Parameterization-based tracking for the P2 experiment

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HK T 89.9

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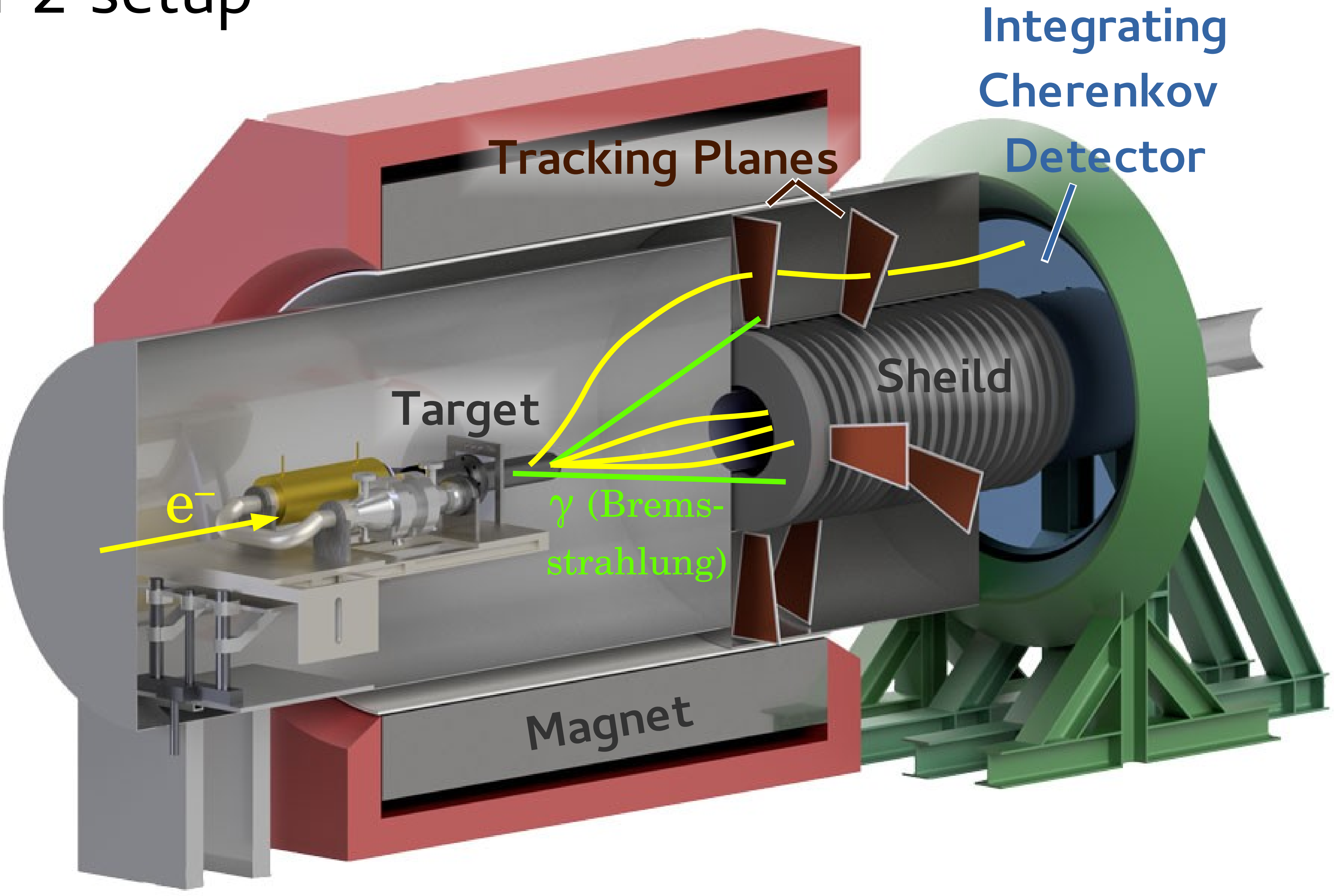
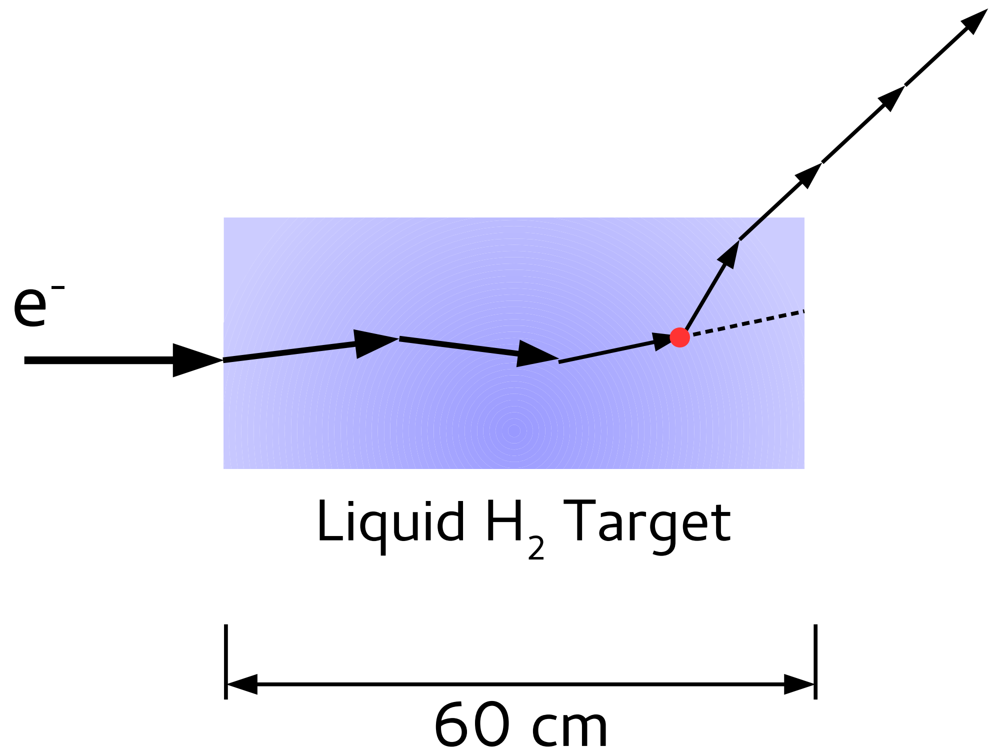
P2 setup


Integrating
Cherenkov
Detector
Tracking Planes
Sheild
Target
e⁻
γ (Brems-
strahlung)
Magnet

Why is tracking necessary?

"Measure" actual Q^2 distribution

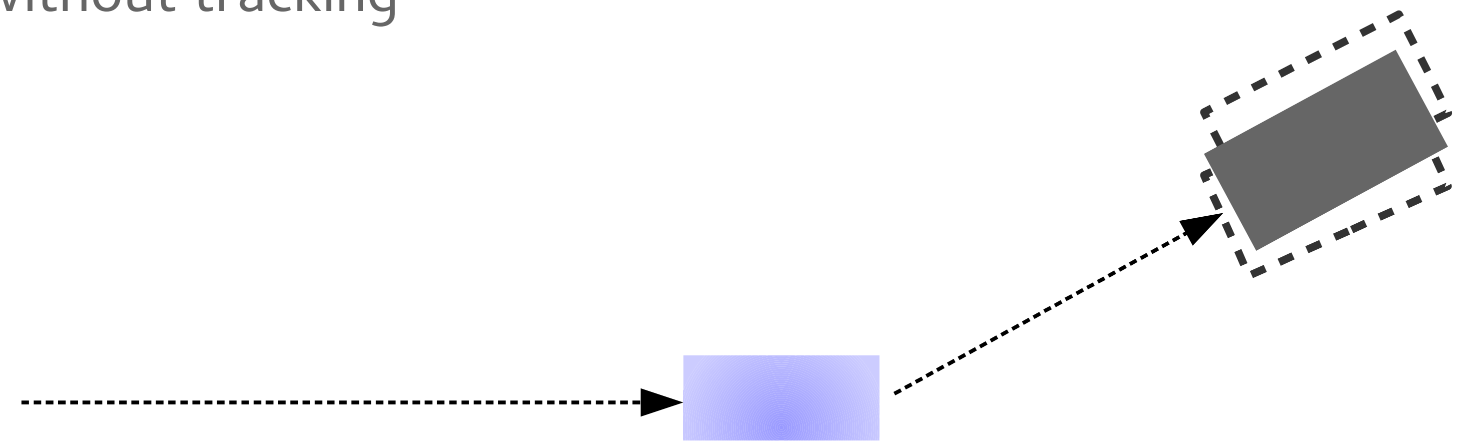


$$A_{PV} = \frac{N\downarrow - N\uparrow}{N\downarrow + N\uparrow} = \frac{\sigma\downarrow - \sigma\uparrow}{\sigma\downarrow + \sigma\uparrow} = \frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left(Q_W - F\left(Q^2\right)\right)$$

Why is tracking necessary?

Validate the acceptance, alignment, and magnetic filed map

The magnetic field is anyways necessary,
even without tracking

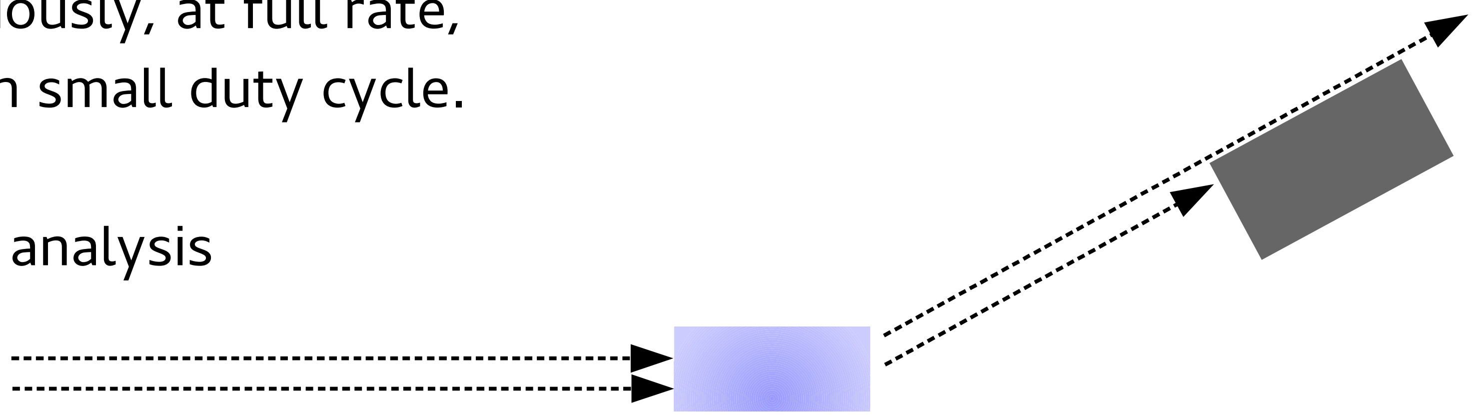


Why is tracking necessary?

Montor the beam and the target conditions (e.g. boiling)

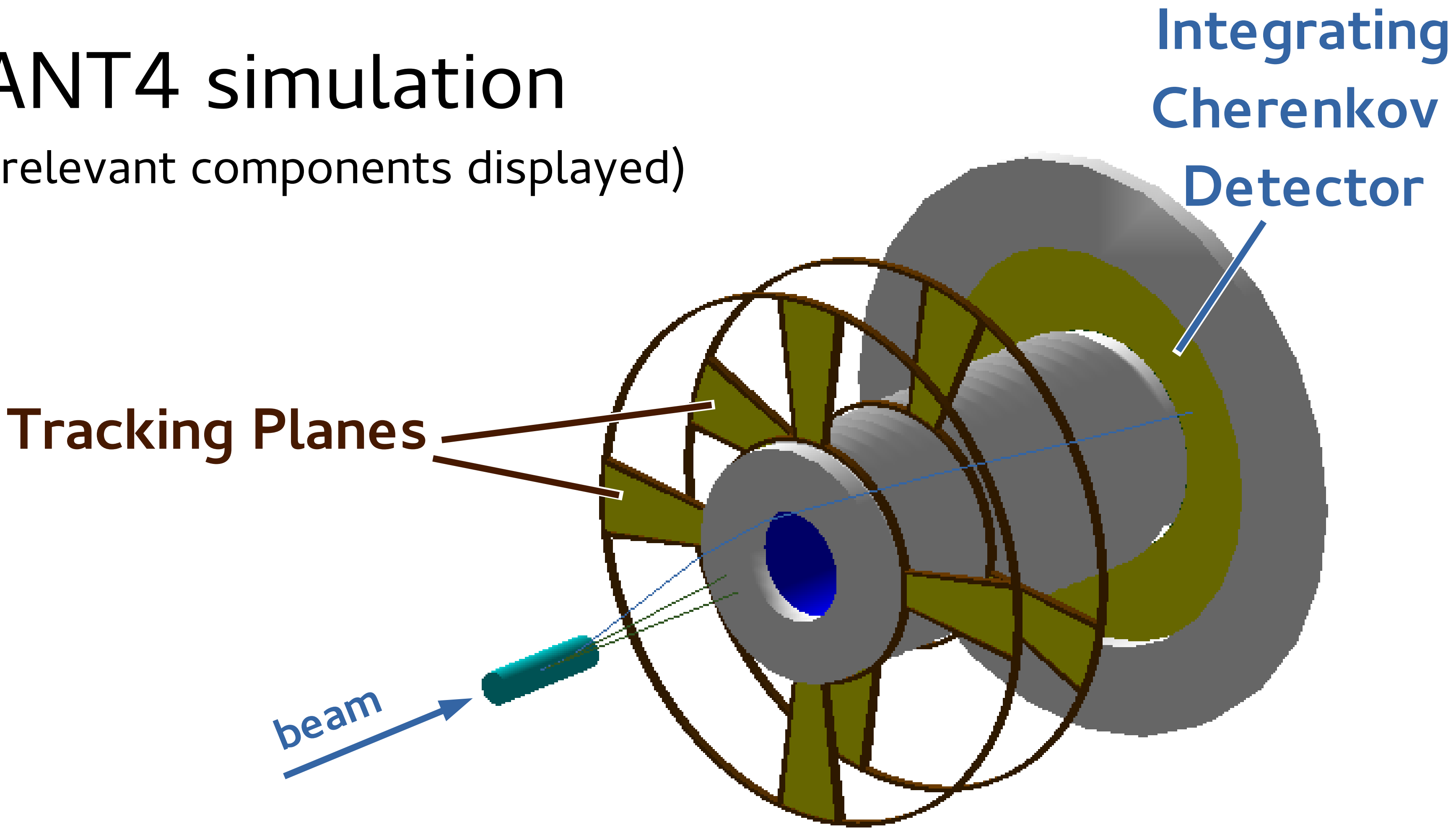
Continuously, at full rate,
but with small duty cycle.

