

High Energy Electron Linear Accelerator.

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(based on talk given July 1959 at National Institute Accelerator Symposium).

This report is based on some considerations of the practicability and importance of a programme of research using a high energy electron accelerator which has been undertaken during recent months by a group at Glasgow University. We have been led to this study by a consideration of our own departmental nuclear physics programme. The experimentalists at Glasgow have evidently not been deterred by their experience of electron machines over the last five or six years, and are proposing, mainly for the study of photo-nuclear reactions, a 100 MeV electron linear accelerator. The current proposal for this accelerator is that the mean beam current should be approximately 200 μa with a duty cycle around 10^{-3} .

No discussion will be presented here of the programme proposed for this 100 MeV accelerator. However, not unnaturally we have been led from this to a consideration of the desirability of an electron accelerator in Britain in the GeV region. Our thoughts on the matter are still at a fairly early state, but can, roughly speaking be given under three headings.

- 1) The range of experiments opened up by a high energy electron accelerator - with a peak energy say up to 10 GeV. In particular we consider the fundamental interest of such experiments for elementary particle physics.
- 2) How well these experiments are likely to be done by existing or planned machines e.g. the Stanford linear accelerator or the Cambridge and Hamburg electron synchrotrons.
- 3) The characteristics desirable in an accelerator, beyond those of existing machines, to secure good accuracy in the experiments considered.

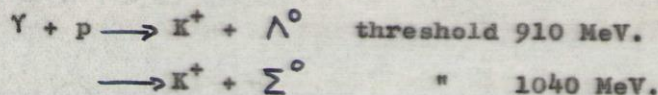
Range of Experiments.

First, then, we consider the range of experiments available to an electron accelerator. These may be listed as follows:-

1. Real Photon Processes.

a) Photoproduction of K-mesons.

Typically we may consider the reactions



These processes have already been qualitatively studied at Cal. Tech. and Cornell. The cross-section rises rapidly above threshold to a value of about 1 μb . Its higher energy variation is unknown, but there is no sign of a resonance peak as observed in photo pion production.

The significance of the photoproduction reactions for K-meson physics is obvious by analogy with the pion case. In the first place the photoproduction reaction forms an interesting and critical test of the whole theory i.e. how far with a knowledge of K-meson nucleon scattering photoproduction can be predicted. There are three respects in which photoproduction experiments go beyond what can be learned from scattering.

i) The direct photoproduction diagram

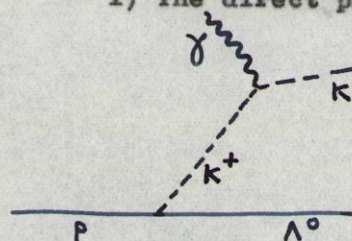


Figure 1

$$\cos \theta = v_K$$

(Fig.1) involves the simple intermediate state where there is just one K^+ -meson. As is well known this diagram gives rise to a pole in the photoproduction amplitude when $(v_K = \text{outgoing K-meson velocity})$, the residue at which is proportional to the K-meson coupling constant and the sign of which shows whether the meson is scalar pseudoscalar. To the process in Fig.1 there have to be/

be coherently added other terms in the transition amplitude (such as the S-wave $\sigma \cdot \underline{E}$ term and the magnetic dipole p-wave term, assuming a pseudoscalar K^+). These terms are quite large, and quite refined experiments, not at present available, are required to make use of this method of extrapolation to the pole.

ii) The magnetic dipole term in the photoproduction amplitude involves a knowledge of the hyperon magnetic moments. It is not obvious how otherwise these moments are to be investigated.

iii) An analysis of photoproduction in terms of K-meson scattering inevitably involves an extension of the scattering to non-physical regions.

b) Photoproduction of K^- -mesons.

