



# Muon Groups Analysis Update

Jim Pivarski

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26 July, 2010



- ▶ Corrections from last time
- ▶ New studies of backgrounds

# Efficiency plots

Corrections from last time

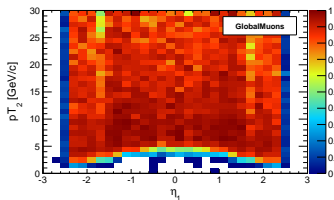
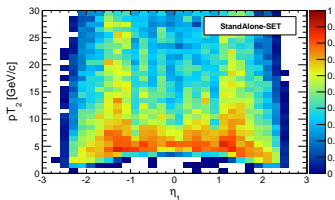
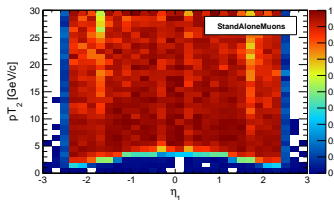
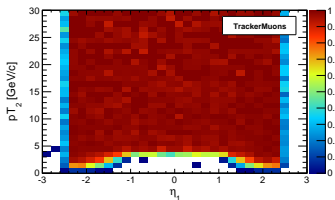
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**Symptom:** StandAloneMuon efficiency seemed to fall off at high  $\eta$ ,  
GlobalMuon efficiency was higher than StandAlone

**Problem:** numerator of “efficiency” required MC-matching

**Solution:**  $\epsilon = \frac{\text{reconstructed 2 muons}}{\text{all generated}}$  (show vs.  $pT_2$  and  $\eta_1$ )



# Efficiency plots

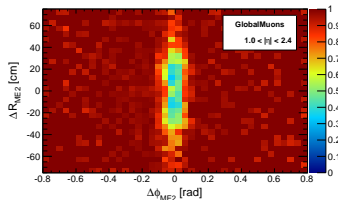
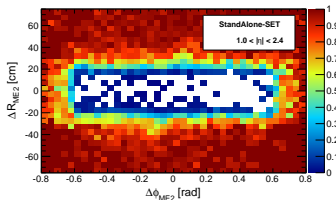
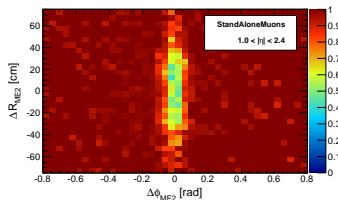
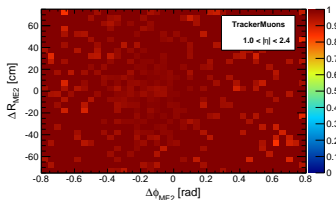
Corrections from last time

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**Problem:** efficiency vs. crossing in muon system didn't cover a broad range: most interesting parts were low-statistics

**Solution:** generated a new muon pair-gun sample with masses uniformly in  $0\text{--}50\text{ GeV}/c^2$ , rather than  $0\text{--}6$



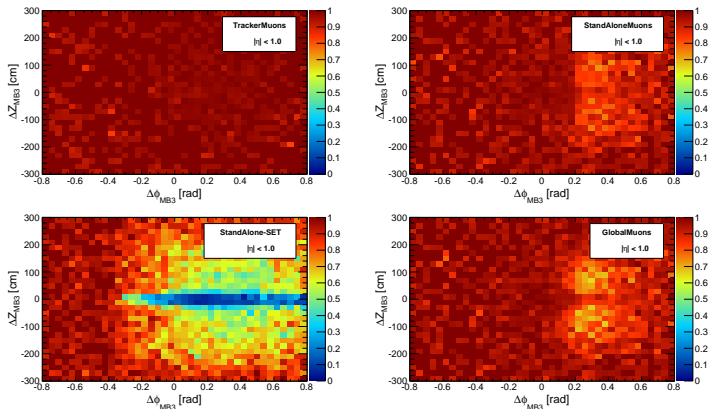
# Efficiency plots

Corrections from last time

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Remaining problem: why is inefficiency vs. barrel crossing maximal off-center? Might I be focusing on the wrong place?



