Measuring Forward Scattered Protons at H1

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- Introduction
- Measurements with the Vertical Stations at z=0.7–0.9
- The Horizontal Stations

Diffraction

LOI, June 24, 1992:

"Deep inelastic ep scattering at low x is of particular interest, because the detection of leading protons will enable us to measure the structure of the Pomeron." Statement preceeds the discovery of rapidity gap events at HERA by one year!



The Concept

Protons from diffractive interactions:

- Leave detector at small angles (<1mrad) through beampipe
- Have very high energies, up to 99.99% of beam energy

The Idea:

- Bring detectors very close to the beam
- Make detectors moveable to provide aperture for injection
 - => Roman Pots
- Use beamline as magnetic spectrometer

The Forward Proton Spectrometer

Roman Pots

Pioneered at ISR:

Volume 43B, number 3

PHYSICS LETTERS

5 February 1973

MEASUREMENTS OF THE PROTON-PROTON TOTAL CROSS SECTION BY MEANS OF COULOMB SCATTERING AT THE CERN INTERSECTING STORAGE RINGS

U. AMALDI, R. BIANCASTELLI, C. BOSIO and G. MATTHIAE Physics Laboratory. Initiato Superiore di Sanità and INFN. Serione Sanità. Rome. Italy J.V. ALLAB C.W. BARTEL, J.M. BLOCK *, G. COCCONI, A.N. DIDDENS R.B. ECODINSON, J. LITT and A.M. WETHERELL CERN, Geneva, Switzerland

Received 21 December 1972

Proton-proton elastic scatte transfer range $0.001 \leq |t| \leq 0.0$ tering and of its interference w tude and of the total proton-pr





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1994: First Tests

Installation of 2 Roman Pot Stations at 81 and 90m Shutdown 1993/94:

Instrumentation: Scintillator tiles with photomultiplier readout

First experience with pot operation, background rates etc.

Diploma theses of :

- Tim Wilksen: Analysis of tile data
- Hanna Mahlke: Simulation of diffraction in photoproduction with POMPYT (Generator by G. Ingelman) for proposal

Proposal

October 1, 1994:

Proposal for a Forward Proton Spectrometer for H1.

Inter-University ULB-VUB, Brussels DESY Hamburg University Hamburg II Institut f. Experimental physik University Kiel School of Physics and Materials. University Lancaster Lebedev Physics Institut Moscow DESY Institut f. Hochenergiephysik Zeuthen

October 1st 1994

Energy resolution: 3.5GeV (achieved: 2.4GeV)

2 stations at 80 and 90m

Instrumentation and Electronics: Hamburg II, DESY-Zeuthen



Linear beam optics: energy dependent linear relation between emission point and angle at IP and at roman pot position Motion in horizontal and vertical planes is decoupled

Neglect beam size at interaction point

Simple relation between measured offset and slope at pot positions and energy and emission angle at interaction point

$$\begin{array}{l} x \\ x' \\ y \\ y' \\ y' \end{array} \right)_{90\mathrm{m}} = \left(\begin{array}{c} a_1 \left(E \right) \\ a_2 \left(E \right) \\ a_2 \left(E \right) \end{array} \right) + \left(\begin{array}{c} b_1 \left(E \right) \\ b_2 \left(E \right) \\ b_2 \left(E \right) \\ b_1 \left(E \right) \end{array} \right) \cdot y'_{\mathrm{IP}} \\ \end{array}$$

Momentum Reconstruction, cont'd

Measure: x: offset from beam axis, x': angle w.r.t. beam, at 85m

Protons of one energy but different emission angles lie on straight line.

Different energy, different line.

Lines of constant emission angle.

Protons can only be observed in a certain "allowed" region.



Calibration: Where Is the Beam?

The problem: We need to measure w.r.t. circulating beam, but Plot observed (x, x') values for all protons in a fill. beam position and slope varies from fill to fill. Apply shift (x, x') to measured values:

deviation of beam from nominal position and slope



Performance

Measured raw energy and angle

spectrum







Difference between energy measurement in *x* an *y* coordinate: typically 4 GeV => corresponds to energy resolution of 2 GeV *F*₂^{LP(3)}: Leading Protons in DIS

published Eur. Phys. J. C6 (1999) 587–602. PhD theses BL (1995), Tim Wilksen (1996)

First measurement of cross sections for leading protons in DIS.





PhD theses Carsten Wittek (1995), Hanna Mahlke-Krüger (1996) published: Nucl. Phys. B619 (2001) 3–21. H1 Leading Proton Data







Forward Scattered Protons

1997: New "Horizontal" Stations

- ◆ 2 New Stations at 63 and 80m
- Approaching the beam in horizontal direction
- Acceptance up to beam energy $(z = E_p/E_p=1, x_{\text{IP}} = 1-z = 0)$
- Allow measurement of "real" diffractive events:
- Photoproduction of ρ^0
- ◆ Measurement of F₂^{D(4)}: diffractive DIS structure function,

with t dependence

Photoproduction of p⁰ Mesons

PhD theses Oliver Karschnick(99), Anatoli Astvatsatourov(00), publication in preparation

Measurement of p⁰ photoproduction in new Wregion



Measuring t with the Horizontal Stations

Photoproduction of ρ^0 mesons well understood.

Measurement of t in agreement with other data.



 $F_2^{LP(3)}$ and $F_2^{D(3)}$ United

Analysis Michail Kapishin, H1 preliminary



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B. List, ETH Zürich

Forward Scattered Protons

Measuring the t Slope in Diffractive DIS



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B. List, ETH Zürich

Retrospect: FPS Students

Diploma Students:

- Robert Casties
- ◆ B. Chen
- Arnd–Boris Fahr
- ◆ Benno List
- Hanna Mahlke–Krüger
- A. Materzak
- Carsten Reich
- ◆ Tim Wilksen
- Carsten Wittek

PhD Students:

- Anatoli Astvatsatourov
- Oliver Karschnick
- Benno List
- Hanna Mahlke–Krüger
- ◆ Tim Wilksen
- Carsten Wittek

Publications

3 Publications finished:

- "The H1 forward proton spectrometer," NIM. A446 (1999) 409–425
- "Measurement of leading proton and neutron production in deep inelastic scattering at HERA," EPJ C6 (1999) 587–602
- "Photoproduction with a leading proton at HERA," NP B619(2001)3–21.

2 Publications in the pipeline:

- "Photoproduction of ρ mesons with a leading proton at H1," -> PL
- "Measurement of semi-inclusive deep-inelastic scattering with a leading proton at HERA," H1-prelim-01-113

Conclusions

- H1 Forward Proton Spectrometer has collected a wealth of data
- Interesting analyses in DIS and photoproduction, at medium and high values of z
- 3 Publications finished, 2 more in the pipeline
- The FPS continues to take data
- We look forward for more forward proton physics from the VFPSI