Natural Philosophy Department,
The University,
Glasgow W.2.

Our Ref: V/N/2.

20th September, 1960.

T.G. Pickavance Esq.,
Director,
Rutherford High Energy Laboratory,
A.E.R.E.,
Harwell,
Berks.

Dear Mr Pickavance,

Working Party on Electron Accelerator in GeV Energy Range.

The next meeting of the Working Party will be held on 28th September at 10 a.m. at the Chadwick Laboratory, The University, Liverpool. I hope you will be able to attend. I enclose a copy of three papers which have been prepared for the Working Party respectively by Drs. Binnie, Rutherglen and Williams.

It is hoped that the meeting on 28th September may be the final discussion meeting of the Working Party prior to the preparation of our report. A more detailed agenda for the discussion will be circulated within the next few days.

Yours sincerely,

J. C. Gunn

J.C. Gunn.

Letter - arrange a room in London 10.30. 8/11 Next Physics Cttee ~~end~~ first ½ of December. (~ middle) ~~last~~ ~~of November~~ 77

Electron Accelerator in GeV Energy Range.

Meeting at Liverpool, 28th September at 10.0 a.m.

Agenda.

Draft working party report by ~~end October~~
meeting of [illegible] first week in November

1. Consideration of reports prepared after the meeting on 4th August.

    a) Note on Storage Rings (By J.G. Rutherglen).

    b) The Production and Use of Annihilation Beams (By D.M.Binnie

    c) Electro-Production of K^+ Mesons (By W.S.C. Williams).

    d) Coincidence Ratio in Photo-Production Experiments (By A.B. Clegg).

2. Further consideration of the estimated performance of the proposed electron accelerators. (For the electron synchrotron, points of particular interest are electron injection and ejection, and also the question of multiple target traversals).

3. Review of the fields of interest for experiment.

2.30 4. Assessment of the efficiency of the proposed accelerators.

5. Arrangements for preparation of report.

6. Any other business.

Synchrotron 4 GeV
N.B. - straight section lengths - big as possible

Linac

electrons { peak E 4 GeV
10 ma pulse ~~at~~ [illegible] 1.5 × 10^{-3}
plant cost £2.7 m. from Vickers

J.C. Gunn.

100,000
400,000
500,000

+ for positrons ? (~ £½ m. ?)
+ for storage ring ? £1 m
+ for bldg of synchrotron £.75 m) £1.5 m total.

2π. 25 m. 150 m.

4 GeV 10 MeV/m. 1000 m. of linac.

T.

Working Party on Electron Accelerator.

Note on Storage Rings

By J.G. Rutherglen

For many experiments with electrons and gamma rays in the GeV energy range, particularly experiments on the photo-production of K-mesons, it seems likely that with present counting techniques the experiments will be limited by peak counting rates.

Cassels quotes an order of magnitude of 5 μa as the limiting electron current in a typical experiment. Presumably he is taking a 2% target efficiency, which means a limiting peak gamma-ray intensity of 6×10^{11} equivalent quanta/sec.

The proposed electron synchrotron would have a peak output of 2×10^{12} e.q./sec and a mean output of 10^{11} e.q./sec (taking 10^{11} e^-/pulse, 50 pulses/sec, beam width 1 m.sec., target efficiency 2%). It thus appears that for many experiments the beam would have to be reduced and the useful output would be determined by the duty cycle. A machine of higher intensity, such as a linear accelerator, would only be of greater value for these experiments if its duty cycle could be increased.

The only machine which seems to give the possibility of a high intensity and a duty cycle in the region of 100% is the combination of a linear accelerator and a storage ring. Although this is obviously an expensive machine it seems worth while to examine its feasibility, in view of the high performance which it offers.

The following rough calculations are based on the description of the 500 MeV storage rings designed for the Stanford Mk III accelerator given in the report of the accelerator conference at CERN in 1959.

These rings are designed for colliding beam experiments in which it is necessary to store a large number of injected electron/

/electron pulses. However for the present purpose it is only necessary to store one pulse and arrange for the bremsstrahlung output to be produced more or less uniformly during the interval between pulses. This means that the electrons can be injected directly at the equilibrium orbit radius. It seems possible that the target could consist of a very thin foil permanently located on the orbit radius.

