QCD Physics in ATLAS

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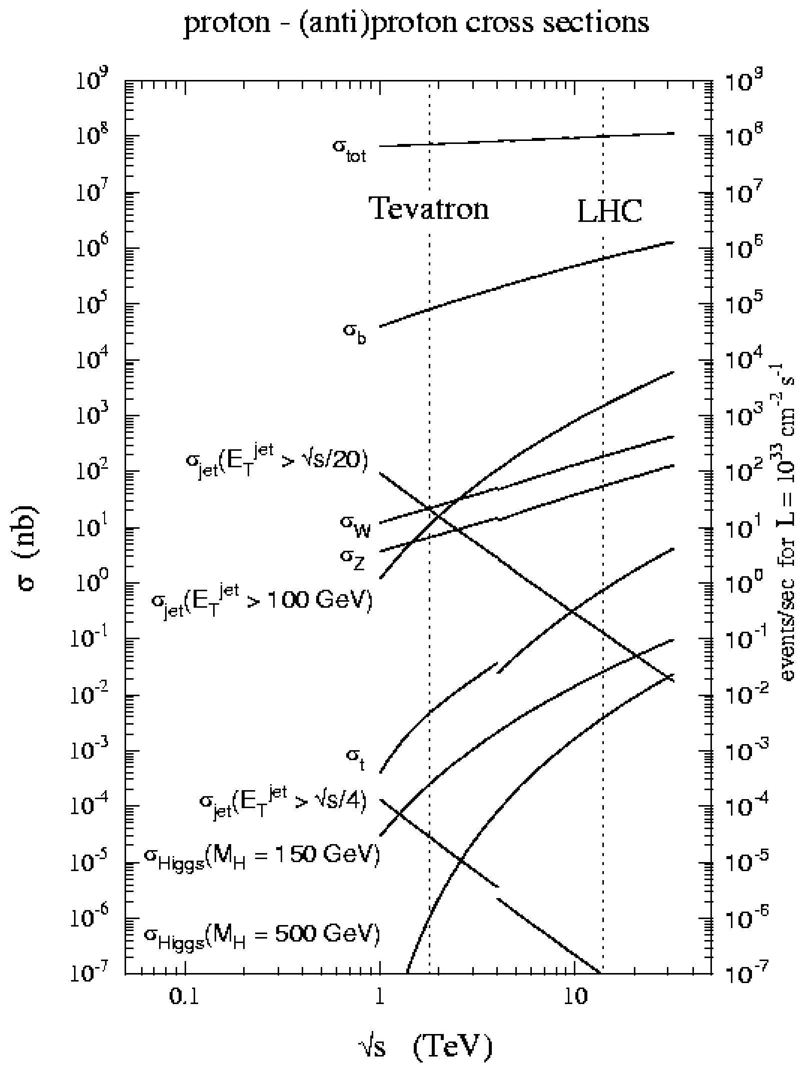
The Large Hadron Collider

