UPDATE TO THE HOUGHTRACKFINDER
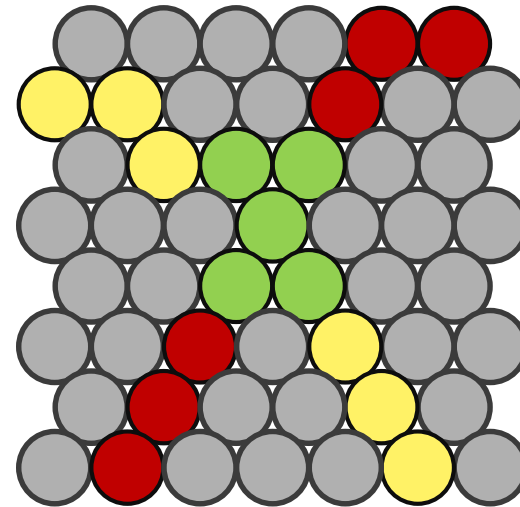
23.06.2020 I PANDA COLLABORATION MEETING | ANNA SCHOLL

panda

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HOUGHTRACKFINDER

Review: basic procedure

- Generate tracklets
  - Cellular automaton
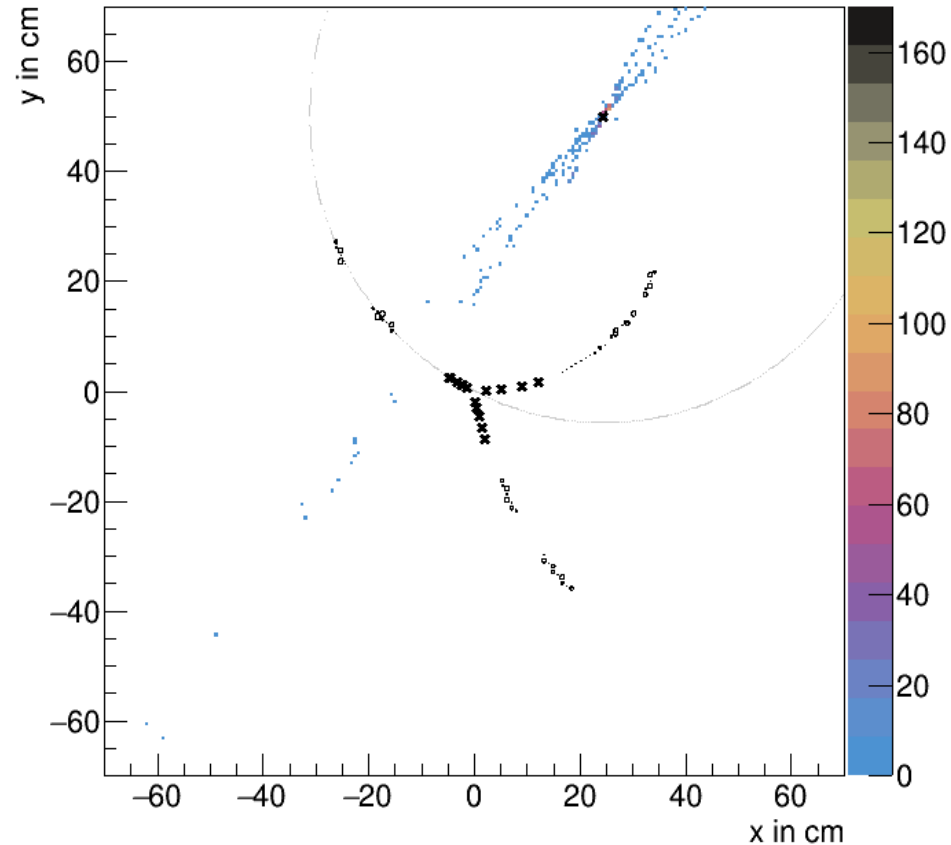 - Segmentation