If we take an energy of 3 GeV and a guide field of 10^4 gauss, the orbit radius would be 10 metres. The time for one orbit is then 0.21 μ sec. The injection would be by means of a pulsed delay line inflector which is capable of turning on a magnetic field of $\sim$ 2500 gauss in about 0.05 μ sec. Thus with single turn injection, the acceptance time would be $\sim$ 0.15 μ sec.

Since the filling time of the linac is 1 μ sec, the linac R.F. pulse would be $\sim$ 1.5 μ sec and the repetition rate could be 1000 c.p.s. With a 10 m.a. peak electron current in the pulse the mean current available for injection into the storage ring would be $1000 \times 0.15 \times 10^{-6} \times 10^4 \mu a = 1.5 \mu a$. However because of the energy spread of 3% not all of these electrons could be accepted by a ring of reasonable cost. If we assume a 20 cm radial aperture then an energy spread of 1% could be accepted, giving a mean current of $\sim$ 0.5 μa.

The R.F. acceleration in the storage ring would have to make up for radiation loss of 700 KeV/turn, for ionisation loss in the target foil of $\sim$ 1 KeV/turn and for low energy bremsstrahlung losses. The target efficiency would be determined by ability of the system to refocus and accelerate electrons which had undergone such low energy bremsstrahlung losses. If we assume all electrons which lost less than 0.1% of their energy (< 3 MeV) could be refocussed then the target efficiency would be $\sim$ 15%. Thus with an injected current of 0.5 μa the output would be 4.5×10^{11} e.q./sec.

In the proposed arrangement the target thickness would be/

/be $\sim$ 1/5000 radiation length so that most of the electrons would radiate usefully in the 5000 revolutions between successive imput pulses. Thus the output would be a series of exponentials with a duty cycle of $\sim$ 50%. Any electrons which were still circulating after 1 m sec would be destroyed by the next inflector pulse.

The peak output would be $\sim 9 \times 10^{11}$ e.q./sec, of the order of the maximum allowed by peak counting rate considerations. However the mean useful output would be ten time greater than that of a synchrotron with a duty cycle of 5%. The intensity could, of course, be increased by increasing the injection current from the linac, which might not be too expensive with an electron beam length of only 0.15 μ sec.

Such a machine would increase the counting rate of photo production experiments by at least one order of magnitude over than obtainable with a conventional synchrotron, There is also the possibility of accelerating longitudinally polarised electrons, which would become transversely polarised after 250 revolutions in the storage ring. The bremsstrahlung beam would then have its polarisation time modulated with a frequency of 1000 c.p.s. The polarised electrons could be produced initially by scattering of low energy electrons ($\sim$ 200 KeV) followed by $\sim 90^{\circ}$ electrostatic deflection to convert the transverse polarisation to longitudinal polarisation.

The Production and Use of Annihilation Beams.

I have looked more fully into the calculations and possibilities of annihilation beams. I have been much struck by the point of view that $K^+ + \Lambda$, $K^+ + \Sigma^0$ form only a small fraction of all the strange particle reactions possible at a few GeV, and that whatever beams and machines we have, we are certainly going to want to work on at least some of the other reactions.

I have assumed throughout that we could accelerate positrons in a linac. only, due to difficulties of angular spread and flux. In this case could we not advocate a positron linear accelerator, of low beam loading, up to as high an energy as we could afford - although even 2 GeV would give us work for years. Such a machine, in addition to the "conventional" advantages of an electron linac. would have a good place in all kinds of photo-production work, especially in reactions complementary to those tackled with bremsstrahlung beams and counters. A high quality positron beam would be available and either from a "fundamental" or from a "second order effects" point of view could surely make a contribution.

All the calculations have been based on 10^{12} positrons/sec, 3% energy resolution, 2 MeV/c transverse momentum. These figures depend very much on the design of the positron source. If the beam is only 10^{11}/sec, this would still be adequate for bubble chamber work. For counter work, 10^{12}/sec. offers significant advantages in a few experiments. If we could raise the intensity appreciably above this we would have great opportunities for ferreting out all sorts of "more difficult" reactions.

