Recoil-proton track reconstruction techniques for tracking fast neutrons

Samuele Lanzi, on behalf of the RIPTIDE project

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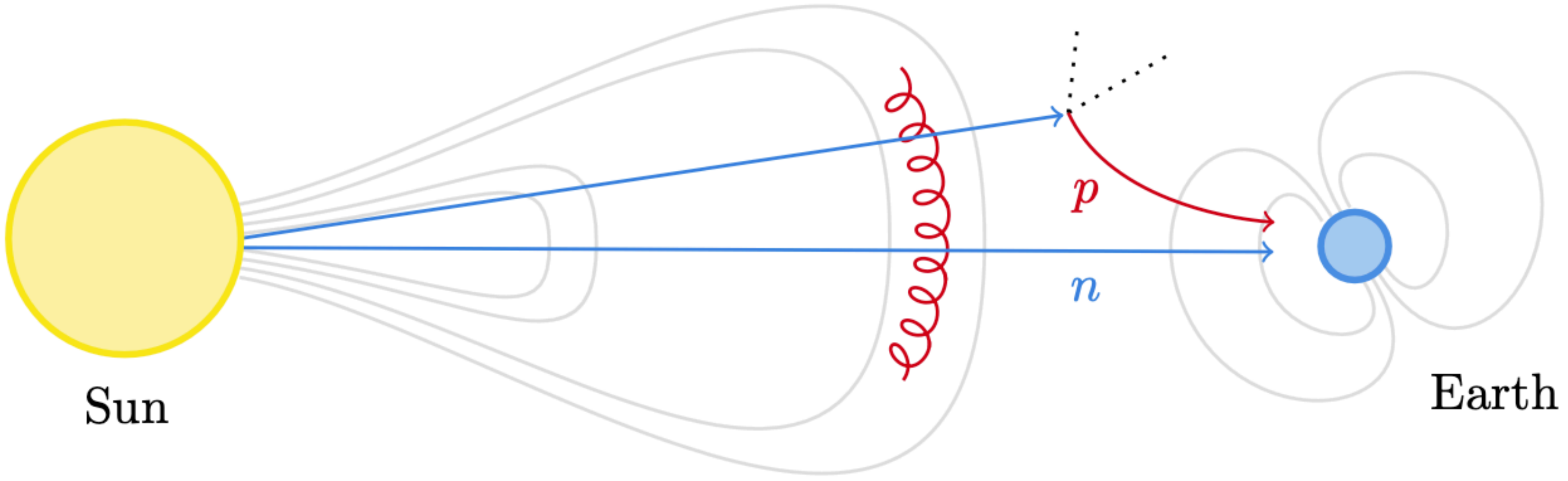
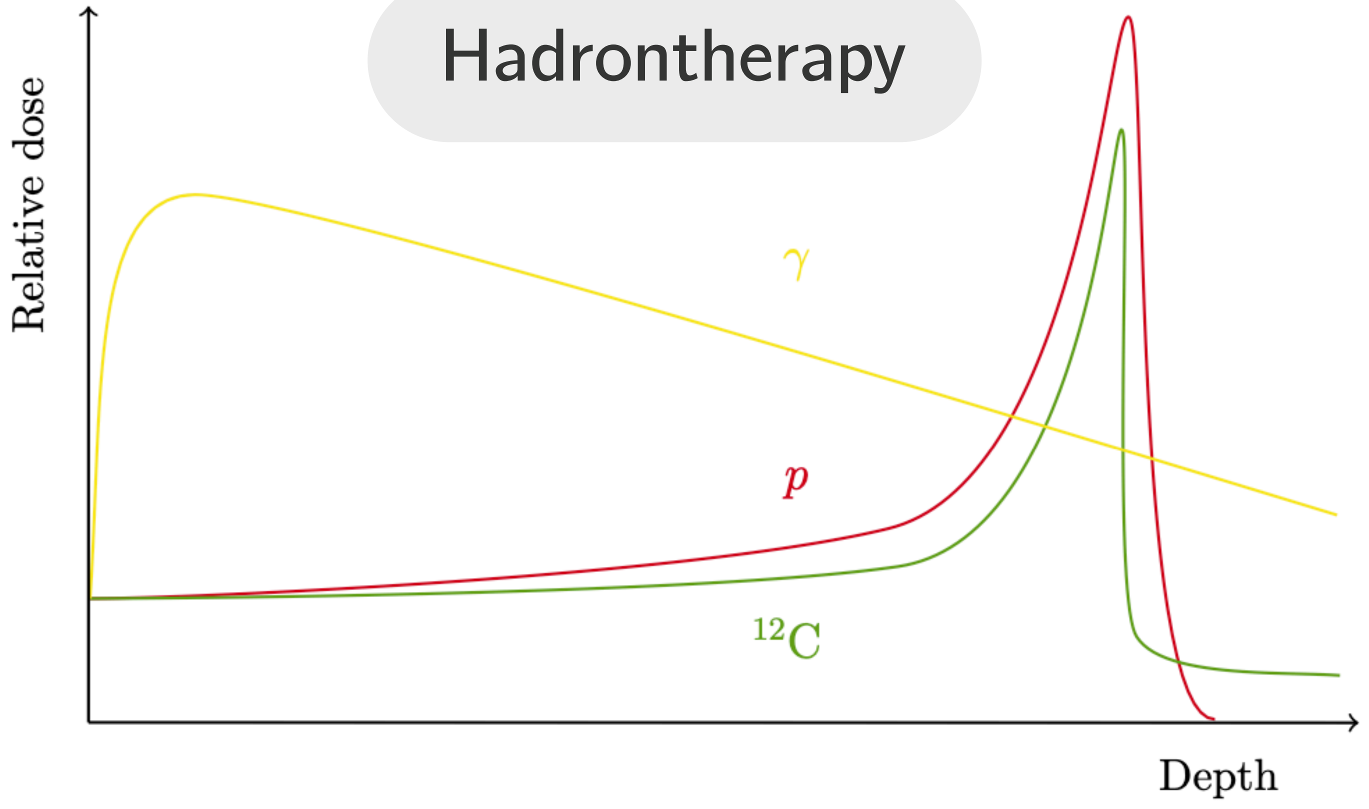
Scientific motivations

