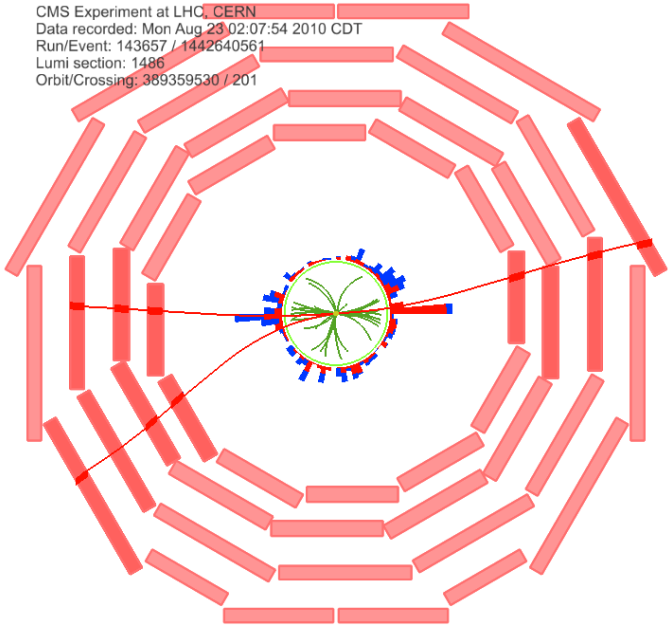
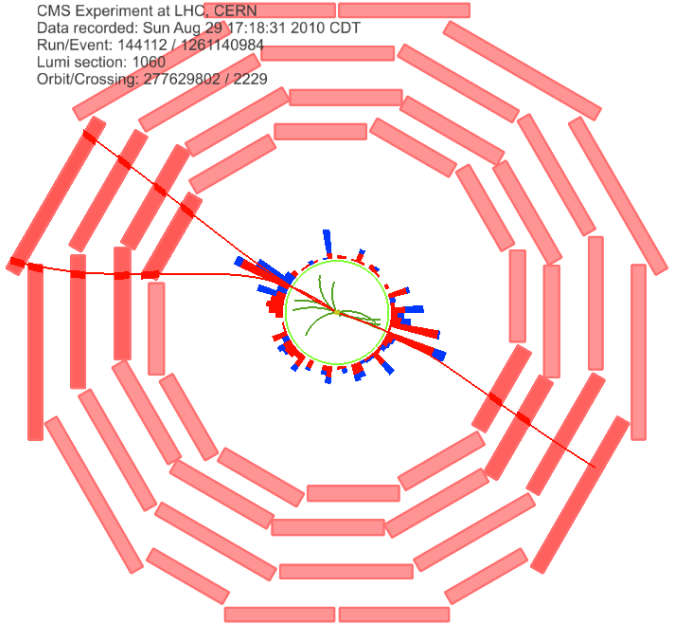
Dimuon + orphaned muon

- Selection: exactly one dimuon (mu-jet containing two muons) and one "orphan" (clean muon not belonging to any mu-jets) with $p_T > 12$ GeV/c, $|\eta| < 1$
- Purpose: the orphan satisfies the trigger, and we get an unbiased view of the dimuon spectrum without having to satisfy the trigger. This is important for the dimuon-dimuon signal channel, where only one of the two dimuons must satisfy the trigger; the other is generic

mass < 3 GeV/c^2



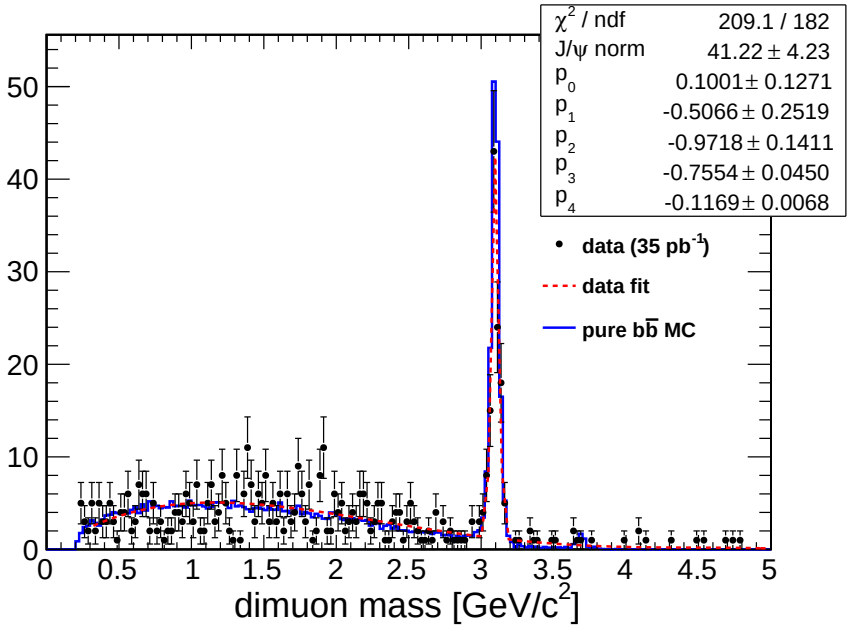
mass in J/ψ window



Dimuon spectrum w/o trigger bias

- Parameterized background shape:

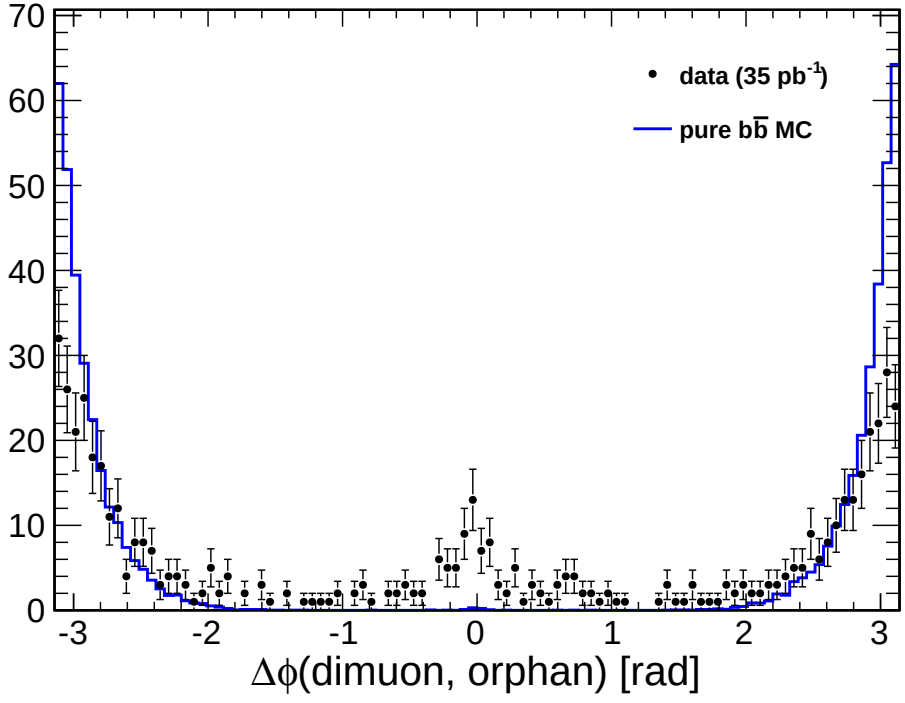
```
41.22*exp(-(x-3.096916)**2 / 2.  / 0.025**2) + 0.10 + -0.51*(x-5) + -0.97*(x-5)**2 +
-0.76*(x-5)**3 + -0.12*(x-5)**4
```



- Not enough statistics to see any resonances other than J/ψ, but they could be there. . . perhaps their normalizations need to be nuisance parameters? (We ought to have poor sensitivity to new resonances whose mass is exactly equal to a Standard Model resonance, especially when we don't know how many events with that Standard Model resonance to expect.)

Data/MC comparisons

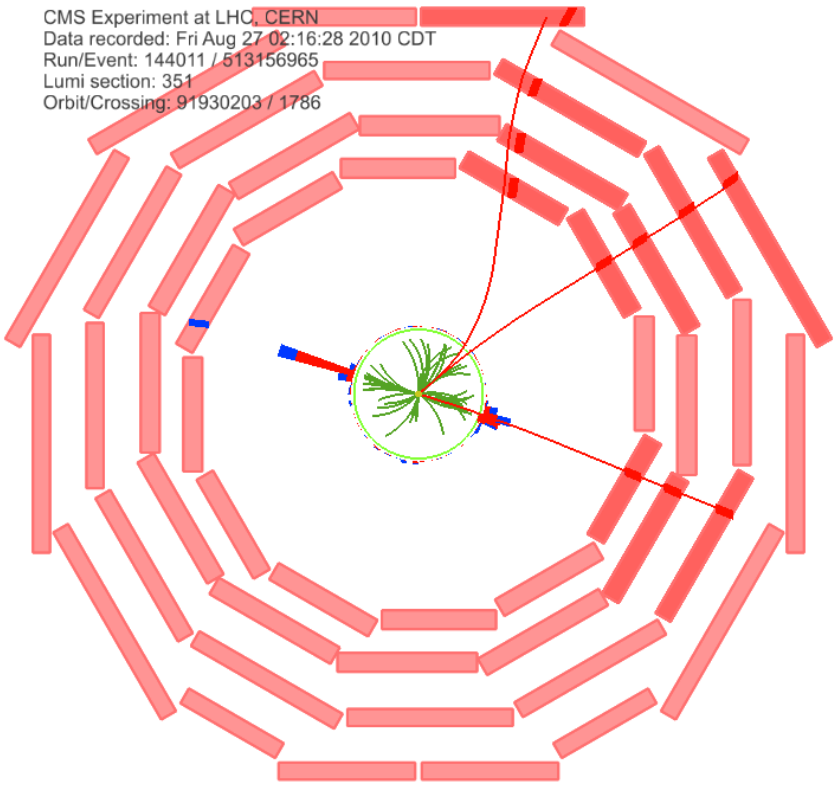
- A (very large int. lumi.) pure $b\bar{b}$ sample describes the observed mass distribution well, but there are discrepancies in some of the other variables
- Azimuthal angle between the dimuon axis and the orphan muon:



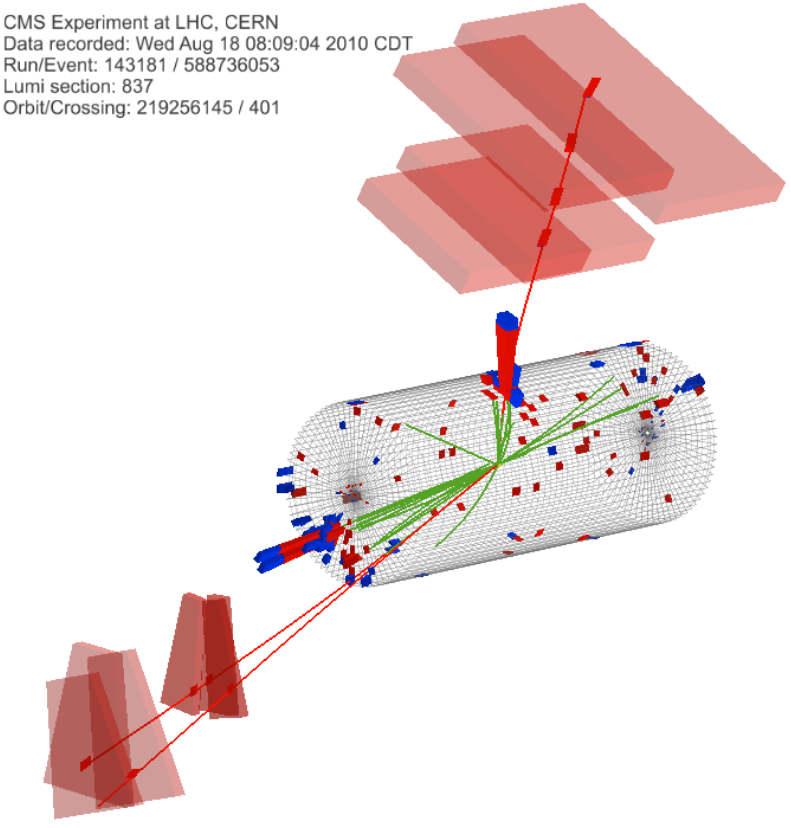
- MC is almost perfectly back-to-back, but data isn't

Examples of acolinearity in data

Example in data of a third jet unbalancing the $b\bar{b}$ (with punch-through!)

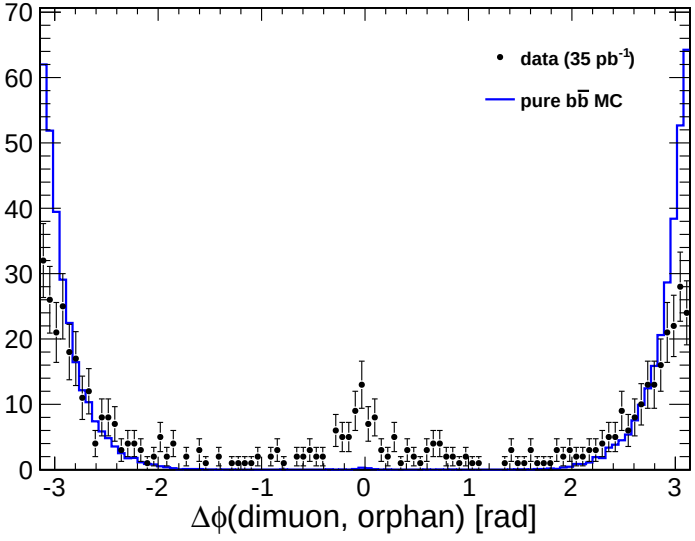


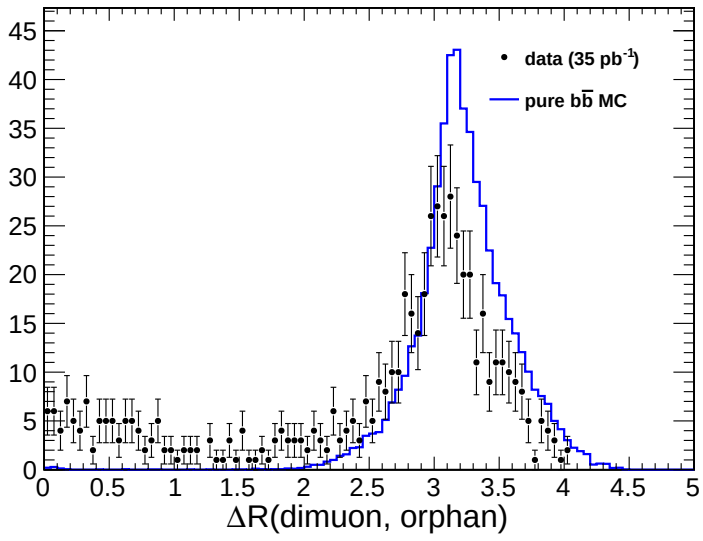
Example in data of dimuon offset from the center of its jet

