Low Emittance Rings - report from WP6

Y. Papaphilippou, CERN,

R. Bartolini, Un. Oxford - DIAMOND, S. Guiduci, INFN-LNF

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

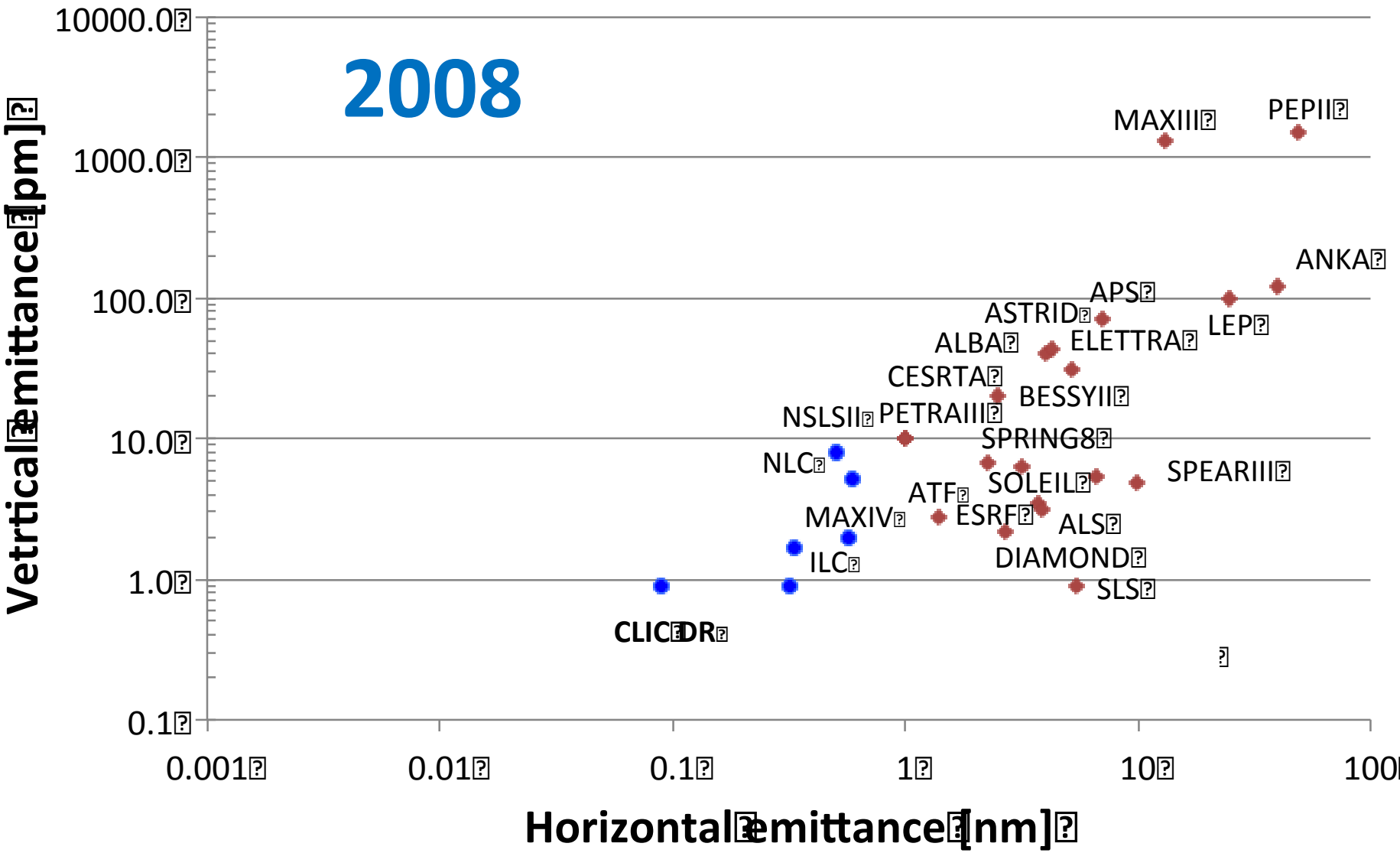
WP6 - Low Emittance Rings: scope and background

- Bring together scientific communities of **synchrotron light sources' storage rings, damping rings** and **e+/e- ring colliders** in order to communicate, identify and promote common work on topics affecting the design of **low emittance electron and positron rings**

