Track Segment Analysis update

L. Weuste
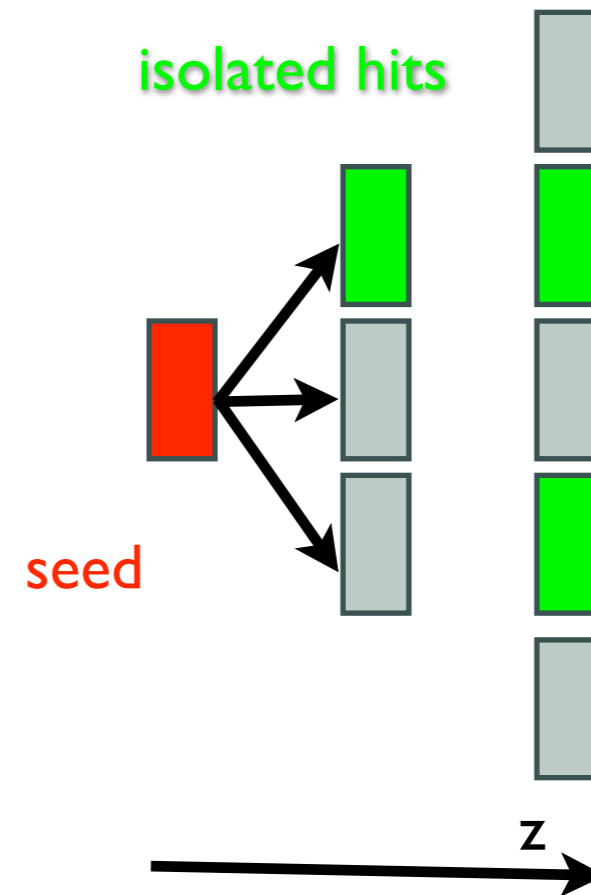**Max Planck Institut für Physik**
Excellence Cluster „Universe"
München

CALICE Collaboration Meeting
Shinshu University - March 2012

Calorimeter for ILC

Excellence Cluster | Universe

Tracking in the AHCal

- Already presented in CAN-022
  - Nearest Neighbour algorithm
  - Needs 1 hit per layer
  - Based on layer isolated hits,
    i.e. hits with no adjacent hits in the same layer
- Plan: Publication (JINST?)
- Rewrite of code
  - No fundamental changes
  - Usage of official geometry classes
  - Made algorithm more general
    - Completely recursive implementation
    - With simplification: No need for special treatment of certain geometric cases
    - Improving identification of inclined tracks with gaps

isolated hits

seed

z

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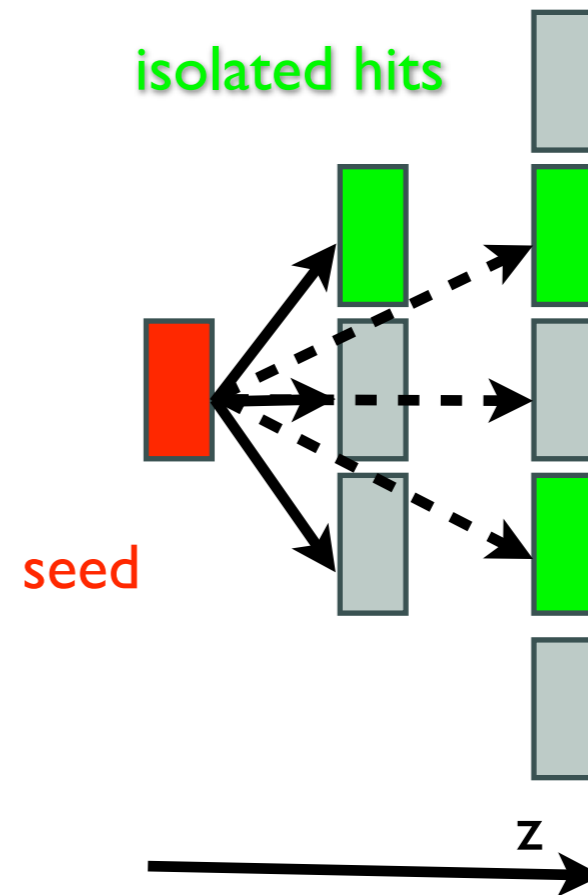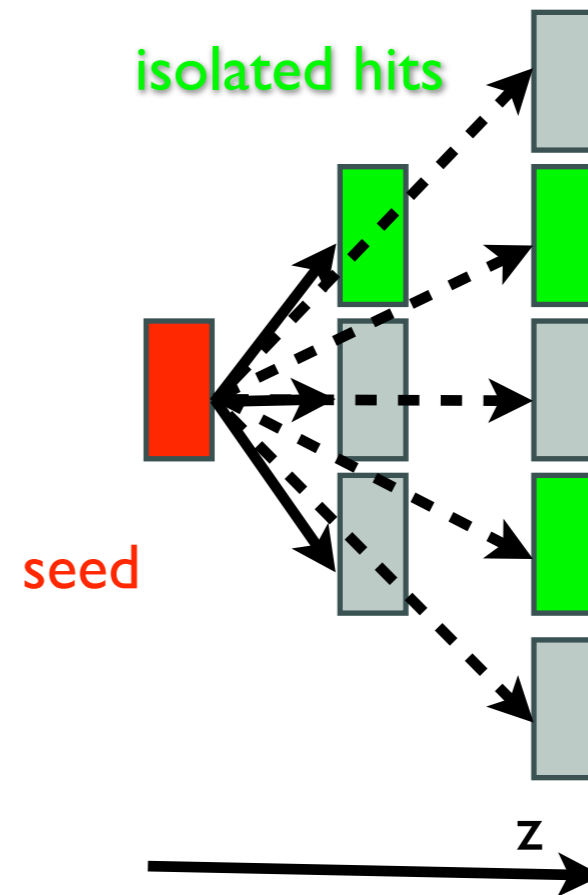
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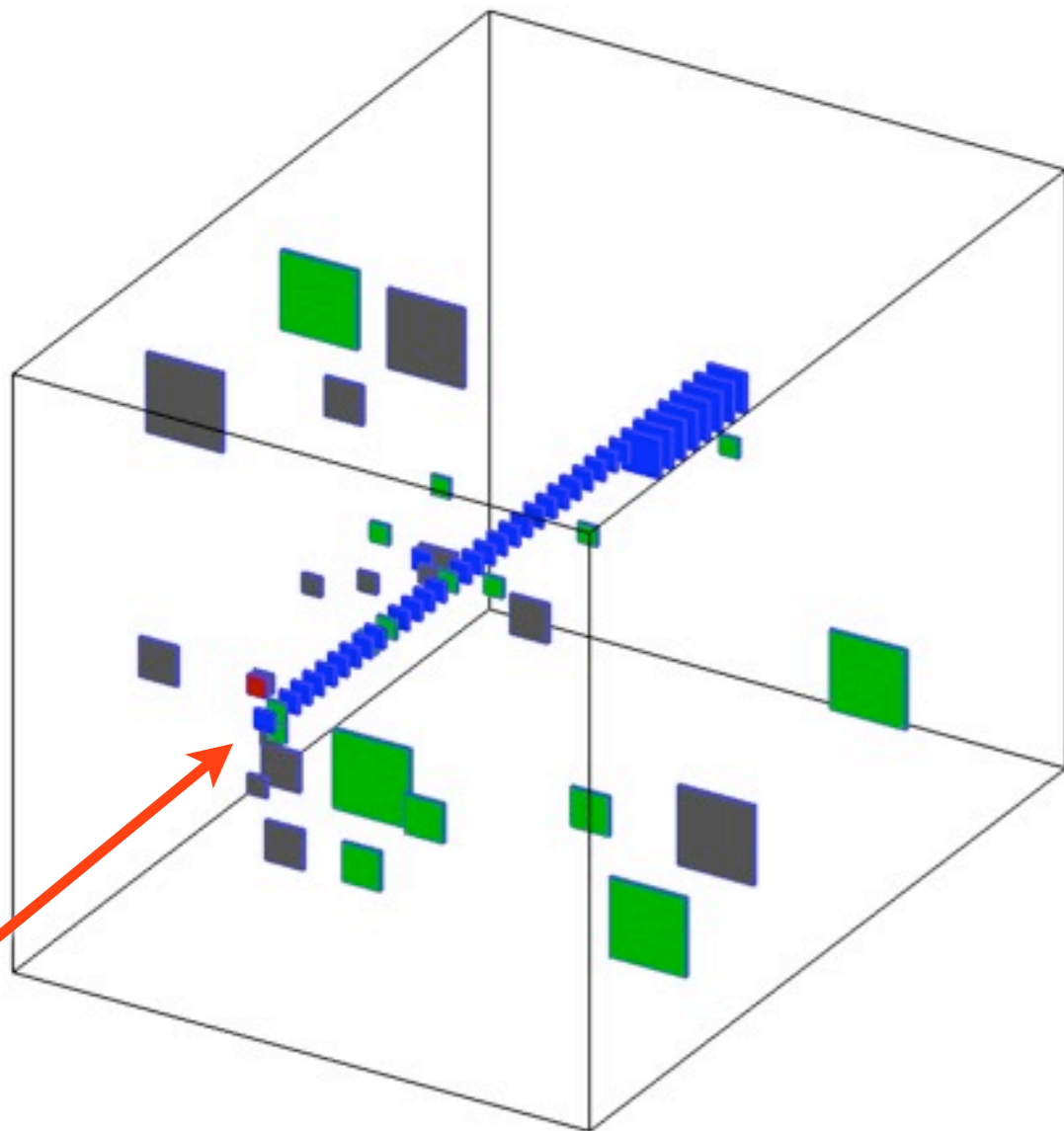
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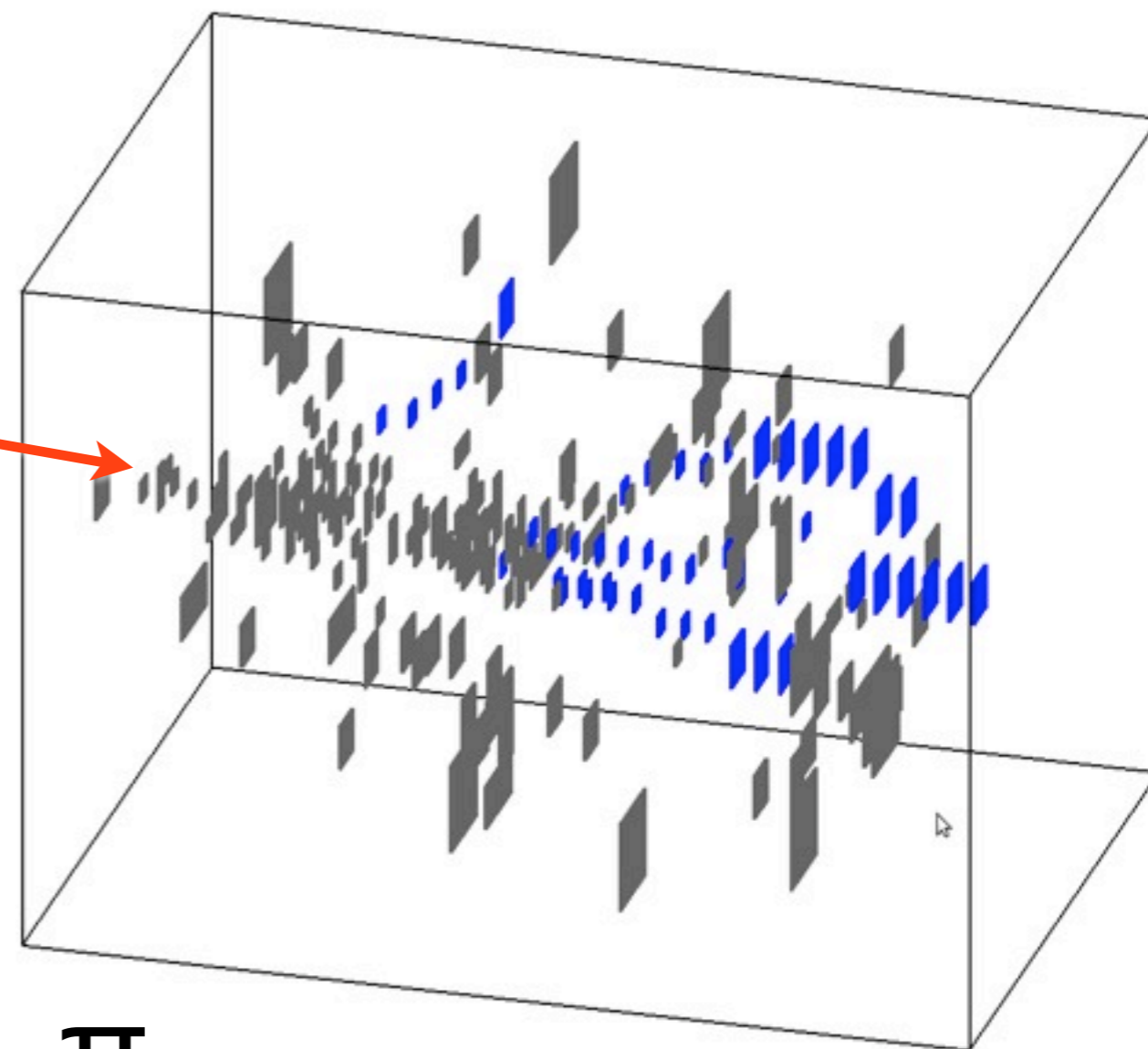
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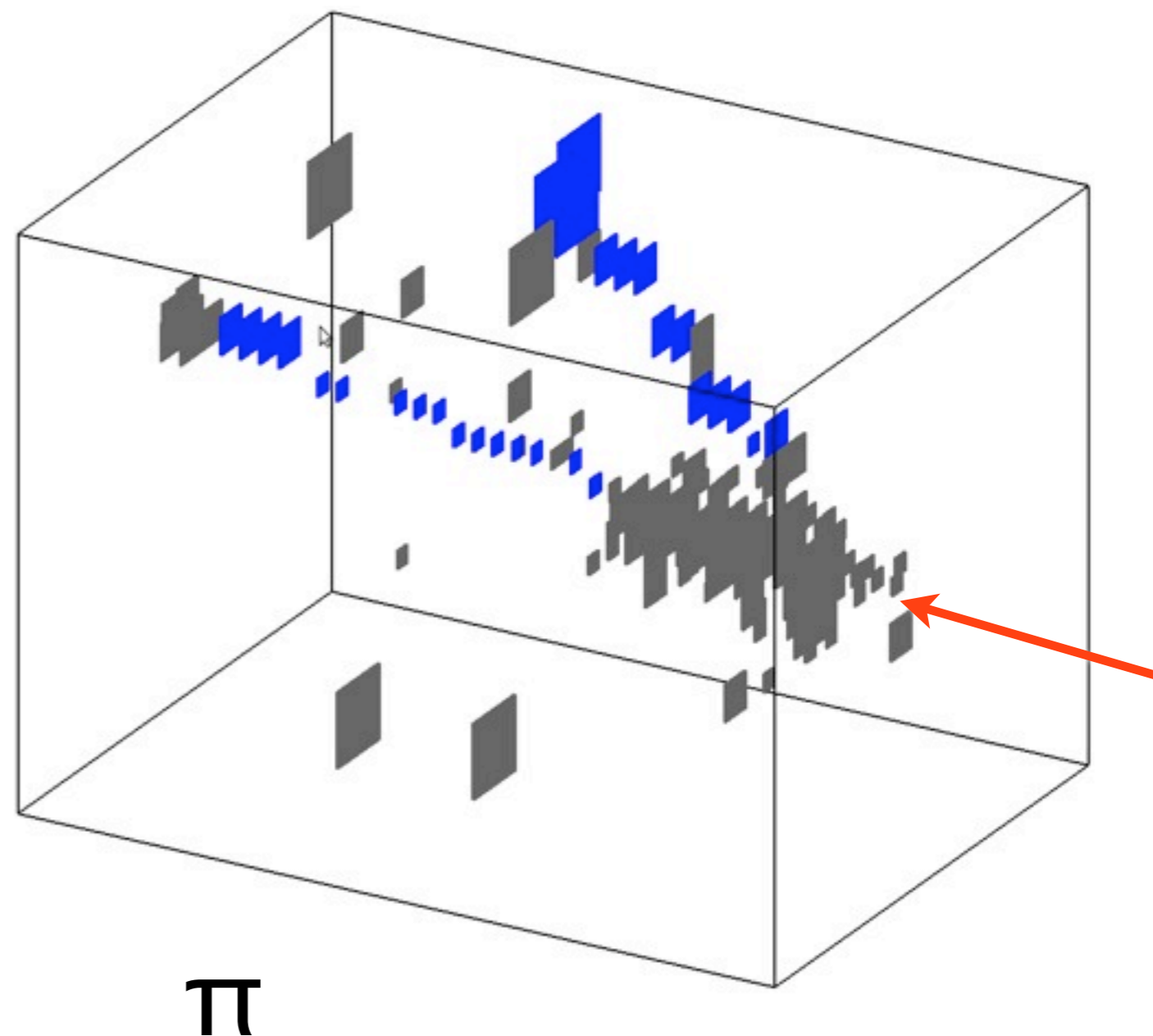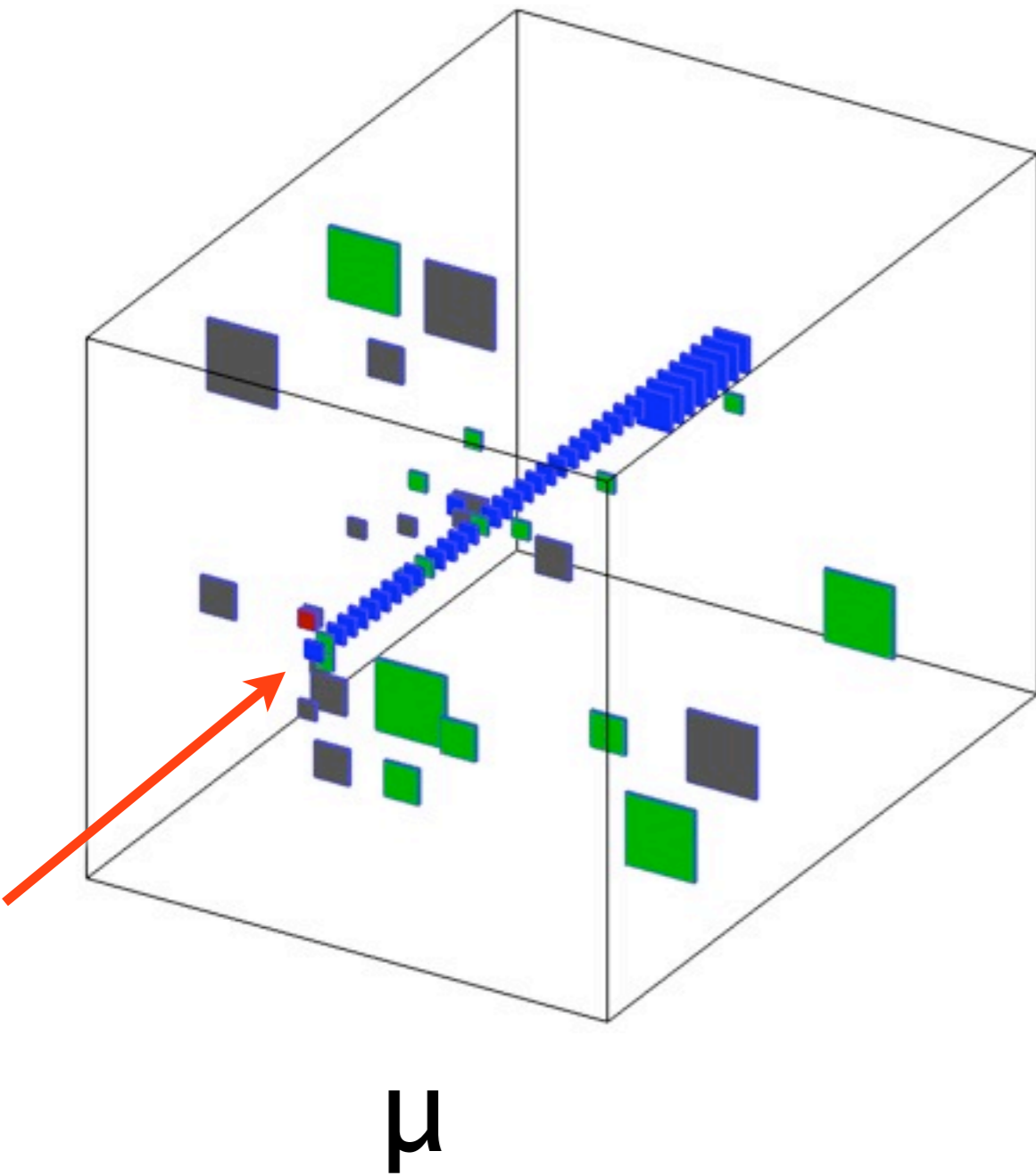
Example events