Solar neutrons

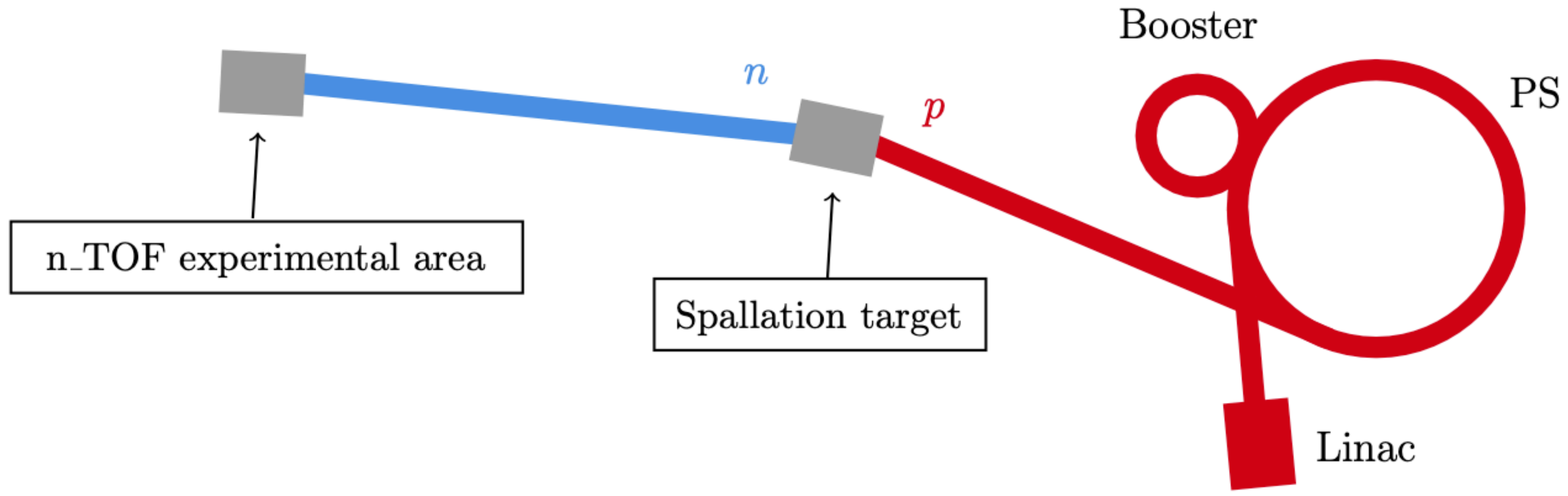


Hadrontherapy

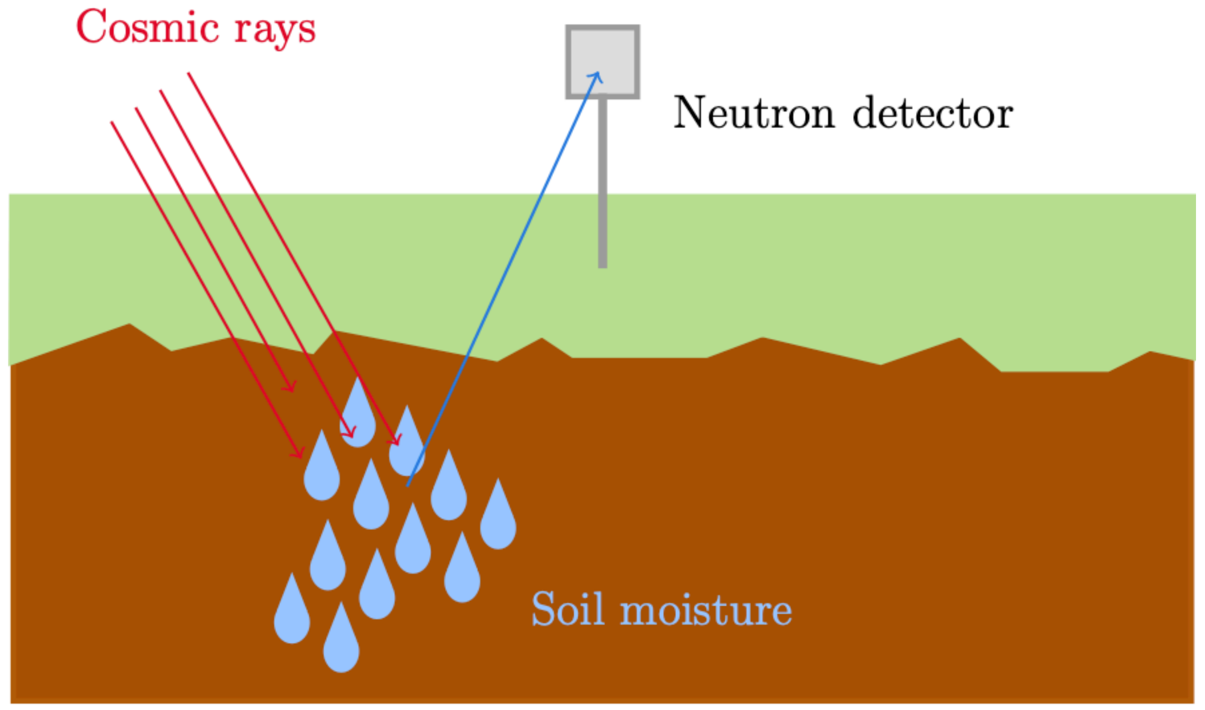


Space radio-protection

Neutron detectors are an essential tool for the development of many research fields



Nuclear physics

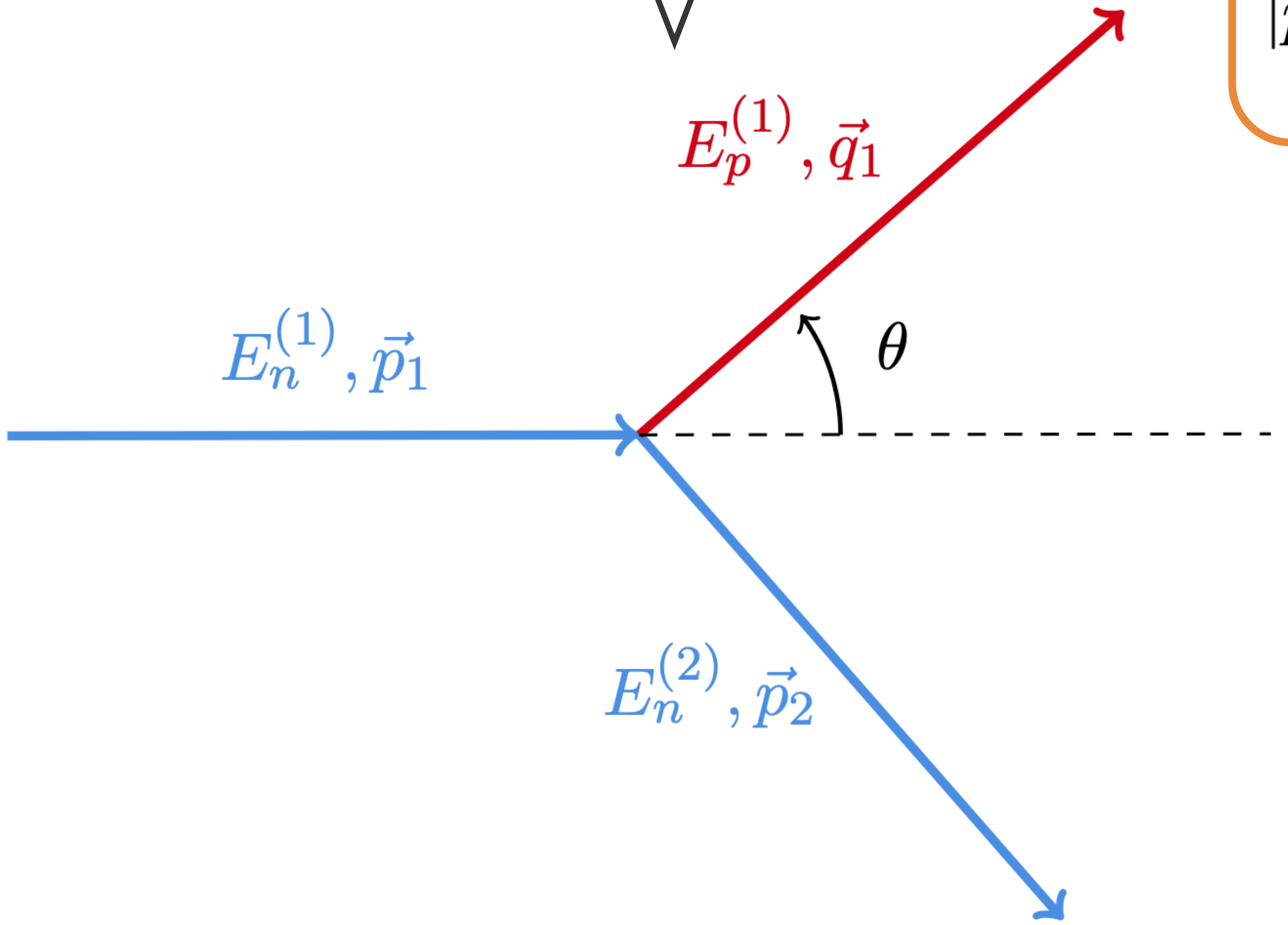


Agriculture

Recoil proton track imaging techniques

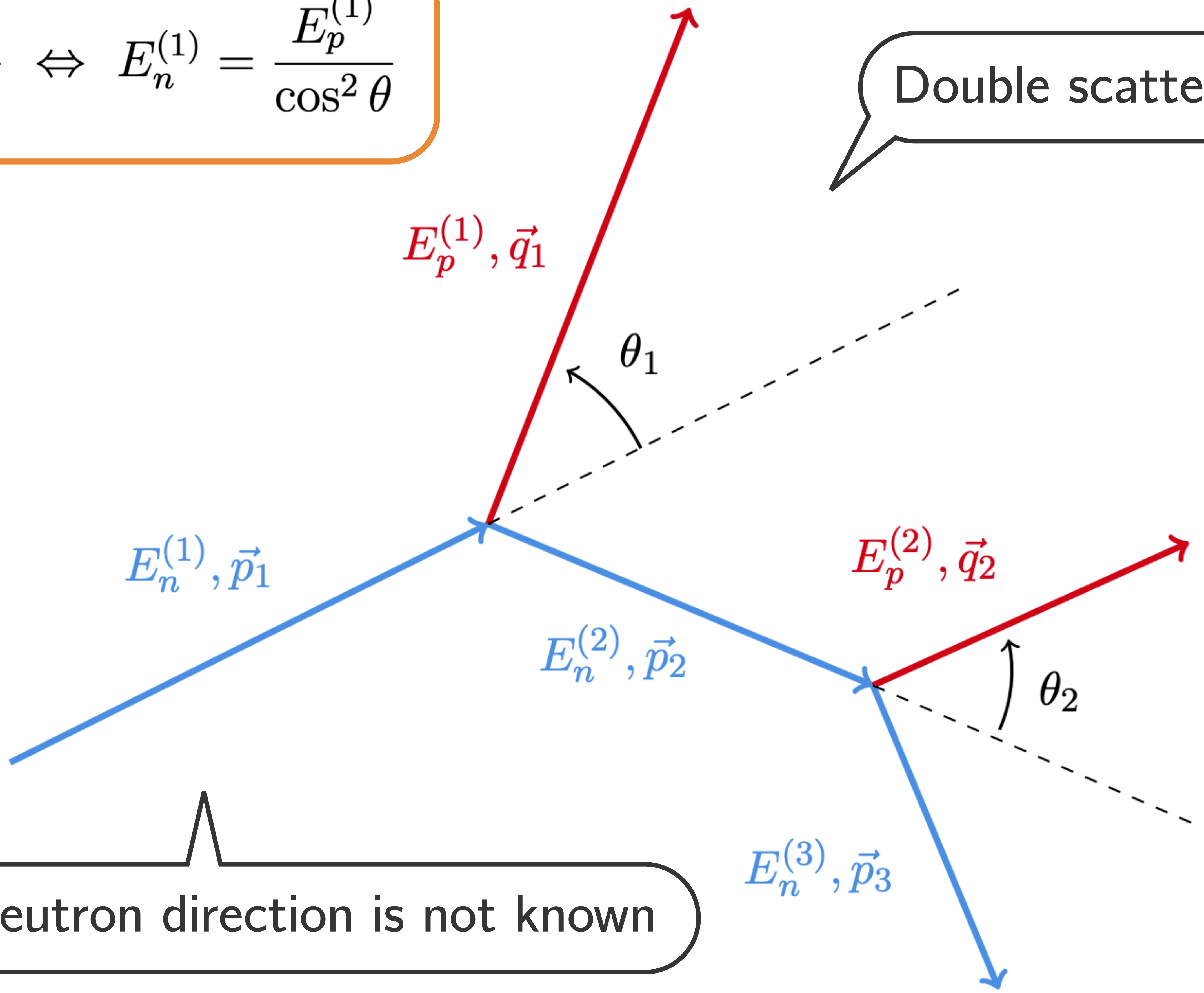
Single scattering (n-p)

$$|\vec{p}_1| = \frac{|\vec{q}_1|}{\cos\theta} \Leftrightarrow E_n^{(1)} = \frac{E_p^{(1)}}{\cos^2\theta}$$



