Data Reduction for the Pixeldetector at Belle II

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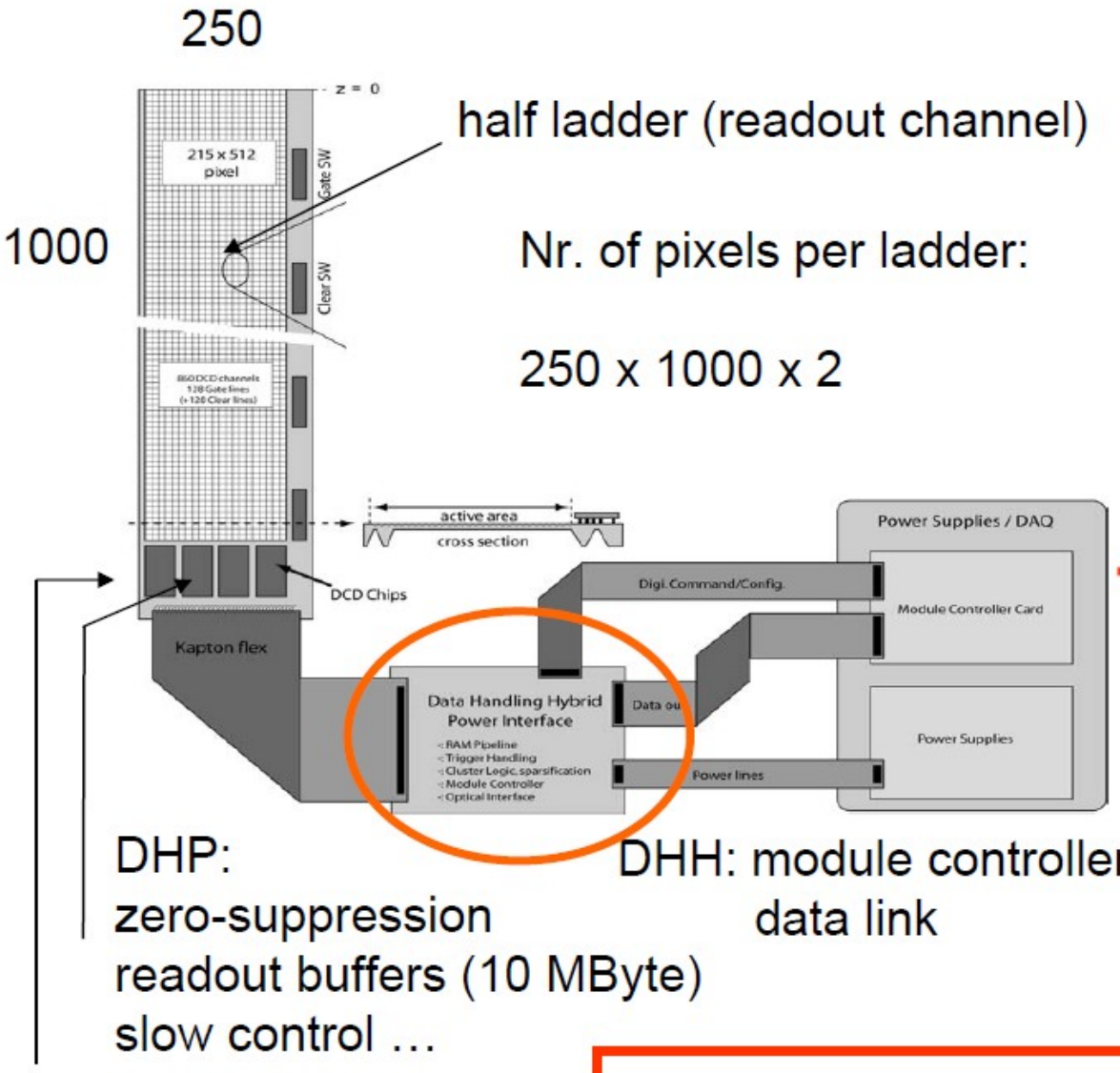
Why Data Reduction?



half ladder (readout channel)

Nr. of pixels per ladder:

250 x 1000 x 2

- 40 half ladders:
  10 Million pixels (px)
- 1-2% occupancy (?)
- 200 kpx on at any time
- → 2 x 10^5 px in each event
- 4 bytes per px (pos + ADC)
- 800 kB/event

DHP:
zero-suppression
readout buffers (10 MByte)
slow control …

DHH: module controller
data link

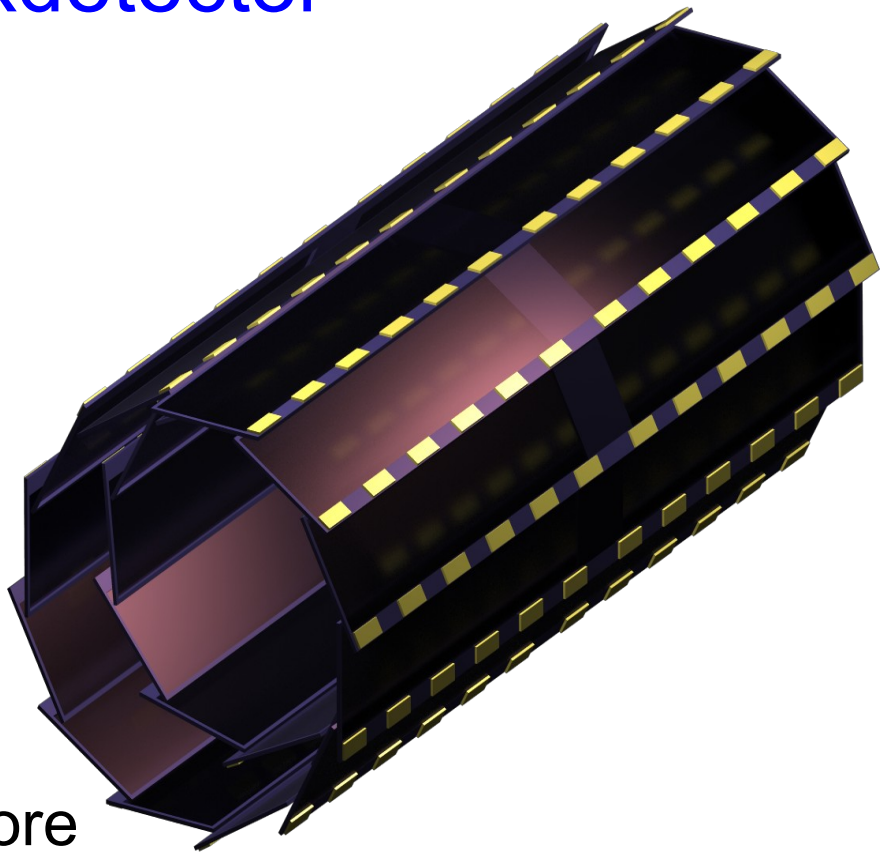
Digitzation (DCD)

Total evt size: ~ 1 MByte

possibly lossless
Data Compression
(clustering):

