Con Panel

PROCEEDINGS OF A MEETING OF THE
JOINT CONSULTATIVE PANEL ON NUCLEAR RESEARCH
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Sir John Cockcroft: First of all I would like to welcome the visitors from CERN, Professor Weisskopf and Dr. Hine. On the order of speaking, Professor Weisskopf will now speak third in place of Professor Bernardini.

I should like to say a few words about the objectives of the meeting. These are, firstly, to consider the future machine facilities at CERN, and, secondly, to consider in a very preliminary way what attitude we might take in any discussions on a world project. You probably know that some discussions have already started and no doubt you will hear about these during the course of the meeting. You may have some views about them.

So far as CERN itself is concerned, Professor Weisskopf will speak to you about that, but it seems to me that there is an order of priorities. The first is to make the best use of the existing machine - by extension of beams, by providing proper housing for bubble chambers and so on - and CERN is currently fighting to get the money it needs for this programme. The next stage is what can be done for the long term improvement of the existing machine - for example by pushing up its intensity and so on - and no doubt we will hear something about this later on. Stage 3 poses the question whether or not we go on to a much more expensive phase, installing storage rings or perhaps having another machine; and we will hear the arguments for and against these tentative proposals. Finally, there is the question of what part we should play in any world project, if it comes off. I think these are the main points that I would like to have discussed. Would you like to say a few words, Sir Harry?

Sir Harry Melville: I would like, if I may, to raise some rather broader points than Sir John has mentioned. Stage 1 at CERN we can predict to some extent on a rising budget, but if some of these other projects ever become practical propositions,

that is feasible propositions technically, then, in this country at least, they will have to be considered in relation to other big investments in science, such as space research, and maybe others, both in this country and abroad. The terrible problem is to decide which things to back and what is a reasonable expenditure for these really expensive developments. I would therefore like at this stage to raise the thought, not that we can decide anything today, of course, that it should really be the scientists in this country who should decide what are the important projects and what particular developments they would like the Government to support. The scientists themselves must advise us on priorities and it is important that this should be borne in mind in thinking ahead in high energy physics, whether it is for some development at CERN for Europe or even a world wide machine.

Sir John Cockcroft: I think that with those introductory remarks we will call upon Professor Weisskopf.

Professor Weisskopf: I thought I would like to introduce my speech with a few general remarks on the future of European high energy physics. I might not be quite sticking to the prescribed theme for the day, but I think these ideas are intimately connected with what is going on now. Well, I think if one looks back over ten years, the development of high energy physics in Europe is certainly extremely impressive. Ten years ago there was practically nothing: most particle physics was concentrated in America - but since then Britain, France, Italy and Germany have all had their own very vital projects - some partially finished, some partly under construction - and, of course, we have CERN. Perhaps it is good to remind oneself why we did all this, why we built CERN. We wanted to have fundamental physics alive and vigorous on this side of the Atlantic, and we wanted to avoid all the good, inventive, people moving over to the United States in order to do the physics that they would like to do -

physics that from our point of view was essential. I think that in Europe we have gone quite a way towards correcting this situation, but so far I think we have done so largely from the point of view of the machines we have available. (Dr. Hine will discuss the situation in a little more detail later.) We do have a quite impressive array of high energy machines in Europe, ready or almost ready. However, the next three to five years will really be decisive, because we now come to the question of how to use these machines, and here we are fighting an uphill fight. In particular, I speak, of course, of the problems of CERN, although I am sure the same applies to all high energy physics in Europe. The great discoveries are still being made in the United States, with very few, too few, exceptions. Now, what is against us here in Europe is perhaps lack of experience, that is the first factor, and lack of manpower - experienced manpower - for a good deal did go to America. So it is quite decisive that in the next five years we concentrate, as Sir Harry Melville has said, on the first priority, that is to make high energy physics in Europe as vital and as impressive and as vigorous as possible. This can only be done by very hard work, by ingenuity, by getting the right people at the right places, by getting the right spirit, and last, but not least, by getting enough financial support. This, for the next three to five years, is decisive for us, and any saving which might be made during this time by forcing us to work with second best facilities for the exploitation of the machines would certainly be deadly for CERN. We are in a difficult position: we are competing with America, and we are not only competing in physics and ideas, but we are also competing as far as machines, and accessories to machines, are concerned; for example, separators, spark chambers, and soon the new cryogenic magnetic developments. In all this we must try to be not second best but equal or better, and this is a typical activity in which Europe has an opportunity to be equal or better - and, if I may

say so, much more than in the space field. It is a field where individual initiative and inventiveness probably count more.

Now, perhaps, I should say that from the point of view of physics, the new machines that we have here in Europe, particularly the P.S., are opening up a new field of physics in this respect. It seems that in the field of a few GeV, let's say the field between zero and five GeV centre of mass, a new and unexpected world has been discovered. I refer here not only to the many interesting developments, but also to the new, so-called, "strange" particles - probably they aren't particles, but excited states of some systems - anyhow, here's a new world of pions, ρ particles, ω particles and K*s, . and it turns out that this field of a few GeV is much richer than some of us expected. So it seems to me that here there is a typical field for exploitation of the P.S. This field will be very rich, and will give us excellent opportunities to do good fundamental physics and to play a leading part in the progress in this field. Provided that we have full support for proper exploitation of the machine we will have the most modern facilities possible. We have to overcome the disadvantages we have compared with America, as far as lack of experience and manpower is concerned, but I am positive that we can do this if we have the support.

Now the topic of today's discussion is not really the next three to five years, but what happens afterwards. It is clear that the machines that we have now will be obsolete after a certain time. The question of whether this is in five or ten years is also a question of what one understands by obsolete: in other words whether the machines are in the centre of the most vigorous interest and discovery, or whether they are doing what is called mopping-up operations (these are, of course, extremely important, but no longer the very centre of excitement). Again I would like to say that if we in Europe do not have a centre of excitement, we will run into the same danger against which we

have built CERN and so many other installations. There are perhaps two ways in which one can view the development in this field from the machine point of view. Let me call them the conservative and the radical views. The conservative one is how can we exploit more fully and more properly the field of a few GeV - the newly discovered world? The machines we have now will become obsolete in this field mainly because of lack of intensity. Now this exploitation can be done in many ways. We can improve the P.S., for example, and also similar machines, to try to give them higher intensities, but there are obviously limits to this, not only from the machine point of view, but because of the dangers of induced radioactivity. In order to explore deeply the field of a few GeV centre of mass we must think of building machines of higher intensity. Now this is certainly possible, although there are many problems - the problem of induced radioactivity for example - which have not yet been thoroughly studied. However, one can also get higher intensity in this few GeV field by going for machines of higher energy. This can be done not only by increasing the intensity and leaving the energy constant, but also by raising both intensity and energy, and I will come back to this point in a moment, because I think it is an important one for our discussion.

The second point of view, which I will call the radical point of view, is to say that while it is very fine to go ahead with the exploitation of the few GeV physics, it certainly should be exploited by more modern machines than at present, and these should also look for and expect other phenomena which are new compared with what we can observe with a few GeV. To mention a few; first, we certainly expect to find new phenomena relating to the core of the nucleon; secondly, only the fringes of the large momentum transfer phenomena have been touched so far; and, lastly, but by no means least, there are the neutrino phenomena - the study of regenerative interactions, for which the present

machines are too weak. Theoretical indications are that the neutrino experiment will really give us new information when you can get neutrinos of a good number of GeV, whereas the present machines only give us small intensities of neutrinos below one GeV, which is not yet into the interesting region. So at high energies we may expect the weak interaction, the core phenomena, the phenomena of large momentum transfer, and the phenomena X, which we don't know, to be of interest; these are probably the most interesting ones that we will expect when we get C.M. energies of a large number of GeV. One of the most interesting new phenomena is this: in the present machine we were surprised by the relatively low yield of interesting particles such as antiprotons, K mesons, and the like, if one compares this with purely statistical considerations which, of course, have no a priori reason to be right. Now the main point is this: it turns out that the percentage of antiprotons (let us call them the interesting particles), compared with pions and the generally uninteresting things which come out of the collision, increases very strongly with energy. In fact the particles of the P.S. beam have many more interesting particles, relative to pions, than the Cosmotron or the Bevatron. This increase is greater than the energy increase and the big question is how far it will go on. If it is more than proportional to the energy then even for the low GeV physics it would pay to build a high energy machine. The cost of the machine is relatively proportional to the energy, and if the yield of more interesting particles is more than proportional to the energy, you gain by investing in a high energy machine (always considering the fact that the intensity problems are not energy dependent). The whole idea is that even for the conservative energy which I mentioned before it might pay to build a high energy machine, because we might get more out of it than just the factor by which we increased the energy. We don't know at what point this increase of interesting particles stops -

it might stop at 50 GeV, in which case it might not be worth while to go much higher than this. I don't think anybody knows.

Of course, in the radical field of research, there is also the much discussed proposal for storage rings, where we have been considering a relatively cheap extension of the P.S. This is aimed at the radical field of new phenomena, because it is designed for research on large momentum transfer. However, it has the disadvantages, which we shall discuss today, of being rather limited in that one cannot get high energy secondary particle beams. So I would perhaps like to leave any further remarks about storage rings, but I would like to invite discussion about them later.

However we look at these plans, we cannot work in a vacuum - that is, in Europe alone. We have to look to the West and to some extent to the East. Now the situation in America is that the general trend seems to be more or less clear except for the time scale. America is now building a high intensity machine for 15 GeV, which in my definition is a conservative physics machine, and there is the also large "Monster" (i.e. the new Stanford electron linac project), which goes more in the radical direction (also because of the fact that we have electrons there). Moreover, the U.S. physicists are talking very loudly about a high energy and high intensity machine and that machine would combine the radical and conservative features. So far the American Government is not ready to underwrite this 300 GeV machine, but I would say that within five years at the most there will be the beginning of the construction of a 300 GeV machine on a national basis in America. Of the Russian plans we know very little; in fact, we do not know at this moment if the 70 GeV machine is well under way, or still in the design stage. Anyhow, it seems that looking at Russia is not too helpful for our own plans because in this respect we are ahead in development.

