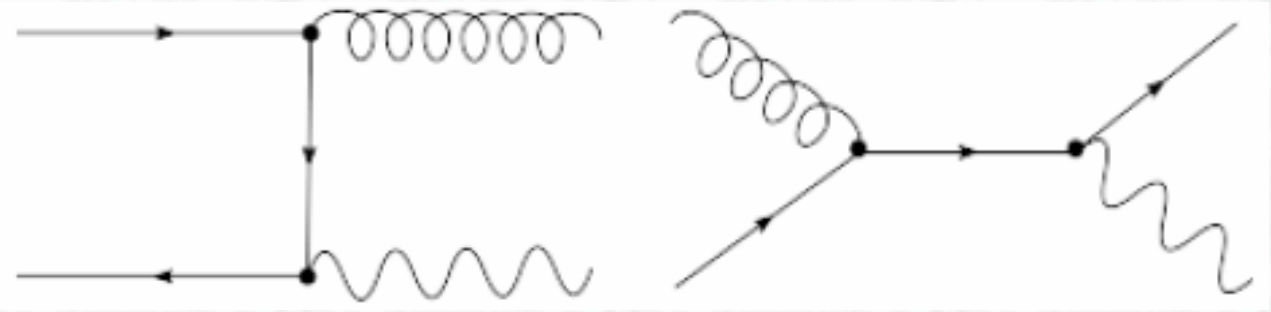
5.5 Direct photon production



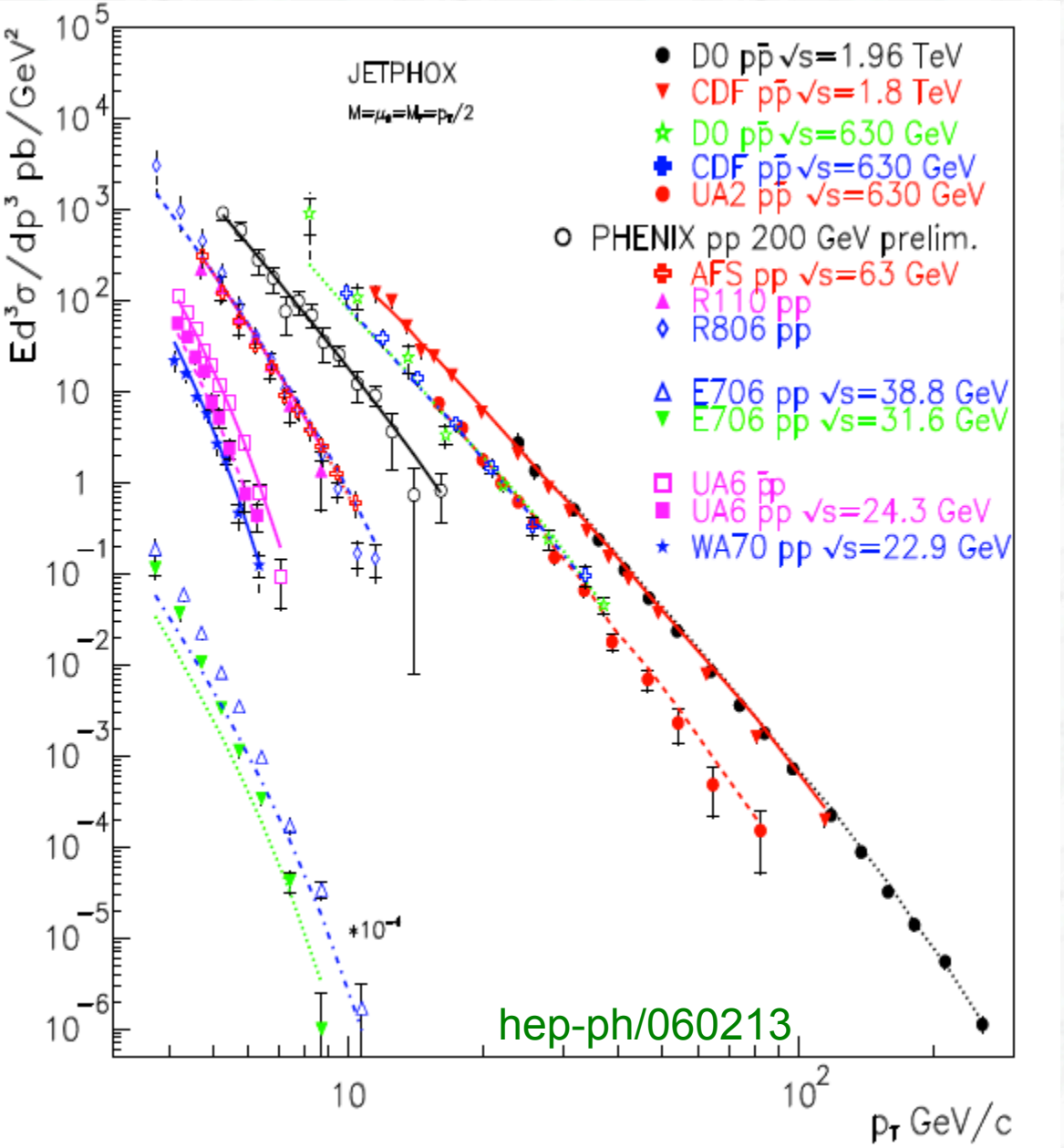
Motivation:

- Test of perturbative QCD
- The gluon-initiated process dominates up to ~150 GeV
  → the high statistics Tevatron and LHC datasets can further constrain the gluon pdf

- Better energy resolution of photons, as compared to jets
  (no decay, fragmentation, no jet algorithm, better el.magn calorimeter resolution)

  → process plays a key role in jet calibration

Direct photon production has been measured in many fixed target and collider experiments:



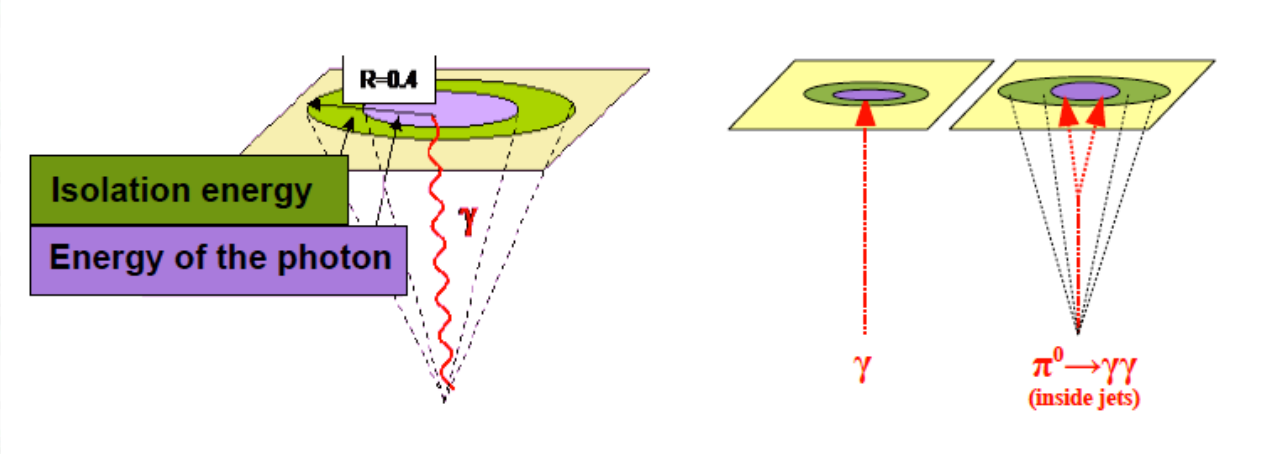
- Highest p_T values from Tevatron experiments so far
- In general, data are well described by NLO pQCD predictions

