

A Note on the Extension of the Rutherford Laboratory
Proton Linear Accelerator .

General

1. There are two factors which would support a proposal to extend the Rutherford Laboratory 50 Mev proton linear accelerator to meson energies. The first, is that pion and muon beams of intermediate energy and intensities considerably greater than those currently available are still highly desirable for the more detailed study of both weak and strong interactions; and the second is that as the proton linear accelerator is a possible way of going to very high energies at high intensity, constructional and operating experience of a medium energy machine first would be very valuable.

If the desirability of an intermediate energy muon generator in the United Kingdom were to be accepted it does not necessarily follow that the proton linear accelerator is the "best" machine to build. However, the Rutherford Laboratory provides one possible starter for such a project and it could be a way of enabling effort elsewhere in the country to be concentrated on larger machines in the Gev energy range.

2. The 50 Mev proton linear accelerator produced its first beam of full energy protons in July 1959. In the eight months following this date experience has shown that it has characteristics which should make it very satisfactory to use for nuclear physics research. In operation it is simple to control and the proton flux remains stable for long periods. It is a pulsed machine with a 1% duty cycle which is a disadvantage but the fine structure of the proton beam can be put to good use in many experiments. Mean currents of about 5 micro amps can easily be obtained and future development could see this ~~increased~~ to 20 microamps or more with little difficulty.

3. Unhappily, in the past eight months the accelerator has been in operation for a very limited amount of time for the following reasons:

- (a) When the accelerator was planned there were no commercially available r.f. valves that could deliver sufficient power. Development of a valve was started in parallel with the construction of the machine and at the present time we are faced with operating the accelerator with valves which are little more than prototypes. Three months of the past eight have been spent in making circuit modifications, because the valves did not produce with reliability quite the necessary power. (I hasten to add that this is no criticism of the valve development programme. The triode development is a remarkable technical achievement and there is no commercial valve made in Britain yet which can produce anything approaching the mean power of the "Dain" triodes).

The lesson to be learnt from this, however, is that a commercial source of reliable well tested r.f. valves is essential for any future proton linear accelerator and the design of such an accelerator should be based on what is commercially available or what should very shortly become available. It would be folly to proceed very far with any design unless the power source was available and tested.

- (b) Much of the rest of the past eight months has been devoted to correcting the bad workmanship of the original installation, replacing and in some cases redesigning faulty items of equipment (such as water-flow relays, vacuum valves and diffusion pumps) and repairing damage caused by the failure of vital components and occasionally by inexperienced staff.

This is a gloomy picture but it is intended to convey that because of the complexity of this type of accelerator the quality of the engineering, of the design staff and of the installation staff is of utmost importance. Much depends

/on training

on training and experience. The possibility of recruiting competent staff in adequate numbers must be kept very much in the forefront. This last point is, I believe, a factor which will determine the extent and duration of any future programme.

4. To illustrate this point further it may be of interest to consider the staff that has been engaged in commissioning the proton linear accelerator during the past few months. The numbers are as follows:

Scientists	7	Professional Engineers	5
Assistants	13	Technicians including	
		Operators	10
		Workshop & Maintenance Staff	15
		Contract labour	5

TOTAL 55

In addition a very great deal of outside manufacturing and design effort is used. Although we suffered very much in the early stages from inexperience, this team is now a very efficient unit working at absolutely full stretch.

EXTENSION TO 150 MEV.

5. Problems connected with the physics of a high energy linear accelerator can, I believe, be overcome. The practicability of a such a project depends on sound technical and engineering effort and clever design particularly aimed at great simplification compared with the Rutherford Laboratory Machine.

Here are some figures which relate to 3 tanks to illustrate this:

Number of Diffusion Pumps	19
Number of vacuum joints	about 1,500
Number of water-flow relays	130
Number of air operated valves	100
Number of indicating lights	720
Number of main control panel meters	70
Number of relays and contactors	250
Inter-rack wiring connections	20,000
Length of cabling involved	250 miles

A machine with thirty or so tanks would clearly be a very formidable undertaking.

