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BEAM DYNAMICS NEWSLETTER

edited by
E. Keil and A. Piwinski

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INTRODUCTION

The second meeting of the ICFA Panel on Beam Dynamics was held at DESY, Hamburg, Germany, from 3rd to 5th November 1986. The panel heard presentations by the members of ongoing and planned beam dynamics studies in their home laboratories and/or regions, and felt that this exchange of information was very useful. Therefore, the panel decided to make written versions of the talks available to a wider audience by collecting them in this Beam Dynamics Newsletter. The panel will repeat such presentations of planned activities during future panel meetings, and publish the Beam Dynamics Newsletter regularly.

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.

Readers who would like to use the Beam Dynamics Newsletter to announce their plans for future beam dynamics work and their unsolved problems are encouraged to get in touch with the panel chairman, Dr. N.S. Dikansky, USSR Academy of Sciences, Siberian Division, Institute of Nuclear Physics, Novosibirsk 90, U.S.S.R.

Thanks are due to the DESY Directorate for its hospitality during the panel meeting, and for making it possible that this Newsletter could be printed. Furthermore, we would like to thank Prof. P. Waloschek for his advice regarding its layout and Mrs. M.-C. Henkel for her help with its assembly.

On-going Beam Dynamics Studies at SSC, LBL and SLAC*

SSC

1. Cell Lattice Optimization

A workshop was held on September 17-18, 1986 at CDG to review the cell lattice parameters (60°, 192m) of the SSC Conceptual Design. A well-defined optimization algorithm was devised and carried out. It was found that by changing to (90°, 230m) cells, there is a 4% increase in the linear aperture and a potential saving of 20M$ on the SSC construction.

2. Analytic Calculation of Linear Aperture

An accurate analytical prediction of "smear" now exists (Forest). Excellent agreement with tracking was obtained. This technique, as well as the analysis program package, is expected to be used extensively in later studies. Extension of this calculation to higher orders is straightforward and will be continued.

3. Aperture Experiment

This is a high priority item. A proposal in collaboration with FNAL was submitted to FNAL PAC to perform aperture studies for the SSC on the Tevatron (10 preliminary shifts plus one dedicated week during spring 87). The goal is to check the linear and dynamic aperture evaluation algorithms assumed and developed for the SSC Conceptual Design.

4. Operations Simulations

This effort (sometimes referred to as "modeling") will increase substantially in 1987 and perhaps beyond. The simulation program TEAPOT (Talman, Schachinger) is further being developed for this purpose and two SUN workstations are being installed. The workstations are interactive, dedicated, with good display and windowing capacities. The simulations will include various issues under a wide range of operation conditions

5. Field Quality

Tolerance specification of magnet field errors, random and systematic, is an on-going effort. Compensation of the systematic field errors (including those due to the persistent current) using trim windings receives much attention. To compensate for the random

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* reported by Alex Chao, SSC Central Design Group, URA.

errors, the idea of "binning" (Talman) is being considered instead of the previous idea of "sorting" adopted in the Conceptual Design.

SLAC

1. PEP Possibilities

Various possibilites have been considered for PEP. Among them (Donald, Helm, etc),

- One single low-ß* IR, with ß*=3 - 5 m, for the TPC detector. The ring has symmetry 1.
- Alternating high- and low-ß*. Symmetry 3.
- Gas jet target for nuclear physics. luminosity = $10^{35}cm^{-2}s^{-1}$.
- PEP as a stretcher ring for nuclear physics.
- 4.5 GeV configuration for upsilons.
- hard synchrotron radiation source. The low-emittance configuration (emittance comparable to European design) was demonstrated to work.

2. SPEAR mini-ß*

SPEAR is the only nice ring where mini-ß* has not worked yet! Single beam optics looks fine down to ß*= 3 cm but the expected luminosity gain at low ß* values did not materialize. Bunch length was found to increase by a factor of 2 but pursue of bunch shortening by intentionally installing some capacitive impedance (Bane) gave only inconclusive results. More studies are needed.

3. Dynamic tracking

This is done at SPEAR and damping rings (Hofmann, Morton, Ruth, etc). The idea is to kick the beam and then measure (x,x') turn by turn to observe the phase space behavior. The trajectory exhibits a triangular shape when tune is close to 1/3. More detailed studies are being done.

4. Impedance Calculations

A field-matching program has been developed (Kheifets and Heifets) and is being compared with other existing programs for various types of vacuum chamber discontinuities. Interesting properties of impedance can be observed from the results (pointed out by J.D. Jackson and H. Lee at CDG).

5. Nonlinear Dynamics

Program for superconvergent tracking has been written and tested (Ruth, Warnock). A paper is written. No continuing work is envisioned for now since the technique seems too slow to put to practical uses.

A program based on the Hamilton-Jacobi technique has also been written and tested for 1-D case. Testing for 2-D cases and actual tracking for practical cases will be pursued. Based on this work, an interesting new criterion (slightly different from the residue criterion of Green's) is conjectured for the on-set of chaos. This idea will also be pursued.

6. Big Collider Studies

The possibility of a "site-filler" linac collider (4-7 Km, 0.5 - 1 TeV center-of-mass energy, luminosity to be derived) is being studied. Choice of rf frequency, for example, is one hot topic. Laser-plasma ideas are apparently not too relevant for this purpose.

One critical issue is the study of beamstrahlung in the high energy linac collider. Quantum modifications (Noble, Himel etc), electroweak radiation (Noble, Chen) and a program that includes quantum effects (Noble) have been done. There is apparently some disagreements among experts (Drell, Blanckenbecler, Chen, etc) as far as the coherence effects are concerned. This has to be clarified because it profoundly affects the scaling property of the basic design parameters.

