50th $\overline{\mathrm{P}}$ANDA Collaboration Meeting (Frascati)

Event Filter for PandaRoot / FairRoot
Pattern Recognition for the FTS

Short Updates of Talks at Earlier $\overline{\mathrm{P}}$ANDA CMs

Martin J. Galuska
Justus Liebig Universität Gießen

This work was supported in part by BMBF (06GI9107I), HGS-HIRe for FAIR and the LOEWE-Zentrum HICforFAIR.

HIC for FAIR
Helmholtz International Center

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

Bundesministerium für Bildung und Forschung

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Event Filter News

Motivation for an Event Filter

- **Problem**: Imagine you want to...
  - … run **PandaRoot full or fast simulation** only for **specific** subsets of **events from** some **event generator(s).**
  - … save **time** and **disk space.**
- **Solution**: **Event filter**
  - **Look at** the **particles produced by the event generator(s)** **BEFORE** they are **transport**ed through the detector model and BEFORE digitization, tracking, PID, …
  - **If** a generated **event** is **interesting**, **run simulation** and analysis on this event. **If not**, **discard** the **event** and **rerun** the **event generator(s)**.
- **Example**:
  - Extraction of signal events from general generator.
  - Background studies (with dpm) for specific signal channel.
  - Subdetector occupancy/performance studies.

Event Filter Tutorial Finally Available!

- Tutorial on
  - Event filter concept
  - How to use the pre-implemented event filters
  - How to implement your own event filter(s)
  - ...

https://panda-wiki.gsi.de/foswiki/bin/view/Computing/PandaRootEventFilterTutorial

FTS Pattern Recognition Brief Status Update

The Forward Tracking System (FTS)

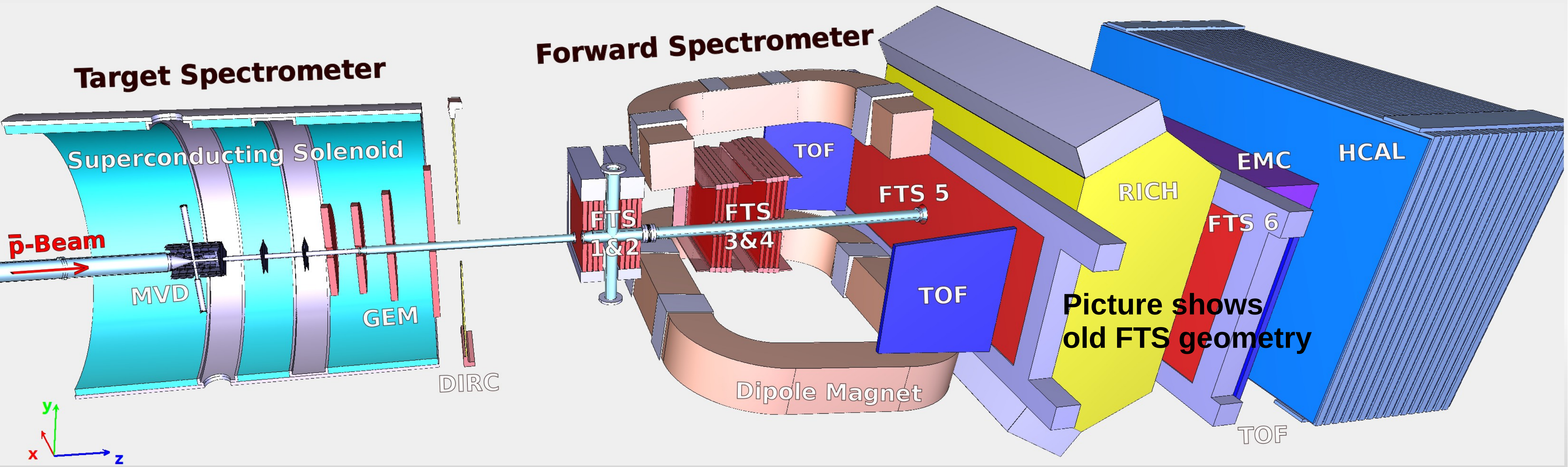
Geometry & Challenges

- Measure deflection of charged particles in dipole field
  - 6 straw tube chambers
  - 4 double layers per chamber
  - 12224 straw tubes total
  - 2.95 m < z < 6.55 m
- Momentum acceptance ≥ 3% p_{beam}
- Drift times ≤ 130 / 150 ns (outside / in dipole field)
  - $Ar+CO_2$ (90 : 10) @ 2 bar, anode wire @ 1.8 kV

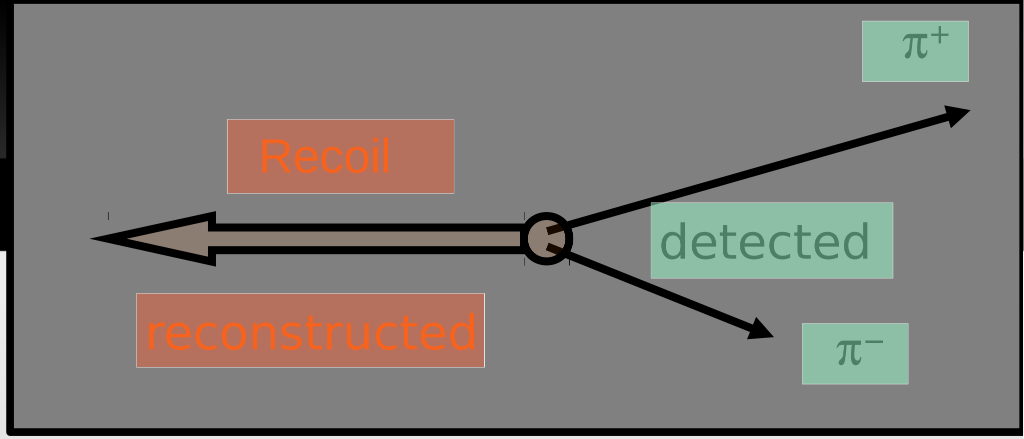
Occupancy

- PANDA @ 20 MHz
  - On average: 50 ns between 2 events
  - ≤ 6 overlapping events with prob. ≥ 96.6%
- Up to 8 charged primary tracks in acceptance

- Combinatorial PR:
  - $O((6*8)^{6*4}) = O(10^{40})$ track candidates



Study of Importance of FTS



- Example: $\bar{p}p \to (c\bar{c})\,\pi^+\pi^-$ @ p_{beam} = 15 GeV/c
- **For a recoil mass study only $\pi^+\pi^-$ need to be reconstructed.**
- Study in how many events ≥1 $\pi^+\pi^-$ from $\bar{p}p \to (c\bar{c})\,\pi^+\pi^-$ can only be recovered by FTS. 10k signal events per channel, FTS ideal PR.

$(c\bar{c})$	m [GeV/c²]	ε(no FTS)	ε(incl. FTS)	**Improve-ment***
J/ψ	3.0969	43.88%	53.65%	22.27%
h_c	3.5259	33.42%	42.88%	28.31%
X(3872)	3.8717	9.82%	18.80%	91.45%

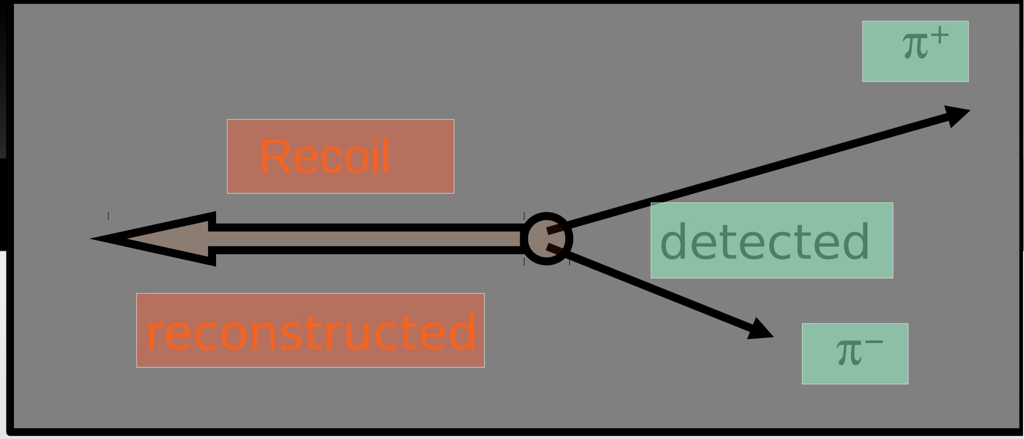
Requirements on π^-

- MC truth matched to charged pions
- Originate from $\bar{p}p$ interaction
- Clones removed
- For FTS reconstructed pions
  - z(last hit) > 280 cm
  - $p_\pi \geq 3\% * p_{beam}$

- **Even for a simple final state of 2 charged pions the signal efficiency can be significantly improved with the FTS.**

* **Improvement** is defined as **ε(incl. FTS) / ε(no FTS) – 1**.
Relative increase in efficiency with FTS present.

Study of Importance of FTS



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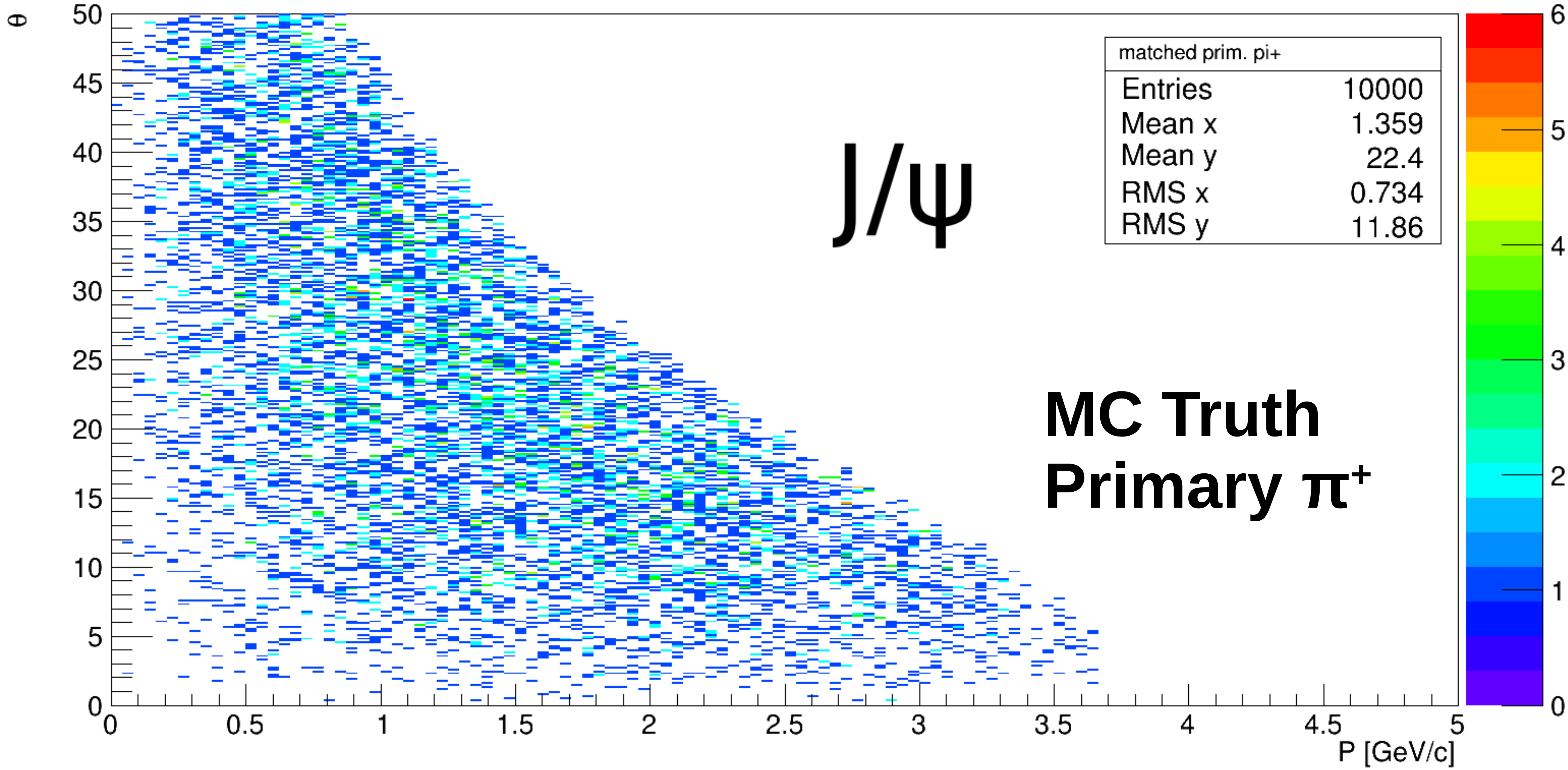

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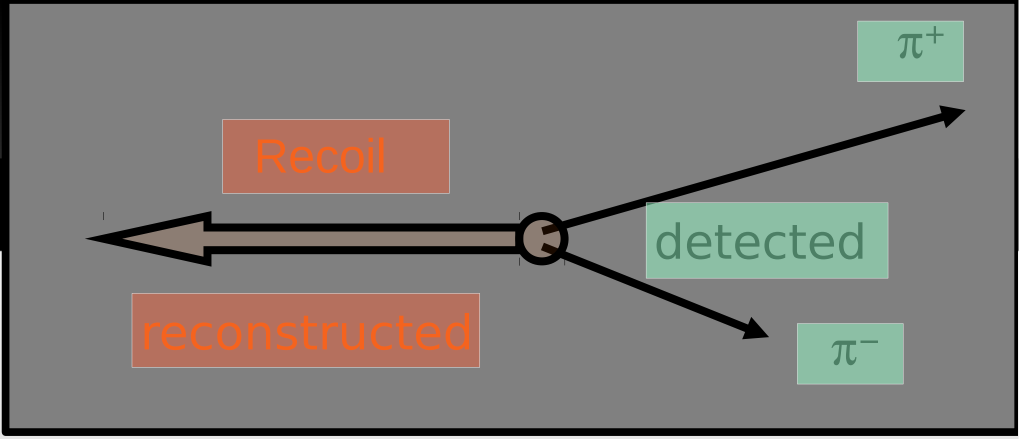

