Reconstruction of the track parameters for polarization measurements

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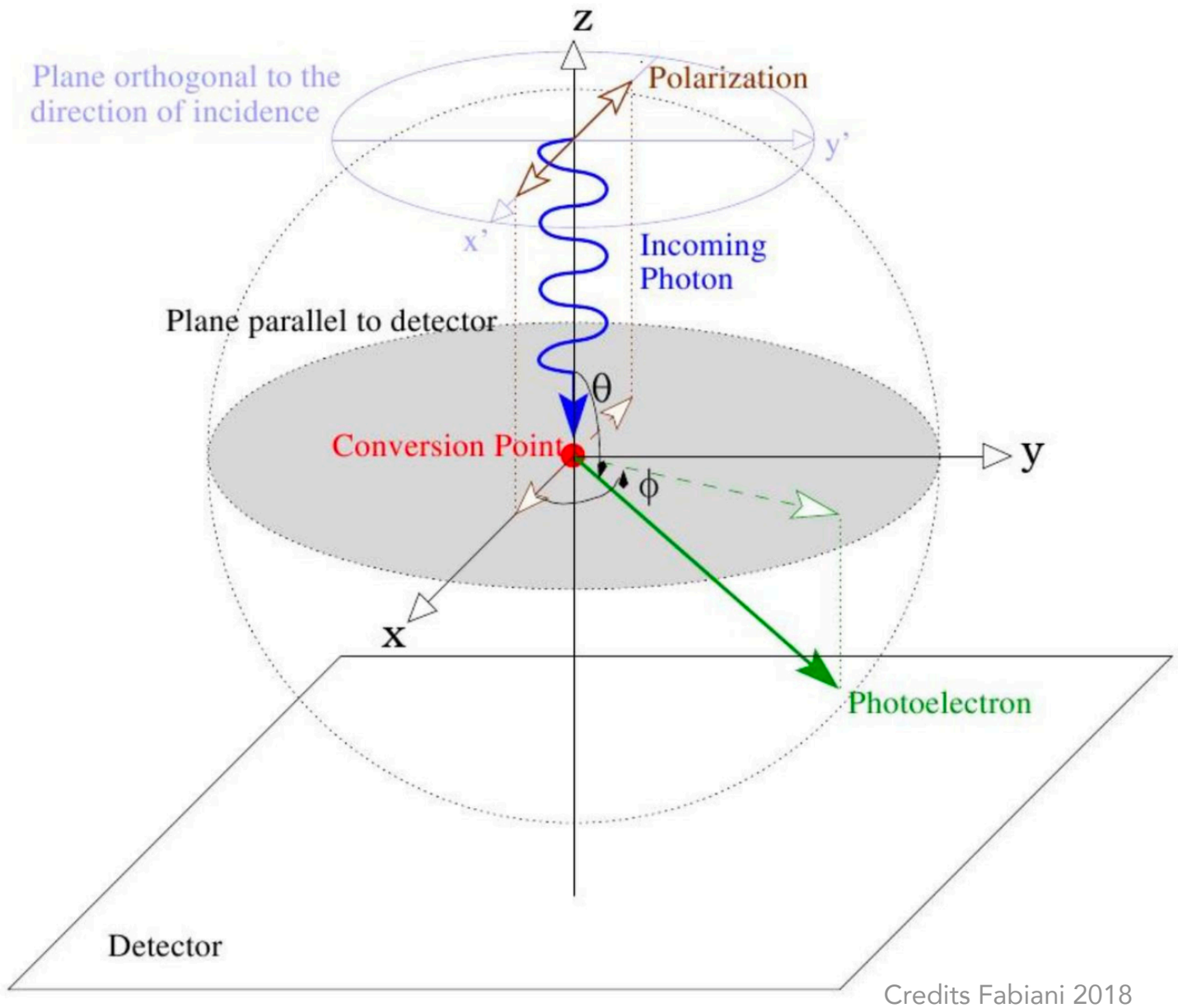
From tracks to polarization

$$\frac{d\sigma_c^k}{d\Omega} \propto Z^5 E^{-\frac{7}{2}} \frac{\sin^2\theta \cos^2\phi}{(1+\beta\cos\theta)^4}$$



