COSY Beam Profile Measurement using elastic Scattering

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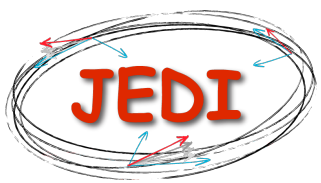
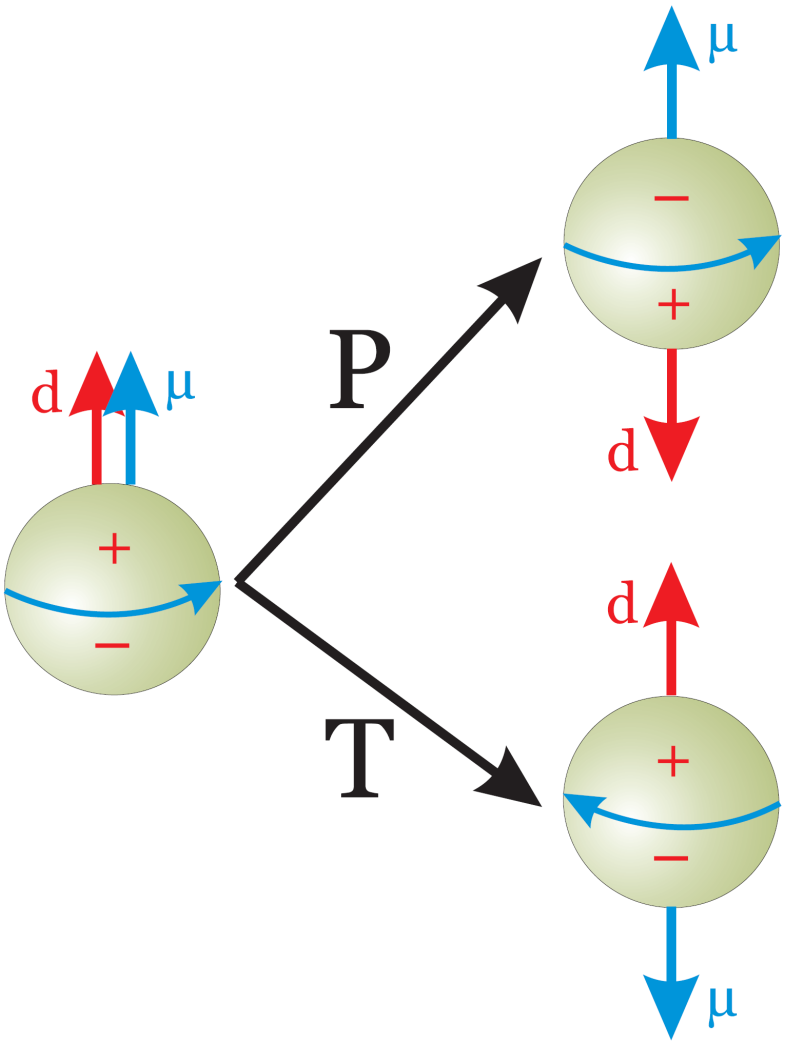
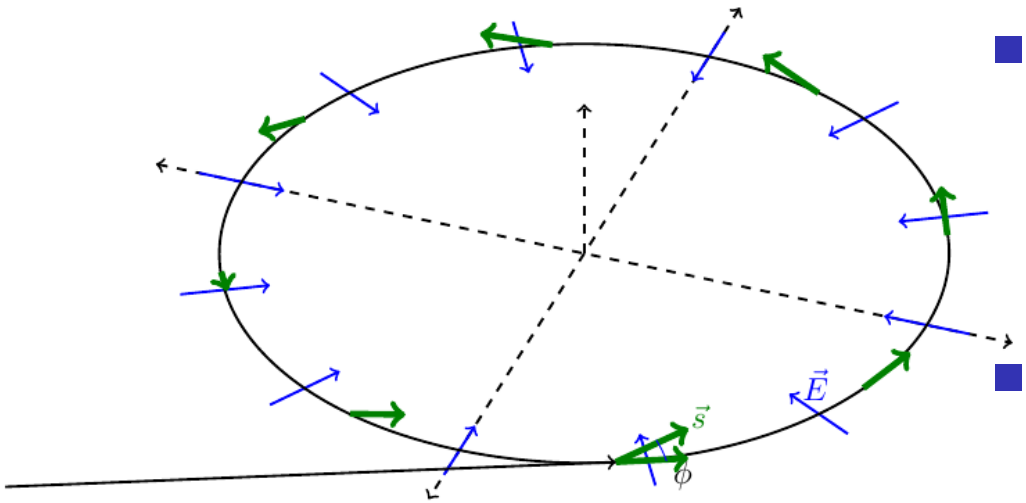


