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STATUS OF SOME U.S. PARTICLE ACCELERATORS IN SPRING 1966

(Notes taken mainly on trip in April 1966)

I. Specific Topics of More General Interest

1. Introduction

The present notes follow the style of the last notes[1], thereby bringing them up to date. Laboratories and items visited are:

Argonne National Laboratory : ZGS

Brookhaven National Laboratory : AGS, Cosmotron

Cambridge Electron Accelerator Laboratory : C.E.A.

Cornell University : 2.2 GeV and 10 GeV E.S.

Los Alamos Scientific Laboratory : PHERMEX and LAMPF Design Study.

Lawrence Radiation Laboratory : Bevatron and 200 GeV PS Design Study.

Midwestern Research Association : 180 MeV Electron Storage Ring.

Princeton-Pennsylvania Accelerator : P.P.A.

Stanford Linear Accelerator Center : 2 mile Linac and 3GeV Storage ring.

Subjects considered in the subsequent paragraphs are:

- New accelerators
- Developments in beam extraction
- Trends in computer control
- New technologies (superconducting magnets, handling of high intensity beam)
- Studies of new types of injectors.

Details of particular accelerators visited are given in section II.

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2. New Accelerators

2.1 Existing or under construction

The CORNELL 2.2 GEV E.S. is operating regularly, the erection and commissioning having taken only $3\frac{1}{2}$ months. The linac, magnet power supply and original R.F. system are the same as used for the 1.3 GeV machine, as is the bulk of the choke (the old 300 MeV synchrotron) to which two spare magnet units were added. A more powerful R.F. system (working at 477 MHz) has just been commissioned and 2.0 GeV have been reached. A resonant extraction scheme is being worked on.

The tunnel for the 10 GEV E.S.[2)] is nearly fully excavated, and half of it is ready for installation. They have successfully dynamited pieces of rock in situ whenever these prevented the special tunnel drilling machine from working properly. Alignment of the tunnel is to within a few centimeters (as checked by drilling holes from the surface). Total drilling time (with interruptions) about 6 months (~900 m circular tunnel 3.3 m wide + ~300 m straight tunnel somewhat narrower). Tunnel walls are build up with reinforced concrete prepared during application by high pressure spraying (gunite). This technique requires no forms nor scaffolding, and permits to finish neatly not only the tunnel walls (of various profiles) but also the necessary alcoves etc. The production of the magnet units is progressing at the rate of about 2 units/week. They will be directly installed in the ring. Hot setting shell resin 828 is used for coil insulation and Hysol R 92039 for repotting [This helps to keep the magnet together, which is otherwise mainly held by some gluing and the external (encasing) vacuum chamber]. Outgassing takes place at 50°C, for 14 days. The magnets are designed as plug-in units (weighing 6 tons), complete with power supply chokes and capacitors. Realignment will be by remote control according to signals from pick up stations (1 per straight section). Vacuum seals are all-metal CONO-seals; pumps NCR oil diffusion pumps.

The LOS ALAMOS PHERMEX[3)] accelerator is a high-current, three-cavity, standing wave linear accelerator producing a beam exceeding 70 A at about 20 MeV for 0.1 or 0.2 μsec , used for flash radiography. (Instantaneous beam power 1400 MW). The electron gun injector provides 165 A at 300 kV. The cavity vessel is 11.3 m long and 4.6 m in diameter, the cavity Q 130 000. It is now powered (at 50 MHz) by 9 one MW RCA A-15034 shielded grid beam triode amplifiers (originally only 6). The amplifiers are located about 100 m from the cavities because of hasards connected with the experiments. Power is transmitted via 35 cm dia transmission lines. A vacuum of 10^{-8} Torr is maintained using Varian Vac-Ion pumps, the first 1000 liter/sec pumps of this type employed.

The SLAC is nearing completion with about 10% of the total length already operational. Performance is roughly as expected. The switchyard and experimental halls are also being readied. Start up is supposed to begin in May or June 1966 and experiments soon after. Besides the usual electron scattering and photoproduction experiments (in beam A), notably a muon experiment and bubble chamber experiments (using L. Alvarez 72" chamber) in a R.F. separated beam are planned from an early stage. Advantages claimed (compared to AGS or CPS) are "point" production of muons (in target), low background in π^+ beams (no overwhelming proton fluxes) and good anti-proton fluxes. K-fluxes may be marginal, as only one burst may be used (the next occurs 2.8 msec later, too late for obtaining good bubble chamber photographs), i.e. the K-flux/sec has to be 360 times higher than at the A.G.S. or C.P.S. to be competitive. The problem of disposing of the 2 MW of mean beam power appears to have been solved as has the radiation "hardening" (See 5.2 below). The fact that both schedule and budget so far are pretty close to the forecasts is said to be also beneficial to the standing of the wider accelerator building fraternity.

