Prospects for inclusive jet cross-section measurements with early data at ATLAS

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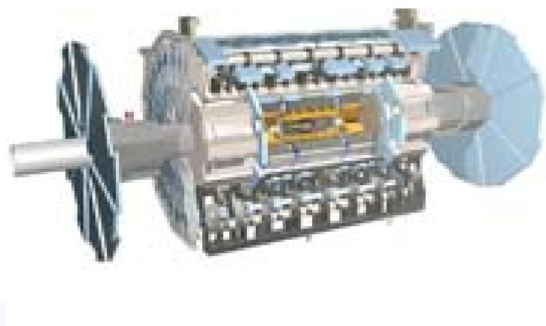
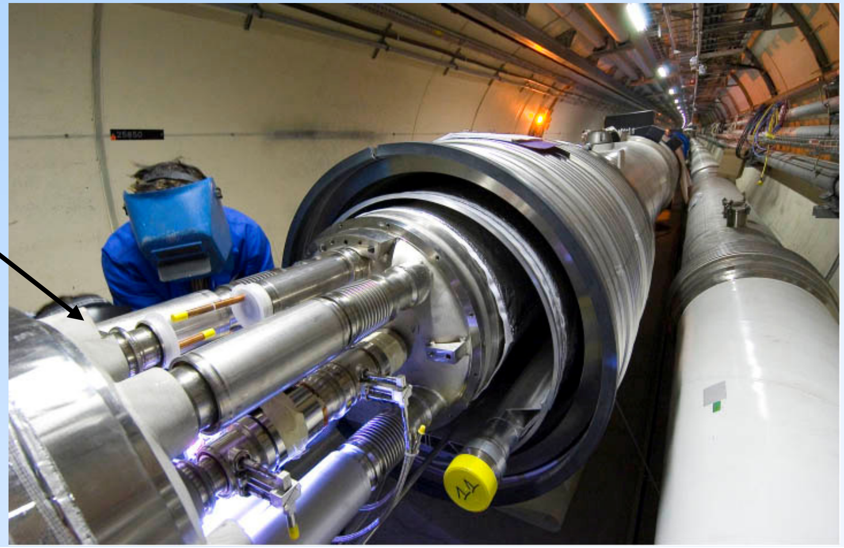


ATLAS and the LHC

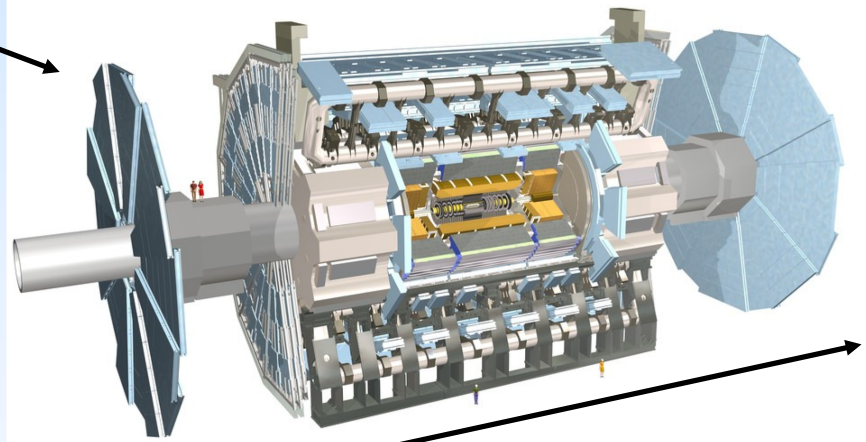
•The LHC (Large Hadron Collider) is a synchrotron 27km in circumference designed to collide protons at an energy of $\sqrt{s}$=14 TeV.



•Low lumi: $2 \times 10^{33} cm^{-2}s^{-1}$ ~ $20 fb^{-1}/yr$

•High lumi: $10^{34} cm^{-2}s^{-1}$ ~ $100 fb^{-1}/yr$

•ATLAS (A Toroidal Lhc ApparatuS) is a general purpose detector designed for the LHC.



