Electroweak and Jet Measurements from CMS

PDF4LHC
July 4, 2011

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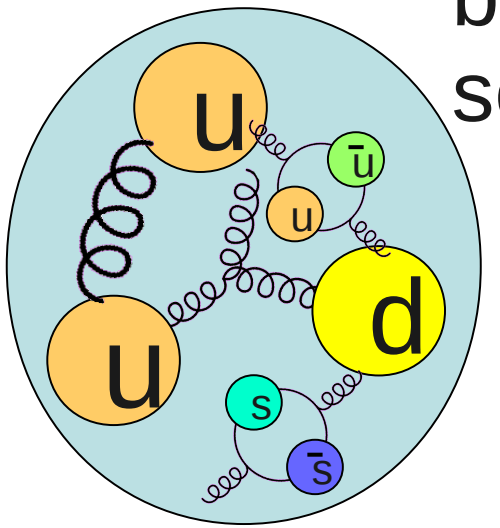
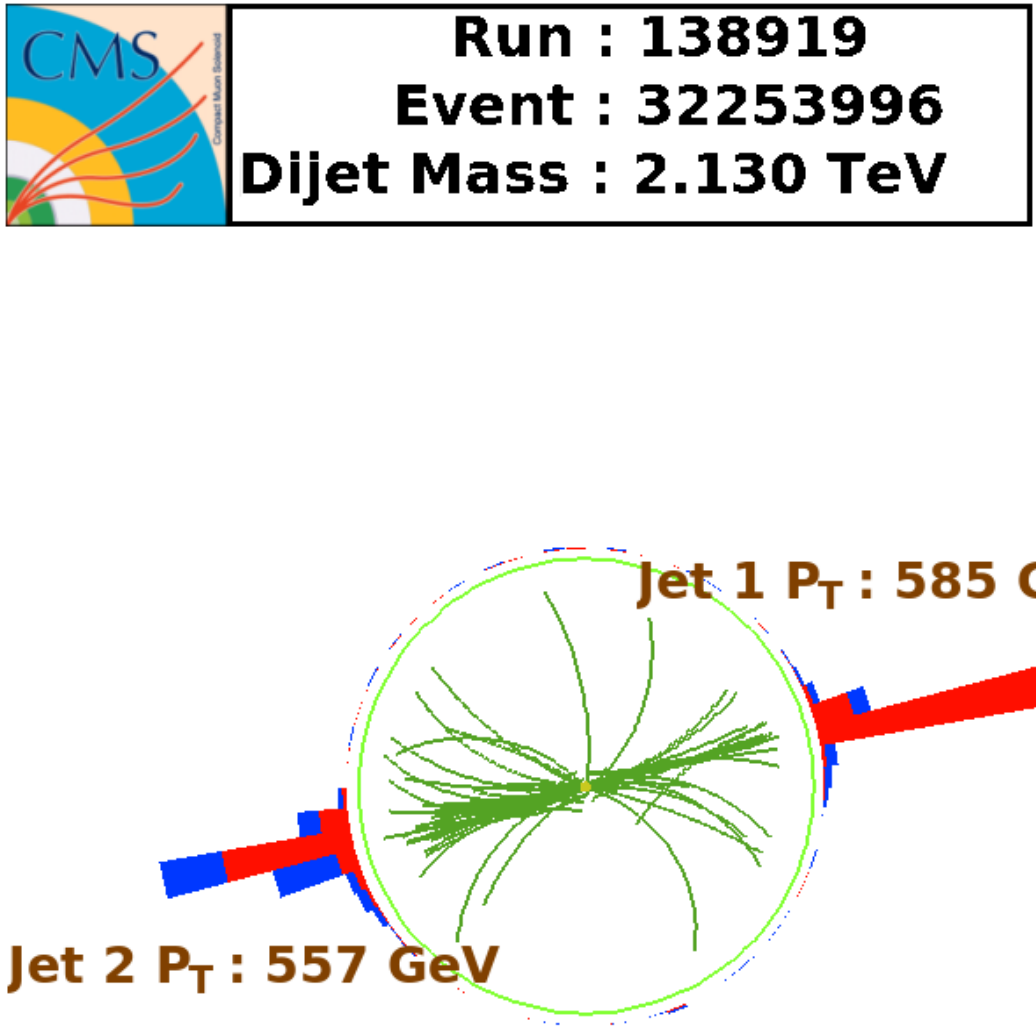
LHC Experimental Inputs to PDFs

- Every process at a hadron collider is affected by the PDFs.
- To constrain PDFs, one must identify processes where the PDF dependence can be cleanly separated from other effects

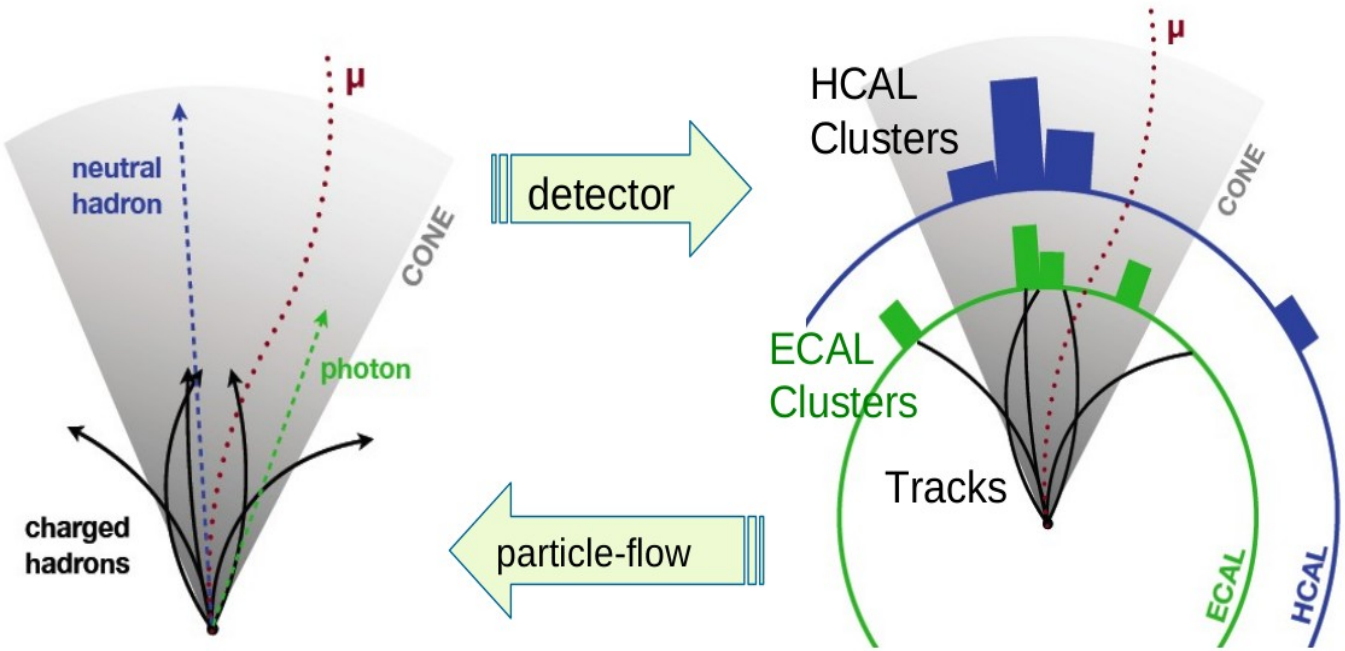


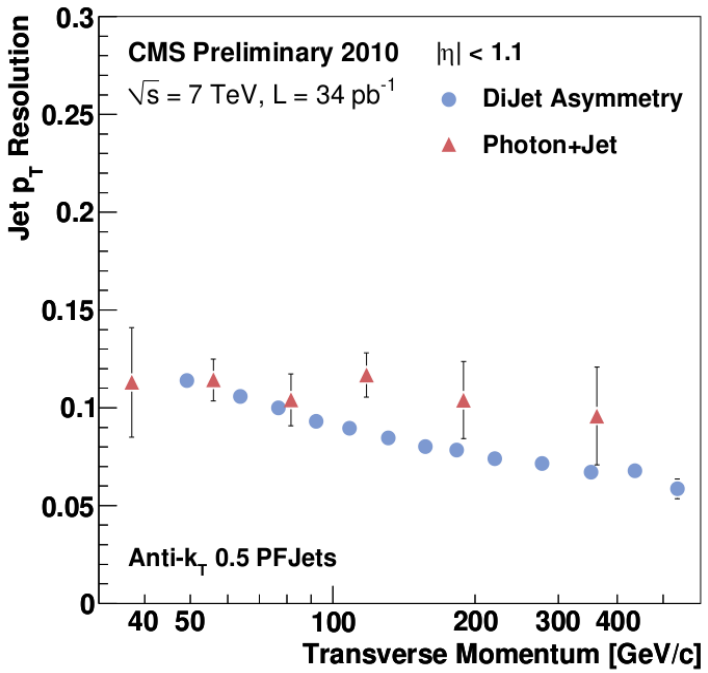
- Direct production of single objects is a powerful class of measurements
  - Inclusive jets
  - Inclusive photons
  - W production
  - Z production
- Given significant uncertainties in luminosity, shape measurements give the most useful input

Jet Measurements

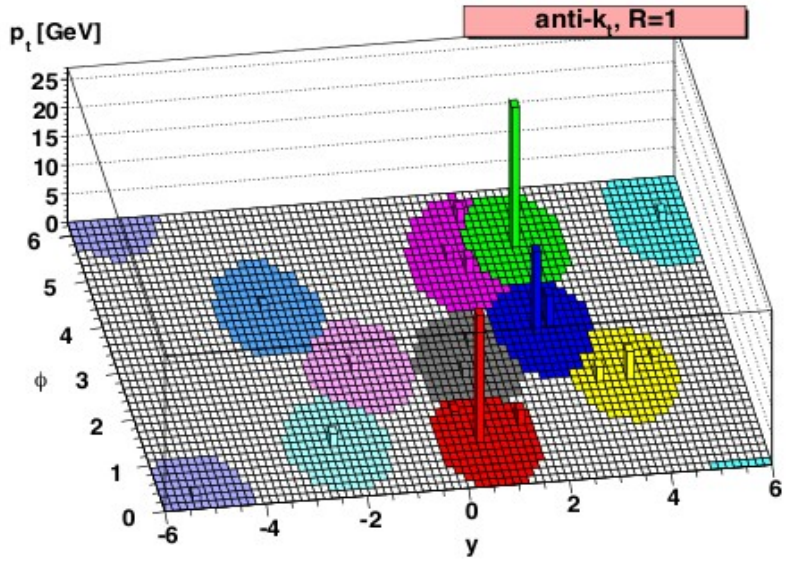


Jet Reconstruction





- Analyses on full 2010 data set use the Particle Flow technique, which provides good resolution down to low transverse momentum
- Results use the anti-k_T jet algorithm, with cone sizes depending on the analysis

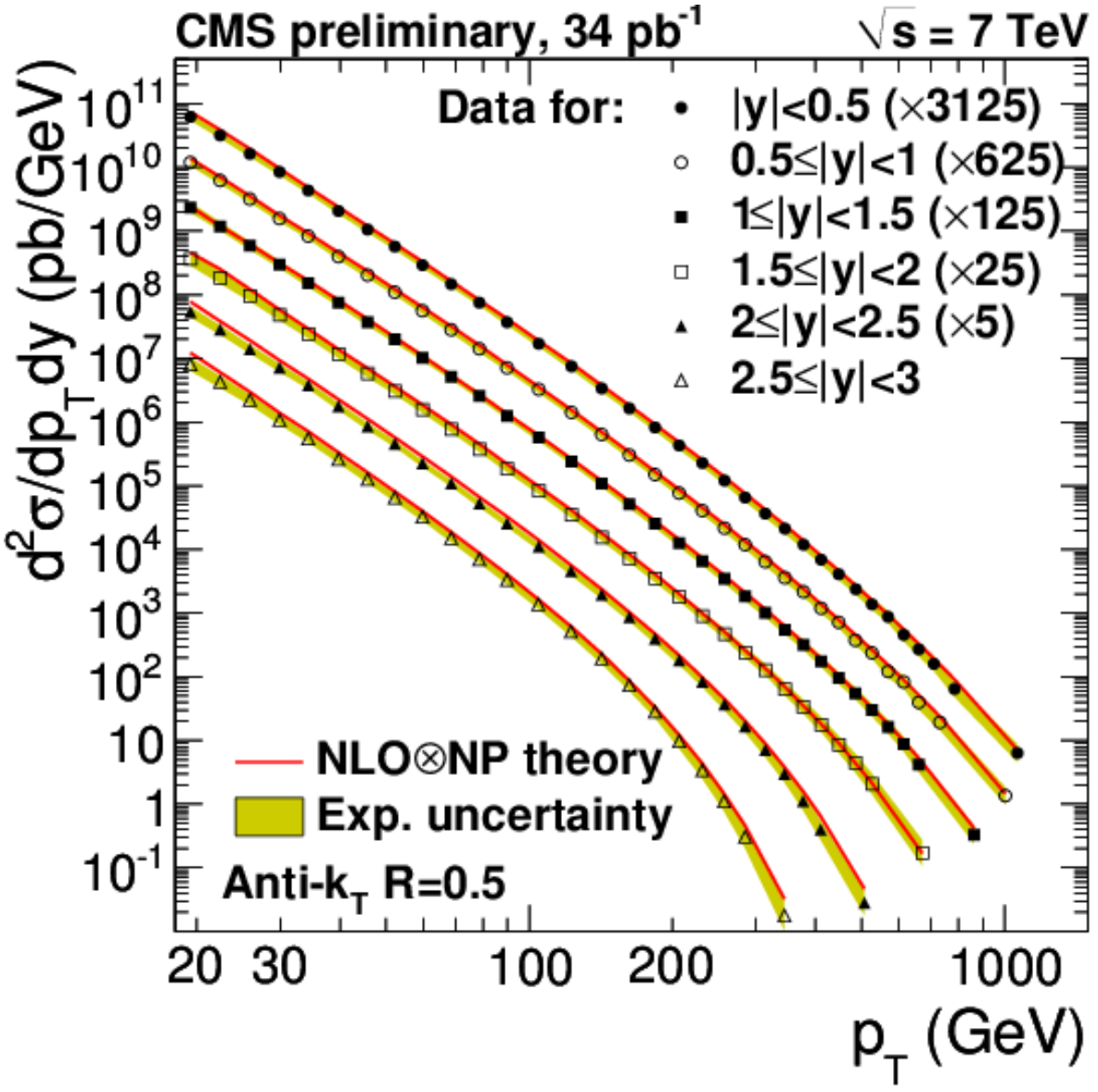


Inclusive Jet Cross-section

- Bin migration corrected using ansatz method

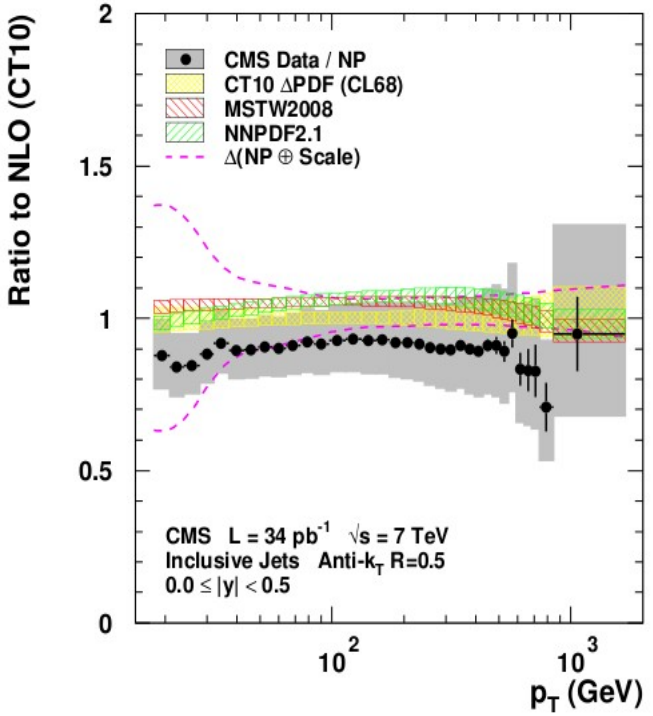
$$N_0 p_T^{-\alpha}\left[1-\frac{2p_T}{\sqrt{s}}\cosh(y)\right]^{\beta} e^{-\gamma/p_T}$$

