Recent Results in Jet Physics from CMS

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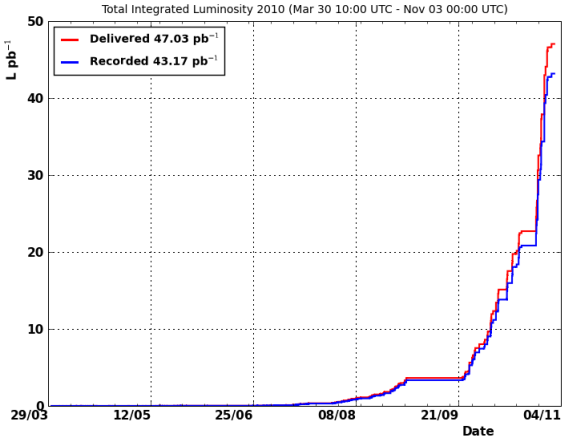
Outline

- The CMS detector
- Jets at CMS
  - Jet Reconstruction
  - Jet Calibration and Resolution
- Recent Jet Results
  - Inclusive Jet Cross Section
  - Dijet Mass
  - Dijet Angular Distributions
  - Dijet Azimuthal DeCorrelations
  - 3 jets/2 jets Cross Section Ratio
- Conclusions

CMS experiment



Steel Return Yolk
(~13000 tonnes)

Superconducting Solenoid
(niobium-titanium coil)
3.8T

Forward Calorimeter
(Steel + Quartz fibers)
~2000 channels

Silicon Tracker
(Pixels: 100 x 150 um^2)
(Microstrips: 80 – 180 um)
millions of channels

Electromagnetic Calorimeter
($PbWO_4$ Scintillating Crystals)
~76K channels

PreShower
(Silicon strips)
~137K channels

Hadronic Calorimeter
(Brass and Plastic Scintillators)
~7000 channels

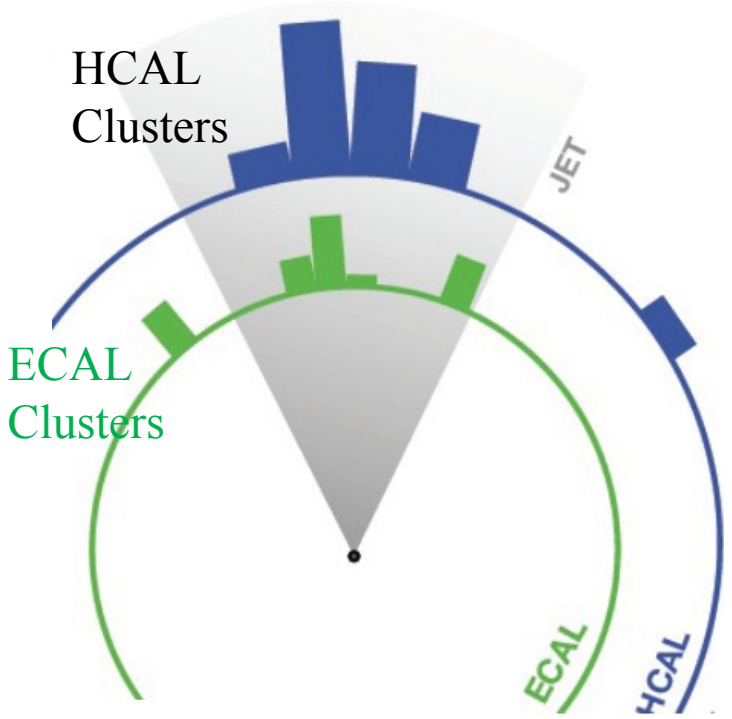
Muon Chambers
(Barrel: 250 DTs + 480 RPCs)
(Endcaps: 473 CSCs + 432 RPCs)

Jet Reconstruction in CMS

Jet algorithms available at CMS: kT, anti-Kt

CMS default algorithm is anti-Kt, R = 0.5, 0.7

- Calorimeter Jets
  - Uses calorimeter towers to construct jets
  - Robust, worst resolution at lower pts



