Analysis of Mille output

CMS Tracker Alignment with Millepede

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Introduction

- The tracker, one of the inner subdetectors at the CMS experiment at LHC consists of silicon strip modules
- Essential for resolution to know the exact position of every module otherwise all measurements biased due to misalignment
- Millepede performs a single linear least square fit to take all sources of information and their correlations into account to determine alignment parameters
- Millepede is split into Mille and Pede step
- Output of Mille step was analyzed in dependence on track models and material effects

Millepede idea

- Residual between measured hit u_{im} and hit prediction u_{ip}

$$r_{ij} = \frac{u_{im} - u_{ip}(\boldsymbol{\tau}_j, \mathbf{p})}{\sigma_i}$$

- Sum over all residuals of all hits i and all tracks j and the make linear approximation to simplify problem

$$\begin{aligned}\chi^2 &= \sum_j \sum_i r_{ij}^2(\boldsymbol{\tau}_j, \mathbf{p}) \\ &\simeq \sum_j \sum_i \frac{1}{\sigma_i^2} \left(u_{im} - u_{ip}(\boldsymbol{\tau}_{j0}, \mathbf{p}_0) + \frac{\partial u_{ip}}{\partial \mathbf{p}} \delta \mathbf{p} + \frac{\partial u_{ip}}{\partial \boldsymbol{\tau}_j} \delta \boldsymbol{\tau}_j \right)^2\end{aligned}$$

- Minimization is done during Mille step of Millepede
- Pede step determines new set of global parameters $\mathbf{p}$

Analysis Setup

- CMSSW 2-0-11 was used with some updated packages that include new trajectory `DualTrajectory`
- Data sample `CSA08 - TkCosmicBON` was used ($B = 3.8T$)
- Only cosmics with momentum $> 1GeV$ used
- Track parameters written in Mille binary as special data
- Program mille2root was developed to read Mille binary, convert it to ROOT and run analysis on converted data
- Analysis done only for TIB and TOB

1. Kalman fit reconstructs track
2. Track is assumed to be a helix (5 parameters and reference plane)
3. Calculate residual between measurement and hit prediction by assuming the prediction to be a helix propagation with initial track parameters from reference plane, corrected by local derivate (First order Taylor expansion $\Rightarrow$ linearize problem)

- Energy loss influences residual (curvature changes $\Rightarrow$ hit prediction changes)
- Multiple scattering influences prediction error
- Multiple scattering influenced by amount of material between reference plane and hit
- Choise of trajectory influences reference plane

