Proposal to measure the spin dependent structure functions $g_1(x)$ and $g_2(x)$ for proton and neutron at HERA

HERMES - Collaboration

(Argonne NL, Caltech, MPI für Kernphysik HD, U. Illinois UC, Los Alamos NL, Madison, Marburg, MIT, New Mexico State U., Münche (Quebec), (Saclay), Stanford, Tarino, TRIUMF/Alberta/Simon Fraser, (Uppsala), W.+M. Williamsburgh)

14 institutes - 65 physicists

Status report

Final proposal will be submitted ~1 month from now.
Reminder:

\[ g_1(x) = \frac{1}{2} \sum_f e_f^2 (q^+_f(x) - q^-_f(x)) \]

EMC/SLAC measurement:

\[ I_1^p = \int_0^1 dx \ g_1^p(x) = 0.126 \pm 0.010 \pm 0.015 \]

Ellis-Jaffe S.R: \[ I_1^p = 0.189 \pm 0.1 \]

If Bjorken S.R correct:

\[ I_1^n = -0.065 \pm 0.010 \pm 0.015 \]

\[ \langle S_2 \rangle_{\text{all quarks}} = 0.060 \pm 0.047 \pm 0.069 \]

\[ \langle S_2 \rangle_{\bar{s}s} = -0.035 \pm 0.016 \pm 0.023 \]

"Spin Crisis"

Explanations:

- Large gluon polarization
- Orbital angular momenta of quarks, gluons,
- Higher twist effect
- Violation of Bjorken S.R
However: Speculations all based on just one number: $I_1^p$ with large error bars.

To distinguish between models and to find true explanation need: precise measurement of $x$ dependence of $g_1(x)$, $g_2(x)$ for both proton and neutron.

\[
\begin{array}{c}
ed \rightarrow N \leftarrow \downarrow \quad e \rightarrow N \leftarrow \uparrow \\
\end{array}
\]

Our proposal

- Long. pol. e beam of HERA
- Polarized internal gas targets (
  - $^{1}H$, $^{2}D$: all nucleons polarizable $f = 1$
    \[ (f(NH_3) = \frac{3}{17}, f(C_4H_9OH) = \frac{11}{17} ) \]
    \[ - ^{3}He: \text{polarized neutron target} \ (f \sim 1) \]
  
  High precision in relatively short running times
Possible problems connected with storage cell

- Synchrotron radiation
  - $O(10^{15}) \gamma/\text{s}$ would hit walls of st. cell
  - $O(10^{12}) \gamma/\text{s}$ would be scattered into spectrometer

Need:
- modified beam line
- movable collimators ($\pm 7 \text{mm}$, $\pm 2.3 \text{mm}$)
- clam shell st. cell ($\pm 12.6 \text{mm}$, $\pm 3.8 \text{mm}$)

$O(10^5) \gamma/\text{s}$ scattered into detector most of them from target gas

- Depolarisation by magnetic bunch field
  Need: Holding field (B ~ 0.33T)

- Depolarisation by wall collisions
  Need: Coating (e.g., dryfilm)
    Holding field

Investigated in detail: o.k.

Good experience with test experiment at VEPP3
Fig. 2.4.4: The energy spectrum of the dipole (a) and quadrupole (b) radiation hitting C.
THE HERMES INTERNAL TARGET

Details being discussed with machine people.
Fig. 2.2.18. THE PRINCIPLE OF HERMES TARGET CELL
Status H/D source

- Vacuum system, diagnostics, controll operational
- First version of dissociator operational
- Systematic studies of
  - degree of dissociation - flux density -
  - beam pressure - velocity distribution
  - Optimize magnet configuration

- Get $> 10^{20}$ H atom/s at dissociator

- Estimate $6.5 \times 10^{16}$ atom/s in one HFSat into acceptance of drift cell
  (Factor of 2 higher than best source)

- Possible improvements: Optimization of dissociator, lower nozzle tem
  $10^{17}$ s$^{-1}$ realistic

- Sextupole magnets ordered, expected end of year
  Pole tip field 1.5T

- First test experiment at Heidelberg TS
  Next spring
Status of $^3$He source (Caltech, MIT)

Principle: Metastability exchange
  optical pumping

- Polarization achieved at Caltech: ~55%
  Paris: ~70%
- Tested at Bates with 40µA 250 MeV e$^-$
  No significant depolarization
- Prototype source under construction at MIT
- Polarimeter constructed and tested
- YRP laser assembled, tuned to He transition
- Flow through system tested at 1.3 mbar with
  $10^{17}$ atoms/s
- Helmholtz coil under construction
- Test of complete system: Fall 89
tube.