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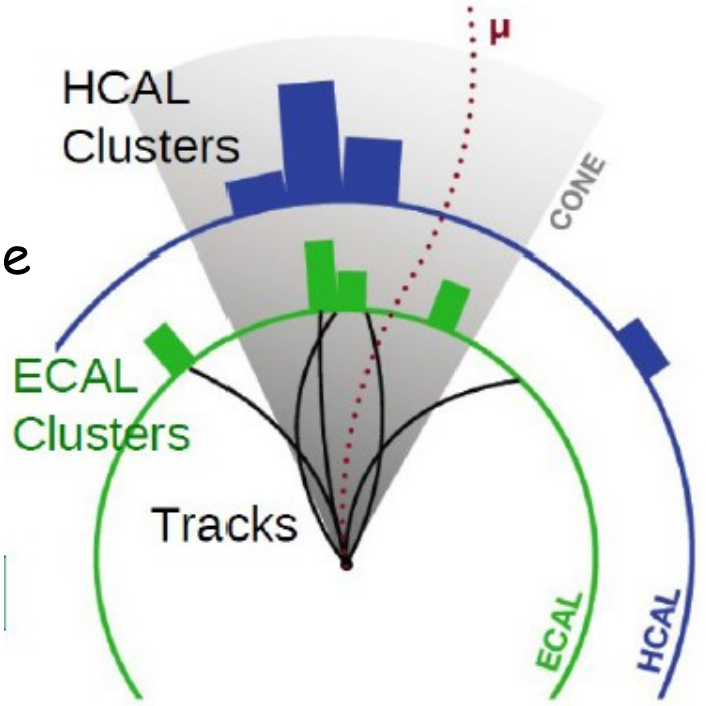
- Jet Plus Tracks
  - Uses CaloJets corrected for tracks
  - Improved resolution and energy response



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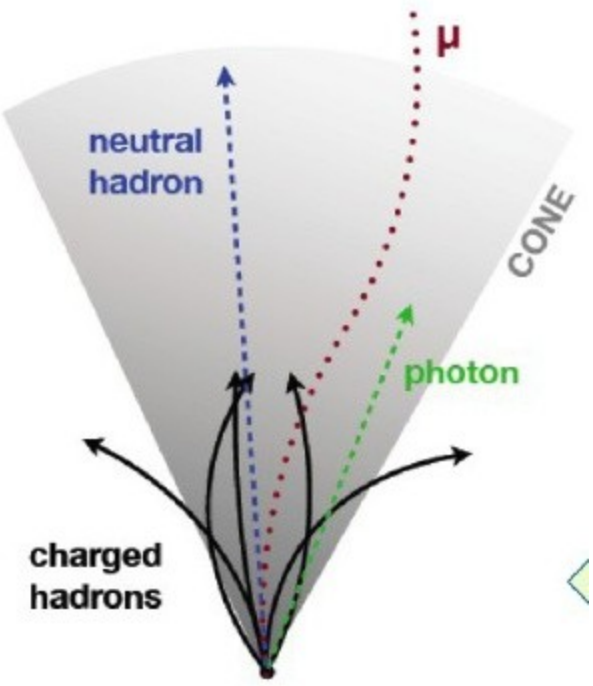
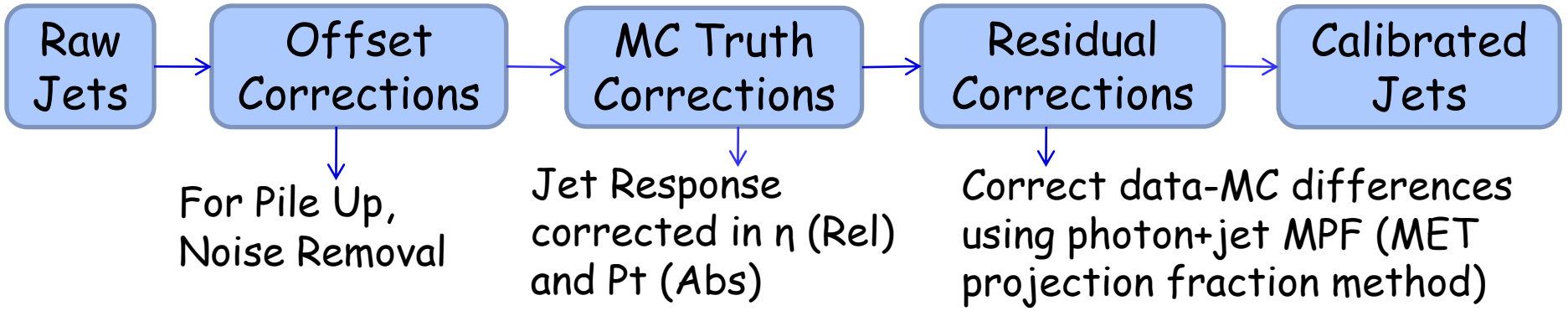
- Particle Flow Jets
  - Uses all identified particles in detector
  - Has the best resolution
  - Used by most analyses



