Status of DATCON

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Recap - Status Santander

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- Tracking was performed with fast "Divide & Conquer" Hough Trafo also in simulation with BASF2
  - By dividing the Hough Space (HS) in half, the number of sectors for horizontal and vertical direction in the HS was the same
  - >95% track reconstruction efficiency
  - especially limited in the low pT region due to multiple scattering and energy loss of low-energy particles
- Additional functions needed to estimate the track curvature / track "charge"
- "Problems" with ROI finding efficiency - events with zero ROI finding efficiency, but still ~86% ROI finding efficiency overall

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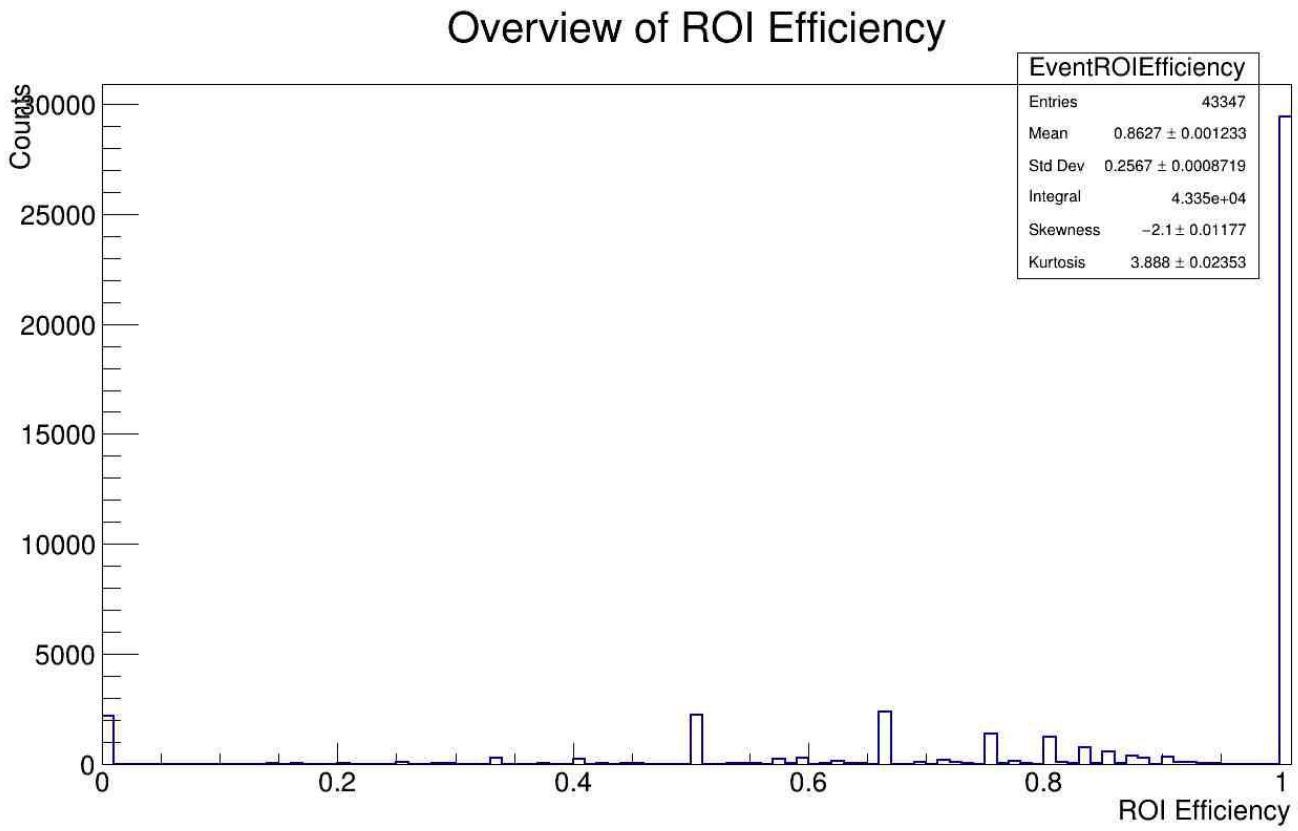

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DATCON - Tracking (Simulation)

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- Using background of campaign 15 instead of campaign 12 significantly increases the number of hits in both SVD and PXD

  → increase in number of fake tracks

- New HT approach (only consider outgoing tracks) reduces number of fakes by factor of ~2
- Implementation and testing of HT without D&C but with checking every (predefined) sector (as on the FPGA)

  → all combinations of sector numbers possible, not only powers of 2

  → decreased number of fakes (less active sectors)

  → increased computation time on PC

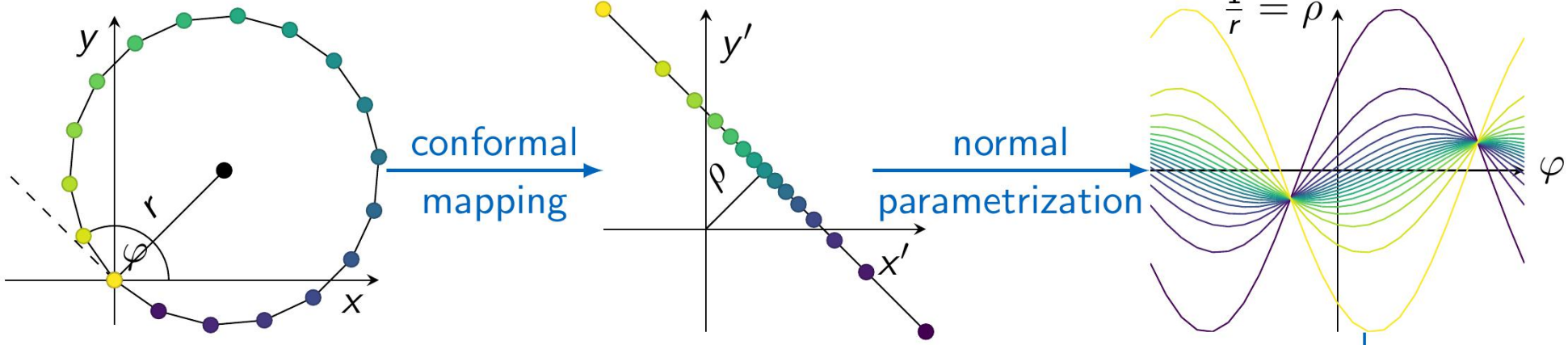
- New approach for clustering of HS (as shown by Bruno)

  - still in testing phase, not used as default by now

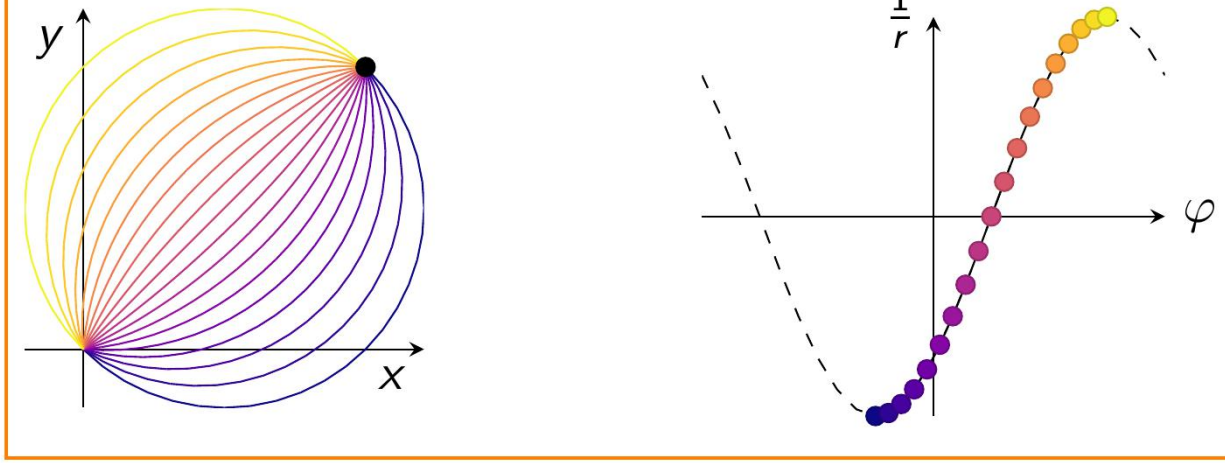
- New TrackMerger: Combine several tracks in close proximity to one track

  → reduces number of fakes

New HT Approach

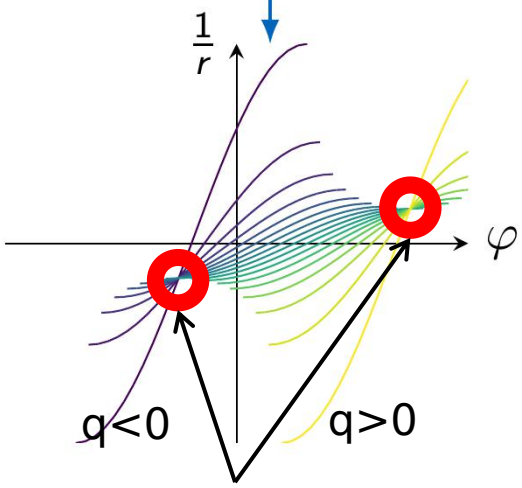


outgoing tracks ≡ rising half of Hough curve



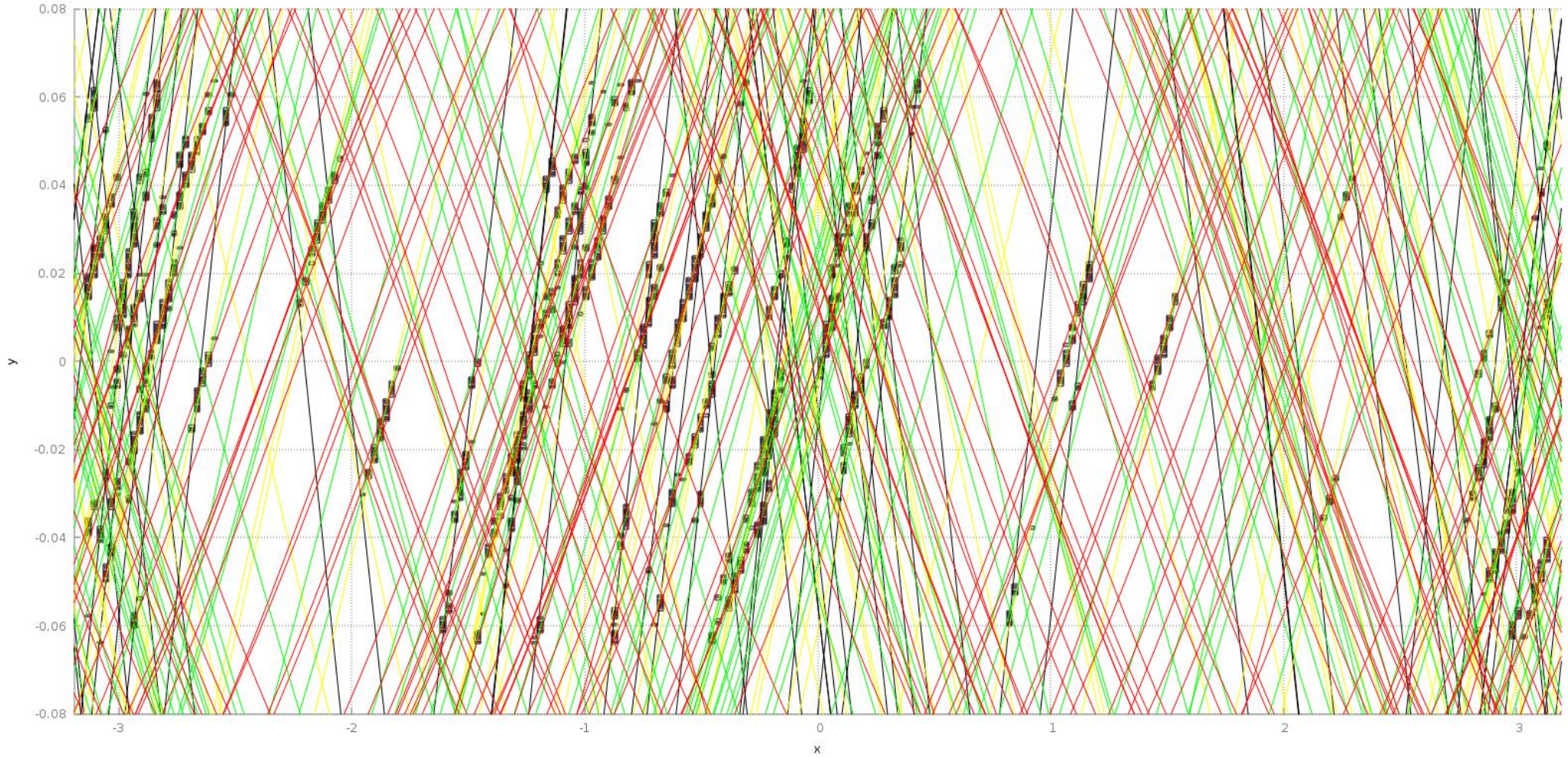
[S. Neuhaus, CTD/WIT 2017]