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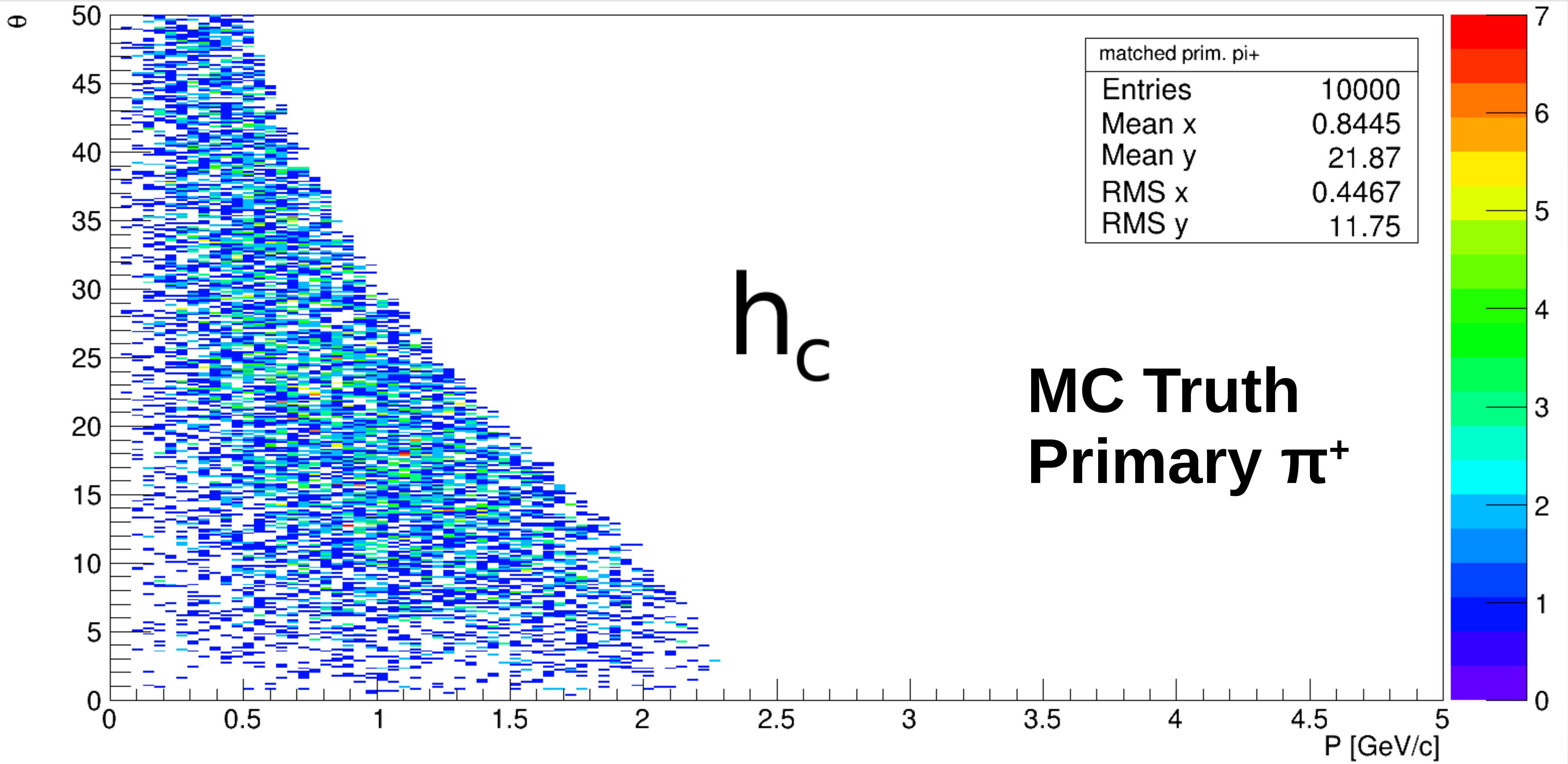

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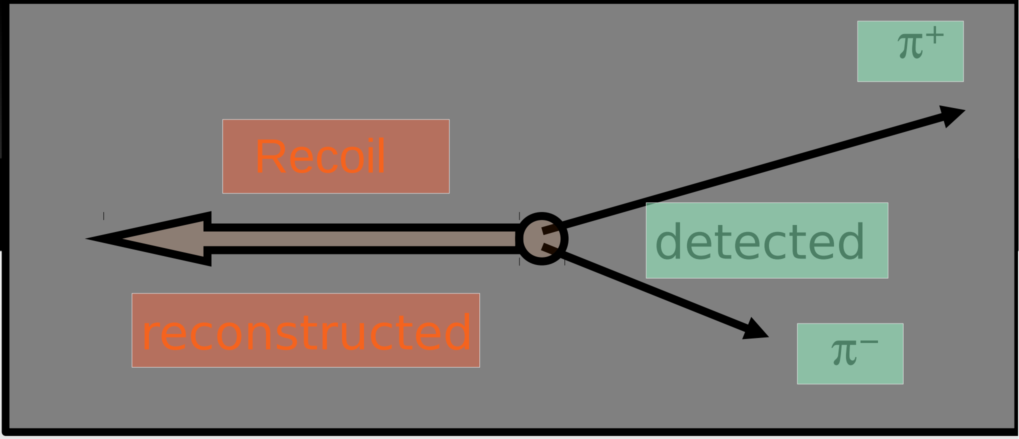

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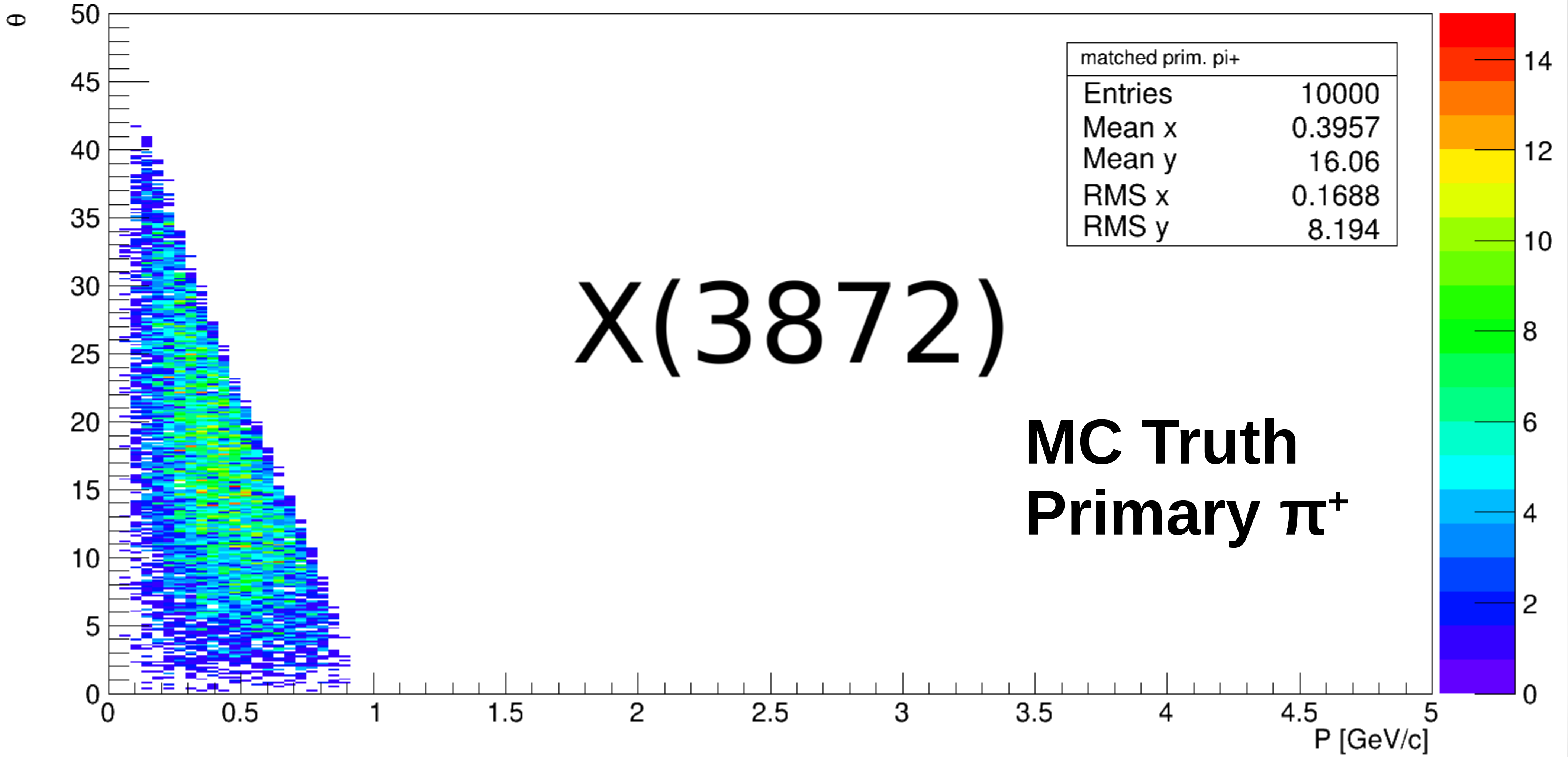

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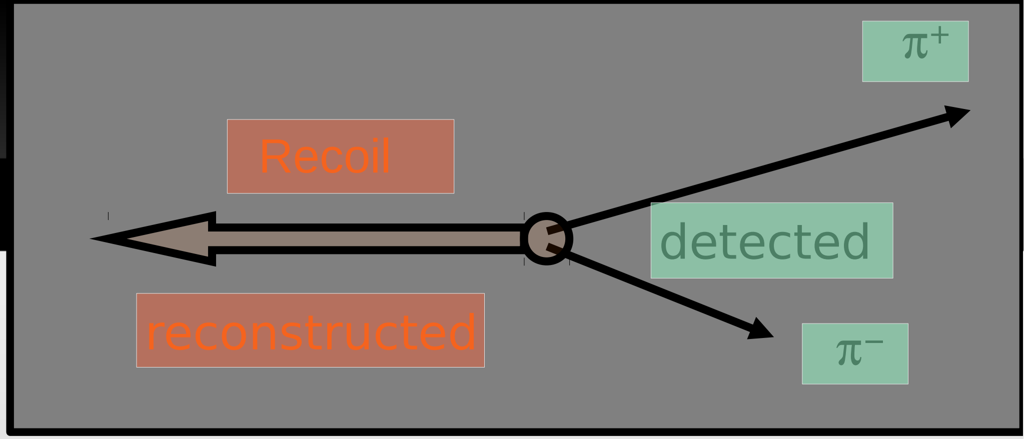

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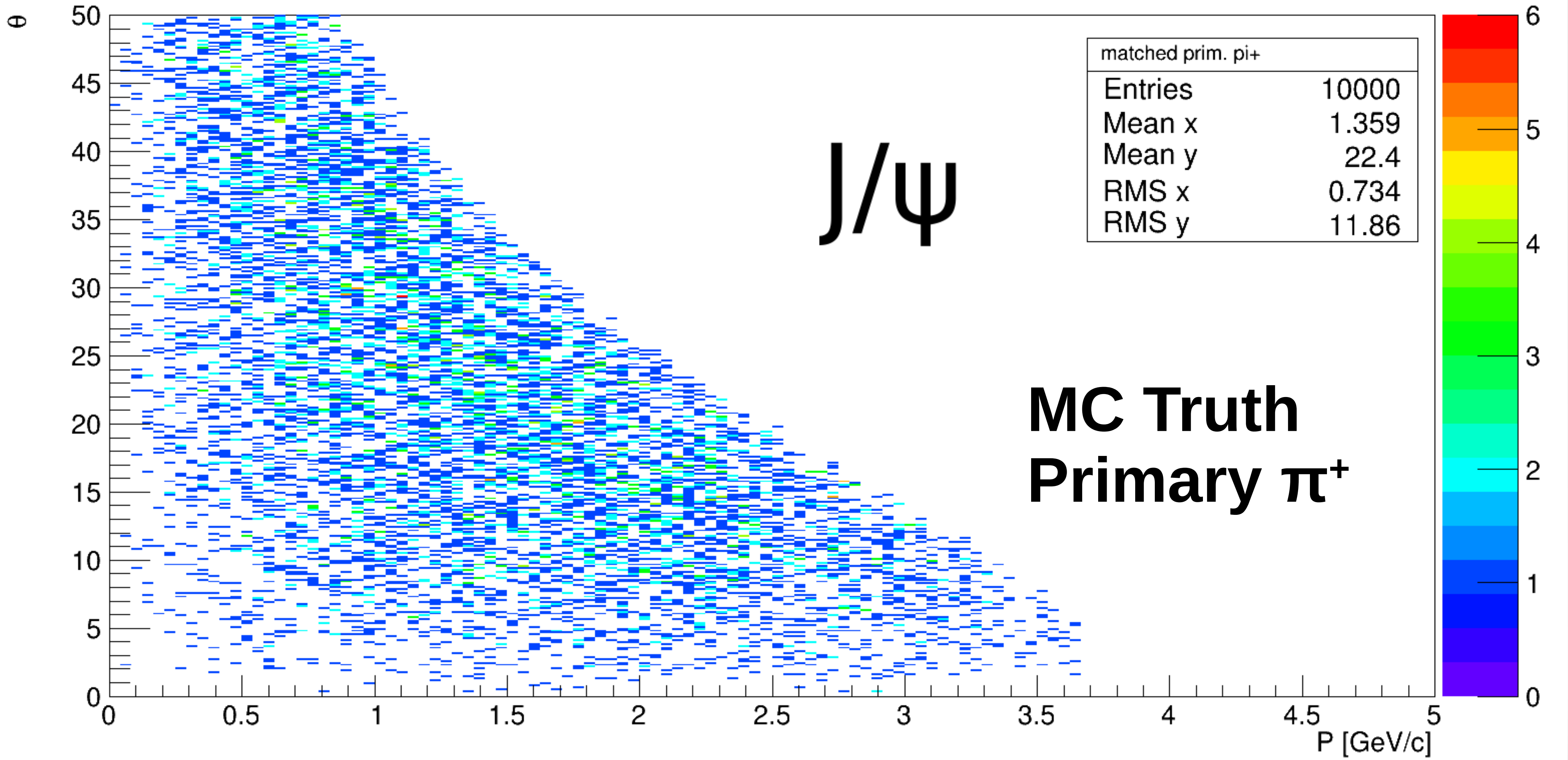

