Love, S. Ozaki, D. Potter and L. C. L. Yuan: A High Capacity Digital Data Handling System for Use with Counter Hodoscopes and Digitized Spark Chambers in On-Line Computer AGS Experiments, BNL 852 (T-338), (1964); S. J. Lindenbaum; Proc. Conf. on Instrumentation for High Energy Physics. CERN, 1962 (North-Holland Publishing Co. 1963) p. 297.

(2) R. R. Rau and R. P. Shutt: Experimental Program Requirements for a 300 to 1000 BeV Accelerator and Design Study for a 300 to 1000 BeV Accelerator, BNL 772 (T-290), (1961, Revised December 1962), pp. 76-80; L. C. L. Yuan: Nature of Matter - Purposes of High Energy Physics, BNL 888 (T-360) (1965), pp. 135-138; Proposal for Construction of a Cryogenic Bubble Chamber of 14 foot Diameter for Use at the Brookhaven AGS, BNL 8266 (R.) (1965).

(3) R. Meunier and J. P. Stroot: Experimental Program Requirements for a 300 to 1000 BeV Accelerator and Design Study for a 300 to 1000 BeV Accelerator, BNL 772 (T-290), (1961, Revised December 1962) pp. 88-89.

(4) P. A. Piroue and A. J. S. Smith: Time of Fligt Measurements Using the r. f. Structure of the Princeton-Pennsylvania Accelerator Beam, Proc. Purdue Conf. on Instrumentation for High Energy Physics, 1965.

(5) P. Franzini, B. Leontic, D. Rahm, N. Samios and M. Schwartz: Phys. Rev. Letters *14*, 196 (1965).

(6) F. Gursey, T. D. Lee and M. Nauenberg: Phys. Rev. *135*, B 467 (1964).

(7) A. I. Alikhanian, T. L. Asatiani, E. M. Matevosian: Zhurn. Eksp. Teoret. Fiz. *44*, 773 (1963); A. I. Alikhanian, M. S. Kozodoev: Proc. Int. Conf. on Instrumentation, Berkeley, 1960; Notes on the Loeb Lectures given by A. I. Alikhanian at Harvard University in February 1965.

(8) F. Turkot: private communication; E. Bleser, E. Anderson, G. B. Collins, T. Fujii, S. Heller, J. Menes, F. Turkot, R. Carrigan, R. Edelstein N. C. Hien T. McMahon, I. Nadelhaft and Yu. D. Prokoshkin: Proc. Purdue Conf. on. Instrumentation for High Energy Physics, 1965.

(9) L. S. L. Yuan: Nature of Matter - Purposes of High Energy Physics, BNL 888 (T-360) (1965) p. 142.

(10) A. I. Alikhanian F. R. Arutyunian, K. A. Ispirian and M. L. Ter-Mikaelian: Soviet Phys. JETP *14*, 1421 (1962).

DISCUSSION

JONES: While I agree with all that Dr. Yuan has said, I was surprized at the omission of mention of photographic spark chambers coupled with automatic film analysis. Such systems are equivalent to wire or sonic chambers in their logic and systems organization, and it can be expected that photographic technique will continue to play an increasing role in more complex spark chamber experiments, for example those in which the trajectories of two or more particles must be followed through a magnet.

YUAN: I fully agree with you that photographic spark chambers coupled with film analysis will continue to play an important role in the future experiments, but the time of my presentation is extremely limited and I can only cover the more general aspects of the subject and cite the few cases which I personally feel can illustrate well the points I mentioned. I am sure that I left out many other specific cases of equal importance.

THE CPS IMPROVEMENT PROGRAMME

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INTRODUCTION

At the beginning of 1964 we began exploring possibilities to improve the CPS as an experimental facility. The improvements considered can be divided into two groups:

A. Increasing the CPS intensity

B. Extending the experimental areas.

A. PROJECTS TO INCREASE THE CPS INTENSITY

The maximum intensity of slightly above $1 \cdot 10^{12}$ protons/pulse is already limited by space charge effects and a further factor of two really seems to be the most that can be expected from the machine in its present state.

