Search for neutrino interactions in the SND@LHC emulsion target

Riunione Gruppo 1 - Napoli

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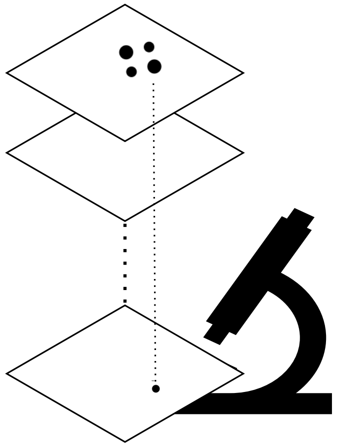
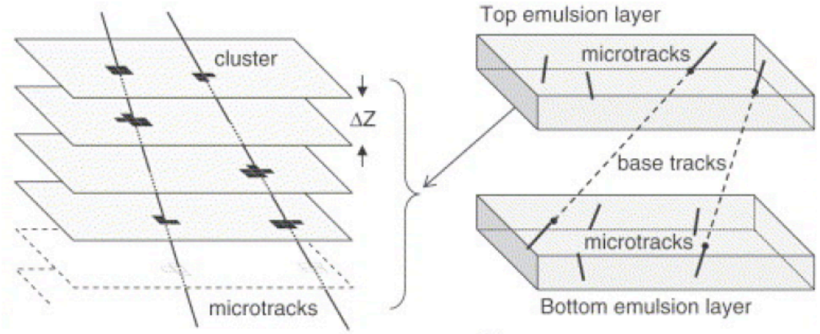
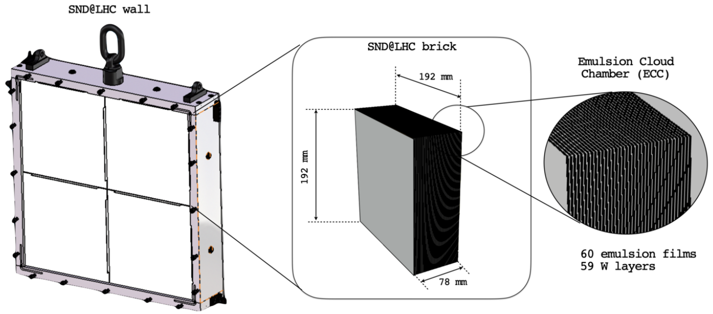
Emulsion Data reconstruction in SND@LHC

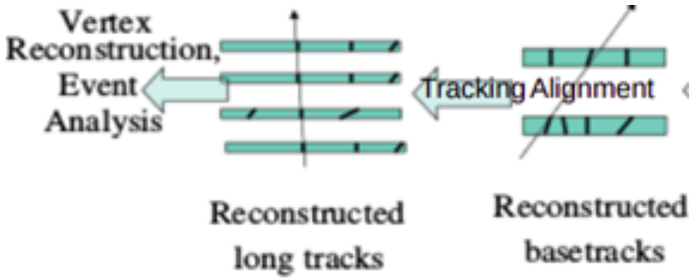
1. Emulsion films scanning (online cluster processing).
2. Correct microscope stage effects.
3. Link two layers of each emulsion film.
4. Align consecutive films.
5. Reconstruct tracks and vertices.

} **Local effects and corrections!**



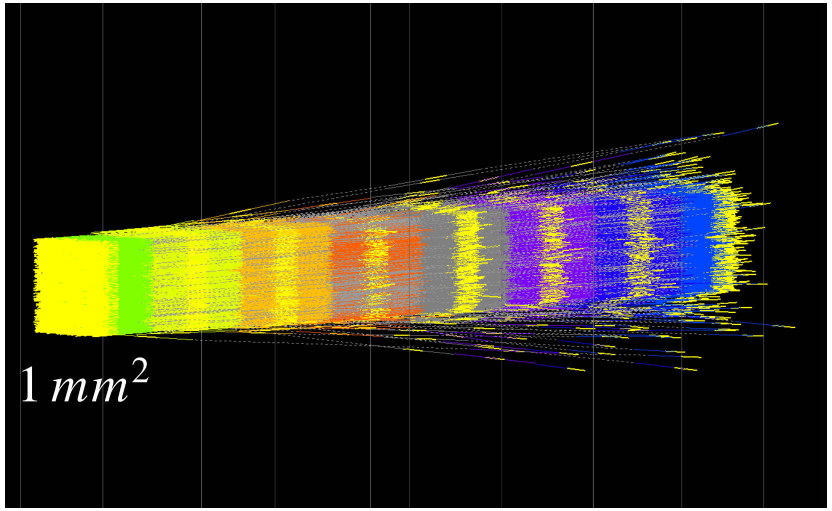


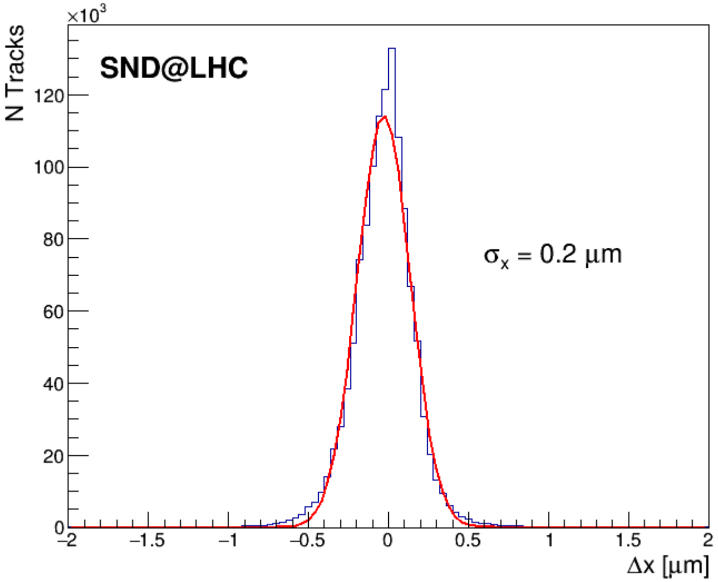


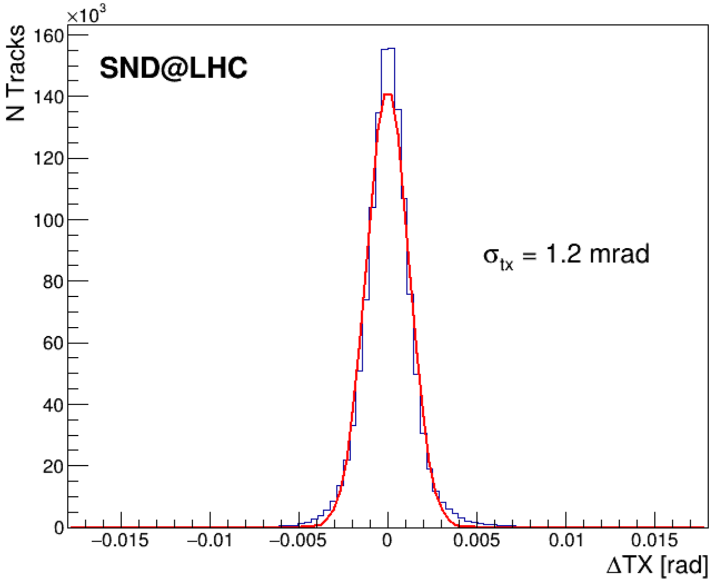


Track reconstruction

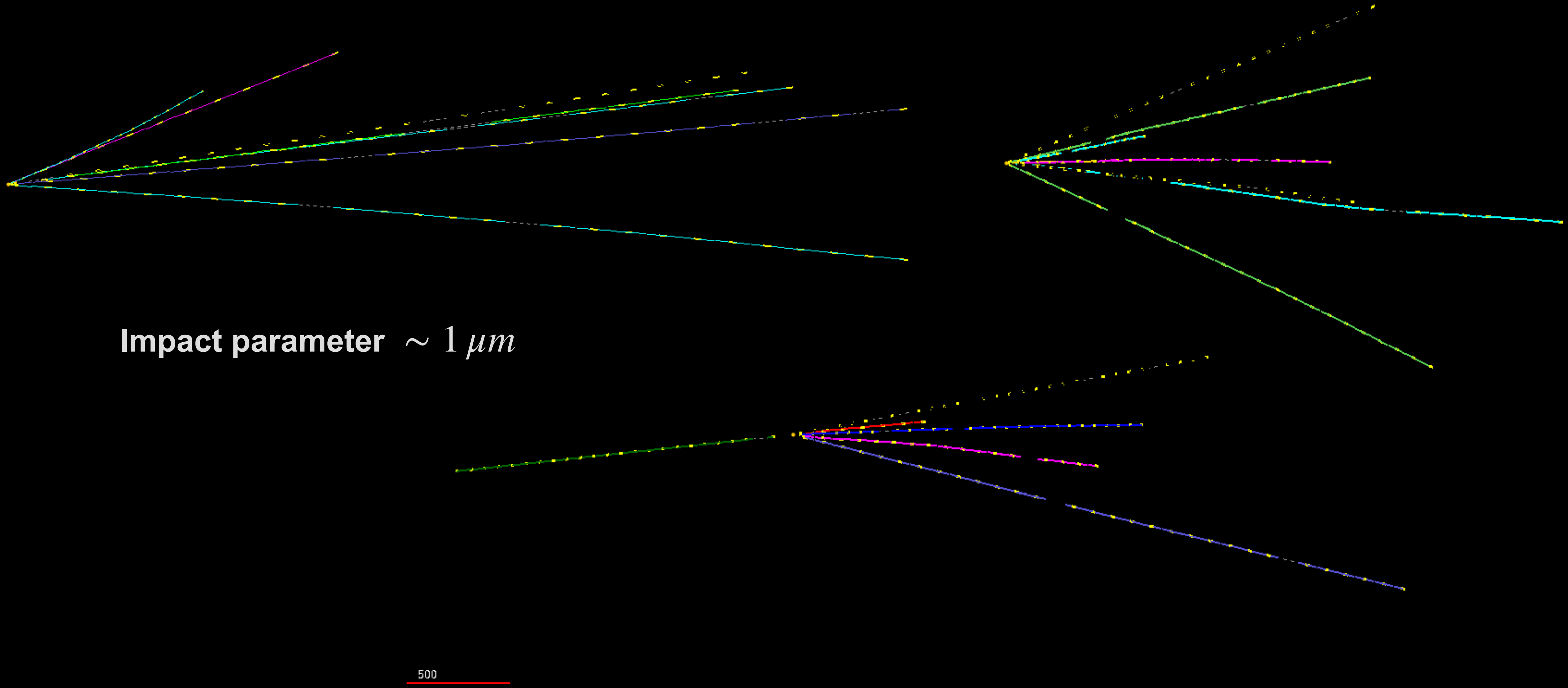
- **High track-density environment:** $2 \div 4 \times 10^5$ **tracks/cm².**
- **Long-track reconstruction efficiency** $\geqslant 90\,\%$ **.**
- **Position resolution of** $200\,nm$**. Angular resolution of** $1.2\,mrad$**.**





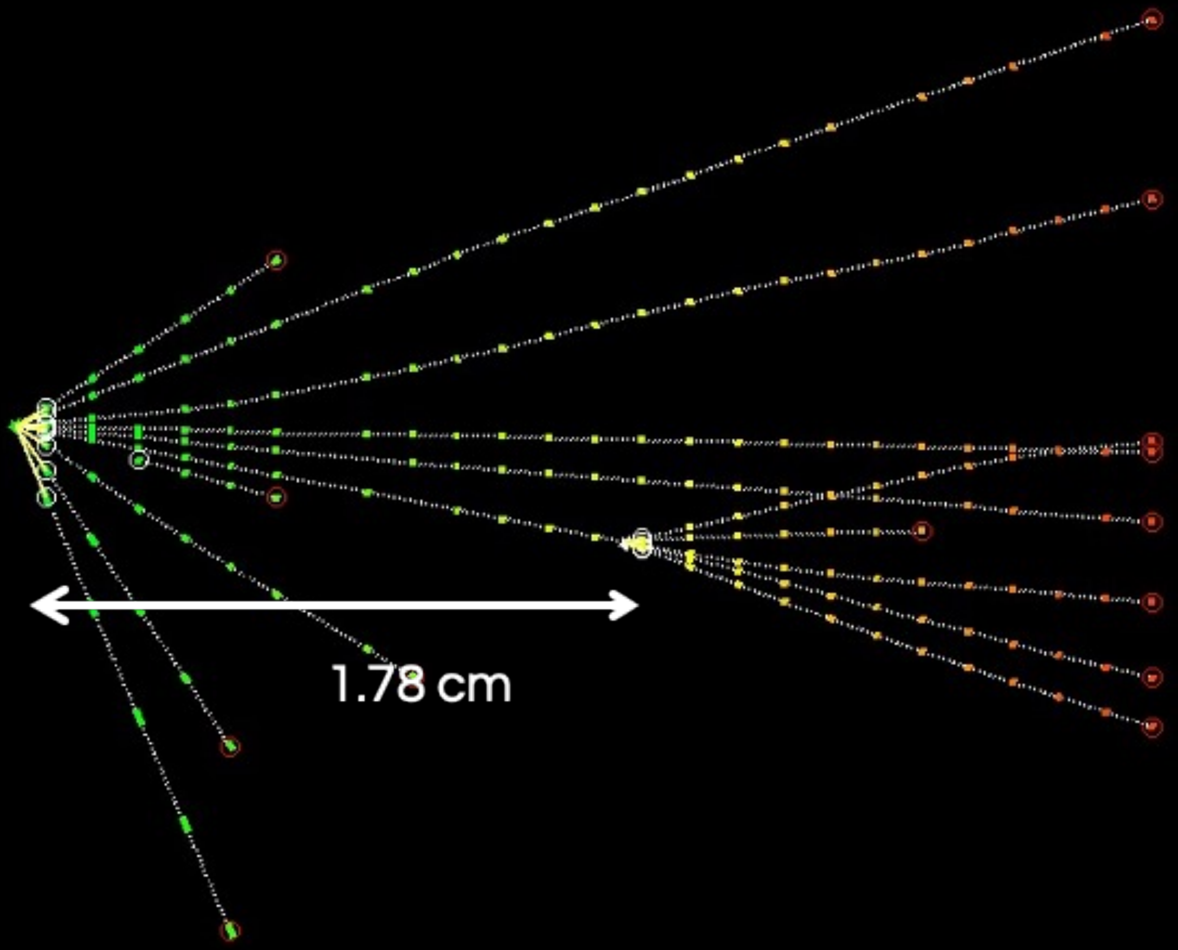


Vertex reconstruction



Impact parameter $\sim 1\,\mu m$

Interaction with secondary vertex



Sub-micron impact parameter of track at 1ry and 2ry vertices

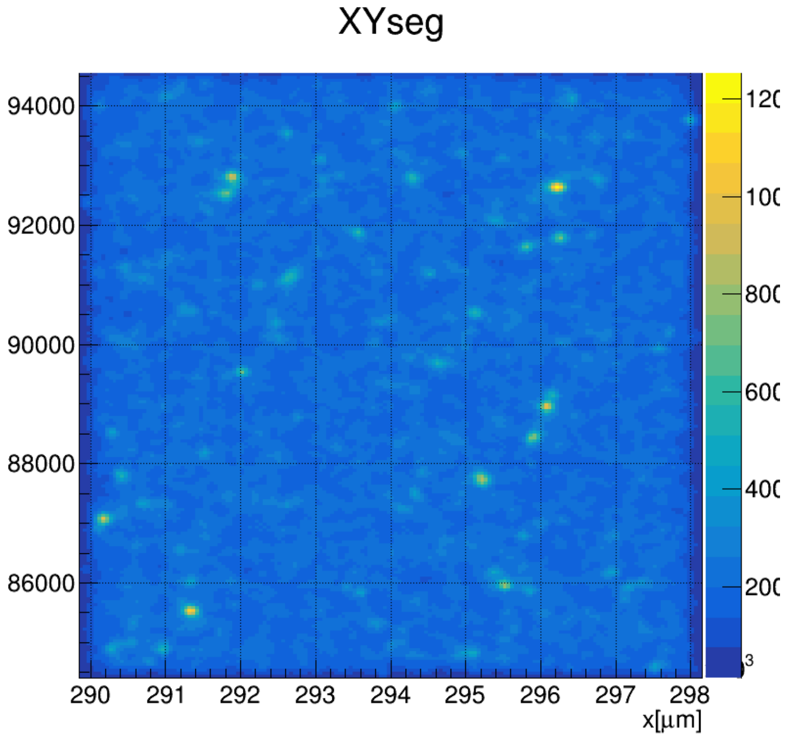
Primary vertex	Secondary Vertex
Impact parameters (μm)	
0.58	0.04
0.79	0.12
1.06	0.17
0.33	0.29
0.05	
0.46	
1.77	
1.00	
0.29	

Shower tagging

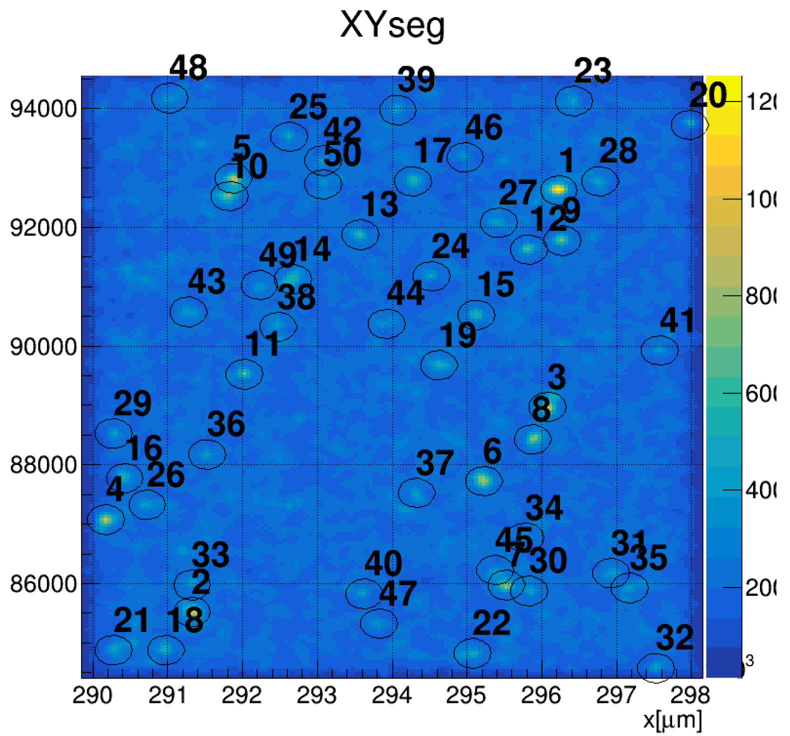
Find highest bins in the cumulative base-tracks distribution.

