PANDA CM Goa: Lumi Session

Helmholtz Association
Helmholtz Institute Mainz

PANDA Luminosity Detector

Status Report: Luminosity Fit

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Luminosity Definition

Typical Scattering Process

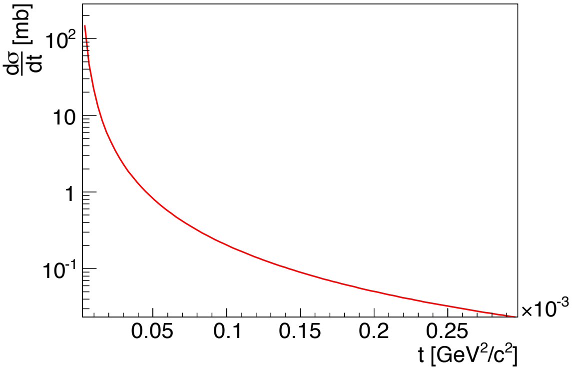
$$\frac{dN(\text{ps})}{d\text{ps}} = L \cdot \frac{d\sigma(\text{ps})}{d\text{ps}}$$

- $\frac{dN}{d\text{ps}}$: measured number of events within phase space element $d$ps
- ps: phase space variables
- $\frac{d\sigma}{d\text{ps}}$: differential cross section
- L: integrated luminosity

Reducing uncertainty of cross section
$\rightarrow$ pick well known process e.g. elastic scattering

$\bar{p}p$ Elastic Scattering Model

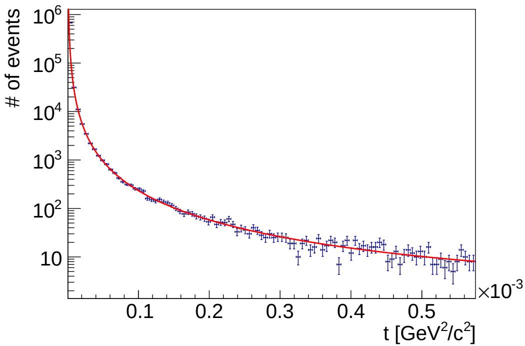
$$\frac{d\sigma(t)}{dt} = \frac{d\sigma_C(t)}{dt} + \frac{d\sigma_{int}(t,\text{par})}{dt} + \frac{d\sigma_H(t,\text{par})}{dt} \qquad p_{\text{lab}} = 1.5\,\text{GeV}/c$$



Generating a Data Sample

$$\frac{dN(t)}{dt} = L \cdot \frac{d\sigma(t)}{dt} = L \cdot \left[\frac{d\sigma_C(t)}{dt} + \frac{d\sigma_{int}(t)}{dt} + \frac{d\sigma_H(t)}{dt}\right]$$

$p_{\text{lab}} = 1.5\,\text{GeV}/c$

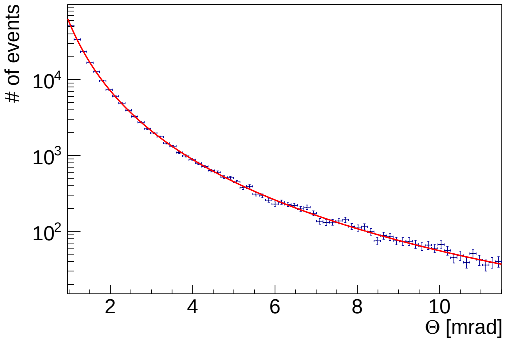


- MC data is generated according to elastic scattering model
- generated luminosity corresponds to $\sim 1s$ of data taking

Step 1: Convert to Scattering Angle θ

$$\frac{dN(\theta)}{d\theta} = L \cdot \frac{d\sigma(\theta)}{d\theta}$$

$$p_{\text{lab}} = 1.5\,\text{GeV}/c$$



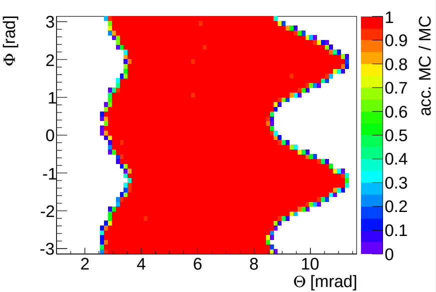
$\rightarrow$ luminosity fit uncertainty: $0.07\% \pm 0.12\%$

- transformation of data and model: momentum transfer t $\rightarrow$ scattering angle θ
- corresponds to measurement of an idealistic detector (no resolution) with 4π spatial coverage