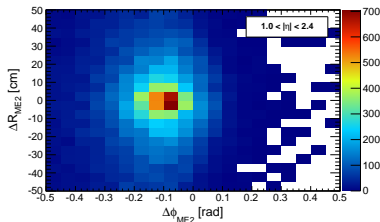
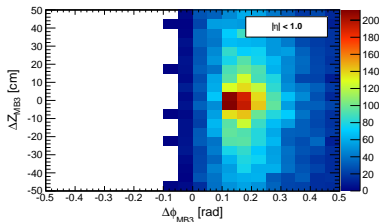
# Efficiency plots

The requested “denominator” plots

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- ▶ These are distributions of where you would land in the muon system if you had dimuons uniformly distributed in mass,  $0\text{--}6\text{ GeV}/c^2$ , uniform in  $p_T$ ,  $0\text{--}100\text{ GeV}/c$ , uniform in  $\eta$ , decaying like a scalar (“spherically”)
- ▶ A different model would have a different distribution (which is why it would be useful to avoid GlobalMuons, so that the efficiency doesn’t depend on the kinematics in a complicated way).



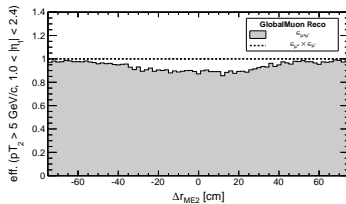
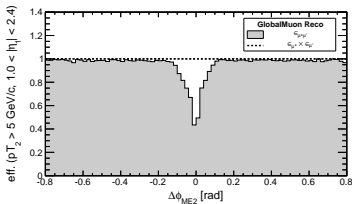
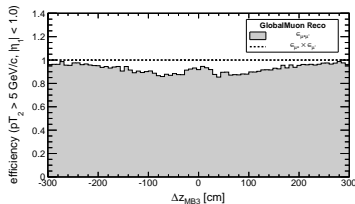
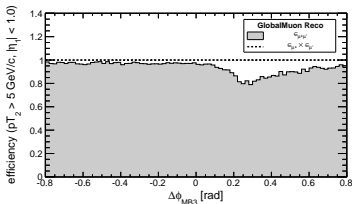
# Efficiency plots

Same in profile

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- ▶ Trying a new technique: every muon in the dimuon-gun sample is also simulated and reconstructed in its own individual event, so that we can see the efficiency of all muons together and the efficiency of each muon separately
- ▶ We don't need to worry about regions in which  $\epsilon_{\mu^+\mu^-} = \epsilon_{\mu^+} \times \epsilon_{\mu^-}$



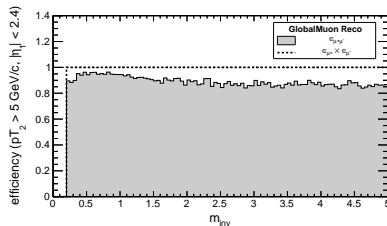
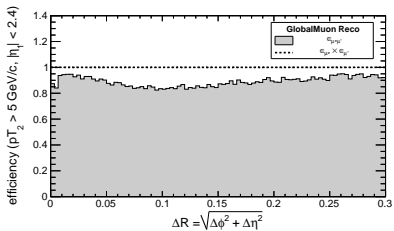
# Efficiency plots

Same vs. other variables

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## ► vs. separation at origin





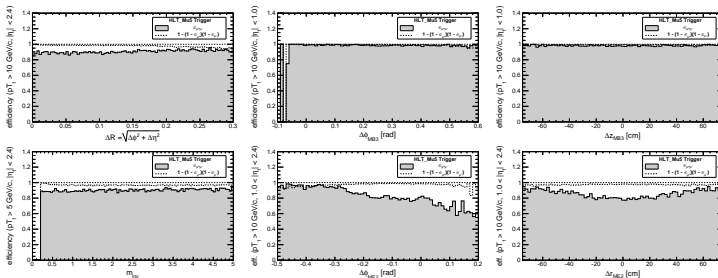
# Efficiency plots

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Trigger efficiency using the same technique

- ▶ Can study trigger efficiencies the same way
- ▶ Now we compare  $\epsilon_{\mu^+\mu^-}$  with  $1 - (1 - \epsilon_{\mu^+}) \times (1 - \epsilon_{\mu^-})$  because a single-muon trigger will fire if  $\mu^+$  **or**  $\mu^-$  is detected
- ▶ But I want to try some simple test-cases before I'm sure that the machinery is working



