



Muon-Groups Analysis Update

Jim Pivarski

Texas A&M University

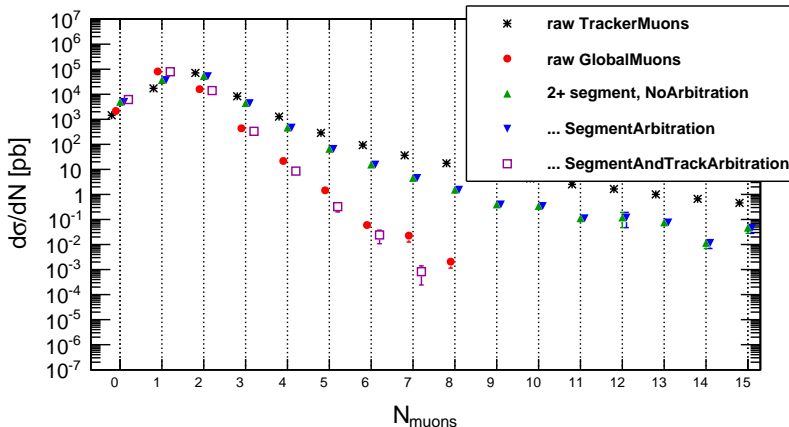
16 August, 2010



- ▶ We found that the $N_{\text{segments}} \geq 2$ cut provided TrackerMuons with the same background-rejection power as GlobalMuons, yet TrackerMuons (even with the cut) have an easier-to-understand reconstruction efficiency. “ N_{segments} ” is defined with segment-and-track arbitration. **Question:** is the two-segment requirement the important thing, or is it important that they be arbitrated segments? (answered in this talk)
- ▶ GlobalMuon inefficiency in the endcap is clearly related to crossing in the muon system. GlobalMuon inefficiency in the barrel seems to be related to crossing somewhere else. **Question:** what is barrel GlobalMuon inefficiency most strongly correlated with? (not answered: on the to-do list)
- ▶ In the set of quality cuts I used last time, some cuts were irrelevant and caused undesirable inefficiencies in displaced muon-groups. **Question:** which ones? (answered in this talk)

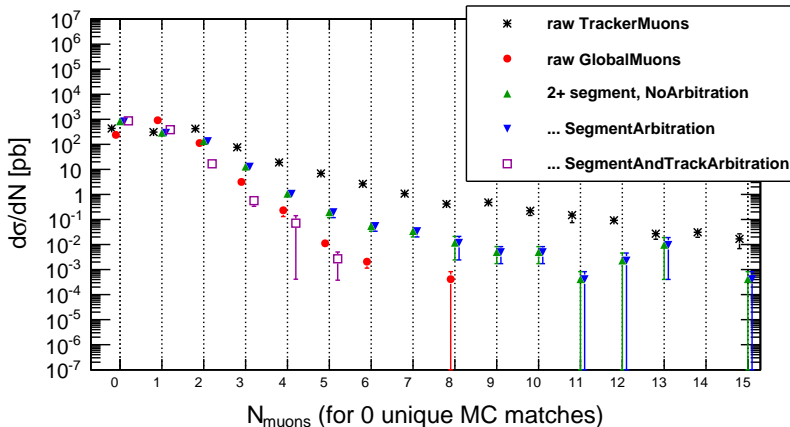


- ▶ **NoArbitration**: count any segments matched to the track, allowing double-counting of tracks to segments and segments to tracks
- ▶ **SegmentArbitration**: count only segment matched as best by $\sqrt{(\Delta x)^2 + (\Delta y)^2}$
- ▶ **SegmentAndTrackArbitration**: count only best segment match and best track match: a one-to-one relationship (only option recommended by μ POG)



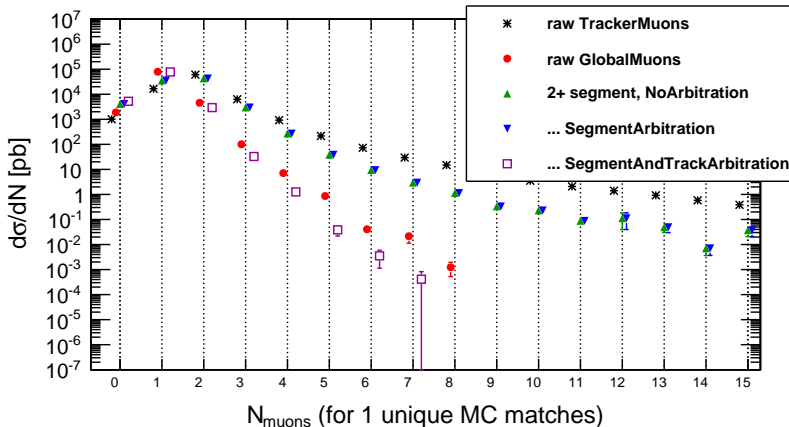


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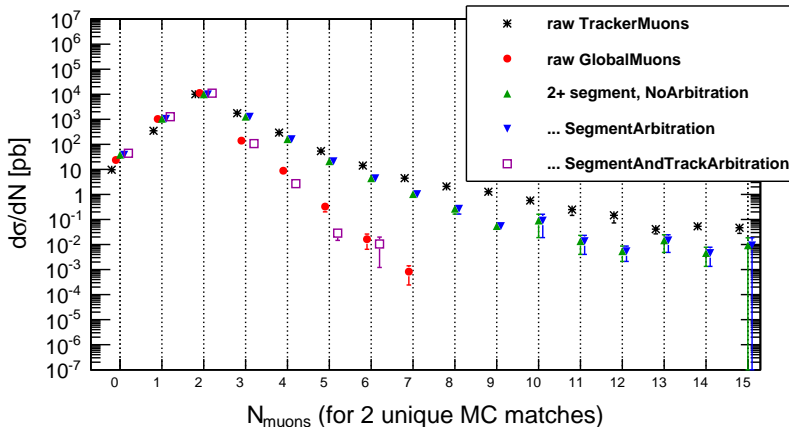


