Some aspects of

Physics at HERA

A very brief introduction

Slides collected from the DESY-Summerstudents-Lectures of
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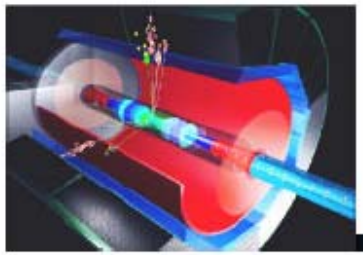
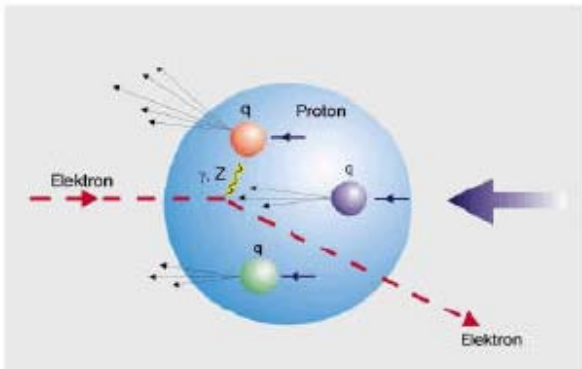
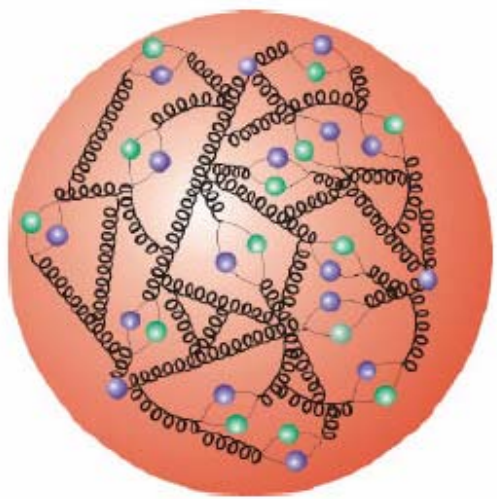
H1
hermes
HERA
ZEUS
HERA
B
PETRA



Proton structure

- Deep inelastic scattering at HERA – a leap of a factor of 100 in precision with respect to previous fixed target experiments
- Resolution = 1/1000 fm
- Resolve the proton's hyper-finestructure





e-p scattering at highest energies

DESY today - HERA

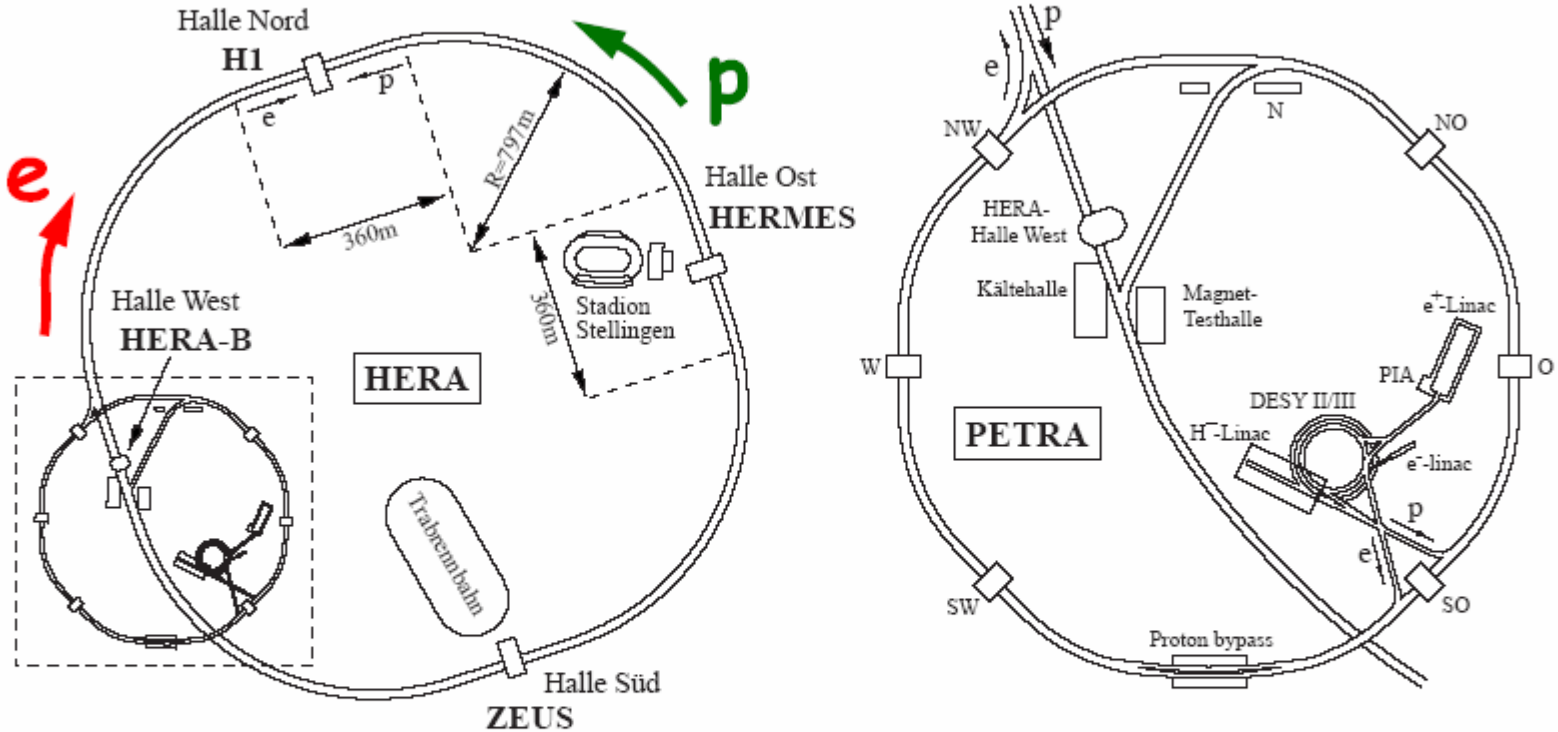
Underground ring,

6.3 km circumference

collider for

- Electrons (28 GeV) and
- Protons (920 GeV)

