Sir John Cockcroft

C.E.R.N. Cyclotron

I have just received a table of cost estimates for the 600 MeV cyclotron - a copy is attached. All the major items, and many of the minor ones, are based on firm estimates received from industry, and the total figure (corresponding to the budget) includes a "grant" of 1 million Swiss francs for the Laboratory Group and 3.2 millions for contingencies.

You will see that the total magnet cost is estimated to be 6 millions, or £500,000. This includes a "prudence factor" - the lowest estimates received from industry are appreciably below this figure.

An overall programme of design and erection has been prepared by Krienen, based on completion 4 years from now. So far as one can judge now this appears to be realistic.

These documents will shortly be given to Verry, incorporating any amendment which Moore, Cassels or I may wish to make.

T.G. Pickavance

Cyclotron Group,
General Physics,
Hangar 7

NATIONAL INSTITUTE FOR RESEARCH IN NUCLEAR SCIENCE,

Telephone:
Abingdon 1220
Ext. 3283

Rutherford High Energy Laboratory,

Harwell,

Didcot, Berks.

25th March, 1959.

Dr. Hobbis
Bldg 412

Dear Dr. Hobbis,

I enclose a draft programme for a short symposium on high energy accelerators which we are planning to hold at the Rutherford Laboratory in the summer, and I should be glad to have your comments.

A series of talks would be given by members of the Institute staff and the 7 GeV project, each followed by a short period for discussion, the idea being to give brief but authoritative general accounts of the various accelerators. These would be aimed at potential users, rather than accelerator specialists. Finally, there would be a general discussion of possible future accelerator programmes.

The formal papers could occupy one day, or possibly a day and a half, and an additional half day would be allowed for the general discussion.

I hope that you will be able to come, and to bring some of your colleagues. A questionnaire is enclosed, to enable us to choose the most convenient dates and to assess the total numbers to be accommodated.

Yours sincerely,

Dorothy Barr

p.p.
T. G. Pickavance

ENC.

RUTHERFORD HIGH ENERGY LABORATORY

Symposium on High Energy Accelerators.

July 1959

Draft Programme

1. The National Institute and the Rutherford Laboratory.
2. The 50 MeV Proton Linear Accelerator.
3. Characteristics of the 7 GeV proton synchrotron.
4. Beam selection and transport problems.
5. High energy electron accelerators.
   - (a) synchrotron
   - (b) linear accelerator.
6. Ridge field (AVF) cyclotrons.
7. Beam storage and colliding beam systems.
8. Possible future programmes - a discussion.

H.L.59/1905.

75

Sir John Cockcroft,
Member for Research,
Building 329.2

N.I.R.N.S. Physics Committee - Heavy Liquid Bubble Chamber

We have been trying to arrange financial support for Massey to continue design work on this project, before the main scheme is approved by the Institute. However it turns out that he still has a small contract with D.S.I.R. and therefore Lord Bridges is unwilling to approve an interim contract with the Institute. We must therefore try to accelerate the progress of the main scheme.

Massey's paper is nearly ready, and we hope that it can be put before the Physics Committee on 10th June. The Committee should also have before them assessors' reports in accordance with the decision made at the last meeting (and endorsed by the Board), and therefore we have to appoint assessors immediately. I had originally intended to suggest Butler and Glaser, but under present circumstances we should not wait for answers from abroad. Would you agree to Butler, Evans and Mullett acting as assessors? The main features of the scheme have already been blessed by the Bubble Chamber Panel, and Evans and Mullett could advise as independent persons - one on the bubble chamber aspects and the other on the project and organisational aspects.

Incidentally, the confusion over the apparently high cost of this chamber probably arises from the fact that it is unusual in having a very large magnet; it is comparable in size with the large hydrogen chamber.

T. G. Pickavance

Rutherford High Energy Laboratory,
Building 412.10
21st May, 1959

c.c. Dr. J. A. V. Willis

45

URGENT

Sir John Cockcroft
Member for Research
Building 329.2

Bubble Chambers

1. **Liquid hydrogen**

The time programme was discussed at the Management Committee yesterday. Butler and his colleagues are confident, and we agreed to table the programme at each meeting to pinpoint any likely delays and to see what extra effort might be needed to minimise or remove them. Contracts are now being placed, and tender documents will go out soon for the magnet. The project appears to be in quite good order at the moment, and we are taking steps to organise the Rutherford Laboratory part of the programme under Mullett's chairmanship. There will be close liaison between the Harwell and University parts of the work, provided mainly by Snowden.