Credits Fabiani 2018

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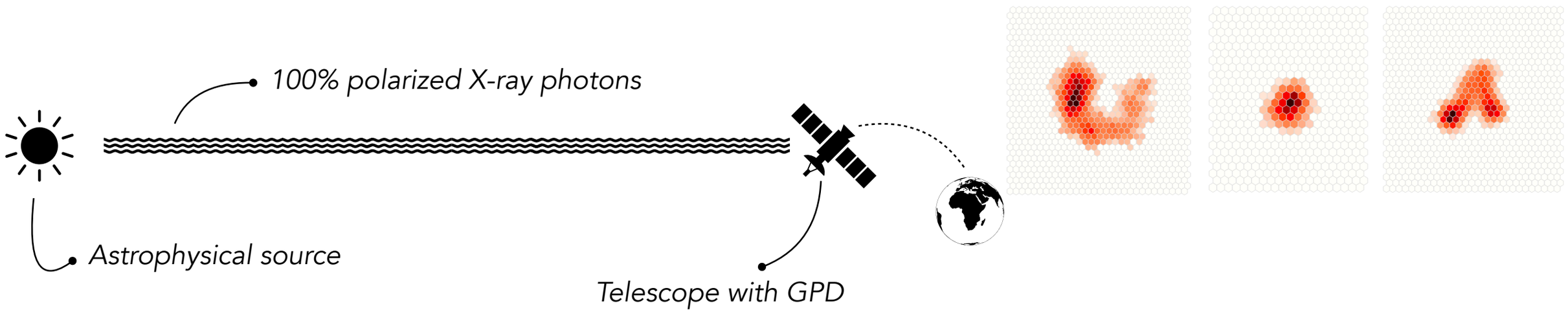
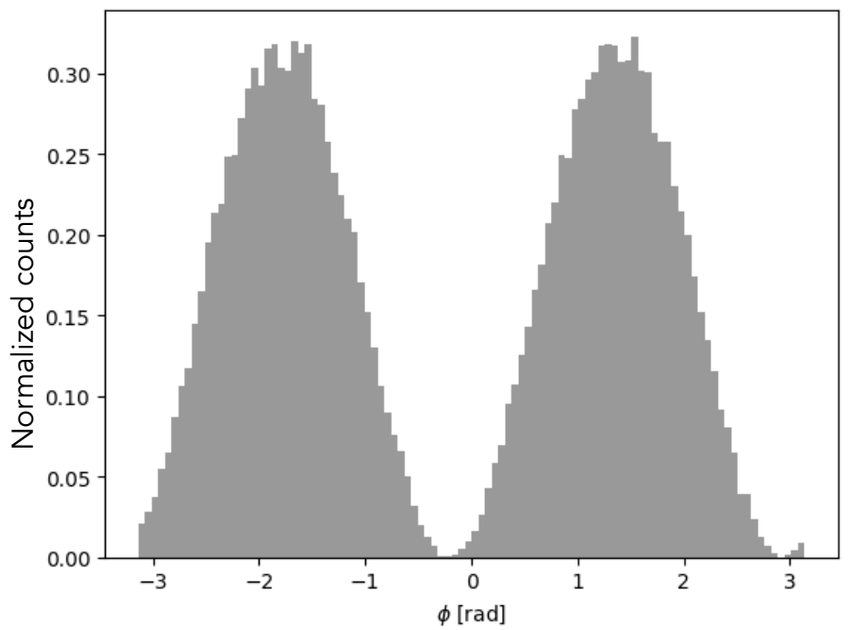


Photoelectrons emission angles distribution for an ideal polarimeter



Moment Analysis

1.Determination of the barycenter and of the second moment of the distribution of charge

$$x_b = \frac{\sum_i q_i x_i}{\sum_i q_i} \quad y_b = \frac{\sum_i q_i y_i}{\sum_i q_i}$$

$$M_2(\phi) = \frac{\sum_i q_i[(x_i - x_b)\cos(\phi) + (y_i - y_b)\sin(\phi)]^2}{\sum_i q_i}$$

2. Determination of the third moment of distribution of charge to select the initial part of the track

$$M_3(\phi) = \frac{\sum_i q_i[(x_i - x_b)\cos(\phi) + (y_i - y_b)\sin(\phi)]^3}{\sum_i q_i}$$