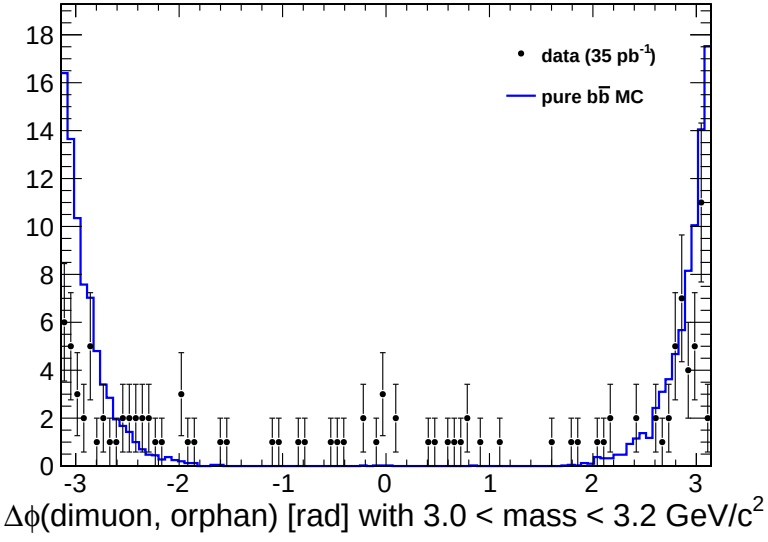


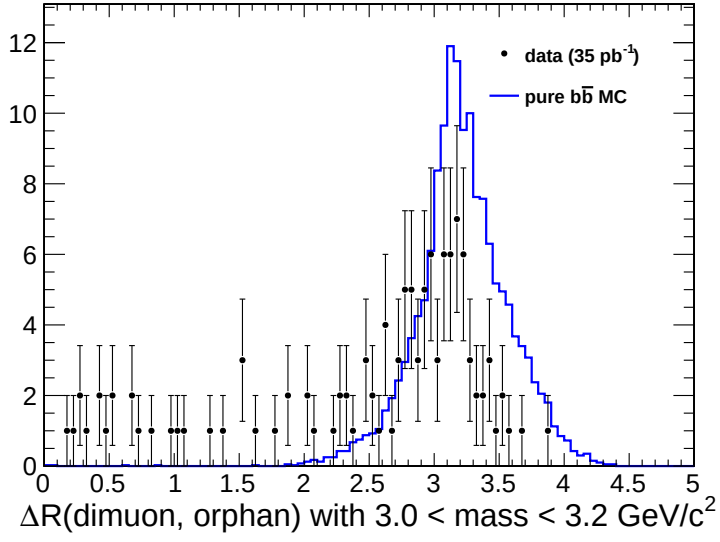
These effects boost the b-quark systems, but invariant mass (our quantity of interest) is insensitive to external boosts

More data/MC comparisons



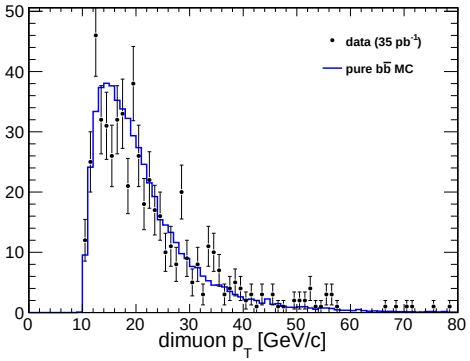


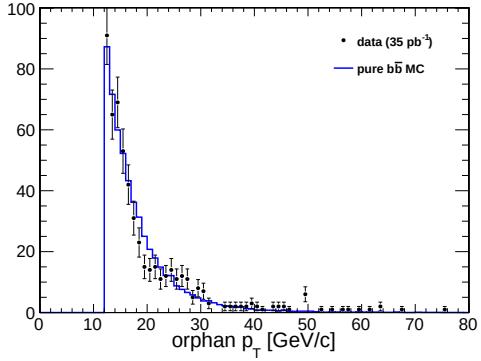


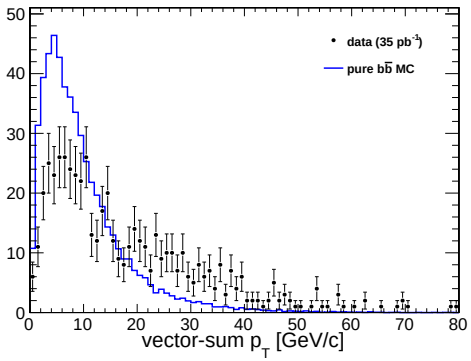


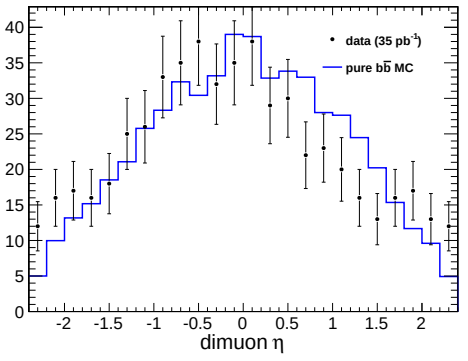
More data/MC comparisons

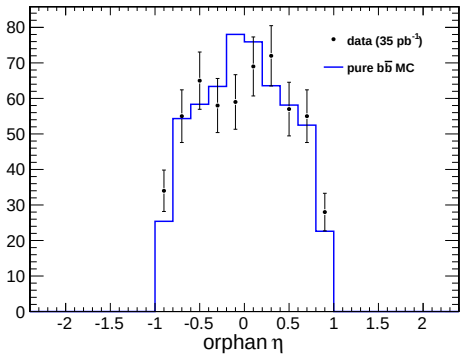
- p_T and η of the dimuon, the orphan, and both
- Only problem is the vector-sum p_T of both, since the whole system is boosted differently in data than it is in MC