For curiosity the electron microscope designed by A. Crewe at Argonne should also be listed under this heading. A departure from the conventional microscope design, it consists simply of a particle accelerator, a target and a detector (scintillators and photomultipliers). This microscope is potentially capable of resolution of nearly 1 Ångstrom. To approach this value from the 80 Angstroms already obtained, improved quadrupole lenses are now under design.

2.2 Planned

The national 200 GEV accelerator is supposed at present to be built in one of six sites, located (from West to East) at Sacramento (California), Denver (Colorado), in the larger Chicago area (3 sites), and at Brookhaven National Laboratory. Funds will be requested as soon as the site is decided upon. Various design changes have been made[4] since the original proposal [5]. These changes include notably optimisation of magnet units for the new (lower) electricity costs, and relocation of the r.f. cavity ferrite tuners (outside the ring tunnel). Injector problems were also studied further (see 6.below).

The design for the LOS ALAMOS MESON PHYSICS FACILITY (LAMPF)[6] is progressing well. The Alvarez section may conceivably be changed to multistem drift tubes[7], the 800 MHz section has definitely be changed from a clover leaf to an outside-coupled structure and computer programmes have been re-written[8]. The operation will be based on the use of a computer[9] (see 4.below).

3. Developments in beam extraction

External beams of primary particles from synchrotrons are listed below, including some European accelerators for completeness

	Type of extraction			Comments
	Energy loss target	Resonant extraction	Direct (fast) deflection	
A G S		1 being built (Q = 8 2/3)	2	
Bevatron	1			Resonant extraction under study
C E A		1 (Q = 6.5 non-linear)		2nd being considered
Cornell		1 being built ($\frac{1}{2}$ integral non-linear)		
Cosmotron	3			2 ejection systems
C P S		2 (Q = 6.0 non-linear)	2(3)	3rd fast ejection being built
D E S Y		2 (Q = 6.5 non-linear)		
Dubna P.S.		1 (Q = 0.5 linear)		
Nimrod	1			First achromatic system. Resonant ejection being studied
P P A		1 (Q = 2/3)		beam being installed
Saturne	1			
Z G S	1			2nd planned
	7	6(9)	4(5)	

From this table it appears that resonant beam extraction is becoming more and more popular : The PPA people changed from a target-loss-method design to use of a 2/3 resonance: at the Bevatron this change is being studied and at the Z G S it is being considered. A new development is use of this type of resonance for single turn or few-turn extraction. Basically, the idea is to kick the beam (partially or entirely) over the closed separatrix[10] using a fast kicker[11] or r.f. knock-out[12] [13]. Advantages claimed are lower intensity of burst, higher repetition rate and lower kicker strength than in the case of conventional fast extraction. Various schemes for shaping the beam in betatron phase space have been studied[10] [11] and a r.f. dipole-quadrupole combination is actually in operation for this purpose at the P P A [14] [15] (see II. below, for more details). On the theoretical side, the perturbation approach has been brought closer to the understanding of practical designers [16] and the vertical stability of a 1/3 or 2/3 resonance has been compared to that of a 3/3 resonance[17]; the conclusions reached are not universally agreed though.

Linear (half-integral) resonances have been studied extensively in view of their use for decaturn extraction from a booster synchrotron [18) 19) 20) 21)]. As it turns out, with the septum and aperture width available, acceptable efficiencies can be obtained for the range of turns considered (5 to 30). The hardware problems look reasonable. To equalise the number of protons extracted on subsequent turns, modulation of the strength of the perturbation[18) 20)] or of the closed orbit[21)] is envisaged. If only a small number of turns is required and the beam is wide enough, reverse multiturn injection seems preferable though[20) 22)].

