Current Alignment Systematics: Consequences for Z'

Jim Pivarski

Texas A&M University

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Motivation

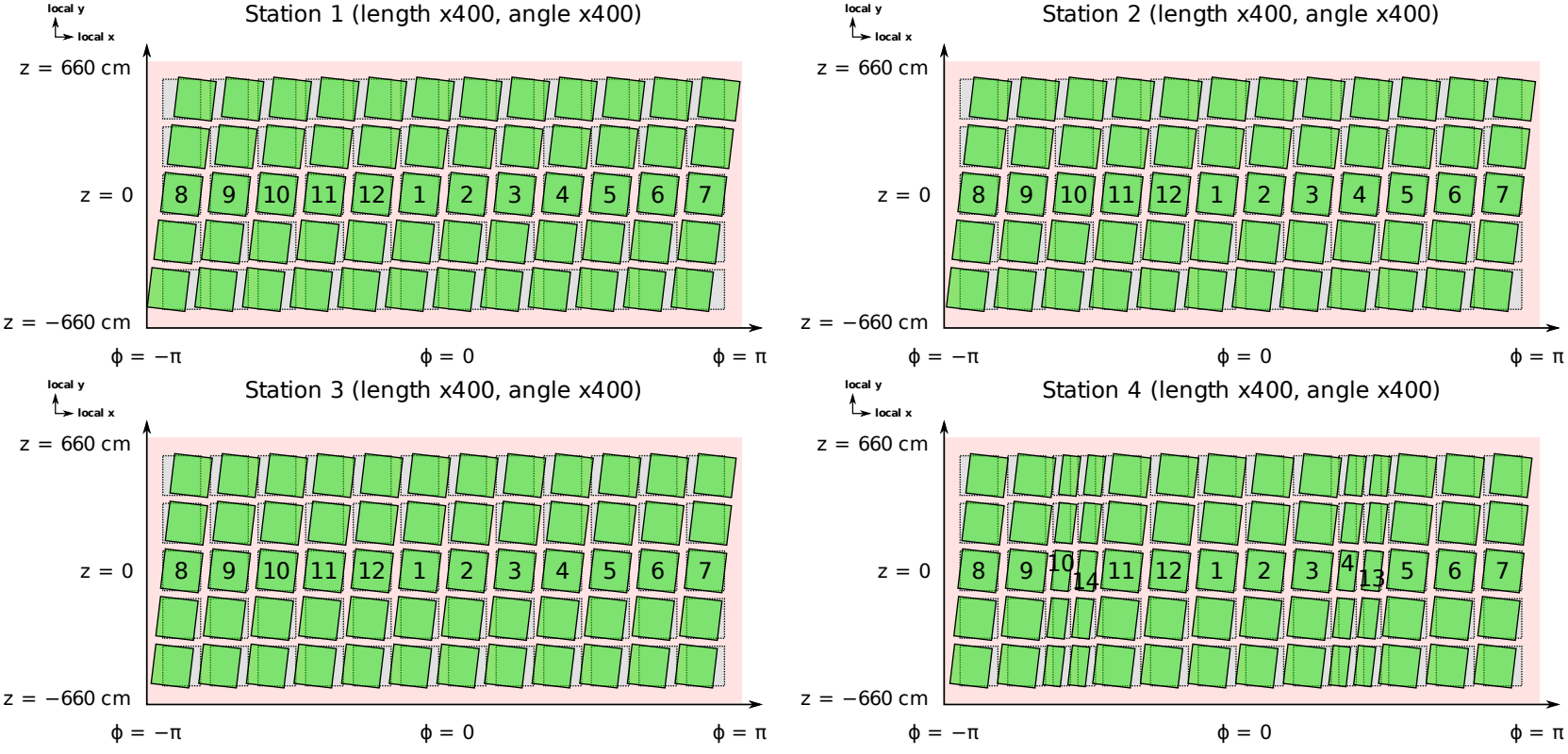
- Motivation #1: we want to know how much the HW-TB discrepancies we've been discussing actually matter for physics (Z' will be the most affected analysis)
- Motivation #2: part of what we need to provide is a quantitiative estimate of our uncertainties for analyses to study systematics
  - typical systematics study: physics result y depends on an imperfectly known quantity x as $y = f(x)$
  - experimenter varies $\Delta x = x_1 - x_2$ and observes change in $f(x_1) - f(x_2)$, but how much Δx variation is appropriate?
  - in the barrel, we can now answer that: $\Delta x = x_{\mathrm{HW}} - x_{\mathrm{TB}}$
  - in the endcap, Samir's disk-shift study quantifies $f(x)$, but we don't yet have a systematic study of Δx
- Only studied leading discrepancies in each dimension:
  - pure twist (0.5 mrad rotations around global $\vec{R}$), no individual-chamber differences
  - local-y differences, chamber-by-chamber
  - Samir's disk-shift study quantifies current leading uncertainty in endcap

Comment

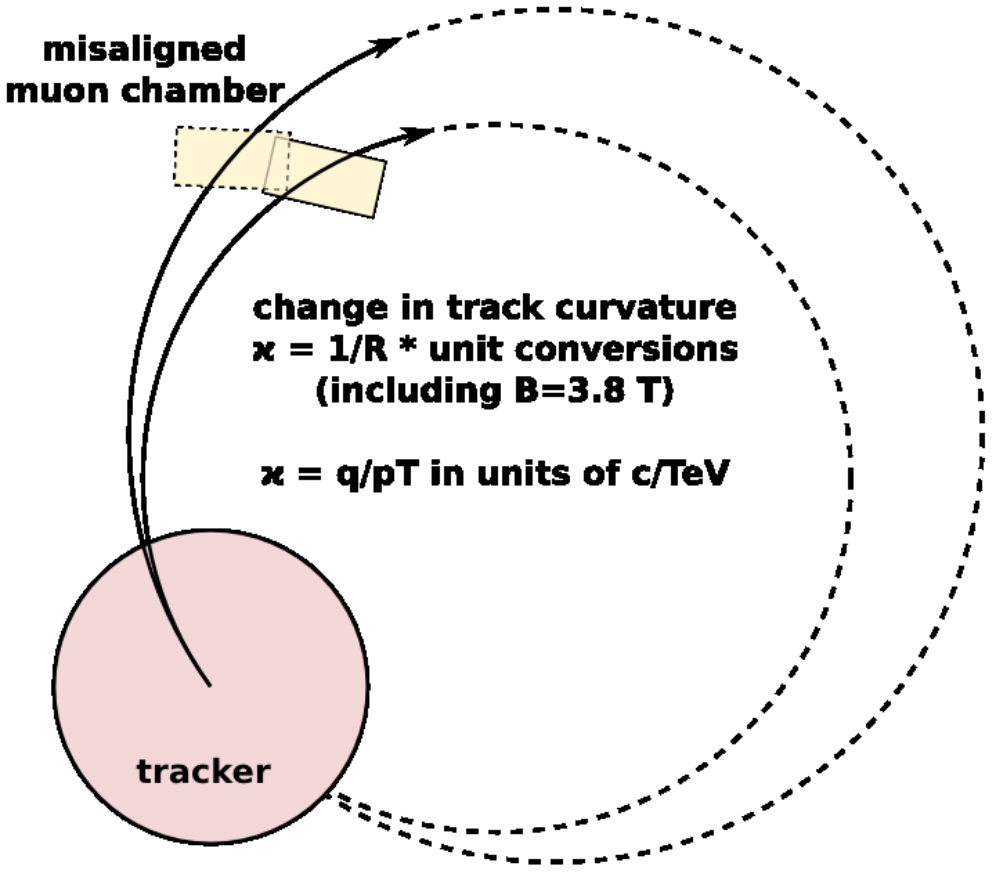
- This is not a statement about whether HW is more correct than TB or vice-versa
  - it does not rely on a model of why either one of them might be biased
  - it relies on the shape and magnitude of the empirically observed differences
- We assume that we don't know which is correct, so we are potentially making an error the size of the difference between them: that's the uncertainty