7. SLC

The present highest priority is to commision the SLC, particularly the damping rings, the collider arcs and the positron line. Understanding of the arc optics with errors is an on-going effort (Brown, Murray, Weng, Sands). Modeling the damping rings for operation has played an important role. Present goal is to provide a start-up luminosity of $6x10^{27}cm^{-2}s^{-1}$ (15 Z^os per day) early 1987.

LBL

1. Light Source Lattice Design

The LBL design (A. Jackson etc) has an emittance of $4x10^{-9}$m-rad at 1.5 GeV. The triple-bend-achromat design (8 quadrupoles, 3 bends and 2 sextupoles per cell) was found to provide better dynamic behavior than the FODO or the Chaseman-Green designs.

2. Program ZAP

This parameter optimization program (Zisman, Chattopadyhay) has been used in several applications. The manual will be available soon. With lattice as input, it calculates the intrabeam scattering, Touschek lifetime and various instability and Landau damping thresholds. The emphases are user-friendliness and the correctness of formulae used.

3. Nonlinearities in Wigglers and Undulators

That nonlinearities in wigglers and undulators may significantly affect the dynamic aperture is a recent recognition. A workshop was held recently at BNL to study this. The study will continue.

4. Impedance Calculations and Measurements

A program COMET is being prepared (Nishimura). It uses Hertz potentials to do the calculations. The program is being prepared to handle 3-D objects. The algorithm promises to be simpler and more numerially stable. Bench measurements of impedances using both the antenna and the wire methods (Lambertson) are being done.

PLANS FOR BEAM DYNAMICS WORK AT CERN

E.Keil

CERN, Geneva, Switzerland

Plans are briefly reviewed for beam dynamics work associated with the circular machines at CERN.

1. PS DIVISION

In this chapter, the activities on the following machines are considered: PS, PS booster, AA and ACOL, LEAR, and EPA.

In the PS, measurements at low energy show that the widths of second and third order resonances increase with the fractional value of the horizontal tune Q_H. The consequences of this unexplained observation are overcome in practice by operating with Q_H just above 6. When the beam is rebunched at 200 MHz just before ejection to the SPS, a coherent horizontal instability is observed. Its risetime is much smaller than that of the resistive wall instability. Trapped electrons are believed to be the cause.

At 10^{13} protons per ring in the PS booster, the vertical incoherent space charge tune shift is about 0.6. Reaching this value needs compensation of four stopbands, one of them systematic, flattening the bunch shape by a second harmonic RF system, an increase of the vertical emittance to the aperture limit, and beam loading compensation. For $\bar{p}$ production, two PSB beams must be combined by an RF dipole, and the energy will be raised to 1 GeV. For the acceleration of protons and ions up to O^{8+} the control and feedback systems must handle between 10^8 and 10^{13} particles.

Beam optics work in the $\bar{p}$ accumulators AA and ACOL is concerned with the amplitude distribution after a first-order correction of the beam envelope distortion, and with second order perturbations of the betatron motion. Studies are carried out of collective effects in coasting beams, driven by wall resistivity, a $\bar{p}$-p collective instability, neutralization pockets and ionized dust. The Fokker-Planck equation is studied for stochastic betatron cooling in the case where the RF structure follows the shrinking beam size. The search for new coupling RF structures continues.

In the low-energy ring LEAR, two nondestructive observation methods are being developed for nonlinear resonances. They are based on the beam transfer function, and on the beam response to a kick and fast Fourier transform.

The e^+e^- accumulator ring EPA has been commissioned with e^-. Commissioning with e^+ will start in March 1987, and will emphasize the comparison of the variation of emittance and lifetime with the beam intensity and the number of bunches in order to identify suspected effects of ions on the e^- beam. Above the design intensity, multi-bunch instabilities are being observed. They will be cured by feedback systems.

2. SPS DIVISION

The Sp$\bar{p}$S has shown the importance of isolated resonances of order up to 16, driven by the beam-beam effect, for the beam lifetime and background, so far in a weak-strong configuration. With ACOL, the Sp$\bar{p}$S will operate in a strong-strong configuration, and new effects are anticipated, due to the difference in p and $\bar{p}$ emittances, tune modulation due to ripple and synchrotron oscillations, and micro-excitation of coherent beam modes. Experiments will be continued after September 1987. Computer simulation has been done with a simplified model for up to 10^6 turns, with linear machine arcs. The Chirikov criterion of resonance overlap gave good agreement with observation.

Strong nonlinearities may be obtained in the SPS by operating at intermediate energy, and exciting either the 8 ejection sextupoles, or a nonlinear lens. Results concerning the size of beams which survive a few seconds as a function of the sextupole excitation are in satisfactory agreement with the criteria on aperture, based on smear and tune shift with amplitude, which are used at present to interpret tracking studies over 10^3 turns. Experiments, planned for the second half of 1987, will measure the beam dimensions over longer times, and lifetimes versus beam size, and compare them to tracking results.

Work continues on the SPS coupling impedance $Z(\omega)$. It is constructed from experimental data on tune shifts, thresholds and growth rates, and from computations for individual components. Both approaches converge reasonably well towards a broad band impedance of $5\ \Omega < Z/n < 10\ \Omega$, with a quality factor of a few units, and a resonant frequency of 1.3 GHz.

Stochastic cooling of bunched beams is mainly a technological challenge. Improved beam diagnostics are a likely by-product : Fine monitoring of coherent mode tune shifts and of the beam-beam induced tune spread have already been obtained.