Fast neutrons make mainly elastic scattering with protons

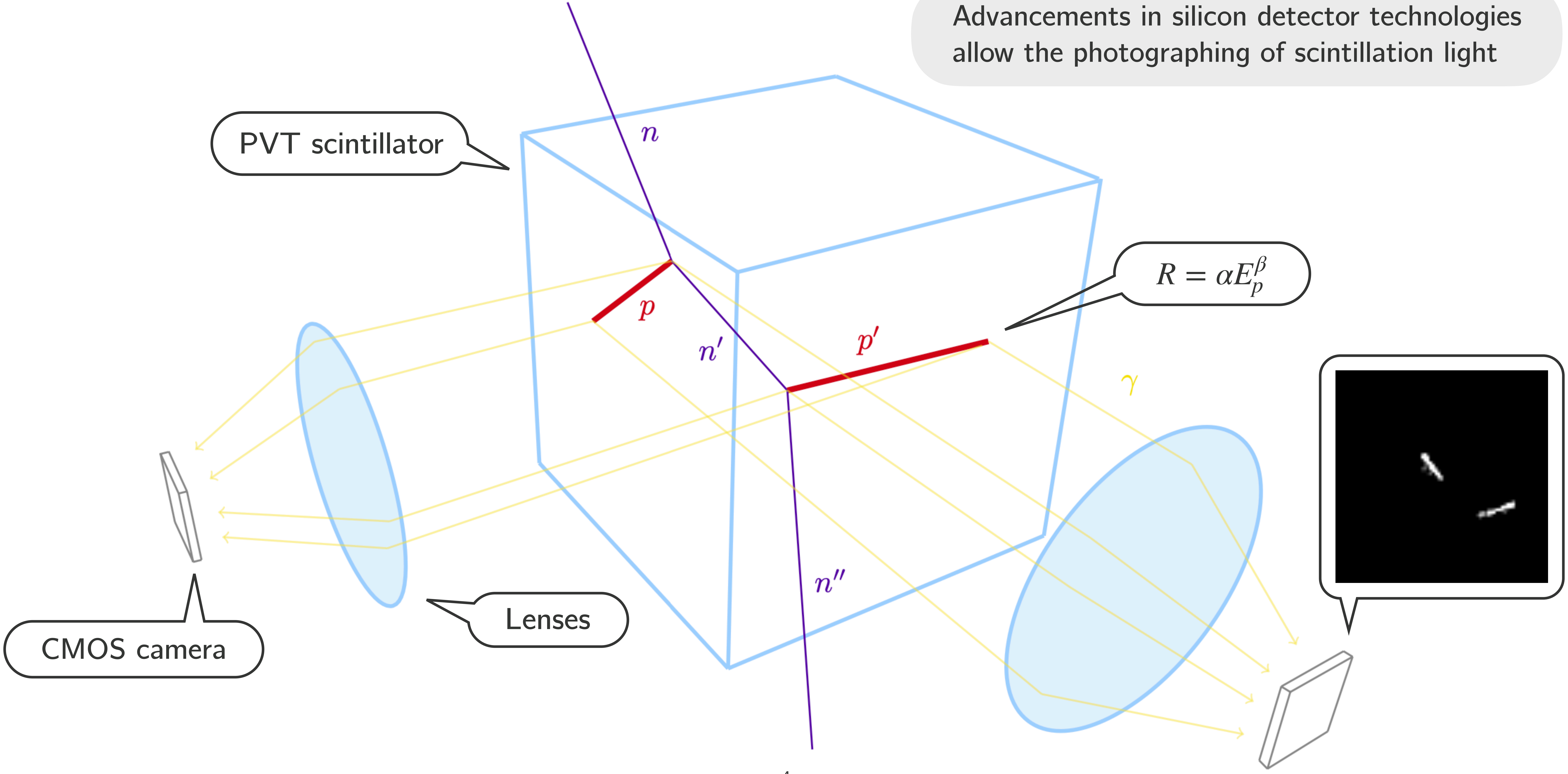
Double scattering



If neutron direction is not known

RIPTIDE detector

Advancements in silicon detector technologies allow the photographing of scintillation light