EDM and Fundamental Symmetries



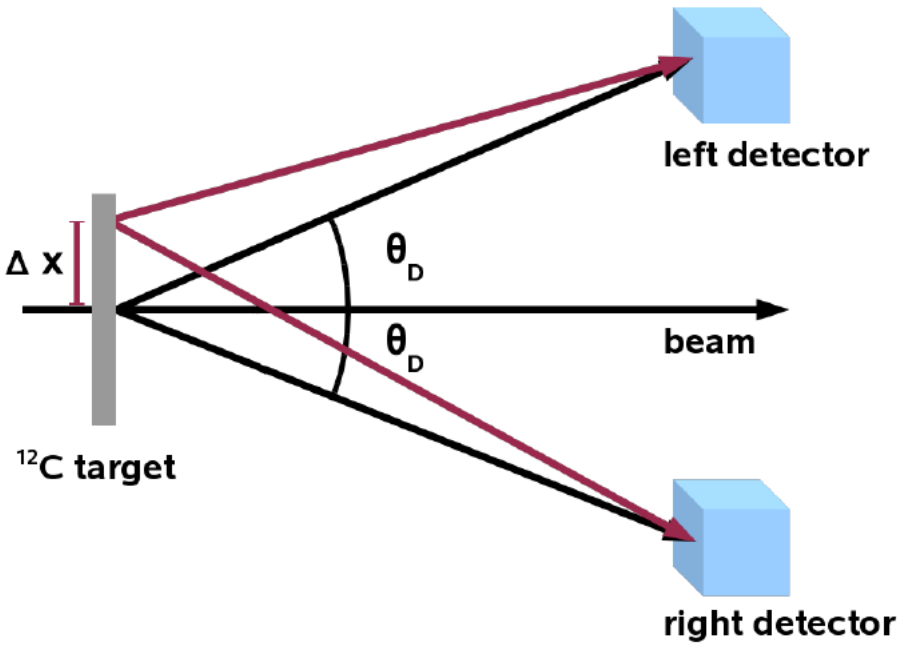
- Nonzero electric dipole moment (EDM) in elementary particle violates CP-Symmetry
- Standard-Model prediction: 10^{-32} to $10^{-31}\,\mathrm{e\,cm}$
- New Physics?

Measurement of Charged Hadron EDM at Storage Rings



- Various Methods
  - E-Field (Pictured)
  - B-Field
  - Combination
- Measure left-right-asymmetries in cross section
- Precursor experiment at COSY, Forschungszentrum Jülich