3. LEP DIVISION

We shall study the effect on the dynamic aperture of the sextupoles, random and systematic multipoles, and of excitation and alignment errors, using tracking programs, analytical tools, modern nonlinear dynamics, e.g. distortion functions and scriptA. We plan to apply the following criteria : dynamic aperture, i.e. particle loss after a few hundred turns at most, boundedness of the motion, linear aperture, smear, tune spreads.

We have standardized the command language of design and on-line modelling programs, using the MAD format. We shall use identical physics modules in both. All on-line programs can therefore be tested by off-line simulation. We are interested in additional algorithms for the design, e.g. improved tracking methods, and in more algorithms for the correction of orbit errors, orbit functions, etc.

The transverse mode coupling instability of individual bunches is mainly driven by RF cavities and bellows. The computation of its threshold by various techniques will be improved. Simulation will be continued with more realistic models. The driving mechanisms for synchro-betatron resonances and single-beam coupled-bunch instabilities will be reviewed.

The beam-beam effect has been extensively studied for e^+e^- storage rings by simulation. A dynamic aperture calculation with beam-beam effect needs an efficient description of machine nonlinearities by maps. The two-beam coherent instability driven by wakefields in RF cavities will be reviewed.

LEP experiments are interested in longitudinally polarized beams at Z° energy. In order to obtain reasonable polarization times, wigglers are needed which also increase the energy spread and therefore enhance the spin resonances driven by synchrotron oscillations. An analytical approach using stochastic differential equations is under way. We look for a spin simulation program which includes synchrotron oscillations, machine errors, and closed orbit correction. The design of spin rotators may follow later.

The review of the procedures needed for setting up, measuring, and correcting the optical parameters will be continued in order to define the specifications of the associated application programs.

4. ACKNOWLEDGEMENTS

I should like to thank B. Autin (AA and ACOL), E. Brouzet (PS), J.P. Delahaye (EPA), J. Gareyte (SPS), D. Möhl (LEAR), and K.H. Schindl (PS booster) for their help with the compilation of this report.

Beam Dynamics Activities at CEBAF

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Areas of Interest Construction of the CEBAF accelerator provides the focus and key motivation for beam dynamics and general accelerator physics work at CEBAF. The CEBAF accelerator will be a cw electron accelerator for nuclear physics covering the energy range from 0.5 to at least 4.0 GeV; it will serve three experimental end stations with cw beams of individually adjusted current levels (a few nA to 200 μA) and up to three different (although correlated) energies. Polarized and unpolarized beams will be available, and high beam quality ($\epsilon \sim 10^{-9}$ m, $\sigma_E/E \sim 2.5 \cdot 10^{-5}$) is demanded.

The design is based on rf superconductivity and four passes of beam recirculation. The accelerator is arranged in a racetrack-shaped layout. The straight sections contain two linac segments, each consisting of 200 cavities of the Cornell LE5 type (1500 MHz, elliptical shape, 5 cells). Each segment provides a minimum of 0.5 GeV voltage gain. The curved sections are made up of vertically stacked recirculation arcs that transport the beam from linac segment to linac segment.

With this configuration and these design goals the most important beam dynamics issues are:

- o The generation of low-emittance beams
- o The maintenance of low emittance and momentum spread through the acceleration cycle
- o Beam stability (i.e., collective effects)

These issues will be addressed below.

Beam Generation This topic essentially encompasses the formation of the beam from gun through choppers, bunchers, rf capture and preaccelerator sections, and finally through the SRF part of the injector, i.e., up to ~50 MeV. The key tool is the code PARMELA, a well-developed tracking code that allows the study of such important effects as space charge and coupling between all phase planes.

Beam Quality Maintenance Quality-deteriorating factors include phenomena such as quantum excitation in recirculation arcs, optical mismatches, phase plane coupling, limitations of rf phase and amplitude control, mechanical vibrations, and potentially ion trapping. Linear and nonlinear optics work is based primarily on DIMAD (extended to include rf cavities) and TRANSPORT. Key examples of this work are the recirculation arcs, which are isochronous, achromatic beam lines that, as a consequence of the attention given to synchrotron radiation effects on beam quality, closely resemble current light source lattice designs. The questions of phase plane coupling, e.g., differential head-tail deflection in the nonsymmetric fields near the rf power couplers, are presently studied by ad hoc programs, while the questions of rf stability and mechanical vibrations are being investigated in a preliminary analytical manner. The potentially important question of ion trapping will be investigated with the simulation code MASK. A comprehensive accelerator computer model allowing a wide variety of effects to be studied, but tailored to our specific needs, is in preparation.

Beam Stability Multipass regenerative beam breakup (BBU) is the instability with the lowest threshold. A simulation program, TDBBU, has been developed that allows the use of realistic machine optics, excitation of higher order modes (HOMs) in two dimensions, and realistic frequency spread of any given mode between the various rf cavities. This code also allows the investigation of "effective" emittance increase due to subthreshold excitation of HOMs.

In addition an "analytical" BBU code has been written that is based on an elegant matrix technique developed by R. Gluckstern of the University of Maryland.

Supporting Tools and Efforts The effort outlined above rests, at least in part, on two important resources, emf codes and class VI computer time. We use the codes of the "Weiland group," i.e., URMEL and MAFIA, extensively, and the types of beam dynamics problems that we address are amenable to rather detailed simulation. This requires substantial computing resources but pays off in detailed, reliable answers. Several hundred hours of supercomputer time will be devoted to this effort in 1987.

