Track Based Alignment Procedure for the CBM Silicon Tracking Detector

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On Behalf of the CBM Collaboration

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Overview

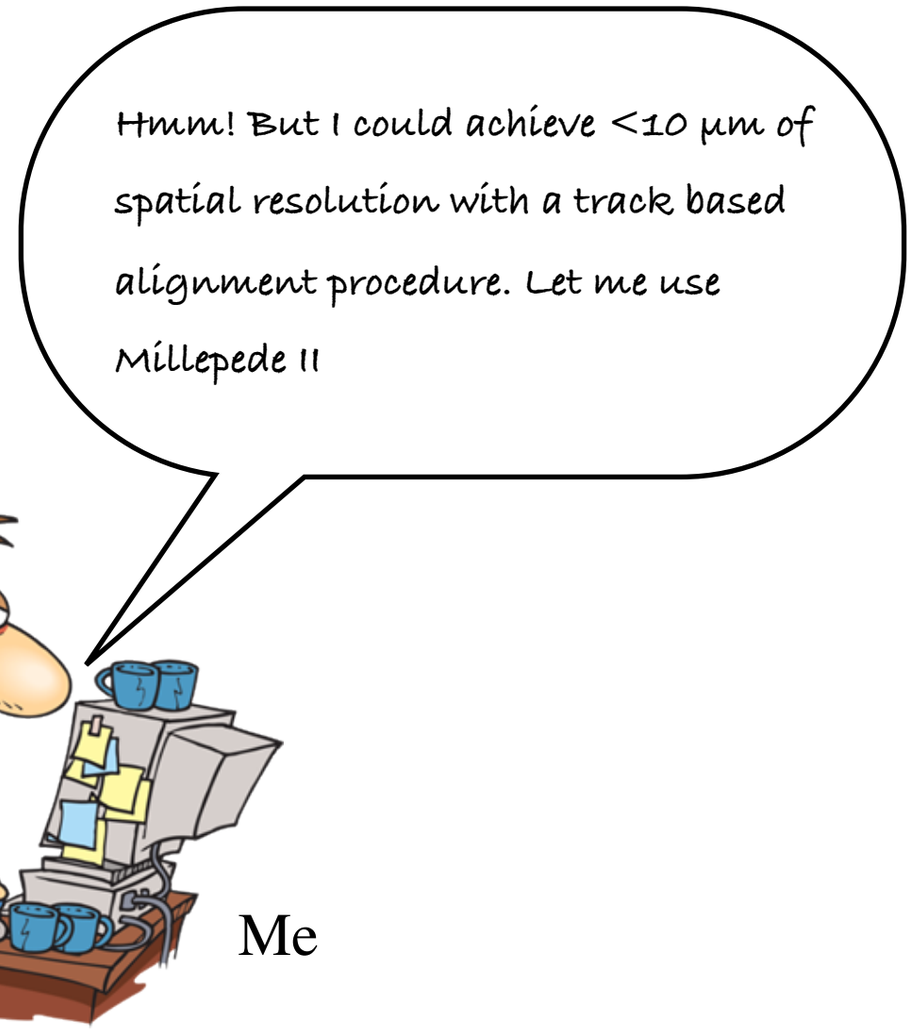
- Motivation
- Effects of Misalignment
- Alignment strategies
  - Track based alignment workflow
  - Hierarchies and constraints
  - Test Setup for result extraction
  - Toy misalignment scenario
- Realignment results
- Outlook

Motivation

Let's Define the Alignment

The purpose of the Alignment of a detector is to determine the accurate space coordinates and orientations of all of its components.