Systematic Errors and Beam Displacement



- Signal is asymmetry
- Detector-Beam-Displacement can fake signal

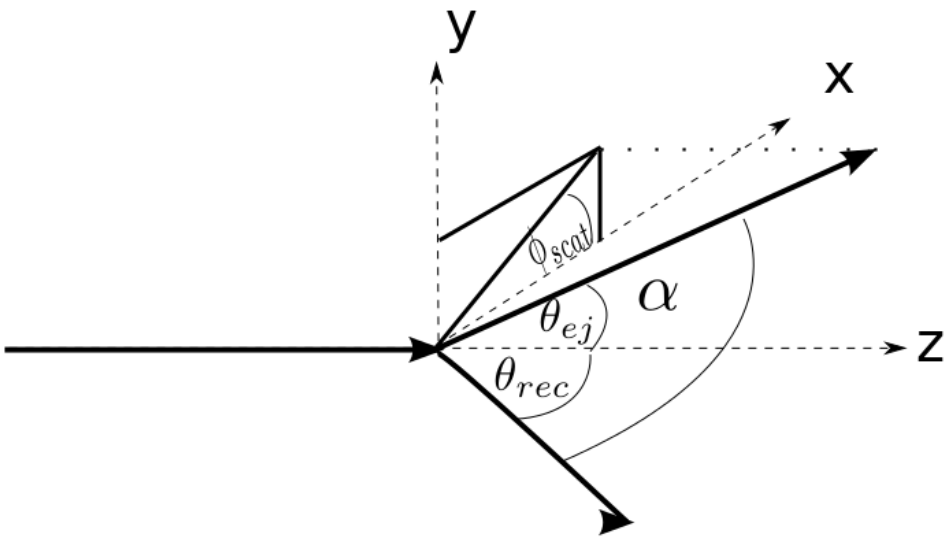
Beam Measurement

- Standard method: Beam Position Monitor, measures only position
- Proposed Method: Elastic Scattering
  - At the position of interaction
  - Measures angle and position for individual particles
  - Proposed by Kurt Kilian (IKP Jülich)

Phase Space of a Beam

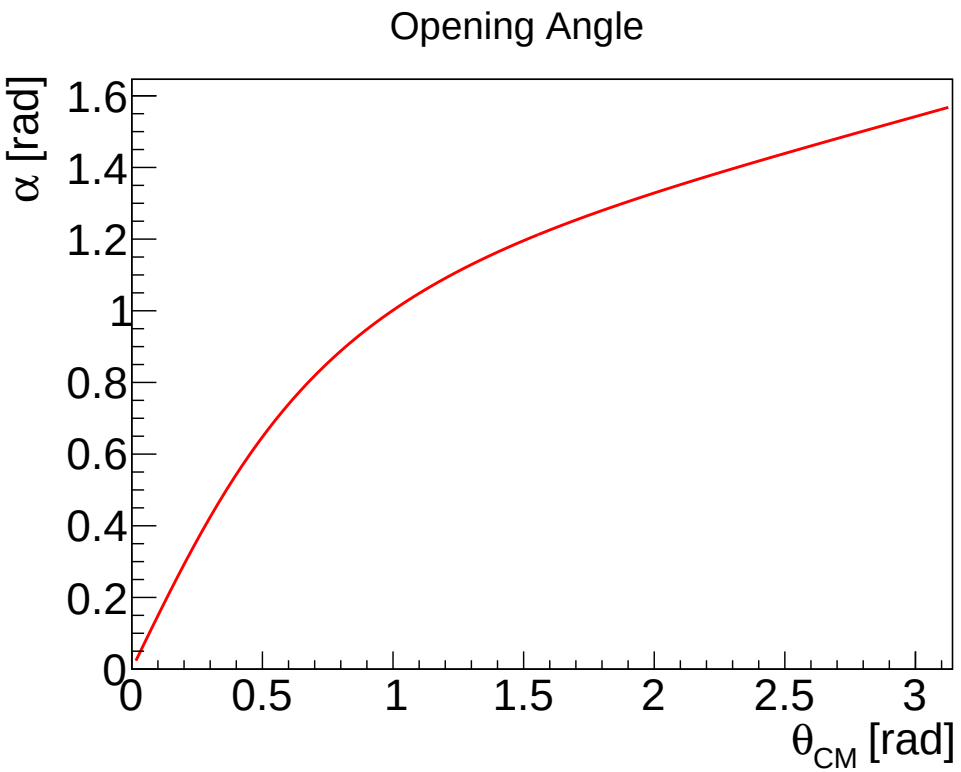
- Ideal beam
  - $\vec{x}_{Vertex} = \begin{pmatrix} 0 \\ 0 \\ z \end{pmatrix}$ and $\vec{p}_{Beam} = \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \cdot p_0$
- Real beam
  - $\vec{x}_{Vertex} = \begin{pmatrix} x \\ y \\ z \end{pmatrix}$ and $\vec{p}_{Beam} \approx \begin{pmatrix} x' \\ y' \\ \sqrt{1 - x'^2 - y'^2} \end{pmatrix} \cdot p_0$
- Measure distribution of x, y, x', y' including correlation
- Magnitude p_0 assumed to be known

