ICFA Beam Dynamics Newsletter, No. 11

Edited by: K. Hirata, J.M. Jowett, S.Y.Lee

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Contents

1: Forewords

1.1 From the chairman of ICFA Beam Dynamics Panel

K. Hirata `hirata@kekvax.kek.jp` The Chairman

Let me start with a personal opinion, which is not the official statement of the panel but is a part of my thinking for working as the chairman.

As stated frequently, the mission of the beam dynamics panel is *to encourage and promote international collaboration on beam dynamics studies for present and future accelerators.* For this purpose, we are publishing the newsletters and organizing workshops. The collaboration does not necessarily mean the "official collaboration" between laboratories for, say, R&D. It should include also the collaboration between individual physicists. To promote such a collaboration, we need a beam dynanmics community.

It seems to me that most of the beam dynamics physicists are rather separated from each other and are bound to projects in their laboratories, when comparerd to the elementary particle physicists, for example. They are also divided into laboratories and universities and work just for particular projects sometimes. Actually, however, they work for "physics": at least they believe so. They have a powerful international community. This is the reason why an organization like ICFA exists and is useful.

The panel should thus work to create such an international community working for "beam dynamics". I think it quite possible, because, I believe, beam dynamics is not the application of existing knowledges to accelerators but is a field where new knowledge in physics is being pursued. In other words, beam dynamics is one of the research subjects of physics.

From this point of view, I want to encourage contributiona to this newsletter from many individuals. Letters to the editors can be used to express personal opinions, reports of stays in other labobarories, statements of hidden histories, etc. Reviews of beam dynamics problems can be used to point out problems that are not understood, to call for collaboration from around the world, etc.

At present, this newsletter is the unique international journal for beam dynamics. I hope the reader can make the best use of it.

From this issue, I decided to show the minutes of the panel meeting, which is held once a year. The minutes of the 10th meeting, as well as the present minutes can also be seen in WWW page, `http://130.87.74.156/ICFA/whatnew.html`, which can be reached by links from the ICFA Beam Dynamics Panel official home pages.

1.1.1 Minutes of the 11th Panel Meeting

The eleventh meeting of the ICFA Beam Dynamics Panel was held at Gran Sitges Hotel in Sitges, Spain on 14 June 1996. The following panel members took part:

Sergey Ivanov	(for V.I.Balbekov)	Jean-Louis Laclare
Kohji Hirata		S.Y.Lee
Albert Hofmann		Helmut Mais
Ingo Hofmann		Luigi Palumbo
C.C.Kuo	(for Chen-Shiung Hsue)	Elcuno A. Perelstein
John M. Jowett		

Apologies were received from Pisin Chen, Dmitry Pestrikov and Chuang Zhang.

1.1.1.1 Reports on Sub-panels

Tau-Charm Factory

Dr.Perelstein has reported the recent activities of the tau-charm factory sub-panel. In February 1996, during the Beijing Tau-Charm Factory workshop, the first meeting was held. The second meeting was held in Sitges during EPAC96, which was a combined meeting with the organization committee of the ICFA Beam Dynamics Workshop on High Luminosity Colliders. The next activity will be the preparation of this workshop from Tau-Charm Factory point of view. One of the next sub-panel meetings is planned to take place during this workshop. It was argued that one person should be invited from Cornell University as a sub-panel member. Dr.Perelstein will find an appropriate person.

Future Light Source

Dr.Laclare has reported the preparation of the sub-panel. Following the list approved by the panel, he has communicated with the candidates. A few candidates of the sub-panel did not reply yet but he hopes to finalize the nomination and get the authorization soon. During EPAC96, he has organized a preliminary meeting. It was pointed out in the preliminary meeting and was also approved in the panel meeting that some link to the synchrotron radiation users community should be established.

New Acceleration Schemes

Dr. Pellegrini could not come and Hirata has explained the present situation. This sub-panel might become a new panel of ICFA and Dr.Pellegrini is organizing this sub-panel from this point of view. A preliminary sub-panel meeting will be held in the occasion of the 12-th ICFA Beam Dynamics Workshop (Arcidosso, September

1996).

New Sub-panels

Discussion was made on the possibility of having more sub-panels. It was agreed that the new sub-panels can be considered seriously for rather limited sulbjects and not for a general and wide subjects (“hadron machines”, for example). Each sub-panel should be chaired by a panel member. The creation will be considered upon a request by panel members who can chair the sub-panels.

Reports on Workshop Preparation

- The 12th Advanced ICFA Beam Dynamics Workshop on Nonlinear and Collective Phenomena in Beam Physics: Dr. Pellegrini could not come and Hirata has explained the present situation. The organization is going well following the agreement within the panel.
- Advanced ICFA Beam Dynamics Workshop on e^+e^- Factories: Dr.Palumbo has shown the present status of the preparation. During EPAC96, he has held an organizing committee. In addition to ICFA, the University of Rome and INFN will sponsor it. Dr.Palumbo asked for further academic sponsorship. The workshop will be held in October 1997 in LNF. The number of participants is assumed to be eighty. Special attention will be paid to the Tau-Charm Factory.
- Advanced ICFA Beam Dynamics Workshop on 2nd Generation Plasma and Laser Accelerators: The workshop will be held in Japan in September 1997. Hirata has reported the preparation status. The first organizing committee will be held in Arcidosso in September 1996. This workshop might become the first workshop of the new panel which Dr. Pellegrini is organizing. It might become a joint workshop by the two panels.

1.1.1.2 Future Workshops

There was some discussion of future workshops, perhaps in 1998. The topics discussed were 1) Final Focusing for High Intensity Linac Beams, and 2) Mathematical Methods in Beam Dynamics. The panel will discuss future workshops through e-mail.

1.1.1.3 Guidelines for Advanced ICFA BD Workshops

The guide lines for Advanced ICFA Beam Dynamics Workshops were discussed. The same topics were discussed also in the previous meeting in 1995. The present guide lines are as follows:

- The workshop should be proposed to the panel by the panel member(s). At least one panel member should be involved as a real organizer. They are responsible for the workshop to the panel.
- The workshop should be reviewed quickly in the newsletter by the organiser(s). The responsible panel member is also responsible for this report.
- The sponsorship is an official declaration by the panel of the importance and urgency of the subject. The subject and the aim should be approved by the panel.
- The panel members are automatically nominated as international advisory committee members. They can also be members of the program and/or the local organizing committees.
- The subject of the workshop should not be oriented to a particular project.
- The proceedings should be published in any form. This should be sent to all the panel members.
- When the discussion on the workshop is done by the e-mail, iteration between members and the chairman should be at least twice in order that everyone knows the opinion of the other members.

1.1.1.4 Newsletters and WWW home page

- Newsletter Editing Policy: It was decided that the camera-ready copy is excluded from the instruction to the authors. In case the contributer has sufficient reason that the only way is to use paper, however, the editor should try to accept the contribution. For figures, the preferred graphics format is Encapsulated Postscript (EPS) files. In addition, the camera ready copy of the figure is encouraged for safety. Small number of figures is encouraged.

  It was agreed that the “Letters to the editor” and “Review of Beam Dynamics Problems” should be encouraged more. It was decided that a panel member should contribute to either the letter section or the review section at least once a year.

- Distribution Policy: Dr.Colestock will take care of all Americas. Dr.Mais will take care of Africa, in addition to Europe and former Soviet Union. Dr.Kamada stop sending newsletters to South America.

- WWW: The formal home page of ICFA Beam Dynamics Panel sits in one place. (KEK for the moment). The mirror sites exist with editors. (Indiana and CERN now). Editors create regional home pages (Americas, Europe/Africa, Asia/Pacific), which are linked from the Home page and the mirror sites of ICFA Beam Dynamics Panel. Except for the mirror sites of the formal home page, and the web version of the newsletter, no copy is made for html and other files, which are linked from the formal home page.

1.1.1.5 Next Meeting

The next panel meeting will be held on the occasion of the PAC97, Vancouver, 12–16 May, 1997.

The panel members would like to thank the organizing committee of EPAC96 for providing the facilities for the eleventh meeting and for the hospitality extended to them.

1.1.2 Future Workshops

1. The 12th Advanced ICFA Beam Dynamics Workshop on *Nonlinear and Collective Phenomena in Beam Physics*, Arcidosso Italy on September 2 to 6, 1996.

