Calculation of effiency for selection cuts used in Z’ baseline selection

Kalpanie Madara Liyanage
Department of Physics
University of Ruhuna

- We are using a separate set of dedicated offline selection cuts (given in the backup) to select high-p_T dimuon events in the search for High-Mass Resonances decaying to muon pairs in pp collisions.

- The efficiency of different ID selections are individually tested with respect to all the other selections, which is known as N-1 Efficiency, to have a better idea on how these cuts work in data and simulations.

- N-1 efficiency is defined as the ratio of the number of events that pass all the selection cuts to the number of events passing all the cuts but the one of interest.

- N-1 efficiency studies are done for all cuts as obtained in data and MC for two different dimuon mass ranges:

  - $60 < M_{\mu\mu} < 120$GeV
  - $M_{\mu\mu} > 120$GeV

- Same calculation is done for the two η categories (BB and BE) and are reported in Figures 01 to 05. The first mass range, around the Z-peak, refers to a well-known physics region.

2018

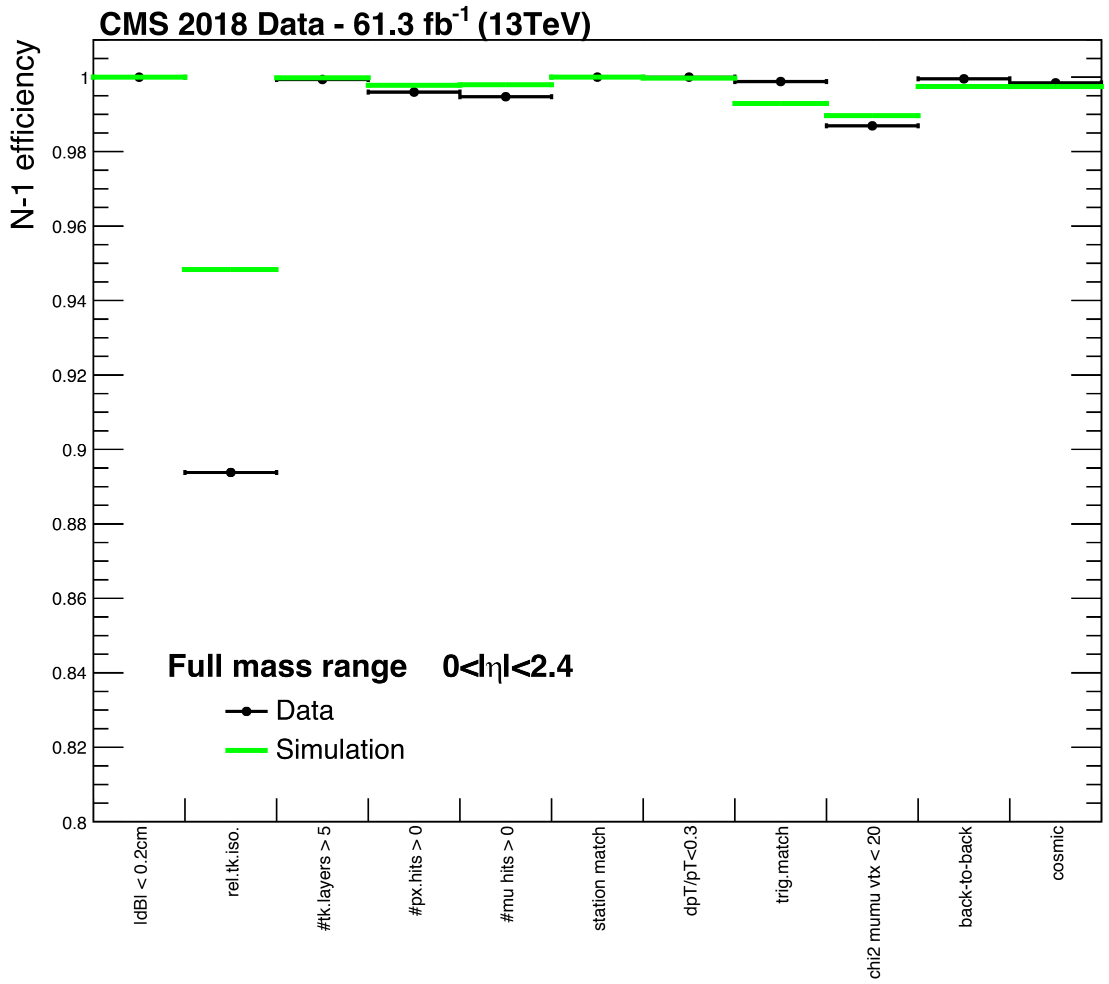
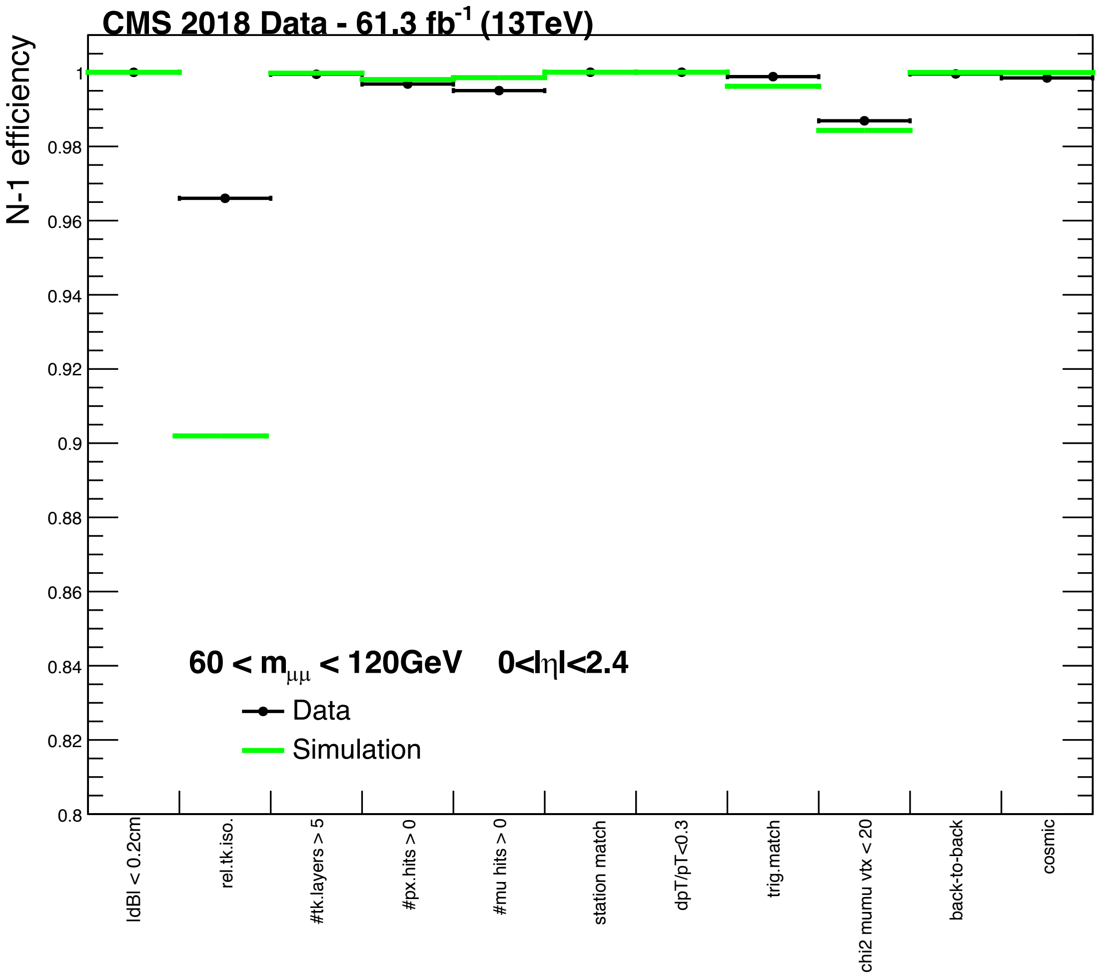


Figure 01: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the full mass range. Here “Simulation” includes all the backgrounds.



