DESY M - 89 - 06
~~August 1989~~

ICFA

International Committee for Future Accelerators

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BEAM DYNAMICS NEWSLETTER

No. 4

edited by

E. Keil and A. Piwinski

August 1989

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INTRODUCTION

The fifth meeting of the ICFA Panel on Beam Dynamics was held in Novosibirsk, USSR, on 4th May 1989. Since the panel meeting was immediately followed by the Advanced ICFA Beam Dynamics Workshop, the reports on ongoing and planned beam dynamics studies in different laboratories and/or regions were presented during the workshop. Speakers were the panel members and workshop participants from different laboratories. These presentations are published in this newsletter.

The Beam Dynamics Newsletter is not intended to be a substitute for journal articles, conference proceedings, etc. which usually describe completed work. It is rather intended as a channel for describing planned work and unsolved problems. The panel hopes that in this way international collaboration can be stimulated and unnecessary duplication of work can be avoided.

As from the last issue, the mailing list for the distribution of the Beam Dynamics Newsletter is being looked after by Dr. Robert B. Palmer BNL for the USA and Canada, Dr. Anton Piwinski DESY for Europe and the USSR, and Dr. Susumu Kamada KEK for the rest of the world. Please get in touch with the person in your region for matters related to the distribution of the newsletter, and with the editors for matters related to its contents.

Since the Beam Dynamics Newsletter has been published already three times and since it will appear in the future about once per year it now gets a serial number.

Thanks are due to the Directorate of the Institute of Nuclear Physics in Novosibirsk for its hospitality during the panel meeting, and to the PR group at DESY for their help with this Newsletter.

Beam Dynamics and related activities at LNF

(Laboratori Nazionali di Frascati dell'INFN)

(reported by M. Bassetti)

During the last year or so, beam dynamics activities at LNF have beeen addressing mainly four general topics:

a) Injection into ADONE. In connection with the resumption of two-beam operation, the Adone injection system had to be revised and major modifications are under way.

The original multiturn scheme, including a single slow orbit bump, is being replaced by a more standard single turn system with two fast kickers per beam expected to provide a positron injection rate of 10÷15 mA/minute. All components are ready and will be installed during the next scheduled shutdown in September 1989.

In order to better understand the details of the injection process and to accurately predict the injection efficiency beam dynamics studies and computer simulations are being carried out. Fine details of the injection process, such as the fact that a small fraction (≈1%) of the current incoming from the Linac can be stored using solely static field are being investigated.

b) Problems connected with beam dynamics in LIS-A, the 25 MeV superconducting Linac now under construction.

While designing a momentum analysing spectrometer channel for the LISA beam at the level of ≈ 1 MeV, it was found that the code PARMELA (or at least the LNF version) was not treating the transverse chromatic effects of dipoles properly. Once this problem had been fixed it was also found that the code had problems with computing of the bunch length through the dipoles.

The code is being further studied to identify the source of the problem.

c) Dynamic behaviour of beams through superconducting cavities.

The energy of LISA electrons at the first cavities is very low. Consequently the transverse focusing of the accelerating cavities is not negligible and it must be carefully taken into account in order to include the measured longitudinal field values in the computation of the overall focusing system.

An algorithm to exactly compute the particle dynamics for the simple modes TM010 e TM011 has been worked out (in collaboration with L. Palumbo of the University of Rome-La Sapienza). When a detailed electric field map for the LISA cavity will be available the method can be improved to achieve a better accuracy.

d) In the framework of an R&D program aimed at developing RF superconductivity and in-house accelerator research work and in the wake of the feasibility study on a superconducting linear collider to serve as a beauty factory and Nuclear Physics continuous beam facility (not approved by the funding agency), work has started on a smaller scale facility consisting of a highly performant 500 MeV superconducting electron Linac, to employ 10 MV/m cavities with Q values in excess of $2\ 10^9$. A feasibility study on its use, in conjunction with a positron storage ring, to achieve high colliding beam luminosities at the energy of the Φ meson has been started. Invariant emittances in the order of a few times 10^{-6} m are required.
Collaborations with the Universities of Rome, La Sapienza and Tor Vergata and with the INFN Sections of Milan and Genova have been established.

Beam Dynamics activities at the INFN - Sezione di Milano

Laboratorio Acceleratori e Superconduttività Applicata (LASA)

(reported by R. Bonifacio)

ELFA Project (Electron Laser Facility for Acceleration).

ELFA has both a fundamental and a technological novel goal:

i) the fundamental goal is to test with short bunches the existence of three different high-gain regimes at the heart of FEL physics, that have been theoretically investigated : the already observed steady-state regime and the two novel regimes of cooperative synchrotron radiation, i.e., weak and strong superradiance;

ii) the technological goal consists in exploring the possibilities of matching the advanced technologies of high-gain FEL's and of superconductive acceleration. The experimental apparatus photocathode injector, accelerating structure with 352 MHz superconducting cavities, wiggler are being studied with emphasis on the problems related to the very high current, $I \approx 400$ A.

The applications of ELFA, which will operate at wavelengths in the 3÷8 mm region, should range from high-gradient particle acceleration to plasma heating in controlled fusion experiments and condensed matter physics.

On-Going Activities on Beam Dynamics
SSC Central Design Group

reported by Alex Chao, May, 1989

The emphases of the present SSC design activities are

- more details
- reviews of all critical issues
- moving to Dallas

In particular, the following activities are on-going:

(1) Lattice Design (contacts: Garren, Johnson, Peggs)

- Site-specific "footprint" : This is to be worked out soon for land acquisition purpose.
- Lattice information is to be digitized and sent to database, which is in turn connected to a variety of other users.
- Crossing angle scheme was worked out. This turned out to be more difficult than expected.
- Bypasses : Various bypass schemes were studied for the interaction regions layout. A new "diamond shaped" bypass scheme is being added as an alternative to the old "crescent" scheme.

