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PRESENT AND FUTURE USE OF THE CERN 600 MeV SYNCHROCYCLOTRON

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1. INTRODUCTION

At its meeting of the 27th June 1968 the CERN Physics III Committee discussed the long term aspects of the scientific activity based on the CERN 600 MeV Synchro-Cyclotron (SC). The Committee appointed a panel of members to summarize the discussion and to supplement it by other information relevant to the future use of the SC. This report is an attempt to present the gist of the views expressed at the meeting and in an earlier document on the use of an improved SC (Physics III-67/38 Rev., 11th September 1967). In addition some facts and data which have come to light thanks to the work of the panel have been included.

The time available for the preparation of the report was short and coincided with the holiday period. This has hampered the work of the panel, and the results are presented in the knowledge that they are incomplete. It is, however, hoped, that the picture which has emerged may be valid at least in its broad outlines.

2. NOTES ON THE CERN SC

2.1 History

The SC was constructed to provide CERN and Europe with an accelerator before the work on the Proton Synchrotron could be completed. However, the machine has proved itself an excellent instrument of research in its own right, and physics has flourished at the SC during the eleven years of its operation. In addition to its use by CERN physicists it has provided research opportunities for visitors to a growing extent, many visiting teams finding in the SC a facility which suited both their interests and resources.

The success of the SC has been established and maintained by experiments of the highest quality, some of which have been unrivalled elsewhere. Among these one recalls the discovery of the electron decay of the pion, the first precision measurement of (g-2) of the muon, the measurement of the branching ratio of pion beta decay and the determination of the muon capture rate in liquid and gaseous hydrogen. Many other experiments have ranked among the best of their kind.

The research at the SC has benefitted from the excellent facilities with which it has been equipped. The SC Muon Channel, the high-resolution variable-energy pion beams and the Isotope-Separator on Line (ISOLDE) Installation are examples of important CERN developments. Combined with a generous provision of more conventional equipment these have permitted a steady expansion of the research, which now ranges from pure particle physics via mesic X-rays to the production and study of new short-lived isotopes and to work in radiobiology and solid-state physics.

2.2 The SC Improvement Programme

The interest in physics performed with particles of kinetic energies lying between about 200 and 1000 MeV -- sometimes referred to as "Intermediate Energies" -- has grown to such an extent that new accelerators of improved performance in this energy range are being planned or constructed in various countries. The desire to keep the CERN SC with its highly developed facilities, its tradition and its experience active and competitive in this field has led to the formulation of the CERN SC Improvement Programme. Proposals, based on extensive studies, were submitted to the CERN Scientific Policy Committee in a recent document (CERN/SPC/249, Nov. 9th 1967).

The aims of the Improvement Programme are to increase the internal beam current from its present value of about 1 μA to about 10 μA and to raise the proton extraction efficiency by improving the quality of the internal beam. At the same time the high duty-cycle of the present SC is to be maintained, since it constitutes an essential advantage of synchrocyclotrons over sector-focused cyclotrons or linear accelerators.

Progress in design and tests in the SC Central Region Model performed since the publication of CERN/SPC/249 give every reason to believe that the aims of the SC Improvement Programme can be achieved.

It is therefore an appropriate moment to look at the field of research of the SC, to consider the role of the improved machine and its needs in terms of man-power and equipment.

3. PHYSICS AT INTERMEDIATE ENERGIES AND RESEARCH AT THE SC

3.1 The Field of Research

Particles of intermediate energies are used to study a range of problems in certain areas of nuclear-structure physics and of the physics of elementary particles.

These can be handled more effectively and economically at intermediate-energy accelerators than by using intermediate energy particles produced by high-energy machines. A subject of special interest in this energy region is that in which nuclear and particle physics overlap and interact.

