Directionality of low energy electron recoil: Preliminary strategy

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Dataset

Working on on electrons from MC by Giulia and Atul:

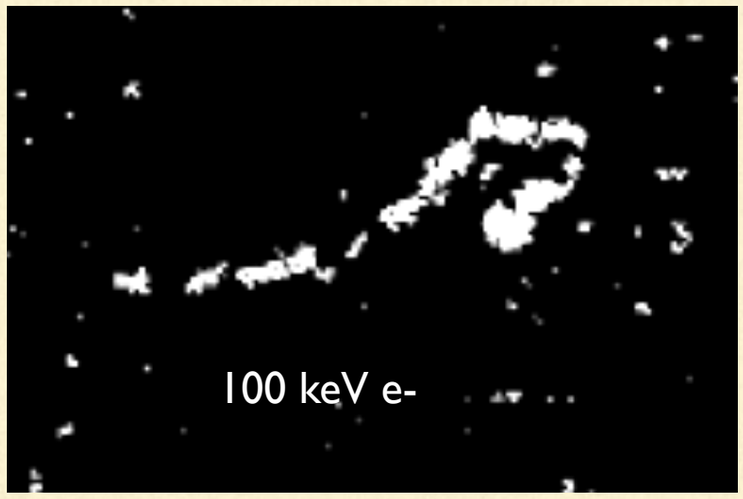
- Electron generated at the center of the image
- Energy of 6 keV, 30 keV, 60 keV, and 100 keV
- Electron shot along the x-axis, in the positive direction
- Distance from the GEM of 25cm (to simulate diffusion)
- 1 Track per event

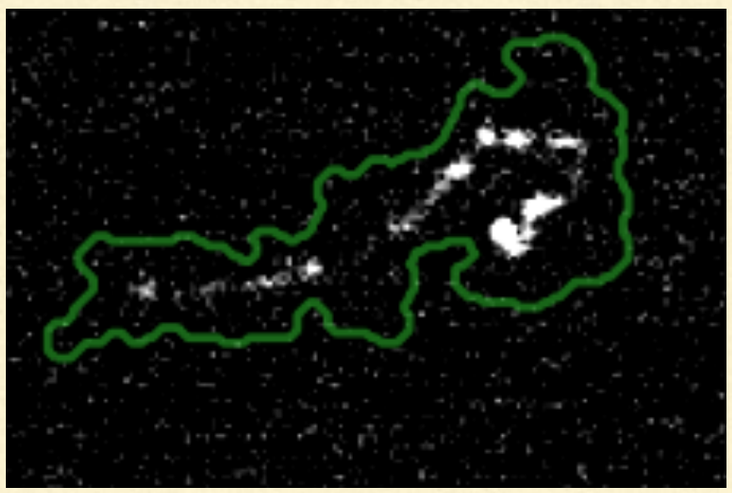
(Most difficult to reconstruct: lower and more discontinuous Energy release at hte beginning)

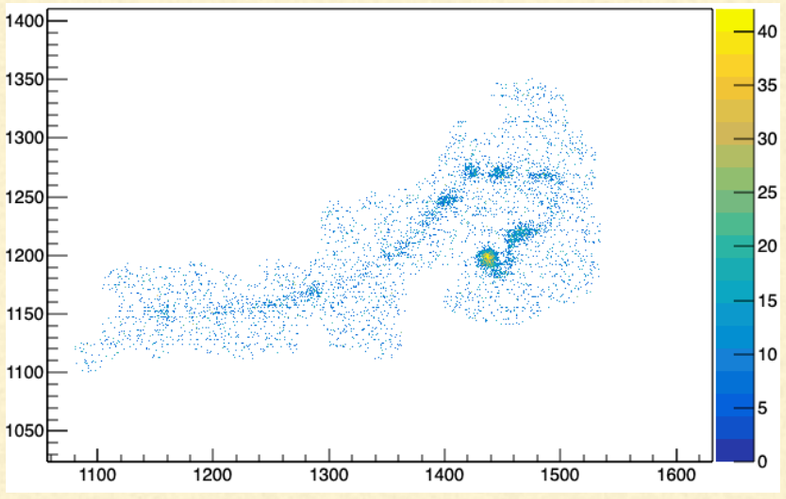
Sc algorithm and data:

Algorithm seems to work well on electrons (full reconstruction)

