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BEAM DYNAMICS NEWSLETTER

edited by

E. Keil and A. Piwinski

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INTRODUCTION

The fourth meeting of the ICFA Panel on Beam Dynamics was held in Lugano, Switzerland, on 10th April 1988. 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. As after the previous panel meetings these presentations will be published in a 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 this issue, the mailing list for the distribution of the BEAM Dynamics Newsletter will be 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 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.

Thanks are due to the CERN Directorate for its hospitality during the panel meeting, and to Prof. P. Waloschek and the PR group at DESY for their help with this Newsletter.

PS BEAM DYNAMICS ACTIVITIES

B. Autin, Editor
European Laboratory for Particle Physics (CERN), Geneva, Switzerland

Beam dynamics in the PS Division covers a variety of topics: heavy ions, LEP pre-injector, high-intensity proton beams, antiproton production and storage and exploratory studies on future linear colliders.

In view of the great interest of the physics community in the acceleration of heavy ions (lead) at CERN, in particular after the successful oxygen and sulphur acceleration, the study was launched to look into the possibilities of accelerating even heavier ions. In the PS and PSB there are mainly instrumentation and vacuum problems. The ion source which has been selected is of the ECR type. In the linear accelerator, the space charge effects are much weaker than for protons after an initial stage of acceleration. A special difficulty occurred in the selection process of the accelerating structure. An Alvarez would cause no difficulties. However, in view of the low current an interdigital H structure looks - because of its very high shunt impedance - extremely interesting. The problem is, however, that none of the conventional computer codes is capable to deal with the RF structure and the beam dynamics of this complicated device. Work is in progress to calculate approximately the beam dynamics with a program developed at Saclay and with the help of people from there.

For the lepton linacs (LIL), studies mainly focus on the use of the same electron gun for both the production of positrons and the delivery of electrons as well as on the adaptation of the beam optics in order to improve transmission, positron conversion and matching to EPA.

In circular machines, single particle trajectories and collective effects are the subject of thorough investigations. The closed orbit correction relies mainly on the MICADO algorithm, refinements have been brought using a betatron oscillation fitting method developed in the LEP Theory Group (EPA) or an acceptance optimization procedure (AC + AA). The complete transverse phase space is explored in PS, AC, AA and LEAR by recording the horizontal and vertical position of a bunch turn after turn; the observation techniques are especially sophisticated in LEAR to monitor the slow extraction on a third integer stop-band. In AC where the beam emittance exceeds 200π mm.mrad in both planes, a dedicated system of correction of non-linear beam envelope distortions is being implemented.

A new rf recombination of 10 into 5 bunches is under development in the PS for the production of high-intensity antiproton beams. The antiproton collection in axisymmetric lenses is to be improved using a 36 mm diameter lithium lens carrying a current exceeding 1 MA (Novosibirsk-CERN Collaboration) or a plasma lens (CERN-Erlangen Collaboration). Stochastic cooling of antiprotons using variable gap electrodes works in a satisfactory way within a 4.8 s cycle. Operation at 2.4 s cycle requests improvements in the reduction of pick-up electrode thermal noise, in the compensation of phase variation with electrode position and in the power sharing between longitudinal and transverse channels. In LEAR, electron cooling will soon come into operation.

For CLIC (CERN Linear Collider), three main studies are about to start:

- design of a damping ring with short transverse damping times and small equilibrium emittances;
- development and test facility set-up of the front end for the drive linac of CLIC delivering high intensity and short length bunches;
- installation of an energy transfer structure scaled-up to S-band frequency in order to study its interaction with the high-intensity beam of the LILV linac.

BEAM DYNAMICS ACTIVITIES AT SSC CENTRAL DESIGN GROUP

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SUMMARY

The envisioned activities in the coming year are

Activity	Possible Contacts
lattice	Garren, Johnson, Peggs
aperture exp't	Edwards, Chao
operation simulation	Talman, Schachinger, Paxson, Chao, Sun
analytic tool	Berz, Forest, Irwin
data base	Talman, Saltmarsh, Peggs
beam-beam	Irwin, Tennyson, Furman
polarization	Yokoya, Chao, Sun
magnet physics	Johnson, Ng, Peterson
injector	Chen, Furman, Johnson
parameters	Peterson
correction schemes	Neuffer, Talman, Forest, Peterson

LATTICE DESIGN

Not much SSC lattice activities since last report October 87. Possible studies in the coming year are:

- site fitting (folding if necessary)
- evolution of IR design for detailed HEP needs
- IR arrangements (bypasses ?)
- a qualitatively different IR design ?

APERTURE EXPERIMENT

The aperture experiment at the Tevatron (Experiment E778, collaboration Fermilab, CDG, Cornell, CERN, SLAC, spokesperson: D.Edwards) has been a high priority item at the CDG. So far, there have been 16 shifts in March to May, 1987 and 13 shifts in February, 1988.

Tentative conclusions so far are

- Simulations and experiments agree quite well.
- The imitated nonlinear SSC environment meets the operational needs during injection.
- For the first time, subtle features (e.g. resonance islands of various orders) in phase space are directly observed.

Possiblity of continuation of E778 (or its equivalent) is being explored. We are most grateful to Fermilab for making E778 possible. Proposals of similar collaboration with other laboratories are welcome.

OPERATIONS SIMULATION (I.E. MODELLING)

Purpose is to simulate the SSC operations realistically. Expected outcomes are

- definition of various operational procedures
- specification of beam monitoring and corrector hardware

The present hardware is a workstation (six SUN terminals + one 800 Mbyte disk).

Present software capacities are

- interactive graphics interface
- calculation of lattice functions
- chromaticity curves
- tune resonance diagram
- particle tracking
- Fourier analysis
- eigenanalysis with linear coupling
- orbit correction

The plan is to apply the tool to simulate

- decoupling operation (done)
- first turn guiding (done)
- injection in the presence of persistent current effects (done)
- handling the beam injected with errors
- effects of time varying error multipoles
- machine function measurements
- failure mode operations

ANALYTIC TOOLS DEVELOPMENT

An optics analysis tool is nearly completed at the CDG. With beam line elements as input, the output is the 6-D linear and nonlinear (up to order>9, limited by storage space and CPU) maps.

The tool is based on the differential algebra (or truncated power series algebra TPSA) technique. It can be incorporated in existing tracking programs (TEAPOT, RACETRACK). As far as we know, this is the most efficient tool to generate precision maps. The map can be used to

- obtain beam dynamics quantities analytically (e.g. tune shifts with amplitude and momentum, smear, effective Hamiltonian)
- obtain the dependence of beam dynamics quantities on strage ring
- parameters analytically (e.g. error multipole strengths)
- perform fast tracking under some conditions

What next?

- compare with other techniques
- limitation as a tracking tool
- applications to the SSC

PHYSICS OF SUPERCONDUCTING MAGNETS

Understanding/learning the physics of superconducting cable/magnet design is one beam dynamics activity envisioned in the coming year:

- field calculation (POISSON)
- sensitivity to coil misalignments, iron properties
- optimal Cu/SC ratio
- cryogenic stability
- flux jumping
- magnet end configuration

MISCELLANEOUS

A database management system is being developed for the SSC.

The long-range beam-beam effect, important to the stability of the tail particles for the SSC, will continue to be studied.

Studies will be made on how many Siberian snakes are needed for the SSC. Discussions with non-CDG experts are expected.

BEAM DYNAMICS ACTIVITIES AND PLANS AT LBL

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On-going beam dynamics studies at LBL are performed in connection with the 1-2 GeV Advanced Light Source (ALS), the SSC, Collider Physics (Novel Power Sources) and Heavy Ion Fusion Accelerator Research (HIFAR). Exploratory activities include generic research on (a) high-brightness, low-emittance storage rings and linacs for the TeV-scale future linear colliders, $b\bar{b}$ facilities, etc., (b) beam dynamics and optics of incoherent and coherent undulator radiation, (c) Free Electron Laser Studies, (d) development of a high-brightness laser-driven RF photocathode electron source for the LBL-LLNL-SLAC collaboration on Relativistic Klystrons and (e) new methods of acceleration.