Then there is the question of the international machine,

which certainly aims to be the most radical and most high energy machine; this is a problem which we have to keep in mind because it will influence our thinking greatly and might perhaps make another big machine in Europe disputable, both from the point of view of budget and from the point of view of new physics. However, you all know that international machines have their difficulties, and I'm sure that the description of the situation which you will hear from Dr. Adams will underline this fact.

Now I would just like to summarise what I have said. First of all, I would like to emphasize that the next three to five years will be absolutely vital for CERN and other European high energy centres. We must get the strongest support for our work, but that, of course, is not enough, and we must ourselves do what we can to make this a really successful period in which high energy physics will shake its centre of gravity from one side of the Atlantic Ocean - at best, to us, at worst, to the middle. However, we must now think of the future as well, because we know very well, if we look at the history of previous machines, that now is the time to do so. I will remind you that the Cosmotron was running for one year when the planning of the P.S. was started, and this means that now is the time for us to look at the next machine. The comparison with the Cosmotron is perhaps not quite right because the Cosmotron was just at the lower limit of this new world which we have discovered, whereas the P.S. is right in the middle, and therefore the kind of work which we are going to do is perhaps richer than what one could do with the Cosmotron. This is, however, a very dangerous conclusion, because the next world might be a much richer one than this. Therefore, it is now right to discuss new plans and to be sure exactly what we want to do. If we give first priority to doing good physics in the next three to five years I think we ought to give priority 1,1 to the planning of the next machine.

Dr. Hine: Following what Professor Weisskopf has said, I

should like to say something more about the detailed situation in CERN and the detailed situation of high energy physics in Europe as far as one can see them in the long term; to explain how far our thinking in CERN has gone; and, finally, to say roughly what we propose doing in the next year or so to try and clarify the position. I think there are a number of specific jobs which have to be done before the accelerator people can come up with something which they feel will hold water, and although that job is difficult, the job of discussing the pros and cons of different kinds of physics is more difficult still. Up till now more people in CERN have been working on accelerator design than have been working on the lines of physics which should be pursued, or experimental means for doing them.

You have all seen this paper which was sent round to you a few days ago. I have tried to summarise the "brute facility" situation in the table at the end of the paper. You can see from the list of machines which I have put down on the paper that Europe has in operation, or very nearly in operation, four major accelerators, which are in fact very comparable to four major accelerators in the United States. The CERN P.S. is very similar to the A.G.S. (potentially not quite so powerful a machine in terms of top energy or current, just because of the size); the two electron synchrotrons, M.I.T. and the Hamburg machine, are also comparable, with perhaps the advantage in favour of the Hamburg machine. Nimrod is comparable with the Bevatron, as the Bevatron will be towards the end of 1962 after they have installed a new 19 MeV injector, with which they hope to get the current up to 5×10^{12} or 10^{13} protons per pulse, i.e. approximately 10^{12} protons per second at 6 GeV. This is comparable with the hopes for the first stage of Nimrod's performance, except that Nimrod will have 7 or 8 GeV, rather than 6 GeV. This 7 or 8 may be quite a significant

improvement on 6 with antiproton beams and so on; but offset against this is that, as the Bevatron exists now, it has an enormous team of physicists hanging around it, there's a large quantity of apparatus prepared, and it has a vast number of experienced people. However, I think one can say that for a few years to come the kind of physics which will be done in Berkeley and the Rutherford Laboratory will be comparable, and with rather the same kind of limitations. With Saturne there is a very similar situation; although Saturne has not yet managed to accelerate as much current as the Cosmotron does, there is not too big a difference to worry about.

The potentialities of all these machines for future improvement depend to some extent on the amount of money that can be put into them. Comparing the two electron synchrotrons - DESY and CEA - I don't think anyone can predict how far they can be developed beyond their present first specifications. Saturne and the Cosmotron could probably both be increased in intensity quite appreciably by installing higher energy injectors - this is my guess, not based on any specific project, but if in the course of the next few years they decided to use a higher injection energy, then all the factors which determine accelerated current are in their favour; this is what they are doing on the Bevatron, in fact, and it should also apply to the smaller machines. I think it is too early, and I certainly don't know enough to speak myself, to say what the potentialities of development of Nimrod are, but there is one thing which I think one must bear in mind, that is that the most recent accelerators have to be much more fully and more carefully designed than the previous generation and there is probably potentially less room for improvement in them since we know now more or less what determines the current, and the overall efficiencies are now quite high - In the AGS and the

CPS something like 15% of the protons at 10 kilovolts get up to 25 GeV, so there isn't much room for spectacular improvement. As for machines that have no European counterpart, in the States we have to face the Argonne machine, which has had a lot of bad things said about it. However, I think the principal bad things that have been said are on the money that has been spent on it, and maybe on the fact that it will be difficult to use for experiments; we should not assume that, in fact, it won't meet its designed performance after its teething troubles have been dealt with: as I said, accelerator design is now more of a science than an art and, so far as I know, no-one has found any mistakes in the American calculations for the AGS. Ultimately I think they will be able to get their high current. The second new machine is the Stanford Linac, which has been worked on for several years now. At the moment, and indeed before they have had any promise of major sums of money, they have 160 people working in the design group - more than the group who built the P.S. So the initial study has got to a stage where they really are in a position to go ahead fast with the construction and so far as we know it will work. This means that if one looks over the next decade to see what the extra facilities are going to be in the States compared with those at home in Europe, there will be at first the Argonne machine (which will come into operation, say, in 1963, and may build up a high current over a one to two years' period); and, starting sometime a few years later, the Stanford Linac; and then again, starting sometime after that, but one guesses within the foreseeable future, the 300 GeV proton synchrotron.

I talked to various people when I was in Brookhaven recently at a conference over there, and I think it will be interesting to relate their general view on the 300 geV machine. My own impression is that American opinion was, for farious reasons, unanimous

that they must have one of these machines, but that there is going to be a good deal more discussion about who is going to have it and where the money is coming from. Moreover, I don't think American physicists will allow themselves to be put off by any international machine; they were also unanimous that if there was an international machine they certainly wanted a machine of their own as well, because a share in the international machine was not going to give them a big enough facility, and was going to be late, and in any case they would have to have a training ground for people who would work on an international machine. So whichever way you look at it, they really want a high-energy P.S. fairly soon.

I will try to sum up what the prospect for big physics is going to be on this side of the Atlantic and on the American side - it's not worth bringing the Russians in since I don't think whatever they do now will seriously affect our planning, whereas what the Americans do will very much affect us. I have put at the bottom of the table in my report two lines of figures, to try and make the comparison quantitative - I am not going to try and draw any great conclusions from them except to say the amount of physics you can do, and the depth and delicacy of the physics which you can do, certainly depends on how much available accelerated beam you have got, and perhaps how high in energy it goes. The figures I have put down give the potential mean accelerated current in microamperes, and the mean kilowatts in the beam if all those machines were turned on at the same time. As I said, I don't know what precise conclusions to draw from that figure, but both of them show a pretty rapid rise over the next three to four years, as these machines I have been talking about come into operation, and the American figures in either case are about three to four times as large as the European ones. Now, this does not seem a

very tragic situation. We know the Americans are using more resources than would probably be considered necessary here, or, to put it another way, if you only had half what they had, you could still get a good deal of good work done. So for three to four years this seems to look not unhappy, provided the European centres can be maintained, and provided the quality of the work done with the rather more limited European resources is of equal quality with that in the U.S. It is in the late 1960's that the balance in accelerators starts to swing hard against Europe.

Now this comes back to the point Professor Weisskopf was making on the support over the next few years for big physics in Europe. Big physics in Europe a year or two from now - CERN will be part of it, but not a very large part of it - should I think be viewed as a whole. The question of who owns what is important, and it certainly is important for small machines in the university departments, but it doesn't seem so important for really large machines; so long as they are at places like CERN, they are accecccible to anyone in Europe. It is easier to get from Geneva to London than it is to get from Oxford to Cambridge and this will become even easier in the future. If Britain eventually gets into the Common Market you may find fcreigners turning up on your doorstep, without getting labour permits, either. I think this means that one has to look at the development of big facilities on the European level. The thing which worries me is the way we suspect the expenditure will be going up from 1962 onwards in America, and yet at the moment we have absolutely no conviction that expenditure will do anything else but keep level in Europe. The thing which I think we have to do is to express the very strong view that, firstly, the general level in the next five years should be expanded at a resonable rate to enable the existing machines to to be used decently; and that means that everybody's budget should go up and not that people should live at the expense of their

neighbours. And, secondly, that the necessary planning work should be undertaken now so that the construction work can be begin at such a time as to ensure that in the 1970s we also are in a position to increase our kilowatts or microamps to match the Americans.

If this is a correct view of the world situation in physics what do we consider is a plausible increase in the European facilities and how do we in CERN see CERN coming into it? I should say right now that we do not have anything like an agreed view on this inside CERN, and I don't think anyone else in Europe has either. However, we have, over the past year, been having meetings, at about three to six months' intervals, of the European Accelerator Study Group to try and reach such conclusions, and, in fact, there will be such a meeting in the Rutherford Laboratory next Monday and Tuesday when we shall be talking on a more technical level about the things people have learnt in the States, and I will try and summarise their views as far as I know them now.

