MMTP Misalignment Corrections

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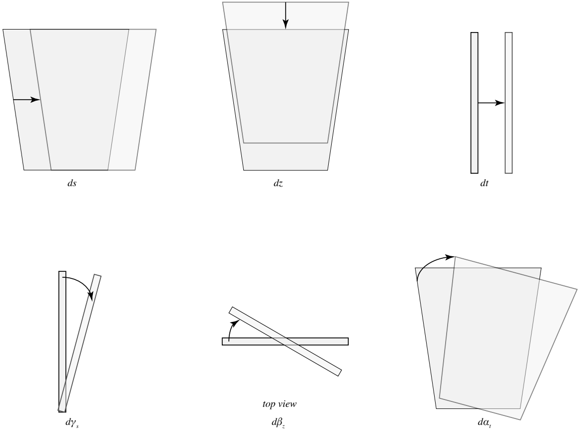
Misalignment Cases

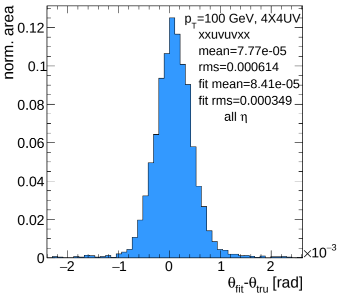


- Local (x, y, z) axes correspond to AMDB local $(s, z, -t)$ axes
- Rotations along these axes are denoted (γ, β, α) and are done before translations

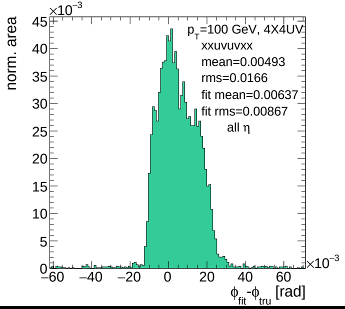
MM Algorithm Summary

- Hits have strip and plane, we find $y = y_{base} + n_{strip} \times w_{strip}$ and a z_{plane}, to give a slope value y/z
- These are used to calculate vertical ($M_X \rightarrow m_y (= M_X^{global}), M_X^{local}$) and horizontal ($M_U, M_V \rightarrow m_x$) coordinates and the following quantities of interest
  - $\theta = \arctan\left(\sqrt{m_y^2 + m_x^2}\right)$, $\phi = \arctan\left(m_x/m_y\right)$, $\Delta\theta = \frac{M_X^{local} - M_X^{global}}{1 + M_X^{local} M_X^{global}}$
- Baseline nominal performance of the algorithm summarized below and **here** and **here**:

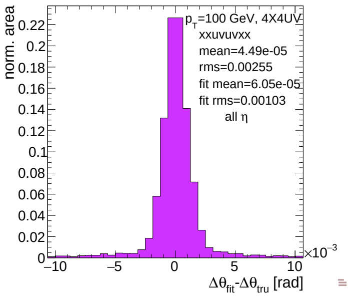
: θ



: ϕ



: $\Delta\theta$



MM Corrections Summary

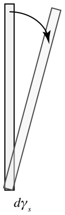
- Corrections are either of the "analytic" or "simulation" based
- Analytic Cases: Use knowledge of misalignment to apply case-specific corrections (summary of requirements (extra constants/operations) given below; n_X is number of X hits in fit)
  - $\Delta z, \Delta t$: Change algorithm constant definitions for station base positions
  - Δs: Apply misalignment weighted constant correction
  - γ_s: Binned constants for plane position along beamline
  - α_t: Const. ϕ corr., θ_{fit}, ϕ_{fit} to correct $\Delta\theta$; can use more consts or more ops
- Simulation Cases: Store mean biases for $\theta, \phi, \Delta\theta$ in θ_{fit}, ϕ_{fit} binned LUT on MC sample (used $p_T = 200$ GeV sample instead of 100 GeV sample to train)
  - Currently, using 10 η bins, 10 ϕ bins for 3 fit quant.: 300 const./6 ops.
- Different approaches better for different cases

Table: A summary of corrections with additional constants/operations for analytic: yes+ means quality of correction is only limited by knowledge of misalignment and memory