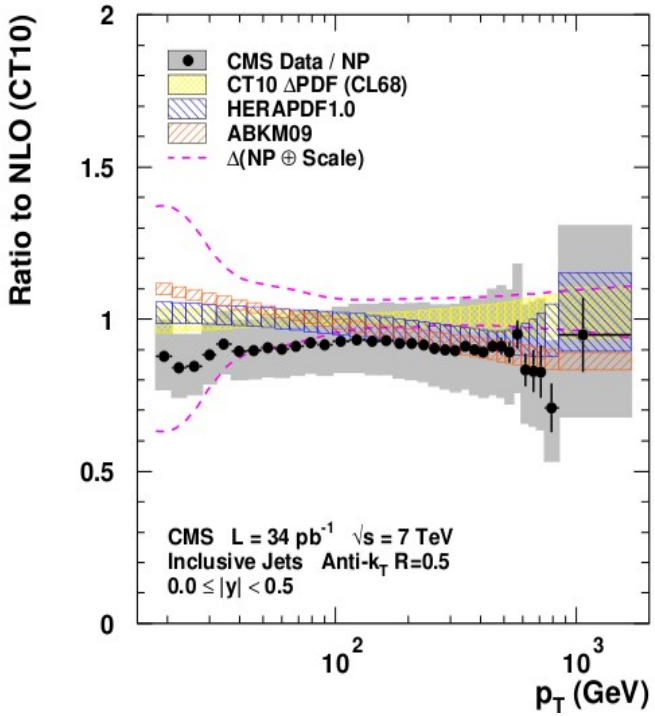
  - Magnitude of corrections 5-10% at central rapidity and 15-50% at large rapidity

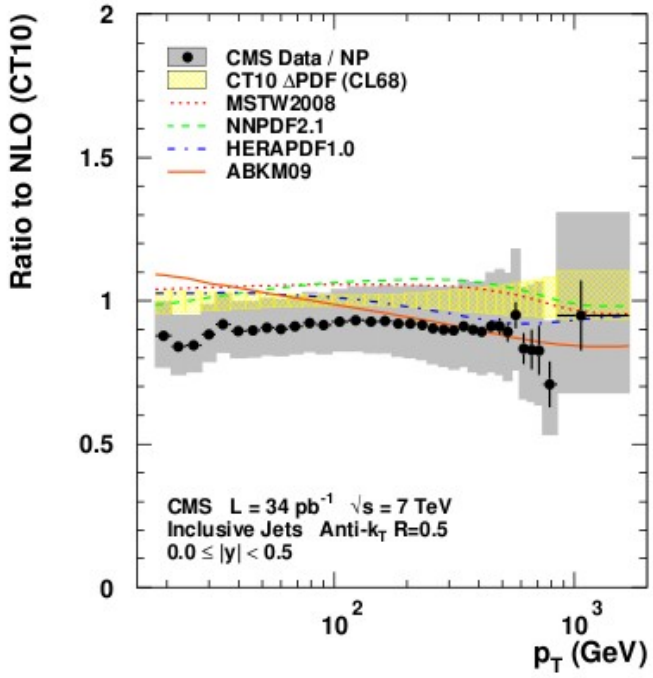


CMS-QCD-10-011

Building Comparisons for PDFs

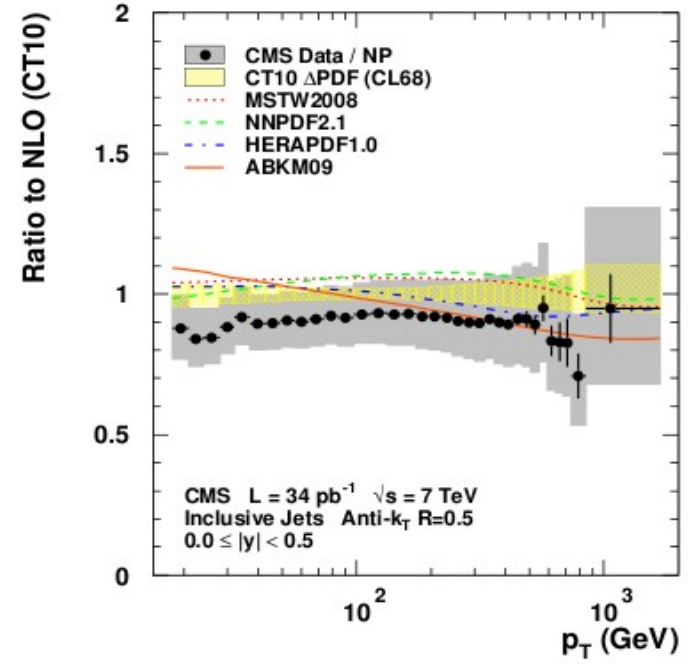


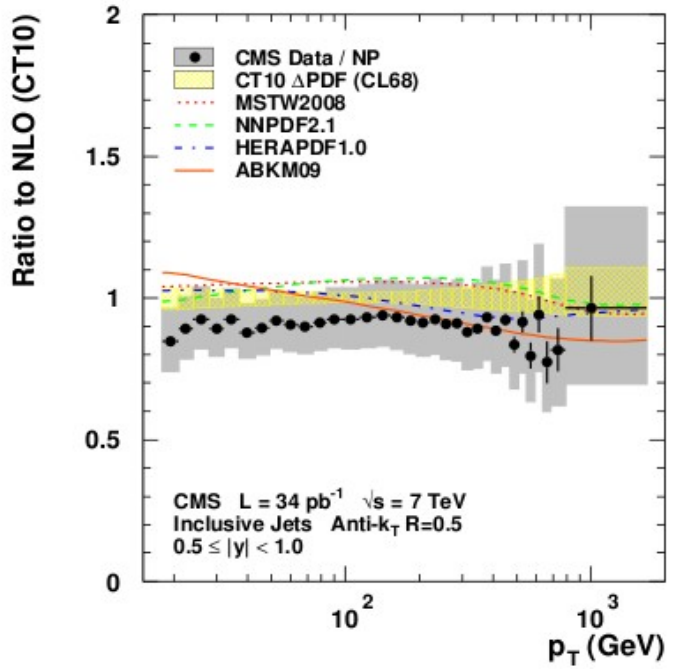


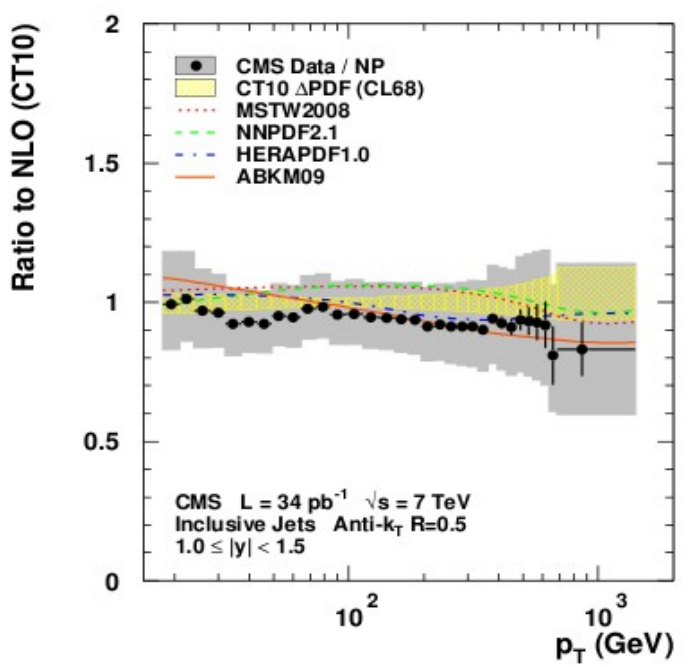


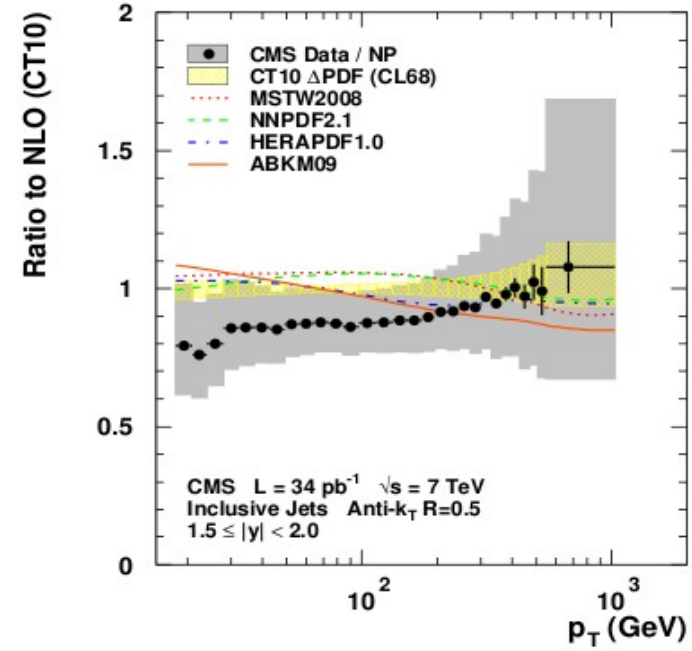
- To avoid statistical effects in data from driving apparent variations in theory, use CT10 as a comparison point, deriving uncertainty bands from five PDF sets
- Generator : NLOJET++ 2.0.1 / fastNLO 1.4

