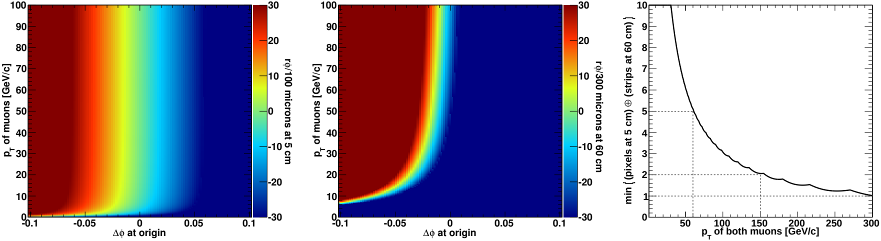
Question: is the signal efficiency affected by interference between muons in the tracker, possibly in a way that is not well modeled by Monte Carlo?

That is, how do we know that our MC-based efficiency is accurate?

Facts about tracking

- Any tracks found in the same iteration can share up to 50% of hits
  - first two iterations of tracking use pixel triplets and pixel seed pairs to find prompt tracks with $p_T > 0.9$ GeV/c, subsequent iterations are for low-p_T and displaced tracks (not our muons)
- To share $\gtrsim$ 50% of their hits, the two oppositely-charged muons must be close enough to merge clusters along most of the two tracks
- For 100 micron-wide pixels at $r = 5$ cm and 300 micron-wide strips at $r = 60$ cm from the beamline, two muons can only get within 5 pixels *and* strips of each other if both muons have $p_T > 60$ GeV/c, within 2 if $p_T > 150$ GeV/c, and within 1 if $p_T > 300$ GeV/c

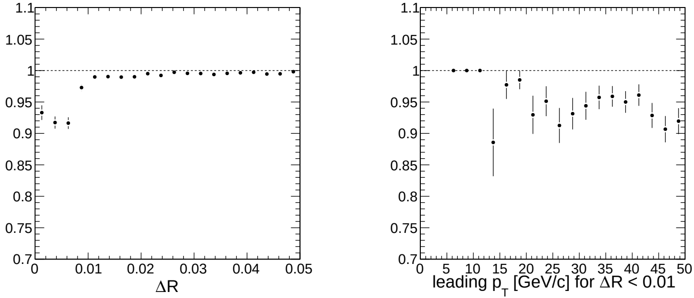
Left: $r\phi$ separation (color) in pixel/strip widths at 5 and 60 cm. Right: minimum pixel/strip widths at a given p_T.



Very collinear muons

Search for the efficiency dip when muons are very close to one another:

- Pair-gun Monte Carlo through full simulation three times for each pair: once with both μ^+ and μ^- in the same event, once with only μ^+, and once with only μ^-
- Define efficiency as: $\dfrac{\text{found tracks individually } \textit{and} \text{ when together}}{\text{found tracks individually}}$
  - "found tracks" means reconstructed, #hits ≥ 8, $\chi^2/N_{\mathrm{dof}} < 4$
  - $\sim$equivalent to normal efficiency definition because "found tracks individually" is about 99.6% everywhere (always $> 99.0\%$)

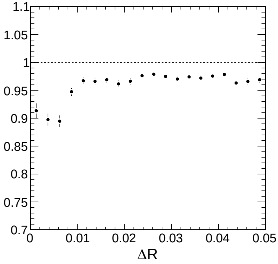


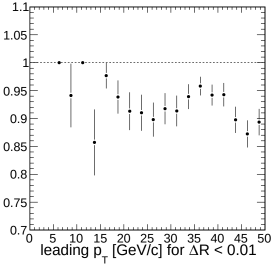
lose about 5% in $\Delta R < 0.01$, $p_T > 20$ GeV$/c$ that isn't lost when the muons are simulated individually

Very collinear muons

Same for muon efficiency:

- Define efficiency as: $\dfrac{\text{found muons individually } \textit{and} \text{ when together}}{\text{found muons individually}}$
- "Found muons" means reconstructed, #hits ≥ 8, $\chi^2/N_{\text{dof}} < 4$, number of arbitrated segments ≥ 2





Conclusion: there is a 5% tracker-interference effect for $\Delta R < 0.01$ and $p_T > 20$ GeV$/c$, and a muon-interference effect for larger ΔR values (already documented in analysis note)