The major physics issues being studied in connection with the ALS are the effects of undulators and wigglers on storage ring beam dynamics (nonlinear stability and stable dynamic aperture), short bunch-length collective phenomena and multi-loop high-fidelity orbit and photon beam feedback for stability of the radiation source. In connection with the first issue, detailed nonlinear behavior of the electron beam in presence of insertion devices in an otherwise symmetric low-emittance lattice are being pursued and various compensation schemes are being investigated. We held a workshop on this specialized topic May 17-20, 1988 at LBL, where participants from international laboratories such as Sincrotrone Trieste, KEK, SLAC, BNL, ANL, etc., participated. Contributions will soon be published as proceedings to this workshop. Considerable insight into the physics of short bunches has been gained through a similar workshop last year on the "Impedance Beyond Cutoff" at LBL, where a realistic picture of the impedance spectrum at high frequencies corresponding to short bunch lengths emerged. The focus at the moment is on the nature of coherent instabilities potentially driven by this high-frequency impedance. Securing a stable photon beam against vibrations and other noise sources simultaneously at several beam lines in a synchrotron radiation source is nontrivial and requires multi-loop orbit feedback system with accompanying cross-talk. A possible control algorithm is under investigation. In other matters, experimental study of dynamic effects with undulators is being planned at BESSY and other laboratories; impedance measurement test facility, instrumentation and feedback, advanced accelerator control systems and optics of synchrotron radiation are being pursued actively. Possibilities of infra-red and XUV FEL's as upgrades to the ALS are also being considered.

Collaboration with LLNL and SLAC for the Relativistic Klystron is an ongoing activity. This promising power-source is being actively investigated both theoretically and experimentally with a goal towards a 1 GeV test experiment in late 1989. In this connection, studies of a conceptual design of a bright injector for the test experiment has been undertaken at Berkeley. The Conceptual Design Report will be completed in October, 1988. The design utilizes a high-brightness laser-driven RF photocathode electron gun, similar to the LANL early experiments, together with achromatic magnetic bunching and transport systems and diagnostics. The design is performed with attention to possible use in an FEL as well.

Heteroenergetic collision optics for a possible $b\bar{b}$ facility based on 12 GeV PEP and a 2 GeV high-brightness ring has been obtained. The possible implications of collective effects is under study presently.

A small but core group of physicists are engaged in pursuing the frontier of knowledge in advanced and efficient methods in nonlinear storage ring dynamics. Extraction of precise nonlinear maps for a modular storage ring, perturbative & nonperturbative analysis on these maps, stability issues, etc., are being pursued. Development of analytical and tracking tools is a major thrust of this activity.

In HIFAR, major attention is focused on two experiments, ILSE and MBE-4. A major cost saving in multiple beam ion induction linacs for fusion arises from the use of a large number of beams (approx. 100) at low energies which are combined into a smaller number after some acceleration. The study of the transverse emittance growth arising from the merging of 16 space charge dominated beams into 4, and the design of the transport system to affect this merge are two of the principal tasks of the forthcoming ILSE (Induction Linac Systems Experiment). The beam dynamics from the time the beams are brought near each other and exposed to each others fields until the new distribution of particles reaches a stable configuration is being studied with particle simulation. The results are becoming understood in terms of a geometric dilution term, which is the same as for ordinary emittance dominated beam merging, and a space charge term which arises from transfer of electrostatic energy into thermal energy. In addition to these transverse beam dynamics studies, longitudinal beam dynamics is also of serious concern. Control of the lengths of the beam bunches during the acceleration process is one of the key beam dynamics issues of the multiple-beam induction linac as an accelerator-driver of heavy ions for inertial fusion. This physics is being studied experimentally in the MBE-4 experiment, that models the longitudinal dynamics of the first 100 MeV of a driver. Measurements of the current amplification and of the behavior of transverse and longitudinal emittance of the four beams as functions of time are currently in progress. Control of the accelerating waveforms, within reasonable amplitude and time jitter tolerances, for proper bunch shaping and emittance is a crucial issue in this study.

In addition, considerable effort is dedicated to student training and Ph.D. thesis supervision in Accelerator Physics, in conjunction with the Berkeley campus.

A B-Meson Factory for P.S.I. [1]

J. F. Crawford, P.S.I. [2]

Future B-meson experiments require a luminosity of $\sim 10^{33}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ at 5 GeV, an order of magnitude more than now available. The physics motivation and a first design study for such a machine have been presented as internal reports [1].

A storage ring was chosen over a linear collider layout to avoid the problems of providing an intense e^+ source and of building a very precise final focus system, and because of the delays to be expected in implementing any new technology. Figure 1 shows a very simplified sketch of the machine layout. A significant feature is that the bunch crossing angle is zero[2].

With certain constraints and substitutions, the luminosity of an e^+e^- storage ring produced by n bunches per beam with a bunch current I_b and emittance ϵ is given by:

$$L = \frac{nI_b^2}{4\pi e^2 f_u \sigma_x^* \sigma_z^*} = 1.5\times 10^{32}[cm^{-2}GeV^{-4}]\frac{n\, f_u\, E^2\epsilon}{\beta_z^*}\Delta Q^2 \qquad (1)$$

Here E is the beam energy, β_z^* the vertical β-function at the interaction point, e the electronic charge and f_u the revolution frequency.

Following equation 1 one has for a given energy E four independent parameters with which to optimize L:

- small β_z^*. By using superconducting quadrupoles only 0.7 m from the interaction point, β_z^* as low as 15 mm can be achieved.
- the emittance ϵ has to be as large as possible. This is limited by magnet aperture and maximum β-functions elsewhere in the machine; taking an aperture of 50 mm, $\beta_{max} \sim 30$ m and allowing 10σ around the beam centre, a horizontal acceptance of 0.83×10^{-6} m.rad is obtained. The beam emittance at 5 GeV is 0.55×10^{-6} m.rad.
- the storage ring should run with many bunches per beam ($n \gg 1$). The problem here is to separate the bunches away from the interaction point. It seems practicable to do this within 15 m on either side of the interaction point, either electrostatically or with an RF magnet, allowing up to 20 bunches in each ring.
- the maximum tune shift ΔQ has to be as large as possible. Experience in other machines [3] suggests that $\Delta Q \approx 0.025$ is possible without special procedures; it is felt that up to 0.05 may be achievable with special methods.

Luminosity is then $0.5\times 10^{33}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ with 0.5 A in each beam (10 bunches), and with $\Delta Q = 0.04$. More can be expected after some R&D.

A list of the most important parameters is given in Table 1.

The lattice has the following characteristics:

- The energy of the rings ranges from 1 to 7 GeV.
- The emittance ϵ is variable.
- The vertical β-function β_z^* at the interaction point is variable.
- Dispersion is small in the interaction and injection regions, and in the RF-cavities.
- The dynamic aperture is almost as large as the mechanical aperture set by the beam pipe.
- Finally, the storage ring provides free straight sections for injection. In the additional free straight section required by symmetry, wiggler magnets can be installed for fine adjustment of the emittance and for users of synchrotron light.

The storage rings are fed at up to 6 GeV by a conventional synchrotron; ramping is needed to reach higher energies. The e^- and e^+ beams are provided by a conventional linac with an accumulator (damping) ring. The e^+ beam is made by the e^- beam hitting a target, probably a few radiation lengths of tungsten.

[1] Paul Scherrer Institute (formerly S.I.N.), CH-5234 Villigen, Switzerland

[2] Based on the work of K. Wille (University of Dortmund), with contributions from R. Abela, R. Eichler, J. Friedl, W. Joho, U. Schryber (PSI and IMP of ETH-Zürich, CH-5234 Villigen, Switzerland)

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[3] A. Piwinski, DESY; M. Donald, SLAC, private communications.

