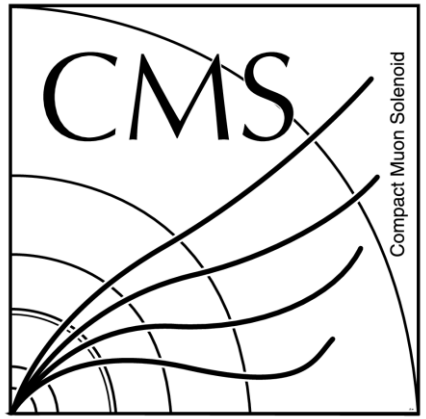
EMTF Studies on Reconstructed Muons

EMTF Working Meeting
March 2018

Wei Shi on behalf of the
EMTF working group

RICE

UF | UNIVERSITY of FLORIDA



Motivations

- Study on EMTF rate and efficiency by track modes/quality
  - Which tracks/modes contribute most to the efficiency? At what pT range?
  - Which tracks/modes contribute most to the rate? At what pT range?

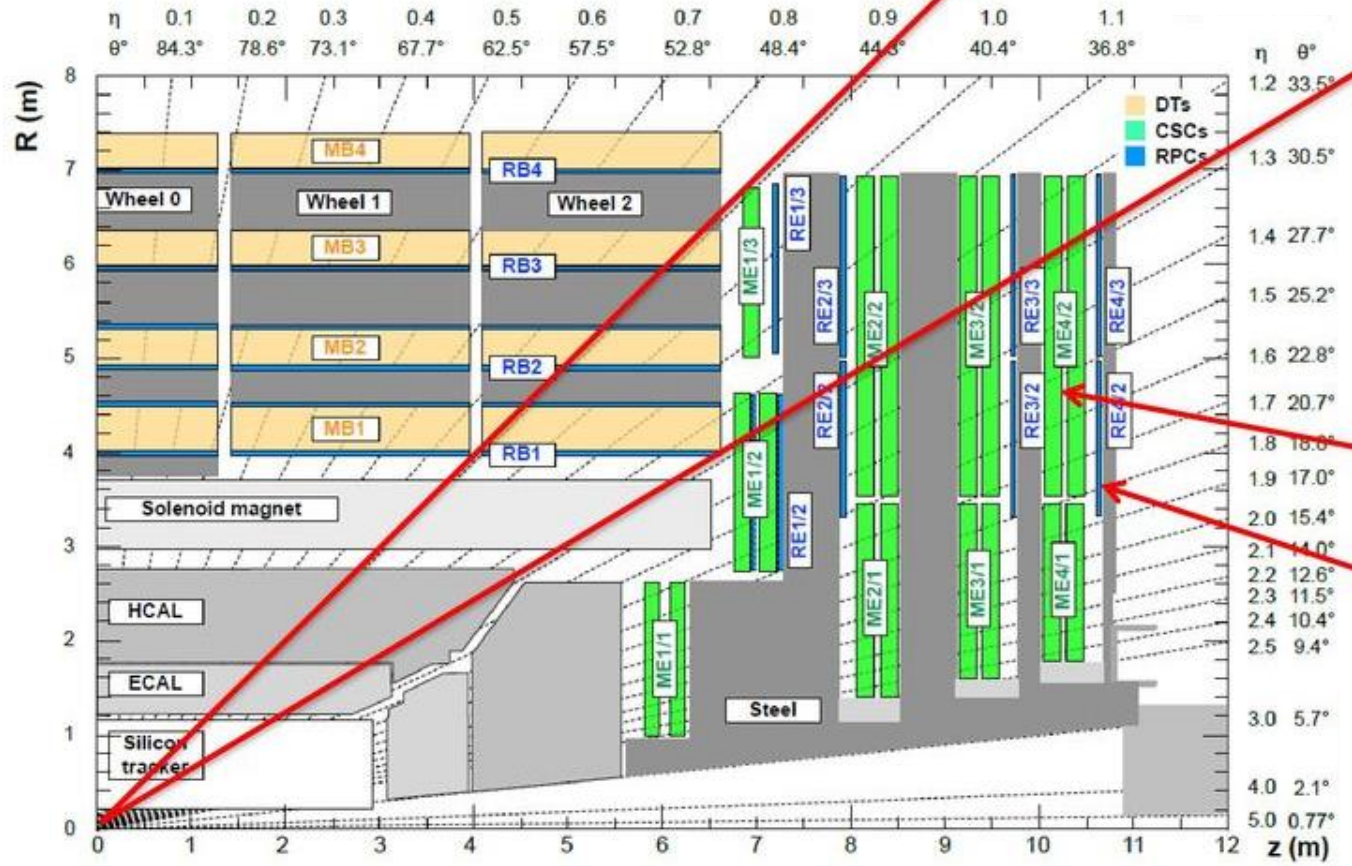
- Implications
  - Modify the current uGMT muon quality assignment for EMTF modes?
  - How to improve the current EMTF track-building?
  - What tracks to use in EMTF pT training in 2018?

- Interested parameter ranges
  - 0 < pT < 30 GeV (L1 muon trigger pT)
  - 1.25 < Eta < 2.4 (Endcap)

Geometry

Barrel Muon Track Finder (BMTF)

Overlap Muon Track Finder (OMTF)



Endcap Muon Track Finder (EMTF)

Cathode Strip Chambers (CSC)

Resistive Plate Chambers (RPC)

EMTF Tracks

- Track-building
  - At most 4 stations (CSC or RPC)
    - Local Charged Tracks (LCTs) or RPC hits correlated in theta (±2°) and phi (±8° in station 1, ±4° in stations 2 - 4)
  - Tracks built from LCTs and RPC hits from 3 consecutive bunch crossing (BX)
    - Will be reduced to 2 BX in 2018
    - LCT mis-timing rate < 1% (conservative) per LCT (the actual collision BX where the LCT is from)
  - Track BX: the 2nd-earliest LCT or RPC hit in the track
    - 3 or 4-station track: the track BX will always be fine if one LCT has mistiming (<1%)
    - 2-station track: if one LCT has mistiming, then it's possible (< 0.5%, mistiming LCT BX late) track BX is wrong
  - Track dBX: track LCTs max BX – min BX
    - dBX = 0 means all LCTs from a track come from the same BX
      - 2-station → (99%)^2 ~ 0.98, 3-station → (99%)^3 ~ 0.97, 4-station → (99%)^4 ~ 0.96
      - Track LCTs not in same BX (dBX > 0): 2-station → 2%, 3-station → 3%, 4-station → 4%

- pT assignment
  - Mostly based on dPhis between stations
  - Magnetic field strongest between stations 1 and 2, very little bending after that → station 1 is important

Matching

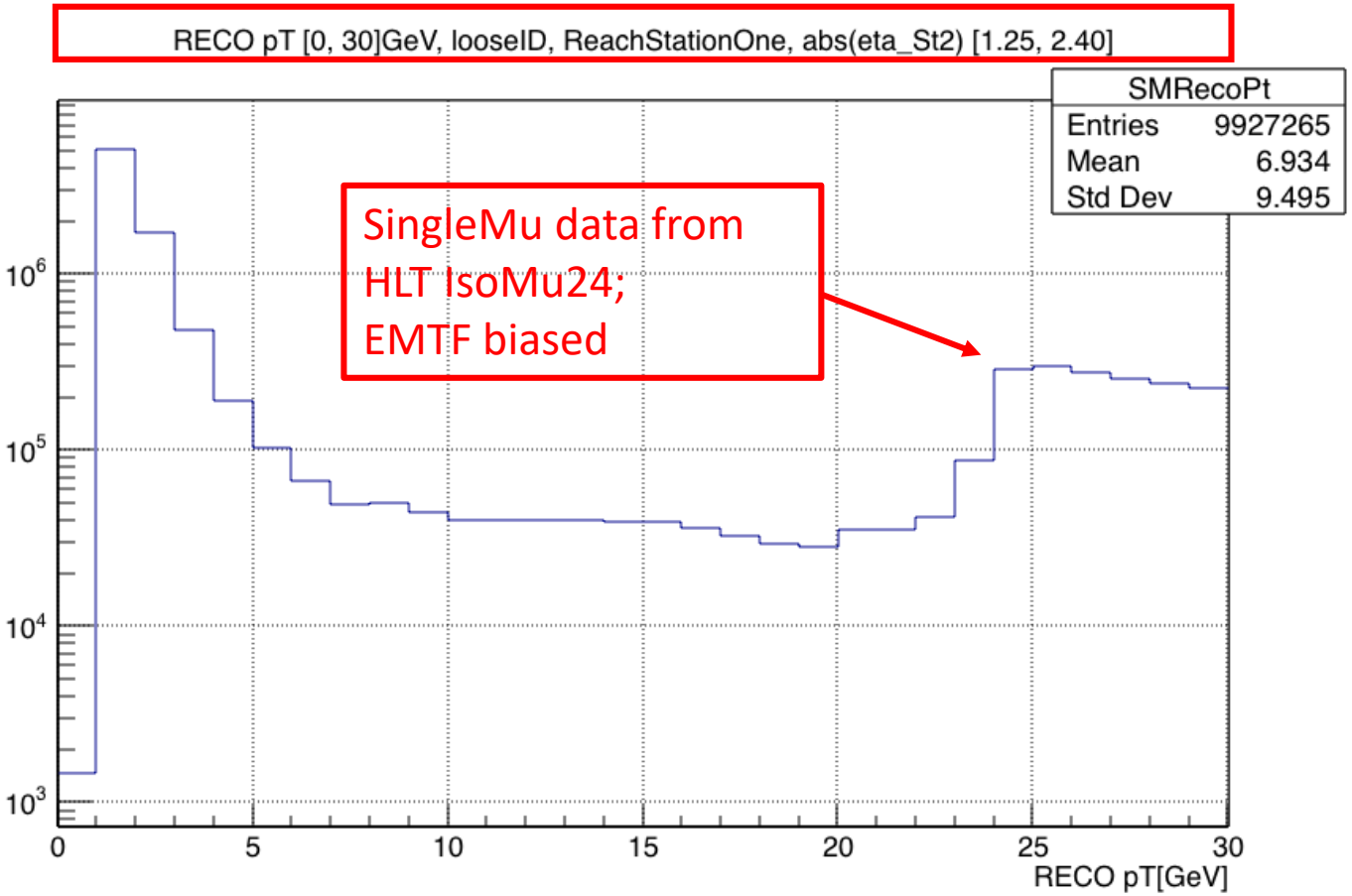
- RECO muon
  - ID [1] : Normal (loose), Soft
  - Coordinates extrapolated to station 1 or 2
- dR based: dR < 0.5
- Unique: match is reciprocal

- Plateau
  - require EMTF track pT > RECO mu pT *(7/8)

- 2017 data
  - SingleMu: 14,750,159 events (efficiency)
  - ZeroBias: 6,247,725 events (rate)

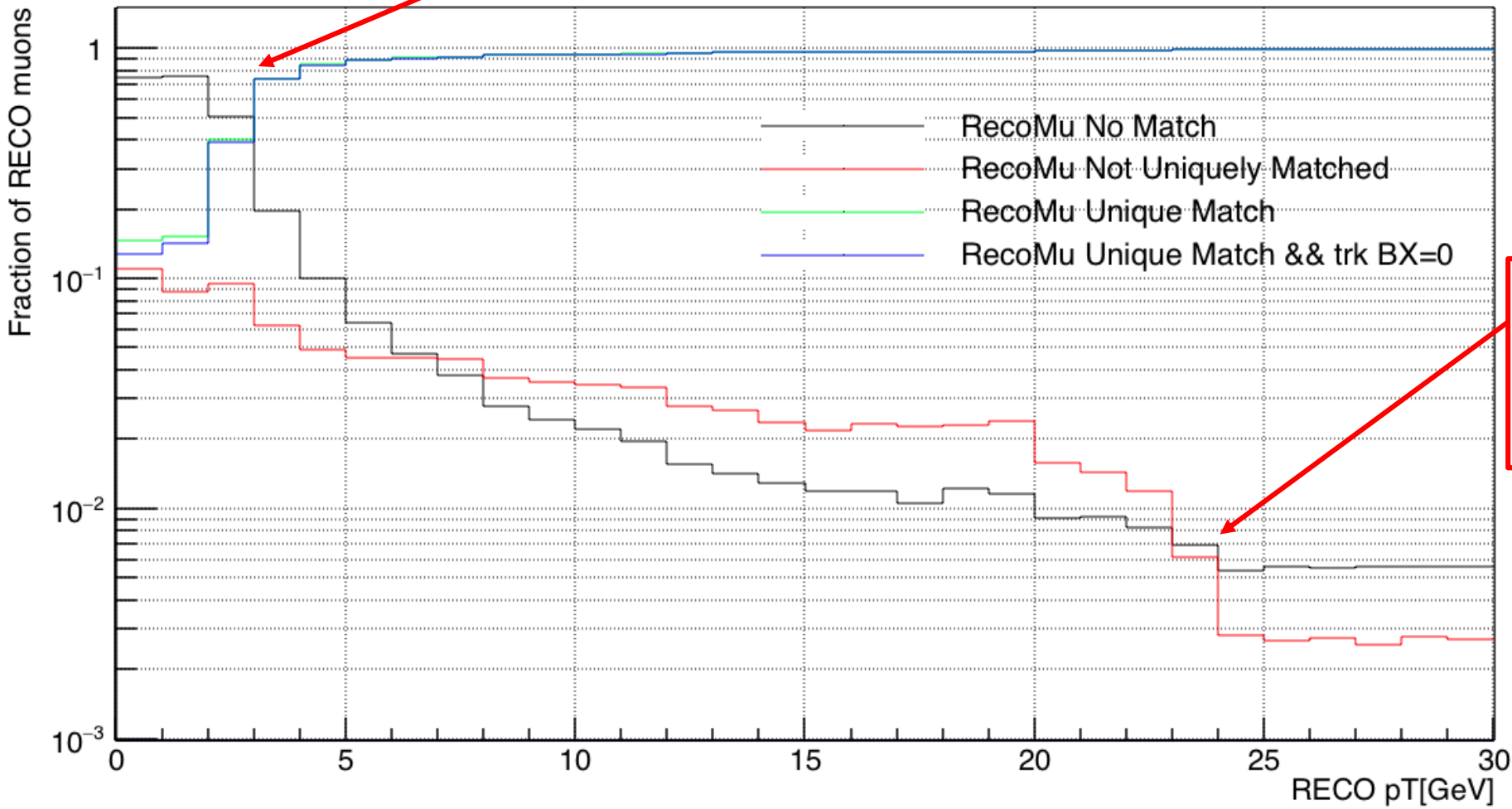
[1] https://twiki.cern.ch/twiki/bin/viewauth/CMS/SWGuideMuonIdRun2#Muon_Identification

