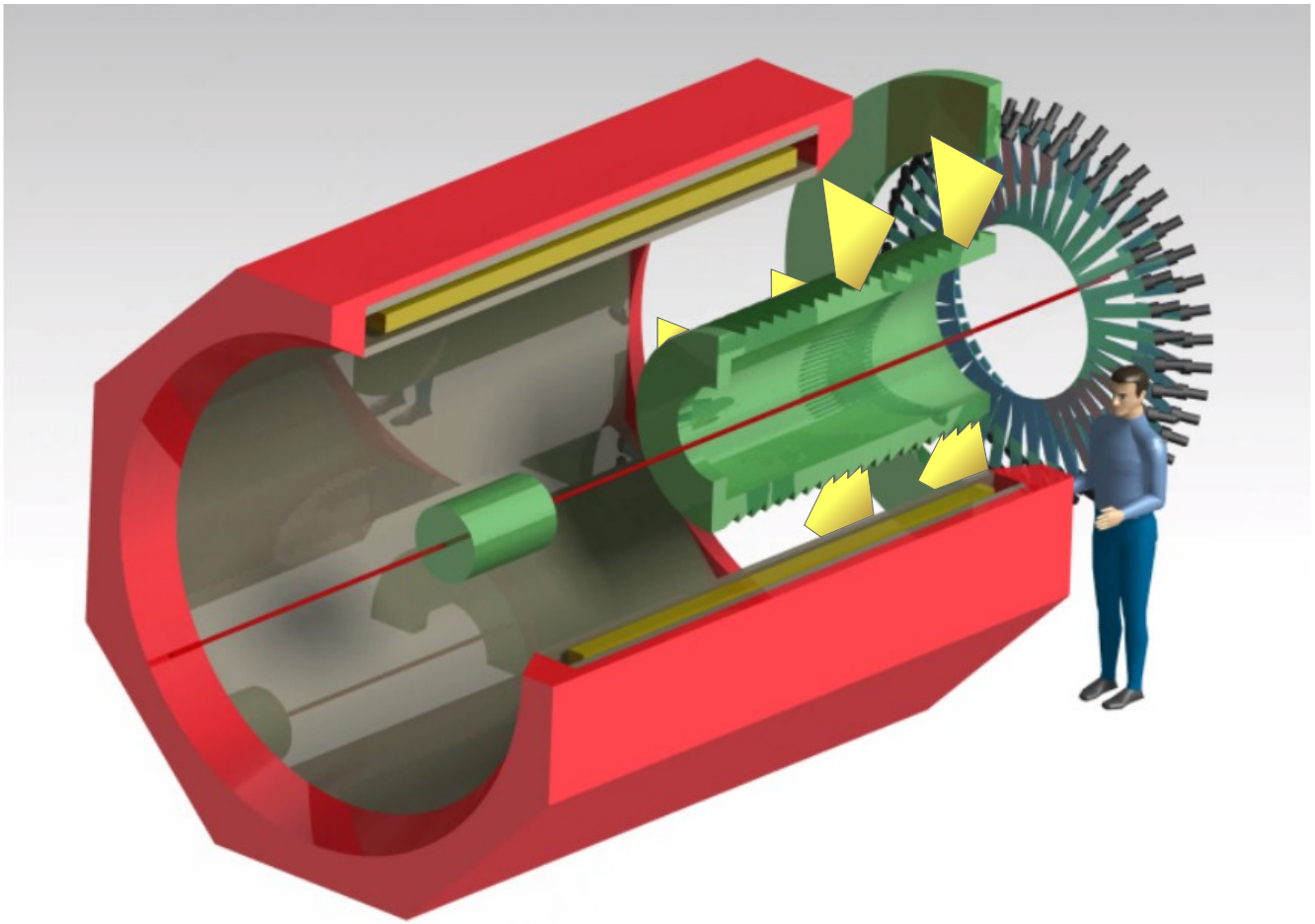

Parameterization-based tracking for the P2 experiment

Iurii Sorokin

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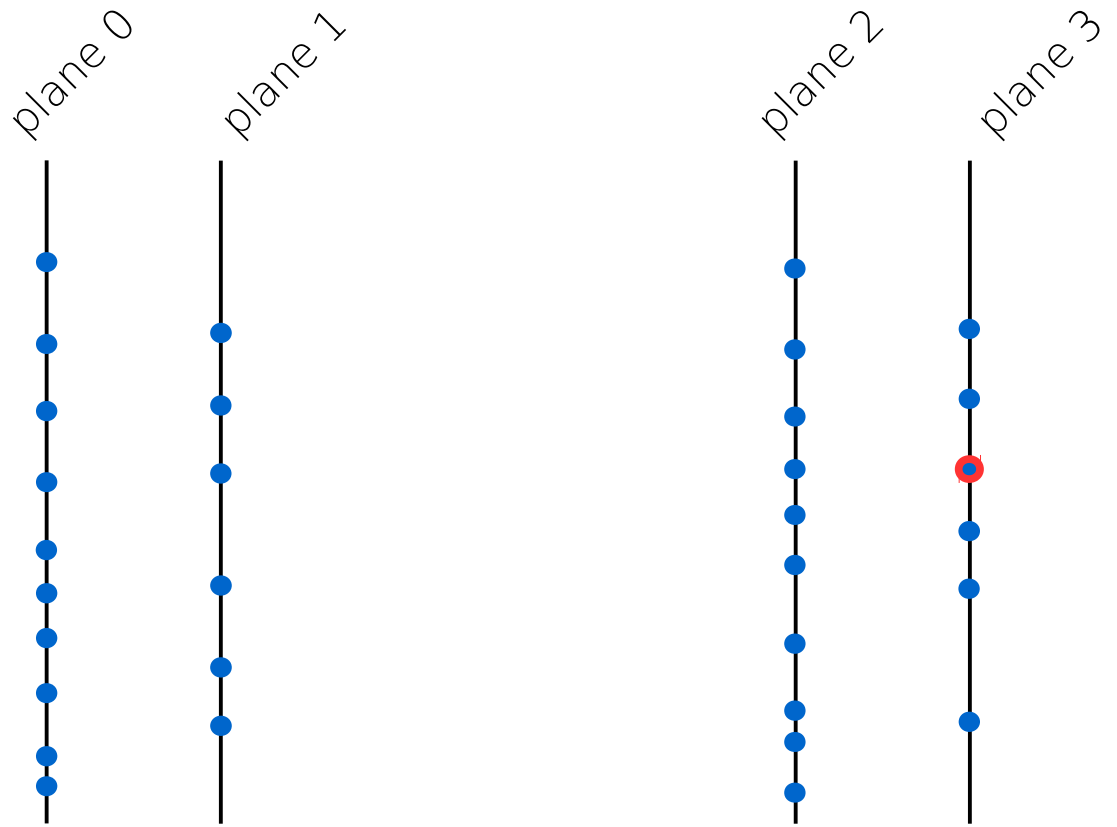
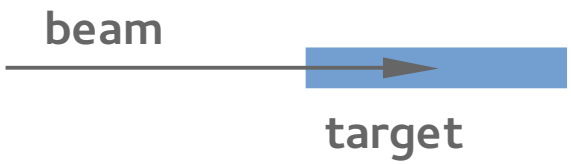
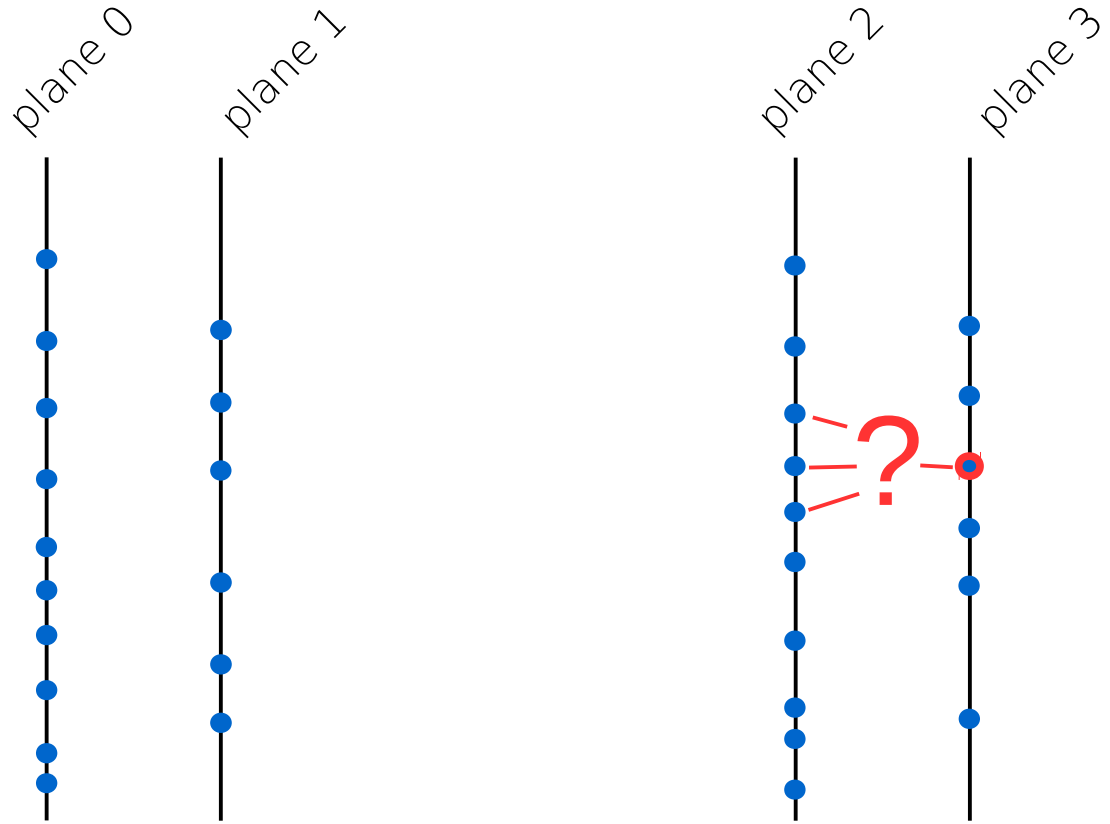
Seed hit





The problem of track reconstruction

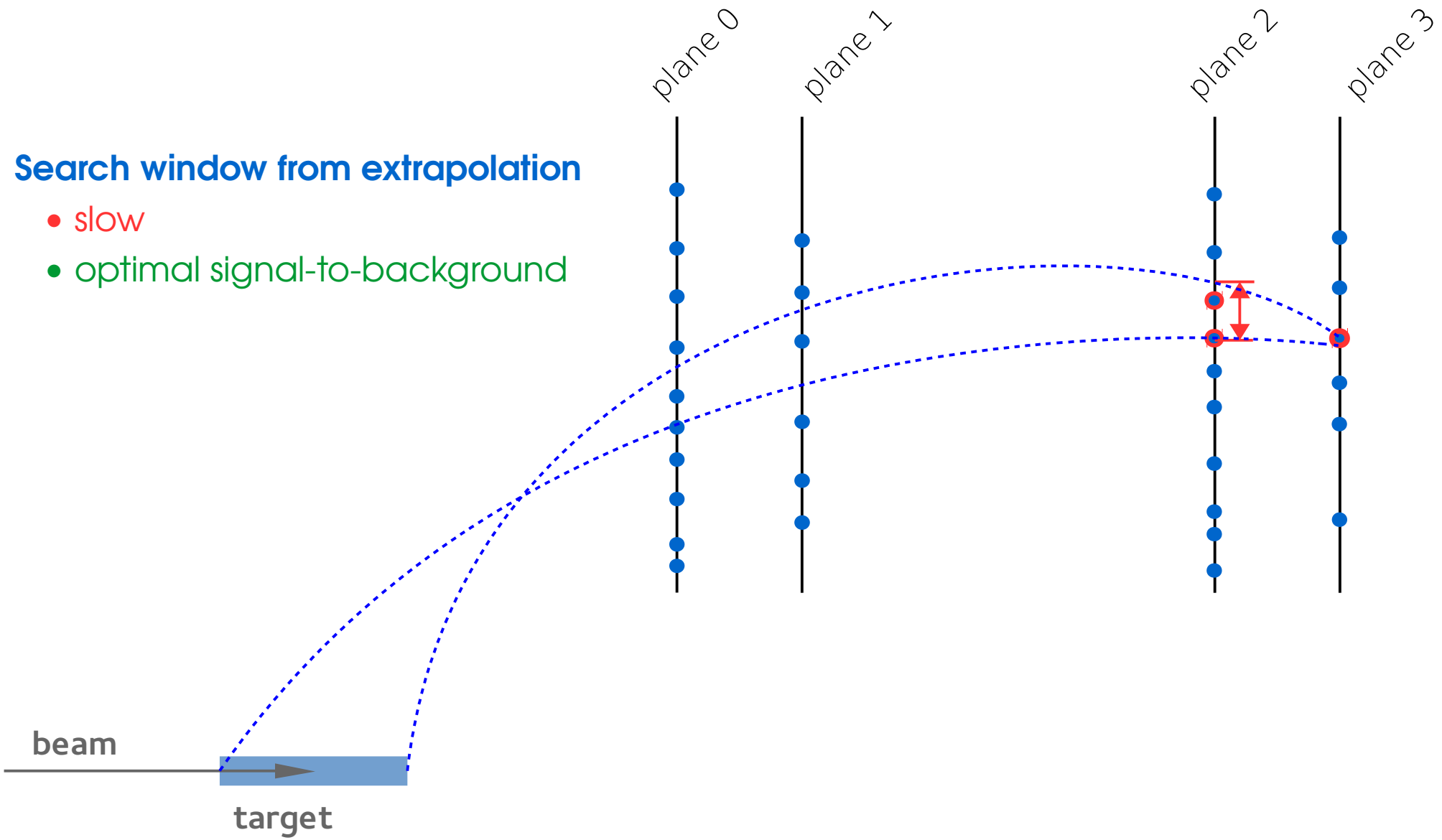
What is the matching hit in plane 2 ?



