Use of the LPS in eA events at HERA
A new stripping channel.

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1 Introduction

To see the utility of a modified LPS in $e - d$ experiments, consider first the limitations without the LPS. The aim is to make measurements on (en) interactions or compare (ep) and (en) or sum them in (ed) or look at coherent (ed) interactions. Q^2 depends only on the electron variables but

$$x_{Bj} = \frac{Q^2}{2(qn)} \; or \; \frac{Q^2}{2(qp)} \tag{1}$$

so here the 4-momentum of the incident proton or neutron must be known. But, inside the deuteron, the neutron, for example, has some momentum distribution determined by the neutrons wave function[1] (Fig1).

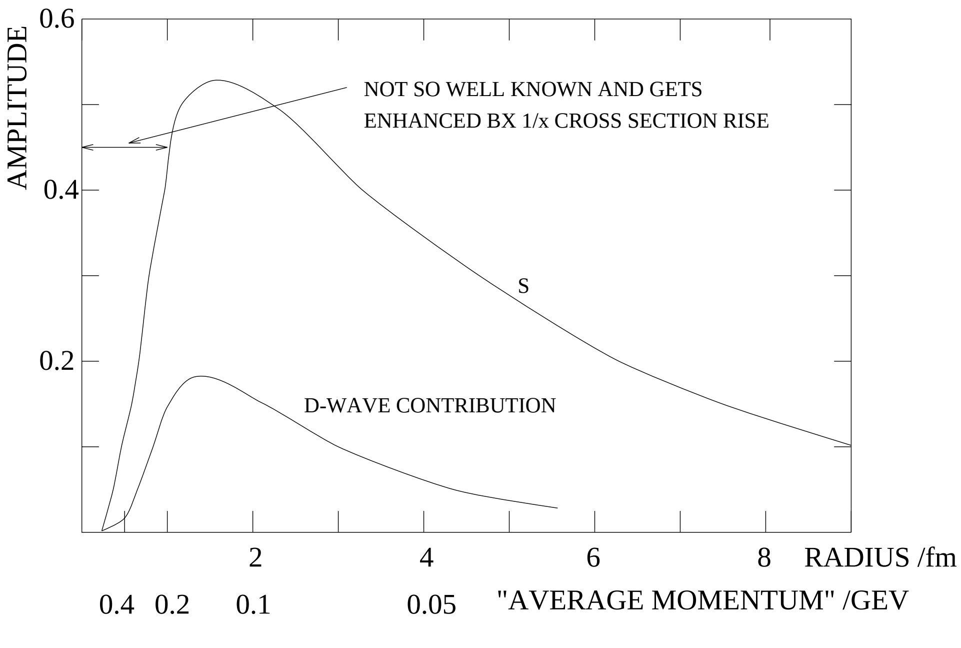

Figure 1: The deuteron wave function.

The Fermi-momentum extends up to about 30% of the nucleon mass, which implies that the incident neutron momentum has a laboratory energy ranging over $400GeV \pm 130GeV$.[2].

The observed cross section is averaged over the values of x_{Bj} given approximately by

$$x_{Bj} = (1 + p^*_{par}/m_n) \times \frac{Q^2}{(qd)} \tag{2}$$

where p^*_{par} is the longitudianal momentum of the neutron in the deuteron system, m_n the neutron mass and the last term is the value of x_{Bj} if the neutron carries just half the deuteron's momentum. For constant Q^2, the relative importance of the momentum distribution is increased at the high momentum end through 2 and the $\frac{1}{x}$ term in the ep inelastic cross section.

The deuteron wave function is well determined at low momentum, but the high momentum part which depends on the repulsive core part of the nucleon-nucleon interaction is not so well known[1]

2 Stripping

Half a century ago the interactions of neutrons with nuclei was being studied, using known-energy deuteron beams, measuring the spectator protons and making various corrections for nuclear effects[3]. The aim now would be to build an efficient *stripping channel* to measure the spectrum of protons around $410GeV$, aiming at a fractional momentum resolution $\Delta p/p \sim 10^{-3}$ compared to the value $\Delta p/p \sim 10^{-4}$ for the deuteron beam. Tagging the spectator proton would be equivalent to making a neutron beam with momentum resolution 0.1% – apart from "nuclear effects", i.e. rescattering, shadowing and so on.

