3. CENTER FOR BEAM PHYSICS

Reported by John Corlett, Program Head

The Center for Beam Physics (CBP) is a cornerstone program of the Accelerator and Fusion Research Division, and the source of many innovative concepts and new projects within AFRD. The Center is vigorously engaged in a highly productive and tightly knit program of both theoretical studies and experimental research. To serve critical needs of the accelerator-based scientific community, we bring to bear expertise in accelerator physics and theory, accelerator modeling using high performance computing, and beam electrodynamics and instrumentation.

The Center is organized into four standing groups (Figure 3-1)*:* Beam Theory, Accelerator Modeling and Advanced Computing (AMAC), Beam Electrodynamics, and Collider Physics. The Center's work is supported by state-of-the-art experimental facilities in rf and laser/optical beam instrumentation in the Lambertson Beam Electrodynamics Laboratory. The advanced simulations work is performed primarily under the auspices of DOE's highly successful SciDAC program, and it benefits greatly from strong collaboration with mathematicians and computer scientists in the LBNL Computational Research Division (CRD), and with the outstanding staff at NERSC. Each of these four groups provide support to projects and initiatives, and it is this diversity of essential accelerator skills within a program that provides the ability to seed and nurture new concepts and to rapidly respond to needs within the accelerator community.

Our activities range from support of presently operating accelerator facilities such as PEP-II to the development of new initiatives and advanced accelerator concepts. We provide leadership for – and make significant contributions to – major High Energy Physics initiatives in both the near and the long terms, including the Large Hadron Collider, the International Linear Collider, High Intensity Neutrino Source (HINS) R&D, and muon accelerators. Center for Beam Physics staff are also making strong scientific leadership and technical contributions outside of high-energy physics—in particular, in developing critical accelerator physics and technologies necessary for next generation synchrotron radiation sources.

Recent Highlights at a Glance

To briefly summarize achievements of 2005 and 2006 to date that will be detailed in the rest of the chapter…

LHC Accelerator Research Program (LARP). The Large Hadron Collider at CERN has substantial US participation, and our involvement in LARP, which looks toward both commissioning and future upgrades, involves almost all of our groups. The *Beam Electrodynamics Group* is developing beam instrumentation needed to support LHC commissioning. A bunch-by-bunch luminosity monitor has been designed and a prototype successfully tested; we are now in production mode to provide this online diagnostic to CERN. A commissioning team is in place, and will be responsible for pre-beam testing and implementation of the device with beam at CERN. We are now pursuing other diagnostics and instrumentation concepts for the LHC.

The *Beam Theory* and the *Accelerator Modeling and Advanced Computing* Groups have together developed a comprehensive parallel 3-D beam-beam code and used it to perform the first ever million-turn, million-macroparticle, strong-strong LHC simulation. An important goal is to couple these efforts to subsequent participation in LHC commissioning by members of our *Collider Physics Group*.

International Linear Collider (ILC). The expertise within CBP in storage ring physics and technologies, gained from the Advanced Light Source and PEP-II as well as design studies for the notional Next Linear Collider damping rings, has brought us into a leadership position for the ILC damping rings. The goal is for LBNL to be given responsibility for the accelerator physics, engineering design, construction, and commissioning of the damping rings. Our ILC initiative also takes advantage of other LBNL areas of excellence, such as superconducting magnet design and low-level RF systems.

Neutrino Factory and Muon Collider. Looking further toward the future of high-energy physics, LBNL serves as lead laboratory for the Neutrino Factory and Muon Collider Collaboration, whose other sponsoring laboratories are Brookhaven and Fermilab. The Center is extensively represented on all the key technical and executive boards associated with both the Muon Collaboration and the Muon Ionization Cooling Experiment (MICE). If a muon-based accelerator were built in the US, LBNL would desire and expect to play a major role, and would plan to take responsibility for a major subsystem, such as the Front End (including Decay Channel, Phase Rotation, Bunching, and Cooling) or perhaps the storage ring.

Staff from the *Beam Electrodynamics* and *Collider Physics Groups* conduct R&D in support of MICE, and considerable progress has been made this year. A notable example has been the successful commissioning of a 201-MHz cavity suitable for the cooling channel specifications of a neutrino factory, designed and built by LBNL. Along with previous LBNL contributions to this effort—the 5 T solenoid and 805 MHz cavity—it has been installed in the MUCOOL test area (MTA) at Fermilab, and CBP scientists are involved in commissioning and in the experimental program there.

Crosscutting Theory and Modeling. Essential to the Center, our expertise in theory and modeling yields diverse benefits to the accelerator community worldwide ; these activities are carried out primarily in the *Beam Theory* and the *Accelerator Modeling and Advanced Computing (AMAC) Groups*. The highly collaborative AMAC Group has as its goal world leadership in developing terascale accelerator modeling tools and applying those tools to solving the most important and challenging problems in accelerator science and technology. *AMAC* has also made significant accomplishments in the development of algorithms, and collaborates closely with the LOASIS Program (see Chapter 4) in the modeling of beams with large energy spread.

Significant advances have been made by the *Beam Theory Group* in understanding the electron cloud effect and its impact on many existing and planned accelerators. Their collaboration with the Fusion Energy Program resulted in a new code to model this effect—an achievement whose beneficiaries will include ILC positron damping rings.

Expertise within the *Theory Group* is also being applied to the study of electron cloud for the High Intensity Neutrino Source (HINS) R&D program at Fermilab, in collaboration with that laboratory.

Future Light Sources. Another important element of the Center's strategic activities is the development of accelerator science and technologies for both existing and future x-ray sources. Aside from developing technologies and concepts for light-source prospects here at LBNL,we are working with others worldwide. As of this writing we are embarking on a formal collaboration with the Linac Coherent Light Source (LCLS) free electron laser (FEL) facility under construction at the Stanford Linear Accelerator Center. We also have a major role in leading the design study for the FERMI@*Elettra* FEL facility. The LBNL team has led the development of physics concepts, as well as accelerator physics and engineering design studies of this novel machine, in a collaboration involving Sincrotrone Trieste and the Massachusetts Institute of Technology.