Search window from extrapolation

Search window from extrapolation

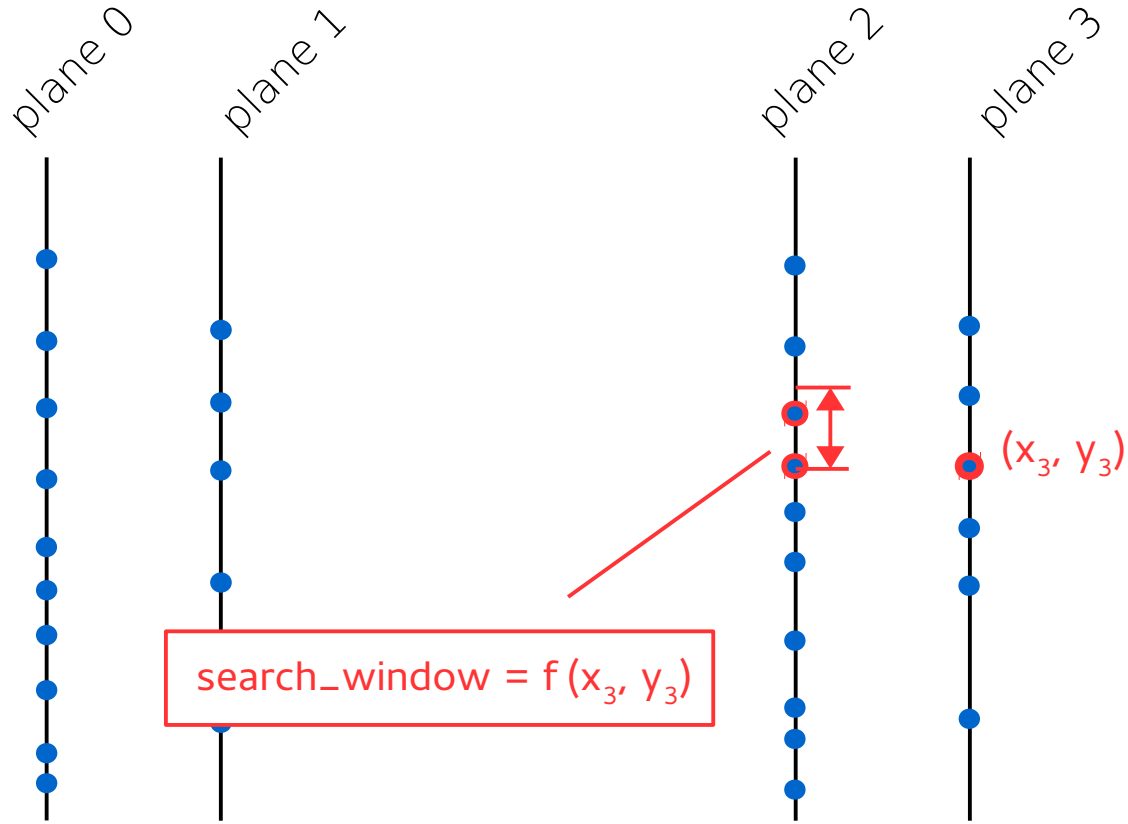
- slow
- optimal signal-to-background



Search window from parameterization

Parameterized search window

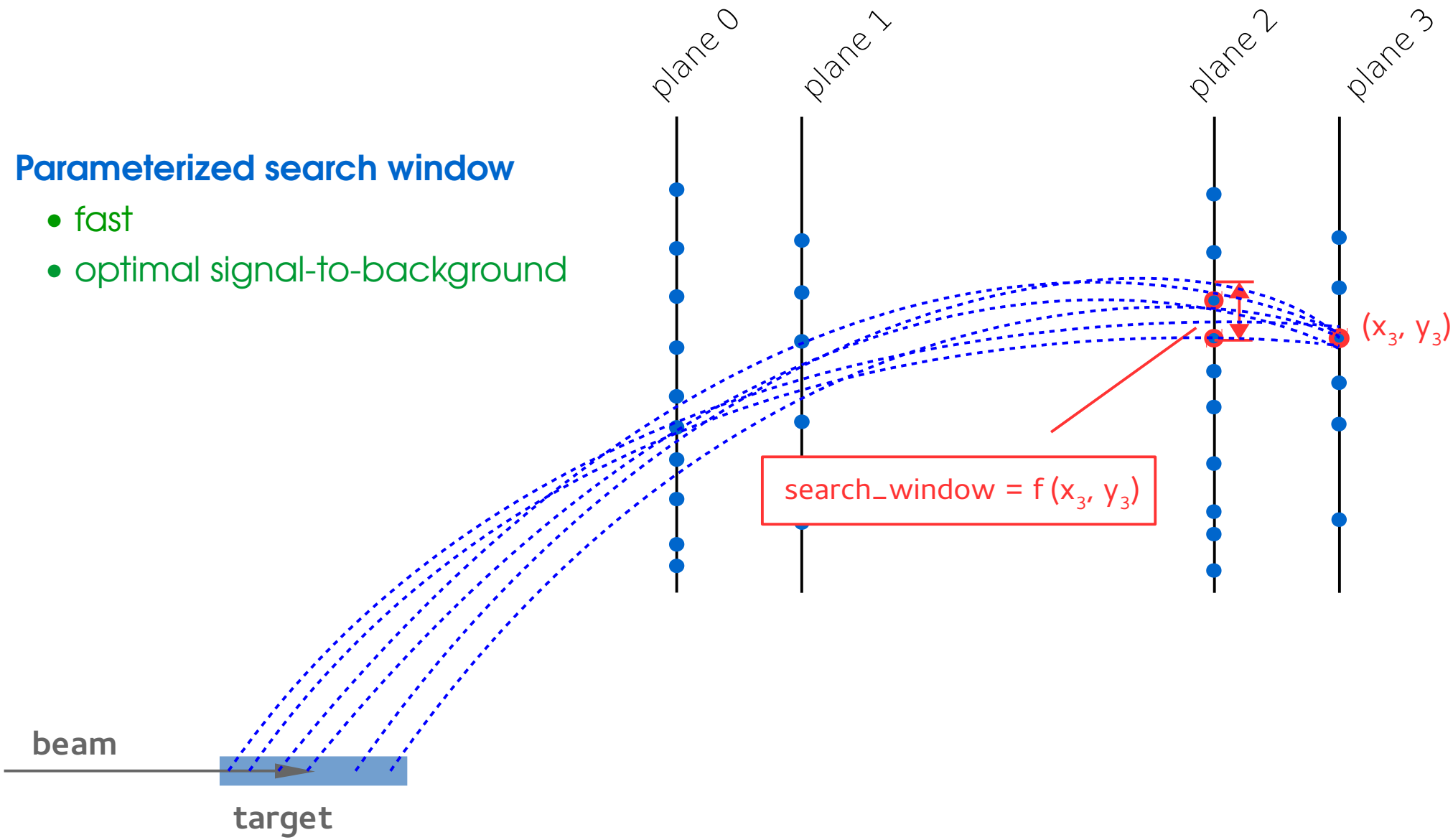
- fast
- optimal signal-to-background



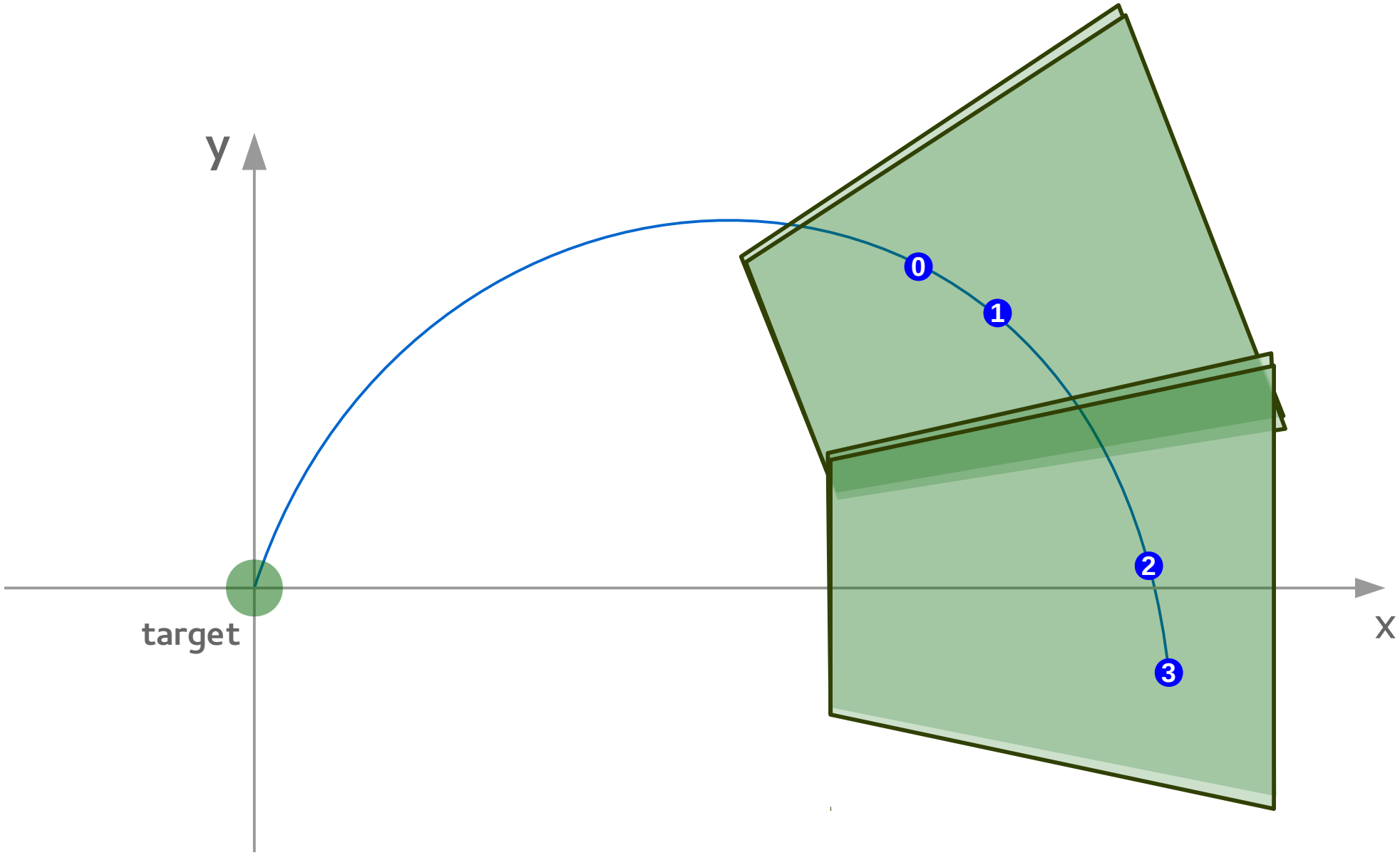
How to find the optimal search window?

Parameterized search window

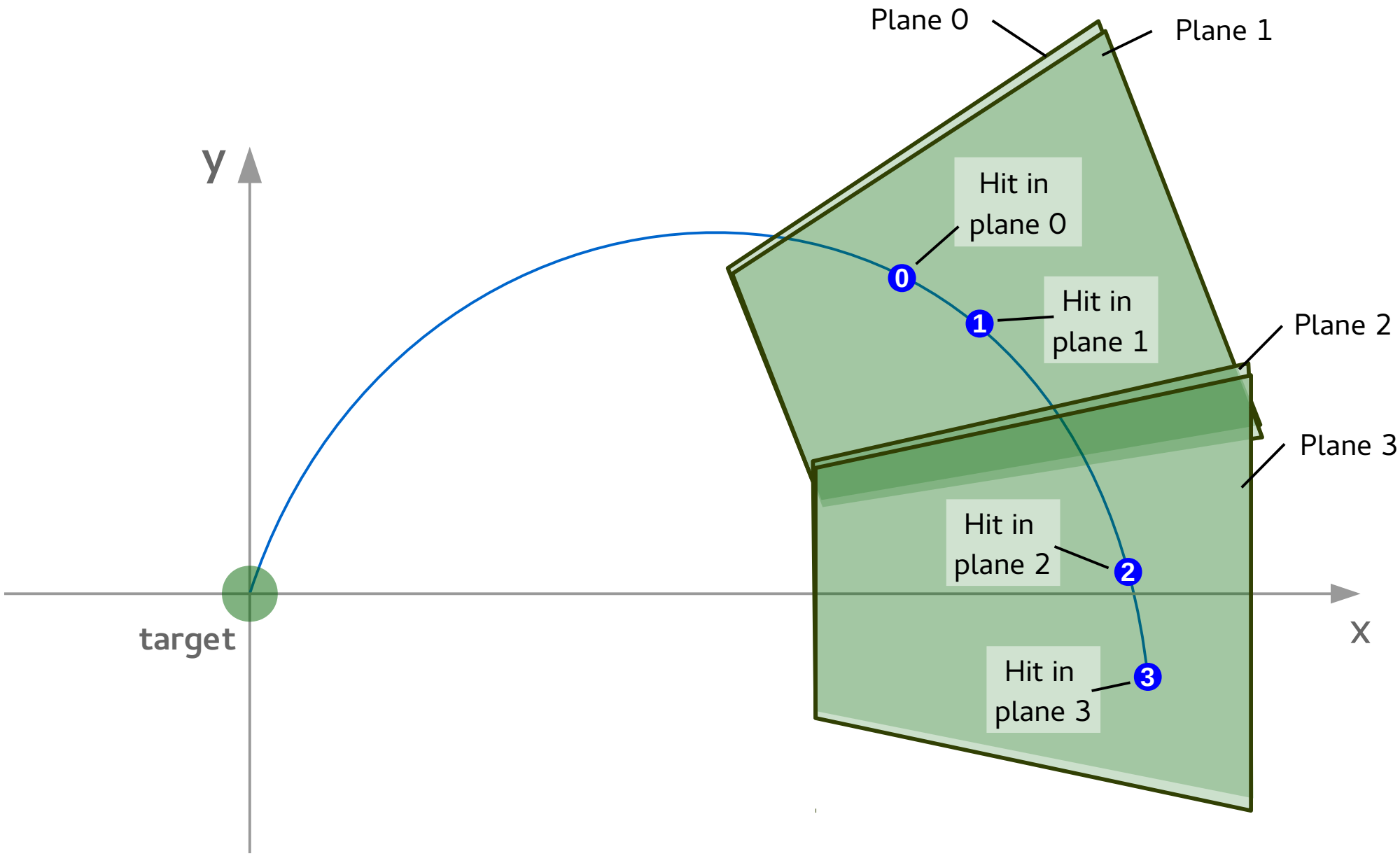
- fast
- optimal signal-to-background



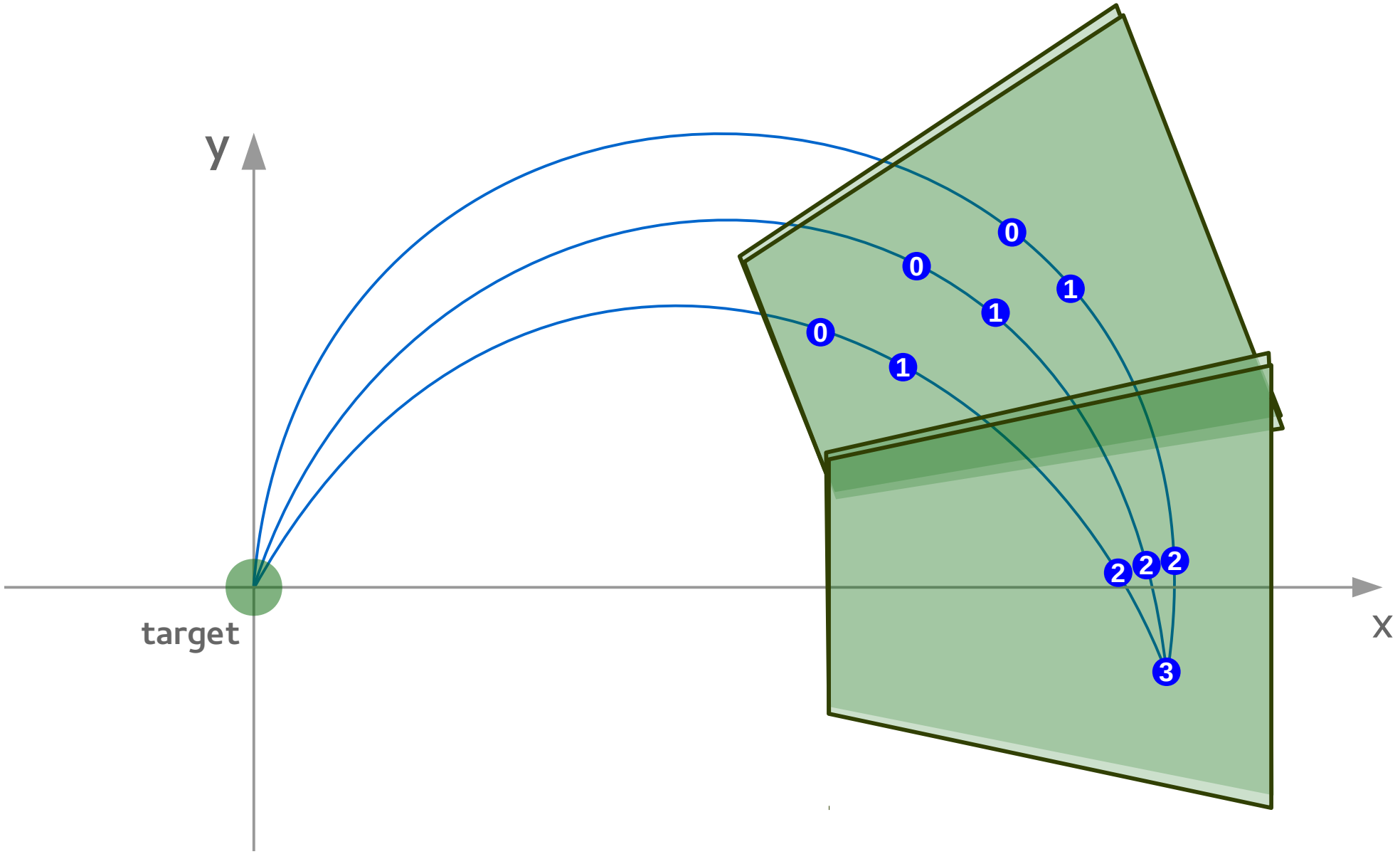
Transverse view



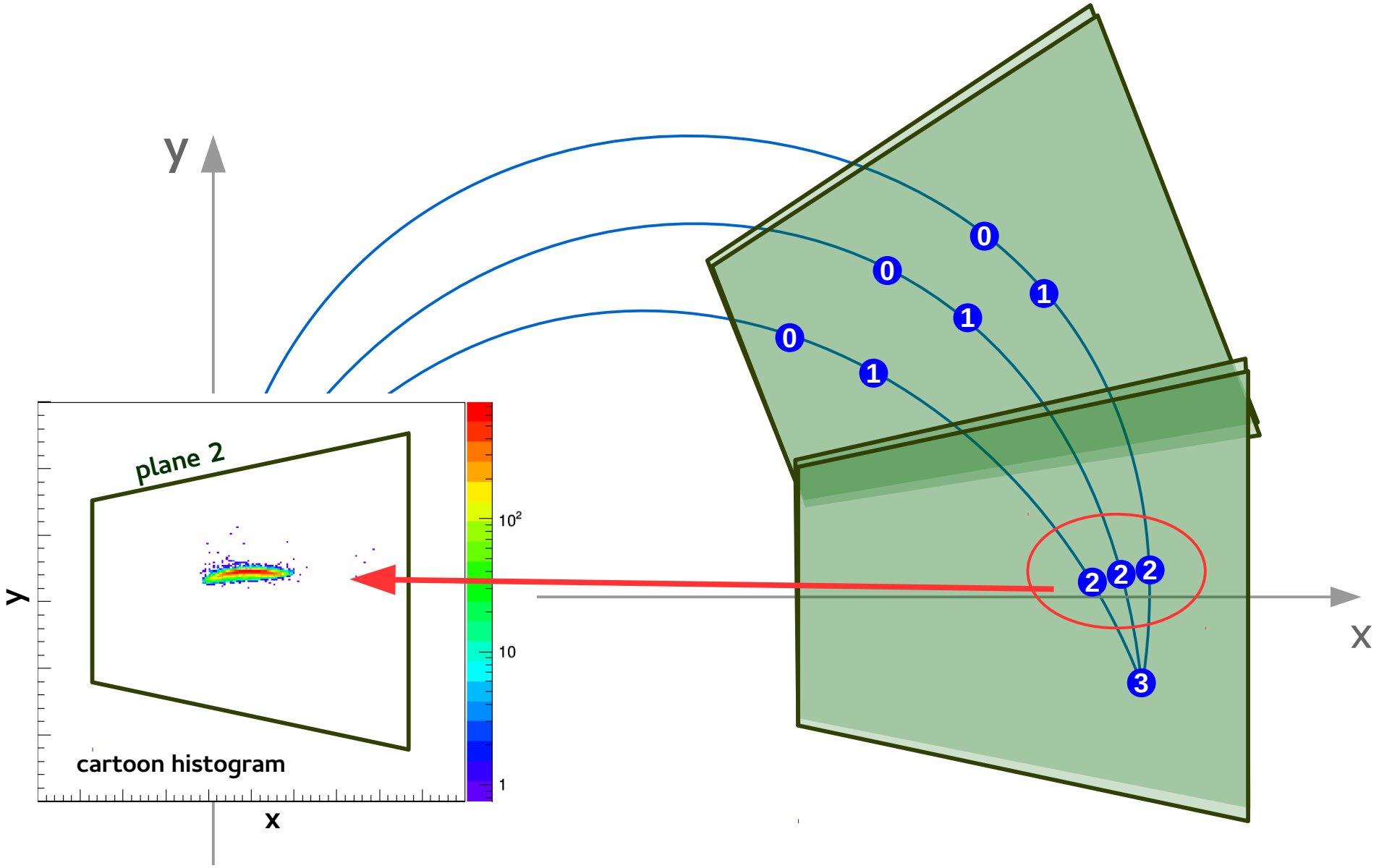
Transverse view



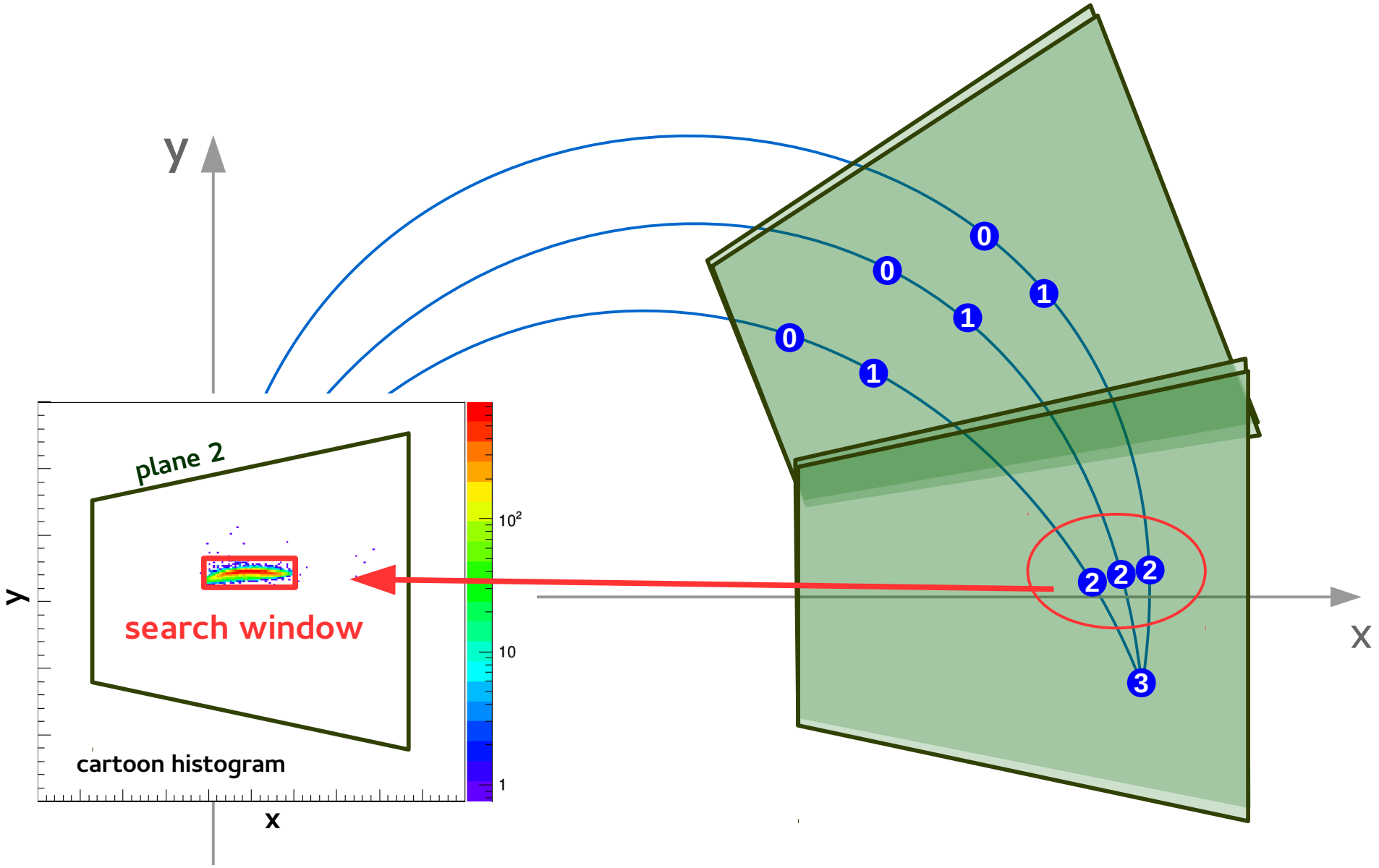
How to find the search window for plane 2