Assuming it doesn't turn out that I have forgotten something right at the beginning, it should be fairly easy to measure the angular distribution of bremsstrahlung and annihilation from H. in the range of angles needed, also to test the positron source design. If the machine does seem feasible then there are many interesting possibilities such as extension to higher energies; a storage ring; the recirculation of the beam to double the energy and the use of R.F. timing effects and the pulsed form of the output in various ways.

D.M. Binnie. September 1960.

THE USE OF ANNIHILATION BEAMS WITH BUBBLE CHAMBERS.

Suppose, for simplicity only, we consider photons of up to 2 GeV incident on Hydrogen and ask what strange particle reactions are possible; then, ignoring mass differences between charged and neutral particles and ignoring charge permutations, there are in all 10, starting with $K^+ + \Lambda$ at .91 Gev, followed by $K^+ + \Sigma^o$ and $K^o + \Sigma^+$ at 1.04 GeV, then $K^+ + \Lambda + \pi^o$, $K^o + \Lambda + \pi^+$ at 1.15 Gev, five permutations of $K + \Sigma + \pi$ at 1.30 GeV, and so on up to $K + \Sigma + 3\pi$ at 1.89 GeV. There will, of course, be a similar state of affairs for Υ + N. There are a couple of reactions producing K^-, at least 10 producing K^o, and at least 20 producing K^+. Although I don't suppose we will find the multiple pion, as opposed to single pion, reactions of much interest in themselves, they will presumably have quite an effect on the $K + \Lambda$ cross section, and become dominant at high energies. They will also make it very hard to pick out three body processes even near their thresholds. A 2 GeV bremsstrahlung beam contains, of course, photons at threshold for all these reactions, so they will all be peaked strongly forward in the lab. system. Even the investigation of such a simple reaction as $K^o + \Sigma^+$, surely interesting in comparison with $K^+ + \Sigma^o$, Λ^o will be very difficult. We can make some approach to K meson pair production by looking for K^- but this is evidently limited.

A bubble chamber could have been very useful in these investigations. The very decay of the heavy mesons and hyperons that makes counter experiments so difficult renders them ideal for detection in a bubble chamber, lifetimes of all except the charged K's being in the region of 10^{-10} sec. We can thus detect most strange particle reactions fairly easily, and identify the particular particle involved from the kinematics of the decay.

The possibilities of bubble chamber work using bremsstrahlung beams are severely hampered by the presence of the lower energy component of the spectrum. Some progress in alleviating this situation has been made by passing the photon beam through LiH which removes most of the photons of a few Mev, but the rate of obtaining useful events in the GeV region is still limited by the number of pairs that can be tolerated in the chamber. I hope to show that the annihilation beam at an angle can be of very significant help in this matter.

The annihilation beam should be useful firstly because, for a given intensity at the energy of interest, most of the lower energy photons that produce the electron background are removed (at least a factor of ten), and secondly the energy of the photons in the annihilation beam can be estimated quite accurately ($\pm$20 MeV at 750 MeV, $\pm$ 50 MeV at 3,500 MeV), the intensity of this annihilation part being at least 25 times (hopefully a factor of two or three more than this) above the surrounding radiation measured over the same energy interval. This allows one to choose the energy or energy range at which to work, makes it possible to compare the different reactions at the same energy, and could be of assistance in interpreting the photographs.

The rate of events is of course very important. I have made an estimate in the following situation. I assume a hydrogen bubble chamber in which we are interested in production over 50 cms. ($3\frac{1}{2}$ gms). Allow 10 e^+e^- pairs per picture and one picture every two seconds. Taking the annihilation beam at an angle giving annihilation photons from 700 to 800 MeV, we find this spectrum produces 10 pairs per pulse in the chamber with an annihilation flux of 100 Υ per second. (a small fraction of the/