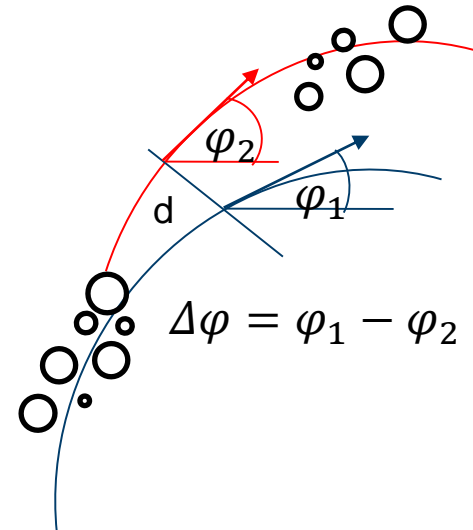# HOUGHTRACKFINDER

Review: basic procedure

- Generate tracklets
  - Cellular automaton
  - Segmentation

- Find circles for tracklets
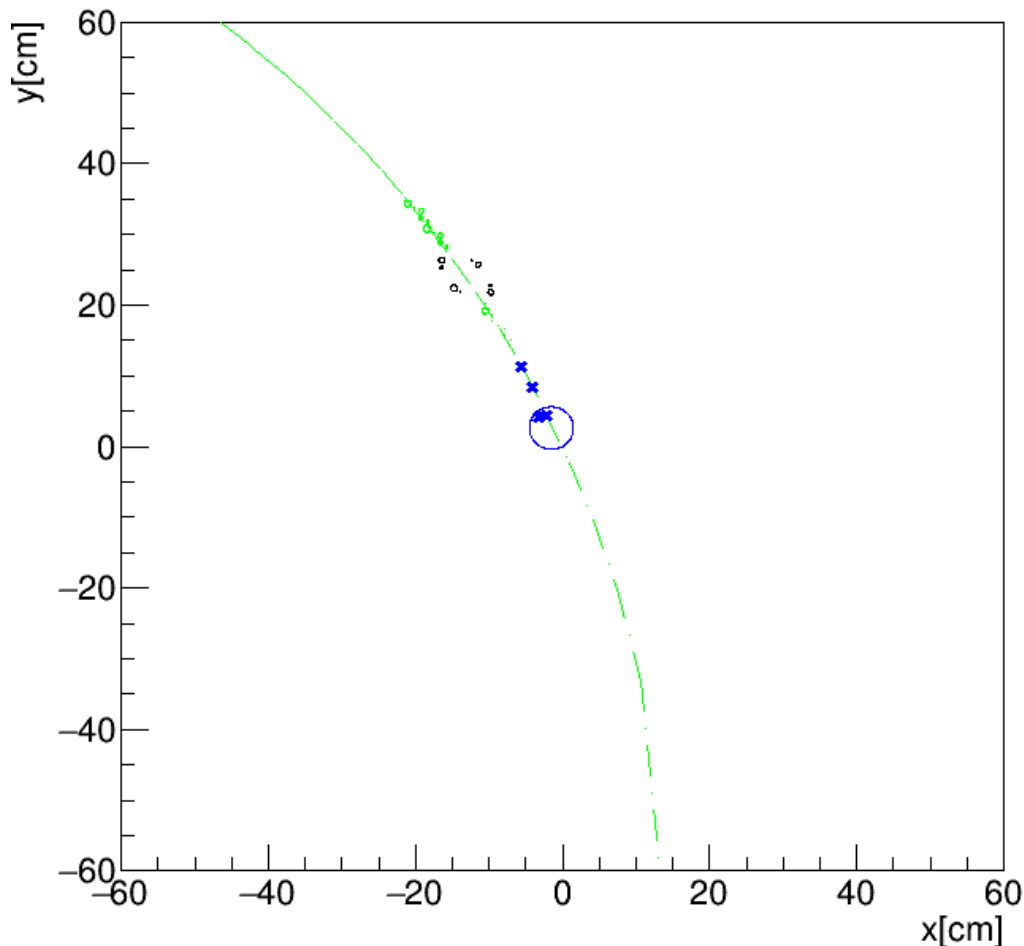 - Hough transformation

HOUGHTRACKFINDER

Review: basic procedure

- Generate tracklets
  - Cellular automaton
  - Segmentation

- Find circles for tracklets
  - Hough transformation

- Merging
  - combine tracklets to particle track

$$\Delta \varphi = \varphi_1 - \varphi_2$$

STILL SOME WRONG TRACKS

- Example (simple case): 1 μ^- with p_T = 1GeV
- → Track with 5 MVD Hits and 18 STT Hits

Why does the Hough transformation still creates wrong tracks?

- Reason: many „maxima" in Hough Space (bins with same entry number)
    → Choosing one by chance

STILL SOME WRONG TRACKS

- Example (simple case): 1 μ^- with p_T = 1GeV
- → Track with 5 MVD Hits and 18 STT Hits

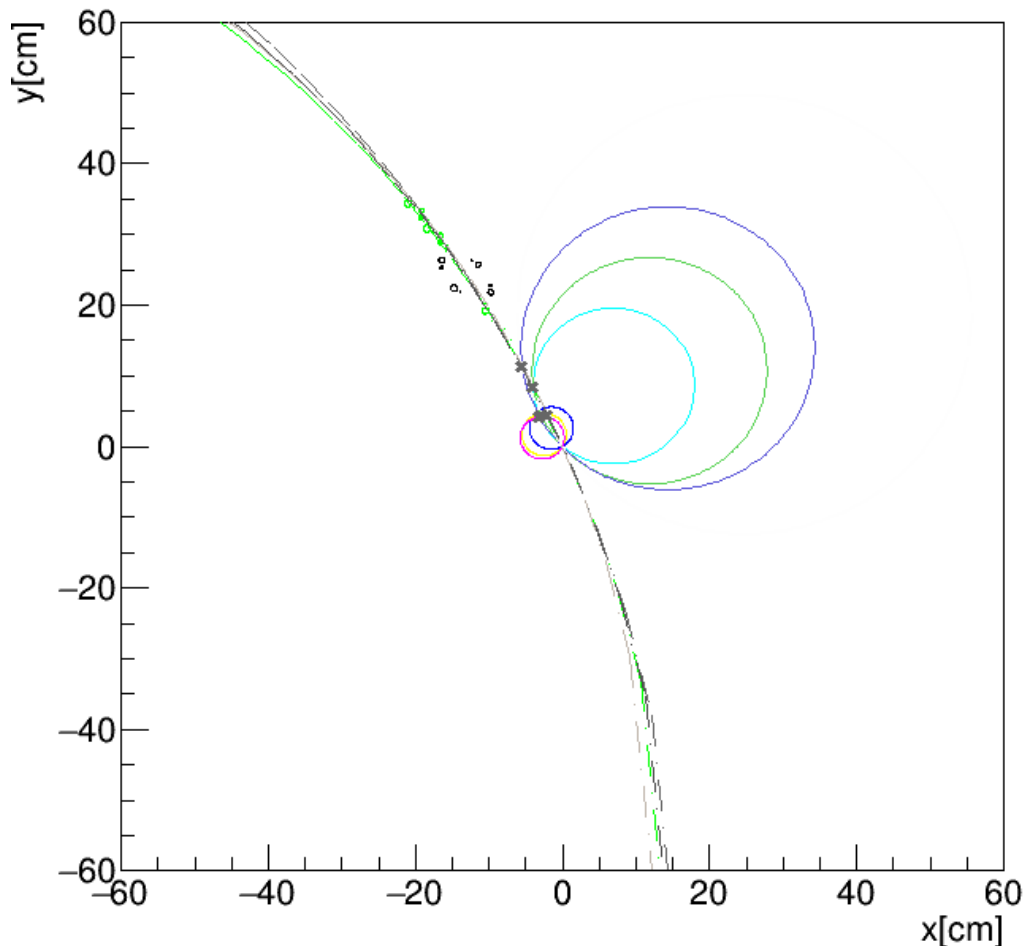Why does the Hough transformation still creates wrong tracks?