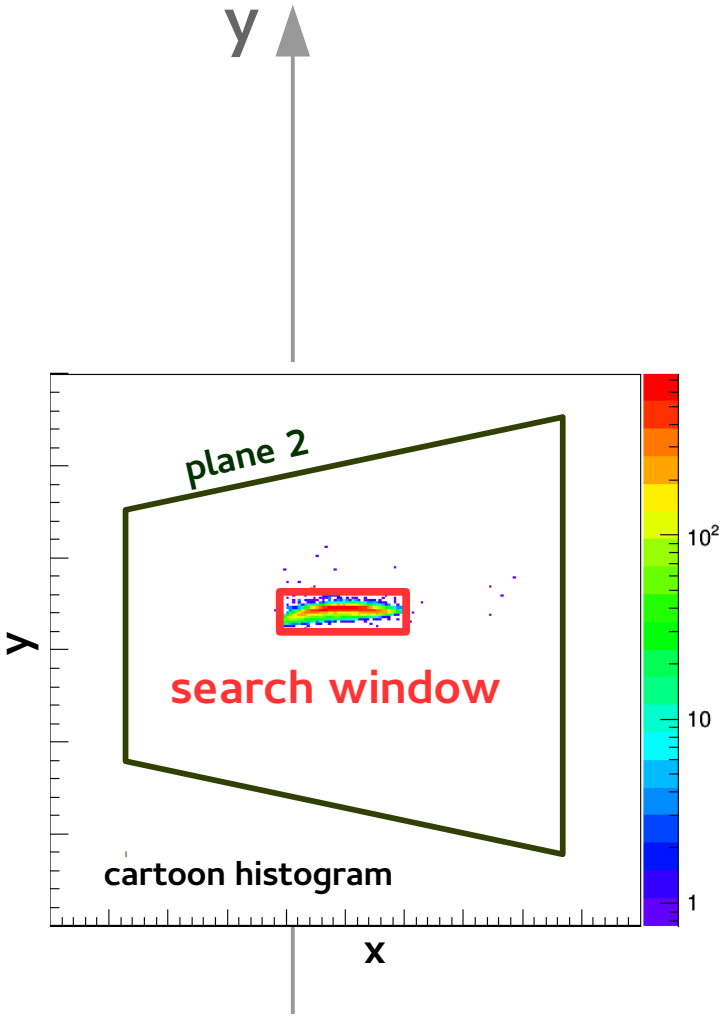
How to find the search window for plane 2

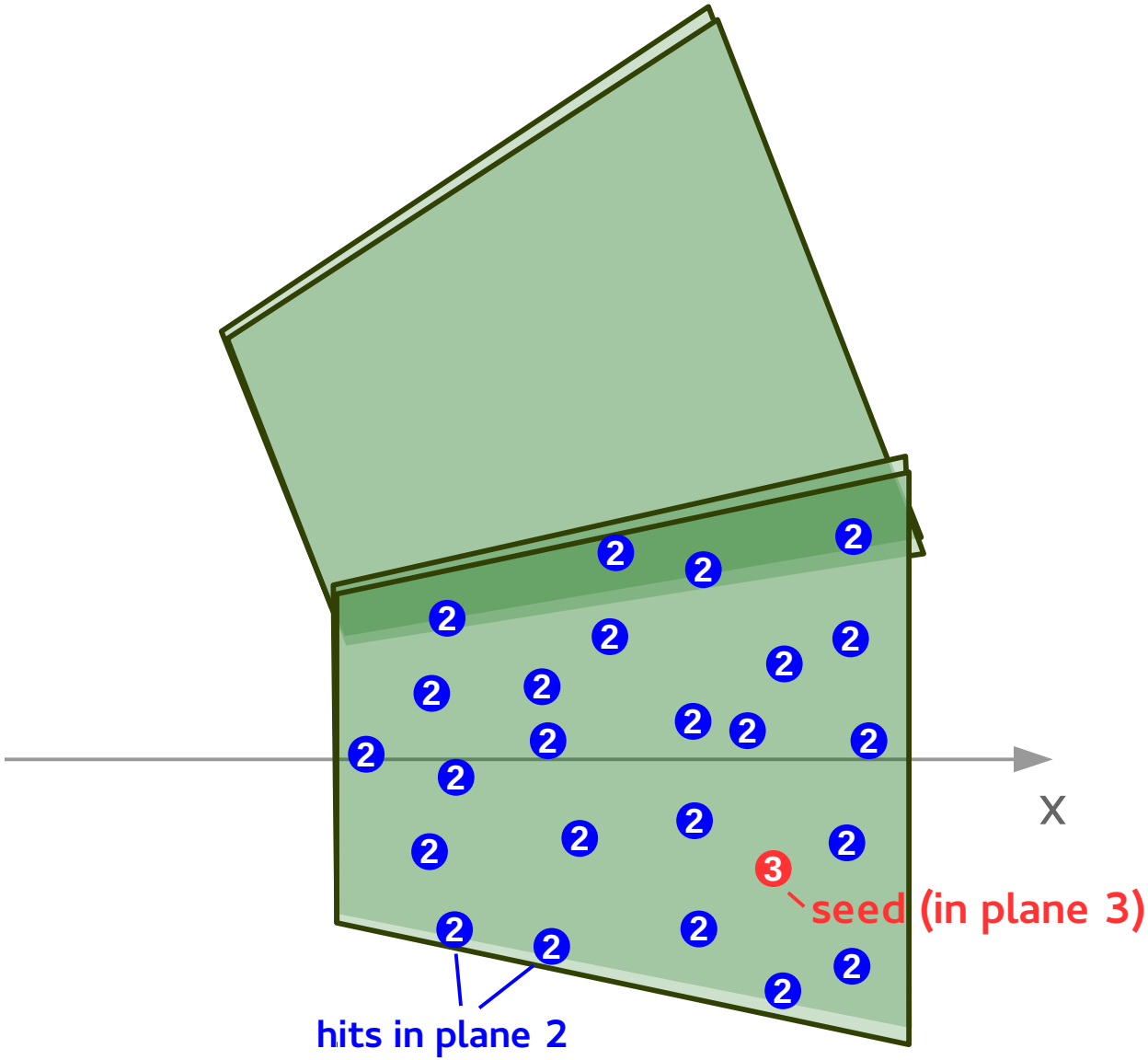


How to find the search window for plane 2

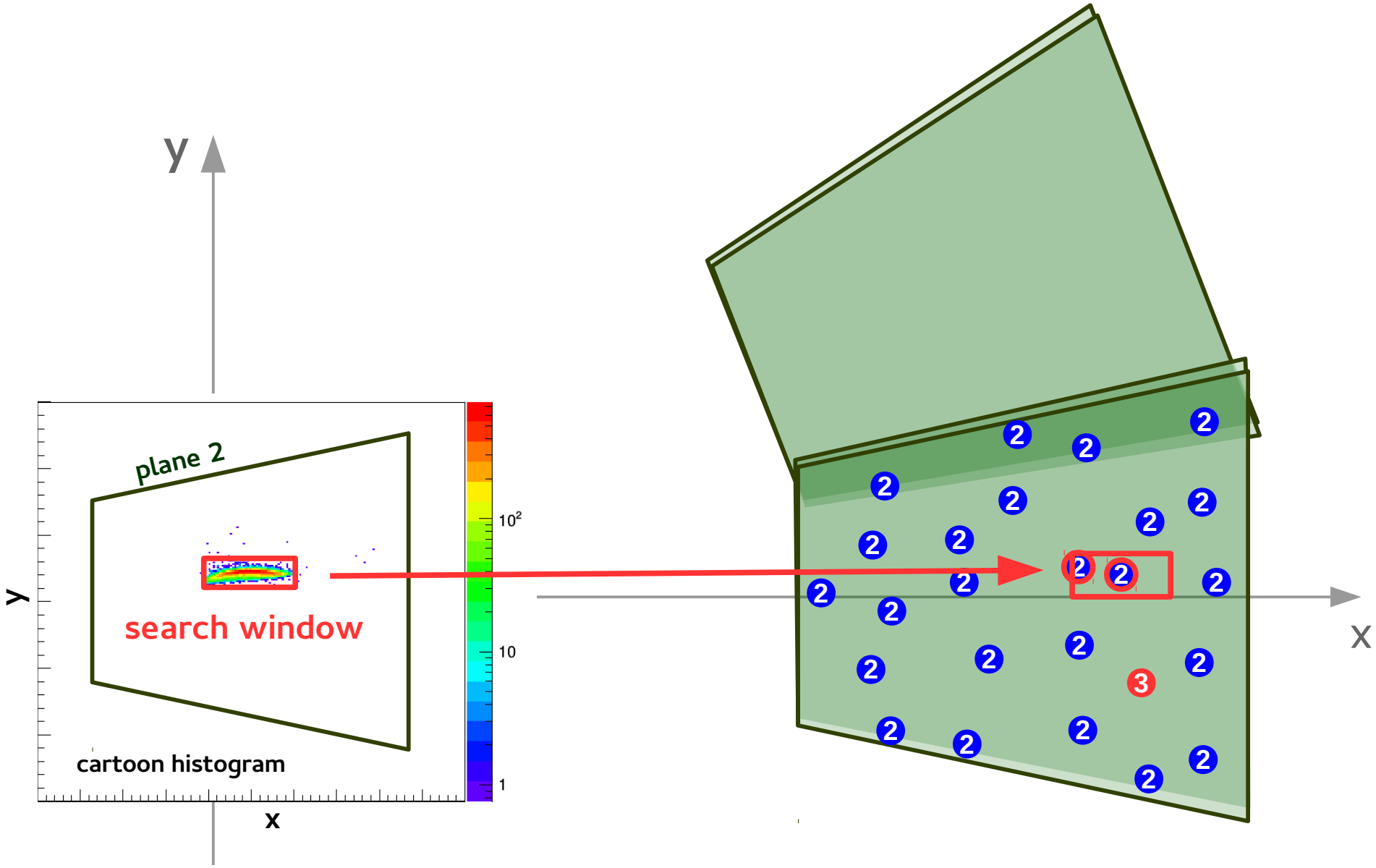


Track reconstruction using the search window

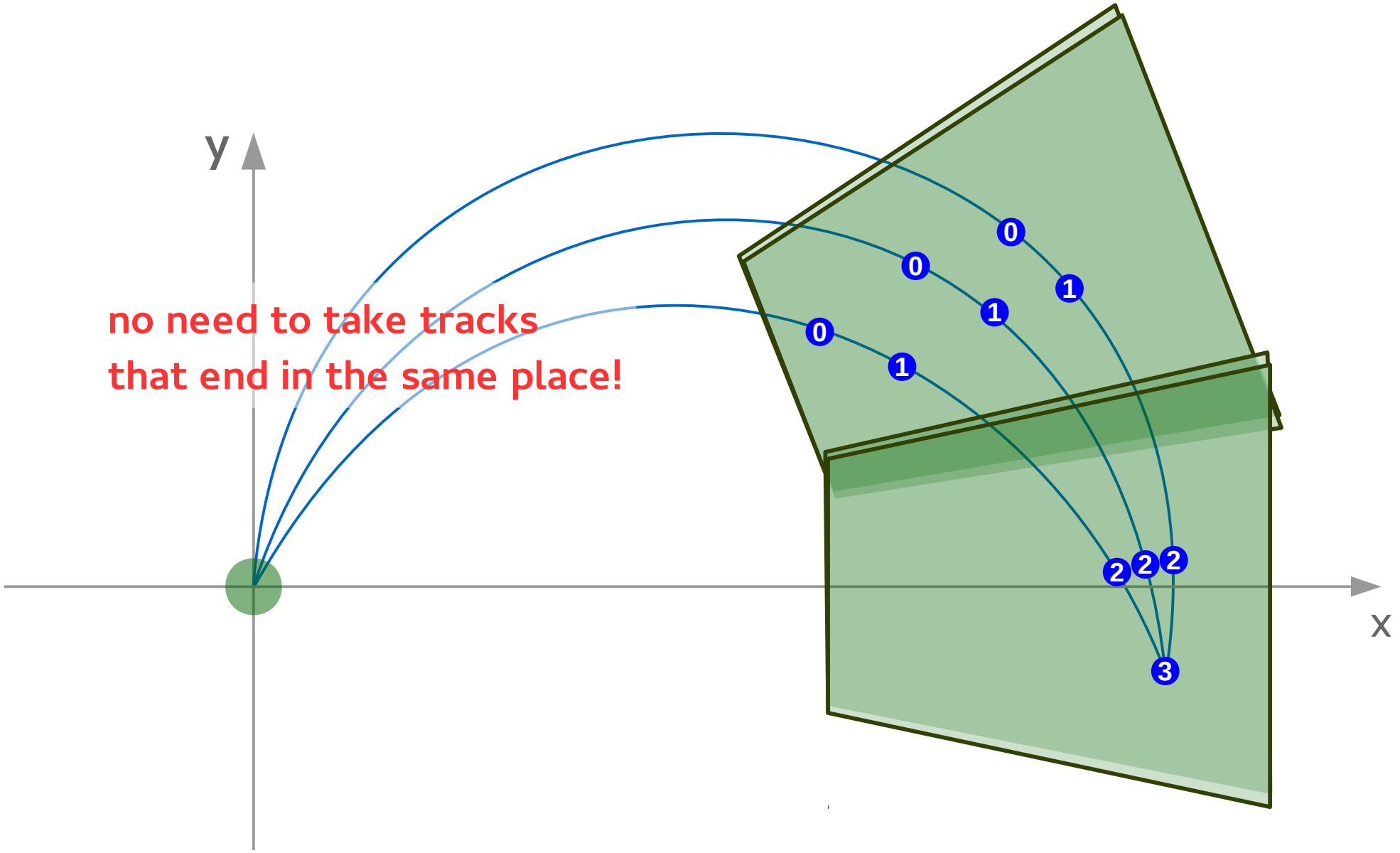




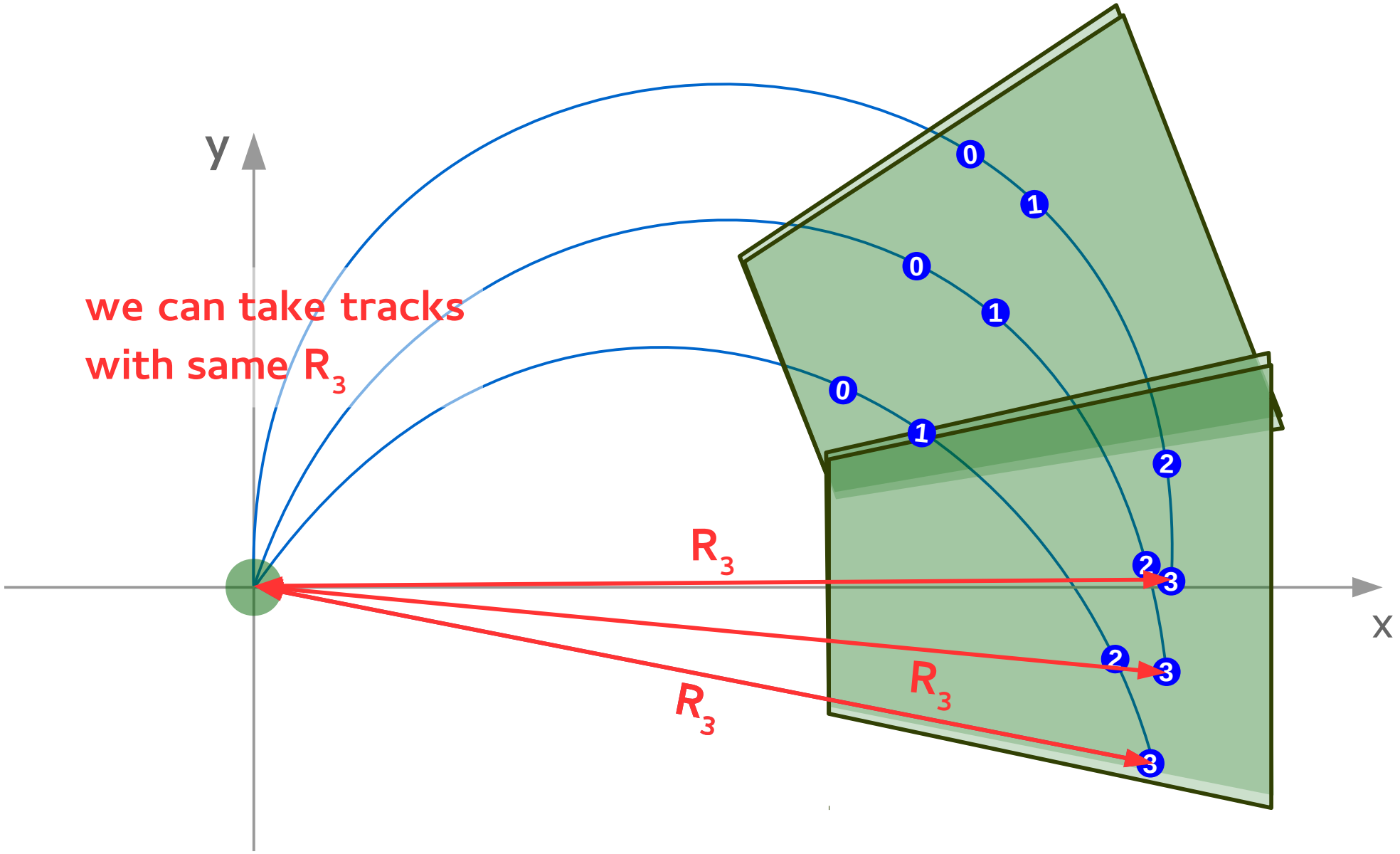
Track reconstruction using the search window



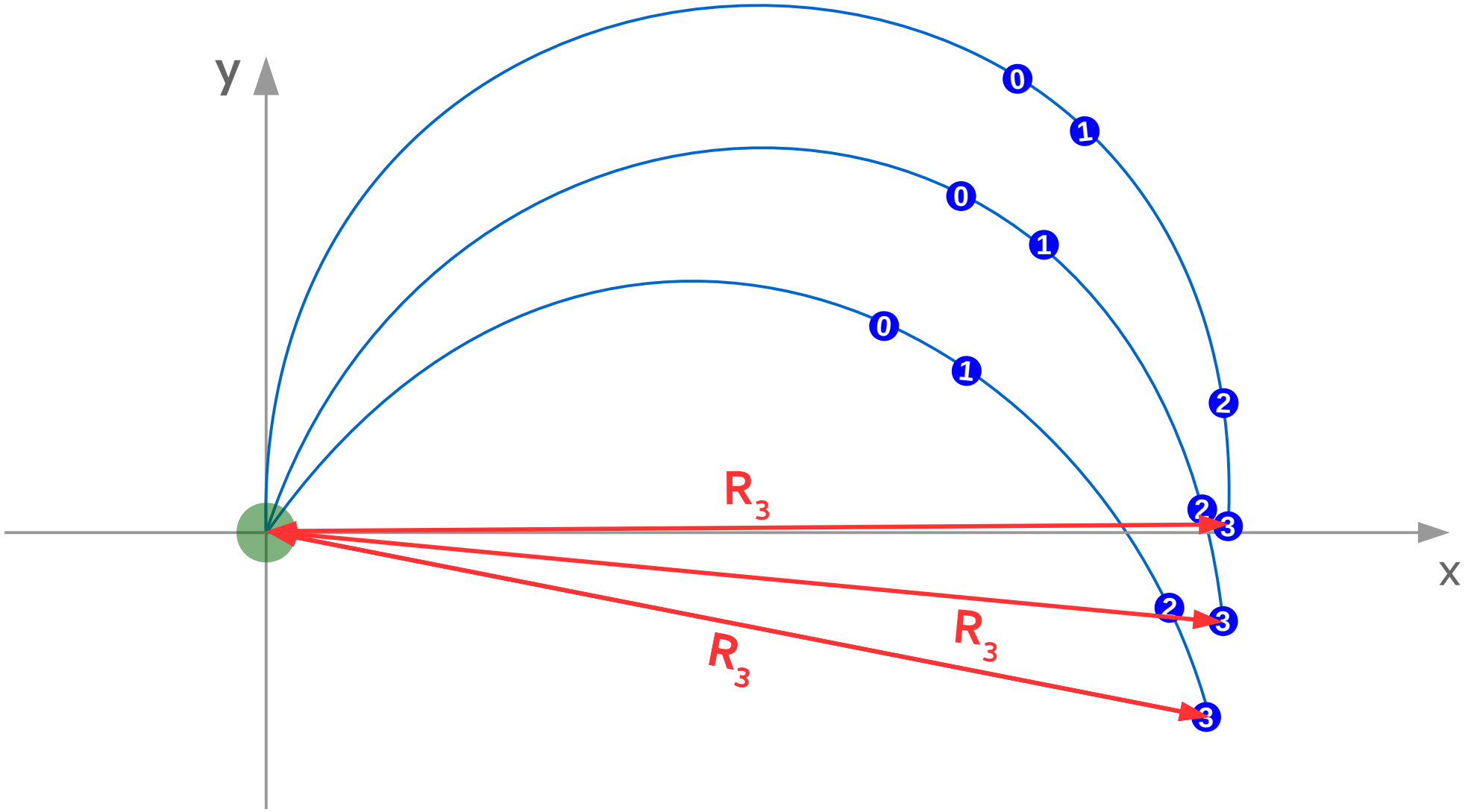
How to find the search window for plane 2