2. Advanced ICFA Beam Dynamics Workshop on *High Luminosity Colliders*, Frascati Italy in autumn 1997.

3. Advanced ICFA Beam Dynamics Workshop on *2nd Generation Plasma and laser Accelerators*, Kyoto Japan in autumn 1997.

1.2 The ICFA Beam Dynamics Newsletter No. 11

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This issue of our newsletter again reflects the continuity, diversity and vitality essential to the health of the field of beam dynamics.

Continuity with the past is reflected in the descriptions of research in the still fertile field of beam dynamics in proton synchrotrons.

Diversity is apparent in the span of activities described in just a few articles. Indeed this has always seemed to me to be a major attraction of being a “specialist” in accelerator physics and one which I think worth emphasising to students considering their career options. Working within what appears from the outside to be a rather narrow field, you get the chance to apply knowledge of a wide range of the sub-fields of academic physics, not to mention mathematics, engineering, computing and, sooner or later, management science. This can be true even when you spend many years working on one machine and the range of applications of particle beams just adds a further dimension. Few research disciplines offer such variety.

Diversity in our institutions is also necessary. Clearly large and small accelerator laboratories contribute to the development of beam physics in different ways. Nowadays the larger laboratories tend to be focused on the problems associated with a small number of large projects. This leaves quite a few avenues of research of long-term importance open to the smaller institutes, including university departments. This research can be theoretical, experimental or computational.

In this newsletter we make a constant effort to better represent the activities of smaller laboratories. While we get a few such contributions, it would be in the interests of better communication and increased awareness to see more of them.

Vitality is necessary if we are to progress towards higher energies for elementary particle physics and greater performance for all applications of accelerators. The articles on work towards linear colliders and muon colliders are good examples. Overawed though we might presently be by the technical problems posed by these machines, we all feel that somehow the ingenuity and audacity of our colleagues will eventually prevail—as it has done so often in the past.

However spinning paragraphs around a few abstract nouns is no more editorial comment than those abstract qualities are sufficient conditions for the health of the field. We all know only too well about the importance of concrete resources. Among these, we have effective means of communication, at least, in abundance. We just need the community spirit (alluded to above by the Chairman) and the willingness to exploit them. As stated near the end, this newsletter exists in order to further rapid, informal communication among practitioners of beam dynamics. Now that it has moved to the World-Wide-Web as *primary* medium of publication, this should be faster, easier[1] and, we hope, more conducive to world-wide collaboration than ever.

[1] Writing for the Web is different from writing for "dead" paper. Documents may be structured in different ways and updated frequently. It is especially important to think about where hyper-text links can judiciously be made to the original copy of some information rather than repeating it.

2: Letters to the Editors

Dear Dr. Hirata,

I appreciate your keeping the accelerator community informed of some of the activities in the field as well as providing a forum for communicating "unsolved problems" and "highlighting important on going work". In that light, you may share the following announcement with your readership to allow them the opportunity to participate and collaborate in an international scientific program.

As you may know, we are organizing a 5 month workshop on "New Ideas for Particle Accelerators" at the Institute for Theoretical Physics (ITP) in Santa Barbara, July 22–December 1996. This is the first long term accelerator program sponsored by the ITP and in US and it provides a unique opportunity for the field.

As part of this effort we have arranged for a week long symposium on "New Modes of Particle Acceleration,Techniques & Sources" which will be held August 19–23, 1996 at the Institute for Theoretical Physics in Santa Barbara, California. This symposium will provide a perspective on Future Direction of Advanced Accelerator Research. It will feature a mix of Physics and accelerator physics talks by many leaders in the field. A sample of confirmed speakers include: N. Andreev, B. Colson, E. Esarey, T. Katsouleas, Z. Parsa, A. Skrinsky, R. Siemann, A. Sessler, G. Mourou, W.B. Mori, C. Barty, B. Breizman, S. Yu, G. Stupakov, C. Joshi, W. Kimura, R. Phillips, D. Umstadter, M. Gunderson, J. Irwin, P. O'Shea, C. Pellegrini, P. Chen, J. Rosenzweig, J. Wurtele, V. Telnov, T. Marshall, R. Macek …

This is the first of the 3 symposia arranged in conjunction with the 5 month program on "New Ideas for Particle Accelerators" at the Institute for Theoretical Physics in Santa Barbara. For information on registration and preliminary programs on World Wide Web, open the following URL

`http://www.bnl.gov/CONF/conferences.html`

and look under "Off-site conferences"

- Aug 19–23, 1996; Santa Barbara. New Modes of Particle Acceleration Techniques & Sources - Physics Conf

- Oct. 21–25, 1996; Santa Barbara Future High Energy Colliders Symposium - Physics Conference

- Dec. 3–5, 1996; Santa Barbara Particle Beam Stability and Nonlinear Dynamics - Physics Conference

- July 22–Dec 20, 1996; Santa Barbara New Ideas for Particle Accelerators - Physics Workshop

For on line Registration on World Wide Web open:

`http://www.itp.ucsb.edu/apply-particle1.html`

Or send your request for Registration packet to

"Dorene" `dorene@itp.ucsb.edu` Tel. +1 (805) 893-3178
Fax:(805) 893-2431

We believe the long term ITP workshop and symposia will benefit the field and the accelerator community as a whole. We hope those with experties would take part, participate and help to solve some of the outstanding problems and improve the present status of the field.

We appreciate your efforts in informing the accelerator community and hope that you will continue with your mission to inform and encourage the international collaboration and forum.

Sincerely yours,

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3: Activity Reports

3.1 Beam Optics and Dynamics Issues for Synchrotron Design of the Japanese Hadron Project

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3.1.1 Introduction

The Japanese Hadron Project (JHP) was revised very recently[1]. The revised design consists of the following three accelerators;

- injector: 200 MeV proton linear accelerator
- booster: 3 GeV proton synchrotron
- main ring: 50 GeV proton synchrotron

The accelerators will be constructed at the north end of the KEK site. The first stage of beam acceleration is provided by the linac, which accelerate H^- ions up to 200MeV. The expected peak beam current in the Injector linac is at least 30 mA and the pulse duration and the repetition rate of the beam is more than 400 μsec and 25 Hz, respectively.

The H^- beam is injected into the booster by charge-exchange multi-turn injection and accelerated to 3 GeV. The 3 GeV booster will be constructed in the existing tunnel for the present KEK-PS main ring. All of the components of the KEK-PS main ring, such as dipole magnets, quadrupole magnets, vacuum chambers and others will be removed. The booster is a rapid cycling proton synchrotron with a repetition rate of 25Hz. The expected beam intensity in the booster is $5\text{x}10^{13}$ ppp (protons per pulse), therefore, the average beam current becomes 200 μA. The total power of the extracted beam from the booster reaches 0.6 MW. The 3 GeV protons are supplied to three experimental facilities; a pulsed spallation neutron source facility (N-arena), a meson facility (M-arena) and an unstable nuclei facility (E-arena) and to the 50 GeV main ring.

Protons from the booster are injected into the main ring and accelerated to 50 GeV. The expected beam intensity in the main ring is $2\text{x}10^{14}$ppp and the repetition rate is about 1/3Hz. Thus, the average accelerated beam current reaches 10 μA in the 50 GeV main ring. The 50 GeV protons are extracted by slow and fast extraction schemes into two experimental areas; one is for experiments using secondary beams (K,π) and primary beams by slow extraction, and the other is for the neutrino oscillation experiment by fast extraction.

In addition to acceleration of high intensity protons, heavy ion and polarized proton beams are also requested. Using the 500 'MeV booster of the KEK-PS as an injector of the 3 GeV booster, it becomes feasible to accelerate these particles.

3.1.2 Imaginary γ_t Lattice

In order to avoid transition energy crossing, we adopt a so called imaginary γ_t lattice [2]. There are several schemes to make a momentum compaction factor negative and so the γ_t is imaginary. An imaginary γ_t can be realized in this design by modulating the curvatures(ρ- modulation)with a missing bend scheme, which makes it possible to minimize the modulation of the beta function. The Moscow KAON factory design took a missing bend scheme. [3] The scheme was inherited to the TRIUMF KAON lattices and the SSC low energy booster.[4] This scheme allows sufficient space for rf cavities, which would be beneficial for a high-intensity machine with a large repetition rate. The momentum compaction factor can be relatively changeable and the linear optics stability is fairly good. The current design of the main ring and booster lattices takes the similar scheme. The modulation of beta function is not so large so that it does not require huge magnet aperture for storing relatively large emittance beams.