All the information of the pixel above threshold in the sc is saved



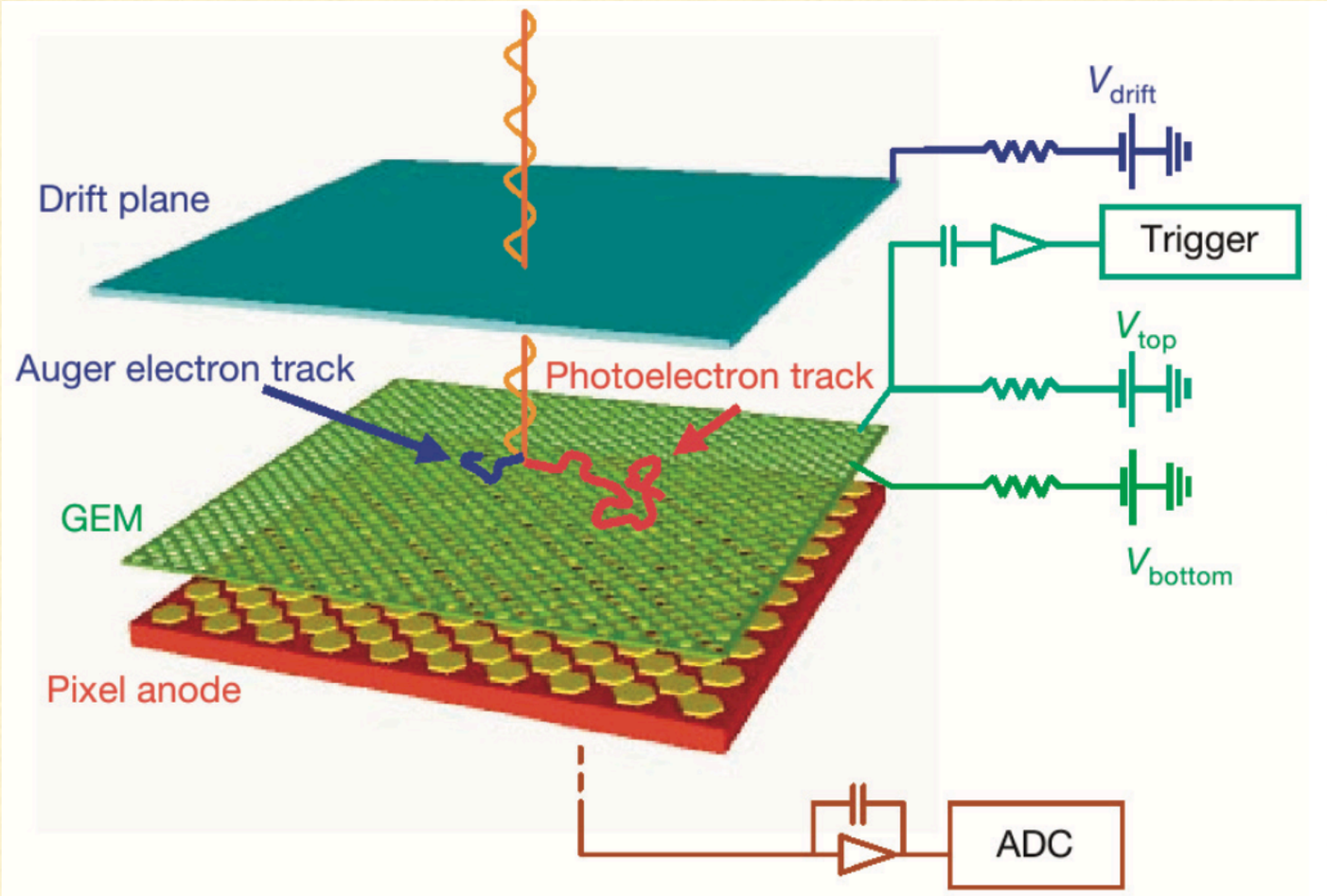


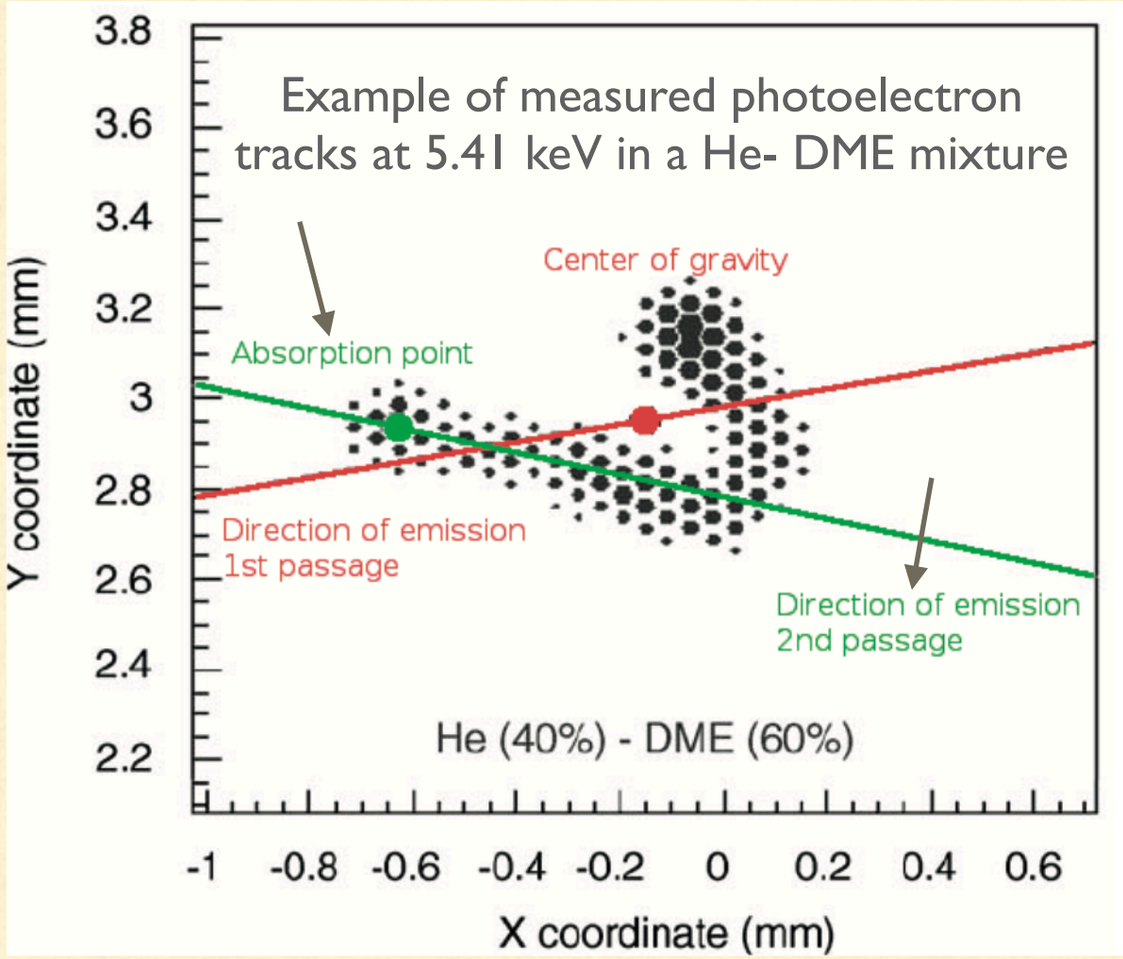


Some noise is taken→ It can be optimised / Second step to fit better the Sc

First algorithm: from Gas Pixel Detector

Algorithm used for X-Ray polarimetry in Gas Pixel Detector





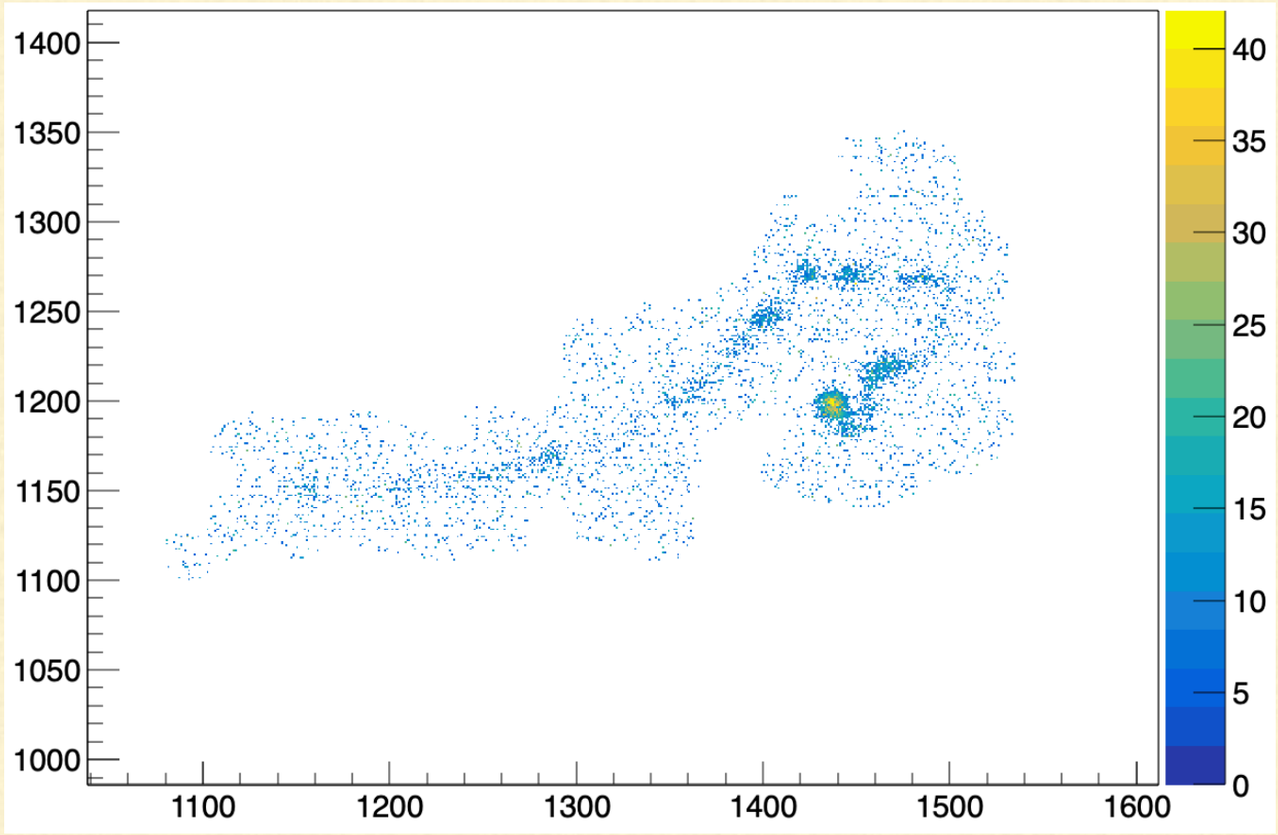
