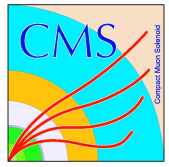


Lepton-jets: data vs MC

Jim Pivarski

Texas A&M University

2 September, 2010

Outline

- Reminder: signal is two or more distinct μ-groups (where a μ-group is at least two near-by muons)

  Standard candle: single dimuon from SM resonances

- Dimuon spectrum in 3_6_3 (0.6 pb^{-1} for HLT_Mu9)
  - make sure our standard candles are visible
  - tests luminosity calculations (MC and data *not* normalized to equal area)
  - check for missing backgrounds (base sample is InclusiveMu5_Pt* only; add others as needed)
- Track-segment matches in 3_8_2 (2.1 pb^{-1} for HLT_Mu9)
  - start from the ground-up: discover low-level problems early
  - tests 3_8_2 tracking developments (relevant events re-reconstructed from hits)
- Next steps

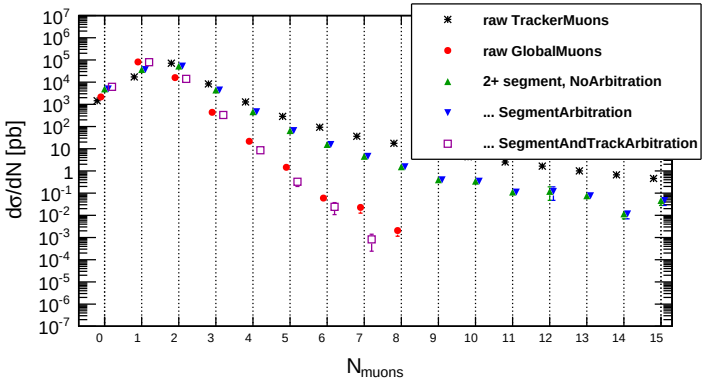
Cuts and object definition

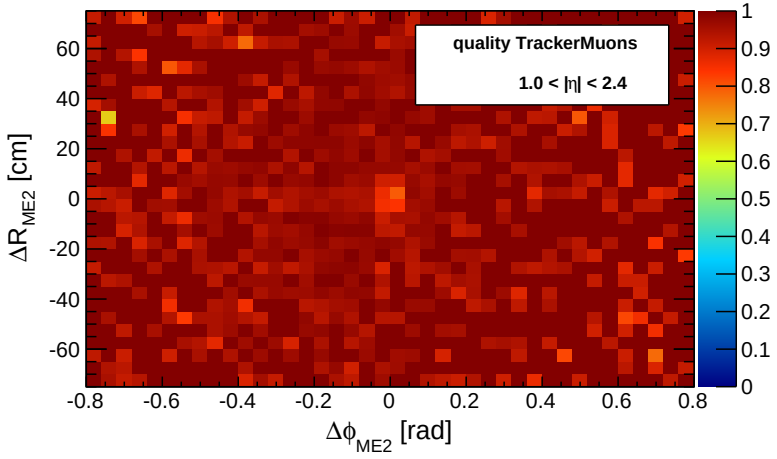
- `/Mu/Run2010A-PromptReco-v4/RECO`
- Run/LS selection: good tracking, muons, and trigger, selected by runregparse.py and luminosity calculated by lumiCalc.py
- Event-level:
  - HLT_Mu9 (unprescaled) or HLT_Mu5 (correcting for prescale)
  - at least one $p_T > 11$ (7) GeV/c muon with $|\eta| < 2.1$
  - at least one primary vertex with $|z| < 24$ cm (hn-cms-PO7TeV)
  - filter out scraping (Collisions2010Recipes)
- Muon tracks:
  - $p_T > 5$ GeV/c, $|\eta| < 2.4$
  - TrackerMuons with $N_{\text{segments}} \geq 2$ (arbitrated)
- Muon-group "closeness" definition:
  - ($m_{\text{pair}} < 5$ GeV/c^2 **and** $P_{\text{vertex}} > 1\%$) **or** $\Delta R < 0.1$
  - pairs must be oppositely charged

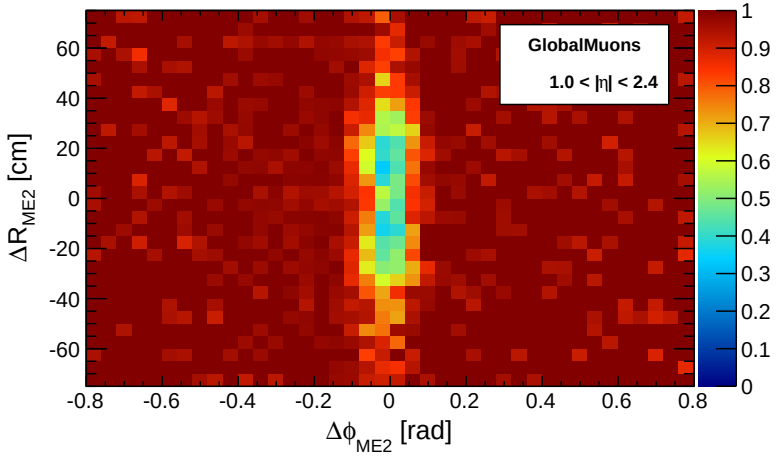
Cuts and object definition

Reminder:

- With these cuts, TrackerMuons have background rejection similar to GlobalMuons (below: InclusiveMu5_Pt* N_{tracks})

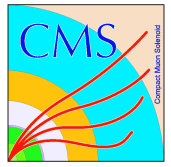






- Even with the cuts, TrackerMuons do not have inefficiencies that depend on closeness of muons in muon system (right: μ-pair gun efficiency as color scale vs. ME2 ΔR, $\Delta\phi$)

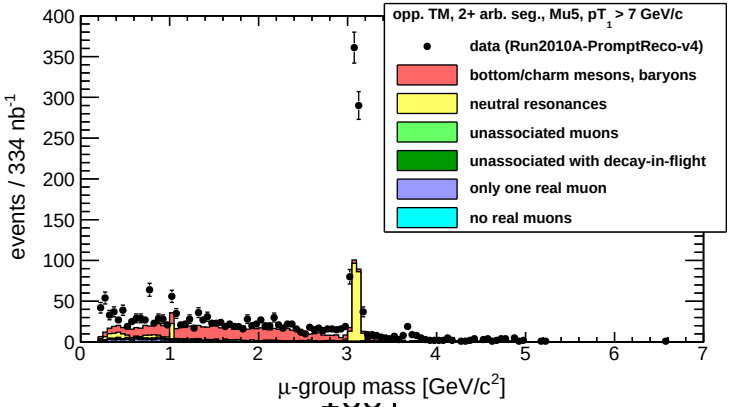
(This is 3_6_3; GlobalMuon inefficiencies likely worse in 3_8_2 due to new cleaning step)



