Damping Ring R&D at CESR-TA

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2. Project Title: Damping Ring R&D at CESR-TA, PI: David L. Rubin

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4. Goals and accomplishments

This grant supported the study of the physics of ultra-low emittance damping rings. The goal of the study was a credible design for the damping rings for the ILC. At the outset of the study, it was anticipated that electron cloud effects would limit the intensity of the positron ring, and fast ion instability the intensity of the electron ring. It was also not clear whether the required single particle vertical emittances (2 pm) could be achieved. The results of this study are significant contributions to the design of both electron and positron damping rings that are documented in the ILC Technical Design Report[1,2,3]. Our contributions include the ring optics, vacuum system and surface treatments for electron cloud mitigation, guide field magnets, and damping wigglers. The alignment tolerances, magnetic field errors, and beam position monitor specifications are based on the emittance tuning method developed as part of the study and proscribed for the rings in the TDR. Electron cloud modelling and simulations developed in support of the ILC damping ring design and performance evaluation have been used to specify mitigations for the positron damping ring. The development and characterization of the damping ring optics, development of real-time low emittance tuning and measurement tools[4,5], development of damping ring instrumentation, R&D into electron cloud mitigation methods, tests of long term durability of EC mitigation coatings, and design of damping ring vacuum system components are complete.

With support from the NSF[1], the Cornell electron/positron storage ring (CESR) was configured beginning in 2009, as a damping ring test accelerator (CesrTA) as a vehicle for the study of the relevant beam physics. The electron cloud effect was considered to be the most serious obstacle to performance of the ILC positron damping ring, and perhaps the least well understood. We developed instrumentation for measuring the growth and decay of the electron cloud[6,7,8,9,10,11] and exploited that instrumentation to test the effectiveness of various surface treatments to reduce the electron secondary emission, and prevent the exponential growth of the cloud[Error: Reference source not found,12,Error: Reference source not found]. Modelling codes were benchmarked against the measurements and refined as design tools for the damping rings[13,14]. We studied the interaction of positron beam with the electron cloud in CesrTA, using specialized beam position and beam size detectors, and established thresholds for electron cloud induced instability and emittance growth[15,16]. Other collective effects important in damping rings, such as intra-beam scattering[17] and the fast ion instability[18] were investigated both experimentally and numerically. Techniques and instrumentation for measuring[19,20] and correcting optical and alignment errors (low emittance tuning) were developed. We also provided support for collaborator experiments and device tests.

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[1] NSF- PHY-0734867 – CESR Conversion (3/15/2008-2/29/2012), and NSF-PHY-1002467 (Lepton Collider 5/1/2011-4/30/2015)

The goals/objectives of the program as enumerated in the proposal are listed below, with a summary of accomplishments.

1. EC simulation in support of the positron damping ring design and performance evaluation

The CESR TA research program investigated the effect of the electron cloud on the positron beam in terms of bunch-by-bunch coherent tune shifts, frequency spectra, and bunch size. The density of the electron cloud in the vacuum chamber is bunch dependent, increasing along the train of bunches. The coherent tune shifts of a particular bunch are a direct measure of the ring-wide electron cloud density experienced by that bunch[[21],[22],[23]]. The measured cloud density is compared with the predictions of cloud buildup models (augmented with a new code, Synrad3D[Error: Reference source not found], to characterize the photoelectrons) in order to validate the buildup models and determine their parameters. Frequency spectra are used to determine the threshold density above which signals for electron cloud-induced multi-bunch and head-tail instabilities develop[Error: Reference source not found,Error: Reference source not found]. An X-ray beam size monitor is used to determine the thresholds for emittance growth, and to correlate these observations with the frequency spectral measurements. Simulation codes that model the cloud induced beam blowup and head-tail instability agree reasonably well with the measurements[[24]].

The success of the cloud buildup and emittance dilution codes in modeling the observations gives confidence that these codes can be used to accurately predict the performance of future storage rings. For the ILC damping ring, an antechamber design was developed with the help of the Synrad3D photon simulation. The effectiveness of the mitigations prescribed for the ILC damping ring were evaluated with simulations[Error: Reference source not found]. The expected ring-wide average cloud density for the ILC damping ring is around 0.35×10^{11} m^{-3}, dominated by cloud in the quadrupoles and sextupoles. Based on simple analytic estimates and extrapolation from CESR TA, the instability threshold in the ILC damping ring will be 4-5 times higher than the expected ring wide average cloud density. These simulations do not include the grooved surfaces recommended for the dipole chambers, which will provide further suppression of the cloud[Error: Reference source not found]. Incoherent emittance growth for the ILC damping ring has yet to be fully understood, but is expected to be small because of the low ring wide average cloud density.

