Dr. G.H. Stafford's Opening Remarks:

The possibility of another accelerator has been discussed at least some 12 or 14 years ago. It may sound to the layman to be a screwball scheme, fantastic development, fantastic cost, but actually the possibility of another accelerator has been discussed for at least 8 years (I don't know the exact time), but certainly it has been under discussion for a very long time.

The initiative over the past few years has been taken by CERN in Geneva, but it is not really a CERN project, and in fact, the responsible committee is a committee now called the European Committee on Future Accelerators (ECFA) under the Chairmanship of Prof. Amaldi. Dr. Hobbis has been concerned with this ECFA and that is one of the reasons why he is able to speak to us authoritatively on this particular project.

In addition, about a year ago, the CERN panel in Britain (a small panel of physicists who advise the S.R.C. on aspects connected with the use of CERN) decided that it was very important to have associated with the 300 GeV project, a physicist who would help the London Office of the S.R.C. in providing the information that was necessary to enable the relevant authorities to decide on a suitable site for this accelerator, because even at this stage there has been no decision taken on the site although there is a British site being put forward as a possible place at which this accelerator can be built. Dr. Hobbis was asked by the CERN Panel to take on this particular responsibility.

He has in fact had two connections with the 300 GeV. Firstly as a member of ECFA and secondly a more direct responsibility for putting forward the best case for a site in Britain.

The Proposed European 300 GeV Accelerator

L.C.W. Hobbis

I think it is a fitting time to review this project on which vital decisions are planned to be taken about the end of this year. The accelerator will cost £150M or thereabouts to construct, something like £25M to £35M per year to operate when it is built, which will perhaps be in about 10 years' time, and ~~it~~ is going to have a profound influence on high energy physics in Europe and the world, and eventually on the role played in the subject by this Laboratory and Daresbury Laboratory.

I can only hope to make a selection here from a huge mass of facts and gossip about this project. I am sure everyone in the audience probably knows some, if not more about each aspect on which I will deal, but I hope in the end to have given everyone something new - an overall picture of the project and the questions it raises.

I am not going to read every word obviously here, but I just thought it would be interesting for you to see the pile of official paper on the 300 GeV project; there are hundreds of internal memoranda of various kinds as well which would probably stack up this high. That is the European project. That is all I have on the United States 200 GeV project. I know of at least one other volume which may or may not bring them up to the same height! Anyhow the U.S. one is off the ground; a site has been chosen and a project team is being formed. It hasn't yet got the money to construct, but it hopes to have it about the middle of next year. So it seems that it is around about this order of magnitude of paper you can get away and we hope that this is what will happen this year.

Now I am going to say what this machine is about; a little bit about what is is for; summarize the features of the whole project; discuss its siting, its finance and staffing; explain how it has been promoted so far and what may be the likely future course; try to look a little at the overall European programme in the late 70's and 80's and finally try to say something how I personally see the significance and motivation of this project. We have a heavy time ahead of us here.

I am going to try to avoid lots of details and giving you too many figures. I will try to get some broad ideas across. Compare things which may be with things with which we are more familiar. The standard on which I deal with various topics in this talk will vary enormously, but I am trying to tell something to everybody.

I am going to be~~ing~~gin by talking about the first principles involved in accelerator design and operation before going on to mention the particular details of this 300 GeV project.

One is concerned with making probes of fast charged particles for the most part, and that can be done by operating on them in some way with electromagnetic fields. The simplest accelerator of this kind you can imagine, is one in which you have a pair of metal plates which you put inside some kind of evacuated bulb, connect them to a torch battery and release the electron or proton somewhere here, and when it is here, it will get accelerated across this gap in which an electric field exists because you have applied voltage across it, and when it reaches the other side of the gap, it will have an energy of 1.5 eV.

Diagram

This simple system extended to higher voltage and elaborated upon with other intermediate electrons is the basis of d.c. accelerators which are used in nuclear structure work and the basis of the pre-injector stages of machines like the Proton Linear Accelerator here and to Nimrod, in which case, e.g. in Nimrod, we are talking about an energy of the d.c. accelerator of 600 KeV.