μ
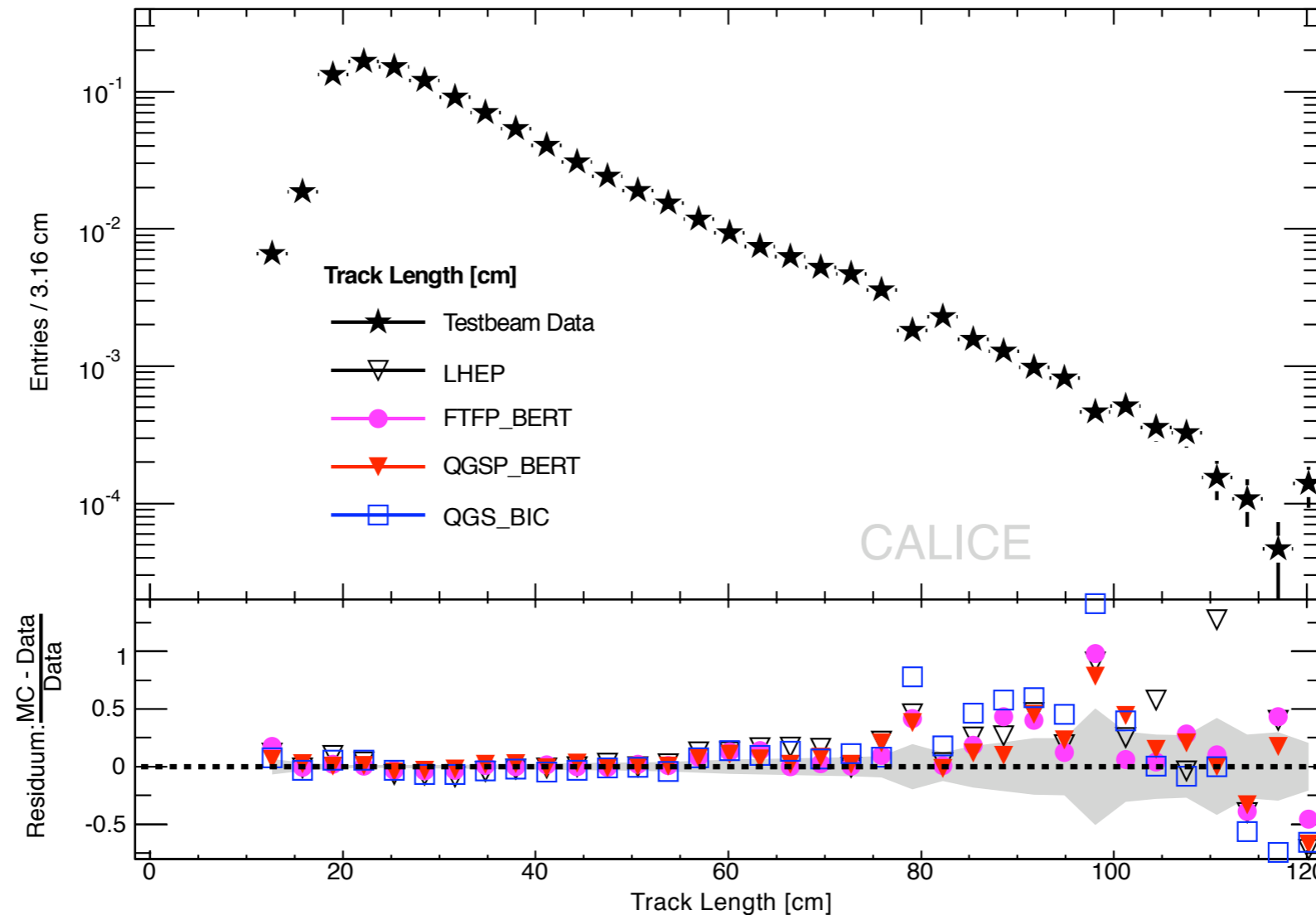
π

Example events

μ

π

Example usage: track length
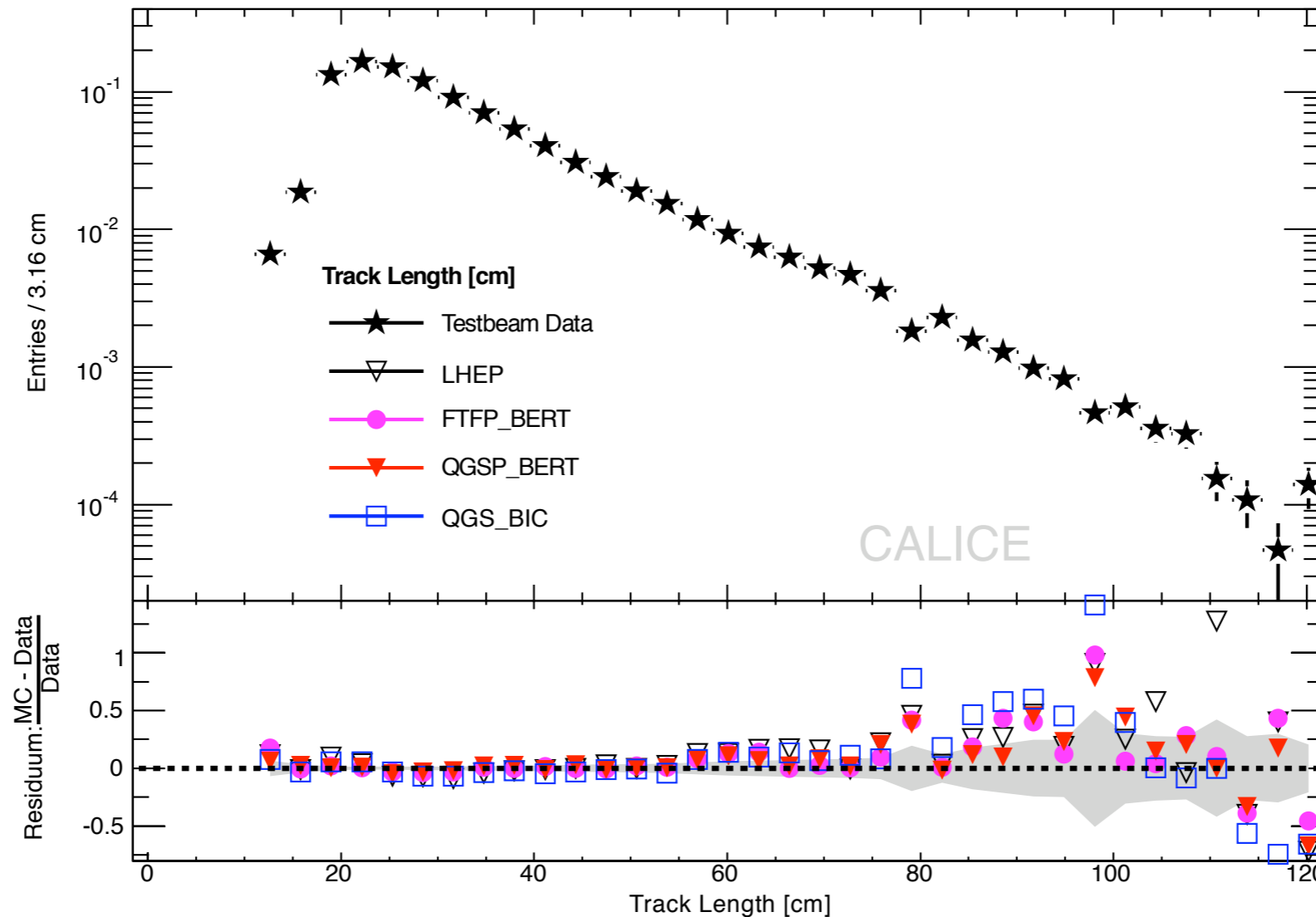
$$l(x) = l_0 \cdot \exp(-\frac{x}{\lambda_{\text{track}}})$$

Example usage: track length

Track length l

$\lambda_{track} \equiv$ slope of exponential fit („typical track length")

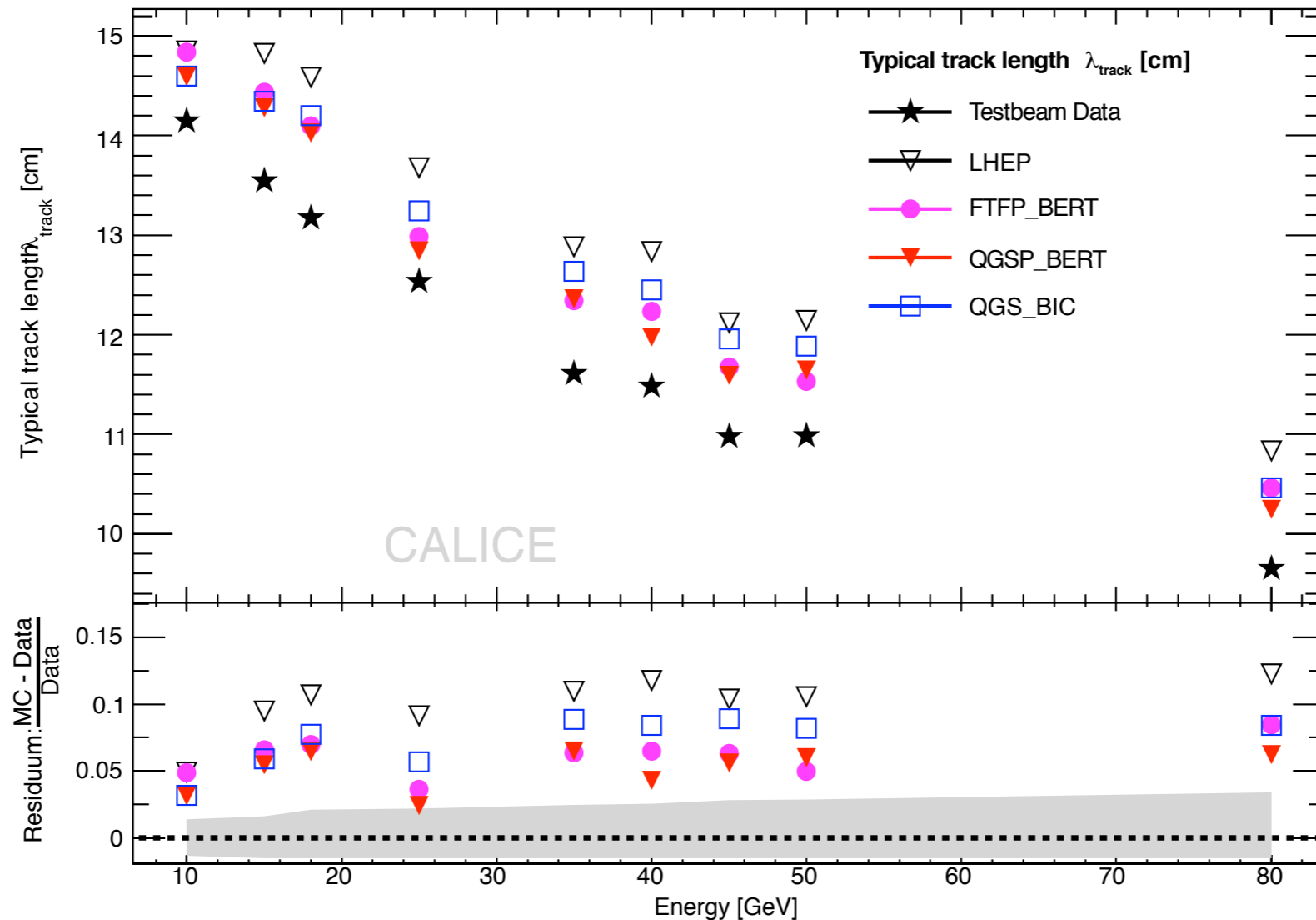$$l(x) = l_0 \cdot \exp(-\frac{x}{\lambda_{\text{track}}})$$

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Efficiency of track finder $\neq 100\% \Longrightarrow \lambda_{\text{track}} \neq \lambda$

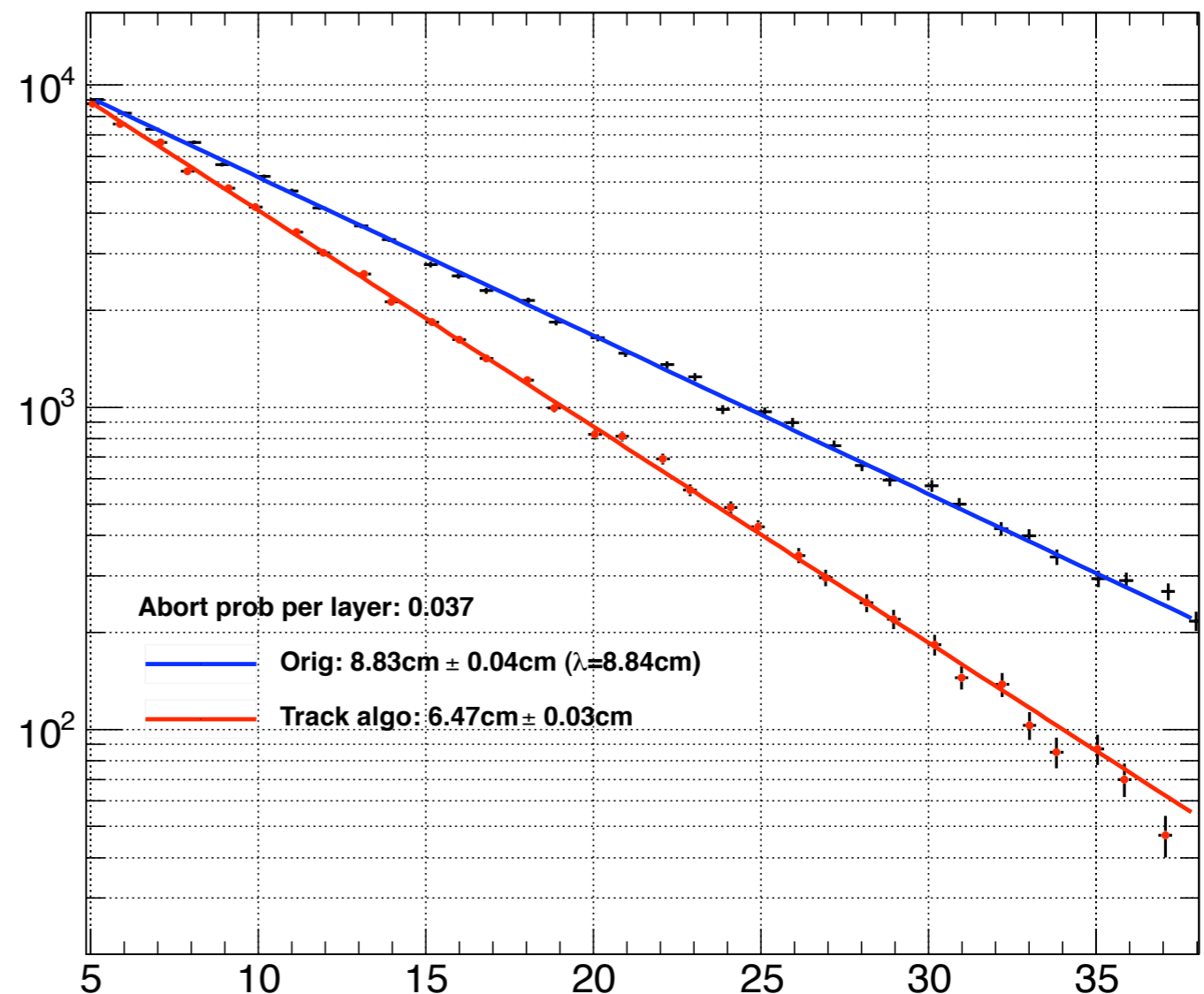- Toy MC to show effect

  - Simulate150k events

    - 38 layers

    - λ = 8.84cm

  - For each layer: assume certain probability to stop tracking

    - blue: true track length

    - red: track length as identified

Abort prob per layer: 0.037

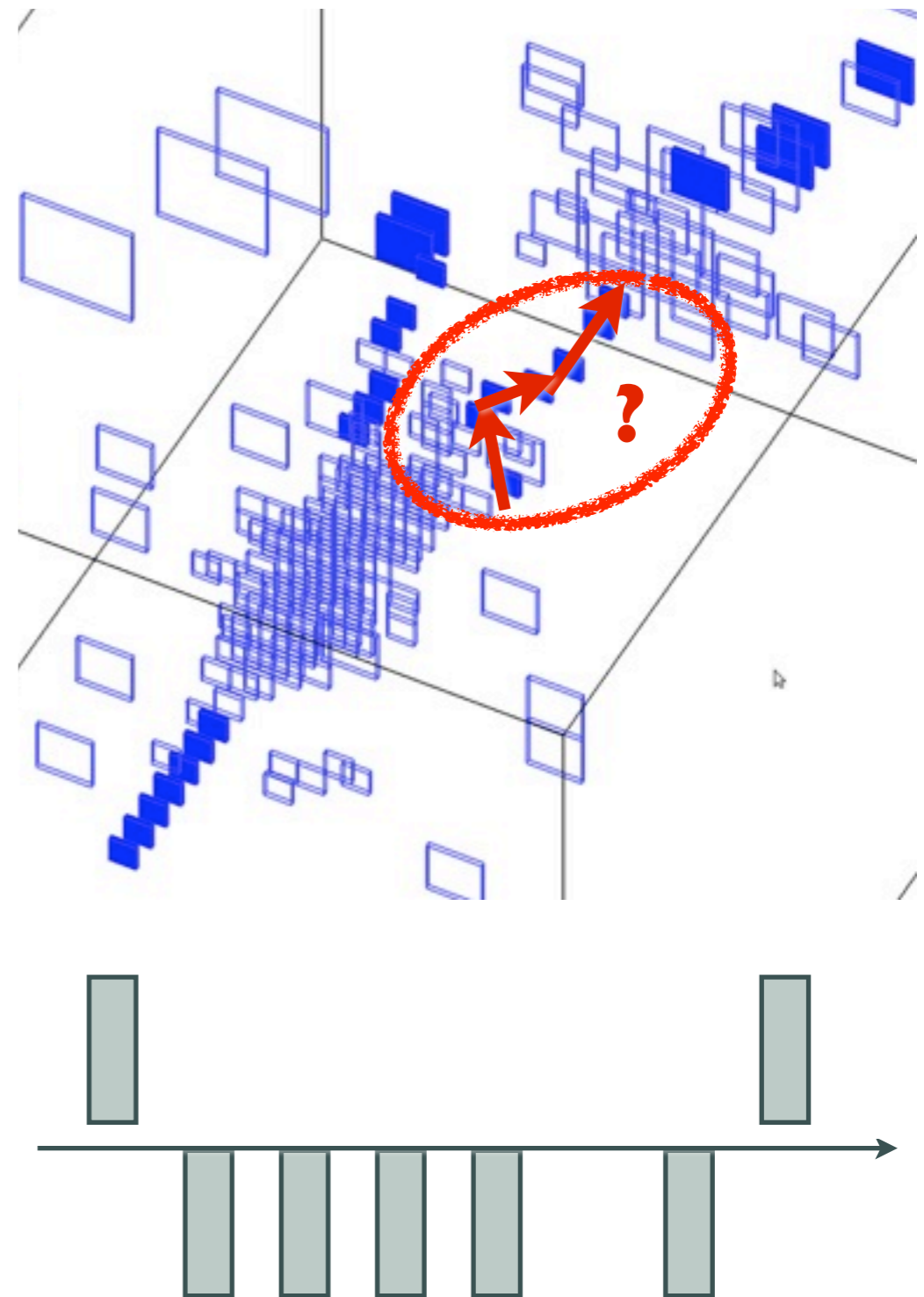Orig: 8.83cm ± 0.04cm (λ=8.84cm)

Track algo: 6.47cm± 0.03cm

Track finding: Imperfections

- Nearest Neigbour Algorithm

  - No usage of physical flight trajectory

  - Noise hits influence track direction

- No/Small influence on MC <=> Data comparison

- Possible solutions:

  - Track Fitting

    - not easy (e.g.: tile size is not „error")

    - cannot fix all track errors

  - Hough Transform based filtering
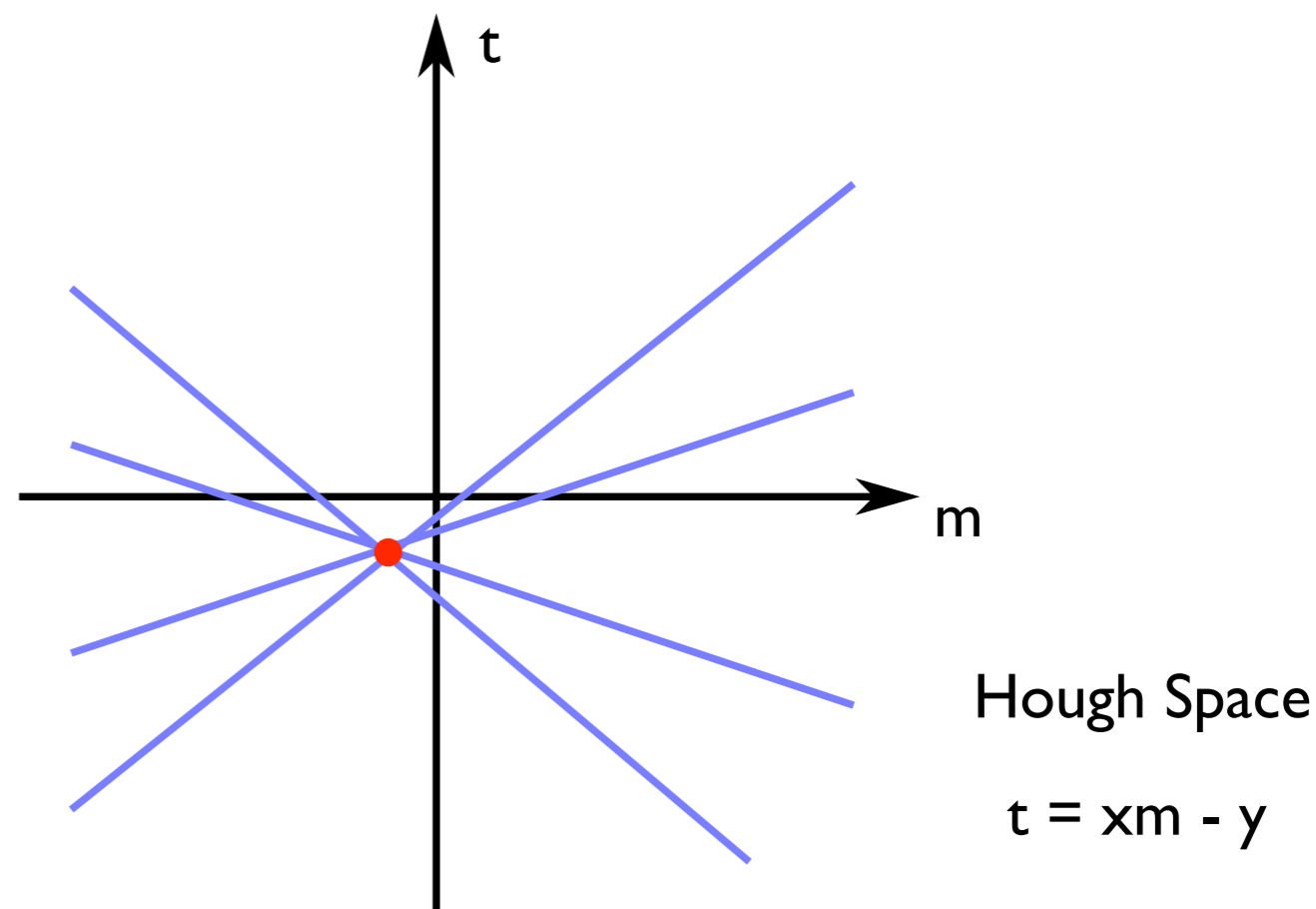
    - Using Fast Hough Trafo with variable binsize