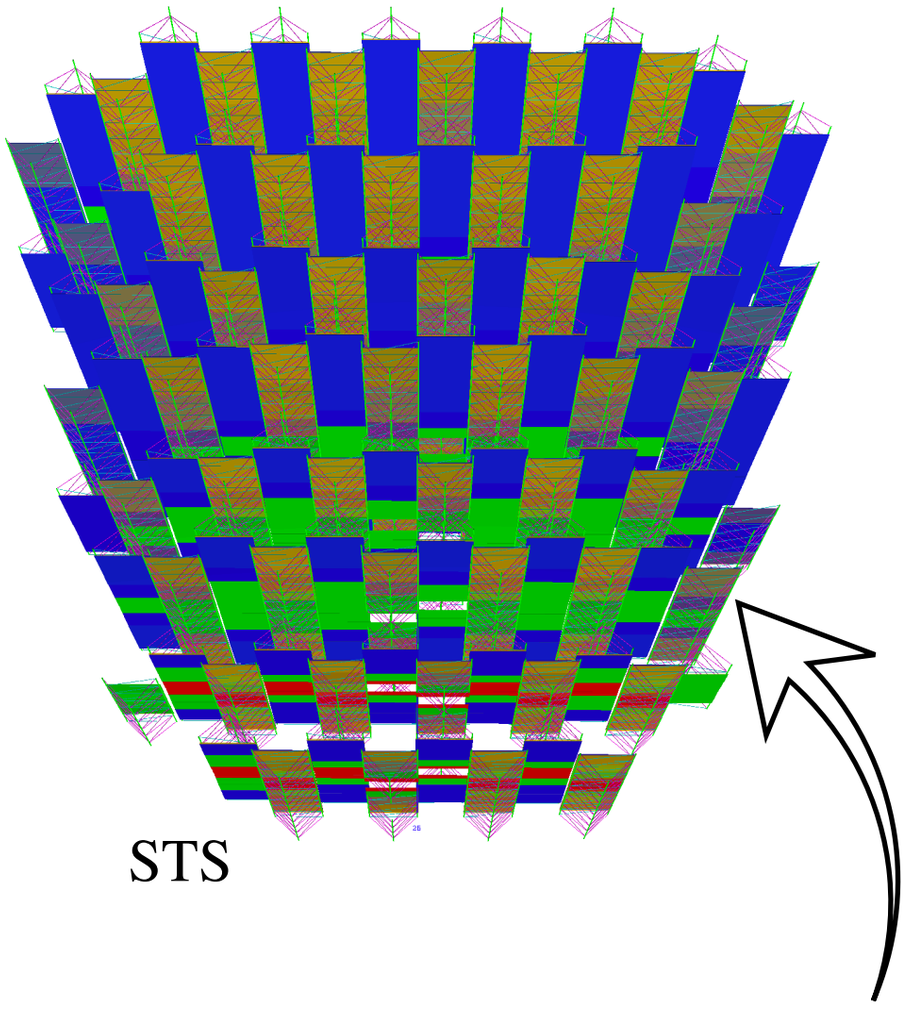
Mechanical Engineer



Me

Effects of misalignment

Test Setup 1



Station Based STS: Elements in Setup

Stations	8
Ladders	106
Halfladders	212
Modules	900
Sensor	1220

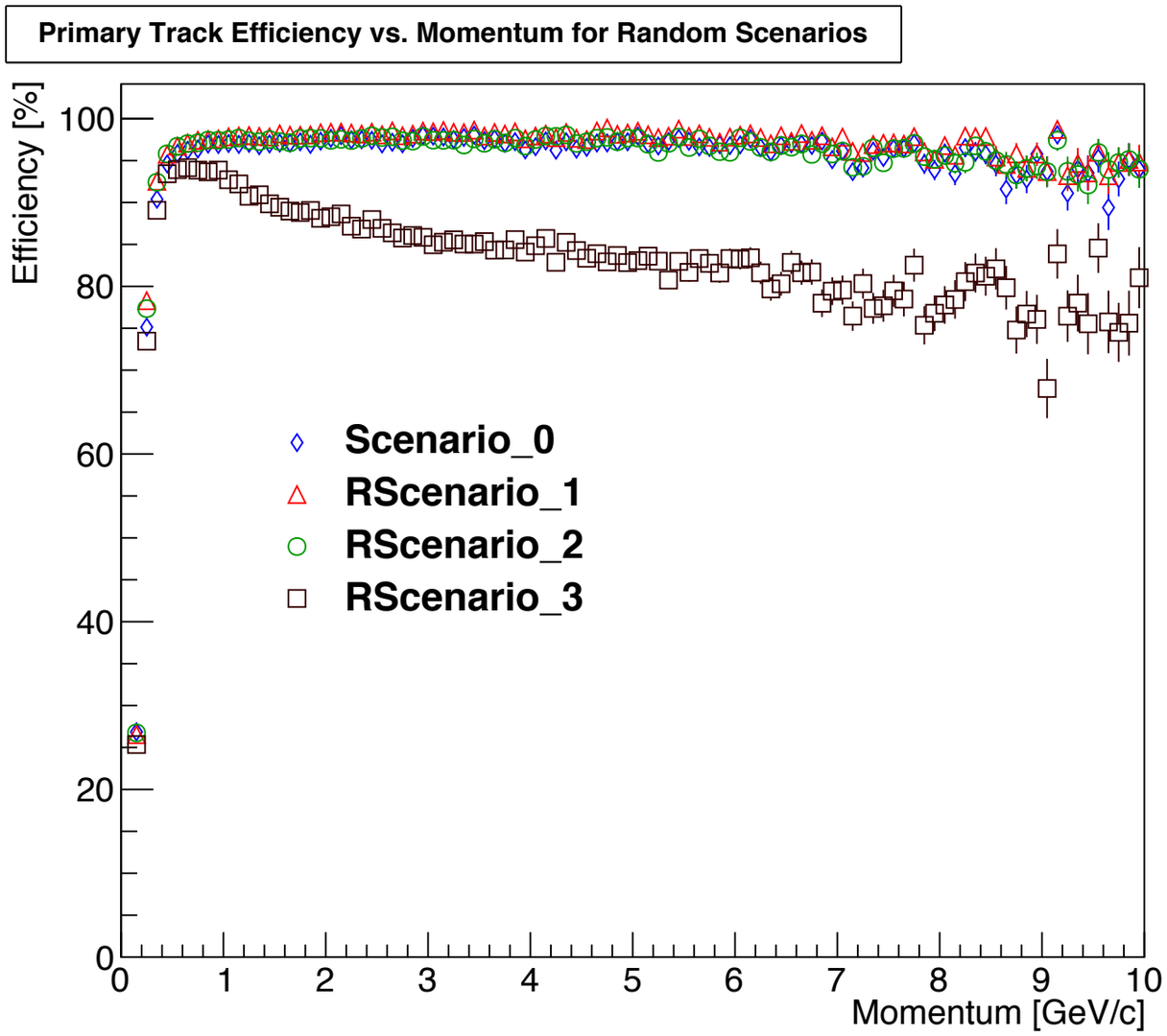
Element	Sensor	Ladder	Station
X	10μm	50μm	200μm
Y	10μm	50μm	200μm
α	50μrad	250μrad	1000μrad