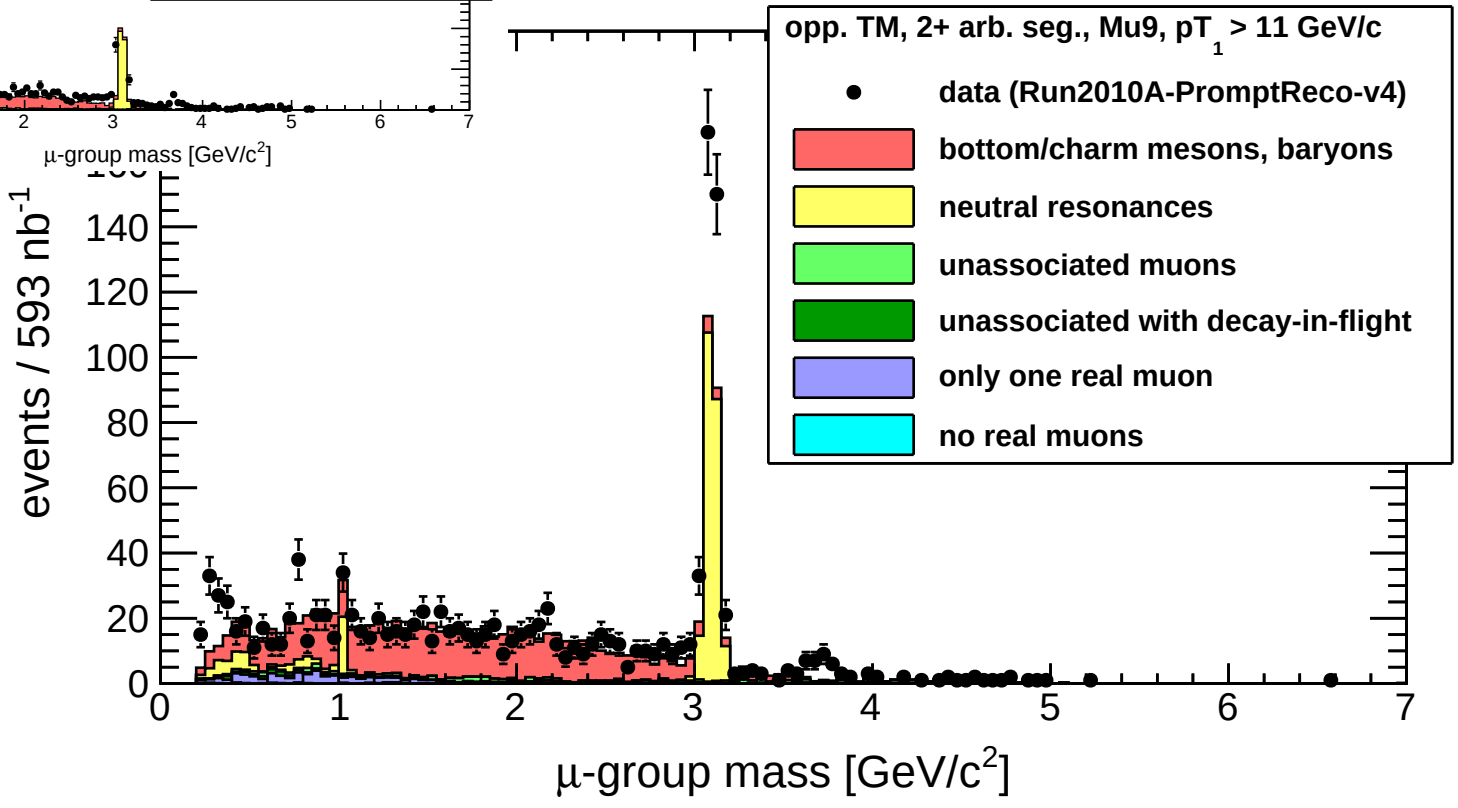
High-level quantities in 3_6_3

High-level data/MC comparison

- Mass distribution; data and MC independently scaled by luminosity
- Big plot: HLT_Mu9 with $p_T > 11$; small: HLT_Mu5 with 7 GeV/c



- Trigger simulation not applied to Monte Carlo



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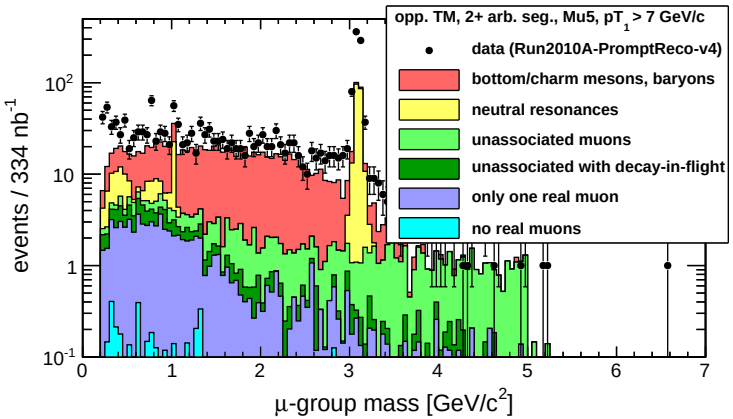

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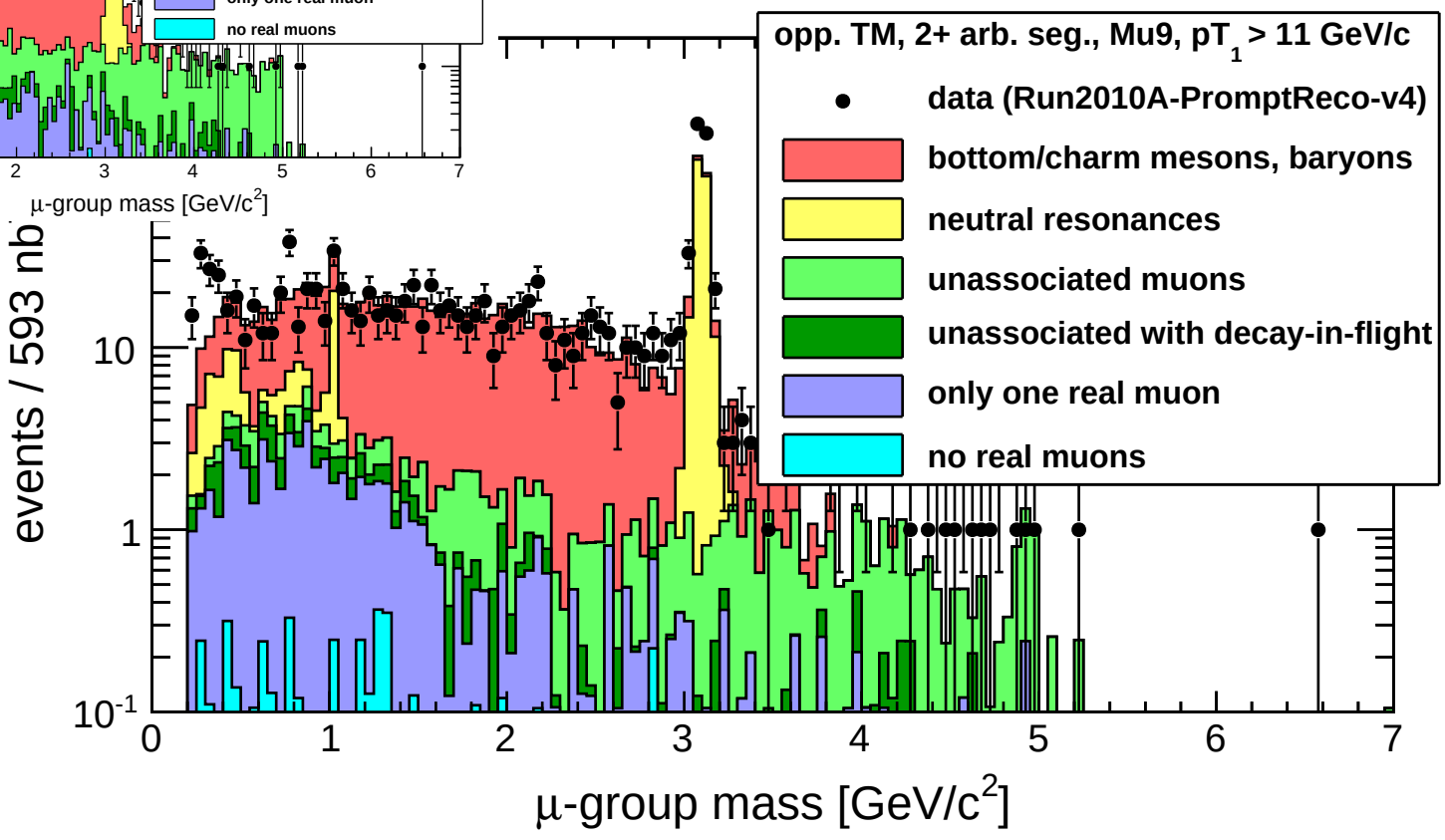
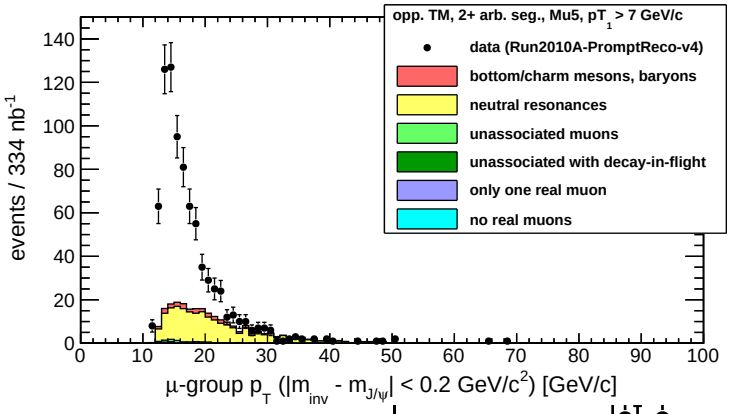
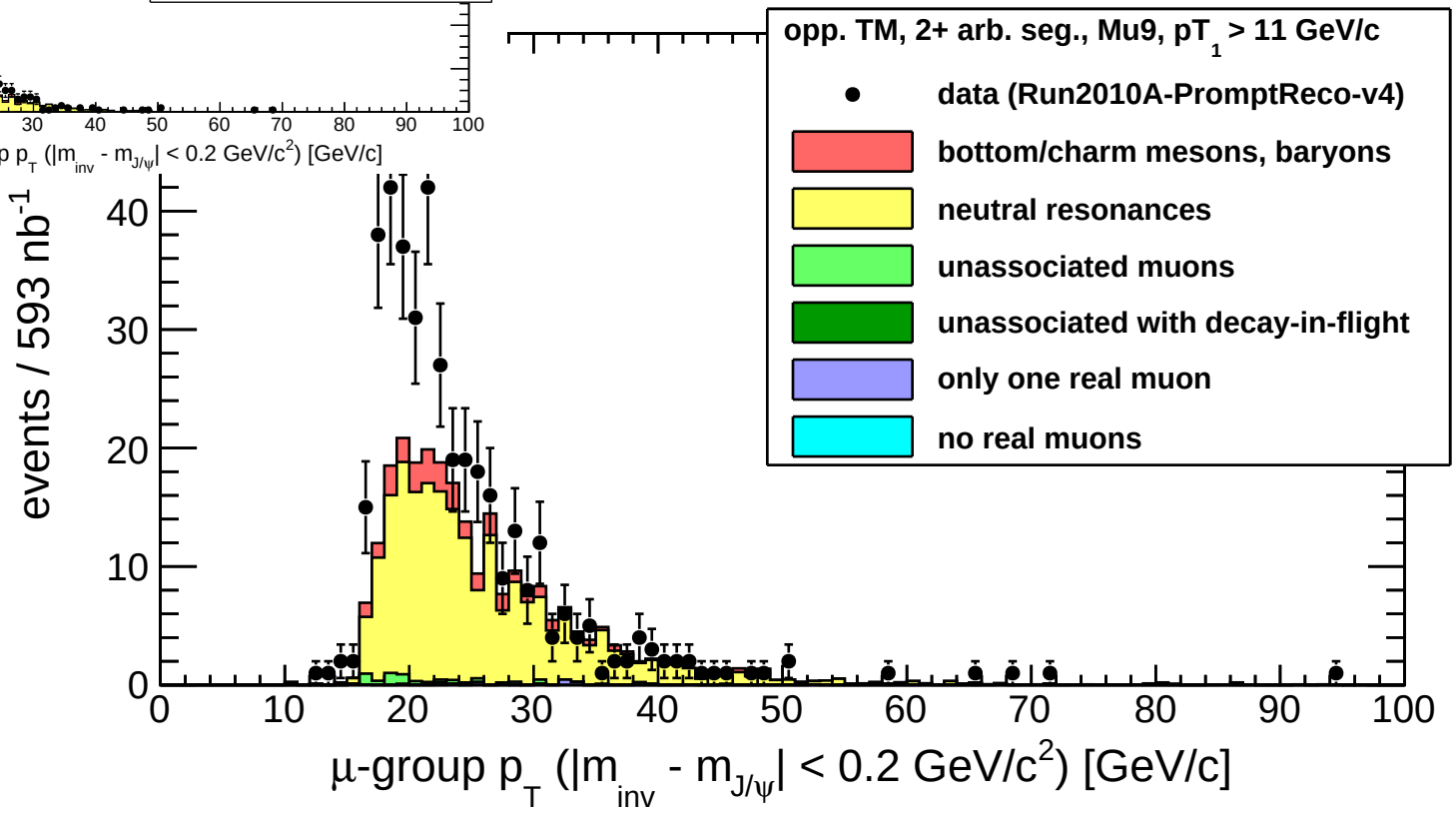