To raise the intensity above that limit, two projects are being studied:

I. to increase the mean intensity (per second) by increasing the repetition rate,

II. to increase the intensity per pulse by using a higher energy injector.

Realisation of both projects should result in an increase of the mean intensity by a factor of about 15 above the maximum obtained so far.

The basic assumption governing the scope of the projects has been that the radiation problems accompanying the increased intensity should be soluble without drastic machine alterations.

Project I. Increased repetition rate (1)

1. *Modifications to the magnet power supply.* The aim is to make possible, at any given momentum and flat top length t_t, a shorter repetition time T.

In Fig. 1

$$T = t_r + t_t + t_f + t_d$$

where t_r and t_f are respectively the rise and fall time of the magnetic field and t_d the dead time between cycles.

At low and medium momenta the repetition time is limited by t_r, t_f and t_d, the first two being inversely proportional to the rate of change of the magnetic field and hence to the magnet voltage. This voltage is limited by the coil insulation but, by adding a second, power supply, it is possible to double the total magnet voltage without increasing the maximum voltage to ground of the coils (Fig. 2). The dead time t_d depends on the minimum recovery time of the supply system and will not exceed the present value of 250 ms.

At higher momenta and long flat-top times, the repetition rate is limited by the mean power available from the power supply. By replacing the power supply and increasing the capacity of the magnet cooling heat exchangers the mean magnet dissipation can be raised from 1600 kW to 2800 kW without increasing the water flow or exceeding the maximum allowed temperature rise in the coils (20 °C, compared with an actual rise of 11 °C at present).

Finally, at momenta above 26 GeV/c and for long flat top times, the repetition rate is determined by the dissipation in the pole face correction windings.

Fig. 3 shows the improvements that will be obtained for different cycles. It is clear that they encourage the use of the CPS at higher momenta.

Table I compares the ratings of the new and existing power supplies:

TABLE I

	Existing supply	New supply
Magnet dissipation	1.6 MW	2.8 MW
Driving motor	2.6 MW	5.5 MW
Alternator	18 MVA mean 47 MVA peak	45 MVA mean 95 MVA peak
Converter set	1840 A mean 2230 A rms ± 3 kV One	2500 A mean 2950 rms ± 3 kV Two in series

The new power supply is now out for tender (2) and it is hoped to place the order at the end of this year.

The new supply will be installed in an extension to the existing power house and is scheduled to be commissioned in mid 1968. The existing supply will not be disturbed so that it should be possible to make the change-over in a normal 4-6 week shutdown.

2. *Modifications to the r.f. accelerating system* (3) (4). Since the magnet voltage and hence $\dot{B}$ are doubled, the energy gain per turn has also to be raised, from 50 keV to 100 keV per turn.

Doubling the voltage per turn and preserving the present frequency ratio of 3.3 cannot be achieved with the existing accelerating system. If, however, the magnet rate of rise is left at its present value for the first 80 ms after injection and then doubled, the additional r.f. requirements are considerably simplified without the magnet repetition time being appreciably affected.

At about 80 ms we find two things in our favour. First, the cavity frequency has risen from 3 MHz to 8.7 MHz so that a frequency swing of only 10% is required from the additional accelerating voltage (Fig. 4). Secondly, the phase width of the accelerated bunch has shrunk from about 180° to less than 90° and so can be contained within the smaller stability envelope that is available nearer the crest of the accelerating wave. Phase focusing suffers, but this effect can be compensated by introducing a second harmonic component into the r.f., which serves to increase the slope in the region of the synchronous particle.

Instead then of simply doubling the peak r.f. voltage (at present 100 kV per turn) and maintaining the 30° stable phase angle, one adds 50 kV peak voltage per turn by means of narrow-band second-harmonic cavities and works nearer the peak of the distorted waves shown in Fig. 6b.

Figures 5 and 6 show the accelerating voltages and buckets just before and just after the second harmonic cavities are switched on at 80 ms. It can be seen that the shaded bunch, which filled the bucket at injection, has shrunk sufficiently to be held in the new smaller bucket.

