The Inclusive Jet Cross-Section at ATLAS (ApplGrid)

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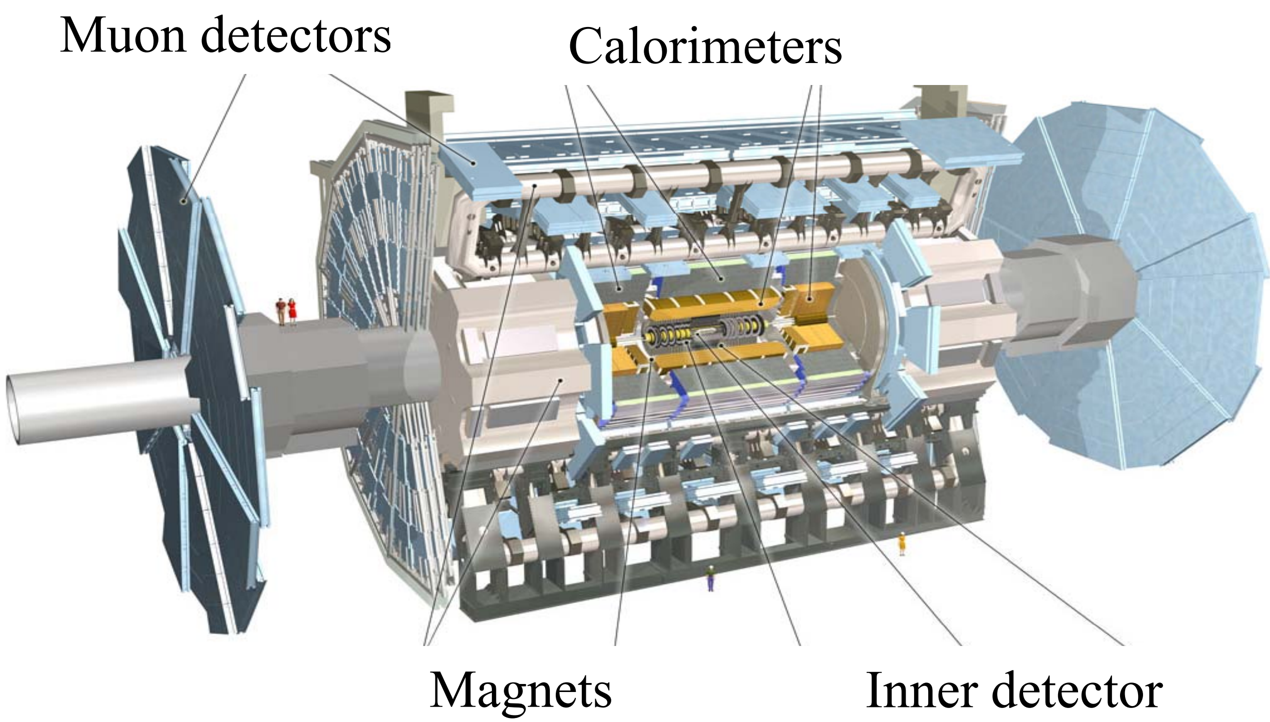
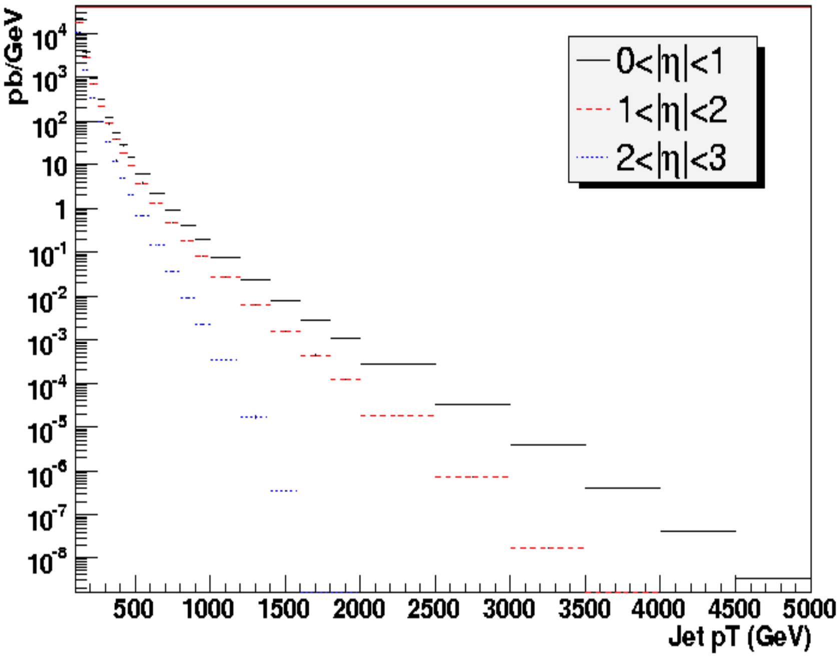
The LHC and ATLAS