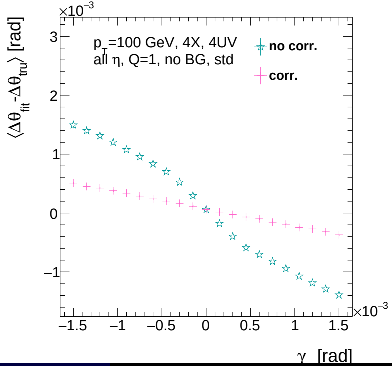
	Δs	Δz	Δt	γ_s	β_z	α_t
Analytic Resources	yes+ 11c/2op	yes+ 0c/0op	yes+ 0c/0op	yes 56c/1op	no —	yes 400c/2$n_X$op, 32c/12$n_X$op
Simulation	yes+	no	no	no	yes+	yes+

MM Analytic Corr. Example: γ_s

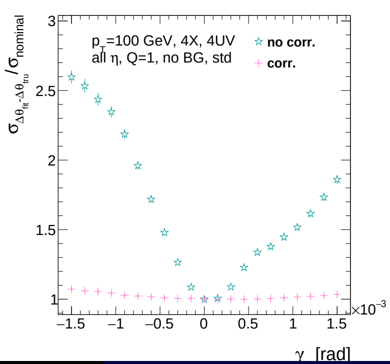
- Misalignment dependent on strip
- Correcting hits too comp. intense—z_{plane} $\rightarrow$LUT: 8 values/plane
- Correction not perfect (most problematic case), but makes changes manageable
  - $\Delta\theta$ for $\gamma_s = 0.3$ mrad ($\sim$ 1 mm): 0.12 mrad bias shift, 1% resolution degradation



: $\Delta\theta$ bias, misal



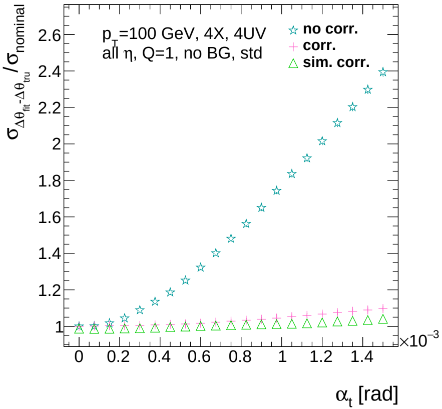
: $\Delta\theta$ rms, misal



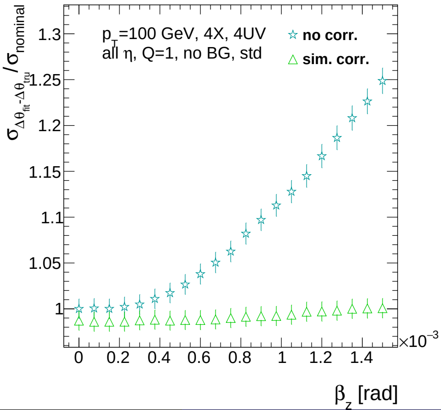
MM Simulation Corr. Example: α_t (β_z)

- Simulation most useful for cases where misalignment depends on horizontal position: the α_t and β_z rotations; nearly perfect correction

: $\Delta\theta$ rms, α_t



: $\Delta\theta$ rms, β_z



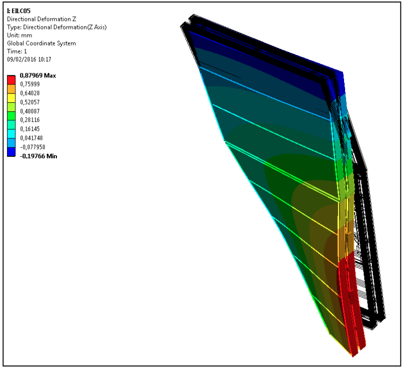
MMTP Tolerance Summary

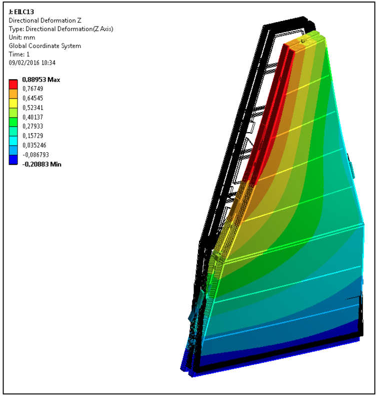
- A summary of levels of misalignment corresponding to a 10% degradation in any residual rms or, for biases shifts of, 0.01 mrad for θ, 1 mrad for ϕ, and 0.25 mrad for $\Delta\theta$ for both the uncorrected and corrected cases; $>$ 5 mm and $>$ 1.5 mrad mean that such a degradation does not occur for the range of misalignment studied. Most affected quantity in parentheses.

