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ATLAS Jets: Measurements, Calibration and Studies

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Overview

- Why do we care?
- What are jets in collider experiments?
- The Measurement of Jets at ATLAS
- Calibration Methods
- Quark compositeness, example of a study
- Conclusions

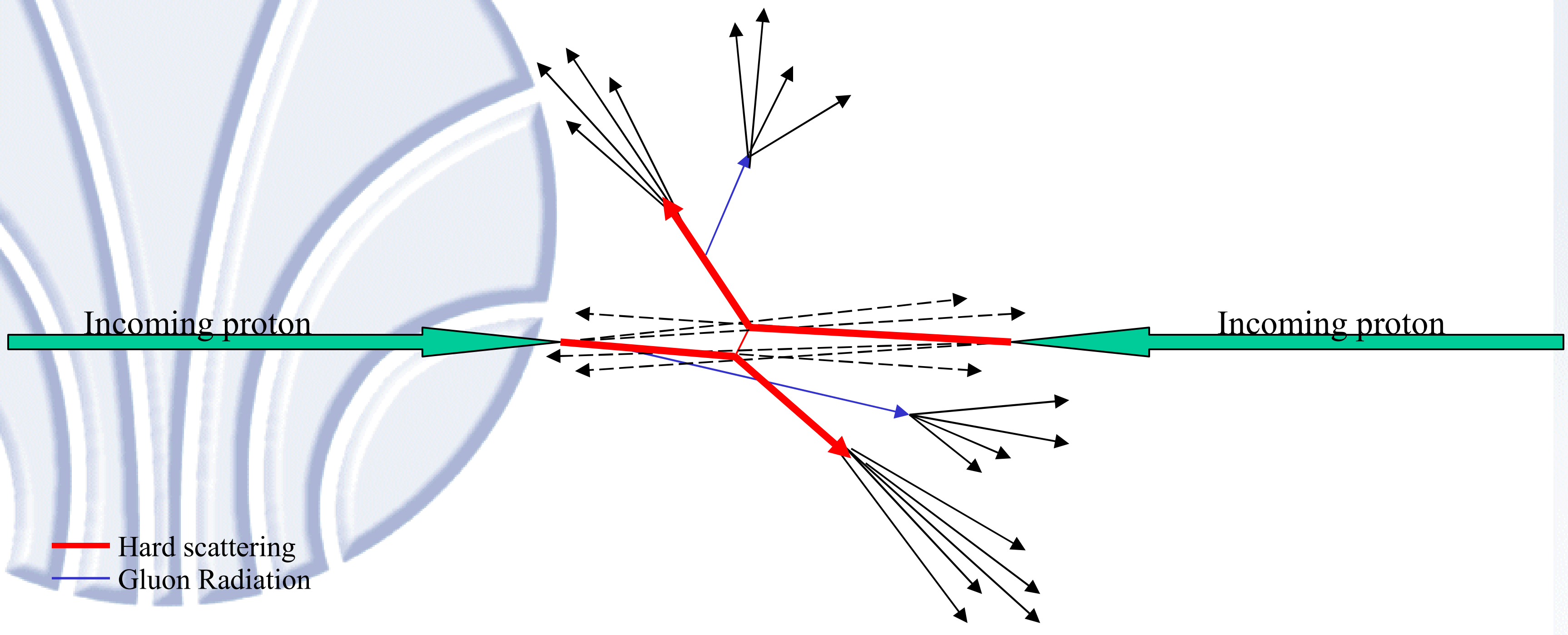
Introduction

- Motivation
- Dijet event sketch
- Confinement & Hadronization

Why do we care?

- Parton jets will dominate most high Q^2 events and many physics signatures
  - The jet energy scale is the largest contribution to the error of many measurements
- Measured jet production rates (e.g..)
  - allow to check QCD in the multi-TeV energy range, sensitivity for new phenomena
  - are vital for the accurate prediction of background for searches for new physics