- The LHC will collide protons at a higher centre of mass-energy than previous accelerators.

- ATLAS is a general purpose detector designed to measure collision products in order to test the Higgs theory and look for signatures of 'New Physics'.



Inclusive Jets



- The inclusive jet cross-section records all jets produced (within acceptance).
- The cross-section provides a test of QCD.
- Deviation of the cross-section from the Standard Model prediction is evidence for new physics.

Hard 2 →2 scattering

$$\sigma(P_1,P_2)=\sum_{i,j}\int dx_1 dx_2\, f_i(x_1,\mu^2)\, f_j(x_2,\mu^2)\,\hat{\sigma}_{ij}\left(x_1P_1, x_2P_2, \alpha_s(\mu^2), Q^2/\mu^2\right)$$

PDFs

Parton momenta

Hadron momenta

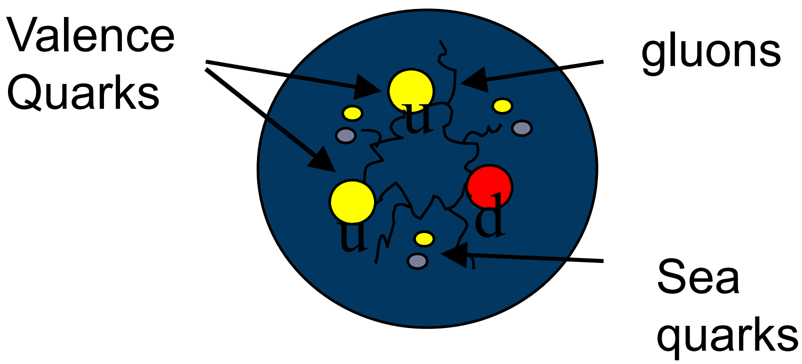
Sum over parton types

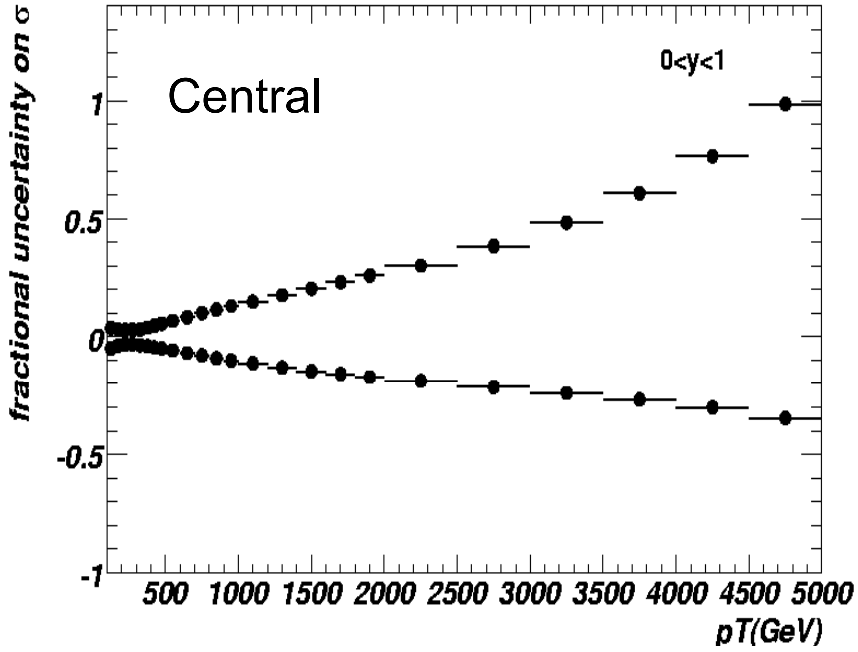
Parton Level Cross-Section

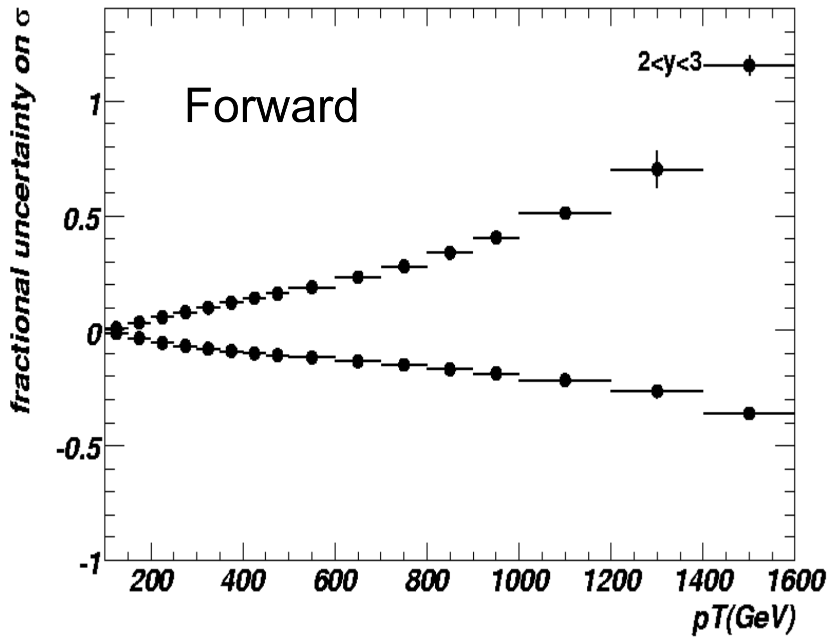
Good control of both theoretical and experimental errors is vital in order to have confidence in any findings.

PDF Errors

- PDF errors arise due to uncertainty in the parton content of the proton.
- The errors lead to uncertainty on the predicted inclusive-jet cross-section in all rapidity ranges.
- The errors increase with pT due to growing uncertainty in the high-x gluon which is poorly constrained from DIS experiments.