They are able to calculate the direction of a 5 keV e- in gas

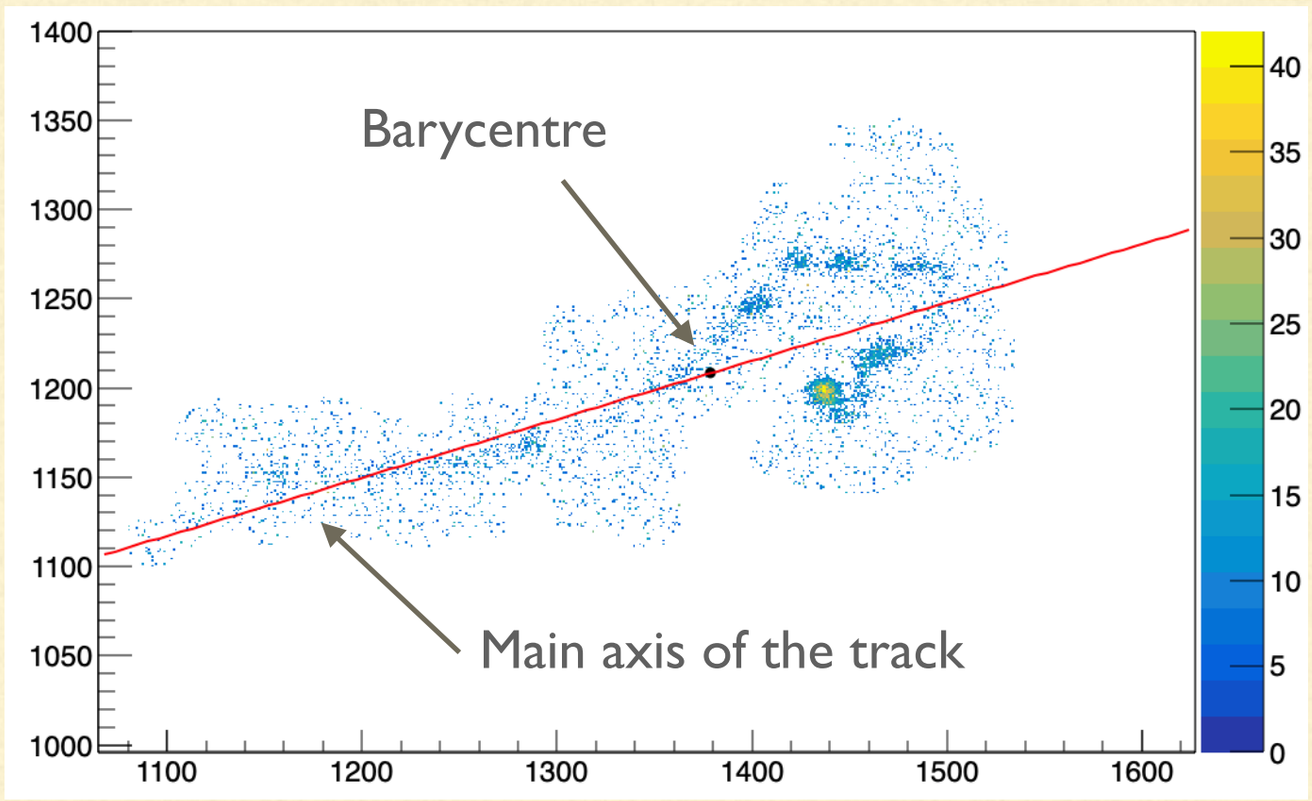
Same strategy can be applied to our detector

Fisrt Algorithm

- 100 keV electron
- All pixels over threshold are taken
- Calculation of the barycentre of the pixel weighted with the charge

$$x_c = \frac{\sum_i Q_i \; x_i}{\sum_i Q_i} \qquad y_c = \frac{\sum_i Q_i \; y_i}{\sum_i Q_i}$$





