

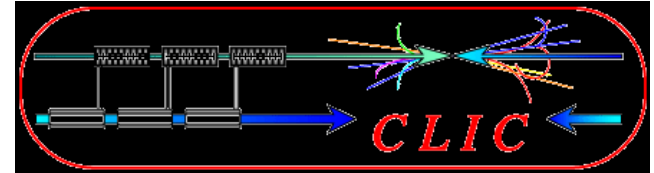


LER 2010 Workshop Summary

Summary of Workshop on Low Emittance Rings 2010

*CERN, 12-15 January
2010*

*Christoph Steier,
Lawrence Berkeley
National Laboratory
March 1, 2010*





Talk Outline

- **Workshop Idea and Scope**
- **Session Program**
- **Selection from closeout talks/summaries**
 - I have used some material from presentations of session chairs:
S. Guiducci, A. Streun, C. Steier, Y. Papaphillipou, G. Rumolo, S. Calatroni, G. Dugan, T. Lefevre, M. Palmer, E. Wallen
- **Some Impression from the Tours**
 - CTF3, LHC control room
- **Summary**

Disclaimer: This talk is my subjective compilation of summary reports from LER 2010 and not an official summary of the workshop organizers.



Workshop Idea and Scope

- The goal of this workshop is **to bring together experts** from the scientific communities working on low emittance lepton rings (including damping rings, test facilities for linear colliders, B-factories and electron storage rings) in order to discuss **common beam dynamics and technical issues**.
- It is organized by the joint ILC/CLIC working group on damping rings and specifically targets **strengthening the collaboration** within the two damping ring design teams and with the rest of the community.
- The workshop will **profit from the experience** of colleagues who have designed, commissioned and operated **lepton ring colliders and synchrotron light sources**.



Workshop Program

A/ Low Emittance Design and Tuning - Tuesday 12 & Wednesday 13/01/2010

- a) Workshop introduction
- b) Design of low emittance cells
- c) Low emittance simulations and experimental tuning
- d) Non-linear dynamics

B/ Collective Effects - Wednesday 13 & Thursday 14/01/2010

- a) Electron cloud simulation measurements and mitigation
- b) Fast ion instability
- c) Intrabeam scattering
- d) Impedance modeling and measurements
- e) Coherent Synchrotron Radiation

C/ Low Emittance Ring Technology - Thursday 14/01/2010

- a) High-field low-period wiggler design including radiation absorption
- b) Kicker system design and stability
- c) Beam instrumentation
- d) Feedback systems

D/ Workshop summaries - Friday 15/01/2010

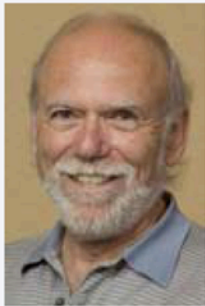
The workshop program with copies of all presentations can be found at <http://ler2010.web.cern.ch/ler2010/>

Background

■ On November 2008, CLIC-ILC collaboration was formalized with the formation of seven working groups in different areas, among which Damping Rings, chaired by M. Palmer (Cornell) and Y. Papaphillipou (CERN)

Director's Corner

13 November 2008

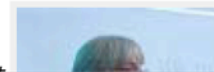


Barry Barish

Formalising the CLIC-ILC collaboration

Collaboration between our ILC R&D and design work and the parallel effort towards the CLIC concept stands to be of benefit to both groups. This direction also promises to help break down barriers between the two groups, making the worldwide effort towards a linear collider more integrated and unified. Of course, the underlying concepts are fundamentally different and affect much of the rest of the design: for acceleration in the main linac, the ILC uses superconducting RF, whereas CLIC accelerates through a drive beam. Nevertheless, there is a great deal of mutual interest in other areas and we have formed [five working groups](#) that are already well [underway](#) and two more working groups are being set up. We have now taken the step to formalise the mode of our collaboration, especially regarding guidelines for communication outside the collaboration. This will help enable the joint work to go forward and be used in ways agreeable to both groups.