Jet Calibration and Resolution

- CMS has a factorized approach to Jet Energy Corrections



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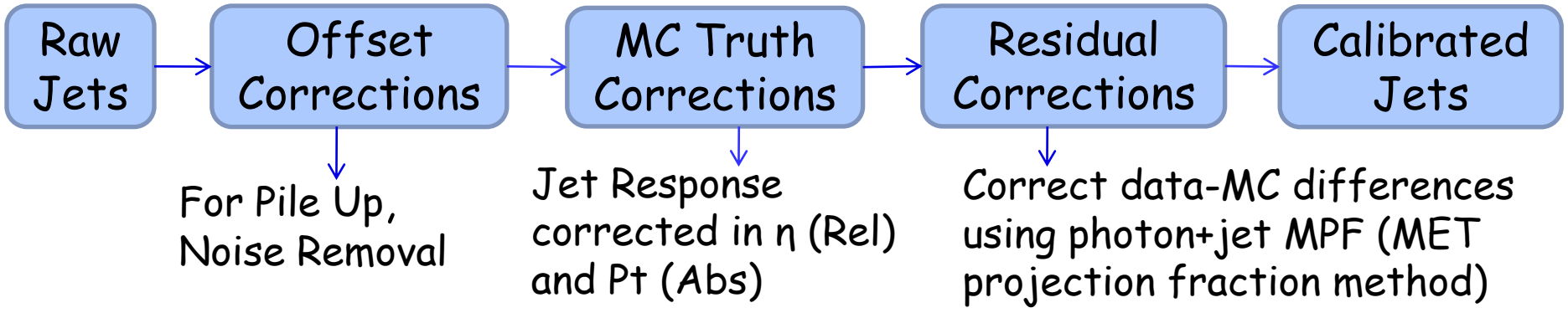
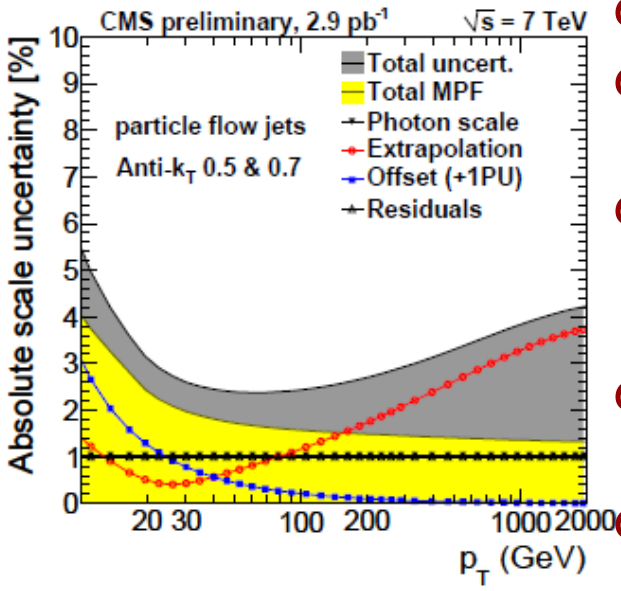
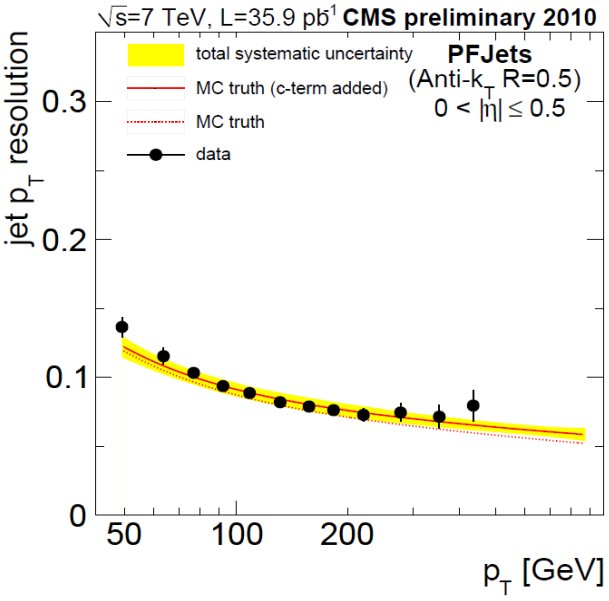




- PF jet results shown
- JES Uncertainty: 3-5% over all pt
- Jet Resolutions are derived from data via Dijet asymmetry
- JetEnergyResolution is 10% @ Pt=100 GeV
- JetPositionResolution in η and Φ is ~0.01 @ Pt=100 GeV