RECO Muon pT


RECO pT [0, 30]GeV, looseID, ReachStationOne, abs(eta_St2) [1.25, 2.40]
SMRecoPt
Entries 9927265
Mean 6.934
Std Dev 9.495
SingleMu data from HLT IsoMu24; EMTF biased
10^6
10^5
10^4
10^3
0
5
10
15
20
25
30
RECO pT[GeV]

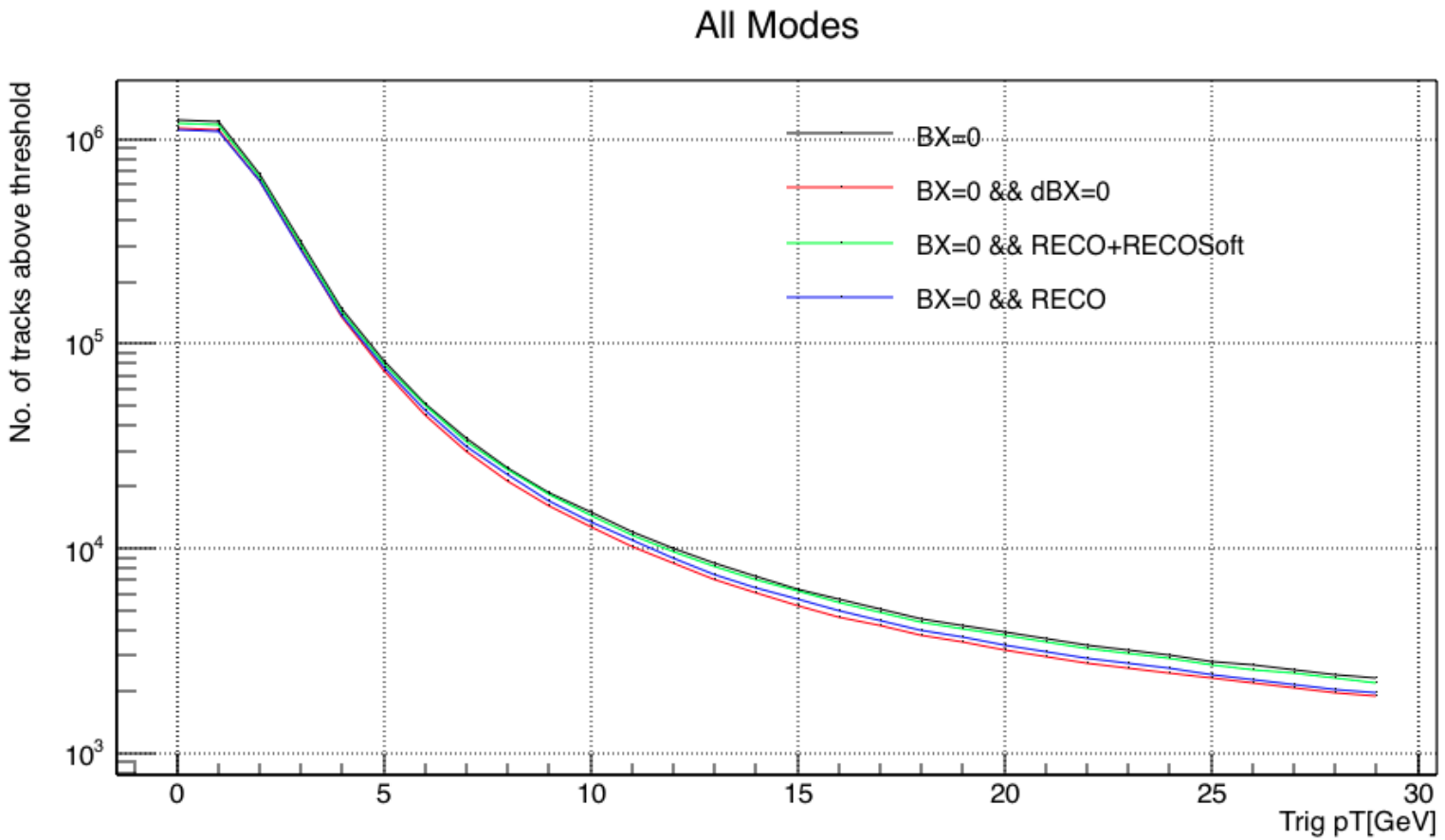
Match Scenarios

EMTF has good track-building efficiency & timing down to 3 GeV



IsoMu24 Biased: Find match because they are fired by EMTF

EMTF Tracks

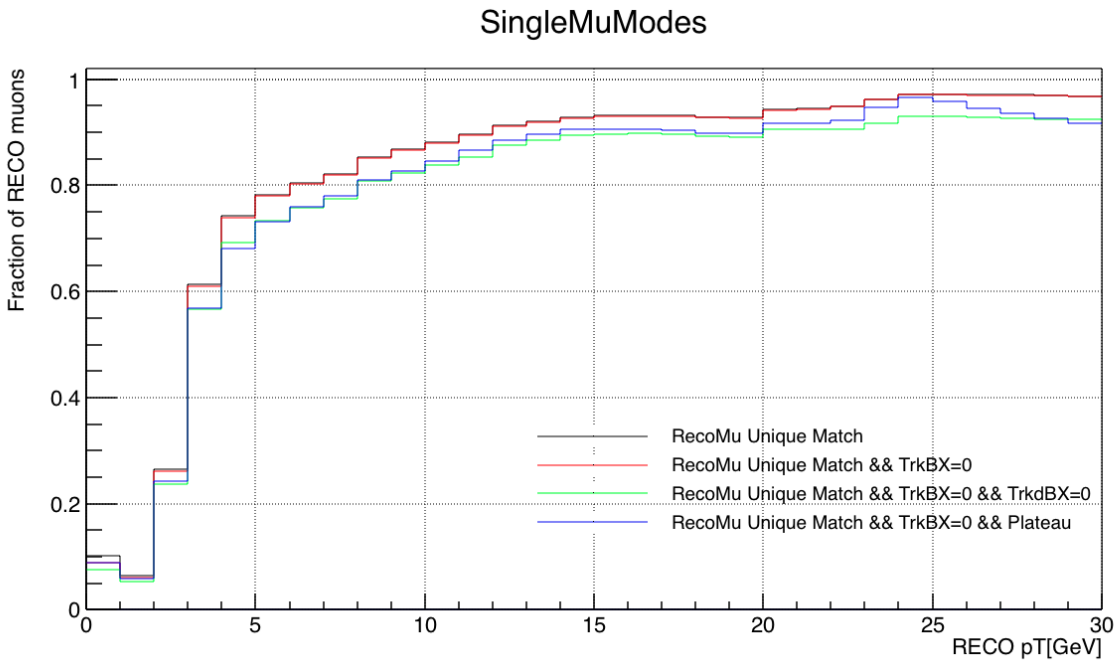

All Modes
No. of tracks above threshold
10^6
10^5
10^4
10^3
0
5
10
15
20
25
30
Trig pT[GeV]
BX=0
BX=0 && dBX=0
BX=0 && RECO+RECOSoft
BX=0 && RECO

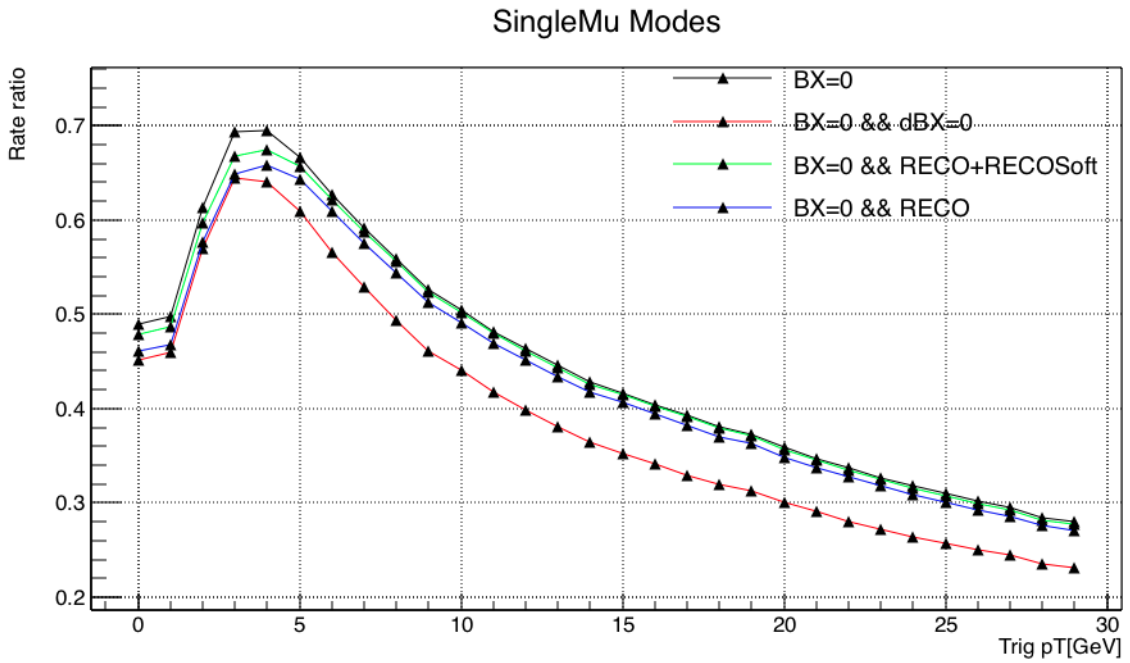
Muon Quality from uGMT

- SingleMu Quality (Q>=12)
  - EMTF mode 15, 14, 13, 11
- DoubleMu Quality (Q>=8)
  - EMTF mode 12, 10, 7
  - EMTF mode 15, 14, 13, 11
- MuOpen Quality (Q>=4)
  - EMTF mode 9, 6, 5, 3
  - EMTF mode 12, 10, 7
  - EMTF mode 15, 14, 13, 11

Mode #	Definition	Stations
15	1+2+4+8	1,2,3,4
14	2+4+8	1,2,3
13	1+4+8	1,2,4
12	4+8	1,2
11	1+2+8	1,3,4
10	2+8	1,3
9	1+8	1,4
7	1+2+4	2,3,4
6	2+4	2,3
5	1+4	2,4
3	1+2	3,4