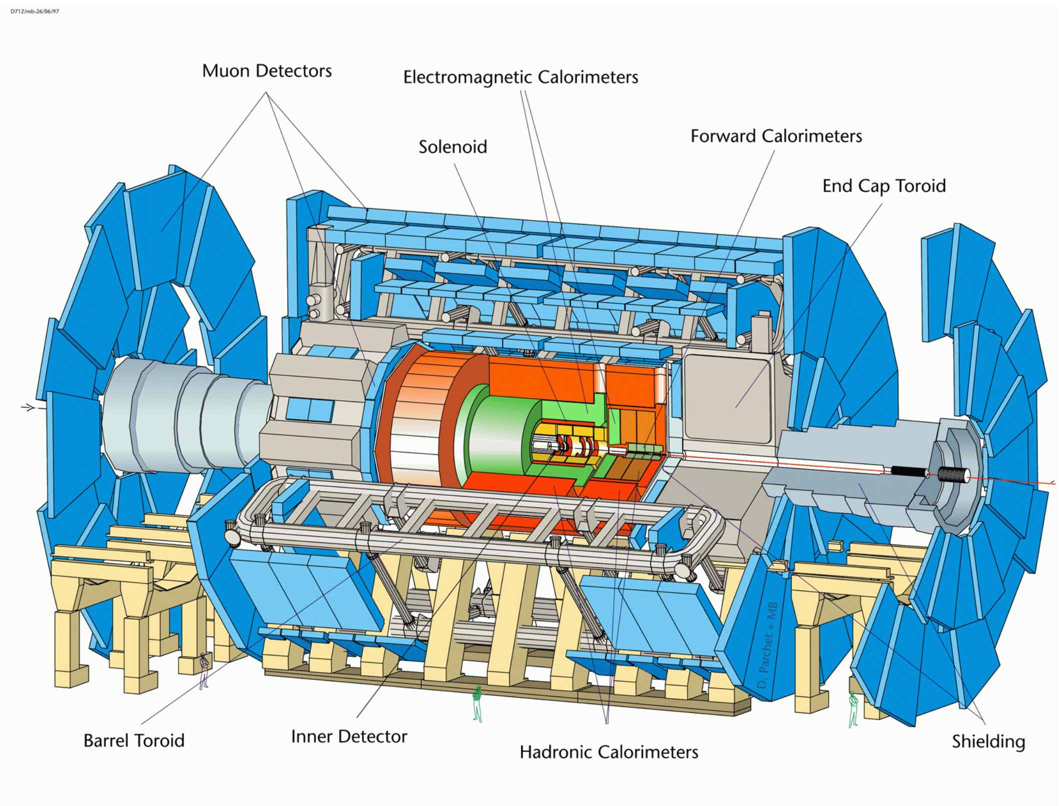
- $\sqrt{s}$ = 14 TeV p on p collider
- **Luminosity**
  - 10^{33} cm^{-2} s^{-1} to 10^{34} cm^{-2} s^{-1}
- **25 ns bunch crossing (40 MHz)**
- **High luminosity and large σ_{inc} at LHC implies:**
  - ~ 23 minimum bias events per BC
  - ~ 70 charged tracks/event with $p_T > 1$ GeV/c for $|\eta| < 2.5$
- **Mass reach up to ≈ 5 TeV**

Production cross-sections and dynamics are largely controlled by QCD



The ATLAS Detector

A General Purpose Detector



- **Tracking in 2T solenoid:**
  - **Si pixel + strips (3+4 layers)**
  - **TRT → particle id.**
  - $\sigma / p_T \sim 5 \bullet 10^{-4}\, p_T \oplus 0.01$ in 2 Tesla field
- **EM calorimeter: Pb – liquid Argon presampler + segmented EM calo.**

  $\sigma / E \sim 10\% / \sqrt{E(GeV)}$
- **Had. Calorimeter:**
  - **Fe –scintillator (barrel)**

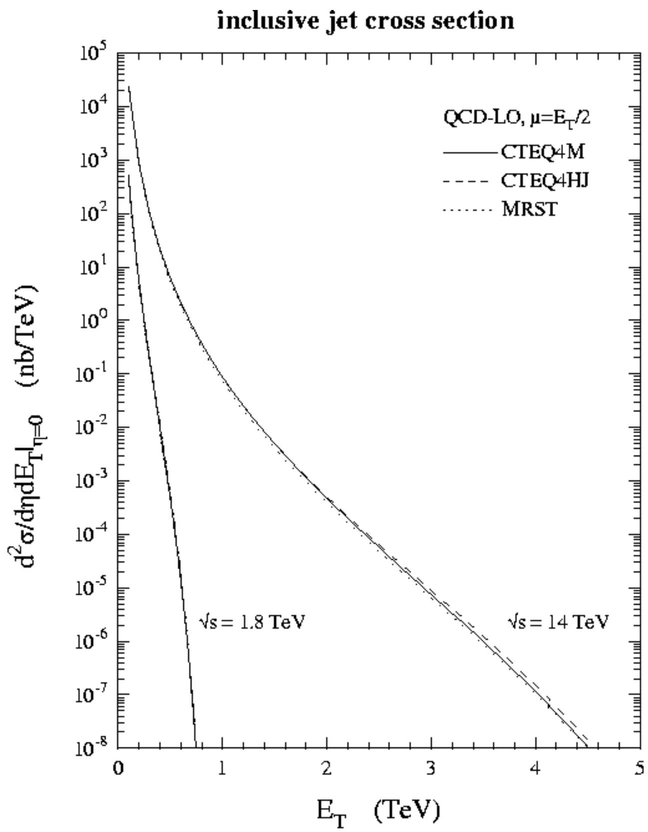
    $\sigma / E \sim 50\% / \sqrt{E(GeV)} \oplus 0.03$
  - **Cu/W – liquid Argon(endcaps/Forwd)**

    $\sigma / E \sim 60\% / \sqrt{E(GeV)} \oplus 0.03$
- **Muons: "Air"; instrumented large toroid magnet**