Task: Analyze Mille output in dependence on them

Pulls versus particle momentum

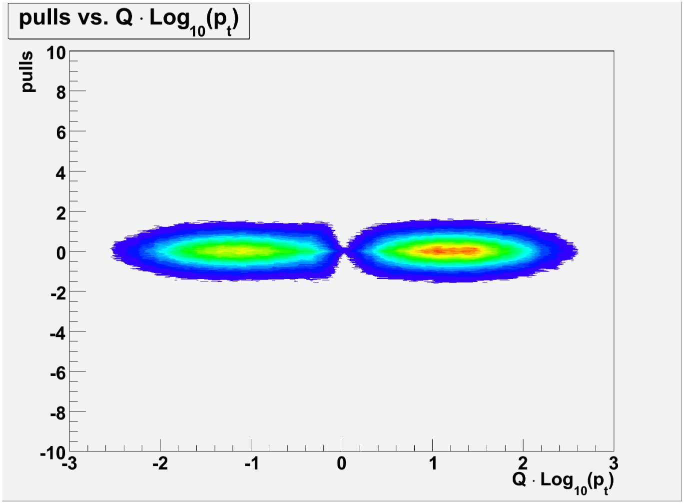


Figure: $pull_i$ versus $Q \cdot Log_{10}(p_t)$ for `DualTrajectory`

Fitted slices

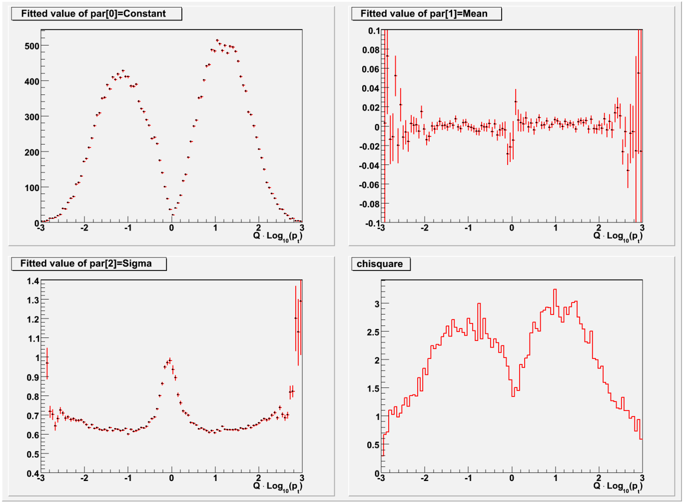


Figure: Fitted slices for `DualTrajectory` with normalization constant c_n, mean m_n, sigma σ_n and χ^2_n

Fitted slices

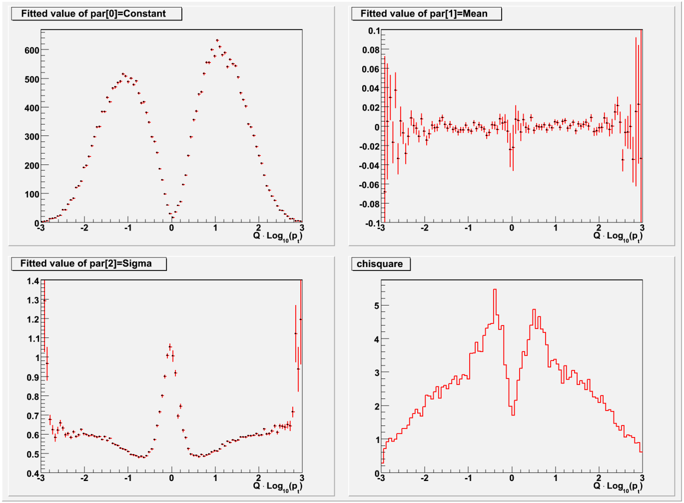


Figure: Fitted slices for `ReferenceTrajectory` with normalization constant c_n, mean m_n, sigma σ_n and χ^2_n