2. **Propane - heavy liquid**

The final proposal by Massey will not be ready for the Physics Committee on Wednesday. The first cost appraisal by Harwell is not good enough, owing to pressure of other work, and further discussion is needed before the project can be put in detail to the assessors and the Committee.

Massey is in considerable difficulty with funds to continue the work. He has the (inadequate) remainder of a small D.S.I.R. contract which runs until October, and there will be difficulty in getting funds from the Institute in time to rescue the project. We cannot arrange Institute finance to overlap the period of the D.S.I.R. grant, without adopting the whole project. It was for this reason that we tried, and just failed, to deal with the whole project next Wednesday.

I propose the following procedure:

(i) Massey should state his position, including his detailed needs for design funds at the Physics Committee next week.

(ii) Willis and I should then discuss the problem with D.S.I.R., to see whether there would be any objection to the Institute guaranteeing design study funds after October.

(iii) A proposal, backed by the Physics Committee, should go to the General Purposes Committee for the Institute to sponsor design work, subject to D.S.I.R. agreement.

At this stage if all goes well, Massey would be able to assure his people of continued employment and restore morale, which is not good.

(iv) A special meeting of the Physics Committee should be held, to consider the scheme and assessors' reports when they are ready. This is urgent, but I know that you have a very tight schedule from now on. Would you be willing for someone else (a member of the Board) to chair this meeting if we cannot find a date to suit you? If so, he would have to be one of the following:

Blackett
Sir George Thomson
Mott
Wilkinson

2/....

Sir John Cockcroft

It would also be difficult or impossible to get a full attendance of members at this time of year. This part of the plan therefore depends on the feelings expressed by members next week, but I feel that we must put the project on the rails quickly.

T. G. Pickavance

Rutherford High Energy Laboratory,
Building 412.10
5th June, 1959

COPY

23 July 1959

Dr. T. G. PICKAVANCE
National Institute for Research in Nuclear Science
Rutherford High Energy Laboratory
Harwell
Didcot, Berks.

Dear Dr. Pickavance,

I am very glad to give you my opinions concerning the value of various types of bubble chambers for high energy research in answer to your request. Although I am sure you have already had expert advice on this question, my experience with propane and xenon chambers may be at some use to you.

It is obvious to me that hydrogen-deuterium chambers possess unique and enormous advantages in the simplicity of interpretation of particle scattering, production, and absorption processes and for this one reason, simplicity of data interpretation, kinematically and otherwise, the hydrogen chamber is the best track detector for experiments feasible with it. Experience in the past few years has shown that there is a class of experiments, some completed, and some in the future, that cannot be done with hydrogen chambers, (at least not economically in terms of exposure time at the machine and analysis time)½

We are in the process of analyzing the first heavy liquid bubble chamber experiment. We have analyzed 80,000 out of 160,000 pictures of the xenon chamber (30 cm diameter, 25 cm deep) exposed to a 1.1 BeV π^- beam. The pictures contain about 1400 Λ^0-Σ^0 productions. At the half-way point we have already found excellent values for the ratio of neutral to charged decay rates of Λ^0 and K^0, as well as a value for the up-down asymmetry of the "unseen" mode $\Lambda \to \pi^0 + n$. For some years cosmic ray Λ's have shown an unexpected forward-backward asymmetry which, if taken seriously, is evidence for parity violation in the strong reactions leading to strange particle production. No such effect is found in hydrogen, but it was argued that perhaps the "asymmetric Λ's" resulted from collisions of Σ's in the heavy atoms (C, Fe, and Pb) in which they were produced in the cosmic ray experiments. To test this idea, a large unbiassed Λ-sample produced in heavy nuclei was needed. Our Λ's were able to show that the asymmetry does not exist for Λ's made in at least one heavy atom (Xe) at one energy (1.1 Bev), and strongly suggests that the cosmic ray data (85 cases for the whole world) were statistically or systematically weak.