Discussing the reasons for building new accelerators, Serber, in his introductory talk at the Brookhaven conference, said there are two ways of expressing theoreticians' reasons for building bigger and bigger machines: firstly, to be able to do experiments dealing with problems which they don't know how to solve today and, secondly, which is probably a better view, to look at the past and say that every time we've increased centre of mass energy by a certain amount, it's paid off much more than we ever imagined at the time, and then ask if there is any reason why this won't be so in the future. As far as Serber was concerned the beauty and strength of this argument stood out most if you didn't ask for things to be justified in detail. If you take this line you just say the bigger the machine the better, and people who talk about a smaller one are merely faint-hearted. One should also point out

that nuclear physics is becoming a relatively cheap branch of science, certainly compared to those on which real money is spent, for example space or weapons. We should therefore take an optimistic and fighting line, and 10 years from now we will have a new big accelerator. As far as CERN's own equipment is concerned, of course, we can talk about various types of machines. An extra problem for us is whether we should be talking about something to be built in Geneva (and if so have we got room on the site, can we get water, electricity supplies and all these kinds of services), or elsewhere. If you're talking about setting up a new group to build a big machine - and this would probably be the case - then if it couldn't be built at Meyrin, it would involve a completely new laboratory somewhere else. I don't know if it could be put next door to the Rutherford Laboratory. (Dr. Pickavance: Very doubtful.) I think the same thing applies to most other labs. It just isn't possible to walk into a nice flat five mile square with about 50 megawatts of electrical power laid on, and able to supply about a million gallons of water per hour. It will take some time to find.

People have therefore started going carefully into the question - do we really need to go to 300 GeV? Could we not adopt a slightly more conservative attitude, and say that in 10 years' time the needs of European high energy nuclear physics, in order to keep up with the States, could be met by something smaller with more emphasis on high intensity and probably at a reduced cost? But against this, when one begins to look at the possible limitations in intensity in big accelerators, and this is something already started in America and now under study in CERN, it looks as though a big machine has got the small one beat hands down in terms of intensity every time. That is to say, the possible intensity in accelerators increases with the radius of the machine. There is

more room for protons with a larger circumference and also, building a large radius machine, you're forced to increase the injection energy, and the limitations in current that we know of from the point of view of particle dynamics become much weaker as soon as we increase the injection energy. So we're up against a nasty problem. If there is on our side of the Atlantic a 70 or 100 GeV machine in which Europe is placing its trust, and which comes into operation not far removed in time from start up of the 300 GeV machine in the States, we shall find that as soon as they start operation they've got us beat in both directions. They have more energy because they've designed the machine that way, and also as a bonus they've got at least our intensity and probably more so. This is also true as far as low energy secondary beams are concerned, and they will have also new beams which will still be interesting 10 years after. Even if the machines were to be equivalent in the, by then, rather conventional field of several GeV physics, as regards the interesting, exciting, new field of 10 GeV physics, the 300 GeV machine will be pouring out enormously more 30 GeV and 50 GeV anti-protons than any 50 GeV machine could possibly hope to do. We may, if we in Europe decide to build a machine like that, find ourselves in the situation of having built another Nimrod. But don't take this remark amiss. One could say that if Europe had only Nimrod at the present moment people would be feeling rather unhappy, but this is not an argument for or against having a machine of this kind at a national level - because, as one sees it, everybody has them and they're absolutely essential for making the lower stories of the pyramid which builds up to the biggest machine of its day, whichever it may be. You would however look rather silly if having

built a pyramid you ran out of stone before you could reach the top storey, i.e. there just wasn't enough to put the spike on top. This is the argument against the 100 GeV machine. There is another superficial argument for it, of course, that is that it costs less. But, as I said, I think we should be adopting the attitude that nuclear physics will cost nothing compared with space research.

The alternative attitude so far as we see it, is to say "Well, perhaps high-energy physics isn't as interesting as all that and perhaps we ought to go for something else" - radio astronomy for example. Perhaps it really is like space research - you put an awful lot of money into one subject and get little return - and possibly the United Kingdom feel that they may not be able to afford it. But then I think CERN will certainly feel like being told this - rather definitely and rather soon - because whereas an international laboratory like CERN has a very good reason for existence as the top of the European pyramid, if we're told we aren't interesting any longer we find the ground cut from underneath us. This, I think, is hardly fair to all concerned and I feel the people who settle the policy will have to decide fairly soon - as Professor Weisskopf said - whether they want to support high energy physics or not. If they do then the resources have to be found; if they don't then let's put our money somewhere else. I think that's probably all I wanted to say about the possibilities and reasons for making new big accelerators. I will come now to the precise details of what we think is worth doing at CERN in the very near future because this will show still more the way in which we are thinking of long term facilities.

I will say something first about the possible improvements to the P.S., because this has been mentioned and this is what

everyone is interested in now. We feel fairly happy with the P.S. as it stands. People who have been out to CERN recently may have found a certain spirit of gloom around the machine. It hadn't been working well, and Brookhaven was working better than we were - altogether it was the kind of morning-after feeling, but I think this is really very superficial. The fact that the P.S. beam has not been very good recently seems to have been cured and we have been up to $3\frac{1}{2} \times 10^{11}$ protons per pulse, so I think the current state of the machine is not too unhealthy; we are also taking some positive steps to try and strengthen some of the engineering and machine physics effort going into it. For the slightly longer term we have a programme running at the moment for making better ion sources, again to increase the current. As I said, an increase in current from where we are now by, say, a factor of 3 to 5, looks possible in terms of what we know about the machine and what we know about the difficulties of induced radio-activity. This we aren't going to offer with any guaranteed time scale but if we can't achieve such an increase within a year or 18 months then we shall have run up against some serious trouble which we aren't expecting. The other immediate improvements to the P.S. which we are thinking about are at the other end and are essentially concerned with ejection and better targeting, and here again the time scale with the new facilities is in the region of a year. There's some disappointment about this also but I think we've found that, like most things, the job is bigger than you imagine at first, and certainly bigger than you were led to believe by your experience on smaller machines. This is true of most improvements to machines and it's also true of experiments - they're all bigger than you think they're going to be. As regards future improvements to the P.S. on a rather longer term, it looks as though a current of about 10^{12}, or 2×10^{12}, proton per pulse will be a limitation with the present injection energy because of space charge effects at injection; there

no proof that this will be a complete limitation but various model accelerators have now been running in which space charge effects have been shown up under experimental conditions and where one can actually recognise them as such. Up to now space charge has been a sort of magic word: you can do some simple calculations about defocusing forces and you come out with a current at which you think these effects will begin to show up, but they are essentially complicated collective phenomena. Moreover there are other things like possible neutralisation by residual gas which upsets the space charge behaviour quite a lot, which means that until somebody actually reaches the limiting current I don't think we're ever going to be able to say just what the space charge limit in a big P.S. is. On the other hand, the limit due to the difficulties of induced radio-activity is something which we can begin to discuss right now. At the moment the CERN P.S. has, in the region of its target at handling distances outside the vacuum chamber, levels of the order of one rem per hour, sometimes higher, and this means that one has to restrict the time that operators, technicians etc. can go near the target to an hour a week or less, or only one week a quarter or only a few hours per shutdown. This level is acceptable. It means proper organisation but it doesn't prevent you doing ultimately what you want to without much increase in expense or time scale. A further increase by a factor of 10 would mean that there would be some operations when it would just not be possible to send a man in to do them in the same way as we do now. One would have to consider at least making lead shields and things like that to stand between the operator and the piece of apparatus, or one would have to redesign a lot of the mechanical side, targets and pieces of vacuum chamber and extraction windows, ejection magnets and so on.

For a further factor of 10 going up to 10^{13} - an order of increase in current beyond what we can foresee with minor developments - I frankly don't know just what will be involved in the way of operating procedures and rebuilding of major parts of the machine. You see, it's not only just near the target, it's pieces of vacuum chamber and magnet section downstream from the target over a length of perhaps 50 to 100 feet in which small angle scattered protons are sprayed and hit the walls of the vacuum chamber all the way down. In addition, of course, a certain number of lost protons spiral in and activate other parts of the machine at a lower intensity; there are several hot spots round the machine at the moment where the induced radio-activity is greater than 10 per cent. of the target area activity. So one will be coming up into a situation where access anywhere in the tunnel will have to be controlled, and quite a lot of components like radio frequency cavities and so on may become so hot that the present techniques for target handling will have to be applied most of the way round to any maintenance of the machine itself; this is something which could reduce the operational flexibility of the machine a great deal. Right now we just don't know how bad this would be and we are not yet in a position - although I hope we shall be fairly soon - to estimate the kind of activities we shall find in different components in different materials in different places in respect of targets inside the machine. So, as regards increase of intensity, I feel there's a very definite programme up to 10^{12}. The next stage beyond that will be dragging us into a lot of problems which will have to be faced with any new machine, because a new machine will be of even higher intensity; however, these will be faced in the design stage and not after the thing has been made.

The only other major improvement to the P.S. which one could consider is possibly the addition of another experimental area.

This, I think again, I wouldn't like to say anything about until we have had experience with operating the present three experimental areas. So far we have only been operating with one, the South Hall. We are bringing the North Hall into use at the moment and the East area will come into use with the British bubble chamber. Operating several areas is convenient for experimenters outside the machine but becomes more and more complicated when you have to consider what is happening inside the machine - and I'm not sure as to where diminishing returns set in. There is also the fact, of course, that whereas you can share protons between experiments in the same experimental area off the same target, you can't share protons between experiments that are on different targets. The experiments will be fighting one against the other for beam intensity and so perhaps the best way of investing one's money is into making multiple operation in one experimental area easier to do, rather than putting the money into building yet another experimental area.