the number available). If this beam were completely free from bremsstrahlung background, we could use about 250 γ/sec; if we used a pure bremsstrahlung beam of 800 MeV this would give 10 γ/sec. (If we limit the energy of interest to a 50 MeV band, the figure of 10 /sec. is reduced to 5). 100 γ in 50 cms. of H give a probability of 2 x 10^{-4} for a 1 μb cross section, one event per 5000 photos.. This, for a 12 hr. day, gives 140 events/μb/month in 700,000 photos! Of course, if we have several strange particle processes each of a few μb at higher energies then the rate of obtaining strange particle production events will become quite reasonable, at least in terms of machine time. Thus, for a 50 μb cross section for $\gamma + p \rightarrow 2\pi + p$ we find 18 events/hour. In a deuterium chamber the rate will be approximately doubled for the same background.

I have also looked into the performance of a 4 GeV e^+ beam to produce nominally 3.4 to 3.5 GeV photons. Similar figures obtain here. The energy of the photons should be known to about $\pm$ 50 MeV. The radiation at 2 GeV from 4 GeV positrons should be appreciably (a factor of two or three) purer with respect to the bremsstrahlung background (simply because the angles involved are greater). This therefore seems a good way of making 2 GeV experiments if the positron energy is available.

One or two subsidiary points; the main uncertainty in the photon energy arises from uncertainty of the photon angle relative to the positron. With the bubble chamber the final angle of the photon will be known extremely well, and the energy uncertainty will then be determined by such factors as positron scattering, the geometry of the positron beam - and, of course, the positron energy. For this reason it is possible to let a large slice of photon energies into the chamber, but still know the photon energies relatively accurately. As a second point, since there would be presumably pressure on the machine for other purposes, it would be perfectly feasible to supply photos of the required energy to several different bubble chambers, even using the same positron beam. We could imagine, for instance, one chamber containing P, and another D. By using different angles, we can work at different energies. Thirdly, the background e^+e^- pairs should give a good calibration of the photon intensity and spectrum.

COUNTER EXPERIMENTS USING ANNIHILATION BEAMS.

At the level of intensity suggested, there seems less scope for counter work using annihilation beams compared with the bremsstrahlung beam from the synchrotron. For some classes of experiment, however, the disparity may be by no means as great as it would appear. In this analysis, I am discussing beams at about 1 GeV.

The synchrotron enjoys a factor of 40 in duty cycle (5% compared with .125%) and a higher intensity. Arthur Clegg's analysis of photoproduction experiments has shown that in the more difficult experiments we could not use a peak current much in excess of 1 μa, giving, at 2% conversion, 3×10^8 photons/sec. in a 50 MeV interval near the top of the spectrum. This limitation, which makes synchrotron fluxes much more comparable with annihilation fluxes, arises because of background, either target induced or general room, and duty cycle. General room background depends very much on the type of machine and shielding design. Target induced background is fundamental to an experiment. This latter background, whether meson or electron, will be produced almost entirely by photons below the energy of interest in the experiment. Thus, if we attenuate these photons by, say a factor 'y' relative to the desired energy band, casual coincidence rates are reduced by a factor y^2. A duty cycle ratio of 40 could therefore be matched by a 'y' of 6½. For higher y's, the annihilation radiation would permit of a better job if the intensity were available.

Using the same idea, but in a rather different context, as we investigate energies much above 1 Gev we are going to have a problem of distinguishing 'wanted' from background K mesons. This is especially true for any 3 body processes (the vast majority). Thus the process $\gamma + p \rightarrow K^+ + \Sigma^0$ has to be investigated against a background of similar momentum K mesons from $K^+ + \Lambda$ produced by photons of some 70 MeV lower energy. It certainly seems possible, at the price of lowered intensity, to design a beam to attenuate this source of photons by at least a factor of 10.

The beams so far discussed have an energy spread in the region of 50 to 100 MeV, and are obtained by using photons at an angle to the positrons. There are occasional suggestions that a much higher resolution could be of use in such as the study of processes in the neighbourhood of thresholds. Angular spreads seem to make it imperative that we use annihilation photons in line with the positrons. While this means that the bremsstrahlung flux is high, the annihilation radiation is gaining ground in relative Flux/MeV as it is so sharply peaked. The important comparison is that between the annihilation flux and the "end point" of the bremsstrahlung spectrum. This is in the "unsereened" region, and I have assumed Heitler's Formula, doubled for the presence of electrons.