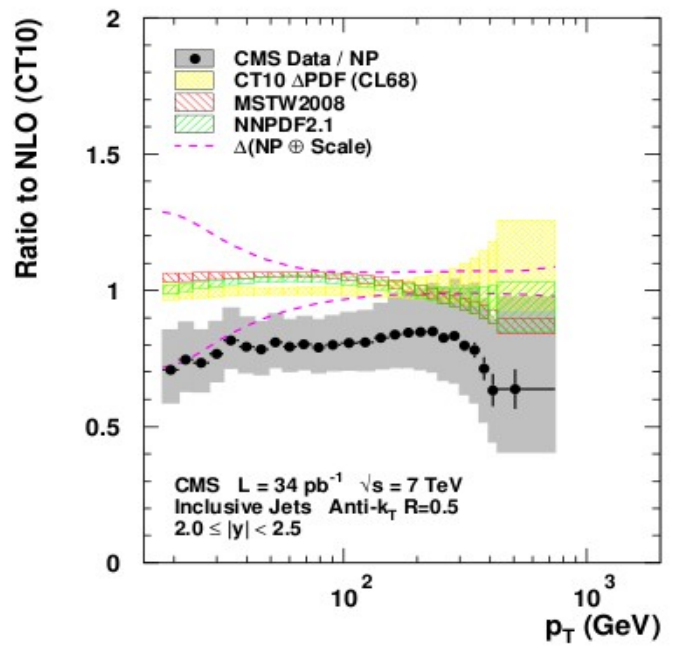
Comparing with different PDF sets

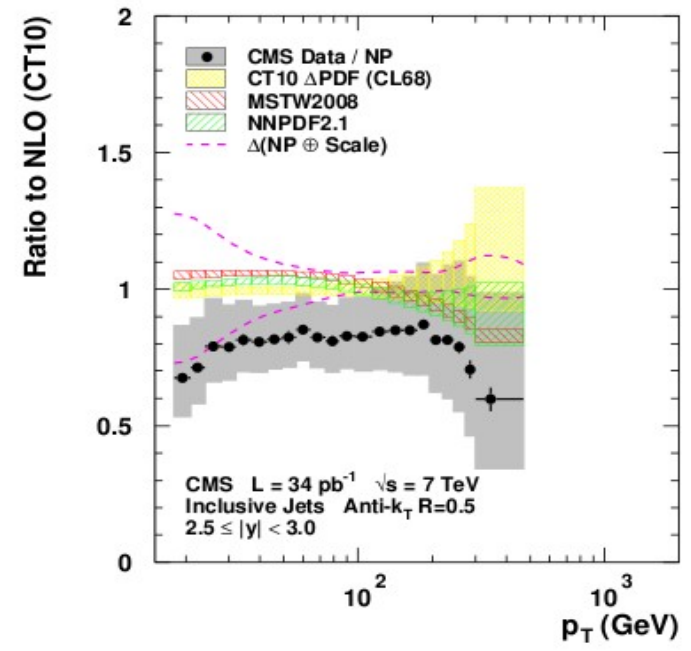






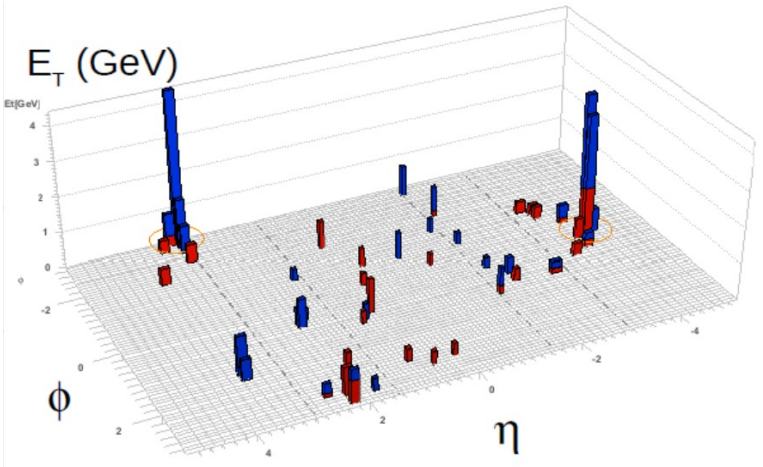


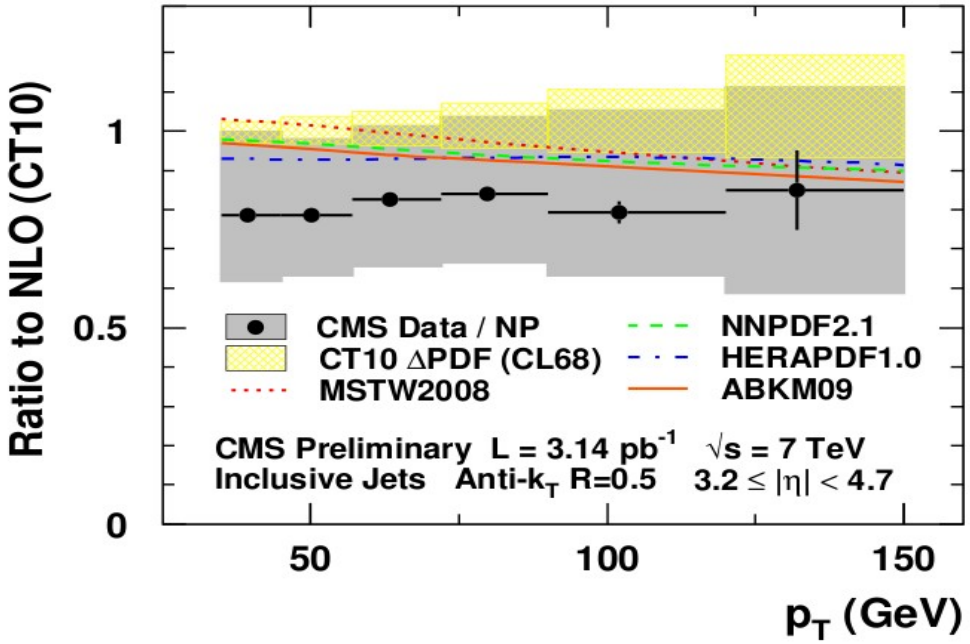


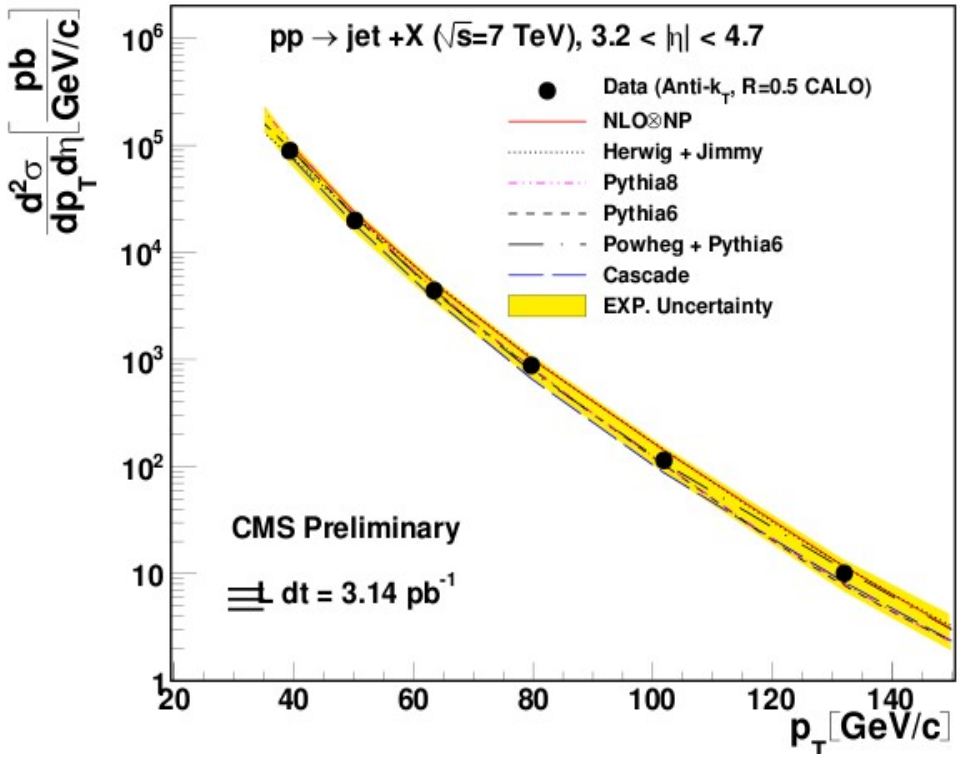


Forward Jet Cross-section

- Forward jets for this measurement are jets with $3.2<|\eta|<4.7$
  - No tracker coverage, so jets are measured entirely from deposits in the HF calorimeter
- 3.14 pb^{-1} used to include only data with minimal impact from pileup



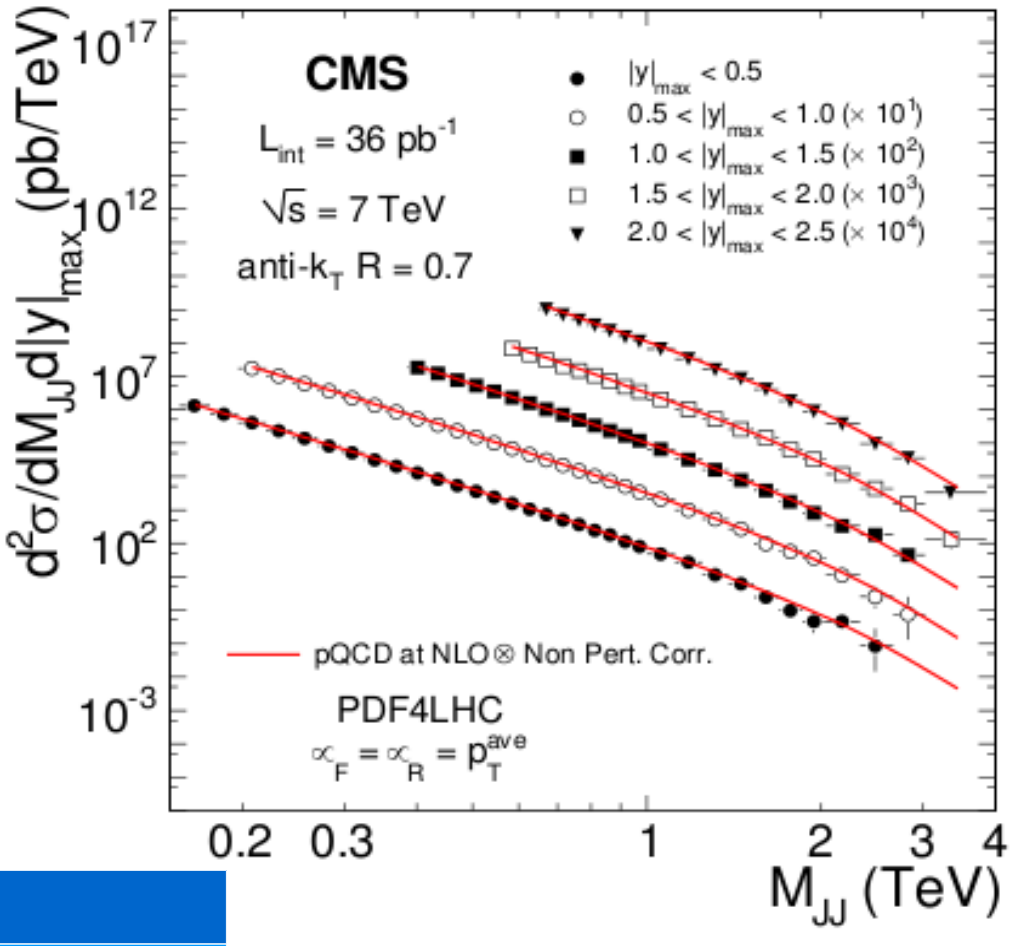




CMS-FWD-10-003

Dijet Cross-section

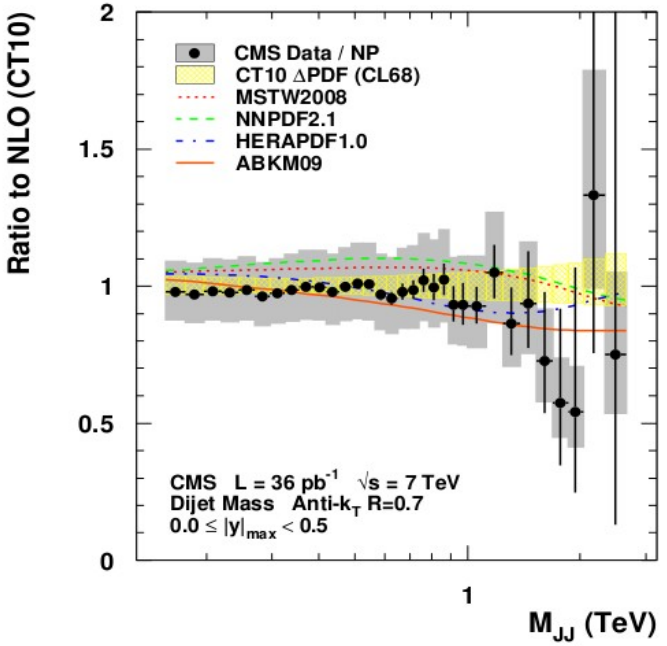
- R=0.7 cone jets used to measure the dijet mass distribution, binned by max($|y_1|$,$|y_2|$)
- Bin migration corrected using bin-by-bin correction factor derived from Monte Carlo, values range from 0.95-0.98

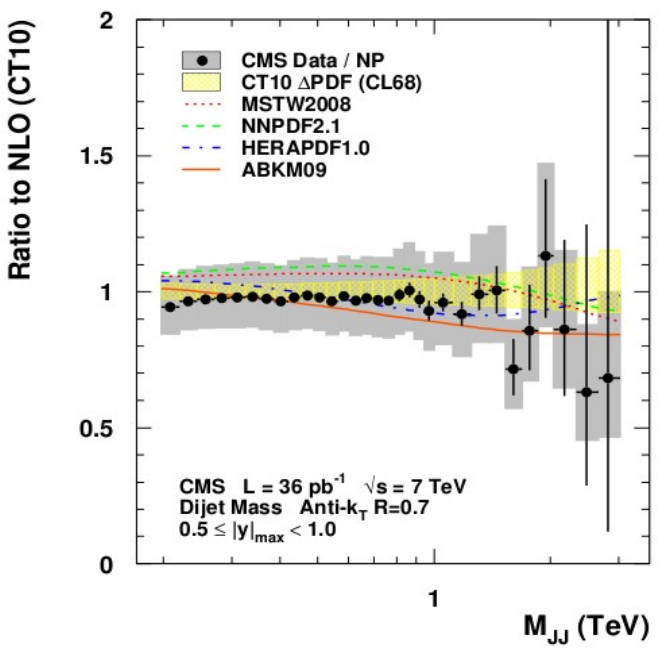


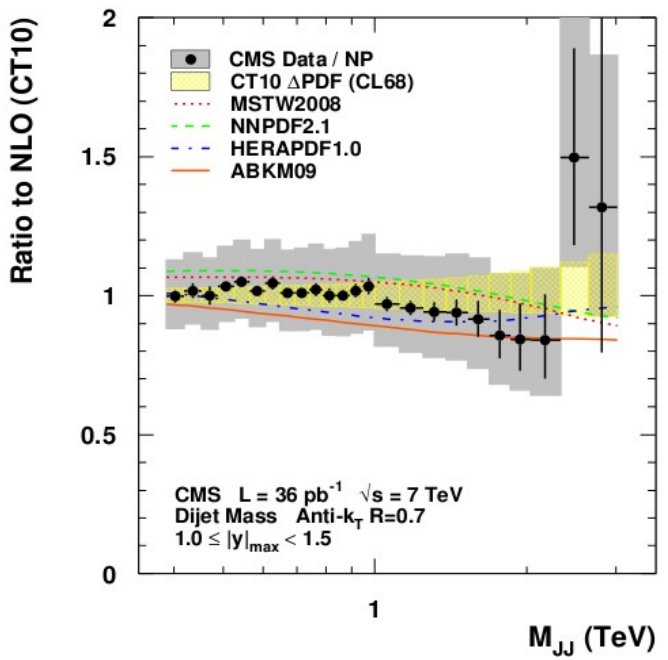
Source	Uncertainty	Error
Jet Energy Scale	3%-5%	15%-60%
Luminosity Uncertainty	4%	4%
Jet Energy Resolution	10%	1%
Scale Uncertainty	2% at 0.2 TeV, 13% at 3 TeV	
Non-perturbative Unc	15% at 0.2 TeV, 2% at 3 TeV	