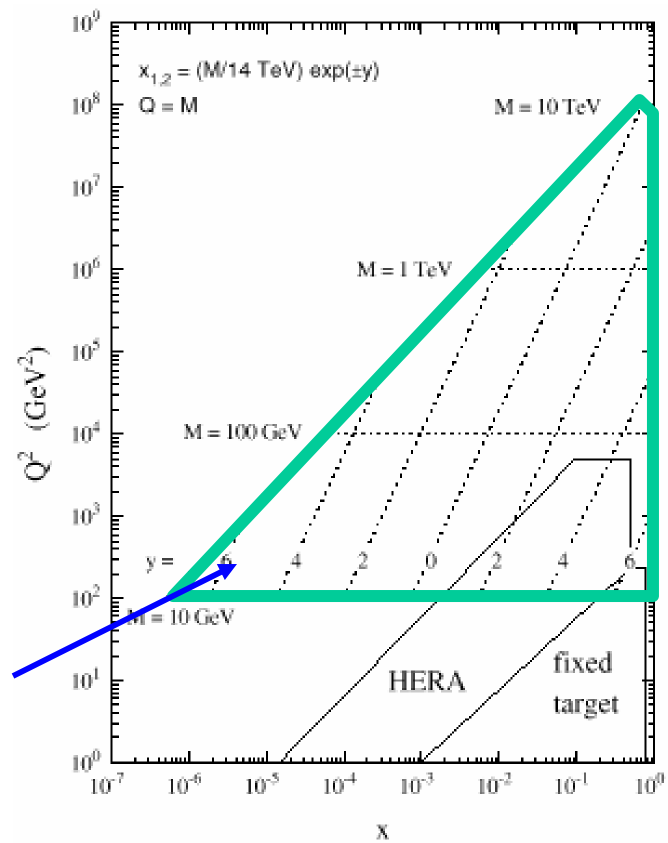
  $\sigma / pT \sim 10\ \%$ at 1 TeV/c
- **Luminosity Uncertainty < 5%**

ALL Systems contribute to QCD Measurements

(x, Q^2) Kinematic Reach



(Extension to forward calorimeter is needed to access very low x)



The LHC provides a unique opportunity to test the predictive power of QCD over a large range of x, Q2 and mass scale

Some "Engineering Details"

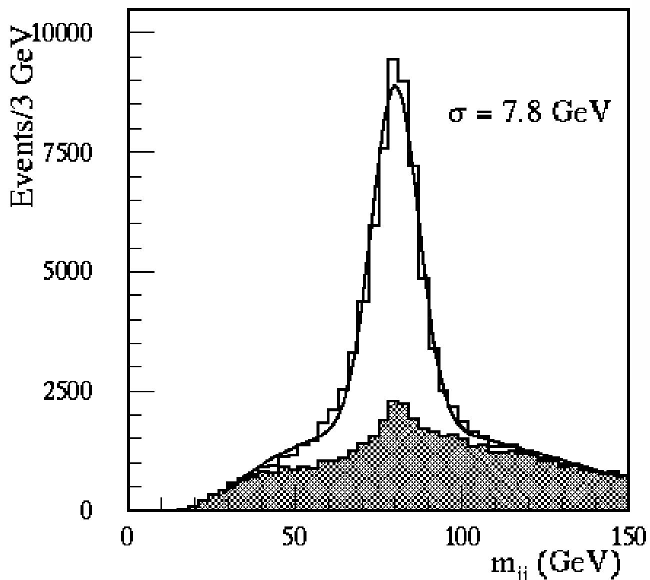
(from 1st 10 fb-1)

Calibrate detector:

- $Z \rightarrow \mu\mu$, ee: → tracker, calorimeter, μ spectrometer calibration
- $t \rightarrow Wb \rightarrow jjb$: jet energy scale and resolution

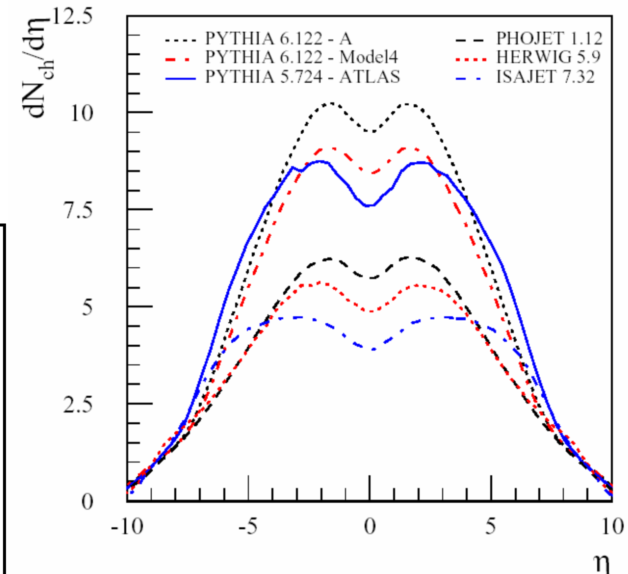
Low Luminosity is Good for these Measurements