The next stage in this process is to use an alternating voltage instead of a steady voltage. That might be done by having some kind of resonant cavity fed with alternating power from a radio transmitter. Put the hole through these walls here, again evacuate the arrangement and if you shoot a charged particle across there, introduce it with a moving charged particle, and when it gets to the other side it will have increased its energy if the alternating electric field is in the right way around. There is a time when it is reversed, and so there will be no acceleration at that stage. This sort of system is going to give you very short bursts every time the field is the right way round; put a lot of these together, one after the other and you have an r.f. linear accelerator like the P.L.A. or the Nimrod injector.

The next thing we can do is to try to accelerate to very much higher energies because a system of that kind accelerating to energies of thousands of millions of eV, is the GeV region that we are talking about with Nimrod. Such a system would be extremely long and costly, so one thinks of having this accelerating gap at some point in the circumference of a very large ring magnet which can bend the particles around, constrain them to follow a roughly circular path using the same accelerator voltage over and over again to accelerate the particles. This turns out to be a very much more efficient way of doing it and therefore we can have a machine like Nimrod which we can build for ~£10M and get 7 GeV from it. One does not in fact have one cavity there -

we can have several of these and system like usually has a central feature like this - A very large ring magnet and it also has other accelerators associated with it which give the particles the initial momentum which they need to be launched into the guide field. So one has a linear accelerator here as well as a d.c. accelerator preceding that.

This system is essnetially pulsed by nature because as the particle energy is increasing, the velocity is increasing, the magnet field has to increase and so this electromagnet has to be supplied from some kind of pulsed power supply, and the normal kind of repetition rate at which such a device runs is in the vicinity of 1%. It normally takes 1 or 2 seconds to accelerate the particle to full energy and get the system into a state to accelerate it again.

516 One important thing we must note in these machines is that the particles we are accelerating just do not stay within the aperture of the vacuum vessel unless we take some very special care to see that they do. There is always some disturbance present which will result in there being lost before they are accelerated to full energy if we don't take care. In a machine like Nimrod the gap in the magnet is of a C shape. This gap in which the particles go around (diagram - sort of N projection of beam) is not absolutely parallel. It has a slight wedge-shape resulting in a bulging of the magnetic field line and this turns out to be a shape of magnetic field which will keep the v particles focussed as they proceed around inside the vacuum vessel which we put in there. This particular type of machine to accelerate a reasonable number of particles requires a very large aperture in this direction. It is something like 3' in the radial direction and about 8" or 9" in the vertical direction. We are talking in this kind of device, of accelerating $\sim 10^{12}$ (million million) protons in each burst/pulse of the accelerator.

In 1952 a new idea was introduced which made this whole system very much simpler indeed. It was discovered that by introducing a rather more violent decrease of change of field in the magnet with radius, and by using a number of magnets in which the wedge-shape was alternately arranged in the way I have drawn it there, and in the next unit, so that the gap gets narrower with increasing distance from the centre of the machine, the particles in the beam could be constrained to follow paths which were very much closer together. If I draw the path of the particle proceeding around this roughly circular orbit (which I now imagine to be drawn out in a straight line) it might be something like this over a certain distance, about half the circumference of a machine like Nimrod, where that distance is 18".

diagram

This particle loops around as it goes round the machine and the vacuum vessel walls say as these + these. This new principle would enable one by considering a particle starting off here travelling along the same angle to this axis, to be brought back towards that axis like this, and so occupy a very much smaller radial with a vacuum vessel. The same is true in the vertical direction which I have not drawn here, and the overall effect of this is that the aperture in the type of machine which became known as the Alternating Gradient Synchrotron as compared with a machine like Nimrod the vacuum vessel might be on a scale like that.

This has enormous repercussions on the cost of the machine. It enabled the 25 GeV CERN machine, for example, to be built for about the same cost as the 7 GeV, Nimrod. Rather more importantly than that, it turns out that this machine has all kinds of desirable properties in its utilization. It is a much easier machine to manipulate the beam about in, to use the high energy physics and it has also proved to be a machine which is relatively easily extended to higher energy operation. A machine like Nimrod is really becoming very uneconomical if you try to make one more than about 10 or 12

GeV whereas this new principle which is now very well proved and understood enables one to consider alternating gradient type of accelerators which could have energies of say 1000 GeV.