Momentum from projections

Monte Carlo data

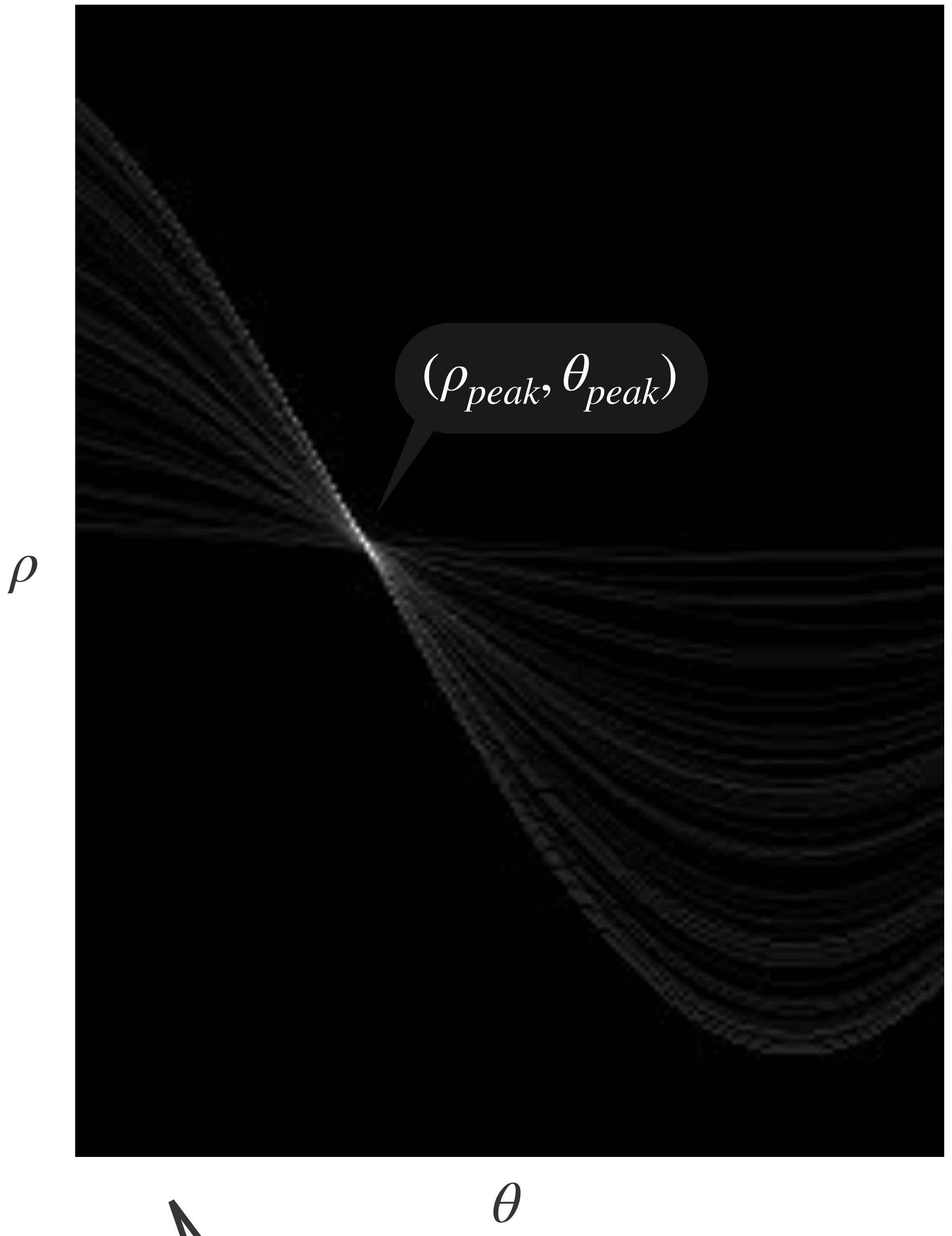
+YZ +XZ

1. Direction
2. Verse
3. Magnitude

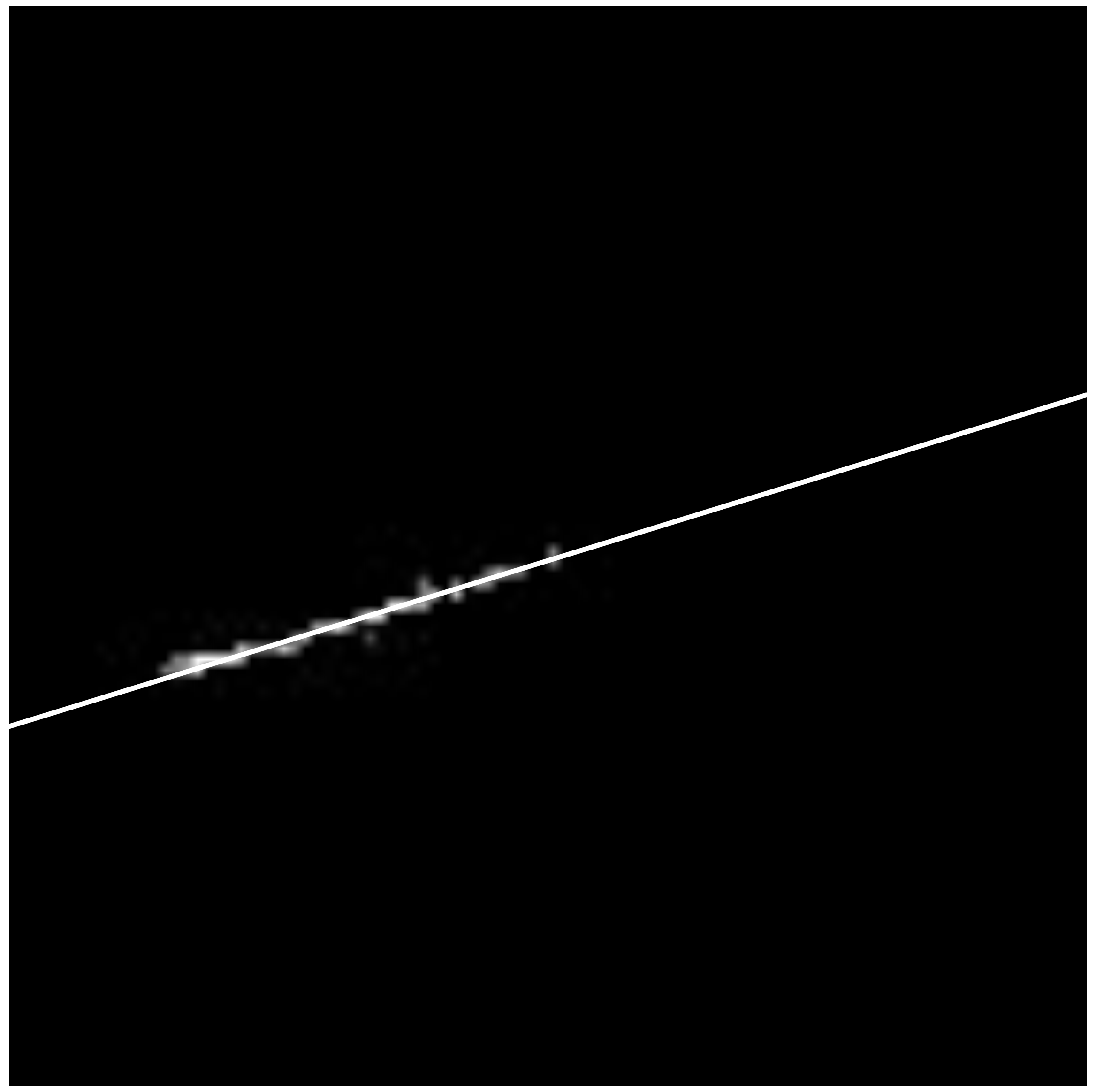
Momentum from projections - Direction

Each (u, v) can be transformed using: $\rho = u \cos\theta + v \sin\theta$

Find the 2d direction of the projected tracks with Hough transform



Fill the (ρ, θ) space and find the peak



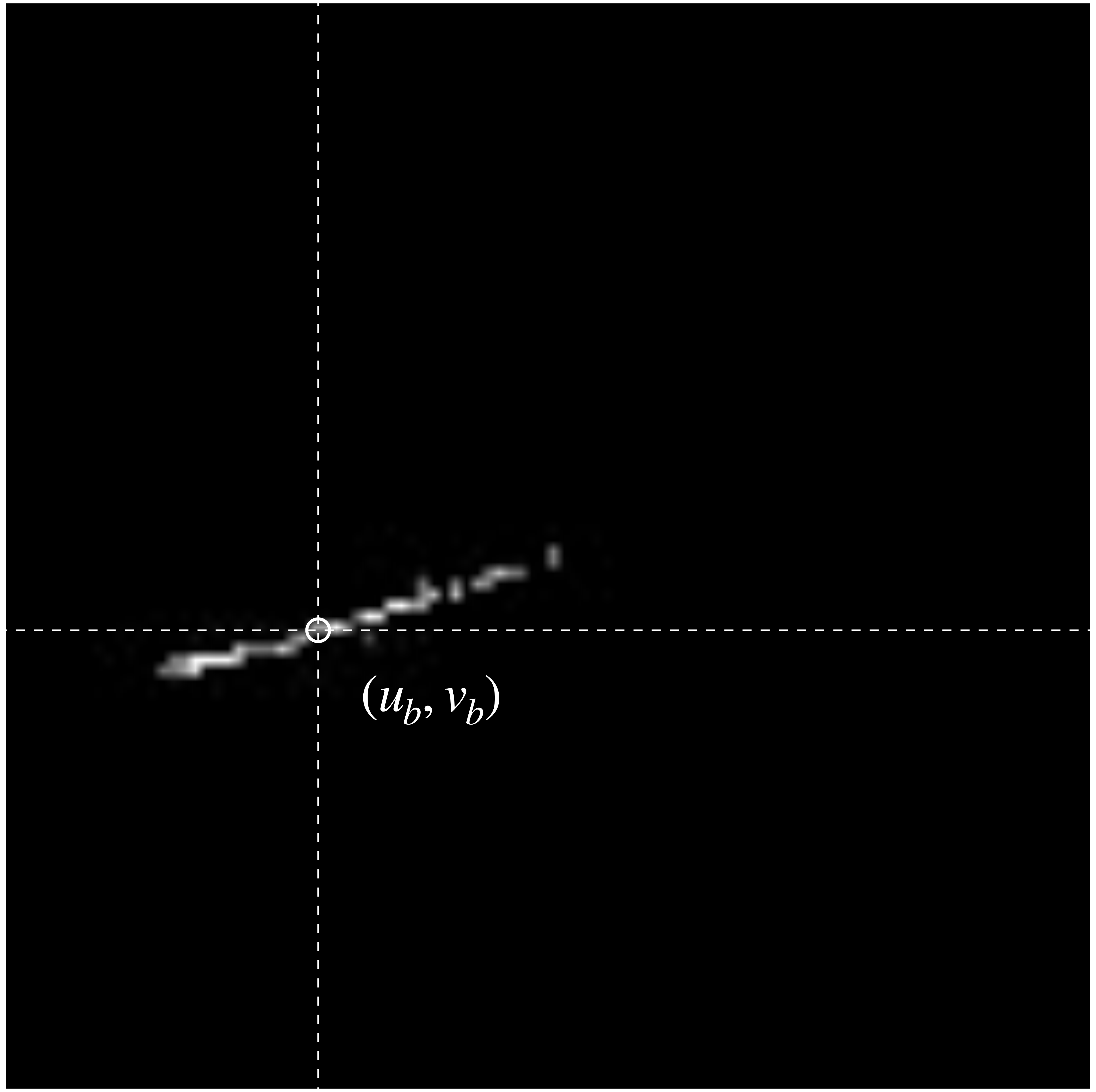
Resolve the ambiguity in the verse

Momentum from projections - Verse

Barycentre

$$(u_b, v_b) = \left(\frac{\sum_i w_i u_i}{\sum_i w_i}, \frac{\sum_i w_i v_i}{\sum_i w_i} \right)$$

$$u_i \rightarrow u_i - u_b \qquad v_i \rightarrow v_i - v_b$$



Momentum from projections - Verse

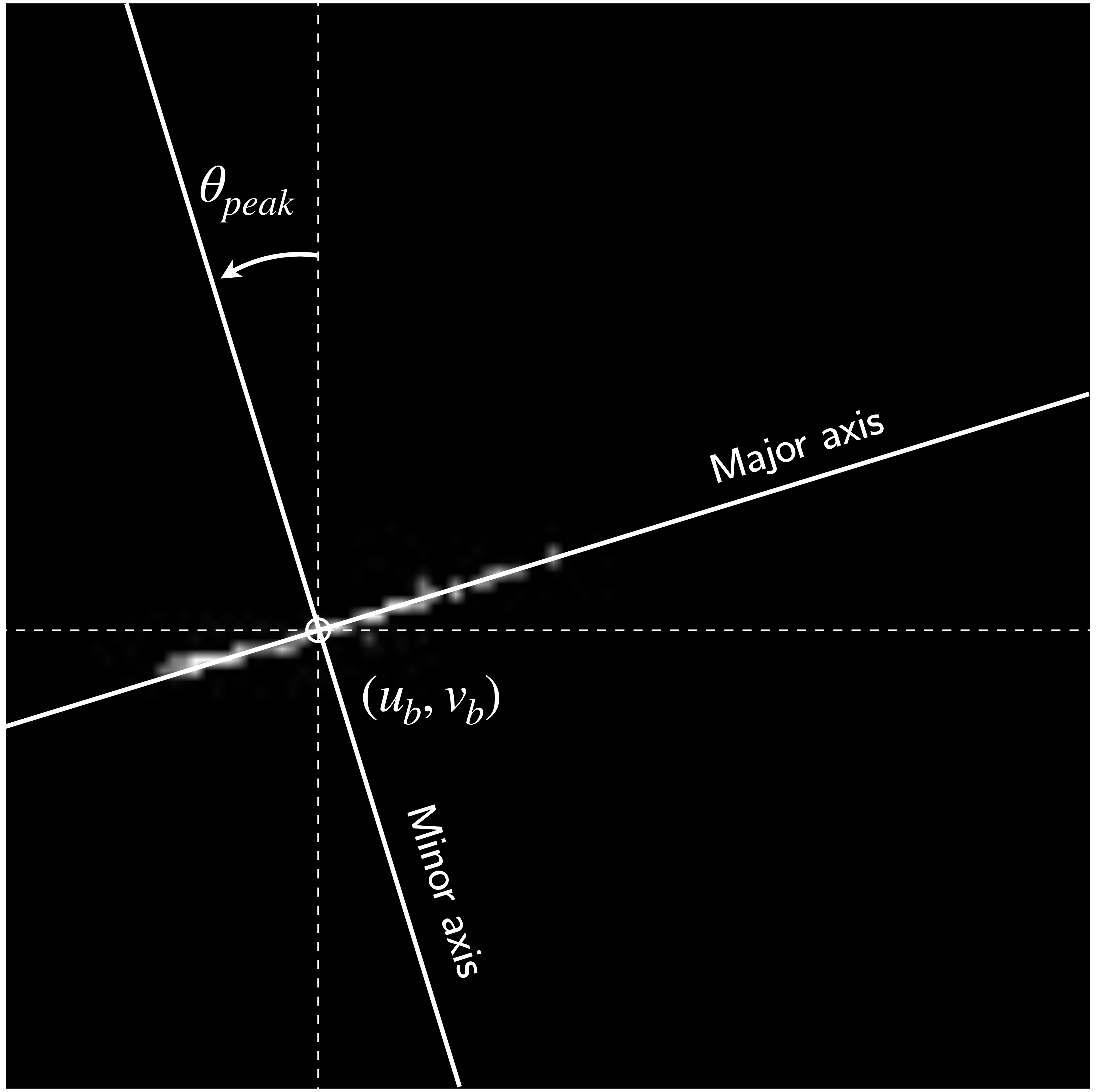
Barycentre

$$(u_b, v_b) = \left(\frac{\sum_i w_i u_i}{\sum_i w_i}, \frac{\sum_i w_i v_i}{\sum_i w_i} \right)$$

$$u_i \rightarrow u_i - u_b \qquad v_i \rightarrow v_i - v_b$$

Rotation

$$\begin{pmatrix} u_i'(\theta) \\ v_i'(\theta) \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} u_i \\ v_i \end{pmatrix}$$