Some details on the experimental measurement:

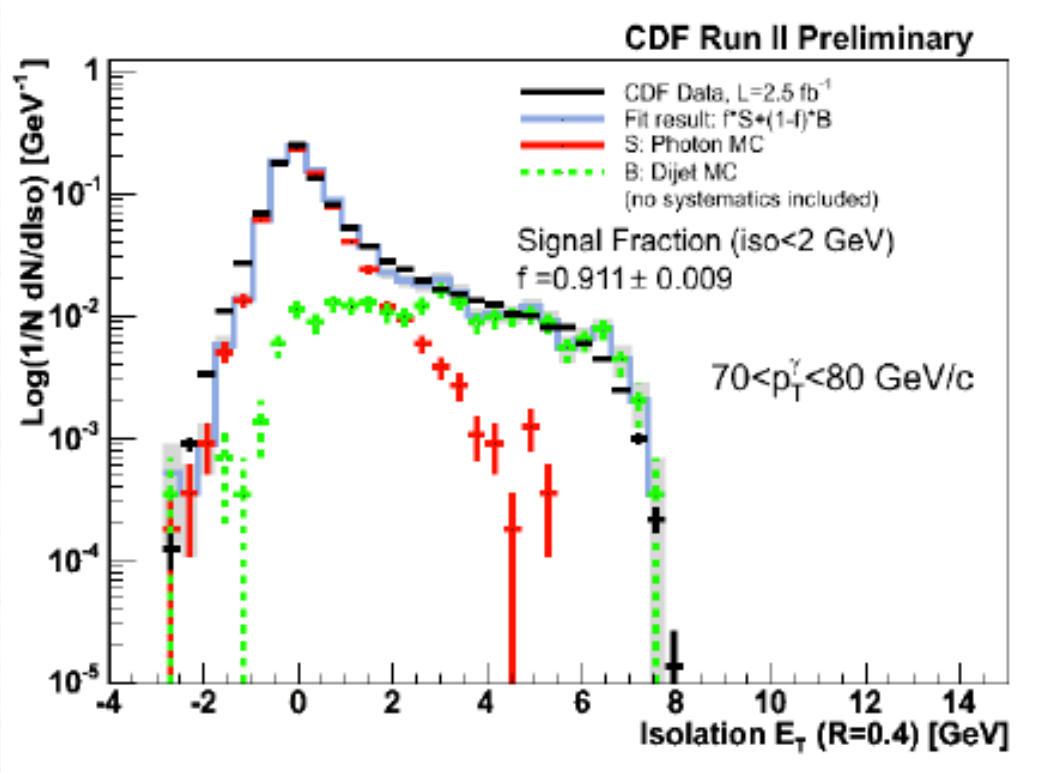
- Main backgrounds: photons from final state radiation off quarks
  → di-jet production is a background

  decays of high p_T π^0 mesons inside jets
  → di-jet production is a background

- To suppress backgrounds: require isolated photons
  (cut on energy deposited in a cone of R=0.4 around the photon)