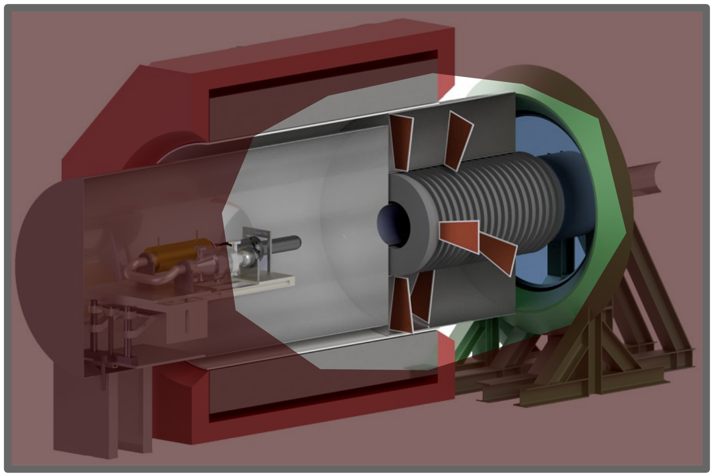
On-line analysis



GEANT4 simulation

(only relevant components displayed)

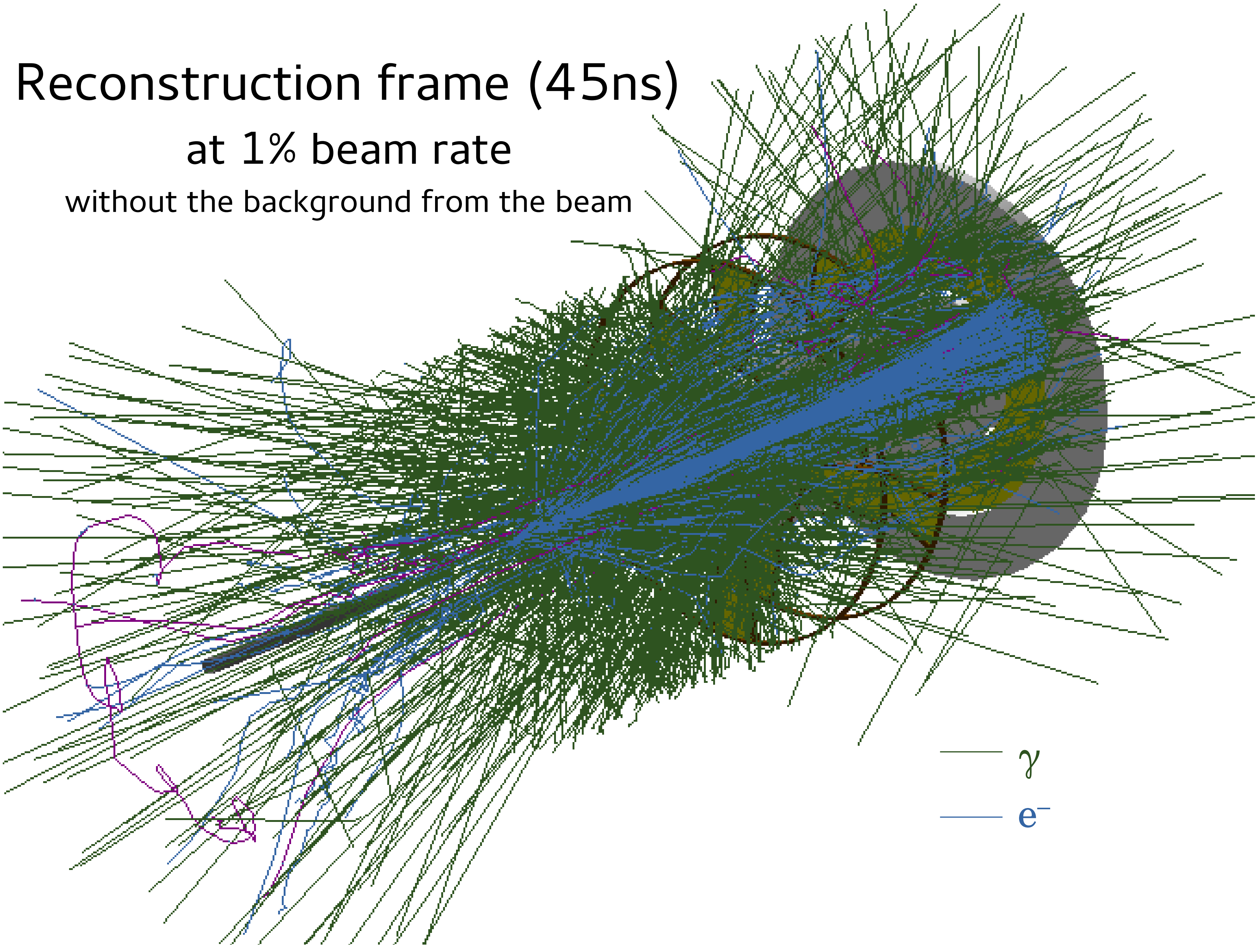


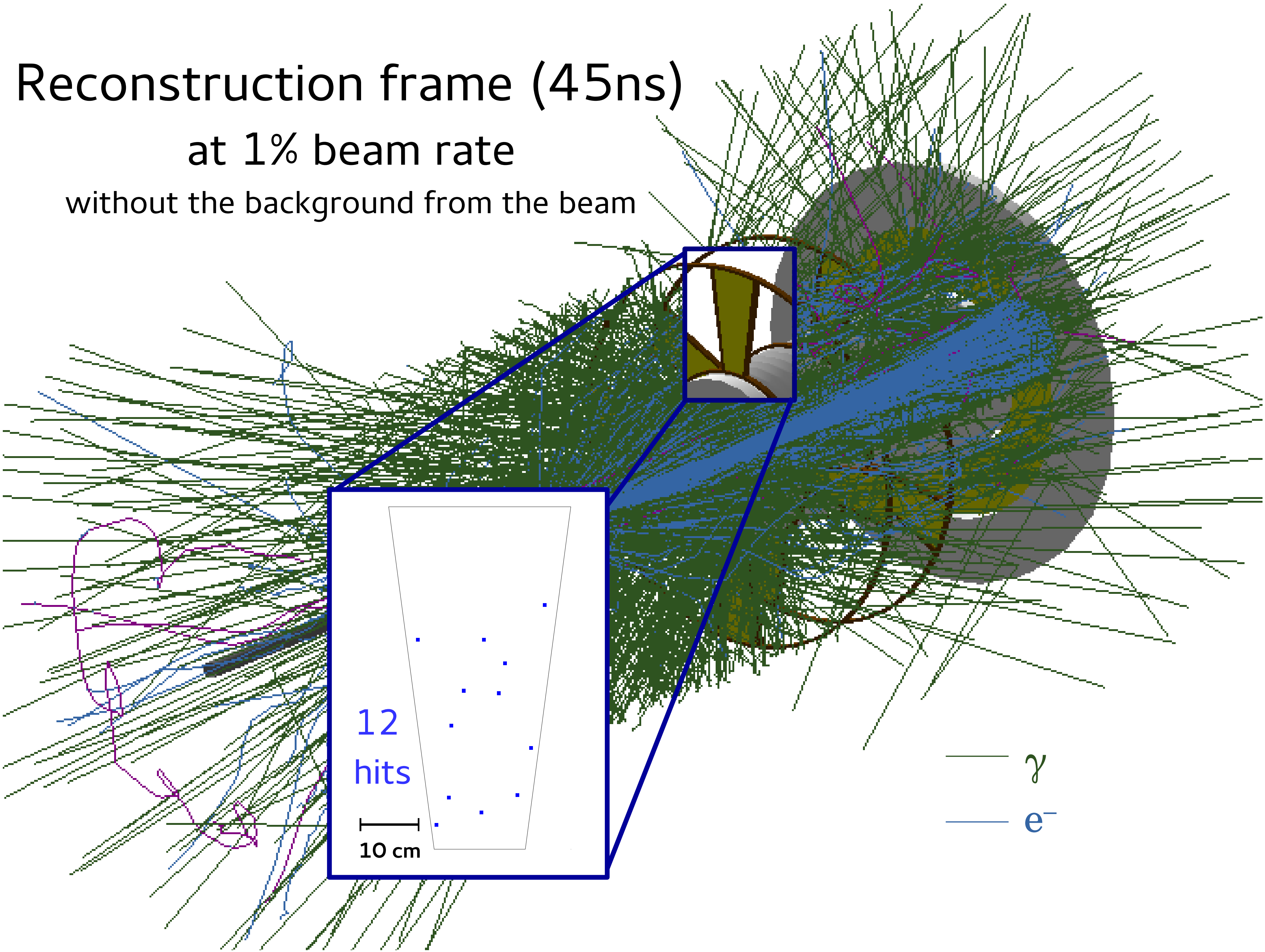


Reconstruction frame (45ns)

at 1% beam rate

without the background from the beam



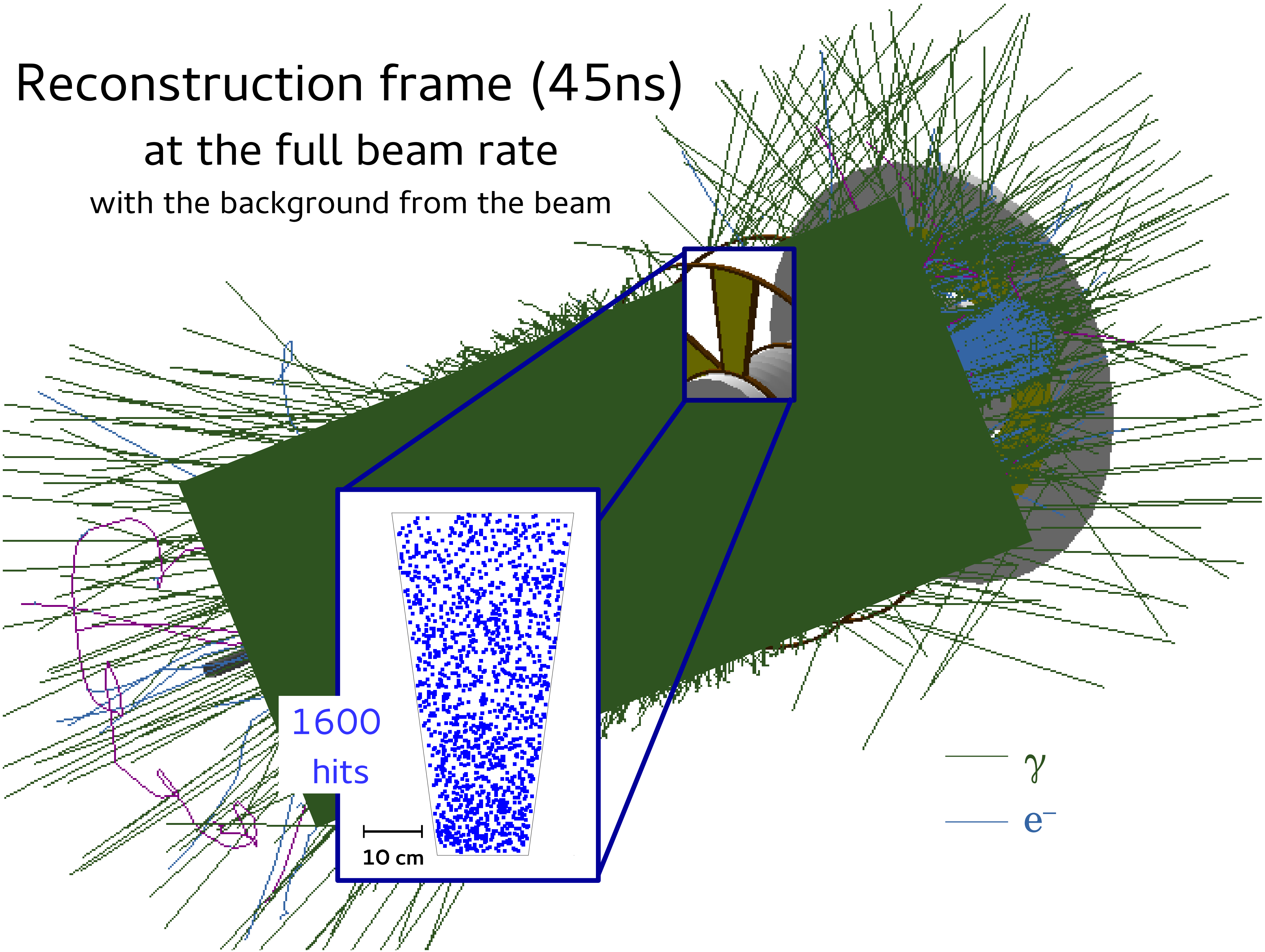


Reconstruction frame (45ns)
at 1% beam rate
without the background from the beam
12
hits
10 cm
γ
e⁻

Reconstruction frame (45ns)

