THE EUROPEAN 300 GeV PROGRAMME

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Abstract

The paper describes the history of events leading up to the decision of the CERN Council to go ahead with the European 300 GeV Programme in February 1971. A brief description of the main characteristics of the Programme is given introducing the idea of an accelerator complex capable of future developments on one site. Finally, progress with the Programme since February is reported.

1. Introduction

On the 19th of February 1971, the Council of CERN gave its approval to the European 300 GeV Programme and ten of its twelve Member States agreed to join the Programme.

This formal act of the CERN Council brought to an end many years of discussion on new experimental facilities for nuclear particle physics in Europe and undoubtedly it is the most important piece of accelerator news that I can bring to your notice today. In the months following this decision we have been building up the project staff, designing the machine and generally getting on with the project as fast as possible, but before I report on this work I would like to say something about the history of the European 300 GeV Programme and how it came about that a decision was finally reached by our Member States.

The idea of a proton synchrotron ten times the size of the Brookhaven and CERN machines was first discussed as long ago as 1960 at the time that the CERN 28 GeV machine was being brought into operation. Some of you will remember that there were many problems presented by the alternating-gradient focusing concept which were only finally resolved when the CERN machine demonstrated in a practical and large scale way that the theory accurately described the critical features of this novel and economic method of focusing protons in accelerators. Inspired by this success, it was only natural that the accelerator builders should wonder whether it was practical to consider even larger machines and what new problems they would present. An order of magnitude increase in energy seemed at that time, over ten years ago, a rather bold step. From the discussions which went on during spare moments in bringing the 28 GeV machine into operation, it seemed that solutions might be found for most of the technical problems but that the cost of the machine was likely to remain a major impediment, at least in Europe.

About 1963 the need for such a machine from the research point of view became apparent and a committee of nuclear particle physicists was set up to consider the characteristics of the accelerator and its role in future experimentation. The conclusion of this committee, called the European Committee for Future Accelerators, or ECFA for short, was that the machine design should aim at 300 GeV energy and an intensity approaching 10^{13} protons per second.

A feasibility study for a proton synchrotron and a laboratory to satisfy these aims was started at CERN in 1963 and a complete design was published in November 1964. Not surprisingly, this machine design followed closely that of the successful CERN and Brookhaven machines, although several novel features were proposed.

Although the ECFA and CERN studies considered building the new machine near the existing laboratory of CERN, it was concluded that no site sufficiently large was available in the vicinity and it was therefore proposed to build it somewhere else in Europe on the territory of one of the CERN Member States.

In view of subsequent events, I should also mention another important step which took place in the autumn of 1964. Several of us in Europe, realizing the high cost of a 300 GeV machine and a new laboratory and having experienced the difficulties of financing the previous 28 GeV machine, had the idea of basing the 300 GeV machine construction on a wider collaboration of participating countries. Why not, we argued, build the next accelerator as a joint project between the United States of America, the Soviet Union and the CERN Member States. A meeting was consequently arranged to discuss this idea in Vienna in the autumn of 1964 and was attended by scientific representatives of these three areas of the world. At the time of this meeting, both the USA and the CERN Member States were considering new machines in the 200-400 GeV energy range and the Soviet Union was constructing the 70 GeV machine at Serpukhov. The conclusion of that meeting was that machines up to about 500 GeV should continue to be built on a continental basis but that for machines above the 1000 GeV level intercontinental collaboration would probably be necessary and should be explored.

As a result, the proposals for building machines in the 200-400 GeV energy range went ahead separately in the USA and in Europe.

In 1965 a proposal was put to the CERN Council to build a 300 GeV machine and a new laboratory as part of a package of new European facilities, the other parts of which were the addition of intersecting storage rings to the CERN 28 GeV machine and an improvement programme for that machine which included a booster synchrotron for its injection system to raise its intensity. The CERN Council in December 1965 approved the second and third parts of this package but came to no decision on the 300 GeV Programme.

In the USA, a design study for a 200 GeV machine went ahead at Berkeley and produced a report in January 1965. Later on, at the end of 1966, a site was chosen for the new American machine at Batavia, near Chicago, and a Director was appointed early in 1967. As you all know this Director, Professor R.R. Wilson, transformed the project into a 200-400 GeV machine and a design report was issued in 1968. Today, this American machine is being brought into operation.

