Parton Distribution Function (PDF)

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What is PDF?

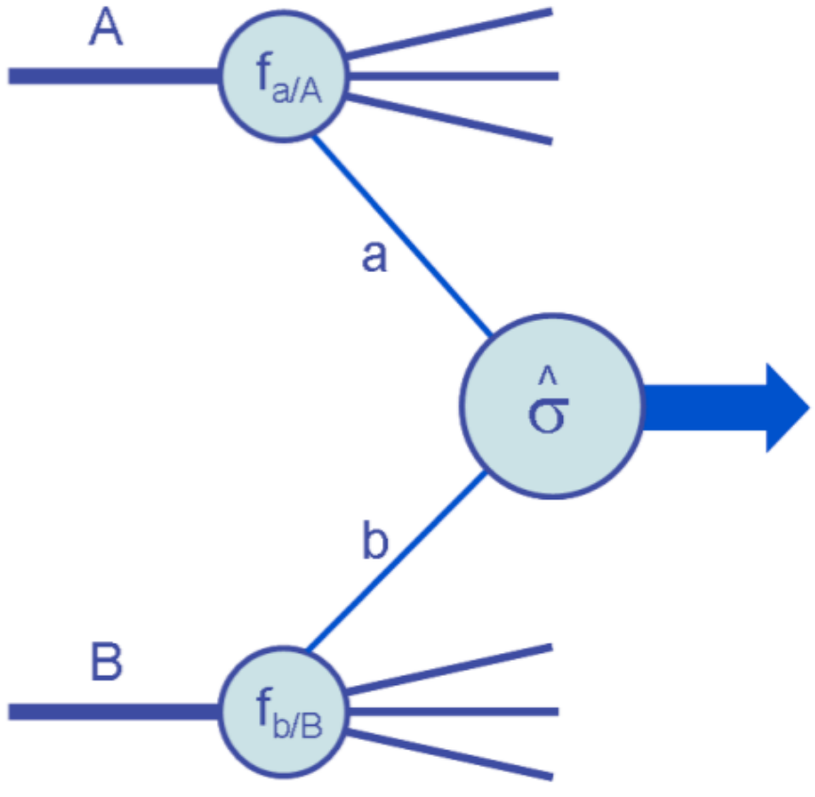
- distribution of momentum fraction x of the partons in a proton in the relevant kinematic energy
- function that partitions hadron momentum to its constituents, *partons*
- universal, can be applied to any processes

What is PDF?

$$\sigma_{AB} = \int dx_a dx_b f_{a/A}\left(x_a, Q^2\right) f_{b/B}\left(x_b, Q^2\right) \hat{\sigma}_{ab\to X}$$

$$X = l^+ l^- \quad ab = q\bar{q}, \bar{q}q$$

Drell-Yan process



A hadronic cross section can be obtained by summing the cross sections of sub-processes with weighting factors

$$f_{a(b)/A(B)}\left(x_{a(b)}, Q^2\right)$$ **PDF**

$$x \equiv \frac{p}{p_{max}} \qquad Q : \text{momentum transfer}$$

How do we get PDF?

- Because of the inherent non-perturbative effect in a QCD binding state, PDFs cannot be obtained by pQCD
  - get the parameters for PDF in certain regions where are experimentally accessible
  - extrapolation to regions where experimental data not available

What we learn from data

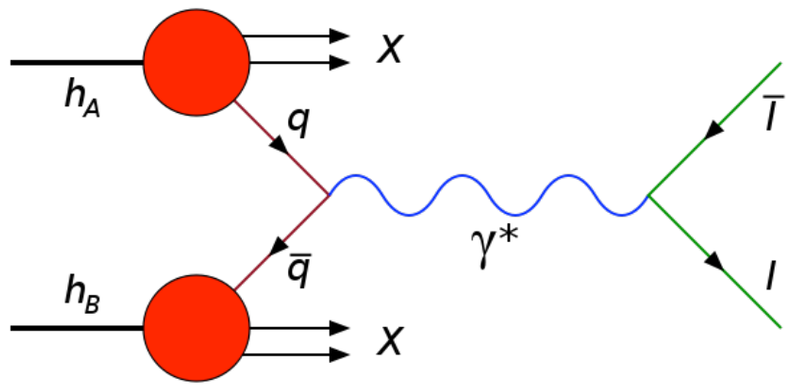
- Lepton-Lepton: $\alpha_s(Q^2)$ and fragmentation functions of partons into hadrons
- Lepton-Hadron: DIS structure functions (F_2, F_3)
- Hadron-Hadron: lepton pair production cross sections, gluon distribution function g(x,Q), direct photon and jet final states

Input Data

PDF is determined by global fits to data from

- DIS: main contribution
- e-p: HERA(H1, ZEUS)
- ν-Fe: CCFR(Chicago Columbia Fermilab Rochester, E770)
- μ-p, μ-d: BCDMS(Bologna-CERN-Dubna-Munich-Saclay),
  NMC(New Muon Collaboration, NA37)