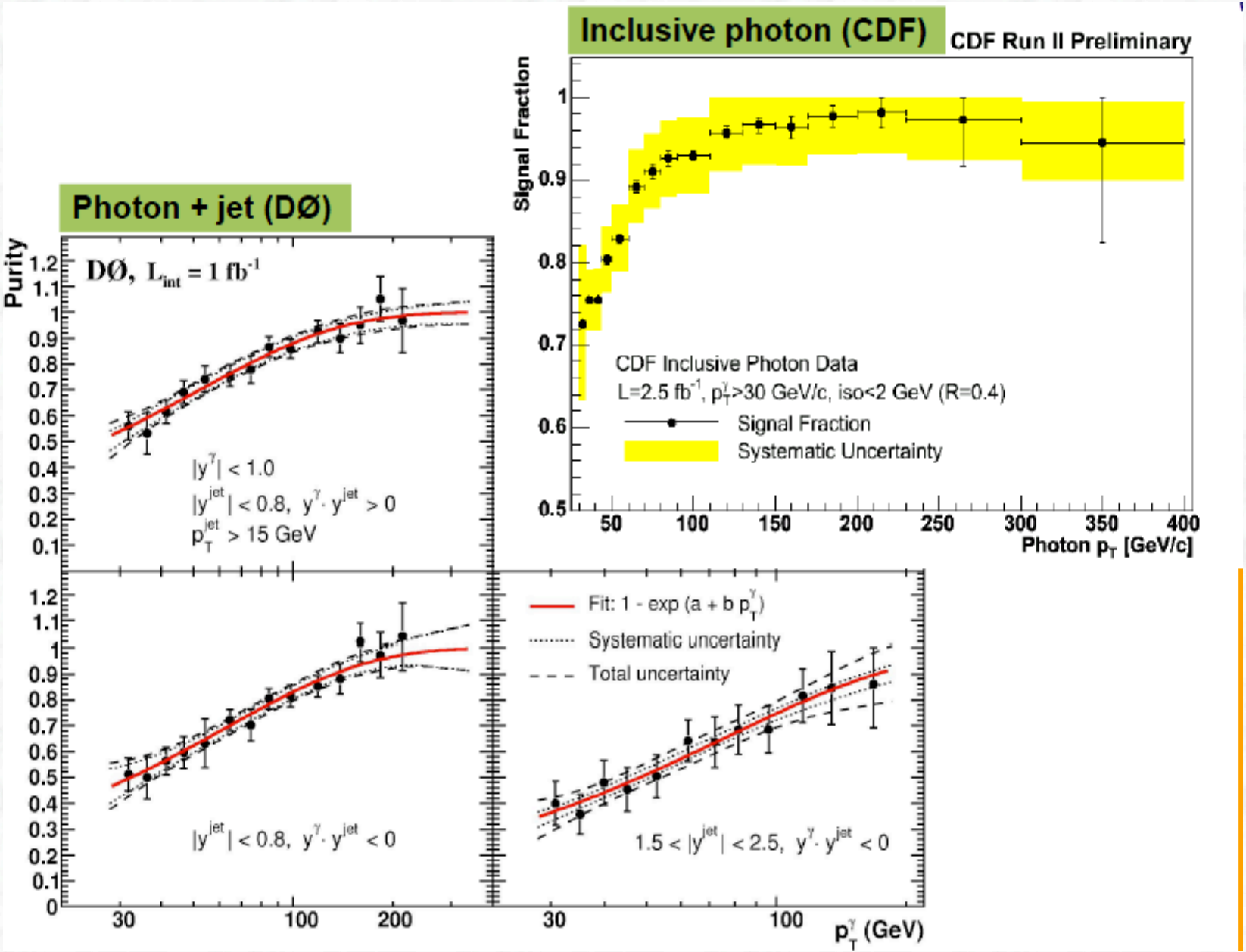


Example: Isolation variable, as measured in the CDF experiment

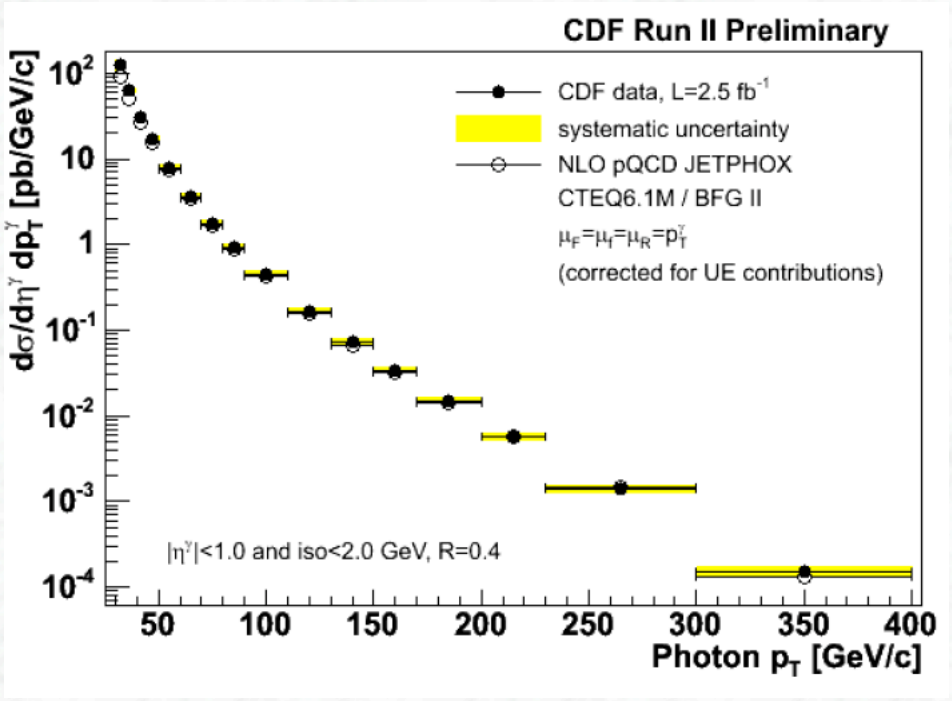


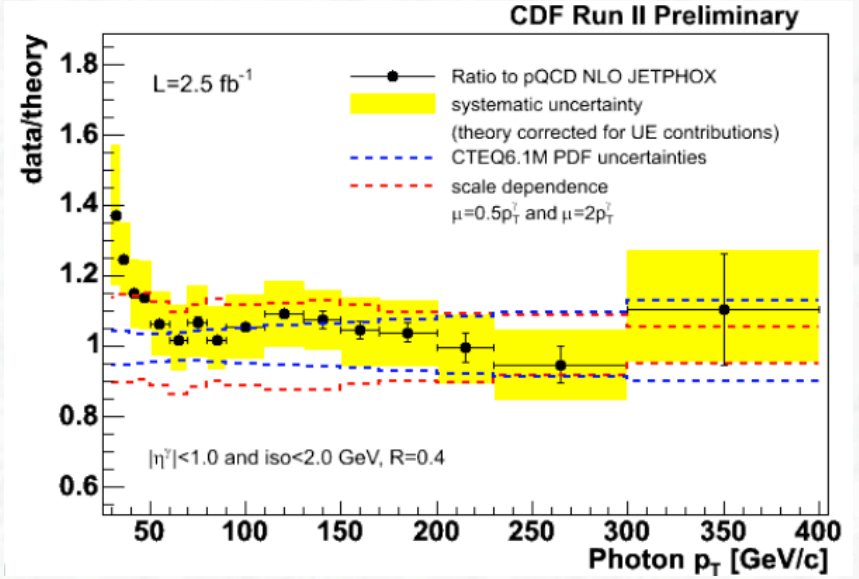
- Photon fraction is determined from a fit to the experimental data (templates, i.e. shapes of photons from Monte Carlo simulation, cross-checked with electron shapes from Z → ee data)

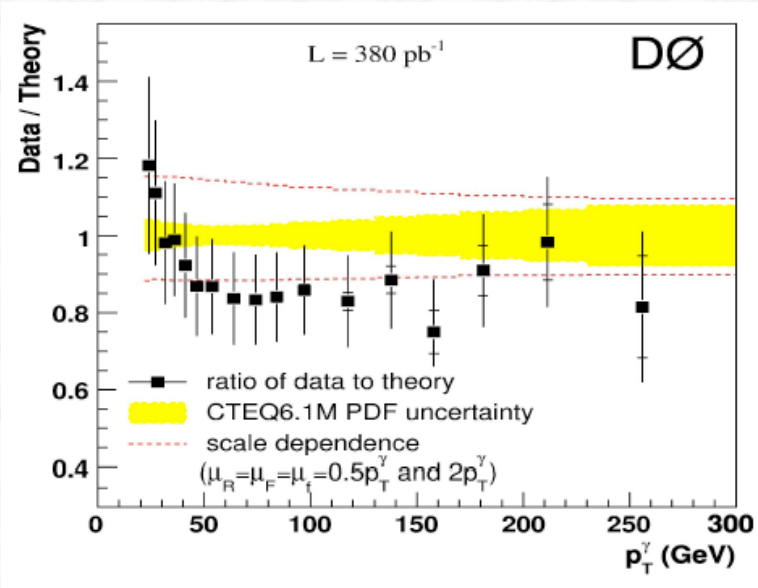
The photon fraction as a function of p_T:



Measured photon p_T spectra at the Tevatron:



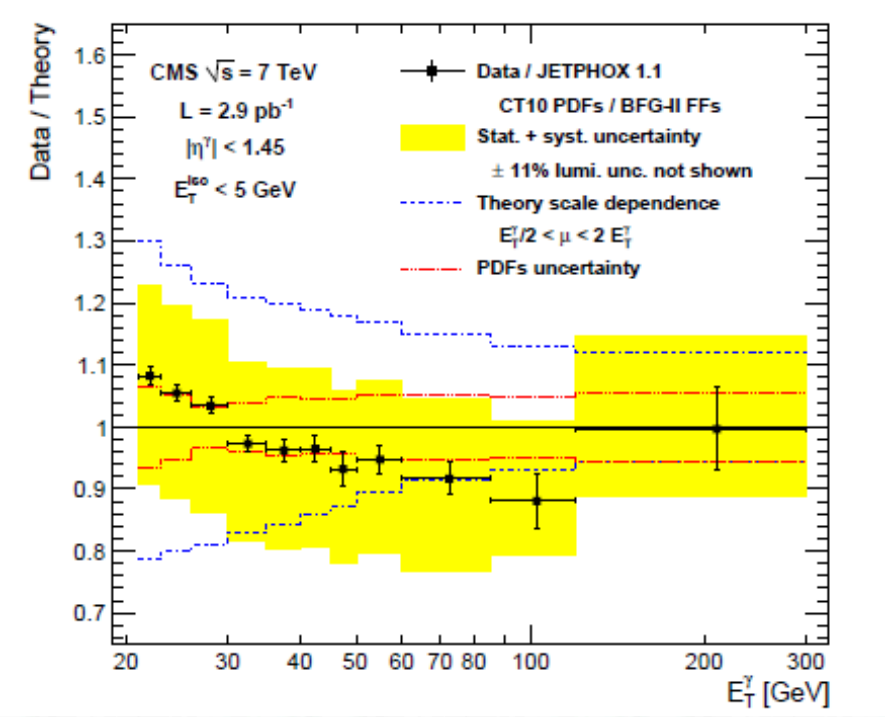


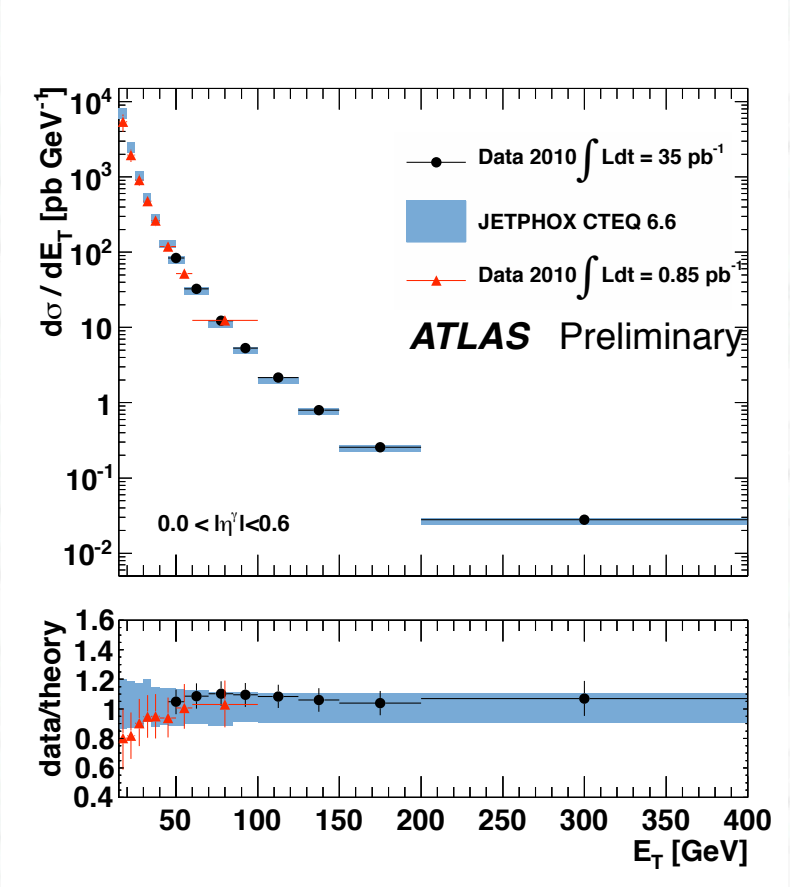


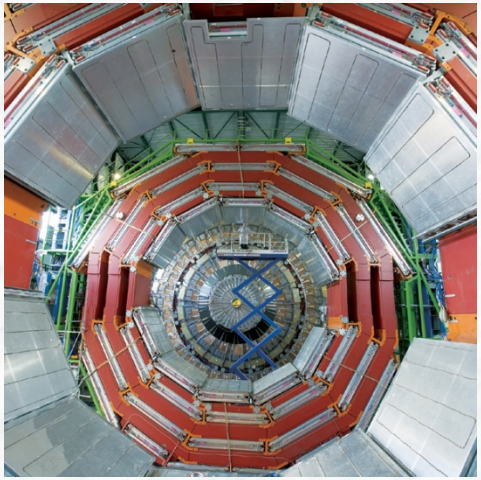
- In general good agreement within the experimental and theoretical uncertainties
- However, both experiments measure an excess (data/theory) in the low p_T region;

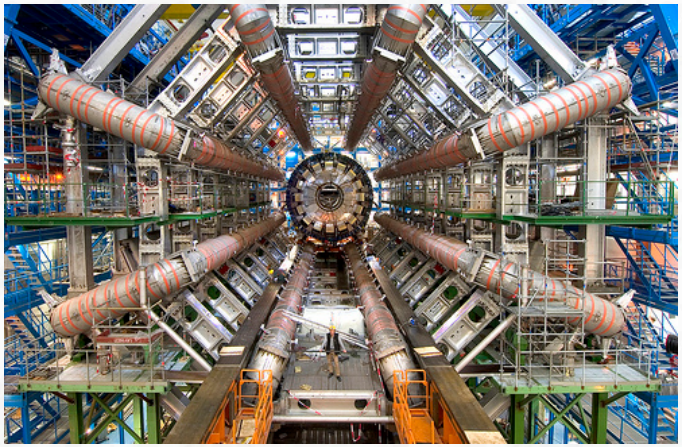
  origin: unclear !!