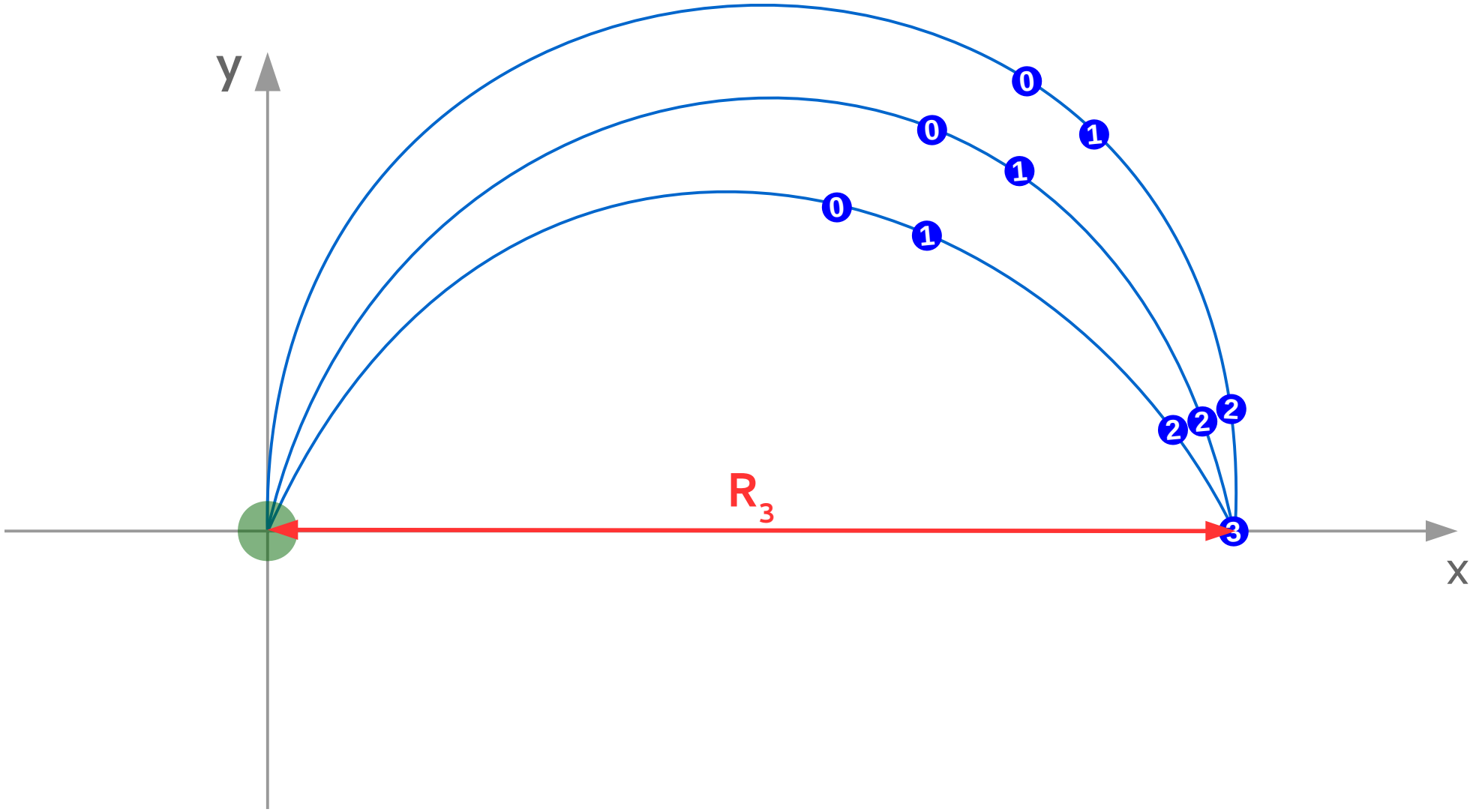
How to find the search window for plane 2



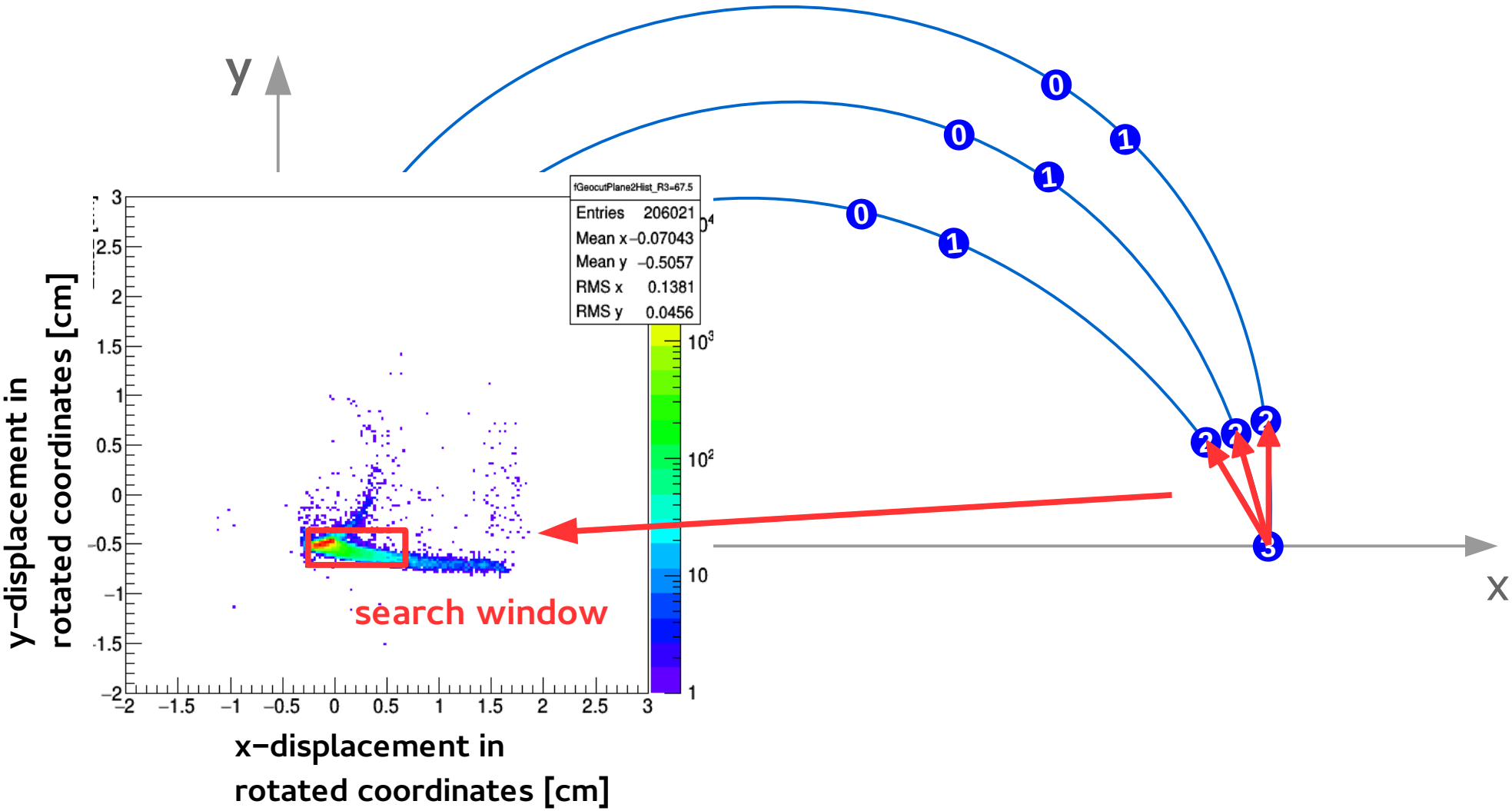
How to find the search window for plane 2



How to find the search window for plane 2

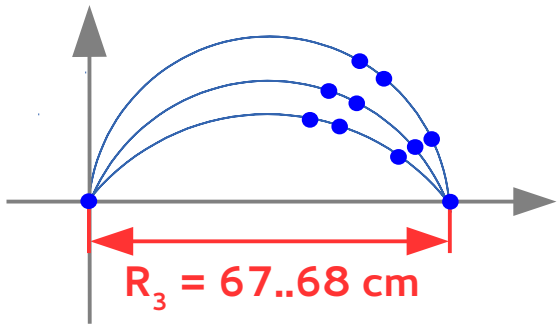


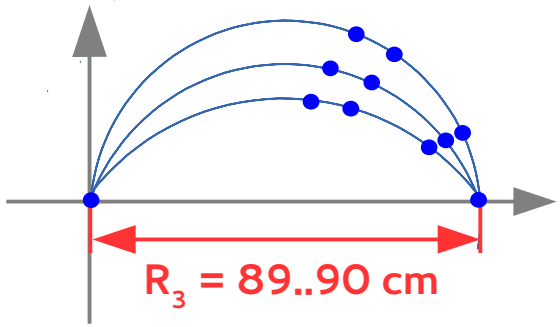
How to find the search window for plane 2

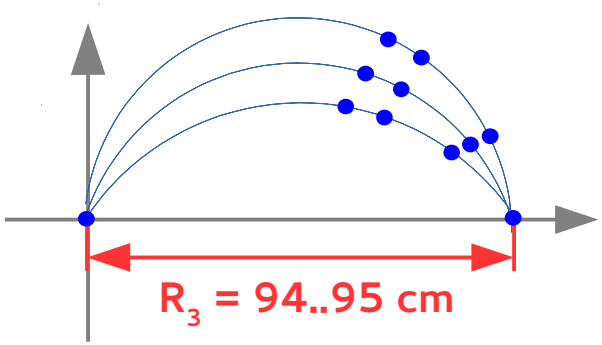


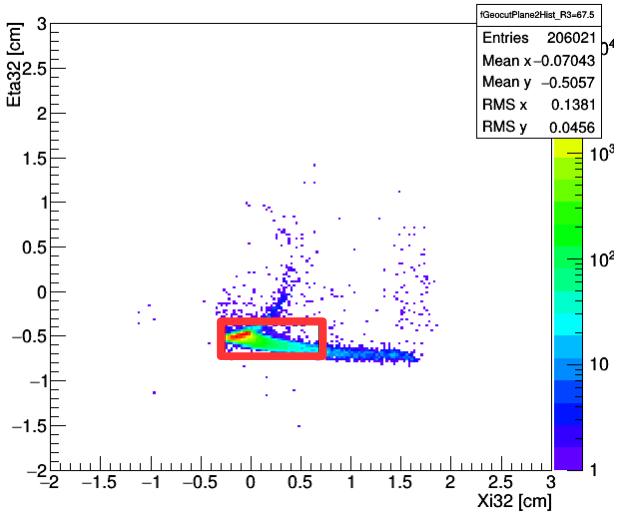
Search window for various R_3

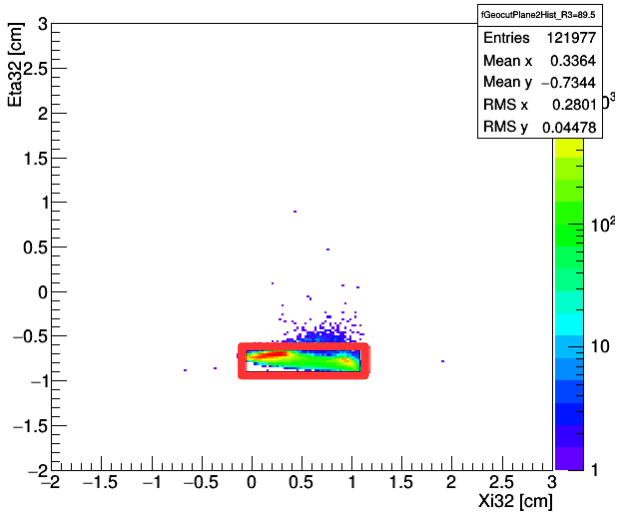
Three arbitrarily selected bins:

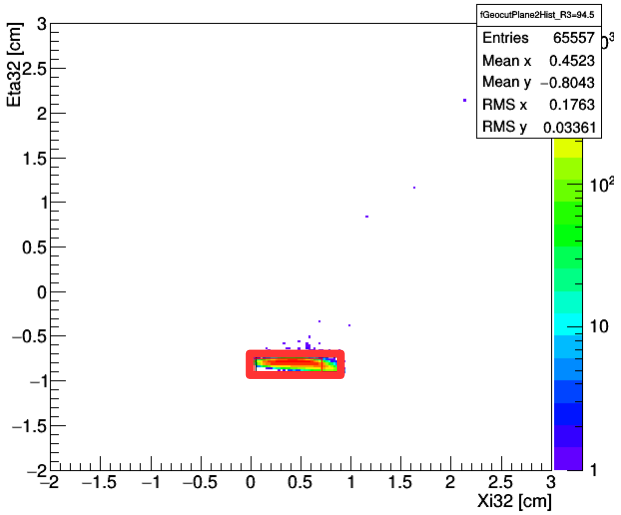




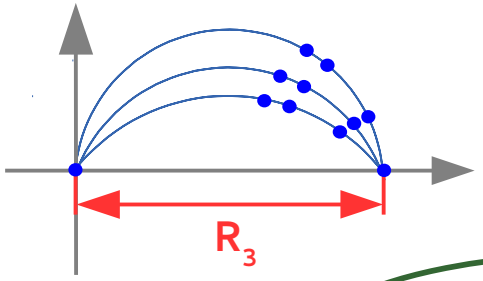




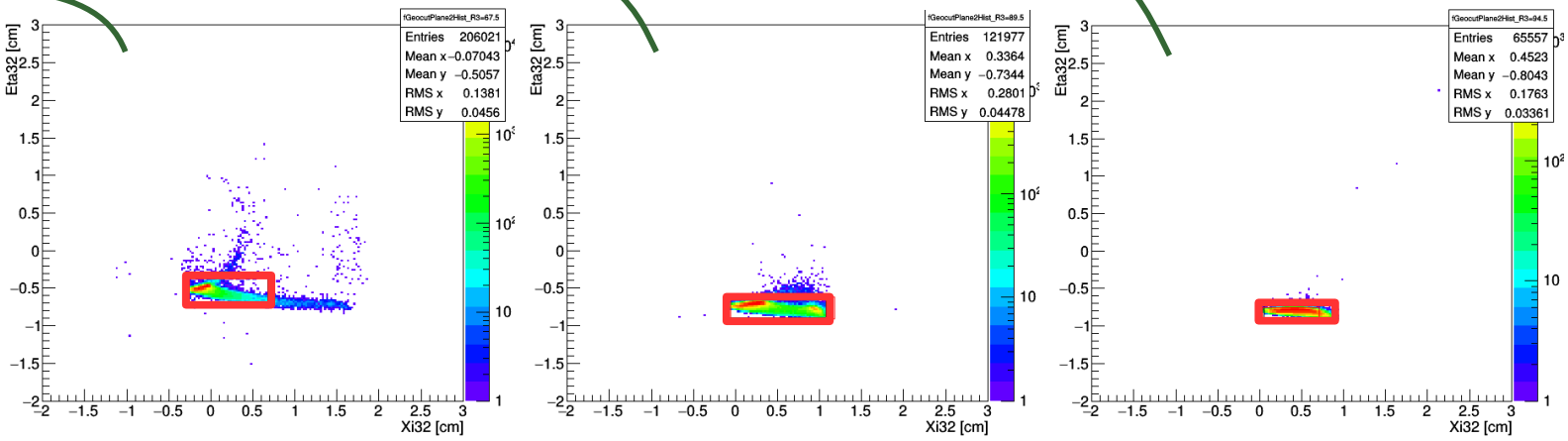




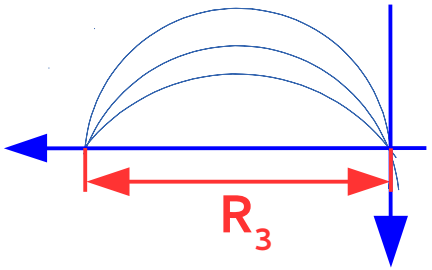
Search window for various R_3



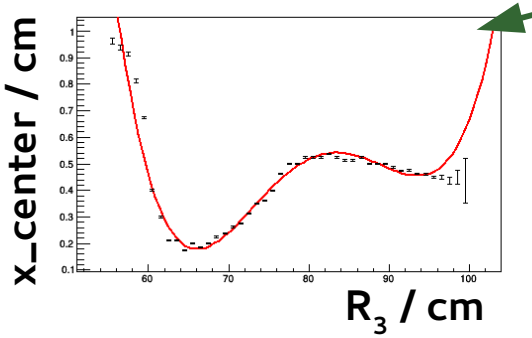
R_3 / cm	x_center / cm	y_center / cm	x_size / cm	y_size / cm
...	...	...	...	...
67-68	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...
89-90	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...
94-95	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...

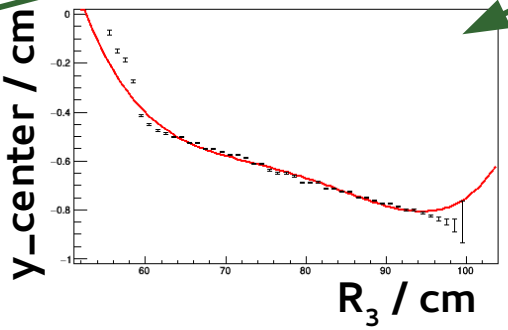


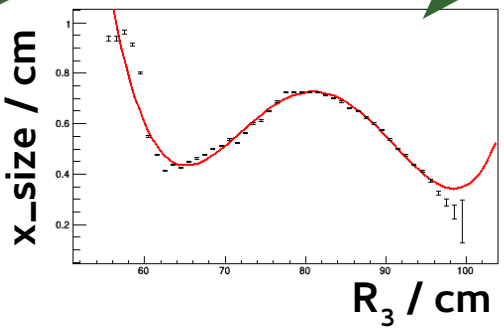
Search window as a function of R_3

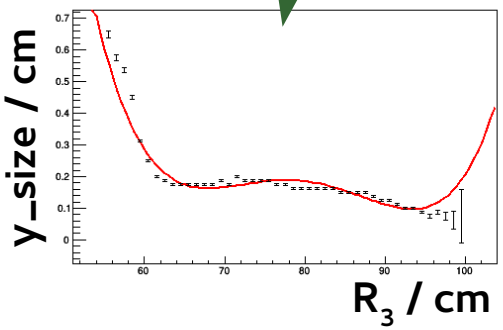


R_3 / cm	x_center / cm	y_center / cm	x_size / cm	y_size / cm
...	...	...	...	...
67-68	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...
89-90	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...
94-95	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...

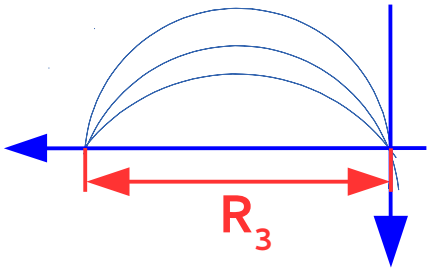




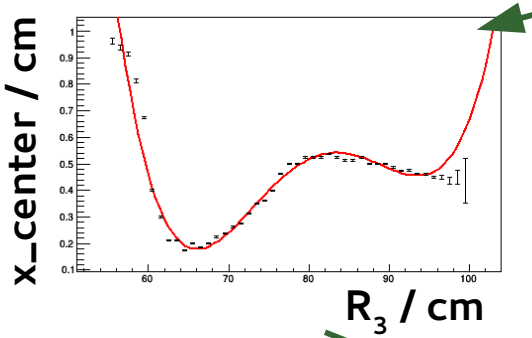


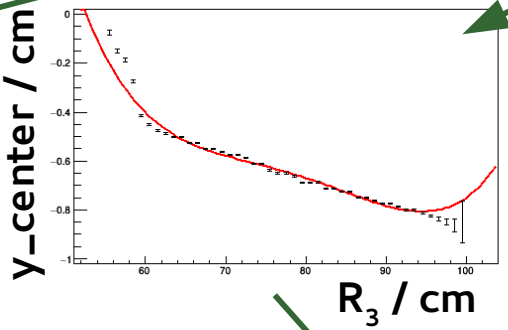


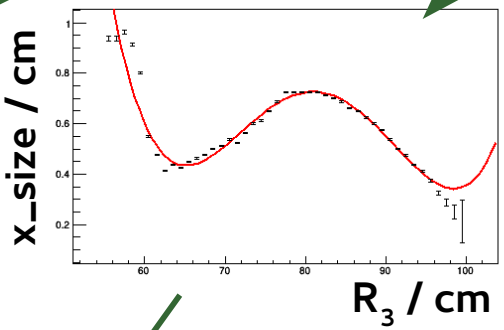
Search window as a function of R_3

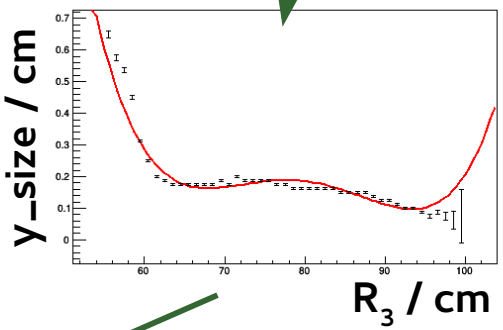


R_3 / cm	x_center / cm	y_center / cm	x_size / cm	y_size / cm
...	...	...	...	...
67-68	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...
89-90	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...
94-95	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...