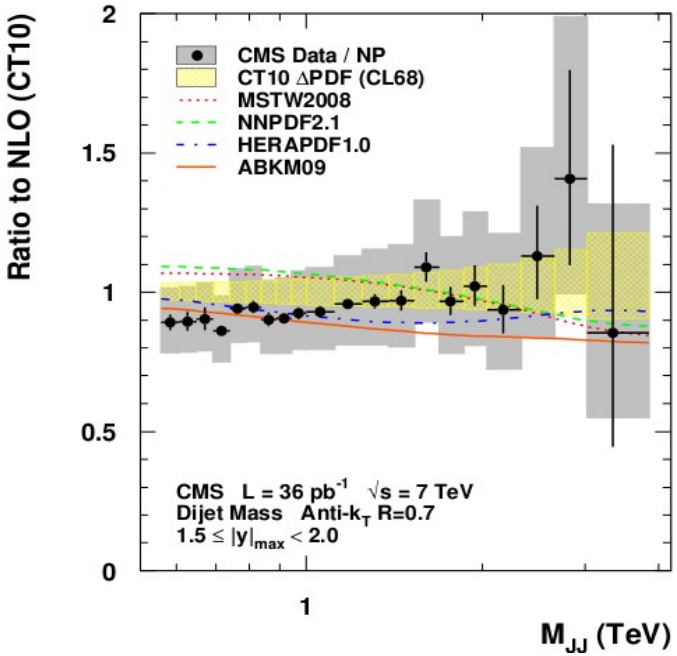
CMS-QCD-10-025

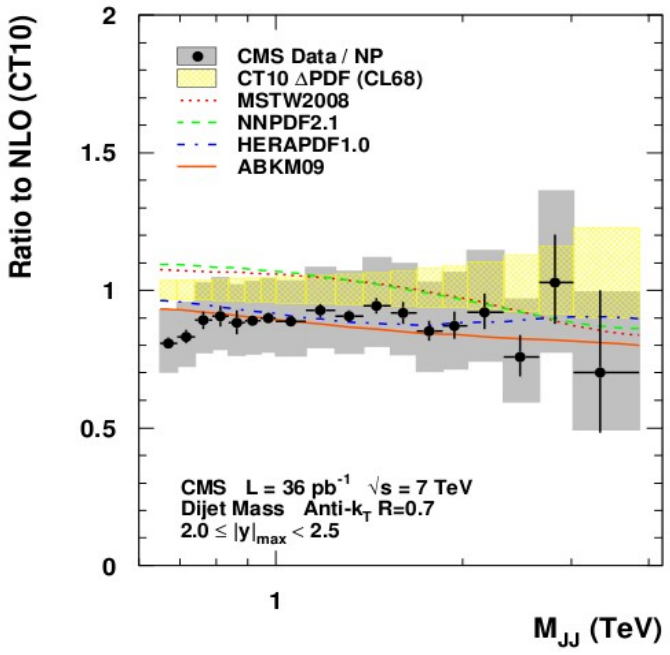
Dijet mass PDF comparison



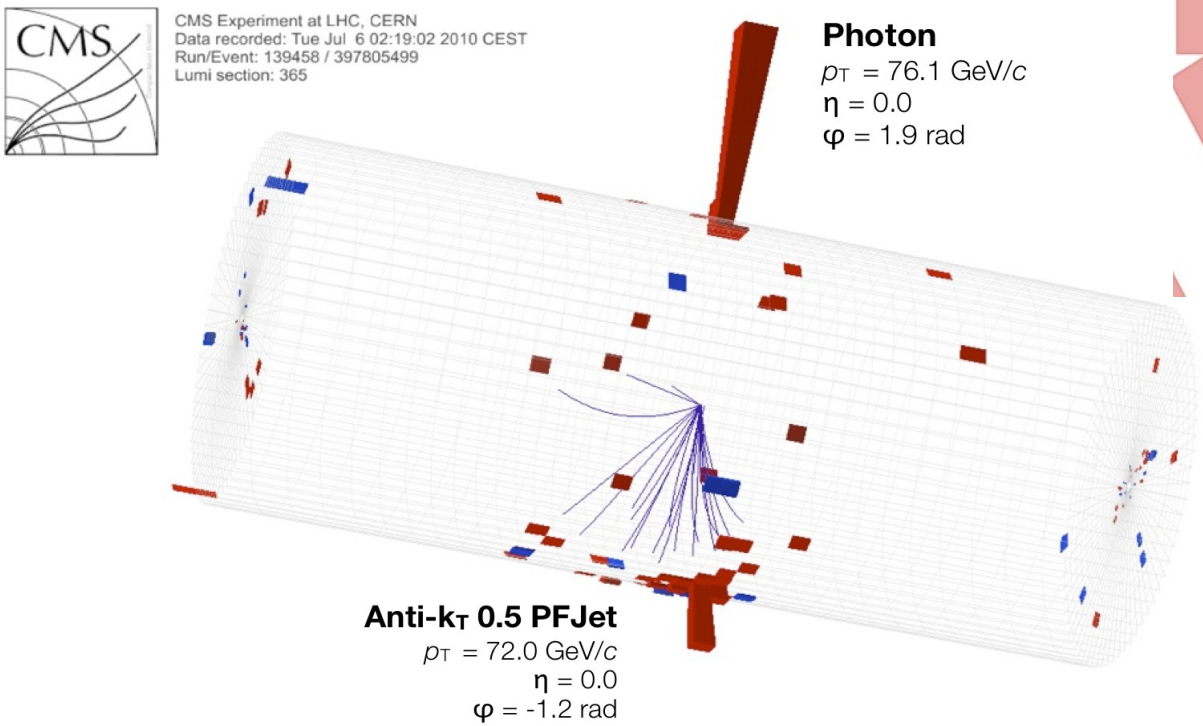


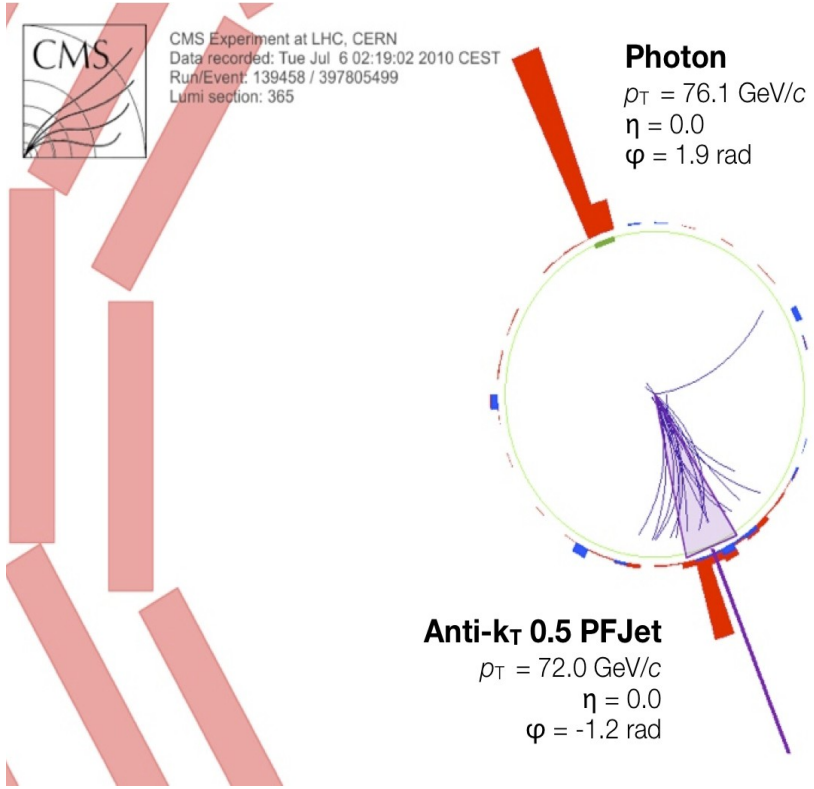




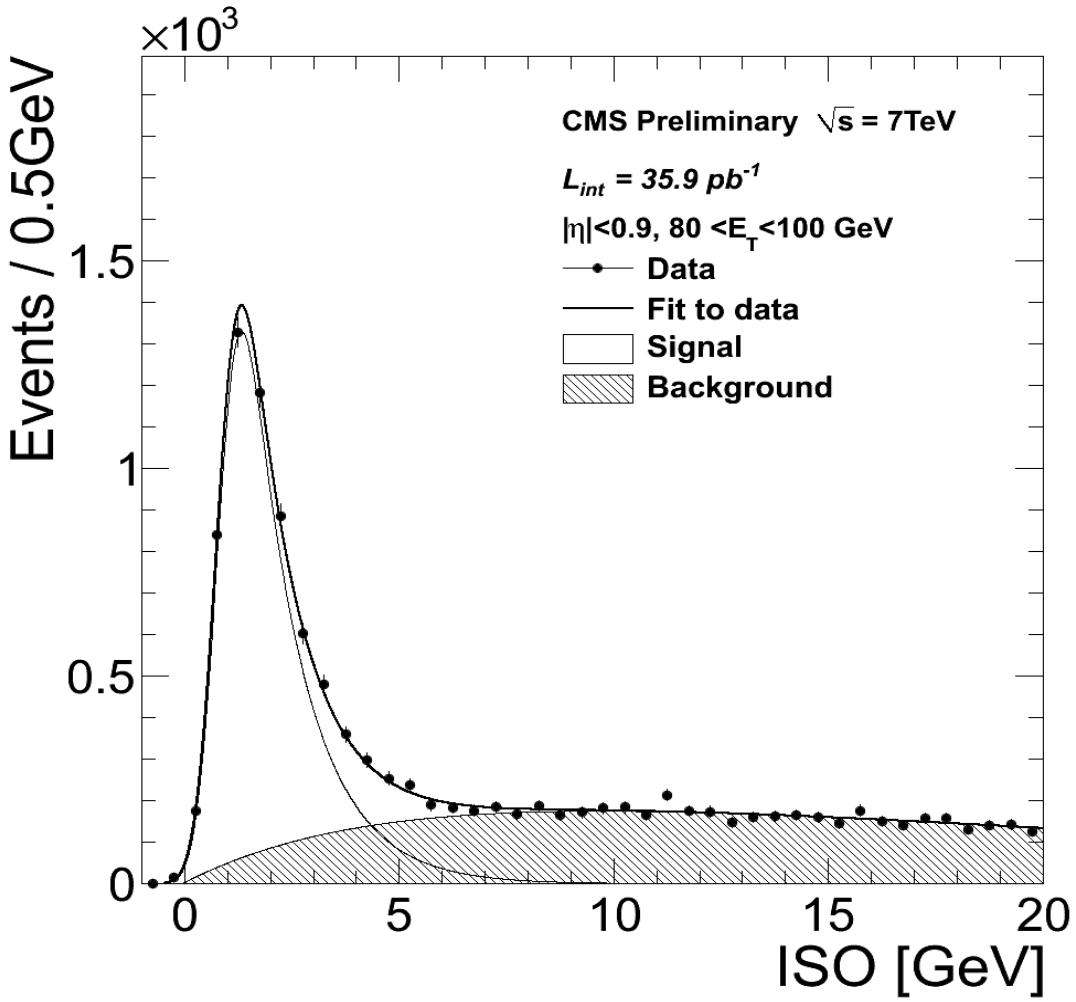


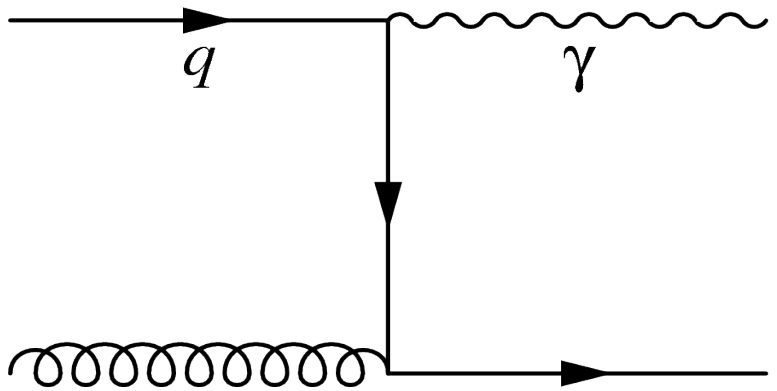
Photon Measurements

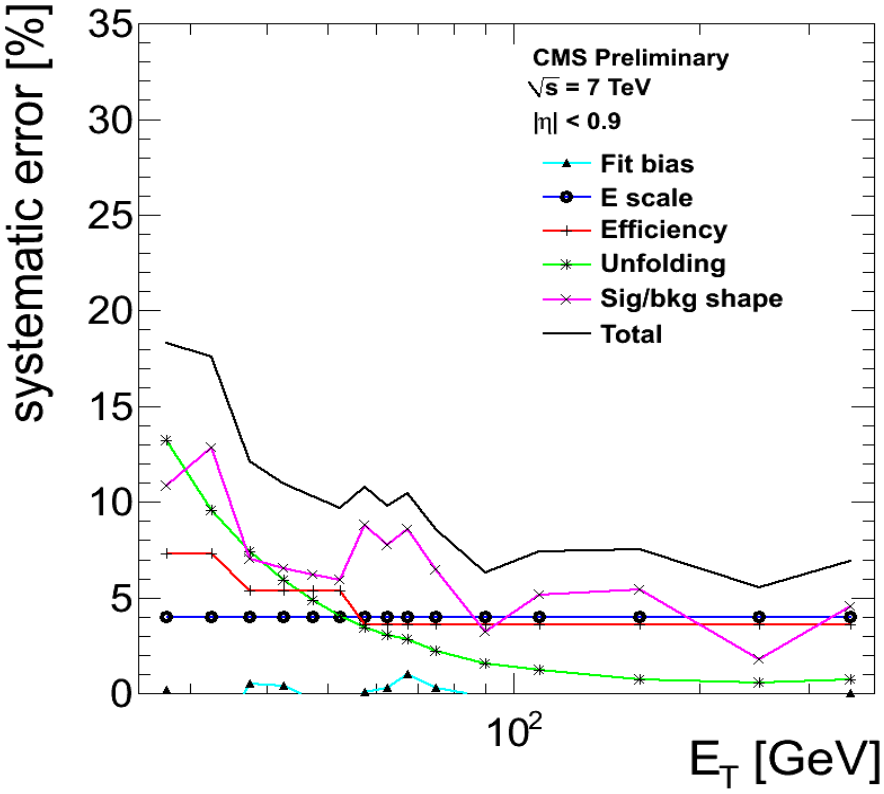




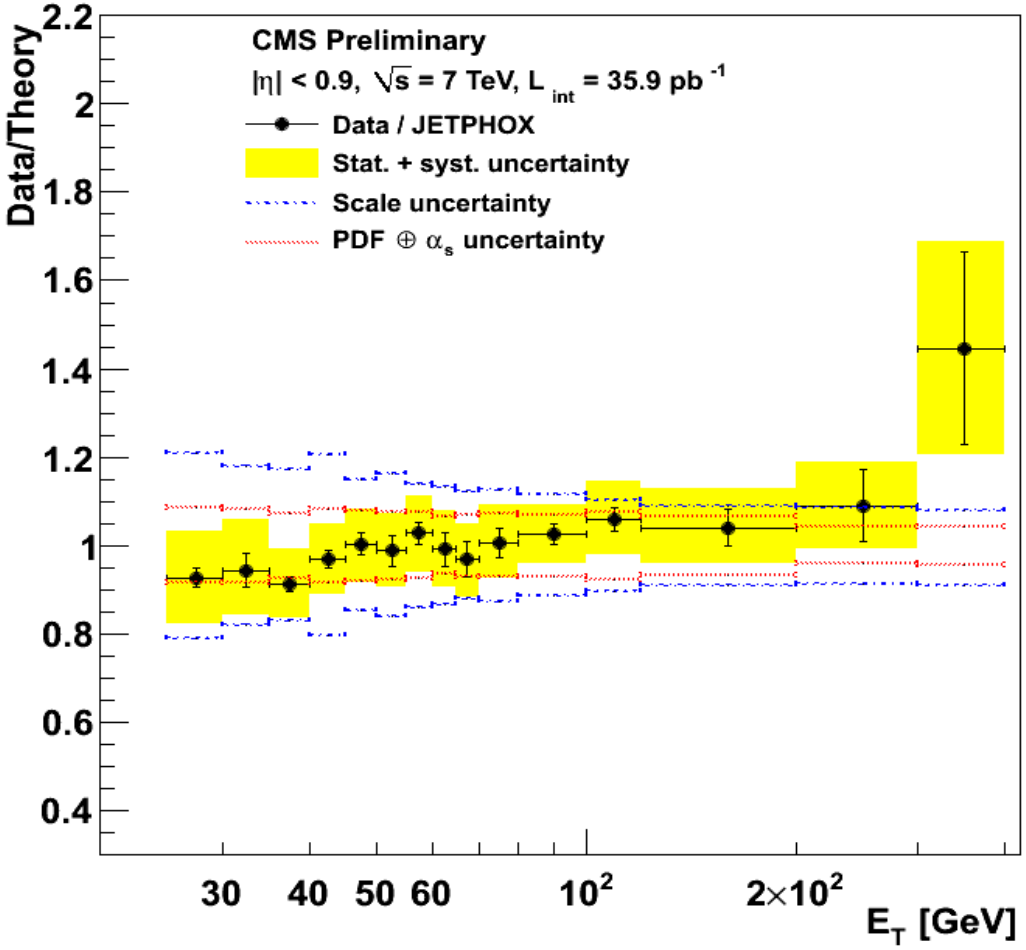
Inclusive Photon Production

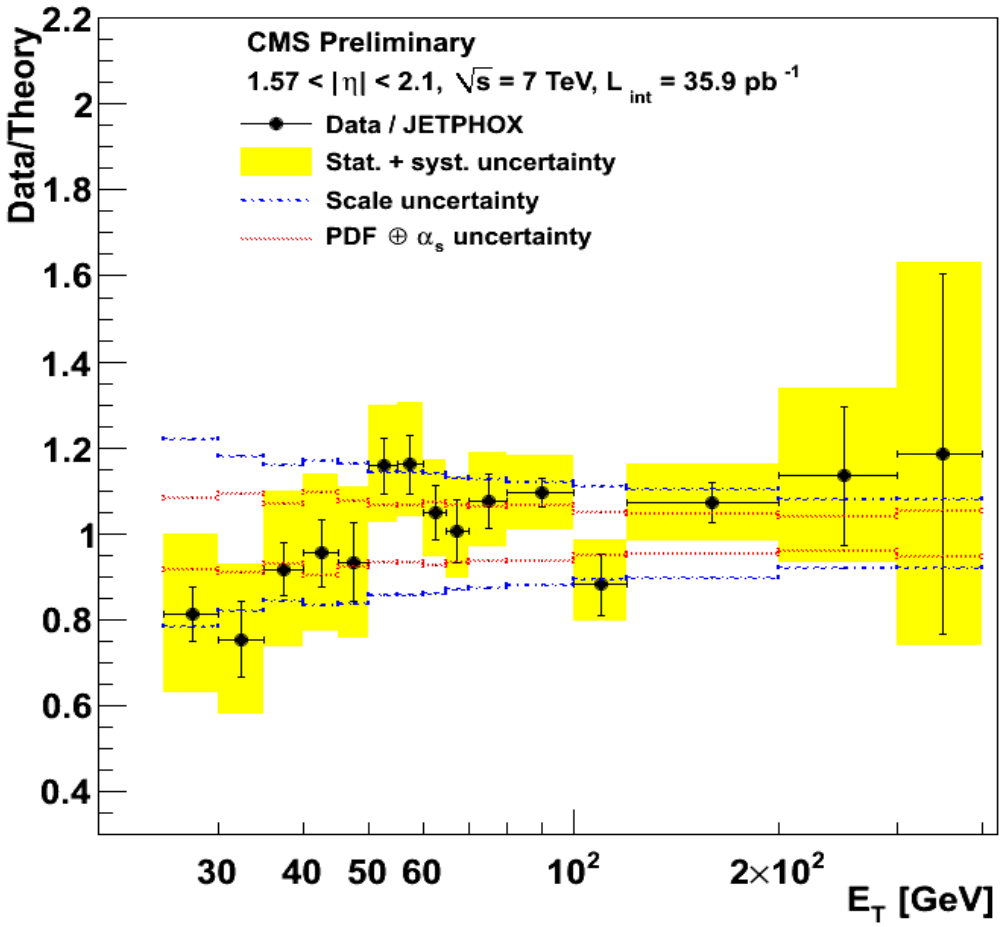






Photon Cross-sections



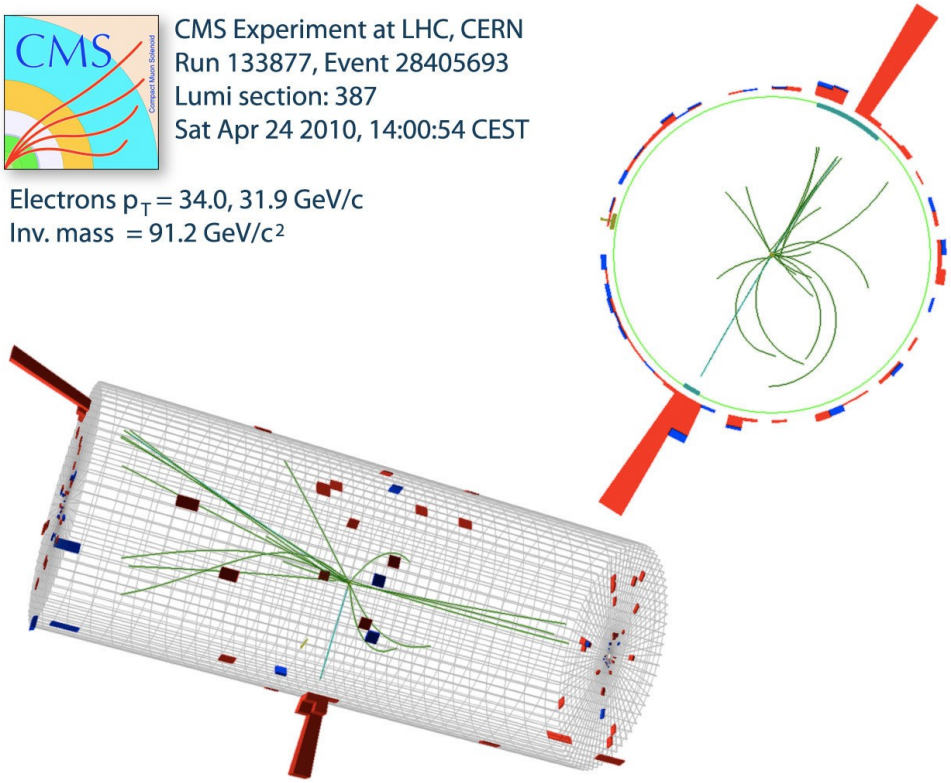


CMS-QCD-10-037

Electroweak Measurements

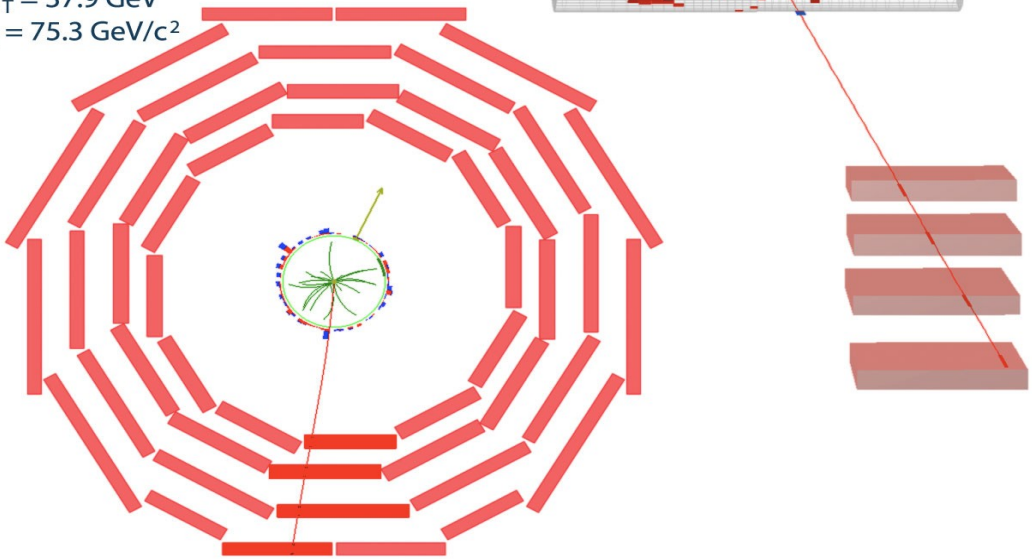
CMS Experiment at LHC, CERN
Run 133877, Event 28405693
Lumi section: 387
Sat Apr 24 2010, 14:00:54 CEST