Tested geometries: 1. twist

- Systematic trends only, no individual-chamber differences (systematic trends are bigger than the individual differences)
  - all chambers rotated 0.5 mrad in ϕ_z and translated in local-x to line up, just as we see in the residuals plots
  - same slope in all stations, just as we see in the residuals plots



Quantities of interest for tracks

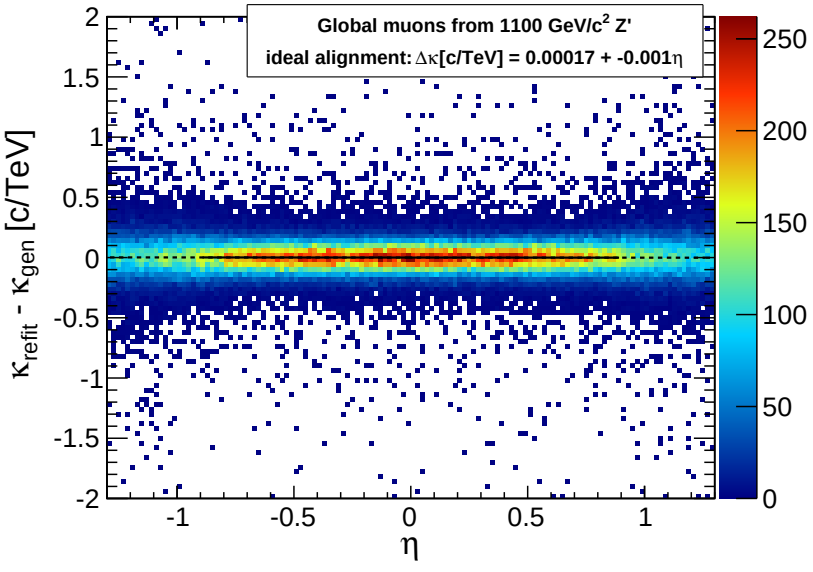


- In principle, misalignment can affect all five track parameters
- But we're only interested in curvature errors for from twist and η errors from local-y
- Express curvature as $\kappa = q/p_T$, errors as $\kappa_{\text{refit}} - \kappa_{\text{gen}}$
- Better than $pT_{\text{refit}} - pT_{\text{gen}}$ because of the simple relationship between κ and residuals: $\Delta\kappa$ is more Gaussian

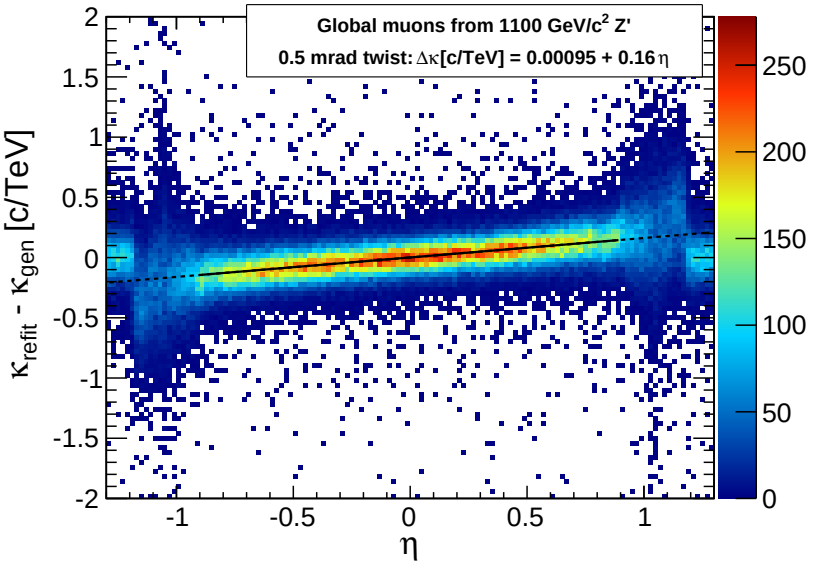
Effect of twist

- Regular pattern within the barrel: error in κ is (0.16 c/TeV) $\times \eta$
- $\eta > 1$ region is the barrel-endcap overlap: complicated in this study because only the barrel was twisted (not something that could happen with TB constants)
- Bias is comparable to resolution: resolving twist is important