Parity violation in hyperon decay leads to a longitudinal polarization of the decay nucleons, their longitudinal polarization being algebraically (sign and magnitude) equal to α , the parity-mixing parameter describing the decay. This longitudinal nucleon polarization is given a transverse component by the laboratory motion of the center of mass of the decaying hyperon so that a right-left asymmetry in the scattering of the nucleon against nuclei in the liquid is expected. Since the asymmetry as well as the total cross-section are small in hydrogen, this is a difficult (or may be altogether unfeasible) experiment in hydrogen. The Berkley propane chamber group has just reported in Moscow a value for the helicity at the Λ decay proton on the basis of a number of scatterings in propane (mostly against C since its "polarizing strength" is much greater than that of H). We hope to obtain a similar result in our xenon pictures. Now that we know that $\Sigma^+ \rightarrow p + \pi^0$ shows a large updown asymmetry, ~~a~~ similar measurement on Σ^+ decay protons is of the greatest interest. Even more interesting would be a measurement of the helicity of neutrons from $\Sigma^{\pm} \rightarrow \pi^{\pm} + n$ although that is much harder but may be feasible in propane.

I could go on adding examples of current and future experiments which use propane or heavier liquids to great advantage for

1) ~~efficient~~ γ ray detection
2) study of particle interaction against nuclei (polarization, isospin arguments as for the He^4, C^{12} etc.)
3) study of possible cooperative phenomena inside nuclei in particle production and interaction
4) cases in which range measurements aid particle identification or kinematical analysis or in which it is desired to stop particles to observe their absorption or decay
5) experiments requiring high density to increase the probability at rare events such as double or triple scatterings or of $K^o - \bar{K}^o - K^o$ conversion and diffraction

Since it is difficult to predict the precise direction of the experiments or of possible future chemical developments concerning practical bubble chamber fillings (price of xenon may drop, some new substituted heavy metal-organic liquid may be usable, etc) I advocate a "universal bubble chamber" in addition to a hydrogen-deuterium chamber. It should be able to operate from about -25^oC to 125^oC (from xenon up to the really easy limit for most diaphragm and gasket materials), be very safe against escape of toxic or inflammable materials, be constructed of the most corrosion-resistant of reasonable materials, have 15,000 to 20,000 gauss field, have at least three cameras, and be as simple and reliable as possible.

To me it has always seemed important in high energy physics to have available a great diversity of techniques so that new theoretical ideas may be tested, and experimental uncertainties resolved with the greatest possible range of conditions of observation. Only with such flexibility can the creative imagination of the experimenter attain its best results in studying the important problems in Physics. To limit oneself to one or several techniques, except in case of dire economic necessity, is to fly in the face of experience in experimental physics and to deny the worth of inventive ingenuity.

I have been a bit long-winded and perhaps allowed myself an excess of philosophy. Please excuse me for this.

With best wishes

Sincerely yours,

D. A. Glaser

sent with letter to Lord Bridges 29th October (filed 3)

Ic

Government Support for Fundamental Nuclear Research

1. Certain aspects of fundamental nuclear research will continue for the foreseeable future to be so costly that substantial sums will be needed from public funds in support of particular projects, both for construction and for subsequent operation and use. At present these funds are channelled through three principal routes:

(1) Bodies such as the U.K.A.E.A., who engage in fundamental research as a minor but important part of their main programmes.

(2) The D.S.I.R., who finance special investigations by universities in association at present with the U.G.C. when additional buildings are required. The D.S.I.R.'s responsibilities are much wider than the provision of funds for major nuclear projects. They support university research in other fields, they award post-graduate grants and fellowships to individual workers in all scientific fields, and they give large numbers of relatively small grants in aid of nuclear research. The D.S.I.R. also finance work by universities at C.E.R.N., of which the United Kingdom is a Member State, and are responsible for British participation in C.E.R.N.'s own work.

(3) The National Institute for Research in Nuclear Science, who are empowered by their Royal Charter to engage in work in the nuclear field, in collaboration with universities and similar bodies. The Institute give direct support to universities in connection with research at the Institute's laboratories, and also for work at the universities in aid of the Institute's own programme.