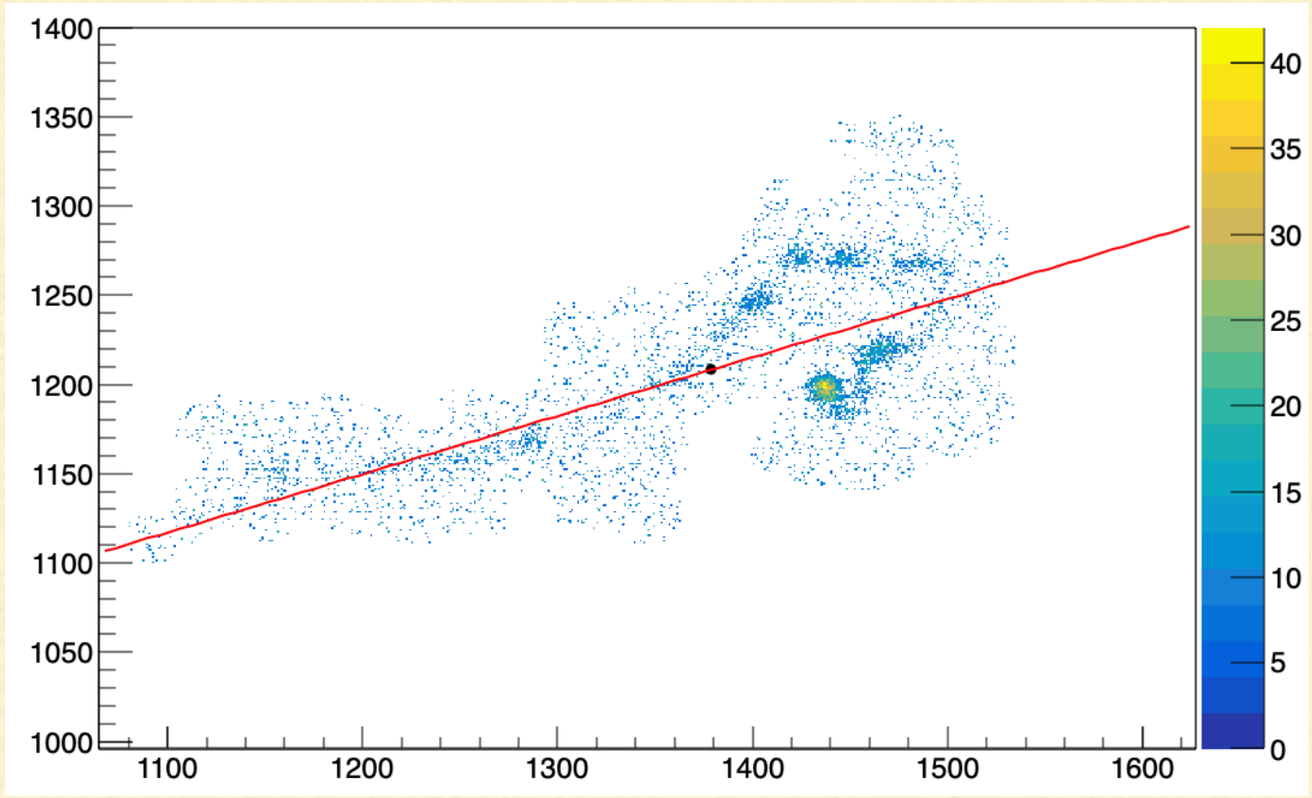
- Calculation of the main axis of the track:
  - Line passing from the barycenter such that the RMS of the histogram resulting from the projection of the track points on the line is maximum

$$M_2(\Phi) = \frac{\sum_i Q_i \; x_i'^2}{\sum_i Q_i} = \frac{\sum_i Q_i \left[(x_i - x_c)\cos\Phi + (y_i - y_c)\sin\Phi\right]^2}{\sum_i Q_i}$$

$$\frac{dM_2(\Phi)}{d\Phi} = 0 \implies \Phi_0 = -\frac{1}{2}\arctan\frac{2\sum_i Q_i \; (x_i - x_b)(y_i - y_b)}{\sum_i Q_i \left[(y_i - y_b)^2 - (x_i - x_b)^2\right]}$$

Φ angle of the line respect to the x-axis

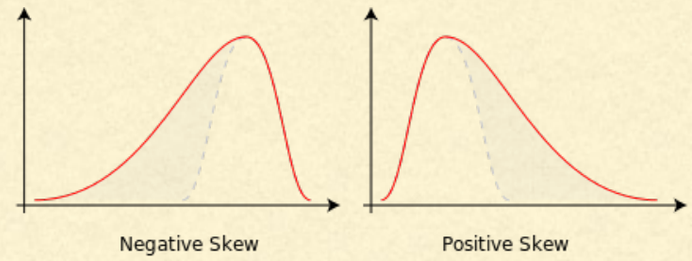
Fisrt Algorithm



- Calculation of the skewness of the track along the main axis respect to the barycenter

$$M_3 = \frac{\sum_i Q_i \, x_i'^3}{\sum_i Q_i} = \frac{\sum_i Q_i \left[(x_i - x_b)\cos\Phi_{\max} + (y_i - y_b)\sin\Phi_{\max}\right]^3}{\sum_i Q_i}$$

