Jet mass predictions in dijet events with PYTHIA8

Reproduction of results published in JHEP 11 (2018) 113 by the CMS collaboration

Ola Lelek, Mees van Kampen

General info

General settings for the predictions:

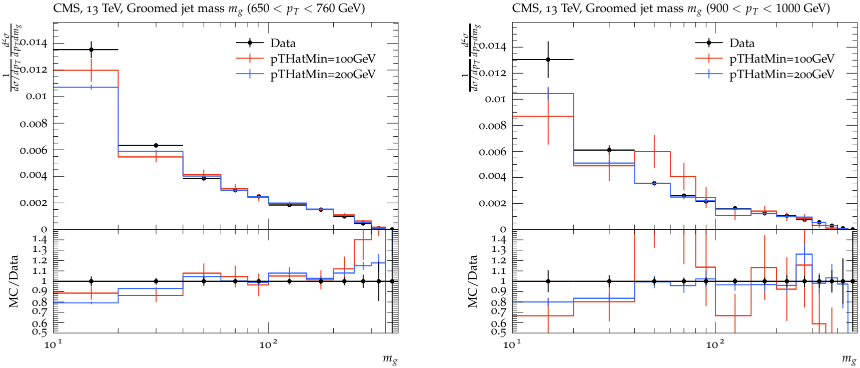
- HardQCD=on $\rightarrow$ 2 jets produced in hard interaction
- Tune and hard limits based on CMS analysis (CMS_2018_I1682495) arXiv:[1807.05974]: CUETP8M1 tune
- Centre of mass energy: 13 TeV
- Jet grooming with the "soft-drop" algorithm

Tested and solved:

- Dependence on lower cut of heavy boson transverse momentum *pTHatMin*
- Test effect from: ISR - FSR - Hadronization - MPI
- Issue: normalization for ungroomed jets with Rivet2.7.0 plugin is wrong
- Difference of Rivet versions

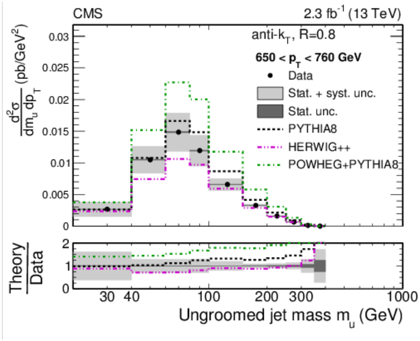
pTHatMin dependence

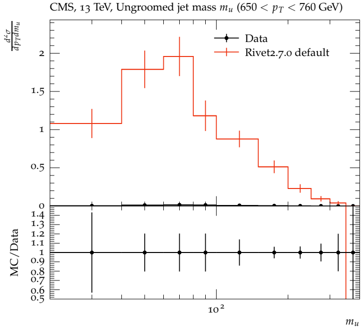
This only influences the precision / statistics.



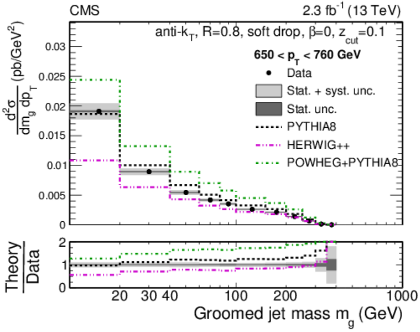
We use $pTHatMin = 200$ GeV, as is done in the paper.

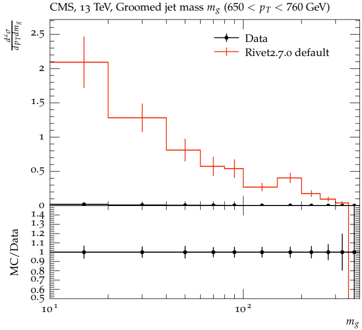
Plots with **absolute cross sections** were not normalized correctly in the default code of Rivet2.7.0. It can be seen by the large overshoot for data.





Here the same overshoot of data occurs. Now the jet mass of groomed jets is shown.





The origin of this incorrect normalization has been found in the analysis code. Differences between the Rivet2.7 plugin and the Rivet3.1 plugin are:

- the events for absolute cross section were weighted with an event weight
- the bins of absolute cross section were not divided by the binwidth

Rivet3.1.2

```
    // Find the appropriate pT bins and fill the histogram
    const size_t njetBin0 = findPtBin(j0.pt()/GeV);
    const size_t njetBin1 = findPtBin(j1.pt()/GeV);
    if (njetBin0 < N_PT_BINS_dj && njetBin1 < N_PT_BINS_dj) {
      for ( size_t jbin = 0; jbin < N_CATEGORIES; jbin++ ){
        _h_ungroomedJetMass_dj[njetBin0][jbin]->fill(j0.m()/GeV);
        _h_ungroomedJetMass_dj[njetBin1][jbin]->fill(j1.m()/GeV);
      }
    }

    // Now run the substructure algs...
    fastjet::PseudoJet sd0 = _softdrop(j0);
    fastjet::PseudoJet sd1 = _softdrop(j1);
    // ... and repeat
    if (njetBin0 < N_PT_BINS_dj && njetBin1 < N_PT_BINS_dj) {
      for ( size_t jbin = 0; jbin < N_CATEGORIES; jbin++ ){
        _h_sdJetMass_dj[njetBin0][jbin]->fill(sd0.m()/GeV);
        _h_sdJetMass_dj[njetBin1][jbin]->fill(sd1.m()/GeV);
      }
    }
  }


  /// Normalise histograms etc., after the run
+--  2 regels: void finalize() {-----------------------------------------
    for (size_t i = 0; i < N_PT_BINS_dj; ++i) {
      normalize(_h_ungroomedJetMass_dj[i][1]);
      normalize(_h_sdJetMass_dj[i][1]);
    }
    // Normalize the absolute cross section histograms to xs * lumi.
    for (size_t i = 0; i < N_PT_BINS_dj; ++i) {
      scale(_h_ungroomedJetMass_dj[i][0],   crossSection()/picobarn / sumOfWeights() / (ptBins_dj[i+1]-ptBins_dj[i]
      scale(_h_sdJetMass_dj[i][0],          crossSection()/picobarn / sumOfWeights() / (ptBins_dj[i+1]-ptBins_dj[i]
    }
  }
  //@}
```

Rivet2.7.0

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    // Find the appropriate pT bins and fill the histogram
    const size_t njetBin0 = findPtBin(j0.pt()/GeV);
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    if (njetBin0 < N_PT_BINS_dj && njetBin1 < N_PT_BINS_dj) {
      for ( size_t jbin = 0; jbin < N_CATEGORIES; jbin++ ){
        //_h_ungroomedJetMass_dj[njetBin0][jbin]->fill(j0.m()/GeV);
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        _h_ungroomedJetMass_dj[njetBin0][jbin]->fill(j0.m()/GeV, weight);
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      }
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  }


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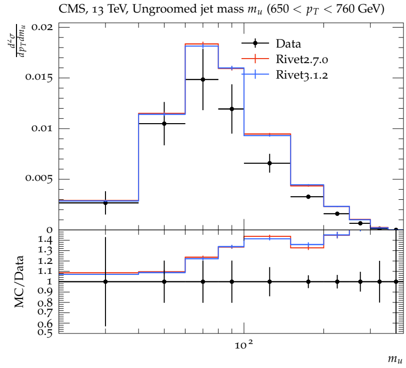
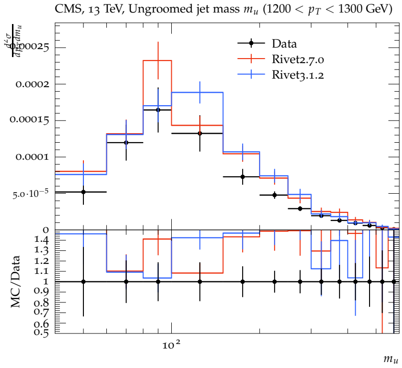
      scale(_h_ungroomedJetMass_dj[i][0],   crossSection()/picobarn / sumOfWeights());
      scale(_h_sdJetMass_dj[i][0],          crossSection()/picobarn / sumOfWeights());
    }
  }
  //@}
```

With changes in the .cc file in Rivet2.7.0, the normalization issue is solved. Also using a newer Rivet version solves the problem with absolute cross sections:





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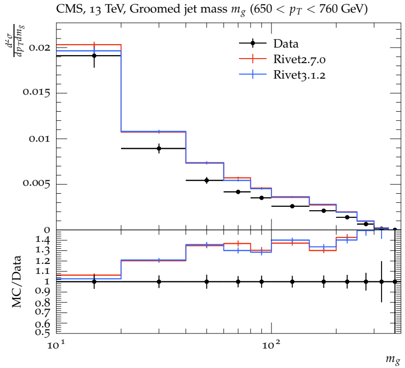
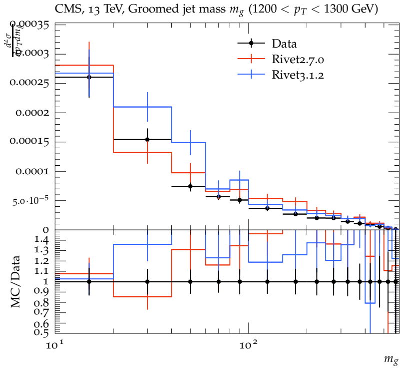
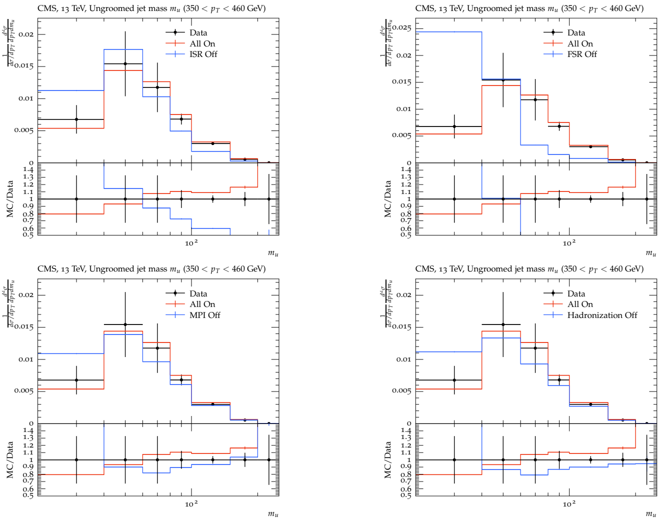




Check influence of ISR - FSR - Hadronization and MPI

The influence of parton showers, hadronization models and multi-parton interaction is investigated.



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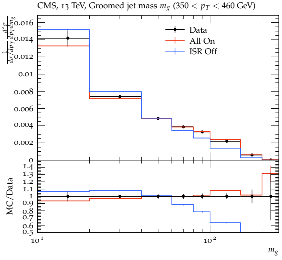
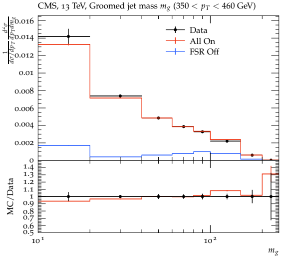
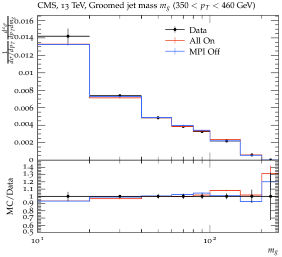
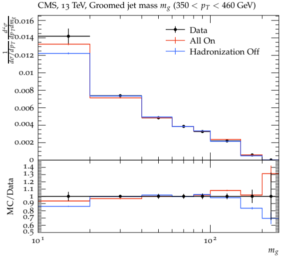
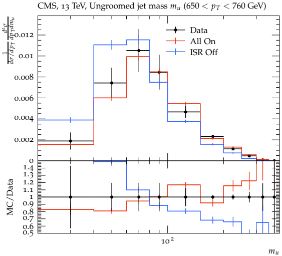


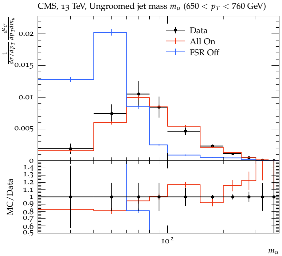


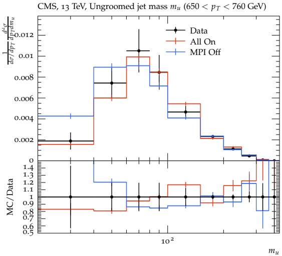


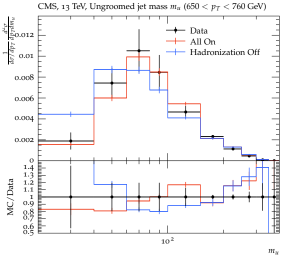


We conclude that the final state radiation is of most influence on the results.









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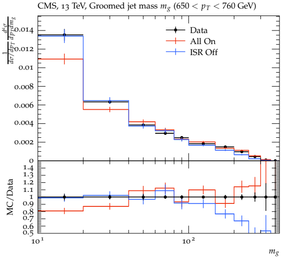
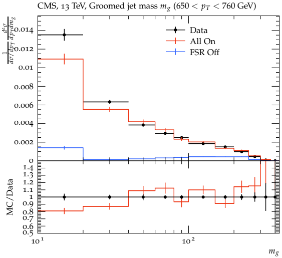
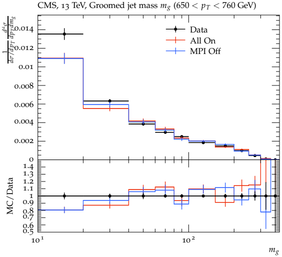
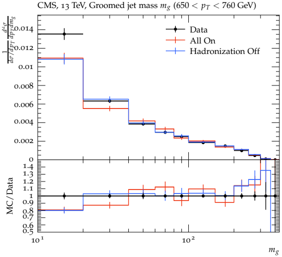




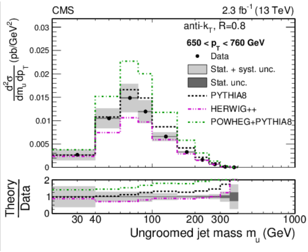


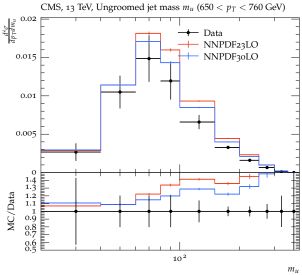


Use of NNPDF30_lo_as_0130 vs default NNPDF23 LO in CUETP8M1

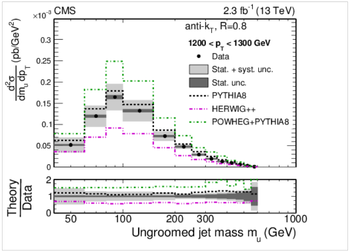
Absolute, Ungroomed cross section

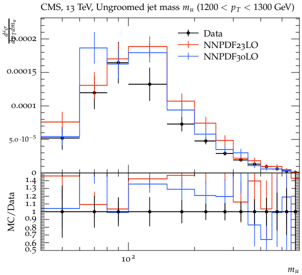
$650 < p_T < 760$ GeV





$1200 < p_T < 1300$ GeV





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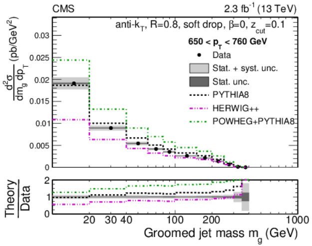

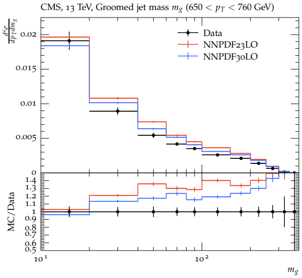

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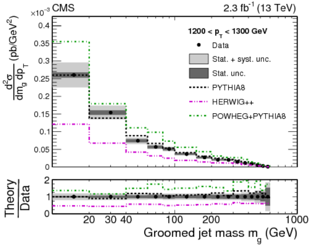
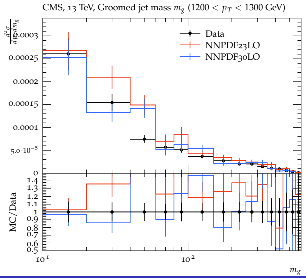
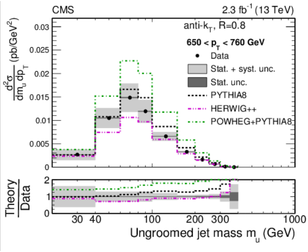
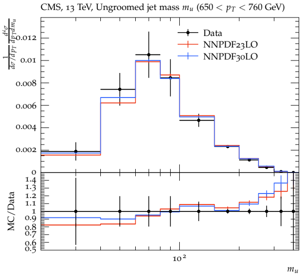




Normalized, Ungroomed cross section

$650 < p_T < 760$ GeV





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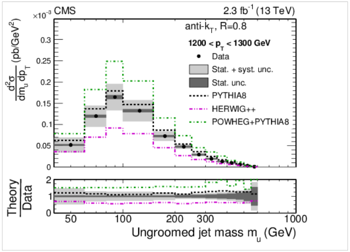
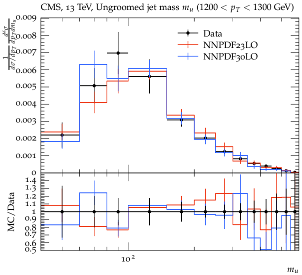
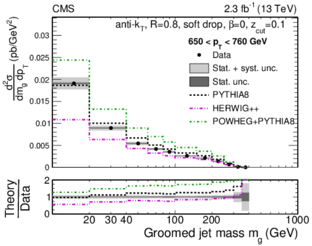