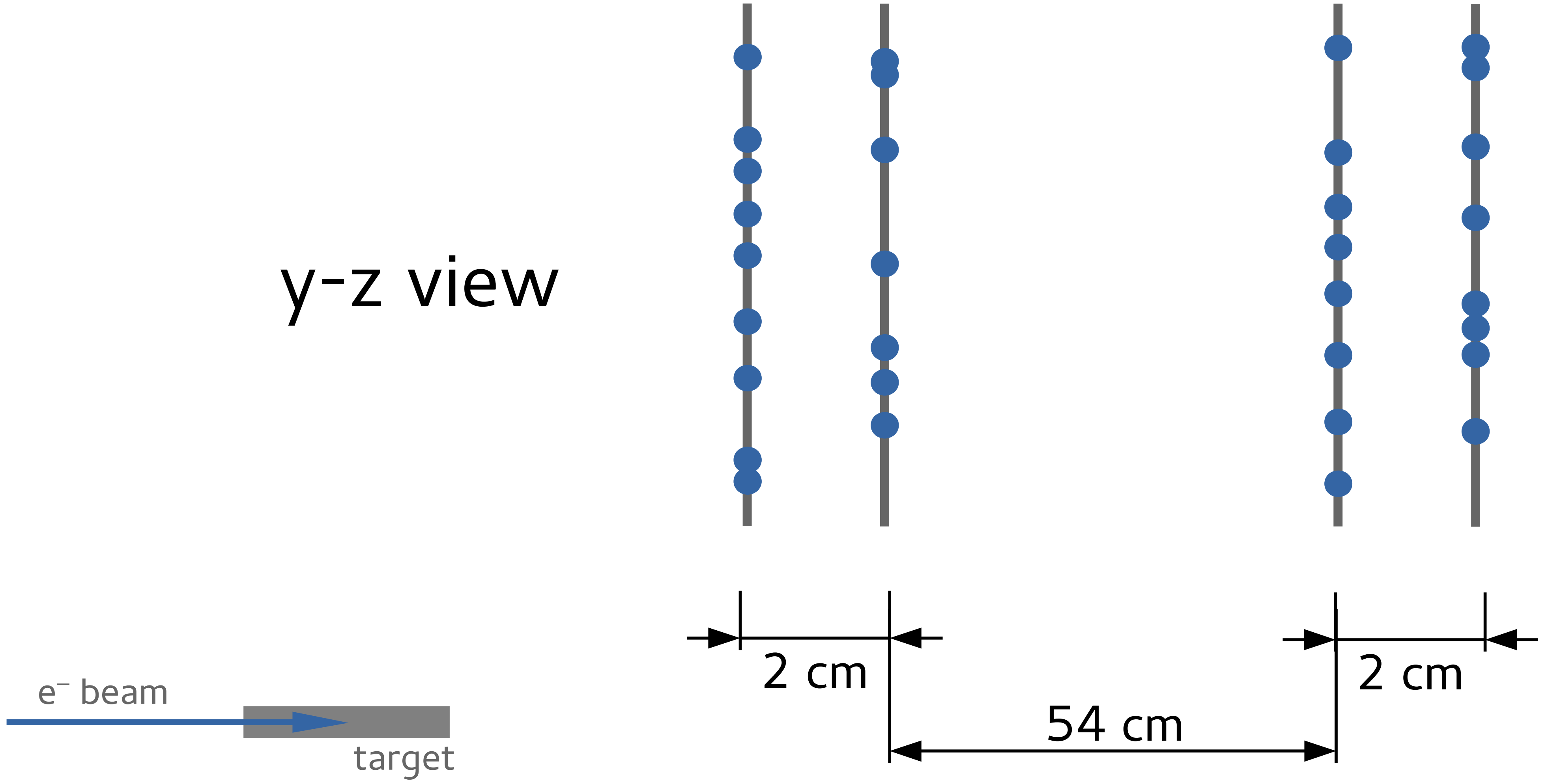
at the full beam rate

with the background from the beam

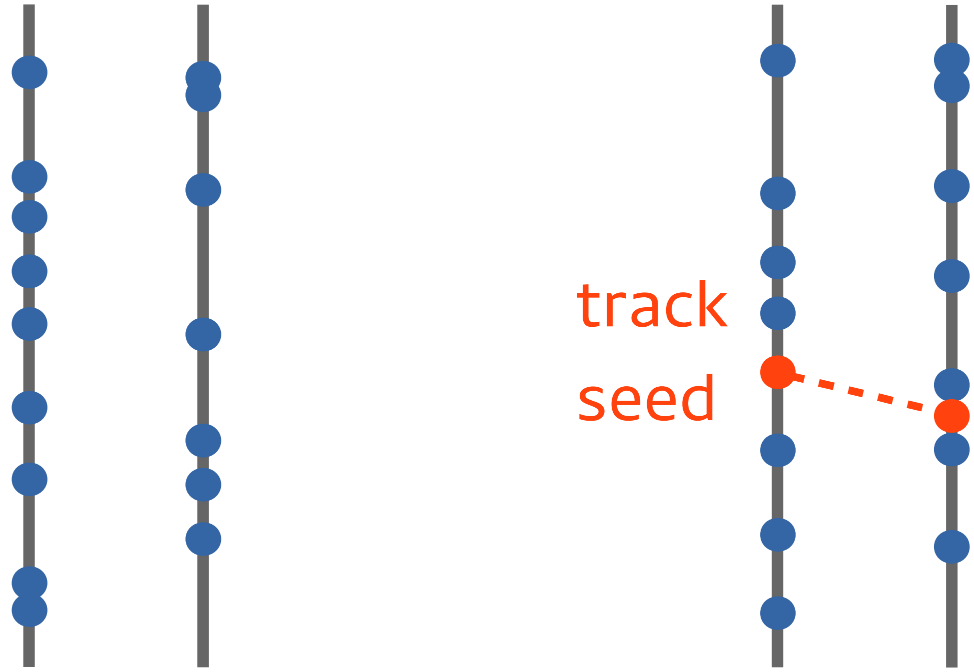


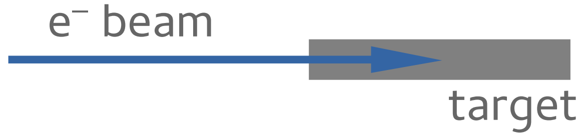
Conventional track following

y-z view

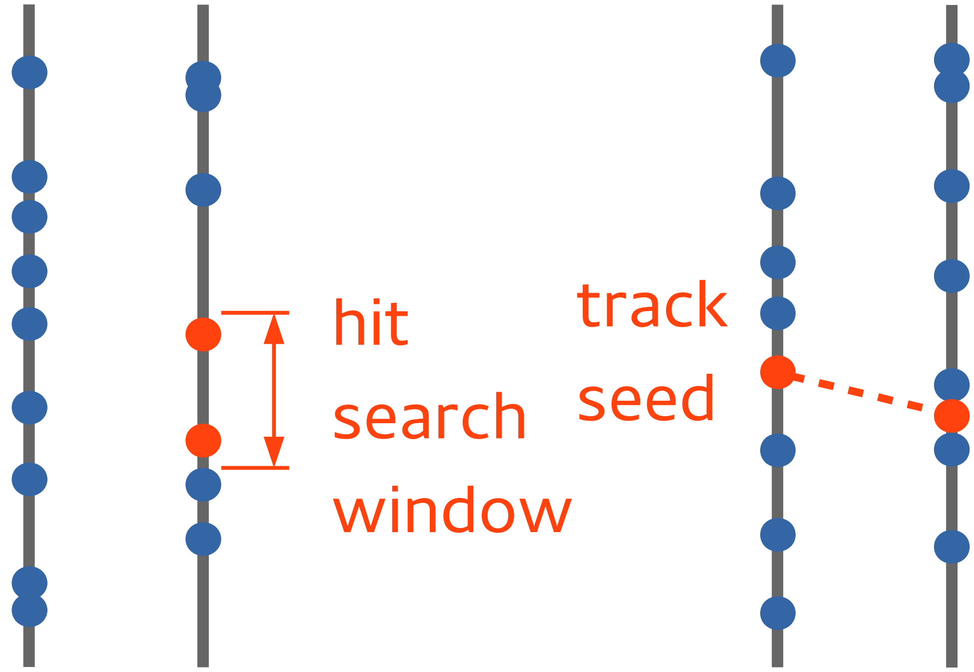


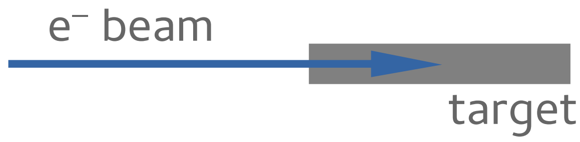
Conventional track following



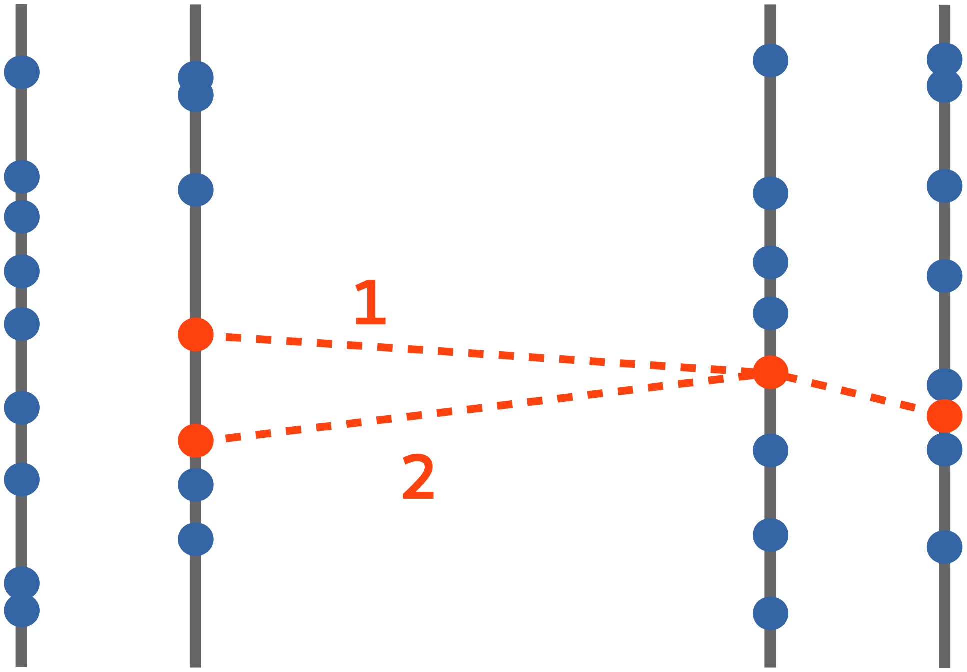


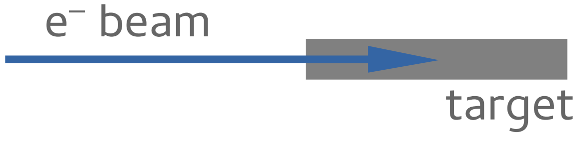
Conventional track following



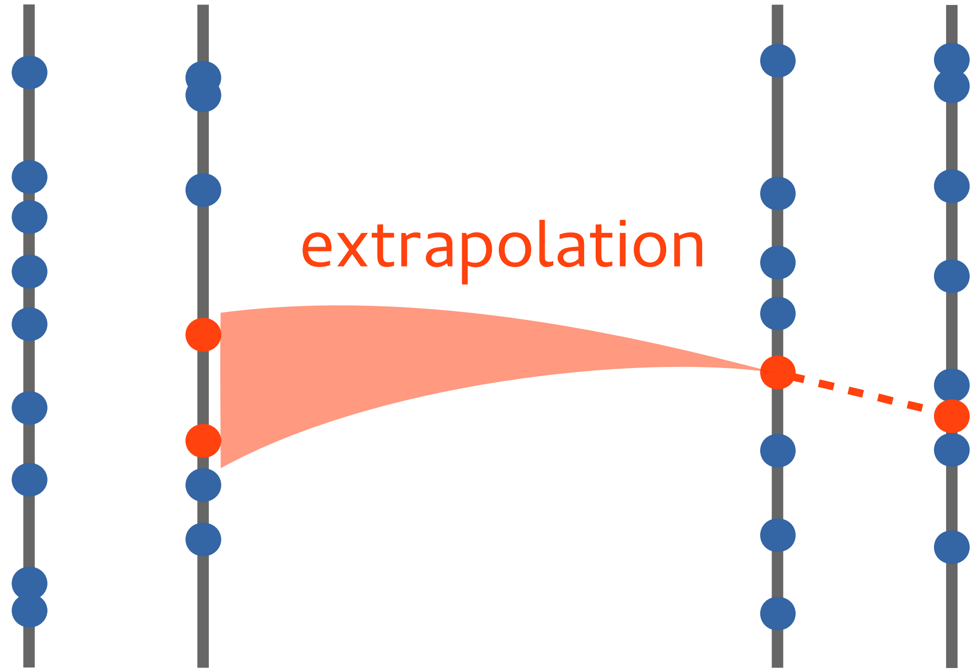


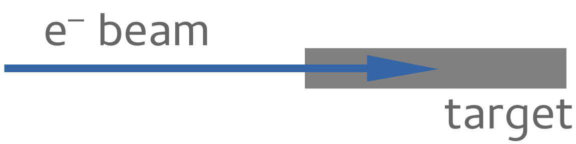
Conventional track following



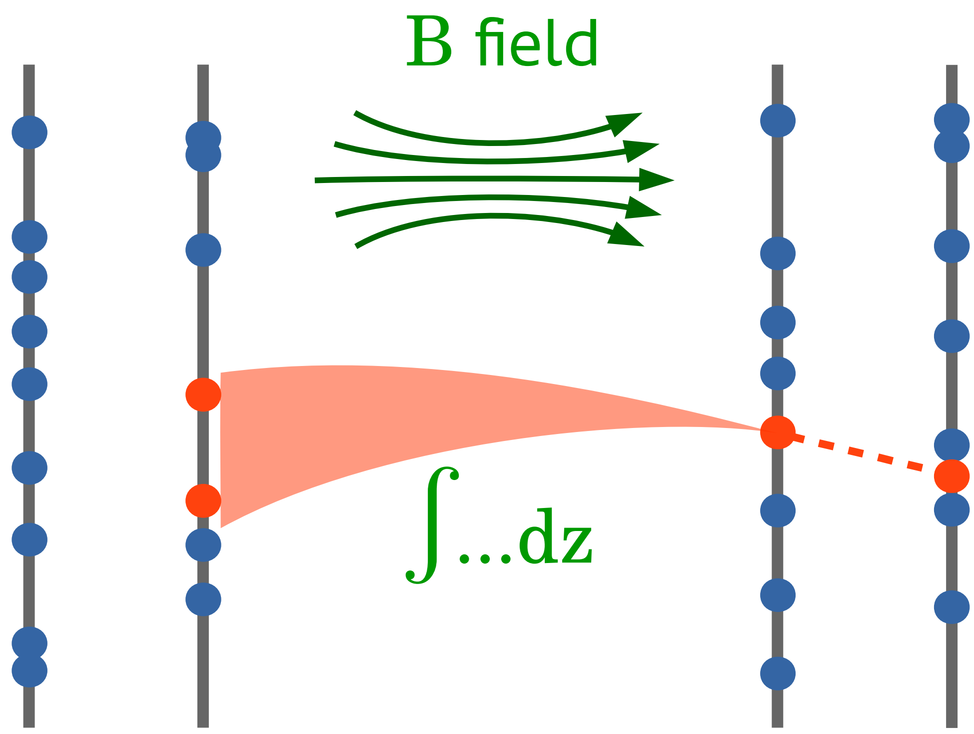


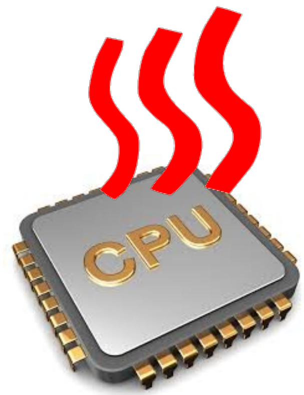
Conventional track following