As pointed out in our recent Programme Advisory Committee (PAC) review that I reported on last week: *"The PAC views very positively the recent start of common activities between the ILC and CLIC on many items such as conventional facilities, beam delivery system, detectors, physics, cost*



CLIC on many items such as conventional facilities, beam delivery system, detectors, physics, cost estimation, etc. This avoids unnecessary duplication of effort, and keeps the particle physics community focused on the goal of a linear collider as the next major new facility for the field."



As we look to the future, we anticipate that LHC results will establish the scientific case for a



Working group mandate

- **Develop synergies and collaborate in beam dynamics and technical issues of common interest in damping ring design**
- **Use common research approaches and studies when possible including numerical tools**
- **Take advantage of existing test facilities or storage rings and participate in a common experimental program**
- **Trigger communication, establish links between the two communities, share knowledge and document common work**

Low Emittance Rings
workshop 2010
Organized by S.
Guiducci (INFN), M.
Palmer (Cornell) and
Yannis Papaphillipou
(CERN)



A Very Busy Week...

- **59 scheduled talks (all plenary)**
 - 56 were successfully presented
 - Our sincerest apologies for the 3 that were not due to the technical difficulties with establishing the WebEx connections
- **The talks covered a broad range of topics:**
 - Status of linear collider damping ring designs, B factory designs, and test facilities
 - Low emittance lattice design
 - Low emittance tuning
 - Nonlinear dynamics
 - Collective Effects
 - Fast Ion
 - Electron Cloud (characterization and mitigations)
 - CSR
 - IBS
 - Impedance Modeling and Measurement
 - Technical Issues
 - Vacuum design (including EC mitigation, wiggler radiation absorbers,...)
 - Kickers
 - Magnets and Wigglers
 - Alignment
 - Instrumentation
 - Feedback systems
 - RF systems



Lattice/Transverse Dynamics: We face common challenges

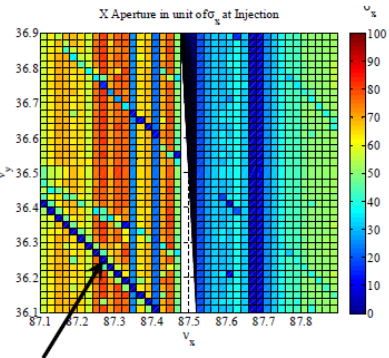
Table by A. Streun

	PDR	DR (CLIC)	DR (ILC)	LS	PF (superB)
Horizontal acceptance in sigma	10 mm mrad?	\	10 mm mrad	10 mm mrad	3 mm mrad
Vertical acceptance in sigma	10 mm mrad?	\	10 mm mrad	1 mm mrad	0.2 mm mrad
Energy acceptance	3%	<1%	<1%	3.5%	>1%
Current	low	< 0.5 A	0.5 A	~0.5 A	2.3 A
Lifetime	\	\	\	10 hrs	~10 min
Horizontal emittance	~10 nm ?	0.1 nm	0.5 nm	0.1 nm	<3 nm
Vertical emittance	~30 pm ?	0.5 pm	2.0 pm	~10 pm	<10 pm
Energy spread	0.10%	0.10%	0.15%	0.10%	0.10%
Energy	3 GeV	3 GeV	5 GeV	3.6 GeV	3.8 GeV

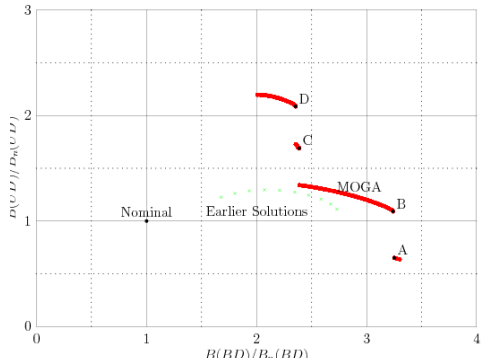
- Injection schemes: accumulation / septum ↔ on-axis
- Emittance minimization: arc cells (MBA ↔ TME ↔ LGB) ↔ damping wigglers
- Methodology (interplay): lattice design (linear ↔ nonlinear) ↔ collective effects