Photons at the LHC

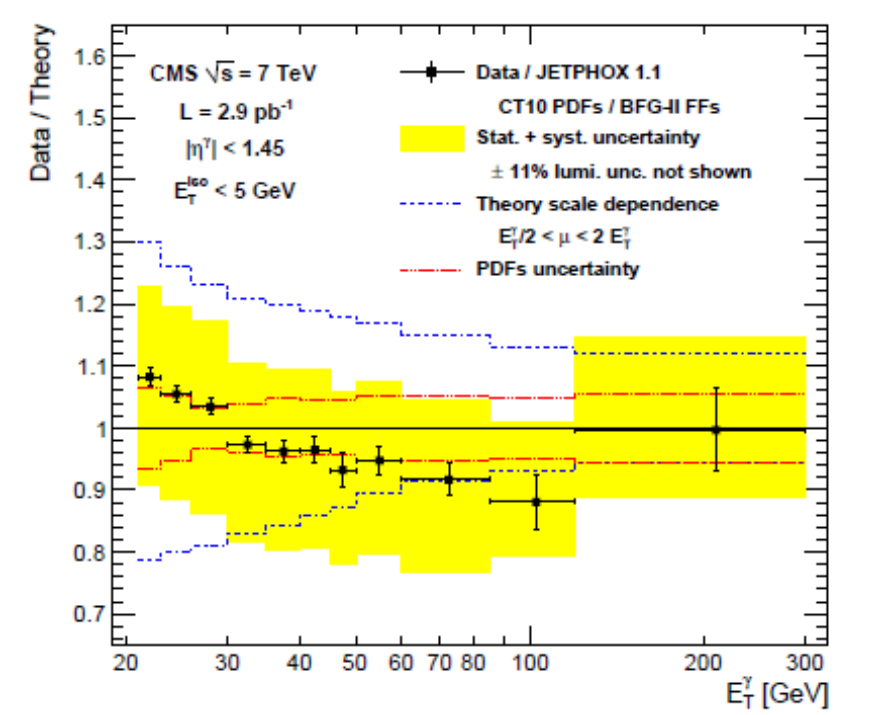


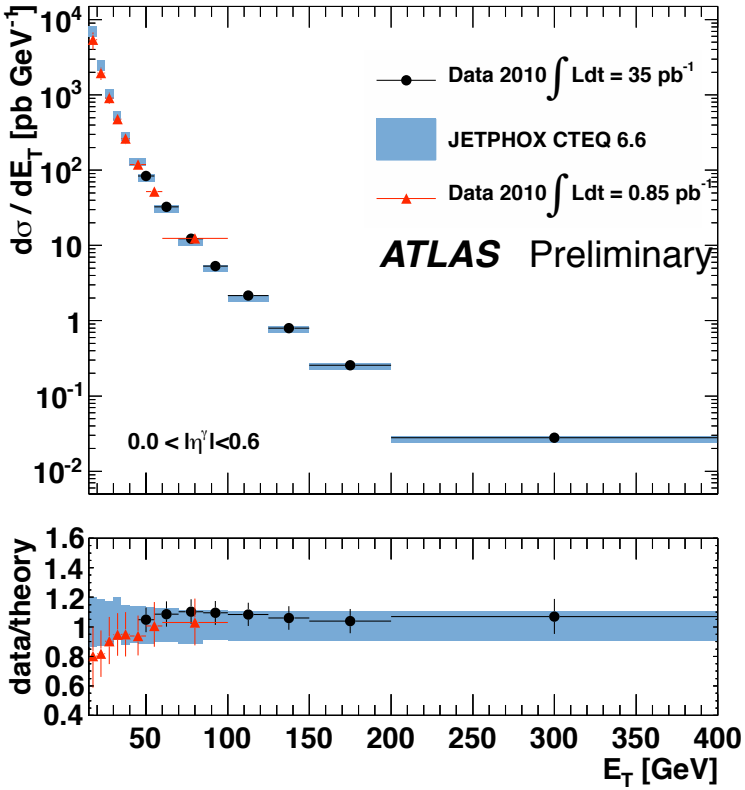






Photons at the LHC

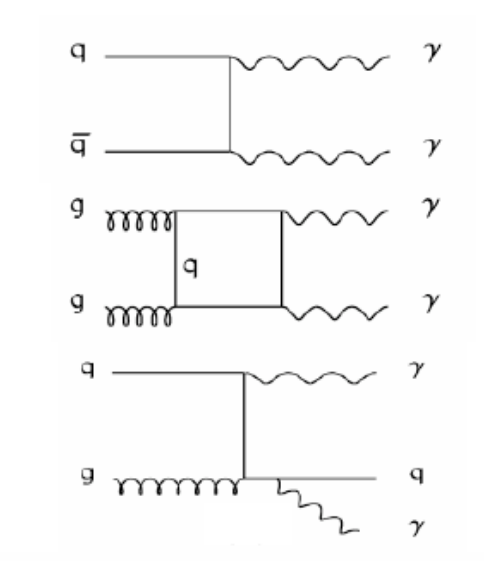




- There is still something not understood going on below 50 GeV
  - However, due to different energies, effects from pdf and matrix elements can be separated (LHC probes a different x-range for the same p_T value)

- The additional kinematic reach of the LHC is apparent
  - For the same x_T, the LHC goes out 3.5x farther in E_T.
  - With only 1% of the data, the kinematic reach is the same as the Tevatron's
  - This represents 1-10% of the data the LHC has already collected
  - The troublesome region below 50 GeV is a tiny piece of what will be studied

The next step: Di-photon production

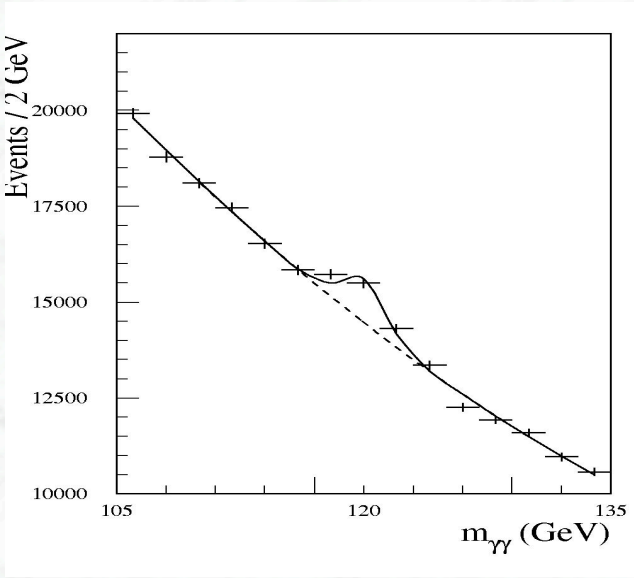


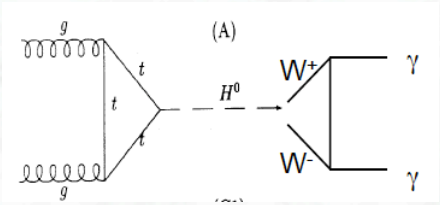
- Direct probe of qq → γγ process (QED)
- Sizeable gg-box contribution

- Irreducible background in searches for new physics

  - Higgs bosons
  - SUSY searches with light gravitinos,….

  …..

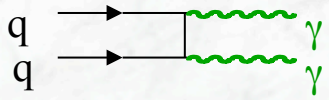




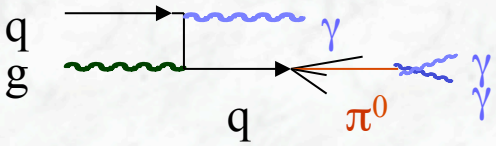
$H \rightarrow \gamma\gamma$

Main backgrounds:

$\gamma\gamma$ irreducible background



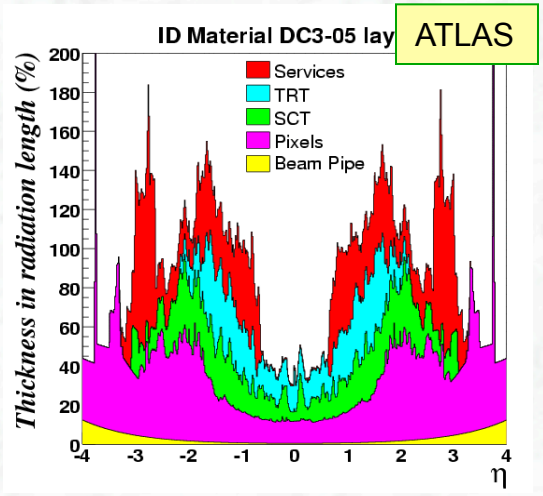
γ-jet and jet-jet (reducible)

