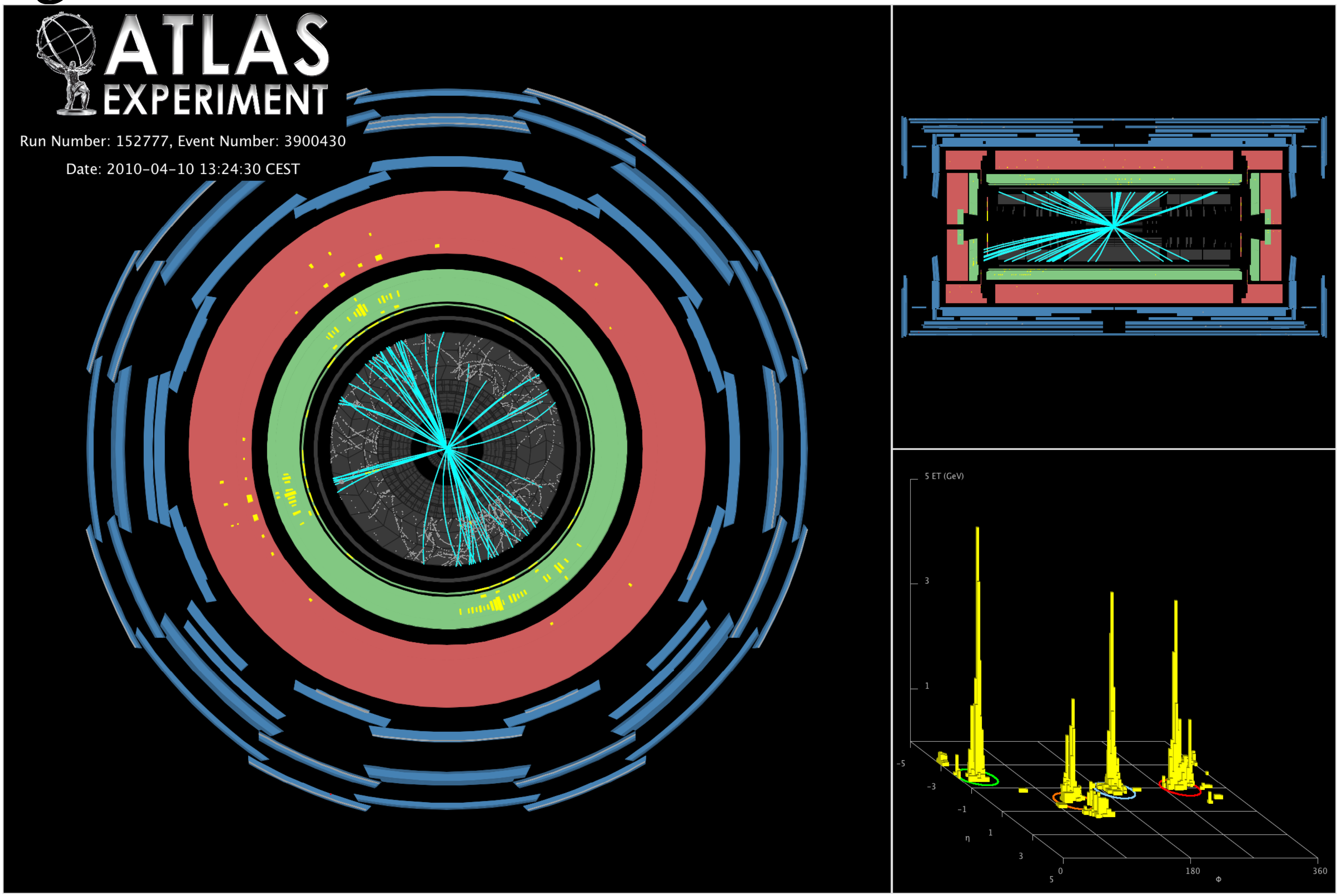
Jet Production in ATLAS at 7 TeV



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Caltech and Columbia University
Sunday, 18 July 2010 (Blois2010)

Brief Outline

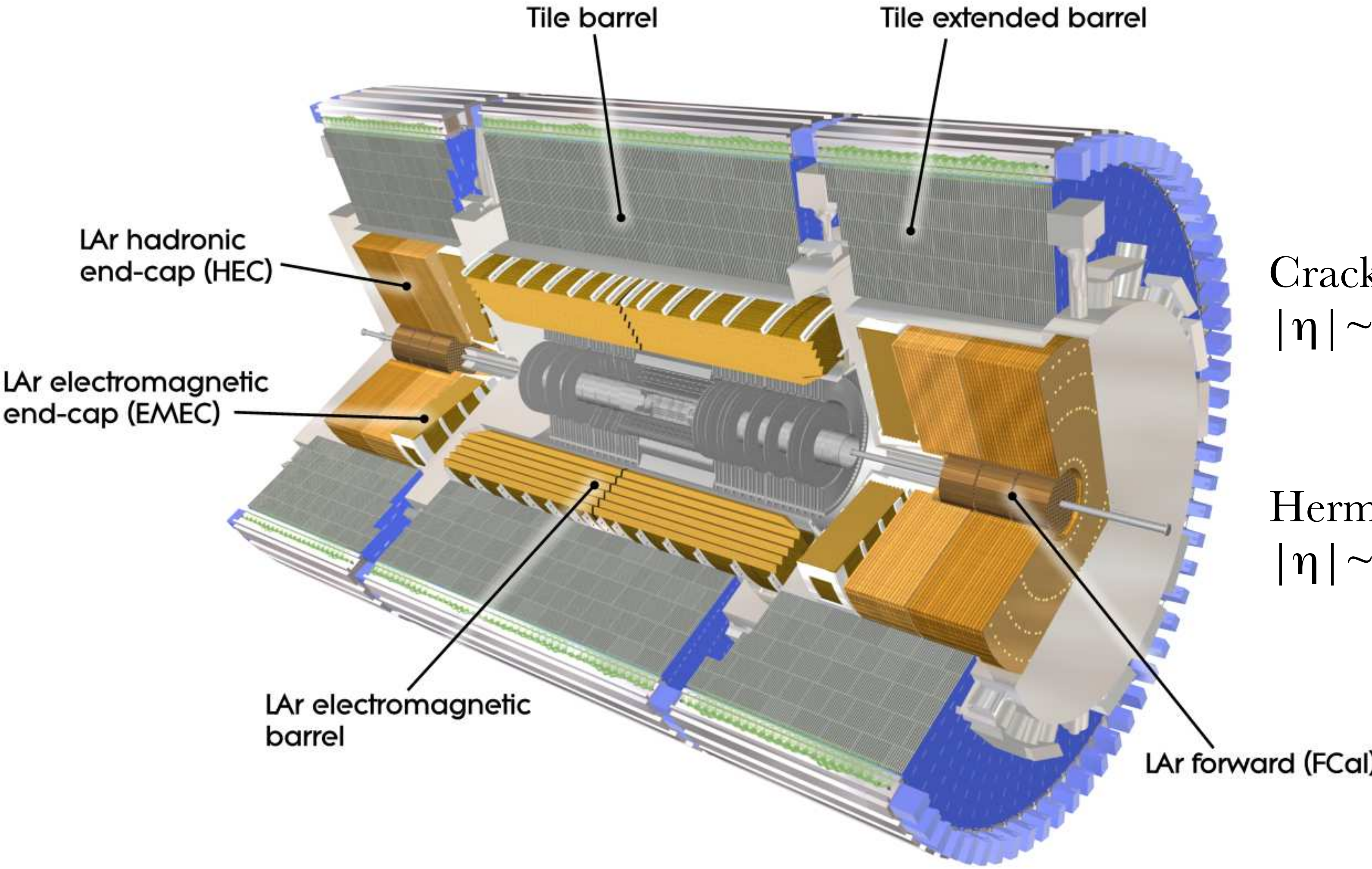
Presenting the first measurement of
inclusive single-jet differential cross-sections
and di-jet cross-sections made in ATLAS at 7 TeV

