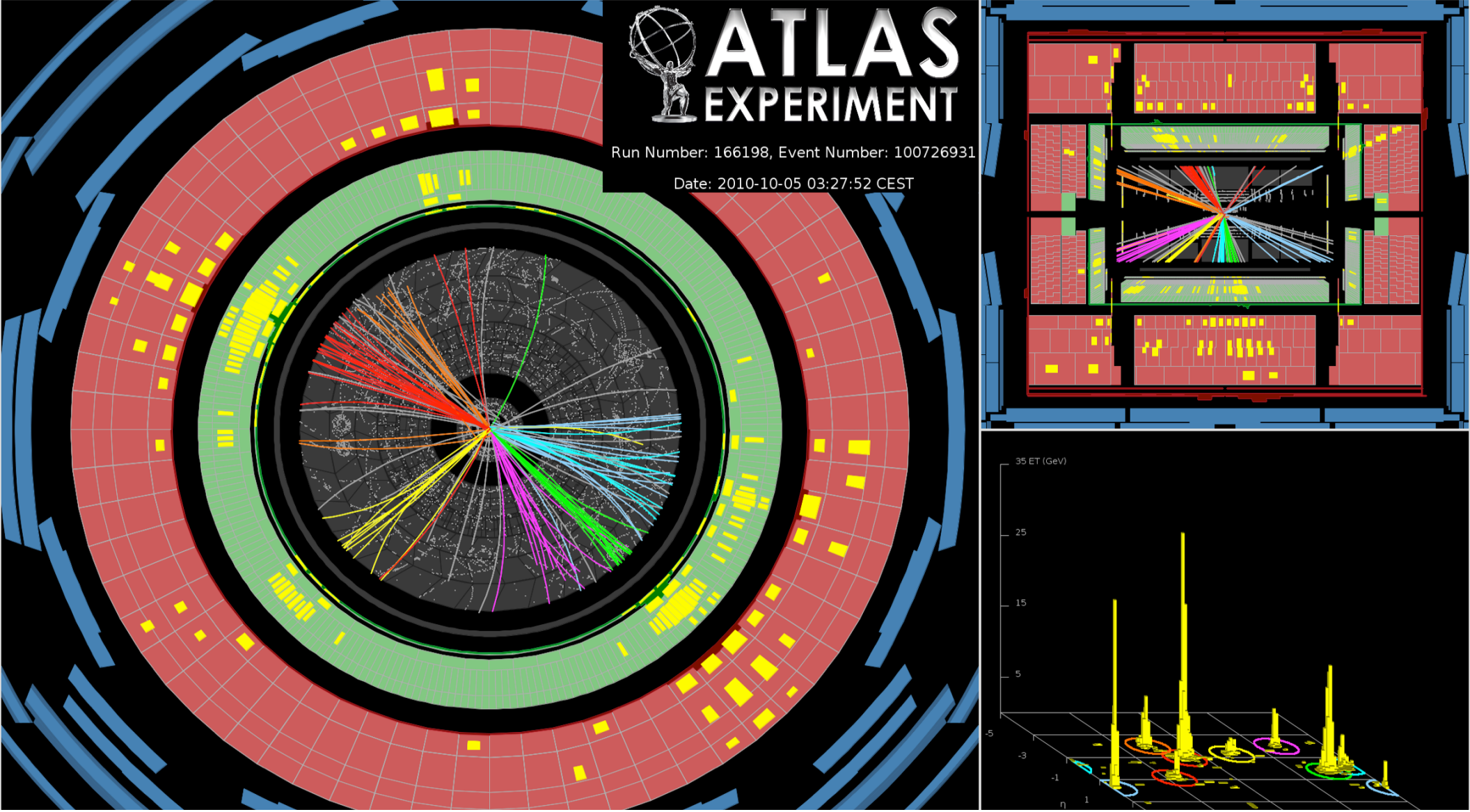


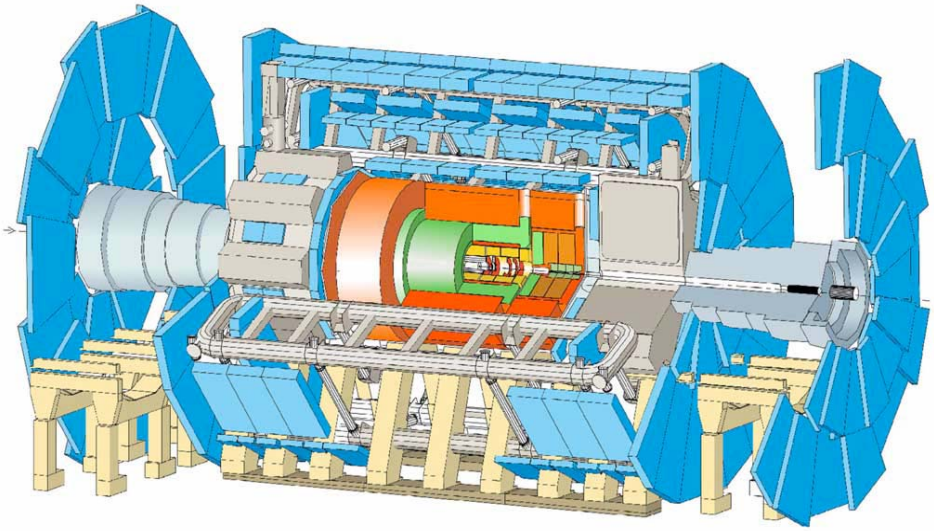
Measurements of Jet Production in pp Collisions with the ATLAS Detector

XX International Workshop on Deep Inelastic Scattering and Related Subjects

Adam Yurkewicz
Northern Illinois University
on behalf of the ATLAS Collaboration

Jet Measurements at ATLAS

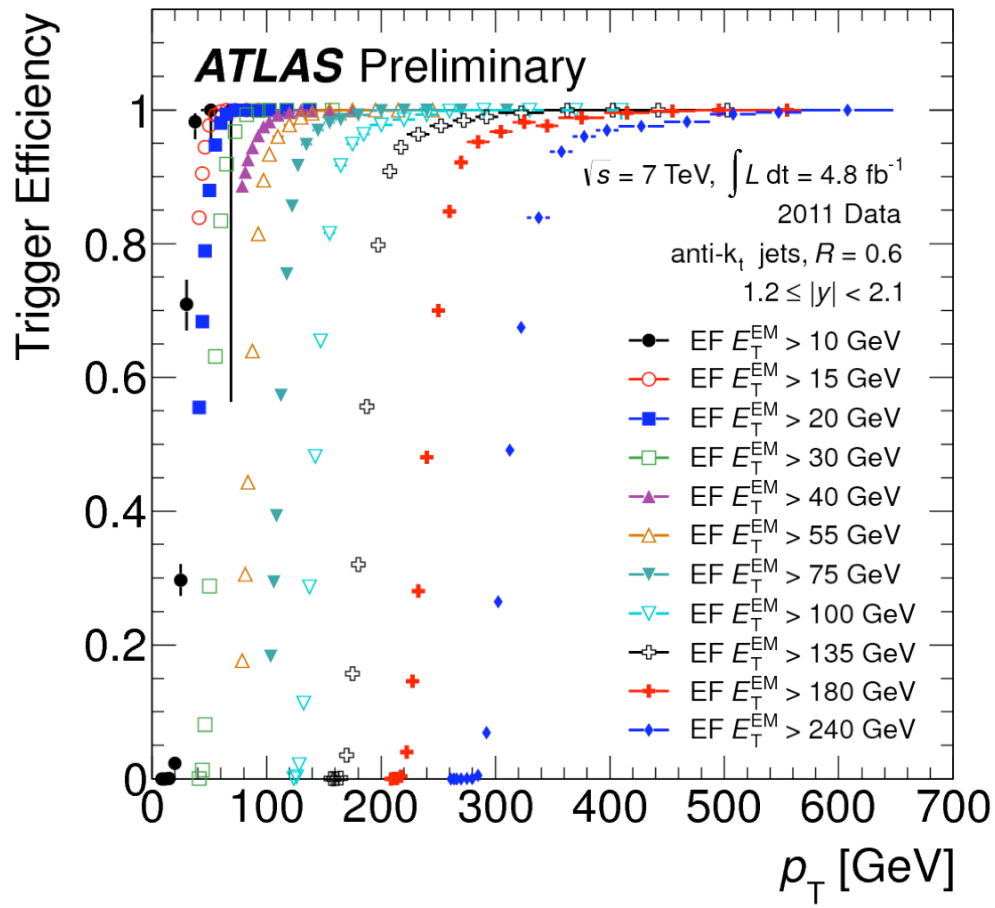
- At the LHC, jet production is the dominant high p_T process
- Provides precise information on the structure of the proton and allows direct tests of QCD predictions at leading and next-to-leading order
- Current results on jets at rapidities up to 4.4, and 20 GeV < p_T < 1.5 TeV
- Dijet mass measurements up to 5 TeV
- Multi-jet measurements are critical for understanding backgrounds in searches for new physics
- Track jet measurements allow comparisons to simulations at very low p_T (4 GeV)



