Parameterization-based tracking for the P2 experiment

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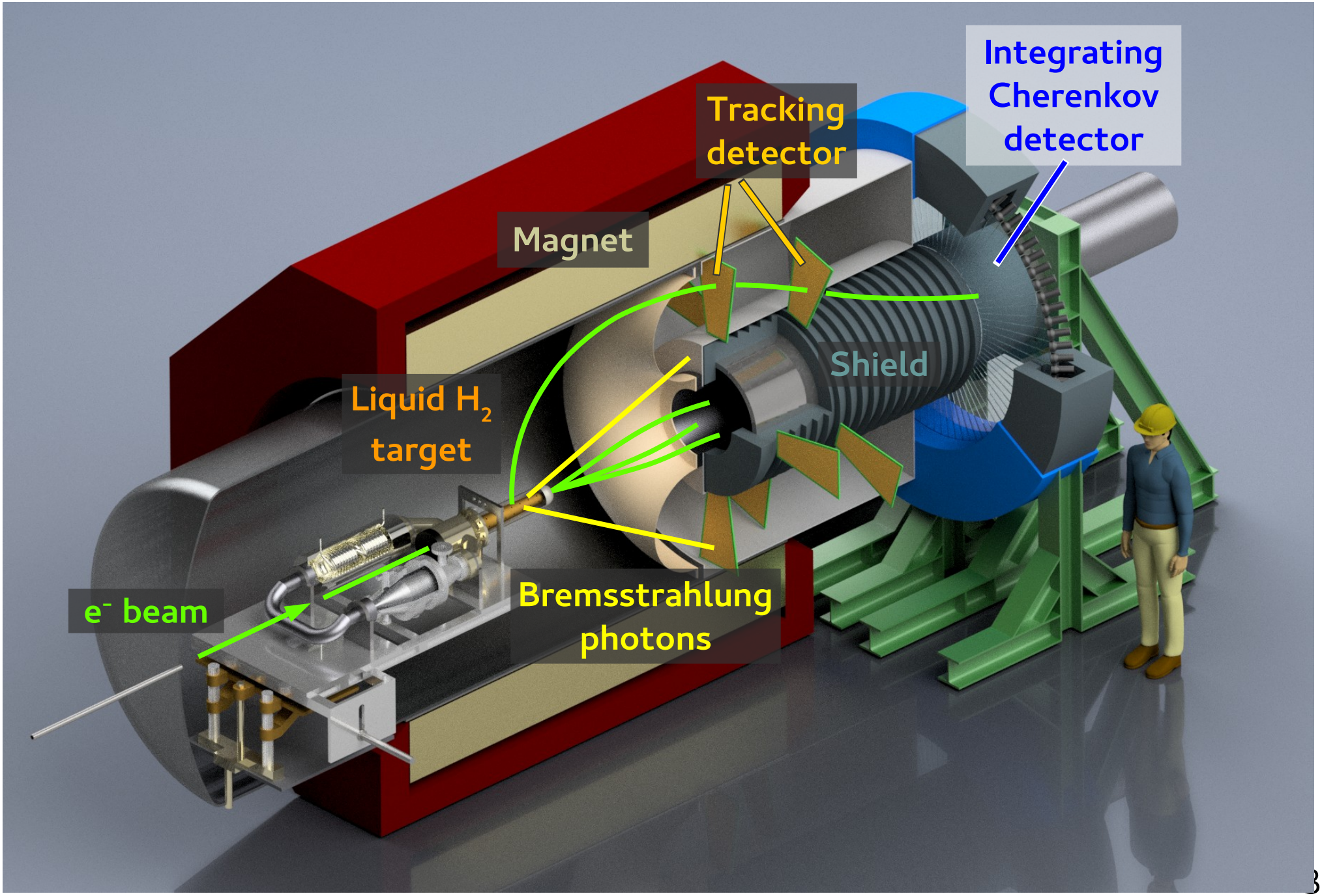
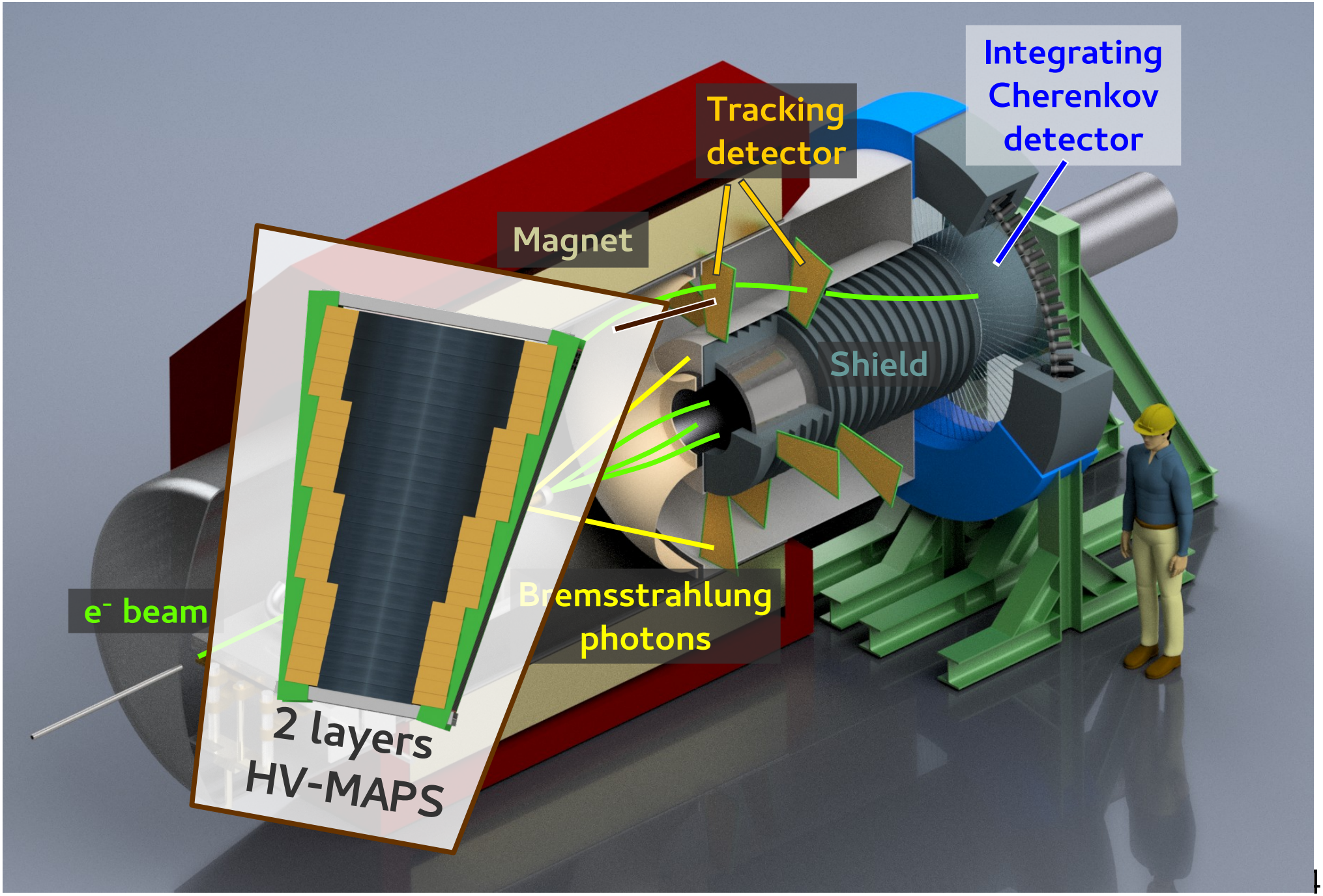
Tracking = track finding + track fitting

P2 setup

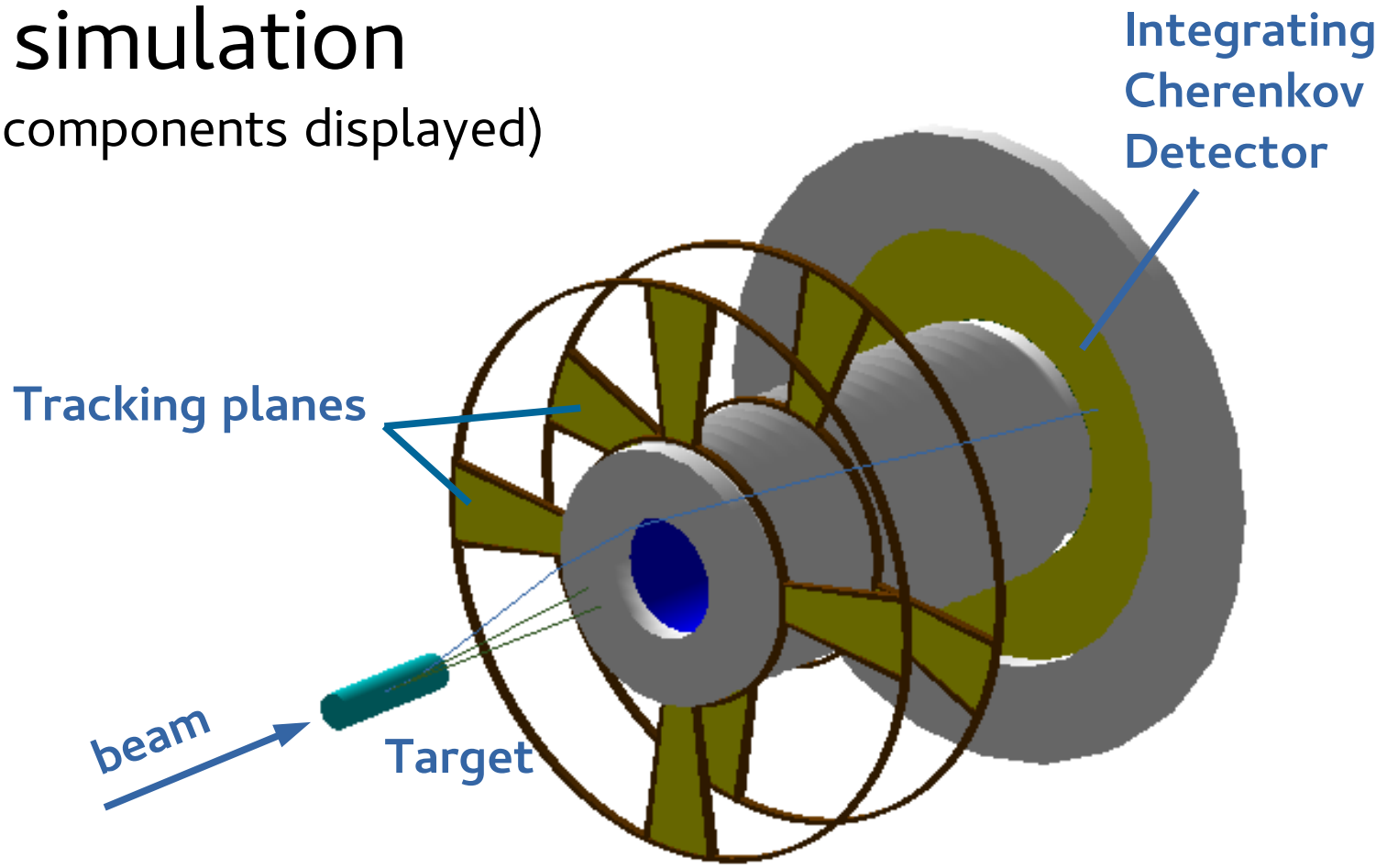

Integrating Cherenkov detector
Tracking detector
Magnet
Shield
Liquid H_2 target
e^- beam
Bremsstrahlung photons

P2 setup


Integrating Cherenkov detector
Tracking detector
Magnet
Shield
e⁻ beam
Bremsstrahlung photons
2 layers HV-MAPS