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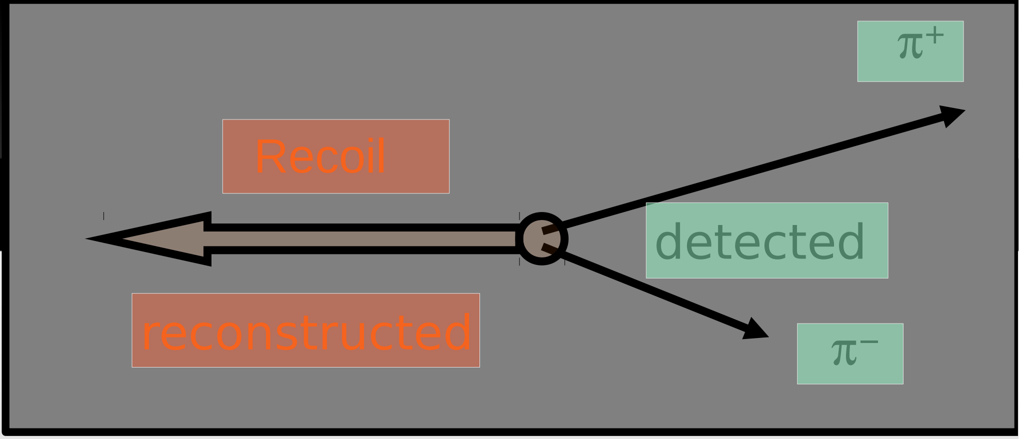

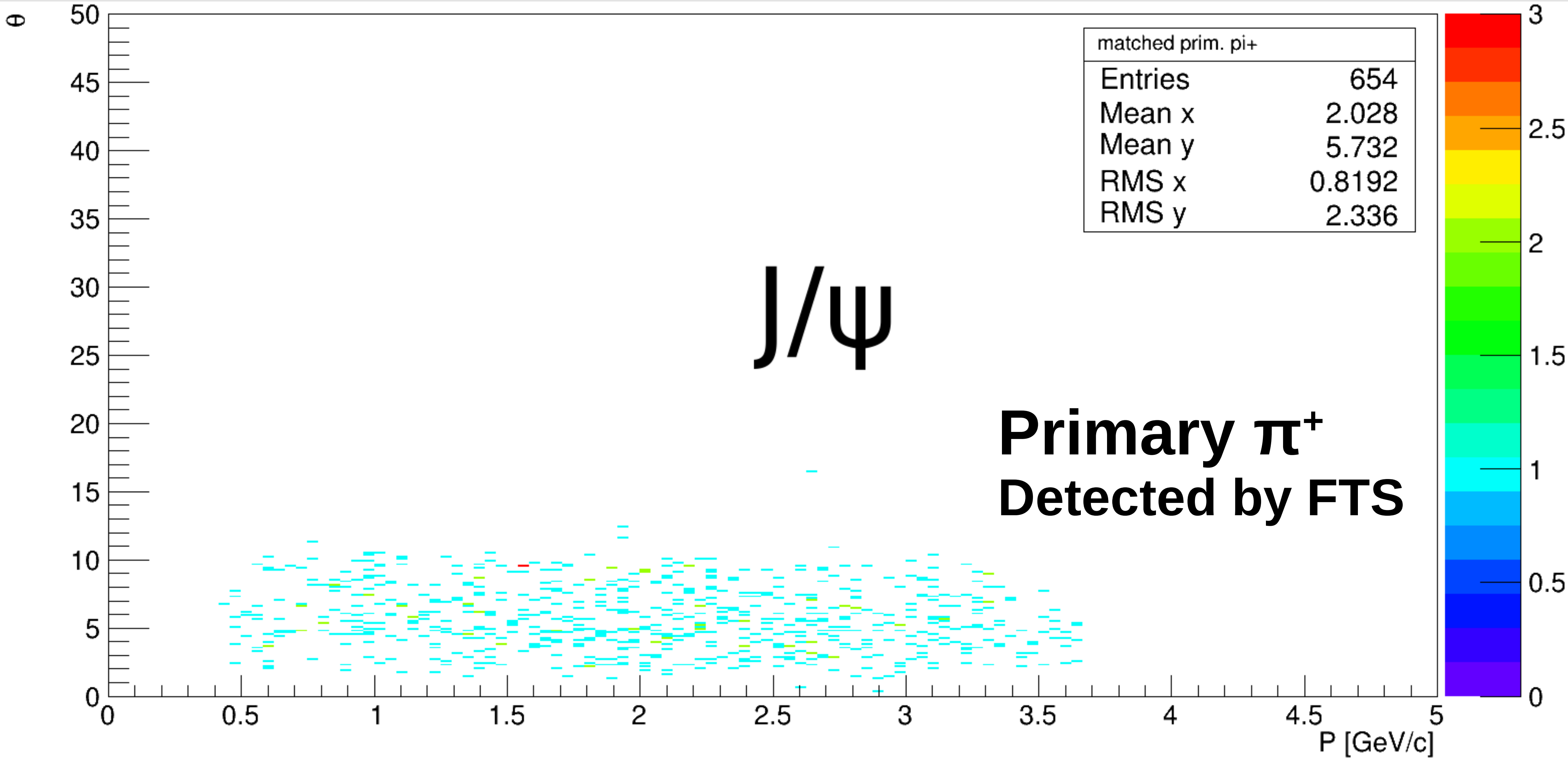

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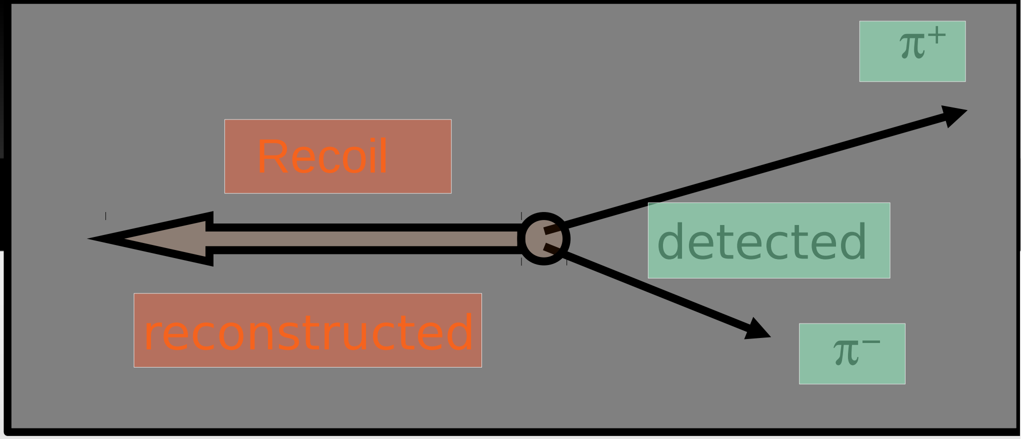

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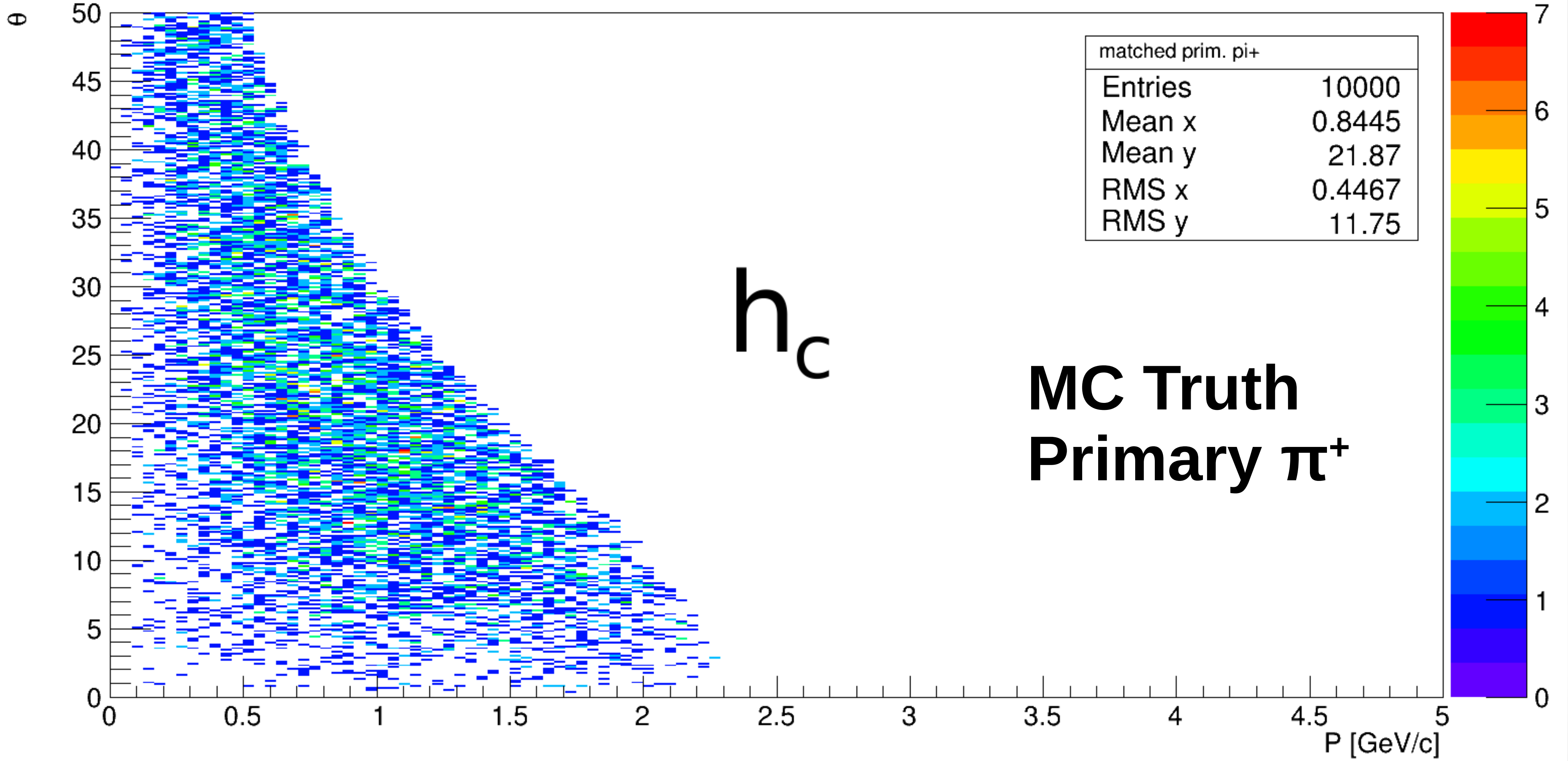

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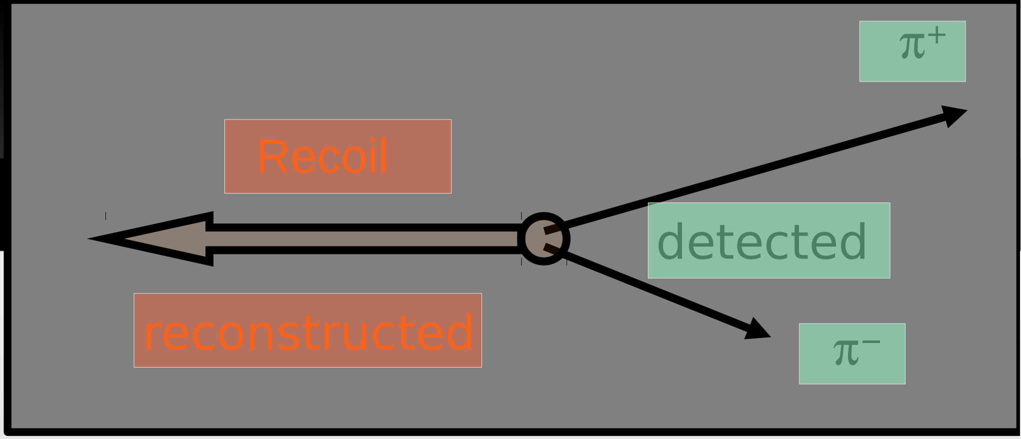