The beam of total width 8 MeV, for instance, has an intensity of 3.3×10^7/sec., six times that of the 8 MeV of the bremsstrahlung spectrum. This compensates for the poor duty cycle as far as target induced casual background is concerned. To produce this flux with the last 8 MeV of the bremsstrahlung spectrum alone would require about 1½ μa peak current for 5% duty cycle. The intensities are therefore similar. We are thus left with the net advantage that the ratio of K's from the 8 MeV of interest to those from lower energy photons is 6 times higher using the annihilation beam.

The proton compton effect might also be amenable to treatment by this type of annihilation beam. One of the main difficulties/

difficulties in detecting this reaction at higher energies is probably that the kinematics are so similar to $\gamma+p \rightarrow \pi^0+p$. Since the protons from $\gamma+p$ have the highest momentum, it turns out that the 8 MeV annihilation peak at 1 GeV is narrow enough to give a fairly clean separation of the protons from $\gamma+p$ from those from all the other sources.

One of the main points behind these ideas is that the background counting rates in the counter telescopes arise from target induced particles. I have no experience in this matter, but some relevant points seem to be:-

(a) the duty cycle.

(b) The ratio of used photons/accelerated charged particles. This is poor in the "annihilation at an angle" beams, good in the high resolution beams.

(c) Where does all the energy go? The linac. beam is hardly affected in intensity of quality by passing through a gram or so of hydrogen, and could surely be taken away and "quietly! buried when we are finished with it. What happens to the synchrotron beam energy?

K^+ Electroproduction.

W.S.C. Williams.

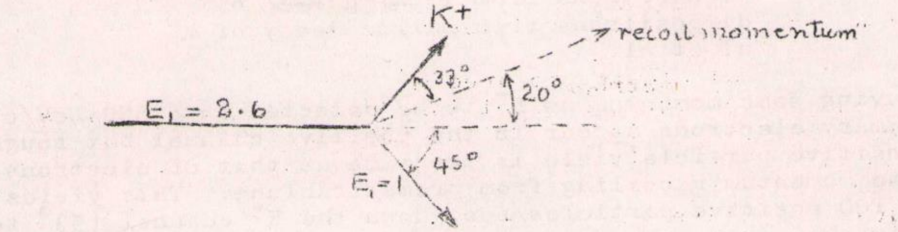
1) Typical Kinematics
(all energies in units of nucleon rest mass)

E_1 = incident electron energy = 2.6

E_2 = scattered electron energy = 1.0

θ = scattered electron angle = 45^o

Recoil momentum is that of the excited recoiling proton which "decays" into K^++n. This momentum is 20^o to incident direction. If this recoil decays at 90^o in its centre of mass (90^o to recoil direction) the K^+ appears in the lab at 33^o to recoil direction with an energy of 0.33.



II) Cross-section for inelastic electron scattering in which a K^+ is produced is less than

$$\text{Limit of}_{\,q^2 \to 0} \quad \frac{d^2\sigma}{d\Omega\, dE_2} = \frac{\alpha}{4\pi^2 E_1} \frac{1}{1-\cos\theta}\, \sigma_\gamma$$

σ_γ = total photoproduction cross-section at energy corresponding to the limit $q^2 \to 0$. Taking $\sigma_\gamma = 10^{-30}\,cm^2$

$$\frac{d^2\sigma}{d\Omega\, dE_2} \lesssim 2.5 \times 10^{-37}\ cm^2/st.\ MeV$$

We assume the following experimental conditions:

(a) 10^{14} incident e^-/sec
(b) $d\Omega\, dE_2$ = 1 MeV st. in e^- channel (e.g. mom. analysed via magnet)
(c) $d\Omega$ = 0.01 st. for K^+ detection system (presumably momentum analysed).
(d) target 3×10^{23} p/sq.cm.

Yield is then $< 5 \times 10^{-3}$ $K^+ + e^-$ coincidences/sec.

i.e. $<$ 1 in 3 minutes.