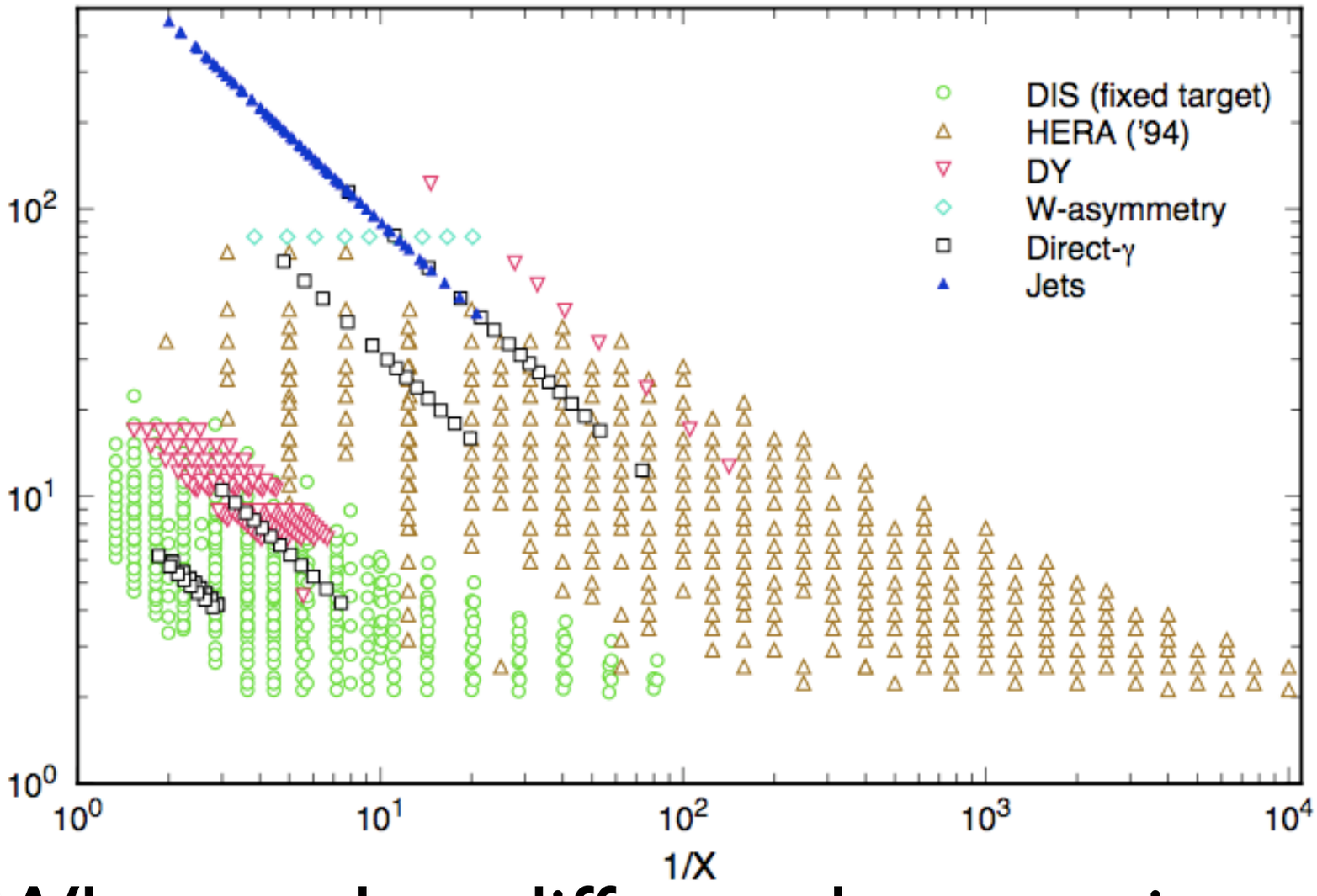
Input Data



- DY
  - p-Cu->$\mu^+\mu^-$X: E605
  - p-p -> $\mu^+\mu^-$: Nusea(Nucleon Sea, E866)
- Hadronic jet: CDF, important for high x gluon distribution
- W asymmetry : CDF

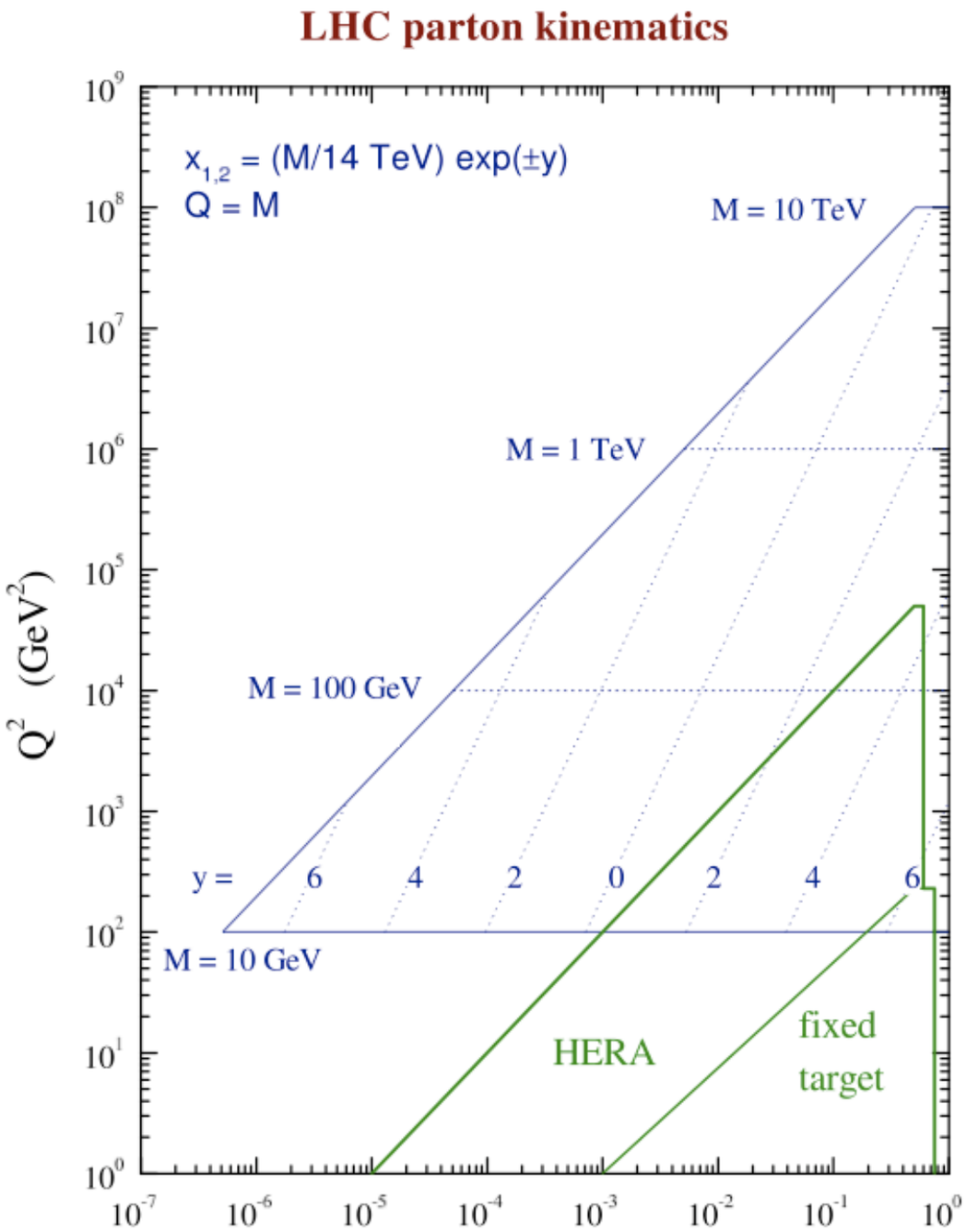
Q^2 vs. 1/x

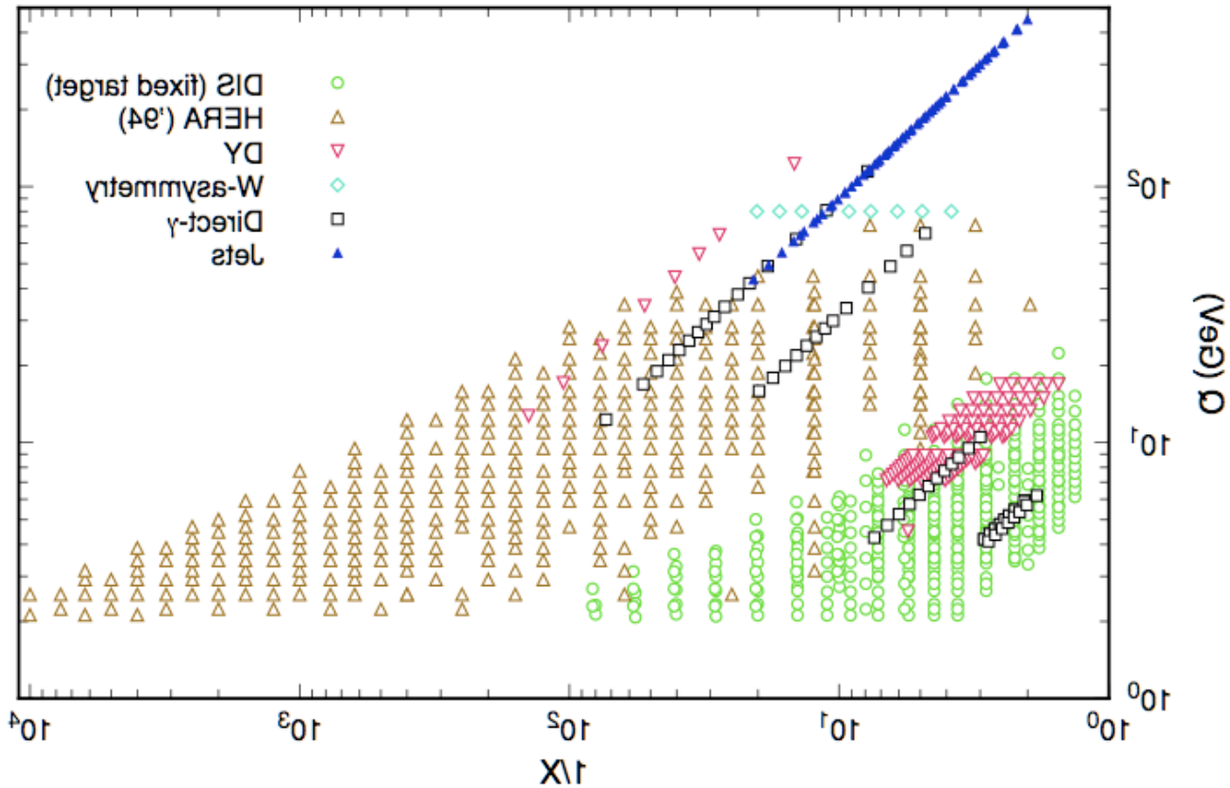
kinematic coverage of current data



Why are they different by experiments ?