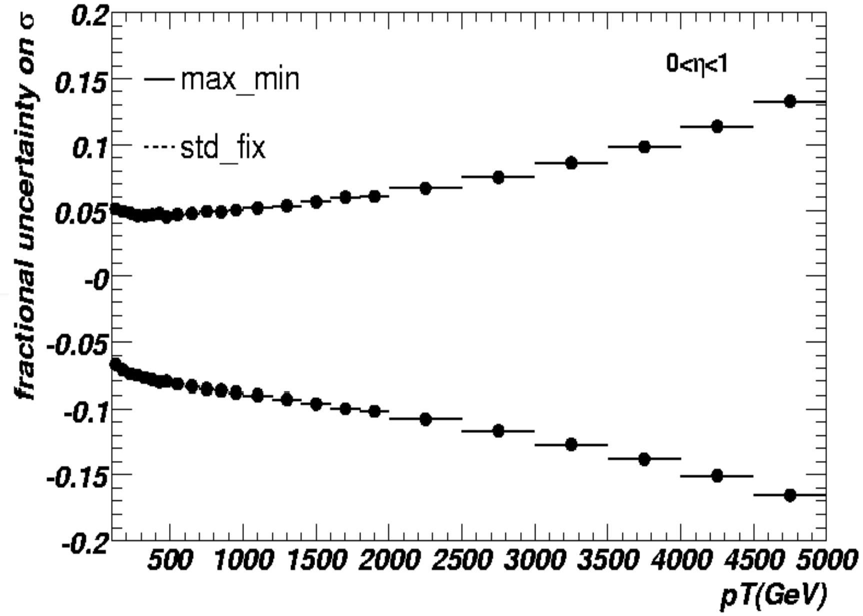


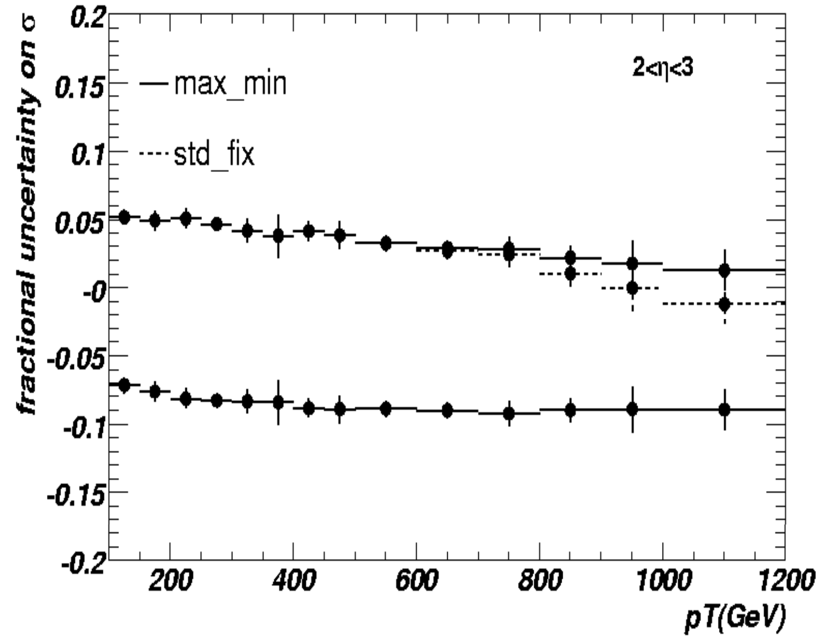
Renormalisation and Factorisation Errors

•Jet cross-sections are calculated to fixed-order (e.g. NLO for NLOJET or JETRAD). The missing orders lead to uncertainties.

•This uncertainty is manifest in a dependency of the cross-section on unphysical scales (Renormalisation and Factorisation).

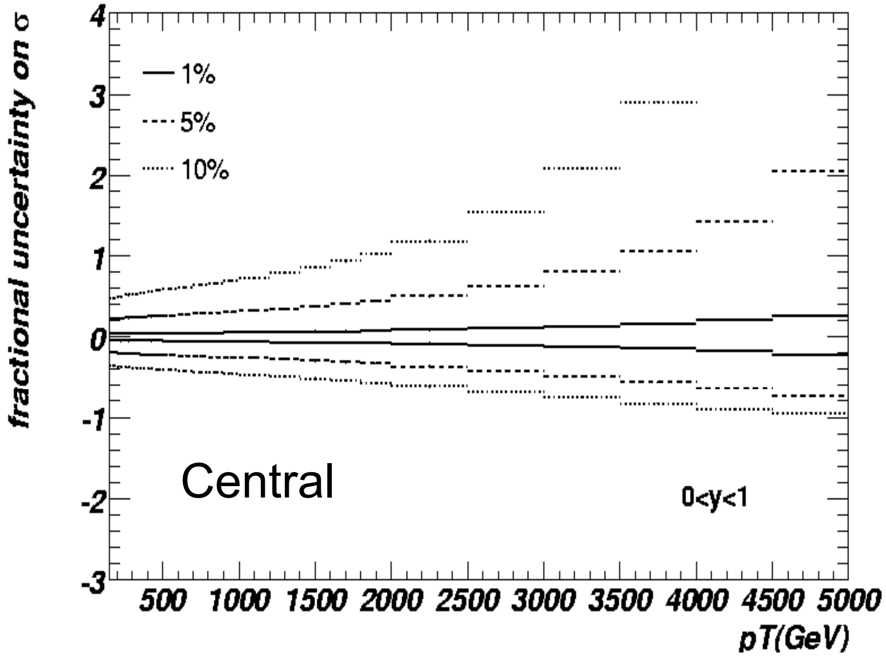
•The magnitude of the errors can be estimated by varying the scales: 0.5→2 pT (max).