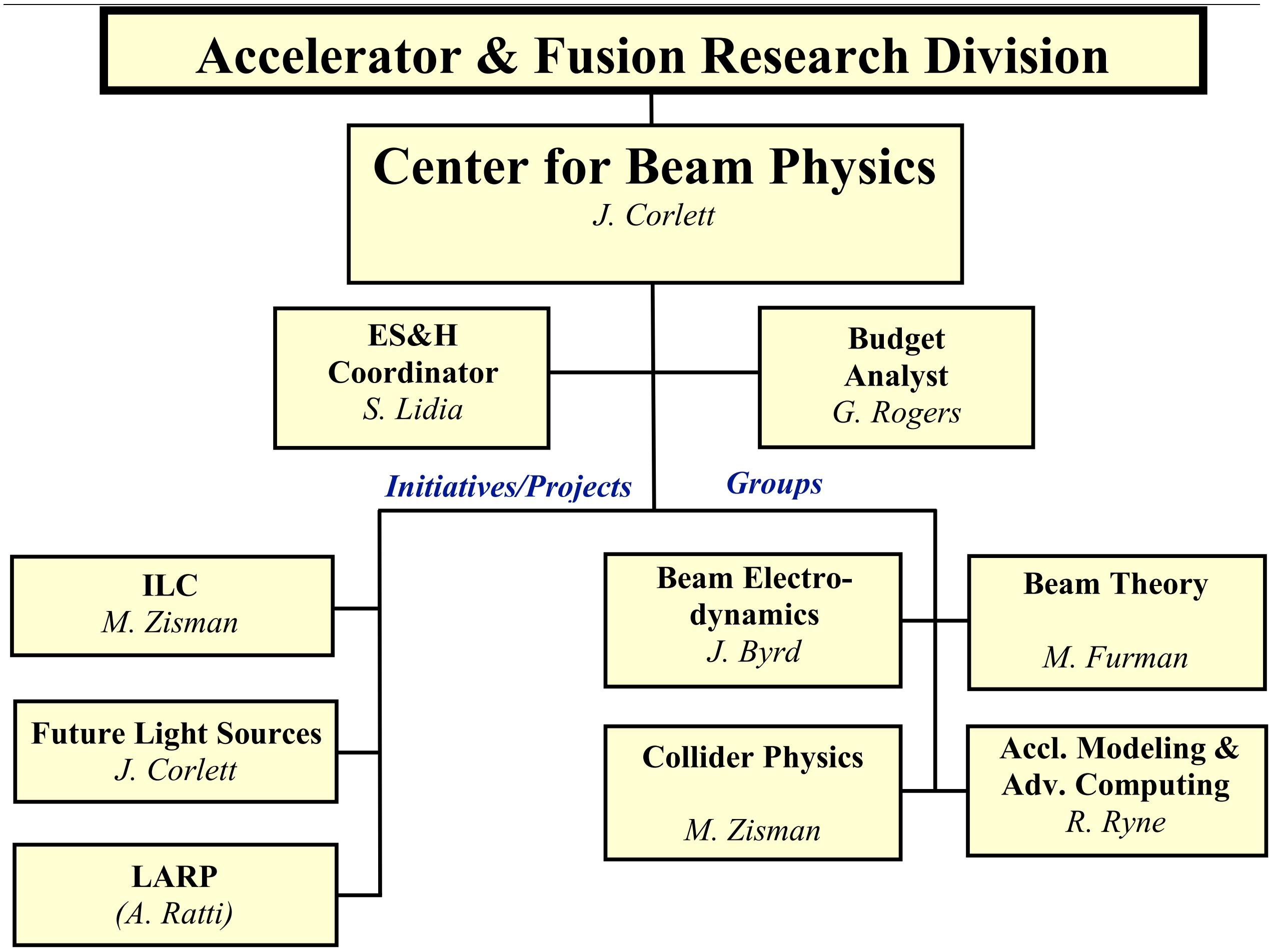
Scope and Results of CBP Efforts

The Center has a total FY06 funding of ~$6.8M and a staff FTE count of approximately 25 full- or part-time members, including scientists, engineers, technical, and administrative support staff. The center also houses a number of students, and training of postdoctoral fellows and students is an important part of the Center's mission; this year there are 6 PhD students, and 6 undergraduates in the Center. We typically host several national and international scientists and scholars each year. We benefit considerably from our proximity to the UC Berkeley campus and have one senior CBP staff scientist as a joint appointment with UC Berkeley Physics Department, in addition to several working relationships with faculty members and students.

The Center has maintained an exceptional record for productivity, which is reflected by the large number of its high quality publications. The work done by Center staff since 2004 has been reported in over 100 publications. A complete bibliography is provided at the end of this chapter.

Staff at the Center also contribute extensively to the national and international accelerator communities through a variety of service and leadership roles. These include participation on program and organizing committees of major accelerator conferences and workshops, participation on machine advisory committees and various facility and program review committees, as journal referees, and through service to the American Physical Society, and various executive and technical boards.

Figure 3-1 shows the organization of the Center, noting its four standing groups and the major projects and initiatives to which those groups also contribute. In addition, many CBP staff collaborate with other programs within AFRD, with other divisions at LBNL, and with institutions outside Berkeley.



Strategic View and Technical Progress

Historically, the Center for Beam Physics has been an incubator of new accelerator concepts that support, sustain and enable forefront science. As a strategic planning model, we work to continue this tradition. To do so, we maintain and build upon our ability to conceptualize and design advanced accelerators, and to provide leadership, commission, and upgrade funded accelerator projects. We apply these skills in a manner consistent with support of ongoing and future national needs as defined by the scientific community and the DOE/Office of Science *Strategic Plan* and *Facilities for the Future of Science* roadmaps. (It should be noted that 60% of the prioritized initiatives in the Strategic Plan involve accelerator-based science.) This approach is evident in each facet of the Center's activities, as summarized below.

Accelerator Science for High-Energy Physics

An important element of the Center's strategic planning relates to our involvement with accelerators and colliders for High Energy Physics. We participate extensively in the development of future accelerator facilities that will be needed by the worldwide HEP community such as the Large Hadron Collider, the International Linear Collider, and the High Intensity Neutrino Source. Our role is one of providing leadership and making significant contributions to R&D in support of project goals, and design, prototyping, and commissioning. The Center also provides a modest level of support for ongoing HEP facilities such as PEP-II and the Tevatron.

Meeting Near-Term Needs through LARP: The Beam Electrodynamics, Beam Theory, Collider Physics, and Accelerator Modeling and Advanced Computing Groups

In support of near-term HEP objectives, we are part of the US LHC Accelerator Research Program (LARP), in which our involvement is expected to grow over the next few years. This DOE-supported activity follows directly from our contribution to construction of the Large Hadron Collider, with components designed and built by LBNL now successfully installed at CERN. Our principal activity in LARP, carried out by the *Beam Electrodynamics Group,* is the development of beam instrumentation needed to support LHC commissioning.

A bunch-by-bunch luminosity monitor has been designed and a prototype successfully tested; we are now in production mode to provide this online diagnostic to CERN. Figure 3-2 shows the prototype luminometer, with the gas ionization chamber removed from its casing. A commissioning team is in place, and will be responsible for pre-beam testing and implementation of the device with beam at CERN. We are now pursuing other diagnostics and instrumentation concepts for the LHC.

CBP contributions to the LARP program are also under way in the *Beam Theory* and the *Accelerator Modeling and Advanced Computing* Groups. Working together, these groups have developed a comprehensive parallel 3-D beam-beam code and used it to perform the first ever 1M turn, 1M macro-particle, strong-strong LHC simulation. An important goal for our LARP activities is to couple these efforts to subsequent participation in LHC commissioning.

The Collider Physics group is participating in LHC commissioning planning for LARP. This group anticipates providing one or more accelerator physicists for the commissioning task at CERN.

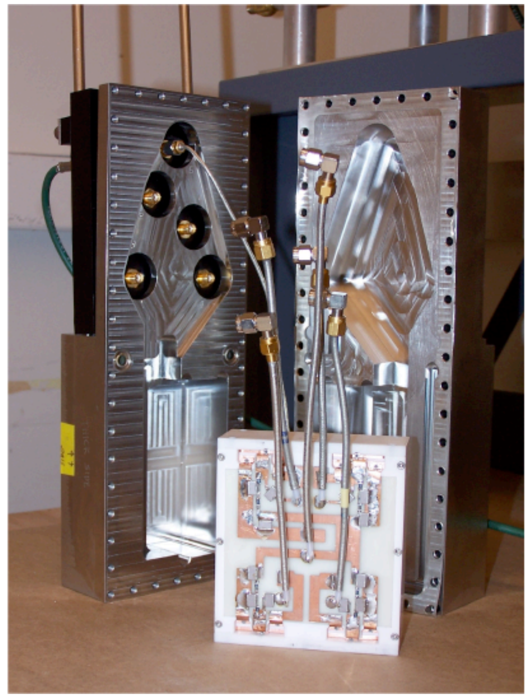


Figure 3-2. *A high-bandwidth luminosity monitor for the LHC developed by the Beam Electrodynamics Group. Having successfully completed the R&D phase, final engineering is in progress and four systems are to be delivered to CERN in the coming winter. These systems will provide bunch-by-bunch measurement of luminosity.*

International Linear Collider Damping Rings: a major initiative within CBP and AFRD

In support of other near-term HEP objectives, the Center has developed a leadership role in R&D for damping rings for the International Linear Collider (ILC). In previous years, the Center had responsibility for design studies of the damping rings for NLC, a proposed linear collider based on normal conducting RF technology. In 2004, the global high–energy physics community made a decision to focus effort on a linear collider (the ILC) based on superconducting RF technology in the main linac. The expertise within CBP in storage ring physics and technologies, gained from our involvement in the design and construction of the Advanced Light Source and PEP-II and their upgrades, and with our experience in design studies for the Next Linear Collider (NLC) damping rings, is an excellent fit to the needs of the ILC damping rings.