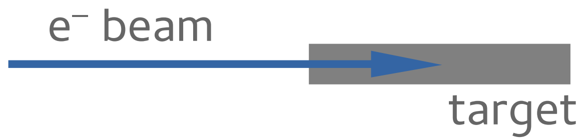




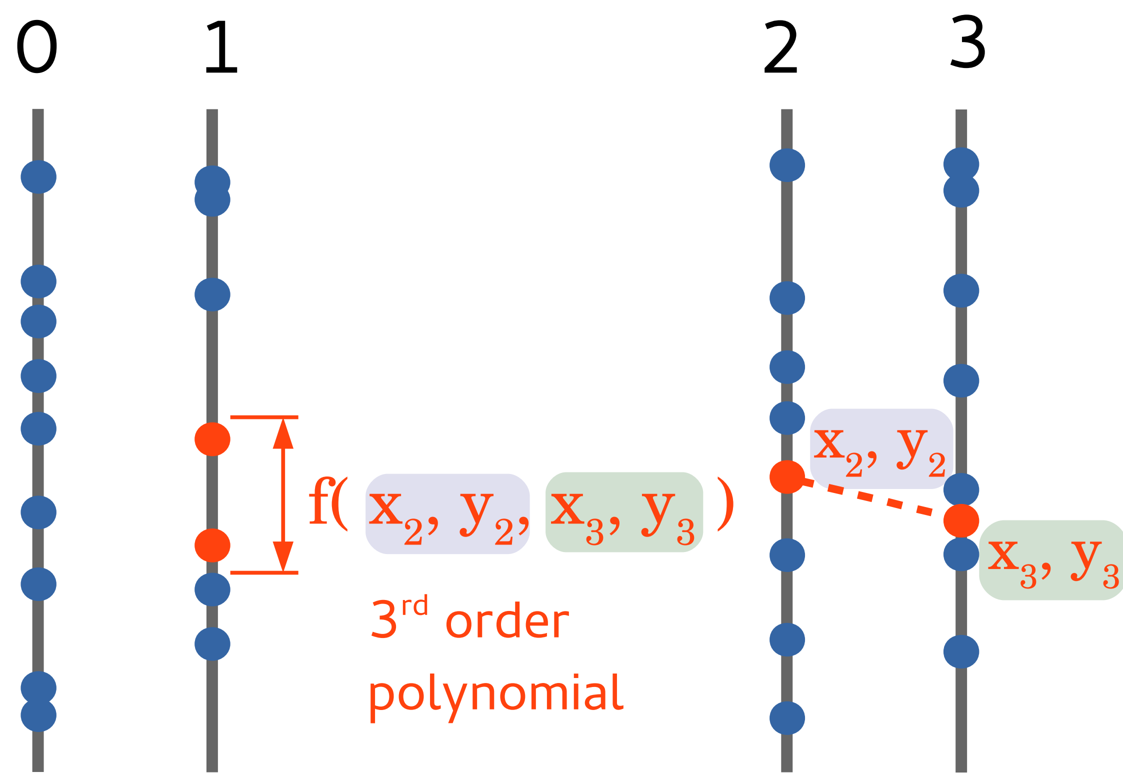
Conventional track following

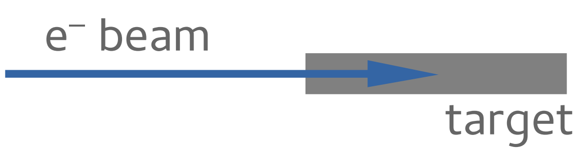






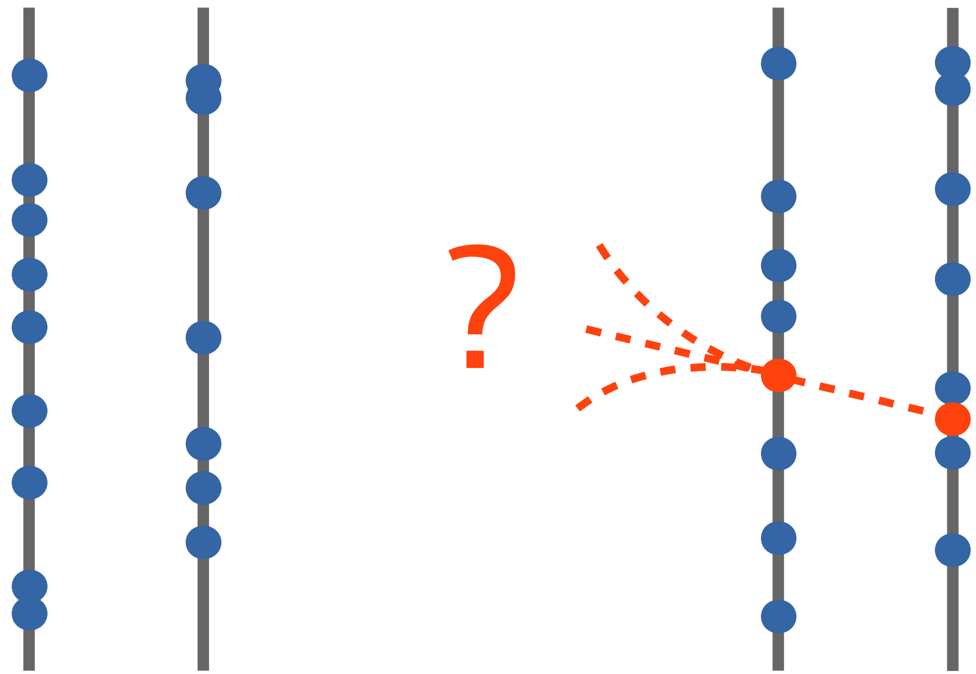
Parameterization-based track finding

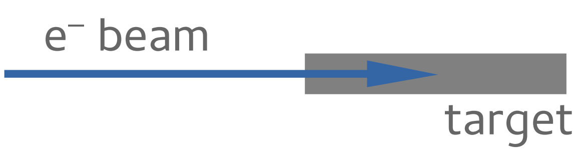




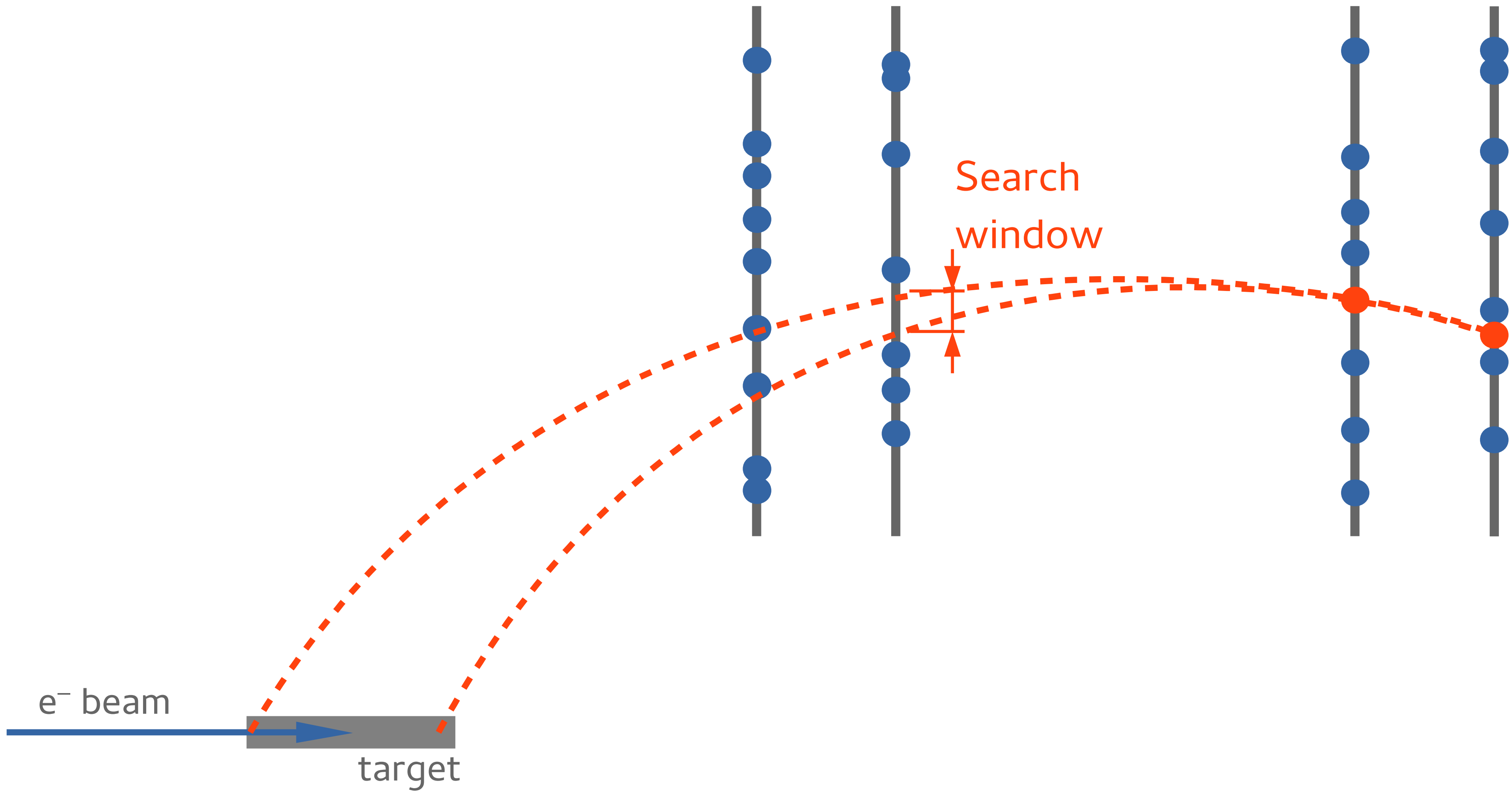
Extrapolation

Extrapolation

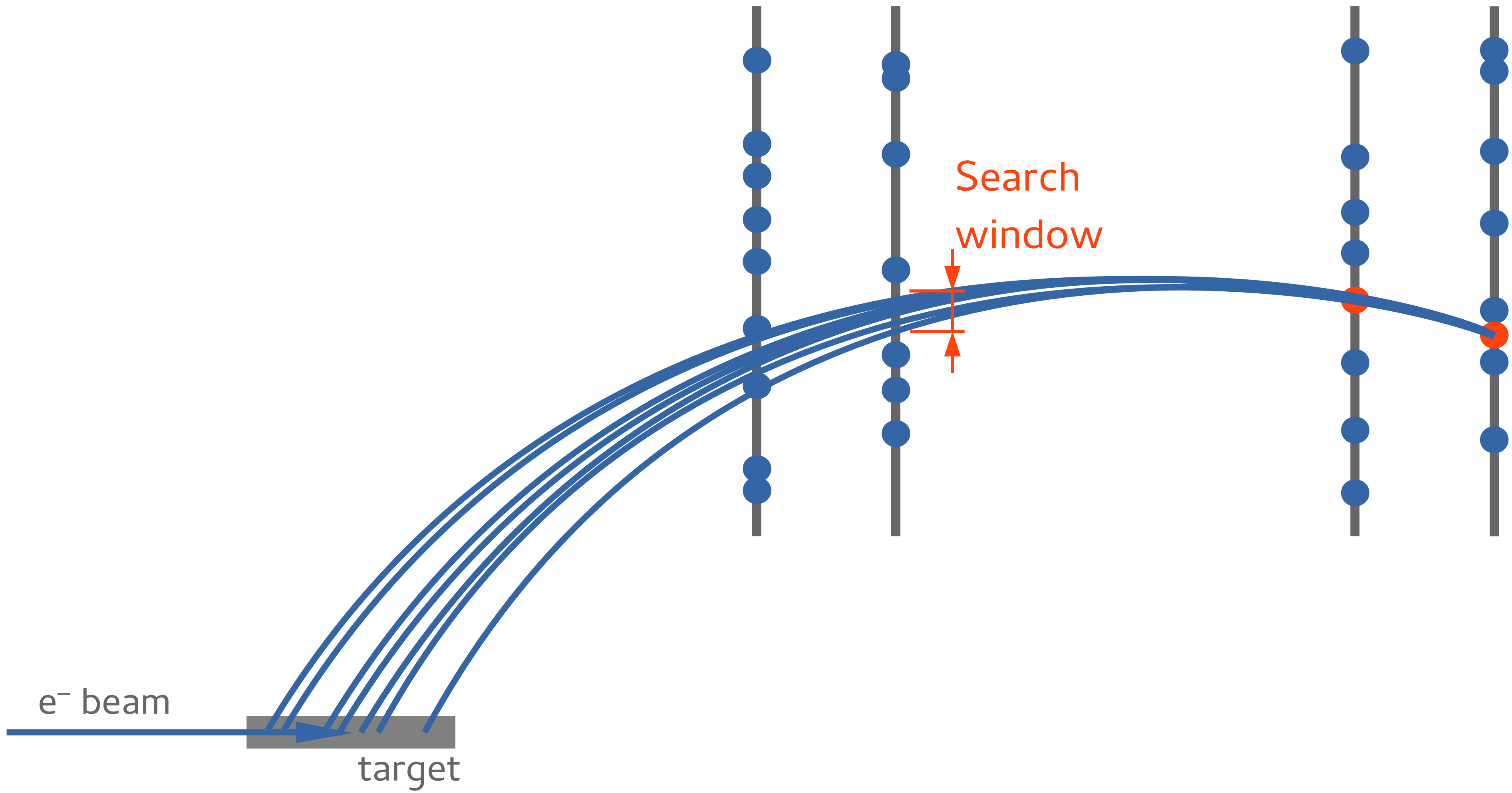




Extrapolation with constraints

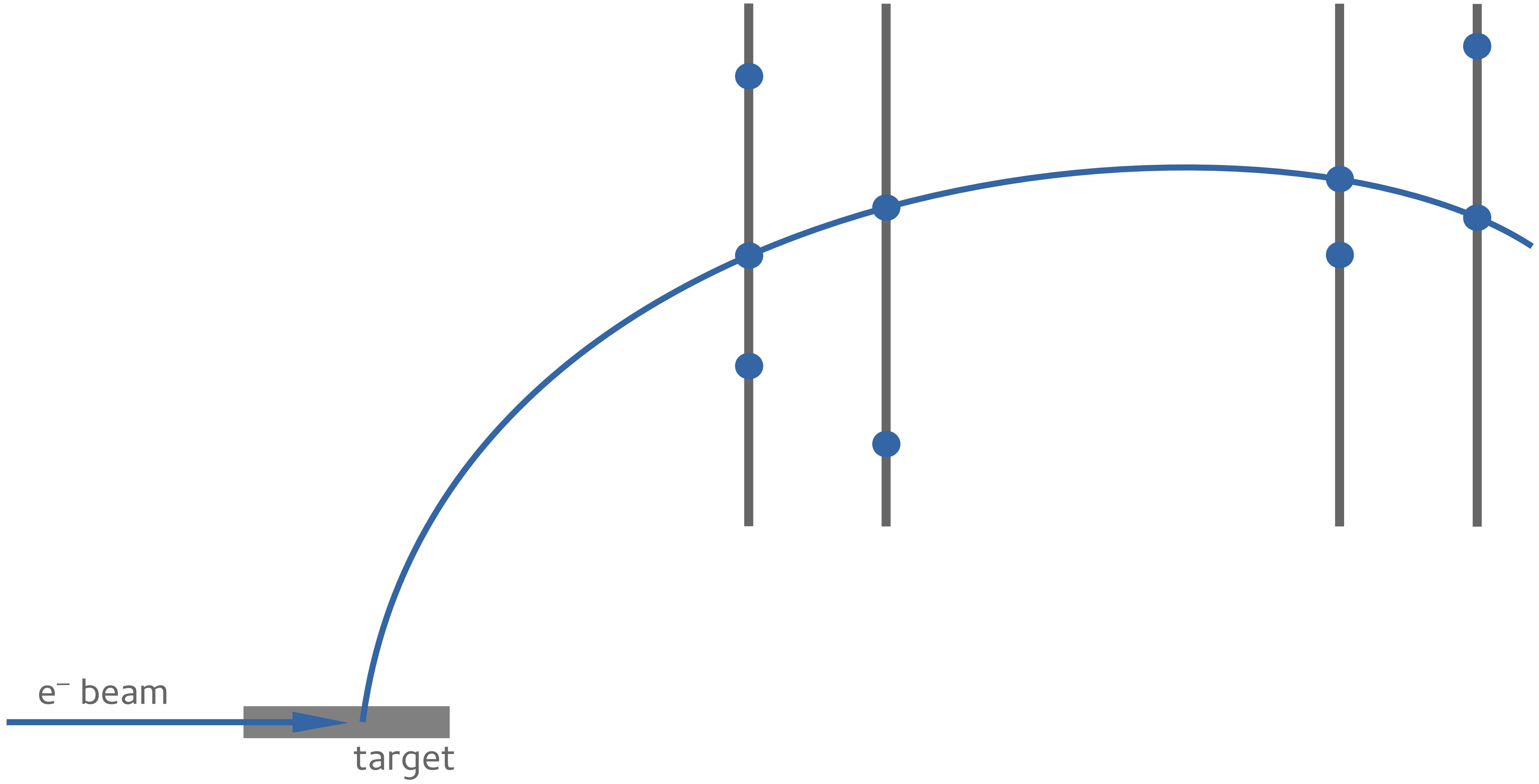


Using reference tracks instead of extrapolation



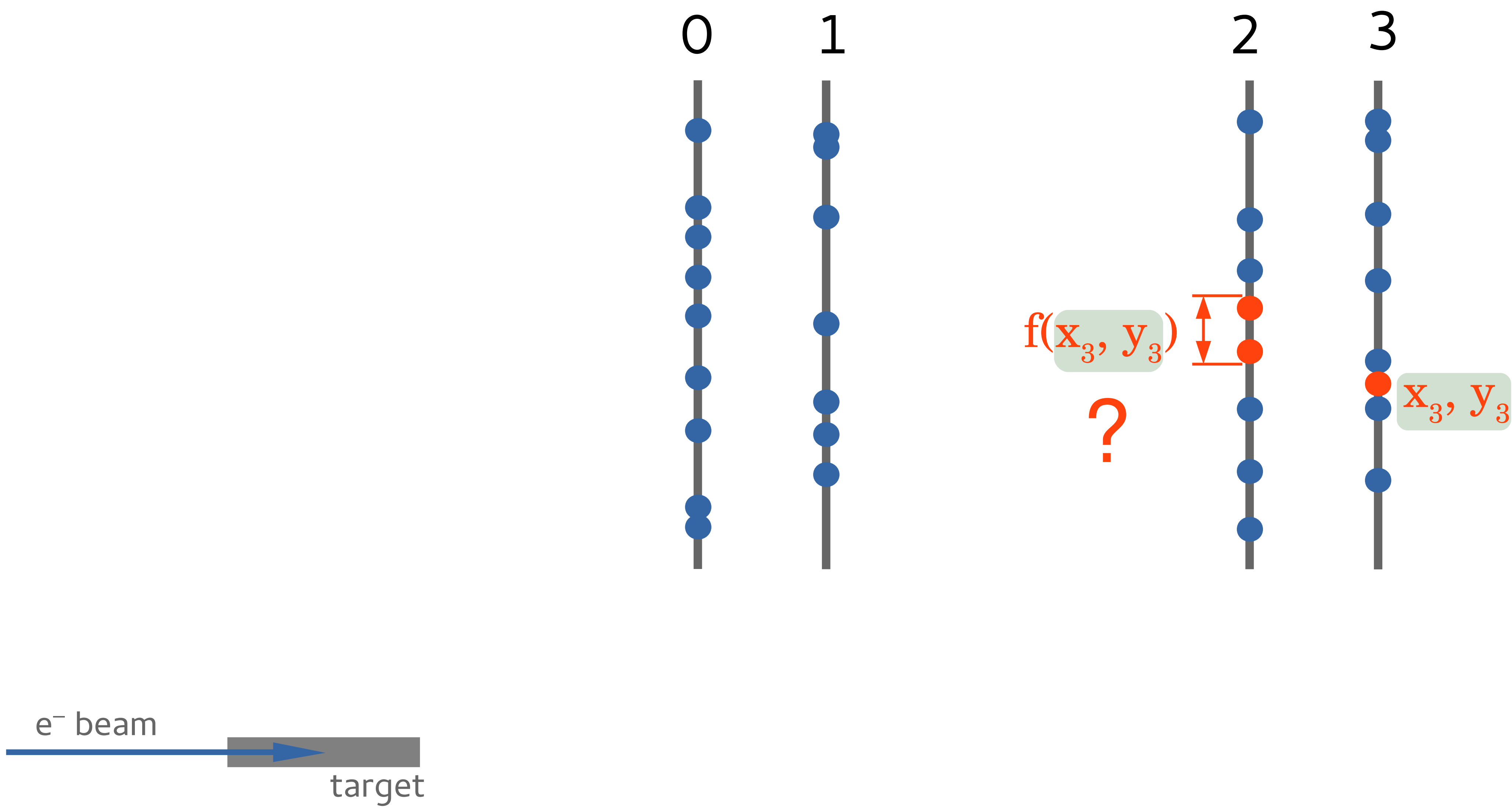
Reference tracks:

- from MC
- brute-force reconstruction at low rate; select by χ^2.