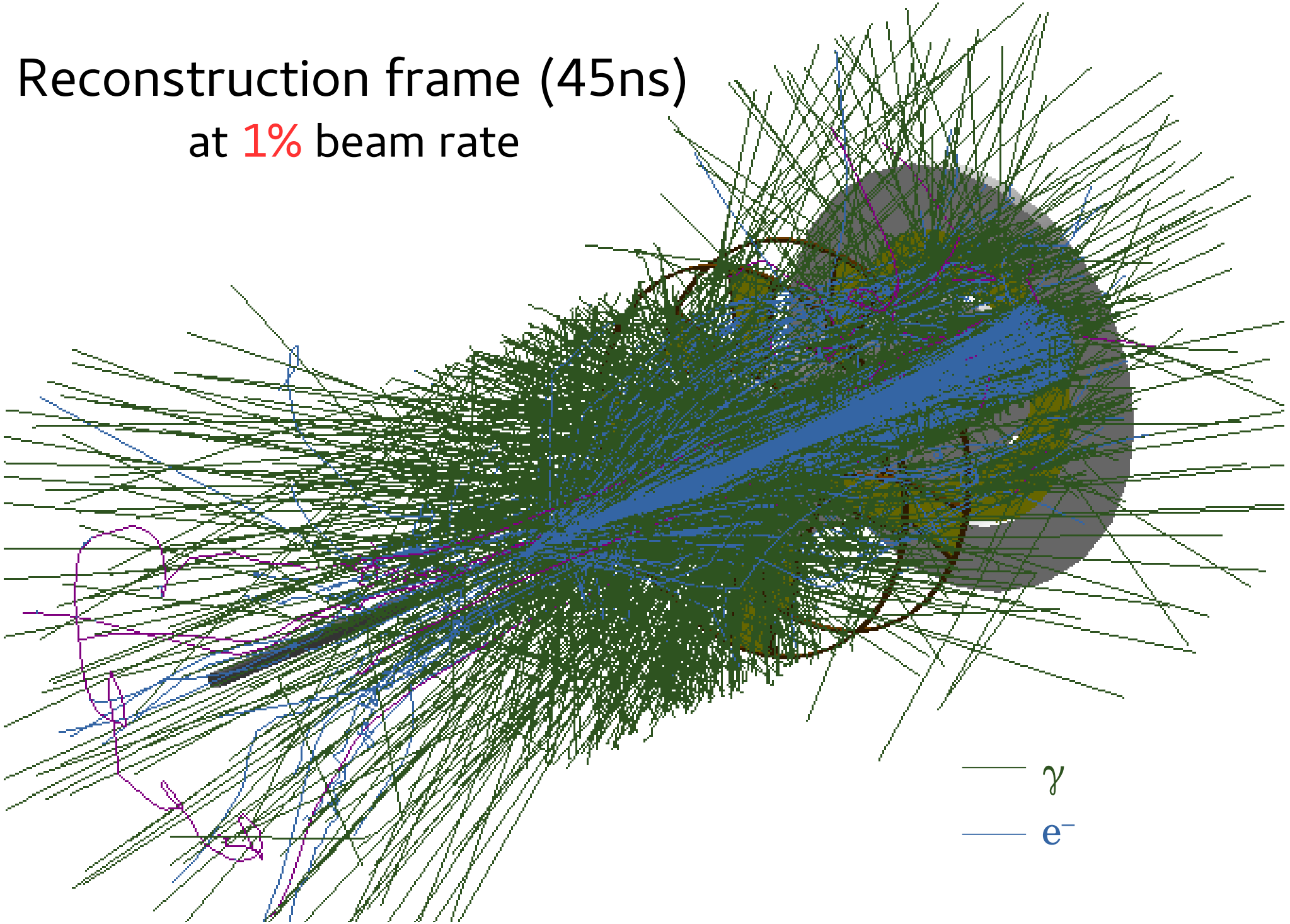
GEANT4 simulation

(only relevant components displayed)



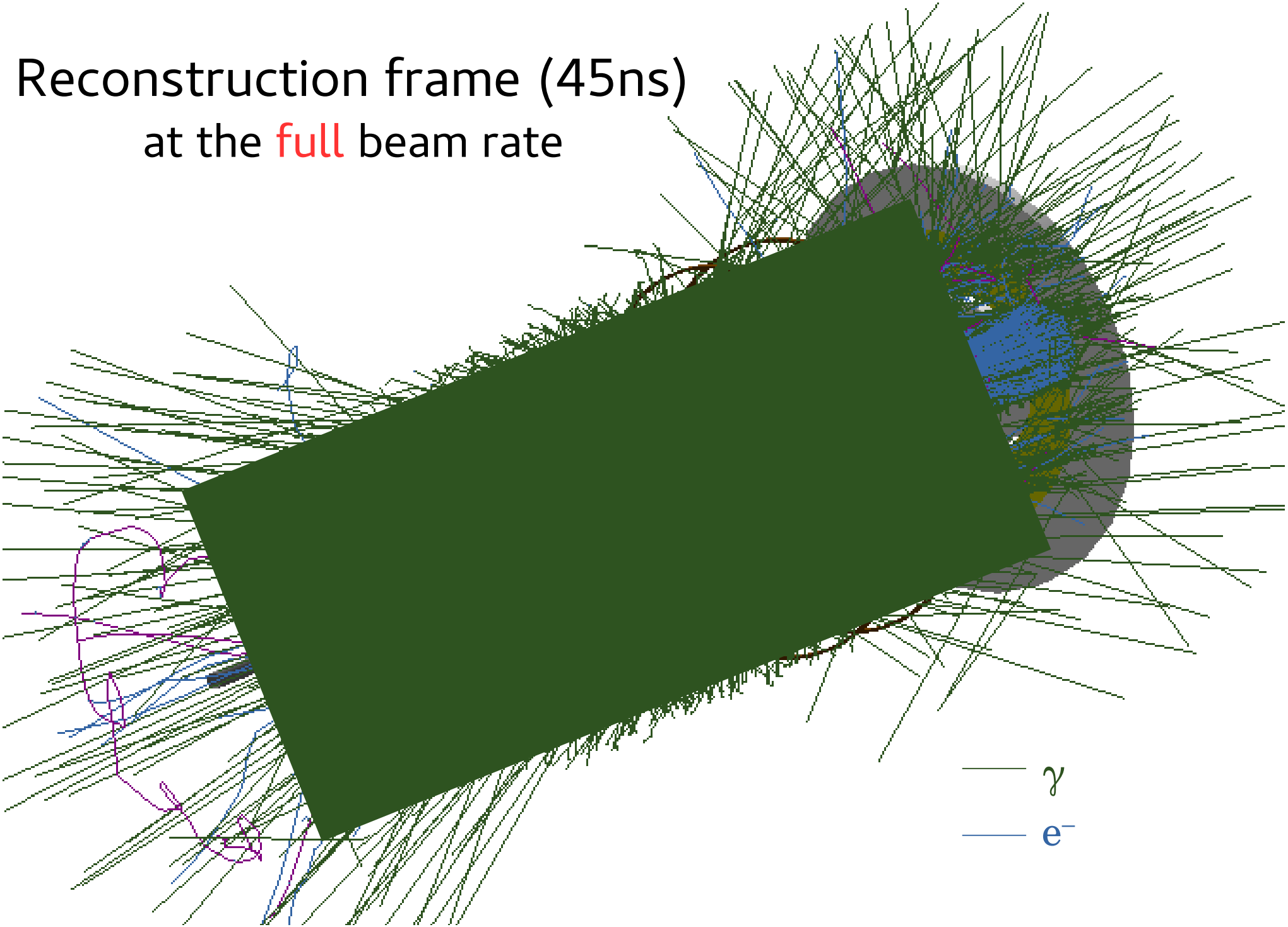
Reconstruction frame (45ns)

at 1% beam rate



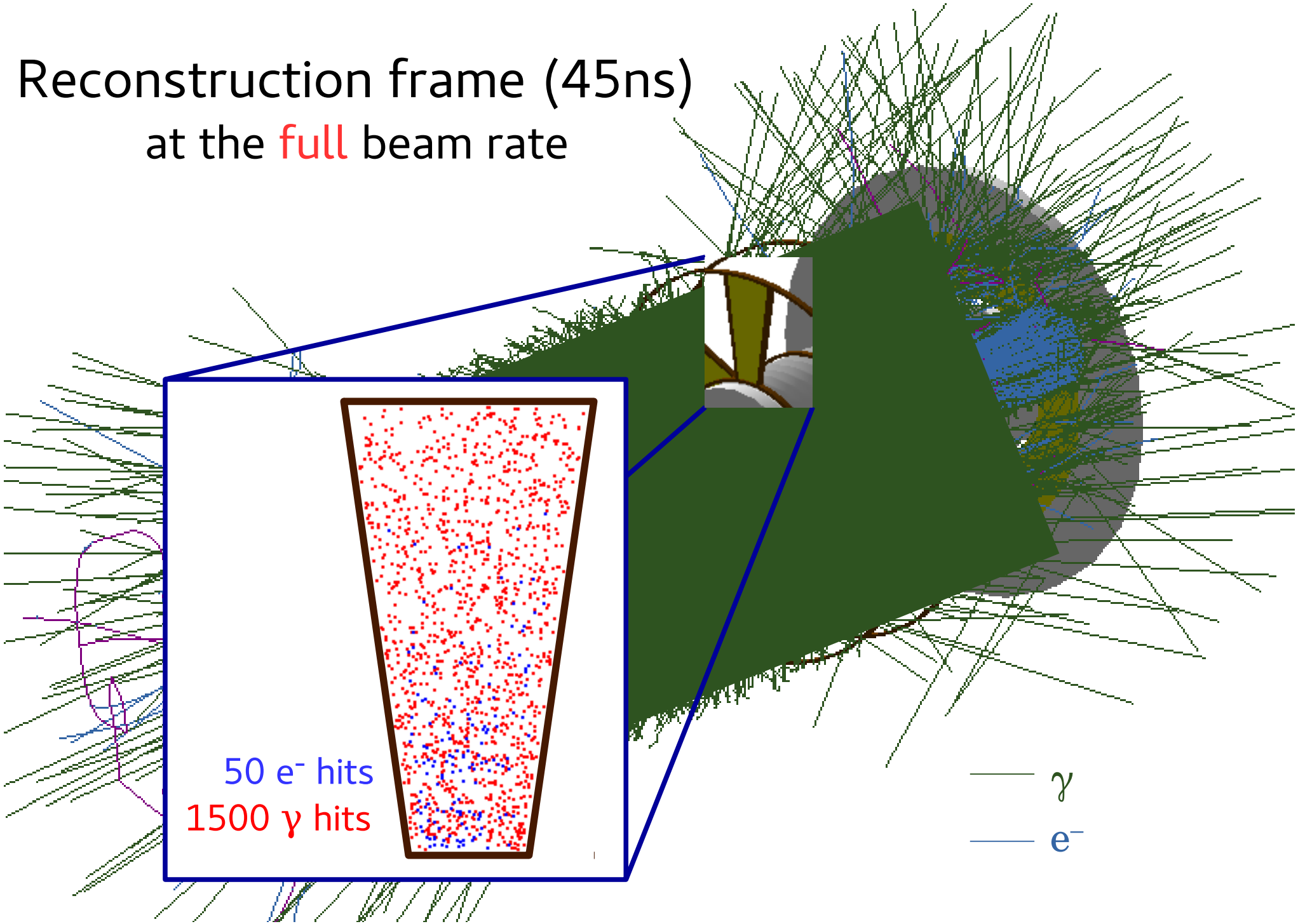
Reconstruction frame (45ns)

at the full beam rate

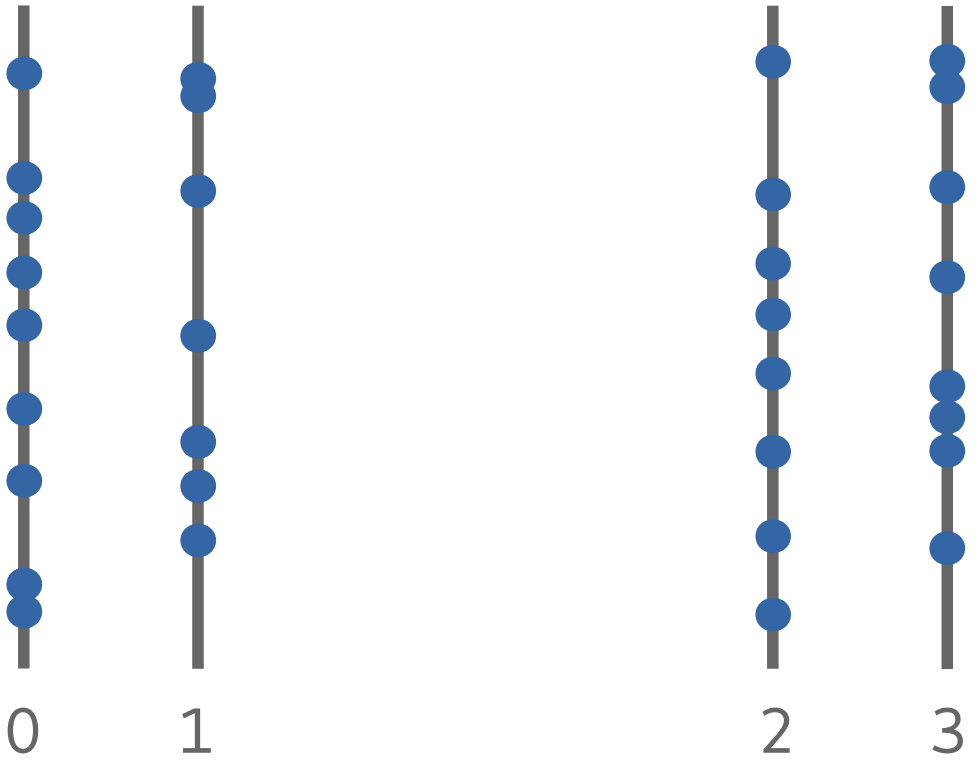


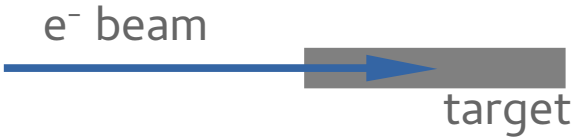
Reconstruction frame (45ns)

