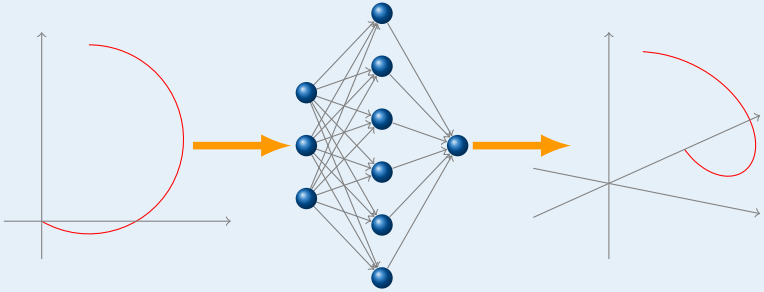
Track vertex reconstruction with neural networks at the first level trigger of Belle II

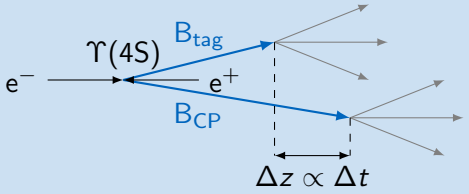
Ringberg Young Scientist Workshop 2017

July 19, 2017



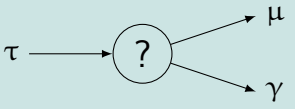
Sara Pohl
Sebastian Skambraks, Christian Kiesling, Steffen Bähr

Task for the first level trigger



- time dependent CP violation in $B\overline{B}$
- typically $\approx 3 - 9$ tracks

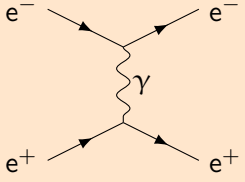
low track multiplicity: $e^+e^- \to \tau^+\tau^-$



- lepton flavor violation
- genuine 2 track trigger

max. trigger rate 30 kHz
total latency 5 µs
pipelined, FPGA

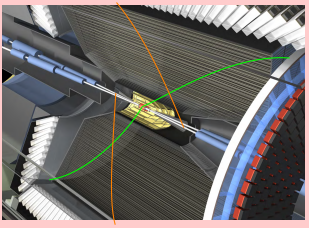
Bhabha scattering



- for calibration
- needs to be prescaled
- Bhabha veto

machine background

- z-vertex $\neq 0$
- suppression requires 3D tracking



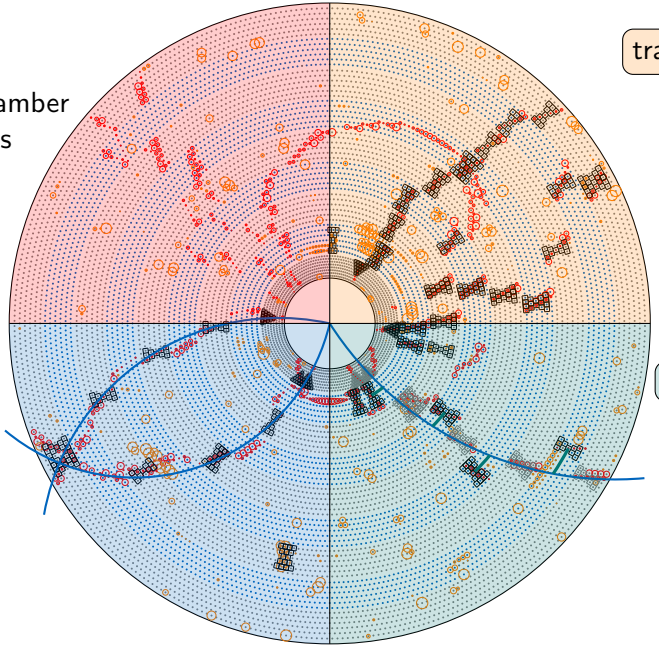
Track trigger – overview

input: CDC hits

Central Drift Chamber
14336 sense wires
56 layers

track segment finder

combine hits
2336 segments
9 super layers



2D track finder

circles in
$x - y$ plane
Hough transform

3D reconstruction

2 methods:
neural network
least squares fit

Track trigger – input

input: CDC hits

Central Drift Chamber
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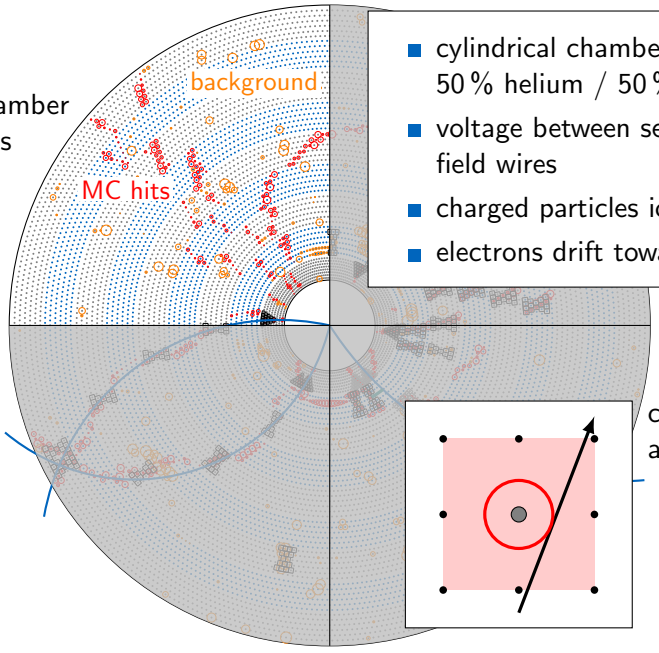