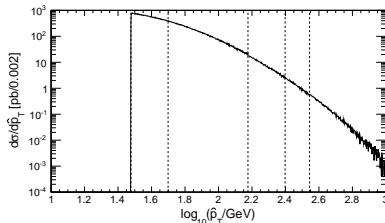
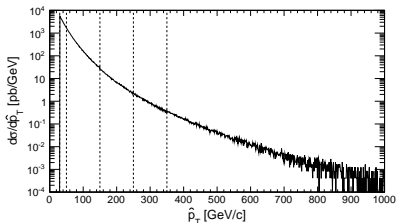
# On to backgrounds

First, a technical note

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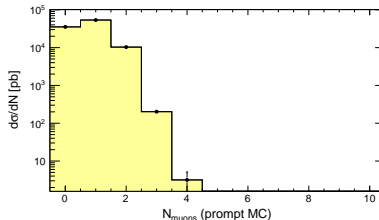
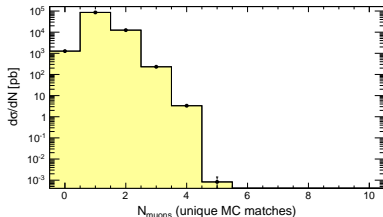


- ▶ InclusiveMu5.Pt\* was produced in 5 bins of  $\hat{p}_T$ : 30+, 50+, 150+, 250+, and 350+ GeV/c
- ▶ Need to combine the samples, cut out double-counting, and scale them all to integrated luminosity
- ▶ On all plots, vertical axis is “picobarns per bin”: number of events you would get if you had 1 pb of data
- ▶ Merged of  $\hat{p}_T$ : no discontinuities means that merging machinery is working... time to go on to physics plots



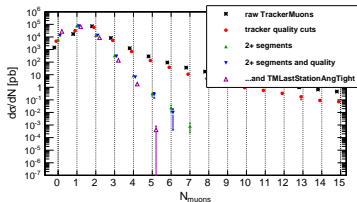
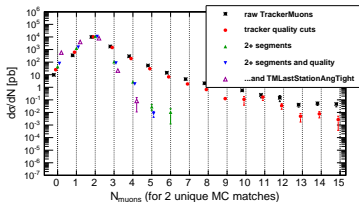
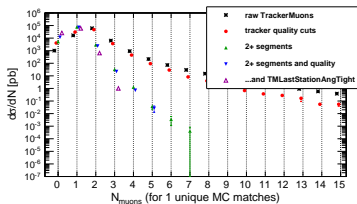
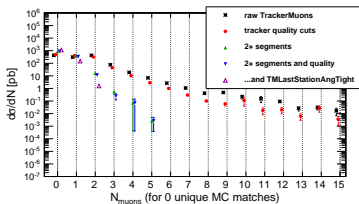


- ▶ Number of real muons per background event is useful, but a little hard to define in this sample because it contains some muons with  $p \lesssim 1 \text{ GeV}/c$  and  $v_{xy} \gg 1 \text{ cm}$
- ▶ I tried two methods (in addition to  $p_T > 5 \text{ GeV}/c$ )
  1. look at MC-matches to all reconstructed muons (full collection: TrackerMuons, GlobalMuons, StandAloneMuons), and count the number of *unique* matched MC muons. Since muon reco efficiency is high within the acceptance region, this is the set of all *reconstructable* muons
  2. look at the list of generator-level particles, and identify the muons which did not come from a  $\pi^\pm$ ,  $K^\pm$ , or  $K_L$  decay

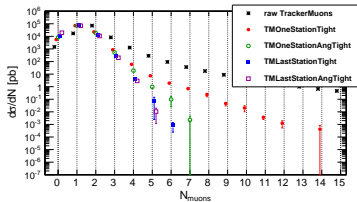
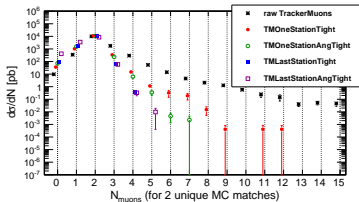
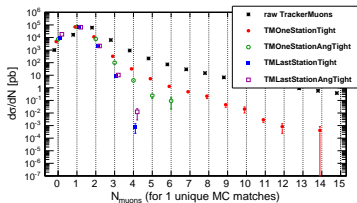
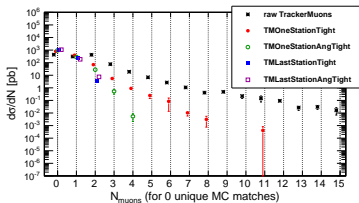