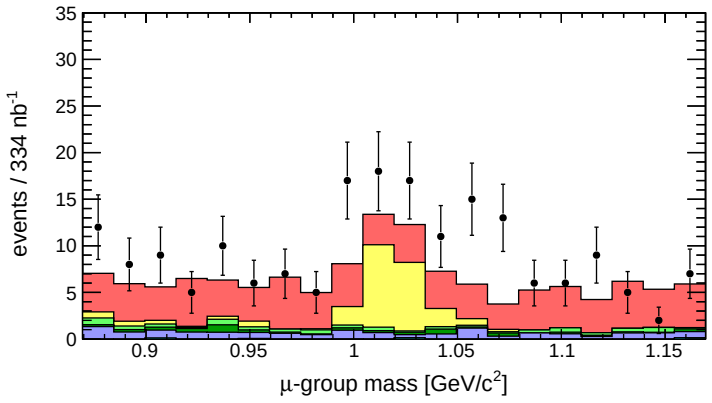
High-level data/MC comparison

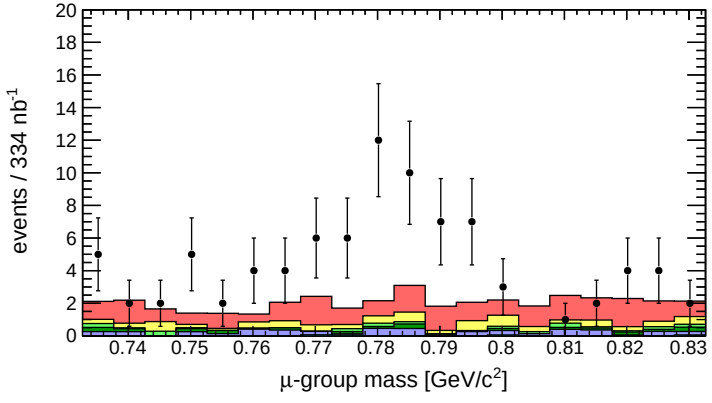
- Prompt J/ψ (and ψ') are not in InclusiveMu5_Pt*
- p_T of μ-groups with masses near J/ψ peak shows that the missing events are at low momentum
- Prompt J/ψ and ψ' will be included in future 3_8_2 study

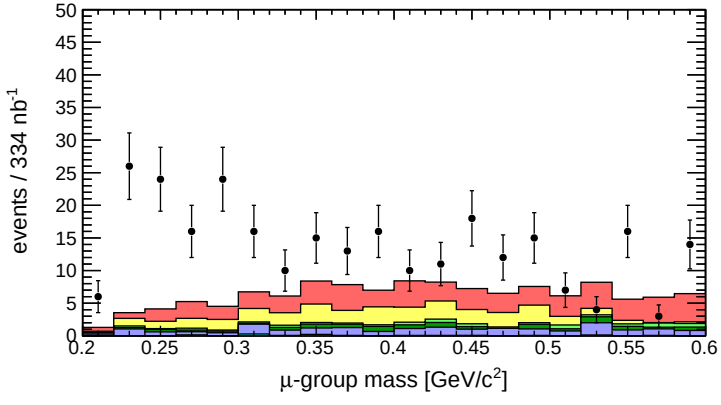




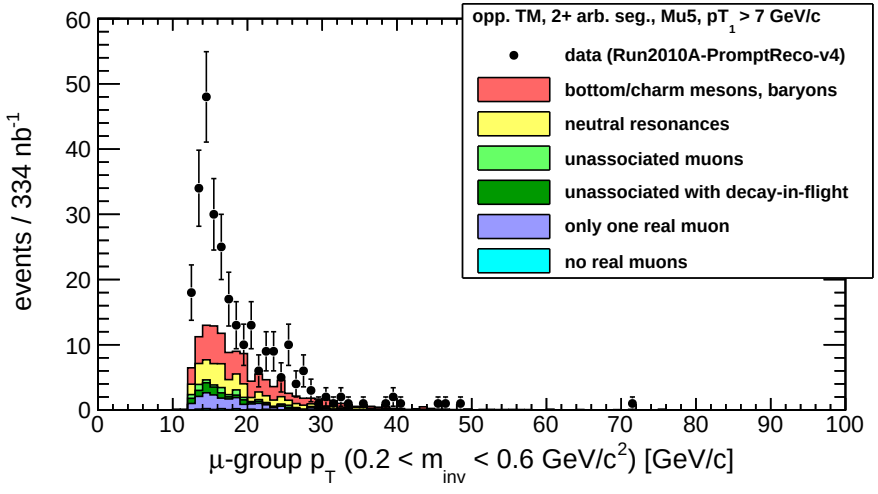
High-level data/MC comparison





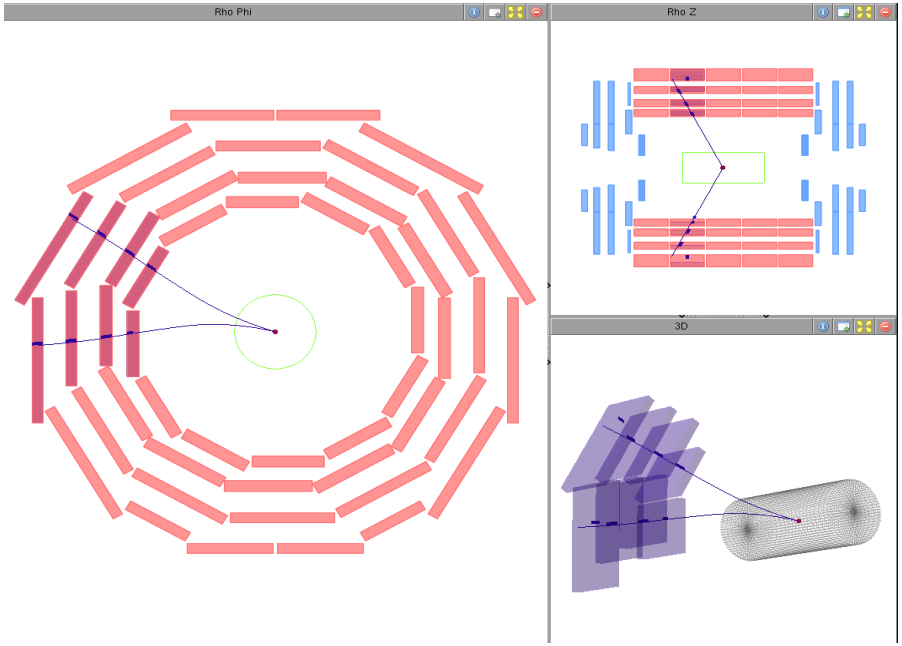


- Zoom in with HLT_Mu5 sample to see more low-mass resonances
- $\phi(1020) \to \mu\mu$ is visible in data/MC but underproduced?
- $\omega(782)$ is in data but not MC
- $\eta(548) \to \mu\mu(\gamma)$ is not responsible for the excess at low mass