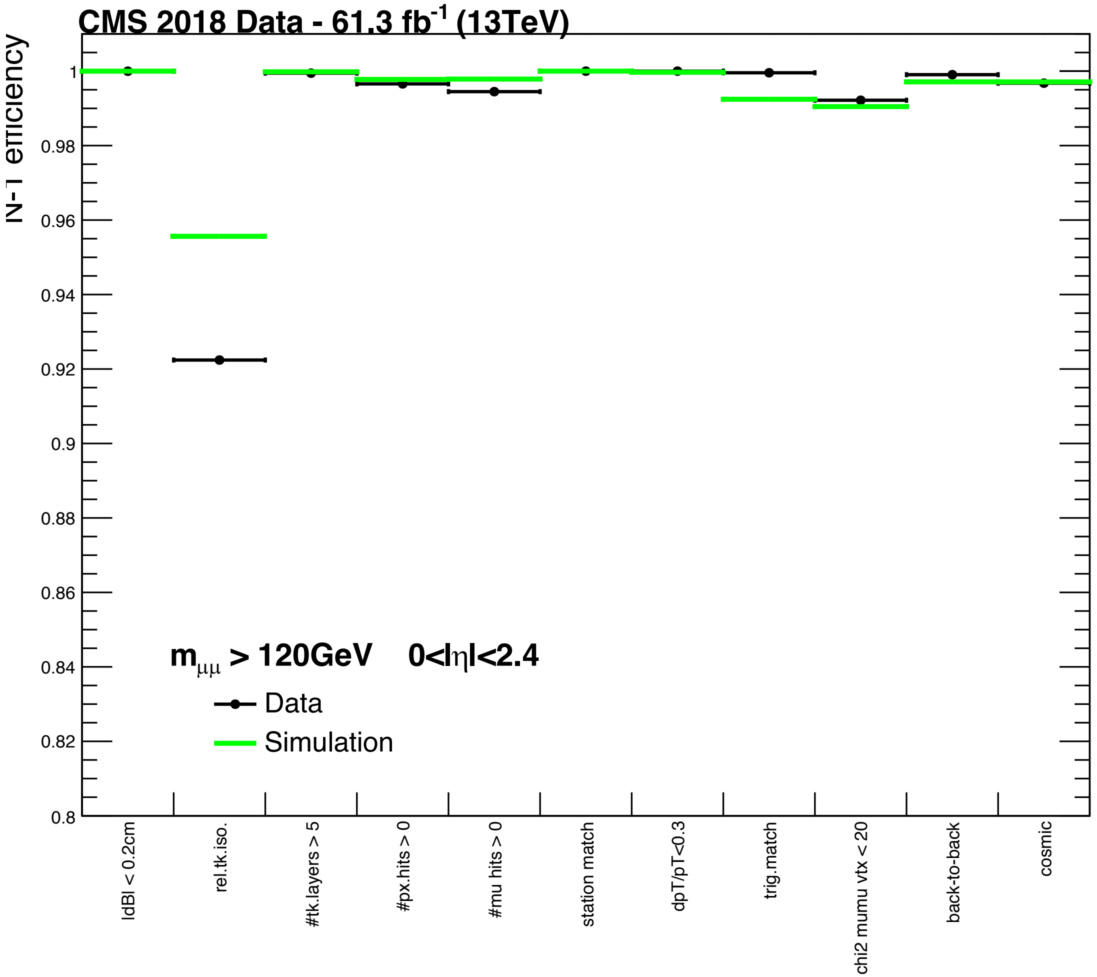


Figure 02: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: $60 < m_{\mu\mu} < 120$ GeV (left) and $m_{\mu\mu} > 120$ GeV (right) for the full pseudo-rapidity range.

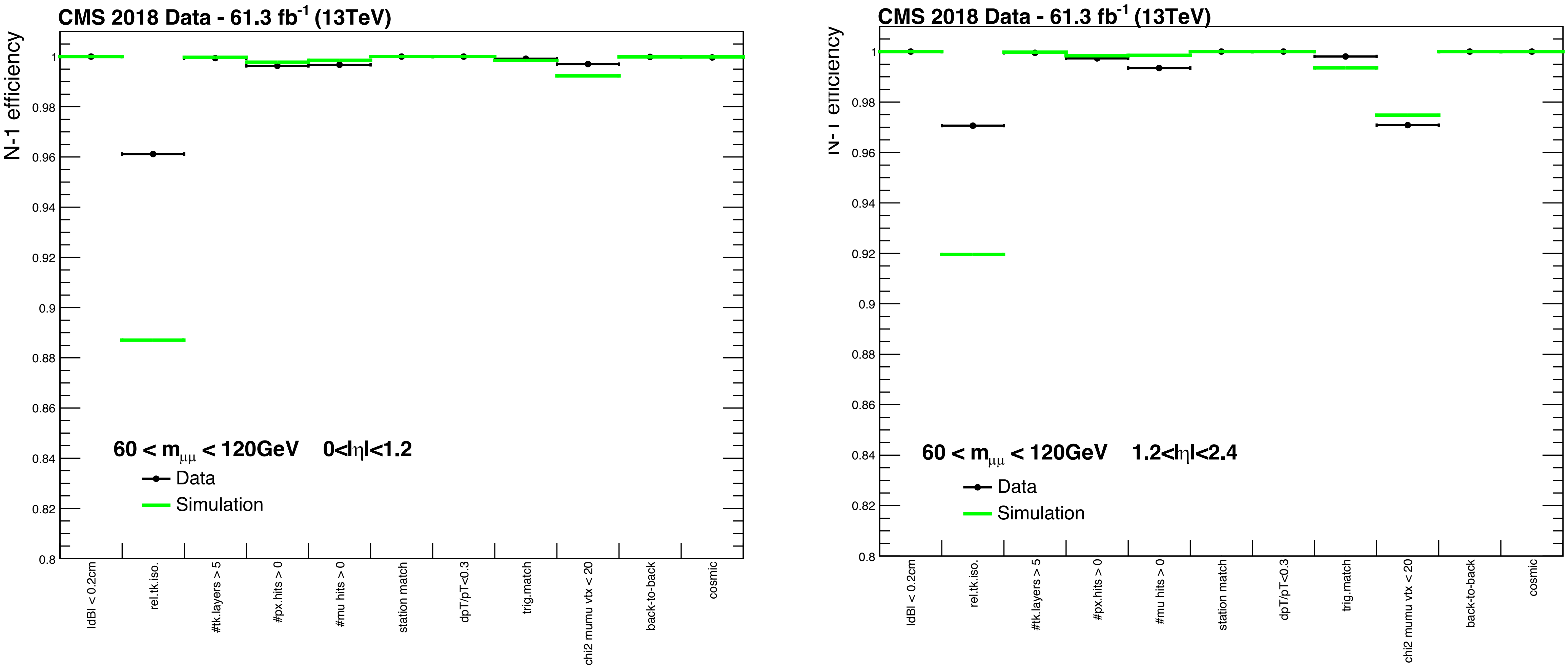


Figure 03: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: 0.0 < | **η** | < 1.2 (left) and 1.2 < | **η** | < 2.4 (right) for 60 < $m_{\mu\mu}$ < 120 GeV.

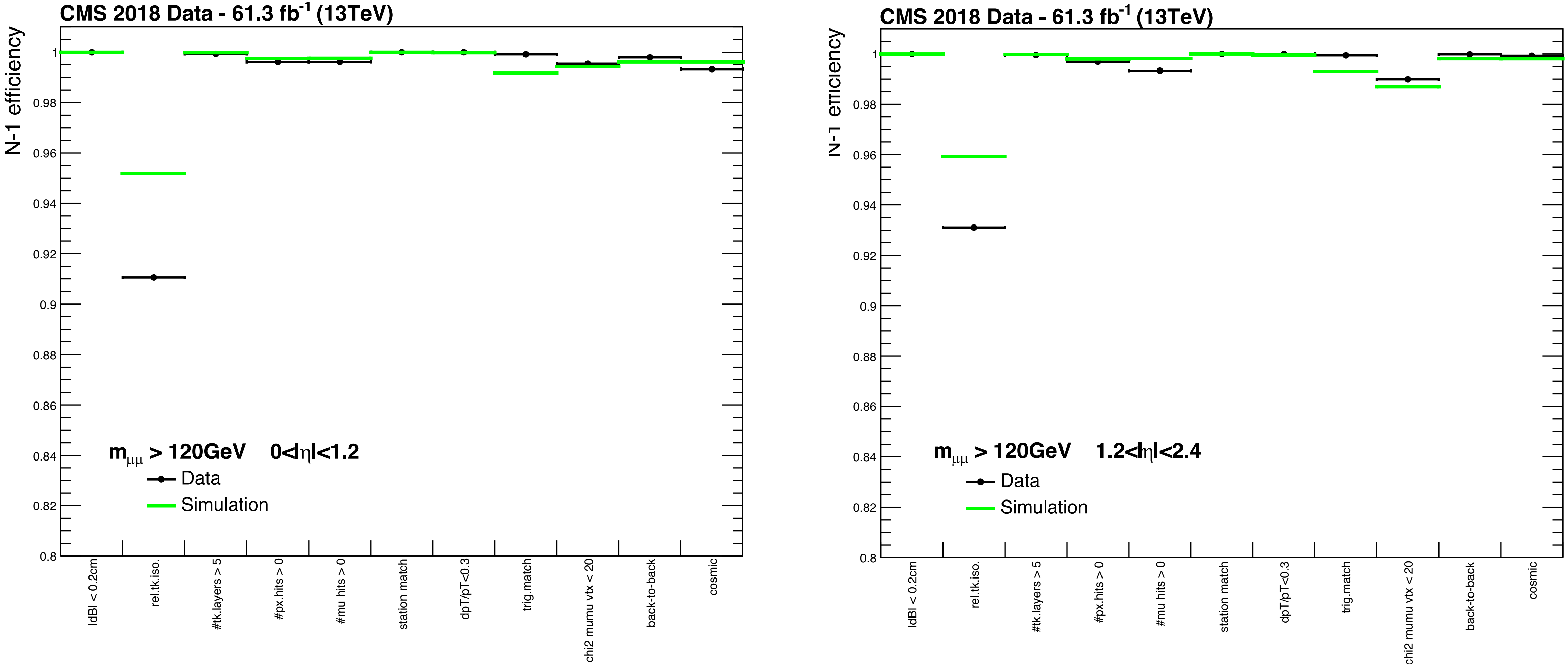


Figure 04: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: $0.0 < |\eta| < 1.2$ (left) and $1.2 < |\eta| < 2.4$ (right) for $m_{\mu\mu} >$ 120 GeV.