Momentum from projections - Verse

Barycentre

$$(u_b, v_b) = \left(\frac{\sum_i w_i u_i}{\sum_i w_i}, \frac{\sum_i w_i v_i}{\sum_i w_i} \right)$$

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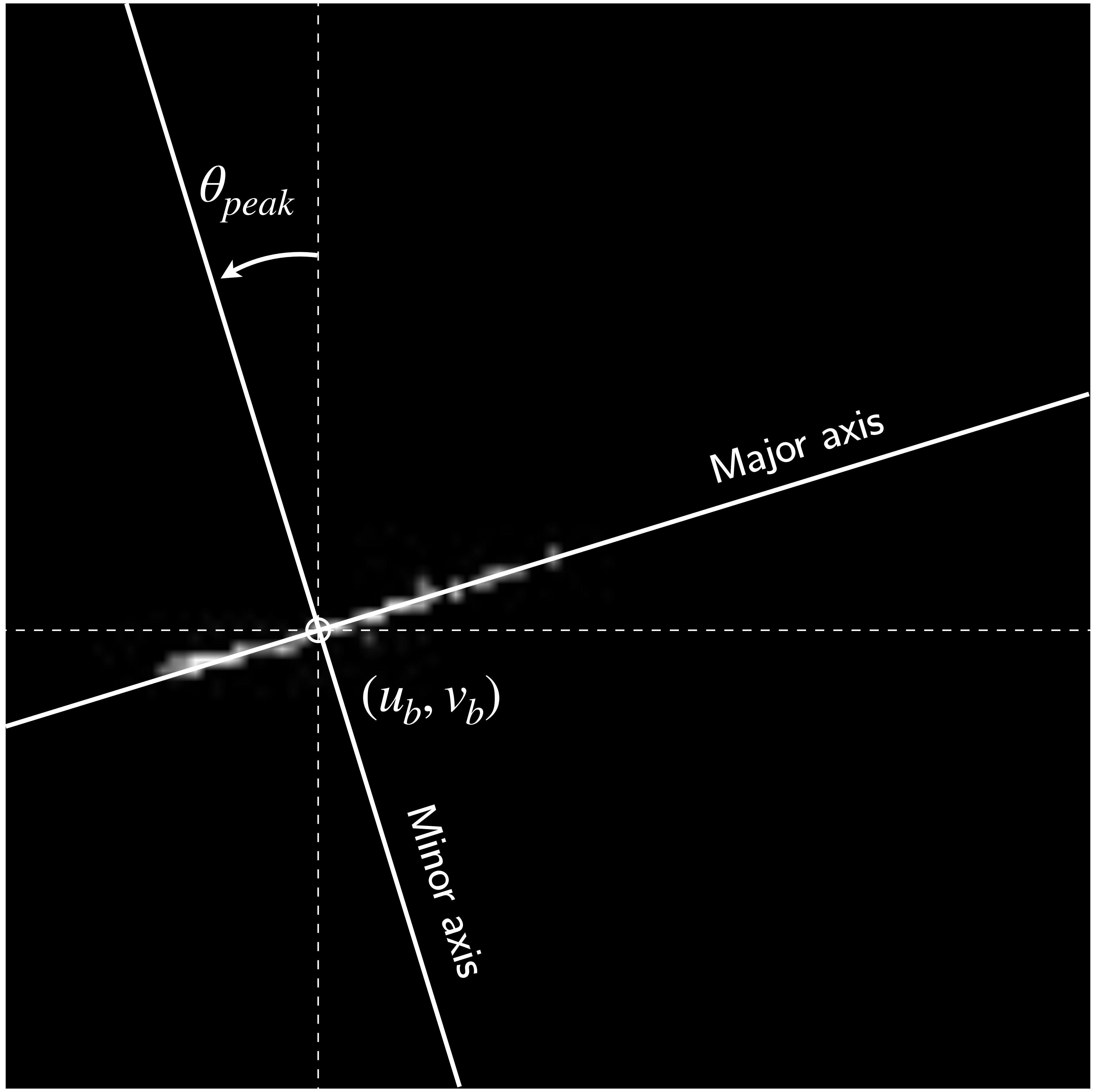
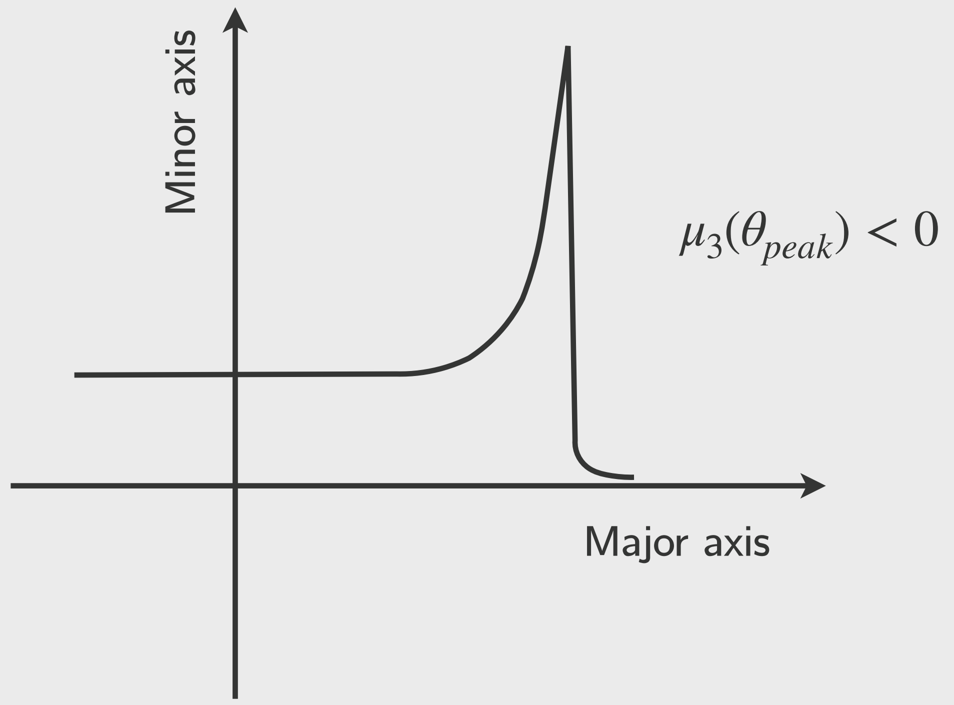
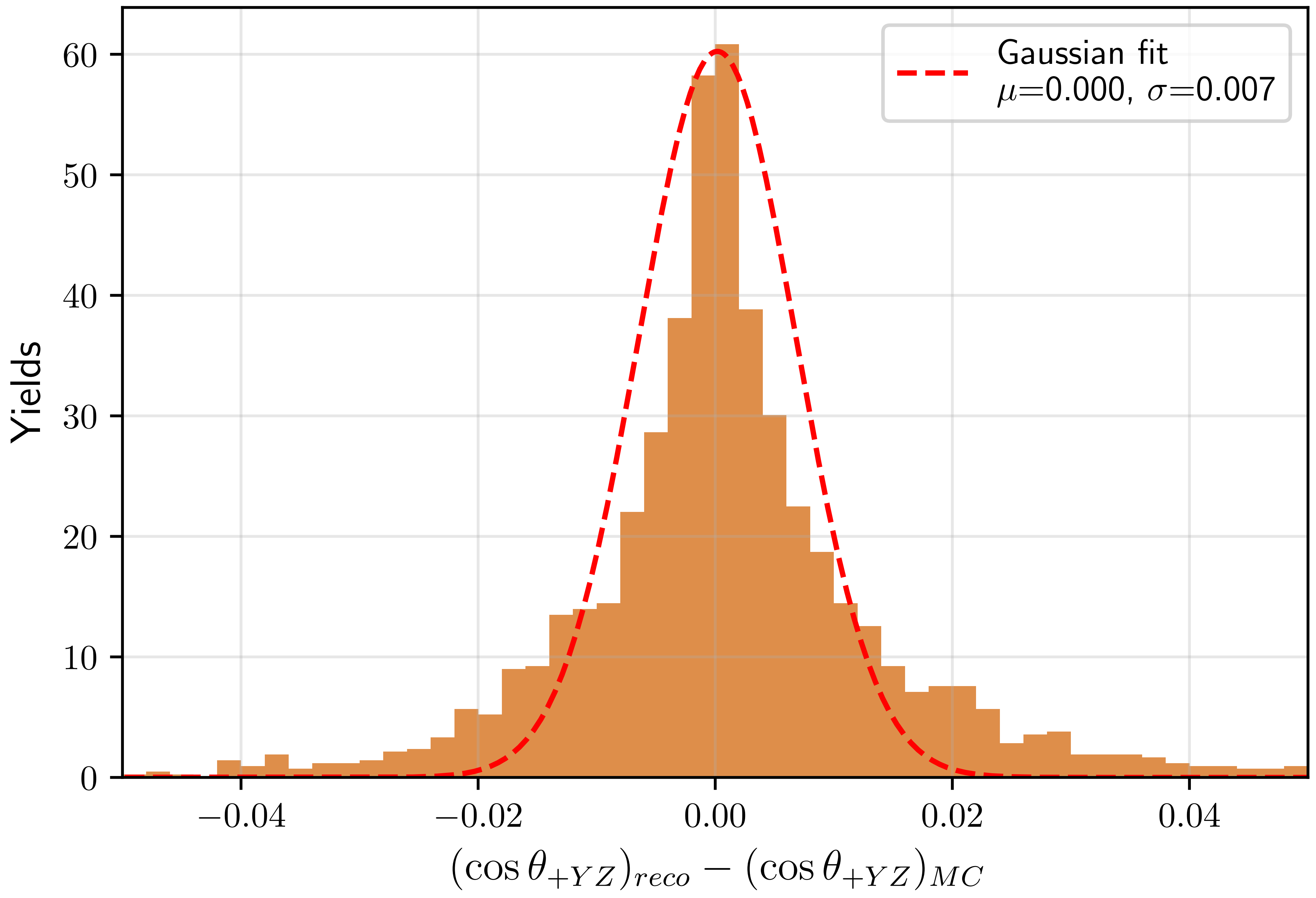