The HERA Accelerator Complex



Proton ring:

Energy*: 920 GeV

Mag. Field: 4.682 T

Current: ~ 100 mA

* before 1998: 820 GeV

Electron ring:

Energy: 27.5 GeV

Mag. Field: 0.164 T

Current: ~ 40 mA

General:

Energy in cms: 318 GeV

Circumference: 6.3 km

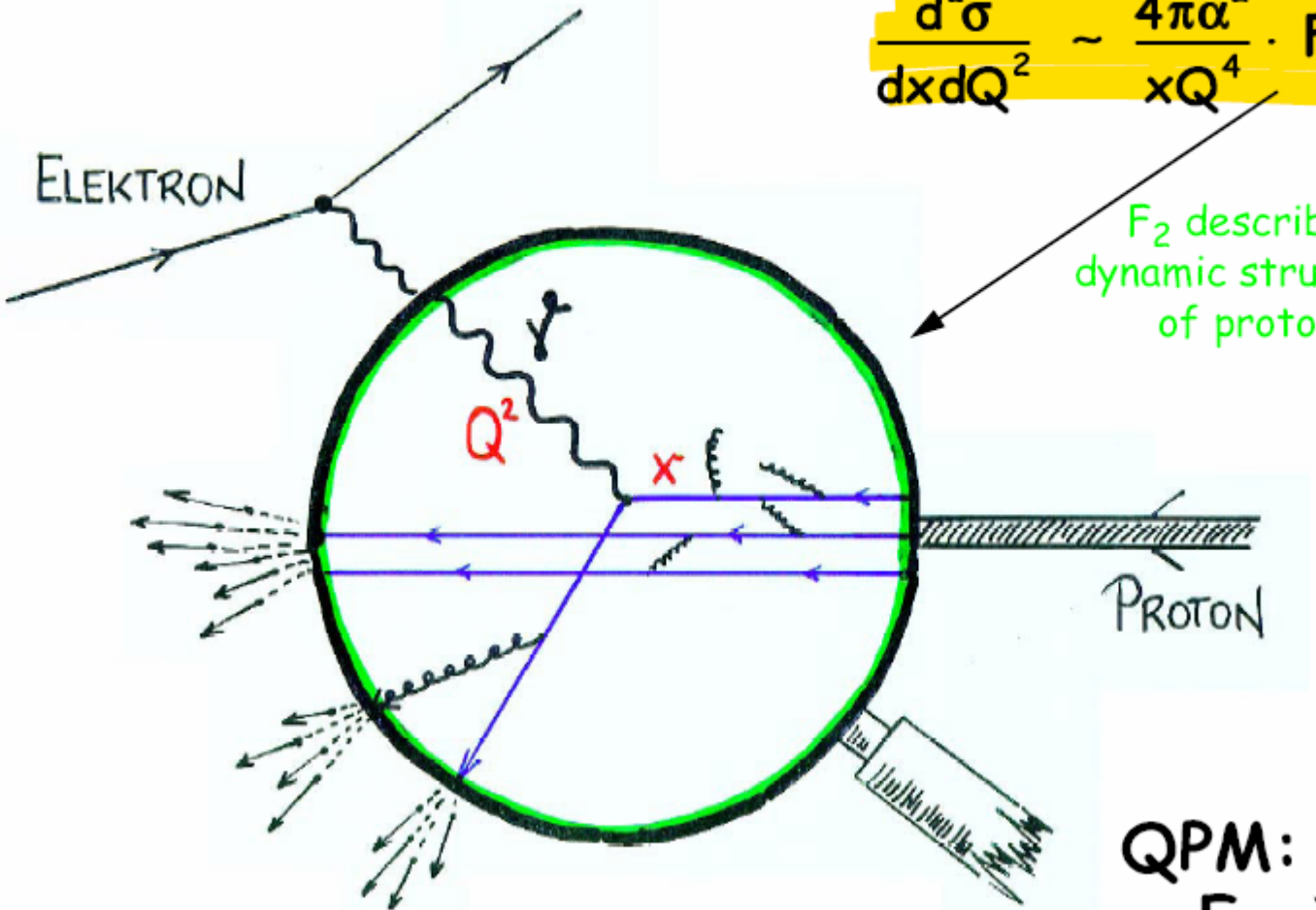
BX rate: 10.4 MHz