only outgoing tracks



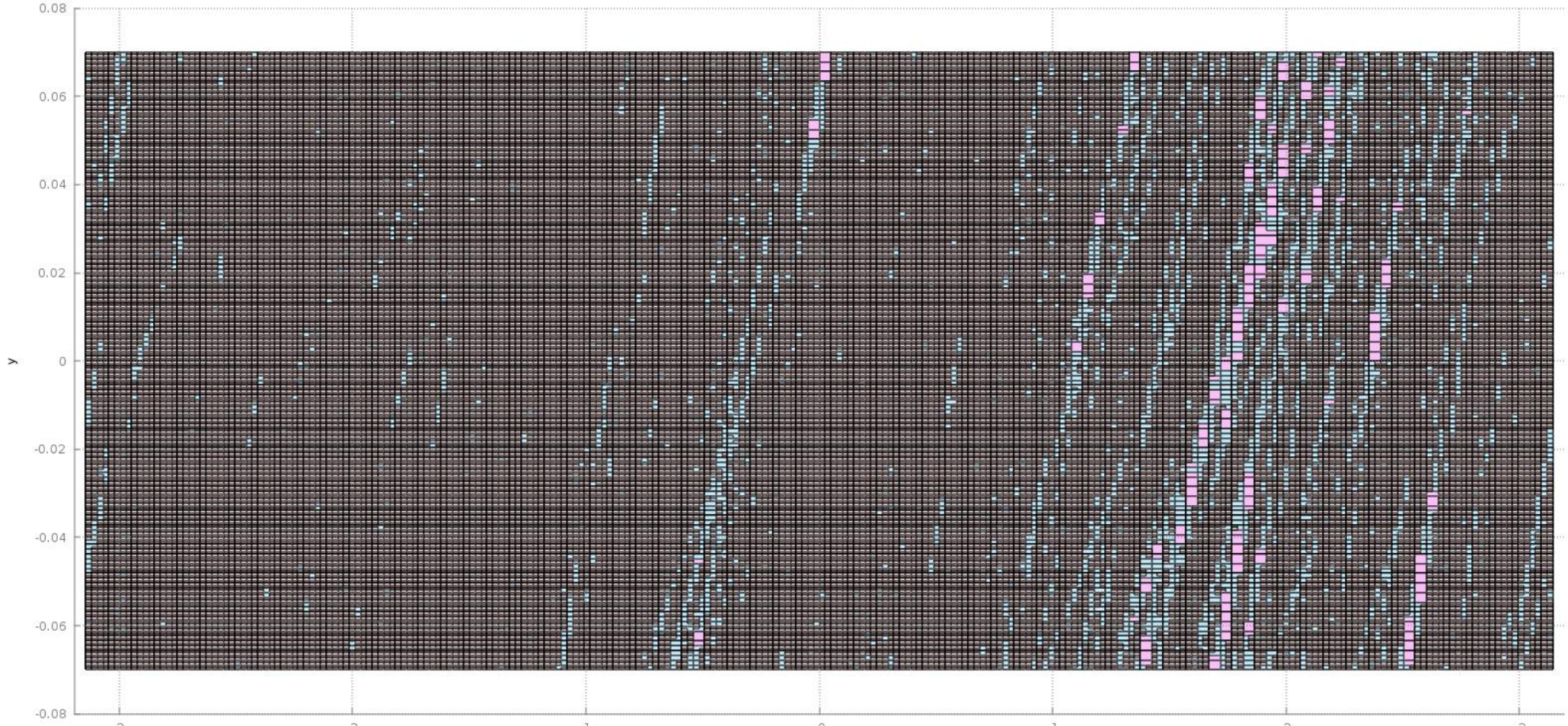
Directly get charge

Tracking - Results



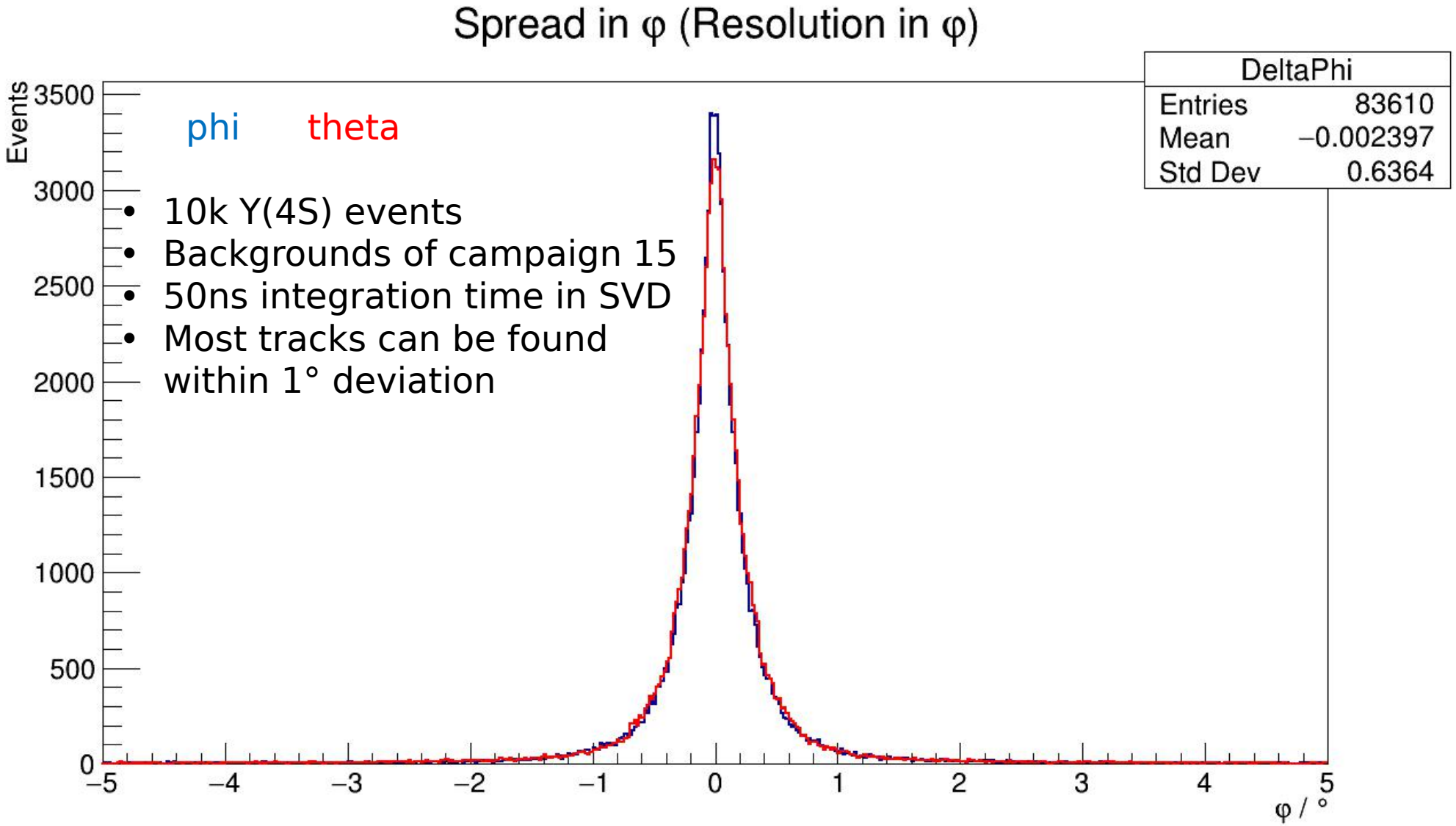
- "Typical" Y(4S) event with background of campaign 15 (integration time 50ns SVD)
- Already hard to find correct intersections by eye (180 hits / lines), but still quite clean considering the sectors

Tracking - Results

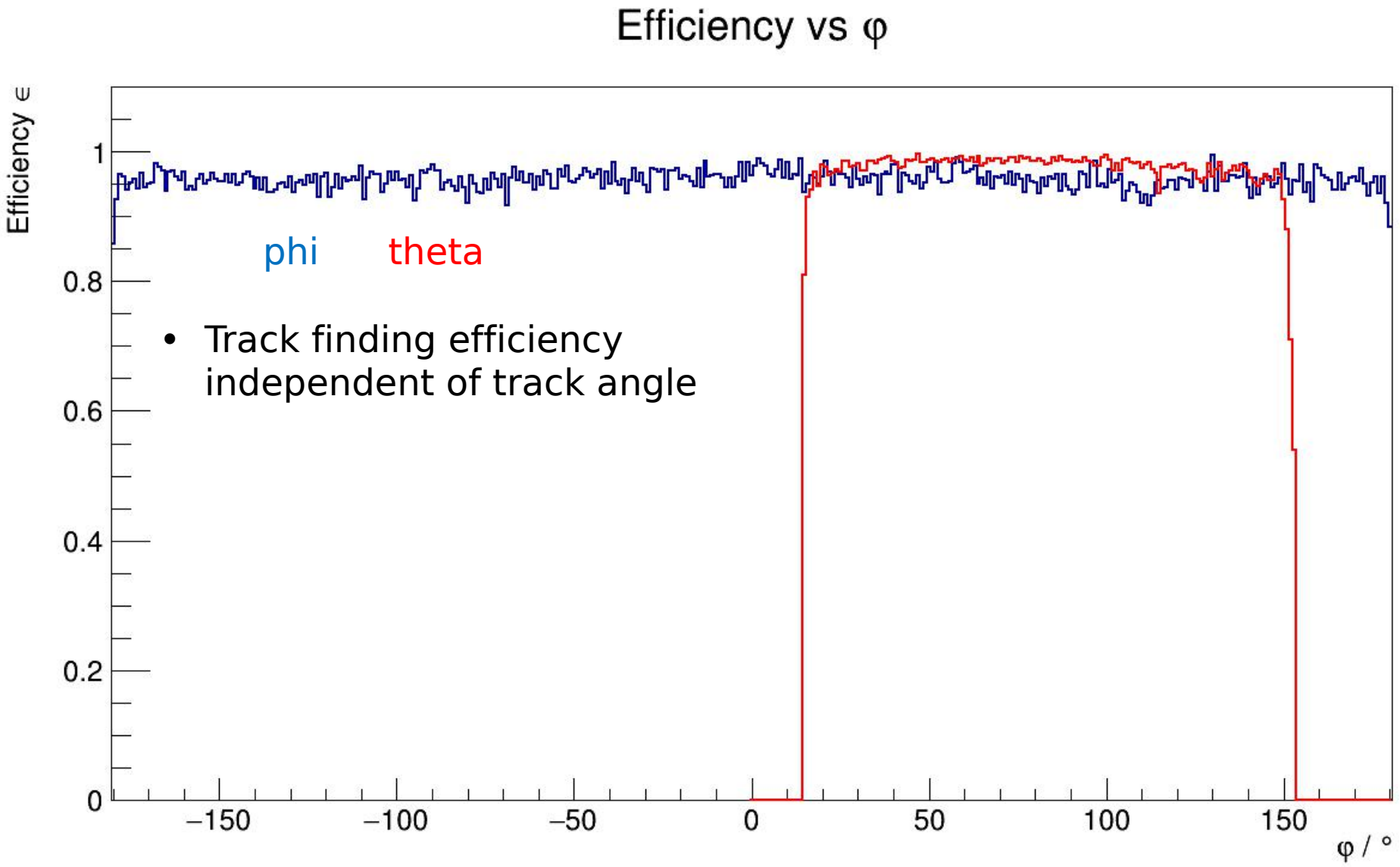


- Very messy, not possible to find intersections (2500 hits / lines, not shown)
- Hard / impossible to perform useful clustering in these events
- Same integration times (50ns SVD)
- These rather rare event with many BG hits contribute much to high fake rate