Elastic Scattering



- Measure both tracks
- Vertex is where tracks intersect
- Direction of beam momentum coplanar to tracks
- Scattering angles in the laboratory frame θ_{rec}, θ_{ej} are NOT known
- Reconstruction reduces to finding θ_{cm}

Reconstruction using Opening Angle



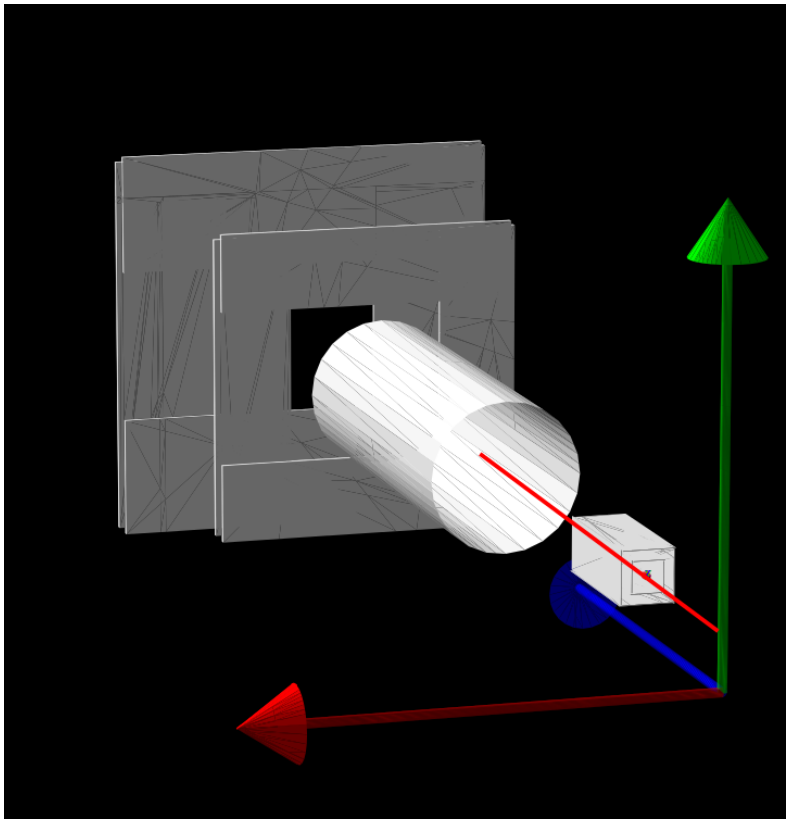
- Deuterons on proton target $E_{kin} = 236\,\mathrm{MeV}$
- Opening angle $\alpha = \theta_{ej} + \theta_{rec}$ of tracks is known. $\alpha = \alpha\left(\theta_{cm}\right)$
  - Measure α
  - Invert function for θ_{cm}
  - Calculate $\vec{p}_{Beam}/|\vec{p}_{Beam}|$

Algorithm

- Constrained Fit
  - 7 Parameters x', y', $\vec{x}_{Vertex}$, θ_{cm}, ϕ_{scat}
  - 8 Measured numbers: Two hit positions for each track
  - Minimize sum of square distances of tracks to hits