Taking into account that only short (1 m) straight sections will be free, it turns out that the mean power requirements for a ferrite-loaded tuned cavity would be about the same as for a cavity fixed tuned to 20 MHz. The disadvantage of the fixed tuned cavity is the initial power pulse of about 15 times the mean power (see Fig. 4). This disadvantage is compensated for by the simple layout of an uncooled cavity without tuning system and the correspondingly smaller effort involved in its development and construction.

Three of the high Q fixed tuned resonators, shown in Fig. 7, will be used. In order to feed the cavity with a sinusoidal current from a low impedance source a triode class B, push-pull output stage will be used coupled symmetrically to the cavity.

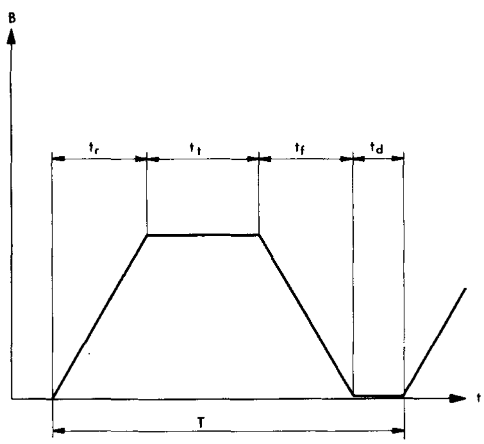

Fig. 1 - Magnet cycle.

3. *Shielding and other modifications.* For this increase of intensity it is only necessary to improve the shielding above the South target area and the concrete bridge between North and South halls (which is too thin even with the present intensity under some targetting conditions and is now being thickened).

Other modifications are rather minor, consisting mainly in replacing power supplies on which higher mean ratings or faster rise times will be imposed by the faster cycles.

Project II. Increased accelerated beam intensity

1. *New injector.* We first considered replacing the existing 50 MeV linac by one of a higher energy (5) (6). Since the major part of a linac cost is proportional to its energy, a rather wide range of energies can be found within which the balance between cost and results looks reasonable. A 200 MeV linac is being studies at CERN in connection with the 300 GeV project (7), and for energies much above this figure, the efficiency of a drift tube structure falls so rapidly that the use of a second type of structure for the high energy end

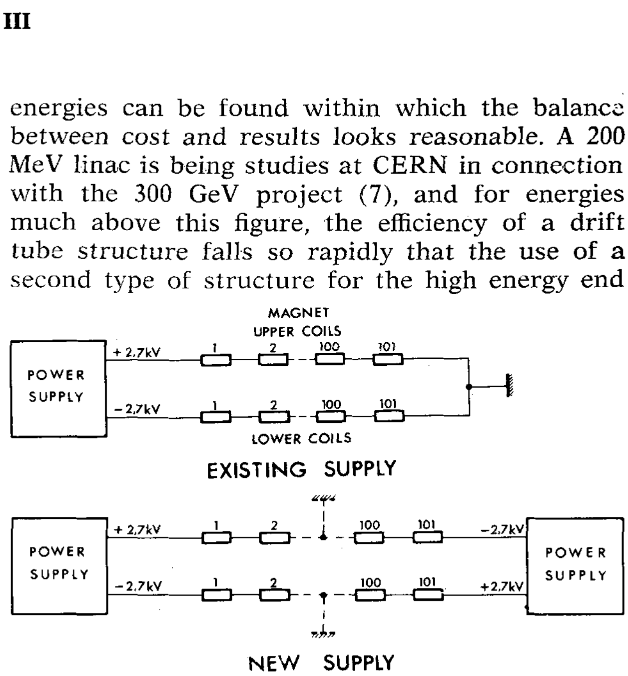

Fig. 2 - Magnet power supply connections.