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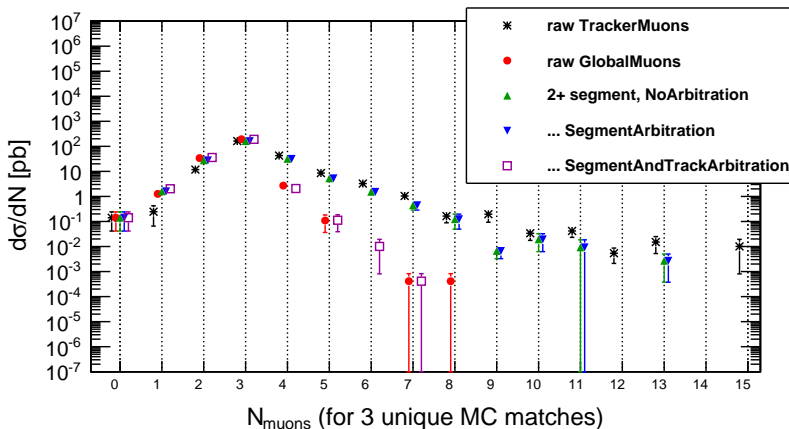


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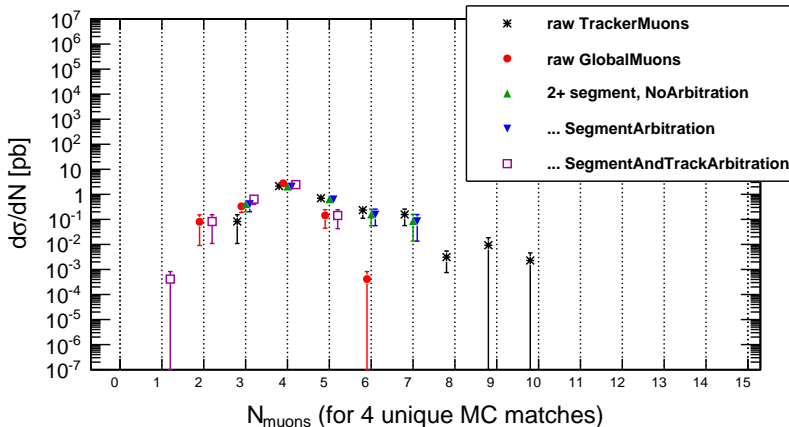


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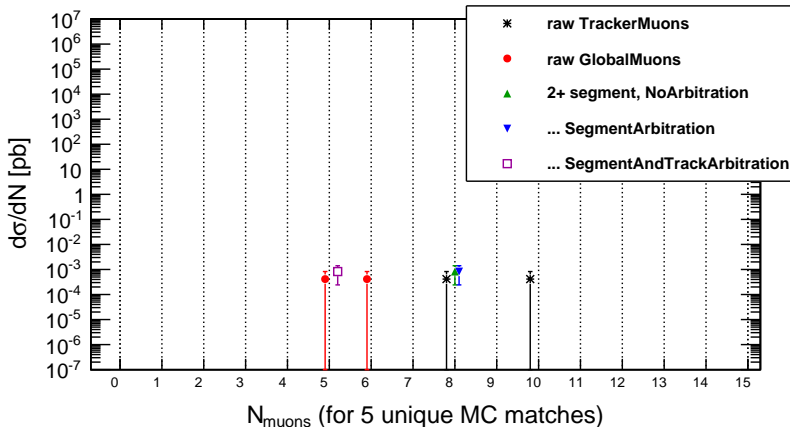


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How is MC-matching done?

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(also an open question; I've since looked it up)

- ▶ Standard PAT-muon MC-matching uses the following algorithm:
 1. compare list of reconstructed muons with list of (stable) generator-level muons
 2. exclude any potential matches with $\Delta R > 0.5$, $\Delta p_T/p_T > 0.5$, or the wrong charge
 3. resolve all ambiguities by ΔR (no more than one reco-muon may match to a gen-muon, no more than one gen-muon may match to a reco-muon)
- ▶ Ambiguity resolution is done in the order that muons appear in the event (i.e. random or with an unknown correlation to some parameters): could be better to turn on `resolveByMatchQuality` which would resolve in the order of increasing ΔR
 - ▶ I'd need to re-run over all samples to turn this option on (I'll do it on the next major re-run; e.g. when updating to a newer CMSSW version)