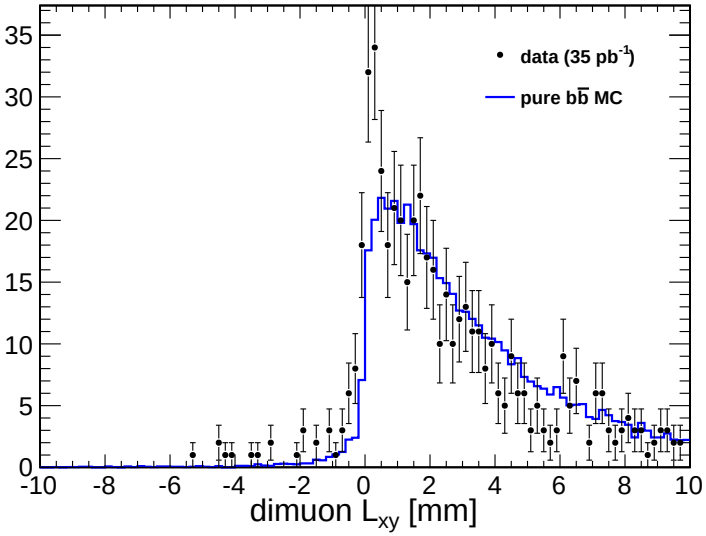


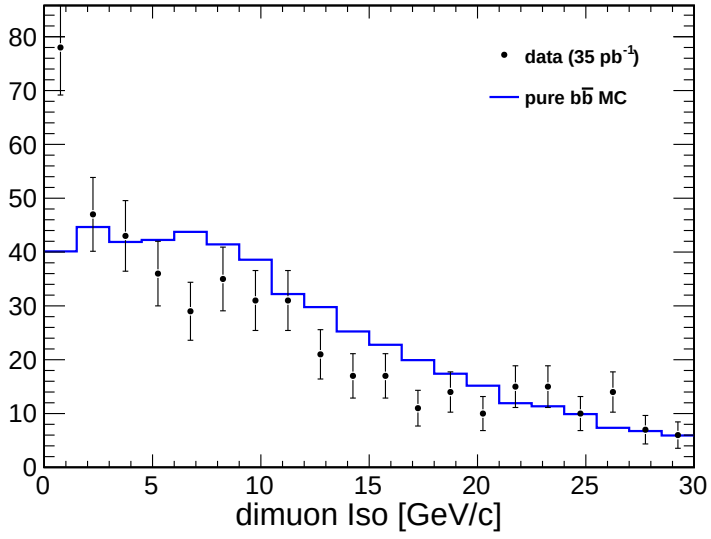


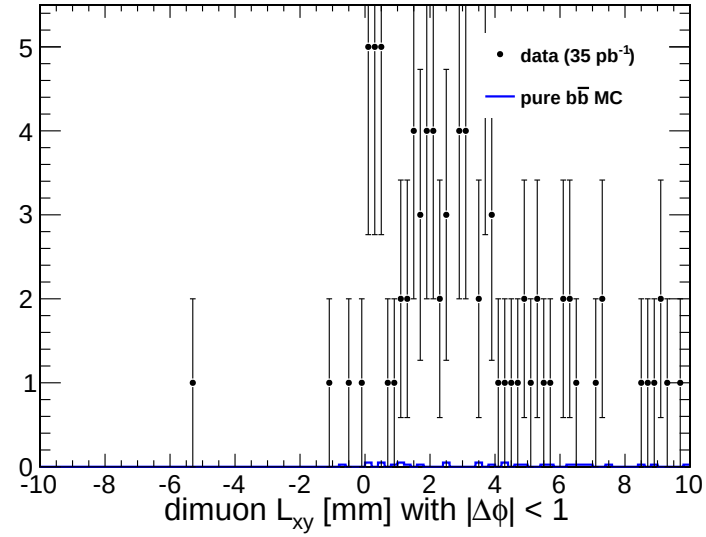


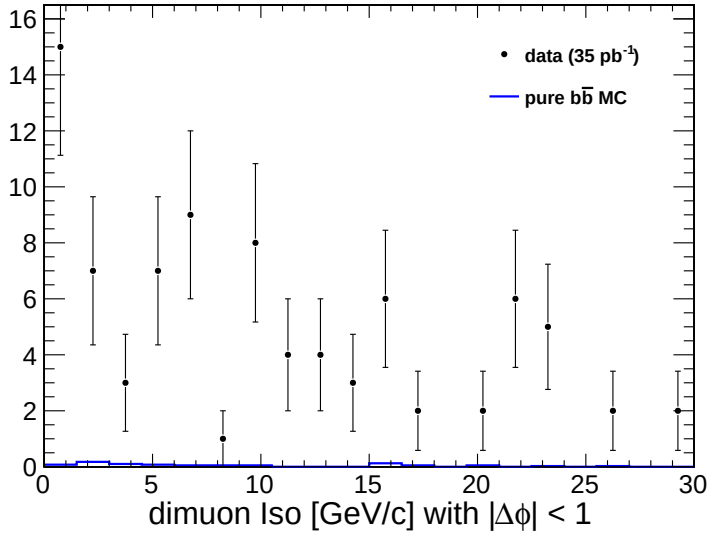
Diagnostic of $|\Delta\phi| < 1$ events

$|\Delta\phi| < 1$ when the dimuon and the orphan are nearly collinear: something that never happens in the $b\bar{b}$ MC





