SIO f. 11

[Institute of High Energy Physics, Serpukhov, 1969-1970]

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STANFORD UNIVERSITY

STANFORD LINEAR ACCELERATOR CENTER

Mail Address
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Stanford, California 94305

March 23, 1970

Professor V. F. Weisskopf, Chairman
Department of Physics
Massachusetts Institute of Technology
Cambridge, Mass. 02139

Dear Viki:

I have written a brief trip report on my recent participation in the Serpukhov negotiations. I think Abe Friedman and I should give a brief report on the whole situation at the next HEPAP meeting. The whole situation does not look good.

With best regards,

Pief

W. K. H. Panofsky
Director

enc.

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TRIP REPORT

W. K. H. Panofsky

March 14 to March 18, 1970 - USSR

At the request of the Atomic Energy Commission I participated as a member of the delegation headed by Dr. Abraham Friedman, Division of International Affairs of the AEC, to negotiate with the State Committee on the Utilization of Atomic Energy of the Soviet Union concerning U.S. participation in the work of the Serpukhov laboratory (IHEP). Other members of the delegation were Dr. Thomas Field of Argonne National Laboratory and Professor Darrell Drickey of UCLA, who served as advisor. This negotiation was a follow up to the discussions held on a scientific level from February 25 to March 5, 1969.

I. DISCUSSIONS.

A meeting was held in Washington on March 14 to discuss the positions to be taken during the negotiations. The first discussions were held in Moscow on March 16th at the headquarters of the State Committee on Atomic Energy. The meetings were continued on the 17th at Serpukhov. On March 18th we inspected the accelerator and target areas of IHEP and continued negotiations further. On the afternoon of the 18th our delegation returned to Moscow. I returned to the U.S. on March 19th since the SLAC Program Advisory Committee meetings were scheduled for March 20. The negotiations continued further in Moscow on March 19th and 20th in my absence.

II. THE STATUS OF THE NEGOTIATIONS.

A detailed report of the negotiations, including the list of the Soviet participants, will be prepared by Dr. Friedman; detailed notes were being kept by Dr. Drickey. In broad outline the situation is as follows:

A. It was decided to prepare a Protocol signed by representatives of the AEC and SAEC which should have independent status of the Memorandum on Cooperation initialled by I. Smolin, Deputy Chief of the Department of International Relations and Scientific and Technical Information of the SAEC, and Dr. Abraham Friedman, Division of International Affairs of the AEC.

B. The question of a large computer as a possible contribution from the U.S. to the Soviet Union has been dropped.

C. Draft Protocols were prepared independently by the U.S. and Soviet teams, each partially modeled after the CERN Agreement. After initial discussion it was agreed to use the Soviet draft as a basis for discussion.

D. The Soviet draft, not surprisingly, contained as a basic *quid pro quo* a proposal for the Soviets to use the National Accelerator Laboratory on a basis reciprocal to U.S. use of IHEP. However the question of material contributions by the U.S. to the work of IHEP was not dropped entirely but was retained through a clause which in essence requested that the equipment provided by the U.S. for the first experiment at IHEP should remain at IHEP after termination of the first experiment.

E. There were extensive discussions on numerous administrative details, none of which appeared to be fundamental obstacles. Phrases were introduced which permitted flexibility of payment of subsistence and housing and the question of responsibility for damages was deferred by permitting a 4-months period to reach conclusions. Several other administrative clauses were negotiated without controversy. A possibly minor controversy remained on the subject of duration of the agreement covered by the Protocol: The Soviets proposed a period of 5 years beginning with the initiation of the first experiment. The U.S. position was to accept the Soviet terms but to superimpose a cut-off date of 1975.

F. The principal points of disagreement are the following:

1. The question of material contributions in terms of releasing the equipment of the first U.S. experiment referred to above, and

2. The details of the experimental program with NAL facilities by the Soviets. The Soviets took the position that since they were prepared to approve one specific experiment (the pion-electron scattering

experiment) by a U.S./Soviet collaboration at IHEP right now, the U.S. should be willing to approve a specific experiment at NAL as part of the provisions of the Protocol. Specifically the Soviets asked for a commitment that if (as is presumed) neutrino exposures in a bubble chamber were made at NAL then some of the film should be analyzed in the Soviet Union. The U.S. representatives (including myself) objected to this strongly since (a) it violated the principle that decisions of this kind were to be made by the Director of the institute in question (in this case NAL) with the advice of a scientific scheduling committee, and (b) that running time and bubble chamber film from NAL were not to be assigned to anyone (including U.S. physicists) until at least the end of this year.

My understanding is that these two points remained unresolved at the end of the negotiations, and in fact the request for material contributions on the part of the Soviets was increased beyond the equipment associated with the collaborative experiments.

G. The Protocol with its resolved and unresolved issues will be reviewed by the U.S. AEC and SAEC for possible revisions. My recommendation to the Atomic Energy Commission is not to shift positions on either of the agreed points of 1 and 2 in F. above. I feel that the Soviets are in fact receiving some *quid pro quo* already out of the UCLA/IHEP/Dubna collaboration since the experiment in question without the UCLA contribution clearly has little scientific value, while with the improved accuracy made possible through the contribution of UCLA equipment and skill, the experiment has a good chance of giving a very important result. Moreover the principle of not making assignments of running time or bubble chamber film by administrative action is an extremely important one and should not be prejudiced under any circumstances in these negotiations. The question remains of course whether in view of our inability to agree on the terms of the Protocol the UCLA/IHEP/Dubna collaboration will continue. Drickey will spend one more week in the Soviet Union to continue technical discussions with his collaborators; I can see that it is possible that the Soviets will permit the collaboration to proceed without the Protocol; however this would increase the risk to the U.S. participants towards future obstructionism against which they would have little recourse in the absence of a formal agreement.

H. In addition to the principal objections made by the U.S. team to assignment of NAL bubble chamber film it is also the fact that IHEP scientists are poorly acquainted with the details of the work at NAL, including the plans for experimental areas, major pieces of research equipment, etc., knowledge without which intelligent proposals are impossible to formulate. Accordingly we agreed that steps should be taken to invite IHEP participants to the NAL Summer Study and also to send documents generated from the earlier Summer Studies to IHEP. I related these conclusions to Dr. Edwin Goldwasser, Deputy Director of NAL, on March 19 and it is my understanding that he has taken appropriate action.

III. PROGRESS AT SERPUKHOV.

There has been substantial progress at Serpukhov since my last visit one year ago. I will not repeat here a detailed list of experiments or progress since this was covered in Professor Krisch's trip report of July 3-17, 1969. Moreover Dr. Field spend an extra period of time with Dr. Prokoshkin to get a formal summary of the proposed program. Professor Prokoshkin had been invited to participate in the conference at the University of Wisconsin at Madison from March 30 - April 1, 1970, on"The expectations for particle reactions at the new accelerators." However Dr. Prokoshkin will be unable to accept the invitation and therefore Dr. Field will give the essence of Prokoshkin's intended remarks.

Some general points of interest aside from the general program are:

A. LIQUID HYDROGEN. It will finally be possible to use liquid hydrogen at IHEP in one month from now when alterations are completed and a duct system has been installed. The whole arrangement documents the enormous inconvenience to the experimental program generated by the use of a gantry crane in the experimental hall. This crane makes it impossible to use either the ceiling or the side walls of the building for vents, piping or wiring and all such facilities have to be run throughout the full length of the building.

B. MIRABELLE, SKAT and Other Bubble Chambers.

1. MIRABELLE. I was given a photographic copy (attached to original and file copies only) of a picture taken at Saclay with Mirabelle. This shows tracks of good quality with some erratic boiling around fiducial marks but otherwise good general behavior. Initial worries about excessive turbulence appear to be dispersed but the optical quality of the objectives (8) in conjunction with the transmission qualities of the hydrogen are still giving problems for picture reconstruction. It appears still that the end of 1972 is the expected date for operation availability of Mirabelle. It is not possible that Mirabelle can be multi-pulsed during one cycle of the accelerator and therefore the picture output rate will be low.

2. There have been delays of manufacture of the SKAT electromagnet and 1973 appears to be the earliest date for availability.

3. The 2-meter heavy liquid bubble chamber from Dubna was fully moved to IHEP during the last year and had its first operational run in the 20-40 BeV pion beam. The run was a failure due to several reasons, none of which appear fundamental. The chamber is being assembled again for cleaning and overhaul.

4. A copy of the 2-meter liquid hydrogen chamber of ITEP, Moscow is being manufactured at Dubna for transport to IHEP in about one year. As will be recalled, the present ITEP chamber is in turn a copy of the unmodified 72" Alvarez chamber and was just barely gotten into operation last year after a very long period of construction and development. This means that even this new Dubna chamber will still not employ more modern bubble chamber technology. Optimistically the 2-meter liquid hydrogen chamber will be operational in IHEP by the end of 1971.

C. OTHER EQUIPMENT.

1. Spark Chamber Spectrometer. A 6-meter, long range, high volume magnet is being adapted as an optical spark chamber spectrometer. The magnet is a very impressive machine; the top pole is slotted to permit optical access to the spark chambers in the field. An elaborate system of mirrors incorporated in a hood above the magnet makes photography by a single camera possible. The optical system is completed and spark chambers are being installed. The initial experiment will be study of the reaction $\pi^- p \rightarrow nK_o\bar{K}_o$, that is a neutral trigger experiment.

2. IHEP has now manufactured in-house approximately 2500 electronic modules, approximately twice the amount observed last year.

3. Accelerator operation continues satisfactorily; four months shutdown is being planned starting in July 1970.

4. The missing mass spectrometer of Kienzle will be delivered to Serpukhov on April 1 and the site for its location was in preparation. It is hoped that operation can start in June for approximately one month before the shutdown. Incidentally the spectrometer will be brought from CERN to Moscow in the Antonov-23 airplane, which is the monster cargo plane which caused much attention at the Paris Air Show.

IV. RECENT EXPERIMENTAL RESULTS.

A. A much publicized result was the measurement of the flux of $\overline{He^3}$ in addition to $\bar{d}$ and $\bar{p}$ fluxes. This is fundamentally not a very interesting experiment beyond permitting some statements useful for publicity purposes about anti-matter. The ratio of anti-deuterium flux to pion fluxes is about 2×10^{-6} while the ratio of $\overline{He^3}$ to pion flux is about 2×10^{-11}. The instrumentation for this experiment involved a rather impressive combination of Cerenkov counters and scintillators for measuring pulse heights. Over-all rejection ratio of pions was close to 10^{-20}.

B. Quark Hunt. The limit in the cross section for production of quarks has now been placed at below 10^{-39} sq. centimeters per nucleon at IHEP energies.

C. The final results on the elastic proton-proton scattering work using an internal hydrogen jet target are now being written up. These results, published previously in preliminary form, exhibit continuous shrinkage of the diffraction peak up to the highest energies. Preliminary results also indicate that the real part of the scattering amplitude decreases only slightly to the highest energies (from .2 to .17).

V. MISCELLANEOUS OBSERVATIONS.

A. Future Fate of Dubna. A new injector to the 10 GeV accelerator is being installed and its intensity will be increased slowly. Shielding will have to be increased to accommodate this intensity. I sensed relatively little enthusiasm for this project but evidentally it was decided to go ahead in spite of this.

B. Budker is recovering from his heart attack. The laboratory is under the direction of Skrinsky with Siderov being responsible for the experimental nuclear physics program. Injection studies into the 3-4 BeV electron-positron storage rings are started and no unusual obstacles have been observed. The date for experimental operation of the storage ring is set to be the beginning of 1971.

C. I had some discussions with Professor Alikhanian; there seem to be no very exciting developments from the experimental program at the 6 GeV accelerator. A new method for the detection of the transition radiation by placing a converter producing transition radiation ahead of the streamer chamber has been placed into operation. As a result the tracks on the streamer chamber show both the original charged particles entering the chamber accompanied by occasional Compton or photo-electrons produced by the transition radiation paralleling the initial track. As a result the track is "coded" with an indicator giving the γ of the particle.