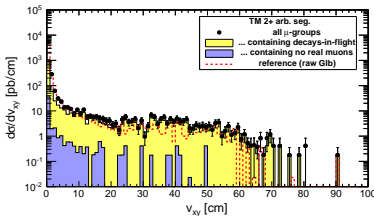
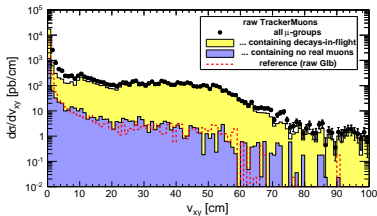
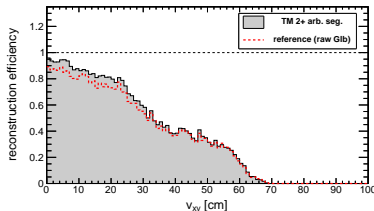
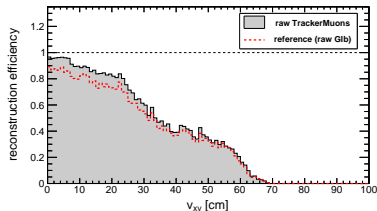
- ▶ Event:
 - ▶ HLT_Mu9 (lowest threshold that is not currently prescaled)
 - ▶ one muon with $p_T > 11 \text{ GeV}/c$
 - ▶ minimum number of muons for desired number of muon-groups (e.g. at least 4 muons for 2 muon-groups)
- ▶ Muon (applied *before* our analysis):
 - ▶ $|\vec{p}| > 2.5 \text{ GeV}/c$ (TrackerMuon identification)
 - ▶ ≥ 8 tracker hits (not strictly; applied by whom? track-finding?)
- ▶ Muon (applied *by* our analysis):
 - ▶ $p_T > 5 \text{ GeV}/c$, $|\eta| < 2.4$ (tighter than defaults)
 - ▶ $N_{\text{segments}} \geq 2$ with track-and-segment arbitration,
 $|\Delta x| < 3 \text{ cm}$, $|\Delta x| < 4\sigma_{\Delta x}$, $|\Delta y| < 5 \text{ cm}$, $|\Delta y| < 5\sigma_{\Delta y}$
- ▶ Muon cuts considered, but they don't improve MC performance:
 - ▶ tracker $\chi^2/N_{\text{dof}} < 5$
 - ▶ $\sigma_\phi < 0.03$, $\sigma_\eta < 0.01$, $\sigma_{dxy} < 0.05 \text{ cm}$, $\sigma_{dz} < 0.1 \text{ cm}$
 - ▶ for GlobalMuons: tracker-standAlone matching $\chi^2/N_{\text{dof}} < 5$

Checking cut performance

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- ▶ Already verified that $N_{\text{segments}} \geq 2$ (arbitrated) is the only cut that visibly improves TrackerMuon background rejection for *prompt* muons
- ▶ Last time, a cut-off in efficiency for highly displaced vertices was observed when requiring all considered cuts: which one?

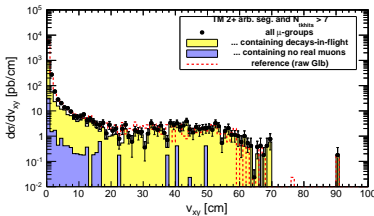
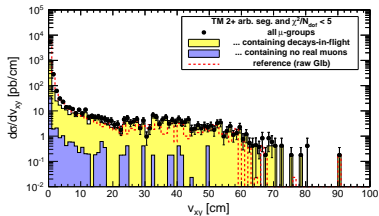
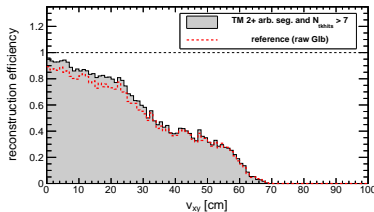
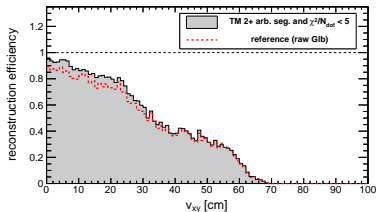


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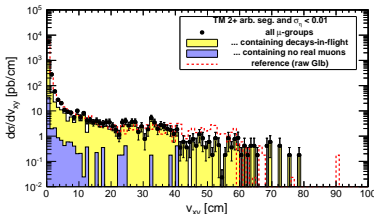
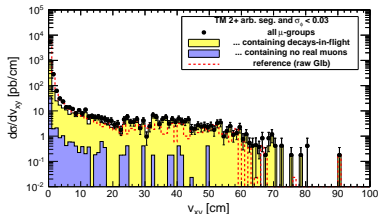
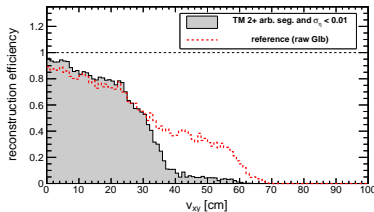
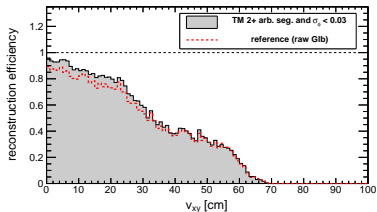


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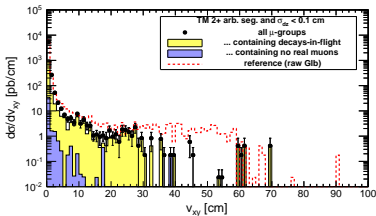
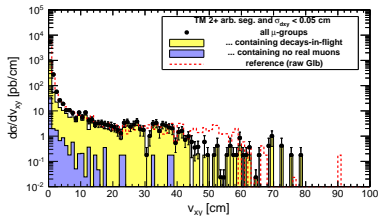
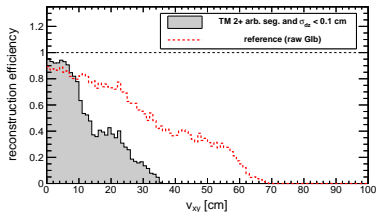
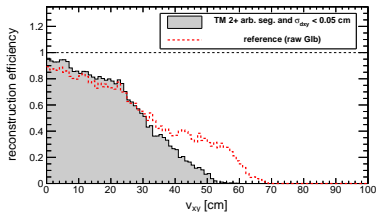