- ▶ Out-of-the-box TrackerMuons yield any track that might point to a muon segment: a huge over-estimate (even including  $p_T > 5 \text{ GeV}/c$ )
- ▶ Track quality cuts can help: which are the most important?
- ▶ Plot  $N_{\text{reco}}$  for each number of  $N_{\text{real}}$  and a general  $N_{\text{reco}}$  distribution;  $N_{\text{real}}$  is defined using method #1 (unique MC-matching)

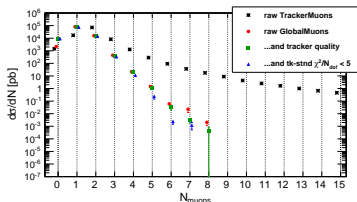
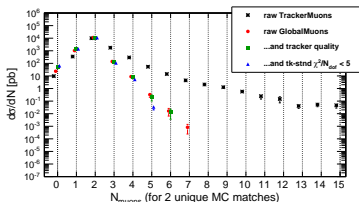
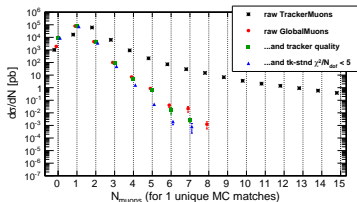
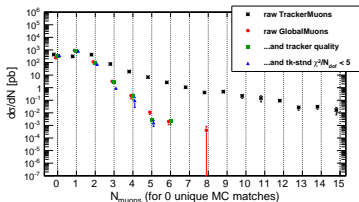


- Standard muon-POG selectors have similar background rejection, but lower efficiencies (not shown here)



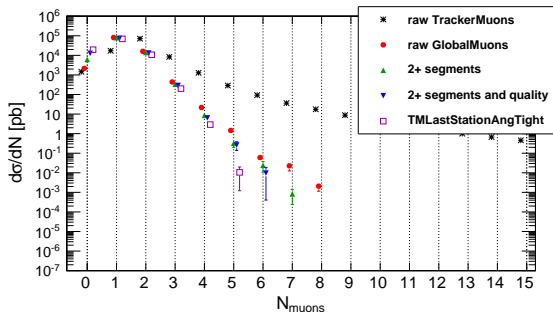


- ▶ GlobalMuons out-of-the-box are already near optimal, adding cuts doesn't help much
- ▶ The tracker/standAlone normalized  $\chi^2$  is consistency of tracker-track and StandAloneMuon (not guaranteed out-of-the-box)





- ▶ All on one page, for your convenience
- ▶ From this point onward, I'm considering only
  - ▶ raw TrackerMuons (straw-man)
  - ▶ quality TrackerMuons, including a  $N_{\text{segments}} \geq 2$  requirement
  - ▶ raw GlobalMuons



“Quality cuts” are:

$$N_{\text{tracker hits}} \geq 8$$

$$\chi^2_{\text{tracker}}/N_{\text{dof}} < 5$$

$$\sigma_{\phi} < 0.03$$

$$\sigma_{\eta} < 0.01$$

$$\sigma_{d_{xy}} < 0.05 \text{ cm}$$

$$\sigma_{d_z} < 0.1 \text{ cm}$$

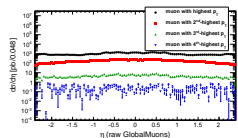
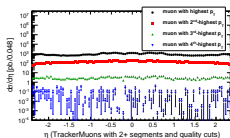
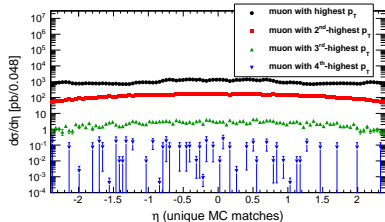
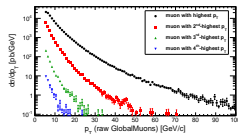
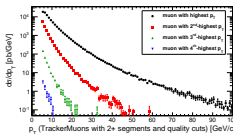
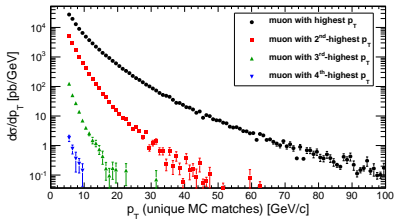
$$N_{\text{segment matches}} \geq 2$$