On the hardware side the magnetic shielding of the end stray field of the PPA extraction magnet was noted ($\int Bdl$ = 1 gauss m outside, 14 k gauss x 1.35 m in gap) as well as their quadrupole RF knock out. At MURA a special Ω shaped 100 kV storage line is used to power a short-circuited kicker magnet without need for a delayed switch to guide the reflected wave into the dumping resistor. The price to be paid is a line of twice the length and twice the power consumption (of no consequence if line short and consumption low). At SLAC studies are under way to select the most suitable ferrite and best surface treatment for a kicker magnet to be placed in ultra high vacuum [23)]. The design of high power backleg windings for orbit deformation in connection with fixed ejection magnets has been refined to minimize creation of stopbands[24)].

4. Trends in computer control

As the writer is no specialist in this field and J.H.B. Madsen is visiting the USA currently, only a few general impressions will be given for the sake of completeness. The dominant one is that control computers are now considered a normal way to take over large parts of accelerator operation. Whereas the ZGS computer control was added on to a more or less classical control system (the accelerator can in fact be operated manually), the trend is to incorporate a computer as indispensable part of the system (as in LAMPF). The reasons for this seem to be

- high reliability of modern computers
- availability from industry of special purpose control computers (many I/O channels with priority interrupt, good-sized memory, more restricted central processing unit than general purpose computers)
- progress in the understanding of centralized data handling
- high number of controls in the case of multi-hundred GeV accelerators.

The tasks assigned to the computer include (not in order of importance) monitoring of interlocks (as distinct from the interlocking itself), multiplexing for signal transmission (by time sharing), making a wide variety of measurements (sampling times being as short as 50 n sec) and furnishing programmed reference values for all sorts of control circuits. It is generally accepted that the computer can only in exceptional case by used to close a feedback control loop because it is too slow for most accelerator applications (bandwidth ~ 500 Hz, 1 kHz in exceptional cases).

Control computers are at present in use at the ZGS[25] and will be used shortly for controlling the SLAC switchyard[26]. Studies and experiments are going on notably at BNL[27], LRLUC[28], and LASL[9]. If successful, their computer will also be used for receptioning the LAMPF modules.

5. New technologies

5.1 Superconducting magnets

As in the case of the computer control, the main impression was that superconducting magnets have come to stay. A study made at ANL for the magnet for the 12 foot H.B.C. showed that the total ten-year cost of a classical magnet would be 6.4×10^6 (electricity cost 0.008 $/kWh) as against 2.6×10^6 $ for a superconducting-magnet.

At the time of the visit the ANL helium bubble chamber (25 cm dia and 35 cm long) was doing its first physics run (stopped K's) and behaving reasonably well. The maximum magnetic field is 41 k gauss, the short term stability 0.4 % and the long term stability an order of magnitude higher. The liquid He consumption is 6 liters/h. corresponding to about 5 watts (at liquid He temperature). At BNL a selenoid for the measurement of the Ξ^- magnetic moment has produced a field of 117 k gauss and 138 k gauss is anticipated once the central bore is changed to a cylindrical one (of 38 mm)[29]. They also study the use of a superconducting magnet for a A.G. synchrotron. At MURA use of superconducting surfaces for shaping magnetic fields of the FFAG type is under study[30].

5.2 Handling of high intensity beams

Points discussed are (i) avoidance of beam loss, (ii) observation of beam loss, and (iii) beam clippers and stoppers, the problem of radiation resistant magnet coil insulation being assumed to have been solved.

At LAMPF the idea is to work with so small an R.F. bucket in the first accelerator section (up to 5 MeV) that all the beam loss occurs up to that point (all being 99.9 % or so) [31]. At SLAC the injection will automatically be stopped if the beam wanders off.

As regards the observation, the SLAC programme[32] is nearing completion. In addition to using radiation resistant materials (metals, ceramics, mica asbestos insulation, non-browning fused silica for windows, mirror optics for TV cameras etc.) attention had to be paid to avoid corrosion by nitric acid formed in the air by radiation (up to 2 l/day anticipated in switchyard). Because of this contacts are gold plated, mirrors chromium plated and special paint is used. Many parts, including zinc sulfide screens and electric motors are easily exchangeable by semi-remote operation (man with tool on long handle standing on upper floor).

Constructed along the lines reported earlier[1], the slits (essentially momentum slits which may have a wide aperture), collimators (narrow beam defining apertures) and beam dumps are all nearing completion. One of the kicker problems was the design of the metal windows for the 2.2 MW water filled beam dumps.