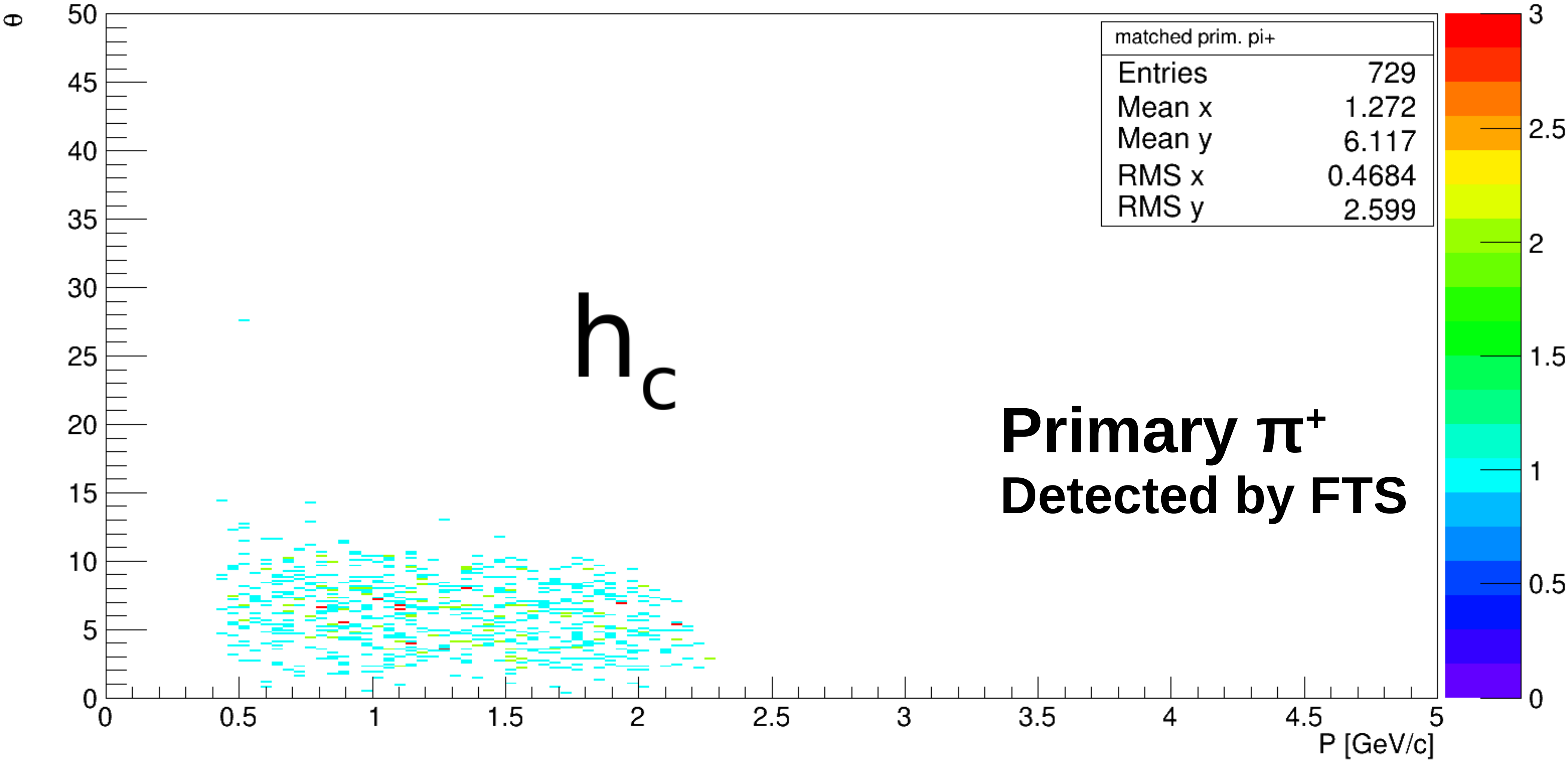

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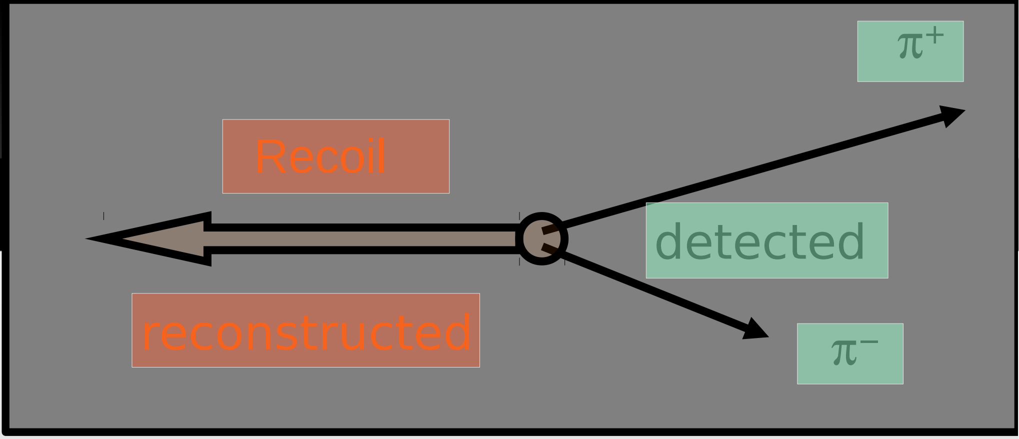

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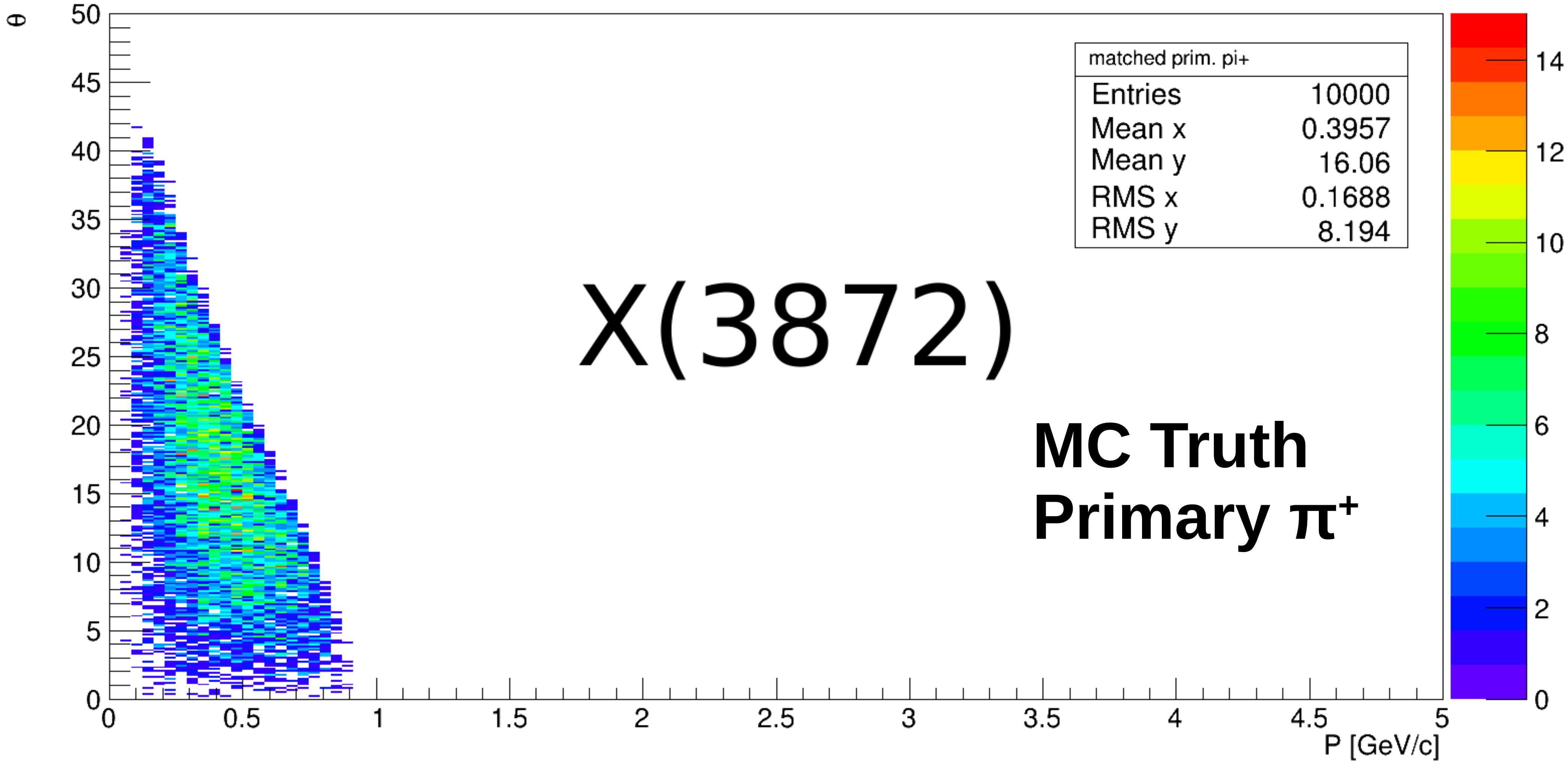

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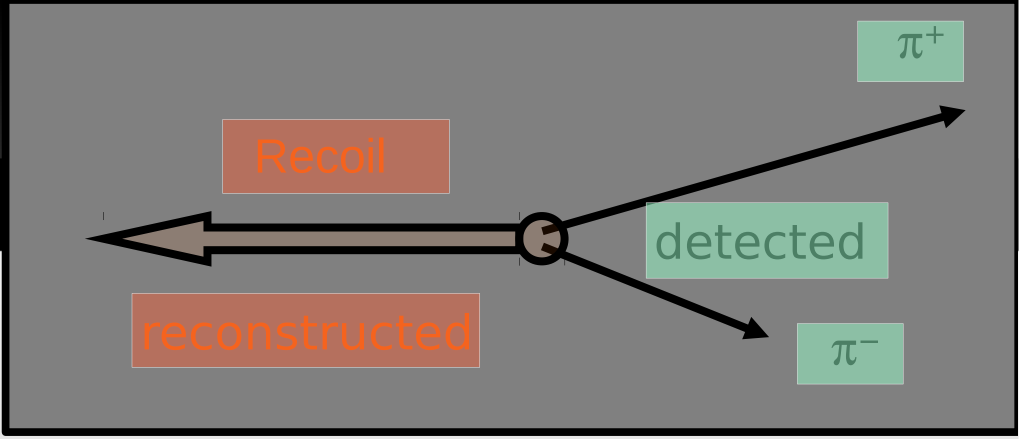
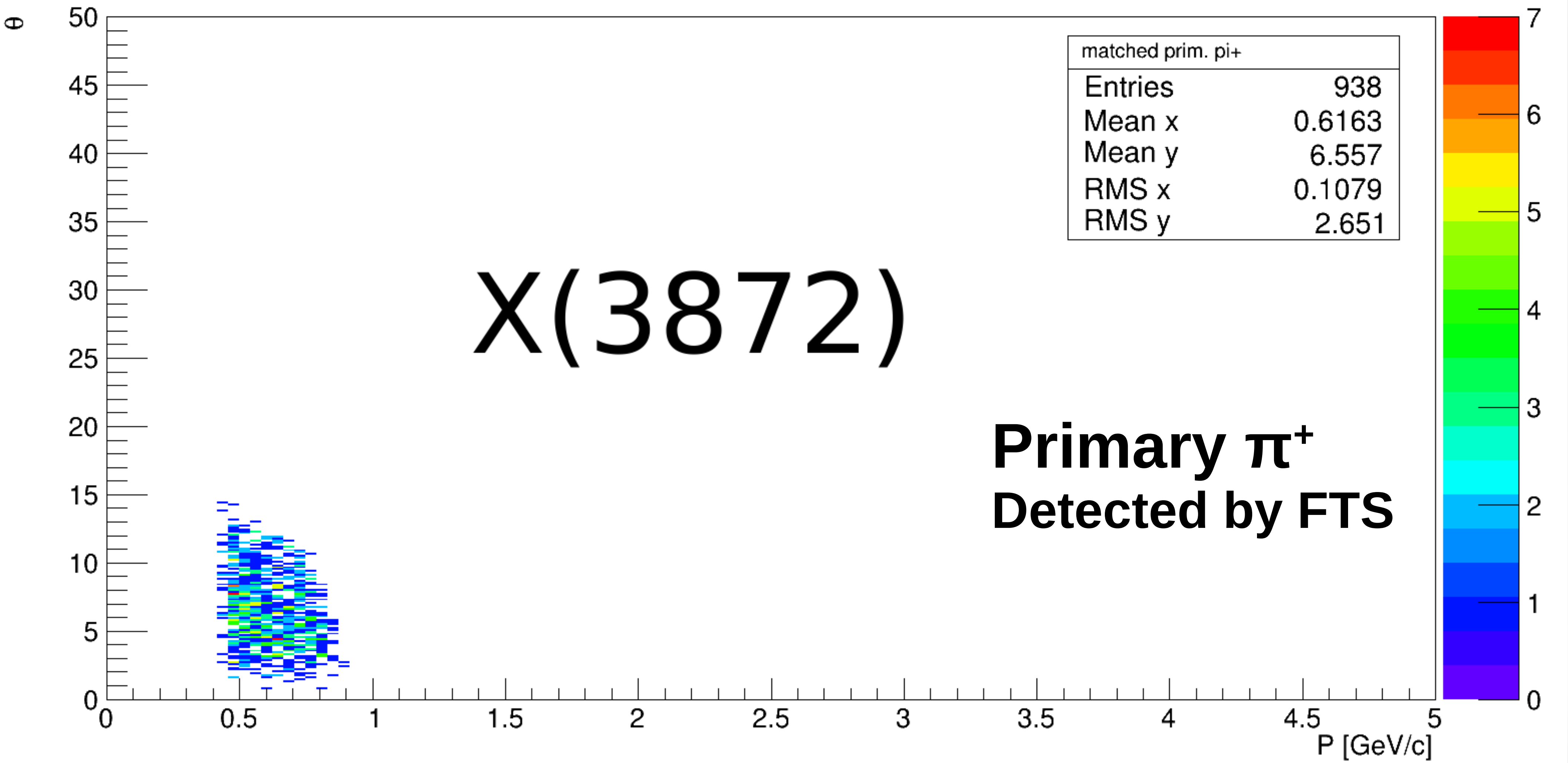
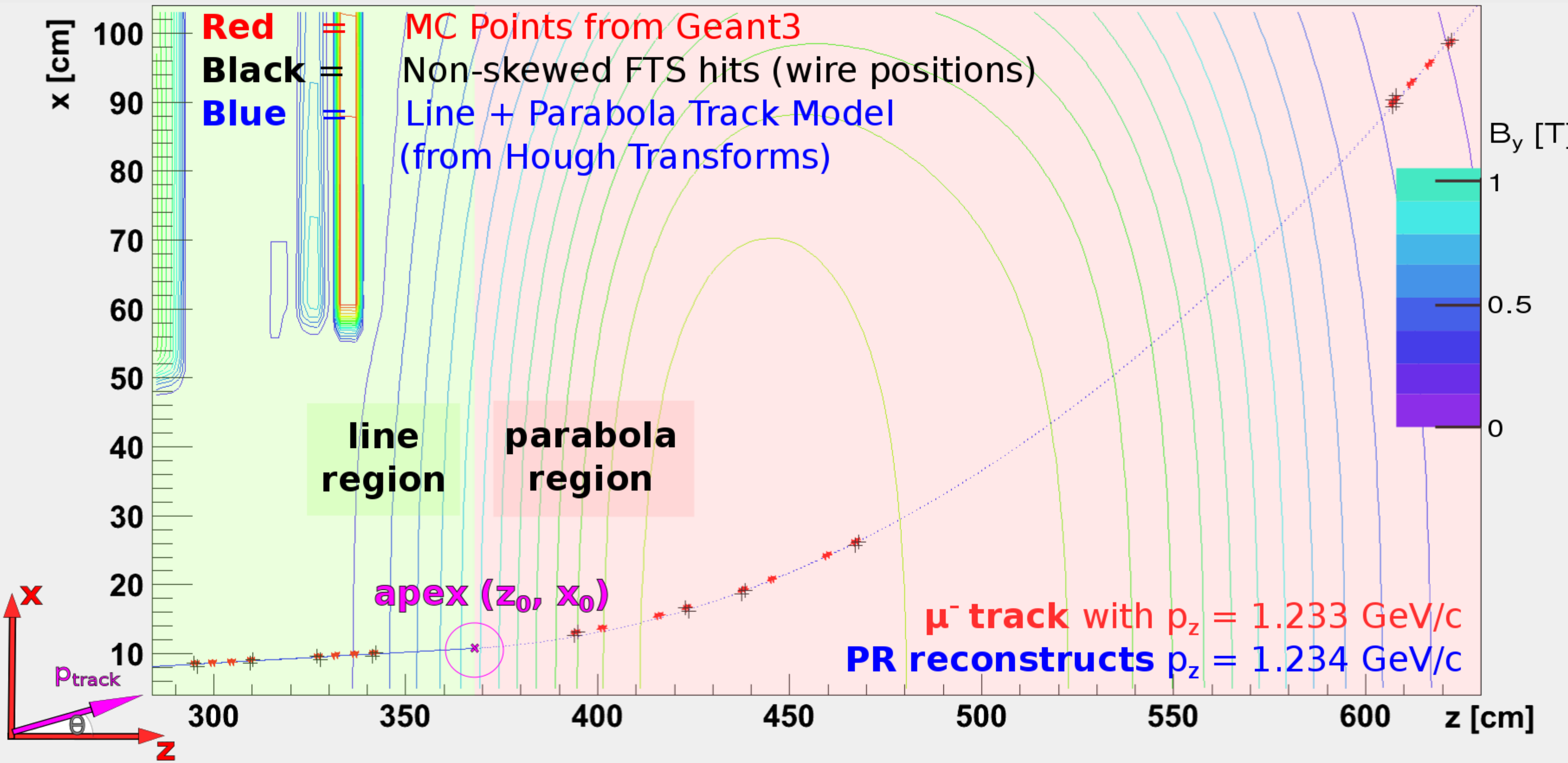