⟶ ~ factor 2

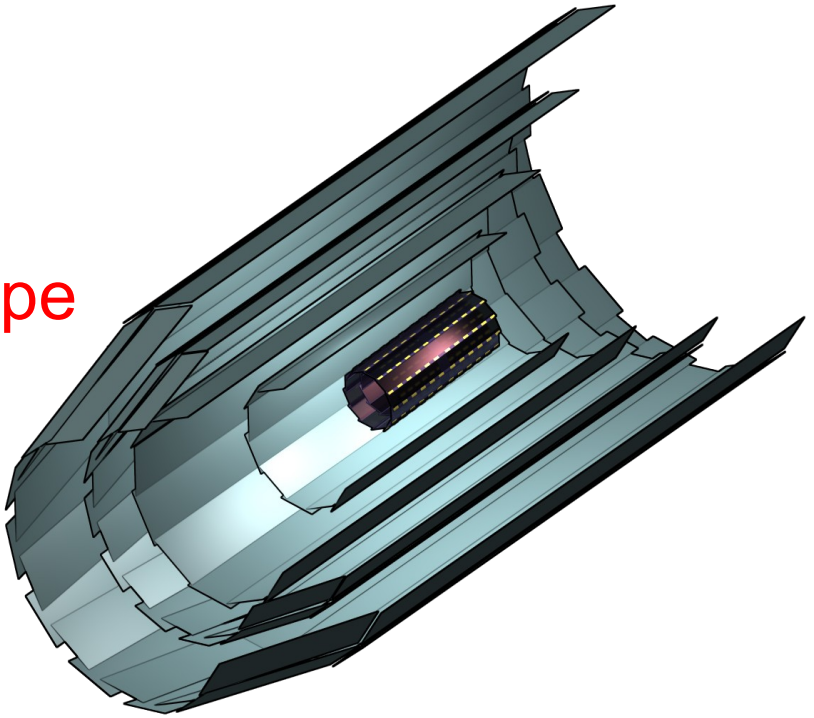
PXD: Pixelvertexdetector



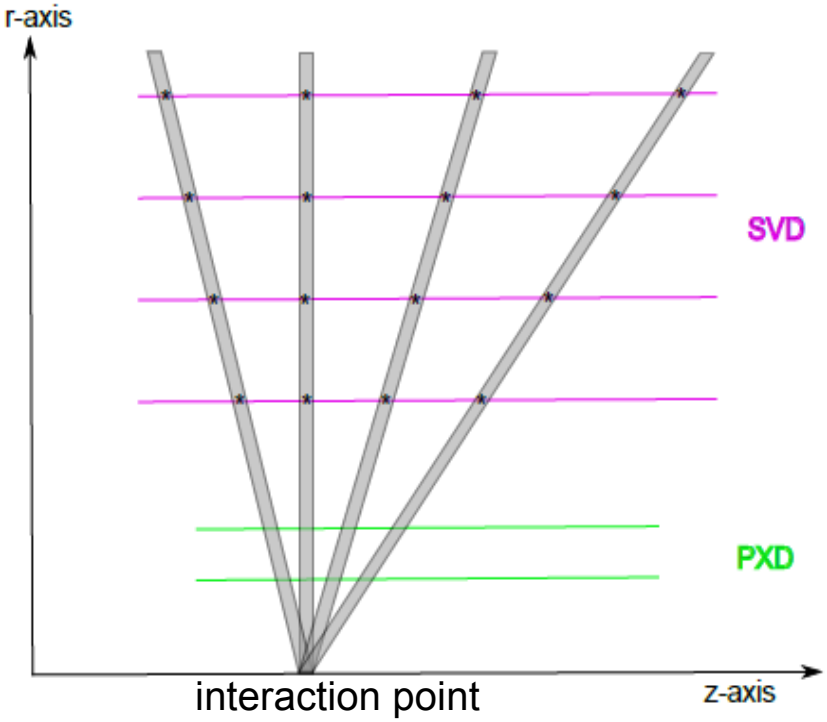
- Beampipe R = 10 mm (nano beam)
- PXD: 2 layer Si pixel detector
  R = 13 mm, 22 mm
- data will be integrated over 10-20 µs
- high amount of background
- expected datarate: 1 MByte/event
- PXD produces about a factor of 10 more data than the entire rest of Belle-II
  -> online data reduction mandatory
- aim: reduce data amount by at least 90 %

Idea

online data reduction before going on tape



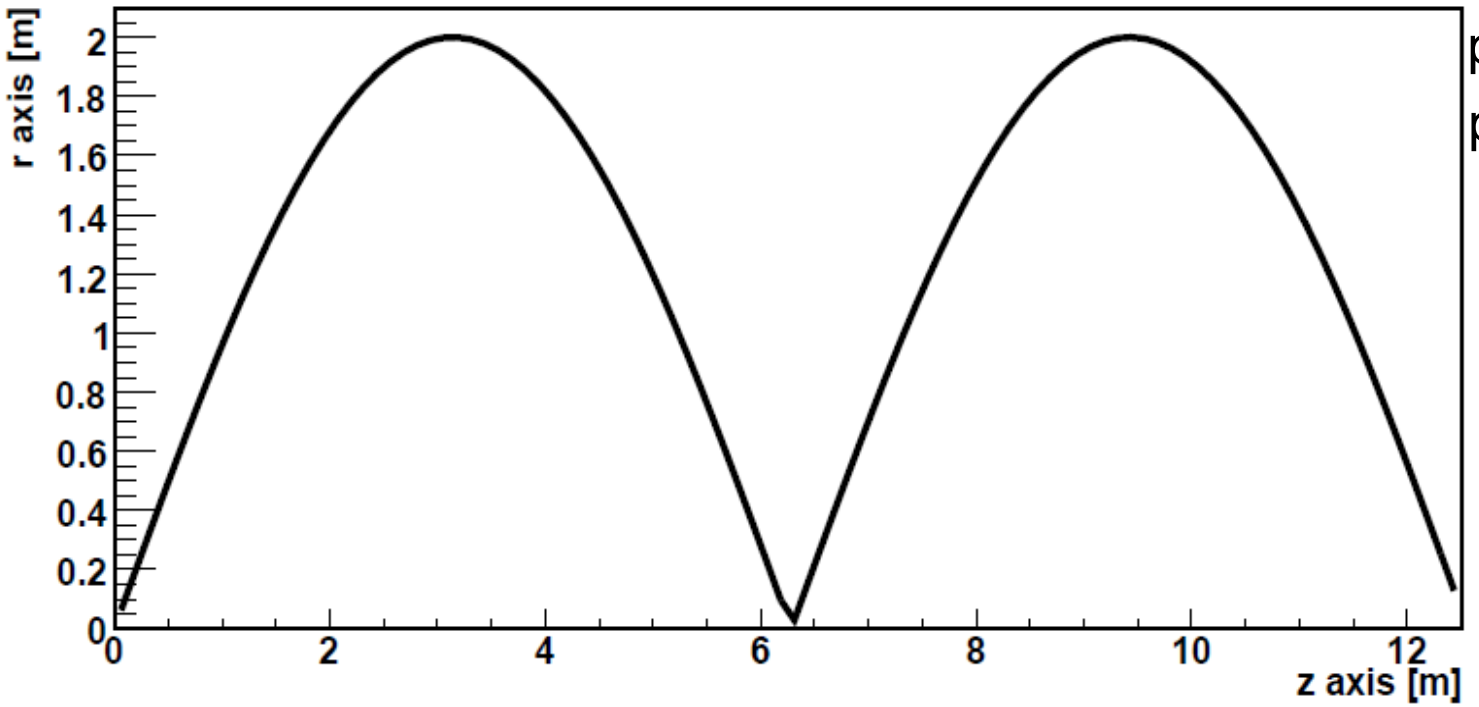
- use SVD data
- SVD: 4 layer Si strip detector (R = 38, 80, 115, 140 mm)
- low occupancy



- z-r-projection of SVD hits
- fast pattern recognition with 2D SVD-only Tracking
- build roads in z-r-space through PXD
- keep only interesting PXD data

How does a Helix look in z-r-projection?

- $r = |a \sin(b\,(z-z_0))|$ $\qquad a = \frac{2 \cdot p_T}{q \cdot B} \qquad b = \frac{q \cdot B}{2 \cdot p_L}$
- can be approximated by a straight line for high momentum particles (p > 250 MeV)

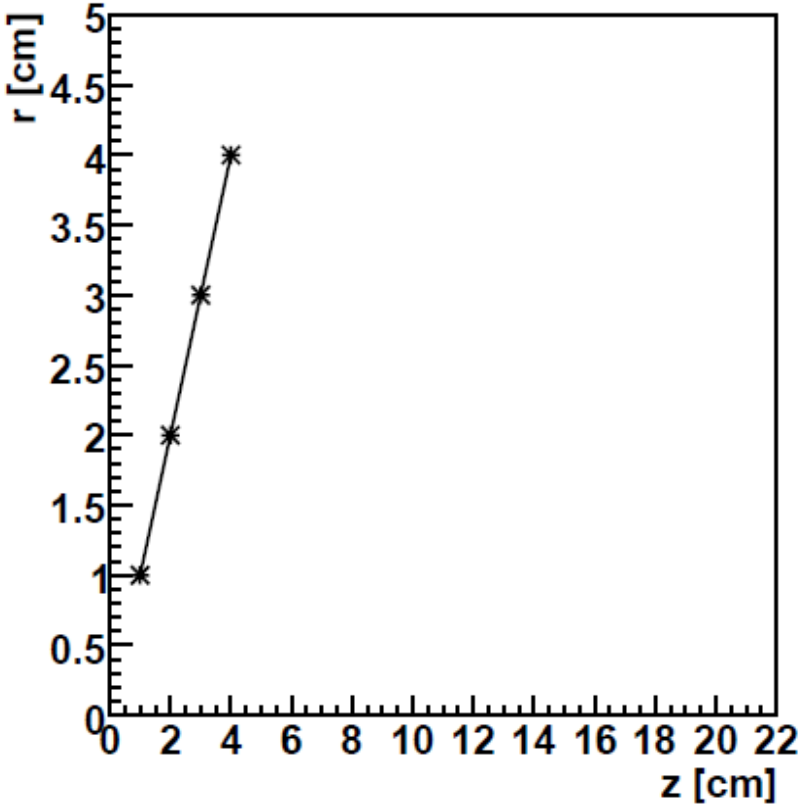


p_T = 450 MeV
p_L = 450 MeV
p = 636 MeV

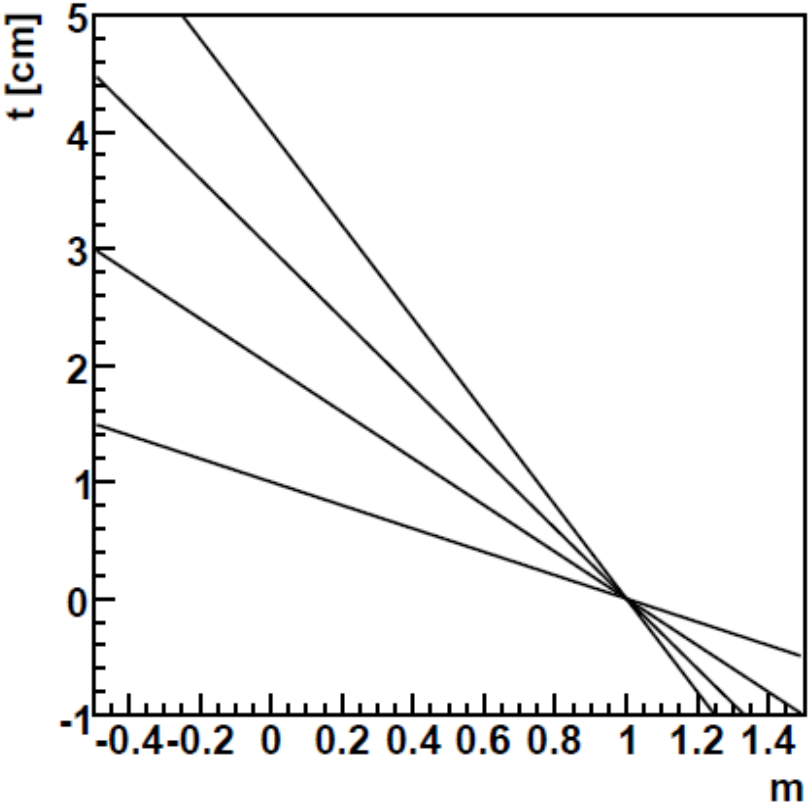
Fast Pattern Recognition: Hough-Transform