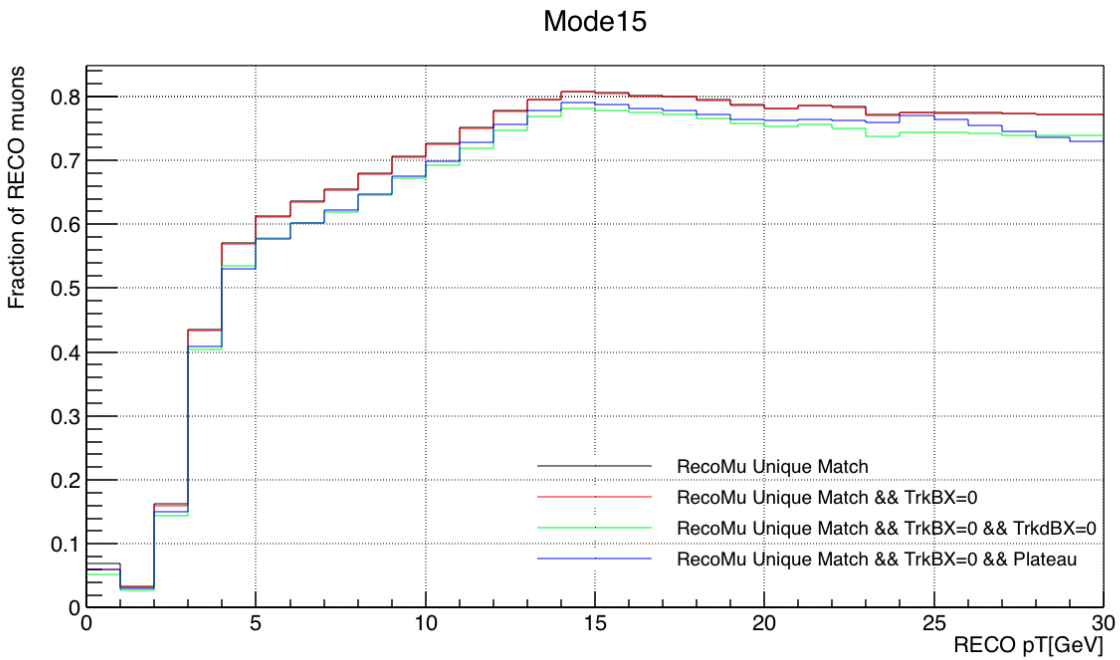
SingleMu Modes

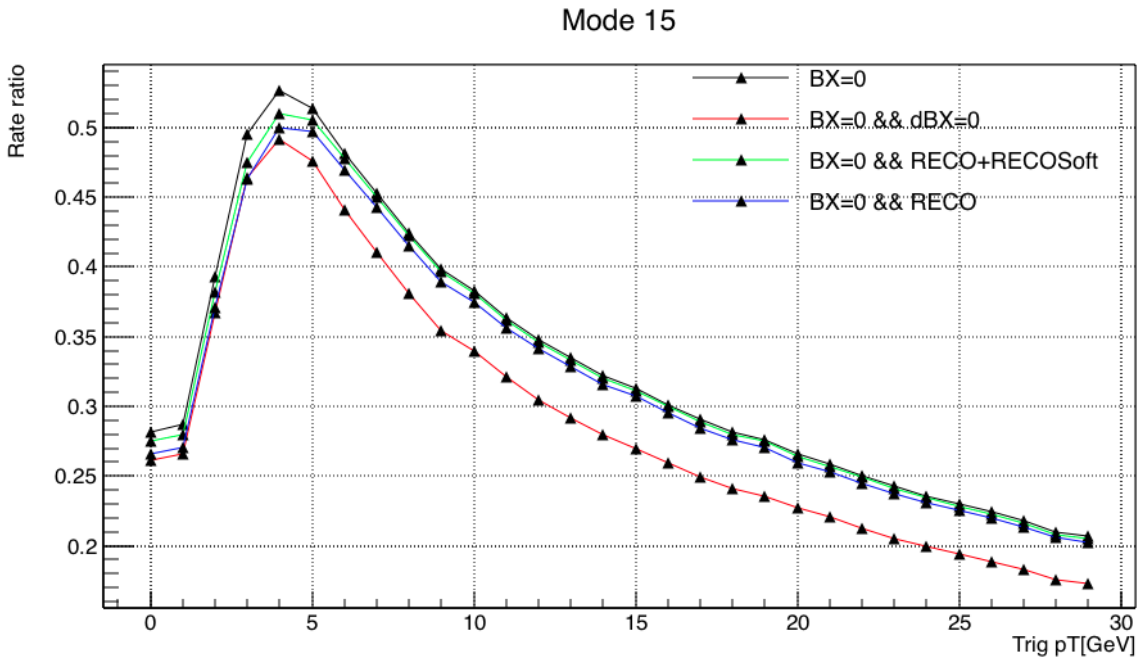




- Left: fraction of RECO muons from SingleMu data; Right: rate ratio = count/total count (BX=0) from Zerobias data
- Left: red on top of black @all pT range due to good trk BX, can find a RECO match;
- Left: green below the red due to higher chance dBX>0 in SingluMu modes (4 or 3-station tracks)
- Right: gap between black and green/blue is due to the noise or matching not ideal
- pT>5 GeV: plateau efficiency is 80%-95%
- pT>5 GeV: contribution to rate decreases from 66% to 22% as pT increases (exactly what we want: high eff, low rate)

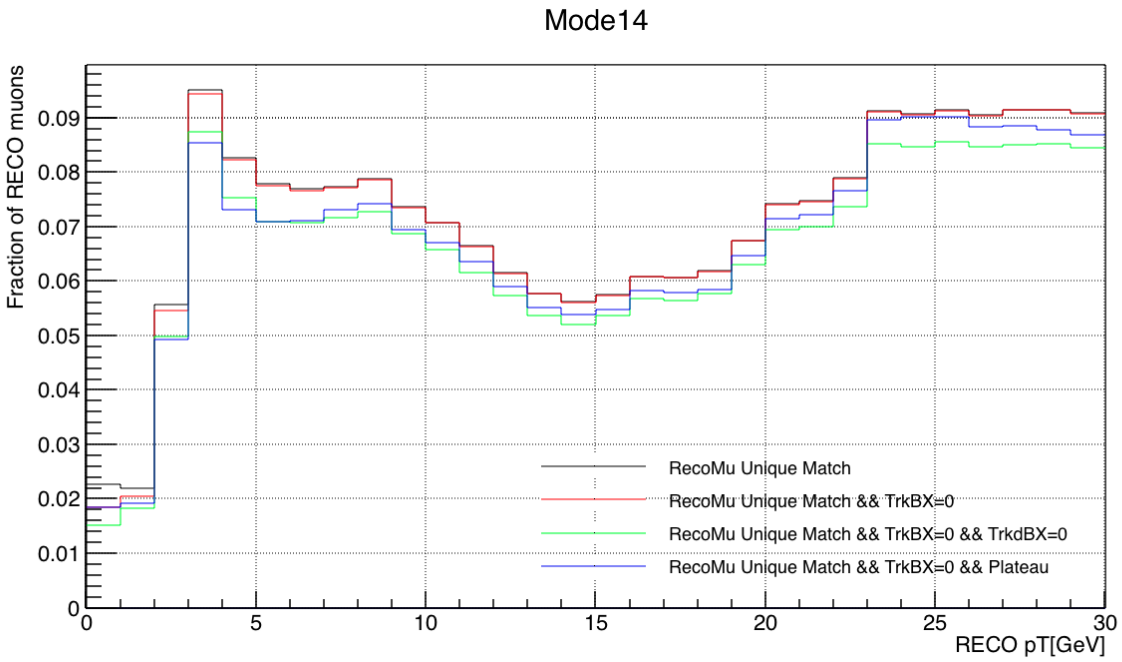
Mode 15 (station 1-2-3-4)

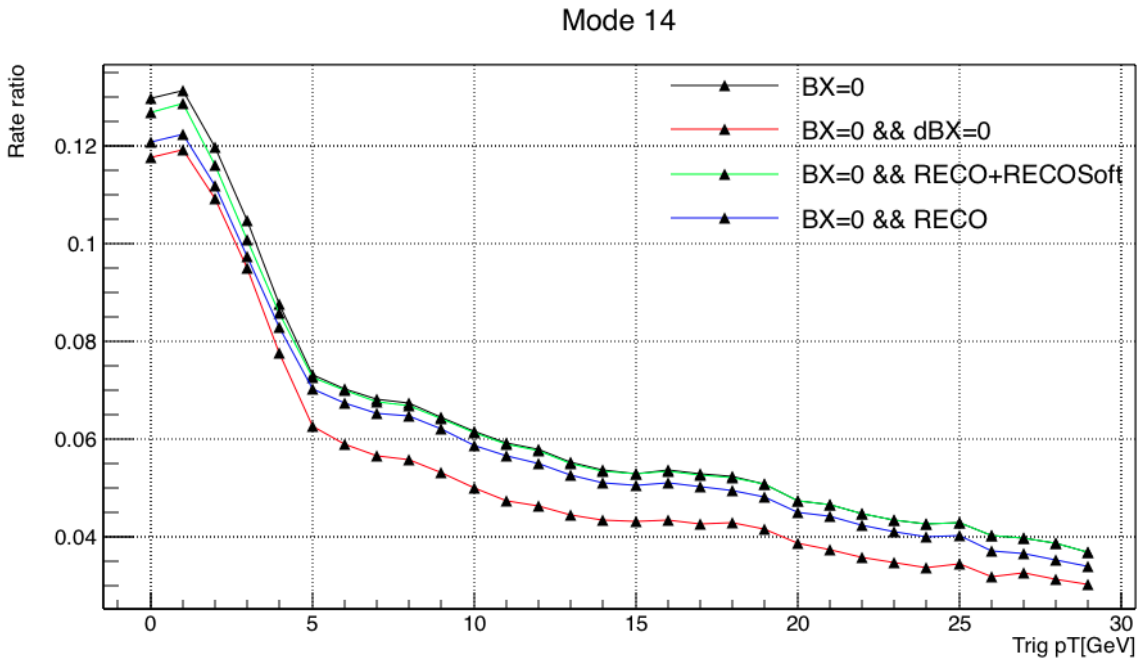




- Account for most efficiency in EMTF tracks, dominant in SingleMu modes
- pT<5 GeV: contribution to rate is reasonable, linear to efficiency;
- pT>5 GeV: plateau efficiency is high (60%~80%), rate contribution decrease from 50% to 30% (typical high eff, low rate)

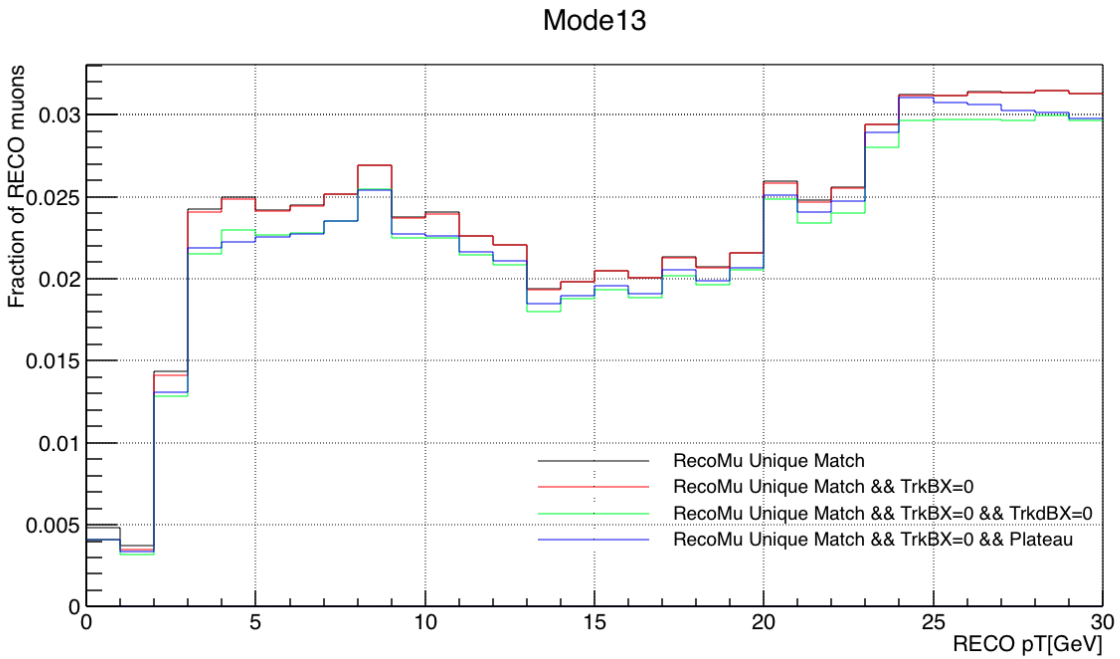
Mode 14 (station 1-2-3)

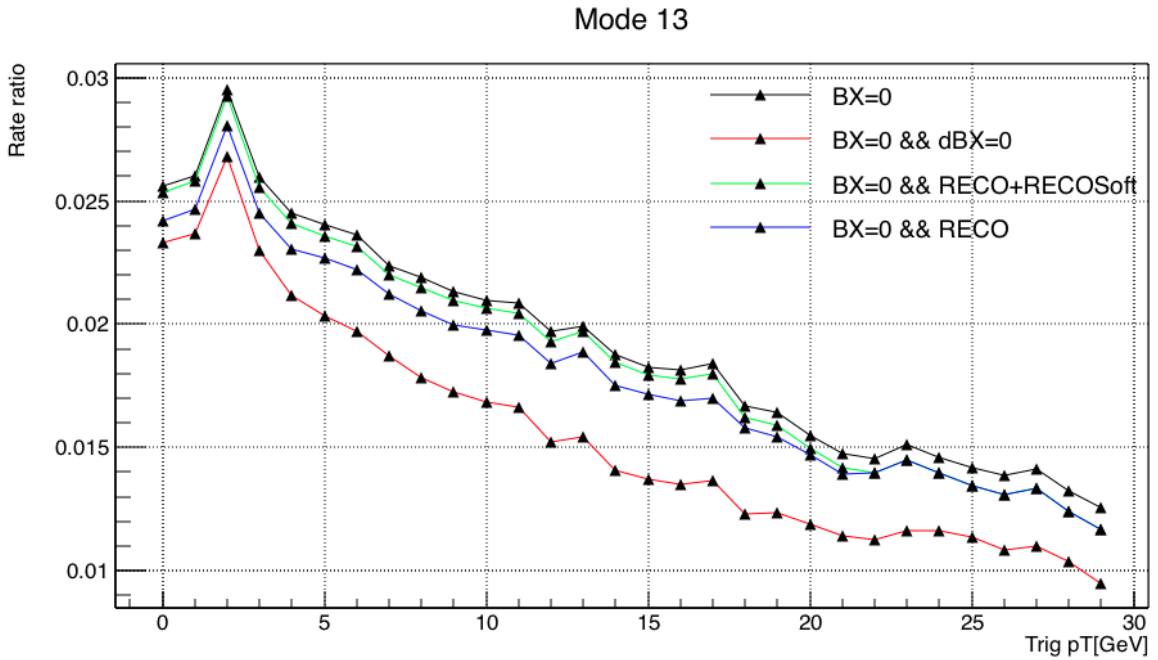




- pT>3 GeV: efficiency is already 10 times smaller than mode 15
- pT>3 GeV: contribution to rate is reasonable, mostly decrease from 12%-4% with a plateau efficiency 5%-9%