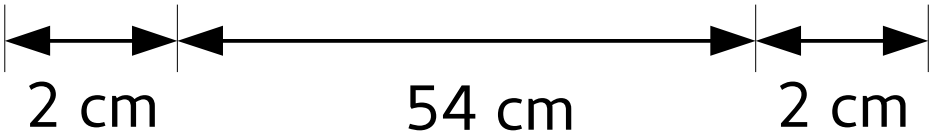
at the full beam rate



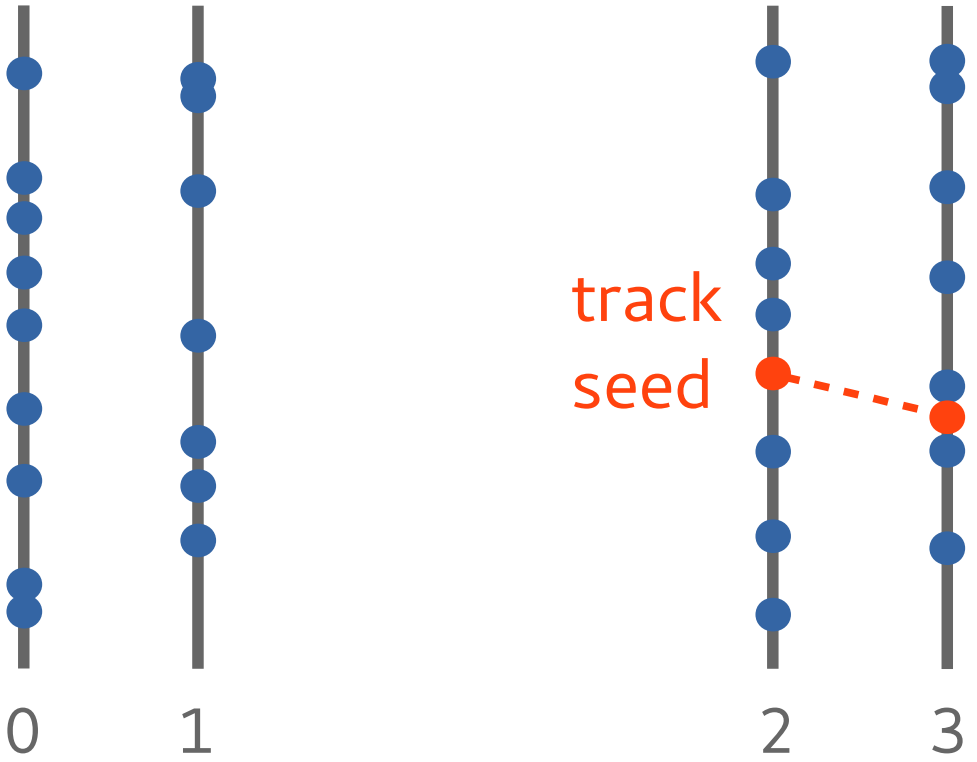
y-z view



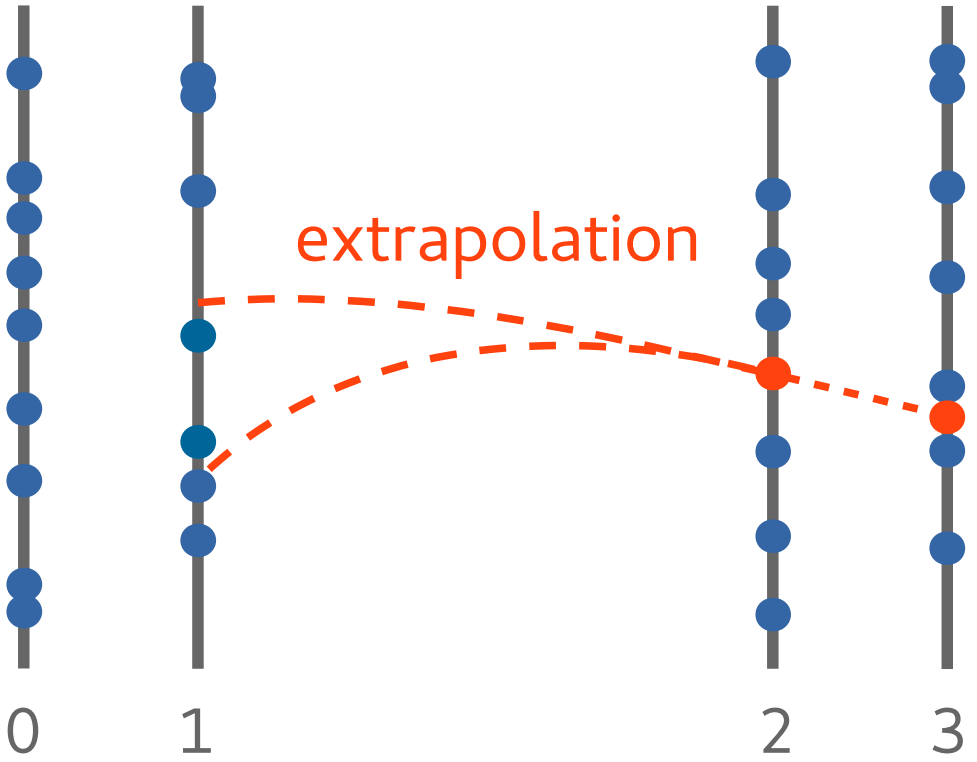




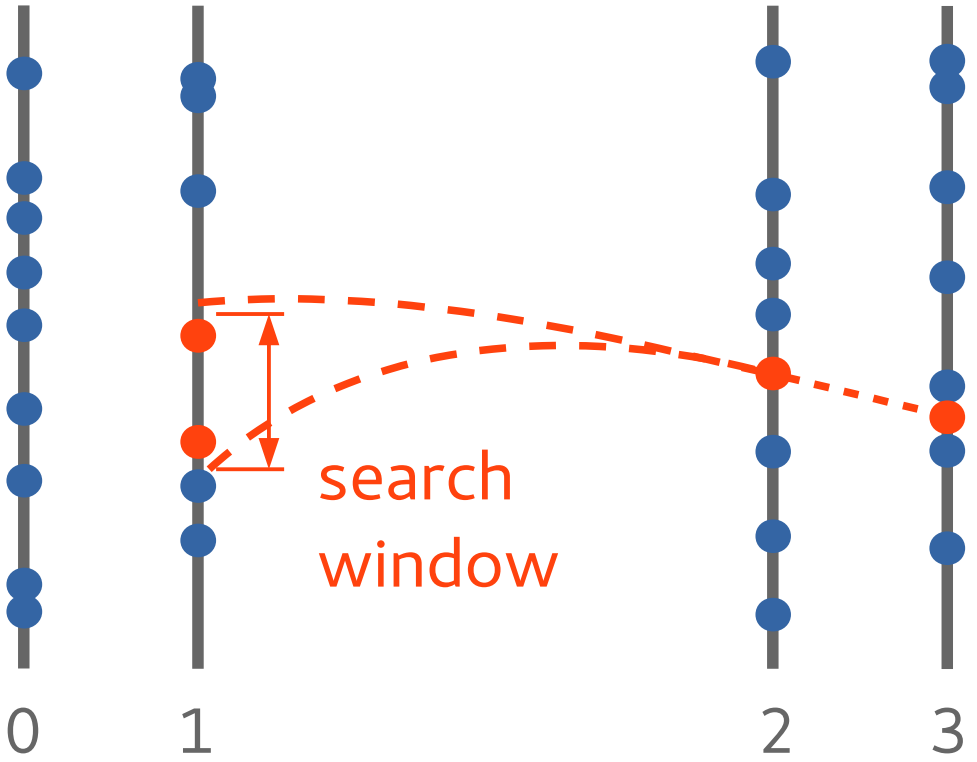
Track following

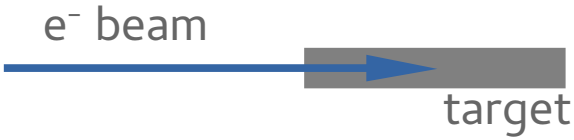


Track following

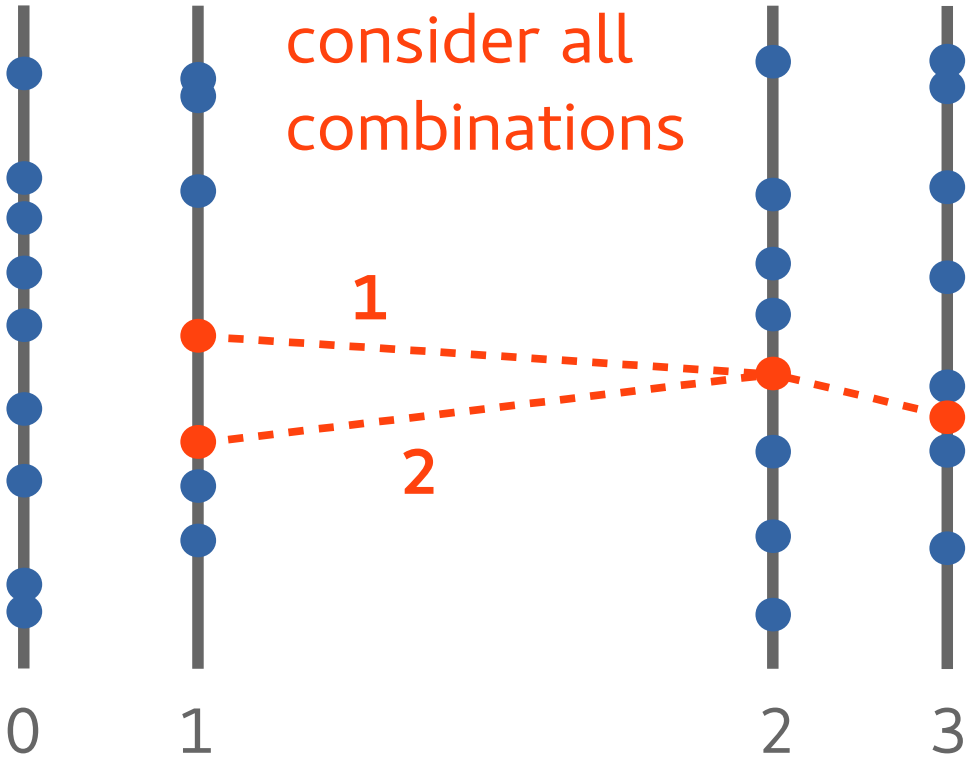


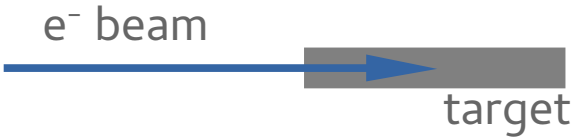
Track following



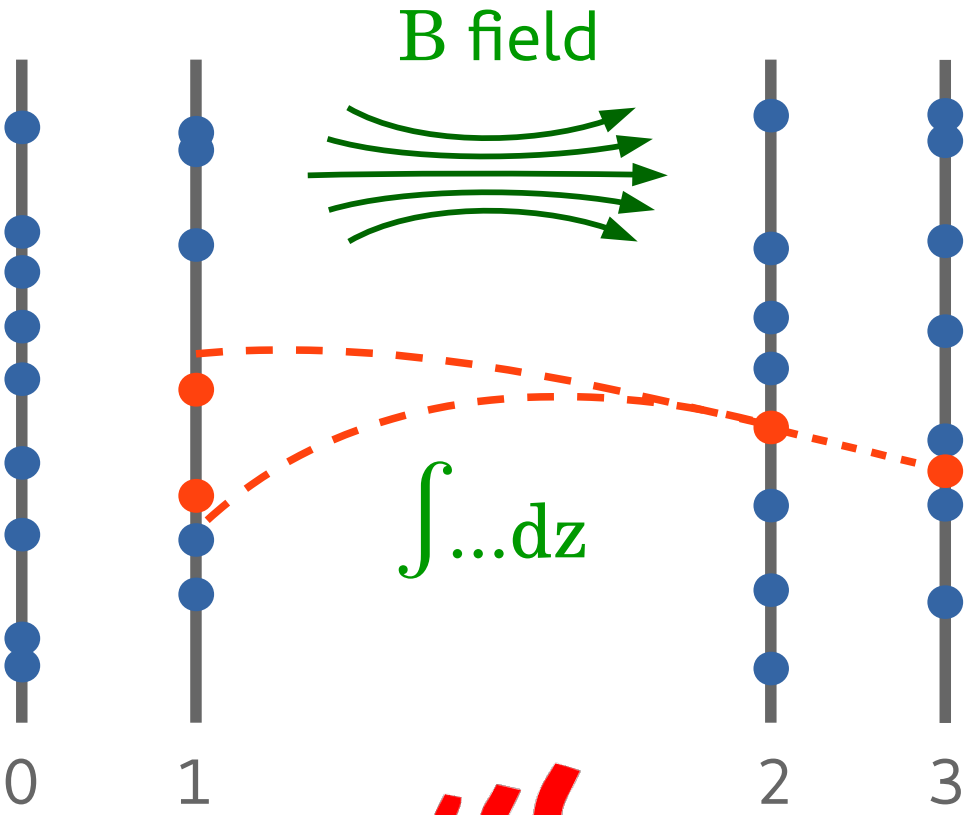


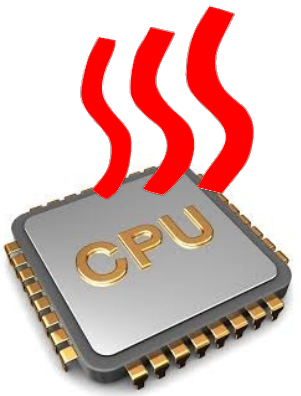
Track following

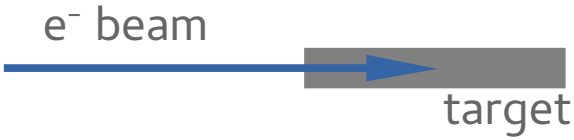




