Jet Measurements at ATLAS (and their errors)

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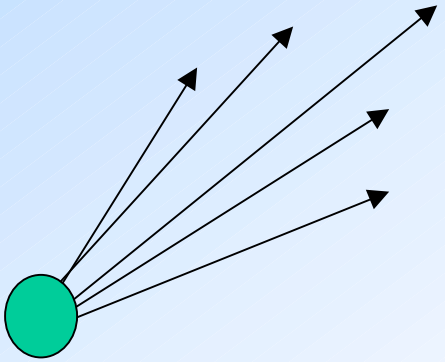
Background……..

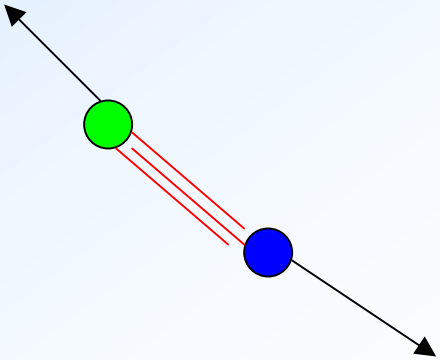
What's a jet?

A jet consists of a cluster of particles (mostly hadrons) travelling in approximately the same direction .



How are jets made?

In an 'event' a parton with colour charge can be scattered from a hadron. QCD confinement leads to particle creation. (The same effect can occur in particle decay).



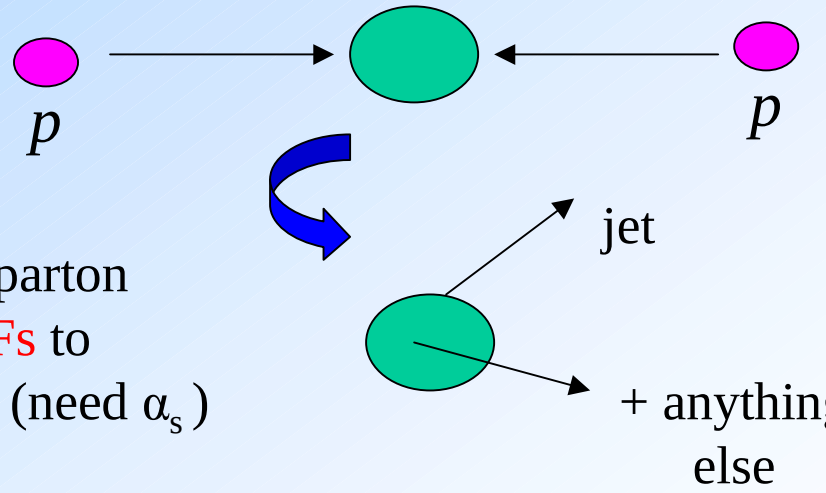
Why Jets?

1) Jets occur in many types of interactions as (hadronic) decay products.
2) Jets observables can be used to test predictions of QCD (e.g. the running of α_s with the hardness (q^2) of the interaction, from the inclusive jet cross-section)
3) Jet measurements can be used to constrain PDFs (e.g CTEQ5HJ from the CDF data)
4) Jet measurements can be used to look for new physics (e.g. quark sub-structure also known as compositeness)

The Inclusive-Jet Cross-Section (pp colliders)

How is it defined?

Probability of event with at least one jet:



How is it calculated?

From perturbative QCD parton-parton cross-sections ‘folded’ with PDFs to account for proton composition. (need α_s)

How is it measured?

By looking for events with at least one jet and correcting for acceptance, efficiency etc…….

Where's the catch?

Error on Theoretical Predictions of Jet Cross-Section:

1. Incomplete knowledge of PDFs
2. Renormalisation and Factorisation Scales (μ_r, μ_f)
3. The value of α_s

Error on Experimental Measurement of Cross-Section:

1. Jet energy scale calibration and resolution
2. Calorimeter non-linearity
3. Knowledge of collider luminosity
4. Statistics (no.of jet measurements)

Integrated Luminosity for 2,000,000 events

The jet-cross section steeply falls with the energy of the leading jet:

CKIN(3) *GeV*	σ(*mb*)	Lt (fb^{-1})
50	2.427×10^{-2}	8.24×10^{-5}
100	1.497×10^{-3}	1.34×10^{-3}
200	7.150×10^{-5}	2.80×10^{-2}
400	2.467×10^{-6}	0.811
600	2.807×10^{-7}	7.130
1000	1.317×10^{-8}	152.0

Quantifying PDF Errors

PDF Errors:

CTEQ have developed a set of 40 error pdfs (CTEQ6) which can be used to estimate the effect of PDF errors on observables.