D. I attended a lecture at the Institute of Physical Problems by a Professor I. V. Obrimov, Head of the Institute of Optics and the original founder of the Kharkov Physical-Technical Institute. Professor Sergei Kapitza was translating for me during the original lecture. Professor Obrimov is 78 years old and was giving a commemorative talk on physics in the time of Lenin; the whole setting was a very impressive one - the audience was primarily composed of older professors from the Moscow area dressed to look like pictures from 1920 and everyone was chuckling at remarks made by the lecturer that seminars went on every Sunday throughout the Revolution period, irrespective of any external circumstances!

E. I inquired as to the status of the Kharkov 2-mile electron linear accelerator. The answer was that the only work done with the machine was some nuclear structure physics through inelastic electron scattering. The physicists outside Kharkov are very critical of the Kharkov program but also imply that financial support given to the laboratory is low.

F. I was told that Japanese participation at Novosibirsk was as good as assured and that the Japanese had contributed approximately $3 million to the operation of the Novosibirsk laboratory. It will be recalled that Novosibirsk has been having difficulties in recruiting qualified and experienced high energy physicists to work at Serpukhov and the Japanese collaboration has been instituted to fill this gap.

G. Alikhanian reports that he will definitely purchase two PDP-9 computers for use at Erevan; I discouraged him further in terms of his opportunity of receiving a CDC-6400.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
DEPARTMENT OF PHYSICS
CAMBRIDGE, MASSACHUSETTS 02139

October 15, 1969

Dr. Paul McDaniel
Director
Division of Research
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Paul:

At its October 1969 meeting, HEPAP considered again the status of the proposed use by U. S. scientists of the 76 Gev accelerator in Serpukhov. As you know, a team of U. S. scientists led by Dr. Panofsky met with Soviet scientists in Russia early last spring at which time potential cooperative programs were discussed.

Dr. Panofsky's report identified two levels of U. S. participation: (1) participation by individual U. S. scientists under the present USAEC-Soviet State Committee Agreement of July 1968; and (2) more extensive collaboration requiring a supplementary agreement which would involve a tangible U. S. contribution to the equipment at Serpukhov if the CERN and French precedents were followed.

HEPAP strongly endorses again the scientific value of joint experiments. HEPAP also is impressed by the benefits in terms of increased contacts and communication which such a collaboration would entail. Even in the face of the desperate current high energy funding situation HEPAP supports the allocation of several hundreds of thousands of dollars per year incrementally over the next few years in support of the proposed experiments.

The Soviets have indicated that they would expect the contribution of a large computer, possibly of the size of a CDC-6600, as a prerequisite for U. S. participation; lately evidence has appeared that the Soviets may be willing to pay for part or all of this device. The Panel is aware of the security aspects of this proposal and is also aware of the possible value of establishing a precedent of an installation operating in the U.S.S.R. under U. S. inspection and control. HEPAP also certifies that a true scientific need exists for more adequate data analysis facilities at Serpukhov. HEPAP is not qualified to balance these sets of values relating to furnishing a computer to Serpukhov, but urges that a decision be made rapidly in order that a U. S. negotiating position can be established promptly.

The Panel wishes to re-emphasize the urgency of quickly starting these negotiations for the following reasons: (1) there has been a very large time lapse since the visit of the U. S. scientific delegation; and (2) the scientific value to U. S. science will diminish if the Serpukhov collaboration does not commence well ahead of the beginning of experimental preparations for NAL. Furthermore, for example, one of the proposed experiments has already been accepted tentatively on the Serpukhov schedule with or without U. S. participation; a final decision on the general agreement is required by February 1970 to maintain the schedule for this experiment. Delay will endanger the experiment since the beam line is committed to other users beyond the scheduled date.

HEPAP hopes that the exciting scientific prospect of this precedent setting collaboration will become a reality.

Sincerely yours,

Victor F. Weisskopf
Chairman
High Energy Physics
Advisory Panel

DRAFT

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

Privileged Information

Professor A. M. Petrosyants
Chairman, State Committee on
Atomic Energy (GKAE)
Staromonetnii per. 26
Moscow 180, USSR

Draft

Dear Professor Petrosyants:

Dr. Friedman has informed me of the interesting conversations which he and his colleagues held with you and your staff, as well as the warm reception they received both in Moscow and in Serpukhov. He noted that there was general agreement on the desirability for cooperation between our two countries in the field of high energy physics although complete agreement was not reached with the State Committee on several points in the Protocol.

I understand that the unresolved points include your suggestions that the cooperation should involve a material contribution of equipment to Serpukhov and that the Protocol include a definite decision for participation by your scientists in neutrino beam experiments which might be carried out at the National Accelerator Laboratory, including the supply of the resultant bubble chamber pictures to the Soviet Union for measurement and analysis.

As Dr. Friedman explained, these points create some difficulties for us and I would like to suggest that you give further consideration to the approach that an arrangement providing for joint projects at Serpukhov and at the National Accelerator Laboratory on a reciprocal basis constitutes in itself a reasonable basis for cooperation. In this regard, while we would find it difficult to agree in advance of consideration of proposals from U.S.S.R. scientists to a specific experiment, we are prepared to provide a categorical assurance that a joint experiment can be performed at NAL.

In spite of our inability to reach agreement on all the terms of a Protocol at this time, we hope that these outstanding issues may be resolved rapidly to our mutual satisfaction. Meanwhile, we look

Privileged Information

DRAFT

forward to continuing the excellent cooperation between our scientists in all fields of peaceful applications of atomic energy, including high energy physics. In this connection, I would like to suggest that we consider the possibility of proceeding on an ad hoc basis with the proposal of Professor Drickey to collaborate with the Institute for High Energy Physics (Serpukhov) and Dubna on a pion-electron scattering experiment. We believe that this experiment affords major benefits to your scientists as well as to ours since we believe that the improved accuracy made possible through the use of Dr. Drickey's equipment and the special techniques he has developed considerably improve the chance that this experiment will produce important results. As you know, the schedule for this experiment at Serpukhov requires that a decision be made in the immediate future concerning the possibility of U.S. participation in it. We would be glad in arranging for such ad hoc cooperation, to assure you of a reciprocal opportunity to participate in a joint experiment at NAL under terms to be agreed upon in a more formal arrangement.

We continue to be interested in working out a Protocol to serve as a framework for more extensive joint projects at Serpukhov and at the National Accelerator Laboratory on a reciprocal basis. If you agree that this would be of mutual interest, we are prepared to pursue the matter further and we look forward to receiving your comments.

Dr. Friedman has informed me that your schedule does not permit your accepting my invitation to visit the United States before October of 1970. I am disappointed not to have the opportunity to see you earlier this year, but I understand and sympathize with the demands of your heavy schedule. I can assure you that we will welcome your visit to the U.S. this fall.

With kindest personal regards,

Sincerely,

Chairman

UNIVERSITY OF CALIFORNIA, LOS ANGELES

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DEPARTMENT OF PHYSICS
LOS ANGELES, CALIFORNIA 90024

May 12, 1970

Dr. Abraham Friedman
U. S. Atomic Energy Commission
Division of Research
High Energy Physics Program
Washington, D. C. 20545

Dear Abe:

Enclosed is a complete copy of my trip report covering the visit to the Soviet Union March 15--27, 1970. I apologize for any lack of completeness or inaccuracies which may exist in this report and would appreciate it if you read this document and make any necessary corrections.

At this late date it is becoming nearly impossible for us to collaborate in the pi-e experiment unless agreement is reached immediately, but I feel strongly that this should in no way influence the possibility for ultimate collaboration. Clearly there are compelling scientific and social reasons to continue our efforts to reach an agreement.

My recommendations in this respect are:

1. Bubble chamber experiments offer the most favorable method for Serpukhov to collaborate. I support the recommendation of Tom Fields to explore ways of offering used automatic film measuring devices to the Russians. The proposals by Ely and by Stevenson appear to be the most fruitful to pursue at this time.

2. We should extend the opportunity for collaborative experiments at NAL even if the present Serpukhov negotiations do not reach an agreement. (I realize that a delicate negotiating point is involved here.)

3. Proposals of the Lindenbaum type are the most welcome electronic experiments at Serpukhov. Discussions on this experiment should be pushed.

4. Some sort of agreement should be reached to define the status of Dubna physicists in these joint experiments. This could be either a direct agreement with Dubna or an agreement with the State Committee covering Dubna physicists.

I want to express my thanks to you and to all of my colleagues for their efforts in behalf of the pi-e experiment.

Sincerely,

Darrell

Darrell Drickey

DD:jt
Enclosure

cc: W. Wallenmeyer (AEC)
V. Weisskopf (MIT)
~~D. Saxon (UCLA)~~
H. Ticho (UCLA)
S. Terry (UCLA)
R. Cool (Brookhaven)
B. Wenzel (Berkeley-LRL)
T. Fields (NAL)
W. Panofsky (SLAC)
B. Hildebrand (AEC)

TRIP REPORT: Moscow, Serpukhov, Dubna

March 15--27, 1970

Darrell Drickey

March 15--21 This period was spent as a part of the AEC delegation negotiating the protocol permitting joint US--USSR experiments at Serpukhov and Batavia. A report has been made separately.

March 21--24 Dubna

Technical

The Tsyganov group and I talked about technical problems of the pi-e experiment and about ways of implementing the collaboration. Equipment to be furnished by each side was further defined. I agreed to supply the computer, spark chamber readout electronics, some fast discriminators and hodoscope latches and to try to find a better shower counter. The Tsyganov group would supply all other equipment. Data would be taken on 9 track magnetic tape and transcribed to 7 track tape compatible with Dubna computers probably by copying them at CERN. The Tsyganov group will redo their electronics using integrated circuits before they run if the collaboration does not take place.

IC's are now available to them. I was given one monolithic and one hybrid circuit to bring back with me.

Kolpakov at Dubna has just received a Hewlett-Packard 2116B computer. It is similar to the UCLA computer we propose to take to Serpukhov except only 8K and no disc. He will now argue for additional money to upgrade this system. There are also rumors of a Varian on-line computer recently received at Serpukhov.

We had many discussions of on-line and off-line software. They are now doing their computing on a CDC 1600 and also on a BESM-6. A BESM-3 is used for on-line tests at Dubna and a BESM-4 will be used at Serpukhov.

I agreed to submit a proposal to Serpukhov covering the collaborative experiment. We agreed that if the collaboration proceeds

1) a test at SLAC is too difficult within the time period remaining.
2) that an exchange of software people for one month apiece in June or July is essential. This would probably be Shepard from UCLA and Niczypouruk (Polish) from Dubna.
3) We would ship all equipment about 1 August.
4) Three U. S. physicists would arrive about the end of August.

5) The experiment would start October 15 and probably end March 15.

6) Off-line analysis would be carried out in parallel at UCLA--SLAC and at Dubna.

Social

Baldin: Tysganov, Kuznetsov and I met with Baldin who is recovering from an illness. Baldin later called Logunov in an attempt to determine a) the price for the American entry into Serpukhov or b) the price of this one (pi-e) experiment. Nothing new resulted except that the figure 1--1.5 million was mentioned. Dubna, as yet, has no official agreement with Serpukhov but would like to include a section permitting Americans to collaborate with Dubna on joint experiments at Serpukhov.

Kuznetsov: Dubna has at least three electronic experiments that they would like to propose at NAL. They are p-p scattering by Nikitin, pi-e by Tsyganov, and K^o regeneration by Savin. In addition, Kuznetsov is very interested in spending one year at Berkeley as suggested by Stevenson-Ely.

We outlined a schedule of invitation. Each invitation must be at least four months in advance. We agreed on

1) an invitation to Nikitin and Tysganov jointly to visit UCLA, SLAC, and NAL for two to three weeks starting October 1. A copy should be sent to Kuznetsov.