The different fields of study are not only linked by a common range of particle energies but also to some extent by common techniques, and there has been a tendency to separate the domain of physics at intermediate energies from low-energy nuclear physics on one hand and from high-energy physics on the other. This tendency has found expression in the establishment of a series of conferences on intermediate-energy physics, which has recently been recommended by IUPAP. One may question if the field constitutes an identifiable subject, but the very diversity of topics provides a large range of applications for intermediate-energy accelerators.

3.2 Factors affecting the choice of programme

The selection of topics for research is often influenced by local factors, e.g. experience and expertise in a certain domain or facilities favouring particular studies. Technological developments are another important factor, new techniques giving an interest to areas previously inaccessible or neglected. Thus the development of polarized targets, muon channels, and lithium-drifted germanium detectors have tended to orientate research towards certain fields. The isotope-separator on line, designed to explore nuclides far from the region of stability, is certain to create a new field of interest as will pion beams of high intensity and resolution. Crucial theoretical questions, e.g. the validity of various conservation laws, have greatly influenced the choice of experiments, and improvements in technique have often led to new tests.

3.3 The CERN SC Research Programme

At the CERN SC there was a shift of interest from the physics of elementary particles to their application to problems of nuclear structure. The ISOLDE Installation is a landmark in this development, and it is certain that research using this unique tool will be an important feature of any future programme. However, more recently, there has been a renewed interest in elementary particle experiments made possible by improved techniques and refined beams. This has been illustrated by the Physicists' Comments on the SC Improvement Programme, the document PH III-67/38 Rev. previously cited, on which many of our views are based. Many problems in elementary particle physics will be re-examined when the present limitations of intensity have been removed. We therefore expect that both nuclear structure and particle physics will be studied in future.

We do not feel justified in going further than noting such general trends but, to fix ideas, we have attempted to list a number of topics which might figure in the SC rsearch programme during the next few years. They are shown in Table I. (p. 4a)

While this list is simply indicative it does illustrate the range of problems which can and probably will be investigated with intermediate-energy machines such as the CERN SC.

4. INTERMEDIATE-ENERGY ACCELERATORS

4.1 Recent developments

Electron synchrotrons and proton synchro-cyclotrons were the sources of intermediate-energy particles until a few years ago. However, as research using these machines progressed it became clear that improvements were desirable. The major concern was for more intense beams; other considerations were energy resolution, variable energy extraction, high extraction efficiency and good duty cycle.

For electron accelerators most of these requirements favoured the linac; for proton accelerators the situation is more complex. The least expensive improvement is to modify existing synchro-cyclotrons in order to increase the beam intensity. Some of these machines were, however, constructed with poor radiation shielding and very small experimental areas, and improvements to these machines would necessitate expensive modifications to buildings. A number of these accelerators are therefore being closed down, but improvements are feasible at others. Some improvement programmes have been funded, others are still under discussion.

The major difficulty with improved synchro-cyclotrons is that the extraction efficiency remains relatively low, which means that the intensity of the internal beam must be limited because of the residual radioactivity in the machine. To overcome this difficulty several new types of accelerator have been proposed, and three varieties are being constructed. Sector focusing ring cyclotrons are being built by Indiana University at Bloomington U.S.A., and by the Swiss Federal Polytechnic at Villigen, Switzerland, whilst a sector focusing H^- accelerator (Triumf) is being

TABLE I

Possible Topics of Research at the CERN SC during 1969 - 74

1. Mu-mesic atoms

   Charge distribution of nuclei (including separated isotopes); check on vacuum polarization; excitation of nuclei; nuclear quadrupole moments; effects due to chemical environment.

2. Pi-mesic atoms

   Matter distribution of nuclei; pion-nuclear interaction; pion-mass; excitation of nuclei.

3. Pion-nucleus scattering and reactions

   Elastic and inelastic scattering; anomalous reaction effects; radiative capture of pions.

4. Proton-nucleus scattering and reactions

   Elastic and inelastic scattering; the (p,2p) and other simple knock-out reactions; production of high-energy pions for the study of high-momentum components of nuclear wave functions; spallation and fission reactions of nuclear and astrophysical interest.