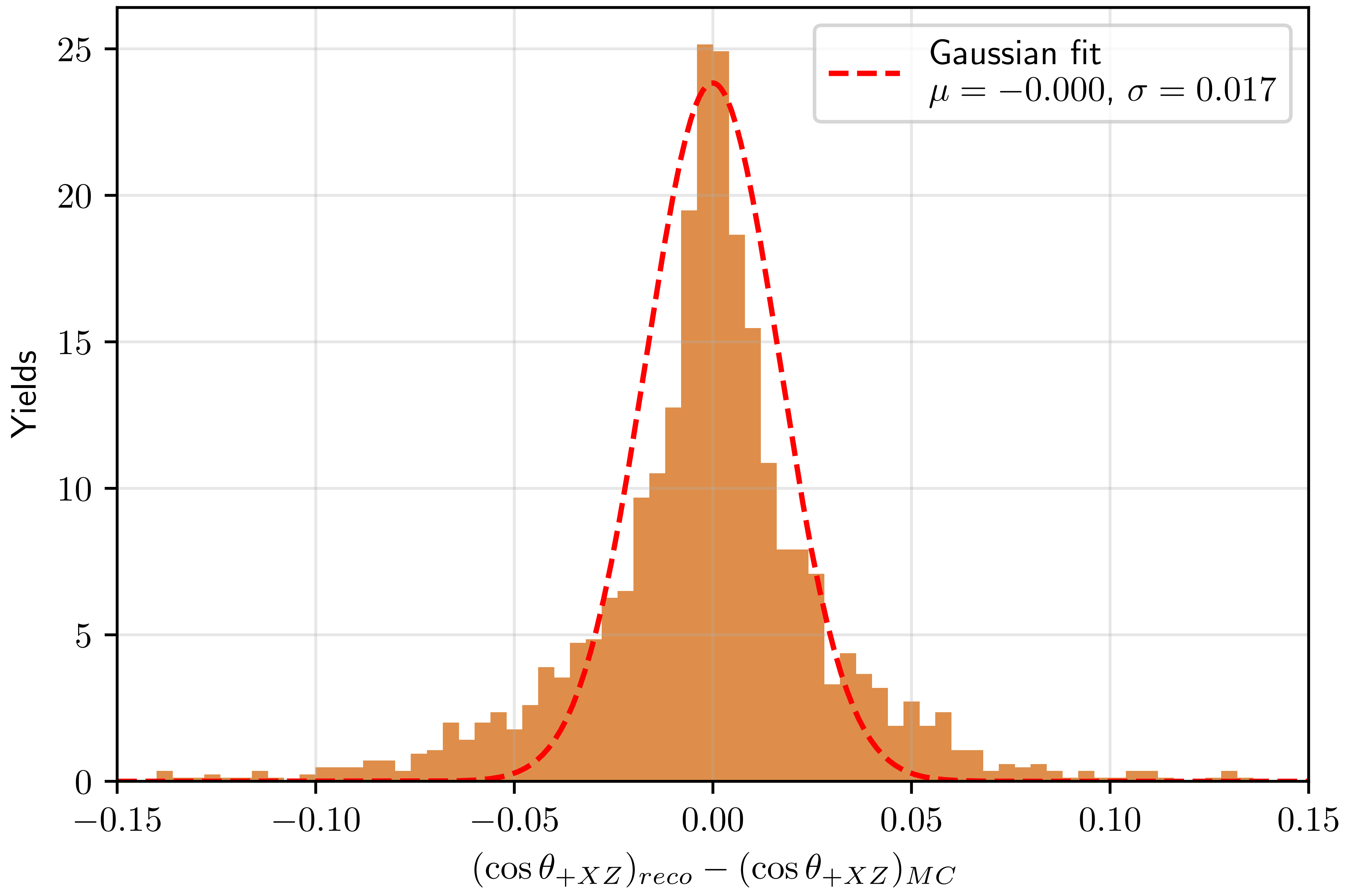
Skewness

$$\mu_3 = \frac{\sum_i w_i (u_i \cos\theta_{peak} + v_i \sin\theta_{peak})^3}{\sum_i w_i}$$