During tests in an electron beam providing heat fluxes of 2-8 kW/cm2 it was found that Al and Cu plates 1.5 - 6.0 mm thick were pitted severely due to compression shocks (up to 2.000 atm. produced by water vapour bubbles) causing work hardening and giving away of the brittle material. This was cured by plating the Cu with Ni (0.02 mm thick) and the Ni with Cr (< 0.01 mm thick), the Ni taking up elastically the difference in thermal expansion. This surface is expected to stand a power transfer of about 2 kW/cm2 into the water dump. Looking at the various elements[33] noted in particular : the backlash-free remotely controlled slit adjustment by means of a pentograph type system. Water conduites are either of 6061 Al alloy or of 316 L stainless steel. The ph value of the water is kept at 5.5 and no organic seals in pumps etc. are tolerated. The water flow in a 2.2 MW dump is 2000 l/min. The steel supporting frames are painted with radiation resistant paint which has been tested with doses up to 10^{13} ergs/gr. (Sperex Co, Los Angeles, Cal., 20 $/l.).

6. Studies of new injectors

The TART proposal[34] has stimulated Berkeley to design a 4-ring injector for the CPS called QUART[35]. In addition to a fast cycling booster and the FFAG injector[36] a separated orbit cyclotron and a synchrocyclotron [38] claimed to be inexpensive have been contemplated as new injectors for the ZGS . Studies at BNL include a classical slow-cycling booster synchrotron. The vertical stacking required could be done either outside (by exchanging vertical phase space for horizontal one[39] or inside the synchrotron [40] [41]. The LRL Group has developed a computer programme for comparing the various types of synchrotrons.

II. Status of particular accelerators

1. AGS

Operating regularly at the 10^{12} p.p.p. level, the AGS has now 2 fast external proton beams, one into the (neutrino) South West area (from B 10) and one into the North area (from I 10), the latter being used to feed the R.F. separated beam. The slow external proton beam (from F 10) will not be in use before 1967. Emphasis is on raising the intensity (10 turn injection, various improvements for increasing the trapping efficiency etc.) and beam sharing (double pulsing of RBD, single bunch ejection etc.).

The long term development is done by the Conversion Division[43]. Points of this active and diversified programme on which the writer can give information include the 200 MeV Linac, the new AGS R.F. system and the vacuum system.

2. Bevatron

Person seen : W.D. Hartsrough. In the little time available *) no large changes were noticed, except the work on a new experimental area (towards engineering building). Because of lack of funds, this will first have only an overhead crane (on rails supported by pillars, no gantry crane), but no roof.

Also as a study for the 200 GeV PS, part of the Bevatron inflector system is run with the aid of a computer.

3. C.E.A.

Persons seen (end 1965) : Professor M.S. Livingston, Messrs T. Collins, J.M. Paterson, G. Voss.

After the explosion probably caused by the breaking of the 30 cm dia 3 mm thick beryllium windows of the 500 l H_2 bubble chamber the experimental hall has been repaired (in particular the roof, total damage ~ 10´ $). At the present time the accelerator is back in full operation. Improvements in progress include a new 70 MeV linac and a new vacuum chamber. They also study the possibility to store simultaneously both e^+ and e^- in the CEA, then let these particles interact in a siding and return them to the synchrotron[44]. To preserve stability some of the damping has to be redistributed between betatron and synchrotron oscillations, which can be done via a control of the quantum radiation (depending on the curvature of the orbit) by means of orbit deforming magnets.

4. Cornell 2.2 GeV E.S.

Persons seen : Professor R.R. Wilson, Messrs L.N. Hand, R.M. Matyas, B.D. Mc Daniel.

For description see I. 2.1 above.

5. Cosmotron

Several 10^{10} deuterons were recently accelerated to full energy in a regular fashion. After 14 years of successful operation, the Cosmotron is now officially scheduled to be phased out by the end of 1966 (i.e. closed down).

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*) The main purpose was to visit the Study Group leading to fruitful discussions and computations with J. Dorst, A.A. Garren, E.C. Hartwig, E.L. Hubbard, G.R. Lambertson, J.M. Peterson and F. Selph.

6. LAMPF

Persons seen : Dr. L. Rosen, Leader, Meson Physics Division,
F. Tesche, Associate Division Leader;
T. Boyd, R.F.
D.R.F. Cochran, Experimental Areas
E. Knapp, Accelerator Structure (Group Leader)
D. Mueller, Liaison with B.N.L.
T.M. Putnam (Group Leader)) Computer Control
H. Butler
D.A. Swenson, Theory, and outside MPD
J. Marshall, Plasma Physics.