Outlook Further efforts will be extensions of the present work. They will obviously include work supporting the commissioning and development of the CEBAF accelerator. Beyond that we expect to work on beam dynamics issues relevant to other applications of SRF technology such as accelerators for FELs, SRF-based "two beam" accelerator concepts, and pure SRF linear colliders. The issues of high-brightness beams, beam stability, and a wide range of phenomena of beam/environment interactions will remain of prime importance.

BEAM DYNAMICS ACTIVITIES AT DESY

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1. INTRODUCTION

The work on beam dynamics at DESY is concentrated on HERA, the electron proton storage ring now under construction. Many computer simulations and analytical studies are being made in order to get a better knowledge of the particle behaviour in this new device. The simulations consider especially nonlinear problems such as the beam-beam interaction, sextupole distributions, magnet errors, and the behaviour of the electron polarization. Analytical studies are being made for instabilities, feedback systems, spin matching, and ground motion.

2. BEAM-BEAM INTERACTION

Simulations of the beam-beam interaction (A. Piwinski) have shown that a crossing angle between electron and proton beam will excite many synchro-betatron resonances for the protons. In particular, if the proton bunches are longer than the electron bunches (which is hard to avoid) many synchro-betatron resonances of higher order will be excited. The distances between these resonances then become so small that it will be extremely difficult or impossible to find a working point. The crossing angle has therefore been given up and head-on collision geometry has been adopted. Work on the beam-beam interaction is going on in order to find the influence of instabilities of the electron beam on the protons.

3. FIELD ERRORS

Simulations have been made in order to investigate the stability of motion of the protons in presence of field errors of the superconducting magnets (F. Schmidt). The computer code "Racetrack" (A. Wrulich), which was extended to include synchrotron oscillations (G. Ripken) and which takes into account multipoles up to the tenth order, was used. Regular and chaotic motion was distinguished by means of the Lyapunov exponent, and three regions could be identified: The first region with large amplitudes is dominated by strong resonances which cause particle losses. In the second region with medium amplitudes the motion is, in most cases, chaotic and amplitudes will reach the first region after many revolutions. In the third region with small amplitudes the motion is finally regular and bounded. It turns out that the aperture is well within the third region.

Tracking investigations have been performed in order to specify the field quality required for the electron dipole magnets (F. Willeke). Racetrack has been used and an interpolation procedure which satisfies Maxwell's equations was added to avoid the time consuming calculation of the multipoles. In addition two generalized invariants of the betatron motion were defined and included into the code. Thus the shape of the magnet poles was optimized and a final acceptance of $A_x = 32\ \pi$mradmm with $A_z/A_x = 0.1$ and without sextupoles was obtained. This corresponds to 32 horizontal standard deviations at 30 GeV.

Tracking was done for protons in PETRA which serves as an intermediate storage ring (J. Rossbach). To compensate the orbit lengthening due to a bypass the closed orbit will be shifted by 12 mm in the arcs. This causes a considerable reduction of the acceptance. By using Racetrack and the measured multipole components of the bending magnets it was shown that the acceptance is, nevertheless, sufficient at injection energy (7 GeV) as well as at extraction energy (40 GeV).

4. SEXTUPOLE DISTRIBUTIONS

The optimum sextupole distribution for the electron ring was found by tracking with up to ten sextupole families (R. Brinkmann, F. Willeke). Optics with phase advance per FODO cell between 60° and 90° were investigated. The resulting acceptances were between 25 and 13 horizontal standard deviations, respectively.

5. SPIN TRACKING

Tracking of electron spins was carried out with the computer code SITROS (J. Kewisch, T. Limberg). This code takes into account all nonlinear elements including the beam-beam interaction and also the excitation of betatron and synchrotron oscillations due to synchrotron radiation. A depolarization rate can be estimated which, together with the known polarization rate, allows the equilibrium polarization to be estimated. As expected SITROS predicts many nonlinear spin resonances.

6. INSTABILITIES

Analytical studies are being made for multi-bunch and single-bunch instabilities. In the first case, interaction of the bunched beam with parasitic modes of the cavities is being investigated using the realistic (measured and computed) cavity modes. The effect of "mode drifting" due to temperature effects has been treated by statistical methods. For the multi-bunch case a new narrow band damper system using frequency splitting between bunches was developed (R.D. Kohaupt). In the single bunch case mode coupling due to localized structures has been investigated and different feedback systems were studied (K. Balewski, R.D. Kohaupt). In order to obtain realistic predictions for maximum currents in the presence of instabilities the mechanism of self stabilization at finite oscillation amplitudes was studied (Y.H. Chin).

7. SPACE CHARGE EFFECTS AT LOW ENERGY

Analytical estimates of the influence of both transverse and longitudinal space charge forces on the beam dynamics in DESY III, the HERA injector synchrotron, have been made (E. Karantzoulis, J. Maidment). Simulation codes are under development to allow the evolution of a general initial beam distribution to be followed. The aim is to optimize acceleration rate, working point, correction multipoles etc. so as to maintain maximum beam brightness.

8. SPIN

The spin behaviour is also being studied analytically. Dipole spin rotators (K. Steffen, J. Buon) will rotate the spin into the longitudinal direction before the interaction points and back into the vertical direction after the interaction points. Since the spin is horizontal in between a pair of rotators and there is a vertical dispersion in the rotators, there will be strong depolarizing effects even for a perfectly aligned machine. These are corrected in linear order (spin matching) by adjusting the optics (D. Barber) using the fitting program SPINOR (L. Hand). Polarization is calculated using the thick lens approximation of SLIM (A. Chao). The full Sokolov-Ternov polarization is then predicted. Since it will not be possible to set up the optics exactly as calculated by the spin matching rules, harmonic correction schemes are being studied which will enable the dangerous Fourier harmonics to be corrected (D. Barber, S. Mane, H. Mais, G. Ripken, R. Rossmanith, R. Schmidt). The stochastic theory of depolarizing effects has been investigated (H. Mais, G. Ripken). New investigations of the Derbenev-Kondratenko formalism have been made (K. Yokoya, S. Mane).