Well that's what we think about our immediate plans. For the possible longer-term we have to consider the problems of the 300 GeV machine in two ways: there might be a European project in this area, or there may be a European contribution to an intercontinental machine, about which Dr. Adams will be speaking in a minute. For the very high energy machine the things which we feel worried about, and therefore the things which we would like to work on after having had close contact with the American work during the Summer, are some specific problems in accelerator design, but, more important, this question of radio-active contamination, the question of experimental area design, secondary beams, how to get secondary beams out and what to do when you've got them out, building and site requirements, and so on. The American work on these things has been extremely superficial, and before anyone can contemplate a project in Europe one has to know a good deal more to make up one's mind, rightly or wrongly, as to

what kind of site we are looking for. At the moment there is a wide divergence of view between the people who say that any site is good enough if you engineer the machine well - and if you put the whole thing underground you don't need to disturb the peasants living on the top - and the people who say that if you are going to start a project like this, a vast new laboratory area is required - you want your 10 miles by 10 miles square completely flat with very good ground stability and so on. This is what we have to look at - to see just what are the really important points and what is merely desirable but not essential. So it's this kind of work on the accelerator side we want to do and, secondly, if we can get it (and here, as Professor Weisskopf said, it's going to be difficult, but we must get it, if only to make the proposition look balanced) a good deal more thought on the kind of experimental facilities, experimental apparatus, etc., which will be needed ten years from now, and how this will affect the questions of the size of the experimental areas and the amount of power which should be made available on the site and so on. The people in the Brookhaven study group during the Summer made a very big effort to produce something on these lines. I imagine most people will have seen the pair of reports which they put out. There is one on the accelerator parameters and one on experimental programme requirements for 300 GeV to 1,000 GeV accelerators, which has got not only forecasts from known physics on the kind of beam intensities and the properties of secondary beams one is likely to come across, and be asked to handle, but also some more examples as to what beams and experiments would look like designed according to present-day techniques. The latter turn out to be fairly frightening according to present-day budgets and present-day manpower estimates. They talked, for example, principally about beams for bubble chambers. I think this is mainly because they had people on the spot who are interested in separated beams and who were prepared to make the

assumption that the hydrogen bubble chamber will be a principal experimental tool in the early 1970s or will at least still be in existence. If you accept this you ask for separated beams which are a couple of thousand feet long, most of which is filled up with electrostatic separator. The unit of cost is ten million dollars and the unit of staff, presumably for one experimental group, is 100. They also make some remarks on the possibilities of superconducting or cryogenic bending magnets for which they give curves of cost against size. The cost scale of these curves starts off with one thousand, then 10,000, then 100,000 and then you read that these are the costs in units of one thousand dollars(!) so a certain amount of rethinking of budgets will have to be done. But, frankly, it's only an indication as to what the physics at a thousand GeV would look like if no improvement in apparatus was made over the next ten years; and, since I don't think there would be much justification for building a 1,000 GeV machine if the experimentalists were not able to improve the apparatus correspondingly over the next ten years, I just don't think what conclusion one can draw from it. I just don't think it is possible to ask for a convincing description of experiments to be made out on these lines. I think that there is more to be done on what kind of beams will be available and involving some ideas on things like magnets and so on, sizes of target areas and amounts of shielding which will be required. How do you stop 300 GeV Mesons? Well, the Americans' answer is that just down stream from the target you put 500 feet of steel, then you put your experimental apparatus on the other end: so you can see why one has to think a lot before putting up a proposition on those lines.

The other kind of work which we are thinking of in CERN is to look at things which could be done in Geneva if we weren't engaged in a big major project of this kind. What can we consider doing at the laboratory itself, with it's present site, or with a small extension; and of course, for this we have put up our project for storage rings with the P.S. Nothing much new has happened on this

recently except that it was talked about rather on the side in the States during the study work on high energy accelerators. I think there are a number of enthusiasts in America for colliding beam experiments who take a positive rather than a negative view of the prospect of storage rings provided that they are added to someone else's P.S.(!) The CERN physicists' attitude has been to take a negative view of this proposal - that is the whole thing is a waste of time from start to finish - let the Russians do it, it will be our revenge for having been side tracked by them with plasma accelerators, to side track them on storage rings. But I think we were sufficiently encouraged in looking again at the possible experimental advantages of storage rings, and at the experimental programmes and experimental means of using storage rings.

The other problem essentially is the argument between large and medium machines. Where does the technical balance lie, going further than the rather superficial arguments I gave earlier, which tend to say that a high intensity medium energy machine is a bit of a snare. This must be checked quantitatively, to pick an optimium size for the machine.

The Chairman introduces Dr. J. B. Adams.

Dr. Adams: I have been asked to speak about the various meetings which took place recently in the States. I will rather quickly go over those. On the question of what is called the Inter-Continental accelerator, the first meeting was at New York. This meeting was called by the American AEC - by Seaborg - and the idea was that this would be a meeting at which the various people conducting study groups in the States could meet with the ones who were presumably studying similar projects in Russia and compare notes and designs of machines. The ACE invited to that meeting some Europeans, myself as one of them, some Japanese, and two people from the International Atomic Energy Agency in Vienna, one

of whom turned out to be Professor Salam. Now this meeting as you know, was a failure, because the Russians did not turn up. However, we did use the time to talk about the study which John Blewett's Committee at Brookhaven had done and to a lesser extent the one going on in Berkeley and Caltech. If I could just summarise this discussion as briefly as possible, the sort of criticisms that were raised - the points which were picked up in this great book which Dr. Hine has been showing you - were I think the following. Firstly, for the first time one could see how to extrapolate P.S.s to 1,000 GeV, and this, although one assumes it now, is really an incredible extrapolation from 3 to 30 GeV to 1,000 GeV. When I say one can see how to do it, I don't mean there are no difficulties here, but that there are really no fundamental difficulties; and if I had to make an analogy it would be that the difficulties would be no worse than those we faced at CERN when we set out to build the 25 GeV machine. The second thing was that the AG machine principle really seemed to imply, as Dr. Hine has just said, that one can't talk about high energy and high intensity machines as alternatives these days; one has to think of them as the same thing, and in fact the higher the energy the more intensity one is likely to get. This is a complete reversal of where we were before, when people said "Well, let's not go for energy, let's go for intensity", so they dropped the energy in an attempt to make a high intensity machine. Anyone who is talking about a machine nowadays, must be careful not to assume that a lower energy machine will give a higher intensity.

The result of these studies then is that within the energy range, say, from 30 to 1,000 GeV, the only thing that is limiting the machine we can build is money. I shall, now come to one or two limitations, because I don't want to appear too optimistic about 1,000 GeV machines. The other problem that came up in a

really big way was this radio-activity problem, which Dr. Hine has already mentioned, and I think one should underline this for all these machines, and especially for a 1,000 GeV machine, which is 30 times the P.S. energy, about 10 to 100 times the P.S. intensity and about 3,000 times the beam power. I think the radio-activity problems are going to be enormous. One must look at them more in terms of reactors than accelerators, and use reactor technology for remote target handling and maintenance, all of which is going to reflect on the cost of the machine. Another difficulty that was mentioned in the discussions concerned the manufacturing problems of such a large machine. The study rather assumed that one could build a 1000 GeV machine with the same accuracies, tolerances, stabilities, and so on, as achieved in the CERN P.S. If you keep the betatron wavelength the same as in the CERN P.S. this should be roughly so, but what I think was ignored in the report, was that industry must supply 10 or 30 times the quantity of apparatus. Even with the CERN P.S. it was difficult to find one firm who could make the magnet to the prescribed tolerances. If you are going to ask industry for a magnet ten times the weight of the C.P.S. magnet, and this is rather a conservative estimate I think, it is by no means certain that you will find one firm capable of manufacturing a magnet with this amount of steel. Remember the troubles that the Russians had with their Synchrophasotron magnet which also weighed 30-40,000 tons. One might have to face up to running many firms in parallel as they did and run into the same troubles. There is thus a quantity problem and there's no let-up on tolerances and accurancies to compensate - just the reverse. In these machine designs you will find that the aperture has in fact decreased as the energy has gone up, and this means that the focusing strength of the magnets are relatively higher, and consequently the

tolerances on field gradients are higher. If you throw together greater accuracies with the quantity problem, you have a general manufacturing problem which I think is an order of magnitude more difficult than that of the CERN machine although it does not look insuperable.

Another thing which came in for quite a bit of criticism was the cost/manpower estimates. The report says that an inter-Continental machine of 1,000 GeV will cost about £250 million, and that it will take about 1,000 staff 10 years to build it. You can easily calculate that this means that each staff member will spend about £25,000 per annum. Now, in fact, nobody has ever spent that amount of money per staff member per annum. At CERN we only spent £10,000 per staff member per annum on building the P.S. machine, and the present rate of expenditure is about £6,000 per staff member per annum. These average figures suggest that you need not 1,000, but 2,500 staff to build this machine, or alternatively it would take 20 years to build rather than 10 years. I think very few people here today would be prepared to wait 20 years for such a machine. Of course, there is the argument that you do not require 10 times the number of people to build a 30,000 ton magnet as a 3,000 ton magnet - it's not linear - but our experience at CERN has shown that if such large sums of money are to be spent wisely and not wastefully it may well take 10 times the staff. Another question is the annual budget of the laboratory. People realised that this machine cannot be appended to an existing laboratory, but will need a new laboratory. At CERN we found that the laboratory cost about the same as the machine. Let us suppose that it's going to take about 2,000 staff to build the machine; at CERN there are about 1,000 staff, extra to those that built the machine, who are engaged in the physics programme. For a 1000 GeV laboratory a reasonable guess for such staff is around 2000 and the total laboratory staff

is therefore about 4000 or about four times the size of CERN. The annual budget for such a laboratory will then be about £40 million per annum. To summarise we can assume a figure of £250,000,000 for the machines, which will take nearly 2,000 staff ten years to build. The annual budget will, I think, be around £40 million; and the total laboratory staff about 4,000. If we now assume that this machine is shared between Europe, Russia and America, each paying one third of the total cost - it works out that Britain would pay a quarter of the European contribution, that is one twelgth of the £40 million per annum, say roughly 3.3 million per annum, and that's about twice the present U.K. contribution to CERN. I think it is very important to get these figures home to people. The question of collaboration between the U.S.A., U.S.S.R. and Europe to build such a machine was discussed in New York. As you know, the McCone-Emilyanov agreement is a bilateral one between the USA and the USSR, and we Europeans were invited to the meeting in New York by the Americans, (the AEC). The question obviously arises "who comes into that joint project." Do you invite the rest of the world; if not what countries do you select - do you have everybody, the Arab states, the African states, and so on? This is not a trivial problem. There are well known problems about China, for example. A sort of guiding principle was mentioned at the meeting regarding the countries who should belong to the inter-Continental laboratory. "Only those countries, having a highly deveoped high-energy physics programme of their own, and possessing their own high energy facilities, should be asked to join". You can see the difficulty here. A country not actively engaged in high energy physics can make no effective contribution to such a laboratory and soon asks itself why it is supporting it financially.