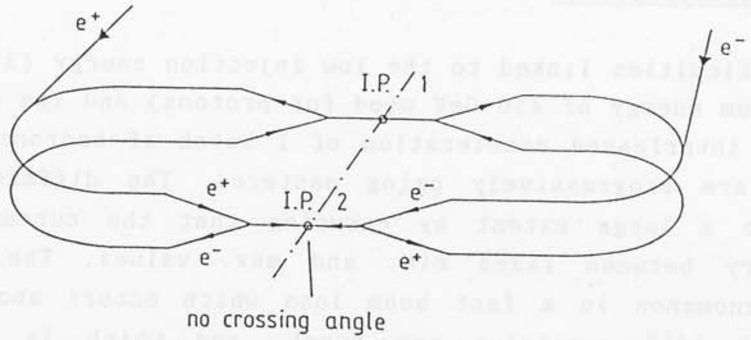

Figure 1: Sketch of the double ring with head-on collision.

Table 1: List of the most important machine parameters: (The numbers are per ring and for a 5 GeV beam)

			Standard Optics	Micro beta
Circumference	L [m]	:	648.0	
Number of bends		:	56	
Bending radius	R [m]	:	41.443	
Energy loss/turn	ΔE [MeV]	:	1.389	
Horizontal β-function	β_x^* [m]	:	1.00	1.0
Vertical β-function	β_z^* [m]	:	0.03	0.015
Tune	Q_x	:	7.779	
	Q_z	:	9.279	
Chromaticity	ξ_x	:	-12.8	-12.9
	ξ_z	:	-19.3	-30.6
Number of sextupole families		:	2	
Compensated chromaticity	ξ_x	:	+1	
	ξ_z	:	+1	
Momentum compaction factor	α	:	2.5×10^{-2}	
Horizontal emittance	ε_x [m·rad]	:	5.5×10^{-7}	
Minimum vertical emittance	ε_z [m·rad]	:	9.9×10^{-10}	
Vertical emittance with 3% coupling	ε_z [m·rad]	:	1.7×10^{-8}	
Energy spread	$\Delta E/E$	:	6.6×10^{-4}	
Damping times	τ_x [msec]	:	16.5	
	τ_z [msec]	:	15.6	
	τ_s [msec]	:	7.6	
RF-frequency	f_{RF} [MHz]	:	500	
Number of cavities		:	10	
Maximum number of bunches		:	20	
Current	I [mA]	:	485	
RF-power	P_{RF} [kW]	:	1050	

Beam Dynamics Studies at the CERN SPS

J. Gareyte

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I. Lepton acceleration:

The difficulties linked to the low injection energy (3.5 GeV compared to the maximum energy of 450 GeV used for protons) and the multicycling of the SPS for interleaved acceleration of 1 batch of hadrons and 4 batches of leptons are progressively being mastered. The different cycles are decoupled to a large extent by ensuring that the current in magnetic elements vary between fixed min. and max. values. The dominant beam dynamics phenomenon is a fast beam loss which occurs above a threshold intensity of 10^{10} particles per bunch, and which is accompanied by transverse signals in the GHz range. Since the injectors can deliver up to 4.10^{10} particles in one bunch, this phenomenon can be studied in a wide range of intensities, both below and above the threshold. It is interpreted in terms of the Mode Coupling theory (below threshold) as well as the Beam Break Up theory (above threshold). Both theories explain rather well the observations: the Mode coupling predicts the threshold (we find $1.4\ 10^{10}$ instead of the observed $1\ 10^{10}$) and the Beam Break Up predicts the number of turns after which a loss should occur. A computer simulation reproduces accurately the observations provided that the transverse coupling impedance of the SPS is adjusted to 23 $M\Omega m^{-1}$ (broad band model assumed, with Q = 1 and F_{res} = 1.3 GHz) a value compatible with earlier measurements mode with protons. Further studies using the short lepton bunches are envisaged in order to better understand the coupling impedance of the SPS in the GHz range.

II. $p\bar{p}$ Collider

A long operation period with the improved $\bar{p}$ source (ACOL) will start in September 1988. Problems are expected when the beam-beam effect (which up to now was in weak-strong régime) progressively approaches the strong-strong régime. An accurate control of the transverse emittances of each individual bunch is foreseen in order to balance the strength of non linear resonances affecting particles in the transverse tails of each bunch. In this way, lifetime and background rates can be optimized at the beginning of each store. Stochastic cooling of individual bunches will be attempted with a high frequency (8 to 16 GHz) experimental system which is now ready to be tested.

III. Non Linear Dynamics

Studies concerning the long term behaviour (over many hours) of stored beams in the presence of strong sextupolar non linearities are being pursued. Comparisons with both short and long term tracking will be made in order to assess the validity of the criteria used in the design of the LHC.

IV. Studies on the LHC

Low beta insertions for the LHC have been designed which allow to reach $\beta^* = 0.5$ m with a free space in between the inner quadrupoles of $L^* = \pm 20$m, and $\beta^* = 0.25$ m with $L^* = \pm 6$ m. Tracking studies are under way to evaluate the influence of multipolar magnetic errors in the insertion quadrupoles on the dynamic aperture.

V. Studies on damping rings for CLIC

A large tunnel like the one of the SPS could be used to house damping rings which would be perfectly adequate for CLIC. This solution is being analysed, and in particular the influence of the long wigglers, which are necessary in this case, on the dynamics of the machine is investigated.

BEAM DYNAMICS WORK IN THE LEP DIVISION

E. Keil

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The following beam dynamics work is planned for 1988 and 1989.

- We look at modelling of LEP by a computer program and the correction of various machine errors by application programs running in the LEP control system, as a preparation for the injection tests in July 1988 and commissioning, starting in July 1989.
- Work on refinements and extensions to the LEP lattice includes a search for configurations with even smaller values of β at the experimental interaction points, the development of criteria how many RF systems are needed to limit the variation of the beam energies around the circumference and its consequences, e.g. the reduction of the dynamic aperture to tolerable values, and the development of insertions for operating LEP with beam energies up to 100 GeV.
- Because of the interest expressed by the LEP experiments, a new round of polarization studies includes simulation by computer programs of the SLIM and SMILE families, the design of spin rotators, and attempts at formulating an analytical theory including the fact that the energy spread in the LEP beam is not small compared to 440 MeV.
- The orbit and beam dynamics program MAD will be the backbone of modelling for LEP. It will soon include polarization simulation in the SMILE style, the determination of the orbit parameters in three dimensions using Chao's eigenvalue and eigenvector technique, intra-beam scattering in the Bjorken-Mtingwa formulation, and the e^+e^- storage ring program BEAMPARAM.
- A perturbation theory and the associated computer program are being developed for the beam size in e^+e^- storage rings in the presence of synchro-betatron resonances driven by dispersion and wakefields in the RF cavities.
- The ABCI program for the computation of electromagnetic fields in objects with cylindrical symmetry and the MOSES program for the computation of the transverse mode coupling instability have been improved and documented.
- We shall look for more realistic solvable analytical models for the beam-beam effect.
- Satisfactory explanations for turbulent bunch-lengthening will be looked for.
- We seek a new broad-band impedance formula which behaves like $\omega^{-3/2}$ at high frequency and remains sufficiently simple that analytical calculations of the resulting collective effects can be done. It will be used for another review of the thresholds for collective effects in LEP.

ONGOING ACTIVITY AT SLAC*

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1. STANFORD LINEAR COLLIDER—SLC (R. Stiening)

On April 6, 1988 both beams were brought simultaneously through the Interaction Point (IP) into dumps. The number of positrons and electrons per pulse were $0.3 \cdot 10^{10}$ and $0.5 \cdot 10^{10}$, respectively, at the repetition rate 10 pps.

The performance of the SLC Arcs has been improved as the result of correction of the betatron phase advances in each achromat, dispersion correction and reducing the cross-plane coupling by smoothing the roll angles. The system to install coherent gradient deviations on the second harmonic of betatron oscillations is being prepared (P. Bambade, A. Hutton, N. Toge). The rms size of the electron bunch measured at the IP is $\sigma_x = 4\ \mu$m by $\sigma_y = 5\ \mu$m. From measured angle divergence of the beam one can evaluate the beam emittances to be $\epsilon_x = 12 \cdot 10^{-12}$ m-rad and $\epsilon_y = 14 \cdot 10^{-12}$ m-rad, respectively (W. Kozanecki). (Nominal emittance is $\epsilon = 4 \cdot 10^{-12}$ m-rad in each plane.) The damping rings routinely produce $2\text{–}3 \cdot 10^{10}$ electrons and positrons per pulse. The bunch lengthening in the rings is still there and the future plans include the installation of the sleeves for shielding the bellows (L. Rivkin).