Bins are enhanced for 0 angle showers (muon bremsstrahlung).

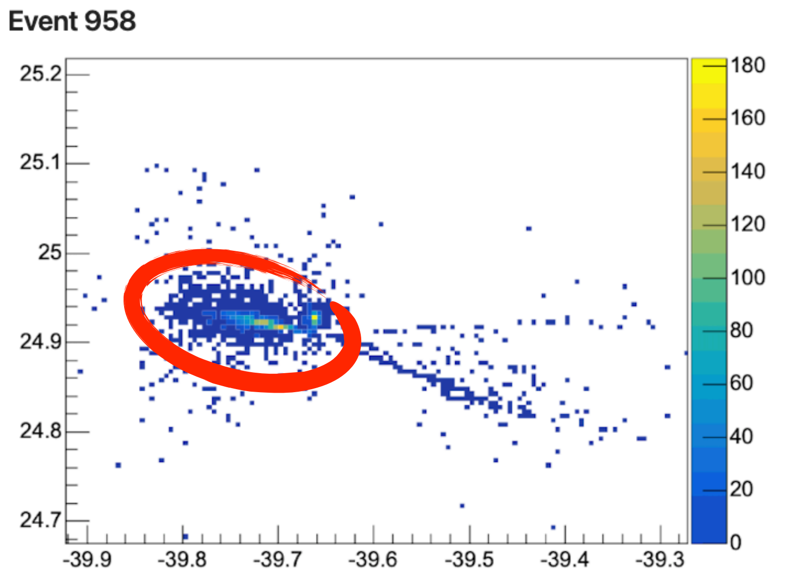
Cumulative base-tracks (Muon MC)



Tag (Muon MC)



High-Pt shower (Nue MC)

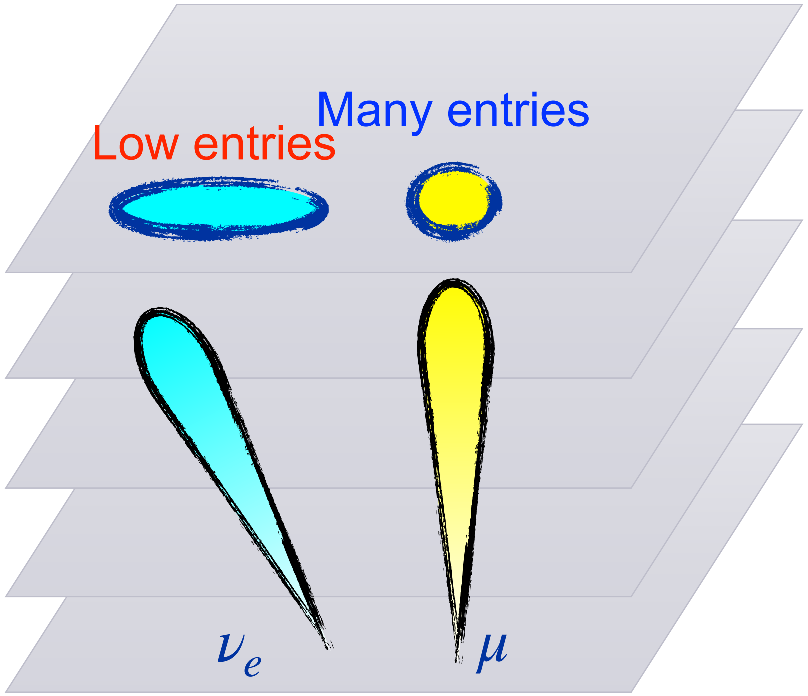


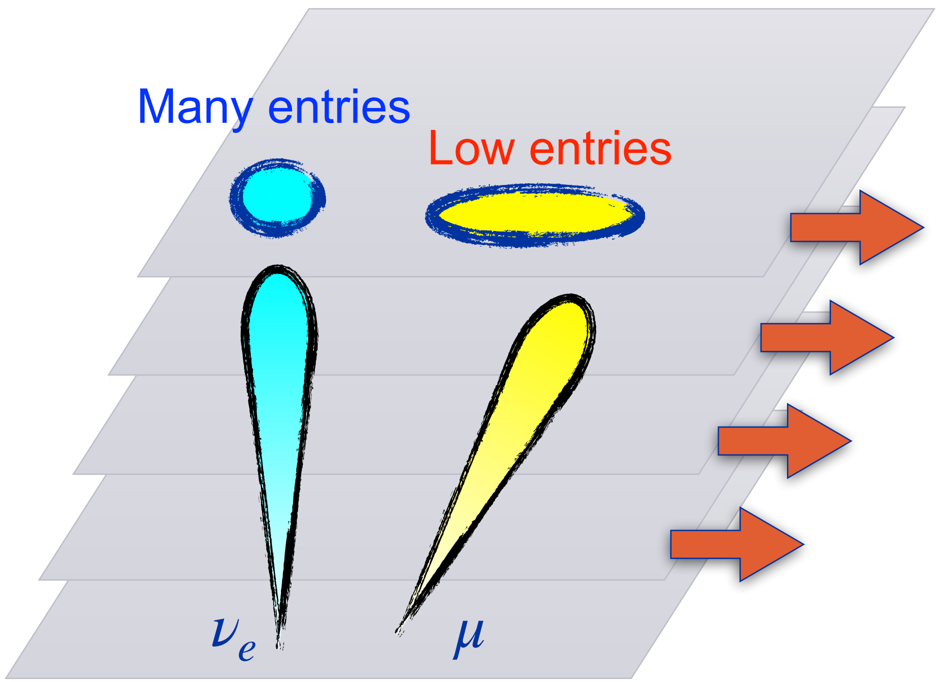
Shifting strategy

In order to find **(TX, TY) inclined shower**, shifts on x and y are applied on the emulsion plates.

SX(pl) = (1000+350) * pl * TX,   SY(pl) = (1000+350) * pl * TY.

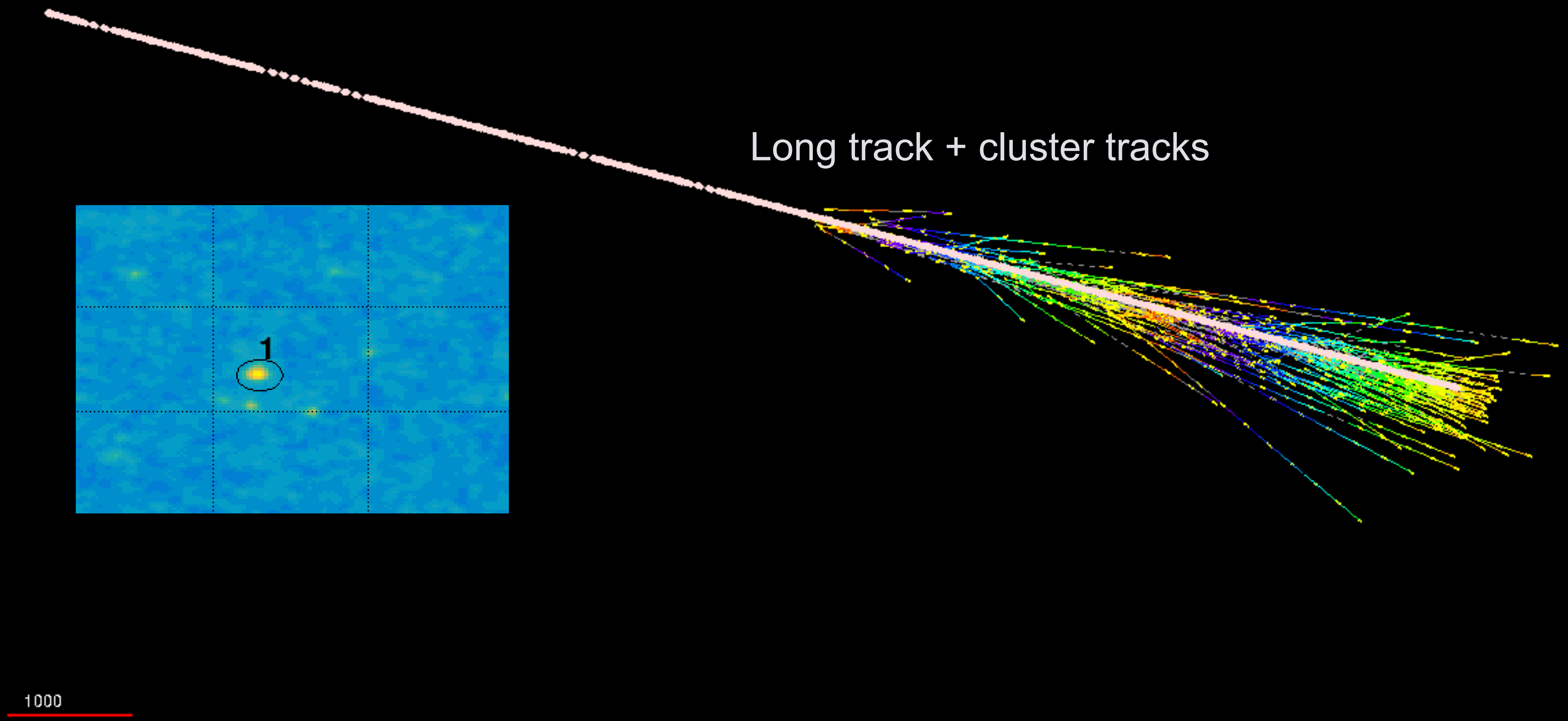
Loop over TX and TY for given step. Find highest peak at some TX and TY combination.