Tracking - Results

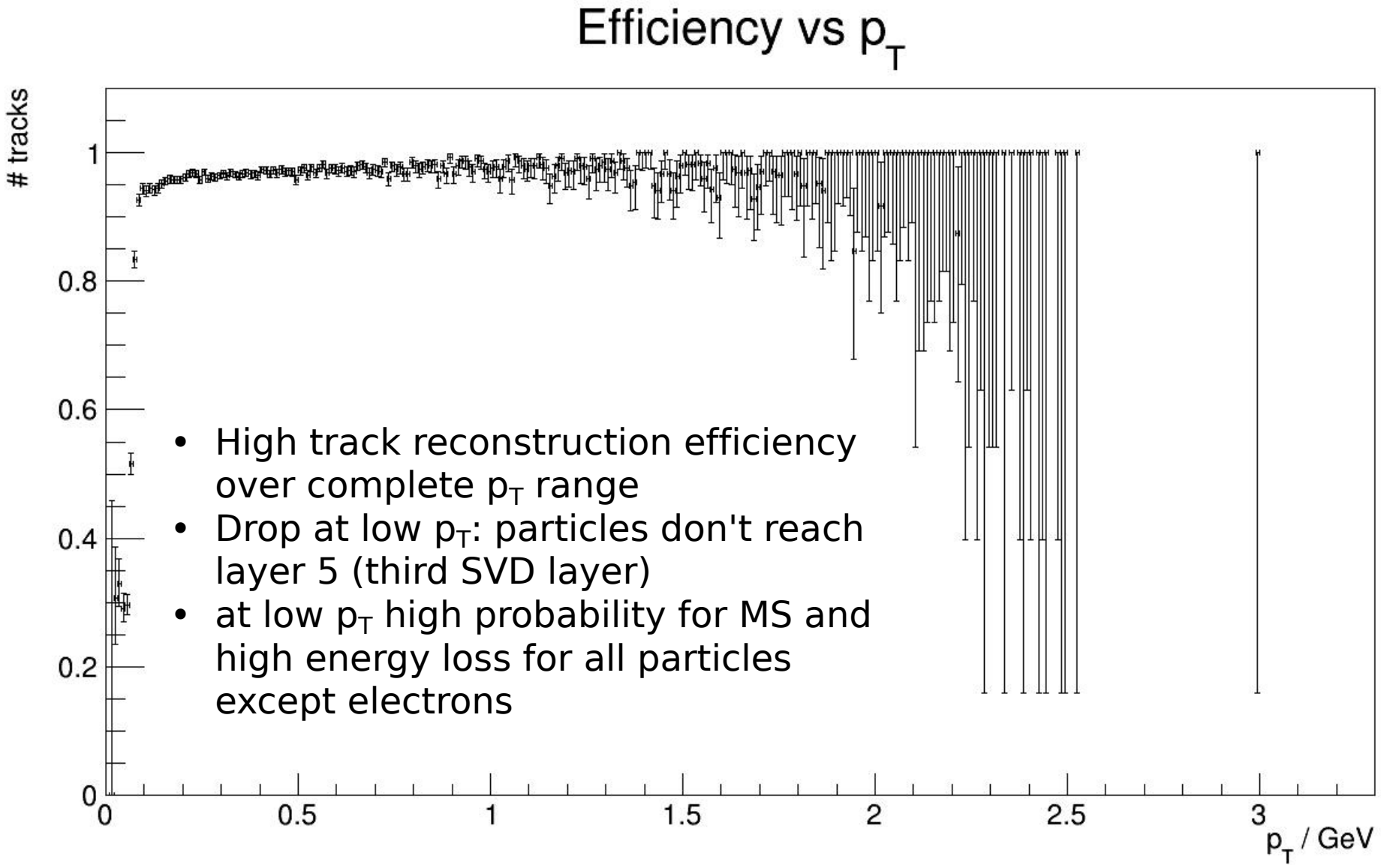


Tracking - Results



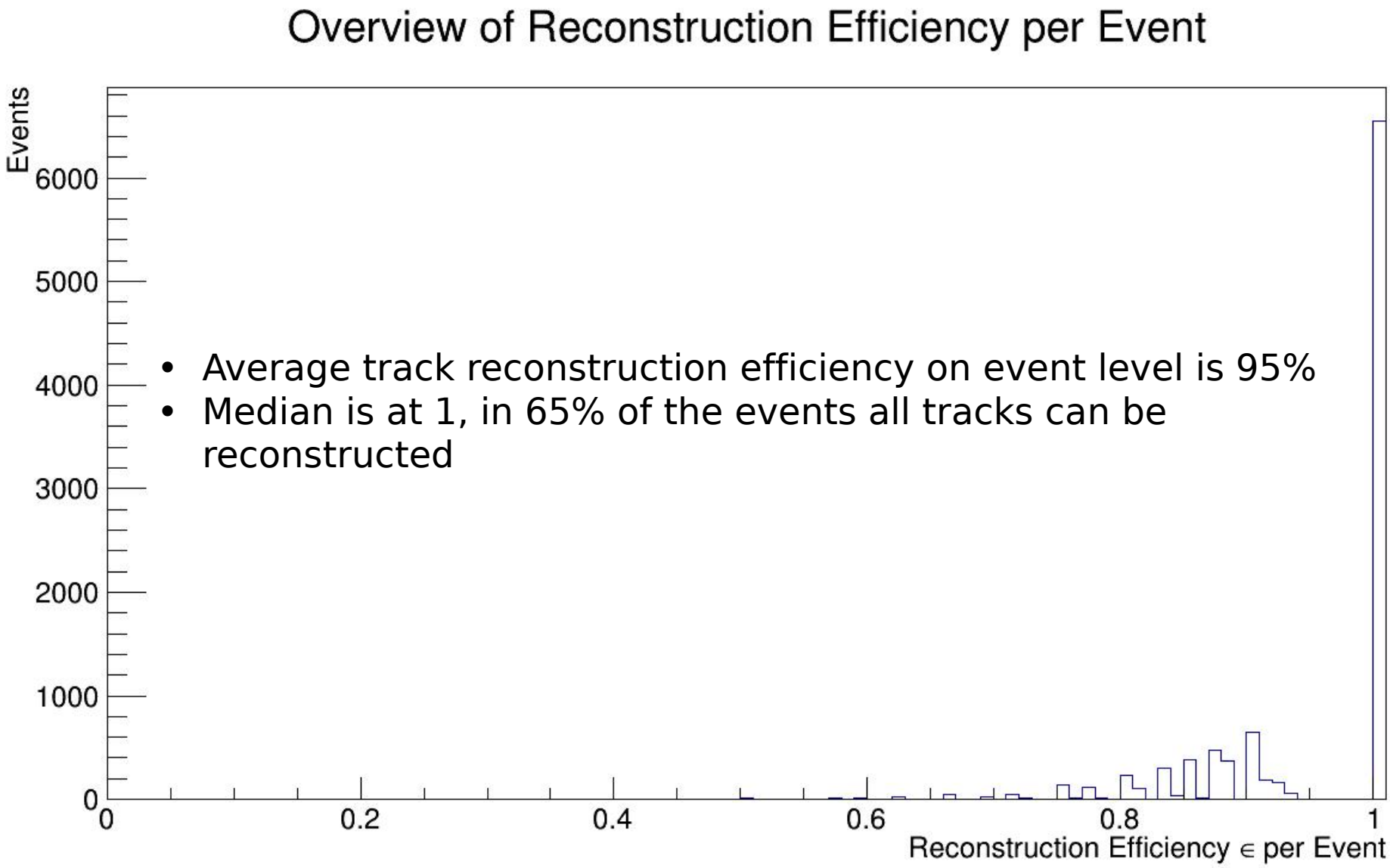
- Track finding efficiency independent of track angle

Tracking - Results



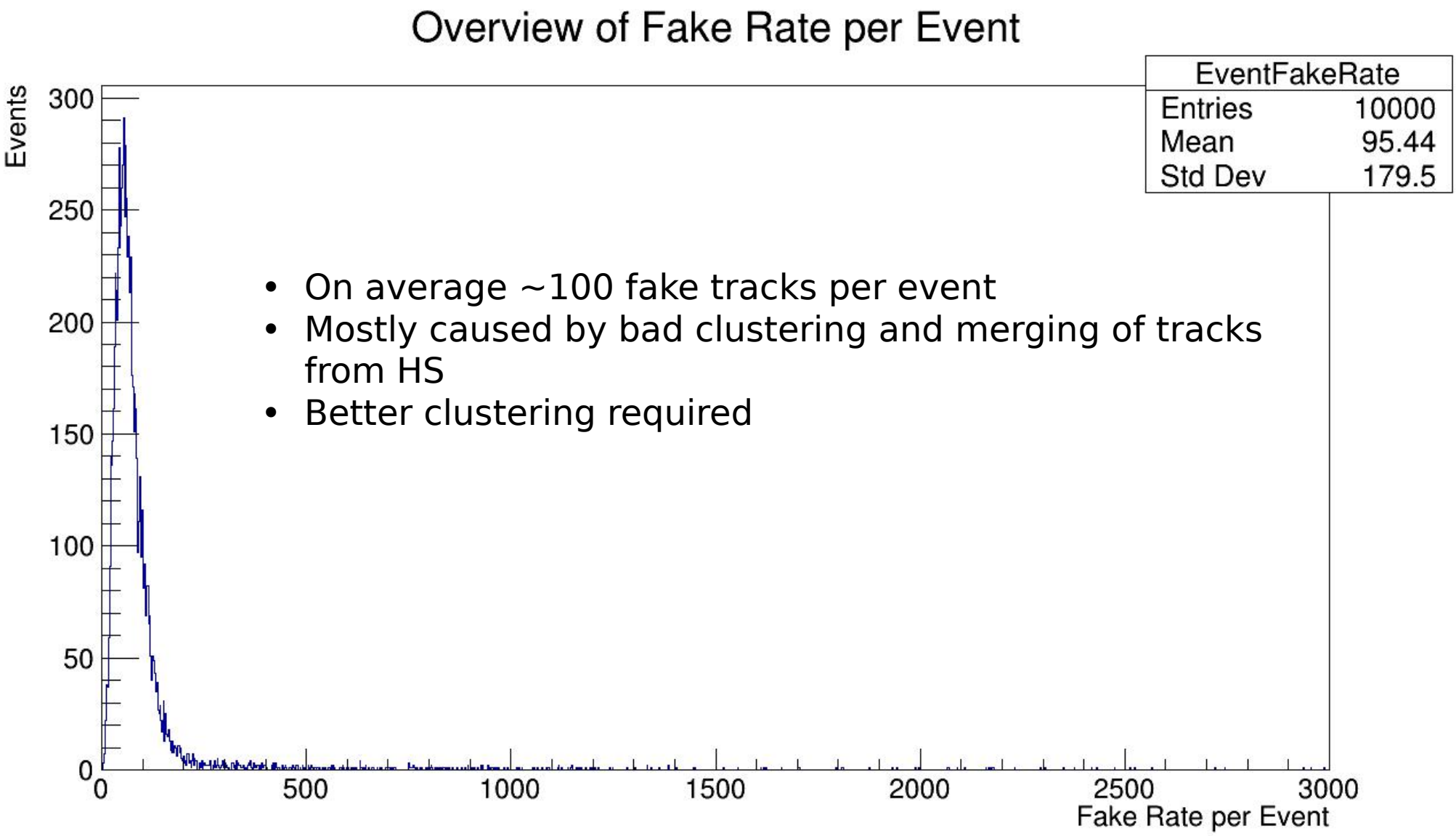
- High track reconstruction efficiency over complete p_T range
- Drop at low p_T: particles don't reach layer 5 (third SVD layer)
- at low p_T high probability for MS and high energy loss for all particles except electrons

Tracking - Results



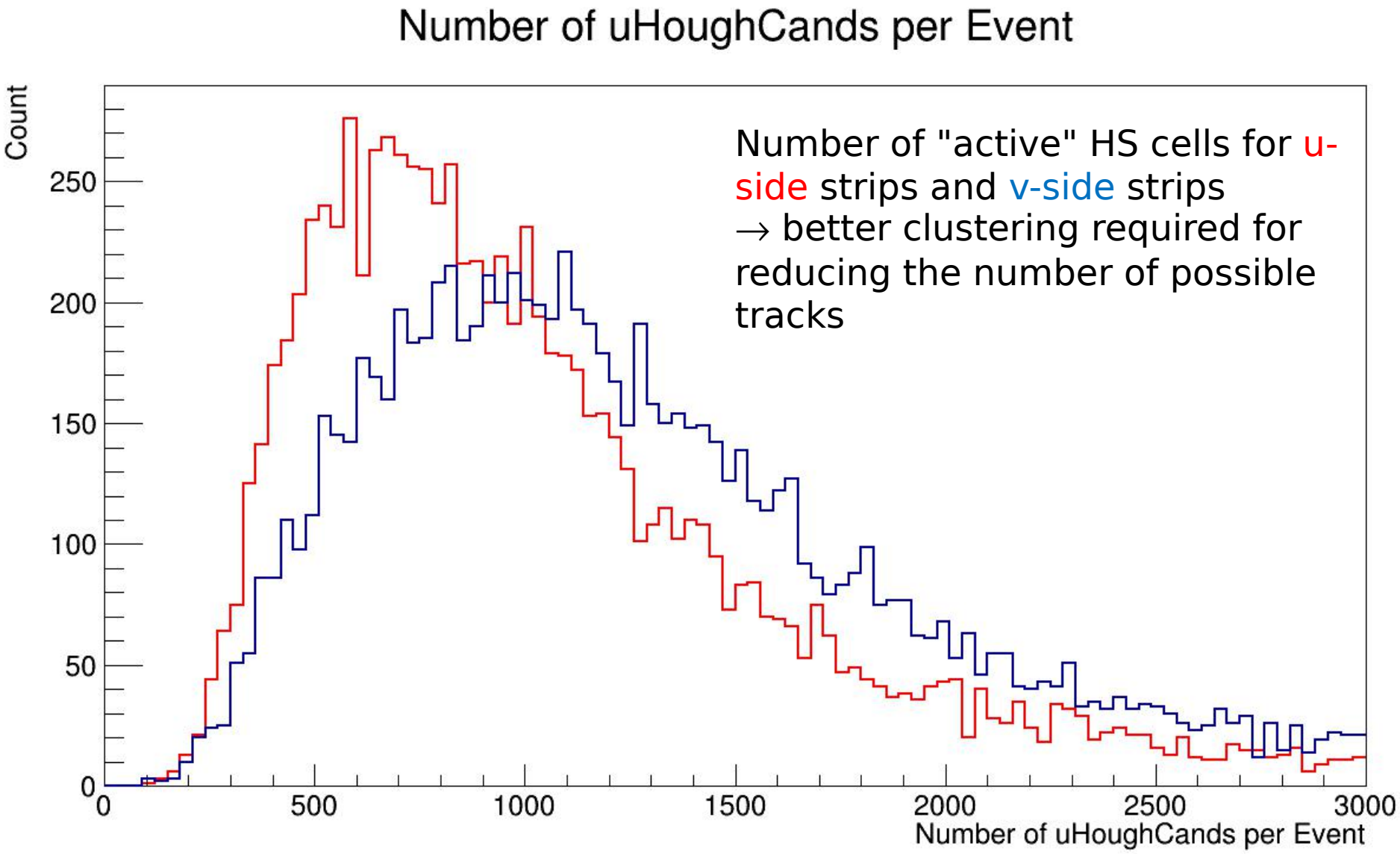
- Average track reconstruction efficiency on event level is 95%
- Median is at 1, in 65% of the events all tracks can be reconstructed

