

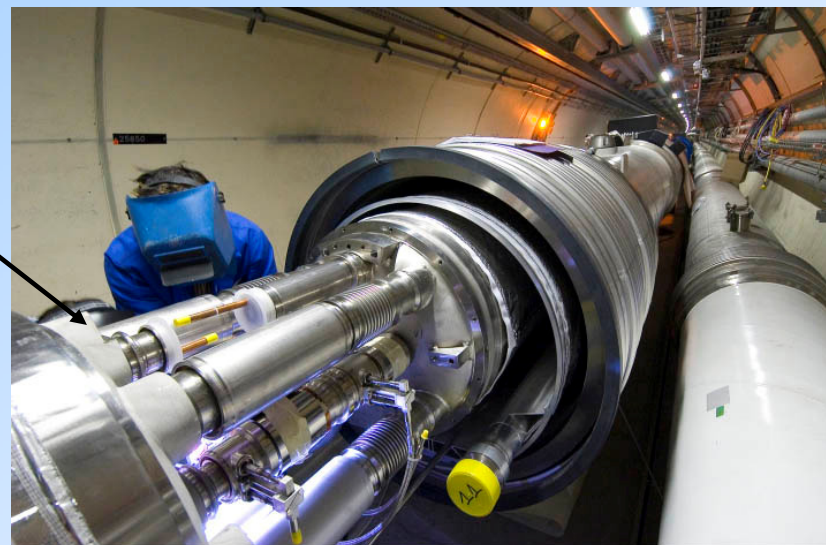
Prospects for inclusive jet cross-section measurements with early data at ATLAS

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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.



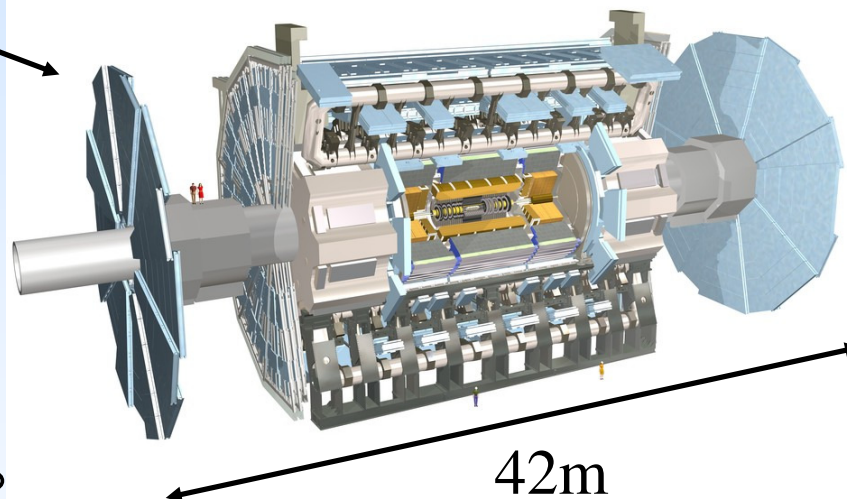
- Low lumi: $2 \times 10^{33} \text{cm}^{-2} \text{s}^{-1} \sim 20 \text{fb}^{-1}/\text{yr}$

- High lumi: $10^{34} \text{cm}^{-2} \text{s}^{-1} \sim 100 \text{fb}^{-1}/\text{yr}$