- cylindrical chamber filled with 50 % helium / 50 % ethane
- voltage between sense wires and field wires
- charged particles ionize gas
- electrons drift towards sense wires

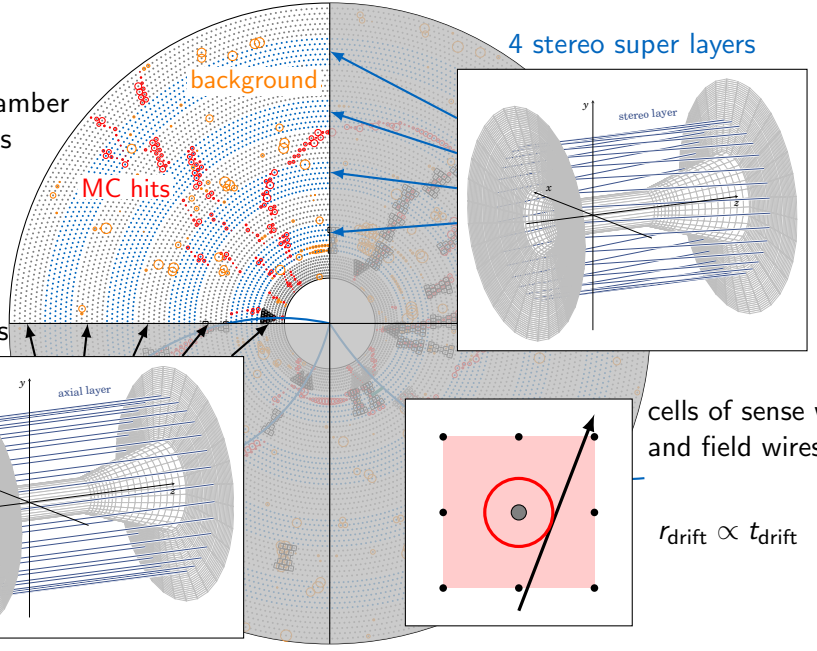
cells of sense wires and field wires

$r_{\text{drift}} \propto t_{\text{drift}}$

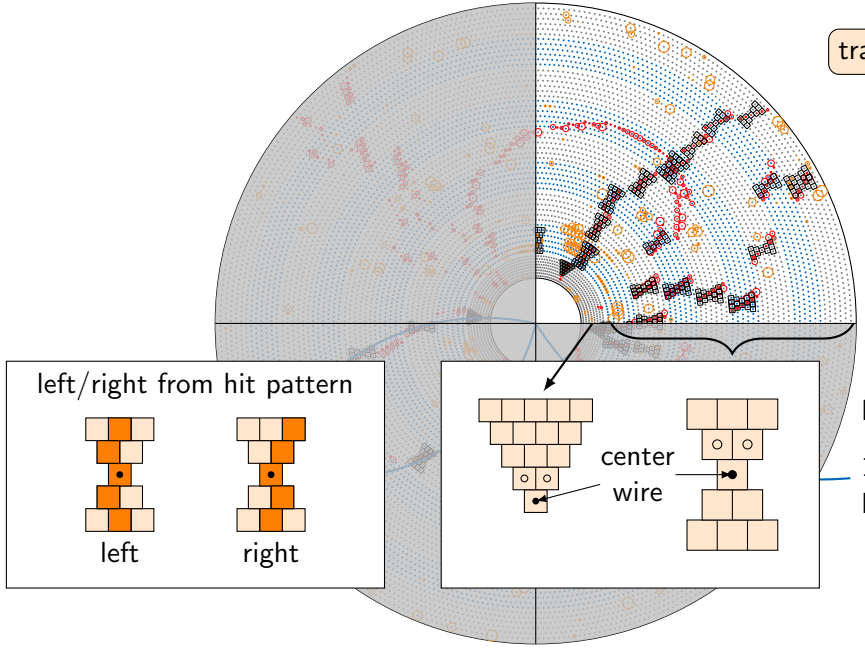
Track trigger – input

input: CDC hits

Central Drift Chamber
14336 sense wires
56 layers



Track trigger – track segment finder



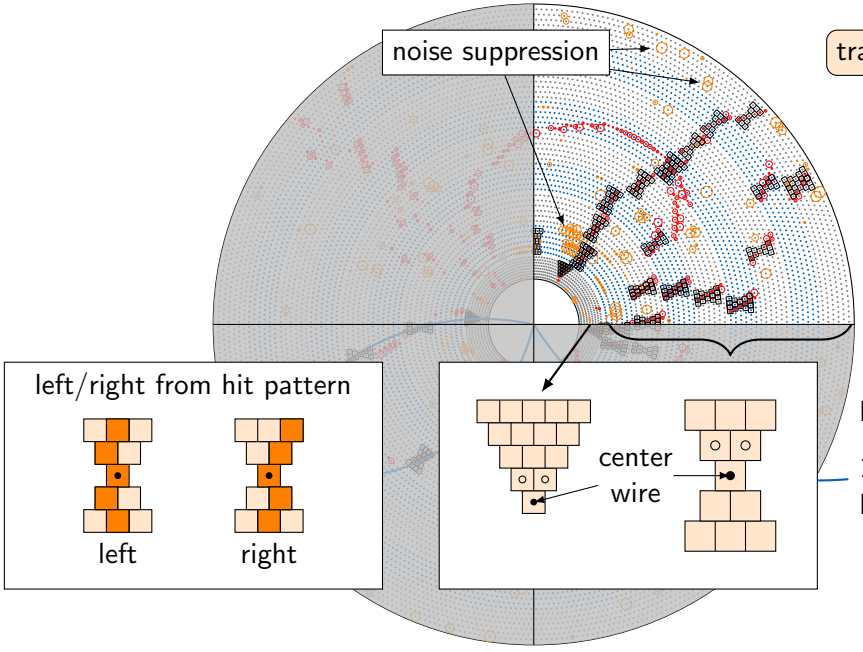
track segment finder

combine hits
2336 segments
9 super layers
→ "layers"