In Europe, after 1965, there was rather a lull in 300 GeV machine design but great activity in other matters relevant to the 300 GeV Programme, notably, the machine utilization studies of ECFA of 1966-67 and the search for sites for the 300 GeV laboratory in the Member States of CERN which started in 1964.

Four years went by without any decision being taken, but at the end of 1969 it appeared to many people that a decision was imminent. Six Member States had announced their intention to join the 300 GeV Programme and five of these were offering sites for the new laboratory. Hopefully, following the American precedent, a Director for the Programme had been appointed and all seemed set for a happy end to many years of earnest endeavour. But again no decision was reached and the new year dawned rather bleakly at CERN in 1970.

Looking back, I think one can discern a number of reasons why our Member States hesitated to reach a decision on the 300 GeV Programme in the form it was presented at that time.

In the first place the economic situation in 1969 for science in general and nuclear particle physics in particular was very different from the ebullient years around 1964 and 1965 when the 300 GeV Programme was first put forward. It was evident that several Member States of CERN and possibly all of them found the cost of the Programme too high compared with their other investments in science and with the growth rates in their total science investments which had dropped from figures around 15% per annum in the 1965's to a few percent per annum in 1969.

In the second place, the idea of constructing a second European laboratory for nuclear particle physics remote from the existing one, which had seemed attractive in 1965, looked inappropriate in the light of the economic situation of 1969, particularly since it implied running down the existing CERN laboratory when the new one got underway.

In the third place, so many delays had occurred in the 300 GeV Programme and the American machine was coming along so fast that an eight year Programme to reach experimental exploitation seemed too long.

Fourthly, it turned out that choosing one site amongst five technically possible sites presented non-trivial political problems for the Member States of CERN.

With these lessons in mind the small group at CERN set out early in 1970 to put together a new Programme which, it was hoped, would avoid the difficulties raised by the 1969 proposal.

To reduce the cost of the Programme, shorten the time to first research operation and ensure the future validity of the capital investments of the existing laboratory, it was proposed to site the new machine next door to the existing laboratory and to use some of its major capital equipment as an integral part of the 300 GeV Programme. By this means and by using the existing technical and administrative services at CERN-Meyrin, the original cost of the Programme could be halved. Also, the new proposal raised no problems of choosing a site for the 300 GeV Laboratory since the large cost reduction was only possible if the machine was located next to the existing laboratory. From the nuclear physics point of view the attraction of the new Programme was that it offered the possibility of starting experimental work in the sixth year after the start instead of after eight years.

Thus the new 300 GeV Programme avoided nearly all the difficulties which had essentially blocked the 1969 Programme and the great questions were whether it would be acceptable to the European physics community as the old one and whether it would gain the support of most, if not all, of the Member States of CERN. The remainder of the year was spent in exploring these two problems and in designing the new machine and its laboratory.

By the end of 1970 all was ready again to put the new 300 GeV Programme to the CERN Council. The physics community was backing the new Programme which had been shaped to fit their requirements and it only remained to be seen how many of the Member States would support it.

In the December meeting of the CERN Council the six Member States which had supported the 1969 Programme also supported the new Programme. These were France, the Federal Republic of Germany, Italy, Belgium, Switzerland and Austria. In addition Britain, which had rejected joining the original 300 GeV Programme, came out in support of the new one. But seven Member States instead of six was still not considered sufficient support for such an important Programme of CERN and the Council session was adjourned to mid-February 1971 when, it was hoped, more Member States would be ready to join.

Finally, at the adjourned Council meeting on the 19th February, three more Member States, Holland, Sweden and Norway, were able to announce their intention to join the new Programme and the Council went ahead and approved it.

So ended almost a decade of planning and decision making for new experimental facilities for nuclear particle physics research in Europe. These new facilities - the intersecting storage rings which are now in operation and being used for research; the improvement programme for the 28 GeV machine including the booster synchrotron which is planned to come into operation next year; and the 300 GeV Programme which is now underway, will provide the basis of experimentation for the next two decades in Europe and probably until the end of this century.