(2) Aperture

This important issue is presently going through reviews. The basic issue is how to balance between safety margin and cost? Present thoughts are shifting toward having more safety margin. For example, orbit error after correction is specified to be rms ~ 0.4 mm, but more safety marging is being considered for the following:

rms = 1 mm => long-term stability
2 mm => good smear and tune shift
3 mm => 400 turn stability

The combination of 4-cm aperture,1-TeV injection energy and 228-m cell length seems to fall short of the new goal. If reconfirmed, something will have to give. Possibilities are 5-cm aperture, 2-TeV injection energy, shorter cell length, or some combination of the above.

(3) Operation Simulation (Talman, Schachinger)

Development continues in the software and hardware areas:

software: X-window, C version of TEAPOT, C++ graphics interfaces, automation of simulation steps, link to database
hardware: more disk spaces, SUN-4's replacing the aging SUN-3's

The simulator sets up the machine including systematic & random errors and corrections of orbit, tunes, chromaticities and linear coupling. The resulted corrected machine configuration is then send as input to other programs for long term simulations and map analyses.

(4) Analysis (Irwin, Bengtsson, Ng)

- Canonical perturbation theory to second order is being developed to give expressions for tune shifts and smear. A statistical analysis was performed and compared with simulations with >100 random number seeds, yielding excellent agreement. Orbit errors are being added to these theories.
- Differential algebra tools XMAP and XORT are being developed:
  XMAP generates the map from Database lattice
  XORT analyses the map

(5) E778 Nonlinear Dynamics Experiments (Edwards, Peggs, Chao)
A total of 27 shifts were taken in 1989 and 1988. A new round of 21 shifts are planned in 6/4–6/10, 1989. So far, studies are 1-dimensional. The new shifts will emphasize 2-dimensional studies, redo some 1-dimensional island measurements, add more tune modulation studies, include sextupole configurations that better emulation of the SSC environment, study the effect of deceleration in the Tevatron to emulate the large systematic multipole errors, and look for slow diffusion effects. As before, these experiments will not only impact on the SSC aperture choice but also are general studies of nonlinear beam dynamics.

(6) Correction Schemes (Talman, Schachinger)
Various correction schemes of the magnet field multipoles are compared. Examples of these schemes are bore tube correctors, Neuffer lumped correctors, magnet end correctors, hybrid bore tube and Neuffer scheme. One of the main tests is whether these schemes perform well when orbit errors are added. Study is continuing, including the option for shorter cells and 2 TeV injection energy. There seems to be a hardware incentive to get rid of bore tube correctors.

(7) Long term tracking (Irwin, Yan)

- Element by element tracking were performed up to $\sim 10^5$ turns with synchrotron oscillations. The simulation codes have been vectorized so that 64 particles can be tracked simultaneously.
- A technique of using the one-turn diffential algebra map to hunt for slow diffusion was developed and applied.

(8) Injector

- The booster chain (LEB, MEB, HEB) was redesigned (Furman, Chen), yielding much better lattices. Like before, these designs do not require transition crossing. Lots of tracking studies were performed on these new designs. These boosters will be redone if the SSC injection energy is to be changed.
- The linac chain design was reviewed in a workshop 10/10-11/88 (Stiening, Johnson). The next workshop is planned to be held on 6/6–6/8/89.

(9) Other activities

- Asymmetric B-factory (Garren)
- Superconducting magnet cable (Ng)

  1- and 2-dimensional analytical models were developed to estimate the optimal Cu/SC ratio.
- Database (Peggs)

  relational management system using SYBASE was developed. When completed, it will contain data on the lattice, the site, the magnet measurments, etc.
- Polarization (Yokoya)

  A workshop was held on 9/7–8/88. Tentative conclusions include the estimate that ~10 pairs of Siberian Snakes are needed to maintain the polarization in the SSC, and that the orbit control may have to be rather tight. More studies will be needed and some of these studies are being continued.
- Ground motion (Peterson, Ng)

  There are 5 railroad tracks crossing the present SSC footprint. The beam dynamics due to ground motion has been analyzed, but more data will be needed. It is envisioned that a feedback system will be needed.

ONGOING OR PLANNED ACTIVITIES WITH BEAM DYMANICS AT FERMILAB

David A. Finley

Fermilab, Batavia IL, USA

Theoretical

Tracking calculations simulating the long range beam beam forces in the Tevatron with separated orbits are underway. The intent of this effort is to help estimate the limitations (if any) placed on the upgraded collider due to these forces.

Instability limits for the upgrade are being calculated at each stage of the accelerator chain. These calculations have not so far uncovered any glaring problems with the upgrade, but they are not yet complete for intensities projected with the Main Injector.

Tevatron Single Beam Instability

For the previous 800 GeV fixed target run, a beam instability was observed at about 700 GeV for intensities approaching 2 E13. This was overcome by spreading out the longitudinal emittance of the bunches; this technique is acceptable during fixed target physics. Nevertheless, this kind of instability may be the limit to the intensity for the fixed target upgrade which is expected to exceed 5 E13 from the Main Injector as presently envisioned.

Beam Separators

The beam separators will be used in future collider runs. During the present (1988-89) collider run, the operational proton brightness, N/e (intensity/emittance), is being deliberately reduced by a factor of about two below that which is available from the present combination of Booster and Main Ring. This is being done in order to keep the total tune spread in the Tevatron below 0.025. For the present working point near (nx,ny) = (0.42, 0.41) this is the maximum tune spread which can be accommodated and preserve luminosity lifetimes exceeding 24 hours. In addition, this tune spread is one of the limits on the present collider run's luminosity; with 6 bunches on 6 bunches and no separators, there are 12 head on collisions.

For future runs, beam separators as presently planned will allow only 2 head on collisions: one at CDF and one at D0. The use of these separators in the next collider run should allow the full use of the proton brightness available from the present Booster and Main Ring, since the schedule still calls for 6 bunches on 6 bunches. This alone should allow the luminosity to double. The schedule has the next collider run beginning in the winter of 1990-91.