β	50μrad	250μrad	1000μrad
γ	50μrad	250μrad	1000μrad

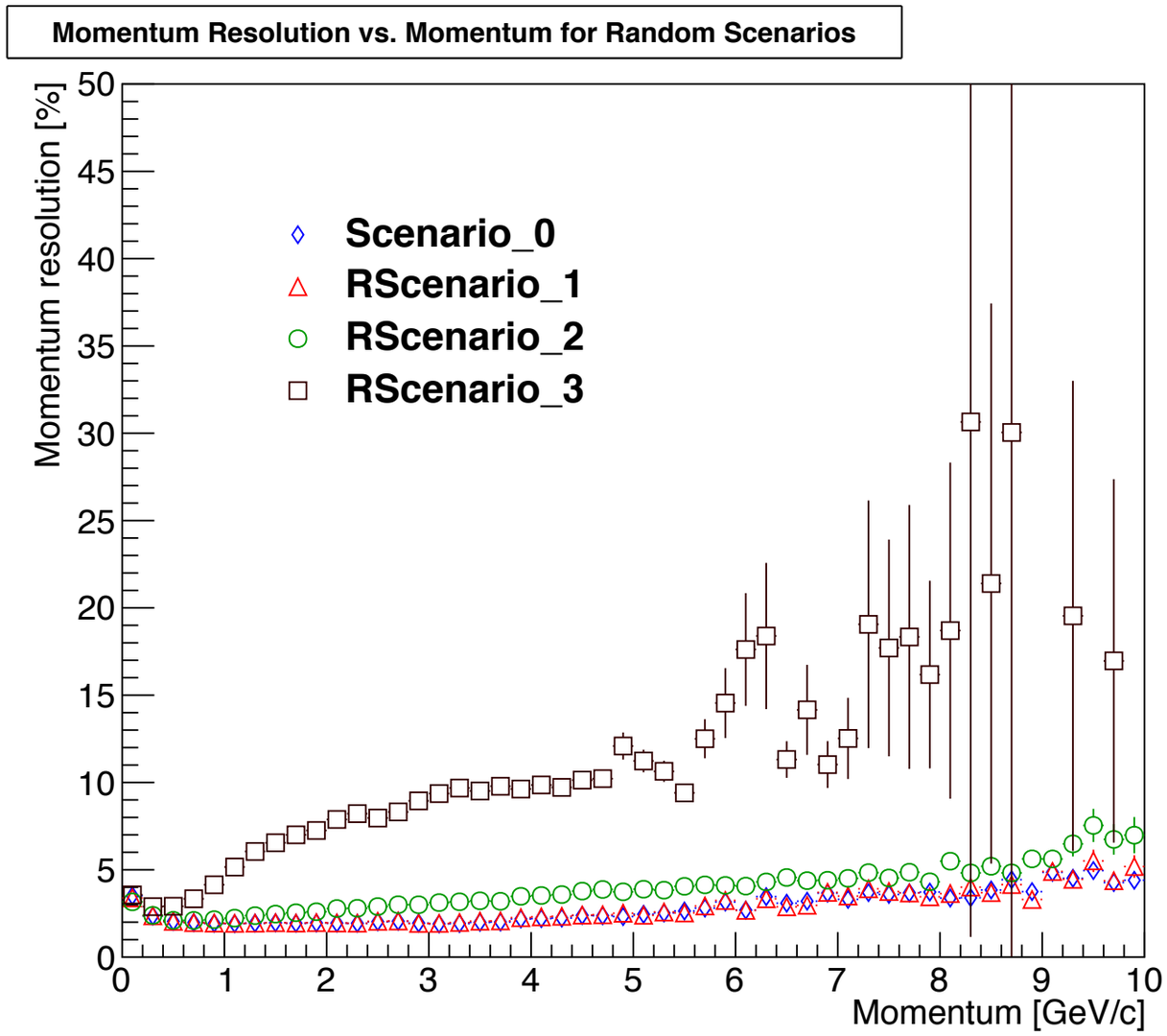
Misalignment Lookup Table

Scenario_0 = Ideal Geometry
RScenario_1 = Sensor Level
RScenario_2 = Sensor + Ladder Level
RScenario_3 = Sensor + Ladder + Station Level

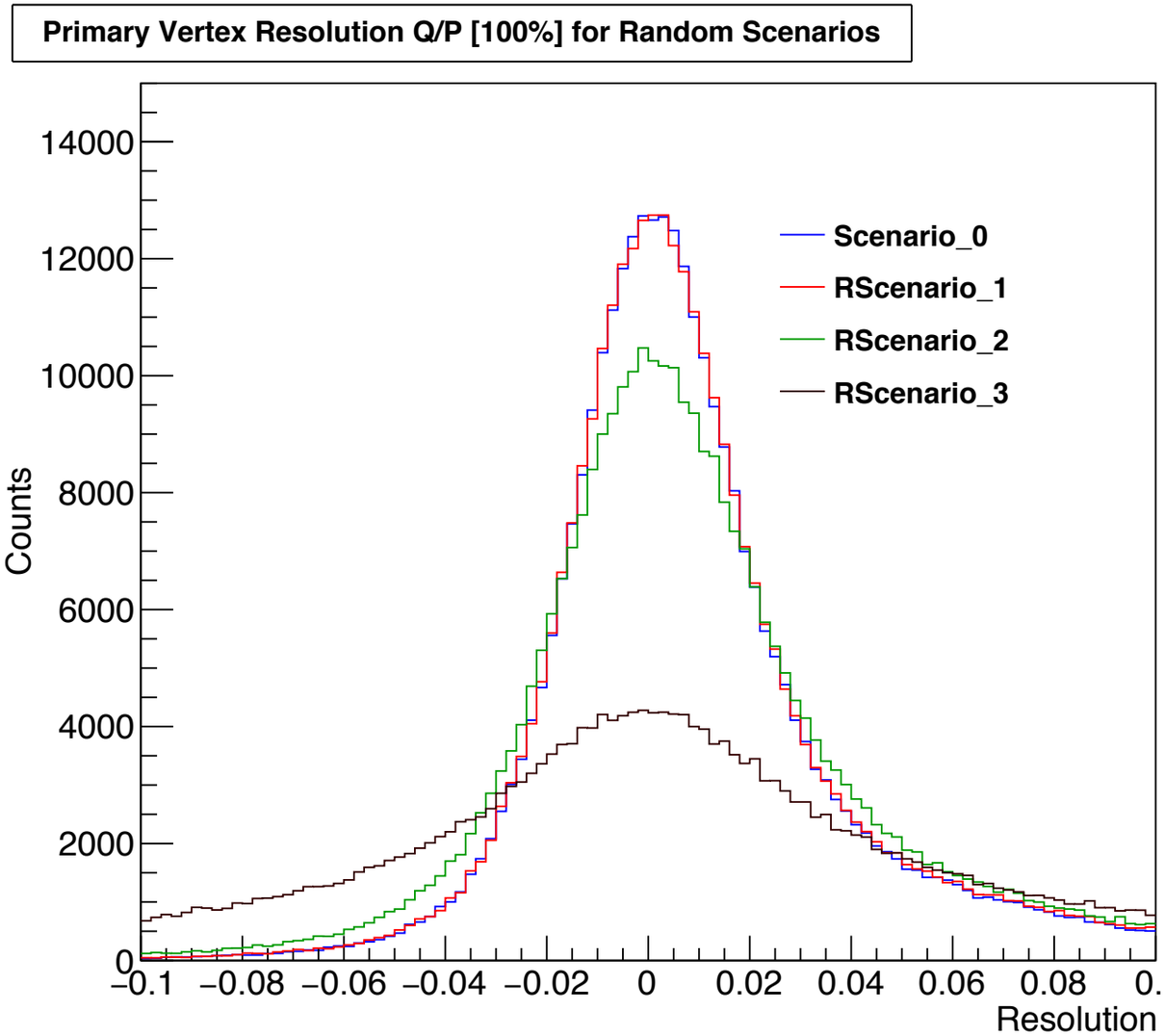
*1000 Central UrQMD events of 10 AGeV AuAu