- Reason: many „maxima" in Hough Space (bins with same entry number)
  → Choosing one by chance
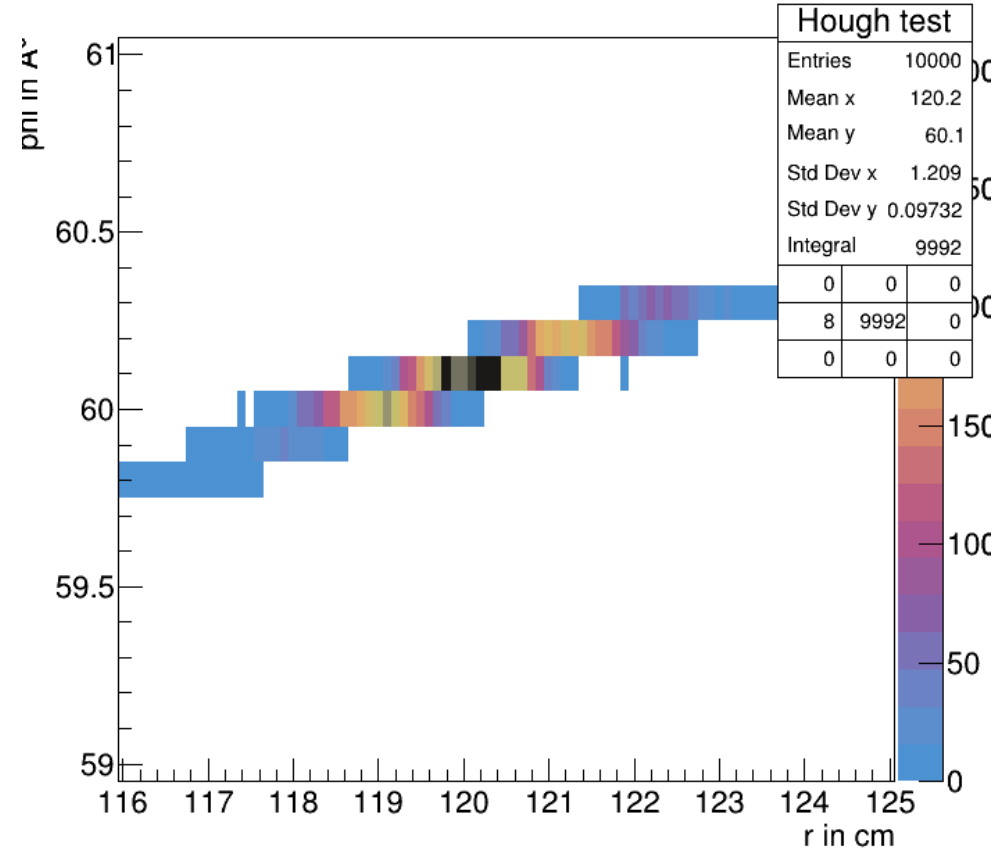
- Have to include all maxima
  → many false tracks (clones with wrong p_T

HOW TO FIND THE BEST MAXIMUM?

Different methods were tested:

1. **Gauß error**

   Apollonius circles have an error, which should be included into the Hough space
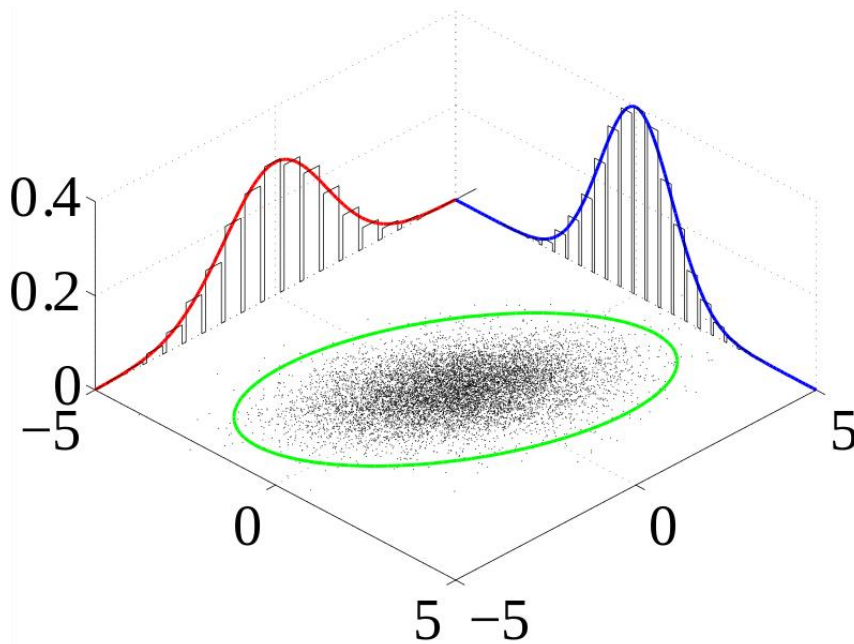
HOW TO FIND THE BEST MAXIMUM?