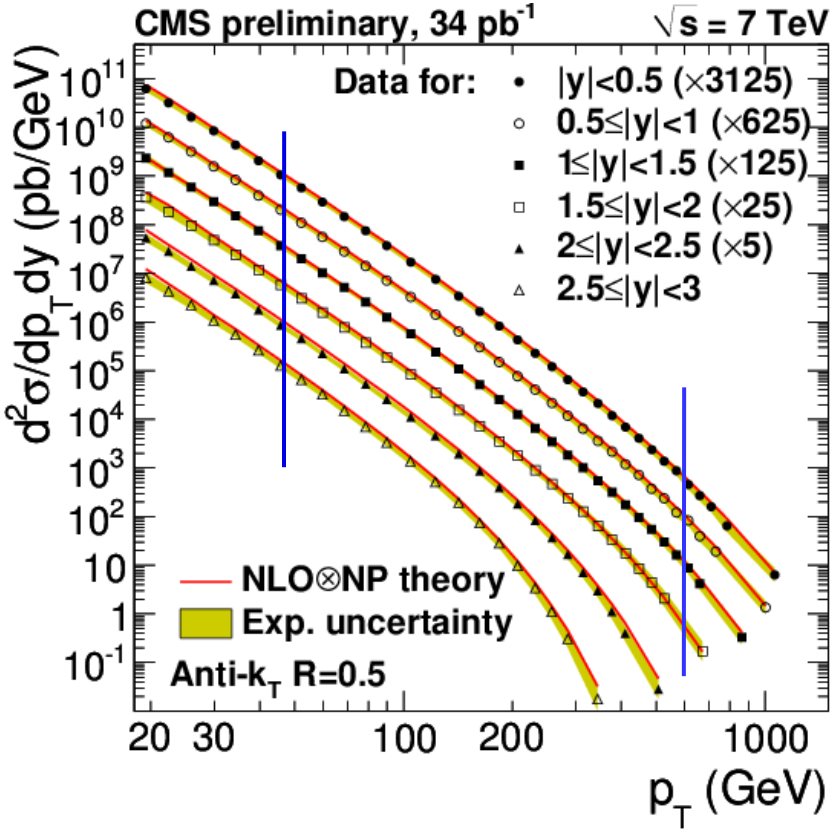


Inclusive Jet Cross Section

- Jet Cross Section Measurements are important as a
  - Tests of the Standard Model, Parton Distribution Functions
  - Test of NLO predictions
  - Contact Interactions Search

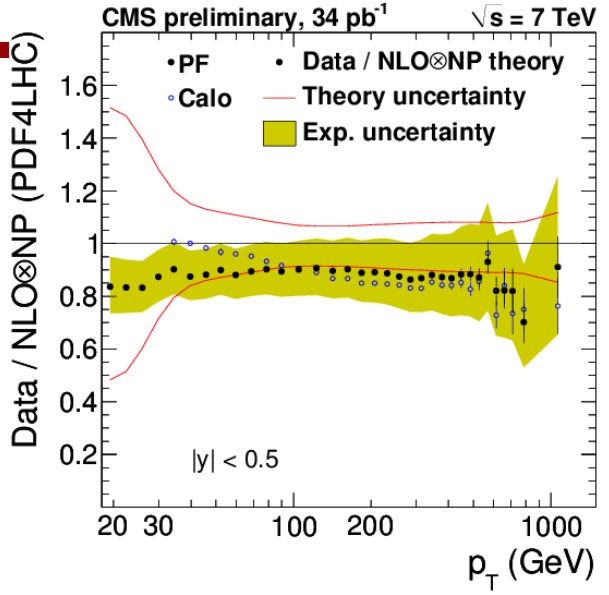
- CMS results have already improved on Tevatron reach
  - Pt range probed: 18-1100 GeV (50-650 GeV Pt range @ Tevatron)
  - 6 different rapidity bins used in the region $|\eta| < 3.0$
  - CMS Jet spectrum measured using Particle Flow Jets

CMS-QCD-10-011

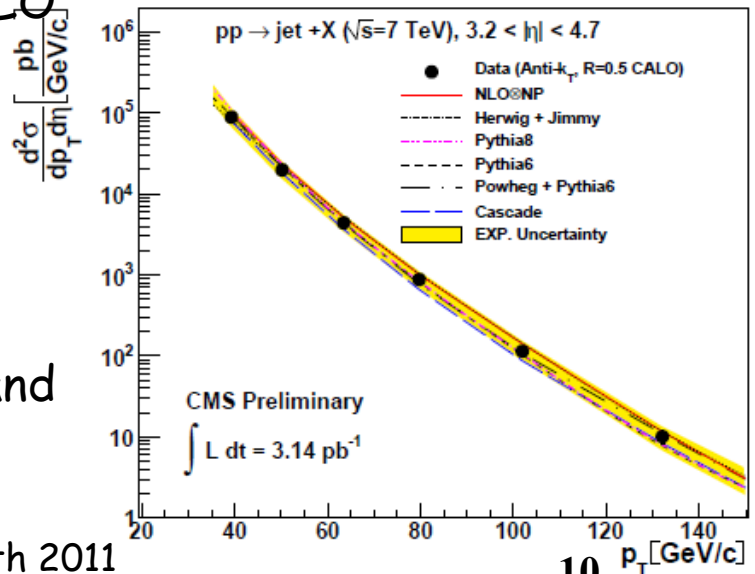


Inclusive Jet Cross Section

- Largest Systematic uncertainties
  - From data: absolute jet energy scale (which is being further improved with new data in 2011) and from integrated luminosity measurement
  - From theory: Scale and PDF uncertainties
- NLO pQCD predictions using PDF4LHC recommendations agree with data
  - PDF4LHC recommendation is the middle of envelope covered by CT10, MSTW2008NLO and NNPDF2.0 uncertainty bands.
- Measured Forward Jet Production
  - 3.2 < |η| < 4.7; Pt range: 35-150 GeV
  - Uses the Forward Hadronic Calorimeter
  - Total systematic uncertainties ±25%
  - First test of forward pQCD predictions and first cross check of QCD background estimates of other scattering processes.