•Calorimetry up to $|\eta|<5$

•Jet Energy Resolution: $50\%/\sqrt{E}+3\%$ (central)

Inclusive Jets

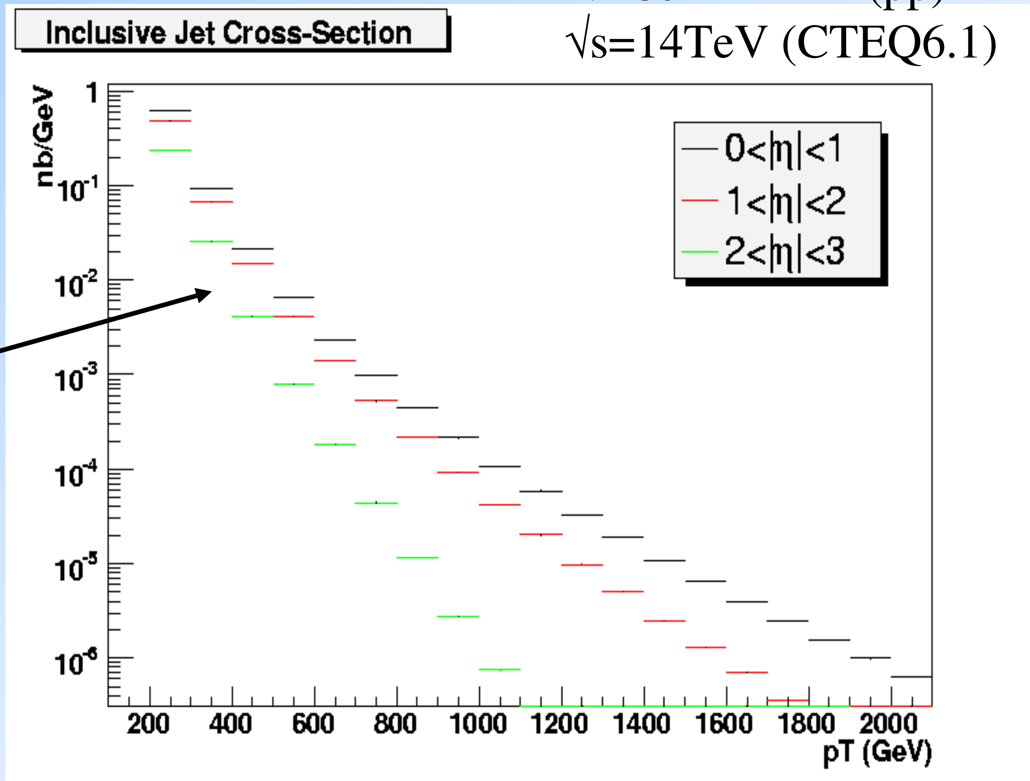
NLOJET++ [1] (pp)
$\sqrt{s}$=14TeV (CTEQ6.1)

•Concerns all events containing jets.

•Characterised by a steeply falling cross-section with jet pT.

•Measurement provides a test of QCD (running of α_s)

•Measurement can also be used to look for new physics (e.g. quark compositeness).



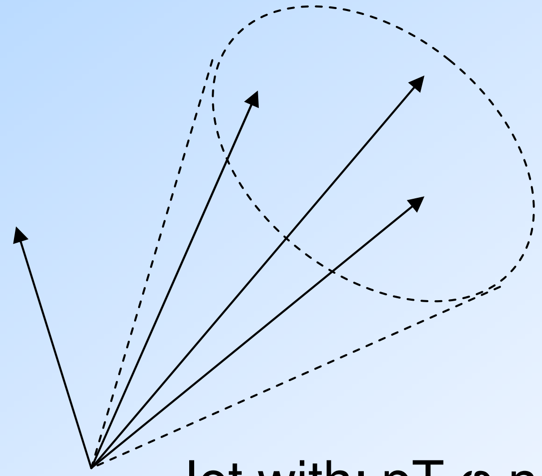
•Understanding errors on jets is important as these can fake/mask new physics.

Offline Reconstruction of Jets

•Need to use a jet algorithm to create jet objects from calorimeter towers (clusters)

•A jet algorithm must decide which particles (hits) belong to a jet and provide a prescription for summing their momenta.

•Ideally a jet algorithm should be infra-red safe, be theoretically well understood, easy to calibrate and fast.



Jet Algorithms

•*Cone Algorithm*: Iterates a circle of fixed radius in η-φ space by calculating an energy-weighted centroid of particles within circle.

•*kT Algorithm*: Progressively merges particles of similar momentum. (FastKT[2] now used extensively)

•*Optimal Jet Finder*: Uses global event properties [3].

Calibration of Jets

•Jets need to be calibrated for detector effects in order to give the best possible estimate of the true deposited energy.

Experimental Errors include:

- •Non-linear response of calorimeter (e.g.non-compensation,uniformity etc.)
- •Non-detected energy from muons and neutrinos in jets, out-of-cone.
- •Underlying event contributions.

After calibration systematic errors remain on:

- •The knowledge of the jet energy resolution.
- •The knowledge of the jet energy scale.

Methods of Calibration

Standard Approach (jet→layer→cell)

•Take jets at the EM scale from algorithms and apply weights to constituents at cell or sampling level to bring jet to hadronic scale.

•The weights can depend on a constituents location (φ,η), sampling and energy.