This week (first week of June 1989) should see the end of the present collider run which produced over 9 inverse picobarns of which about 5 were written to tape by CDF. Later this month, beam studies will be done using a pair of beam separators in the Tevatron for the first time.

Increase Linac Energy

One of the earliest steps in the upgrade is to increase the Linac energy from 200 to 400 MeV. This will reduce the space charge limit at injection into the Booster which is one of the main limits on the Booster's performance. It is hoped that the proton intensity out of the Main Ring might consequently double. On the other hand, it may also point out additional improvements in the downstream accelerators which are required to reap the full benefit of the Linac upgrade. The upgraded Linac should be in place for the collider run after the next.

Bunched Beam Cooling

An effort is beginning which explores the feasibility of implementing bunched beam cooling for the collider. If successful, this will increase the luminosity lifetime by combatting transverse emittance growth due to intrabeam scattering, gas scattering and other effects. The hope here is to further increase the integrated luminosity delivered to the experiments.

Future Courses

The head on tune shift will be reduced by a factor of 6 in going from 12 collisions to 2 by using the beam separators. However, the above considerations only increase the proton brightness by a factor of 4: one factor of two comes from not reducing the brightness available from the present Booster and Main Ring, and another factor of two comes from the increased intensity allowed by the upgraded Linac. Thus, there is another factor of 3/2 available before the head on tune shifts have re-saturated the previous 1988-89 values. Two possibilities for re-utilizing this tune space could involve bringing on the Main Injector and/or a third interaction region. The Main Injector path is being given very serious consideration by Fermilab.

BEAM DYNAMICS STUDIES AT THE CERN SPS

J. GAREYTE

CERN, Geneva, Switzerland

1 Beam-Beam Studies

The S$\bar{p}$PS collider will stop operating at the end of June 1989 for more than one year. Experiments are being made to gather detailed data on different subjects which were seen to be of importance during operation. These are :

- . effect of single high order resonances (16th and 13th orders)
- . effect of different emittances in the two beams
- . effect of coherent excitation of the opposing beam
- . possibility to collide a flat beam with a round beam (Hera oriented studies)
- . precise measurements of changes in distribution.

Then, the work will concentrate on theoretical estimates and tracking studies.

The influence of a crossing angle and long range effects in the LHC are being investigated using computer tracking.

2 Heavy ions collisions in the LHC

Following indications that the Higgs particle could be detected in very high energy collisions of heavy ions, the performance of the LHC in lead-lead collision mode has been evaluated. The luminosity was found to be limited around 10^{28} cm^{-2} s^{-1} by electromagnetic dissociation of the nuclei as well as by e^+e^- pair production followed by the capture of an electron.

3 Acceleration of Leptons

Experimental activity in the second half of 1989 will be devoted to the acceleration of electrons and positrons from the injection energy of 3.5 GeV up to 20 GeV and subsequent injection into LEP. The intensity of lepton beams in the SPS is at present limited to 10^{10} particles per bunch (the design value) by the transverse mode coupling instability.

Higher intensities can be obtained by injecting longer bunches and further increasing their longitudinal emittance during acceleration through RF shaking. Last year, up to 2.6 10^{10} particles per bunch could be accelerated in this way on an experimental basis. These studies will be pursued with the aim of providing denser bunches for LEP.

4 Non Linear Dynamics Studies

The experiment done in June 1988 has been analysed. By energizing 8 strong sextupoles, the dynamic aperture of the SPS was reduced below the geometrical acceptance, and measured for different working points and different sextupole currents. Within the "short term" dynamic aperture, inside which particles survive at least for a few seconds, the tune versus amplitude variation was measured and found to agree very well with tracking predictions. In storage mode the diffusion rate of particles in the tails of the beam distribution was measured as a function of transverse amplitude.

The program SIXTRACK was used to simulate the experiment : it detects the onset of chaotic motion by calculating the increase of the distance in phase space between two particles launched very close to each other, and evaluates the Lyapunov exponents.

The program predicted accurately the measured "short term" dynamic aperture. However, it failed in reproducing the slow diffusion measured at smaller amplitutdes, even when run over 10^6 machine turns. It was necessary to introduce low frequency (around 10Hz) tune modulations with a realistic amplitude to be able to detect the onset of chaotic motion with very slowly growing amplitudes.

Later this year, this type of experiment will be repeated on other working points. Controlled tune modulations will be introduced, and accurate measurements of particle distributions will be made with the help of a newly built precision wire scanner.

5 S$\bar{p}$PS Collider performance

The collider operates now regularly with an initial luminosity between 2 and 3 10^{30} cm^{-2} s^{-1} and a luminosity lifetime of 10 hours at the beginning of a store and 20 hours towards the end, 12 hours later. There are six bunches of protons of 1.3 10^{11} particles each colliding in three places with a beam of six antiproton bunches of 7.5 10^{10} particles each. The beam-beam tune shift per crossing approaches 0.005. With careful tuning the beam-beam effect does not limit the collider performance in the present mode of operation. It is rather the conjunction of beam-beam and direct space-charge effects at the injection energy of 26 GeV/c which limit the intensity of the protons, while the antiproton intensity is governed by the stacking capabilities of the accumulator.

In order to increase the performance, a new RF system working at 100 MHz has been added to the normal 200 MHz system of the SPS. It allows longer bunches to be accepted at low energy, therefore easing all space charge effects, and provides more RF bucket area at high energy, thereby increasing the intrabeam scattering limited lifetime.

The simultaneous adjustment of these two systems proved to be very delicate.

Coupled bunch longitudinal instabilities limit the attainable proton intensity, and investigations are going on to find their cause and to cure them.

Since the two experiments do not require forward detectors any longer, the distance of the inner low beta quadrupole to the crossing point can be diminished from its initial value of 14 m down to 7 m. In this way, the beta values at the crossing points can be lowered from 1 m down to 0.6 m in the horizontal plane and from 0.5 m down to 0.15 m in the vertical plane. Taking due account of the finite bunch length the resulting gain in luminosity will be a factor 2. This new scheme will be implemented for the next operating period in 1990.