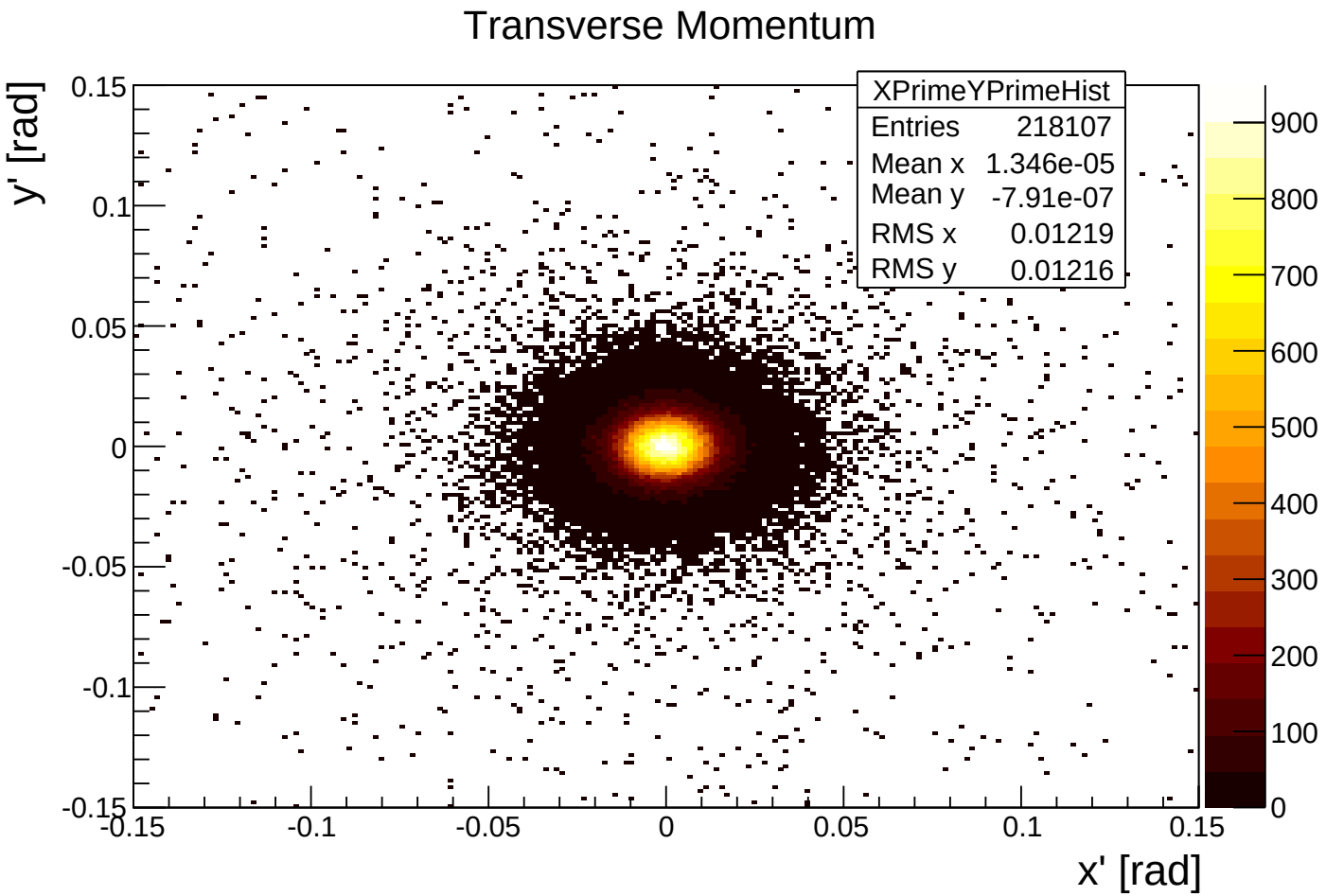
$$\chi^2 = \sum \frac{\left|\vec{x}_{Hit} - \vec{x}_{Track}\right|^2}{\sigma^2_{Hit}}$$