hits in ≥ 4 layers

1 t_{drift} value
left/right passage

Track trigger – track segment finder



track segment finder

combine hits
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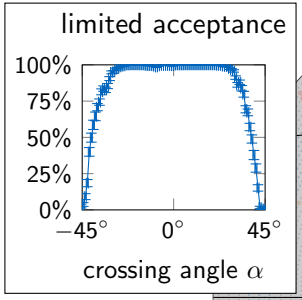
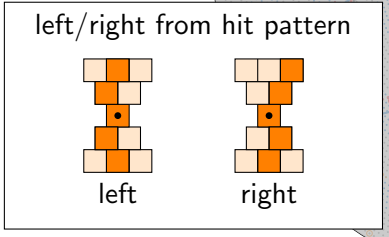
Track trigger – track segment finder

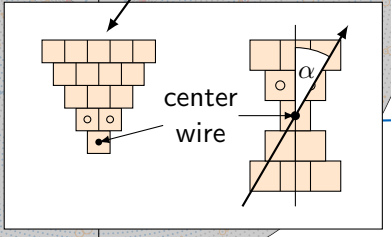


noise suppression

track segment finder

combine hits
2336 segments
9 super layers
→ "layers"

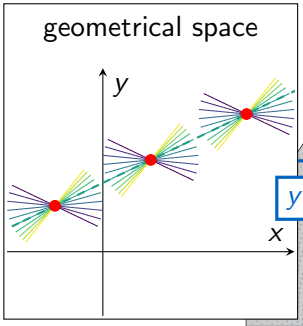


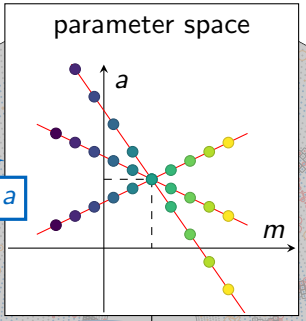


hits in ≥ 4 layers

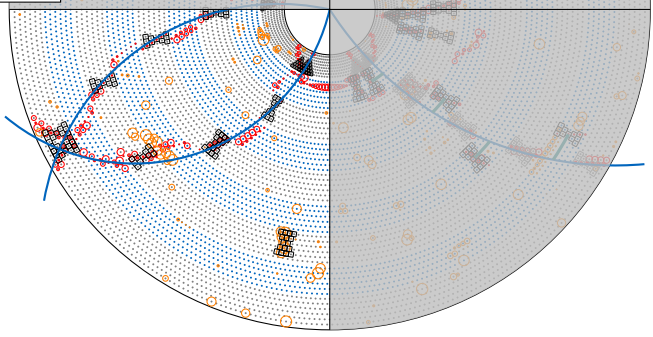
1 t_{drift} value
left/right passage

Track trigger – 2D track finder





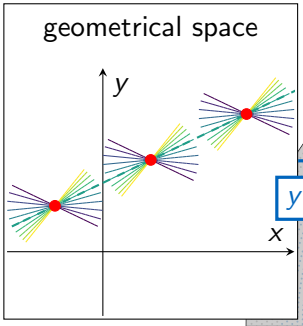
$y = mx + a$



2D track finder

circles in
$x - y$ plane
Hough transform

Track trigger – 2D track finder



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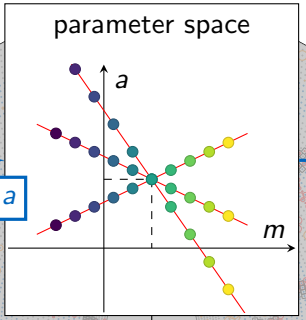
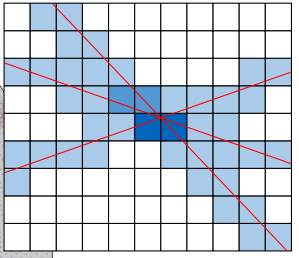
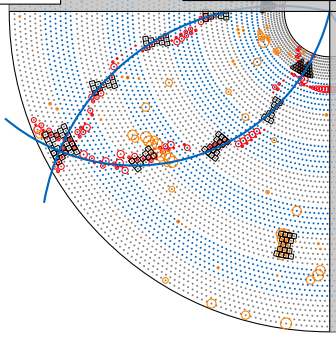