- The ATLAS Calorimetry in brief
- Event selection criteria
- Jet reconstruction, selection, and calibration
- Corrections applied to data and calculation
- Results

ATLAS Calorimetry

Two technologies:
Liquid Argon: >98.5% channels good
Scintillating Tile: 97.3% channels good

Detector giving good data:
Liquid Argon: >95%
Scintillating Tile: 100%



Cracks near $|\eta|\sim1.0$, $|\eta|\sim1.4$

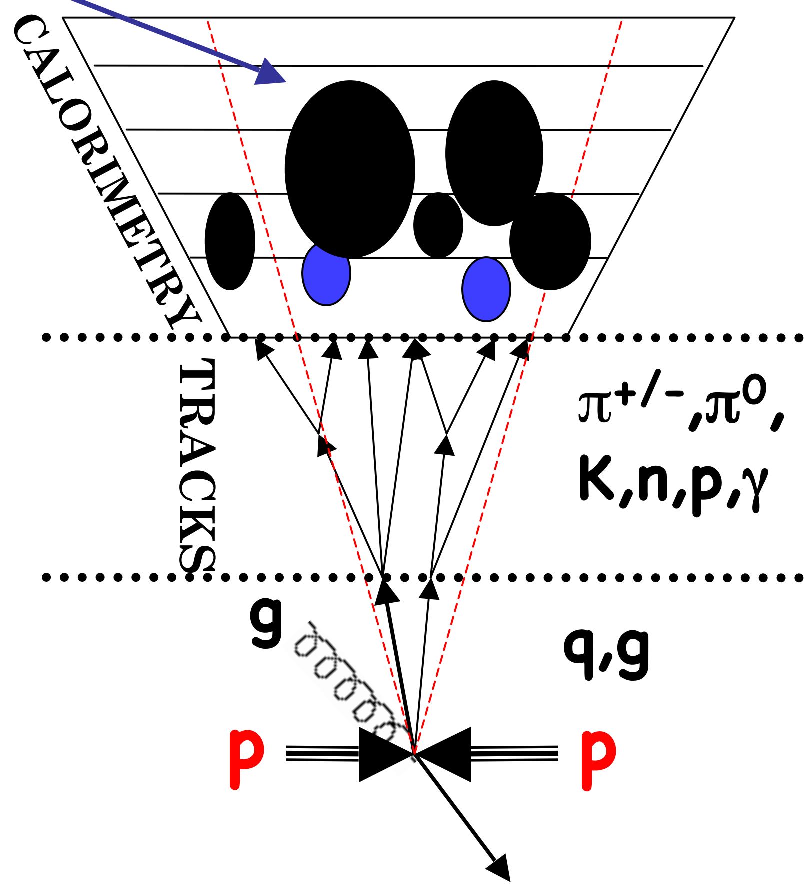
Hermetic to $|\eta|\sim4.9$

Event Selection

- "Good" data quality
  - Requires no readout problems, normal detector settings
  - Any problems (e.g. noisy cells) dealt with appropriately
- Two trigger selections
  - Minimum bias trigger scintillator (2%) - See talk from G. Hare
    - Requires one hit in the scintillators on one side of the detector
    - ~100% efficient, but pre-scaled early on
  - Level one calorimeter trigger (98%)
    - Requires two filled bunches automatically (lower backgrounds)
    - Lowest threshold trigger 99% efficient at 60 GeV
    - Not pre-scaled (yet)
- Reconstructed vertex with at least five associated tracks
  - $|z|<10$ cm and near the luminous region (>99% efficient in data)
- After cuts, essentially *zero background*
- 16.6 ± 1.8 nb^{-1} recorded (30 March - 5 June)
  - 11% luminosity systematic uncertainty *not shown* everywhere