III) The only background which can be estimated is due to particles of the same sign and momentum coming into the detection systems.

IIIa) e^- channel: the particles will be

a) e^- inelastically scattered in π electroproduction
b) e^- recoiling from bremsstrahlung
c) e^- from $\pi \to \mu \to e$ decay in target
d) e^- from Dalitz decay of π^o
e) π^- from electroproduction
f) et al.

(a)/

(a) is probably the most importante and from the experience of Panofsky and Allton may be 5X that from (b). The latter can be calculated and gives for (a)

$$\frac{d^2\sigma}{d\Omega dE_2} < 0.5 \times 10^{-36} \ cm^2/st.MeV.$$

Under the given experimental conditions this yields 15 e^- per second. The remaining processes will contribute at the most as much again of e^- and π^-. Say 30e^- per second.

IIIb) K^+ channel: the particles will be

a) electroproduced π^+
b) protons recoiling from various processes
c) positrons from $\pi^+ \rightarrow \mu^+ \rightarrow e^+$
d) positrons from Dalitz decay of π^0
e) et al.

All having same momentum as K^+ to be detected ($\sim$ 550 MeV/c). No primary electrons appear in the positive channel but roughly the positive particle yield is the same as that of electrons of same momentum recoiling from bremsstrahlung. This yields about 100 positive particles/sec. down the K^+ channel (53° to incident beam).

With a duty cycle of 10^{-3} the instantaneous flux in the channels are

K^+ channel	10^5	particles/sec.	Instantaneous.
e^- channel	3×10^4	" "	Instantaneous.

X A simple coincidence circuit, resolving time of 5×10^{-9} sec. X would yield a random coincidence rate 3×10^{-2}/sec. which is about 10X the real K^+e^- rate. However all the above cross-sections will be reduced by form factors, the random rate depends quadratically on these factors whilst the K^+e^- rate depends linearly on these factors. This reduces the ratio of random to real rates. In addition a very selective counter system in the K^+ channel would reduce even further the random coincidence rate.

The momentum transfer (to nucleon) in electroproduction is given by

$$q^\mu q_\mu = 2E_1E_2(1 - \cos\theta)$$

if m_e is neglected. Therefore $q^\mu q_\mu = 0$ if $\theta = 0$.

Thus photoproduction can be done by inelastic scattering of electrons at 0° in coincidence say, with K^+ at the angle normally expected in photoproduction. By picking E_2, a monochromatic photon beam is simulated.

Reference.

Panofsky and Allton, Phys. Rev. **110**, 1155, 1958.

DRAFT

NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE

Working Party on Future Accelerator Policy

Minutes of Meetings held in Liverpool on
27th and 28th March, 1960.

1. The Working Party considered whether further high energy accelerators were necessary in the United Kingdom during the next ten years in order to enable the country to play a leading role in the field of elementary particle physics.

2. The Working Party had before it the following papers which were discussed at the meetings.

(a) Further Accelerators in the United Kingdom - Mullett.
- an analysis of Accelerators which might be built in the next decade.

(b) Notes on A.G. Proton Synchrotons - Hine.

(c) Some factors in High Intensity Beams - Galbraith and Morgan.

(d) The Possibility of Neutrino Experiments - Salam and Matthews.

(e) Electron and Positron Linear Accelerators - Gunn and Moorhouse.

(f) A Note on the possible extension of the Rutherford Laboratory Proton Linear Accelerator - Stafford.

3. The conclusions of the Working Party were that there was a clear need for additional high energy accelerators, in order

(a) to maintain and expand those schools of high energy physics at Universities which were already working in this field of research and

(b) to extend our knowledge of the interaction between elementary particles.

In this connection the need for accelerators which would produce beams of secondary particles of intensities ten or even one hundred times the presently available intensities was strongly emphasised and so was the need to give special attention to the design of accelerators which would yield intense beams of low energy secondary particles.

reworded

4. In connection with 3 (a) above, Professor Cassels made out a strong case for an electron synchroton of energy between 3 and 4 Gev. It was emphasised that there was a clear cut field of research that could be covered by such a machine, but it was important that the accelerator should be built as soon and as quickly as possible.