BEAM DYNAMICS WORK IN THE LEP DIVISION

E. Keil
CERN, Geneva, Switzerland

1 LEP Commissioning

LEP commissioning will start in July 1989. Preparations include the following activities:

- Transfer of information from design programs to the controls database, and the design and implementation of procedures for setting up, correcting various errors, exciting orbit bumps, changing tune and chromaticity, etc.

- Modelling of single-particle dynamics will be available by an on-line version of the MAD program, and on-line computation of collective effects with the BBI program.

We shall continue the theoretical study of synchro-betatron resonances driven by dispersion and wakefields in RF cavities, and start a theoretical study of bunch lengthening by solving the equations of motion for the second moments.

Many experiments in beam dynamics are planned in the early phases of LEP commissioning: Threading the beams through LEP quadrant by quadrant, measuring the optical parameters through the arcs, trapping the beam in the RF system, measuring and correcting betatron and synchrotron tunes, chromaticities, and the closed orbit, measuring the beam lifetime, injection efficiencies and losses, finding the limit of the bunch current, measuring coherent single-beam tune shifts, luminosity and beam-beam tune shifts.

2 MAD Developments

The development of the MAD program continues with the following design principles: (i) One program in standard ANSI Fortran 77 for off-line and on-line work, (ii) Use of the 1984 standard accelerator description language, (iii) Memory management by the widely used and fully debugged ZEBRA system, (iv) Graphics based on the ISO standard GKS, (v) Communication with the user by a standard command language and with other programs by self-describing tables.

Version 8 is under development. It will eventually be capable to perform all the calculations of Version 7, and then replace it. MAD Version 8 contains new features needed for modelling LEP in the framework of the LEP control system. The most significant new feature seen by the user are "classes of elements". It runs on CERN central computers and on Apollo workstations in the LEP control system. New modules for computing e^+e^- beam parameters in the BEAMPARAM style, intra-beam scattering in the Bjorken-Mtingwa style, and polarization will be added.

3 Beam Dynamics for LEP Upgrades

In the context of the LEP energy upgrade by the installation of superconducting RF cavities, the following beam dynamics studies are continuing:

- The sawtooth energy variation around the LEP circumference depends on the energy the number of RF systems installed, and their degree of symmetry. We look for criteria, based on dynamic aperture and Bassetti effect, which determine the number of RF systems.

- The lattice around the superconducting RF cavities must be adapted to their lengths.
- The low-β and high-β insertions need to be adapted to the higher operating energy.

In the context of the LEP luminosity upgrade the following beam dynamics studies are foreseen:

- Operation of the low-β insertions with smaller than the nominal values of $\beta_x = 1.75$ m and $\beta_y = 0.07$ m. By how much β_x and β_y can be reduced depends on the dynamic aperture.
- Operation with a higher than the nominal current per bunch $I = 0.75$ mA. By how much the bunch current can be increased depends both on how well the transverse mode-coupling instability can be controlled and on the dynamic aperture.
- Operation with more than four bunches in each beam by horizontal separation in the arcs, developing criteria for the beam separation, finding the dynamic aperture, and simulating the beam-beam effects.

In the course of the ongoing studies of longitudinally polarized beams in LEP at the Z^0 energy the following activities are foreseen:

- Installation of the spin-simulation programs SLIM and SMILE as stand-alone programs and as MAD modules in collaboration with DESY
- Simulation of the spin behaviour with realistic assumptions about the alignment and excitation errors and their correction
- Design and spin-matching of spin rotators

Studies have been launched how to install the components needed for all three upgrades in LEP at the same time.

INVESTIGATION OF PARTICLE DYNAMICS AT THE P.N.LEBEDEV PHYSICAL INSTITUTE

A.A.Kolomensky

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The beginning of investigations in particle dynamics at the P.N.Lebedev Physical Institute dates back to the forties, when V.I.Veksler discovered the principle of autophasing. One after another there were developed and constructed electron synchrotrons with an energy of 30 MeV, 100 MeV (in Leningrad), 280 MeV, 700 MeV and 1,3 GeV; proton synchrotrons with an energy of 180 MeV and 10 GeV (Dubna); and a ring-phasotron electron storage-ring (FFAG) with an energy of 45 MeV. The theory of electron motion taking into account the effect of synchrotron radiation was elaborated in conjunction with general problems of particle dynamics in accelerators and storage rings. Circulating beam instabilities - negative mass effect, transverse and longitudinal dissipative instabilities etc.- were discovered and experimentally confirmed.

In the fifties and sixties, particle acceleration methods using plasma and laser beams were proposed and developed. Plasma bunches can be used as objects of accelerator by means of an electromagnetic wave, or plasma can be used as the medium in wich waves accelerating particles are excited. Laser acceleration was developed in two variants: autoresonance of particle and wave in a longitudinal magnetic field and quasi-linear acceleration of particles in a periodic transverse magnetic field (inverse free-electron-laser). Experiments were conducted for the first time on Compton backscattering of laser photons on electrons circulating in a synchrotron.

Since the end of the sixties several high-power pulse generators of electron beams have been developed and constructed. These beams have a power of tens and hundreds of GW and electron energies of several MeV with pulse durations of the order of tens and hundreds of nanoseconds. Experiments have been performed in collective acceleration of particles: ions - in the passage of intense electron beams through gas, and electrons - by autoacceleration, when part of the electron beam is accelerated in fields excited by the beam itself.

Below is a brief account of some investigations performed in our institute during recent years.