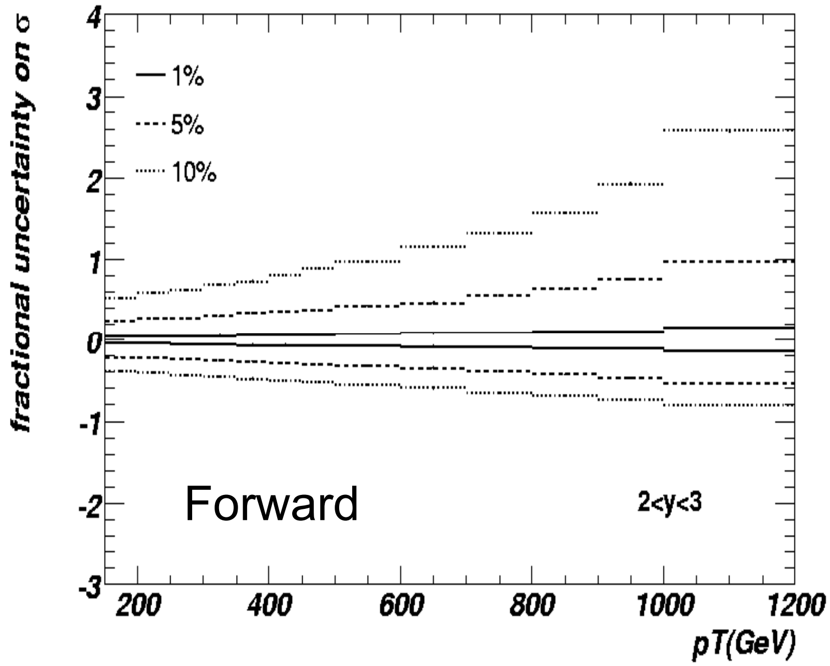




Jet Energy Scale Errors

- Experimentally the inclusive-jet cross section is very sensitive to the jet energy scale.
- The JES is essentially a mis-calibration of the energy of jet, leading to a systematic error.
- The JES at low pT is calibrated by connecting the hadronic to the better known EM scale via Z+jet and gamma+jet events.
- At high pT the JES is hard to constrain.





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The ApplGrid project - Motivation

1. NLO Monte-Carlo QCD calculations are necessary to provide accurate predictions for experimental cross-section measurements.
2. NLO Monte-Carlo calculations however can require long CPU times to achieve sufficient accuracy (typically of order days/weeks).
3. If the PDF is changed the cross-section must be recalculated.

This makes it difficult to use data from hadron-colliders to constrain PDFs using iterative techniques.

→ Want a method to separate PDFs from the QCD cross-section calculation…………

The ApplGrid project

Hard 2 →2 scattering

PDFs

Parton momenta

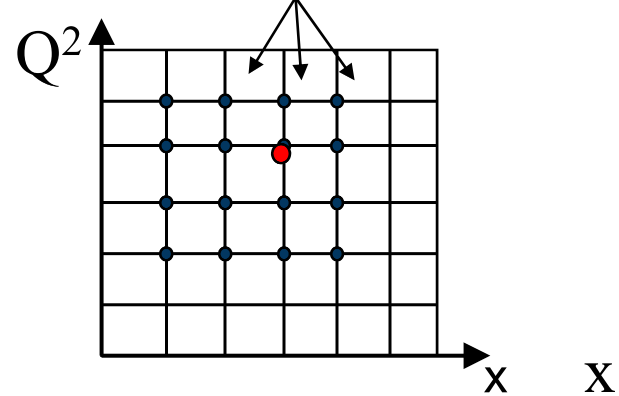
$$\sigma(P_1,P_2)=\sum_{i,j}\int dx_1 dx_2\, f_i(x_1,\mu^2)\, f_j(x_2,\mu^2)\,\hat{\sigma}_{ij}\left(x_1P_1, x_2P_2, \alpha_s(\mu^2), Q^2/\mu^2\right)$$

Hadron momenta

Sum over parton types

Parton Level Cross-Section

PDF defined at discrete points in x and Q^2.



•Solve problem by use of integration grids.

•The PDF is described by using interpolation functions between discrete grid-points.

•The PDF can then be separated from the hard to calculate NLO weights.