5. ISOLDE

   Study of new nuclides; precision measurements on nuclides now incompletely known; study of yields.

6. Pion-nucleon interaction

   Pion-proton elastic and charge-exchange scattering; radiative capture; pion-proton bremstrahlung.

7. Weak interaction

   Muon capture in hydrogen and in complex nuclei; neutrino interactions, pion beta decay.

8. Nucleon-nucleon interaction

   Neutron-proton elastic scattering; nucleon-nucleon bremstrahlung; meson production from $T = 0$ state.

9. Electromagnetic properties of particles

   Magnetic moment of muon; elastic and inelastic muon scattering, study of muonium; decay of π^0.

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10. Biological and medical physics

Dosimetry, radio-biological effects of protons, neutrons and possibly of pions.

11. Miscellaneous

Solid-state effects of fast and slow particles. Muonium chemistry.

designed by the University of British Columbia at Vancouver, Canada. These machines will have internal beam current of 50 - 100 μA and high extraction efficiencies. For beam intensities exceeding 1 mA a linear proton accelerator seems more appropriate and a machine of this type is being built at Los Alamos, U.S.A. We list in Appendix A the properties of the machines which will be operating in the early seventies.

As distinct from proton-accelerators serving for the study of pion, muon and nucleon interactions, electron linear accelerators were built primarily as tools for nuclear-structure research and were intended to complement proton accelerators rather than to compete with them. However, reasonable pion beams can be obtained from electron linacs, and in this respect direct comparisons become possible. The likely pion-beam intensities will be greater than those at the present synchrocyclotrons but not as good as those for improved synchrocyclotrons, and well below those of the new proton accelerators. The energies of the pions will be quite low (up to 100 MeV), but these beams would be suitable for stopped pion and muon experiments. The main disadvantage of electron linacs is the very low duty cycle (1% is typical) and for this reason such accelerators will probably be able to cover only a limited range of pion and muon physics.

The machines which are closest to CERN geographically and which are liable to take over some of the CERN SC research effort are the Villigen proton accelerator and the Saclay electron linac. These will be discussed in somewhat more detail.

4.2 The Villigen Accelerators

The Swiss Federal Polytechnic (ETH) is establishing an institute for nuclear research (SIN) at Villigen, Aargau, which will be equipped with an isochronous ring accelerator designed to supply 30 to 100 μA of protons at a fixed energy of about 520 MeV, although an extension to 580 MeV is a possibility.

The ring-accelerator is fed by a sector-focused cyclotron. Used as an injector this will deliver 70 MeV protons, but it is planned to design this machine as a variable-energy accelerator for multiply charged ions and to use it during part of the time directly for nuclear-physics studies.

As isochronous machines the injector and ring accelerator will operate in the C.W. mode, but the phase acceptance of the radio-frequency system will restrict the microscopic duty cycle to less than about 5%, e.g. 1 ns bunch every 20 ns. For fluxes of rather less than one particle per bunch this is of no consequence, but the effect of duty cycle will become important at mean counting rates exceeding a few times 10^7 per second, i.e. just in that region where the isochronous machine is superior to an improved SC. New techniques of experimentation will certainly be developed and allow a full exploitation of the potentialities of these machines.

Start of construction of the Villigen installation is planned for 1968, and operation of the ring-accelerator should begin in 1972/3. Full operation is expected for about 1975 and it is thought unlikely that SIN will take a significant share of the European load before that date. It is believed that SIN will eventually accomodate about twelve research teams, nine of which might come from Swiss Universities or Institutes and about three from other countries or CERN.

It is certain that SIN, equipped for nuclear-structure work and for intermediate-energy proton, pion and muon physics with beams exceeding those now available by one or two orders of magnitude, will be an important facility in the field of physics now covered by the CERN SC, but the improved CERN machine will remain competitive at least until techniques capable of dealing with high intensities at low duty cycles have been perfected.