Undulator Radiation (UR) and Free Electron Lasers (FEL)

Theoretically UR spectral and angular characteristics have been obtained and various regimes using undulators considered: generation and amplification of radiation, linear acceleration, grouping of particle beams and measurement of their parameters in proton accelecelerators. The theory of weak and strong amplification was elaborated. The combination of undulator and a storage ring has been considered. The generation of stimulated radiation in an undulator with modulated exially symmetric magnetic field has been investigated, "double" resonance analyzed, and waveguide modes considered. These investigations were performed by *D.F.Alferov, E.G.Bessonov, A.N.Lebedev, G.V.Martirosyan and I.I.Pakhomov.*

Experiments at a voltage of 0.6 MV-1.2 MV and 0.8 kA-3.8 kA were performed on accelerator ERG. The longitudinal magnetic field along the undulator was 9 kGs-18 kGs and the transverse field of 3-cm period - 0.15 kGs-1 kGs. Radiation in the millimeter range was obtained with a 10-15 MW pulse power. These experiments were conducted by V.A.Bogachenkov, V.A.Papadichev, I.V.Sinilshchikova and O.A.Smith.

Coherent, spontaneous radiation in the millimeter range was obtained when an electron beam passed from a 7-MeV microtron through an undulator. For this, it was necessary to satisfy the relation $\lambda \gtrsim l$, where λ is the radiation wavelength and l the bunch length. When an optical resonator was introduced, induced undulator radiation was generated in the 3 mm - 12 mm interval. FEL for the submillimeter and infrared ranges are being reached on a 7-MeV linear accelerator and 30-MeV microtron respectively. This work is being performed by K.A. Belovintsev, A.V.Serov and V.I.Alekseyev.

Negative Ions

Intense beams of negative ions find important application in accelerators, controlled thermonuclear research (CTR) and other fields. Stripping such ions to fast atoms by means of a laser or thin target only slightly disturbs emittance and practically does not worsen the quality of the focussed beam of neutral atoms. In experiments with coaxial magnetically insulated diodes (H ~ 7-19 kGs), H^- currents up to 7 kA and 200 A/cm density have been obtained in 100-200 ns pulses at a voltage of 0.8 MV. Cathode plasma, as a source of H^-, was formed by surface discharge of dielectric by means of a bipolar pulse or irradiation by a laser beam. When conditions are optimized, H^- current density can be increased to a value $\gtrsim$ 1 kA/cm^2. This work is being conducted by V.A.Papadichev, S.A.Pikuz and T.A.Shelkovenko.

Recirculators

A procedure for mumerical analysis of particle dynamics in electron recirculators has been developed. On this basis, processes of capture and acceleration of electrons in a sectioned microtron have been modelled for 30 MeV and 250 mA. In it, a developed system of beam focussing on orbits, when the accelerating structure is heavily loaded by beams, is used. Thresholds of instability excitation as functions of microtron parameters have been determined. The predicted beam autooscillatory instability has been observed experimentally.

Construction conseptions for electron recirculator of the polytron type-with continuous beams, small emittance and high-degree of monochromaticity - have been developed. Design proposals have been made for a three-stage system of recirculators at an energy of 4.5 GeV and 300 µA average current, in which the microtron plays the role of injector. The main authors are K.A.Belovintsev, A.I.Karev and V.G.Kurakin.

Partially Neutralized Electron Beams (PNEB)

PNEB is formed when intense electron beam (IEB) is transported in a vacuum channel which has plasma on butt-ends or on walls. Plasma can arise as a result of surface breakdown of dielectric or of evaporation of metall and ionization of its vapor. In its turn IEB extracts neutralizing ions. This process is accompanied by the acceleration of protons and simultaneously ions which are a component of the plasma. Thus, for an electron energy of 0.5 MeV and current density of 3 MA/cm^2, the energy of C and Fe ions is 19 and 56 MeV, respectively. A broad spectrum of ionization multiplicity for Fe and Al, accelerated to an energy of 0.2-0.4 MeV/nucleon, has been obtained. The number of ions is 10^{10}, which corresponds to the yield of multi-charged ions in modern sources. The forms of accelerated ion spectra and the proportionality of their energy to the IEB pulse duration and the energy of electrons are indicative of the stochastic nature of the acceleration process.

As to the propagation of IEB in a vacuum dielectric channels (VDC) one can form and control the transverse dimensions and current density of IEB by using various VDC geometry, for example by a conical VDC. Another possibility of controlling the IEB transverse form in VDC is by space distribution of return current. If this current flows through two wire conductors placed near the walls at 180°, the IEB has the form of plate (quadrupole focusing) and four wires placed simmetrically (octupole focusing) poduce a star-like form. To increase the effectivness of IEB propagation in VDC Cu-needls were placed in the walls in the azimuthal and axial directions. The front velocity in the "needle" VDC increased by a factor 4 as compared with smooth VDC. The theoretical and experimental investigations were performed by A.V.Agafonov, A.Sh.Airapetov, E.A.Kostrikina, E.G.Krastelev, D.B.Orlov and B.N.Yablokov.

Acceleration of Particles in Plasma

Theoretical investigations indicate that effective acceleration of electrons in a plasma wave excited by a two-frequency laser pulse is possible only for highly homogeneous plasma. Deviation of density from resonance value at the percent level not only decreases the amplitude of the plasma wave, but changes its phase velocity and interrupts acceleration. The distance from the leading edge of the laser pulse at which electrons are injected has been determined for the least stringent requirement as to plasma homogensity. Under such conditions, compensation of linear and non-linear phase variations occurs.

It has been shown that by exciting wake plasma waves with a short single-frequency laser pulse, one can achieve a quite large rate of acceleration of electrons. The excitation of a wake wave by means of an electron bunch in a non-homogeneous plasma has been considered and the law of change of its density for which a particle is not displaced in phase relative to the plasma wave has been found. These investigations are been performed by L.M.Gorbunov, V.I.Kirsanov and R.R.Ramazashvili.

Z-Pinch in a High-Current Diode

High-current accelerators as power generators marked a new approach to the experiments with Z-pinch. Interest in this phenomenon is due to the success increating a high plasma density and temperature, multicharged ions, neitron and X-ray emission. We used generator "Don" (100 kA, 200 kV, 50 ns) and applied not only well known methods of plasma creating (single-wire and wire-array explosions), but proposed and investigated new methods: surface discharge through a dielectric vacuum channel, laser evaporation of cathode material, wire configuration type of "X-pinch" (two or more crossed wires).