The background in the Mark II detector has been analyzed (D. Burke). The main problem arises not from the synchrotron radiation but from the production of the μ mesons by the particles in the tails of the transverse distribution. The installation of additional collimators in the Beam Switchyard and the reverse bend Sections of the Arcs is planned. That should cut the background to a level which will allow operation of the Mark II with currents $1.0 \cdot 10^{10}$ in each beam.

2. STORAGE RINGS (P. Morton)

The installation and commission of the low emittance lattice in the PEP storage ring has been successfully performed (M. Donald and others). That transformed the ring into the brightest source of synchrotron radiation in the world. The evaluated horizontal emittance of the ring is $6.4 \cdot 10^{-9}$ m-rad at the energy 7.1 GeV (H. Winick). PEP has been commissioned with a mini-β lattice in one interaction region and is ready to resume runs for high energy physics. Future plans include development of the timing system for filling the SPEAR and PEP storage rings using the SLC complex and construction of independent injectors for SPEAR and PEP. The last one might well be designed as a test facility for future linear colliders.

3. BEAM DYNAMICS AT SLAC (E. Paterson)

The main beam dynamics activity besides the SLC is now shifted to the future TeV Linear Collider—the *TLC*.

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

3.1 TLC

Much progress has been made on the development of the basic concepts and parameters of the linear collider in the TeV energy range. The main conceptual features of the collider are: a) flat beams ($\epsilon_x/\epsilon_y = 100$), b) multibunch system (21 bunches), c) crossing angle at collision point, d) high frequency of accelerating field (17 GHz), e) a possible cluster of 10 relativistic klystrons (1 unit per each 8 m) as the RF power source and f) RF structure with damping of higher modes. Table 1 contains main parameters of the latest R&D design.

Table 1. Main Parameters of the TLC.

N	Parameter	Value	Comment
1	Energy (TeV)	2×0.5	$\gamma = 10^6$
2	Luminosity ($\mathrm{cm}^{-2}\mathrm{sec}^{-1}$)	$1.6 \cdot 10^{34}$	no dilution
3	Luminosity ($\mathrm{cm}^{-2}\mathrm{sec}^{-1}$)	$0.5 \cdot 10^{34}$	with dilution
4	Beamstrahlung parameter (%)	20	
5	Linac length (km)	7.41	
6	Acceleration gradient (MeV/m)	186	
7	Average RF power (Mw)	100	36% efficiency
8	Peak RF power (Gw)	5	
9	Length of RF pulse (nsec)	50	
10	Repetition rate (sec^{-1})	186	
11	β_x^* (cm)	1.2	
12	β_y^* (cm)	$3.8 \cdot 10^{-3}$	
13	σ_x^* (μm)	0.16	
14	σ_y^* (μm)	$8.7 \cdot 10^{-4}$	
15	$\gamma\epsilon_x$ (m·rad)	$1.9 \cdot 10^{-6}$	
16	$\gamma\epsilon_y$ (m·rad)	$1.9 \cdot 10^{-8}$	
17	σ_z (mm)	0.76	
18	σ_p (%)	0.14	

Two types of relativistic klystrons are being developed by the collaboration of SLAC, LLNL and LBL: 1) a high gain one-cavity klystron and 2) a low gain subharmonic two-cavity klystron. First experimental runs with a high gain klystron *SL4* were performed at the frequency 11.4 GHz. The RF generation was obtained but the pulse shape is not yet satisfactory (no flat top). In the second design a breakdown, probably due to a vacuum problem, was observed in a low gain klystron. Simulations of a relativistic klystron with the program *MASK* showed 45% efficiency (M. Allen, K. Eppley, T. Lavine, R. Miller, P. Morton, R. Palmer, R. Ruth, A. Vlieks, the Klystron Group at SLAC, W. Barletta, D. Birx, G. Westenskow, S. Yu at LLNL and A. Sessler at LBL).

A test RF structure for 11.4 GHz has been built (G. Loew, H. Hoag). Experiments on this facility will start as soon as the RF power is available. Suppression of higher modes has been checked in a single cavity with carefully designed cuts. The results for the frequency 17 GHz are given in Table 2 (R. Palmer).

Computer study of tolerances for the linac are underway. To preserve small vertical emittance of the beam, the orbit and alignment of quadrupoles in the linac must be kept very tight (R. Ruth): $y_{rms} \leq 30\mu m$. Simulations of the multibunch instability in the linac (K. Thompson, R. Ruth) show that the breakup could be controlled by a combination of a) transverse modes damping and b) tuning the fundamental transverse mode frequency to place bunches close to zero crossings of the wake field.

Table 2. Suppression of Higher Modes.

N	Mode	Q - Value	f (GHz)	Comment
1	Main	$5.8 \cdot 10^3$	17	
2	First Transverse	15	22	no. of waves between bunches ≥ 3
3	First Longitudinal	40	37	$Q \leq 80$

The beam-beam multibunch interaction at the IP could cause an exponential growth of the bunch displacement and as a result dilution of the luminosity (K. Yokoya). Measures which could control this effect are found to be (R. Palmer): a) large bunch separation (number of the RF wave lengths between bunches ≥ 5), b) small distance of septum to the IP, in the present design $l_{sept} = 18$ cm and is smaller than the distance to the first quadrupole magnet $l_{quad} = 36$ cm and c) large crossing angle, $\alpha = 4.2$ mrad. The first example of a Final Focus System was developed (B. Spence) utilizing a quad with a bore 150 μm. It is similar in concept to the SLC FFS and is satisfactory for a beam energy spread of 0.2%. The study of the beam-beam effects continues (K. Yokoya, P. Chen). The self-adjustment of flat beams found in Novosibirsk was confirmed. The disruption for the flat beams is different from that for the round ones.

3.2 Theoretical Studies (R. Ruth)

The longitudinal impedance of the linac-like RF structure in the high frequency limit (S. Heifets, S. Kheifets) was shown to agree both with the diffraction model (K. Bane, M. Sands) for a small number of cavities, which gives $\omega^{-1/2}$ dependence, and with the optical resonator model for a large number of cavities, where the impedance decreases as $\omega^{-3/2}$. The criterion for the transition from one regime to another was found. An important consideration in the design of the linac structure should be to ascertain the proper decrease of the impedance.

A numerical solution of the Hamilton–Jacobi equation was used to construct simplectic whole-revolution maps for tracking and to find invariant curves for nonlinear particle motion (R. Ruth, R. Warnock, W. Gabella). A similar method utilizing perturbation approach has been used to develop a theory of the second-order achromat (S. Kheifets, T. Fieguth, R. Ruth).

3.3 Miscellaneous Studies

The SLC klystron modeling (W. Herrmannsfeldt) was used to define and cure the RF pulse instability.

Collisions of substantially different energy beams for a B-factory has been proposed (G. Feldman) and luminosity of such an arrangement examined (R. Rees).

Overview of Ongoing and Projected Work at CEBAF

C.W. LEEMANN

Continuous Electron Beam Accelerator Facility (CEBAF)
12000 Jefferson Avenue, Newport News, Virginia, USA

To support the goal of an rms energy spread of 2.5 10^{-5} work is underway to provide an integrated analysis of the klystron-cavity system. This model will include klystron-cavity coupling, cavity-to-cavity coupling, low-level feedback, microphonics, and beam loading. This effort is to provide input for optimization of the system design and to address machine commissioning.

Three dimensional calculations of the crosstalk between members of the cavity pair is underway. Preliminary work with MAFIA indicates the importance of the breaking of cylindrical symmetry by the fundamental power couplers in enhancing this coupling.