Accuracy of the Monte Carlo

- Start with data/Monte Carlo comparisons from the Tracker DPG early 7 TeV paper (http://arxiv.org/abs/1007.1988):
  - low-level comparisons show we have a good bottom-up simulation

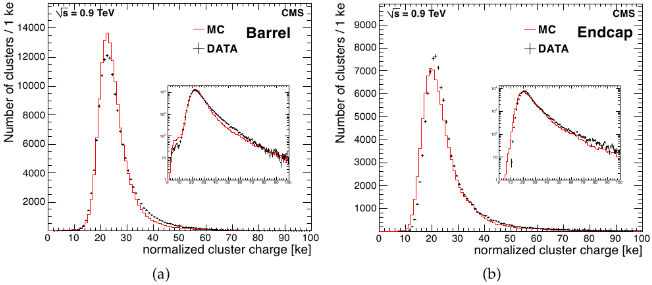
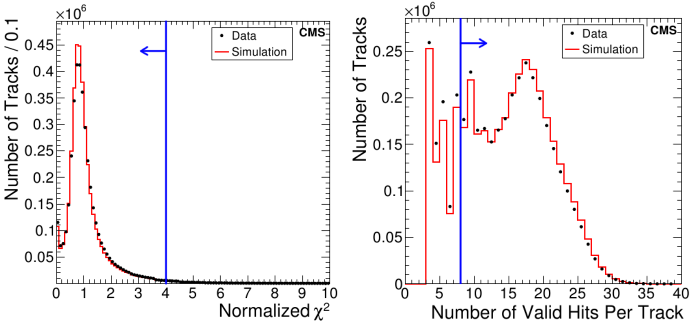


Figure 4: The normalized cluster charge measured in the (a) barrel and (b) endcap pixel detectors for the sample of 0.9 TeV minimum bias events. The insets show the same distributions on semi-log scales.

Accuracy of the Monte Carlo

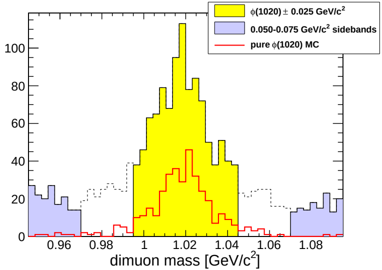
- Also from the Tracker DPG paper
  - high-level quantities that we apply cuts to



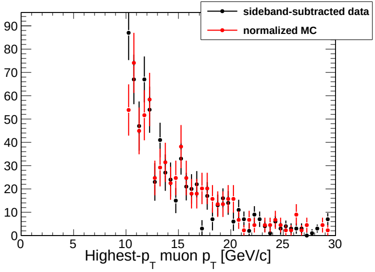
- Non-quantitative argument: low and high-level tracking distributions are well-modeled by Monte Carlo; our low-mass, high-p_T signal differs only in geometry— hard to imagine more than few-% disagreement
- In the following slides, we perform an explicit test to make this intuition more precise

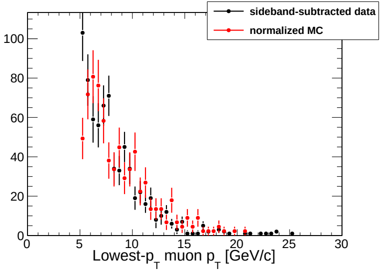
$\phi(1020)$ resonance study

Data/MC comparisons of "close-by muons" in our sample ($\Delta R \sim 0.1$)



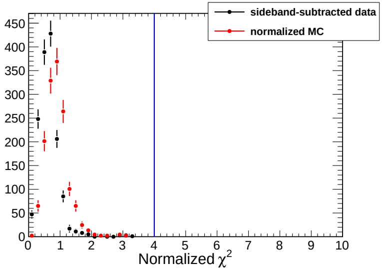
- Compare data and MC distributions of the $\phi(1020)$
  - exactly two muons/event
  - prompt ($L_{xy} < 1$ mm)
  - in jets ($Iso > 3$ GeV/c)
  - one muon $p_T > 10$ GeV/c
  - sideband-subtracted data, normalized MC