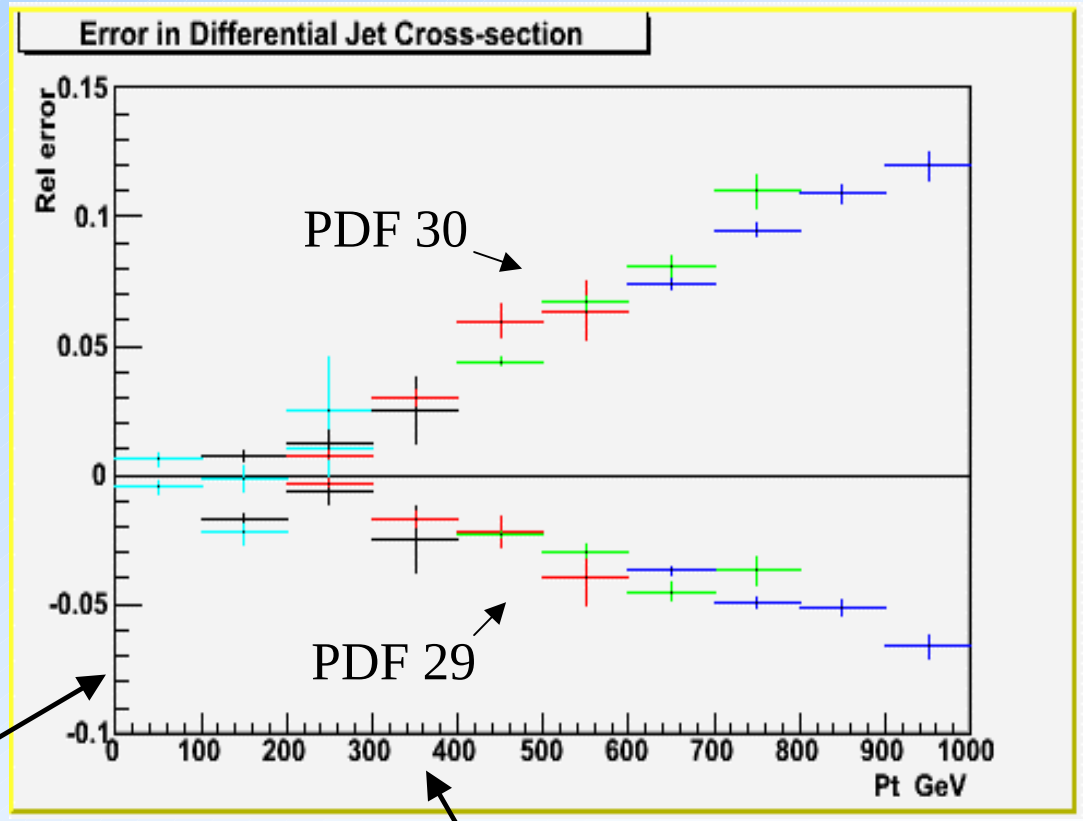
Calculate Observable for each PDF error set.

Compare the observables with that found using the central (best-fit) PDF.

For the inclusive jet cross-section PDF error sets 29 and 30 dominate error at high p_t. (high x-gluon)

PDF results from PYTHIA

Pythia was linked to the error pdf sets and a CDF jet finding algorithm (JETCLU).