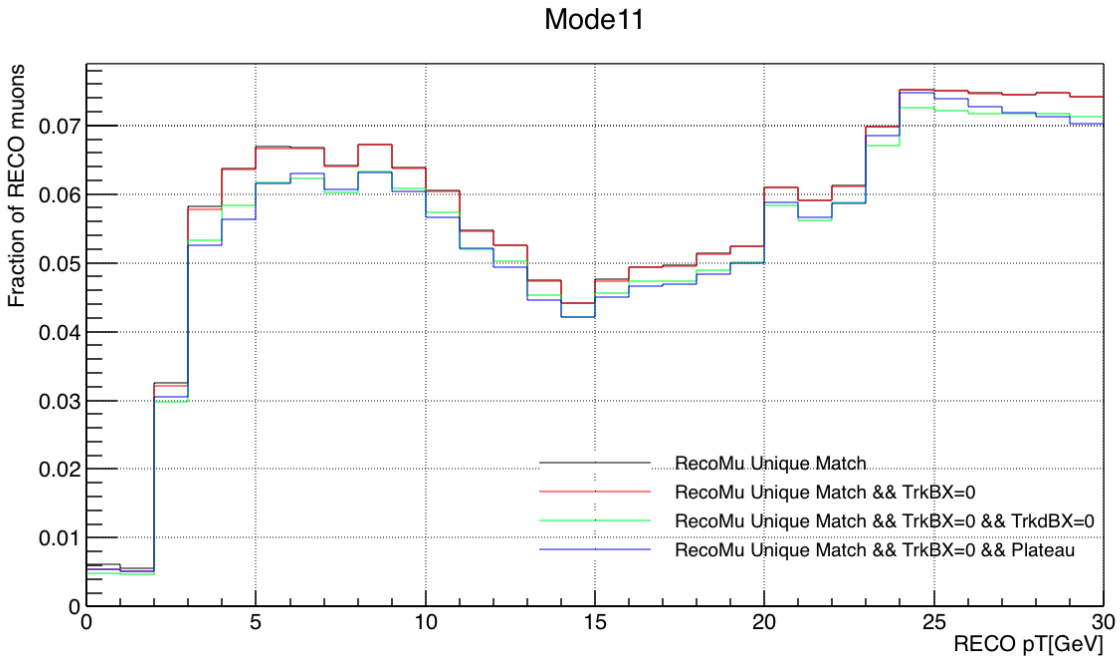
Mode 13 (station 1-2-4)

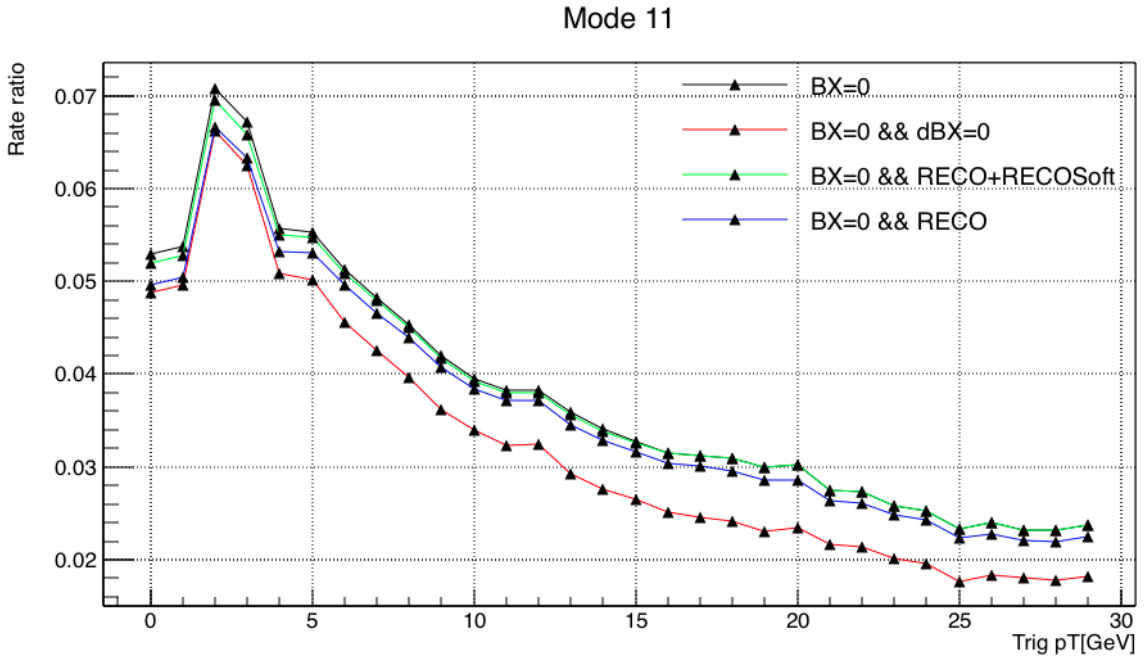




- Efficiency is even lower than mode 14 (station 1-2-3)
- Contribution to rate is reasonable, mostly decrease from 3% to 1.3% with a plateau efficiency 2%-3%

Mode 11 (station 1-3-4)





- Efficiency is between mode 13 (station 1-2-4) and mode 14 (station 1-2-3)
- Contribution to rate is reasonable, mostly decrease from 7% to 2.5% with a plateau efficiency 5%-7%

Muon Quality from uGMT

- SingleMu Quality (Q>=12)
  - EMTF mode 15, 14, 13, 11
- DoubleMu Quality (Q>=8)
  - EMTF mode 12, 10, 7
  - EMTF mode 15, 14, 13, 11
- MuOpen Quality (Q>=4)
  - EMTF mode 9, 6, 5, 3
  - EMTF mode 12, 10, 7
  - EMTF mode 15, 14, 13, 11

Mode #	Definition	Stations
15	1+2+4+8	1,2,3,4
14	2+4+8	1,2,3
13	1+4+8	1,2,4
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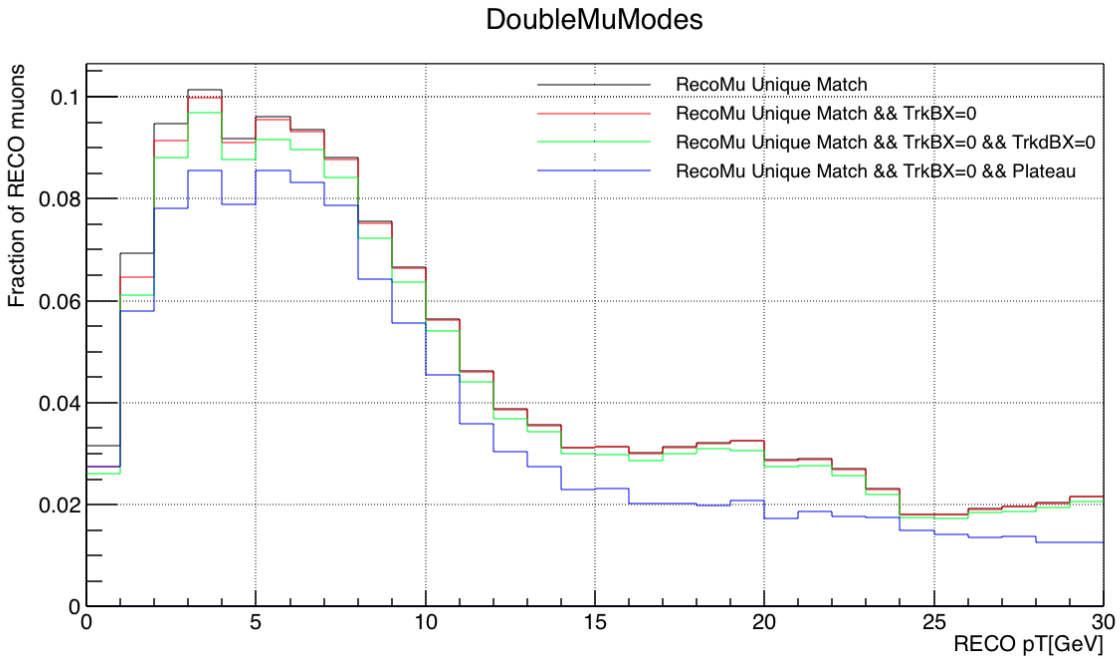
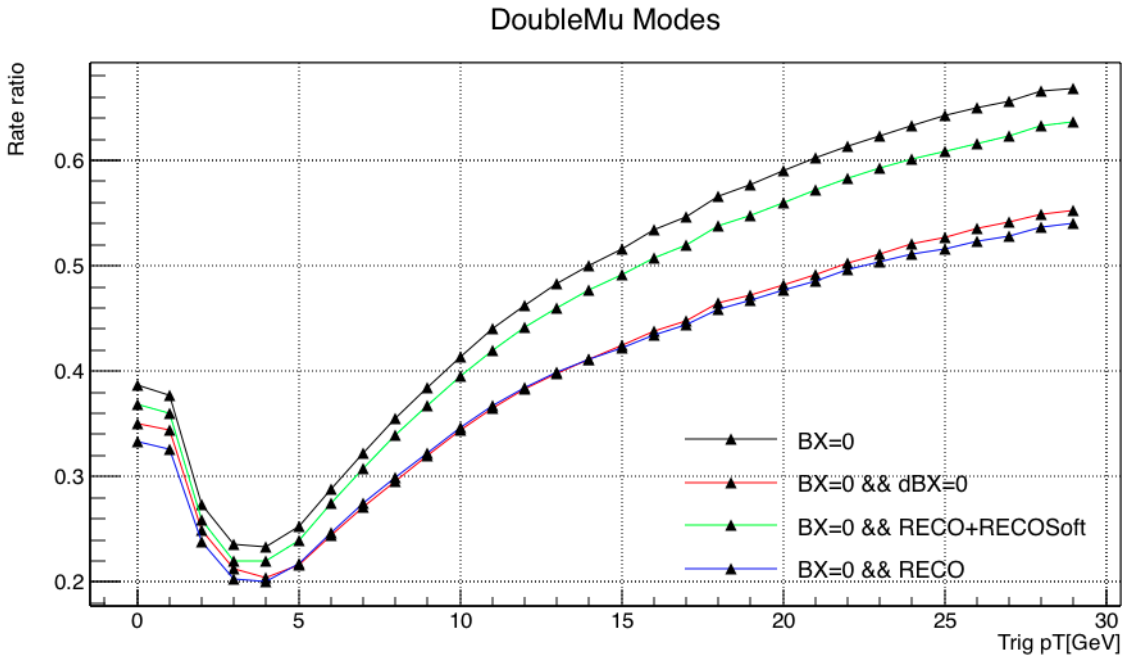
11	1+2+8	1,3,4
10	2+8	1,3
9	1+8	1,4
7	1+2+4	2,3,4
6	2+4	2,3
5	1+4	2,4
3	1+2	3,4