Momentum from projections - Direction reconstructed

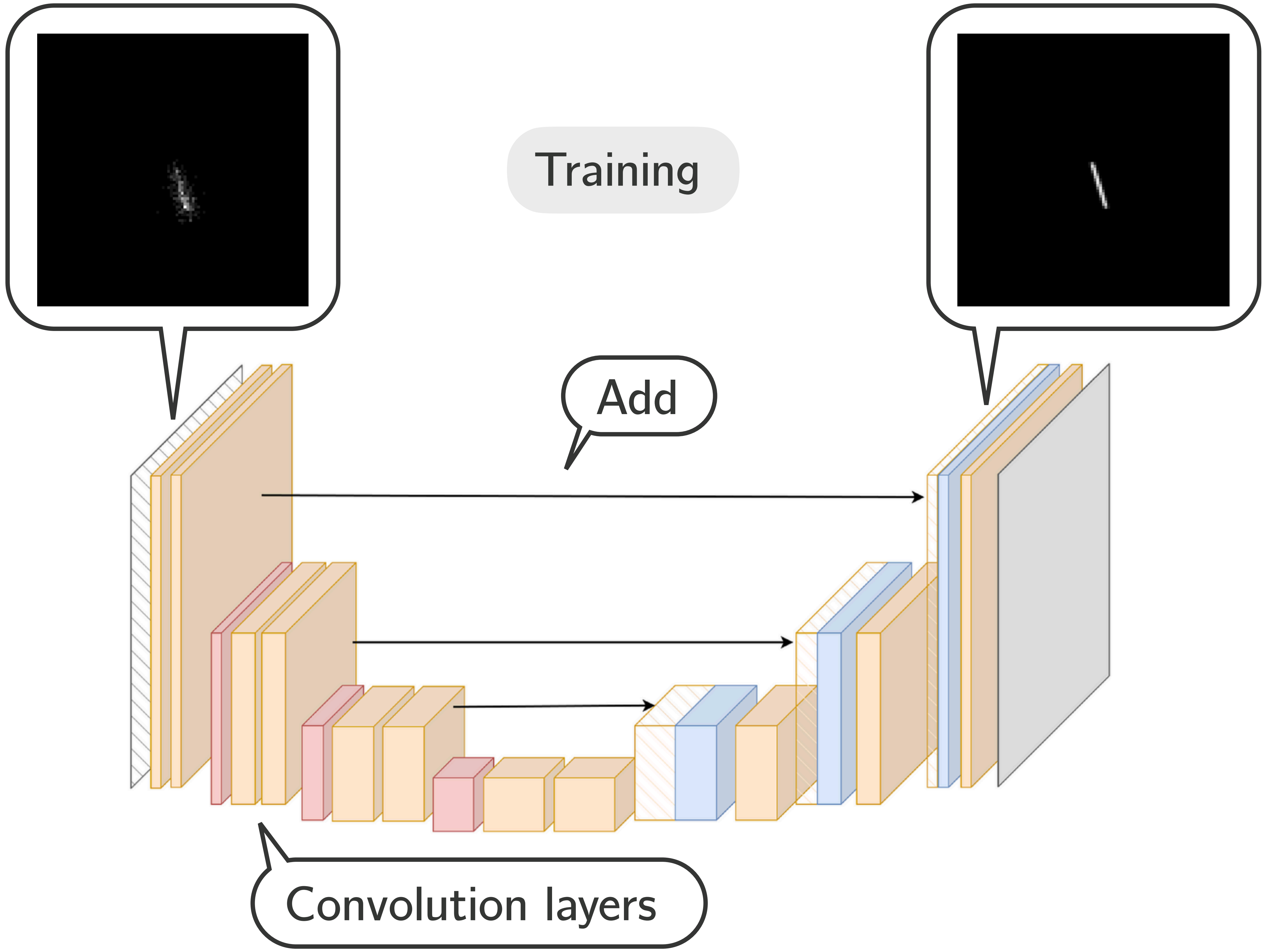


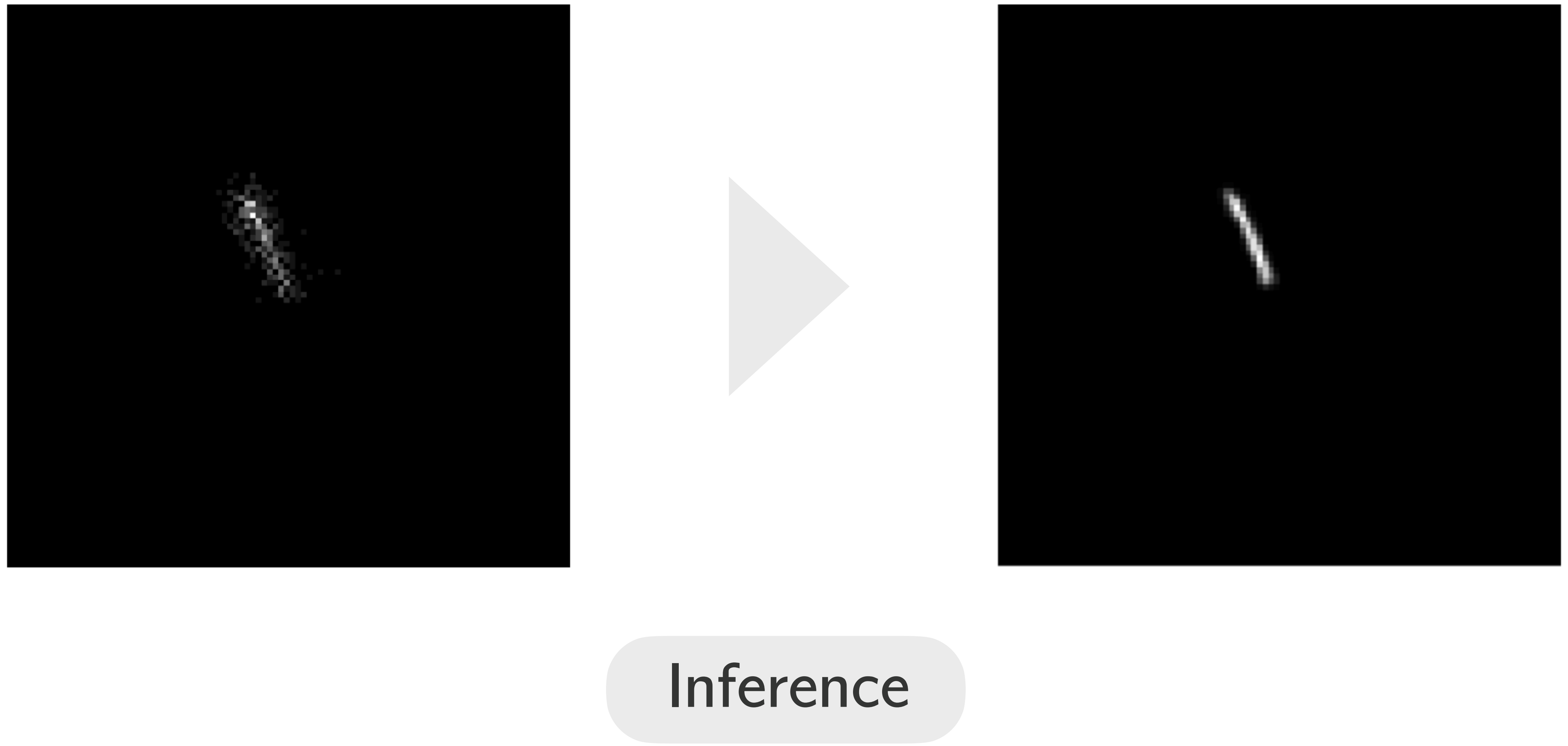


Reconstructed directions compared with MC directions

Momentum from projections - Magnitude

In order to remove aberrations in the range reconstruction a UNet is implemented





Momentum from projections - Magnitude

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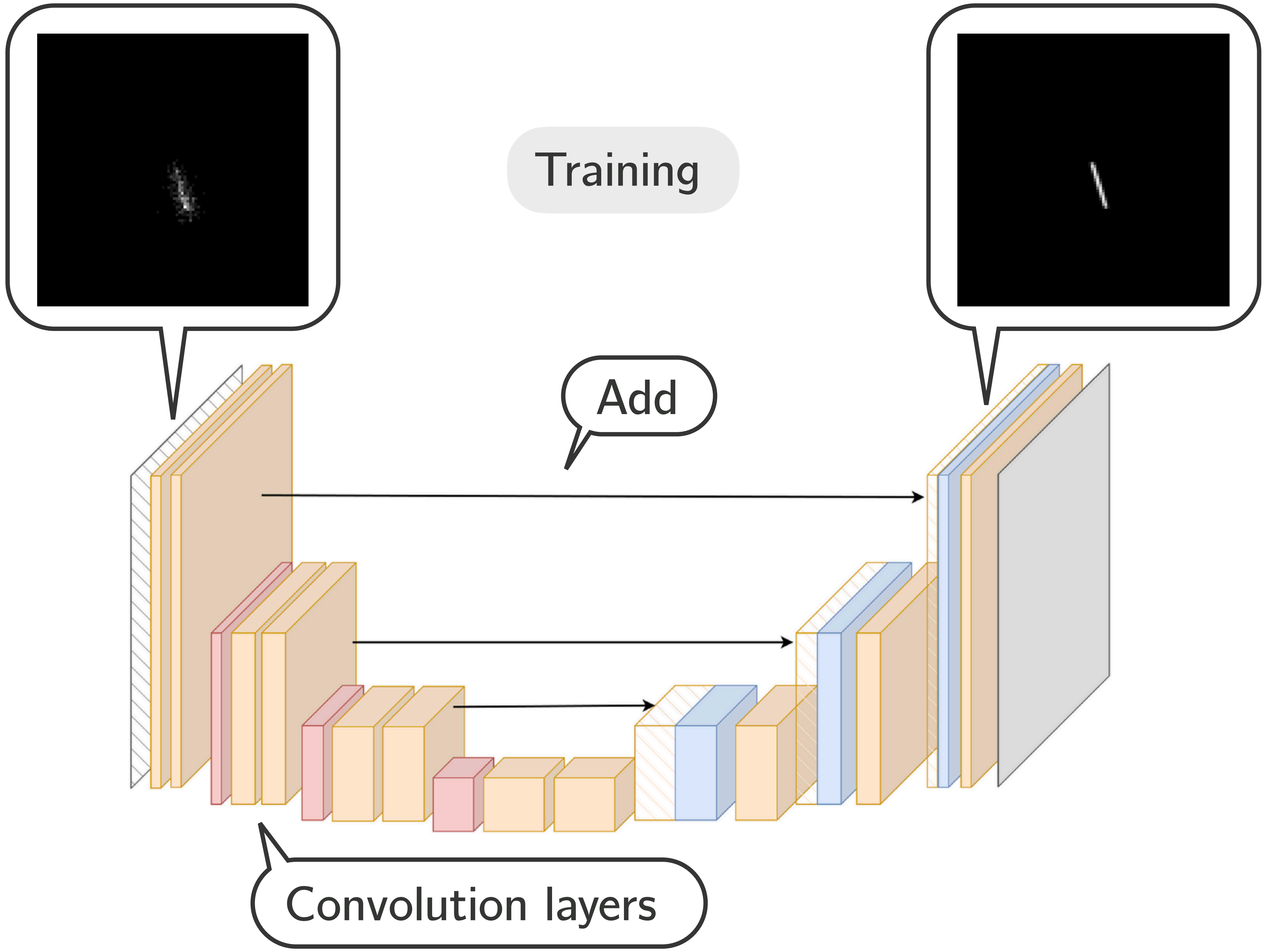
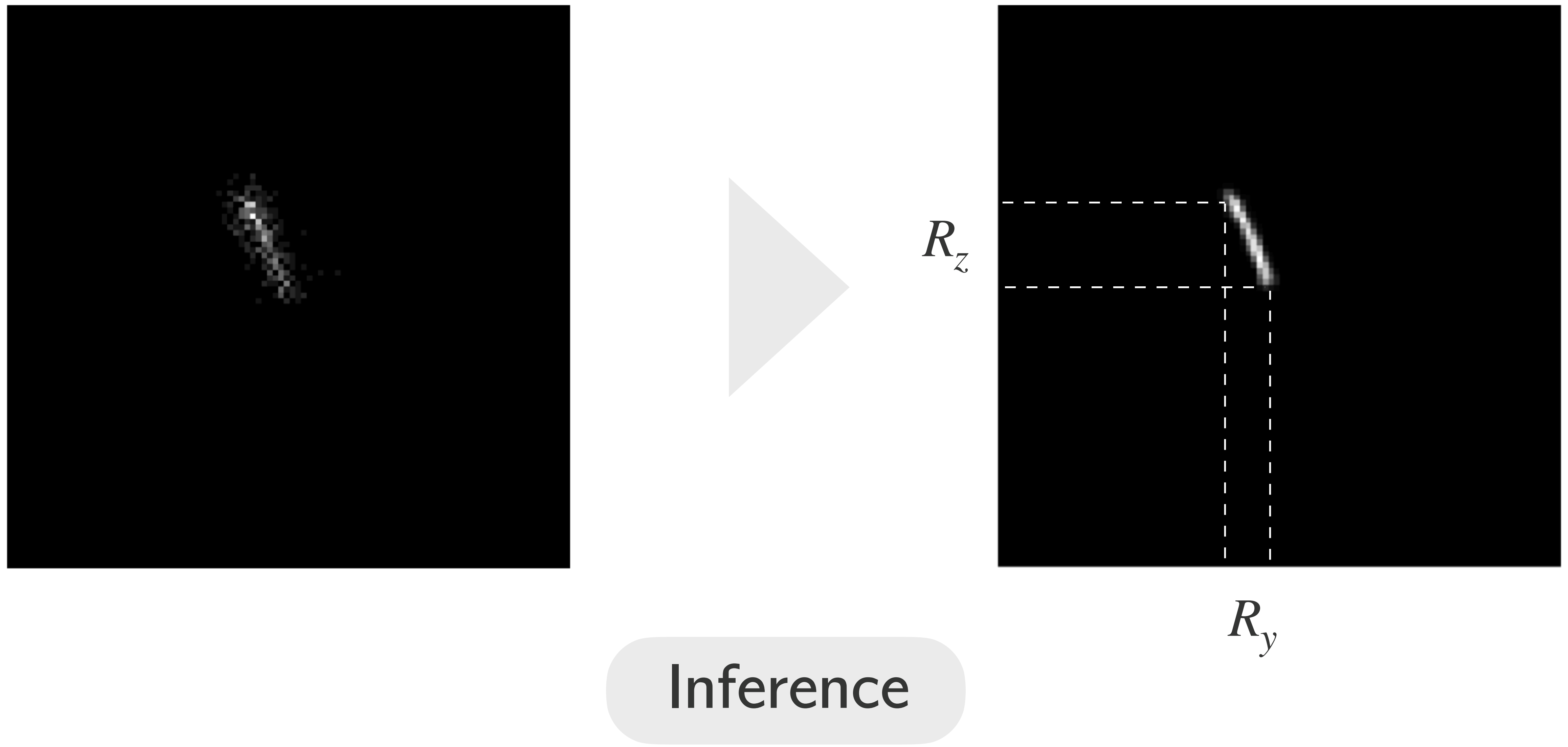
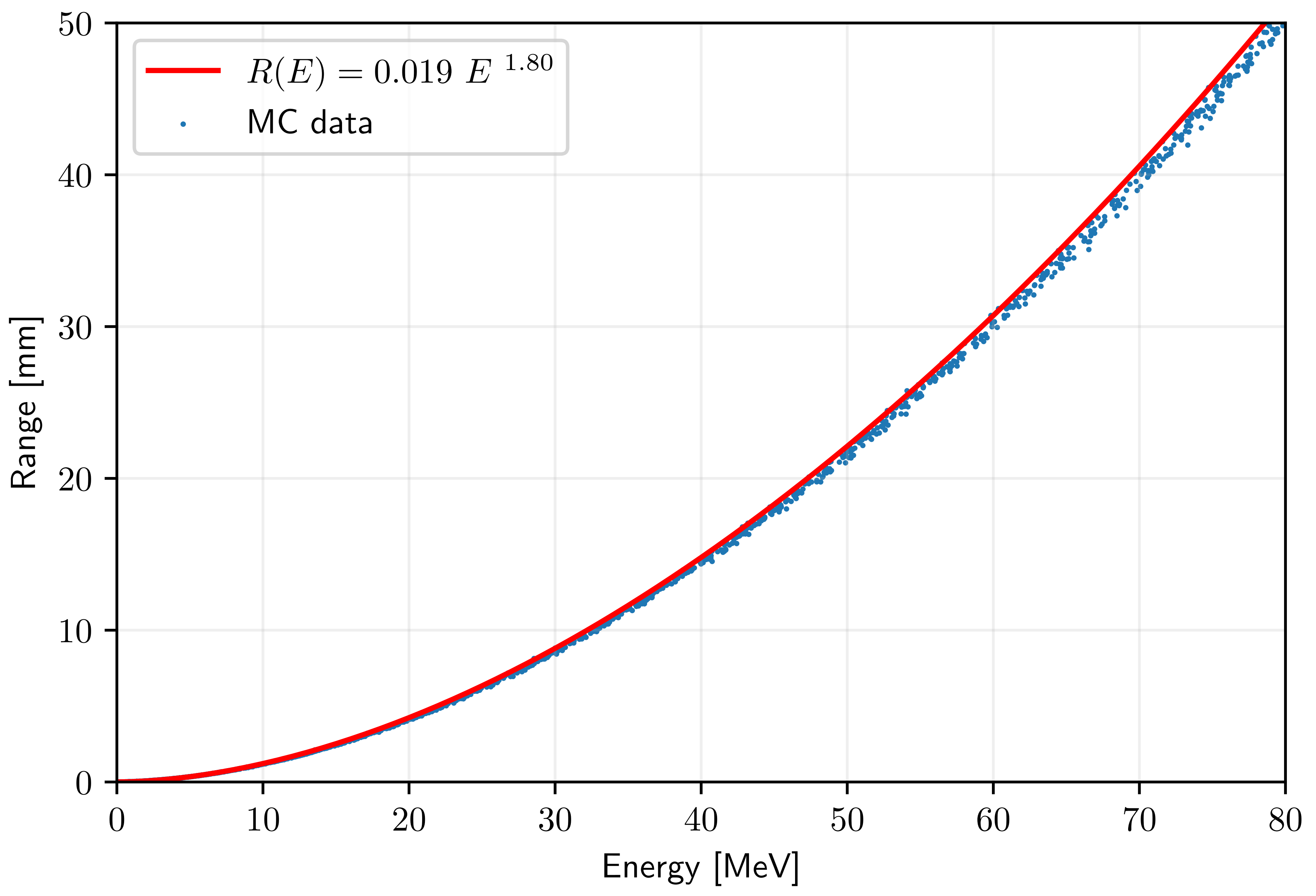