	No Correction	Correction
Δs	4 mm (ϕ bias)	$>$ 5 mm
Δz	0.25 mm ($\Delta\theta$)	$>$ 5 mm
Δt	0.25 mm ($\Delta\theta$)	$>$ 5 mm
γ_s	0.15 mrad ($\Delta\theta$ bias)	0.75 mrad
β_z	0.9 mrad ($\Delta\theta$ rms)	$>$ 1.5 mrad
α_t	0.375 mrad ($\Delta\theta$ rms)	$>$ 1.5 mrad

Preliminary results on large sectors

- Worst cases on sector 05 and 13 → ~1mm deviation

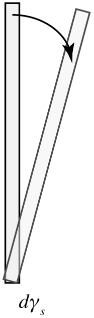




What is the impact on trigger performances with twist on MM detectors?

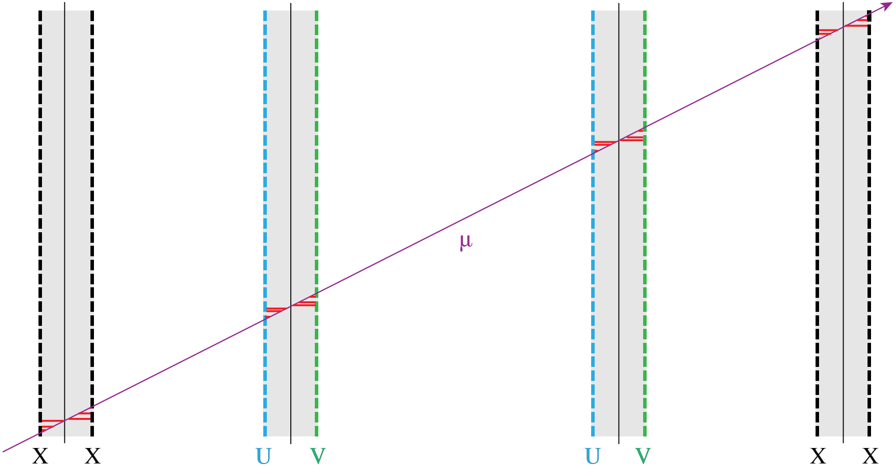
Correction Sketch

- The deformations are a combination of two types of rotations: a tilt and a twist
  - The tilt—γ_s
    - This is a LUT in simulation, but it consists of redefining constants, so probably no extra overhead in firmware
  - The twist—$\beta_z(y)$
    - This is a LUT in simulation and ϕ dependent, so will likely need to be a LUT in firmware
    - The details of the calculation will change since β_z is not constant, but implementaiton is the same
- If the deformation can be parameterized, the β_z portion of the deformation can probably be fully corrected
  - The overall impact of β_z is very small, due to the shallow stereo angle
- One thing to note is that in our studies, one plane was misalgined with respect to the other. If we have both planes similarly misaligned, the effect on $\Delta\theta$ will be mitigated