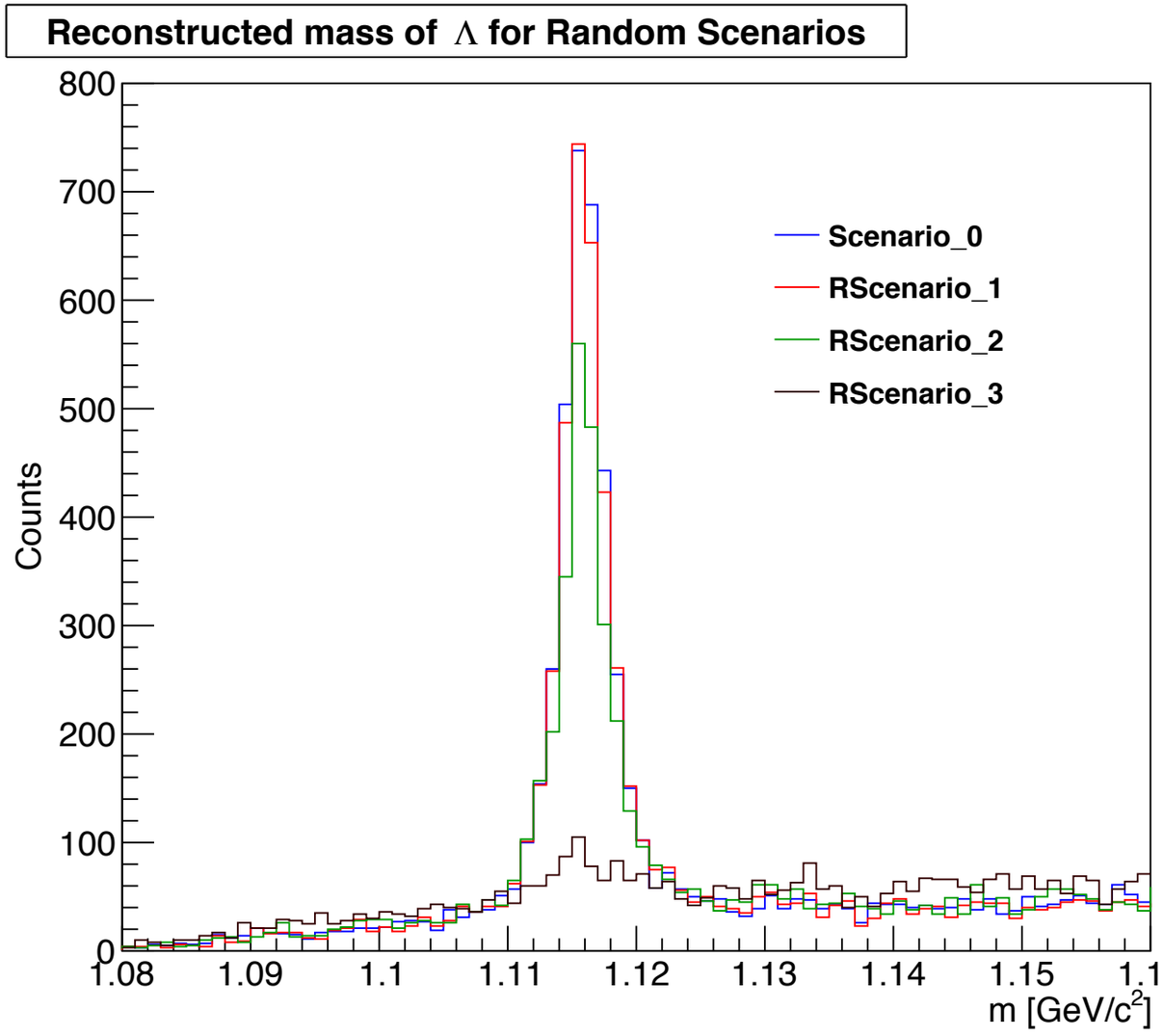
Misalignment Results





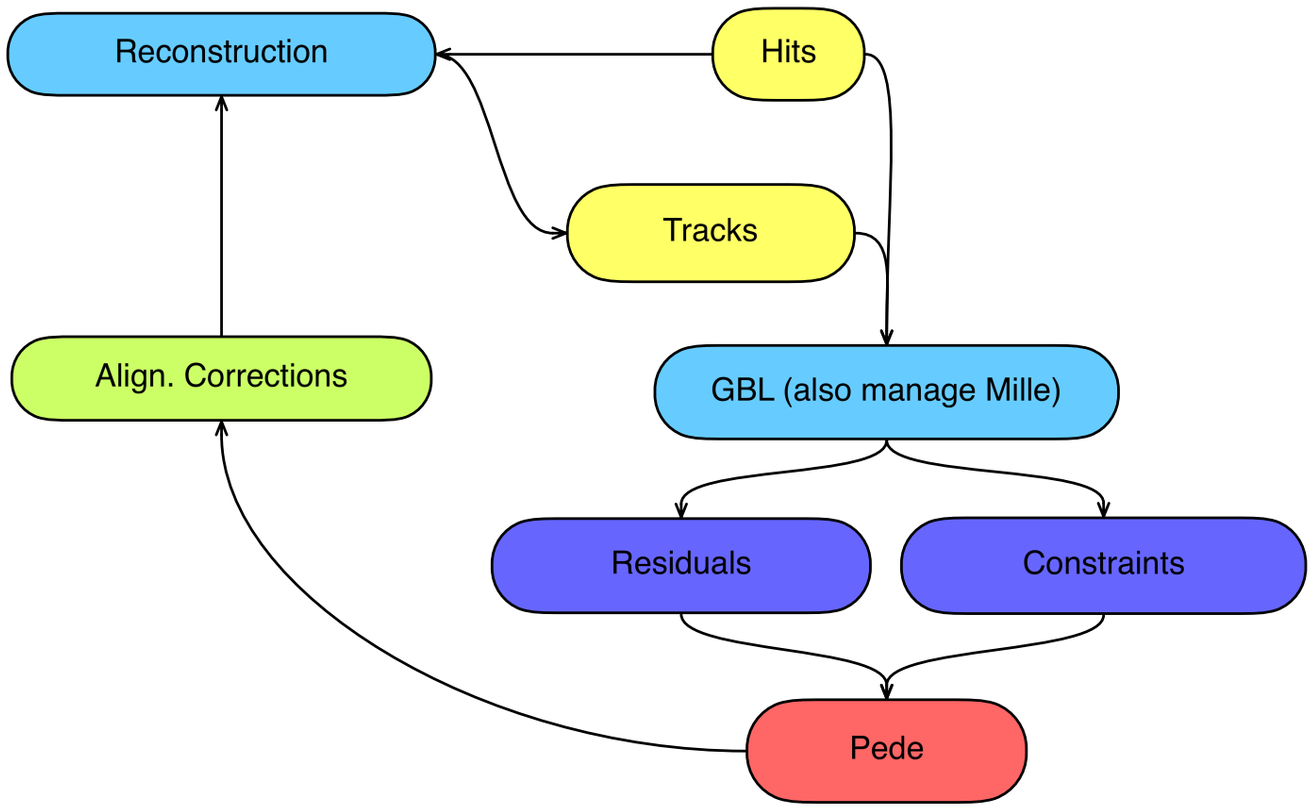
Misalignment Results



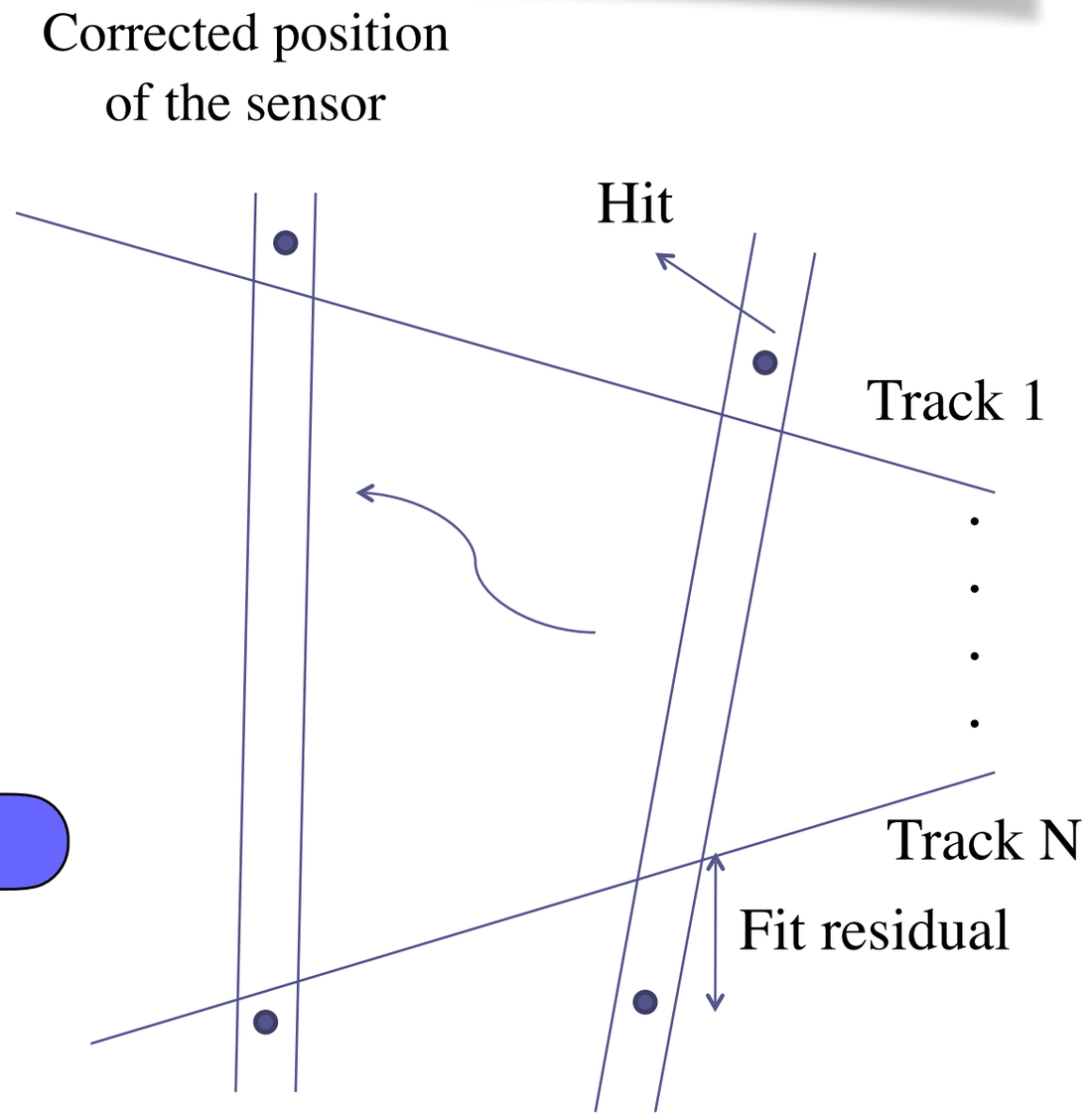


Alignment Strategies

How Does the Track Based Alignment Work ?