- line: r = m z + t
- Hough transform: t = r – m z

z-r-space



Hough space



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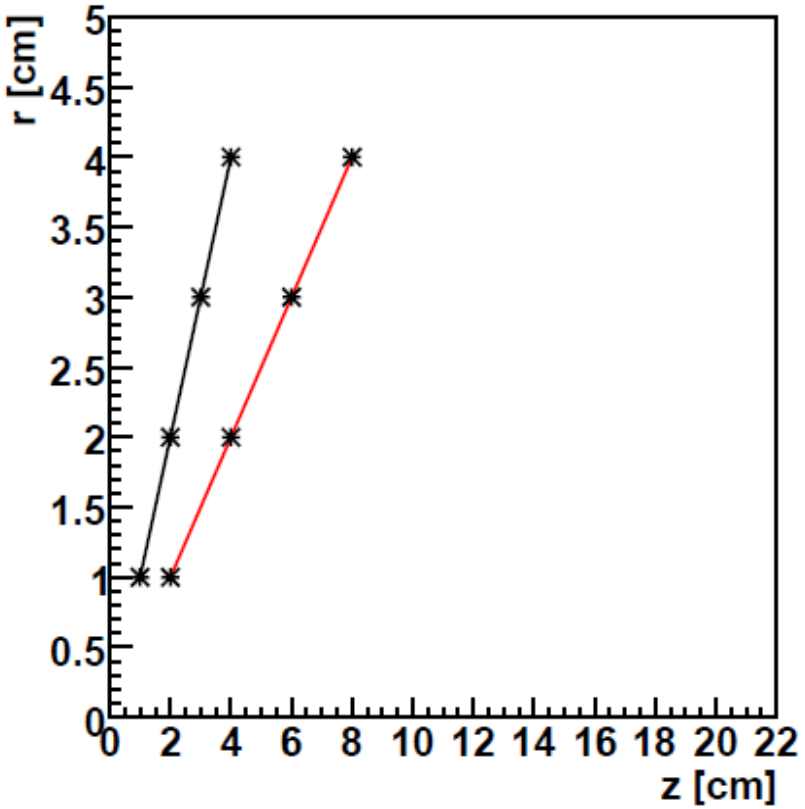
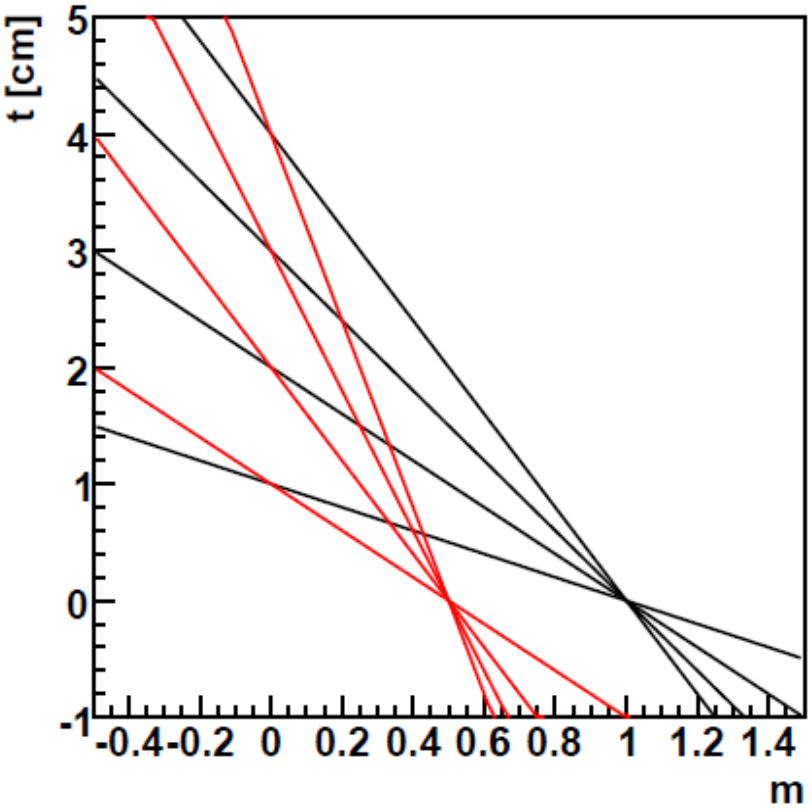


Hough space



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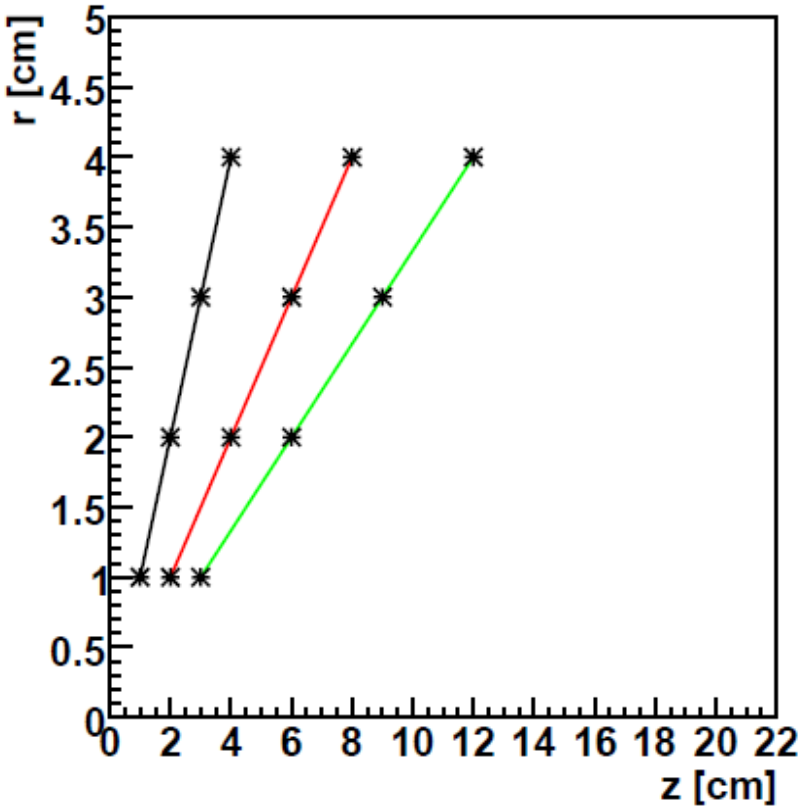

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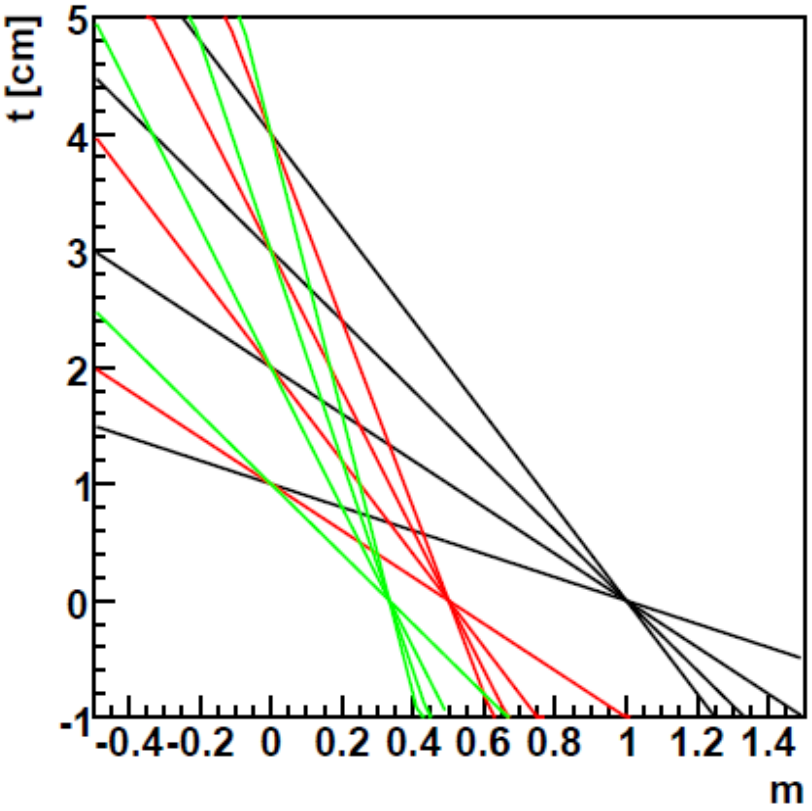