The main points have already been reported (I. 2.2, 4 and 5.2 above). The servicing of the experimental area is planned to be done partly by remote handling. In this, the experience gained in other projects at Los Alamos is felt to be very helpful.

Seen among other things in the plasma physics laboratory : 3 M Joule capacitor bank (1 MJ is considered equivalent to 0.5 kg of high grade explosive, as for as destructive power is concerned) and 50 kV 10 MA spark gap switches for connecting this bank to Scilla 4.

7. MURA Storage Ring

Persons seen : F.E. Mills; R.S. del Castillo, R. Johnsen, C.H. Pruett, D. Rowe, S. Snowdon.

Strictly speaking this ring should be classed as a small new accelerator as the electrons (or positrons) are injected at 50 MeV (from the existing 50 MeV FFAG electron accelerator) and accelerated to about 180 MeV. [To get more (adiabatically shrunk) beam into the ring] . The ring diameter is about 3 m, AG focusing vertically by bending magnet edge fields, horizontally by lenses. The oval vacuum chamber (about 5 x 10 cm) is made by deforming a seamless cylindrical stainless steel tube (filled with Wood's metal) and electropolishing. The electrostatic pick-up stations may be used for observation or driving, as dipoles or quadrupoles. The development of ejection theory and of the 200 gauss kicker magnet have already been reported (I. 3) as has the superconductivity work (I. 5.1).

Noted in passing : Measurements of characteristics of linac tank model by automatically sliding bead through and plotting results via computer.

8. PPA

Persons seen : Professor M.G. White; J. Kirchgessner, J. Riedel.

The emphasis during this visit was to see the developments in resonant extraction from this 3 GeV C.G. fast cycling synchrotron. (19 cycles/min.). The extraction system uses a 2/3 radial resonance excited by four special excitation magnets[46] placed symmetrically in four short straight sections. The aperture of these current sheet (picture frame) magnets is 6 cm x 18 cm and they are 30 cm long. Left and right side of the magnets are separately powered with a transistor type current modulator, each supplying up to 200 amps (at up to 75 volts). The sum of the currents in the two halfs determines the quadrupole component of the field (used to tune Q_r required value ~ 85 gauss/cm.). The difference of the currents determines the sextupole component, used to drive the resonance. In the centre a value of $\partial B^2 / \partial x^2 = 10$ gauss/cm2 may be produced softening to a uniform gradient of about 25 gauss/cm at the edges. As a result of this "softening" the turn-to-turn amplitude growth rate is not faster than exponential, thereby decreasing the fractional loss on the septum. For extraction the polarity of the sextupole field alternates from one magnet to the next. An additional "in phase" component (no polarity reversal) is used to make the resonance frequency either independent of he radius or strongly dependent (see below). All these elements, power supplies and controls, are installed and working.

The 14 k gauss septum magnet is in the assembly stage. The integrated strayfield is said to be of the order of 1 gauss m achieved by magnetically shielding the gap (giving a total septum thickness of 5 mm) and the end fields. The magnet is periodically pivoted* at 19 Hz with a peak to peak amplitude of the "loose" end of 5 cm. The mechanically resonant hydraulic actuator looks well engineered, as do the bus bar and cooling systems. The beam transport magnets (d.c. and a.c. to follow the 10 % variation in momentum of the proton beam during the desired extraction time of about 5 msec) are being assembled and power supplies being checked out. The beam is hoped to be operational laterthis year.

On studying this system it was found that the small betatron amplitudes (2 mm at 3 BeV) make it somewhat difficult to control the spill and render it uniform in time. To improve this state of affairs, a range of betatron oscillation amplitudes and randomly distributed phases are generated by an "Oscillation driver" as follows. A transverse magnetic dipole field in resonance with the betatron oscillation frequency (2.7 MHz at 3 BeV) and a transverse magnetic quadrupole field operated at the second harmonic (5.4 MHz) are excited simultaneously[14] for about 100 μ sec, the excitation frequencies being tracked to 0.1% during this time. This R.F. knock out action will both excite coherent betatron oscillation and provide an increased spread in amplitudes. To cause a distribution of the phases, the "in phase" sextupoles are next switched in for about 10 msec, the polarity being the one which increases the dependance of Q on r. The beam is then ready for resonant extraction. Both "knock out" magnets are installed in the PPA and trials have just begun.