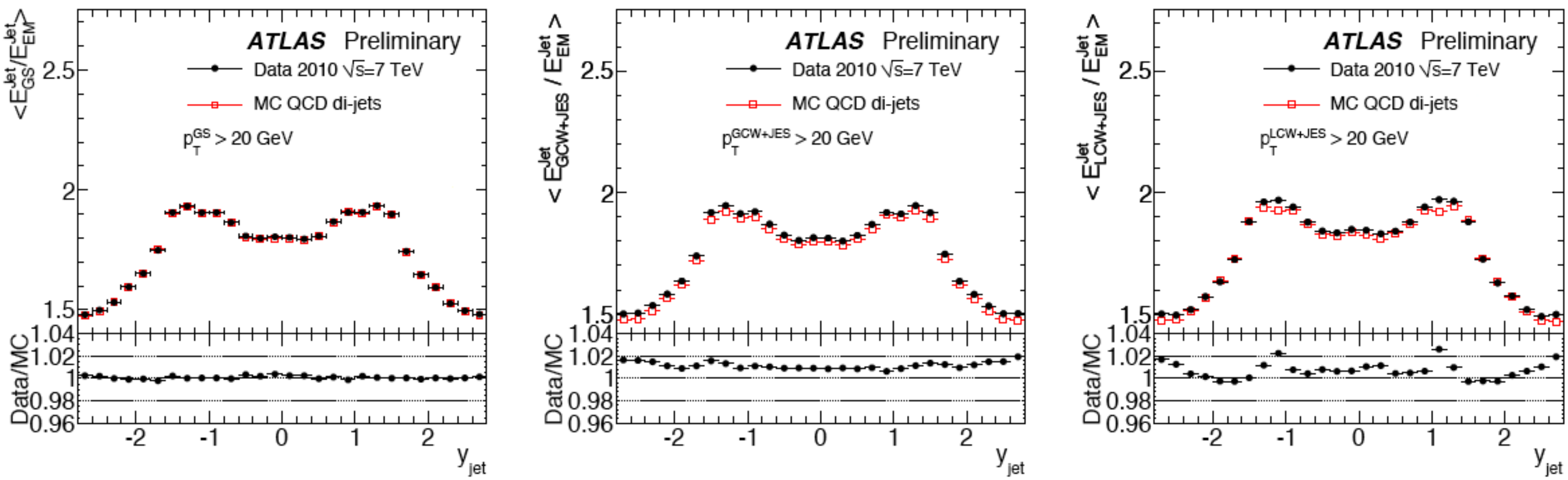
Jets Selection and Calibration

- Jets are constructed from topological clusters of energy
- Using the anti-k_T jet algorithm
  - I will mostly show results with R=0.6
    - Have produced results with R=0.4 as well - same conclusions
  - Momenta are calculated in the detector frame and then corrected according to the primary vertex
  - After correction, require $|y|<2.8$ and $p_T>60$ GeV
- Several cleaning cuts applied
  - Mostly removing detector noise (e.g. single cell jets or larger noise bursts)
  - All cuts highly efficient



Jets Selection and Calibration

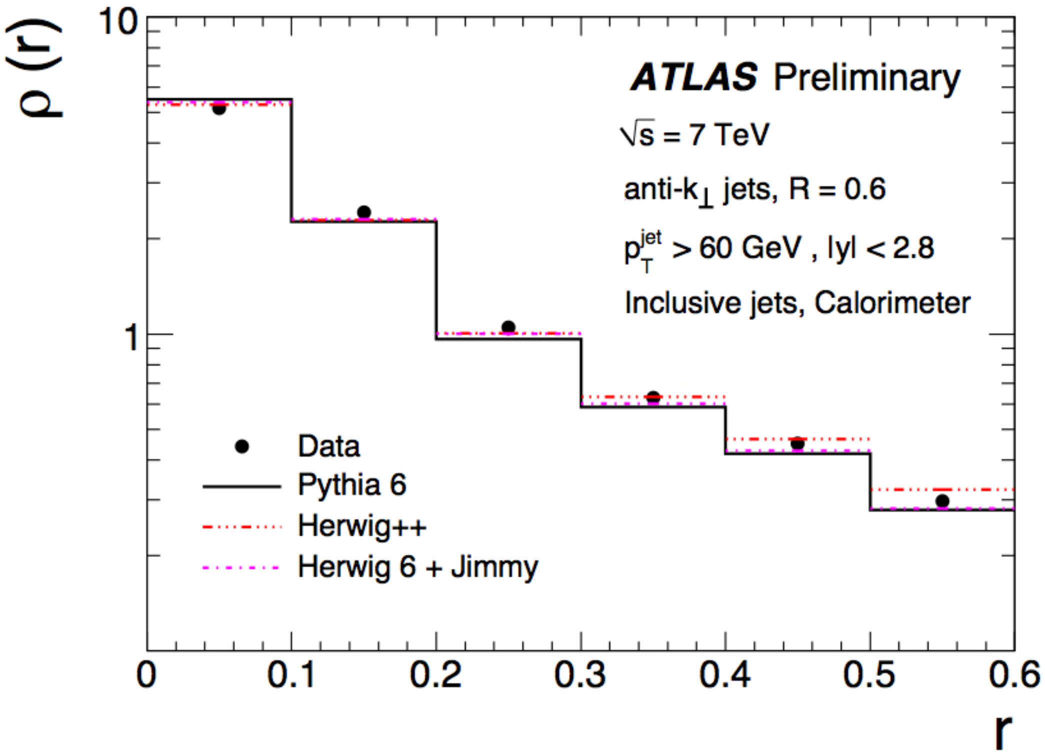
- Calibration done using "numerical inversion"
  - Simple p_T and η dependent calibration
  - More advanced calibrations await in-situ tests
  - Jet energy scale systematic <9% (<7% for central jets)
    - Evaluated using Monte Carlo, checked for consistency with test-beam and single particle (in-situ) data
    - Still dominates the systematic uncertainty by far

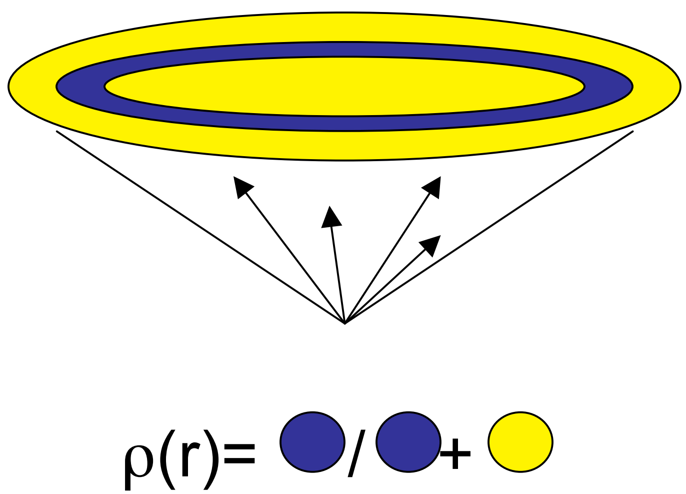


(a) Global sequential calibration (b) Global cell-weighting calibration (c) Local cluster calibration