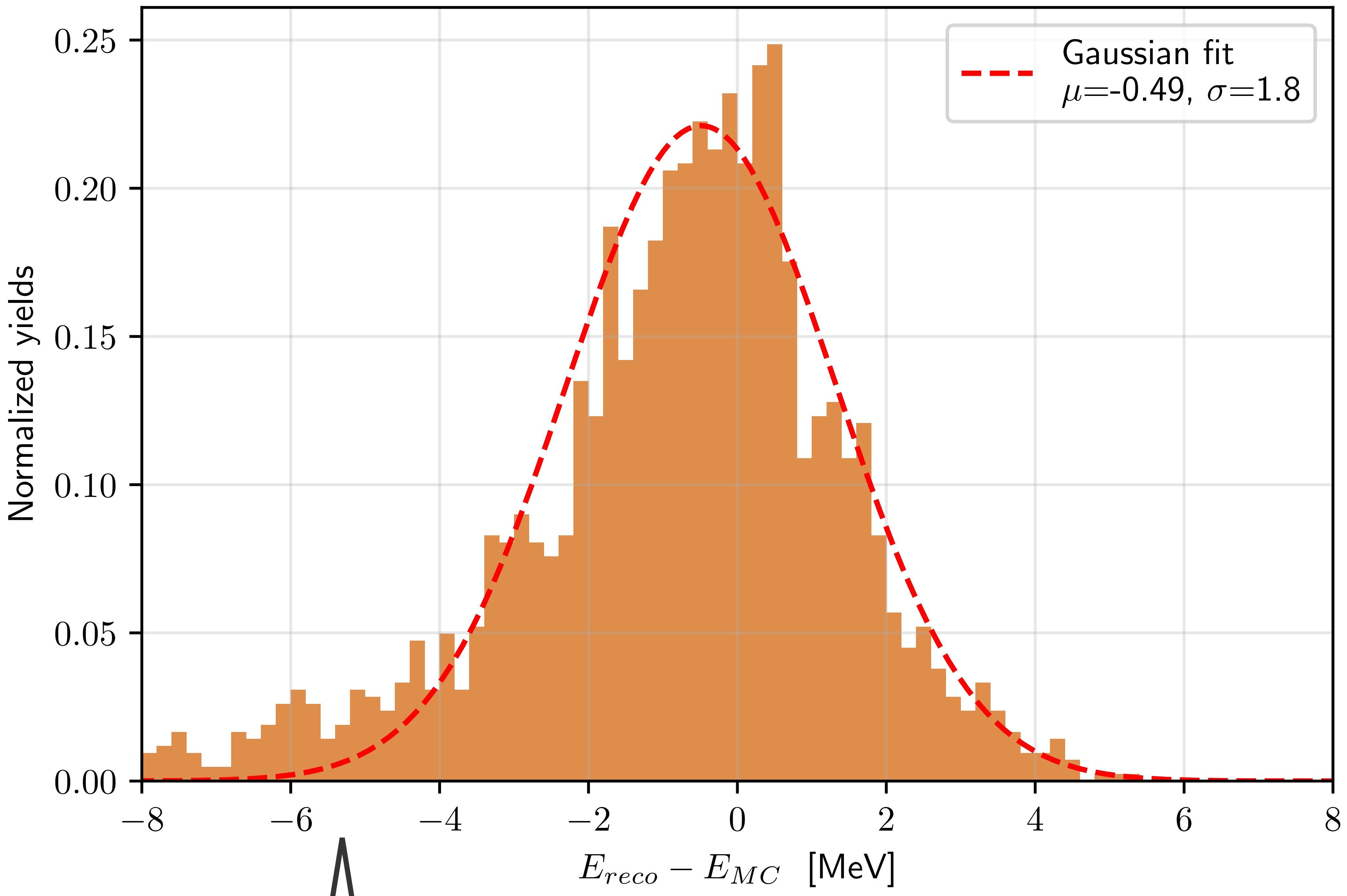
Range is calculated by projecting unaberrated tracks on each axis



Momentum from projections - Magnitude

Relationship between the proton range and energy based on MC simulation





The proton energy obtained from Monte Carlo simulations is subtracted from the proton energy reconstructed from the range

Conclusions

1. The track reconstruction method appears promising
2. It is suitable for application in the case of double scattering
3. It will be used for the complete reconstruction of neutron kinematics.