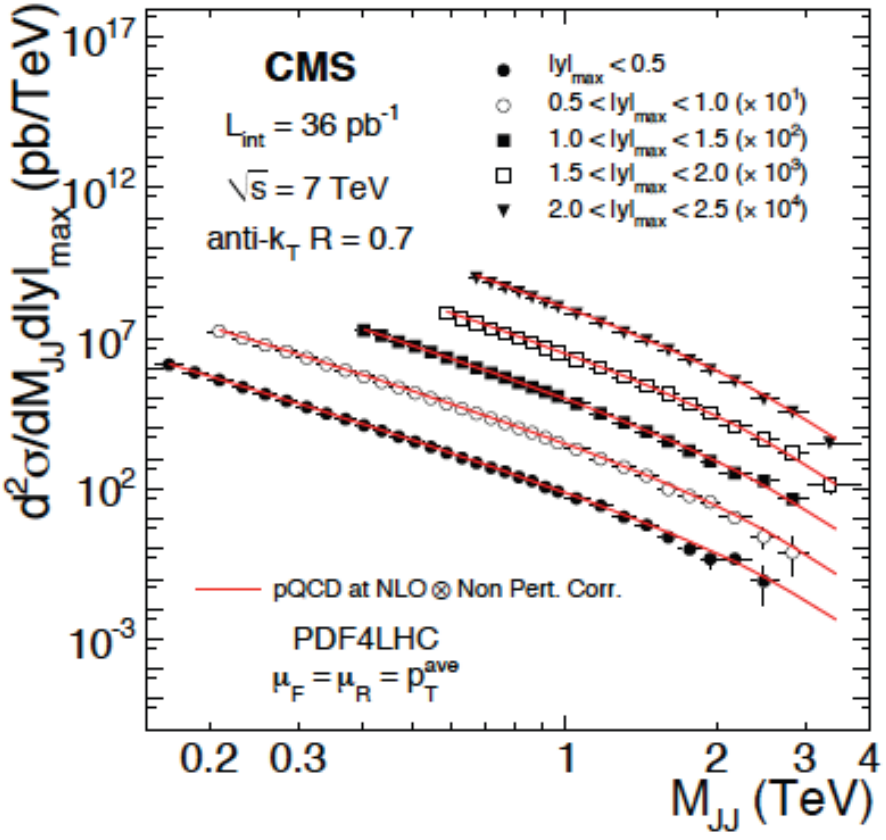
CMS-FWD-10-003



Dijet Mass

- Dijet mass measurements are a test of SM pQCD predictions
  - They can also be used as a probe for new physics such as dijet resonances and contact interactions.
- Parton momentum fractions probed: $8 \cdot 10^{-4} \leq x_1 \cdot x_2 \leq 0.25$
  - Dijet mass: 0.2-3.5 TeV
  - Measured for 5 bins in rapidity
  - Particle Flow jets used
- Systematic Uncertainties is dominated by jet energy scale (data) and PDF @ high mass, non perturbative correction @ low mass (theory)
- Data in good agreement with theoretical prediction in this kinematic region