-> Can be done in first years of LHC operation



W → jj in top events

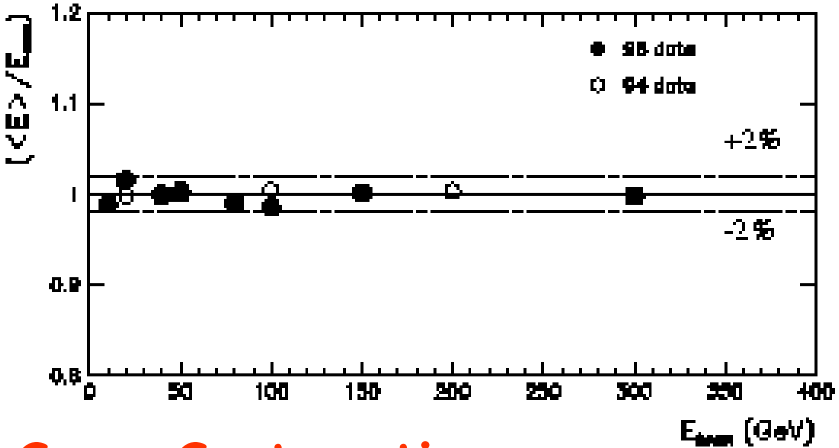
Understand physics environment



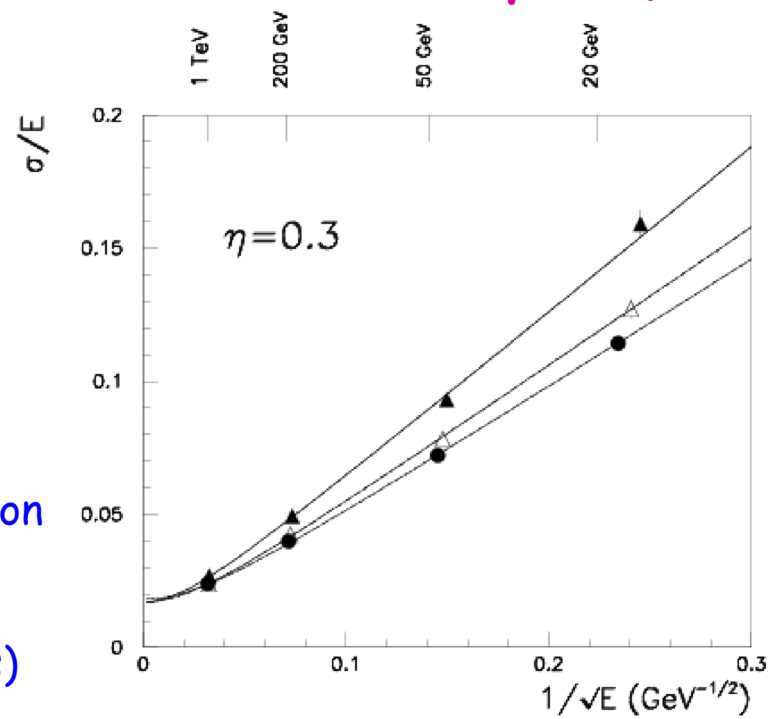
Charged particle multiplicity in minimum bias events

Jet Energy Measurement

Barrel Hadron Calorimeter linearity from testbeam data using a weighted energy sum



Jet Energy Resolution from Geant plus detector simulation (incorporating testbeam response)



Some Systematics:

- Jet energy scale ~ 1% from in situ calibration
- Calorimeter linearity (< 3%)
- Jet energy resolution (~2% for high E_t jets)
- Underlying event & jet cone size/algorithm