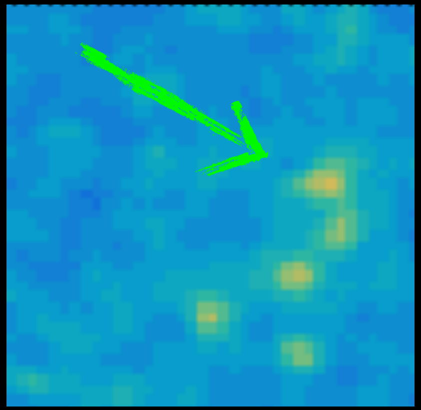
Tagged shower I

Shower tagged with low angle

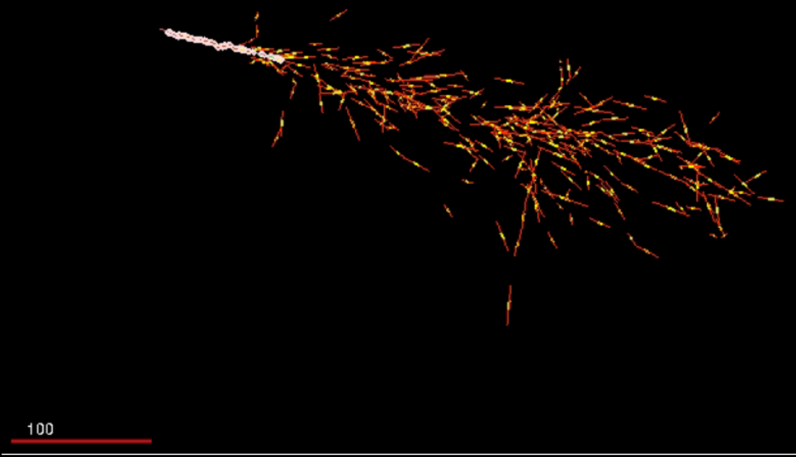


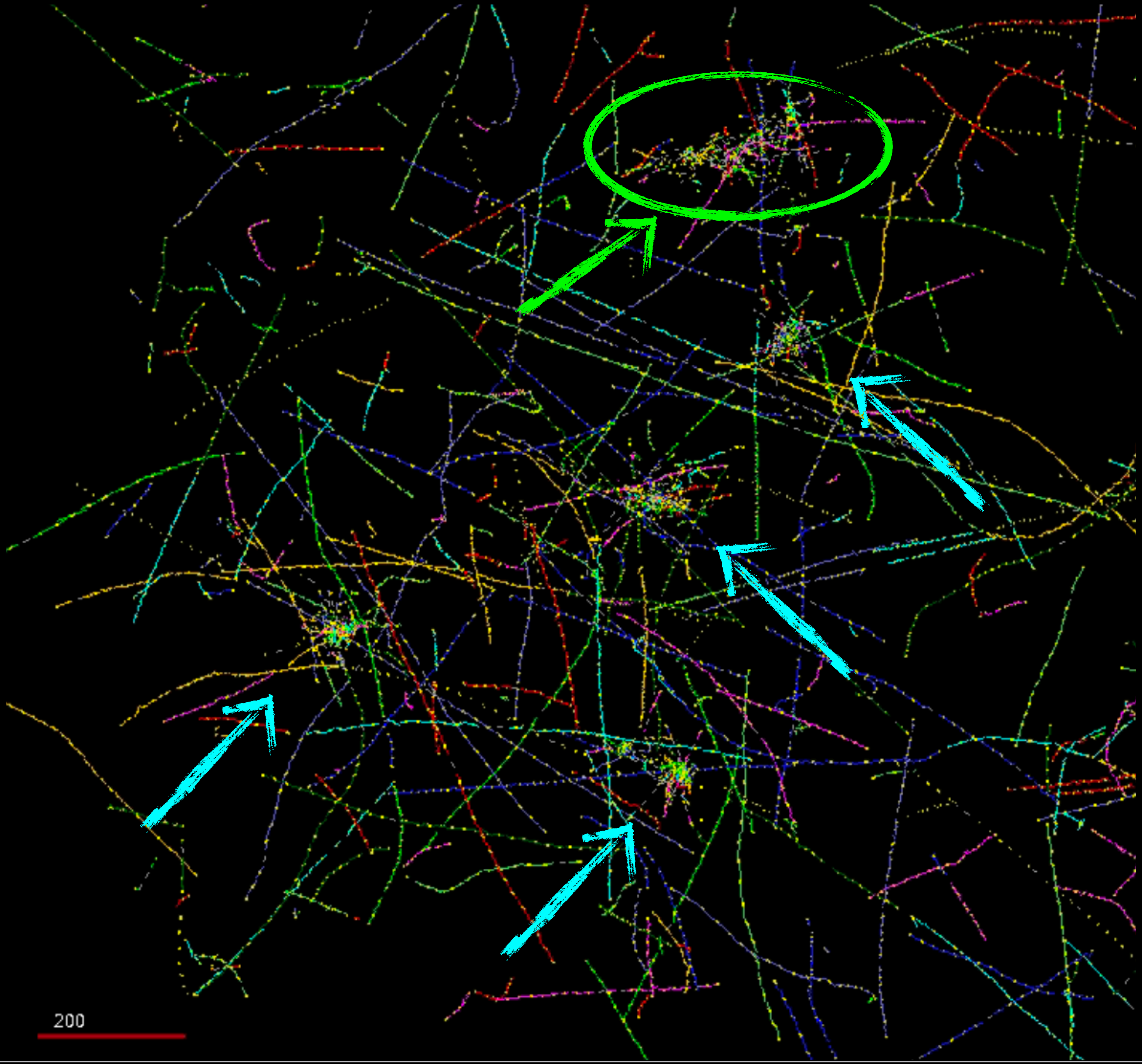
Tagged shower II

Shower tagged with 8 mrad



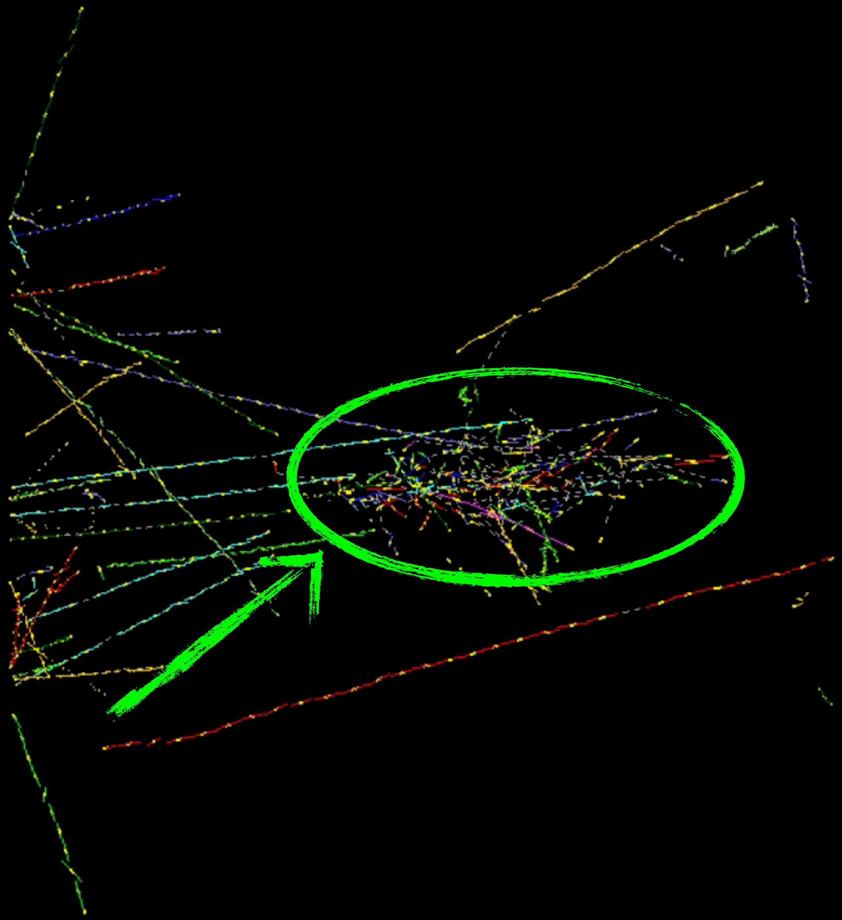
315 segments



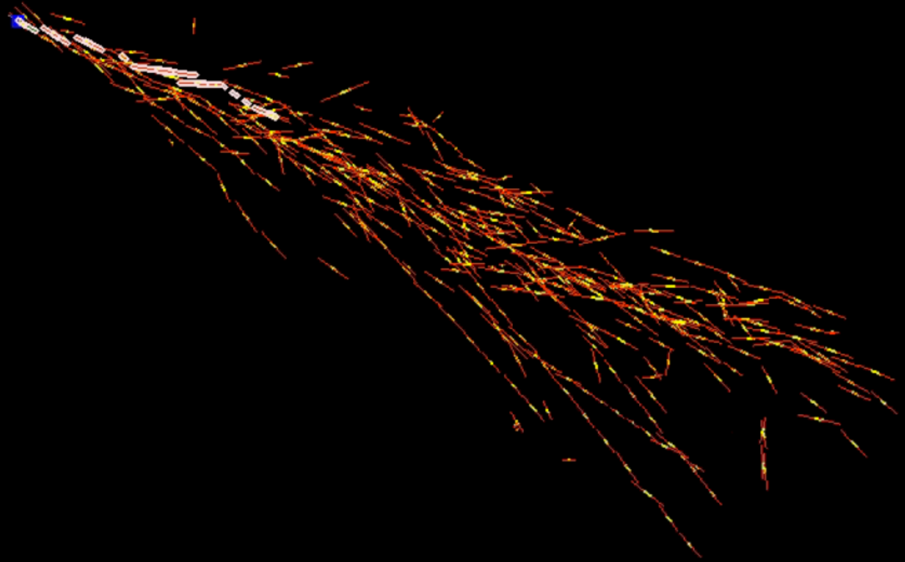


Tagged shower III

Shower tagged with 8 mrad



393 segments



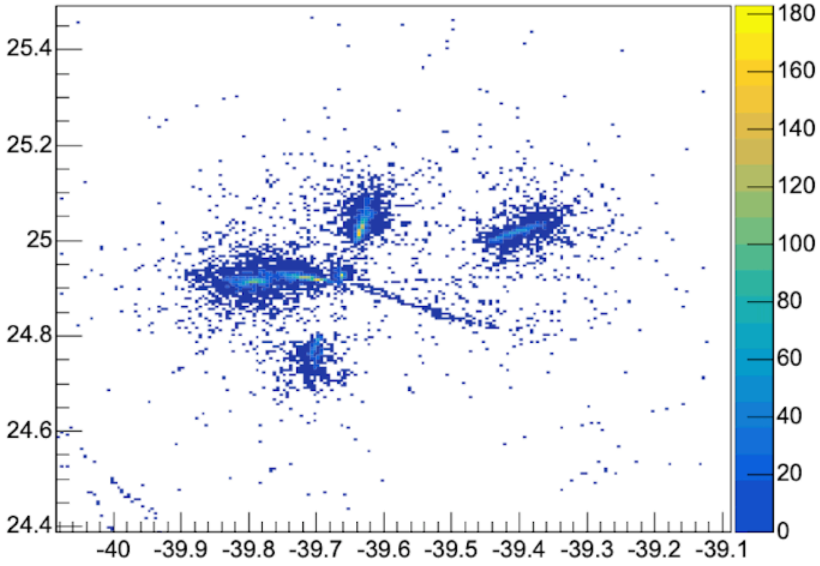
Conclusions and next step

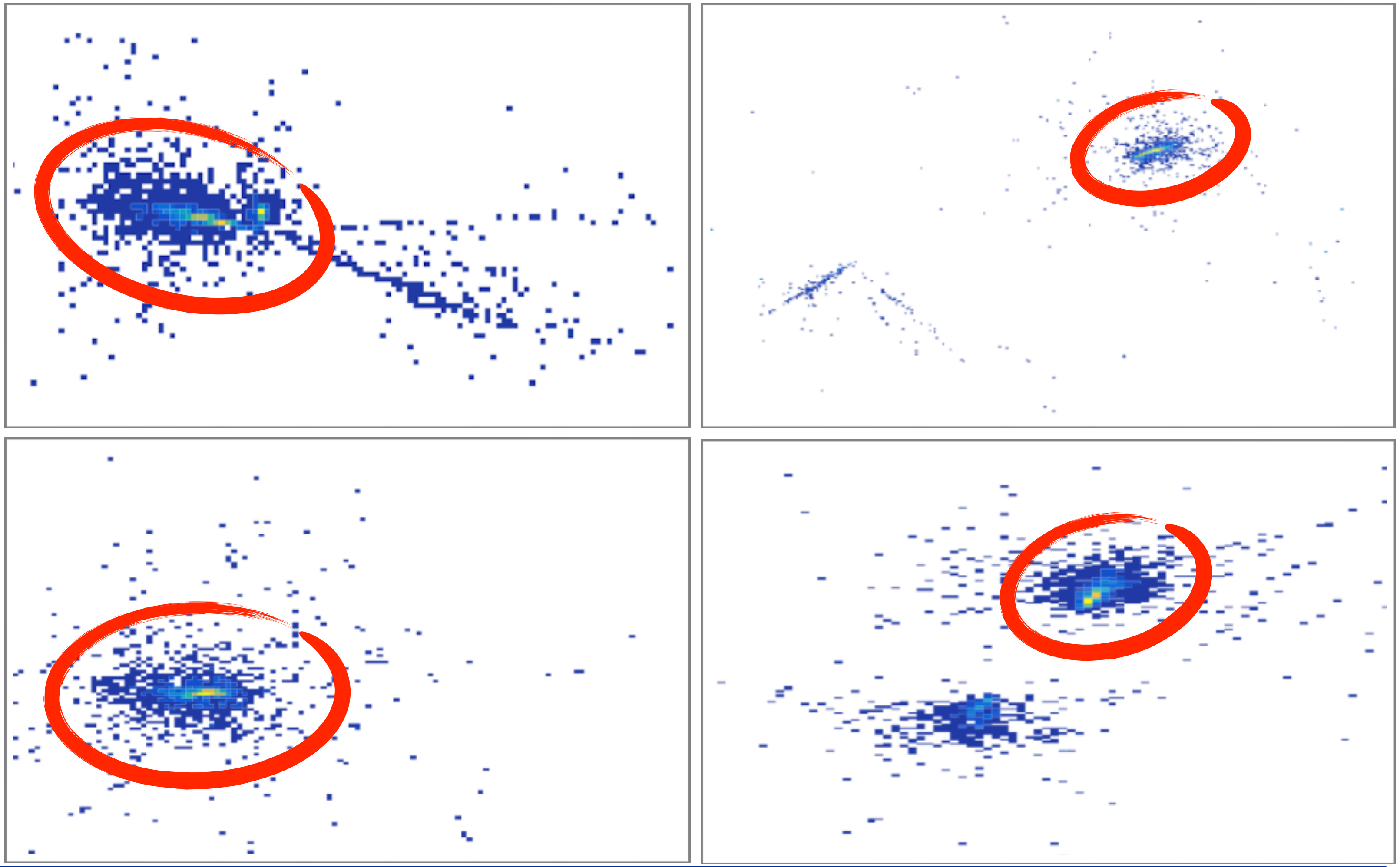
- ✓ High efficiency and resolution achieved in SND@LHC emulsion detector.
- ✓ Clean and genuine vertices reconstructed.
- ✓ Electromagnetic showers easily tagged exploiting the emulsion granularity.
- ✓ High-Pt shower tagging strategy proved to work.
- ◉ Grasp the ν_e showers distinguishing features from Monte Carlo simulations.
- ◉ Increase data reconstruction and shower-vertex hunting.

Back-up slides

Feasibility study

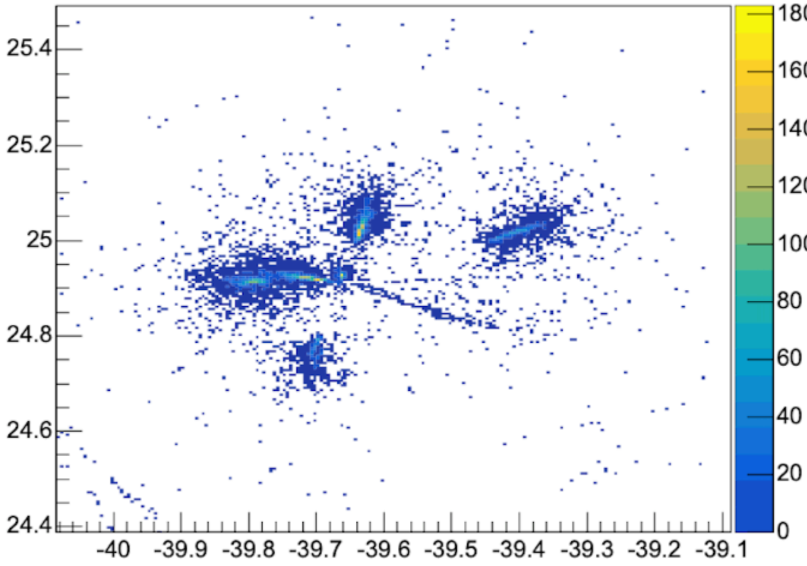
4 MC $\nu_e\,CC$ interactions (with different electron slope) in 1cm².

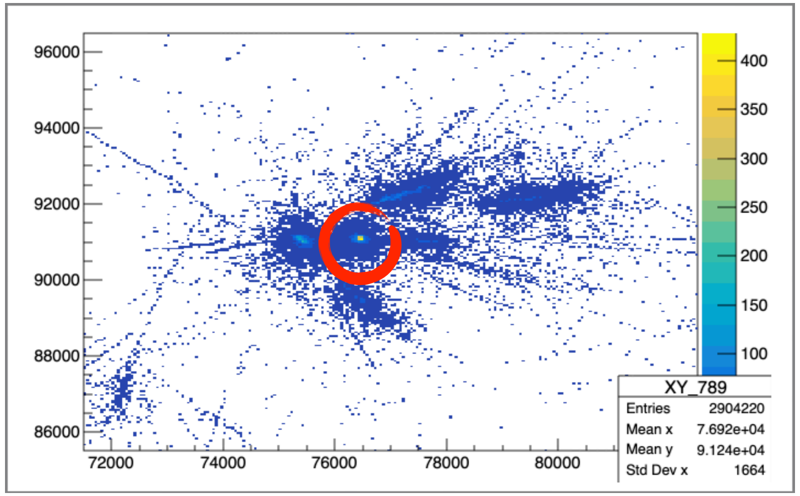


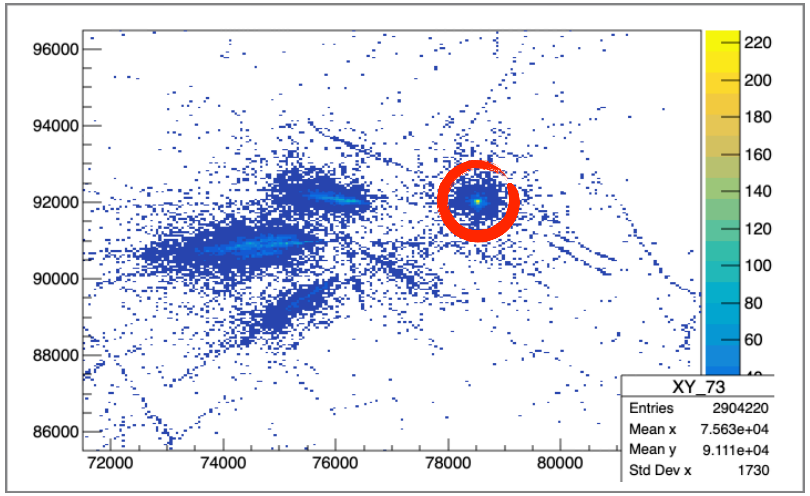


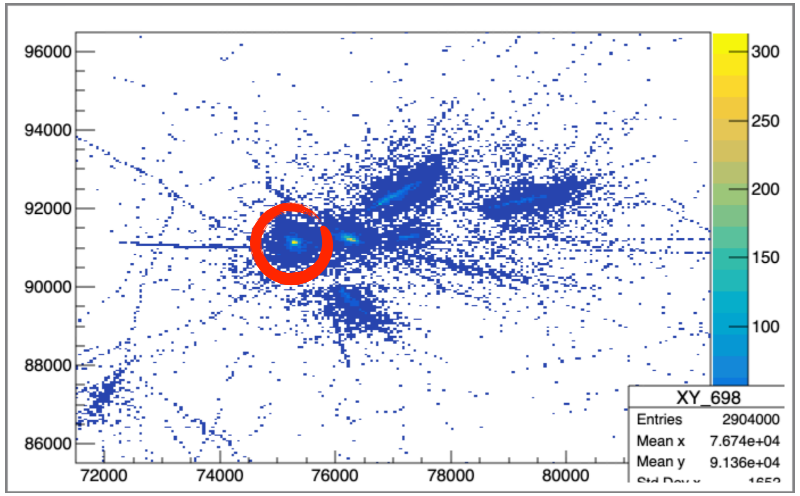
Applying manual shifts

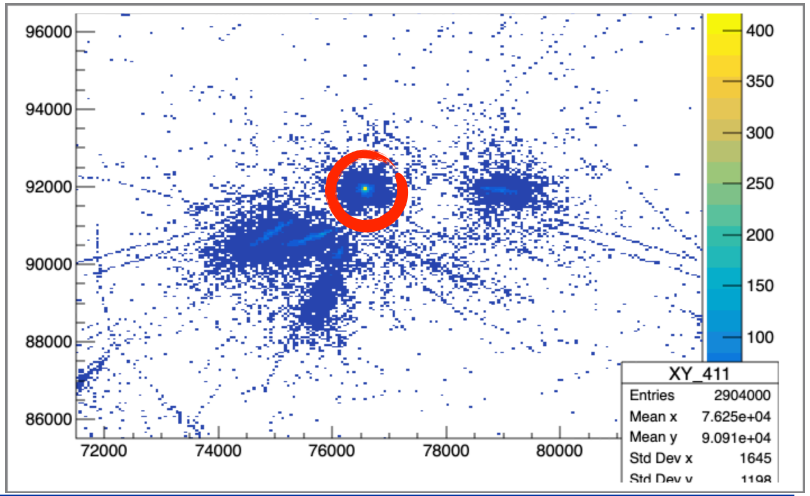
Tagged bin is enhanced, other showers are spread out.