4.3 The Saclay Electron Linear Accelerator

The Saclay electron linac has a design energy of 600 MeV and a current of about 600 μA. It is primarily a machine intended for electron scattering work, but it is planned to produce pion and muon beams via pion photo-production in a carbon target. The expected pion spectrum peaks at about 60 MeV; it is hoped to obtain about 10^6 pions per second per MeV at the peak. Low-energy muon beams of ten times the present CERN intensity can be obtained with a conventional muon channel. A superconducting solenoid could provide muons of very low energy and of very high intensity, permitting a gain of several orders of magnitude in muon stop rate per gram compared with present values.

There are plans for two pion beams, one of which will be a high-resolution beam, and in addition for a muon beam. Reduced intensity beams can be obtained parasitically. These beams will be valuable for low-energy and stopping-pion and muon work. Intense beams of low-energy pions should be particularly valuable. The lack of such beams has prevented accurate measurements of the pion nucleon cross section below about 60 MeV in the past. The high muon stop rates will furnish interesting experimental possibilities. The accelerator has a macroscopic duty cycle of 1 -2 %, which will restrict its usefulness for certain experiments.

It is thought that there will be facilities for about three groups of experimenters at the pion and muon beams. The Saclay machine will therefore not take a substantial fraction of the present SC load, but it will supplement existing facilities in an interesting and worthwhile manner.

4.4 Other Intermediate Energy Accelerators

The list of existing and planned accelerators in Appendix A shows that there will be a strong increase of research facilities in North America by 1972, for although three machines are closing down they will be replaced by the Indiana, Triumf and Los Alamos accelerators. The major modification of the Columbia machine and the possible improvement of the Berkeley 184" and the NASA 600 MeV synchrocyclotrons will add to the research potential. In Western Europe two machines are closing down, one new proton accelerator is being built and the CERN SC will be modified. There will be an improvement in research capability, but this will be overshadowed by that of North America.

4.5 Long-Term Aspects

The imbalance between Europe and America will become critical in the late seventies when the Los Alamos Accelerator is operating with its intense beam and the full range of its planned equipment. Furthermore, there are other projects (ING at Chalk River, Omnitron at Berkeley and the Separated Orbit Cyclotron at Oak Ridge) being considered, of which one or the other may be constructed.

Under those conditions neither an improved SC nor a national accelerator like the Villigen machine will provide Europe as a whole with facilities comparable to those of America. During the next five years Europe will therefore have to decide whether it wishes to continue its activity in physics at intermediate energies. A positive decision would almost inevitably entail the construction of a new, internationally accessible accelerator in Europe.

The SC Improvement Programme is thus a holding-operation which will permit Europe to remain active during the time required to make long-term decisions.

5. UTILIZATION OF THE SC - PAST, PRESENT AND FUTURE

5.1 Past use

In order to predict the future needs of the SC we have analyzed the past utilization of the SC to see if any patterns could be established. In Table II we have divided the experimental groups who have used prime time into three classes: principal users (> 14 days machine time i.e. 42 shifts), major users (< 14 days but > 3 days machine time) and minor users (< 3 days machine time). The number of visiting teams has been noted and we have included the number of groups who have used only parallel running or parasiting time.

TABLE II

Groups at the SC

	1961	1962	1963	1964	1965	1966	1967	1968
Principal Users	7	5	6	4	6	5	8	7
Major Users	4	7	4	7	5	3	4	6
Minor Users	2	5	6	7	4	6	4	6
Mixed Teams	N.A.	N.A.	N.A.	4	7	6	7	6
Visiting Teams	6	7	7	3	5	6	8	12
Parasites and Parallel Users	2	1	3	3	4	12	6	9

(N.A.= not available)

The number of groups which use prime time has remained approximately constant; this is due to the fact that at any time there is only one prime user controlling the conditions of operation of the machine. However, the number of groups which parasite only has shown a steep rise; many of these groups are testing equipment for subsequent use on the CERN PS. One can also see that the number of visitors has steadily increased, indicating the improved contact between the synchrocyclotron and the universities and research institutes in Europe. At present essentially all groups are mixed or visitors.