Lumi: $1.5 \cdot 10^{31}\ cm^{-2}s^{-1}$

Investigating the

Structure of the Proton

$$\frac{d^2\sigma}{dx\,dQ^2} \sim \frac{4\pi\alpha^2}{xQ^4} \cdot F_2(x, Q^2)$$

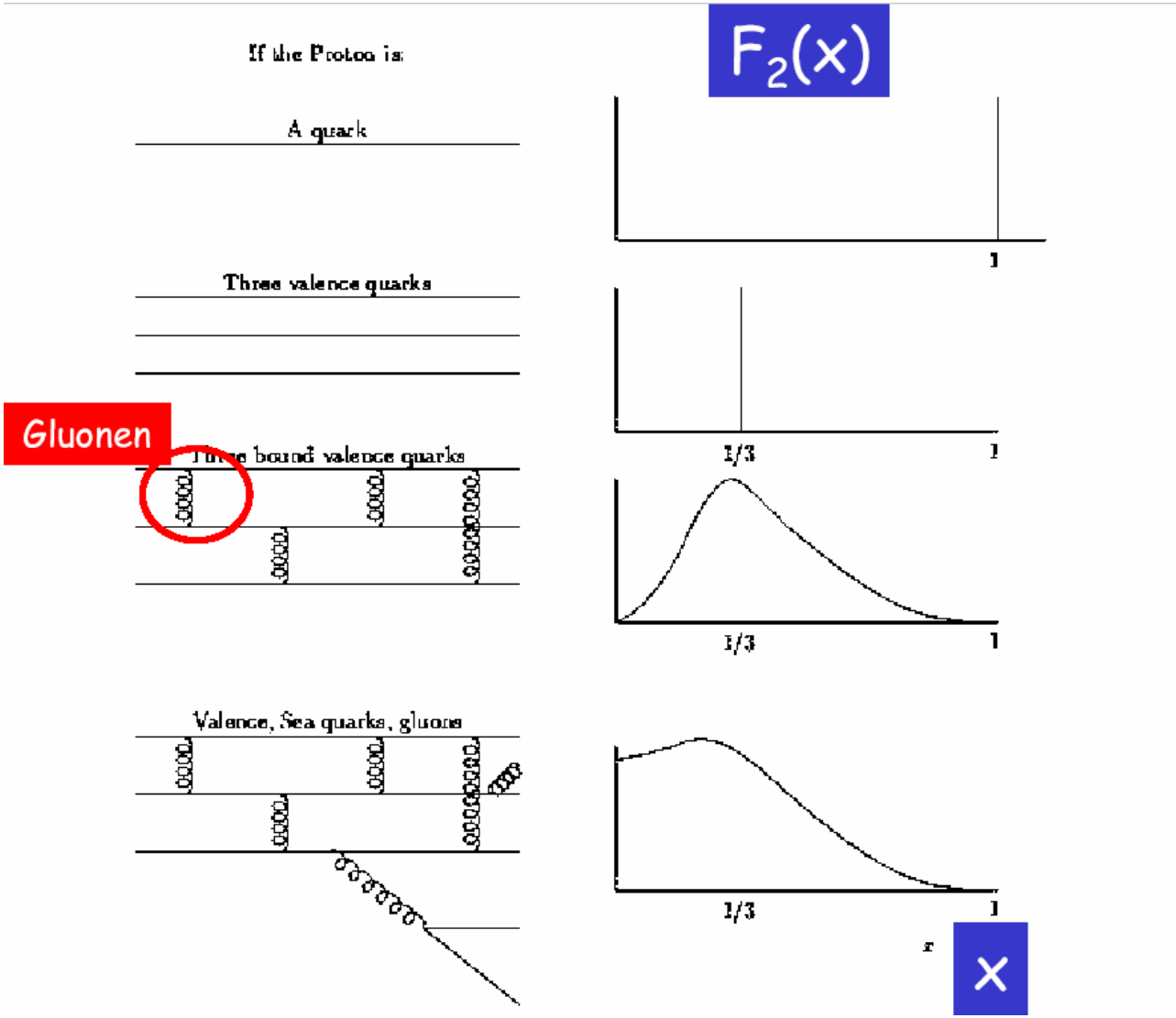


F_2 describes dynamic structure of proton

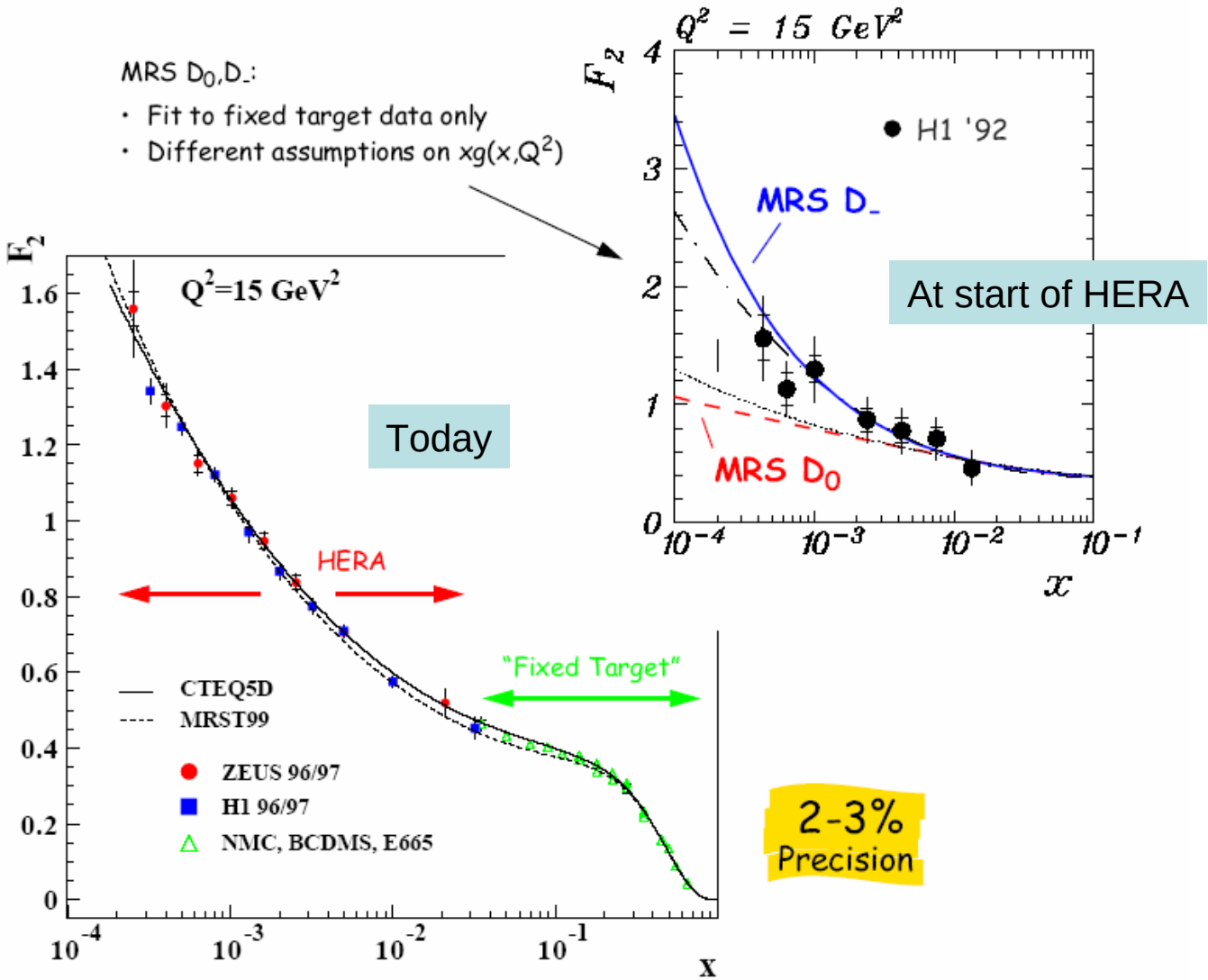
QPM:

$$F_2 = \Sigma e_q^2 \, xq(x)$$

Distribution of quarks in the proton



Quark distribution in the proton: HERA results



Determination of PDFs

fitting the F2 data

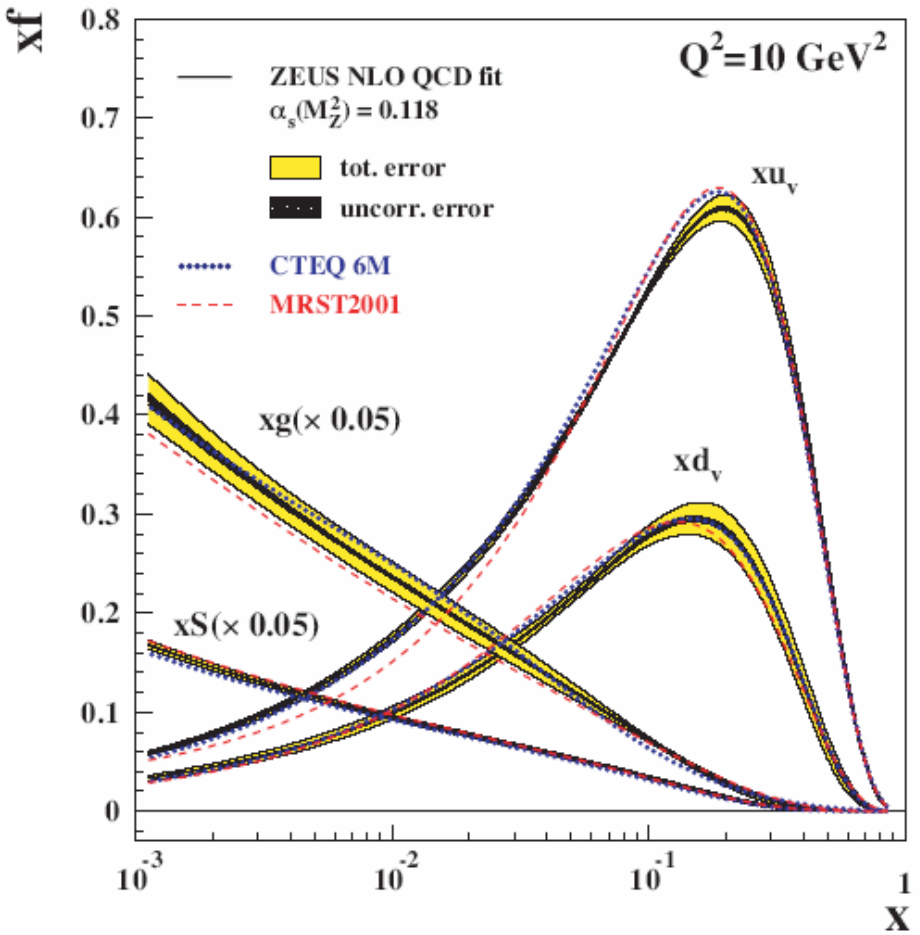
Procedure:

- Assume parametric form of parton distribution functions at starting scale $Q_0^2 \sim O(1\ GeV^2)$.
  [# Parameters: O(10)]
- Fit all data by evolving the PDFs to higher Q^2

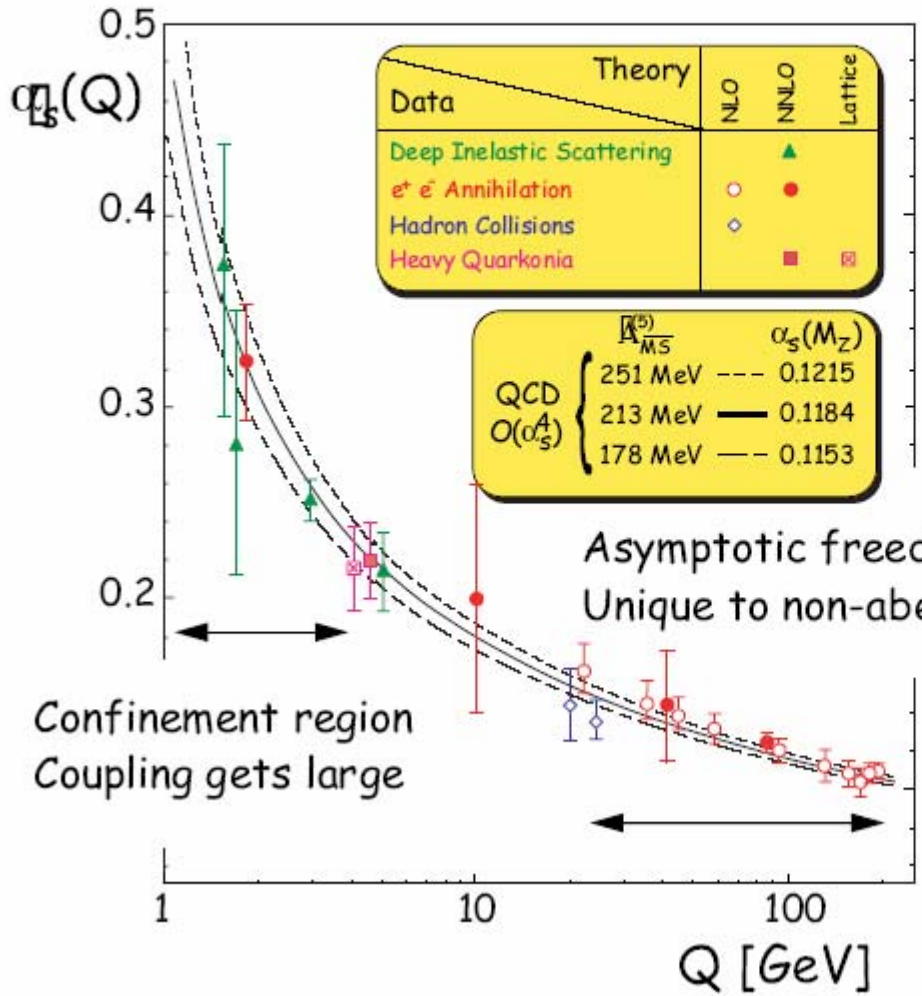
Parametric Forms:

- $xg(x) = ax^b(1-x)^c\ \zeta(x)$
- $xu(x) = a'x^{b'}(1-x)^{c'}\ \xi(x)$
- ...

e.g.: H1 $\rightarrow \zeta(x) = 1+d\sqrt{x}+ex$
ZEUS $\rightarrow \zeta(x) = 1$



The Strong Coupling Constant
[A Reminder]



$$\alpha_s(Q^2) = \frac{\alpha_s(\mu^2)}{1 + \beta_0 \alpha_s(\mu^2) \log \frac{Q^2}{\mu^2}}$$

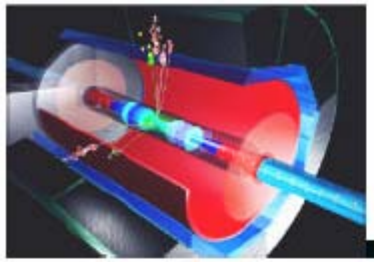
[Evolution equation]

$$\alpha_s(Q^2) = \frac{1}{\beta_0 \log \frac{Q^2}{\Lambda}}$$

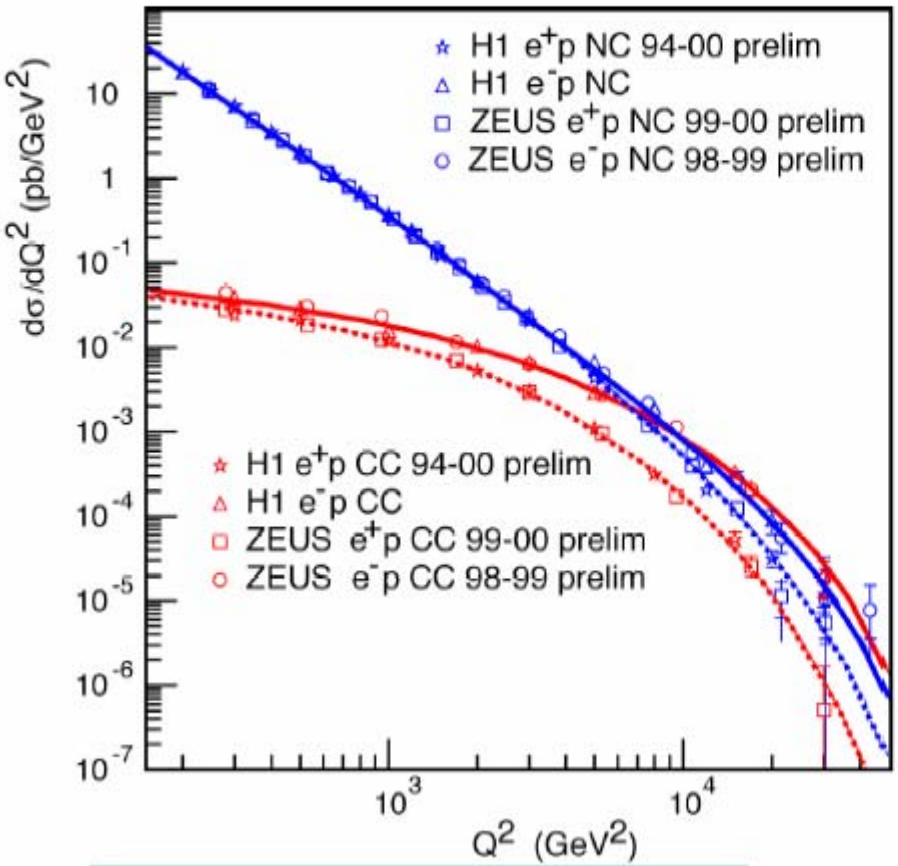
Scale of process

Fundamental QCD parameter

[Needs to be measured]



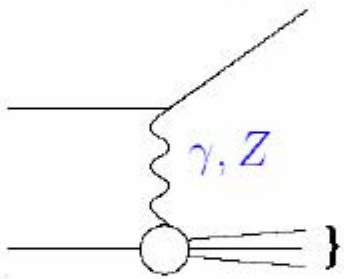
Electroweak unification

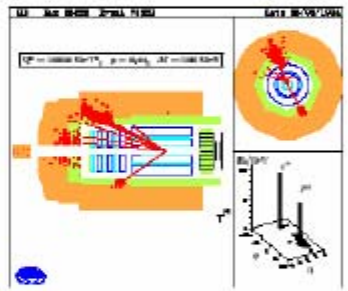


Soon to come: polarized e

- Neutral Current $ep \to eX$

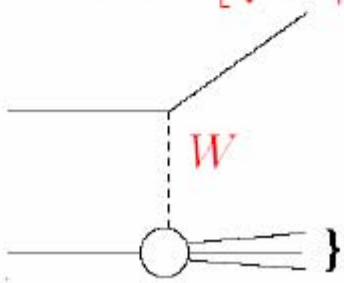
$$\sigma_{NC} \sim \left[\frac{1}{Q^2} \cdot C_\gamma + \frac{1}{Q^2+M_Z^2} \cdot C_Z\right]^2$$