Ideal

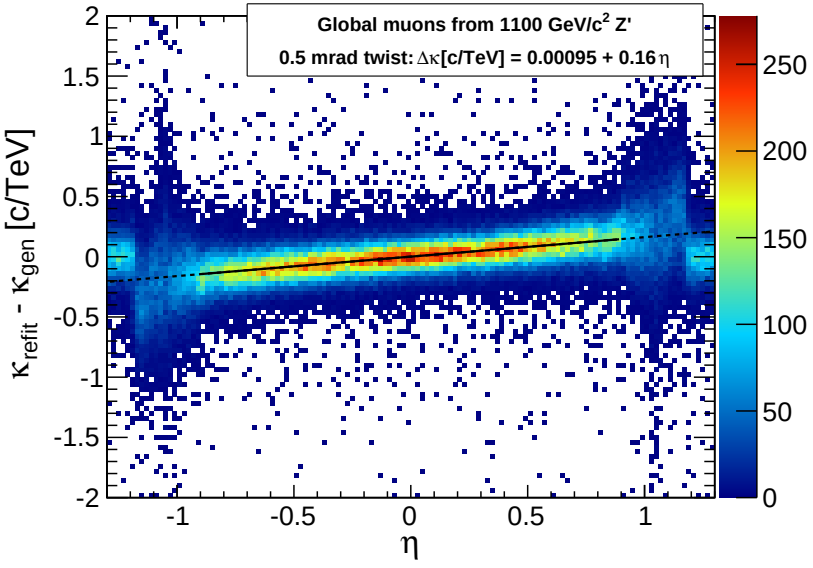


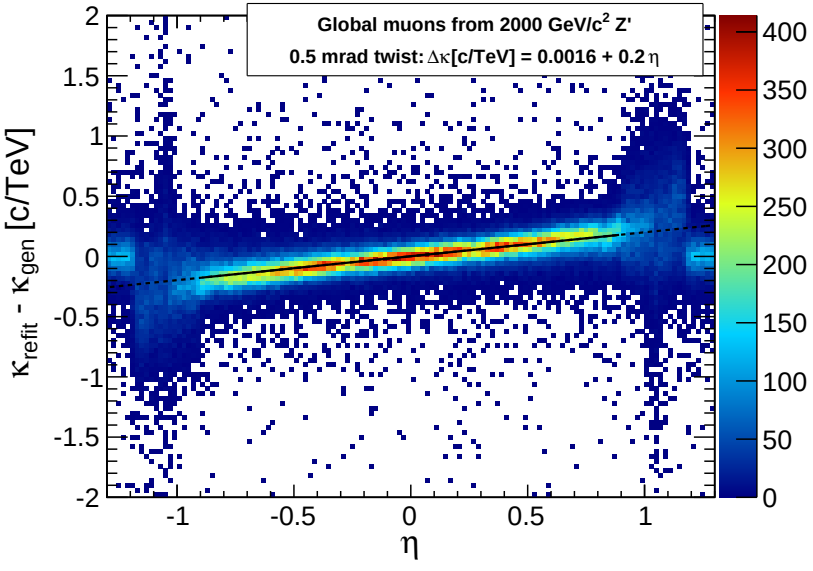
0.5 mrad twist



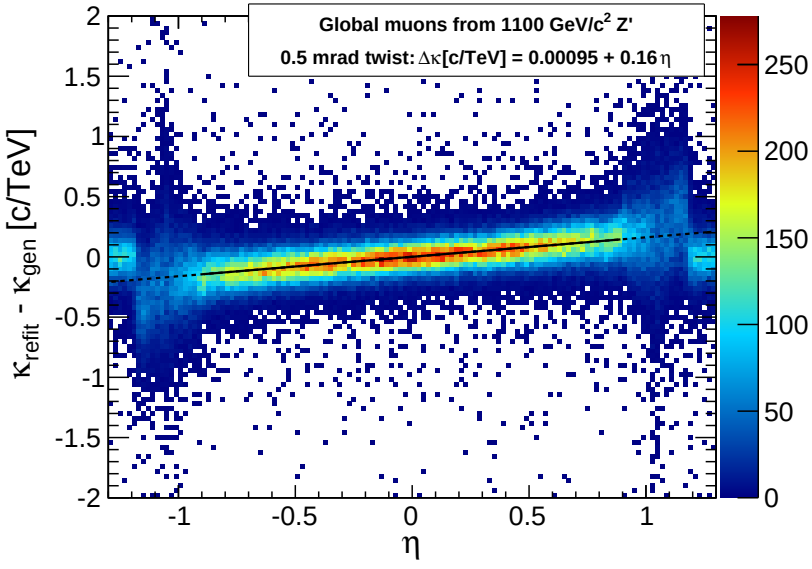
Effect of twist: more tests

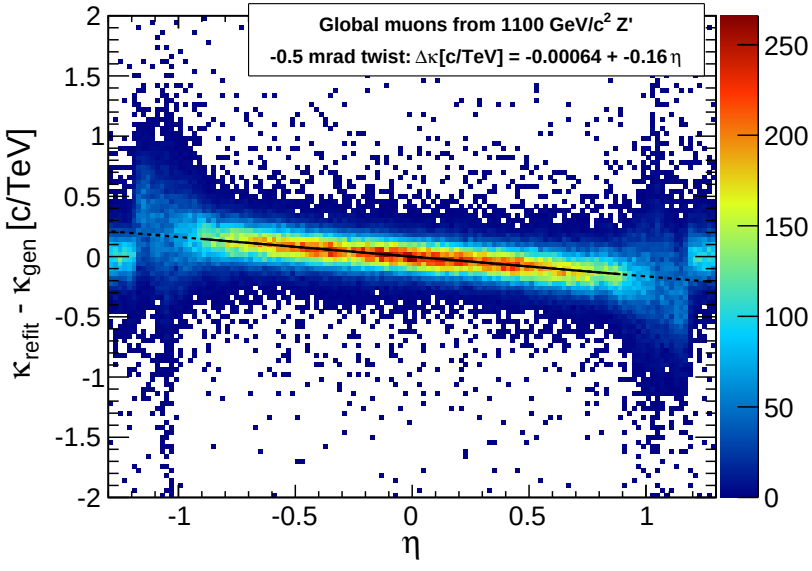
Increases with track momentum (e.g. from higher-mass Z's)





Reverses when twist is reversed

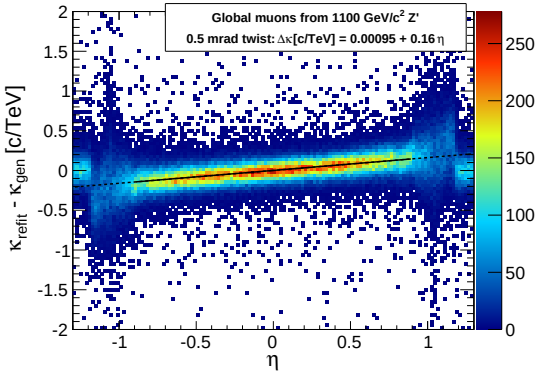




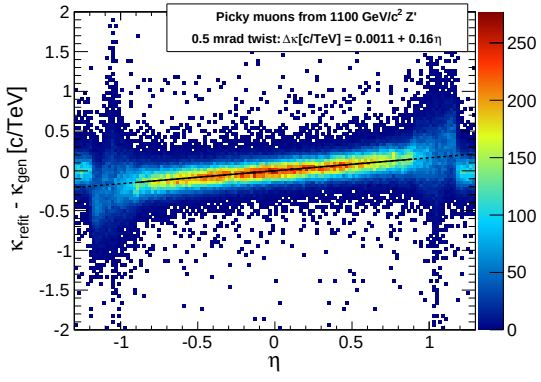
Effect of twist: more tests

- There are multiple refitting algorithms for reconstructing TeV-muons to try to solve the problem of muon-showering
- Misalignment effect doesn't depend strongly on algorithm

