NAL PROPOSAL No. 181

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The Direct Production of Electron Pairs in Nuclear Emulsion by 100 and 200 GeV Protons

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A Proposal to the National Accelerator Laboratory

1. Title of Experiment: The Direct Production of Electron Pairs in Nuclear Emulsion by 100 GeV and 200 GeV Protons.

2. Experimenter: Arthur S. Cary, Harvey Mudd College, Claremont, California

3. Spokesman: Arthur S. Cary

4. Equipment Required:

   a. Beam: 100-500 GeV protons at NAL

   b. Intensity: 10^4-10^6 protons/cm^2. It would be necessary to make test exposures to determine the optimum intensity.

   c. Emulsion: Ilford G5 pellicles of size (2.5 x 13 cm^2) x (200 μ), the 2.5 cm edge along the beam.

   d. Accessory Apparatus: Emulsion storage facilities to protect from background radiation, high humidity and high temperature.
   Darkroom facilities for developing testplates.

Abstract

It is proposed to study the direct production of electron pairs produced when a high energy proton interacts with the Coulomb field of a nucleus. This process occurs at fourth order in quantum electrodynamics. This phenomena, called trident production when the incident particle is an electron, is characterized by a single incident primary track and three emerging tracks.

Accelerator experiments on direct pair production by protons have not been previously reported, due to the small cross-sections at energies less than 100 GeV. However, at an energy of 100 GeV the cross-section for the direct creation of electron pairs by protons in emulsion is about 10^{-25}cm^2.

The Direct Production of Electron Pairs
in Nuclear Emulsion by Protons at 100 and 200 GeV

I. Physics Justification:

Electromagnetic processes in which a high-energy electron in the field of a nucleus directly produces an electron-positron pair have long been the subject of theoretical and experimental studies[1-10]. The processes,

$$e^- + A \rightarrow e^- + e^+ + e^- + A,$$

where A represents either a nucleus or nucleon, are commonly called tridents and occur as fourth order processes in quantum electrodynamics. The direct production of lepton pairs by protons, $p^+ + A \rightarrow p^+ + \ell^+\ell^- + A$, is of intrinsic interest and in addition represents a unique opportunity to test the validity of quantum electrodynamics at high energies.

The measurements of the mean free path for the direct production of an electron pair by a high energy electron (>10 GeV) in emulsion are hampered because of the large fraction of bremsstrahlung pairs (BSP) produced which cannot be distinguished from the true cases of direct pair production. Experimental results have been found to be inconsistent with the theoretical predictions; the discrepancies are considered due mainly to BSP.

A recent emulsion experiment at SLAC[11], studying low-momentum-transfer trident productions, has been able to correct adequately for BSP and the results seem to support the validity of quantum electrodynamics for 14 GeV electrons producing direct pairs.

In the range of 100 GeV, a machine experiment using protons as the incident particles has a direct pair production cross-section large enough to produce satisfactory experimental statistics. However, the probability of a pseudoprocess will have decreased by a factor proportional to the square of the proton rest-mass. Thus, essentially all multiple-particle process will be eliminated.

The calculated mean free path in emulsion for 100 GeV and 200 GeV protons is about 190 cm and 125 cm respectively. Thus one would expect reasonably good statistics by following several thousand meters of track. In addition, by following tracks into the emulsion for distances of no more than 1 cm, the probability of pairs produced by materializing photons is sharply reduced. Most production events should be easily identifiable as a sudden increase in the grain density of the incident track (3 times) with the resulting particles all proceeding in the forward direction.

Accelerator experiments on direct electron pair production by protons have not been investigated due to the small cross-section for the interactions. However, at energies of 10^{11} eV, the theoretical cross-section for proton trident production is about 3×10^{-25} cm^2. This is well within the capability of an emulsion study.

The foregoing has defined the essential reasons for this experiment. Thus, we propose a large-statistics experimental investigation of the direct production of electron pairs by protons in nuclear emulsion. Such an investigation of this electrodynamic mechanism will provide us a better understanding of high-energy electromagnetic processes and could be important in assessing the range of validity of quantum electrodynamics.

II. Experimental Outline:

1. Emulsions: We propose an exposure of individual emulsion plates to the proton beam. The number of plates per exposure will be determined by the beam dimensions. In experiments at SLAC, emulsions have commonly been placed at the entrance window of the bubble chamber. The Ilford G5 plates, 400 microns in thickness, will be arranged (a) so that the protons will lose only a small amount of their initial energy and (b) to minimize cascade production effects.

2. Beam Exposure and Running Time: A beam intensity of 10^4-10^6 protons per cm^2 should produce between 10 and 20 tracks per field of view in the scanning microscope.

   Including time needed to make preliminary test runs, the entire exposure should be completed during an eight-hour shift.

3. Estimated Cross-Sections and Number of Events: With a total track length per plate of 31×10^5 cm, we shall have approximately 1500 events per plate at each energy. Exposing 20 plates at each energy will yield a total of 60,000 trident events. We anticipate measuring about 1000 events at each energy.

4. Scanning and Measuring: For scanning and measuring, Harvey Mudd College and the High Energy Group of the University of California, Riverside, will provide two or more scanning microscopes and a Koritska microscope for measuring. Interactions will be obtained by the "along-the-track" scanning technique. Angular measurement will be made on all secondary tracks. Estimating conservatively

on the basis of 50 cm/hr, it will require about twelve months to scan for 1000 events at one energy and also include some rescanning and scattering measurements.

III. Comparison with Other Proton Trident Exposures and Summary:

The emulsion proposals currently listed by NAL indicate no experiment which has as its specific subject the study of direct pair production.

In summary we propose a large statistic emulsion experiment to study in detail the direct production of electron pairs by protons of energy 100 GeV and 200 GeV. We request that, if the proposal is approved, the exposure of the emulsion at 100 GeV be given as soon as beam is available. Indeed if we are extremely fortunate, we shall be able to make satisfactory exposures during the initial Beam Tests.

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