PRL 105:221801, 2010

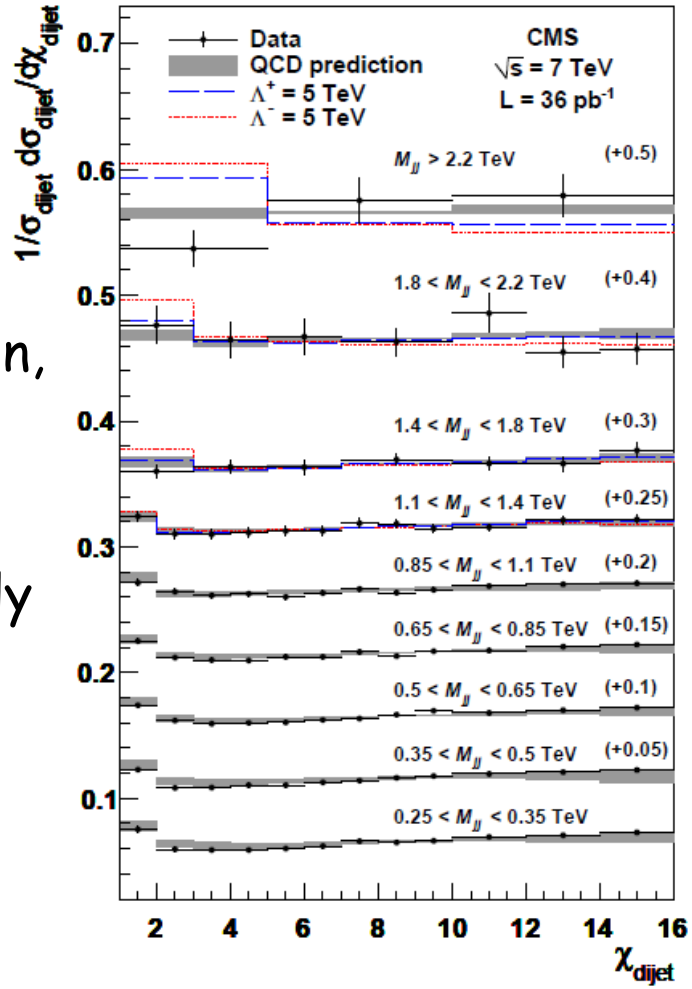


Dijet Angular Distributions

- Probes the parton-parton scattering angle θ*

CERN-PH-EP-2010-092

- $X_{dijet} = (1+|\cos\theta^*|)/(1-|\cos\theta^*|)$
  where $|\cos\theta^*| = \tanh(0.5 \cdot |y_1 - y_2|)$
  - Measured over wide range of dijet invariant mass
- While QCD predicts a flat X_{dijet} distribution, new physics would show an excess at low values of X_{dijet} due to quark compositeness
- Normalized X_{dijet} distributions are relatively insensitive to overall jet energy scale but sensitive to the rapidity dependence of jet energy calibrations
- Good agreement with NLO pQCD found



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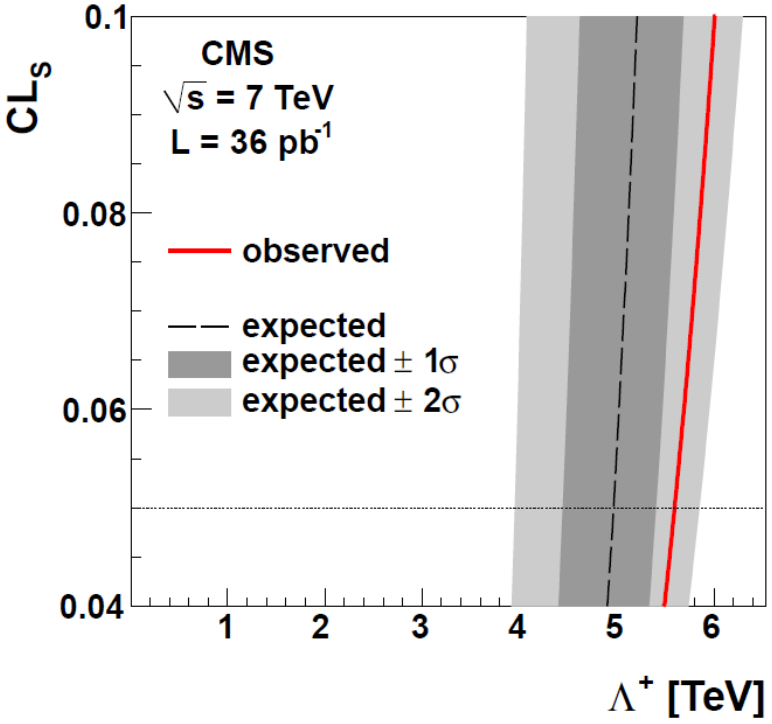