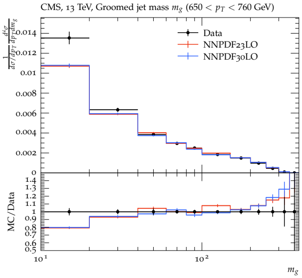




Normalized, Groomed cross section

$650 < p_T < 760$ GeV





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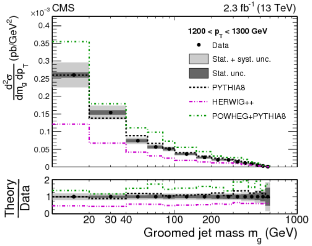
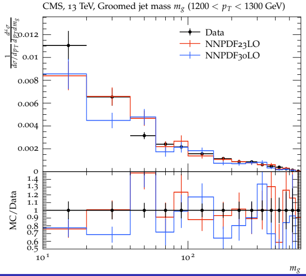
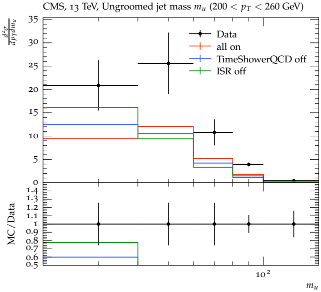
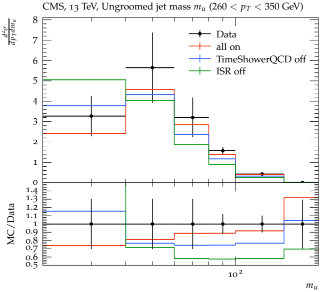
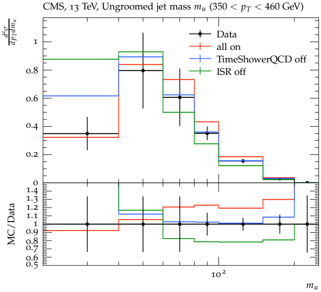


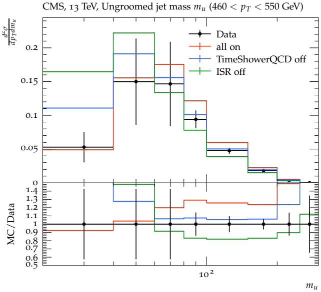


Checks to see the effect of the TimeShower:QCDshower.









Initial state showering (with NNPDF3.0)

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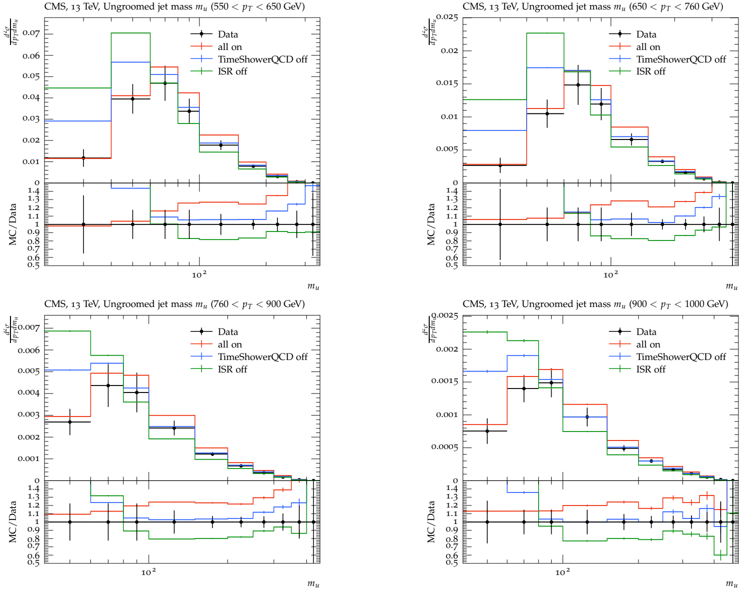

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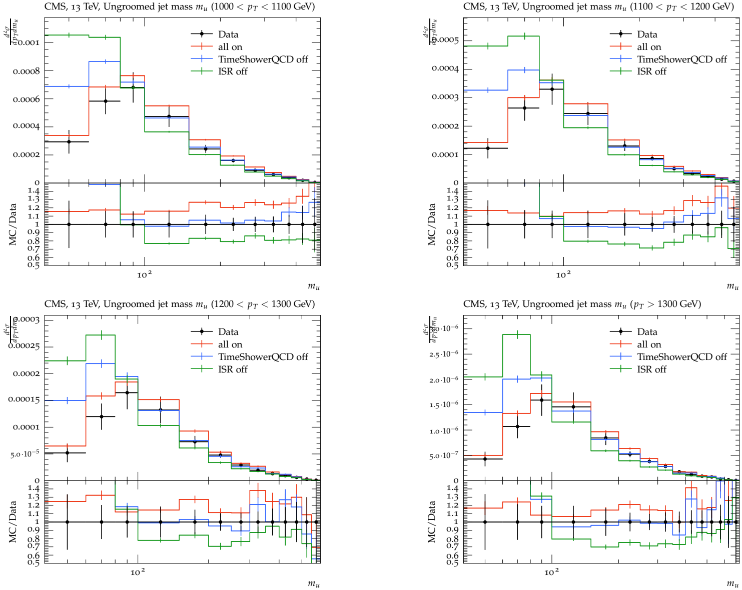

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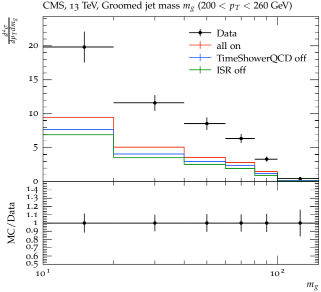

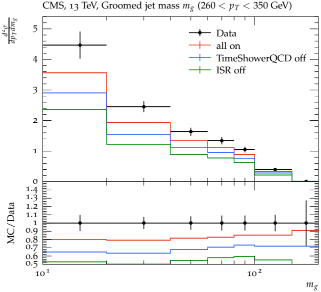

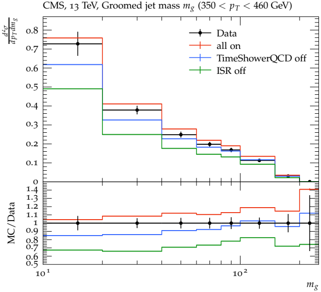

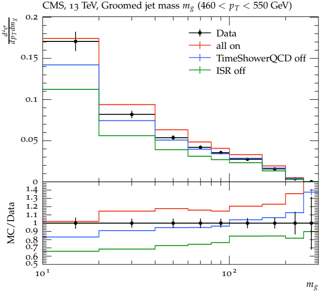

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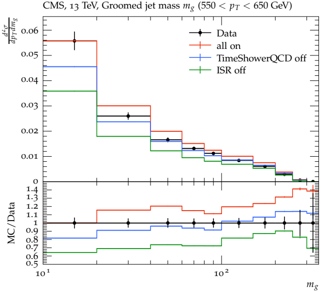