Another meeting that took place around the time of the New York meetings was the Pugwash Conference, which was going on at Steive in Vermont. At this meeting, there were Russians present and the concept of an international accelerator was warmly supported by all the participants. They suggested a machine of greater than 300 GeV energy and what is most significant, recommended that it should be sited in Europe. The Pugwash conference is not an official meeting - the members attend in their individual capacities - but it is a very useful test of the feelings of people. The discussions suggested a new future for Europe, which should not be ignored, namely that Europe might become a science centre for the world. The idea is that the different fields of international scientific collaboration, of which high energy physics is only one, would group their laboratories in some area in Europe, which would be built up as a sort of world scientific community - space research, computors, radio astronomy, and other subjects were mentioned as possible world laboratories. I think that we Europeans should encourage this idea. Lastly, to complete this report on meetings, I should mention an unofficial one that took place in Vienna betweenEmilyanov, Rabi, Haworth and others. Rabi and Haworth passed through Geneva afterwards and Weisskopf, Hine and myself talked to them about it. It appeared that although the Russians didn't turn up at the conferences in New York, Emilyanov was still in favour of an inter-Continental machine. He felt that it should start off bilaterally, under the McCone-Emilyanov agreement (already approved by the politicians). He wanted to get a team of experts together to talk about the design of this machine. We discussed whether it would be worthwhile to set up a joint project between the United States and Europe if the USSR withdrew. Rabi's opinion (and also that of some other Americans at the New York meeting) was that this would still be worth while, although obviously siting problems arise. If it is put in Europe, then American physicists wouldn't feel very happy,

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and similarly in the reverse case. The last problem he mentioned, which affects us here at this meeting, is how can the European countries act in concert in intercontinental discussions about accelerator laboratories. It is too cumbersome to write to every European Government or every Academy of Sciences during the formulative stages. Rabi asked whether CERN could act as a suitable agency for Europe in this respect. I think that this is a feasible idea which would facilitate the early scientific and technical discussions. Of course, if the idea eventually reaches a project stage every government would have to ratify individually.
Luncheon was taken at this stage.

Professor Weisskopf: There is one thing which I would like to say on what Dr. Adams mentioned this morning about a possible tripartite machine. I should like to correct any false impressions which might have arisen from Rabi having changed his mind. He does not represent United States opinion. We got the definite impression that the American A.E.C. are still in favour of a tripartite machine, and would not be in favour of a bilateral arrangement. I think we should, therefore, be careful in interpreting these remarks. Another point I would like to make is the attitude of the Russians. Emilyanov did not give an explanation as to why the Russians did not come to New York, but he did not lead us to believe that there was any lack of Russian interest in an inter-Continental machine. Probably the American request had been made too late or through the wrong channels. As far as European participation is concerned, Emilyanov is quoted as having said that he expects broad participation fairly soon; now whether this means tripartite, or every country in the world, for example, China, Japan, etc., I don't know. This wasn't stated. In other words we can't really bank on the Russians as thinking of a purely

tripartite machine in the way we do. On the other hand, as far as the Americans are concerned, I think they will be forced into a tripartite machine because of location; that is it could not be placed in America because of the Russian interest and vice versa, and, therefore, it would have to be in Europe, and therefore Europe would have to participate. However, this argument does not exclude a wide-open world plan, although I think most of us would accept that this would lead to difficulties. This is one thing. The second thing is that the actual procedure proposed was as follows. Emilyanov was very eager to go ahead with an exchange of plans such as should have taken place in New York. These would take place on a bilateral basis in November or December of this year. He showed me some 30 odd papers which the Russians had already written to whet the appetite of the Americans. Unfortunately, and I'm not quite sure how this happened, the initiative was left to Emilyanov. In other words Emilyanov was supposed now to invite the Americans for the next meeting. This should take place in November or December, and my last information from the Americans, dating a week or so, is that nothing has been heard.

Dr. Pickavance:

I had intended to run through the National Institute programme as we see it, but I will now leave this to come out in open discussion. I think I will make just one remark, in the spirit of what Sir Harry Melville said this morning. This applied certainly to this country and probably to some of the other major member-states of CERN; namely that there are essentially three ways in which one can do research. Firstly, universities do this research with their own resources, though it's pretty expensive and these have to be augmented, in our case through D.S.I.R.; and, secondly, there are bodies like N.I.R.N.S. where things are bigger and in a sense have to be nationalised, for conomic and organisational reasons, but where, and I think this is important because it is a part of the fundamental policy of the National Institute, we try as far as we can to integrate this

research work the universities themselves, and not just with individuals who come to work with the machine. Then, thirdly, there is the international type of laboratory which is necessarily far more remote from the particular universities as such, not only by reason of distance, but because of the very large number of universities in the 12 or 13 member states of CERN. The only point I want to make, which is what Sir Harry Melville said, is that when we can, we must, as scientific people, make a case for a particular programme, a particular amount of money which we feel is justified, and finally when we get whatever fraction of that we can, we have to be very careful in dividing this sum (and the manpower corresponding to this sum) between these three different levels. It is my opinion that these three methods are all extremely important since they serve somewhat different needs, although possibly some of them vary between one European country and another.

Professor Powell: Well, sir, we've heard this morning a very detailed account of the considerations which are before CERN, and I thought the most useful thing I could do would be very briefly to distinguish what seem to be the essential points. Let me begin by saying that at CERN we proceed from the assumption, as Professor Weisskopf mentioned, that the physics of elementary particles will, for a long time to come, be a centre of great interest in the general body of physics. This is a point of great importance in discussions about the rival claims of different scientific disciplines. Professor Weisskopf has already said that we can have much more confidence about this than would have been reasonable two years ago. We now know that there are worlds within worlds here, we have increasing reason to believe that there will be a great extension in knowledge, and a great field of research for the next 20 years. One cannot look at the present complexities in the subject and the level of our theoretical understanding, without seeing that

we must expect to make profound advances. With the evidence for new kinds of particles, ephemeral particles; and for the core of the nucleon with all the experiments related to it, already we see a tremendous field of investigation. It is therefore certain that this field of physics will command the attention and enthusiastic support of the elite among the scientifically disposed young people all over the world. A lot of them will gravitate in this direction. For the general standing of European science it is therefore vital that the efforts already made to establish an international centre of high standing should be properly supported. This is absolutely vital for retaining within Europe a large proportion of the best creative talents that it throws up. Anything which illuminates this point of view is valuable to us, and I think that at some stage we might try and formulate a document which would be an instrument in the battle for proper recognition of this field, nationally and internationally.

Now, in this situation, as Professor Weisskopf has emphasized, the Scientific Policy Committee is convinced that proper support should be given to the present machine, on which so much effort has been devoted, so that it proceeds with the maximum possible momentum, generates prestige, and allows as much experience to be gained as possible. There is a common belief in the Scientific Policy Committee that the basic case is well founded, and that we shouldn't estimate the resources in manpower and the material within Europe as a whole to be less than those available to the U.S.A. or the U.S.S.R. Our resources in both these respects are commensurate with those of these other Powers.

Provided that the first priority of the fullest exploitation of the present machine is affirmed, then I think it would be the general view of the Scientific Policy Committee that the various possibilities for new machines should be fully explored. This is essential if CERN is to retain its status in the future.

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The Committee believes that there should be proper support for design and development studies, taking account of all the new technical innovations. It will then be possible to reach an informed decision in the next year or two, when it will be necessary to formulate final conclusions. With regard to the international proposal for a really great accelerator, I think that one feature that hasn't been mentioned is that there is a very general disposition within the Scientific Policy Committee to think that whatever decision is reached in this matter, CERN should retain its independence; CERN should not be the centre round which the machine should be designed and constructed. The idea here is that for the proper promotion of physics within Europe, CERN is a vital and essential instrument, - just as laboratories within the national state are essential. It is not in the best interests of European physics that CERN should lose its identity in a general international organisation. Nevertheless the Scientific Policy Committee is very much alive to the fact that the establishment in Europe of such a great new international laboratory - possibly not far from CERN, or in fairly close relation to CERN - would be a great advantage for European science.

Finally, it may be mentioned that in relation to any projected new accelerator, the job of the Scientific Policy Committee is to consider the scientific justification for the machine, irrespective of the resources involved and the way in which those resources might be obtained. The terms of reference of that Committee are such that it advises on scientific grounds alone.