2. This note is concerned with research by or in collaboration with universities, which must continue to be the main source of new fundamental knowledge if they are to perform their proper function, and is mainly concerned with major projects; the term "major" will need definition. It has long been a responsibility of the D.S.I.R. to support university research in the physical sciences, but the need for special provision for major projects in nuclear science led some years ago to British participation in C.E.R.N. and, more recently to the establishment of the National Institute. The Institute are inevitably involved in supporting university work in their own field, and to that extent they have already encroached upon the D.S.I.R.'s province, but this does not necessarily make a case for special treatment of all nuclear science. The D.S.I.R., in dealing with those aspects of nuclear science which do not need special provision, are able to help the universities to conduct balanced programmes in science generally.

3. The Government will, however, need to be advised on the nature and relative merits of major new facilities which should be provided, for adequate participation by British scientists in this field, before approving projects and budgets. Irrespective of the number of financial channels which remain open the Government will wish, as expenditure rises on constructing new facilities and operating existing ones, to arrive at a satisfactory overall budget for the field. The second most costly commitment at present is C.E.R.N., costing the U.K. about £1½ millions annually, exclusive of British university work at C.E.R.N., and financed through the D.S.I.R. The most costly is the Institute, engaged in the same field of high energy physics which is only one part (though the most costly one) of fundamental nuclear science. The fact that the Government may also need to seek advice on the overall balance between nuclear and other fields needing exceptional support seems only to strengthen the case for presenting advice on major projects in nuclear science through a single body authoritative in that field.

However, the juxtaposition of C.E.R.N. and the National Institute introduces a difficulty in this connection. C.E.R.N. is an international organisation and it is obviously proper for the D.S.I.R., as the most appropriate Government Department, to handle British participation in C.E.R.N.'s own work, which is a major project on any definition. Moreover it is convenient for the D.S.I.R., through its general responsibilities for supporting university work, to look after the needs of universities who wish to make use of C.E.R.N.'s facilities. Provision of these needs will be costly, and may well involve sizeable projects within the universities in preparation for work at C.E.R.N.

If a single advisory body is to be used, then either the Institute or the D.S.I.R. (or both) will suffer embarrassment in submitting their cases through that body. This can be lessened, but not eliminated, by proper consultative arrangements.

4. The advice offered to the Government on any research project must be based on the opinions and programmes of active research workers in the field and cannot be generated in a committee of manageable size, however eminent the members may be. The National Institute are well qualified to act as an advisory body in this field since, unlike the D.S.I.R., they are engaged in major programmes of research on their own account in close collaboration with the universities. They have, and will continue to have, the largest and most costly installations for fundamental nuclear research in the country; this is deeply involved in the reason for their existence. They must therefore have free access to the Government with applications for funds for their work, based on the advice of university research workers with whom they collaborate and whom they serve with the facilities which they operate. This advice is made available through the established Institute committees, and at working level through the Institute's research laboratories where their staff work side by side with those of the universities.

The marshalling of authoritative advice on general future major programmes in nuclear research would clearly be a natural and simple development.

5. In principle there is no reason why advice should not be presented through a single channel while finance passes through several, provided that proper consultative arrangements are made with the interested parties, but there may well be pressure to reduce the number of financial channels to one. For this reason, and also because the D.S.I.R. have certain well established duties towards universities which should not fall to the Institute, it may become important to devise rational definitions of "major projects" for both the advisory and financial activities. The research reactors are a case in point. Here the Institute marshalled the advice at a time when it was believed that large central Institute facilities might be needed, but they may or may not be asked to provide the finance now that the needs have been shown to be different. The financial issue will probably turn on the issue of technical Institute activity in the work.

The Institute is the obvious channel if the definition of a "major project" includes a need for functional as well as financial assistance to universities. In deciding who should finance a project, this would be a better criterion than either the sum of money needed or the number of universities involved.

6. <u>Conclusions</u>

1. There is a case for a single authoritative body to advise the Government on fundamental nuclear research, but this body should offer advice only on projects requiring special treatment, i.e. major projects. Other projects should be dealt with on a broader basis, as at present.

2. The definition of the term "major project" should include the requirement by the universities of technical assistance in design, construction and/or operation of the facilities proposed, and might include other provisos which need study.

3. It is impossible to exclude consideration of work connected with C.E.R.N. from the function of an advisory body in this field.