In case of laser plasma pinching in a diode with an Al cathode electron plasma temperature $T_e \approx 0.2\text{-}1$ kEv and density $n_e \approx 10^{20}$ cm^{-3} were measured. For Al-wire explosion it was determined that $T_e \approx 0.4$ kEv, $n_e \approx 5 \cdot 10^{22}$ cm^{-3} for hot spots of plasma column. The most multicharged ions (Mo^{+32}, W^{+46}, Au^{+51}...) were observed in X-pinch configuration. In this case there were not many "sausages" along the plasma column. A single neck was created only in the region of wire crossing. Plasma jets were observed from this neck. X-ray spectral lines corresponding to multiply-charged ion emission also located in the neck region.

The theoretical and experimental investigations were performed by G.V.Ivanenkov, S.A. Pikuz, A.I.Samokhin, S.M.Zakharov.

Beam Dynamics activities at theUniversity of Rome-La Sapienza

(Dip. Energetica)

(reported by L. Palumbo)

There were two main subjects studied:

a) The electromagnetic fields excited by a dipole charge distribution traveling past a sharp discontinuity of the vacuum chamber have been derived analytically by using advanced diffraction theory. Simple formulae for the longitudinal and transverse dipole impedances have been worked out in the case of ultrarelativistic charges.

b) Analytical and numerical analysis of the longitudinal and transverse dynamics of a beam passing through a multicell accelerating cavity, including wakefield effects is being developed (in collaboration with LNF).

BEAM DYNAMICS ACTIVITIES AT DESY

A. Piwinski

Deutsches Elektronen-Synchrotron, DESY, Hamburg

1. Longitudinal Emittance Growth in DESY III

A strong increase in bunch length is observed during acceleration. Random phase jumps of the rf frequency source during frequency ramping have been simulated using a tracking code. Part of the losses and bunch lengthening could be explained by phase jumps (J.Maidment).

2. Polarization in HERA

Calculations of polarization continue using the program SMILE. The program is being upgraded in collaboration with the LEP theory group. Preparations are underway for practical implementation of closed orbit correction schemes designed to minimize depolarization effects (D.Barber, E.Gianfelice).

A polarimeter is now being designed and one of the special sections of the beam pipe has been constructed (HERA Polarimeter group).

3. Stochastic Particle Motion in Storage Rings

A treatment of stochastic particle motion in electron storage rings has been undertaken using the Fokker-Planck equation for fully coupled (6×6) synchro-betatron motion. The investigation has also been extended to include linearised spin motion in storage rings (D.P.Barber, K.Heinemann, H.Mais, G.Ripken).

4. Beam-Beam Interaction in HERA

Simulations of the beam-beam interaction of protons and electrons including noise in the electron ring and beam separation due to ground motion continue. Very long time behaviour will be studied (A.Piwinski).

5. Instabilities and Feedback

Coherent multi bunch instabilites in PETRA and HERA are being studied for realistic parasitic cavity modes including tuning during acceleration and heating. A longitudinal and transverse broad band feedback system for electrons in PETRA and HERA is under construction (K.Balewski, R.D.Kohaupt).

6. Fast Ground Motion at HERA

Measurements of ground motion have shown average vertical displacements of HERA magnets of 0.4μm which cause a beam separation of 0.2σ at the interaction points. For these displacements only frequencies larger than 1 Hz were taken into account.

If the velocity of the ground waves is of the order 1 or 2 km/sec, frequencies below 1 Hz which showed rather large amplitudes will not play any role since their wavelength is larger than the HERA diameter. Therefore, measurements of the velocity are necessary. This will be done by measuring the quadrupole correlations (J.Rossbach).

7. B-Factory Activities

First studies for an asymmetric B-meson factory at DESY have been made. The idea is to use PETRA at 10 to 14 GeV as the large ring and build a small ring (C$\approx$150-200 m) for 2 to 2.8 GeV. For a luminosity of $10^{33}\text{cm}^{-2}\text{sec}^{-1}$ currents of 0.2 and 1 A with bunch numbers of 192 and 12 in the large and small ring, respectively, are necessary.

Extrapolating the damping decrements and the collision frequency from measurements with PETRA, tune shifts of 0.06 and 0.03 with head-on collision in the two rings seem possible. Simulations of beam-beam interactions will start soon.

A reference design has been made which provides the necessary focusing using CoSm permanent magnetic quadrupoles. Beam separation should be done with help of combined function magnets such that the synchrotron radiation from the high energy beam can be reduced drastically.

Special rf cavities are being developed which have a smaller number of parasitic modes in order to avoid multi bunch instabilties. For the time being, beam currents as limited by multi bunch instabilities of up to 300 mA in the high energy ring and up to 3 A in the low energy ring seem possible even without feedback systems. (F.Willeke).

ONGOING ACTIVITY AT SLAC*

R. D. RUTH

Stanford Linear Accelerator Center, Stanford University, Stanford, California 94309, USA

1 SLC Status (June 1989) (A. Hutton, J. Sheppard)

The SLC is continuing its run at the Z^o. The repetition rate has been increased to 60 Hz, and presently the peak luminosity has been 1.2 Z^o/hour while the maximum integrated luminosity has been 12 Z^o/day.

A basic problem has been background in the detector which is much improved with the addition of collimators at the end of the linac. The emittance at the end of the linac has been steadily improving; presently the emittance dilution is typically less than 50%. Spot sizes at the IP are measured only with beam-beam scans. These measure $\Sigma \equiv \sqrt{\sigma_{e^+}^2 + \sigma_{e^-}^2}$ which is about 4 μm usually. The positron yield has been brought up to about 80% and both beams now are typically 1.2×10^{10}. This is limited by background in the detector. Attempts to increase the luminosity will continue on all fronts.

2 PEP and SPEAR (M. Cornacchia, M. Donald)

There was a high energy physics run for PEP and SPEAR in Nov.-Dec. 1988. The PEP mini-beta worked well ($\beta^* \sim 5$ cm). The current limit was not the beam-beam effect but was due to vacuum chamber heating within the detector. Beam-beam tune shifts of .05 were observed.