# Kinematics of backgrounds

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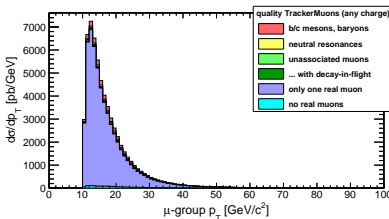
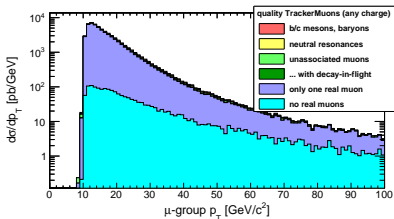
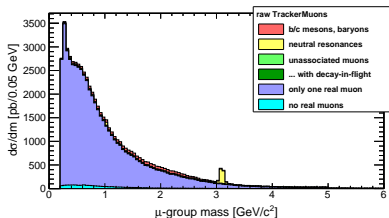
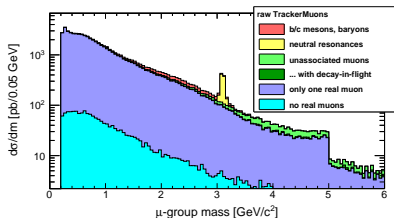


- $p_T$  and  $\eta$  of four highest- $p_T$  muons
- First at generator-level, then for quality TrackerMuons and raw GlobalMuons

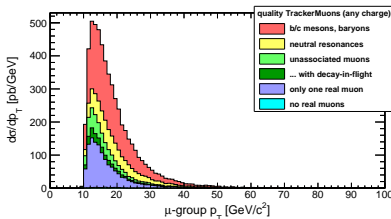
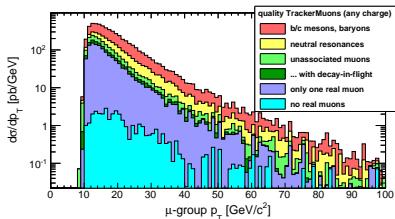
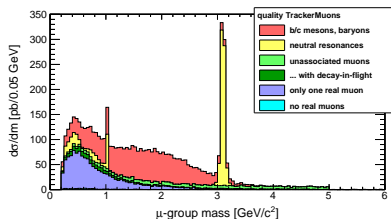
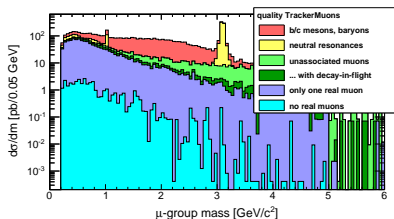




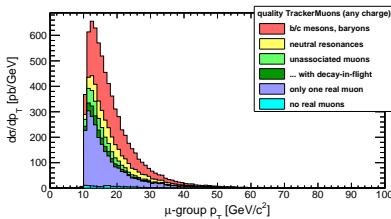
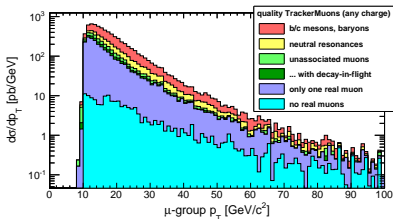
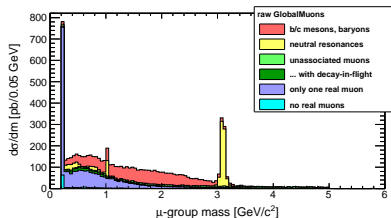
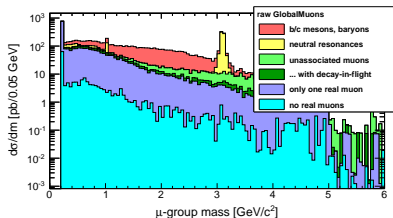
- ▶ Forming muon-groups with **raw TrackerMuons**
- ▶ Where do the events come from? (6 disjoint gen-level categories)