Different methods were tested:

1. **Gauß error**

    Apollonius circles have an error, which should be included into the Hough space

2. **Hough maxima**

    Calculate distances between maxima of different Hough spaces

Hough space 1

Hough space 2
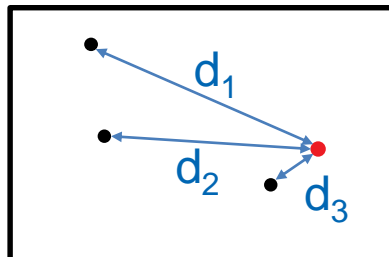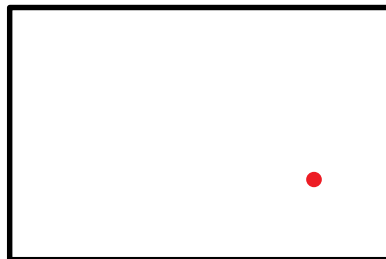
→ „Best maximum" is chosen as the one with smalles distance

→ Example: d_3

d_1

d_2

d_3

HOW TO FIND THE BEST MAXIMUM?

Different methods were tested:

1. **Gauß error**

   Apollonius circles have an error, which should be included into the Hough space
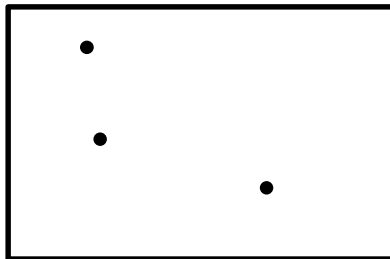
2. **Hough maxima**

   Calculate distances between maxima of different Hough spaces

3. **Sum of distances from hits to circle**

   Best maximum should fit better to the hits of the tracklet
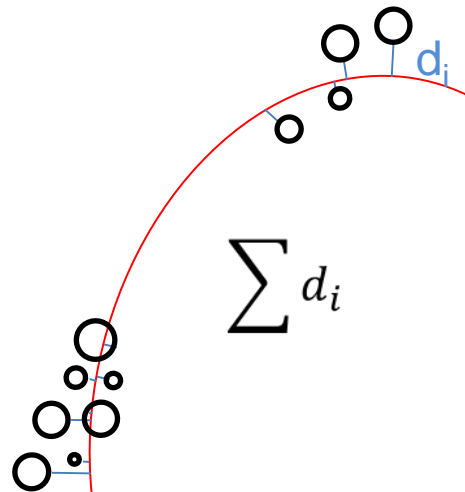
$$\sum d_i$$

d_i

HOW TO COMPARE THE METHODS?

- Used data: 1000 events of 1 μ^- with p_T = 1 GeV

- Interesting parameters:
  - p_T resolution before merging
    → smaller σ_{pT}: better merging
    → less outliers

    ↓

  deviation of more than 10 %
  ($|p_{T,Reco} - p_{T,MC}| > 0.1$ GeV)
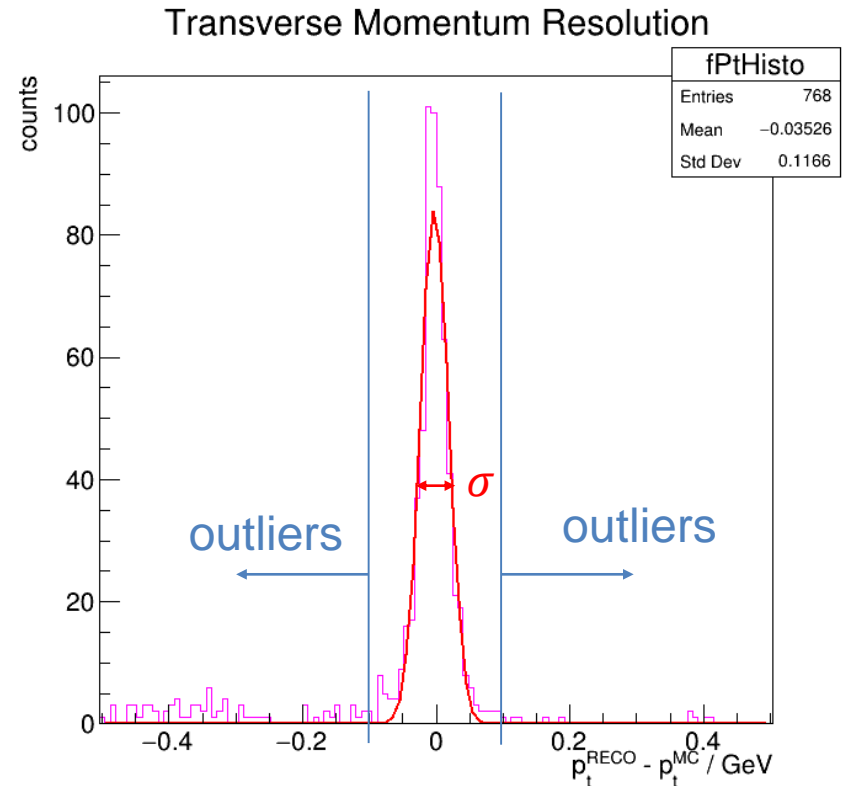
Transverse Momentum Resolution

HOW TO COMPARE THE METHODS?