Presently various options are being studied for a luminosity upgrade at PEP with separated bunches. Various B-factory options are being studied in collaboration with LBL. Finally, the option of a τ/charm factory was studied in a workshop held May 23-27, 1989.

3 TLC Studies (E. Paterson, R. Ruth)

3.1 Damping Rings (T. Raubenheimer)

The first round of studies of TLC damping rings are complete, but we are far from a detailed design. These studies will continue with further work on flat beam issues, kicker options, wiggler options, and collective effects.

3.2 Bunch Compression (S. Kheifets)

Bunch Compression in two stages has been studied, and it seems possible to combine a 180° bend with bunch compression at 20 GeV to achieve 50 μm bunch length. Tolerance studies are ongoing.

*Work supported by the Department of Energy, contract DE-AC03-76SF00515.

3.3 Linac (K. Bane, K. Thompson)

Studies are ongoing to carefully simulate the TLC linac in the presence of errors and wakefields. Various tuning strategies will be examined to relieve tight tolerances.

Multibunch effects are being evaluated in all subsystems of TLC. Damped RF cavities (Q's ~ 20–50) seem to be necessary for both the damping ring and linac. Careful energy control is also necessary; initial studies indicate that bunch-to-bunch control to $\Delta E/E \sim 10^{-3}$ is possible.

3.4 Power Sources (M. Allen, R. Miller)

The Relativistic Klystron collaboration (SLAC, LLNL, LBL) has succeeded with a 190 MW output with a 20 nsec flat top at 11.4 GHz. This has been used to power a 30 cm RF structure which has produced 30 MeV electrons both from dark current and also from an electron gun.

A high power test of RF pulse compression is being constructed. This will be driven by a 100 MW, 11.4 GHz klystron presently under construction also. To test magnetron-type devices, a 100 MW cross-field amplifier is being designed and constructed. Theoretical power source studies have been concentrating on a cluster klystron which consists of many parallel, coupled klystrons. Because of the reduced space charge effects, very high efficiencies are predicted in simulations (70%).

3.5 RF Structures (G. Loew, J. Wang)

The work at SLAC on RF structures is concentrated on RF structures which damp transverse and higher-order longitudinal wakefields. These structures have slots in the irises coupled to radial waveguides which are expected to lower the Q's of the higher transverse modes to the range 10–50. Measurements are presently underway to determine the breakdown characteristics of such structures and also to measure the mode spectrum and damping.

3.6 Final Focus (D. Burke, E. Paterson)

Examples of TLC final focus systems have been designed and have achieved the goal of a factor of 500 demagnification with momentum bandwidth of ± .3%. In order to demonstrate such large demagnification, a Final Focus Test Beam has been proposed at SLAC by a collaboration of SLAC, KEK, INP and CERN. The SLC beam will be used straight ahead into the old C-line at SLAC. The present lattice in that region will be replaced by an extended one which is a scaled TLC-style final focus. The goal for the collaboration is to produce and measure a $0.1 \times 1.0\mu$m spot. The Final Focus Test Beam will also be viewed as a facility for testing new final focus lenses and new measurement techniques for beam size and position.

3.7 Beam-Beam Effects (P. Chen)

The usual effects of disruption, beamstrahlung, single and multibunch two-stream instabilities, etc., have been studied for the TLC. However, during the Next Linear Collider Workshop held in Dec. 1988, a new effect was discovered which may alter interaction point design considerably. This is pair production by beamstrahlung photons. These additional "low energy" electrons are deflected strongly by the fields of the opposing bunch and may cause serious background problems. Most likely, large crossing angles combined with crab crossing will be needed to allow large exhaust holes in the final doublet. Study of this problem is ongoing.

4 Nonlinear Dynamics (R. Warnock)

There has been much progress on the calculation of invariant surfaces using the Hamiltonian-Jacobi Equation (and related techniques) for two transverse degrees of freedom. The estimates of the breakdown of these surfaces have also been refined. A new method which provides a rigorous bound on the motion for finite (but very long) time has been developed. All calculations are now done with real accelerator lattices. Work will continue on these fronts and also on the beam-beam interaction using these techniques.

BEAM DYNAMICS ACTIVITIES AT CORNELL

Reported by Robert Siemann, June, 1989.

Not Directly Connected to B-Factory.

(*i*) A collaboration with Fermilab and the Central Design Group is continuing their investigations of nonlinear beam dynamics at the Tevatron, motivated primarily by the desire to validate the SSC design. (Experiment E778) Issues being studied are two dimensional motion, resonance islands in the presence of modulation, "diffusion" induced by nonlinearity, and phenomenological investigations such as reducing the operating energy to the lowest possible level, and otherwise mocking-up the SSC. Data taken in early June is being analysed.

(*ii*) A data acquisition system, copied from the E778 system just mentioned, has been assembled at CESR. It will be used, both in CESR and in the synchrotron, for various transfer function investigations, for diagnosing multibunch instabilities, both transverse and longitudinal, for automating routine operations like chromaticity measurement and decoupling, and for nonlinear investigations. It will also be used for logging and playing back signals preceding beam loss, to aid in diagnosing malfunctions.

CESR+.

A continuous process of upgrading the performance of CESR adiabatically will continue with the next phase being named CESR+, with the goal being to achieve a peak luminosity of $5 \times 10^{32} cm^{-2} sec^{-1}$. Machine experiments that are anticipated relate to,

(*i*) near misses in the arcs,

(*ii*) longitudinal single bunch stability,

(*iii*) and feedback.

CESR B.

A more ambitious plan, for which the lab is in the preliminary stages of generating a design proposal, is named the CESR-B project, with the B standing for B meson factory. The goal of this project is to achieve a luminosity of $10^{34} cm^{-2} sec^{-1}$. The major beam dynamics issues facing such a project include both single beam and colliding beam effects.

(*i*) Collective effects.