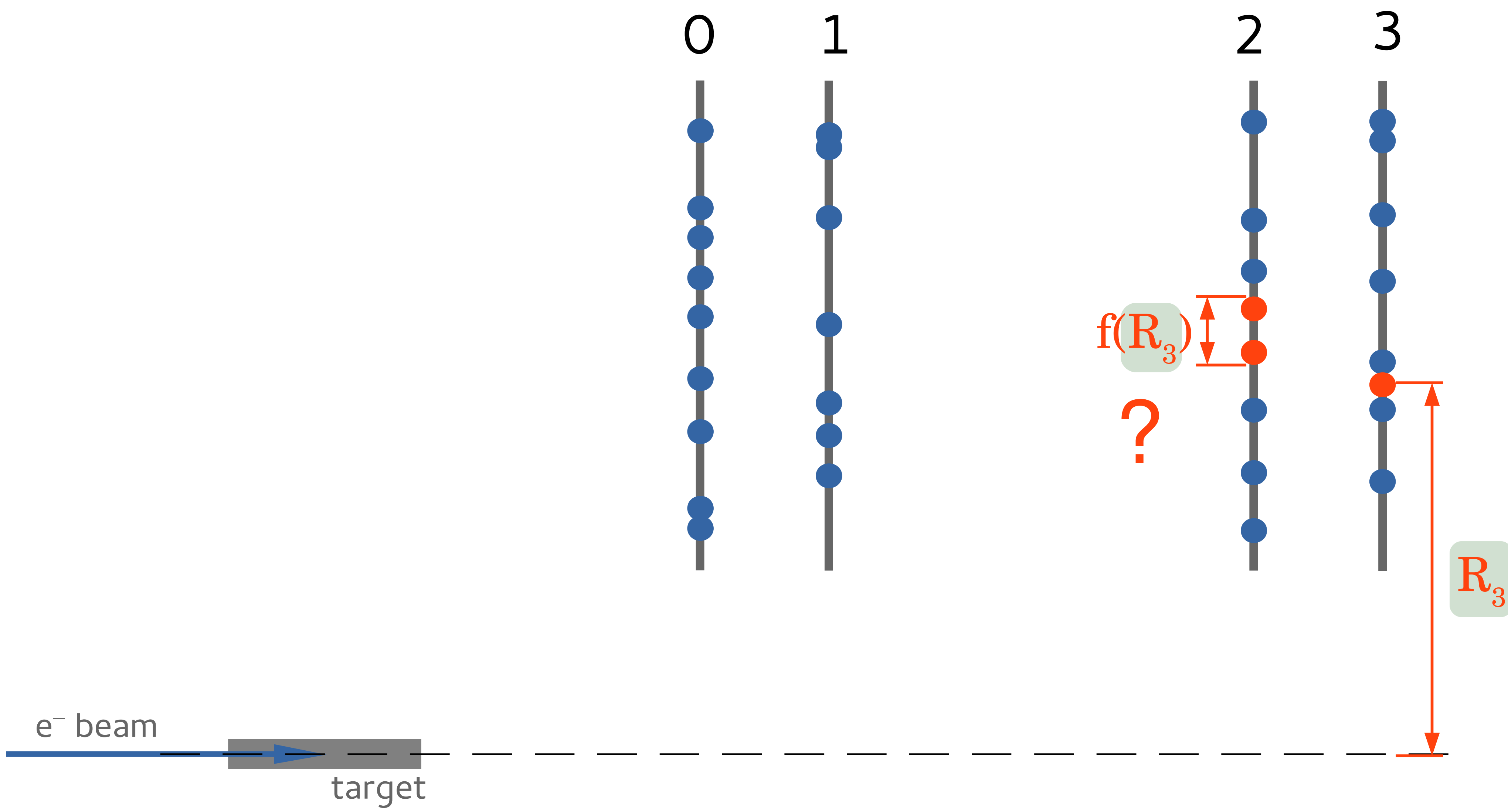


How to construct the parameterizations?

Search window for plane 2



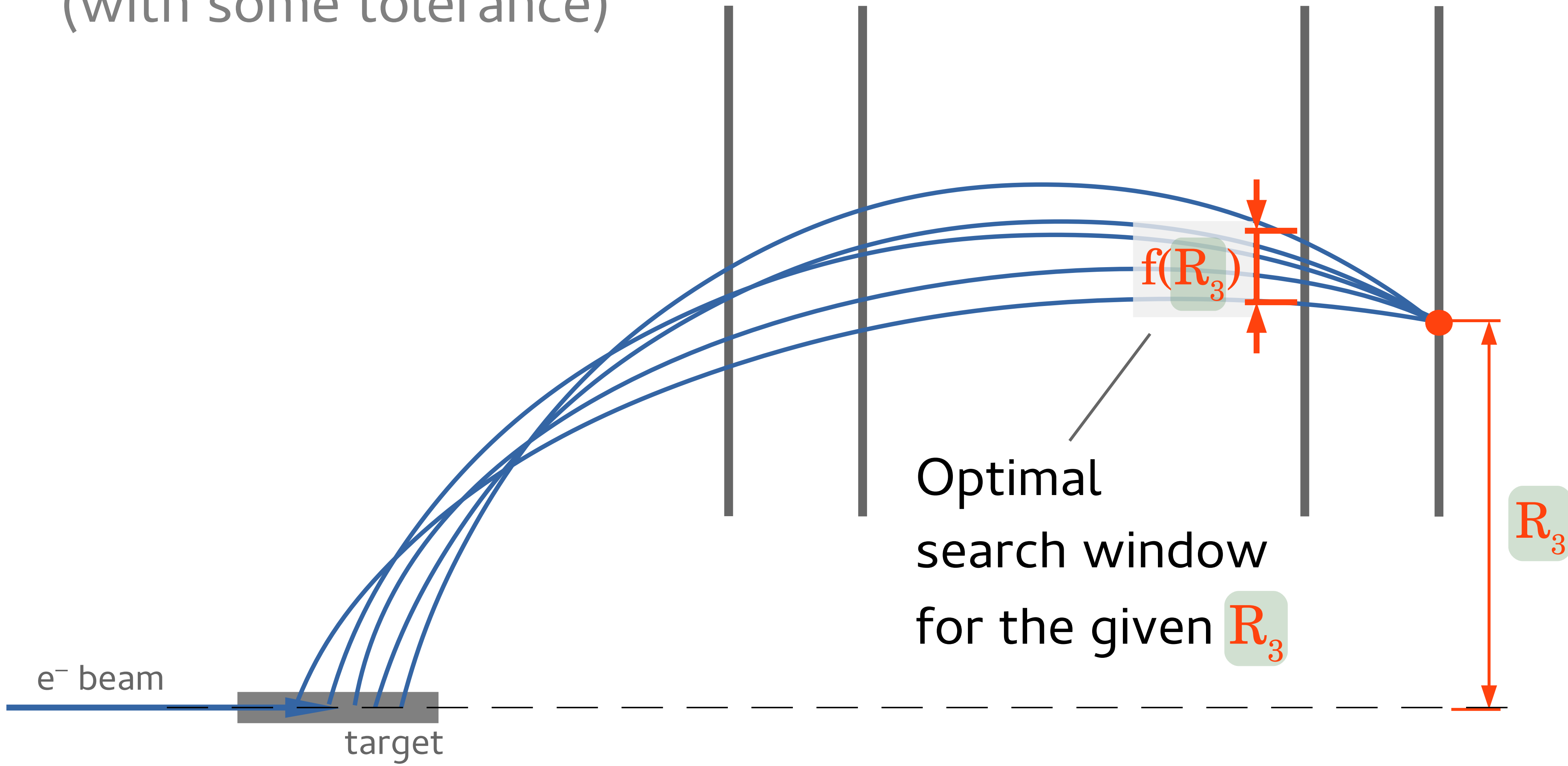
Search window for plane 2



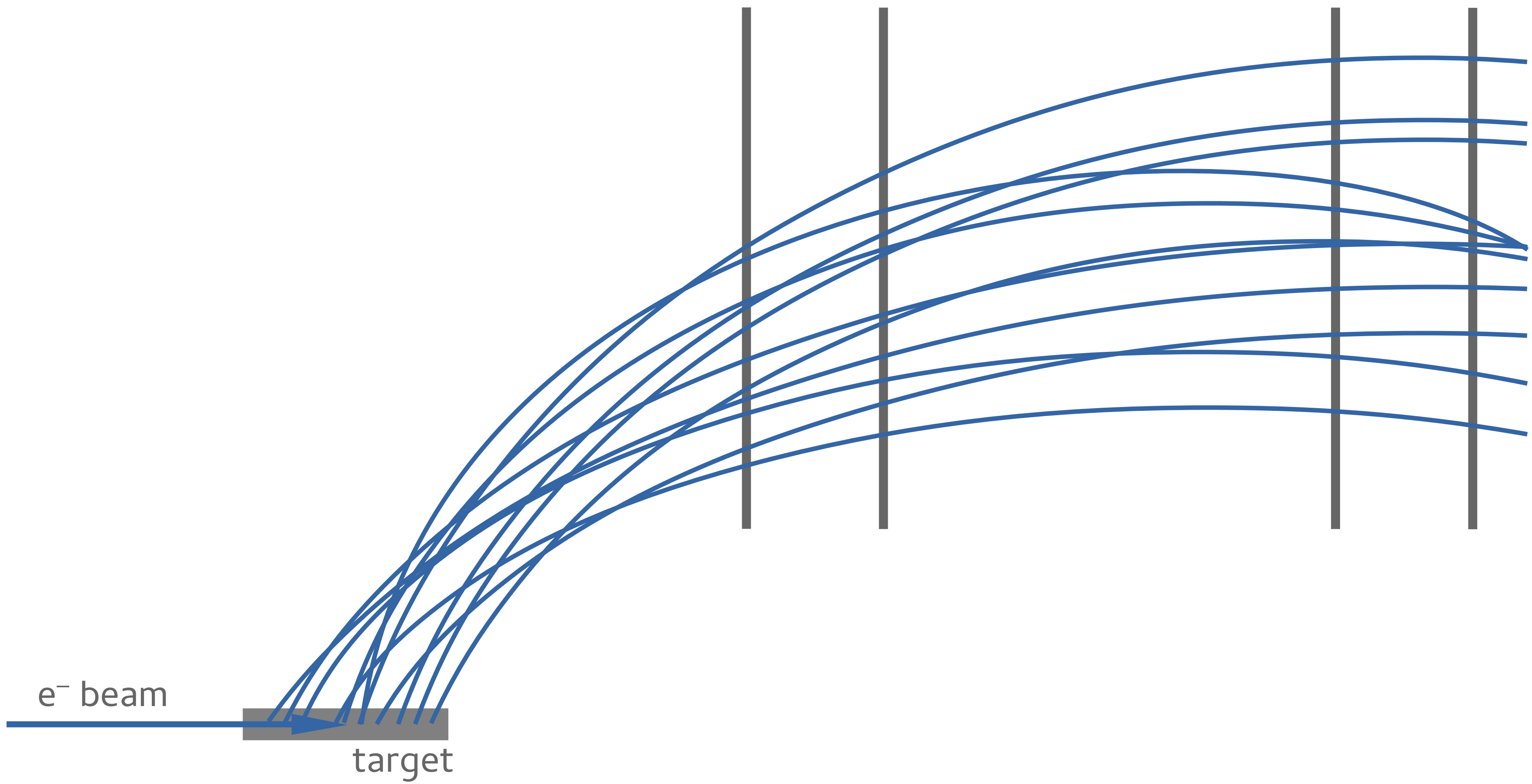
Take reference tracks

with the given R_3

(with some tolerance)