In Table III we have listed the number of eight-hour shifts available for research in a particular year, the number of parasite shifts used and the maximum number of shifts given to one group. (There are 1095 shifts in a typical calendar year).

TABLE III

Research Shifts per Year

	1961	1962	1963	1964	1965	1966+	1967
Prime shifts	736	701	723	739	664	620	827
Parallel and Parasite shifts	176	384	305	500	439	463	533
Max. to one group	166	215	314	312	138	136	121

+) Major shut down in 1966.

Again the number of prime shifts remains approximately constant, but the number of parallel and parasite shifts has increased over the years. This increase is due to the development of parallel running facilities. An extrapolation indicates that there will be about 700 parallel and parasite shifts in 1970 and about 800 in 1973. Table III also illustrates that in the years 1962, 1963 and 1964 there was a tendency for a single experiment to use a very large fraction of the available beam time, but this is not longer true -- an indication of the increased pressure on machine time.

5.2 Present Use

At present there are about 90 physicists working in 17 research teams at the SC. In addition about 25 scientists collaborate in the ISOLDE project, so that in all about 115 research-workers depend on the SC.

The table of Appendix B shows that only 23 of these are CERN Staff, Fellows or CERN-paid visitors. The statistics do not take into account the groups who are using the SC only as parasite or parallel users.

The machine is usually booked for several months ahead and time allocations made by the Physics III Committee can be met only by intricate scheduling.

5.3 Future Use

In order to assess the probable demand for SC time during the next few years we have attempted to obtain information on plans for work at the SC from physicists in various member-states. The results of our enquiry are also listed in Appendix B; they are incomplete but even now they suggest that there will be a 20% increase in users over the next two to three years, with a net increase of abour four groups. This increase may be halted when the Villigen machine comes into full operation, but it is very unlikely that there will be a sudden fall-off in demand.

For the next few years the increase in pressure will have to be met by an extension of beam-sharing facilities. The more intense beams furnished by an improved SC might shorten the time required for individual experiments, but past experience suggests that higher intensities are frequently used to obtain better precision. Beam-sharing will be possible to an increased extent, but this will cause inevitable demands for more beam elements and power supplies.

6. POSSIBLE FUTURE RESEARCH FACILITIES AT THE SC

Apart from the increased demand for conventional equipment the physics programme for an improved SC may call for specific large items of apparatus or new installations needed, on one hand, to take full advantage of the higher beam intensities available and, on the other, to keep pace with developing techniques.

The following large items have been suggested:

1. Magnetic Spectrometer for proton and pion interactions.
2. Installation of a bubble chamber for particle or nuclear physics.
3. New beam devices, e.g. a superconducting muon channel.
4. One or several polarized targets, possibly using air-cored solenoids.
5. Fast ejection of the proton beam.
6. Extension of the Underground Experimental area, including a Biological Irradiation Facility.
7. Permanent on-line computer for users' groups.

A strong focusing storage ring used as beam-stretcher and designed to combine the advantages of internal target operation with a better choice of secondaries has been proposed by Brianti and Skarek. It is a possible development to be borne in mind but falls outside the scope of the present SC programme.

The above list suggests that the budget needs of an improved SC will probably include about 1 MS frs per annum to provide for certain large installations to be constructed over a number of years.

Recent expenditure on conventional experimental facilities has amounted to about 0.8 MFr per annum. During the three-year period of heavy spending on the SC Improvement Programme this expenditure will be reduced, but a resumption is foreseen in the years following the modification of the machine.

7. COST OF CERN SC OPERATION AND RESEARCH

7.1 Method of evaluation

The cost of the SC and the research performed with it is made up of five principal items, namely

(i) the annual SC budget, corrected for services rendered to NP, which are not connected with the SC operation.