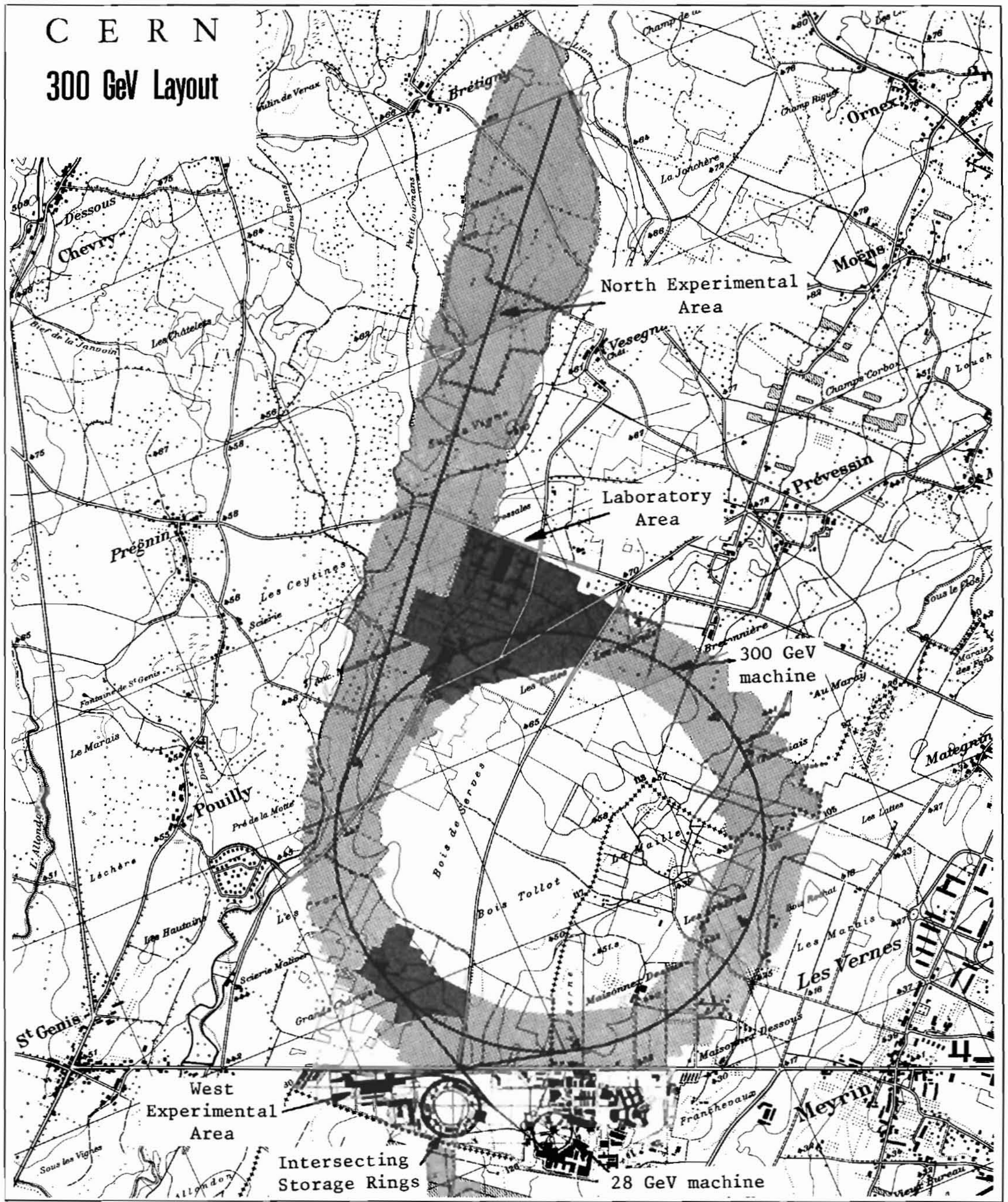


Fig. 1

2. The 300 GeV Programme

The 300 GeV Programme, on which we are now engaged at CERN, has been fully described in a CERN report issued at the end of 1970 and is now being worked over by the project team. A new version will be issued at the end of this year. Therefore only a brief outline of the design will be mentioned in this report.

The basic concept of the new Programme is to set up on one site a complex of accelerators, coupled together in various ways, which can provide a range of experimental facilities for many years to come.