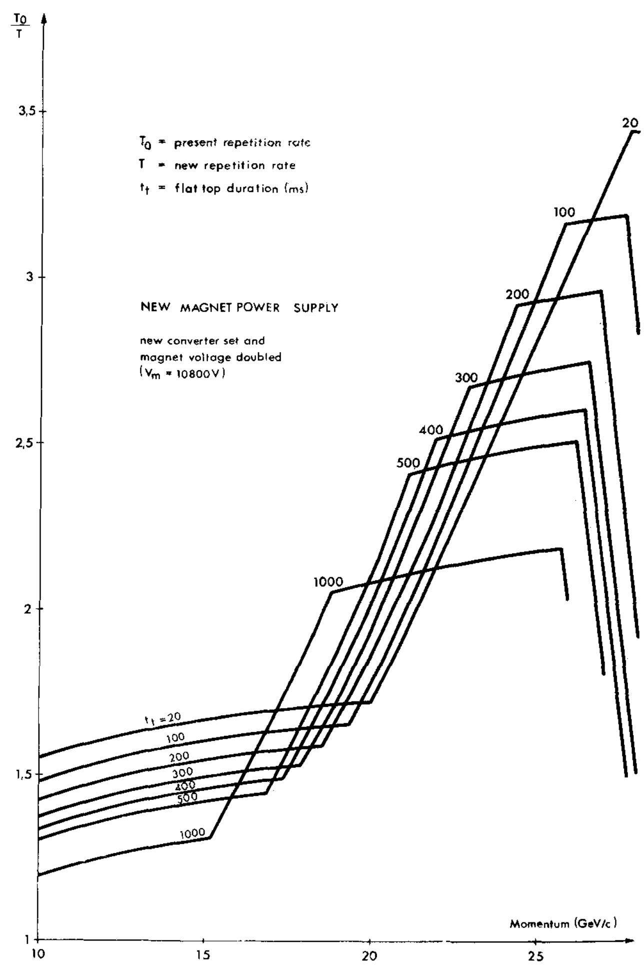

Fig. 3 - Increase of PS repetition rate.

is obligatory . For these reasons a linac of about 200 MeV has been considered for the CPS.

Assuming that the accelerated beam in the synchrotron is proportional to the space charge limit at injection, the 200 MeV linac should give a factor of 4-5 increase. Coupled with an average increase of 2.5 in repetition rate with the new power supply the total gain to be expected is a factor of 10-12 over the best intensity accelerated so far.

Following the «bootstrap» proposal of Maschke et al. (8) this and various forms of booster synchrotron have been considered, and the choice now lies between the linac and the Twin Accelerating Ring Transfer (TART) System to be reported on later in this conference by Hardt (9) (10).

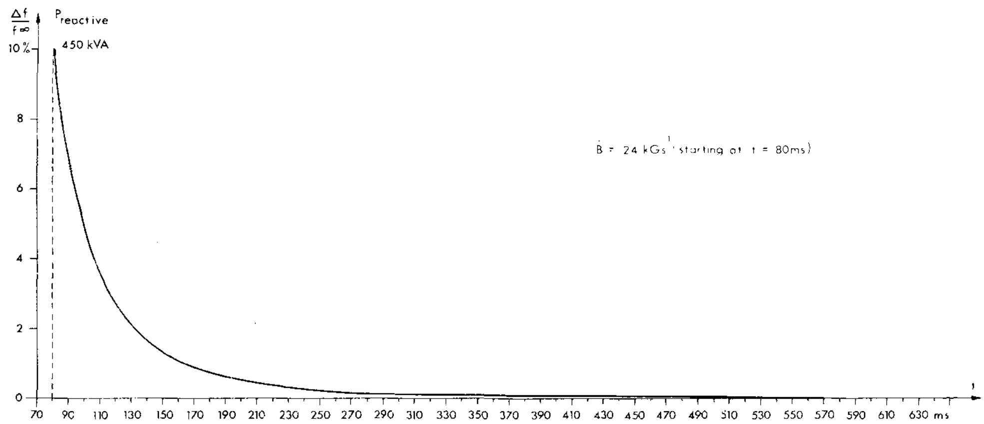

Fig. 4
Frequency variation
and reactive power
of second
harmonic cavities
as function of time.