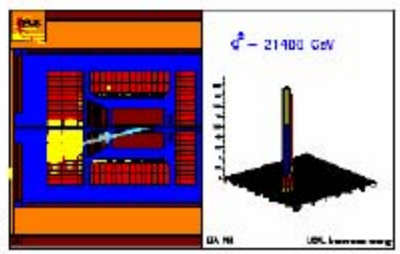




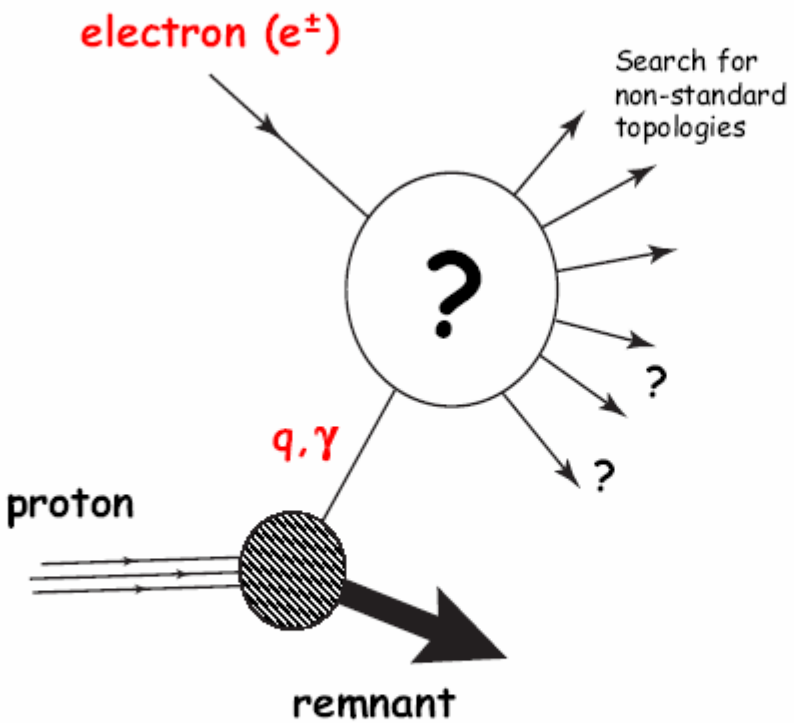
- Charged Current $ep \to \nu X$

$$\sigma_{CC} \sim \left[\frac{1}{Q^2+M_W^2} \cdot C_W\right]^2$$





Searches at HERA



Topics:

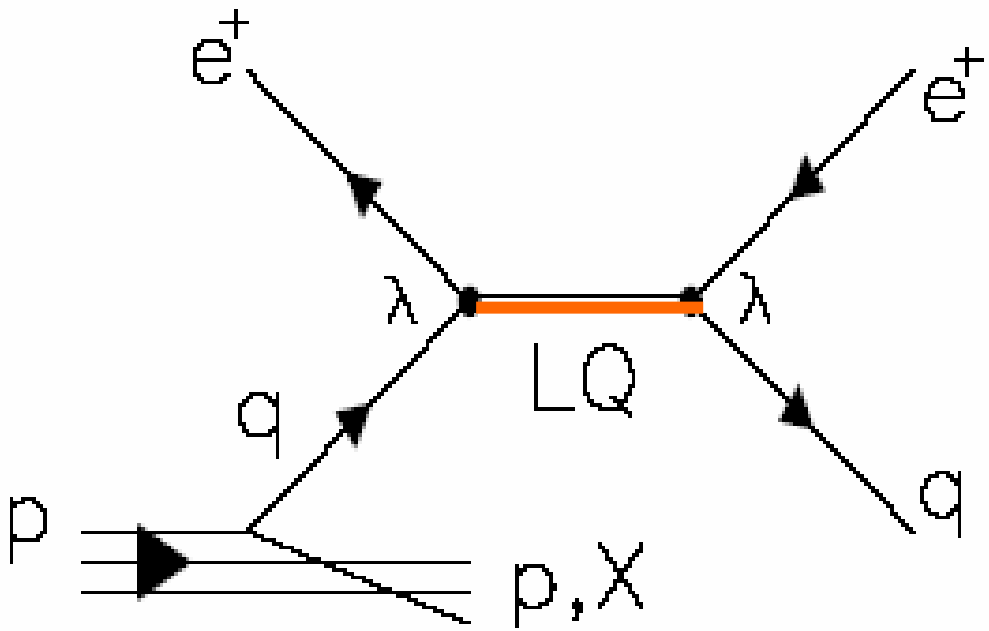
- Lepton Flavour Violation
- Leptoquark Searches
- Excited Fermions
- R-Parity Violating SUSY
- Quark Sub-structure

Competition between HERA and Tevatron

[... but HERA will search uncovered phase space in many channels]

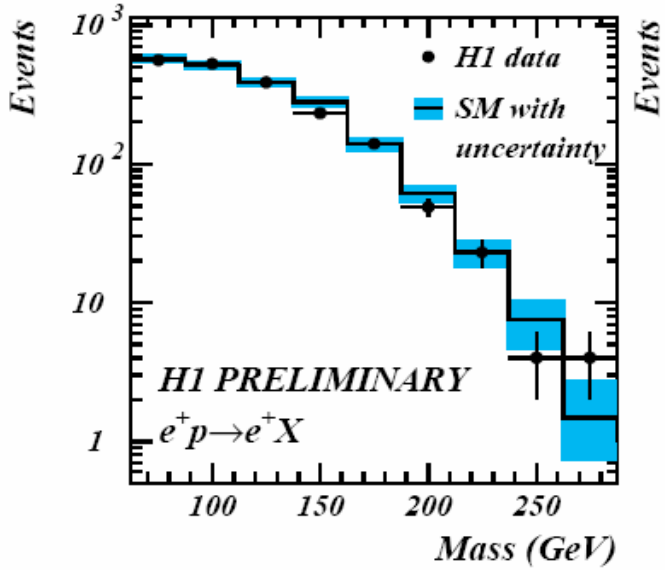
Leptoquarks: $e^{\pm}q \rightarrow e^{\pm}q$