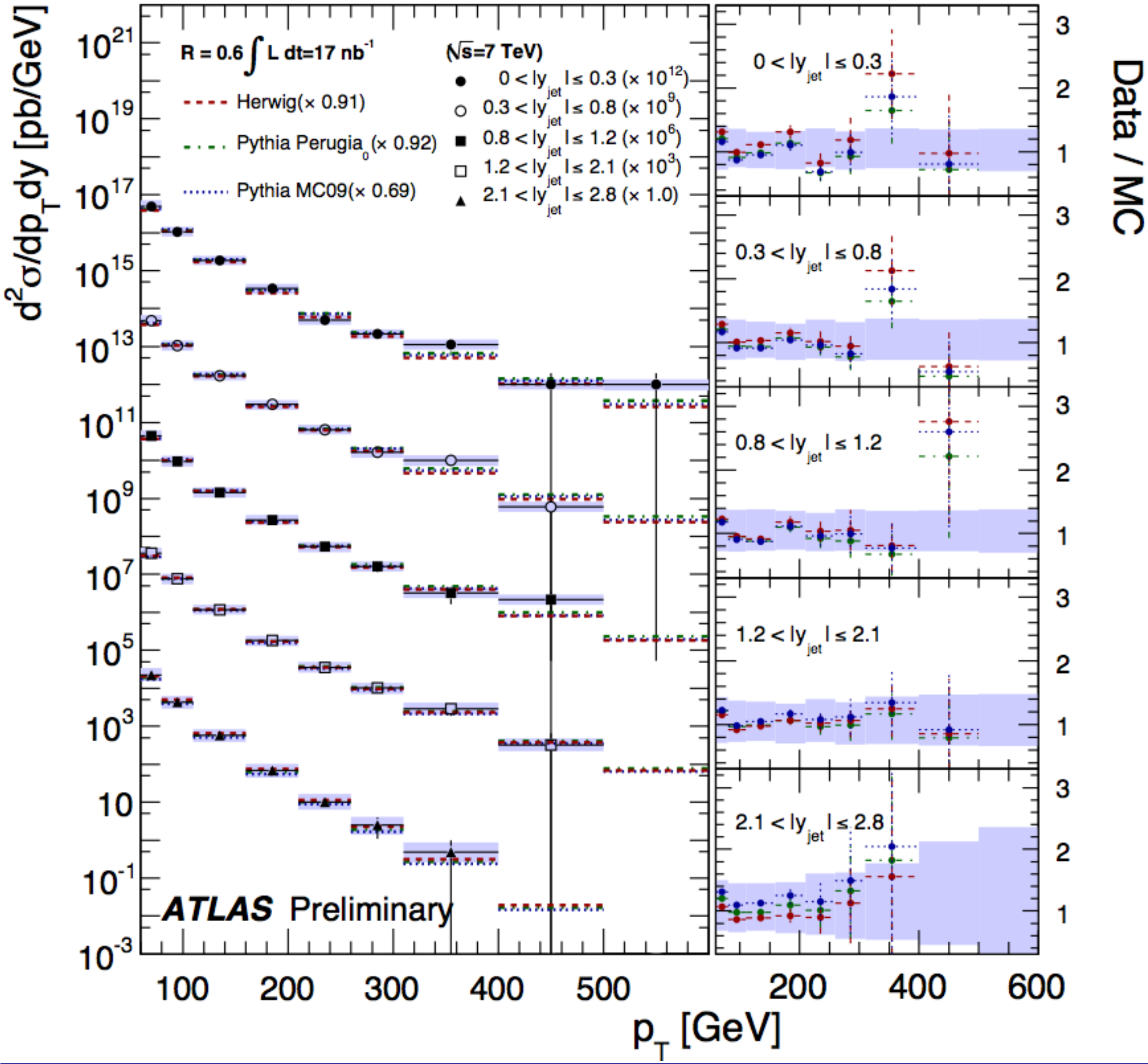
Jet Shapes are as Expected

- The jets look as expected: like collimated clusters of energy
  - Here *uncorrected* jet shapes with *no systematic errors*
- Good enough agreement to give us some confidence in our detector simulation and in the leading-log generators
  - Big problems with detector noise, noise modeling, or the behavior of the jet algorithm would show up here





Spectra Shapes in LL Generators



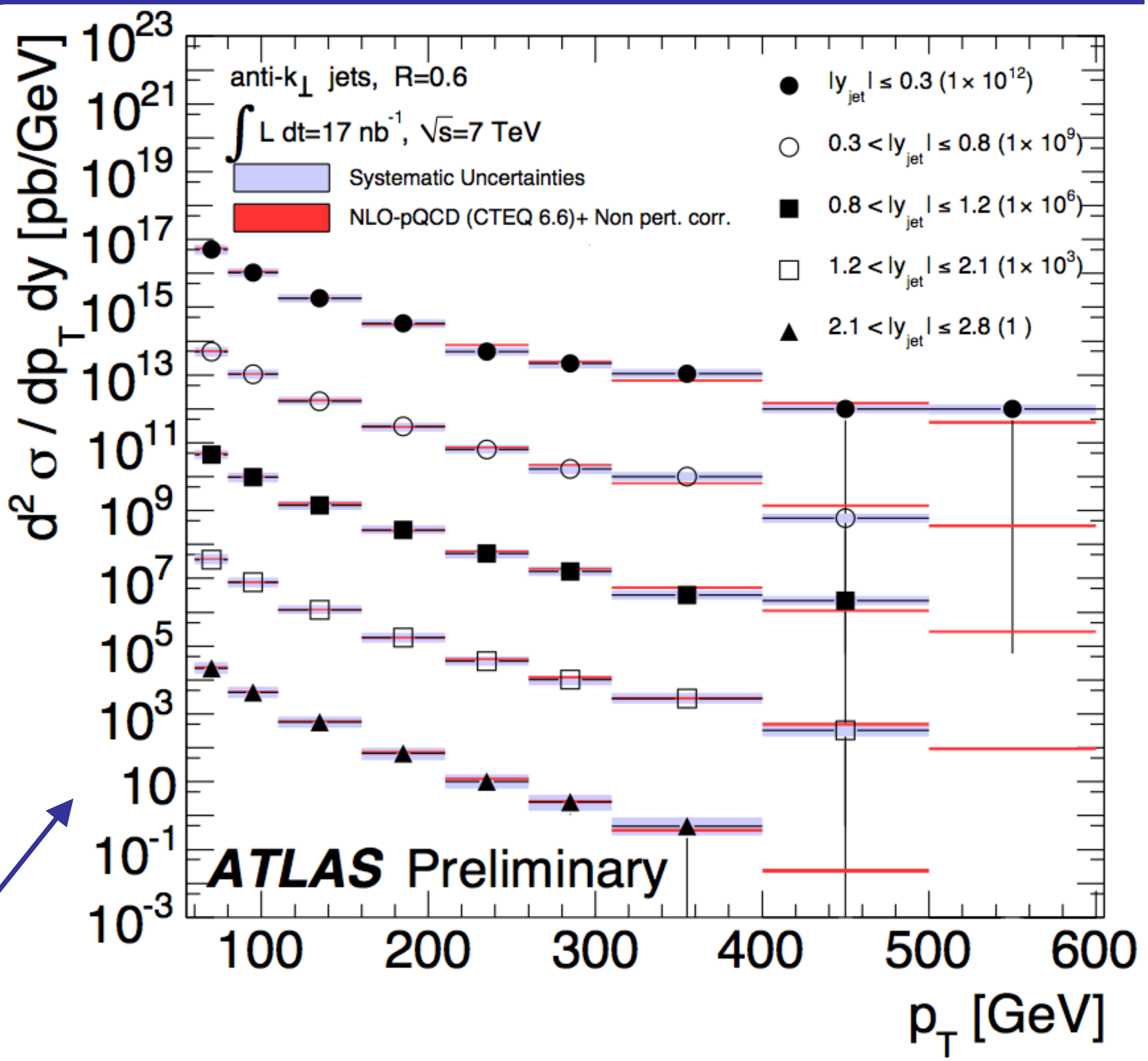
- Light blue band is total systematic uncertainty
  - Dominated by JES (+40/-30%)
- Samples all scaled to the number of jets
  - Only a test of the *shapes* of the distributions
- Agreement is quite good across all p_T and rapidity bins
- Uncertainties not yet small enough to say whether Pythia or Herwig is better