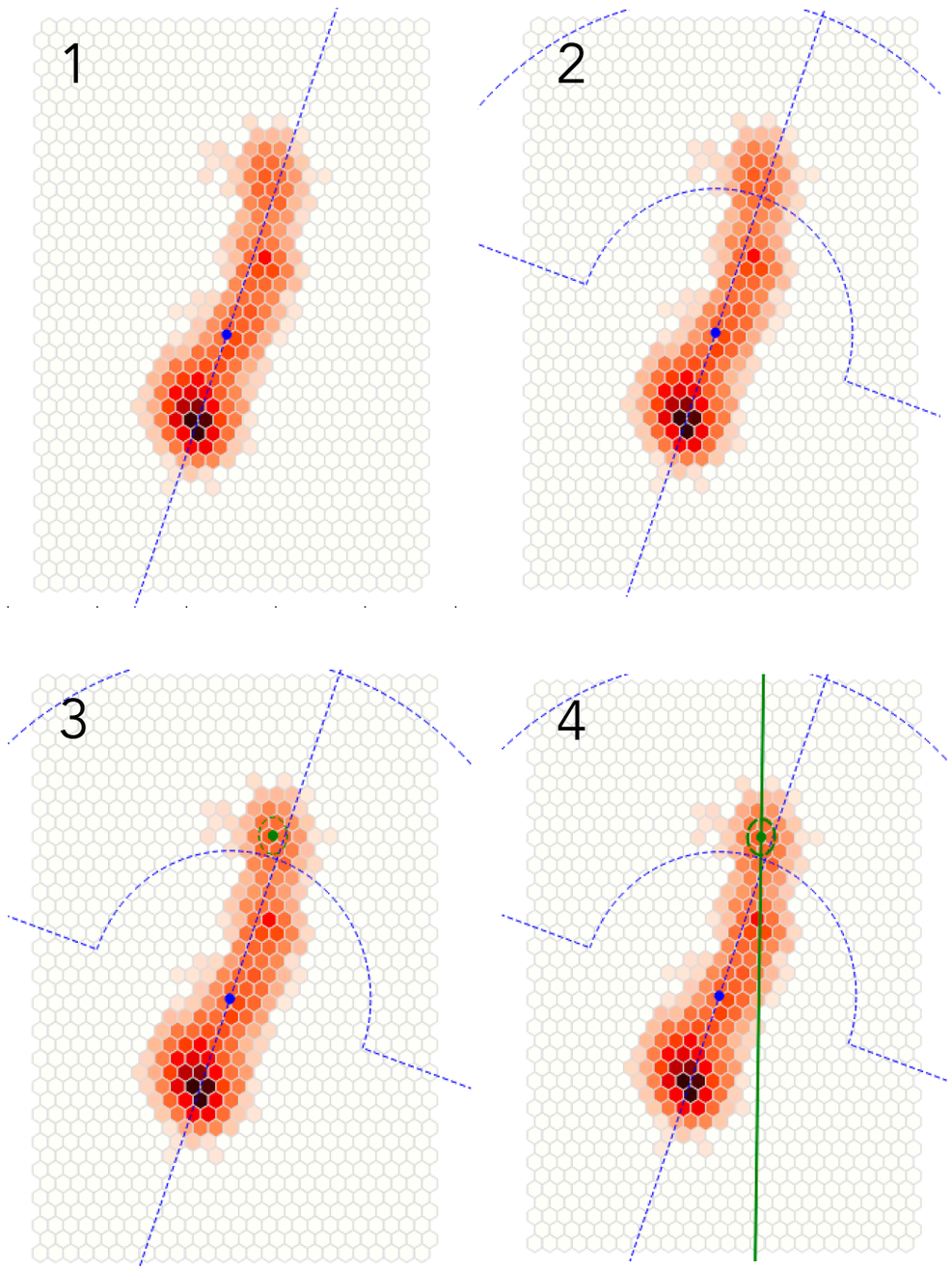
3. Calculation of the weights respect to the initial part of the track, and subsequent determination of the impact point

$$w_i = e^{-\frac{d_{b,i}}{d_s}}$$

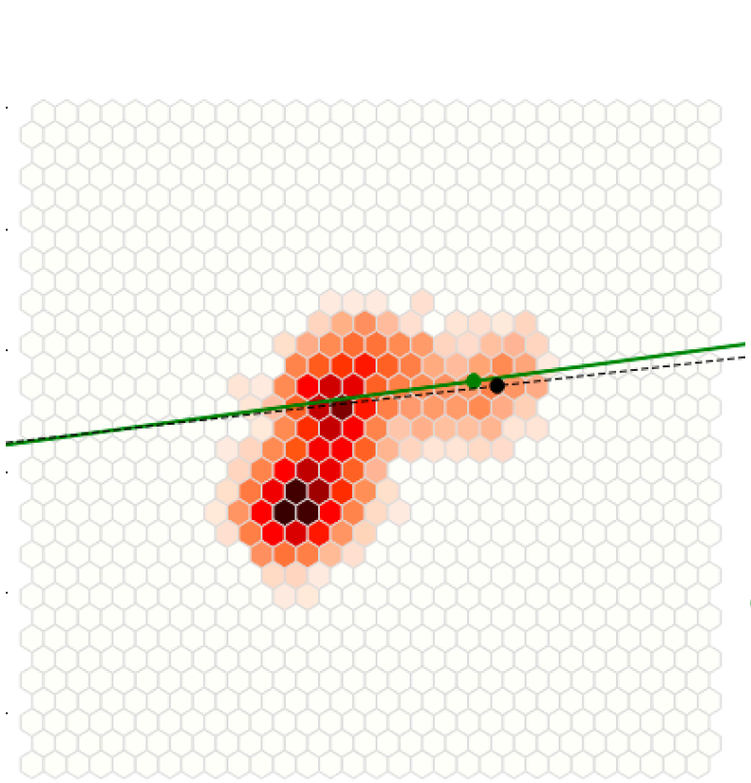
$$x_{IP} = \frac{\sum_i w_i x_i}{\sum_i w_i} \quad y_{IP} = \frac{\sum_i w_i y_i}{\sum_i w_i}$$