Simulation of electron cloud density for the ILC damping ring (DTC04) depends on knowledge of details of the magnetic guide field lattice and of the vacuum chamber geometry and the specific mitigations. The design of the lattice[Error: Reference source not found], and conceptual design of the vacuum chambers and mitigations[[25]] are complete and defined as the baseline for the Technical Design Report. Many of the physics parameters of the electron cloud model are extracted from measurements at CesrTA[Error: Reference source not found,Error: Reference source not found]. Techniques for extracting those parameters, and the results of the simulations of cloud evolution, were reported at KILC 12, the Joint ACFA Physics/Detector Workshop and GDE meeting on Linear Collider, in Daegu, Korea, and in submissions to the 2011 Particle Accelerator Conference and the 2011 and 2012 International Particle Accelerator Conferences[[26],[27]] and in a Ph.D. thesis[Error: Reference source not found].

More sophisticated simulations are required to distinguish the thresholds for incoherent emittance growth due to the electron cloud, from coherent growth related to the head tail instability driven by the cloud. The CMAD[Error: Reference source not found] code that has been developed at Cornell and SLAC, promises to resolve the coherent from incoherent effects, and to make predictions that can be tested at CesrTA. Another approach for studying the interaction of the positron bunch with electron cloud, that promises faster convergence, will use as starting point the electric fields for the cloud generated separately by a buildup code such as ECLOUD or POSINST. A series of measurements was completed in the most recent CesrTA run to benchmark the codes and enhance the predictive power of the simulations.

We have used global fits of retarding field analyzer(RFA) data collected at CesrTA to extract the physics parameters of the electron cloud model. That it has been possible to obtain good fits to many distinct data sets, corresponding to a variety of beam conditions and mitigations, and all with a unique set of model parameters, suggests that the model does indeed capture all of the relevant physics. Furthermore, the secondary and primary emission yields extracted in this manner represent what the beam actually sees, as compared to the traditional bench measurements that cannot possibly reproduce the realistic beam environment[Error: Reference source not found].

An important contribution to the suite of electron cloud modeling tools is the Synrad3D[Error: Reference source not found] code developed at Cornell. The motivation for developing Synrad3D was to better estimate the energy and position distribution of synchrotron radiation photon absorption sites, which are critical inputs to codes which model the growth of electron clouds. Synrad3D includes scattering from the vacuum chamber walls, based on X-ray data from an LBNL database for the smooth-surface reflectivity, and an analytical model for diffuse scattering from a surface with finite roughness. Synrad3D can handle any planar lattice and a wide variety of vacuum chamber profiles. There is an ongoing effort to benchmark the Synrad3D reflectivity model with x-ray scattering measurements.

2. Development and characterization of the damping ring optics

The design and characterization of the 3.2km circumference ILC damping ring lattice and layout has been completed. The ring layout is a racetrack with long straights that house RF, damping wigglers, phase trombone, circumference chicane, and injection and extraction kickers. The arc cell is a simple TME style designed to minimize momentum compaction and horizontal emittance while maintaining dynamic aperture adequate to accept the large phase space of the positrons that emerge from the conversion target. We have computed dynamic aperture, including the effects of guide field magnet nonlinearities and misalignments. Alignment tolerances have been defined, and the effectiveness of an emittance tuning algorithm developed at CesrTA[Error: Reference source not found] has been demonstrated (in simulation) to achieve the specified sub 2pm-rad vertical emittance of the ILC damping ring[Error: Reference source not found].

We are exploiting the capability of our suite of single particle dynamics analysis tools for damping ring value engineering, by investigating the optimal placement and minimum number of beam position monitors, and the largest tolerable misalignments and multipole errors of the guide field elements. And we were recently able to use the same tools to quickly consider the implications of unlocking the damping ring RF frequency for a fraction of the storage cycle to alter the path length and adjust for differences in arrival time of electrons and positrons at the interaction point[[28]].