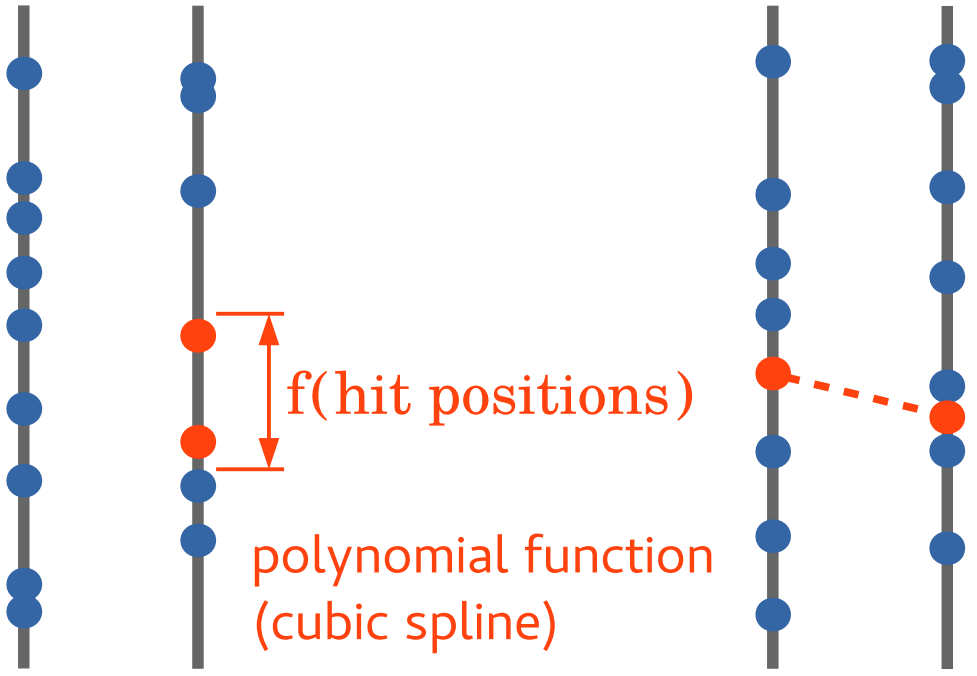
Track following



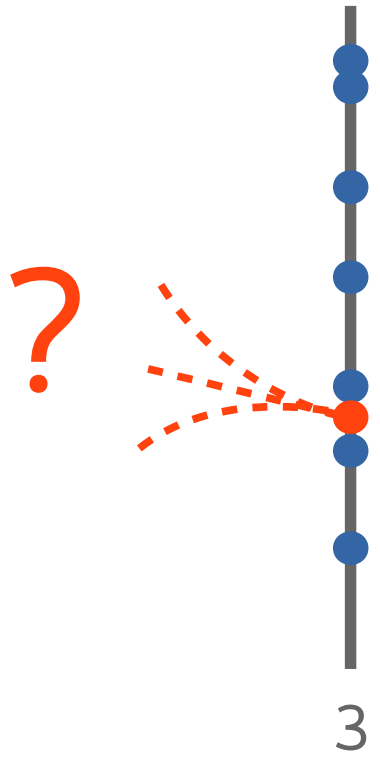




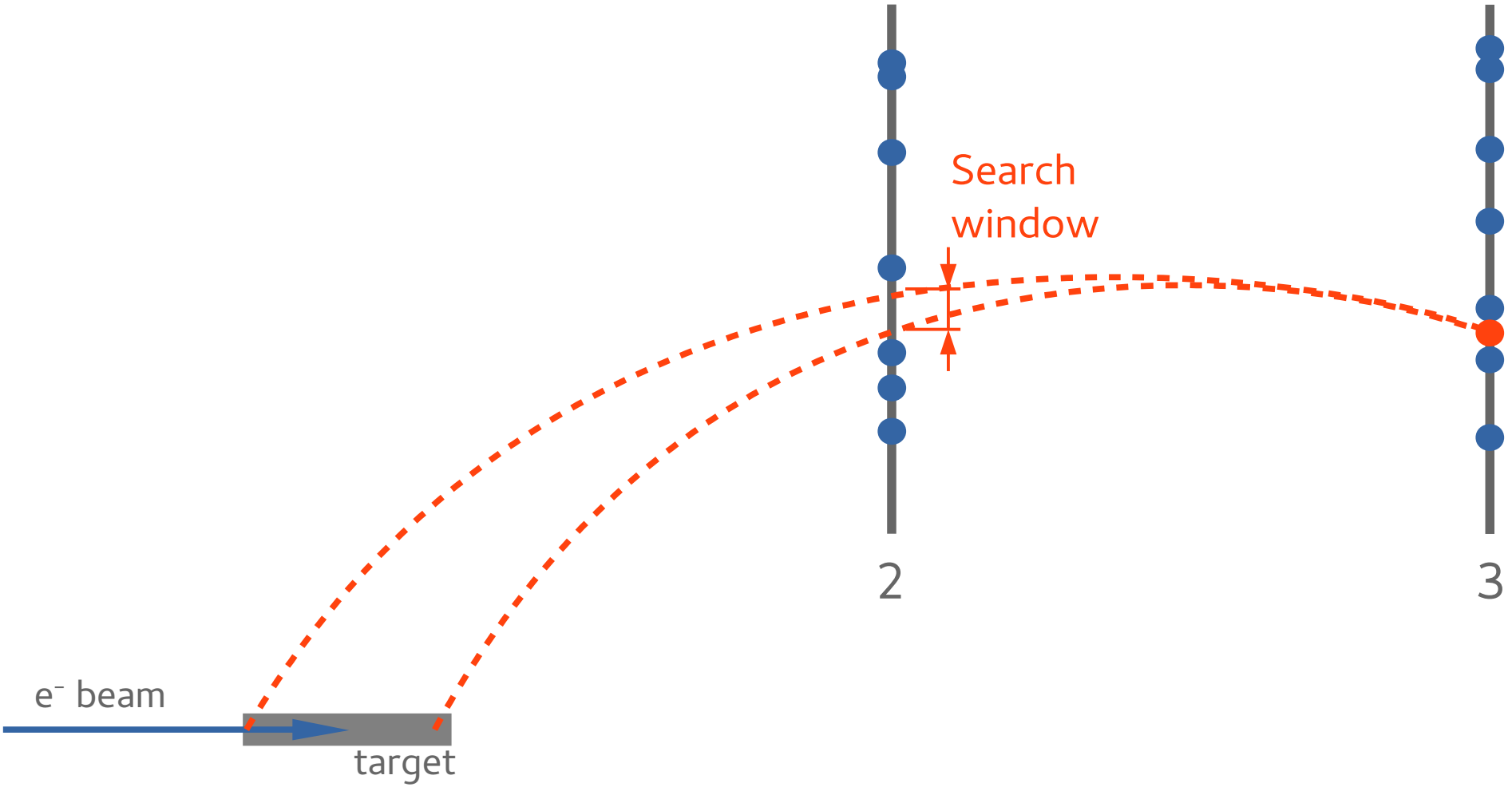
Track following with parameterized search windows



How to extrapolate?

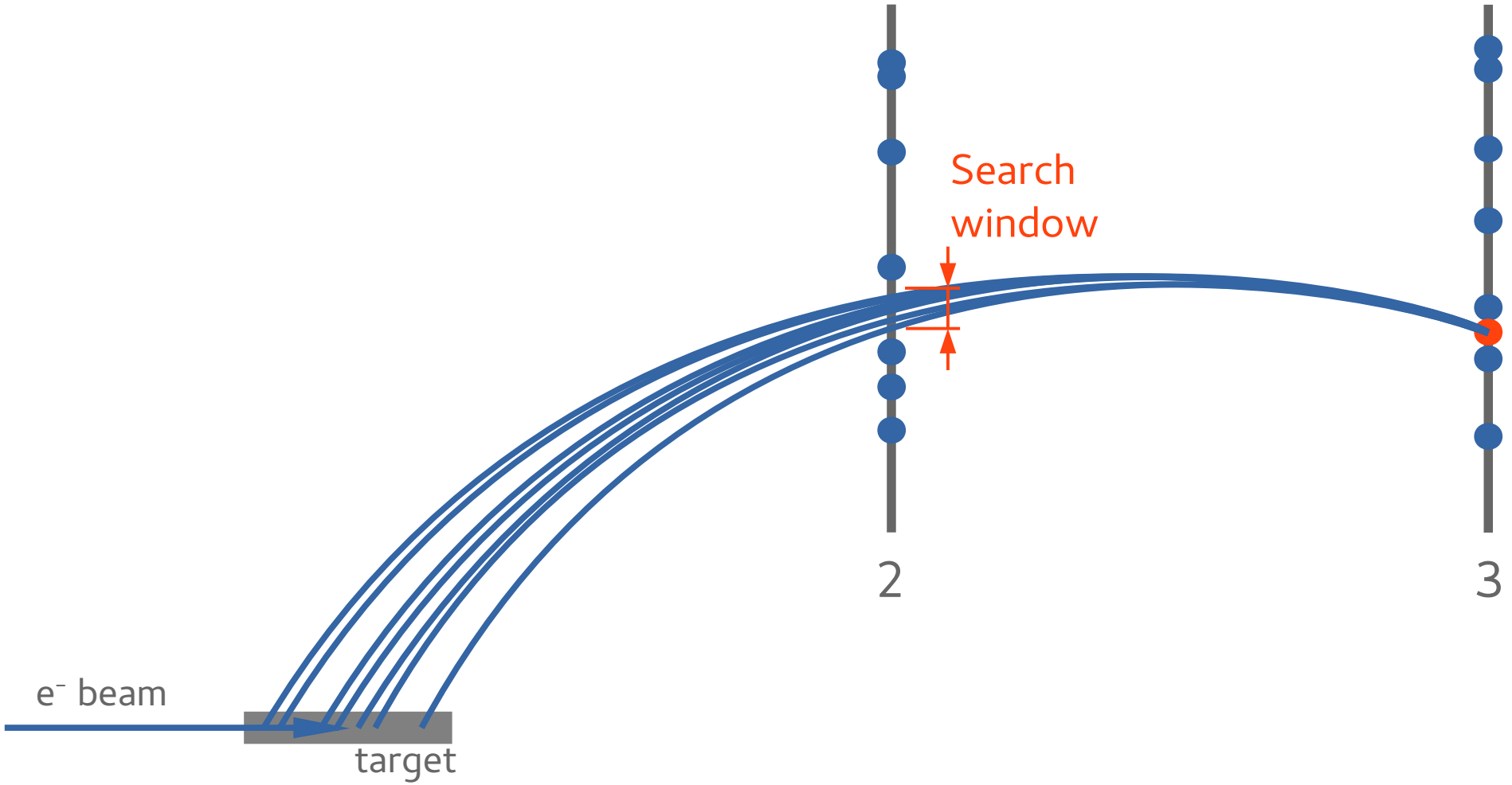


Extrapolation with constraints



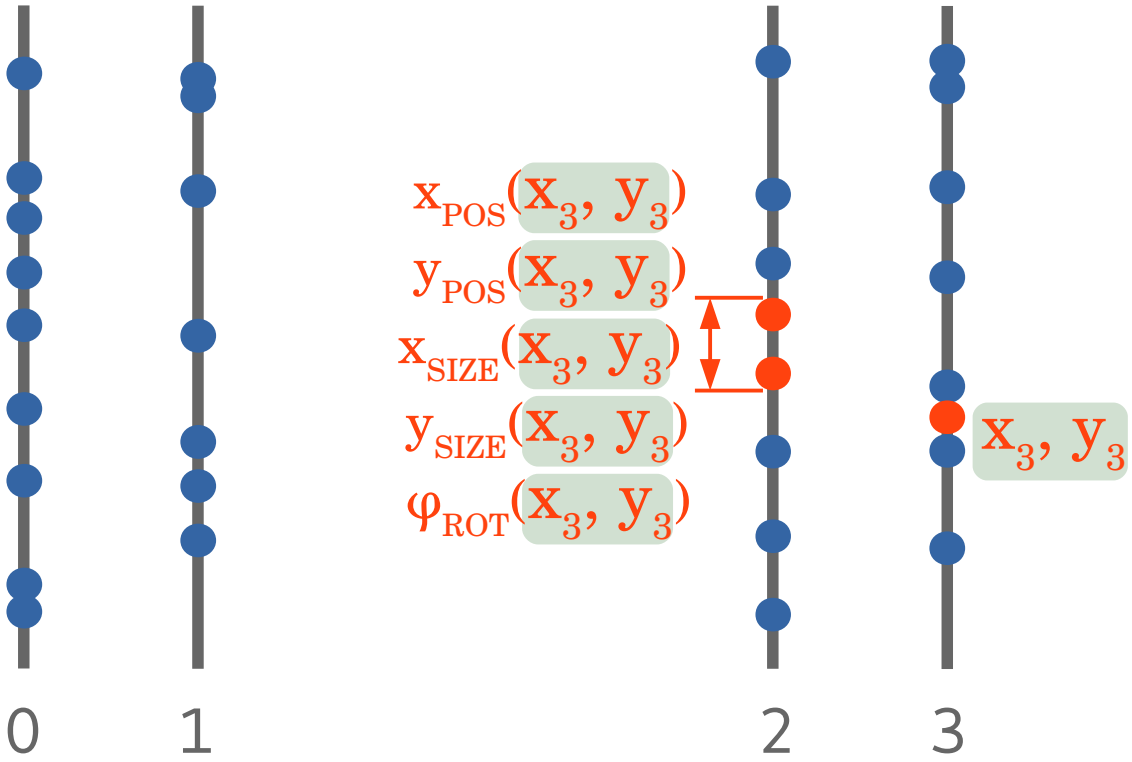
Compare with reference tracks

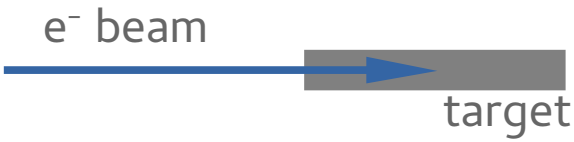
- from MC
- run at low beam rate; consider all combinations; select by χ^2.