(error pdf-central)/central

Transverse momentum of leading jet

Jet Energy Scale – Systematic Errors

The differential jet cross-section is steeply falling in p_t:

Small systematic error in jet energy

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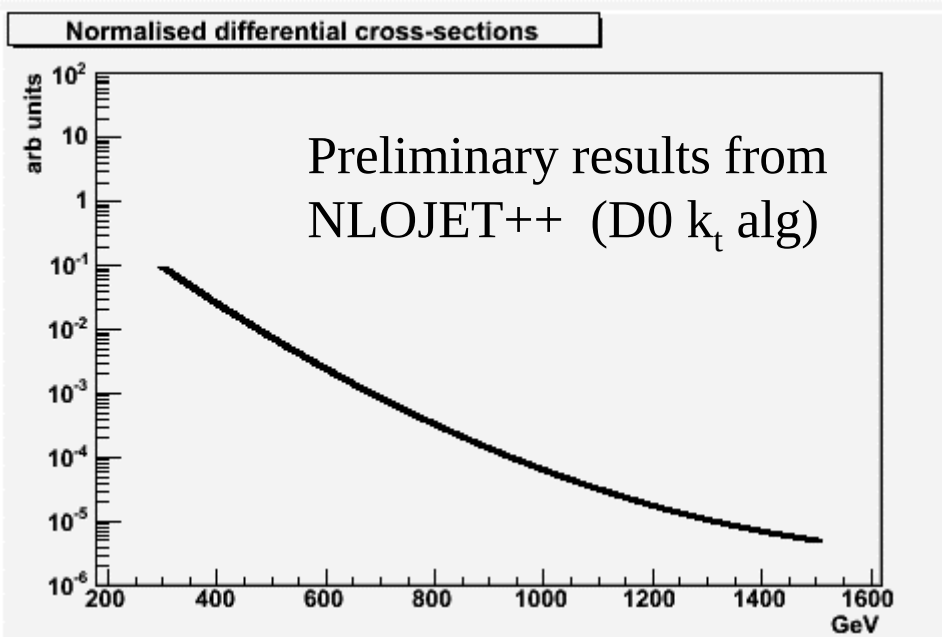
Much larger effect in differential cross-section



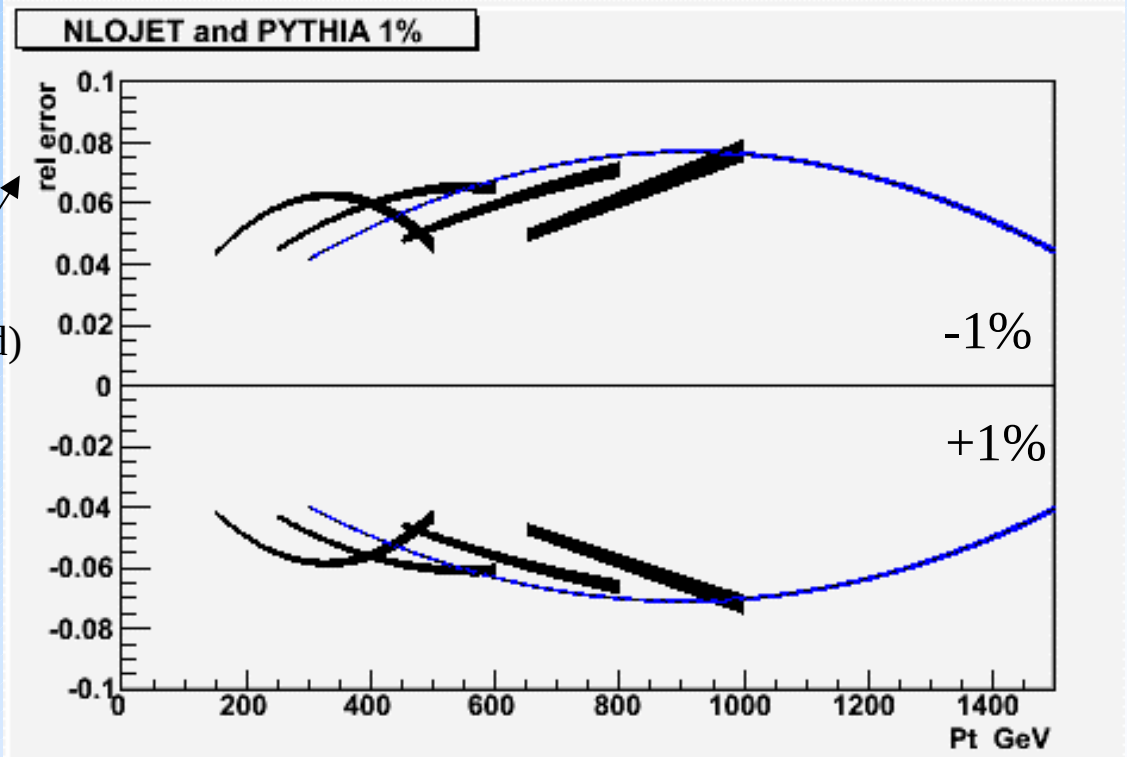
What we did…….