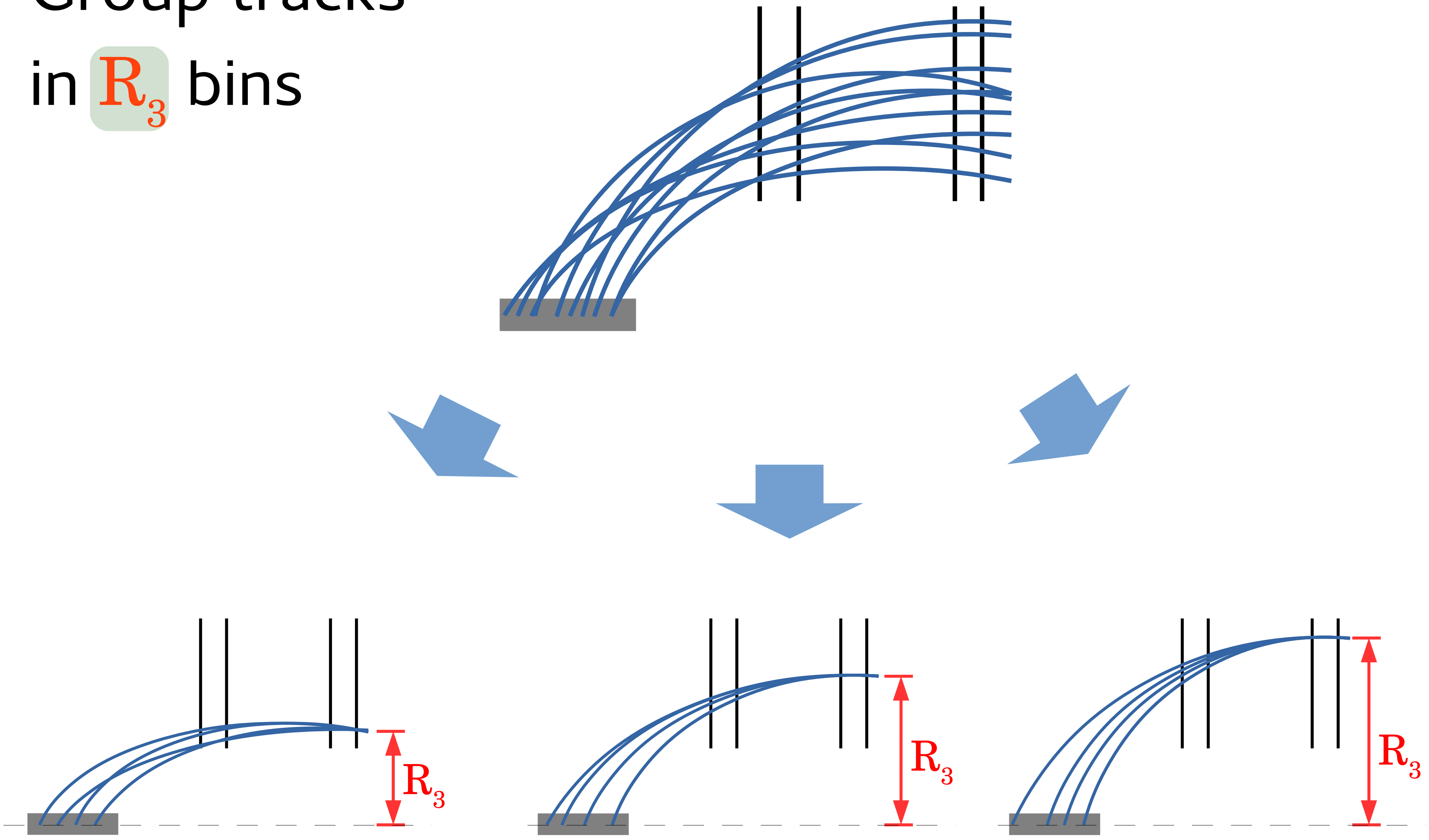


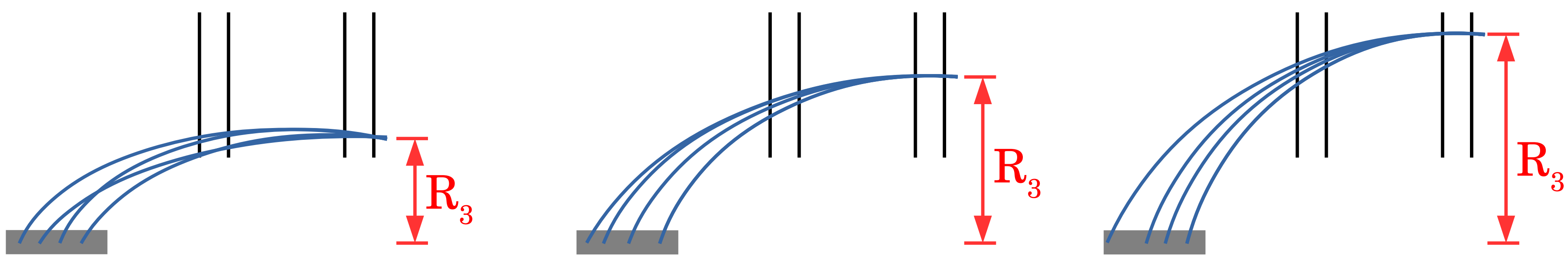
Take large number of reference tracks

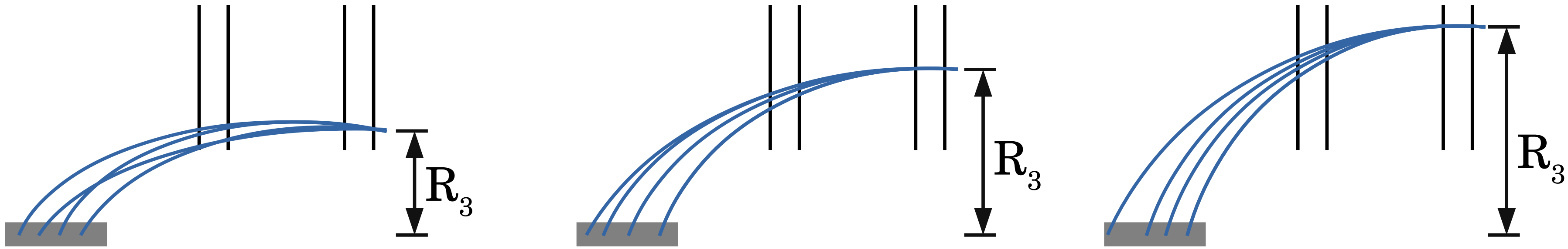


Group tracks

in R_3 bins

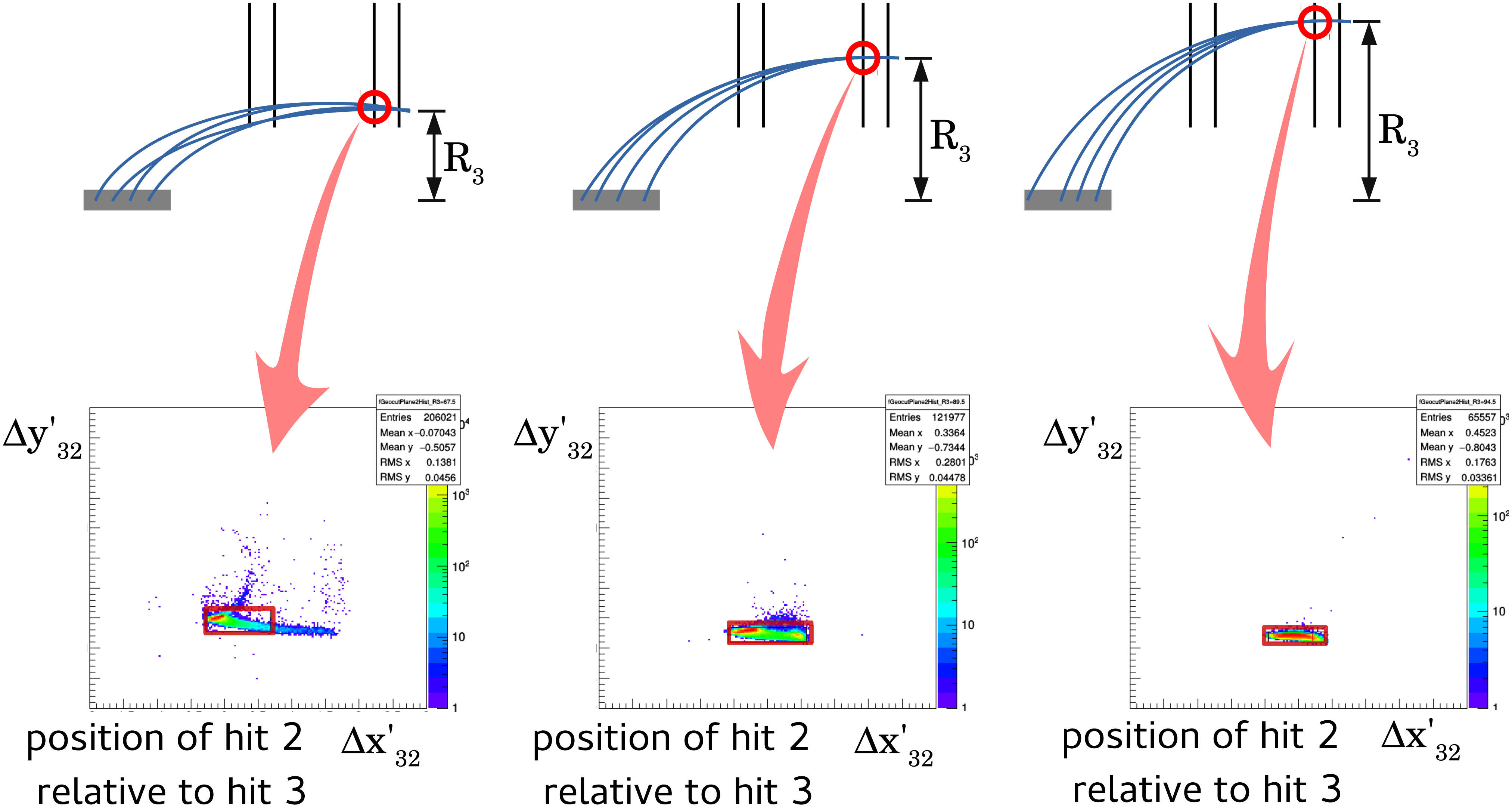


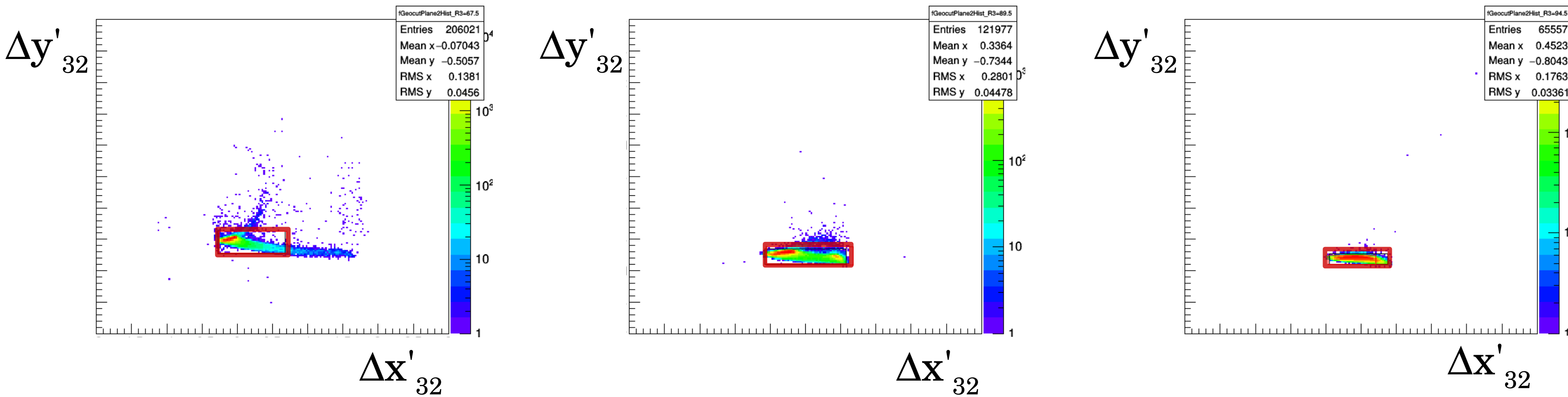

R3
R3
R3



R_3
R_3
R_3

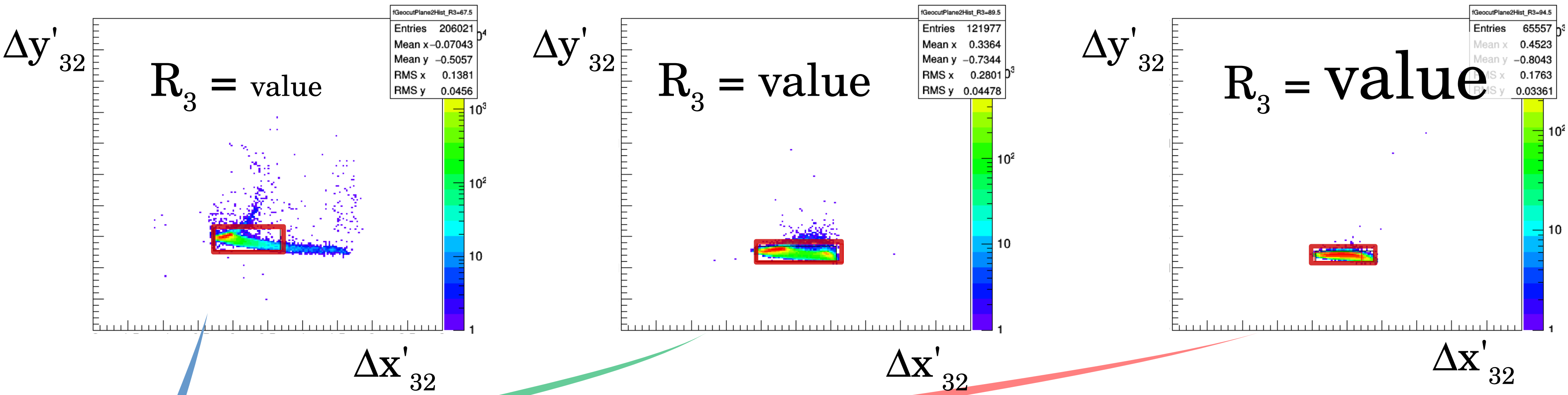
Search window for every R_3 bin:





Δy'32
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
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
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:

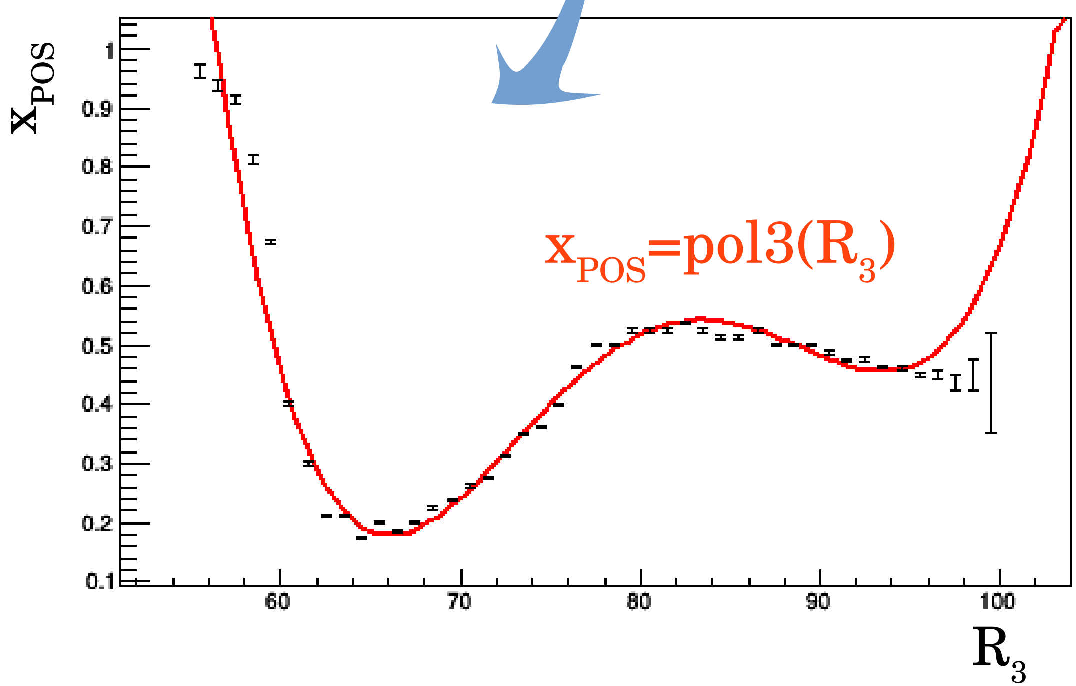


R_3	x_{POS}	y_{POS}	x_{SIZE}	y_{SIZE}	φ_{ROT}
...	...	...	...	...	...
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...

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

Fit

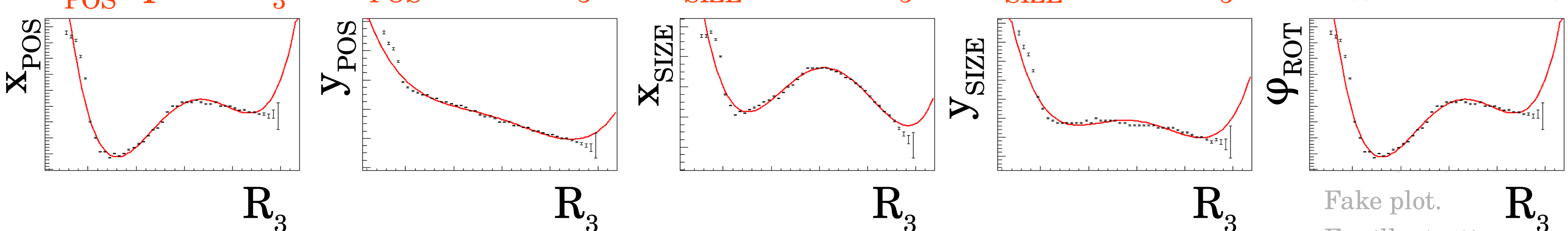
R_3	x_{POS}	y_{POS}	x_{SIZE}	y_{SIZE}	φ_{ROT}
…	…	…	…	…	…
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
…	…	…	…	…	…



Fit

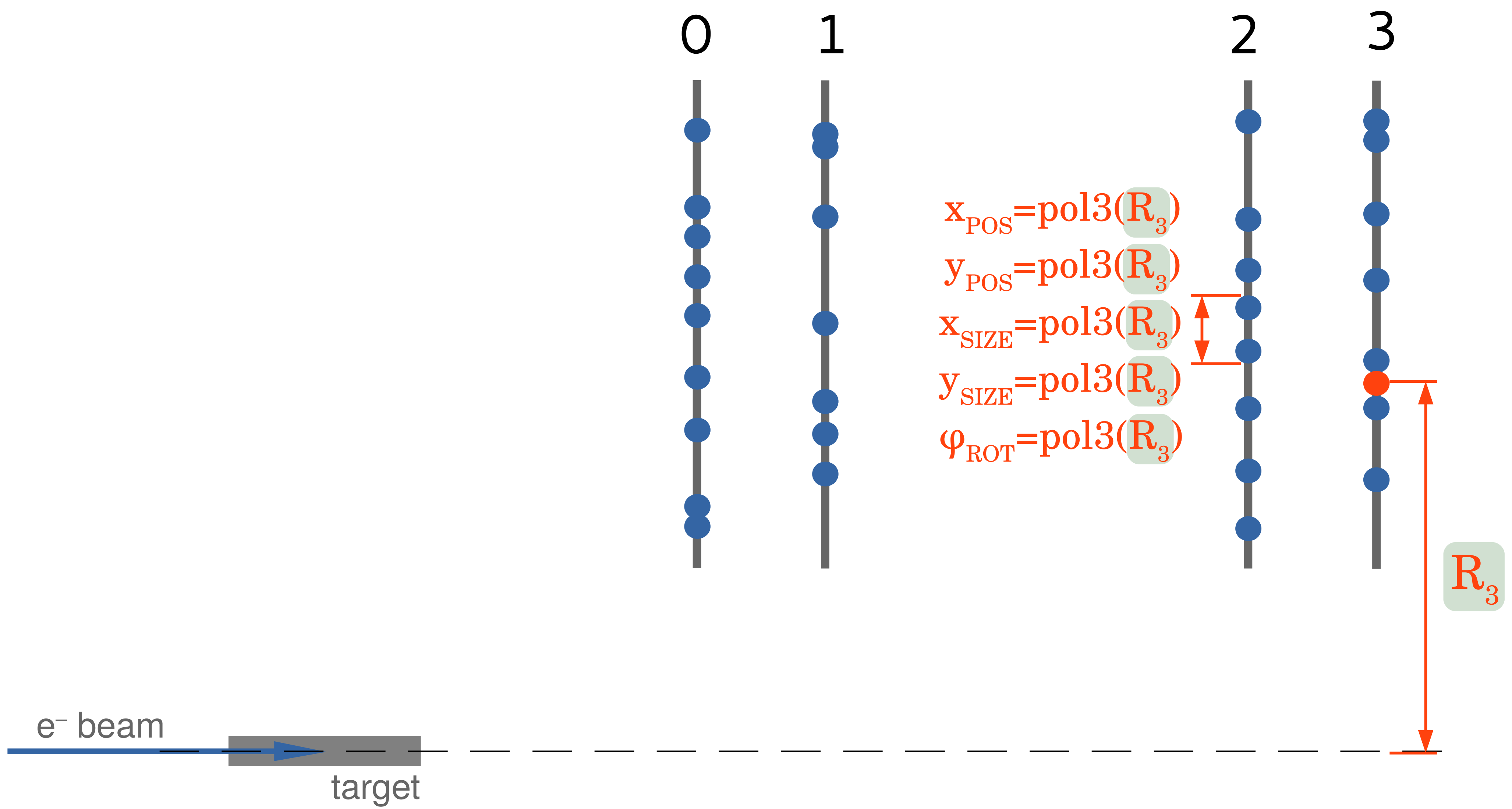
R_3	x_{POS}	y_{POS}	x_{SIZE}	y_{SIZE}	φ_{ROT}
...	...	...	...	...	...
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
value	■■■■	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...