This however defines only the kinematics. To obtain a cross section measurment requires knowing the neutron luminosity as a function of momentum which in turn requires a good knowledge of the deutron's momentum wave function. Supplementary information on the high momentum tails of the fermi distribution might be obtained by studying the transverse momentum distribution of the spectator, but this would require high-β operation of HERA to keep the transverse momentum spread of the deuteron beam low enough. (The transverse momentum spread of the present beam is $25MeV$ horizontally and $90MeV$ vertically.)

3 A first design trial

Designing a stripping channel is essentially an accelerator design problem, with specifications requiring high acceptance for $0.35 \leq x_L \leq 0.65$ and $p_T \leq 0.3GeV$. These ranges would allow the measurement of background outside the range containing the majority of the spectator protons. The present beam optics has been used to gain some insight into the problem. The impact of the proposed HERA low-β optics is not discussed[4].

Fig.2 shows a section of the present beam line with the vacuum chamber limitations and trajectories which span most of the spectator proton phase space. After the station $S3$ particles with $x_L \sim 0.5$ diverge strongly from the beam line so that the acceptance of a typical silicon detector area becomes small. To understand the possibilities, assume that there is a detector station at S3 to measure position and that another station $S7$ is added some drift-distance after S3 to measure the track direction. This information together with the position of the

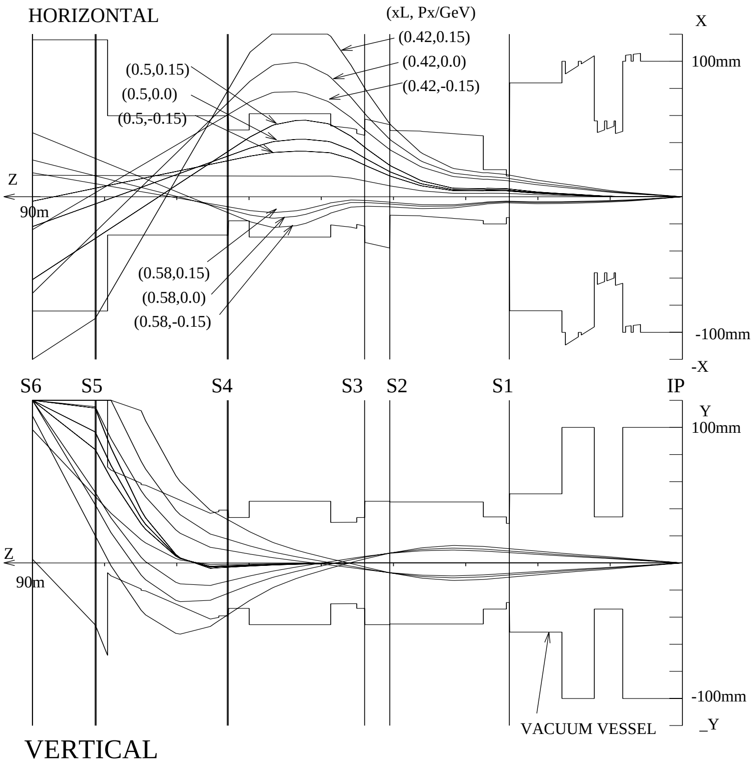

Figure 2: The present beamline showing the vacuum chamber limits and some spectator proton orbits which span the expected transverse and longitudinal momentum ranges.

interaction vertex allows the momentum of the particle to be reconstructed using the two-station reconstruction method which was developed for the LPS.

Limitations arise because of the finite size of the beam because detectors cannot be placed closer than the 10σ profile of the beam. There are also limitations because of blind-spots on the detectors where there is no momentum dispersion in both horizontal and vertical planes. Consider the vertical projection of the beam before $S3$. There are no vertical bending magnets so a particle on the horizontal plane through the quadrupole axes sees no deflecting field and so no momentum dispersion. In the horizontal projection there are bending magnets and then the combined affect is to displace the blind-spot off axis by an amount which depends on the beam energy.