Line+Parabola+Line Track Model for the FTS



- Simulations show that the tracks can be approximated by a line before, a parabola within, and a line behind the dipole field

Status of Code

- Code is in svn, is compiled by default and runs without crashes
- Recent Activities:
  - Work on new peak finder
    - Concept presented at the last PANDA CM
    - Peak finder follows the curves in the Hough Space
    - 2d problem → 1d problem + peak merging
  - Work on inclusion of skewed straws

How to Use the Hough Transform Based PR for FTS

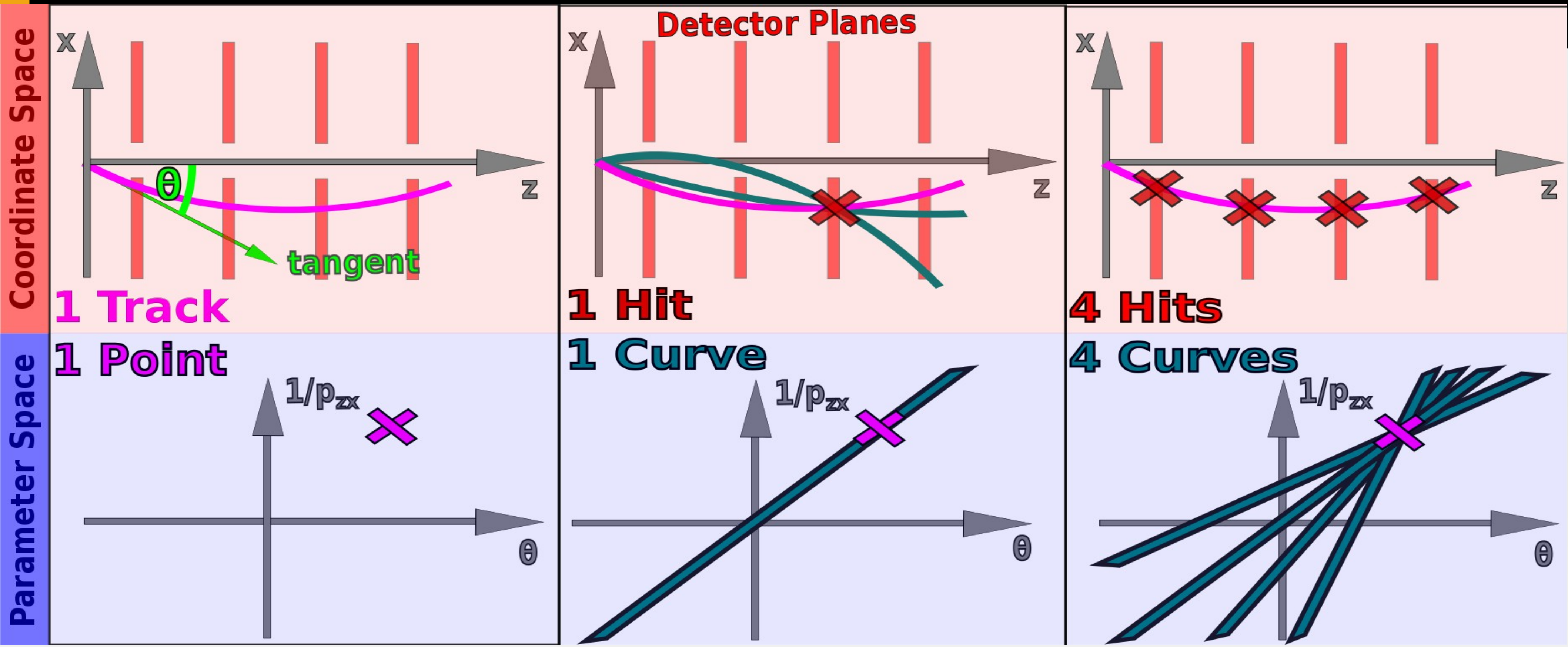
- The (preliminary) code is located in **PandaRoot/trunk/fts/FtsTracking**
- A macro to run it can be found in **PandaRoot/trunk/macro/fts/reco_fts.C**
- Usage:
  - **In reco macro** replace the ideal FTS PR with

    ```
    PndFtsHoughTrackerTask* trackFts = new PndFtsHoughTrackerTask();
    fRun->AddTask(trackFts);
    ```

Thank You!

Backup Slides

The Hough Transform for Pattern Recognition



- Can be used for wide variety of approximated analytical track shapes
- Robust against noisy, missing or additional detector hits
- Operations per event proportional to number of detector hits
- Suited for implementation on FPGA

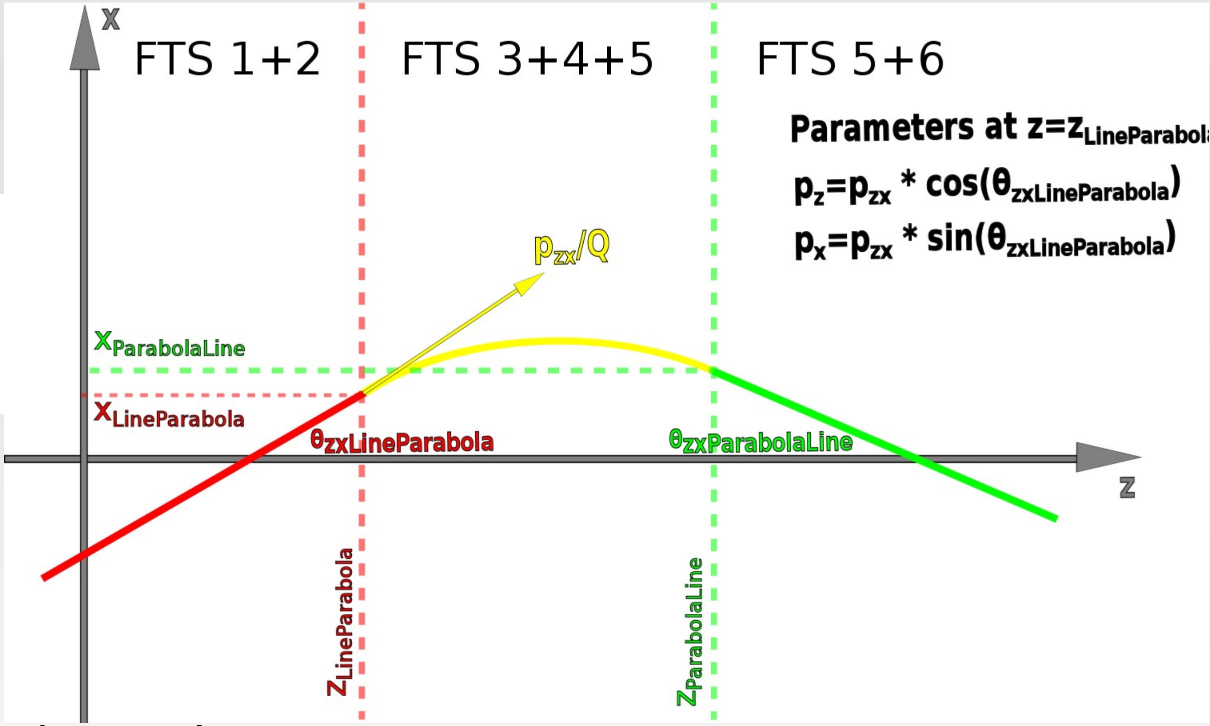
Hough Based Tracking for FTS (z-x-plane)

- Line before and after dipole field:

$$x_0 = -\tan\theta_{zx} \cdot (z_{hit} - z_0) + x_{hit}$$

- Parabola within dipole field:

$$\frac{Q}{p_{zx}} = \frac{2 \cdot (x \cdot \cos\theta_{zx} - z \cdot \sin\theta_{zx})}{B_y \cdot (z \cdot \cos\theta_{zx} + x \cdot \sin\theta_{zx})^2}$$



with

- (x_{hit}, z_{hit}): Hit coordinates
- $(x, z) = (x_{hit} - x_0, z_{hit} - z_0)$
- p_{zx}: Projection of track's momentum in z-x-plane
- Q: Charge of particle
- B_y: Max. y-component of B-field

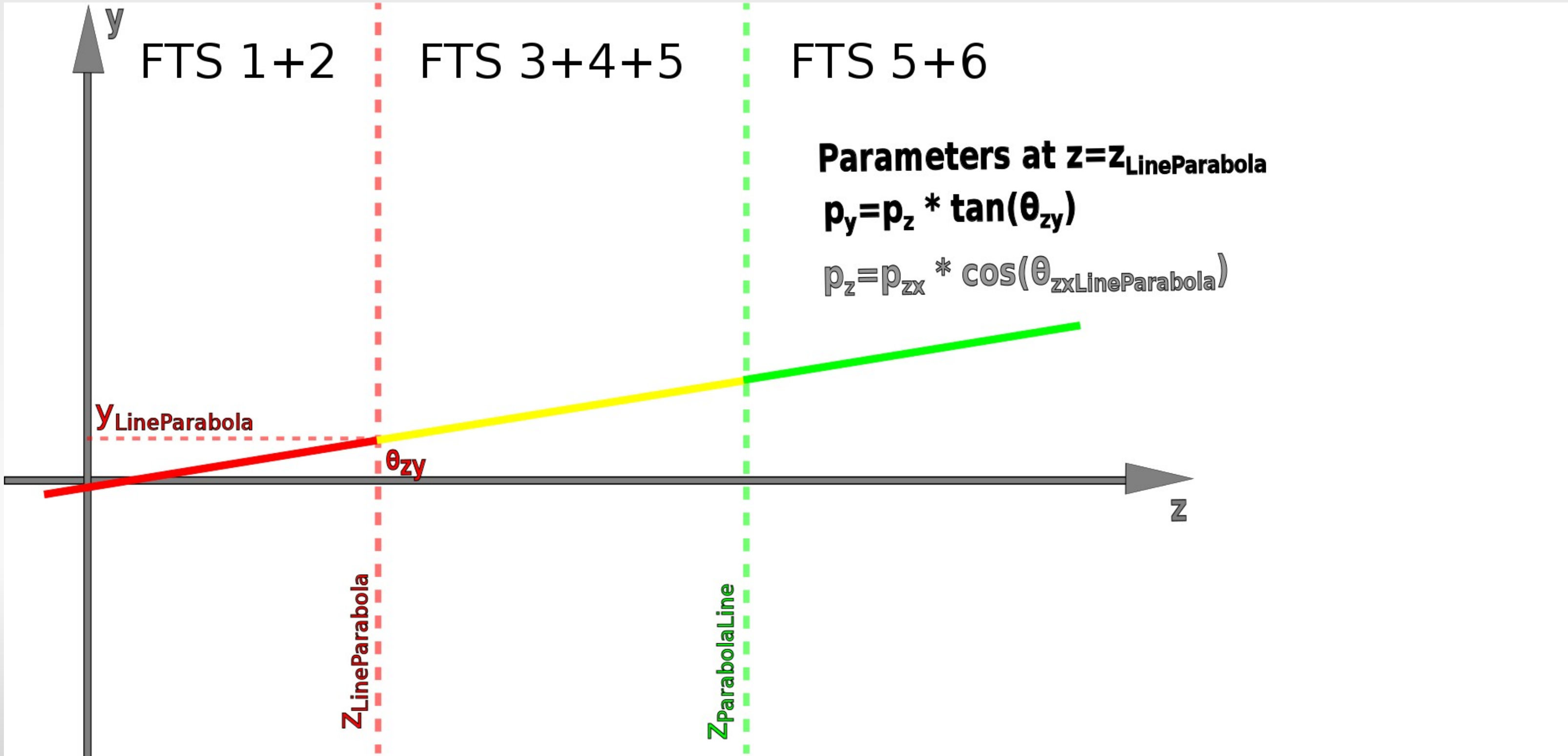
Hough Based Tracking for FTS (z-y-plane)