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

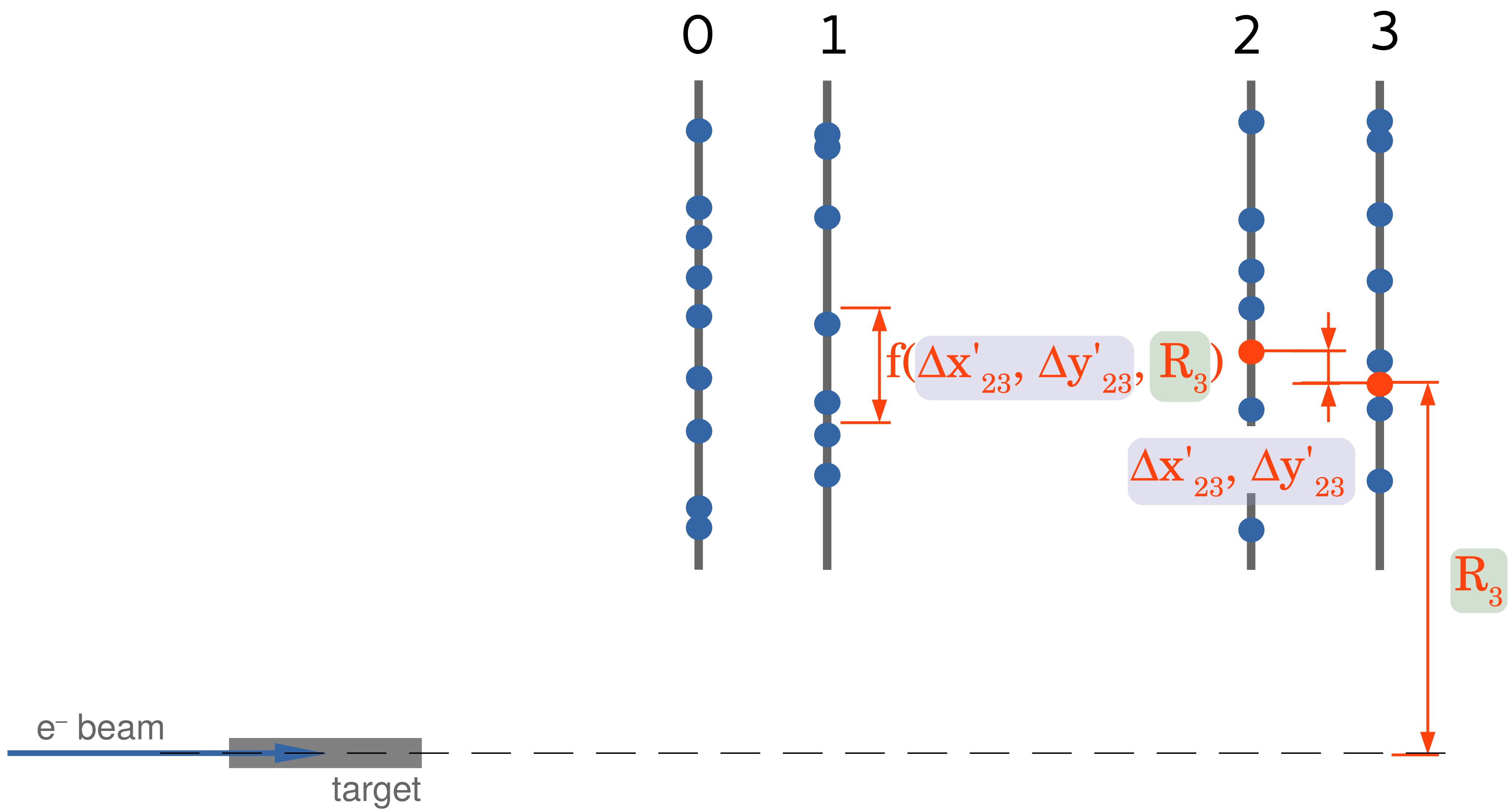


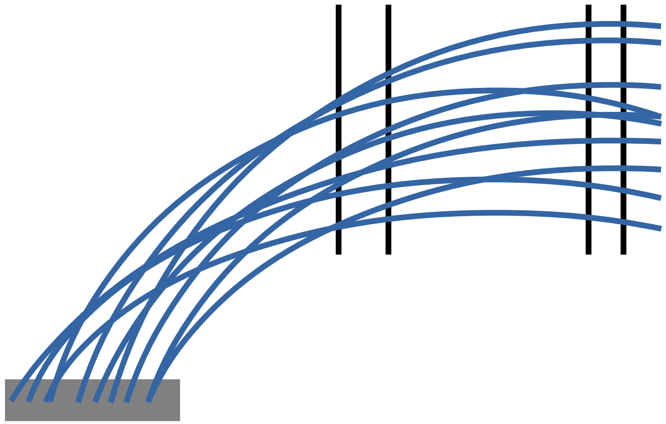
Fake plot. For illustration only.

Search window for plane 2



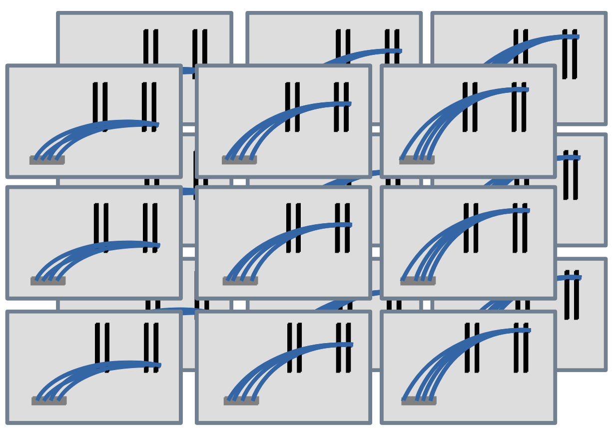
Search window for plane 1





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

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

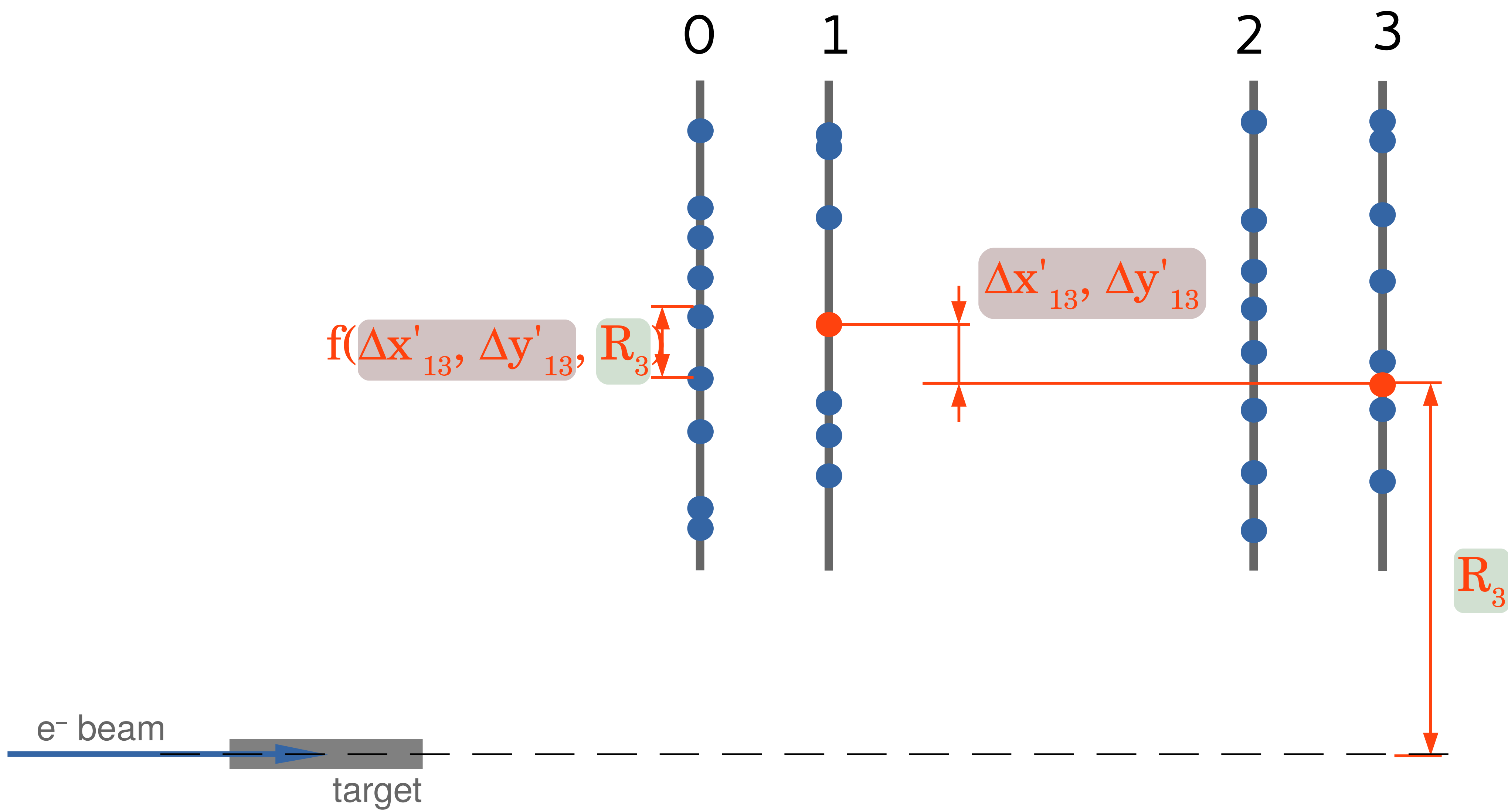


determine the search windows

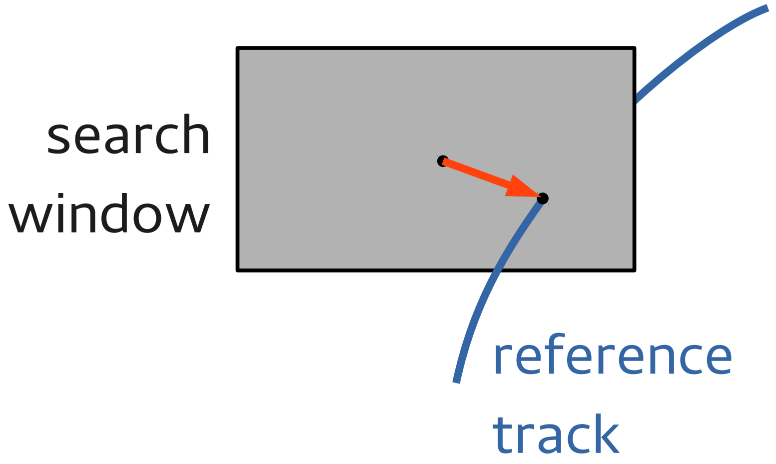
Fit (in 3D)

$$x_{SIZE} = \mathrm{pol3}(R_3, \Delta x'_{23}, \Delta y'_{23})$$
$$y_{SIZE} = \mathrm{pol3}(R_3, \Delta x'_{23}, \Delta y'_{23})$$
$$x_{POS} = \mathrm{pol3}(R_3, \Delta x'_{23}, \Delta y'_{23})$$
$$y_{POS} = \mathrm{pol3}(R_3, \Delta x'_{23}, \Delta y'_{23})$$
$$\varphi_{ROT} = \mathrm{pol3}(R_3, \Delta x'_{23}, \Delta y'_{23})$$

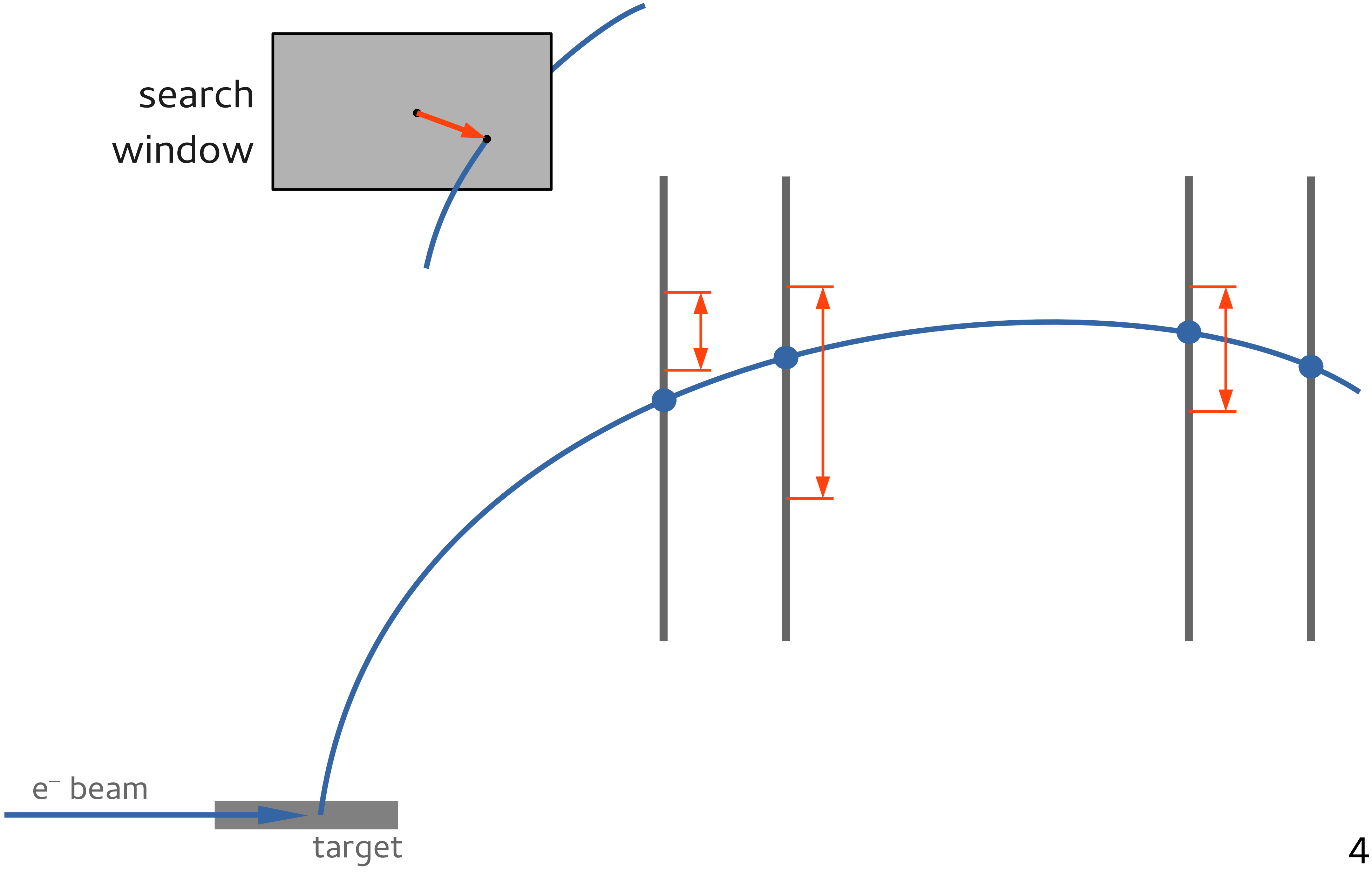
Search window for plane 0



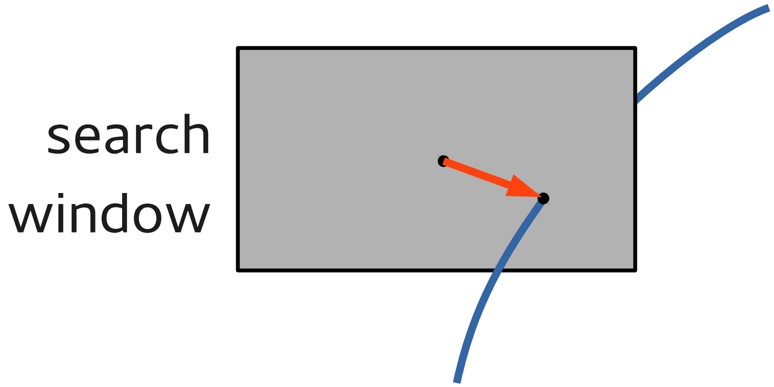
Relative distance from the center of the search window

