Track Fitting with the SciFi Trackers

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on behalf of the Tracker Group

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Overview

1. Kalman Track Fitting
   - Misalignment Search
   - χ^2 and P-Value of the fit
2. First hints of Emittance Analysis
   - Resolution of the track parameters
   - Bunch Emittance
   - Single Particle Emittance
   - Resolution of Single Particle Emittance
   - Emittance change in Stage 4 with LH_2

Misalignments

The precision can't be limited by misalignments

They are taken into account by:

- shifting expectation of where the particles hit the detector;
- feeding uncertainty in the misalignment into covariance matrices - reduces weight of the measurements.

Impacts P-Value of the track.

Misalignment Search

By construction, the station is displaced from the centre by less than the channel width (1.4 mm) - Geoff Barber

Precision laser measurements have verified this for the input tracker - David Addey's NIM paper.

Despite all that...

Added an algorithm which looks for misalignments in the station planes.
Integrated with the Kalman Filter.
Iterative: if run is a misalignment search, misalignment values are updated after each track.

Performance tested with misaligned detector simulation.

Misalignment Search

Update of misalignment (s):

$$s_1 = s_0 + GainMatrix \times (measurement - optimal_{removed}) \qquad (1)$$

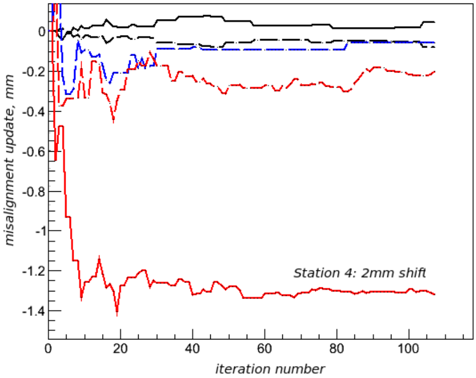
$optimal_{removed}$: optimal estimation when the station measurement is removed from the fit.

The error associated with s_0 is also updated. As it becomes smaller, the convergence of the misalignments is damped.

The precision is limited by the measurement error - the channel width.

Misalignment Search

Figure shows update of misalignment parameters in (x, y) of stations 2, 3, 4. All stations are aligned expect station 4: $\Delta x = 2mm$.



Optimal estimations are already found after 10 tracks.
$\rightarrow$ compare with classical method (mean of residuals of large number of tracks...)

RMS spread of $\sim 350\mu m$**.**

χ^2 and P-Value of the Fit

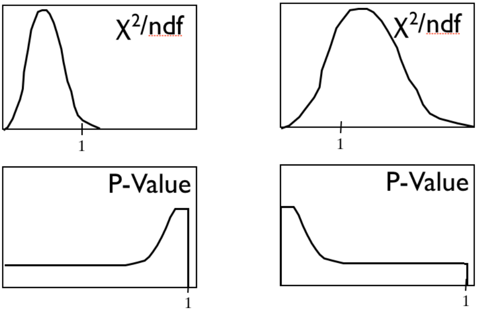
P-value is the probability that the observed χ^2 exceeds the expected χ^2 value by chance.

We might overfit:

- pull towards data points is too strong;
- the residuals are too small, the χ^2 is too small

We might underfit:

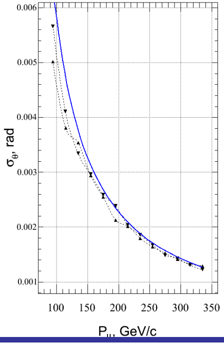
- the residuals are too large the χ^2 is large

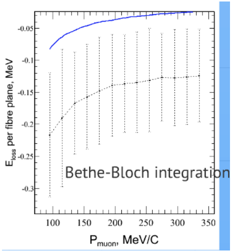


χ^2 and P-Value of the Fit

It's a balance between:

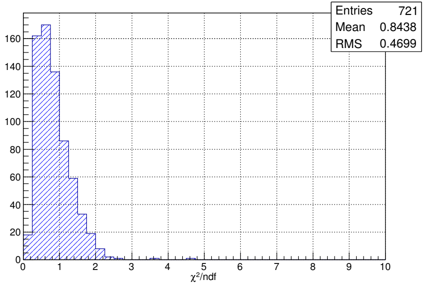
- error assigned to the measurement;
- MCS and E_{loss} models;
- seed covariance;
- misalignments (themselves and their covariance).