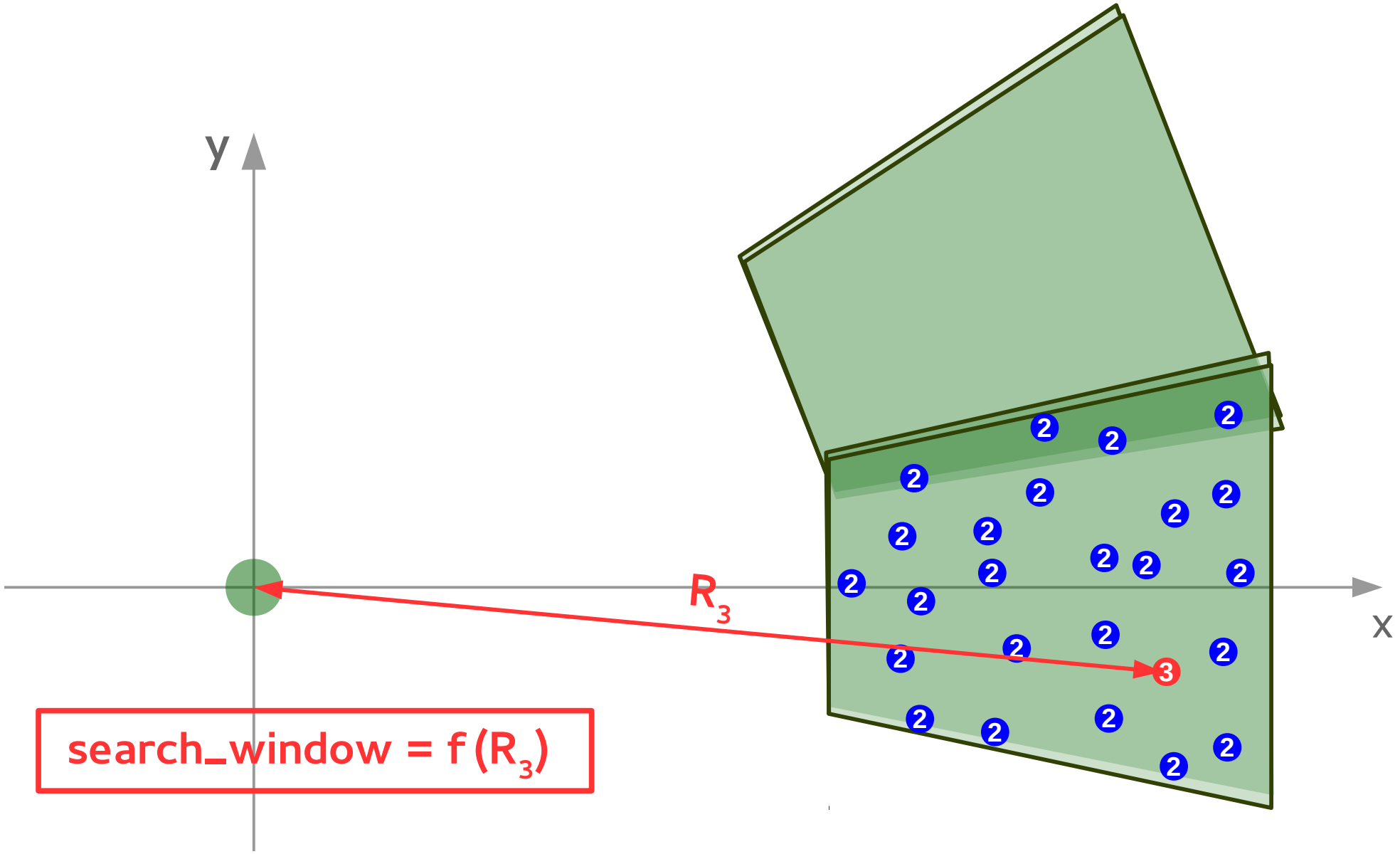




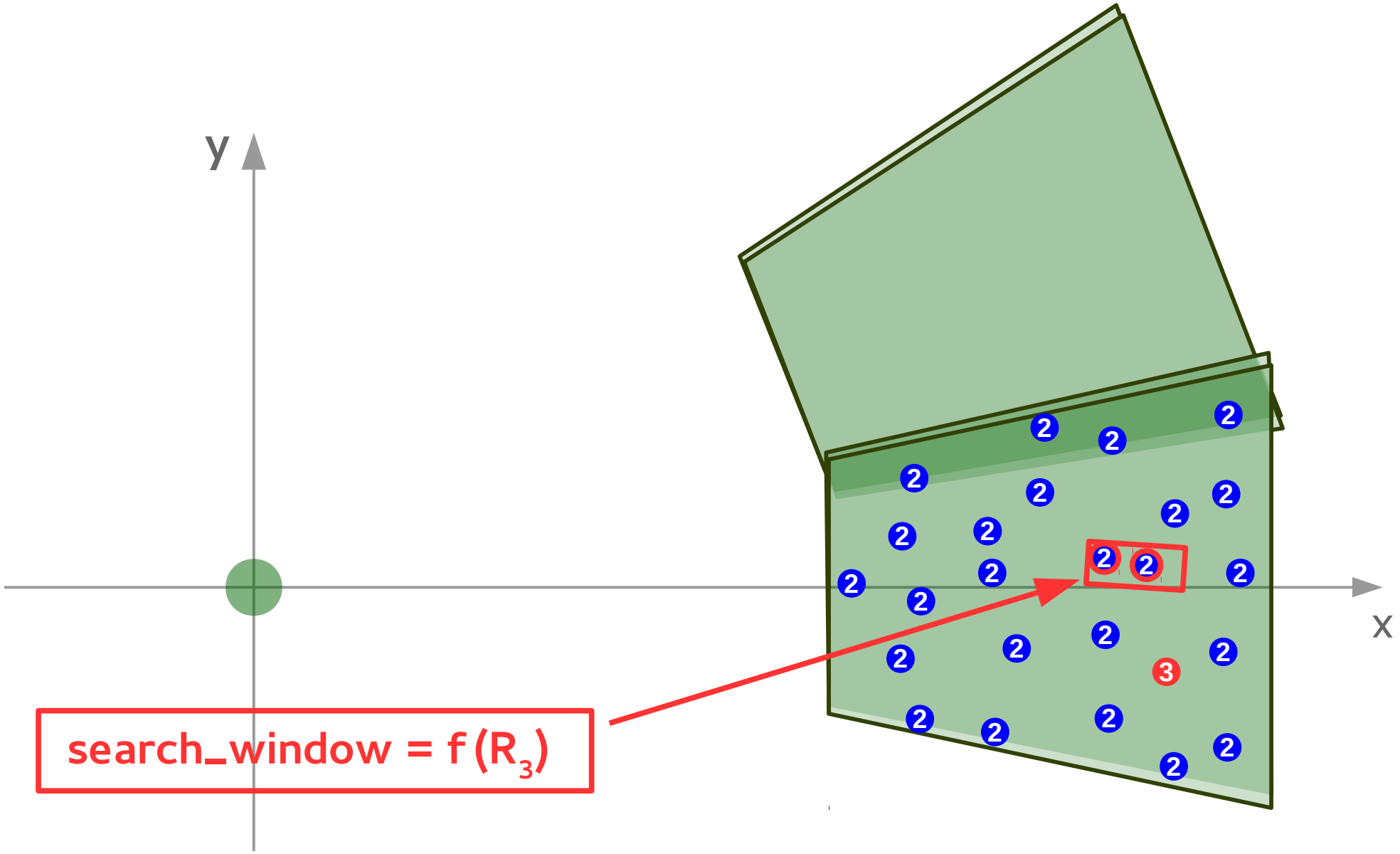


search_window = f (R_3)

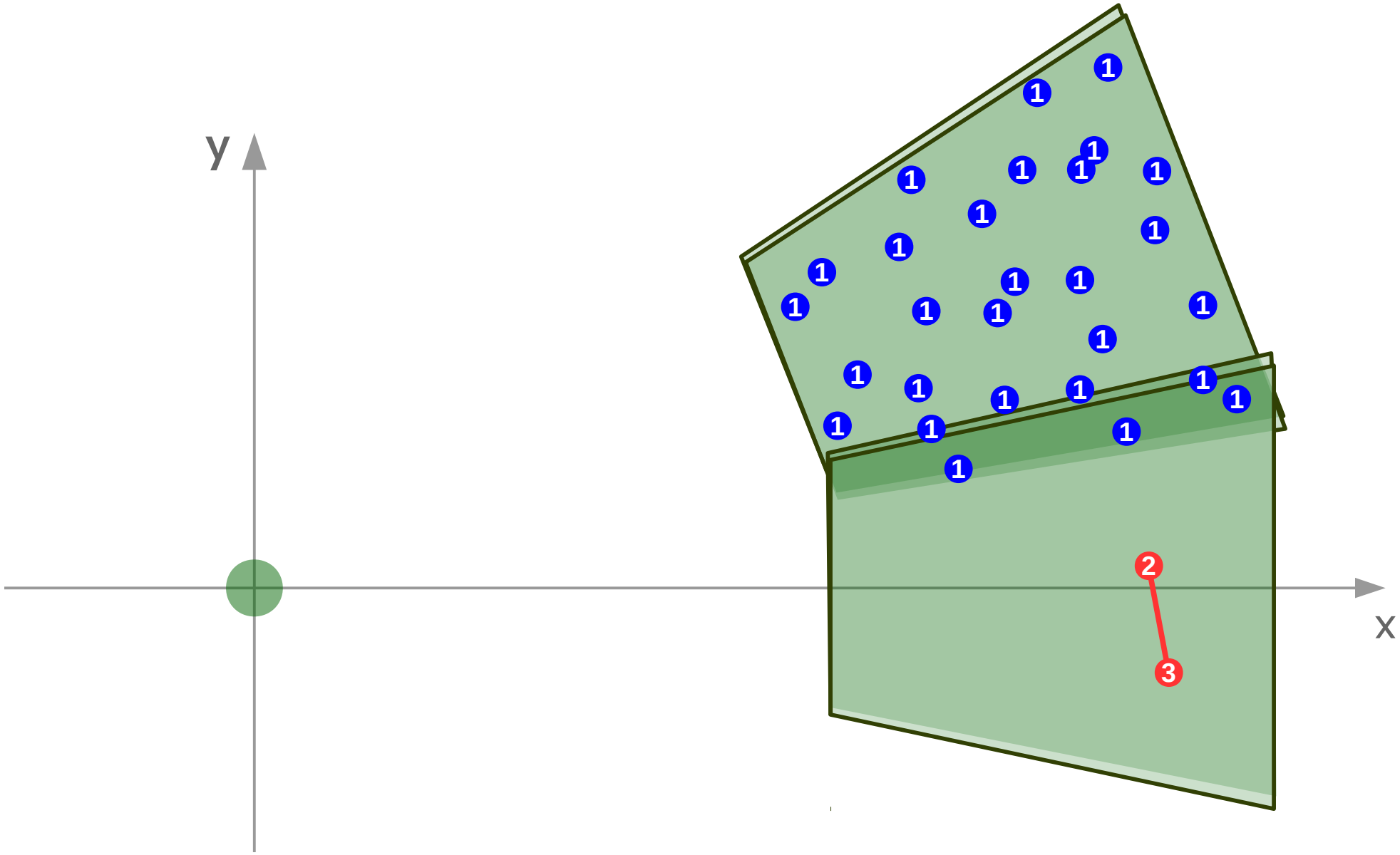
How to apply the parameterized search window?



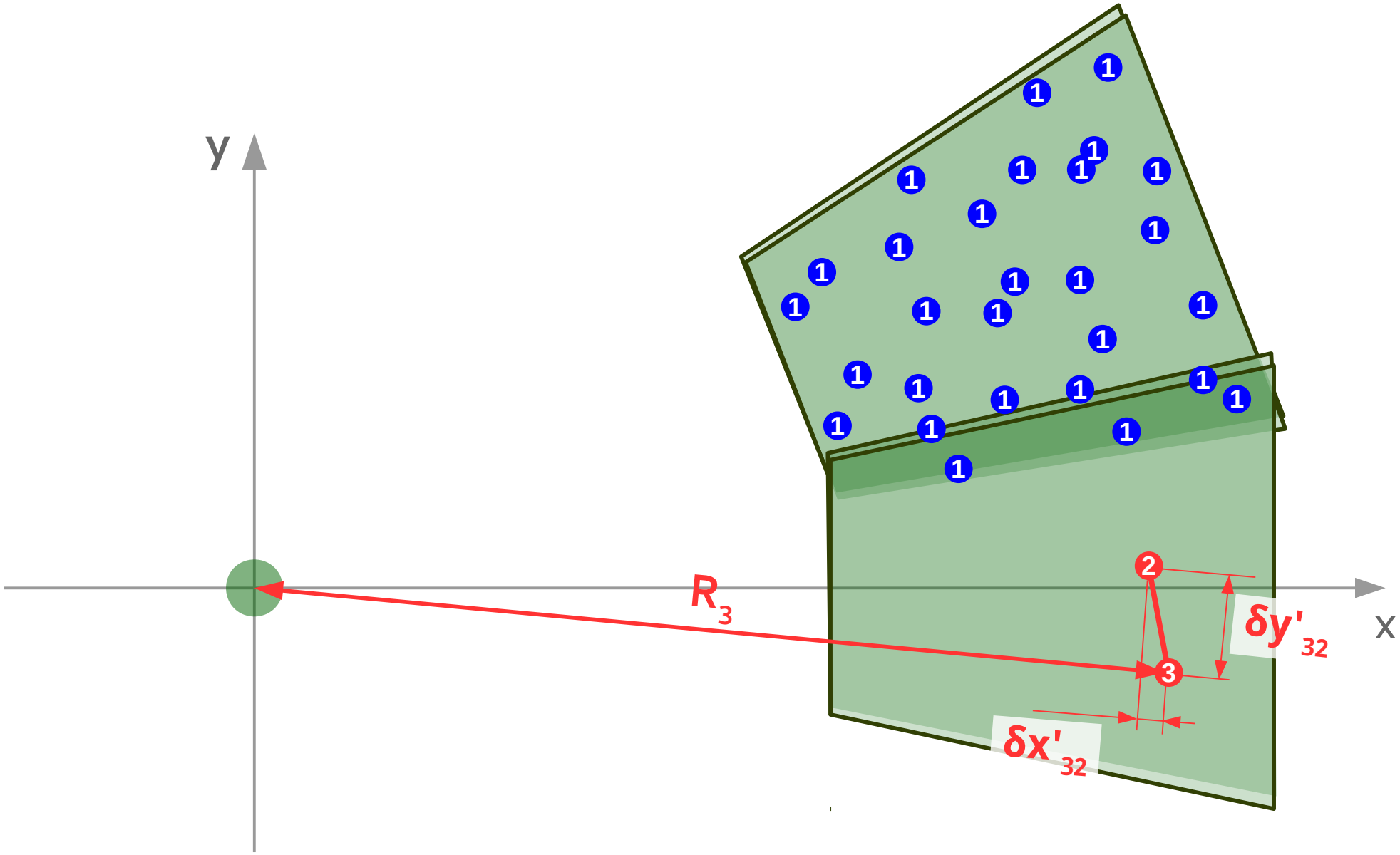
How to apply the parameterized search window?