Corrections

- Calorimeter- to hadron-level with bin-by-bin corrections
  - Correct for calorimeter showering, out-of-cone effects, etc
  - Good agreement between data and MC in kinematics and trigger turn-on means bin-by-bin should be reasonable
  - Correction derived using ATLAS's MC09 Pythia tune
    - Herwig, Herwig++, Alpgen, and Sherpa all used for cross-checks
    - Used MSTW LO* PDFs - murky theoretical picture, so agreement between data and MC doesn't say anything about QCD directly
- Add non-perturbative corrections to NLO calculation
  - Start from NLOJet++ full NLO calculation
  - Bin-by-bin, with MC09 Pythia tune before and after hadronization and the addition of the underlying event to derive corrections
    - Cross checked using other generators
  - Calculation done using CTEQ 6.6 NLO PDFs
    - Not yet sensitive to the differences between PDFs
- Comparisons are all at the hadron-level
  - Hadron level here includes all leptons (incl. neutrinos)

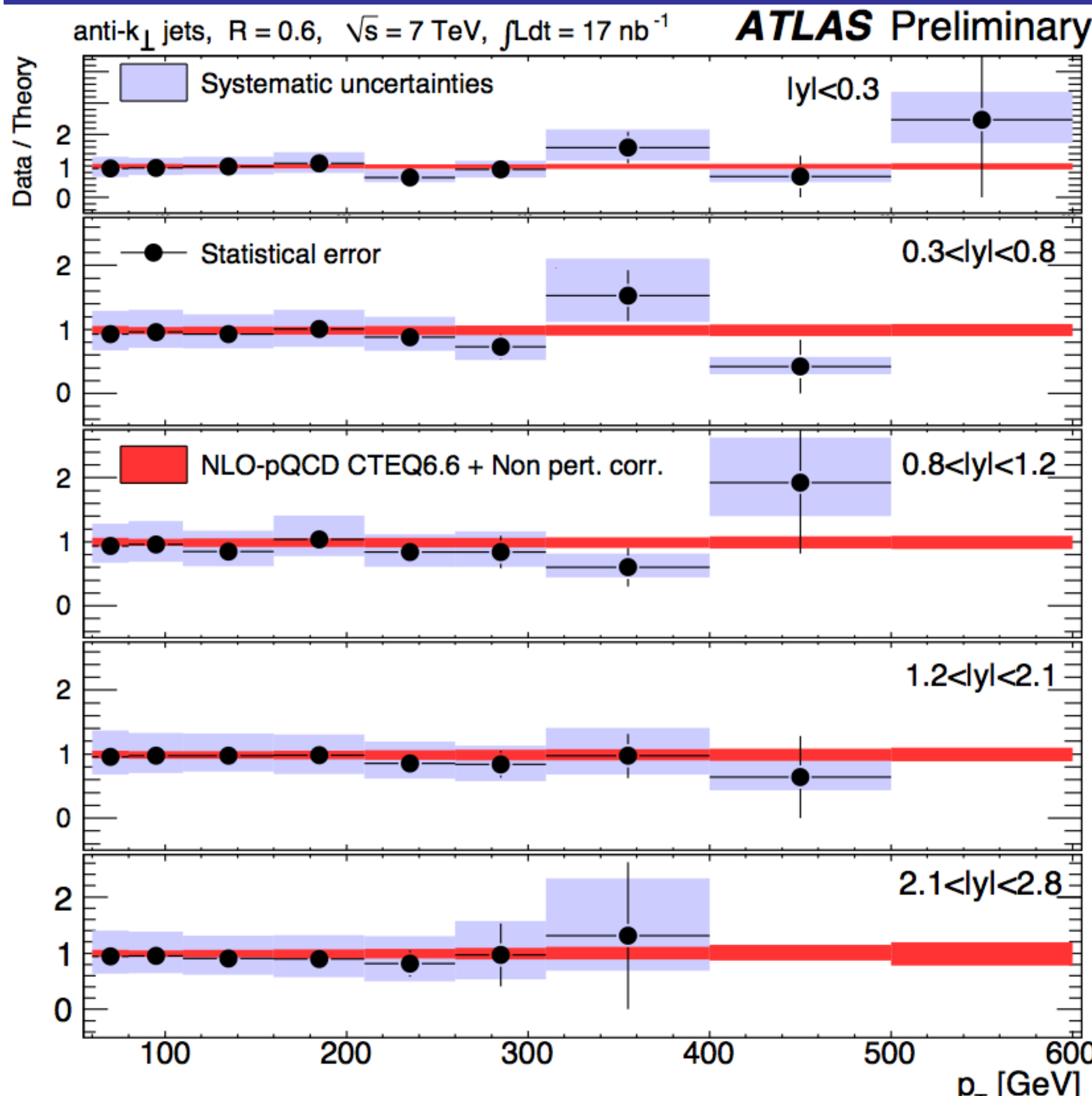
Cross-section in Jet p_T

- Comparison to NLO QCD - real test of *theory*
- Rapidity regions 3 and 4 include the calorimeter cracks
  - Agreement there means detector simulation is good
- Good agreement between data and calculation