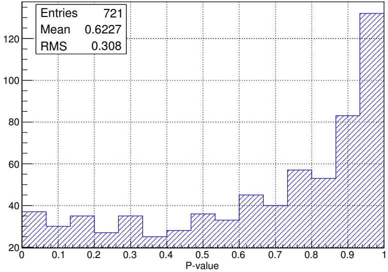




χ^2 and P-Value of the Fit

Example of χ^2 distri





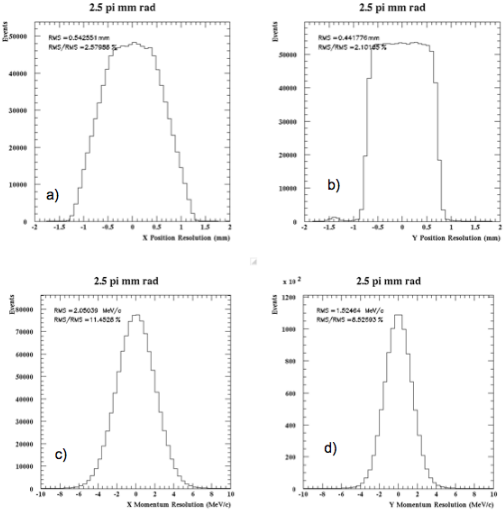
Goals for the analysis:

Reproduce results of MICE Note 90.

Reconstruct Single Particle Emittance.

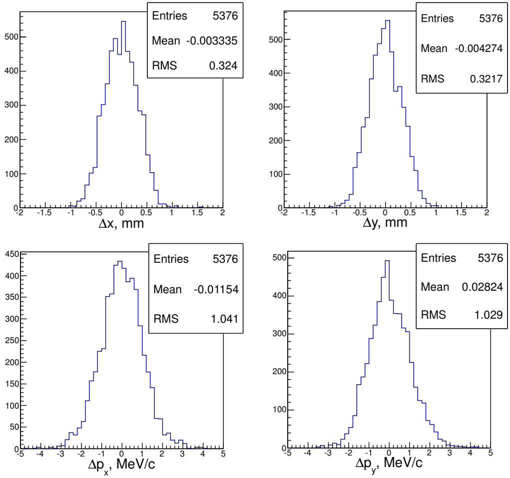
Resolution of the Reconstruction

From MICE Note 90: (cites an RMS value of 370μm single-view position reconstruction)

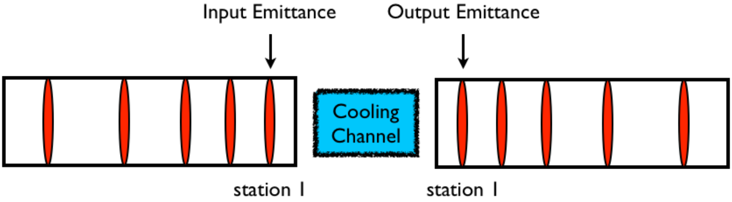


Resolution of the Reconstruction

Current results: (beam 4d emittance = 4; $E_\mu = 200 MeV/c$)



Definitions for the next slides



ϵ_N is bunch emittance; ϵ_i is single particle emittance.

Test geometry: only the two tracker solenoids (diffuser, trackers, coupling coils, cryostats).