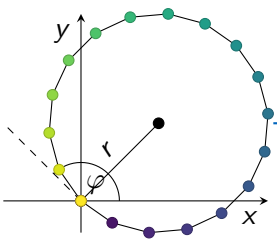




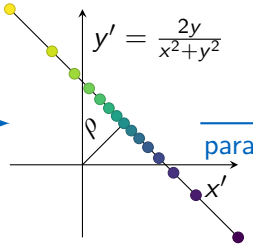
2D track finder

circles in
$x - y$ plane
Hough transform

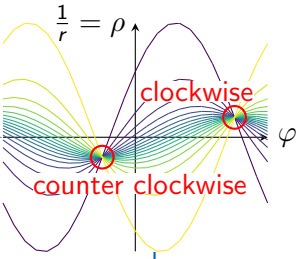
- track segments from axial layers
- grid in parameter space
- count lines from different layers
- cluster center gives track parameters



conformal mapping

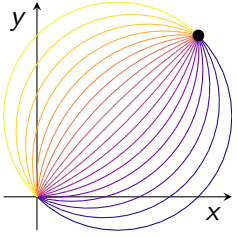


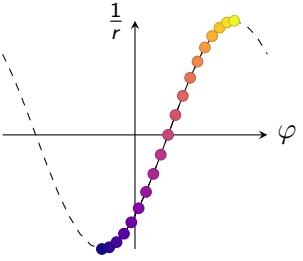
normal parametrization

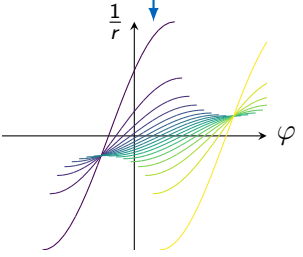


only outgoing tracks

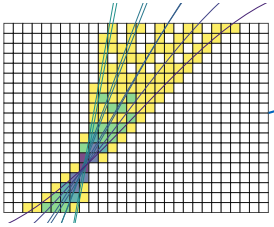
outgoing tracks ≡ rising half of Hough curve



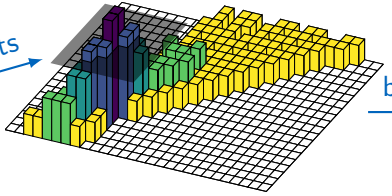




Parallel clustering

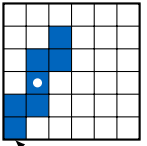


≥ 4 hits

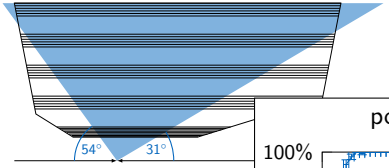


binary grid

cluster area 6×6



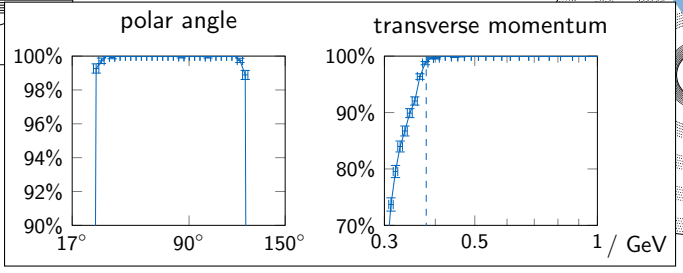
seed: isolated corner

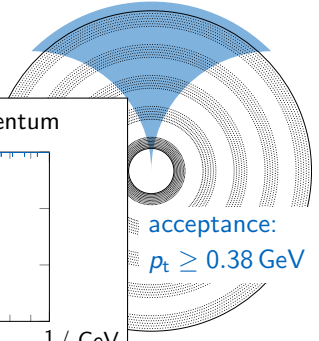


acceptance:

$\theta \in [31°, 126°]$

track finding efficiency

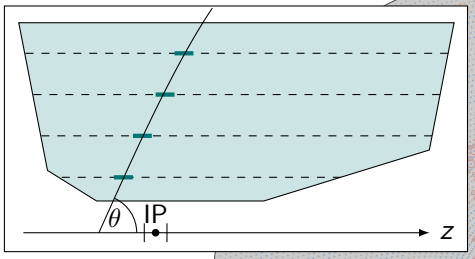


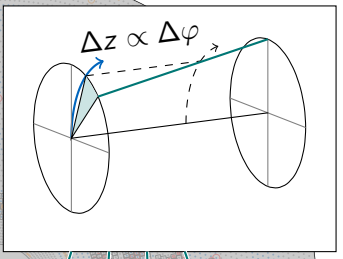


acceptance:

$p_t \geq 0.38\,\text{GeV}$

Track trigger – 3D reconstruction





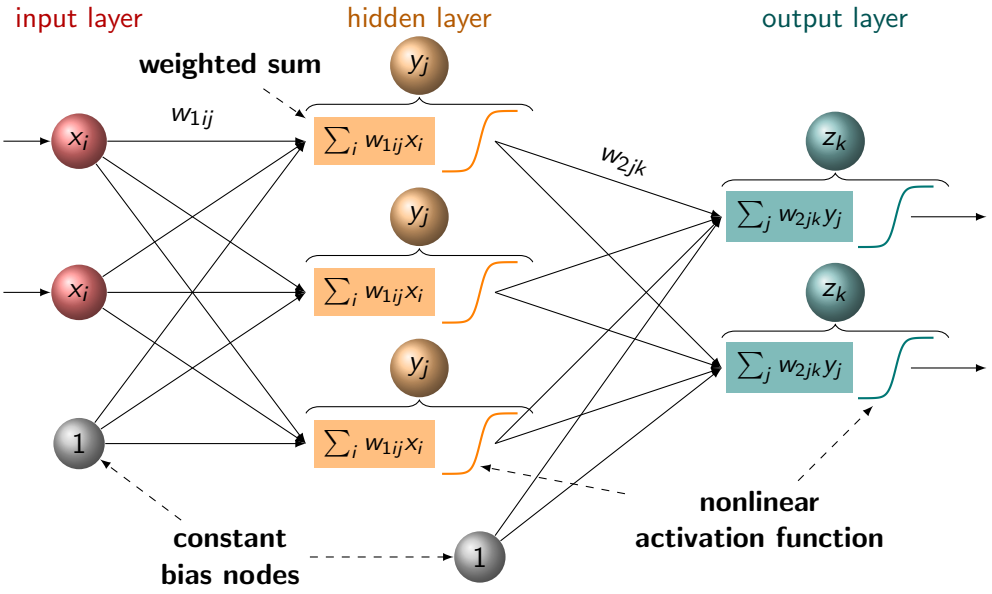
4 z-coordinates from stereo hits and 2D tracks

