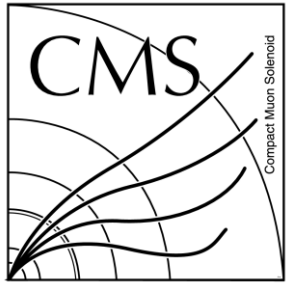
# Muon Trigger Status for 2018

## L1 Trigger CMS Week Parallel Meeting

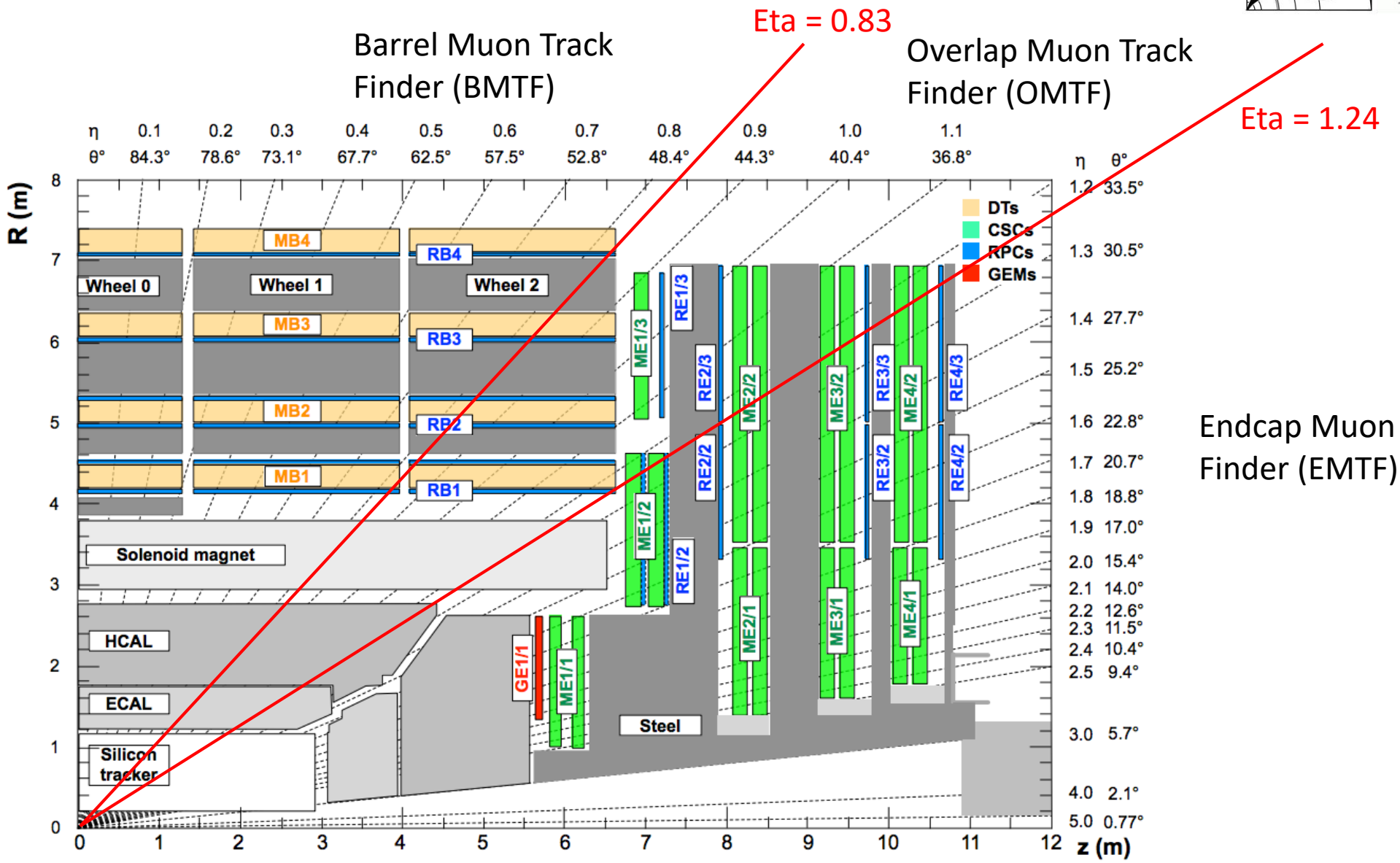
April 2018

**Wei Shi** on behalf of the

BMTF, OMTF and EMTF group




# Geometry


Barrel Muon Track Finder (BMTF)
Overlap Muon Track Finder (OMTF)
Endcap Muon Track Finder (EMTF)
Eta = 0.83
Eta = 1.24
η 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1
θ° 84.3° 78.6° 73.1° 67.7° 62.5° 57.5° 52.8° 48.4° 44.3° 40.4° 36.8°
η θ°
1.2 33.5°
1.3 30.5°
1.4 27.7°
1.5 25.2°
1.6 22.8°
1.7 20.7°
1.8 18.8°
1.9 17.0°
2.0 15.4°
2.1 14.0°
2.2 12.6°
2.3 11.5°
2.4 10.4°
2.5 9.4°
3.0 5.7°
4.0 2.1°
5.0 0.77°
R (m)
z (m)
DTs
CSCs
RPCs
GEMs
Wheel 0
Wheel 1
Wheel 2
MB4
MB3
MB2
MB1
RB4
RB3
RB2
RB1
Solenoid magnet
HCAL
ECAL
Silicon tracker
Steel
GE1/1
ME1/1
ME1/2
ME1/3
RE1/2
RE1/3
RE2/2
RE2/3
ME2/1
ME2/2
ME3/1
ME3/2
RE3/2
RE3/3
ME4/1
ME4/2
RE4/2
RE4/3

# BMTF (S. Mallios)

- Integration of Kalman algorithm in parallel with BMTF

Latest Firmware studies with different Kalman IP versions

| Date | Kalman IP version | Slack | Kalman Latency | BMTF Latency | Algorithm CLK |
|---|---|---|---|---|---|
| 29/03/2018 | Kalman v1.0 | - 0.299 ns | 8.5 BXs | 6.5 BX | 160 MHz |
| 09/04/2018 | Kalman v1.1 | + 0.084 ns | 10 BXs | 6.5 BX | 160 MHz |