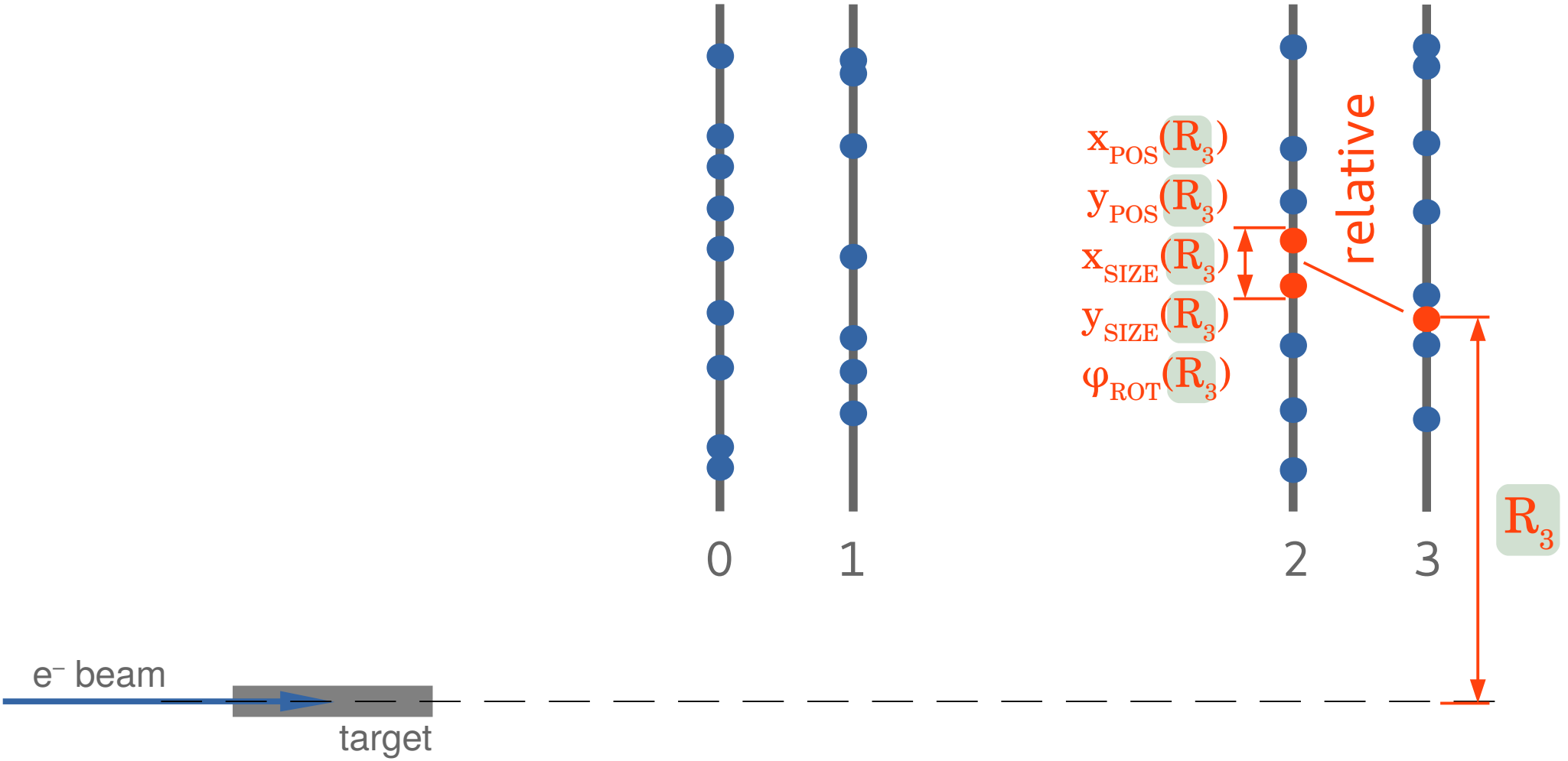
How to construct the parameterizations?

Search window for plane 2

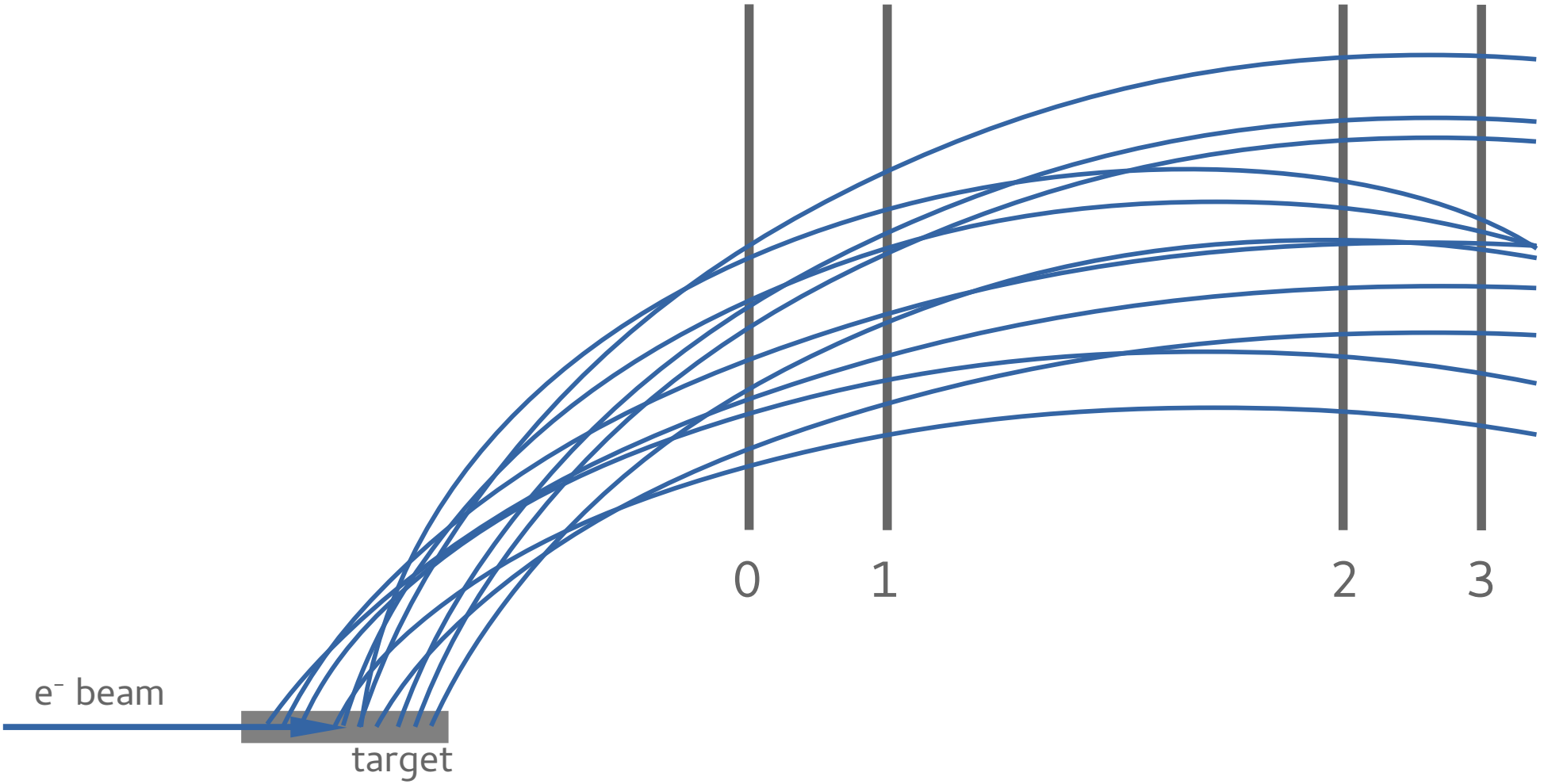




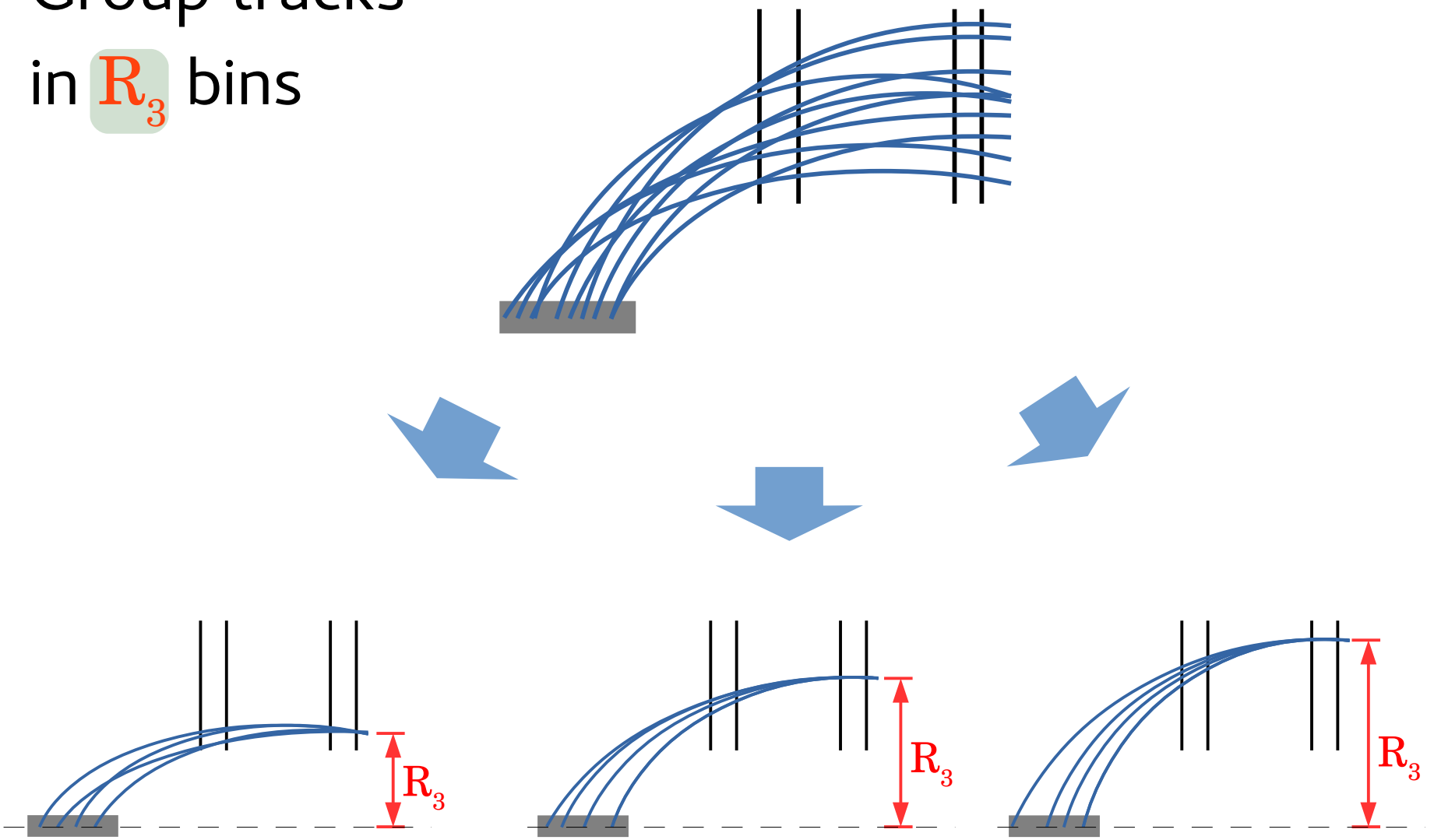
Search window for plane 2

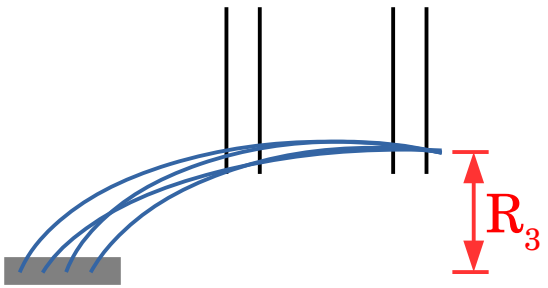


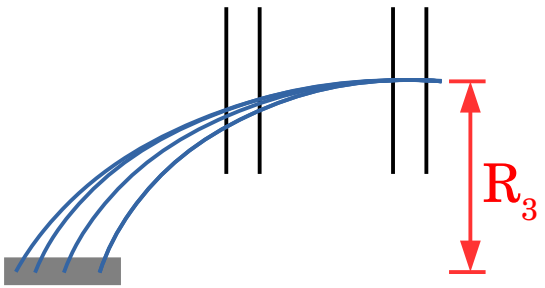
Collect large number of reference tracks