•Sampling method: Apply different weights to the EM and hadronic samplings.

•H1, Pisa: Apply weights to calorimeter cells according to energy density / jet energy-cell energy

Alternate Approach (cell->layer->jet)

•Local hadronic calibration aims to identify EM and Hadronic clusters based on topological properties before jet-algorithm is applied.

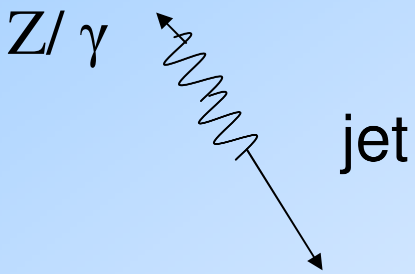
Calibration Benchmarks

- Need benchmarks with which the calibration can be tuned.

- Typically the electromagnetic scale is known to greater accuracy than the hadronic one.

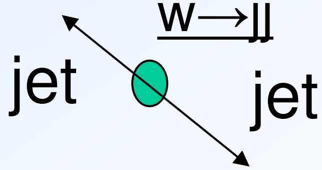
- Many benchmarks try to connect the hadronic to the EM scale:

Z/γ + jets



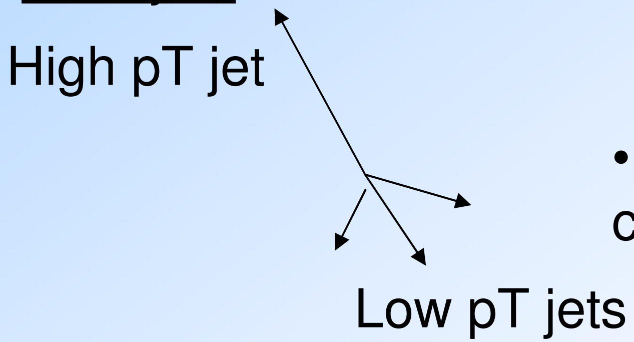
- Demand pT balance between Z/ γ and the recoiling jet. Good for calibrating jets with pT < 500GeV.