The goal of this effort is for LBNL to be given responsibility for the accelerator physics, engineering design, construction, and commissioning of the damping rings for a future linear collider. This work is a major initiative within AFRD and involves each of the Center's Groups, and CBP provides leadership through the Collider Physics Group for the integration of AFRD contributions to Global Design Effort (GDE) of the ILC. Our contributions to ILC also include superconducting magnet design and low-level RF systems, areas of excellence in the Superconducting Magnet Program (in the former case) and the Engineering Division.

The damping rings differ significantly from existing electron storage rings (for example, those in synchrotron light sources), in their rapid cycling of injection and extraction, as well as strong damping from extensive wiggler magnets, and small vertical emittance. Techniques developed in previous years for modeling nonlinear effects from the wigglers on particle trajectories are being applied to the ILC damping rings, and will lead to an optimized design for the wigglers. Also, the AMAC Group is providing advanced simulation tools for parallel particle tracking, and these tools have been modified in collaboration with AMAC to study space charge effects.

There are more effects that threaten the beam quality in the damping rings than in the rest of the ILC. Many of these effects—for example, space-charge effects, coherent synchrotron radiation in the dipoles and instabilities driven by vacuum chamber impedance—are relevant to accelerators used in a variety of other applications, notably synchrotron light sources, so the work will take good advantage of our skills and experience and may yield spinoff benefits to other fields. The specifications for beam stability in the ILC damping rings are extremely challenging, and meeting these goals will require advanced techniques that will be of benefit in a wide range of accelerator applications. Currently, we are emphasizing engineering of the vacuum systems and mechanical integration into a stable and robust configuration, with a view to providing integrated and comprehensive support for damping rings physics and engineering.

The scale of the damping rings is indicated by estimates for the hardware costs, which are of the order of $300M. Construction of a linear collider would therefore provide the opportunity for a substantial contribution from LBNL for developing, delivering and commissioning the damping rings. The Center for Beam Physics is playing a leading role in coordinating the ILC damping rings work effectively among different institutions in many different time zones.

We are planning for significant expansion in our roles within the ILC, maintaining a focus on damping rings physics and engineering, and leadership of a program including some other targeted areas where AFRD and Engineering Division skills and experience provide needed expertise to the ILC Global Design Effort. As our work progresses, we build on the existing skills and leadership role of the Center, and strengthen our ability to contribute to other accelerator projects.

Laying Groundwork for the Long-Term Future of HEP: Muon Colliders and the Collider Physics Group

In support of long-term HEP objectives, the Center continues its leadership role in R&D for muon colliders, primarily through our Collider Physics Group and hardware design from *Beam Electrodynamics*. This work evaluates feasibility of technical approaches that will be needed to build an advanced muon storage ring to support research in neutrino science. A high-intensity muon storage ring is generally viewed as the ideal source of such neutrinos.

LBNL, along with BNL and FNAL, is one of the sponsoring laboratories of the Neutrino Factory and Muon Collider Collaboration, and serves as lead laboratory for this effort. The Center is extensively represented on all the key technical and executive boards associated with both the Muon Collaboration and the Muon Ionization Cooling Experiment (MICE). If a muon-based accelerator were built in the US, LBNL would desire and expect to play a major role, and would plan to take responsibility for a major subsystem, such as the Front End (including Decay Channel, Phase Rotation, Bunching, and Cooling) or perhaps the storage ring.

LBNL plans to have a substantial role in MICE. We have responsibility for engineering design of the spectrometer solenoid for Phase 1 of MICE, and are to provide the RF-Coupling Coil (RFCC) modules for MICE Phase 2. Staff from the Beam Electrodynamics and Collider Physics Groups conduct R&D in support of this effort and considerable progress has been made this year. An LBNL-built 805 MHz cavity has already been used in a series of important tests at Lab G at FNAL. A 5-T solenoid that we designed continues to be used to support the rf cavity test program at FNAL. A notable achievement this year has been the successful commissioning of a 201-MHz cavity suitable for the cooling channel specifications of a neutrino factory, designed and built by LBNL. Figure 3-3 shows the 201 MHz prototype cavity before completion of assembly. The 5 T solenoid, the 805 MHz cavity, and now the 201 MHz cavity are located at the MUCOOL test area (MTA) at Fermilab, and CBP scientists are involved in commissioning and in the experimental program at the MTA.

Figure 3-3. *A prototype 201 MHz cavity designed in the Beam Electrodynamics Group as part of muon cooling activities led by the Collider Physics Group. The cavity is now installed in a test stand at Fermilab, where commissioning has been very successful. The cavity will be used to test technologies for a muon cooling channel, including the use of beryllium windows seen as a large dark-colored disk on the side of the cavity.*

Crosscutting Collaborations in Theory and Modeling: The AMAC and Theory Groups

Other distinguishing capabilities within the Center include our expertise in theory and modeling; these activities are carried out primarily in the Beam Theory, and Accelerator Modeling and Advanced Computing (AMAC) Groups, This overarching expertise is essential to the success of our mission and is applied interactively throughout the activities of the Center. AMAC operates at the interface between computational science and accelerator science; it works closely with organizations in the Lab's Computational Science Directorate (namely, the NERSC and CRD divisions) and with other CBP groups as well as other parts of the Division, LBNL, and other institutions. Collaborations are key to its success. Its goal is to be a world leader in developing terascale accelerator modeling tools and applying those tools to solving the most important and challenging problems in accelerator science and technology.

The AMAC Group maintains close working relationships with many laboratories, and develops and maintains a suite of parallel, 3-D, multi-physics codes for modeling beam dynamics in linacs, rings, and colliders. The group is home to IMPACT, BEAMBEAM3D, MARYLIE/IMPACT, WARP, and WARP/POSINST. IMPACT—a high intensity, high brightness code suite with 3-dimensional and parallel capabilities--is being adopted at many institutions as the tool of choice for modeling both ion and electron accelerators.

AMAC has also made significant accomplishments in the development of algorithms, including Poisson solvers based on integrated Green functions, shifted Green functions, wavelets, and multi-grid techniques. The group has close collaborations with the LOASIS Program (see Chapter 4) in the modeling of beams with large energy spread.

Significant advances have been made by the Beam Theory Group in understanding the electron cloud effect and its impact on many existing and planned accelerators. The Group continues to develop understanding of this potentially performance limiting effect, carrying out further detailed calibrations of the electron cloud simulations against measurements. These simulations, which include impedances and electron-cloud effects, will help with commissioning and upgrade planning for machines like SNS and LHC.

The Theory Group has in recent years participated with the Fusion Energy Program (see Chapter 1) for the integrated study of the electron-cloud effect. This activity, coordinated with a parallel Laboratory-Directed R&D project from Lawrence Livermore National Laboratory, is centered around the HCX driver accelerator located at LBNL, and it encompasses simulations, experimental measurements, and diagnostics developments. The resulting simulation tool, WARP/POSINST, continues to be developed and compared with experimental results, and is a 3D self-consistent code, which has recently yielded a first-ever simulation of a realistic FODO cell of the arcs in the LHC, as shown in Figure 3-3. This tool is arguably the state of the art in the field, and the model it encompasses will continue to be augmented for ever more realistic and accurate simulations with a goal of a validated predictive tool. An important new application will be in detailed study of electron cloud effects in the ILC positron damping rings, where the new code will allow self-consistent modeling of important details such as the damping wiggler regions.