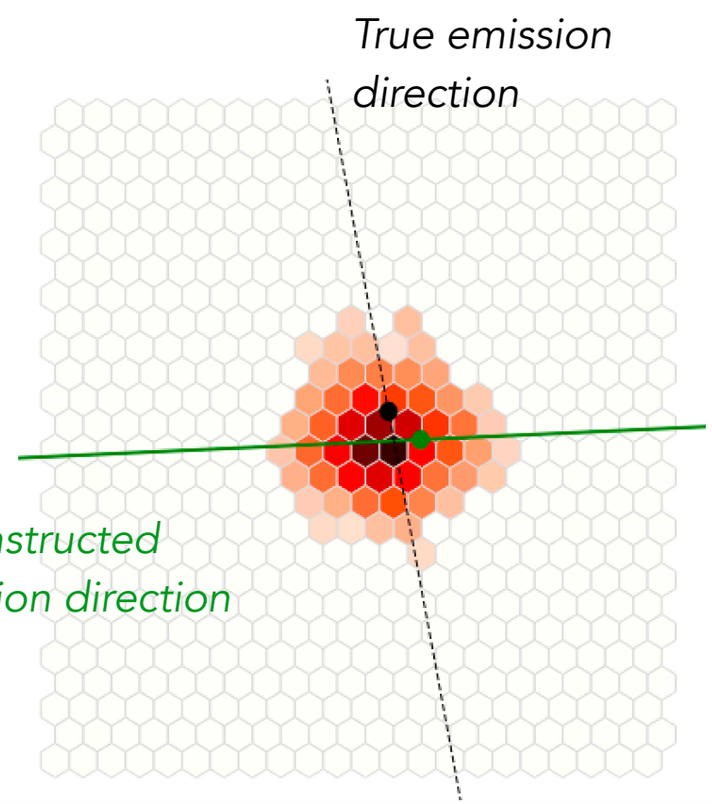
4. Re-determination of the second moment of charge distribution, this time respect to the predicted impact point

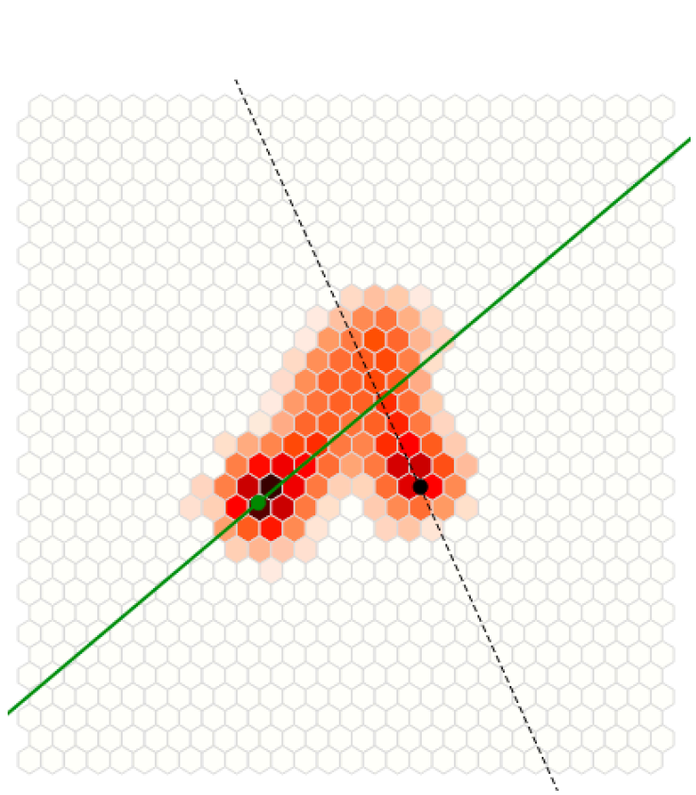
$$M_2'(\phi) = \frac{\sum_i w_i[(x_i - x_{IP})\cos(\phi) + (y_i - y_{IP})\sin(\phi)]^2}{\sum_i w_i}$$