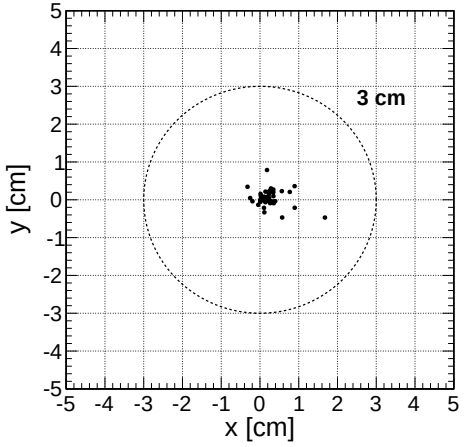
Low-mass excess

- Excess of dimuons below 0.3 GeV/c^2 is not explained
- Looked at all $\mathcal{O}(100)$ by hand: they're all good-looking muons

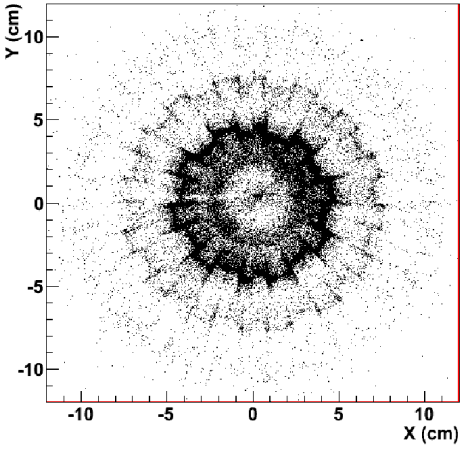


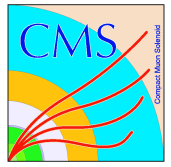
- The dimuon vertices are not consistent with $\gamma X \to \mu^+\mu^- X$ conversions (right)
- Centrally distributed in η (not ME1/1a triplets)

Vertex positions of $m_{\text{inv}} < 0.3$ GeV/c^2 events



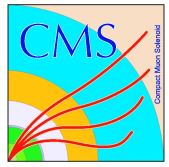
$\gamma X \to e^+e^- X$ conversions (for reference)





Low-level quantities in 3_8_2

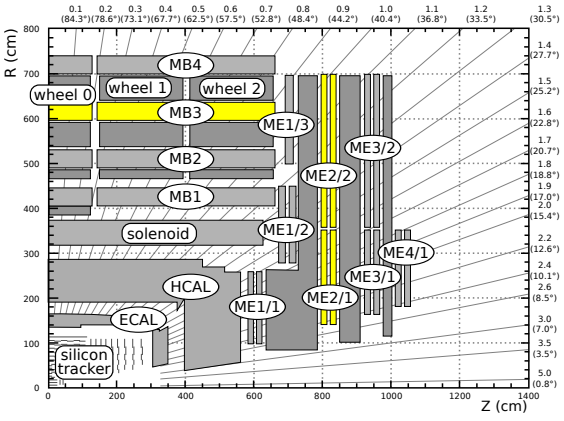
Low-level data/MC comparison



- Start with segment/propagated track comparisons to check for detector effects; later, work upward to kinematics again
- Avoiding trigger bias: only look at muons that were not solely responsible for the HLT_Mu9 trigger
- Using latest alignment GlobalTag and 3_8_2 algorithms (re-reconstructed all tracks from the hits in data and MC)
- Check residuals (segment-minus-propagated track) as a function of
  - inverse momentum (q/p_T or $q/|p|$): sensitive to propagation issues (e.g. $\vec{B}$-field bias, material budget)
  - wheel/disk/station: sensitive to misalignment
- Four segment/propagated track parameters:
  - x: local coordinate equivalent to $r\phi$; "ϕ residual" $= x/R_{\text{chamber}}$
  - y: parallel to beamline (DT) or radial (CSC)
  - dx/dz (entrance angle in bending plane)
  - dy/dz

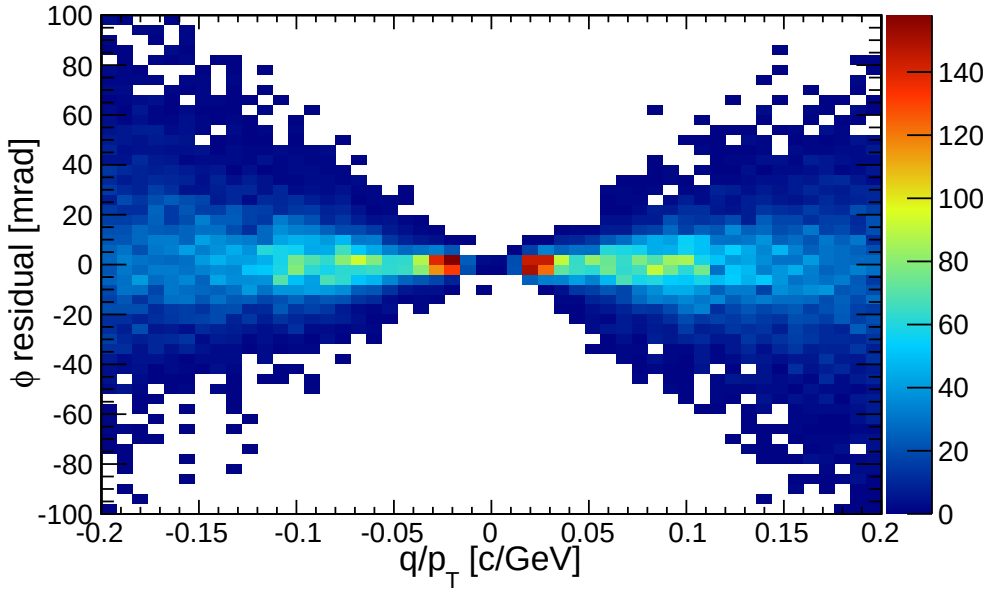
Dependence on momentum

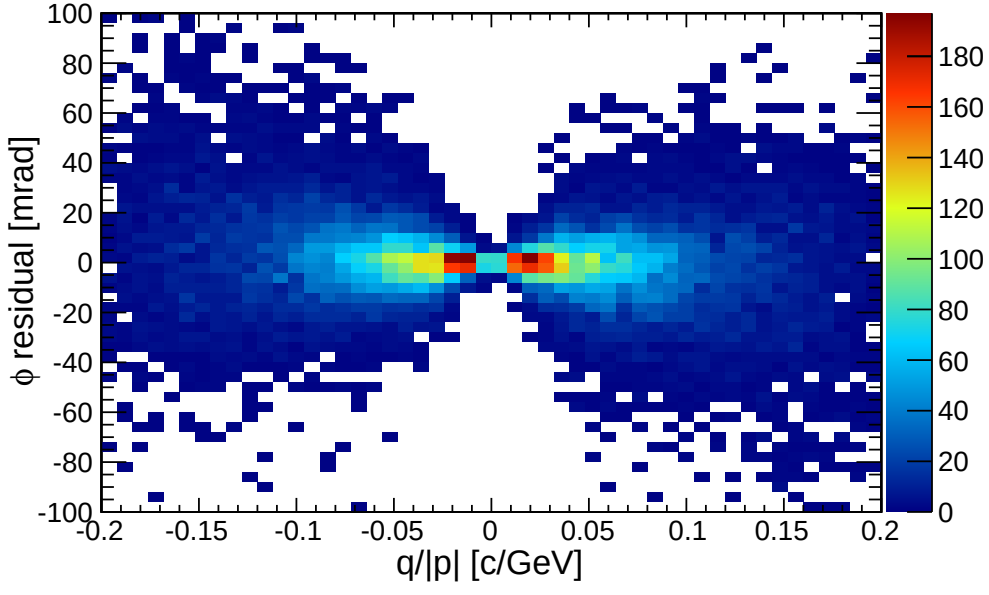
- Plot ϕ residuals from MB3 and ME2 only