Another vital feature of them is that it turns out to be natural that as the energy of such a machine is increased its intensity also can increase. It does not have to, we don't build it that way, but one can very easily get increases of intensity so that it is common to talk of machines in the 100s of GeV range as having intensities of 10^{13} p.p.s. instead of the 10^{12} which is where all good machines of today are operating.

Well there was one thing which had to be paid for in achieving this revolutionary step, because it really was a revolutionary step. It was a vital change in the particle dynamics of all good theory which did not require for its realization, any real revolution in technology. This was an extremely important thing. It did however, demand extremely accurate alignment of the magnets on the desired position. This could be calculated of course. The effects of this alignment in the magnet structure could be worked out; also the accuracy with which the fields in the magnets have got to be realized, and in which the field shape has got to be controlled. These things turned out to be possible, but care ~~needs~~ needed to be taken.

In the case of the machine which we are going to talk about today, ~~firstly~~ mostly, the alignment requirement is that the magnets should stay where you put them, and that you should be able to align them within an accuracy of .15 of a mm. This is on a very large scale. I will have a little more to say about that in a moment.

Now I want to say why one wants to increase the energy in the intensity above the region which we are able to work today. There are many of the features of fundamental particle physics which are studied at the moment, which can be studied up to proton energies of about 30 GeV which simply require extending, extrapolating into the unknown energy range beyond. There is of course the possibility that the higher energies available would reveal new phenomena (this has always happened in the past and is bound to happen again). Studies involving the use of neutrinos in weak interaction physics demand the increase in energy range, as well as an increased intensity in the neutrino beams available. Another feature we must mention is that ~~in~~ the amount of energy available in one of these particle, collisions which one is causing for the creation of a new situation, is not proportioned to the primary proton energy that you have available, but to the square root of that. This is the reason that one builds machines like the Intersecting Storage Rings at CERN, whereby having 28 GeV protons colliding together, one can realize the amount of energy available or the reaction, which is the same as one would have from a straightforward synchrotron of energy about 1700 GeV, and therefore when one talks about increasing the energy of a simple straightforward machine, one must make a significant step.

If you increase its energy from 30 GeV to 300 - a factor of 10, you get a bit over 3 in the energy available for the creation of new particles.

Then when one thinks about higher intensity, ~~which~~ perhaps the most obvious thing is that the higher the intensity of the beam available, the more protons you have got to share out in a sort of unit system, which is sometimes a problem around accelerators. There are many experiments which simply need higher intensities in order to get a significant number of events. Experiments which are either just possible today, or not possible today at all, will simply require higher intensities in order to do them. There are some experiments which even now demand intensities of 10^{14} p.p.s. but there is really not much hope of getting that at present ~~now~~.

One fortunate thing about higher energy machines is that they automatically produce a higher intensity of secondary particles as well, so there you have a bonus which makes the higher energy worth having. As you go up in energy, there is really no cut-off technically at the moment for what you could do. You could make this 1000 GeV machine if you wanted to and had the money.

It seems that 300 GeV is a reasonable step to take in terms of the cost and time scale. Intensitywise, 10^{13} p.p.s. seems possible. It may not quite be achievable, but on the other hand one may achieve it with some safety margin to spare, and so it is a compromise from what is technically possible, and the demands of the physics.//Another important fact in ~~is that~~ the operation of these machines today with higher intensity results, which many of you know, is the ~~are~~ difficulty ~~difficulties~~ in operating the accelerator itself from induced radioactivity and radiation damage in organic materials that are used in the machine. Now it is recognized that if one could extract all the beam from the machine, nearly all of it could then be used externally from the main beam and this particular problem can be moved to an experimental area where it can be more easily dealt with, without shutting down the machine.

If one supposes that one can get 90% of the circulating beam extracted from an accelerator, then it means that increasing the intensity by a factor of about 10 beyond present practice will leave you with about the same problem inside the machine to deal with, as you have to deal with ~~today~~ at present, and it is around about the tolerable maximum, not far from it, today. So again this figure of 10^{13} is a reasonable one to aim at until we have learnt better how to operate accelerators in an active condition, and how to use materials that are not going to suffer from radiation damage.

Dr. H is to go through
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