Sample Event Sketch



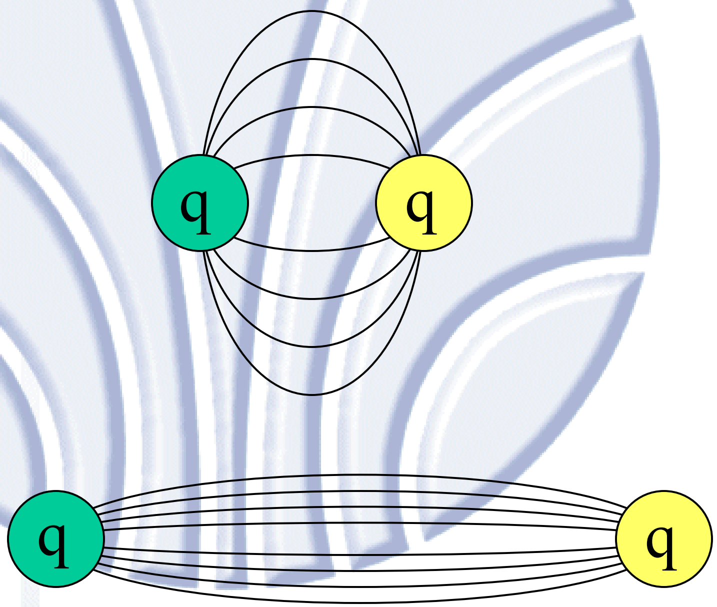
- The event topology is given by:
  - The outgoing partons
  - Initial and final-state radiation (of gluons)

Hadronization

- Hadronization is the process of formation of hadrons from „free“ quarks and gluons
  ➡ **Jets**
- QCD perturbation theory is not applicable at long distances
- **Hadronization is not understood from first principle!**

Several phenomenological models exist, mainly
- String fragmentation (Lund-Model)
- Independent fragmentation
- Cluster fragmentation

Confinement



- At short distances the field of the two quarks behaves quite QED like with gluons as „lines of flux“
- At long distances the flux lines attract each other, leading to a linear field

String Fragmentation:

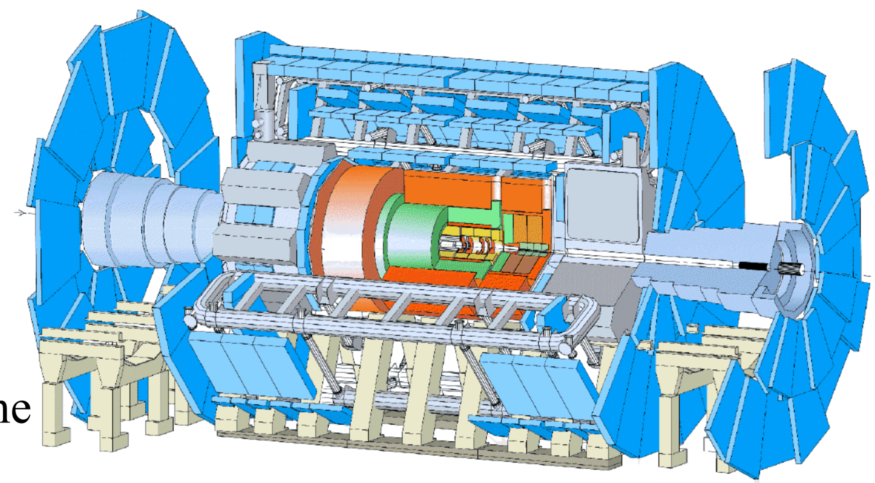
- The gluons are seen as a string between the quarks with a mass density per length unit
- The string breaks up in multiple places, by forming new quark pairs

Experimental Methods

- The ATLAS Detector
- Jet reconstruction
- Jet Calibration

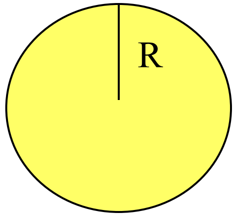
Jet Measurement at ATLAS

- Electromagnetic Calorimeter
  - LAr/lead sampling calorimeter
  - ~200,000 readout channels
- Hadronic Calorimeter
  - Sampling calorimeter with scintillating tiles embedded in iron(barrel) and LAr/copper in the endcaps
  - ~21,000 readout channels

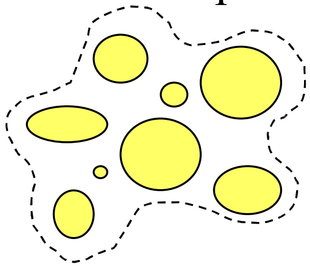


- The inner detector consisting of 3 Layers:
  - Innermost: High resolution pixel detectors
  - Silicon microstrip detectors to provide further high precision space points for tracking
  - A transition radiation tracker (built of straw tubes)