- **"Measurement of inclusive jet and dijet production in pp collisions at sqrt(s) = 7 TeV using the ATLAS detector"**
  - http://arxiv.org/abs/arXiv:1112.6297
- **"Measurement of high mass dijet production in pp collisions at sqrt(s)=7 TeV using the ATLAS detector"**
  - https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-021/
- **"Measurement of multi-jet cross sections in proton-proton collisions at a 7 TeV center-of-mass energy"**
  - http://arxiv.org/abs/arXiv:1107.2092
- **"Properties of jets measured from tracks in proton-proton collisions at center-of-mass energy sqrt(s) = 7 TeV with the ATLAS detector"**
  - http://arxiv.org/abs/arXiv:1107.3311

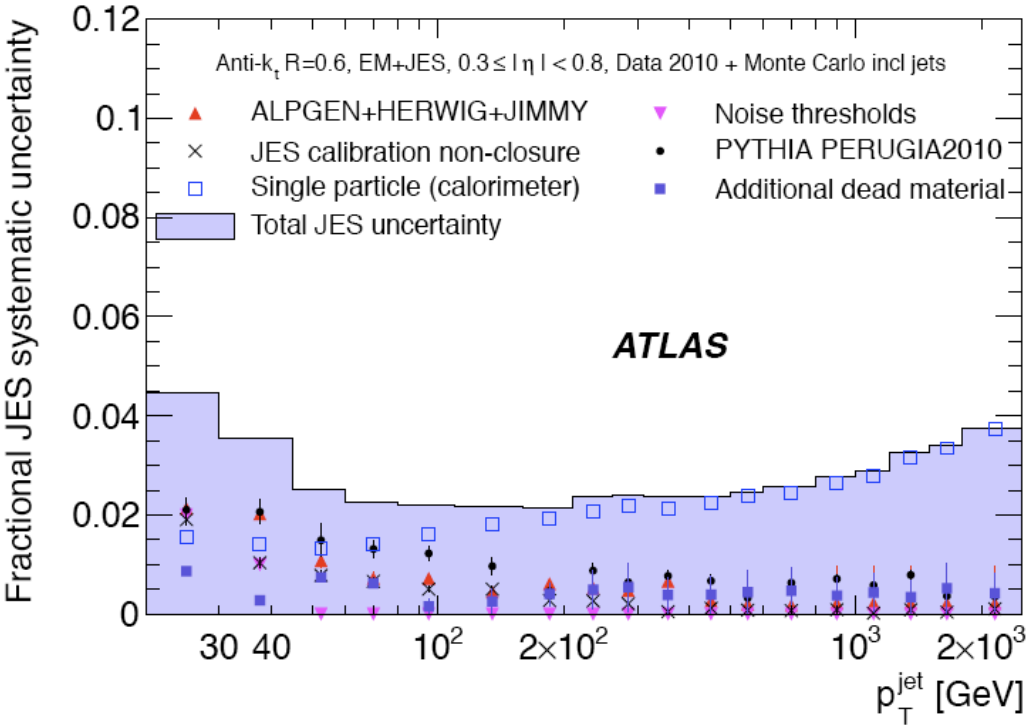
Inclusive and Di-jet Measurements

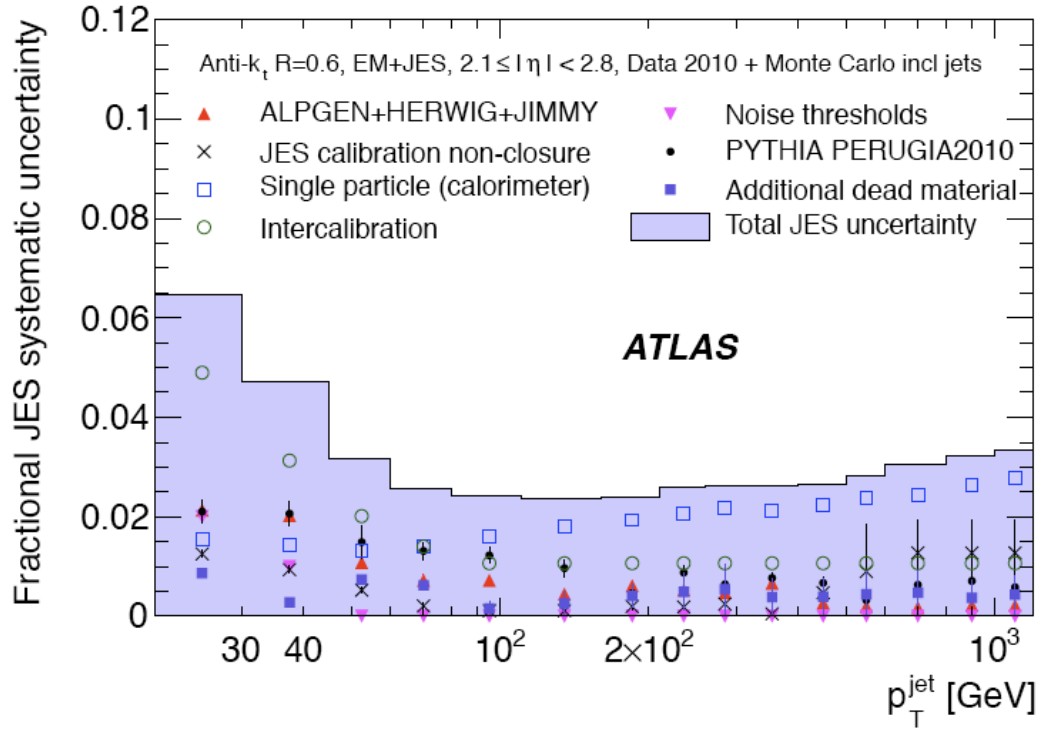
- Using 2010 data set (37 pb^{-1}) for inclusive and 2011 data set (4.8 fb^{-1}) for di-jet results
- Using anti-k_T jet-finding algorithm
- PYTHIA with MRST LO* PDF used to simulate and correct for detector effects
- Measurements compared to
  - fixed-order predictions from NLOJET++ corrected for non-perturbative effects with PYTHIA
  - NLO matrix element and parton shower predictions from POWHEG and PYTHIA or HERWIG
- See talk by B. Malaescu for more details (Thursday morning)