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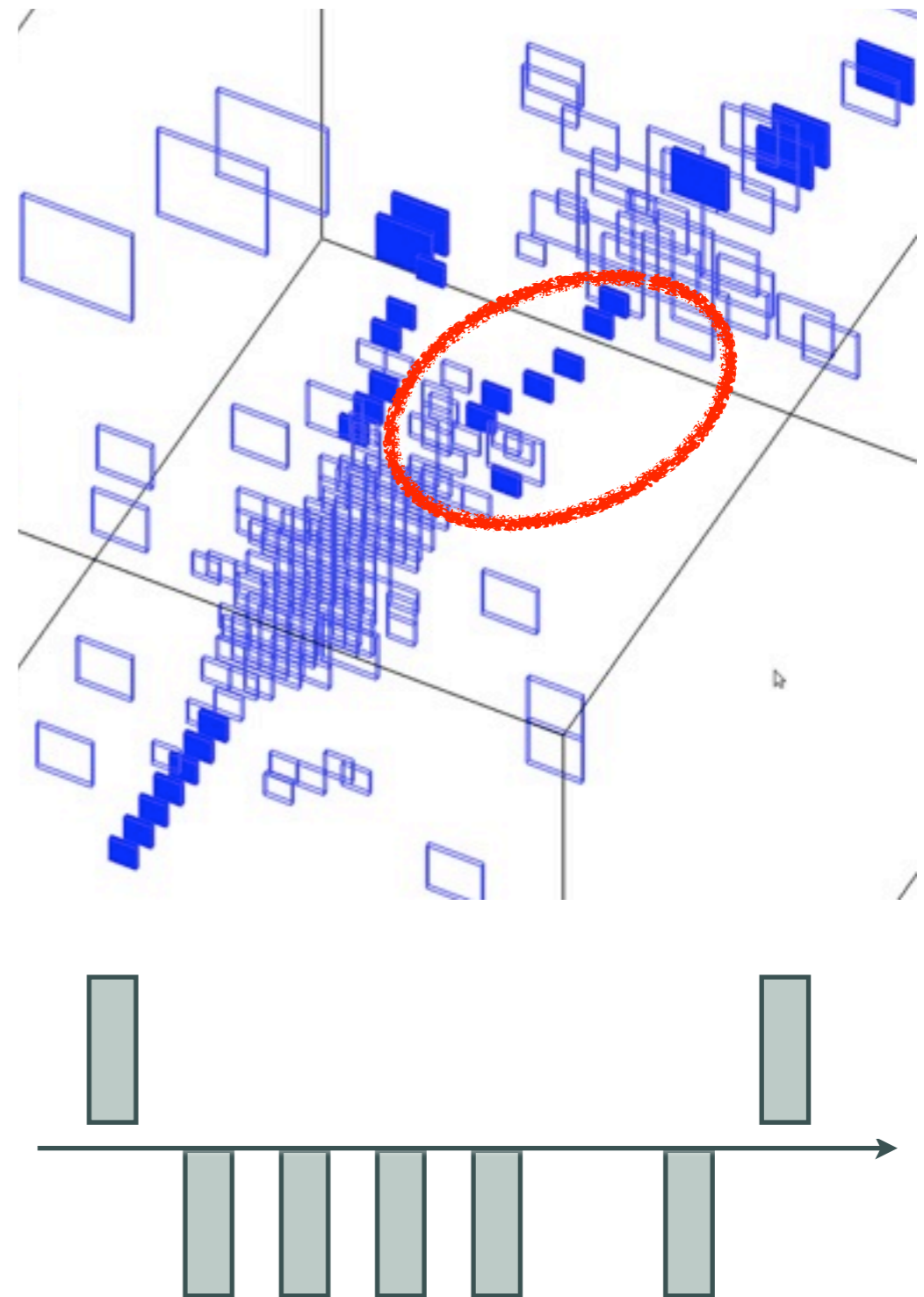
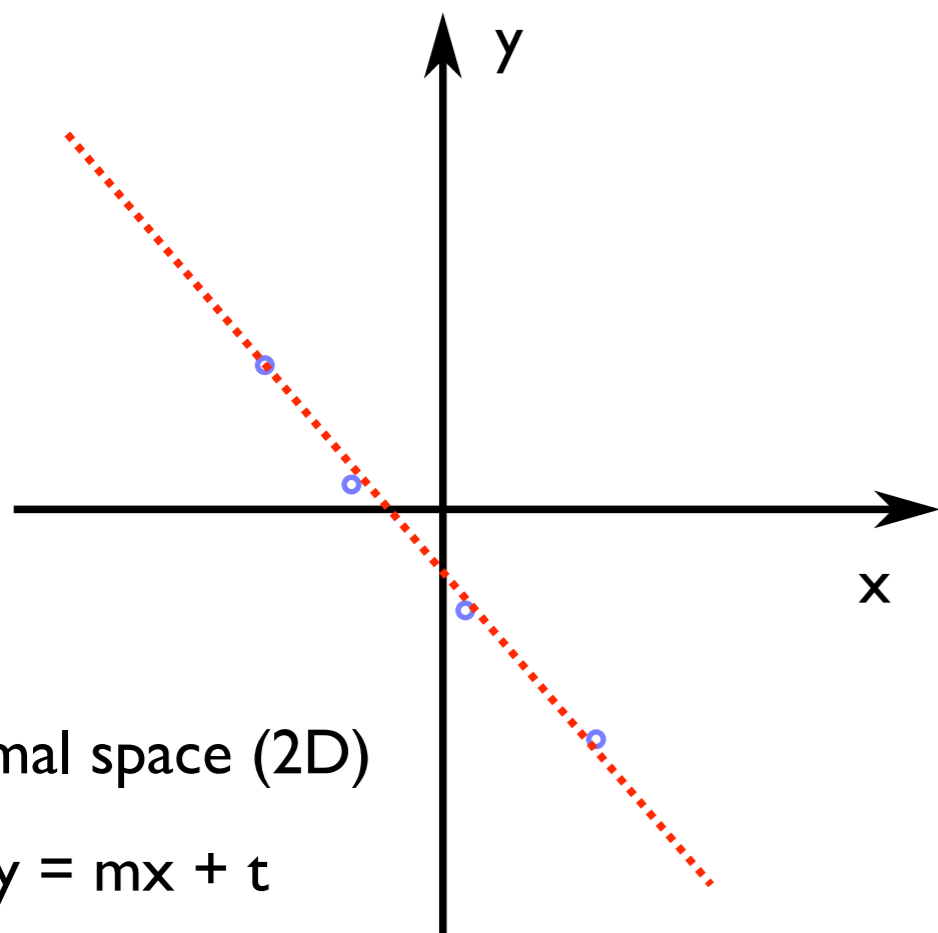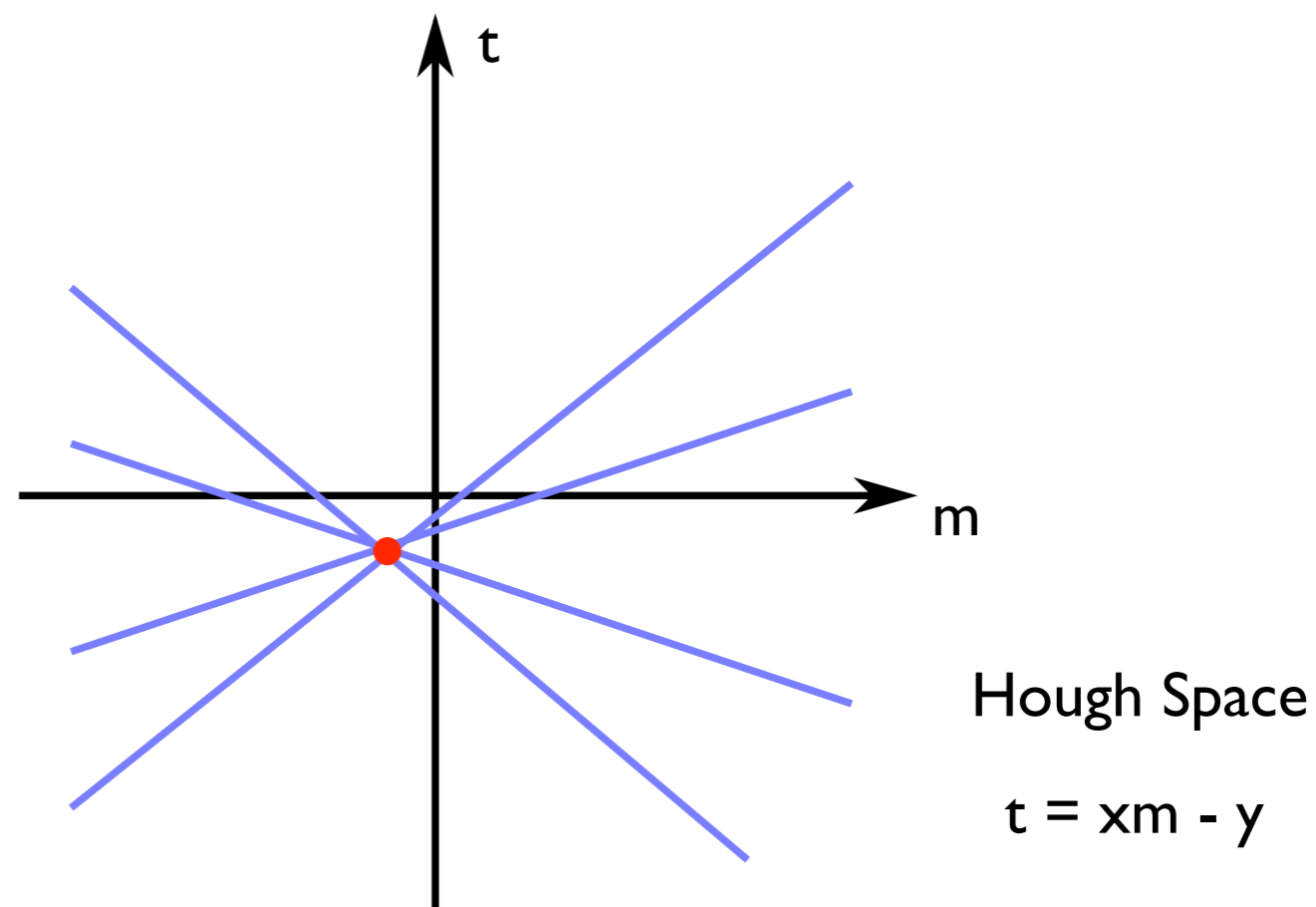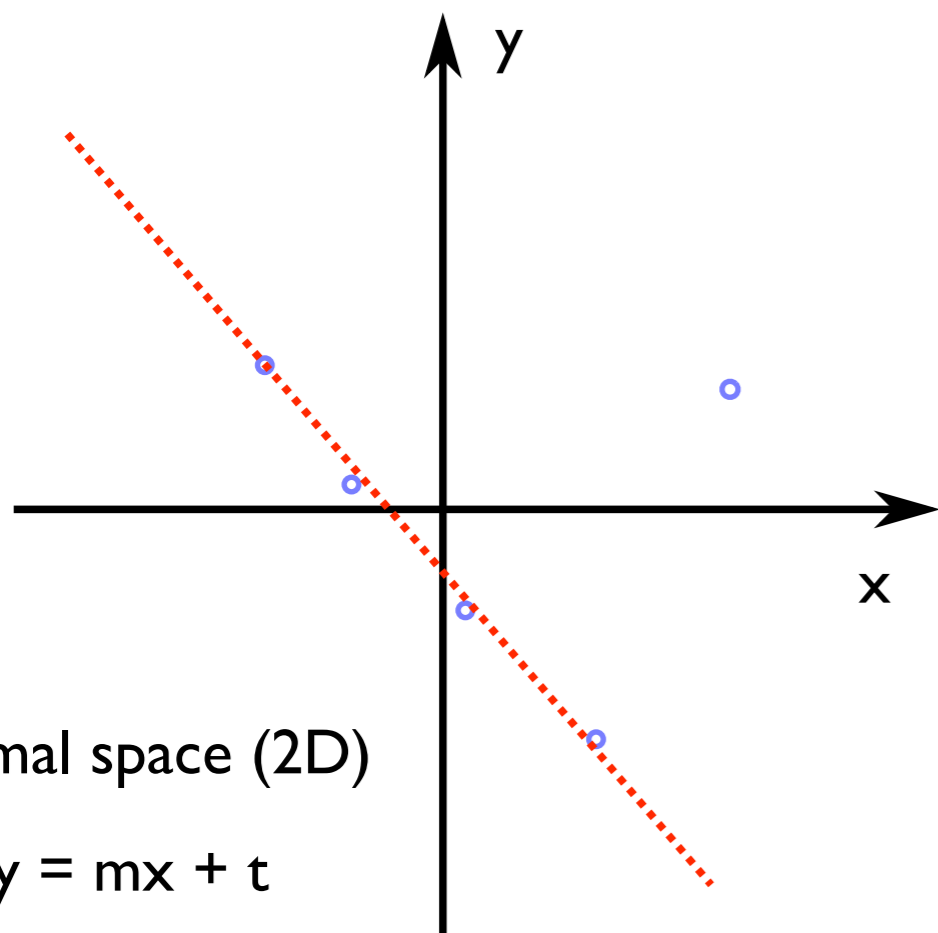 - Using Fast Hough Trafo with variable binsize

Hough transformation: Variable binsize

normal space (2D)

$$y = mx + t$$

Hough Space

$$t = xm - y$$

- Standard procedure
- Here: Use in 2D (x/z and y/z)
- Hough Space needs to be binned
  - RAM/CPU Usage
  - Binsize?

- Variable binsize
  - Calculate all intersections @ Hough Space
  - Take points in between two intersections as bin borders
  - Divide each bin further by 3

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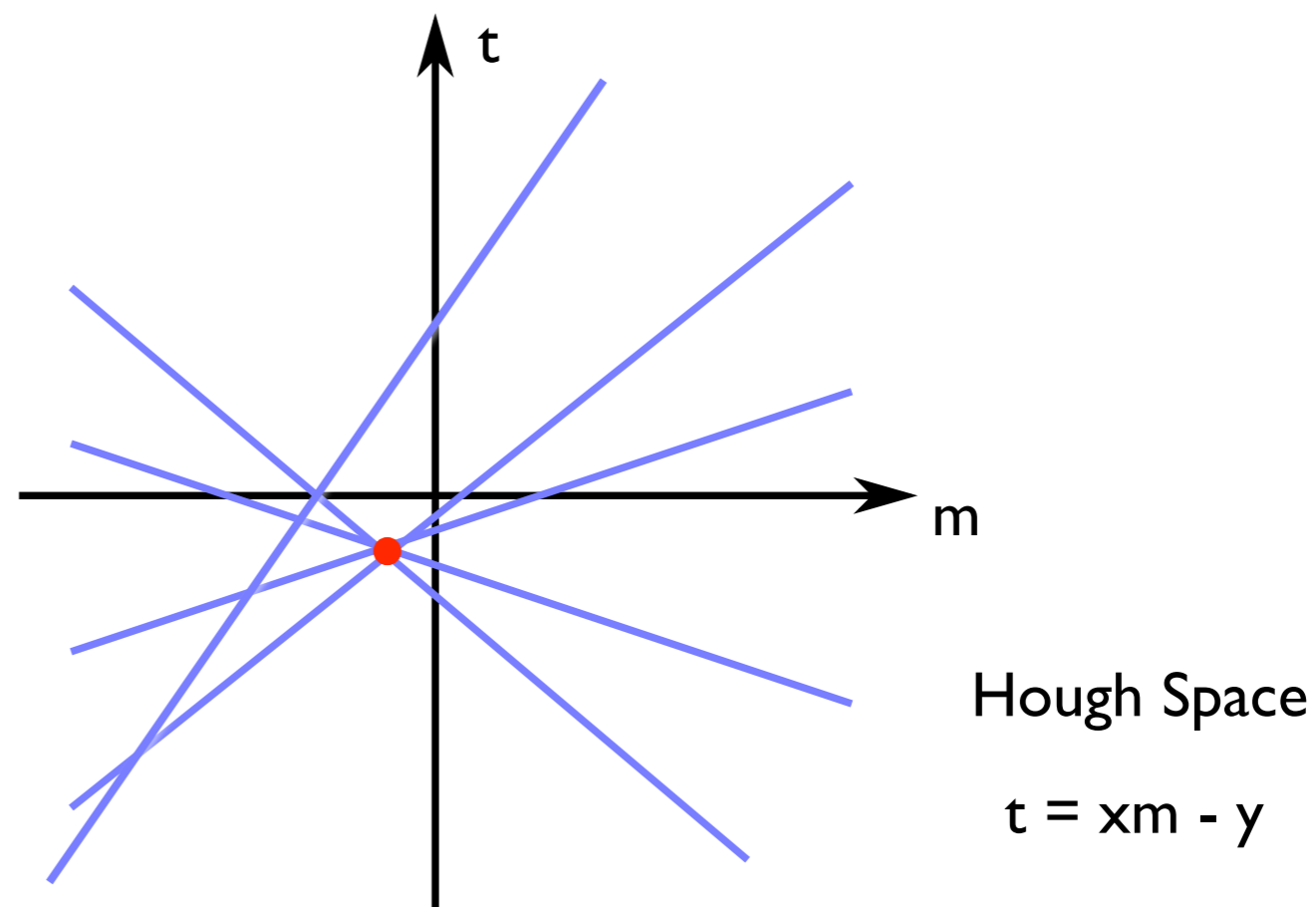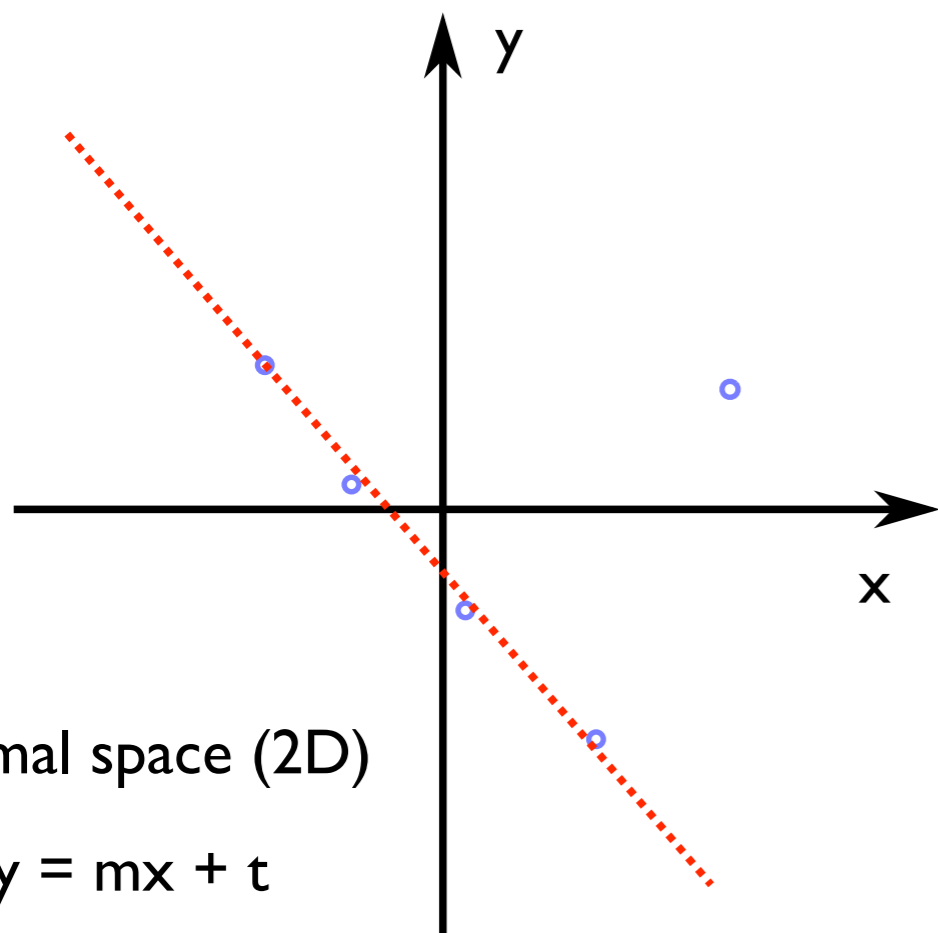 - Divide each bin further by 3

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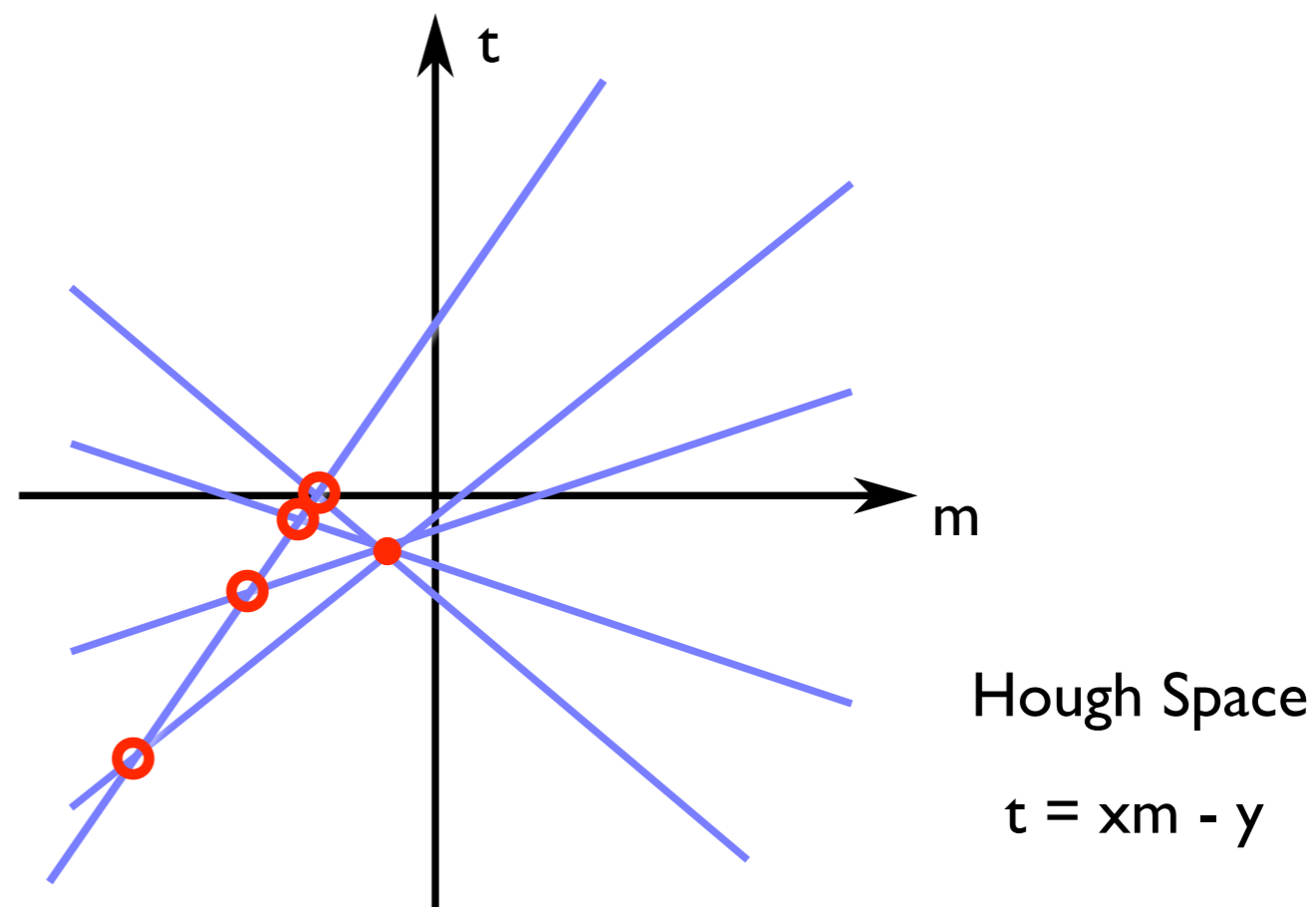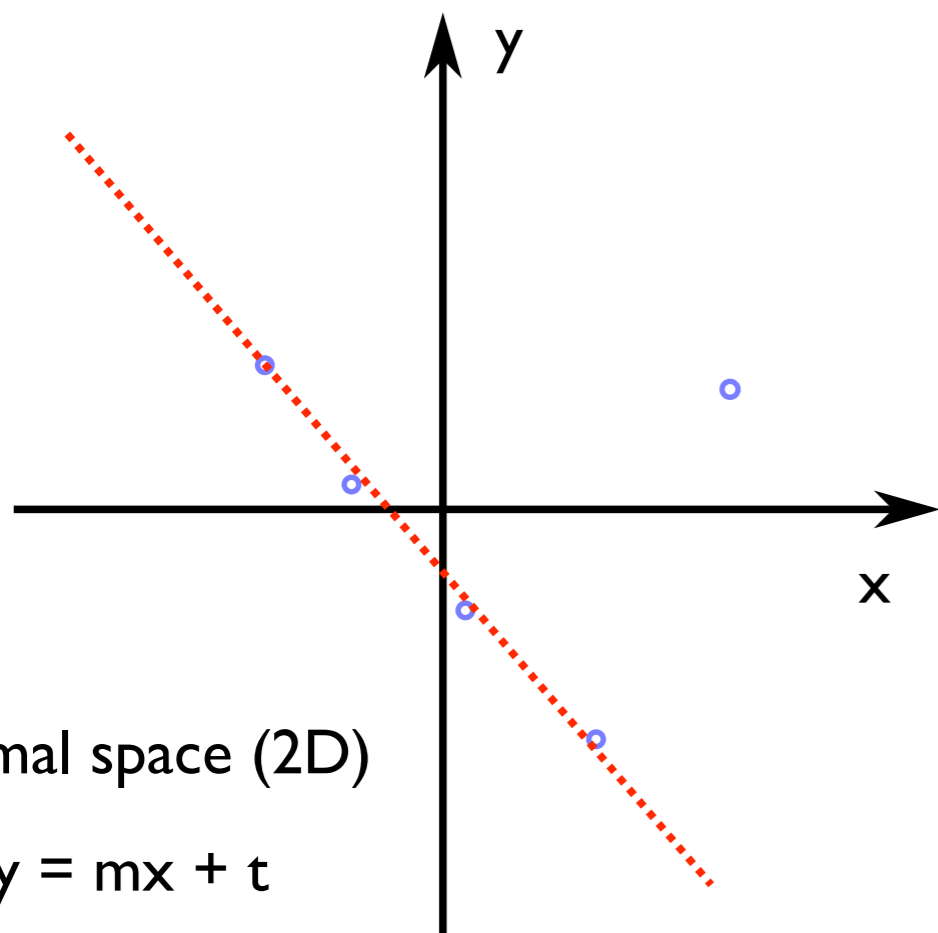 - Divide each bin further by 3