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

- Calorimetry up to $|\eta| < 5$

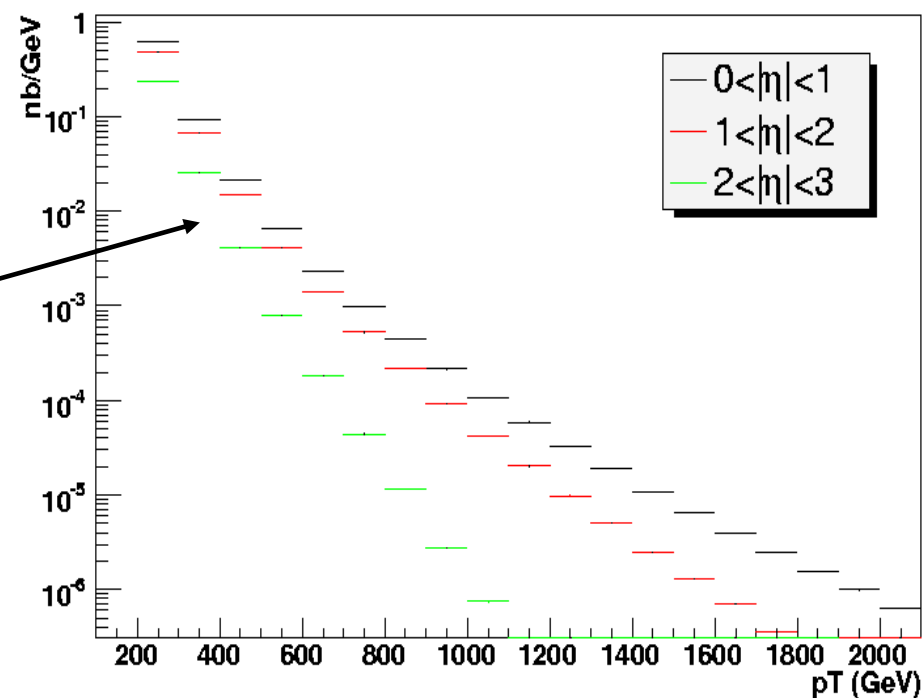
- Jet Energy Resolution: $50\%/\sqrt{E} + 3\%$ (central)



Inclusive Jets

- Concerns all events containing jets.
- Characterised by a steeply falling cross-section with jet p_T .
- Measurement provides a test of QCD (running of α_s)
- Measurement can also be used to look for new physics (e.g. quark compositeness).

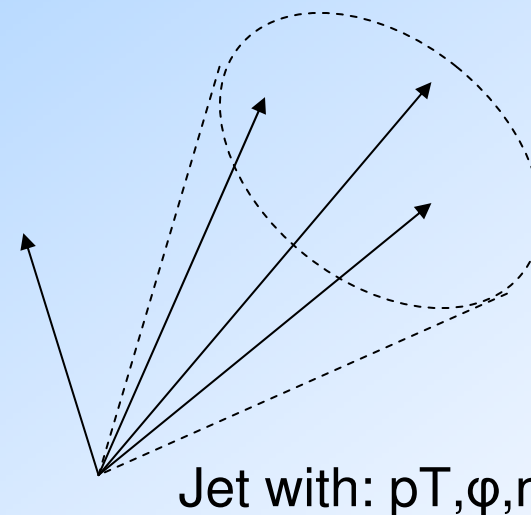
Inclusive Jet Cross-Section



- 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.
- k_T 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

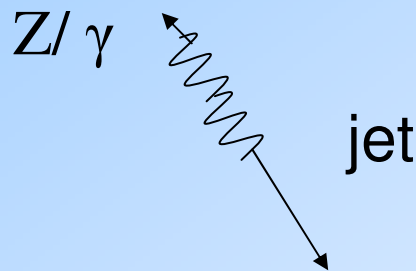
Alternate Approach (cell->layer->jet)

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

Calibration Benchmarks

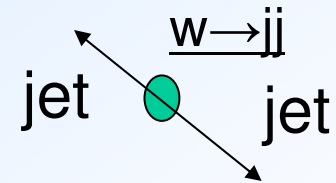
- Need benchmarks with which the calibration can be tuned.
- Typically the electromagnetic scale is known to greater accuracy than the hadronic one.
- Many benchmarks try to connect the hadronic to the EM scale:

Z/ γ + jets

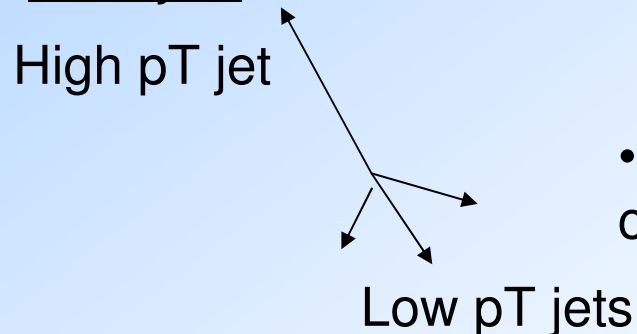


- Demand pT balance between Z/ γ and the recoiling jet. Good for calibrating jets with pT < 500 GeV.

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



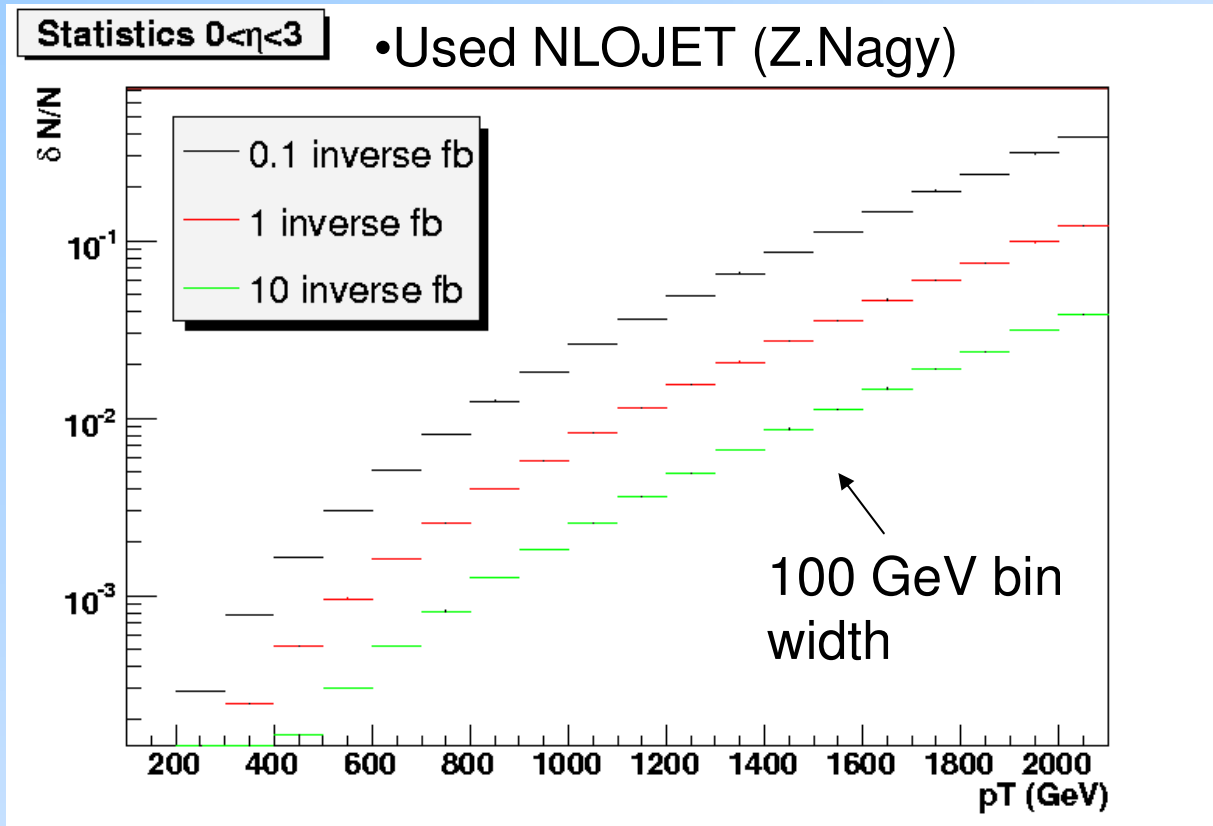