- Line for entire FTS region:

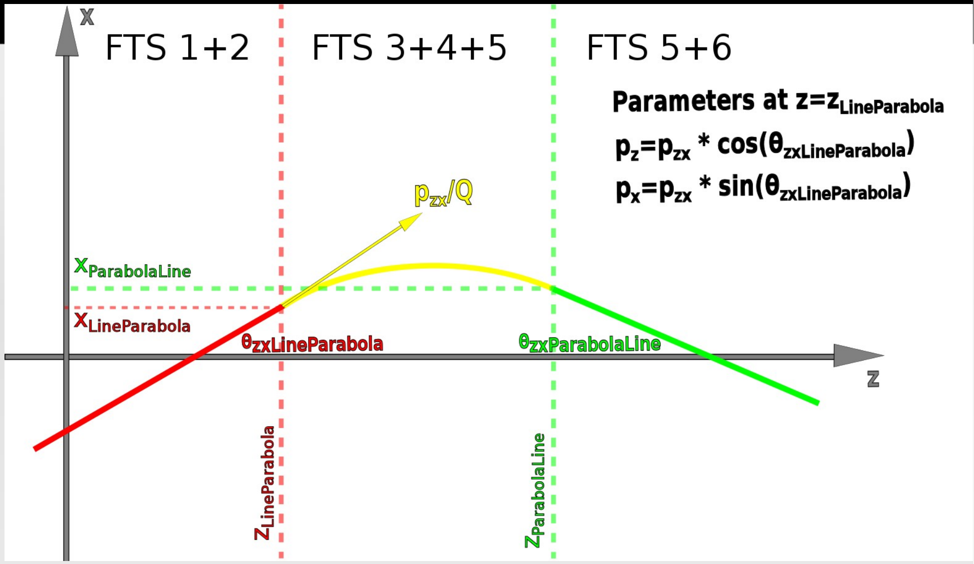
$$y_0 = -\tan\theta_{zy} \cdot (z_{\text{hit}} - z_0) + y_{\text{hit}}$$

with

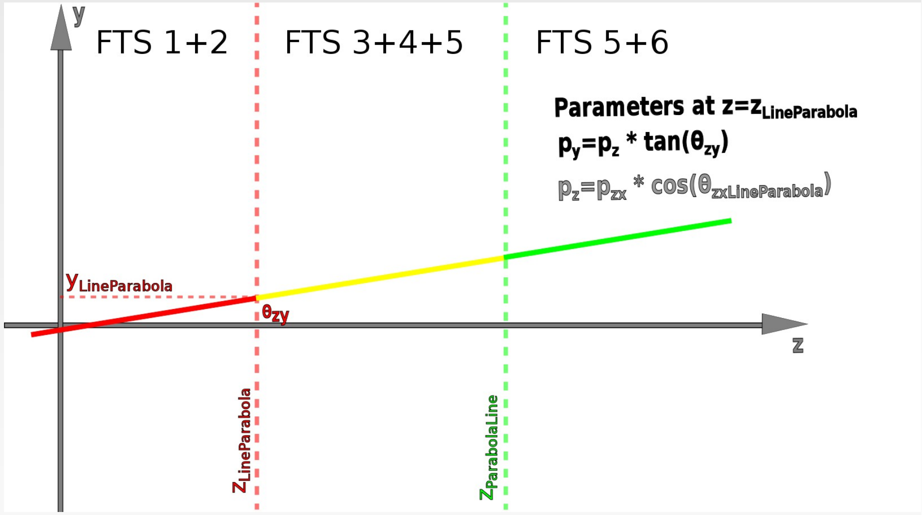
- (y_{hit}, z_{hit}): Hit coordinates
- p_{zx}: Projection of track's momentum in z-x-plane



Code Structure – Class Descriptions PndFts...

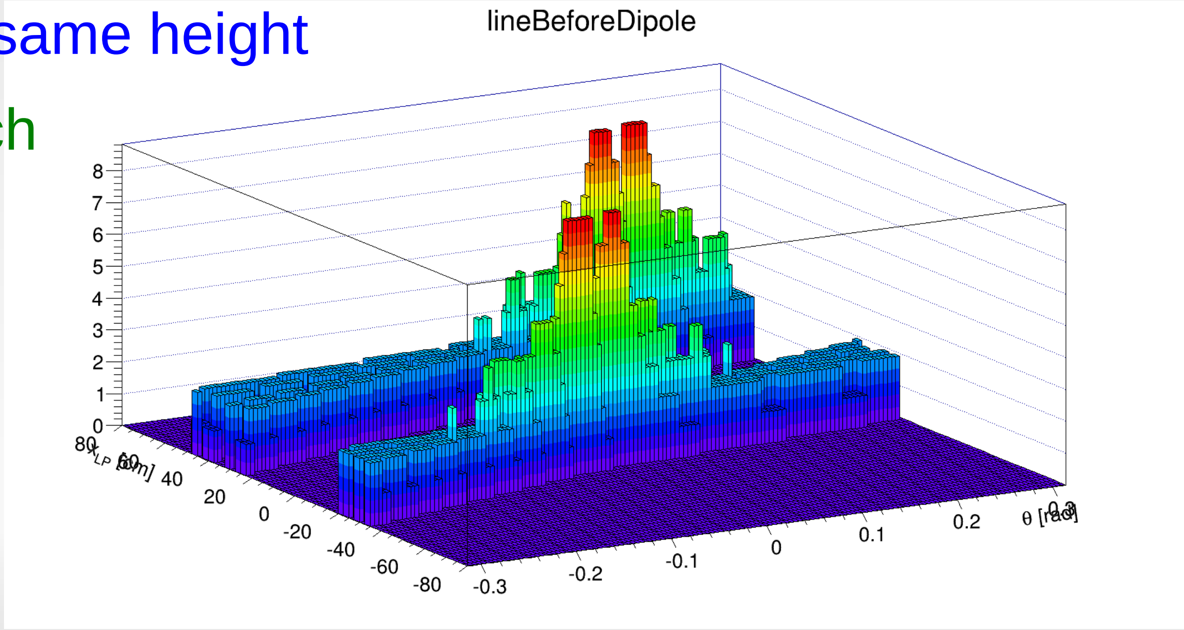


- **...TrackerTaskHough** (FairTask)
  - Interface between PandaRoot and track finder class ...HoughTrackFinder
  - Handles inputs and outputs
  - Provides QA + debugging / development output
- **...HoughTrackFinder**
  - Implementation of PR algorithm
- **...HoughSpace** (TH2S now, later map<UInt_t, vector<...**HoughTracklet**> >)
  - Creates and stores 2-dimensional Hough space
  - Provides peak finder
- **...HoughTracklet** (PndTrackCand)
  - 1 tracklet = 1 peak from 1 Hough transform
    + associated FTS hits
  - Used to store 1 (partial) line or parabola
- **...HoughTrackCand** (PndTrackCand)
  - 1 track candidate = 3 matched line tracklets + 1 parabola tracklet
  - Provides conversion to PndTrackCand and PndTrack

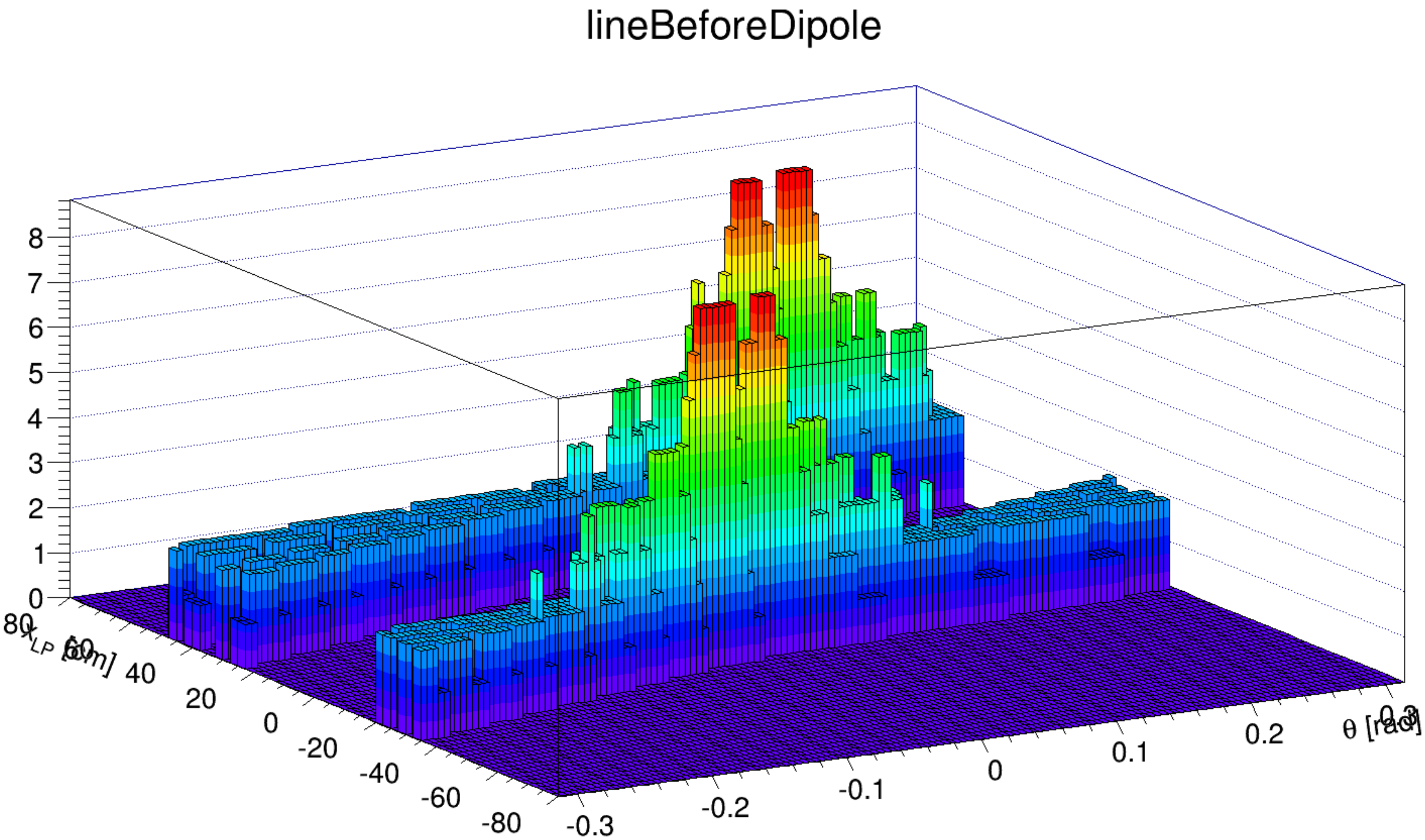


New Peak Finder

- Simple Peak Finder
  - Peak = bin with a min. height
- New Peak Finder
  - Require minimum height of bin
  - Follow the curves of each hit in Hough space (2d → 1d)
  - Remove rising and falling ”sides” of each peak
  - Merge neighboring bins of same height
  - Require peak width to match given range determined by simulations