2) An invitation to Kuznetsov for one year starting October 1 with copies to Petrosyants, Bogolyubov, and Baldin.

3) An invitation at a date later than January 1 for Savin to visit NAL regarding his experiment.

It was manifestly clear that there is not enough time remaining for anyone to come to the 1970 NAL Summer Study.

Romanov: (International Division) I was paid 37.50 roubles for five days work at Dubna. In addition, my hotel was paid. Romanov and Kuznetsov are eager for a US--Dubna agreement. This could perhaps be carried out as an exchange of letters once the protocol is agreed upon.

March 25--26 Serpukhov

Tsyganov and I negotiated the wording of Appendix A covering the pi-e experiment with Sulyeav. I also visited the apartments proposed for our use.

Logunov (Galina translating, Tsyganov, Sulyeav present)

We had a long discussion concerning the failure of the recent protocol negotiations. Each of us restated our positions; all was done in an extremely friendly atmosphere. I believe I made the points very strongly with him,

a) without pi-e there is little chance of a collaboration

b) the decisions are that of the physics community

c) we are all in desperate straits because of increasing NAL expenditures and a constant budget.

d) I admitted that there is no overwhelming interest in Serpukhov experiments.

e) it is impossible for us to guarantee ν film, but, for example the Stevenson collaboration could naturally provide the vehicle for obtaining it.

In exchange, Logunov made these points

a) Their price is a Molly plus some on-line computers, about 1--1.5 x 10^6 \$. Tsyganov feels that this is negotiable downward.

b) They do not feel Batavia is a realistic exchange

c) 10^6\$ is really not much; they will not be overwhelmed by it in comparison to their total budget.

d) They were disappointed that the Americans were not ready to discuss specifics.

We agreed that exchanges should continue; and I told them that Lindenbaum was intended as the next visitor. Logunov had talked to Lindenbaum (at least someone had) and was under the impression that he was all ready to come. I attempted to clarify the situation, explaining that the system is a part of the AGS Users'. They were afraid that there had been some misunderstanding with Krisch. I explained his ISR commitment.

ANNEX A

in English and Russian

ANNEX A

To the Protocol of

PION-ELECTRON SCATTERING

1. About October 1970, a pion-electron scattering experiment using an on-line computer system previously developed and tested shall be started at the Institute of High Energy Physics by a mixed team of scientists from the U.S. and from the Soviet Union and other member countries of the Joint Institute for Nuclear Research. The purpose of the experiment is to determine if the pion is as big as the proton. Both are predicted to have a radius 0.64 f from ρ dominance, yet the proton radius is 0.81 f. It is important to understand if this difference is due to a peculiarity of the nucleon or to a breakdown of vector dominance.

2. The Soviet Party will supply:

   a) a previously tested 50 GeV/c pion beam;

   b) a 20cm x 50cm by 3m spectrometer magnet;

   c) necessary beam time, electricity, water and other support services;

   d) wire spark chamber and pulsing system;

   e) necessary counters;

   f) liquid hydrogen target.

The U.S. Party will supply:

   a) an on-line computer system consisting of a 16K, 16 bit computer, a 184K, 6 millisecond access time disc, teletype, paper-tape reader, line printer, storage oscilloscope display and the on-line software system;

ПРИЛОЖЕНИЕ А

к Протоколу от

ПИОН-ЭЛЕКТРОННОЕ РАССЕЯНИЕ.

I.Приблизительно в октябре 1970 г. в ИФВЭ силами объединенной группы ученых из США и СССР и других стран-участниц Объединенного Института Ядерных Исследований будет начат эксперимент по пион-электронному рассеянию с использованием не осредственной связи вычислительной машины и аппаратуры, предварительно подготовленной и опробованной.Цель эксперимента состоит в том, чтобы определить, является ли размер пиона настолько же большим, как и размер протона.По предсказанию - доминантности радиус как пиона, так и протона должен быть равен 0,64 ферми, в то время как в действительности радиус протона равен 0.8I ферми. Важно понять, вызвана ли эта разница особенностями нуклона, или векторная доминантность нарушается.

2.Советская сторона обеспечивает:

а) Настроенный и опробованный пионный пучок с импульсом 50 Гэв/с,

б) Анализирующий магнит с рабочей областью 20 x 50 x 300 см^3,

в) Необходимое время на пучке, электроэнергию, снабжение водой и работу других вспомогательных служб.

г) Проволочные искровые камеры и систему их высоковольтного питания,

д) Необходимые счетчики,

е) Жидководородную мишень.

Американская сторона обеспечивает:

а) Вычислительную систему в линию, состоящую из собственно вычислительной машины, с оперативной памятью I6 К I6 разрядных слов, дисков на I84 К с временем обращения 6 миллисекунд, телетайпа, считывающего устройства с бумажной ленты, графикопостроителя, системы представления данных на запоминающем осцилографе и систему програмного обеспечения для работы в реальном масштабе времени.

б) Систему промежуточной памяти для записи координат с магнитострикционных камер.

в) Медленную электронику для амплитудного анализа и регистрации информации с годоскопа.

г) Быструю электронику, необходимую для запуска искровых камер.

3. Другие научные, технические и организационные вопросы будут решаться в соответствии с Протоколом по согласованию сторон.

PROTOCOL

SOVIET DRAFT

Drickey

P R O T O C O L

on carrying out of joint projects in the field of high energy physics at the accelerators of the Institute for High Energy Physics (Serpukhov),USSR, and the National Accelerator Laboratory (Chicago),USA, between the State Committee for the utilization of atomic energy,USSR, and the US Atomic Energy Commission

The State Commission for the utilization of atomic energy of the USSR (State Committee) and the U.S.Atomic Energy Commission (AEC)

bearing in mind the co-operation in the field of the utilization of atomic energy for peaceful uses;

taking into consideration the fact that the State Committee is using at Serpukhov the 70 Gev synchrotron and the AEC is constructing the 200 Gev synchrotron at the National Accelerator Laboratory in Chicago;

proceeding from article VI of the Memorandum on co-operation in the field of peaceful uses of atomic energy between the State Committee for the utilization of atomic energy of the USSR and the U.S. AEC to the agreement between the Union of the Soviet Socialist Republics and the United States of America on the exchange in the fields of science, technology, education, culture and in other fields for the period of 1970-1971,

have agreed as follows:

ARTICLE I.

I.The State Committee and the AEC will carry out the programme of joint research at the 70 Gev synchrotron at the Institute for High Energy Physics (Serpukhov) and at the 200 Gev synchrotron at the National Accelerator Laboratory (Chicago).

2.This co-operation shall initially cover the following experiments carried out at IHEP:

- the study of pion-electron scattering at high energies with the view of determining pion form-factor;
- the study of pion and caon scattering on protons at small angles;
- the study of non-elastic proton scattering processes on protons.

3. This co-operation shall be further on carried out in joint projects at the 200 Gev synchrotron at the National Accelerator Laboratory, including carrying out the utilization of the joint experiment with neutrino beam and liquid hydrogen bubble chamber, transferring the obtained pictures to the State Committee for further processing in the Soviet Union. The forms of participation of Soviet physicists in the above mentioned experiment as well as in further experiments at the National Accelerator Laboratory and the list and topics of the experiments shall be agreed upon by the parties additionally.

4. The carrying out of joint projects shall provide for publication of joint reports.

ARTICLE 2.

1. Within the term of the present Protocol the State Committee and the AEC shall provide all the assistance for carrying out:

1.1. Travel of personnel and transport of their property within the USSR and the USA.

1.2. Transport of equipment of auxiliary devices, etc. between their laboratories.

1.3. Exchange of the relevant documentation, blueprints, photographs, films, experimental data and other kinds of unclassified information.

2. The equipment supplied by USAEC for making joint experiments, ~~except the equipment, specified in Annex I~~ shall remain its property and shall be returned to the USA on the completion of the related experiment, if no other agreement is reached.

3. USAEC will supply all the necessary spare parts for the equipment, which together with the replaced parts shall be returned to AEC on its request.

ARTICLE 3

1. For carrying out joint experiments AEC shall supply all the necessary equipment, including on-line computer systems and the AEC shall give to the State Committee as soon as possible a detailed list of the equipment to be provided together with the relevant specification and technical and information documentation.

2. This equipment shall only be brought into operation at the Institute for High Energy Physics by mutual agreement between the parties.

3. The State Committee shall provide at the Institute for High Energy Physics room necessary for the equipment and supply them with electricity, water, gases etc. in accordance with technical requirements which shall be agreed upon additionaly.

4. The host party [State Committee] shall ensure the operation of the accelerators and the beams of particles as necessary for the joint projects.

ARTICLE 4.

1. Responsibility and expenses for the transport of the equipment and materials from the United States to the Institute for High Energy Physics(Serpukhov) and back as well as the responsibility for the safety and insurance of the equipment on route shall rest with the AEC.

2. Expenses for the transport of the equipment specified in Annex I as well as responsibility for the safety and insurance of the equipment on route shall be established under the conditions, described in this Annex.

3. Responsibility and expenses for the transport of the equipment and materials from the Soviet Union to the National Accelerator Laboratory (Chicago) and back as well as the res onsibility for the safety and insurange of the equipment on route shall rest with the State Committee.

ARTICLE 5.

1. Each Party shall ensure the selection of the staff of the necessary skills and competence to take part in the program of the joint projects. In the coarse of their work in realization of the joint projects this staff shall be assigned to the host Party.

2. Each Party shall be responsible for the salaries, insurance and allowance to be paid to its staff.

3. The staff of each Party shall conform to the general rules of work and safety in force at the host establishment.

4. The Parties will provide each other with the technical norms and safety rules in force at their establishments and they shall agree upon them for their common use.

5. Each Party shall pay for the travel and living expenses of its staff when staying at the laboratories of the other Party. The Parties however may agree upon other principles in particular the Parties agree to consider the principle of the exchange of the specialists on the currency free and equiva;ent basis.

6. Each Party shall provide the personnel of the other Party and families appartments for the corresponding charge. The Parties agree to consider at a later date the proposal for the provision of the apartments free of charge on the equivalent basis.

7. Each Party shall provide all the necessary assistance to the personnel and families of the other Party in respect of administrative formalities (visas, travel arrangements etc.

8. The status of the staff of each Party while at the laboratory of the other Party shall be defined in accordance with the laws of the host Party. In this connection the Parties will exchange letters within 4 months agter the signing of this Protocol.

ARTICLE 6.

1. Within four months after signing the present Protocol the Parties shall work out additional Terms, determining the responsibility for all kinds of damages.

ARTICLE 7.

1. Each Party shall be responsible for providing funds necessary to meet the respective abligations resulting from the present Protocol and shall control their spendings.

ARTICLE 8.

1. All questions arising during the terms of the Protocol shall be settled by the Parties by mutual agreement.

ARTICLE 9.

The present Protocol shall come into force from the day of its signing and shall be valid during 5 years ~~from the day of the beginning of the first experiment at IHE (Serpukh~~

One Party shall be informed in the written form of the other Party's intention to suspend the presnet Protocol six months before it expires.

The present Protocol is drawn in two original copies, each in Russian and English both being authentic and equally valid.

ITINERARY

March 15	Arrive Moscow 8 p.m. Delegation Members: Panofsky, Fields, Friedman, Drickey
March 16	Meeting at the State Committee in Moscow. Exchange of draft protocols. In the afternoon, travel by car to Serpukhov.
March 17	Two meetings in Serpukhov to discuss the protocol.
March 18	Tour of Serpukhov laboratory followed by the final meeting at Serpukhov. Return to Moscow by car in the evening.
March 19	Final meeting on the protocol at the State Committee in Moscow.
March 20	Meeting with Chairman Petrosyants at the State Committee. Departure from Moscow of all other U. S. delegates.
March 21	Travel to Dubna by car.
March 21--24	Technical discussions with the Tsyganov group about the pi-e experiment. Discussions with Dubna officials about collaborative experiments.
March 25	Travel by car to Serpukhov accompanied by Tsyganov.
March 25, 26	Discussions with Sulyeav, Logunov and Tsyganov concerning American participation at Serpukhov and Soviet participation at Batavia. Draft Annex A of the protocol covering the collaborative pi-e experiment.
March 26	Return to Moscow by car.
March 27	Depart Moscow.