- Used data: 1000 events of 1 μ^- with $p_T = 1$ GeV

- Interesting parameters:
  - p_T resolution before merging
    - → smaller σ_{pT}: better merging
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  - CPU time of the algorithm

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HOW TO COMPARE THE METHODS?

- Used data: 1000 events of 1 μ^- with p_T = 1 GeV

- Interesting parameters:
    - p_T resolution before merging
        - → smaller σ_{pT}: better merging
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    - CPU time of the algorithm

    - Quality parameters after merging
        - Found possible primary tracks
        - Number of ghosts
        - Number of clones

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COMPARISON OF MAXIMUM SELECTION

p$_T$ resolution before merging

Transverse Momentum Resolution
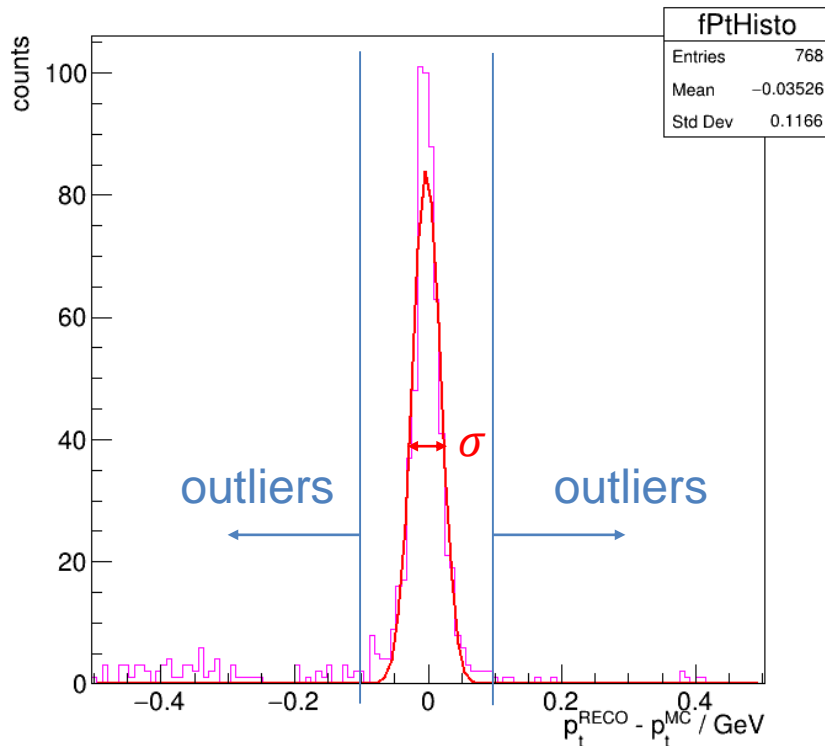
	Sigma [GeV]	Outliers [%]
No method (take "first" maximum)	0.04	14.3
Gauß error	0.03	10.9
Hough maxima	0.03	7.5
Sum of distances from hits to circle	0.02	2.0

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COMPARISON OF MAXIMUM SELECTION

p$_T$ resolution before merging

	Sigma [GeV]	Outliers [%]
No method (take "first" maximum)	0.04	14.3
Gauß error	0.03	10.9
Hough maxima	0.03	7.5
Sum of distances from hits to circle	0.02	2.0

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COMPARISON OF MAXIMUM SELECTION

CPU time of the algorithm

histoTime	
Entries	4
Mean	0
Std Dev	0

Gauß error is too time consuming

runtime [s]

250

200

150

100

50

0

XY, no selection method   RPhi, Gaus error   RPhi, Hough maxima   RPhi, distance to track

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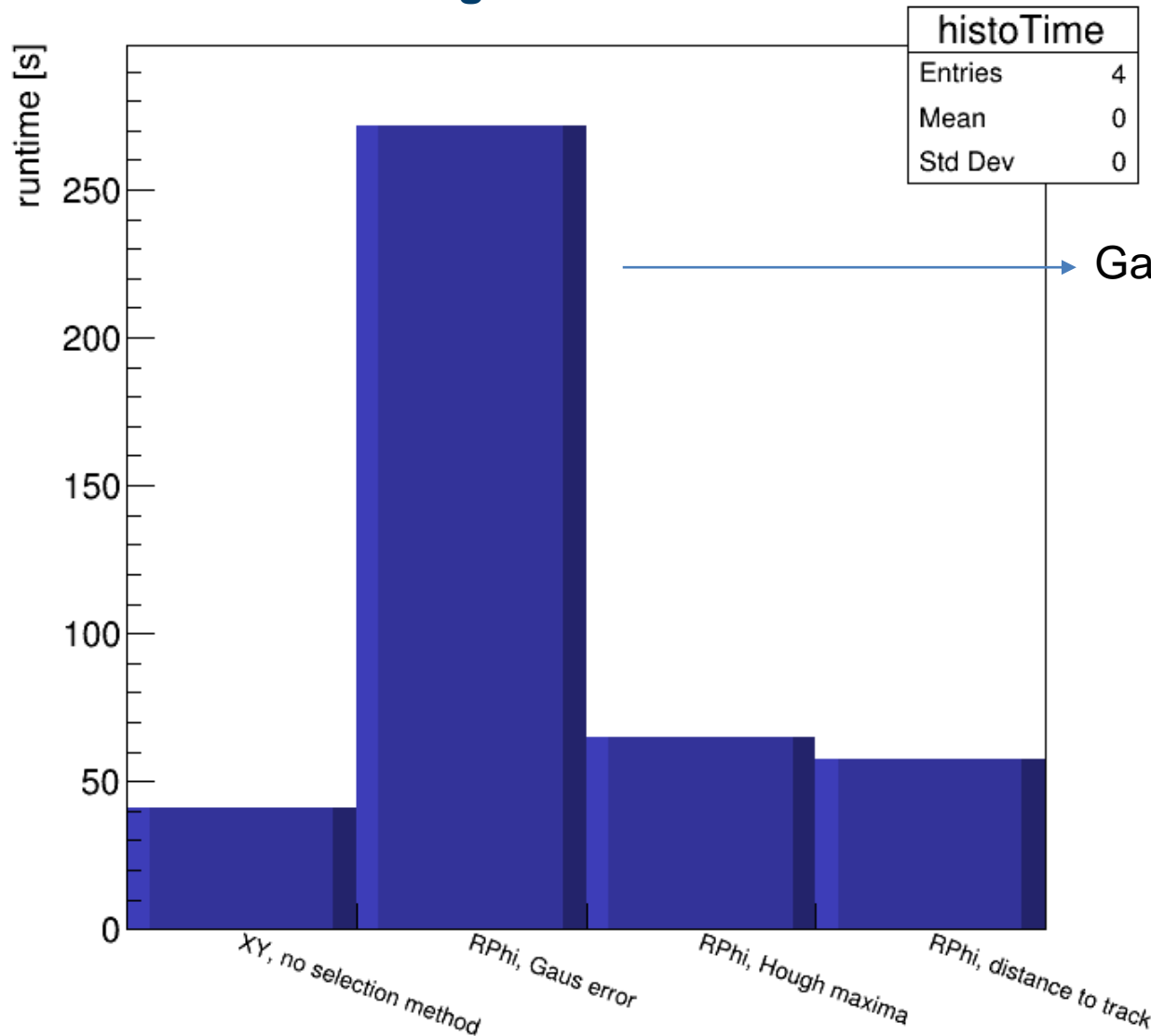
COMPARISON OF MAXIMUM SELECTION