Difference in u and v measured hits

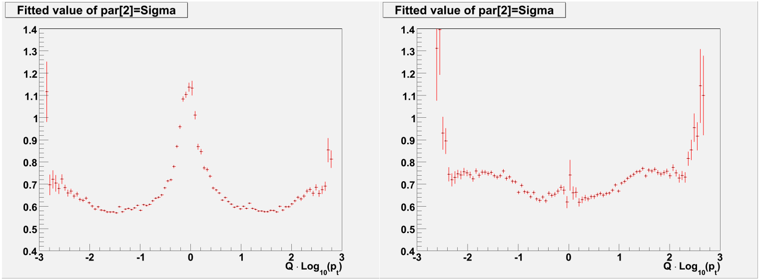


Figure: σ_n for `DualTrajectory` in u and v direction

Difference in u and v measured hits

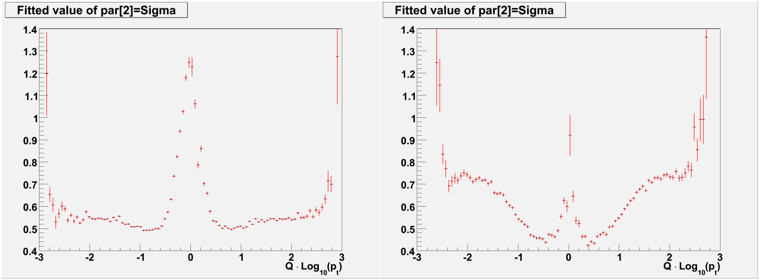


Figure: σ_n for `ReferenceTrajectory` in u and v direction

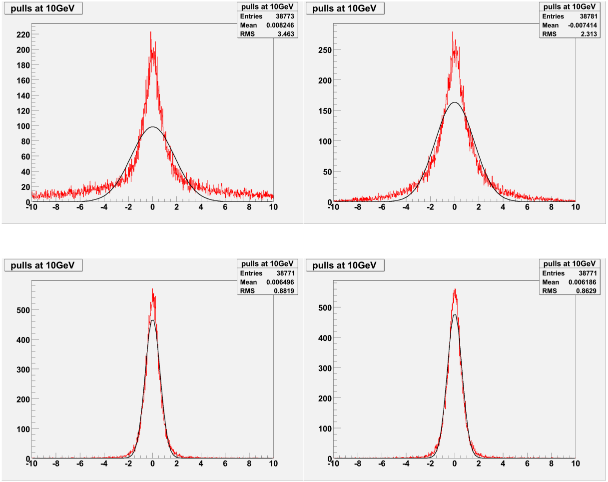
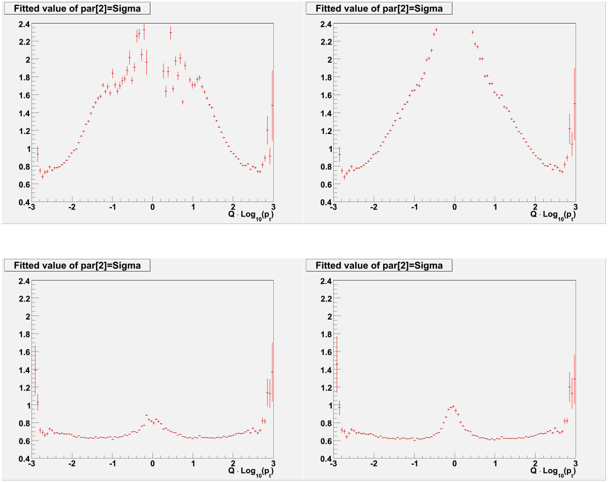


Figure: Fitted slice in bin at $10 GeV$ for no material effects, energy loss, multiple scattering and with combinded material effects

Material effects for DualTrajectory



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Material effects for ReferenceTrajectory

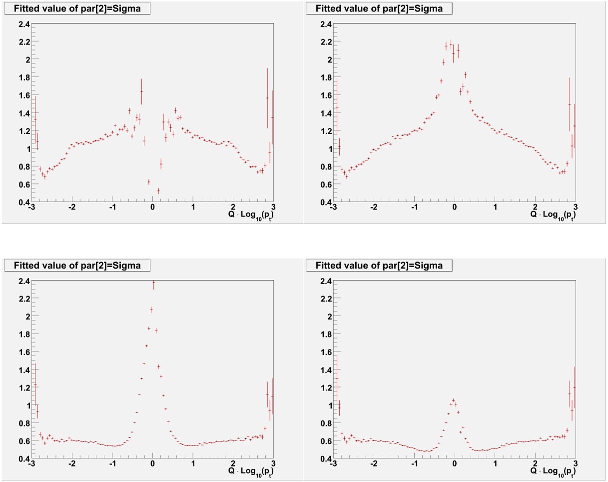

Figure: σ_n for no material effects, energy loss, multiple scattering and with combined material effects

- Influence of multiple scattering on prediction error is big but nearly constant over more then one order of magnitude. Inverse momentum dependence not really observable although multiple scattering dominates residual's error
- Energy loss influences results only for low momentum. In combination with multiple scattering it acts different for both trajectorys
- In generel `DualTrajectory` shows the better results. Behavior in u and v can be explained