(ii) the part of the NP budget devoted to research at the SC.

(iii) the fraction of the CERN central services used by (i) and (ii) pro rated on the basis of expenditure.

(iv) outside contributions to SC research.

(v) the capital cost of the SC.

We have neglected (v) on the assumption that the initial capital cost is no longer an important item after eleven years of operation. (i) to (iii) are obtained from the CERN budgets. The estimation of (iv) is difficult on account of the varied financing of mixed teams. For simplicity we have taken a standard sum of 70 kfrs per annum for the cost incurred by a parent institution per visitor at the SC. For a fully supported scientist, receiving both his salary and material backing, this is rather low, but a number of visitors get only their salaries from outside.

The figure for outside contributions calculated for 1968 has been scaled for the preceding years by assuming it to be proportional to the number of visiting groups.

It is clear that the result of our evaluation can only be a rough guide with a maximum error of 20% arising from lack of detailed knowledge of outside support.

7.2 Estimated Expenditure

Results of the estimates are given in Table IV, and are shown graphically in Fig. 1.

TABLE IV

Estimated cost of SC Operation and Research

Mfr

Year	1962	1963	1964	1965	1966	1967	1968
SC + NPSC	4.6	5.6	6.7	7.3	8.7	9.3	10.5
Central Serv.	4.4	6.0	6.3	7.1	7.1	9.6	8.8
Total CERN SC	9.0	11.6	13.0	14.4	15.8	18.9	19.3
Outside SC	NA	NA	1.7	2.9	3.4	4.6	6.3
Total SC			14.7	17.3	19.2	23.5	25.6

NA = no data available

The overall rate of increase of expenditure is about 11% p.a. at then existing prices. With a cost increase of ~ 4% p.a. this corresponds to a real growth rate of 7% p.a. The outside support seems to have grown by about 40% p.a. during the past few years, but this rate is bound to decrease since about 80% of the physicists working at the SC are already paid by outside bodies.

Our enquiry suggests that the rate of increase of outside support will be about 10% p.a. during the next few years. CERN expenditure on the SC is expected to level off after the completion of the SC Improvement Programme, which at present accounts for an annual expenditure of about 2 MSfrs. From about 1971 this sum of money could be used to cover the improvements in support facilities which will then be needed, including some of the major items listed in section 6.

<u>We must therefore expect expenditure to grow at approximately the present rate until the early 1970's.</u>

After that the commisioning of the SIN machines will probably reduce the growth of activitiy around the CERN SC.

7.3 Comparisons

Total SC expenditure seems at present to be about 0.22 MFr. p.a. per scientist served. This may be an overestimate since the SC use of central CERN services may be less than assumed. The figure is to be compared to the ECFA 67 estimate of about 0.3 MFr p.a. per high-energy physicist working at CERN in 1966.

The annual member-state expenditure on nuclear-structure physics is several hundred million francs. About two thirds of the SC time was given to nuclear-structure physics in 1967. The corresponding fraction of the SC expenditure is 15.5 MFr, representing less than 5% of the nuclear-structure physics funds spent by the member-states.

8. CONCLUSIONS

1. Activity at the CERN SC covers a wide and expanding field of research.

2. Outside groups and visitors now perform most of the SC research work.

3. Demand for SC machine time is increasing and is expected to grow further until about 1975.

4. Other Eueopean accelerators are unlikely to take a major part of the CERN SC load during the next seven to eight years.

5. An improved SC will make important and, in some areas, unique, contributions to research. The SC will therefore remain a major instrument for physics at intermediate energies for five to ten years.

6. The annual expenditure on SC work from all sources is now about 25 MSfrs. A growth rate of 5 to 8% in real terms will make it possible to meet foreseeable demands.

7. A decision on a new intermediate-energy proton accelerator in Europe will have to be taken within the next five years.

