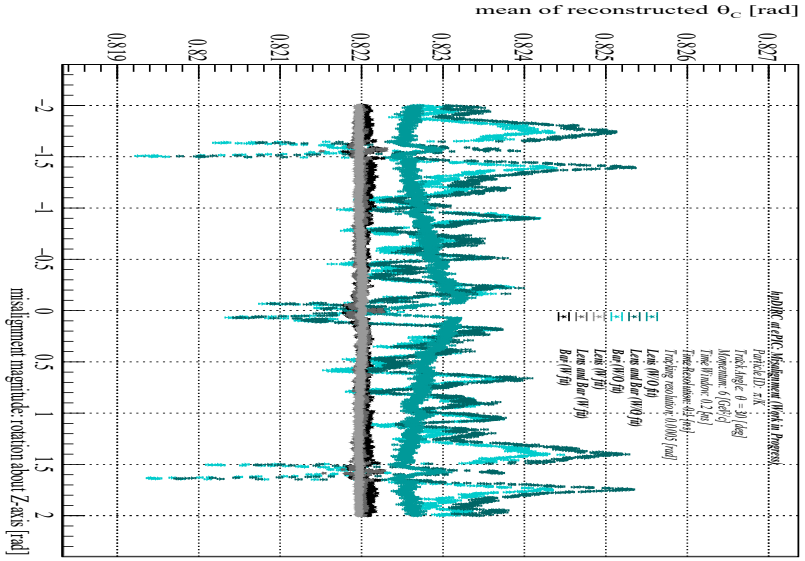
Nominal detector

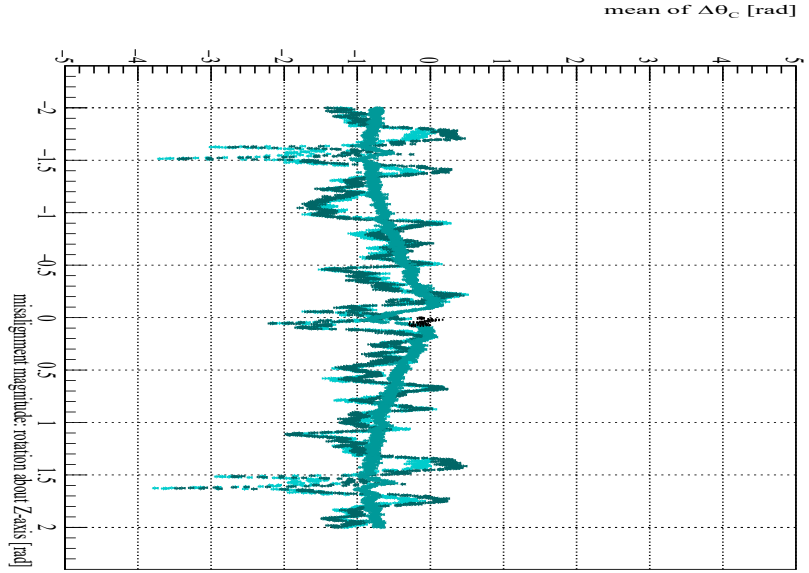


Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Kaon:

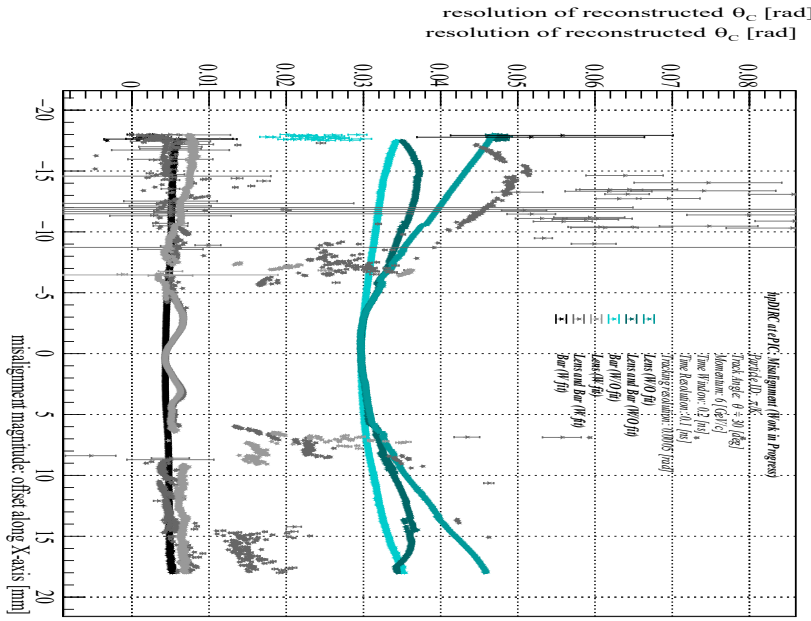


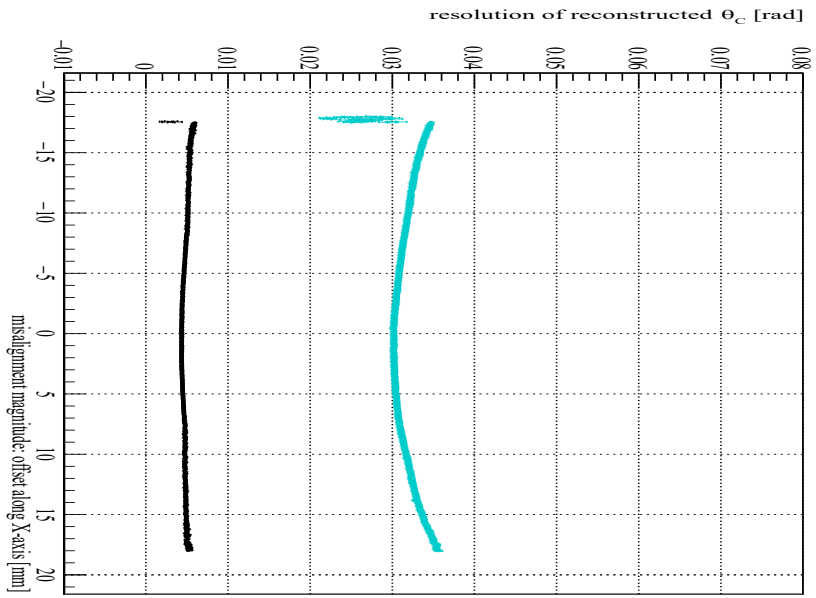


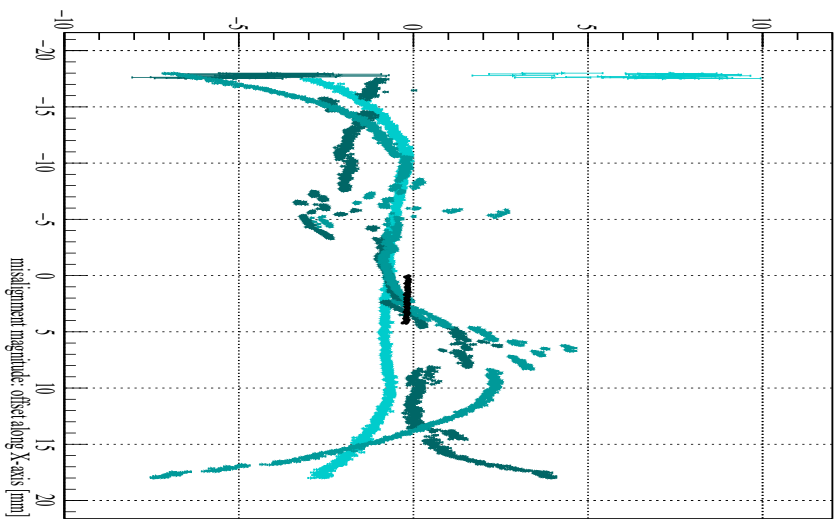


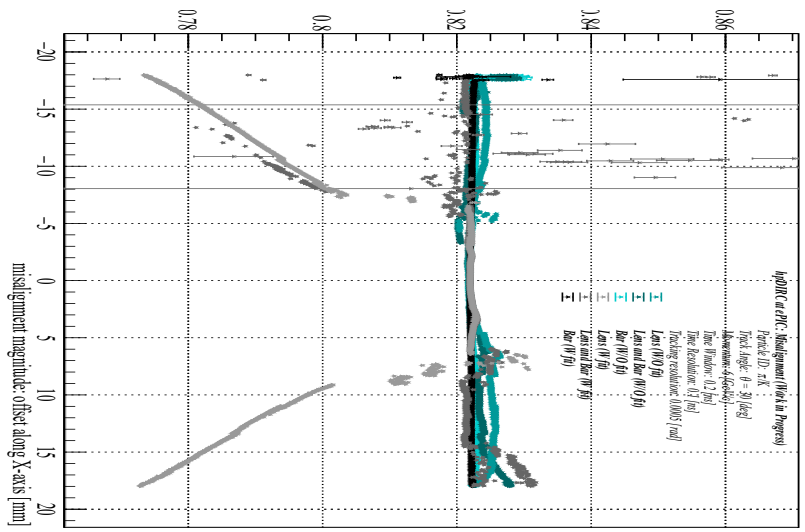


Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Kaon:









Reconstructed and Residual of Cherenkov Angle for Nominal and Misaligned Detector for Kaon: