

Status of inclusive jet production with full 2016 Data

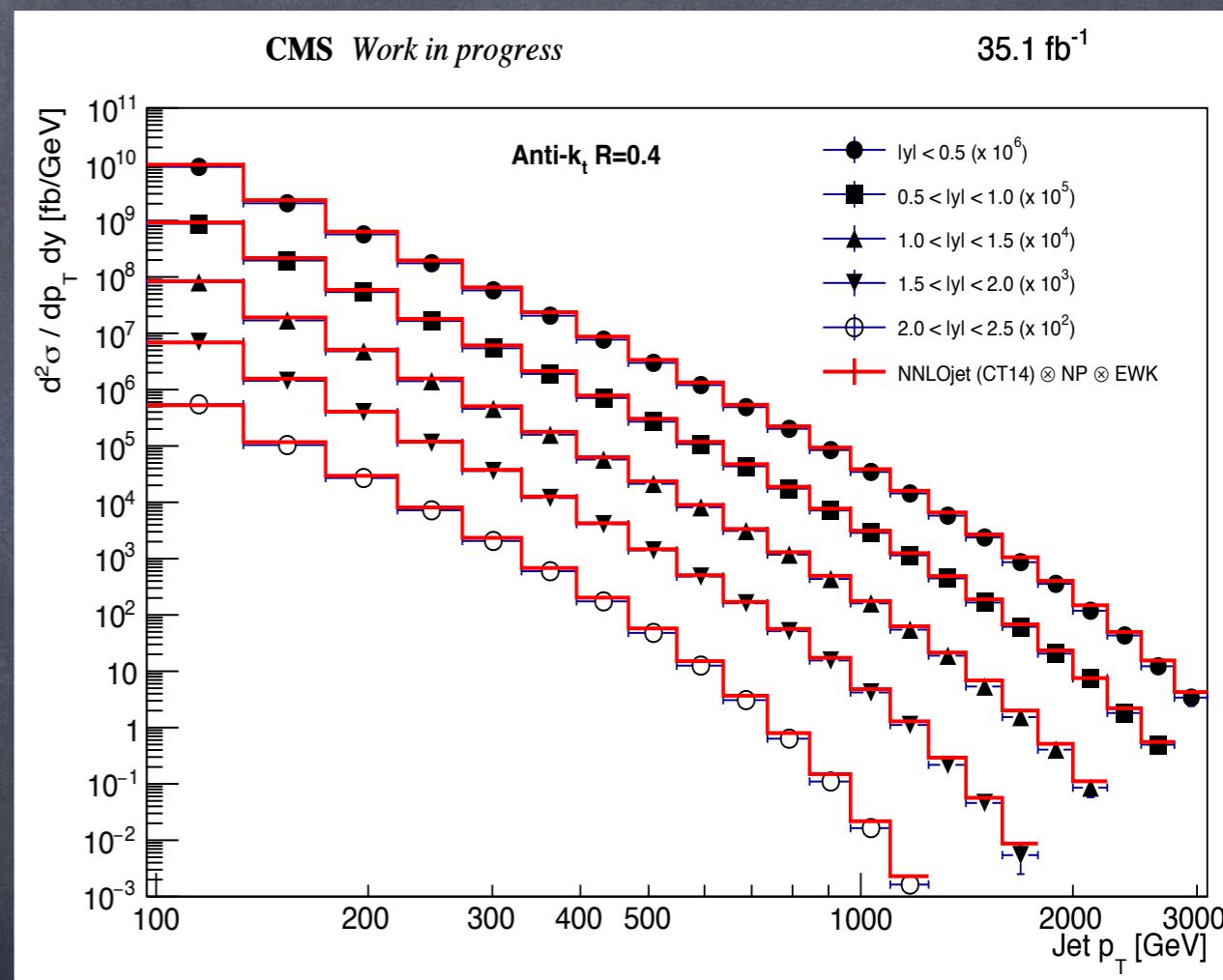
**Engin Eren (DESY), Paolo Gunnellini (DESY),
Panos Kokkas (University of Ioannina), Katerina Lipka (DESY)
Mikko Voutilainen (Helsinki Institute of Physics)**

Cross section of the inclusive jet production at 13 TeV

- Data of 2016 is used, integrated luminosity = 35.1 fb^{-1}
- Cross section is measured as a function of jet p_T and y

$$\frac{d^2\sigma}{dp_T dy} = \frac{1}{\epsilon L_{int}} \frac{N_j}{\Delta p_T \Delta y}$$

- p_T range : 97 GeV to 3 TeV
- y range :
 - ▶ 5 bins in steps of 0.5 up to 2.5
- Anti- k_t algorithm is used with $R=0.4$ and 0.7
- Triggers :
 - HLT_PFJetX for AK4
 - HLT_AK8PFJetX for AK7
 - X : 40, 80, 140, 200, 260, 320, 400, 450



More : <https://twiki.cern.ch/twiki/bin/viewauth/CMS/InclusiveJetsLegacy>

Theory predictions used in this analysis

- Recent calculation at NNLO [*J.Currie, N. Glover, and J.Pires, Phys.Rev.Lett. 118, 072002*]
- In contact with the *NNLOJET* authors, DESY group provides the calculation for 13 and 8 TeV
- Very CPU intensive calculation, interface to fast-grid techniques on the way (fastNLO/Appgrid)

Settings :

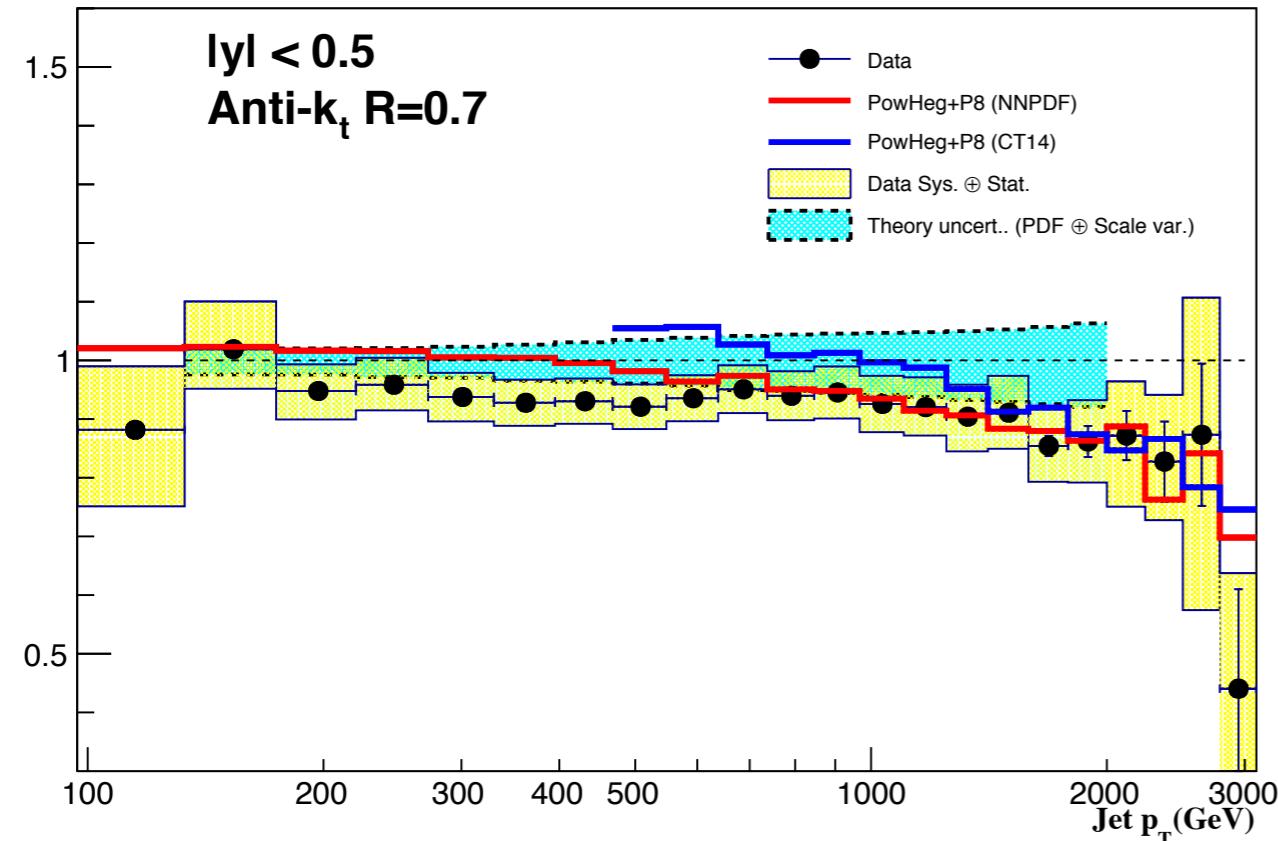
CM	Cone size	PDFset	Scale choice	Scale variations	Total CPU time
13 TeV	0.7	CT14nnlo	$p_{T\max}$ and p_T	3	105587h
13 TeV	0.4	CT14nnlo	$p_{T\max}$ and p_T	3	55228h
8 TeV	0.7	CT14nnlo	$p_{T\max}$ and p_T	3	26941h
					187756h

Here, the scales $\mu_F = \mu_R$ are set to jet p_T , as used in the analysis

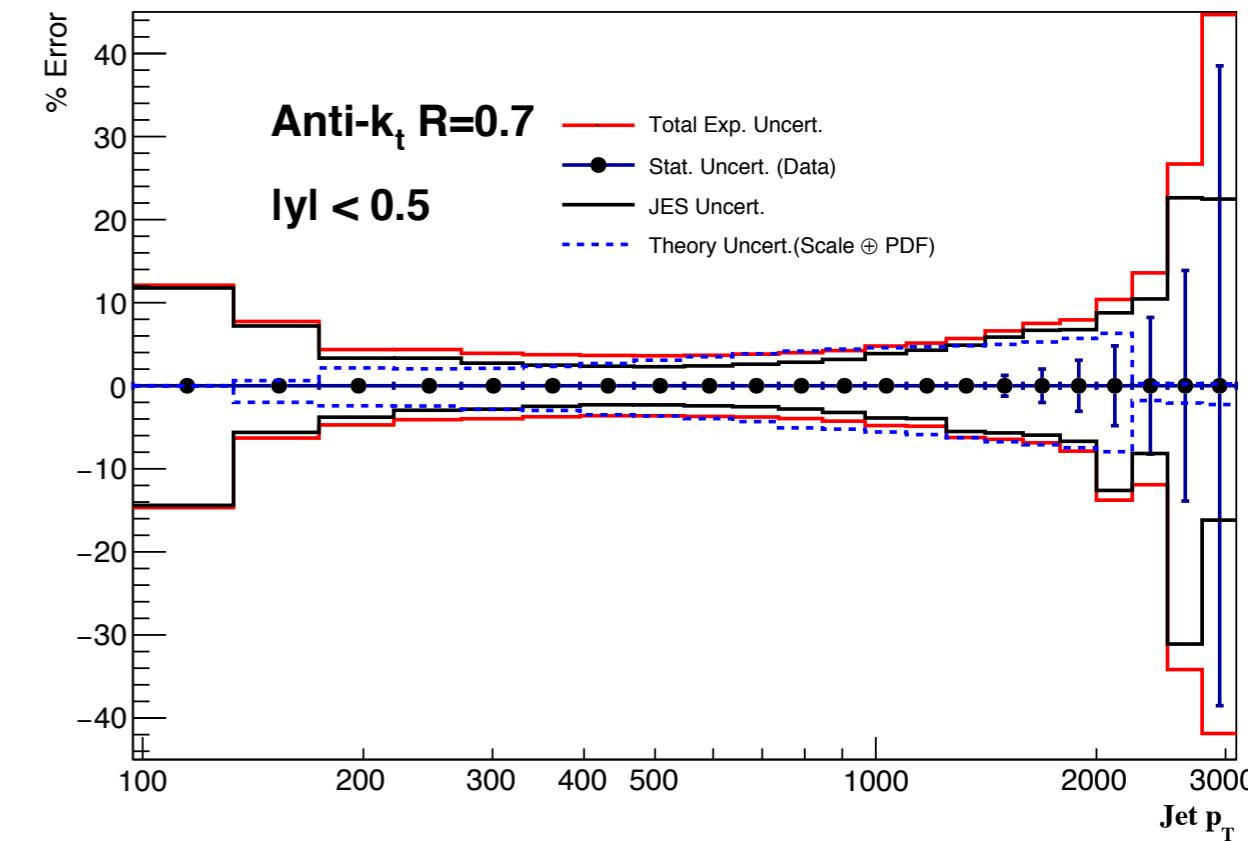
AK7 jets particle level

CMS Work in progress

29.4 fb^{-1}

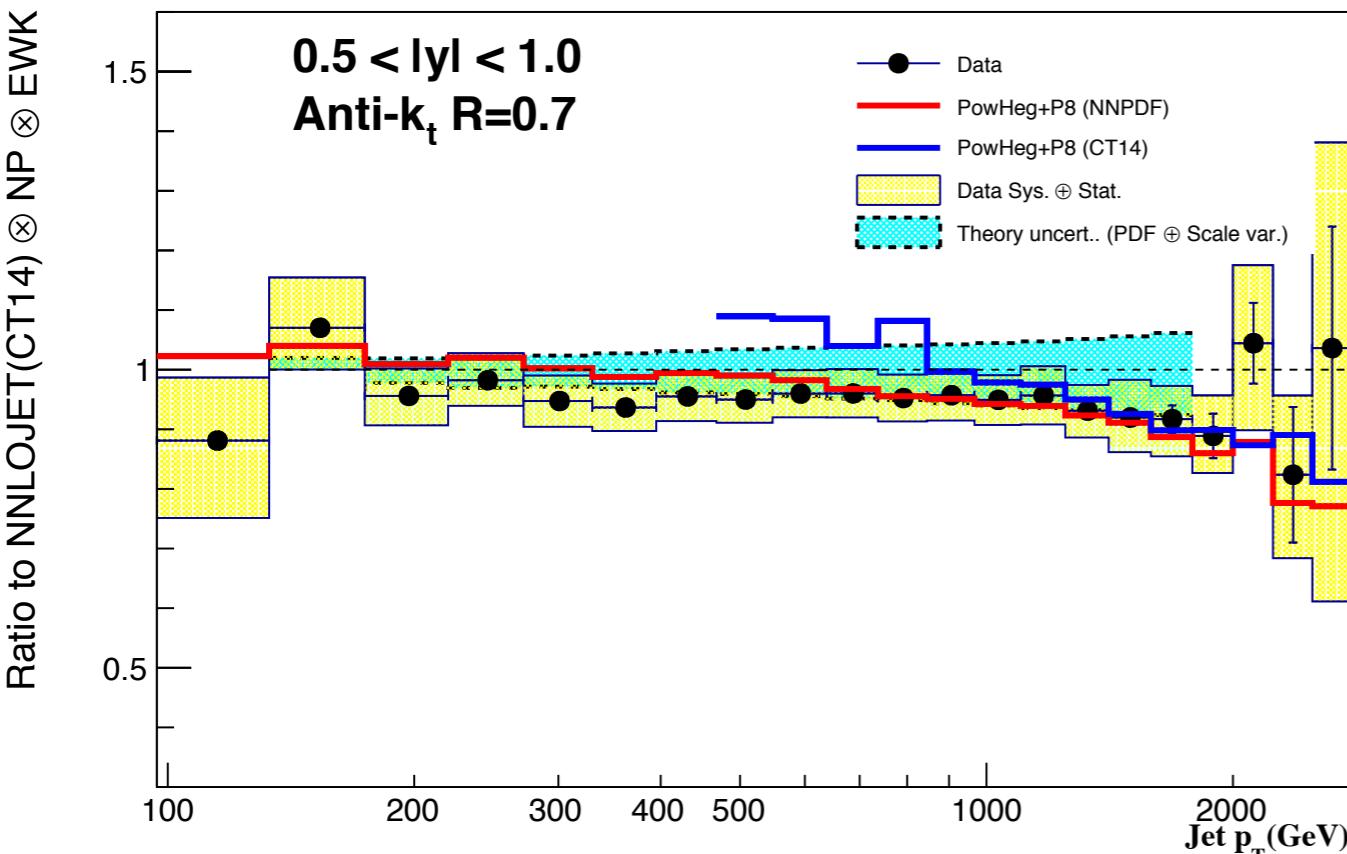


29.5 fb^{-1}

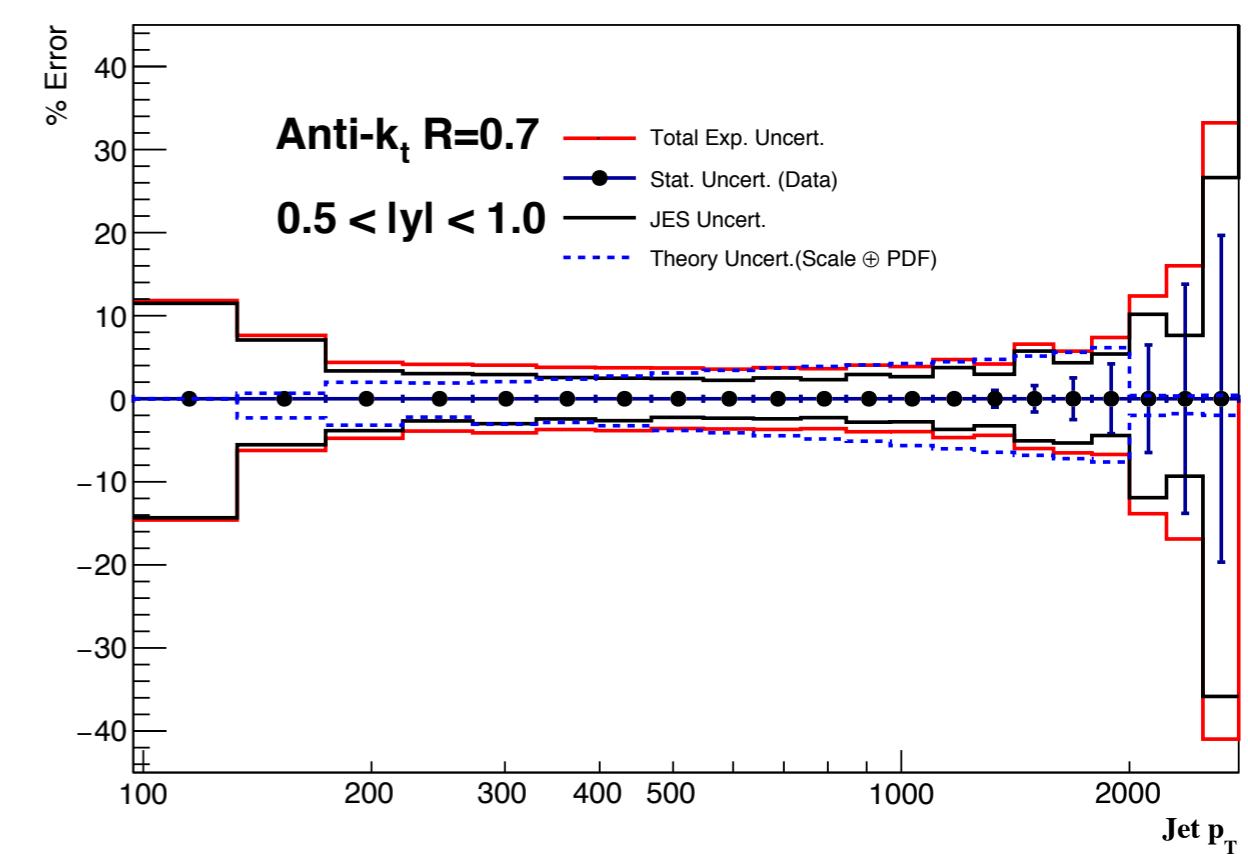


CMS Work in progress

29.4 fb^{-1}



29.5 fb^{-1}



AK7 jets particle level

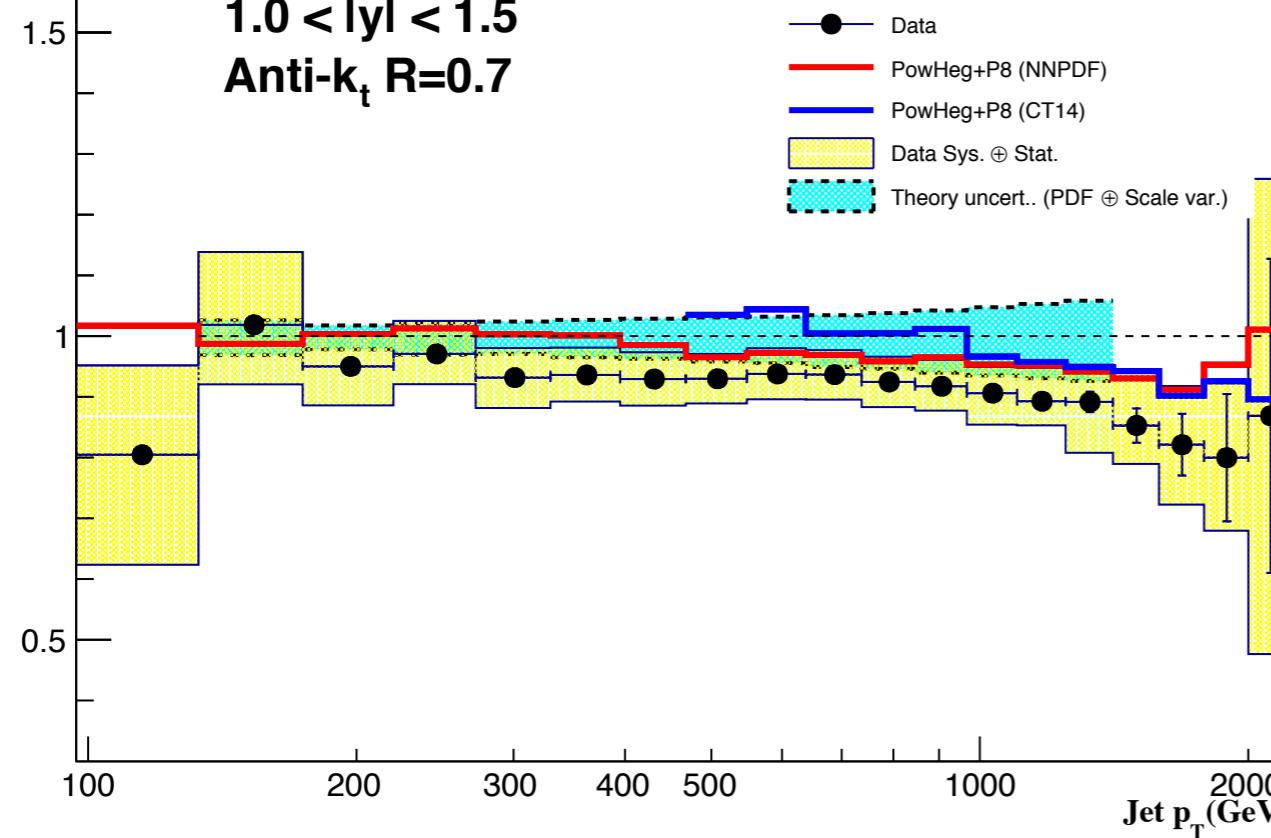
5

CMS Work in progress

29.4 fb^{-1}

$1.0 < |\eta| < 1.5$
Anti- k_t R=0.7

- Data
- Red line: PowHeg+P8 (NNPDF)
- Blue line: PowHeg+P8 (CT14)
- Yellow shaded: Data Sys. \oplus Stat.
- Cyan dashed: Theory uncert.. (PDF \oplus Scale var.)



29.5 fb^{-1}

Anti- k_t R=0.7

$1.0 < |\eta| < 1.5$

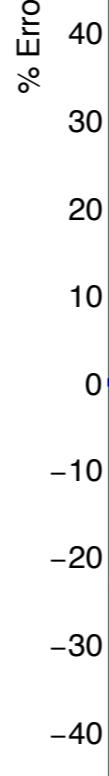
Total Exp. Uncert.

Stat. Uncert. (Data)

JES Uncert.

Theory Uncert.(Scale \oplus PDF)

% Error

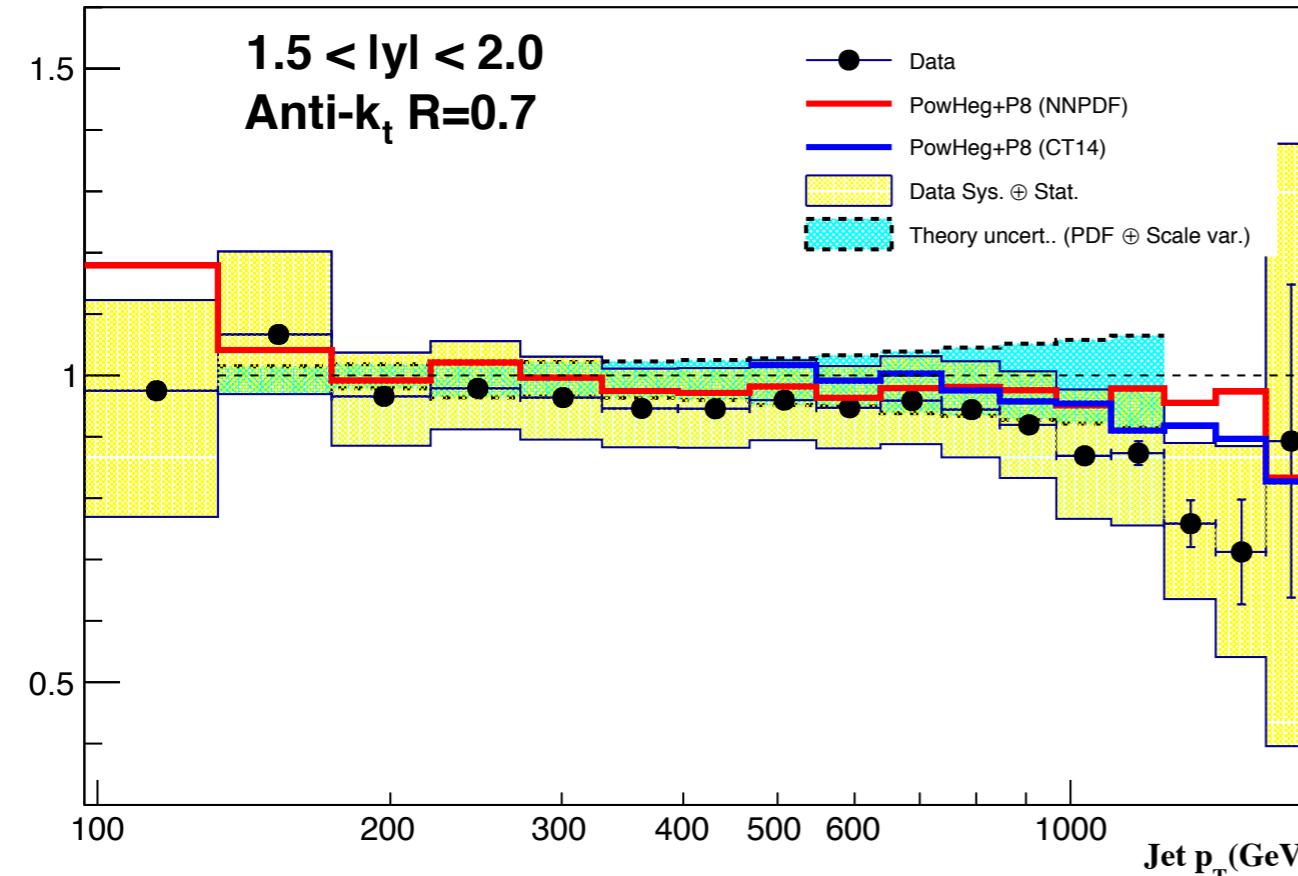


CMS Work in progress

29.4 fb^{-1}

$1.5 < |\eta| < 2.0$
Anti- k_t R=0.7

- Data
- Red line: PowHeg+P8 (NNPDF)
- Blue line: PowHeg+P8 (CT14)
- Yellow shaded: Data Sys. \oplus Stat.
- Cyan dashed: Theory uncert.. (PDF \oplus Scale var.)



29.5 fb^{-1}

Anti- k_t R=0.7

$1.5 < |\eta| < 2.0$

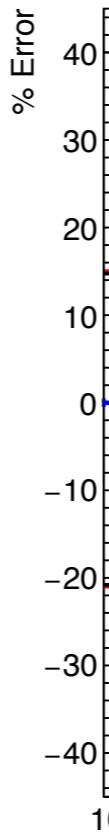
Total Exp. Uncert.

Stat. Uncert. (Data)

JES Uncert.

Theory Uncert.(Scale \oplus PDF)

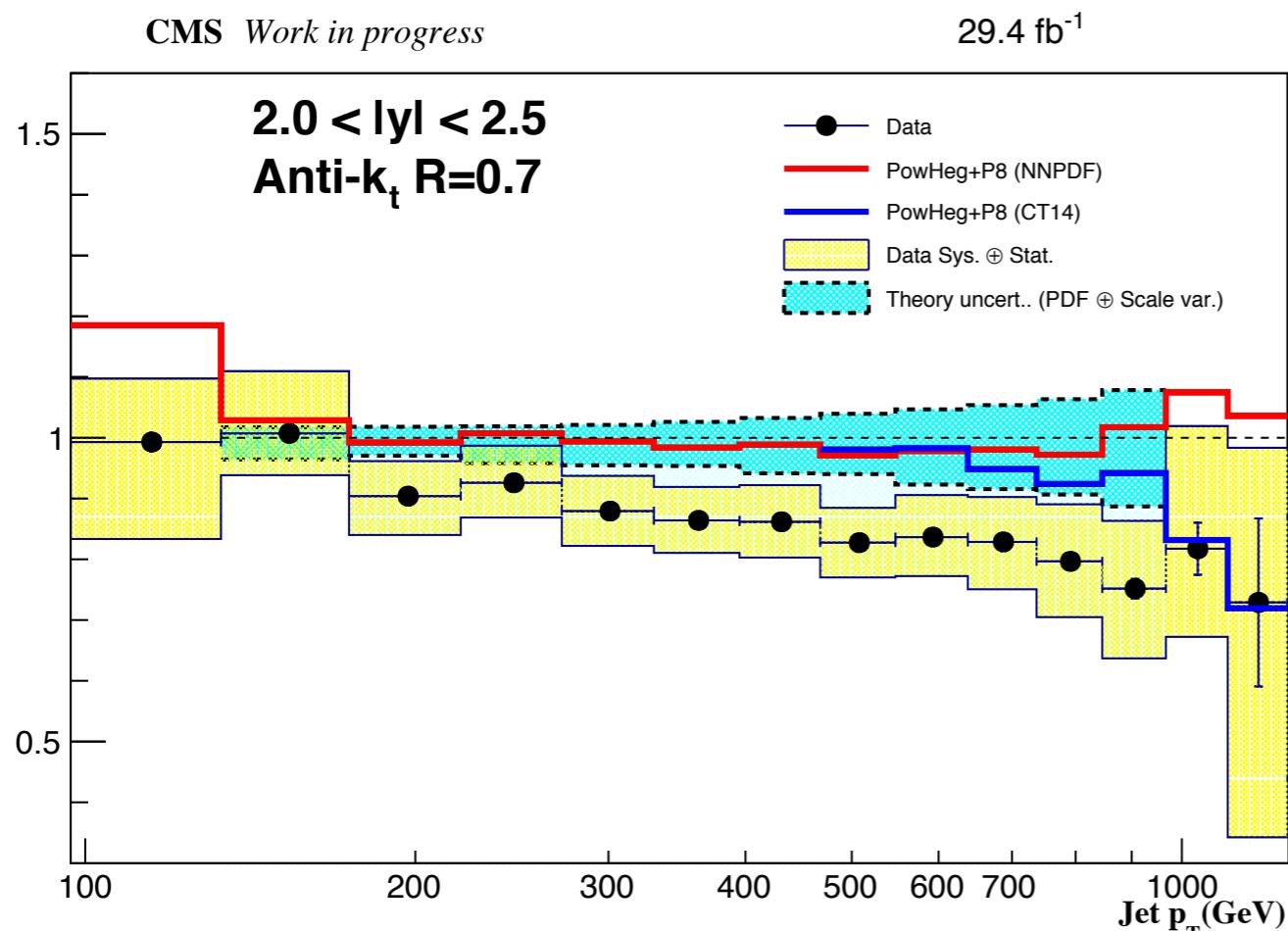
% Error



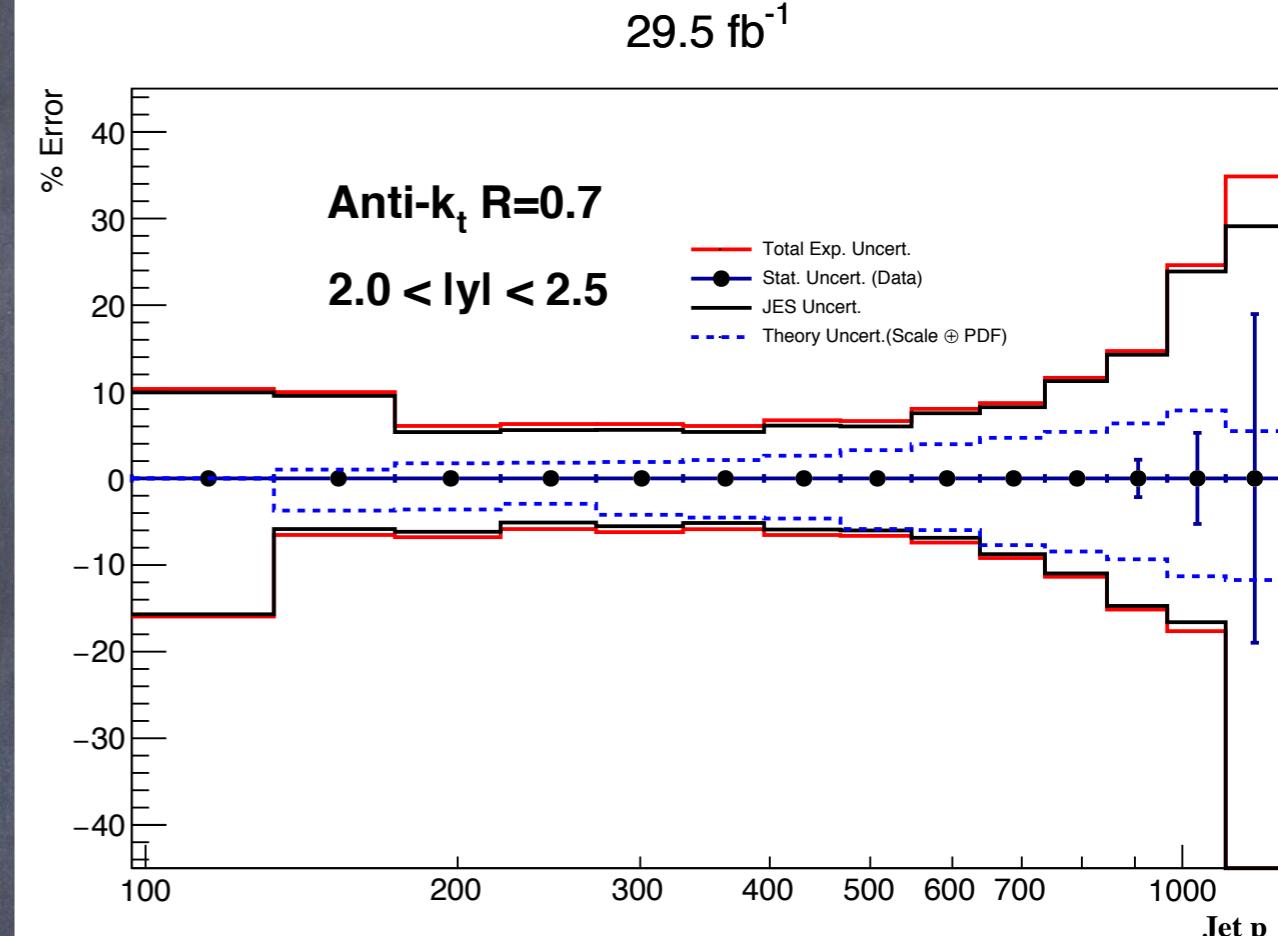
AK7 jets particle level

CMS Work in progress

29.4 fb^{-1}



29.5 fb^{-1}



- Within theory uncertainties, NNLO slightly overestimates the measurement for R=0.7
 - ▶ Reminder : Jet data in LHC has never been used for QCD@NNLO

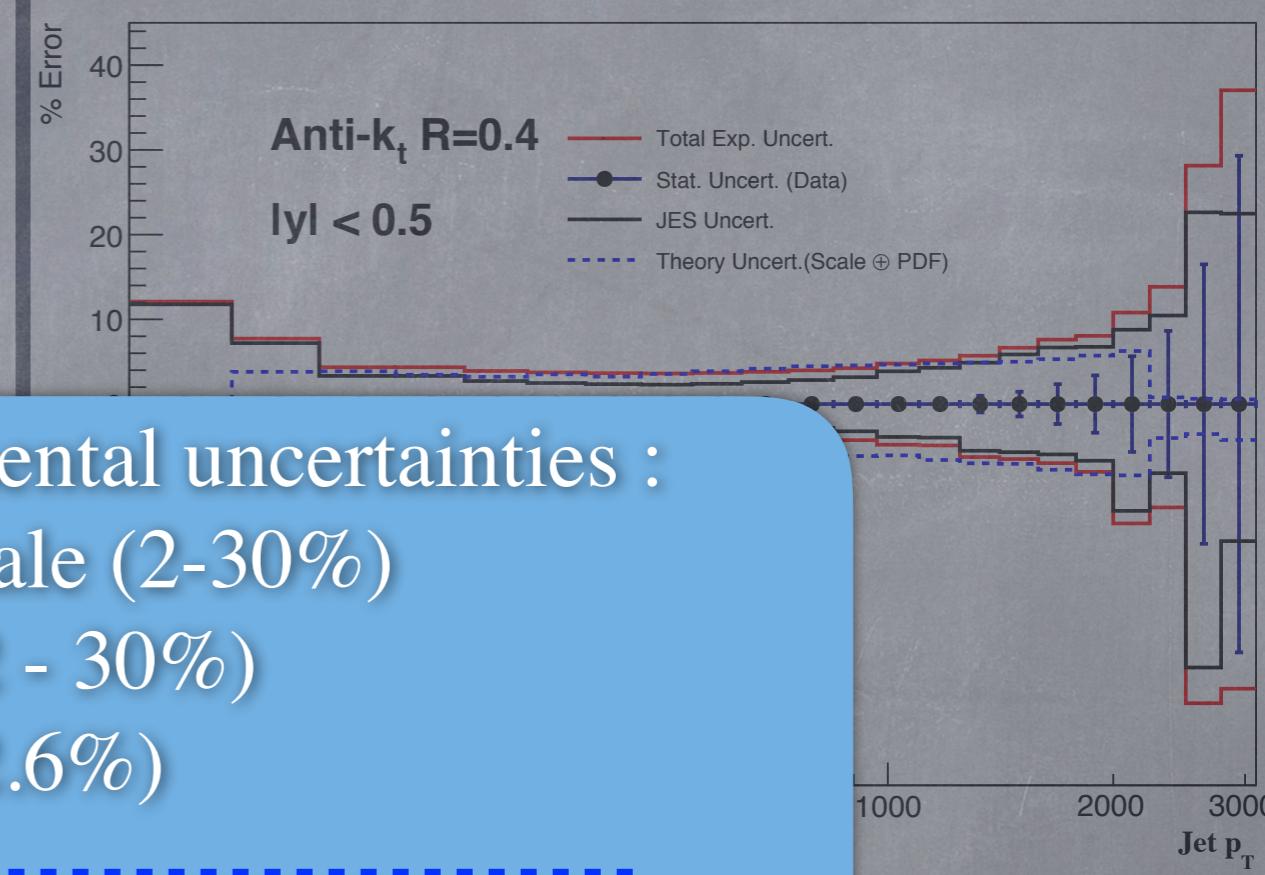
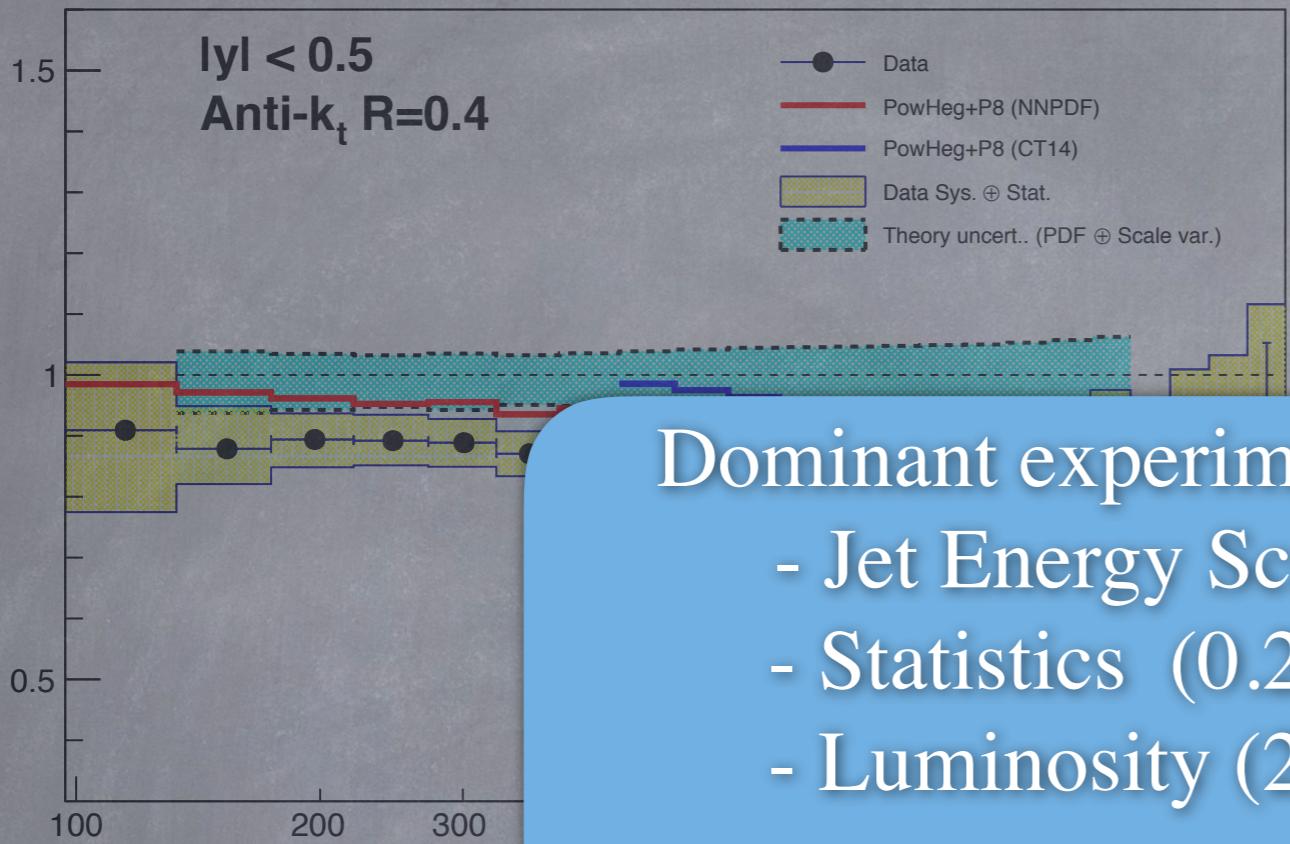
Keep an eye on JetMet updates
and final calibration!!

Uncertainty

Ratio to NNLOJET(CT14) \otimes NP \otimes EWK

CMS Work in progress

35.1 fb^{-1}



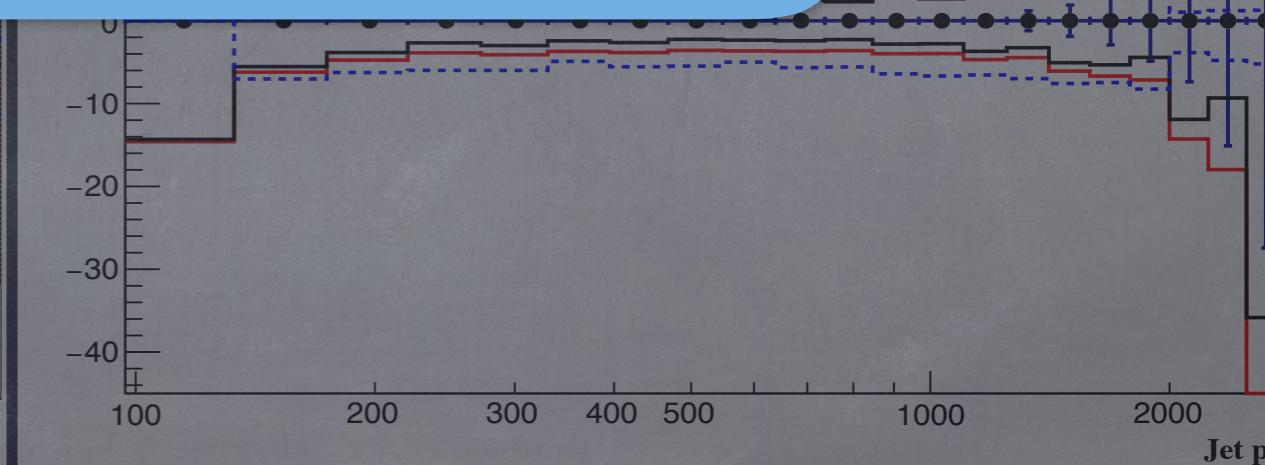
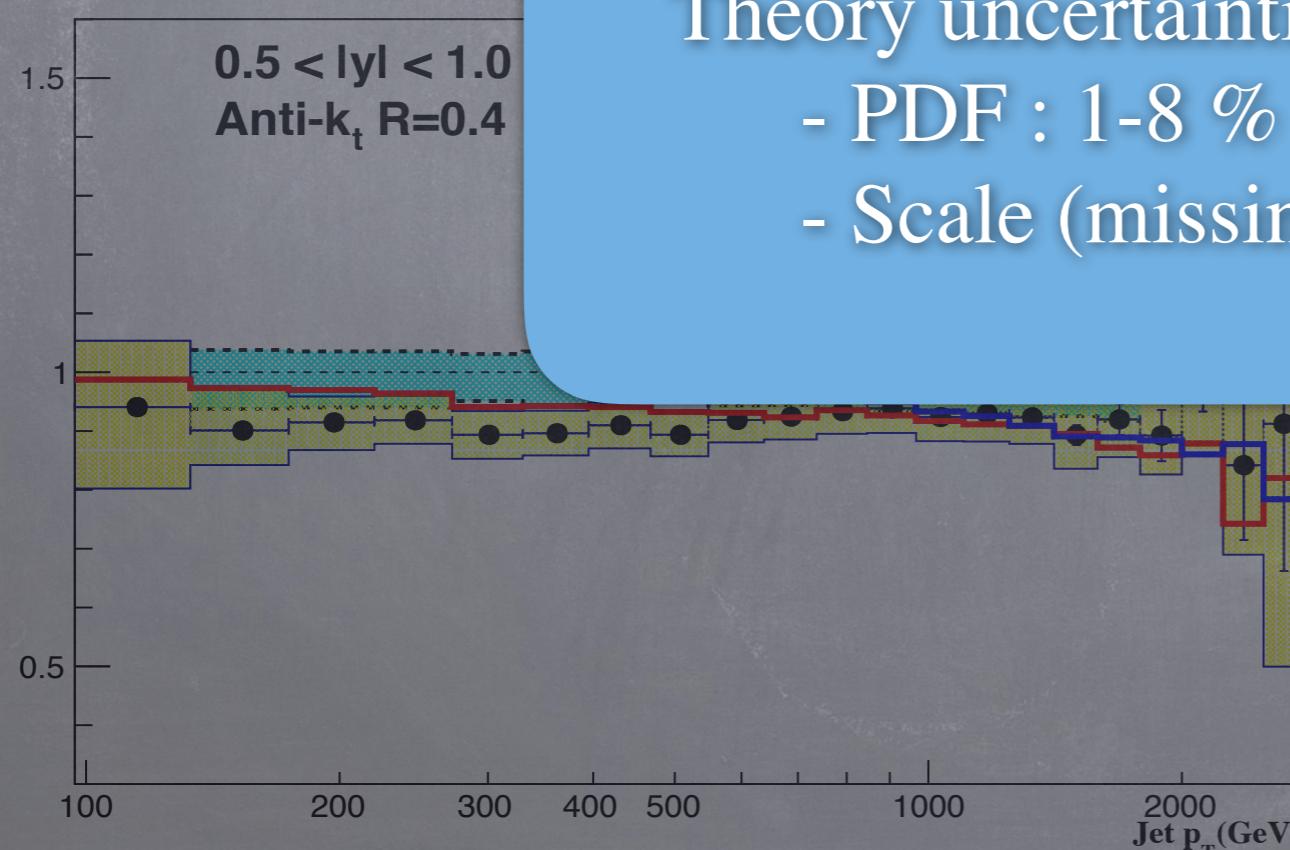
Dominant experimental uncertainties :

- Jet Energy Scale (2-30%)
- Statistics (0.2 - 30%)
- Luminosity (2.6%)

Ratio to NNLOJET(CT14) \otimes NP \otimes EWK

CMS Work in progress

35.1 fb^{-1}



Theory uncertainties (up to 2TeV)

- PDF : 1-8 %
- Scale (missing h.orders) : 1-2 %

QCD analysis plan

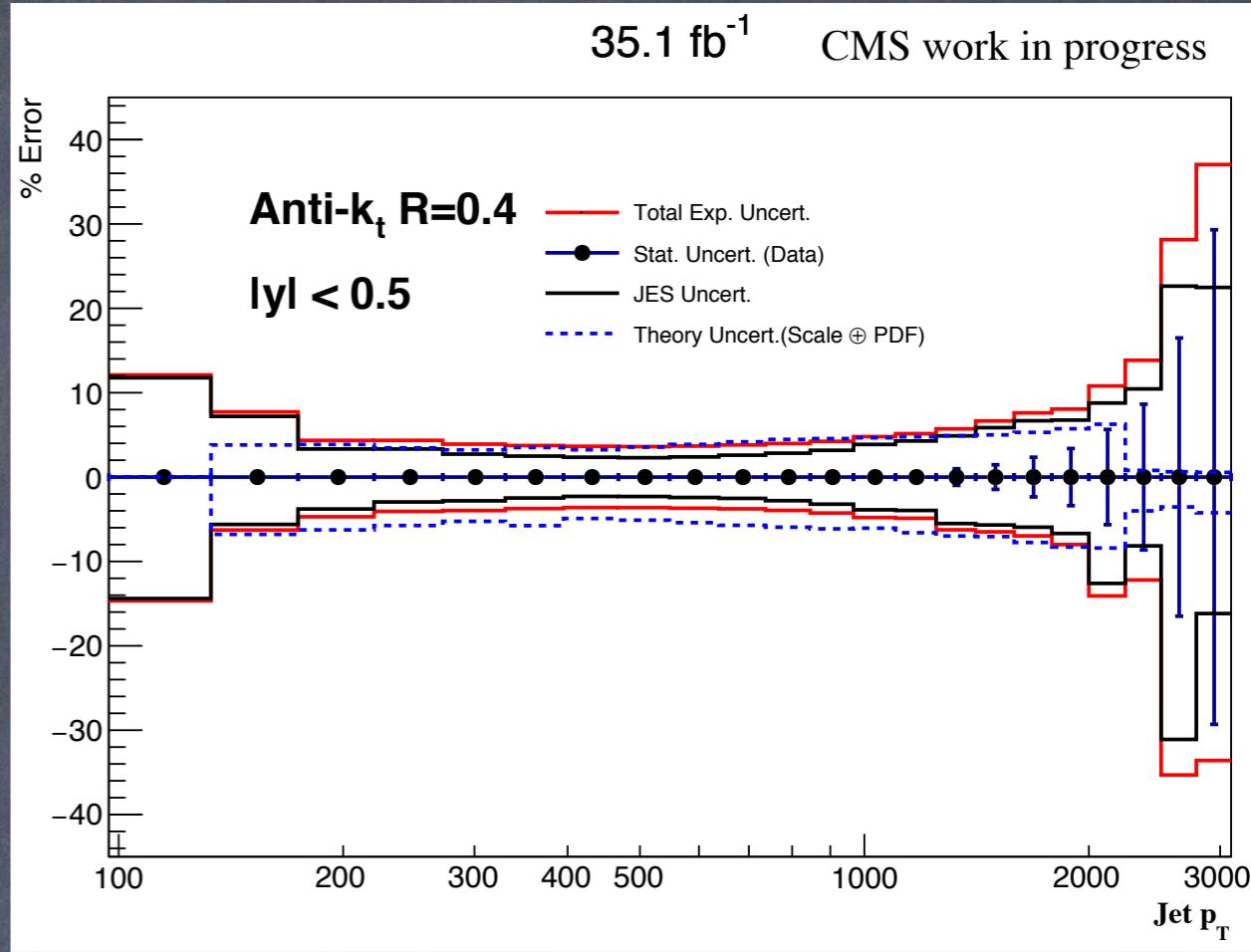
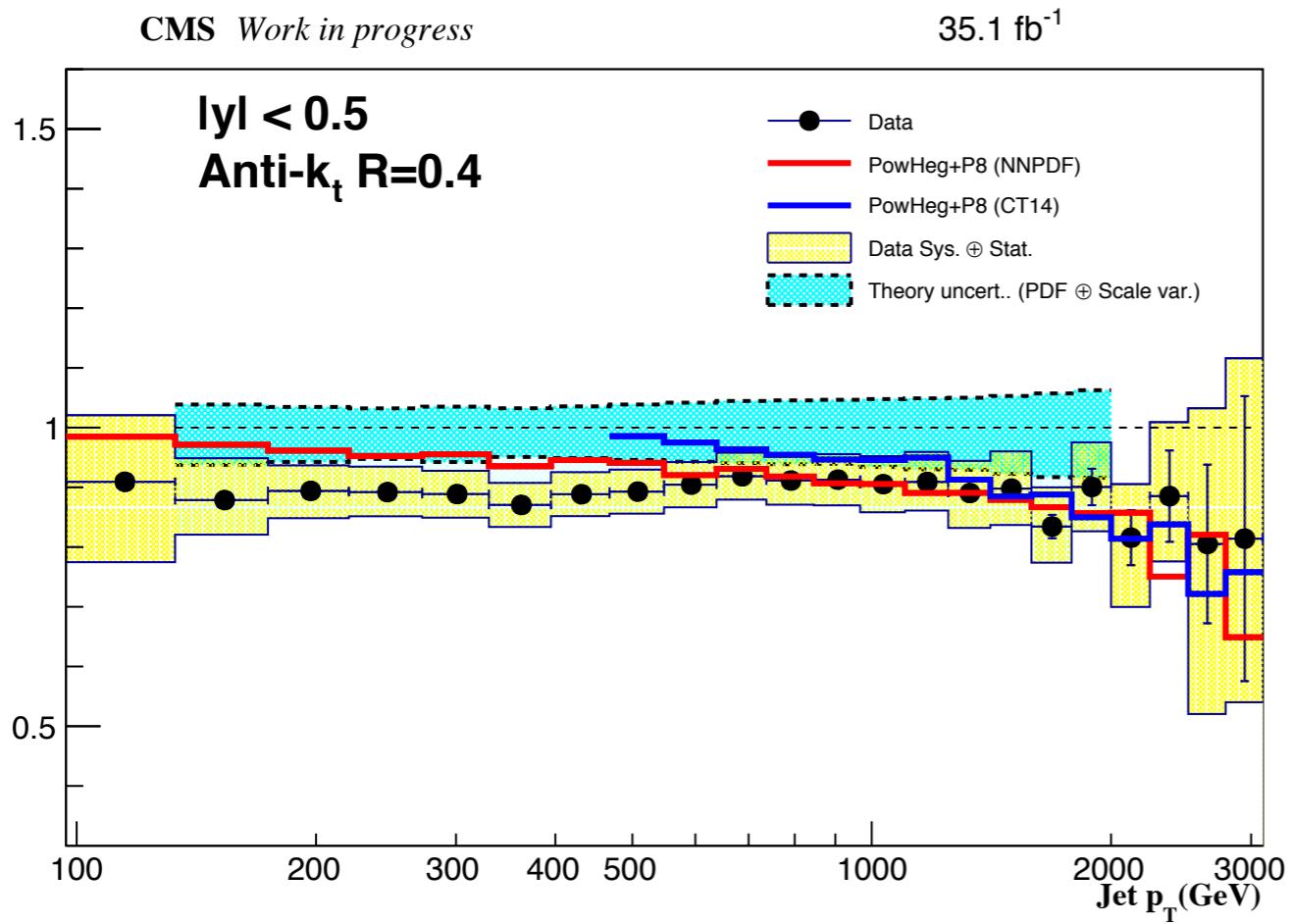
- Full analysis @NNLO
 - Show the impact on gluon pdf & α_s
 - Providing all systematics correlations of the data will be beneficial for PDF community (e.g CTEQ, NNPDF etc..)
- Requirements :
 - Fast interpolation tables & grids
 - Detailed investigation of the effect of JES sources and correlations

Backup Slides

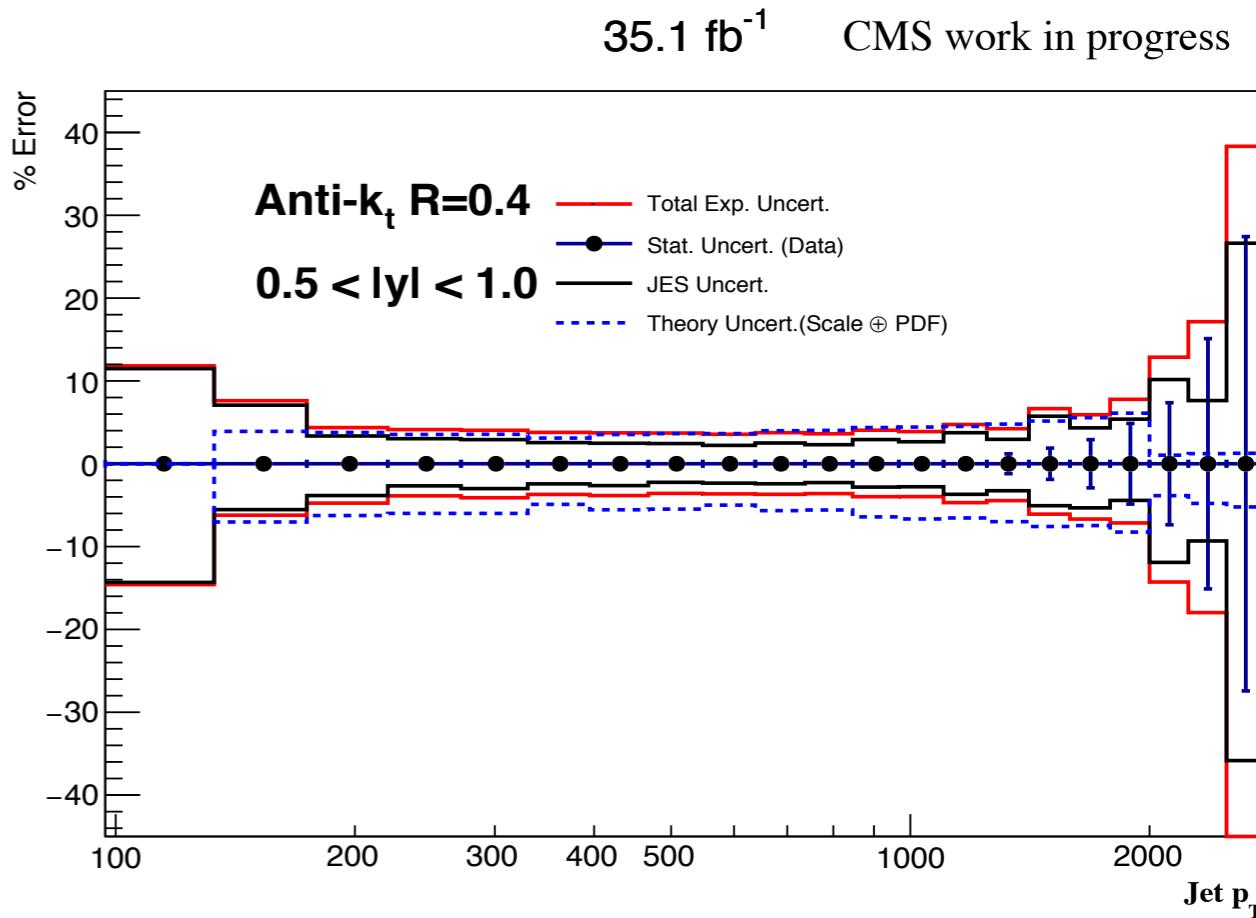
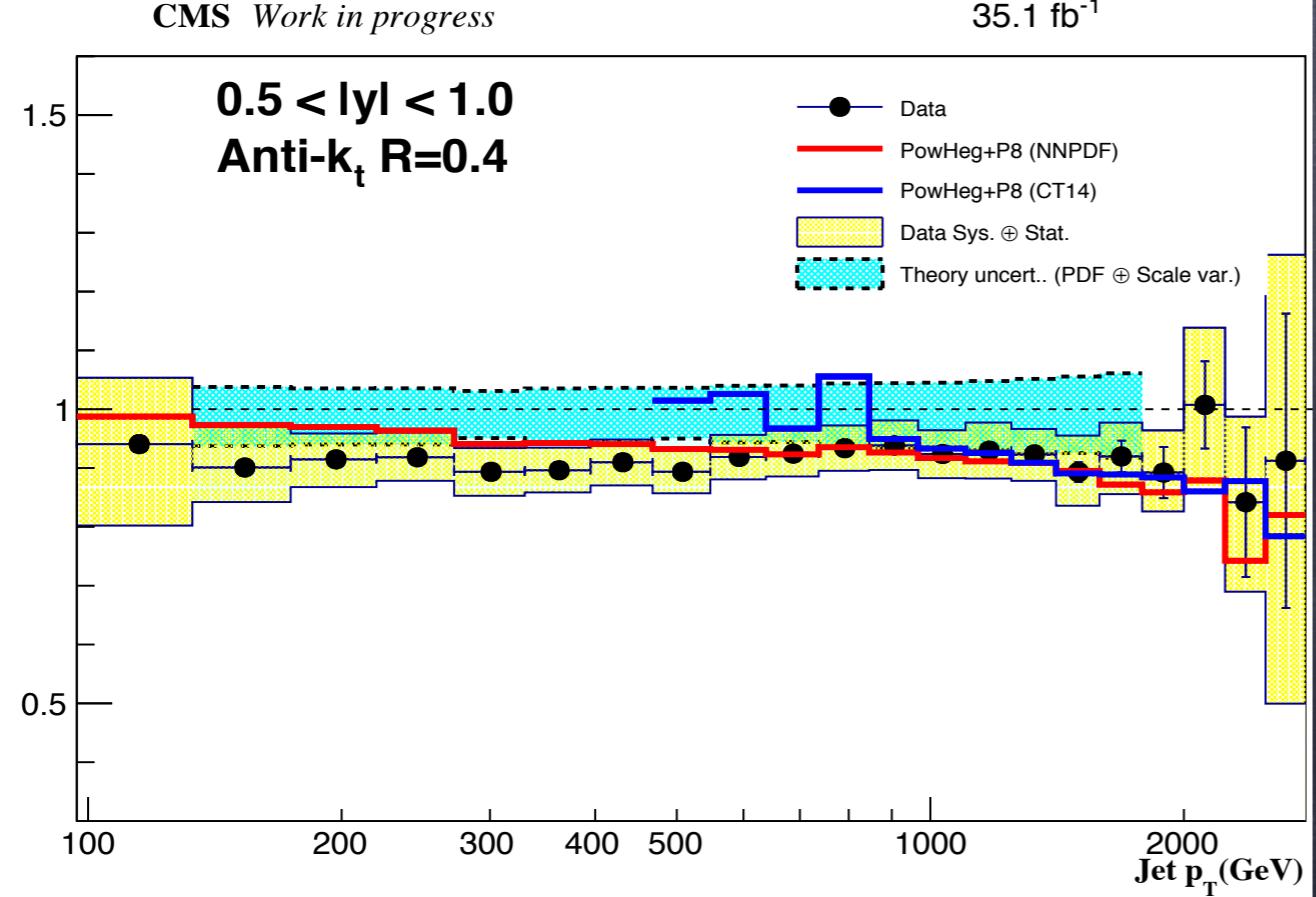
AK4 jets particle level

10

Ratio to NNLOJET(CT14) \otimes NP \otimes EWK



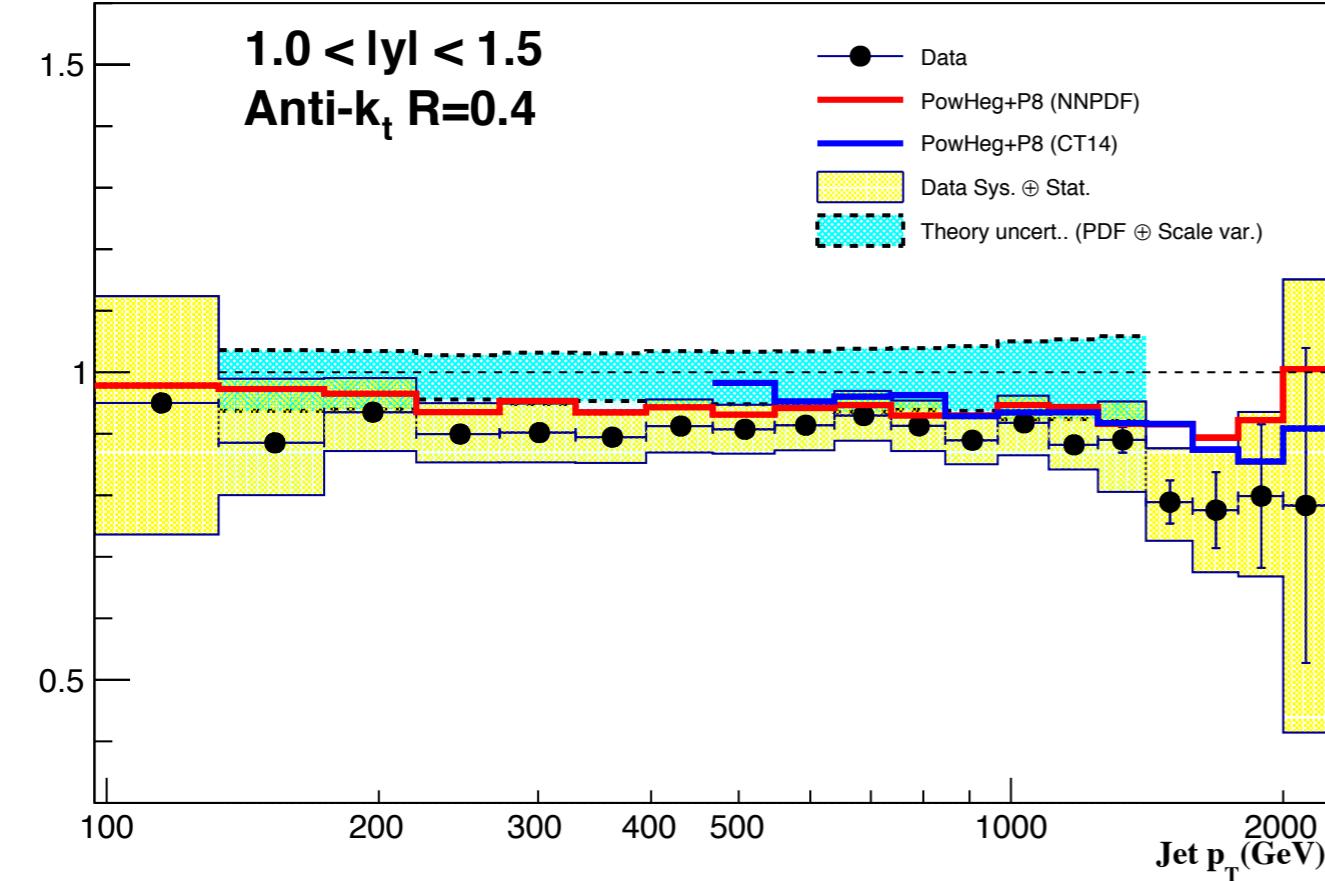
Ratio to NNLOJET(CT14) \otimes NP \otimes EWK



AK4 jets particle level

11

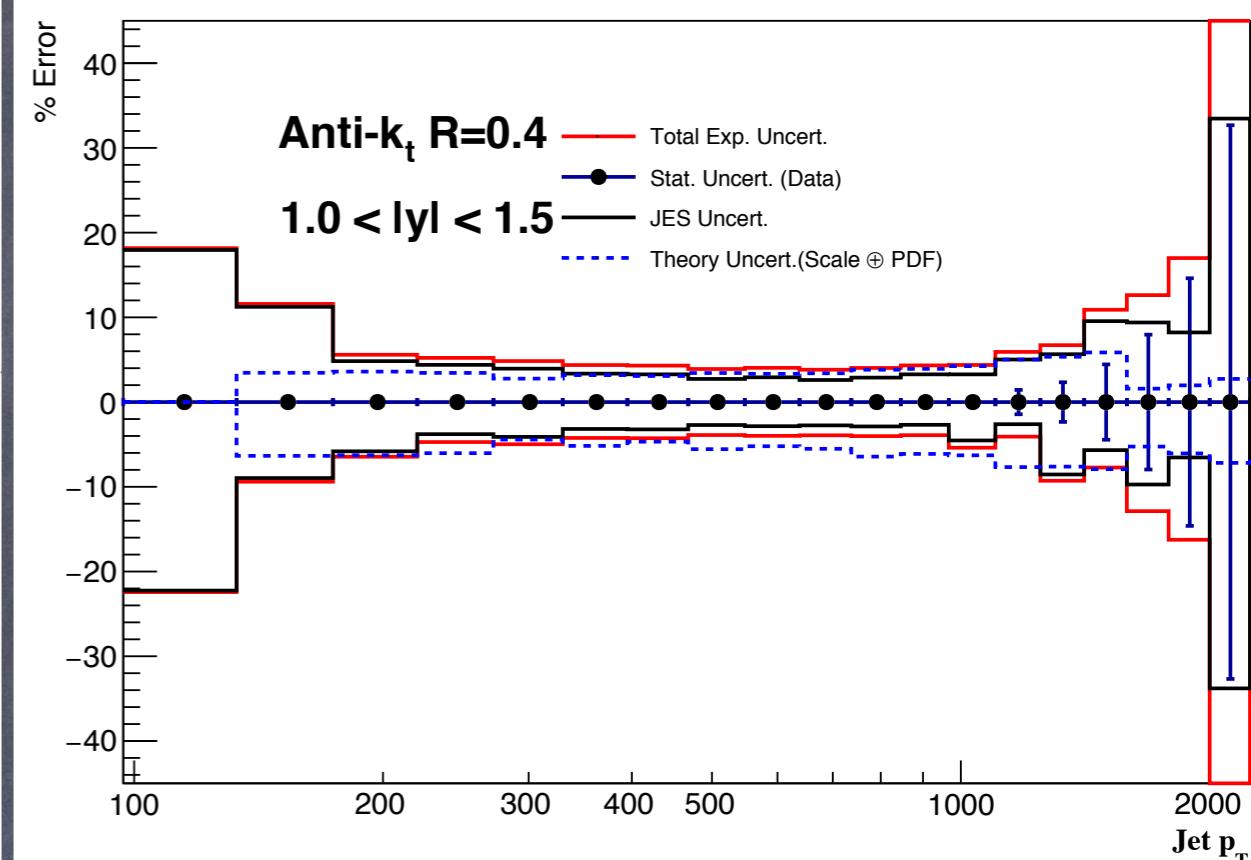
CMS Work in progress



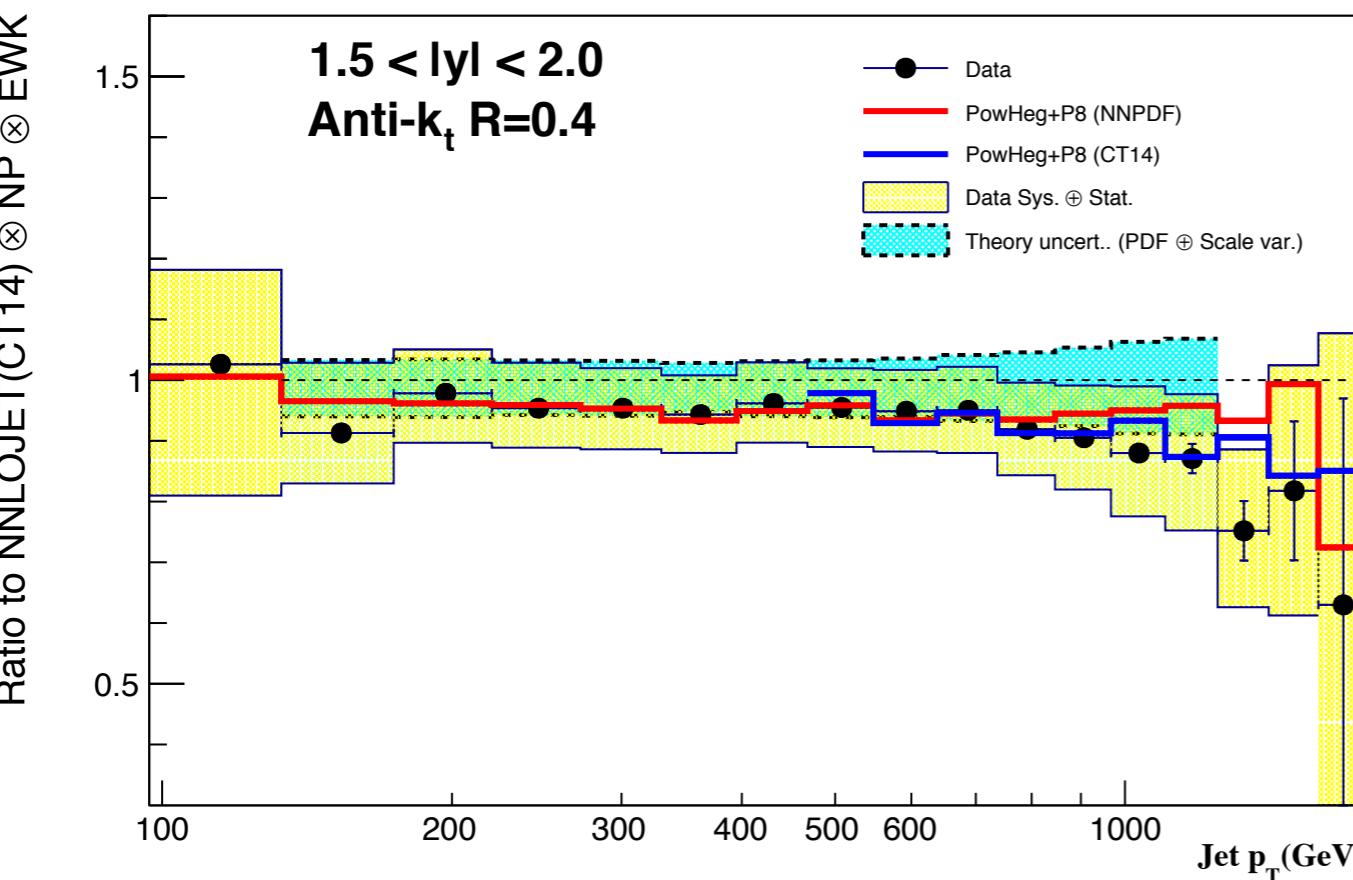
35.1 fb^{-1}

Anti- k_t R=0.4

1.0 < $|y| < 1.5$

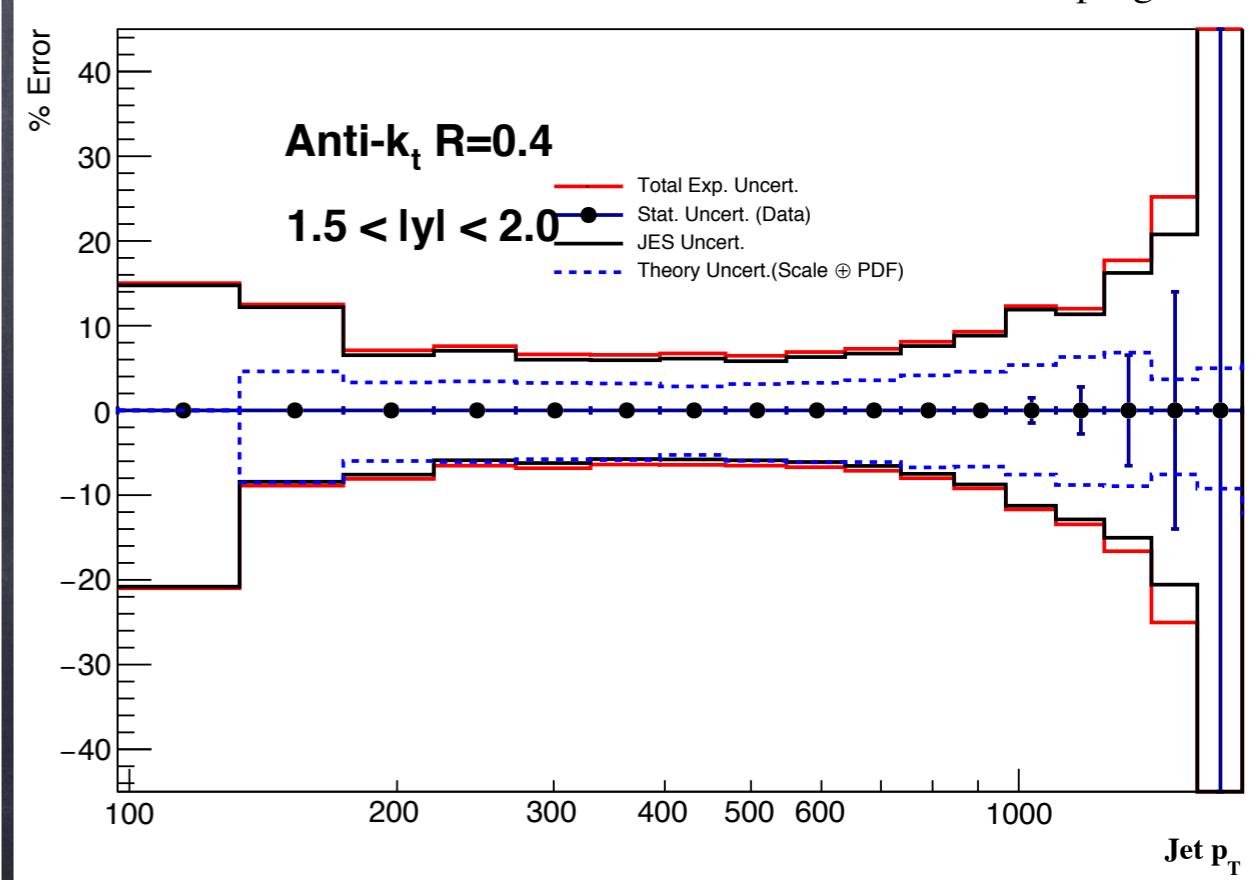


CMS Work in progress



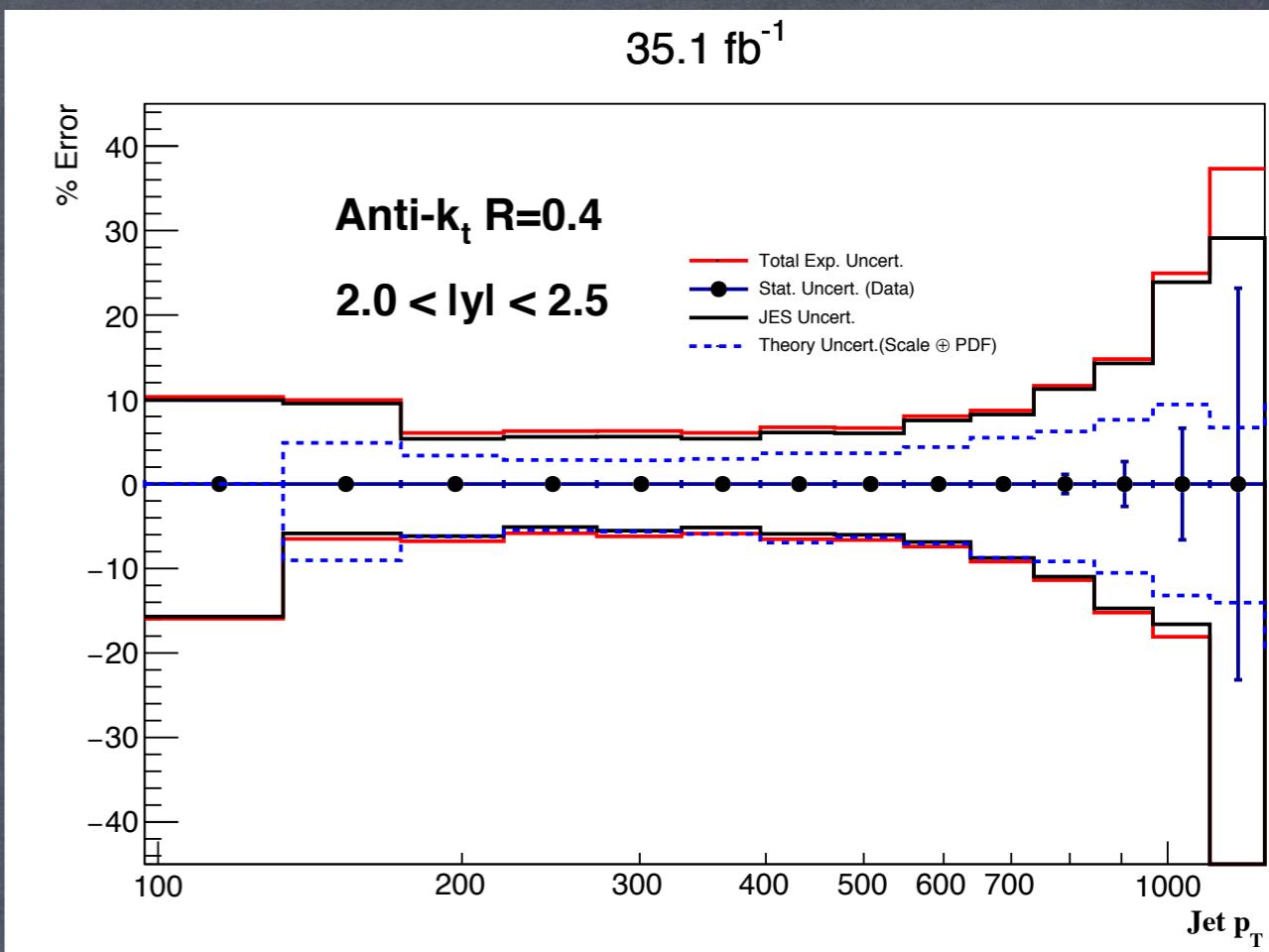
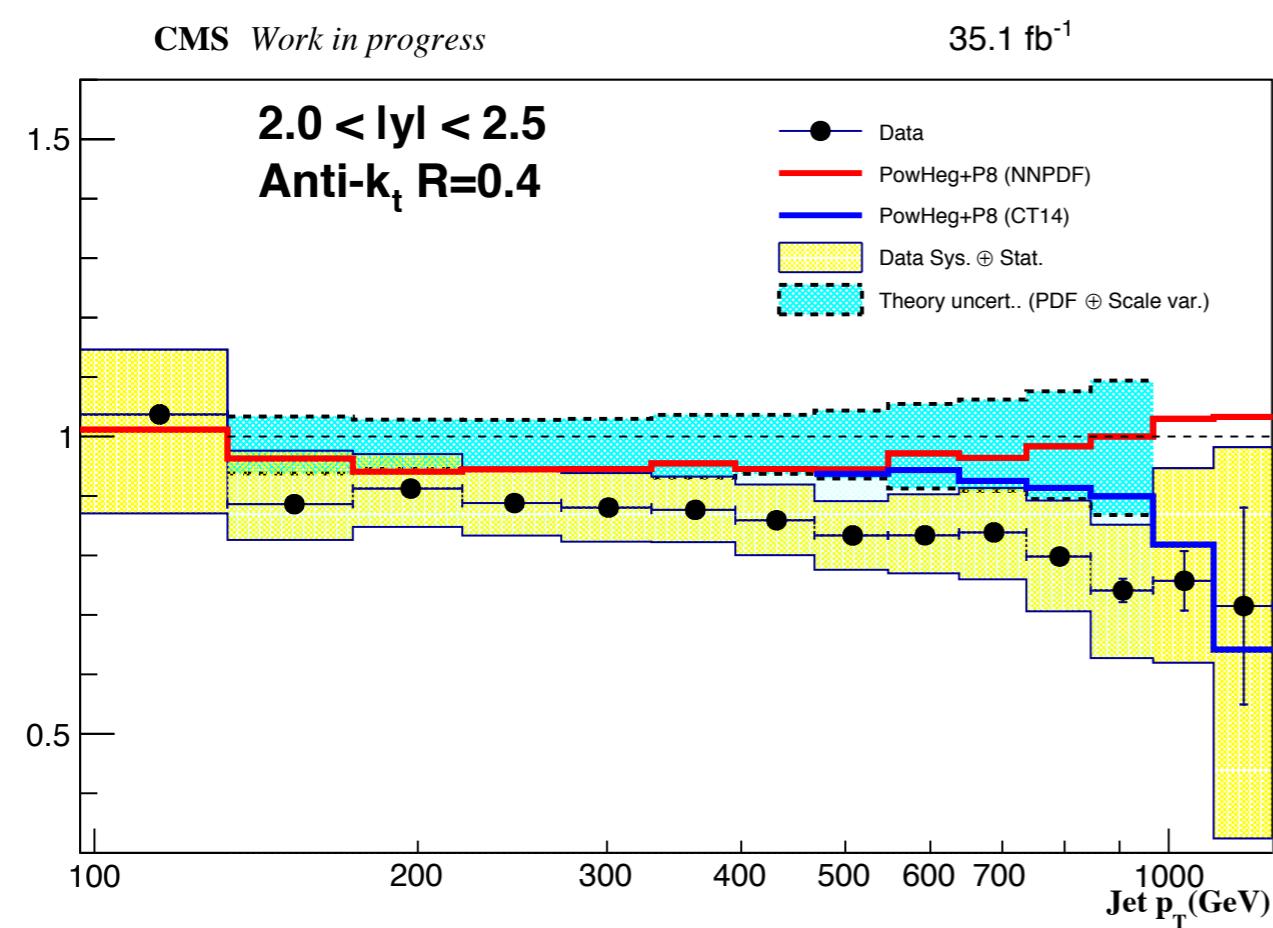
35.1 fb^{-1}

CMS work in progress

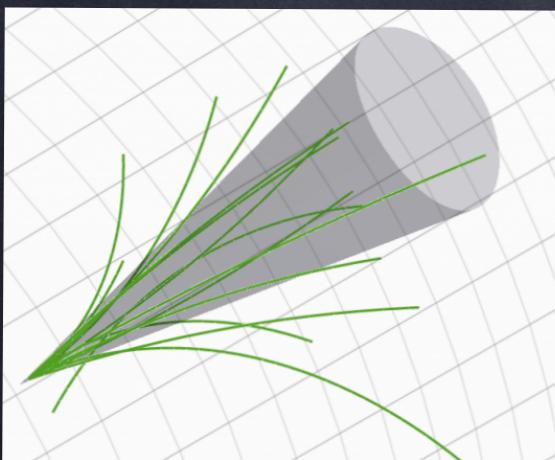


Particle Level Results

CMS Work in progress

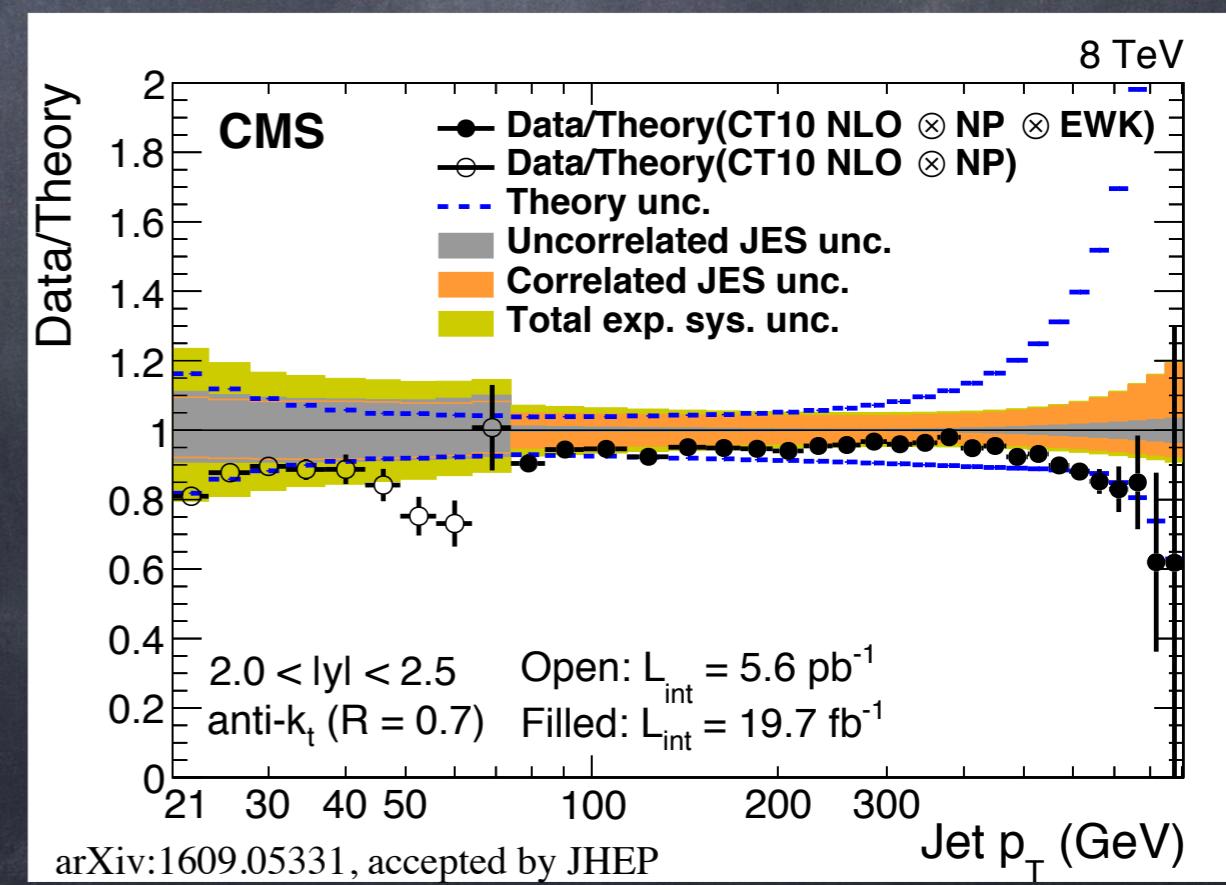
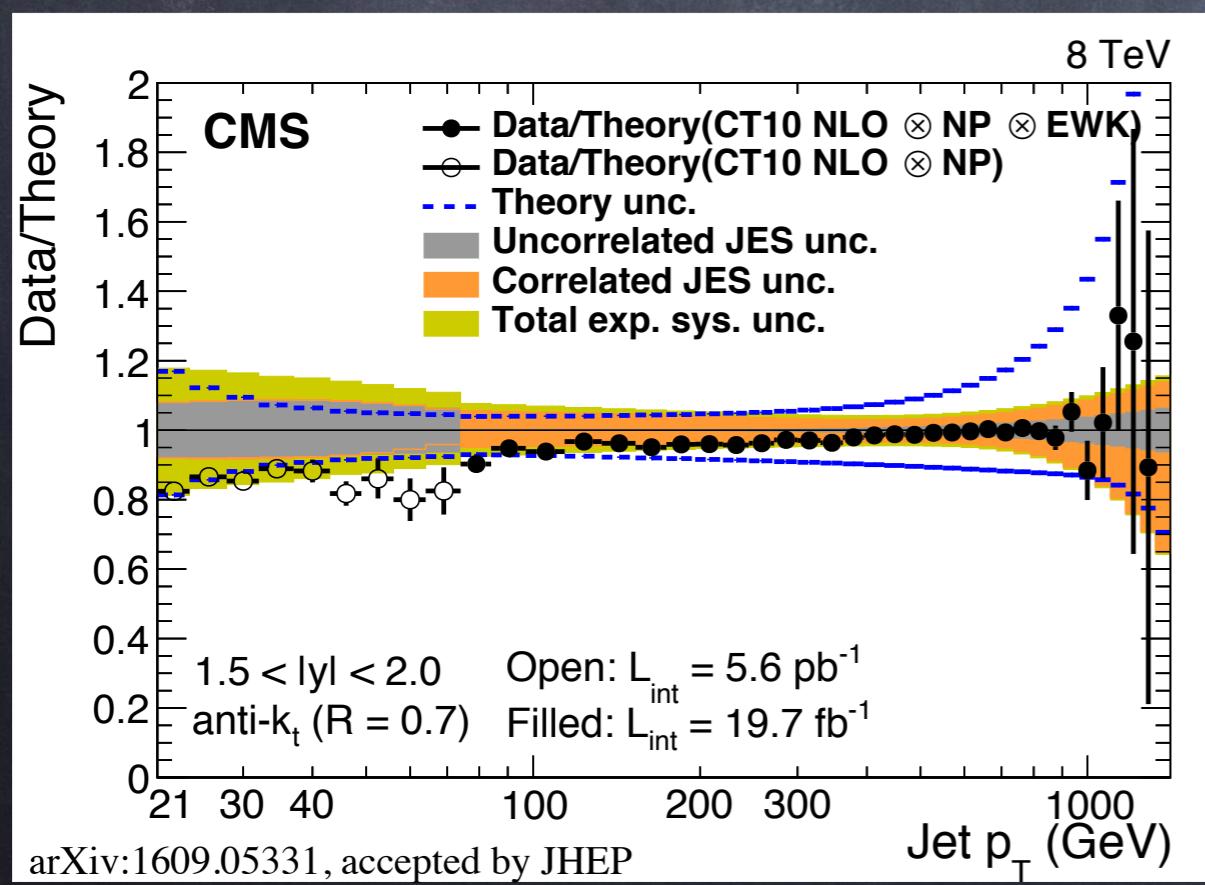
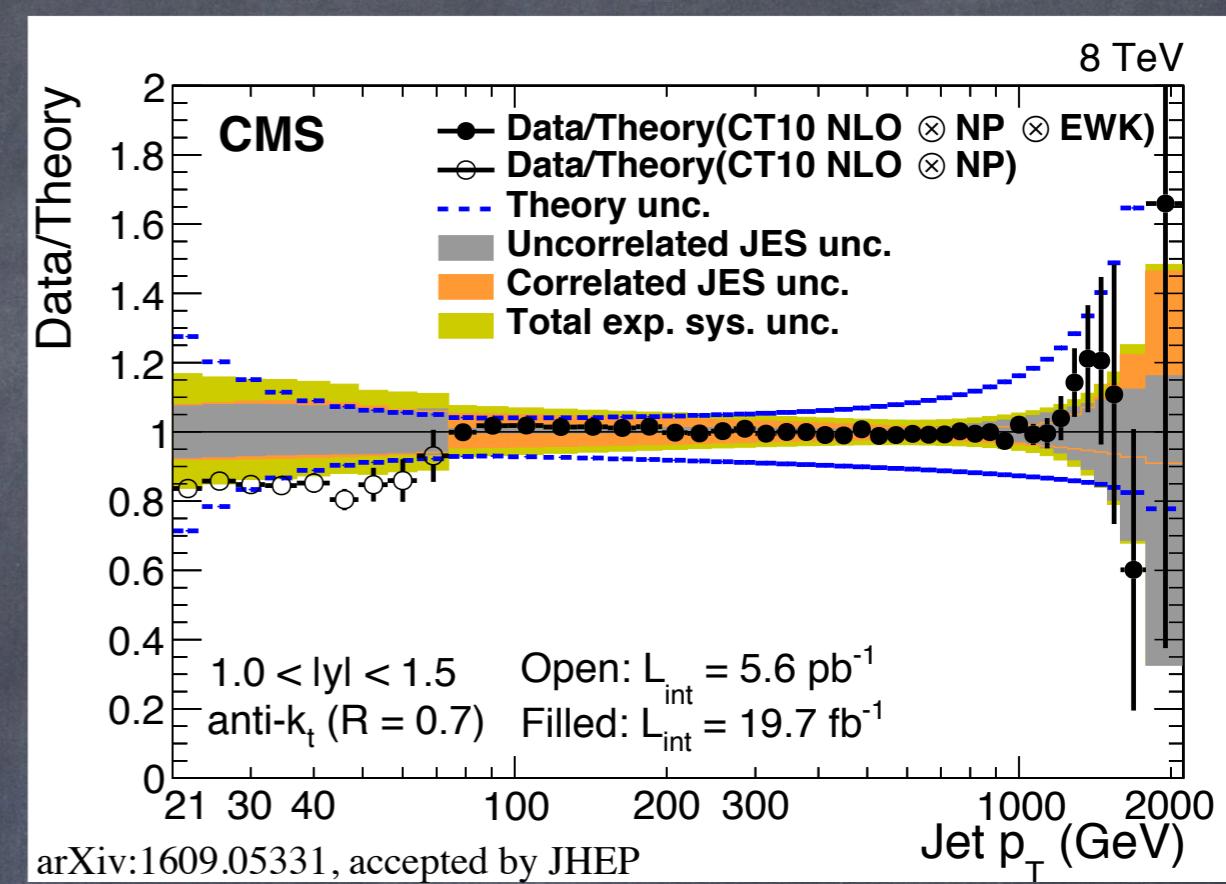
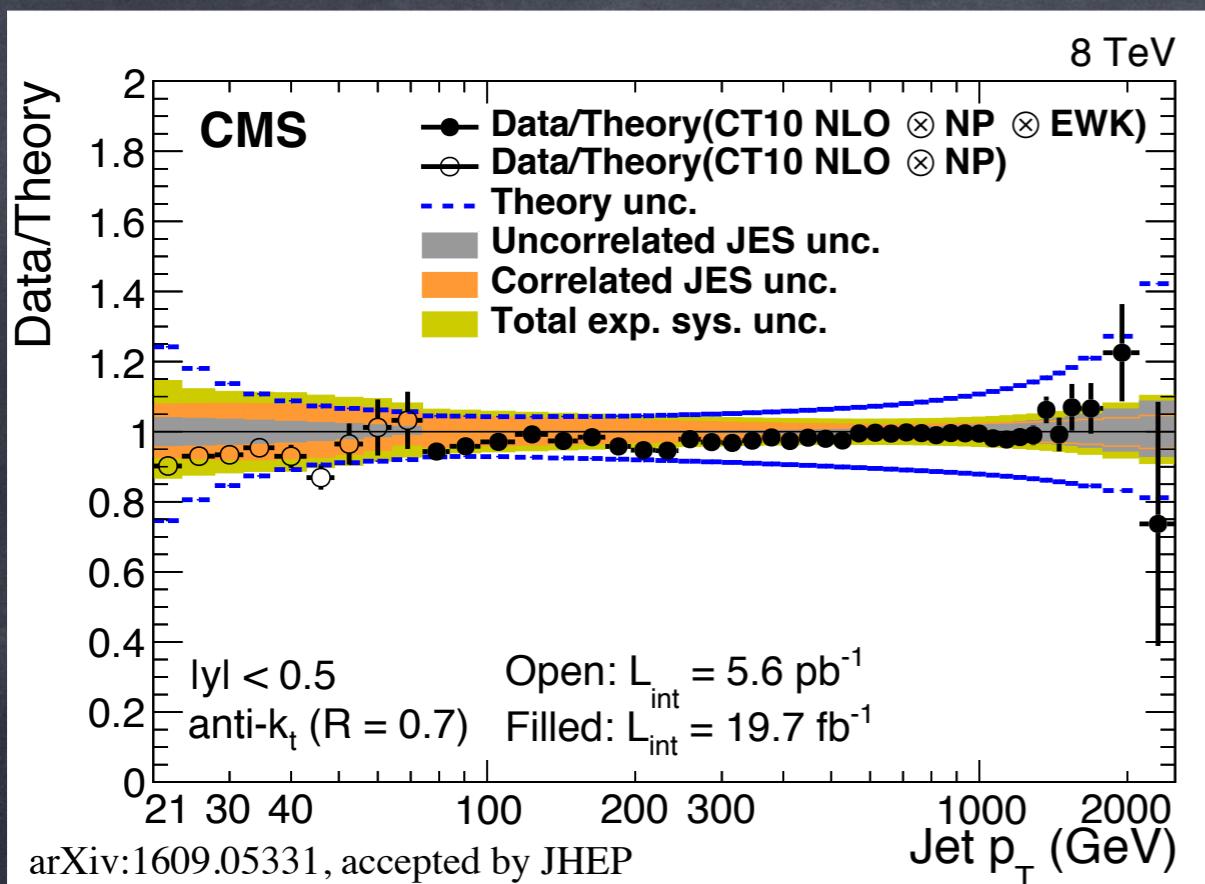


- Within theory uncertainty, NNLO tends to overestimate the measurement for R=0.4
- PS and soft-gluon resummation contributions are more relevant for R=0.4 (than 0.7)
 - ▶ Leads to “out of cone effects” in (fixed order) theory calculations



Keep an eye on JetMet
and final calibration!!

Inclusive jet measurement @ 8 TeV



Impact of JES uncertainty sources

25 JES sources,
uncorrelated among each other

```
AbsoluteMPFBias
AbsoluteScale
AbsoluteStat
FlavorQCD
Fragmentation
PileUpDataMC
PileUpPtBB
PileUpPtEC1
PileUpPtEC2
PileUpPtHF
PileUpPtRef
RelativeBal
RelativeFSR
RelativeJEREC1
RelativeJEREC2
RelativeJERHF
RelativePtBB
RelativePtEC1
RelativePtEC2
RelativePtHF
RelativeStatEC
RelativeStatFSR
RelativeStatHF
SinglePionECAL
SinglePionHCAL
```

They are fully
correlated in p_T
and η

JES source	y _{low}	y _{high}	pT _{low}	pT _{high}	Up variation (%)	Down variation (%)
PileUpDataMC	1.0	1.5	97.0	133.0	-3.14903750782	-4.41104548981
PileUpDataMC	1.0	1.5	133.0	174.0	1.96447026472	1.67055525404
PileUpDataMC	1.0	1.5	174.0	220.0	-0.123818899685	-0.676218173163
PileUpDataMC	1.0	1.5	220.0	272.0	0.235049802959	0.0608756256501
PileUpDataMC	1.0	1.5	272.0	330.0	0.101325251876	-0.246746630131
PileUpDataMC	1.0	1.5	330.0	395.0	0.0891277205606	-0.0266697344325
PileUpDataMC	1.0	1.5	395.0	468.0	0.122035052163	-0.137176312694
PileUpDataMC	1.0	1.5	468.0	548.0	0.0656825715147	-0.0418689161563
PileUpDataMC	1.0	1.5	548.0	638.0	0.0532875173899	-0.0665765326969
PileUpDataMC	1.0	1.5	638.0	737.0	0.0496659689421	-0.0586600165398
PileUpDataMC	1.0	1.5	737.0	846.0	0.0436104456287	-0.0341289508378
PileUpDataMC	1.0	1.5	846.0	967.0	0.0706889621749	-0.0803189162915
PileUpDataMC	1.0	1.5	967.0	1101.0	0.00248840734112	0.0240559583338
PileUpDataMC	1.0	1.5	1101.0	1248.0	0.0225573653562	-0.0731770779715
PileUpDataMC	1.0	1.5	1248.0	1410.0	-0.00998868174797	0.0778023107984
PileUpDataMC	1.0	1.5	1410.0	1588.0	0.0394393837627	-0.118285910159
PileUpDataMC	1.0	1.5	1588.0	1784.0	-0.0396292802748	0.0471978616151
PileUpDataMC	1.0	1.5	1784.0	2000.0	0.0378805355364	-0.0281382830659
PileUpDataMC	1.0	1.5	2000.0	2238.0	-0.043486375591	0.0299332017611
PileUpDataMC	1.0	1.5	2238.0	2500.0	0.407072478059	-0.40154698308
PileUpDataMC	1.0	1.5	2500.0	2787.0	-0.0471849428164	0.0348148222959
PileUpDataMC	1.0	1.5	2787.0	3103.0	-0.122141619506	0.0847942971814

JES source	y _{low}	y _{high}	pT _{low}	pT _{high}	Up variation (%)	Down variation (%)
RelativePtEC2	2.0	2.5	97.0	133.0	-0.908784630591	-3.48220318887
RelativePtEC2	2.0	2.5	133.0	174.0	1.97883693539	0.39009800275
RelativePtEC2	2.0	2.5	174.0	220.0	0.497590788218	-0.85979460031
RelativePtEC2	2.0	2.5	220.0	272.0	0.476679191227	-0.330676427311
RelativePtEC2	2.0	2.5	272.0	330.0	0.241496267347	-0.285675995065
RelativePtEC2	2.0	2.5	330.0	395.0	0.0724441132242	-0.0461402158195
RelativePtEC2	2.0	2.5	395.0	468.0	-0.122213234594	0.0656208453593
RelativePtEC2	2.0	2.5	468.0	548.0	-0.187434924475	0.232105896613
RelativePtEC2	2.0	2.5	548.0	638.0	-0.327935503889	0.321886553993
RelativePtEC2	2.0	2.5	638.0	737.0	-0.248243274648	0.284293587347
RelativePtEC2	2.0	2.5	737.0	846.0	-0.300452477408	0.200019724405
RelativePtEC2	2.0	2.5	846.0	967.0	-0.00668043313993	0.0140820726399
RelativePtEC2	2.0	2.5	967.0	1101.0	-0.0539554880665	0.166679016827
RelativePtEC2	2.0	2.5	1101.0	1248.0	0.0907640965036	-0.261932363428
RelativePtEC2	2.0	2.5	1248.0	1410.0	-3.71985766298	10.6520000653
RelativePtEC2	2.0	2.5	1410.0	1588.0	1.04256783376	-2.9818790057

JES source	y _{low}	y _{high}	pT _{low}	pT _{high}	Up variation (%)	Down variation (%)
SinglePionECAL	0.0	0.5	97.0	133.0	-2.87298865733	-1.96675791873
SinglePionECAL	0.0	0.5	133.0	174.0	0.897973462204	1.20470177586
SinglePionECAL	0.0	0.5	174.0	220.0	-0.328412925133	-0.0441357558624
SinglePionECAL	0.0	0.5	220.0	272.0	0.081600568767	0.0604304107932
SinglePionECAL	0.0	0.5	272.0	330.0	0.0438910954477	-0.104114873051
SinglePionECAL	0.0	0.5	330.0	395.0	0.0907360557523	-0.0621410111236
SinglePionECAL	0.0	0.5	395.0	468.0	0.153517083845	-0.176466192177
SinglePionECAL	0.0	0.5	468.0	548.0	0.171167178724	-0.157036796069
SinglePionECAL	0.0	0.5	548.0	638.0	0.310269609997	-0.328077168982
SinglePionECAL	0.0	0.5	638.0	737.0	0.244043167272	-0.230773890026
SinglePionECAL	0.0	0.5	737.0	846.0	0.399164241224	-0.371026196969
SinglePionECAL	0.0	0.5	846.0	967.0	0.308374720788	-0.361573866115
SinglePionECAL	0.0	0.5	967.0	1101.0	0.515831776413	-0.465358292635
SinglePionECAL	0.0	0.5	1101.0	1248.0	0.399257935184	-0.43744977965
SinglePionECAL	0.0	0.5	1248.0	1410.0	0.608458733066	-0.634784374698
SinglePionECAL	0.0	0.5	1410.0	1588.0	0.461815024753	-0.436150334539
SinglePionECAL	0.0	0.5	1588.0	1784.0	0.849249641983	-0.458040709535
SinglePionECAL	0.0	0.5	1784.0	2000.0	0.29082503453	-0.695348893674
SinglePionECAL	0.0	0.5	2000.0	2238.0	0.675478168402	-1.38172498776
SinglePionECAL	0.0	0.5	2238.0	2500.0	0.855459667806	0.651108816864
SinglePionECAL	0.0	0.5	2500.0	2787.0	3.32456484211	-2.78161006987
SinglePionECAL	0.0	0.5	2787.0	3103.0	-2.04495388299	-2.3176331784

Impact of JES uncertainty sources

25 JES sources,
uncorrelated among each other

```
AbsoluteMPFBias
AbsoluteScale
AbsoluteStat
FlavorQCD
Fragmentation
PileUpDataMC
PileUpPtBB
PileUpPtEC1
PileUpPtEC2
PileUpPtHF
PileUpPtRef
RelativeBal
RelativeFSR
RelativeJEREC1
RelativeJEREC2
RelativeJERHF
RelativePtBB
RelativePtEC1
RelativePtEC2
RelativePtHF
RelativeStatEC
RelativeStatFSR
RelativeStatHF
SinglePionECAL
SinglePionHCAL
```

They are fully
correlated in p_T
and η

$|y| < 0.5$

$2.0 < |y| < 2.5$

97.0	133.0	3.81123687318	5.81992178011
133.0	174.0	3.71541501925	1.94251166224
174.0	220.0	2.2583840103	2.52286454832
220.0	272.0	2.3686949998	2.07223277107
272.0	330.0	1.80715440894	1.88068655797
330.0	395.0	1.6328420427	1.60788740461
395.0	468.0	1.34803369813	1.31305578454
468.0	548.0	1.31679767297	1.30930195505
548.0	638.0	1.41493274957	1.42683773887
638.0	737.0	1.46870181657	1.40889223221
737.0	846.0	1.53175618783	1.49724307446
846.0	967.0	1.69960650331	1.60308485371
967.0	1101.0	2.1572799019	2.3521895249
1101.0	1248.0	2.50149156206	2.37576939859
1248.0	1410.0	3.15916937889	2.83801907652
1410.0	1588.0	3.46125144677	4.26934972869
1588.0	1784.0	3.2739760127	3.08115703381
1784.0	2000.0	5.38978045461	5.54015802019
2000.0	2238.0	4.14229594921	4.97447034501
2238.0	2500.0	6.35510109682	4.82158654131
2500.0	2787.0	10.3185784588	18.4038813337
2787.0	3103.0	18.2465557991	7.30925203691

pT bins

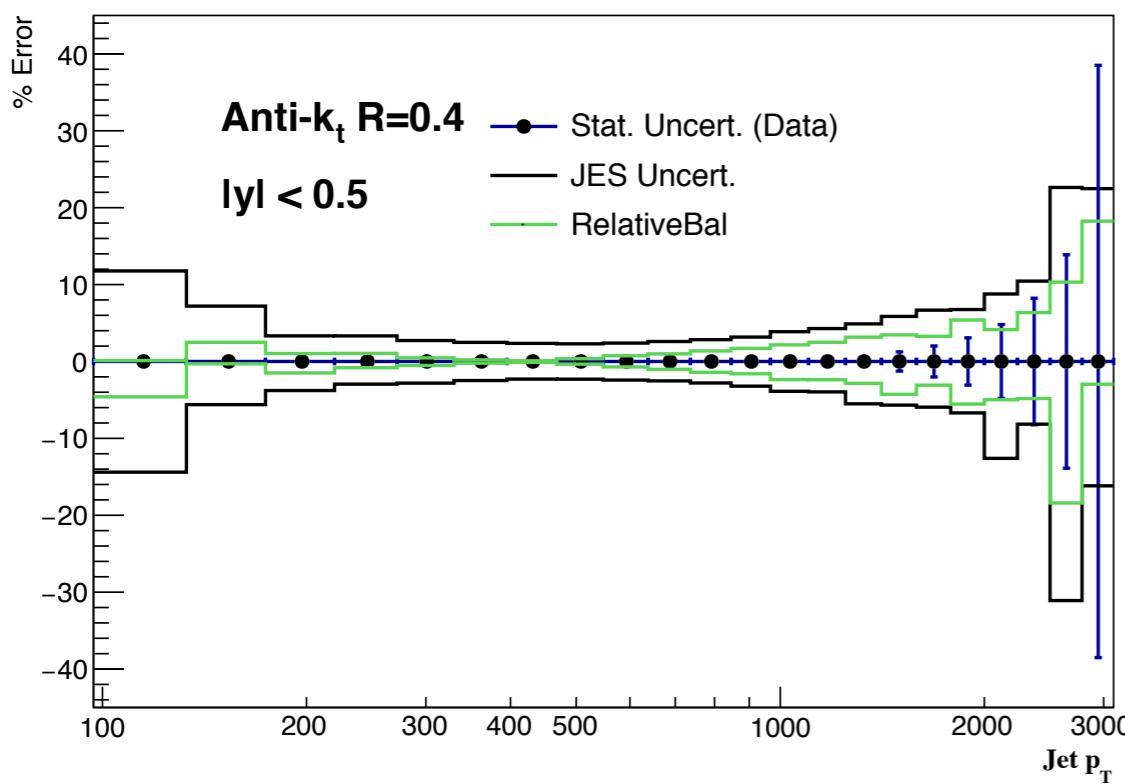
97.0	133.0	3.06927377575	6.20318836047
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174.0	220.0	3.3427705086	3.79018047583
220.0	272.0	3.61074323297	3.15410814254
272.0	330.0	3.38035233885	3.31001204048
330.0	395.0	3.27244736115	3.03151074932
395.0	468.0	3.39636708406	3.26317821704
468.0	548.0	3.36853558828	3.2158931393
548.0	638.0	3.97839591688	3.58144038573
638.0	737.0	4.46875172824	4.79949257872
737.0	846.0	6.46681403096	6.23353754646
846.0	967.0	7.82221903824	7.89190598497
967.0	1101.0	12.4990636626	9.27618436212
1101.0	1248.0	17.2930984832	33.9725737683

dominant uncertainty sources

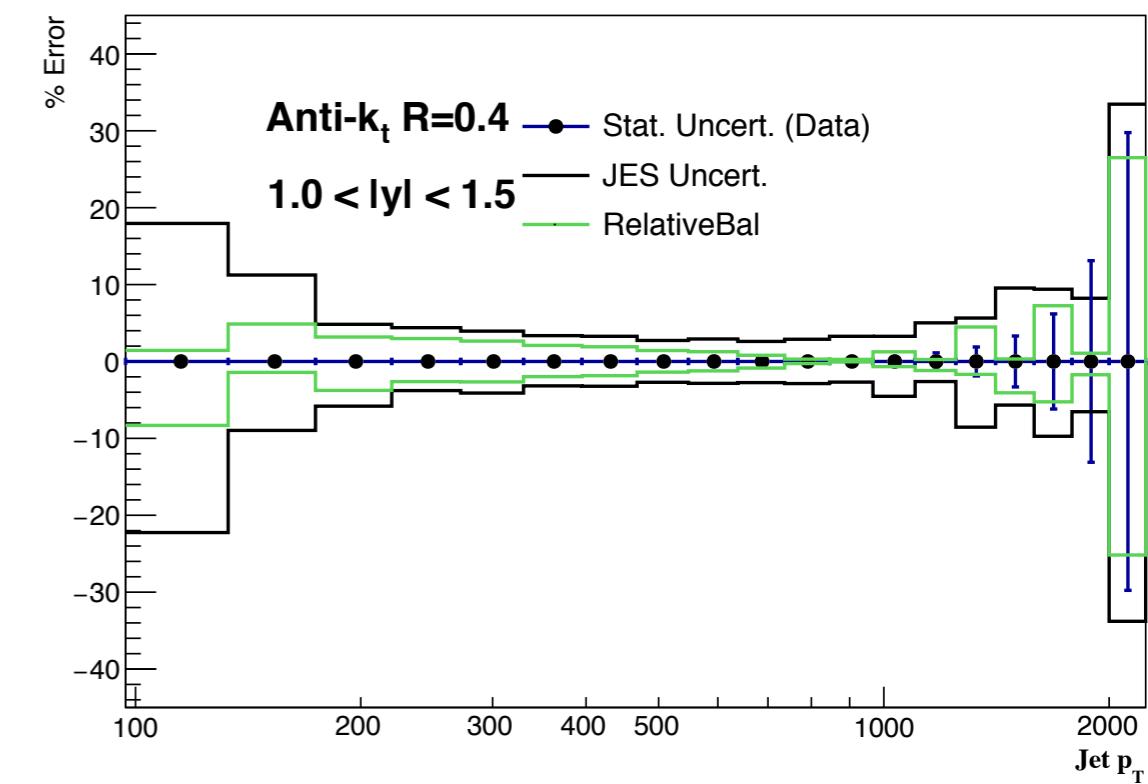
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FlavorQCD+	RelativeFSR-
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FlavorQCD+	FlavorQCD-
FlavorQCD+	AbsoluteMPFBias-
AbsoluteMPFBias+	AbsoluteMPFBias-
RelativeBal+	RelativeBal-
RelativeBal+	PileUpPtBB-

RelativeBal source

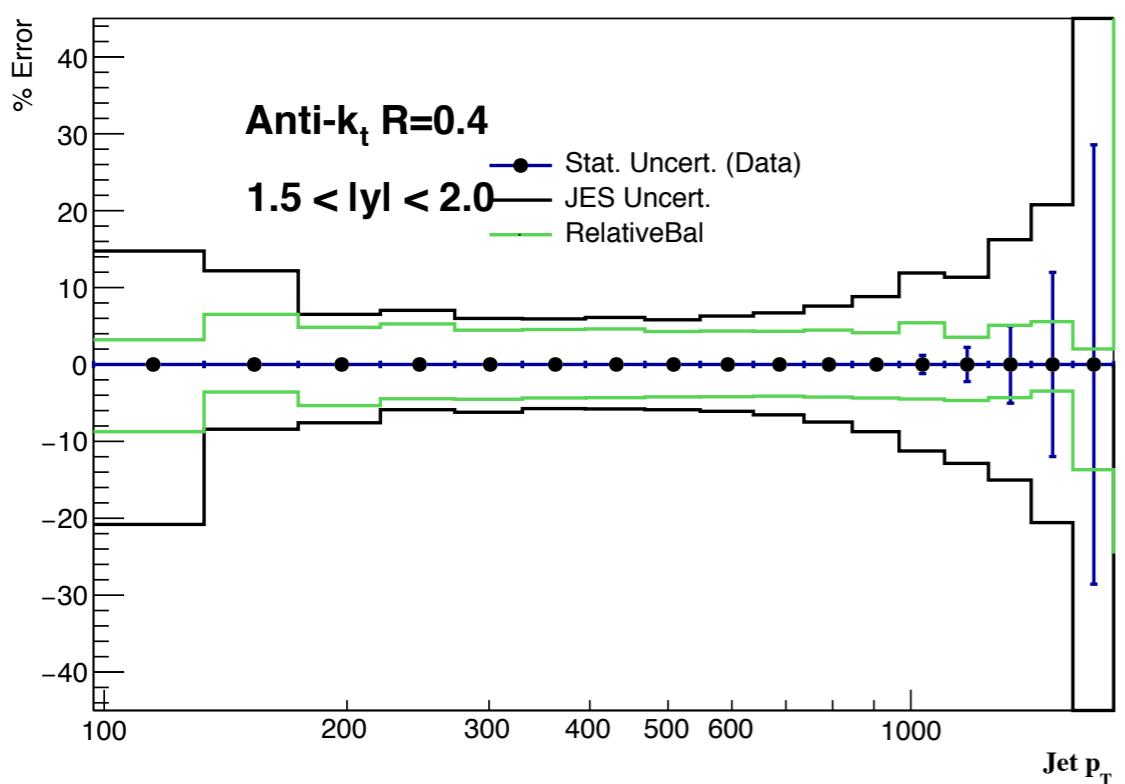
29.5 fb^{-1}



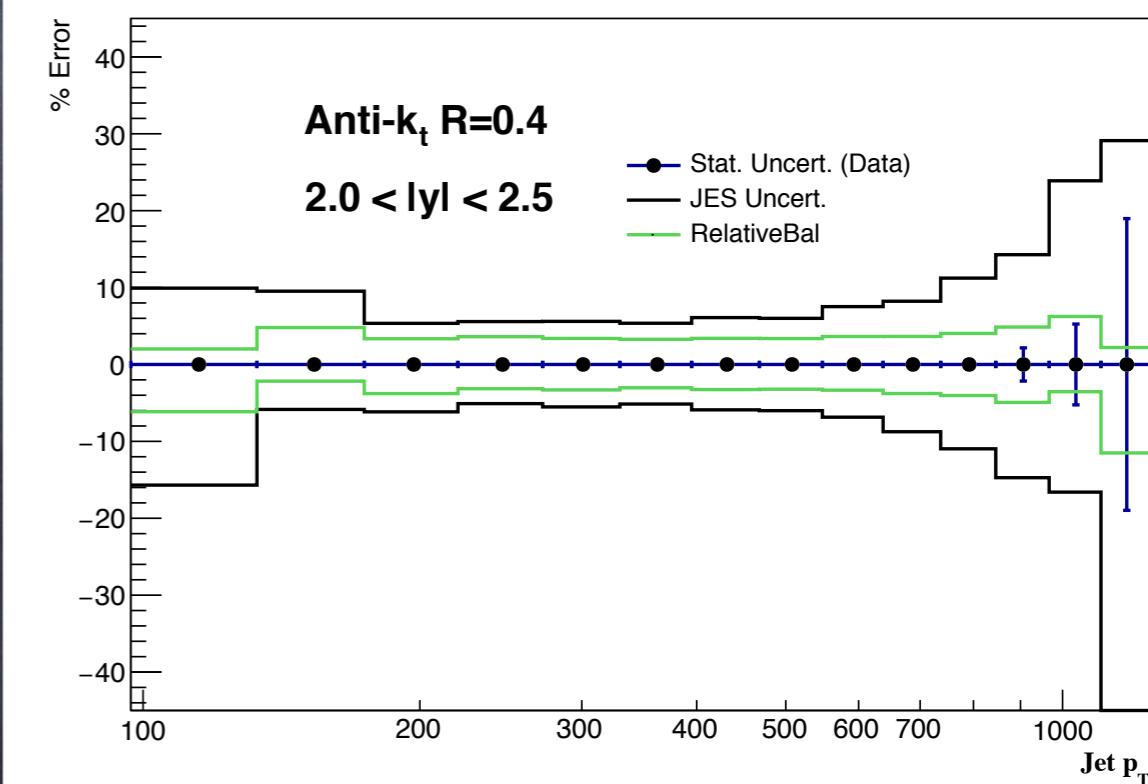
29.5 fb^{-1}



29.5 fb^{-1}



29.5 fb^{-1}



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- **RelativeBal:** full difference between log-linear fits of MPF and pT balance methods. This difference was negligible in Run I, but is inexplicably large in Run II. The reason is not yet understood, and this uncertainty source may still underestimate the true uncertainty.