CPU time of the algorithm
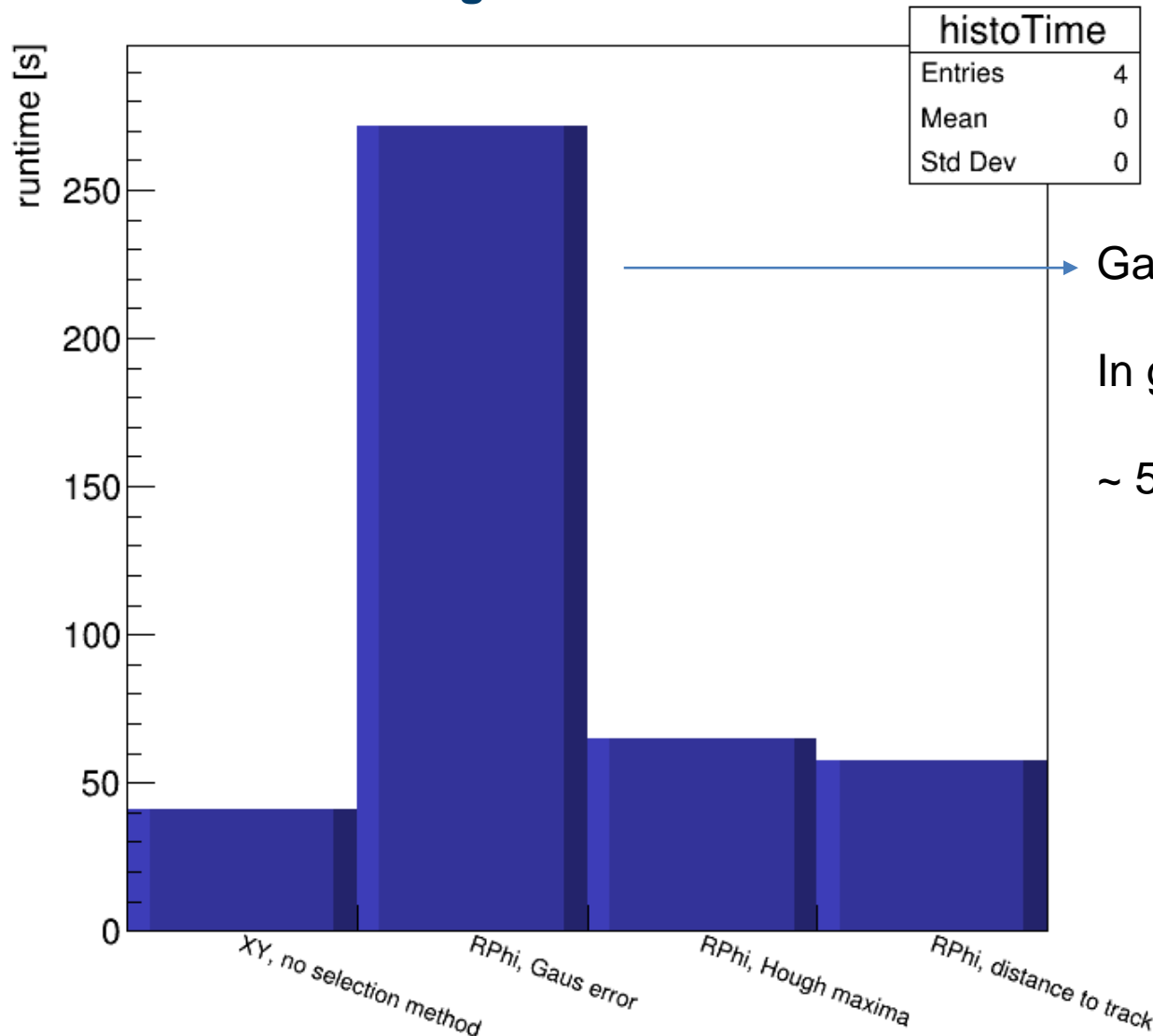
Gauß error is too time consuming