Tracking - Results

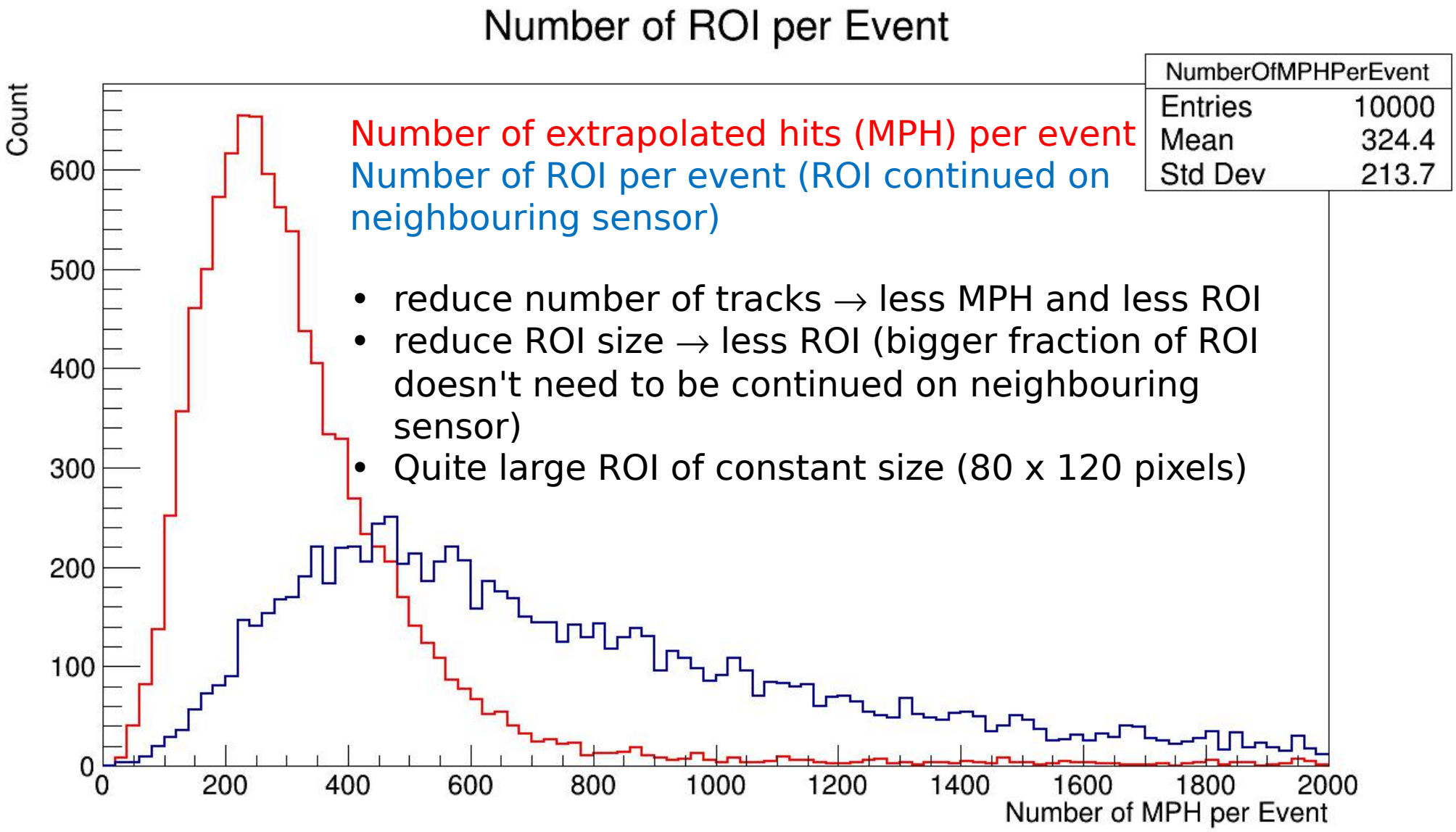


- On average ~100 fake tracks per event
- Mostly caused by bad clustering and merging of tracks from HS
- Better clustering required

Tracking - Results



ROI Finding - Results

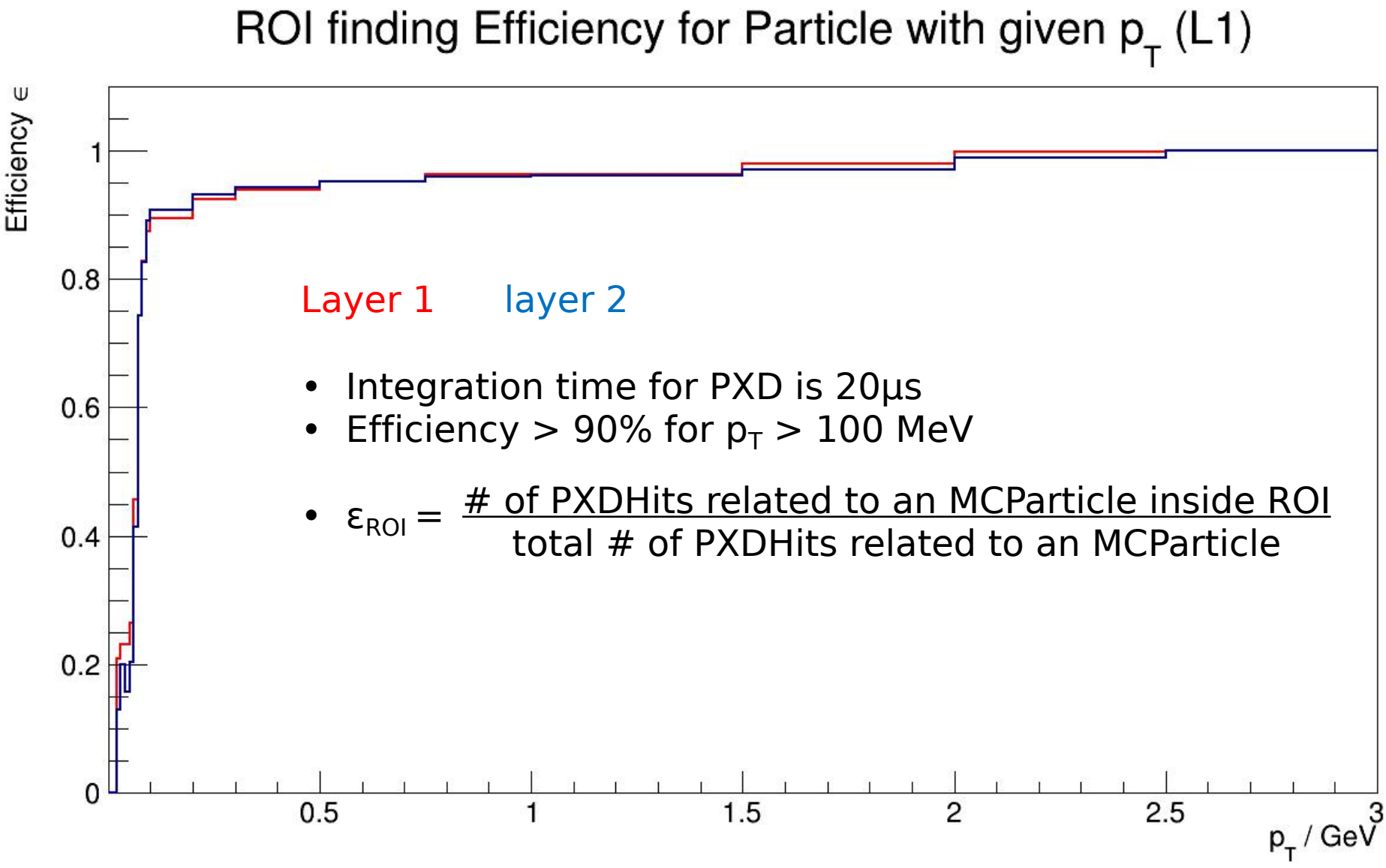


Number of extrapolated hits (MPH) per event

Number of ROI per event (ROI continued on neighbouring sensor)

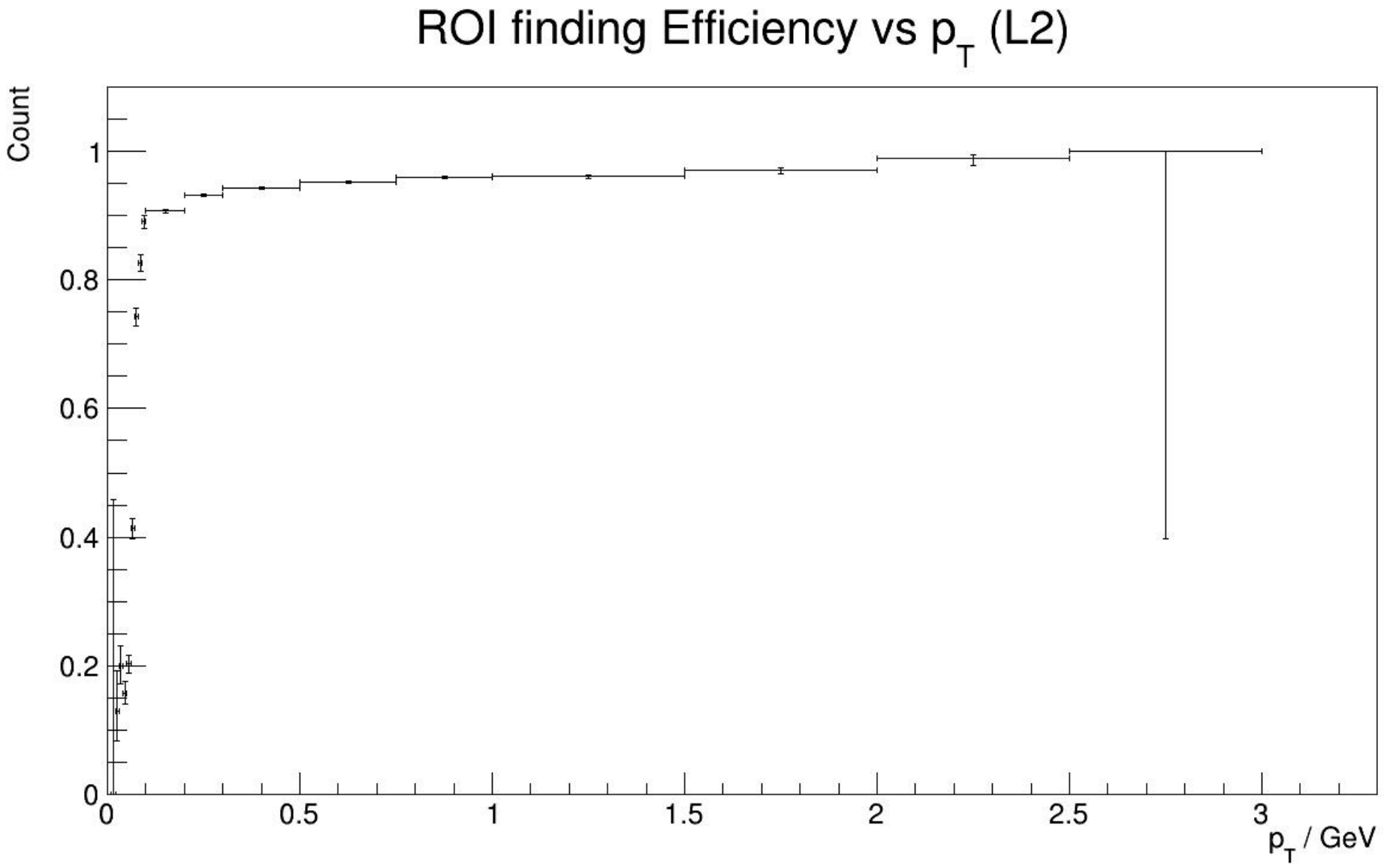
- reduce number of tracks → less MPH and less ROI
- reduce ROI size → less ROI (bigger fraction of ROI doesn't need to be continued on neighbouring sensor)
- Quite large ROI of constant size (80 x 120 pixels)