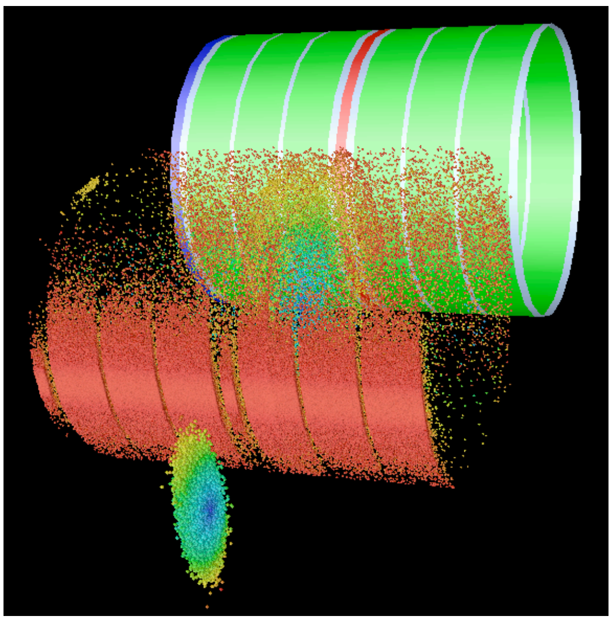


Figure 3-3. *Results from the self-consistent modeling of electron cloud production in a cell of the LHC lattice, using the WARP/POSINST code. WARP/POSINST is a fully self-consistent 3-D electron cloud code, and provides for significant advance in understanding of the potentially performance limiting electron cloud effects. Artificially displaced for visualization purposes, the upper right (green) cylinder represents the FODO magnet cell, the red "cloud" in the center the electrons produced as a proton beam passes through the cell, and a snapshot of the proton beam traversing the cell is shown at lower left.*

Expertise within the Theory Group is also being applied to the study of electron cloud for the High Intensity Neutrino Source (HINS) R&D program at Fermilab. The HINS could involve an upgrade to the main injector which would increase the bunch intensity by a factor of 5 from its present value of 6×10^{10} particles per bunch would place the Main Injector in a regime in which significant electron-cloud effects have been observed at other hadron machines. The Theory Group is leading studies of these electron cloud effects, in collaboration with Fermilab colleagues.

Future Light Sources

Another important element of the Center's strategic activities is the development of accelerator science and technologies with application in existing and future x-ray sources. National facilities based on advanced accelerator technologies have been identified as highly attractive future light sources (see for example "BESAC Subcommittee Workshop Report on 20-Year Basic Energy Sciences Facilities

Roadmap," February 22-24, 2003). A future x-ray science facility at LBNL would enhance the existing substantial scientific activity at LBNL, provide a world-class resource in x-rays, and support the development of scientific and engineering infrastructure at Berkeley Lab.

Using the integrated resources available within the Center, we have developed conceptual designs for accelerator-based facilities and related technologies for future–generation light sources. In addition to developing concepts for future facilities at LBNL, we are actively engaged in support for other light-source projects. We are embarking on a formal collaboration with the Linac Coherent Light Source (LCLS) free electron laser (FEL) facility under construction at the Stanford Linear Accelerator Center, and we have a major role in leading the design study for the FERMI@*Elettra* FEL facility.

FERMI@*Elettra* is a funded project for an FEL facility to be built at Sincrotrone Trieste in Italy. Based on experience gained from high energy physics and synchrotron light source design and construction, the CBP group was selected by the Sincrotrone Trieste management to lead their conceptual design studies for a state-of-the-art FEL facility based on a 1.2 GeV linac. FERMI@*Elettra* will be unique as the world's first purpose-built seeded harmonic cascade FEL facility, and would incorporate features for exquisite control over both the electron and photon beams.

The LBNL team has led the development of physics concepts, as well as accelerator physics and engineering design studies of this novel machine, in a collaboration involving Sincrotrone Trieste, MIT, and LBNL. FERMI@*Elettra* is expected to facilitate important scientific advances through its capabilities to provide intense, tunable, VUV to soft x-ray beams with temporal and spatial coherence. A novel feature will be the ability to provide both ultrafast (100 fs and shorter) photon pulses for time-domain exploration, and also longer pulses with very high temporal coherence (resulting in output radiation bandwidth of a few meV) to provide extremely high resolving power directly from the FEL. Figure 3-4 illustrates these different operating modes for a seeded FEL, and self-amplified spontaneous emission (SASE) under similar conditions for comparison. In pursuing even shorter x-ray pulse production, LBNL scientists have used their expertise in optical manipulation of electron beams to develop concepts for producing photon pulses as short as 100 attosecond in an FEL similar to FERMI@*Elettra* as a future upgrade to the facility. Such a capability would open up as-yet unexplored territory in science at timescales of electronic transitions.

CBP expertise from the Theory, AMAC, and Beam Electrodynamics Groups has been used to develop concepts and technologies for this state-of-the-art FEL facility. Our involvement in physics design studies has included all major areas of the machine; gun, injector, main linac, bunch compressors, beam distribution, FEL's, instrumentation and diagnostics, and timing and synchronization systems. Our physics studies have led to deep understanding of electron bunch production in an RF photocathode electron gun, manipulation and control of beams in the presence of strongly perturbative wakefields, and the intricacies of seeded FEL's, as well as development of world-leading timing and synchronization systems. We have applied accelerator physics expertise and modeling tools developed in CBP such as IMPACT for beam dynamics, and FEL codes such as GINGER.

Synchronization between the interrogating x-ray pulse and a sample pump laser pulse will be critical for high-resolution pump-probe experiments with ultra-short x-ray pulses on future light sources. Addressing this issue, we have designed and built a timing and synchronization system based on a 1.5 μm wavelength master laser and stabilized optical fiber distribution system for providing precision timing pulses and frequency references over 100-1000 m scale length. Timing errors in a stabilized 100 m fiber have already been demonstrated at the femtosecond level, and we are actively incorporating a set of optical techniques to provide an integrated system for timing (for RF and instrumentation systems) and synchronization (of remote laser systems), with timing jitter of tens of femtoseconds . We plan to design, construct, and commission such a comprehensive and robust, fiber-optic based system at the LCLS, and are currently negotiating our role in the LCLS project. In another area, the AMAC group has provided support in photoinjector modeling for the LCLS, using the IMPACT code.

Building on expertise in design of RF cavities, the Beam Electrodynamics Group has developed concepts for deflecting cavities which may be used in a synchrotron light source to provide ultra-short x-ray pulses. By imparting a time-varying deflecting force such that the head and tail of each electron bunch are given a kick in opposite directions, the bunch "flutters" as it progresses around the machine. Taking the radiation form the bunch at particular stages of the head and tail displacements allows for compression of the x-ray beam, or selection of a short time-slice of the x-ray pulse. These cavities also have application as "crab cavities" in high energy physics colliders such as the ILC.