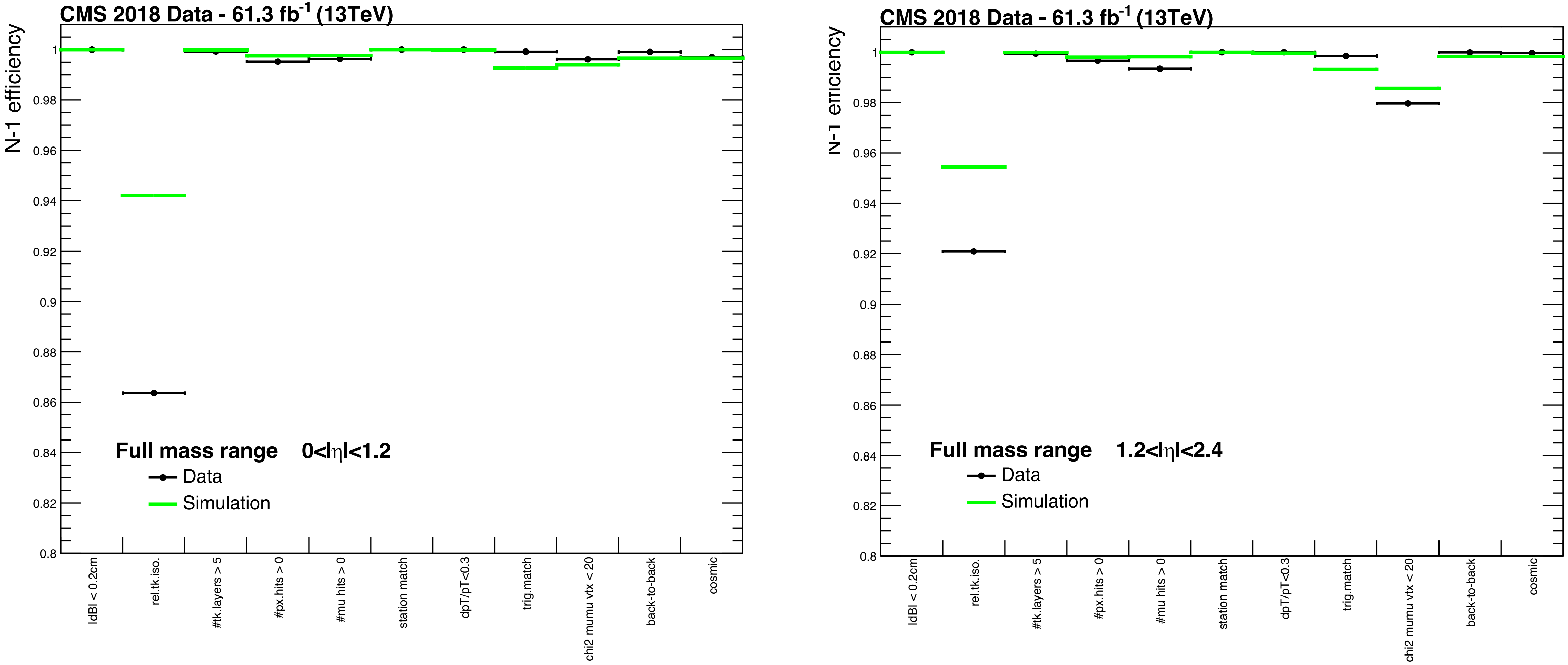


Figure 05: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: 0.0 < | η | < 1.2 (left) and 1.2 < | η | < 2.4 (right) for the full mass range

- It is observed that there is a good agreement between data and simulation for all cuts except for the relative tracker-only isolation cut : the drop in efficiency is due to multi-jets events that are instead not considered in MC, since their contribution is evaluated with a data driven technique.

- For the relative tracker-only isolation cut, efficiency is higher in data than in MC in the low mass region around the Z-peak($60 < m_{\mu\mu} < 120$ GeV) and it is lower in data than in MC in high mass region ($m_{\mu\mu} > 120$ GeV.

- N-1 efficiencies are recalculated for MC removing W+jets and Z+jets samples. Results are shown in the following slides. No significant fluctuation is observed for all cuts except for a drop of efficiency in the relative tracker-only isolation cut around Z-peak in both BB and BE categories.

Jet bkgs are removed from simulation

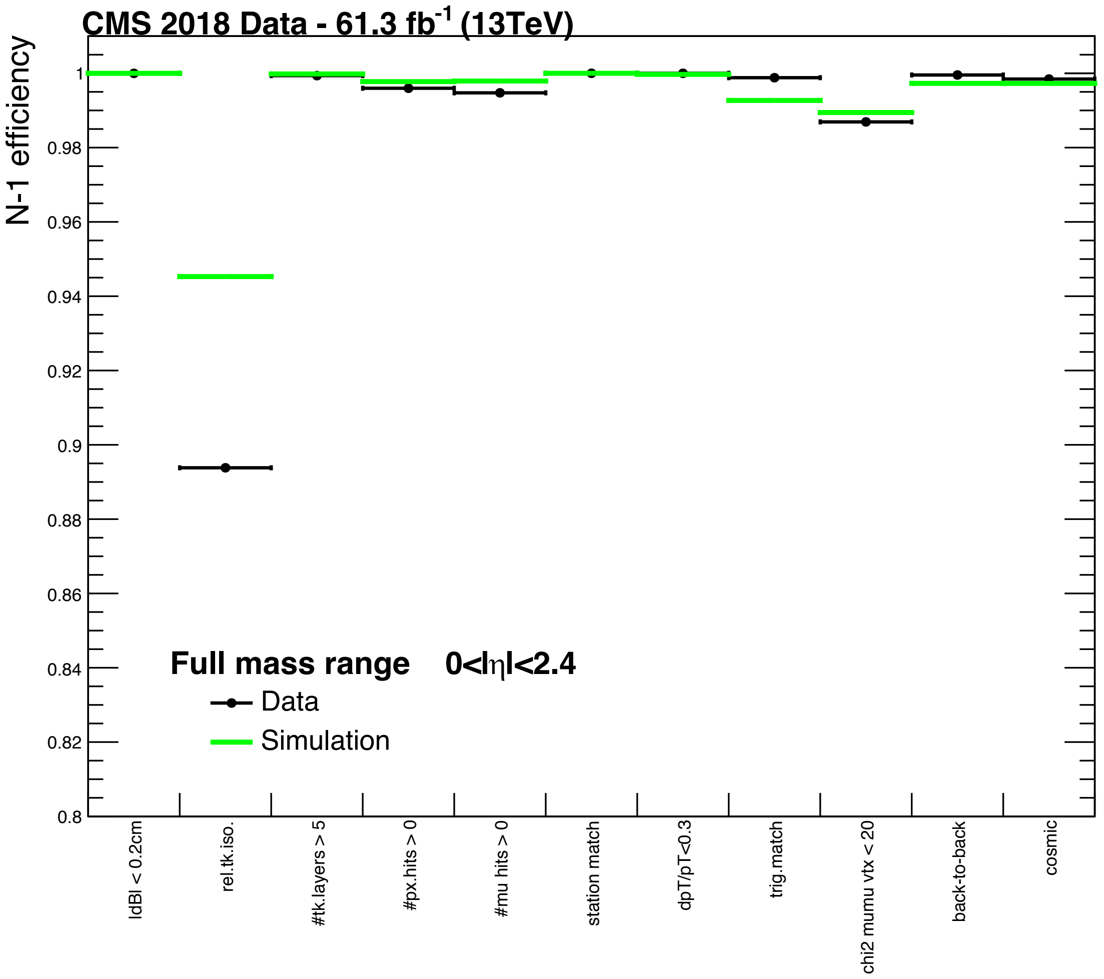
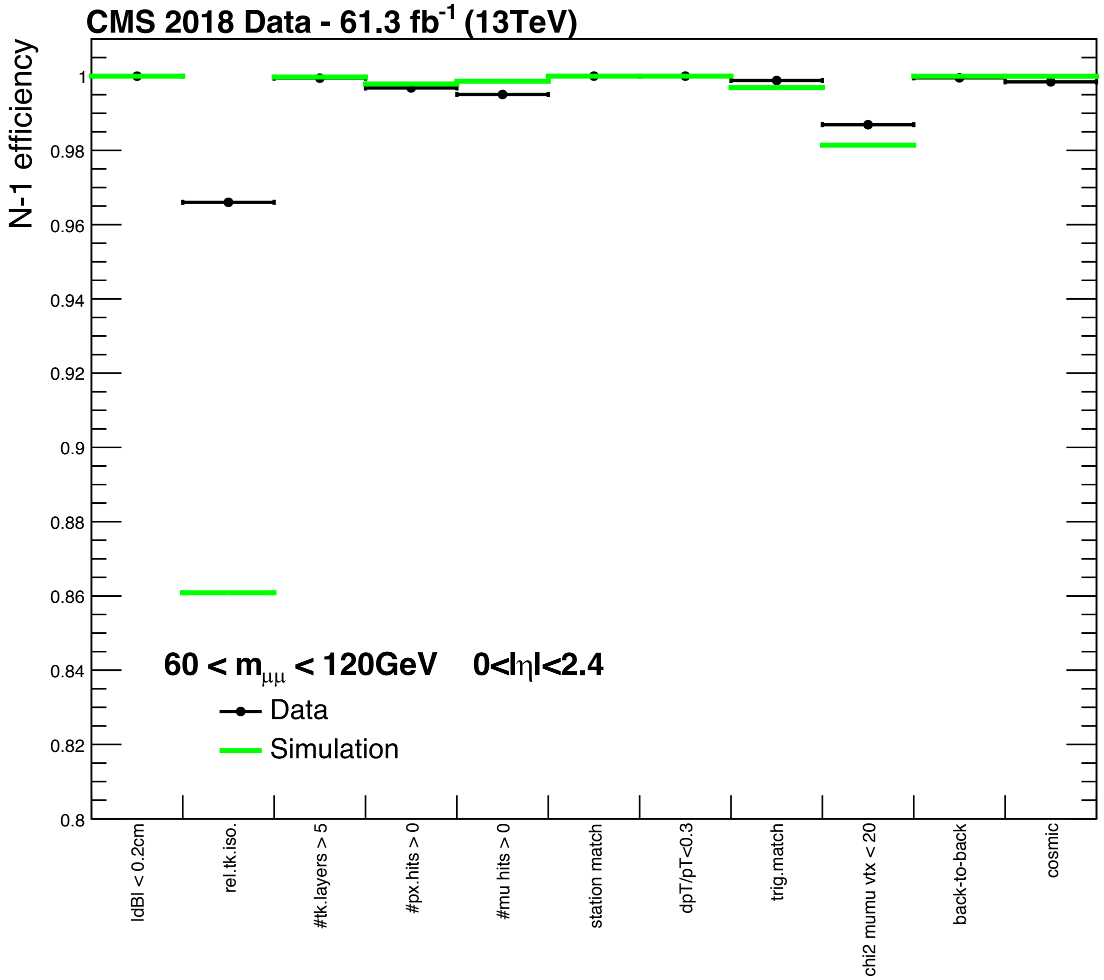


Figure 06: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the full mass range. Here “Simulation” includes all the backgrounds.