The K^- -meson is first produced in the pair creation process.

$$\gamma + p \longrightarrow K^- + K^+ + p \quad \text{threshold } 1.5 \text{ GeV.}$$

The process has not as yet been observed and it would be rash to predict a cross-section. Clearly, however, the process will be enhanced as compared with its cross-section estimated purely on the basis of electromagnetic interactions.

c) Photoproduction of Nucleon-antinucleon pairs.

The typical process considered here is

$$\gamma + p \longrightarrow p + \bar{p} + p \quad \text{threshold } 3.75 \text{ GeV.}$$

This process, together with the comparable production by π -mesons, clearly constitutes the most elementary process of nucleon pair creation. Indeed the photon process, only involving one strong interaction, may be the most likely to be susceptible to theoretical analysis. Again it would be rash to predict a cross-section though we might expect that the photoproduction cross-section might be of the order of 1/100 of the pion production cross-section. At present there is little prospect of the detailed theoretical interpretation of such processes. However/

However, it seems certain that in the future they will become of great theoretical interest.

It should be added that for the production of pairs of all known hyperons photon energy greater than 6.2 GeV is required.

d. Photon-Nucleon Scattering.

This is another important fundamental experiment, but of very great difficulty.

2. Electron Beam Experiments.

Here we are concerned with essentially two types of experiment, both of which are characterised by the fact that the invariant moment transfer squared, q^2 , for the virtual photons in electron processes is different from zero.

a. Electron-Nucleon Scattering.

This experiment, and the information it yields on the nucleon form factors $F(q^2)$ has been very much studied at Stanford.

b. Electro-Production of Mesons.

This is a difficult experiment on account of the continuous spectrum of mesons given by a single energy of electrons. It is of special interest as yielding photoproduction matrix elements off the energy shell.

3. Electrodynamic Experiments.

There has recently been interest in several proposals for testing the validity of electrodynamics at high energies in phenomena that cannot be explained in terms of nucleon structure. Collision of high energy electrons with stationary electrons is not good for this purpose as the total centre of mass system energy is much reduced, being only 100 MeV for 10 GeV electrons. Typical of the sort of experiment that might be attempted is large angle e^+e^- pair production. If the e^+ and e^- are both produced at an angle of say 14° to an incident 10 GeV photon then the electron/

electron propagator is tested at $q^2 = (1730 \text{ MeV})^2$. This experiment seems just about practicable.

4. Production of Strange Particle Beams.

In the pion physics region it has been well established that pion beams are not efficiently produced by electron accelerators. Proton accelerators are very much superior for this purpose. It would therefore be very rash to advocate an electron accelerator for its production of K-meson or anti-particle beams. Theoretical estimates do however indicate that the margin between electron and proton accelerators will certainly become smaller in the high energy region, both because electron beam currents (in a linear accelerator) can be larger than proton currents, and because the photoproduction cross-sections are becoming more comparable with the π -meson and proton production cross-sections. For example we now propose an electron accelerator with a beam of approximately 10^{15} electrons per second. The cross-section for photoproduction of K^+ mesons is about $1 \mu\text{b}$, and, with reasonable targets, we might estimate a total production of about $10^8 K^+$ per second, taking the electron peak energy as, say 2 GeV. There will be background difficulties in the way of obtaining a separated K^+ beam, but a rough estimate is that we might hope to obtain $10^3 K^+$ mesons per second in a separated beam of 5% momentum resolution. (K^+ decay has been allowed for in this estimate). More detailed study is required of these questions, including also an assessment of K^- and $\bar{p}$ beams.

Characteristics of Accelerator.

The characteristics of an accelerator suitable for carrying out the above experimental programme have been considered during the last months, and are reported in an attached paper. In this paper we describe both the mean electron beam current and duty cycle considered desirable for an electron linear accelerator in the GeV energy range, and the design of a system permitting the acceleration of positrons. (Recently attention has been given to the idea of using a positron beam/

beam as a source of photons, so that, superposed on the bremsstrahlung there is an approximate line spectrum from two photon positron annihilation).