(one representative residual per track)

- Width of residuals distribution scales roughly as $1/|p|$, cut at $1/p_T < 0.2\ c/\text{GeV}$
- Any biases in the mean are much smaller than the width of the distribution



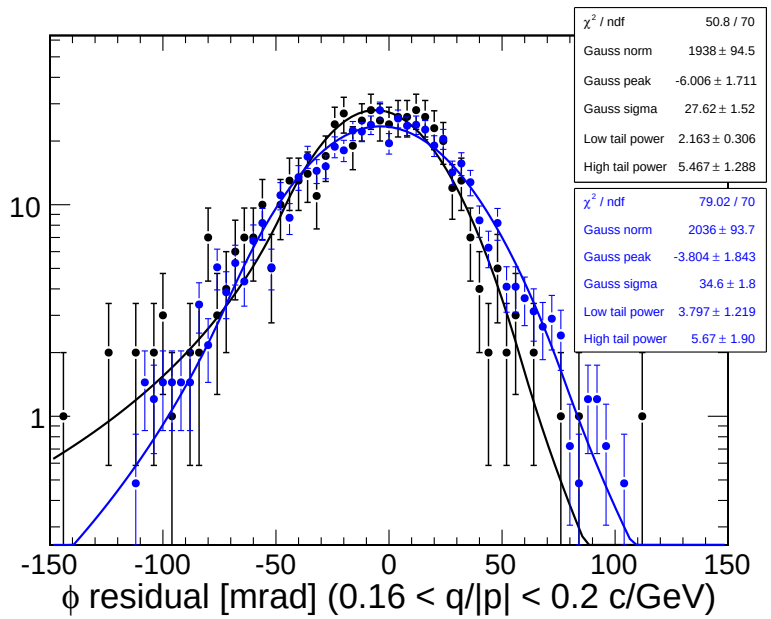


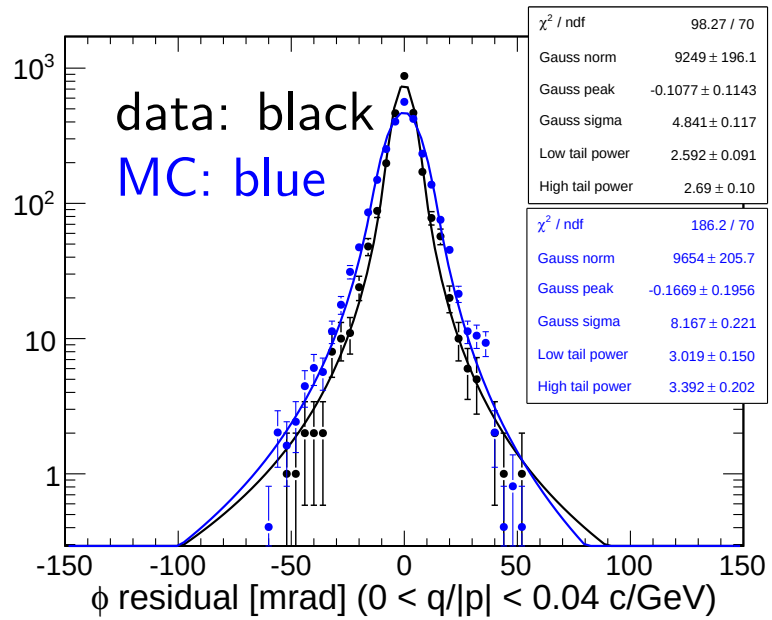
Dependence on momentum

- To quantify bias in the Gaussian part of the residuals peak (not the tails), fit distributions in momentum bins to

$$p(x) = \begin{cases} A\exp\left(-(x-x_0)^2/(2\sigma^2)\right) & |x-x_0| < m \\ B/|x|^{p_1} & (x-x_0) > m_1 \\ C/|x|^{p_2} & -(x-x_0) < -m_2 \end{cases}$$

where A, B, C, m_1, and m_2 are chosen to make the function continuous and differentiable

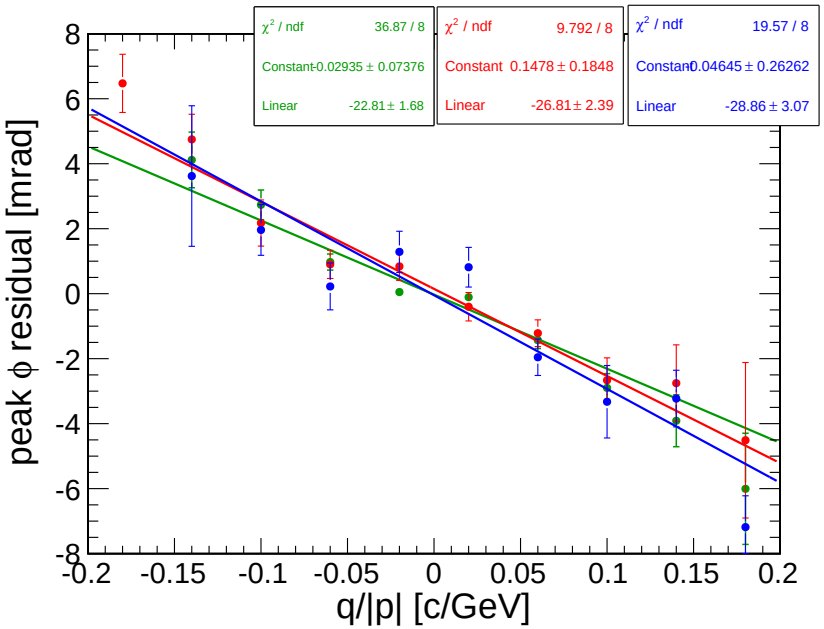




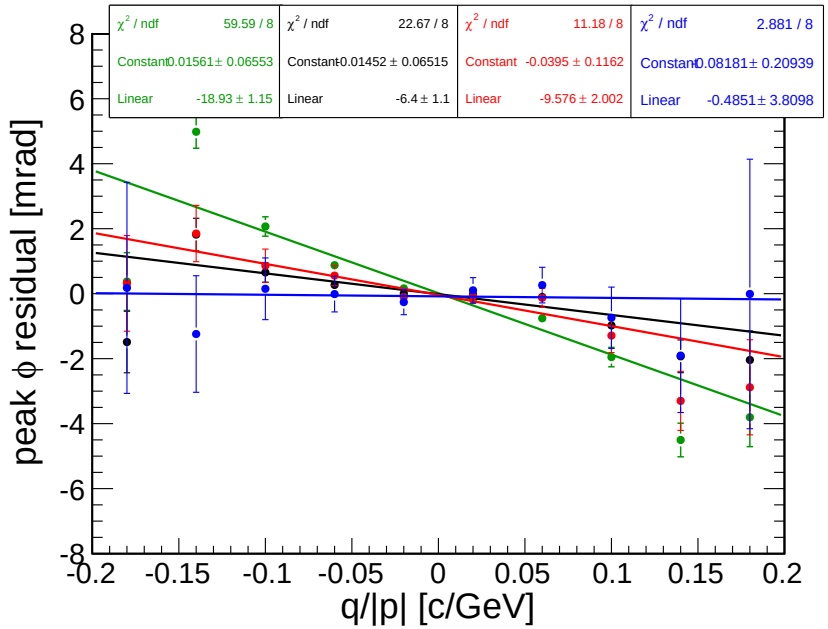
Dependence on momentum

- Slope of Gaussian peak vs. $q/|p|$ obscured by decays-in-flight
  - Green: all muons (TM with $p_T > 5$ GeV/c and $N_{\text{segments}} \geq 2$)
  - Black: excluding muons matched to decay-in-flight (MC only)
  - Red: member of μ-group ($P_{\text{vertex}} > 1\%$ with another muon)
  - Blue: within 0.2 GeV/c^2 of J/ψ peak (very pure muons)
- Removing that, there's a bias in data not present in Monte Carlo