The same lattice hardware configuration but a different excitation of magnets can make a dispersion free straight section. The total phase advance in the arc is tuned as an integer and the dispersion function is closed inside the arc.

3.1.3 Dynamics

A tracking study has been performed to see the beam dynamics in both main and booster rings. In the following, some results will be shown.

3.1.3.1 Dynamic Aperture of 50-GeV Main Ring

The relatively large emittance (54 π.mm.mrad, unnormalized) requires enough machine aperture. The dynamic aperture as a function of momentum amplitude and chromaticity is examined.

When the chromaticity is half corrected (natural chromaticity is around -20), the dynamic aperture of small momentum amplitude is better than the case with full correction. Nevertheless, at the moderate momentum amplitude, full correction of chromaticity gives slightly bigger dynamic aperutre.

A preliminary study of dynamic aperture with space charge effects has been also carried out. Although the tune shift due to space charge effects is not so large,

-0.35 for the booster and -0.11 for the main ring, the dynamic aperture may be deteriorated by space charge nonlinear force. Taking space charge force as an external force, meaning that electrostatic potential created by Gaussian charge distribution almost continuously distributed around the ring. Up to the nominal intensity, that is 7A, the dynamic aperture is larger than the emittance, that is 54 π.mm.mrad (unnormalized), nevertheless, some reduction of dynamic aperture due to space charge above 4 A is observed.

3.1.3.2 Synchro-betatron Coupling in 3-GeV Booster

In the booster ring, the synchrotron tune is relatively high (0.015 at injection) because of the fast cycling nature and high required RF voltage [5]. The emittance growth due to synchrobetatron coupling is examined taking horizontal tune as a parameter. Above 7.85, some growth is observed, around the nominal tune, that is 7.80, no significant growth is seen.

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3.2 Beam Dynamics Activities at the Svedberg Laboratory

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The Gustav Werner Cyclotron can operate in isochronous and synchrocyclotron mode to accelerate protons and other ions up to a rigidity of 2 Tm (180 MeV protons) [1]. Unpolarized beams are generated either in an internal PIG or an external ECR source. A polarized atomic beam source [2] is also available but not yet reliably operational. The accelerated beams are used for nuclear physics and materials science experiments, as well as for proton therapy, radio-biology, and radio-isotope production. A large fraction of the time the beam is used to fill the CELSIUS storage ring [3] that can accelerate beams up to a rigidity of 7 Tm (1.36 GeV protons). CELSIUS is equipped with an electron cooler that operates up to 300 kV and is used for accumulation and to improve the beam's quality for experiments. Intermediate energy physics reactions are investigated with WASA/PROMICE and other detectors using an internal gas jet target and soon using a target that produces 20 micron frozen hydrogen pellets.

Beam dynamics activities currently focus on two subjects: Beam lines and CELSIUS. We are developing an on-line model of the 200 m beam lines that can be used to display the current beam optics. Integral to this method is an emittance measurement procedure near the cyclotron using quadrupole scans and a wire scanner [4]. Furthermore we are developing a slow feedback system to ease operation of the proton therapy beam line.

Beam dynamics activities on CELSIUS include analysis of the dynamics of the beam's interaction with the cooler and observing the beam profile with a magnesium jet profile monitor [5]. A new tune-measurement and correction system, based on mixing the raw BPM signals down with the expected betatron frequency and Fourier-transforming the mixed signal qis currently being commisioned [6]. We are also rewriting the closed orbit correction programs to utilize Singular Value Decomposition in order to remove degeneracies due to neigboring correctors [7]. Moreover, a careful analysis of the BPM-corrector response matrix [8] has been used to locate faulty hardware and detect discrepancies between the model and the accelerator. Finally, we plan to increase the energy of CELSIUS to 9 Tm. The application for this very inexpensive upgrade has been submitted.

Furthermore, TSL contributed to the design of the ESS target beam lines [9] within an European collaboration and we are developing methods to diagnose nonlinear aberrations in LHC using a wobbling method [10].

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3.3 Plasma and Accelerator Physics Group at the University of Colorado at Boulder

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The plasma and accelerator physics group at the University of Colorado, Boulder, does accelerator physics related to long-time dynamics, collective instabilities, and adiabatic trapping. We are also interested in the application of object oriented methods to computational modeling of physical systems. Our web site, `http://beams.colorado.edu/`, provides more information about our group.

Our long-time dynamics interests are concerned with the development of methods for increasing dynamic aperture in accelerator lattices. Our early work [1] showed that the dynamic aperture of the uncoupled horizontal motion in an accelerator lattice could be increased by reducing the Greene's residue for the fixed points, which provides a simple measure of the sizes of the islands that overlap to cause chaotic dynamics. We have now extended our method to coupled transverse degrees of freedom [2]. Our initial results are encouraging - we have seen modest increases in dynamic aperture for two coupled transverse degrees of freedom after reducing our measures of chaos. However, it remains to develop additional computational tools for, e.g., finding the best quantities to vary to minimize chaos and to determine the most important fixed points to use.

We have recently completed work on the dynamics of bunching produced by the interaction of a coasting beam with a cavity [3]. The linear part of this work provides a complete discussion of the instability applicable to the beam-cavity interaction of accelerator physics as well as the beam-plasma interaction of plasma physics. The difference between the two is that for the former the mode typically has a modest Q (around 20-100), while for the latter, Q is of the order of the plasma parameter. This work, among other things, points out that accelerator physics usage of the term "Landau damping" is at odds with the traditional usage in the plasma literature. This work also provides a thorough discussion of the various regimes and modes of instability.

The nonlinear dynamics of the bunching are studied both by simulation and through the development of a reduced ODE model. The simulations are based on a single-resonance approximation. The simulations show that if Q is sufficiently small, a bunch from the beam can break off on the low-energy side and continue to decelerate. Thus, the cavity damping extracts energy from the system by the mode continuing to shift to lower frequency, slowing down this beam bunch.

Another research project within the group is the study of adiabatic trapping in the free-electron laser interaction. Our work indicates that the free-electron laser interaction could be made significantly more efficient by trapping and detrapping adiabatically and then recirculating the beam [4]. Another application of this work is to use adiabatic trapping and abrupt detrapping to obtain tight bunching at short wavelengths as is needed for loading into plasma accelerators [5].

Finally, our group has become interested in the use of object oriented methods for modeling of physics systems in general, but accelerators in particular [6]. We are interested in the object methods for describing accelerator elements. Additionally, we are investigating the use of object methods for studying collective effects. Some of this work is carried out in collaboration with Tech-X Corporation, a small business in Boulder, Colorado. Tech-X Corporation has recently won an

SBIR Phase I grant to develop an accelerator modeling code with a graphical user interface.

The current researchers of our group are Peter Stoltz and Scott Hendrickson, Ph.D. candidates in physics; Drs. Svetlana G. Shasharina, Isidoros Doxas, and Weishi Wan, Research Associates; and John R. Cary, Professor of Physics. Dr. William E. Gabella of the FEL project at Vanderbilt University and Dr. David Bruhwiler of Northrop-Grumman, whose recent work is on halo formation, received their education through our group at the University of Colorado.

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3.4 Progress on the Design of a High Luminosity $\mu^+\mu^-$ Collider

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Parameters are presented for a 2 + 2 TeV muon collider with a luminosity of $\mathcal{L} = 10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The design is not optimize for performance, neither for cost; however, it does suffice to allow us to make a credible case that a muon collider is a serious possibility for particle physics, that could open up the realm of physics above the 1 TeV scale, allowing, for example, copious production of supersymmetric particles or a detailed study of the strongly-interacting scenario of electroweak symmetry breaking.