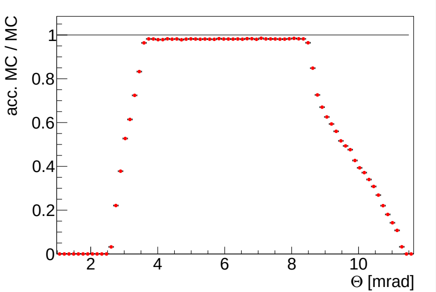
Step 2: The Detector Acceptance

$\epsilon(\theta, \phi)$ $p_{\text{lab}} = 1.5\,\text{GeV}/c$

$\epsilon(\theta, \phi)$: 2D Acceptance



$\epsilon(\theta)$: Projection

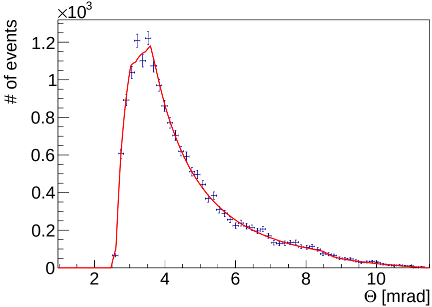


- Efficiency in plateau ≈ 98%

Step 2 contd.: Acceptance Corrected Fit

$$\frac{dN(\theta)}{d\theta} = L \cdot \left[\frac{d\sigma(\theta)}{d\theta} \cdot \epsilon(\theta)\right]$$

$p_{\text{lab}} = 1.5\,\text{GeV}/c$



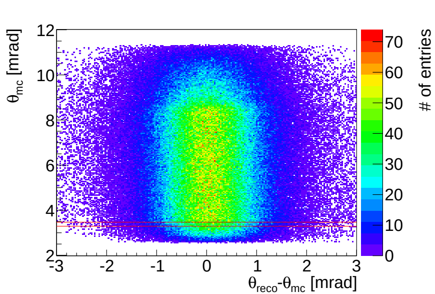
$\rightarrow$ luminosity fit uncertainty: $0.23\% \pm 0.75\%$

- generated and successfully reconstructed data without the influence of detector resolution
- corresponds to measurement of an idealistic detector with finite spatial coverage

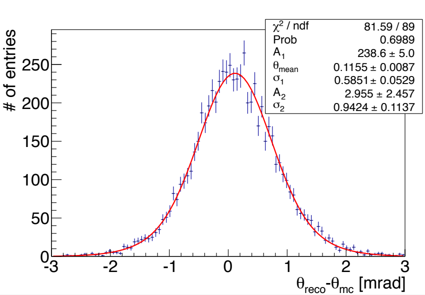
Step 3: Detector Resolution

$Res(\theta)$ $p_{\text{lab}} = 1.5\,\text{GeV}/c$

Θ Resolution vs Θ



Θ Resolution Slice

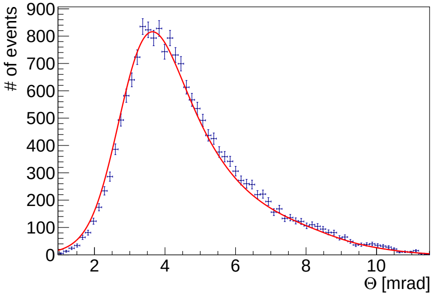


$$Res = \frac{A}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\theta_{\text{mean}}}{\sigma}\right)}$$

STEP 3 CONTD.: COMPLETE FIT

$$\frac{dN(\theta)}{d\theta} = L \cdot \left[\frac{d\sigma(\theta)}{d\theta} \cdot \epsilon(\theta)\right] \otimes Res(\theta)$$

$p_{\text{lab}} = 1.5\,\text{GeV}/c$

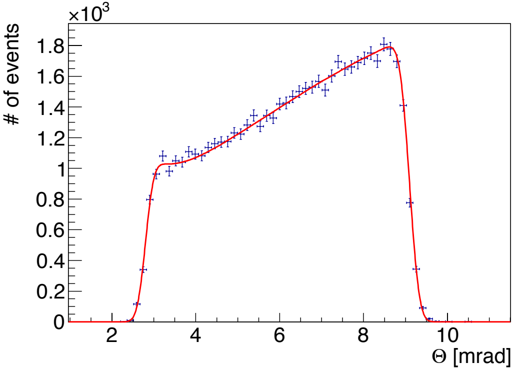


→ luminosity fit uncertainty:
$1.22\% \pm 0.75\%$

- reconstructed data (full simulation)
- corresponds to a realistic measurement of the luminosity detector