- Calorimeter trigger thresholds for jets in each p_T bin chosen to maintain efficiency of > 99% with as low as possible prescale
- Minimum-bias trigger used for jets with 20 GeV < p_T < 60 GeV

Systematic Uncertainties

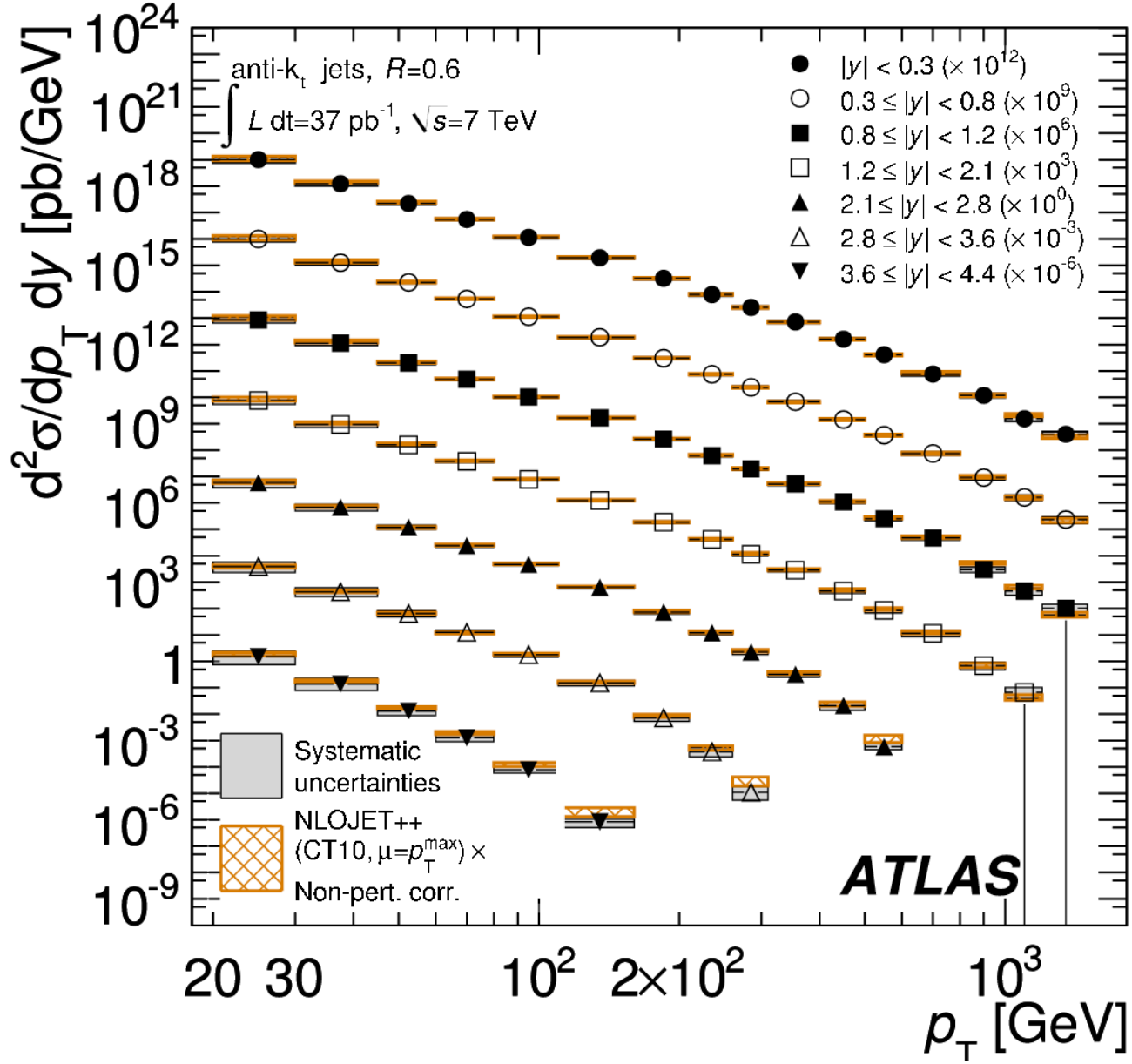




- Jet energy scale is the dominant source of uncertainty
- Uncertainty in jet energy resolution becomes more important in forward detectors

Inclusive Jet Cross Section

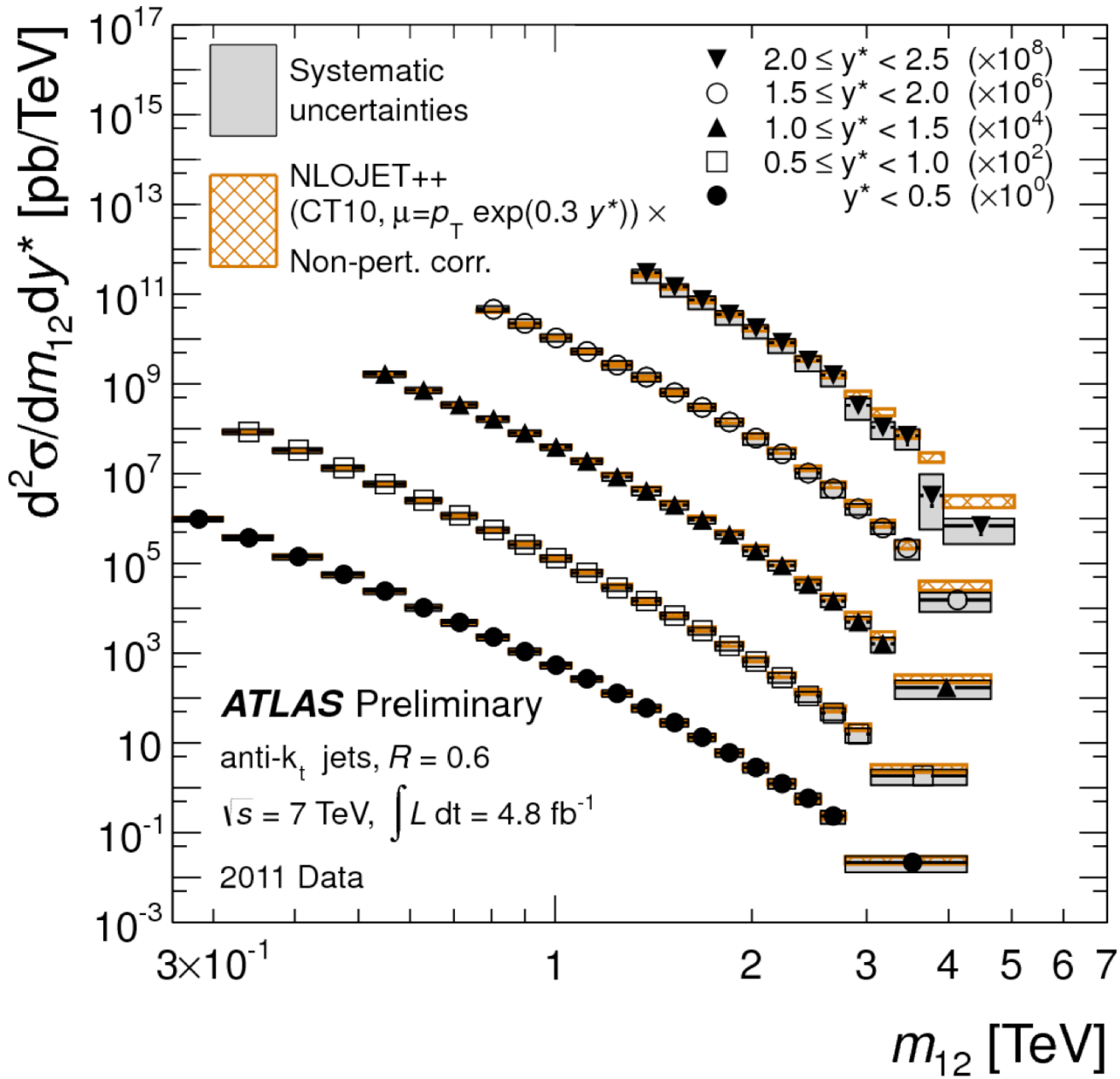
- Inclusive jet double-differential cross section compared to NLO pQCD using NLOJET++
- Probe 7 x $10^{-5} < x < 0.9$ (parton momentum fraction)
- Agreement over 10 orders of magnitude in the cross section



