DIS AT FUTURE COLLIDERS

A THEORISTS' POINT OF VIEW

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1. STANDARD MEASUREMENTS
2. QCD ANALYSIS
3. LOW x
4. DIFFRACTION
5. POL. E + POL. P
6. THE EXPECTED UNEXPECTED
7. CONCLUSIONS
$Q^2$ RISES BY $\times 100$!
1) **STANDARD MEASUREMENTS**: LARGE $Q^2$

\[ \sigma_{e^+p}^{\text{NC}}, \sigma_{e^+p}^{\text{CC}}, \sigma_{\bar{e}^+p}^{\text{NC}}, \sigma_{e^-p}^{\text{CC}} \text{ (DIS)} \]

**WHY?**

\[ \rightarrow \text{ SHORT DISTANCE BEHAVIOUR} \]

& **FLAVOURS.**

**THE UNEXPECTED NEW STRUCTURES MAY BE FLAVOUR DEPENDENT**

\[ \rightarrow \text{ NEED } L = 1 \text{ fb}^{-1}/\text{yr} \text{ TO HAVE A REASONABLE STATISTICS TO WORK WITH.} \]

**YIELD:**

\[ u, d, \bar{c}, \bar{b} \]

\[ S = \sum_q (q_s + \bar{q_s}) \]
2) QCD Analysis: Large $Q^2$ ($x \gtrsim 10^{-2}$)

Clean $\alpha_s$ Measurement

$$\Delta \alpha_s^{\text{THY}}(M_Z) \approx 0.001$$ (3 Loop)

New

Necessary to unrev. structures from SM Standard Evolution

By Product $G(x, Q^2)$ (High Prec.)

Different Observables

$$\begin{align*}
\frac{\partial F_2}{\partial \log Q^2} & \quad \left\{ \begin{array}{c}
G^{\overline{MS}}(x, Q^2) \\
F_2^{CC} \\
F_2 \\
F_L
\end{array} \right. \\
\text{Universality !?}
\end{align*}$$

Clean QCD Test:

$\sim$ Several $10^{-1}$! (To exploit full potential)
WHY DO WE NEED TO KNOW $\alpha_s$?

$@ \quad \Delta \alpha_s = \pm 0.001$

UNIFICATION: GUTS

MSSM, $SO_{10}$, ... WHICH GUT?
UNIFICATION AT ALL

HERA WILL PAVE THE WAY.

MIGHT TURN OUT THAT

$\alpha_s^{\text{non\,dis}} + \alpha_s^{\text{dis}}$

↓

FINAL STATE EFFECTS? (DIFFICULT)

WHAT IS $\alpha_s$? $\rightarrow \alpha_s^{\text{dis}}$. 
Figure 10. Two evolutions of the strong coupling constant $\alpha_s$. A smaller value of the quark mass leads to a smaller value of $\alpha_s$. 
3.) Low $x$

Domain for measurement.

$\Delta F_2^{\text{exp}} (x, Q^2) \leq 1\%$ wanted.

$\rightarrow$ Search for structures.

- Screening

No theory yet. $\rightarrow$ Systematic higher twist calculations quantum field theory needed (QCD)

Something like fans, but not naively.

$\rightarrow$ It is likely that one will need a gradual understanding of twist by twist.

This is not a small $x$ (or $s \rightarrow \infty$) approach only

Low $x$ $\leftrightarrow$ Medium $x$
HARD THEORETICAL PROBLEM.

'BFKL' & STRUCTURE FUNCTIONS.

→ THE 3-LOOP COMPLETE RESULTS WILL YIELD A FRESH LOOK!

TWIST 2 IS NOT SO MUCH DIFFERENT FOR SMALL XIF COMP. TO MEDIUM X.

MORE CALCULATIONS NEEDED,
LESS OPINIONS ON KNOWN CALCULATIONS.

* MORE STABLE RESULTS CAN ONLY BE ACHIEVED BY WORKING OUT MORE.
4) DIFFRACTIVE STRUCTURE FUNCTIONS

"F_2" (HARD SCATTERING)

→ MEASURE IT TO HIGH PRECISION

↔ QFT TREATMENT POSSIBLE.

→ INTERESTING LEADING TWIST RESULTS WITHOUT TOO MUCH MODELLING.

→ NOT ONLY INTERESTING AT SMALL X
   BUT AT ALL X.