- ▶ Forming muon-groups with **quality TrackerMuons**
- ▶ Where do the events come from? (6 disjoint gen-level categories)

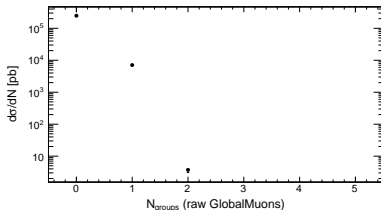
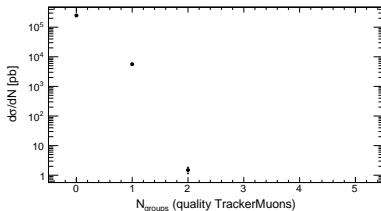
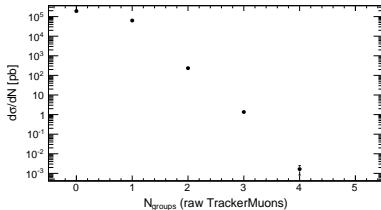


- ▶ Forming muon-groups with **plain GlobalMuons**
- ▶ Where do the events come from? (6 disjoint gen-level categories)



# Number of $\mu$ -groups

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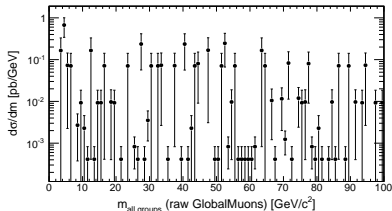
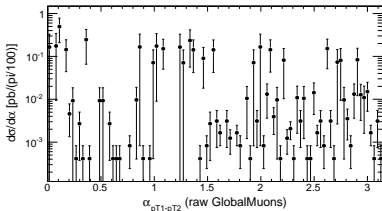
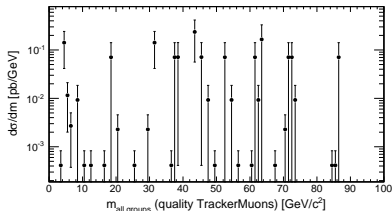
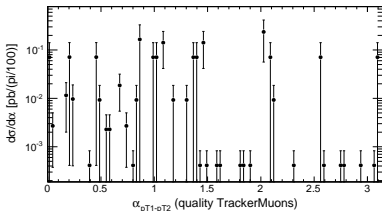
- ▶ Background events with more than one  $\mu$ -group are at the level of 1–3 pb
- ▶ Target for signals is at about the same level
- ▶ So far, so good...

# Angle between $\mu$ -groups

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- ▶ Expressed as an angle between two  $\mu$ -groups ( $0-\pi$ , left) or as a mass of all groups (right)
- ▶ When you actually do have a second  $\mu$ -group in a background event, it seems to be uncorrelated with the first (they're not just wide sprays of muons being split into two nearby groups)



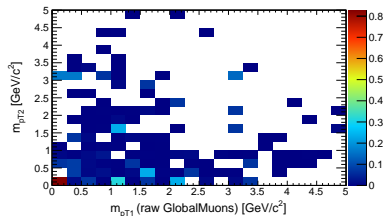
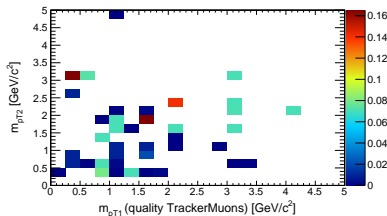
# $m_{12}$ vs. $m_{34}$ plots

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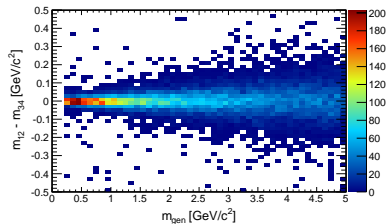
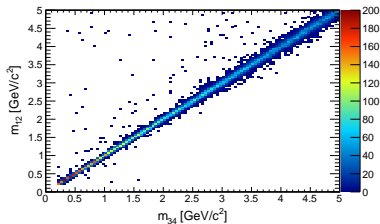