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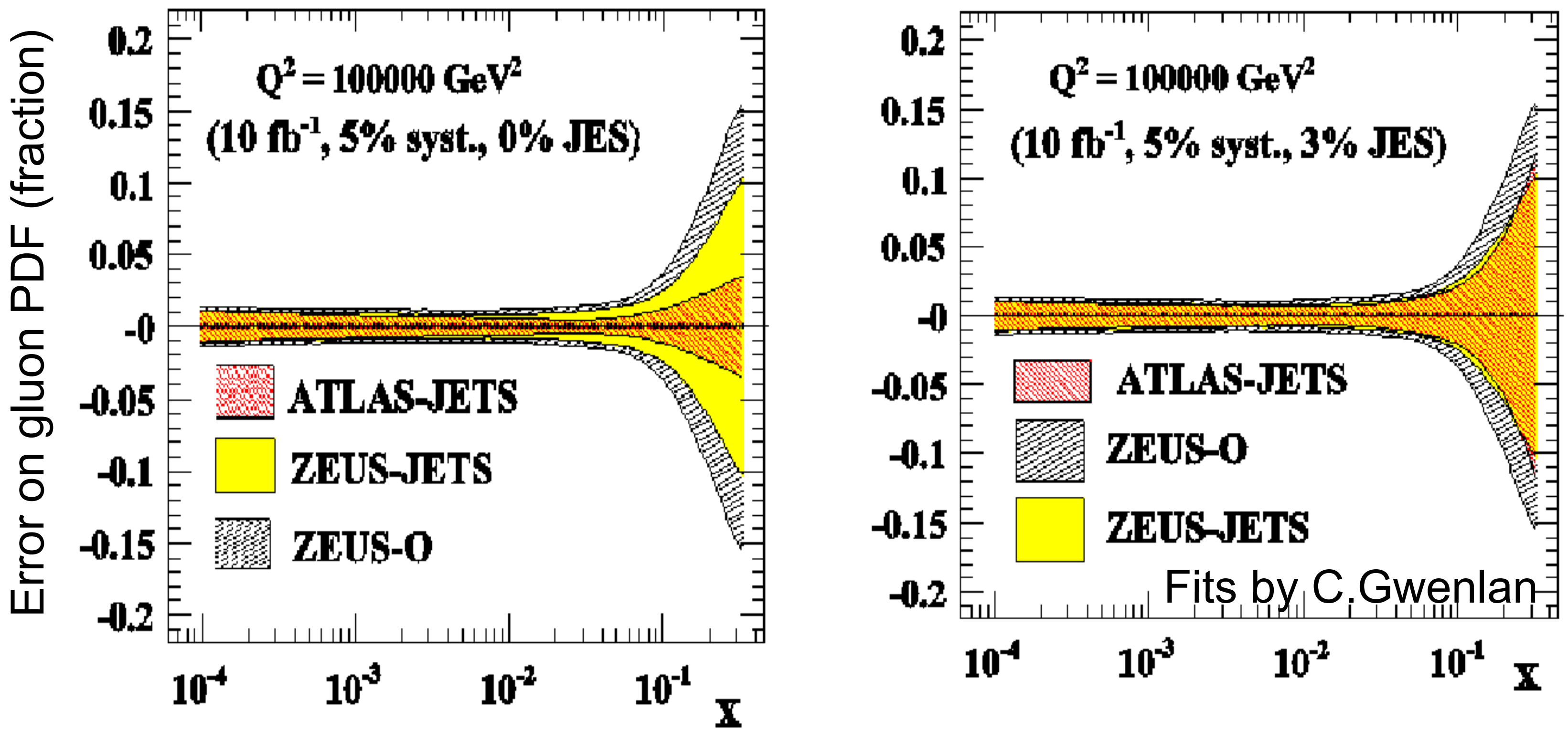
- Using these techniques ATLAS jet data can be included into global PDF fits to constrain the high-x gluon.
- A good constraint of the high pT JES is needed to constrain the gluon:



New Physics - Compositeness

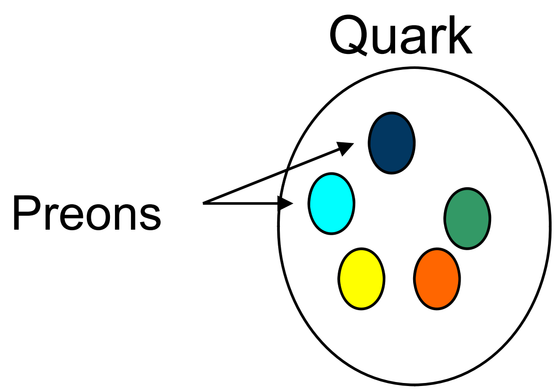
•The inclusive jet cross-section at high pT is sensitive to quark-compositeness.

•Quark compositeness is a theory that suggests quarks are not fundamental objects but are comprised of ‘preons’ held together by a ‘hypercolor’ interaction.

•The quark compositeness has an associated scale Λ, which defines a length scale of the quark.

•At sufficiently high Q2 the substructure of the quark may become apparent.

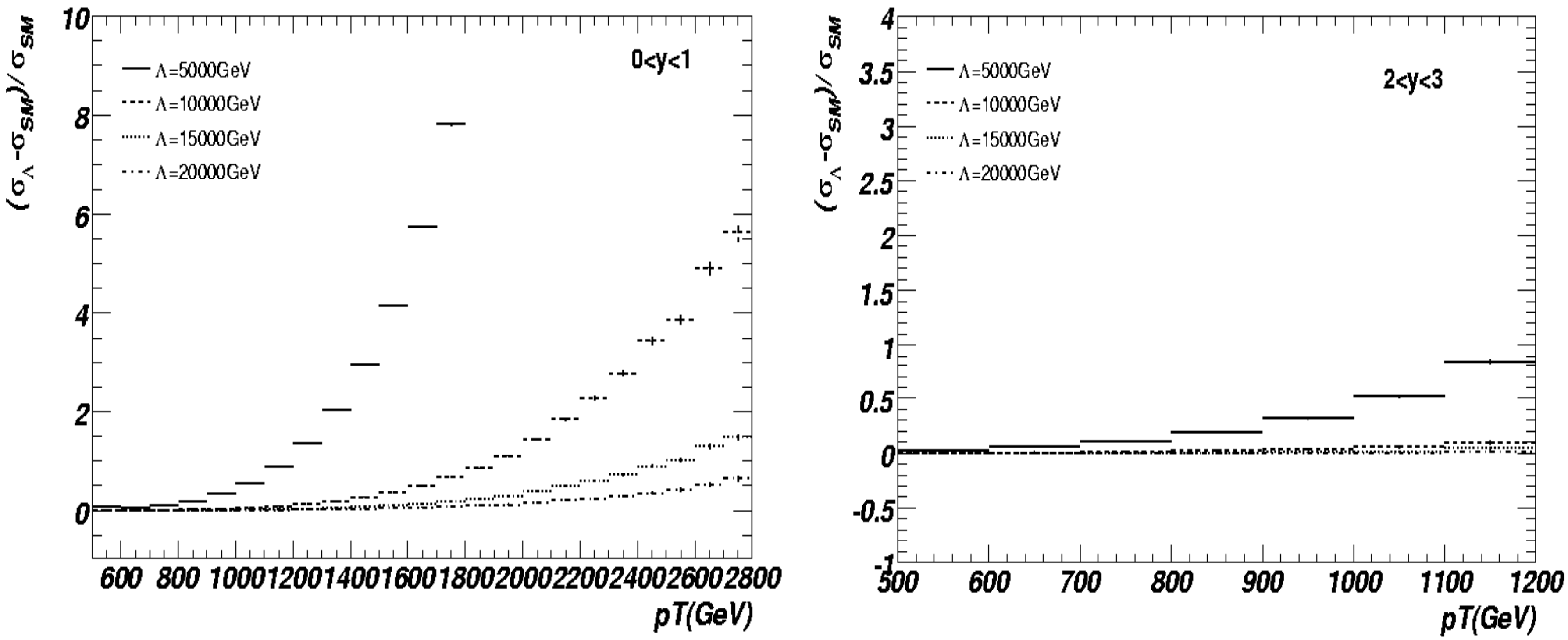
•Compositeness appears as an excess in the inclusive jets cross-section at high pT.