3. Development of real time emittance tuning and measurement tools with application to CesrTA and ILC damping ring

The low emittance tuning algorithm developed at CesrTA consistently achieves geometric vertical emittance of order 10 pm-rad, which is indeed somewhat greater than required for the ILC damping ring, but is consistent with CesrTA survey tolerances and beam position monitor (BPM) accuracy[Error: Reference source not found,[29]]. The tuning algorithm depends on beam based measurements of the closed orbit, transverse coupling, and vertical dispersion. Coupling is determined by resonantly exciting a bunch at the transverse normal mode tunes, and measuring out of plane response, amplitude and phase, of horizontal and vertical motion, at each BPM. Dispersion is similarly measured as the horizontal and vertical response at the synchrotron tune. A tune tracker[Error: Reference source not found] is used to drive the beam on resonance and to monitor the phase of the drive on each turn for comparison with the measured phase of the bunch at each BPM. The on board memory of the tune tracker records the phase information for later analysis of turn by turn data, a feature essential for applications at other machines, like ATF and the ILC damping ring.

Because the data is collected in a fraction of a second, the emittance tuning technique is insensitive to drifts in timing and BPM gain. Insofar as no guide field magnets need be changed, the method is relatively non-destructive. Of course the resonant excitation of the bunch dilutes its emittance and is therefore incompatible with damping ring operation. In order that the measurements not interfere with operation we propose to designate a witness bunch that serves to monitor machine conditions. We drive the witness bunch at the normal mode tunes and measure horizontal and vertical position of the witness bunch with the beam position monitors. The CESR BPM electronics, upgraded during Phase I of the CesrTA program for turn-by-turn and bunch-by-bunch capability for bunches spaced by as few as four nanoseconds, have the requisite capability. The digital tune tracker is the instrument that we use to drive the single witness bunch. The tune tracker locks onto the tunes and drives the bunch via the strip line feedback kicker. It also records the phase of the kicker drive, at each of the normal mode frequencies, on each turn for later comparison with the phase measured at each BPM. It is equipped with an ethernet interface so that it can be deployed at other laboratories. Basic operation of the tune tracker[Error: Reference source not found] has been demonstrated at CesrTA. We are developing software to add necessary functionality.

We continue to investigate and resolve systematic errors that limit the resolution of the beam – based measurement of transverse coupling and dispersion. A particularly insidious systematic is due to the physical tilt of the beam position monitors. If a BPM is tilted, horizontal dispersion (which tends to be order of 1 m in CESR) will contaminate the measurement of the vertical dispersion and limit effectiveness of the emittance tuning procedure. We are developing a technique to measure the physical tilt of the beam position monitors with milli-rad resolution, using turn-by-turn BPM data. Calibrations based on turn-by-turn measurements are especially useful as very little machine time, (typically seconds), is required to collect the data.

4. Development of damping ring instrumentation

The xray beam size monitor measures bunch by bunch and turn by turn vertical beam size with resolution of a few microns. A coded aperture optic, optimized for operation in the low beam energy regime (1.8GeV) where the xray spectrum is soft and the photon statistics limited, was successfully tested, demonstrating a significantly improved resolving power. The new optic was used for measurements of intra-beam scattering[30,31]. There are presently two xray monitors in CesrTA, one for measuring positron beams and the other for the counter rotating electrons, installed in CHESS (xray user) hutches. Both the electron and positron xbsm beam lines are all vacuum lines to allow full transmission of the softer xrays characteristic of lower beam energy.

We measure horizontal beam size with precision of a few percent using a visible light interferometer[32]. This capability was essential to our measurement of charge dependent emittance growth (intra-beam scattering)[Error: Reference source not found,33,Error: Reference source not found]. The angular acceptance of the optics was recently increased with a taller mirror in order to enhance resolution for measurements of vertical size. A fast photomultiplier array was implemented for bunch-by-bunch and turn-by-turn beam size measurement[34] to make possible synchronous measurements of horizontal beam size with the visible light interferometer and vertical size with the x-ray beam size monitor. However the photomultiplier array pitch is incompatible with the structure of the interference pattern for precise measurement of vertical beam size. A gated ccd camera will be tested with the visible light monitor in December 2014. The gated camera will reduce our sensitivity to motion of the beam and the optics that transmit the light from the accelerator tunnel into the experimental hall. Beam motion currently limits the resolution of the measurement of vertical beam size with visible light interferometry.

The electron cloud mitigations that are installed in the wiggler, dipole and drift chambers in CESR are exposed to beam and therefore synchrotron radiation as well, during operation of the storage ring for the CHESS x-ray facility. Retarding field analyzers continuously monitor the electron cloud, thus providing a measure of the durability of the chamber treatments to exposure to the beam environment[[35]].