50 hour laser stability run (YAP)
Some details of spectrometer

Magnet: (LANL)

Modify existing magnet at LANL
(Vandalize two others)
$\mathbf{B} \mathbf{d} \mathbf{e} \sim 1.5 \ \text{Tm}$

Field in bore of septumplate:
$0.014 \ \text{Tm} \ e \quad 0.0045 \ \text{Tm} \ p$

Calorimeter: (Caltech, Illinois, LANL)

Options:
- Dense Pb-glass (SF57-DF6)
  (well understood)
  $\gamma \in [3.5, 3.6]\% / \sqrt{E} + C \%$

- Pb-Scint, fibers
  (high radiation resistance - Mva
  new device - further studies
  needed)
  $\frac{\Delta E}{E} \sim 6\% / \sqrt{E}$

Size: $288 \times 72 \ \text{cm}^2$; 32x8 elements, $9 \times 9 \times 41 \ \text{cm}$

Pion rejection ($E > 4.5 \ \text{GeV}$):
- On-line \sim 30
- Off-line \sim 300
HERA EXPERIMENT SCM 105 MAGNET SCHEMATIC
CALORIMETER STRIP-CLUSTER TRIGGER LOGIC

\[ \Sigma(1) \Sigma(3) \Sigma(5) \cdots \]

\[ \Sigma(30) \]

\[ \Sigma(31) \]

\[ p_{\text{GLASS ELEMENT,} G_{ij}} \]

\[ \text{STRIP-CLUSTER} \]

\[ \text{ADC} \]

\[ \text{STRIP SUM} \]

\[ \text{SCALER, TDC} \]

\[ 31\text{-FOLD STRIP-OR} \]

\[ \text{ADC} \]

\[ 256/\text{HALF} \]

\[ 31/\text{HALF} \]

\[ 31/\text{HALF} \]
DF6
Orito et al
95% electron efficiency

Pion rejection ratio, $R_{\pi}$

Beam Energy (GeV)

$\pi$ TRIGGER RATE E > 4.5 GeV

RATE (1/Hz)

$p_\pi$ (GeV)
Figure 2. Resolution for a 10 x 10 x 22 cm$^3$ module (BIG BLOCK) at all energies plotted vs $\sigma/E$, with $E$ in GeV. Note that the highest energy points will be remeasured as the detector-electronics chain exhibited a degree of non-linearity.
TRD (TRIUMF/Alberta/Simon Fraser)

6 modules - total length 60 cm
Radiator (6.5 cm): polypropylene fiber
Chambers (2.5 cm): cell size ≈ 27 cm
  gas - Xe + 10% quench

Second level trigger:
Combine information from TRD
  + Calorimeter
  (vertical rows)
Additional π rejection: on-line ≈ 10
  off-line > 100

Total π rejection: ~ 30000

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Prototyping started
Tracking

Si-strips (0.115 mm pitch) (Torino)

Front chambers (3.5 mm drift, <0.2 mm res.) (MIT)

Magnet chambers (1 mm res.) (RAL)

Back chambers (5 mm drift, <0.2 mm res.) (MPI)

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Resolution dominated by multiple scattering and straggling.

\[
\frac{\Delta E}{E} \sim 0.7 - 1.7\%
\]

\[
\frac{\Delta Q^2}{Q^2} < 1.5\%
\]

\[
\frac{\Delta x}{x} \sim 1 - 8\%
\]

\[\sigma_z \sim 0.5 \text{ cm}\] \(\gamma\) vertex resolution

\[\sigma_y < 0.03 \text{ cm}\]
Other projects

- **SMC - CERN**; 100 GeV muons
  
  \[ C_4H_9OH, C_4D_9OD \text{ target} \]
  
  \[ f = \frac{10}{74} \quad f = \frac{10}{42} \]
  
  \[ L \sim 1.4 \times 10^{32} \text{ cm}^{-2} \text{ s}^{-1} \]

  Approved: scheduled for end 91-early 92

  Target construction.

  2 years data taking, > 2 years analysis;
  results for \( q_1^N(x) \) earliest late 95
  Too large errors

- **HELP - LEP**; 50-100 GeV electrons
  
  \( H/D \text{- jet target} \)
  
  \[ L \sim 2-20 \cdot 10^{29} \text{ cm}^{-2} \text{ s}^{-1} \]

  Polarisation physics in 95?Rejected

- **SLAC**
  
  25-50 GeV electrons
  
  High pressure \( ^3\text{He} \text{- target} \)
  
  \[ L \sim O(10^{35}) \text{ cm}^{-2} \text{ s}^{-1} \]

  Problems: High current on glass cell
  Same rate from cell walls as from \( ^3\text{He} \)
  \( N_2 \text{ quench} \)

  Restricted kinematic range
  Data taking 2 years from now? Only \( q_1^N \)
Our proposal is still unique!