Jet bkgs are removed from simulation



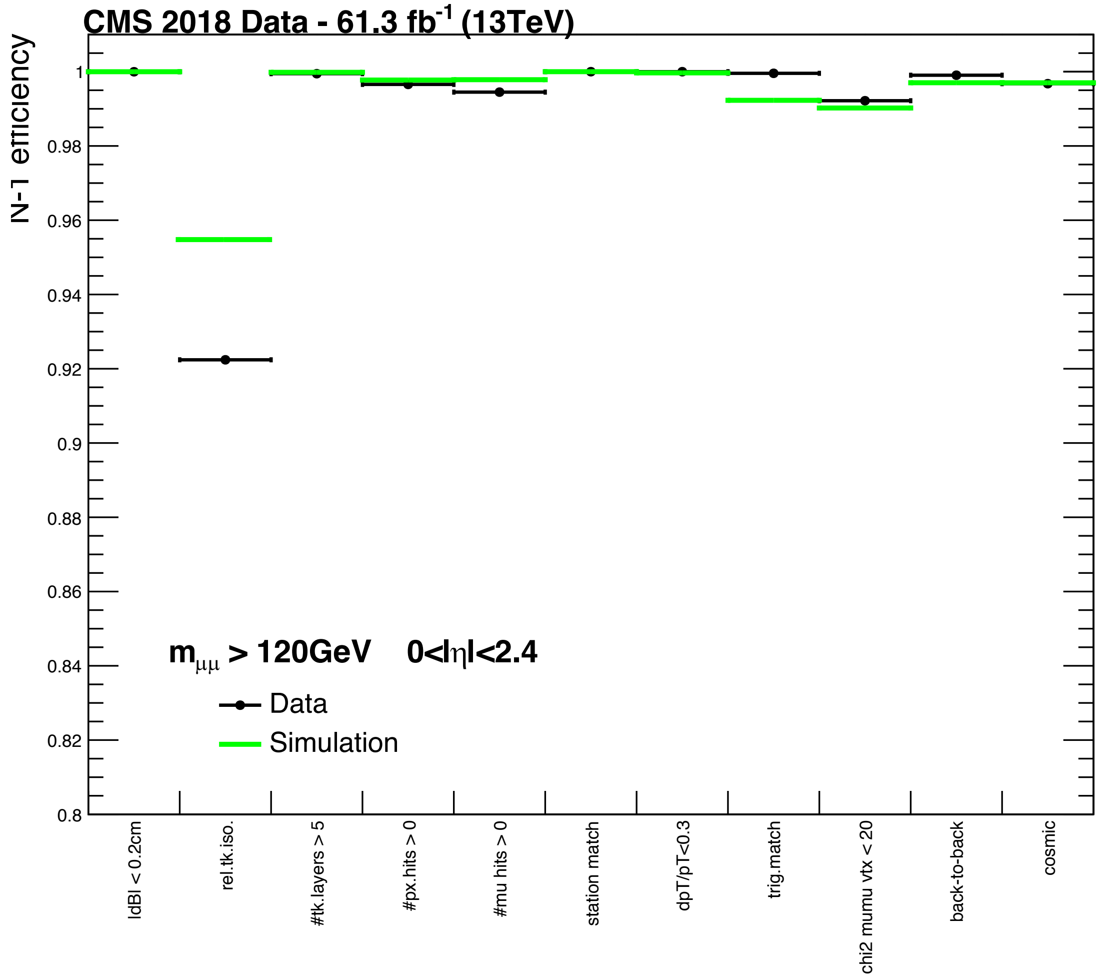
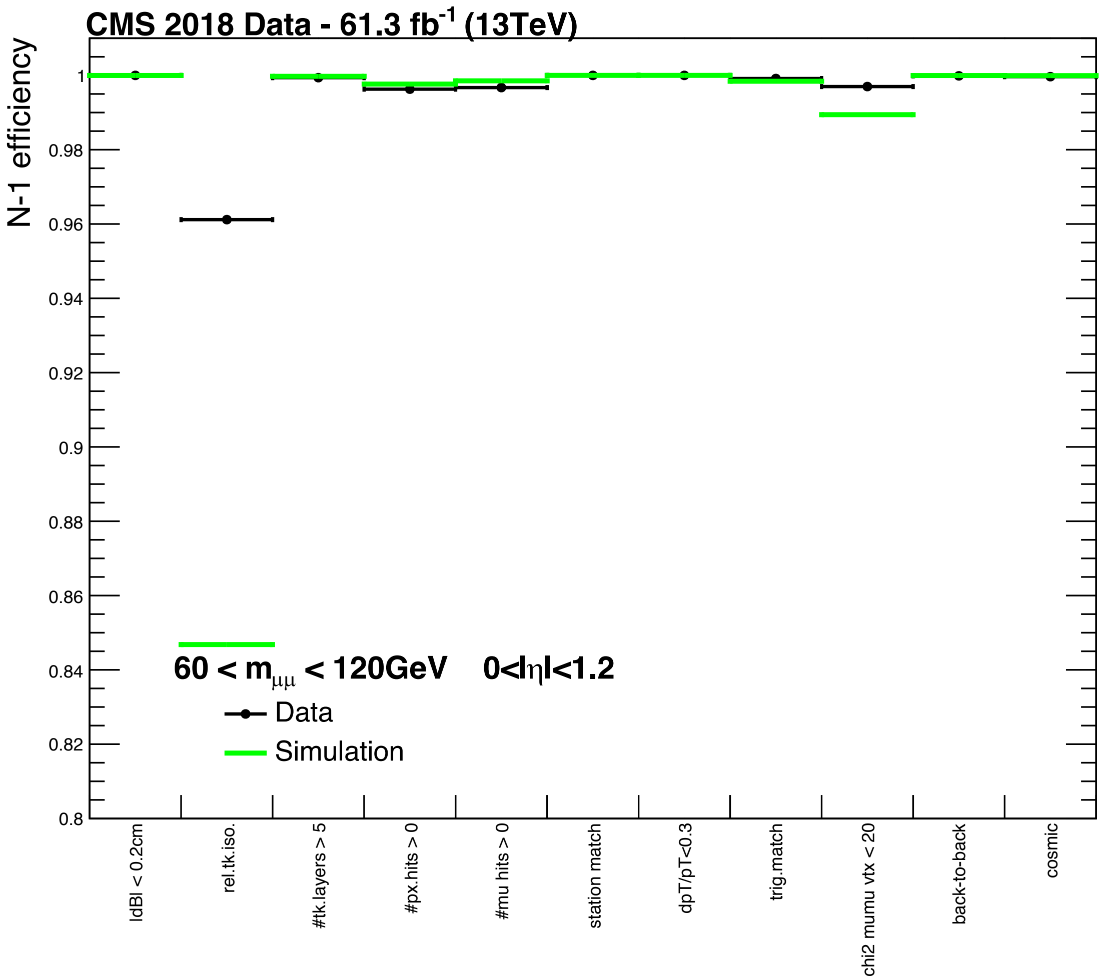


Figure 07: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: $60 < m_{\mu\mu} < 120$ GeV (left) and $m_{\mu\mu} > 120$ GeV (right) for the full pseudo-rapidity range.