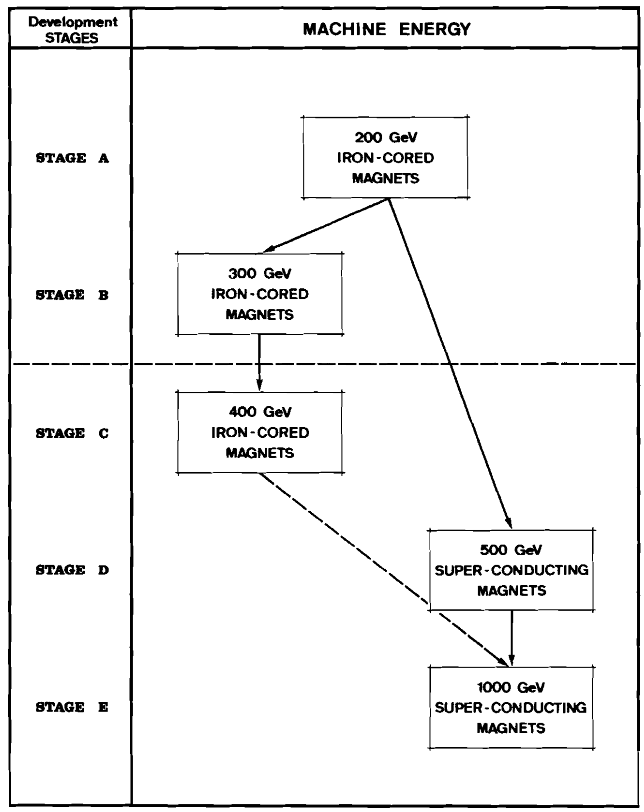
This accelerator complex consists of the original 28 GeV proton synchrotron, the intersecting storage rings and the 300 GeV machine, together with several experimental areas in which are installed a variety of large detectors. The layout of the complex is shown in Fig. 1.

At the heart of the complex is the 28 GeV proton synchrotron, now in its eleventh year of operation, which serves three purposes. Firstly, it provides protons up to 28 GeV energy for experimental research in two main areas; the East Area and the South Area. Secondly, it provides protons up to 28 GeV energy for storage in the intersecting rings which allow experimentation up to 56 GeV energy in the centre-of-mass system in a number of areas around the rings. It is worth noting that it would require a primary beam of over 1700 GeV energy striking a target to produce 56 GeV in the centre-of-mass system but, of course, the reaction rates using intersecting beams are several orders of magnitude less than can be obtained with a primary beam and a target. Thirdly, the 28 GeV machine provides protons for injection into the 300 GeV machine which feeds two experimental areas, namely, the existing West Area with two large detectors now under construction - the European bubble chamber called BEBC, and the spark chamber apparatus called OMEGA - and a large new area about 4 km long to the north of the 300 GeV machine.

Later on, after the completion of the 300 GeV Programme, it is possible to envisage extensions of this accelerator complex in several ways and the Programme and layout are designed to allow many such options to be taken up in the future if and when they are required. For example, superconducting intersecting storage rings might be installed in the present ISR tunnels and fed from the 300 GeV machine. At a magnetic field of about 45 kG such rings might be able to store proton beams up to 100 GeV energy which would give reaction energies of 200 GeV in the centre-of-mass system. Also, there is sufficient space reserved on the 300 GeV site to build new storage rings of 1 to 2 km diameter which could be fed from the 300 GeV machine.

The 300 GeV Programme as it is presently defined and financed will allow an energy of 200 GeV to be reached in the sixth year of the Programme and 300 GeV energy at the end of the Programme in eight years' time. The 200 GeV protons will be fed to the West Experimental Area and the 300 GeV protons to the North Experimental Area.

The accelerator is therefore designed to be extendible in energy and the energy stages are shown in Fig. 2. Using a separated-function magnet lattice and a missing-magnet design, the installation for the 200 GeV energy stage will consist of half the maximum possible number of bending magnets and all the focusing magnets, the latter running at half the maximum magnetic field gradient. To reach 300 GeV energy level additional bending magnets are installed in the lattice and if all possible bending magnets are installed the machine can reach 400 GeV.



NOTE - ONLY STAGES A AND B ARE FORMALLY COVERED BY THE COST ESTIMATES AND TIME SCHEDULES OF THE 300 GeV PROGRAMME DEFINED IN CERN/958

Fig. 2

Thus the maximum energy of the machine using classical iron-cored bending and focusing magnets is 400 GeV, but the missing-magnet system allows superconducting magnets to be installed during the Programme if they are found technically satisfactory and economically advantageous. For example, after the 200 GeV energy stage is reached, a set of superconducting bending magnets could be installed in the lattice rather than another set of classical magnets. Alternatively, a superconducting magnet system could be installed above the main ring magnet system in the same tunnel and the 200 GeV machine used as an injector into the superconducting ring. The diameter of the ring tunnel, which is 2.2 km, would allow an energy of 1000 GeV to be reached with a complete superconducting magnet system. If, many years hence, superconducting storage rings are built on the new site capable of storing 1000 GeV particles, reaction energies of 2000 GeV in the centre-of-mass system could be obtained and this may be the only way of reaching such high energies in the future since to obtain them from a primary beam on a target would require a primary beam energy of about 2 million GeV.