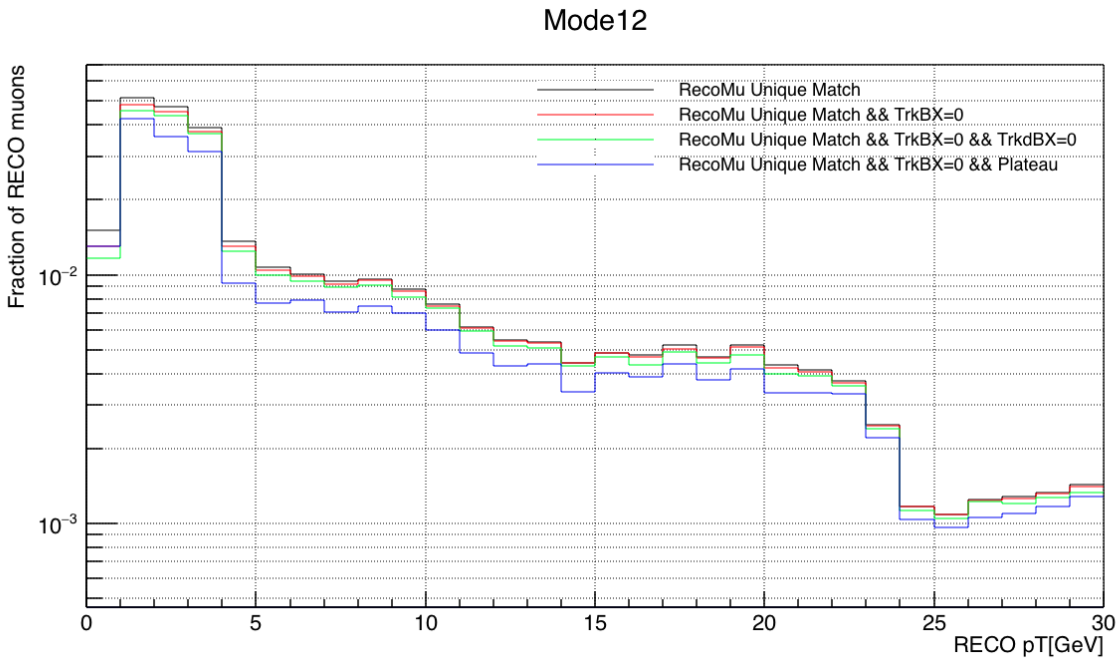
DoubleMu Modes

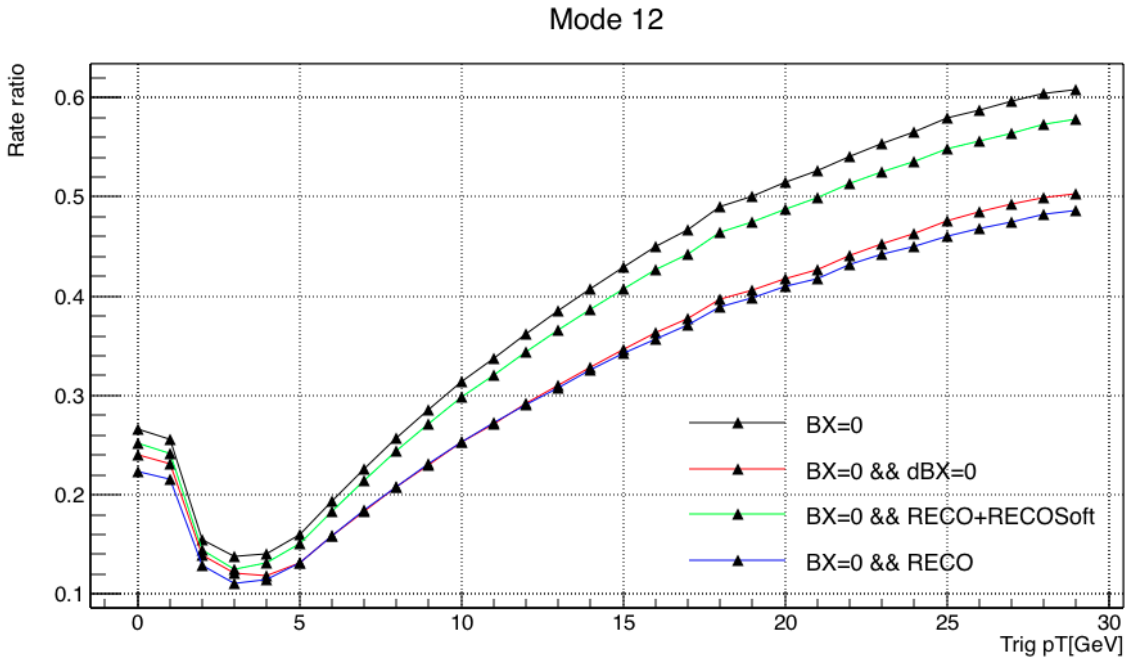




- Plateau efficiency is 10 times smaller than SingleMu modes
- Left: green almost overlaps red due to lower probability dBX>0 in 2-station tracks (mode 7 doesn't have station 1)
- Right: gap between red & black, applying dBX=0 can reduce ~16% of rate from current DoubleMu modes (pT>5 GeV)
- pT>5 GeV: contribution to rate is surprisingly high, increase from 25% to 68% as pT increases

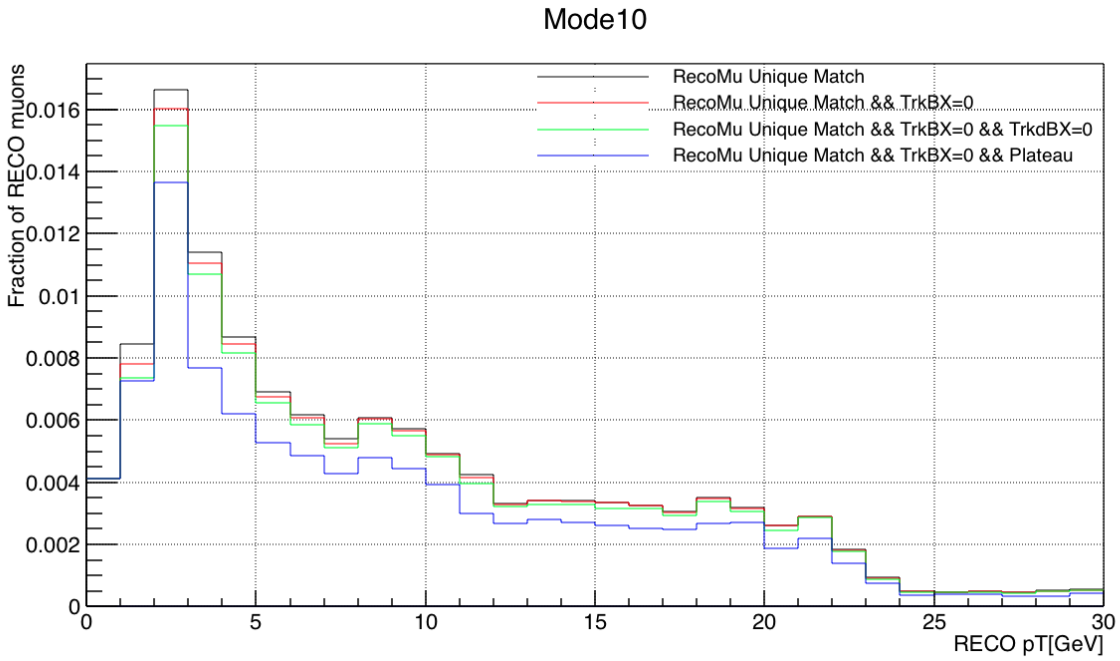
Mode 12 (station 1-2)

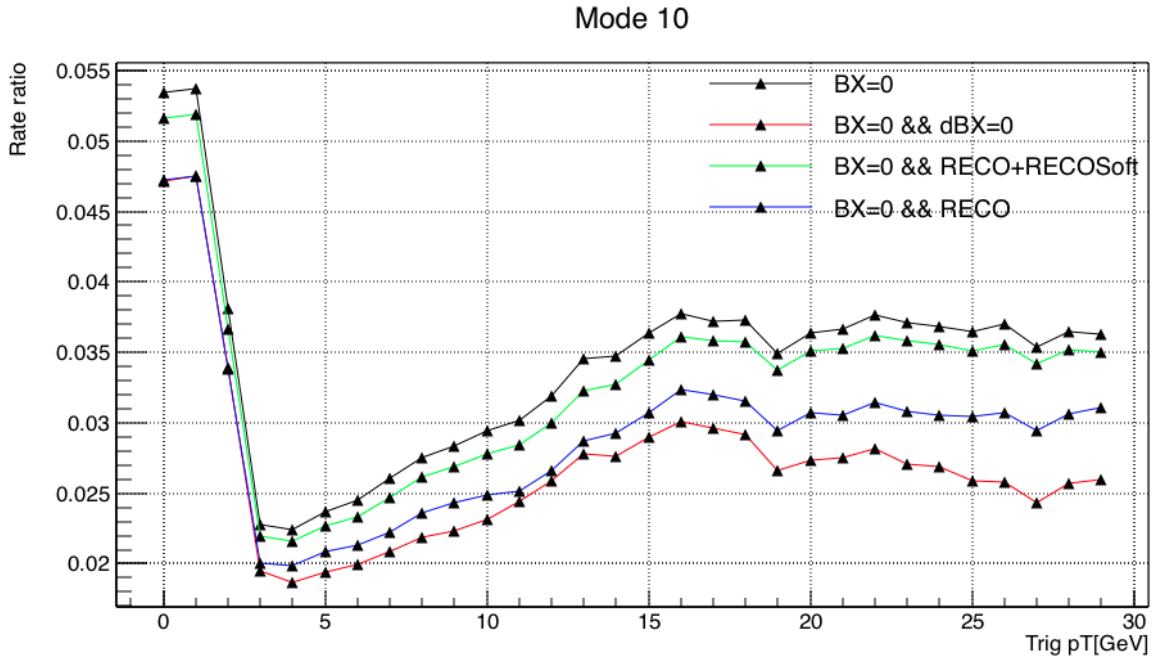




- Dominent contribution to DoubleMu rate: eff peak (left) and rate dip (right) in pT<5 GeV, very MuOpen-like
- pT>5 GeV: plateau efficiency is 100 times smaller than mode 15 (station 1-2-3-4)
- pT>5 GeV: contribution to rate is surprisingly high, increase from 15% to 60% as pT increases
- May put it in MuOpen quality without two much eff loss, but huge rate reduction for DoubleMu

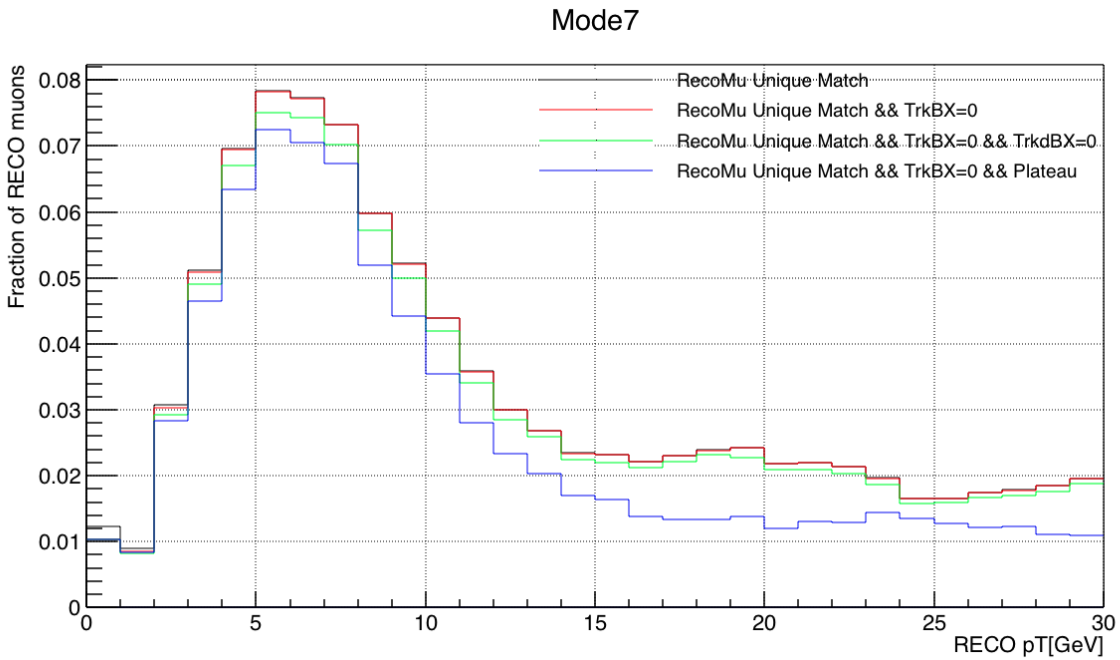
Mode 10 (station 1-3)

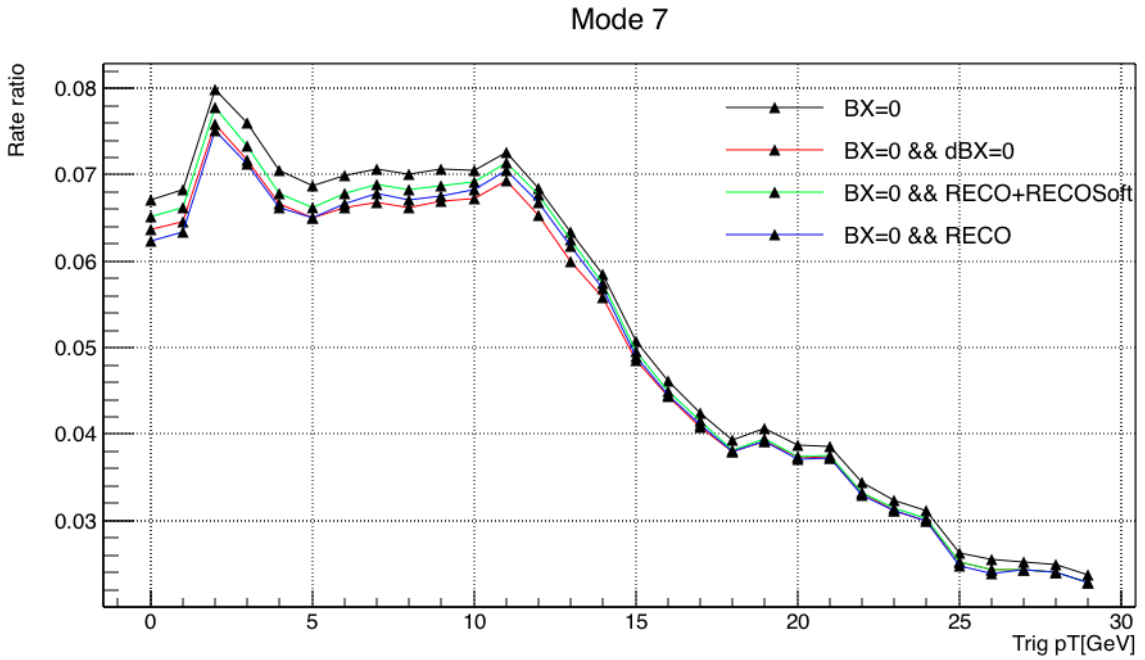




- pT>5 GeV: plateau efficiency is 100 times smaller than mode 15 (station 1-2-3-4)
- pT>5 GeV: overall contribution to rate is reasonable, but it increases from 2.4% to 3.7% as pT increases

Mode 7 (station 2-3-4)





- Contribute most to DoubleMu eff
- pT>5 GeV: plateau efficiency is 10 times smaller than mode 15 (station 1-2-3-4), even lower in pT > 15 GeV
- pT>5 GeV: contribution to rate is reasonable, 7%-2% as pT increases with plateau efficiency 8%-2%

Muon Quality from uGMT

- SingleMu Quality (Q>=12)
  - EMTF mode 15, 14, 13, 11
- DoubleMu Quality (Q>=8)
  - EMTF mode 12, 10, 7
  - EMTF mode 15, 14, 13, 11
- MuOpen Quality (Q>=4)
  - EMTF mode 9, 6, 5, 3
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  - EMTF mode 15, 14, 13, 11