Q^2 vs. x of LHC





LHC coverage

Evolution to high Q^2 region

$$Q^2 \frac{dG_q\left(x,Q^2\right)}{dQ^2} = \frac{\alpha_s\left(Q^2\right)}{2\pi} \int \frac{dy}{y} \left(P_{qq}(y) G_q\left(\frac{x}{y},Q^2\right) + P_{qg}(y) G_g\left(\frac{x}{y},Q^2\right)\right)$$

$$Q^2 \frac{dG_g\left(x,Q^2\right)}{dQ^2} = \frac{\alpha_s\left(Q^2\right)}{2\pi} \int \frac{dy}{y} \left(\sum_q P_{gq}(y) G_q\left(\frac{x}{y},Q^2\right) + P_{gg}(y) G_g\left(\frac{x}{y},Q^2\right)\right)$$

- DGLAP-based NLO(and NNLO) pQCD
- DGLAP(Dokshitzer–Gribov–Lipatov–Altarelli–Parisi) eqn: Coupled set of equations whose solutions show how the PDFs change with variations in the scale Q

Global fits

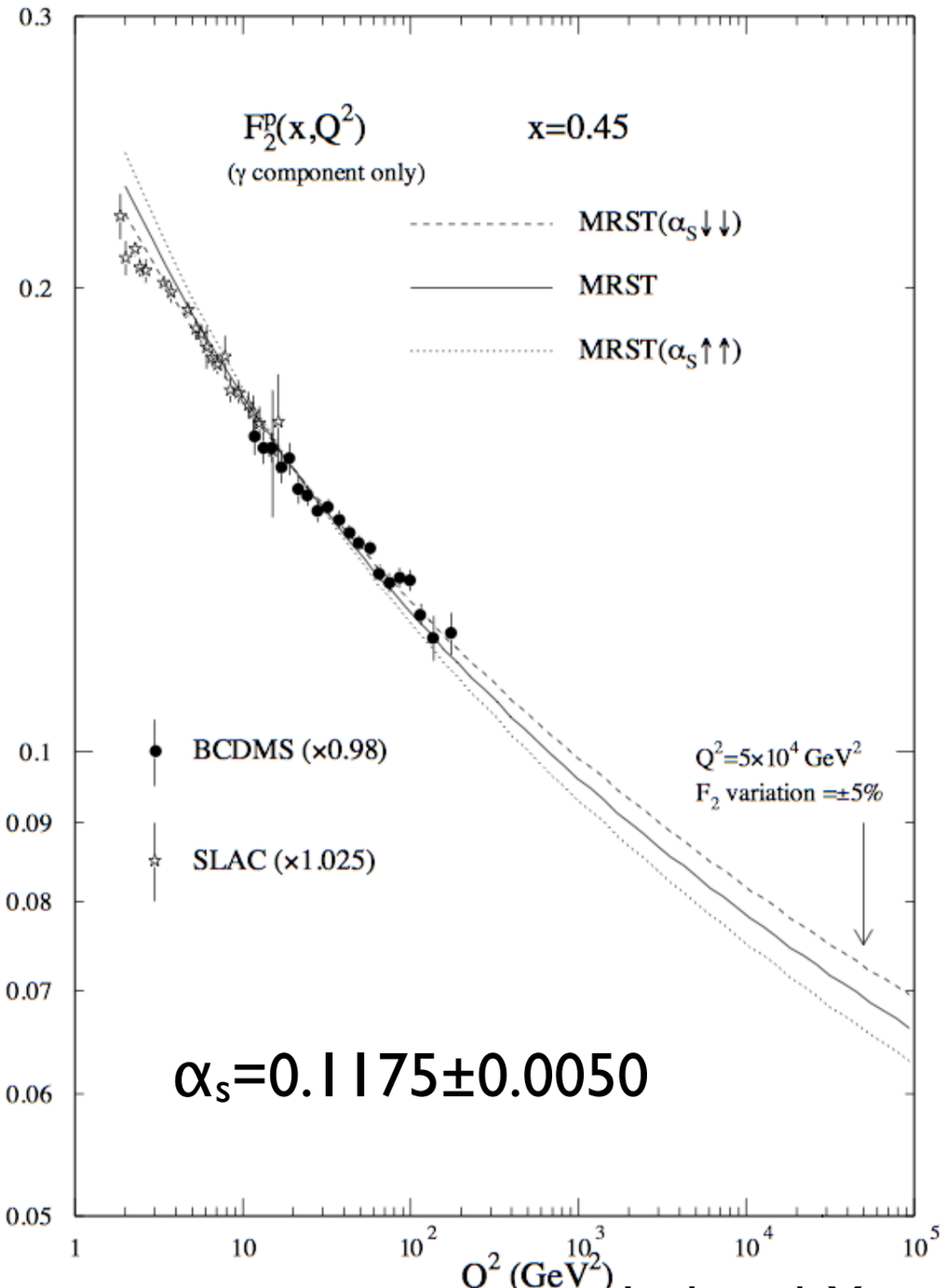
$$F(x, Q_0) = A_0 x^{A_1} (1-x)^{A_2} P(x; A_3, ...)$$

- Q_0: reference value, 1-2 GeV
- A_1: small-x behavior
- A_2: large-x valence counting rules
- $P(x; A_3, ...)$: smooth function adding more flexibility to PDF parameterization