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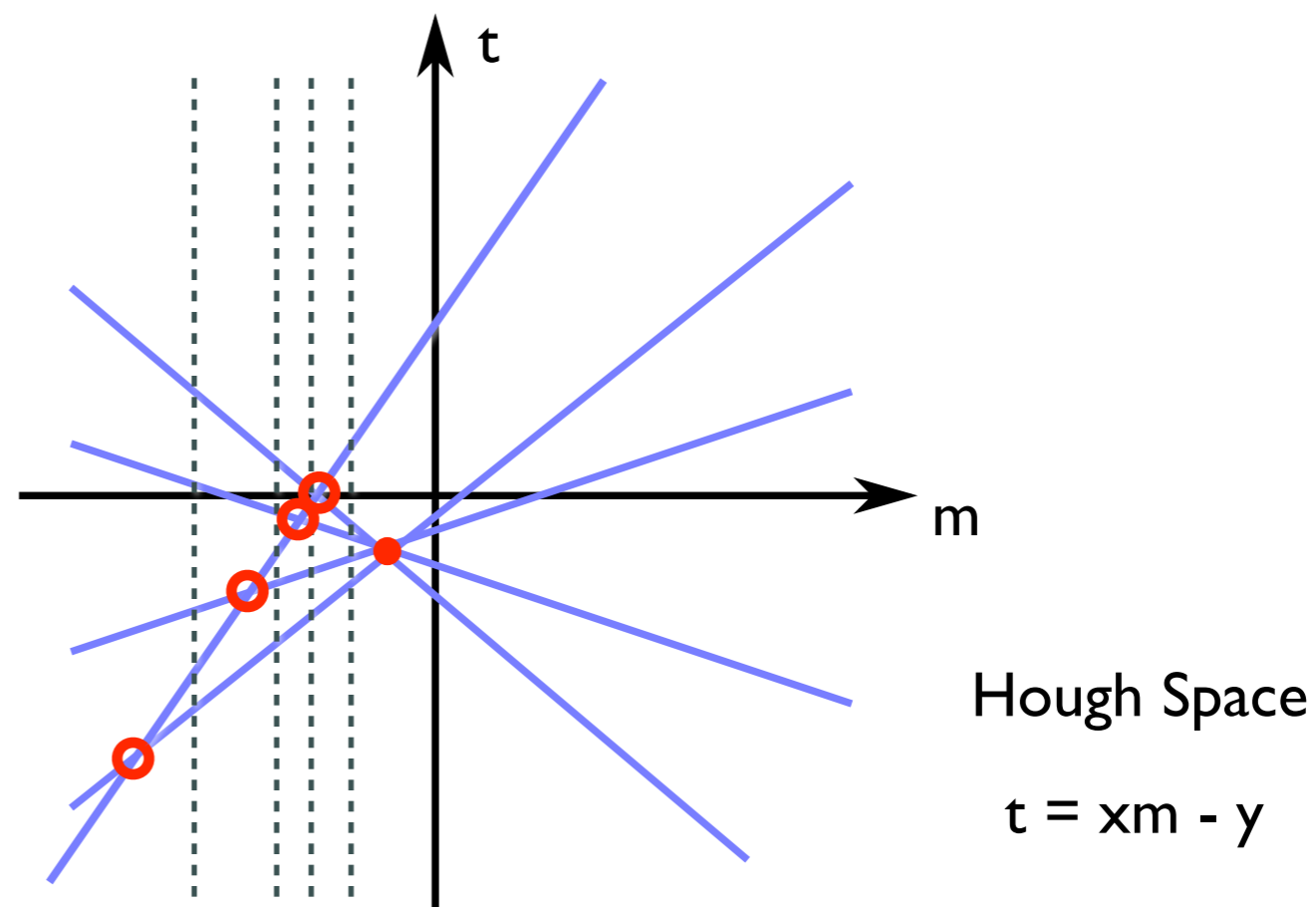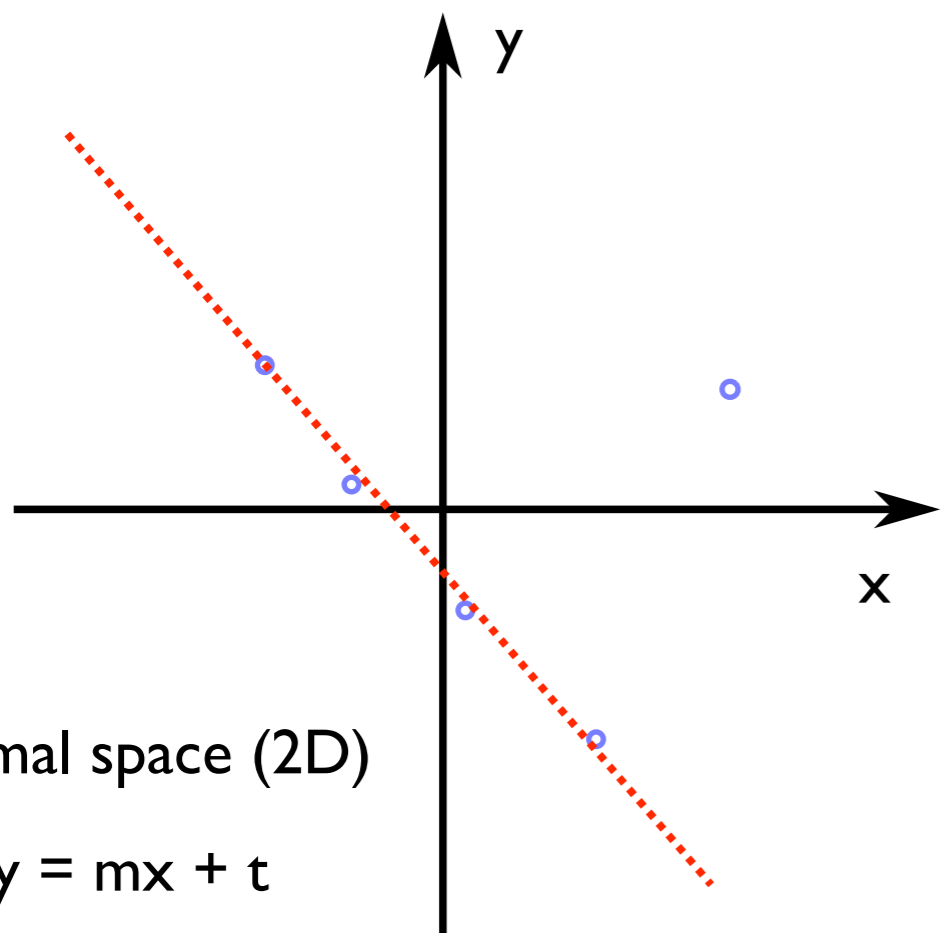
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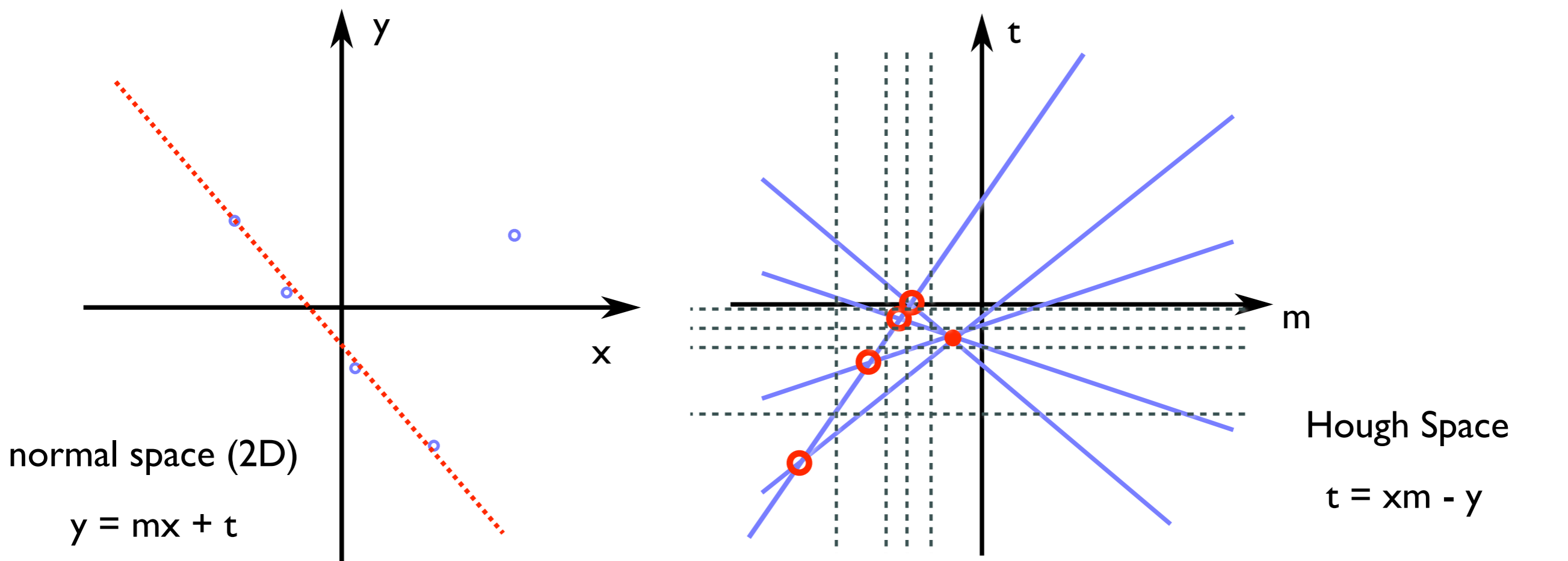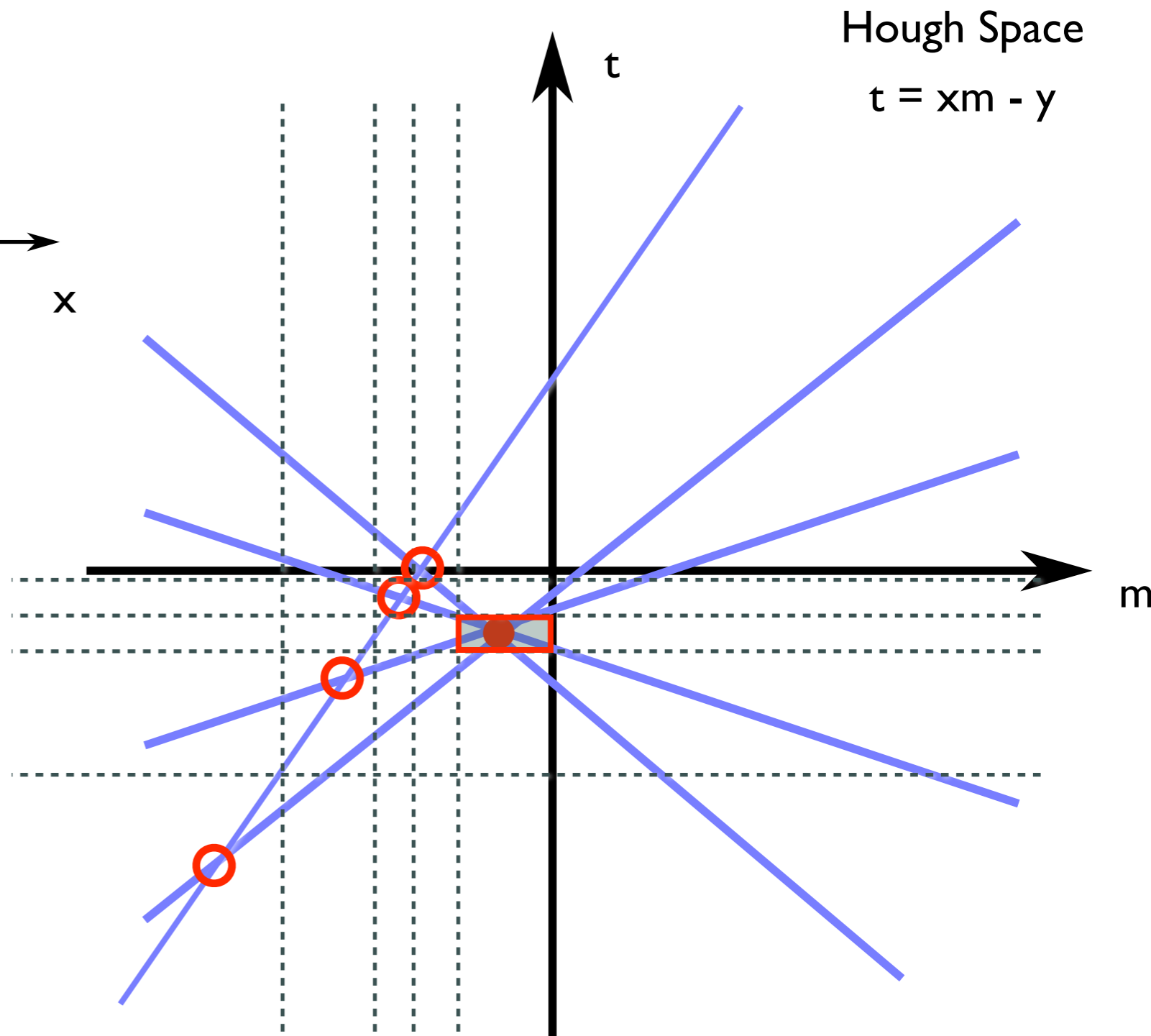 - Divide each bin further by 3

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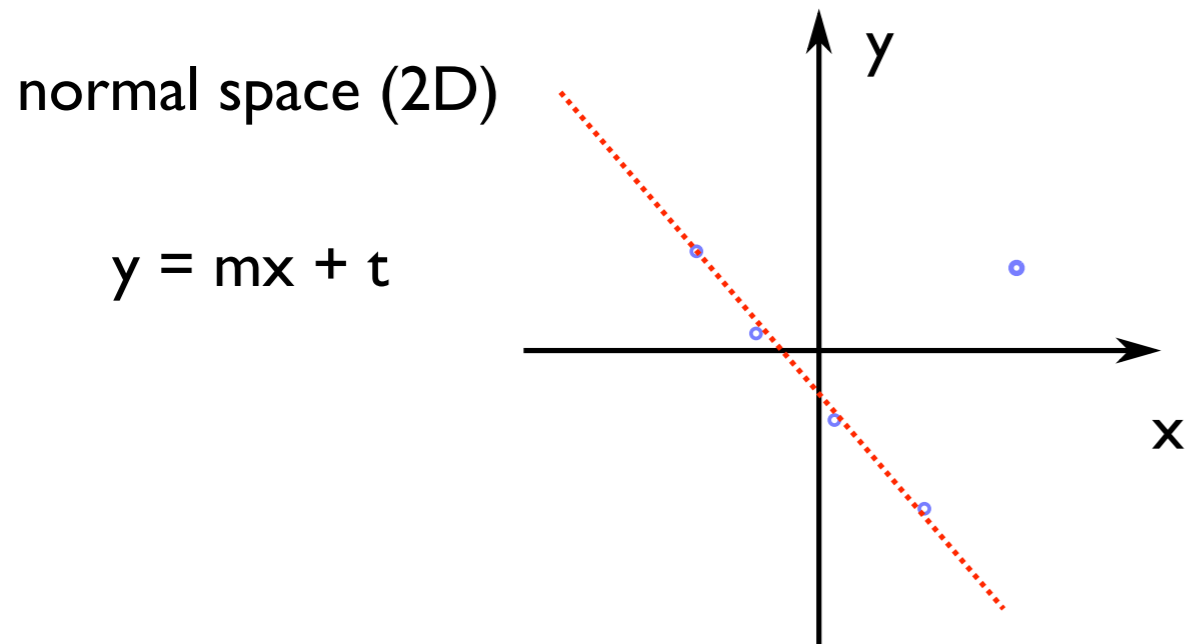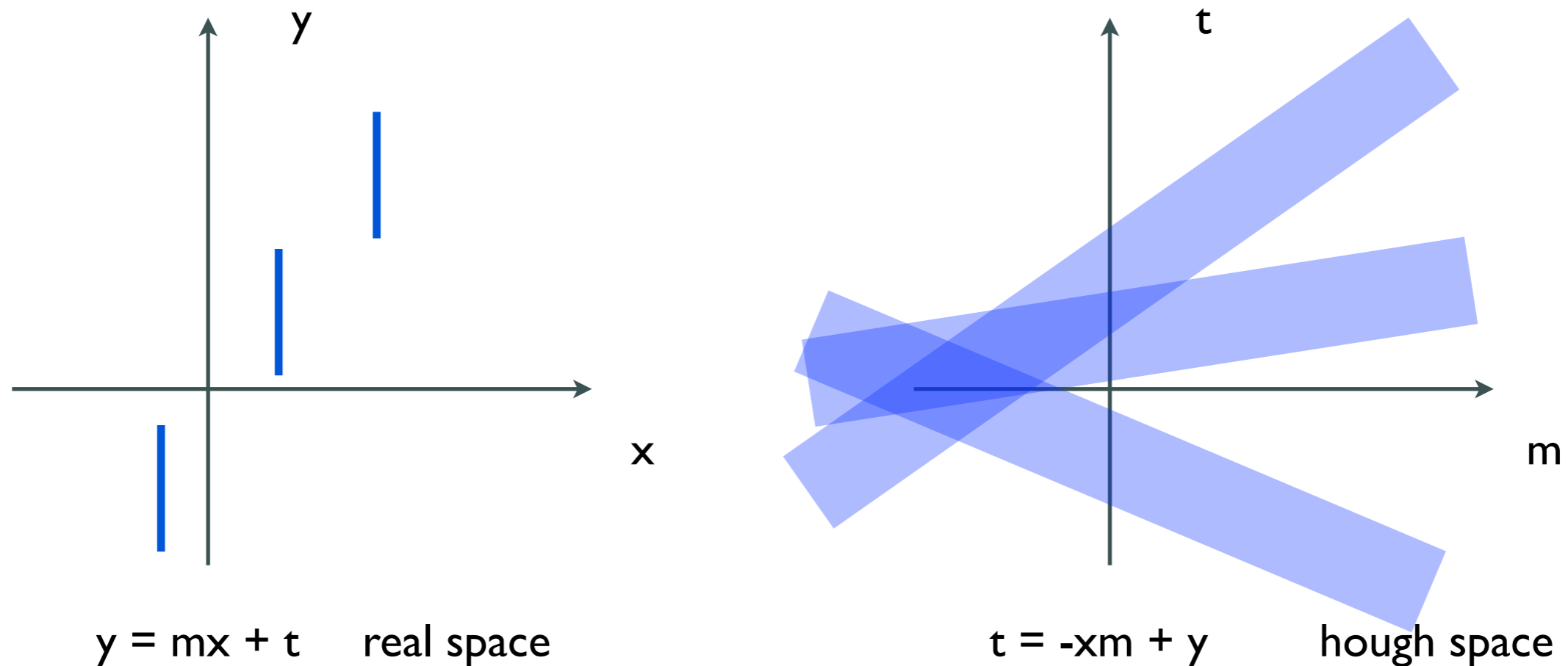 - Divide each bin further by 3

Hough transformation: Filtering

normal space (2D)

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Hough Space

$t = xm - y$

- Search through the Hough Space (w/ „Divide & Conquer")
- Identify that bin with most entries
  - All lines (hits in real space) not part of this bin ≡ noise
- HCal: cell size ≠ point like
  - use bands instead of lines in Hough Space

y = mx + t   real space

t = -xm + y   hough space

— Hit: cell size 3x3x0.5 cm^3

   — Band in hough space (neglecting thickness of 0.5cm)

— Intersection „point" (area) difficult to calculate analytically ==> binned hough space