Di-Jet Cross Section

- Dijet Cross Section versus Mass, binned in y*
- $y^* = |y_1 - y_2| / 2$, rapidity in the two-parton center-of-mass frame of two leading jets in p_T

- $P_{T,1} > 100$ GeV
- $P_{T,2} > 50$ GeV

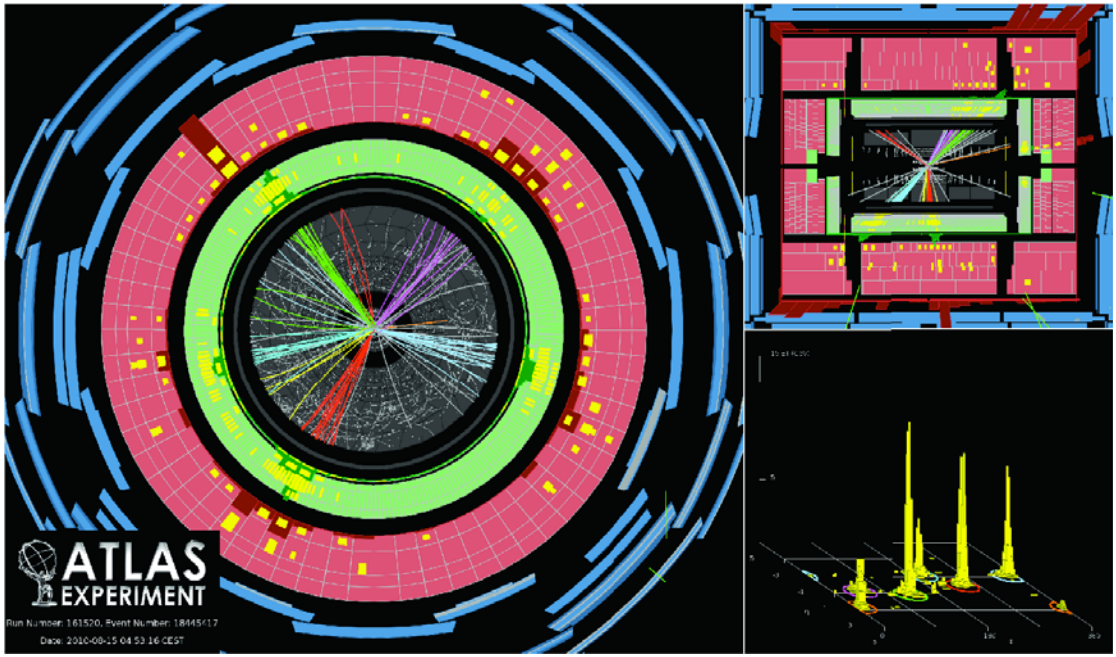


Multi-jet Measurements

- Using 2010 data (2.4 pb^{-1})
- Two types of comparisons to theory
  1) Shape comparison done with different leading-order simulations for use in new particle searches
  2) Comparison to NLO pQCD - NLOJET++ with MSTW 2008 PDF, corrected for non-perturbative effects with PYTHIA

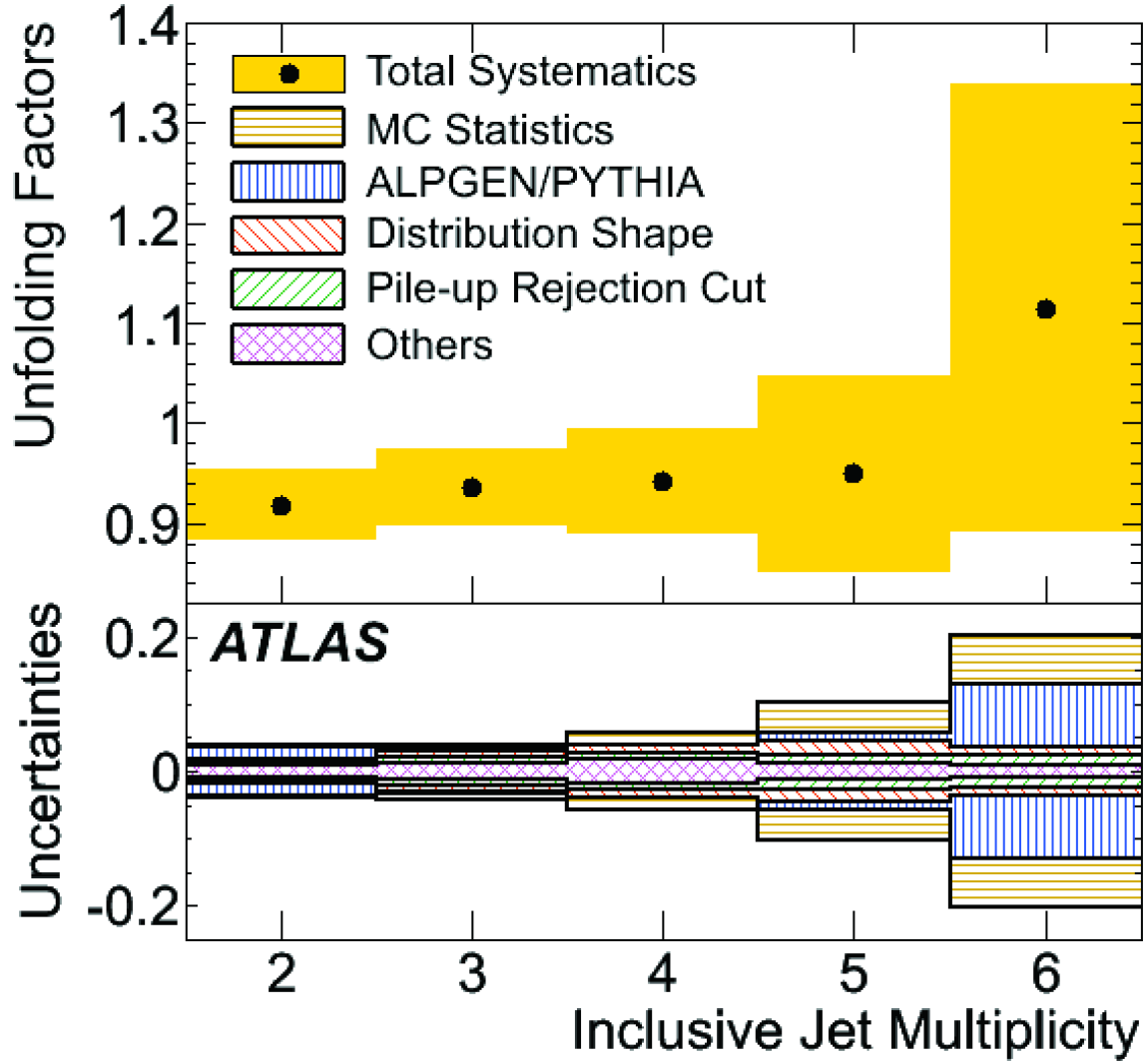
Generator	PDF	tune
ALPGEN+HERWIG/JIMMY	CTEQ6L1 [14]	AUET1 [22]
ALPGEN+PYTHIA	CTEQ6L1 [14]	MC09′ [21]
PYTHIA	MRST2007 LOmod [24,25]	AMBT1 [21]
PYTHIA*	MRST2007 LOmod [24,25]	MC09 [21]
SHERPA	CTEQ66 [29]	Default (v1.2.3)
HERWIG++*	MRSTMC al [24,25]	Default (v2.5)