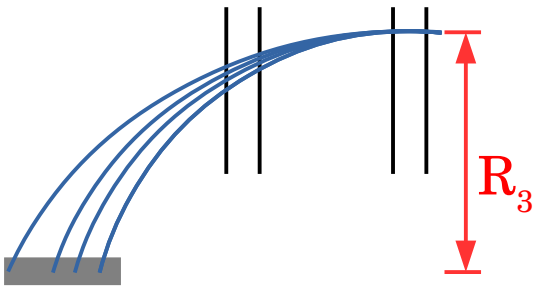


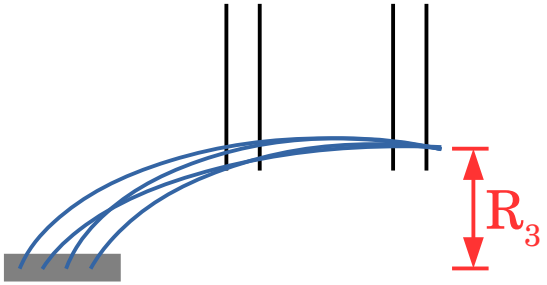
Group tracks in R_3 bins

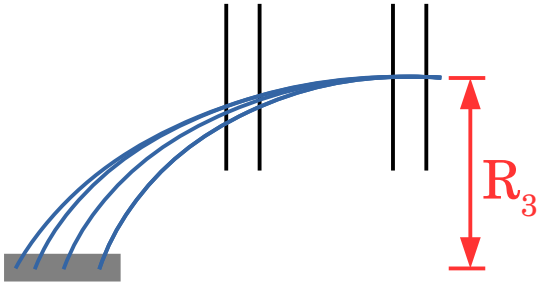


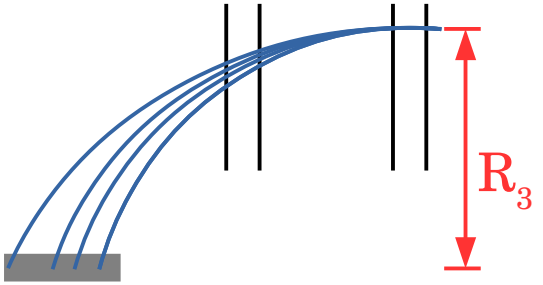

R3


R3

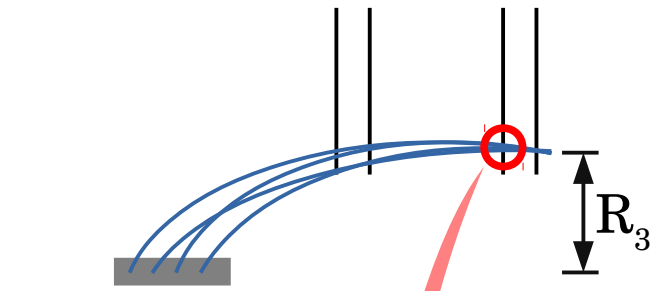

R3


R3

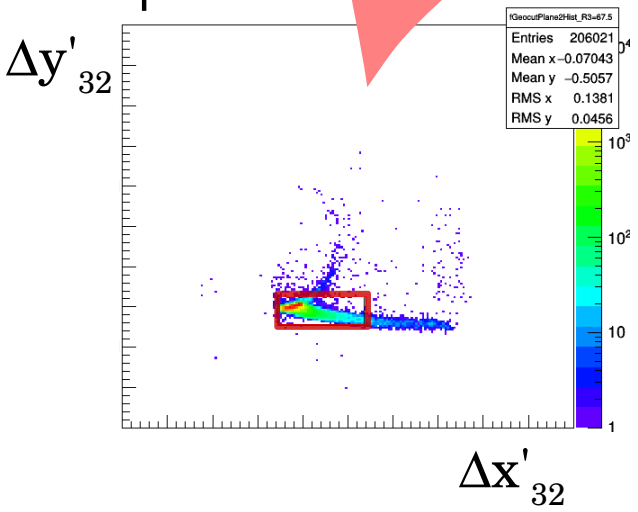

R3

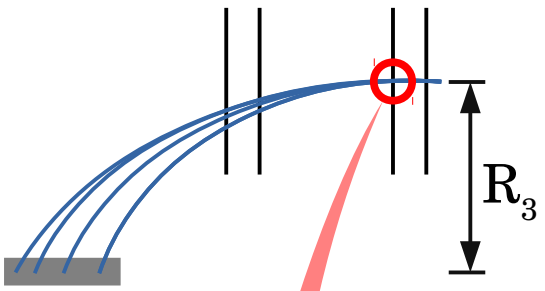

R3

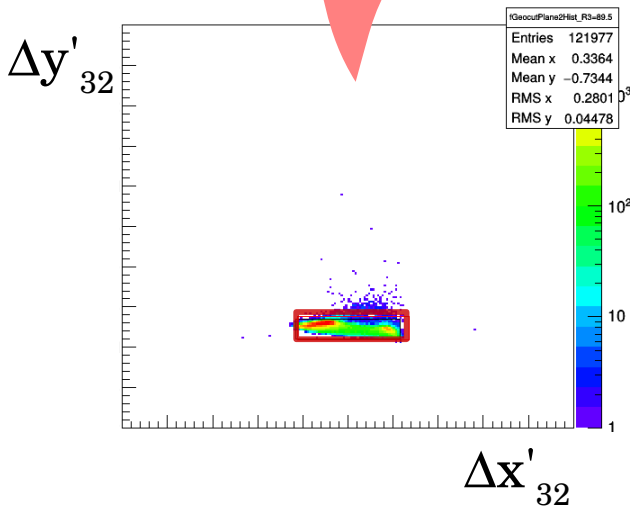
Search window for every R_3 bin:

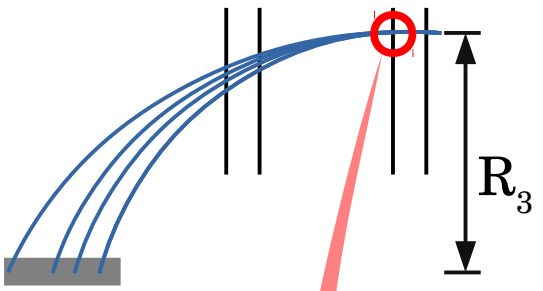


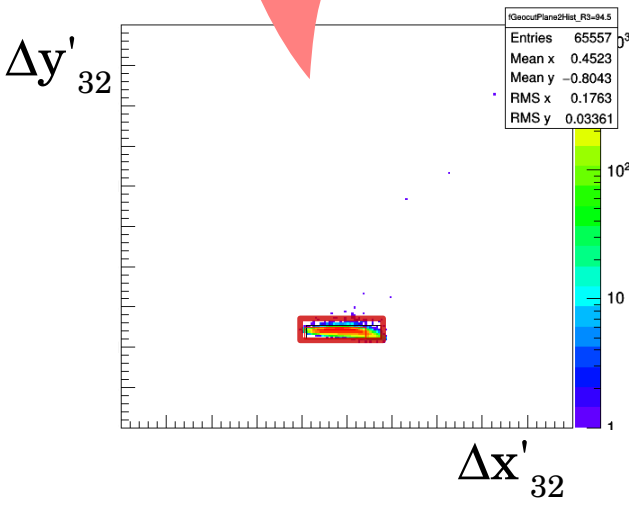
relative position

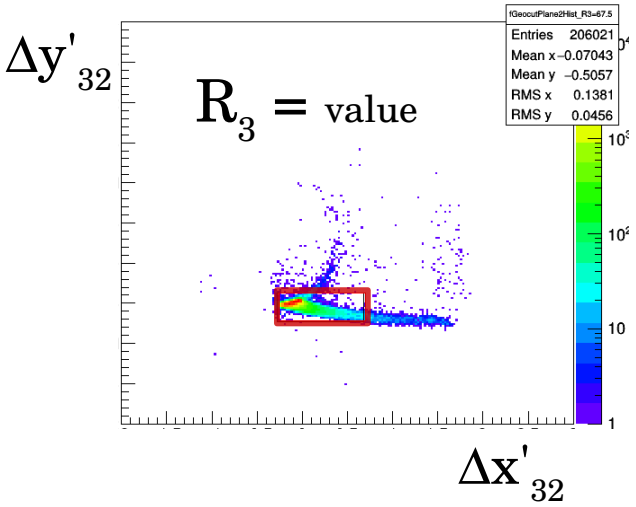


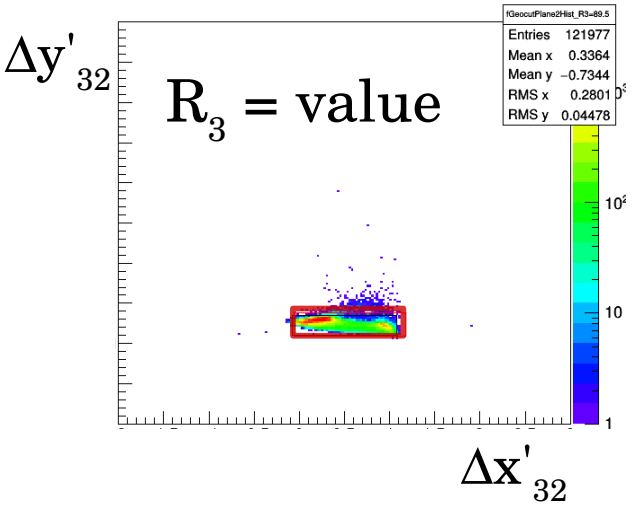


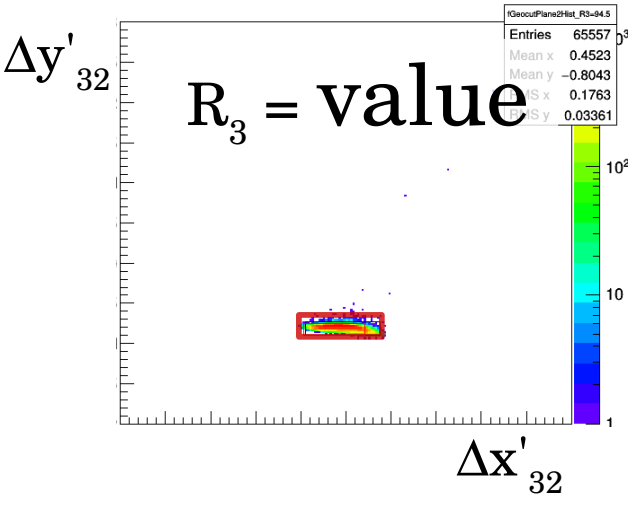




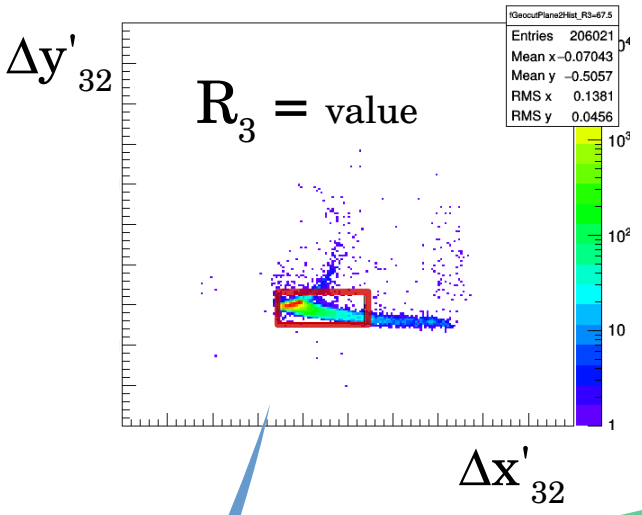


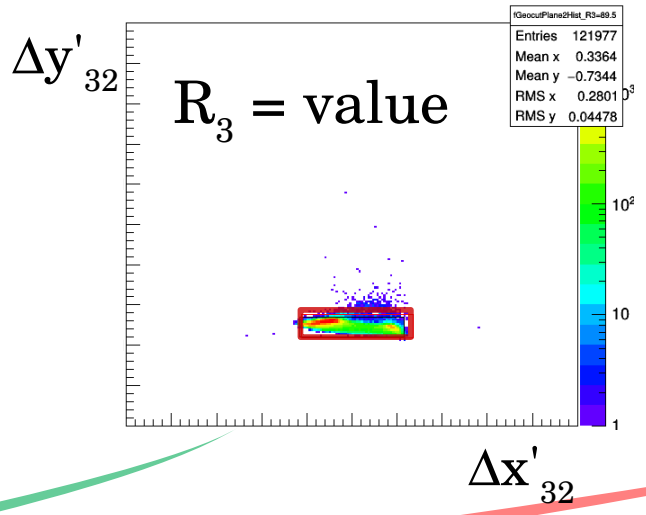

Δy'32
R3 = value
fGeocutPlane2Hist_R3=67.5
Entries 206021
Mean x −0.07043
Mean y −0.5057
RMS x 0.1381
RMS y 0.0456
Δx'32