Minimum Latency

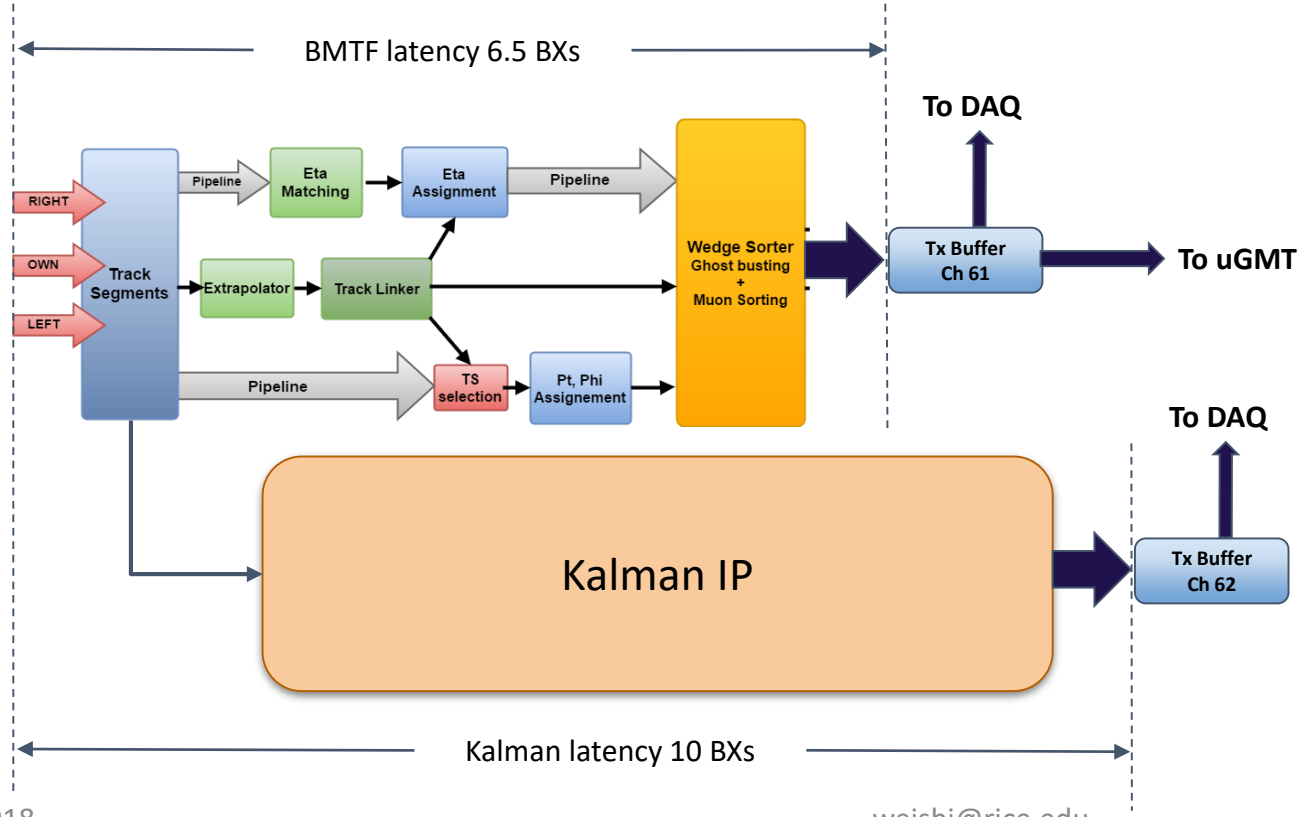
Best timing performance
(Suitable for parallel running)

- Firmware studies targeting the FPGA on the MP7s (Virtex 7 690T speed grade -2)
  - FPGA occupancy
    - LUTs: 58% , FF: 27% , BRAMs: 50% , DSPs: 25%
  - Kalman v1.0 firmware
    - Reduced latency but with a few timing errors
    - Not suitable for running at P5
  - Kalman v1.1 firmware
    - Achieved timing closure, but would not “fit” if we choose to trigger
    - Good for parallel running; BMTF performance not affected

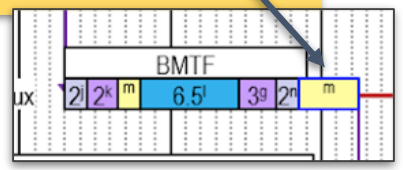
| FW validation on data (vs emulator) - Run 313910 | | |
|---|---|---|
| Processed Events : 75,862 ( Muons: 129,189 ) | | |
| | Mismatches | BMTF Agreement (%) |
| pT | 115 | 99.91 |
| phi | 377 | 98.81 |
| Eta | 144 | 99.89 |

# BMTF (S. Mallios)

- Plan to parallellize BMTF and Kalman filter algorithm at P5 during p-p commissioning
  - Trigger only with BMTF muons
  - Read-out both BMTF and Kalman muons
- Ongoing Work
  - Debug Kalman algorithm with data
  - Reduce Kalman latency from 10 BXs to 8.5 BXs
  - Achieve better Kalman firmware vs emulator agreement (Currently ~90%)




BMTF latency = 6.5 BXs
KMTF (current) latency = 10 BXs
Available Latency = 4 BXs
Using 3.5 out of 4 BXs of the BMTF contingency is not recommended