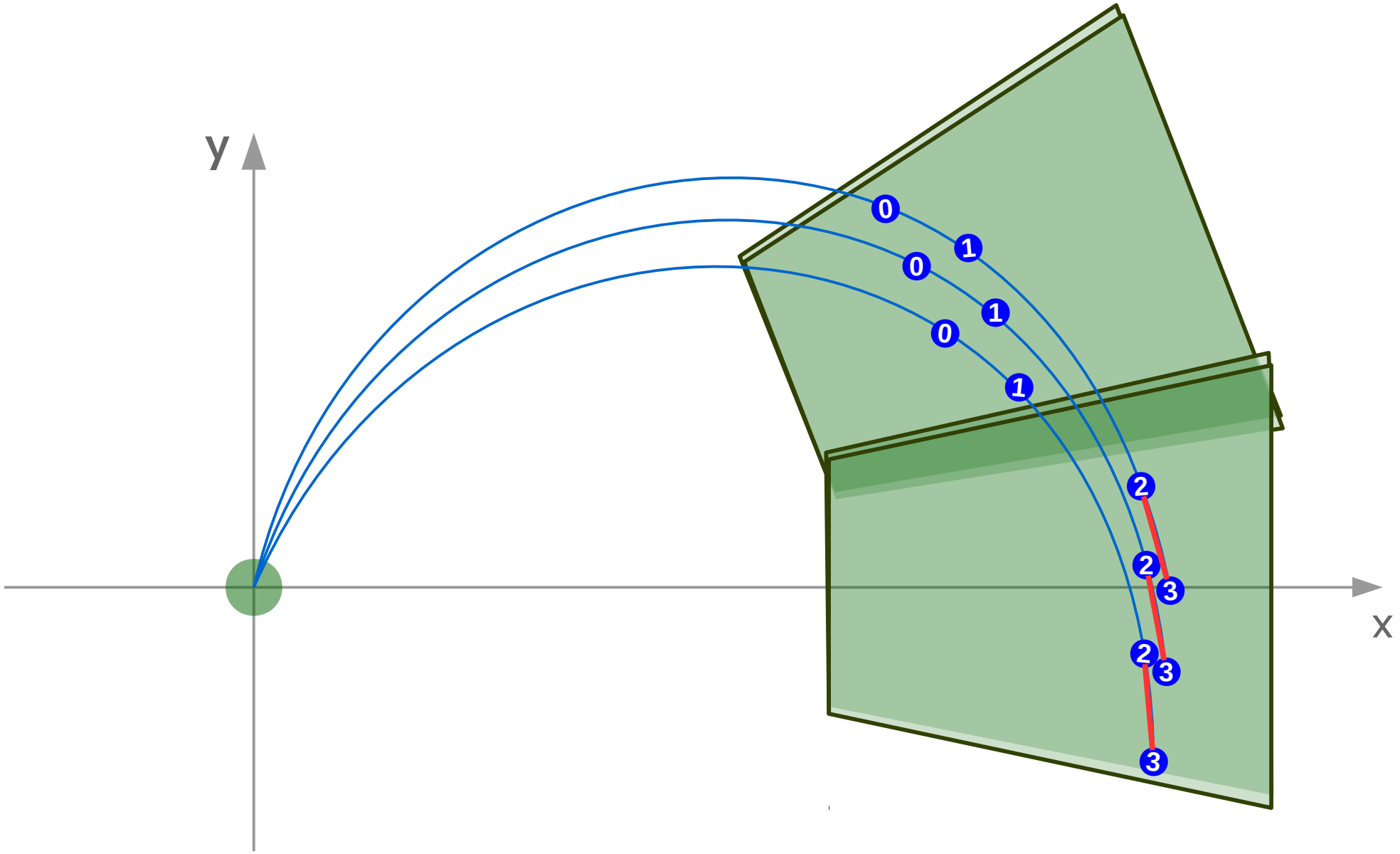
Search window for plane 1



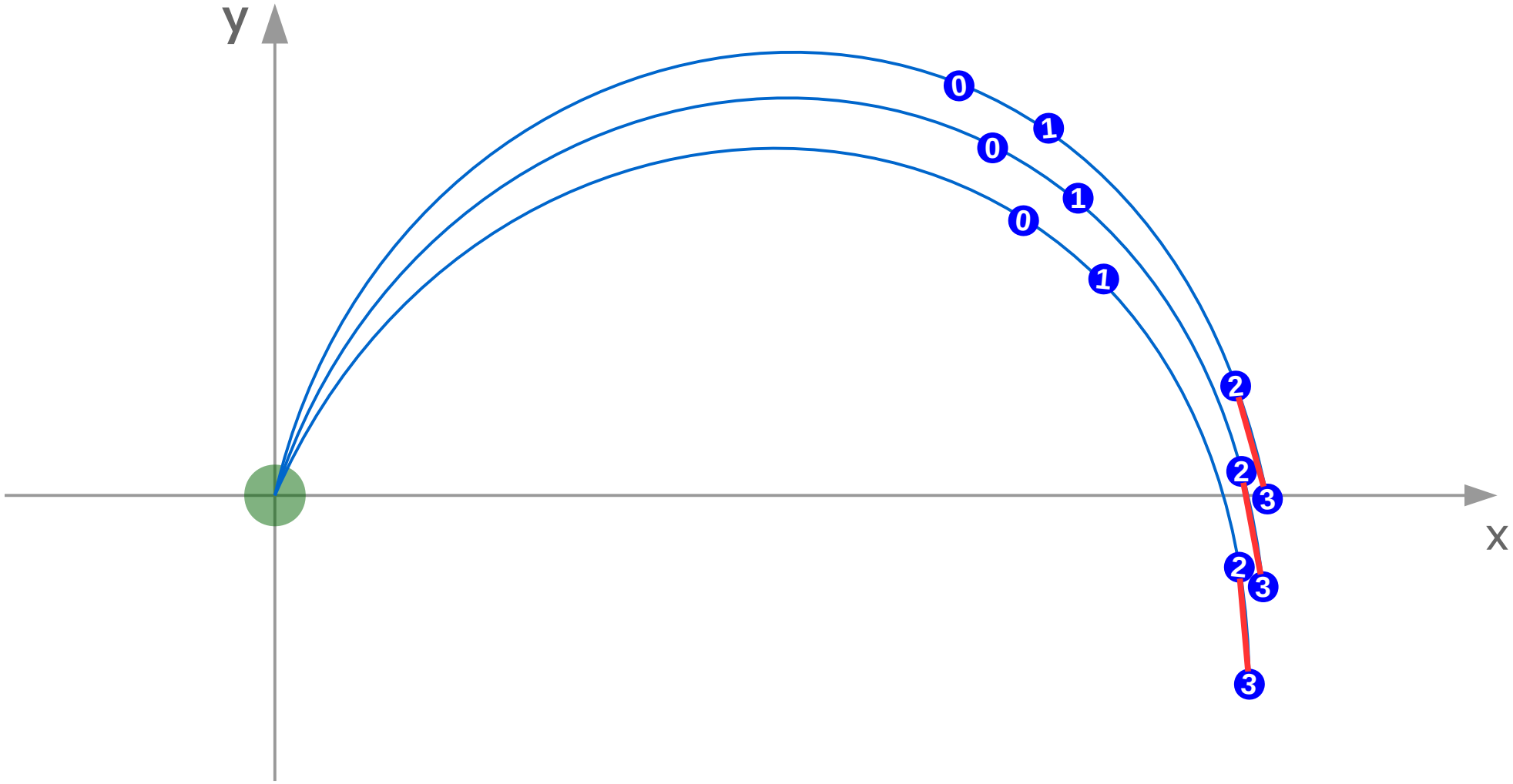
Search window for plane 1



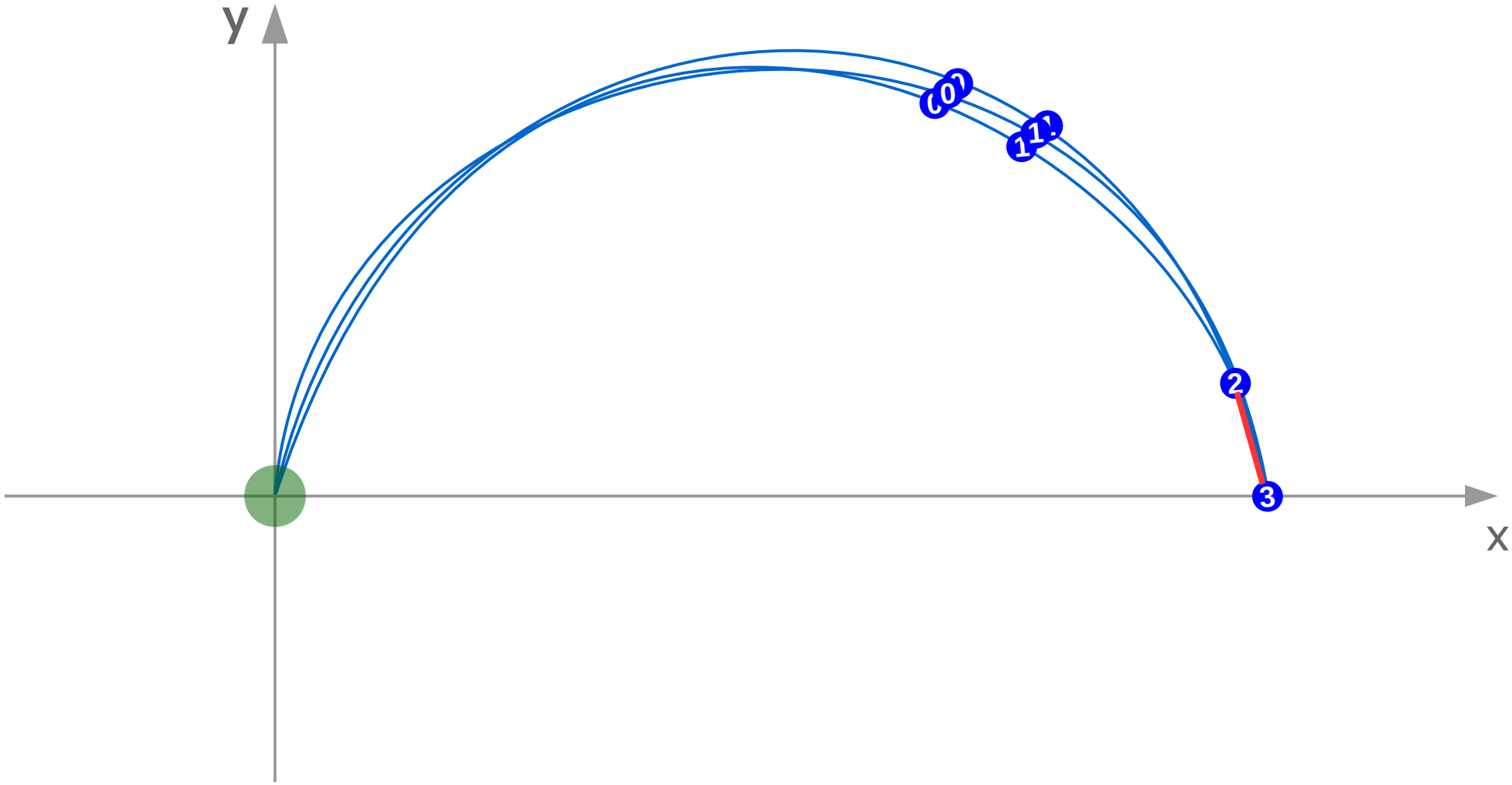
Search window for plane 1



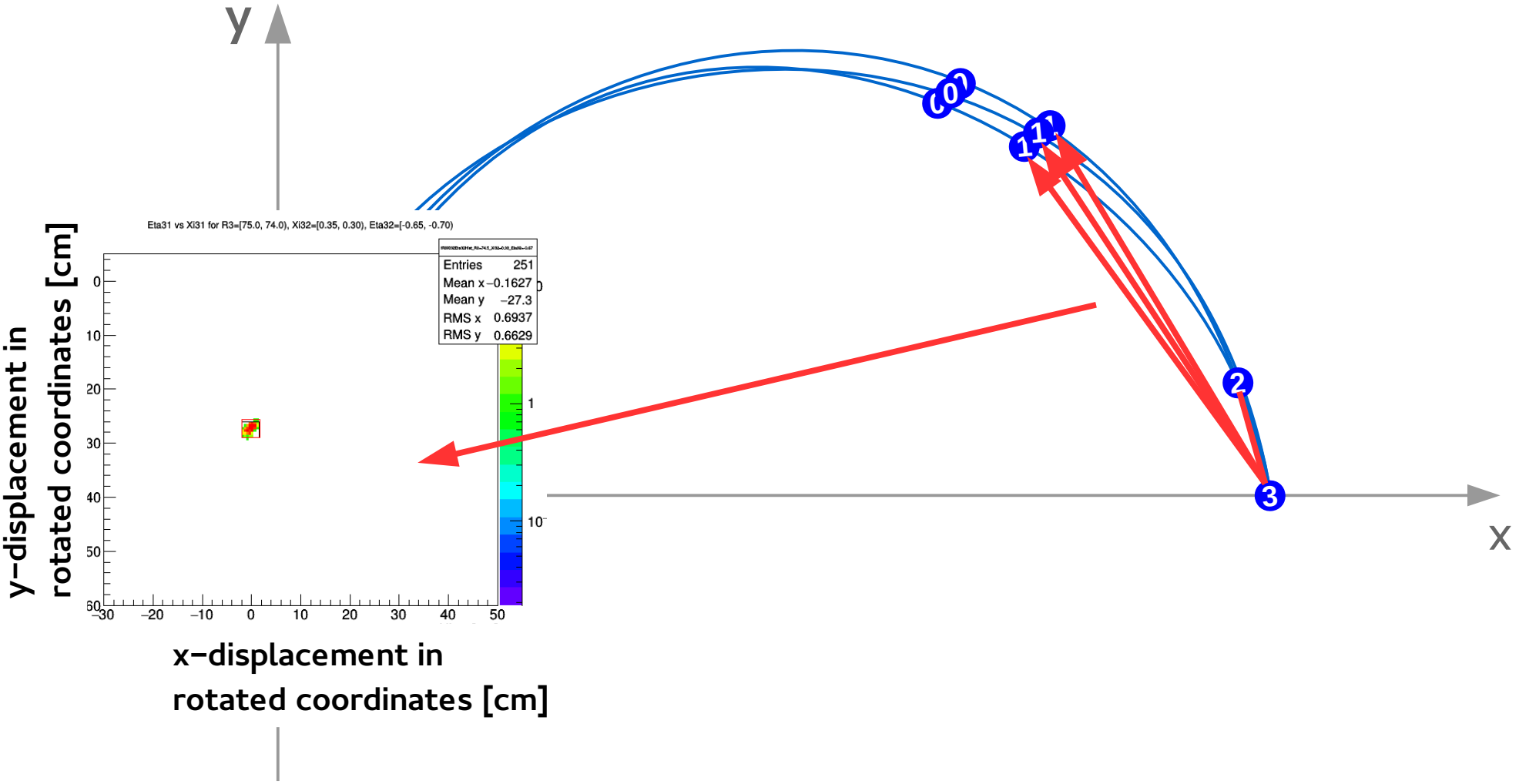
Search window for plane 1



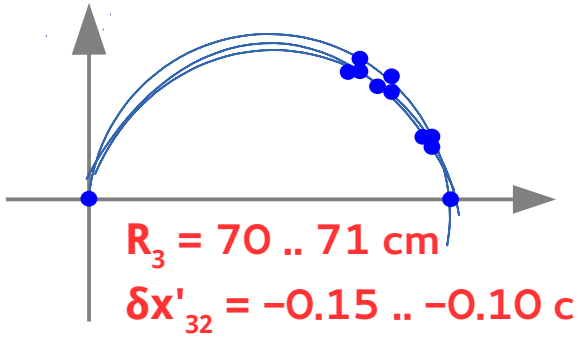
Search window for plane 1



Search window for plane 1



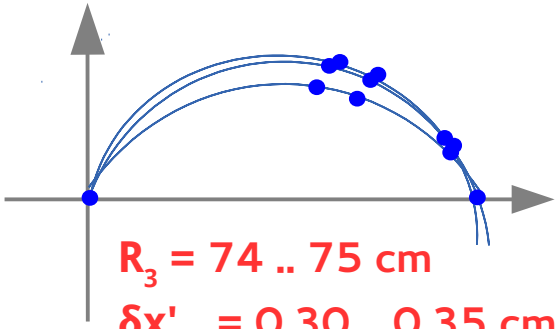
Search window for plane 1



R_3 = 70 .. 71 cm

$\delta x'_{32}$ = −0.15 .. −0.10 cm

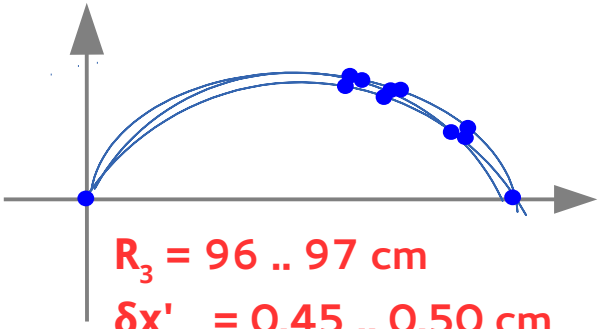
$\delta y'_{32}$ = −0.60 .. −0.55 cm



R_3 = 74 .. 75 cm

$\delta x'_{32}$ = 0.30 .. 0.35 cm

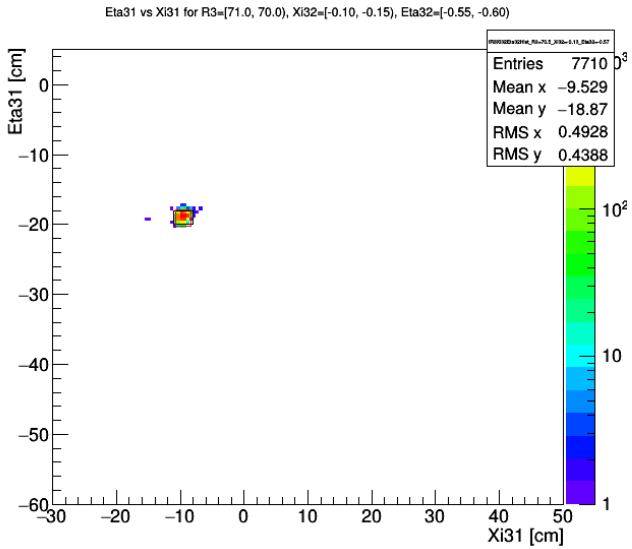
$\delta y'_{32}$ = −0.70 .. −0.65 cm

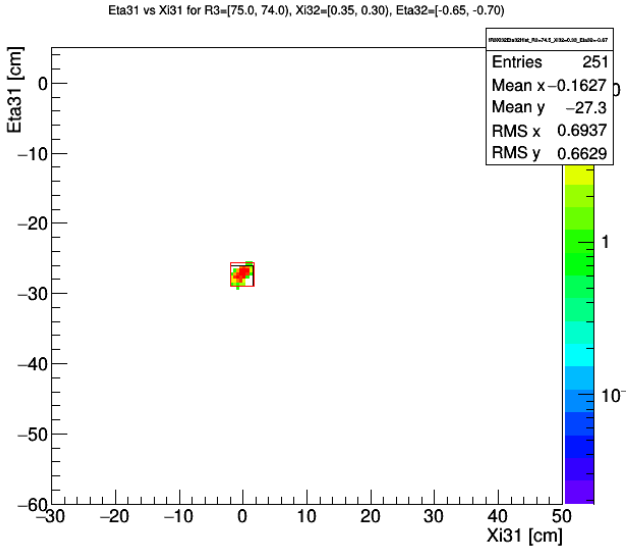


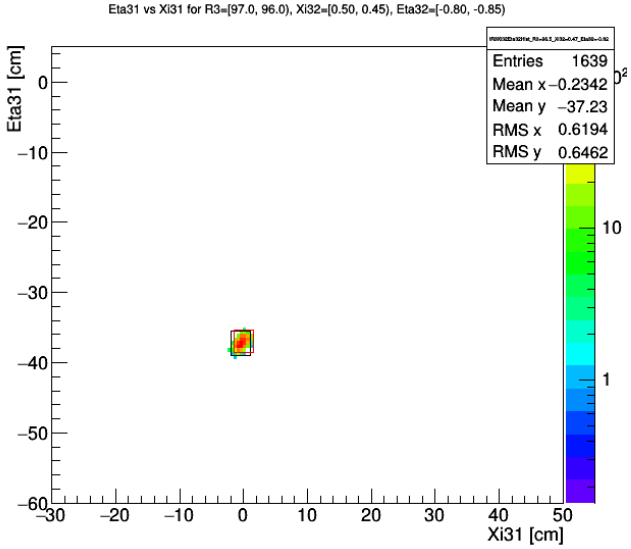
R_3 = 96 .. 97 cm

$\delta x'_{32}$ = 0.45 .. 0.50 cm

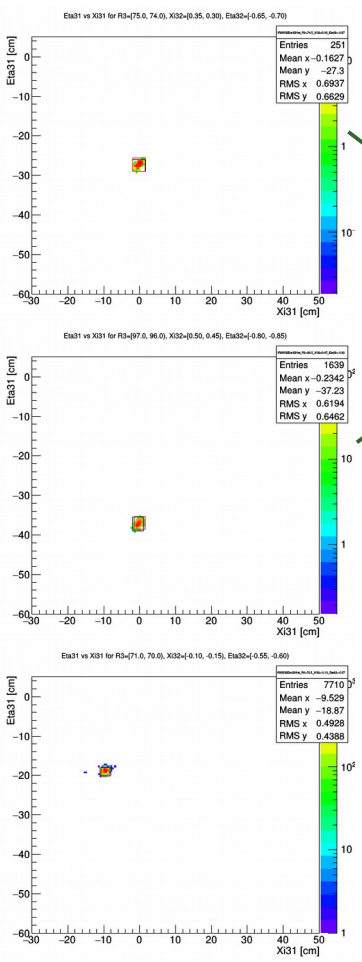
$\delta y'_{32}$ = −0.85 .. −0.80 cm





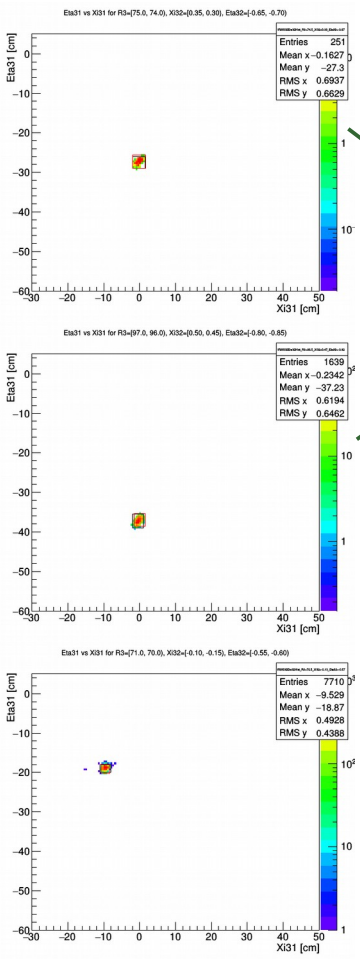


Search window for plane 1



R_3 / cm	$\delta x'_{32}$ / cm	$\delta y'_{32}$ / cm	x_center / cm	y_center / cm	x_size / cm	y_size / cm
...	...	...	...	...	...	...
70-71	-0.15 .. -0.10	-0.60 .. -0.55	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...	...
74-75	0.30 .. 0.35	-0.70 .. -0.65	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...	...
96-97	0.45 .. 0.50	-0.85 .. -0.80	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...	...