- precise position: drift time
- event time determined parallel to track finding
- problems with fit: approximations, background

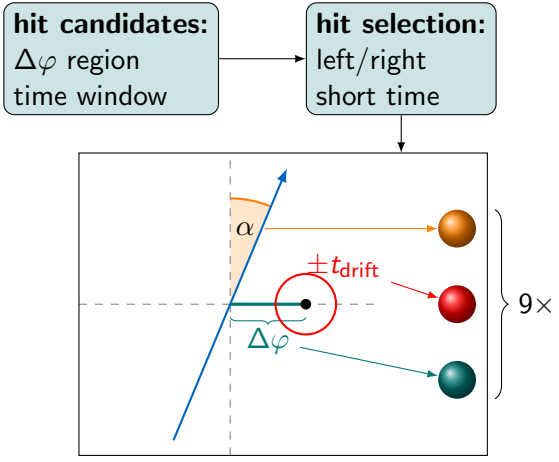
3D reconstruction

2 methods:
neural network
least squares fit

Multi Layer Perceptron (MLP)

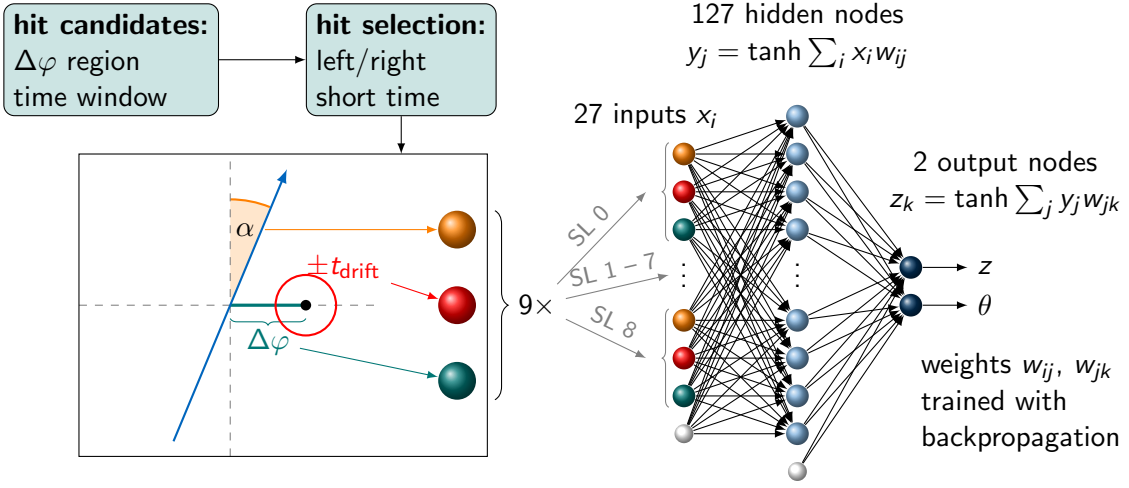


MLP for z-vertex reconstruction



- drift time separately → nonlinear corrections
- crossing angle α: track curvature
- axial inputs: 2D track corrections

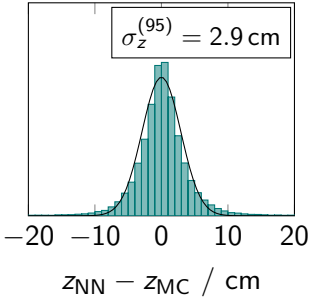
MLP for z-vertex reconstruction

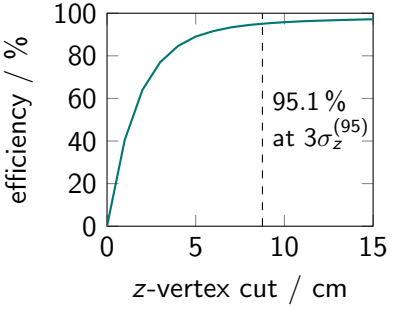


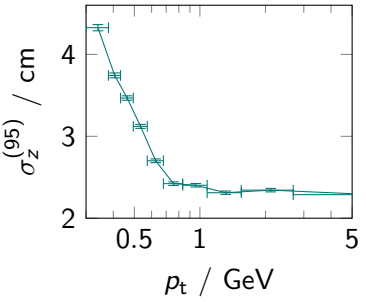
- drift time separately → nonlinear corrections
- crossing angle α: track curvature
- axial inputs: 2D track corrections