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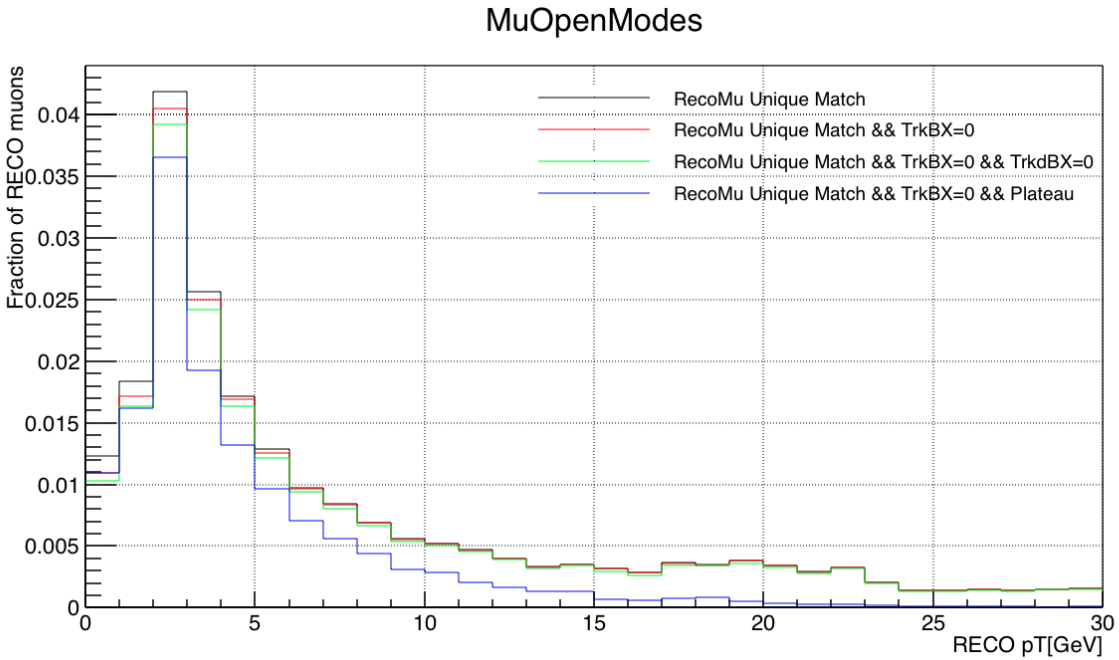
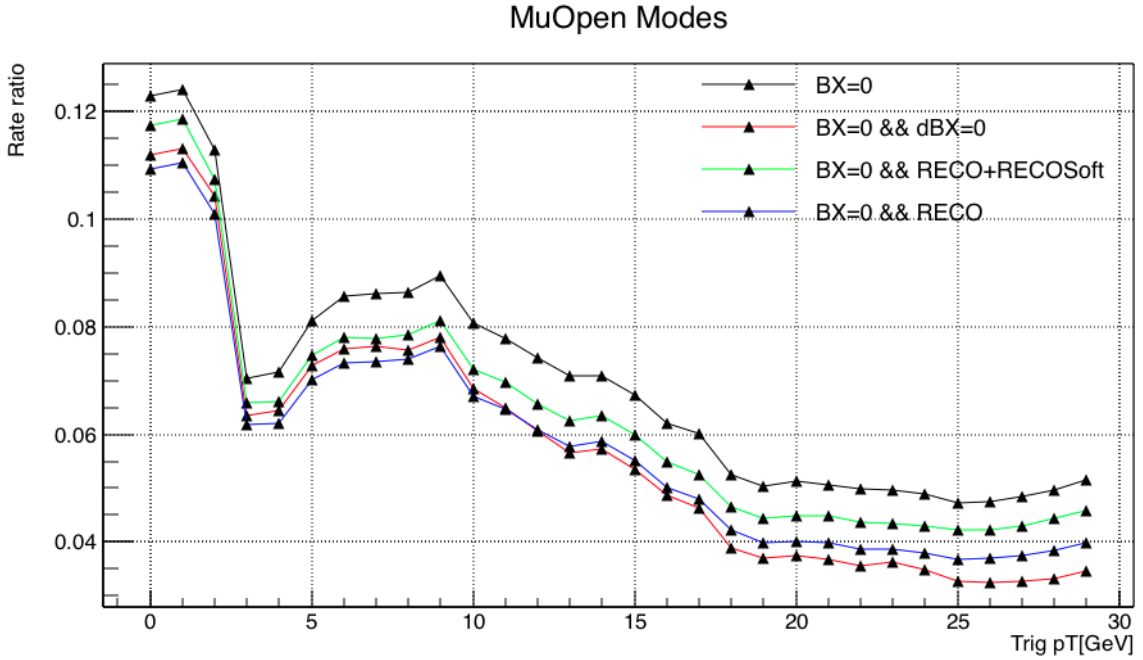
10	2+8	1,3
9	1+8	1,4
7	1+2+4	2,3,4
6	2+4	2,3
5	1+4	2,4
3	1+2	3,4

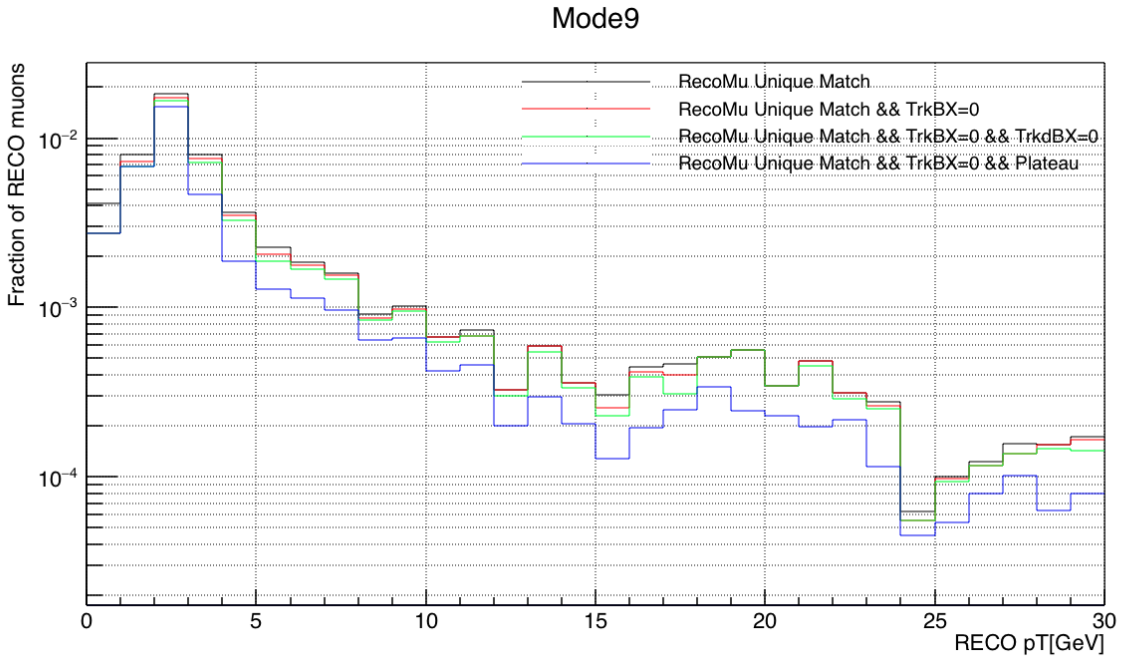
MuOpen Modes

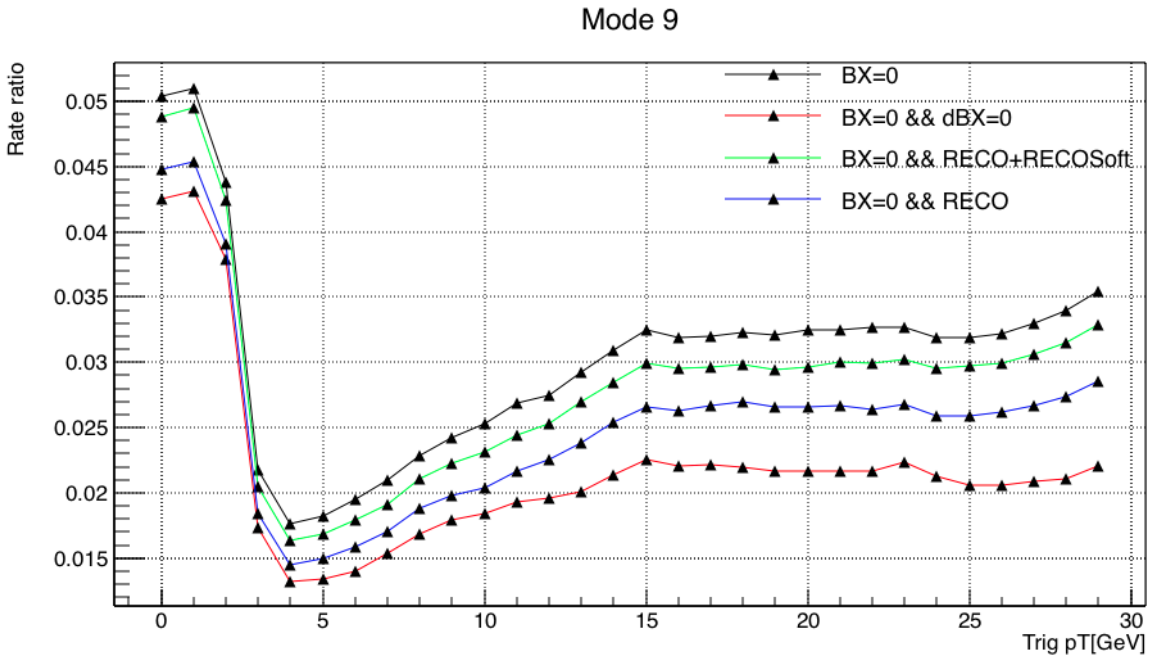




- Left: green overlaps red due to low dBX probability in 2-station tracks
- Left: high eff peak at very low pT (pT<5 GeV)
- Right: gap between red & black, applying dBX=0 can reduce 12%-40% of rate from current MuOpen modes (pT>5 GeV)
- pT>5 GeV: plateau efficiency is 1000 times smaller than SingleMu modes
- pT>5 GeV: contribution to rate looks reasonable, decreases from 9% to 5% as pT increases

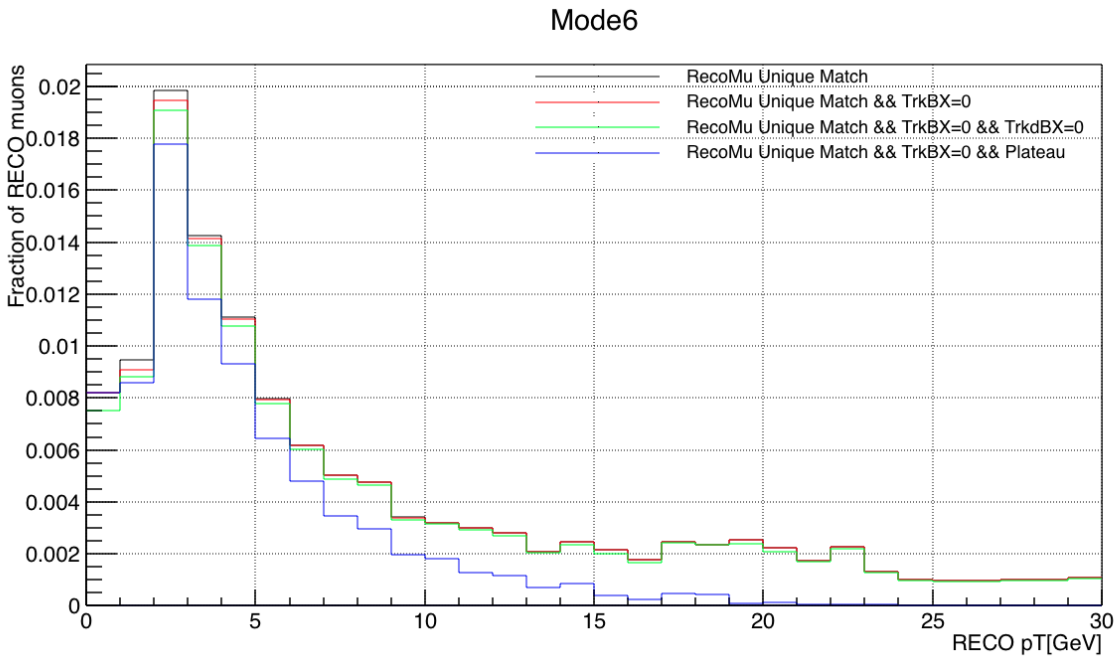
Mode 9 (station 1-4)