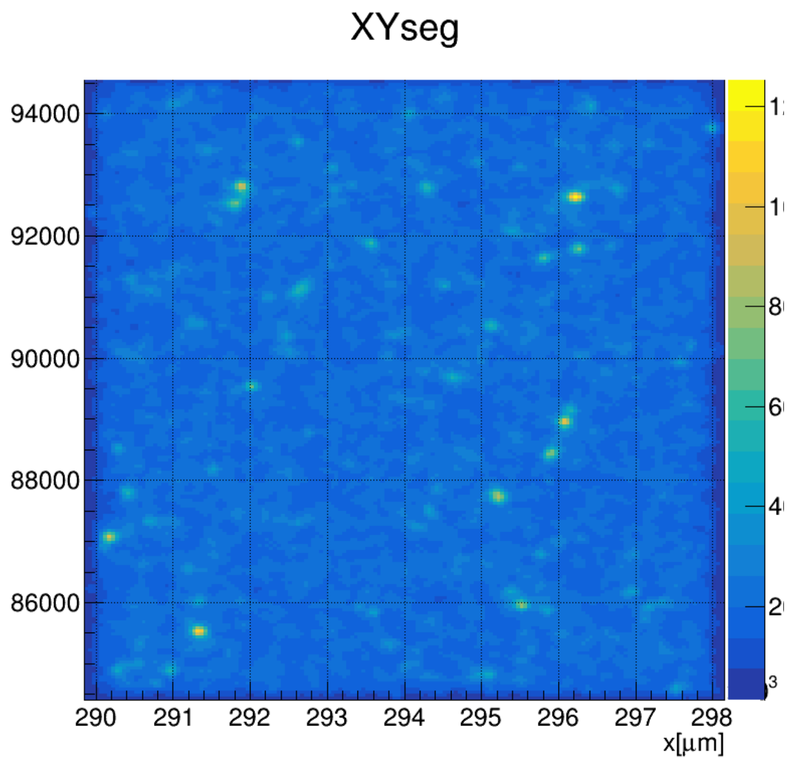




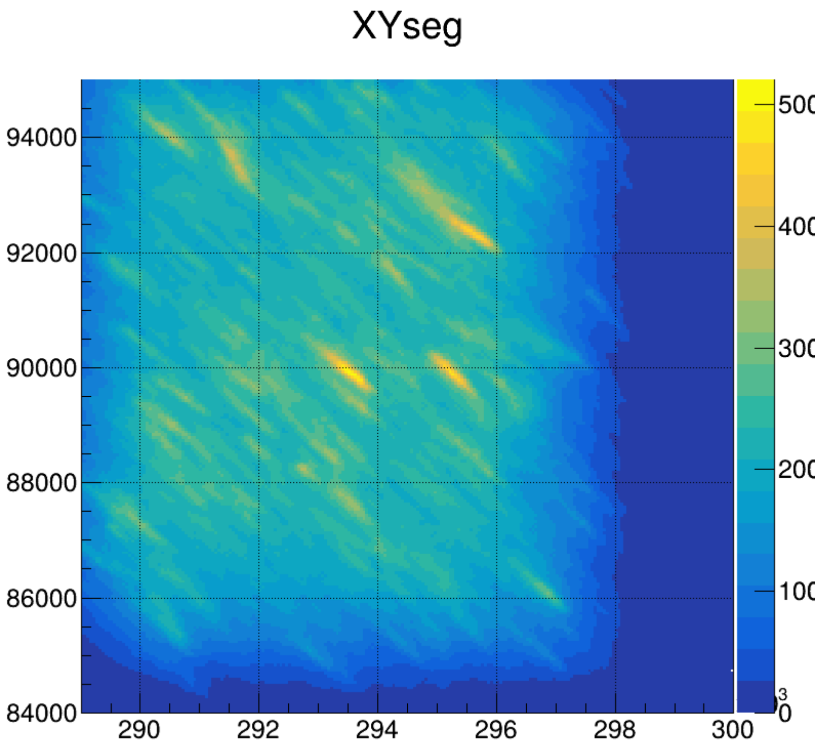
Muon MC shift

For every shifted cumulative plot, shower tagging is performed (one bin in the Tmap).

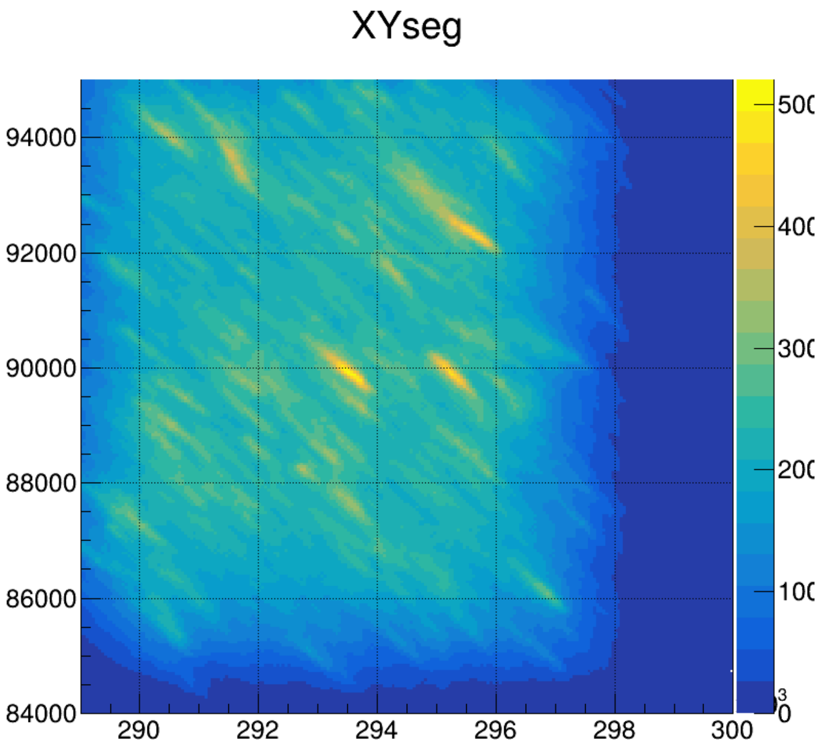
Original plot



(-22, 26) shift plot



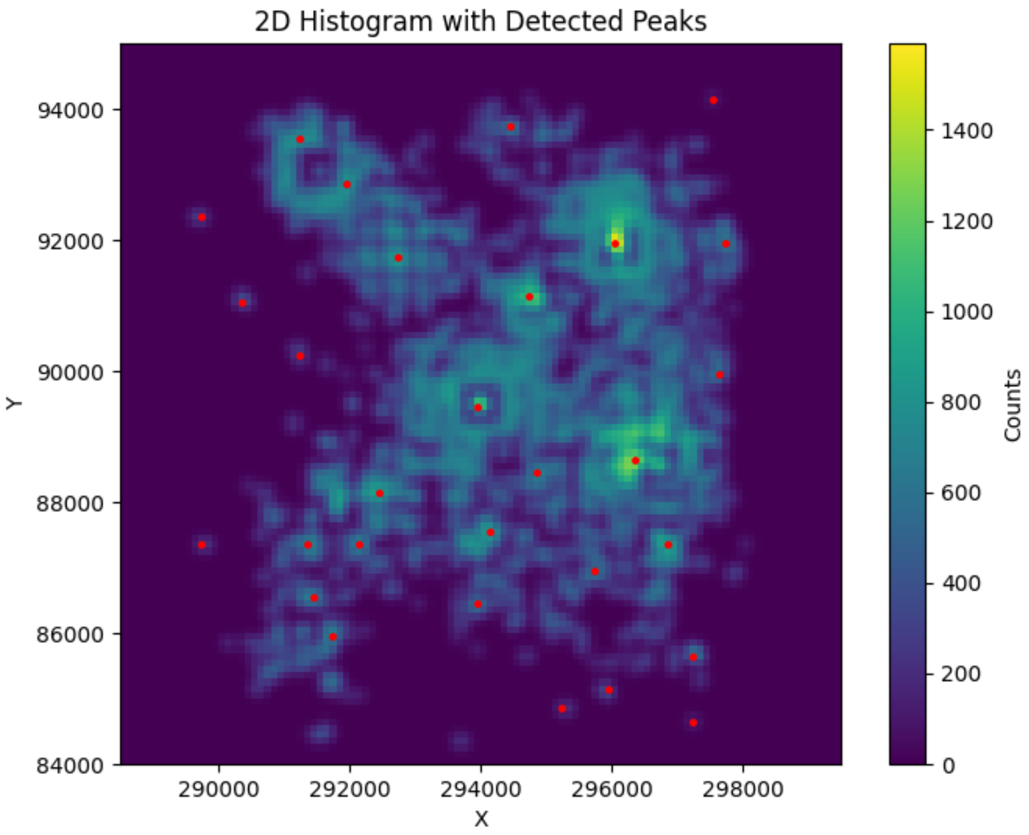
(-22, 26) shift plot



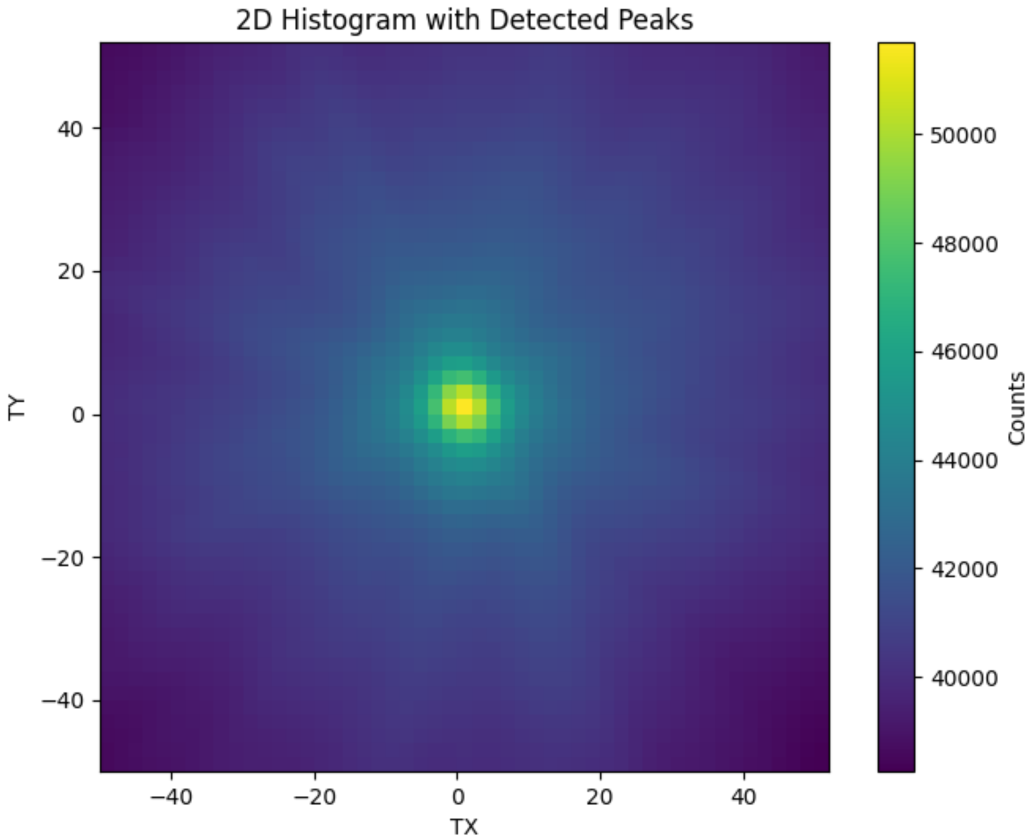
Muon simulation shift map

Computing all the TX, TY combinations. Z axis are the entries in the tagged bin.

X0, Y0 tagged showers



TX, TY tagged showers

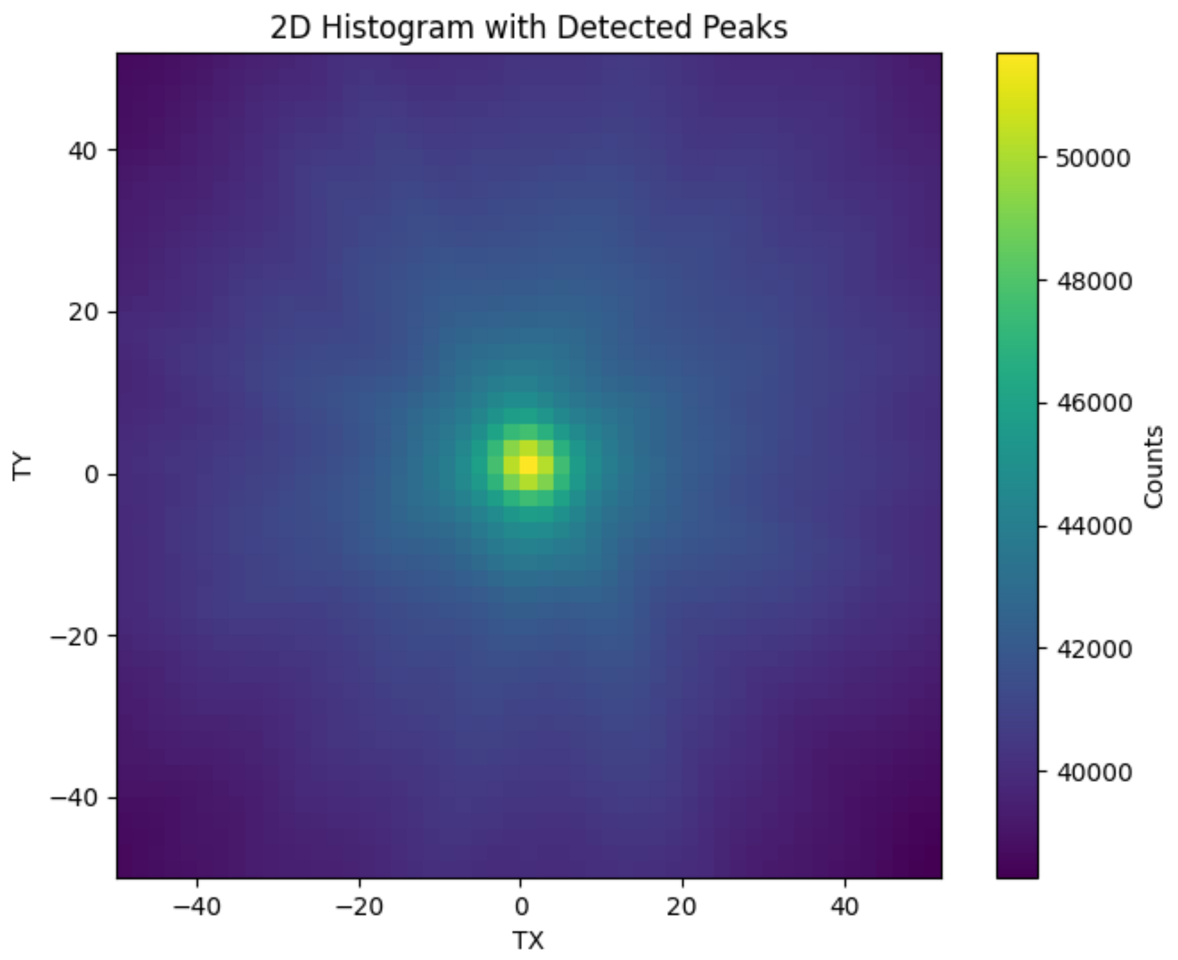


Background rejection

If we discard the combinations with ~0 shift

Primary electron slope from ν_e interactions:

Angle	% e
±2	94
±4	82
±6	72
±8	62
±10	55

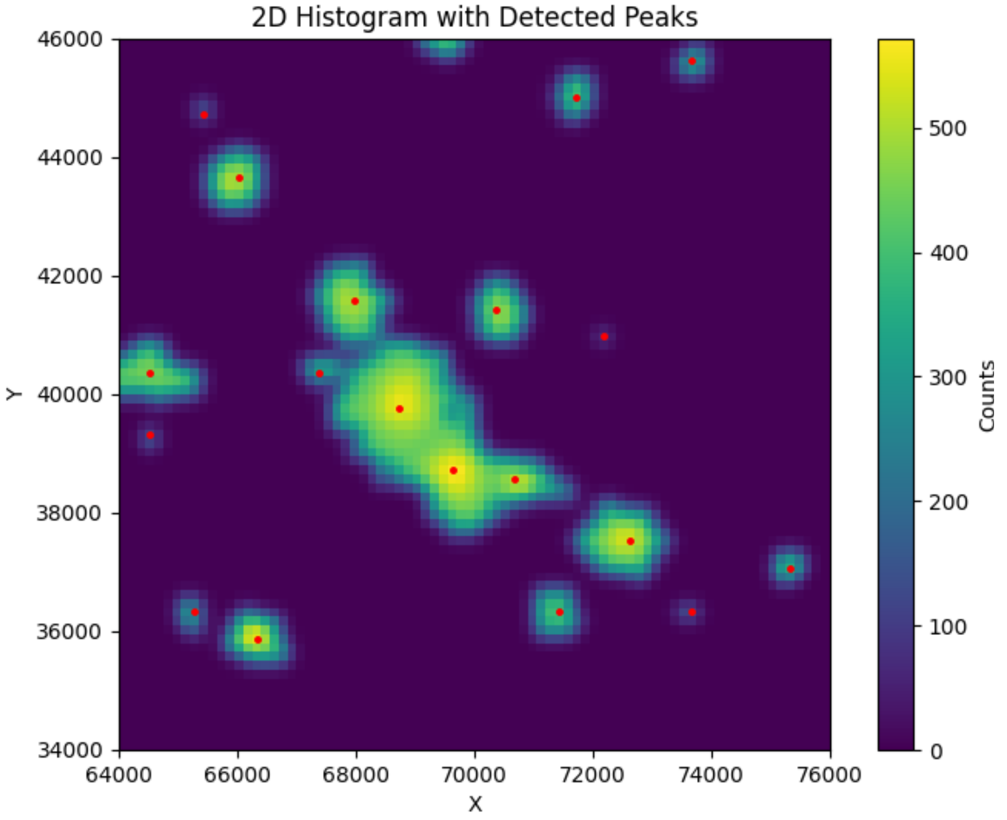


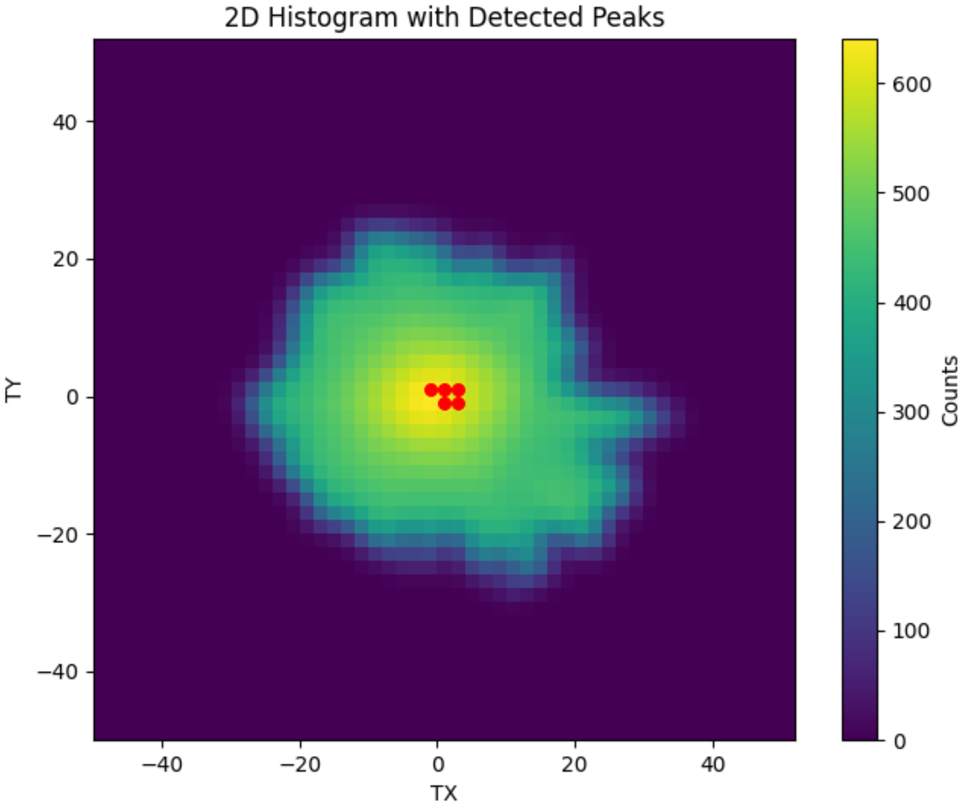
Data shift map

Peak finding is performed on the XY shift map after applying `scipy.ndimage.gaussian_filter`.

With `skimage.feature.peak_local_max` the TX TY that maximized the XY peak is found.

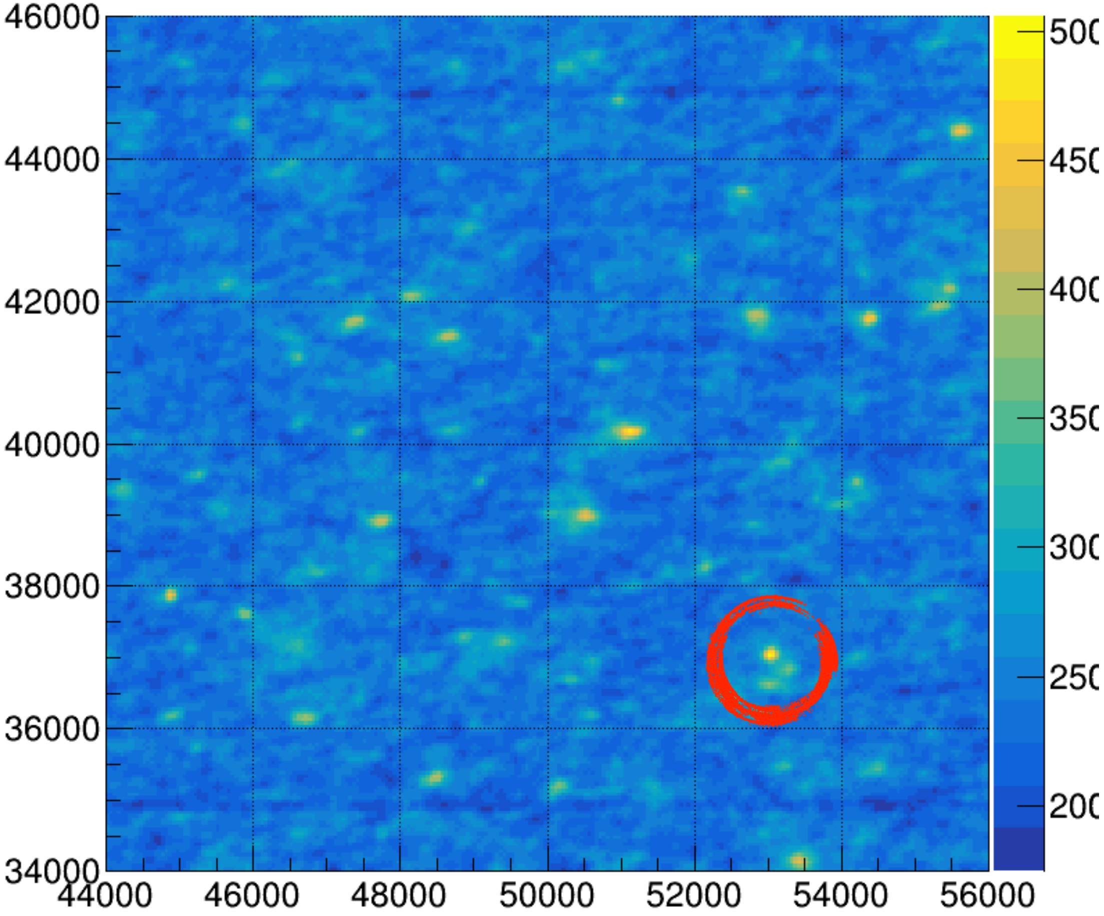
34 cm^2 of RUN1 W2 B1 analyzed



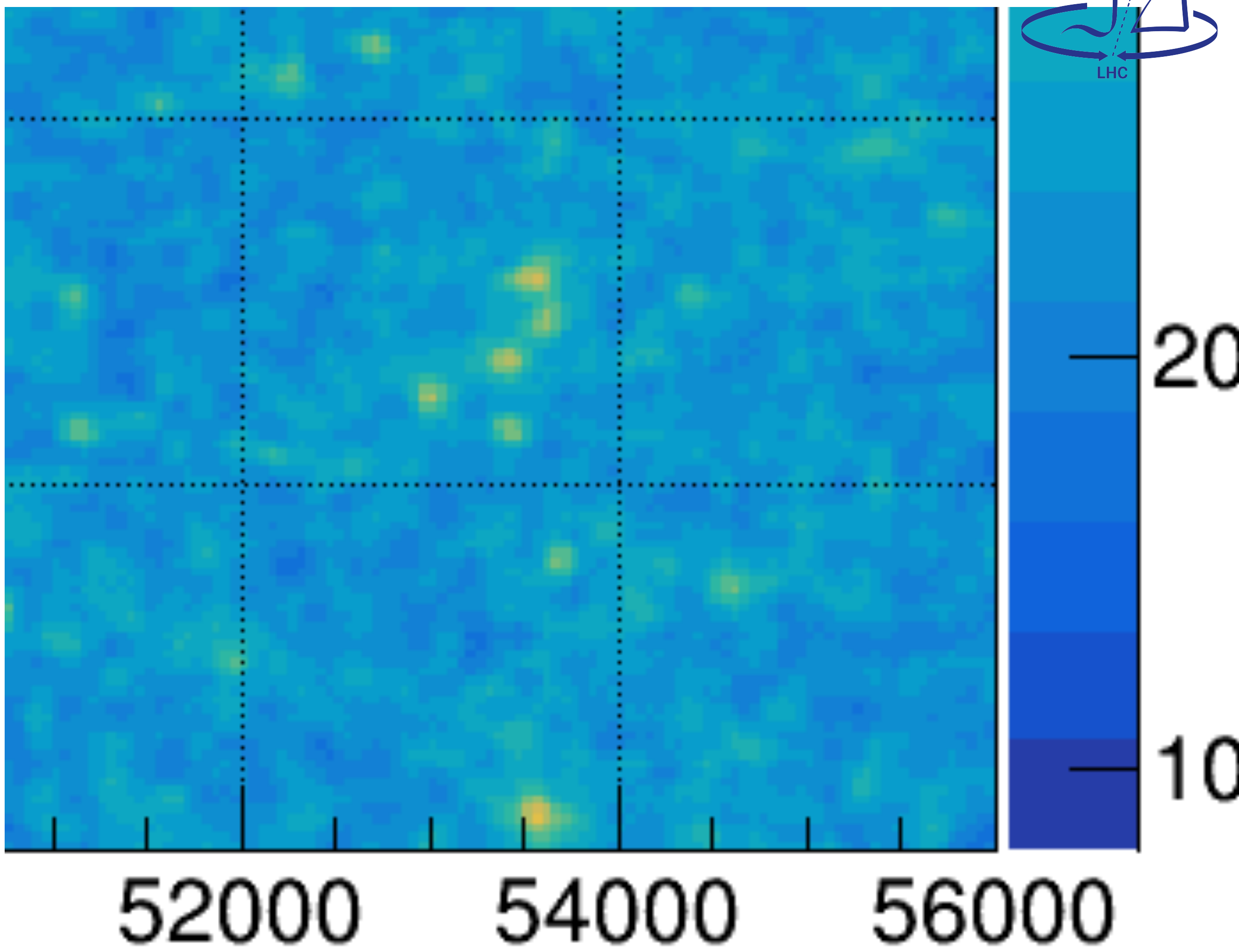


Candidate I

Shifted plot



Original plot



Neutrino expectations

- Data considered is from emulsion run1 wall 2 brick 1
- Exposure of 9.5 fb^{-1}, closest brick to beam axis
- Neutrino interactions expected in this brick:

ν	$\nu_e\ CC$	$\nu_\mu\ CC$
4.3	0.7	2.6

Peaks found

Angle	#peaks	True showers
> ±10	17	0
±10	5	1
±8	16	8
	38	9

(TX, TY):