New Physics - Compositeness

•Compositeness signals are clearer in the central region.

•Sensitivity to Λ~10-15TeV can be reached if a 1-5% JES uncertainty is achieved.



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Summary

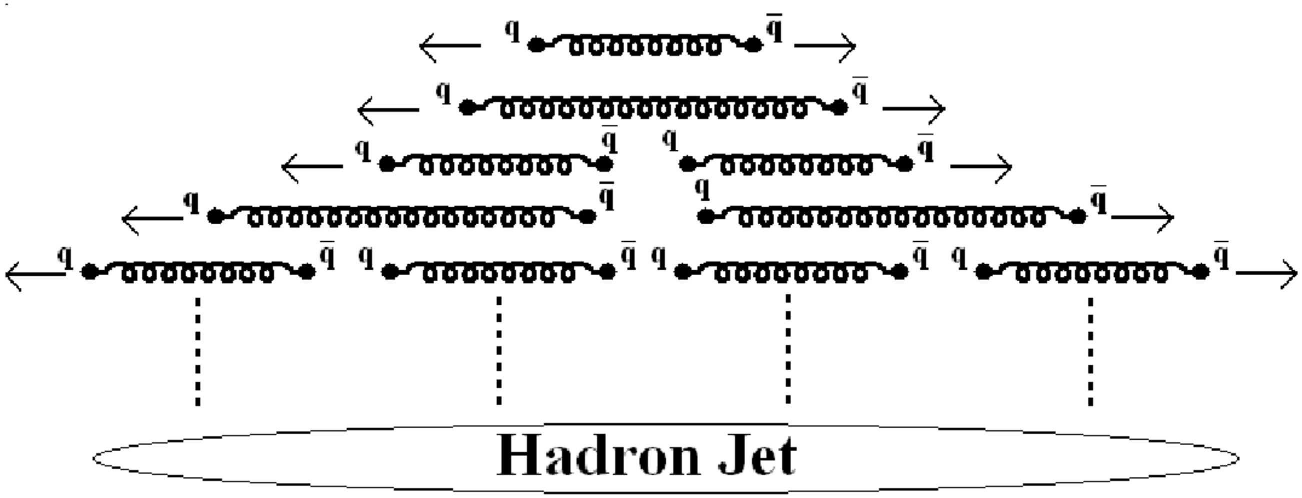
- The inclusive-jet cross section will provide a test of QCD and offer the opportunity to look for ‘new physics’ such as quark compositeness.
- The error sources on both the theoretical prediction and the experimental measurement must be carefully considered before reaching any conclusions.
- High pT jet data at hadron-colliders can be integrated into global PDF fits by use of integration grid methods to constrain the high-x gluon.
- The sensitivity to both ‘new physics’ and constraining PDFs is highly dependent on the ability of ATLAS to control its jet energy scale uncertainty.

Backup Slides

Jets At A Hadron Collider

•Jets are produced in a hadron-collider and are observed as a collimated spray of particles (pions, photons etc.).

•The multi-particle state is a result of a coloured parton being scattered from a hadron and the resulting QCD confinement:



Backup Slides

Compositeness Model

•Compositeness refers to a class of theories as the premise does not lead to a precise description of the underlying hypercolor interaction.

•At scales below Λ, the compositeness is simply modelled as a contact interaction.

•Normally the sub-structure scale would be expected to set the mass of the composite object (i.e. QCD scale sets the mass of hadrons ~ 1GeV). Constraints give Λ>2TeV (Tevatron) but the low mass of quarks can be explained naturally by symmetry constraints (t'Hooft).

•Flavour changing interactions are possible but are constrained to scales Λ>100TeV from experiments.

•A potential flavour conserving interaction used in this study is given below:

$$L_{qq} = \eta_0 \frac{g^2}{2\Lambda^2} \bar{q}_L \gamma_\mu q_L \bar{q}_L \gamma^\mu q_L$$

•η can =±1 leading to destructive and constructive interference with SM terms in the lagrangian (only constructive plots were shown earlier).

Slide Title

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