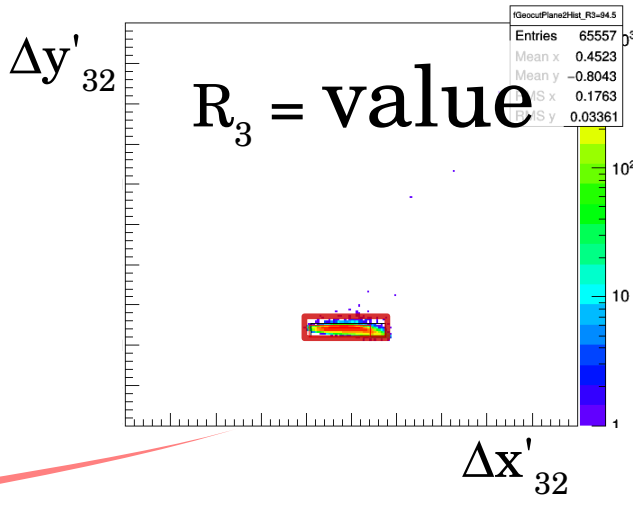

Δy'32
R3 = value
fGeocutPlane2Hist_R3=89.5
Entries 121977
Mean x 0.3364
Mean y −0.7344
RMS x 0.2801
RMS y 0.04478
Δx'32


Δy'32
R3 = value
fGeocutPlane2Hist_R3=94.5
Entries 65557
Mean x 0.4523
Mean y −0.8043
RMS x 0.1763
RMS y 0.03361
Δx'32

Extract window position and size:





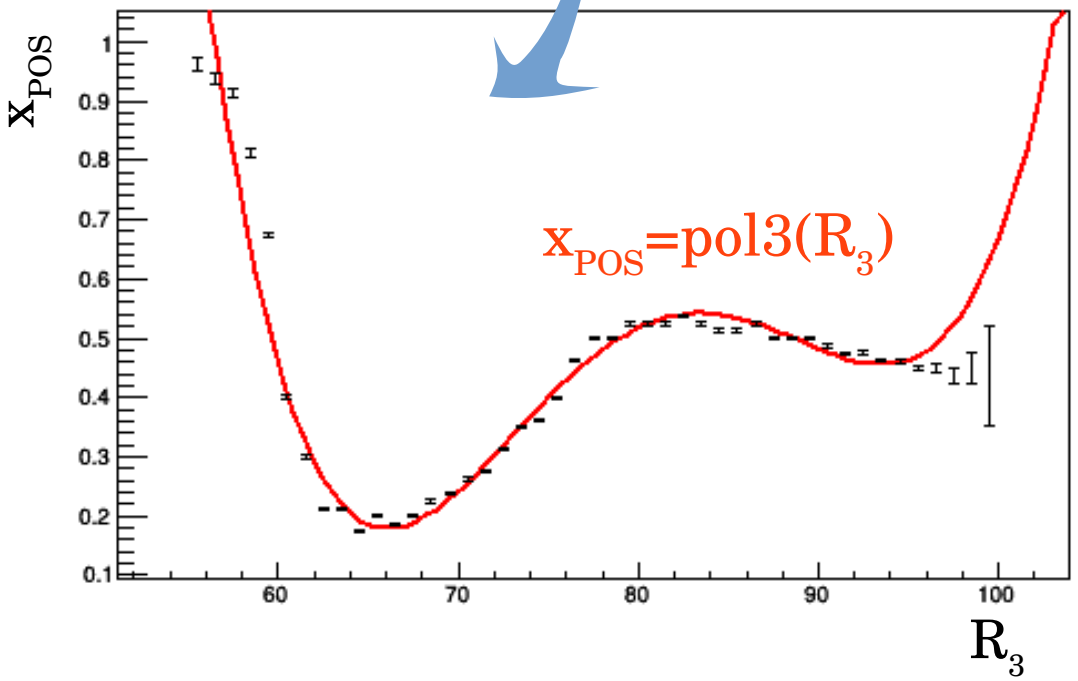


R_3	x_{POS}	y_{POS}	x_{SIZE}	y_{SIZE}	φ_{ROT}
…	…	…	…	…	…
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
…	…	…	…	…	…

R_3	x_{POS}	y_{POS}	x_{SIZE}	y_{SIZE}	φ_{ROT}
...	...	...	...	...	...
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...

Fit

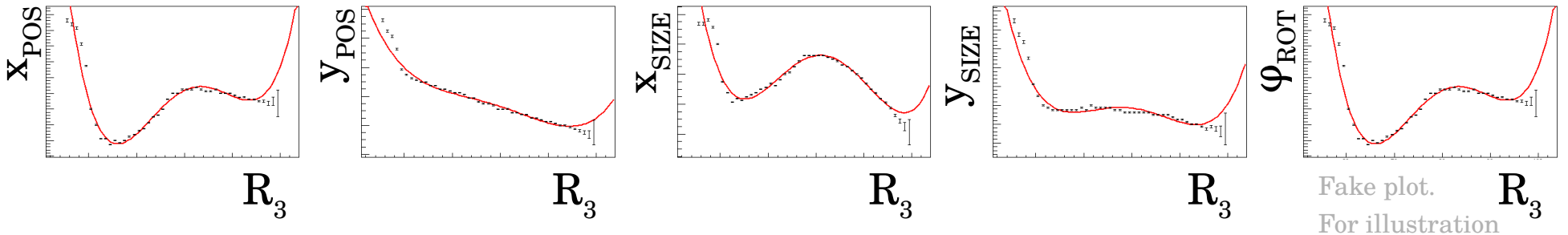
R_3	x_{POS}	y_{POS}	x_{SIZE}	y_{SIZE}	φ_{ROT}
…	…	…	…	…	…
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
…	…	…	…	…	…



Fit

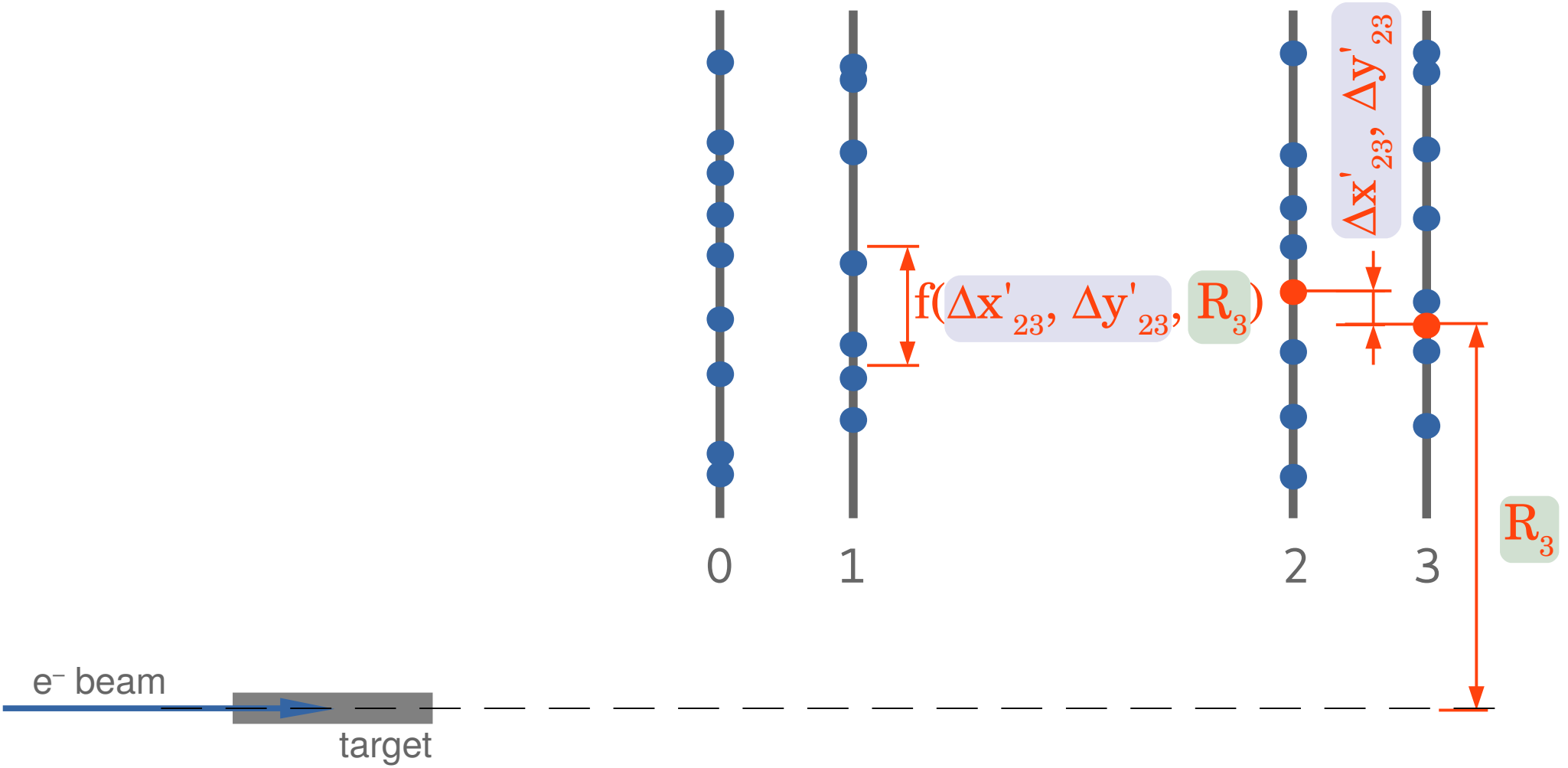
R_3	x_{POS}	y_{POS}	x_{SIZE}	y_{SIZE}	φ_{ROT}
…	…	…	…	…	…
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
…	…	…	…	…	…

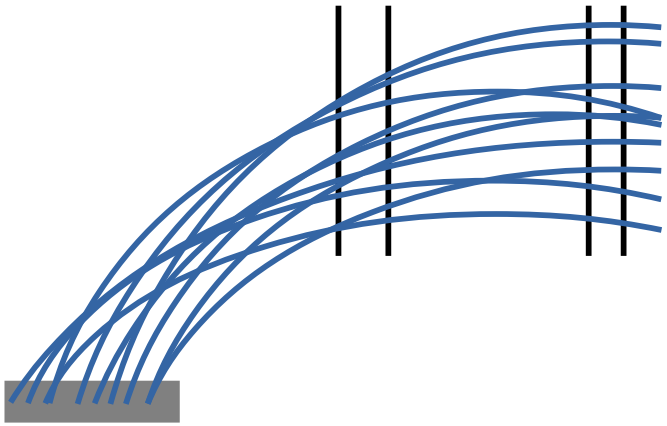
$x_{POS}=pol3(R_3)$ $y_{POS}=pol3(R_3)$ $x_{SIZE}=pol3(R_3)$ $y_{SIZE}=pol3(R_3)$ $\varphi_{ROT}=pol3(R_3)$



Fake plot. For illustration only.

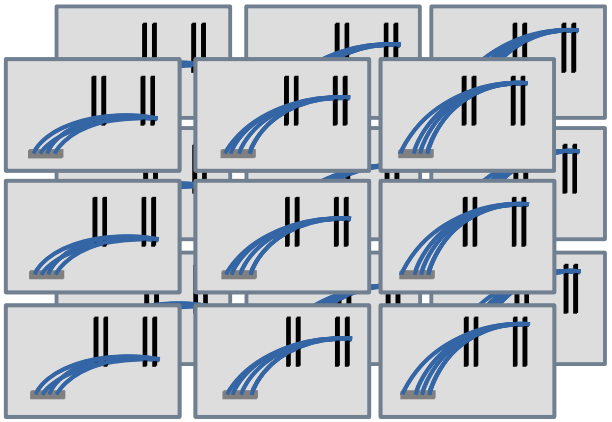
Search window for plane 1





R_3	$\Delta x'_{23}$	$\Delta y'_{23}$	x_{POS}	y_{POS}	x_{SIZE}	y_{SIZE}	φ_{ROT}
▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪
▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪	▪▪▪