(-10, 0),

(-8, 0),

(-8, 0),

(-8, -2),

(-8, 0),

(-8, 0),

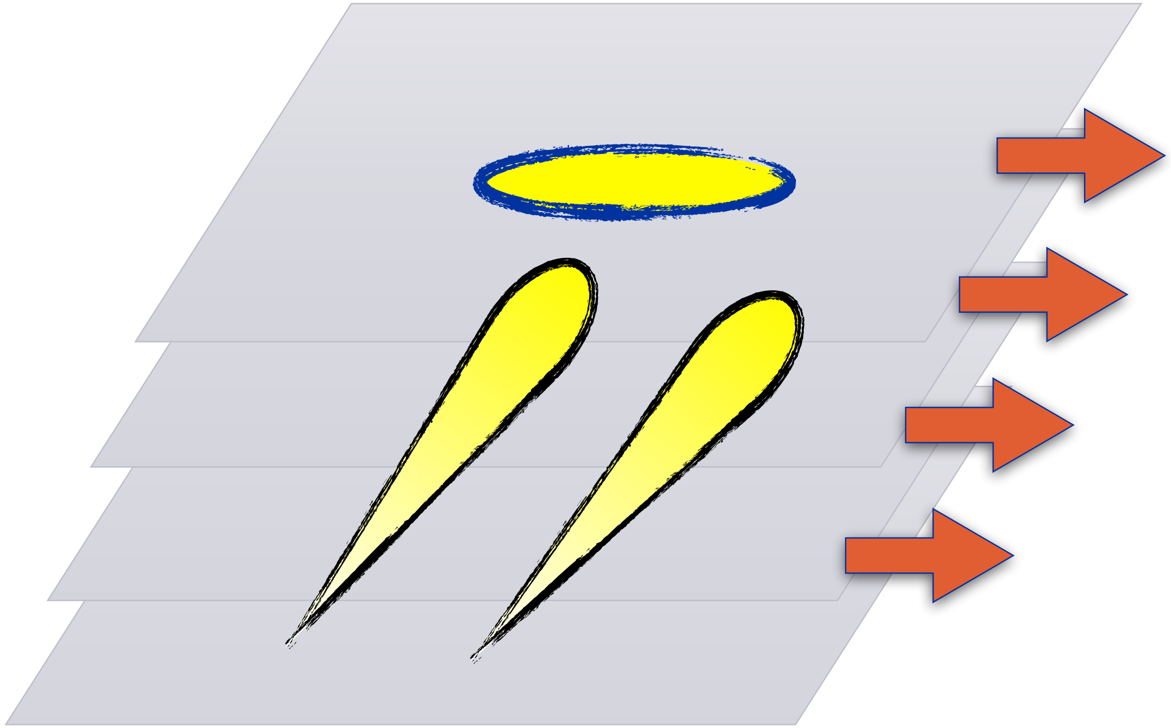
(-8, 0),

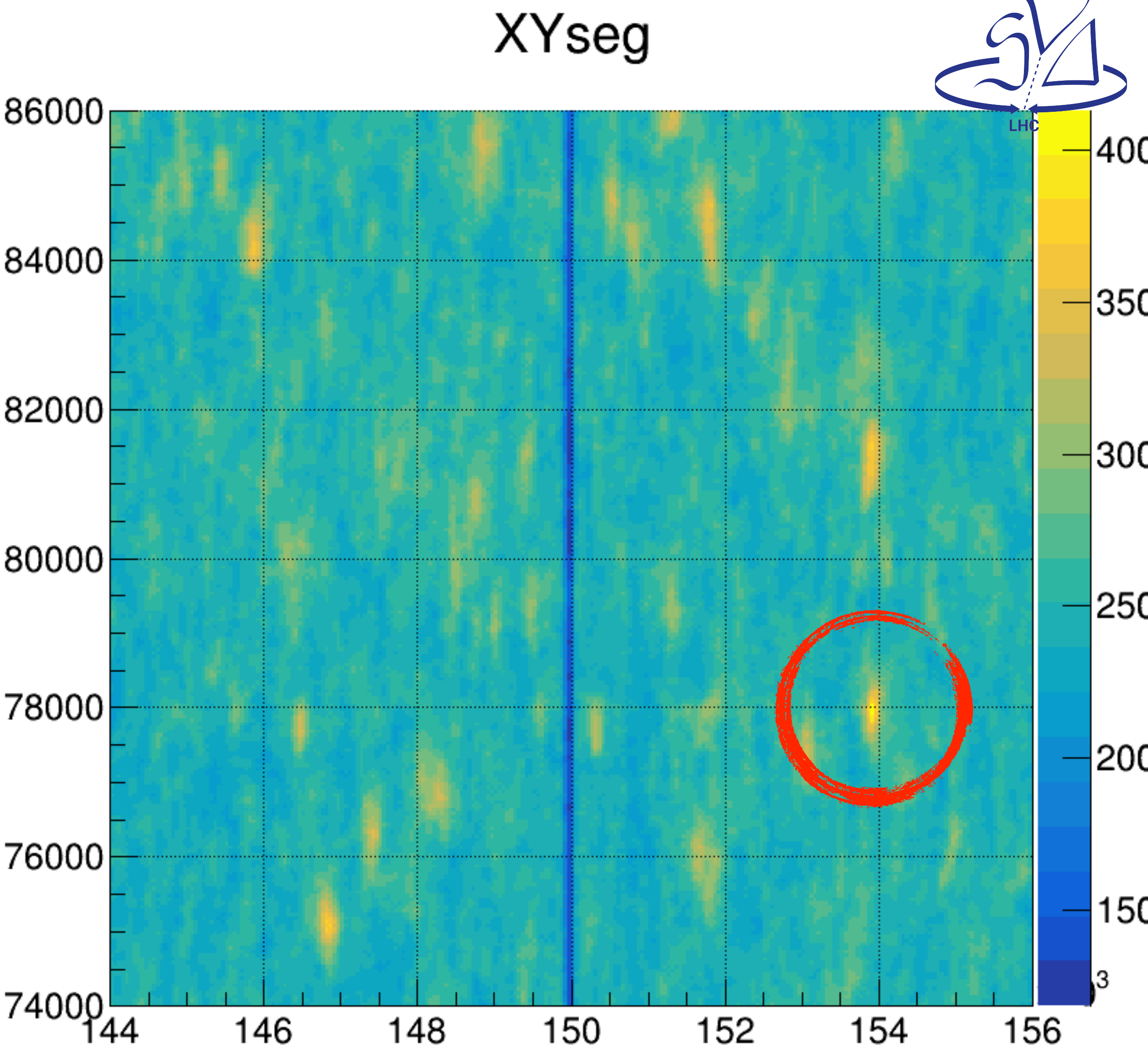
(-8, 0),

(-8, -2)

Pathologic peaks I

Multiple zero angle showers crossing the same tagged circle.

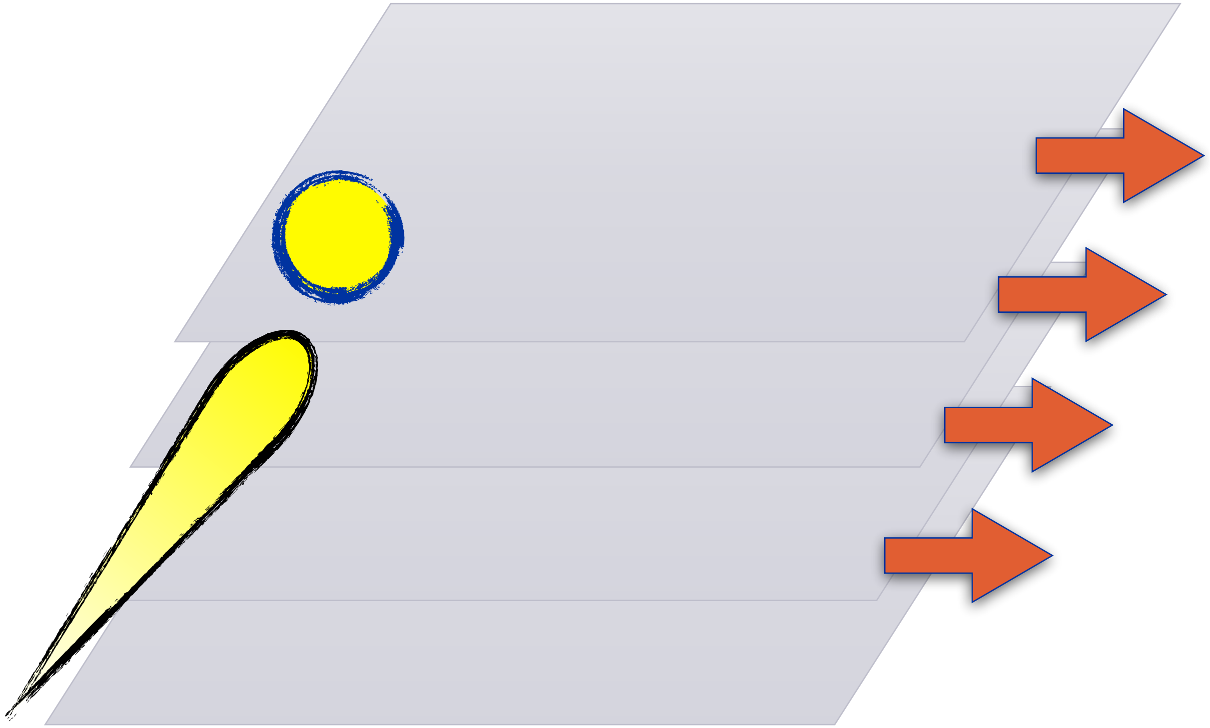


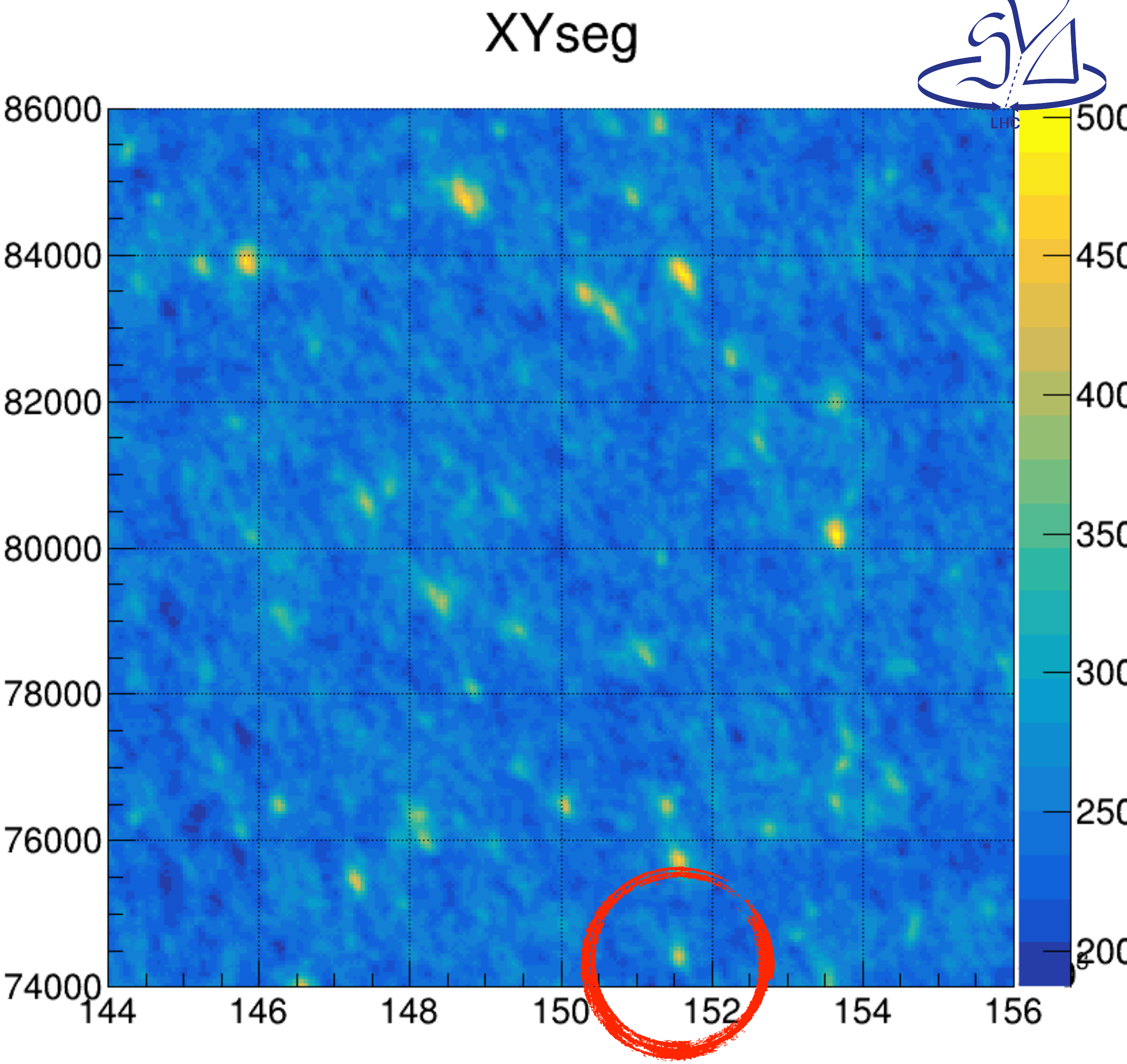


Pathologic peaks II

Zero angle shower entering from the side.

Extra peak, not tagged in (0, 0) shift.





Longitudinal profile

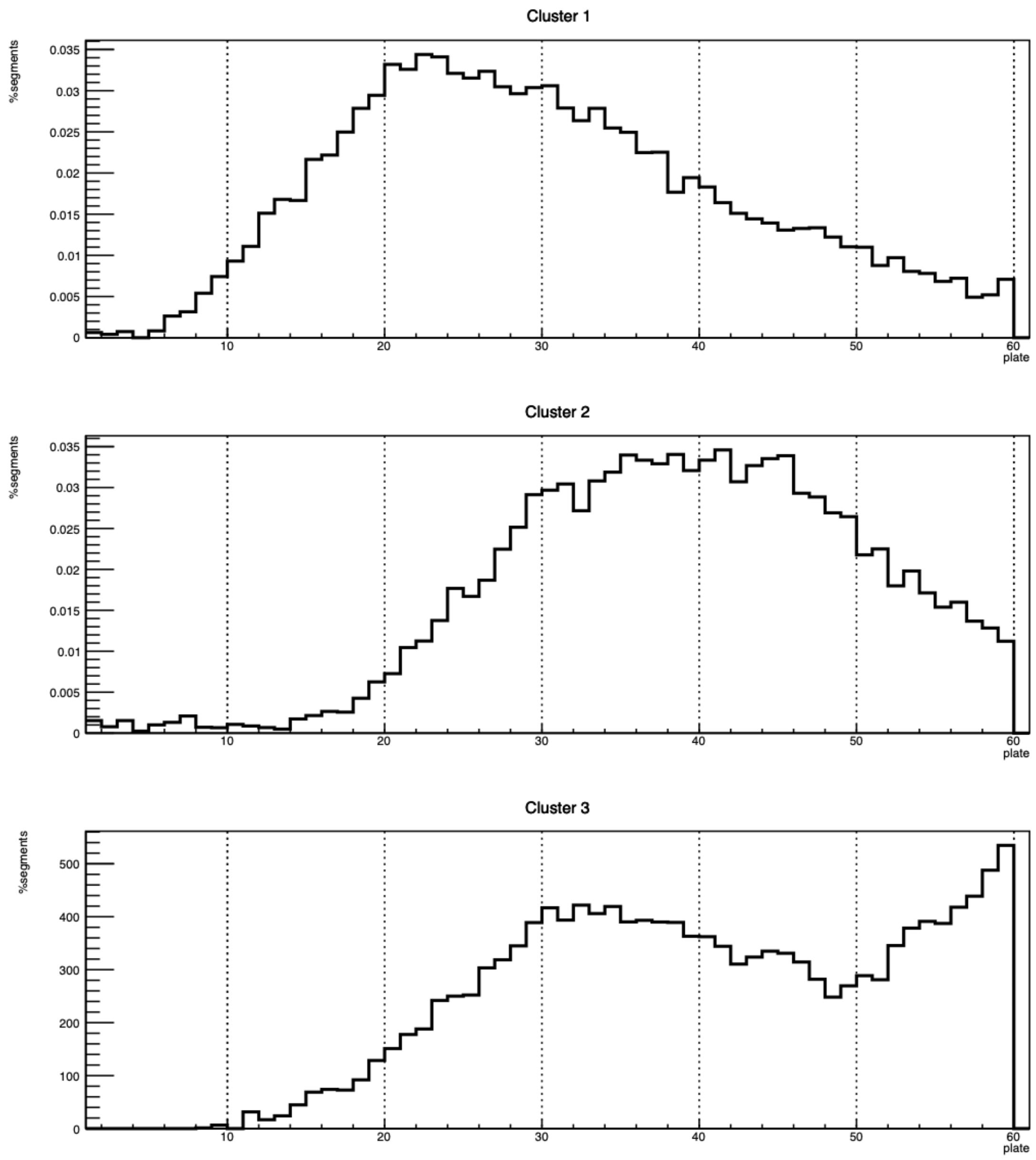
Position, maximum plate, starting and ending plate, nseg are saved

Background subtraction is considered

First and Last bin above 10% of total segments

3rd stage: base-tracks in 300μm tagged cylinders are analyzed

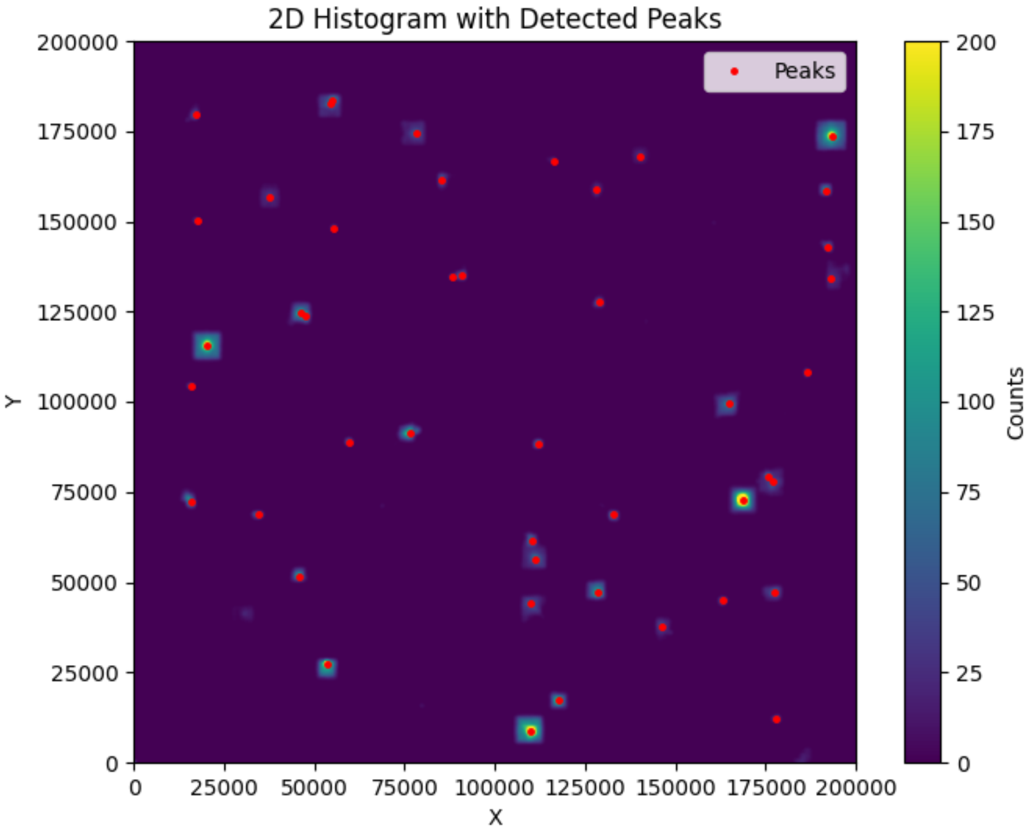
Some variables can be evaluated and studied for signal, background and data