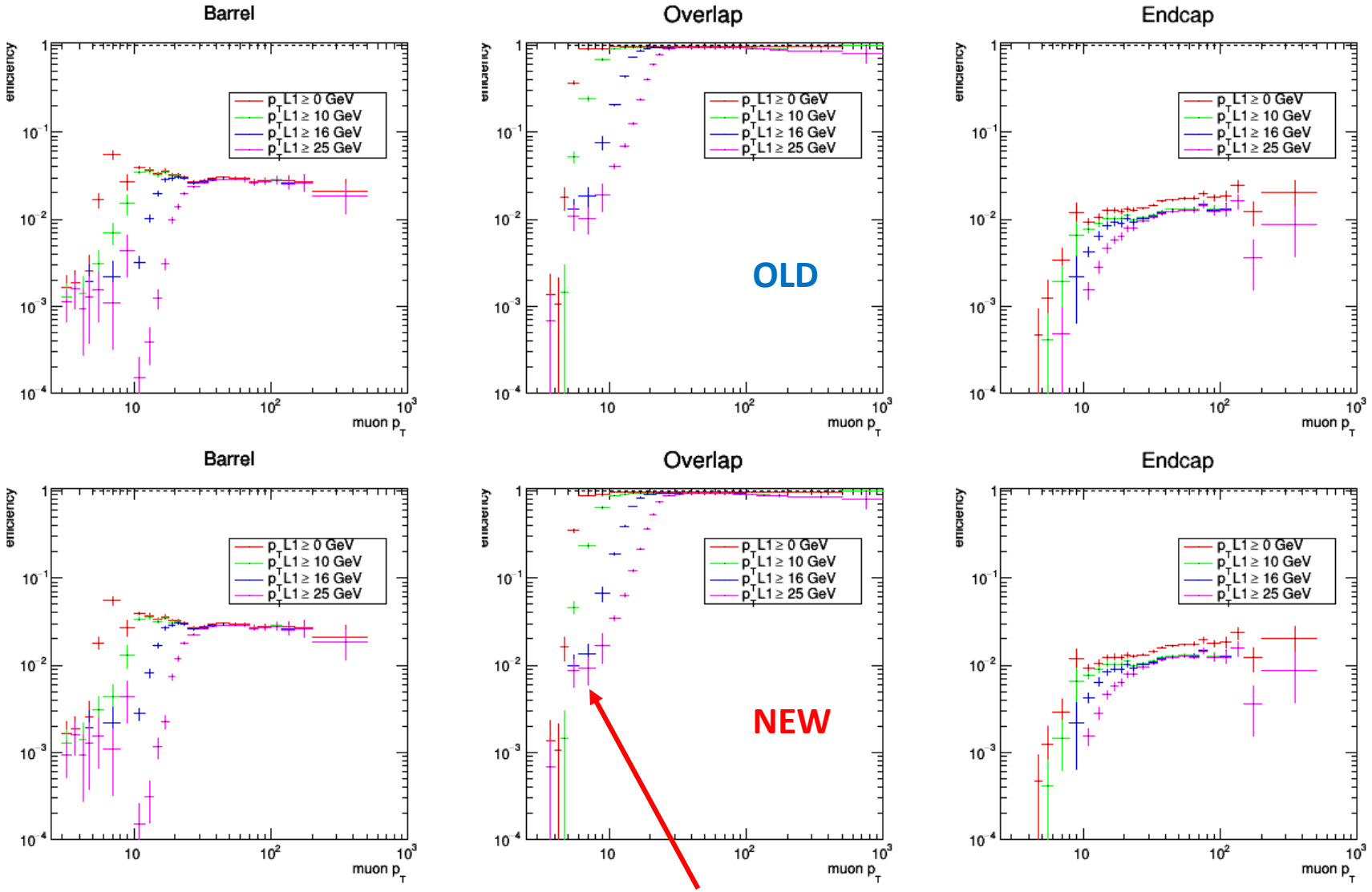
# OMTF (M. Konecki)