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APPENDIX A

Machines in the Energy Range 200 - 1000 MeV

A. Machines going out of operation

Place	Type	Energy (MeV)	Estimated date of termination
Rochester, U.S.A.	Proton SC	240	1968
Liverpool, U.K.	Proton SC	380	1969
Carnegie, U.S.A.	Proton SC	440	1969
Chicago, U.S.A.	Proton SC	460	1972
Birmingham, U.K.	Proton synchrotron	1000	1967

B. Machines operating (or about to operate) in 1972 (a)

Place	Type	Particles	Extraction Energy (MeV)	Internal Current (μA)	Extraction Efficiency (%)	Typical good pion beam (sec-1)	Macro duty-cycle(c) (%)
1. North America							
Indiana, U.S.A.	SFC	pdα	80-230	10-100	100	1×10^6	100
Triumf, Canada	SFC	H^-	200-500	10-100	100	1×10^8	100
Columbia, U.S.A.	SFSC	p	600	5-50	50	5×10^7	50
VARC, U.S.A. (b)	SC	p	600	1	5	5×10^5	50
Berkeley, U.S.A.(b)	SC	pdα	740	1	5	1×10^6	50
Los Alamos,U.S.A.	LA	$p(H^-)$	200-800	1000	100	5×10^9	6
MIT	LA	e^-	220-440	~400	100	2×10^6	2-6
2. Europe							
Zürich, Switzerland	SFC	p	500	100	90	2×10^8	100
Dubna, U.S.S.R.(d)	SC	pdα	680	2.3	5	1×10^6	50
Leningrad,U.S.S.R.	SC	p	1000	1	5	1×10^6	50
Saclay, France	LA	e^-	140-600	~600	100	2×10^6	1
Frascati, Italy	LA	e^-e^+	450		100		1-2
CERN (improved)	SC	p	600	10	10	5×10^6	50

Abbreviations: LA: linear accelerator; SC: synchrocyclotron; SFC: strong focusing cyclotron; SFSC: strong focusing synchrocyclotron.

Notes:

a) We have not included the following proposed machines: ING at Chalk River, Canada; SOC at Oak Ridge, U.S.A.; Omnitron at Berkeley, U.S.A.

b) We have assumed that VARC and Berkeley will not be improved by 1972 although improvement programmes are being discussed.

c) We have considered only the macro duty-cycle. The micro duty-cycle is important but is a complicated subject. In strong focusing machines (Indiana, Zürich, Triumf) it will be between 3 and 10%, depending on modifications made to the R.F. In proton linear accelerators (Los Alamos) it is about 5% but it can be improved by increasing the energy spread in the beam. For synchrocyclotrons it is about 100% for internal targets but as low as 20% for the extracted beam. For electron linacs it is about 5%, but because of the very high frequency used for accelerators, very few detectors will be sensitive to this microstructure.

d) The improvement of the Dubna SC is likely to take place around 1973; the scheme will be similar to the Columbia one.

APPENDIX B

	No of Physicists Depending on SC		Others Showing Interest for 2 or 3 years hence
	Long Term > 3 years	Short Term < 3 years	
CERN			
Staff, Fellows	14		
Paid visitors	9		
Austria	-	-	-
Belgium	7	-	4
Denmark	5	-	-
France	12	-	4
Germany	27	4	5
Greece	-	1	-
Italy	4	4	5
Netherlands	-	-	4
Norway	2	-	-
Sweden	13	-	-
Switzerland	7	-	6
Spain	-	-	-
United Kingdom	3	3	4
Totals	103	12	32

Notes:

1) Figures refer to September 1968.

2) Physicists not supported by CERN are listed according to nationality. Unpaid visitors from non-member states (~3) are included in the total of the country supporting the team of which they are members.