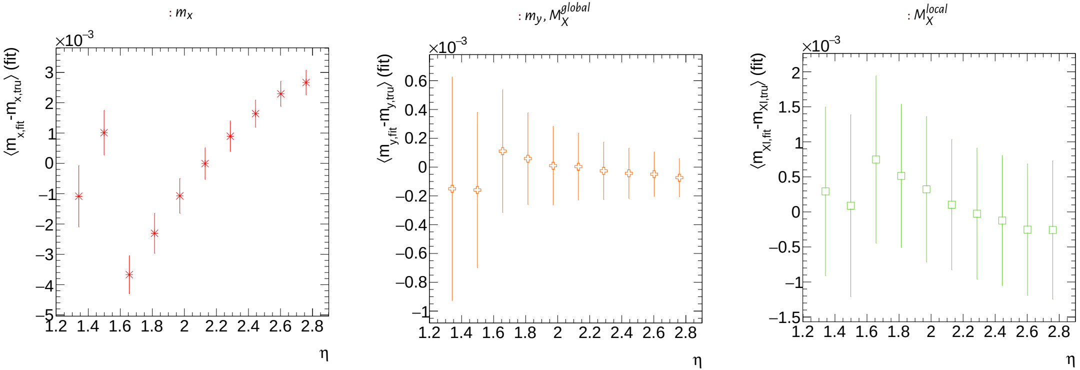
Backup

ϕ Shape I: Ionization



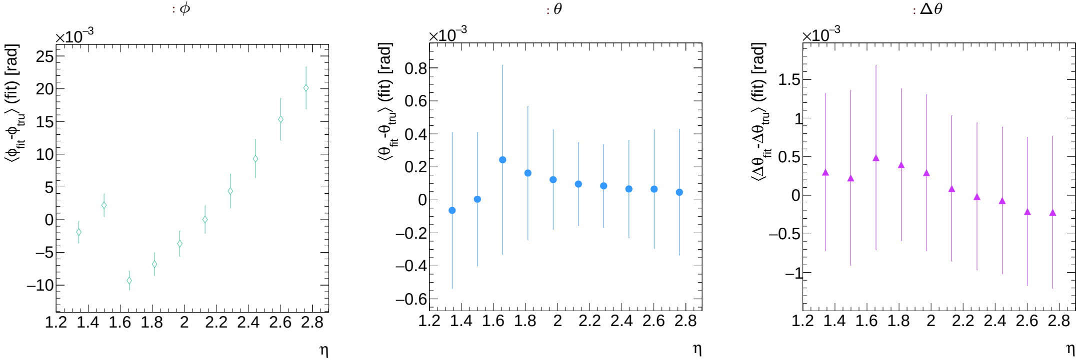
ϕ Shape II: Composite Slopes

- This shows up in the composite slopes: residuals of slopes have η dependence (discontinuity from two stations in η)
- Stereo hits affect m_x most



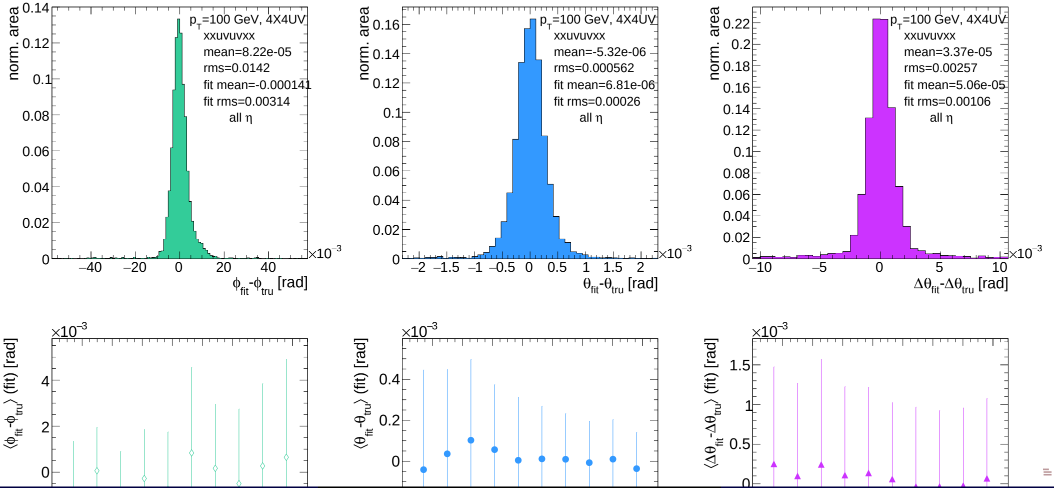
ϕ Shape III: Fit Quantities

- This in turn causes some η dependence to the residuals of fit quantities; particularly *phi*
- The spread over two stations gives the characteristic shape of the ϕ residual distribution



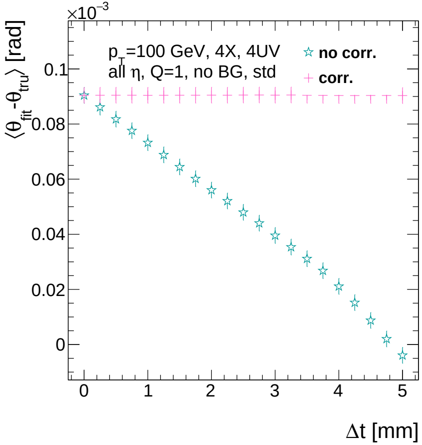
Simulation Corrections Under Nominal Conditions