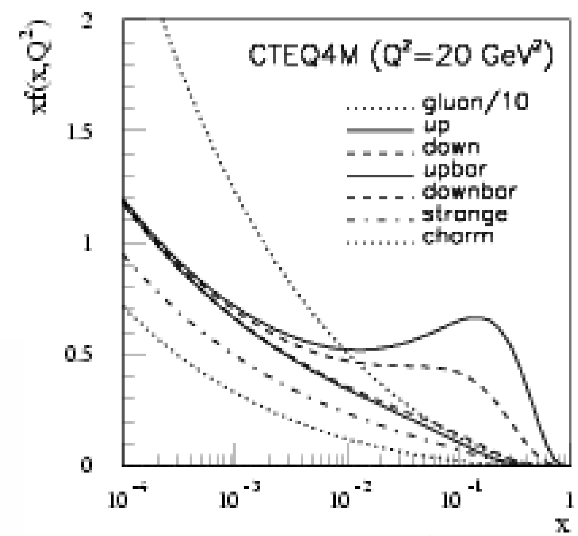
pdf's and Cross-sections

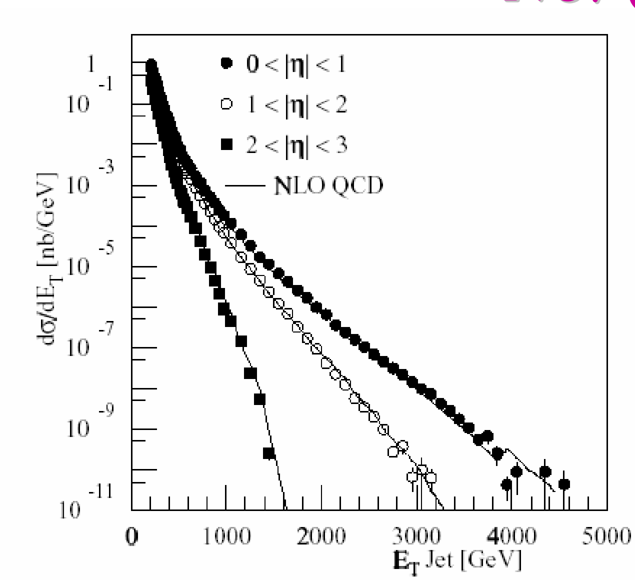
Measure σ and dσ/dE$_t$ for inclusive Jets, photons, W, Z, top.. di-jets, di-photons…

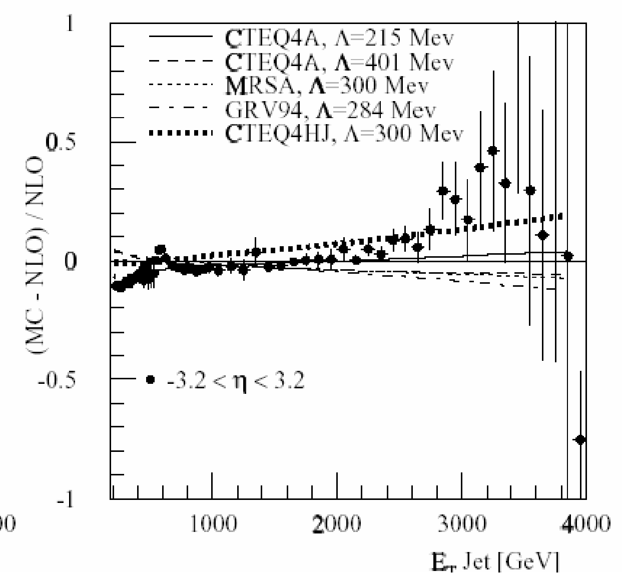
Less non-perturbative contributions

Systematic uncertainties dominate – goal is better than 1% (10%) for Jet Et < 1TeV (>3 TeV)