Note: multiplicative offset by rapidity bin

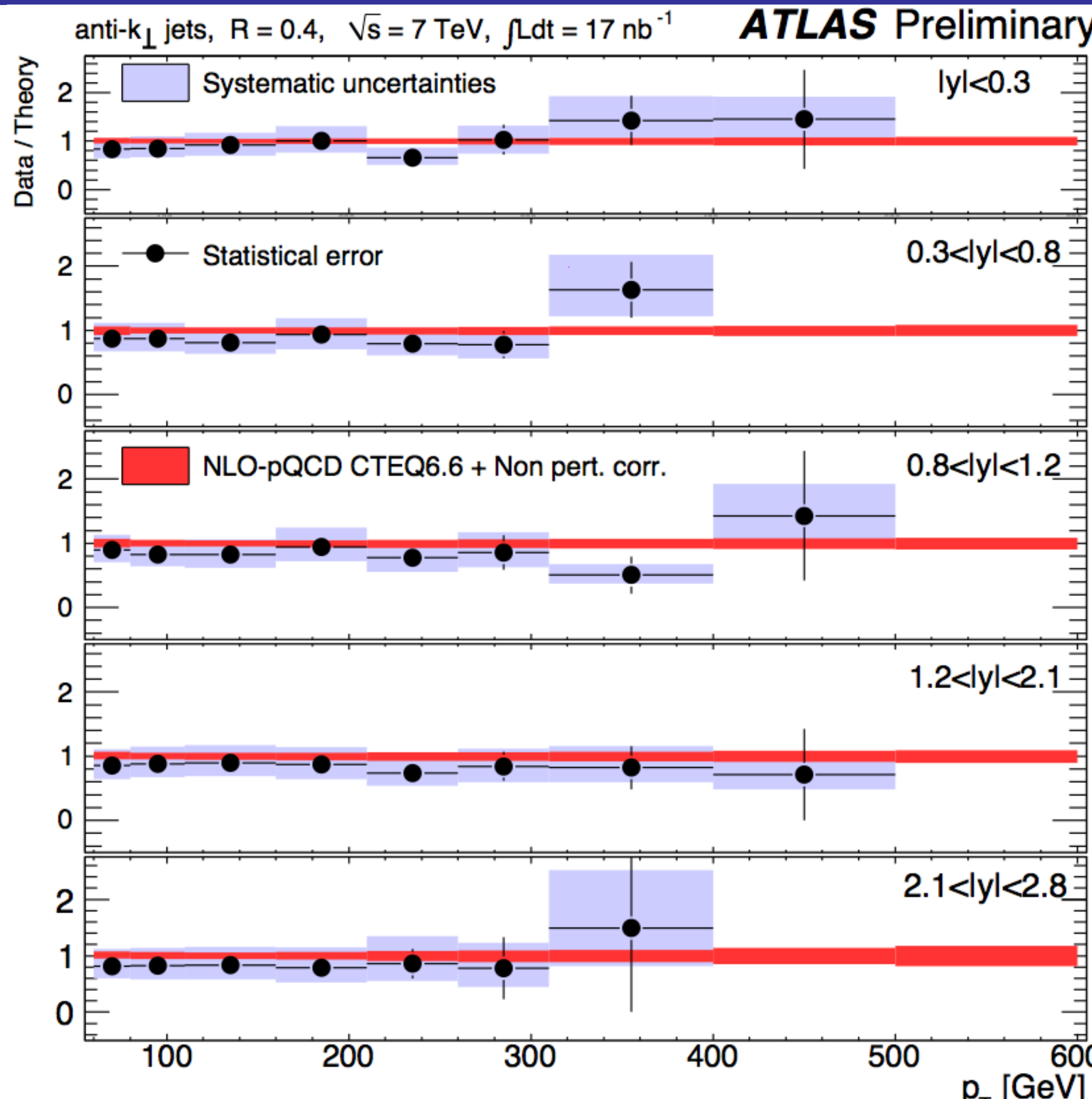
Ratio of Data to Theory



- Cross section falls by four orders of magnitude
- Rapidity regions 3 and 4 include the calorimeter cracks
- Everywhere ~ within the uncertainties
- Uncertainties will go down with re-tuning of PDFs and generators

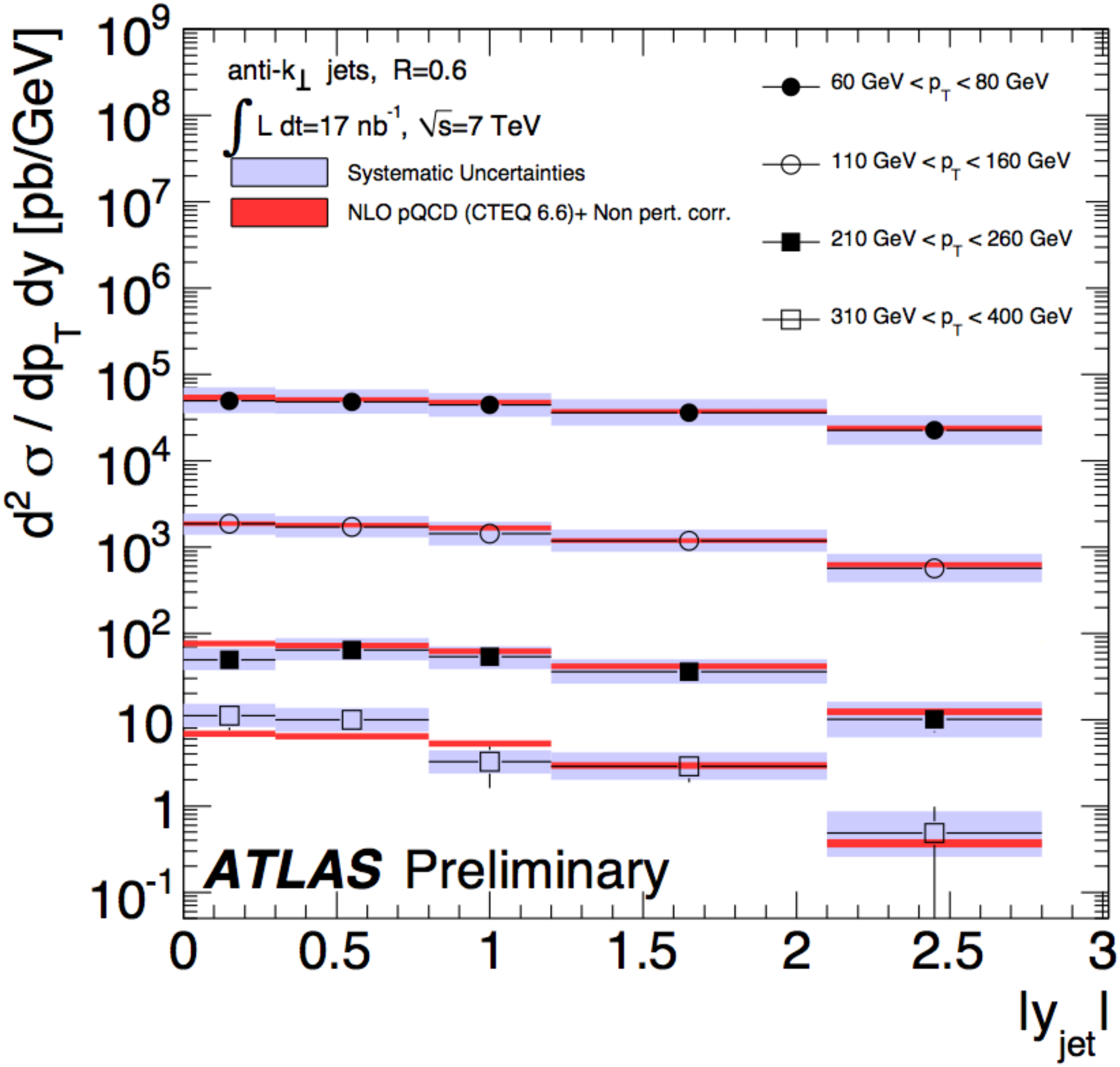
Cross Section in Jet p_T

- Results are consistent between R=0.4 and R=0.6
- More sizes will improve our understanding of hadronization and underlying event contributions
  - And, of course, different analyses want jets of different sizes…