3.4.1 Introduction

This article is a brief summary distilled from the report, *Muon-Muon Collider: A Feasibility Study* [1] to be presented at the 96 Snowmass Workshop, which contains the collaborative effort of scientists from Brookhaven National Laboratory (BNL), Fermi National Laboratory (Fermilab), Lawrence Berkeley National Laboratory (LBNL), and significant contributions from individual researchers from U.S. universities, SLAC, and KEK.[2]

The muon collider complex consists of components (see Fig. 3.1) which first produce copious pions, then capture the pions and the resulting muons from their decay; this is followed by an ionization cooling channel to reduce the longitudinal and transverse emittance of the muon beam. The next stage is to accelerate the muons and, finally, inject them into a collider ring wich has a small beta function at the colliding point. This is the first attempt at a point design and it will require further study and individual optimization of components and overall optimization. Tb. 3.4.2 shows the main parameters of the muon collider complex. Experimental work will be needed to verify the validity of diverse crucial elements in the design which can be enumerated as:

- ionization cooling channel
- superconducting and/or fast pulsed magnets for the accelerator
- study and modeling of magnets for the collider ring.

Muons because of their large mass compared to an electron, do not produce significant synchrotron radiation. As a result, there is negligible beamstrahlung and high energy collisions are not limited by this phenomena. In addition, muons can be accelerated in circular devices which will be considerably smaller than two full-energy linacs as required in an $e^+ - e^-$ collider. A hadron collider would require a CM energy 5 to 10 times higher than $4\ \mathrm{TeV}$ to have an equivalent energy reach. Since the accelerator size is limited by the strength of bending magnets, the hadron collider for the same physics reach would have to be much larger than the muon collider. In addition, muon collisions should be cleaner than hadron collisions.

There are many detailed particle reactions which are open to a muon collider. Most of the physics accesible to an $e^+ - e^-$ collider could be studied in a muon collider. In addition the production of Higgs bosons in the s-channel will allow the measurement of Higgs masses and total widths to high precision; likewise, $t\bar{t}$ and W^+W^- threshold studies would yield m_t and m_W to great accuracy. These

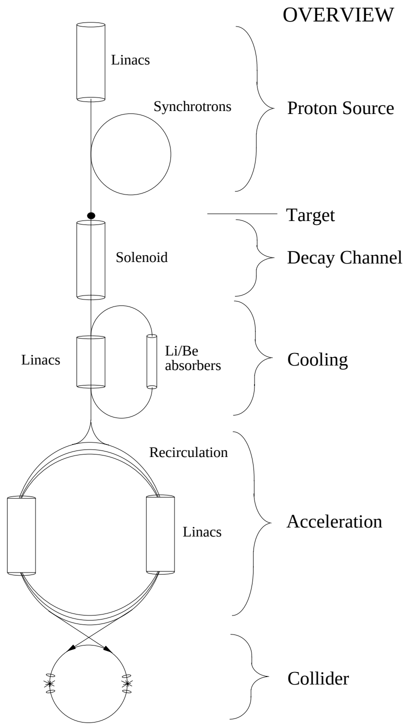

Figure 3.1: Schematic of the $\mu^+\mu^-$ Collider Complex.

reactions are at low center of mass energy (if the MSSM is correct) and the luminosity and $\Delta p/p$ of the beams required for these measurements is detailed in [1]. On the other hand, at $\mathbf{2} + \mathbf{2}$ TeV, a luminosity of $\mathcal{L} \approx \mathbf{10^{35}}\ \mathrm{cm}^{-\mathbf{2}}\ \mathrm{s}^{-\mathbf{1}}$ is desirable for studies such as, the scattering of longitudinal W bosons or the production of heavy scalar particles.[3] Not explored in this work, but worth noting, are the opportunities for muon-proton and muon-heavy ion collisions as well as the enormous richness of such a facility for fixed target physics provided by the intense beams of neutrinos, muons, pions, kaons, antiprotons and spallation neutrons.

To *see* all the interesting physics described herein requires a careful study of the operation of a detector in the very large background. Three sources of background have been identified:

- The first is from any halo accompanying the muon beams in the collider ring. Very carefully prepared beams will have to be injected and maintained.

- The second is due to the fact that on average $35\,\%$ of the muon energy appears in its decay electron. The energy of the electron subsequently is converted into EM showers either from the synchrotron radiation they emit in the collider magnetic field or from direct collision with the surrounding material.

The decays that occur as the beams traverse the low beta insert are of particular concern for detector backgrounds.

- A third source of background is $e^+ - e^-$ pair creation from $\mu^+ - \mu^-$ interaction. Studies of how to shield the detector and reduce the background are addressed in the Detector Chapter.[1]

Polarization of the muons allows many very interesting measurements which are discussed in the Physics Chapter.[1] Unlike the electron collider in which the electron beam is highly polarized and the positron beam unpolarized, both muon beams may be partially polarized. It is necessary to select forward moving muons from the pion's decay and thus reduce the available number of muons and hence the luminosity. The necessary machine technology needed to achieve such a collider is discussed in the Option Chapter;[1] at the moment it is not part of our point design, although such capability would almost certainly be incorporated into an actual device.

3.4.2 Description of the Machine

	4 TeV
Beam energy (TeV)	2
Beam γ	19,000
Repetition rate (Hz)	15
Muons per bunch (10^{12})	2
Bunches of each sign	2
rms Norm. emittance ϵ^N $(10^{-6}\pi\,\mathrm{m}-\mathtt{rad})$	50
Bending Field (T)	9
Circumference (km)	7
Average ring mag. field B (T)	6
Effective turns before decay	900
β^* at intersection (mm)	3
rms beam size at I.P. (μm)	2.8
Luminosity $(\mathrm{cm}^{-2}\mathrm{s}^{-1})$	10^{35}

Table 3.1: Parameters of Collider Rings

The *driver* of a muon collider is a $30\,\mathrm{GeV}$ proton synchrotron capable of providing 2.5×10^{13} protons per bunch with four bunches per pulse and $15\,\mathrm{Hz}$ pulse rate. The repetition rate, but not the number of protons, is beyond that of any existing machine, but not so far beyond as to seem unrealistic. In fact, the criteria are almost met by the design of KAON.[4] The protons are driven into a target, most likely a liquid target, where copious pions are produced (about one pion per proton). Questions of target survivability are discussed in the Target Chapter.[1] The target is surrounded by a $20\ \mathrm{T}$ solenoidal field, which is adiabatically matched to a $5\ \mathrm{T}$ solenoid in the decay channel. The captured pions have a wide range of energy, with a useful range from $100\ \ \mathrm{MeV}$ up to $1\ \ \mathrm{GeV}$. A strong *phase-rotating* rf field is used to reduce this energy spread as well as the longitudinal extent of the beam. This results in approximately, 0.3 muons per proton with mean energy of $150\,\mathrm{MeV}$ and a $\pm 20\,\%$ rms energy spread. The muons (about 8×10^{12}) are subsequently cooled by means of ionization cooling which is achieved in a periodic channel consisting of focusing elements, solenoids and/or lithium lenses and absorber at places of small beam size (but corresponding large transverse beam angles) and rf cavities to make up for the energy loss. In some locations along the channel, dispersion is introduced and wedge shaped absorbers are used to produce longitudinal cooling. This is described in the Cooling Chapter.[1] We allow for further loss, beyond natural decay, between the number of captured muons and the final number of muons, coming out of the cooling section is 3×10^{12} per bunch.

After cooling, the muons are accelerated in a cascaded series of recirculating linear accelerators, as described in the Acceleration Systems Chapter.[1] A conventional synchrotron cannot be used as the acceleration is too slow and the muons will decay before reaching the design energy. On the other hand, it is possible to consider synchrotron-like pulsed magnets in the arcs of a recirculator. It should be noted that the primary cost of a muon collider complex is in the acceleration, so care and attention must be devoted to this matter. However, the process is reasonably straight-forward.

The collider ring is injected with two bunches of each sign of 2×10^{12} high energy muons. Approximately 1000 turns occur within a luminosity lifetime, thus making a ring (in contrast with a single collision) advantageous. In order to reach the desired high luminosity, it is necessary to have a very low β^*, of the order of 3 mm, (and associated very large betas in the focusing quadrupoles) at the insertion point.[5] Since the muons only live about 1000 turns, numerical simulations can easily provide us with quantitatively correct information. It is necessary to run the ring nearly isochronously so as to prevent bunch spreading and yet keep the rf impedance low enough as to avoid collective instabilities. Space charge effects, and beam-beam effects, in the collider ring are being studied and some conclusions are presented in the Collider Ring Chapter.[1] Such a ring has never been built, but should be possible to construct and operate.