W→jj



- Look for decay of W→jj and demand $M_{jj}=M_W$

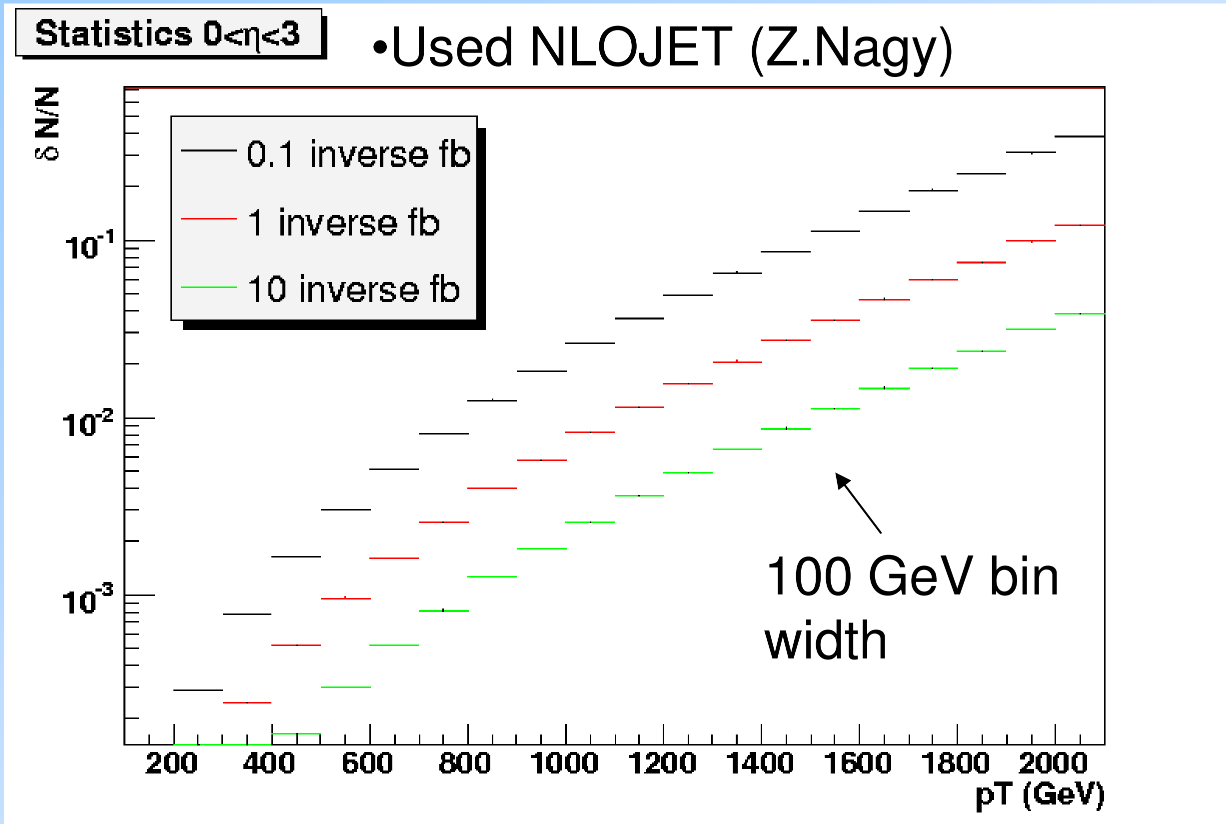
Multi-jets



- Look for pT balance in multi-jet events to calibrate high pT jets against many low pT jets.

Experimental Errors

•The principal sources of experimental error on the inclusive jet cross-section arise from statistics and the knowledge of the JES.

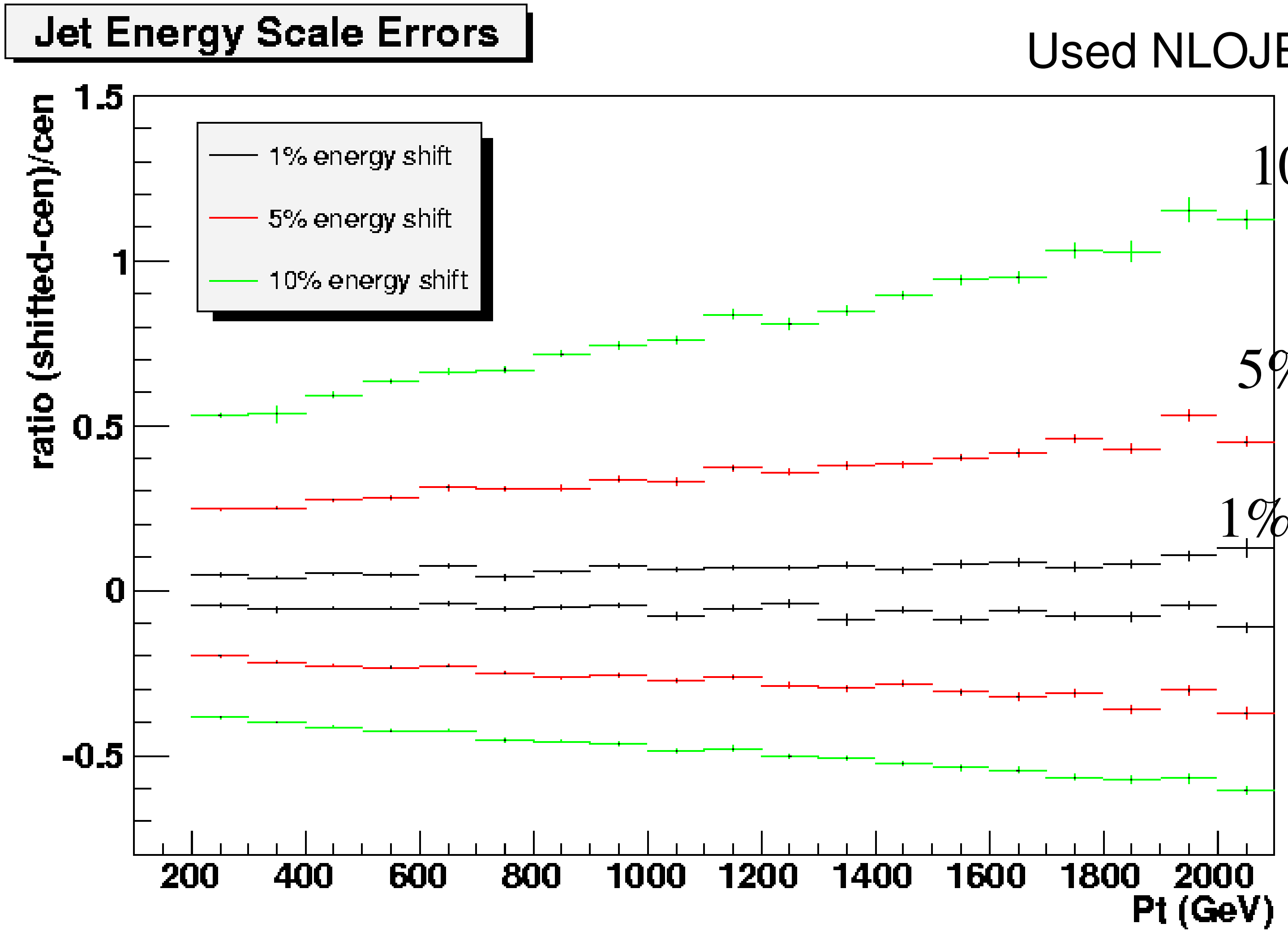


•Used NLOJET (Z.Nagy)

•Estimate statistical errors as √N/N, where N=number of jets in a bin.