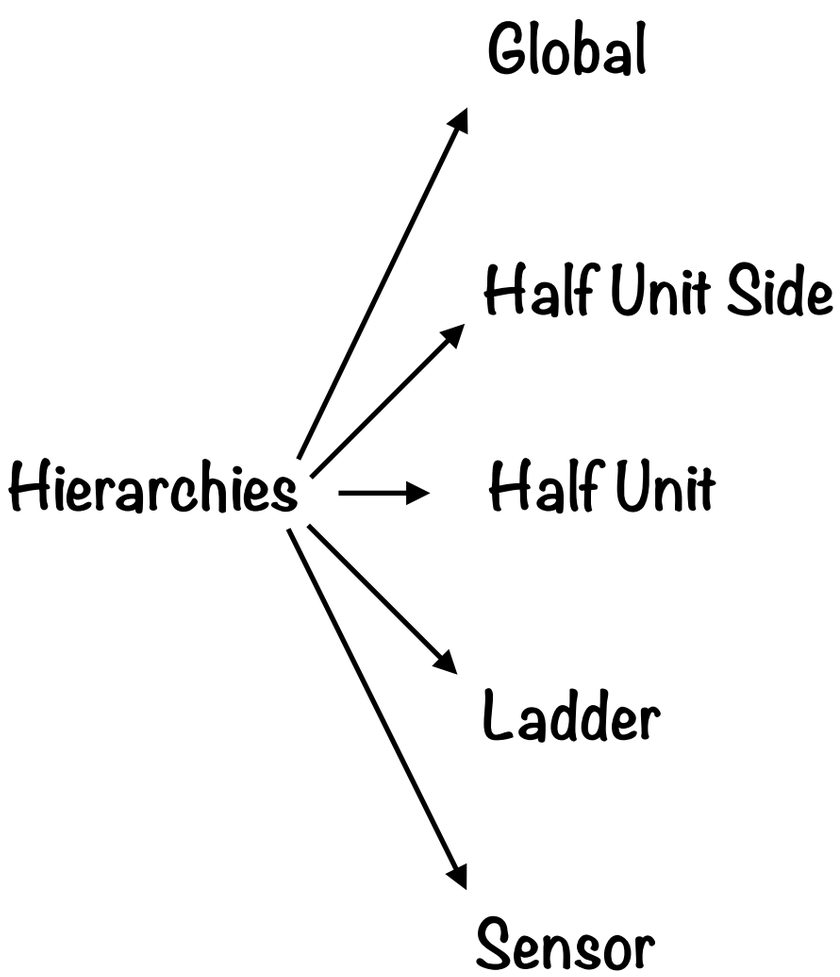


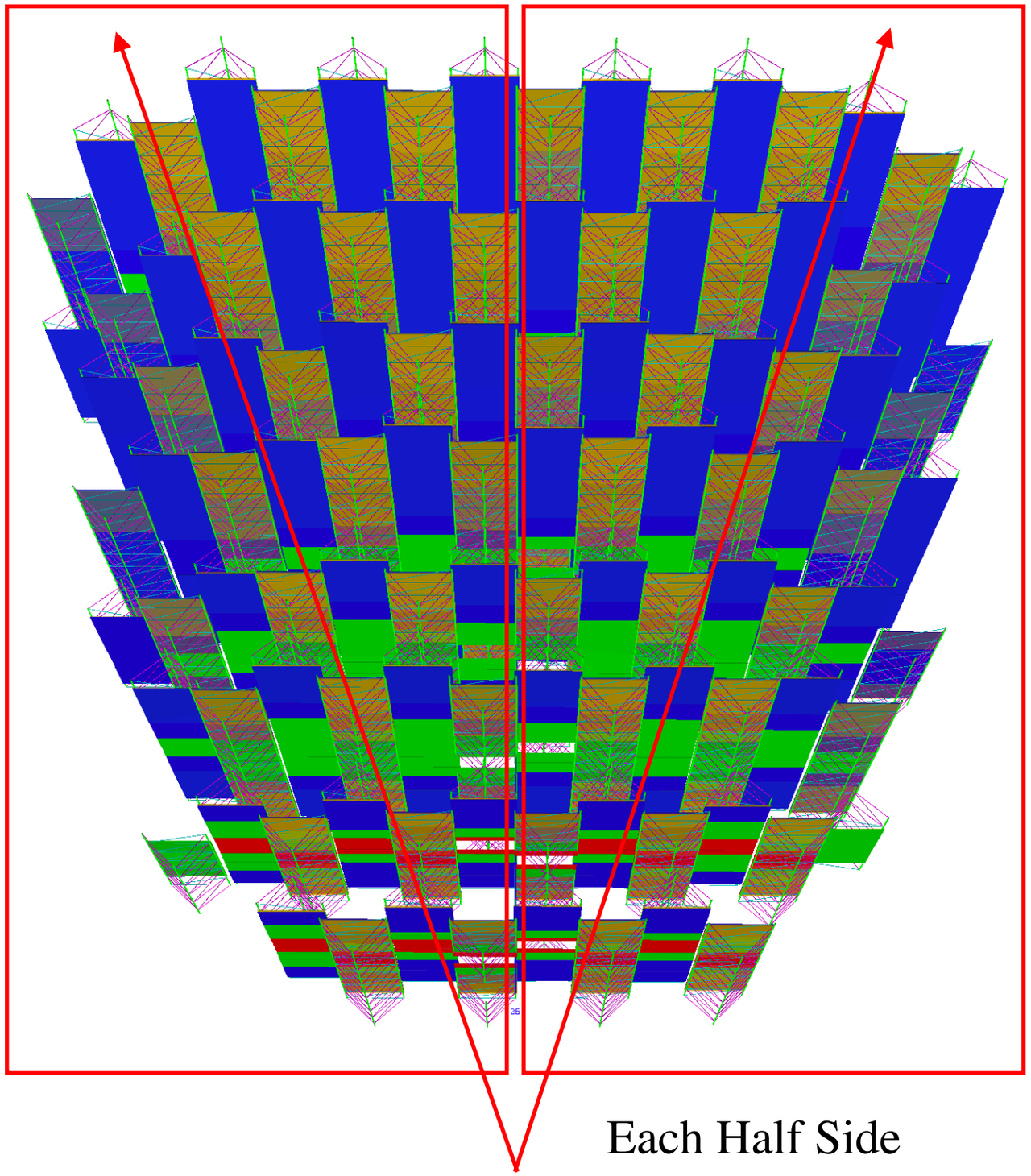
Working Flowchart



Track based alignment method

Hierarchy levels and Constraints



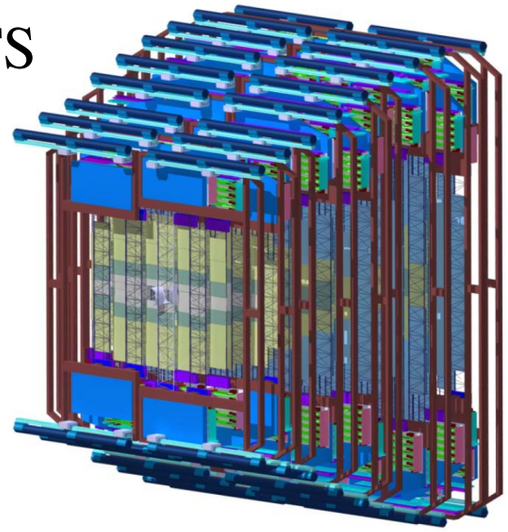


Realignment Scheme

Test Setup II

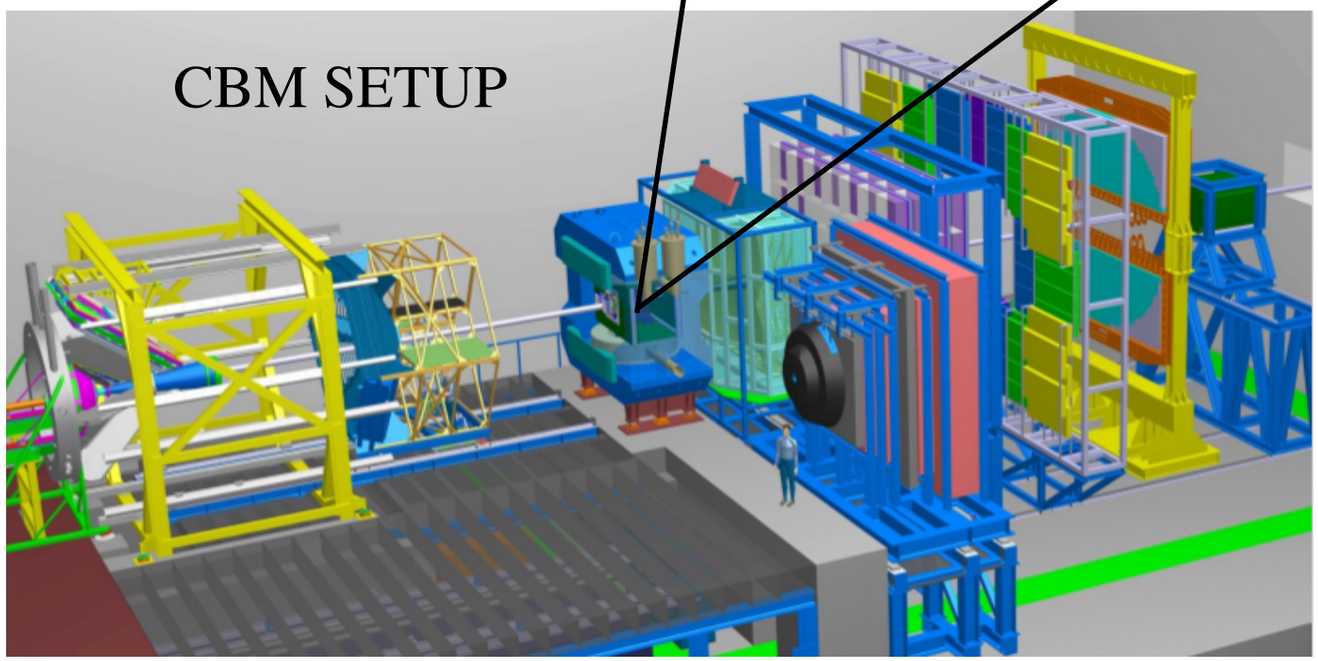
Unit Based STS: Elements in Setup

Units	8
Ladders	106
Halfladders	212
Modules	876
Sensor	876



Conditions

- 100 Muon events with 1000 multiplicity
- No magnetic field
- 2 GeV/c (fixed) momentum particles
- Minimum 4 hits to form a track
- Ideal track finder in use



Toy Misalignment Scenario and Realignment Results

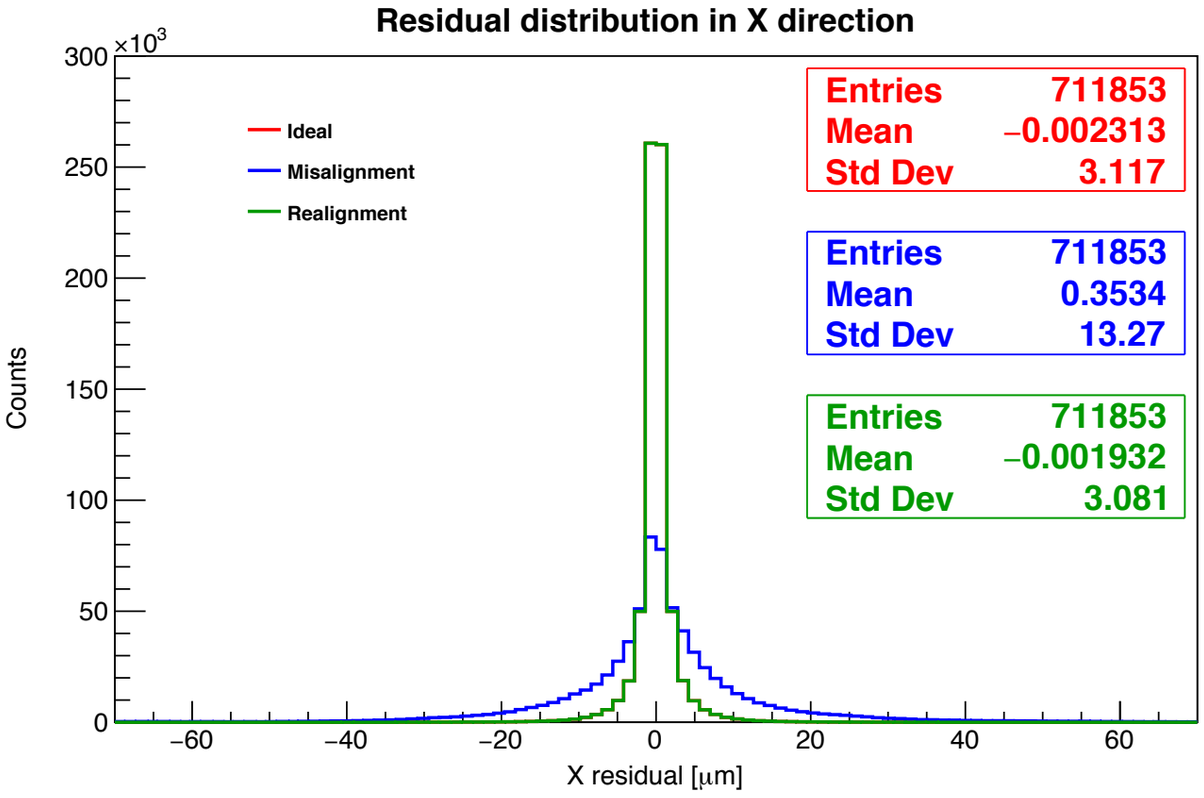
Half Unit level misalignment scenario: $\sigma_x = 150\mu m$