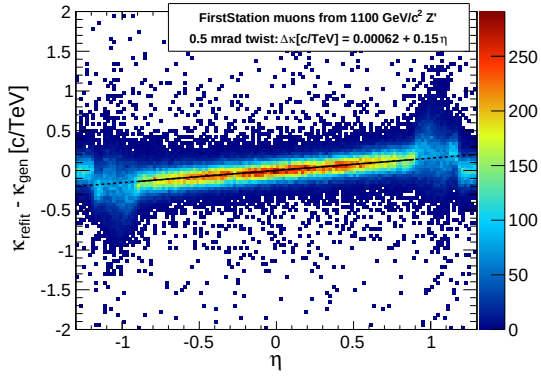
GlobalMuons



Picky



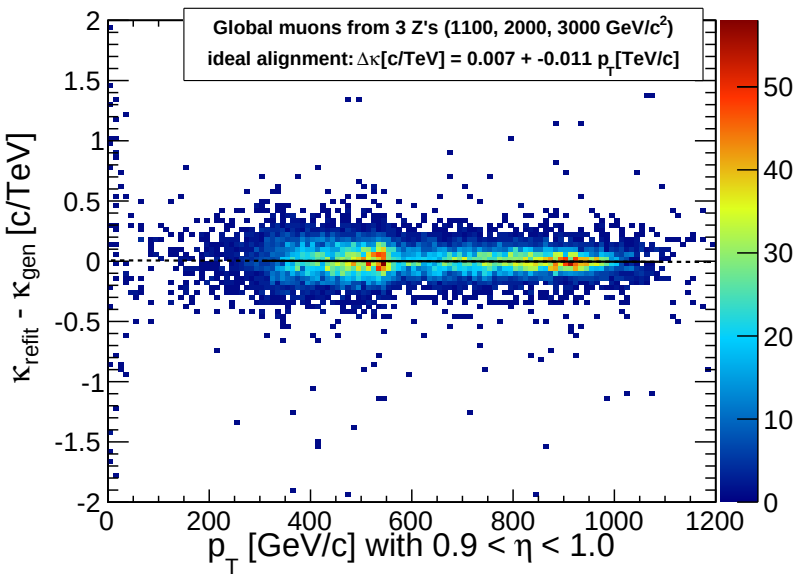
FirstStation



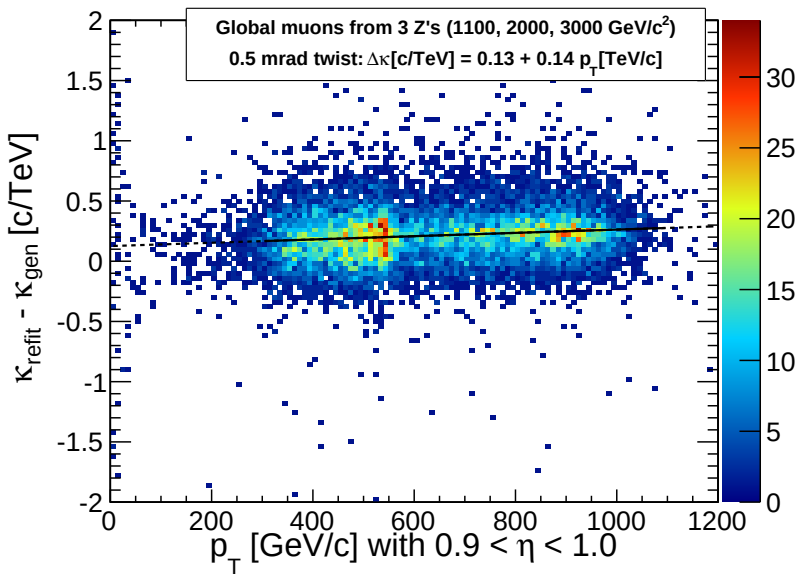
Effect of twist: versus p_T

- Since the effect also depends on p_T (high-momentum tracks rely on muon chambers more, and get more biased), look at bias in an extreme $0.9 < \eta < 1.0$ slice
- This would be done better with a muon-gun with a uniform distribution in p_T