5. The Working Party considered that this was a very suitable machine to be built immediately and that it could be closely associated with existing University Departments. The next step

ACTION
Mullett
Cassels

should be to make an estimate of the cost of building and operating such an accelerator, to estimate the manpower requirements and to begin a preliminary design study.

6. In connection with 3 (b) it was concluded that there was need to accumulate experimental information on the yields of secondary particles as a function of the primary proton energy in order to help to settle the energy of any future high intensity accelerator. Dr. Pickavance agreed to write to the N.I.R.N.S. staff working on the Bevatron and Cossmotron in the U.S. to ask them to obtain what information was available and possibly to initiate some experimental measurements. It was also suggested that a team should be sent to C.E.R.N. especially to make measurements of yields, but itwwas decided that these results would automatically come out of work already in hand there and that it was unreasonable to ask for time on the CERN P.S. for this purpose. Professor Merrison agreed to provide the Working Party with the information as it became available.

ACTION
Pickavance

ACTION
Merrison

7. It was agreed that a more detailed study of possible high ~~energy~~ intensity proton accelerators should be pursued. The available effort should be devoted to a study of the following:

(a) A proton linear accelerator with an energyof a few GeV. (This is going on at Manchester University already).

ACTION
Manchester University) Rutherford Laboratory)

(b) A resonated alternating gradient synchroton with an energy of approximately 15 GeV.

ACTION
Walkinshaw)
Mullett)

(c) F.F.A.G. accelerators.

This study should lead to a clarification of the practicability of such an accelerator and an estimate of the total cost, the manpower requirements to build, the running costs and when such a machine could be started.

8. There were also two electron accelerators which it was considered should be investigated in greater detail.

ACTION
Mullett
Cassels

Glasgow University

These are (a) a 12 Gev electron synchroton
and (b) an electron-positron linear accelerator with a peak energy of 6 Gev.

The experiments which could be carried out with the electron linear accelerator were described by Professor Gunn at a Symposium on Accelerators held by the National Institute for Nuclear Science in July 1959. The cost and complexity of such a machine were considered to be serious disadvantages as also was the poor duty cycle when compared with the electron synchroton. Higher mean currents were, however, a point in its favour.

9. In all high intensity accelerators the need to improve the low duty cycle becomes of great importance. The most promising line of attack on this problem is the use of a Storage Ring and it was agreed

that work should be pursued in this field of accelerator research. It was suggested that the best approach would be to send staff to CERN to collaborate in the work that is going on there.

ACTION Wilkinson Galbraith

10. As experiments with high intensity secondary beams involve ~~s~~ not only the provision of an accelerator with a large primary beam intensity but also suitable beam transport systems and detecting equipment it was agreed that work should also be initiated on the latter as well.

11. The need for high intensity secondary beams includes mesons of energies up to a few hundred Mev. It was agreed that the Rutherford Laboratory Proton Linear Accelerator was a possible method of providing such particles. Proton Linear Accelerators remain potentially very promising machines particularly if they can be used with storage rings so that research on, and the development of, machines of this type should be encouraged as valuable experience for the future.

ACTION STAFFORD

12. In order to assist the Working Party in drawing up its final report it was agreed that it would be of value to have available a comparison between the annual expenditure on high energy physics in the U.S.A. and the U.K.

Note. (I have written to Professor Bethe for information. G.H.S.)

13. Because of the long time it takes to build large accelerators an immediate step that should be taken is to ensure that the best use is made of existing accelerators, including those at CERN. This is likely, inter alia, to require the provision of additional staff for University Physics Departments.

14. Finally, it was felt that money could very profitably be spent during the next five years in improving the performance of existing accelerators.

15. In summary, it was decided that subject to a suitable design study and general assessment of the project, the Working Party would recommend that an electron synchroton with an energy of between 3 and 4 Gev should be built as soon as possible. At the same time those lines of development and research should be pursued which could lead to a firm decision by about 1965 on the practicability of constructing a high intensity accelerator.

Overall budget for whole programme by Phys Comm