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ACCELERATOR DEPARTMENT
Informal Report

MASTER

PHOTOPRODUCTION EXPERIMENTS AT ISABELLE

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June 16, 1972

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Photoproduction from 15 GeV electrons impinging on 70 GeV protons has been discussed in the LBL-SLAC report on "Particle Physics with Positron-Electron-Proton Colliding Beams". The purpose of this CRISP report is to make trivial extensions to the ISABELLE e-p parameters of 5 GeV electrons on 200 GeV protons. The ISABELLE e-p option offers the opportunity for studies of photoproduction to extremely high energies corresponding to 1000-2000 GeV laboratory photon energies. In the finite future only the proposed 2000-5000 GeV Soviet machine would reach this energy region and our ability to obtain enough photons from a proton machine to perform viable experiments at such high energies remains to be seen. Finally, in examining two possible photoproduction experiments, we conclude that their performance places certain restrictions on the e-p interaction experimental area, and these requirements will need to be fed into the machine design.

In order to understand the energy range involved in these experiments, we need only consider the Doppler-shifted photon energy. In the laboratory system, consider a virtual photon of energy $k_L = E_0 - E$ where E_0 and E are the initial (5 GeV) and final electron energies. The equivalent laboratory photon energy for a real photon impinging on a stationary proton is

$$k'' = \sqrt{\frac{1 + \beta_2}{1 - \beta_2}} k_L$$

But

$$\theta_2 = \frac{P}{E_p}$$

$$\approx 1 - \frac{M_p^2}{2P^2}$$

and

$$k'' \approx \frac{2P}{M_p} (E_0 - E)$$

The highest energy available is $k''_{\max} \approx 400 (E_0 - E) = 2000$ GeV.

For virtual photons produced at small, but finite, values of q^2 , the inelastic electrons of energy E appear at small, but finite, angles with respect to the initial electron beam direction as seen in Figure 1., i.e., $-q^2 \approx E_0 E \theta^2$. The virtual photon spectrum peaks strongly at low momentum transfer so that electrons from $q^2 \approx m_\pi^2$ are desired; a tagging magnet covering the angular range 10 -50 mr seems sufficient. The total electroproduction cross section $\frac{d\sigma}{dE} = \frac{\alpha}{2\pi} \frac{E_0^2 + E^2}{E_0 - E} \frac{\sigma_T}{E_0^2} \ln \frac{\theta_{\max}^2}{\theta_{\min}^2}$ yields 1.3 μb when integrated over the variables

$$k''_{\max} = 2000 \text{ GeV} , \quad k''_{\min} = 200 \text{ GeV}$$

$$(E = 0 , \quad E = 4.5 \text{ GeV})$$

$$\theta_{\min} = 10 \text{ mrad} , \quad \theta_{\max} = 50 \text{ mrad}$$

using $\sigma_T = 100 \mu\text{b}$ and $E_0 = 5$ GeV.

The electroproduction total cross section for these conditions as a function of equivalent laboratory photon energy is shown in Figure 2.

Can viable experiments be done using these cross sections and the expected luminosities? To answer this question, we consider elastic Compton scattering, a process fundamental to sum rules, Pomeron exchange, vector dominance, etc. The

expected cross section with real photons is $0.1 \mu\text{b}$. At ISABELLE luminosity of 5×10^{32} , the rate is

Rate = 1 per minute

for $-t > 0.15 (\text{GeV}^2)$

in a 100 GeV band centered at 1000 GeV. The experiment would involve detection of an electron at, for example, $\theta_{\min} = 10 \text{ mrad}$ and $2.5 \pm 0.125 \text{ GeV}$, a photon at $\theta_{\min} = 6 \text{ mrad}$ and $2.5 \pm 0.125 \text{ GeV}$, and a proton at $\theta_p = 2 \text{ mrad}$ and 200 GeV. Since the reaction is elastic, application of three constraints (at high energy) are possible. These might be total momentum and transverse momentum plus coplanarity with respect to the initial photon direction. These constraints have proved amply adequate in the kinematically similar pion-electron scattering experiment at Serpukhov. Unfortunately, a major problem arises in the e-p case. The high luminosities are achieved by using a low θ interaction region so that typical beam divergence angles are $\approx 1 \text{ mrad}$. Detection of a 2 mrad, nearly elastic proton will require a very long straight section to separate from the beam. Even more serious is the fact that the transverse momentum and coplanarity errors will be large. At 1 mrad uncertainty, the transverse momentum uncertainty is 200 MeV where 20 MeV is desired. An acceptable interaction region must have $\Delta \theta \text{ beam} \approx \pm 0.1 \text{ mrad}$ and length = 25 meters to provide a 5 cm separation of the scattered proton from the beam.

Further experimental details are left to the imagination but these reactions may pose severe design requirements on the interaction region. Note that a process with very similar kinematics is $e + p \rightarrow e' + \pi^+ + n$. Here the π^+ kinematics are similar to those of the gamma ray in Compton scattering and the neutron kinematics are analogous to the proton. These events may be simpler to detect since the neutron is not charged, but unfortunately, the cross section is very low and counting rates are probably of the order of a

few per day even at peak luminosities.

We conclude that photoproduction experiments in a new energy range are possible with the ISABELLE e-p option even for the very difficult Compton scattering process provided care is taken in design of the interaction region.

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ISABELLE PROJECT

Fig. 1

Fig. 2