Ideal

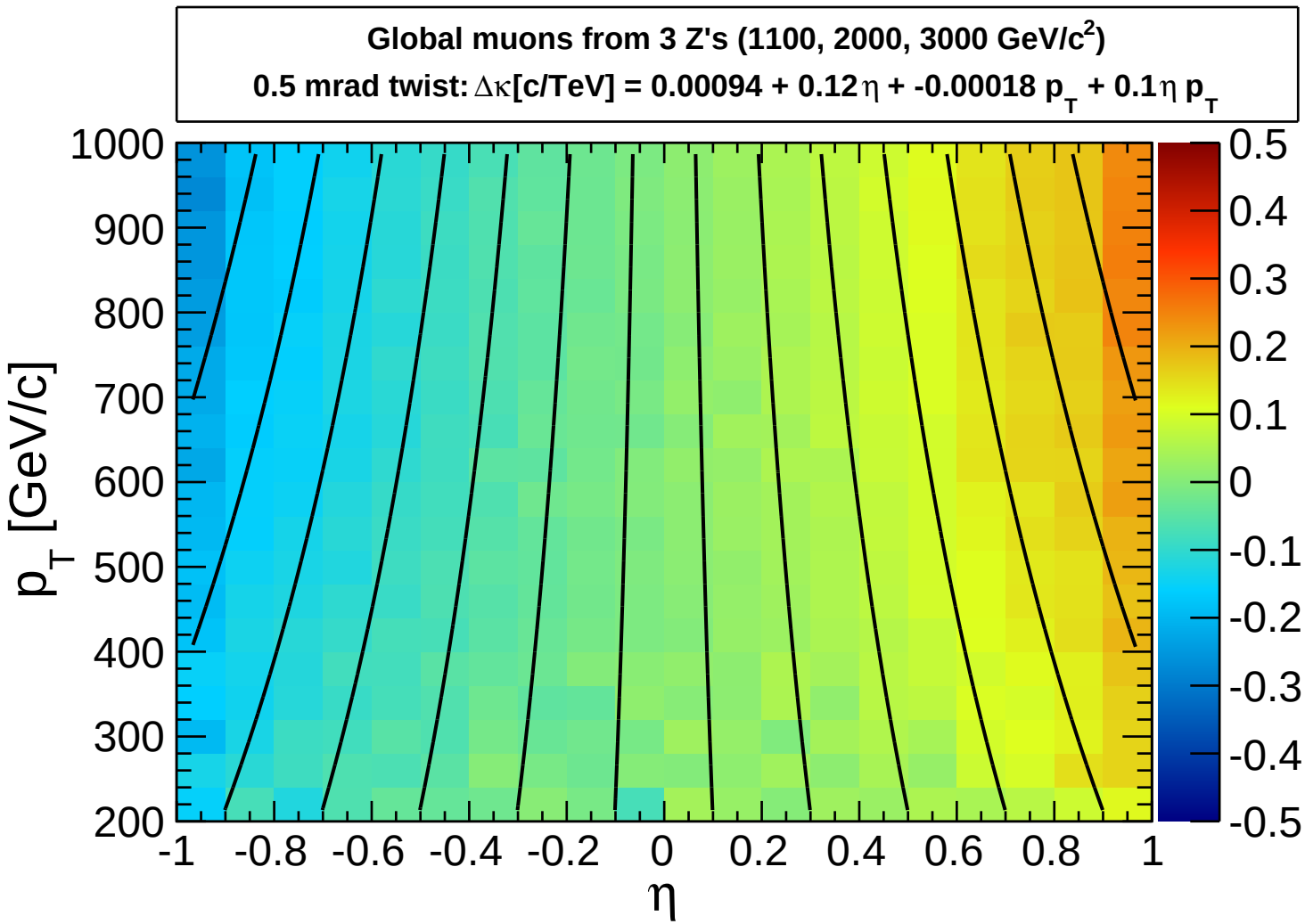


0.5 mrad twist



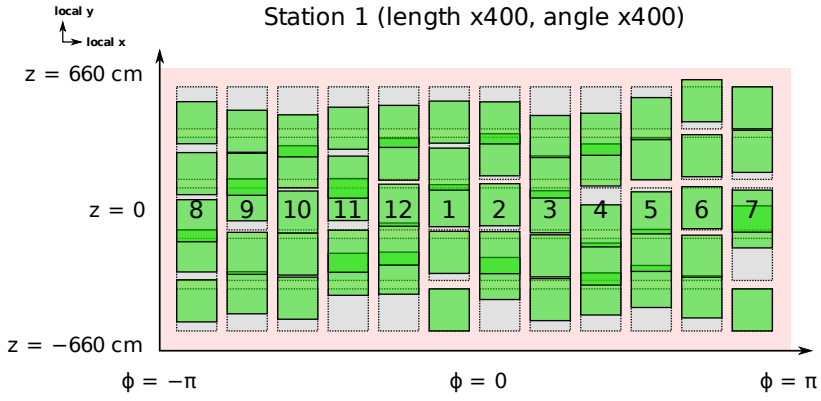
Effect of twist: summary

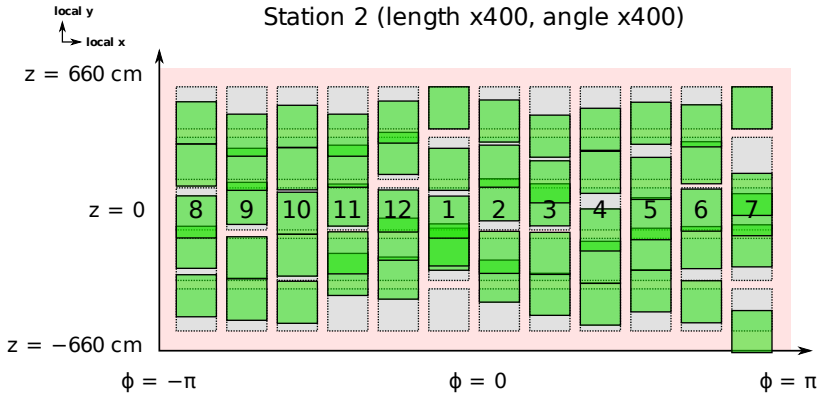
- Both dependencies on one plot; color scale is average $\Delta\kappa$ in c/TeV (we get to see the bias, but not the width of the distribution)
- Bilinear fit to the 2-D distribution: $\Delta\kappa \approx (0.12\ c/\text{TeV})\eta + (0.1)\eta p_T$

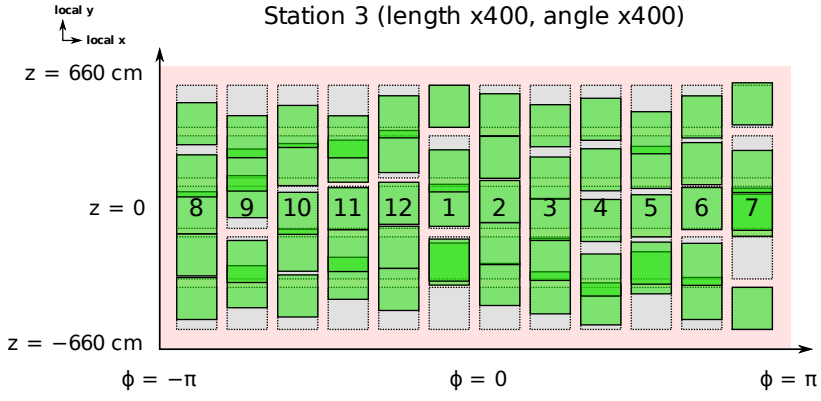


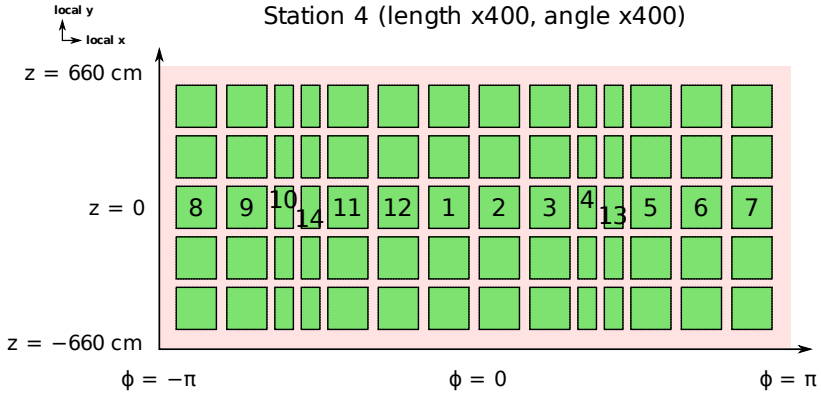
Tested geometries: 2. local-y

- The HW−TB differences that Aysen sent by HyperNews
- Only local-y, no other directions