New Peak Finder Example Events



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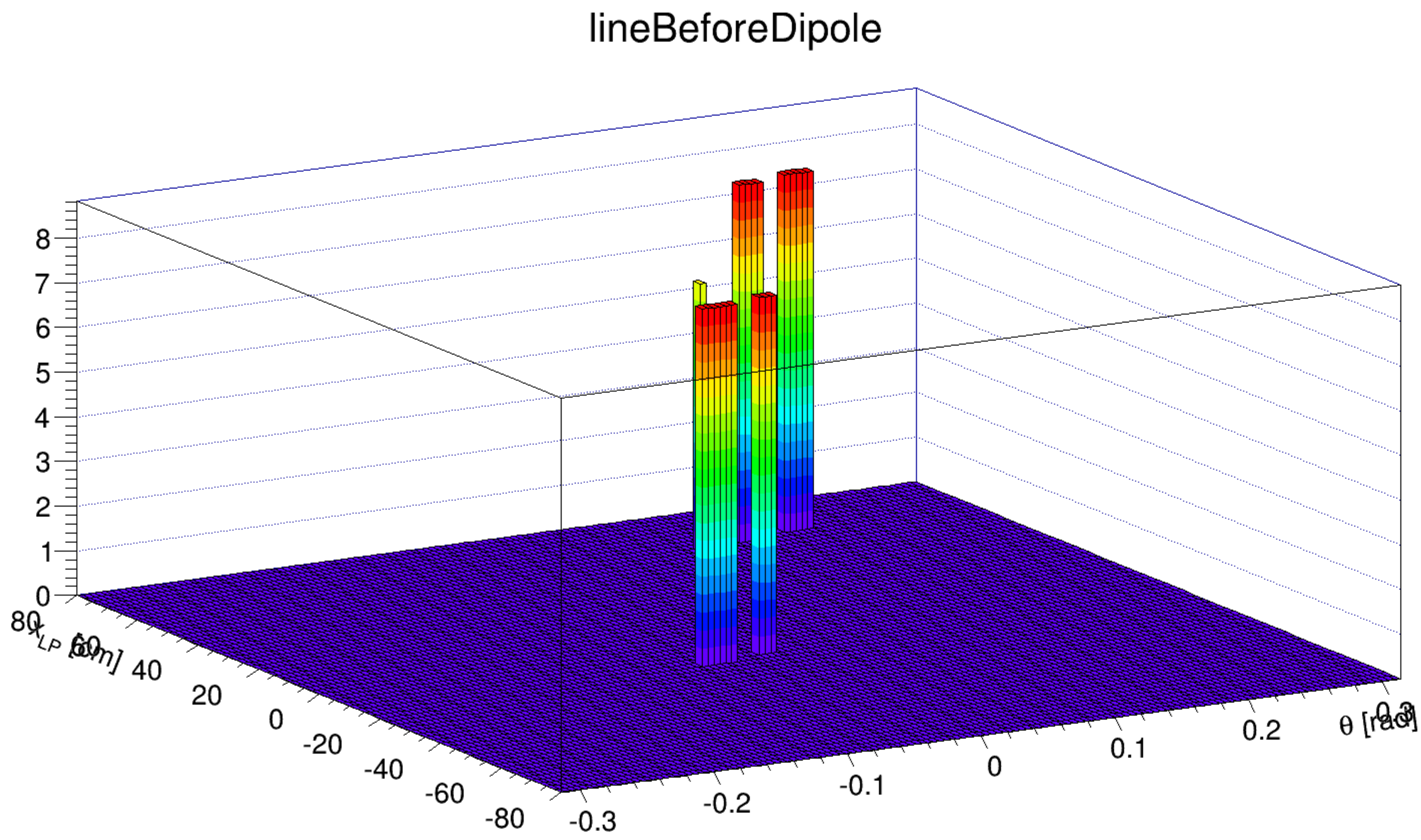

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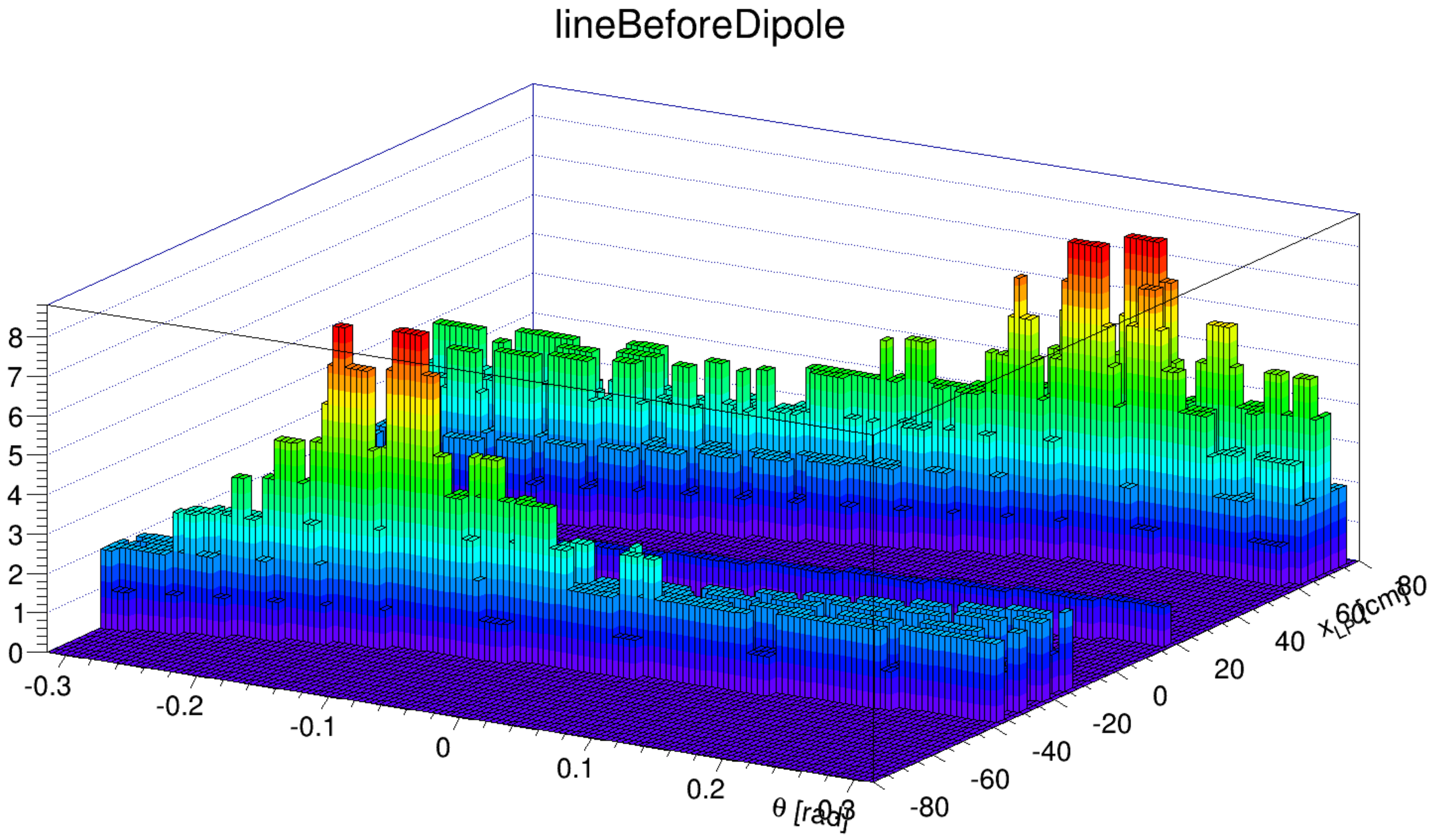

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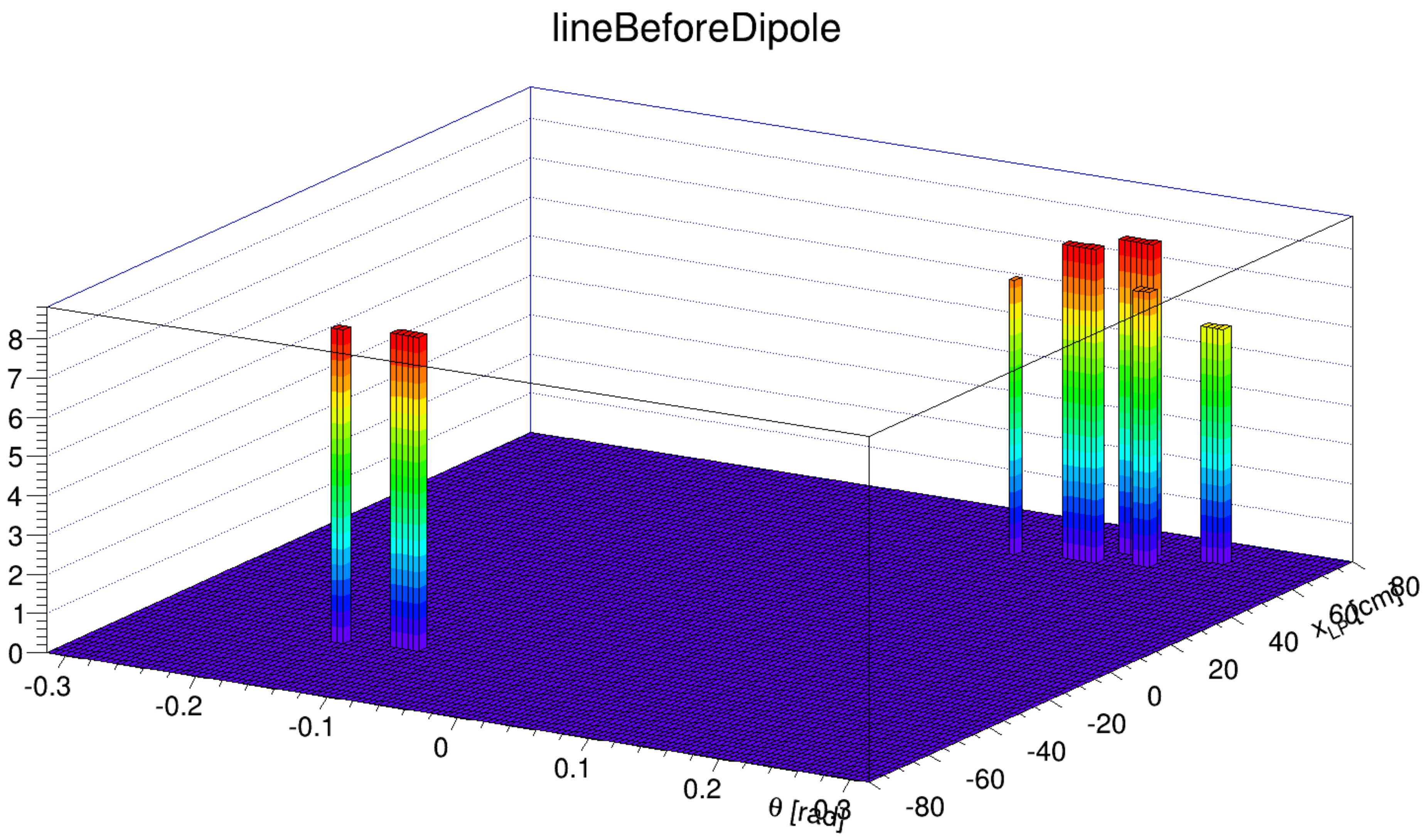

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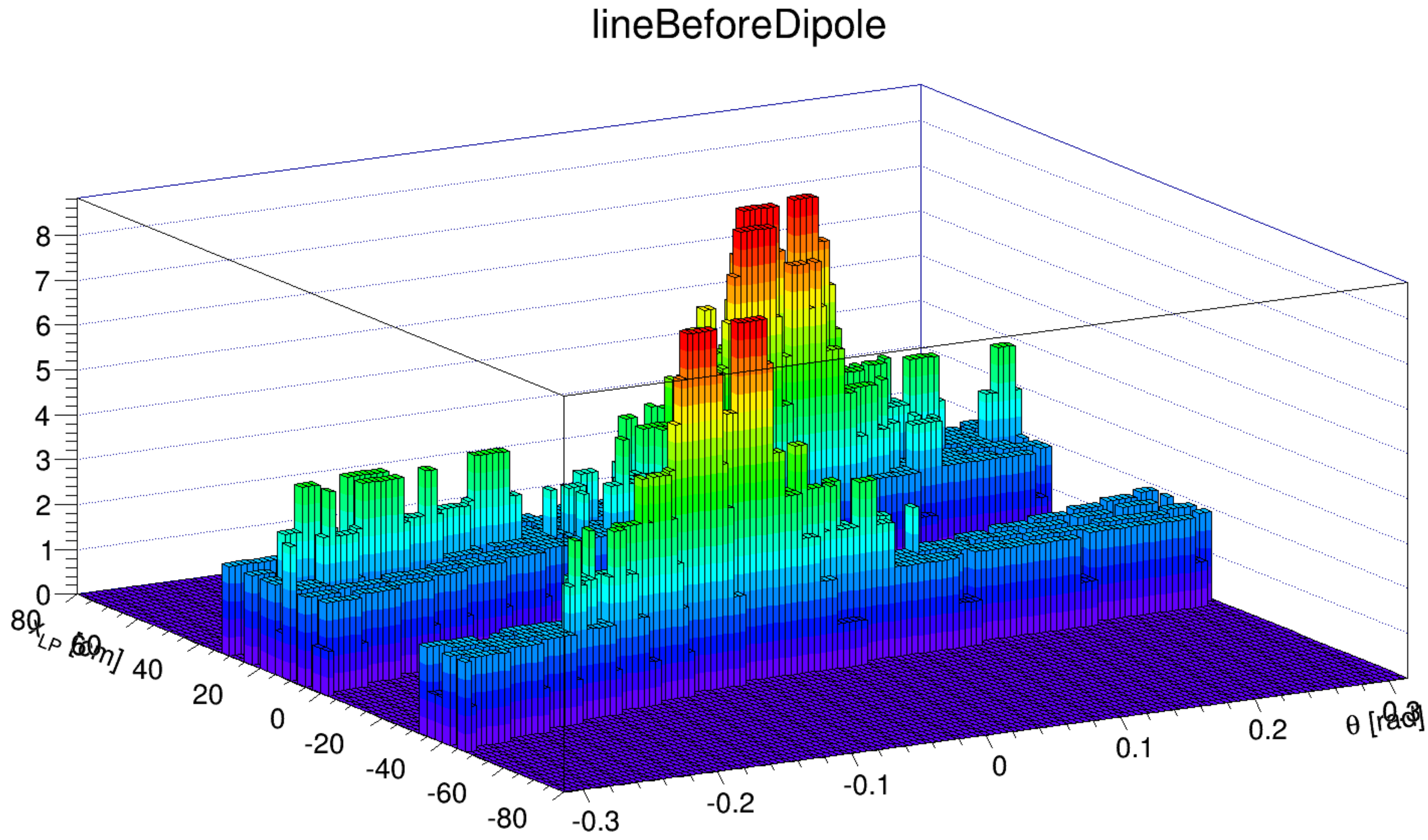

