Damping Rings

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D. Rubin, Cornell

Key luminosity issues of the damping rings

In your talk, please highlight the key luminosity related challenges for your area for both projects. The goal is not to have a complete list of all issues but rather to focus on a limited number of most critical ones and answer the following questions:

How are these key issues being addressed using hardware component tests, theoretical studies and in particular system tests?

What is the status of these studies? What is needed to complete them successfully?

Have the resources been allocated?

Are there new efforts that should to be launched?

Key luminosity issues for ILC Damping Ring

Electron cloud

- For baseline parameters (5Hz, 1312 bunches) estimated cloud density ~ 1/10 instability threshold
- High luminosity mode ?
- Measurements of emittance dilution and instability threshold are all at vertical emittances 5 – 10 times ILC- DR spec.
- => Extrapolation to DR parameters may be optimistic

Tests at lower emittance desirable

- CesrTA phase III?
- SuperKEKB ?
- Further development and benchmarking of simulation
- Measure dependence of emittance diluting threshold on bunch charge and vertical size

Fast Ion instability

- Simulation indicates multi-bunch feedback with ~ tens of turns damping times is required
- Measurements of instability qualitative
- It would be good to measure instability threshold (without compromising machine vacuum)
- And to determine if there is emittance dilution that will not be corrected with feedback

Quantitative measurements essential

- Measure bunch by bunch vertical size and amplitude in train with ~ 32 bunches
- At x-ray light source with few pm vertical emittance and appropriate instrumentation
- (CesrTA study planned)

High Luminosity Mode

- Evaluate increased synchrotron radiation load on vacuum system
- Including wiggler photon stops
- Review instability thresholds for
  - Electron cloud
  - Fast Ion

CesrTA proposes to address all of the above.

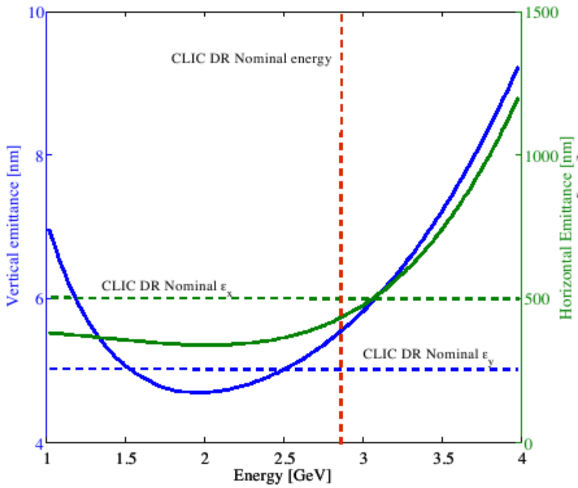
Successful completion requires renewal of CesrTA program

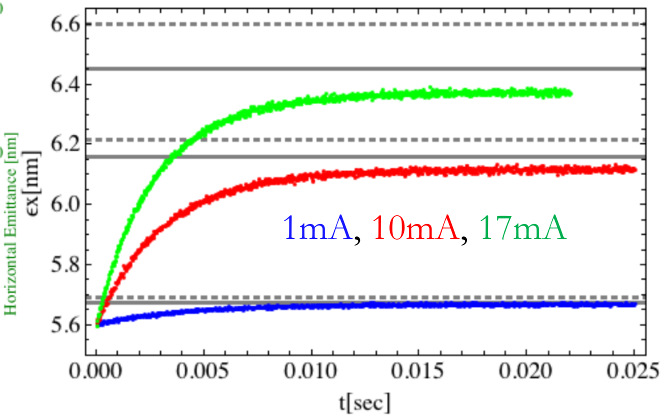
CLIC DR challenges and adopted solutions

Parameters, Symbol [Unit]	2 GHz	1 GHz
Energy, E [GeV]	2.86	
Circumference, C [m]	427.5	
Bunch population, N [10^9]	4.1	
Basic cell type in the arc/LSS	TME/FODO	
Number of dipoles, N_d	100	
Dipole Field, B_0 [T]	1.0	
Norm. gradient in dipole [m^{-2}]	-1.1	
Hor., ver. tune, (Q_x,Q_y)	(48.35,10.40)	
Hor., ver. chromaticity, (ξ_x,ξ_y)	(-115,-85)	
Number of wigglers, N_w	52	
Wiggler peak field, B_w [T]	2.5	
Wiggler length, L_w [m]	2	
Wiggler period, λ_w [cm]	5	
Damping times, (τ_x,τ_y,τ_l) [ms]	(2.0,2.0,1.0)	
Momentum compaction, α_c [10^{-4}]	1.3	
Energy loss/turn, U [MeV]	4.0	
Norm. hor. emittance, $\gamma\epsilon_x$ [mm·mrad]	472	456
Norm. ver. emittance, $\gamma\epsilon_y$ [mm·mrad]	4.8	4.8
Energy spread (rms), σ_δ [%]	0.1	0.1
Bunch length (rms), σ_s [mm]	1.6	1.8
Long. emittance, ϵ_l [keVm]	5.3	6.0
IBS factors hor./ver./long.	1.5/1.1/1.2	1.5/1.1/1.2
RF Voltage, V_{RF} [MV]	4.5	5.1
Stationary phase [^{o}]	62	51
Synchrotron tune, Q_s	0.0065	0.0057
Bunches per train, n_b	312	156
Bunch spacing, τ_b [ns]	0.5	1
RF acceptance, ϵ_{RF} [%]	1.0	2.4
Harmonic number, h	2851	1425

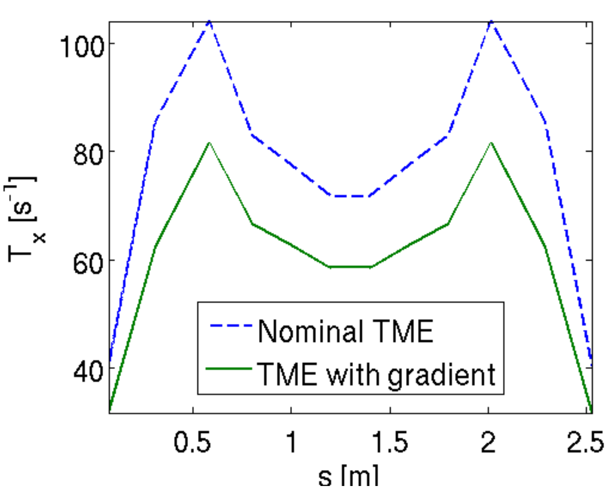
- High-bunch density in all three dimensions
  - **Intrabeam Scattering** effect reduced by choice of ring energy, lattice design, wiggler technology and alignment tolerances
  - **Electron cloud** in e^+ ring mitigated by chamber coatings and efficient photon absorption
  - **Fast Ion Instability** in the e^- ring reduced by low vacuum pressure and large train gap
  - **Space charge vertical tune-shift** limited by energy choice, reduced circumference, bunch length increase
  - Other **collective instabilities** controlled by low –impedance requirements on machine components
- Repetition rate and bunch structure
  - Fast damping times achieved with SC wigglers
  - RF frequency reduction @ 1GHz considered due to many challenges @ 2GHz (power source, high peak and average current, transient beam loading)
- Output emittance stability
  - Tight jitter tolerance driving kicker technology
- Positron beam dimensions from source
  - Pre-damping ring challenges (energy acceptance, dynamic aperture) solved with lattice design

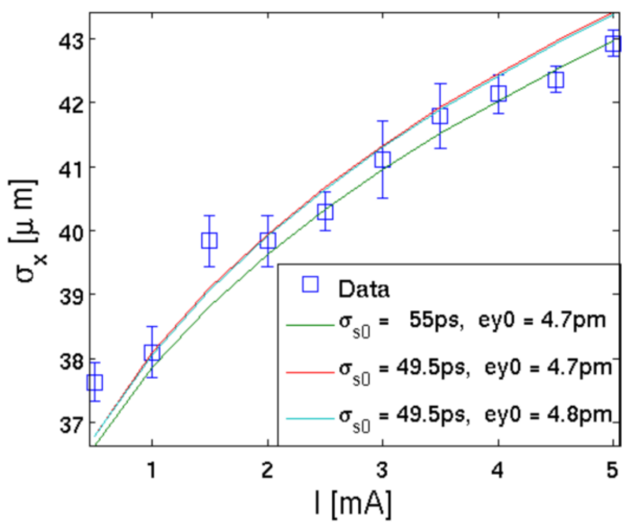
Intrabeam Scattering theory, simulations and measurements





F. Antoniou, et al.





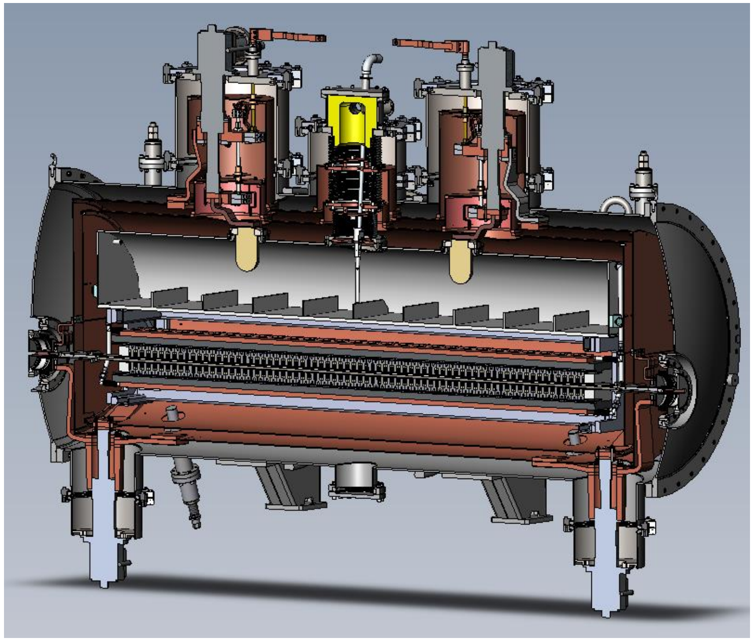
- Energy choice and lattice design for reducing effect from IBS
- Monte-Carlo tracking codes developed based on Ratherford Coulomb scattering cross section
  - Code agreement for lower currents, more divergence at high currents
- First measurements at SLS-PSI with good agreement with theoretical predictions

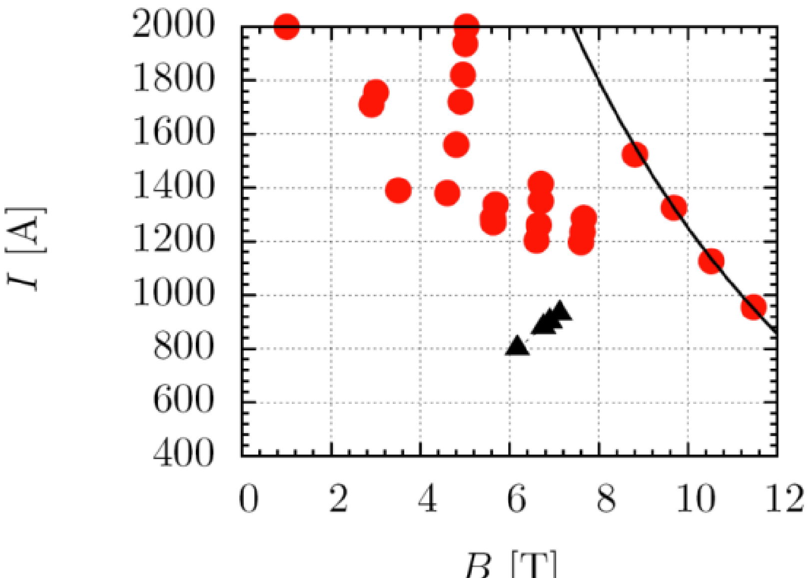
Other collective effects

- Space-charge reduced <0.1 with combined circumference reduction and bunch length increase
  - Tests in future light sources
- e-cloud imposes limits in PEY (99.9%) and SEY (<1.3) achieved with wiggler absorption scheme and chamber coatings (amorphous carbon)
  - CESRTA is the best test bed for testing chamber coatings and photon desorption
- Fast ion instability in e^- DR constrains vacuum pressure to around 0.1nTorr (large train gap also helps)
  - Experiments in existing light sources (e.g. SOLEIL) but also test facilities (CESRTA, ATF)
- Single bunch instabilities avoided with smooth vacuum chamber design (effect of coating)
  - Measurements at ESRF, SOLEIL, PSI, ALBA
- Resistive wall coupled bunch controlled with feedback
  - Conceptual design of 1-2GHz b-b-b feedback by T. Nakamura (SPring8)
- Coherent synchrotron radiation still needs to be fully evaluated
  - Measurements in light sources (BESSY, ANKA)

SC wiggler development

A. Bernard, P. Ferracin, N. Mesentsev, D. Schoerling, et al.

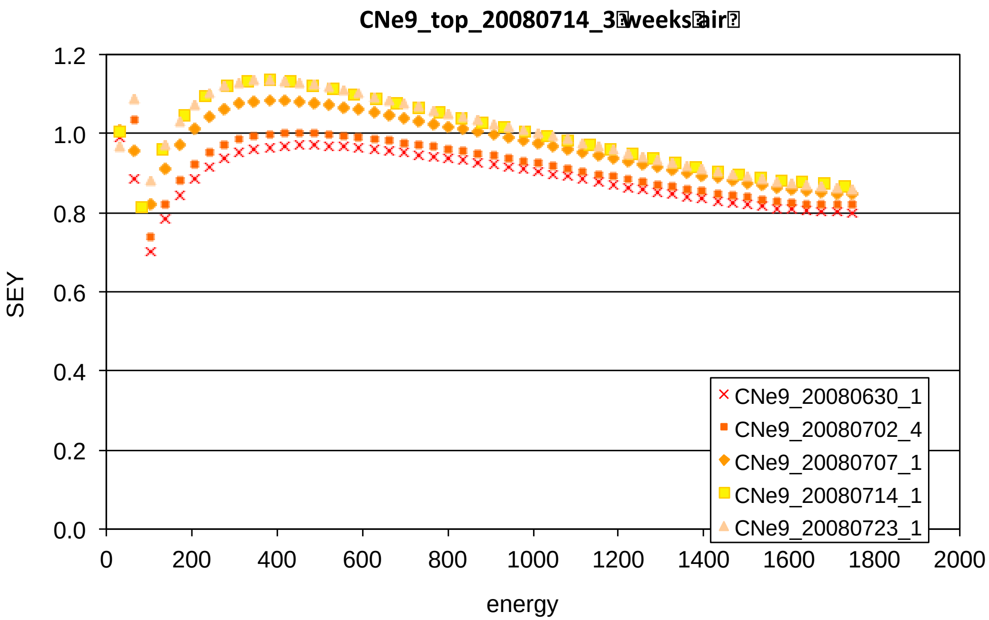




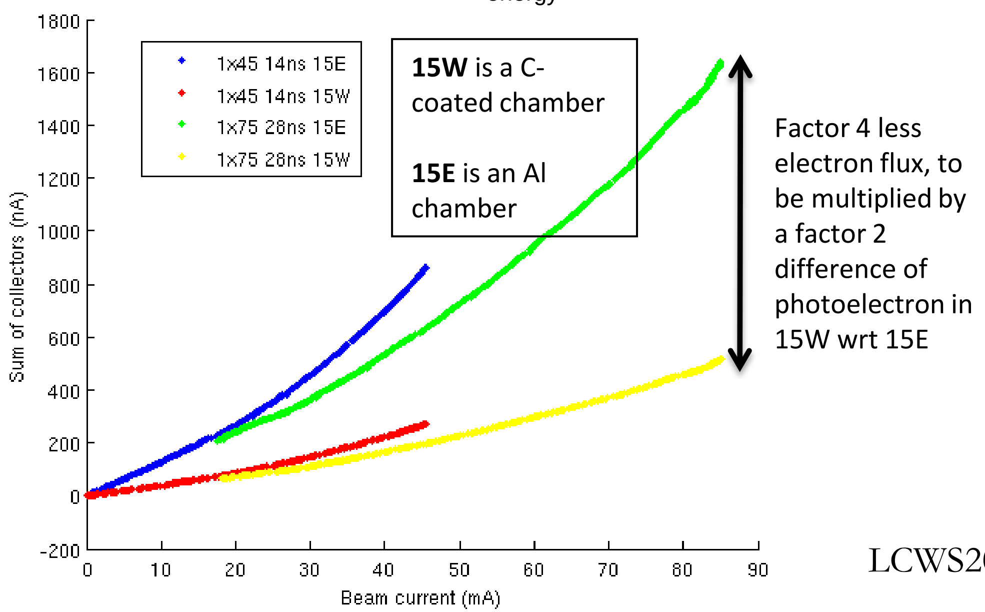
- Two paths of R&D
  - NbTi wire, horizontal racetrack, conduction cooled (BINP/KIT collaboration)
  - Nb_3Sn wire, vertical racetrack, conduction cooled (CERN)
- Full NbTi length prototype
  - Higher than 3T, 5.1cm period, magnetic gap of 18mm
  - Under production by BINP to be installed in 2014 in ANKA for beam tests
  - Operational performance, field quality, cooling concept
- First vertical racetrack magnet (3-period) tested in 2011
  - Reached 75% of max. current
  - Limited by short coil-to-structure
  - Still higher than NbTi (900 A vs. 700 A)

Vacuum technology

S. Calatroni, M.Palmer, G. Rumolo, M. Taboreli et al.



- Amorphous-C coating shows maximum SEY starting from below 1 and gradually growing to slightly more than 1.1 after 23 days of air exposure
  - Peak of the SEY moves to lower energy
- Experimental tests
  - Huge amount of data at SPS
  - Run with 5 GeV positrons at CESRTA, for different intensities and bunch spacings
  - The total electron current reduced significantly (1 order of magnitude) as compared to Al
  - Continuing collaboration with test facilites for PEY tests in a dedicated beamline



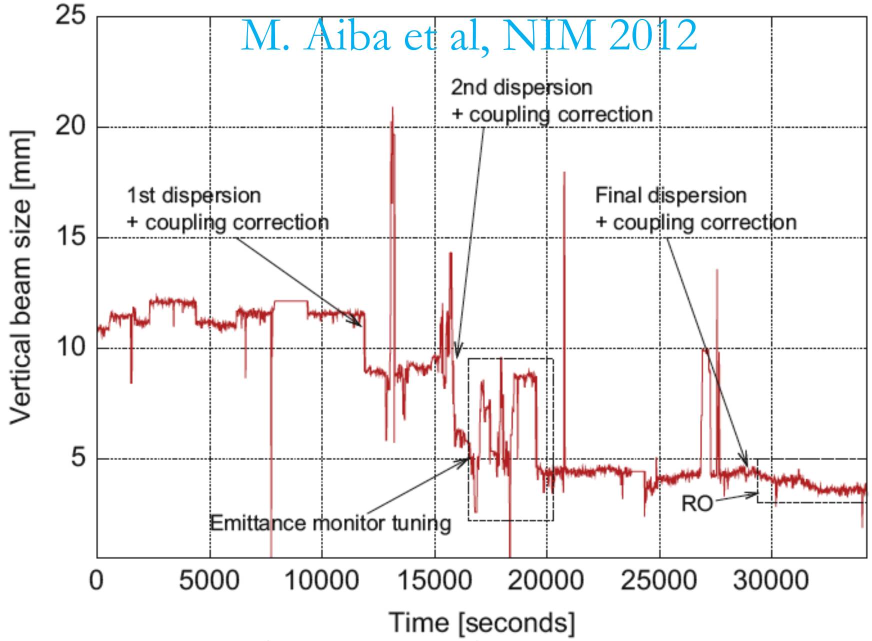
A. Grudiev

RF system

- Single train of 312 bunches spaced at 0.5ns necessitates 2GHz system
  - R&D needed for power source
  - Large average and peak current/power introduces important transient beam loading
- Considered 1GHz system
  - Straight-forward RF design but train recombination in a delay loop is needed
- Need collaborators for taking over full design and experimental tests