In general: algorithm is too slow:

~ 50 ms per event

Work in progress 🙂

COMPARISON OF MAXIMUM SELECTION

Quality parameters after merging

	Possible primaries [%]
No method (take "first" maximum)	97.0
Gauß error	97.0
Hough maxima	97.9
Sum of distances from hits to circle	97.1

Similar results

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COMPARISON OF MAXIMUM SELECTION

Quality parameters after merging

	Possible primaries [%]	Ghosts [%]
No method (take "first" maximum)	97.0	3.6
Gauß error	97.0	8.0
Hough maxima	97.9	3.2
Sum of distances from hits to circle	97.1	3.4

→ Much more ghosts

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COMPARISON OF MAXIMUM SELECTION

Quality parameters after merging

	Possible primaries [%]	Ghosts [%]	Clones [%]	
No method (take "first" maximum)	97.0	3.6	31.8	
Gauß error	97.0	8.0	39.0	⎫ More clones
Hough maxima	97.9	3.2	36.2	⎭
Sum of distances from hits to circle	97.1	3.4	29.7	

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COMPARISON OF MAXIMUM SELECTION

Quality parameters after merging

	Possible primaries [%]	Ghosts [%]	Clones [%]
No method (take "first" maximum)	97.0	3.6	31.8
Gauß error	97.0	8.0	39.0
Hough maxima	97.9	3.2	36.2
Sum of distances from hits to circle	97.1	3.4	29.7

$\longrightarrow$ Taken for comparison

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APPLY TO MORE REALISTIC DATA

- Data:
  - 1000 events
  - Beam momentum: 7 GeV
  - DPM background

- Used maximum selection method:
  - Sum of distances from hits to circle

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APPLY TO MORE REALISTIC DATA

Quality parameters after merging

Method	Ghost reduction	Possible primaries [%]
No method (take "first" maximum)	No	85.4
Sum of distances from hits to circle	No	88.1

→ Increase of 2.7 % points

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APPLY TO MORE REALISTIC DATA

Quality parameters after merging

Method	Ghost reduction	Possible primaries [%]	Ghosts [%]
No method (take "first" maximum)	No	85.4	30.1
Sum of distances from hits to circle	No	88.1	31.2

→ Increase of 1.1 % points

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APPLY TO MORE REALISTIC DATA

Quality parameters after merging

Method	Ghost reduction	Possible primaries [%]	Ghosts [%]	Clones [%]
No method (take "first" maximum)	No	85.4	30.1	24.8
Sum of distances from hits to circle	No	88.1	31.2	29.2

→ Increase of 1.1 % points

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APPLY TO MORE REALISTIC DATA

Quality parameters after merging

Method	Ghost reduction	Possible primaries [%]	Ghosts [%]	Clones [%]
No method (take "first" maximum)	No	85.4	30.1	24.8
Sum of distances from hits to circle	No	88.1	31.2	29.2

➜ Too many ghosts and clones
  ➜ Ghost reduction!

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GHOST REDUCTION

Summary:

Cut on parameters found by ROC analysis:
Example parameter: Number of hits in tracks consisting of only GEM hits
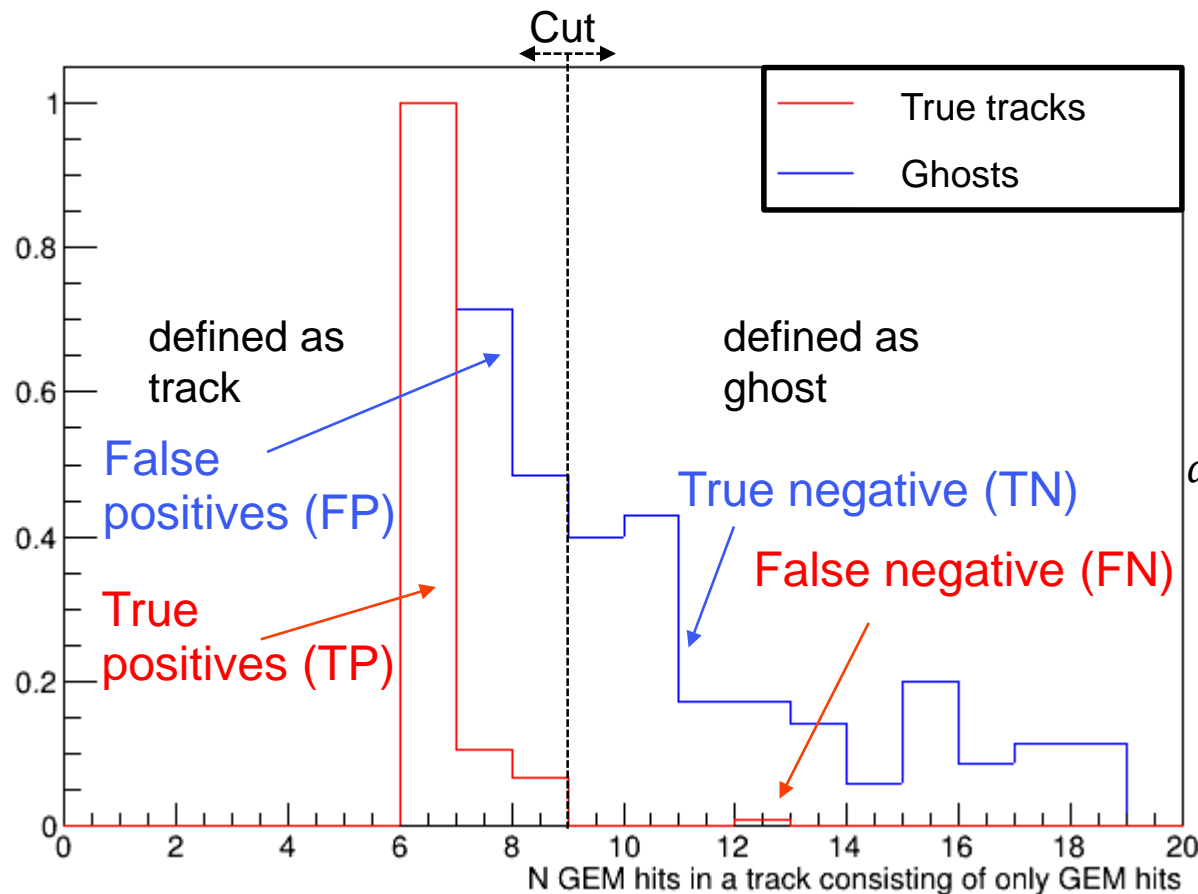
$$FPRate = \frac{FP}{FP + TN}$$