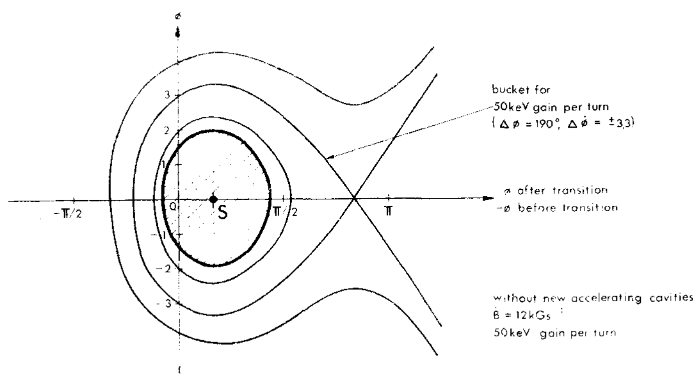

Fig. 5 a - Bunch and buckets 80 ms after injection.

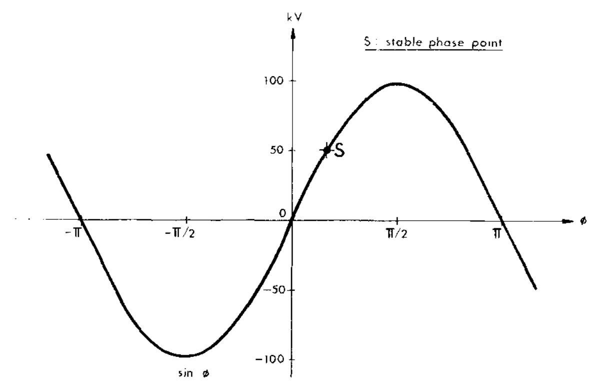

Fig. 5 b - Accelerating voltage.

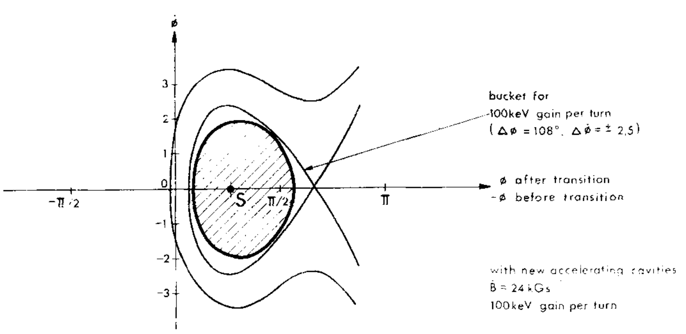

Fig. 6 a - Bunch and buckets 80 ms after injection.

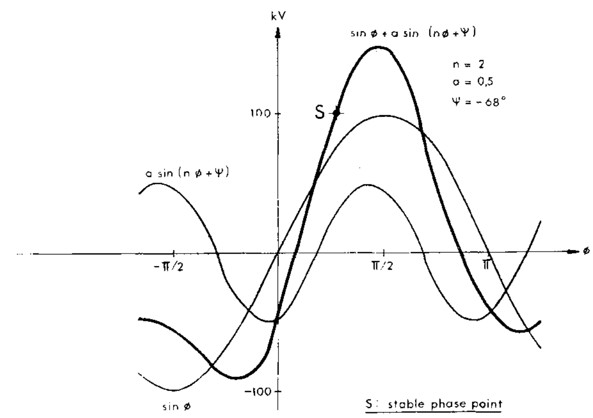

Fig. 6 b - Accelerating voltage.

Preliminary estimates do not show significant differences in cost; it is planned to make the choice at the beginning of next year and to start the 4 year construction period in mid 1967.

2. *Shielding modifications and exploitation at high intensity.* With an increase of the mean intensity above a factor of 10 it will be necessary to thicken the top shielding, at present 3.3 m earth equivalent, over at least the target areas and preferably over the whole ring (11). The ring structure is, fortunately, able to support a further 1 metre layer of earth which should provide an extra attenuation of about 3 to 3.5 and therefore be sufficient.