Preliminary Session I

Moscow

March 16, 10:00 a.m.

Present:

Soviet: Smolin, Fillipov, Titkov, Sulyeav,

U.S. Friedman, Panofsky, Fields, Drickey, Harbin

This preliminary meeting at the State Committee in Moscow was for the purpose of arranging the schedule and for the exchange of draft protocols. The previous understanding was that their version would be used as a basis for the negotiations. Smolin presented their version, which was in Russian only; we presented our version in both English and Russian. It was agreed that we travel together to Serpukhov in the afternoon for two days of discussions and return to Moscow for final discussions on Thursday and Friday. Smolin announced that we were to meet Chairman Petrosyants on Friday at 5:00 p.m. The Russian version of the protocol mentioned specific experiments in contrast to ours. They were at Serpukhov

1. pi-e scattering
2. pi and K scattering at small angles
3. inelastic pp scattering

at Batavia

1. Hydrogen bubble chamber pictures from a neutrino beam exposure. We pointed out our limited time schedule (Panofsky had to return on Thursday) and that we hoped to complete discussions on the protocol plus one annex. They pointed out the symmetry in their protocol between the 78 GeV accelerator and the 200 GeV accelerator and that

there was one protocol plus several annexes. They agreed to provide us with a translation of their draft by the following morning.

Serpukhov Session I

March 17, 10:15 a.m.

Present

Soviet: Prokoskin, Sulyeav, Logunov, Titkov, Smolin, Zoikovsky, Kuznetsov, Tsyganov, Yarba, Naumov

U.S.: Friedman, Panofsky, Drickey, Fields, Harbin

A translation of the Soviet draft protocol was given to us just prior to this session; the session began after we had spent about one-half hour reviewing the document.

The procedure adopted for the discussions was to start at the beginning of the draft protocol and proceed article by article. We agreed to the preamble to the protocol and to the first part of Article 1. These discussed, in a general way, that the purpose of the agreement was to provide for joint experiments in high energy physics both at Serpukhov and at NAL.

We could not agree to two subsequent clauses in Article 1. These clauses covered pi-e scattering, the Lindenbaum (pi-K proton scattering) and the Krisch (p·p scattering) experiments at Serpukhov and a neutrino exposure in a hydrogen bubble chamber at NAL. Panofsky discussed our position, pointing out that only the pi-e experiment had a fixed schedule. The others needed an exchange of the proposing scientists followed by a proposal submitted to the appropriate scientific review committee. Only the committee can approve an experiment. Of the four experiments under consideration, only pi-e scattering was an approved experiment. He discussed Lindenbaum's proposal and suggested that a visit was required in order to discuss problems in detail. An annex based on specific arrangements by Lindenbaum could then be arranged.

Logunov agreed that this procedure must be followed for any experiment, but both he and other members of the delegation, particularly Prokoskin, were concerned that the scope of the collaboration was undefined. This was particularly important for the accelerator people. In reply, Panofsky reiterated that the steps in implementing a collaboration are

1) Informal discussions to form a group
2) A scientific decision on scientific merit in conjunction with the experimental abilities of the group.

He also discussed the proposal schedule for future experiments. These were

a) The Lindenbaum visit
b) A visit by Ely (Berkeley) to discuss bubble chamber collaborations.

In addition, Kuznetsov was invited to visit Berkeley for one year, the exchange serving as the basis for future plans.

c) The Krisch proposal must wait until 1973 because of the ISR experiment by his group scheduled for next year.

Friedman proposed that we modify their draft to exclude specific experiments since they must be decided on the basis of scientific proposals submitted to a program committee. Furthermore, the NAL program is not, at present, clear and no decisions on large pieces of equipment have, as yet, been made.

Logunov emphasized

1) They must have a kind of guarantee for participation.

2) A definition of the scope of the collaboration.

They do not require specific experiments only the right is necessary. He proposed several times to use the phrase "If NAL decides to do the experiment, then some pictures can be made available to Serpukhov."

After further discussion, we agreed to drop this point but return to it later.

We proceeded to the next article of the protocol with only minor changes until we arrived at the next big topic. Article 2.2 of their draft stated that equipment supplied by the USAEC shall remain their property except for that specified in Annex I. We proposed to exclude this phrase. In response Smolin said that Annex I was not yet defined; by excluding Annex I, the possibility of a material contribution was not left in. This position is similar to that in the CERN and French agreements.

Friedman pointed out that the "quid pro quo" in these discussions was 200 GeV for 70 GeV, in fact an asymmetrical arrangement already. There could be some scientific advantage in leaving equipment at Serpukhov after experiments were over; the proposed language left this possibility open. There was no preclusion, but the intent would be different from the French and CERN agreements.

A long discussion followed. Sulueav said that the question of a material contribution was raised in order to improve the quality of physics overall. Logunov was concerned that an asymmetrical situation could arise if the scope of the collaboration was not defined. Panofsky attempted to define the scope by saying that we visualized the program as one experiment following another, i.e. one at a time. During this discussion, Logunov mentioned that on-line computers were needed and could be a part of the material contribution. In exchange, they could offer an asymmetry at Batavia. Friedman and Panofsky both said that it is impossible to agree in the protocol to leave equipment and that a negotiated asymmetry was impossible because of the necessity for scientific review of proposals. The symmetry of opportunity existed, but because of the length of the agreement, it is possible that there could be more Soviet experiments at Batavia than U.S. experiments at Serpukhov. Friedman also stated that we are prepared to consider methods to assist experiments at Serpukhov but could not make a formal agreement to leave equipment. Logunov asked us if the material contribution was eliminated in favor of Soviet participation at NAL. After a long discussion where we pointed out that it is possible that some equipment could indeed be left at Serpukhov after an experiment, Friedman answered that no material contribution was considered in the U.S. We propose joint experiments at Serpukhov and NAL and had no authority to agree to other alternatives. It is possible that no equipment at all need be furnished by the Soviets for Batavia experiments.

Article 3 of their draft protocol dealt with equipment. We agreed to supply all necessary equipment for experiments at Serpukhov, with the understanding that the scientific direction of each experiment would decide what was necessary. They would undertake the same obligation at NAL. The problem of export controls was raised by Logunov (with respect to NAL experiments). We agreed that, in some cases, the problem unfortunately exists. Friedman and Panofsky both gave their personal opinion that, although regulations exist, one could apply for exemptions and that they would support such applications. A successful collaboration would increase the chances that such exemptions would be granted. Logunov seemed to emphasize the wording that each party supply all equipment as in the CERN agreement. Although the point was not completely clear, there seemed general agreement that such decisions would be made on a scientific basis and would, in any case, be defined in the annexes covering specific experiments. Logunov used the AGS as an analogy, where users supply all of the equipment.

Discussion then proceeded to Article 4 covering shipment of equipment. A legal point was raised by the Russians. Equipment should be sent by the sending party to the receiving laboratory so that the question of damages during shipment would not be confused. (The CERN agreement states that responsibility of the sending party stops at the Soviet border.) They have had difficulties with insurance in such cases. We agreed to their wording subject to legal review.

Article 5 dealt with administrative arrangements. No substantive disagreement appeared although we agreed that the scientific direction of each experiment should be free to select the staff necessary to carry out the experiment. Housing was also discussed; Friedman and Smolin agreed to explore methods of reciprocal exchange since the charging for housing in the Soviet Union is different than in the U.S. Each host party would provide emergency medical aid, the terms of these administrative arrangements to be marked out later in a memorandum.

Serpukhov Negotiating Session II

March 17, 1970 - 5:45 p.m.

Present:

Soviet	Prokoshkin, Sulyeav, Logunov, Titkov, Smolin, Zoikovsky, Kuznetsov, Tsyganov, Yarba, Naumov
U.S.	Friedman, Panofsky, Drickey, Fields

After a long lunch we resumed the negotiations by agreeing to cover medical aid in a special memorandum and not specifically in the protocol. Article 5 was then agreed upon as were 6, 7 and 8 dealing with administrative problems, damage responsibility, funding, and grievances respectively. Article 9 of the Russian draft protocol defined the term of the agreement to be five years from the date of the first joint experiment at Serpukhov. We objected, primarily because the beginning of an experiment is difficult to define. We did propose three solutions:

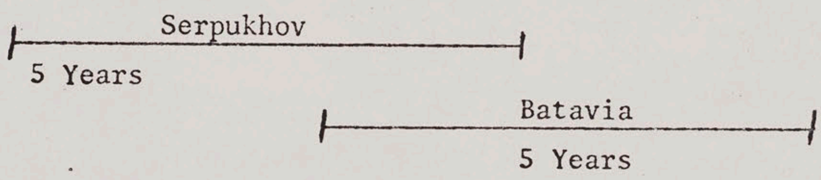
1) five years from now.

2) until December 31, 1975.

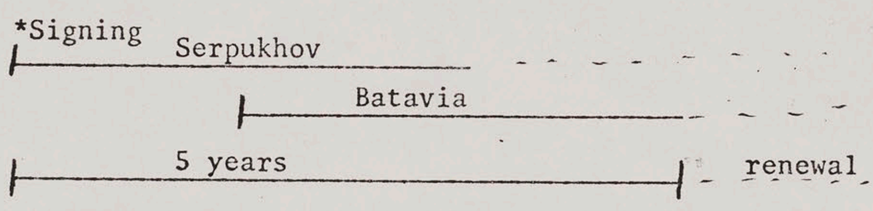
3) five years from the beginning of the first experiment at Serpukhov. but not later than December 31, 1975.

None of these proposals was definitively accepted.

During the discussions, Logunov proposed a term that looks like this.



Friedman proposed



The term of the French agreement is six years from the beginning of the operation of Mirabelle. Logunov pointed out that this is, for physicists, a well-defined period. Friedman argued that a fixed term was required. If pi-e does not start in 1970, the agreement had no fixed ending in time. He proposed that the term be not later than December 31, 1975. Logunov was still disturbed by a possible inequality. NAL experiments could start as late as 1974 so that Soviet participation would not be practical in only a one-year period. He, in fact, proposed that we could go back to a full symmetry and to the question of material contributions. Panofsky pointed out that pi-e preparation was already started and the experiment scheduled for October 15, 1970 so that there was in fact no discrepancy in our proposal and theirs except that we were unable to accept other than a fixed time limit. This position was reiterated by Friedman. Logunov also came back to his point that the scope must be defined. Panofsky said that we anticipate one experiment at a time at both places for planning purposes except for possible new and interesting experiments. Furthermore, in practice, the Americans would bring a lot of gear to Serpukhov whereas initially the Soviets might participate at Batavia without bringing substantial equipment. Exact symmetry was difficult to define.

Logunov's position was that Serpukhov is a working laboratory--short of people and funds. They are too busy to start a Batavia group. On the other hand, our (American) interest in Serpukhov decreases as Batavia approaches. He felt that the same number of experiments would be a good solution. We eventually left the term to be defined during the final meeting in Moscow. The session ended by our agreeing to send them copies of Batavia proposals as soon as they were available and by our pressing on them the invitation to send Soviet scientists to the 1970 summer study at NAL.

Serpukhov Negotiating Session III

March 18, 1970 - 11 a.m.

Present:

Soviet	Sulyeav, Logunov, Titkov, Smolin, Prokoshkin, Zoikovsky, Kuznetsov, Tsyganov, Yarba, Naumov
U.S.	Frideman, Panofsky, Drickey, Fields

This session started after a morning tour of the accelerator. Fields and Prokoshkin entered later because they were busy discussing the experimental program for Fields' talk at the Wisconsin 200 GeV meeting.