- missing axial hit:
  default inputs $(0, 0, 0)$
- missing stereo hit: expert network

z-vertex resolution

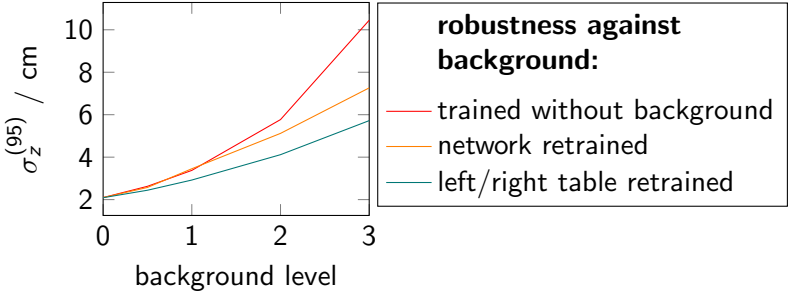






resolution depends on

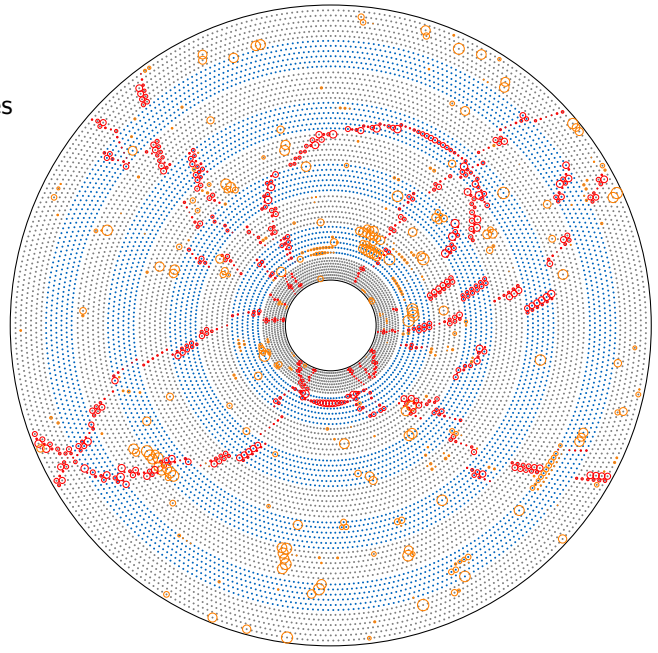
- missing hits
- track curvature
- background hits



Track trigger – summary

input: CDC hits

14336 sense wires
axial & stereo
drift time



Track trigger – summary

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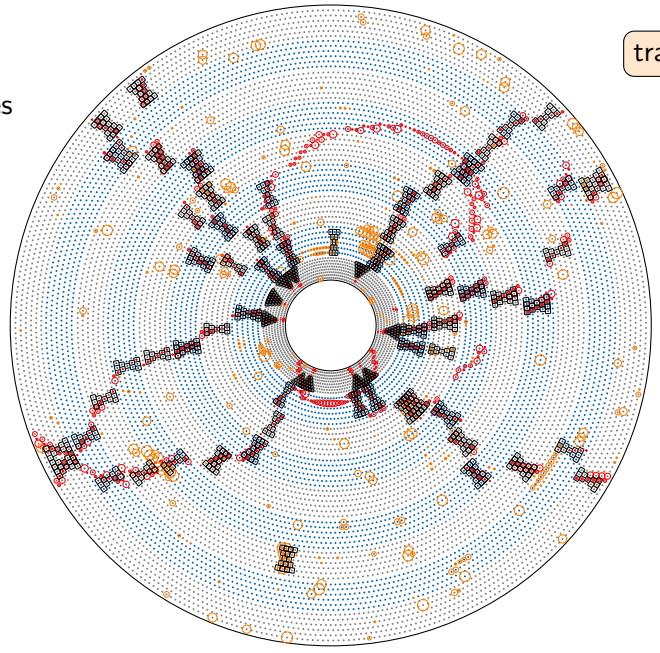