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Professor Butler: Well, sir, I don't think I can add much that is new to what various speakers have said already, but maybe I should mention some of the conclusions which were reached a while ago by the CERN Panel. We did in fact meet to discuss one or two of the early papers on the storage ring system, back in May of this year, and we took the opportunity to have a brief discussion in that Panel of the future developments at CERN. I think essentially we reached two conclusions, both of which have already been reached by many other people as well. Perhaps they are worth repeating. First of all, it was certainly clear to us, as I think it must be to everybody now, that there is still room for an enormous amount of work, and probably expansion of support for developing the proton synchrotron to its utmost. Certainly this must be of the highest priority, and the first charge on any new funds that can be got for the corporate high energy enterprise in CERN. It is clear that there is a big programme of work in the next few years - for example, just this commissioning of the Eastern Experimental Area, and the equipping of it properly with separated beams, is something which has got to be pressed ahead with, we hope, very energetically, in order that about a year from now there can be something which is really working there. So we felt quite certain that this activity should have top priority. Secondly, I think those members of the Panel with experience of building accelerators certainly felt that the storage ring proposal was one of great interest technically, and looked a very feasible and a very elegant device, but some of the experimentalists - without, I must admit, a great deal of thought and study - had great doubts, very much along the same lines as their colleagues in CERN (i.e., its lack of secondary beams, the fact that it appeared that this machine would not support a lot of experimental groups - it would be a device for one very limited study - the strong reactions of the protons and so on). It might only support a very limited number of experimentalists and this in a European laboratory,

where many different groups would want to work, seems something of a snag. The attractive thing at the moment is to have more beams, good separated beams for bubble chamber work, and a great variety of good beams for counter work, and we haven't achieved all these yet with the P.S. This new project therefore seemed to us to be rather limited, useful though it might be (and it might be the only way to tackle a problem, or a rather narrow range of problems); it didn't seem wide enough to make a really attractive thing as the next phase of development for a great European laboratory.

I think that is really all I would like to say on the Panel's remarks, and perhaps I can make one or two very small remarks of my own, which again are, perhaps, reiterating points that have been made already but seem important. It does seem to me that for the first time we can, perhaps, plan a new project in a more physical way than was done in the past, and I'm quite sure that when the C.P.S. was planned - I feel this must be so - people didn't really understand exactly how it was going to be used. I can certainly remember a very distinguished American experimentalist, who lives on the West Coast, saying only a few years ago, just before the machine worked, that, well, it wasn't going to be a very useful machine, because one just could not handle beams of 20 GeV. I mean, these things were just too high an energy, no-one had thought of any beam-handling at this energy that was practical, and therefore the machine was not going to be a very great success. What had been overlooked, of course, and what has been mentioned today, was that the energy of the secondary beams at their most useful flux comes out at a few GeV, and so it's an excellent machine for producing strong secondary beams at a couple of GeV or so. Well, we've all got the feeling, intuitively perhaps, but nevertheless I think it's a feeling that all high energy physicists would agree on, that it's going to be worthwhile putting up the energy of strong secondary beams, also

worthwhile trying to get the intensity of the existing energy range up as well. But if we are going to push on, surely the right way of doing so is to say, well, the secondary beams of the CERN machine are best in the region of 2 GeV and so, and have a tail which runs up right into the 10 or 15 GeV region (but the flux is not terribly good up there); therefore what we want to decide on is a machine with an optimum for the future in the 10-20 GeV range, and then presumably the engineers and the physicists can get busy and design a number of machines and cost them out to meet this kind of secondary specification. So you start not by talking about kilowatts in the beam, but about kilowatts in the secondary beam, and then try to do an operational research study on what the machine would look like. One has the slight feeling at the moment, of course, that it would be a machine of volts rather than amps in the main vacuum chamber. None of this study, of course, would tell you how much money you ought to spend. I don't think there can be any argument of physics which will say that it is worth spending a given amount of money, but it is certainly worthwhile saying what has got to be done to push up one stage further, perhaps an order of magnitude, the useful secondary beams of the C.P.S. Maybe this will not come to be the world machine, but my own view is very much that I think we ought not to let this inter-Continental device befog the issue at the moment. CERN is certainly not going to diminish, and not going to be shut down suddenly, I feel sure. Like everyone else, I've got tremendous admiration for what has been done there; we want to see this level of activity develop in the next few years and be maintained into the 1970s, and this can only be done, in my view, if CERN has a new machine of its own, for Europe. I would like to see a machine with good secondary beams, with the possibility of having these beams an order of magnitude up in energy on what we have got at the moment.

Professor Salam: Well, Sir, listening to Dr. Hine and

Dr. Adams, I was a little disappointed. If 300 GeV is the upper limit one has already fixed for the national effort, and 1000 GeV for the international machine, one has not set one's sights high enough. I want to associate myself fully with what Professor Weisskopf has said about the very exciting vistas of physics which one can look forward to from the higher energy machines. The situation in our subject is like a television screen, with a lot of dots appearing. These dots form into a pattern after a long and intensive programme of experimental work which has really just got into a stride. I wish to emphasize that so far as strong interactions and weak interactions are concerned, we have only got a very few dots on the screen, hardly making a pattern. All the present machines give is 5 GeV in the centre of mass system concerned. The projected machines will give no more than 25-30 BeV. The pattern I am talking about is almost certainly not going to appear at 5 GeV centre of mass. This is just too low when compared to the rest energies of our projectiles (1 BeV or so). Higher energies are an absolute necessity. I would also take the point of view that Professor Butler took. The international machine is probably a very long way off. Conversation about it should not deflect Europe from embarking on a project of the 300 GeV type on its own and worrying about it now in a preliminary manner.

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Dr. Adams: Could I make just one or two points that may fire off a few starters in the discussion? I think we have got a rather practical problem. This is as follows: that for the local CERN programme, if we want to have protons accelerated to higher energies, then the choice one has to make is between machines of 50 to 300 GeV - I stop at 300 GeV only because the Americans decided that was the biggest national machine. The choice lies somewhere in that range for the local CERN programme, if one wants protons. If you want electrons - the only thing we don't match up in Europe with America is, of course, the Stanford electron linac (40 GeV, or thereabouts) - you can consider a very big electron synchrotron; but listening to people one rather has the feeling, at least until recently, that protons are better than electrons in these sort of energy ranges. However, I just mention the point because I think perhaps somebody might want to come back on that one. So this is the local CERN programme. If you want to go outside that to the inter-Continental programme, bearing in mind what Professor Weisskopf said about the American attitude, it means you have got to think of about a 1,000 GeV machine, and the practical problem then is - can we afford both? Because, as I tried to point out this morning, the 1,000 GeV world machine will cost up to, if it's a tri-partite arrangement, about twice the annual budget of CERN; and if you throw in, let's say, a 300 GeV machine for the CERN local programme as well, you can put in another factor of two. This is an increase in physics, looked at from our point of view in this country, by a very large factor, and the point is, can we afford it, can we persuade people to pay for it?

Now the last point is, exactly on the same theme, in the last year or so I've had the feeling that one is discussing the merits of Rolls-Royces and Mercedes, whilst most people are wondering where their next bicycle is going to come from. One gets the sort of guilty feeling in CERN that there must be some way of working out how much you are going to spend on these extremely elegant,

very nice, machines that are going to be used by the elite (and must be available in Europe, otherwise we just lose our good people) and to balance that against the University-type machine, without feeling hopelessly guilty about these decisions. You can do a very simple sum. I talked in terms of this very big machine costing 25 times as much as the CERN P.S.; in other words you can buy 25 CERN P.S.s for that amount of money. Even if you take our one-third share, then it is still eight P.S.s; and if you scatter those around in Europe, then you can do a lot of physics with them. You see we are at opposite poles and I can go back and say you can afford thousands of small university machines for the cost of the one big one. Somewhere, I think, in this country, we have got to have a system whereby we can make some judgments on this enormous scale and come to some sensible conclusions. Otherwise, I think, we will always feel that CERN is running off with all the money and, after CERN, it's the world machine which will be running off with it.

Sir Harry Melville: Well, I think Dr. Adams has only touched on one part of the problem. The real problem, you must realise, is that the dilemma will have to be faced in this country when there are other fields with expenditure of much the same order of magnitude, such as space research. Radio astronomy is on the horizon already. There are other fields which may well come into the category too, almost extensions of pure physics, and the trouble will be that it reacts badly on those people in the universities who are desperately anxious to have what they need for "normal" research. So it's not just the problem of backing nuclear physics, and trying to balance the effort at the national and international levels: it is really a question of what is reasonable to try and urge this country to spend on those fields of pure science which have obviously no practical application, and this is a terribly difficult thing. Once upon a time the amount of money was so small that it didn't have the slightest

effect on the total research work of this country. But if you remember that the U.K. spends, altogether, rather more than £300 million on research and development of all kinds, defence and civil, then these figures which we are talking about are beginning to reach a significant fraction of that sum of money. So this really makes the problem a national one, and not just a matter-of-fact argument with each case going up to the Treasury to get the money. How we solve it I just don't know. We have tried, in D.S.I.R., to balance University nuclear physics against other desirable things like radio-telescopes; we've got some kind of balance, but that has only been achieved with the utmost degree of difficulty. The people who advocate the various types of apparatus, the accelerators or telescopes for example, all press their own claims independently, and say they can't reach a decision between an accelerator and a radio-telescope. Then you have to appeal to some higher body to make the decision. But who is that higher body going to be? As I said this morning, if you get a sufficient body of scientists who are willing to make these very hard decisions - some are bound to be disappointed - then much better to do it this way.

Dr. Adams: I think the first thing must be that we should put our own house in order in high energy physics.

Professor Cassels: I must say I would like to support this last point very strongly. Dr. Hine was drawing a picture of high energy physics with a broad base at the bottom of the triangle going up to this pinnacle of a 1,000 GeV machine; but, in fact, the triangle we are building in this country is not that shape at all, and unless we have strong university Departments for turning out the high energy physicists who will be going into this higher field it's not worth building the machine. At Liverpool, for example, we turn out some eight or ten high energy physicists each year with Ph.D.s who are all absorbed in the enterprises given in Dr. Hine's list at the end of his report; but we can't go on doing

this indefinitely unless we have a strong school of high energy nuclear physics. Now in our case I am fairly confident that in the future we are going to be supported by a new machine, but it seems clear that the Glasgow case is a glaring example of a situation where one of these important sources is not being supported. I think we must cut the base of the triangle to suit what we are trying to do at the top and that is not being done too well at the moment.