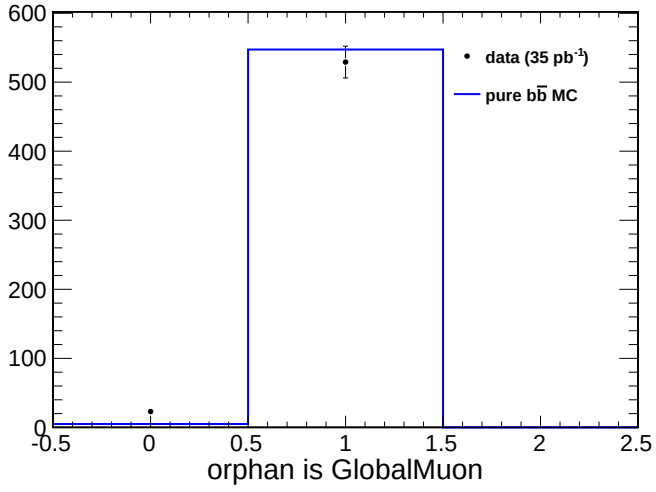


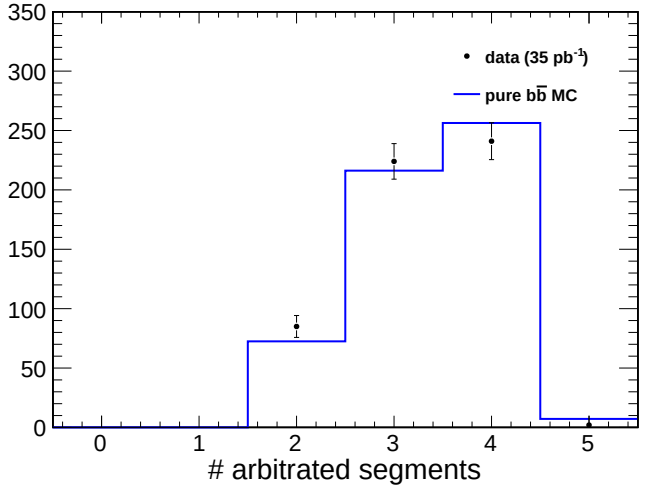


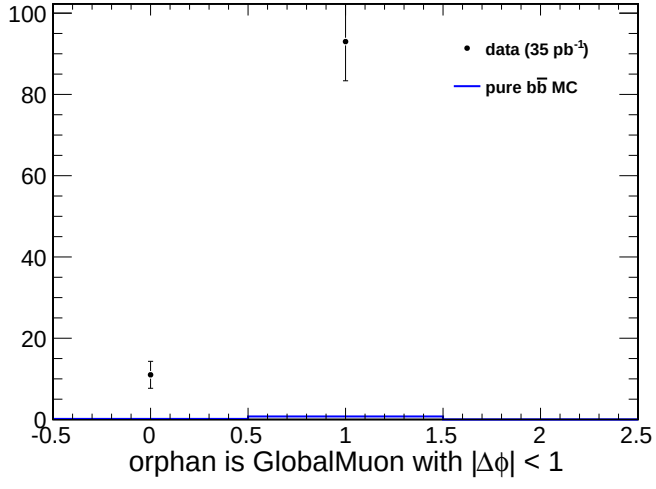
Diagnostic of $|\Delta\phi| < 1$ events

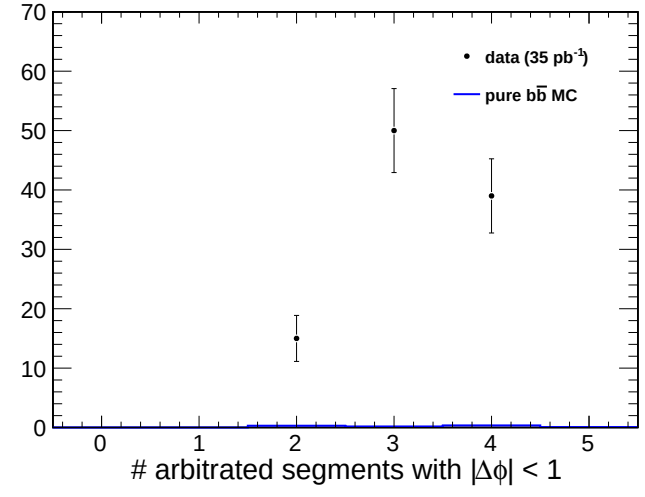
$|\Delta\phi| < 1$ when the dimuon and the orphan are nearly collinear: something that never happens in the $b\bar{b}$ MC