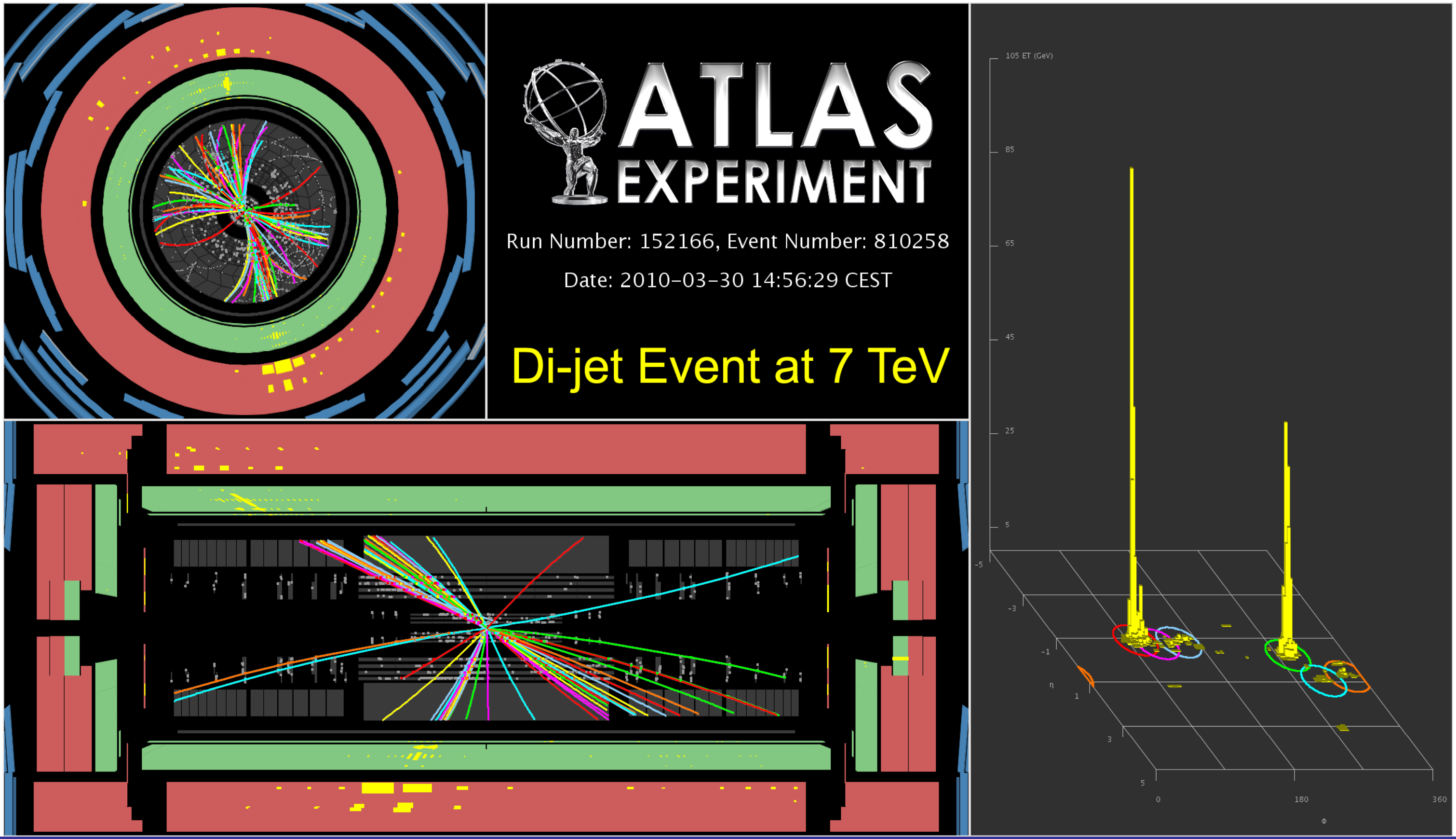
Cross Section in Jet Rapidity

- Cross section in rapidity shows same good agreement
- Calorimetry hermetic to y~4.9
  - For now, only the best-understood parts of the detector
- Will be able to cover a significant range in the future
  - Beginning to see the trends: decrease with rapidity, and high p_T jets more central



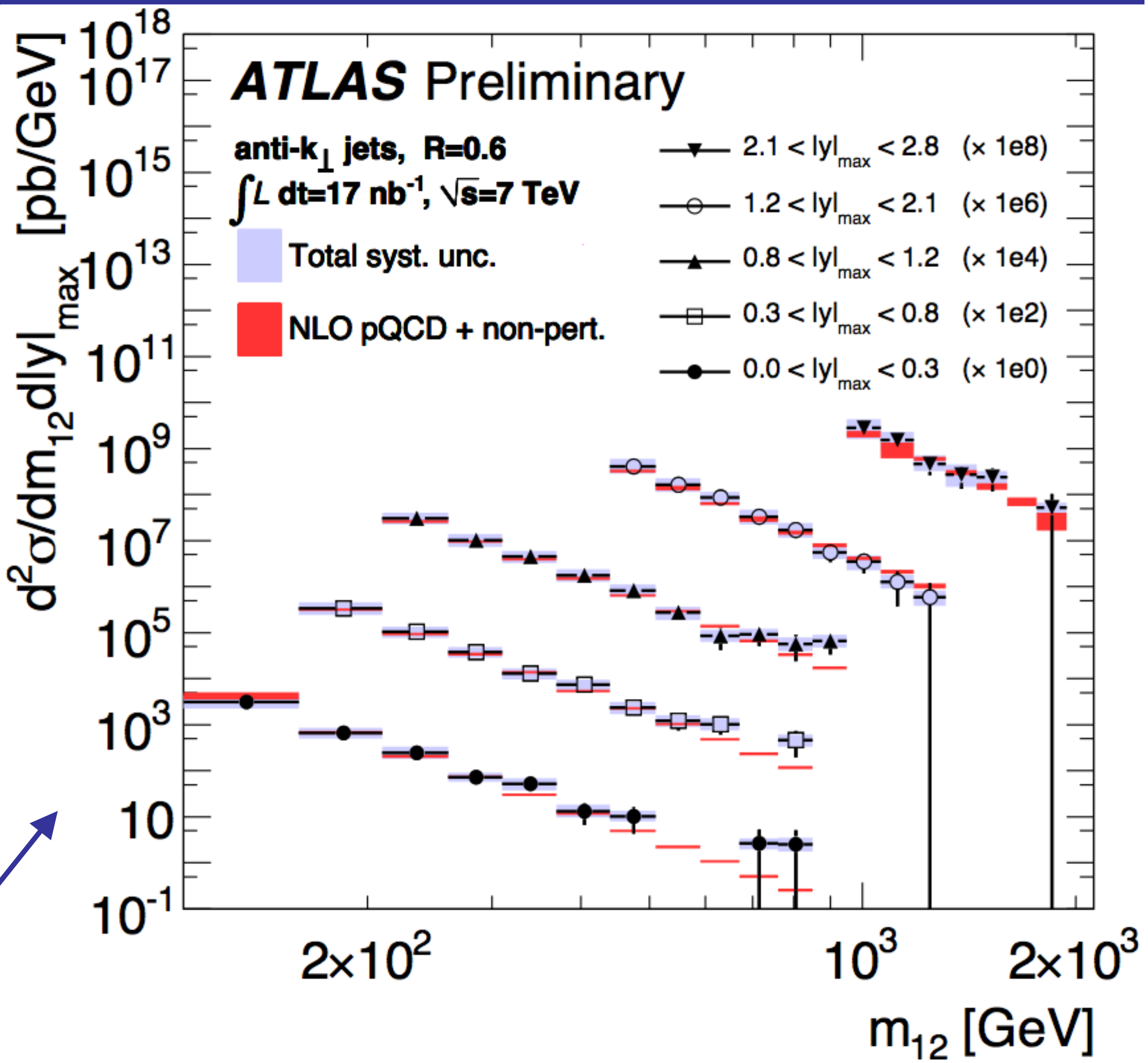
Di-jet Results As Well!