6. The original intention was to continue with the Alvarez type of structure up to about 150 Mev but to change frequency at tank 4 from 202.5 Mc/sec to 405 Mc/sec. This greatly simplifies the design. Ideas on the design of tank 4 are still at a very rudimentary stage but it may be possible to make an accelerating tank out of a copper tube approximately 15 inches in diameter and 20 feet in length. Cooling of the body would be by pipes on the outside. Drift tube alignment could be done from the outside and the cooling of the drift tubes and the quadrupole magnets could be arranged so that it had no contact with the main vacuum system. The tank which would be very much lighter than the existing ones could be mounted on a raft, tested in a laboratory and finally wheeled into position fully assembled.

The development of the Getter-ion pumps such as those made by Varian Associates in the United States simplifies the vacuum system enormously for the following reasons:

- (a) They require no water cooling.
- (b) They are not damaged by a vacuum failure.
- (c) They are claimed to continue pumping for thousands of hours with no maintenance.
- (d) Neither liquid nitrogen nor refrigerated baffles are needed.

/It should

It should be possible, therefore, to dispense with nearly all the complicated system of automatic shut-off valves, water flow relays, and other safety arrangements so vital to the conventional vacuum system.

A second equally important fact is that there are two klystrons available commercially in the United States which would be able to deliver adequate power for individual tanks. These are the Varian VA-842 and the Eimac X626. The latter could be manufactured under license in the United Kingdom if large numbers were required. Full details on these valves, on modulating systems and on operating experience is being obtained from the manufacturers at the time of writing this note.

7. The cost of such an accelerator is important so a very rough but liberal estimate of the cost of one 20 foot tank is given below:

One Klystron plus accessories	£10,000
R.F. plumbing	5,000
Modulator	20,000
Vacuum system	15,000
Tank 4 including drift tubes	20,000
Control system and installation	15,000
TOTAL	£85,000

For this one could get an extra ¹⁵~~30~~ Mev.

8. The philosophy that is being adopted in thinking about extending the accelerator is as follows:

- (a) Allow until the end of 1960 for work on the present 3 tanks.
- (b) By the end of 1961 complete the design of tank 4.
- (c) By the end of 1962 complete manufacturing, installation and laboratory testing of tank 4.

It is believed that the above work could be carried out with little or no increase in the present staff. Design and installation would be the responsibility of the group. Manufacture would be done by outside firms but to the group's design and under its supervision.

No further buildings would be required for this part of the work.

9. If the above venture showed promise and a good design were evolved parameters could be settled and detailed drawings made for six further tanks during 1962 so that if the laboratory tests on tank 4 came up to expectations a major project to extend the accelerator could be started in 1963. The duration of this would depend on the scale of effort that could be deployed and on the importance of the nuclear physics experimental programme that was being carried out at that time. (By then NIMROD would be available for nuclear physics).

Allowing 2 months installation time per tank 1964 or probably mid 1964 to mid 1965 could be a shut down year to convert to a 150 Mev accelerator.

Allowing for a slight reduction in cost because of large scale production the total additional cost of the 150 Mev accelerator with a mean current of at least 20 microamperes would be £500,000.

To this should be added the additional cost of buildings (A 200 ft x 100 ft tunnel at £5 per square foot).

plus concrete shielding, more experimental space etc.....	£100,000
	£100,000
Total	£200,000

EXTENSION ABOVE 150 MEV

10. Whereas parameters could be fixed quickly for an Alvarez structure up to about 150 Mev, much thought has to be given to the accelerator beyond this energy. The next jump should be up to 300 Mev, at least, for obvious reasons.

It is very desirable to start some theoretical and experimental work on structures that could be used beyond 150 Mev as soon as possible. The aim would be either to continue installation of further tanks in the second half of 1965 or to allow a period for nuclear physics at 150 Mev.

11. The time scale of the above programme has been determined mainly by an estimate of the manpower resources on which one will be able to draw. If the project were considered sufficiently important the time scale could probably be shortened a little but not a great deal as the shortage of experienced staff will probably continue to be the limiting factor. Furthermore, if valuable results are being produced on an existing machine it would be a pity to disrupt this work merely for the sake of making the machine bigger.

G. H. STAFFORD.

16th March, 1960.