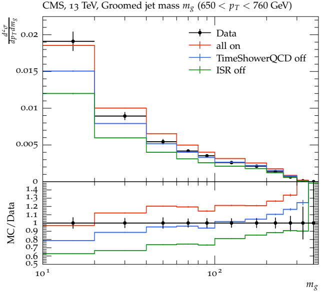

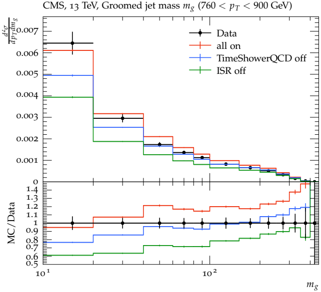

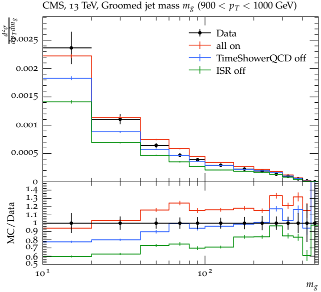

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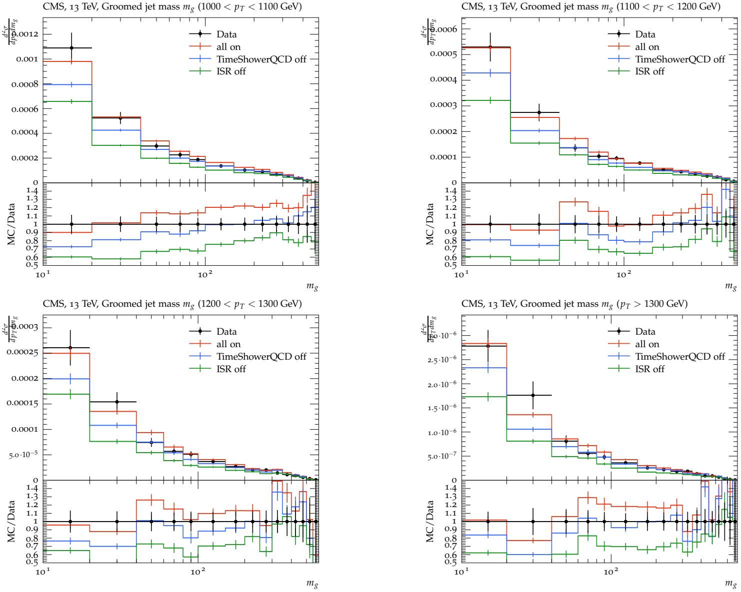

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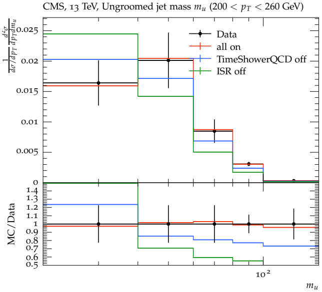
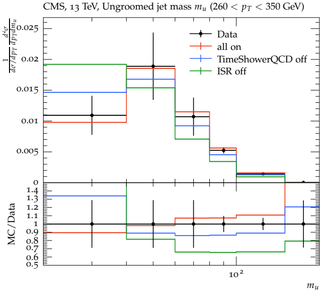
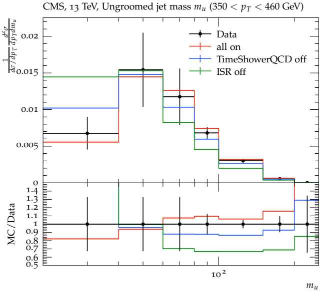
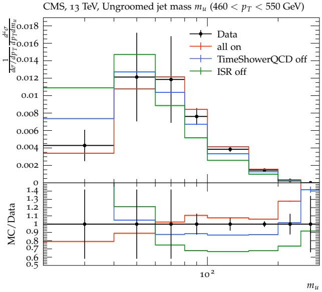
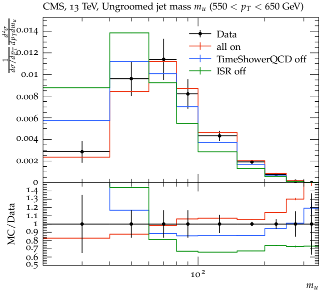


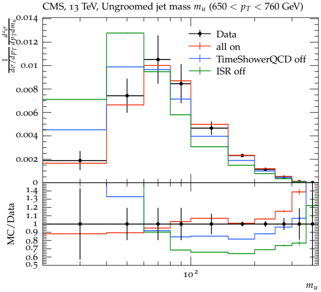


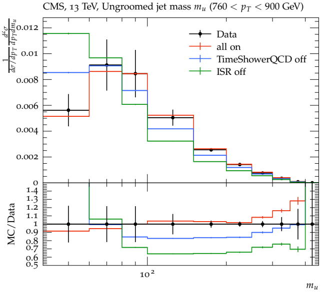


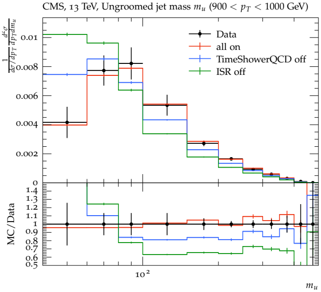


Checks to see the effect of the TimeShower:QCDshower.

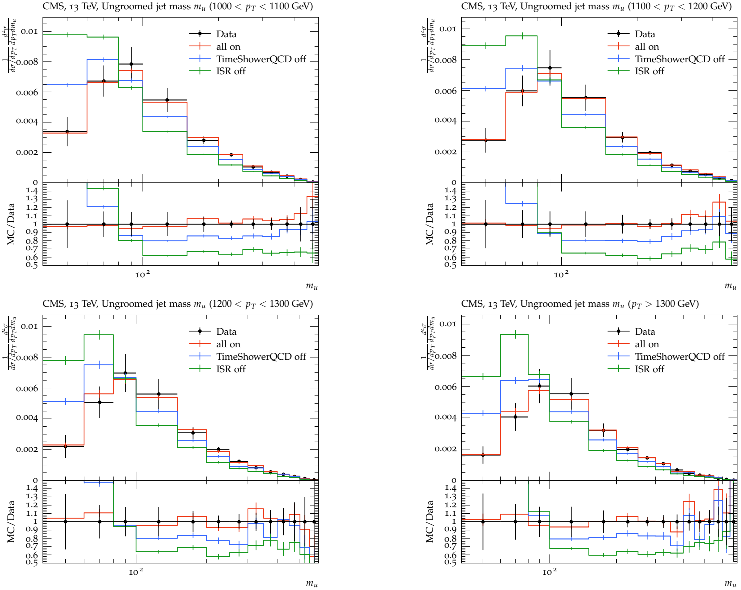






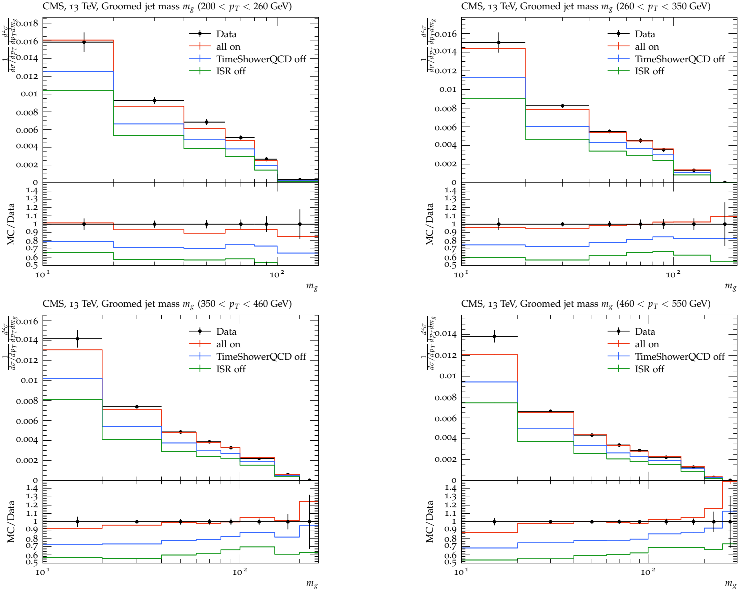


Checks to see the effect of the TimeShower:QCDshower.

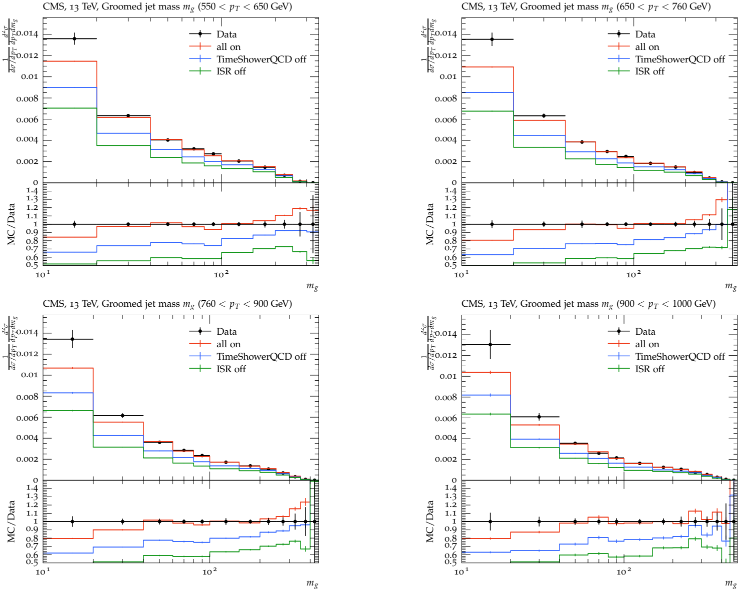


Initial state showering (with NNPDF3.0)

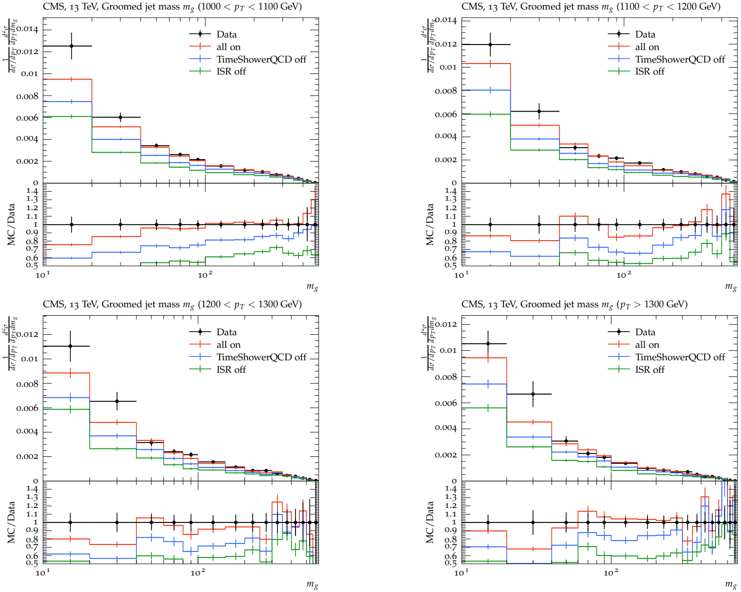
Checks to see the effect of the TimeShower:QCDshower.



Checks to see the effect of the TimeShower:QCDshower.