Examples

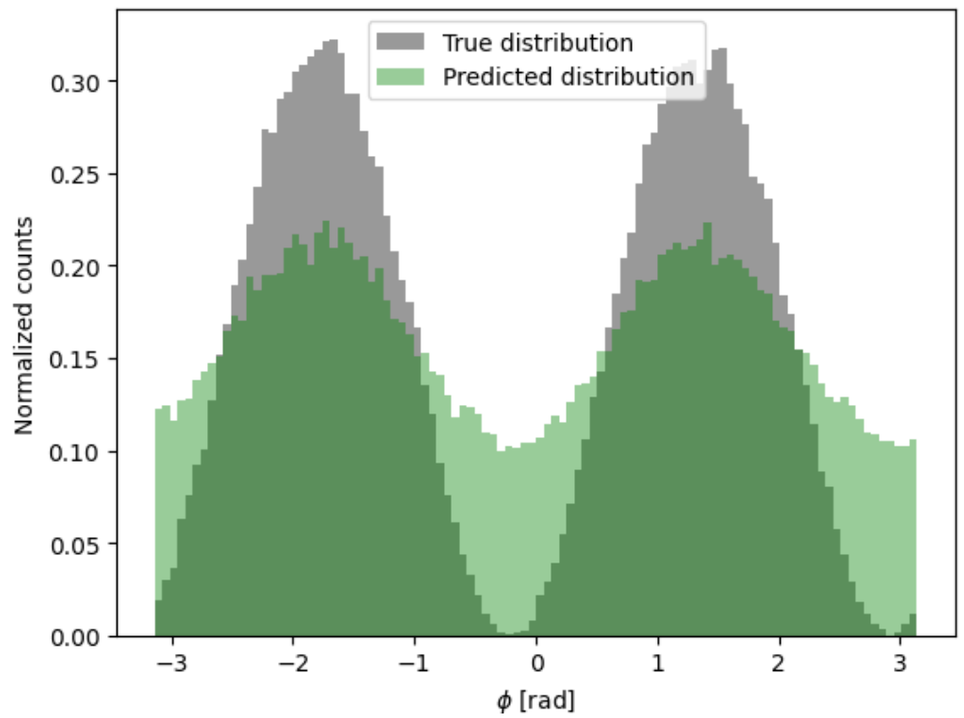




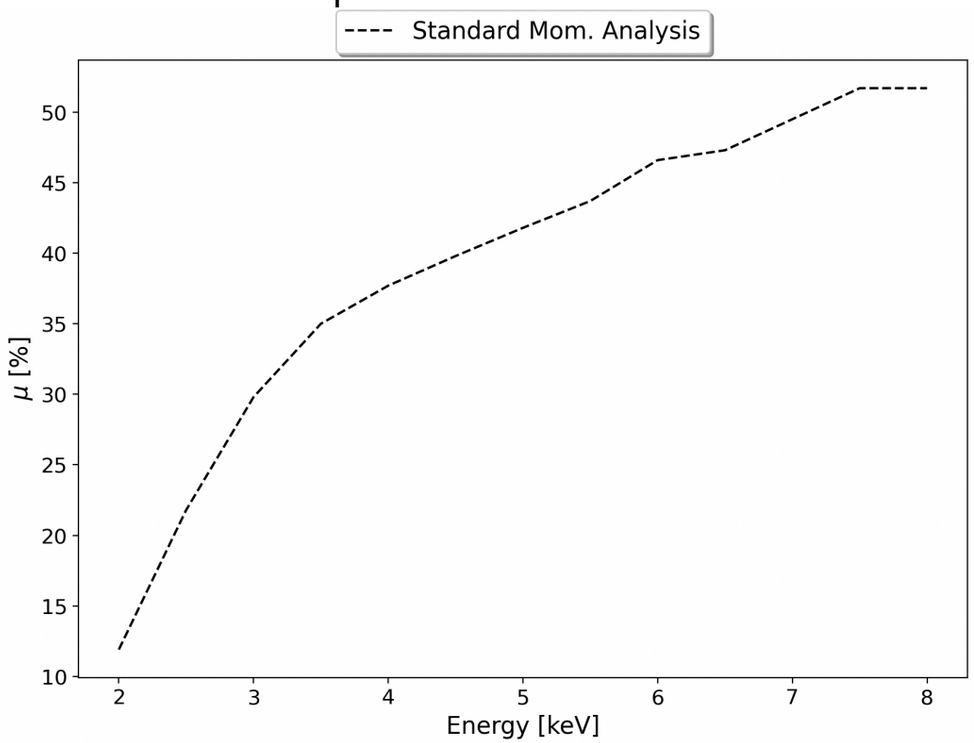


The reconstruction of the emission angle ϕ depends on the quality of the impact point reconstruction