Search window for plane 1

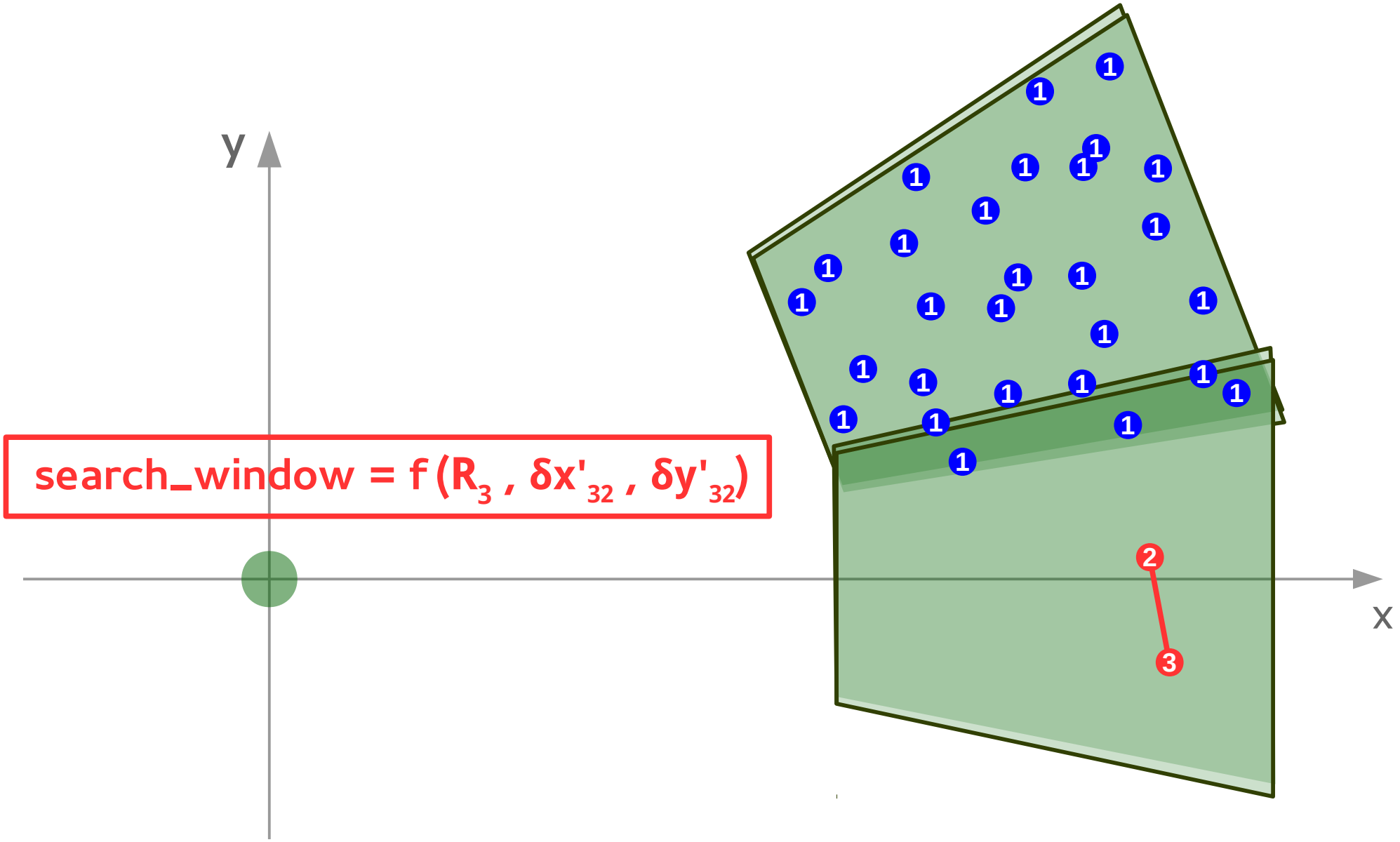


R_3 / cm	$\delta x'_{32}$ / cm	$\delta y'_{32}$ / cm	x_center / cm	y_center / cm	x_size / cm	y_size / cm
...	...	...	...	...	...	...
70-71	-0.15 .. -0.10	-0.60 .. -0.55	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...	...
74-75	0.30 .. 0.35	-0.70 .. -0.65	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...	...
96-97	0.45 .. 0.50	-0.85 .. -0.80	■■■■	■■■■	■■■■	■■■■
...	...	...	...	...	...	...

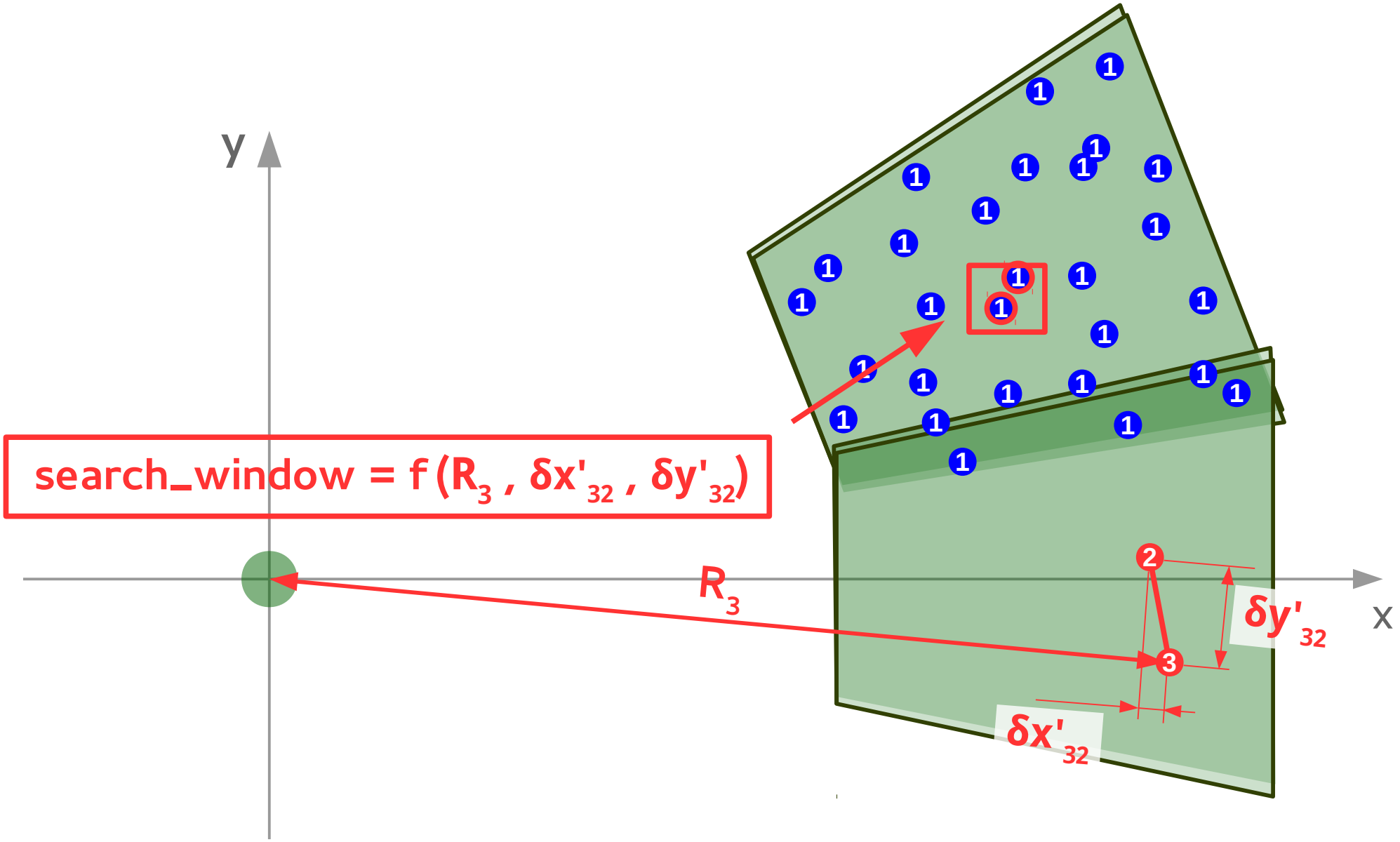
FIT FIT FIT FIT

$$\text{search\_window} = f(R_3 , \delta x'_{32} , \delta y'_{32})$$

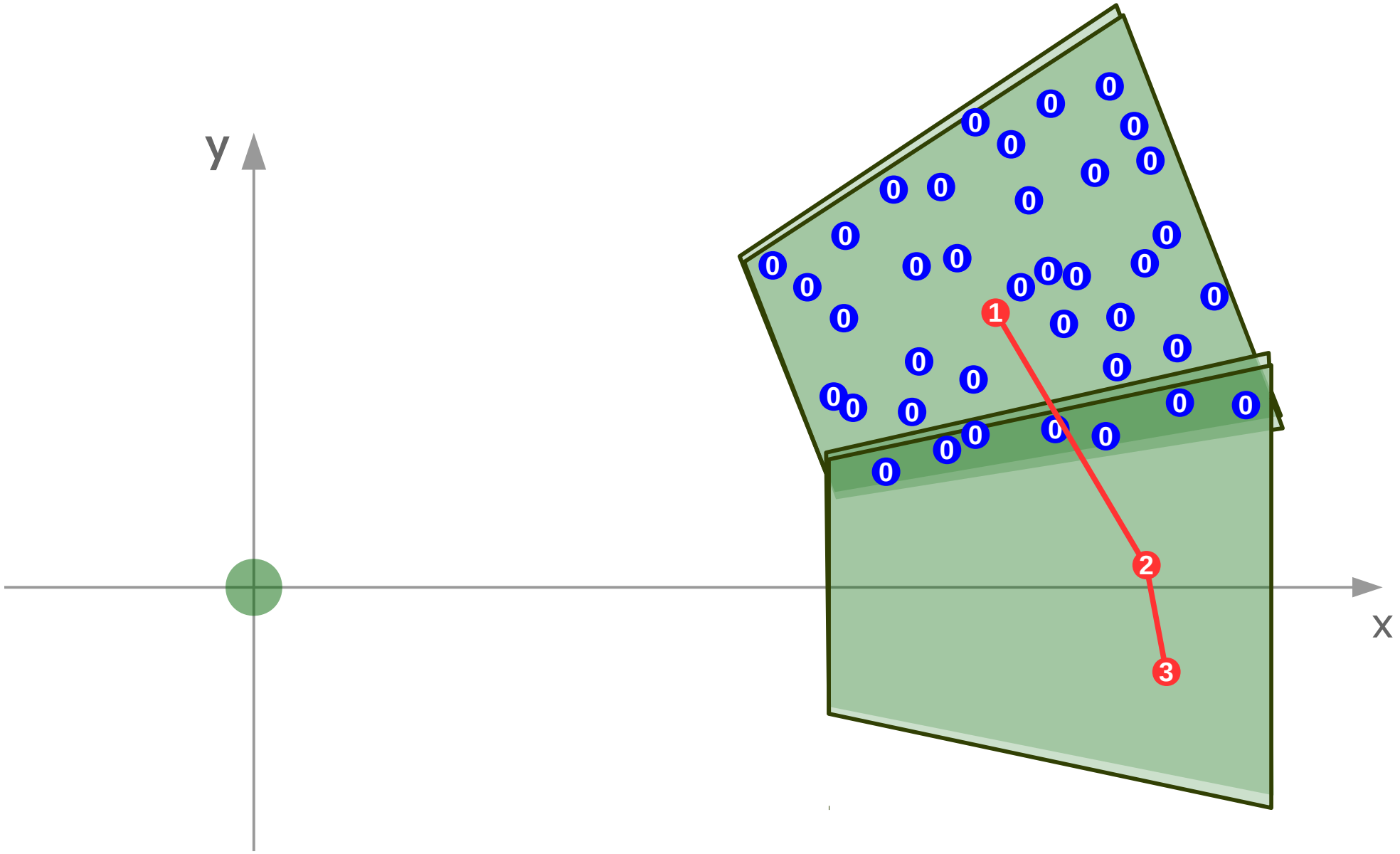
Applying the search window for plane 1



Applying the search window for plane 1

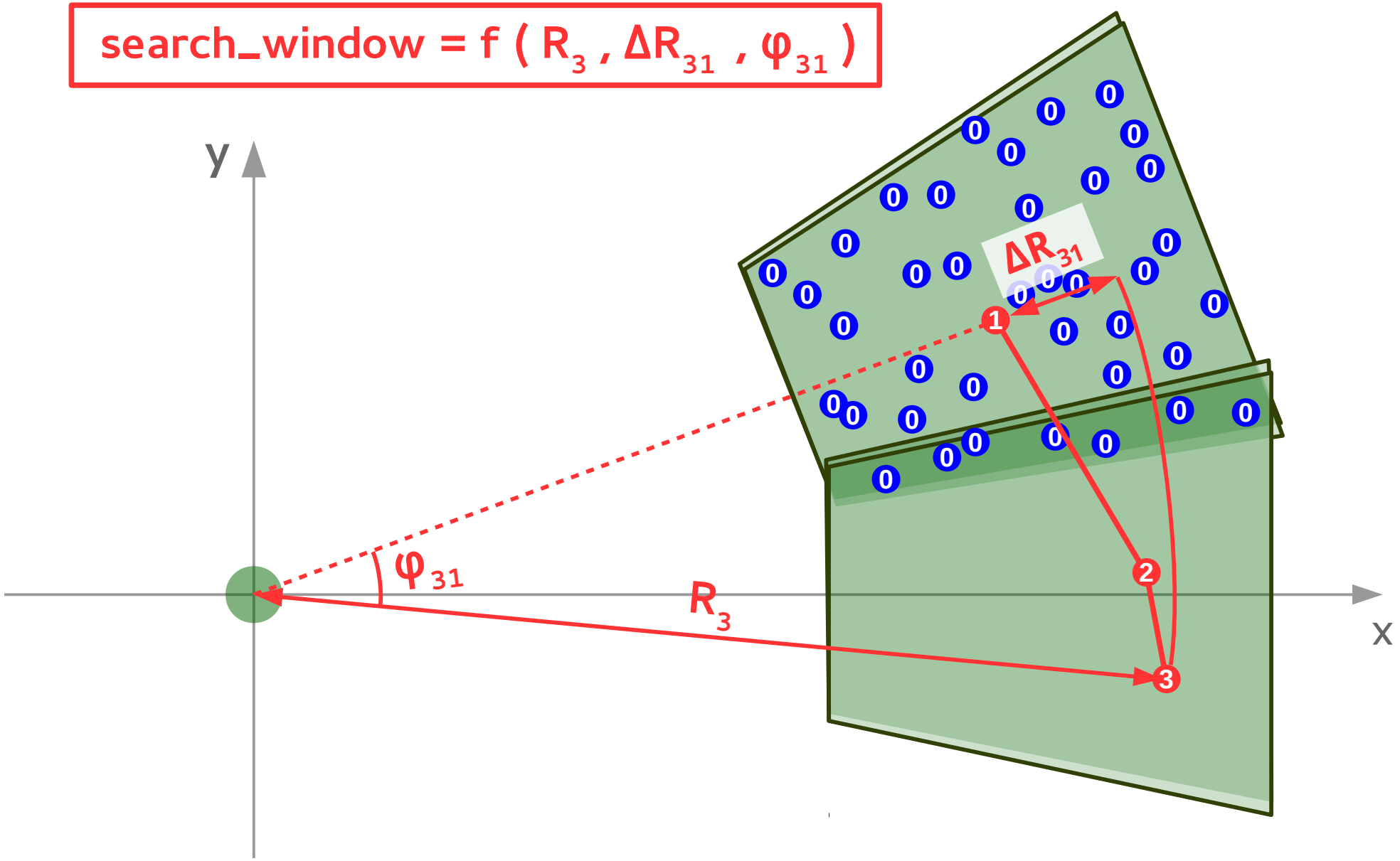


Search window for plane 0



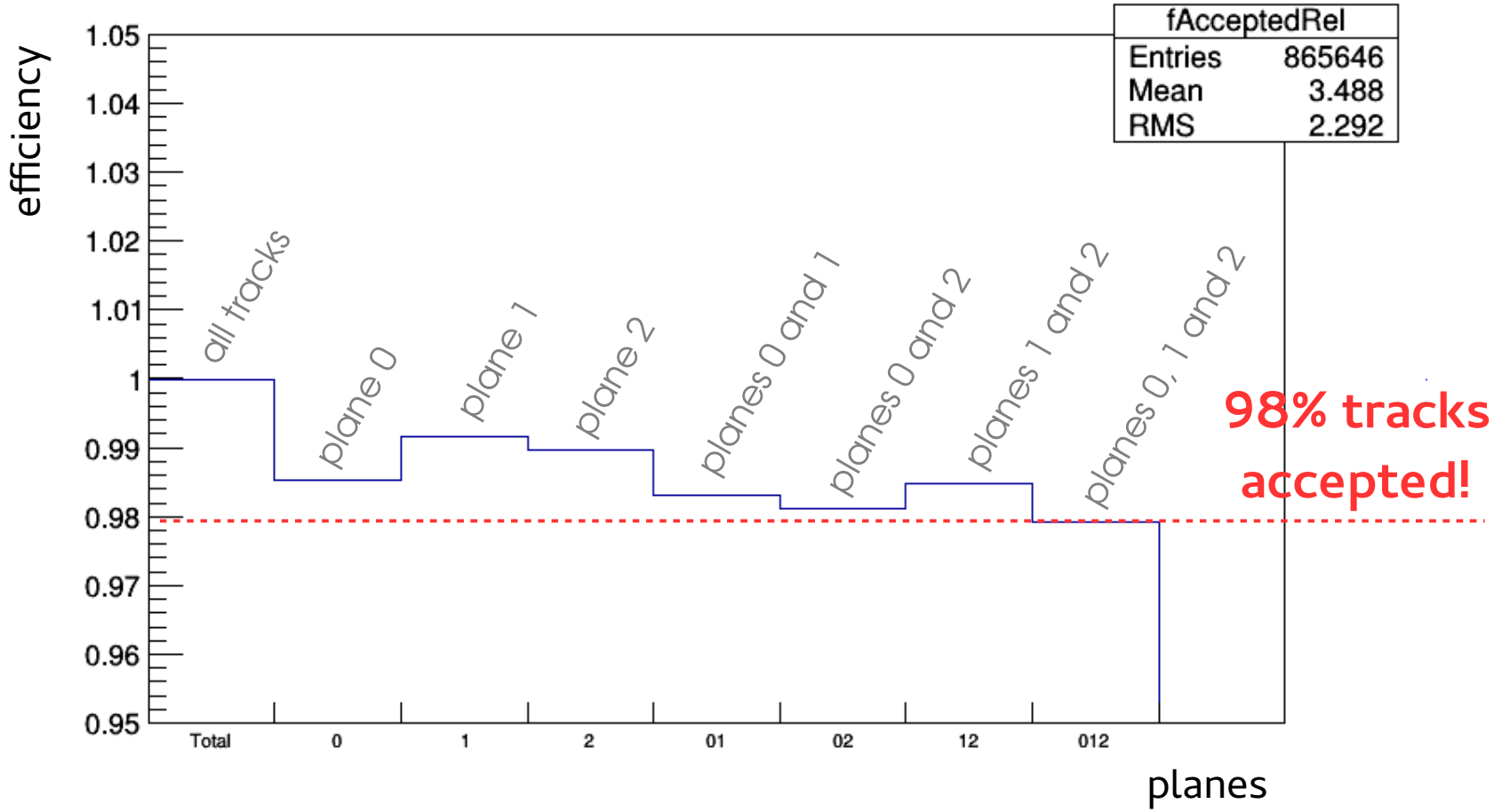
Search window for plane 0

search_window = f (R_3 , ΔR_{31} , φ_{31})