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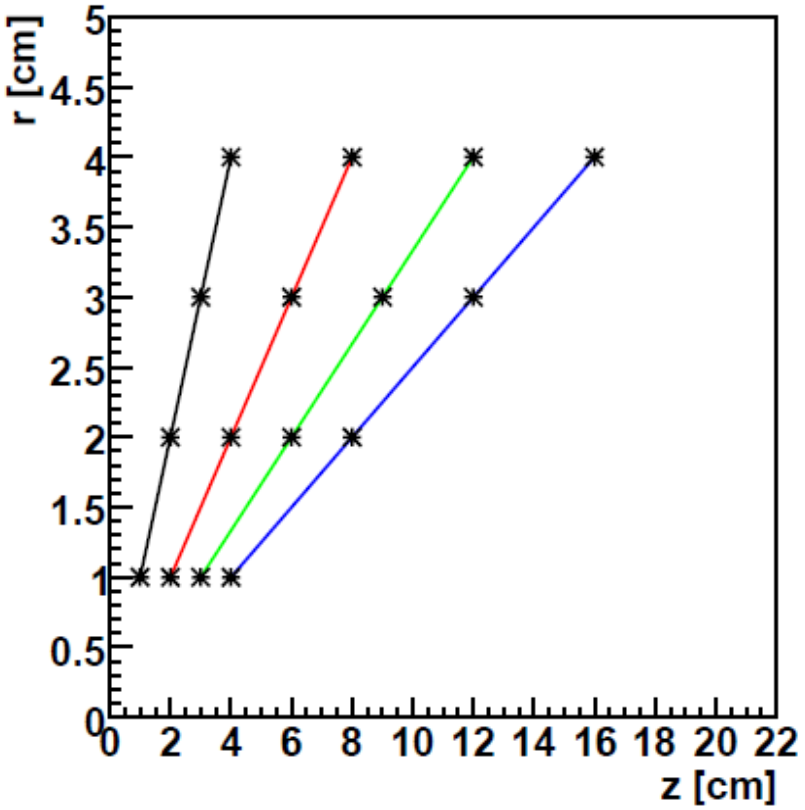
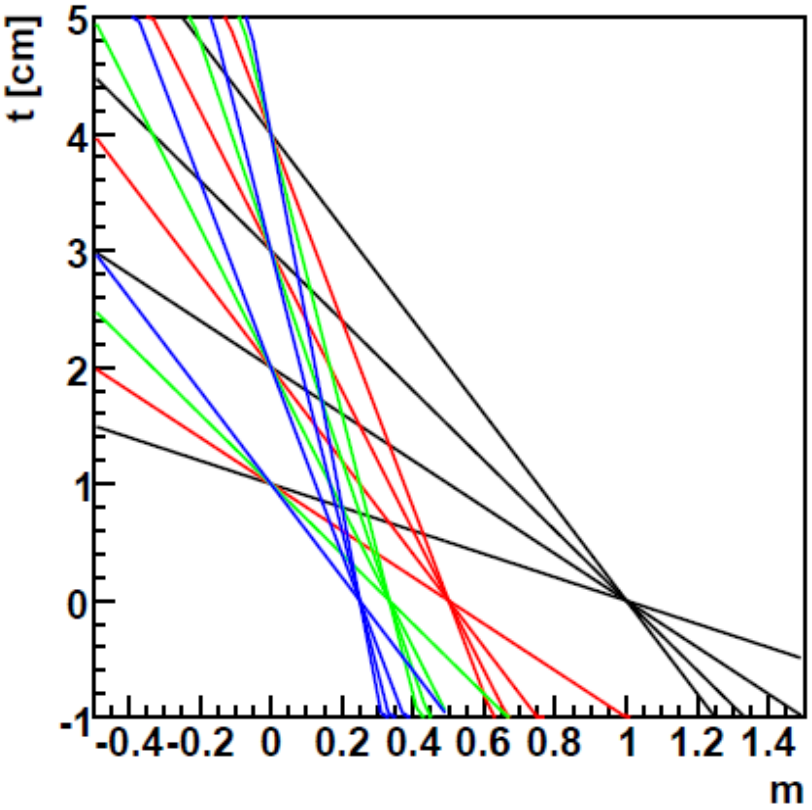


Hough space



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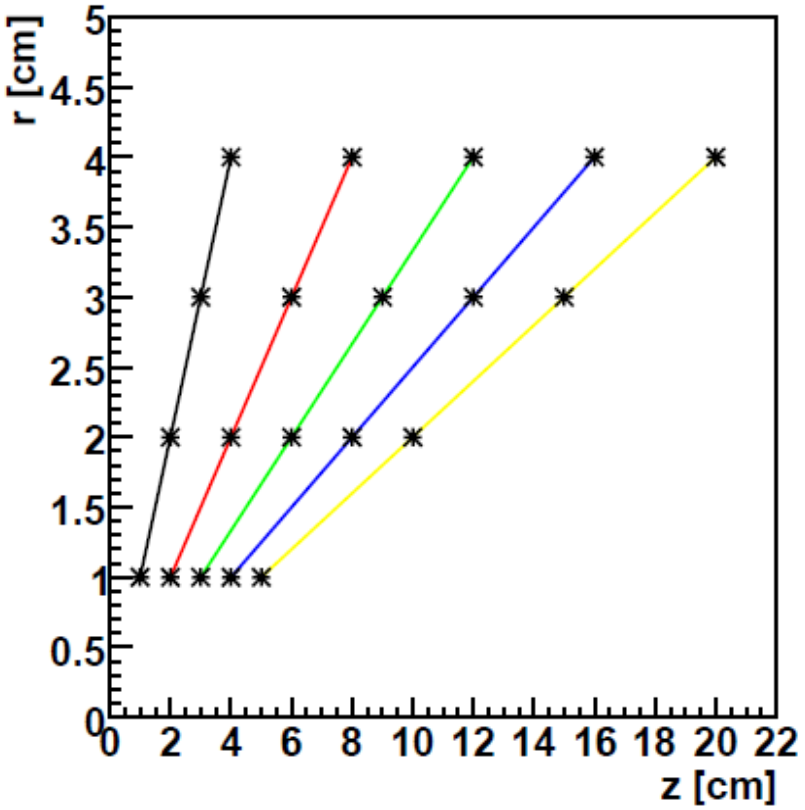
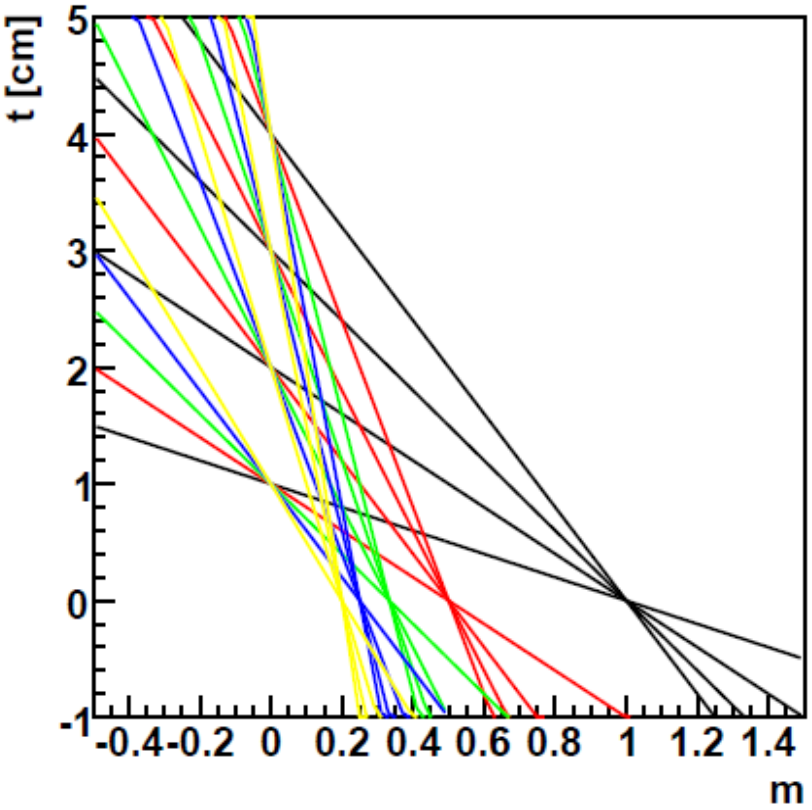
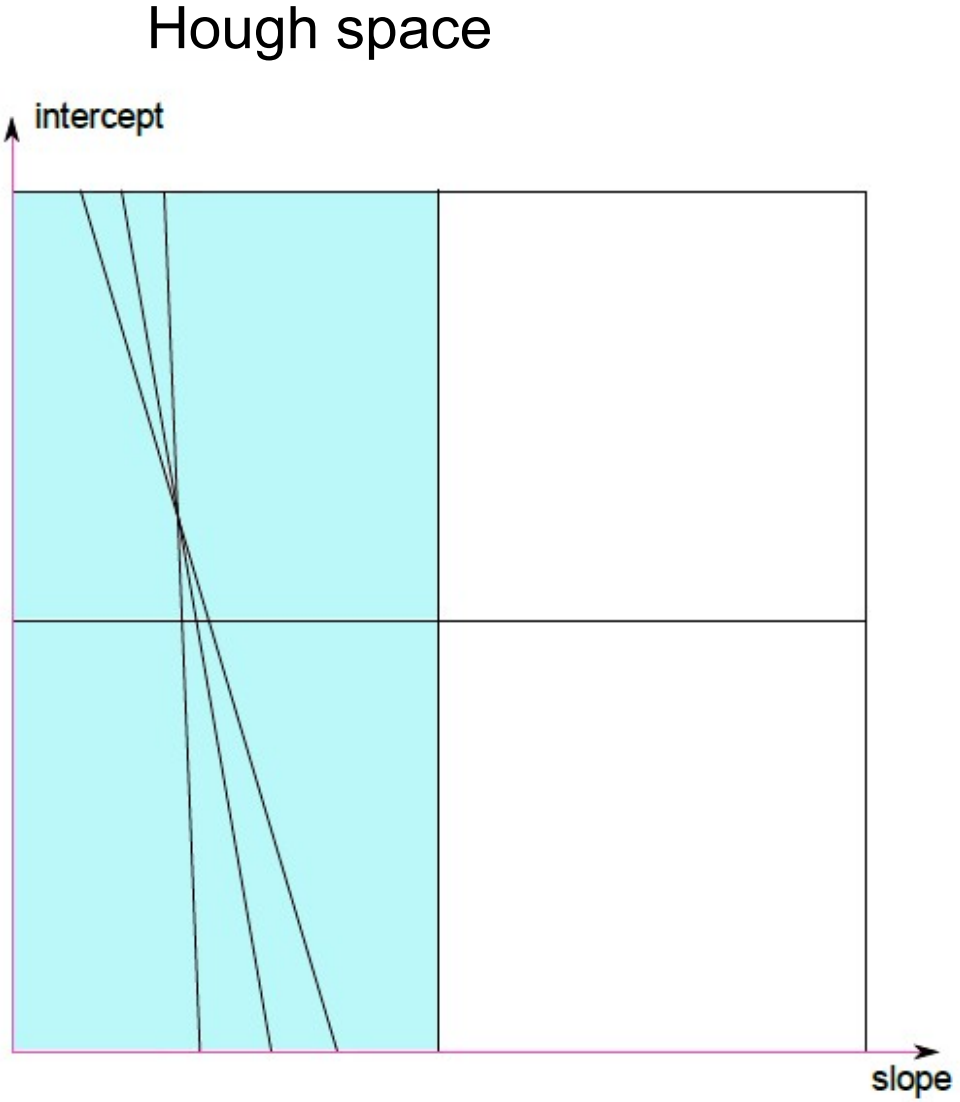