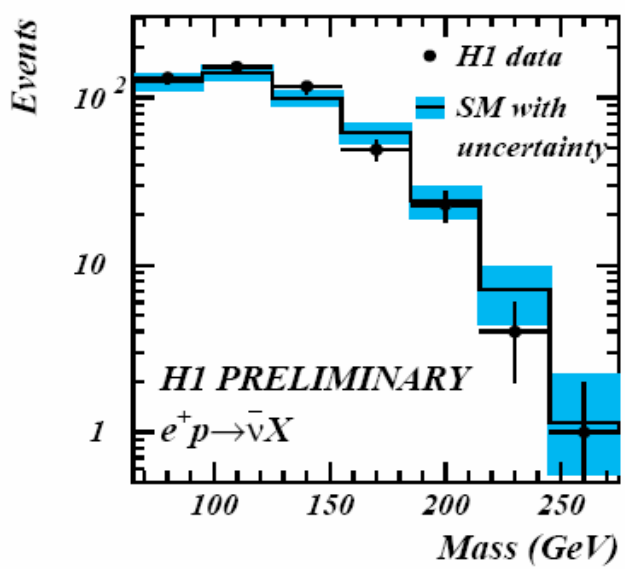
[Signature: NC/CC @ high Q^2]



Leptoquark Search

Mass Spectrum

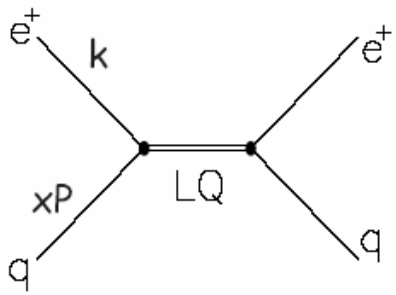




$M_{LQ} = (k+xP)^2$

$= xs$

[since $s = 4E_eE_p$]

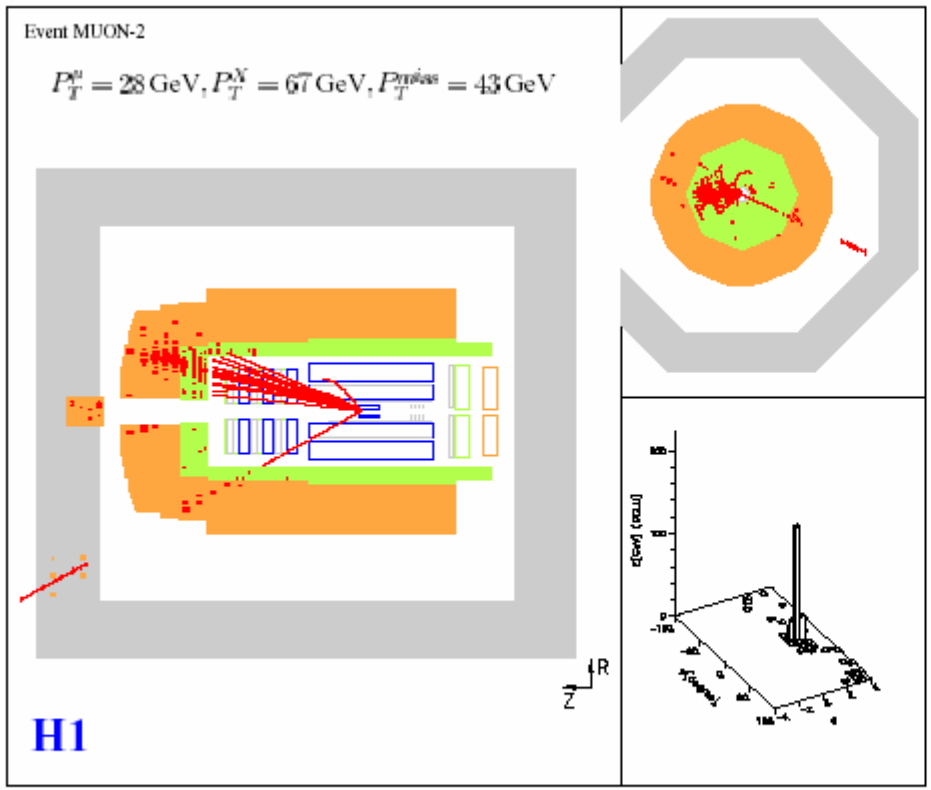


No deviation from SM seen (yet) !

No sign of a Leptoquark (yet) !