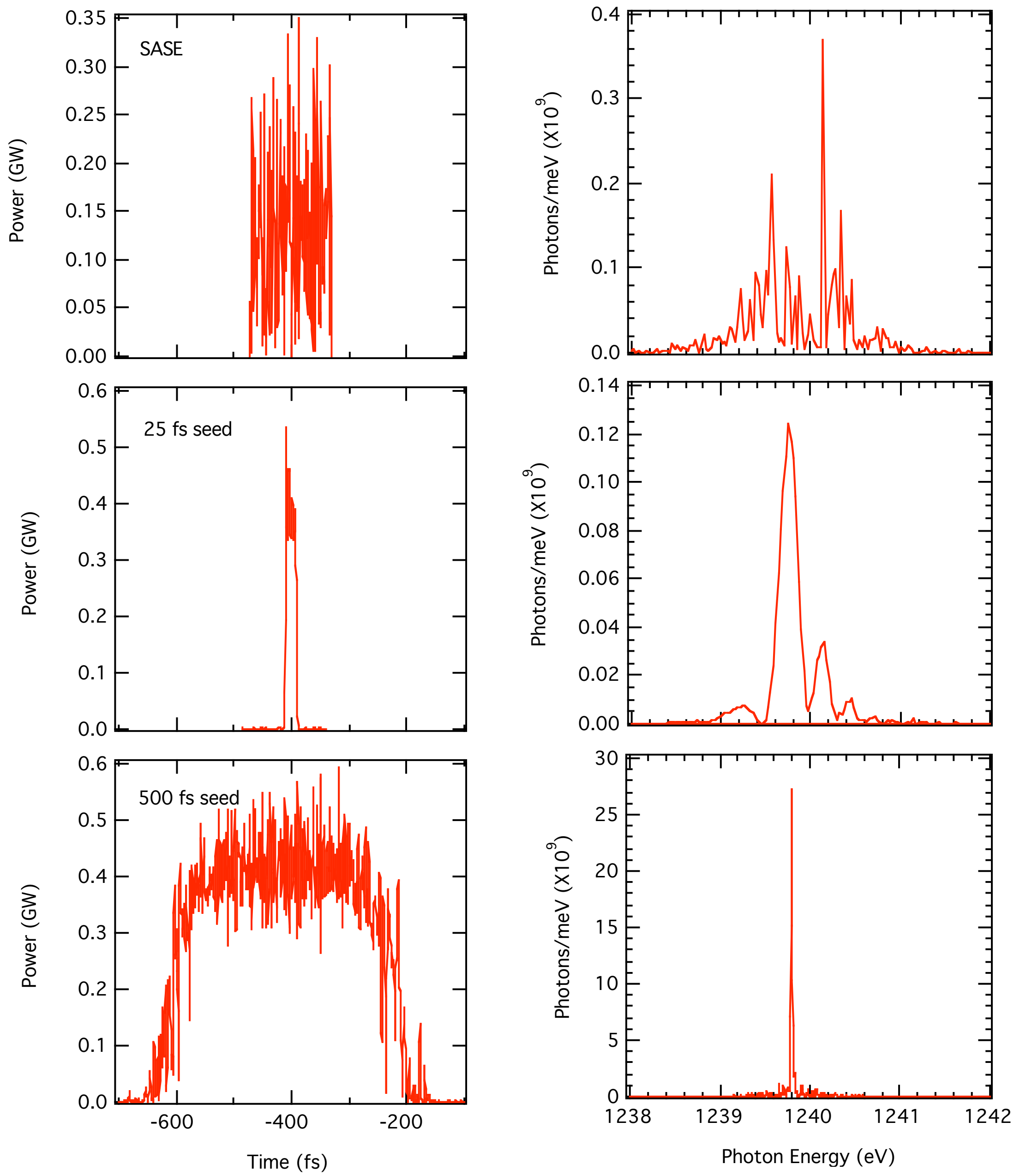


Figure 3-4. *Comparison of SASE and seeded FEL output at 1 nm, for an electron beam of 1.5 GeV, energy spread 100 keV, 250 A current, 0.25 micron emittance; laser seed is 100 kW at 32 nm; undulator period 1 cm. Time profile of the x-ray pulse is shown to the left, and the corresponding spectrum to the right, for the cases of (top to bottom) SASE, 25 fs seed, and 500 fs seed. Seeding with an external, longer wavelength, laser pulse provides coherent control of the x-ray pulse, allowing generation of short pulses for pump-probe type experimentation, or long pulses with narrow bandwidth and high resolving power. CBP scientists are leading design studies of the FERMI@Elettra FEL facility, as well as developing concepts for seeded FELs as a potential new facility at LBNL.*

As a result of these collaborations, which are based significantly on previous work supported by internal LDRD funding, LBNL has gained in knowledge and detailed understanding of many accelerator physics and engineering challenges that may be applied directly to present and future accelerator projects at LBNL, within the Office of Science, and elsewhere. We combine the analytical, computational, and experimental approaches from the Theory, AMAC, and Beam Electrodynamics Groups to develop concepts and technologies related to the production of x-rays in future accelerator-based facilities. The critical areas we address are:

- Design of rf photocathode guns for production of high-brightness and high power (high repetition rate) electron beams
- Development of integrated concepts for production of tailored electron beams by controlled use of laser systems in the rf photocathode gun
- Design and demonstration of ultra-stable timing and synchronization techniques for accelerator facilities.
- Accelerator physics studies of systems for manipulation and control of the electron beam 6-D emittance.
- Physics studies of optical manipulation of electron beams to enhance radiation production.
- Physics studies of the production of wide-band and tunable temporally and spatially coherent radiation in free-electron lasers (FELs).
- Development of multi-physics modeling codes for both electron beam dynamics and for FELs.

In Summary…

AFRD's Center for Beam Physics serves as a national resource supporting the accelerator-based scientific community. It is maintaining its historical role of leadership and many and varied contributions to the field, and has a strategic approach to carry this tradition into the future.

The next section of this chapter lists our featured publications — those papers that we thought representative of our best recent achievements. PDFs of the featured publications are included on this CD, and we encourage you to follow the links and read those which you find interesting. The final section gives a full bibliography.

Featured Publications

These publications, chosen upon the advice of the Center's group leaders, best represent our accomplishments from January 2005 to the present.

A. Wolski, "Alternative Approach to General Coupled Linear Optics," Physical Review Special Topics-Accelerators and Beams 024001 (2006), LBNL-59145.

M.A. Furman and V.H. Chaplin, "Update on Electron-Cloud Power Deposition For The LHC Arc Dipoles," Physical Review Special Topics-Accelerators and Beams **9**, 034403 (2006); LBNL-59062, CBP Note 723 (January 30, 2006). http://prst-ab.aps.org/pdf/PRSTAB/v9/i3/e034403

M. Venturini, R. Warnock, R. Ruth, and J. Ellison, "Coherent synchrotron radiation and bunch stability in a compact storage ring," Physical Review Special Topics-Accelerators and Beams **8**, 014202 (2005); LBNL-54866. http://prst-ab.aps.org/pdf/PRSTAB/v8/i1/e014202

A. Zholents, "Attosecond X-ray Pulses from Free-Electron Lasers," Laser Physics **15**, 6 **(**2005**)**, pp. 855-862**;** LBNL-58782.

J.M. Byrd, Z. Hao, M.C. Martin, D.S. Robin, F. Sannibale, R.W. Schoenlein, A.A. Zholents, and M.S. Zolotorev, "Tailored terahertz pulses from a laser-modulated electron beam," Phys. Rev. Lett. **96**, 164801; LBNL-58991. http://scitation.aip.org/getabs/servlet/GetabsServlet?prog=normal&id=PRLTAO000096000016164801000001&idtype=cvips&gifs=yes

M. Zisman, "Review of U.S. Neutrino Factory Studies," in *Proceedings* of NuFact05, the 7th International Workshop on Neutrino Factories & Superbeams (INFN Frascati, Italy, June 2005), Nuclear Physics B (in press, 2006); LBNL-56830.

D. Li, "201 MHz NC RF Cavity R&D for Muon Cooling Channels," in *Proceedings* of NuFact05, the 7th International Workshop on Neutrino Factories and Superbeams (INFN, Frascati, Italy, June 2005), Nuclear Physics B (in press, 2006).

J. Qiang, M. A. Furman, R. D. Ryne, W. Fischer, K. Ohmi, "Recent advances of strong-strong beam-beam simulation," Nuclear Instruments & Methods in Physics Research A **558**, 351 (2006); LBNL-55539.

Full Publications List

This list, covering 2005 and 2006 to date, is organized by research group; then by whether the publication venue is refereed; and finally by date.

Center for Beam Physics staff were among the authors of 21 publications that appeared in or were submitted to scholarly archival journals or refereed conference proceedings. Another 63 were published in or submitted to venues such as the LBNL Report series or unrefereed proceedings. (Minor overlap is possible due to the collaborative and interdisciplinary nature of many of the Center's activities.)

Although we have not formally tracked the affiliations of co-authors, a substantial majority of these publications may be seen to involve colleagues from other institutions. FERMI@Elettra, the Linac Coherent Light Source, the Large Hadron Collider, the International Linear Collider, and muon accelerators and cooling are examples of the Center's collaborative workstyle and diverse involvement in the worldwide accelerator community that may be observed in this list.

Theory Group

Refereed Journal Articles

A. Wolski, "Alternative Approach to General Coupled Linear Optics," Phys. Rev. Special Topics-Accelerators and Beams **9**, 024001 (2006); LBNL-59145. http://prst-ab.aps.org/pdf/PRSTAB/v9/i2/e024001

M.A. Furman and V.H. Chaplin, "Update on electron-cloud power deposition for the LHC arc dipoles," Physical Review Special Topics-Accelerators and Beams **9**, 034403 (2006); LBNL-59062, CBP Note 723 (January 30, 2006). http://prst-ab.aps.org/pdf/PRSTAB/v9/i3/e034403

M. Venturini, R. Warnock, R. Ruth, and J. Ellison, "Coherent synchrotron radiation and bunch stability in a compact storage ring," Physical Review Special Topics-Accelerators and Beams **8**, 014202 (2005); LBNL-54866. http://prst-ab.aps.org/pdf/PRSTAB/v8/i1/e014202

M. Venturini, R. Warnock, R. Ruth, and J. Ellison, "Impedance description of coherent synchrotron radiation with account of bunch deformation," Physical Review Special Topics-Accelerators and Beams **8**, 014402 (2005). http://prst-ab.aps.org/pdf/PRSTAB/v8/i1/e014402

E. Keil and A. Sessler, "Muon Acceleration in FFAG Rings," Nuclear Instruments and Methods A **538**, 159 (2005); CBP Note–515, LBNL-54798.