- Third momentum of the distribution contains the information on the Bragg Peak

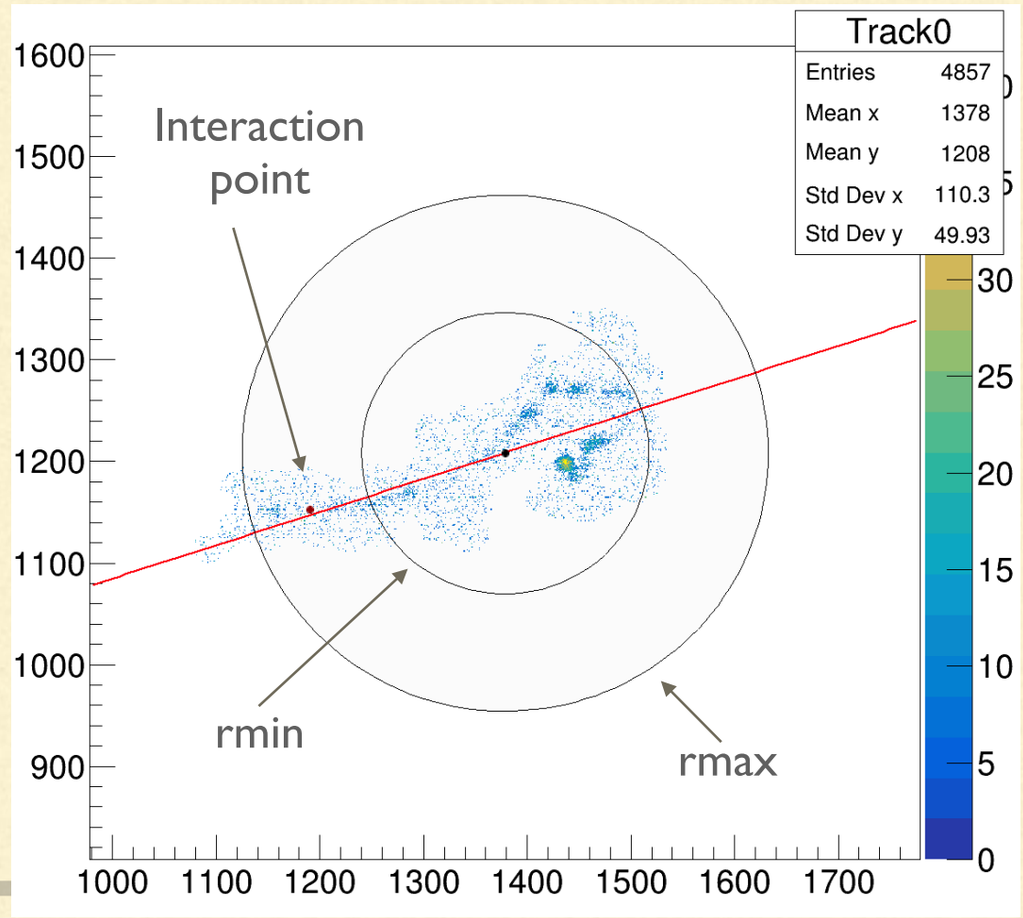


- Calculation of the first part of the track as points such that:
  - The point is on the other side of the Bragg peak

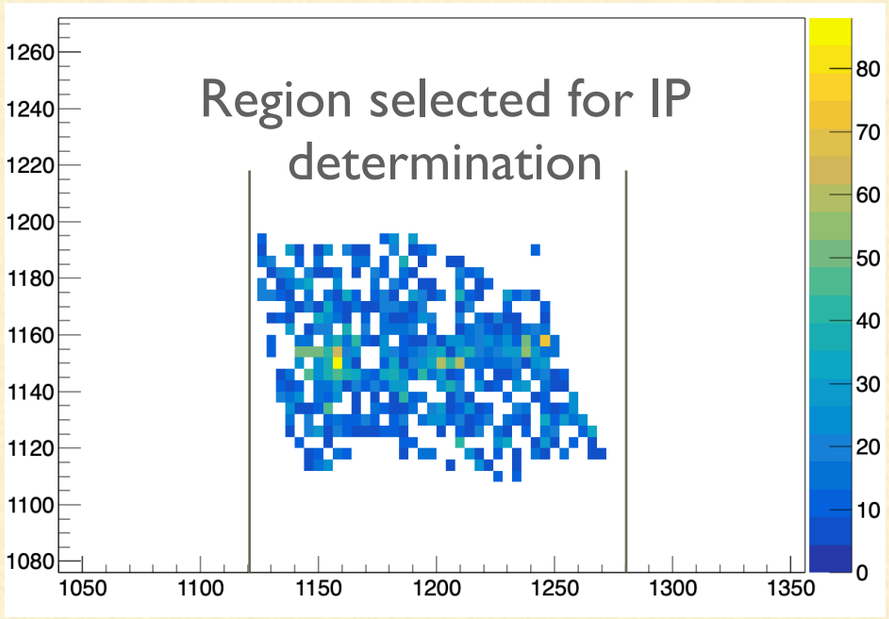
$$\frac{x_i'}{M_3} < 0 \implies \frac{(x_i - x_c)\cos\Phi_{\max} + (y_i - y_c)\sin\Phi_{\max}}{M_3} < 0.$$

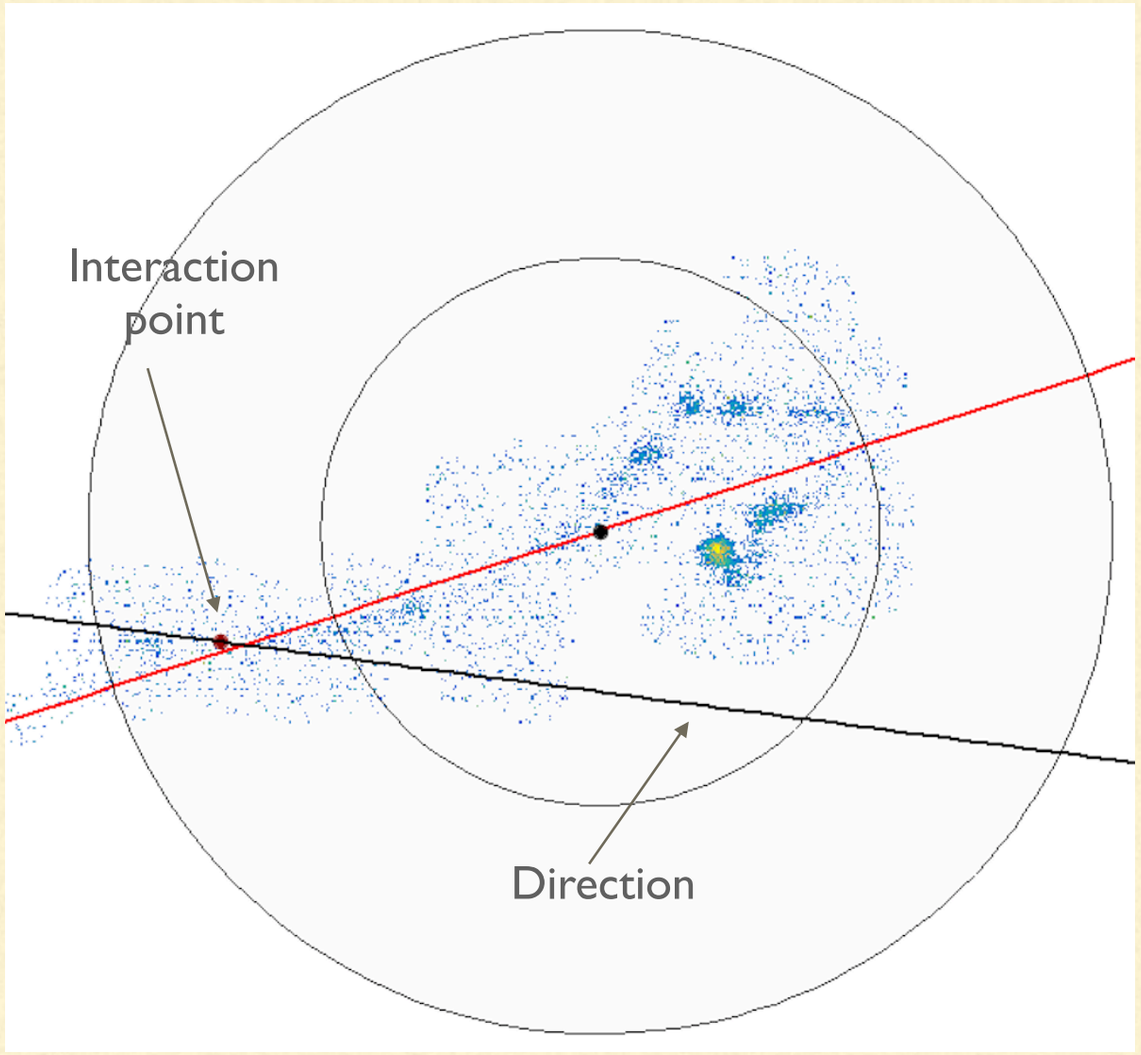
  - The distance of the point from the barycenter is

$$r_{\min} < d_{cm} < r_{\max} \qquad d_{cm} = \sqrt{\frac{(x_i - x_c)^2 + (y_i - y_c)^2}{M_2^{\max}}}$$