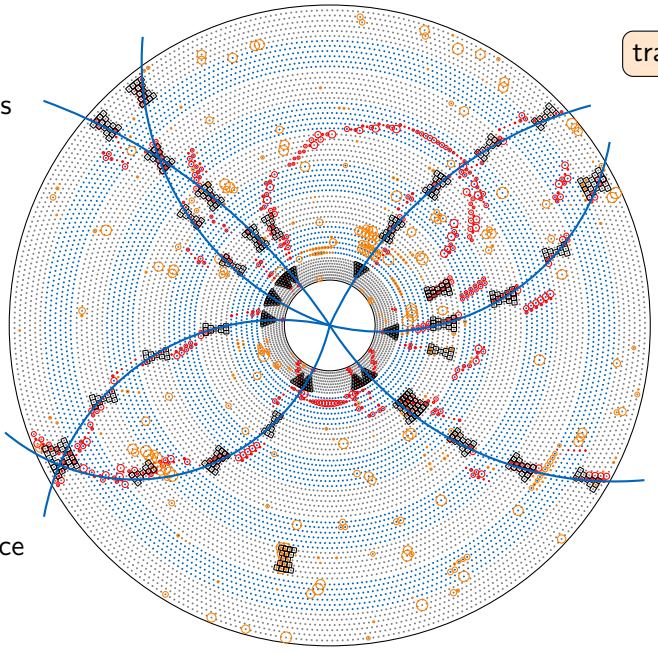
track segment finder

data reduction
2336 segments
left/right

Track trigger – summary

input: CDC hits

14336 sense wires
axial & stereo
drift time



track segment finder

data reduction
2336 segments
left/right

2D track finder

axial hits
Hough transform
crossing points
in parameter space

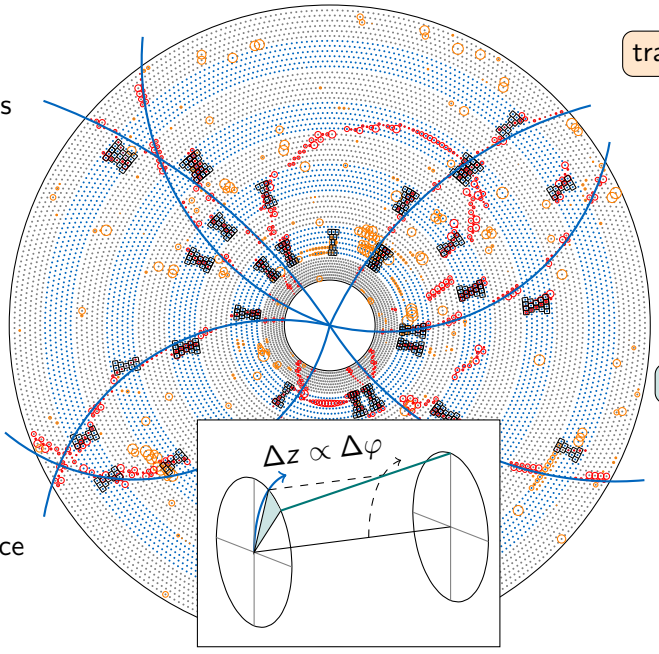
Track trigger – summary

input: CDC hits

14336 sense wires
axial & stereo
drift time

track segment finder

data reduction
2336 segments
left/right



2D track finder

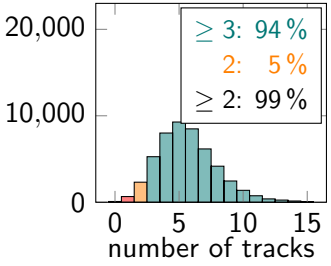
axial hits
Hough transform
crossing points
in parameter space

3D reconstruction

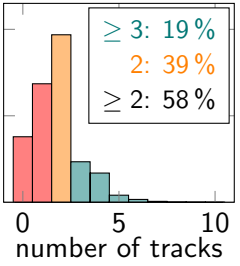
per 2D track
add stereo hits
neural network

Track trigger efficiency

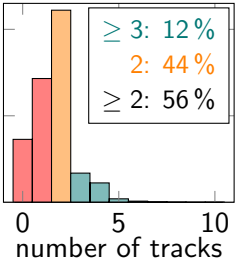
$B\overline{B} \rightarrow$ generic



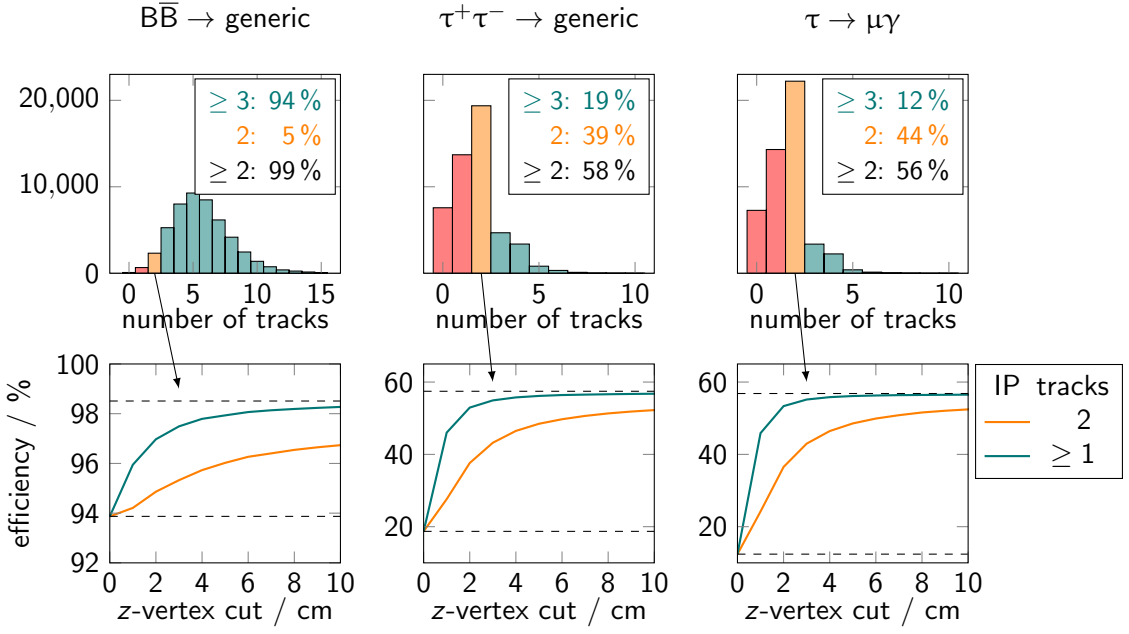
$\tau^+\tau^- \rightarrow$ generic



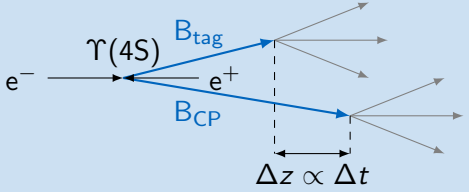
$\tau \rightarrow \mu\gamma$



Track trigger efficiency

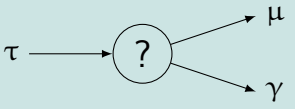


Summary – trigger performance



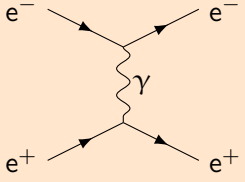
- time dependent CP violation in $B\overline{B}$
- typically $\approx 3 - 9$ tracks