For single bunch extraction gating of the oscillation driver with a square wave of about 10 n sec duration has been proposed[12]. The ferrite magnet has in this case to be terminated rather than resonate. A corresponding design study was made but is not yet being executed.

*) A fixed magnet and orbit bump are not practical because of the long betatron wavelength (C.G.P.S.).

Some difficulties were experienced with obtaining smooth beam spills on internal targets by means of R.F. steering. To improve this spill a ferrite dipole magnet feedback controlled from a spill counter [48] was built [49] and has brought about a certain improvement, using self correcting pedestal generators in the control loop [50]. To improve things in a big way a "long spill beam ring" seems attractive [117]. This ring would be located in the synchrotron building and would enclose the PPA : B_{max} = 14 kgauss or less, aperture 1 in. x 3 in.; Q_r = 0.67 and Q_v = 1.1. For the extraction again a combination of a fast kicker and resonant extraction is proposed leading to beam extraction in 3 - 10 turns . Injection into the ring (from the inside) would be along the incoming separatrix of the stable area characterising a 2/3 resonance. Extraction from the ring would be by the same resonance. While it is clear that the sextupole pattern set up for the injection could directly be used for extraction, it remains to be seen whether this simple scheme would permit obtaining the desired burst length. In any event this problem can be solved by reducing the sextupole current to zero in a suitable fashion and increasing it again at a later moment.

Noted in passing : Beam transport bending magnets which can be changed over to either C or H type by shifting the coils and part of the yoke, quadrupoles with staircase poles (for easier machining) the fast cycling bubble chamber and the huge alternator sets for the Stellerator C.

9. SLAC

Persons seen : Professor W.H.K. Panofsky, M. Sands; J. Ballam, H. Brechna, K.L. Brown, G.E. Fischer, J. Harris, D.A.G. Neet, C. Olson, D. Walz.

The overall situation (I. 2.1) and the various technical developments (I. 5) have already been reported. The steering magnets with the radiation resistant coil insulation[45] are coming along too, though some difficulty was experienced in the fabrication process until the manufacturer had learned how to use these different types of insulating materials.

The 3 GeV storage ring studies include working out the injection of both electrons and positrons into the same ring. The problem of turn off of the perturbation, important in this connection, has been solved previously [46].

10. ZGS

Persons seen : R. Adams, A.N.L. Assistant Director
L.C. Teng, Director, Accelerator Department
R. Martin, Associate Director, ZGS
R. Jones, Associate Director, Experiments
E.A. Crosbie, Acc. Physics (Group Leader)
R. Jurgens, Chief mechanical engineer
L. Lewis, Computer Control (Group Leader)
J. Martin, Electronics (Group Leader)

The ZGS is now operating regularly at 5×10^{11} ppp (instead of the expected "theoretical" value of 2.5×10^{12}). The reason for this is being investigated and not yet quite clear. Possibly a resonance may be causing loss of the large amplitude particles shortly after injection. Another potential loss of intensity results from the fact that the planned multiturn stacking in vertical betatron phase space could not be made to work (because of the difficulty to adjust the Q values properly without creating stop bands). As the injected beam cannot easily be brought back to the medium plane, the present injection situation is actually worse than would be expected with straightforward radial multiturn injection.

The damping of the coherent vertical betatron oscillations has been reasonably successful. At present "analogue" programmed circuitry is used to apply the damping force at the right moment to the right bunch (first proposed for, and tried out at the MURA 50 MeV accelerator). This involves fast switching delay lines to keep the signal transmission time in steps with the increasing R.F. An entirely different electronic system (basically of the "phase-look" type) should be ready for trials soon. The information from the pick up electrode will be put into a shift register and control the voltage on the driver electrode at the moment the particular bunch arrives there (i.e. the timing information is taken by counting the numbers of passing bunches.

Present ZGS improvements include extended computer control (see I.3) a new vacuum chamber, and a second external proton beam. They expect to improve the energy-loss type extraction by raising efficiency (through use of a thinner septum) and increasing its versatility (by enabling extraction at lower momenta). The main drive is however for higher intensity.

Noted in experimental hall : 5-6 GeV/c separated K beam, new 1 m heavy liquid bubble chamber with 45 kgauss magnet (power consumption 11 MW), series targets in external proton beam.

K.H. Reich

<u>Distribution</u>

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and as requested to K.H. Reich

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Important notice : All references labeled "Technical Note" are normally not available from the particular laboratory and should not be quoted as such but only as "Private communication" (with the agreement of the author).

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