9. 6-DIMENSIONAL HAMILTONIAN FORMALISM

Not only linear betatron motion but also linear synchrotron motion can be described using Twiss parameters. A 6-dimensional Hamiltonian formalism has been developed therefore (D. Barber, H. Mais, G. Ripken, F. Willeke), which allows easier calculation of some coupling effects using perturbation theory.

10. GROUND MOTION

Some investigations and measurements have been made of the effect of ground motion (J. Rossbach). The influence on the orbits in HERA has been estimated. In particular, attention has been paid to the displacements of the orbits at the interaction points. This is important for the luminosity and the beam-beam interaction.

Ongoing and Planned Beam Dynamics Activities in KEK

Toshio SUZUKI (KEK)

I. Introduction

There are four machines in KEK: 12 GeV proton synchrotron, 500 MeV booster synchrotron, Photon Factory 2.5 GeV linac + 2.5 GeV storage ring for synchrotron radiation, and TRISTAN 30 GeV e^+-e^- storage ring. Beam dynamics studies in KEK are naturally related to these machines. Particularly, since the TRISTAN Main Ring was completed recently, much effort will be devoted to the analyses of phenomena in TRISTAN. Further we have two future accelerator plans in KEK; the Japanese Hadron Facility project and the Japanese Linear Collider project. The former is a short-range project in which the present proton synchrotron will be upgrated by the addition of a 1 GeV proton linac as a new injector. It is a joint effort of INS, University of Tokyo, and KEK. The latter is a long-range project. Several beam dynamical studies are directed to these future projects.

II. Instability

From about 1980, extensive studies were done to investigate the collective beam instabilities in electron storage rings especially induced by RF cavities. The persons involved are Y. Chin, H. Nishimura, K. Satoh, T. Suzuki and K. Yokoya. The subjects include: coupled-bunch instability, transverse mode coupling instability (strong head-tail effect), longitudinal mode coupling instability (bunch lengthening) and Landau damping.

Experimental studies were also done after the TRISTAN Accumulation Ring was completed in 1983. For the coupled-bunch instability, a good agreement between the experiment and Sacherer's theory is reported if we use experimentally determined damping times. The transverse mode coupling was studied by inserting bellows intentionally to increase the impedance. The agreement between the experiment and theory was good. There is some discrepancy between theory and experiment in threshold current for the anomalous bunch lengthening. The spectrum of coherent oscillations does not clearly merge at the onset of instability. These give some doubt on the concept of longitudinal mode coupling. However, the scaling law of Chao and Gareyte is satisfied quite well, which supports mode coupling. In the theory, only radiation damping is included. Other damping mechanisms such as Robinson and feedback dampings may play a role. This should be studied further.

There is still an unidetified instability in the Accumulation Ring, which was reported by K. Satoh et al. in Vancouver Conference. It is a single bunch transverse instability. There is no appreciable coherent dipole oscillation and the beam size grows and shrinks at several to 10 Hz. It causes beam loss. The instability does not depend on tune and does not depend much on chromaticity. The instability depends on bunch length and it disappears when the RF voltage at injection is reduced. It is also cured by wiggler magnets. My personal guess is that it may be a pure m = 1 (quadrupole) head-tail effect, but the coherent m = 1 oscillation spectrum has not been observed clearly. More study is needed.

Y. Chin developed WELL which is a three dimensional extension of TBCI. T. Shintake developed FCI, which is a wakefield calculation program suited for klystrons and lasertrons.

III. Synchrobetatron Resonance and Polarized Beam

A Hamiltonian formulation of synchrobetatron resonances was developed by T. Suzuki. He applied the formalism to synchrobetatron resonances in TRIUMF KAON Factory project. The effects of spurious dispersions were also studied recently. Several works were done by K. Yokoya to explain the depolarization mechanisms for a stored electron beam and to propose methods to cure the depolarization.

IV. Lattice and Chromaticity Correction

For TRISTAN design, MAGIC was fully used. It was much extended by K. Yokoya. PETROK, the KEK version of PETROS developed at DESY, includes MICADO as a subroutine and is extensively used for on-line simulation of TRISTAN. For chromaticity correction, HARMON and PATRICIA are fully used. Six families of sextupoles are used in the TRISTAN main ring.

A. Ando studied emittance distortion by sextupoles. Y. Chin and M. Cornacchia studied higher order sextupole effects to be corrected by octupoles. More analytical work is necessary.

V. Linear Colliders

Conceptual design of the Japanese Linear Collider project was made public at several Japanese workshops the procedings of which were published as KEK reports. Experimental works on a lasertron and a resonant ring are going on. K. Yokoya published a paper on the quantum fluctuation effect in beamstrahlung. He also wrote a simulation program which includes both beamstrahlung and disruption. He at DESY also developed a theory of Landau damping due to different eigenfrequencies from cavity to cavity. T. Suzuki developed a very elementary theory of Landau damping in linear colliders.

Naturally more work is needed: the design of a damping ring and a final focus system, the collective beam instability (beam breakup and beam loading), the optimization of RF frequency, and a method to avoid unnecessary collisions in multi-bunch operation, etc.