Measurements of the time dependence of cloud buildup using BPM-style shielded pickups have been shown to provide tight constraints on electron cloud models[Error: Reference source not found,[36],[37]]. Time-resolving retarding-field analyzers (TR-RFA) were designed, installed and commissioned in dipole and quadrupole chambers. These detectors, in principle combine the time-resolving feature of the shielded pickups with the fine transverse segmentation and cloud electron energy sensitivity of the time-integrating retarding field analyzers used previously. There has been considerable progress in modeling these measurements and quantifying their sensitivity to various parameters describing the underlying physical processes contributing to cloud buildup.

Of primary interest in the installation of the TR-RFAs in the chicane configuration was to measure the effectiveness of the TiN coating with and without the addition of grooves[[38]]. The recommendations for the mitigation to be employed in the positron damping ring for the International Linear Collider include grooved vacuum chambers with TiN coating in the dipole magnets. Four time-resolving retarding field analyzers were installed and commissioned in a dipole chicane at CESR TA. The electron cloud buildup simulation code ECLOUD was adapted to describe the recorded signals in the four custom vacuum chambers with uncoated aluminum and TiN-coated interior surfaces, smooth and grooved. The modeling results show that the grooves in the uncoated chamber reduce the effective peak secondary yield from a value of 2.0 to 1.2 with a sensitivity of better than 10%[Error: Reference source not found]. The measurements in the TiN-coated chambers in an 810G dipole field show that the grooving and TiN-coating mitigation technique proposed for the dipole sections of the ILC positron damping ring reduces cloud buildup by more than an order of magnitude.

With time resolving RFAs installed in quadrupoles we observe a long-lived component of the electron cloud. The cloud[Error: Reference source not found,Error: Reference source not found] is evidently trapped for several times the 2.56μs period of revolution in CESR, as compared to the typical decay time of the cloud in dipoles and field free regions of ~100ns. The trapped cloud may be important in very strong focusing rings with a high density of quadrupoles. Simulations of cloud build-up in quadrupoles over a time scale of several microseconds are in good agreement with the measurements.

5. R&D into EC mitigation methods including: tests of long-term durability of coatings; exploration of new EC mitigation techniques, and participation in the design of ILC DR vacuum system elements

Measurements in CesrTA of a limited set of mitigations over an extended period of time indicate no degradation in performance and continued beam processing. Studies at CesrTA are the basis for the design of the ILC damping ring mitigations. There are conceptual designs for all of the damping ring vacuum chambers[Error: Reference source not found].

Direct measurements of the secondary electron yield (SEY) of technical surfaces are done in the CESR in-situ system[Error: Reference source not found]. The system allows for SEY measurements as a function of incident electron energy and angle on samples that are exposed to a realistic accelerator environment, typically 5.3 GeV counter-rotating beams of electrons and positrons with 150 to 200 mA of current per beam. The system was designed for periodic measurements to observe beam conditioning of the SEY and discrimination between exposure to direct photons from synchrotron radiation versus scattered photons and cloud electrons. Measurements so far have been made on bare metal surfaces (aluminum,copper, stainless steel) and EC-mitigatory coatings (titanium nitride, amorphous carbon, diamond-like carbon). The SEY results are being used to improve predictive models for EC build-up and EC-induced beam effects.

6. A general program of experiments and device prototyping for linear collider R&D

We are supporting development of an optical diffraction radiation (ODR) measurement of beam size in collaboration with CERN. Three sets of measurements have been completed, beginning in December 2012[[39],[40]]. The next test is scheduled for April 2015.
Intrabeam scattering(IBS) dilutes the emittance of low energy, low emittance beams. Because CesrTA can be operated at low energies and with low transverse emittances and high bunch intensity, it is an ideal laboratory for the study of IBS effects. We exploit the instrumentation described above, that provides for accurate beam size measurements in all three dimensions (we use a streak camera to measure bunch length), to make a complete determination of the intensity dependence of emittances. Models based on classical IBS theories and multi-particle simulations are used to estimate the effect of IBS at CesrTA at different single particle beam emittances, intensities and energies. The theory, with some qualification, in particular the requirement of a tail cut to exclude rare events, is in good agreement with the data and has been extensively reported[Error: Reference source not found,Error: Reference source not found,[41]]. Measurements at lower energy were performed in December 2013 and April 2014 using the specially designed coded aperture xray optic[Error: Reference source not found]. Intra-beam scattering is expected to dominate the emittance of the CLIC damping rings.