bin by $\{R_3, \Delta x'_{23}, \Delta y'_{23}\}$

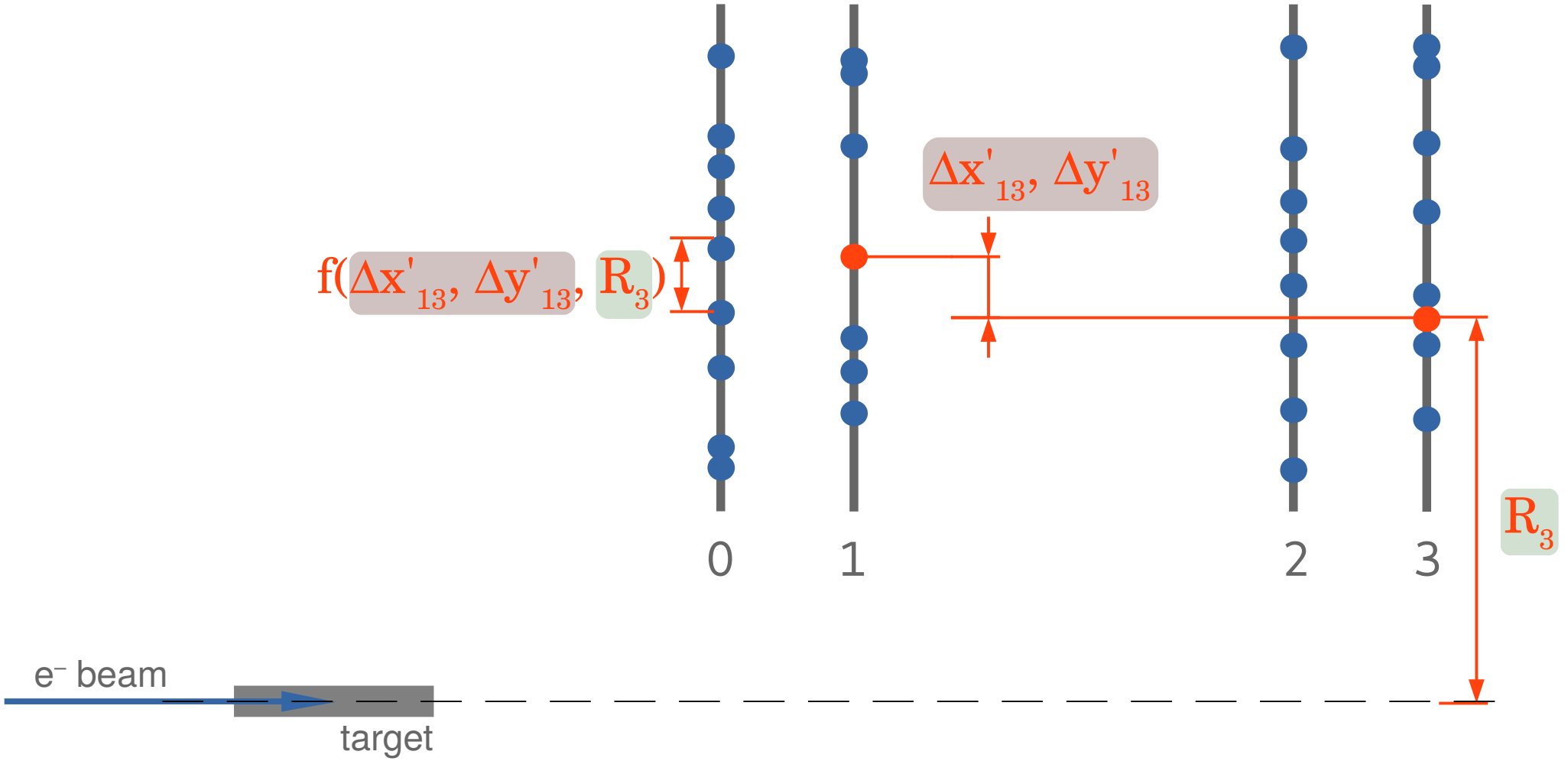


determine the search windows

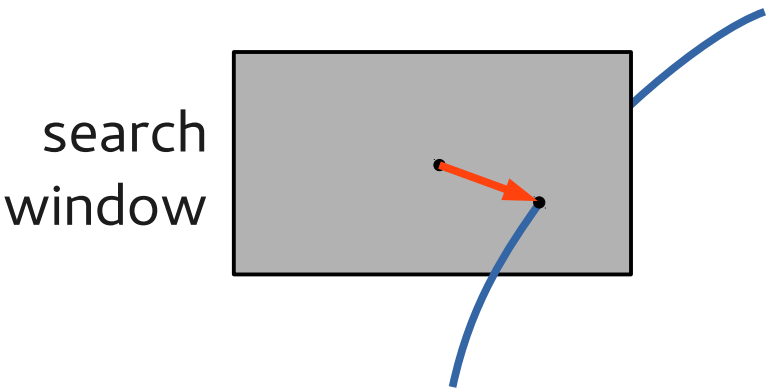
Fit (in 3D)

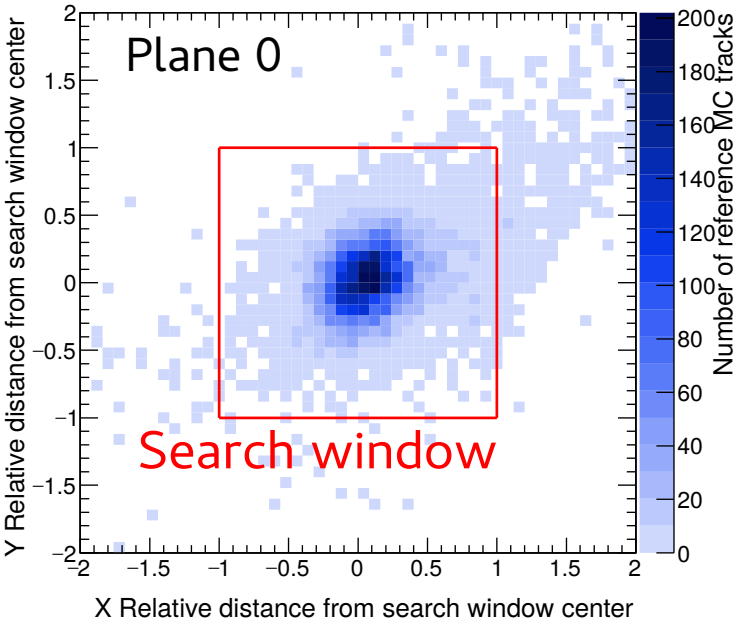
$$x_{SIZE} = x_{SIZE}(R_3, \Delta x'_{23}, \Delta y'_{23})$$
$$y_{SIZE} = y_{SIZE}(R_3, \Delta x'_{23}, \Delta y'_{23})$$
$$x_{POS} = x_{POS}(R_3, \Delta x'_{23}, \Delta y'_{23})$$
$$y_{POS} = y_{POS}(R_3, \Delta x'_{23}, \Delta y'_{23})$$
$$\varphi_{ROT} = \varphi_{ROT}(R_3, \Delta x'_{23}, \Delta y'_{23})$$

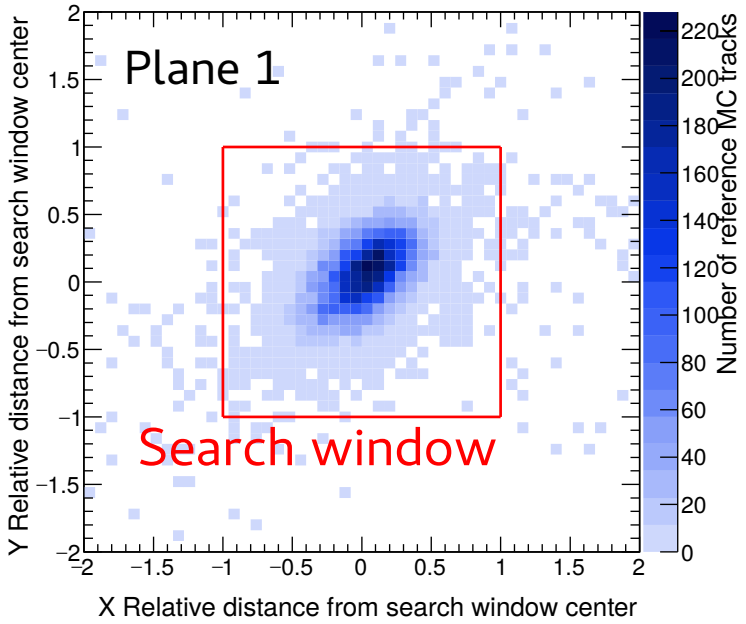
Search window for plane 0

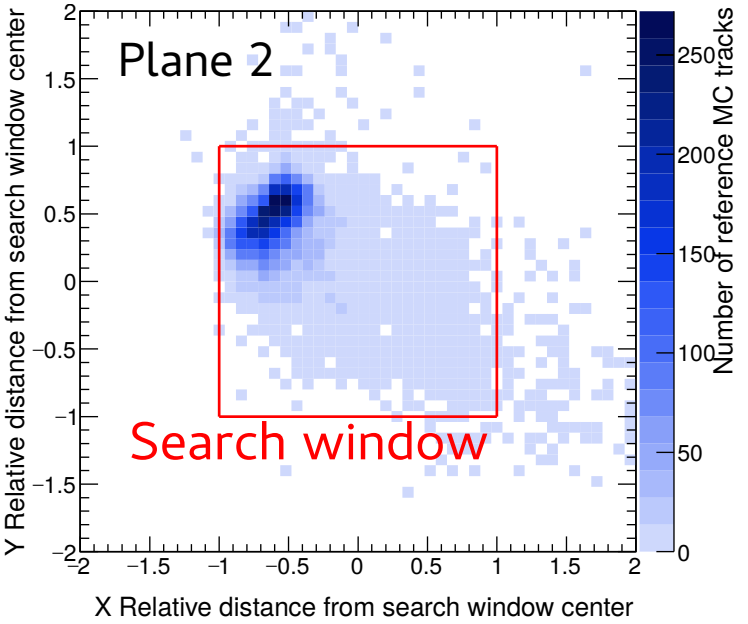


Relative distance from the center of the search window





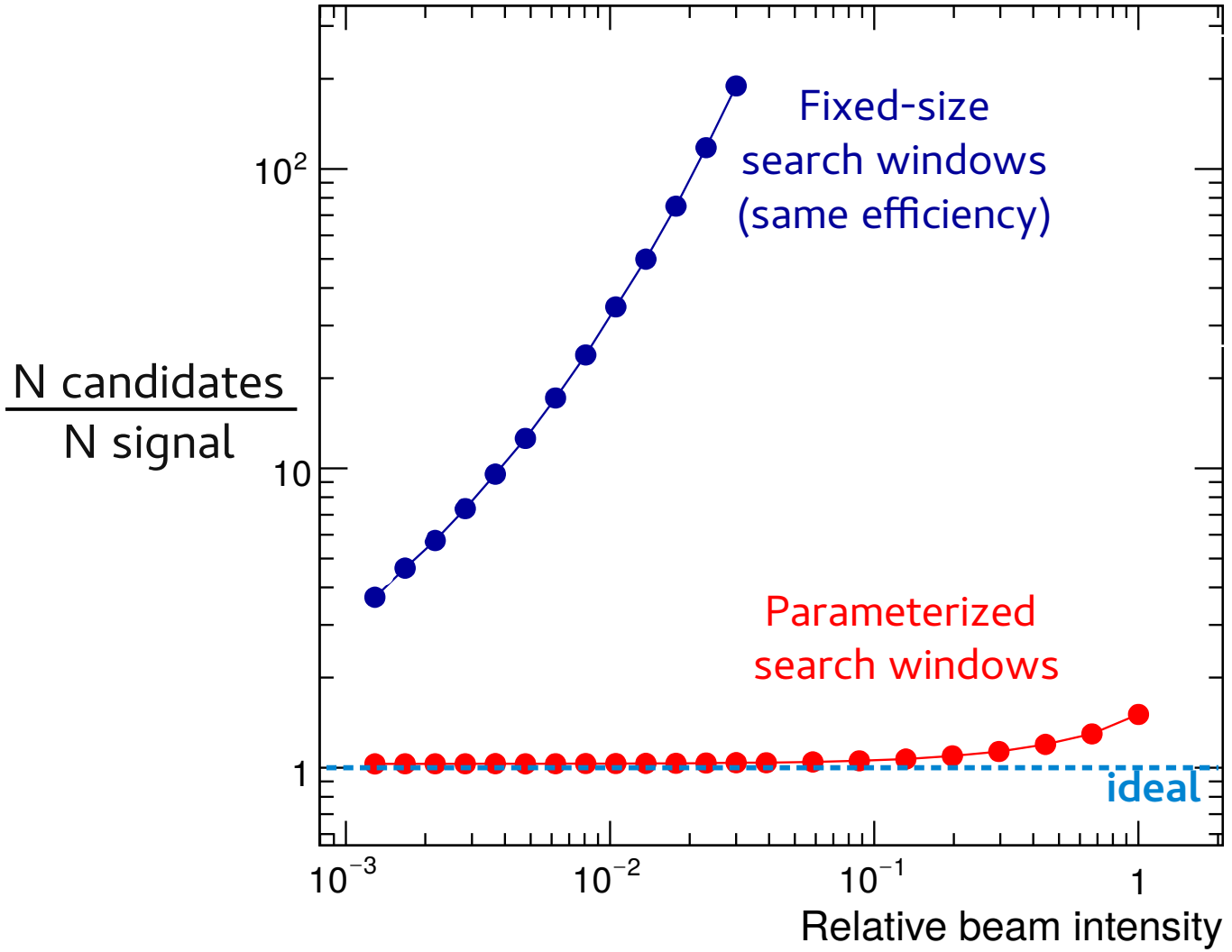




Overall about 90% efficiency (depending on settings).

Performance

Number of candidates per signal track



Summary

Parameterization-based tracking:

- replaces rigorous model calculations
  by simple analytical parametric functions
- parameters can be tuned based on real data or simulation
- enables accurate, efficient, and very fast track finding
- works well for P2 due to narrow momentum range