The more difficult problems are radiation damage to the synchrotron and high levels of induced activity in the ring. Clearly, the best way of reducing these effects is to remove all accelerated protons from the ring with high efficiency ejection systems. The efficiency of the new slow ejection system is 70%, in agreement with theory, and the improved version (12) should have an efficiency of 95%; the level in the ring can therefore be held below what is found to be a reasonable working limit by limiting internal targetting.

By accepting about 10% lower internal target efficiencies it should be possible to concentrate about 90% of the random loss of protons around the synchrotron in a defined dumping zone (13). Thus the hottest region should be limited to the dumping zone and the region immediately downstream from internal targets. In these areas some remote handling will be necessary; a single arm manipulator is on order and will be mounted with a 2 ton hoist and 3 movable TV cameras on the existing ring crane rails. It will be interesting to discover how much this device will do and how long it will take to do it.

Independently of the improvement programme efforts are being made to reduce maintainance time, by improving materials used (14) and design of equipment near the beam. As an example, the septum magnet for the East Area Ejection System is designed as a plug-in unit and can be removed in about 10 minutes.

B. EXPERIMENTAL AREAS

There are now two experimental areas (Fig. 8*): of these the South area has been in full operation since 1963, and the East area will become so when the slow ejected beam straight section 62 is in use early next year.

It was originally proposed to increase the area available by extending the East Hall southwards. However, the fact that ejection is now possible from an even numbered *short* straight section (15) has made it possible to lay out a new neutrino area (16) between the East Hall and the NPA building, so freeing normal hall space in the South Hall. The CPS shielding was pierced during this summer shutdown and the area should be in operation in the second half of next year, using the CERN 1.1 m^3 HLBC as detector. Later the 10 m^3 HLBC, Gargamelle, a joint project of the « Laboratoire de l'Ecole Polytechnique de Paris », the « Laboratoire de l'Accélérateur Linéaire de la Faculté des Sciences à Paris » and of the « Département Saturne du Commissariat à l'Energie Atomique », will be installed behind the CERN chamber. The decay tunnel will be an earth shielded corrugated steel tube about 3.5 m in diameter, large enough to accommodate the neutrino beam reflector (17) and also an unseparated pion beam for Gargamelle.

The next major increase in experimental hall space will be a 10000 m^2 general purpose hall in France, West of the ISR (18). It will be served with fast and slow ejected beams from the PS and later from the ISR. The PS ejected beam will follow part of one of the transfer tunnels to the ISR and will then continue under the latter, so that access to the ISR will not be limited. It is scheduled to have this hall in use at the beginning of 1970.

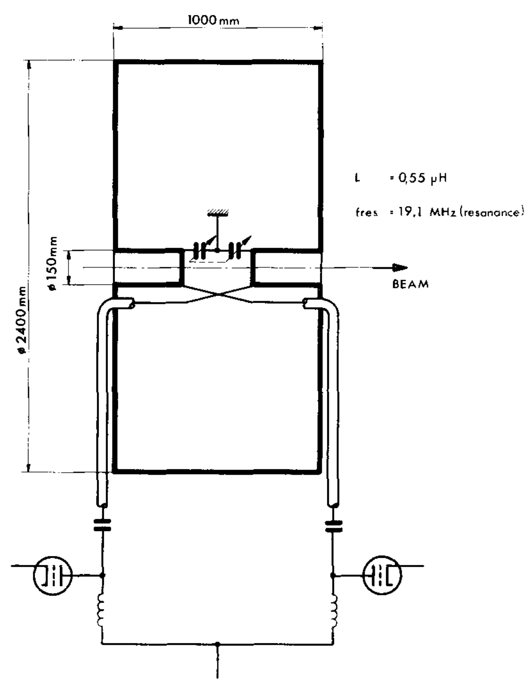

Fig. 7 - Accelerating cavity.