A preliminary study on a free electron laser for a two beam accelerator is going on. K. Takayama works on several theoretical problems related with high-current beam transport system.

VI. Photon Factory

At Photon Factory, ion trapping was studied extensively. Orbit dynamics of a 5 T vertical wiggler magnet is also studied because it is a highly nonlinear magnet. Much effort was devoted to stabilize a light beam and the stabilization of several hundred Å is now achieved.

VII. Others

K. Hirata analyzed beam-beam interaction and bunch lengthening by a mapping technique. K. Oide and K. Yokoya studied reactive feedback for transverse mode coupling instability by including multi-turn effects. The proposed feedback system will be tested in the TRISTAN Main Ring.

PLANNED BEAM DYNAMICS EXPERIMENTS IN THE EASTERN UNITED STATES

Richard Talman
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1. CORNELL

1.1 Luminosity Optimization of the e^+e^- Storage Ring, CESR.

Investigations are continuing with the purpose of realizing the maximum luminosity in the new "micro-beta" intersection region configuration, which exploits a rare-earth cobalt permanent magnet quadrupole adjacent to the IR. Injection and lattice tuning has not been impaired in the new geometry. Eventual operation with 7 bunches is planned but investigations at very low values of β have been restricted to one bunch. Some early results are given in the next paragraphs.

There are well-known formulae by which the luminosity $\mathcal{L}$ and the tune-shift parameters ξ_x and ξ_y are given in terms of measureable quantities: I, the beam currents (assumed equal), γ, the relativistic factor, the IR lattice factors β_x and β_y, and the transverse emittances ε_x and ε_y. Since ε_y is normally too small to be measured accurately, another quantity Δf_y, which is the frequency splitting between the two normal modes of the beam-beam system, may be preferable. It satisfies

$$\frac{\Delta f_y}{f} = C_y \, \xi_y$$

where f is the revolution frequency and C_y is a numerical constant, calculable in principle, but treated empirically here. Combining formulae one derives

$$"\mathcal{L}" = \frac{\gamma}{2er_e} \frac{1}{f} \frac{1}{C_y} \frac{I\Delta f_y}{\beta_y}$$

where e is the charge and r_e is the classical electron radius. The right hand side of this equation contains directly measurable accelerator parameters which, combined as they are here yield what can be called the "monitor-free luminosity". This can be compared with the

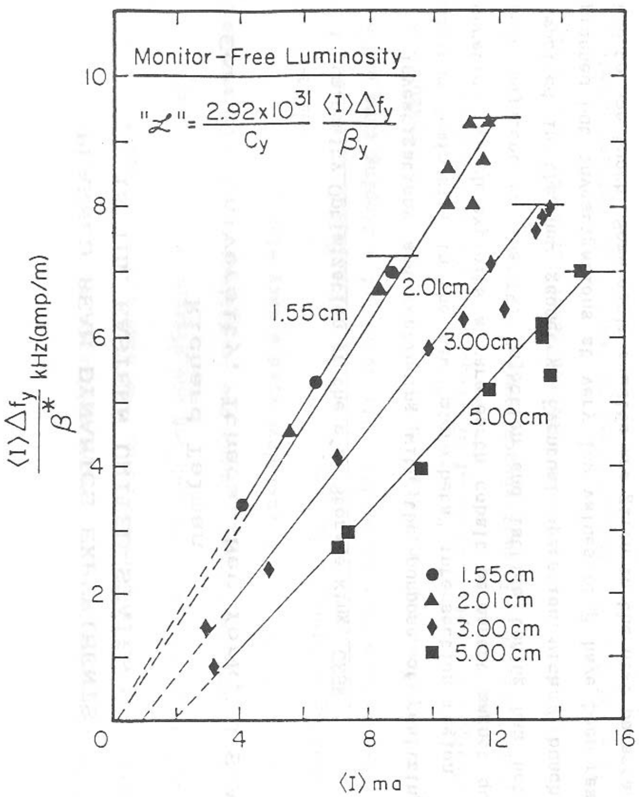

Figure 1. Dependence of luminosity on β_y and <I>.

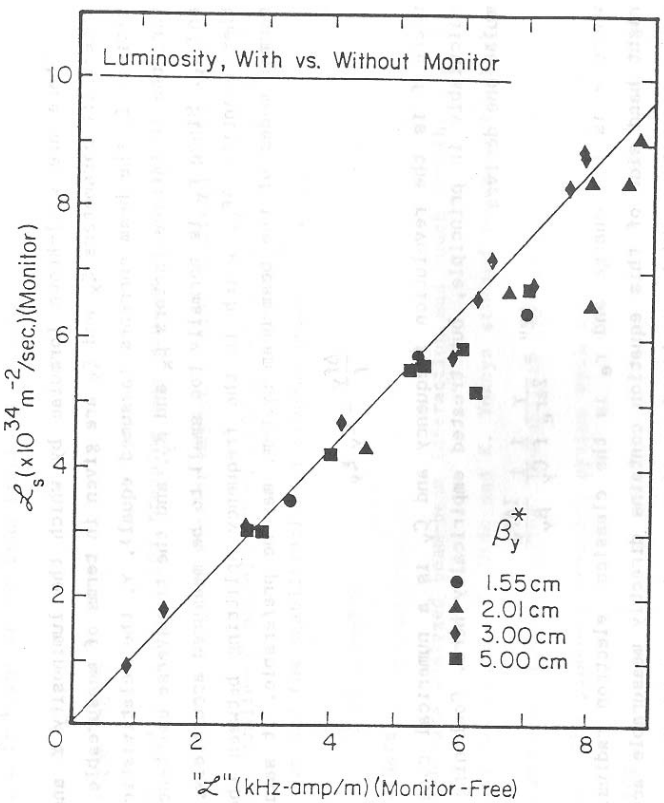

Figure 2. Relation between two luminosity measures.