Detector Design



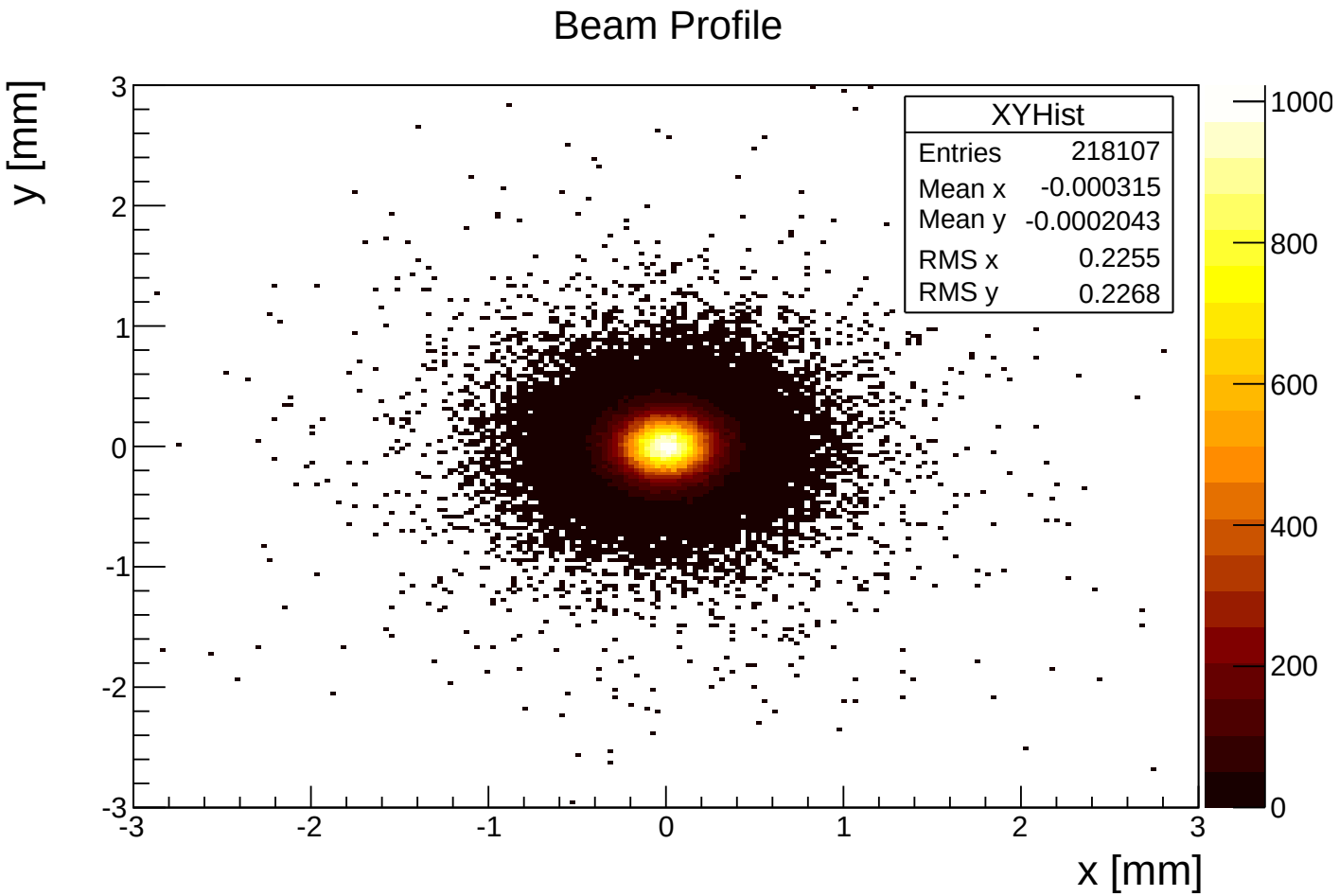
- Deuterons on Proton target at 236 MeV at COSY
- Two layers as endcap (not used here)