Jet reconstruction



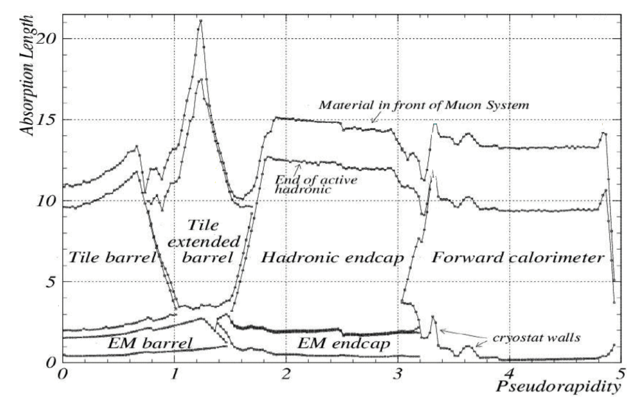
- Cone algorithm
  - A jet is a cone of radius R
  - Using a „precluster“ as a seed, the cone is iteratively moved to a „stable“ position, where the jet axis coincides with summed direction of all its particles
  - „Seedless“ cone (starting with many seeds distributed in a fine grid) is theoretically more accurate, but requires significantly more computing resources



- kT algorithm
  - A jet is a number of clusters with a certain nearness in relative transverse momentum
  - Forms the jet from preclusters by combining clusters close in relative transverse momentum

Challenges of jet energy calibration

- One basic problem is the precise energy measurements of hadrons
  - Noncompensating calorimeter:
    - The hadronic and electromagnetic energy scale is different
    - A large number of secondary particles produced are pions, the π^o decay nearly instantly into gammas
    - **The number of π^o created and thus the energy deposited as electromagnetic component is subject to high statistical fluctuations**
  - Energy deposited that produces a very small or no response
    - Excitation and break-up of nuclei
    - Leakage
    - Slow neutrons
- Jet composition and geometry can vary widely with initial parton
- **The π^o content of a jet can already be substantial before it interacts with the calorimeters, thus leading to a high electromagnetic component**

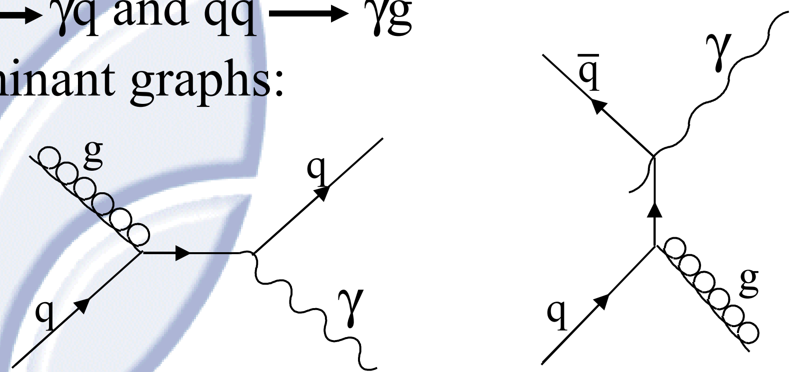


Jet energy calibration in ATLAS

- Examples of calibration approaches:
  - H1-style
    - Electromagnetic showers (and hadronic showers with dominant electromagnetic component) are denser
    - Weights are applied on cell-level depending on the energy density
  - Pisa
    - Weights are applied based on cell energy and jet energy
  - Sampling
    - Weights are applied to the different calorimeter layers
- A bottom up approach in three steps is pursued by the Hadronic calibration group:
  - Cell corrections on the cell level (following the H1 approach)
  - Topology dependant corrections on the cluster level
  - Event topology corrections

In situ calibration methods, examples

- Prompt photon production
  - $qg \longrightarrow \gamma q$ and $q\bar{q} \longrightarrow \gamma g$
  - Dominant graphs:



  - The well measured energy of the isolated photon is used to calibrate the jet
- Dijet events can be used to
  - Calibrate one part of the detector against another
  - Check the calibration and linearity across the detector
  - **High statistics**