Lattice/Nonlinear Dynamics

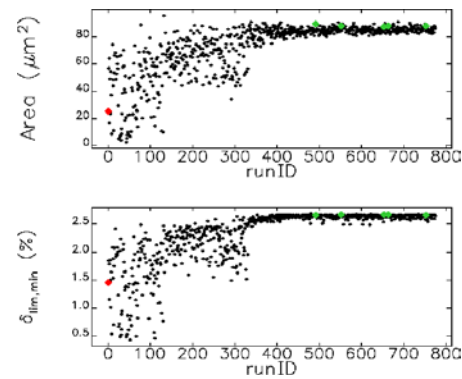
- First 4 sessions were devoted to
 - Lattice Design and Optimization (new+existing rings)
 - Low Emittance Tuning
 - Non linear dynamics – simulation, measurements, optimization
- Selection of some new developments:
 - Genetic algorithms (linear or non-linear lattice optimization), further use of frequency maps, resonance driving terms, multi bend achromats, TME optimization



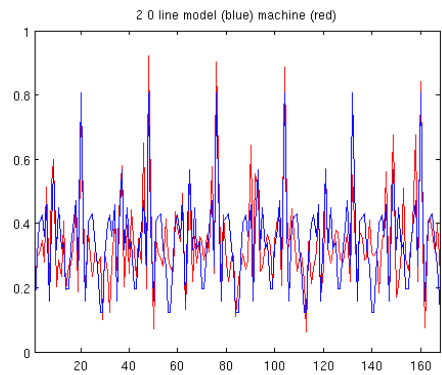
$2v_x + 2v_y = 247$
 Y. Cai, et al.
 TME optimization



L. Yang, et al.
 MOGA (genetic optimizers)
 For linear lattice



M. Borland, L. Emery, et al.
 genetic optimizers for
 Non-linear lattice



R. Bartolini, et al.
 Resonance Driving Terms
 Nonlinear lattice
 symmetrization



Nonlinear dynamics

- **Code comparison: lessons learned ?**
- **Catalog of standard measurements
(taken from Louis Emery / Riccardo Bartolini list)**

Energy (spin depolarisation)
Momentum compaction
Dispersion
Natural chromaticity
Nonlinear dispersion
Detuning with momentum
Detuning with amplitude

Apertures (on/off momentum and engineering apertures)
Lifetime
Frequency Maps ($x-z$ and $x-dp/p$)
Resonance driving terms
Chromatic phase advance
Effect of IDs

⇒ Possible collaborations ?

- **Genetic algorithms....**
—simultaneous linear/nonlinear optimization
- **Integrated lattice & collective effect design**



Low Emittance Tuning – Successful Variations of Standard Technique

- Profiting from Experience – an example:
 - Major concern for damping ring teams has been the attainability of

Vertical emittance in the range required for the ILC Damping Rings has been demonstrated

Demonstrated emittances are also very similar to the values proposed for the Super B factories

Values are rapidly approaching the CLIC damping ring regime!

Plans for future light sources are in even closer proximity to the damping ring parameters

⇒ Greatly improves our confidence in the proposed designs!

