Northern Accelerator Study Group
File
Dr. T. G. Pickavance
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Building 412.10,

5th September, 1958.

Professor H. W. B. Skinner,
Nuclear Physics Research Laboratory,
University of Liverpool,
Mount Pleasant,
LIVERPOOL, 3.

Dear Professor Skinner,

Herewith as promised by Walkinshaw some impressions and data from Hamburg.

<u>The Political Background</u>

It was originally hoped that other Universities would come in on a communal project, but in the end it became a joint Hamburg/Atomic Energy Commission project. The other major Universities prefer to try for their own individual accelerators. There was obviously a great deal of politics involved.

<u>The Personnel</u>

Professor Jentsche was on holiday but we met most of the operational people. A diagram showing their staff structure is enclosed. They are at present concentrating on the recruitment of engineers, designers, and draughtsmen where they have none at present, and are fully aware of the magnitude of effort required. They are keen to point out that Livingston does not have enough staff, and that he has by no means a satisfactory division of responsibility for clearly defined sections of the work.

We were particularly impressed with Worster. Besides being a first rate theoretician, he has a wide knowledge and understanding of all the work in this field and we assessed him as the key man in the team.

They clearly intend to maintain direct contact with other projects, particularly C.E.R.N. and Livingston, and one man has just returned after 18 months at Cambridge.

<u>The choice of machine</u>

Most of the reasons are familiar to you already. In favour of the electron synchrotron are the various nuclear physics reasons such as higher duty cycle, and the fact that they have a team built around a synchrotron project. Factors against a linear accelerator were that the site was not long enough especially from the point of view of radiation hazard to nearby houses, and that a change of scheme might well have provoked the political situation and prejudiced having the machine at Hamburg. Although the choice is now very firmly for the synchrotron we were assured that they would have chosen a linear accelerator rather than build a synchrotron with Livingston's parameters.

<u>Cost Estimates</u>

We have some breakdown of cost on some of the items, but in short the total cost of buildings and plant will be about 60 million marks or 5 million pounds. The operating cost for the machine and nuclear physics is estimated at 10 million marks per annum. They seem to approach the business of cost estimating with Germanic thoroughness, and I felt at times that too much emphasis was being placed on for example minimising running costs to the possible detriment of the machine or at least the time scale.

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Again we found them to be critical of Livingston on costs. His latest estimate is 5 M$ for the machine and 2 M$ for buildings. They are careful to point out that one would expect a not inconsiderable difference due to the more conservative (or realistic) Hamburg parameters, and the cost of setting up an entirely new site. How much this carping at Livingston is justified I wouldn't like to guess, I would only comment that a German cost is probably more relevant to our own circumstances.

<u>Buildings</u>

They have at the moment a very nice Lab. and office block with an excellently equipped workshop for about six to ten mechanics. A Van de Graaf building has just been started.

A foundation study has been made, and they seem to have various kinds of sand with a few layers of clay and no rock at accessible depth. Nevertheless they plan to have a temperature-controlled concrete-ring foundation supported by quite elaborate piles. The piles are to be cross connected so as to form effectively a cylinder of considerable depth.

Two layouts of the ring building, experimental areas and experimental preparation area have been made. The first had two experimental areas simply extending outwards from the machine with the preparation area in between, the whole occupying less than half the periphery. The form of shielding originally proposed was a 5 metre barytes wall in removable blocks on railway lines, much like cars. The thickness is only a first guess and corresponds roughly to our 30 feet of ordinary concrete. The second layout they called their "Mickey Mouse" since the experimental areas were like circular ears.

They have a theoretician working on shielding problems and a nuclear physicist on shielding, experimental area and nuclear physics rigs.

<u>General Accelerator design</u>

The major differences from Livingston are as follows.

	<u>Cambridge</u>	<u>Hamburg</u> (D.E.S.Y.)
r_o	26 m	32.75 m
r_m	36 m	51.67 m
Rep. rate	30-60 p/s	50 p/s
B max (7.5 GeV)	9.1 kg	7.63 kg
Longest straight section	1.27 m	2.45 m
Vertical gap	5 cm	7 cm
Injection Energy	20 MeV at 25 gauss	40 MeV at 40 gauss

The magnet period will be F,O,D,O. and not $\frac{F}{2},O,\frac{F}{2},\frac{D}{2}\,O\,\frac{D}{2}$. DESY and Cambridge have the same number of periods (24). They plan to have different shapes for F and D apertures so as to accommodate the form factors and hence make maximum use of aperture for a given stored energy. The two sets of dimensions might be 5.25 cm. x 14.3 cm. and 8.75 cm. x 9.1 cm. The first dimension is vertical gap at the centre point of the second dimension, which is the useful radial region.