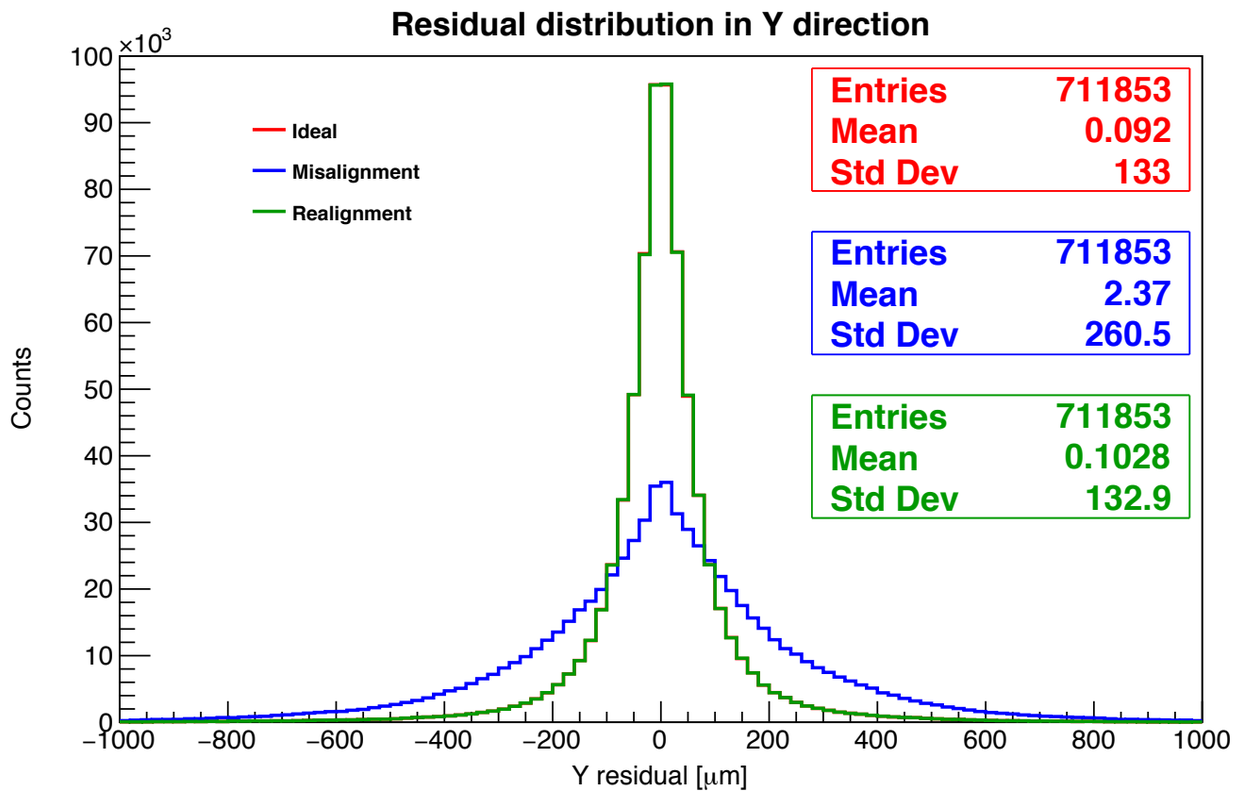
$\sigma_y = 150\mu m$

$\sigma_\gamma = 2.5mrad$

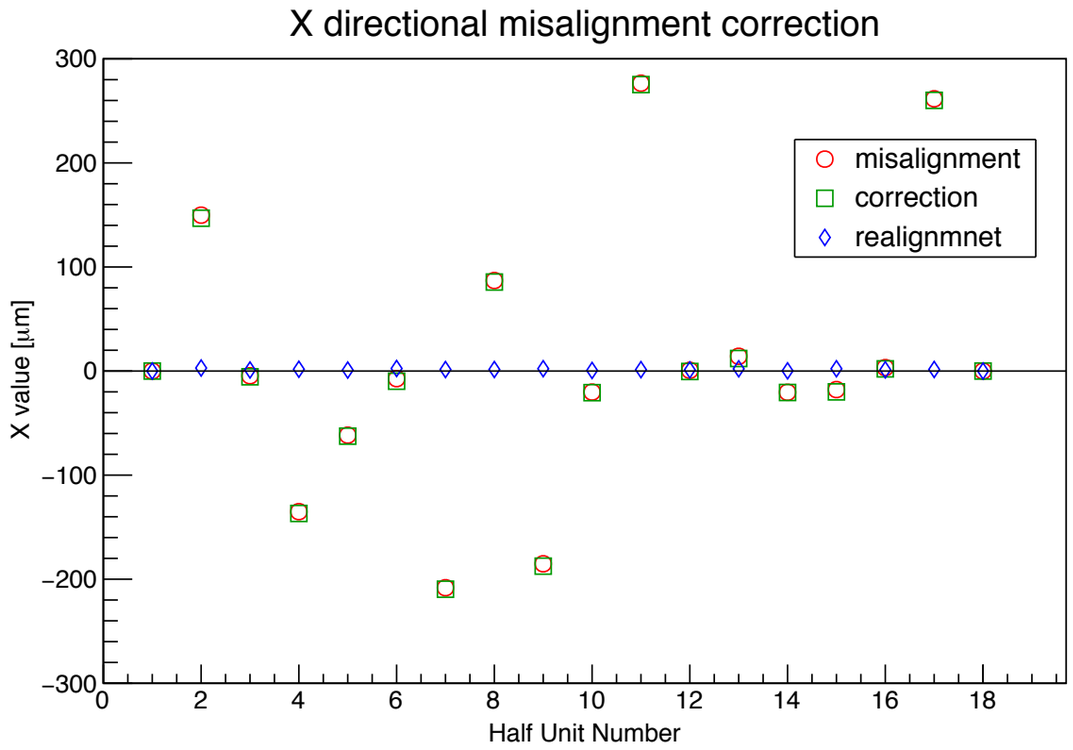
*Half Unit no. 1 and 18 are fixed!

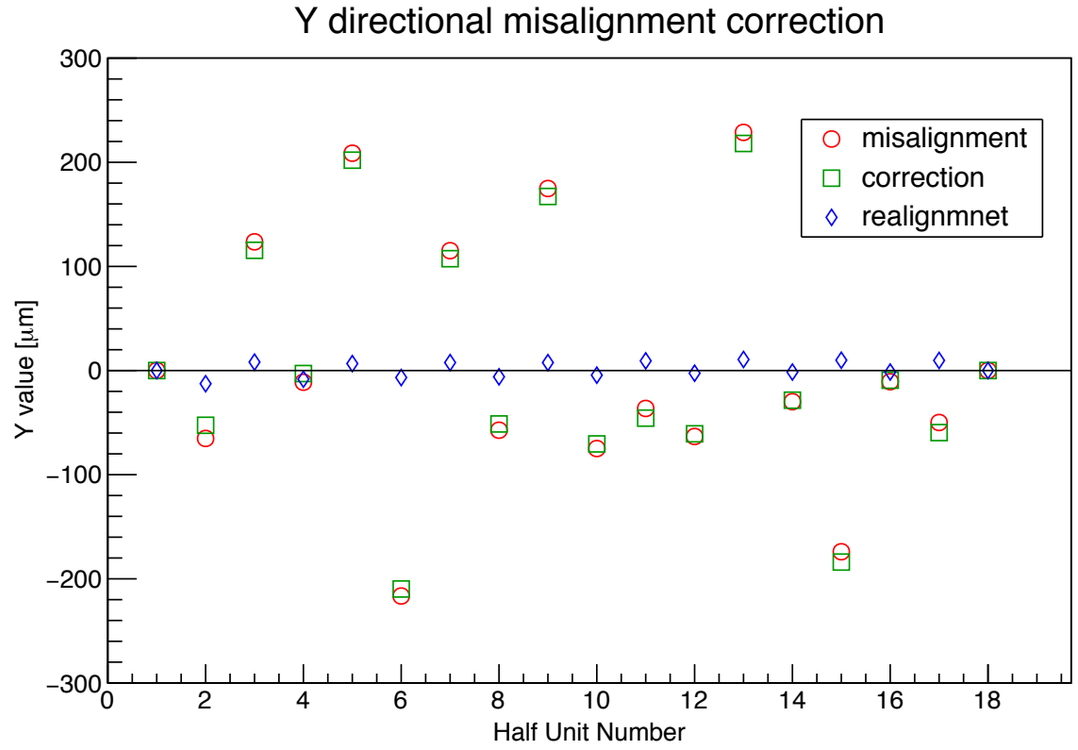
**Z Co-ordinate is fixed during the entire process(insensitive! DOF)