(a) To reduce the machine impedance, superconducting cavities are envisaged, as they can be fewer in number and lower in impedance. Cavities with low loaded Q's or other ways of controlling higher mode properties must be developed.

(b) Impedance estimates of other machine components are required.

(c) RF systems with heavy beam loading must be analysed.

(*ii*) In the area of beam-beam effects much of the effort will be concentrated on the potential benefits of using round beams.

(a) Round beam simulations are continuing. Major issues are the effects of synchrotron oscillations and efforts to compare simulations with relevant round beam experience at D.C.I.

(b) An experiment is planned at CESR, for late summer-fall, 1989, to test operation with round beams. The required vertical beam emittance will be obtained by introducing vertical dispersion into the CESR lattice, not by the use of coupling between the planes. This can be done with no hardware changes. The emittances will be $\epsilon_x = \epsilon_y = 1.4 \times 10^{-7} m$. The beta-function values at the crossing point will be $\beta_x = 28cm, \beta_y = 12cm$. and there will be no dispersion at the crossing point. According to simulation, tune shifts as high as $\xi_x = 0.085, \xi_y = 0.065$ should be achievable in this configuration, at beam currents of 38 ma, with the emittance growth factor being about 30 percent.

FORTHCOMING BEAM DYNAMICS EVENTS

7th COMPUMAG Conference on the Computation of Electromagnetic Fields, Tokyo, Japan, 3 - 7 September 1989. Contact: COMPUMAG Secretariat; c/o Nuclear Engineering Research Laboratory; Faculty of Engineering; The University of Tokyo; TOKAI, Ibaraki, 319-11; Japan, Tel.: (0292) 82 1611, Telex: (0292) 84 0442

1st European Conference on Accelerators in Applied Research and Technology, Frankfurt/Main, FR Germany, 5-9 Sept. 1989, Contact: K.Bethge, Nucl.Phys.Inst., University of Frankfurt, August-Euler-Str.6, D-6000 Frankfurt/Main 90

Discussion Meeting on a Consortium for a Southern California B.bar B Factory, Los Angeles, CA, USA (UCLA), 28 Oct. 1989

CERN Accelerator School - Advanced Accelerator Physics, Uppsala, Sweden, 18-29 September 1989. Contact: CERN Accelerator School, Mrs. S. von Wartburg, LEP Division, CH-1211 Geneva 23, Switzerland.

SIAM Conference on Parallel Processing for Scientific Computing, Chicago, IL, USA, 11-13 Dec. 1989. Contact: SIAM Conf. coordinator, Tel.: (215)564-2929, 117 s. 17th st., 14th floor, Philadelphia, PA 19103-5052

8th Conference in the series "Computing in High Energy Physics": Computing for High Luminosities and High Intensity Facilities, Santa Fe, New Mexico, USA, April 9-13, 1990; Contact: Roberta Marinuzzi, Los Alamos National Laboratory, P.O. Box 1663 MS-h831, Tel.:(505)667-5759

Beam Dynamics School on "Beam Dynamics and Engineering of Synchrotron Light Sources", Trieste, Italy, 14-25 May 1990; Deadline for application: 31 Dec 1989; Contact: Prof. L. Bertocchi, ICTP, P.O.Box 586, I-34100 Trieste, or E. Keil, CERN, CH-1211 Geneva, Switzerland

EPAC - European Particle Accelerator Conference, Nice,France, 11-16 June 1990. Contact: EPAC Secretariat; c/o Mme Ch. Petit-Jean-Genaz; CERN - LEP Division; CH-1211 GENEVE 23; Switzerland, Tel.: + 41 22 833275, Telex: 419000 cer ch, Telefax: + 41 22 830221.

17th European Conference on Controlled Fusion and Plasma Heating, Amsterdam, Netherlands, 25-29 June 1990. Contact: F.C.Schuller, FOM Inst. voor Plasma-fysica 'Rijnhuizen', Postbus 1207, NL-3430 BE Nieuwegein, Netherlands

9th International Symposium on High Energy Spin Physics, Bonn, F.R.G., 10-15 Sept. 1990. Contact: Dagmar Fassbender, Symposium Secretary, Physikalisches Institut Universitaet Bonn, Nussallee 12, Tel.: (228)733247, Bitnet: SPIN90 at DBNPIB5.

CERN Accelerator School - General Accelerator Physics, Juelich D, 17-28 September 1990. Contact: CERN Accelerator School, Mrs. S. von Wartburg, LEP Division, CH-1211 Geneva 23, Switzerland.

13th Intern. Conference on Plasma Physics and Controlled Nuclear Fusion Research, Washington, DC, USA, 10-19 Sept. 1990, Contact: Cof. Service Section; IAEA, POB 100; A-1400 Wien, Austria, Sponsored by: International Atomic Energy Agency

4th Advanced ICFA Beam Dynamics Workshop-Collective Effects of Short Bunches, KEK, Tokyo, Japan, 7-13 Oct. 1990; Contact: Toshio Suzuki, KEK, Tokyo; El.Mail: SUZUKI-JPNKEKVM

Joint US-CERN Particle Accelerator School - Frontiers of Particle Beams : Intensity Limitations, Hilton Head Island, SC, USA, (Mariott's Hilton Head Resort), 7-14 Nov. 1990; Contact: CERN Accelerator School, Mrs. S. von Wartburg, LEP Division, CH-1211 Geneva 23, Switzerland.

IEEE Particle Accelerator Conference, San Francisco, CA, USA, 6-9 May 1991; Contact: L.Costell-535, Nat.Bureau of Standard, Gaithersburg MD 20899, USA

18th European Conference on Controlled Fusion and Plasma Heating, Berlin (East), Germany, 3-7 June 1991; Contact: Mr. J.Lingertat, Akad. d. Wissenschaften, Zentralinstitut fuer Elektronenphysik, Hausvogteiplatz 5-7, DDR-1086 Berlin, Germ. Dem. Rep.

15th International Conference on High-Energy Accelerators, DESY, Hamburg, Fed. Rep. Germany, 20-24 July 1992