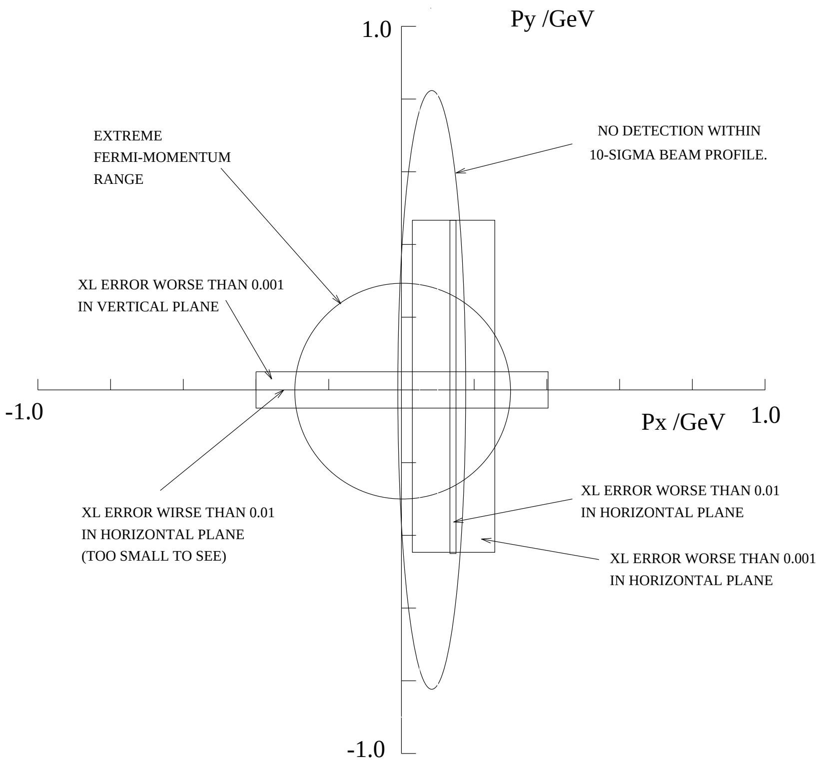

Figure 3: The transverse phase space plane at the interaction point showing the various limitaions to the acceptance.

Fig.3 gives a summary of the different factors influencing the acceptance. Everything has been mapped back onto the transverse momentum plane at the interaction point using a particle momentum of $410 GeV$ to perform the tracking. The features to note are:

1. The circle containing the wanted events defined by the fermi-momentum spread. Note that the population of this area is sharply peaked at $p_x = p_y = 0.0$ so the picture gives an optimistic impression.

2. The part lost because the detector at $S3$ cannot be put in the beam.

3. The limits of 1% and 0.1% resolution for independent momentum measurements in the horizontal plane and in the vertical plane, calculated assuming $15 \mu m$ position resolution

and $2\mu radian$ angular resolution. (The latter would require a much longer drift space after $S3$ than is at present available.) Where the resolution is good in both planes there are two independent momentum measurements. Only when the measurement is poor in both planes must the track be rejected with cuts which must be included in efficiency calculations. If accuracy of 1% is adequate, the loss from this cause is negligible.

4. The region with poor x_L resolution in both planes is inside the cut which is imposed by the 10σ size of the beam at $S3$.

5. Limitations by the beam's vacuum vessel. This has not been included.

4 Conclusions

It looks encouraging to study further a HERA stripping channel, but serious design problems are evident. Though the beam and the spectator protons from the deuterons are widely separated in longitudinal phase space there is not enough deflection to separate the two "beams" and at the $S3$ station position so the detectors cannot be placed at the position of maximum intensity of the spectator protons. Further station positions must be investigated to reach an optimum solution.

Ideally, to fully understand *ed* events, there should be high acceptance for both forward protons and forward neutrons. A comparison of the proton and neutron spectators and ambiguities which can arise is given in [2].

References

[1] The nucleon-nucleon interaction. G.E.Brown ans A.D.Jackson, North Holland, 1976.

[2] The momentum spread quoted here correspod to a level of 2% in the spectrum quoted by G. Levman, these proceedings.

[3] Nuclear stripping reactions. S.T.Butler and O.H.Hittmair, Wiley 1957.

[4] A first study of the LPS in a low-β machine has been made. T.Massam, these proceedings.