- Reconstructed hits compared to precomputed Golden Patterns (GP) [1]
  - GP represents muon tracks with defined pT range and sign
    - Average track bending between consecutive detector layers, stochastic effects
    - Represented in associated probability density functions (PDF)

- Reference layers
  - 8 out of 15 detector layers (barrel: 5 RPC, 3 DT layers; endcap: 4 CSC, 3 RPC)
  - Up to 4 hits in the 8 layers are selected for muon reconstruction
  - 128 reference hit ranges defined to detect reference hit

# OMTF (M. Konecki)

- OLD case: the assigned reference hit with the highest score in matching to PDF distribution was selected
- However different reference hits may correspond to different systems (RPC, DT, CSC), such a selection may be not always optimal
- NEW case: add priority DT>CSC>RPC for reference hits in muon sorter
- Small efficiency improvement for pT below thresholds



# OMTF (M. Konecki)

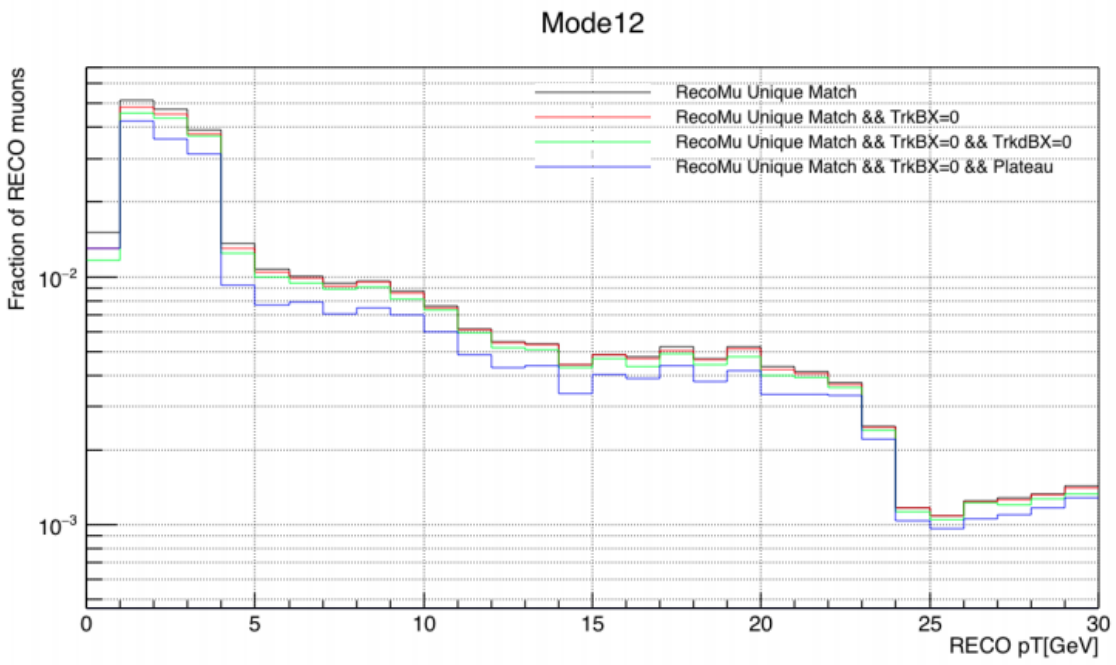
- Ongoing work
  - Still working on PDF improvement
    - Change quality for some events that are triggered based on ME2 and ME3 only (+RPC)
  - Plan to have patterns with a new threshold close to triggering values
    - For example: 20, 22, 25, 28 GeV (now 20, 25, 30 GeV)
  - Rename some thresholds