Positive ions, trapped in the potential of an electron beam, can destabilize a train of electron bunches by coupling the motion of one bunch to the next. It is anticipated that the fast ion instability will ultimately limit the intensity of a multi-bunch electron beam in a damping ring. In all previous studies of fast ion effect (at other accelerators), it was necessary to spoil the ring vacuum with the help of a controlled leak in order that there be sufficient ions to initiate the instability. The instrumentation developed at CesrTA for studying the effect of the electron cloud on positron beams was well suited to the investigation of the effect of clouds of positive ions on electron beams. A systematic study of ion effects at CesrTA was completed during the past year[Error: Reference source not found]. We measured dependence of the threshold for the multibunch instability on bunch charge, train length, as well as the pressure of residual gas. The measurements are in good agreement with a simulation that was also developed at CesrTA during the past two years. Significantly, no incoherent emittance growth was observed in bunch trains stabilized with feedback.

6. Cost Status

Table 1 shows expenses incurred to date, and projections through July, 2014 on DOE funding in the amount of a $1.2M base grant received on 9/20/11 and the $950k installment received 9/12 for a total of $2.15M. The travel expenses were predominantly to support participation in linear collider workshops.

Table 1. Budget summary

	Salaries & Fringe	Capital Equipment	Travel M&S	Indirect	Total
Total	$1,452,938.77	$29,679.49	$66,499.00	$600,882.77	$2,150,000.03

7. Schedule Status

We have completed the design of the lattice and layout of the ILC damping ring lattice. Adequate dynamic aperture and error tolerance has been demonstrated. The simulation of electron cloud density in the damping ring is based on our conceptual design of the vacuum chambers and the mitigations developed and tested at CesrTA. Simulations for the 5Hz operating (low wiggler field) and 10Hz (high wiggler field) mode of the damping rings, indicate that with this design, the beam intensity will not be limited by the electron cloud effect. We specify emittance tuning instrumentation and define alignment tolerances consistent with the required 2pm-rad vertical emittance. Our findings are the basis of the baseline design of the damping rings as documented in the ILC Technical Design Report.

The CESR Test Accelerator Phase I Report[Error: Reference source not found], which documents the; (a)conversion of CESR from colliding beam machine to damping ring test accelerator, (b)beam instrumentation, (c)lattice and layout, and (d)findings during the first 3 years of the program was published in January of 2013.

We continue to monitor the RFAs in CESR during CHESS operations as well as during dedicated CesrTA machine time, to inform our study of beam processing effects and the durability of mitigation coatings. There was a third round of tests of the CLIC ODR beam size monitor during the April 2014 machine studies period. Scheduled for the December 2014 machine studies period (supported by NSF) is further development of the real time emittance tuning technique, measurements of incoherent emittance growth due to the electron cloud, test of a gated ccd camera for the visible light beam size monitor, and measurements of emittance growth due to IBS and impedances at low energy. This grant supported the participation of graduate students, postdocs, and staff scientists making measurements, analysing data, and documenting the results.

11. Products

11. a Publications

2014 Publications

J. R. Calvey, W. Hartung, Y. Li, J. A. Livezey, J. Makita, M. A. Palmer, D. Rubin, “Comparison of Electron Cloud Mitigating Coatings Using Retarding Field Analyzers,” *Nucl. Instrum. Methods Phys. Res.* **A760**, October 2014, p. 86-97. Article (Science Direct) E-Print (arXiv)

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11.b Web sites

Two principal web sites have been maintained as part of this project:

The CESRTA Collaboration Wiki Page
https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/WebHome

The ILC Damping Rings Wiki Page
https://wiki.lepp.cornell.edu/ilc/bin/view/Public/DampingRings/WebHome

The CESRTA Wiki site provides a central access point for the collaboration, where meeting notes, presentations and general information relevant to the research program are maintained. The ILC Damping Rings Wiki site has been the standard location for maintaining ILC Damping Rings information since the time when the ILC Reference Design Report (RDR) was being prepared. It contains detailed lattice information, a database of damping rings components specified in the RDR, and an archive of teleconference meeting presentations.

11.c Networks and Collaborations Fostered

The principal collaboration fostered as part of this grant has been the CESRTA Collaboration. This collaboration is composed of researchers from around the world with interests in:

- Electron cloud physics and its suppression in future high intensity particle accelerators;
- Advanced instrumentation techniques;
- Machine correction and tuning tools for future accelerators, which will be operating in the ultra low emittance regime.

The collaboration has involved over 50 senior researchers from over a dozen institutions around the world. Some details about collaborators and areas of involvement are summarized in Table 2.

Table 2. CESRTA collaborators and their areas of involvement with the R&D program.