ROI Finding - Results

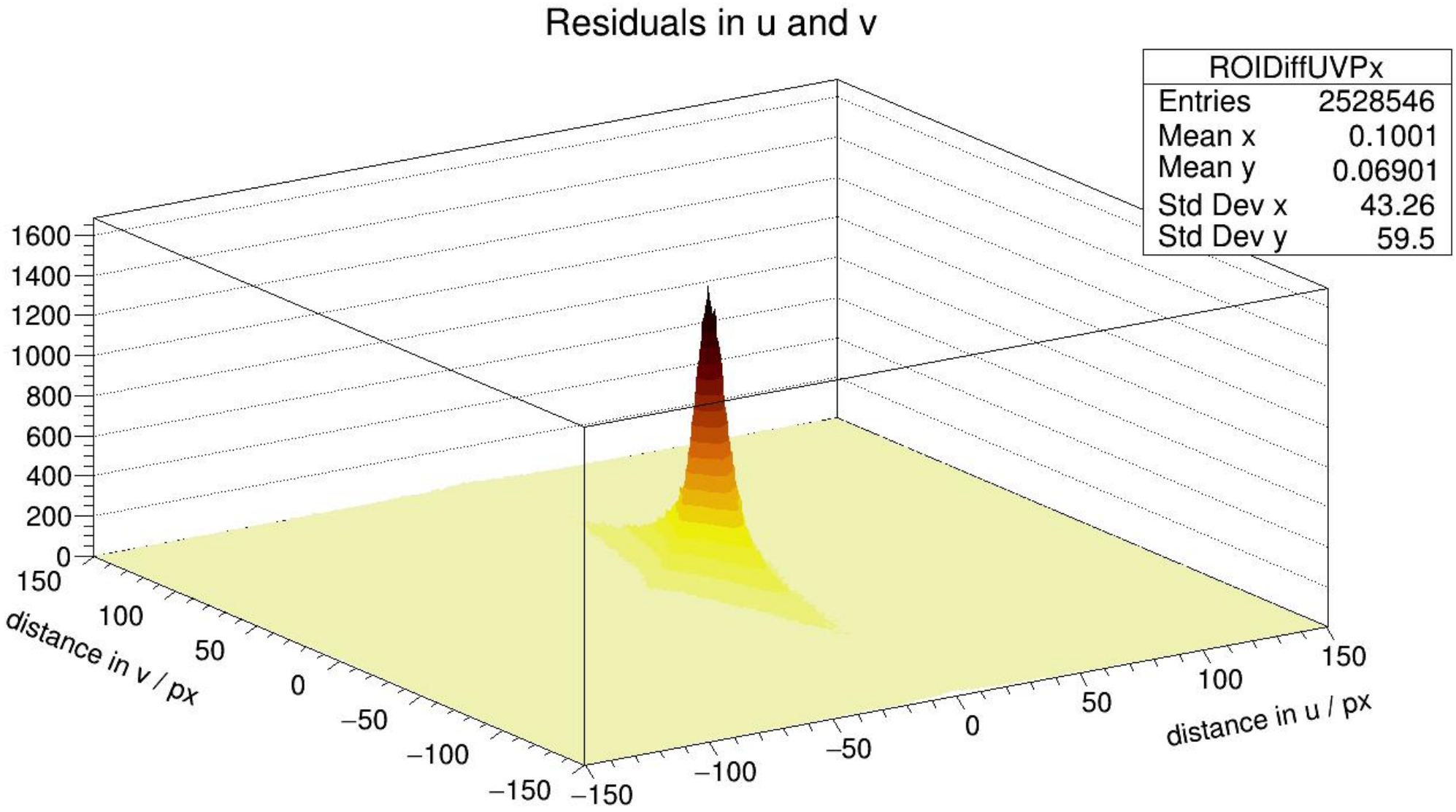


- Integration time for PXD is 20µs
- Efficiency > 90% for p_T > 100 MeV
- $\varepsilon_{ROI} = \frac{\text{\# of PXDHits related to an MCParticle inside ROI}}{\text{total \# of PXDHits related to an MCParticle}}$

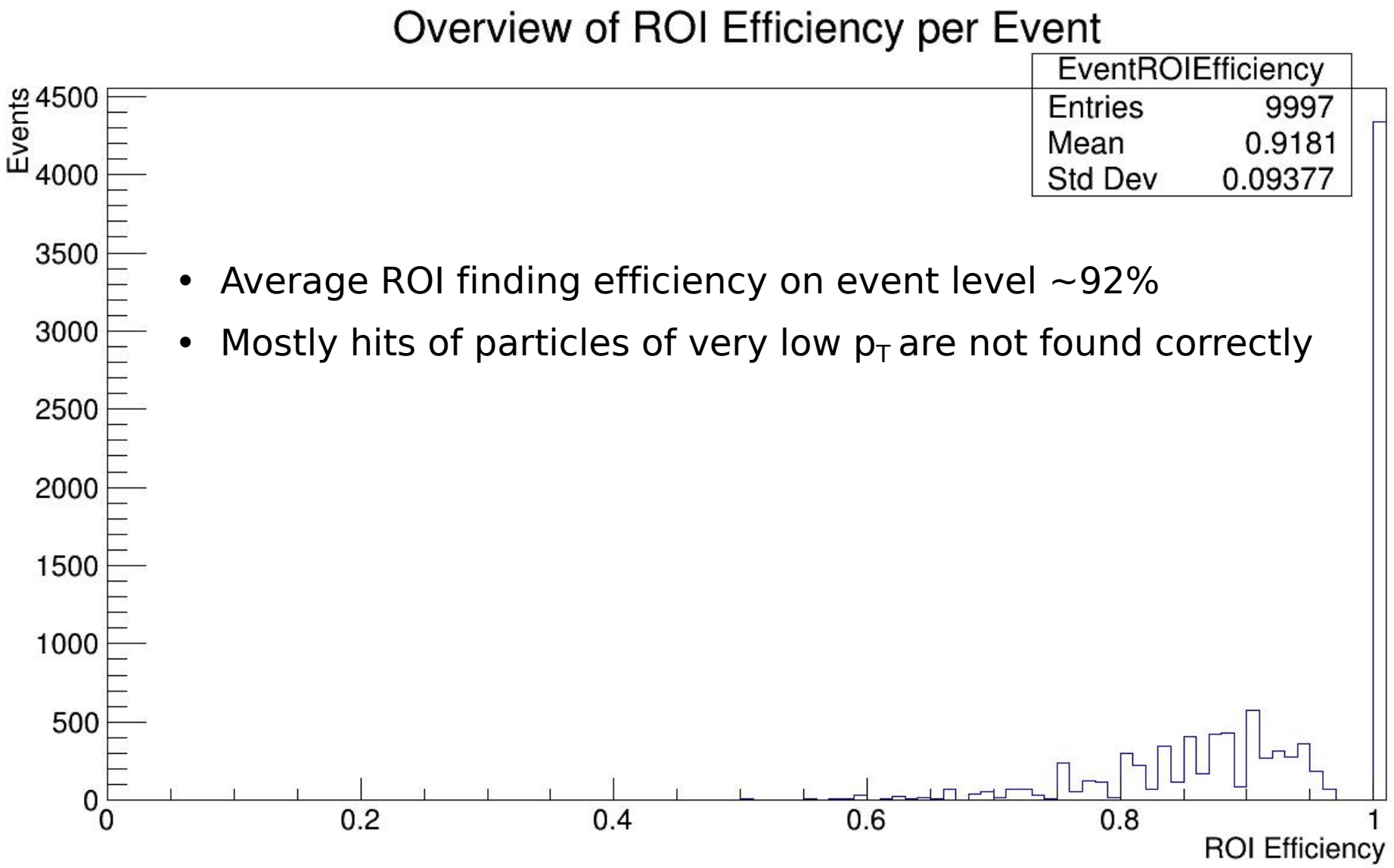
ROI Finding - Results



ROI Finding - Results

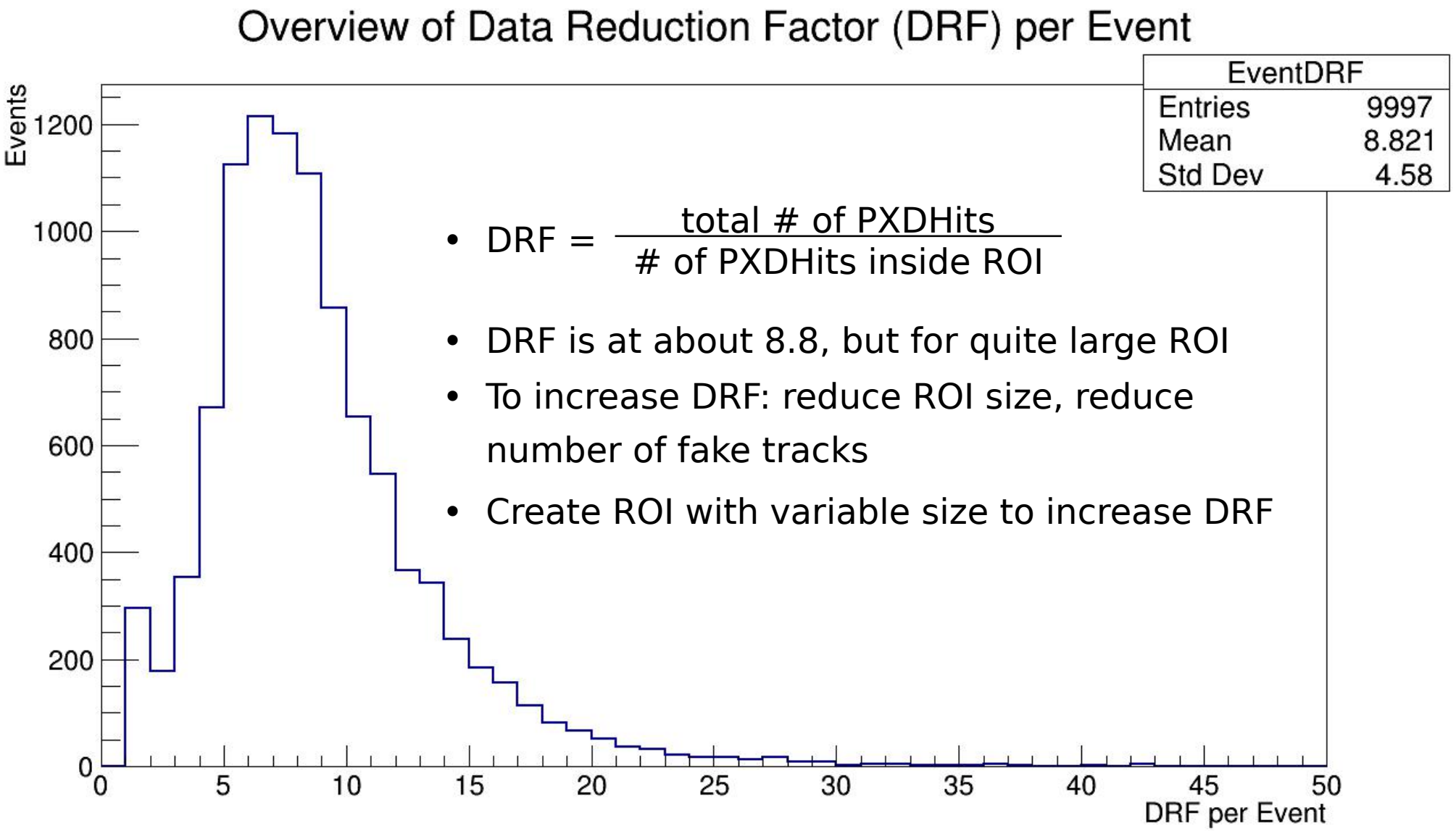


ROI Finding - Results



- Average ROI finding efficiency on event level ~92%
- Mostly hits of particles of very low p_T are not found correctly

ROI Finding - Results



- DRF = $\frac{\text{total \# of PXDHits}}{\text{\# of PXDHits inside ROI}}$
- DRF is at about 8.8, but for quite large ROI
- To increase DRF: reduce ROI size, reduce number of fake tracks
- Create ROI with variable size to increase DRF

Conclusions

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- Very good tracking performance of BASF2 DATCON algorithm (> 97%) for generic Y(4S) events with background of campaign 15, but
  - Quite high number of fake tracks $\rightarrow$ crucial for data reduction factor
- Good ROI finding efficiency of 92% (complete p_T range)
- O(10-20) parameters to tune for optimisation of tracking and ROI calculation
- DRF could be increased by using ROI of variable size instead of fixed size
- Still need for optimisation of ROI finding performance for (very) low p_T tracks

Outlook

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General Plans

- Implementation of complete SVD-like data chain
  - DATCON only receives SVDDigits and strip ID, not SVDClusters or space points
  - trying to be as close as possible to BASF2 SVD data chain, considering what is possible to do on FPGA
- BASF2 implementation of DATCON very close to hardware implementation
- Optimisation of parameters for HT, TrackMerger, ROI sizes (variable or fixed size), ...