ALS					
APS					
ASPF					
CLS					
Dia					
ESF					
SLS					
SOLEIL	3.73 nm	3.70-3.75 nm	0.3 %	0.1%	4 pm
SPEAR3	9.8 nm	9.8 nm	< 1%	0.05%	5 pm
SPRing8	3.4 nm	3.2-3.6 nm	1.9% H; 1.5% V	0.2%	6.4 pm



Vertical emittance: common issues

- **Requirements**
 - natural limit (iso-mag.)
 - Light Source and Particle Factory goals: few pm
 - DR: ~ 0.5 pm (CLIC), 2 pm (ILC)
- **Measurements**
 - pinhole with point-spread functions (Diamond)
 - visual polarized light (SLS)
 - 100 keV profile monitors (ESRF)
- **Tuning algorithms**
 - optics correction using LOCO
 - optics corrections based on turn by turn data
 - skew quadrupole schemes
 - girder alignment and sextupole centering
- **Drifts and long term stability**
 - orbit (and other) feedback

$$\varepsilon_y \approx 0.2 \text{ pm} \frac{\langle \beta_y \rangle_{MAG}}{\rho}$$



Collective Effects

- **4 sessions were entirely devoted to collective effects over Wednesday and Thursday**
 - **Ion effects and IBS**
 - **Electron cloud**
 - **Simulations, measurements**
 - **Mitigation techniques**
 - **Impedance related issues**



Why are collective effects so important for the CLIC and ILC Damping Rings

ILC-DR

From S. Guiducci

Number of bunches	2625
Number of particles per bunch	2×10^{10}
Repetition frequency (Hz)	5
Normalized e ⁺ injected emittance $\gamma\epsilon_{x,y}$ (m)	0.01
Energy acceptance	$\pm 0.5\%$
Normalized horizontal extracted emittance $\gamma\epsilon_x$ (μm)	< 8
Normalized horizontal extracted emittance $\gamma\epsilon_x$ (μm)	0.02
RMS relative energy spread	< 0.15%
RMS bunch length (mm)	6

Bunch spacing

6 ns

- High number of bunches
- High intensity per bunch
- Close bunch spacing and short bunches
- Low transverse emittances, low gaps

CLIC-DR

Parameter	Symbol	Value
Energy	p_0 (GeV)	2.86
Norm. transv. emitt.	$\epsilon_{xn,yn}$ (nm)	480, 4.7
Bunch length	σ_z (mm)	1.4
Momentum spread	σ_δ	1×10^{-3}
Bunch spacing	ΔT_b (ns)	0.5
Bunch population	N_b	4.1×10^9
Circumference	C (m)	493.05
Coupling	(%)	0.1
Mom. compact.	α	6×10^{-5}
Number of bunches	n_b	312
Tunes	$Q_{x,y,s}$ (m)	58.2, 18.8
Store time/train	T_{st} (ms)	20
Energy loss	ΔE (MeV/turn)	5.9
Damping times	$\tau_{x,y,z}$ (ms)	1.6, 1.6, 0.8
RF frequency	f_{rf} (GHz)	2
RF voltage	V_{rf} (MV)	7.2
Bend length	L_{bend} (m)	0.4
Bend chamber rad.	R_{bend} (cm)	1
Number of bends	N_{bend} (m)	96
Wiggler length	L_w (m)	2
Wiggler field	B_w (T)	2.5
Number of wigglers	N_w (m)	76
Wiggler radius	r_w (mm)	9



Talks about collective effects

- **Overview talks**
 - Ion effects, impedance in lepton machines
 - Chamber coatings
- **Experimental results from running machines and lab measurements**
 - CSR at Anka
 - Electron cloud studies at CEsr-TA and KEKB
 - Electron cloud instabilities at DAFNE
 - Use of NEG coating at Soleil
 - Impedance studies and reduction at DAFNE, ELETTRA
 - Scrubbing as a function of electron energy
- **Studies for future facilities (using simulation codes)**
 - Electron cloud in SUPERKEK and SUPERB
 - IBS and Touschek for PEP-X
 - Vacuum design for ILC-DR
- **Results of novel methods of calculation**
 - IBS with self-consistent beam distributions
 - Taper impedances
 - Resistive wall impedance with coating and in the THz regime