$$TPRate = \frac{TP}{TP + FN}$$

$$accuracy = \frac{TP + TN}{TP + TN + FP + FN}$$

GHOST REDUCTION

Summary:

Cut on parameters found by ROC analysis:

All Cut parameters:

- number of hits in track (GEM only tracks)
- number of STT neighbors (to reduce curling tracks)
- number of GEM neighbors (to reduce curling tracks)
- distance between hits (ghost tracks can contain hits from different regions)

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GHOST REDUCTION

Summary:

Cut on parameters found by ROC analysis:

All Cut parameters:
- number of hits in track (GEM only tracks)
- number of STT neighbors (to reduce curling tracks)
- number of GEM neighbors (to reduce curling tracks)
- distance between hits (ghost tracks can contain hits from different regions)

	Cut	Ghost reduction abs.[% points]	Efficiency loss abs. [% points]
Number of hits in track (Only GEM hits)	<= 8	16.2	3.6
Number of STT neighbors	<= 3.45	4.0	0.8
Number of GEM neighbors	<= 3	9.7	3.5
distance between hits	<= 4.1	6.9	2.4
All Cuts		16.2	3.6

APPLY TO MORE REALISTIC DATA

Quality parameters after merging

Method	Ghost reduction	Possible primaries [%]	Ghosts [%]	Clones [%]
No method (take "first" maximum)	No	85.4	30.1	24.8
Sum of distances from hits to circle	No	88.1	31.2	29.2
No method (take "first" maximum)	Yes	81.9	11.1	14.1
Sum of distances from hits to circle	Yes	83.2	9.4	12.8

➜ Improvement in all Quality parameters!

COMPARISON TO OTHER TRACKING ALGORITHMS

Use results from panda-wiki (data set 7 GeV/c beam momentum, DPM, Geant4):

TRACKING

Algorithm name	Attached Person	Platform	In PandaRoot?	Output PndObjects?	SVN?	Online?	Secondaries?	Barrel/Fwd	Used Detectors	Notes
PndTrkTracking2	Gianluigi	CPU	yes	PndTrack	yes	no	no	Barrel	MVD STT GEM	Main offline track finder
PndSttMvdGemTracking	Lia	CPU	yes	PndTrack	yes	no	no	Barrel	MVD-STT-Tracks with GEM hits	Combines Tracks in the STT and MVD with GEM hits. Runs after PndTrkTracking2 as standard.
BarrelTracker	Radoslaw Karabowicz	CPU	yes	PndTrack	yes	no	no	Barrel	MVD/STT/GEM	
Barrel Cellular Automaton	Ivan Kiesel	CPU	yes	PndTrack	yes			Barrel	MVD(Barrel) STT	Does not use the MVD disks

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COMPARISON TO OTHER TRACKING ALGORITHMS

Use results from panda-wiki (data set 7 GeV/c beam momentum, DPM, Geant4):

	Possible primaries [%]	Ghosts [%]
HoughTrackFinder	83.2	9.4
BarrelTracker	83.6	9.2
CellTrackFinder	70.7	10.1
PndTrkTracking2	66.2	4.8
Barrel Cellular Automaton	67.7	2.0

➔ For primaries already similar to BarrelTracker
➔ HoughTrackFinder can be expanded to secondaries

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SUMMERY

- Investigate methods to find the best maximum (Gauß error, Hough maxima, distance hits to track)

  - Distance hits to track: improvement in finding rate, ghost ratio and number of clones for DPM background

- Comparison to other Track Finder

  - Efficiency and Ghost ratio similar to BarrelTracker for primaries

  - Can be easily expanded to find secondaries

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Thank you for your attention!

BACKUP

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REDUCE NUMBER OF MAXIMA

- Comparison (DPM background 7 GeV beam momentum):
  - Merging parameters: dA = 0.48 % , d = 8 cm, dPhi = 20.1° lead to best accuracy for all methods

	Accuracy	Correctly merged	Wrongly merged	Correctly not merged	Wrongly not merged
x-y first maximum	87.9	49.2	1.6	98.4	50.8
Distance of maxima between hough spaces	86.4	54.7	2.1	97.9	45.3
Sum of distances hits to circle	89.2	54.3	1.6	98.4	45.7

➔ improved Merging (correctly merged) by 5.1 percent points

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