Check pdf's and normalise MC Generators







For 10 fb-1 expect 10000 events with

E$_t$^{jet} > 1 TeV

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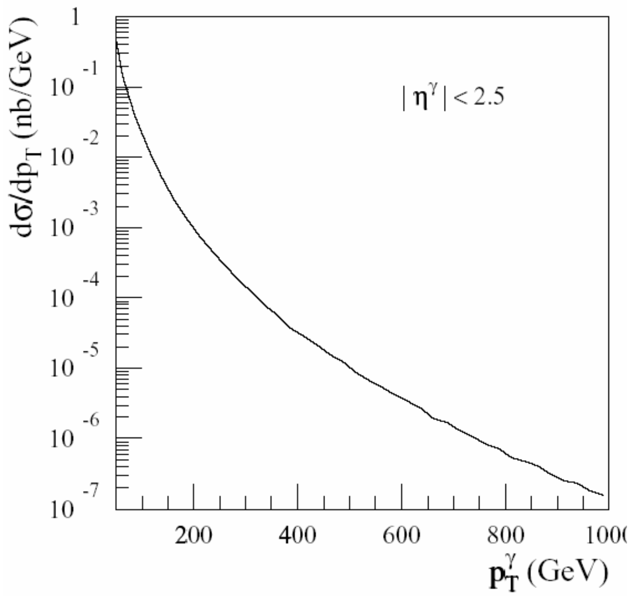
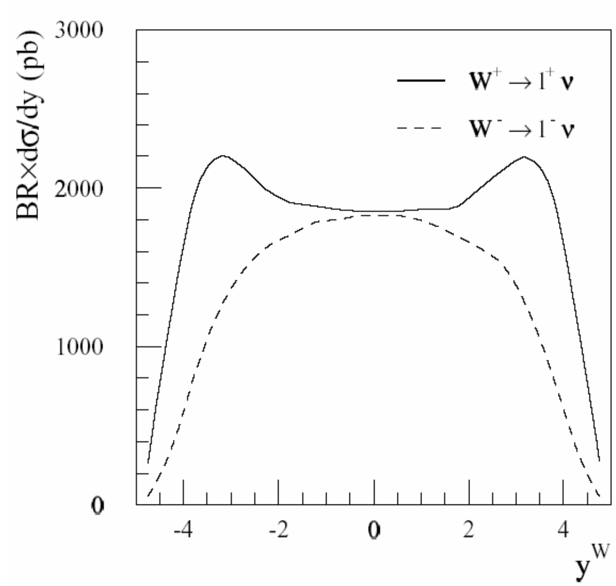
Two More Representative Processes