Electrons $p_T = 34.0, 31.9$ GeV/c
Inv. mass $= 91.2$ GeV/c^2



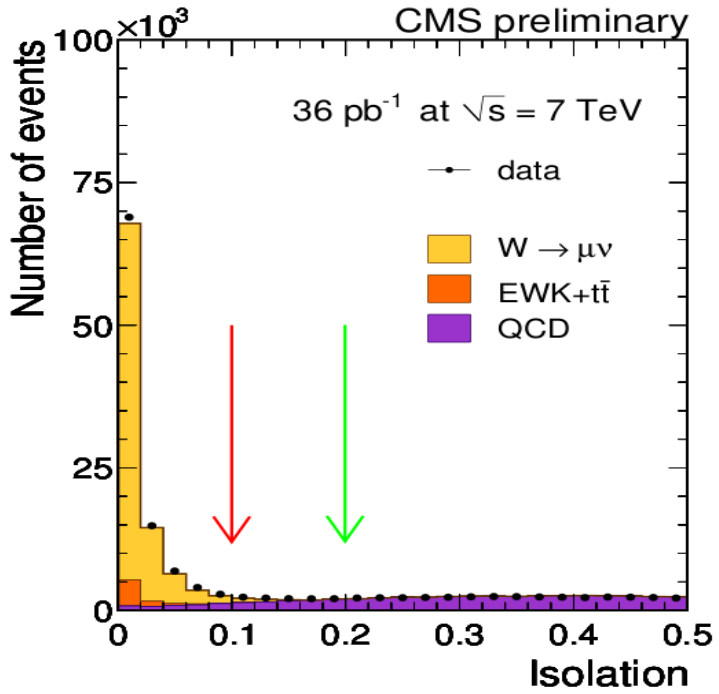
CMS Experiment at LHC, CERN
Run 133875, Event 1228182
Lumi section: 16
Sat Apr 24 2010, 09:08:46 CEST

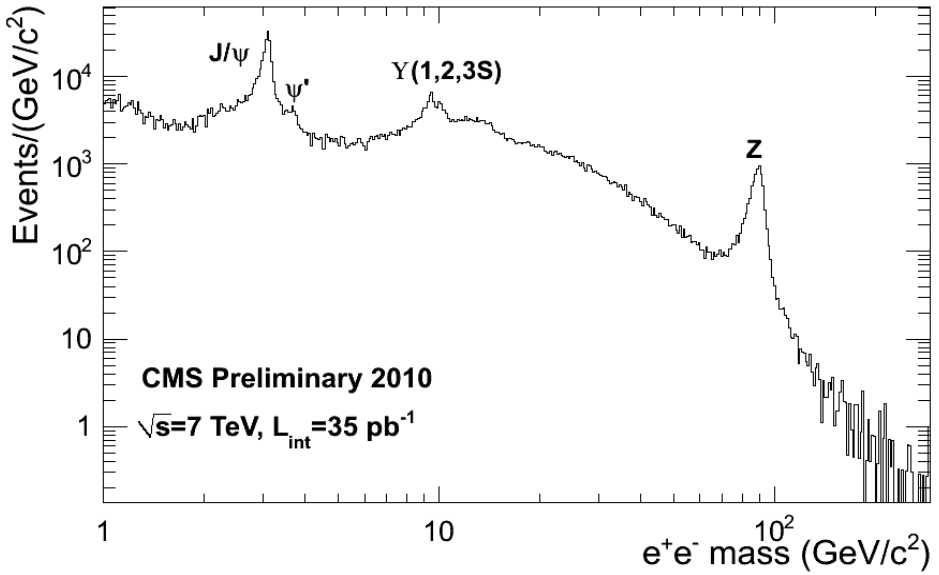
Muon $p_T = 38.7$ GeV/c
$ME_T = 37.9$ GeV
$M_T = 75.3$ GeV/c^2



Common Selection for Electroweak Measurements

- Muon selection
  - Require consistent, quality measurements in both tracker and muon chambers
  - Isolation defined by sum of tracks and calorimeter E_T around muon direction
- Electron selection
  - Requirements on cluster shape, track-cluster consistency, and isolation
- MET
  - Corrected based on studies of hadronic recoil in Z events