Checks to see the effect of the TimeShower:QCDshower.



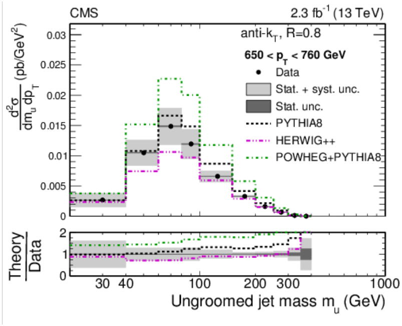
Final results for jet mass in dijet events with PYTHIA8.2.44

Final predictions with PYTHIA8

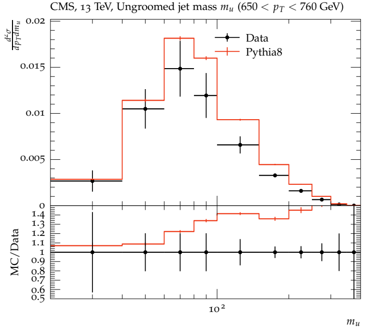
- #events = 10,000,000
- Rivet3.1.2
- Plugin: CMS_2018_I1682495
- pTHatMin = 200 GeV
- with ISR, FSR, MPI and Hadronization
- CUETP8M1 tune (with NNPDF23_lo)

Absolute cross section
$650 < p_T < 760$ GeV
Ungroomed

Paper

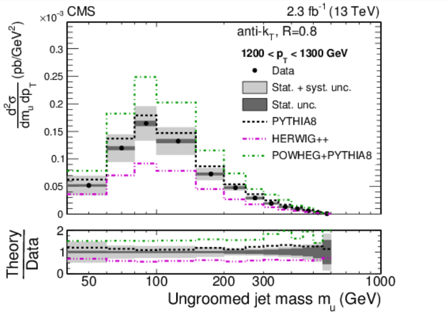


PYTHIA8

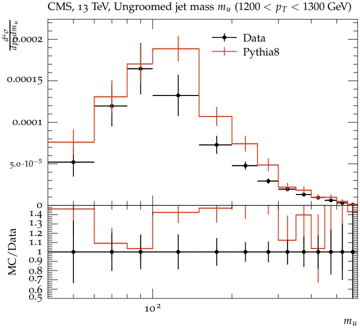


$1200 < p_T < 1300$ GeV
Ungroomed

Paper

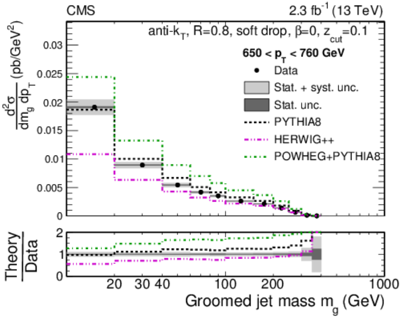


PYTHIA8



$650 < p_T < 760$ GeV
Groomed

Paper



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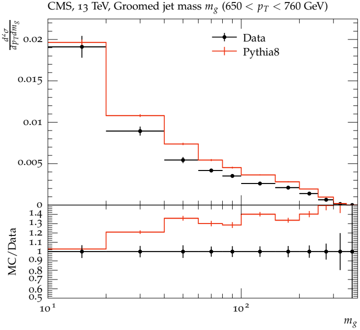
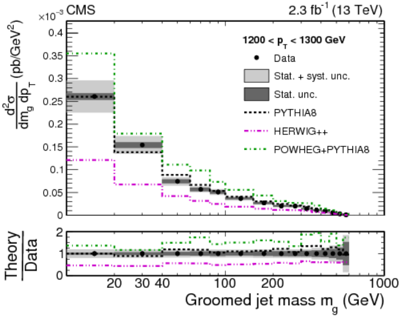
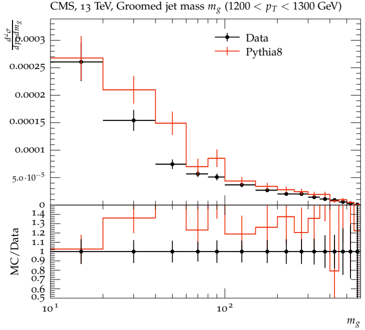


$1200 < p_T < 1300$ GeV
Groomed

Paper

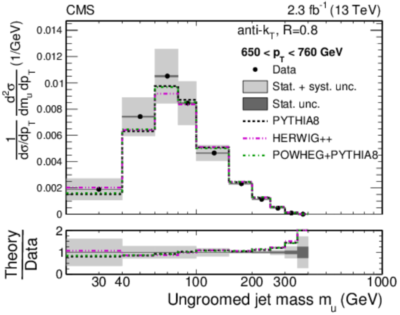


PYTHIA8

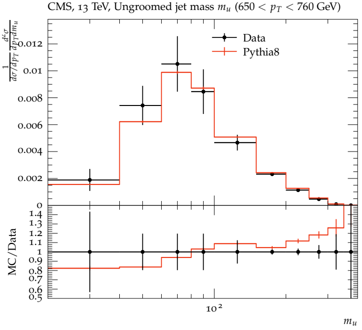