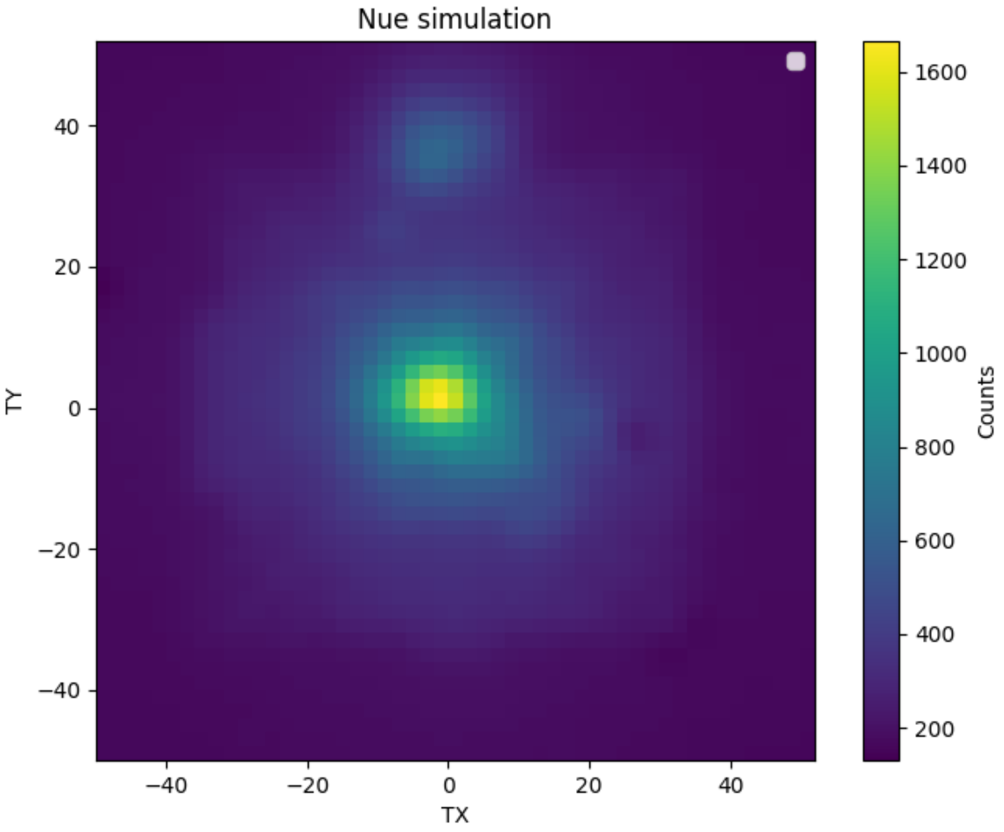
Nuecc simulation

Complete efficiency study ongoing…

X0, Y0 tagged showers



TX, TY tagged showers



Rank bin

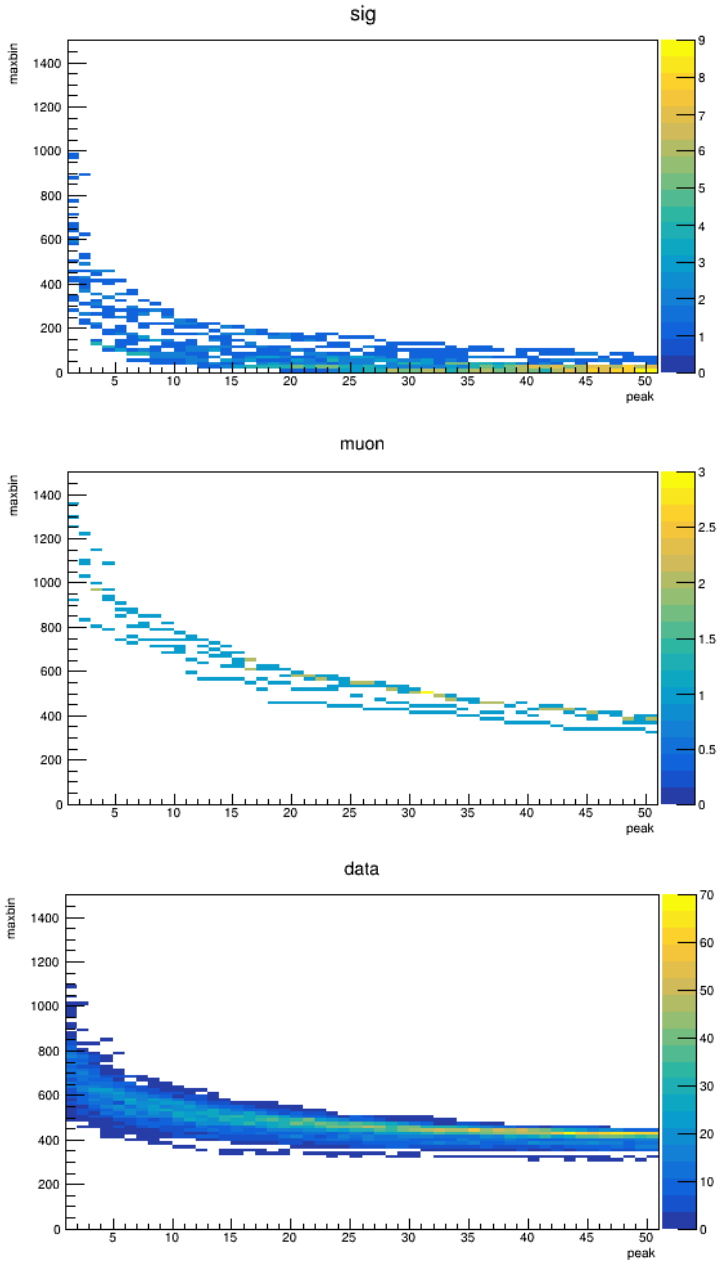
Number of entries in the bin tagged.

Search is done with $50\mu m$ bins in $300\mu m$ radius.

50 highest bins in the nue MC are lower than muon MC and data.

This method is efficient to tag small angle showers:

- cumulative plot enhances bin population.



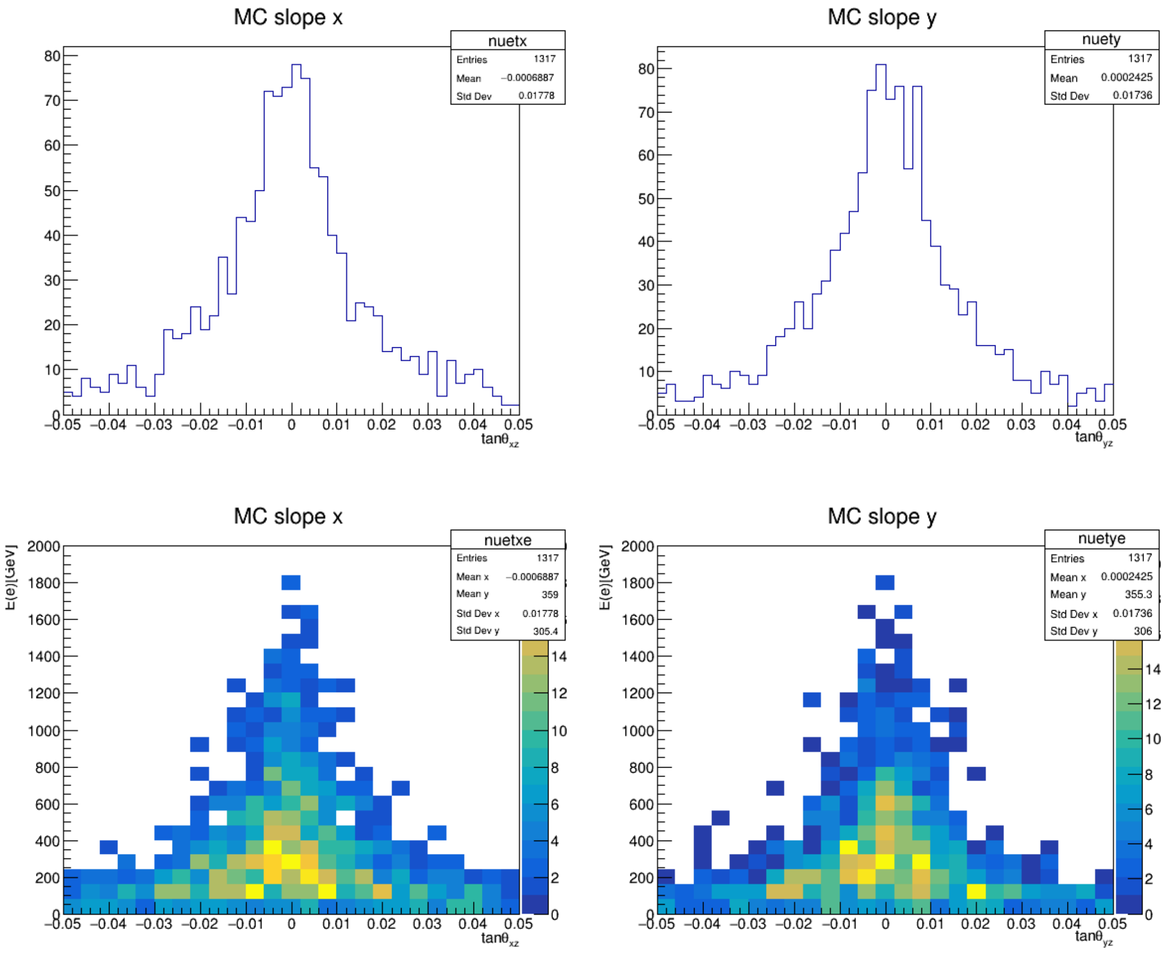
MC electron slope

Primary electron slope from ν_e interactions.

$$90\,\%\ \text{within}\ \pm 50\,mrad$$

Slope vs Energy correlation:

higher energy electrons have smaller slope.

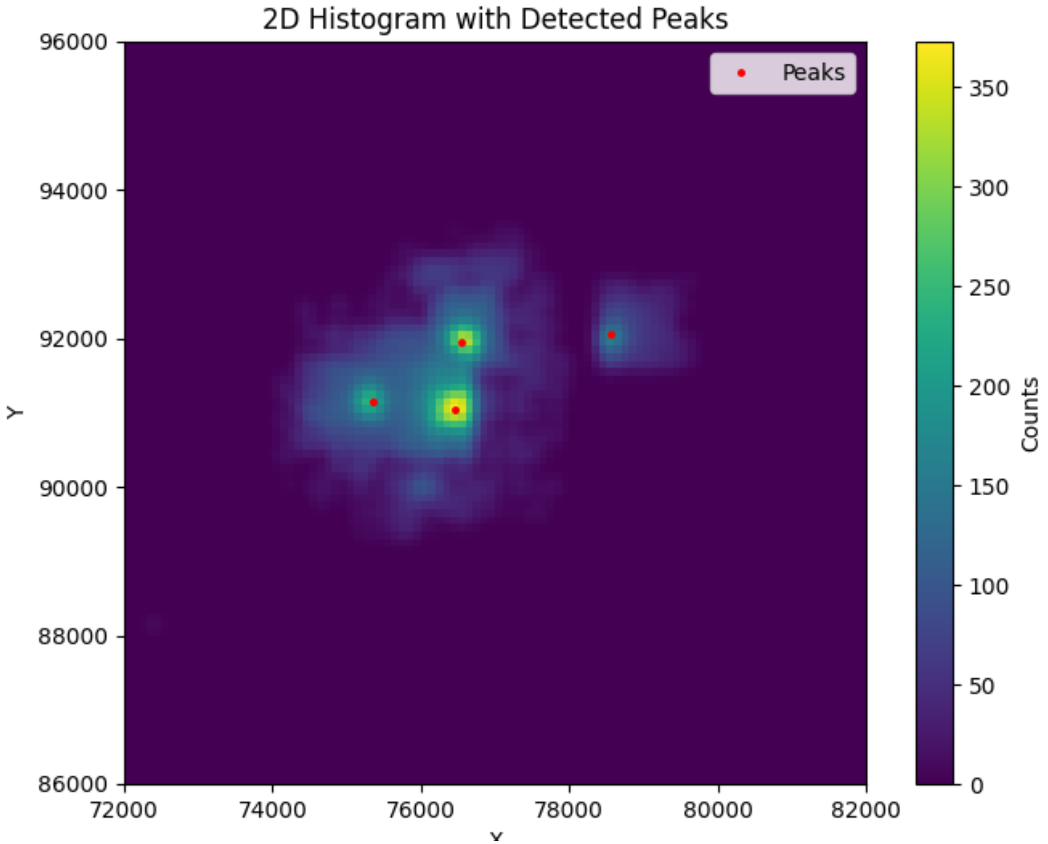


Shift in $\pm 50\,mrad$ range with $2\,mrad$ step: 2601 combinations!

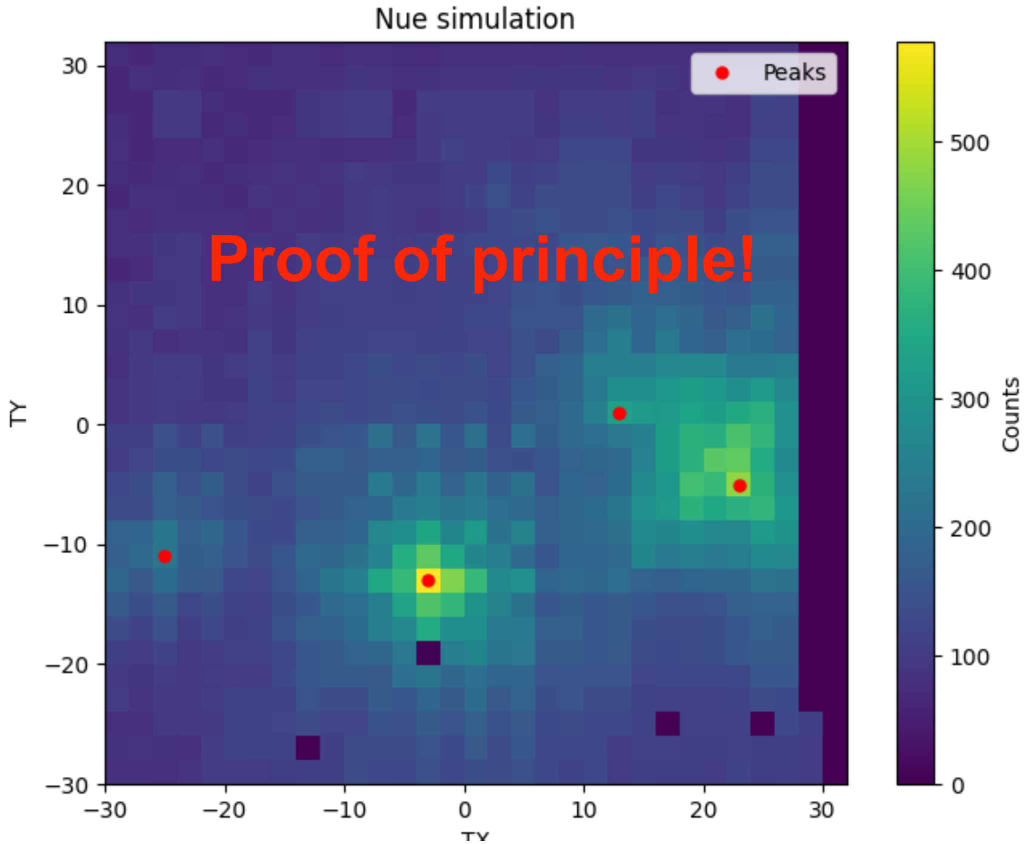
Shift map

Computing all the TX, TY combinations. Z axis is the tagged rankbin.