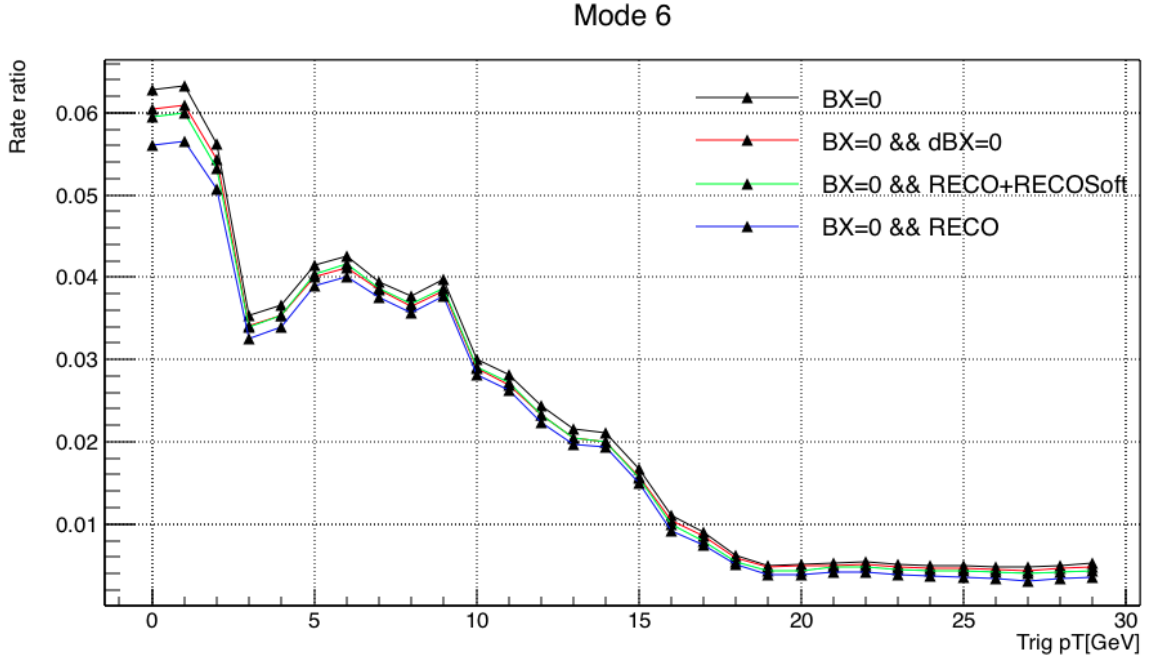




- Account for more than half the rate from MuOpen at 15-30 GeV
- pT>5 GeV: plateau efficiency is 1000 times smaller than mode 15 (station 1-2-3-4)
- pT>5 GeV: overall contribution to rate is reasonable, but increases from 1.8% - 3.5% as pT increases

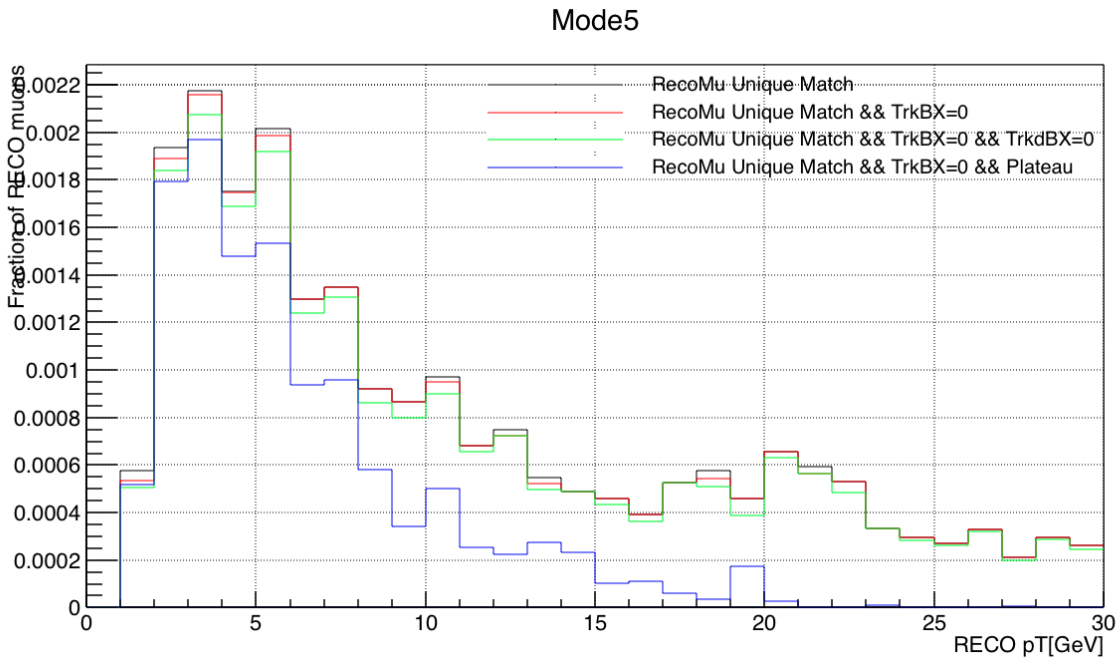
Mode 6 (station 2-3)

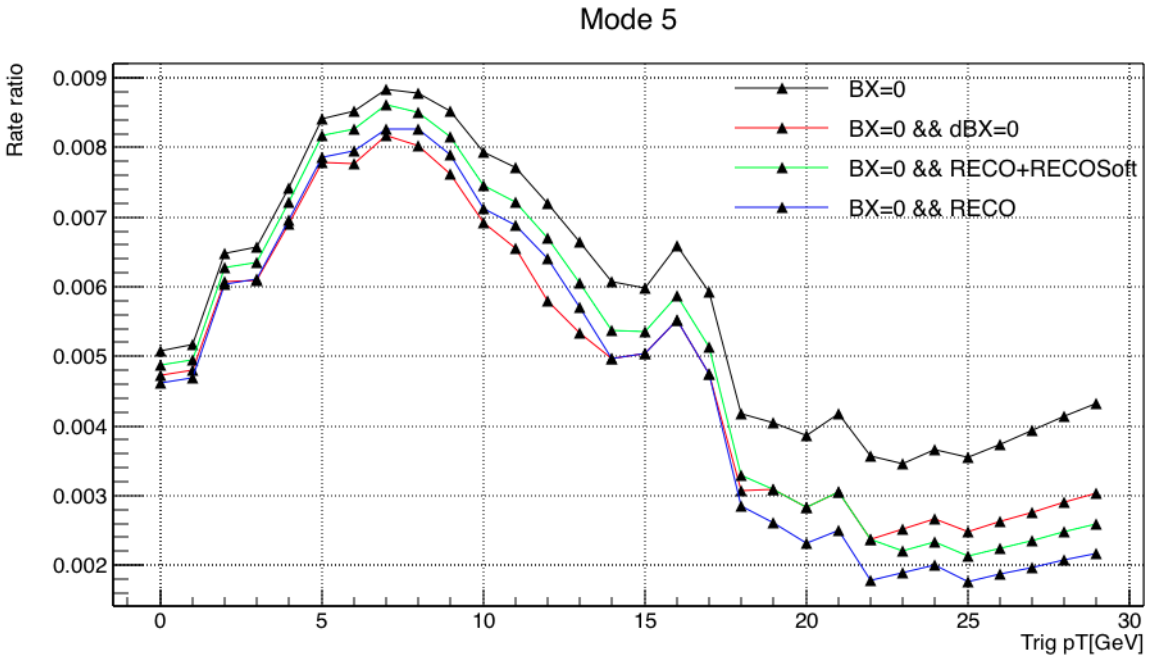




- Account for more than half MuOpen eff, 50% rate contribution at low pT end, 20% rate at high pT end
- Right: different dBX behavior to mode 9 (station 1-4), dBX=0 don't affect rate much, may due to less likely mistiming when station 2 and 3 are close
- pT>5 GeV: plateau efficiency is 100 times smaller than mode 15 (station 1-2-3-4)
- pT>5 GeV: overall contribution to rate is reasonable, 4% - 0.5% as pT increases

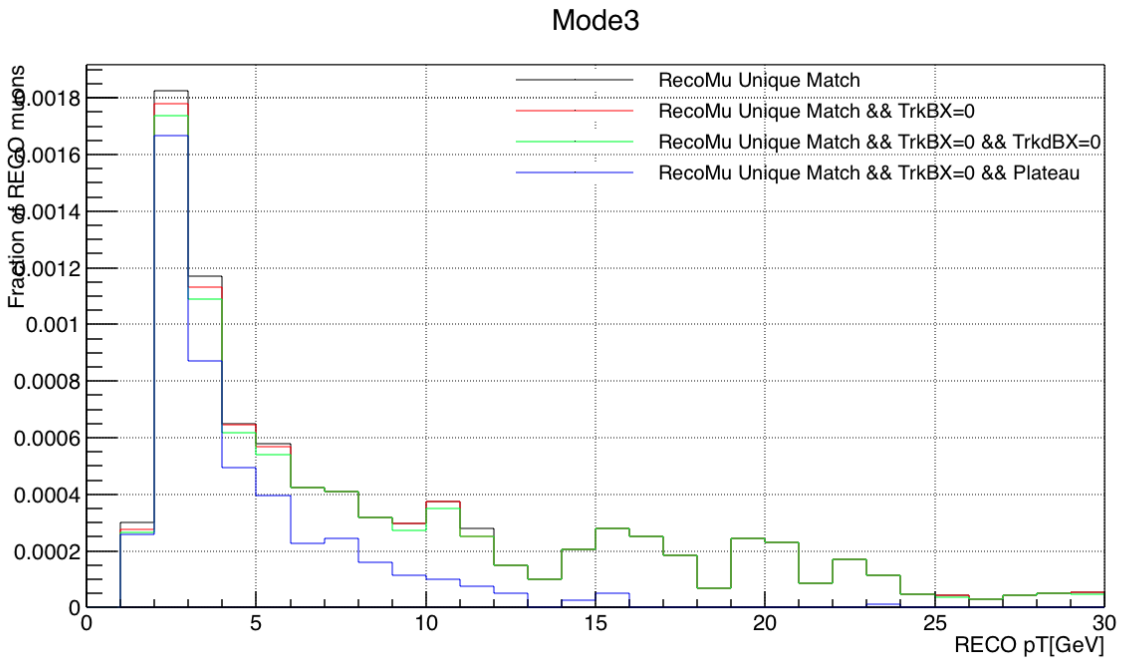
Mode 5 (station 2-4)

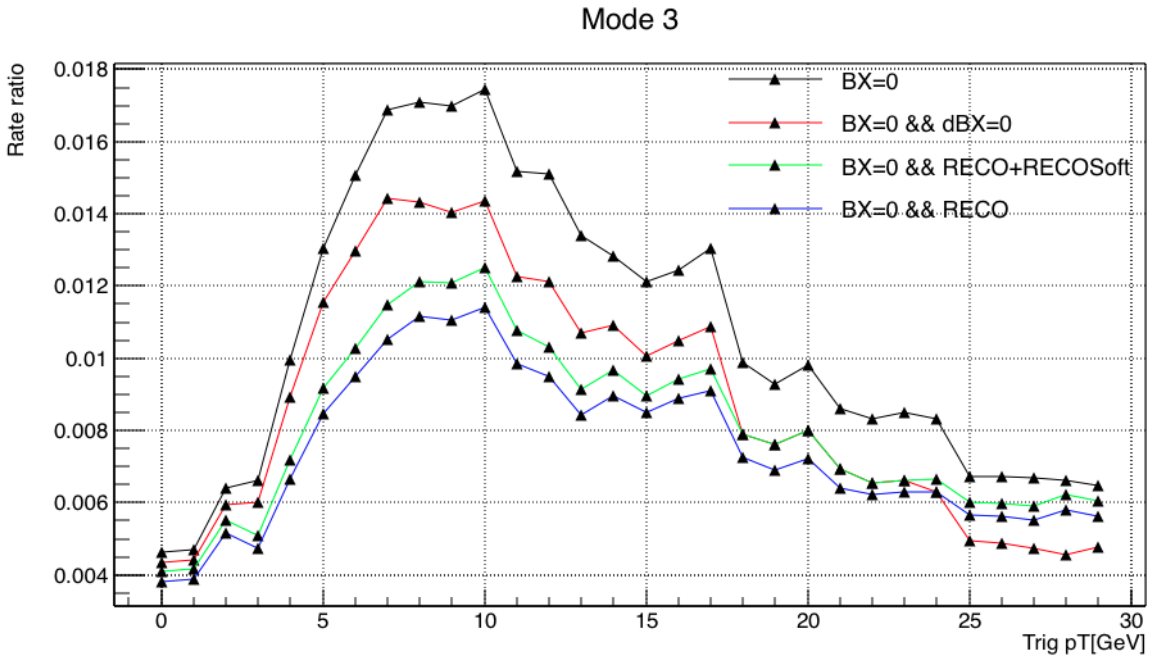




- pT > 5 GeV: plateau efficiency is 1000 times smaller than mode 15 (station 1-2-3-4)
- pT > 5 GeV: overall contribution to rate is reasonable, 0.9% - 0.4% as pT increases

Mode 3 (station 3-4)