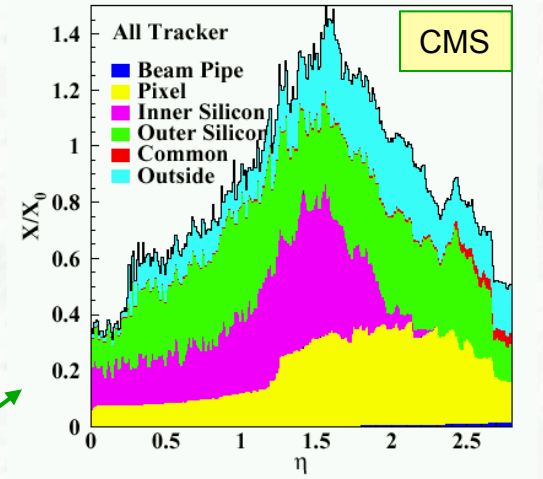


$\sigma_{\gamma j+jj} \sim 10^6 \, \sigma_{\gamma\gamma}$ with large uncertainties

$\rightarrow$ need $R_j > 10^3$ for $\varepsilon_\gamma \approx 80\%$ to get

$\sigma_{\gamma j+jj} \ll \sigma_{\gamma\gamma}$





- Main exp. tools for background suppression:
  - photon identification
  - γ / jet separation (calorimeter + tracker)
  - note: also converted photons need to be reconstructed (large material in LHC silicon trackers)

CMS: fraction of converted γs

Barrel region: 42.0 %

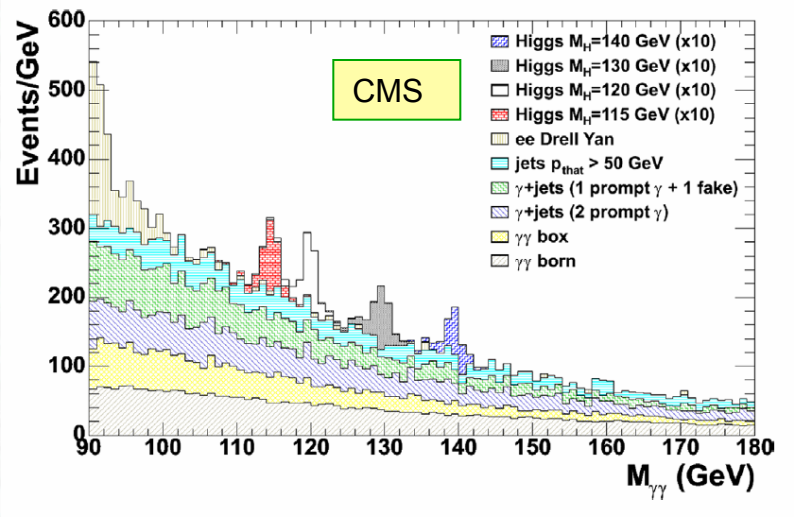
Endcap region: 59.5 %

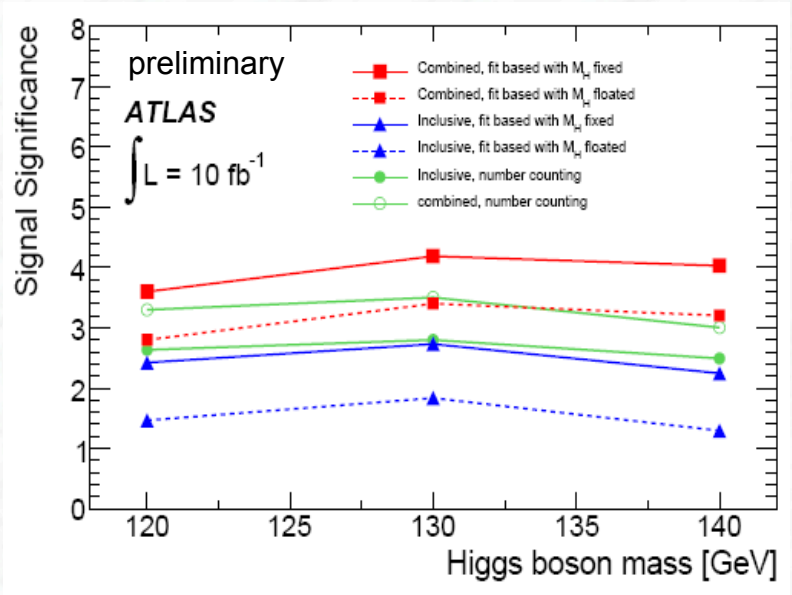
Elements of the analyses:

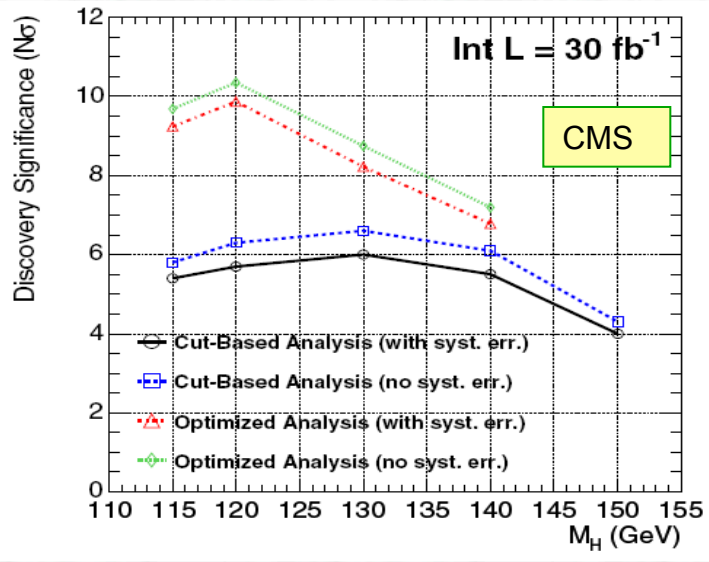
- NLO calculations available
  (Binoth et al., DIPHOX, RESBOS)

- Realistic detector material

- NLO K factors (for signal and background)