Hough Transformation: Filter results

Track energy deposition per hit
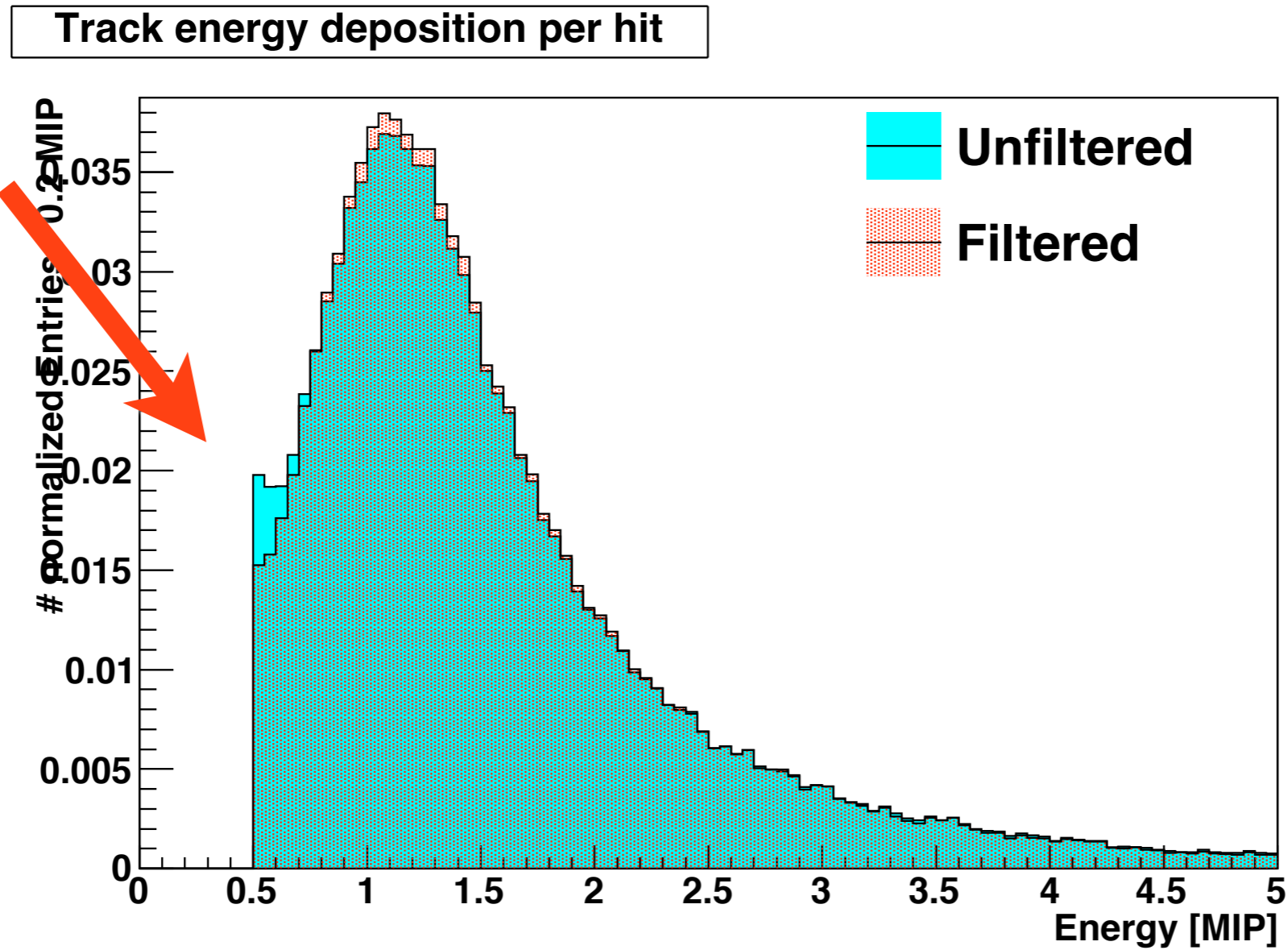
- Filterung reduces noise hits (which are main reason for unphysical tracks)

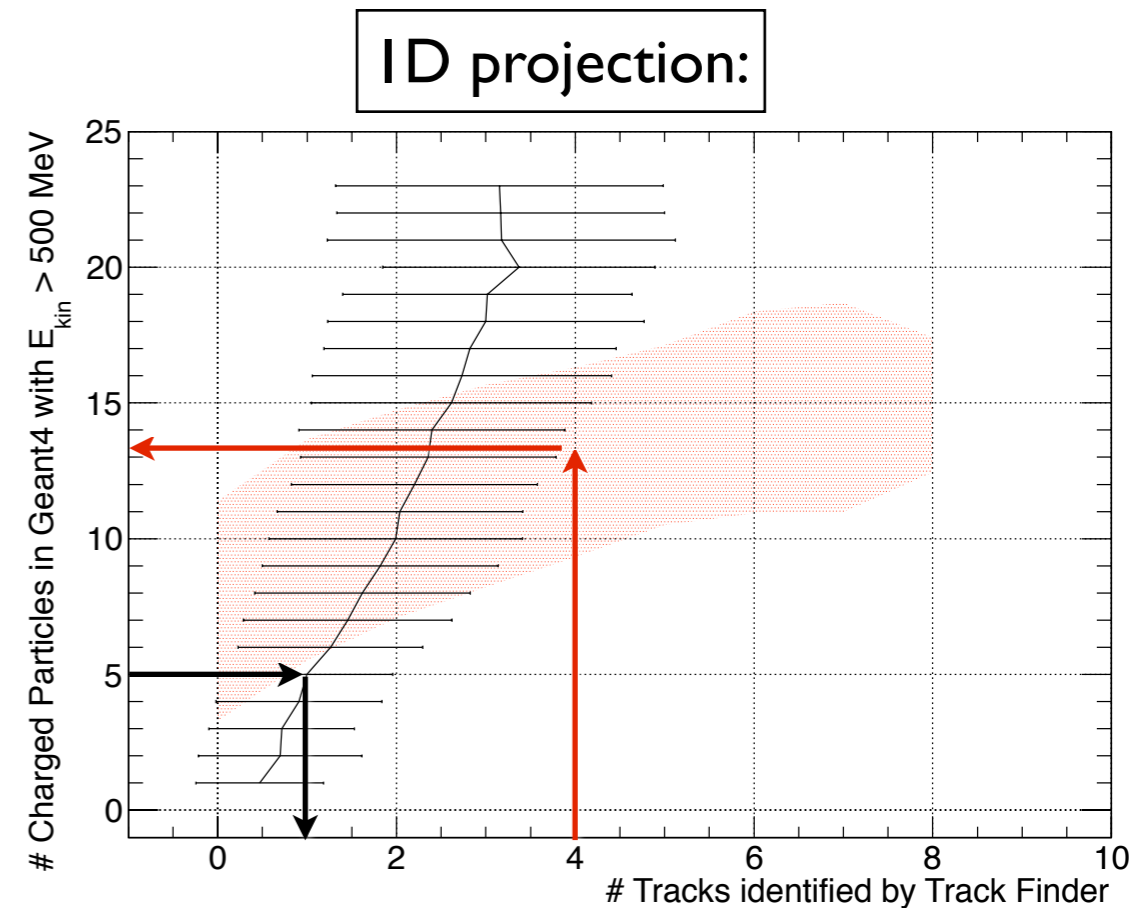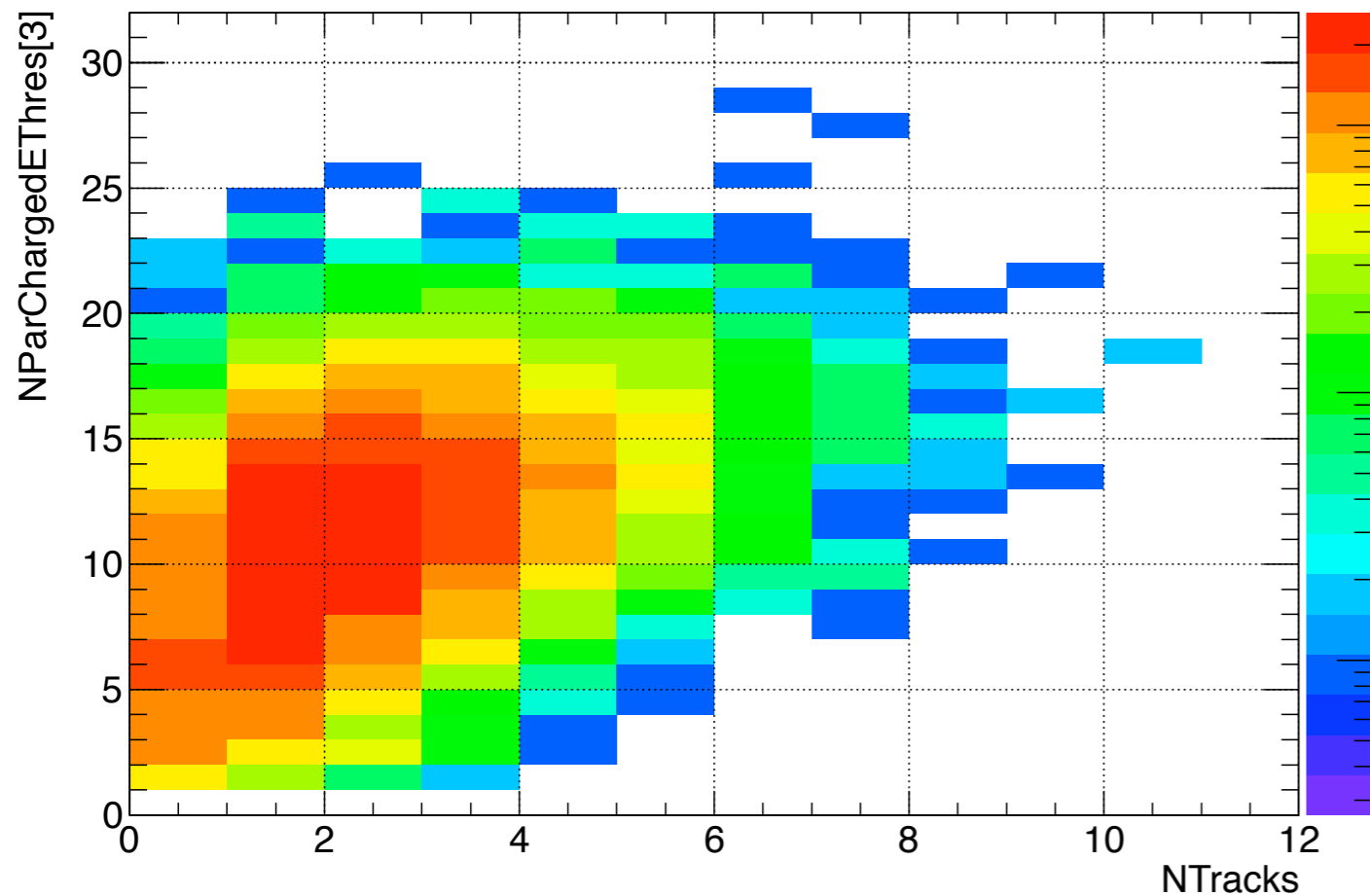- Here: Barely visible (low noise runs)

Track Multiplicity

- Track multiplicity <=> # Particles in hadronic shower: Correlation?

  - Mokka Hack: Convert each particle in StackingAction into MCParticle

- Here: # Tracks VS # Charged Particles with $E_{kin} > 500MeV$ (w/o $e^{\pm}$)

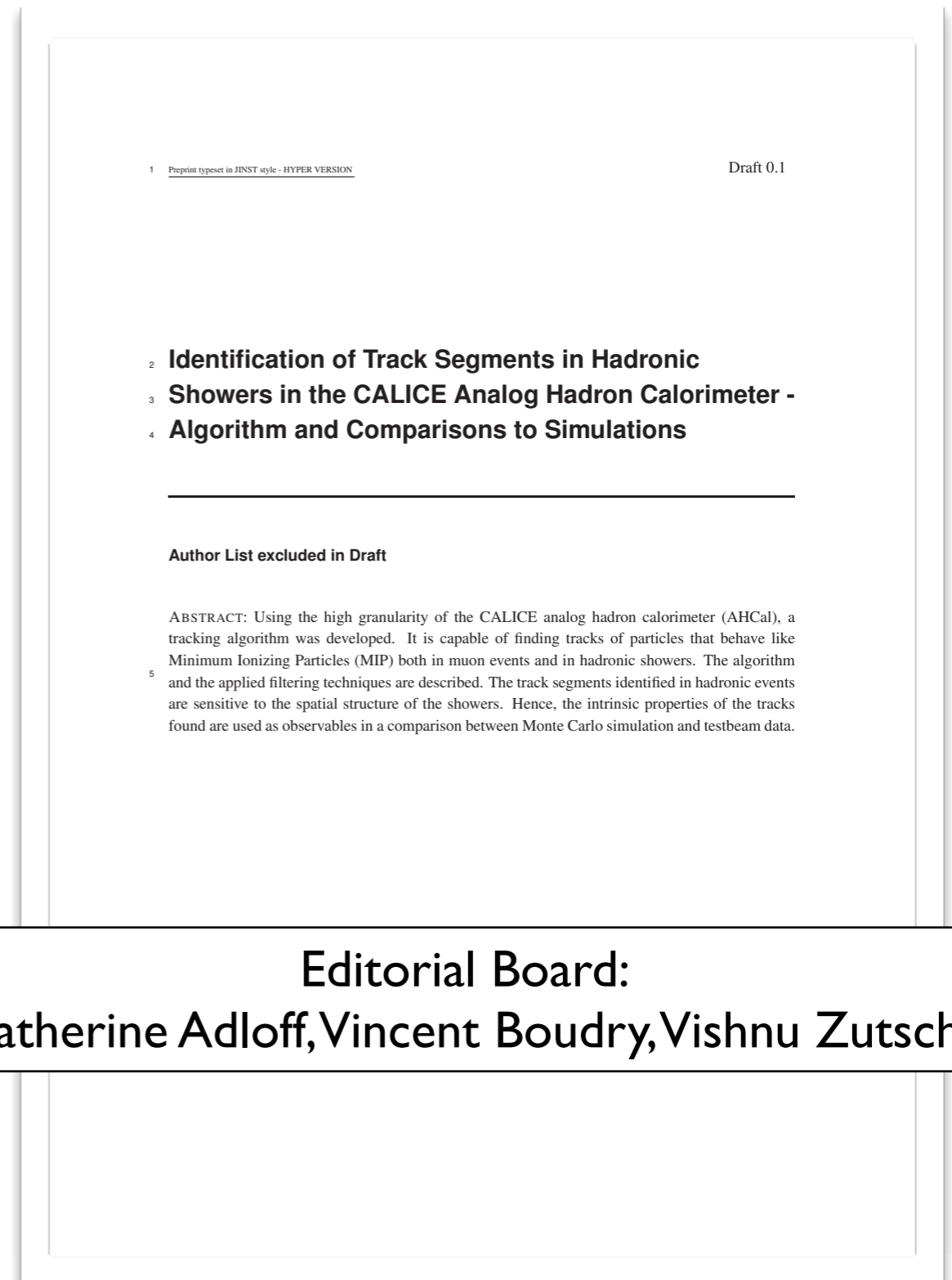 - Correlation: ~0.4 for QGSP_BERT and FTFP_BERT (LHEP: ~0.3)

  - Low multiplicity limits correlation

ID projection:

FTFP_BERT

Publication Plan

- Description of Algorithm + Track Filtering

- Track algorithm systematics
  - MIP Cut
  - Noise

- Data - MC comparison
  - physics lists (as requested by Geant4 team):
    - QGSP_BERT (old LHC production)
    - FTFP_BERT (new LHC production)
    - LHEP (to show how physics list evolved)
    - QGS_BIC (for systematic uncertainties)
  - Observables
    - track multiplicity
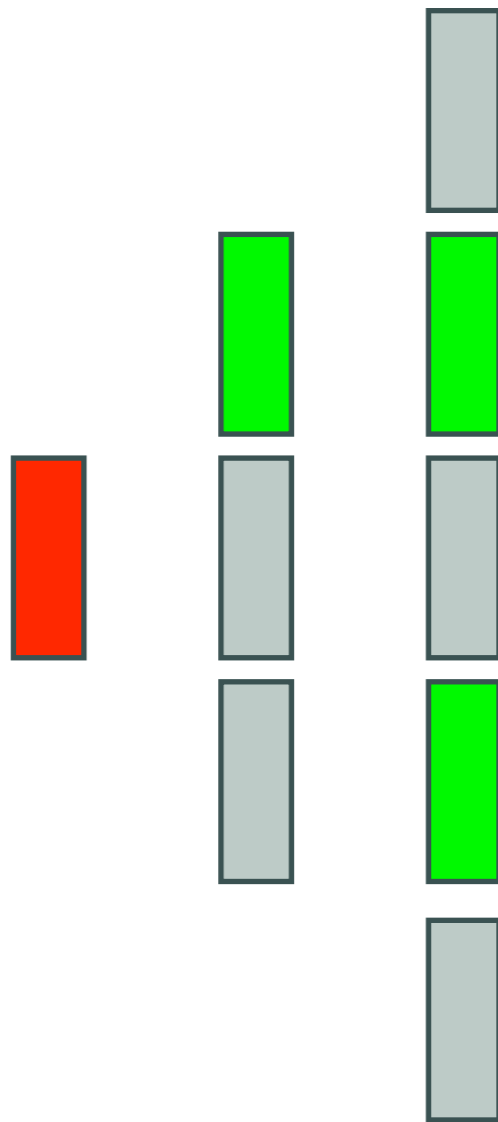   - (typical) track length
    - track inclination

1   Preprint typeset in JINST style - HYPER VERSION   Draft 0.1

2   **Identification of Track Segments in Hadronic**
3   **Showers in the CALICE Analog Hadron Calorimeter -**
4   **Algorithm and Comparisons to Simulations**

Author List excluded in Draft

ABSTRACT: Using the high granularity of the CALICE analog hadron calorimeter (AHCal), a tracking algorithm was developed. It is capable of finding tracks of particles that behave like Minimum Ionizing Particles (MIP) both in muon events and in hadronic showers. The algorithm and the applied filtering techniques are described. The track segments identified in hadronic events are sensitive to the spatial structure of the showers. Hence, the intrinsic properties of the tracks found are used as observables in a comparison between Monte Carlo simulation and testbeam data.

Editorial Board:
Catherine Adloff, Vincent Boudry, Vishnu Zutschi

Summary

Tracking algorithm is working

New Hough Transformation based filter to reject outliers

Correlation: track mulitplicity <=> # charged particles

First draft almost complete
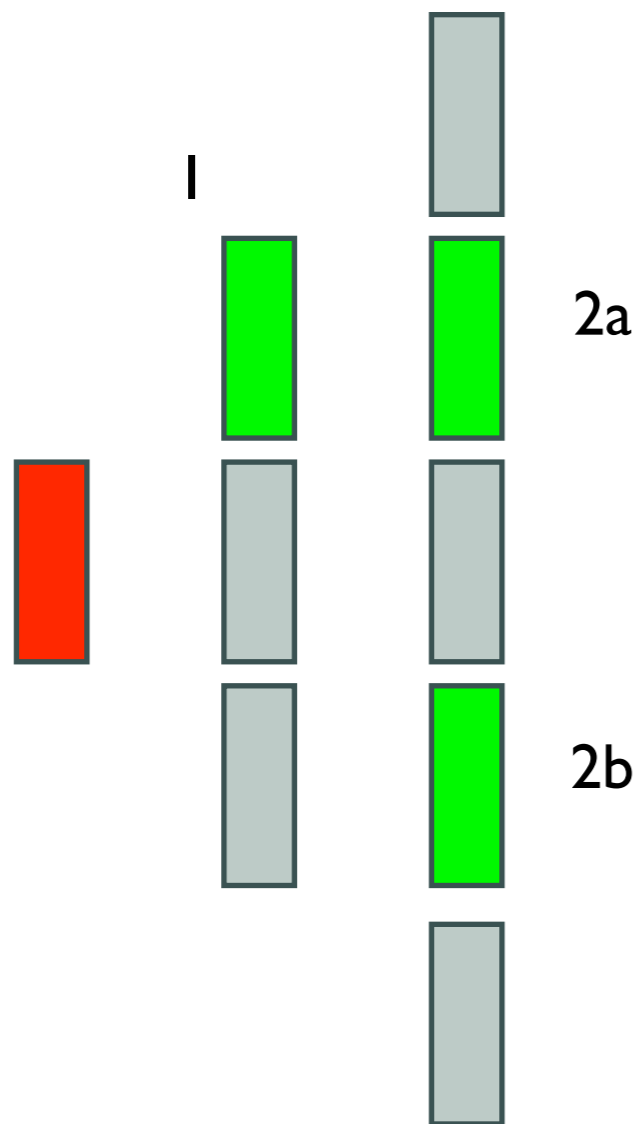
Backup: Tracking Algorithm
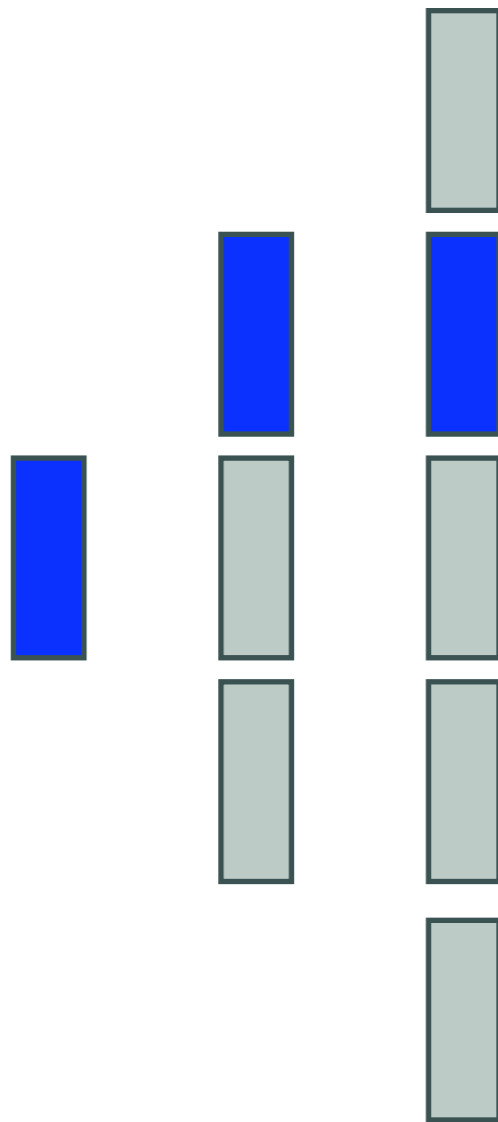

For each isolated hit as track start:

— Collect isolated hits in the consecutive 2 layers

— Sort them by distance to track start

— Search for tracks with each of these as new track start point

  — Avoid double counting of hits

  — (Here: Hit 1 will use Hit 2a in its track, hence there is no possibility to start an independent track from Hit 2a)
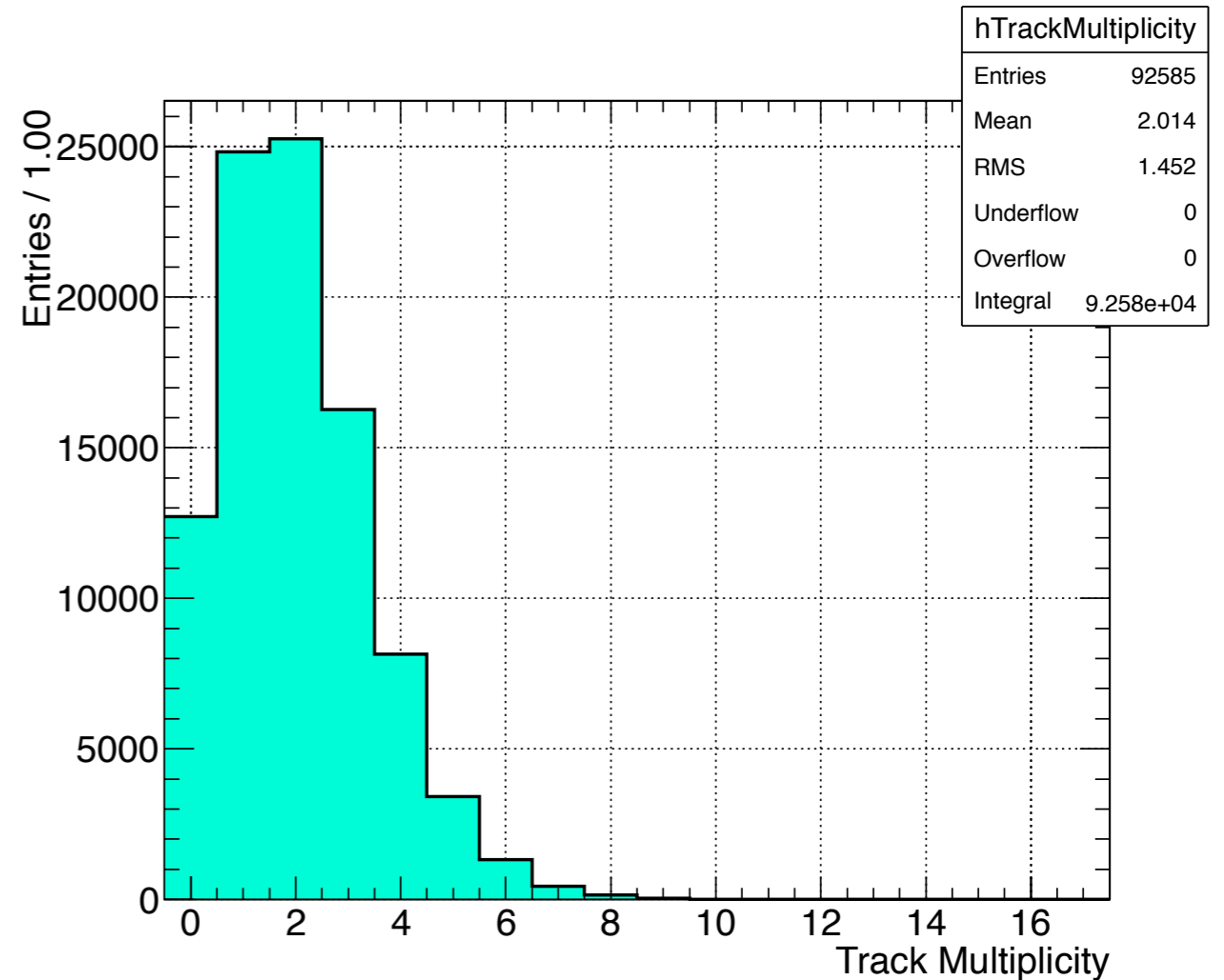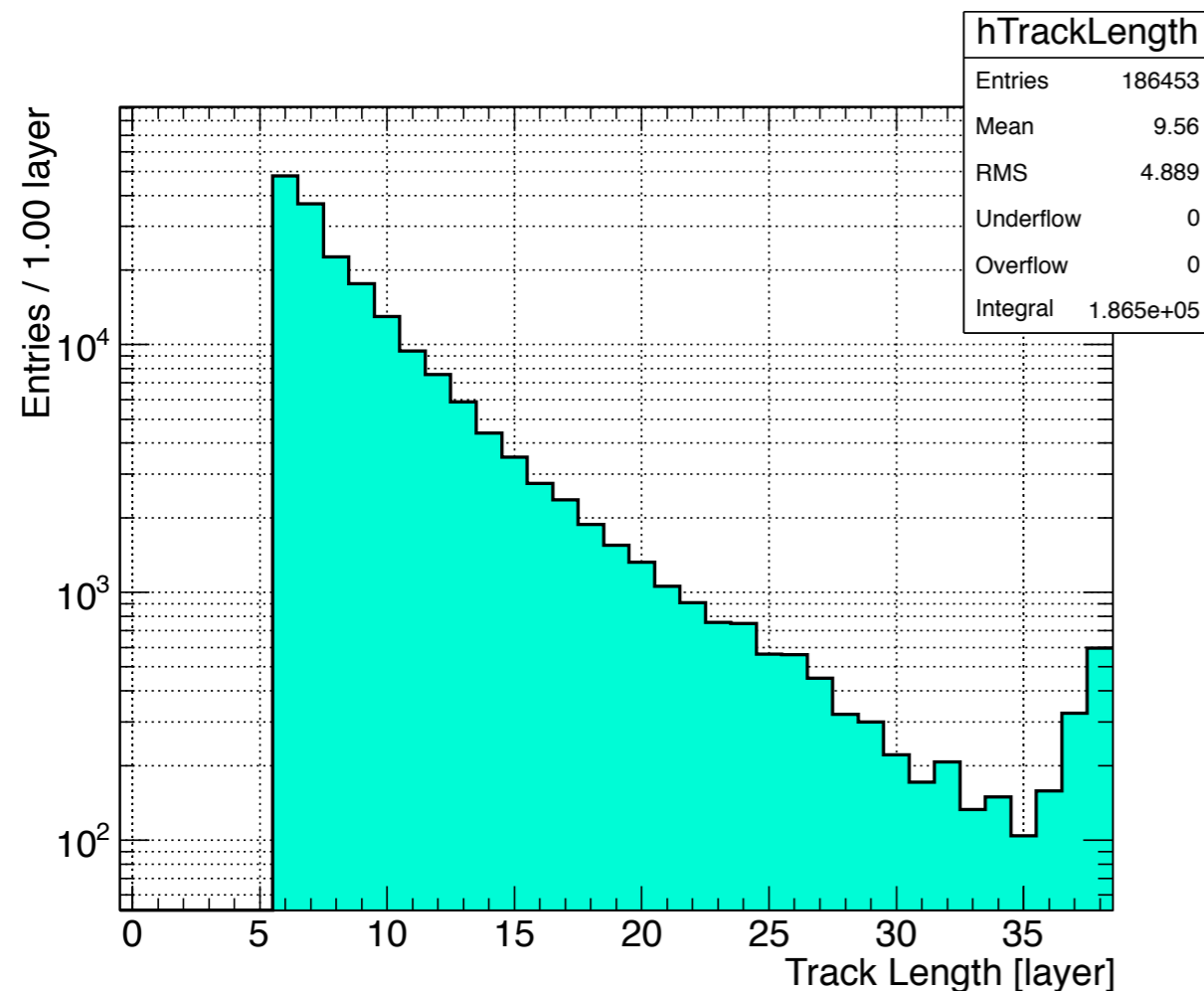
— Merge with longest track

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- Merge with longest track

Track multiplicity / Track length

- For Run 330325
  - 25 GeV pi-
- On average: 2.01 tracks / evt
  - Old tracker (different 25 GeV run): 1.6 tracks / evt

hTrackLength

Entries	186453
Mean	9.56
RMS	4.889
Underflow	0
Overflow	0
Integral	1.865e+05

hTrackMultiplicity

Entries	92585
Mean	2.014
RMS	1.452
Underflow	0
Overflow	0
Integral	9.258e+04

- Exponentially decreasing tracklength
  - → hadronic interaction length λ_0
- Quick estimation of λ_0 (straight, primary tracks):

$$\lambda_0 = 8.1 \text{ layers}$$
$$\lambda_{0,PDG} = 8.88 \text{ layers}$$

Track segments by MIPs: Langau

- Energy deposition of MIPs:
  - Landau $\otimes$ Gauss: „Langau"

- Similar Fit like in FitMip package:
  - MPV = 1.08 GeV (all tracks)

- Energy deposition higher for inclined tracks
  - MPV = 0.99 GeV (straight tracks)

A RooPlot of "E_{MIP}"

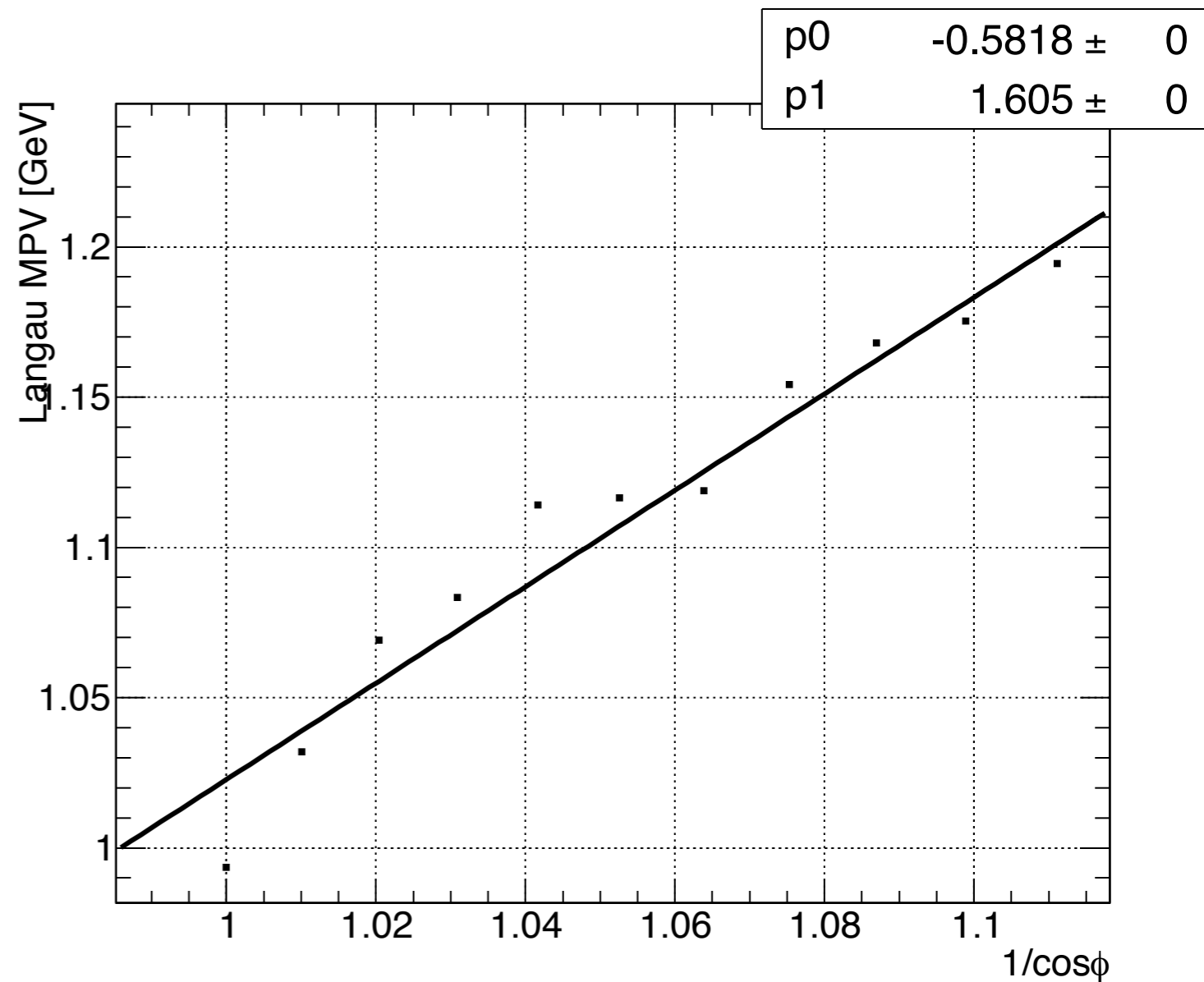GS = 0.4458 ± 0.0033
LM = 0.9459 ± 0.0021
LS = 0.18359 ± 0.00080

$\cos\phi$: all
MPV: 1.081913 GeV

Events / (0.05 GeV)

E_{MIP} (GeV)

Run 331333: 60 GeV Pion

Excellence Cluster
Universe

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A RooPlot of "E_{MIP}"

GS = 0.3268 ± 0.0043
LM = 0.8959 ± 0.0028
LS = 0.1407 ± 0.0011

$\cos\phi$: 1.0
MPV: 0.993484 GeV

Events / (0.05 GeV)

E_{MIP} (GeV)
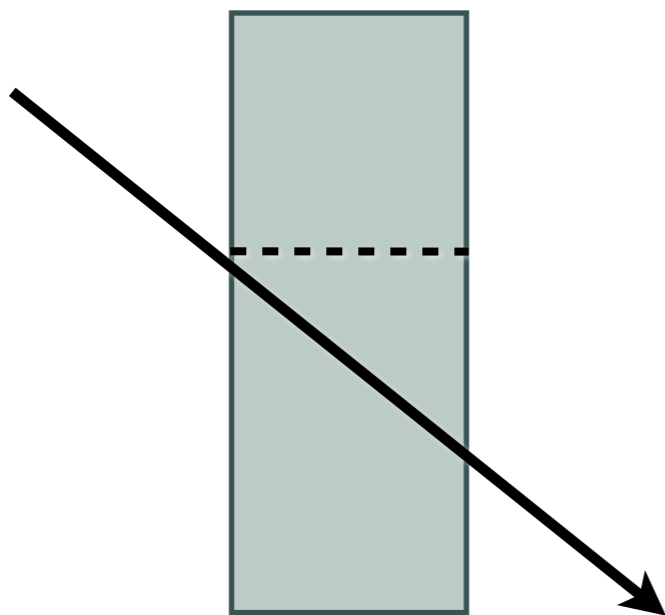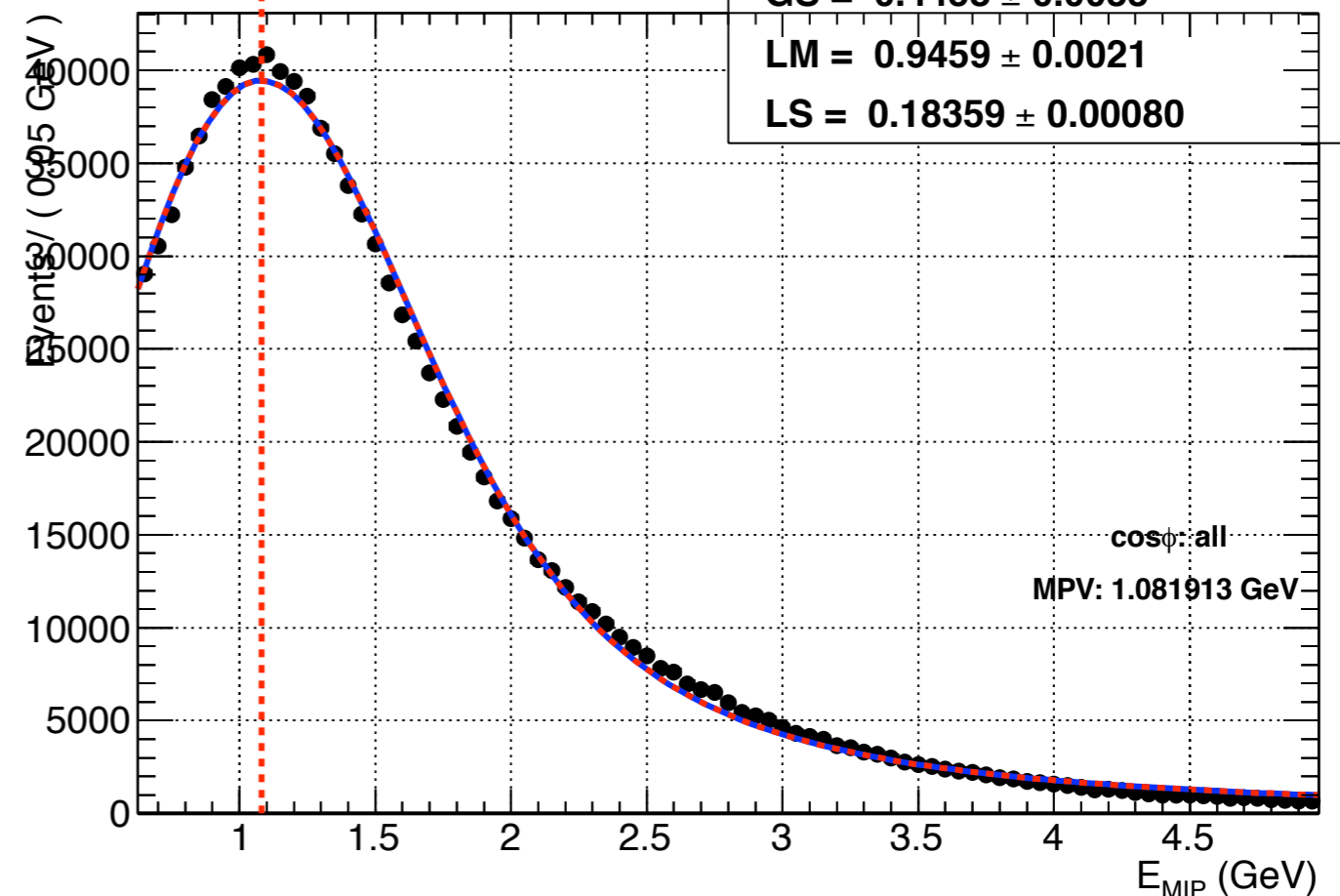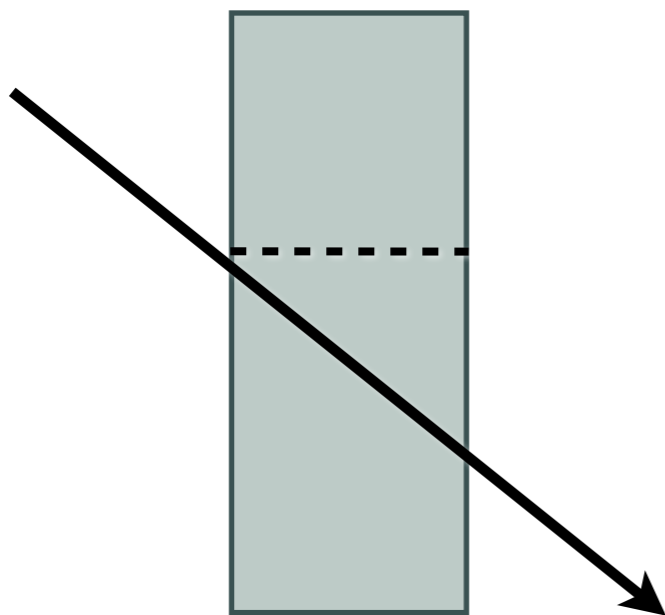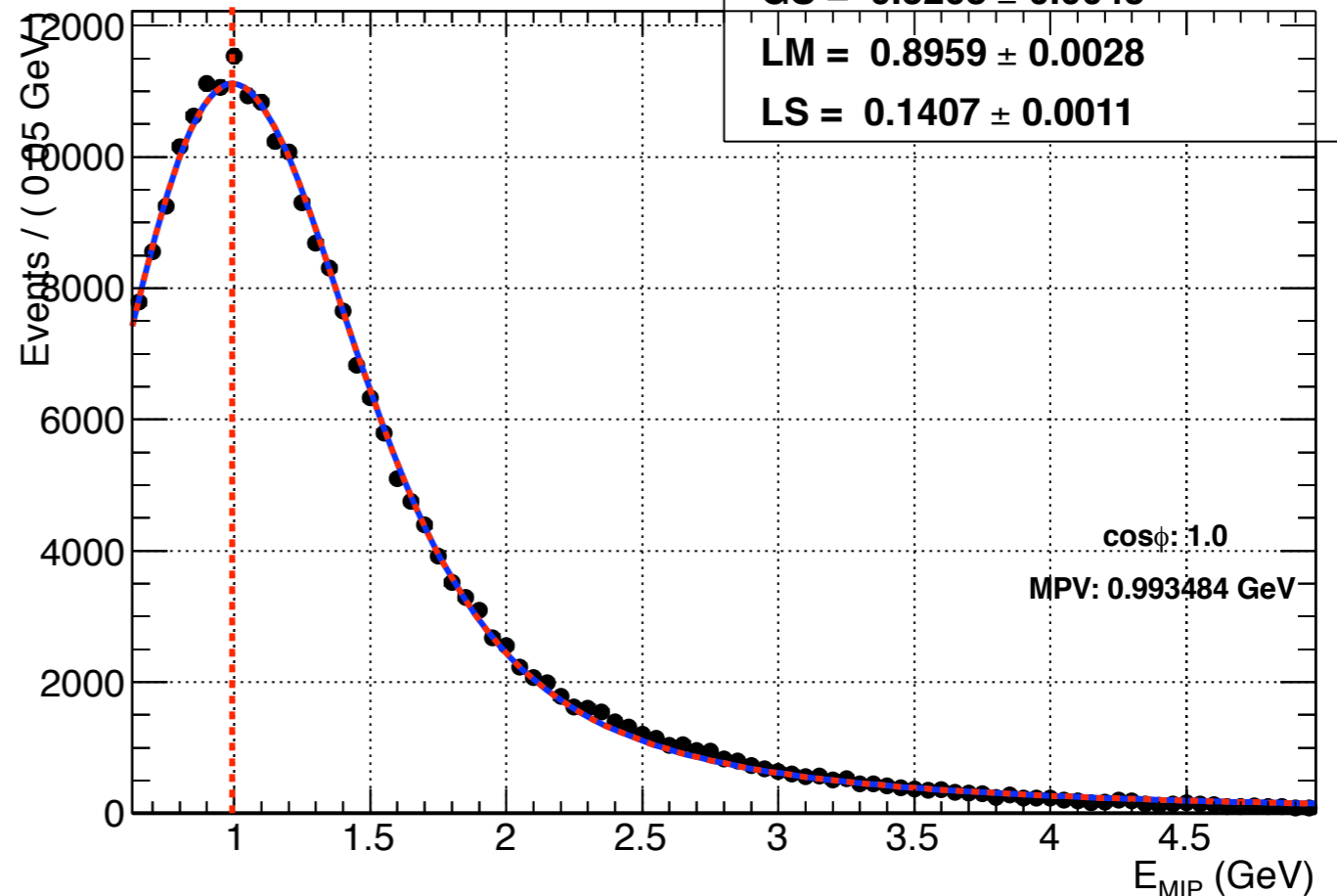
Run 331333: 60 GeV Pion

Langau MPV: Track angle dependence
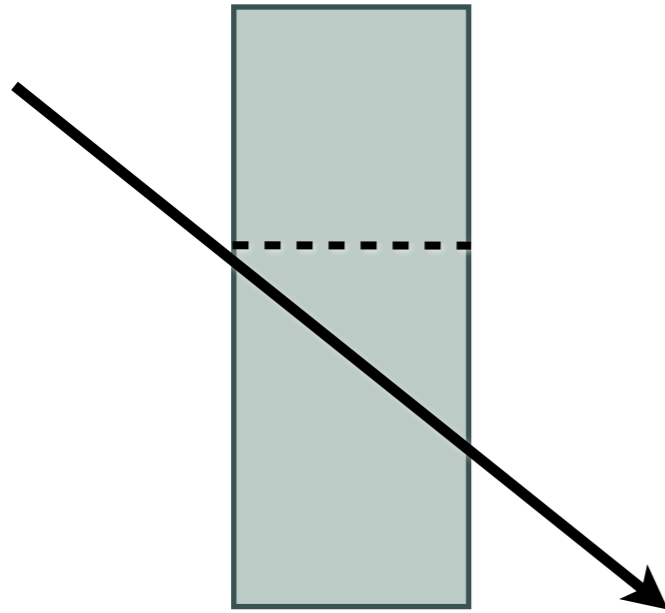
- Longer distance @ inclined tracks