Hough space



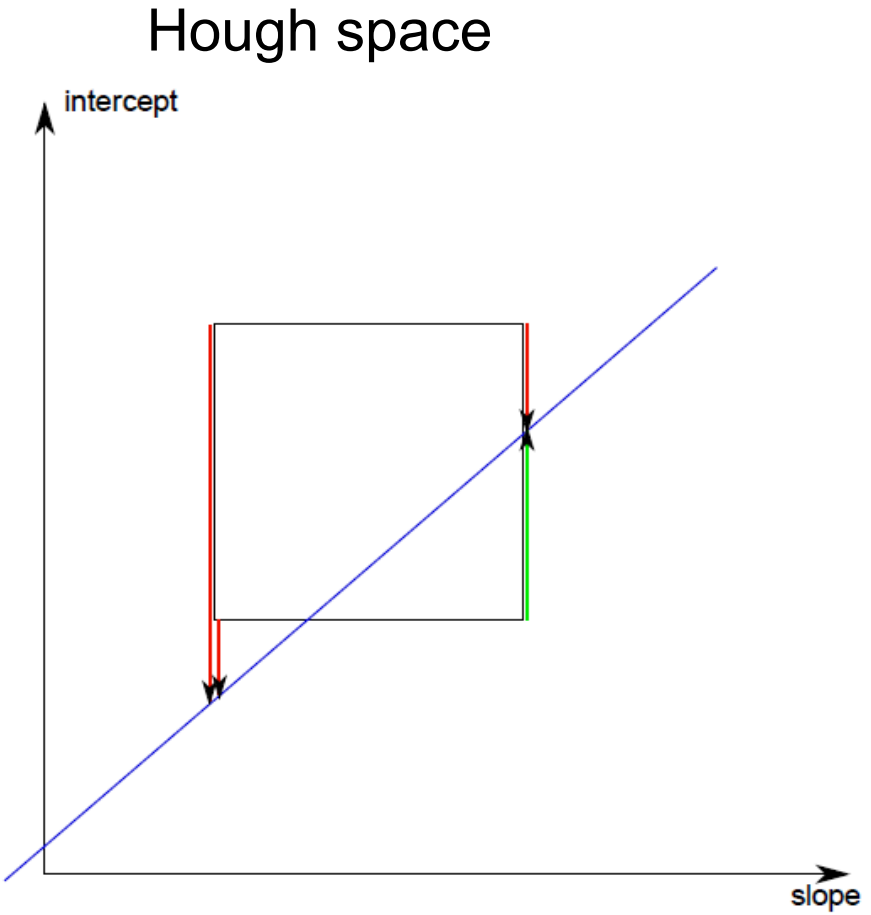
Fast Peak Finding in Hough Space

- divide relevant Hough space by 2 for each axis
- calculate the number of lines in each rectangle
- keep only rectangles containing at least 3 lines
- repeat steps with remaining rectangles



Lines in the Rectangle

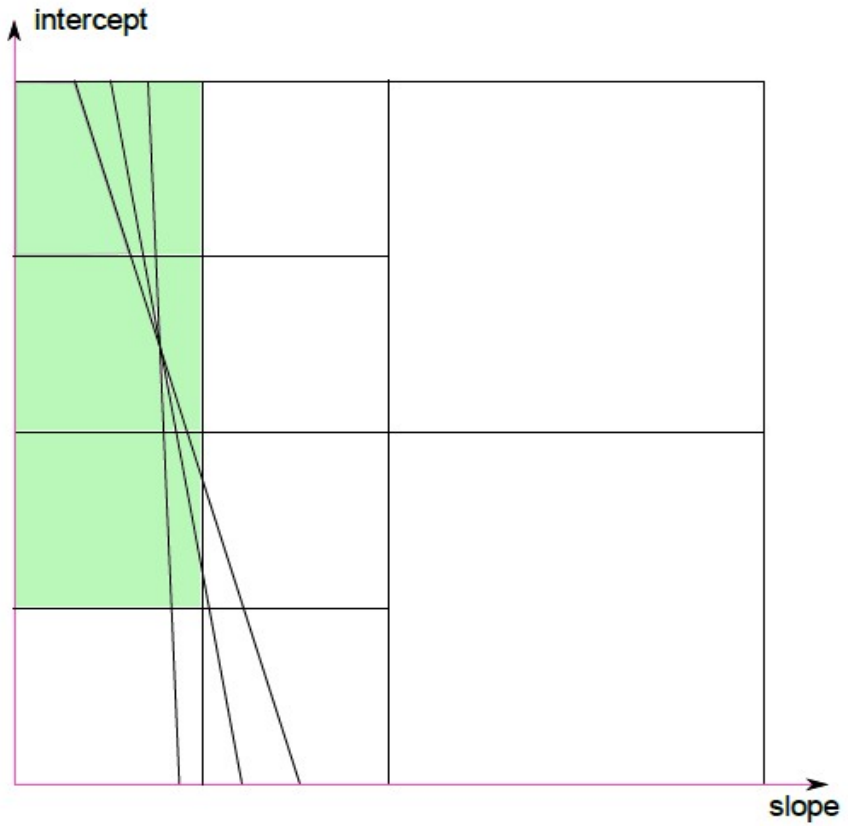
- evaluate difference between rectangle corners and values of the Hough transformed point at the corresponding coordinates
- scan for sign change
- when a sign change occurs the line intersects the rectangle