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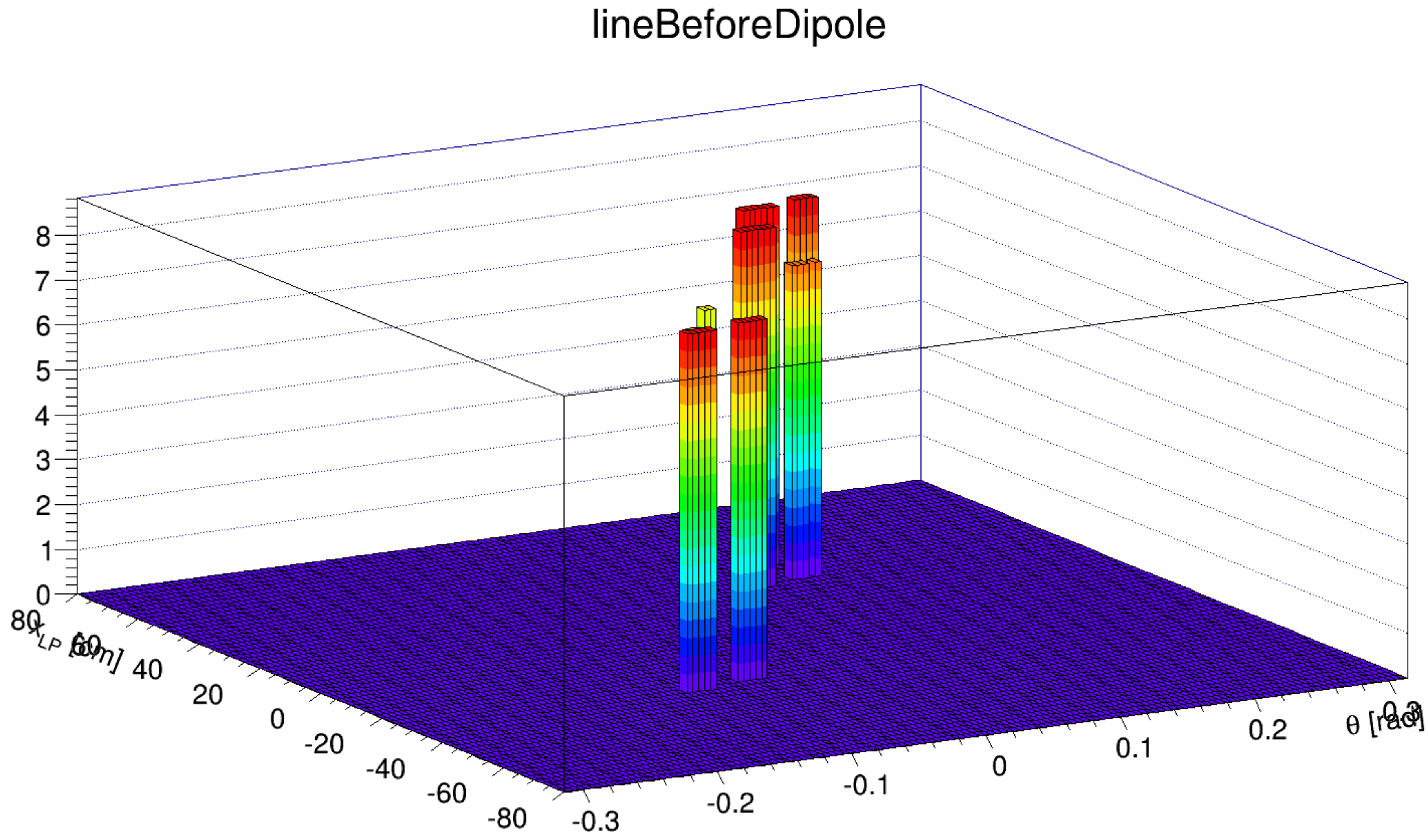

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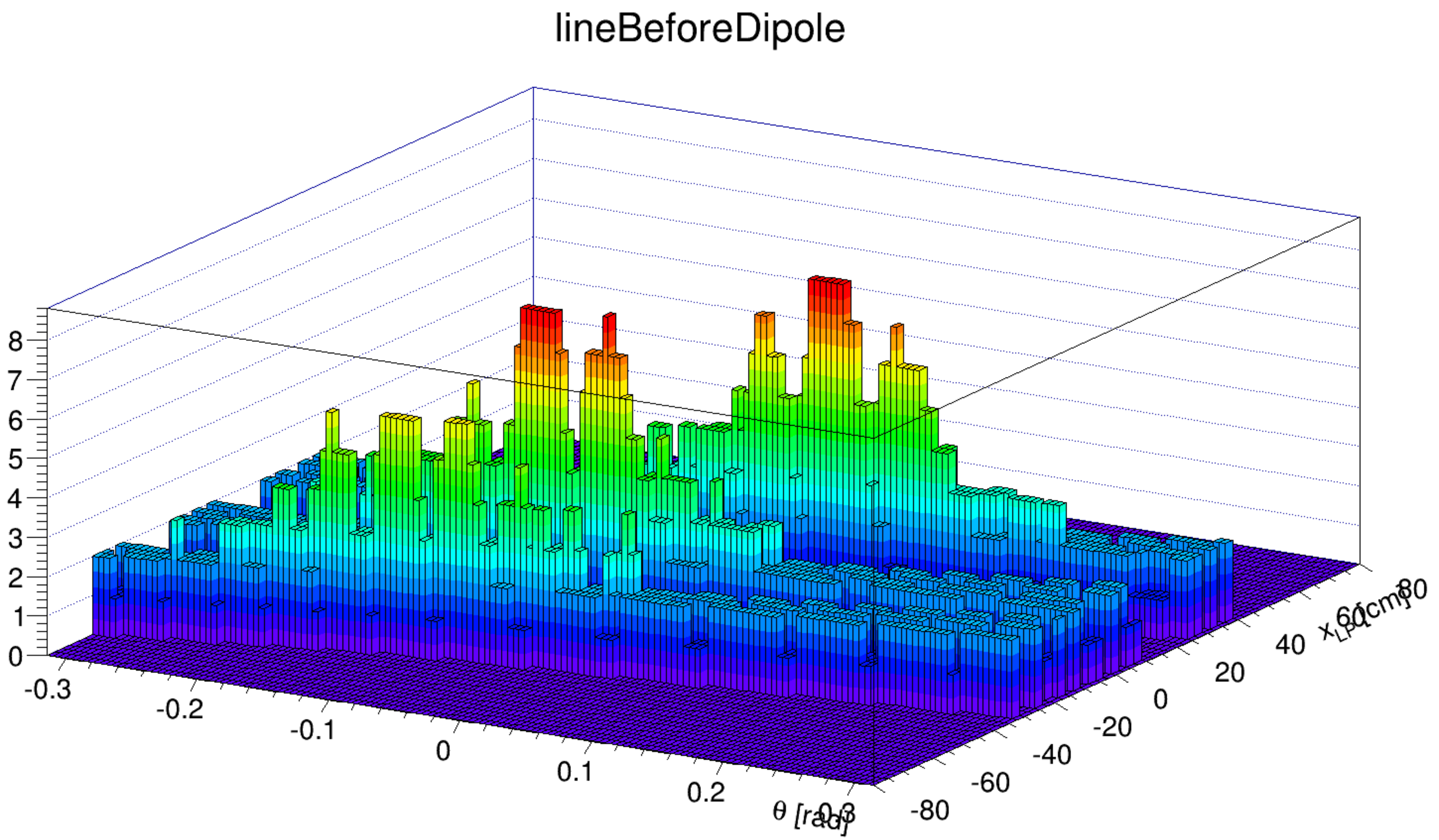

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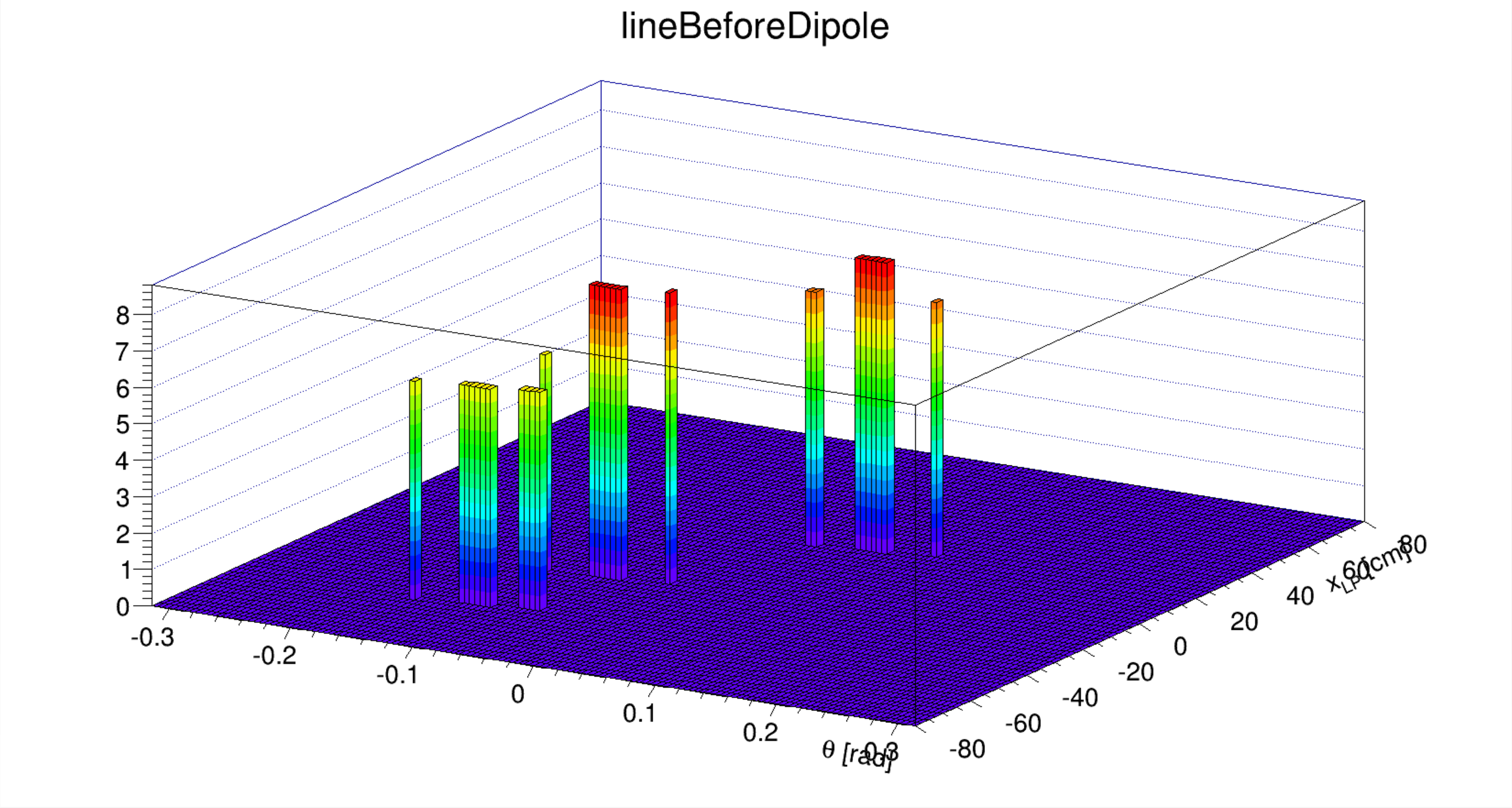

Want More Details?

PROCEEDINGS OF SCIENCE

Hough Transform Based Pattern Recognition for the $\overline{\text{P}}$ANDA Forward Tracking System

Martin J. Galuska*[(1)]†, Jifeng Hu[(1)], Wolfgang Kühn[(1)], J. Sören Lange[(1)], Yutie Liang[(1)], David Münchow[(1)], Stefano Spataro[(2)], Björn Spruck[(1)] and Milan Wagner[(1)] for the $\overline{\text{P}}$ANDA Collaboration

(1) *Justus-Liebig-Universität Gießen*
II. Physikalisches Institut
Heinrich-Buff-Ring 16
D-35392 Gießen

(2) *Universita' di Torino*
Dipartimento di Fisica
Via P. Giuria, 1
I-10125 Torino

The planned $\overline{\text{P}}$ANDA fixed-target experiment will produce up to $2 \cdot 10^7$ antiproton-proton or antiproton-nucleus collisions per second. Up to 8 primary charged particles per event are expected to reach the acceptance of the $\overline{\text{P}}$ANDA Forward Tracking System (FTS) detector. Due to a drift time of ≤ 150 ns for the FTS straw tubes the signals of on average 3 events will overlap in this layered detector at the peak interaction rate of 20 MHz. The number of overlapping events is ≤ 8 with a probability of $\geq 99.6\%$.

In this paper we describe a Hough transform based charged particle tracking algorithm for the $\overline{\text{P}}$ANDA FTS detector. In the region of the $\overline{\text{P}}$ANDA Forward Spectrometer (290 cm $\leq z \leq$ 780 cm with the z-axis pointing into the beam direction) we use a 3-stages track model of line+parabola+line for the projection of the track into the bending x-z-plane. The projection into the non-bending y-z-plane is approximated by a line for this region.

Preliminary results for single particle momentum resolutions obtained with a proof-of-concept implementation of the described algorithm are presented. Simulations were carried out in PandaRoot, the official framework for simulation, reconstruction and analysis for the $\overline{\text{P}}$ANDA experiment.

This work was supported in part by BMBF (05P12RGFPF), HGS-HIRe for FAIR and the LOEWE-Zentrum HICforFAIR.

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Bormio (Italy)

*Speaker.
†E-mail: Martin.J.Galuska@physik.uni-giessen.de

You can find a published in-detail description of the algorithm here:

http://pos.sissa.it/archive/conferences/184/023/Bormio%202013_023.pdf

(M. Galuska et. al., PoS(Bormio 2013)023)

Thank You!

And many thanks for help to S. Spataro, S. Lange, D. Münchow, M. Wagner, J. Hu, Y. Liang, M. Al-Turany, W. Kühn and B. Spruck