Beam Angle



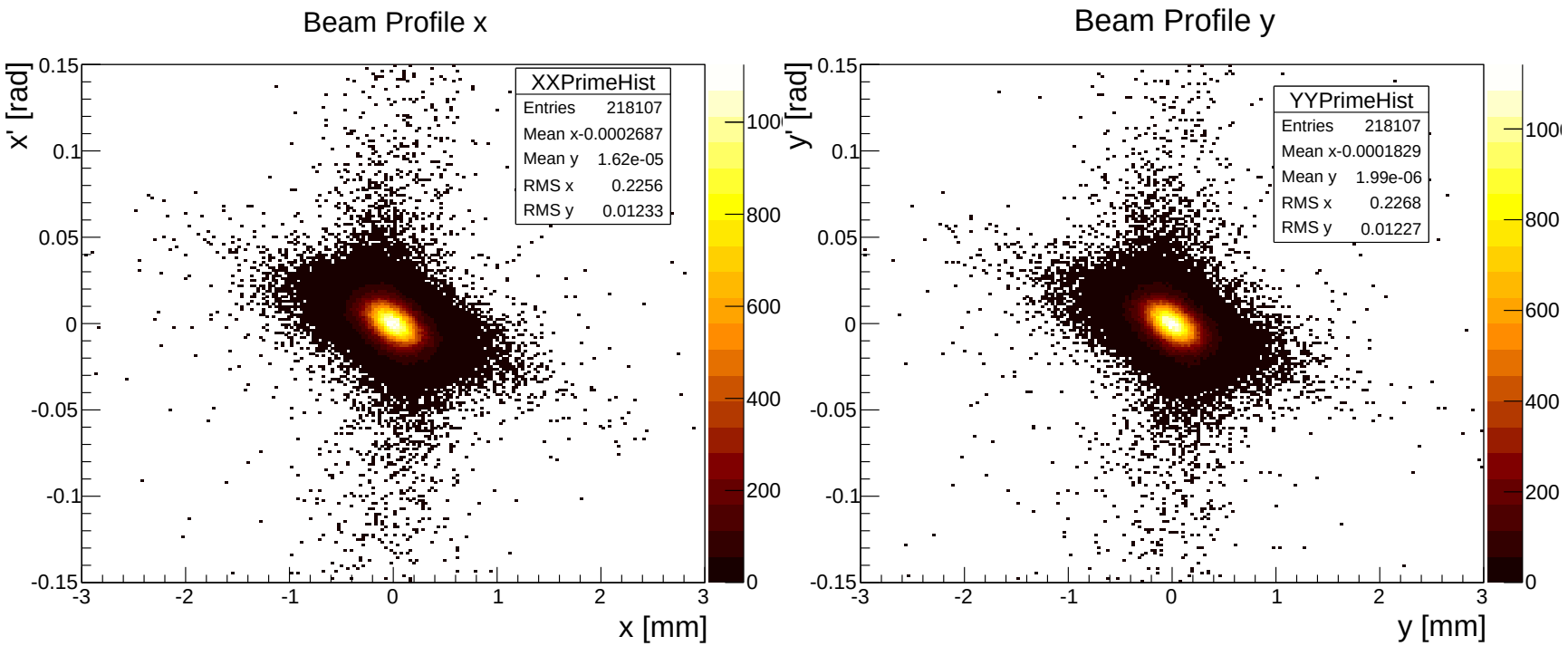
- Simulation assuming ideal beam

Vertex Position



- Simulation assuming ideal beam

Reconstructed Emittance



Outlook

- Phase space reconstructed using elastic scattering
- Resolution using only hit position: $\mathcal{O}\left(10\,\mathrm{mrad}\right)$ and $\mathcal{O}\left(0.2\,\mathrm{mm}\right)$ for detector concept
- Goal for angle: $\mathcal{O}\left(0.1\,\mathrm{mrad}\right)$
- Limited by multiple scattering
- Usage of deposited energy: Work in progress

Cross Ratio

- Double Ratio: $r^2 = \frac{L^- R^+}{L^+ R^-} = \frac{1+A_L P_y^- - A_R P_y^+ - A_L A_R P_y^- P_y^+}{1+A_L P_y^+ - A_R P_y^- - A_L A_R P_y^- P_y^+}$
- Asymmetry: $\epsilon_{LR} = \frac{1-r}{1+r}$
- Beam Displacement: $\delta\epsilon_{LR} \approx \frac{1}{A}\frac{d^2 A}{d\theta^2}\psi^2$ with $\psi = \frac{|\vec{x}_{vertex}|}{R}\cos\theta_{Beam}\left(1 + \frac{|\vec{x}_{vertex}|}{R}\sin\theta_{Beam}\right)$ and $A_L = A_R = A$