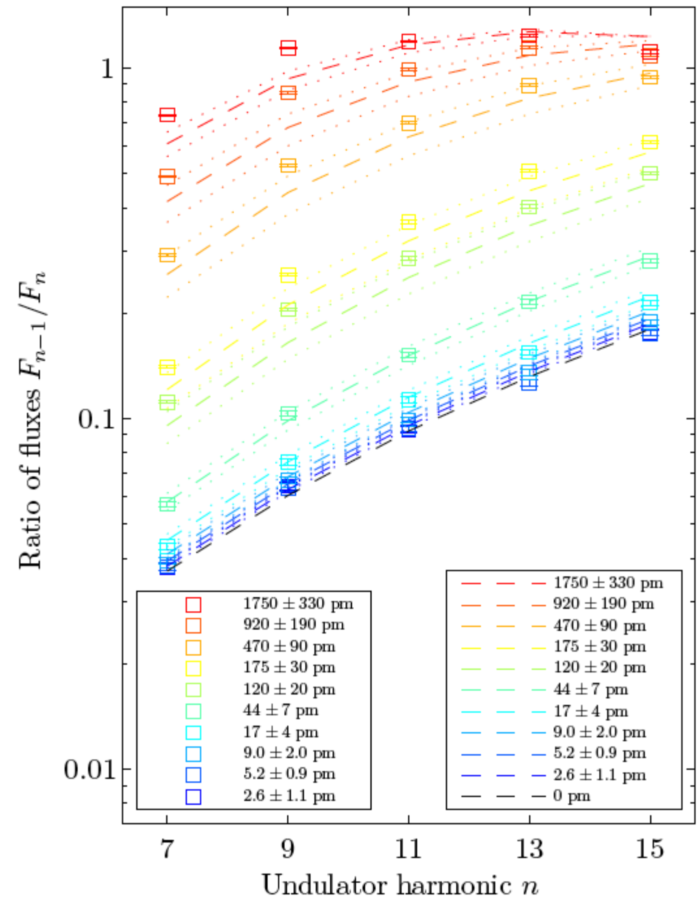
RF design concepts	1 GHz	2 GHz **no train interleaving after DR**
Classical RF system based on the NC ARES-type cavities	Baseline P_{RF} = 3.8 MW; L = 32 m; Cavity design: OK	Alternative 2.0 P_{RF} = 5.9 MW; L = 48 m; Cavity design: ok?
Classical RF system based on the SCC cavities	Alternative 1.1 P_{RF} = **0.6** MW; L = 108 m; Cavity design: **ok?**	Alternative 2.1 P_{RF} = **0.6** MW; L = **800** m; Cavity design: **NOT OK**
RF system with RF frequency mismatch	Alternative 1.2 P_{RF} = **1.3** MW; L = **16** m; Cavity design: **OK**	Alternative 2.2 P_{RF} = 2.1 MW; L = 24 m; Cavity design: OK
"A-la-linac" RF system with strong input power modulations	Alternative 1.3 P_{RF} = 3.3 MW; L = **8** m; Cavity design: **OK**	Alternative 2.3 P_{RF} = 5.8 MW; L = **12** m; Cavity design: **OK**

Reaching Quantum L_{imit} O_f $V_{ertical}$ $E_{mittance}$



- Tousheck lifetime vs. RF voltage in ASLS points to ε_y = 0.5pm!!!
  - New technique for resolving ultra-low beam sizes using vertical undulator

K. Wootton, et al, PRL, accepted



- EU collaboration between PSI-SLS (Maxlab), INFN-LNF and CERN (TIARA-SVET) for low emittance tuning techniques and instrumentation
  - SLS achieved ε_y record of 0.9 ± 0.4pm (confirmed with different techniques)
  - New emittance monitor for resolutions below 3µm (vertical polarized light) under installation for measurements in 2013

DR technology and experimental program

- **Super-conducting wigglers**
  - Demanding magnet technology combined with cryogenics and high heat load from synchrotron radiation (absorption)
- **High frequency RF system**
  - 1-2GHz RF system in combination with high power and transient beam loading
- **Coatings, chamber design and ultra-low vacuum**
  - Electron cloud mitigation, low-impedance, fast-ion instability
- **Kicker technology**
  - Extracted beam stability
- **Diagnostics for low emittance**
  - Profile monitors, feedback

- Experimental program set-up for measurements in storage rings and test facilities
  - ALBA (Spain), ANKA (Germany), ATF (Japan), Australia Synchrotron (Australia), CESRTA (USA), SOLEIL (France),…
- Ideas for a DR test facility within a future LC test facility

Low Emittance Rings' Collaboration

- Initiated by the ILC-CLIC working group on damping rings and catalyzed by the organization of two workshops (01/2010 @ CERN, 10/2011 @ Heraklion)
  - Common beam dynamics and technology items for synchrotron light sources, linear collider damping rings, b-factories
- Formed a EU network within EUCARD2
  - Coordinated by EU labs
  - Extended collaboration board including colleagues from US and Japan
  - 30 participating institutes world wide
  - First network workshop with 80-participants on 07/2013 at Oxford
- Next collective effects workshop on 01/2014 at SOLEIL