Smolin presented the results of their caucus on the protocol.

1) They agreed that pi-e should be directly mentioned in the protocol, i.e. that specific mention of the Krisch and Lindenbaum experiments should be dropped.

2) They insisted on the inclusion of the neutrino experiment at NAL.

Logunov pointed out that they must have a guarantee of participation at NAL. Friedman presented our willingness to agree to guarantee one experiment at NAL to be mutually agreed upon after scientific review. This did not seem to satisfy them. Smolin and Logunov both used the phrase "proposal" in discussing the neutrino experiment. Logunov once again was willing to add a phrase such as "in case such an experiment is performed". He emphasized that we were here talking about programmatic physics and that they want to participate in only one experiment out of many in the program. Panofsky replied that we could not agree to an experiment in any specific field nor to any specific experiment. It will probably be one and one-half years before any specific decisions are made. Logunov expressed surprise that no one from NAL was a part of the delegation. Fields and Panofsky are on the Program Committee of NAL and this seemed to be satisfactory. In response to Friedman's opinion that a specific proposal would take at least a year to clear the NAL program committee, Logunov said, "We hereby propose such an experiment, if there is no such experiment, you undertake no obligation." "On the behalf of many Soviet physicists, this is a matter of principle for us also." Our reply was that we had no authorization to undertake such a commitment; we could only guarantee that one experiment would be performed and that all proposals would be considered.

We continued discussion on the protocol, agreeing on minor points and wording. Smolin reserved the right to clear some of the wording with the State Committee in Moscow. The final Serpukhov session dissolved at 1:30 p.m. and we returned to Moscow that evening.

State Committee Session II

March 19, 1970 - 11 a.m.

Present:

Soviet	Smolin, Titkov, Sulyeav, Fillipov, Kuznetsov, Tşyganov
U.S.	Friedman, Fields, Drickey, Harbin

Smolin opened the session by announcing a shift in our meeting with Petrosyants from 5:00 p.m. on Friday to 10 a.m. Friday. He then announced that they wanted to reopen the question of a material contribution because of difficulties in comparison with the French and CERN agreements.

Friedman's reply pointed out that we were offering a unique opportunity; access to a 200 to 400 GeV accelerator whereas France and CERN could not make such an offer. Our costs were huge in comparison with the cost of Mirabelle and the CERN equipment. The pi-e experiment was of interest both to us and to Dubna and this was our primary concern. There are two problems with the material contribution: a) principle and b) the scientific details. We attempted, at this point, to determine specifically what equipment would satisfy them, in particular if the equipment for the pi-e experiment would be sufficient. After some discussion, it was clear that they were not interested in this equipment but in a much larger (at that time undefined) contribution. We pointed out that our collaboration on pi-e is itself a substantial contribution since the experiment would be substantially improved. Smolin did not deny this, but said that the time required might be longer but the result would probably be approximately the same. Smolin said specifically that a large computer was not required, but that some material contribution was necessary. He ultimately mentioned small on-line computers and automatic film-processing equipment. (This equipment was, perhaps, better defined in a subsequent discussion between Drickey, Tsyganov, Sulyeav, and Logunov.)

We then agreed on the final wording of the protocol except for our points of disagreement.

a) the material contribution

b) the NAL neutrino film

c) the term of the agreement.

Titkov presented the itinerary for the visit of U.S. fast reactor specialists in the Soviet Union. Shevchenko was not included contrary to previous agreement. Friedman pointed out that he must take this matter up with Petrosyants at our meeting on the following morning.

MEETING WITH CHAIRMAN PETROSYANTS

March 20, 1970--10:00 a.m.

Present

Soviet	Titkov, Petrosyants, Smolin, Fillipov, and a translator
U. S.	Friedman, Fields, Drickey, Harbin

Petrosyants Thank you for the letter from Mr. Seaborg. He seemed to enjoy our joint visit to Dubna. Concerning this letter, we actually discussed the exchange of high-level visits. Frankly, things are moving slowly concerning this visit. My schedule is very tight for this year; I go abroad only once a year. I will make an official visit to Britain in May and so will be unable to visit Dr. Seaborg, and am very sorry. I would like to go to the U. S. in October/ November and would like to receive a special letter. I am interested in the visit, since I last visited the U. S. in 1963 and many changes have taken place. We would be pleased to receive Seaborg in December, 1970 or any month in 1971; but I prefer December, 1970 even though it is cold. Seaborg could visit the Caucuses, Armenia, Georgia and Ukraine. Please convey these proposals to Seaborg. I will visit in October and November and in December, Seaborg can visit here. As far as the signing of the Memorandum, I propose Seaborg sign it in Washington and send it to the State Committee. We will immediately sign it.

Friedman — Seaborg asks me to convey his best greetings and to say he enjoyed his visit and, although he is disappointed, he appreciates your tight schedule. I will inform him that Mr. Petrosyants will appreciate a letter regarding the visits. We are agreeable to signing the memorandum by mail.

Petrosyants — Frankly, I will not write this but will tell you, we expected the invitation from Seaborg in October or November. After that, I decided to accept the British invitation. I am a little to blame and also Seaborg for the delay.

Friedman — I appreciate the frankness expressed from you and Smolin. I also speak frankly. Perhaps it is the mail that is to blame. Seaborg had written many months ago about high energy physics cooperation and did not receive an answer. When Mr. Smolin came, he brought a copy of the letter, which had still not been received. Immediately Seaborg prepared a letter.

Friedman — Let me continue. We have had long, difficult interesting negotiations on high energy physics cooperation. Both sides have had the same objective, to cooperate. In spite of this, there are a few points of non-agreement. I have agreed to discuss these with Professor Seaborg and our commission but I think they will be difficult to resolve. Let me mention the two major points. One is the desire for a

Friedman (cont)

material contribution in exchange for the availability of Serpukhov. We propose the use of NAL and that this would serve as the quid pro quo. Secondly, a more technical point was the request for NAL neutrino film to be supplied. We cannot agree to this because we cannot even agree to American requests since no decisions will be made until the end of the year or perhaps even later. Panofsky and Fields are on the NAL advisory committee.

Fields

A more general point, that of the scientists, as summarized by Panofsky, is that of a collaboration between two equal facilities and communities. For the first part, Serpukhov would be the frontier facility, later, NAL would be the frontier. We are anxious to share these facilities in an equal and fair way. We believe that by proceeding in this way, the quality of physics and of the facilities will be maximized. I believe and my colleagues believe, that a collaboration at Serpukhov will make significant contributions, not material contributions, but technical contributions, i.e. advice and collaboration. We hope to continue to improve the communication so that we can maximize output of the two machines.

Petrosyants

All is clear, the foundation is solid. Logunov and Smolin have kept me informed. I believe that this protocol should not affect our cooperation. There are many points of agreement. This should not prevent cooperation on other problems.

Petrosyants (cont.)

Frankly, we have some difficulties. I do not quite understand these problems, you are a rich, organized country. The scientific contribution of the Americans is very great. I opened the conference at Yerevan last year; the American contribution was great. The Russian delegation was the largest, but the Americans were four times more numerous than from any other foreign country. Their quality was also high. CERN and France made large material contributions to Serpukhov. We do not want strategic material, only a major contribution.

Friedman — I will not belabor this issue. The French and CERN have no large accelerator and only unsettled plans. The U.S. contribution is an accelerator costing us 300 to 400 x 10^6 rouble, and we feel that access to this accelerator is a very important contribution. If this protocol fails, we must be sure that cooperation continues. I hope that we can encourage meetings and visits, not only Kiev but also the NAL Summer Study.

Fields — I particularly emphasize the importance of individual exchanges and visits to provide the groundwork for future large scale agreements even if an agreement cannot be made now.

Petrosyants — I propose. The points of view of each side are clear. We agree in general, but we have specific disagreements.

Petrosyants (cont.)

Perhaps you can make more specific proposals, if not, it is not a frightening matter, we will continue our cooperation. We cooperate closely with France. I believe that joint projects are the best vehicle for cooperation. The French minister, Ortoli, will visit Serpukhov; we have signed a polarized target protocol with the French. CERN also emphasises our collaboration. If Americans live at Serpukhov, contacts will be close and the material contribution will be small compared to the importance of the contacts. That is all there is to be said about this problem. We believe that the scientists will be able to persuade the AEC that our point of view is correct.

Friedman — I will present Professor Petrosyants' point of view clearly to Chairman Seaborg. Let me move on to another subject.

The schedule arranged by Mr. Smolin for the reactor specialists' visit is interesting, but we are very disappointed that Shevchenko is not included. Specifically, Petrosyants told Chairman Seaborg that it could be visited by our reactor team. They had planned to arrive only ten days from now. They find it unfortunate because they thought it already approved. Furthermore, Shevchenko has already been visited by the United Kingdom, France, and Sweden. Smolin said that Shevchenko is under construction, but Indian Point and Dresden were both in the midst of major construction during the Soviet visit. I have been informed

Friedman (cont.)

that our people consider this as very serious. I hope that you can still make arrangements for a visit on a timely basis.

Petrosyants — I will reconsider this problem. If there is a possibility of it being solved, I will do so. Americans were the first to visit Shevchenko; they were the ground breakers.

Friedman — That is why we want to see it. They saw a hole in the ground; now we want to see what you have put in it.

Petrosyants — If I cannot solve the problem, tell Chairman Seaborg that he will visit Shevchenko. I will, in any case, visit Shevchenko with Seaborg. Convey that Seaborg can visit under any circumstances, personally, with me.

Friedman — Seaborg is a Nobel prize winner, an expert in chemistry and physics, but not in fast reactors. Can you estimate when Shevchenko can be visited by our fast reactor team? It may be more useful to postpone the visit of our specialists if there is only a short delay.

Petrosyants — I don't know when. I will find out and reply. I will summon the head of construction at Shevchenko. Novovoronezh is under power now and would be very interesting to visit.

Friedman — All sites will be interesting. Can I have an answer by Monday? We will then know whether or not to postpone.

Petrosyants — You are very efficient in the U.S.; we cannot do it. He, the construction chief, cannot come from the Caspian Sea until next week. Smolin had responsibility for the itinerary up until now, and I only learned of the trouble recently. It is not just the construction. I will look at all of the problems. Any more remakrs?

Friedman — Our thanks to you, Smolin, Titkov and their colleagues.

Petrosyants — These talks have been interesting and important. After consideration of the problem, I hope it can be solved. If not, it is not a tragedy.

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1000-GeV CYBERNETIC ACCELERATOR DEVELOPMENT: PRESENT STATUS

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I feel it greatly encouraging to speak to a qualified audience like this one that requires no further argument in favour of the importance of perpetual technological advancement into the field of super-high energy particles. This point has been clearly brought to evidence by esteemed scientific experts at a number of conferences held in the USSR, the USA and West Europe. At present it is impossible to foresee everything that is to be discovered with the help of 200, 300, 400, or 1000-GeV protons. Nevertheless, broad and quite lucid programs of experimental research based both on continuation of modern experimental investigations and on scientific extrapolations and forecasts of at least trends of future research have been outlined.

In 1961, when the 70-GeV proton synchrotron (Serpukhov, USSR) was just under construction a group of Soviet scientists proposed a new principle to be used in a proton accelerator design for essentially higher energies [1-2].

In 1963, at the International Accelerator Conference in Dubna I had the honour to present a paper describing our work on the design of a 1000-GeV proton accelerator which we named "cybernetic" [3]. At the same conference reports were made containing general views on the design of this machine, main parameters of its scale model, theoretical principles of further development of the 1000-

GeV accelerator, etc [4-12]. At a number of subsequent international and national conferences studies of this institute in the field of this challenging problem were presented [13-25].

In addition to this general report, some other papers will be presented by our colleagues at this conference.