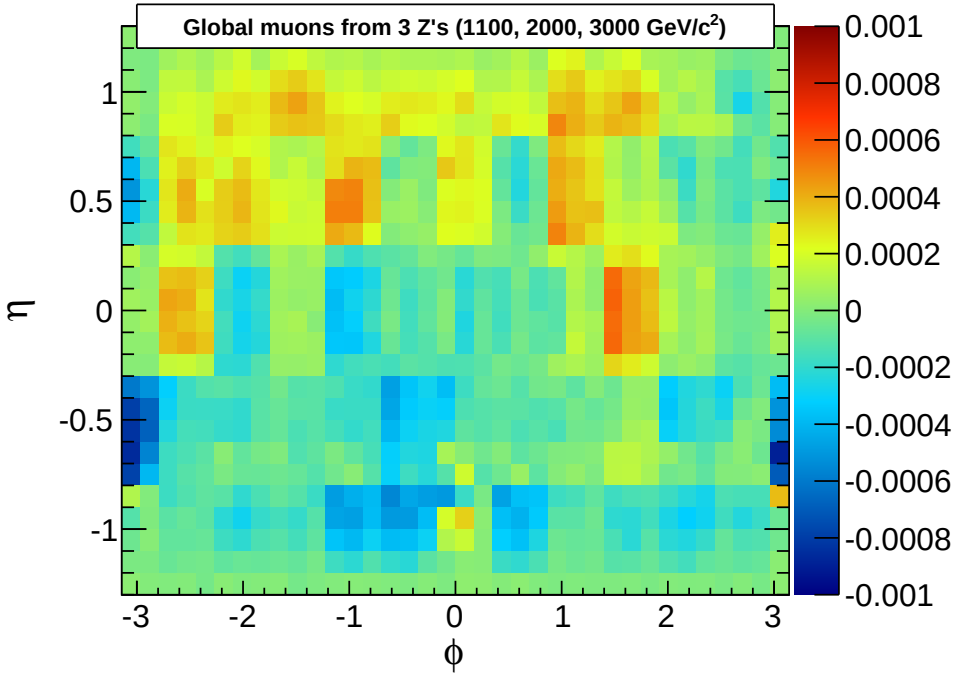


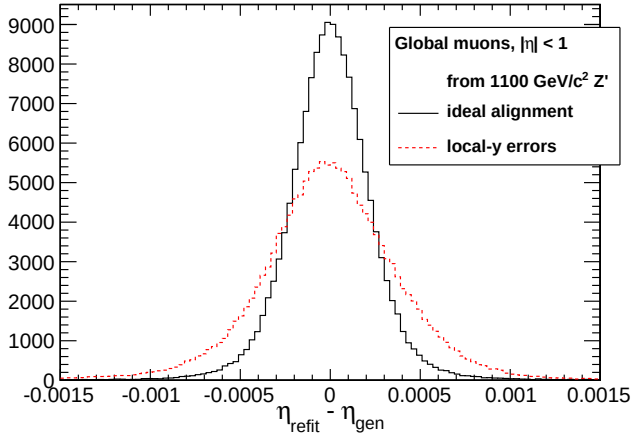




Effect of local-y

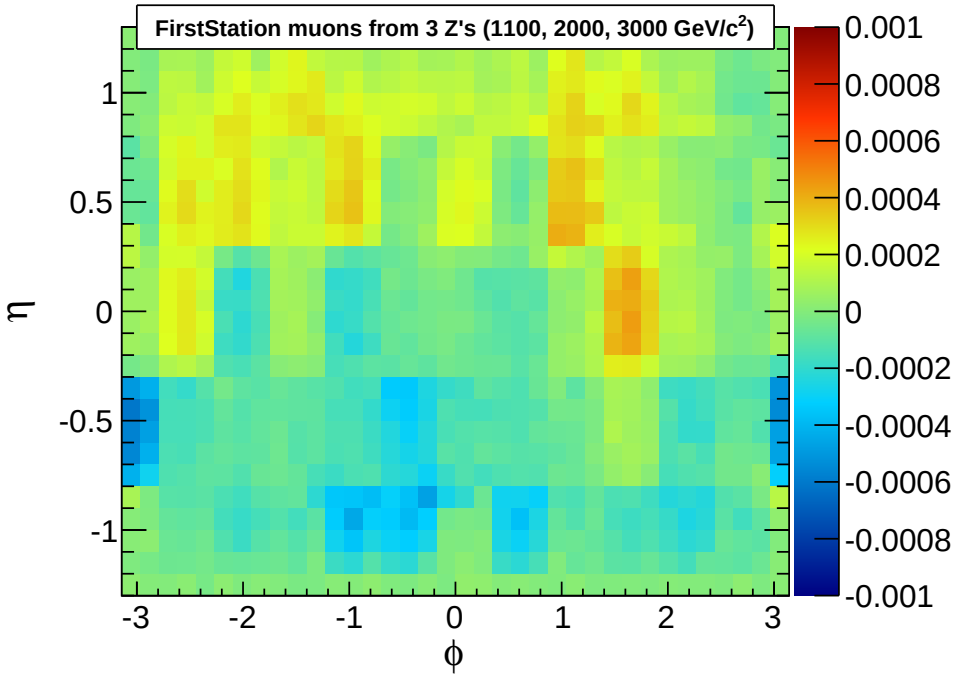
- Left: $\eta_{\text{refit}} - \eta_{\text{gen}}$ color scale versus η and ϕ (you can see the individual chambers, even though high η tracks pass through different wheels
- Right: 1D $\eta_{\text{refit}} - \eta_{\text{gen}}$ distribution with and without misalignment; biases are comparable to the resolution

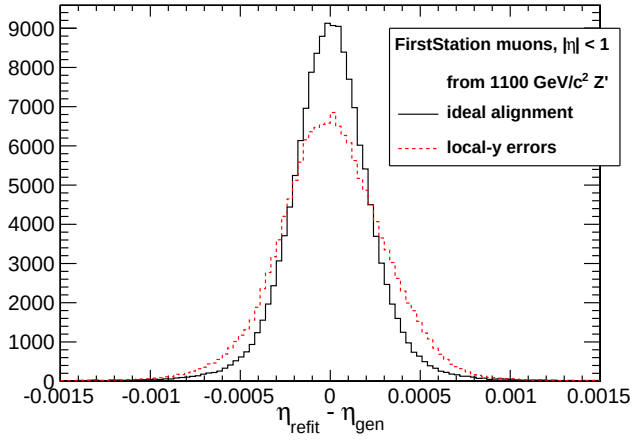




Effect of local-y

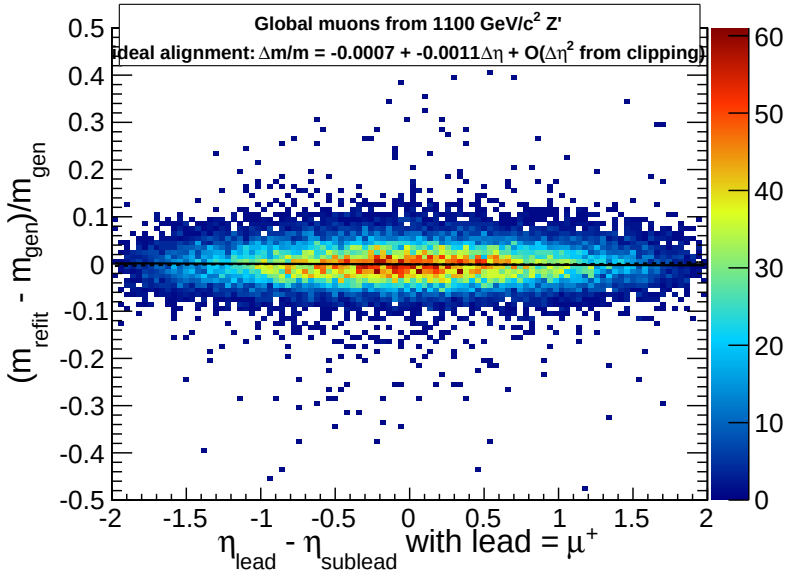
- Different reconstruction method: FirstStation instead of GlobalMuon, only sensitive to station 1
- Track-fits no longer mix different wheels
- Less of an impact on $\Delta\eta$