No evidence for new physics has been found

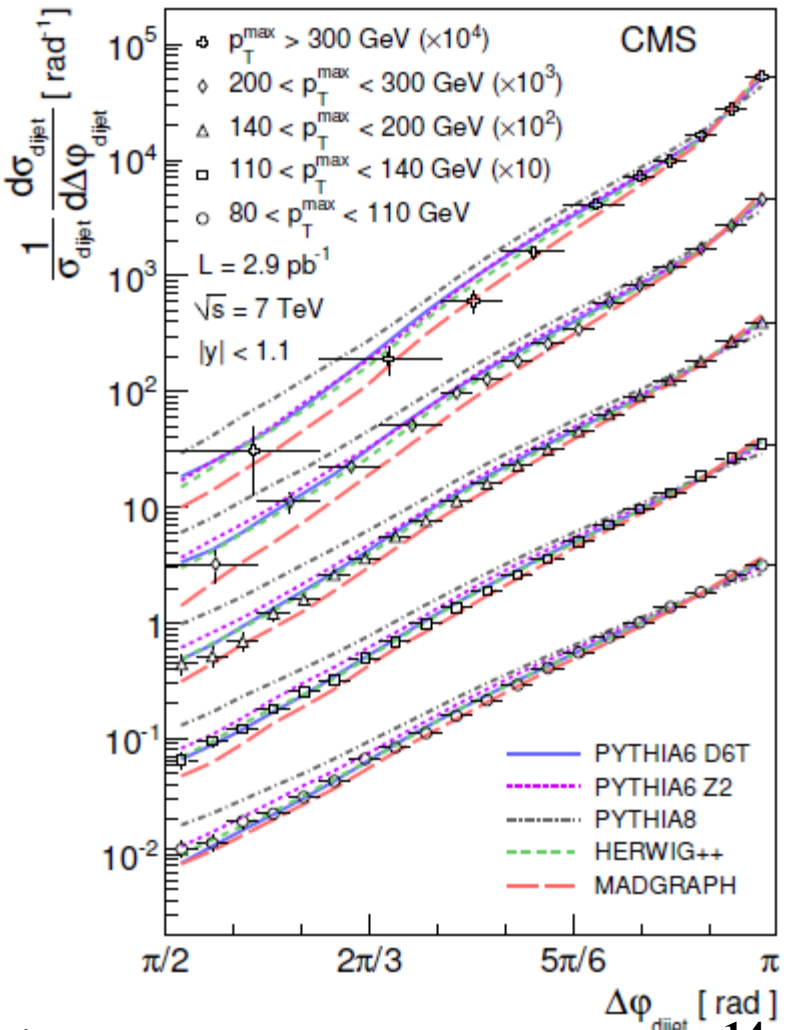
- X_{dijet} measurement is used to set limits on quark compositeness
  - 4 fermion contact interaction term is added to the QCD Lagrangian
  - Mass scale Λ denotes strength of quark substructure binding interactions and physical size of composite states
- Following CLs limits were set
  - Exclude $\Lambda^+ < 5.6$ TeV @ 95% CL for destructive interference
  - Exclude $\Lambda^- < 6.7$ TeV @ 95% CL for constructive interference

Dijet Azimuthal DeCorrelations

- $\Delta\varphi_{dijet} = |\Phi_{jet1} - \Phi_{jet2}|$
  - $\Delta\varphi_{dijet}$ DeCorrelations are used to study QCD radiation effects over a wide range of jet multiplicities without having to measure all the additional jets
  - Measurement is sensitive to initial state gluon radiation

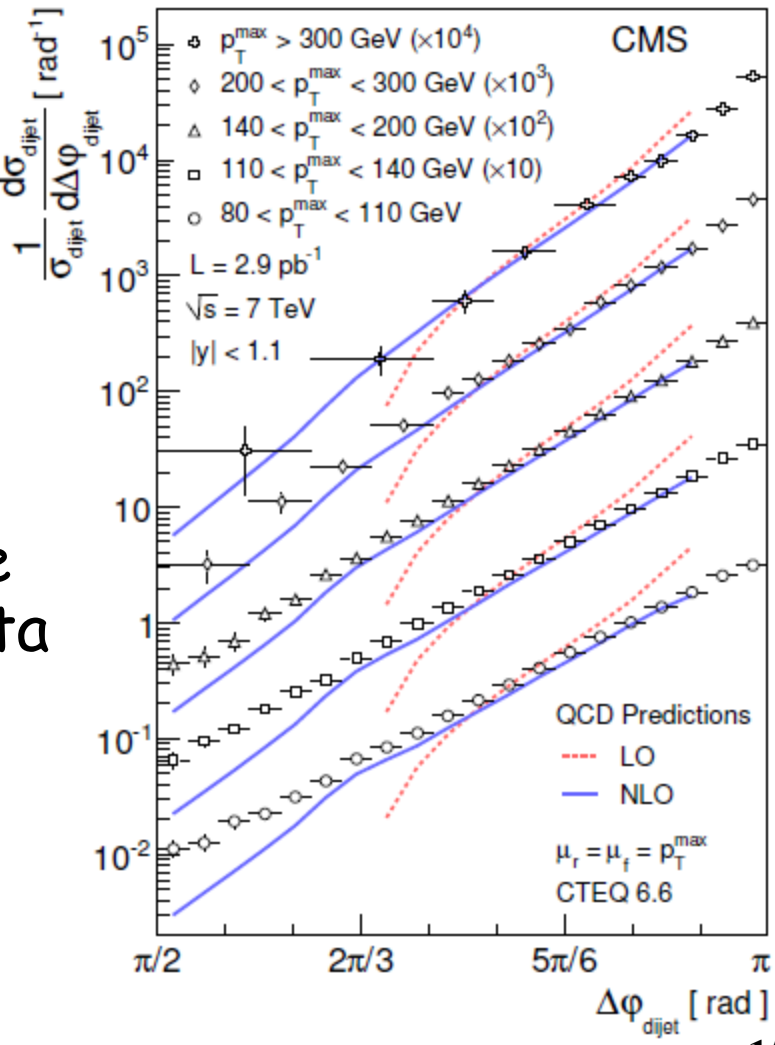
- Pythia6 and Herwig++ are found to best describe the shape of the distributions
  - Π ~signifies a 2 jet event
  - $2\Pi/3$ ~signifies a 3 jet event
  - $<2\Pi/3$ is the multijet regime