- higher E_{dep}

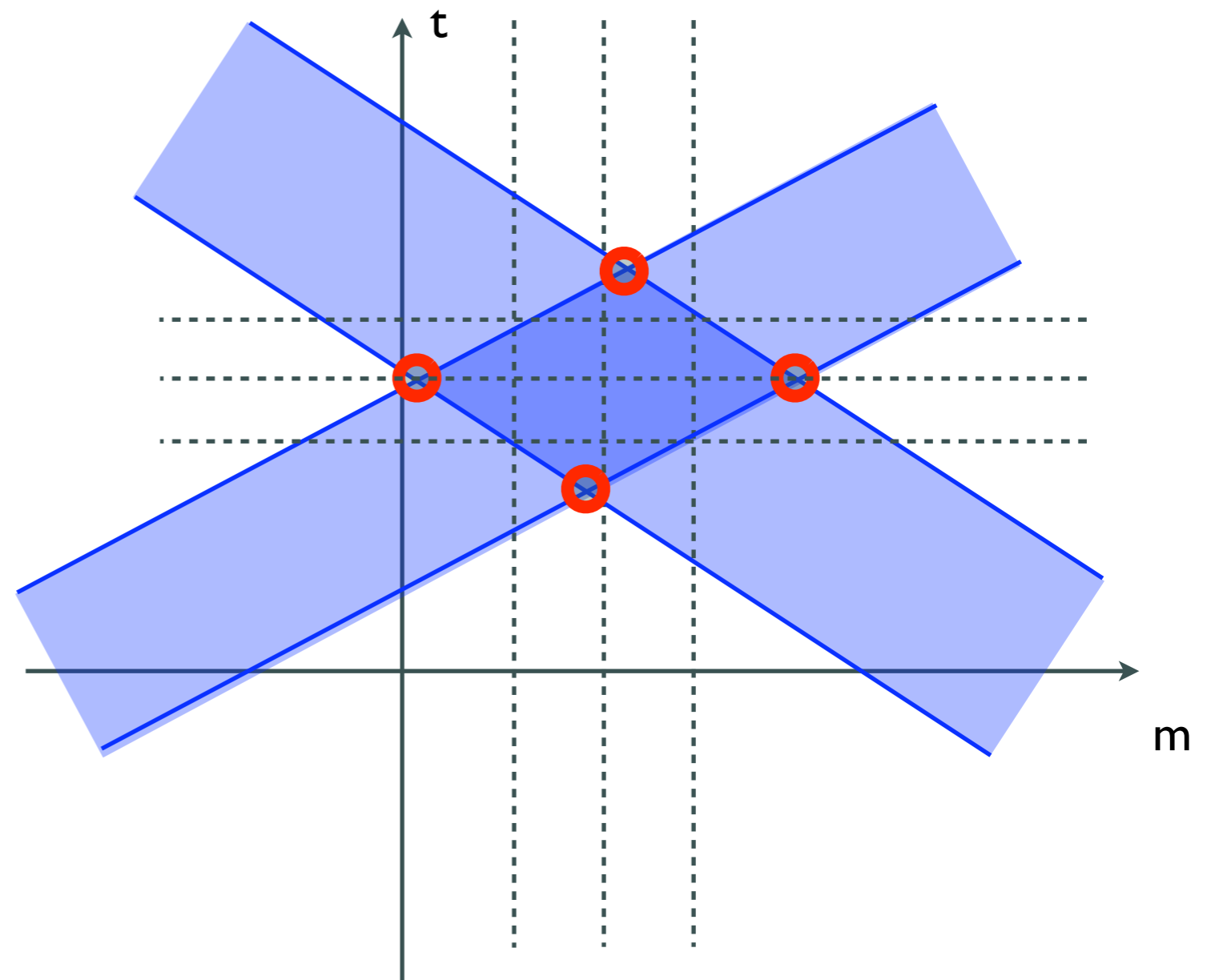- expected: $E_{dep} \propto 1/\cos \varphi$

Hough Transformation: Variable binsize

Use lines limiting the bands
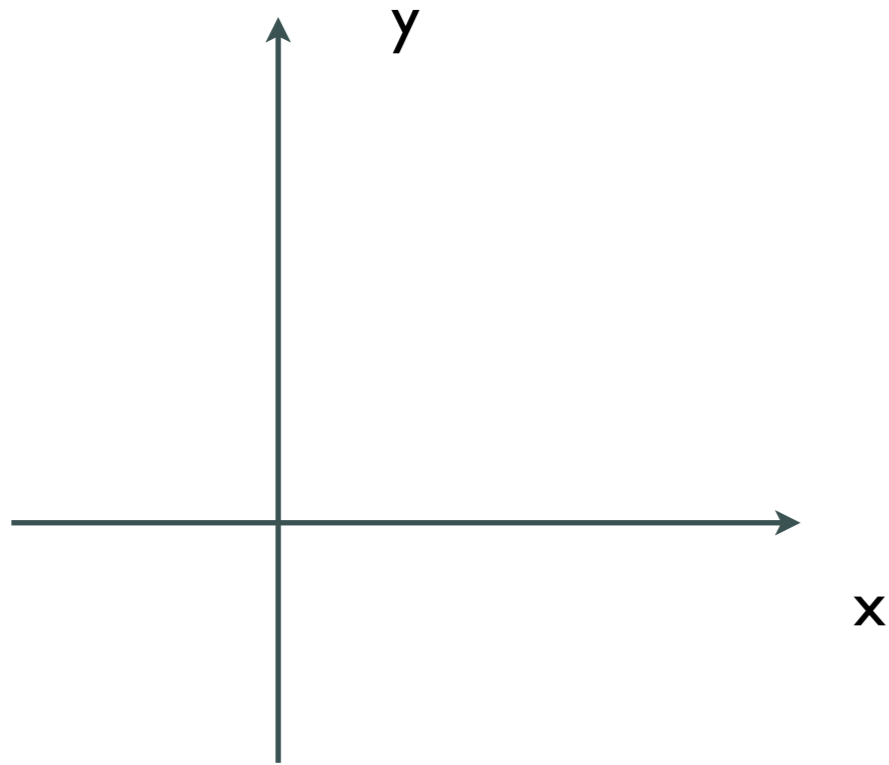
Calculate intersections between all limiting lines

Bin border = mid between 2 intersections in m (t)

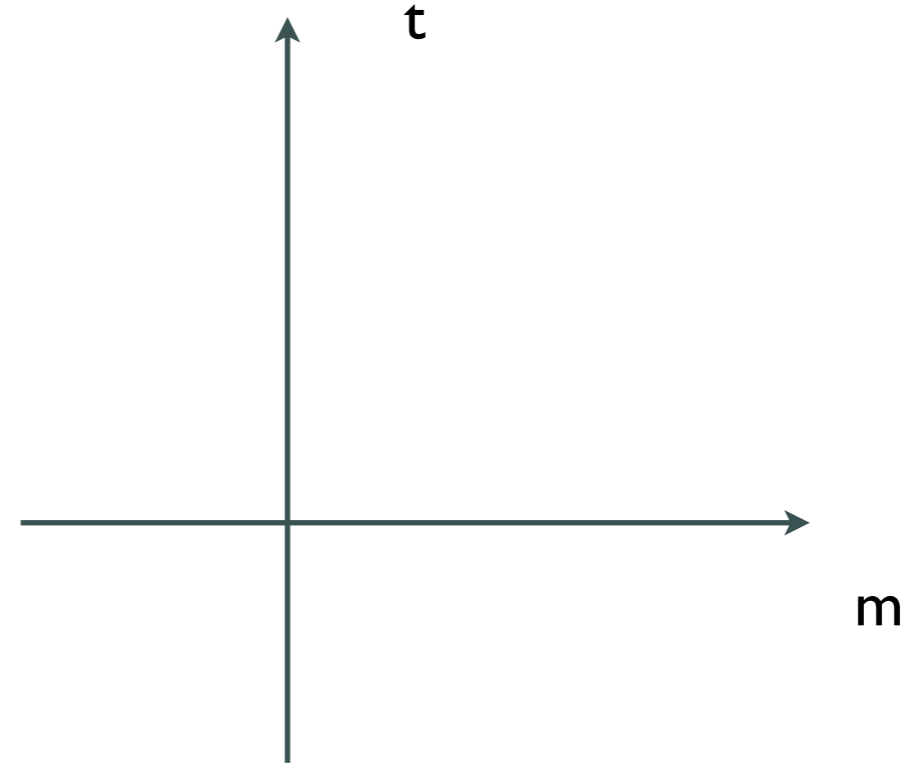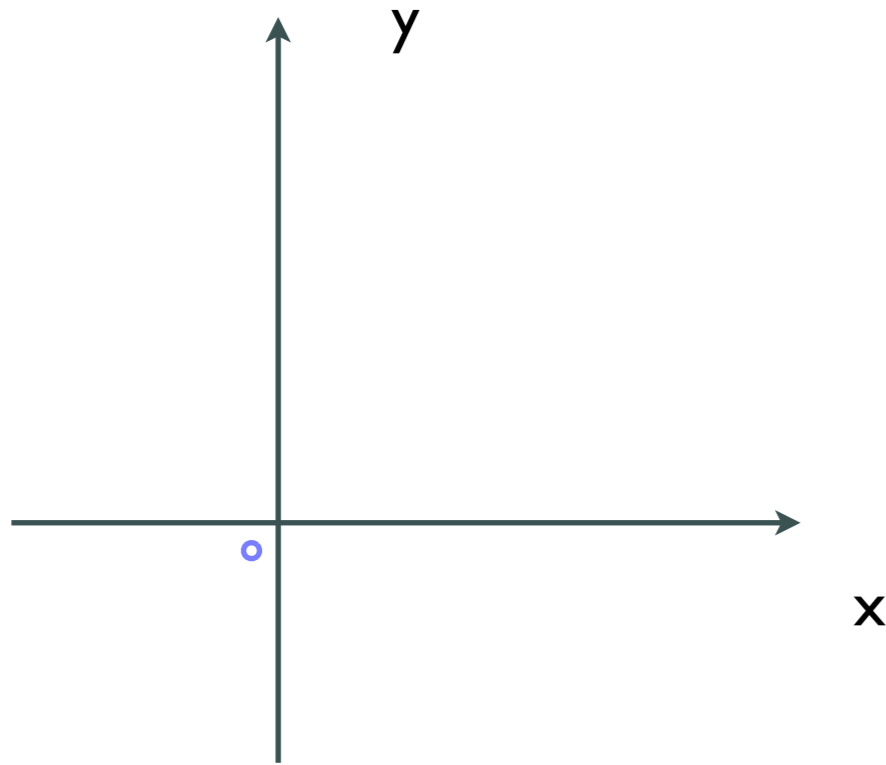Fill bin if band traverses bin

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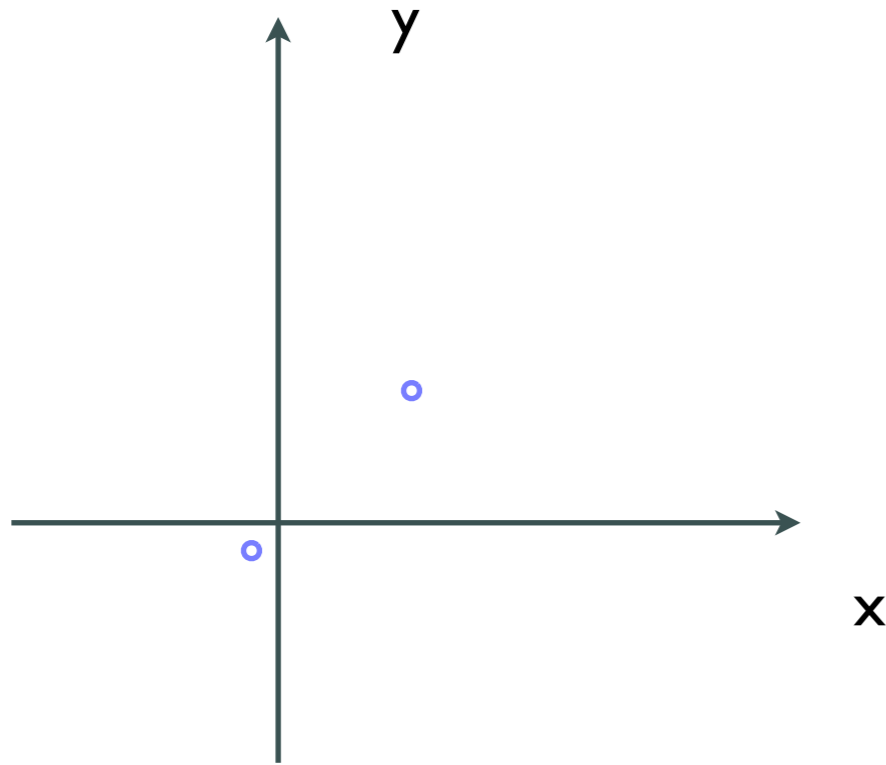Fill bin if band traverses bin

Hough Transformation: Principle

y = mx + t   real space

t = -xm + y   hough space

- Point in normal space = line in Hough Space (and vice versa)
- Get point with most intersections
  - Reject non corresponding points in real space

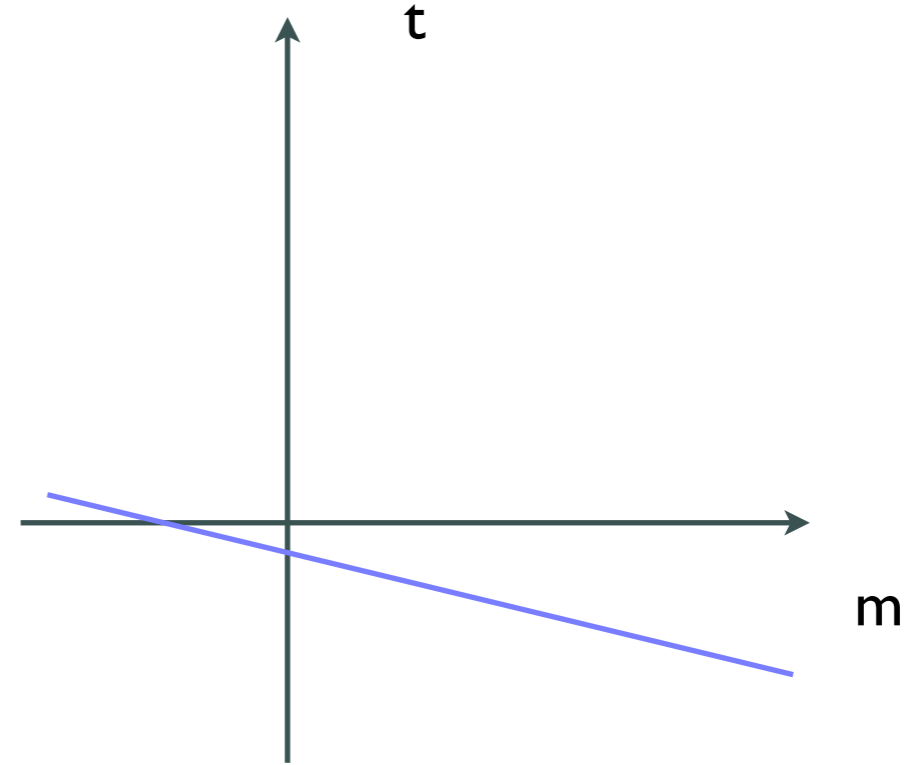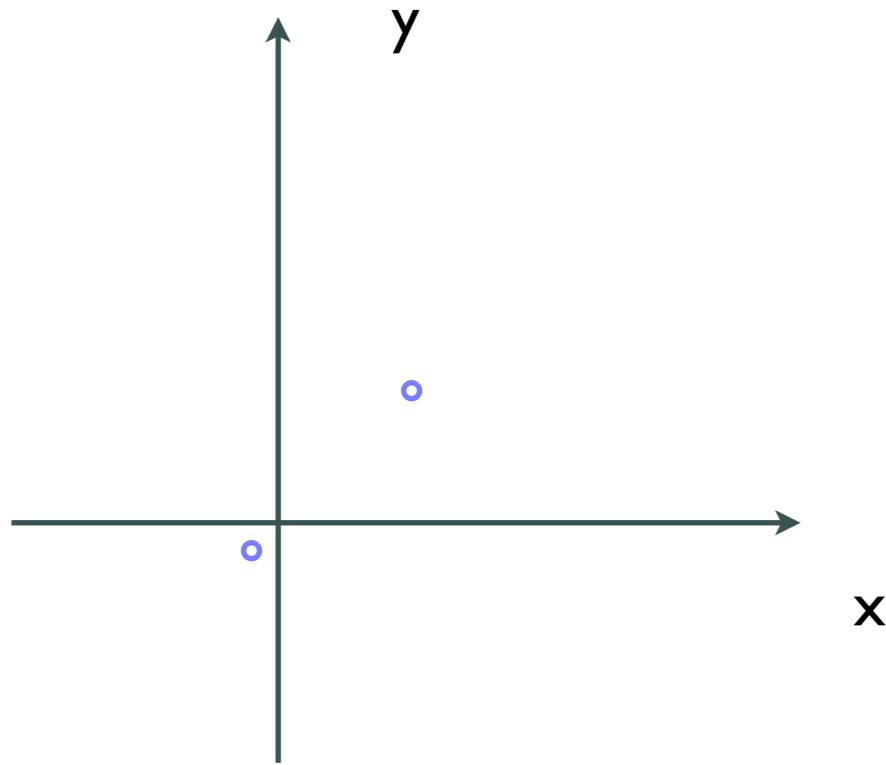# Hough Transformation: Principle
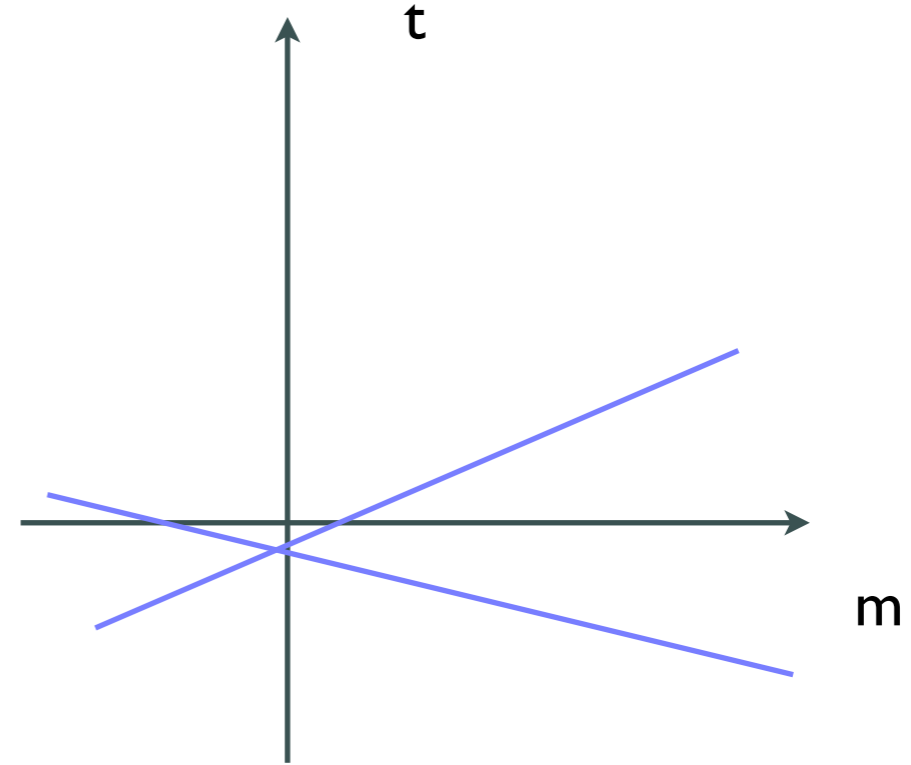

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  - Reject non corresponding points in real space

Hough Transformation: Principle

y = mx + t   real space

t = -xm + y   hough space

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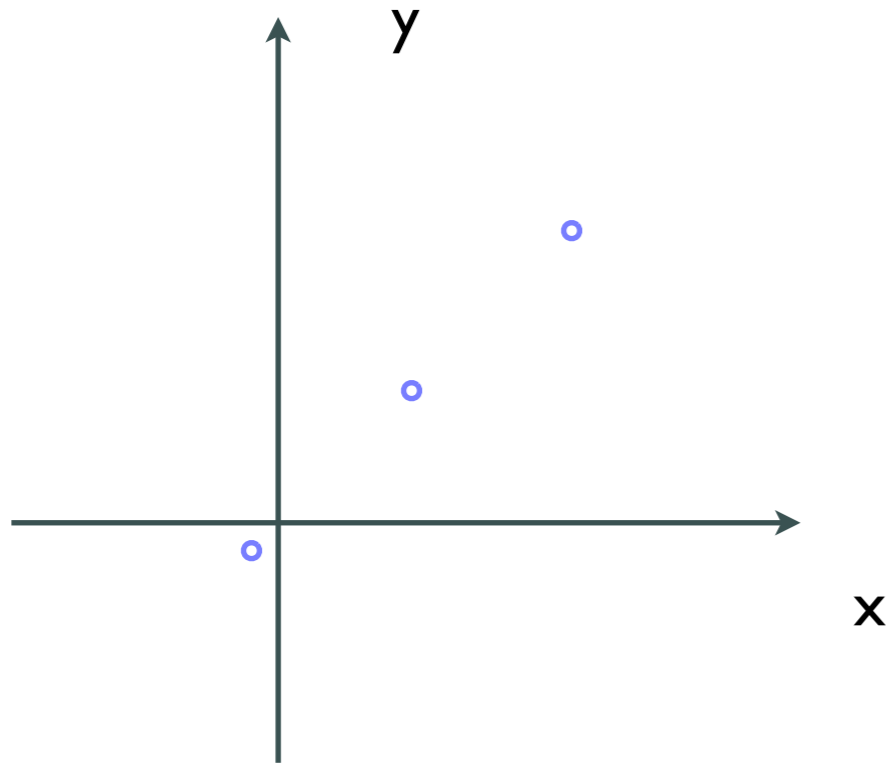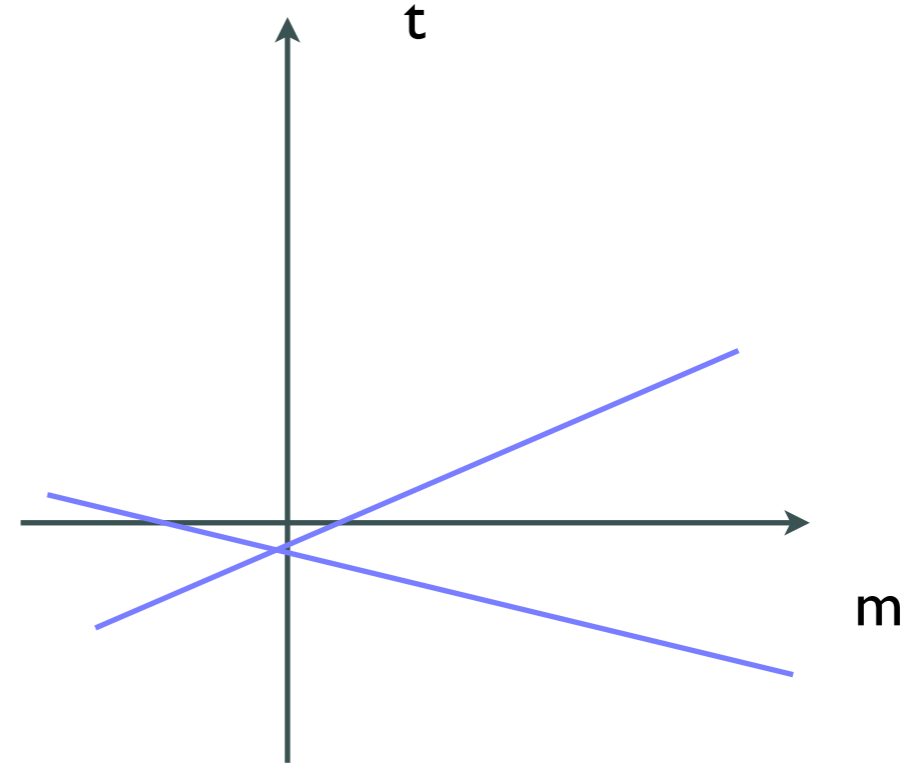— Reject non corresponding points in real space