"monitor" luminosity measured by detecting the photons from the reaction $e^+ + e^- \rightarrow \gamma + \gamma$.

Using "$\mathcal{L}$" the dependence of luminosity on β_y and I is given in Fig. 1. Bars indicate maximum settings-higher currents yield unacceptably short beam lifetimes. Fig. 2, containing the same points as are plotted in Fig. 1, compares the monitor-free and the monitor luminosity. The excellent agreement at low currents gives a very satisfactory confirmation of the formulae entering the analysis (C_y is 2.5 ± 0.2).

1.2 <u>High Tune Lattices.</u>

Investigation of high tune horizontal tune lattices ($\approx$ 14 instead of $\approx$ 9) have been started. The chief motivation is to reduce the bunch length (at fixed rf voltage) in order to better exploit the ultra-low vertical beta function.

1.3 <u>Ultra-Small IR Beam Tubes.</u>

For detection of particles having very short but non-zero lifetimes a precision vertex detector is comtemplated. The expected relation between bore diameter and vertex position resolution is indicated in the table.

Bore Diameter	Position Resolution
cm	microns
4	32
6	48
8	64
10	80

Theoretical and (eventually) experimental investigations are being performed to find the minimum acceptable IR beam tube. Potential limitations are due to injection requirements, beam lifetime, and excessive synchrotron radiation in the vertex detector. The last of these is expected to set the limit.

2. FERMILAB

2.1 SSC Motivated Investigation of Aperture Limitations from Nonlinearity

One of the critical issues in planning for the Superconducting Super Collider relates to the required magnetic field uniformity of the dipole magnets. By increasing the bore size the field quality can be improved arbitrarily but, to hold down the cost, the smallest acceptable bore size must be determined. Although there is no reason to doubt theoretical analysis of this issue, experimental verification would be reassuring and that is the purpose of the investigation.

If the betatron oscillations of a particle in a synchrotron are linear, then the oscillation amplitude will be a constant of the motion. If there is no coupling between the two transverse degrees of freedom, the horizontal and vertical amplitudes will separately be invariant. A plot, from turn to turn, of one of these against the other, will yield a single point. Nonlinearities will cause gradual changes of these amplitudes and the single point will develop into an area. A criterion which has been adopted for specifying the "linear aperture" is that the fractional changes in these amplitudes should be less than $\pm$ 10 % for 5 mm amplitudes. Is this a correct criterion for acceptable performance?

The Tevatron exhibits excellent linear behaviour. Though not yet measured, deviations at the 1 % level are anticipated from tracking calculations. This proposal calls, first, for a verification of that prediction, second, for the introduction of nonlinear field components sufficient to yield amplitude variations of up to 20 % and, third, for measurement of the correlation between increased amplitude deviation and performance degradation. It is particularly important to relate tracking calculations to beam measurements.

3.0 In this report there has been no attempt to survey other laboratories, or even to survey the two laboratories mentioned.

ACTIVITIES IN ITALY AND AT EUROPEAN SYNCHROTRON RADIATION SOURCES

S.Tazzari
INFN - Laboratori Nazionali di Frascati, P.O.Box 13 00044 Frascati (Italy)

1. BEAM DYNAMICS ACTIVITIES IN ITALY

1.1. INFN - University of Milano

A superconducting cyclotron with K = 800 is in the final phases of construction. The main beam dynamics activities are connected with the computation of proper field configurations and in general with the study of the stability of trajectories, and of injection and extraction. Since the machine is to become a post-accelerator for a Tandem, phase space matching at injection and extraction for all different possible ions and in the presence of strong fringe fields is a particularly delicate problem.

1.2. LNF - (Laboratori Nazionali di Frascati dell'INFN)

The Laboratory operates two accelerators: Adone a 1.5 GeV electron/positron storage ring now mainly used for Nuclear physics and Synchrotron radiation and its 350 MeV e^+/e^- injector Linac also used to produce very high flux e^+ beams for nuclear physics.

Activity in beam dynamics is mainly connected with the design of low emittance lattices a significant effort was devoted to design studies for the ESRF): lattice optimization, minimization and correction of geometric and chromatic aberrations - up to high order - in strong focussing lattices, study of the effect of systematic and random field and positioning errors on the aperture, of linear and nonlinear effects of insertion devices, of collective effects and instabilities limiting the current and/or the lifetime. Most of the existing lattice design, correction and tracking programs (MAD, PETROS, PETROC, DIMAT, PATRICIA, MARYLEE, etc) are operational, in addititon to the ones developed in house and to programs dealing with collective effects such as BBI and ZAP.

The dynamics of low energy, space charge dominated beams is also being studied in connection with the Linac gun and injection system upgrade program, aimed at obtaining very high peak current, short e^+ pulses.

FEL dynamics is being studied in connection with an experiment in progress at Adone in the range of 5000 to 6000 Å. A 17 m long laser cavity under vacuum is installed on the ring. To achieve lasing a significant improvement in beam quality at low energy is necessary and is being worked on.

1.3. ENEA - TIB Frascati

Is operating in the field of microtrons , small Linacs for industrial applications, race track microtrons and and single pass FEL's. Dynamics of high current microtrons is being studied : 150 mA in 6 ms long pulses have been obtained on a 20 MeV machine and 200 mA in 4 ms pulses on a 5 MeV one. An 80 MeV racetrack is in the final stage of design and should be operational in '88.