Two volumes on the design of this accelerator and the future experimental program have been issued by the Radiotechnical Institute and afterwards published in English by the USA Atomic Energy Commission. All this shows a certain interest in this design. The Organizing Committee of this conference has invited us to make this report alongside the reports on the design and construction of 200-400-GeV accelerators in Batavia (Illinois, USA) and that of 300-GeV in West Europe under the leadership of CERN.

Of course, a question arises: will this major project be entirely sponsored by this country or shall one give thoughts to some form of international co-operation? I believe it would be most appropriate to have a preliminary exchange of opinions on this question here in Erevan either at a special panel or in the lobbies.

Now leaving this financial and political problem, let me turn to the scientific and engineering aspects of my report.

When starting a 1000-GeV accelerator design the fundamental question is the choice of its system. It is particularly essential for during the two decades of successful application of at first weak-focusing and later strong-focusing proton synchrotrons new proposals have appeared and are still appearing which at first sight seem to be more economical than the classical system of a fixed-target circular proton synchrotron.

During recent years both theoretical and experimental studies of systems with colliding beams of charged particles were conducted in some institutes in the USSR, the USA, France, and Italy. Collision of proton beams of only about 25-GeV energy corresponds to having a proton beam with an energy of more than 1000 GeV. However, the program of experimental research that can be carried out with the use of colliding beams is far from being exhaustive. Intense beams of secondary short-life particles such as antiprotons, mesons, hyperons as well as neutral particles with high energies can be obtained only in accelerators with protons hitting fixed targets.

On the other hand, the colliding beams principle can be useful in expanding the capabilities of super-high-energy machines either existing or under design. The construction of storage rings, for instance, is also envisaged in the 1000-GeV design of the Radiotechnical Institute.

In recent years substantial progress and improvements have been made in the so called methods of collective acceleration proposed by V.I.Veksler and developed by V.P.Sarantsev in this country [26-27]. Many works dealing with the development of these methods are being carried out in various countries [28]. The development of these accelerators encounters a fairly large number of fundamental and engineering dificulties in achieving acceleration as well as in the effective use of such machines for physical experiments. I shall not produce any more proofs in favour of coexistence of fixed-target proton synchrotrons, colliding-beam machines and collective-type accelerators. I should like only to draw your attention to the fact that although all these new methods of acceleration are being widely studied and partially realized, none of the projects of 200-400-GeV or 300-GeV classical-type accelerator has been rejected as yet.

It is proposed a wide use of computers in these projects for design and diagnostics [29-32].

In dealing with the development, improvement, modelling, and designing our 1000-GeV machine our efforts are directed to increasing the efficiency, reducing the construction costs and easing the strict allowances for the magnetic-field structure. At the same time, with the far future of the machine in mind, we are striving to provide for a design that in the long run would allow an increase of output energy up to 4000-5000 GeV.

We have already indicated in previous papers that in the 1000-GeV accelerator design a system had been adopted that involves a 0.8-GeV linear accelerator-injector and an 18-GeV booster. Then after further investigations on a number of magnet units, we have come to conclusion that it is possible to raise the field in the magnet gap up to 16 kG. This allowed to reduce the radius of orbit curvature down to 2080 m and therefore its length from 20.0 to 17.0 km.

Since construction of a 1000-GeV accelerator is a very expensive affair we - like the people constructing an accelerator near Chicago - envisage its realization in two stages: first reaching 500 GeV (at an increased acceleration time of about 2.5 s) and then going up to 1000 GeV (at 1-s acceleration time).

It is supposed that the preceding accelerator stages will also operate in underrated conditions, i.e. the circular booster will accelerate only up to 6 GeV and only the first part of the linac up to 200 MeV will be used.

Considerable experience gained on a scale model with small-aperture vacuum chamber (22x16 mm^2) has convinced us that when correcting the magnetic field through a computer one can well keep the deviation of beam from the center line of vacuum chamber within quite small limits. As a result, for the 1000-GeV machine a chamber have been chosen with elliptic cross-section having radial length of 66 mm and being 40 mm high.

The energy gain per turn in the main ring is 56 MeV. Transfer to the injection energy in the main ring equal to 18 GeV allows to have very small frequency modulation of RF accelerating voltage $\Delta f/f = 0.12$ per cent. The duration of acceleration cycle is 1 s with 20 cycles per minute. The total RF power consumed by the accelerating system is about 23 MW.

The cybernetic accelerator is known to have a system of automatic control of orbit position. This system is intended to accomplish automatic correction of magnetic field to ensure the beam travelling close to the chamber center line. The operational principle of the system is to process signals from pick-up electrodes giving the transverse coordinates of beam and to correct for the value of the magnetic field on the ground of these signal data.

Of prime importance in the cybernetic accelerator is the choice of method for compensation of magnetic field distortions. This is achieved by a system of correcting magnet lenses placed in between the magnet units.

The control of orbit shifts is supposed to be done in two stages: transverse deviations of beam during the injection period and transverse deviations of instantaneous equilibrium orbit during the entire acceleration period.

The orbit position control system contains 264 pick-up electrodes (of capacitor type) to measure beam deviation and 528 correcting lenses with amplifiers which feed lens windings. A special computer derives from pick-up electrode signals the appropriate values of current in the lens windings. To control the betatron frequency a special device is used that excites coherent betatron oscillations of accelerated particles. Pick-up electrodes whose voltage is proportional to the shift of bunch center-of-mass are placed at a distance equal to an integer number of betatron half-waves plus one quarter of wave length. From pick-up signals a certain frequency component is drawn out that is compared with a pre-calculated reference frequency. The error signal masters current in magnet lenses that correct the gradient in the steering magnet. The perturbations of betatron oscillations of the bunch center-of-mass should be such that, on the one hand, these oscillations persist while the frequency is being measured and, on the other hand, the transverse beam dimensions should not increase essentially by the end of acceleration cycle.

Provision is also made for other systems of automatic control that maintain the resonance between the accelerating RF electric field and the frequency of particle revolution and ensure the production of a required number of secondary particle beams.

Now I would like to go into some details of the 1-GeV scale model of cybernetic accelerator and of the results obtained during the experiments.

The circular magnet consists of 100 magnet units arranged into a strong-focusing system of FODO type and placed alternately inside and outside the orbit. The magnet structure of the accelerator involves 10 superperiods of 5 minor magnet periods consisting each of a focusing sector, a straight section, a defocusing sector, and a straight section. The pole faces have a steep profile with the field index $n = -\frac{r}{B}\frac{\partial B}{\partial r} = 191$. The transverse focusing force of magnet system is characterised by a betatron number per turn $Q = 6.25$. For an accelerator with a 17-m diameter magnet this corresponds to a very high focusing force. Owing to this the maximum dimension of beam inside the vacuum chamber at an injection energy of 1-MeV is less than 8 mm (without account for synchrotron oscillations). The dimensions of vacuum chamber cross-section are only a little higher than those determined by the beam free betatron and synchrotron oscillations.

Because of its small cross-section the vacuum chamber is evacuated to the required 5.10^{-7}mm Hg with the help of a vacuum system consisting of an annular pipe with the cross-section much greater than that of the vacuum chamber. This pipe (collector), connected to the chamber in 20 equally spaced points, is made of stainless steel and is pumped out by means of five titanium pumps. All the gaskets in the joints of vacuum chamber are made of indium.

The magnet has a somewhat larger gap (24 mm at the chamber center line) than is required to house the vacuum chamber thus giving place enough for auxiliary correcting pole windings. The presence of these windings with 40 correcting lenses placed between the magnet units would allow a number of investigations of particle motion in magnetic fields with different field vs. radius dependence to be carried out. Auxiliary pole windings and correcting lenses are fed by a system consisting of 28 reverse thyristor amplifiers and 86 reverse transistor amplifiers. These amplifiers obtain signals either from a multichannel function generator controlled by an integrator whose output is proportional to the magnetic field or from analogue-type outputs of a 'Dnieper-I' computer.

In order to insert controlled perturbations into the magnet system during experiments and to study their effect on beam behaviour the magnet units should be manufactured with as high accuracy as possible. To obtain this high precision, magnet laminations were manufactured by stamping consecutively with three different stamps, the last and the most precise of them being of a special hard alloy In addition, all of the 120 thousand laminations have undergone heat treatment and afterwards have been shuffled. An individual certificate has been compiled for each of the 100 magnet units. The data of these certificates have been processed by an 'M-20' computer to determine the optimal arrangement of the units along the circumference of the accelerator. The equivalent geometrical error including the spread of iron magnetic characteristics as found from measurements of beam deviations was about $30\,\mu m$. All the magnetic field measurements were carried out by using special high-precision semi-automatic magnetometers in which the intensity and the gradient to be measured were compared to those of a magnet unit chosen as a standard one.

Two injection modes are provided for the cybernetic accelerator:

a) protons are injected at a constant magnetic field intensity, the latter beginning to increase after the particles have been circulating for some hundreds of microseconds. This mode is characteristic for the multistage fixed-magnetic-field proton synchrotron with storing the particles that have been accelerated in the previous accelerator stage during a sequence of cycles;

b) protons are injected at an increasing magnetic field as it is done, for example, in the 76-GeV machine (Serpukhov). Particles are injected into the cybernetic accelerator from a Van de Graaf electrostatic generator. Measures have been taken to maintain the energy of injected bunches within 0.1 per cent.

Fifteen RF accelerating stations are installed along the circumference of the vacuum chamber to produce the frequency that is 5 times the frequency of particle revolution, i.e. varies from 1.25 to 15.0 MHz.

The suppression of coherent synchrotron oscillations is achieved by usual methods. Electrostatic pick-up electrodes placed in 20 points along the accelerator circumference are used to measure the beam displacement from the chamber center line.

Signals induced onto the electrostatic plates of pick-up electrodes are amplified by broadband amplifiers and after rectification are converted into signals whose values and signs give the values and signs of beam displacement from the chamber center line in the 20 points. By processing the output signals one can obtain information on the orbit shifts due to any perturbation.

The measured orbit perturbation may be expanded into a set of orthogonal functions characterizing the given magnet structure and one can perform control in such a way that the magnitudes of the most undesirable components are reduced essentially. If the period of betatron oscillations is much greater than the magnet structure period the system of orthogonal functions is close to a set of trigonometric functions, the harmonics close to the betatron frequency Q being most essential. In a small-aperture machine it may occur that the beam propagates only a part of the accelerator chamber before hitting its wall. In this case the information on the beam behaviour along the entire circumference of accelerator required for the above-mentioned method is not available. Therefore use should be made of a step-by-step control system to adjust the "first-turn" beam position.

The beam displacement from the chamber center line is measured at the end of each of many sections into which the magnet structure of the machine is subdivided, and is brought to zero by means of a correcting magnet. An amplified signal from pick-up electrodes serves as an input signal for the amplifier that controls the current in the correcting magnet winding. Proceeding in this way in consecutive equidistant cross-sections along the chamber it is possible to carry the beam throughout the entire circumference. Calculations show that the number of such "down-to-zero" sections should not be very large. Thus, only 264 sections are sufficient for a 1000-GeV machine with a 17-km long orbit.

The circular magnet of the model is subdivided into 20 "down-to-zero" sections. Thus within each period of betatron oscillations the orbit undergoes correction in three points.

Of all the experiments carried out on the model most interesting are those which should have checked the accelerator main parameters and the possibility of proton acceleration in a small-aperture chamber. Of no less significance is testifing the efficiency of the automatic system controlling the beam position.

It has been shown experimentally that the parameters of magnet system ensure such focusing of the beam outcoming from the injector (at 1 mA) that all the injected particles accomplished the first turn with no losses. Use was made of position and intensity pick-ups arranged along the beam guide and the accelerator ring. Putting into operation the sectionized first-turn control system has resulted in a five-fold reduction of initial beam displacement. While because of insufficient accuracy of magnet units arrangement and imperfection of their characteristics these initial displacements were as high as 3 or 4 mm, the step-by-step system would bring them within 1 mm. To obtain a considerably higher initial displacement, the magnetic field in one of the magnet units was deliberately lowered by about 10 per cent by short-circuiting a part of the winding. With the control system switched on it was possible to correct automatically this perturbation as well. The degree of displacement reduction could be changed by varying the gain of closed control loop.