Transverse beam breakup phenomena have been extensively modeled for the CEBAF linac, with developed codes capable of studying both single-bunch and multipass effects. With nominal damping of the low frequency higher order modes, threshold currents are found to exceed the design values by nearly a factor of 100. The study of the impact of very high frequency HOMs (5-20 GHz) will continue in support of the design of HOM loads. E & M calculations indicate that no modes in this range are "trapped" in the inner cells. Further field calculations will be performed to understand the modal structure of coupling to the HOM waveguides and in support of possible measurements during the front end test (a beam test up to 45 MeV planned for 1990).

Work is underway to evaluate the longitudinal analogue of multipass beam break. Nominally, in an isochronous machine the bunches are locked into longitudinal position, irrespective of energy offsets. However, this condition can be held only approximately with acceleration, and a finite, albeit high, threshold current, is expected. This effect may be of importance in a low energy recirculating linac using undamped superconducting cavities.

Single-bunch, internal beam breakup can yield unwanted emittance degradation at high peak currents. A preliminary cataloging of sources of strong transverse wakefields indicate that smoothing of the vacuum chamber environment in the room temperature portions of the machine can significantly reduce the beam-environment coupling. Component and design evaluation using both two and three dimensional codes is being pursued with regard to steps, shielded bellows, and flanges. Extensive analytic effort has been devoted to the very high frequency behavior of both the transverse and longitudinal impedance.

Extensive modeling work will be continued and intensified. This effort includes detailed particle tracking in as realistic a fashion as possible, the operations simulation of an imperfect machine, and the development of intelligent and automated tuning procedures using actual control systems hardware.

BEAM DYNAMICS ACTIVITIES AT BESSY

P. Kuske, BESSY GmbH, Berlin, Germany

As BESSY is a dedicated light source, all our activities aim at the generation of synchrotron radiation. We are actually working on three main subjects: improving the performance of the existing 800 MeV electron storage ring, comissioning a super conducting compact storage ring (COSY), and planning a light source of the third generation (BESSY II).

LIFETIME

In the low emittance mode the lifetime of the stored electron beam at high currents is dominated by the Touschek effect. To counteract this effect we recently raised the energy from 755 to 800 MeV and corrected the horizontal orbit which reduced its rms deviation from 3.8 down to less than 1 mm. The lifetime increased by 30 min to more than 120 min at a current of 400 mA. The strong sextupoles and the remaining closed orbit distortions brake the symmetry of the ring. We have measured a beat of the beta functions of up to 20 percent. Therefore off-energy particles still get lost at non-structural resonances. This leads to a reduction of the energy acceptance of the storage ring and consequently to severe particle losses due to the Touschek effect. We hope to achieve a lifetime of 3 h at 400 mA if we can restore the four fold symmetry of the storage ring by an even better correction of the horizontal orbit.

BUNCH LENGTH MEASUREMENTS

A streak camera with a temporal resolution of 2 ps has been reinstalled at one of the beamlines of the storage ring (W. Anders). We are planning to measure the bunchlength in single bunch mode as a function of beam current. The electrons are stored either in the low (62.5 MHz) or the high frequency (500 MHz) RF-system. The natural bunchlength can be reduced even further by choosing an electron optic with a momentum compaction factor of only .003 which is 4 times smaller than in the usual METRO optic. Therefore the natural rms bunchlength can be changed from 15 ps to a few hundred ps and we might be able to check the SPEAR scaling of the frequency dependence of the longitudinal impedance.

INSERTION DEVICE AND BEAM DYNAMICS

In spring 1987 a 35 period undulator/multipole wiggler with a period length of 7 cm has been installed at the BESSY storage ring. This insertion device is an optimized pure REC Halbach-type magnet structure. If the magnetic gap is closed we observe not only the expected vertical tune shift but also: a vertical closed orbit distortion, a considerable tune shift in the horizontal plane, an increase in the vertical beam size and a reduction of the lifetime exceeding the expectations for a purely physical aperture restriction. The origins of these effects are not yet understood. A solution of these problems, however, is essential for synchrotron light sources of the third generation where the radiation is produced primarily by these insertion devices. Therefore we will collaborate with Berkeley (ALS), Grenoble (ESRF) and other groups to do more experimental and theoretical work to improve the understanding of these effects.

COSY

COSY is a compact synchrotron radiation source dedicated to X-ray lithography utilizing super conducting dipole magnets. The injection process at low energy (50 MeV) and the lifetime limitations have been studied experimentally with normal conducting magnets. Good vacuum conditions and ion clearing are essential to accumulate currents of more than 90 mA with a lifetime of 2 min at 50 mA. Details of these experiments and the design of COSY will be presented at the 1988 European Particle Accelerator Conference in Rome (E. Weihreter). In the meantime the super conducting magnets have been installed and both dipoles have been cooled down.

BESSY II

BESSY II is a 1.5 GeV synchrotron ligth source of the third generation and still in its design phase. During the last year much effort has been put into the analytical description of the triple bend achromat lattice to find all possible solutions under the constraints imposed by the desired emittance, the need for strong sextupoles, the requirements of the insertion devices, the circumference of the machine, etc. Some non-linear effects have been included into the analytical calculations to estimate the amplitude dependent tune shift caused by the sextupoles. This approach uses the distortion functions as proposed by Collins. It is very convenient to have an indication of the strength of non-linear effects in the early design phase of the lattice. First results of this approach will be presented at the Rome conference (B. Simon and G. Wuestefeld).

A REPORT ON LOS ALAMOS BEAM DYNAMICS ACTIVITIES*

David Neuffer

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The major accelerator facility at Los Alamos is the LAMPF 0.8-GeV proton linac. That linac was the originating basis for Los Alamos expertise in proton linacs, as expressed in such accomplishments as the pioneering development of the radio-frequency quadrupole (RFQ).

A new facility at LAMPF is the Proton Storage Ring (PSR), a 0.8-GeV storage ring that accumulates protons from the linac to provide intense pulses for neutron and neutrino experiments. The operating intensity is currently limited by losses during injection and storage. The losses are due to a complex interplay of injection mismatch, foil scattering, nonlinear fields, and aperture restrictions and are currently being studied by R. Macek and collaborators. Removal of an extraction aperture restriction has greatly reduced losses. Future upgrades in the injection procedure may also improve performance. A high-intensity, transverse collective instability has also been identified; its causes and possible cures are being investigated.

A future high-intensity hadron facility (AHF) is being designed for Los Alamos by H. A. Thiessen and collaborators. The current plan is for a 60-GeV synchrotron complex. An important issue for this and all high-intensity facilities is the problem of high-efficiency slow extraction. Currently an extraction channel using a long straight section and a massless magnetic preseptum is being developed. Another important problem is obtaining a beam pipe with low eddy-current losses and a small beam-coupling impedance. A striped, ceramic-metal pipe is proposed. A facility has been developed by L. Walling et al. for measurements of the impedances of beam pipes and other devices. Optimization of injection ("painting") and space-charge and instability studies are other important issues under study by E. Colton, H. A. Thiessen, and others.

An important, recent invention by D. Neuffer is the development of a new method of multipole correction and adjustment of nonlinear motion using multipole element placed at the center (C) of the accelerator half-cells, as well as near the F and D quadrupoles. Correction of systematic, random, first-order, and higher-order nonlinearities by more than two orders of magnitude is obtained. The method is valid for any synchrotron (or transport line). Applications to the superconducting supercollider (SSC), large hadron collider (LHC), and AHF have been developed, and a generalization of the correction procedure has been obtained.

Further studies and development of RFQ concepts are also in progress. A review article on RFQ progress by Stokes and Wangler will appear in Annual Review of Nuclear and Particle Physics (1988). A particular concern is the degree of emittance growth in RFQs and other transport systems. A general formalism for describing transverse and longitudinal emittance growth is being developed (see Wangler, 1987 PAC).

* Work supported by the US Department of Energy, Office of High Energy and Nuclear Physics.

An important concern is the effect of space charge in beam transport. Recent theory and simulation results indicate that small, strongly-focused beams show less space-charge emittance growth than large beams (Wangler, AT-1 Note 88-120). The effects of image charges in beam transport structures are also being studied.