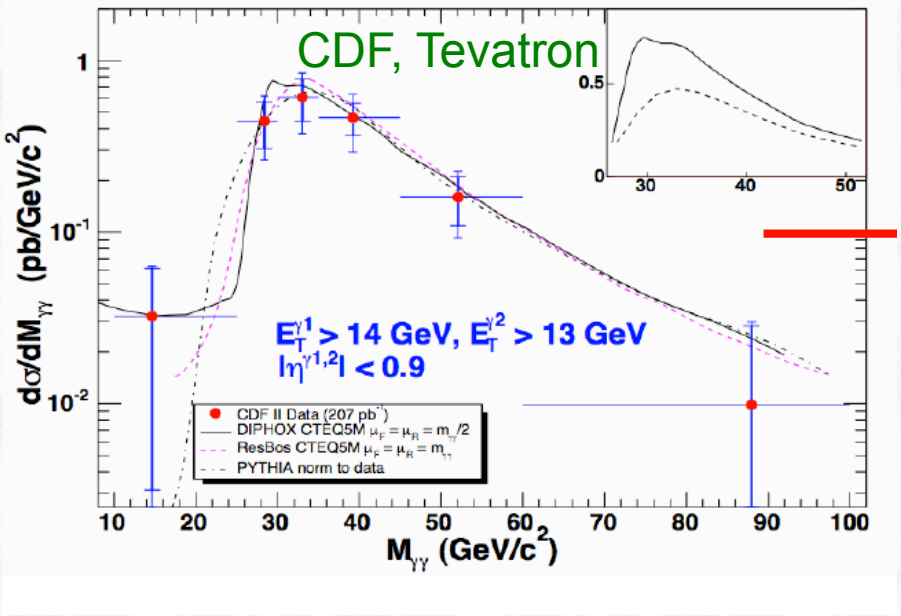


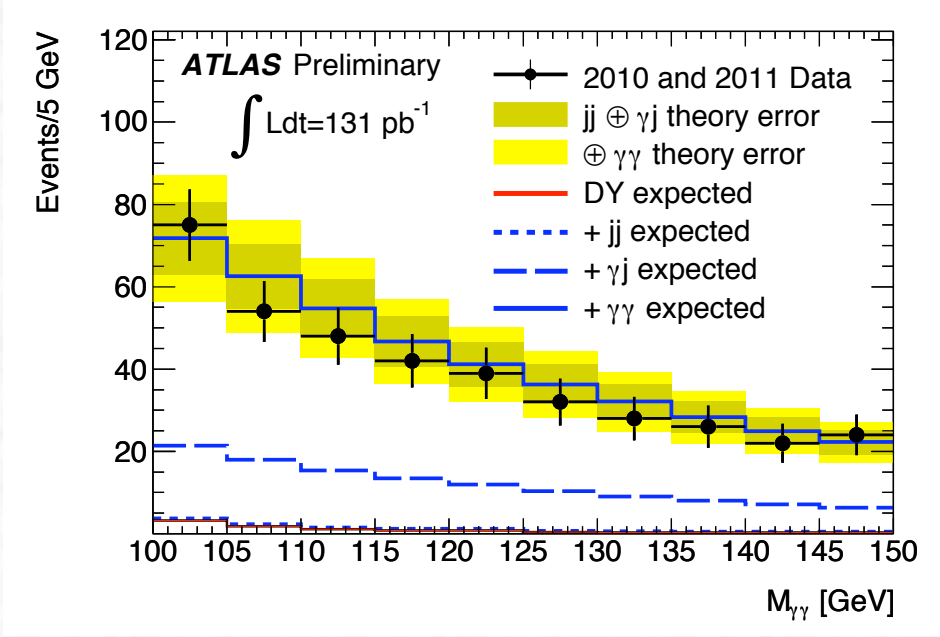




- Comparable results for ATLAS and CMS
- Improvements possible by using more exclusive γγ + jet topologies

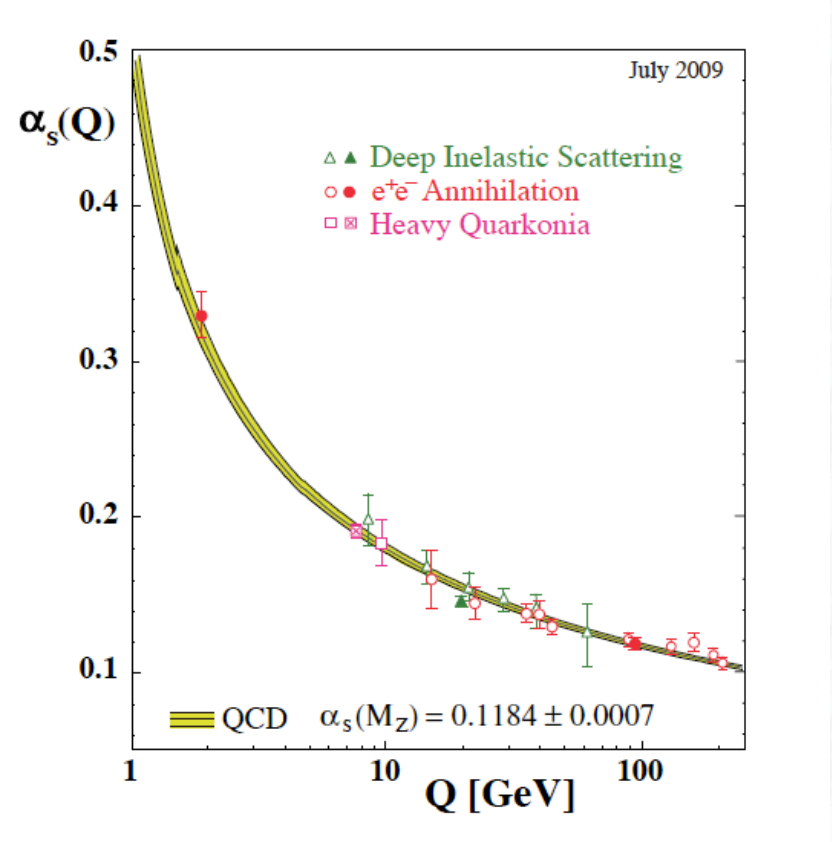
Results on di-photon production from the Tevatron and LHC:

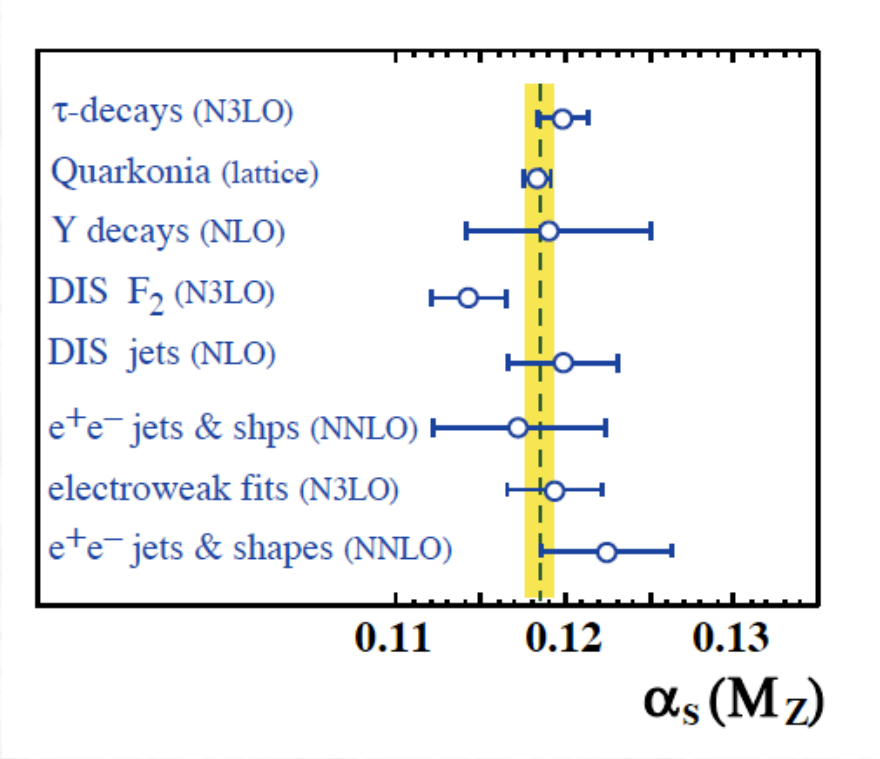




- Data both at the Tevatron and at the LHC agree with expectations
- Higher energy / potential of the LHC already clearly visible (even at this early stage of data taking)
  → LHC is on the way towards Higgs discovery or exclusion !