$650 < p_T < 760$ GeV
Ungroomed

Paper

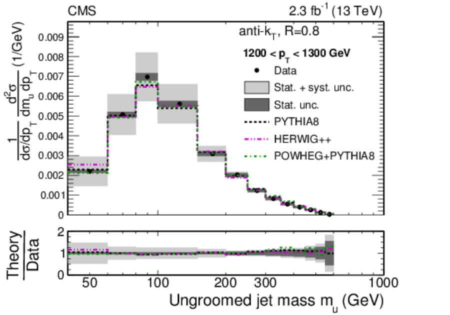


PYTHIA8

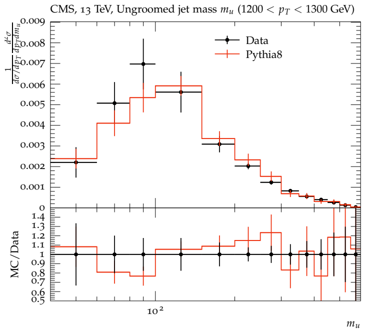


$1200 < p_T < 1300$ GeV
Ungroomed

Paper

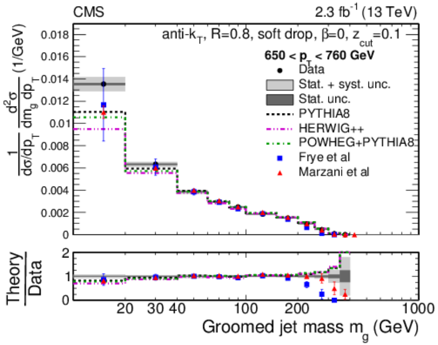


PYTHIA8

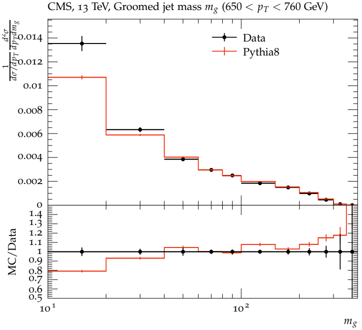


$650 < p_T < 760$ GeV
Groomed

Paper

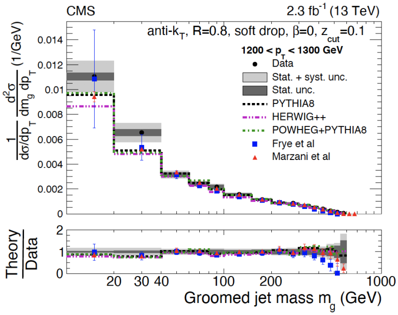


PYTHIA8

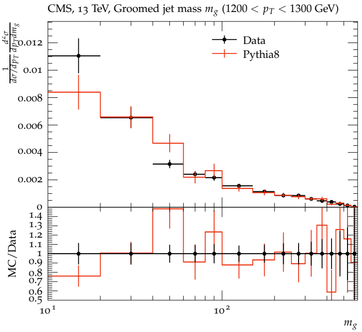


$1200 < p_T < 1300$ GeV
Groomed

Paper



PYTHIA8



Bins with deviations: by eye comparison

The predictions done with Pythia8 by CMS and by ourselves seem to differ in some mass bins. This comparison is done by eye.

Bins that deviate from CMS results

Plot	#bin with deviation
Absolute, ungroomed, 650 < pT < 760 GeV	-
Absolute, ungroomed, 1200 < pT < 1300 GeV	4, 6
Absolute, groomed, 650 < pT < 760 GeV	2
Absolute, groomed, 1200 < pT < 1300 GeV	2, 3, 5
Normalized, ungroomed, 650 < pT < 760 GeV	-
Normalized, ungroomed, 1200 < pT < 1300 GeV	2, 3
Normalized, groomed, 650 < pT < 760 GeV	-
Normalized, groomed, 1200 < pT < 1300 GeV	2, 3