Significant activity is in progress on single pass FEL's : a 10 mm device has lased and is being upgraded in view of achieving higher efficiency, a microwave Cerenkov FEL experiment is being set up.

1.4. INFN - University of Rome (Dip. Energetica)

Electromagnetic radiation from relativistic particles passing by discontinuities in the vacuum chamber or traversing cavity like structures are being studied. Couplin impedances, radiation losses and wake potentials are derived. Problems and codes connected with the collective behavior of particle beams in low emittance lattices for SR sources are also being studied (in collaboration with LNF).

1.5. INFN - Universities of Trieste, Pavia, Pisa, Lecce

A collaboration has been set up to study, design and build a 140 KeV proton RFQ. Theoretical and numerical studies of the longitudinal and transverse motions are being pursued. Novel cavity configurations are being studied and modeled.

1.6. INFN - Universities of Padua and Bologna

Beam stability in proton synchrotrons and storage rings (ISR, SPS collider, SSC, CERN AA) is being studied (in collaboration with CERN) using mathematical techniques to simulate particle motion. Nonlinear effects such as space charge, magnet imperfections, nonlinear forces and beam-beam interaction are taken into account. Transverse and longitudinal dynamics of high current intermediate energy proton beams are also being studied in connection with EHF.

Work is underway on nonlinear dynamics (chaotic motion, Arnold diffusion, resonances in dynamical maps, etc.) in view of producing improved tracking codes. Studies of tracking including spin motion are also being pursued.

1.7. INFN - University of Naples

Plasma wave acceleration is being studied. An experiment at microwave frequencies is in progress. By working in the microwave region lower plasma density is needed and larger physical dimensions can be used to ease the study of basic principles. Stochastic cooling using the microwave Cerenkov effect is also being studied in connection with ACOL and the SPS collider.

Diffractive energy losses suffered by ultrarelativistic particles interacting with variously shaped surrounding conductors are being studied. Conclusive results are being obtained for cylindrical pipes or circular holes in a conducting plane.

2. BEAM DYNAMICS ACTIVITIES AT SYNCHROTRON RADIATION DEDICATED SOURCES IN EUROPE

Based on information received from: W. Brefeld/HASYLAB/DESY, J.L. Laclare/ESRF, M.Sommer/LURE/Orsay, V. Suller/SRS/Daresbury, E. Weihreter/BESSY.

Most of the activities at Synchrotron radiation laboratories are connected with the design and operation of 'third generation' storage rings having energies in the range from .8 to 6 or 7 GeV and emittances in the range of a few 10^{-9} π m rad .

The work being pursued by the group designing the European Synchrotron Radiation Facility in Grénoble is rather typical of all of them. It includes:

- The optimization of various low emittance lattices by the choice of the best working points, the compensation of resonance driving terms and the minimization of tune shifts on momentum and on amplitude. The problem of aperture, with all its technical complement of tracking codes, analytical approaches etc., is a central one and is being attacked from various angles.
- The study of the sensitivity of lattices to errors, of alignment and magnetic field tolerances, of the effects and the correction of orbit errors, of the effects on aperture of nonlinear field components in the lattice magnets and in insertion devices, and of matching of insertion devices into the lattice.
- The effect of ground vibrations on the beam emittance and on the beam stability.
- The study of single beam and collective effects and of instability thresholds, including the investigation of the electromagnetic properties of the beam surroundings.

The same kind of activity is under way at BESSY, where a 1.5 GeV third generation ring (BESSY II), is being designed.

Activities for HASYLAB are included in the report on DESY.

At Orsay where the .8 GeV new dedicated storage ring SUPERACO is in the final stages of commissioning, attention is at present devoted mostly to application computer codes for storage control and diagnostics.

At SRS an upgrade of the present machines to lower emittance is being implemented and special attention has been devoted to the theoretical and experimental study of beam instabilities and collective phenomena that could limit the upgraded machine performance. A single pass FEL program (in collaboration with the University of Glasgow) is also in progress.

In all the above Laboratories the theory and optics of synchrotron radiation, expecially in connection with devices where important interpherence or coherence effects are present (many pole wigglers, undulators, FELs) are being actively studied.

FORTHCOMING BEAM DYNAMICS EVENTS

1987 Particle Accelerator Conference, March 16-19, Omni Shoreham Hotel, Washington D.C. Contact : G. Sawyer MS H811, Los Alamos National Laboratory, Los Alamos NM 87545, USA.

ICFA Workshop on Low-Emittance Beams, March 20-25 1987, BNL. Contact : Dr. J.B. Murphy (JBM at BNL.BITNET), BNL, Upton L.I. NY 11793, USA.

Workshop on New Developments in Particle Acceleration Techniques, June 29 - July 4 1987, Orsay, Paris, France. Contact : Mrs N. Mathieu, LAL, Bat. 200, F-91405 Orsay Cedex, France.

US Particle Accelerator School, Session I - University style, July 20-31 1987, FNAL. Contact : US Particle Accelerator School, Fermilab, M.S. 125, P.O. Box 500, Batavia, Ill. 60510, USA.

US Particle Accelerator School, Session II - University style, August 3-14 1987, FNAL. Contact : US Particle Accelerator School, Fermilab, M.S. 125, P.O. Box 500, Batavia, Ill. 60510, USA.

Advanced Accelerator Physics Course, September 14-25 1987, Berlin West. Contact : Mrs S. von Wartburg, LEP Division, CH-1211 Geneva 23, Switzerland.

The views expressed in this newsletter do not necessarily coincide with those of the editors. The authors are responsible for their text.