For cases in which both  $\mu$ -groups are coming from the same resonance

Backgrounds:

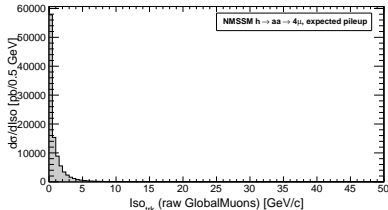
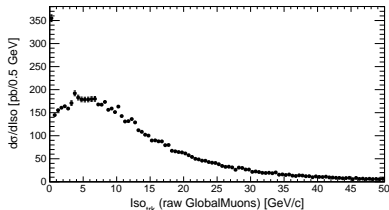
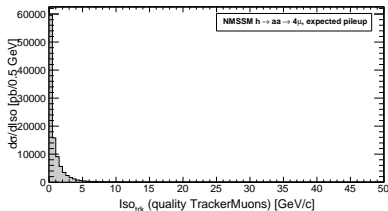
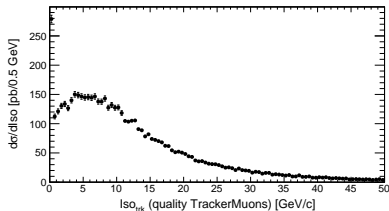


Signal (pair-pair gun with uniformly distributed mass):



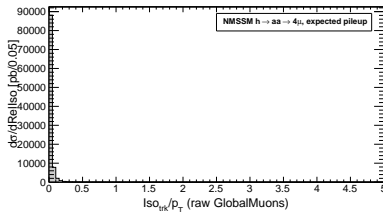
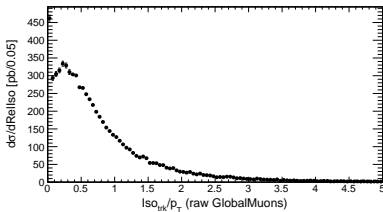
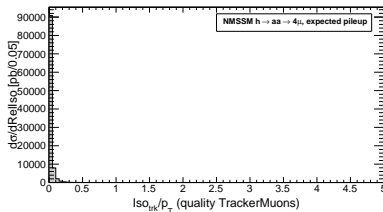
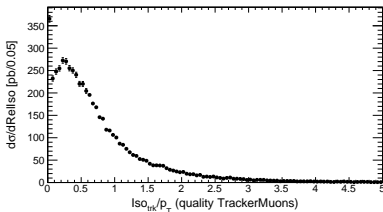


- ▶ Background (left) compared with NMSSM signal (right)
- ▶ Similar distributions for dimuon-gun with pile-up and Extra- $\mathcal{U}(1)$  model, but my script over-wrote them!
- ▶ NMSSM vertical axis is wrong (it's number of events in the sample, not anything to do with "pb")





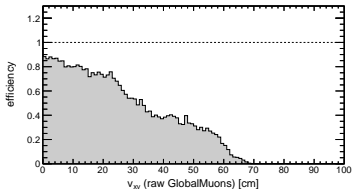
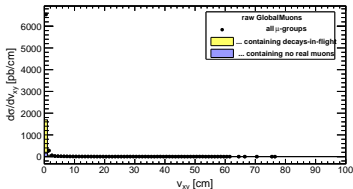
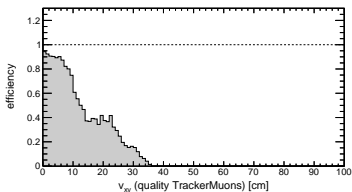
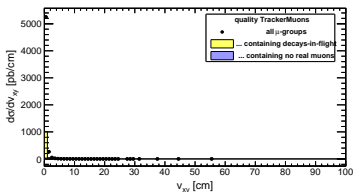
- Even better separation of signal and background (need to zoom in)







- ▶ Backgrounds fall off very quickly as a function of displaced vertex (except raw TrackerMuons, which are contaminated by muons from decays-in-flight)
- ▶ Unfortunately, the final plot got drawn in linear scale (need to fix)
- ▶ More unfortunately, the choice of quality cuts has low efficiency for highly displaced vertices (I need to check and possibly fix it)



# Conclusions

Jim Pivarski 26/26



Work in progress!