Jet bkgs are removed from simulation



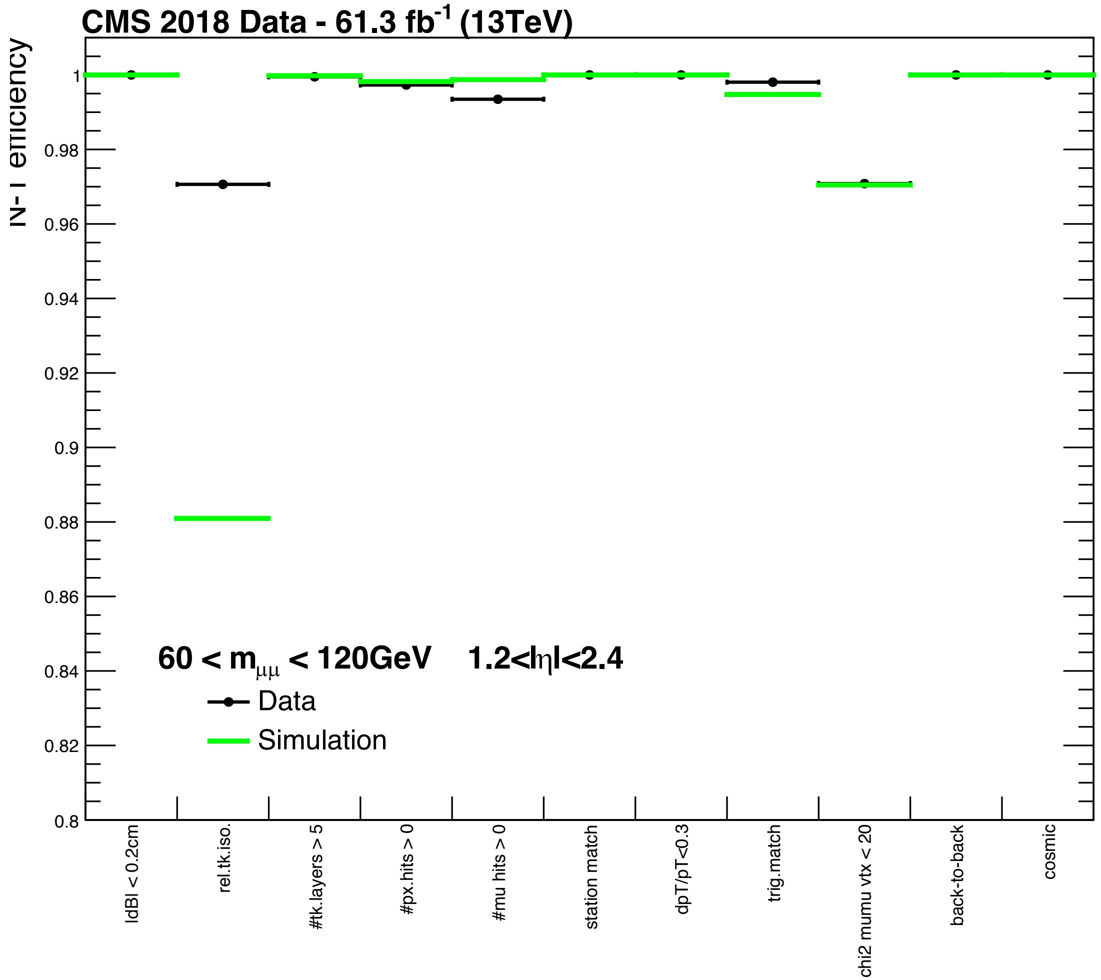
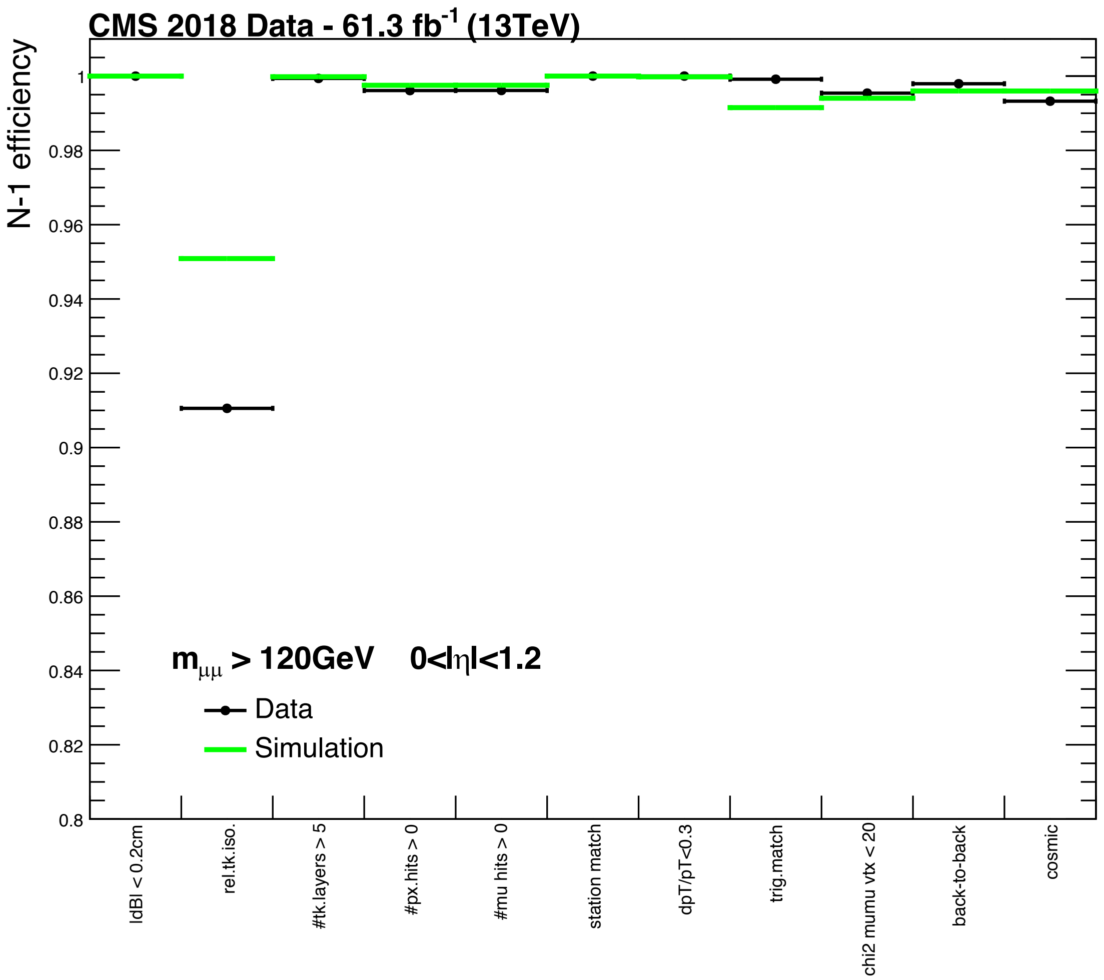


Figure 08: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: 0.0 < | **η** | < 1.2 (left) and 1.2 < | **η** | < 2.4 (right) for 60 < $m_{\mu\mu}$ < 120 GeV.

Jet bkgs are removed from simulation



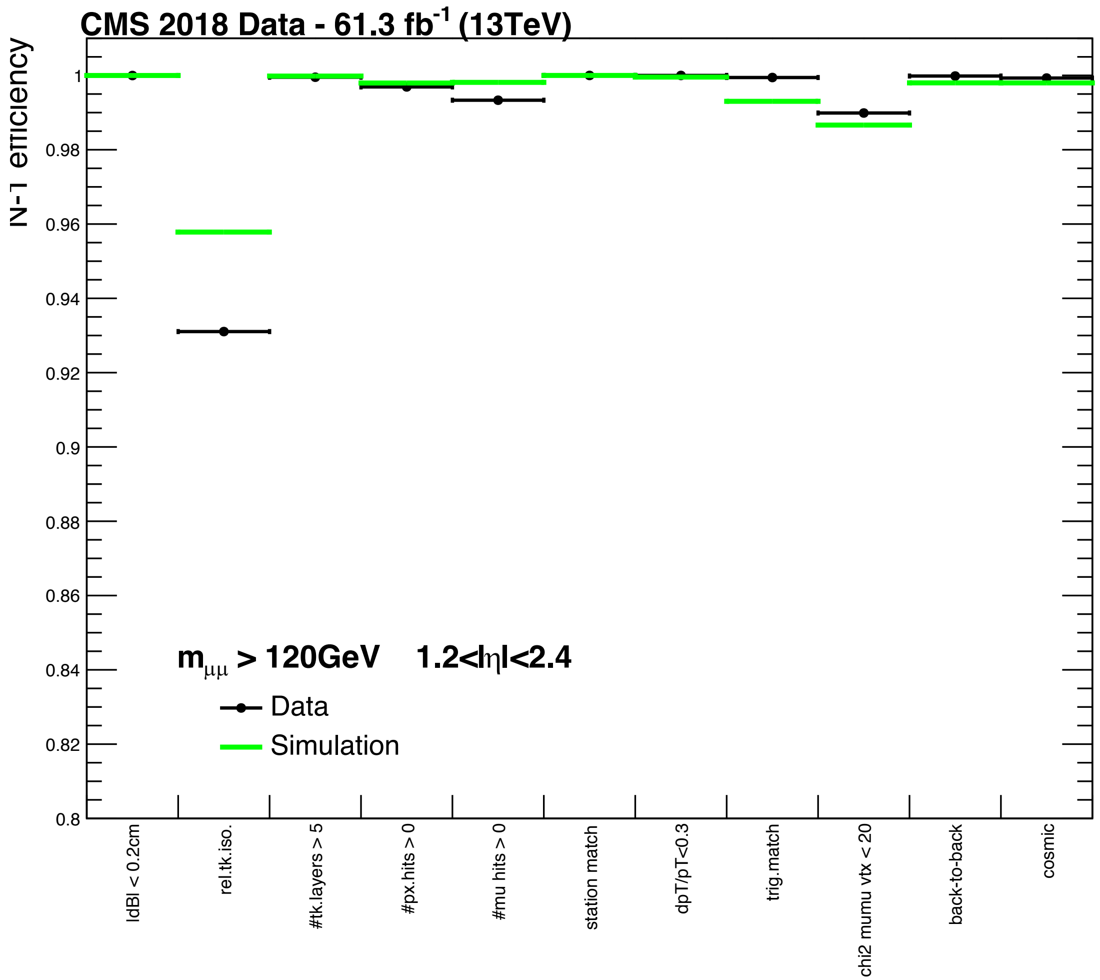


Figure 09: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: 0.0 < | **η** | < 1.2 (left) and 1.2 < | **η** | < 2.4 (right) for $m_{\mu\mu} >$ 120 GeV.

Jet bkgs are removed from simulation

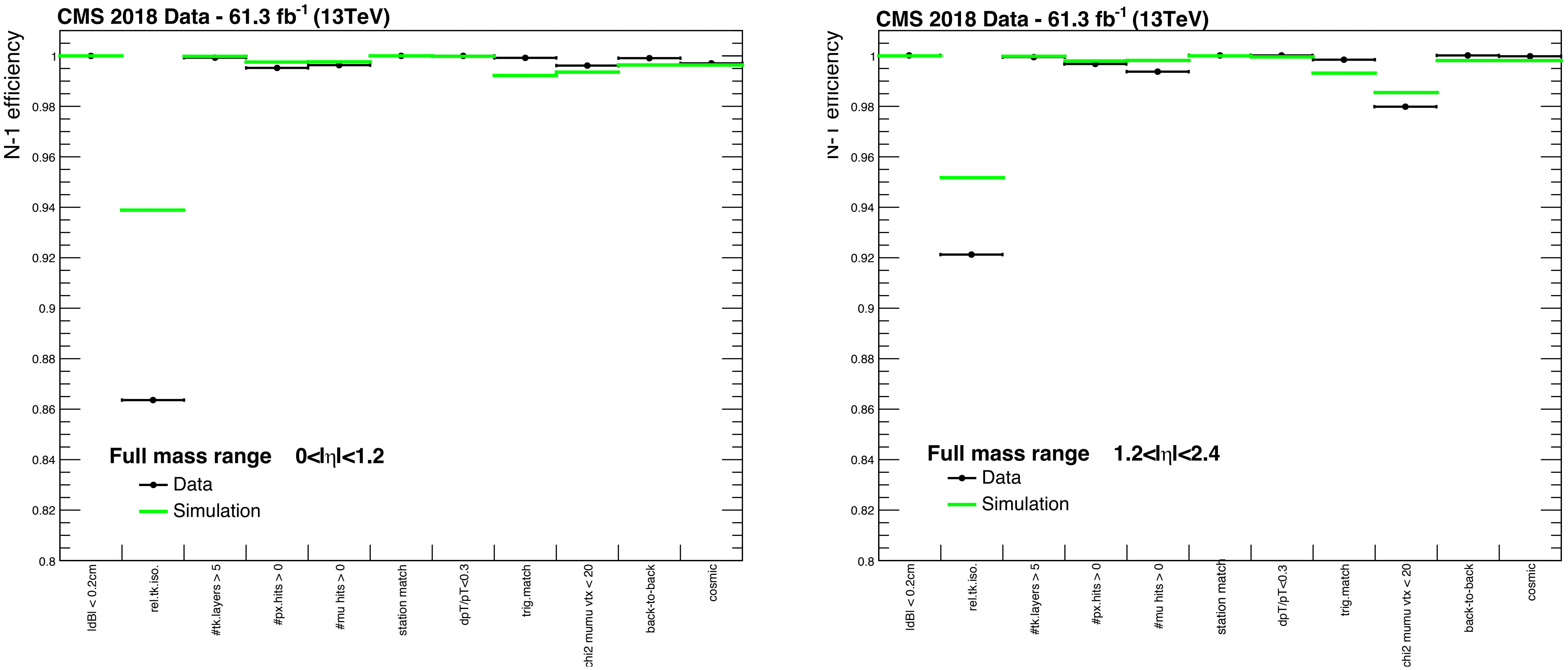


Figure 10: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: $0.0 < |\eta| < 1.2$ (left) and $1.2 < |\eta| < 2.4$ (right) for the full mass range