Multi-jets



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

Experimental Errors

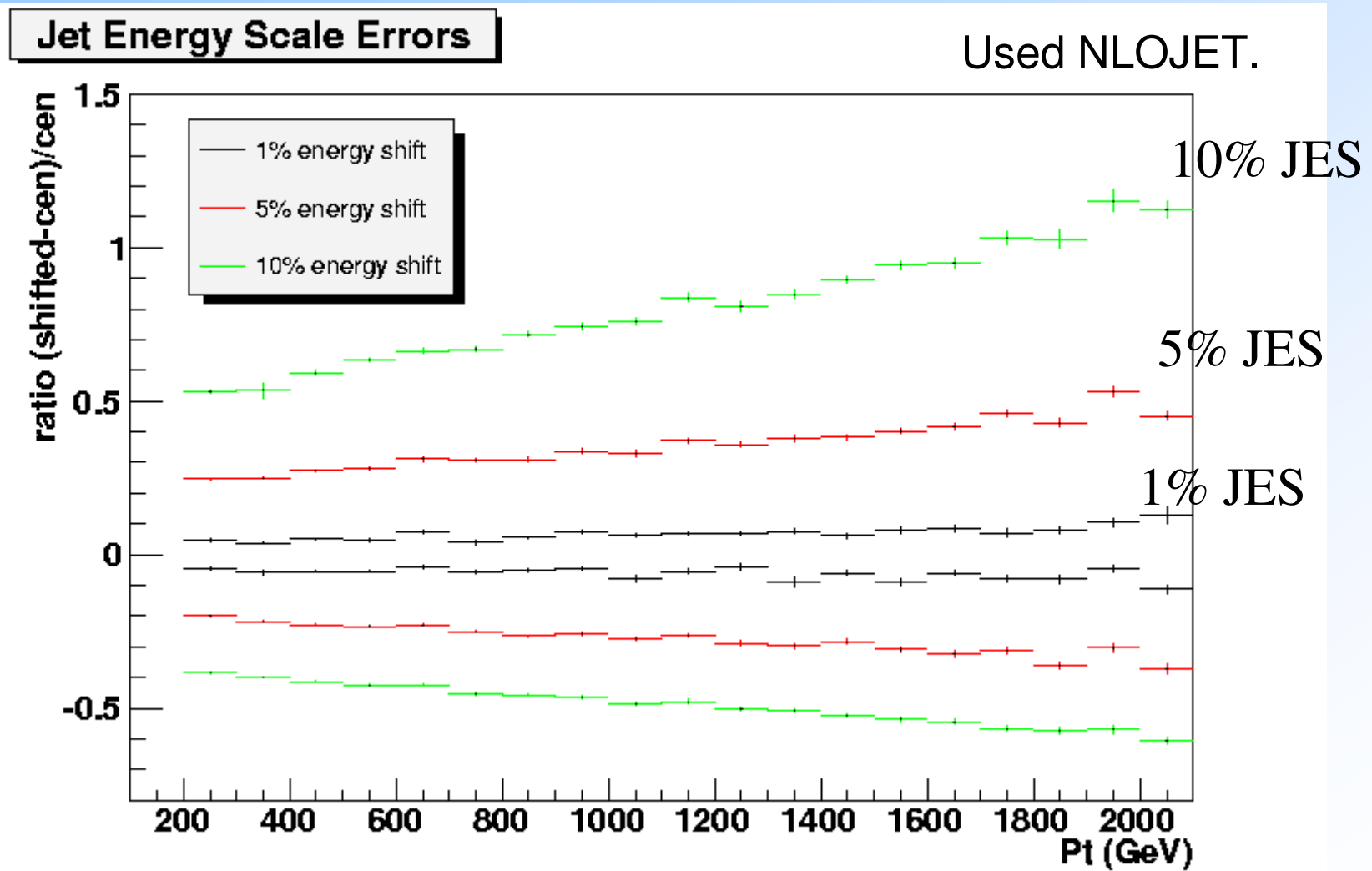
- The principal sources of experimental error on the inclusive jet cross-section arise from statistics and the knowledge of the JES.