Step 3 contd.: Complete Fit

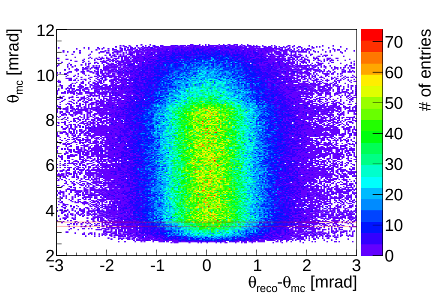
$$\frac{dN(\theta)}{d\theta} = L \cdot \left[\frac{d\sigma(\theta)}{d\theta} \cdot \epsilon(\theta)\right] \otimes Res(\theta) \qquad p_{\text{lab}} = 15.0\,\text{GeV}/c$$



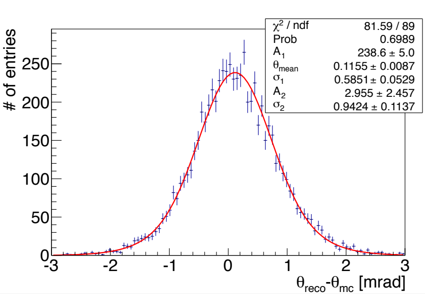
→ luminosity fit uncertainty: $0.12\% \pm 0.42\%$

Smearing Problem Cause: Θ resolution

Θ Resolution vs Θ



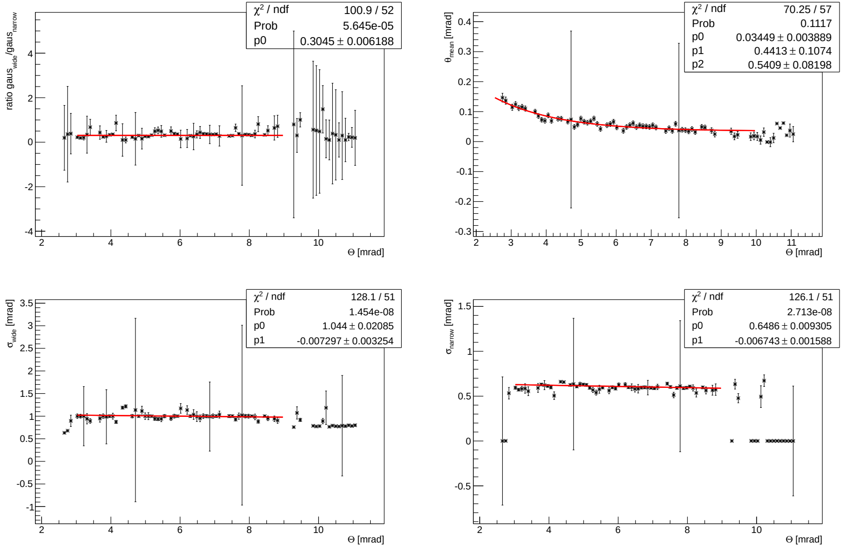
Θ Resolution Slice



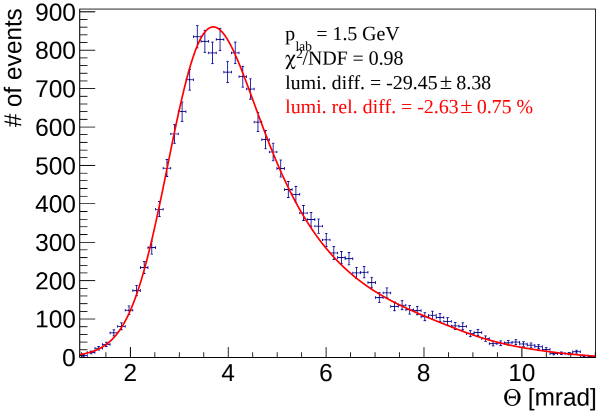
$\rightarrow$ offset in resolution ($\sim +0.1$mrad)

$$\frac{r}{1+r}\frac{1}{\sigma_w\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\theta_{mean}}{\sigma_w}\right)^2} + \frac{1}{1+r}\frac{1}{\sigma_n\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{x-\theta_{mean}}{\sigma_n}\right)^2}$$