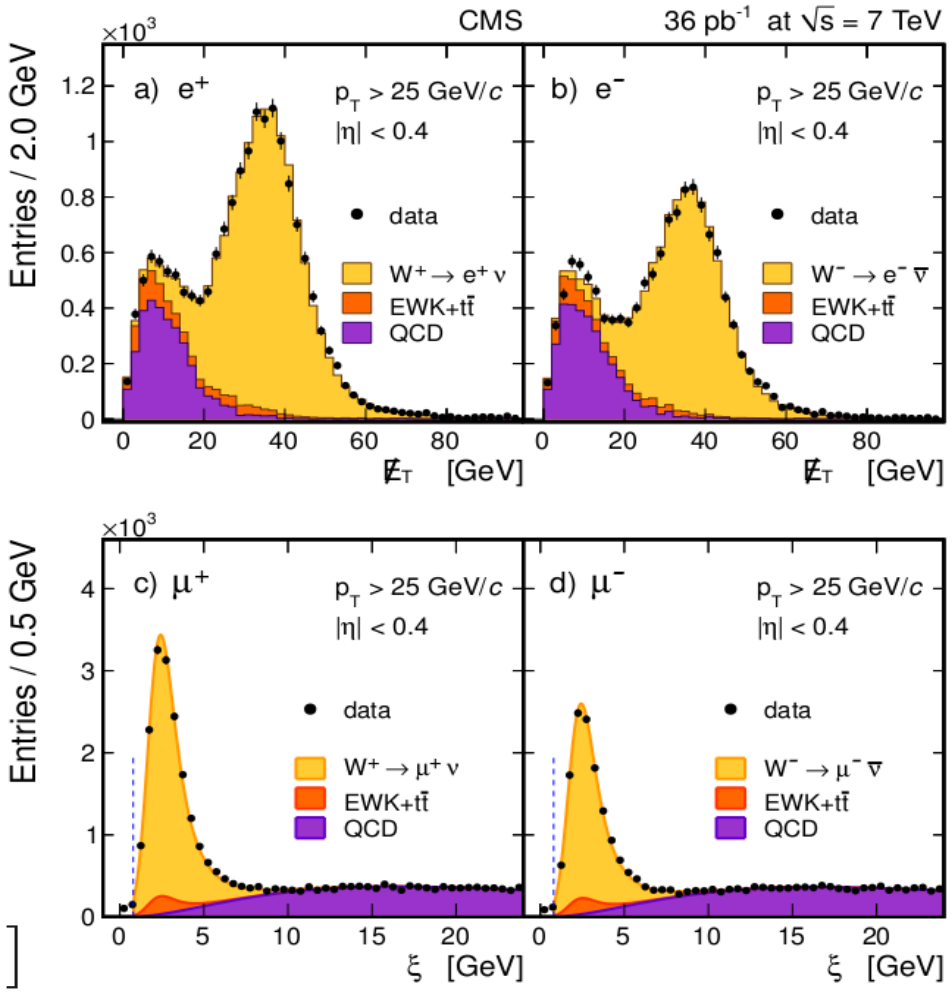


Lepton Charge Asymmetry

$$\mathcal{A}(\eta) = \frac{d\sigma/d\eta(W^+ \to \ell^+\nu) - d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}{d\sigma/d\eta(W^+ \to \ell^+\nu) + d\sigma/d\eta(W^- \to \ell^-\bar{\nu})}$$

- Valence and sea distributions change as a function of *x*, leading to a change in the W charge distribution as a function of y_W
  - Measurement with η_l is a good substitute with fewer uncertainties.
- Electron analysis uses a fit to MET, while muon analysis performs a fit to the total isolation sum

$$\xi = \sum_{\Delta R < 0.3} [\, p_T(tracks) + E_T(em) + E_T(had)\,]$$



JHEP 1104 (2011) 050 / CMS-PAS-EWK-10-006

Systematic Uncertainties

- Charge misidentification small
  - Rate shown to be < 10^{-4} for muons based on cosmic ray data
  - Electron charge misidentification reduced by requiring consensus of three charge extraction techniques
- Leading uncertainties are the efficiency difference between positive and negative leptons and the energy/momentum scale
- Two lepton p_T ranges considered:

  > 20 GeV/c

  > 30 GeV/c

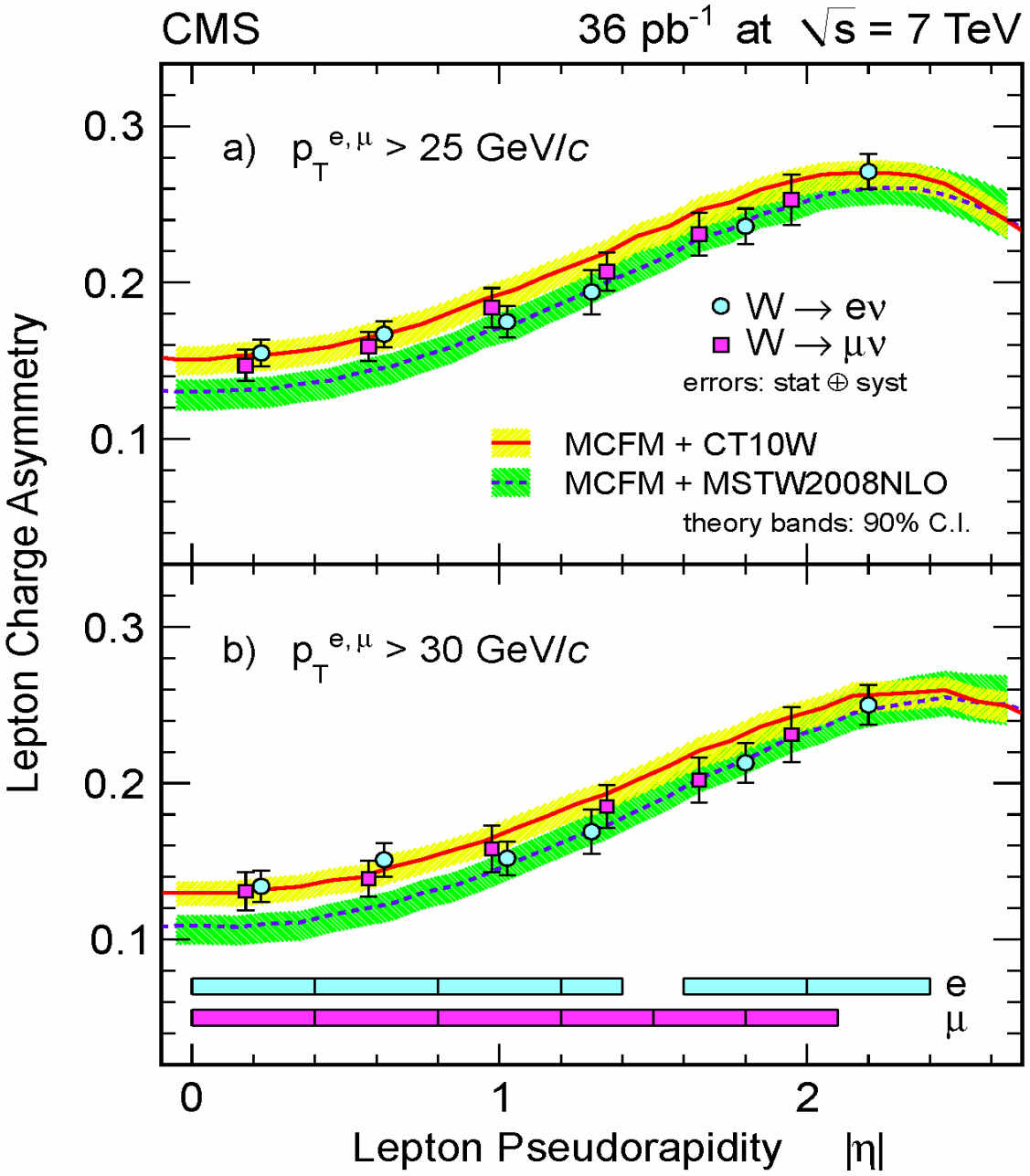
$p_T^\ell > 25\,\text{GeV}/c$

	Electron Channel						Muon Channel					
$\lvert\eta\rvert$ bin	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.4]	[1.6, 2.0]	[2.0, 2.4]	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.5]	[1.5, 1.8]	[1.8, 2.1]
Charge Misident.	0.02	0.03	0.03	0.08	0.09	0.10	0	0	0	0	0	0
Eff. Ratio	0.70	0.70	0.70	0.70	0.70	0.70	0.59	0.39	0.92	0.72	0.81	1.17
e/μ Scale	0.11	0.09	0.19	0.47	0.40	0.45	0.50	0.48	0.50	0.48	0.50	0.42
Sig. & Bkg. Estim.	0.16	0.19	0.26	0.33	0.25	0.25	0.23	0.29	0.34	0.40	0.53	0.58
Total	0.73	0.73	0.77	0.90	0.85	0.87	0.80	0.68	1.10	0.95	1.08	1.37

$p_T^\ell > 30\,\text{GeV}/c$

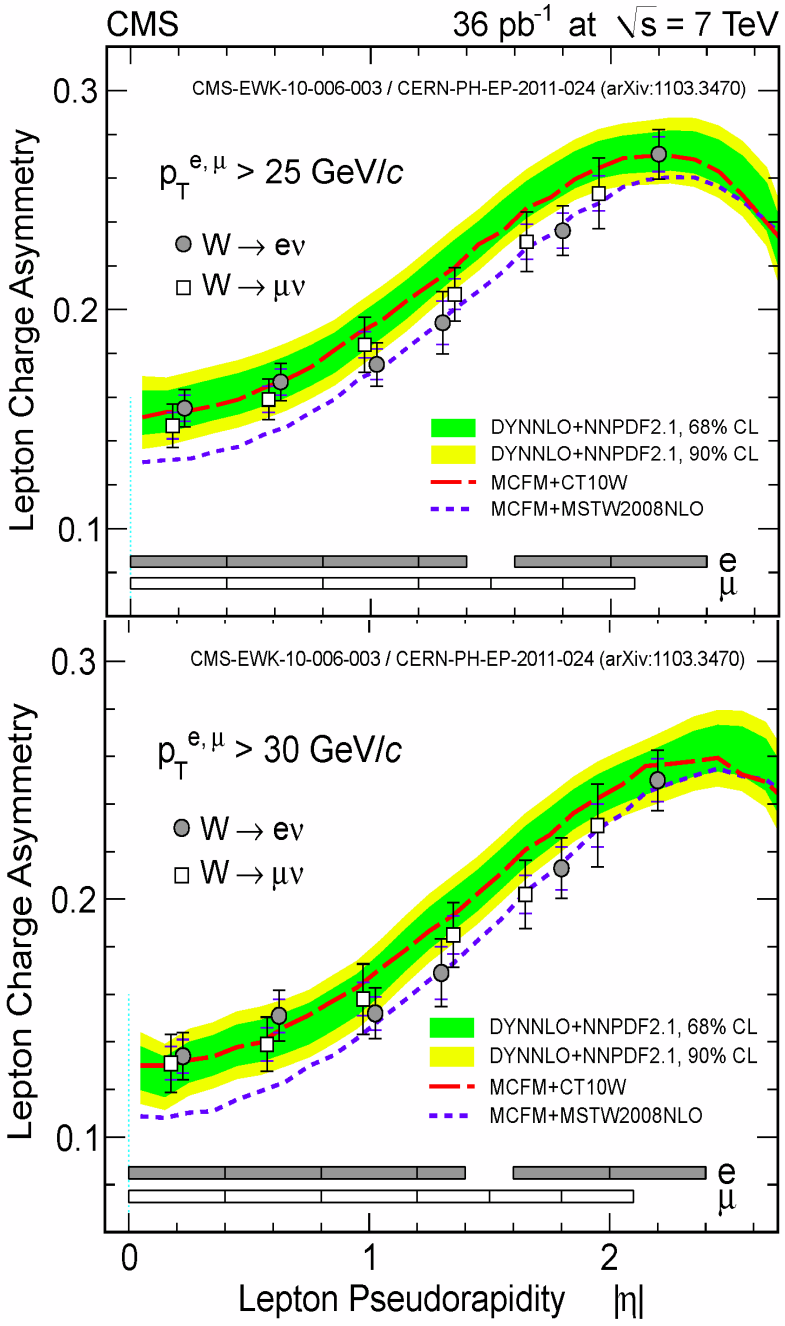
	Electron Channel						Muon Channel					
$\lvert\eta\rvert$ bin	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.4]	[1.6, 2.0]	[2.0, 2.4]	[0.0, 0.4]	[0.4, 0.8]	[0.8, 1.2]	[1.2, 1.5]	[1.5, 1.8]	[1.8, 2.1]
Charge Misident.	0.02	0.02	0.03	0.07	0.08	0.10	0	0	0	0	0	0
Eff. Ratio	0.70	0.70	0.70	0.70	0.70	0.70	0.59	0.39	0.93	0.72	0.82	1.18
e/μ Scale	0.07	0.17	0.26	0.46	0.53	0.55	0.80	0.78	0.83	0.81	0.73	0.77
Sig. & Bkg. Estim.	0.16	0.19	0.26	0.33	0.25	0.25	0.20	0.20	0.27	0.35	0.51	0.56
Total	0.72	0.75	0.79	0.91	0.92	0.93	1.01	0.90	1.27	1.14	1.21	1.52

Results

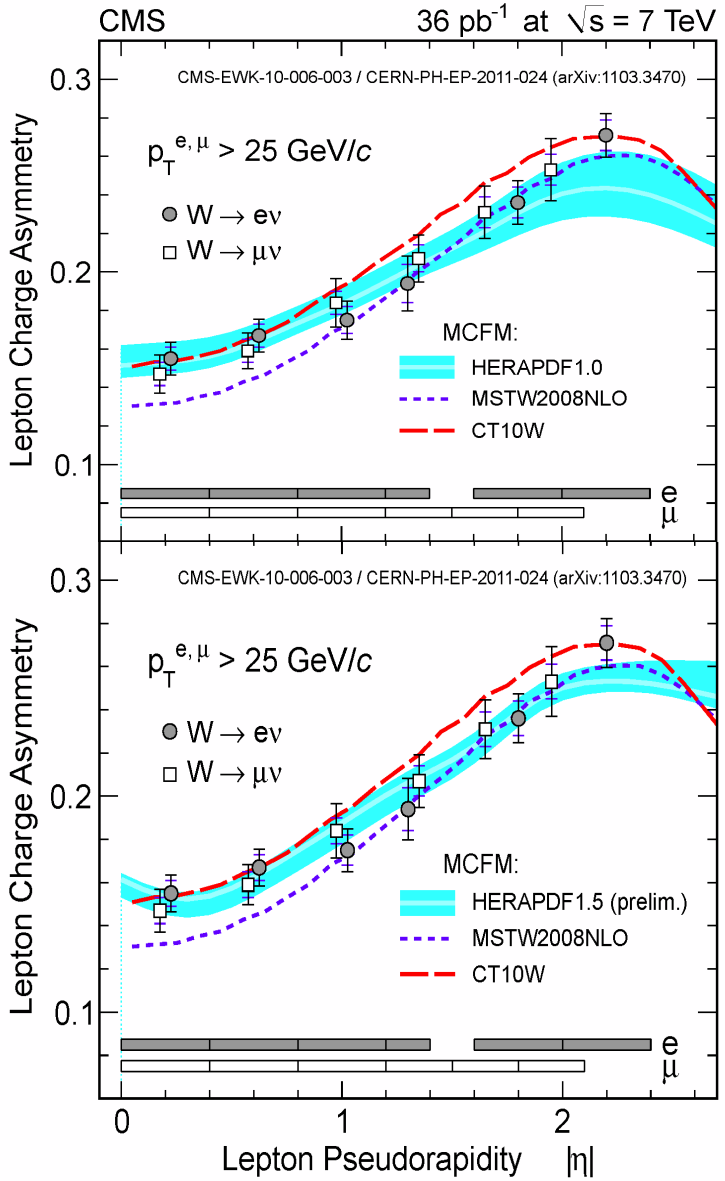


JHEP 1104 (2011) 050 / CMS-PAS-EWK-10-006

Comparison to NNPDF and HERAPDF



NNPDF predictions courtesy of Juan Rojo



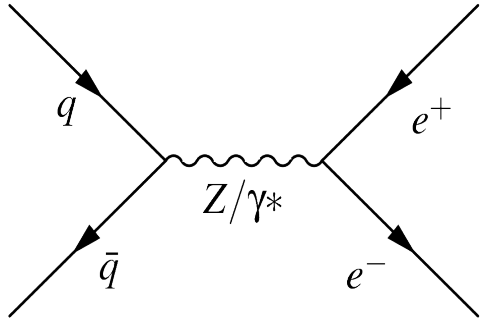
HERAPDF predictions courtesy of Katerina Lipka