- $p_{T,leading} > 80$ GeV
- Count jets with $p_T > 60$ GeV

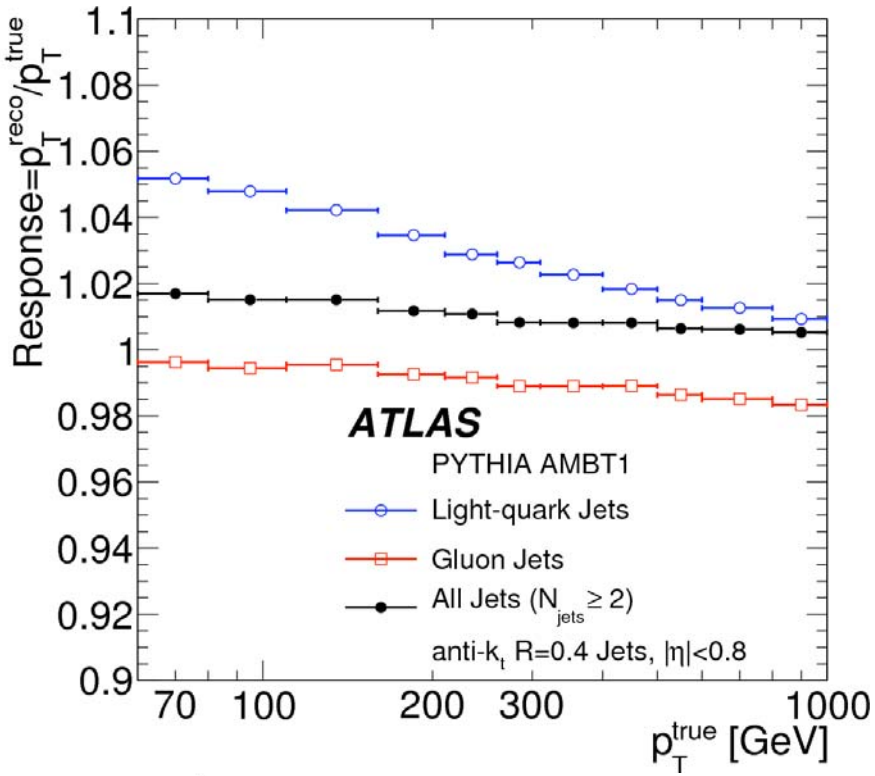


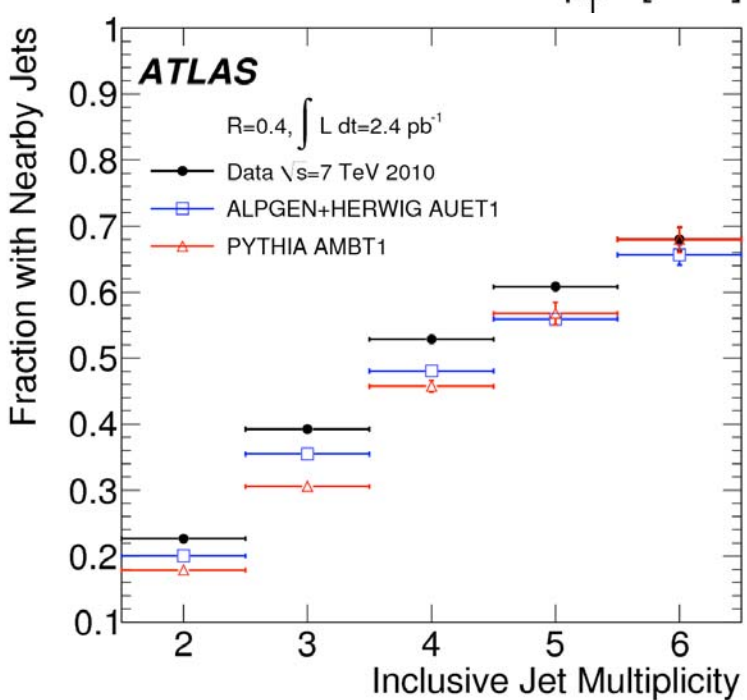
Unfolding and Uncertainties

- Bin-by-bin unfolding using ALPGEN+HERWIG/JIMMY simulation
- Uncertainties from
  - comparisons to PYTHIA
  - Variations of jet resolution within measured uncertainty
  - Jet energy scale including flavor composition, nearby jets, and pileup



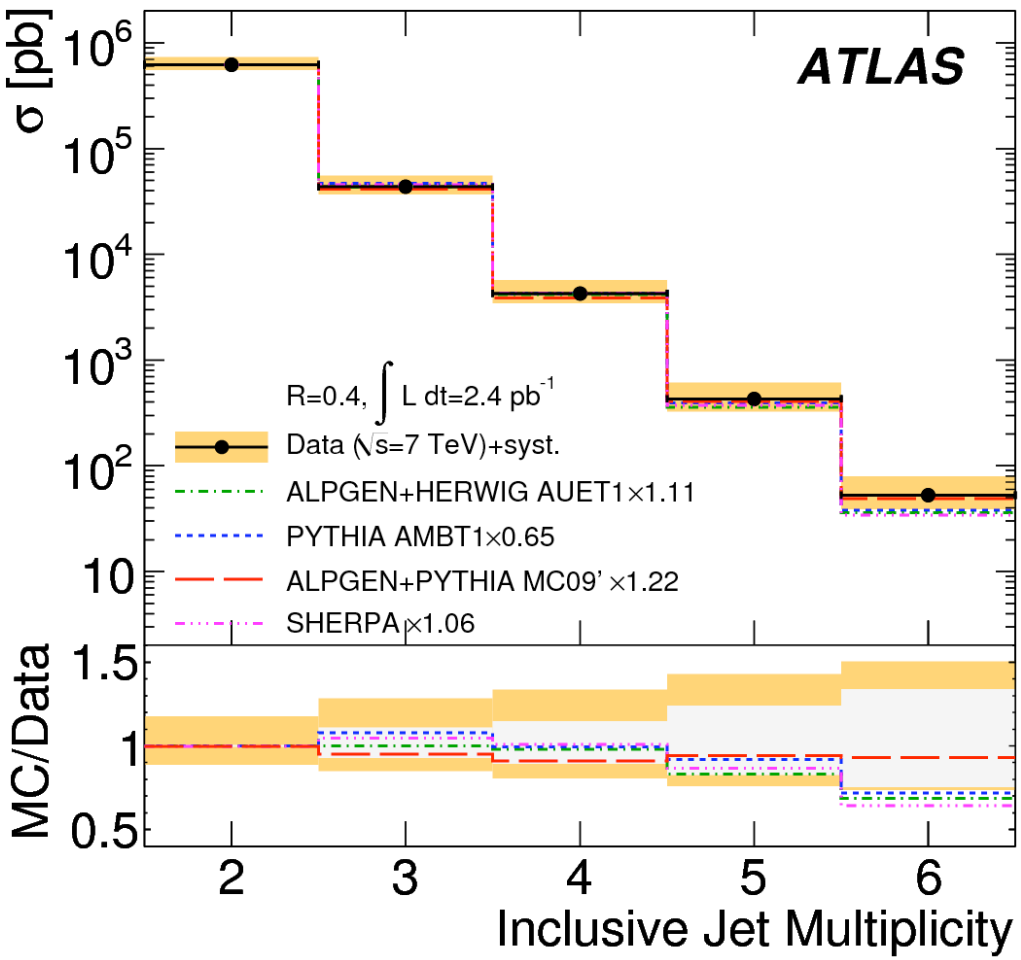
Uncertainties from Flavor Composition and Nearby Jets