The Q values will be 6.25 not 6.4 as at Cambridge, and no intentional coupling will be required for transferring radiation-induced radial-oscillation into the vertical plane. Now that Livingston is talking of even higher rep. rate than before his vacuum chamber troubles, he will not require coupling up to 6 GeV. He will introduce coupling quadrupoles at 45° when necessary, to get to 7.5 GeV.

The radiation loss at 6 GeV is 3.5 MeV/turn as compared with 5 MeV for Livingston, and is 8.55 MeV/turn at 7.5 GeV. Although they do not seem to have any objections to Livingston's new vacuum chamber they still talk of using

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ceramic which they believe will have a life two or three orders better than epoxy resin i.e. 10^{11} to 10^{12} rads. They are also enthusiastic about their water cooled metallic trap for radiation on the outside of the vacuum chamber. It is simply a system of fins pointing towards the radiation. The secondary radiation is then partially trapped so that instead of having a line source which re-radiates the rest of the vessel with a $\frac{1}{r}$ law, a law more like $\frac{1}{r^2}$ is obtained.

They are familiar with all the new possible sources of trouble that we have heard of, and a few more besides. The three most important ones are

(i) Loss of particles from the R.F. potential well due to noisy growth of phase oscillation forced by the statistical distribution of quantum radiation. It appears that only mean-square quantum effects had been considered previously. It now seems so obvious that a gaussian distribution can result in a continuous leak of particles. Although this theory explains the energy limitation on the Pasadena Synchrotron (reference R. F. Christy - Cal. Tech.), the effect is highly dependent on accelerating time and it looks as though the big electron synchrotrons will be safe.

(ii) Accentuation of space charge forces along the orbit due to variation of time around the orbit. The bunch can spread or contract depending upon whether the energy is above or below transition energy. Again Hamburg are not concerned.

(iii) Neutralisation of electrostatic space-charge force by positive ions, leaving the self magnetic field in the case of a relativistic electron beam. Since the electrons are well and truly relativistic at injection, the effect of the self magnetic field will come in as the beam is neutralised and hence the Q values will change. No calculations had yet been made, but for some reason Worster did not seem to be perturbed.

Injector and expected intensities

We were able to contribute to the discussion on the linear accelerator injector. The rough specification is 40 MeV, 250 ma in the pulse, with a total energy spread of 1%, 1 cm dia. 1 milliradian spread. The radiation loss has been based on 10^{11} electrons per pulse, i.e. about 1 μamp mean at 6 GeV. This is equivalent to about 30 ma during the injection pulse. One can either regard the 250 ma from the injector as a safety factor, or as a bonus when the machine is working to 1 or 2 GeV.

The major difficulty is energy spread. Vickers are proposing a pre-bunching cavity in conjunction with a transverse chopping system. Hamburg seem keen on a demodulation system. This latter is analogous to our plan for injection into the Proton Synchrotron, where the particles are allowed to drift after leaving the injector whereupon the velocity spread arranges the particles in a favourable order in time for the energy spread to be removed by a further R.F. cavity. In the electron case the variation in drift time with energy has to be obtained from variation of path length in a magnetic field. With a magnet consisting of three wedges a radius of curvature of 80 cm will suffice. The only difficulty is that the net effect turns the beam through an angle, and therefore the line of the injector building to ring is dependent on the performance of the injector. A somewhat more complicated five wedge system gets over this difficulty and would occupy a length of only 2 m. There are however some messy edge effects to look at.

R.F.

There will be 80 accelerating gaps in 16 groups. Each group will probably be coupled in π mode. Work has been done on coupling within the Groups, but the overall feeding system has not been decided. We have some very definite feelings about this and know exactly how we would begin to analyse the problem. Again we were able to make some contribution, notably in persuading them not to have drift-tubes in the π mode cavities, they serve little purpose and make the coupling problem difficult.

The power required is 200 KW peak, 70-75 KW mean. There is a suitable Eimac Klystron (X602) for 474 Mc/s (corresponding to an injector R.F. frequency of 2848 Mc/s). Because of the reduced radiation loss DESY would require two valves as compared with 4 for Cambridge. The R.F. requirements have been based on 2×10^{11} electrons/pulse, and at the high energy end the power loss in the cavities is roughly equal to the power transfer to the beam.

Magnet Power Supply

The preliminary thinking is in favour of a White circuit.

A final word about time scales. Hamburg envisage a 5 year programme from now to a commissioned machine. The latest target date from Livingston is 1st January, 1960, but again the Hamburg people were sceptical.

We have more detailed information and will be sending you translations of their papers very soon.

I have recently been reading the O'Neill, Panofsky proposal for a double storage ring system at 500 MeV. We are not completely sure about one rather important feature, but apart from this the scheme looks a real winner. Besides the electron-electron application there is the obvious possibility of achieving with a single storage ring either a continuous electron beam or at least one with a good duty cycle. The current will be low, but we might think about it a little.

Yours sincerely,

L. B. Mullett