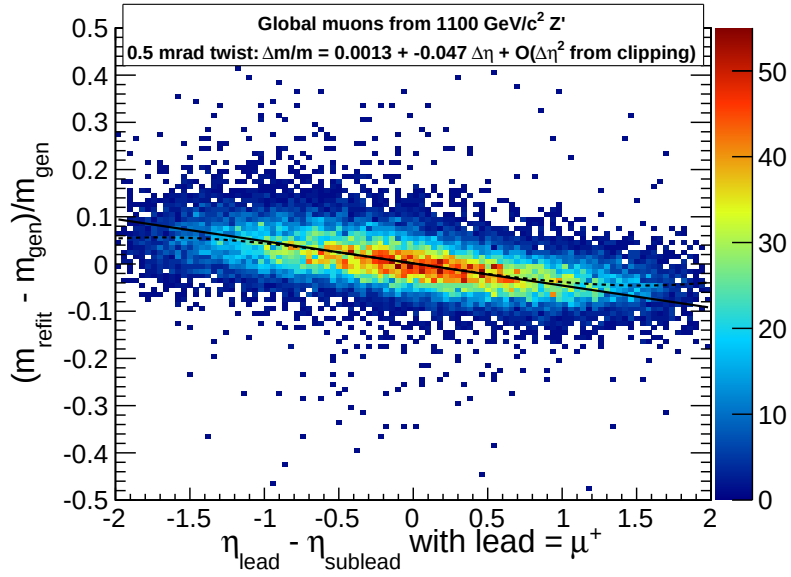




Effect on Z' mass

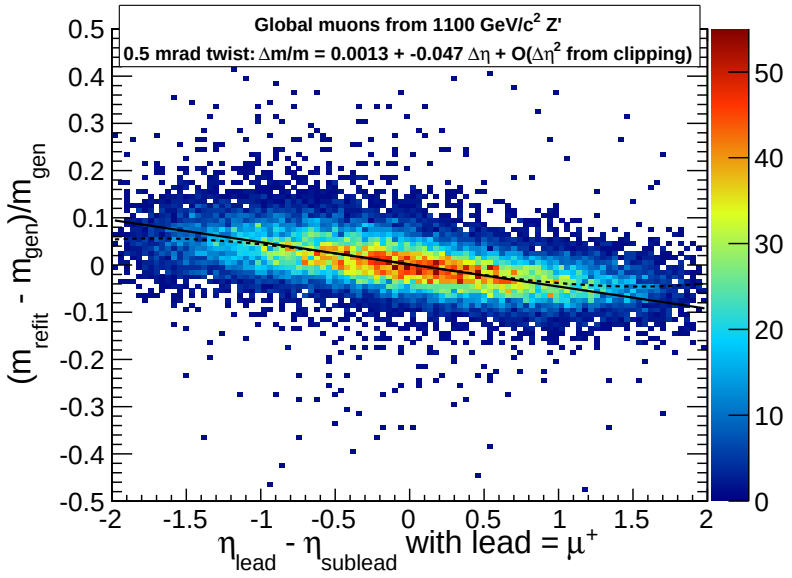
- Want to quantify fractional error in mass: $(m_{\text{refit}} - m_{\text{gen}})/m_{\text{gen}}$
- Complicated by the fact that Z' has two daughters, sampling different parts of the detector
- Key variable 1: $\eta_{\text{lead}} - \eta_{\text{sublead}}$ where the leading muon is the one with the highest p_T
- Key variable 2: q_{lead} ($\Delta\kappa$ that *raises* μ^+ p_T must *lower* μ^- p_T)
- Shape far from $\eta_{\text{lead}} - \eta_{\text{sublead}} = 0$ depends on clipping (next slide)

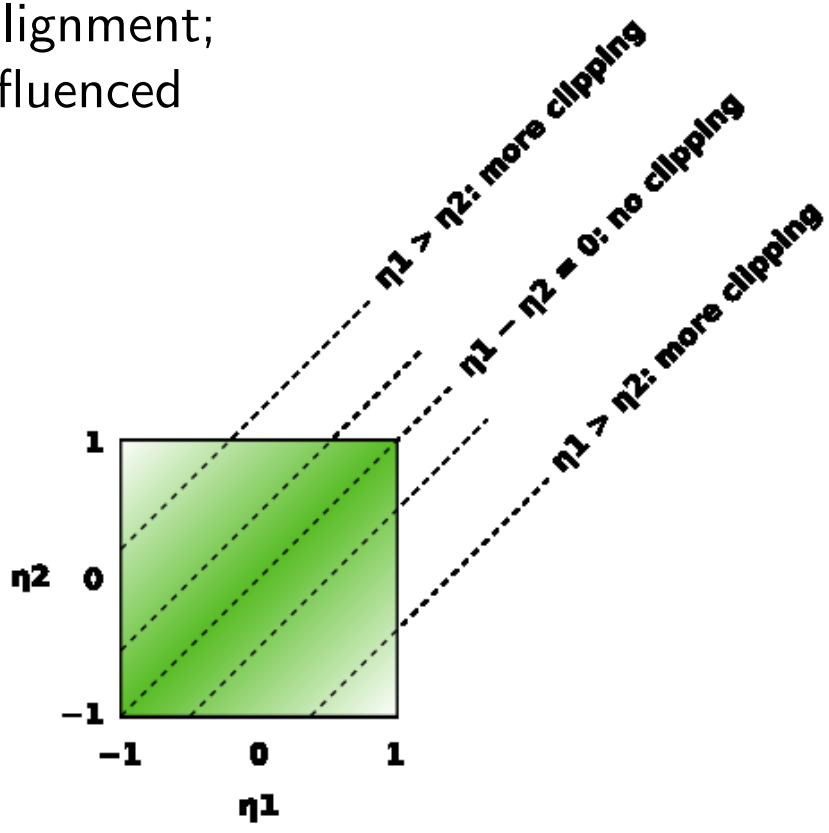




Effect on Z' mass: aside

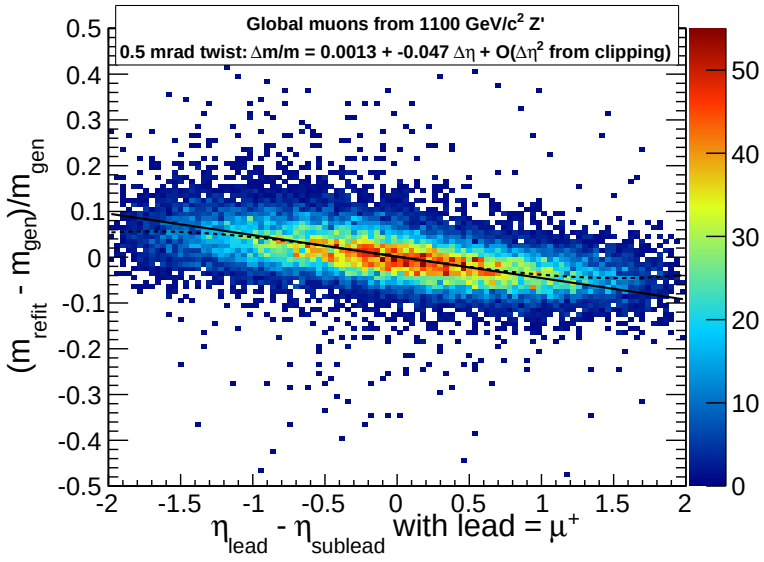
- To see only the effect of barrel twist on this plot, we must impose $|\eta| < 1.0$ for both daughters
- This confines the daughters to a sqaure region in η_1-η_2 (always the case for a Z' analysis, but usually $|\eta| < 2.4$)
- The slope of $(m_{\text{refit}} - m_{\text{gen}})/m_{\text{gen}}$ near $\eta_1 - \eta_2 = 0$ is due to misalignment; the slope at high $|\eta_1 - \eta_2|$ is influenced by clipping