A group at Los Alamos (AT-3, E. Heighway et al.) is collaborating with Argonne in a beam telescope experiment. The purpose is to devise a long, focal-length device with minimal aberrations or emittance growth. Particular concerns are the large geometric aberrations that may be obtained in large lens systems.

R. Cooper, R. L. Gluckstern, and collaborators have produced a series of studies on "beam breakup" in linacs that have explored the dependencies on fluctuations in bunch intensity and deflecting mode frequencies and on external focusing (see Particle Accelerators).

P. Channell has studied laser focusing for high-luminosity colliders and has recently proposed a method of field cancellation using a self-generated electron-positron plasma in the final focus to reduce beam-strahlung.

There are a large variety of Los Alamos beam dynamics activities and this report is only a short summary of some of these; I apologize for any significant omissions.

BEAM DYNAMICS ACTIVITIES AT DESY

A. Piwinski

Deutsches Elektronen-Synchrotron, DESY, Hamburg

1. Space Charge Effects at Low Energy

A longitudinal multiparticle tracking code has been developed which includes space charge forces. It has been used to study longitudinal motion in DESY3 during the first 300 msec of acceleration. Some small particle losses were predicted. In addition the code was used to investigate a phase space accumulation scheme proposal for the TRIUMF Kaon factory. (E.Karantzoulis, J.Maidment)

2. Compensation of Multipoles in the HERA Superconducting Magnets

Persistant currents produce large 10-poles (10^{-3}) in dipoles and 12-poles ($4 * 10^{-3}$) in quadrupoles at $40 GeV$. Tracking results have shown that the transverse acceptance is reduced by a factor of 3. The quarter resonance is especially driven by these multipoles. It is necessary to compensate at least the 12-poles by additional coils on the vacuum chamber (R.Brinkmann, F.Willeke).

3. Electron Polarisation

Now that the program SMILE (S.Mane, FNAL) is running at DESY, it is possible to calculate *analytically* the polarisation for arbitrarily high orders of spin resonances. This is a very substantial improvement over the previous situation where only the first order resonance effects could be calculated *analytically*. The program is now being used for a detailed investigation of the effects of machine imperfections (D.Barber).

4. Proton Resonances Caused by an Oscillating Electron Beam in HERA.

These resonances, which were first investigated for DORIS1, can become important also for HERA. They have the same structure as the satellite resonances caused by the beam-beam interaction with a crossing angle, and their resonance frequencies are given by $Q_p + mQ_e = n$ where Q_p is the betatron frequency of the protons, Q_e is the coherent betatron frequency of the electrons, and l,m,n are integers. Simulations show resonances up to the 12^{th} order with a coherent electron amplitude of 0.05 sigma. Variation of proton amplitudes and the width of the resonances are small (A.Piwinski).

5. Increase of Proton Emittances due to Noise in the Electron Cavities.

Noise on the electron accelerating voltage will excite coherent betatron oscillations if the dispersion does not vanish in the cavities. Noise and coherent synchrotron amplitudes were measured in PETRA. The spectral density of the noise at the synchrotron frequency was $10^{-10} Hz^{-1}$ and the coherent amplitude was 0.1 sigma which is consistent. The dispersion invariant in the cavity section of HERA is one third of its value in the bending magnets. With these numbers one gets a rise time for the horizontal proton emittance in HERA of about 50 hrs.

An improvement will be obtained by installing an additional filter for the master oscillator which reduces the noise by a factor of 3 so that the rise time is increased by an order of magnitude (R.Brinkmann).

6. Instabilities

Instead of calculating threshold currents due to instabilities, maximum currents are calculated which take into account self- stabilisation due to finite amplitudes in nonlinear fields. The self-stabilisation is considered in the framework of nonlinear Fokker-Planck equations (R.D.Kohaupt, J.Feikes).

7. Feedback

The narrow-band multi-bunch feedback system using frequency splitting has been modified. The pick-up and low power part is replaced by a wide band system (10 MHz). The active device is still a narrow band system. The single bunch signals are digitized and are added to produce a narrow-band signal which modulates the active device. This procedure replaces the factor (C+ln(N-1)) (C=Euler's const., N=number of bunches) in the original scheme by nearly one, which is, in the case of HERA, an improvement by a factor 4 to 5 (R.D.Kohaupt, M.Schweiger, H.J.Stuckenberg).

8. Investigation of Ground Motion in HERA.

Measurements of ground motion have now been made on electron magnet modules in the HERA tunnel. It turned out that the displacements were larger on the magnets than on the concrete floor by a factor of 3. The rms-value is now $1\mu m$. An analytical investigation of the resulting vertical orbit displacements which takes into account strong focusing shows that the two beams will be separated at the interaction points by about 0.2 sigma (rms-value).

More measurements are planned. In particular the motion of the superconductors will be measured. This can be done by measuring the motion of the vacuum chamber (J.Rossbach).

Beam Dynamics and related activities at LNF (Laboratori Nazionali di Frascati dell'INFN)

(reported by M.Preger)

The Adone storage ring is in the process of being recommissioned after significant upgrading of its injector, diagnostics, vacuum and RF systems. The Linac injector was replaced by a triode gun and a new buncher to add the capability of producing high peak current short bunches (≈10 A, 20 ns) to the more usual long macropulse (≈2 μs) mode of operation. Two beam operation will also be resumed after several years of running with a single beam, with luminosities in the $10^{29} \div 10^{30}$ $cm^{-2}s^{-1}$ range at around 1 GeV.

Another important R&D activity in progress in Frascati (LNF-INFN) is connected with the project called LIS-A. The project is aimed at building a Linear Superconducting Accelerator (500 MHz, 5 MeV/m) to accelerate a high quality electron beam, to an energy of up to 25 MeV at the nominal gradient. A recirculation channel to either double the energy or recover part of it is also foreseen. As a first application LIS-A will be utilized to set up a free electron laser experiment in the infrared wavelength region.

The main parameters of the whole complex have already been fixed. The injection chain has been designed with a double system of choppers to optimize the behaviour of peak current versus power dissipation and meet the free electron laser requirements (6 A peak current for a microbunch length of 1-3 mm). The beam transport along the injector and the Linac has been simulated with a modified version of the program PARMELA that includes space charge effects. A preliminary study of the recirculator has been carried out taking into account the need to minimize cumulative beam break-up effects. Beam breakup and other wakefield effects are also under study in collaboration with the University of Rome, CEBAFand Stanford University. The stringent requirements on beam quality require specific diagnostics: the problem is under investigation.

A feasibility study of a superconducting linear collider to serve as a beauty factory and Nuclear Physics continuous beam facility is also underway.

The structure under study consists of twin superconducting Linacs, each with an energy of about 1 GeV, connected by four recirculation channels in order to reach the desired energy of up to ten GeV per beam. The very small beam emittances required for high luminosity can be achieved for the electron beam by using low emittance electron guns and making use of the adiabatic damping. A properly designed focusing system along the Linac prevents the emittance from being blown up. For the positron beam, low emittance is only achieved by making recourse to a damping ring. For the collider to reach the desired luminosity, the D.R. repetition frequency and bunch current density have to meet very stringent requirements. Also, to keep the DR circumference within practical limits, the lattice has to include wiggler magnets; a preliminary solution that satisfies practically all requirements has been found.

The problems related to the introduction of wigglers in the ring, the feasibility of low transverse and longitudinal emittances and collective effects affecting the emittances (such as intrabeam scattering and turbulent bunch lengthening) are being studied. Preliminary work has also been carried out on the magnetic structure of the recirculators and on the transverse focusing lattice for the Linacs.

BEAM DYNAMICS ACTIVITIES AT THE ESRF

A. Ropert

ESRF, BP 220, 38043 Grenoble Cedex, France.

The work being pursued includes the following topics:

The optimization of various low emittance lattices is based on the choice of the best working points, the compensation of resonance driving terms and the minimization of tune shifts on momentum and amplitude. The problem of dynamic aperture, with all its technical complement of tracking codes, analytical approaches etc., is a central one and is being attacked from various angles. In connection with this work, the performance of a new very low emittance lattice in the 10^{-10} m.rad range, which is based on the use of multipole magnets only, are being investigated.