Imperfect reconstruction: implication

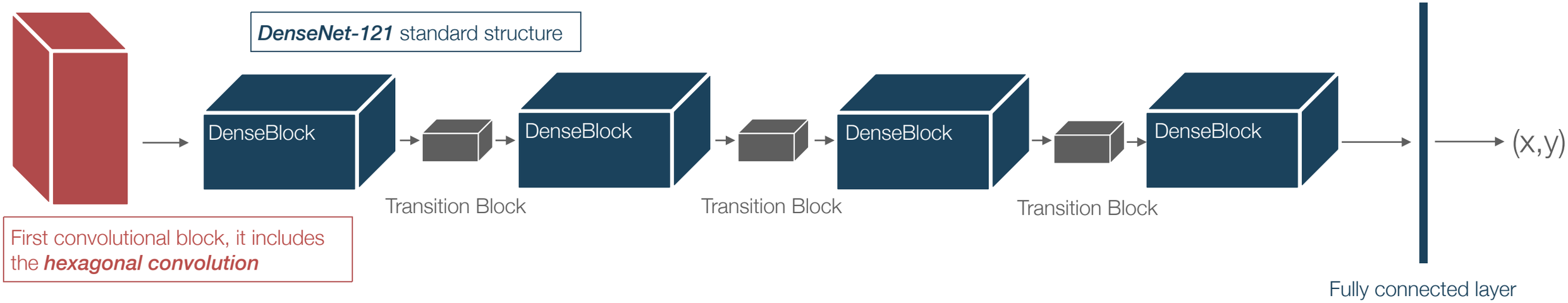


Modulation factor: reconstructed polarization fraction for a 100% polarized beam



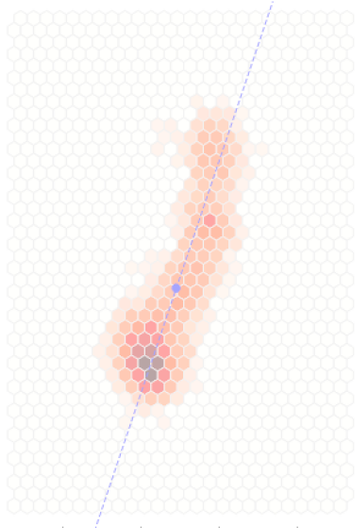
Hybrid algorithm: joining CNN and moment analysis

We developed a network specifically for the impact point reconstruction

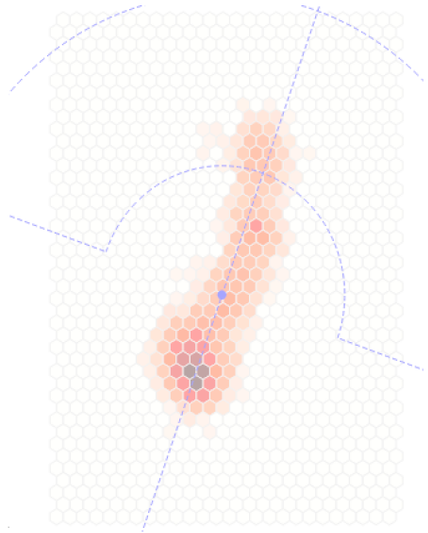


The CNN-predicted impact point replaces the one predicted by the standard moment analysis

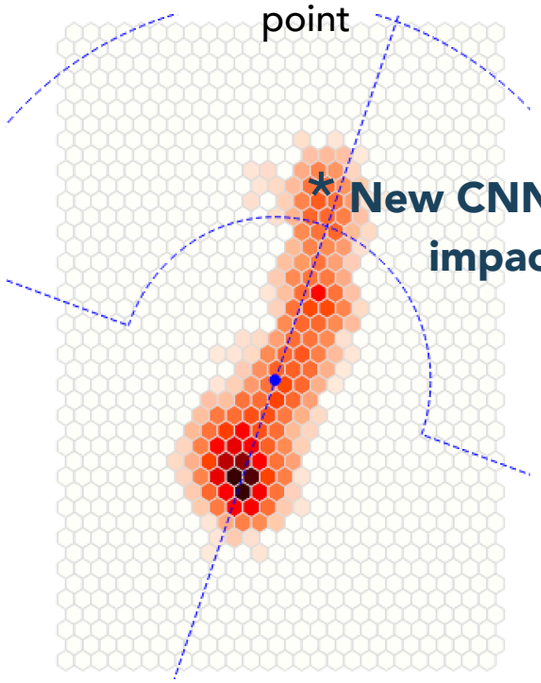
1. Barycenter and second moment of the charge distribution