Data

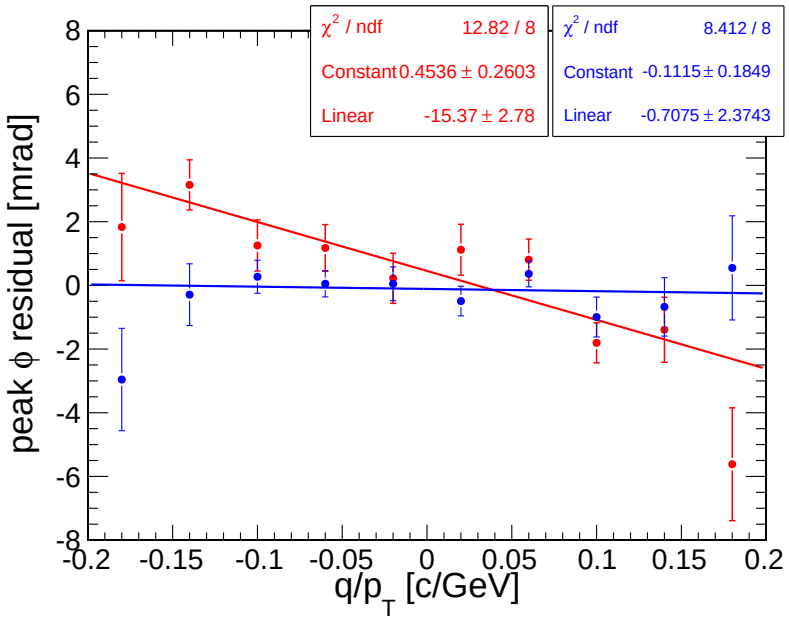


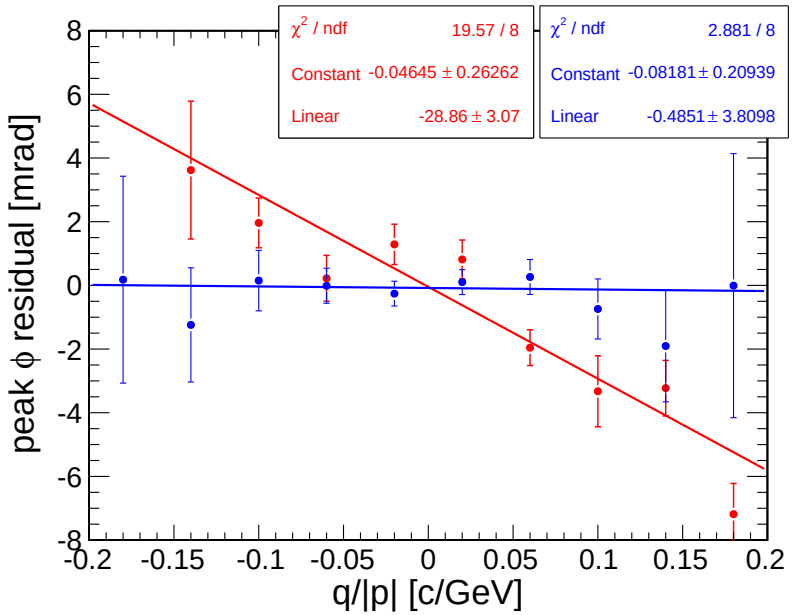
Monte Carlo



Dependence on momentum

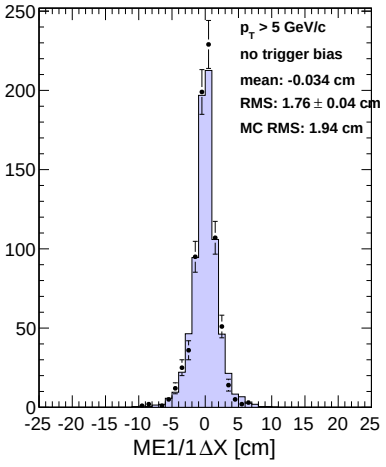
- Re-drawing residual vs. q/p_T and $q/|p|$ for muons from J/ψ
  data in red, Monte Carlo in blue
  - trend is stronger vs. $q/|p|$ (but that might be different influence of the endcap detectors relative to the barrel)
  - bias is about 10% of the width of the distribution at 5 GeV/c
- Modifying dE/dx in SteppingHelixPropagator tunes this plot (but I don't plan to apply an ad-hoc tune)

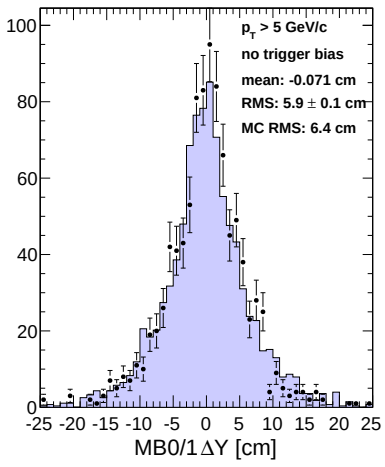


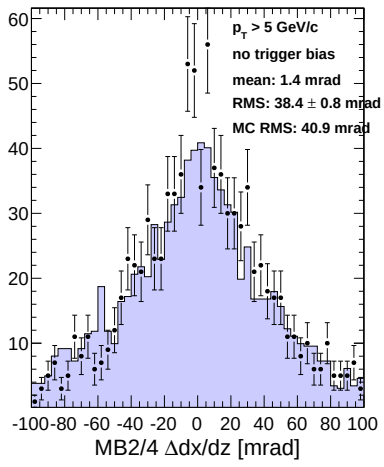


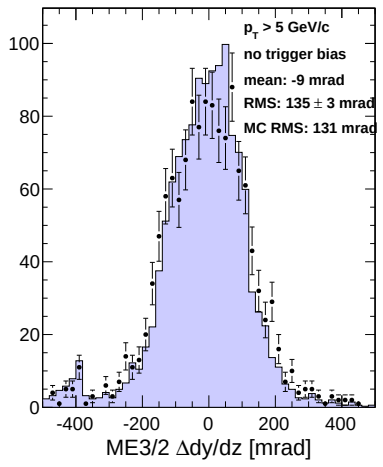
Dependence on detectors

- Plot four components of residuals (x, y, dx/dz, dy/dz) for each distinct ring of detectors
  - barrel wheels 0, ±1, ±2 and stations 1, 2, 3, 4
  - endcap stations 1/1, 1/2, 1/3, 2/1, 2/2, 3/1, 3/2, 4/1, 4/2
- No trigger bias (only look at muons not solely responsible for HLT_Mu9 trigger)
- Select only muons in μ-groups (similar results in J/ψ-only)
- Examples (points are data, shaded blue/grey is Monte Carlo):