I hope that this brief review of the options opened up by the 300 GeV Programme will explain why we feel that the idea of an accelerator complex is so advantageous for the long-term planning of experimental facilities in Europe. Certainly, the idea arose out of necessity, which so often is the mother of invention. Having been blocked in the original idea of building a new laboratory somewhere else in Europe, we have come to appreciate the many advantages of extending the present CERN laboratory and of building up a flexible accelerator complex on one site. Financially, as I have explained, it also has considerable advantages, not only in reducing the initial capital cost of the 300 GeV Programme, but also in the cost of operating all the CERN facilities year by year in the future and in adding new facilities as time goes on.

Certainly, the use of existing facilities imposes some restrictions on the new Programme, but these have not been found onerous. The use of the 28 GeV machine, for example, especially when the new injection booster-synchrotron is added, determines to some extent the beam size and apertures of the 300 GeV machine, and, if a bunch by bunch transfer scheme is used between the 28 GeV and the 300 GeV machines, it determines the mean diameter of the 300 GeV machine which works out to be exactly eleven times that of the 28 GeV machine. Also, the size of the West Area limits experimentation at the 200 GeV energy level but on the other hand it allows experiments to start three years earlier than originally proposed and it is being equipped with very large detection apparatus which will be ready and tested a long time before they are used with the new machine.

The rest of the detailed technical design of the 300 GeV machine and its laboratory can be found in CERN report MC/60 which was issued at the end of 1970. A recent list of parameters has been included in the publications of this conference and we are revising the design of the machine components almost daily. There seems little point in my going into technical details now. Those of you interested in the details are therefore referred to the reports just mentioned.

3. Progress since February 19, 1971

In conclusion I would like to mention the progress we have made since the decision to go ahead with the project in February of this year.

We started with a total staff of four, including a secretary, and the first job was to build up a project staff for the execution of the Programme. All the group leaders have now been recruited and the staff now numbers about 60.

Temporary laboratories and offices are being erected for the project staff and contracts for the permanent buildings and machine tunnels will be let in the next few months. We expect to move into the new laboratories before the end of next year.

The land for the new laboratory is being provided by France and Switzerland and the acquisition of this land is proceeding just ahead of the building programme. Communications between the new laboratory, which is in France, and the existing one, which is mainly in Switzerland, pose some interesting frontier problems but these are steadily being resolved.

Detailed design work on the component parts of the machine is gaining momentum as the groups build up their staff. For instance, preliminary enquiries for the steel for the magnets have just been sent out.

The complete survey of the site to determine the levels and nature of the underlying rock has been completed without any nasty surprises. This survey was particularly important since we plan to build the machine in a tunnel bored deep underground in the rock and to link it with the 25 GeV machine and the West Hall by other underground tunnels.

Figure 3 gives an impression of the scale of the 300 GeV Project and its disposition in the countryside. Because the machine is deep underground it has very little effect on the appearance of the site at ground level. The only visible evidence of the machine on the surface will be the six equipment buildings over the long straight sections of the machine and they are not big enough to be noticeable in such a large area. The most visible part is the laboratory buildings and the large assembly hall which are partially hidden by the existing woods. Even in the North Experimental Area we expect to keep most of the secondary beams underground bringing them up to ground level to relatively small buildings which will house the particle detection equipment.

Most of the new site, even after the Programme is completed, will therefore look much the same as it does today, and most of it will continue to be used for farming and forestry. To use a phrase which is popular these days, the ecology of the site will not be seriously disturbed by the 300 GeV Programme and the machine is so deep underground that radiation levels on the surface can be kept well below tolerance for a normal population.

In this way we hope to live and work at peace with our neighbours despite the proximity of this giant machine to a large European city and to an international airport, both of which have brought so many advantages to the CERN Laboratories.

Fig. 3

DISCUSSION

G. BRIANTI: I would like to make a small correction in the historical facts. The principle of the CPS Improvement Programme was approved in 1965, but the PS Booster in its present form was only approved and financed as from 1.1.1968.

E.G. KOMAR: Why do you have the tunnel instead of using the cut-and-fill method that is used at Batavia?