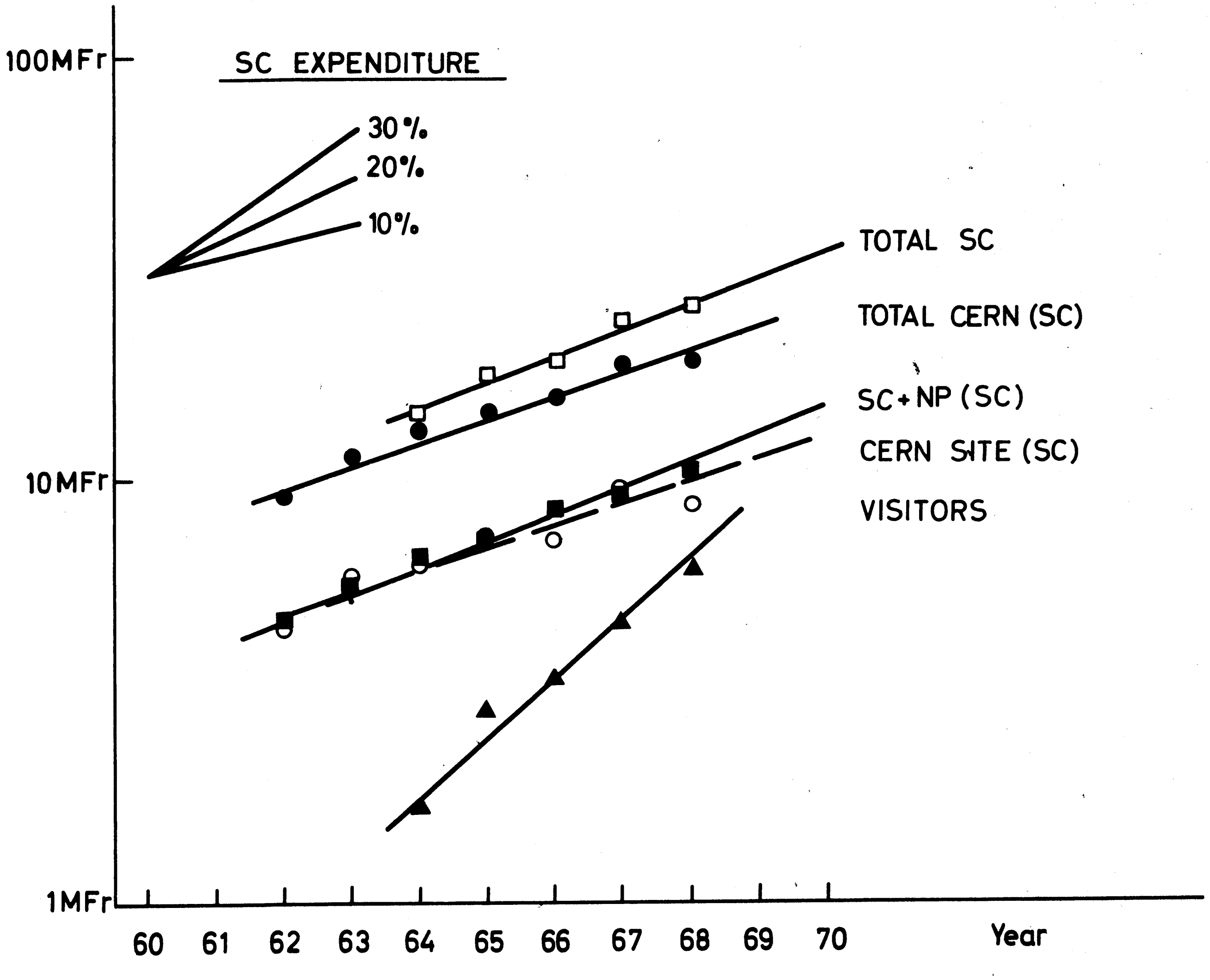
100MFr
10MFr
1MFr
SC EXPENDITURE
30%
20%
10%
TOTAL SC
TOTAL CERN (SC)
SC+NP (SC)
CERN SITE (SC)
VISITORS
60
61
62
63
64
65
66
67
68
69
70
Year

FIG.1.