* See Fig. 1 of paper K. Johnsen: *The CERN Intersecting Storage Ring Project, Session IV.*

REFERENCES

(1) MPS Division: Project to increase the repetition rate of the CPS, CERN, report MPS/DL 65-8, (1965).
(2) Spécification concernant la nouvelle alimentation de l'aimant du Synchrotron à Protons du CERN, CERN, MPS/Int. EE 65-10, (1965).
(3) H. Fischer: Proposed accelerating units for doubling the rise of the magnet field at 80 ms after injection, CERN report MPS/RF 64-13, (1964).
(4) H. W. Isch: Oscillations synchrotroniques dans le PS avec deux tensions d'accélération d'amplitude et de fréquences différentes. CERN report MPS/RF 65-2, (1965).
(5) C. S. Taylor: 200 MeV injector for the CERN PS, CERN report MPS/LIN 64-1, (1964).
(6) C. S. Taylor: Morphology of a new injector, CERN, report MPS/LIN 64-4, (1964).
(7) CERN Study Group: Report on the design study of a 300 GeV Proton Synchrotron, CERN, report AR/SG 64-15, (1964).
(8) A. W. Maschke et al.: A Bootstrap method for 500 MeV injection into the AGS, BNL Accelerator Department (AGS), report AWM-3, (1964).
(9) W. Hardt: A circular injector for the CPS (TART Scheme), CERN, report AR/SG 65-10, (1965).
(10) W. Hardt: Slow cycling injection method for intensity improvement of the CPS (TART Scheme), Paper presented to this conference, see Session IV.
(11) J. Y. Freeman: PS shielding efficiency and possible modifications for higher intensities, CERN report MPS/CO 64-10, (1964).
(12) C. Bovet: Variation des paramètres de l'éjection lente, CERN report MPS/ DL 65-6, (1965).
(13) W. Richter: Dumping zone inside PS tunnel and remote controlled work in target areas, CERN report MPS/CO 64-9, (1964).
(14) J.H.B. Madsen: Radiation damage, CERN report MPS/ DL 64-28, (1964).
(15) C. Bovet, A. Nakkasyan and K. H. Reich: Slow and fast ejection from a short straight section of the CERN proton synchrotron, Paper presented to this conference, see Session IX.
(16) G. Plass: Outline of the new neutrino area, CERN, report, NPA/65-19, (1965).
(17) A. Asner: Proposal for a focusing system increasing the present neutrino beam flux density, CERN, reports MPS/MA 65-2, (1965); MPS/MA 65-2a, (1965).
(18) F. Bonaudi: Experimental areas and interaction regions of the CERN Intersecting Storage Rings, Paper presented to this conference, see Session IV.

DISCUSSION

TENG: What is the advantage of the second harmonic acceleration over, say, untuned first harmonic cavities?

FISCHER H.: There are 2 advantage of adding the 2nd harmonic instead of increasing the amplitude of the fundamental acceleration voltage:

1) The bunch can more easily be matched from the bucket before doubling $\dot{B}$ to the bucket afterwards.

2) Only short straight sections are available for the installation of the new cavities. The shunt impedance is twice as high for the 2nd harmonic (for the same length) as compared to the fundamental. That means we will gain a factor 2 in power.

STATUS REPORT OF THE ITEP PROTON-SYNCHROTRON OPERATION

L. L. Goldin, K. K. Onosovsky, V. S. Kuryshev, P. R. Zenkevitch, L. Z. Barabash, Yu. A. Bolshakov, M. A. Veselov, V. P. Zavodov, I. P. Kleopov, Yu. Ya. Lapitsky, P. I. Lebedev, A. I. Mosharov, N. I. Natchaty, V. I. Nikolayev, G. F. Orlov, Yu. S. Pligin, L. N. Plyashkevitch, N. I. Porubai, Ye. V. Pushkin, L. I. Sokolov, A. N. Talyzin, V. S. Khoroshkov and V. A. Schegolev.

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(Presented by K. K. Onosovsky)

The ITEP accelerator (1) operates at present on two-week schedule. The accelerated beam is given for the experiments from 22, tuesday up to eight, friday of the next week. The mean intensity in $4 \cdot 10^{10}$ particles in the pulse the maximal is $6 \cdot 10^{10}$.