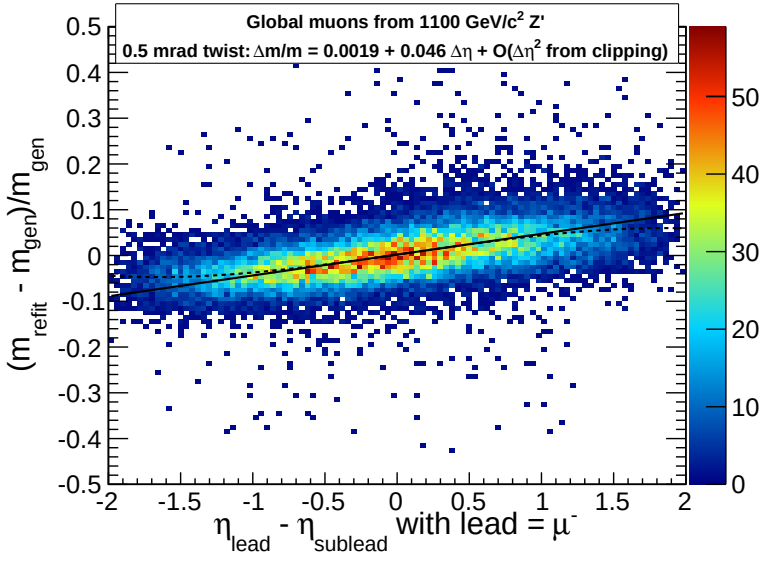




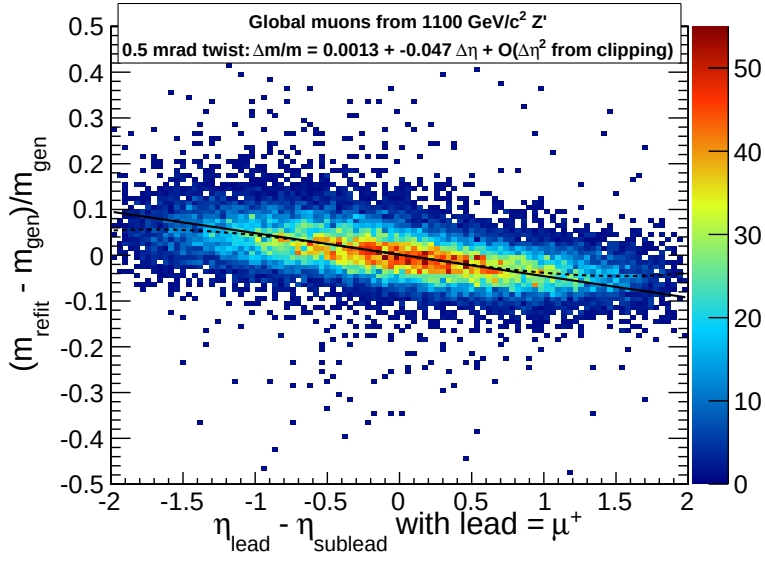
Effect on Z' mass: more tests

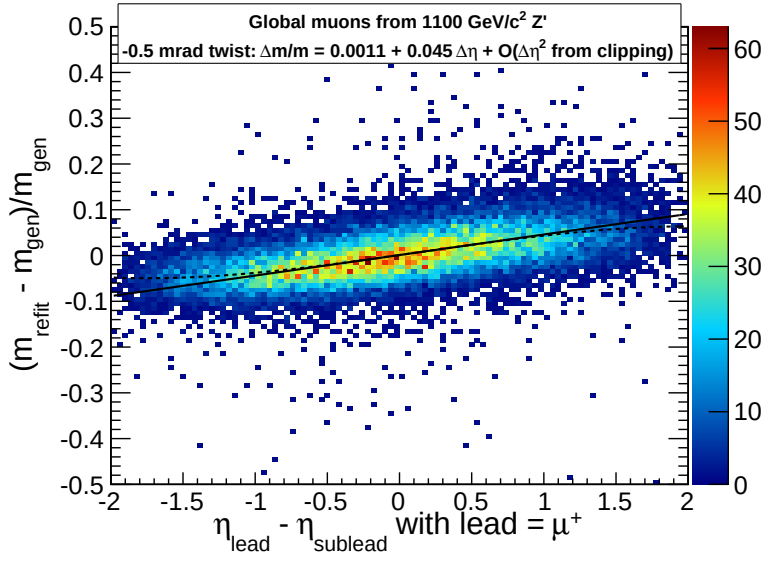
Direction flips when we look at leading muon $= \mu^-$





Direction flips when we reverse twist

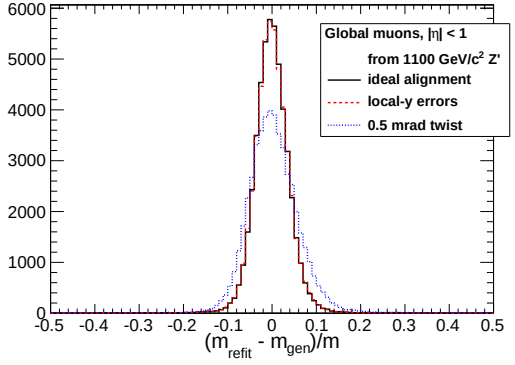


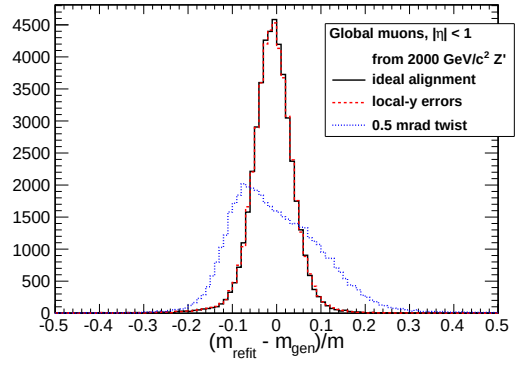


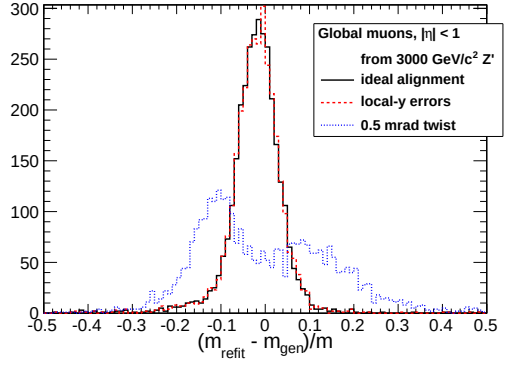
Effect on Z' mass: bottom line

- Now showing $(m_{\text{refit}} - m_{\text{gen}})/m_{\text{gen}}$ in profile to see how error from misalignment compares with intrinsic resolution
- Local-y errors (red) are never an issue: mass resolution is dominated by p_T uncertainties
- Twist (blue) broadens 4.3% barrel resolution $\longrightarrow$ 5.8% for an energy-frontier Z' (1100 GeV/c^2)— 50–100 pb^{-1} analyses

  Smeared peak is about $\sqrt{2}$ times lower than ideal peak: would require twice the data for a discovery
- Becomes worse for higher masses







Conclusions

- The HW-TB comparisons in the barrel quantify the leading systematic uncertainties in chamber positions; this study relates them to muon momentum and Z' mass bias
- The twist and the local-y differences that we have been discussing both lead to noticible biases in physics quantities (comparable in size to the resolution for an ideal detector)
- But only the twist leads to noticible biases in Z' mass (and hence could delay discovery due to a less-significant peak)

Post-conclusion

- Curvature bias in fully-fitted tracks provides a way to test for twist with existant data: $\Delta\kappa$ from split-cosmics should be $\Delta\kappa = (0.12\ c/\text{TeV} + 0.1 p_T)\cot\theta$ for a twisted geometry (from page 10), where θ is the angle with respect to horizon
- Different technique from TB alignment: fully-fitted tracks, checking for agreement between top and bottom halves, rather than tracker-vs-muon system
- Do we have enough 200 GeV/c tracks at $\cot\theta \approx 1$ to see a 0.13 c/TeV difference in curvature? No, the whole CRAFT-08 sample (without splitting by $\cot\theta$) had only sensitivity to 0.6 c/TeV. But maybe Jordan applied cuts that can be loosened?