2017

Jet bkgs are removed from simulation

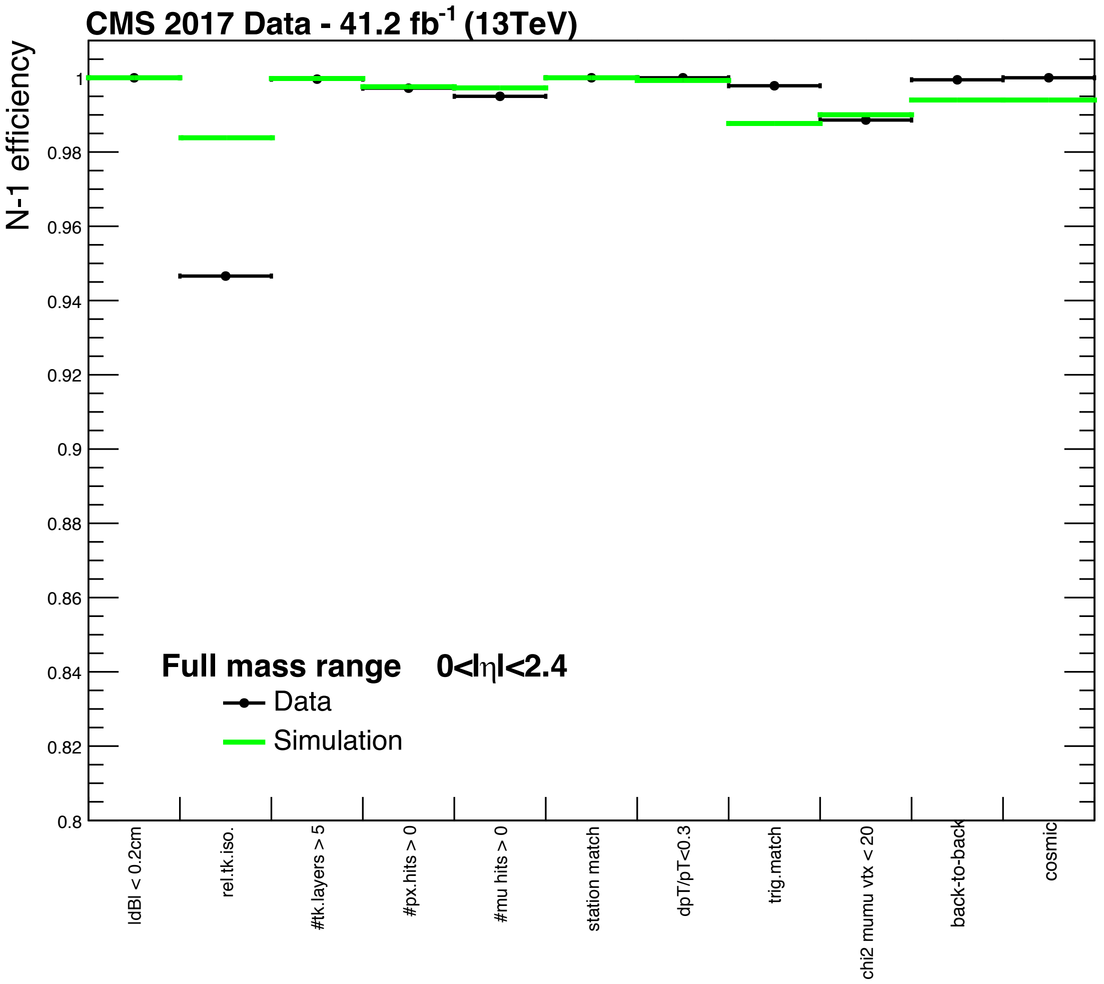
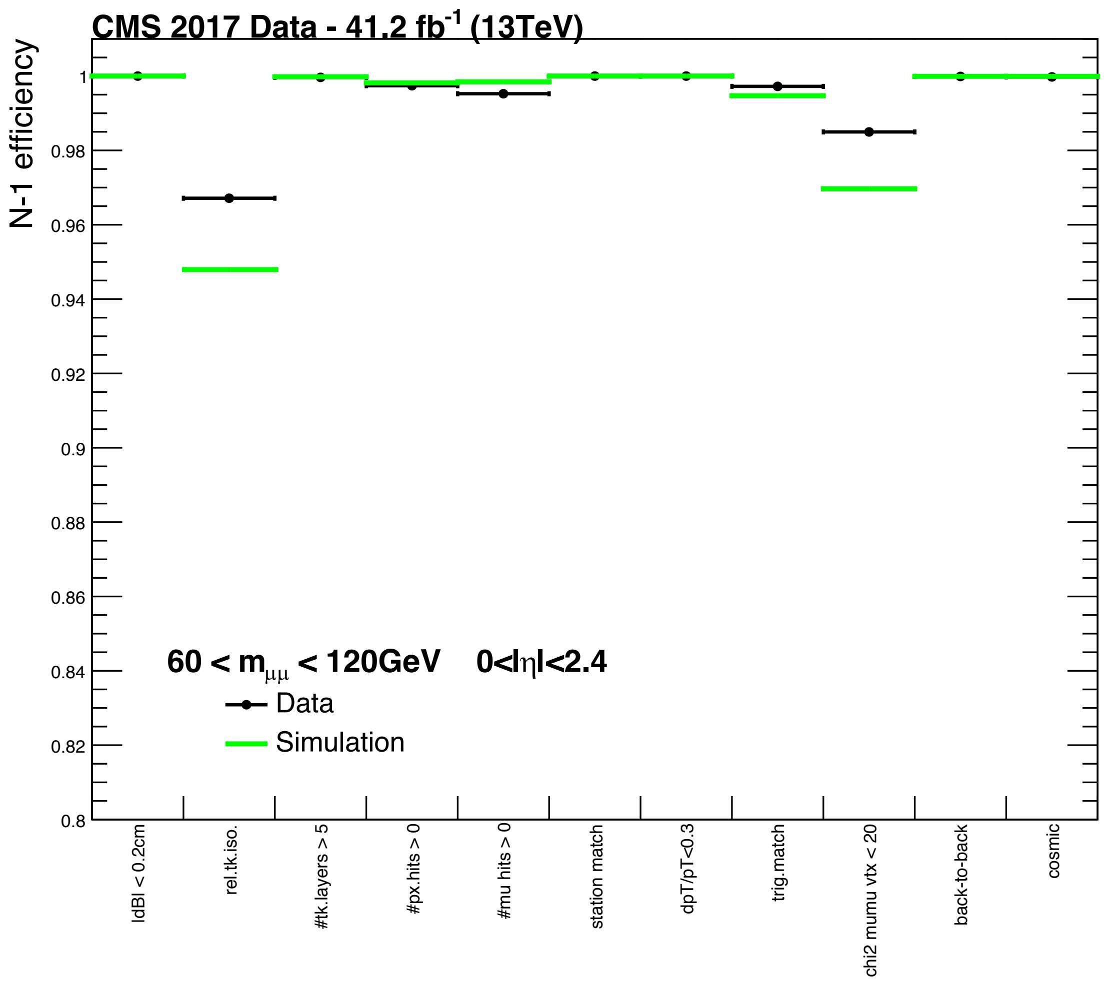


Figure 11: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the full mass range. Here “Simulation” includes all the backgrounds.