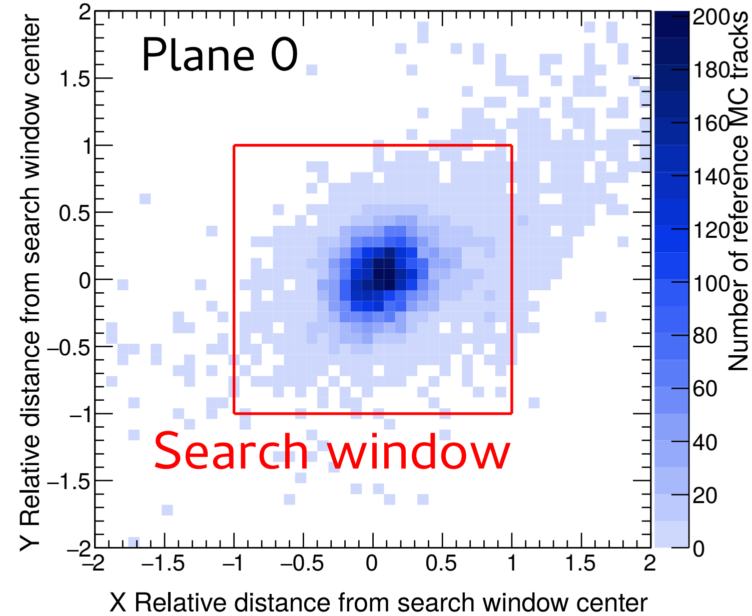


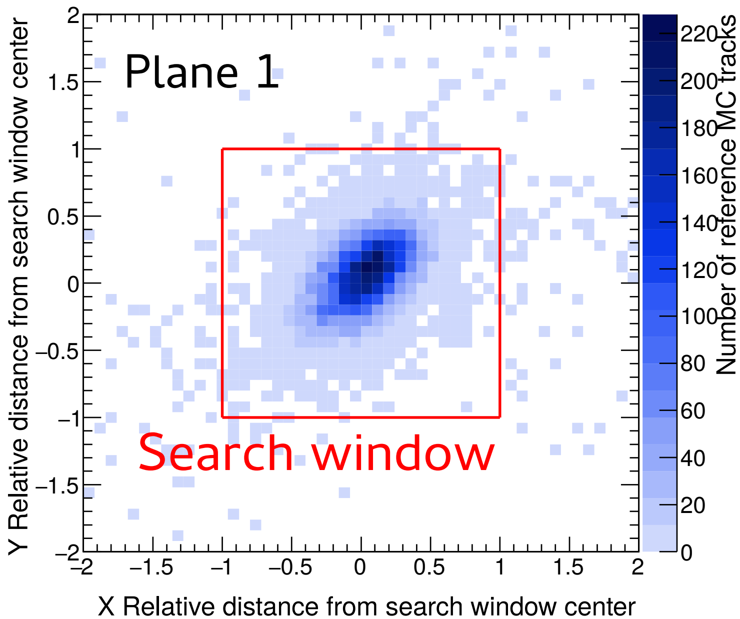
Relative distance from the center of the search window

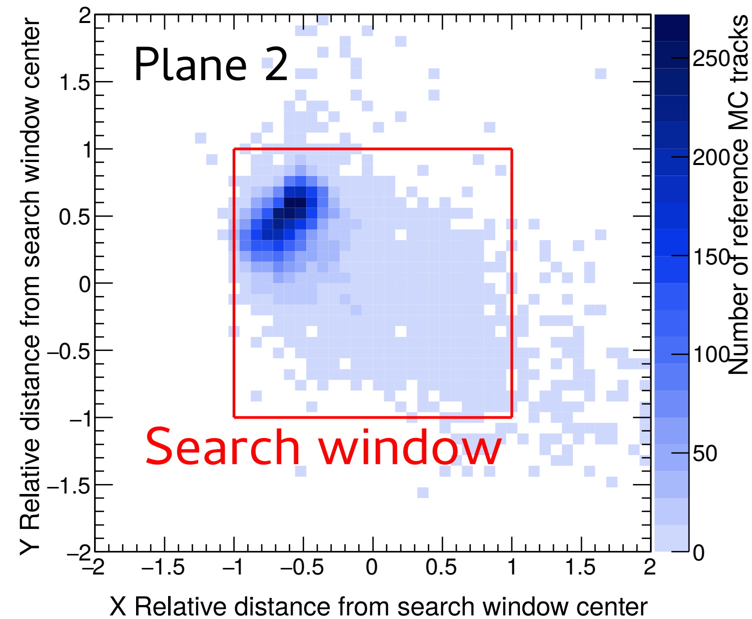


Relative distance from the center of the search window





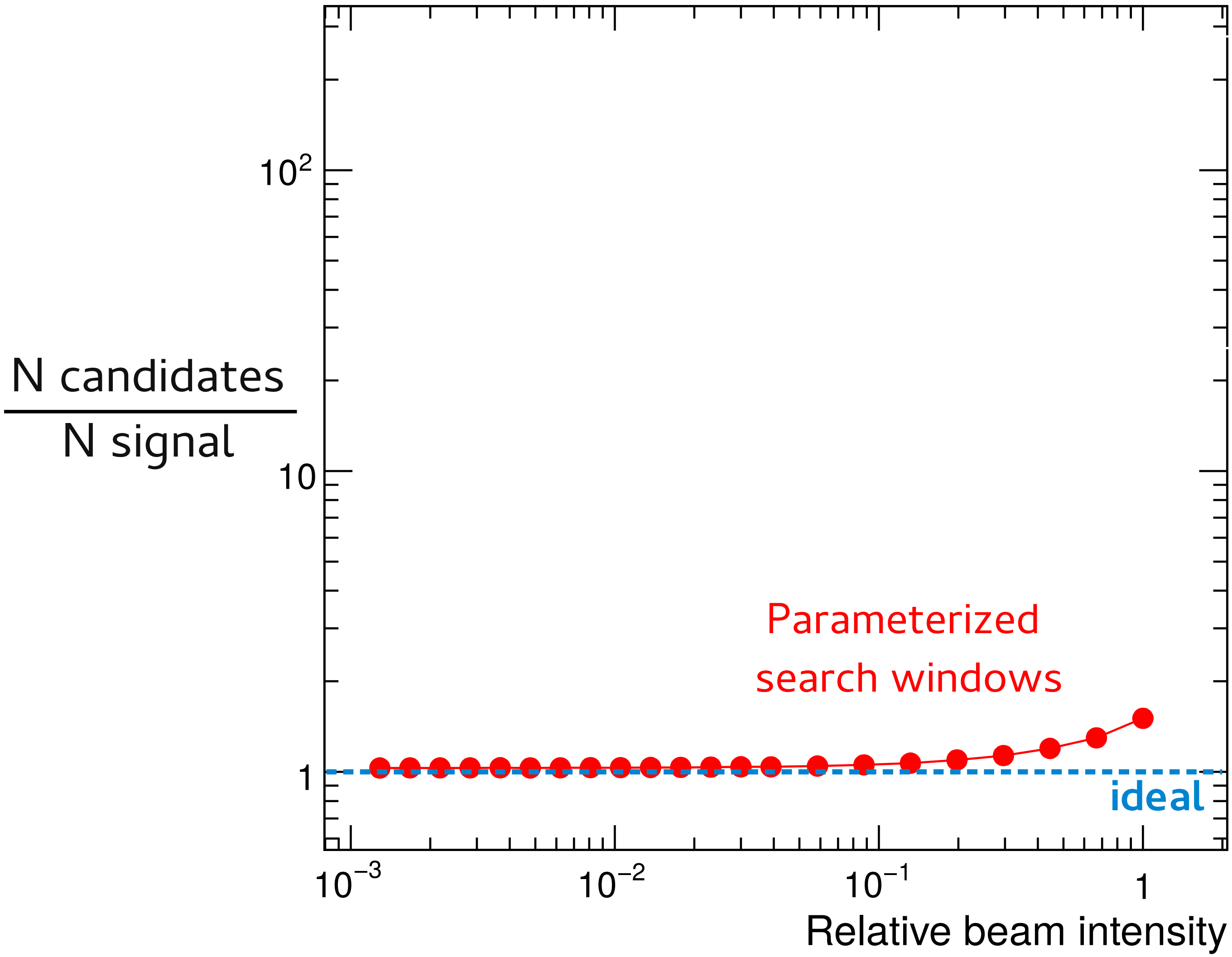




Overall about 90% efficiency (depending on settings).

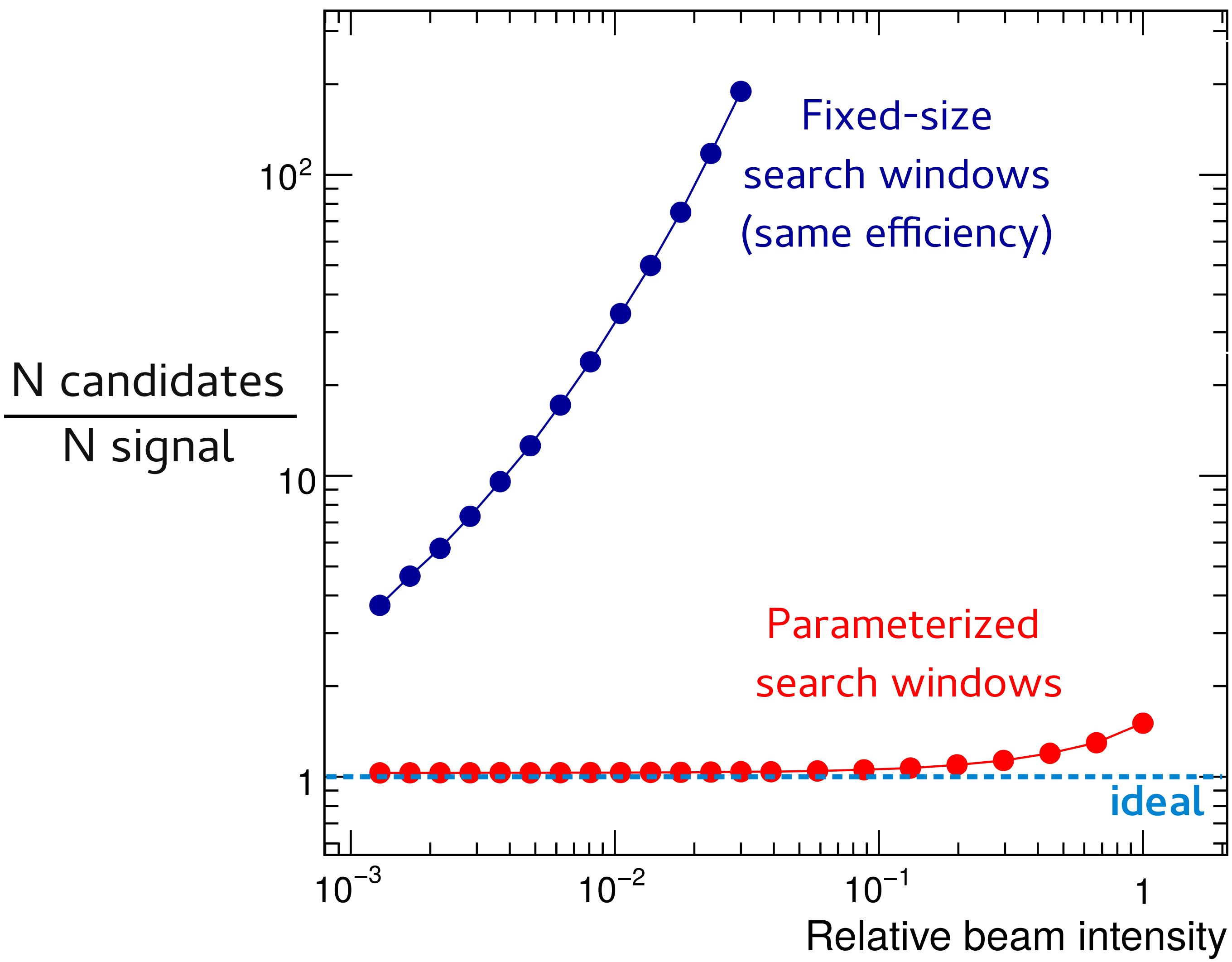
Performance

Number of candidates per signal track



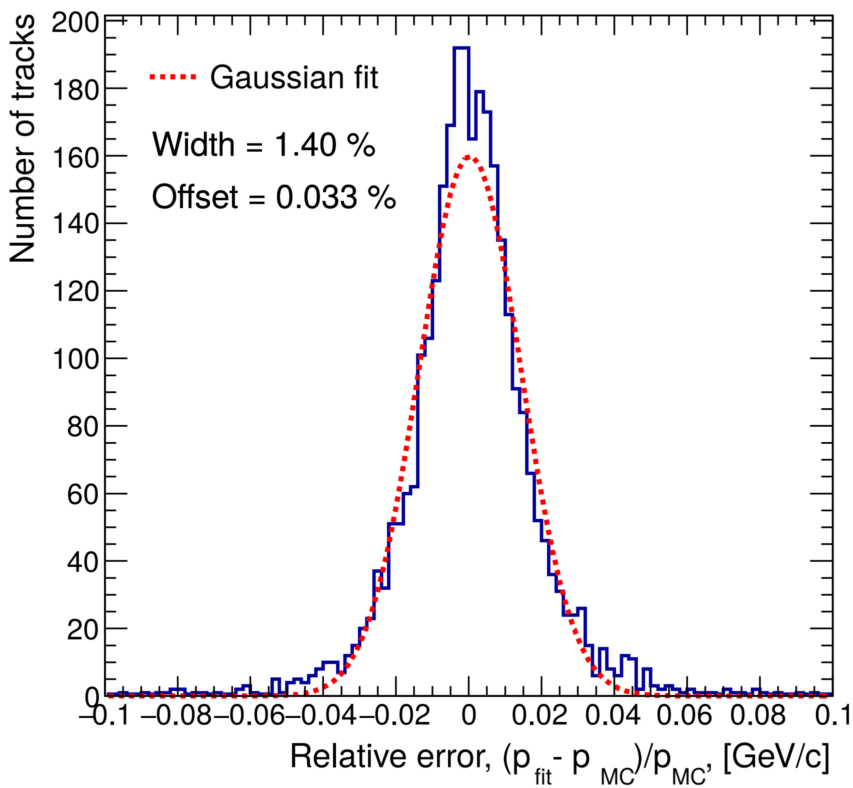
Performance

Number of candidates per signal track



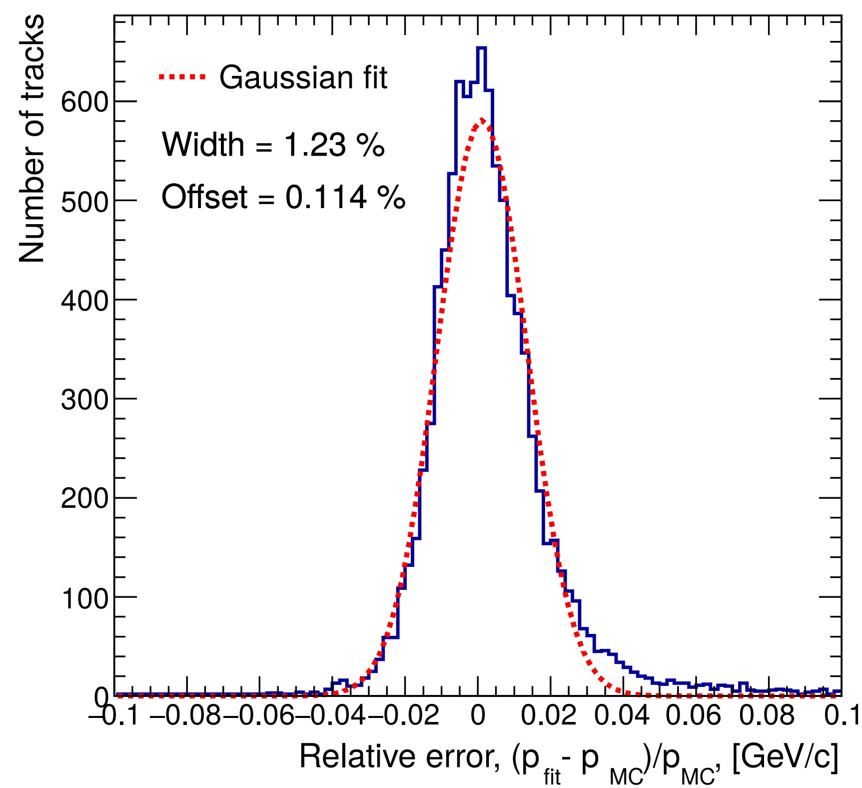
Parameterization instead of fitting

Rigorous fit



Fit replaced by parameterization:

momentum = pol3(R_3, ΔR_{31}, $\Delta\varphi_{31}$)



Using GBL fit within the GENFIT framework

GBL: Kleinwort C. General Broken Lines as advanced track fitting method
http://dx.doi.org/10.1016/j.nima.2012.01.024

GENFIT: Rauch J., Schlüter T. GENFIT — a Generic Track-Fitting Toolkit
https://doi.org/10.1088/1742-6596/608/1/012042

Summary

Parameterization-based tracking:

- replaces rigorous model calculations
  by simple analytical parametric functions
- parameters can be tuned based on
  real data or model (MC or deterministic with covariance)
- enables accurate, efficient, and very fast track finding
- can be used to estimate the kinematic parameters
- works well in P2 due to narrow momentum range