Elastic scattering analysis in 1D and 2D

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The aim of the project

- analysis of elastic scattering in proton-proton collisions
- comparing different strategies for fitting the θ distribution: 1D fit and 2D fit performed with two different fitting methods

The scattering angle θ

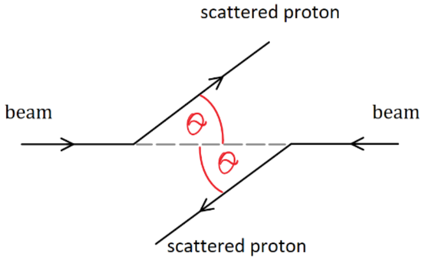


Figure: A scheme of proton-proton elastic scattering

The differential cross section

Four-momentum transfer:

$$t = -\theta^2 E_0^2 = -(\theta_x^2 + \theta_y^2) E_0^2$$

The differential elastic cross section, used to generate data in MC simulation:

$$\frac{d\sigma}{dt} = \frac{{\sigma_{tot}}^2}{16\pi} e^{-B|t|} \quad \rightarrow \quad \frac{d\sigma}{d\theta_x d\theta_y} = \frac{{\sigma_{tot}}^2 E_0^2}{16\pi} e^{-B E_0^2 (\theta_x^2 + \theta_y^2)}$$

Where:

- E_0 is energy of a single proton in scattering
- σ_{tot} is a total cross section
- B is the nuclear slope

Monte Carlo simulation

1. Generating number of events in the data sample - poisson distribution of avarage number of events: $N_{av} = L\sigma$
2. For each event generating t from the differential cross section:
    - without uncertainties of θ
    - only accepting events with $\theta_y > \theta_{y_0}$
    - smearing the θ_x and θ_y values
3. Generating many equivalent, but statistically independent data samples.

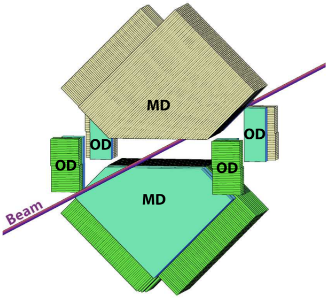


Figure: A schematic view of a pair of ALFA tracking detectors in the upper and lower RPs, source: CERN-PH-EP-2014-177.

Simulated data

$$\frac{d\sigma}{dt} = \frac{{\sigma_{tot}}^2}{16\pi} e^{-B|t|}$$

$$\frac{d\sigma}{d\theta_x d\theta_y} = \frac{{\sigma_{tot}}^2 E_0^2}{16\pi} e^{-B E_0^2(\theta_x^2+\theta_y^2)}$$

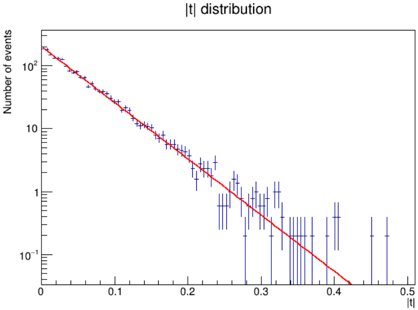


Figure: exponential fit on the |t| distribution

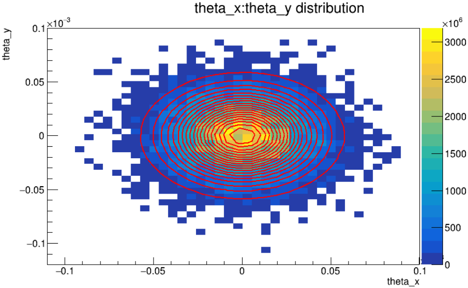
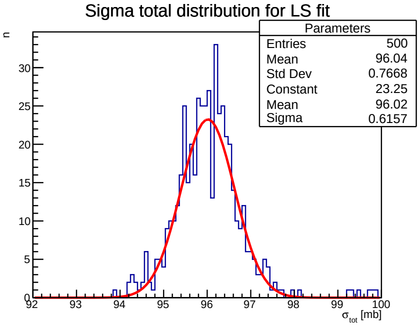


Figure: exponential fit on the θ_x and θ_y distribution

Different fitting methods

In terms of mathematical approach:

- Least Squares method (LS) - minimization of function χ^2, for binned data;
- Maximum Likelihood method (ML) - maximization of likelihood function, for unbinned data.



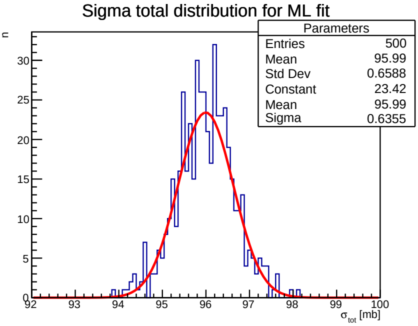


Figure: Difference between σ_{tot} distribution when using LS and ML fit - for smeared data.

Different fitting methods

In terms of type of fitted function:

- function of t (1D);
- function of θ_x, θ_y (2D).

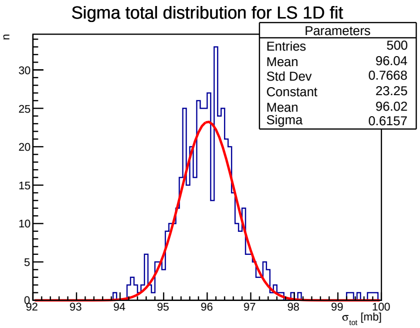


Figure: Difference between σ_{tot} distribution when using 1D and 2D fit - for smeared data.

Convolution and acceptance

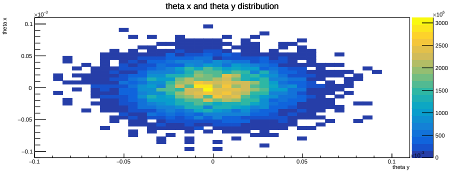


Figure: θ_x and θ_y distribution without uncertainties.

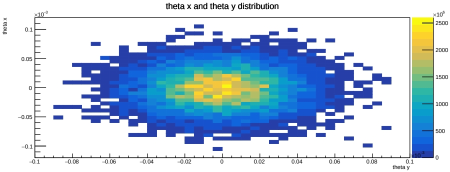


Figure: θ_x and θ_y distribution convoluted with smearing distribution.

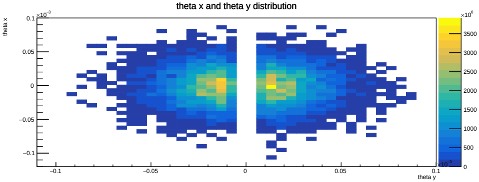


Figure: θ_x and θ_y distribution with acceptance.

Summary

- We did the Monte Carlo simulation and generated data in three different ways
- We performed different fitting methods (ML, LS) with two different approaches
- We have prepared code to fit the function with applied acceptance and convolution
- What's next?

Thank you!