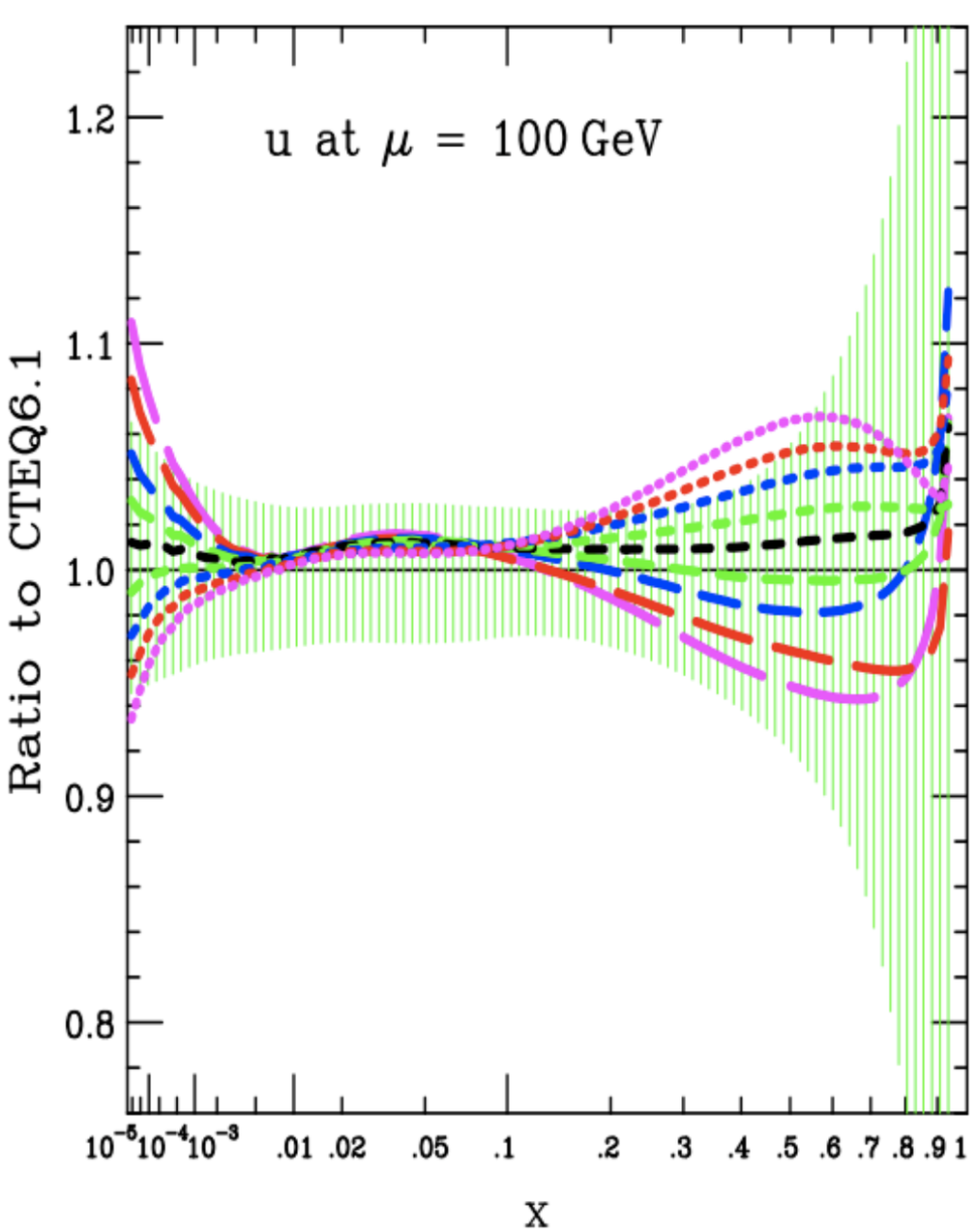
Accuracy of Evolution

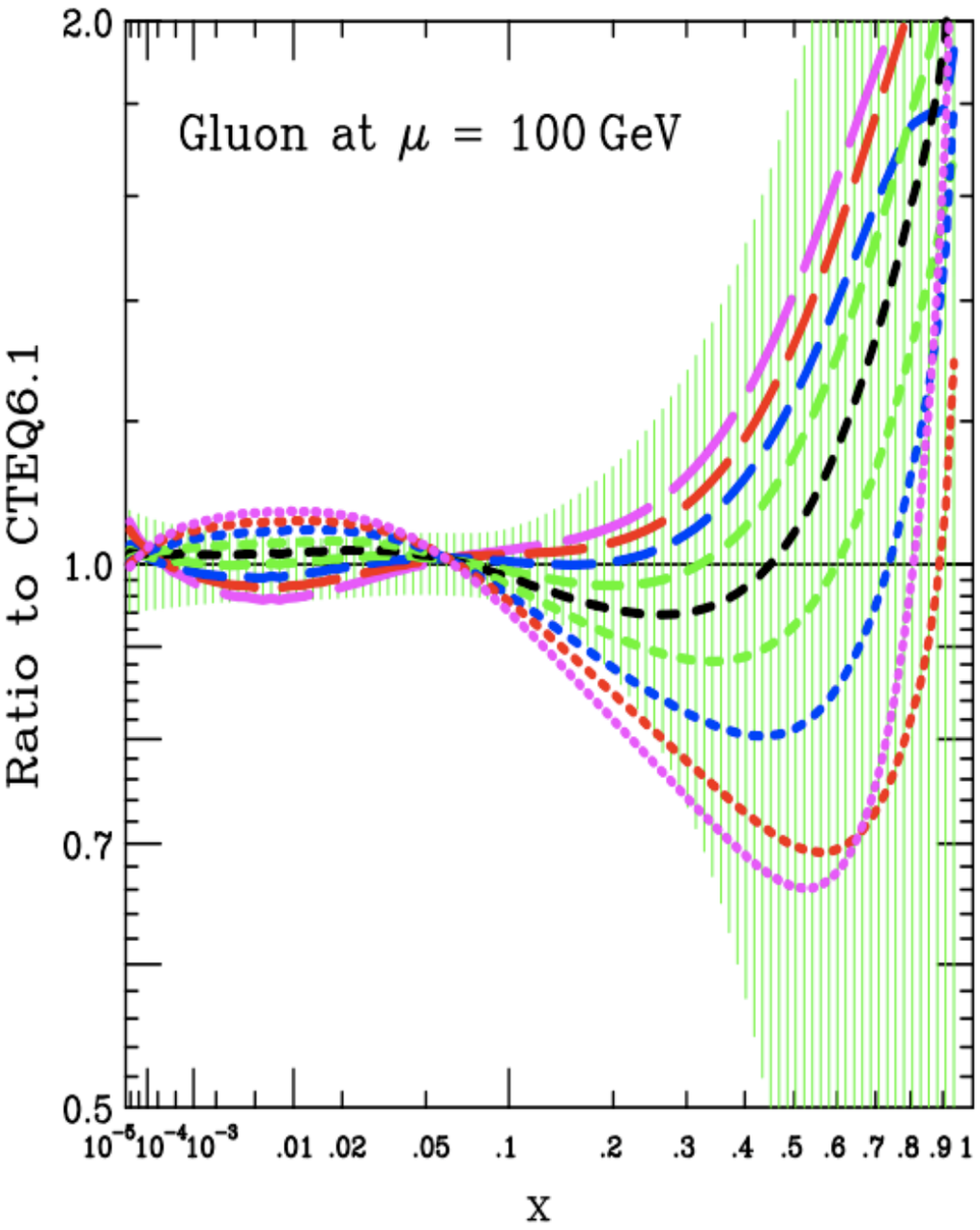
depends on

- accuracy of original measurement
- uncertainty on $\alpha_s(Q^2)$



