Jet Measurements in CMS

International Conference In High Energy Physics 2012

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On behalf of CMS Collaboration

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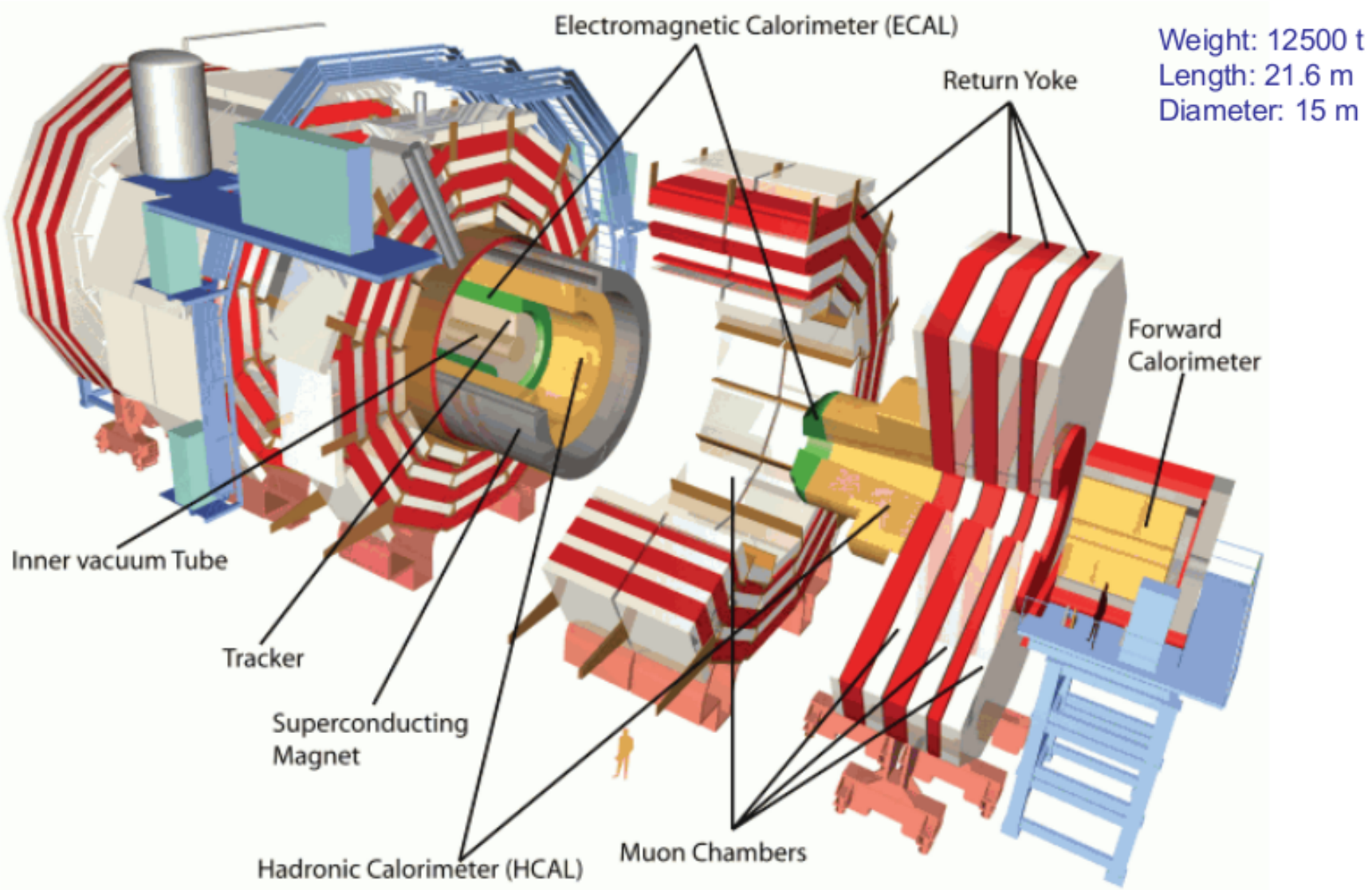
The CMS Detector



Motivation

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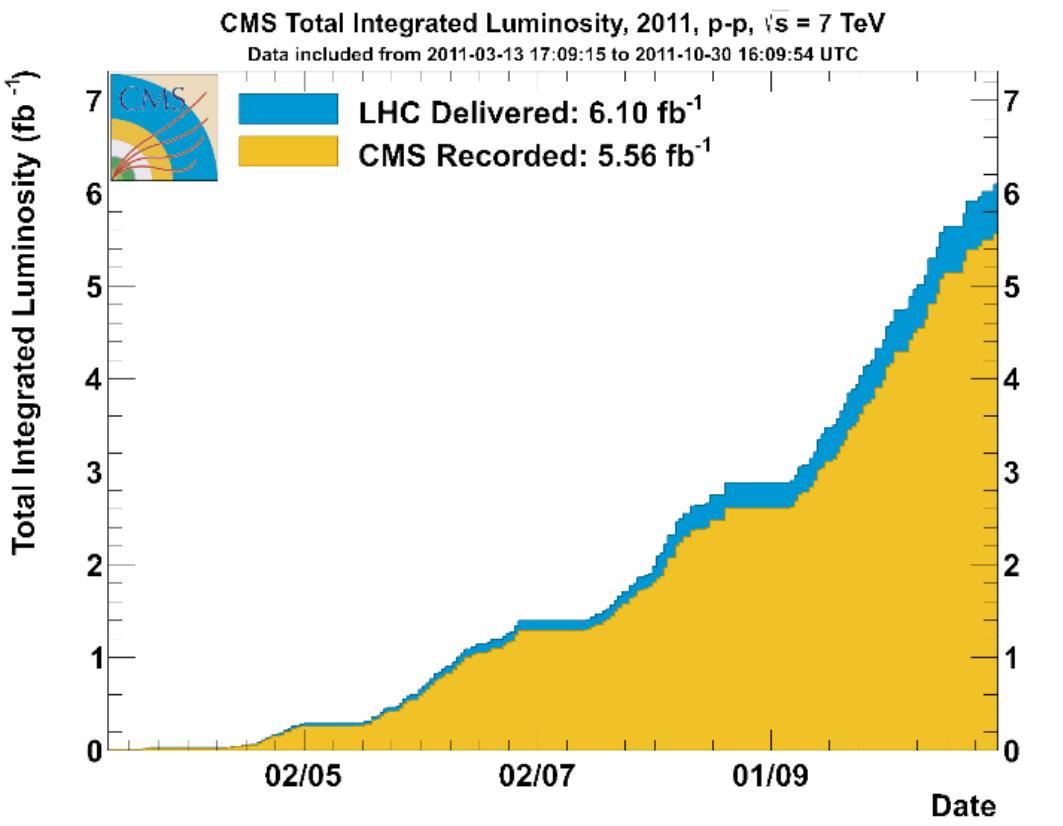
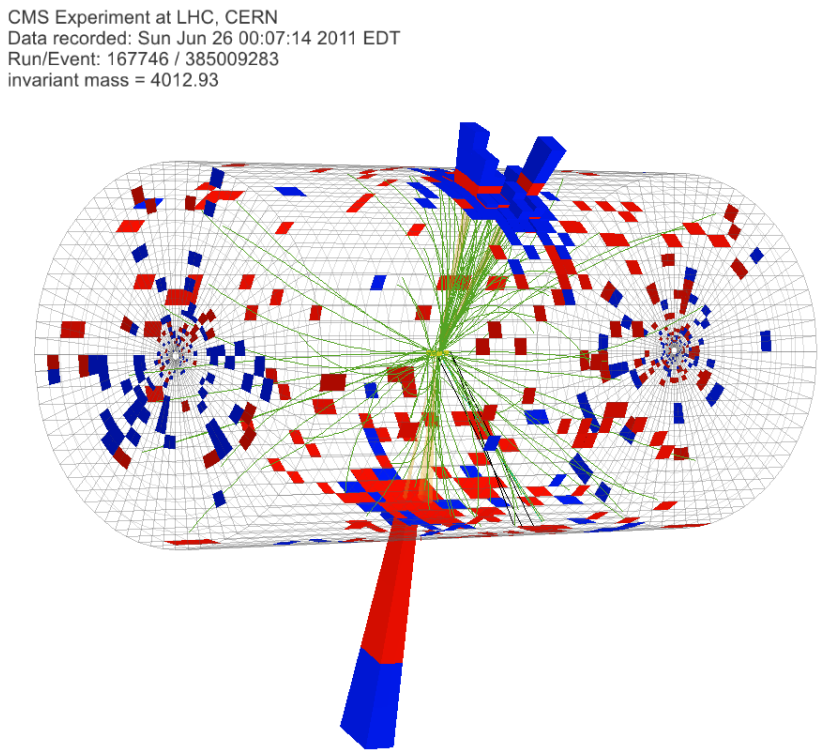
- Jet observables are used to constrain the parameters of Parton Distribution Function (PDF).
- From different jet observables, one can constrain the value of strong coupling constant α_s.
- Jet substructure studies help us to understand and tune the Monte Carlo simulations better.
- Jet sudies are used to test different parton shower models and NLO theory prediction.

Luminosity In CMS



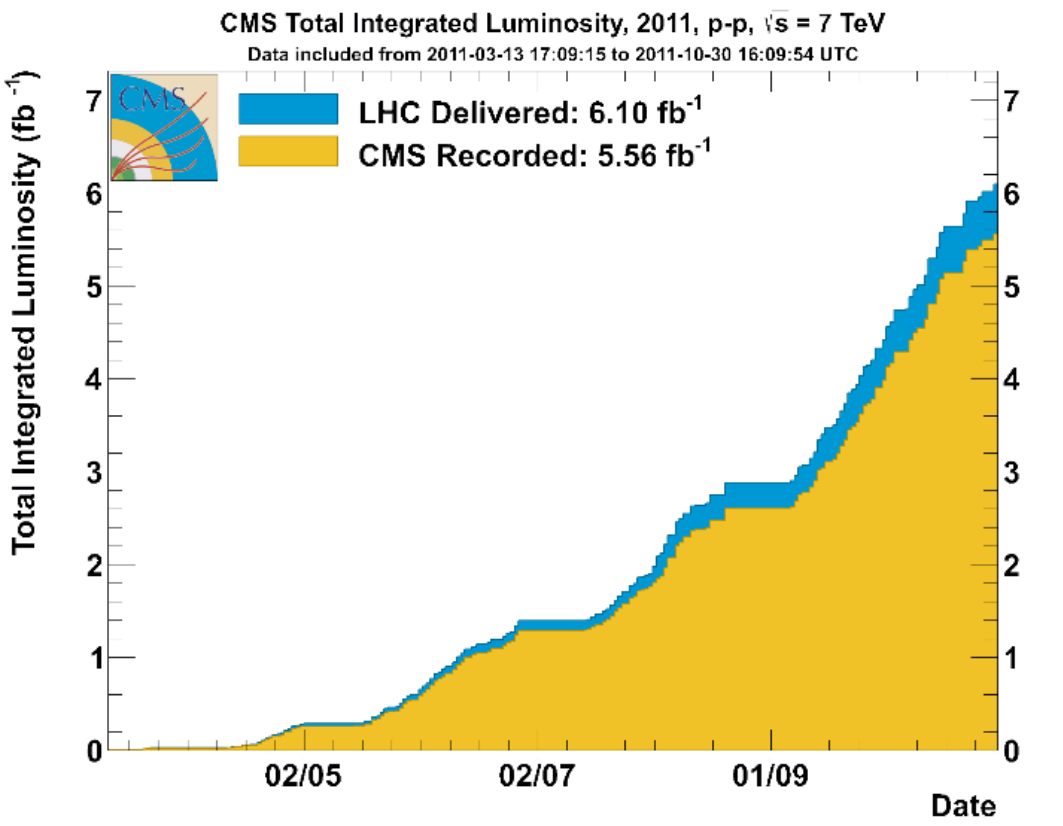


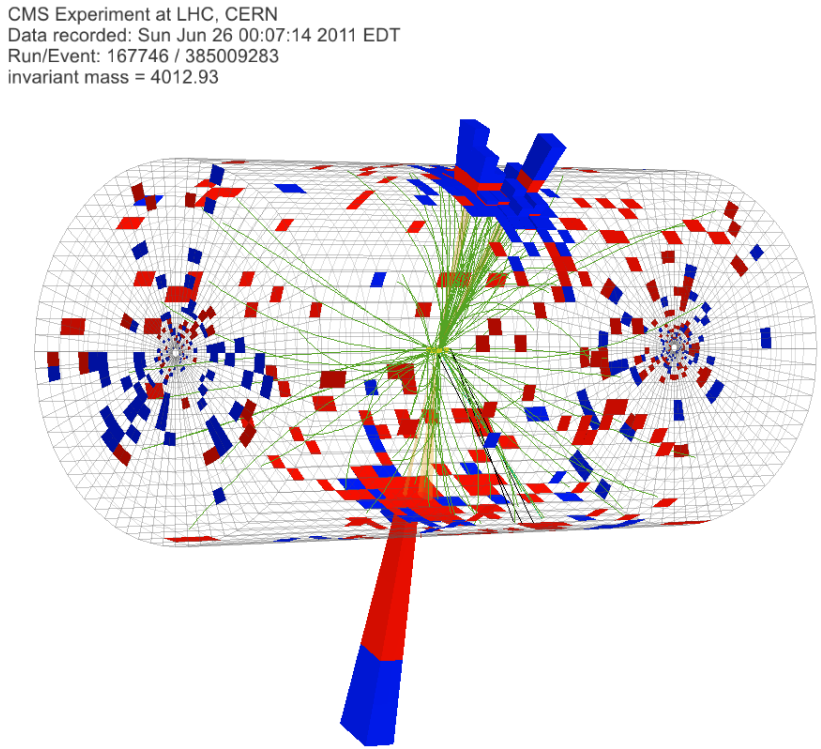
Increasing luminosity with time

A DiJet Event

Increasing Energy and Luminosity may lead to NEW Physics

Luminosity In CMS





Increasing luminosity with time

A DiJet Event

Increasing Energy and Luminosity may lead to NEW Physics

- At such energy scales Jet p_T varies from 0.1 to 2 TeV.
- Dijet Invariant Mass for Jets lies between 0.3 to 5 TeV.

Particle Flow Algorithm

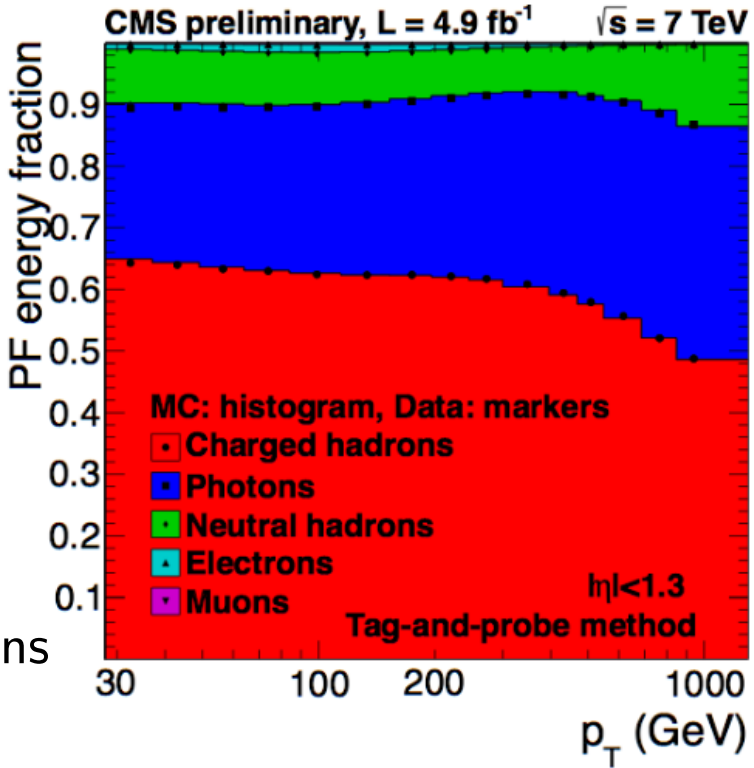
- Particle Flow (PF) algorithm is an event reconstruction technique which attempts to reconstruct and identify all stable particles in an event.

•Particle flow algorithm combines all information from several sub detectors .

Tracker + Ecal + Hcal Info $\rightarrow$ Stable Particles :

$$\mu^+,\mu^-,e^+,e^-,\gamma,\pi^+,\pi^-,\pi^0,K^+,K^-,K^0,..$$

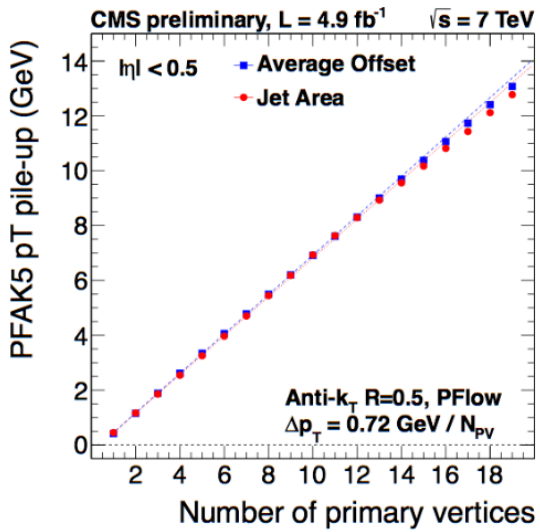
Jet compositions



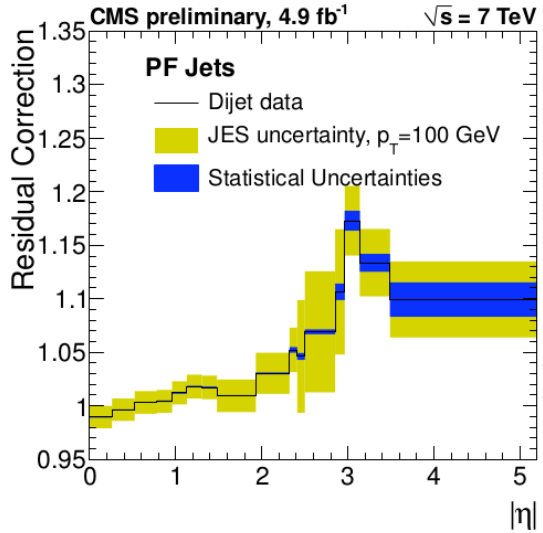
Jet Energy Correction

•Jet Energy Correction is necessary to measure the correct energy spectrum of the jets.
The main three type of corrections required are OffSet(PU Subtraction), Relative(for η dependent response) and Absolute(for p_T dependent response) + Residual corrections.

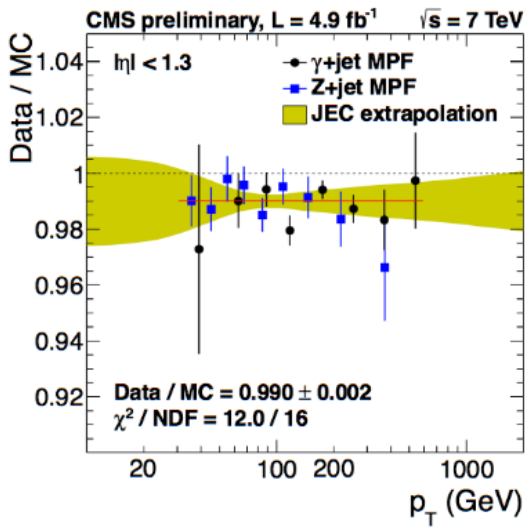
•OffSet $\rightarrow$ Subtracting $\rho \times A$
•Relative $\rightarrow$ Dijet Balance
•Absolute $\rightarrow$ $\gamma + jet$ or $Z + jet$ p_T Balance



PU Energy vs NPV



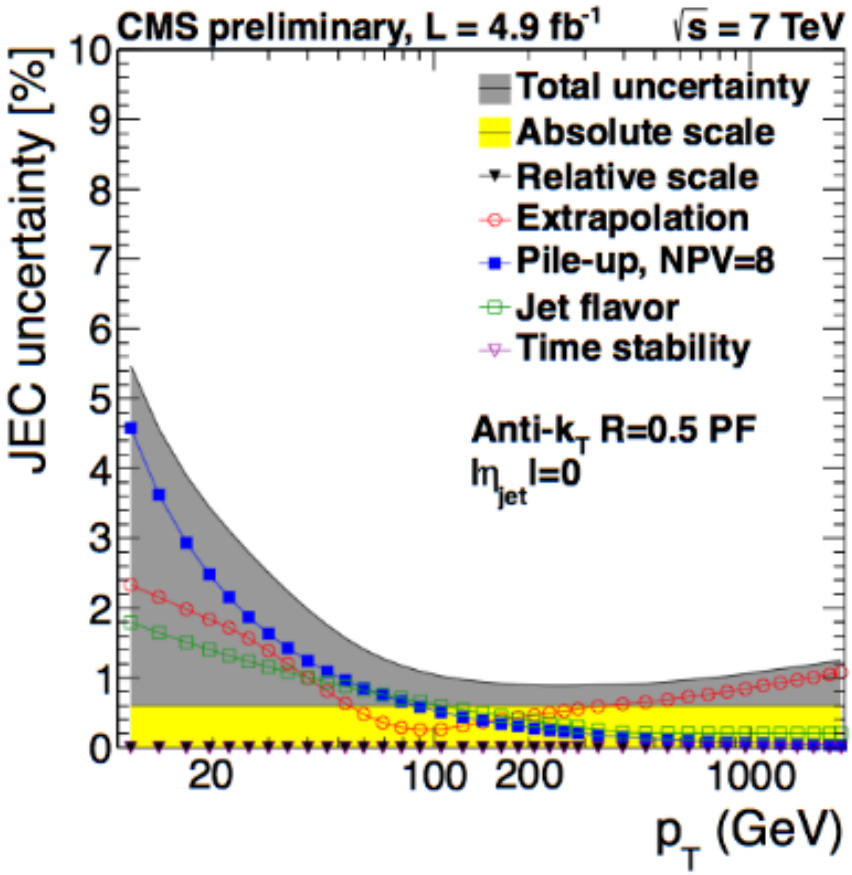
Relative Factor vs $|\eta|$

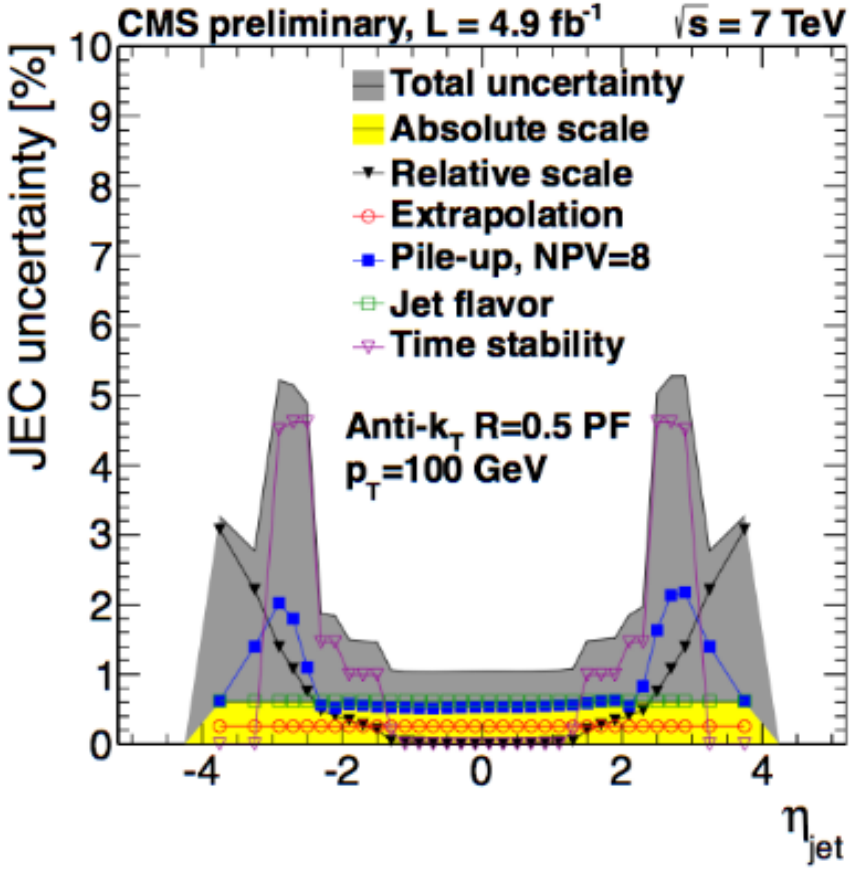


Absolute Factor vs p_T

Jet Energy Correction (CMS DP -2012/006)

•The JEC Uncertainty factor is combined of several correlated and uncorrelated sources. Its variation as a function of jet p_T and η is the following :



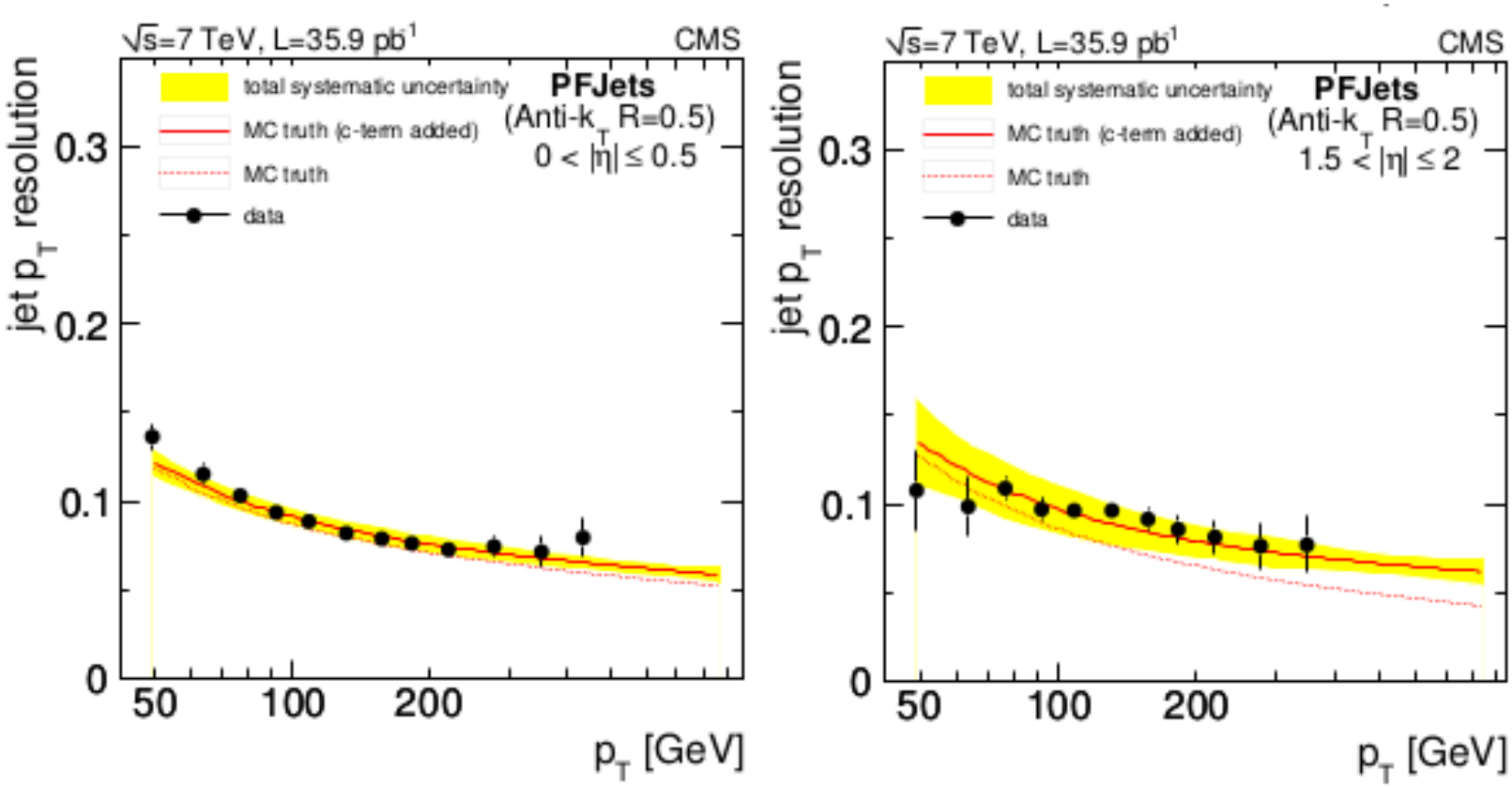


JEC factor varies from 5% to 1% with increasing p_T

JEC factor varies from 5% to 1% with varying η

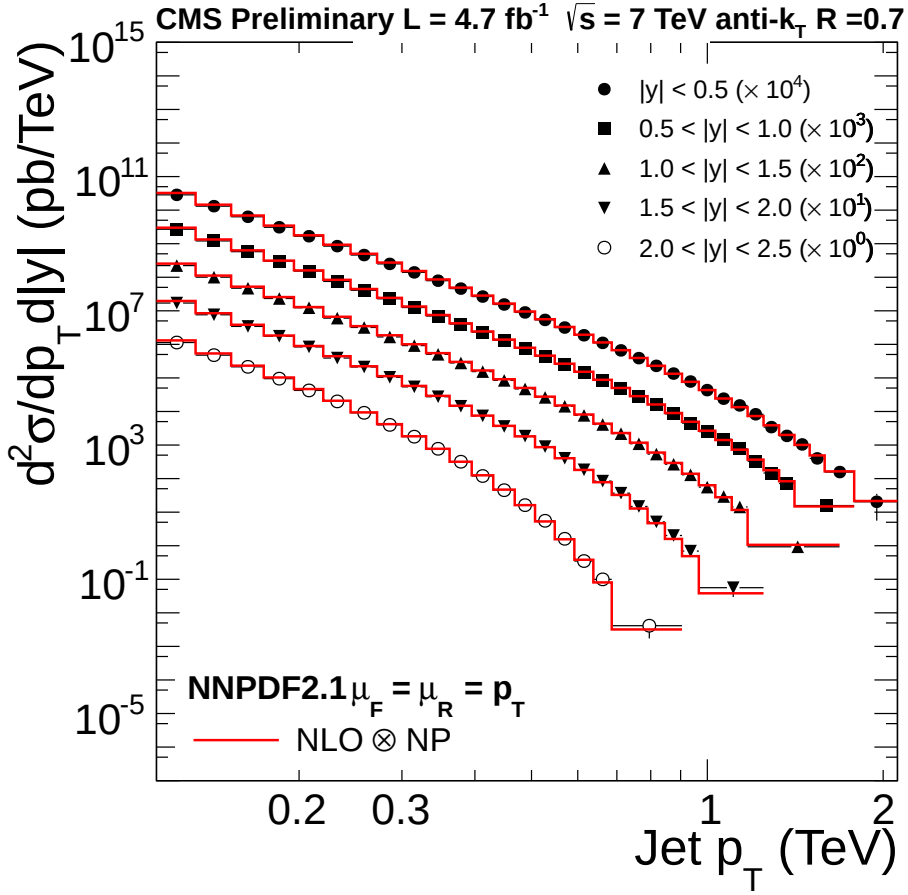
Jet Energy Resolution (2011 JINST 6 P11002)

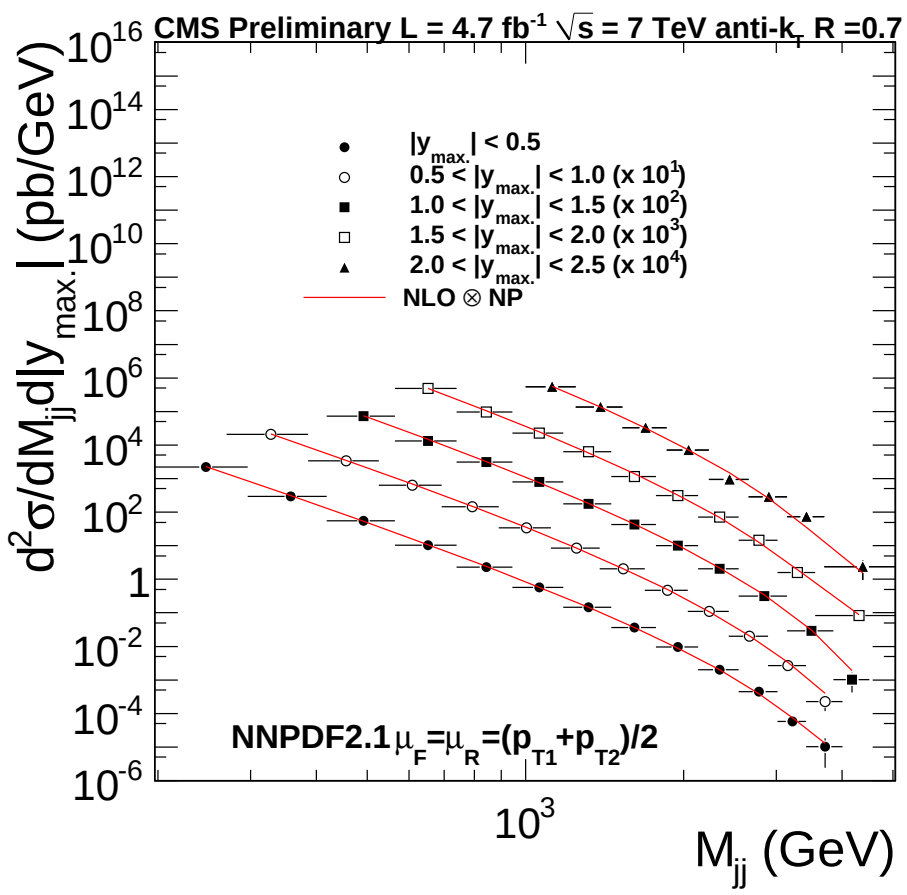
•JER $\frac{\sigma(p_T)}{p_T}$ is determined from data by Dijet Asymmetry, $\gamma + jet$ and $Z + jet$ balance method



JER factor varies between 15% to 10% with increasing p_T

Differential Cross Section Spectrum (CMS PAS QCD-11-004)





Unfolded Double Differential Spectrum as function of Jet p_T and M_{jj}

$NLO \times NP$ theory prediction(with NNPDF) is compared with the measured spectrum. The measurement is done upto rapidity $|y| = 2.5$ at an interval of 0.5

Experimental Uncertainty and NonPerturbative Correction

•The uncertainty on the measured cross section due to several uncertainty sources are following :

→ Jet Energy Scale : 10% - 30%

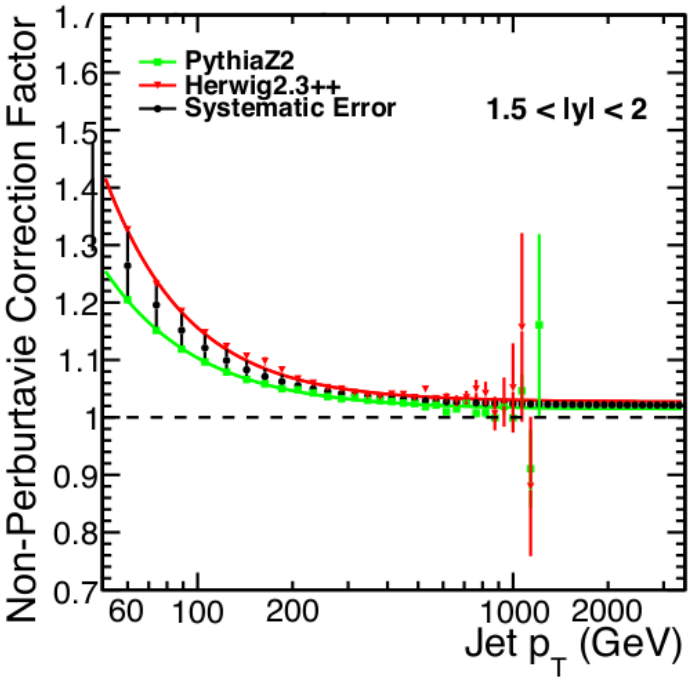
→ Luminosity : 2.2%

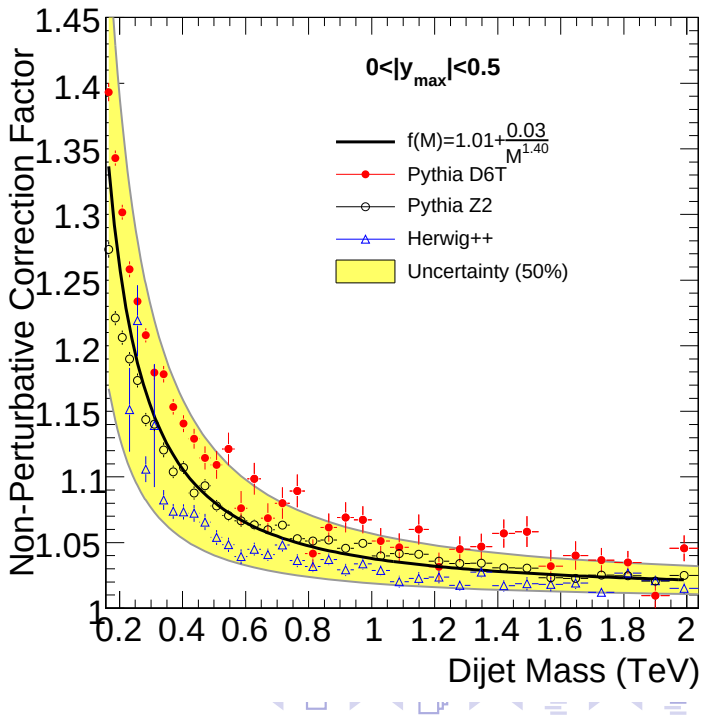
→ Jet Energy resolution : 1% - 3%

•NP correction is applied on parton level calculations to match the particle level results. It is applied to account for

→ Multi Parton Interaction (MPI)

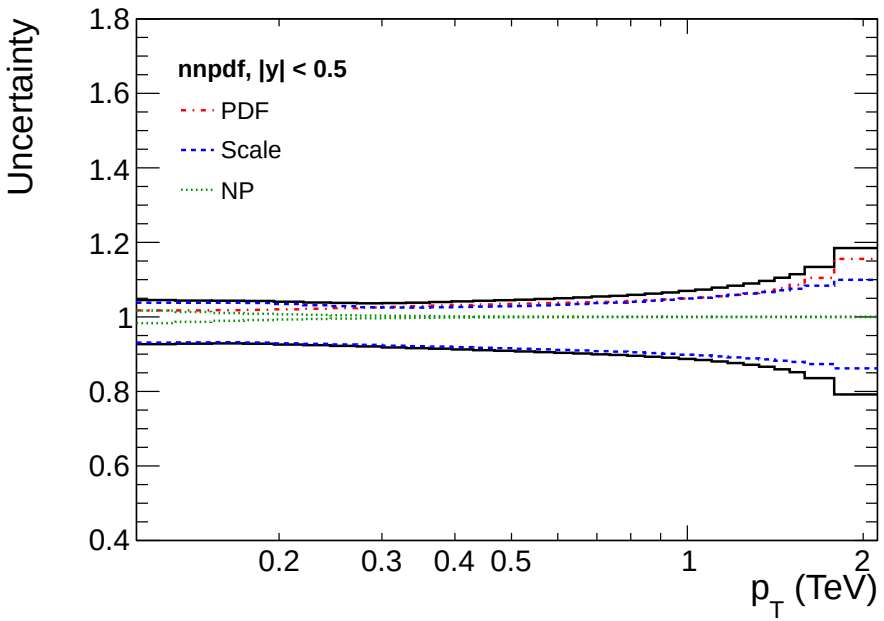
→ Hadronization Effects

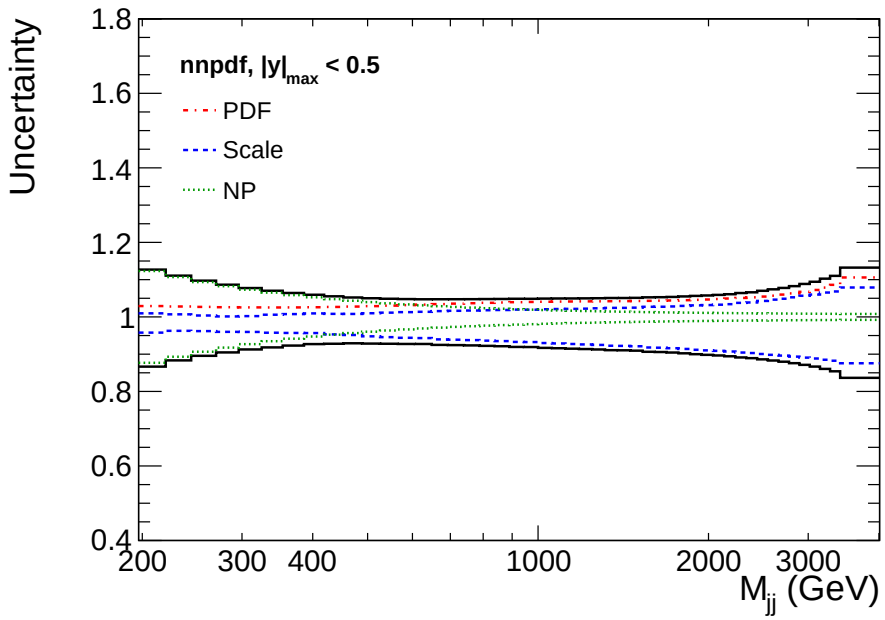




NLO QCD Calculations and Uncertainties

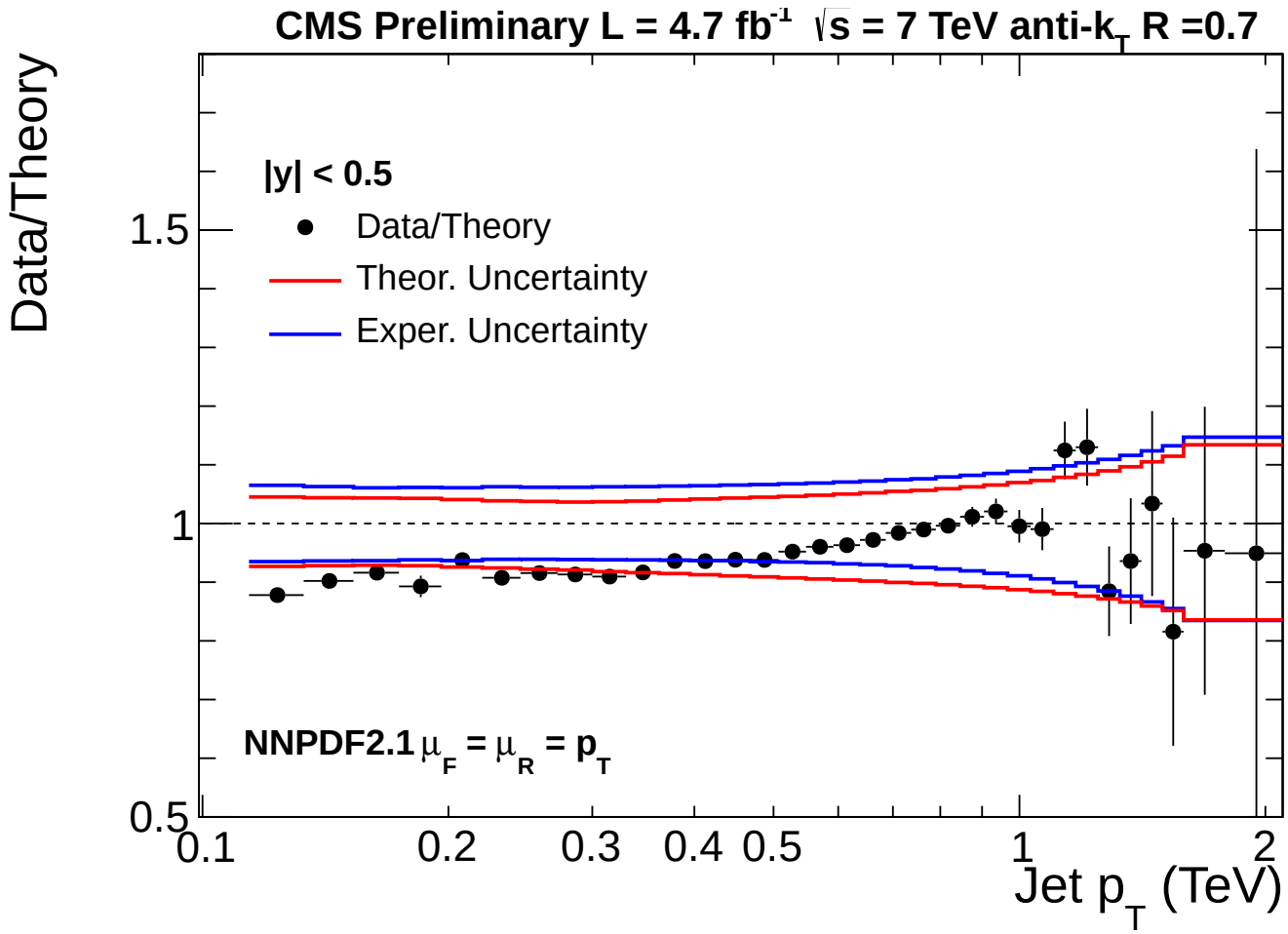
- The NLO calculations are done using the NLOJet++ program using the FastNLO package.
- To calculate the NLO QCD prediction, the scales
  $\mu_R = \textbf{Jet } p_T = \mu_F$ for Inclusive Jet
  $\mu_R = \textbf{Avg } p_T = \mu_F$ for DiJet
- The NLO prediction is derived for five different PDF sets viz: CT10, MSTW, NNPDF2.1, HERAPDF1.5, ABKM09.
- The PDF variation introduces upto 30% uncertainty.





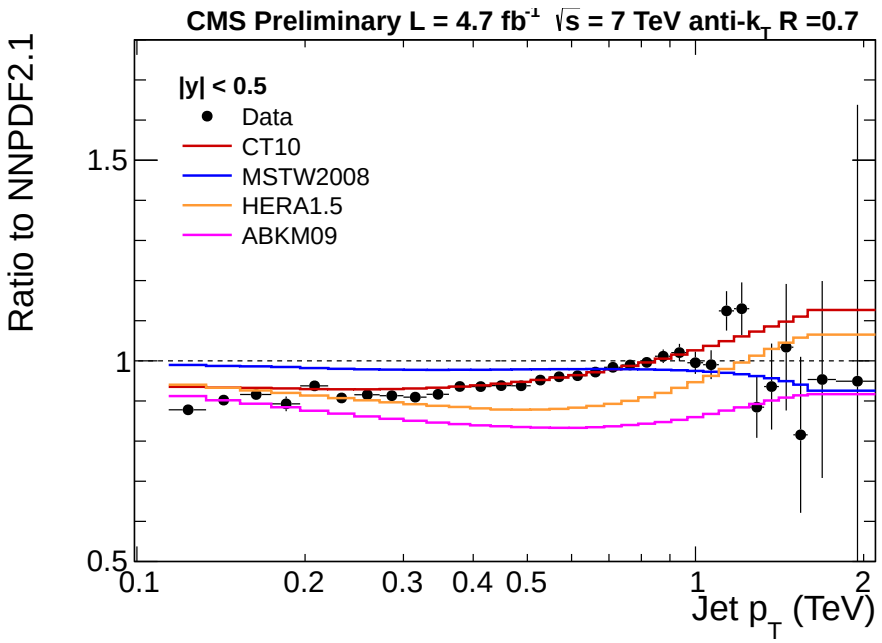
Total theoretical uncertainty varies upto 20%

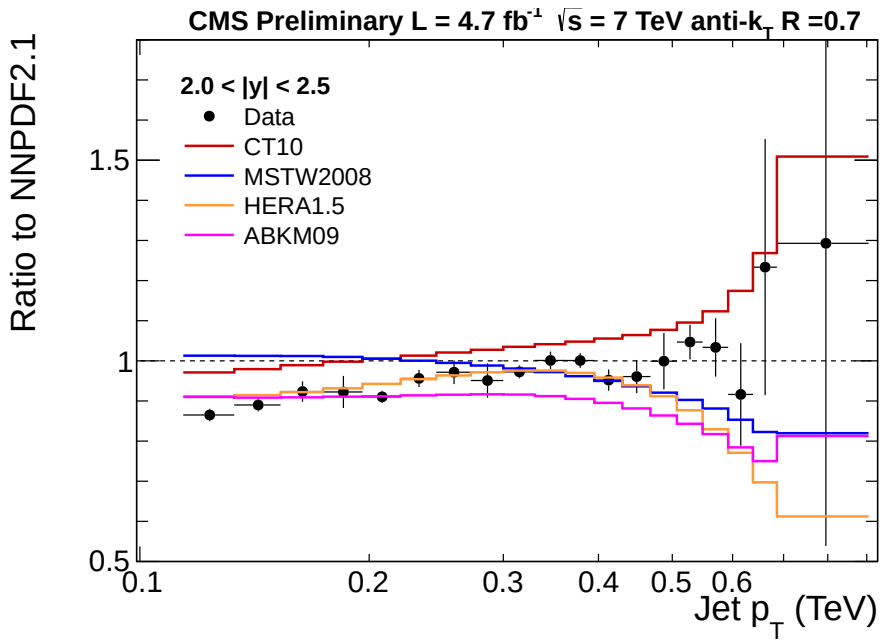
Data Theory Comparison For Inclusive Jet



Within the Theoretical and Experimental Uncertainty bands, Data shows a good agreement with theory.

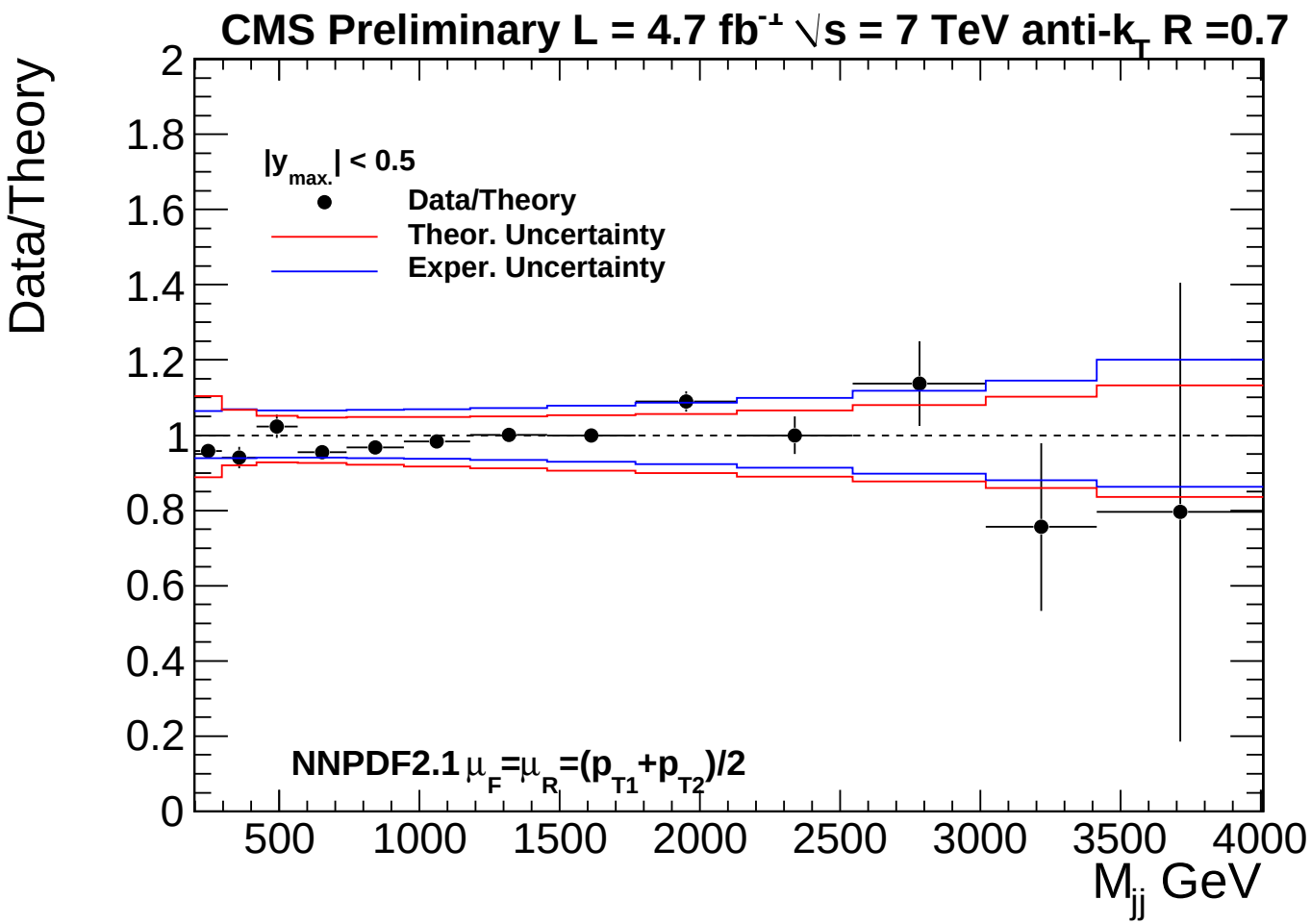
Comparison Between Different PDF Sets for Inclusive Jet





Data Over Theory Ratio Compared with Ratio of theory predictions with different PDF sets

Data Theory Comparison For DiJet



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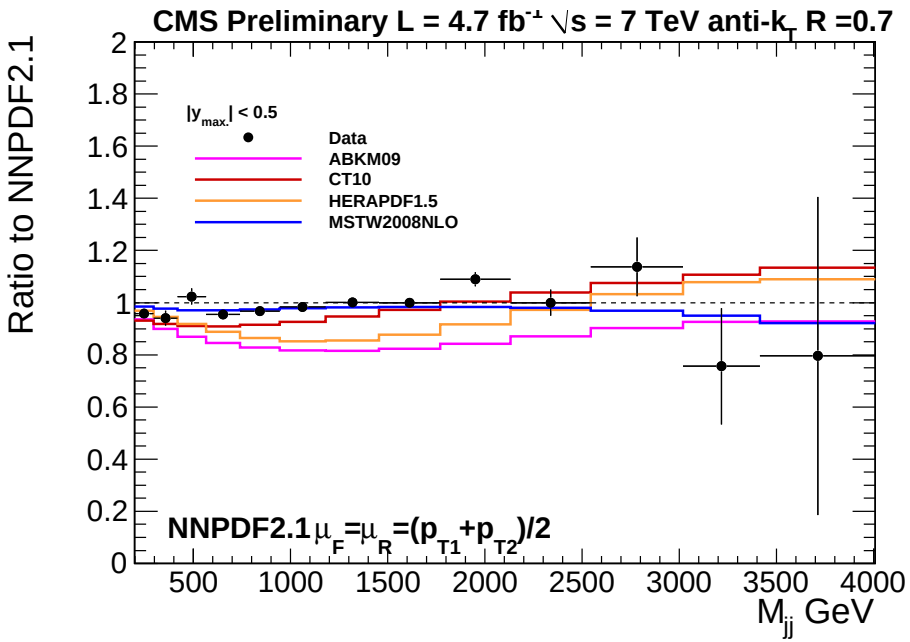

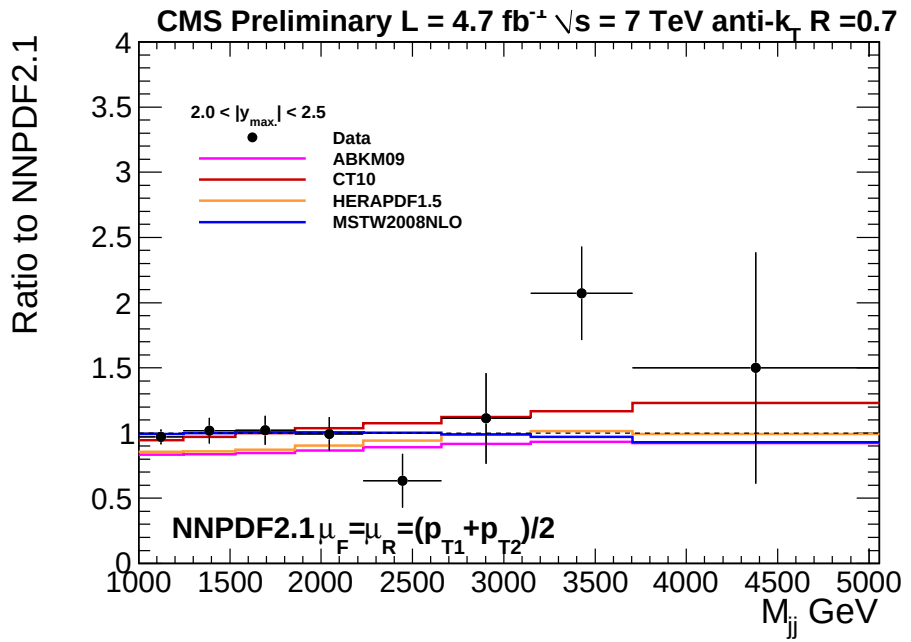

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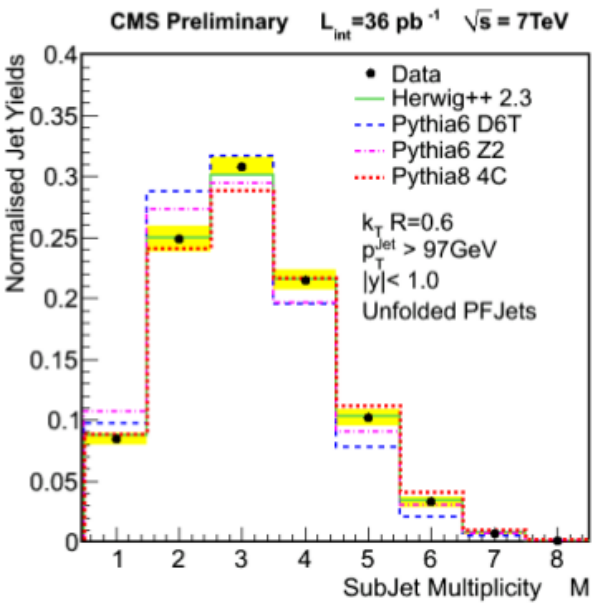
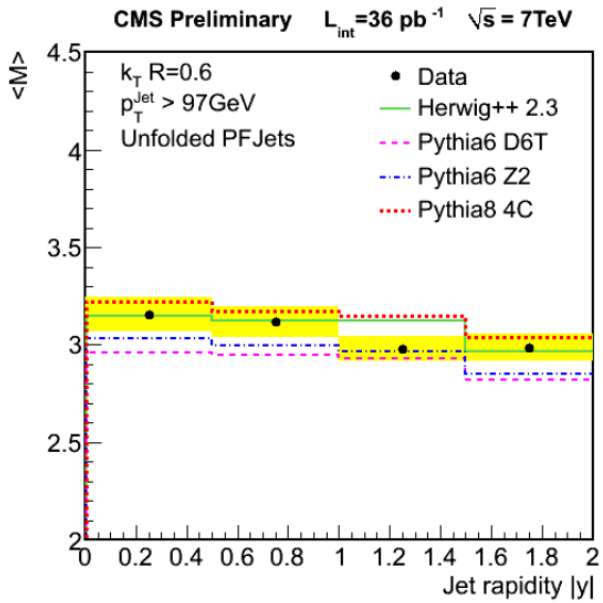
SubJet Studies (CMS PAS QCD-10-041)

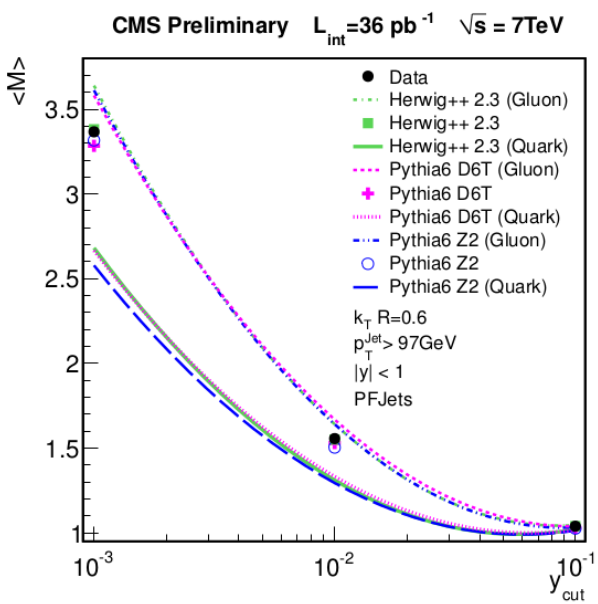
Subjet Multiplicity is an obsrvable to study Jet Substructure.
$\rightarrow$ *k_T Clustering Algorithm* is applied on the constituents untill $d_{ij} \geq d_{cut}$, where
$d_{cut} = y_{cut}.p_T^2(jet)$, $d_{ij} = min(p_{Ti}^2, p_{Tj}^2)\frac{\Delta R_{ij}^2}{R^2}$

- Average Subjet Multiplicity :

$$\langle M \rangle (y_{cut}) = \frac{1}{N_{jet}} \sum_{i=1}^{N_{jet}} M(y_{cut})$$







Subjet Multiplicity Distribution compared with different Pythia and Herwig tunes.

Summary

- Jet Reconsruction , Jet Energy Correction and Several Jet Measurements are presented from 7 TeV CMS Data.
- From 7 TeV , 4.7 fb^{-1} data, JEC factors are determined.
- Inclusive Jet and Dijet cross section measurement is presented and a comparison with Next To Leading Order (NLO) theory prediction are done for five PDF sets.
- The size of experimental uncertainties are comparable to that of theoretical uncertainties.
  This data can be used for global PDF fits and constrain the uncertainties
- Subjet Multiplicity is measured from 36 pb^{-1}, 7 TeV CMS data.
  •The measurement is compared with HERWIG++ and Two different PYTHIA tunes.
  Within Uncertainty limits, there are good agreement beween Data and MC.
- Overall good Jet performance is observed in all the measurements in CMS.

Back UP

Cross Section Measurements

•The double differential Inclusive Jet cross section is measured using the formula:

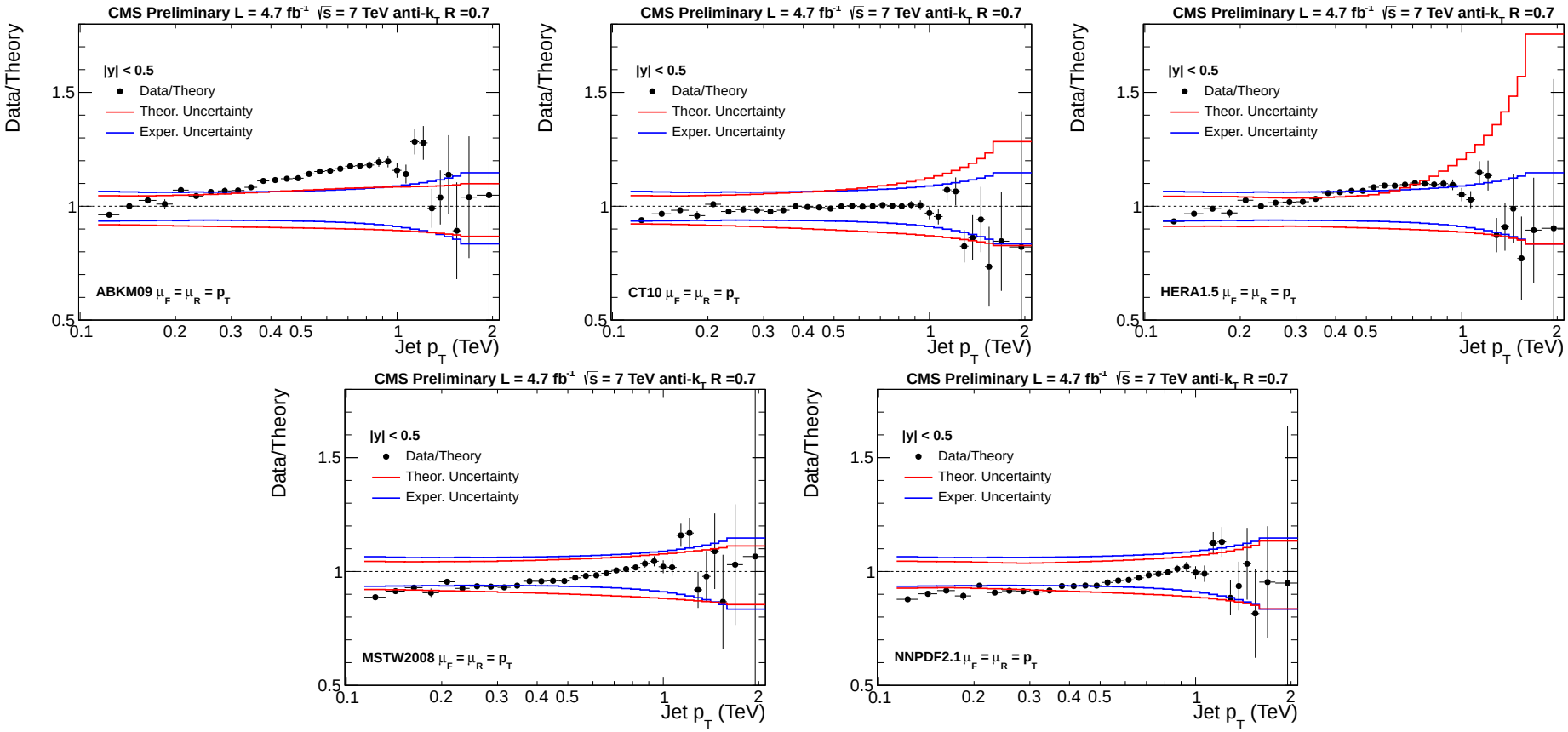
$$\frac{d^2\sigma}{dp_T d|y|} = \frac{1}{\epsilon L}\frac{N}{\Delta p_T \Delta|y|} \times C_{unsmearing}$$

•The double differential DiJet invariant cross section is measured using the formula:

$$\frac{d^2\sigma}{dM_{jj} d|y|} = \frac{1}{\epsilon L}\frac{N}{\Delta M_{jj} \Delta|y|} \times C_{unsmearing}$$

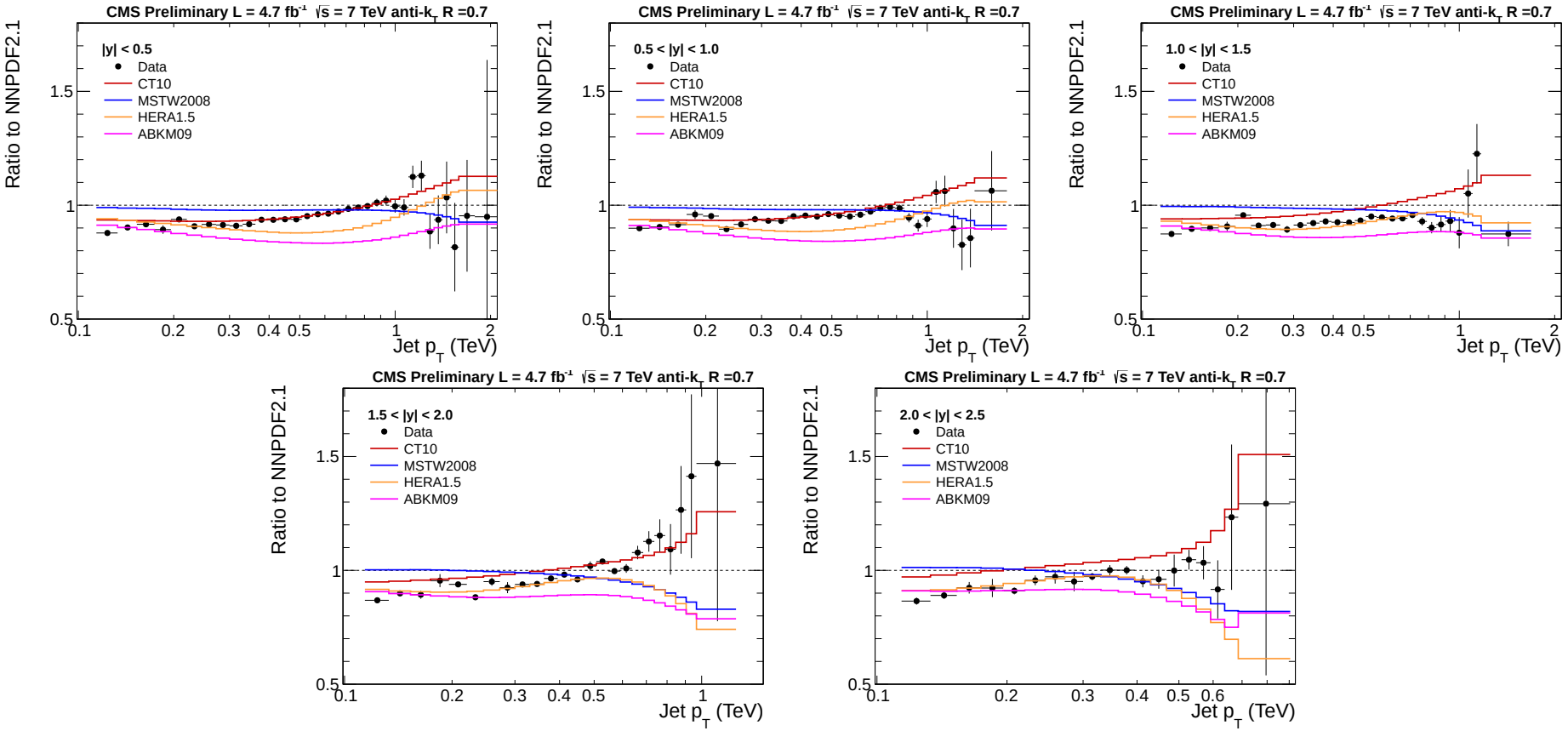
N : Number of jets in Δp_T or M_{jj} bin.
$\Delta p_T, \Delta M_{jj}$: p_T, M_{jj} bin width
$\Delta|y|$: Rapidity bin width.
ϵ : Product of Trigger and Event selection efficiencies.
L : Total Integrated Luminosity.
$C_{unsmearing}$: Unsmearing correction factor

Data Theory Comparison For Different PDF Sets for Inclusive Jet



Ratio of Data to Theory for each of the PDF sets for central Rapidity bin. Within the Theoretical and Experimental Uncertainty bands, Data shows a good agreement with theory.

Comparison Between Different PDF Sets for Inclusive Jet



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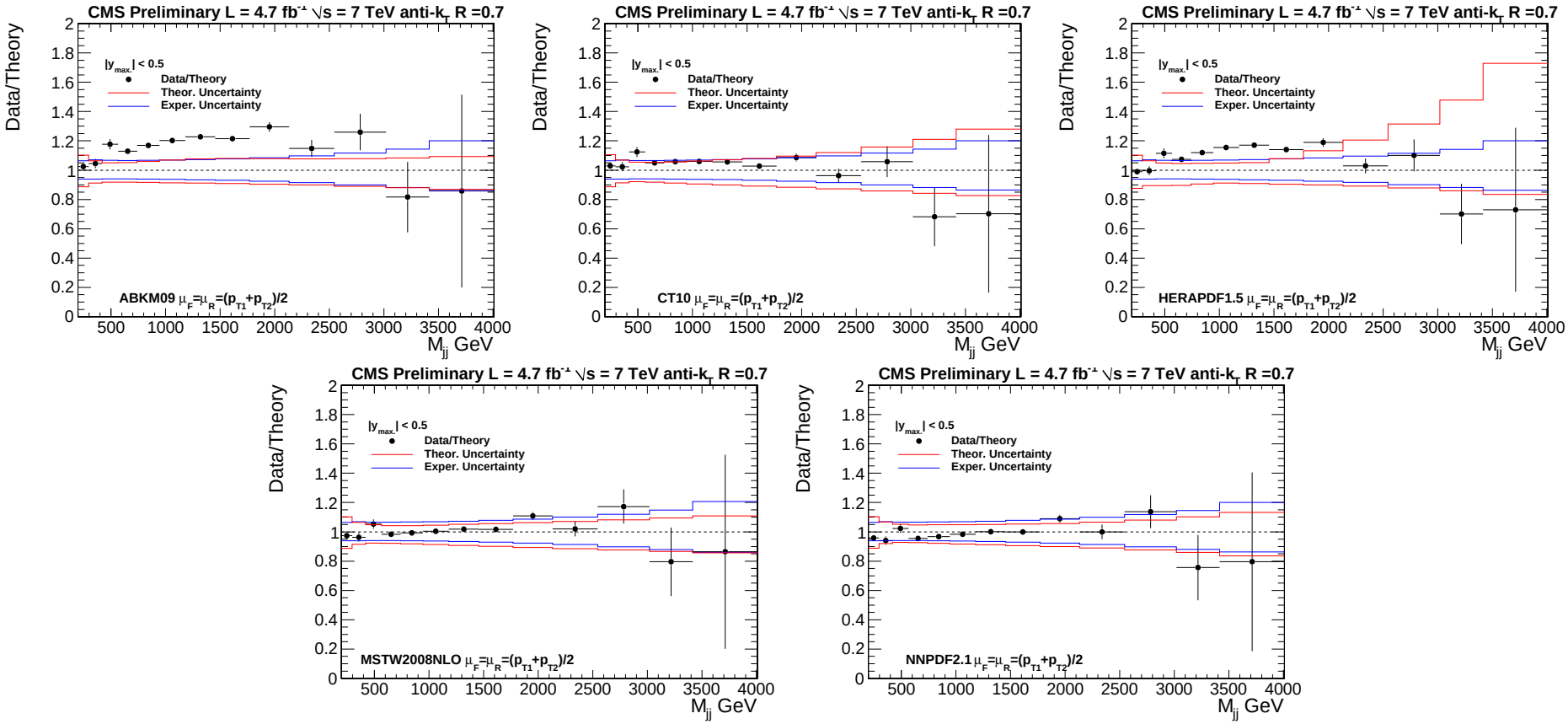

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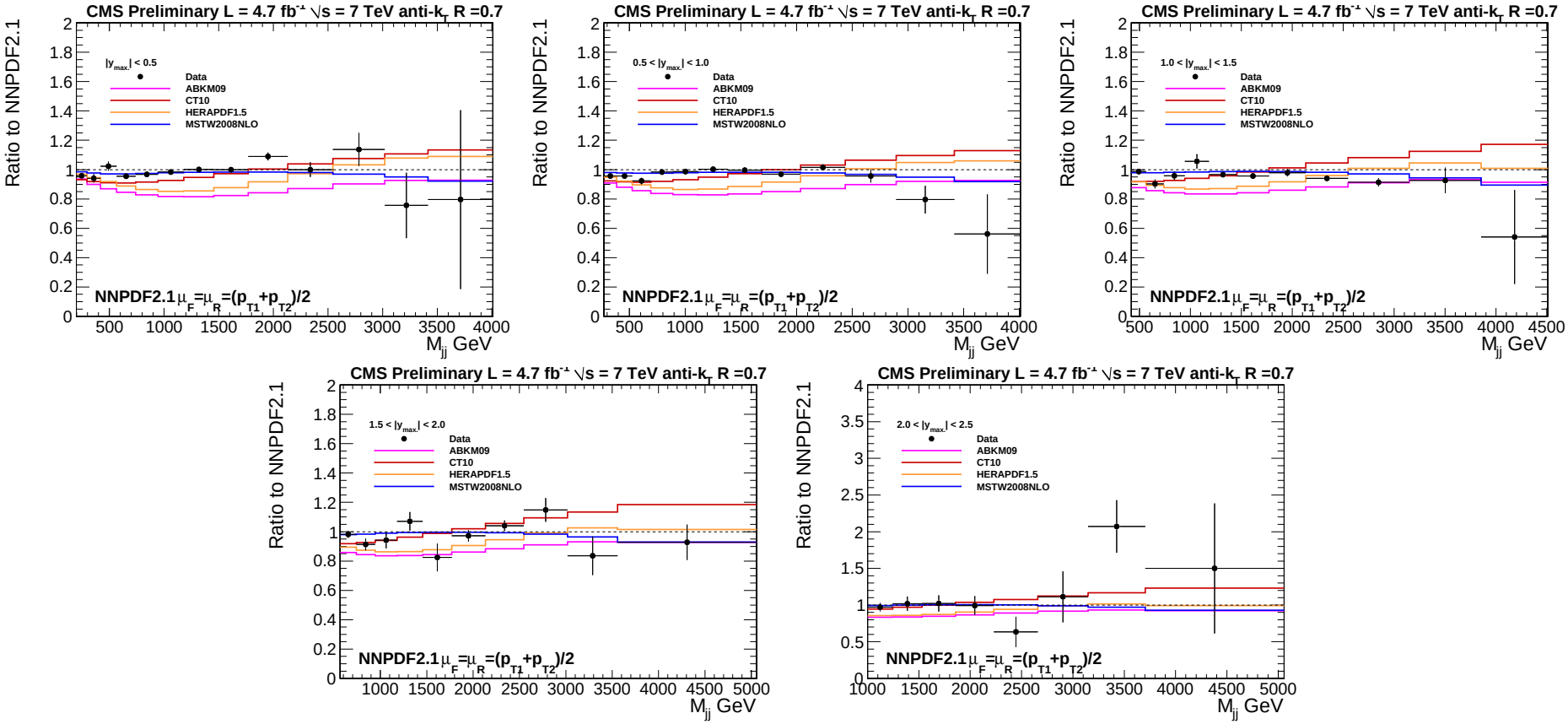

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