X.-P. Li, H. Enokizono, H. Okamoto, Y. Yuri, A. Sessler, J. Wei, "On the Maintenance Condition of Crystalline Beams," Physical Review Special Topics-Accelerators and Beams **9**, 034201 (March 9, 2006); LBNL-59538. http://prst-ab.aps.org/pdf/PRSTAB/v9/i3/e034201

K. Kubo, S. Mtingwa, and A. Wolski, "Intrabeam Scattering Formulas for High Energy Beams," Physical Review Special Topics-Accelerators and Beams **8**, 081001 (August 12, 2005); LBNL-58772. http://prst-ab.aps.org/pdf/PRSTAB/v8/i8/e081001

A. Zholents, "Attosecond X-ray Pulses from Free-Electron Lasers," Laser Physics **15**, 6 **(**2005**)**, pp. 855-862**;** LBNL-58782.

Refereed conference proceedings

R. Ryne, D. Abell, A. Adelmann, J. Amundson, C. Bohn, J. Cary, P. Colella, D. Dechow, V. Decyk, A. Dragt, R. Gerber, S. Habib, D. Higdon, T. Katsouleas, K.-L. Ma, P. McCorquodale, D. Mihalcea, C. Mitchell, W. Mori, C. Mottershead, F. Neri, I. Pogorelov, J. Qiang, R. Samulyak, D. Serafini, J. Shalf, C. Siegerist, P. Spentzouris, P. Stoltz, B. Terzic, M. Venturini, and P. Walstrom, "SciDAC Advances and Applications in Computational Beam Dynamics," in *Proceedings* of the 2005 Scientific Discovery through Advanced Computing (SciDAC) Conference (San Francisco, CA, June 2005), Journal of Physics Conference Series 16, pp. 210-214; LBNL-58243. http://www.iop.org/EJ/S/3/100/GRsfgRNTkY,L4ILQ05l21Q/article/1742-6596/16/1/028/jpconf5_16_028.pdf

Non-refereed conference proceedings

A. Sessler, "Comment on the Word 'Cooling' as it is used in Beam Physics," in Proceedings of COOL05, the International Workshop on Beam Cooling and Related Topics (Eagle Ridge Resort and Spa, Galena, IL , September 18-23, 2005), American Institute of Physics Conference Proceedings 821 (March 2006), ISBN 0-7354-0314-7; LBNL-59536.

K.-J. Kim and A. Sessler, "Transverse-Longitudinal Phase-Space Manipulations and Correlations," in *Proceedings* of COOL05, the International Workshop on Beam Cooling and Related Topics (Eagle Ridge Resort and Spa, Galena, IL , September 18-23, 2005), American Institute of Physics Conference Proceedings 821 (March 2006), ISBN 0-7354-0314-7; LBNL-59529.

P. Emma, Z. Huang, C. Limborg-Deprey, J. Wu, W. Fawley, M Zolotorev, and S. Reiche,, "An Optimized Low-Charge Configuration of the Linac Coherent Light Source," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), pp. 344-347; LBNL-58549. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TOAB004.PDF

W. Fawley, C. Eckdhal et al., "DARHT-II Long-Pulse Beam-Dynamics Experiments," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), pp. 19-23. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/ROAB001.PDF

W. Fawley, B.A. Prichard, Jr., et al., "Technological Improvements in the DARHT II Accelerator Cells," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), pp. 169-173. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/FOAA002.PDF

W. Fawley, G. DeNinno, W.S. Graves, and G.E.Penn, "Optimization Studies of the FERMI at ELETTRA FEL Design," in *Proceedings* of FEL2005, the 27th International Free Electron Laser Conference (Palo Alto, CA, Aug. 21-26, 2005), pp. 59-62; LBNL-58618. http://accelconf.web.cern.ch/AccelConf/f05/PAPERS/MOPP013.PDF

K.L.F. Bane, W. Fawley, et al., "LCLS X-Ray FEL Output Performance in the Presence of Highly Time-Dependent Undulator Wake fields," in *Proceedings* of FEL2005, the 27th International Free Electron Laser Conference (Palo Alto, CA, Aug. 21-26, 2005), pp. 510-513; LBNL-58593. http://accelconf.web.cern.ch/AccelConf/f05/PAPERS/THPP027.PDF

C.J. Bochetta, W. Fawley, and 20 others, "FERMI @ Elettra: A Seeded Harmonic Cascade FEL for EUV and Soft X-Rays," in *Proceedings* of FEL2005, the 27th International Free Electron Laser Conference

(Palo Alto, CA, Aug. 21-26, 2005), pp. 682-685. http://accelconf.web.cern.ch/AccelConf/f05/PAPERS/FROA003.PDF

M.C. Martin, J. Byrd, H. Zhao Hao, D. Robin, F. Sannibale, R.W. Schoenlein, A. Zholents, M. Zolotorev, "Tailored terahertz pulses from a laser-modulated electron beam," in *Proceedings* of the Joint 30th International Conference on Infrared and Millimeter Waves (IEEE, Piscataway, New Jersey, USA, Cat. No. 05EX1150) **2** (2005), pp. 489-902; LBNL-58991.

J.M. Byrd, Z. Hao, M.C. Martin, D. Robin, F. Sannibale, R.W. Schoenlein, A. Zholents, and M.S. Zolotorev, "Terahertz coherent synchrotron radiation from femtosecond laser modulation of the electron beam at the Advanced Light Source," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), p. 3682; LBNL-57592. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPAE066.PDF

M. Zolotorev et al. "An ultra-bright pulsed electron beam with low longitudinal emittance," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), p. 770; SLAC-PUB-11685; LBNL-57593. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TPAT001.PDF

P. Emma, Z. Huang, C. Limborg-Deprey, J. Wu, W. Fawley, M. Zolotorev, and S. Reiche, "An Optimized Low-Charge Configuration of the LINAC Coherent Light Source," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), pp. 344-7; SLAC-PUB-11243; LBNL-58549. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TOAB004.PDF

J. G. Wang, N, Tsoupas, and M. Venturini, "3D-Simulation Studies of SNS Ring Doublet Magnets," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57665. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/MPPT072.PDF

J.-L. Vay, M. Furman, P. Seidl, R. Cohen, A. Friedman, D. Grote, M. Kireeff Covo, A. Molvik, P. Stoltz, S. Veitzer, J. Verboncoeur, "Filling in the Roadmap for Self-Consistent Electron Cloud and Gas Modeling," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), LBNL-56869. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/ROPB006.PDF

Y. Cai and A. Wolski, "Achieving Large Dynamic Aperture in the ILC Damping Rings," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005; LBNL-57589. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPPP054.PDF

T. Raubenheimer, P. Tenenbaum, and A. Wolski, "Multi-Stage Bunch Compressors for the International Linear Collider," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57588. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPPP034.PDF

D. Bates, J. Byrd, A. Wolski, "Simulations of Resistive-Wall Instability in the ILC Damping Rings," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57590. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPPP053.PDF

K. Harkay, K. Ohmi, M. Pivi, T. Raubenheimer, R. Wanzenberg, A. Wolski, F. Zimmermann, "Single-Bunch Instability Driven by the Electron Cloud Effect in the Positron Damping Ring of the International Linear Collider," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57591. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPPP045.PDF

E. Keil, D. Trbojevic, and A. Sessler, "Fixed Field Alternating Gradient Accelerators (FFAG) for Hadron Cancer Therapy," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57566. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPAP020.PDF

X.-P. Li, H. Enokizomo, H. Okamoto, Y. Yuri, A. Sessler, J. Wei, “Phonon Modes and the Maintenance Condition of a Crystalline Beam,” in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57178. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TPAT082.PDF

J.-L. Vay, M. Furman, R. Cohen, A. Friedman, and D. Grote, "Initial Self-Consistent 3D Electron-Cloud Simulations of the LHC Beam with the Code WARP+POSINST,” in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57600. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/FPAP016.PDF

Other non-refereed publications

J. Gao, S. Guiducci, A. Wolski, “Configuration Studies and Recommendations for the ILC Damping Rings”; LBNL-59449.

M. Venturini and K. Oide, “Direct Space-Charge Effects on the ILC Damping Rings”; LBNL-59511.

A. Sessler, G. Westenskow, and I. Wilson, “Two-Beam Accelerators,” 1.6.19 in Chao and Tigner, editors, Handbook of Accelerator Physics and Engineering, 3rd edition (World Scientific Publishing, in press, 2006), ISBN 981-02-3500-3; LBNL-59532.