Inclusive Photon Production



p=(u,u,d) => W^+ production > W^- production at large |y|



For 10 fb^{-1}

~10^8 W -> $l\nu$

~10^4 γ with E_t^γ >500GeV

Sensitive to g(x, Q2) via: QCD Compton: qg -> qγ

Annihilation graph: $q\bar{q}$ -> gγ

$5\times10^{-4} < x < 0.2$ for γ E_t from 40 to 500 GeV

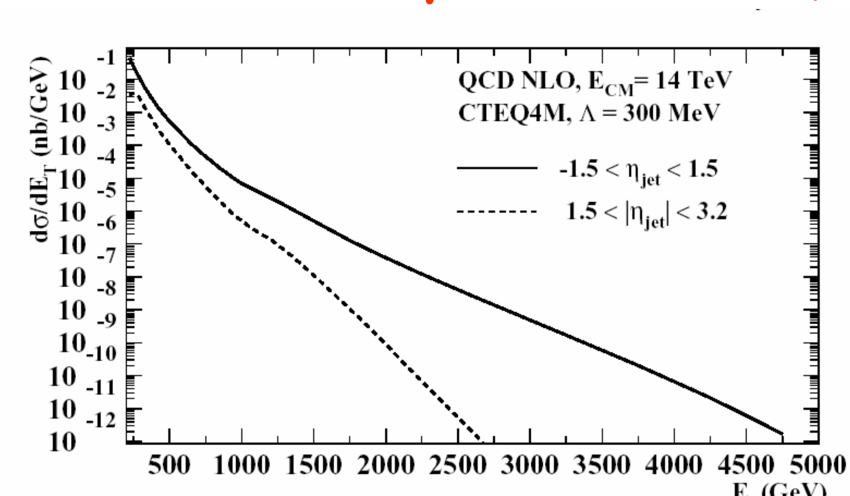
For W Production

$x_1x_2 \sim 3\times10^{-5}$

=> sensitive to sea and valence quark pdfs

Determination of α_s

The "running" of of α_s with energy scale is a key element of QCD

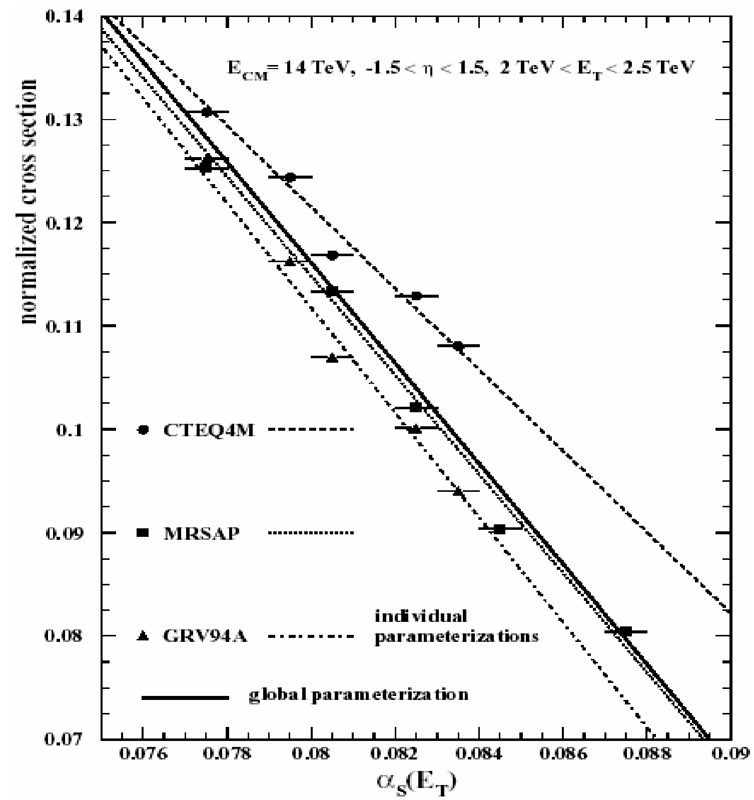


Parameterise inclusive jet cross-section as a function of E_t in two bins of pseudo-rapidity as a function f(E_t, $\alpha_s(E_t)$)

Invert fit to determine as α_s a function of jet E_t (and η)

Can also study other distributions such as the 3-jet to 2-jet ratio, and the ratio of photon to jet production

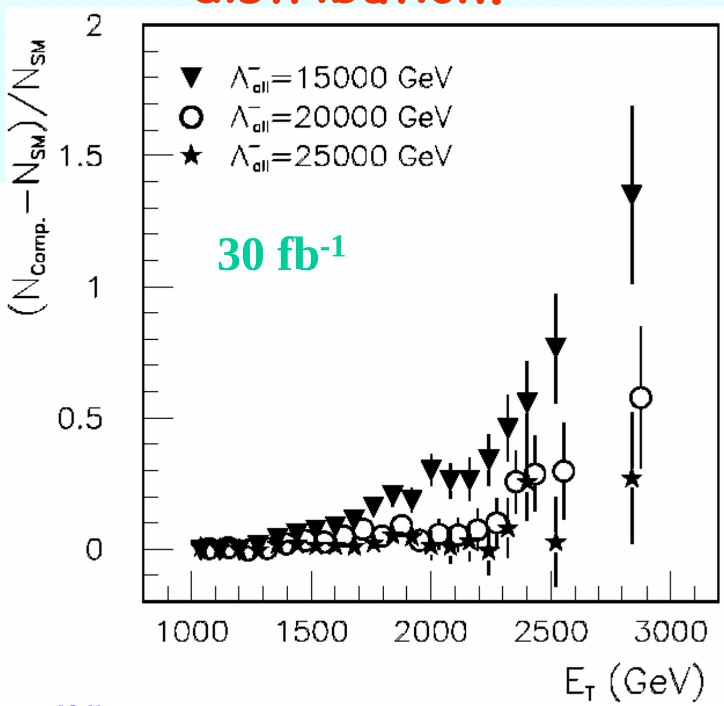
Representative Et Bin



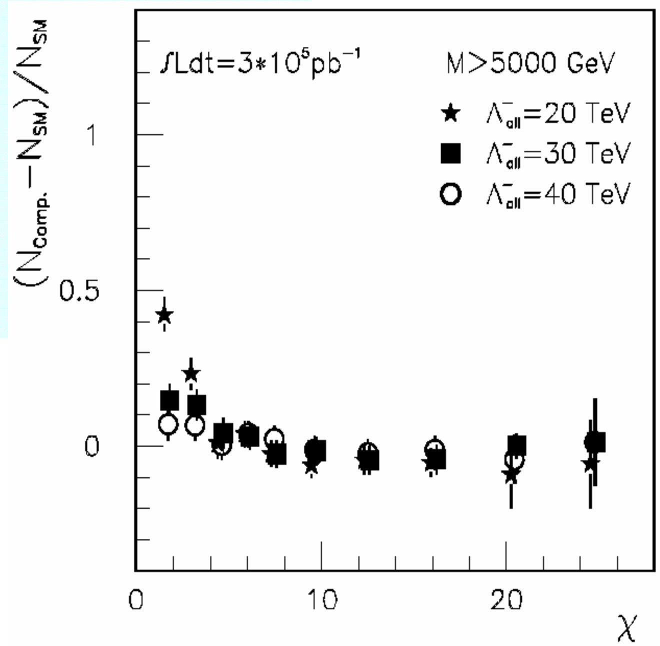
α_s can be determined over a wide kinematic range with a precision of ~10% to scales of order (1TeV) with a contribution to the uncertainty of ~3% coming from pdf's

Compositeness

The deviation from QCD predictions of jet rates. Measure inclusive jet x-section and di-jet angular distribution.