The muon complex requires numerous superconducting magnets. These are needed in the capture section, in the decay channel, in the arcs of the recirculating accelerators, and in the collider ring. Attention has been given to these magnets, as well as to the very special magnets required for the interaction region, and these various considerations may be found in the appropriate chapters of reference[1].

A study of the scaling laws governing muon colliders is presented in the Options Chapter.[1] Naturally, one would, if the concept is shown to be of interest, initially construct a lower energy machine (perhaps in the hundreds of GeV region) and thus the scaling laws are of special interest. In particular, a *lower energy demonstration machine* of $\mathcal{L} = 10^{33} cm^{-2} s^{-1}$ at 500 GeV CM energy could serve as a breadboard for exploring the properties and technologies needed for this class of colliders, while providing useful physics.

3.4.3 Conclusions

We suggest that to make sensible decisions about the future, the potential of a muon collider must be explored as rapidly and aggressively as possible. The document[1] of which this paper is a brief summary furnishes a solid base for identifying areas where more study and/or innovations are needed. In particular, **R&D** needs to be done related to the muon cooling channel, recirculating superconducting magnets or pulsed magnets for the accelerator in order to arrive at a design that minimizes cost. The magnets for the collider ring have a high heat load from muon decay electrons.

A sustained, extensive and integrated program of component development and optimization will have to be carried out in order to be assured that the design parameters can be attained and the cost minimized. The technology for the most part already exists within the High Energy Physics community and the work should involve the US, Europe, Russia, Japan and the international HEP community as a whole.

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3.5 Beam Dynamics Activities at Pohang Light Source

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Pohang Light Source (PLS) is the first synchrotron light source in Korea, which has been in normal operation mode for general users since September 1995. It had gone through the commissioning in two phases, from September to December 1995 and from April to July 1995, respectively. In the meantime, beam dynamics activities have been concentrated on two jobs:

- measuring ring parameters (such as beta function, dispersion function, chromaticites etc.) and adjusting them to design values,
- identifying and curing existing instabilities.

The first job has been successful [1, 2] except measuring electron beam emittance, which will be done after installing diagnotic beam line within this year. As for the second job [3], we have still many things to do. Our main concerns are as follows;

1. multi-bunch instability,
2. ion effect,
3. unexplained phenomena.

We observed multi-bunch instability in both transverse and longitudinal directions and identified RF HOMs responsible for it [3]. As for the curing, we have tried to control the RF cavity cooling temperature. The method has been proved very effective, but our narrow range of control of cooling temperature (5°) made the application of this method very restrictive. Hence damping systems in both directions are under development. As for 2, we have many indirect evidences for ion trapping, though we do not have the direct observation of bremsstraulung induced by ion trapping. It is highly probable that we have coherent beam oscillation induced by beam-ion interaction. We are going to put more effort on this topic. Recent issue of fast beam-ion instability [4] will also be explored. Especially its presence will be tested using PLS storage ring as a joint project with KEK, Japan. As for 3, we observed strong low-frequency transverse oscillation, for which we do not have an adequate explanation. A similar phenomena was recently reported in Elettra, Trieste [5]. Since this oscillation limits the performance of PLS seriously, it will be our main subject of study.

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3.6 Beam Dynamics Activities at CERN

Other beam dynamics activities at CERN were described in the previous newsletter.

3.6.1 Beam Dynamics on CLIC

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Single bunch emittance control must eventually reach a perturbation regime, in which the blow-up is only a fraction of the emittance at injection, in order to fully profit by the high accelerating gradient and high RF frequency. Using the most advanced correction method that involves a simultanous minimization of the dispersive effects and of the wakefield effects (requiring to measure different trajectories for variable quadrupole settings and charge per bunch), a recent breakthrough in the emittance preservation showed that a relative growth of 70 % was at hand in CLIC with the nominal parameters (published in the Technical Review Committee report). In order to possibly reduce this growth even more and/or relax the alignment tolerances, other parameter variations are now being revisited, like increasing the accelerating gradient by 20%, reducing the bunch length accordingly and doubling the number of quadrupoles.

This extra focusing also helps the control of multibunch break-up. Simulations on this topic progressed significantly, and an interesting tool, based on tracking and delivering an animated graphic that shows as a movie the behaviour of each individual bunch travelling down the linac, has been developed. Preliminary results indicate that a damping by a factor 100 of the transverse wakefield is at least required between two consecutive bunches, in order to get a train of 10 bunches transversely stable, though the energy distribution is not yet satisfactory. Transporting more bunches without too large a deterioration of the emittance and designing high frequency damped cavities remain significant challenges.

A new code has been worked out in order to make a statistical analysis of the main linac beam line, based on the response coefficients of the linac components to unit displacements. This approach allows a direct estimate of the final average emittances and of the variance of this quantity in the presence of imperfections. It aims at giving the possibility to analyse, in addition to the effects of random misalignments, the medium and long distance correlations associated with the machine survey and their consequences on the emittance blow-up. Analytical work has been launched in parallel to the numerical studies, on possible treatments leading to approximate but closed expressions for the transverse single-bunch and two-bunch emittances in a linac with srong focusing.

The optics of the rebuilt CLIC test facility which should demonstrate the feasibility of a two-beam scheme, though at low energy, has been re-examined and re-optimized in order to better cope with the strong expected wakefields at these energies (40 to 60 MeV) and the given aperture of the damped transfer structures of the drive beam.

4: Workshop Reports

4.1 The 11th International Advanced ICFA Beam Dynamics Workshop on Beam Cooling and Instability Damping

This workshop was dedicated to the 30th Anniversary of Electron Cooling

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The 11th International ICFA Beam Dynamics Workshop on beam cooling and instability damping took place in Russia (18–26 June 1996) on board a ship, the "Alexander Suvorov", which sailed along the Volga river from Moscow to Nizhny Novgorod and back. The Workshop continued and developed the traditions of previous conferences held at Karlsruhe, Legnaro and Montreux. It was nominated as a jubilee: exactly 30 years ago G. Budker suggested electron cooling to damp noncoherent oscillations in an antiproton beam.

Although the workshop almost coincided in time with a couple of accelerator conferences (EPAC'96, BEAMS'96), several tens of enthusiasts including some from CERN, FNAL, JINR, BINP and several smaller laboratories had the possibility to discuss exotic methods to struggle through Liouville's theorem and to assure themselves that these methods really open the way for challenging accelerator projects of the next century.

The Workshop Proceedings will be published in nearest future either in "Nuclear Instruments and Methods" or as a special JINR edition, so I will not try to comment all presentations or even to mention all authors. Only main points of discussion are presented here.

Damping of coherent oscillations has never been presented before to a special workshop. A special session was devoted to the problem including a survey of damping methods both in hadron and lepton machines and to a discussion of general relations between the damping system parameters (CERN, FNAL, JINR). More specific problems, e.g., damping systems for LHC and SPS, non-linear systems for transverse damping (JINR), systems based on use of recursive digital filters, the reactive feedback systems against transverse mode coupling, a high frequency (non-stationary) component of a signal from proton bunches were also presented at the session.

All other sessions were devoted to the stochastic and electron cooling physics and its applications. Some attention, however, was paid to laser cooling of ion beams where the influence of interbeam scattering on Schottky noise was considered. The theory appears in a reasonable agreement with the experiment at ASTRID storage ring (Denmark).

The general problems of stochastic cooling were listed in an excellent review by D. Möhl (CERN) who reminded the main milestones: from the first ideas by S. van der Meer and from the experiments at ISR, ICE, AA, LEAR, and at the antiproton source at FNAL up to AAC and plans for COSY and ESR. As the main open problems Möhl mentioned cooling in bunched beams when a coherent signal prevents large amplification of a non-coherent one and use of very broad- band systems including attractive but yet not proved ideas on optical stochastic cooling. All this was well illustrateds by surveys on stochastic cooling at CERN (F. Pedersen) and at FNAL (M. Church, presented by J. MacLachlan)

The review on electron cooling celebrating its 30th anniversary was presented by I. Meshkov. At this respectful age the main idea still delivers new interesting physics. It is understood now that neutralization of space charge under certain conditions can increase the cooling force. So detailed investigation of many component beams, kinetics of secondary particles accumulation, and threshold currents of corresponding instabilities became now a special branch of electron cooling physics both experimental and theoretical. Another problem is cooling of a bunched beam. Certain new methods of deep cooling, in particular adiabatic beam expansion, experimentaly tested at CRYRING, are also of great interest.