•For a jet of pT=1TeV statistical errors are ~1% for 0<η<3 at $1fb^{-1}$.

Experimental Errors



Used NLOJET.

For a jet with pT=1TeV:

1% error on jet energy -> 6% on σ

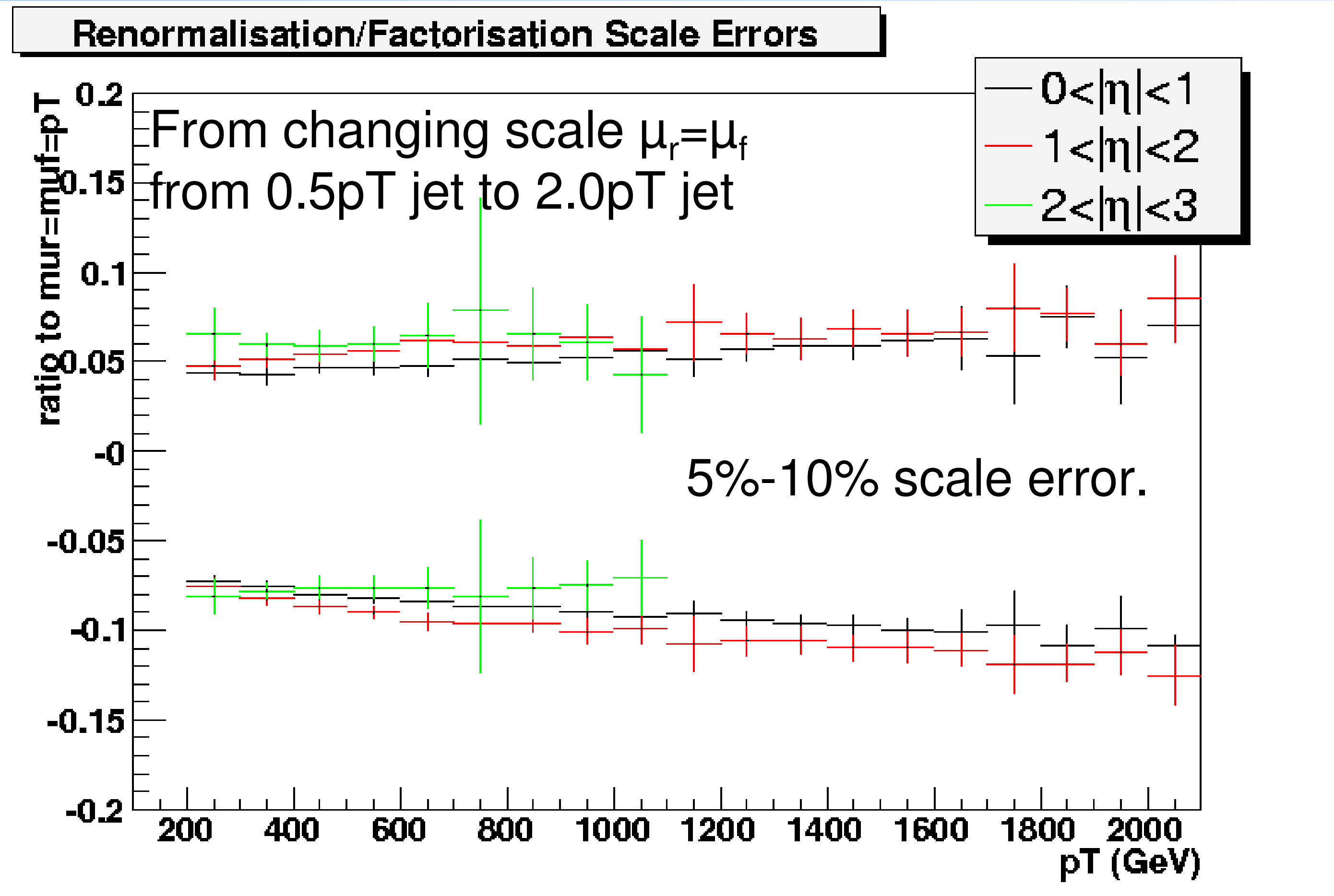
5% error on jet energy -> 30% on σ

10% error on jet energy -> 70% on σ

Theoretical Errors

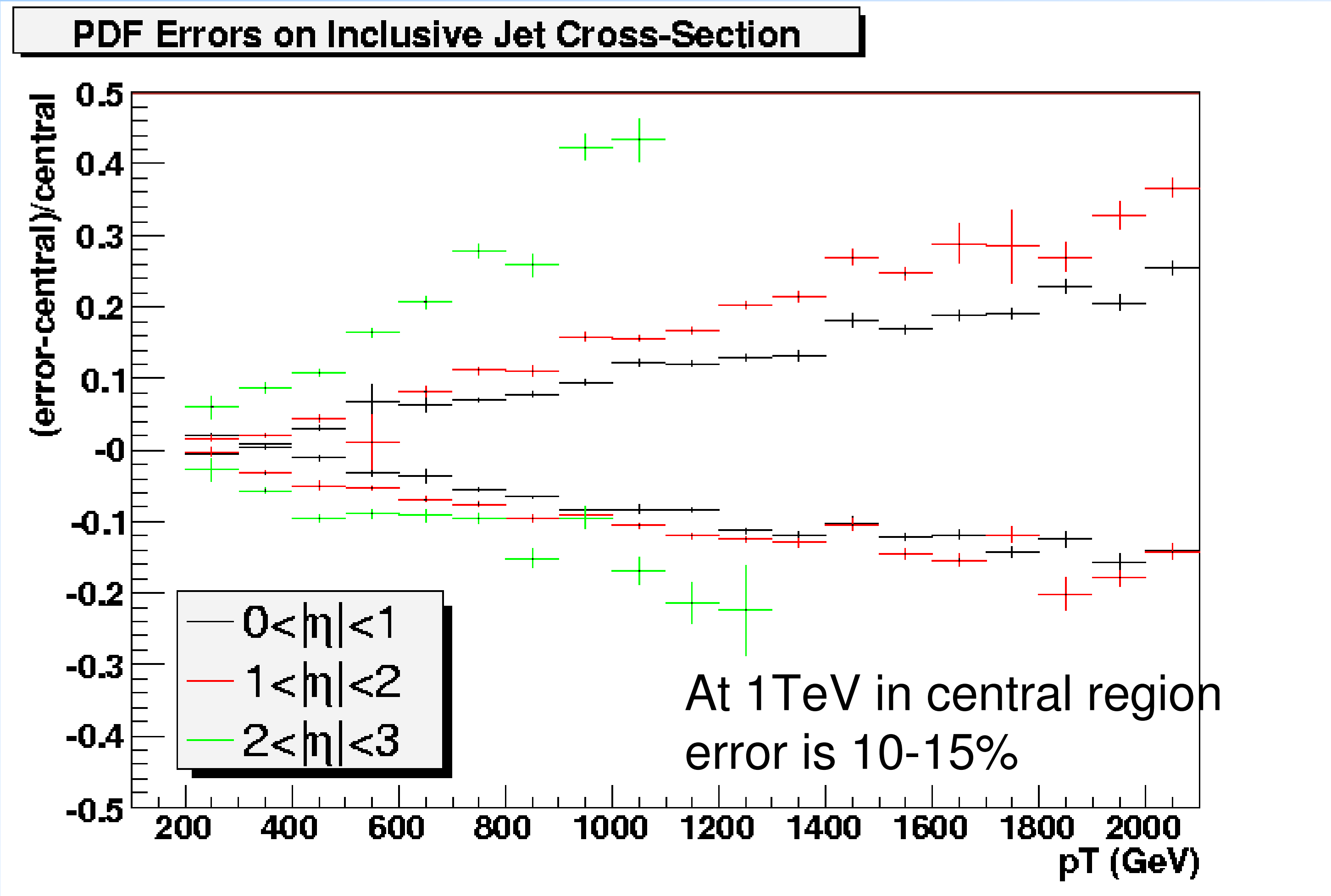
•NLO QCD cross-sections can be calculated to compare with the experimental results.

•There are errors on the theoretical prediction due to PDFs and the finite order of the calculation (renormalisation and factorisation scales).



Theoretical Errors

•High pT PDF errors dominated by the high x-gluon. Estimates below from CTEQ6.1 error sets 29 and 30 compared to best fit (NLOJET).



Analysis – Constraining High x-Gluon

•PDF errors originating from the high x-gluon dominate the theoretical uncertainty at high pT.

•PDF errors can fake physics signals, such as compositeness (CDF).

•PDF's are generally constrained from DIS data (e.g. HERA), collider data is traditionally difficult to put into global fits due to need to recalculate NLO cross-section for a change in the PDF.

•Work has been carried out on integration grid methods to separate PDFs from the NLO cross-section calculation to allow introduction of collider data into PDF fits.