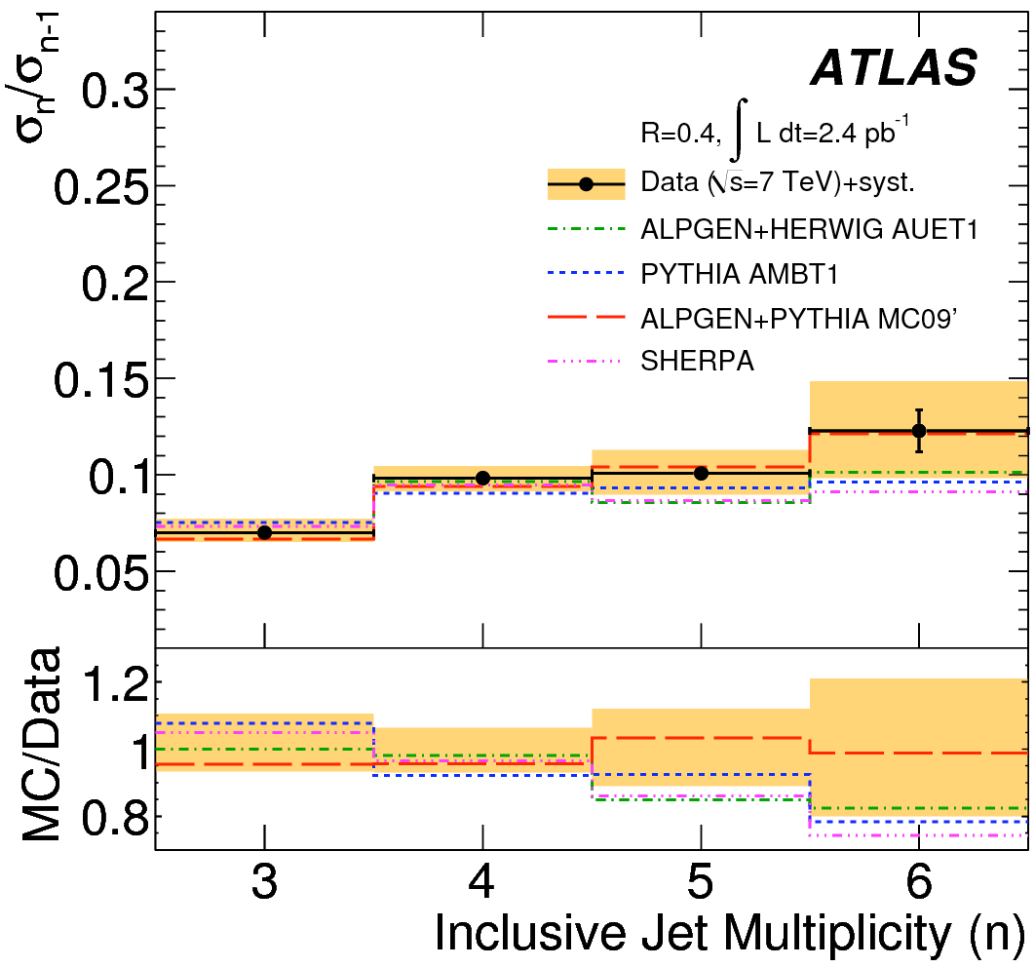




- The fractions of light-quark and gluon jets in multi-jet samples determined in data using template fits to the distribution of jet widths and the number of tracks in jets
- Presence of nearby jets alters jet energy scale
  - Has been studied by comparing momenta of tracks and calorimeter deposits associated to jets