CMS-PAS-EWK-10-006

Z Rapidity Measurement

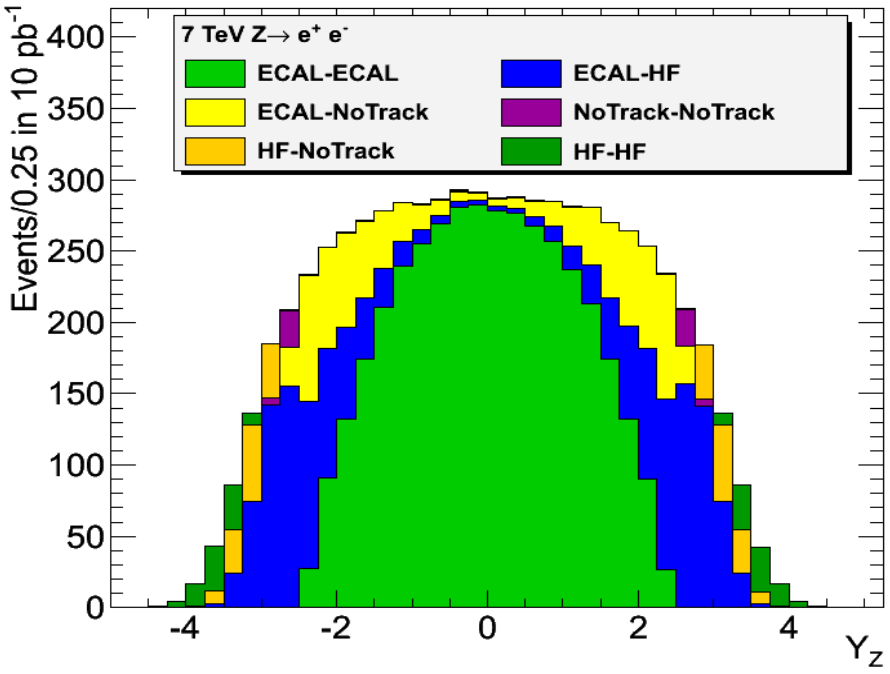
- Rapidity measurement probes PDF distributions, with particularly simple correlation for tree-level production:

$$\frac{1}{\sigma}\frac{d\sigma\left(Z\rightarrow l^{+}l^{-}\right)}{dy} \qquad y=\ln\frac{x\sqrt{s}}{m_{Z}}$$



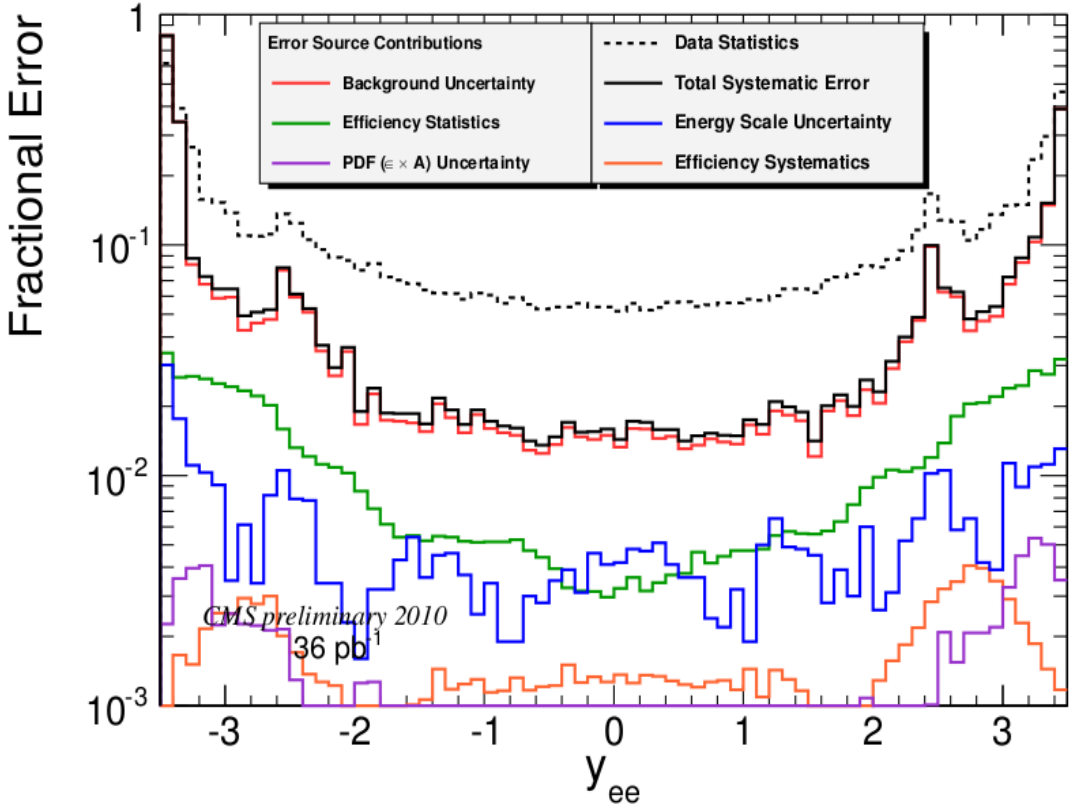
- Electron measurement includes forward electrons (HF)
  - $|\eta| < 2.5$ or $3.1 < |\eta| < 4.6$
- Muon measurement for $|\eta| < 2.1$
- Final measurement made in |y|, unfolded for resolution effects using matrix-inversion technique

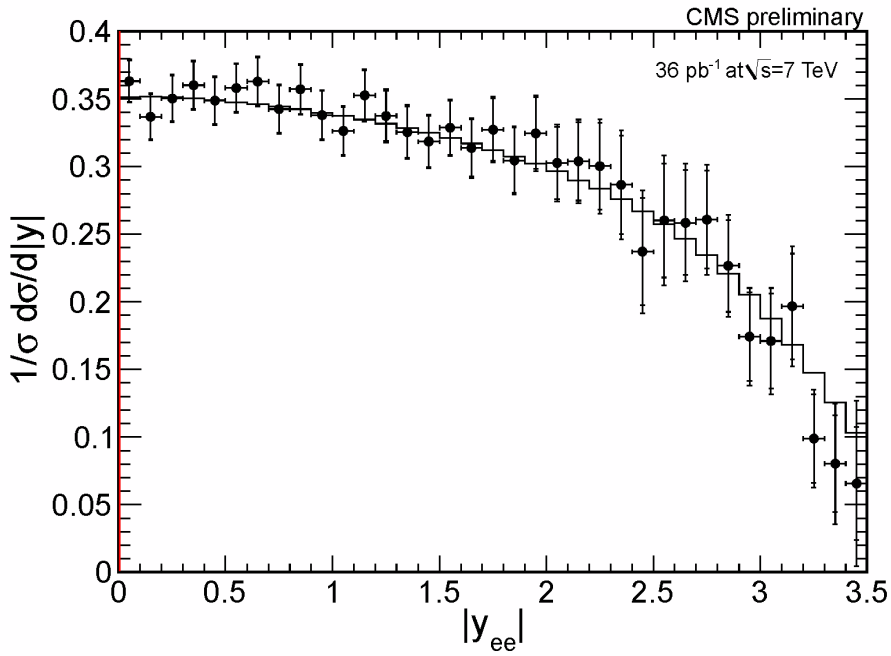
$60\ \text{GeV} < m_{ll} < 120\ \text{GeV}$

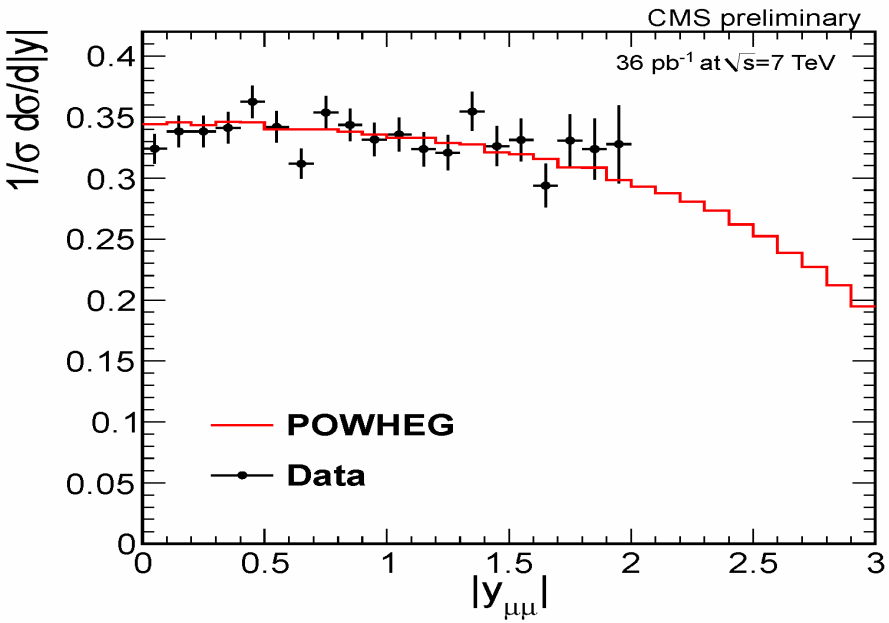


Rapidity Measurement

- Statistical errors dominate systematic ones in current measurement
  - Leading systematic errors have significant statistical component (e.g. background sideband statistics)