- Estimate statistical errors as $\sqrt{N/N}$, where N=number of jets in a bin.

- For a jet of $pT=1\text{TeV}$ statistical errors are $\sim 1\%$ for $0 < \eta < 3$ at 1fb^{-1} .

Experimental Errors



For a jet with $p_T=1\text{TeV}$:

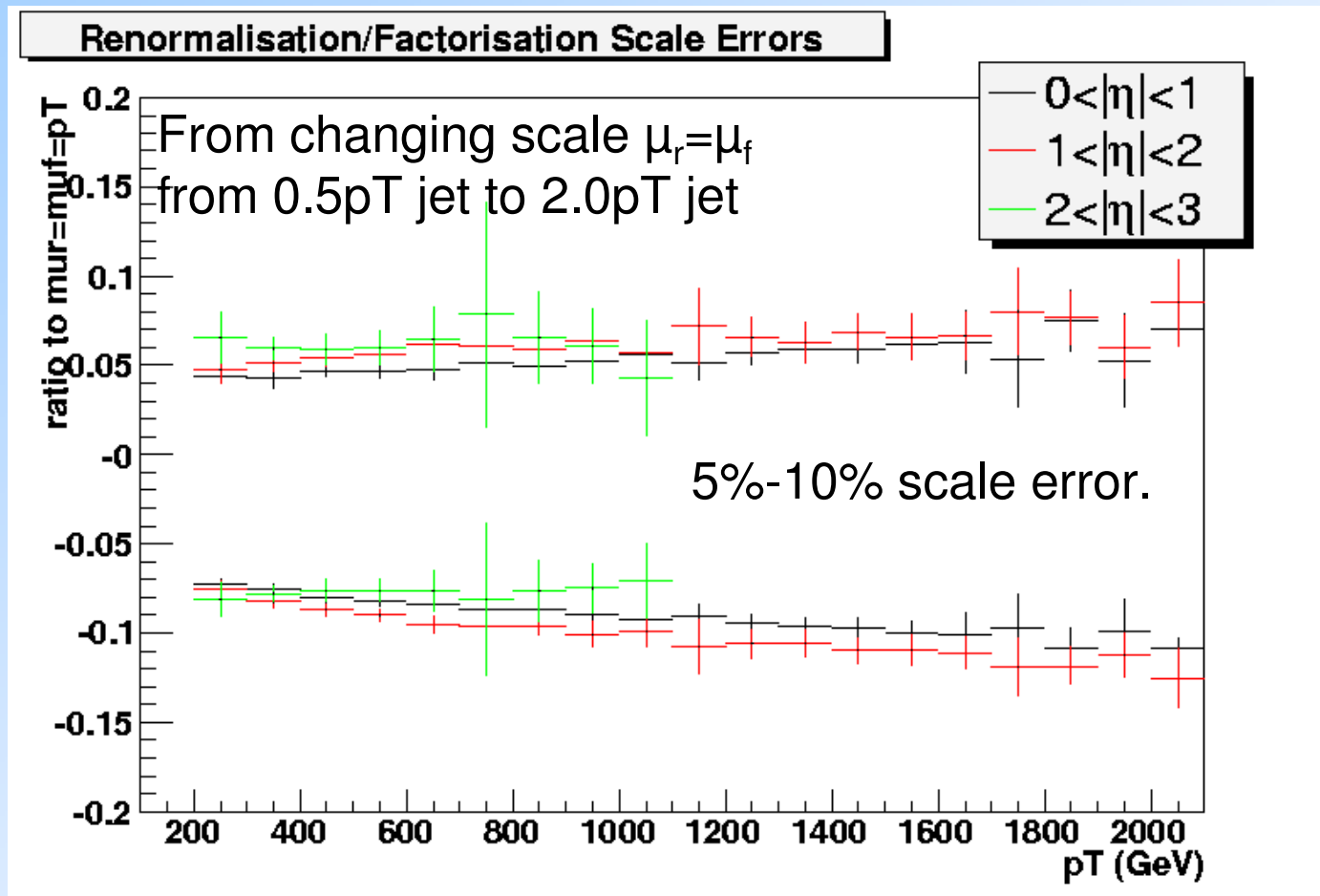
1% error on jet energy \rightarrow 6% on σ