Muon quality plots for the orphan





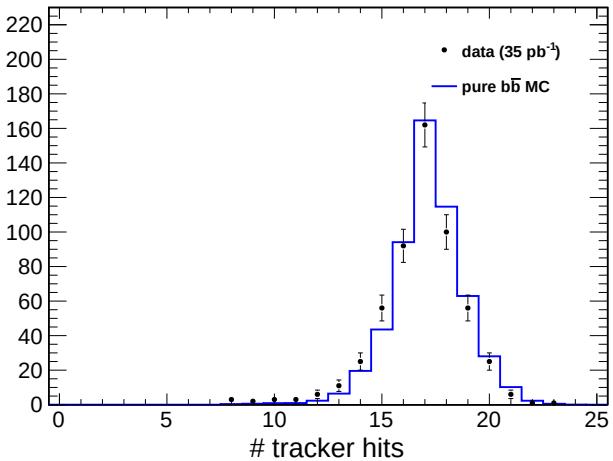


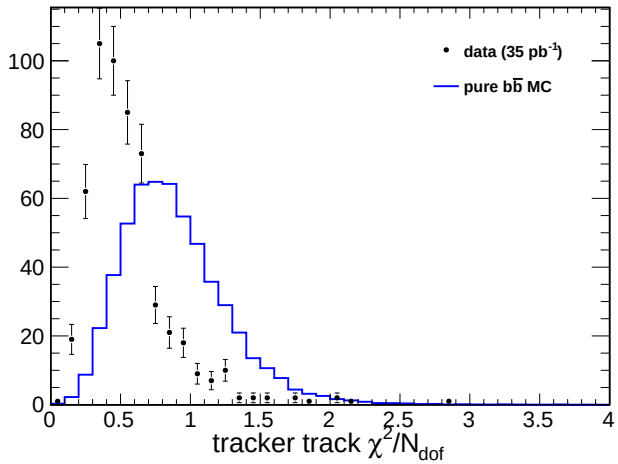


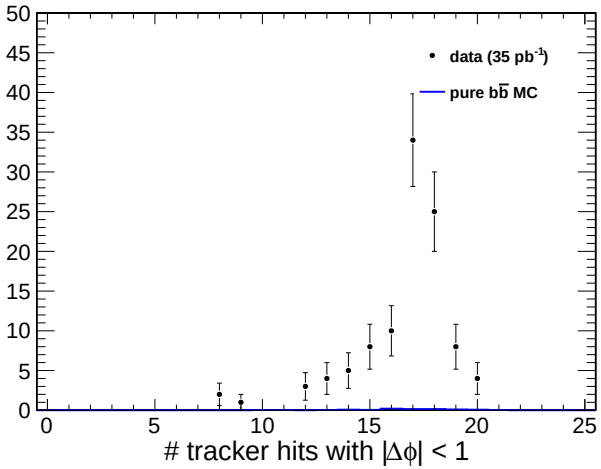
Diagnostic of $|\Delta\phi| < 1$ events

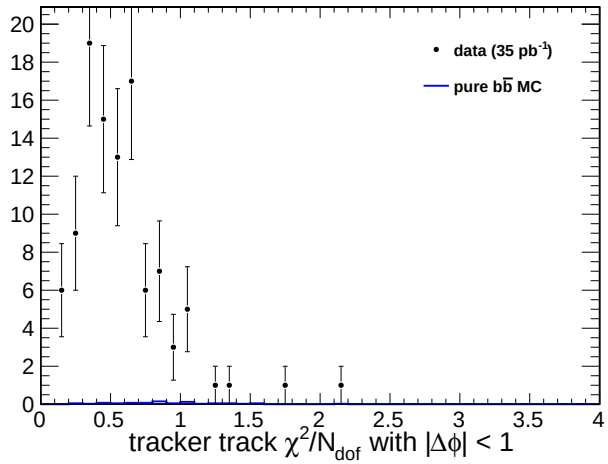
$|\Delta\phi| < 1$ when the dimuon and the orphan are nearly collinear: something that never happens in the $b\bar{b}$ MC

Tracker-track quality plots for the orphan







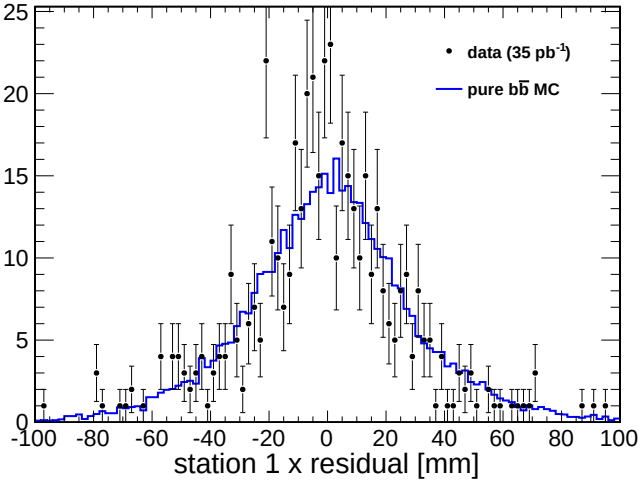


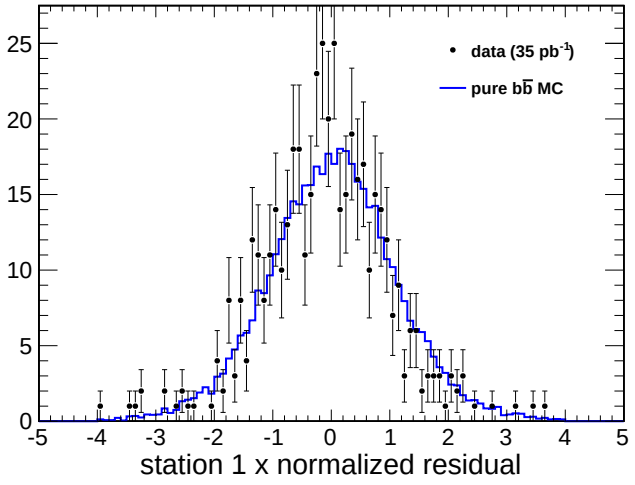
$\chi^2/N_{\text{dof}} \ll 1$ can happen in data if the APEs are too large (and would cause vertex probabilities to be biased toward 1, something else we've seen). MC alignment is ideal.

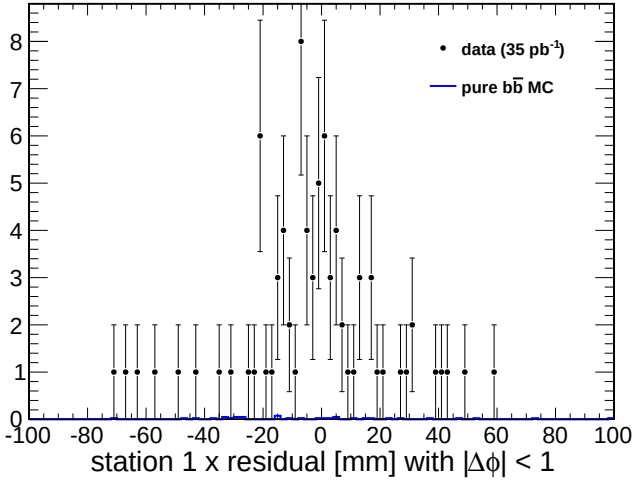
Diagnostic of $|\Delta\phi| < 1$ events

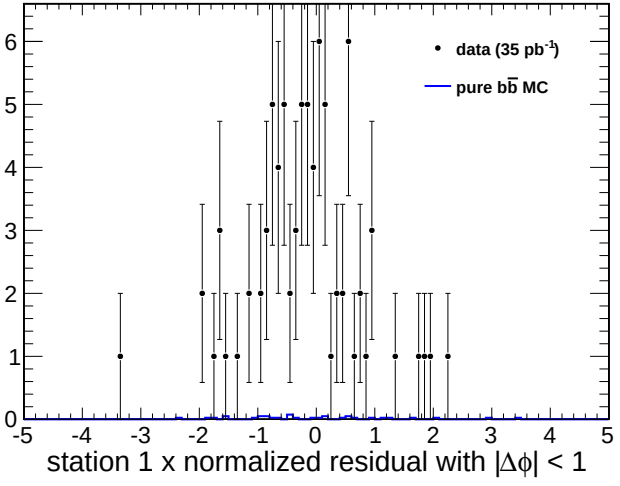
$|\Delta\phi| < 1$ when the dimuon and the orphan are nearly collinear: something that never happens in the $b\bar{b}$ MC