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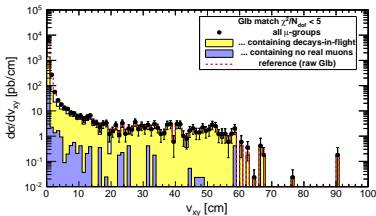
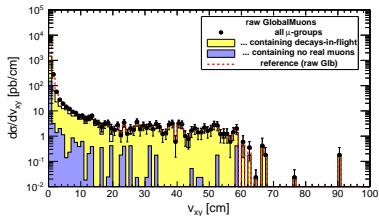
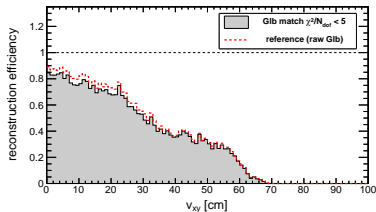
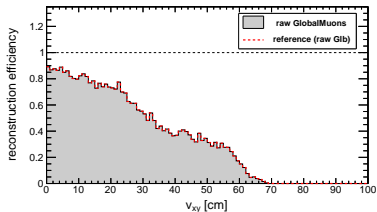


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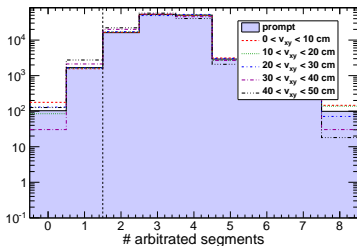
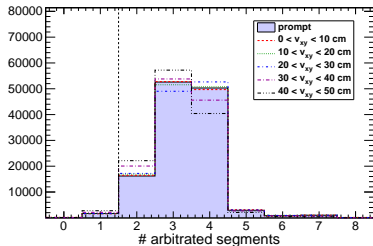


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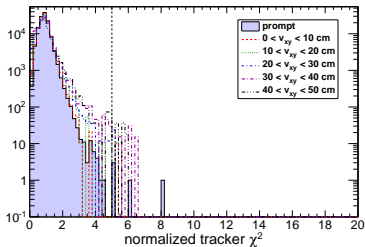
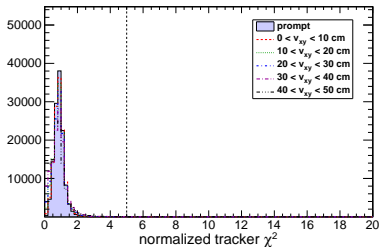


- ▶ Linear scale on left; log scale on right
- ▶ Showing both a purely prompt sample (filled) and samples with displaced vertices (the distribution for each v_{xy} range is normalized to the prompt sample)
- ▶ All samples are uniform in pair mass 0–5 GeV/c^2 , pair p_T 0–100 GeV/c



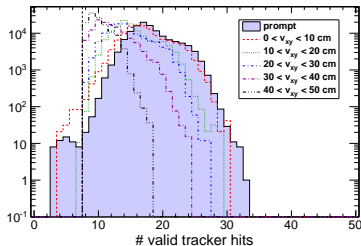
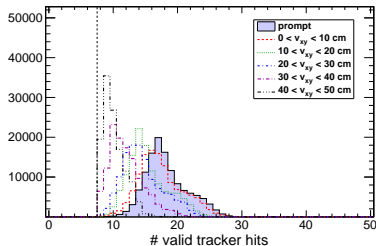


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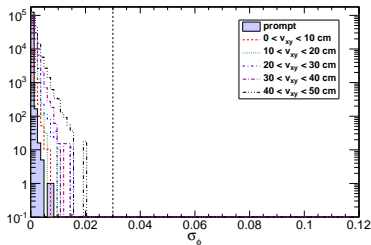
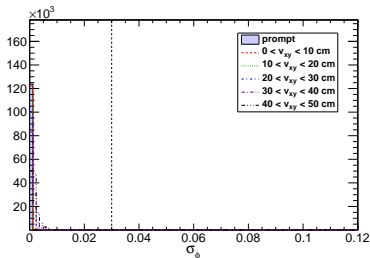


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- ▶ Who's applying a cut in $N_{\text{tk hits}}$? It's driving high-displaced vertex efficiency (not a high priority, but worth knowing. . .)



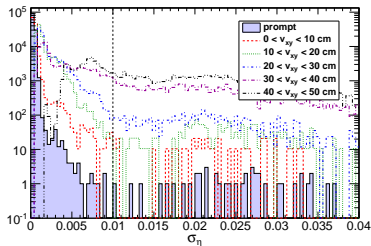
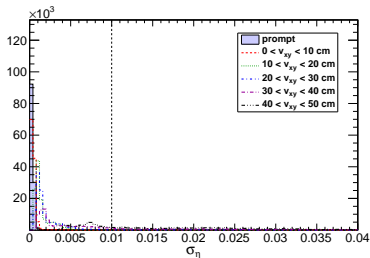


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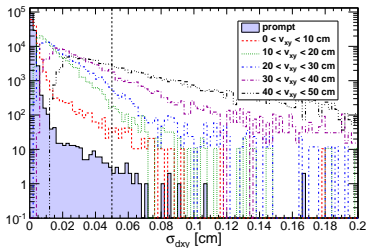
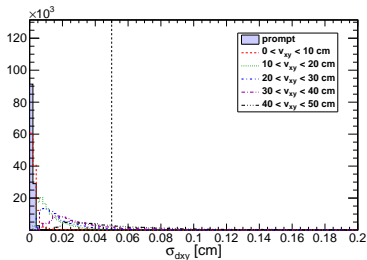