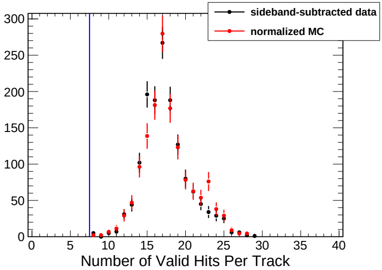




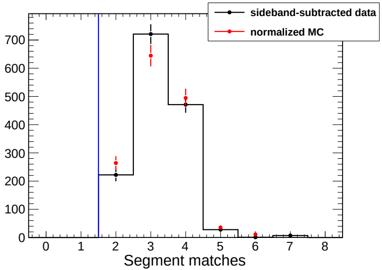
$\phi(1020)$ resonance study

Track quality cuts:





Muon quality cuts:



"Normalized χ^2" and "Number of Valid Hits Per Track" are the same as page 6, but for our muons ($p_T > 5$ GeV/c), cuts are far from bulk of distribution

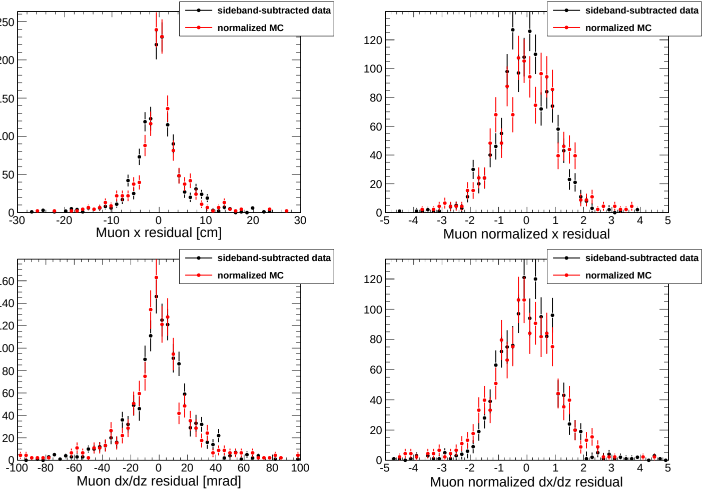
MC has STARTUP conditions applied

Comparisons made after all cuts

$\phi(1020)$ resonance study

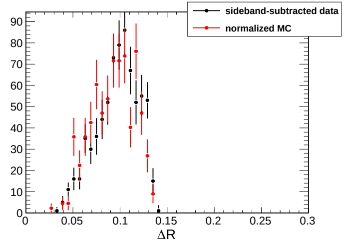
Muon residuals:

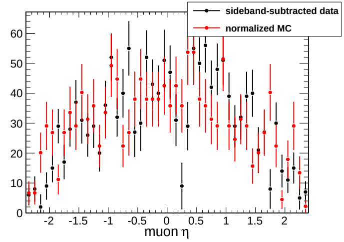
- Relevant for number of muon segments cut (track $\rightarrow$ segment must match)
- Muon alignment effect is negligible because of large multiple scattering



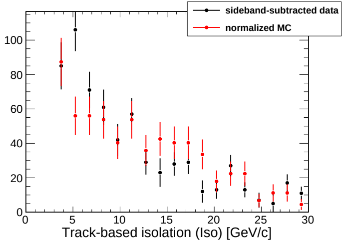
$\phi(1020)$ resonance study

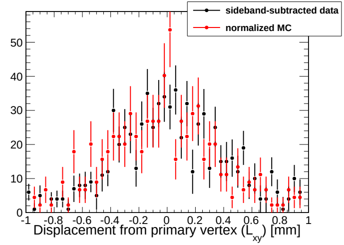
Additional comparisons:





Cuts used to define this sample (so that data and MC would have the same production mechanism: $\phi(1020)$ in light quark jets):





Conclusions

- In MC, we don't expect significant interference between tracks until both muons have $p_T \gtrsim 100$ GeV/c because tracks are allowed to share up to 50% of their hits
- a $\sim$5% tracker reconstruction effect is visible for $\Delta R < 0.01$, $p_T > 20$ GeV/c
- interference of nearby muons is a larger effect and applies to a wider range of ΔR (and is documented in the analysis note)
- MC simulation reproduces low-level quantities well, and the rest is geometry
- $\Delta R \sim 0.1$ was tested explicitly using the $\phi(1020)$ resonance: all in good agreement except normalized χ^2 distribution, but this difference is well below the cut