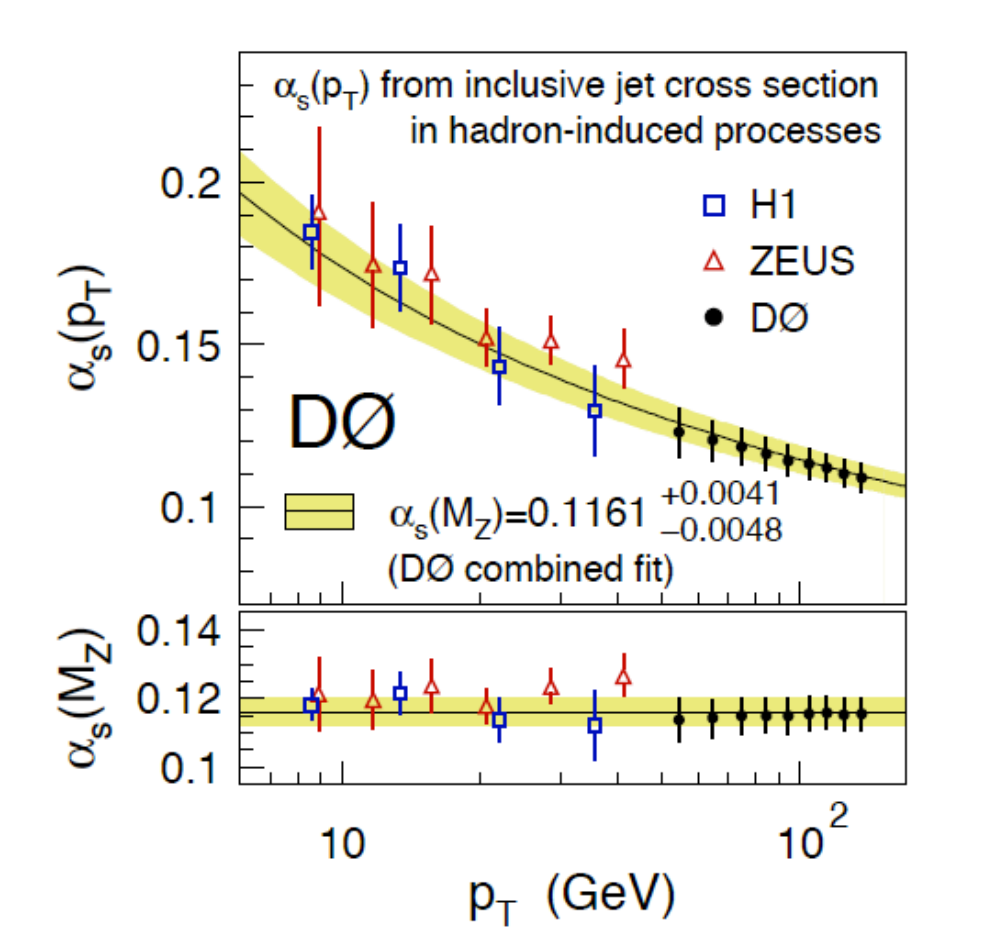
5.6 Measurements of the strong coupling constant α_s



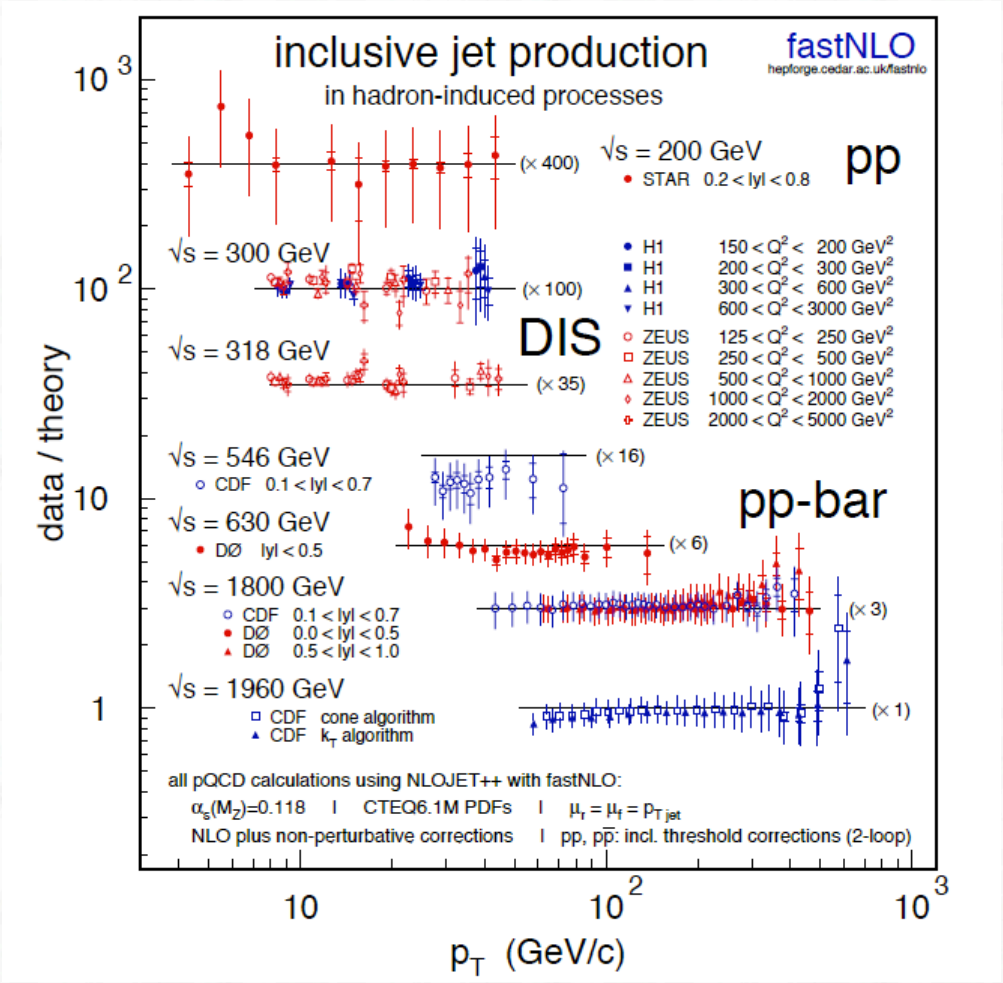


- Running of α_s well established, in agreement with predictions from QCD

World average (2010): $\alpha_s = 0.1184 \pm 0.0007$



The results for α_s (p_T) top and α_s (m_Z) (bottom). The results are based on 22 selected data points. For comparison, results from HERA DIS jet data have been included. The running of a s for the value measured in D0 is superimposed as yellow band. All data points are shown with their total uncertainties, the D0 values are correlated.



Jet cross sections over large energy range and for many hadron collider experiments consistent
with $\alpha_s = 0.118$

A compilation of data-over-theory ratios for inclusive jet cross sections as a function of the jet transverse momentum (pT), measured in different hadron-induced processes at different centre-of-mass energies (Particle Data Group, 2010).
The various ratios are scaled by arbitrary numbers (indicated between parentheses) for better readability of the plot. The theoretical predictions have been obtained at NLO accuracy, for parameter choices and structure functions as indicated at the bottom of the figure.