Isolated leptons and missing transverse momentum

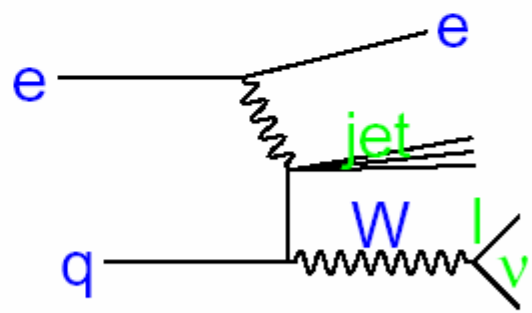
$e^+p \to \mu^+X$



1 isolated lepton (μ,e),

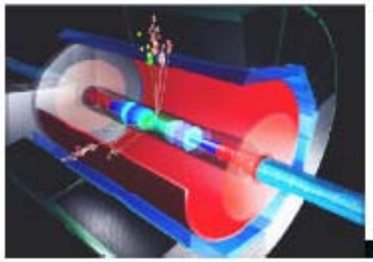
with high p_T, p_T^{miss}, jet (p_T^X)

Main SM process:



SM: < 1 event expected

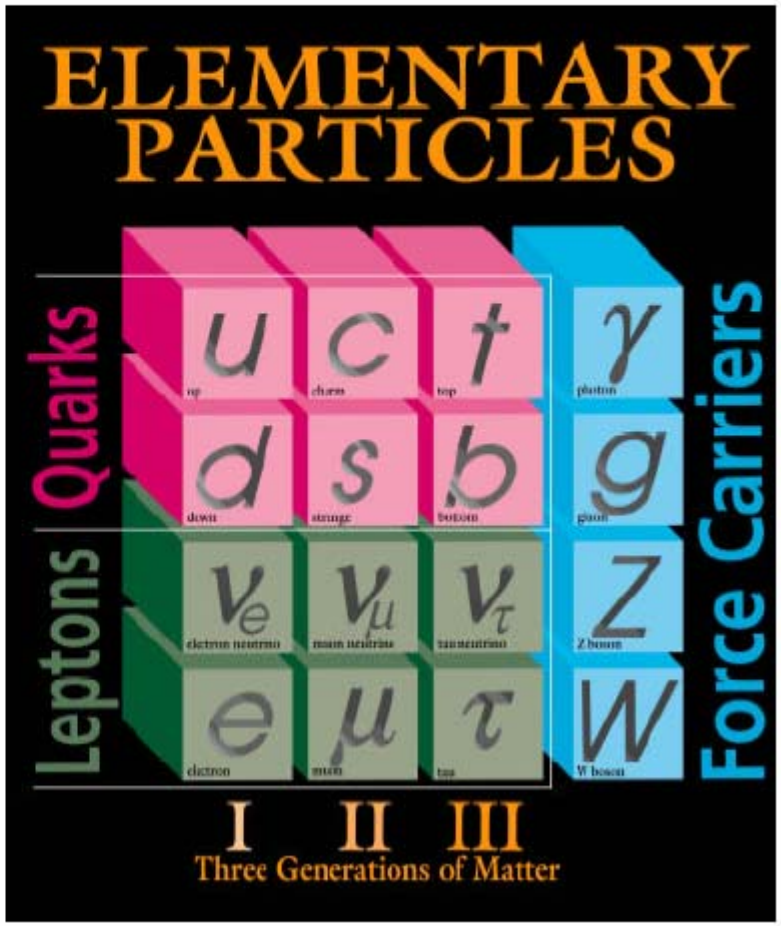
Spectacular events found by H1 in e^+p data



The Standard Model

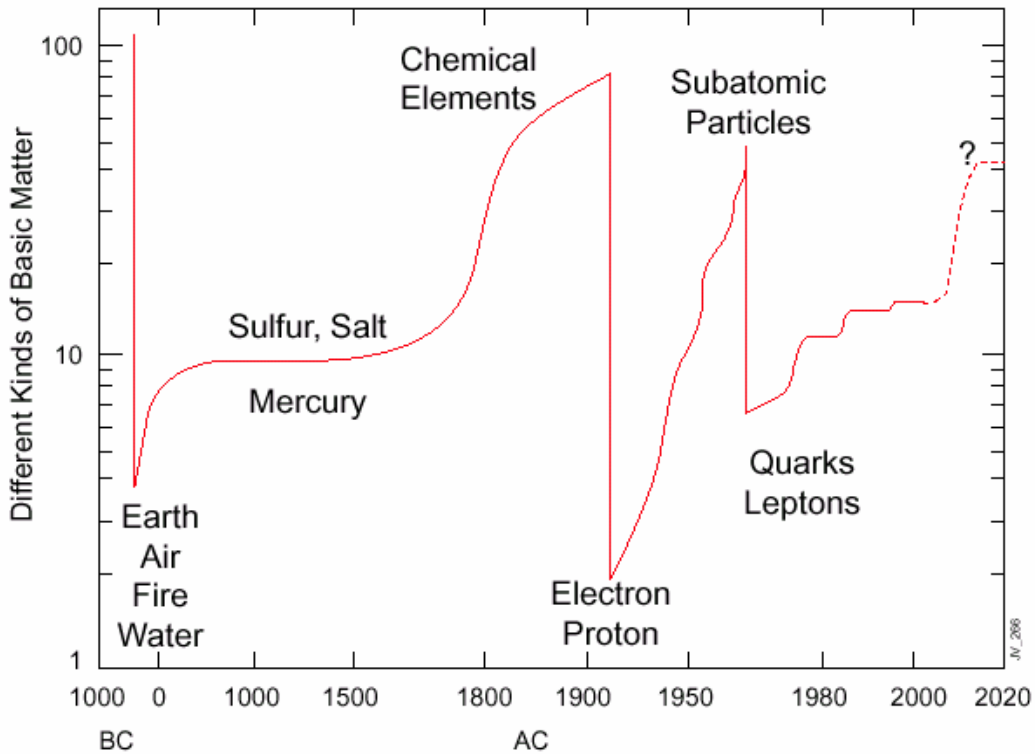
- A precise (0.1%) description of all known subatomic phenomena
- Down to 10^{-18} m HERA !
- Back to 10^{-10} s after the Big Bang

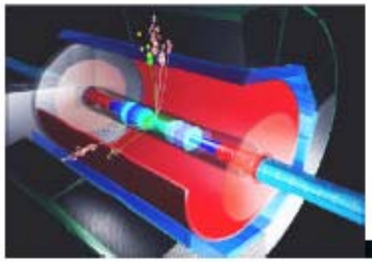
- (but nothing said about mass & gravity)



What was considered ‘elementary’ changed quite a lot over the times.

Constituents of Matter





What is the world made of?