5% error on jet energy \rightarrow 30% on σ

10% error on jet energy \rightarrow 70% on σ

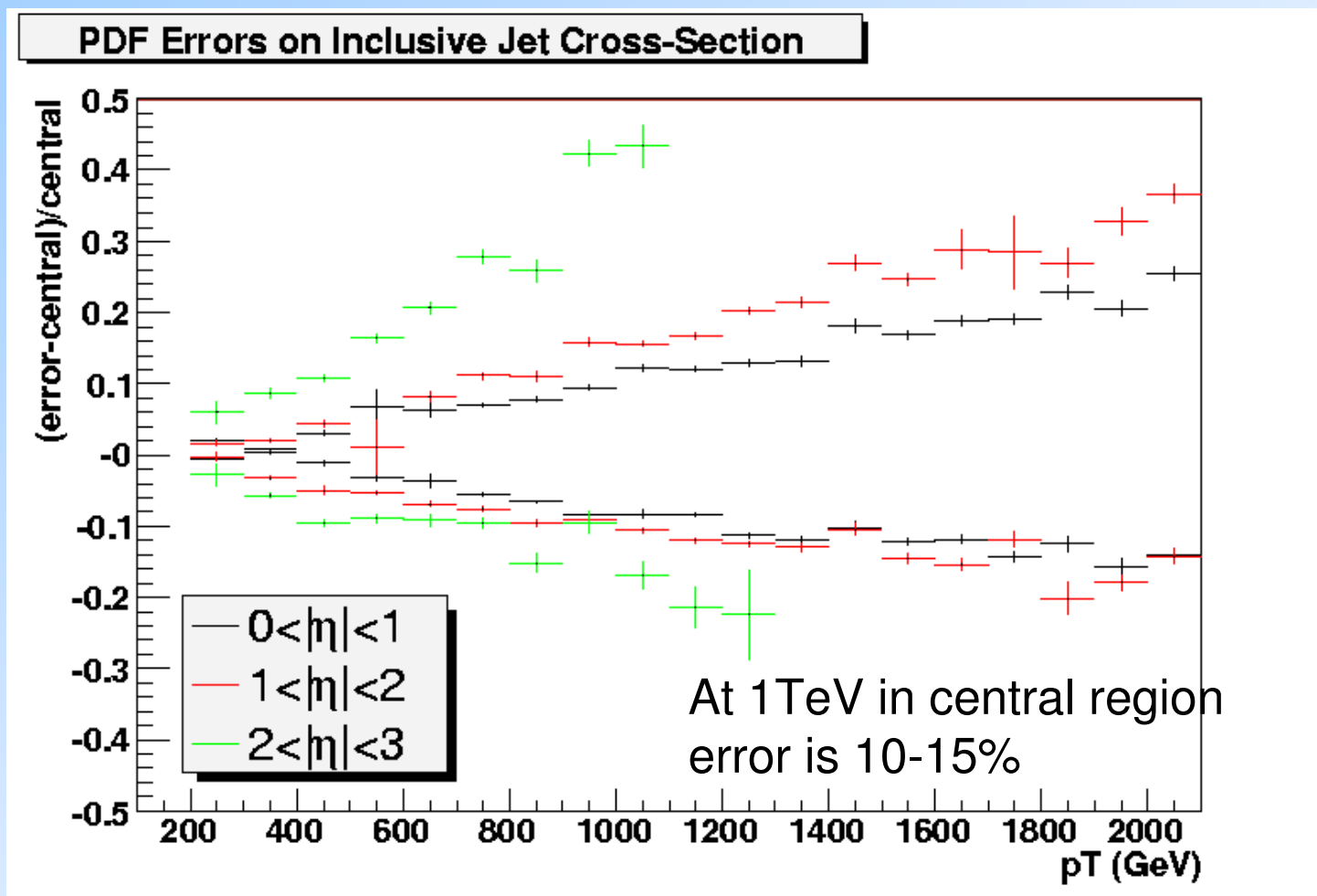
Theoretical Errors

- 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 p_T 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

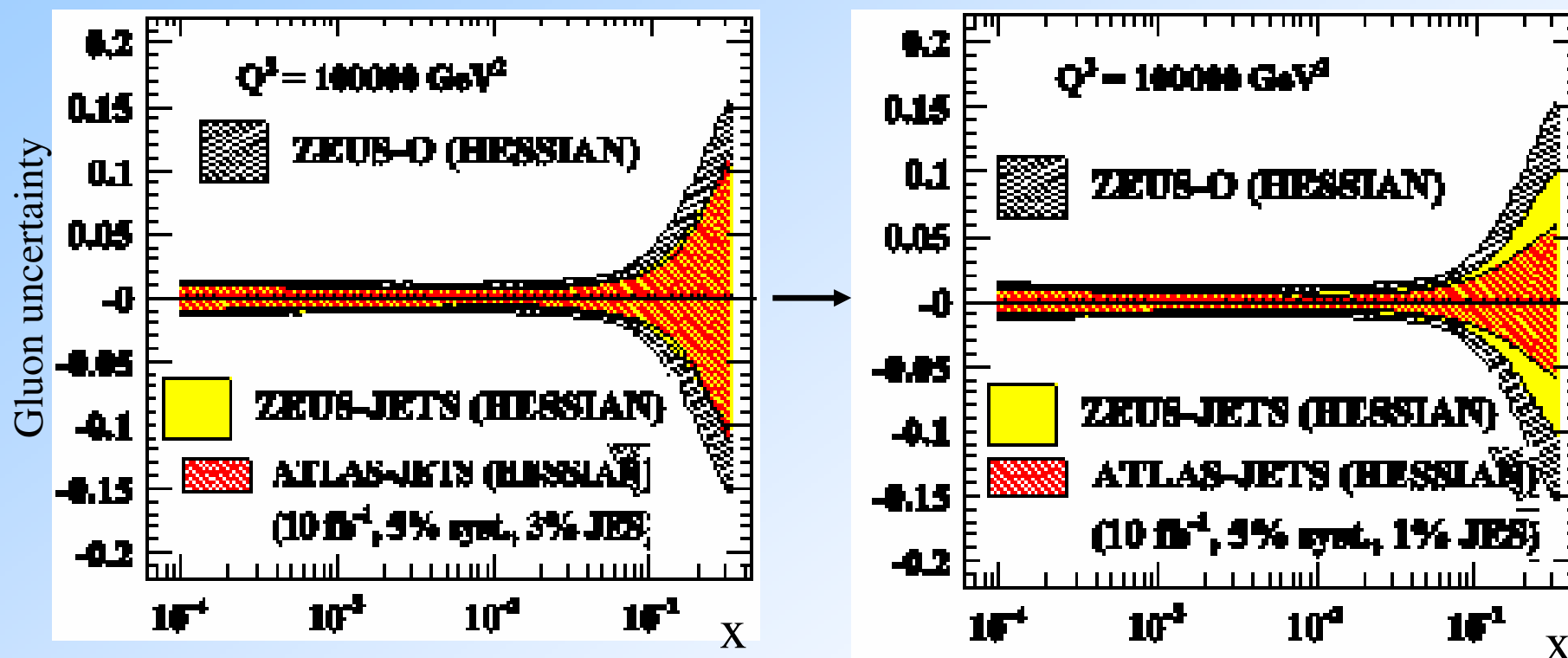
- PDF errors originating from the high x-gluon dominate the theoretical uncertainty at high pT.
- PDF errors can fake physics signals, such as compositeness (CDF).
- PDF's are generally constrained from DIS data (e.g. HERA), collider data is traditionally difficult to put into global fits due to need 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:

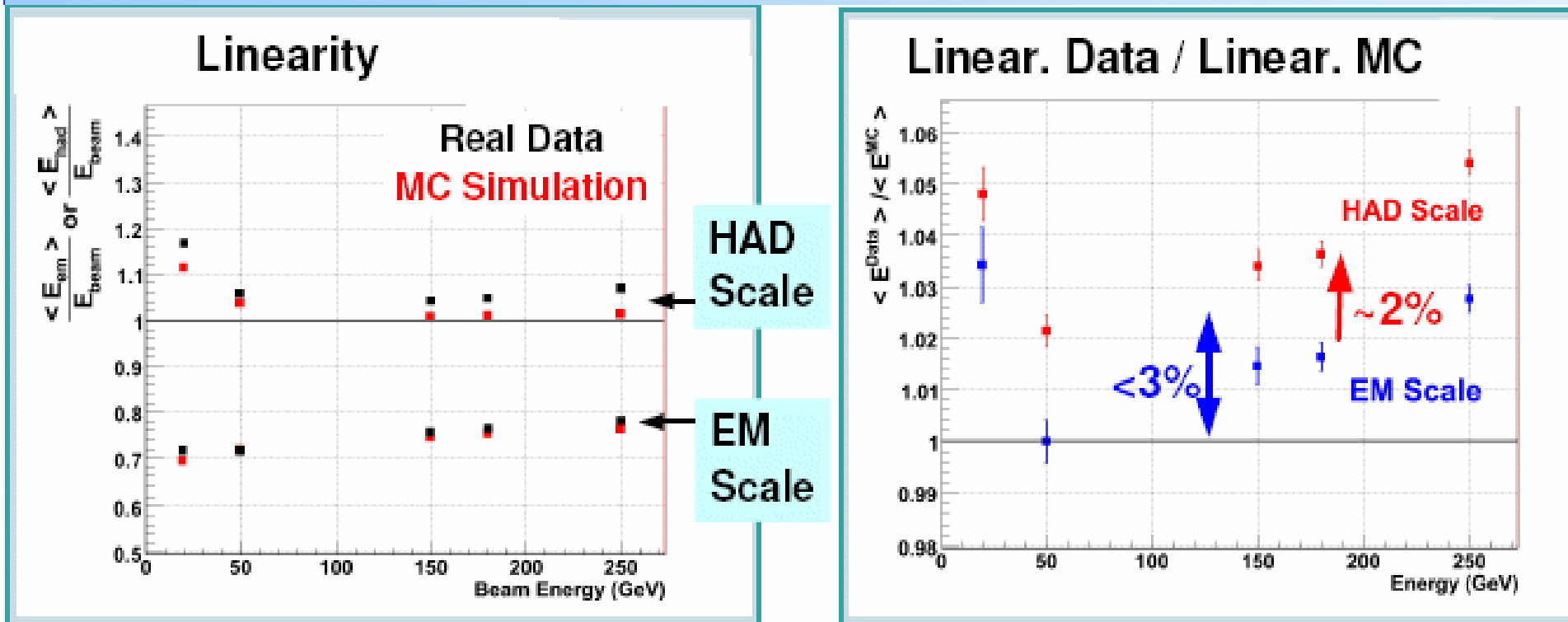
Reducing JES from 3% to 1%



- 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 $\sim 3\%$
- **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 p_T 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 $\sim 1\%$.

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