Sample Study – Quark compositeness

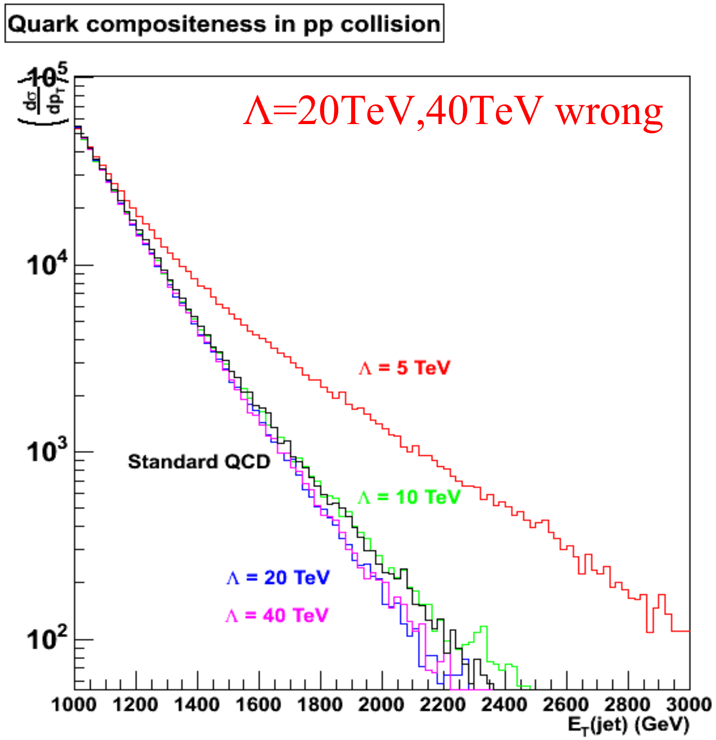
- Introduction
- Inclusive jet production rate
- Dijet angular distribution

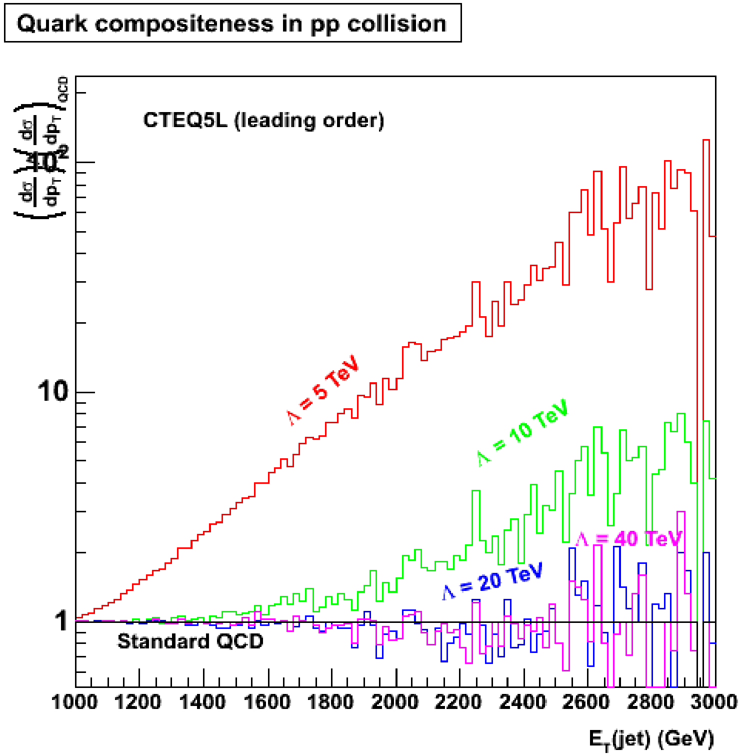
Quark compositeness

While quarks appear point-like from distances accessible in collider experiments so far, quark compositeness is an intriguing possibility.
A possible composite nature of quarks can be characterized by an interference sign and the compositeness scale Λ.