Conclusions – Collective Effects

- **Most of the collective effects play equally important roles in the design of both the ILC and the CLIC DRs, as well as of future high energy lepton machines**
 - Electron cloud (DRs, SUPERKEKB, SUPERB), ions
 - IBS (DRs, PEP-X), space charge
 - Impedance driven instabilities enhanced by the low emittance design
- **Efforts to find solutions and suppression techniques are conducted in synergy between different communities**
 - Lab measurements (coatings, scrubbing efficiency)
 - Learn from experience of running machines (vacuum, methods for instability suppression, impedance reduction campaign based on beam measurements), understand impedance degradation, which can lead to heating, pressure rise and ion instabilities
 - New tests in the existing machines, benchmark of e-cloud simulation codes (Cesr-TA)
 - Design of accelerator components optimized for the beam impedance (nonlinear tapers, strip-line kickers, low impedance clearing electrodes, ...)
 - Better understanding of resistive wall in the THz frequency regime and of coated walls



Technology Connections Between Groups

- **Potential or existing areas for collaboration between groups:**
 - **Pulsed magnets and kickers**
 - **Low impedance strip-line kickers**
 - Broadband requirements, high voltage reliability
 - Ongoing collaboration: DAΦNE, Damping Rings groups
 - **Fast rise- and fall-time high voltage pulsers with good amplitude stability and high reliability**
 - Ongoing collaboration: DAΦNE, Damping Rings groups
 - **Methods to minimize kicker-induced orbit errors**
 - **Pulsed magnet design for on-axis injection schemes**
 - **Magnet Designs**
 - **High Field Wigglers and Undulators**
 - Aperture, peak field, field quality and shimming, and non-linear optimization for widely varying applications
 - SC wire choices, properties, and methods for SC designs
 - Connection with vacuum chamber design: photon absorbers, electron cloud build-up, cold-mass heat loads, protection against losses, radiation damage
 - **Conventional magnet approaches for low emittance cell design, particularly when “high occupancy” cells are required**



Technology Connections Between Groups

- **Alignment**

- Precision alignment and magnet fiducialization

- Vibrating wire technique (with detailed study/suppression of systematic effects) provides alignment capability which is well-matched to low emittance ring requirements.

- Beam-based alignment techniques

- Real-time alignment technologies

- Girder alignment/movers \Rightarrow magnet movers \Rightarrow correctors

- **Instrumentation**

- BPM Systems

- Turn-by-turn capabilities and correction methods
- Orbit feedbacks and maximum attainable bandwidths
- Calibration and stability/repeatability issues

- Synchrotron Radiation Monitors for Emittance Characterization and Tuning



Technology Connections Between Groups

- **Feedback Systems**
 - Impact of digitization resolution on low emittance operation
 - Specifications for control of instabilities in high intensity, low emittance rings
- **RF Systems**
 - Low Level RF Design
 - RF Power – solid state amplifiers vs klystrons
 - Cavity design for various bunch structure requirements



Effectiveness of workshop ...

- **Bringing together experts...**
 - 69 registered participants representing a cross section of all the major groups working on low emittance rings
- **Profiting from experience...**
 - 56 presentations highlighting critical design issues for low emittance electron and positron rings
 - An impressive range of observations from light sources, B factories and test facilities presented
 - Clear areas of mutual interest identified
 - Many design issues highlighted
 - There appear to be many synergies between plans being developed for future light source development and the plans for low emittance high energy physics rings
- **All leading to...**
 - a range of animated discussions
 - exploration of possibilities for collaboration



How to move further

- **Strengthening collaboration**
 - Many discussions explored the possibility of developing new collaborations or enhancing existing ones
 - Summary presentations clearly identified areas where further collaboration across the community can yield benefits for all
 - This shows great promise, but how should one proceed?

A proposal discussed and accepted at the workshop...