New Resolution Parametrization



New Fit Results at $p_{\text{lab}} = 1.5\,\text{GeV}/c$



- better agreement with data
- larger luminosity fit uncertainty

Influence of the Beam Parameters

Categories

Beam Offset

parallel shift of beam w.r.t. z-axis

- equivalent to displacement of detector vertical to beam axis
  $\rightarrow$ acceptance changes
- advantage: measured directly and independently
  $\rightarrow$ complete correction with acceptance

Oblique Beam

$\bar{p}$ enter with an angle w.r.t. z-axis

- equivalent to rotation of detector
  $\rightarrow$ acceptance changes
- however: additional change in coordinate system
  $\rightarrow$ model correction required
- difficulty: direct/independent measurement impossible

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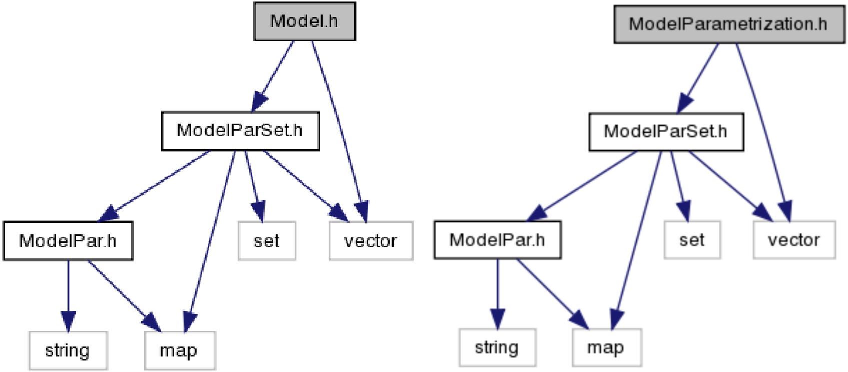
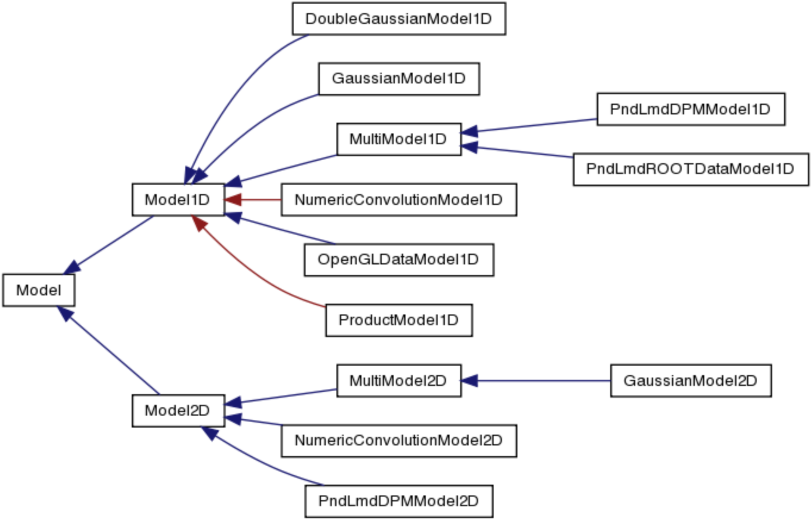
note: beam divergence is an additional angular resolution

The Model Framework



Model Example: PANDA LMD



LMD Specific User Workflow

- model allows full customization
- however for LMD
  - creation of models via factory only
    → usage simplified
  - parametrizations automatically built-in
    → parameter initialization and connections
  - only "superior" parameters (here: p_{lab}) MUST be set by user

Conclusions & Outlook

- extraction of luminosity with high precision
- now: good agreement with data for all beam energies
- however: still small problem with smearing at $p_{\mathrm{lab}} = 1.5\,\mathrm{GeV}/c$
- finish model framework

END

Thanks for your Attention!

Elastic Cross Section

$$\frac{d\sigma}{dt} = \frac{d\sigma_C}{dt} + \frac{d\sigma_{int}}{dt} + \frac{d\sigma_H}{dt}$$

with

$$\frac{d\sigma_C}{dt} = \frac{4\pi\alpha_{EM}^2 G^4(t)}{\beta^2 t^2}$$

$$\frac{d\sigma_{int}}{dt} = \frac{\alpha_{EM}\sigma_{Total}}{\beta|t|} G^2(t) e^{\frac{1}{2}Bt} (\rho cos(\delta) + sin(\delta))$$

$$\frac{d\sigma_H}{dt} = A_1 \cdot \left[e^{t/2t_1} - A_2 \cdot e^{t/2t_2}\right]^2 + A_3 \cdot e^{t/t_2}$$