The study of the sensitivity of lattices to errors and the correction of orbit errors are currently under way. Tolerances on magnets have been finalized after a thorough study of the effects of different kinds of errors on storage ring performance, including alignment, random and systematic field errors. These tolerances have been set in order to keep the deterioration of performance (reduction of the dynamic aperture as well as distortions of the linear optics) within a realistic range. The quadrupole and sextupole positioning were found to be the most critical to achieve.

A correction scheme for compensating half-integer stopbands was investigated. The results indicate that the simple harmonic correction still leaves a significant percentage of the initial distortion. In a large ring, numerous correctors are required to obtain a good correction efficiency.

The effects on dynamic aperture of non-linear field components in insertion devices and the matching of insertion devices into the lattice have been studied. In addition the flexibility of the lattice and its ability to accommodate a variable number of wigglers and undulators have been investigated.

New developments in the in-house tracking codes have been performed: the non-linear effecs of insertion devices on beam dynamics and treatment of synchrotron motion have been implemented in the BETA code.

The effects of ground vibrations on the beam emittance and on the beam stability have been computed, using the results of the measurements of environmental noise and of the study of underground properties.

The study of single beam and collective effects and of instability thresholds, including the investigation of the electromagnetic properties of the beam surroundings, has been carried out. The contribution of various elements of the vacuum chamber to the coupling impedance has been estimated by computing wake potentials and the loss parameters with the TBCI code.

ONGOING AND PLANNED BEAM DYNAMICS ACTIVITIES IN KEK

Toshio Suzuki
KEK, Ibaraki-ken 305, Japan, and
CERN, Geneva, Switzerland.

Last year, the 6th Japanese accelerator conference was held in INS, University of Tokyo. English proceedings are available.

The TRISTAN intensity was increased to 4.9 mA for a single bunch by choosing the best tunes $Q_x = 36.64$, $Q_y = 38.73$ and $Q_s \approx 0.1$. It was confirmed experimentally that the former intensity limit was due to synchrobetatron resonances. The resonances are sensitive to vertical dispersion and/or closed orbit distortions. They are also dependent on intensity. Thus the resonances are considered to be Sundelin's effect (c.o.d. + transverse wakefield) or the effect caused by the combination of the dispersion and the longitudinal wakefield. The latter effect is studied by J. Hagel and T. Suzuki at CERN and the report will be published. It will be necessary to analyze the case of TRISTAN later.

The beam-beam effect was also studied extensively. At the injection energy at 7.5 GeV, the beam blows up very much vertically (without separators). The cause of this may be the synchrobetatron resonances or the beam-beam effect itself. The veretical beam-beam tune shift at the maximum energy of 28 GeV is 0.035 and no saturation (beam blow-up) has been observed yet. Ieiri observed the nonlinear coherent dipole oscillations (forced oscillation by deflector) by beam-beam effect. A hysterisis curve of amplitude of coherent oscillations vs tune was obtained, as predicted by K. Hirata.

Since I have been away from KEK for more than one year, I cannot say much about the planned activities. However, the publication of many interesting beam behaviours with suitable theoretical explanations will definitely be an important future work.

Hirata, Kamada, Oide, Yokoya and Yamamoto are working on the program SAD (strategic accelerator design). This performs Lie algebraic perturbation calculations for betatron, synchrotron and spin motions as well as three-dimensional particle tracking. The program uses the input format of MAD. This should be completed.

Hirata, now at CERN, is interested in extending his former theory of bunch lengthening further. Bunch lengthening is not yet a solved problem.

Works towards Japanese linear collider and Japanese hadron facility are going on. For information, please refer to the accelerator conference proceedings cited at the beginning of this report.

Beam Dynamics Activities at Cornell Laboratory of Nuclear Studies.

Reported by Richard Talman, SSC Central Design Group, Lawrence Berkeley Laboratory, Berkeley, California, 94720

Recent Past. Fully satisfactory 7×7 bunch operation has become routine. Peak luminosity slightly in excess of the symbolically important level of 10^{32} $cm^{-2}sec^{-1}$ has been achieved. Some of the improvements leading to this, with names of individuals from whom more information can be obtained follow:

(*i*) narrow band feedback to stabilize multibunch operation, R. Littauer.

(*ii*) RF cavity window redesign to handle higher mode power accompanying high current, short bunch operation, D. Hartill.

(*iii*) "Microbeta" (i.e. low beta in the range 1 to 2 cm) operation using rare earth permanent magnet quadrupoles, S. Herb.

(*iv*) "Clean living" (i.e. improved efficiency in many areas), D. Rice, M. Billing, S. Peck, D. Rubin, and others.

As an aside this reporter wishes to mention that, though his permanent address is Cornell LNS, he has not been there recently and has not contributed to these recent successes.

Present. Tests are being performed with a small diameter (22 mm) beryllium intersection region beam tube, under the direction of R. DiSalvo. The purpose is to allow the use of a micro-vertex detector of the smallest possible size in order to obtain vertex locations with the highest possible accuracy. The dominant issue is the requirement of shielding the vertex detector from synchrotron radiation. The main beam dynamics issues of interest have to do with particle and photon distributions. Monte Carlo calculations have included concatenated tracking around most of the accelerator, detailed tracking through the intersection region, photon generation using Schwinger formulas, reflection, absorbtion and scattering of photons, design of masks and coatings and so on. H. Jawahery, M. Mestayer and R. Talman.

Synchrotron Radiation.

(*i*) For the first time in the history of the laboratory there will be an extended period (one month this spring) of dedicated use of the accelerator for synchrotron radiation.

(*ii*) A test of a low emittance (5×10^{-8} m at 5 GeV) configuration of CESR is planned. E. Blum. The possibility of reconfiguring CESR in this way is due to the independent powering of every quadrupole. On the other hand, another reduction factor of say, five, possible in principle at this energy and radius, is excluded by geometric and equipment constraints.

(*iii*) A test of undulator radiation is planned. E. Blum

Planned or Possible Lattice Modifications.

(*i*) Vertical electrostatic separators are present in the lattice now because they were once thought to be necessary for injection of one beam in the presence of a counter-circulating beam. Since this is no longer thought to be true they will be removed to relieve congestion in the intersection region. D. Rice. The need for injection studies accompanying this change is anticipated.

(*ii*) Lattice configurations with higher tunes (11 to 13 instead of 9 as at present,) which can potentially lead to higher luminosity by reducing bunch length, exist and may be tried. D. Rubin.

(*iii*) Instead of the present "ribbon-beams" there is a possibility of reduced sensitivity to beam-beam forces in "round-beam" geometry. Theoretical studies are in progress. R. Siemann.

B Meson Facilities. Two plans have been considered, the first being reasonably adiabatic and the second much more ambitious.

(*i*) CESR Plus. Operation with 14×14 bunches is expected to be possible but at the required beam currents the need for a new vacuum chamber is anticipated. Use of one intersection region, instead of two as at present will increase the damping decrement which is expected to increase the limiting beam-beam tune shift parameter. (Studies have exhibited improvement for single bunches but not for multiple bunches so far.) By this approach peak luminosity of 5×10^{32} cm^{-2}sec^{-1} is possible.

(*ii*) CESR B. This would be a two ring facility with high beam currents permitting a peak luminosity of 2×10^{33} cm^{-2}sec^{-1}

Shutdown. A shutdown for 10 months, starting June, 1988 is planned for final installation of the CLEO II detector installation.

The Trieste Synchrotron Light Source ELETTRA
(Sincrotrone Trieste)
(Reported by A.Wrulich)

The synchrotron radiation facility currently under construction in Trieste is a storage ring optimized for low emittance electron beams in the energy range from 1.5 to 2 GeV. The design incorporates 12 six meter long straight sections, out of which 11 will be used to accomodate wigglers and undulators for the production of intense radiation beams, complemented by up to 12 radiation beam lines out of bending magnets.

The low emittance lattice has a double bend achromat structure and has been chosen after a comparative study with the triplet bend achromat. Connected with the strong focusing required to achieve the small emittance are large chromatic effects which must be compensated by means of strong sextupoles which in turn reduce the dynamic aperture. The problem of dynamic aperture optimization, as well as variation of tune with momentum and amplitude, has been solved by means of tracking codes supported by analytical approaches.