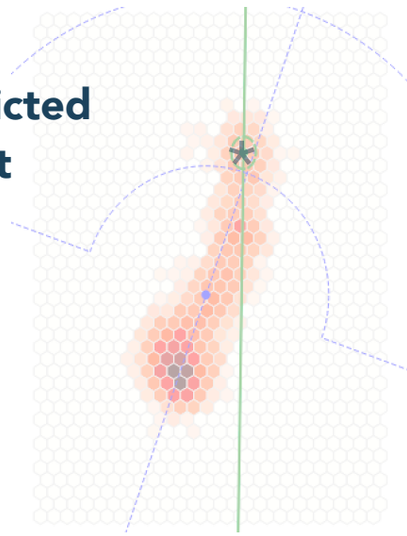
2. Identification of the initial part of the track



3. Reconstruction of the impact point



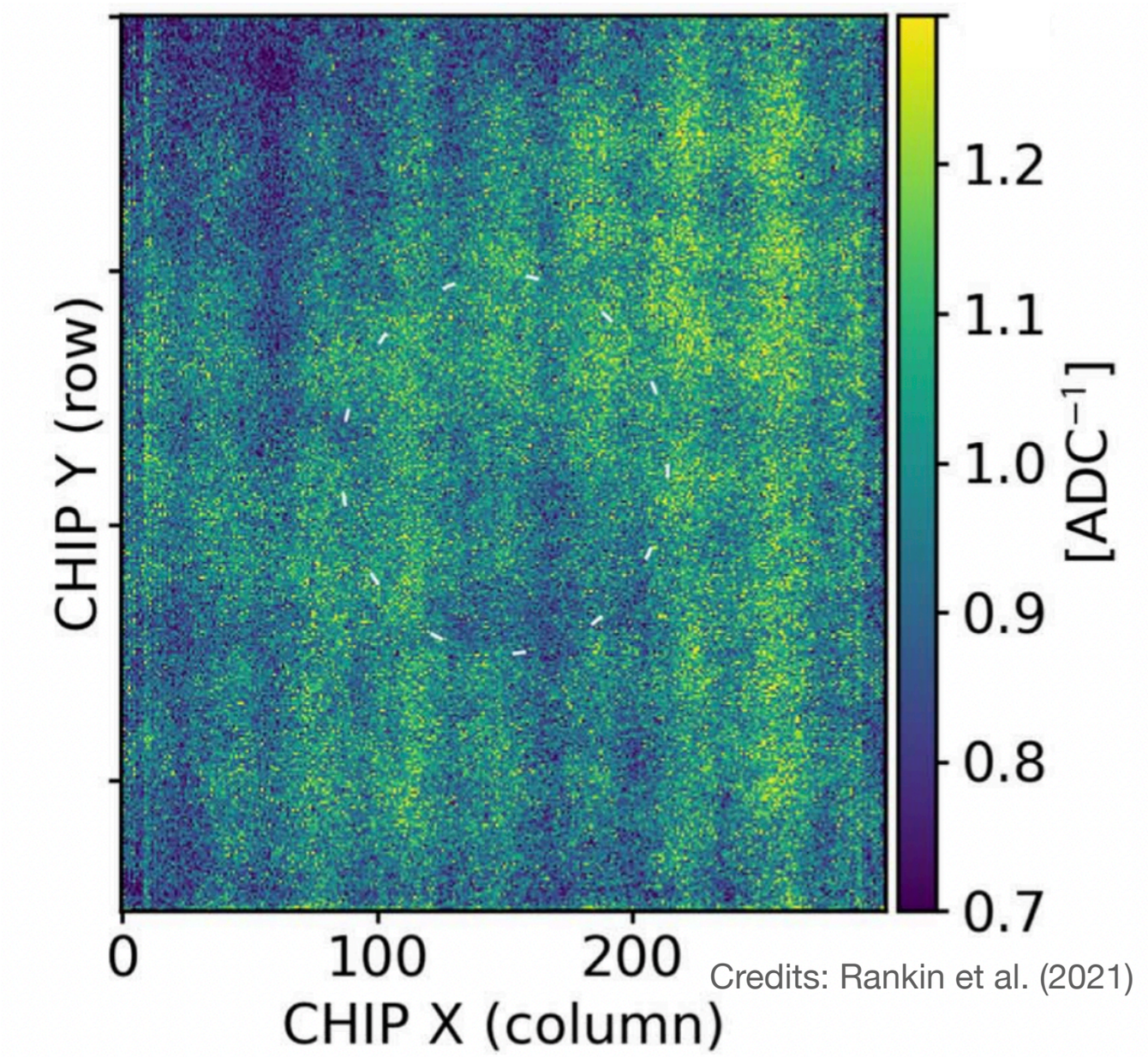
4. Reconstruction of the emission direction



Calibration before flight

GPDs were calibrated at IAPS in Rome.

As is common in detectors made of pixels, the different pixels have a different gain.



Credits: Rankin et al. (2021)

Calibration before flight

Before measuring the response to polarized light, it is crucial to verify the response to unpolarized light.