Jet bkgs are removed from simulation



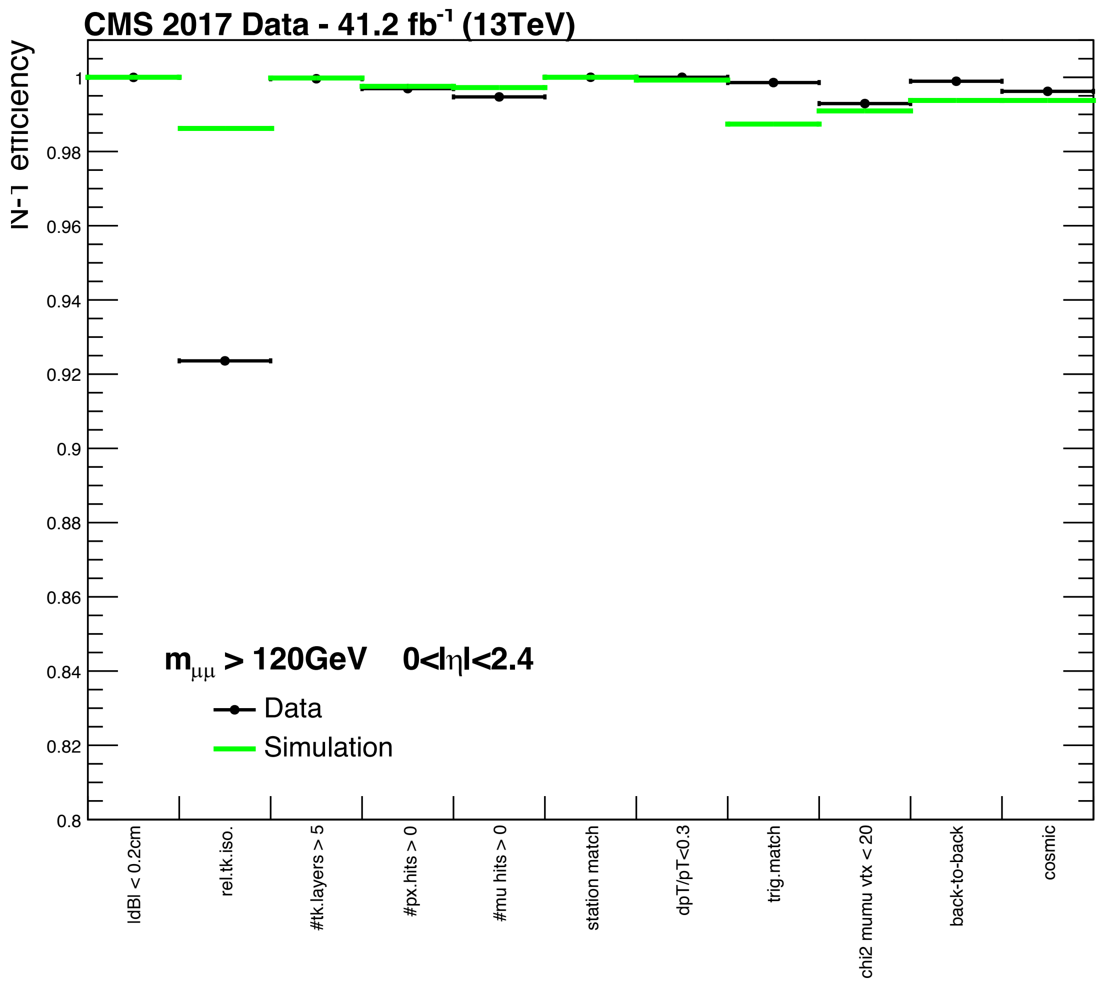


Figure 12: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: $60 < m_{\mu\mu} < 120$ GeV (left) and $m_{\mu\mu} > 120$ GeV (right) for the full pseudo-rapidity range.

Jet bkgs are removed from simulation

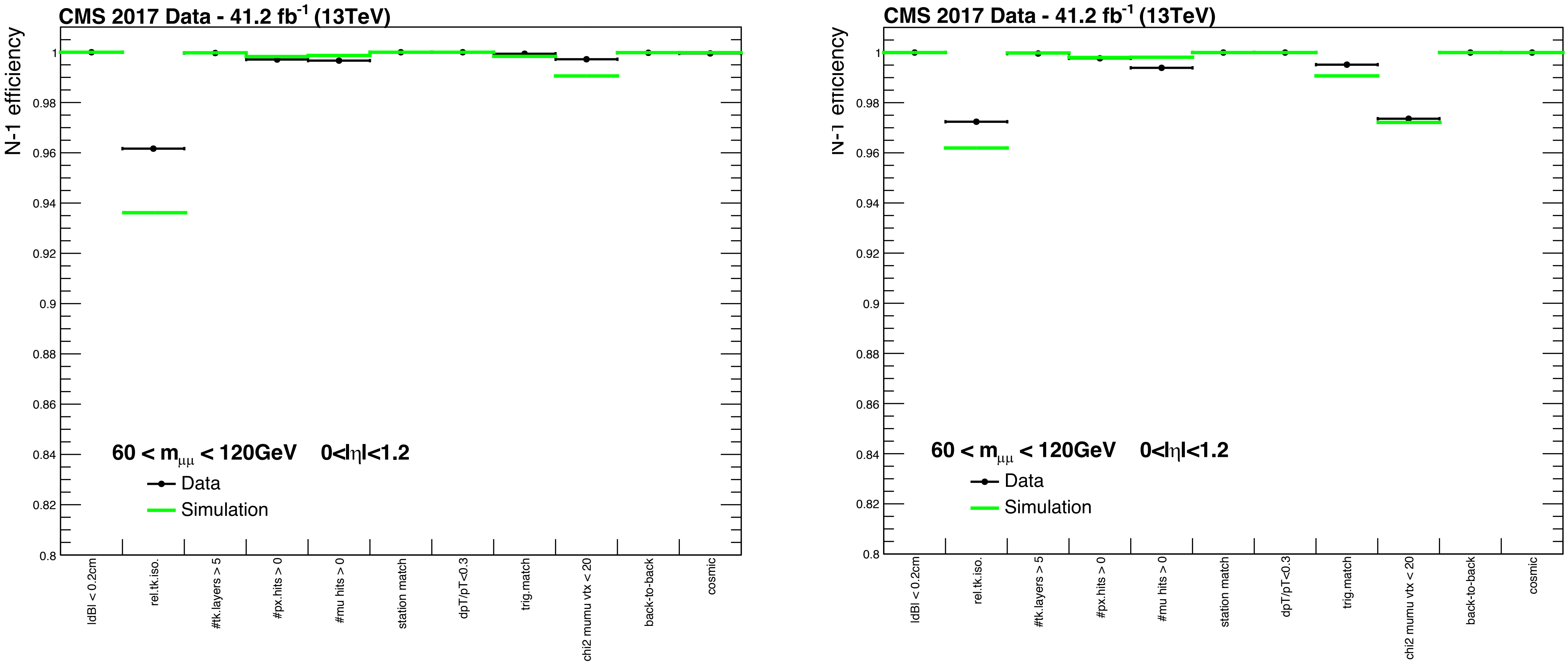


Figure 13: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: $0.0 < |\eta| < 1.2$ (left) and $1.2 < |\eta| < 2.4$ (right) for $60 < m_{\mu\mu} < 120$ GeV.

Jet bkgs are removed from simulation

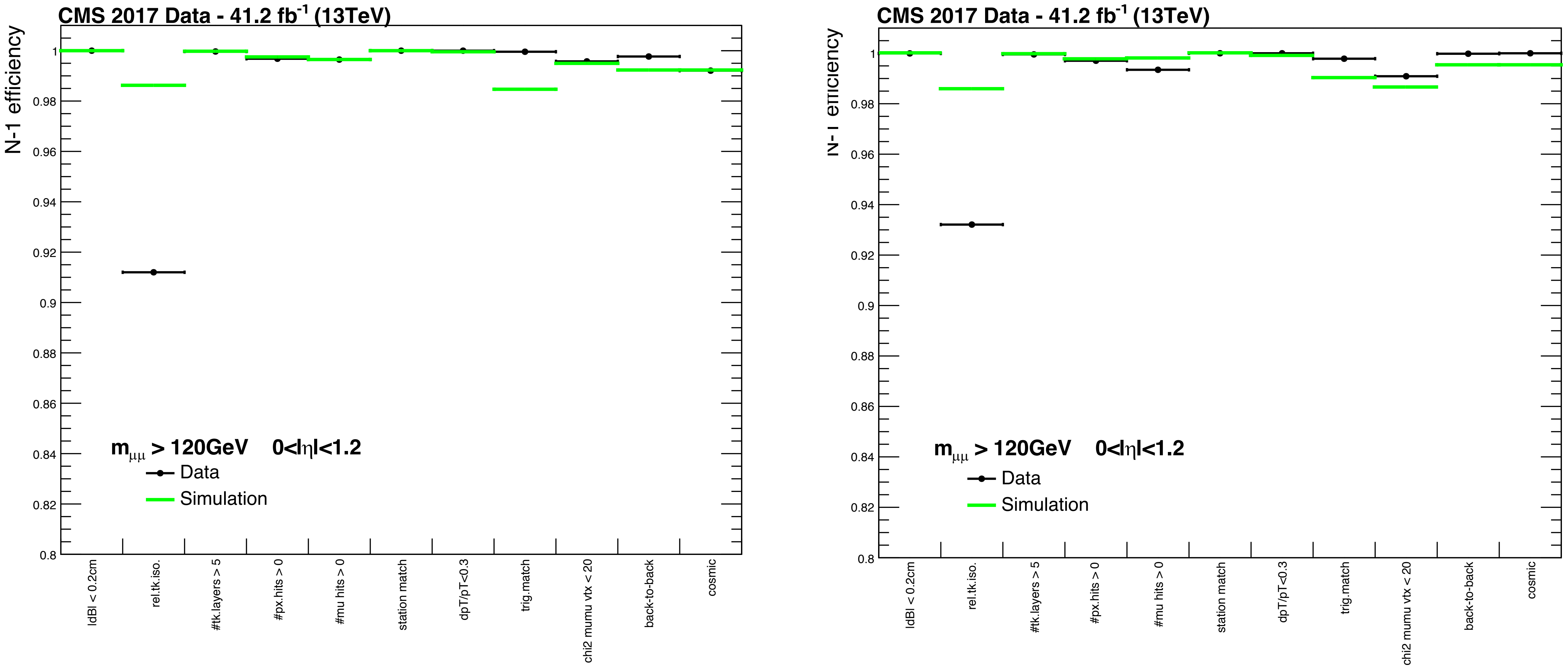


Figure 14: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: $0.0 < |\eta| < 1.2$ (left) and $1.2 < |\eta| < 2.4$ (right) for $m_{\mu\mu} > 120$ GeV.