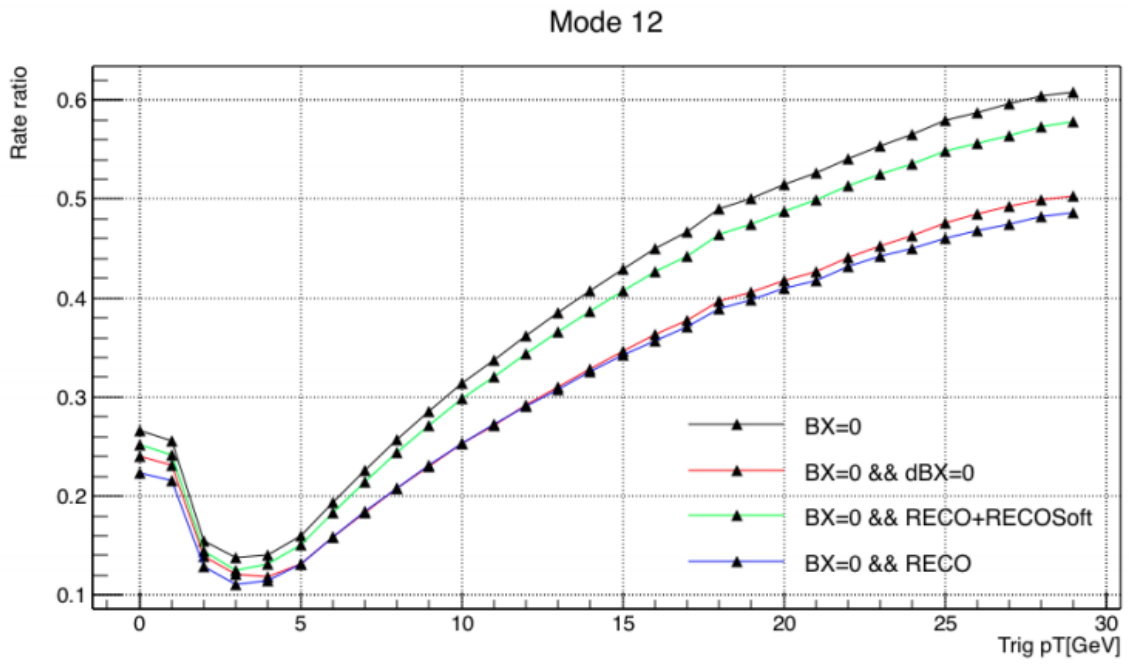
# EMTF (A. Brinkerhoff)

- Changes already in firmware
  - Reduced "BX window" for LCTs and RPC hits used to build a single track from 3 BX to 2 BX
    - i.e. a track in BX = 0 can now include LCTs from BX = -1 and 0, or BX = 0 and +1, but not from BX = -2 or +2, and not both -1 and +1
    - Should reduce the rate at high pileup by a few %, no efficiency loss
  - Modified "Δθ window" cuts on LCTs included in track
    - Previously, could have LCTs from station 1, 2, and 4 in a track (for example) if Δθ(1-2) < cut and Δθ(1-4) < cut, even if Δθ(2-4) > cut
    - Should reduce rate at high PU a little, may even improve efficiency