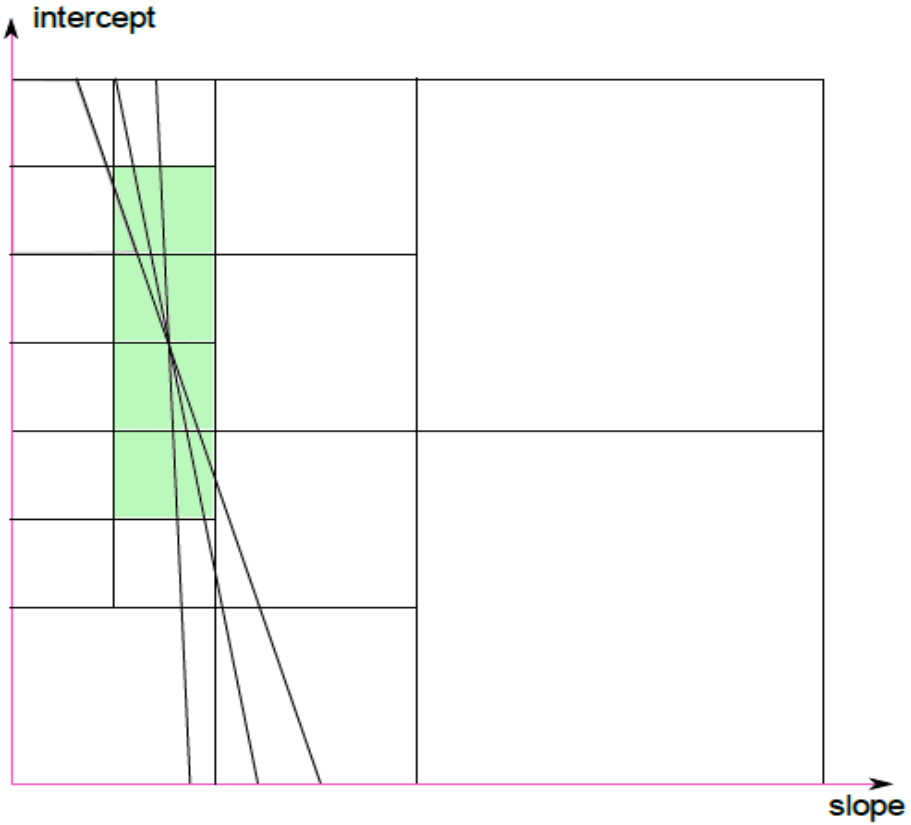
Fast Peak Finder

Repeat steps with remaining rectangles

Iteration 2

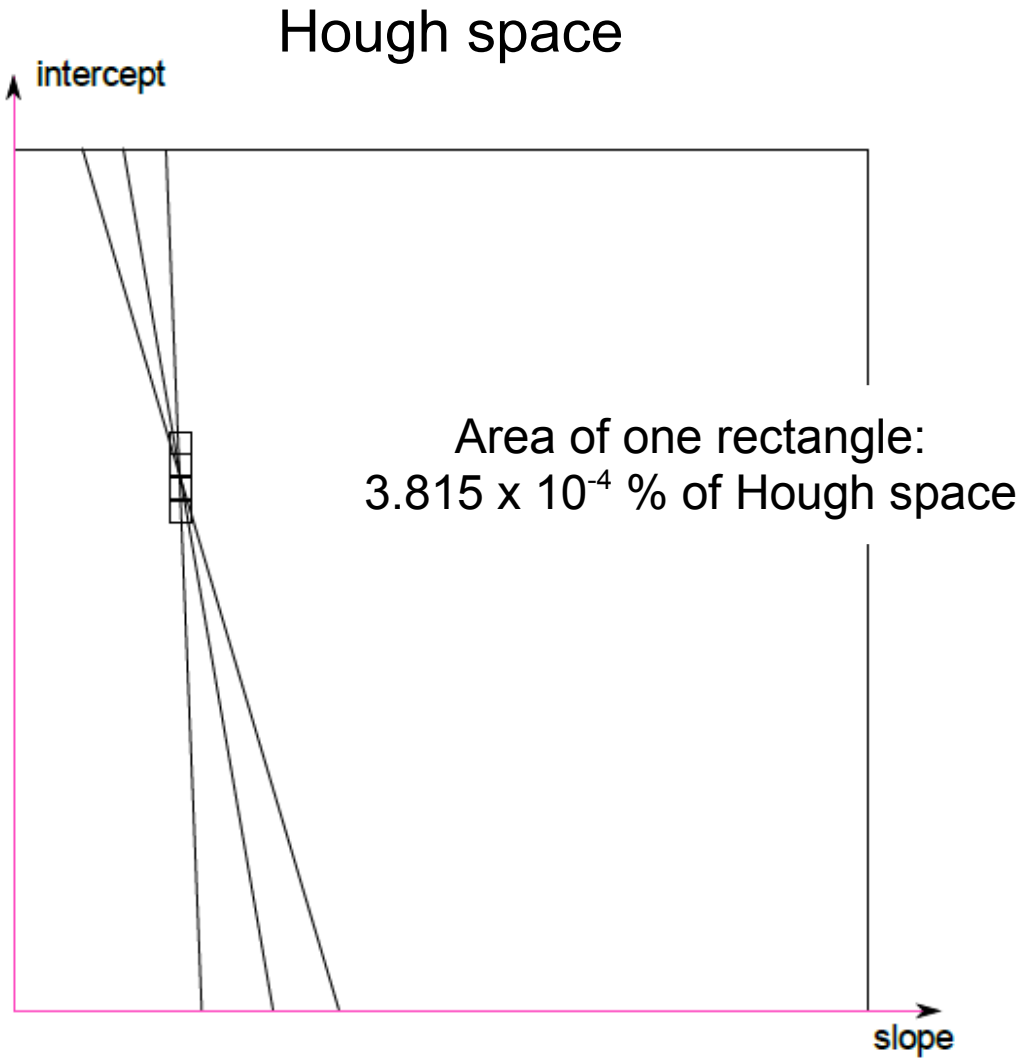


Iteration 3



Fast Peak Finder

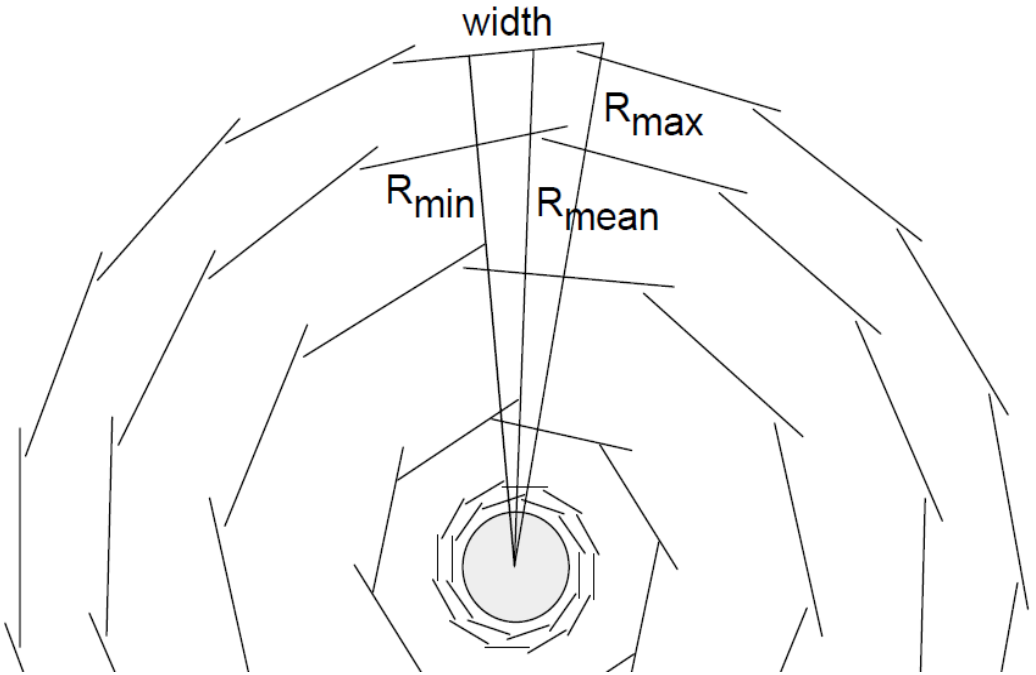
- after 9 iterations only a few small rectangles are left
- parameters at the center of a rectangle
- transform back to imagespace
- width & height of box determine errors
- width of the roads 0.3 - 0.8 mm



SVD Data

- Idea: use only z-information of SVD and a mean Radius of the SVD ladder
- SVD geometry has been changed
- Ladder width is too big
- also use r-information
- disadvantage: ghost hits