Plans until June B2GM

- Usage of RecoTracks as track objects for tracking analysis
- Usage of Giulias ROI classes $\rightarrow$ Probably more reliable information on ROI finding efficiency and data reduction factor

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Thank you

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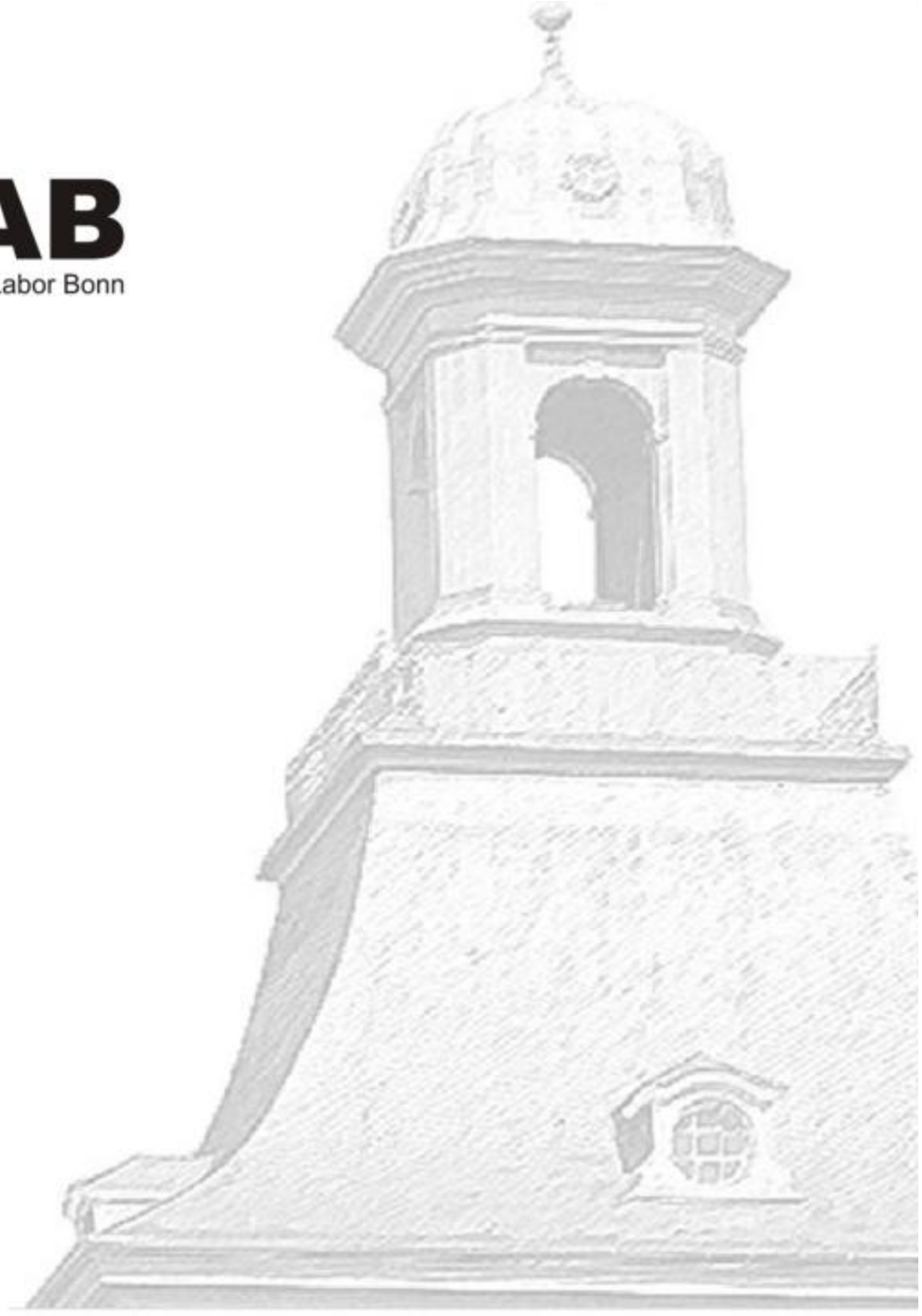

Backup

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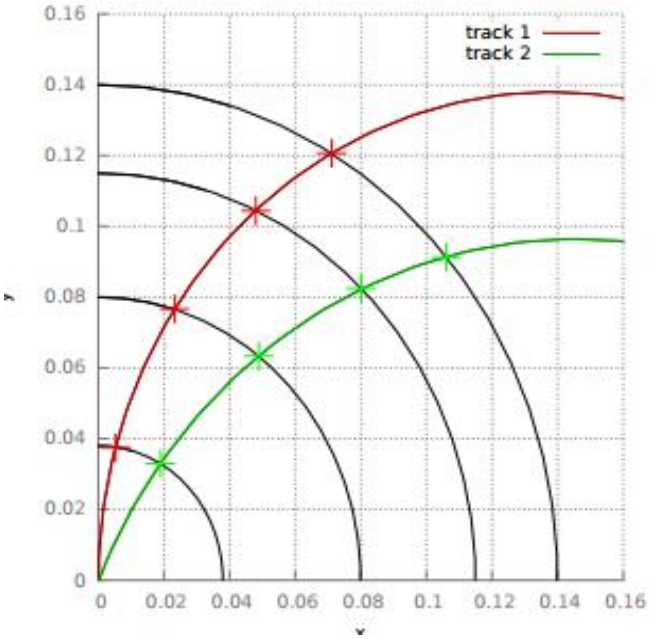
SVD Track Reconstruction

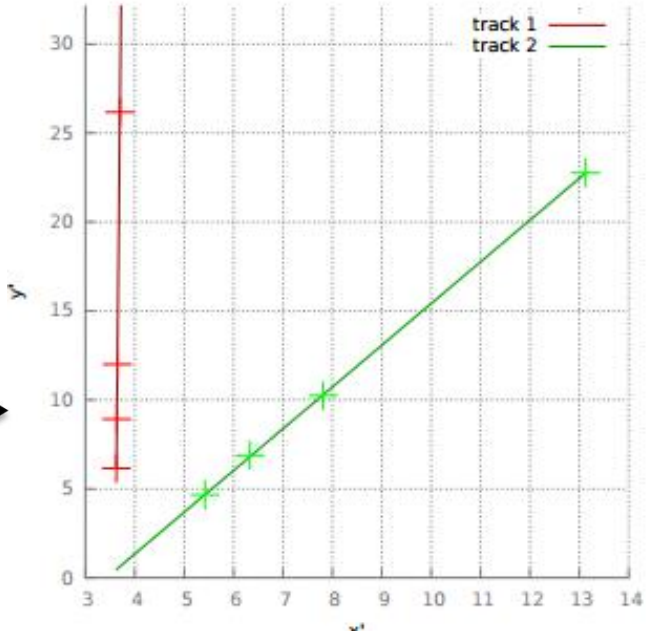
- Use of the Hough transformation:

$$d = x \cdot \cos\alpha + y \cdot \sin\alpha$$

- Drawack: Can only be applied for straight line (as previously implemented on FPGA)
- For circular track a conformal transformation is needed



$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \frac{1}{r^2} \cdot \begin{pmatrix} x \\ y \end{pmatrix}$$



Extrapolation

- Simulations with Y(4S) events are performed
  ⟶ results look promising, but further improvements necessary

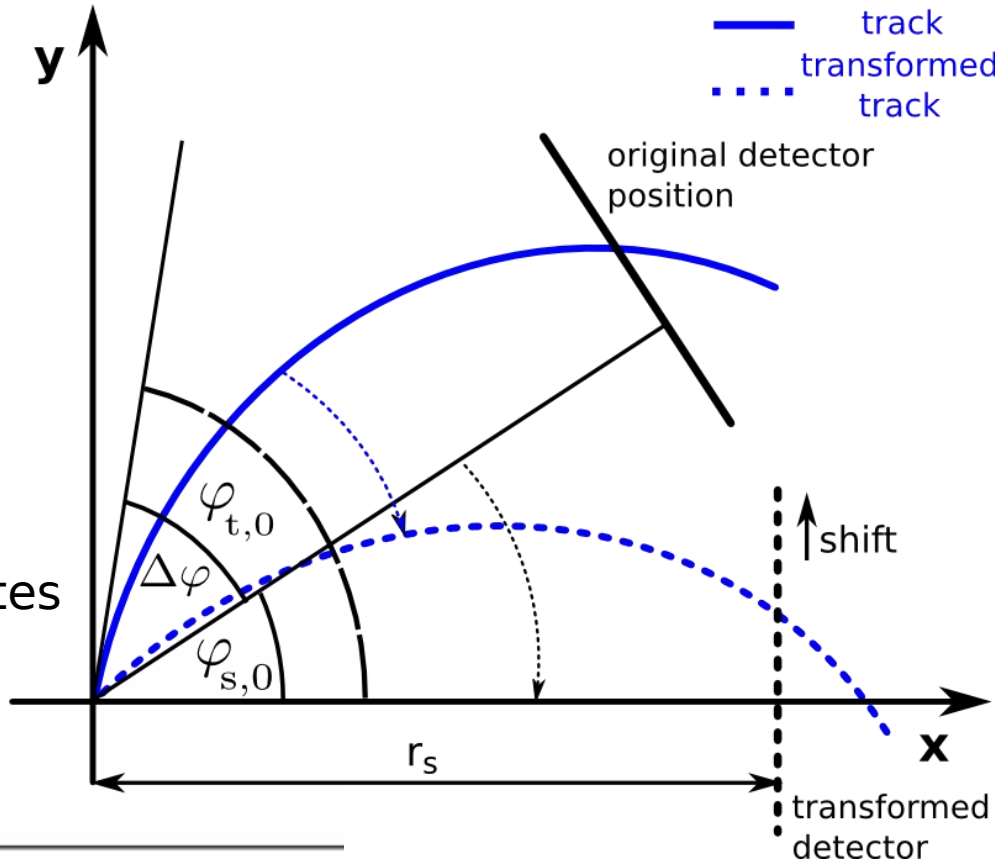
- Also new extrapolation method implemented:
  intersection of circle (= track) with straight line (= detector plane)

- Afterwards: multiplication of (x,y) with rotation matrix to obtain 3d MPH (most probable hit) coordinates

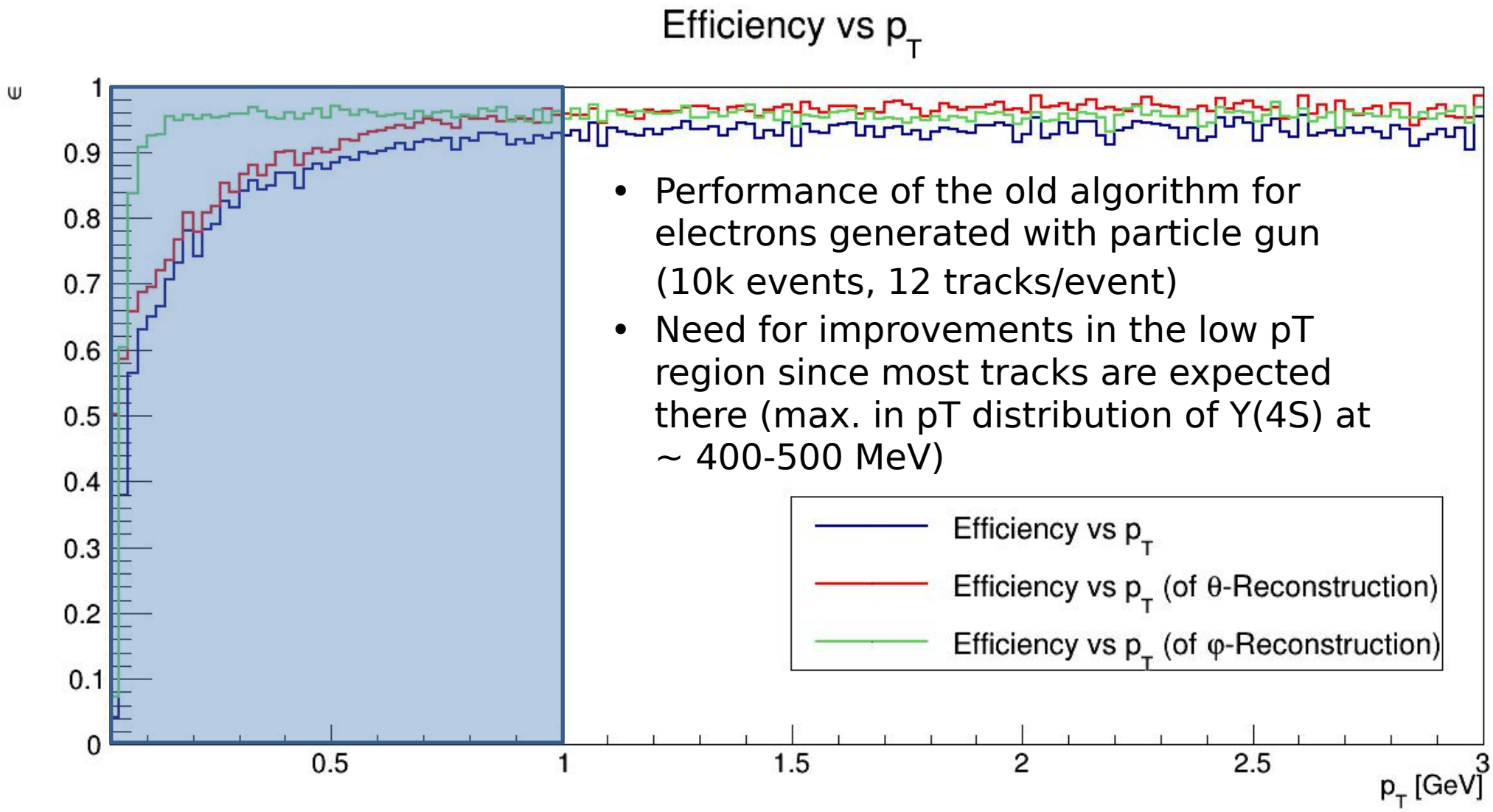
$$\Delta\varphi = \varphi_\mathrm{t} - \varphi_\mathrm{s}$$

$$x = r_\mathrm{s}$$

$$y = r_\mathrm{t} \cdot \cos\Delta\varphi + \sqrt{r_\mathrm{t}^2 - (r_\mathrm{s} - r_\mathrm{t} \cdot \sin\Delta\varphi)^2}$$