Fisrt Algorithm





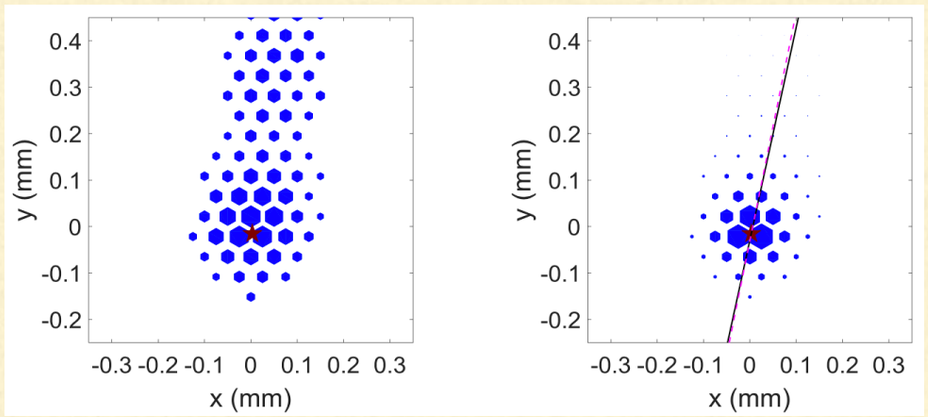
For directionality:

- Naive version: Fit the selected point with a line and extract the direction
- Version Lv1: Find the line passing for the IP for which the RMS of the point on the line is Max
- Version Lv2: Same of Lv1 wighting the point such that they weight less if far from IP

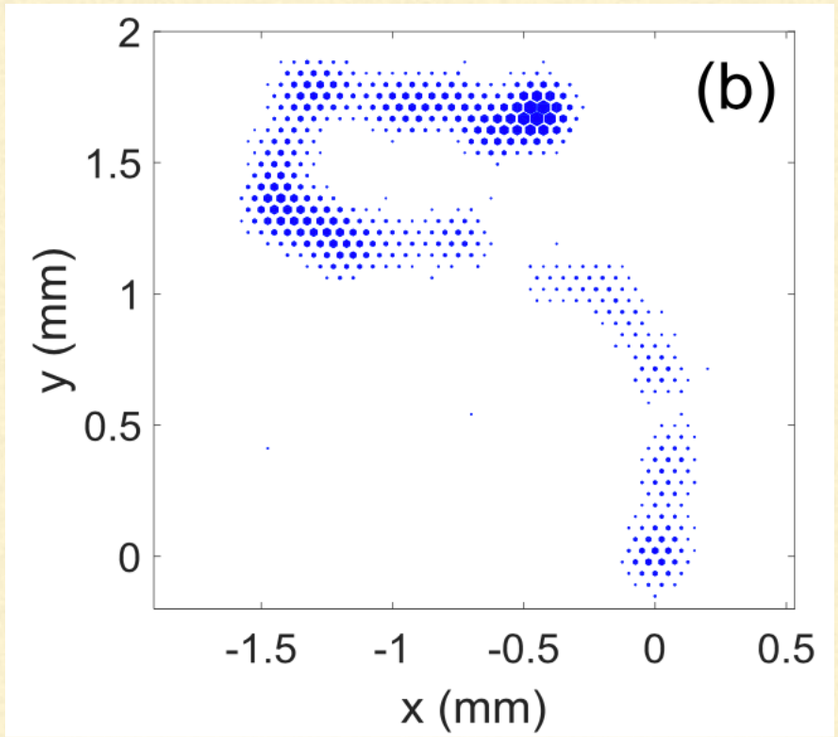
$$W(d_{\mathrm{ip}}) = \exp(-d_{\mathrm{ip}} / w)$$