The effect of insertion devices on beam dynamics has been studied. RACETRACK has been upgraded to take wigglers and undulators into account. The numerical evaluation of the magnetic field for pure REC undulators by the finite element method has been implemented to perform the tracking. Various procedures have been investigated of matching the insertion devices into the lattice.

Collective effects and beam lifetime reductions due to scattering have been investigated. Studies will continue to investigate the electromagnetic properties of the beam environment, to calculate the contribution of vacuum chamber elements to the impedance with the help of numerical field codes (TBCI and MAFIA).

The possibility of using the 100 MeV injector Linac for FEL experiments in the infrared region has been studied. A bypass scheme for a FEL working in the spontaneous emission mode is under investigation. Studies have been made about the possibility of colliding the storage ring beam with a low energy electron beam from a linear accelerator.

THE FEL STORAGE RING DELTA

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ABSTRACT
A short presentation of the on-going and planned activities at the University of Dortmund will be given. The main project is the 1.5 GeV electron storage ring DELTA[1]).

The central research project at the Institute for Accelerator Physics in Dortmund is DELTA, which stands for Dortmund Electron Test Accelerator. Approval and funding for this project is expected in the second half of 1988.

DELTA is a racetrack shaped electron storage ring with maximum energy of 1.5 GeV. The arcs consist of 16 FODO cells each. With 32 short bending magnets this guarantees a small natural emittance. The arcs are separated by 20m straight sections which can almost freely be used for experiments. The design data of DELTA are displayed in Table 1.

Table 1: DELTA Design Data

Circumference	:	115.2 m
Maximum energy	:	1.5 Gev
Natural uncoupled emittance	:	$1.5\ 10^{-8}$ m-rad
Natural energy spread	:	$7.2\ 10^{-4}$
Energy loss per turn	:	143.0 keV
Momentum compaction factor	:	0.0062
Longitudinal damping time	:	$4.0\ 10^{-3}$ s

The electrons will be injected at working energy into DELTA. To achieve this a booster synchrotron with a combined function lattice is planned. Horizontal antidamping is usually encountered with such lattices, but this can be compensated with additional quadrupoles. The booster itself will be injected by a 50-100 MeV linear accelerator which will be bought from industry.

DELTA serves many purposes, which arise from the fact that it will be built at a university and that it is a test accelerator.

i) Free Electron Laser experiments. The long straight sections and the small emittance combined with short damping time make DELTA suitable to drive a FEL at 10 nm.

ii) Testing of machine components.
- Undulators and Wigglers
- Magnets with additional integrated multipoles
- Monitors
- RF-components

iii) Machine experiments.
- Low energy injection into the booster
- Dynamic aperture experiments
- Experiments with vanishing momentum compaction factor

*) supported by the Bundesminister für Forschung und Technologie under contract 05 334 AX B2

iv) Education of students. (Currently 10 undergraduate and 3 graduate students)

v) Provide synchrotron radiation.

Other projects include i) the design and test of various monitors[2] (position, emittance, current) ii) a feedback loop to stabilize vibrations of the beam in a frequency range below 100 Hz[3] (collaboration with ESRF and HASYLAB), iii) the developement of a tracking code for vacuum structures[4] iv) the lattice design of a B-Factory which is done in collaboration with PSI in Zürich[5], v) the inclusion of a Free Electron Laser into Hirata's theory of localized wakes[6].

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L. Falck, Knopfmonitore für Synchrotronstrahlungsquellen, Diploma Thesis, Univ. Dortmund, in preparation

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5) : K. Wille, J. Friedl, in B-Factory Design Report, PSI, Villigen, 1988

6) : K. Hirata, Part. Acc. 22, 57 (1987)

FORTHCOMING BEAM DYNAMICS EVENTS

Main CAS course on "General Accelerator Physics", Salamanca, Spain, 19-30 September 1988. Contact: Mrs. S.von Wartburg, CERN, Geneva, Switzerland.

1988 Linear Accelerator Conference (Linac 88), Williamsburg, VA, USA, 3-7 October. Contact: C.W.Leemann, CEBAF, Newport News, VA 23606, USA.

Workshop on Crystalline Ion Beams, Wertheim/Main, Germany, October 4-7, 1988. Contact: Ms. Siglind Rais, GSI Darmstadt, Postf.110552, D-6100 Darmstadt, Germany.

Joint US-CERN course on "Beam Observation, Measurement, Diagnosis and Correction", Capri, Italy, 20-26 October 1988. Contact: Mrs. S.von Wartburg, CERN, Geneva, Switzerland.

National Accelerator Conference, Dubna, October 25-27, 1988. Contact: N.S.Dikansky, Institute of Nuclear Physics, Novosibirsk 90, U.S.S.R.

10th Conference on the Applications of Accelerators in Research and Industry, Denton, TX, USA, 7-9 November 1988. Contact: L.Duggan, Physics Dept., North Texas State Univ., Denton, TX 76203, USA.

The Third Biennial IEEE Conference in Electromagnetic Field Computation, Washington, D.C., National Capital Area at Bethesda, Hyatt Regency Hotel, December 12-14, 1988. Contact: Wasyl Wasylkiwsyi, George Washington University.

1989 Particle Accelerator Conference, Chicago, USA, March 20-23, 1989. Contact: F.T.Cole, D.E.Young, FNAL, P.O. Box 500, Batavia, IL 60510

Course on Synchrotron Radiation and Free Electron Lasers, Chester, UK (Chester College), 6 - 13 April 1989. Contact: CERN Accelerator School; Mrs S von Wartburg; LEP Division; CH-1217 GENEVA 23, Switzerland; Comp. mail: CASDARS(at)CERNVM; Participants: 150; Applications: 15 Jan 1989

Computing in High Energy Physics, University of Oxford, England, April 10-14, 1989. Contact: c/o Mrs. Jacky Hutchinson, Atlas Centre, Rutherford Appleton Laboratory, Chilton

APS Spring Meeting, Baltimore MD, May 1-4, 1989. Contact: W.W.Havens Jr., APS, 335 E.45th st. New York, NY 10017.

3rd Advanced ICFA Beam Dynamics Workshop - Beam-Beam Effects in Circular Colliders, Novosibirsk. USSR (Institute of Nuclear Physics), 29 May - 3 June 1989. Contact: A. Tumaikin; Chairman, Organizing Committee; Inst. of Nuclear Physics; SU-Novosibirsk 90; USSSR.

International Microwave Symposium and Workshops, Long Beach, CA, USA (Hyatt Regency Hotel), 14 - 16 June 1989, Sponsored by: IEEE.

International Conference on High Energy Accelerators, Tsukuba, Japan (KEK), 20 - 26 August 1989. Contact: S Ozaki, KEK, Oho-machi, TSUKUBA-gun, Ibaraki-ken 305, Japan.

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, Papers: 3 Sep 1989, Abstracts: 30 Dec 1988.

CERN Accellerator 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.

1989 Conference on Magnetism and Magnetic Materials Boston, MA, USA (Sheraton Hotel), 4-7 December 1989. Sponsored by: IEEE; American Institute of Physics.

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 83 32 75, Telex : 419000 cer ch, Telefax : + 41 22 83 02 21.

CERN Accelerator School - General Accelerator Physics, Unknown place, September 1990. Contact: CERN Accelerator School, Mrs. S. von Wartburg, LEP Division, CH-1211 Geneva 23, Switzerland.

1990 Conference on Magnetism and Magnetic Materials, San Diego, CA, USA (Town and Country Hotel), 30 October - 2 November 1990. Sponsored by: IEEE; American Institute of Physics.

3rd Advanced ICFA Beam Dynamics Workshop - Beam-Beam Effects in Circular Colliders, Novosibirsk, USSR (Institute of Nuclear Physics), 29 May - 3 June 1989. Contact: A. Tumaikin; Chairman; Organizing Committee; Inst. of Nuclear Physics, SO, Novosibirsk 90, USSR.

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