PRL 106 (2011) 122003



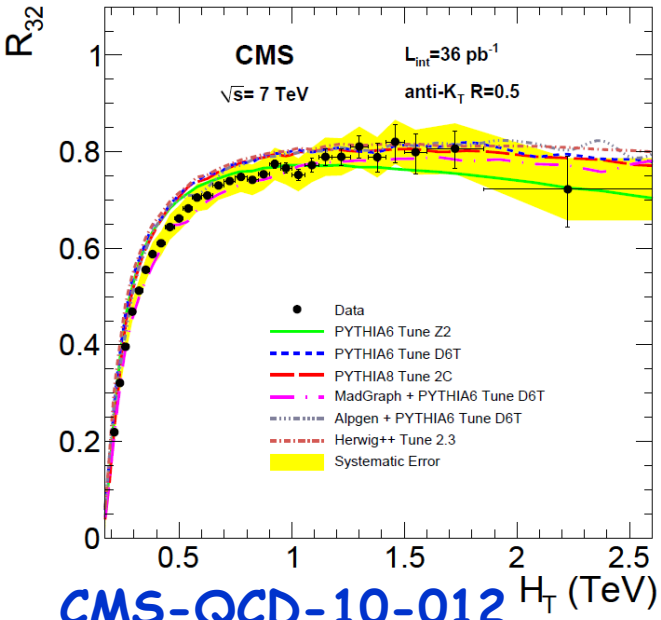
Dijet Azimuthal DeCorrelations

- Comparisions are also made to pQCD predictions
- Predictions near $\Delta\varphi_{dijet} = \Pi$ have been omitted due to their sensitivity to higher order corrections
- Predictions from NLO pQCD are in reasonable agreement with data except at small $\Delta\varphi_{dijet}$, where multi parton radiation effects dominate

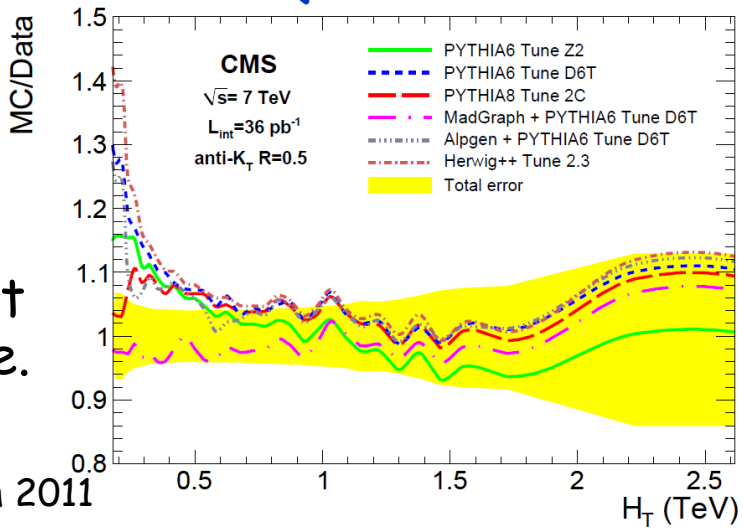


3jets/2jets Cross Section Ratio

- R_{32} is defined as the ratio of cross section of inclusive 3 jets to 2 jets
- R_{32} provides a complimentary probe for various pQCD based MC models
- Extend transverse momentum reach beyond 600 GeV @ Tevatron
- Major systematic uncertainties cancel out (JES, luminosity)
- Measurement compared to several MC generators (Pythia, Herwig++, Madgraph, Alpgen)
- Good agreement with predictions
  - Study extends the validity of different MC generators considered at TeV scale.



CMS-QCD-10-012



Conclusions

- LHC and CMS performed very well in 2010.
  - Several successful QCD analyses performed and published
  - Our robust understanding of the Jet reconstruction and energy calibration made these measurements competitive

- Data agrees with pQCD predictions at the new $\sqrt{s}$ = 7 TeV
  - CMS measurements will be made for further tuning of the MC generators to account for small observed discrepancies

- New data in 2011 is already being analyzed
  - CMS plans to perform precision studies with the new data as in measurement of α_s and to differentiate between various PDFs
  - Increased statistics will allow us to further reduce uncertainties related to jet quantities.