At present the scale model delivers protons accelerated up to 700 MeV, i.e. up to the highest energy obtainable with no system to correct for magnet field saturation. Protons are injected at a constant magnetic field and then after the circulation has been maintained for several hundreds of microseconds the magnetic field begins to increase.

Of considerable interest seems to be the fact that protons have been accelerated in a small-aperture machine with relatively high non-linearity of magnetic field vs. radius typical for a high-gradient magnet.

A broad research program is still to be carried out on the cybernetic accelerator. However, the experiments already carried out have confirmed the possibility of proton acceleration in a machine with a small aperture chamber as well as the feasibility of an automatic system that uses the data of beam position to control the parameters determining betatron oscillations.

A separate report of a group of our collaborators headed by A.A.Vasiliev will deal with the problems of beam position control in the cybernetic accelerator with the help of a 'Dnieper' computer. Therefore we would only state here that this study has yielded quite satisfactory results in spite that the parameters of this computer are quite modest. It has an average speed of 8-10 thousand operations per second and an operational memory capacity of 4096 words.

The main parameters of the 1000-GeV cybernetic accelerator corresponding to the three stages of its realization are listed in the following table:

Table I

Accelerator parameters	1st stage	2nd stage	3rd stage
1. Ejection energy (GeV)	500	1000	4000-5000
2. Intensity (protons/s)	2.10^{12}	3.10^{13}	10^{13}
3. Diameter (m)	5435	5435	5435
4. Maximum magnetic field (kG)	8	16	60-80
5. Aperture	40x66 mm^2	40x66 mm^2	i.d. 66 mm
6. Magnet weight (t)	18000	18000	60 (weight of superconductor)
7. Repetition rate (ppm)	10	20	5
8. Energy gain per turn (MeV)	12	56	60
9. Main ring injection energy (GeV)	6	18	18
10. Number of betatron oscillations	34.25	34.25	34.25
11. Number of pick-up electrodes	264	264	264
12. Number of correcting magnet lenses	528	528	528
13. Radio frequency (MHz)	120	120	120

It is obvious that the initial efforts should be concentrated primarily on the construction of a strong-focusing iron-core magnet system having the maximum field of 16 kG. However, the design should be carried out in such a way that afterwards when the capabilities of our cryogenic technology rise up considerably it would be possible to replace the standard-type magnet units by superconducting ones thereby bringing the maximum field up to 60-80 kG and the output energy up to 4000 or 5000 GeV. This reconstruction could be made while retaining the already built tunnel and many other components.

Of course, availibility of cryogenic technology will make it expedient to put forth a problem of decreasing RF losses.

It should be noted that even before the onset of "iron-core" magnet development it will be necessary to elaborate the designs of all the three stages of the accelerator so that in future the transfer to a still larger accelerator would take as low time and expenditures as possible.

In conclusion, let me show you some slides which give an idea about the design of the 1000-GeV cybernetic proton synchrotron. The study of this problem from the engineering and economical points of view has brought us to the conclusion that it would be most expedient to mount the main ring in a tunnel constructed by the methods developed and realized when constructing the Moscow Underground System. This implies utilization of tunneling shields with ring-shaped reinforced-concrete elements serving as the walls of the cylindrical part of tunnel. The approximate cost per kilometer of tunnel is about 1 mill. roubles.

If the corresponding decisions were adopted I believe a 1000-GeV accelerator could be realized in the late seventies and a 5000-GeV one a decade later.

From the bottom of my heart I wish all attending this conference to be either participants or eye-witnesses of these challenging events.

REFERENCES

1. E.L.Burshtein, A.A.Vasiliev, A.L.Mints, V.A.Petukhov, S.M.Rubchinsky, Doklady Akad.Nauk SSSR, 141, 590 (1961).
2. E.L.Burshtein, A.A.Vasiliev, A.L.Mints, V.A.Petukhov, S.M.Rubchinsky, Atomnaya Energiya, 12, 111 (1962).
3. E.L.Burshtein, A.A.Vasiliev, A.L.Mints, Proc. Int. Conf. High Energy Accelerators, Dubna, 1963, Atomizdat, Moscow, 1964; p. 67.
4. F.A.Vodopyanov, ibid., p. 213.
5. G.I.Batskikh, A.A.Vasiliev, A.I.Dzergach, A.L.Mints, N.L.Sosensky, ibid., p. 217.
6. E.L.Burshtein, ibid., p. 860.
7. A.A.Vasiliev, ibid., p. 865.
8. E.L.Burshtein, ibid., p. 863.
9. A.I.Dzergach, V.A.Karpov, ibid., p. 867.
10. A.A.Vasiliev, ibid., p. 871.
11. A.I.Dzergach, N.L.Sosensky, ibid., p. 874.
12. N.L.Sosensky, ibid., p. 878.
13. E.L.Burshtein, A.A.Vasiliev, A.I.Dzergach, V Int.Conf. High Energy Accelerators, Frascati, 1965; p. 34.
14. A.A.Vasiliev, IEEE Trans., NS-14, 1186 (1967).
15. A.L.Mints, A.A.Vasiliev, E.L.Burshtein, Proc. Sixth Int. Conf. High Energy Accelerators, Cambridge, 1967; p. 4.
16. A.L.Mints, A.A.Vasiliev, A.I.Dzergach, N.L.Sosensky, G.I.Batskikh, ibid., p. 352.
17. A.A.Vasiliev, N.L.Sosensky, A.I.Dzergach, E.S.Mironov, ibid., p. A-100.
18. F.A.Vodopyanov, B.M.Gutner, V.V.Elyan, A.A.Kalinin, V.N.Litvinov, ibid., p. A-115.
19. A.A.Vasiliev, E.L.Burshtein, "Trends in super-high energy proton accelerator technology", Proc. USSR Nat. Conf. Particle Accelerators, 1968 (to be published).
20. Yu.N.Antonov, A.A.Vasiliev, V.A.Kurochkin, B.M.Urlin, "Accelerating system of the 1000-GeV proton cybernetic accelerator", ibid.
21. F.A.Vodopyanov, B.M.Gutner, Yu.F.Dushin, V.N.Litvinov, "Accelerating-field generation system of booster for the 1000-GeV cybernetic accelerator", ibid.

22. A.A.Vasiliev, N.I.Andryushchenko-Lutsenko, V.V.Vladimirov, T.A.Latypov, R.A.Meshcherov, "Magnet for cybernetic accelerator scale model", ibid.

23. A.A.Vasiliev, G.I.Batskikh, G.I.Klenov, "Electrostatic injector for small-aperture accelerator", ibid.

24. A.A.Vasiliev, A.I.Dzergach, G.P.Skepsky, V.F.Aleshin, "Measurements of high-gradient magnetic field", ibid.

25. N.I.Andryushchenko-Lutsenko, A.A.Vasiliev, A.I.Dzergach, V.F.Kuzmin, S.M.Rubchinsky, G.N.Soloviev, "Problems of using computer to control accelerator", ibid.

26. V.I.Veksler, Atomnay Energiya, n. 5 (1957).

27. V.I.Veksler, V.P.Sarantsev, et al., Proc. Sixth Int. Conf. High Energy Accelerators, Cambridge, 1967; p. 289.

28. Symposium on Electron Ring Accelerators, LRL, Berkley, Calif., 1968.

29. G.R.Lambertson, L.J.Laslett, Proc. of the V Intern. conf. on accelerators. Roma, 1966, p. 26.

30. National accelerator laboratory, design report, Univ. research assoc., 1968.

31. L.Resegotti, ISR-MAG 168-30, Geneva, CERN, 1968.

32. Y.Baconnier, CERN 65-35, 1965.

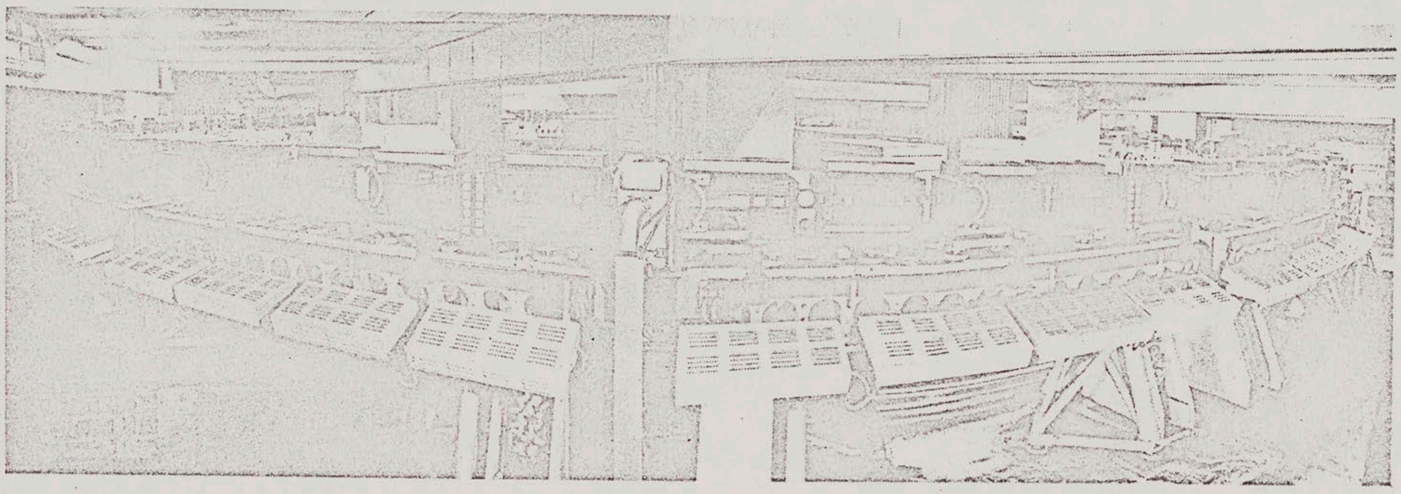

Fig.1. General view of cybernetic accelerator model.