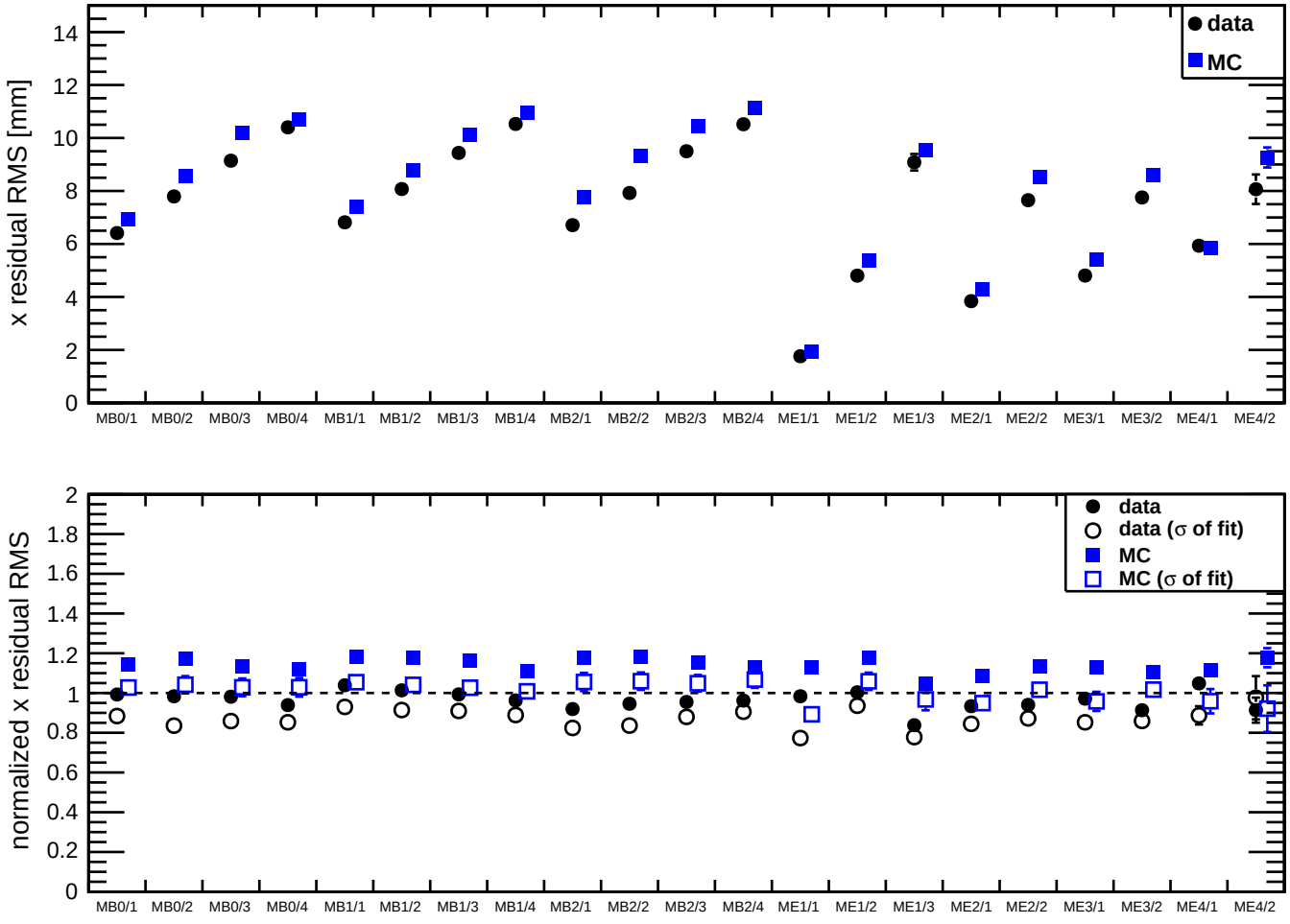






Dependence on detectors

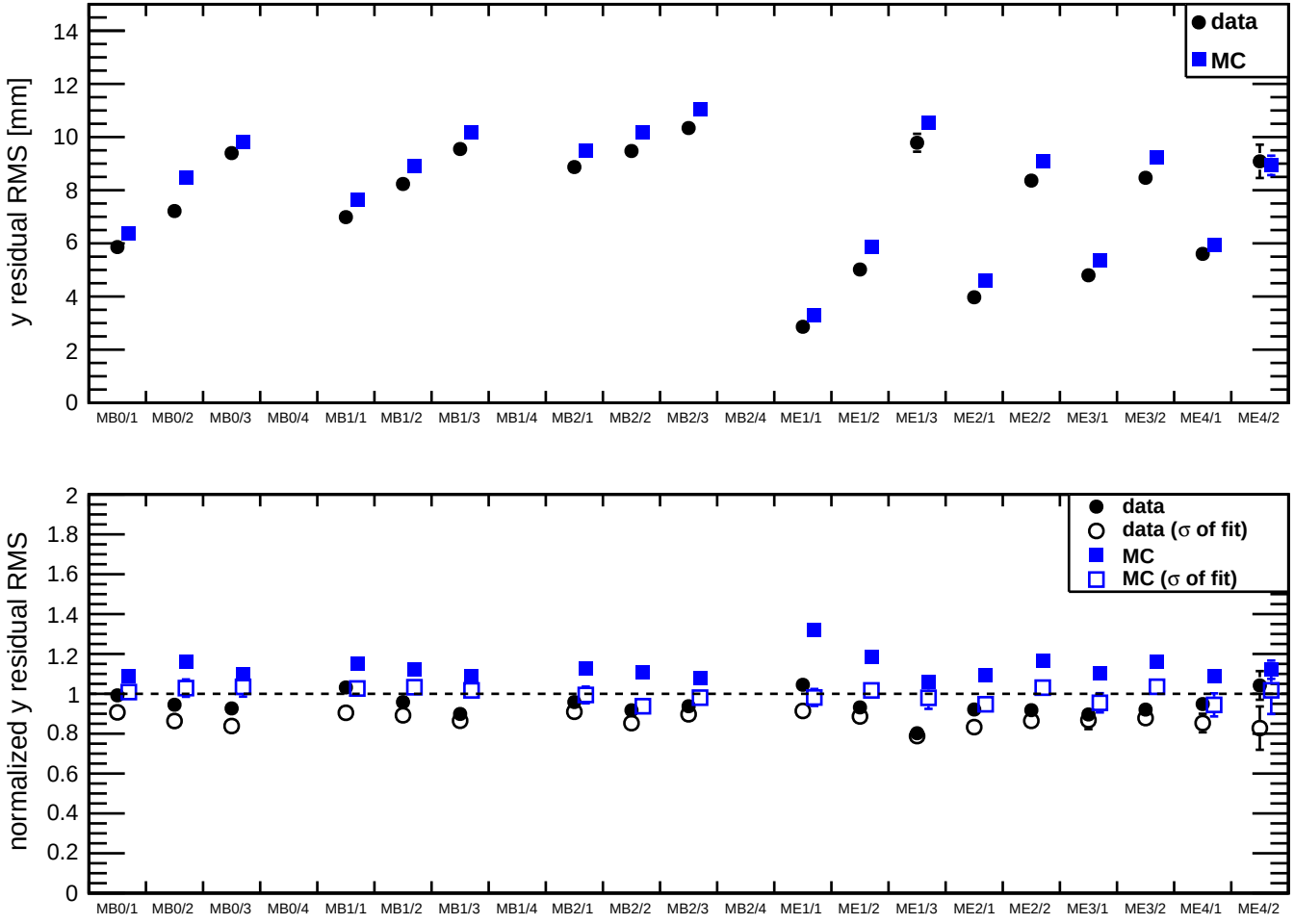
- MC is a little wider than the data everywhere
- MC has STARTUP conditions re-tracked with IDEAL alignment: could be the influence of mis*calibrated* hits?



Dependence on detectors

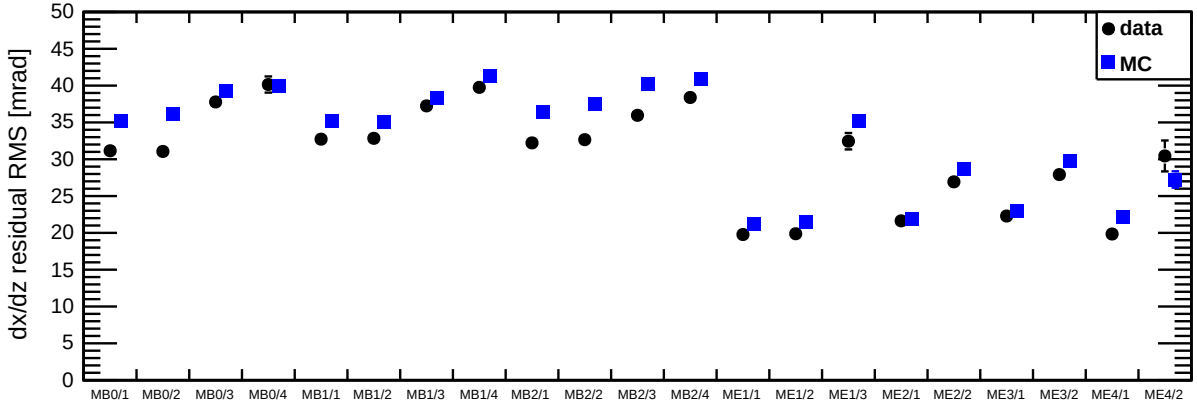
- Same for y
- Compared with standard RelVals (similar results):

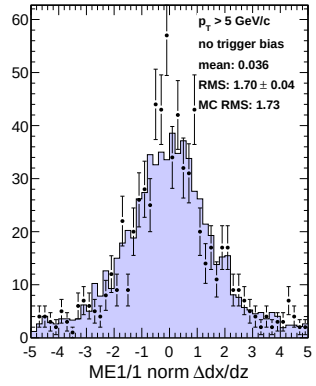
http://cmsdoc.cern.ch/cms/Physics/muon/CMSSW/Performance/RecoMuon/MuonIdentification/

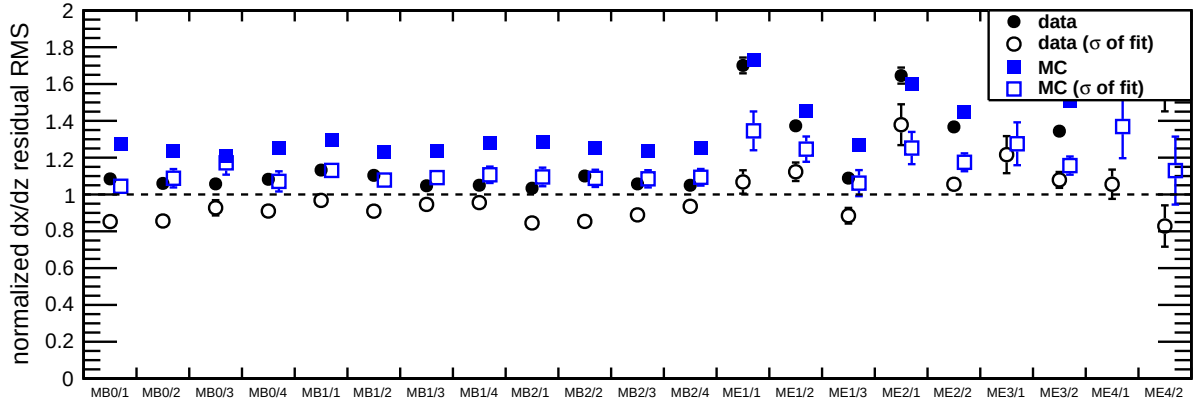


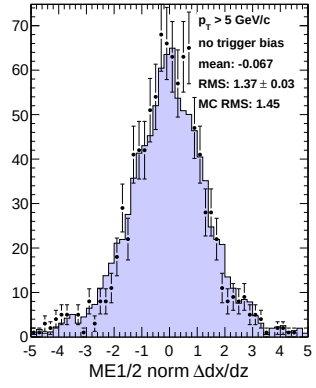
Dependence on detectors

- Endcap normalized dx/dz distributions have tails (RMS $> \sigma$)
- dx/dz has not been aligned in the endcap
- But this pattern is reproduced in MC— doesn't seem like misalignment is the problem