Can decouple new physics from pdf's by measuring jet cross-section as a function of pseudo-rapidity

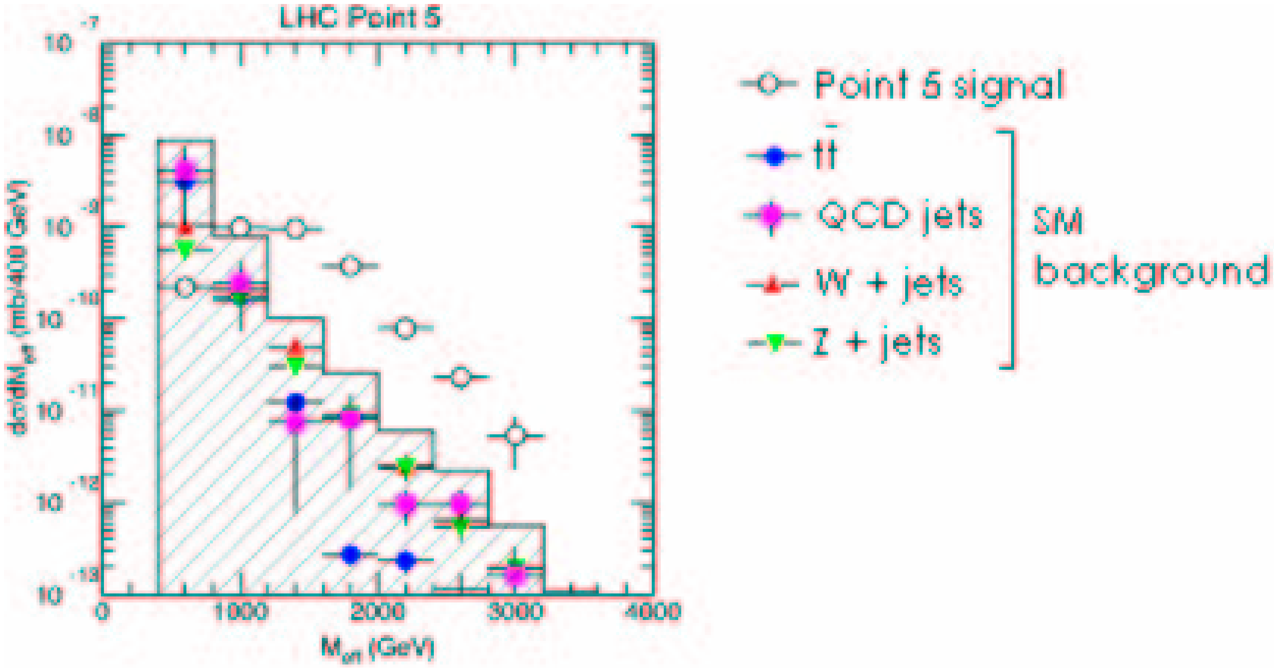


$\chi = e^{|\eta_1-\eta_2|}$ where for $2 \to 2$, $\chi = \frac{1+|\cos\theta^*|}{1-|\cos\theta^*|}$

At 95% cl can exclude compositeness scale < 40TeV for an integrated luminosity of 300 fb-1

SUGRA Mass Scale – An Example

- **Once discovered, determine M_{SUSY} ($\equiv \min(m_{\tilde{q}}, m_{\tilde{g}})$) from energetic jets and E_t^{miss} :** $$M_{eff} = \sum_{j=1}^{4} p_{T,j} + E_T^{miss}$$



QCD as a Background to searches beyond the Standard Model

- **S / B ~ 10 for large M_{eff} with accepted cross section > 1pb .**
- **LHC Point 5, $m_{\tilde{q}} \approx$ 680 GeV/c^2, $m_{\tilde{g}} \approx$ 770 GeV/c^2**

Summary

- **The LHC will provide a unique opportunity to test the PREDICTIVE power of QCD probing regions of x and Q^2 well beyond those studied to date**
- **Almost any measurement one can think of will be relevant:**
  - **measurements of jets and photons**
  - **to measurements of inclusive production of b's, t's, W's and Z's**
  - **to discovery of the Higgs boson and measurement of its properties**
  - **I gave a sampling but had to leave out a lot (e.g. hard diffraction)**
- **In searches for physics beyond the Standard Model, QCD also plays a key role since QCD processes generally are the most important backgrounds to such searches**
- **It will be an EXCITING time for QCD and high energy physics**

Many thanks to my Atlas Colleagues who have produced much of the material used in this presentation