Sir John Cockroft: I think, if I may say so, that the D.S.I.R. Research Grants Committee holds the quite general belief that we should give first priority to backing up the inexpensive forms of physics which are carried out in the universities. If we have any money left over we can go for the larger and more expensive projects, but the "university" level science should take priority and have its natural growth provided for. I don't think there is any doubt about this.

[Some discussion then followed about the Glasgow Linear Accelerator Project, for which D.S.I.R. had been unable to announce an award.]

Professor Dee: I think the real relevance of what Professor Cassels has said was in the sense that Dr. Hine and Dr. Adams brought it up and I don't want to pursue it further than that. But I think the essential point is simply that here we are talking about a school which at the moment is producing of the order of six to ten Ph.D.s a year - this is a very cheap activity compared with the things we are talking about. I am talking about £200,000 a year, whereas Dr. Hine was talking about two hundred million a year. This is the essential thing for this Committee. There is this factor of 1,000 involved here, and I think it is a relevant point which we should have in our minds that we are talking of an expenditure of 200 millions for one thing while failing to provide £200,000 for the other.

Professor Cassels: I was of course only trying to make a general point. We have got to nourish the roots if any of this is going to be worthwhile; and it has to be done over a long period.

The two other points which I would like to make are first that

I would not agree with Professor Butler that it is essential that CERN should have another project at this time. It seems to me that CERN has got the task of keeping up Europe's position in high energy physics and that this can best be done by really making a first-class show with the physics done with the present machine at CERN. I don't think anyone would disagree with this for a moment. CERN is already accepted as being at least equal first in building machines so that is taken care of for the time being; but it is not generally accepted that CERN is equal first in doing physics and I think the most important thing is that it should set itself that target in the next few years. The new machine is not necessary really to sustain morale or the flow of physicists to CERN from European countries.

The third point I wanted to make was that it seemed to me rather essential that if there is going to be an intercontinental project we should not be left out in the way that some of us remember Britain was left out for a time at the beginning of the CERN project. Is there not some way in which we can get more formally into the intercontinental negotiations - for example by the Prime Minister making a speech - it seems to be left to the Americans and Russians at the moment.

Professor Weisskopf: I am in many ways very much in agreement with Professor Cassels. First of all I would like to come back to this first point about the triangle, or rather the formation of the base of the triangle. This is also very important from the point of view of CERN. For example, if we are cut down, I mean if we have strict upper limits for the budget and yet at the same time are talking about spending some money in connection with a new European machine, then we must get a reasonable increase in the CERN budget which will allow the most modern methods of exploitation for the present machine. If we do not get this and yet are thinking of spending money on a new machine, then we are making the same mistake but at a higher level. I would also like to make one remark in which I might be influenced by my American

experiences; this is what one might call the Bose statistics effect. There is an effect in America certainly, and I think also in Europe, that where one engages in large projects the small projects do profit by it. There is not a conservation law of pounds or dollars for financial support. You can also call it the "shirt-tail" effect, the smaller machines are pulled up by the bigger ones. It is very noticeable in America - I don't need to give you any examples of it. It is, of course, important that there should be more small machines in Europe, but I think it is wrong to say let us cross out the big machine and then divide up the money for so many small ones. It is rather the other way, let us get the big machine, and we will find there is enough money going round for the small machines too. This may be over-simplifying the position but I think it is valid to some extent.

Now the discussions we have heard here are going on in every European country and should perhaps be going on on an inter-European level. This, together with the last remark of Professor Cassels, namely are we a real third partner in the international game, brings me back to a point which Dr. Adams made - we must have a European high energy physics body which allows Europe to be represented in discussions on a tripartite machine and gives us a chance to take an active part. But more than this it must be a body which acts as a central collection point, of ideas and of discussions, as to high energy policy in Europe. Where should one machine be built and so on. For example, the French are now talking about - I don't know how seriously - a high intensity 25-60 GeV machine - well it might be a good idea and it might not - but I think a machine of this kind ought to be considered on the European level. Now this is why I think this Panel should take this point up in discussion. In what form can we establish a place to represent Europe in respect to thinking about new machines and planning machine strategy. This, I think, is an important point, and though we mustn't assume that CERN will be the place for a new machine - and I agree with some of the observations that have been

made, for example, that if there is a new international machine it might not go to CERN - this centre for discussion has already been created at CERN. I should like to ask your advice on how to establish such a centre and whether you agree with me that the centre should not only think about new machines and the experiments which can be done with them, but should also think about the European situation, for example where machines, including those of the smaller type, are needed, and how the whole European equilibrium can be maintained, i.e., how the triangle can be maintained.

Dr. Ashmore: We are talking about the base in this country and can I just say that the base is even worse in some other European countries, Holland for example. This kind of body we are talking about now should surely be able to help countries like that in developing their high energy physics.

Professor Powell: I think that if such a body were established and if it took into consideration not only the great machines but also the general development of this aspect of physics - and if, as Professor Weisskopf said, it was supported from within the universities - it would be a very powerful instrument in helping to secure wise policies in a great number of states.

Professor Weisskopf: Well, let me add this; I think that in a second international machine it is almost a condition that we should have reasonable faith. When the challenge to join in comes it will certainly be impossible to start a second international machine project on a country by country basis. We must have for this international machine at least, if not for others, some kind of body which represents Europe - not in a political sense because it would be unable to enter any commitments, but a body that can be approached and that can talk in the name of European high energy physicists.

Sir John Cockcroft: Well I can't see why CERN shouldn't do this - we don't want to set up a new body, we've got far too many

already.

Dr. Pickavance: Well I think that's the answer - one wants an informal approach at the moment, the less formal the better. The main thing is that the scientific people - the technologists on the machine side and the physicists on the experimental side - should know what each other are thinking in various countries. I think someone mentioned earlier on that there was already a small beginning in this direction where CERN had taken the initiative and which everyone else very much welcomed: that is, this travelling European study group, which is at least making it unlikely that if separate countries pursue their own national programmes according to their own needs they do not fail to get together on machine design.

Professor Weisskopf: I think it needs a positive statement from the Council that CERN can represent Europe in this sense.

Professor Cassels: But presumably the CERN Council can take the necessary steps to empower itself to represent Europe in these intercontinental machines discussions - and I think it should do that.

Professor Powell: I think the terms of reference should be wider. It seems to me the whole effect of this body would be much more powerful if it was manifestly concerning itself also with the background which is supporting CERN and which in the long run is absolutely essential to the future health of CERN. Its pronouncements will be much more weighty if it has considered the proper support of nuclear physics in the member states and the health of the university institutions.

Professor Cassels: You've got to be a little careful about this. For example, we might find that University 'X' can't go ahead with a project of its own without asking European permission. Let's use instruments of policy at each level which are appropriate to the scale of what you are doing.

Professor Powell: I am anxious about the situation which we have discussed here today where CERN is also concerned with the

proper support of its roots in the member states.

Dr. Adams: Well perhaps what one could do is this. CERN has got to exist by having roots in each member state, and it might make general observations on the level at which these roots should be nourished, for example countries should spend this sort of fraction or that sort of fraction on purely university types of activity, i.e. this is the proper expenditure to support the other end. Observations of that sort would be very useful and would, I think, give valuable guidance to the member states as well.

Professor Gunn: I should have thought we didn't need to give CERN any formal powers here. NIRNS already has a programme where projects are put up and considered at the national level and I should have thought that on the whole we don't want to use CERN as a further consultative body. I feel that CERN's office should be informal and that one should discuss national machines at the national level. One doesn't gain by spreading the discussion too much.

Dr. Pickavance: I certainly agree with what Professor Gunn says on the part which NIRNS might play nationally but I had assumed that we were talking about securing views on national programmes - and not in any way about determining them.

Professor Merrison: I think one thing which would be helpful here is the following. When we talk about relations between the groups and international organisations like CERN, we think of sending young men to CERN, seeing them coached up and then returning again. It would be extremely interesting to know what in fact does happen as an overall picture to the young people sent to CERN. We found at Liverpool - however, we've only got a few figures to work from - that in fact they don't return. There are two reasons - one is that they meet Americans there and good high energy nuclear physicists are in just as short a supply in the States as they are anywhere else and they are whisked off to America. The other reason they don't return is, of course, that we have very little to offer them - once they've tasted the glories of

a machine like the P.S. at CERN they want to go on to a machine at least as good if not better - so I think it would be interesting to know these numbers.

Professor Weisskopf: I think this is part of the shirt tail argument - you won't get good people back from these organisations unless you offer them a good carrot.

Dr. Hine: May I make one point on this question of general European co-ordination. There has been running this study group, so called, on accelerator planning for about a year now, where the accelerator engineering design groups have quite unofficially been getting together to try and see what their opposite numbers are cooking up. Already a certain amount of clarification has come about and instead of everybody wanting to build a 12 GeV high intensity P.S., now nobody wants to build it! In particular as far as CERN is concerned we are very anxious about our own manpower supply: just as Professor Merrison says - how many people are coming in and how many are likely to be coming in in the future, and where are they likely to go to. In fact I have suggested that at the next meeting of this accelerator group we should start to look seriously into the supply and demand problems of high energy physicists over the next decade from what is supposedly going to be available in the light of Governments' policies, i.e. what staff we think will be required for a new big accelerator somewhere and the effect this will have on national programmes. These things we had quite independently proposed looking at and I think it is most interesting that the same ideas should come up from people here. What would be a most valuable thing to find out about is how are the various levels of this pyramid going to be built up in future years: is it completely ridiculous to commission a new European machine in terms of the staff who will be available to work on it? I don't know, but I think it is interesting to do something on these lines.