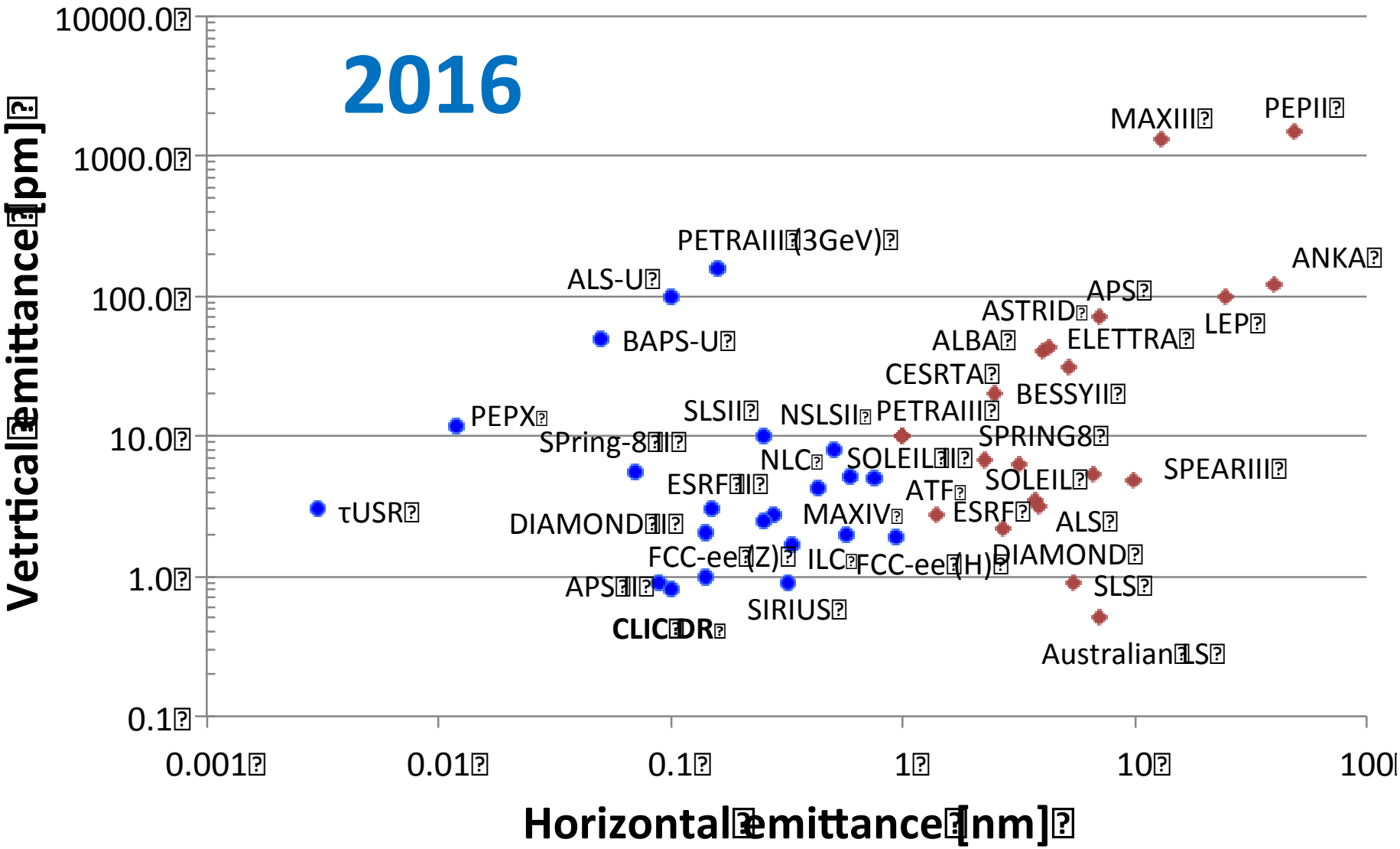
- Initiated by the CLIC-ILC collaboration working group on damping rings…
- ...and overtaken by the light source community towards diffraction limited storage rings

- State of the art in design of accelerator systems especially in **X-ray storage rings** approaches the **goals of damping rings** for linear colliders and **future e+/e- ring collider** projects