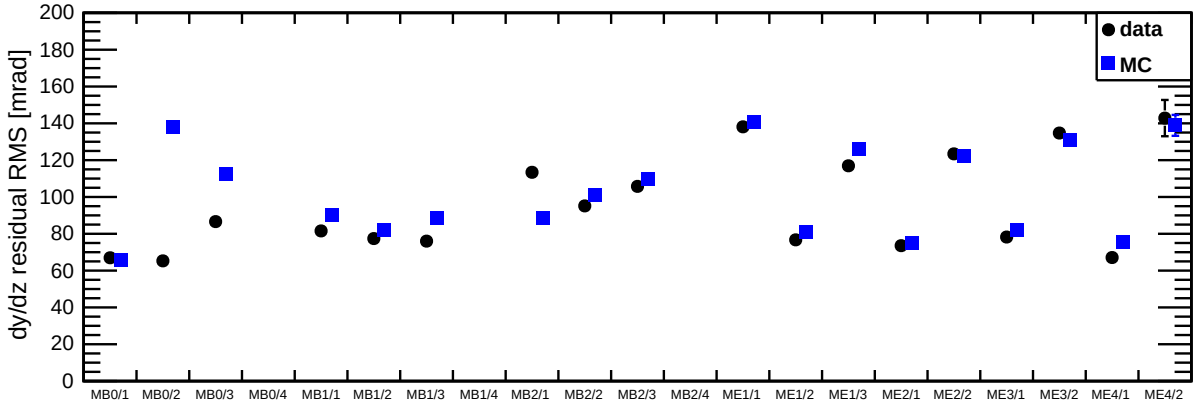


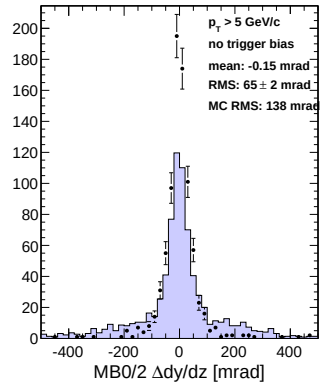


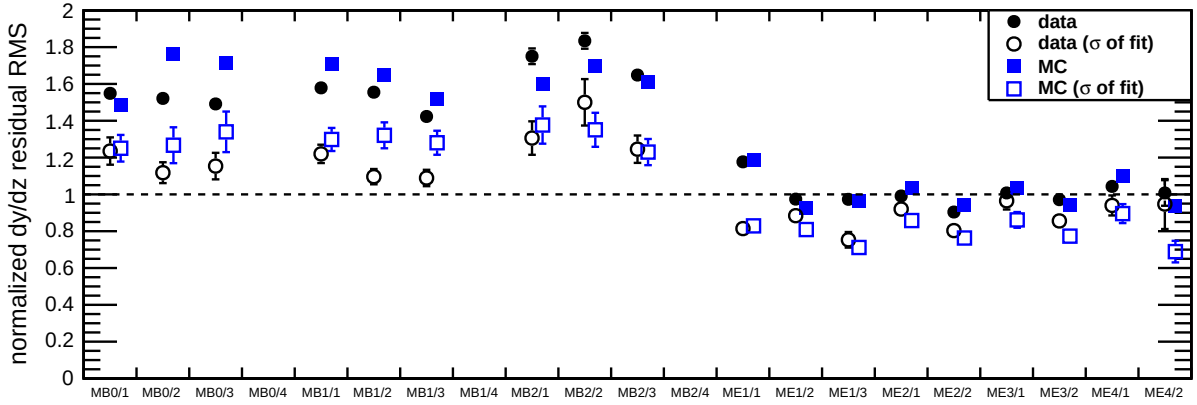


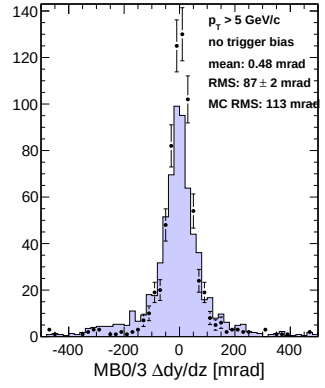
Dependence on detectors

- The same can be said for dy/dz in the barrel
- Discrepancy in MB0/2 and MB0/3: MC has large tails. . . ?



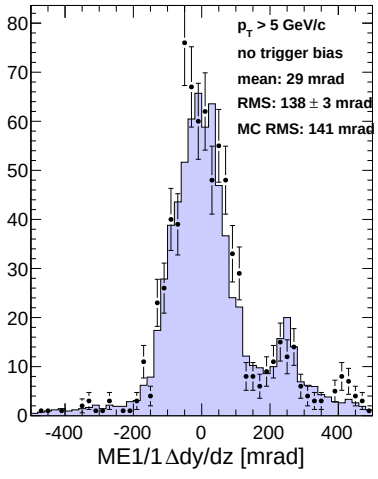


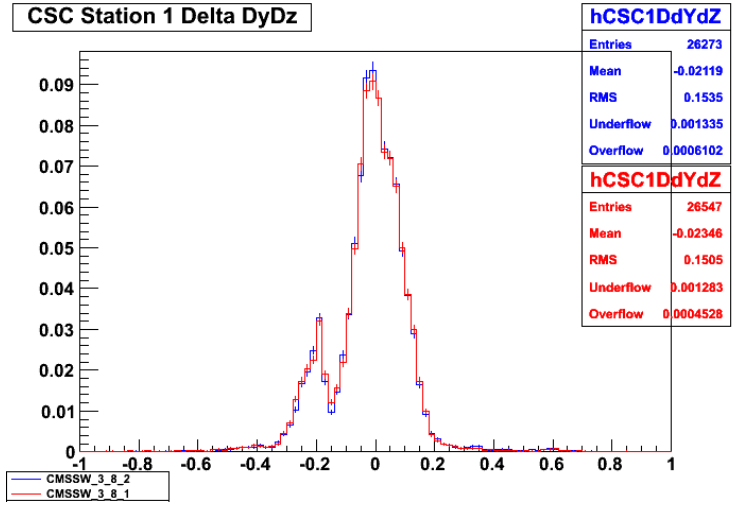




Dependence on detectors

- Oddity in endcap: discrete peaks in dy/dz residuals, reproduced by Monte Carlo and observed in standard RelVal plots (right)
- Could be related to granularity of CSC wire-groups?

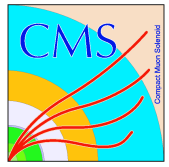




Next steps

- Data/MC comparisons
  1. ~~check residuals distributions with these track/event cuts~~
  2. modifications to residuals distributions when two muons cross (pair-gun MC; enough statistics to check data, too?)
  3. compare kinematic quantities (momenta, angular distributions)
  4. find all missing background samples (particularly the mysterious low-mass contribution)
- Trigger efficiency study
  1. reconstructing one $p_T > 11$ GeV/c, $|\eta| < 2.1$ StandAloneMuon in the presence of nearby/overlapping muons
  2. HLT and L1 efficiencies, given the above
- Estimating backgrounds from data
- Efficiency from tag-and-probe of boosted J/ψ?

Conclusions



- Basically good data/MC agreement out-of-the-box
- Discrepancies:
  - missing prompt J/ψ, ψ' (not a problem; just add them)
  - underproduced $\phi(1020)$ and missing $\omega(782)$ (possibly produce prompt samples by following example of prompt J/ψ? is it necessary? only at few-percent level...)
  - excess of $m_{\text{inv}} < 0.3$ GeV/c^2 events: *needs to be understood*
  - residual vs. momentum bias in data and not Monte Carlo
  - residuals distributions are generally narrower in data
- Discrepancies in residuals are not large enough to make much difference in cut efficiencies, since cuts are wide
  - if efficiencies are taken from J/ψ tag-and-probe in the future, it won't matter at all
- Residuals information will be useful for muon alignment studies, but for this analysis, I can move on to higher-level distributions