Electron cooling is currently successfully used in many experiments in nuclear and atomic physics. Reports from ESR and CRYRING discussed the dependence of cooling of multichared ions upon ion charge. Some new results from CELSIUM storage ring on cooling of oxigen ions at different energies, electron currents and beam alignments were presented. The IUCF group demonstrated results of electron cooling of bunched beams. The bunch length was determined by a space charge dominated regime, so some intensity dependent electron cooling effects were found which had not been observed before. Measurements of transverse cooling rate performed with a bunched proton beam showed unexpectedly low cooling time.

Perhaps one of the most picturesque applications of deep cooling is beam crystallization meaning some ordering in the cold beam. Starting from the very first ideas by Novosibirsk people at KFK cooling workshop and from the first experimental evidence of ordering in e-beams (BINP, LNL, 1991) this effect was demonstrated in ion traps and storage rings (with laser cooling). Several general conditions have been formulated: the ring must operate below the transition energy; linear resonances between phonon modes of the crystalline structure and the machine lattice periodicity are dangerous; to avoid envelope instability tune shift should be small enough, and a smooth lattice is desirable to prevent intrabeam scattering. Under these conditions ground states of crystalline beans in storage rings exist and can be maintained. L. Tecchio reported a project of a storage ring for crystalline beam studies elaborated at Legnaro and finished his presentation with a request for ideas on possible relevant experiments.

During presentation of advanced electron cooling technology it was stressed that the technical problems of HV supply, recuperation efficiency and focusing scheme for the interaction region are tightly coupled. J. MacLachlan concentrated mainly on Fermilab scientific policy bearing in mind the Recycler (8 GeV antiproton ring) and proclaimed: "We will not need to wait another 30 years to see electron cooling fulfill its original purpose of making bright antiproton beam for high energy collisions".

A. Skrinsky presented a conceptual project of a muon collider as the next step in developement of lepton colliders. The main parameters of interest are the following:

- center of mass energy 2 TeV + 2 TeV;
- luminosity up to 10^{34} – 10^{35} cm^{-2}s^{-1};
- longitudinal polarization;
- affordable cost.

This requires to solve the problem of efficient collection of pions produced at a target and of decay muons; to organize effective 6-D ionization cooling of the muon beam and fast enough acceleration of muons. On author's opinion using 10 T magnets one can provide several thousands collisions of muon bunches before their decay.

Now it is perfectly clear that the combination of particle storing and deep cooling really opens new possibilities in elementary particle physics. At a special session on exotic beam generation we heard very stimulating reports on a variety of possible experiments including:

- measurements of the masses of circulating cooled beams of rare isotopes;
- experiments with internal targets + cooling;
- accumulation of exotic rare ions;
- overlapping storage rings with formation of exotics

starting from antihydrogen and protonium up to $A^Z\bar{p}$ systems.

So: "cooling and storing of beams makes possible a whole new class of precise experiments which will extend the limits of our knowledge. Cooling of antiprotons has and cooling of exotic ions will give fundamental new results" (D. Möhl).

The last but not the least. Many participants of the workshop had a rather rare opportunity to see middle Volga region with hundreds of kilometers of wild forests ashore, with snow-white ancient russian monasteries and giant artificial lakes. The weather was excellent, living conditions good and people friendly and jolly.

4.2 Report on Transition Crossing Mini-Workshop

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The Mini-Workshop on Transition Crossing was held from May 20 to 23, 1996, at Fermilab. This was the first in a series of mini-workshops on high intensity, high brightness hadron beams. Twenty five people from CERN, KEK, BNL, Fermilab and University of Houston attended the workshop.

The first day was a plenary session with nine presentations. On the second day, three working groups (WG) were formed:

- WG-I was on theory, simulation and measurements, led by J.-P. Riunaud (CERN) and P. L. Colestock (Fermilab)
- WG-II was on γ_t-jump systems, led by T. Roser (BNL) and W. Chou (Fermilab)
- WG-III was on new schemes, led by Y. Mori (KEK) and J. Griffin (Fermilab).

Because of the mini size of the workshop, the agenda was flexible so that these groups could work either together or separately, and participants may switch between groups at will. The group leaders worked hard for coordinating the activities and leading the discussions. Each group gave a presentation at the final plenary session. The summaries from the three working groups are included in this report. During the workshop, P. Martin gave a guided tour of the Main Injector tunnel, which is under construction at Fermilab.

The next three mini-workshops in this series have been tentatively scheduled.

Second Mini-Workshop: From November 29 to December 1, 1996, at KEK. The topic is "*Beam Loss Mechanism in Intense Hadron Synchrotrons.*"

Third Mini-Workshop: From May 19 to 22, 1997, at BNL. The topics are:

- RF cavities (higher order modes, narrowband passive and active mode dampers, wideband passive dampers, beam loading, barrier buckets, *etc.*).
- Coalescing/Debunching-Rebunching (efficiency, emittance dilution and instability problems, slip stacking, *etc.*).

Fourth Mini-Workshop: Late 1997 at CERN. The topics are:

- Longitudinal and transverse emittance budget (emittances growth and preservation, controllable longitudinal emittance blow-up schemes, *etc.*).
- Diagnostics (BPM and orbit measurement, emittance measurement, *etc.*).

4.2.1 Summary of Working Group I—Theory, Simulation and Measurements

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4.2.1.1 Theory and Simulation

Presentations were made regarding aspects of longitudinal stability at transition, particularly with regard to microwave modes. At issue was the ability to predict high frequency modes, as well as the associated emittance growth, with current simulation tools.

An analytical treatment of the linear stability problem was carried out by P. Colestock and J. Holt, which showed an unstable band just above transition. A numerical criterion, similar to the Keil-Schnell criterion was investigated, which showed significant reduction of the stable operating region in this frequency band above transition.

Bill Ng made a presentation regarding issues encountered in the simulation of microwave stability. In particular, the choice of binning in the simulations was discussed. He has found that there is a direct relationship between the bin width and the characteristics of the resulting unstable spectrum in the simulations. Reference was made to the work of Hardt at CERN who has shown analytically that the unstable microwave spectrum should contain frequencies which are not accessible in most simulations due to the constraints on bin width.

Chandra Bhat presented simulations of longitudinal stability in crossing transition in the Fermilab Main Ring. These simulations showed the development of unstable oscillations which were attributed to microwave modes. Discussion ensued which questioned the origin of these effects. A large increase in the beam emittance was shown, however, the concept of emittance was brought into question in situations where a large coherent motion was involved. This was consistent with the fact that the final emittances well away from transition were smaller than those at transition.

Discussion followed regarding the available simulation codes. Almost all work has been based on ESME, which has not universally included the effects of space charge, and is restricted to longitudinal dynamics. However, a fully six-dimensional code, SIMPSON, has been developed by Shinji Machida and could be effectively used to study transition crossing, and the effect on emittance growth. The consensus of the participants was that it would be beneficial to use this more general code to study transition crossing. It was cautioned that such a general code may have to be adapted slightly to be suitable for studying transition crossing.

4.2.1.2 Measurements

J.-P. Riunaud expressed the concern that we need to understand the effect of transition crossing on the blowup of the transverse emittance, a subject that has received rather scant attention to date. T. Roser indicated that at the AGS, operators had found that it was necessary to precisely tune the skew-quadrupoles at transition to prevent transverse emittance blowup later in the cycle. This interesting finding was discussed, but no direct reason for this dependence was found.

Measurements from the PS at KEK were presented which showed vertical emittance blowup at transition at high intensities. Discussion followed with regard to the possible effect of chromaticity changes at high $\dot{\gamma}_t = 1000\ \mathrm{s}^{-1}$. Such a chromaticity change could lead to a head-tail instability.

M. Brennan presented measurements of α_1 made at the AGS. These were based on precise measurements of transition crossing with a small $\Delta p/p$ and a flat γ_t. Accuracy in these measurements was rather good, with about 25% agreement with MAD calculations.