Professor Weisskopf: I think we are on an expanding plane where we shall need more physicists yet, and therefore this is

the worst time to stand back. On the other hand we do all we can to keep physicists and prevent them from going to America. The fraction coming back from America through CERN I don't think is so good; I think they have too many commitments.

Professor Merrison: I was really not criticising CERN, I was emphasizing the argument that CERN should interest itself in the national programmes in each country and reinforce those programmes. For example, a very peculiar remark of one of your young people at CERN - a Dutchman: just a few weeks ago, I asked him whether he was thinking of going back to Holland. He said "No, I'm not old enough to look at bubbles". He had nothing in Holland to do except look at bubble chamber pictures and his inclinations in fact did not turn that way.

Professor Weisskopf: I think this is a problem typical of countries such as Holland and Sweden. It is less of a problem for England because let's not forget that small machines do have attractions too; for example, there are quite a number of young people at CERN who prefer to work with the small machines because of the more personal relationship, and such people might not go back to Liverpool, or even to England.

Dr. Pickavance: We have even smaller machines than that which may even be more attractive.

Dr. Adams: Professor Cassels was saying, and I think we all agreed quite rightly, that CERN's next step is to do some good physics. This is quite evident, though, if I may say so, the other problem is that if we don't think of what we want to do in ten years' time, and this is the really difficult thing to do, then we won't have anything ready in ten years' time. Most of the things we have been talking about seem to have a time scale of the order of ten years, so that really one has to do the two together: to think about the facilities for the next decade and, of course, to make absolutely sure that you are going to do some good physics in the meanwhile. If you don't do both, nobody's going to support you; so you've got to do both.

Professor Cassels: I agree with you. But what I suggested was that we should get rather more out of the Continental discussions with a view to being able to see within, say, two years, whether or not it is going to come to anything.

Dr. Adams: Yes, well that would be the sort of solution: I mean what Dr. Hine has said about a disarmament conference on high energy accelerators. Anyhow, there is this idea that even 300 GeV is getting so large that it is more appropriate to an intercontinental basis; and if one can get agreement that the Russians, the Americans and the Europeans won't build any more national machines then we can all build one 300 GeV one together; meanwhile we get on with what we've got. This, I think, frankly, would be ideal; and a most sensible programme bearing in mind the money situation and all the other problems that we were talking about, staff and other competing interests. But I don't know how you can get this disarmament conference going. If it is the feeling of the Panel that this is the right course, then perhaps CERN should try and press more in that sense rather than trying to get its own programme and a share in the intercontinental project.

Mr. Mullett: Berkeley are in the situation where they need a new machine even more desperately than CERN. And we know in fact that they've been doing studies, not necessarily for a 300 GeV machine, but 100 to 300 GeV. They've been doing studies of cost and manpower and so on. These people are quietly working away to achieve, I think, a purely Berkeley proposal. Maybe they would consider collaboration with Brookhaven but I think we shall find a Berkeley proposal and it may not be 300 GeV.

Dr. Adams: Well, there was one statement made by the A.E.C. that any new project of 100 GeV upwards would have to be a national project, - the A.E.C. would not support a Berkeley or a Caltechor a Brookhaven project - it's got to be a national one.

Professor Cassels: Surely the time scale for finding out the kind of international politics involved in an intercontinental machine is not too long. I mean, political ideas either grow or wither, they don't stand still. So surely within, say, 18 months

to two years, we can see whether it's going to come to anything or not. If it's not going to come to anything then I agree we have got to make another European effort. However, one thing worries me here. I think that 1 to 5 GeV may be the classic energy of elementary particle physics and that beyond that everything will go off in an asymptotic fashion. We were told this morning that every step in energy has led to new and exciting physics. Well this isn't quite true in the step from 6 to 25 GeV. We haven't had any new physics from the CERN P.S., although that machine is a much more powerful engine for doing what the Bevatron did before. So it's not clear to me that another step by a factor of 3 or 4 is specially needed.

Professor Salam: The trouble with CERN is that the energy is too low. I am sorry, but this is the truth.

Dr. Adams: I would have thought a third share of a 1,000 GeV machine was a good next step to take.

Professor Wilkinson: This is surely the sort of thing that we could try to find out: what is the feeling in this country on this question? I think that at the moment Professor Cassels is probably in a reasoned minority. There is this emotional friction against having another big step taken by Europe. Certainly in CERN more than in this country I heard the view put forward that Professor Cassels put forward, but I think this is probably because we haven't really sat down and weighed the two things against each other. My own feeling is for another step in Europe. In this connection I would like to put forward a viewpoint which is radically different from the one we have had so far; that CERN does not exist for satisfying the aspirations of the member states, it exists rather as an expression of the increase in the intellectual standard of living in Europe. If I am right, we have a responsibility towards Europe as a whole which is not simply a reflection on our own use which we hope to make of CERN. We have a very big share in the budget - and this will have to continue presumably - and if

we want to express this responsibility in what must be an expanding situation, we do have to find means of getting more money out of our Government and into CERN. This must be recognised now whether or not we immediately start on a new programme in CERN - whether a design study or a more serious consideration. We can always put it off a year or two, but very clearly it's going to come sooner or later, and now is not too early to try and get out of the Government the doubling or quadrupling of the CERN budget. I would like to see this sort of money put in competition not with small local projects in nuclear physics, or in science generally, but put in competition with things like egg subsidies. This is a matter on the political level which we as a Panel can't do much about, but I think that as a Panel we have to recognise this problem and that we ought to start using our influence, such as it is, to find a solution. I think part of the argument one would make for this idea of a big development in CERN is the political one that Europe has got itself into the position of a first class power in elementary particle physics and unless something of the sort that I am talking about is done it will not remain a first class power. These are the sort of short sentences I think those above can understand.

Professor Powell: In relation to this general discussion, Dr. Adams has put the point that there would be very great advantages in a general moritorium and an international project to make a machine of 300 GeV, the understanding being that the present machines and the predicted machines would be fully exploited. The advantages of such an international project are so great that they might find wide support. Our justification for a very big step forward is based at present on very general considerations. The position will get clearer in five years. Perhaps, therefore, a general moritorium as the basis for an international project - that might be a sensible suggestion in relation to the scientific advantages we are going to get from this field as far as we can see them at the present time.

Dr. Adams: I would only add one condition to that, and that

is that the machine should be in Europe.

Sir Harry Melville: I think what Professor Powell has said would appeal to those at a higher level because then it would be big money being approached on a rational basis; this would be very desirable and would be much better than, say, a multiplicity of 50 GeV machines, which might not get the support which you expect.

Professor Merrison: I think that would only be scientifically desirable for CERN's project if at the same time one had the base of the pyramid supported to a greater extent than it is at the moment. I don't think anyone is suggesting that we should not ask for money, it is this conflict of interest in universities and at the national level which causes difficulties with an international project. It is a difficult situation and postponement may help this conflict of interest, but it wouldn't really stop us asking for money at the lower level.

Professor Cassels: There couldn't be any moritorium if the Americans didn't keep to it.

Dr. Adams: Could I ask another question. Do people here think there is any chance of stepping up the support of high energy nuclear physics by a factor of two or three. I mean, are we talking about something that can really be done. You know that the American high energy physics budget is going up from 100 million dollars to four hundred million dollars by, if I remember rightly, 1970. Anyhow they're planning on that sort of order. Now are we in Europe clear that we are going to be able to raise the necessary money?

Sir John Cockcroft: Well, we don't know the answer; we shall have to wait and see. At the moment we've got this freeze and I

think we shall know much better in about a year's time what the prospects will be of raising more money. Anyhow we can't place any confidence in getting more money on what we know at the moment.

Dr. Adams: So you would advise just going on without studies, which will in fact lead to new proposals.

Sir John Cockcroft: Yes, I think so.

Professor Wilkinson: The point is surely that in space we cannot hope to compete with the Americans, whereas in high energy physics we can. We're not talking about some astronomical figure - we're being realistic; and we can make a real competition from Europe - we can't in space. Someone has got to get up and say this - we don't have, at, so to speak, the working scientist level, representation on the Councils where this sort of thing is gone into. But surely we should say - and can say - that this is the situation and we can compete with the Americans.

Sir Harry Melville: But we've also got radio astronomy and the next radio telescope is going to cost as much as the P.S. itself; the radio-astronomers think they have very strong arguments.

Dr. Pickavance: I think this does emphasize a point which is rather analagous to what Professor Wilkinson was saying: that we have a good case for persuading our Government - the same applies to other European countries - to spend more in competing in those fields where we have a chance of being right among the leaders. Radio astronomy is one certainly, space may not be, but elementary particle physics is.

Sir John Cockcroft: Perhaps I can run over the principal points which it seems to me have come out of this discussion. First of all the importance of making the best use of the existing facilities at CERN - which does require a reasonable increase in the budget. The second point was the possibility of improving the P.S. intensity by a factor of ten and looking into the limitations such as radioactivity and space charge which would stop us going much further. The third point was that it seemed to me that the

storage rings' proposal was not thought very highly of at the present time. The fourth point was that in general people seemed to be more in favour of going to higher energies rather than simply putting up the intensity. Then the point about not losing sight of the importance of research in universities and that this should not suffer because we are going ahead with bigger machines. The next point was about CERN taking responsibility for inter-continental discussions on behalf of European countries. Then finally there was Professor Powell's point about somebody drawing up a very appealing document supporting the continuation of work in high energy physics. I think this is very important and perhaps Professor Powell and Professor Wilkinson might prepare such a document together.