Distance from IP

Constant from MC

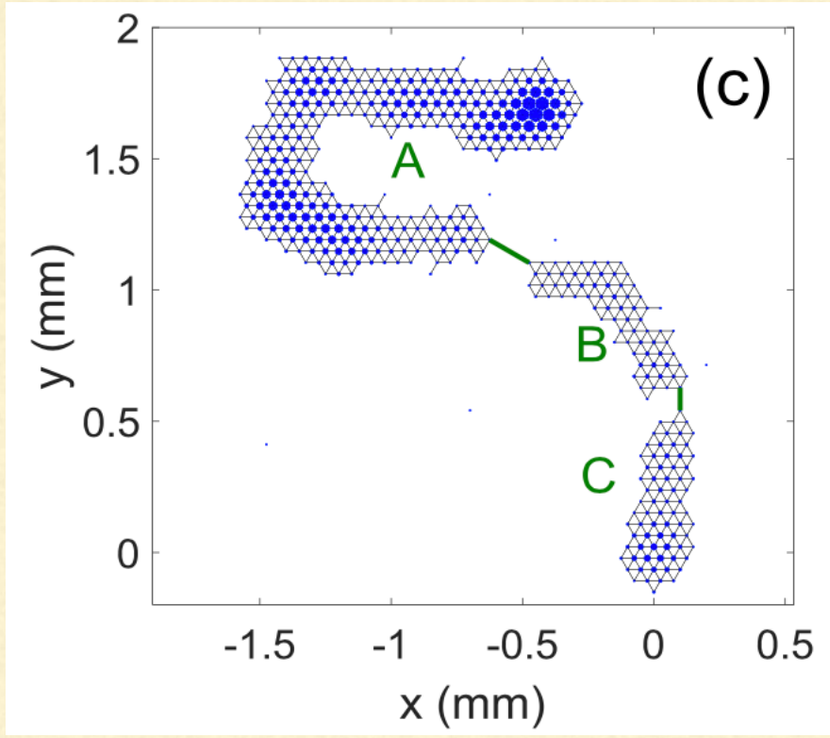


Second Algorithm

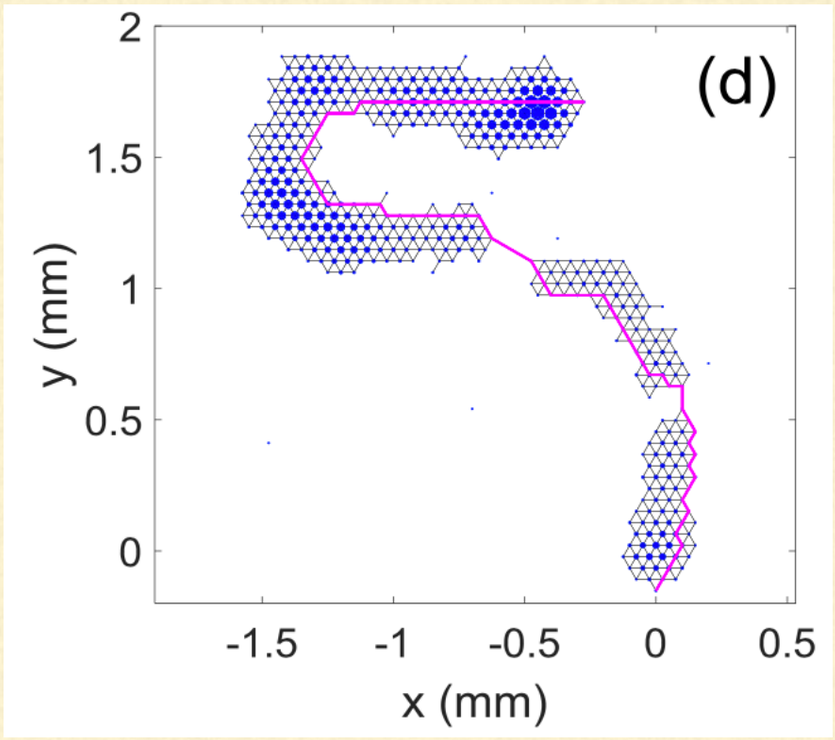


Simulated charge distribution produced by a 15 keV X-ray

Connection of neighbour points, two points are connected with a line if they are next to each other



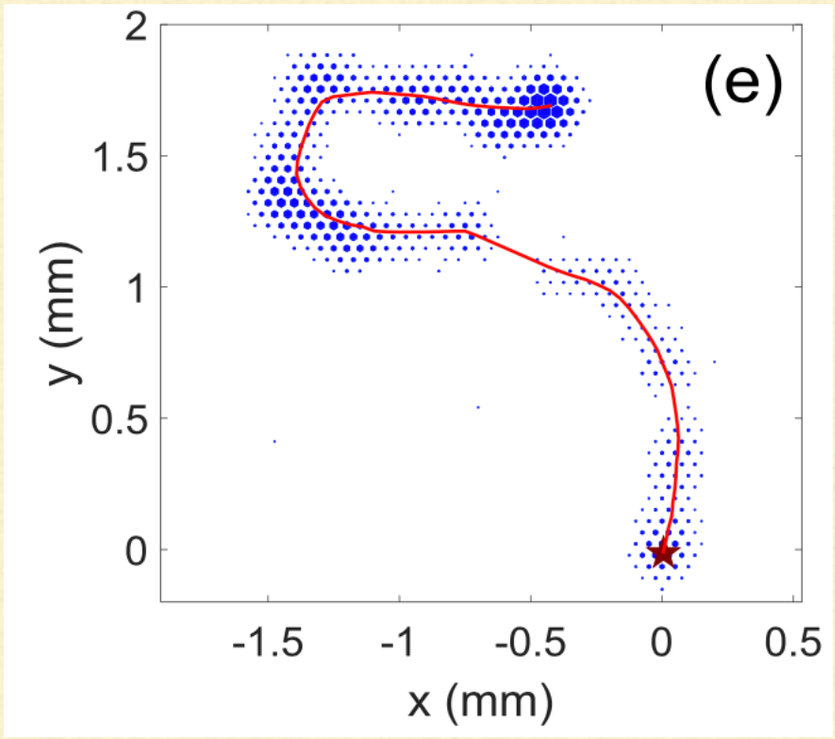
Second Algorithm



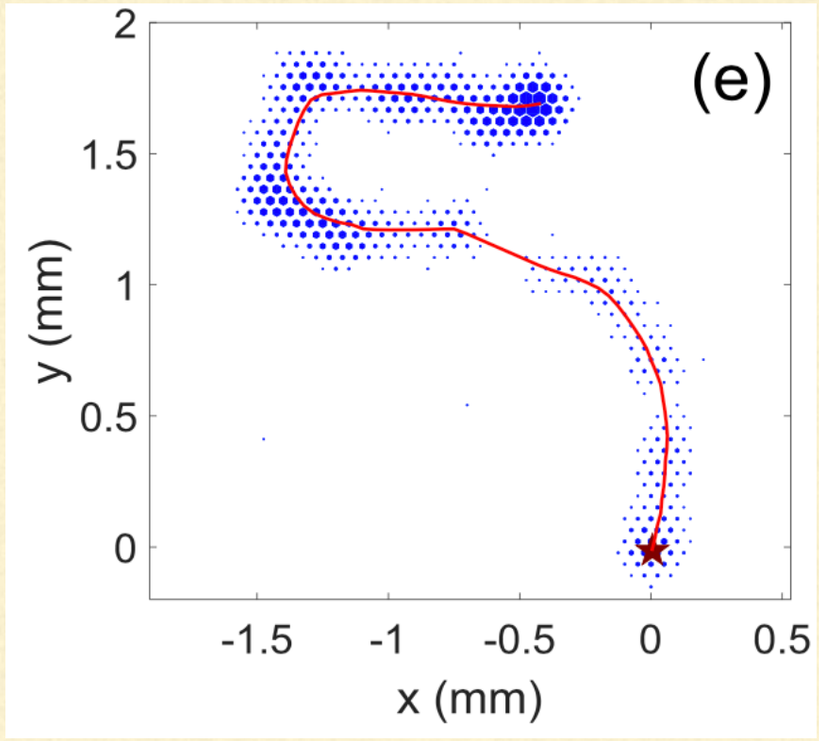
The shortest path is calculated according to the shortest path problems in graph theory.

Amongst all the shortest paths between two points the longest one is selected (?).