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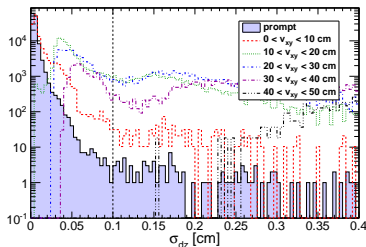
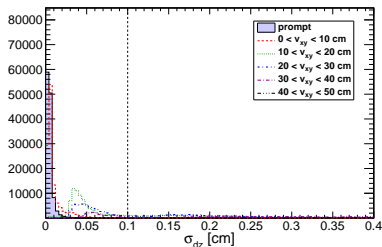


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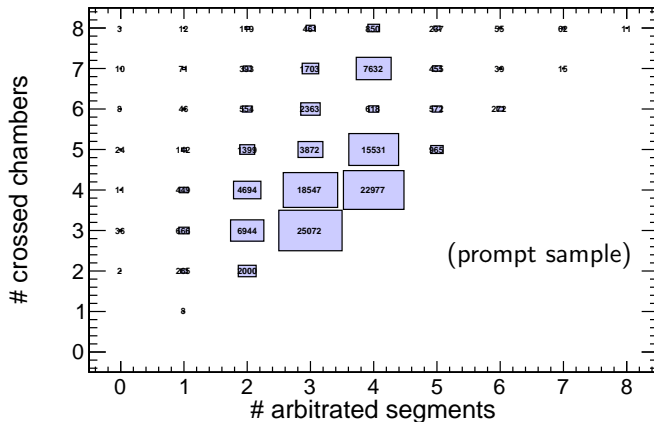


One more thing...

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- ▶ The arbitrated segments are not necessarily on different chambers
- ▶ No evidence yet that we can get an improvement by requiring a minimum number of segments on different chambers, but we should just keep it in mind





- ▶ Event:
 - ▶ HLT_Mu9 (lowest threshold that is not currently prescaled)
 - ▶ one muon with $p_T > 11$ GeV/c
 - ▶ minimum number of muons for desired number of muon-groups (e.g. at least 4 muons for 2 muon-groups)
- ▶ Muon (applied *before* our analysis):
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- ▶ Muon (applied *by* our analysis):
 - ▶ TrackerMuons (GlobalMuons offer no known advantages)
 - ▶ $p_T > 5$ GeV/c, $|\eta| < 2.4$ (tighter than defaults)
 - ▶ $N_{\text{segments}} \geq 2$ with track-and-segment arbitration,
 $|\Delta x| < 3$ cm, $|\Delta x| < 4\sigma_{\Delta x}$, $|\Delta y| < 5$ cm, $|\Delta y| < 5\sigma_{\Delta y}$
- ▶ Additional quality cuts
 - ▶ at least one primary vertex with $|z| < 24$ cm (hn-cms-PO7TeV)
 - ▶ filter out scraping (Collisions2010Recipes)
 - ▶ ...



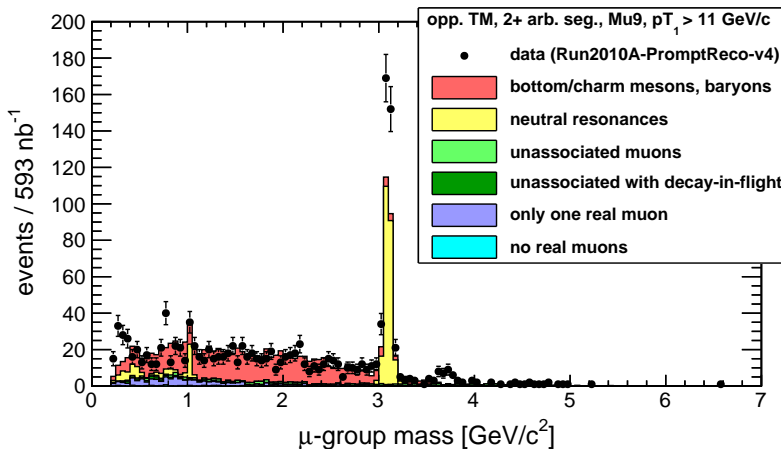
- ▶ Even the best BSM theories predict ~ 1 pb: we can safely study backgrounds with the existing sample
 - ▶ can expect Pythia normalizations to be wrong by a factor of a few (and differently for resonances as for b-jets)
 - ▶ but we want to understand and protect ourselves against differences in distributions
- ▶ Select runs/lumisections with good tracker, muon (including RPC), and trigger; ignore quality of calorimeters (gain a factor of 1.5)
- ▶ Consider only /Mu/Run2010A-PromptReco-**v4**/RECO (137437–142467, or Jun 10–Aug 07) when primary datasets were already set up; modern triggers; most of the good data
- ▶ Integrated luminosity:
 - ▶ HLT_Mu5 (prescaled starting 141956, requires L1SingleMu3): 333.75 nb^{-1}
 - ▶ HLT_Mu9 (unprescaled, requires L1SingleMu7): 592.78 nb^{-1}
- ▶ Following all recommended recipes (RunRegistry, lumicalc.py, etc.)