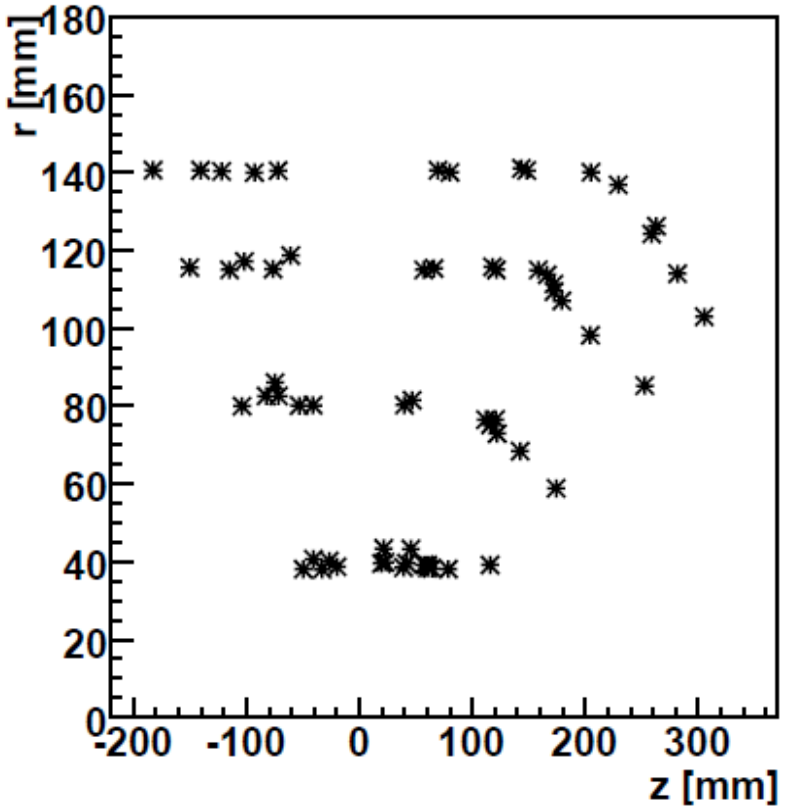
r-phi-view



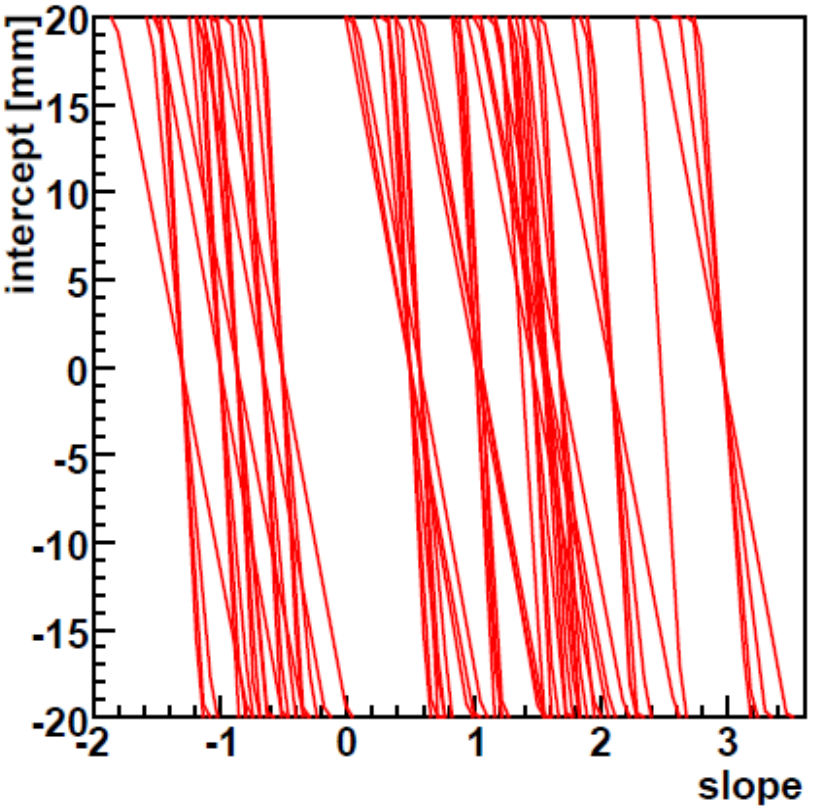
Example: SVD Hits & Hough Space

14 tracks (μ+) with momentum
of 900 MeV starting at the origin

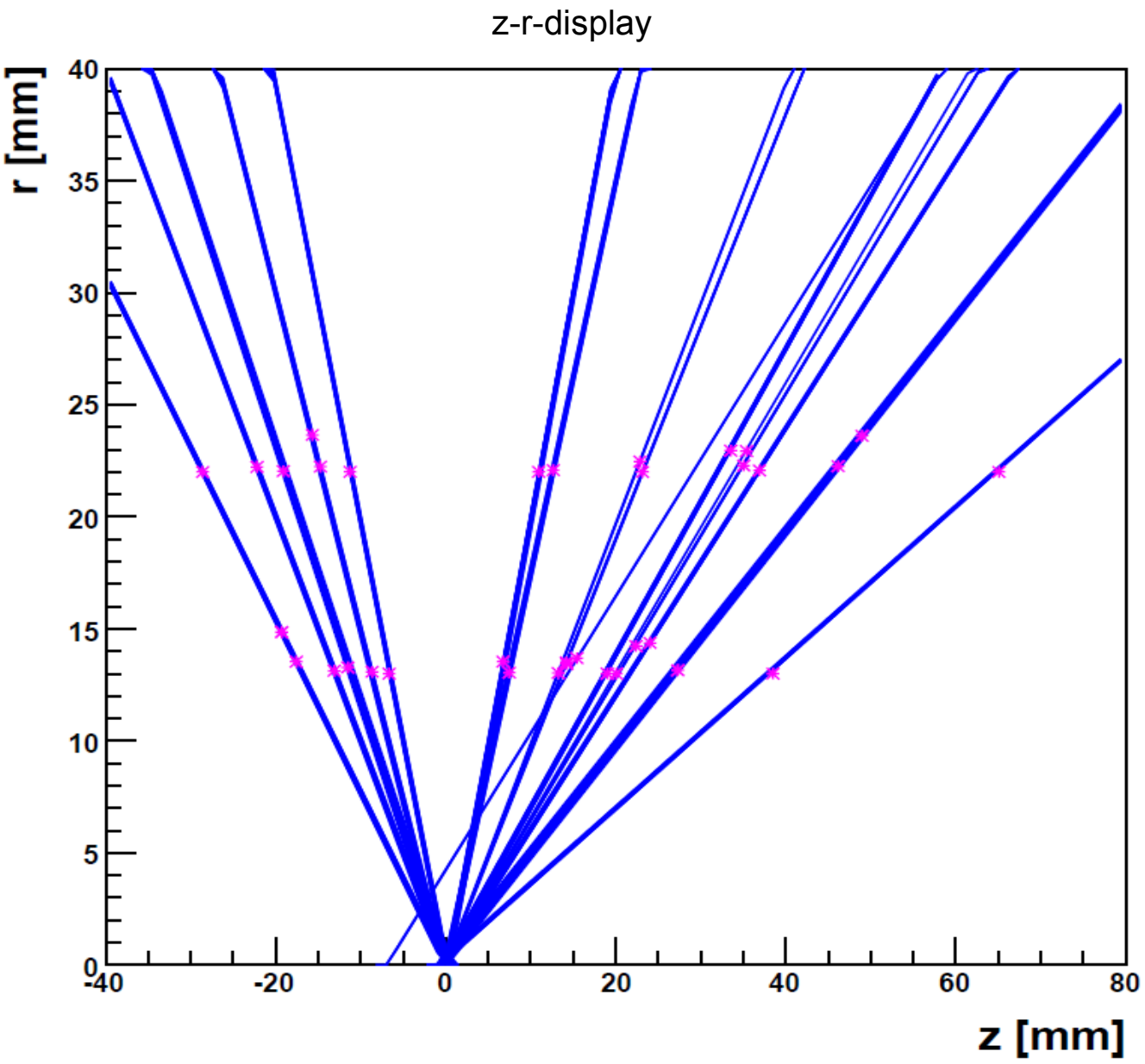
SVD hits in z-r-projection



Hough space



Example: Reconstructed Tracks & PXD Hits



14 μ+ p = 900 MeV

pink: PXD hits

blue: reconstructed tracks

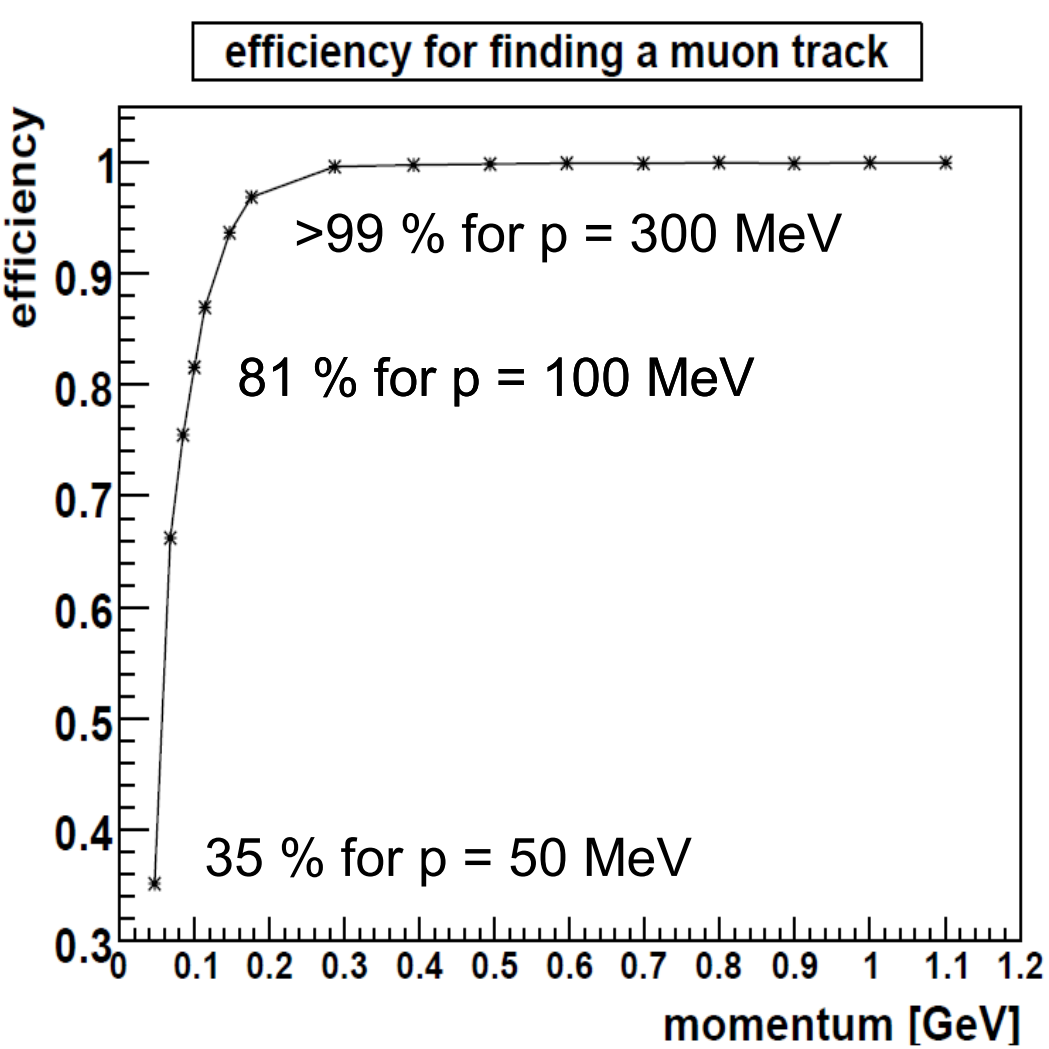
Reduction of PXD volume to ~ 30 %

⟶ sectors in r-phi factor ~ 1/15

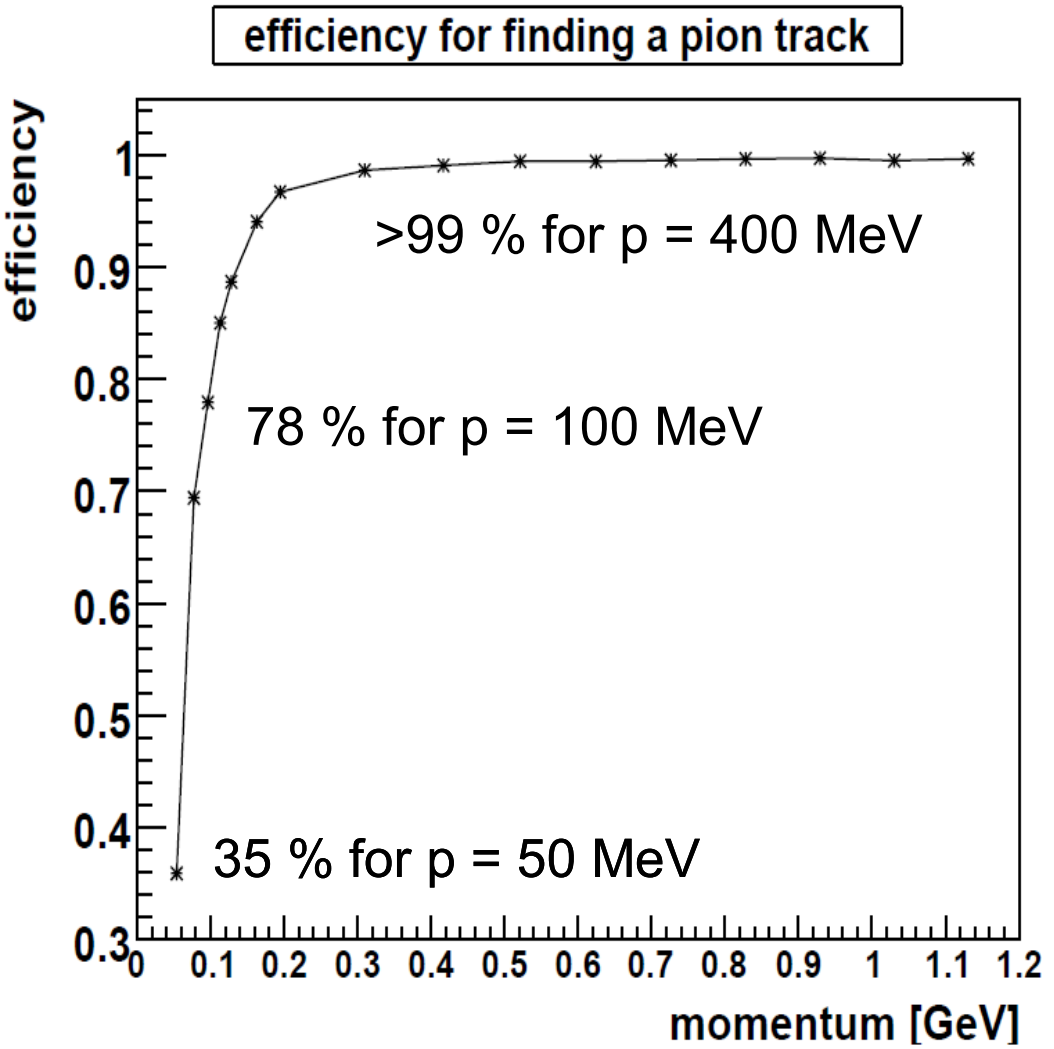
Estimated Reduction of PXD volume to ~ 2 %