UNPOLAIRZED BEAMS:

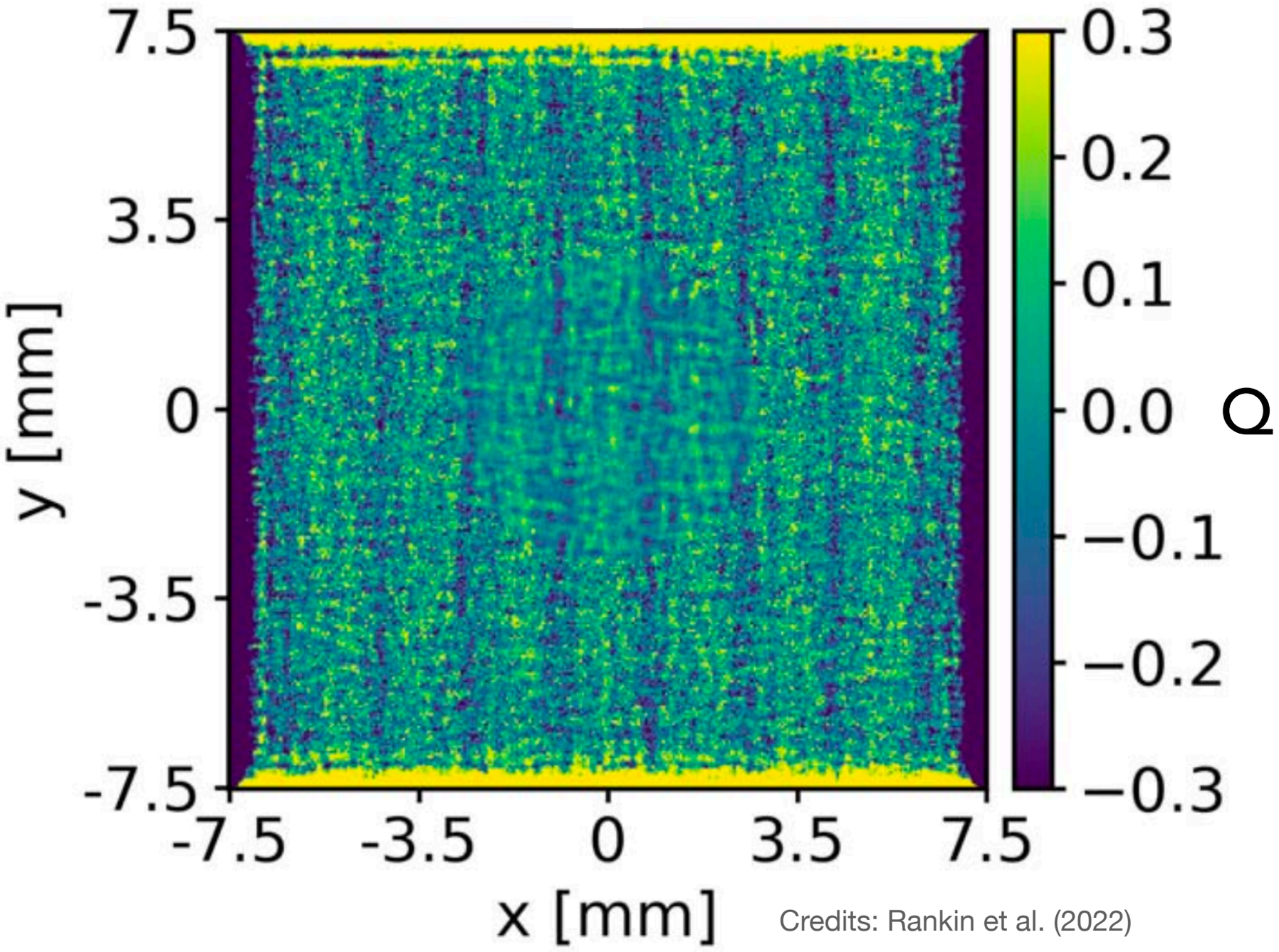
Configuration	Energy [keV]
Fluorescence of Zr target illuminated by Rh anode	2.04
Fluorescence of Mo target illuminated by Ag anode	2.29
Direct X-rays with Rh anode	2.70
Direct X-rays with Ag anode	2.98
Direct X-rays with Ca anode	3.69
^{55}Fe nuclide	5.89

Spurious modulation

When illuminated by unpolarized beams, the detected polarization is not 0!

Energy [keV]	Standard Moment Analysis μ [%]
2.04	1.5 ± 0.2
2.29	1.2 ± 0.2
2.70	1.6 ± 0.2
2.98	4.0 ± 0.2
3.69	0.8 ± 0.2

Calibration before flight



Credits: Rankin et al. (2022)