1. Parameterised differential cross-section with an analytic function. [$\exp(a_1+a_2E+a_3E^2)$]
2. Calculated the relative change in the cross-section with a 1% and 10% systematic jet energy error.

Jet Energy Scale Results – PYTHIA and NLOJET++

A 1% error in the jet energy scale leads to an error of between 4% to 7% on the differential cross-section. (between 200GeV to 1500GeV).

(Shifted-unshifted) /unshifted



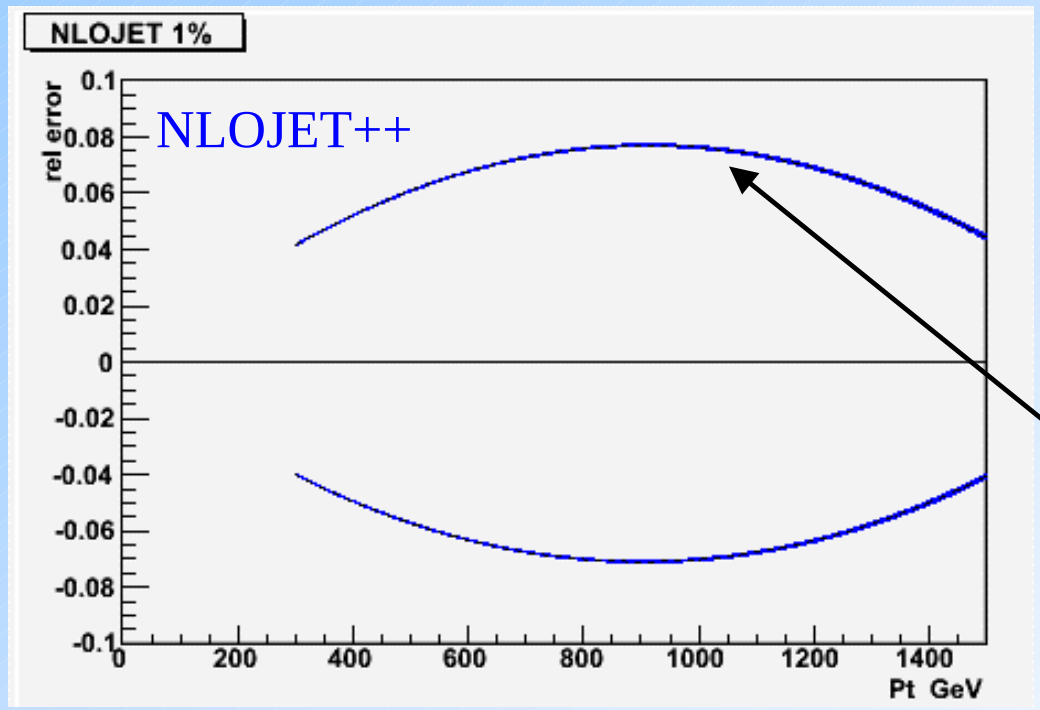
Key

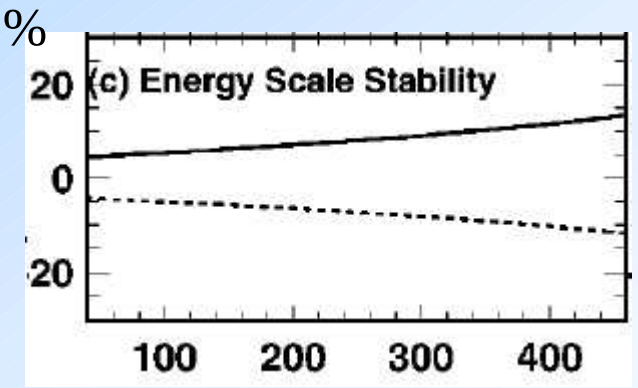
NLOJET++

PYTHIA

Odd shapes (in PYTHIA) caused by threshold effects for samples run at different CKIN(3)