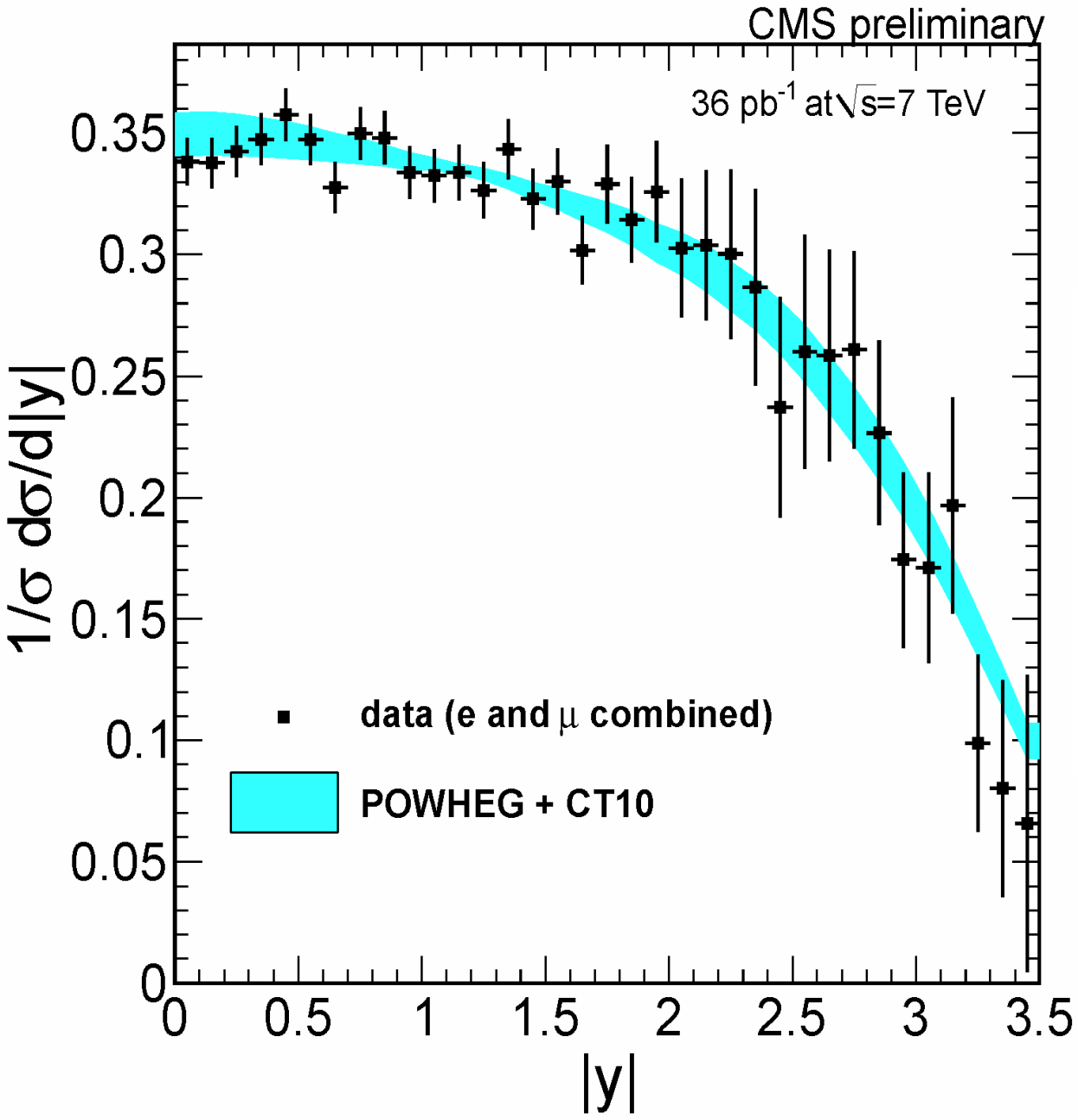


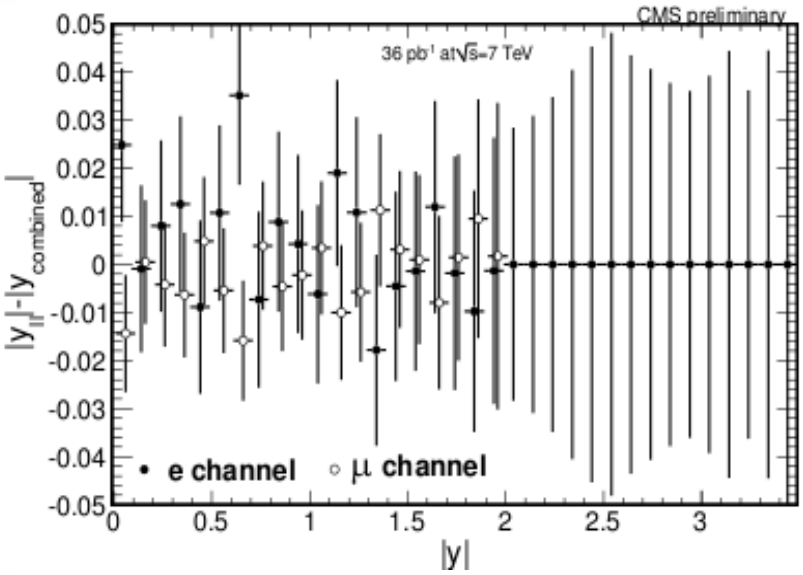




CMS-PAS-EWK-10-010

Combined Measurement

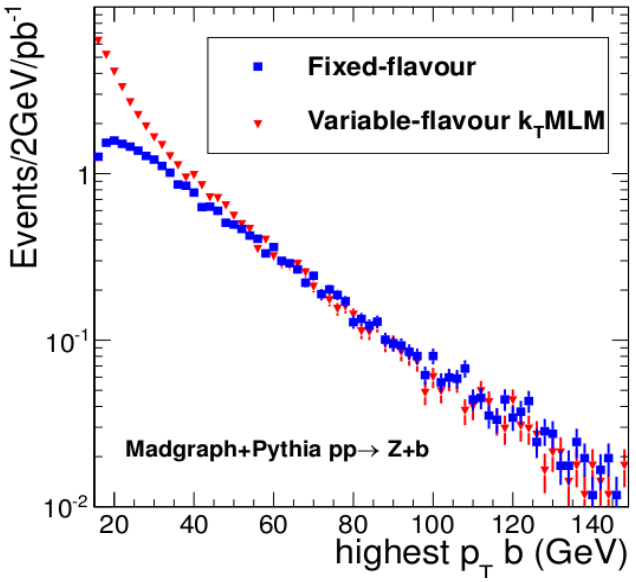




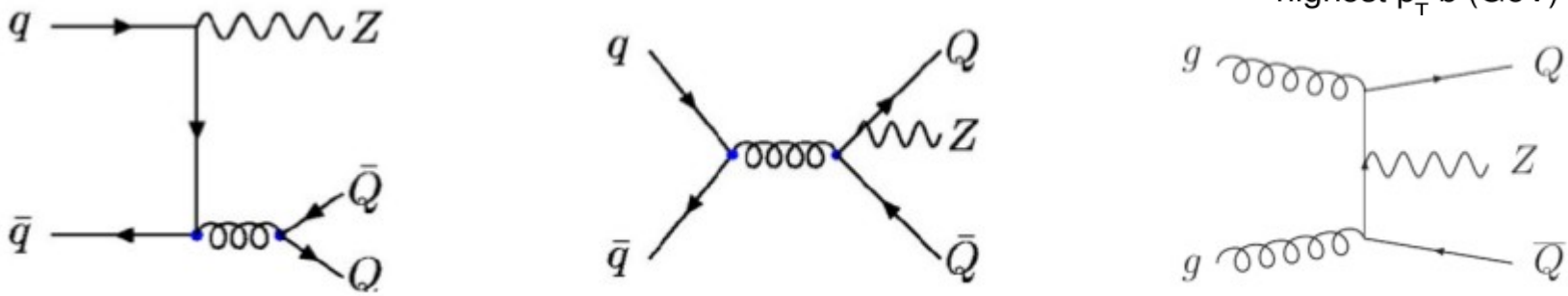
CMS-PAS-EWK-10-010

Z+b

- Z+b measurement can provide useful information on the b-quark portions of the sea
- Results can be interpreted in two different schemes



Fixed Flavor

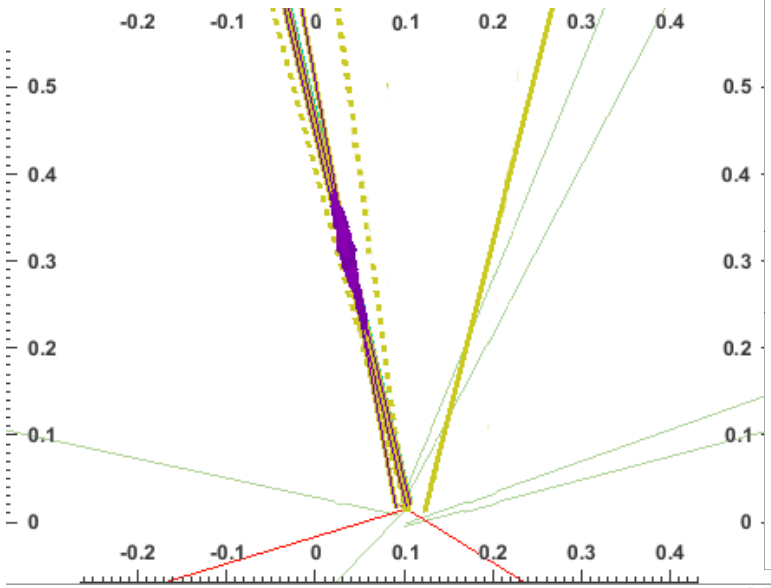


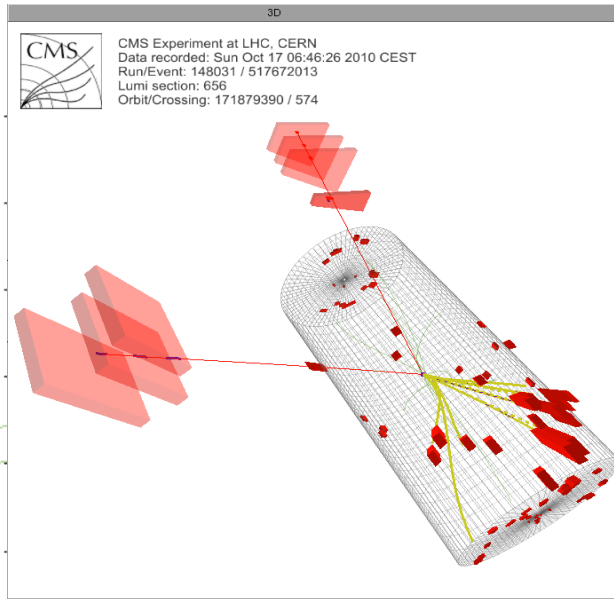
Variable Flavor

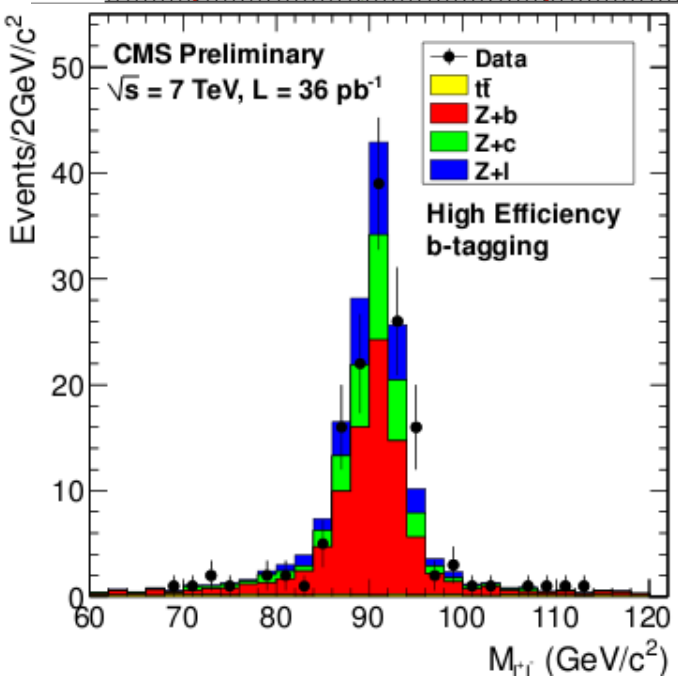
CMS-PAS-EWK-10-015

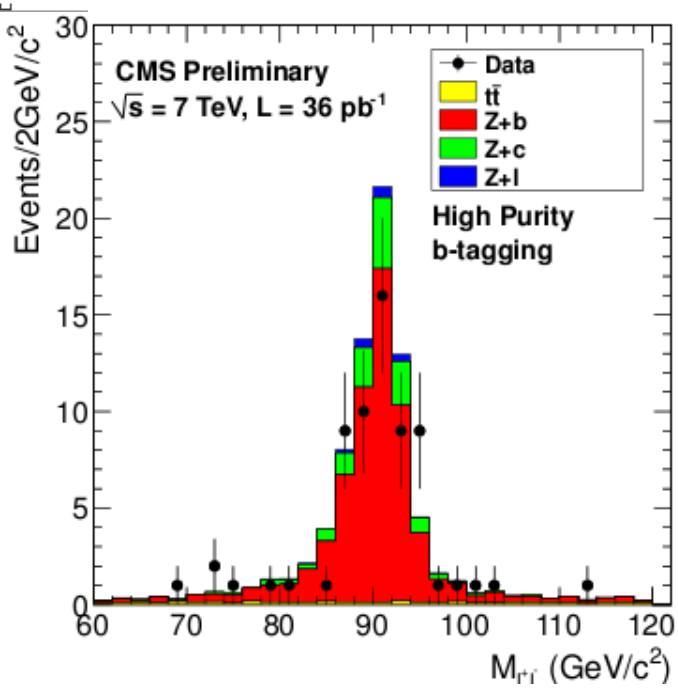
b-jet Identification

- b-tag based on 3d distance between primary vertex and secondary
- Two operating points:
  - High Efficiency (minimum 2 tracks), mistag < 1%
  - High purity (minimum 3 tracks), mistag < 0.1%





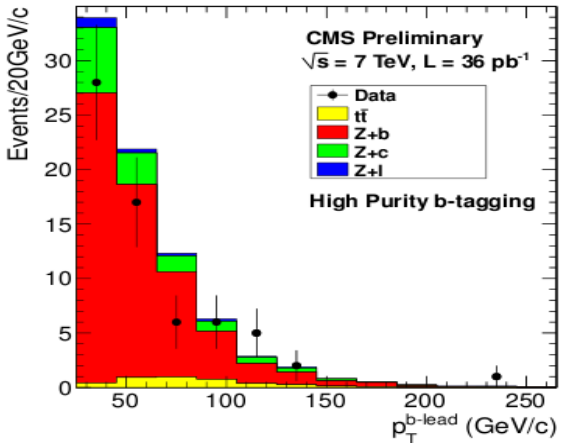


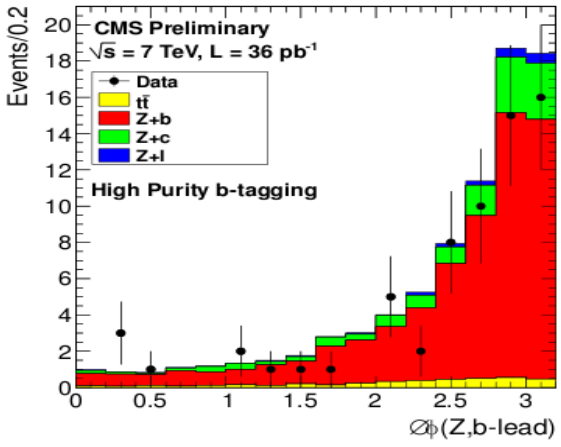


CMS-PAS-EWK-10-015

Results

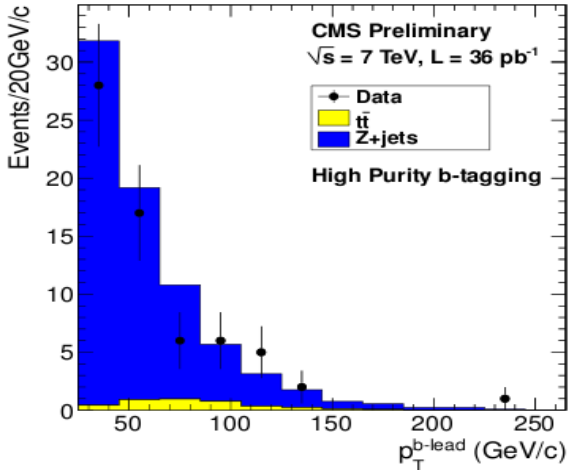
Fixed Flavor

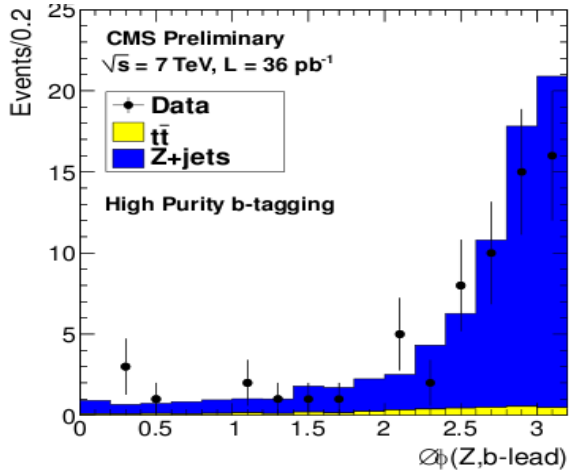




CMS-PAS-EWK-10-015

Variable Flavor





Sample	$\mathcal{R}(Z \to ee)$ (%), $p_T^e > 25$ GeV, $\lvert\eta^e\rvert < 2.5$	$\mathcal{R}(Z \to \mu\mu)$ (%), $p_T^\mu > 20$ GeV, $\lvert\eta^\mu\rvert < 2.1$
Data HE	$4.3 \pm 0.6(stat) \pm 1.1(syst)$	$5.1 \pm 0.6(stat) \pm 1.3(syst)$
Data HP	$5.4 \pm 1.0(stat) \pm 1.2(syst)$	$4.6 \pm 0.8(stat) \pm 1.1(syst)$
MADGRAPH	$5.1 \pm 0.2(stat) \pm 0.2(syst) \pm 0.6(theory)$	$5.3 \pm 0.1(stat) \pm 0.2(syst) \pm 0.6(theory)$
MCFM	$4.3 \pm 0.5(theory)$	$4.7 \pm 0.5(theory)$

Measurement Futures

- Additional improvements to JES have been completed => updates to the measurements, including some 2011 data as well, are planned
- Photon analysis will benefit from strong ongoing effort on photons to support $H \rightarrow \gamma\gamma$
- Updated measurement of W charge asymmetry including 2011 data is under preparation
- Z rapidity measurement from 2010 dataset is being finalized for publication with full covariance matrix, 2011 analysis effort beginning
- Z+b analysis will use additional luminosity to help reduce errors. W+c analysis in the approval process