Muon Fake Rates
This may not be exactly what Ingo & Derek used but it is close enough
Basically an extrapolation in impact parameter and isolation
Fake Rate from QCD30

NOTE: we have lousy lousy statistics at high pt
There are only 34 muons passing all cuts with pt>20
Check on W and top samples

- 20-10 hypothesis
- Require leptons to be separate by $\Delta R > 0.4$
- One of leptons truth matched to $W \rightarrow \text{lep}$ via `leptonIsFromW()` function
  - This can be $e$ or $\mu$
- Second lepton is a $\mu$ and **is not** truth matched to $W \rightarrow \text{lep}$ via `leptonIsFromW()` function
- Second lepton is a muon numerator object or a FO but not a numerator object. In this latter case I get the “prediction” by weighting by $FR/(1-FR)$
Check on W sample

W Same Sign. Triangles=expected

W Opposite Sign. Triangles=expected

-----W Same Sign counts
Number of FO  pt>10 = 108
Number of FO  pt>20 = 12
Number of num pt>10 = 14
Number of num pt>20 = 1
Prediction  pt>10 = 15.8247
Prediction  pt>20 = 1.03202

-----W Opposite Sign counts
Number of FO  pt>10 = 246
Number of FO  pt>20 = 33
Number of num pt>10 = 32
Number of num pt>20 = 2
Prediction  pt>10 = 34.8471
Prediction  pt>20 = 2.65558

Works OK but the statistics are terrible…particularly for pt>20
Check on top sample

-----Top Same Sign counts
Number of FO  pt>10 = 1986
Number of FO  pt>20 = 812
Number of num  pt>10 = 135
Number of num  pt>20 = 22
Prediction  pt>10 = 249.654
Prediction  pt>20 = 61.2652

-----Top Opposite Sign counts
Number of FO  pt>10 = 2172
Number of FO  pt>20 = 881
Number of num  pt>10 = 210
Number of num  pt>20 = 61
Prediction  pt>10 = 265.019
Prediction  pt>20 = 63.0364

BTW: in OS it may look better than it really is at pt>20. There may be a handful of true OS WW→dileptons that failed the anti-truth match. This needs to be checked carefully.
Check on jet80

-----qcd80 counts
Number of FO   pt>10 = 2286
Number of FO   pt>20 = 708
Number of num  pt>10 = 236
Number of num  pt>20 = 26
Prediction     pt>10 = 296.37
Prediction     pt>20 = 52.6176

This is also off, particularly at high pt. If we had used the QCD80 sample to derive the FR for the top test, the test would not have looked nearly as bad. See next page
Check on top but using the qcd80 FR

Now it is a bit better, maybe the jet Pts are more appropriate. There is a problem with OS Pt>20. It may be because of real WW sneaking through? Will come back to it in a couple of pages.
Isolation distributions for FO with pt > 10

QCD30

QCD 80

Top SS

Top OS
Isolation distributions for FO with pt > 20

A previous version of this had a bug. This looks better than before, but as we have seen in the fake rate test it does not work very well
WW Sneaking through in OS analysis?

- Veto events with > 1 e-μ-τ in DOC lines (use leptonGenpCount() function)
- SS FO(pt>20): 812 → 546
- OS FO(pt>20): 881 → 579
  - Makes sense: this is dominated by b→μ. If it was 100% b→μ it ought to be the same. Reduction is the same
- SS Numerator: 22 → 14
- OS Numerator: 61 → 23
  - Much bigger drop off in OS numerator. Something is DEFINITELY going on
- SS Prediction: 61 → 41
- OS Prediction: 63 → 42

Now SS and OS have the more similar behaviors: the prediction is high.

FO isolation for SS and OS. Still different near 0 but not as much as on previous page
Repeat check on top using QCD30 FR && requiring < 2 e-µ-τ in DOC lines

--- Top Same Sign counts
Number of FO pt>10 = 1309
Number of FO pt>20 = 546
Number of num pt>10 = 88
Number of num pt>20 = 14
Prediction pt>10 = 163.632
Prediction pt>20 = 41.3644

--- Top Opposite Sign counts
Number of FO pt>10 = 1429
Number of FO pt>20 = 579
Number of num pt>10 = 107
Number of num pt>20 = 23
Prediction pt>10 = 177.527
Prediction pt>20 = 42.5222
More stuff (Feb 13)

- I do not think that the problem that we see in top has to do with the fact that top is b-rich and QCD is b-poor
- My contention: FO and numerator muons in QCD are mostly from $b \rightarrow \mu$, so we already have a FR that is from heavy flavors – even if we start from a QCD poor sample.
- To investigate that, only consider muons from HF in QCD
- Technically:

```cpp
// Require muons to be from heavy flavor
int idummy = leptonIsFromW(imu, 13, mus_p4().at(imu));
if (idummy != -1 && idummy != -2) continue;
```

<table>
<thead>
<tr>
<th>QCD30: requiring HF muons</th>
<th>QCD30: taking all muons (standard)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of FO $pt &gt; 10$ = 3513</td>
<td>Number of FO $pt &gt; 10$ = 3935</td>
</tr>
<tr>
<td>Number of FO $pt &gt; 20$ = 359</td>
<td>Number of FO $pt &gt; 20$ = 410</td>
</tr>
<tr>
<td>Number of num $pt &gt; 10$ = 512</td>
<td>Number of num $pt &gt; 10$ = 567</td>
</tr>
<tr>
<td>Number of num $pt &gt; 20$ = 29</td>
<td>Number of num $pt &gt; 20$ = 34</td>
</tr>
</tbody>
</table>

FO and numerator muons are 85-90% from HF irrespective of $pt$. 
One more check: are b’s different from c’s

QCD30
b→μ pt>10
78% of FO
Iso<0.1 : 16%

QCD30
c→μ pt>10
22% of FO
Iso<0.1 : 9%

QCD30
b→μ pt>20
85% of FO
Iso<0.1 : 8%

QCD30
c→μ pt>20
15% of FO
Iso<0.1 = 9%

Yes, they are different. The b-component dominates in QCD just as it does in QCD.
Status as of 22 Feb (1)

• Tried muon FR from QCD30 that is extrapolation in d0 & isolation
• Jet dependence: using QCD30 FR, yield in QCD80 is overpredicted by
  – Factor of 1.25 for Pt > 10
  – Factor of 2 for Pt > 20
• Test in W sample (OS & SS) work OK, but the stats are terrible
• Test in top sample work equally badly for OS & SS (provided that care is taken to not count real W→mu, see page 11). Then using QCD30 FR the yields in the top sample are overpredicted by
  – Factor of 1.75 for Pt > 10
  – Factor of 2.3 for Pt > 20
• It has been verified that the FO in QCD events are dominantly from bottom (~72%) with some charm (~16%) and other junk (~12%)
  – Thus the QCD30 is a HF FR which should be appropriate for the top sample
  – Note: bottom and charm in QCD30 do have some differences in isolation, mostly at low Pt
• There is a big difference between the QCD30, the QCD80, and the top sample is in the isolation of the muon.
Status as of Feb 22 (2)

• Have not looked at differences in impact parameter between QCD30, QCD80, and top. I don’t expect that this makes a difference, but I will check.

• The current hypothesis is the difference arises from the jet Pt spectrum. For this statement to make sense, we would need to demonstrate that
  – $<\text{Jet Pt (QCD30)}>$ less than $<\text{Jet Pt (QCD80)}>$ (This is certainly true)
  – $<\text{Jet Pt (QCD80)}>$ less than $<\text{Jet Pt (top)}>$ (This I am not so sure—will check)