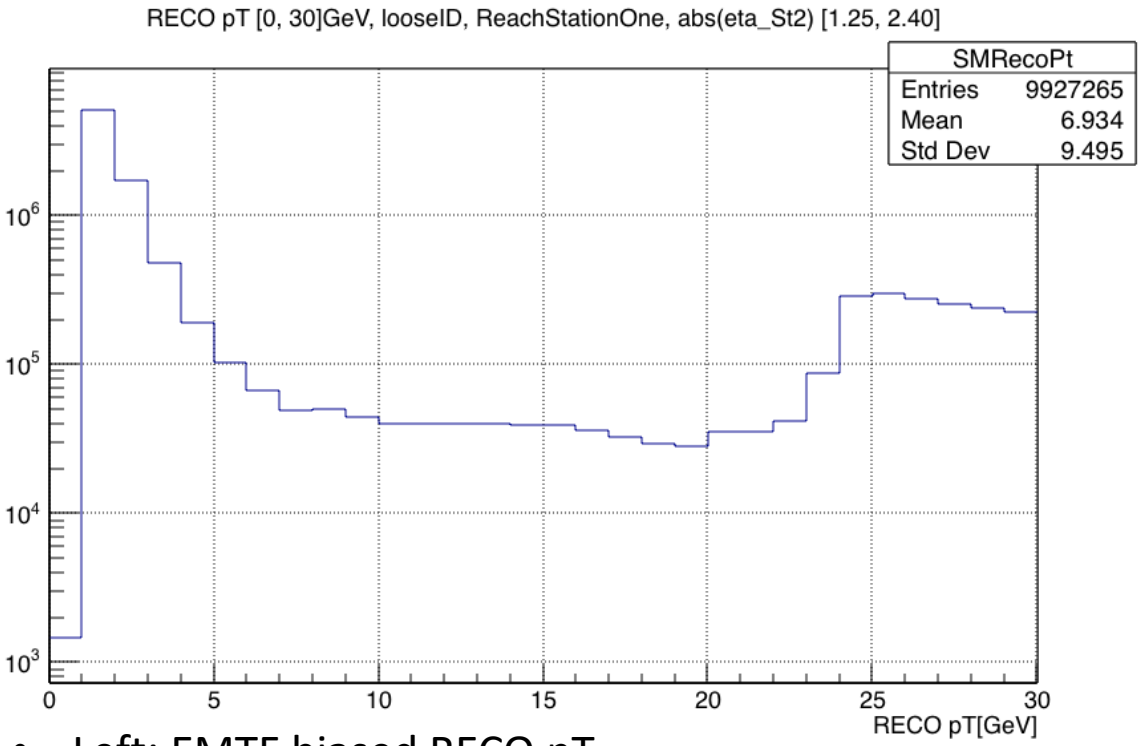
- pT>5 GeV: plateau efficiency is at least 1000 times smaller than mode 15 (station 1-2-3-4)
- pT>10 GeV: overall contribution to rate is reasonable, 1.7% - 0.6% as pT increases

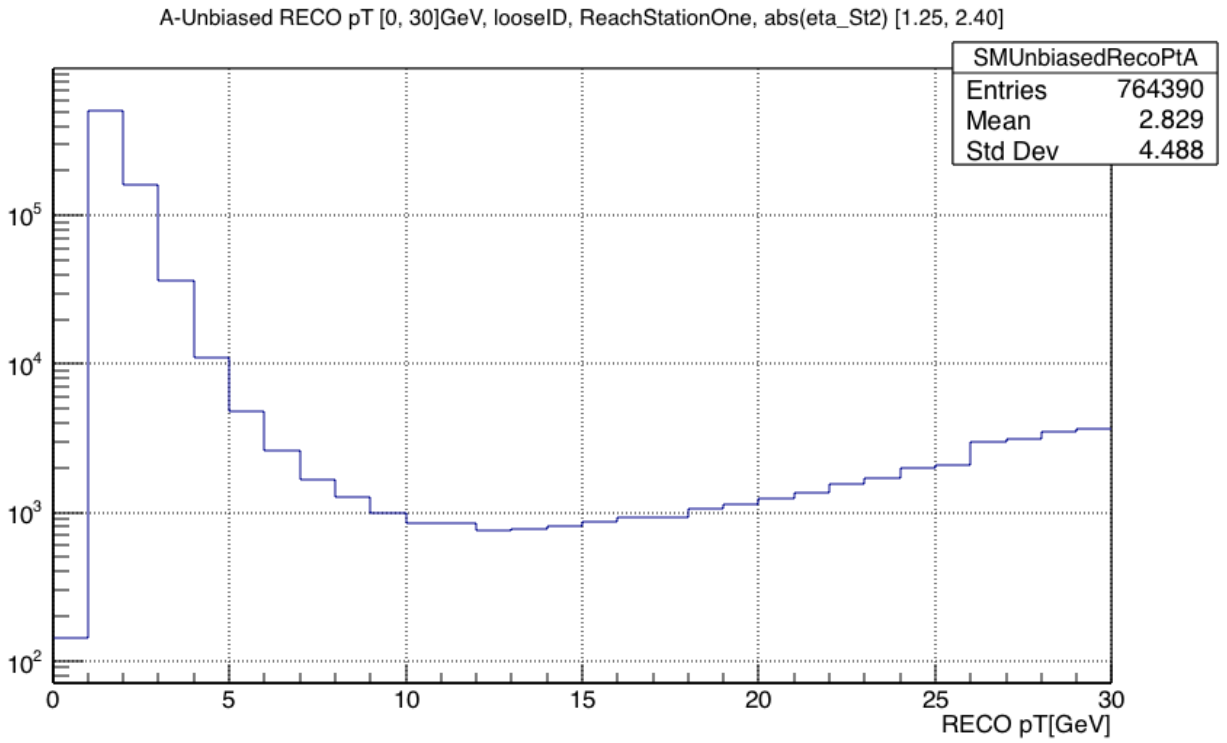
Conclusions

- EMTF builds tracks with very high efficiency and good timing down to pT values of 3 - 5 GeV
- May re-map quality vs. mode - e.g. mode 12 -> MuOpen
  - Reduce rate while barely affecting efficiency
- Could add dBX == 0 requirement for 2-station tracks
  - Again, significant rate reduction for almost no efficiency loss
- Working to tighten dTheta windows between stations in track-building
  - Should help reject EMTF tracks built from multiple different muons in high-PU environment
  - Need to find a working point which will not reduce efficiency, even for fairly low-pT muons (5 - 10 GeV)

Back Up

Remove EMTF Bias #A

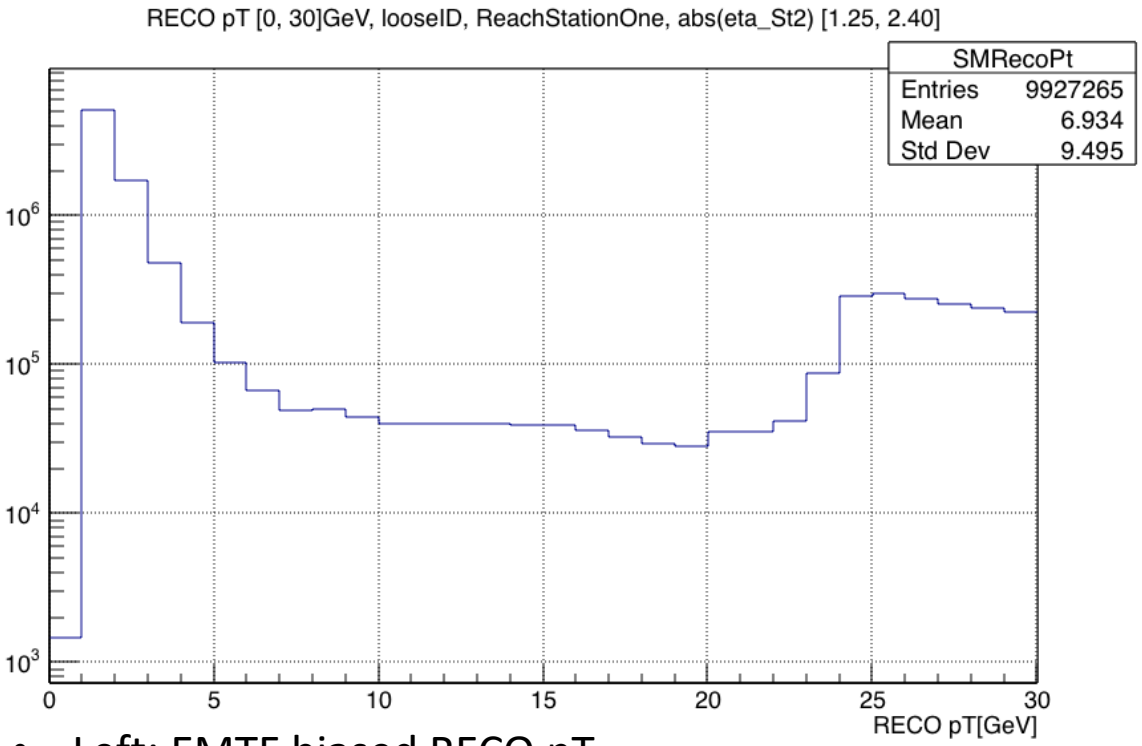


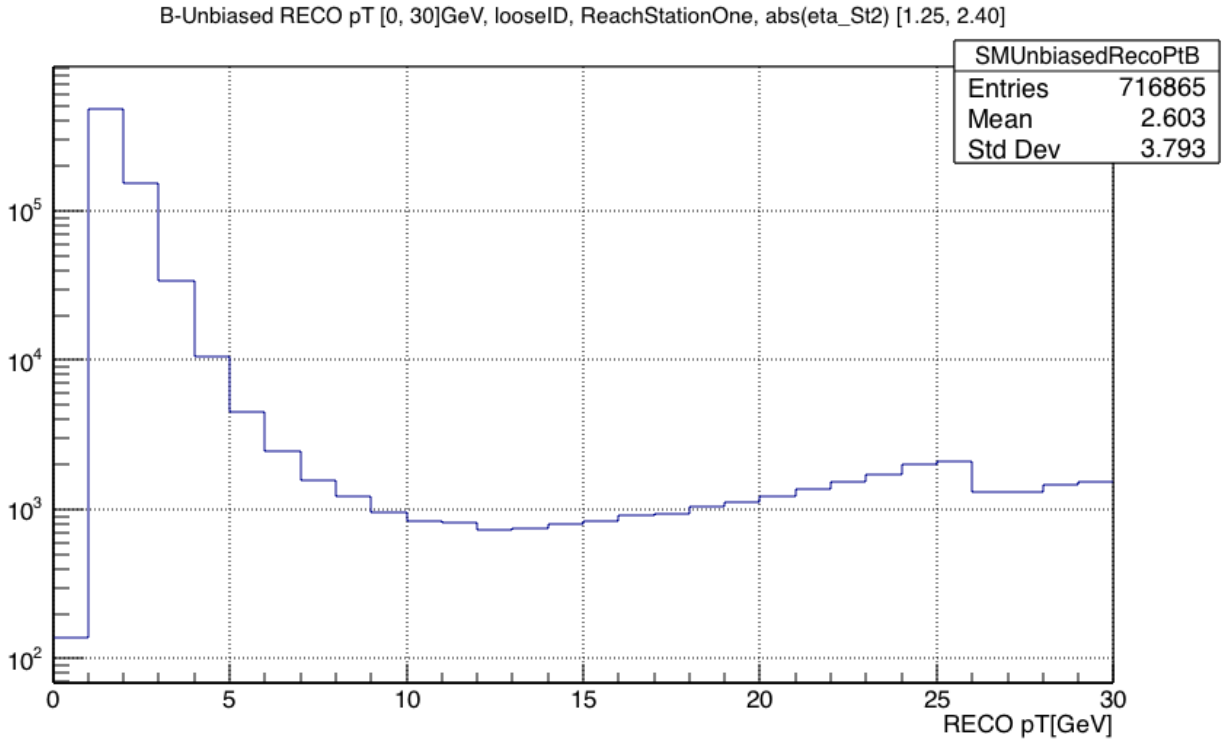


- Left: EMTF biased RECO pT
- Right: Try to remove the bias from IsoMu24 fired by EMTF
  - Require event: >=1 RECO mu in barrel (abs(eta)<1.0), RECO mu medium ID=1, ID_St1=1, pT> 26 GeV, Iso<0.25

  OR
  - Require event: >=2 RECO mu in endcap (abs(eta)>=1.0), RECO mu medium ID=1, ID_St1=1, pT> 26 GeV, Iso<0.25

Remove EMTF Bias #B





- Left: EMTF biased RECO pT
- Right: Try to remove the bias from IsoMu24 fired by EMTF
  - Require event: >=1 RECO mu(>26 GeV) in barrel (abs(eta)<1.0) && no endcap RECO mu > 26 GeV
    - Common requirement: RECO mu medium ID=1, ID_St1=1, Iso<0.25

Data Files

root://eoscms.cern.ch//store/user/abrinke1/EMTF/Emulator/ntuples/HADD/

- SingleMu
  - NTuple_SingleMuon_FlatNtuple_Run_306092_2018_03_02_SingleMu.root
  - NTuple_SingleMuon_FlatNtuple_Run_306135_2018_03_02_SingleMu.root
  - NTuple_SingleMuon_FlatNtuple_Run_306154_2018_03_02_SingleMu.root
- Zerobias
  - NTuple_ZeroBias1_FlatNtuple_Run_306091_2018_03_02_ZB1.root
  - NTuple_ZeroBias2_FlatNtuple_Run_306091_2018_03_02_ZB2.root
  - NTuple_ZeroBias3_FlatNtuple_Run_306091_2018_03_02_ZB3.root
  - NTuple_ZeroBias4_FlatNtuple_Run_306091_2018_03_02_ZB4.root

Codes

- EMTF tracks
  - https://github.com/abrinke1/EMTFAnalyzer/blob/master/NTupleMaker/src/FlatNtupleBranches/EMTFTrackInfo.cc
- RECO muons
  - https://github.com/abrinke1/EMTFAnalyzer/blob/master/NTupleMaker/src/FlatNtupleBranches/RecoMuonInfo.cc
- RECO muon-EMTF track dR match
  - https://github.com/abrinke1/EMTFAnalyzer/blob/master/NTupleMaker/src/FlatNtupleMatchers/RecoTrkDR.cc
- Macro
  - https://github.com/weishi10141993/EMTF_CSCTF_pTResolution_TrackBuild_dR_Matching/blob/master/ModesRateEff.C