low track multiplicity: $e^+e^- \to \tau^+\tau^-$



- lepton flavor violation
- genuine 2 track trigger

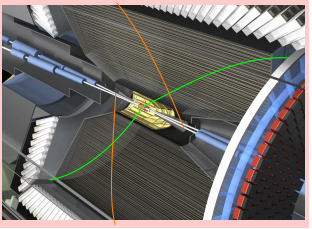
Bhabha scattering



- for calibration
- needs to be prescaled
- Bhabha veto

machine background

- z-vertex $\neq 0$
- suppression requires 3D tracking



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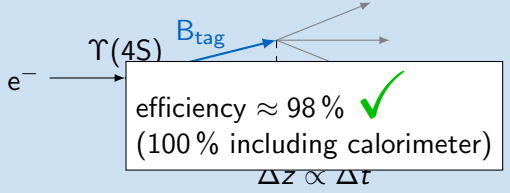

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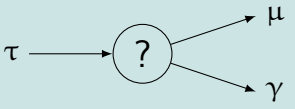

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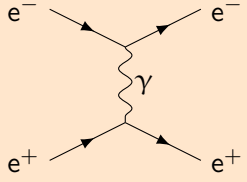

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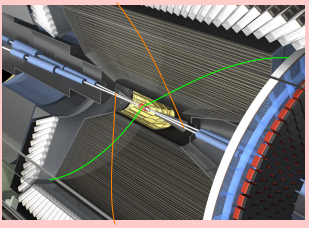

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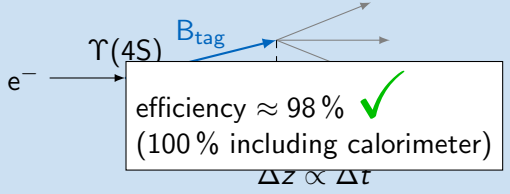

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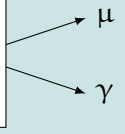
efficiency $\approx 56\,\%$
(12 % for ≥ 3 tracks)
$\to$ gain factor **4.7**



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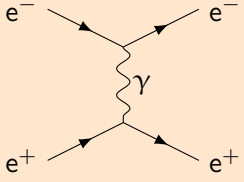

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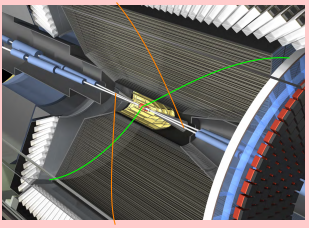
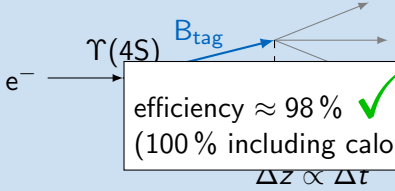


Summary – trigger performance



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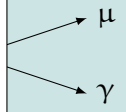

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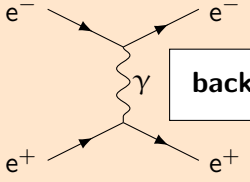
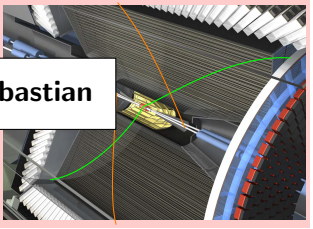


- for calibration
- prescaled
- Bhabha veto

machine background

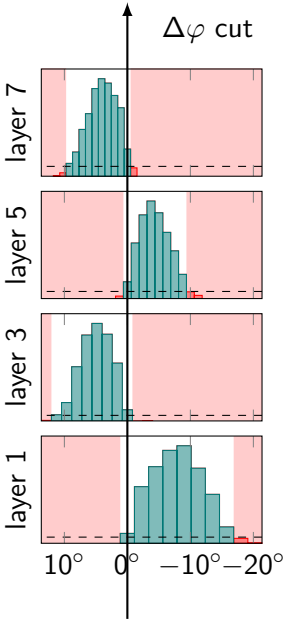
- z-vertex $\neq 0$
- requires 3D tracking

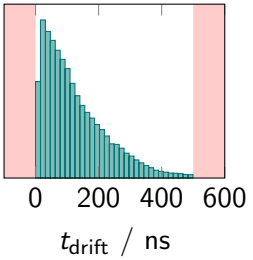
background suppression: following talk by Sebastian



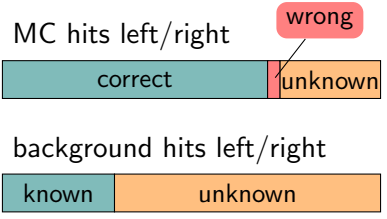
Backup

Hit and network selection





hit in layer 1/3/5/7				expert
✓	✓	✓	✓	#1
✓	✓	✓	—	#2
✓	✓	—	✓	#3
✓	—	✓	✓	#4
—	✓	✓	✓	#5

several hits per layer:

1. known left/right
2. short drift time