Efficiency

single muons



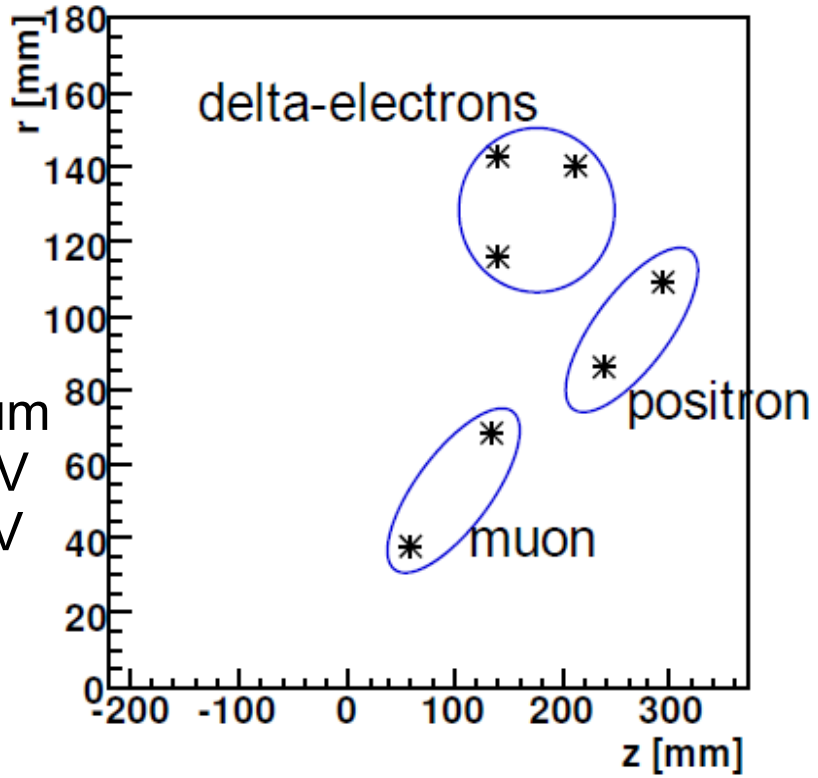
single pions



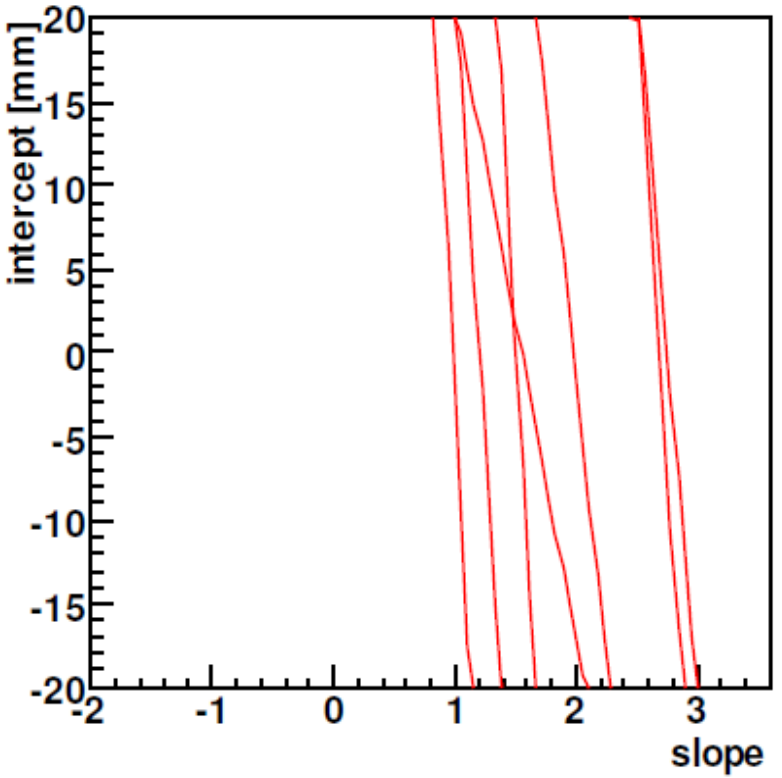
Why does the efficiency go down for low momentum?

- Particles curl within the SVD (p_T < 63 MeV)
- Line approximation of the sine curve fails
- multiple scattering in detector material
- particles decay within SVD

μ+ momentum
p = 100 MeV
p_T = 55 MeV

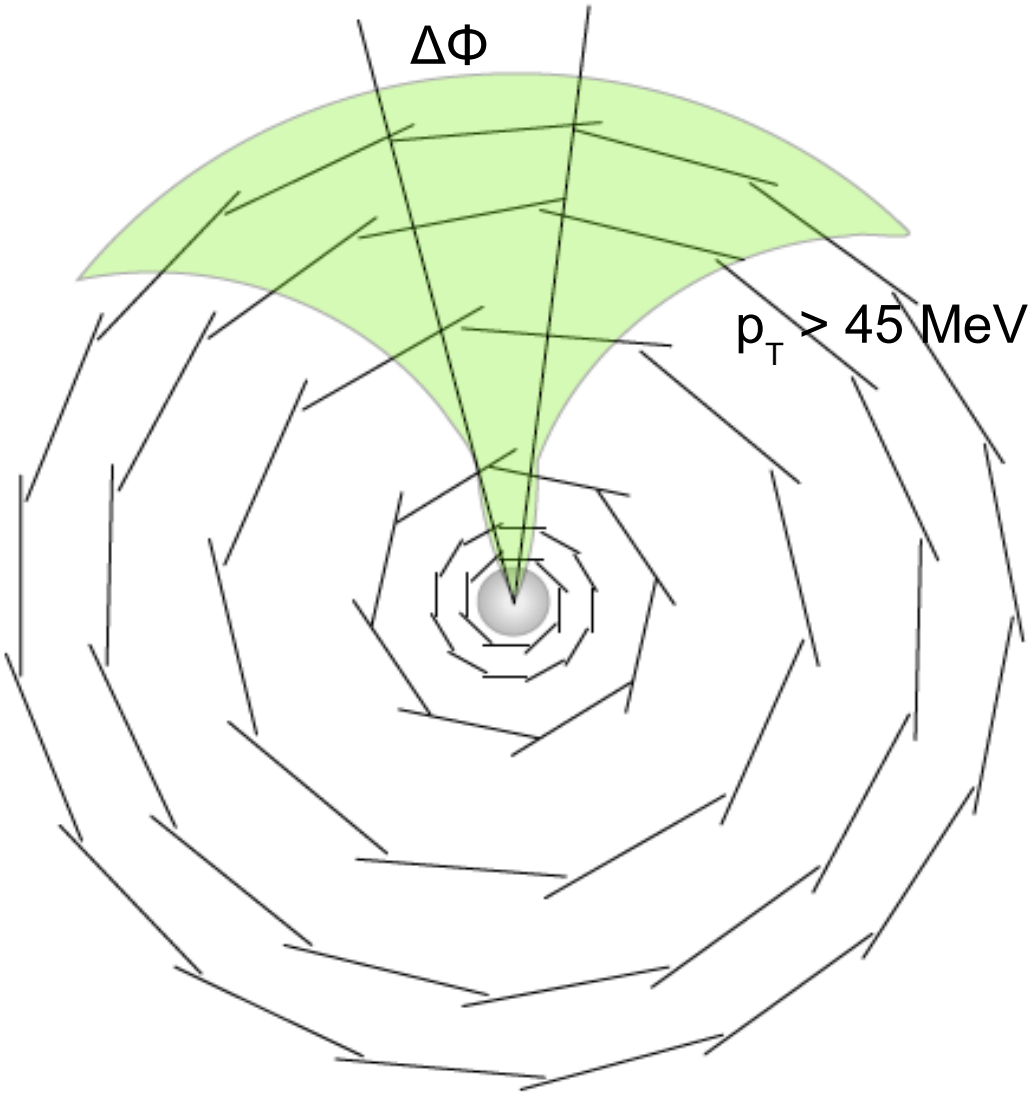


Hough space



Sectors in r-phi

- Reduce number of hits to be hough-transformed
- Decrease readout area for each road
- Shape corresponds to a p_T- cut
- 17 sectors rotated by ΔΦ
- Sectors can be computed in parallel



Conclusion

- PXD data need to be reduced (10 times the size of all other data in Belle II)
- Fast algorithm using SVD data propsed
- Initial studies with Hough-transform encouraging
- Find solution for low momentum particles (p< 250 MeV) !
- ready to start detailed MC studies
- Background studies planned
- Implementation in FPGA or GPU intended (data transfer needs to be studied)