J.B. ADAMS: The nature of the terrain gives us no choice. We must make the tunnel at such a depth that we probably could not use cut-and-fill or, it would be extremely expensive.

R.R. WILSON: If I might add a comment, we had a similar situation at Cornell with the 10 GeV machine. We reached the same conclusion for the same reasons.

K. JOHNSEN: Could you comment on the requirements to be met by the slow ejection system and consequent tolerance requirements on the main-ring system?

J.B. ADAMS: I would ask de Raad to answer this.

B. DE RAAD: The extraction efficiency is mainly determined by the thickness of the first septum and by the question of how well one can control the build-up of the resonant oscillations. The amplitude growth per turn can be made 10 to 15 mm. The effective thickness, including non-straightness of the first (electrostatic) septum is about 0.15 mm. Allowing for the divergence in the beam one finds an efficiency of 97 to 98%. If, at high fields, there is a systematic field distortion in the magnets due to saturation, the Q-value of the resonant oscillation depends on its amplitude, especially for off-momentum particles. Calculations indicate that the maximum permissible field drop near the edge of the aperture is about $\Delta B/B \simeq 3 \times 10^{-4}$.

K. JOHNSEN: There seems to be a difference of nearly an order of magnitude between expected losses as quoted by de Raad and figures we have heard from NAL. Are there comments from NAL on this?

R.R. WILSON: It is true that Maschke, who has designed the NAL extraction system, sticks to his original high estimate for its efficiency, i.e. ∿ 99.8%, and I continue to believe him. Do not forget that, as he points out, even protons that strike the wires of the septum (0.05 mm) will not be lost. If they scatter into the extractor, they will come out; if they scatter back into the donut, they can have other chances to be extracted. Of course, we will live with whatever extraction efficiency we get - and 99% will be fine.

R. SANTANGELO: Does the design of the 300 GeV PS include the possibility of future acceleration of heavy ions? The interaction of nucleons at high energy may turn out to be interesting for elementary particle physicists in connection with the hypothesis of democracy between hadron states.

J.B. ADAMS: We have not yet looked into this question. I believe the CPS could accelerate deuterons and feed them to the 300 GeV machine.

H. SCHOPPER: I could comment on this: The possibility of accelerating deuterons in the PS has been discussed recently at CERN. Deuterons have already been accelerated but this requires a special timing. As a consequence a double pulse operation (one pulse to 300 GeV machine, one pulse for 25 GeV physics) would not be possible. Also the injection into the ISR would be hampered. Since, from the physics point of view, the use of deuterons seemed interesting but not of dominant importance, it was suggested to renounce the acceleration of deuterons and give higher priority to a reliable operation of the PS.

H. HERNINGHAUS: On the RF system, what is the field gradient and how much is the beam loading?

C. ZETTLER: The field gradient is 5.4 MV over 3 cavities and the beam loading is about 25% of full power for 10^{13} p/p.

E.G. MICHAELIS: By your choice of 10 GeV as injection energy from the CPS you are obliged to cross the transition energy in both machines. Does the experience at Serpukhov not suggest that beam limitations through instabilities are most likely to occur at transition when intensities are high?

J.B. ADAMS: The 25 GeV CPS has very little difficulty in accelerating protons through its transition energy and we foresee no serious difficulties in taking protons through the transition energy of the 300 GeV machine.

F. MILLS:

1. What straight-section lengths would be available for experiments in the two storage-ring options you mentioned: (a) 200 GeV in the ISR tunnel, and (b) superconducting storage rings in the new tunnel?

2. Recent experimental studies at BNL have indicated that high energy storage rings require very long straight sections, certainly greater than 300 m for the 200 GeV case. Have you considered this in the design of the "300 GeV" tunnel?

J.B. ADAMS:

1(a) Conversion of the existing ISR to superconducting magnets would limit the straight-section lengths available, or one might rearrange the structure in a large-scale conversion.

1(b) Using a new tunnel one is obviously free to chose the appropriate straight-section lengths. We have not studied this problem sufficiently to arrive at appropriate lengths.

2. We have not yet studied this matter. However, the site for the 300 GeV machine would allow the construction of storage rings with very long straight sectors. We are not considering using the 300 GeV machine tunnel for storage rings.

K. JOHNSEN: If I might add a comment, we are asking the physicists doing colliding-beam experiments at the ISR about desirable straight-section lengths. Since we now have some twelve experiments distributed among five crossing regions, we think it would be difficult to crowd them together at one or two crossing regions even if they were much longer.