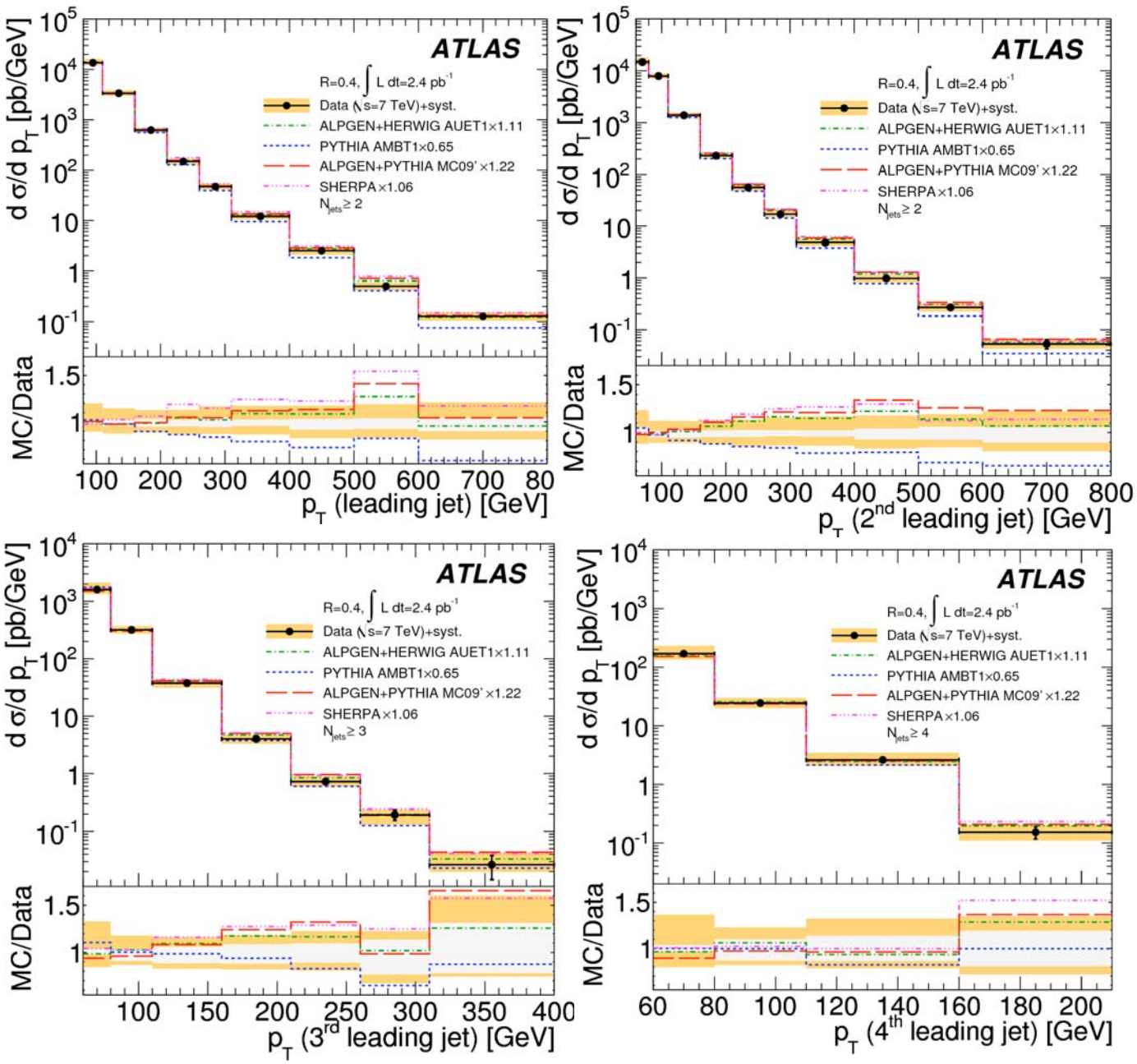
Jet Multiplicity





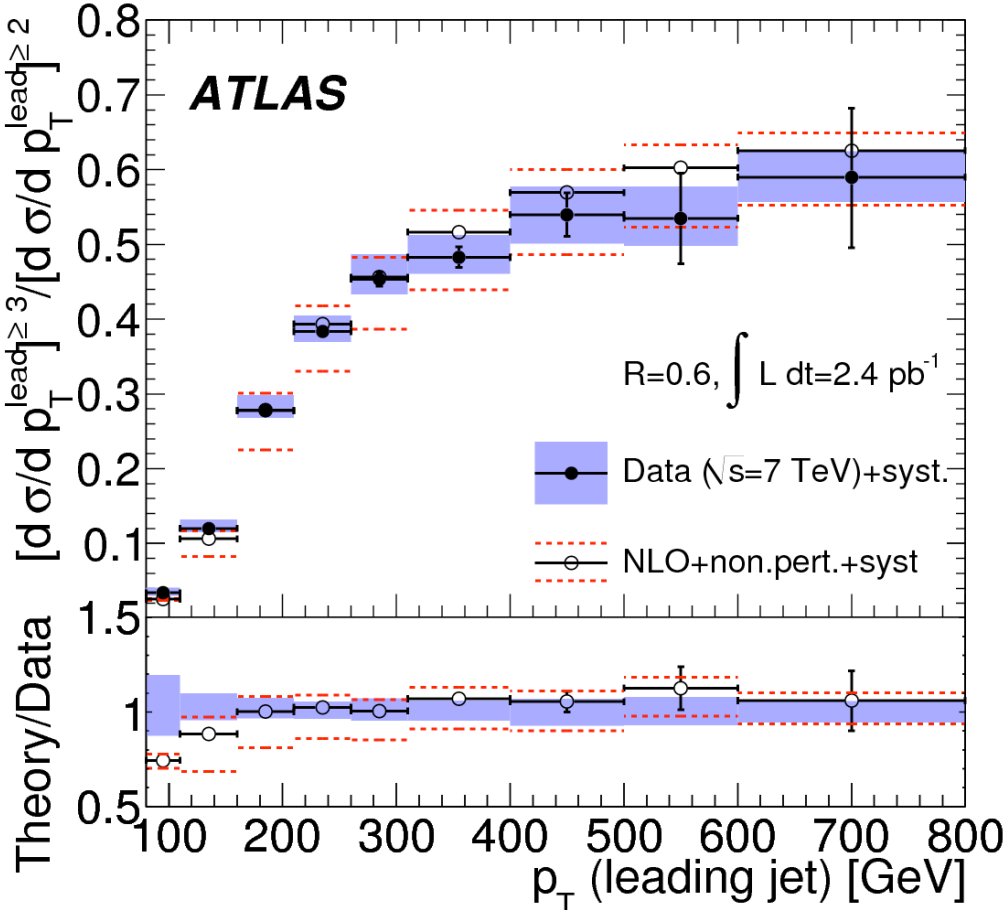
- Jet cross section compared to LO simulations
- Ratio of n-jet to (n-1)-jet cross section
- Monte Carlo simulations are normalized to the measured two-jet cross section

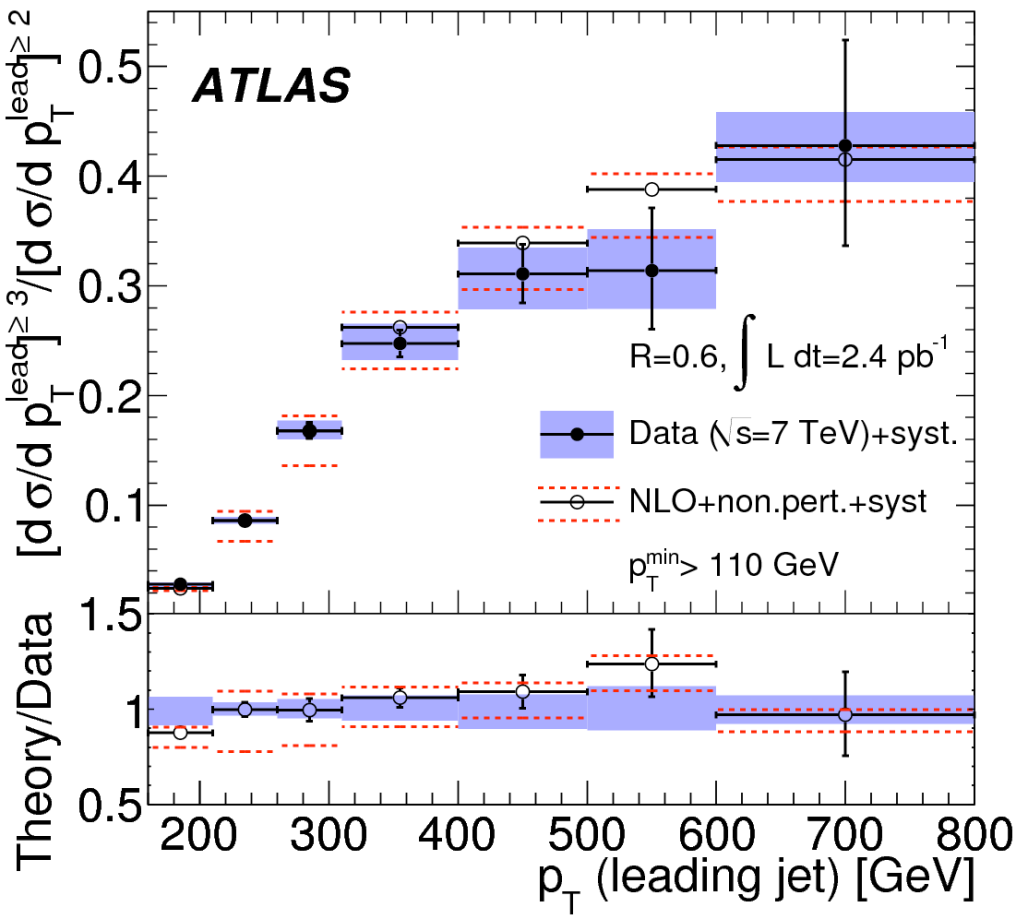
Jet p_T Spectra



- Jet p_T spectra in reasonable agreement with data
  - Large spread in predictions from different simulations
- Monte Carlo simulations are normalized to the measured two-jet cross section

Comparisons to NLO pQCD Simulations





- Three-to-two-jet cross section ratio as a function of leading jet pT
- Direct comparison to NLO pQCD corrected for non-perturbative effects
- Good agreement except in lowest pT bin, diminished with higher jet pT cut