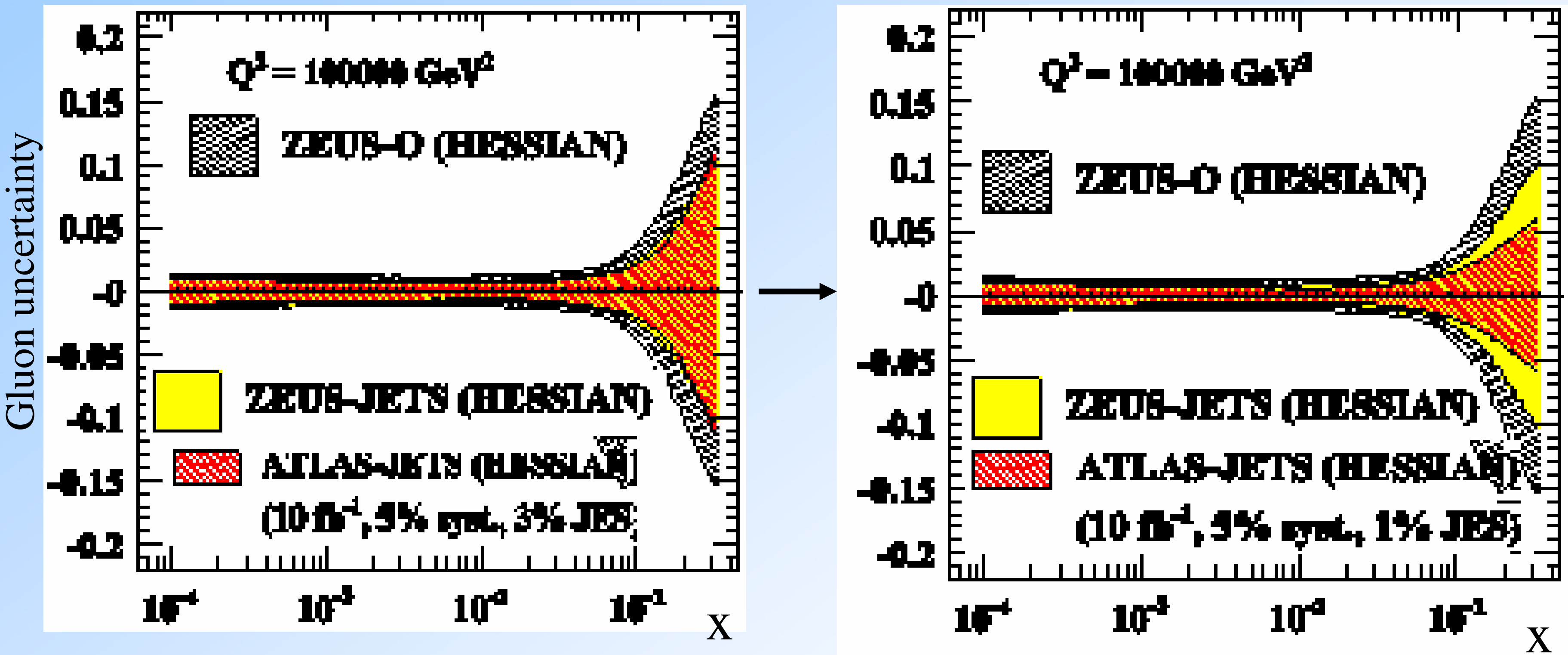
•NLOGRID (T.Carli, G.Salam, F.Siegert et al hep-ph/0510324)

•FASTNLO (T. Kluge, K. Rabbertz, M. Wobisch hep-ph/0609285)

Analysis – Constraining High x-Gluon

•Effect of adding simulated ATLAS collider data to gluon uncertainty in a global PDF fit (NLOGRID) Fits by Claire Gwenlan:

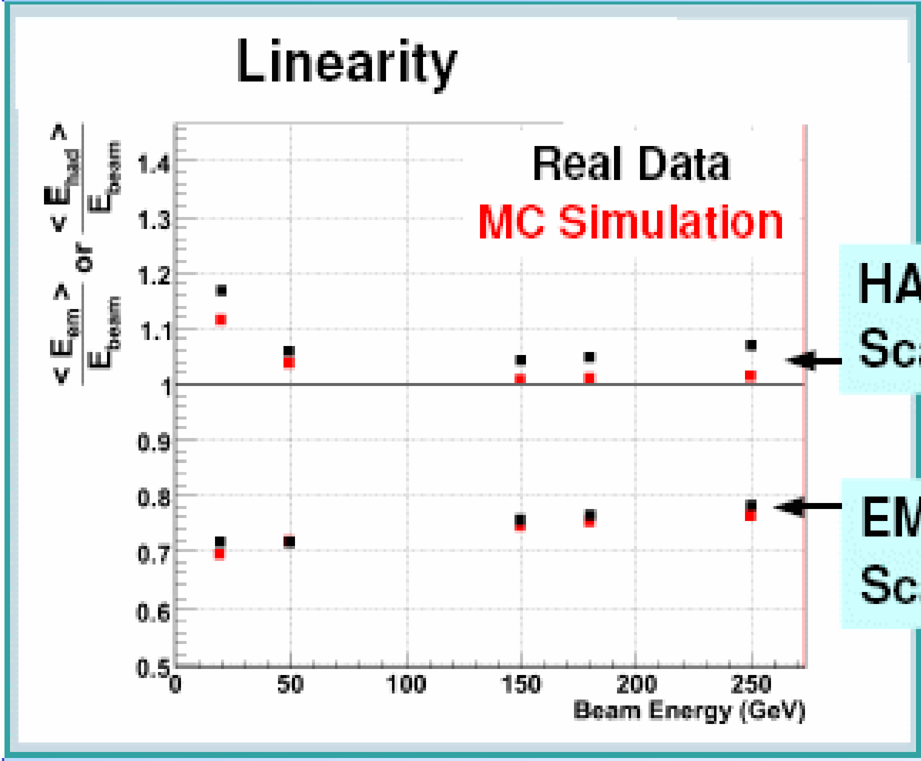
Reducing JES from 3% to 1%

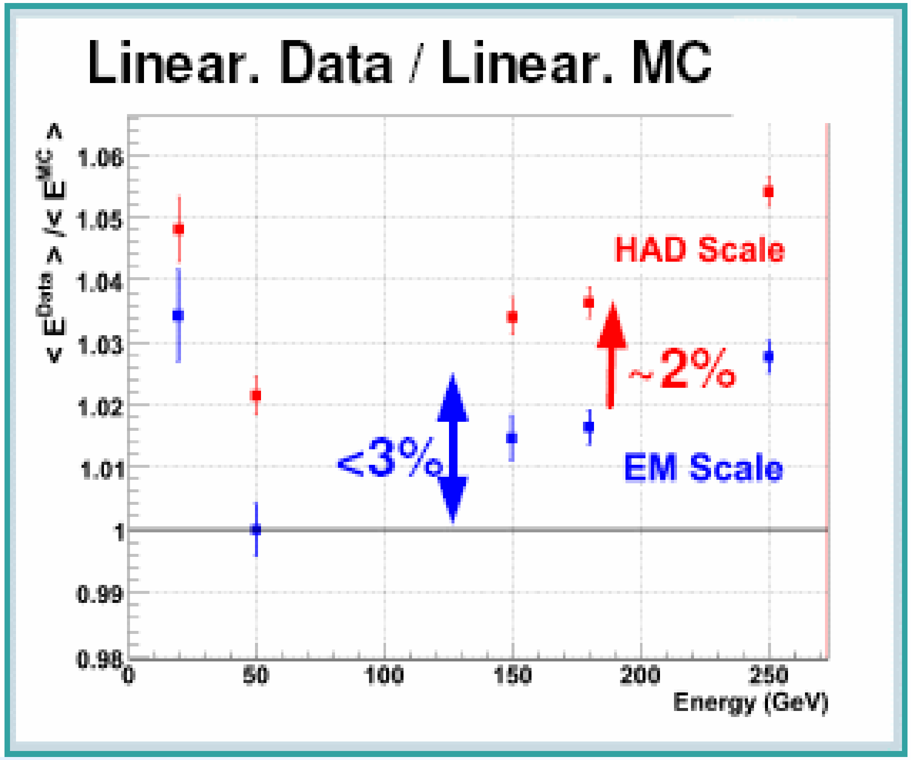


•A very good control (1%) of the Jet Energy Scale is needed in order to constrain PDFs using collider data.

First Estimate of JES uncertainty at LHC Start-Up

•Apply Jet Calibration to Combined test beam data for pions (MC and data)





Plots by Paolo Francavilla (INFN-Pisa)

•**At EM scale**: Data and MC disagree by ~ 3%

•**At Hadronic scale**: Data and MC 4-5%

Summary

- The inclusive jet cross-section at ATLAS offers an opportunity to provide tests of QCD and to look for new physics e.g. compositeness.
- A good control of the errors both theoretical and experimental are vital to have confidence in any results.
- Experimental errors are dominated by the Jet Energy Scale (JES).
- Theoretical errors at high pT are dominated by uncertainty on the high-x gluon PDF.
- Integration grids may allow for the inclusion of collider data into global PDF fits which will be worthwhile if the JES can be controlled to within ~1%.

References

[1] Z. Nagy - Phys Rev Lett 88 (2002) 122003

[2] M.Cacciari,G.Salam - Phys Lett B 641:57-61 (2006)

[3] D Yu Grigoriev et al -Phys Rev Lett 91, 061801