Jet bkgs are removed from simulation

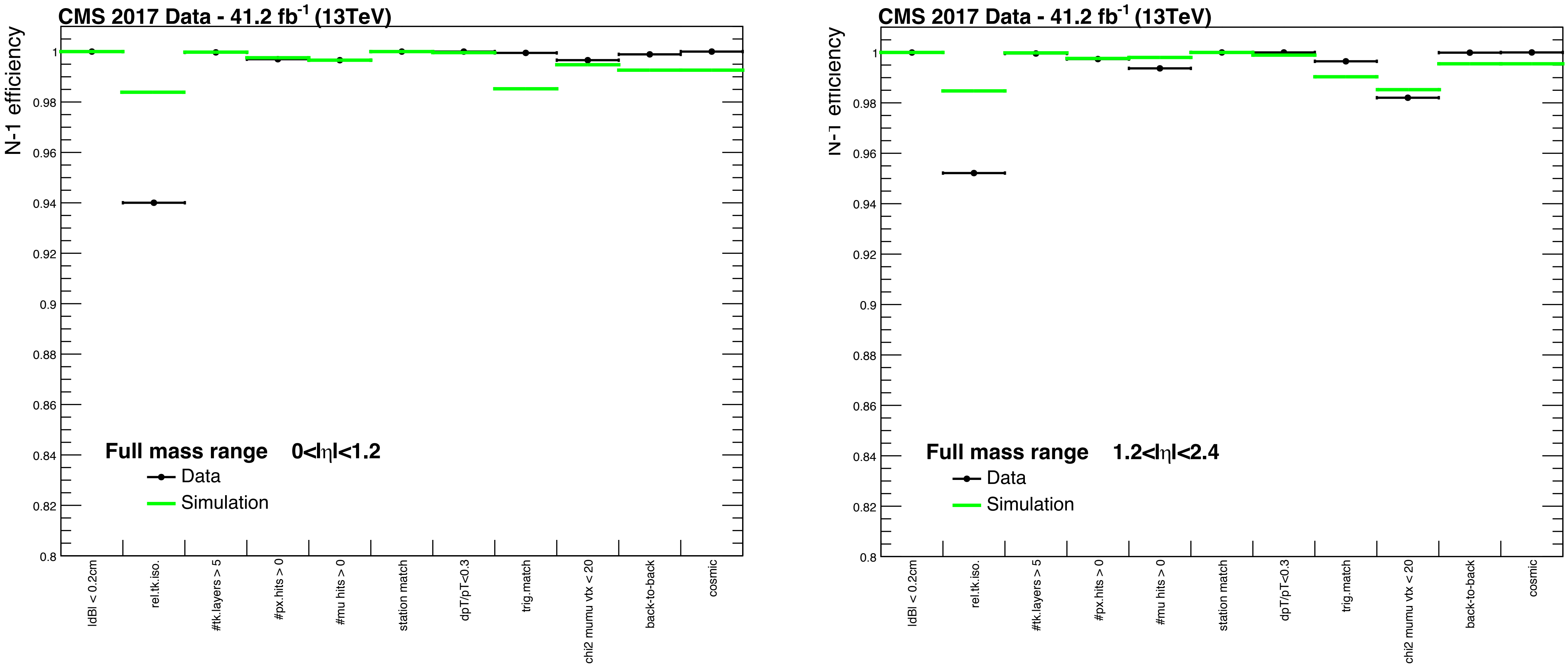


Figure 15: The ratio of the number of events that pass all selection cuts to the number of events passing all cuts but the one indicated, for the regions: $0.0 < |\eta| < 1.2$ (left) and $1.2 < |\eta| < 2.4$ (right) for the full mass range

Backup

Data sets and run selection

Data set	Run range
2017	
/SingleMuon/Run2017B-31Mar2018-v1	297050 – 299329
/SingleMuon/Run2017C-31Mar2018-v1	299368 – 302029
/SingleMuon/Run2017D-31Mar2018-v1	302031 – 302663
/SingleMuon/Run2017E-31Mar2018-v1	303824 – 304797
/SingleMuon/Run2017F-31Mar2018-v1	305045 – 306460
2018	
/SingleMuon/Run2018A-17Sep2018-v2	315257 – 316995
/SingleMuon/Run2018B-17Sep2018-v1	317080 – 319077
/SingleMuon/Run2018C-17Sep2018-v1	319337 – 320065
/SingleMuon/Run2018D-22Jan2019-v2	320673 – 325172

Table 01

- Integrated luminosity up to 42.1 fb^{-1} and 61.3 fb^{-1} for 2017 and 2018 runs, respectively calculated with the normtags using the corresponding Collisions17/13TeV/Final/Cert 294927-306462 13TeV PromptReco Collisions17 JSON MuonPhys.txt and Collisions18/13TeV/ReReco/Cert 314472-325175_13TeV_17SeptEarlyReReco2018ABC_PromptEraD_Collisions18_JSON_MuonPhys.txt

- The HLT path used: OR between three paths: HLT_Mu50, HLT TkMu100 and HLT OldMu100

2018 MC samples

Other background samples	***Cross-section[pb]**
/WJetsToLNu_TuneCP5_13TeV-madgraphMLM-pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	61526.7
/DYJetsToLL_M-50_TuneCP5_13TeV-madgraphMLM-pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v1/MINIAODSIM	6077.22
/ZZ_TuneCP5_13TeV-pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	16.523
/WZ_TuneCP5_13TeV-pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v3/MINIAODSIM	50.2
/WW_TuneCP5_13TeV-pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	118.7
/ST_tW_antitop_5f_inclusiveDecays_TuneCP5_13TeV-powheg-pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15_ext1-v1/MINIAODSIM	35.6
/ST_tW_top_5f_inclusiveDecays_TuneCP5_13TeV-powheg-pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15_ext1-v1/MINIAODSIM	35.6
/TTTo2L2Nu_TuneCP5_13TeV-powheg-pythia8/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v1/MINIAODSIM	88.29

Table 03

*Xsec values were cross checked and validated. Values in blue have been changed after the discussion with Alexander

2018 MC samples

Drell-Yan samples	***Cross-section[pb]**
/ZToMuMu_NNPDF31_13TeV-powheg_M_50_120/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	2112.904
/ZToMuMu_NNPDF31_13TeV-powheg_M_120_200/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	20.553
/ZToMuMu_NNPDF31_13TeV-powheg_M_200_400/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	2.866
/ZToMuMu_NNPDF31_13TeV-powheg_M_400_800/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	0.2517
/ZToMuMu_NNPDF31_13TeV-powheg_M_800_1400/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v1/MINIAODSIM	0.01707
/ZToMuMu_NNPDF31_13TeV-powheg_M_1400_2300/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	0.001366
/ZToMuMu_NNPDF31_13TeV-powheg_M_2300_3500/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	0.00008178
/ZToMuMu_NNPDF31_13TeV-powheg_M_3500_4500/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	3.19E-06
/ZToMuMu_NNPDF31_13TeV-powheg_M_4500_6000/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	2.79E-07
/ZToMuMu_NNPDF31_13TeV-powheg_M_6000_Inf/RunIIAutumn18MiniAOD-102X_upgrade2018_realistic_v15-v2/MINIAODSIM	9.57E-09

Table 04

- Moved to "RunIIFall17MiniAODv2-MUOTrackFix_12Apr2018_94X_mc2017_realistic_v14_ext1-v1" data set from "RunIIFall17MiniAODv2-PU2017_12Apr2018_94X_mc2017_realistic_v14-v2".

*Xsec values were cross checked and validated. Values in blue have been changed after the discussion with Alexander

4. Muon reconstruction and event selection

I. Trigger

- In the L1 trigger, single muons with p_T > 22 GeV are accepted.
- The main HLT path used for this analysis is *HLT Mu50*, that selects single muons with p_T>50GeV in the pseudo-rapidity range of the muon detector acceptance, $|\eta|$< 2.4. The main soup is (*HLT Mu50* OR *HLT OldMu100* OR *HLT TkMu100*)
- We use pre-scaled triggers *HLT Mu27* and a correspondingly reduced value of 30 GeV for the p_T cut for the offline muon to obtain the number of the Z events for Z-peak normalization.

II. Muon and dimuon selections

- We require a "good" offline-reconstructed primary vertex (PV) to be found in the event: at least four tracks must be associated to the vertex and the vertex must be located within |r| < 2 cm and |z| < 24 cm of the nominal interaction point (IP).

4. Muon reconstruction and event selection cont…

II. Muon and dimuon selections cont…

- To form a dimuon, we take two opposite charged muons that pass the following selection, denoted as High p_T selection:
  - the muon has to be reconstructed as “global” and “tracker” muon
  - the offline muon p_T must be at least 53 GeV, so as to be in the plateau of the single- muon trigger efficiency.
  - the relative p_T error dp_T / p_T is required to be smaller than 0.3, to ensure the quality of the p_T measurement.
  - transverse impact parameter of the muon with respect to the primary vertex, as measured by the tracker-only fit, must be smaller than 0.2 cm.
  - the muon must pass a relative tracker-only isolation cut: the scalar sum of the p_T of all other tracks in a cone of $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\varphi)^2} < 0.3$ around, excluding tracker track of the muon, must be less than 10% of the tracker track pT of the muon. To be used in the calculation of the tracker isolation, tracks have to be within $\Delta z = 0.2$ cm of the primary vertex with which the muon candidate is associated.

4. Muon reconstruction and event selection cont…

II. Muon and dimuon selections cont…

- the global muon track must have at least 6 tracker layers with hits in the fit.
- the global muon track fit must include at least one hit from each of the pixel detector and the muon system.
- the global muon track or the *TuneP* track should contain at least one valid muon hit in the muon system.
- the tracker muon must be matched to segments in at least one muon station if the muon is passing through the barrel crack and less then 2 segments are expected, or the muon station is not on the first layer of the muon system, or if matched to one muon station on the first layer with additional more then two RPC layers, or that the muon is matched in at least two muon stations.

- Once we have a dimuon candidates passing above requirements, at least one of the two muons should be matched (within $\Delta R < 0.2$) to the HLT muon candidate which triggered the events.

4. Muon reconstruction and event selection cont…

II. Muon and dimuon selections cont…

- We perform a fit to a common vertex to compute the kinematics of the dimuon system and its invariant mass. We only keep event for which the fit value returns a $\mathcal{X}^2$/ndof < 20. This ensures that the two muons originate from the same vertex, as a guard against the pile-up and as a check on reconstruction quality.
- Backgrounds from cosmic muons are rejected by requiring that the angle between the two muons be less than $\pi - 0.02$.
- If there are more than one opposite-sign dimuon pair passing all the above requirements, we first select a pair with invariant mass closest to the Z boson mass if the mass is within ±20 GeV of Z boson mass, and then the two muons with highest p_T are selected.