Search window efficiency

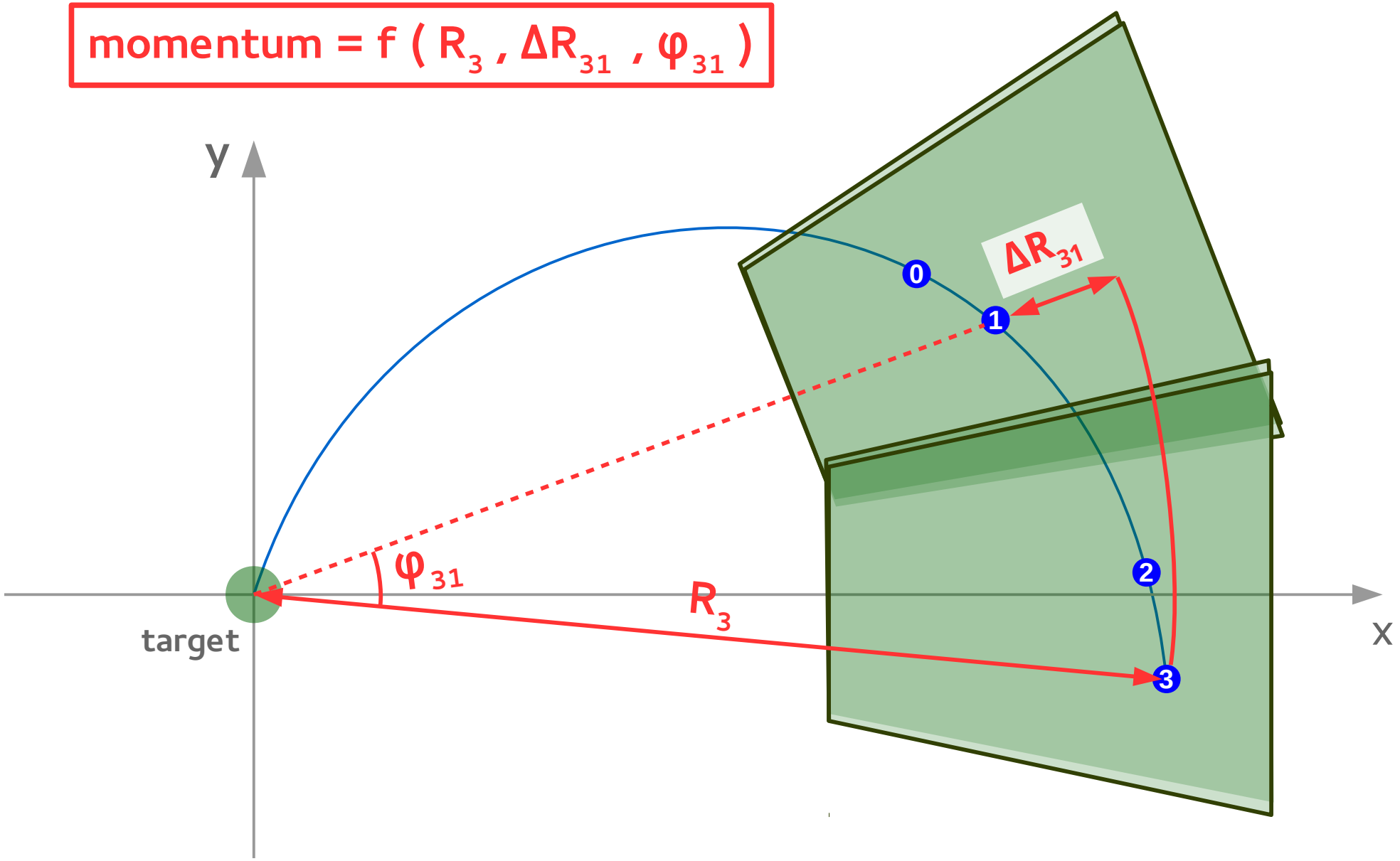
Fraction of good signal electrons, accepted by combinations of search windows:



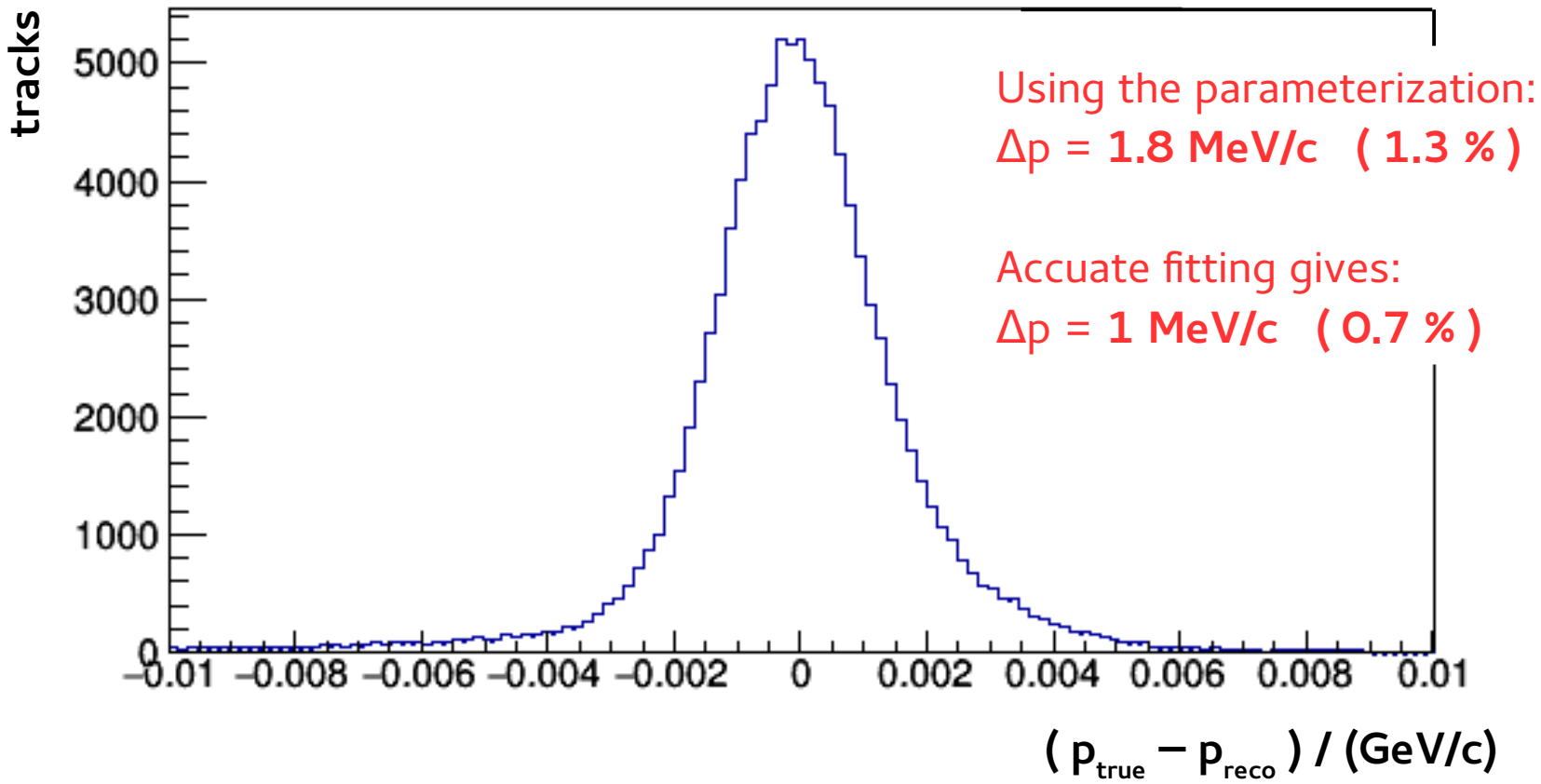
Parameterization instead of track fitting

Momentum parameterization

momentum = f (R_3 , ΔR_{31} , φ_{31})



Momentum residual



Summary

The challenge of tracking in P2 are the rate and the background

Fast and efficient reconstruction is possible with parameterization-based tracking:

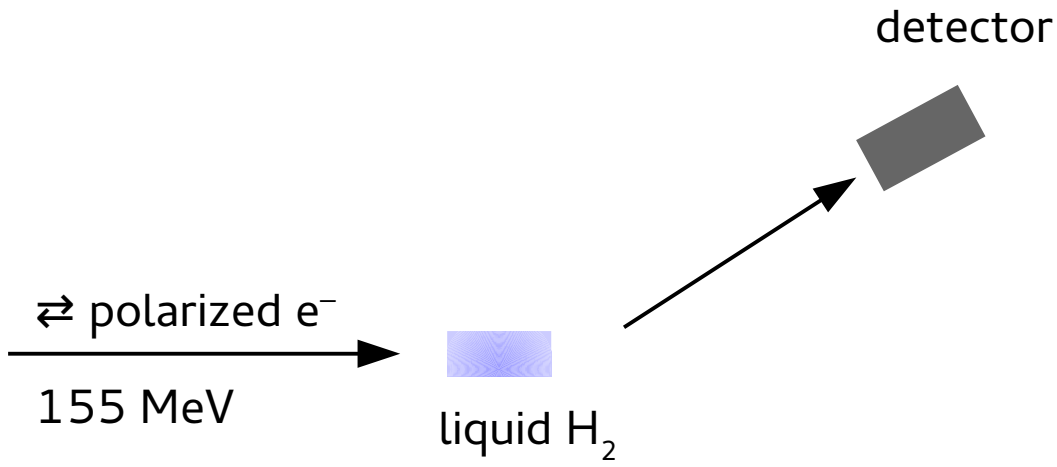
1) based on a set of reference tracks (MC or real) extract the dependence of track characteristics (e.g. momentum or relative hit location) on the hit positions

2) apply this dependence to events /frames to reconstruct

Works well for P2 due to small phase space

P2 experiment

precision measurement of the weak mixing angle Θ_W at low Q^2 in elastic e-p



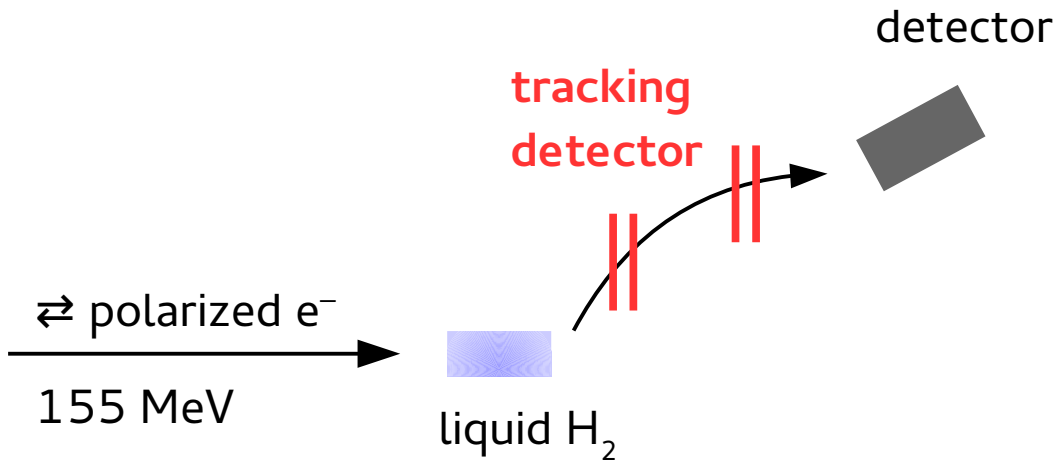
asymmetry w.r.t. e^- helicity flip is measured

$$\frac{N_- - N_+}{N_- + N_+} = \frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left(Q_W - F\left(Q^2\right)\right)$$

$$Q_W = 1 - 4\cdot\sin^2\left(\theta_W\right)$$

P2 experiment

precision measurement of the weak mixing angle Θ_W at low Q^2 in elastic e-p



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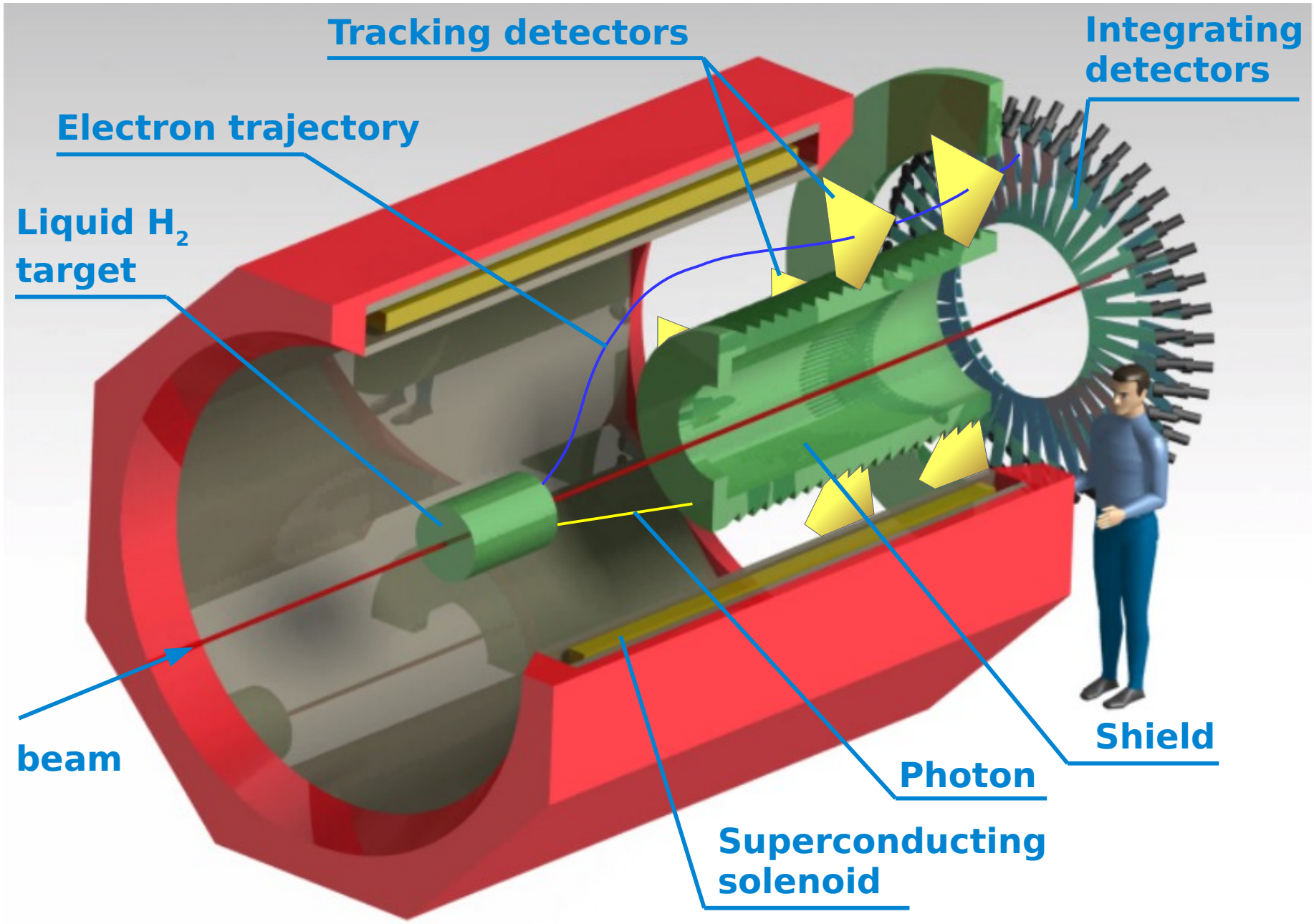
The setup


Tracking detectors
Integrating detectors
Electron trajectory
Liquid H_2 target
beam
Photon
Shield
Superconducting solenoid

Tracking techniques

Track following

construct seed, add hits one-by-one
e.g.: Kalman Filter

extreme occupancies
but only for small number of layers

Cellural automaton, Hopfield network

construct track segments, then combine them

many layers
but only moderate occupancies

Elastic net

fit track patterns to all hits simltaneously

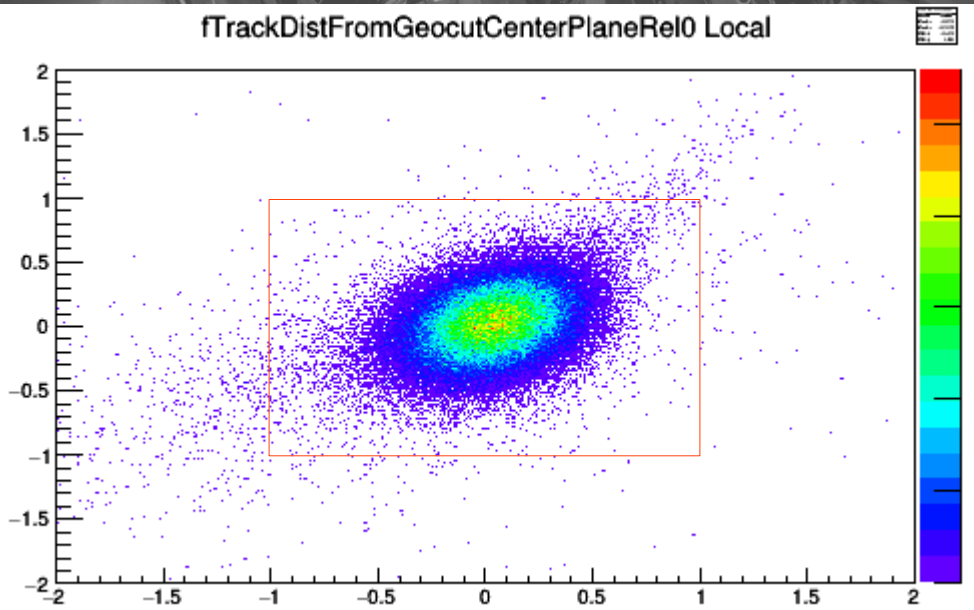
extreme occupancies
heavy computations
the more layers the better

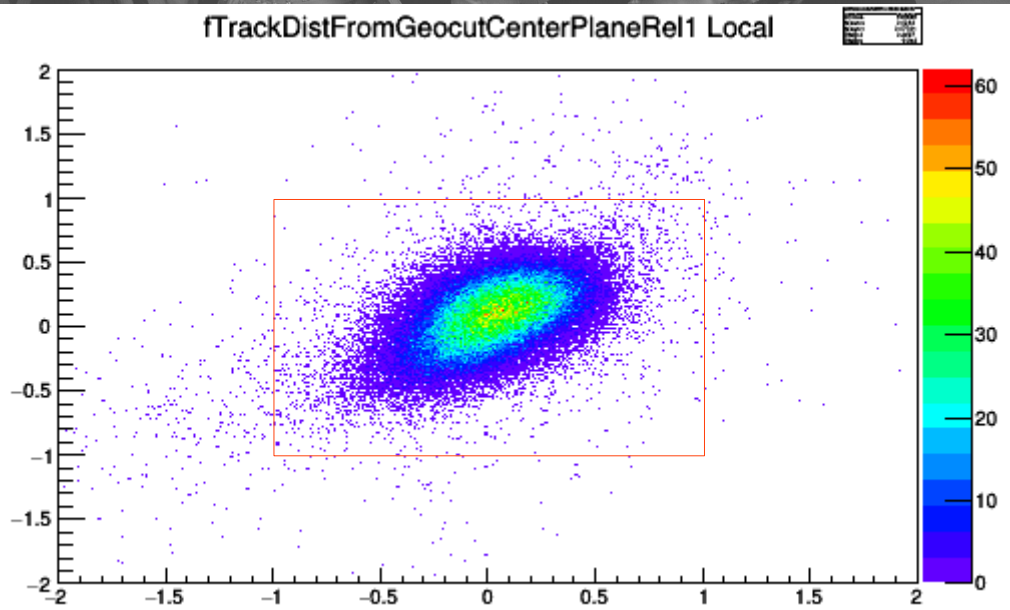
Hough transform, **Legendre transform**, **Conformal mapping**

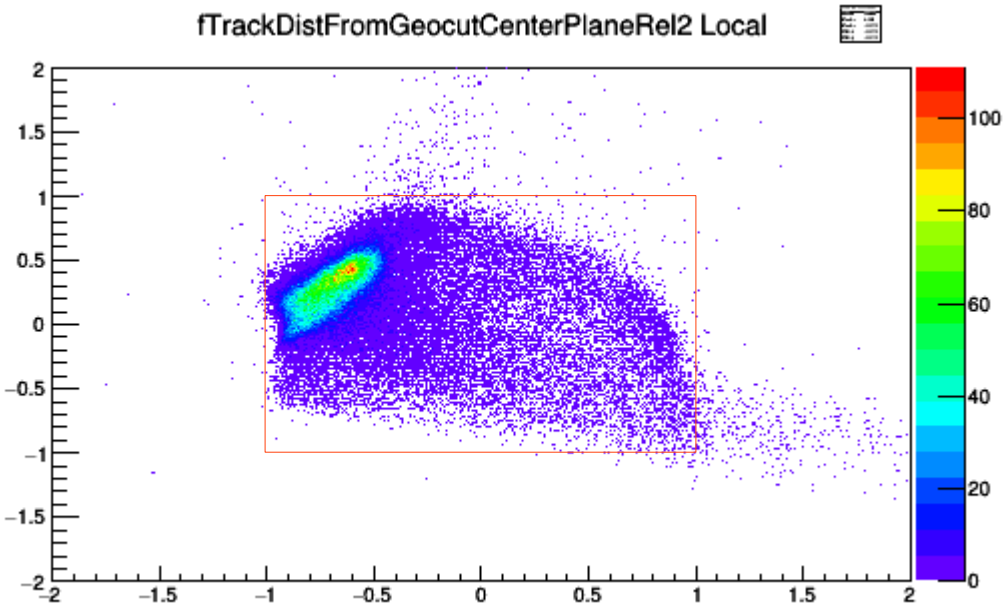
map hit positions into a space where true tracks make clusters

only with uniform B field
require many layers

How well do the parameterizations work?







Distance of track from the
center of the search window
over
the size of the search window

Tracking challenge

? background hits / plane

? signal tracks tracks

at full rate