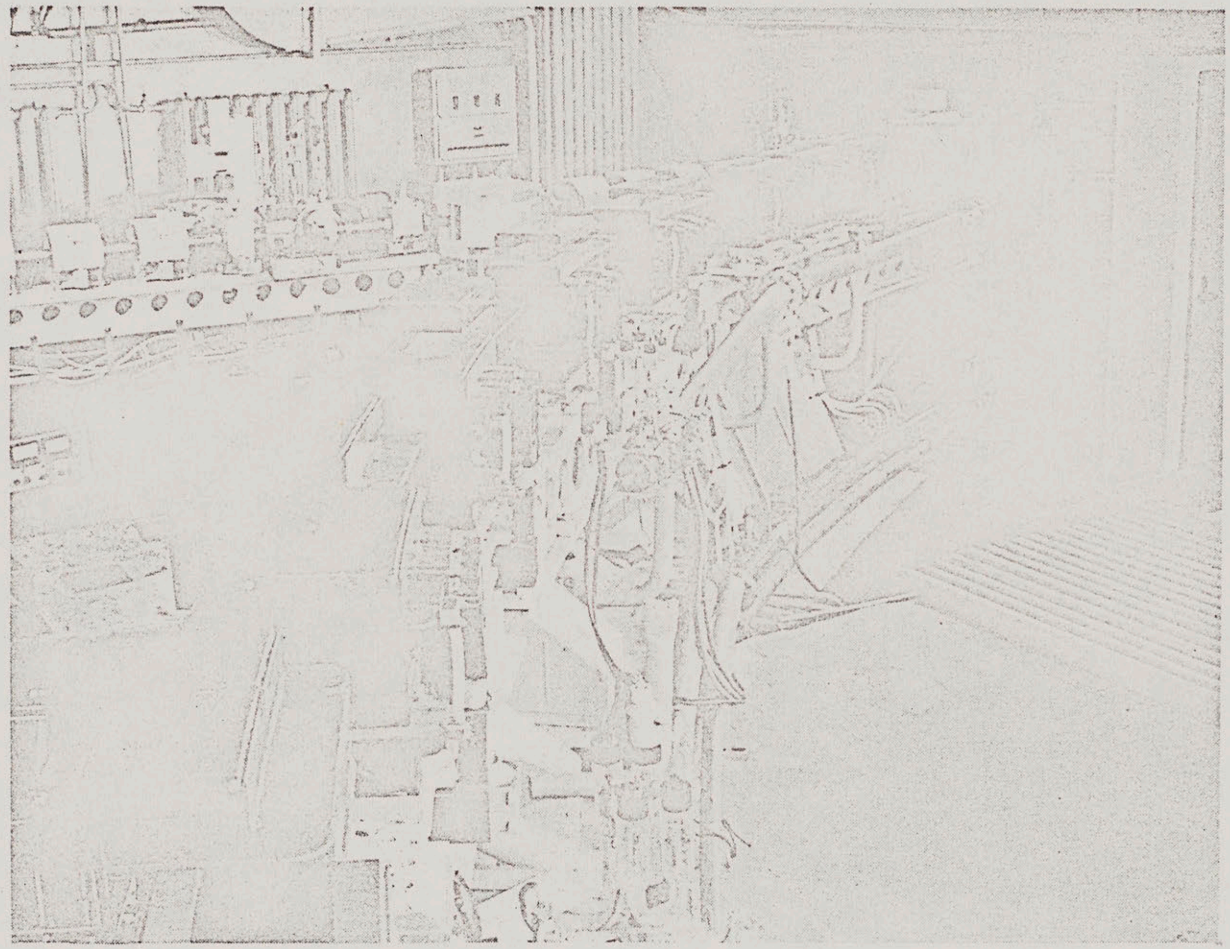

Fig.2. A section of cybernetic accelerator model.

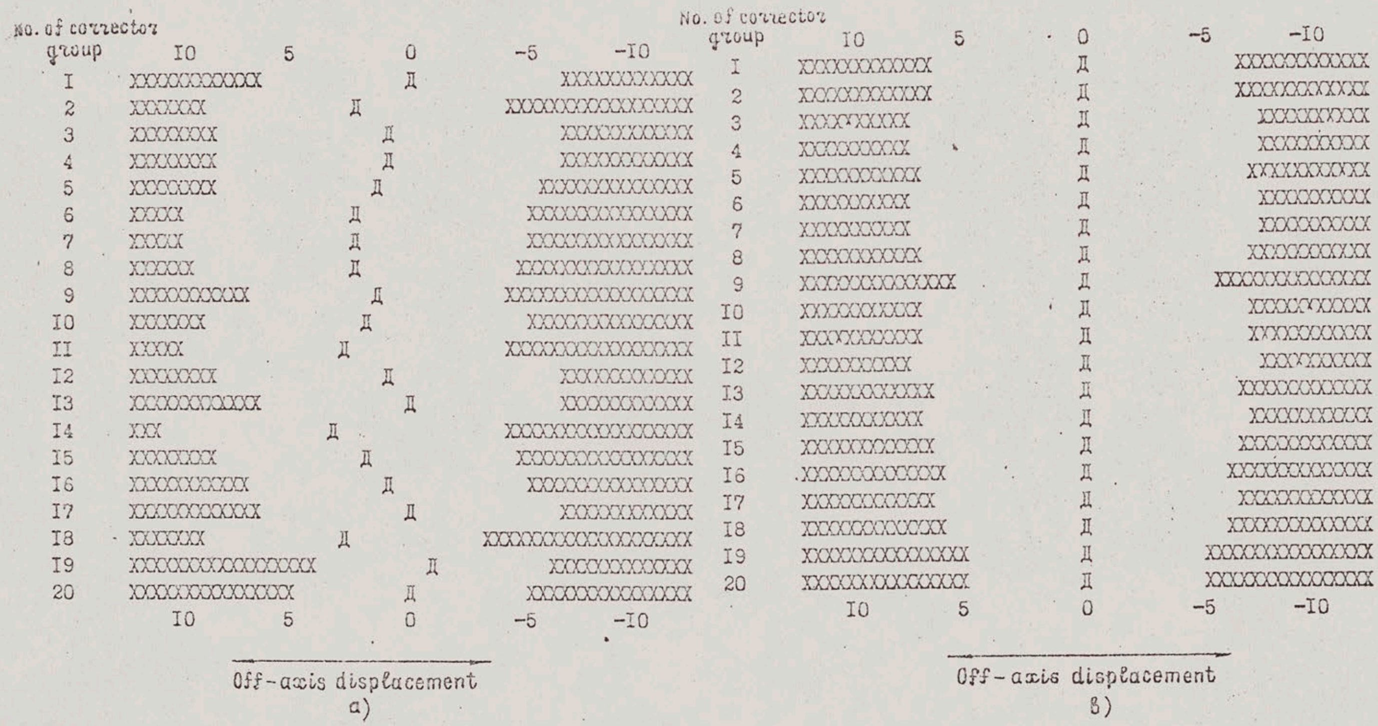

Fig.3. The region of possible radial beam displacements with the control system off (a) and on (b). The beam is moved by means of the group of three correctors until the boundaries of this region are achieved (beam disappears). D denotes the middle point between the boundaries.

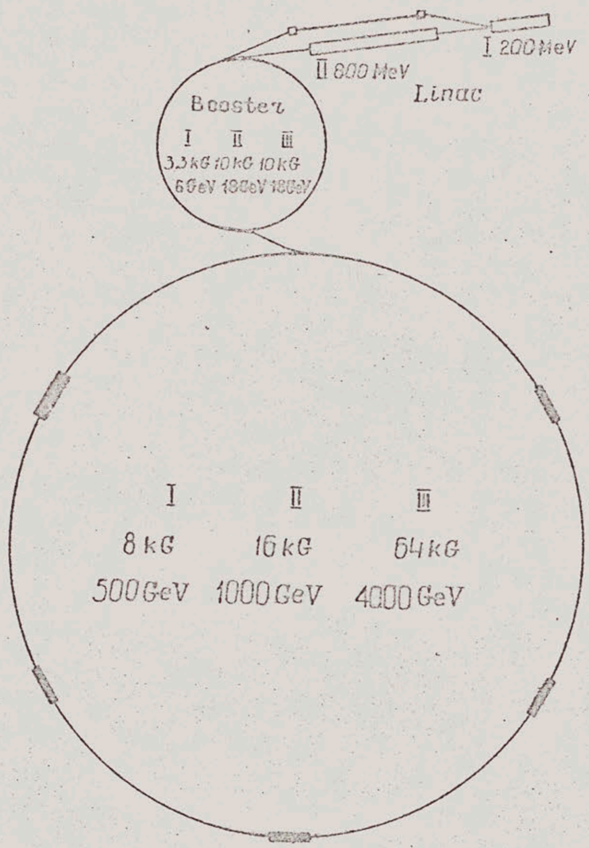

Fig.4. 3-stage program of designing the cybernetic accelerator.

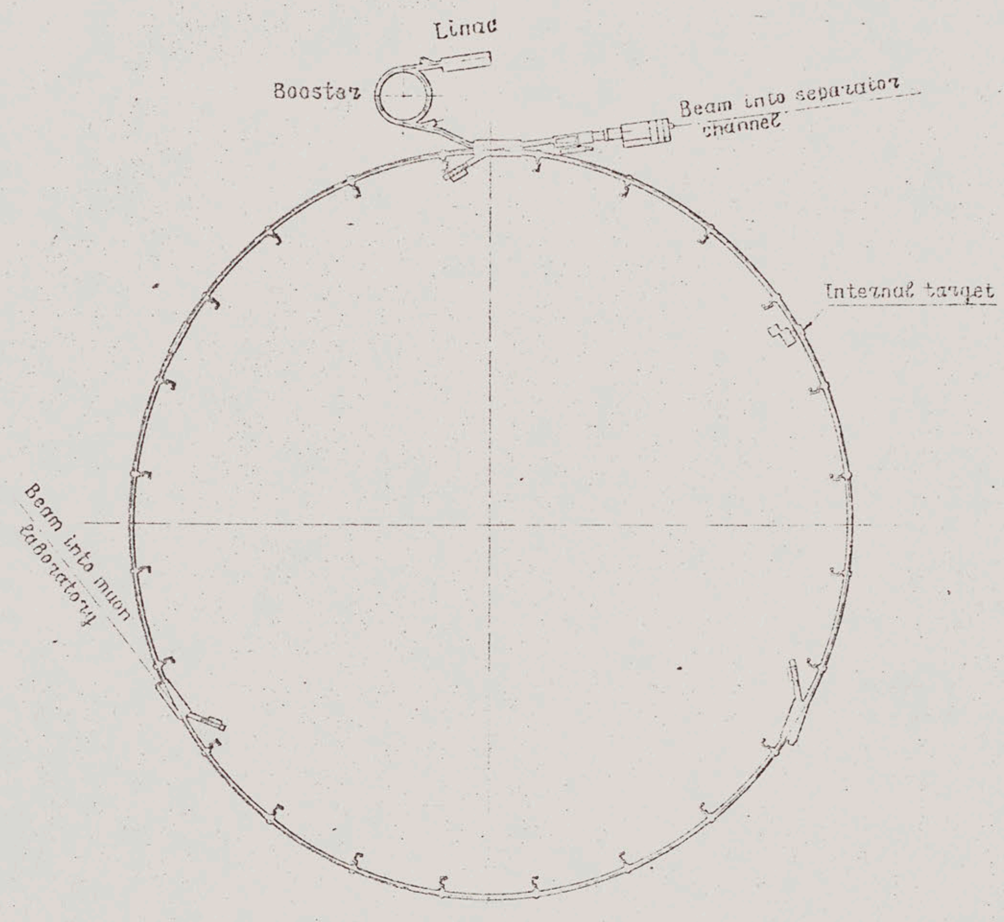

Fig.5. Cybernetic accelerator layout.

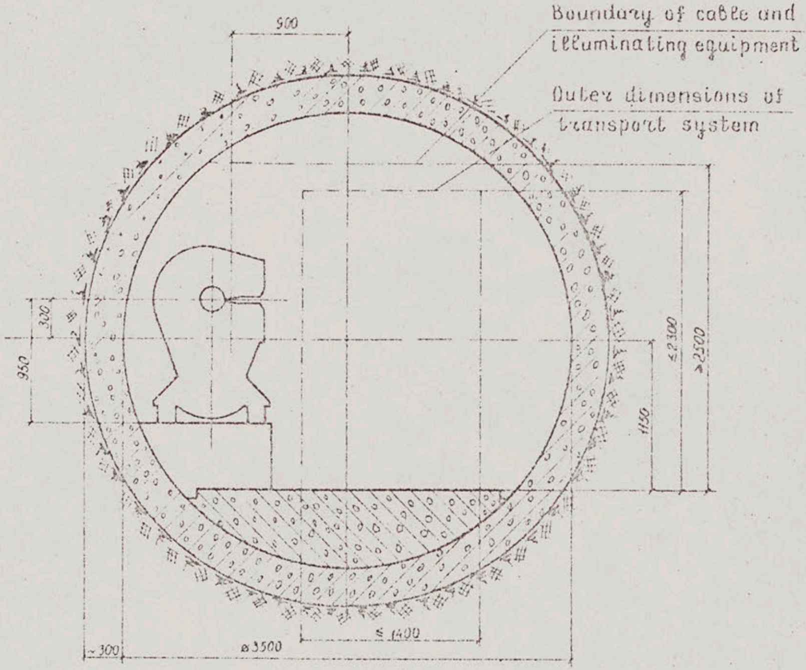

Fig.6. Cross-section of main ring tunnel.