P. Colestock presented a scheme to measure diffusive effects at transition using an echo technique, similar to the echoes that have been studied in unbunched beams. Although a bunched-beam echo model has not been formulated, ESME simulations carried out at the SSC have shown a workable scenario, and measurements have been successfully carried out in the Tevatron. The benefit of transition is to provide a natural phase reversal which can lead to an echo formation with a single longitudinal kick. Discussion followed which indicated issues of nonlinearity in echo formation, however, the echo shape itself may carry information on α_1. Efforts should be made to produce a viable model, as well as tests of the concept near transition.

4.2.2 Summary of Working Group II—γ_t-Jump Systems

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Transition energy jump systems have been around for quite a while and are being used successfully at the CERN PS, BNL AGS, Fermilab Booster and KEK PS. The technique of rapidly changing the transition energy using pulsed quadrupoles is well developed. The working group therefore focussed on a number of topics that are of particular interest for new machines and possible upgrades of existing machines.

4.2.2.1 Limitations of Transition Jump Systems and Possible Upgrades

All transition jump systems currently in operation use a global distortion of the dispersion to change the transition energy. The number of quadrupoles and their required strength is quite modest. However, the main drawback is a maximum dispersion that is up to five times larger than the regular value either just before transition for unipolar jumps or both before and after transition for bipolar jumps. The large dispersion distortion has mainly two consequences that can limit machine performance: First the large dispersion limits the momentum aperture and therefore the bunch area. This is a beam intensity limitation at the BNL AGS. Second, the large dispersion distortion also gives rise to a large value for α_1, the momentum dependence of the transition energy. This leads to a chromatic mismatch of the bucket shape during the jump causing emittance growth and possibly beam loss. Note that neither of these effects are intrinsically intensity dependent. In fact, there seem to be no obvious space charge effects observed in the operating transition jump systems except for signs of microwave instablities which, however, don't lead to any beam loss and only minor emittance blow-up.

If locations with zero dispersion are available a jump in transition energy can be accomplished more easily since it is then possible to change the dispersion only locally and compensate the resulting betatron tune shift at the zero dispersion location. This scheme works well in new lattices and is planned for RHIC and the Fermilab Main Injector. The same scheme could also be used in the AGS if a zero dispersion location is created prior to transition crossing with a one-wave-length dispersion distortion.

The local dispersion distortion would probably also result in a reduced value for α_1. Even if that is not the case and for global distortion systems α_1 can be reduced and maybe even tuned to its ideal value of -1.5 by using sextupoles. Ideally these sextupoles would have to be pulsed together with the pulsed quadrupoles to account for the changing dispersion function.

This means that it seems possible that a transition jump system could be developed that would allow transition crossing without beam loss or emittance growth even at the highest intensities or bunch brightness. The justification for special lattices with very high transition energy or imaginary transition energy should therefore be based primarily on the higher likelihood of encountering instabilities above transition rather than on beam loss or emittance growth from crossing transition.

4.2.2.2 Improvements in the Pulsed Quadrupole Hardware

There was significant discussion on the plans for the pulsed quadrupole system for the Fermilab Main Injector. The vacuum chamber would be made of Inconel 718 which can be made thinner than stainless steel and also has a higher resistivity. The design of the quadrupoles must have a high Q value to allow for a bipolar operation using a ringing circuit.

For future designs of power supplies for pulsed quadrupoles, it would be interesting to provide for the possibility to independently adjust the jump size and the crossing speed. In all current systems these two parameters can only be changed together.

4.2.2.3 Summary of Proton Synchrotron Performances

Table 4.1 is a summary of the performance of proton synchrotrons that need to cross transition. Also included are the performance numbers of planned or upgraded synchrotrons that will need to cross transition or would need to cross it if they used a FODO lattice. The longitudinal brightness defined as the bunch intensity divided by the bunch area is a good measure of the difficulties encountered at transition crossing.

Machine	E_{max} (GeV)	N_{tot} (10^{12})	N_{b} (10^{12})	A_{b} (eV-s)	$N_{\mathrm{b}}/A_{\mathrm{b}}$ (10^{12}/eV-s)	$\epsilon_{rms}^{\mathrm{H}}$ (μm)	$\epsilon_{rms}^{\mathrm{V}}$ (μm)	$N_{\mathrm{b}}/\epsilon_{rms}$ ($10^{12}/\mu$m)
Existing:								
BNL AGS	24	63	8	4	2	10	10	0.8
CERN PS	14	25	1.25	0.7	1.8	12.5	10	0.13
KEK PS	12	3.6	0.4	2	0.2	5	15	0.08
FNAL Booster	8	4	0.05	0.1	0.5	3	3	0.02
FNAL MR	150	20	0.03	0.2	0.15	2	2	0.02
Planned:								
AGS for RHIC	25	0.4	0.4	0.3	1.3	1.5	1.5	0.3
PS for LHC	26	14	0.9	1.0	0.9	2.8	2.8	0.3
FNAL Main Inj	150	60	0.12	0.1	1.2	2	2	0.06
KEK JHP	50	200	12.5	5	2.5	55	55	0.2
$\mu\mu$ Proton Dr	30	100	25	4	6.3	50	50	0.5

Table 4.1: Proton Synchrotron Performance

4.2.3 Summary of Working Group III—New Schemes

Y. Mori `moriy@kekvax.kek.jp` INS, Univ. of Tokyo

The following two topics were mainly discussed by working group III.

- Focus free transition crossing (FFTC)
- Imaginary γ_t lattice

In addition to the following, a bunch-shortening scheme and a quasi-isochronous bucket related to the transition crossing were also discussed.

4.2.3.1 FFTC

This scheme was proposed by Griffin some years ago, the concept of which was reviewed by him at the workshop. The growth of momentum spread occurs at a transition crossing by non-adiabaticity due to the RF focusing force. If the RF focusing force can be eliminated by flattening the RF voltage near to transition energy, momentum spread and longitudinal emittance growth can be avoided.

A proof-of-principle experiment was recently carried out by Bhat *et al.* at the FNAL Main Ring with the 3rd-harmonic RF cavity (f = 159 (53) MHz, V = 0.27 (2.1) MV). No beam loss was observed with the FFTC at a beam intensity of 2.2x10^{10} ppb, while there was beam loss of 5% without FFTC at the transition crossing.

A transition crossing with the FFTC treats any longitudinal potential or bucket distortion. On the other hand, the ordinary transition γ_t jump scheme with an α_1 correction is based on the beam dynamics. There are many advantages in a transition crossing with the FFTC, such as a small beam size at large dipersion and small longitudinal and transverse emittance distortions, because the momentum spread is small and the bunching factor is large. However, it has also been pointed out that small Landau damping due to a small tune spread might be a problem in suppressing any microwave instability when the beam intensity becomes relatively higher.

4.2.3.2 Imaginary γ_t lattice

Three examples of imaginary or high-γ_t lattice designs have been invoked at the workshop.

FNAL Main Ring Ng showed a ring design with an imaginary γ_t lattice for the FNAL Main Ring. This design has the following features:

1. There is no large dispersion, which is unlike Teng's lattice.

2. The packing factor is good.
3. The cell length is relatively longer.
4. The dispersion is zero at the straight sections.
5. Modulation of beta functions are relatively large.

JHP 50-GeV PS Machida presented the lattice design of the JHP (Japanese Hadron Project) 50-GeV PS. An imaginary γ_t can be realized in this design by modulating the curvatures (ρ-modulation), which makes it possible to minimize the modulation of the beta function. This scheme allows sufficient space for RF cavities, which would be beneficial for a high-intensity machine with a large repetition rate. Although the dispersion becomes large at the position of the missing bending section, the value is not very large. Zero dispersion in the long straight section is also possible. The momentum compaction factor can be relatively changeable and the linear optics stability is fairly good.

AGS & Proton Driver for μ^+/μ^- collider Roser showed the high-γ_t option of the present AGS lattice, which is realized by modulating the dispersion function by invoking additional Q magnets. In this modification, the transition energy becomes close to the extraction energy. Roser also showed an example lattice design for the proton driver of a μ^+/μ^- collider. This is the same lattice as that for JHP, except that γ_t is not imaginary.