# EMTF (A. Brinkerhoff)

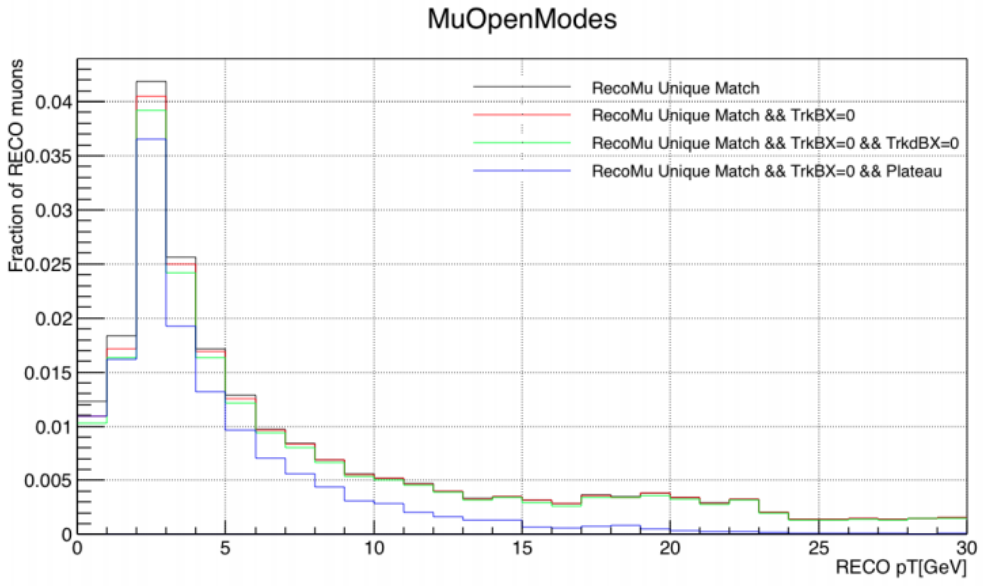
- Changes to be implemented in FW
  - Reduce quality for station 1-2 tracks (mode 12) [2]
    - These tracks add < 1% efficiency for muons with pT > 5 GeV, while increasing the rate substantially
    - Belongs in “Open” quality (4 ≤ Q < 8), not “DoubleMu” (4 ≤ Q < 12)

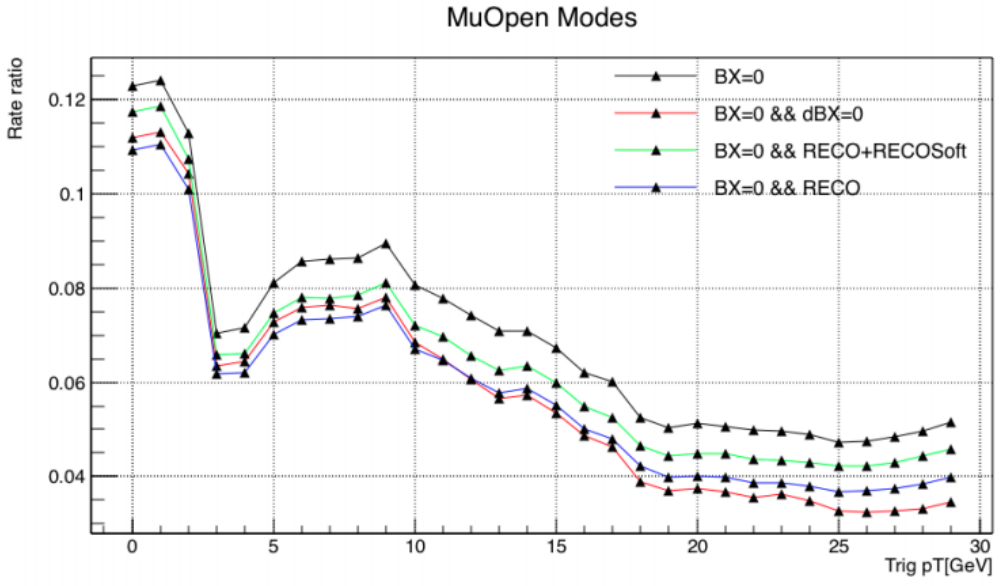


# EMTF (A. Brinkerhoff)

- Changes to be implemented in FW
  - Remove 2-station tracks if the LCTs in the track are not in the same BX [2]
    - Essentially junk, the track timing in these cases is a 50-50 guess




  - Tighter "Δθ window" cuts in "Zone 0" [3]
    - Roughly covers CSC ring 1 (|η| > 1.7), does not include RPC hits
    - In this region, no RPC hits (which have worse θ resolution), so wide Δθ windows (8 units, ~2°) are not necessary, and add rate from PU

# Summary

- Many activities going on in muon trigger groups
- Some changes are still under test in each group
- Foresee muon rate reduction and improved trigger efficiency in 2018