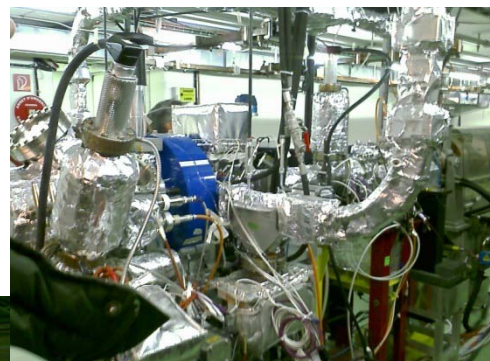
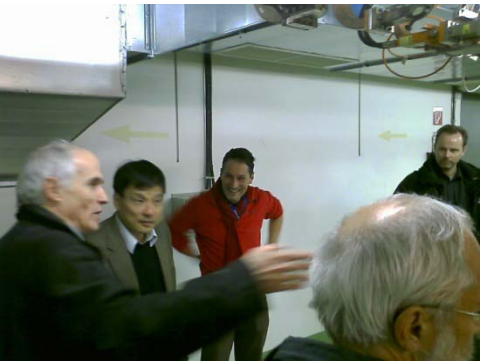
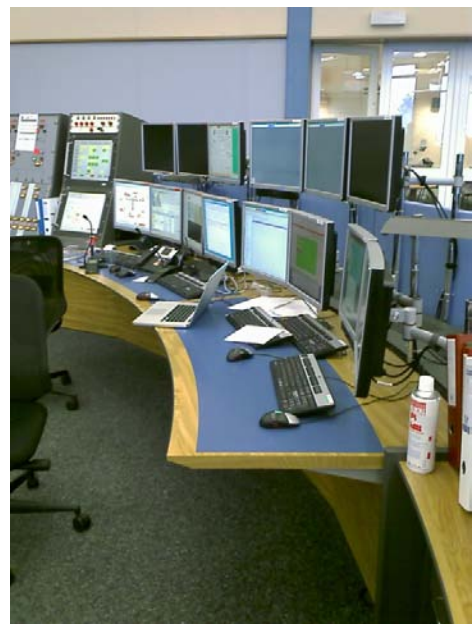


Beyond LER2010

- **Low emittance rings working groups**
 - Any other subjects?
 - Coordinators to be confirmed (others to be added?)
 - Task: Identify collaboration items as discussed in the workshop
 - Collect “expressions of interest” from community (LER2010 participants and beyond)
 - Start collaboration work to be reported at the 2nd workshop in a series!

	Subject	Coordinators
1	Low emittance cells design	M. Borland (APS), Y. Cai (SLAC), A. Nadgi (Soleil)
2	Non-linear optimization	R. Bartolini (DIAMOND/JAI), C. Steier (LBNL)
3	Minimization of vertical emittance	A. Streun (PSI), R. Dowd (Australian Synchrotron)
4	Integration of collective effects in lattice design	R. Nagaoka (SOLEIL), Y. Papaphilippou (CERN)
5	Insertion device, magnet design and alignment	S. Prestemon (LBNL), E. Wallen (MAXlab)
6	Instrumentation for low emittance	M. Palmer (Cornell), G. Decker (APS)
7	Fast Kicker design	P. Lebasque (Soleil), C. Burkhardt (SLAC)
8	Feedback systems (slow and fast)	A. Drago (INFN/LNF), B. Podobedov (BNL), T. Nakamura (JASRI/Spring8)
9	Beam instabilities	G. Rumolo (CERN), R. Nagaoka (SOLEIL)
10	Impedance and vacuum design	K. Bane (SLAC), S. Krinsky (BNL), E. Karantzoulis (Elettra), Y. Suetsugu (KEK)

Friday Tour: CTF3 + LHC control room





Summary

- **Workshop with many excellent talks with very recent results, sufficient time for discussion**
- **Excellent mix and quality of participants**
- **The participating communities work on similar challenges and do not necessarily communicate enough, yet.**

- **Agreed on path to improve on this and create working groups that will organize further focused workshops and eventually collaborations ...**