A spatial energy filter to smooth the polyline is applied, to make the primary path trace the centroid of the track: every point in the primary path is replaced by the charge barycentre within a certain radius around it



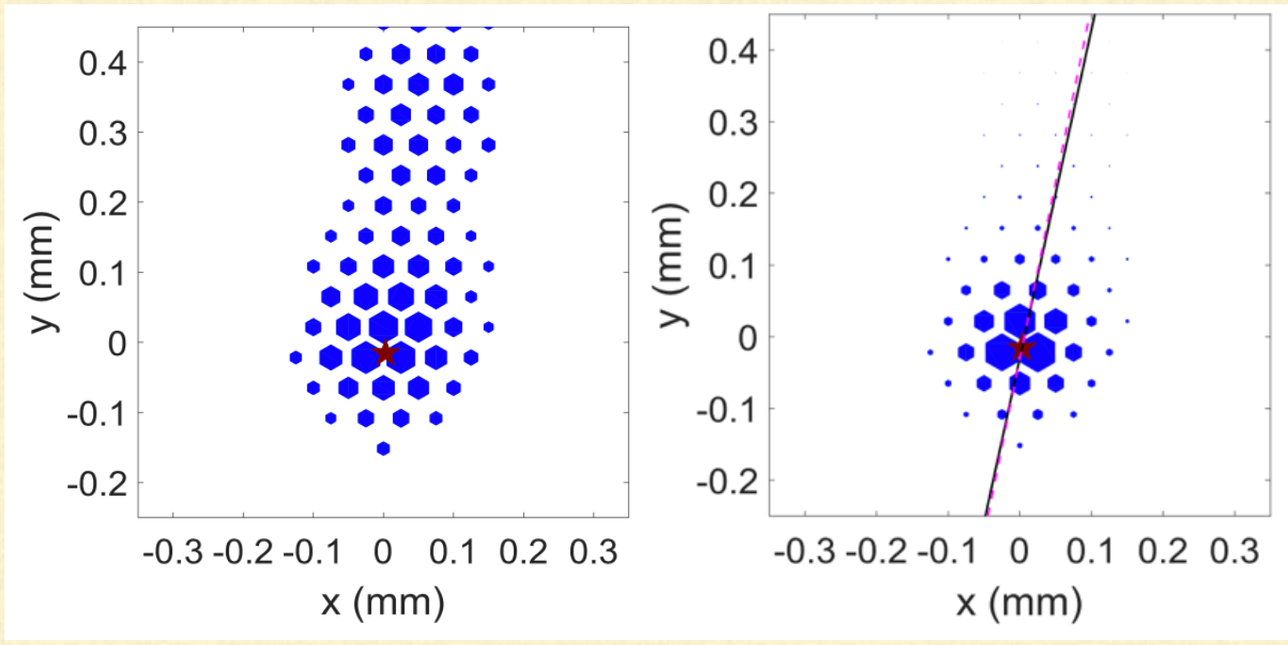
Second Algorithm



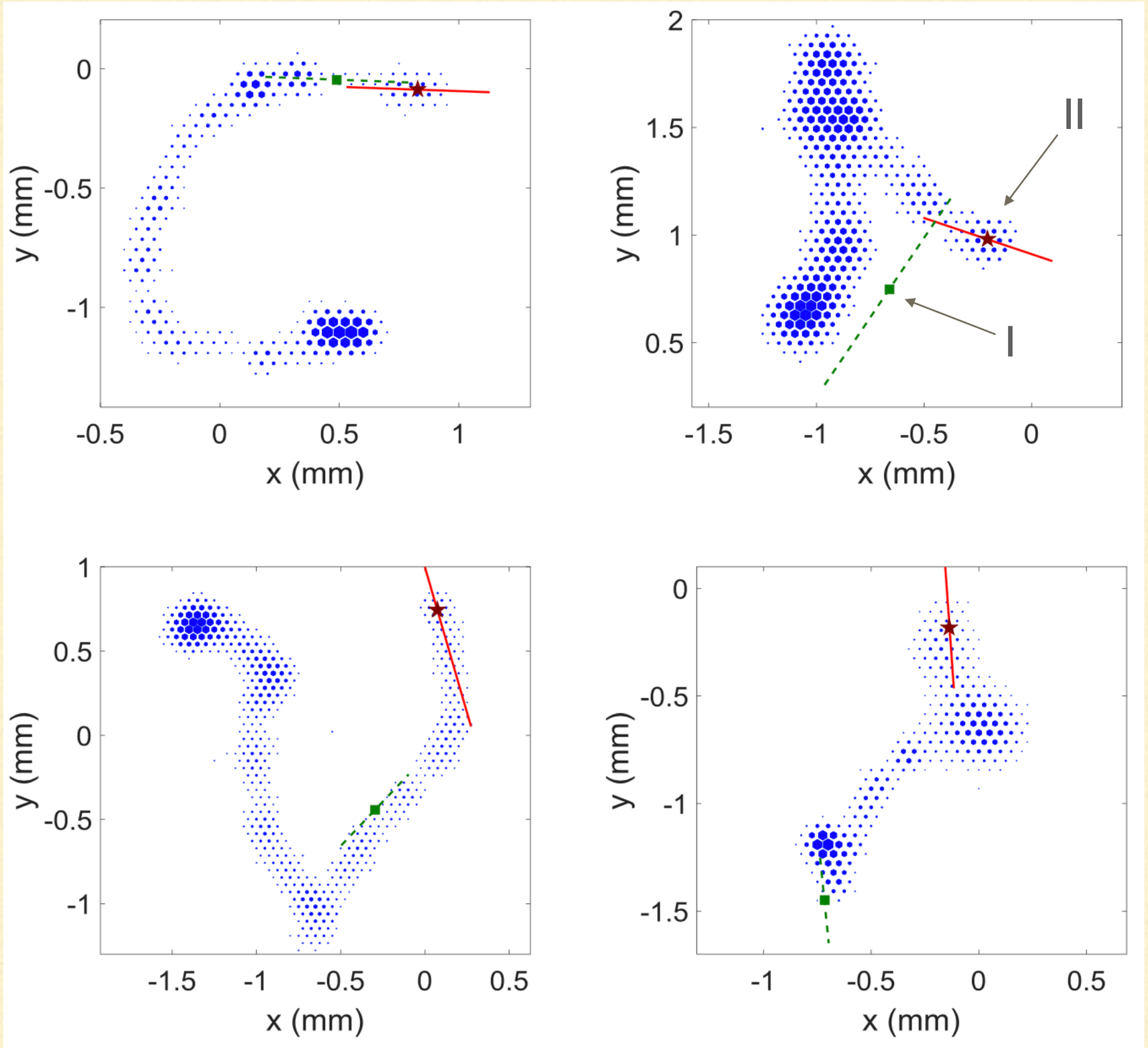
The charge around the two ends of the track is calculated, the end with low energy is taken as the beginning of the track

Direction calculated with previous method:

- Point weighted with distance
- RMS maximization



First vs Second Algorithm



Conclusions

- The information of all the points of the track seems to be the best information to use for directionality purposes.

- The reconstruction algorithm previously mentioned works in GPD for very low Energy electrons.

- Our setup is very similar to the GPD, so the same algorithm can be used.

- A preliminary analysis seems to give promising results on directionality

- The final version of the algorithm should be tested, and compared with the naive version