M. Furman, "A preliminary assessment of the electron cloud effect for the FNAL main injector upgrade”; FERMILAB-PUB-05-258-AD; LBNL-57634.

M. Venturini, “First-Order Space-Charge Tuneshift in a Linearly Coupled Lattice”; LBNL-57664.

J. Nelson, M. Ross, A. Wolski, M. Woodley, “Initial Studies of Nonlinear Dynamics in the KEK-ATF Wigglers ,” Formal Report, (March 1, 2005), CBP Tech Note-333, LBNL-57047.

A. Wolski, “Lattices with Large Dynamic Aperture for ILC Damping Rings”; LBNL-57045.

Y. Honda, J. Nelson, M. Ross, A. Wolski, and M. Woodley, “Coupling Correction in the KEK-ATF Using Orbit Response Matrix Analysis”; LBNL-57046.

W. Fawley and R.J. Briggs, “Induction Linac Cells”; LBNL-56796.

Beam Electrodynamics Group

Refereed journal articles

J.M. Byrd, Z. Hao, M.C. Martin, D.S. Robin, F. Sannibale, R.W. Schoenlein, A.A. Zholents, and M.S. Zolotorev, “Tailored terahertz pulses from a laser-modulated electron beam,” Phys. Rev. Lett. **96**, 164801; LBNL-58991.

Non-refereed conference proceedings

J. Shi, H. Chen, S. Zheng, J. M. Byrd, D. Li, “A Three-Cell Superconducting Deflecting Cavity Design for the ALS at LBNL,” in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-58399. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/WPAT093.PDF

M. Ferianis, J.M. Byrd, J.W. Staples, R.B. Wilcox, J. Chen, F.O. Ilday, F.X. Kaertner, J. Kim, A. Winter, "Generation and Distribution of Stable Timing Signals to Synchronize RF and Lasers at the FERMI FEL Facility," in *Proceedings* of FEL2005, the 27th International Free Electron Laser Conference (Palo Alto, CA, Aug. 21-26, 2005), pp. 134-7. http://accelconf.web.cern.ch/AccelConf/f05/PAPERS/MOPP041.PDF

D. Li, "Status of Neutrino Factory Design and R&D," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/FOAC002.PDF

M. Green, D. Li, S. Virostek, M. Zisman, Y. Ivanyushenkov, W. Lau, A. White, H. Witte, and S. Yang, "Progress on the Coupling Coil for the MICE Channel," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/MPPT059.PDF

X. Bian, H. Chen, S. Zheng, D. Li, "Calculating of Coupling Factor of Microwave Electron Gun," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TPPE065.PDF

R. Rimmer, S. Manning, R. Manus, L. Phillips, M. Stirbet, G. Wu, D. Li, R. MacGill, J. Staples, S. Virostek, M. Zisman, R. Hafley, R. Martin, K. Taminger, M. Reep, D. Summers, "Fabrication of the Prototype 201.25 MHz Cavity for a Muon Ionization Cooling Experiment," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TPPT029.PDF

S. Virostek, D. Li, "RF, Thermal and Structural Analysis of the 201.25 MHz Muon Ionization Cooling Cavity," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TPPT030.PDF

D. Li, M. Green, S. Virostek, M. Zisman, W, Lau, A, White, S, Yang, "Progress on RF Coupling Coil Module Design for the MICE Channel," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/WPAE045.PDF

J. Norem, R. Sandstrom, A. Bross, A. Moretti, Z. Qian, Y. Torun, R, Rimmer, D. Li, M. Zisman, R. Johnson, "The RF Experimental Program in the Fermilab MUCOOL Test Area," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/WPAT029.PDF

D. Li, "201 MHz NC RF Cavity R&D for Muon Cooling Channels," in *Proceedings* of NuFact05, the 7th International Workshop on Neutrino Factories and Superbeams (INFN, Frascati, Italy, June 21-26, 2005), Nuclear Physics B (to be published).

D. Robin, J. Byrd, P. Fischer, P. Heimann, D.-H. Kim, S. Kwiatkowski, D. Li, F. Sannibale, C. Steier, W. Wan, A. Zholents, W. Wittmer, "Generation of Picosecond X-Ray Pulses in the ALS Using RF Orbit Deflection," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-58402. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPAE065.PDF

J. Byrd, Z. Hao, M. Martin, D. Robin, F. Sannibale, R. Schoenlein, A. Zholents, M. Zolotorev, "Terahertz Coherent Synchrotron Radiation from Femtosecond Laser Modulation of the Electron Beam at the Advanced Light Source," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57592. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPAE066.PDF

A. Wolski, J. M. Byrd, "Simulations of Resistive-Wall Instability in the ILC Damping Rings," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-57590. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPPP053.PDF

J. Shi, H. Chen, S. Zheng, J. Byrd, D. Li, "A Three-Cell Superconducting Deflecting Cavity Design for the ALS at LBNL," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-58399. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/WPAT093.PDF

D. Alesini, C. Biscari, G. Benedetti, M.E. Biagini, R. Boni, M. Boscolo, A. Clozza, G. Delle, Monache, G. Di Pirro, A. Drago, A. Gallo, A. Ghigo, S. Guiducci, M. Incurvati, C. Ligi, F. Marcellini, G. Mazzitelli, C. Milardi, L. Pellegrino, M.A. Preger, P. Raimondi, R. Ricci, C. Sanelli, M. Serio, F. Sgamma, B. Spataro, A. Stecchi, A. Stella, C. Vaccarezza, M. Vescovi, M. Zobov, C. Pagani, E. Levichev, P. Piminov, D. Shatilov, J. Byrd, F. Sannibale, J. Fox, D. Teytelman, "Proposal of a bunch length modulation experiment in DAPHNE," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005); LBNL-58398. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/ROAA003.PDF

R. Thurman-Keup, E. Lorman, T. Meyer, S. Pordes, S. De Santis, "Measurement of the Intensity of the Beam in the Abort Gap at the Tevatron Utilizing Synchrotron Light," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/RPAT036.PDF

FERMI @ Elettra Project

LBNL Reports

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, "Enhanced FEL Simulations using Updated Medium-bunch and Long-bunch Configurations, and Two-mode Resonant Cavity Response under Measured or Simulated RF Drive ," 9th deliverable to the FERMI @ Elettra Technical Optimization Study, April 1st, 2006, CBP Note-733, LBNL-60065.

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, "Seed Laser Chirp, Exploration of Long Electron Bunch Sensitivity, FEL Performance with Alternate Long Bunch Distributions, RF Gun Cavity Mode Transient Response, and Timing and Synchronization Systems Overall Design ," 8th deliverable to the FERMI @ Elettra Technical Optimization Study, Mar. 1st, 2006, CBP Note-732, LBNL-59830.

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, "Microbunching instability revisited, medium and long-bunch FEL simulations with Genesis, discussion of spectral broadening effects in FEL's, and initial studies of wiggler errors ," 7th deliverable to the FERMI @ Elettra Technical Optimization Study, Feb. 1st, 2006, CBP Note-731, LBNL-59601.