• MAY DEVELOP INTO A STABLE TEST AREA
  FOR PT. QCD

   MANY MORE THINGS TO
   STUDY.
5. POLARIZED e- POLARIZED p SCATTERING

1ST HIGHER TWIST IN VIVO

• LOWER \( q^2 \): TWIST 3

\[ \rightarrow q_{\perp}^{III} \]

NEW INTEGRAL RELATIONS.
(FIXED TARGET)

• HIGH \( q^2 \): \( \Delta \Sigma, \Delta G, \Delta s \) ...

\[ \rightarrow \] WATCH OUT FOR NOVEL HIGH \( q^2 \) STRUCTURES.
DUE TO NUCLEON POLARISATION

• DIFFRACTION: NEW TESTS OF QCD
\( g_1^D, g_2^D \) TWIST 2.

(FIXED TARGET)
Why do we want to microscopize the nucleon any further?

We would like to see, whether quarks & gluons have pieces.

They are too many not to have pieces.

To see the pieces of a whole one has to use microscopes.

Note: Light partons were not found with hadron colliders. Prions may be heavy... but how do we know?

Is it the Higgs who gives the mass to the top quark — or is this a prion mechanism?
CAN HADRON COLLIDERS ESTABLISH PREONS UNAMBIGUOUSLY?

SPACELIKE & TIMELIKE RESOLUTION IS NOT THE SAME.

THE MISSING LINK IN THE SM IS NOT ONLY THE HIGGS.

ONE WANTS TO UNDERSTAND THE ROOTS FOR 3 QUARK & 3 LEPTON TYPES!
BEING OTHERWISE EQUAL (UP TO THEIR MASS)

ONE POSSIBILITY: PREONS

PREONS SHOULD DECONFINE.
Quark–Compositeness

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- Example: purely electromagnetic interactions

- \( Q^2 \ll \Lambda_{\text{Preon}}^2 \): elastic lepton–quark scattering with a point–like coupling
  \[
  J_{\mu}^{\text{em}} = e_q^2 \bar{u}_q(p') \gamma_{\mu} u_q(p)
  \]

- \( Q^2 \sim \Lambda_{\text{Preon}}^2 \): quasi–elastic lepton–quark scattering
  \[
  J_{\mu}^{\text{em}} \to e_q^2 \bar{u}_q(p') \Gamma_{\mu}(q^2) u_q(p)
  \]

\[
\Gamma_{\mu}(q^2) = F_1(q^2) \gamma_{\mu} + \frac{F_2(q^2)}{2M} \sigma_{\mu\nu} q'_{\nu}
\]

\[
G_E(Q^2) = F_1(Q^2) - \frac{Q^2}{4\Lambda^2} F_2(Q^2)
\]

\[
G_M(Q^2) = F_1(Q^2) + F_2(Q^2)
\]

\[
G_M(Q^2) = \frac{\mu}{(1 + \frac{Q^2}{\Lambda^2})^2}
\]

- assume \( \mu = 1 \) and \( G_M = G_E \)

\[
\frac{d^2 \sigma}{dxdQ^2} = \frac{d^2 \sigma_0}{dxdQ^2} \times \frac{\Lambda^8}{(\Lambda^2 + Q^2)^4}
\]

with

\[
\frac{d^2 \sigma_0}{dxdQ^2} = \frac{2\pi \alpha^2}{xQ^4} \left[ 1 + (1 - y)^2 \right] F_2^{\text{em}}(x, Q^2)_{\text{partonic}}
\]
HERA×TESLA, LEP×LHC : \( \sqrt{s} \approx 1.8 \text{ TeV} \); \( Q_{\text{max}}^2 \approx 5 \times 10^5 \text{ GeV}^2 \).

Still higher scales:

- \( Q^2 \gtrsim \Lambda_{\text{Preon}}^2 \): one may expect also resonant contributions depending on the yet unknown binding force
- \( Q^2 \gg \Lambda_{\text{Preon}}^2 \): New Scaling: elastic lepton–preon scattering, if both the leptons and the photon remain pointlike
CONCLUSIONS

1667 R. HOOK USED THE MICROSCOPE AND FOUND THE CELL.

1969 SLAC-MIT FOUND THE PARTON USING A MICROSCOPE TOO.

ONE SHOULD SEARCH FOR DEEPER STRUCTURES AS AT THE MOMENT TOO MANY "EQUAL" ANIMALS ARE FLOATING IN FRONT OF THE LENSE.

--- BETTER MICROSCOPE(S) NEEDED.

--- WELL EQUIPPED WITH ENOUGH LIGHT! SEVERAL $10^{-1}$.

--- WILL BE A CHALLENGE FOR TESLA * HERA.

(NOT CLEAR WHETHER IT CAN BE SOLVED.)

STANDARD PROGRAMME: RICH

MAIN GOAL: SUBSTRUCTURE!

FROM THE BEGINNING.