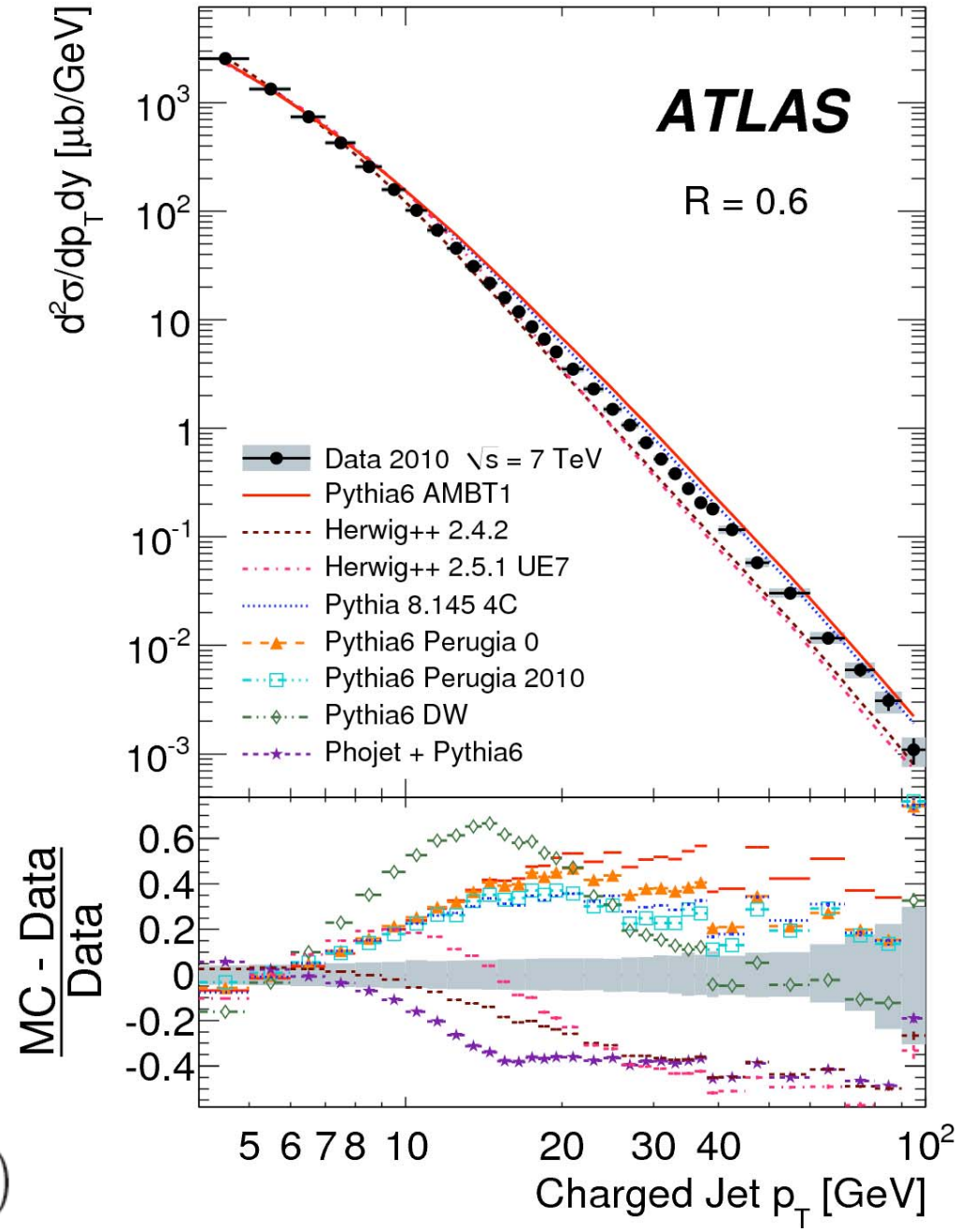
Jets from Charged Particles

- Anti-k_T jets reconstructed from all charged particles with p_T > 300 MeV
- Events are selected using a minimum bias trigger allowing study of jets at very low pT

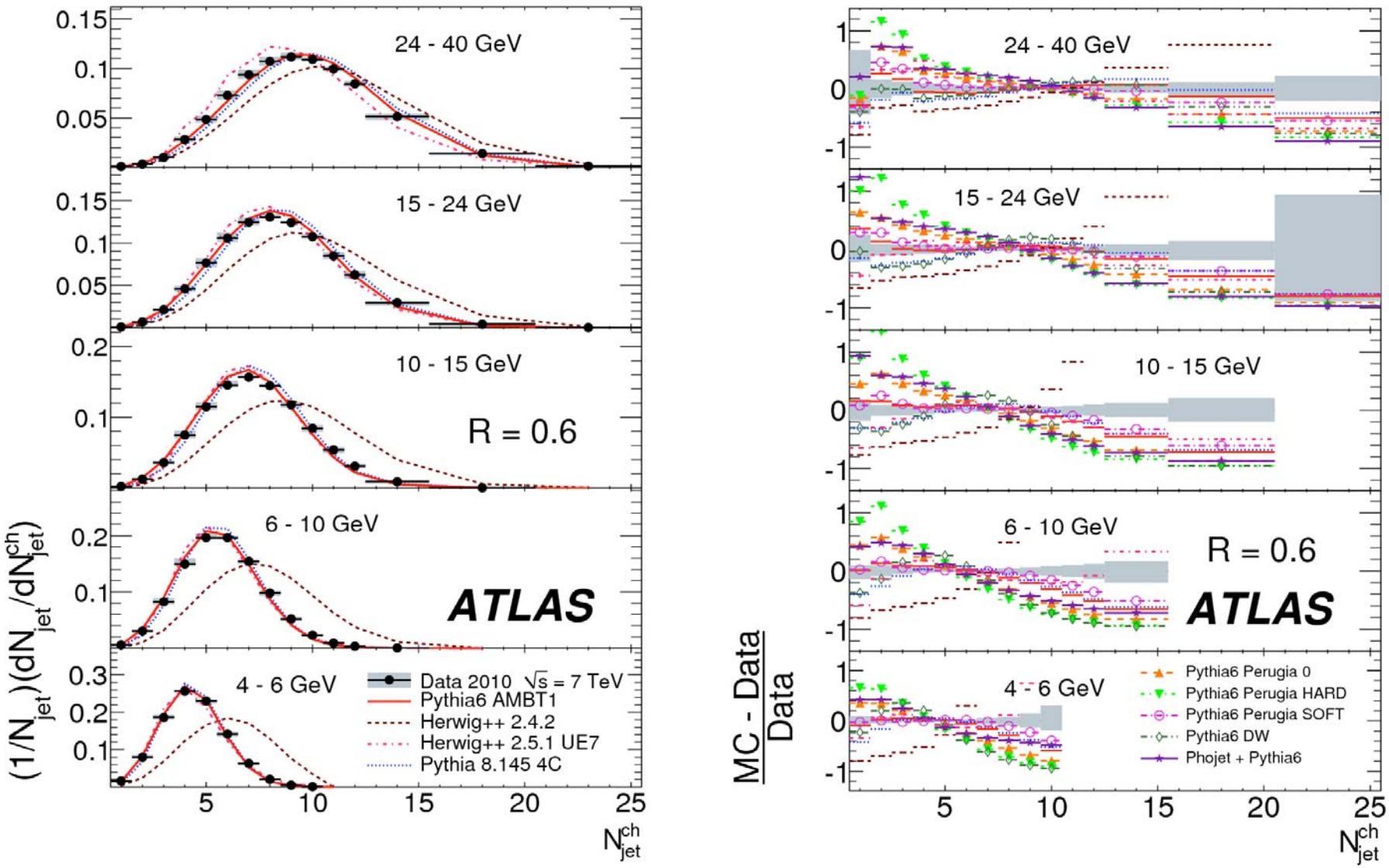
- Five quantities measured for charged particle jets:

$$\frac{d^2\sigma_{jet}}{dp_{\mathrm{T}jet}dy_{jet}};\quad \frac{1}{N_{jet}}\frac{dN_{jet}}{dN^{ch}_{jet}}$$

$$\frac{1}{N_{jet}}\frac{dN_{ch}}{dz};\quad \frac{1}{N_{jet}}\frac{dN_{ch}}{dp^{rel}_{\mathrm{T}}};\quad \rho_{ch}(r)$$



Charged Particle Multiplicity



- Measurements made for $|y_{jet}| < 1.9$
- No tune describes all of the kinematic distributions well
- Most models underestimate the contribution of the underlying event

Conclusions

- ATLAS has measured jet, dijet, and multijet differential cross sections
- First ATLAS results on jet cross sections using 2011 data presented
- Jet energy scale uncertainties of a few percent allow precision measurements extending into new kinematic regimes
- Jets reconstructed from charged particles allow measurements of very low-p_T jets