$\alpha_s(Q^2)$ uncertainty effect on PDF

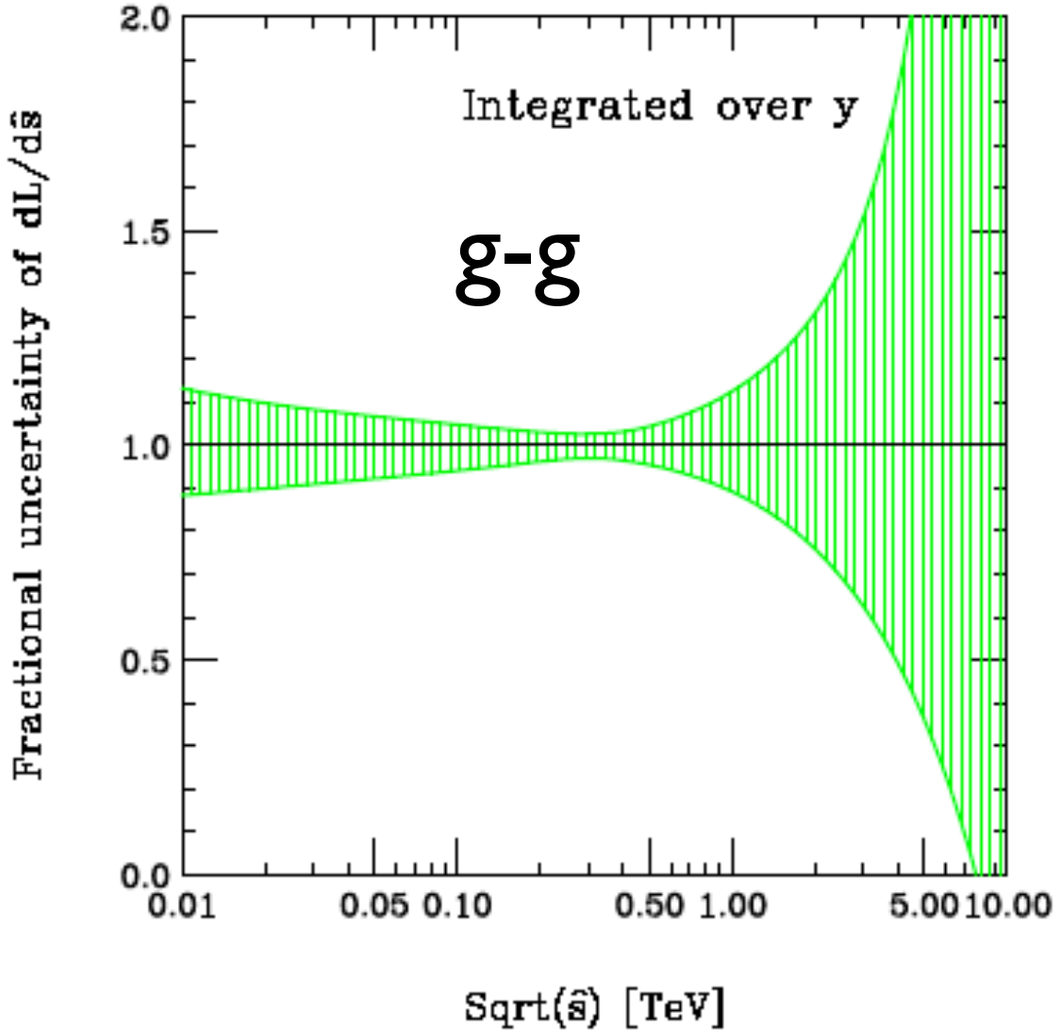


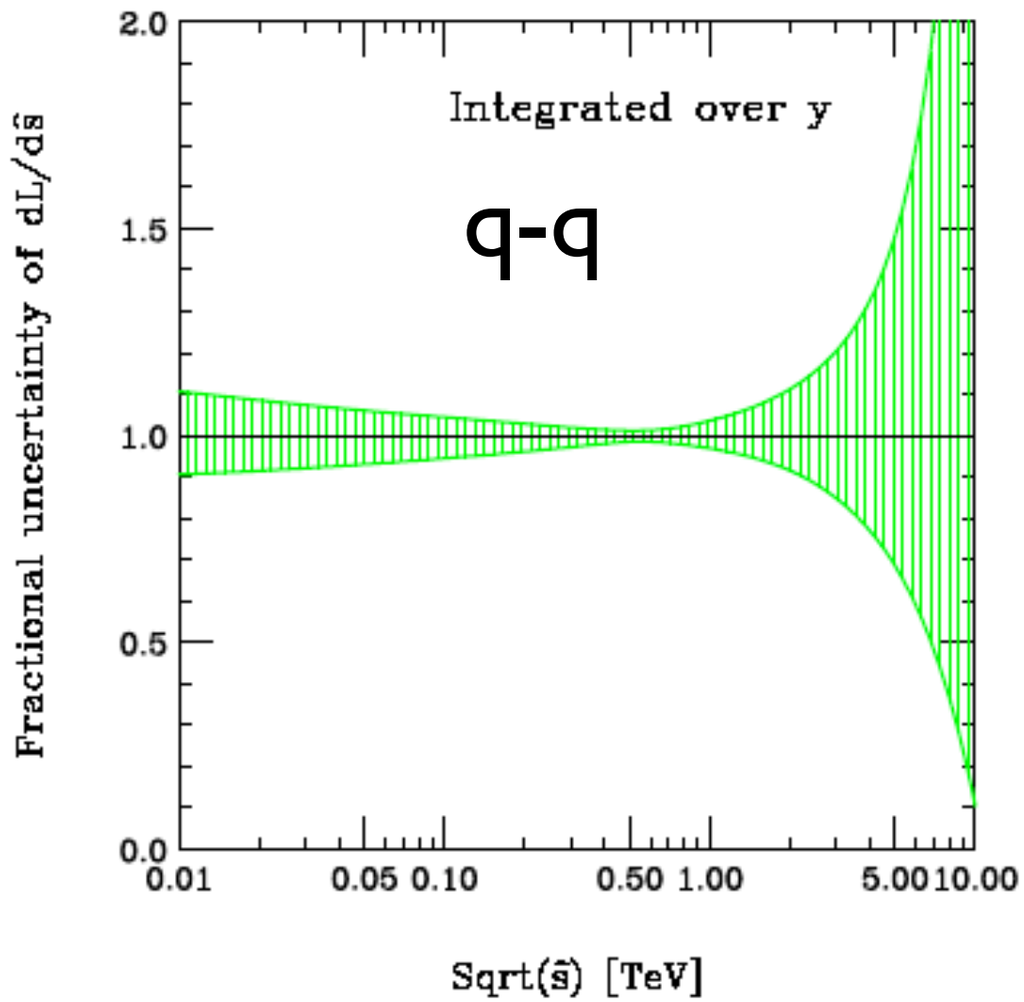


α_s varies from 0.110 (short-dash) to 0.124 (long-dash) in increments of 0.002.