1. Bunch Emittance

Used ensemble of many particles to calculate bunch emittance:

$$V = < (u_i - \bar{u}_i)(u_j - \bar{u}_j) > \tag{2}$$

where $u = [x, p_x^c, y, p_y^c]^T$.

$$\epsilon_N = \frac{\sqrt[4]{|V|}}{m_\mu} \tag{3}$$

With the test geometry and the beam previously defined:

$$\epsilon_N^{Input} = 4.33$$

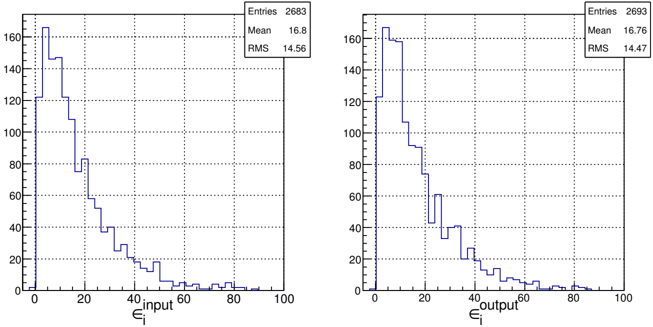
$$\epsilon_N^{Output} = 4.28$$

Emittance calculated from MC truth: 4.299 and 4.306 respectively.

2. Single Particle Emittance

Single particle emittance calculated from the bunch emittance[1]:

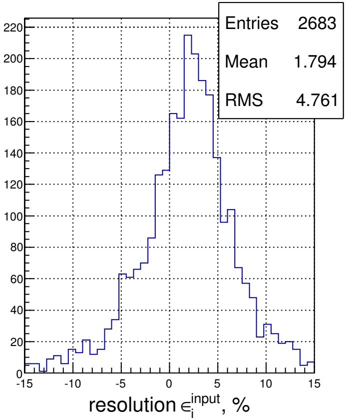
$$\epsilon_i = \epsilon_N u^T V^{-1} u \quad (4)$$

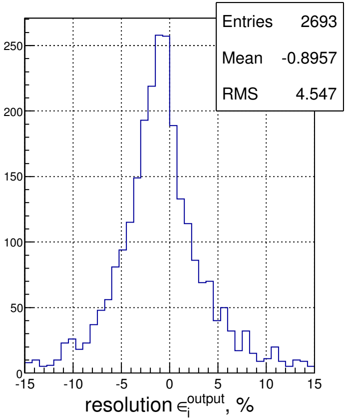


Verifies $< \epsilon_i >= 2N\epsilon_N$.

[1] Chris Rogers thesis

Emittance Resolution



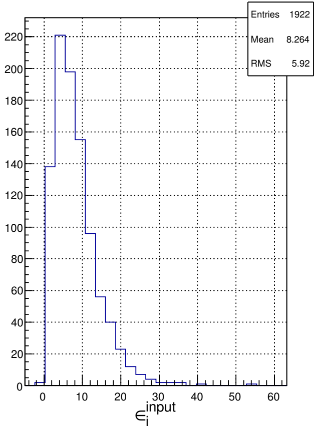


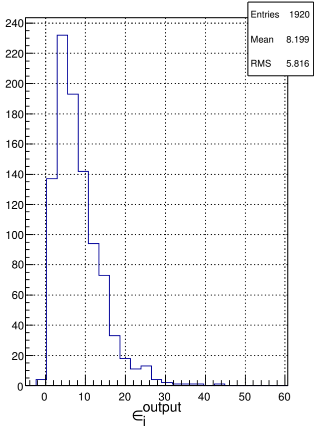
Centroid is displaced.

Emittance change in Stage 4 with LH_2. Initial beam emittance = 2

Bunch Emittance: 2.12, 2.06

Bunch emittance from SPE mean: 2.08, 2.06





Conclusion

Kalman Filter at polishing stage:

- flattening the P-value is challenging.

Emittance studies underway:

- repeat and extend MICE Note 90.

Acknowledgements:
To Prof. Kenneth Long and Dr. Jaroslaw Pasternak for helpful conversations.