- ▶ I apparently don't know the proper way to apply trigger cuts using offline variables
 - ▶ on my first attempt, factor-of-10 discrepancy between normalizations of data and MC
 - ▶ tracked down to the way I was selecting “HLT_Mu9 passed” events
 - ▶ when I apply the same requirement in a different way, we get near-perfect agreement
 - ▶ I have external reasons for being more confident in method #2, because it's copied from the way it was done in AICaReco production (set up by experts)
 - ▶ method #2 is less convenient because it requires whole samples to be cut, not an ntuple-level thing
- ▶ Because of this, the following pages will have data selected by HLT_Mu9, MC with no trigger requirement, and both with $pT_1 > 11 \text{ GeV}/c$ (pT_1 is the leading-muon p_T)

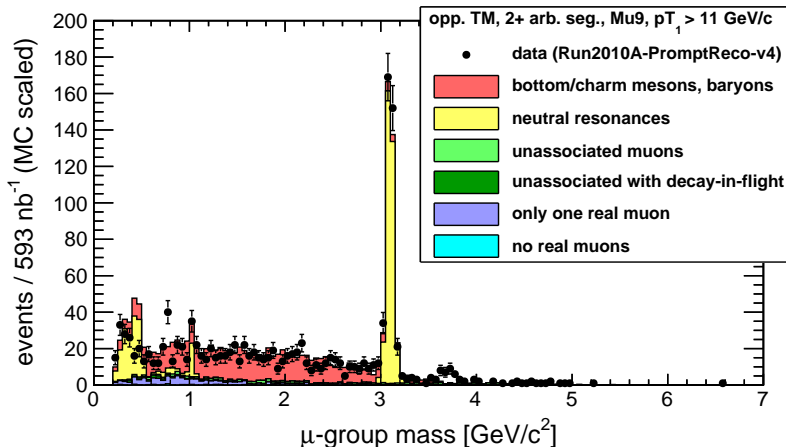


- ▶ Out-of-the-box, normalization of everything except the resonances seems to be pretty good after all
- ▶ Reminder of cuts: opposite-sign, $p_T > 5$ GeV/c TrackerMuons with $N_{\text{segments}} \geq 2$ (arbitrated), HLT_Mu9 in data only, $p_{T1} > 11$ GeV/c



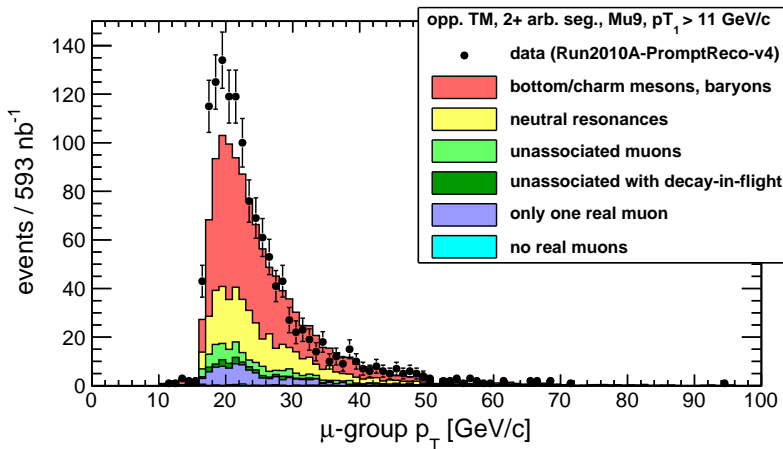


- ▶ Attempt to correct MC by (inappropriately) scaling the resonances
 - ▶ J/ψ increased by 1.48
 - ▶ $\eta(548)$ increased by 5.2
 - ▶ $\omega(782)$ and $\psi(2S)$ are *missing* from MC
 - ▶ $\phi(1020)$ looks right (but wasn't s , \bar{s} overproduced in our MC?)



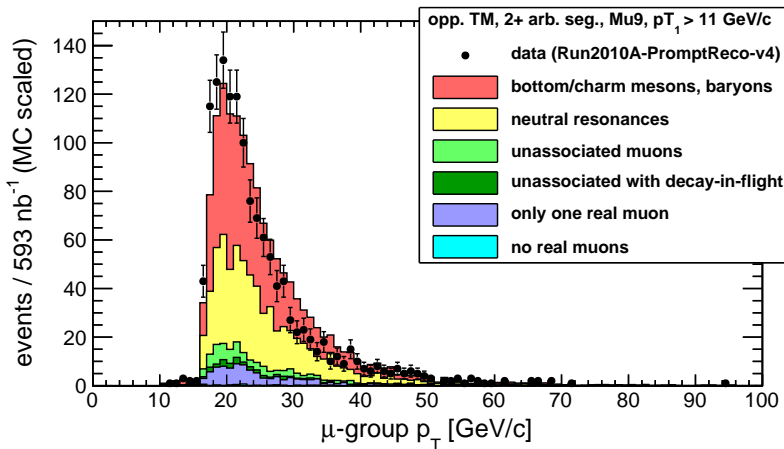


- ▶ This is p_T of the muon-groups (can only be less than 16 GeV/c if the muon group does not contain the leading muon; can never be below 10 GeV/c)
- ▶ Scaling does not reproduce the shape of the distribution