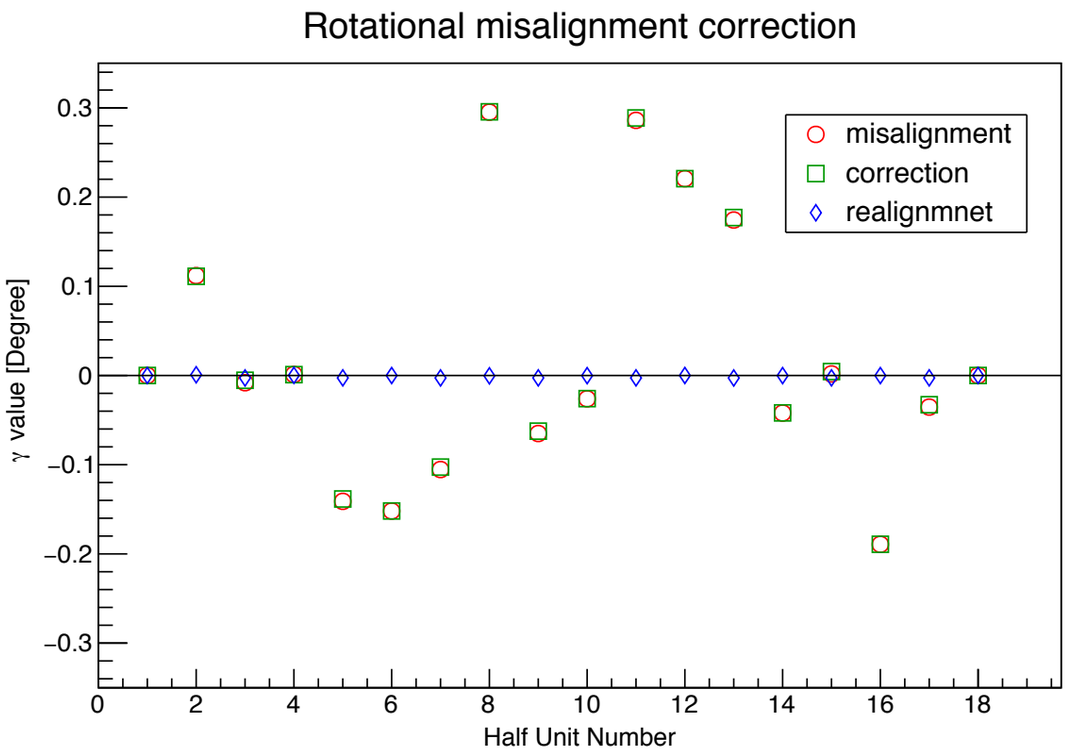




Realignment Results







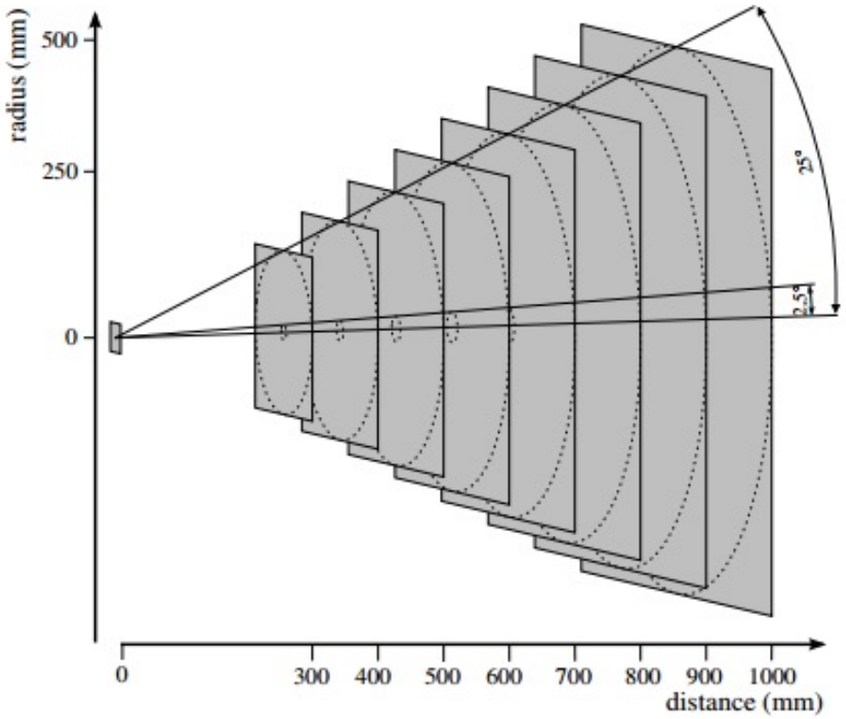
*Accuracy of the corrections are following:

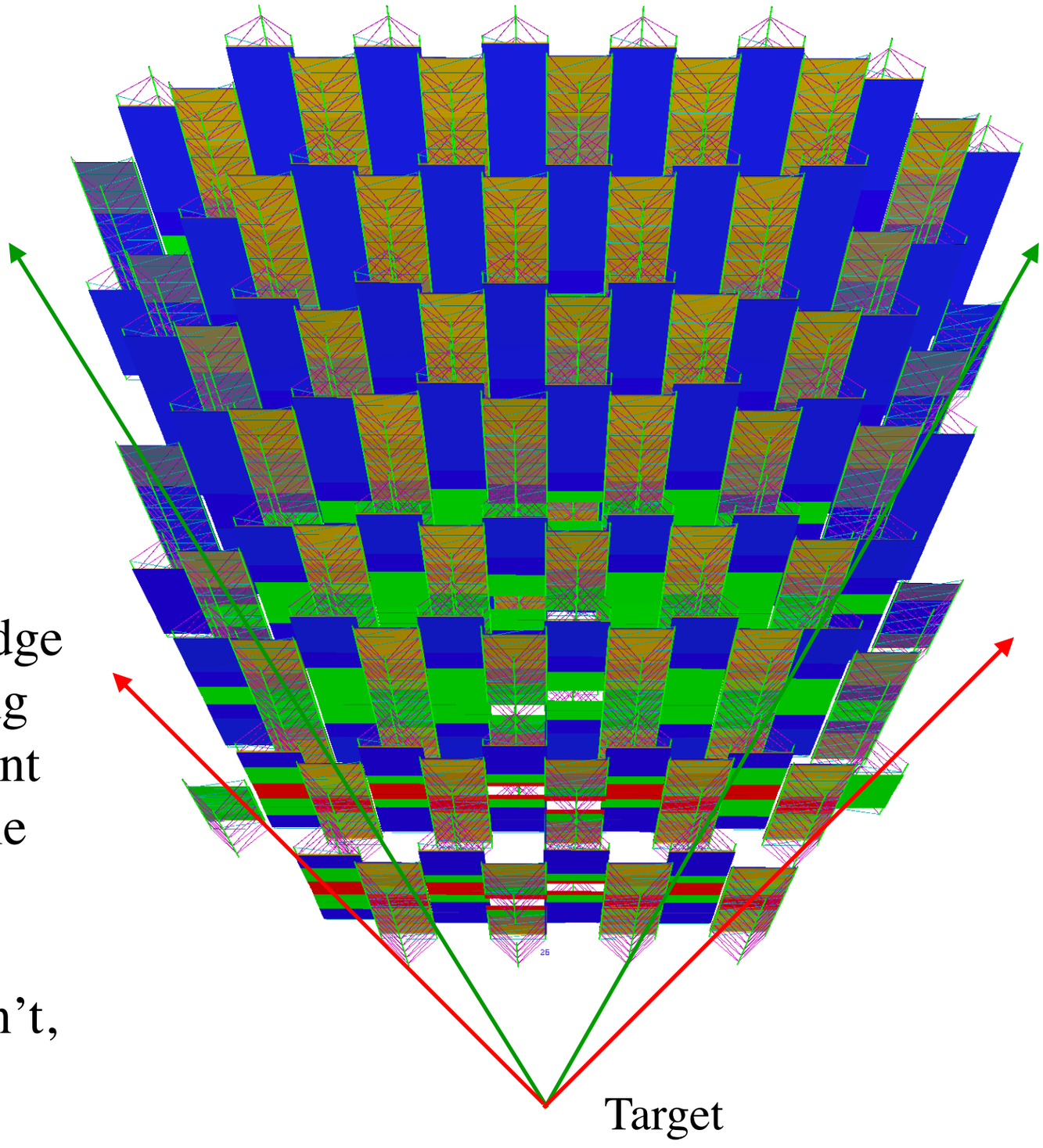
$$\Delta X < 5\,\mu\mathrm{m}$$

$$\Delta Y < 15\,\mu\mathrm{m}$$

$$\Delta \gamma < 50\,\mu\mathrm{rad}$$

What About the Ladder and Sensor Level Alignment?





*Basically, ladders placed on the edge of the half units are not participating in the tracking(so are the constituent sensors) because of the used particle generator (point like source).

**Shockingly, 16 edge ladders didn't, when $2.5 < \theta < 25.0$

Outlook

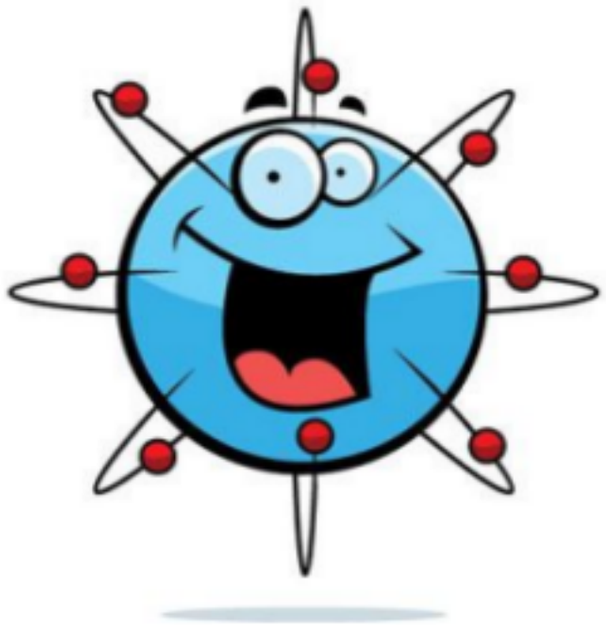
- Upgrading to the new unit based geometry was quite challenging but now it is implemented with 3 active hierarchy levels.

- The edge effect on the ladders and sensors is a big concern. Cosmic air shower(**CORSIKA**) should solve the problem. (work in progress)

- On the next step, the algorithm should be smart enough to decide whether it needs one step or iterative steps to achieve the desired corrections (work in progress).

- Z co-ordinate insensitivity could be solved by introducing an extra hierarchy level called "**quadra unit**".

- Soon, more realistic and adaptive misalignment scenarios will be introduced, and Millepede II will be used for the alignment.



Thank You

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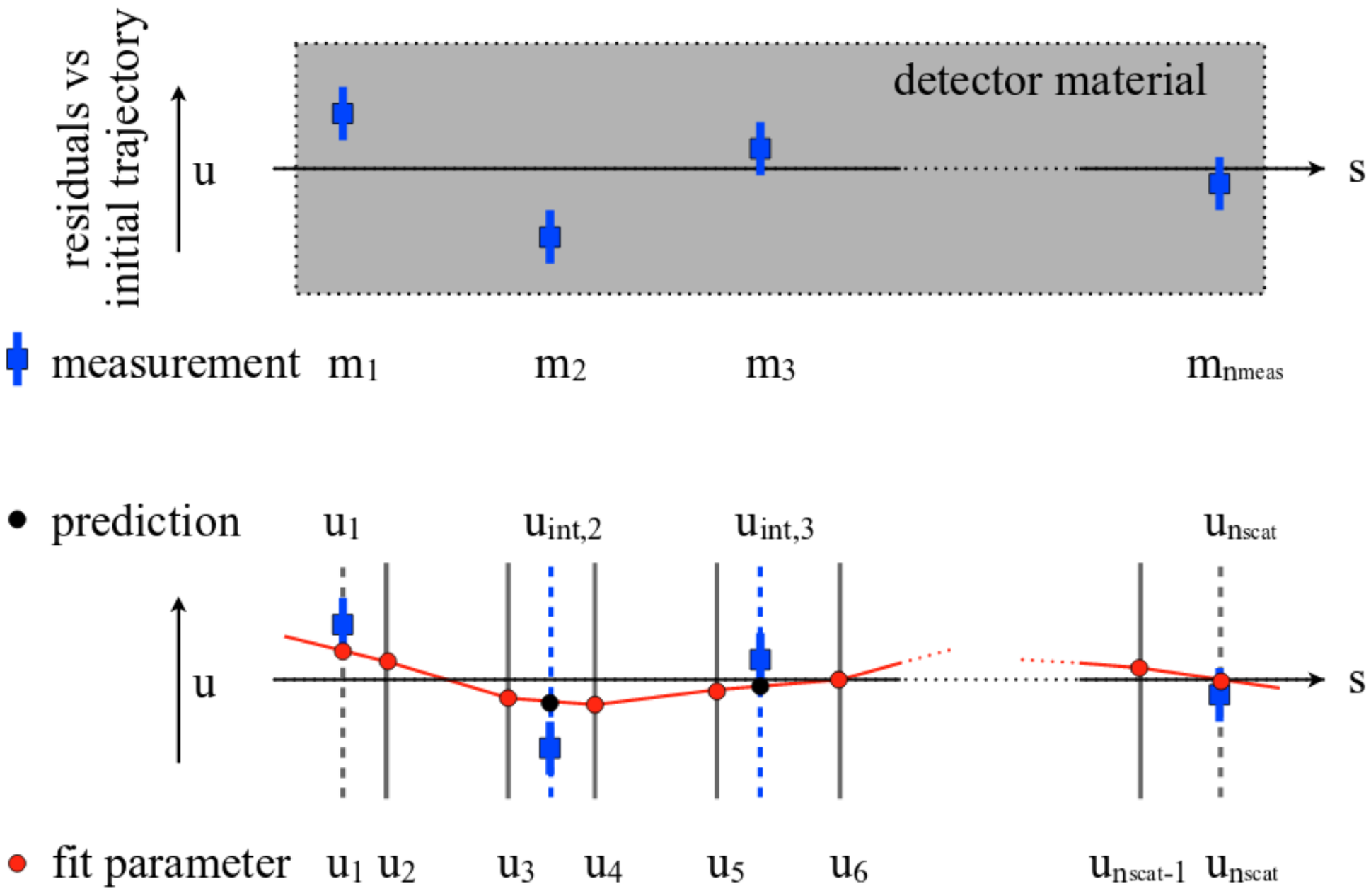
[9] "Introduction of General Broken Lines refit algorithm for CBM-STS", Susovan Das and H. R. Schmidt et al., CBM Progress Report, 2017

[10] "Track Based Alignment Procedure for CBM-STS Using Millepede II", Susovan Das and H. R. Schmidt et al., CBM Progress Report, 2017

Extra Slides

General Broken Line Track Fit



Advantages of using GBL

The fit parameters $\mathbf{q} = (\Delta\kappa, u_1, \ldots, u_{nscat})$ are determined by minimising,

$$\chi^2(\mathbf{q}) = \sum_{i=2}^{n_{\mathrm{scat}}-1} \boldsymbol{\beta}_i(\mathbf{q})^T \mathbf{V}_{\beta,i}^{-1} \boldsymbol{\beta}_i(\mathbf{q}) + \sum_{i=1}^{n_{\mathrm{meas}}} (\mathbf{m}_i - \mathbf{P}_i \mathbf{u}_{\mathrm{int},i}(\mathbf{q}))^T \mathbf{V}_{\mathrm{meas},i}^{-1} (\mathbf{m}_i - \mathbf{P}_i \mathbf{u}_{\mathrm{int},i}(\mathbf{q}))$$

- ☑ KF already provides the necessary input for GBL.
- ☑ Uses linear least square method for track fitting, writes binary input for Millepede.