- Could be used to address η dependence of residuals and point way to future improvements

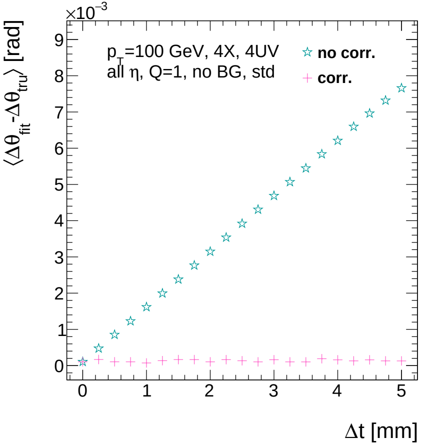


- By changing y_{base} and z_{plane} for misaligned planes. . .

: θ bias



: $\Delta\theta$ bias



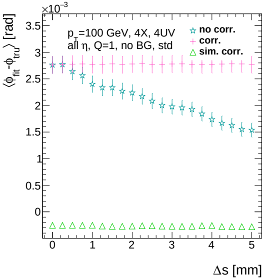
A Slightly More Complicated Case: Δs

- In the horizontal shift case, θ and $\Delta\theta$ are essentially unaffected, but ϕ bias shifts slightly
- The shift acts like a constant offset in the calculation of m_x, the horizontal coordinate.
- For a given track fit, apply a weighted correction:

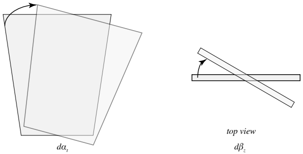
$$\Delta m_x = \frac{1}{N_{stereo}} \sum_{i,misal\ stereo} \frac{\Delta s}{z_{i,plane}}$$

  - Where N_{stereo} is the total number of stereo planes in the fit, and the sum is over only the misaligned stereo planes
- These can be put in a lookup table (LUT) similar to the local slope calculation constants

: ϕ bias

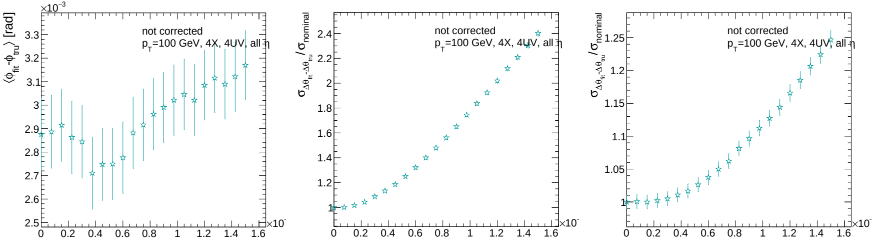


Corrections Binned in η, ϕ: α_t (β_z), Analytic



- The final two rotations lead to ϕ/horizontal pos. dep. misalignments
- Affects ϕ bias and $\Delta\theta$ rms for α_t, $\Delta\theta$ rms slightly for β_z

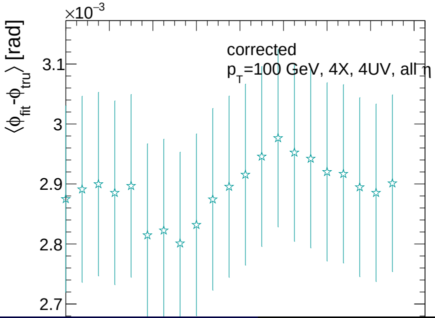
: ϕ bias, α_t : $\Delta\theta$ rms, α_t : $\Delta\theta$ rms, β_z



Corrections Binned in η, ϕ: α_t, Analytic

- Analytic: calculate uniform ϕ correction and make a θ_{fit}, ϕ_{fit} binned LUT for corrections to hits that go into M_X^{local} calc.
- $M_X^{local} = B_k \sum_i y_i \left(\frac{z_i}{\bar{z}} - 1\right)$, where $\bar{z}$, B_k are constants
- Use same calculation for generic misalignment to calculate corrections to y and z in θ_{fit}, ϕ_{fit} LUT ($\Delta\theta$ done after θ and ϕ)

: ϕ bias, α_t



: $\Delta\theta$ rms, α_t