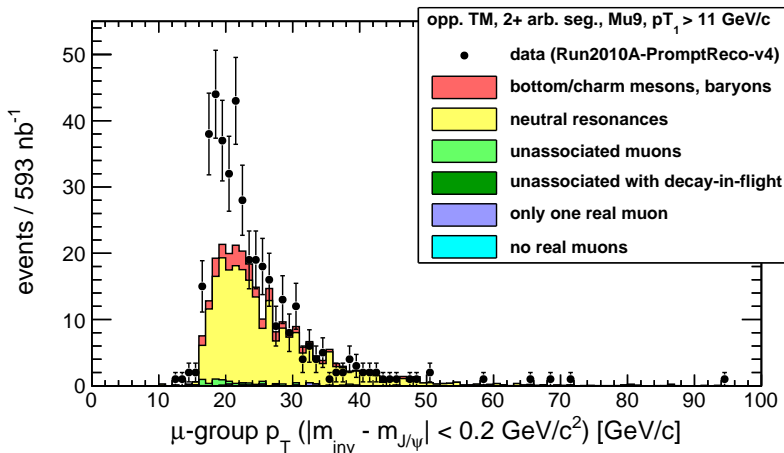


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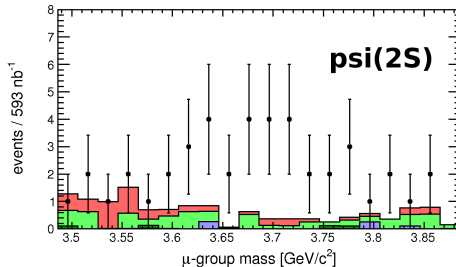
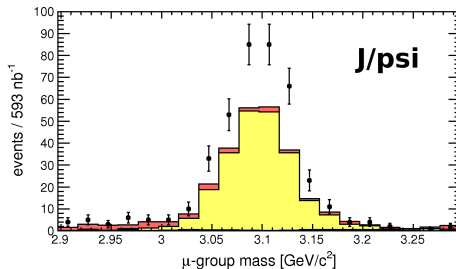
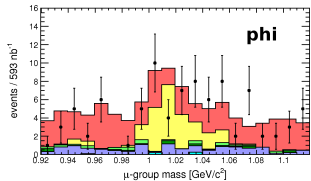
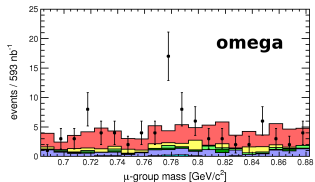
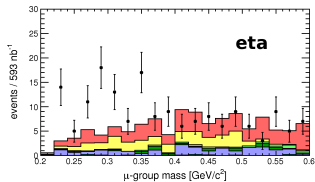


- ▶ In more detail: look at only J/ψ mass region
- ▶ Clearly, it's just because we're missing the prompt J/ψ (and $\psi(2S)$) contributions (if I include those MC samples, then perhaps everything will line up without any MC-tuning. . .)



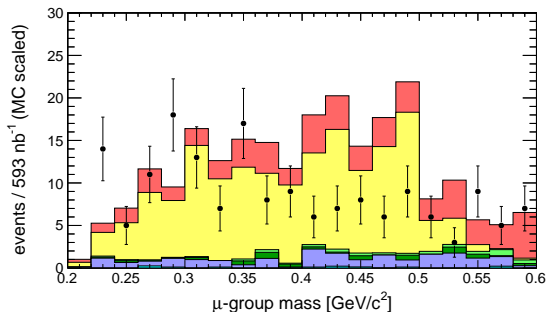
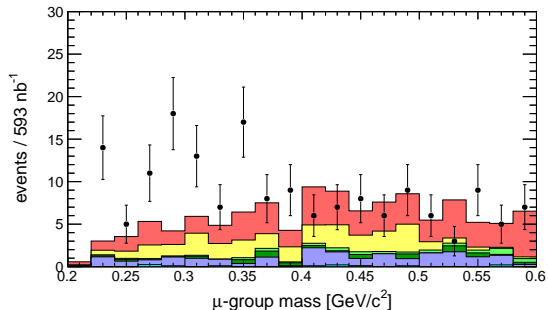
Gallery of resonances

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Low-mass stuff isn't right

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Scaling the η s by 5.2
is a completely wrong
thing to do

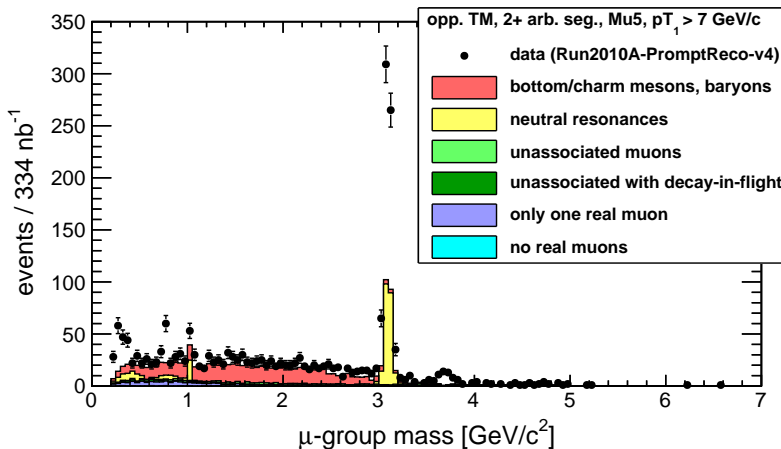


Everything from this point onward is repeated for the Mu5 trigger/ $7 \text{ GeV}/c$ cut, where we get to see some of the resonances more clearly because they are produced with lower momenta

(This is where I ran out of time, writing this talk)