- With $\Lambda \to \infty$ quarks are point-like and standard QCD applies
- A lower Λ leads to $qq \to qq$ cross-sections increasing starting at Q^2 in the order of Λ. While pointlike from afar, at close distances, corresponding to high Q^2, the size of the quarks starts to play a role
- **The lower limit on Λ from the Tevatron is 2.0 TeV**, independent of the interference sign

Inclusive jet production rate

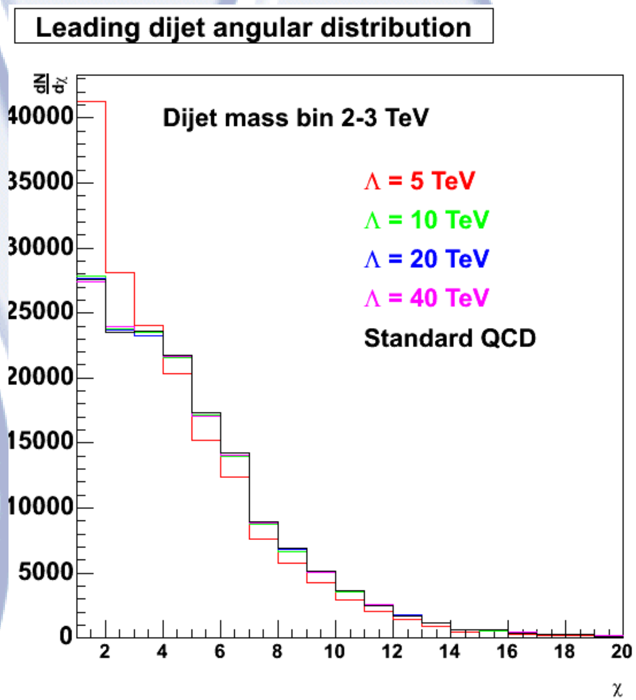


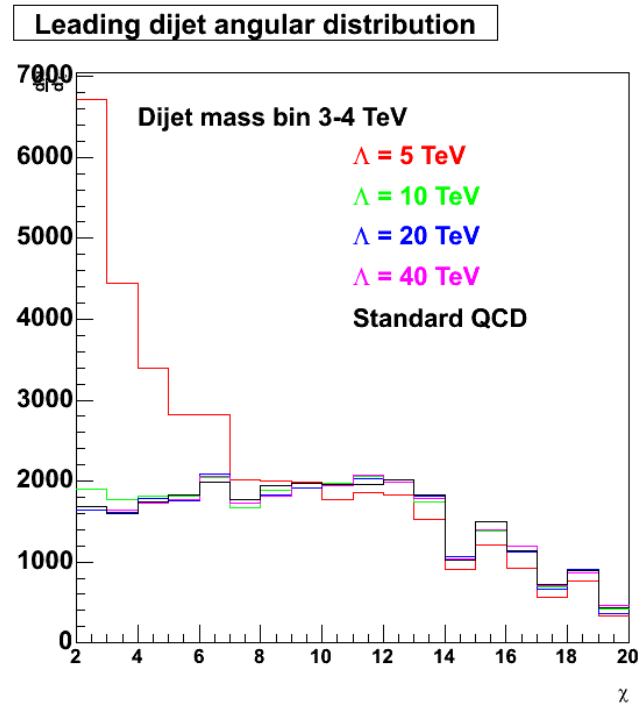


- An excess of extremely high energy jets is clearly visible for low a low scale Λ
- At Λ=5 TeV ten times the number of jets with ~2 TeV would be observable compared to standard QCD expectations

Plots: L.Přibyl, Studies on quark compositeness in ATLAS, 16.06.04

Dijet angular distribution





- The measurement of leading dijet angular distributions is quite robust in respect to the error of the jet energy scale and the jet energy resolution
- But: Higher statistics is needed

Plots: L.Přibyl, Studies on quark compositeness in ATLAS, 16.06.04

Summary

- Conclusion
- Outlook

Conclusion

- The understanding of jets, and a precise calibration at ATLAS is vital and quite challenging
  - The accuracy of most measurements at ATLAS will be highly dependant on the error of the jet-energy scale
- The statistics available at ATLAS for jet studies will be immense, but even already with low statistics the available energies allow promising studies
  - e.g. after only one good week of running, Λ can be probed up to ~5TeV, with 100 fb^{-1} to 20 TeV and beyond

Outlook

- A private farm of our group is not only up and running, but at last ATHENA is installed and working
- An increasing fraction of working time will be put into calibration and physics issues

Results will follow, stay tuned