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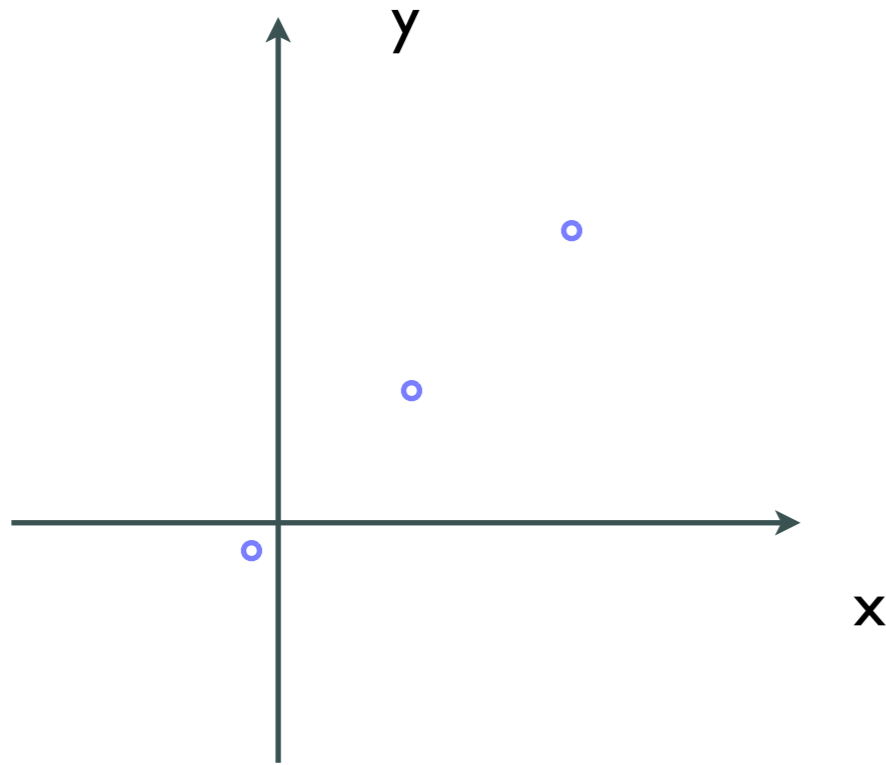
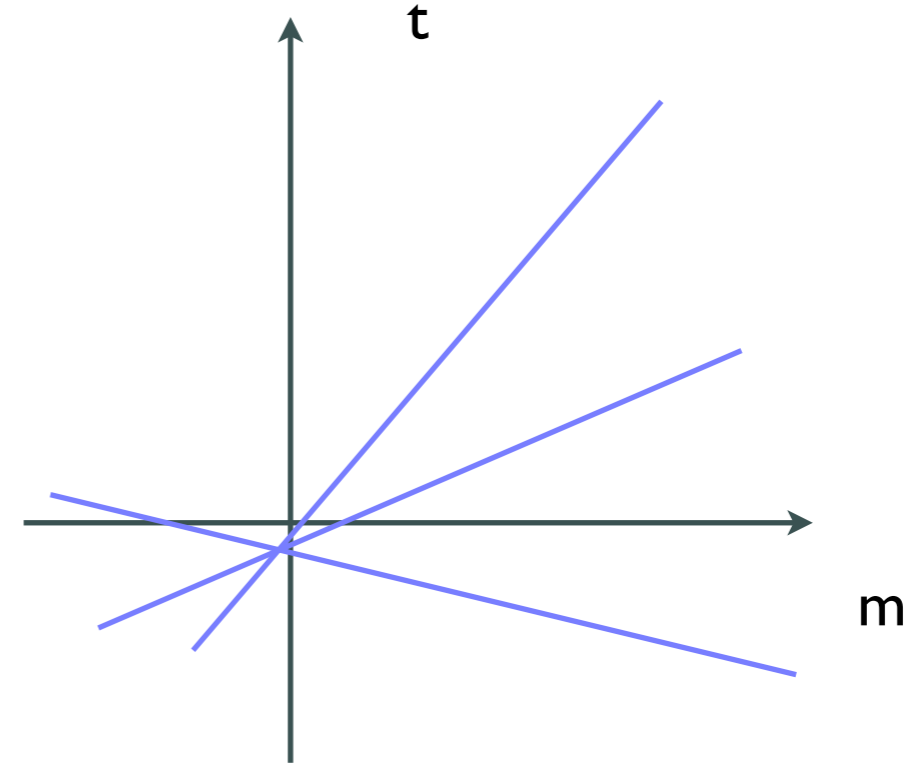# Hough Transformation: Principle

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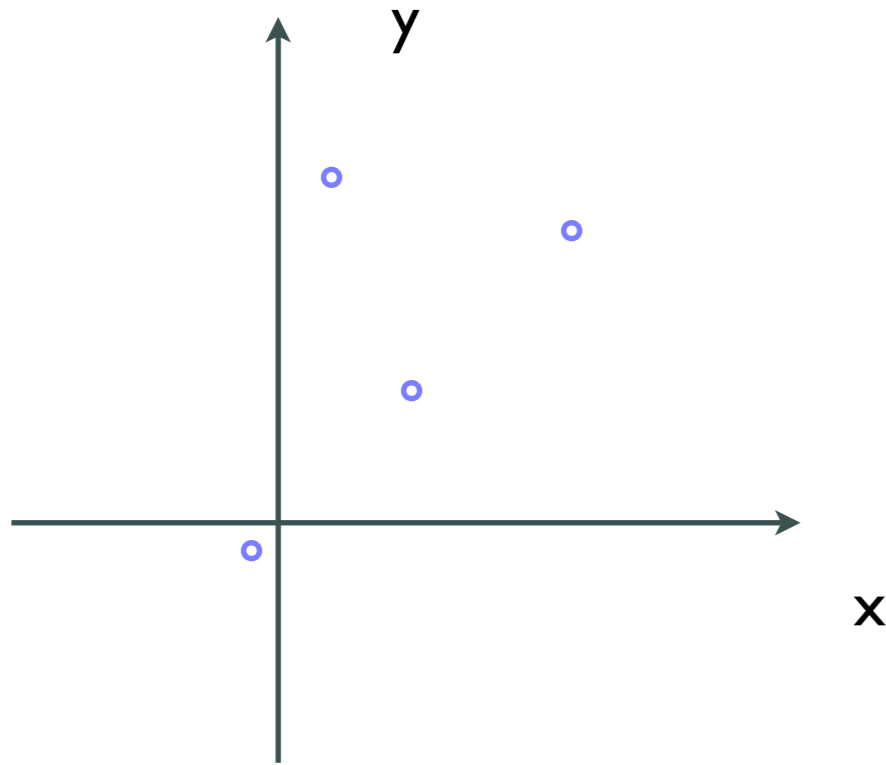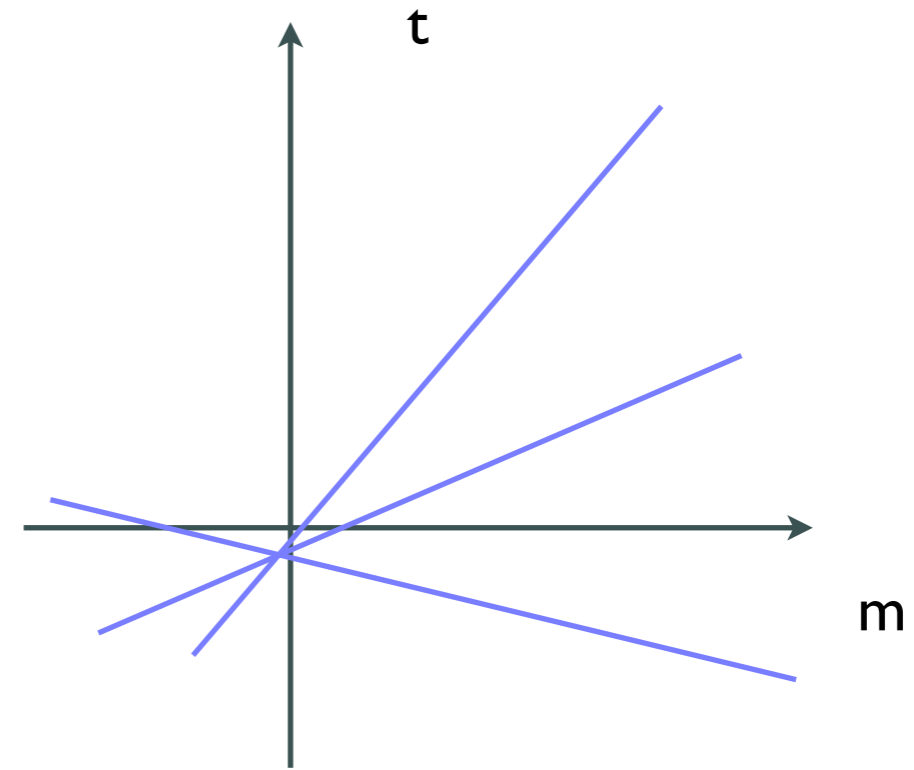
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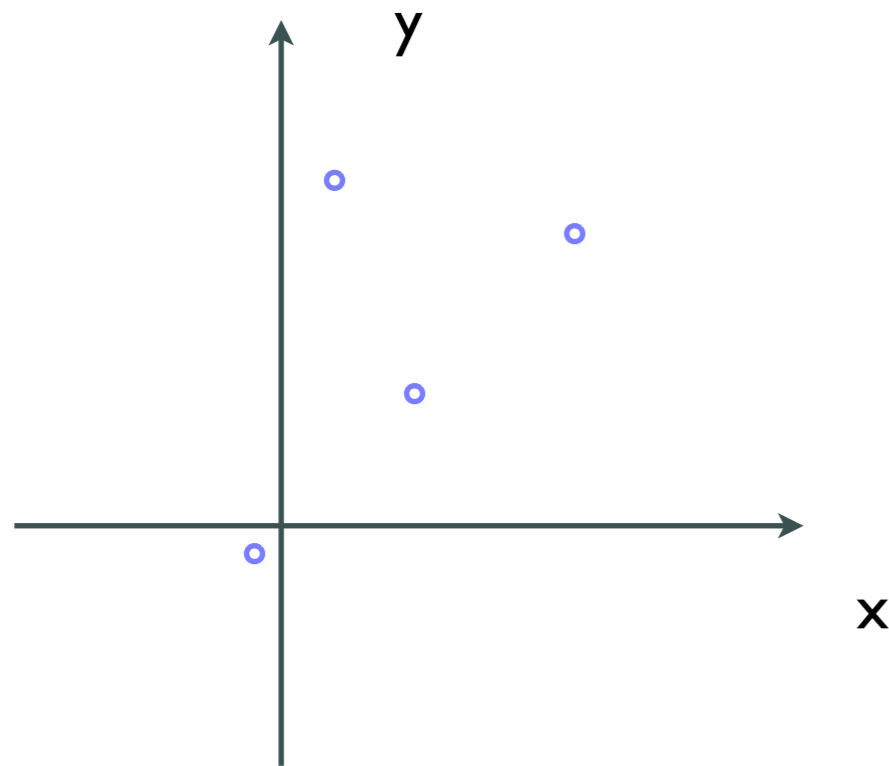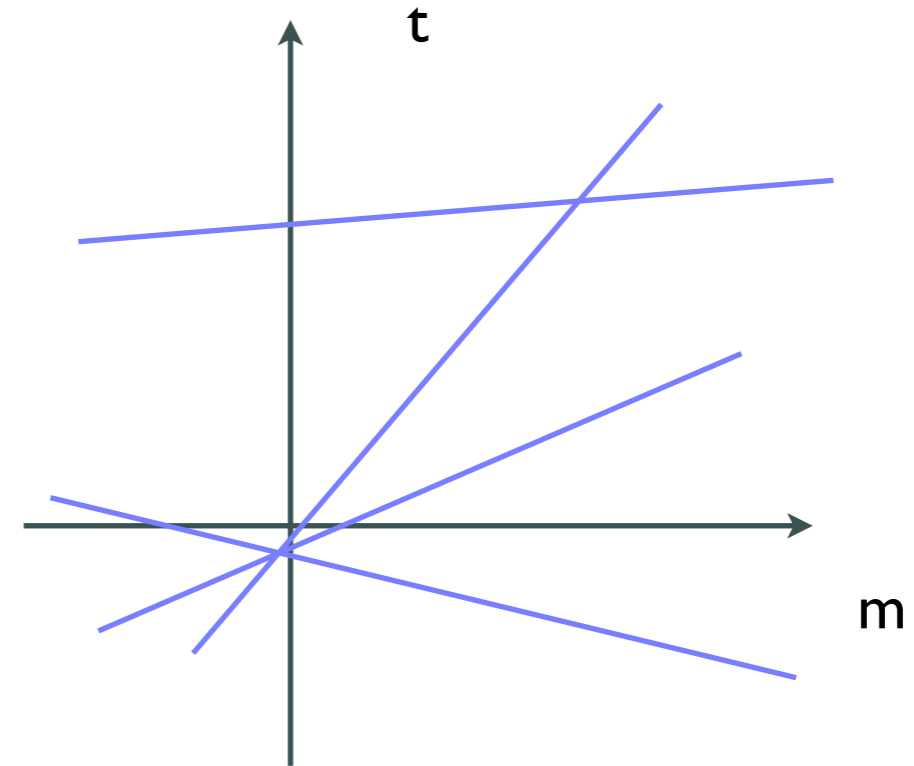

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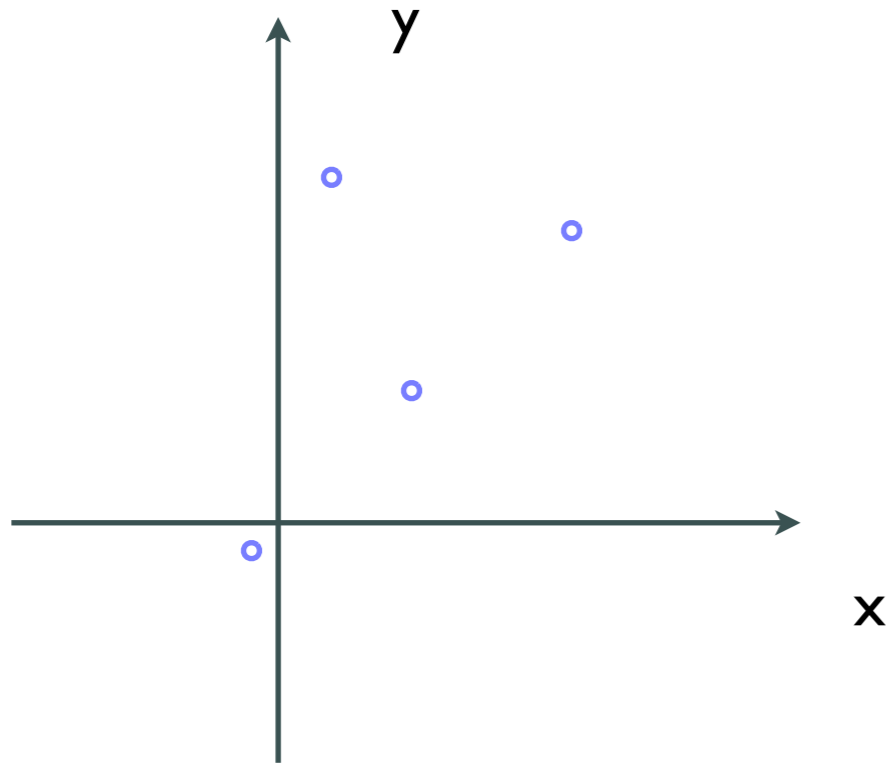
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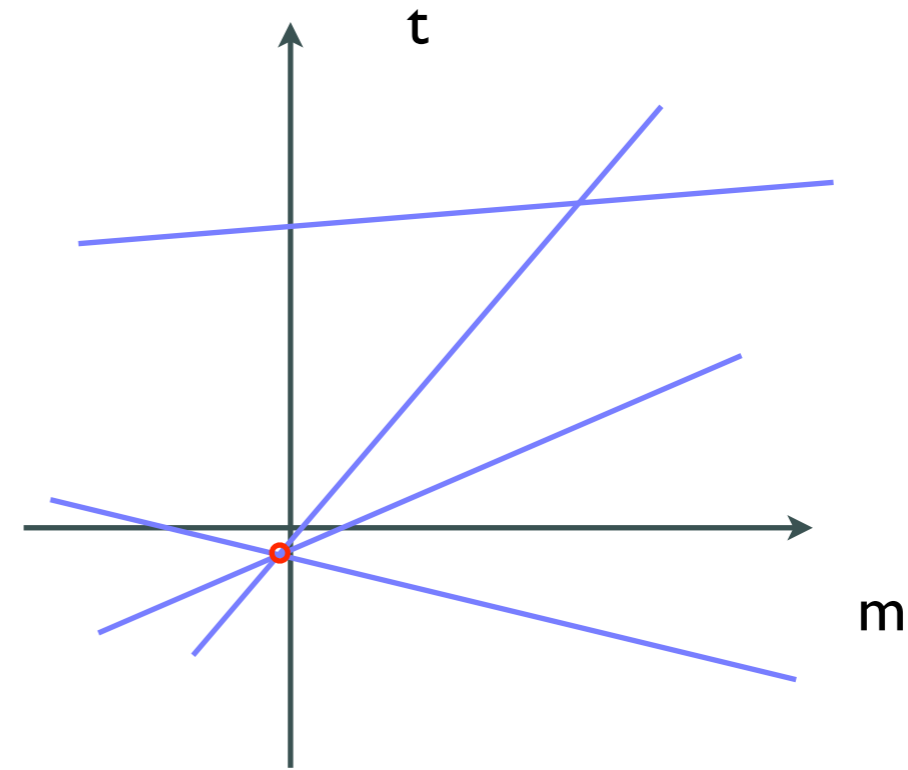# Hough Transformation: Principle

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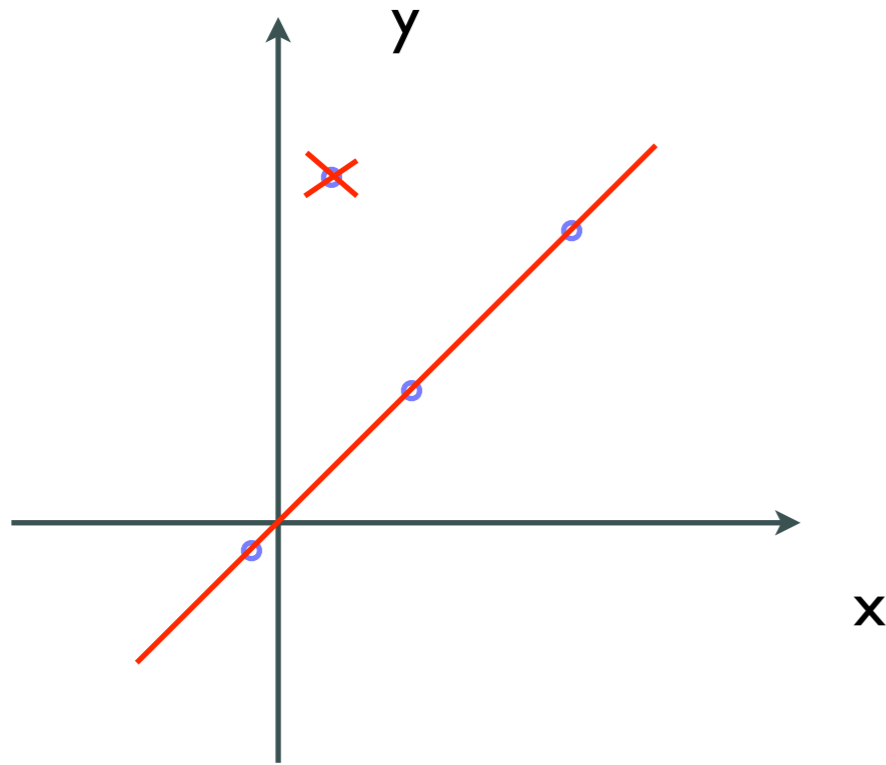
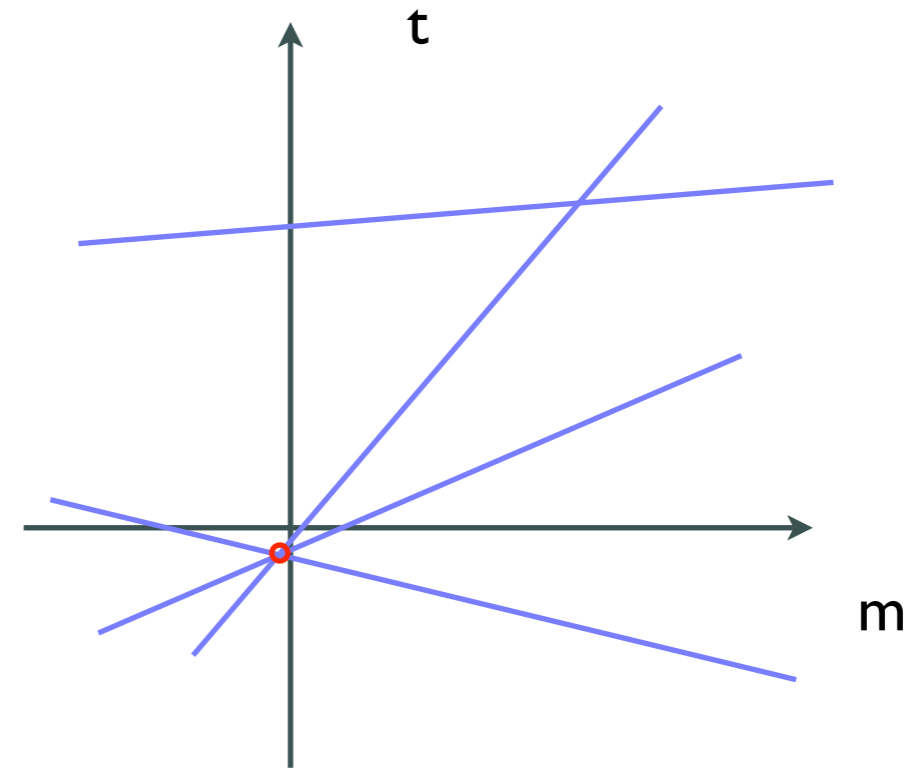# Hough Transformation: Principle

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