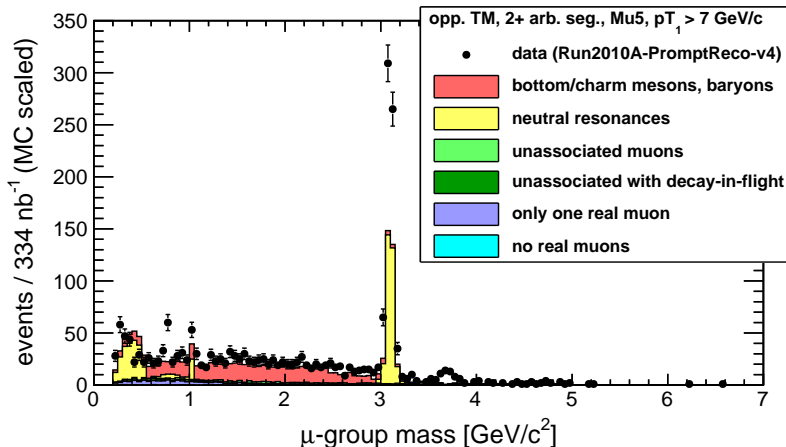


- ▶ Out-of-the-box, normalization of everything except the resonances seems to be pretty good after all
- ▶ Reminder of cuts: opposite-sign, $p_T > 5$ GeV/c TrackerMuons with $N_{\text{segments}} \geq 2$ (arbitrated), HLT_Mu5 in data only, $p_{T1} > 7$ GeV/c



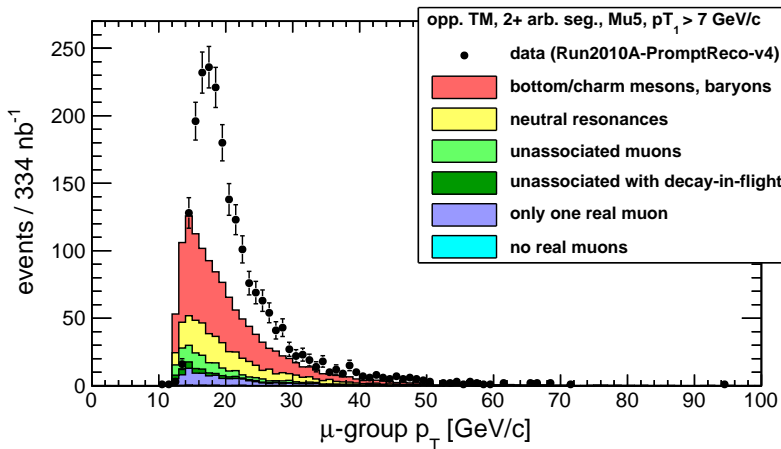


- ▶ Attempt to correct MC by (inappropriately) scaling the resonances
 - ▶ J/ψ increased by 1.48
 - ▶ $\eta(548)$ increased by 5.2
 - ▶ $\omega(782)$ and $\psi(2S)$ are *missing* from MC
 - ▶ $\phi(1020)$ looks right (but wasn't s , \bar{s} overproduced in our MC?)



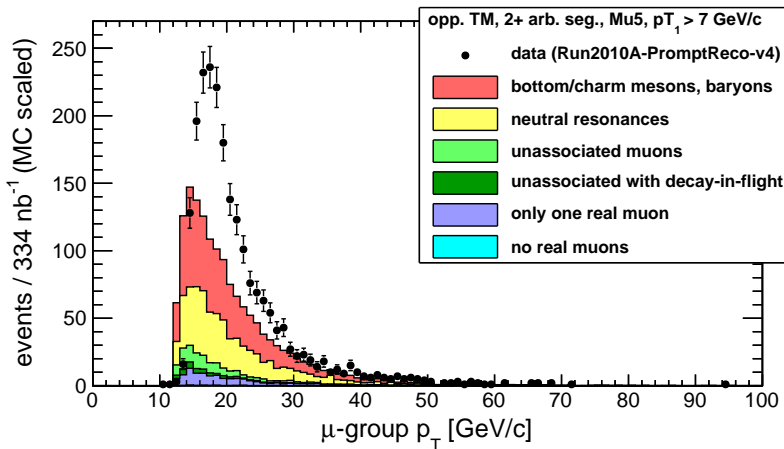


- ▶ This is p_T of the muon-groups (can only be less than 16 GeV/c if the muon group does not contain the leading muon; can never be below 10 GeV/c)
- ▶ Scaling does not reproduce the shape of the distribution



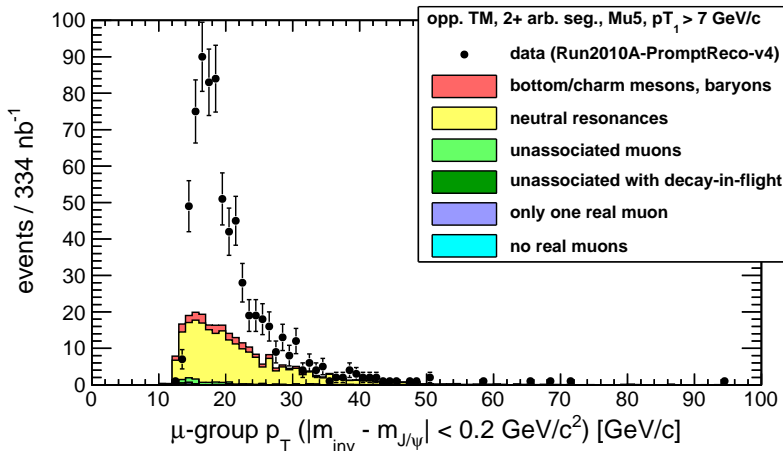


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Gallery of resonances

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