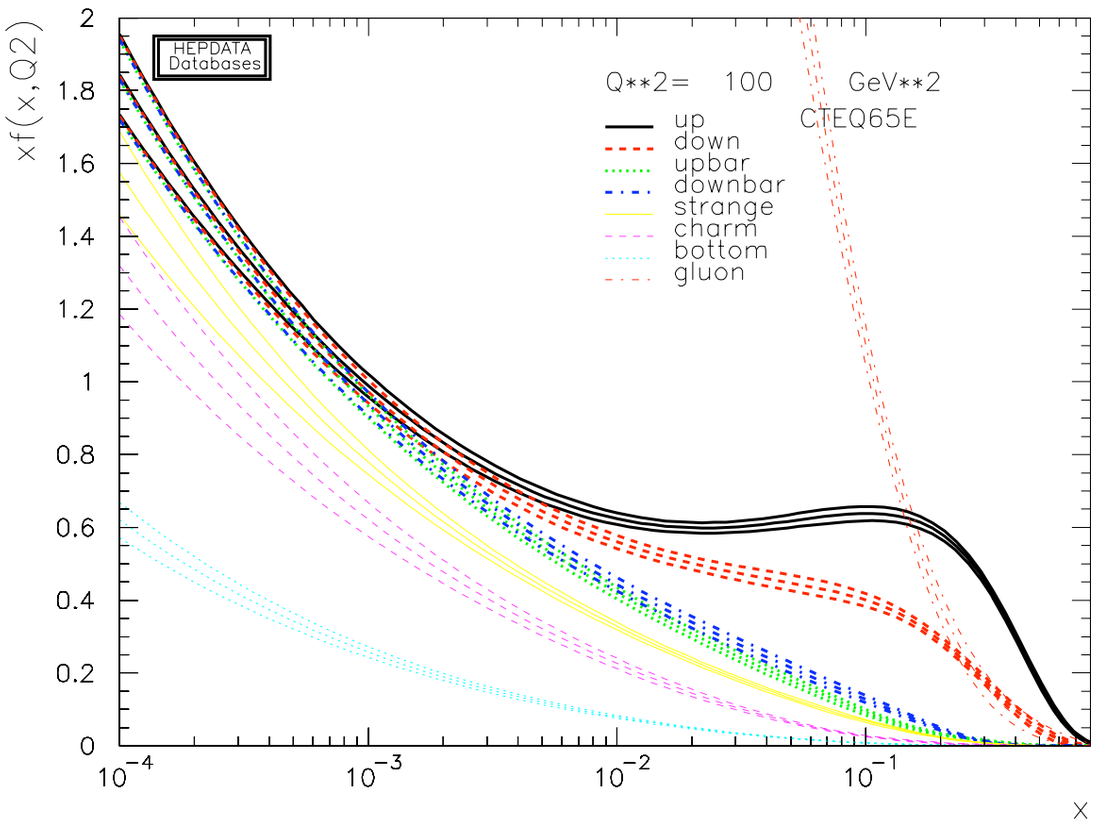
LHC uncertainty

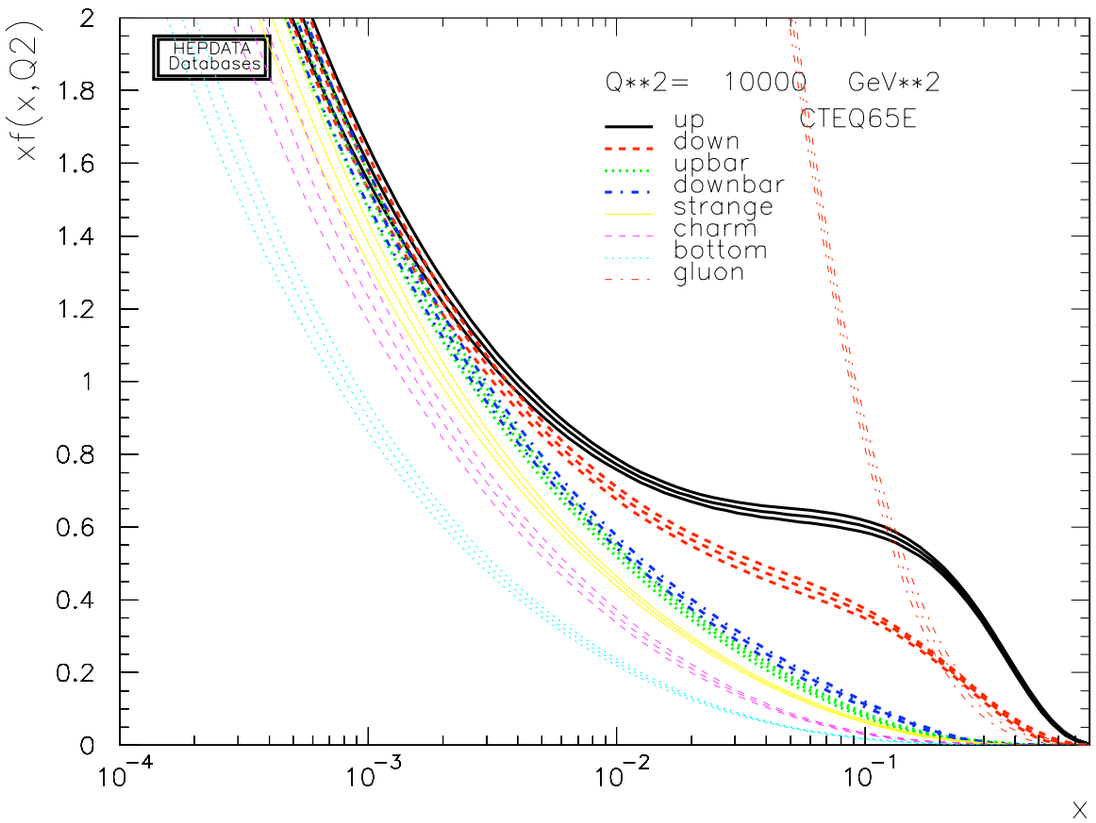
parton-parton luminosity uncertainties

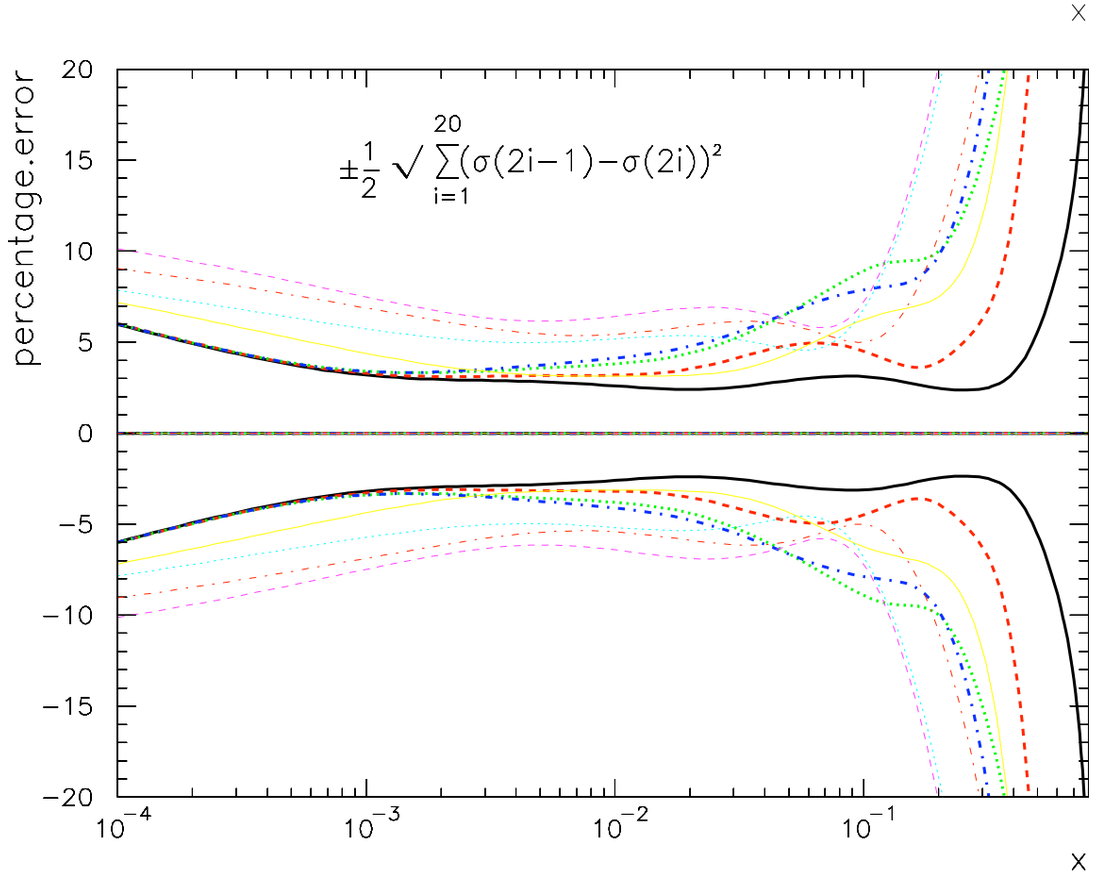


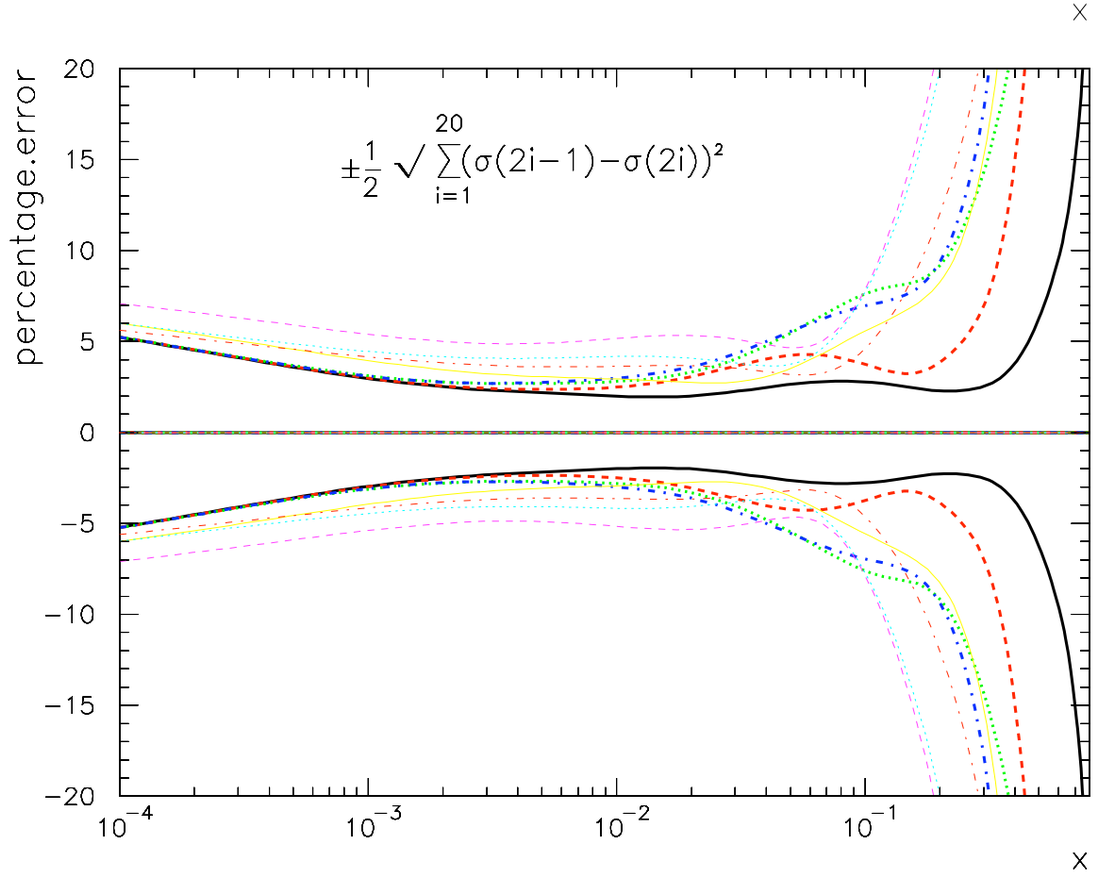