Collaborators	Institution	Topics
K. Harkay	ANL	Electron cloud measurements and simulations with a particular focus on validation of the primary photoelectron models.
R. Dowd	Australian Synchrotron	Low emittance tuning.
R. Holtzapple	CalPoly	Instrumentation and beam dynamics measurements.
F. Antoniou, S. Calatroni, F. Caspers, M. Gasior, I. Papaphilippou, J. Pfingster, G. Rumolo, H. Schmickler, M. Taborelli	CERN	Electron cloud measurements and simulations, beam instrumentation, microwave transmission techniques, machine stability, and beam dynamics studies.
J. Jones, A. Wolski	Cockroft Institute	Low emittance tuning.
C-Y. Tan, R. Zwaska	FNAL	Electron cloud measurements and secondary electron yield measurements.
Theo Demma	INFN-LNF (Frascati, IT)	Electron cloud measurements and simulations.
K. Kubo, K. Ohmi, K. Oide, J. Flannagan, H. Tajima, M. Tobiyama, Y. Suetsugu and K. Shibata, J. Urakawa	KEK	Electron cloud measurements and simulations, feedback system, low emittance instrumentation (eg, high resolution x-ray beam size monitor).
J. Byrd, C. Celata, J. Corlett, M. Furman, D. Munson, R. Kraft, G. Penn, D. Plate, S. De Santis, M. Venturini	LBNL	Electron cloud measurements and simulations, wiggler chambers for electron cloud suppression, microwave transmission techniques for characterizing plasmas.
A. Garfinkel, L. Boon	Purdue U.	Electron cloud simulations with with a particular focus on validation of the primary photoelectron models.
D. Kharakh, J. Ng., M. Pivi and L. Wang	SLAC	Electron cloud measurements and simulations, dipole and wiggler chambers for electron cloud suppression, secondary electron yield measurements.
L. Schächter	Technion-Haifa	Electron cloud measurements & analysis.

Much of the work conducted throughout the program has been directed towards providing critical R&D results to be incorporated in the final ILC Technical Design Report.

An outgrowth of interactions between the ILC GDE and the Compact Linear Collider (CLIC) group based at CERN, has been the formation of a CLIC-ILC Joint Working Group on Damping Rings. Research efforts, past and future, at CESRTA have been closely coordinated with this group which encompasses the majority of the world-wide research community interested in damping rings. The research capabilities of CESR in its current damping ring configuration are broadly applicable to a range of experimental questions and technical development required for any of the proposed future damping rings.

We have worked closely with the SuperKEKB design team and the Project X researchers evaluating EC issues for a Project X upgrade of the Fermilab Main Injector (MI). The results of our EC mitigation studies are relevant to both of these projects and the results of our research program have been incorporated into planning for the SuperKEKB positron ring vacuum system. In addition, the SuperKEKB beam size monitors are closely related to the technology that has been developed for the CESRTA xBSM. The effort at Cornell has both benefitted from technology developments for SuperKEKB as well as providing a crucial venue for prototyping new hardware being proposed for use in SuperKEKB.

The Low Emittance Rings Collaboration developed out of the CLIC-ILC Joint Working Group on Damping Rings. The stated goal of this collaboration is to:
"bring together experts from the scientific communities working on low emittance lepton rings. This includes damping rings, test facilities for linear colliders, B-factories and electron storage rings. The theme will be common beam dynamics and technology challenges for producing and controlling ultra low emittance beams and the participants will benefit from the experience of colleagues who have designed, commissioned and operated such rings."
The CESRTA research program has a great deal to contribute as well as to gain from the expertise and topical coverage of this collaboration.

11.d Technologies and techniques

As described above, technologies developed at CesrTA include single bunch single pass capable x-ray beam size monitor, various electron cloud mitigations, and a digital tune tracker. The CesrTA low emittance tuning technique offers the possibility of monitoring and compensating emittance diluting effects in real time.

11.f Research Data

Data acquired as part of the research program is being maintained in an archive available to all collaboration members. The experimental data archive can be found at:
https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/CesrTAData

Because this data represents one of the most detailed collections of electron cloud measurements in existence, which allows us to systematically characterize the build-up of the EC over a broad range of operating conditions, the long-term availability of the data for analysis is an issue of particular significance. Multiple archives of the raw data are being maintained on high reliability servers at LEPP. The data is also backed up to tape archives. Finally, we have deployed analyzed archives for use in higher-level experimental analyses. We expect to maintain all of these archives for ongoing research use throughout the course of the extended CESRTA R&D program.

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