Jet Energy Scale Results – CDF and NLOJET++





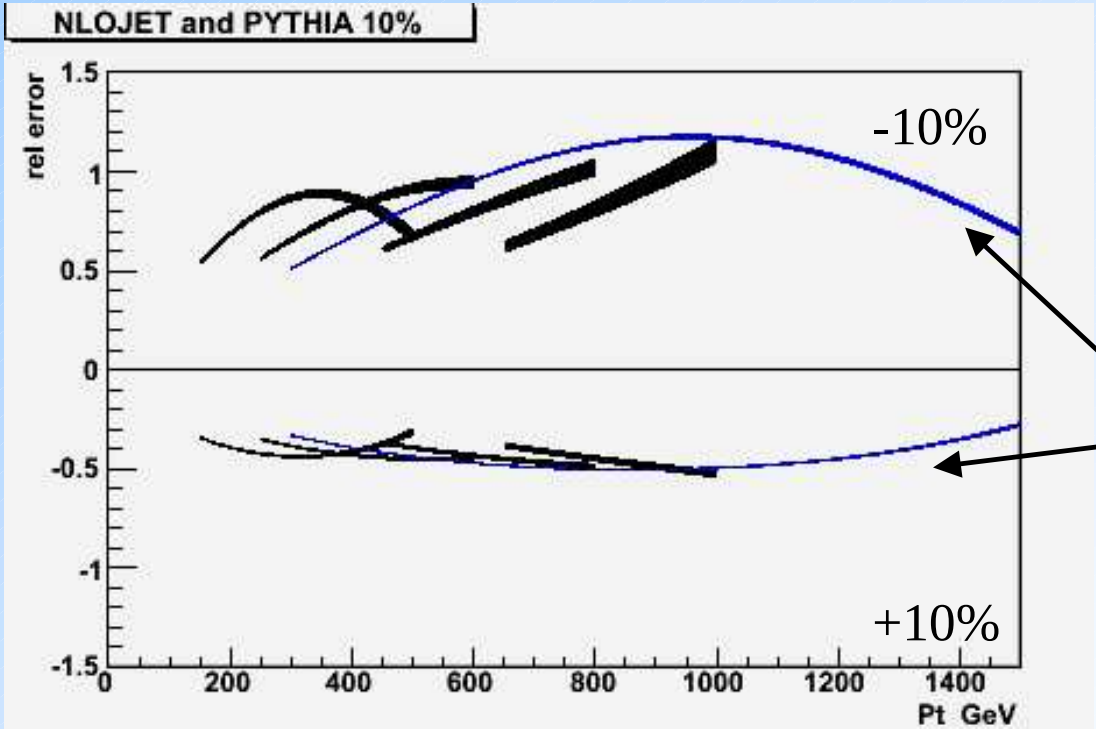
[1]

Shape due to increase in size of error boundaries at 1% (with increasing P_t) and decreasing gradient of differential cross-section.

[1] From Measurement of the inclusive jet cross-section in p-pbar collisions at sqrt(s)=1.8TeV, Phys Rev D, V64, 032001, 2001

Jet energy scale errors at 10%

A 10% error in the jet energy scale leads to an error of between 40% to 120% on the differential cross-section. (between 200GeV to 1500GeV).



Key

NLOJET++

PYTHIA

Asymmetry caused by shape of differential jet cross-section.

Summary + Outlook

1. Uncertainty on existing PDFs could lead to a 10% error on the differential jet cross-section (around 1TeV)
2. A 1% error of the jet energy scale could lead to an error of about 7% to 8% on the differential jet cross-section at 1TeV

Further Research:

1) Investigate jet resolution (smearing) effects.
2) Investigate dependency of renormalisation and factorisation scales on theoretical calculation of jet cross-section.
3) Assess the effects of different jet-finding algorithms on results.
4) Combine main sources of error to give overview of uncertainty