http://durpdg.dur.ac.uk/hepdata/pdf3.html

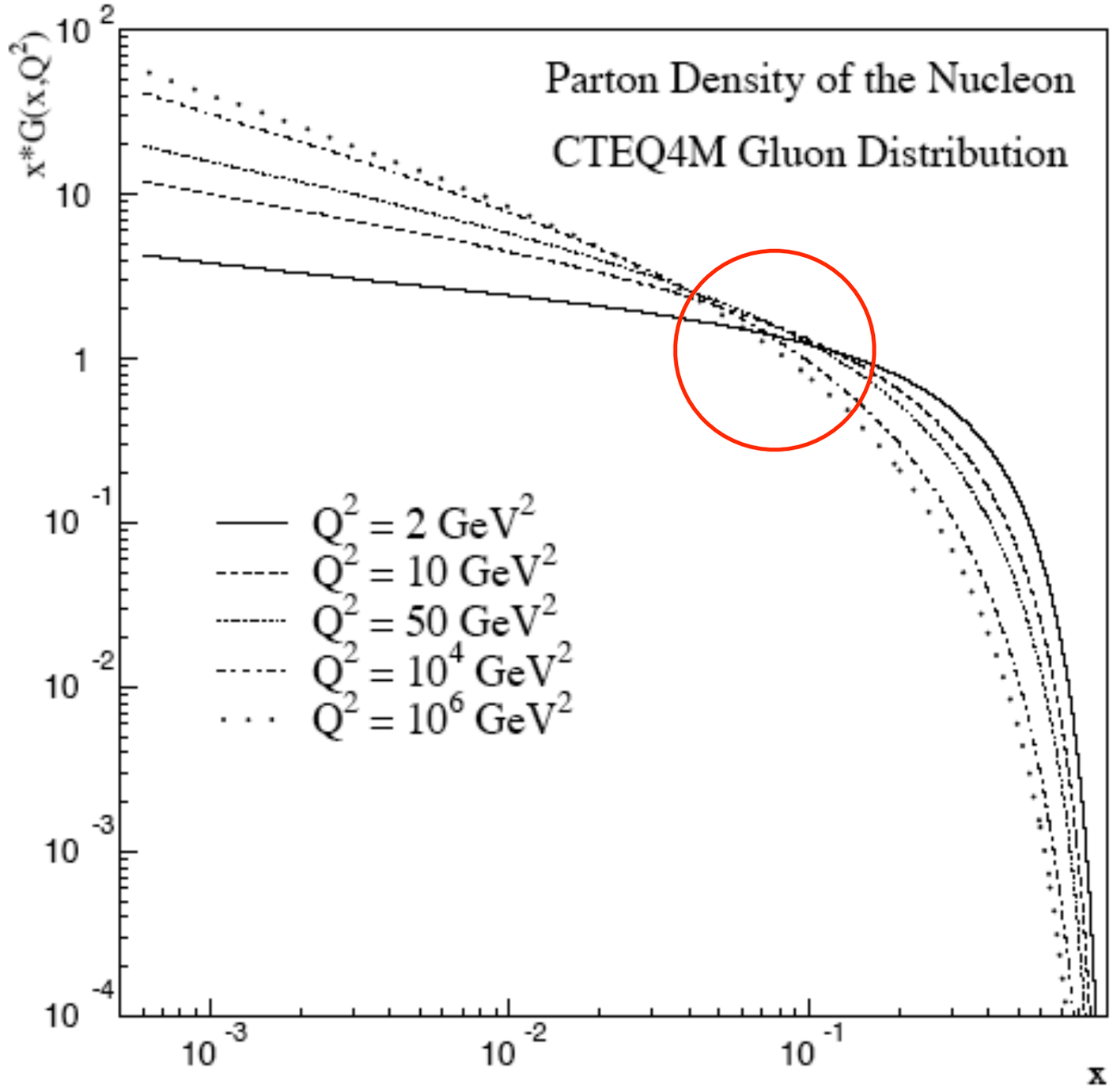






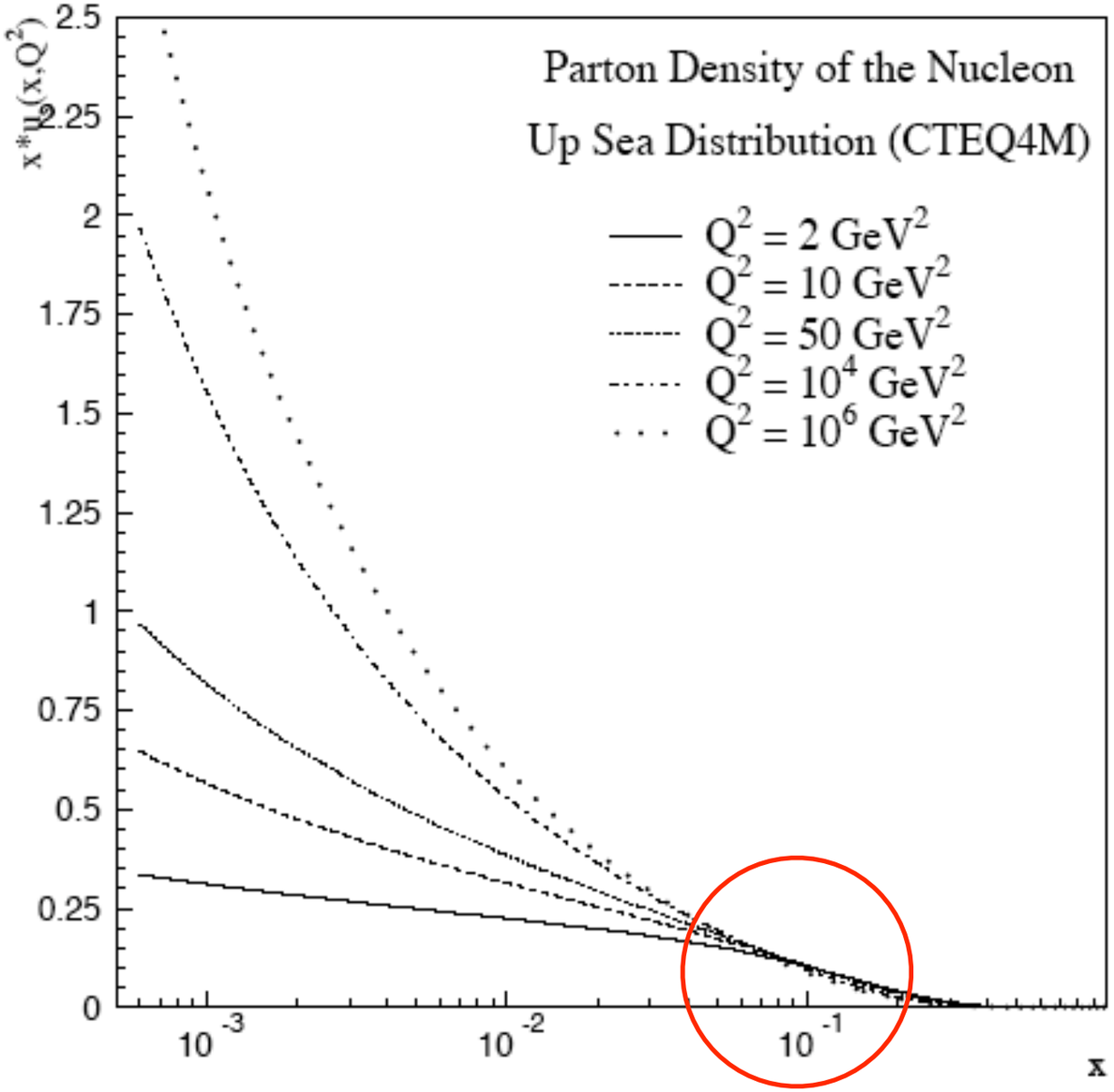


Gluon PDF

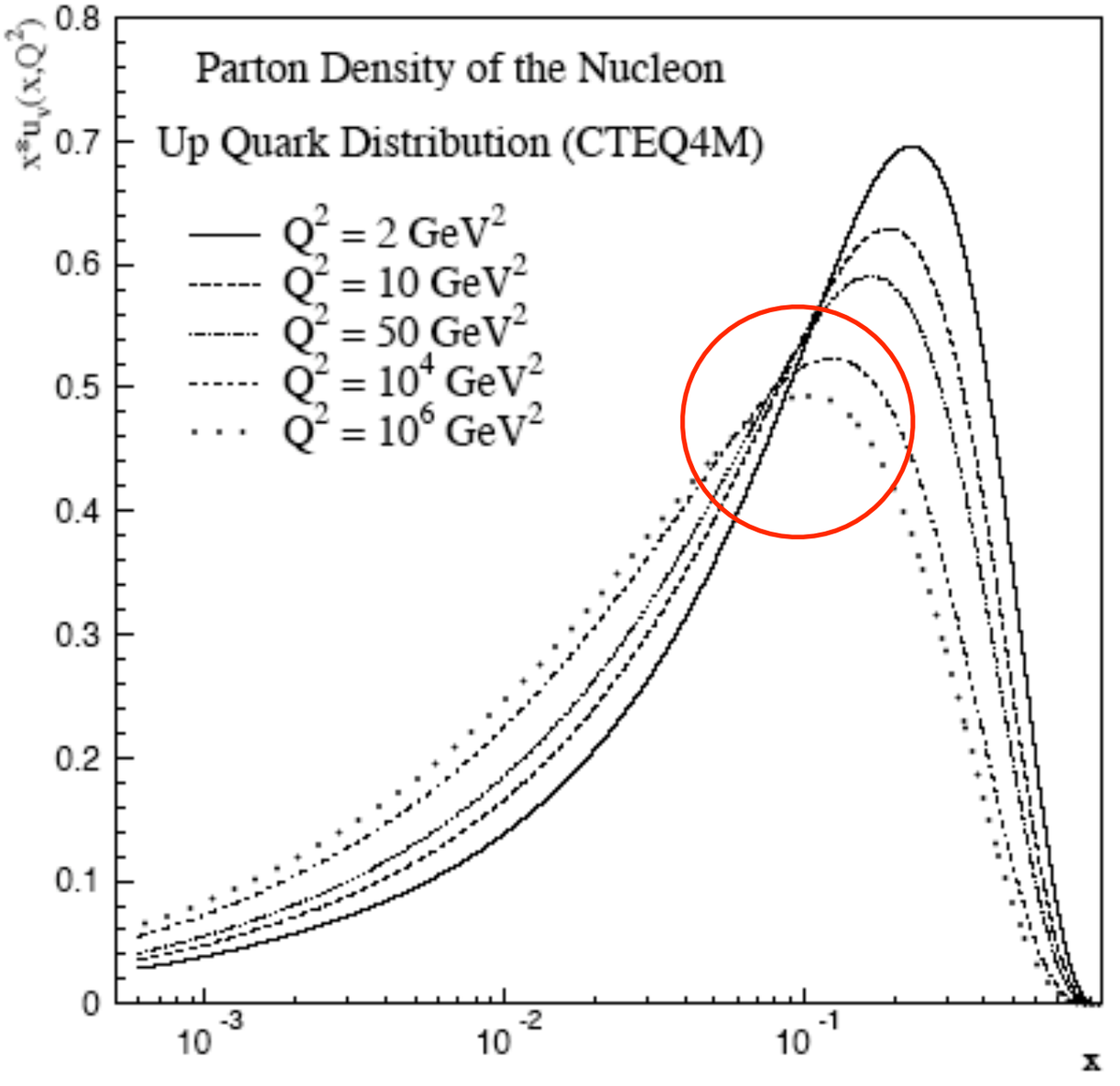


Large Q^2 dependence at small x

sea up quark



valence up quark



Summary

data

DIS, jets, DY, W-asymmetry ...

Evolution

DGLAP-pQCD, error

Global fit

error

References

1) ATL-Physics -99-008

2) arXiv:hep-lat/9609018v1

3) arXiv:hep-ph/0611148v1