- Require a second jet in the event with p_T>30 GeV
  - All other cuts and event selection criteria remain the same
- Construct the di-jet mass cross section
  - Need to be a bit careful about where biases are not an issue



Di-jet Mass Cross-Section

- Binned by $|y|_{max} = \max(|y_1|, |y_2|)$
- Agreement between data and theory is good
- Already covering up to almost 2 TeV!!!
  - This is probably t-channel, and s-channel is most interesting for new physics…

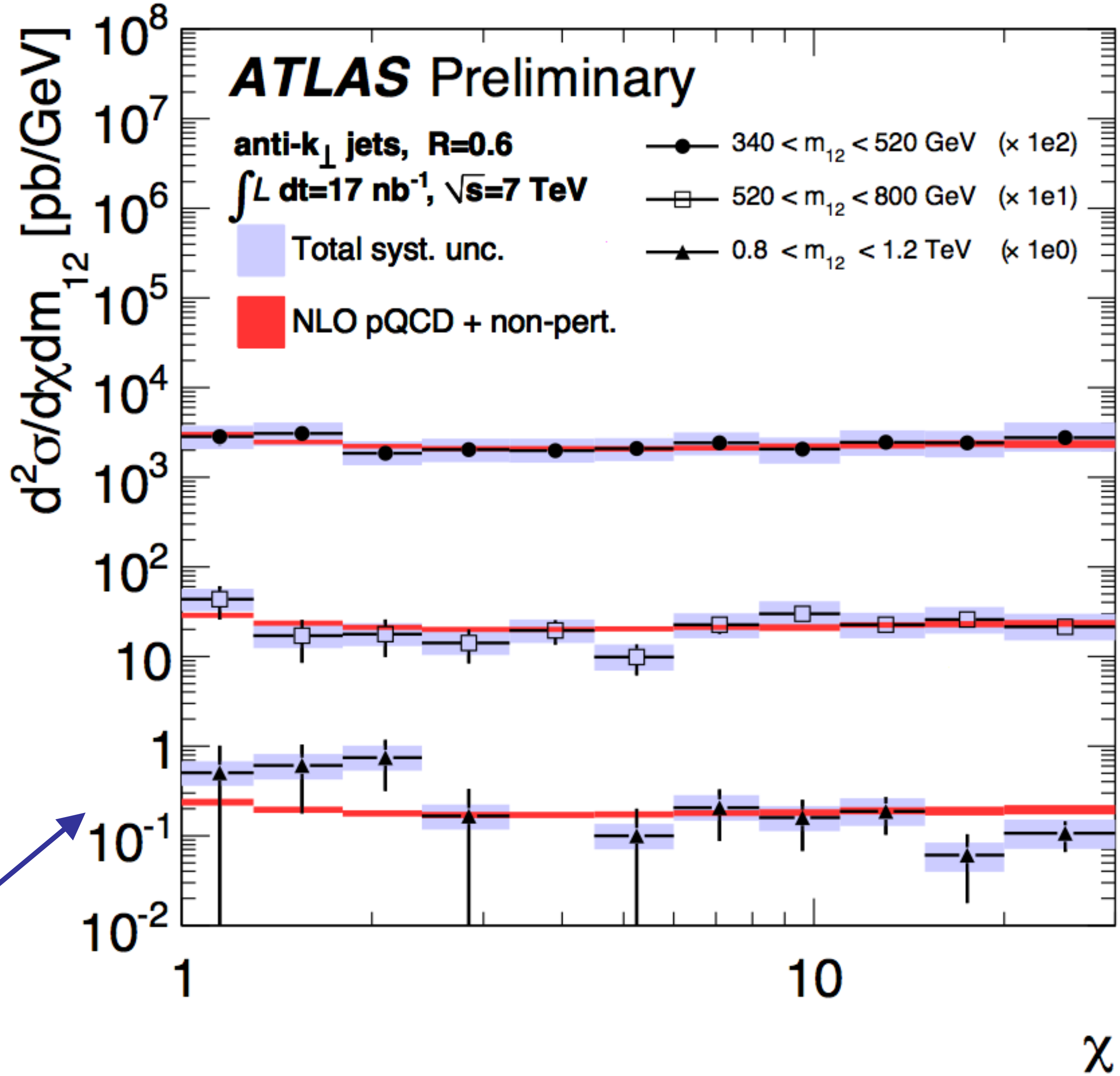


Note: multiplicative offset by rapidity bin

Di-jet Mass Cross-Section: χ

$$\chi = e^{|y_1 - y_2|}$$

- Standard Model expectation: flat
  - Resonance (or contact interaction) will show up here
- Good agreement with theory across a broad mass range



Note: multiplicative offset by mass bin

Summary and Conclusions

- First results for the inclusive jet cross-section are in
  - Agreement between data and LO+LL PS is quite good
  - Agreement between unfolded data and NLO calculation is good
    - Though still with large error bars
- First results for the di-jet mass cross section are in as well
  - Agreement between unfolded data and NLO calculation is good
  - Already have reach up to almost 2 TeV in dijet mass
    - Beginning to pass the Tevatron reach, but will take some time to surpass the Tevatron sensitivity to new physics
- Looking forward to re-tuned generators and PDFs
  - Perhaps soon we can start to collapse the uncertainties and really search for new physics!

Thank you! Any questions?