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, "Time-independent whole-bunch model for FEL-2, time-dependent medium bunch model for FEL-1, and laser heater lattice development ," 6th deliverable to the FERMI @ Elettra Technical Optimization Study, Jan. 1st, 2006, CBP Note-728, LBNL-59396.

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, "Accelerator optimization, injector modeling, FEL time-dependent simulations, and timing system noise ," 5th deliverable to the FERMI @ Elettra Technical Optimization Study, Dec. 1st, 2005, CBP Note-724, LBNL-59244.

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, Timing jitter characterization, concepts for a timing and synchronization system,

re-entrant RF gun studies, SASE performance, and further time-dependent modeling of FEL-I and FEL-II ," 4th deliverable to the FERMI @ Elettra Technical Optimization Study, Nov, 1st, 2005, CBP Note-722, LBNL-59129.

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, "General Layout & Parameters & Physics Studies of Longitudinal Space FERMI @ Elettra R&D Requirements, RF Gun Mode Studies, FEL-2 Steady-State Studies, Preliminary FEL-1 Time-Dependent Studies, and Preliminary Layout Option Investigation ," 3rd deliverable to the FERMI @ Elettra Technical Optimization Study, Oct. 1, 2005, CBP Note-721, LBNL-59038.

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, "General Layout & Parameters & Physics Studies of Longitudinal Space Charge, the Spreader, the Injector, and Prelimiary FEL Performance ," 2nd deliverable to the FERMI @ Elettra Technical Optimization Study, Sept. 1, 2005, CBP Note-719, LBNL-58965.

J. Byrd, J.N. Corlett, L. Doolittle, W. Fawley, S. Lidia, G. Penn, A. Ratti, J Staples, R. Wilcox, J. Wurtele, and A. Zholents, "Preliminary Parameter Set and Initial Studies ," 1st deliverable to the FERMI @ Elettra Technical Optimization Study, Aug. 1, 2005, CBP Note-718, LBNL-38963.

Muon Cooling

Refereed journal articles

J. Berg, S. Bogacz, S. Caspi, J. Cobb, R. Fernow, J. Gallardo, S. Kahn, H. Kirk, D. Neuffer, R. Palmer, K. Paul, H. Witte, M. Zisman, "Cost-Effective Design for a Neutrino Factory ," Physical Review Special Topics-Accelerators and Beams **9**, 011001 (2006).

A. Moretti, Z. Qian, J. Norem, Y. Torun, D. Li, and M. Zisman, "Effects of High Solenoidal Magnetic Fields on RF Accelerating Cavities ," Physical Review Special Topics-Accelerators and Beams **8**, 072001 (2005).

D. Li, "201 MHz NC RF Cavity R&D for Muon Cooling Channels," in *Proceedings* of NuFact05, the 7th International Workshop on Neutrino Factories & Superbeams (Frascati, Italy, June 2005), Nuclear Physics B (in press, 2006).

M. Zisman, "Neutrino Factory Accelerator R&D: Status and Priorities," in *Proceedings* of NuFact05, the 7th International Workshop on Neutrino Factories & Superbeams (Frascati, Italy, June 2005), Nuclear Physics B 151, 1 (May 2006), pp. 143-7.

M. Zisman, "Review of U.S. Neutrino Factory Studies," in *Proceedings* of NuFact05, the 7th International Workshop on Neutrino Factories & Superbeams (Frascati, Italy, June 2005), Nuclear Physics B (in press, 2006).

D. Li, "Neutrino Factory R&D in the U.S.," in *Proceedings* of NuFact04, the 6th International Workshop on Neutrino Factories & Superbeams (Osaka, Japan, July 2004), Nucl. Physics B 149, 44 (May 2005).

Non-refereed conference papers

M. A. Green, D. Li, S. Virostek, W. Lau, H. Witte, S. Yang, P. Drumm, and Y. Ivanyushenkov, "Progress on the Coupling Coil for the MICE Channel," in *Proceedings* of the 2005 Part. Accel. Conf.

(Knoxville, TN, May 2005), p. 3468; MICE Note 117, LBNL-57693. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/MPPT059.PDF

D. Li, M. A. Green, S. Virostek, M. S. Zisman, W. Lau, A. White, and S. Q. Yang, "Progress on the RF Coupling Module for the MICE Channel," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), p. 2869; MICE Note 115, LBNL-56730. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/WPAE045.PDF

D. Li, "Status of Neutrino Factory Design and R&D," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), p. 209, (May 2005). http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/FOAC002.PDF

R. Rimmer, S. Manning, R. Manus, L. Phillips, M. Stirbet, K. Worland, G. Wu, D. Li, R. MacGill, J. Staples, S. Virostek, M. Zisman, K. Taminger, R. Hafley, R. Martin, D. Summers, M. Reep, "Fabrication of the Prototype 201.25 MHz Cavity for a Muon Ionization Cooling Experiment," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), p. 2080. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TPPT029.PDF

S. Virostek and D. Li, "RF, Thermal and Structural Analysis of the 201.25 MHz Muon Ionization Cooling Cavity," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), p. 2119. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/TPPT030.PDF

J. Norem, R. Sandstrom, A. Bross, A. Moretti, Z. Qian, Y. Torun, R. Rimmer, D. Li, M. Zisman, R. Johnson, "The RF Experimental Program in the Fermilab MUCOOL Test Area," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), p. 2104. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/WPAT029.PDF

I. Reichel; M. S. Zisman, K. Gollwitzer; S. Werkema, "Studies to Increase the Anti-Proton Transmission from the Target to the Debuncher Ring," in *Proceedings* of the 2005 Part. Accel. Conf. (Knoxville, TN, May 2005), p. 3357. http://accelconf.web.cern.ch/AccelConf/p05/PAPERS/MPPE056.PDF

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Refereed Journals

G. Fubiani, J. Qiang, E. Esarey, W.P. Leemans, and G. Dugan, "Space charge modeling of dense electron beams with large energy spreads," submitted to Physical Review Special Topics-Accelerators and Beams (2006); LBNL-60089.

J. Qiang, S. Lidia, R. D. Ryne, and C. Limborg-Deprey, "A Three-Dimensional Quasi-Static Model for High Brightness Beam Dynamics simulation," Physical Review Special Topics-Accelerators and Beams **9**, 044204 (27 April 2006); LBNL-59098.

J. Qiang, M. A. Furman, R. D. Ryne, W. Fischer, K. Ohmi, "Recent advances of strong-strong beam-beam simulation," Nuclear Instruments & Methods in Physics Research A **558**, 351 (2006); LBNL-55539.

J. Amundson, P. Spentzouris, J.Qiang and R. Ryne, "Synergia: An accelerator modeling tool with 3-D space charge," J. Comp. Phys. **211**, 229 (2006); LBNL-60082.

J. Qiang, D. Todd, and D. Leitner, "A 3D model for ion beam formation and transport simulation," submitted to Computer Physics Communications (2006); LBNL-59586.

Refereed Conference Proceedings

H. Shan, J. Qiang, K. Yelick and E. Strohmaier, "Performance analysis of a high energy colliding beam simulation code on four high-performance computing architectures," submitted to the *Proceedings* of ICPP-06, the 35th International Conference on Parallel Processing (Columbus, OH, September 2006); LBNL-60085.

Non-Refereed Conference Proceedings and Other Publications

T. Wangler, J.. Qiang, and J. Billen, "RIAPMTQ Benchmarking Study of the ANL Low-Beta Linac Design," LANL report (February 22, 2006); LBNL-60086.

T. Sen, J. Johnstone, N. Mokhov, W. Fischer, R. Gupta, and J. Qiang, "US-LARP Progress on LHC IR Upgrades," in *Proceedings* of LUMI05, the CARE-HHH-APD Workshop on Scenarios for the LHC Luminosity Upgrade (Arcidosso, Italy, September 2005); LBNL-60083. http://care-hhh.web.cern.ch/CARE-HHH/LUMI-05/Proceedings/Thursday%20Plenary/Sen-LUMI05-LARP_LHCIR.pdf