X0, Y0 tagged showers

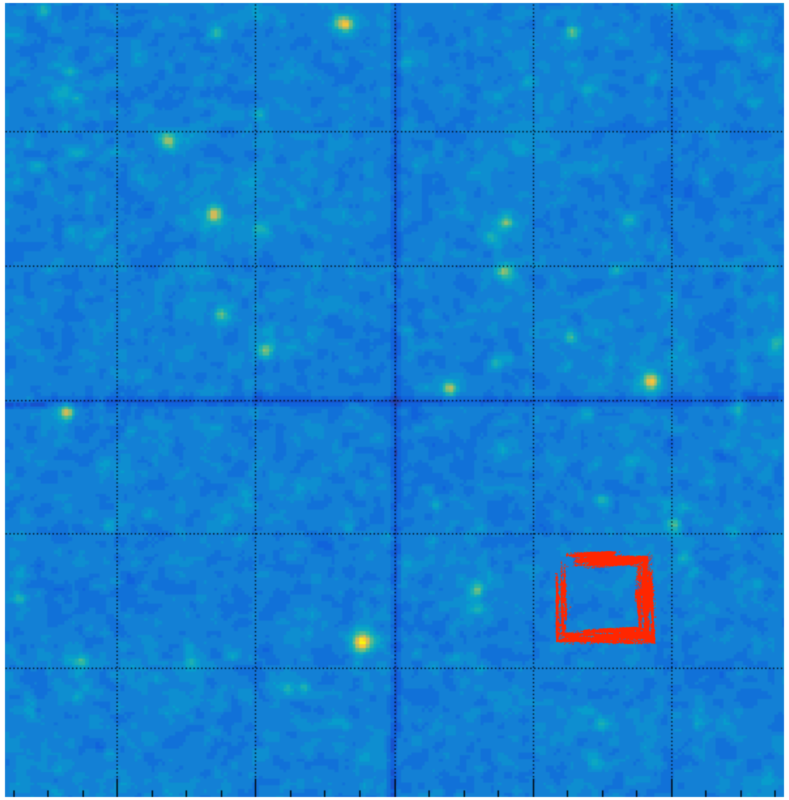


TX, TY tagged showers

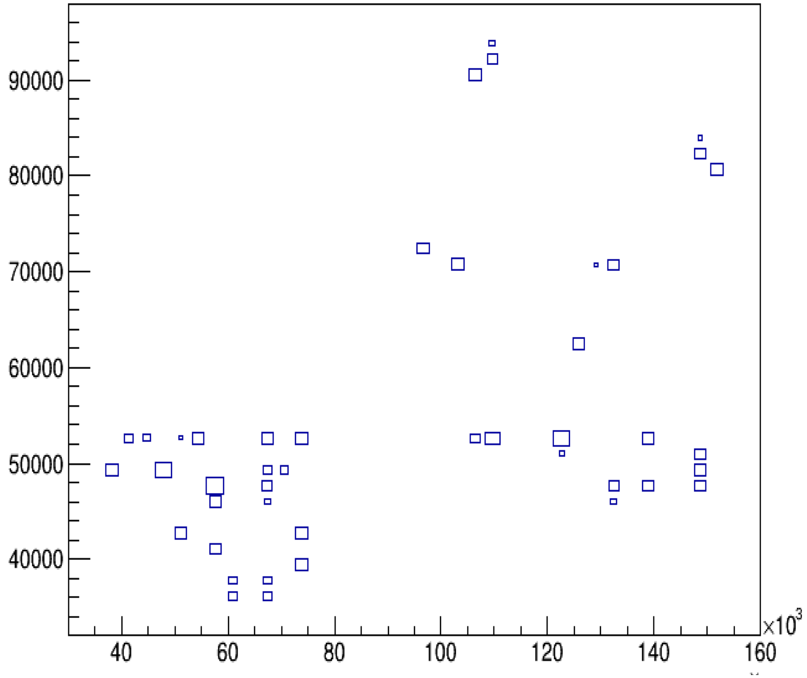


Base-tracks background evaluation

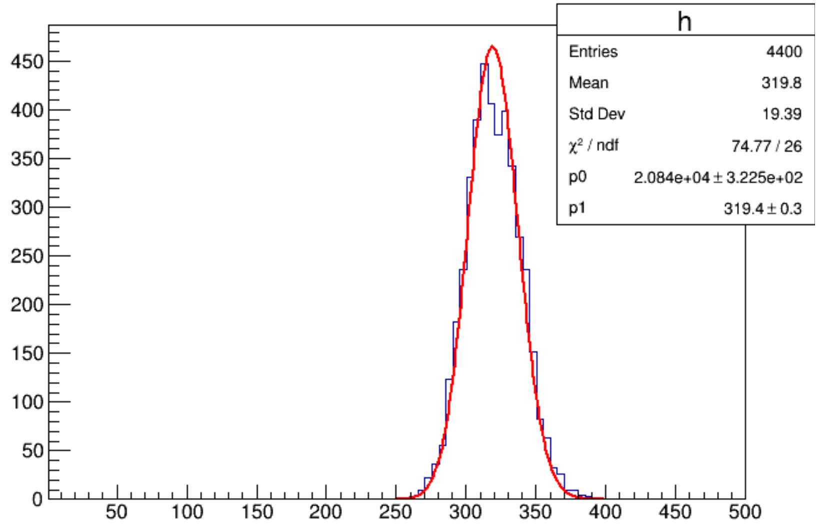
A. Counting base-tracks in no-shower regions



B. Sparse measurements



C. Poisson-like evaluation

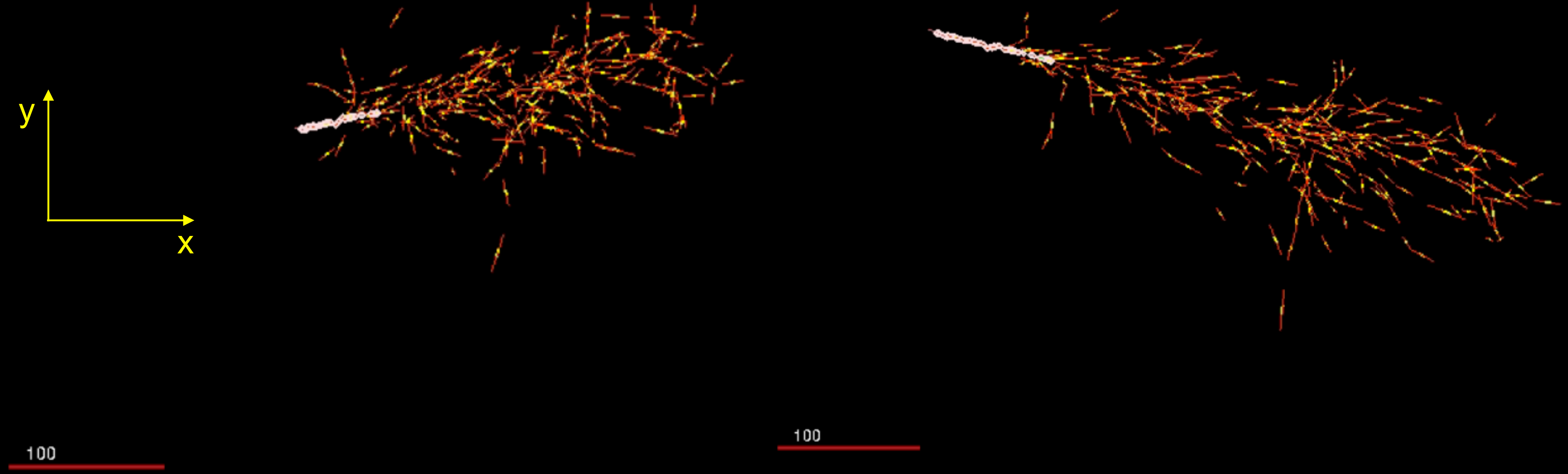


Candidate III

Shower is reconstructed with an injector and parameters:

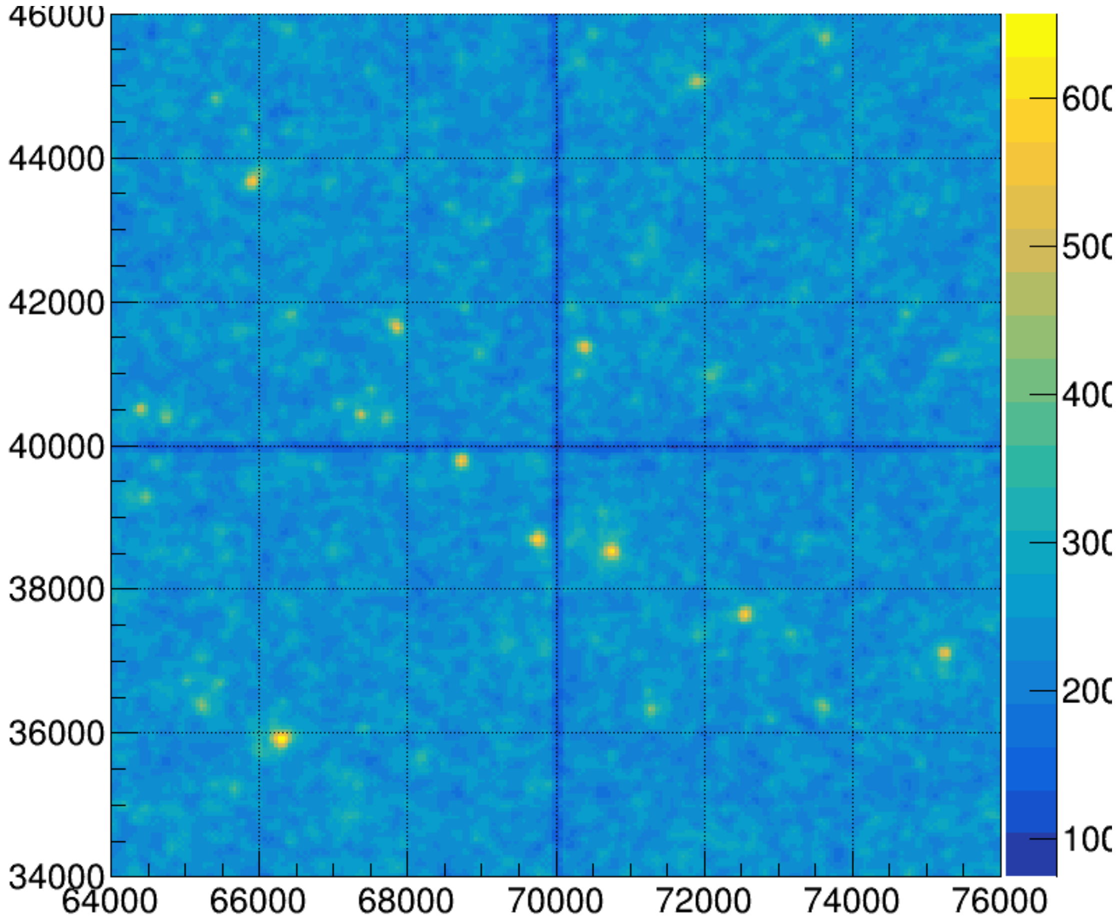
cylinder radius = $100\ \mu m$**, max d =** $50\ \mu m$**, max dt =** 0.03

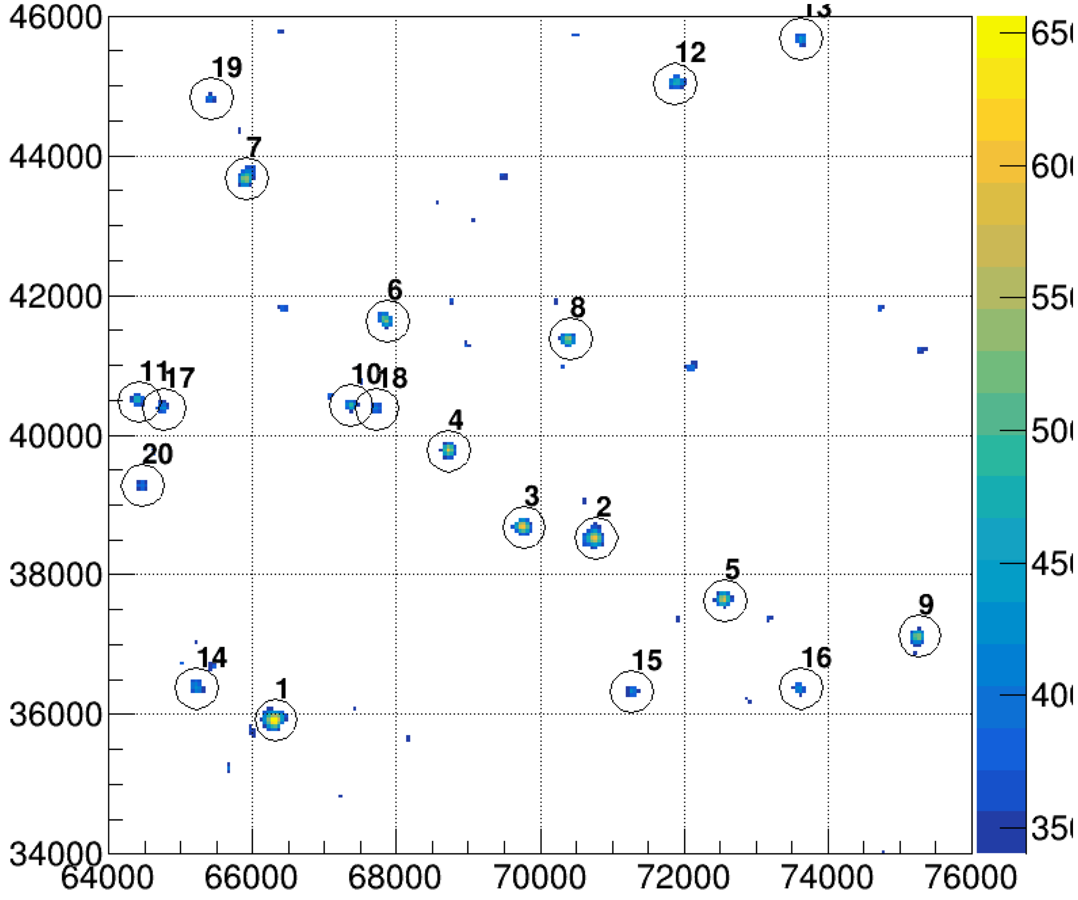
315 segments



Noise-free showers

Tagging only clusters above 5σ of the Poisson fit.

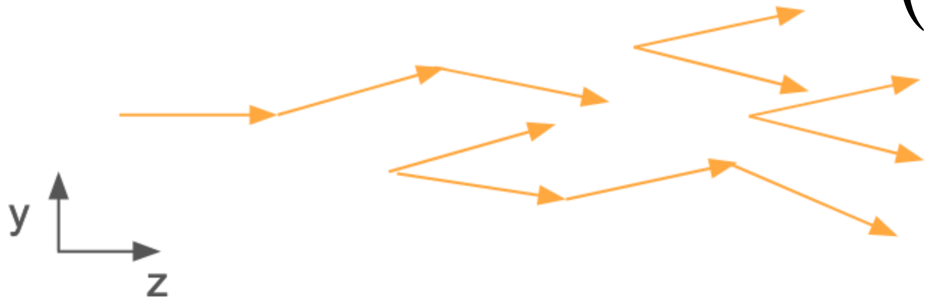


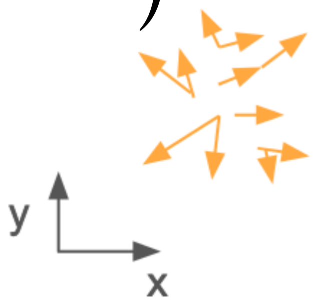


Spherocity

$$S = \frac{\pi^2}{4}\left(\frac{\sum_i \left|\vec{p}_{Ti} \times \hat{n}\right|}{\sum_i p_{Ti}}\right)^2$$

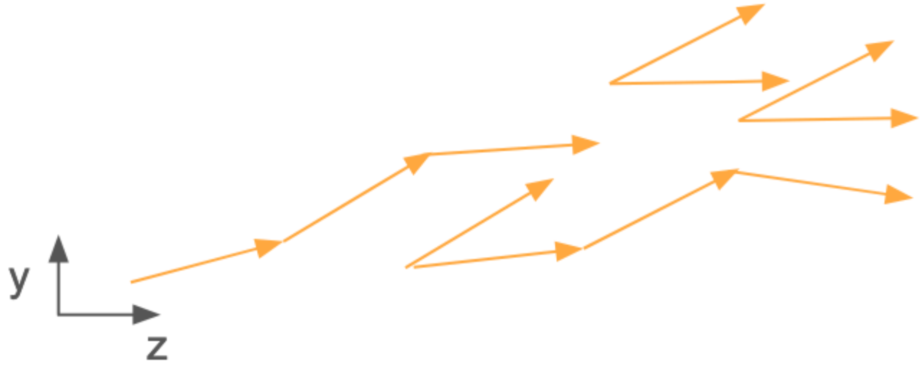
Low pt shower

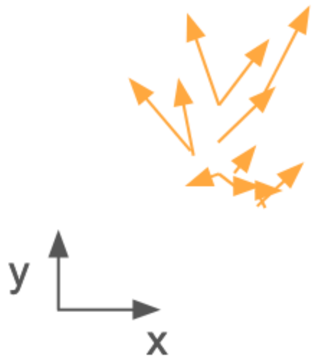




Isotropic, high spherocity

High pt shower





Less isotropic, lower spherocity

Spherocity

$$S = \frac{\pi^2}{4}\left(\frac{\sum_i \left|\vec{p}_{Ti} \times \hat{n}\right|}{\sum_i p_{Ti}}\right)^2$$

The variable well discriminates sig and bkg

Data behaves as background

Some events are in the tail

Evaluation of TPR and FPR:

- Signal efficiency
- Bkg misclassified as sig