Station 1 muon residuals (x) for the orphan







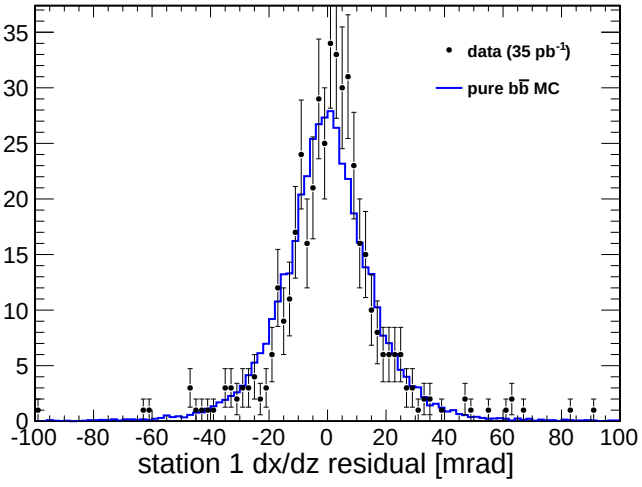


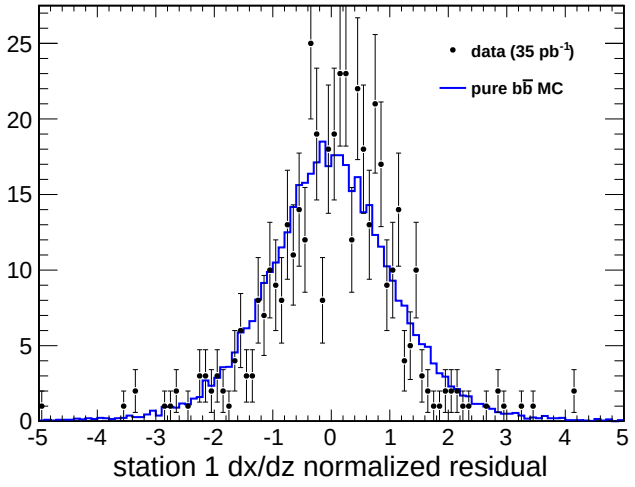
Diagnostic of $|\Delta\phi| < 1$ events

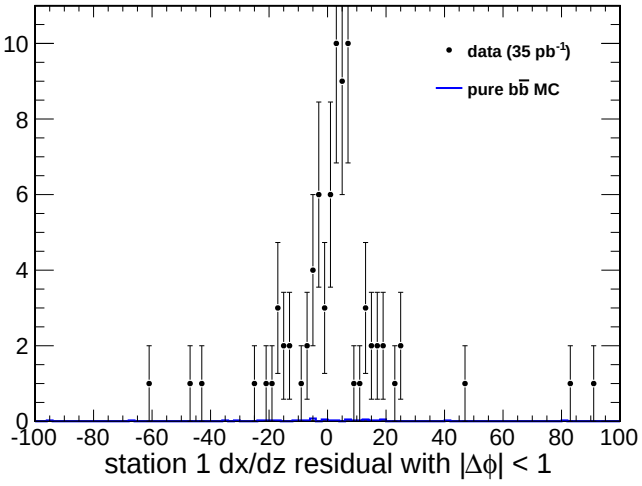
Jim Pivarski

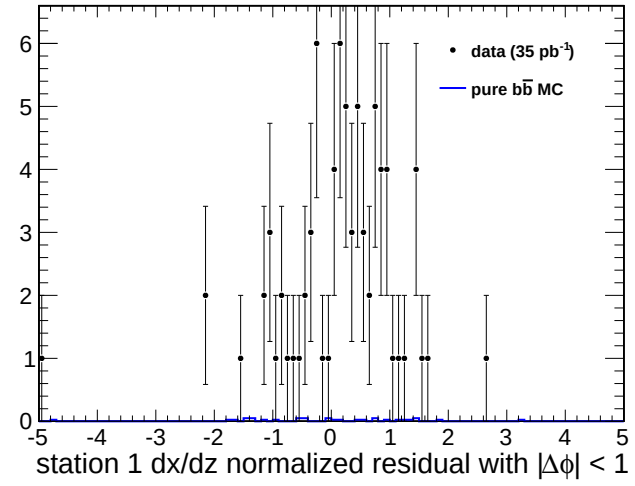
$|\Delta\phi| < 1$ when the dimuon and the orphan are nearly collinear: something that never happens in the $b\bar{b}$ MC

Station 1 muon residuals (dx/dz) for the orphan









Conclusions

- Now we have a complete set of background mass templates for the dimuon-dimuon signal region.
  - the dimuon-dimuon signal region should have the "central dimuon" on the vertical axis (which contains the $p_T > 12$ GeV/c^2, $|\eta| < 1$ muon we used to satisfy the trigger) and the "other dimuon" on the horizontal axis
  - the background mass template for the "central dimuon" comes from the single-dimuon control sample (sent last time)
  - the background mass template for the "other dimuon" comes from this study with dimuon + orphan, allowing for unknown contributions from Standard Model resonances
- The data and MC differ in how much boost the b-quarks get, but
  - the orphan is always a good muon, even in these cases
  - the dimuon looks like a b-quark decay; it just looks like the whole event is boosted by other hadronic jets
  - invariant mass is insensitive to boosts
- Moving on...