4. The advisory body should be the National Institute.

5. There is no reason in principle why financial responsibility should always reside with the advisory body but, if the Government decide to finance the work through one body, this function also should be restricted to major projects and might exclude C.E.R.N.'s work in Geneva as well as "minor" university projects directed towards C.E.R.N.

T. G. Pickavance

29th October, 1959.

COPY

CORNELL UNIVERSITY

Laboratory of Nuclear Studies
Ithaca, New York

6th November, 1959.

Dear Gerry,

Have you heard of the suggestions of T. D. Lee, now at the Princeton Institute, for research into high energy neutrino interactions?

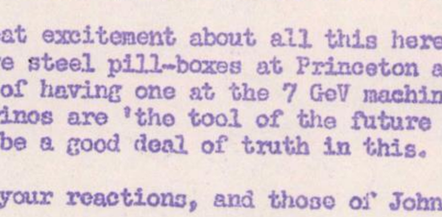
Suppose you take a beam of π^- mesons at about 2 GeV. The π^- will decay by $\pi^- \to \mu^- + \tilde{\nu}$, and in the laboratory system the antineutrinos will be thrown forward into a well-collimated beam. This is then filtered through 25 m. of steel (expensive!) which removes everything else so that quiet experiments can be done.

The antineutrinos could induce inverse β decay reactions like $\tilde{\nu} + P \to e^+ + N$, which would be detected as a high energy shower. The cross-section for this reaction rises as $p_{\tilde{\nu}}^2$. The matrix element in the expression,

$$w = \sigma c = \frac{2\pi}{\hbar} |M|^2 \rho_E$$

w = transition rate
σ = X section
M = matrix element
ρ_E = final state density

would be constant, while ρ_E relativistically rises as $p_{\tilde{\nu}}^2$. In fact σ at 1 GeV reaches such a size that it might induce one reaction per hour per ton of detector, which should be observable. At 1 GeV the above cross-section would level off because of the finite size of the proton, but the total cross-section would go on up



because of such reactions as $\tilde{\nu} + P \to e^+ + P + \pi^-$, which start more slowly because of unfavourable ρ_E at low energies. It is said that σ_T would reach geometric proportions at 100 GeV. Not so weak interactions!

There is great excitement about all this here, and much talk of installing massive steel pill-boxes at Princeton and Argonne, so maybe you should think of having one at the 7 GeV machine. The general idea is that the neutrinos are 'the tool of the future for exploring the nucleon'. There really may be a good deal of truth in this.

Let me know your reactions, and those of John Bell for example.

Yours,

Jimmy.

20 copies please B.M. Bell

Extract from letter received from Professor J. M. Cassels

CORNELL UNIVERSITY

Laboratory of Nuclear Studies
Ithaca, New York

18th November, 1959

"Dear Gerry,

Thanks for your letter. We are still only hearing rumours here about the neutrino story and what I wrote you was a personal reconstruction of the physics. However Lee will visit us on the 30th November and I will send a more solid story then. Meanwhile:-

1) I calculate the 2-body cross-section as:-

$$\sigma \sim \frac{g^2 (p_{\bar{\nu}} c)^2}{\pi (\hbar c)^4} \sim 4 \times 10^{-38} \text{ cm}^2$$

g = weak interaction constant 2×10^{49} erg-cm^3

$p_{\bar{\nu}} c$ = neutrino energy $\sim$ 1 GeV

which agrees with the number you mention.

2) The 3-body cross-sections will rise as $p_{\bar{\nu}}^5$, the 4-body as $p_{\bar{\nu}}^8$, and so on. This explains how σ_{tot} can reach geometric dimensions by 100 GeV (centre-of-mass, be it noted.) I am not clear how to think of form factors for many-body reactions, so I don't know whether σ_{tot} would in fact go up so far. Some 3-body reactions might get well under way near Nimrod.

3) I think the shielding must be 25 feet, not metres. It would have to be some kind of igloo to avoid neutrons coming round corners, obviously. However the sides may not need to be too thick, since the neutrino reactions produce high-energy collimated showers.

4) The best detector may be a big ingot of lead glass.

5) The pion beam producing the neutrinos need not be too formally organised. Inside the machine there will be a big density of pions running downstream from any target, for example."

Yours,

Jimmy.