Discussions The fundamental problems concerning an imaginary γ_t lattice have been discussed. In a hadron machine, LEAR at CERN is the only operational machine to have an imaginary γ_t. In order to make γ_t imaginary, it is unavoidable to have some irregularities and a smaller periodicity for the lattice parameters. These might affect the dynamic aperture, especially when the beam intensity becomes high. On the other hand, it was also pointed out that an imaginary γ_t machine might have a better performance against a longitudinal microwave instability. Since LEAR is an anti-proton decelerator, its beam intensity is relatively low. Discussions concerning an imaginary γ_t lattice have mainly concentrated on these issues, although simulations including space-charge effects for the JHP PS lattice seem to show sufficient dynamic aperture. Every member of this working group has agreed that a “dry run” to simulate practical control and operation of an imaginary γ_t machine is essential to understand the problems and difficulties. It was also pointed out a measurement of α_1 is very important, particularly in a commissioning run.

Others One of the requirements for the proton driver of a μ^+/μ^- collider is to make very short bunches, which gives an RF phase rotation to increase the longitudinal acceptance and provide better muon beam polarization. The required bunch length should be less than 1 ns. In order to make such a short bunch, a scheme with RF manipulation near to transiton energy has been proposed. Norem presented this scheme at this working group. He mentioned that (1) fast bunch rotation should be possible, and (2) bunching and extraction without instabilities seem to be possible.

5: Announcements of Forthcoming Beam Dynamics Events

5.1 Workshop on Mathematical Aspects of Accelerator Physics

This is an informal workshop to be held in the Physik- zentrum of the German Physical Society in Bad Honnef from 9–13 December 1996.

List of preliminary topics:

- general dynamical systems (qualitative theory)
- stochastic systems
- Hamiltonian dynamics
- differential algebra techniques
- spin-dynamics
- perturbation theory
- classical mechanics and differential geometry
- collective theory of many particle systems
- solitons

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Final information about program and speakers and further details will be available at the end of September.

5.2 LHC96—International Workshop on High Brightness Beams for Large Hadron Colliders

This workshop was announced in the previous newsletter. Further information is available at `http://hpariel.cern.ch/keil/lhc96.html`.

6: Announcements of the Beam Dynamics Panel

6.1 12th Advanced ICFA Beam Dynamics Workshop on Nonlinear and Collective Phenomena in Beam Physics: Theory and Experiments

This workshop was announced in the previous newsletter. Further information is available at `http://vesta.physics.ucla.edu/conference`.

6.2 ICFA Beam Dynamics Newsletter

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Instructions to the authors

6.2.1 Instructions to the authors

The ICFA Beam Dynamics Newsletter is intended as a channel for describing unsolved problems and highlighting important ongoing works, and not as substitute for journal articles and conference proceedings which usually describe completed work. It is published by the ICFA Beam Dynamics Panel, one of whose missions is to encourage international collaboration in beam dynamics.

It is published every April, August and December. The deadlines are 15 March, 15 July and 15 November, respectively.

The categories of articles in the newsletter are the following:

1. Anouncements from the panel

2. Reports of Beam Dynamics Activity of a group

3. Reports of Beam Dynamics related workshops and meetings

4. Anouncements of future Beam Dynamics related international workshops and meetings.

   Those who want to use newsletter to anounce their workshops etc can do so. Articles should typically fit within half a page and include descriptions of the subject, date, place and details of the contact person.

5. Review of Beam Dynamics Problems

   This is a place to put forward unsolved problems and not to be used as the achievement report. Clear and short highlights on the problem is encouraged.

6. Letters to the editor

   It is a forum open to everyone. Anybody can show his/her opinion on the beam dynamics and related activities, by sending it to one of the editors. The editors keep the right to reject a contribution.

7. Editorial

All articles except for 6) are by invitation only. The editors request an article following a recommendation by panel members. Those who wish to submit an article are encouraged to contact a nearby panel member.

The manuscript should be sent to one of the editors as a LaTeX file or plain text. The former is encouraged and authors are asked to follow the example below.

Each article should have the title, author's name(s) and his/her/their e-mail address(es).

To avoid wrapping problem, please do not put comments (through e-mail.

6.2.1.1 An example of LaTeX format

The following can be used as a model for preparing contributions.

```
\documentclass{report}
\usepackage{graphics}

% PLEASE USE THESE DUMMY DEFINITIONS FOR DRAFTING AND
% DO NOT CHANGE THEM !!
% They will facilitate the conversion to hypertext for WWW.

% use this to give a link on WWW
\newcommand{\htmllink}[1]{\texttt{#1}}

% use this to give a person's name and email address
\newcommand{\email}[2]{#1 (\texttt{#2})}

% use this to give name, email and address at the top of a
% contribution
\newcommand{\contact}[3]{{\noindent%
                          \parbox[t]{0.6\columnwidth}%
                                    {\textit{#1}\hfill\texttt{#2}
                                    }%
                          \hfill%
                          \parbox[t]{0.35\columnwidth}
```

```
                                      {\small\raggedright#3}\\%
                          }%
                         }

% The following can be used for long comments
\newcommand{\comm}[1]{}

\begin{document}

\section{Beam Dynamics Activities at KEK}

\contact{K.~Hirata}{hirata@kekvax.kek.jp}{KEK\\
                     National Laboratory for High Energy Physics}

Recent developments at KEK include \ldots

\subsection{Further instructions}

You can refer to these instructions at
\htmllink{http://130.87.74.156/ICFA/instruction.html}.

Please prepare your contribution as plain text or straightforward
\LaTeX, following this example.  Remember that the final version
(fonts, layout, etc.) of the newsletter (whether on the World-Wide Web
or on paper) will look very different from your draft so it is
\emph{useless to include any visual formatting commands} (such as
vertical or horizontal spacing, centering, tabs, etc.).  Use only
structural markup as recommended in~\cite{Lamport}.

Above all, avoid \TeX\ commands that are not part of standard \LaTeX.
These include the likes of \verb|\def|, \verb|\centerline|,
\verb|\align|, \ldots.

These restrictions are necessary so that we can automate production
and conversion of the newsletter into HTML for the Web.

Please include the author's name, electronic mail and laboratory
addresses as above and keep the title of your section concise.

Please keep figures to a minimum.
The preferred graphics format is Encapsulated Postscript (EPS) files.

Remembering that this is a newsletter and not a journal or laboratory
report, please also avoid using too much mathematics and giving formal
statements of results.

\begin{figure}[htbp]
    \resizebox{\columnwidth}{!}
         {\includegraphics*[144bp,598bp][349bp,720bp]{dummy.eps}}
```

```
    \caption{Example of a figure.
             The optional arguments give the coordinates of the
             lower left and upper right corners of the part of the
             image which is to be included.
             The units bp are the same ``points'' used in Postscript.
             The image is resized to the width of the current column.
             See~\protect\cite{Lamport}, pp.129--131.
            }
    \label{fig:example}
\end{figure}

A short bibliography may be included.

\begin{thebibliography}{99}

\bibitem{Lamport}
      \LaTeX: A Document Preparation System, Second Edition
      Addison-Wesley, Reading, Massachussets, 1994.

\end{thebibliography}

\end{document}
```

6.2.2 World-Wide Web

Recent issues of this newsletter are available through the World-Wide-Web via the addresses given below. This is now intended as the *primary method of communication.*

The home page of the ICFA Beam Dynamics Panel is at the address

`http://130.87.74.156/ICFA/icfa.html`

(which happens to be in Japan). For reasons of access speed, there are mirror sites for Europe and the USA at

`http://hpariel.cern.ch/jowett/icfa/icfa.html`
`http://www.indiana.edu/~icfa/icfa.html`

All three sites are essentially identical and provide access to the Newsletters, Future Workshops, and other information useful to accelerator physicists. There are links to information of local interest for each area.

6.2.3 Distribution

The ICFA Beam Dynamics Newsletters are distributed through the following distributors:

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Europe* and Africa: Helmut Mais (`mais@mail.desy.de`)

Asia and Pacific:** Susumu Kamada (`kamada@kekvax.kek.jp`)

(*) including former Soviet Union.
(**) For mainland China, Chuang Zhang (`zhangc@bepc5.ihep.ac.cn`) takes care of the distribution with Ms. Su Ping, Secretariat of PASC, P.O.Box 918, Beijing 100039, China.

It can be distributed on a personal basis. Those who want to receive it regularly can ask the distributor to do so. In order to reduce the distribution cost, however, please use WWW as much as possible.

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