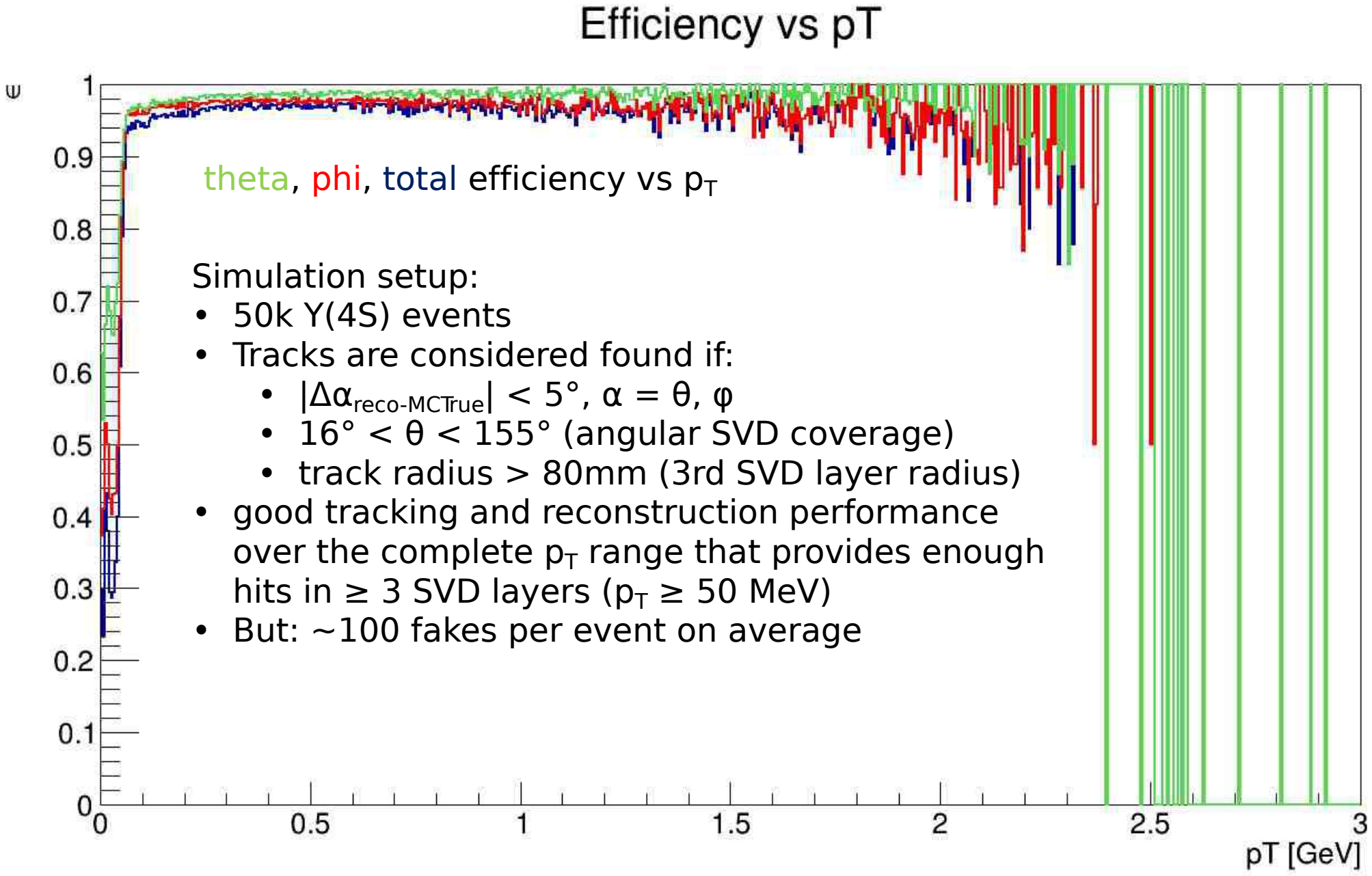


Simulation Results - Tracking Performance



- Performance of the old algorithm for electrons generated with particle gun (10k events, 12 tracks/event)
- Need for improvements in the low pT region since most tracks are expected there (max. in pT distribution of Y(4S) at ~ 400-500 MeV)

Simulation Results - Tracking Performance

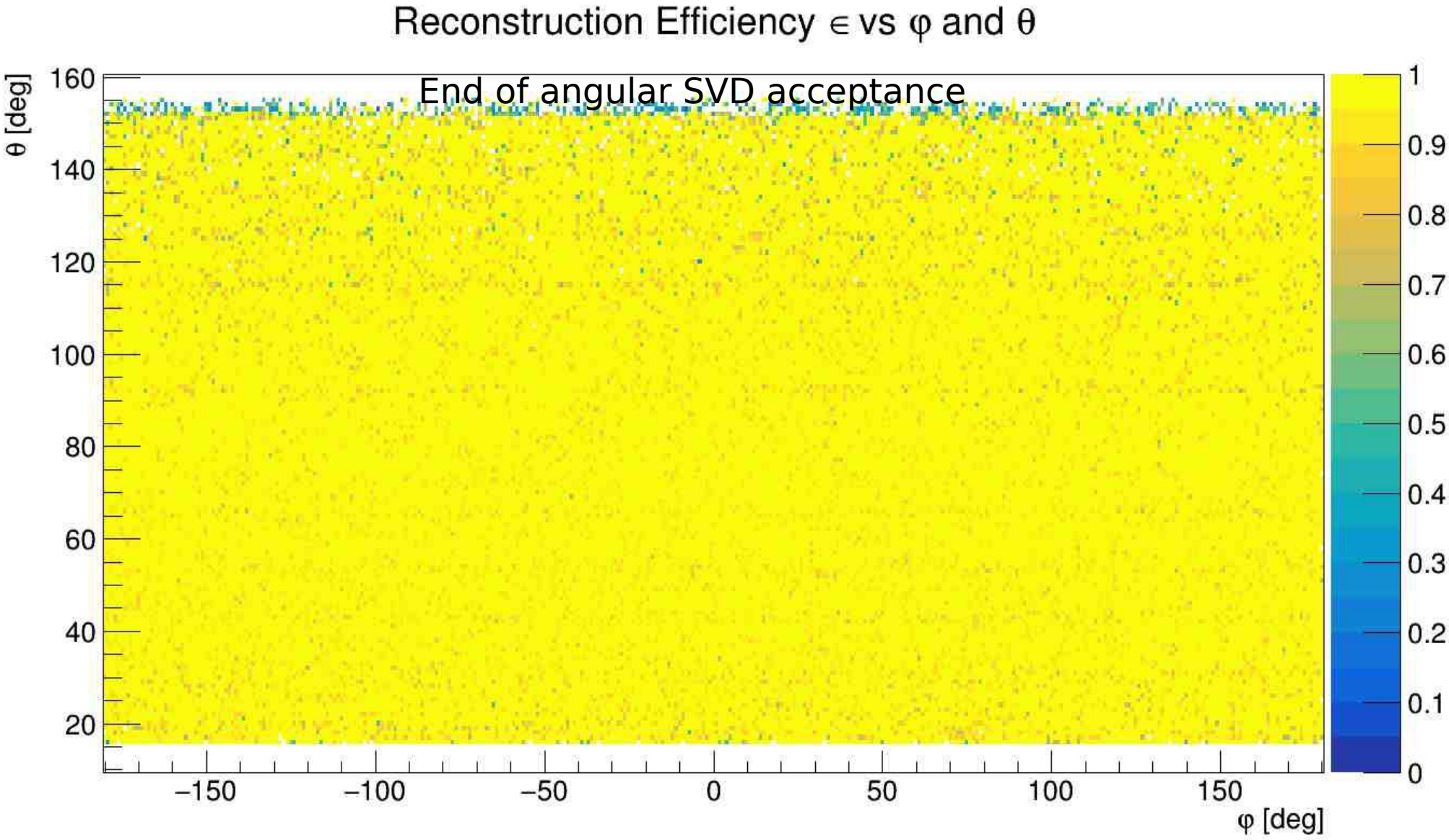


theta, phi, total efficiency vs p_T

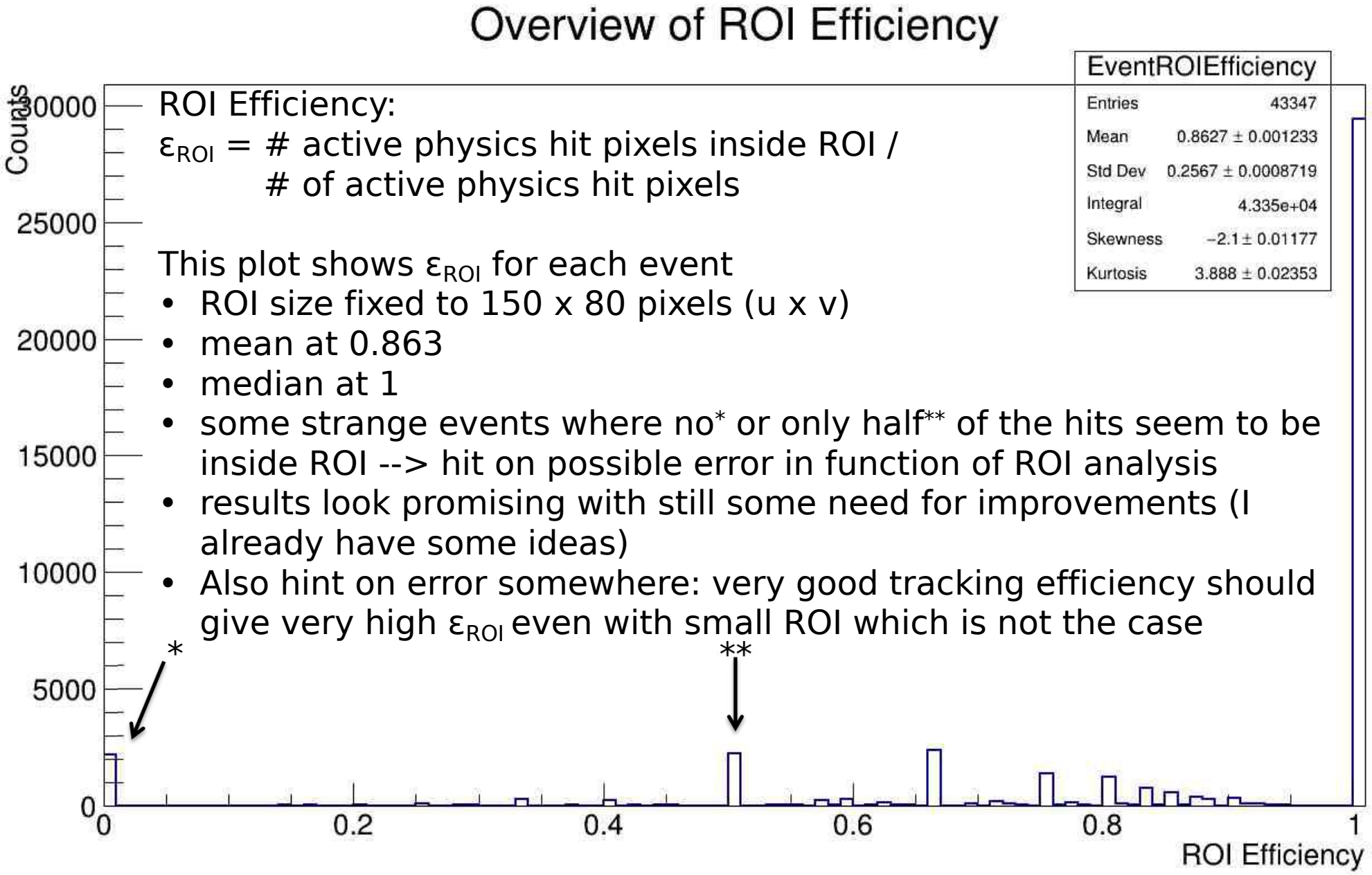
Simulation setup:

- 50k Y(4S) events
- Tracks are considered found if:
  - $|\Delta\alpha_{\text{reco-MCTrue}}| < 5°$, $\alpha = \theta, \varphi$
  - $16° < \theta < 155°$ (angular SVD coverage)
  - track radius > 80mm (3rd SVD layer radius)
- good tracking and reconstruction performance over the complete p_T range that provides enough hits in ≥ 3 SVD layers ($p_T \geq 50$ MeV)
- But: ~100 fakes per event on average

Simulation Results - Tracking Performance



Simulation Results - ROI Performance



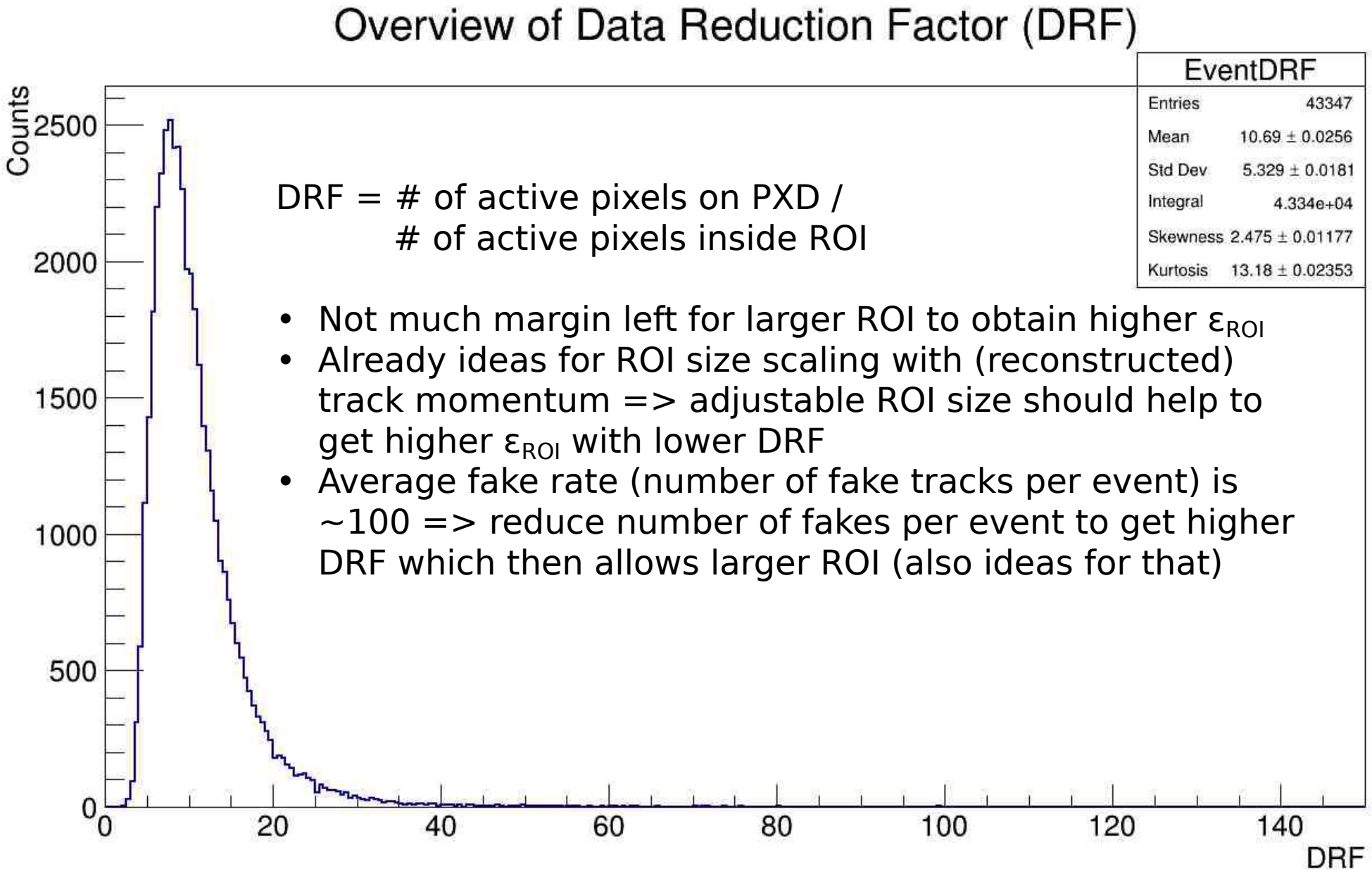
ROI Efficiency:

ε_{ROI} = # active physics hit pixels inside ROI / # of active physics hit pixels

This plot shows ε_{ROI} for each event

- ROI size fixed to 150 x 80 pixels (u x v)
- mean at 0.863
- median at 1
- some strange events where no* or only half** of the hits seem to be inside ROI --> hit on possible error in function of ROI analysis
- results look promising with still some need for improvements (I already have some ideas)
- Also hint on error somewhere: very good tracking efficiency should give very high ε_{ROI} even with small ROI which is not the case

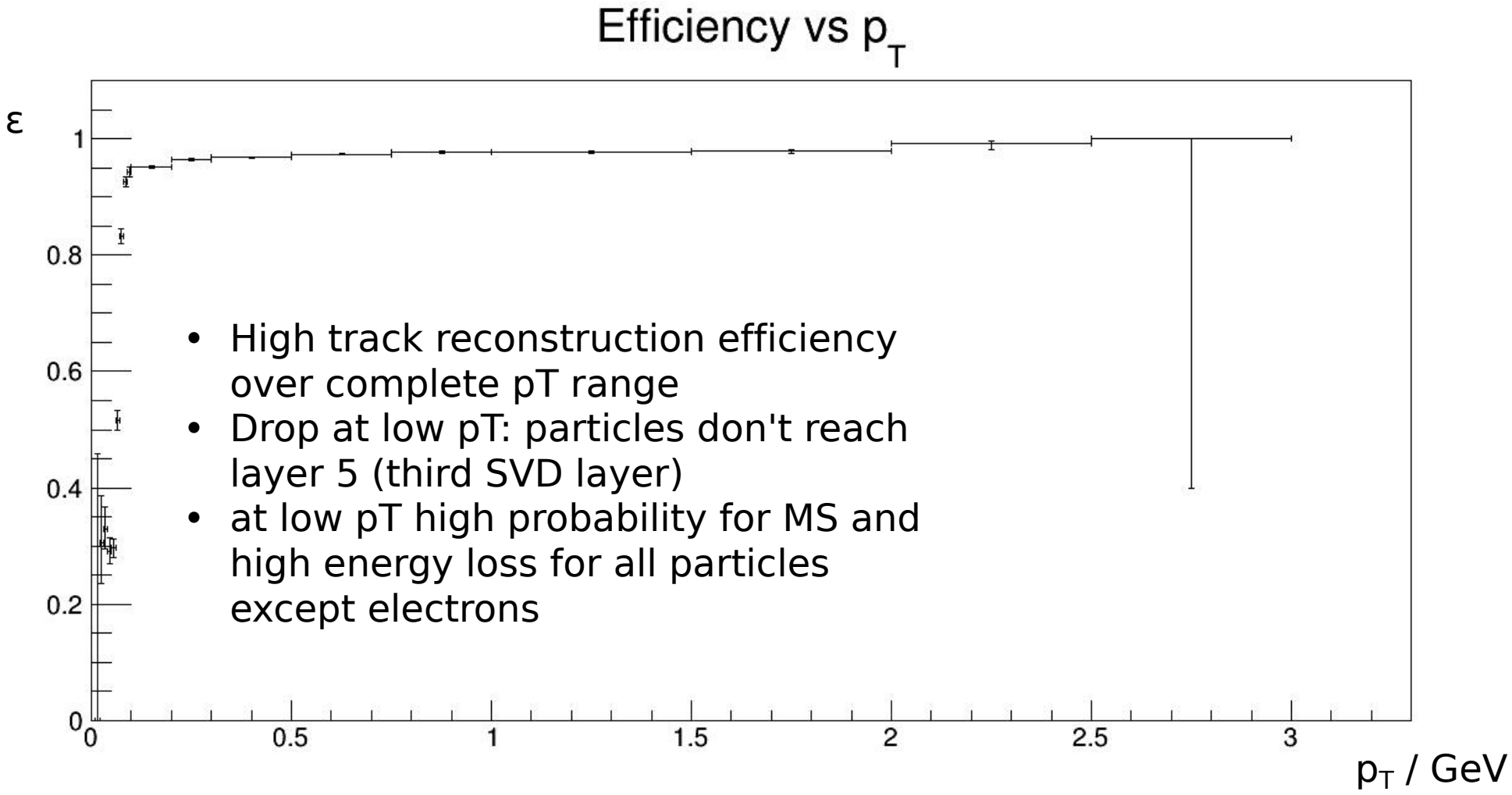
Simulation Results - ROI Performance



DRF = # of active pixels on PXD /
# of active pixels inside ROI

- Not much margin left for larger ROI to obtain higher ε_{ROI}
- Already ideas for ROI size scaling with (reconstructed) track momentum => adjustable ROI size should help to get higher ε_{ROI} with lower DRF
- Average fake rate (number of fake tracks per event) is ~100 => reduce number of fakes per event to get higher DRF which then allows larger ROI (also ideas for that)

Tracking - Results



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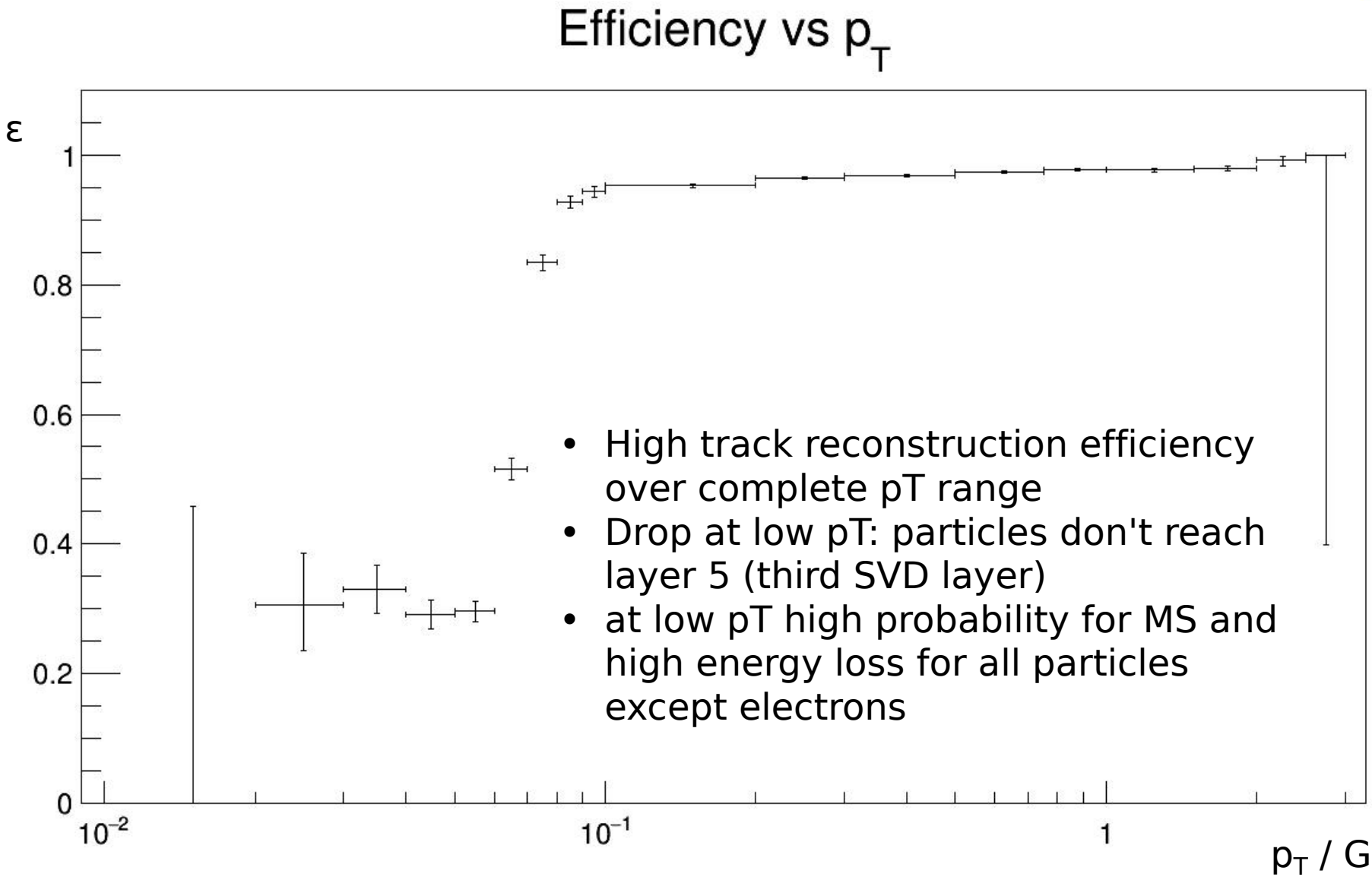

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