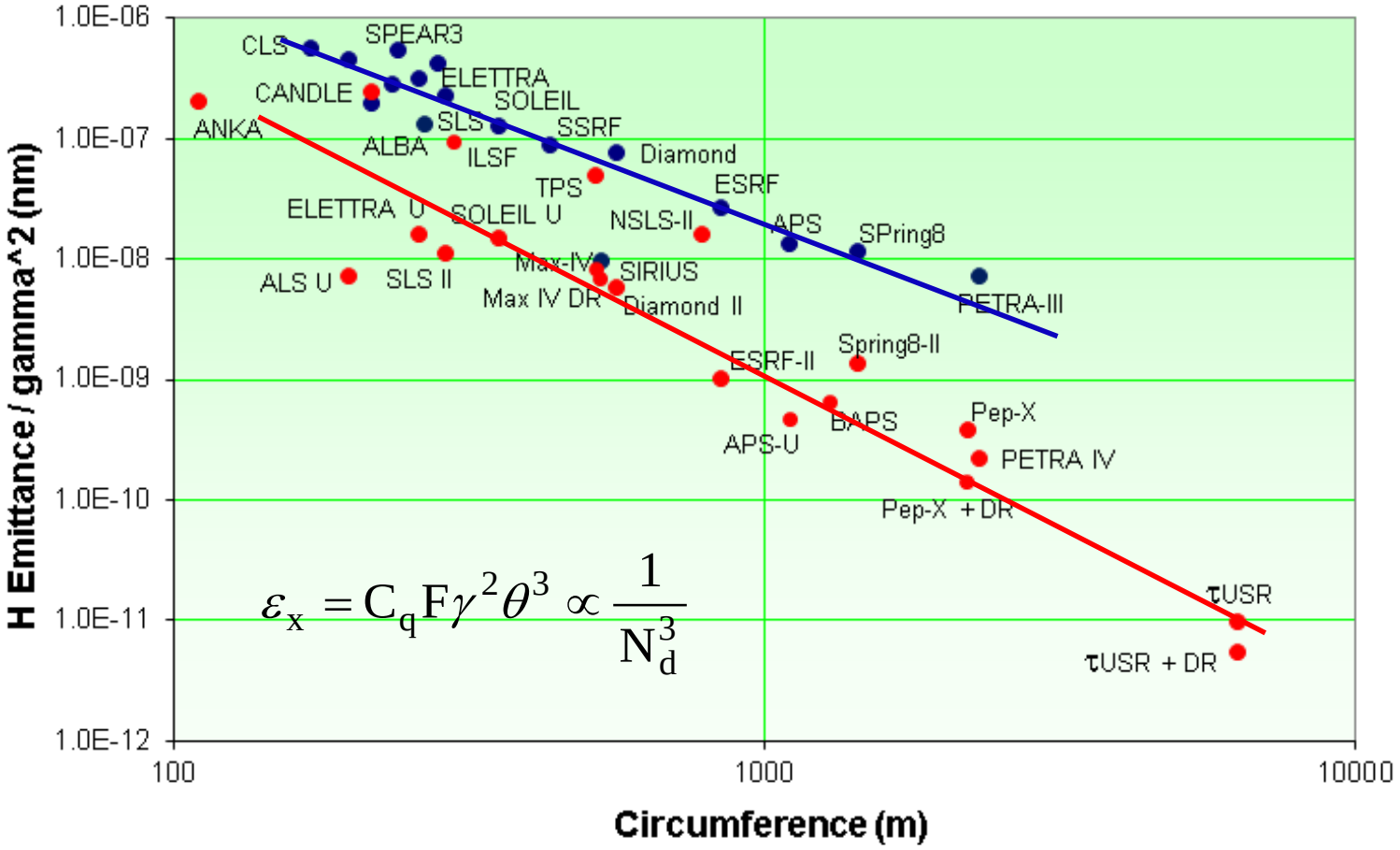
Emittance targets



Emittance targets



Survey of low emittance rings



Objectives and Results

- Coordinators:
  - R. Bartolini (UOXF)
  - S. Guiducci (INFN-LNF)
  - Y. Papaphilippou (CERN)

  } Each one representing community of X-ray storage rings of e+/e- colliders and damping rings

- Form a **coordination board**, representing the Low Emittance Rings community (including non-EU members)
  - B. Hettel (SLAC)
  - Q. Qin (IHEP)
  - D. Rubin (Cornell)
  - J. Urakawa (KEK)

  } Representing "Ultimate-storage ring" community and damping ring test facilities

  - Task coordinators: M. Böge (PSI), R. Nagaoka (Soleil), H. Schmickler (CERN)
- Organize Low Emittance Rings' general and topical workshops

WP6 present status

Workshops (milestones):

2013 July – 1st general Workshop - Oxford 81 participants
2014 January – Collective effects (TWIICE) – Paris 75 participants
2014 May – Technology (ALERT) – Valencia 52 participants
2014 September – 2nd general Workshop – Frascati 78 participants
2015 April – Low emittance ring design – Barcelona – 50 participants
2015 September– 3rd general Workshop – Grenoble 67 participants
2016 February – Collective effects (TWIICE-II) – Oxford 59 participants
2016 September – Technology (ALERT) – Trieste
2016 October – 4th general Workshop – Paris
TBD – Low emittance ring design – TBD

Deliverables:

EuCARD2- DEL – D6.1: Low emittance ring design - interim report
EuCARD2- DEL – D6.2: Instabilities, impedance, collective effects - interim report
EuCARD2- DEL – D6.3: Low emittance ring technology - interim report

6.2. Low Emittance Ring Design (LERD)
Objectives and Results

Enable evaluation of methods, approaches and numerical tools for designing ultra-low emittance optics

Integrate studies and measurements of sub-picometer vertical emittances with high-intensity beams

LOWεRing design (task 6.2)

Issues and topics related to Task 6.2 discussed so far in the general meetings

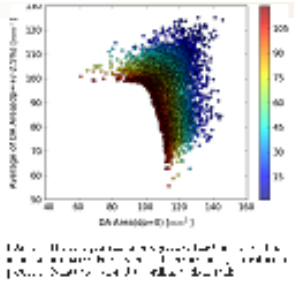
Topical workshop organised by PSI/ALBA

April 2015

Optimisation of beam dynamics

EuCARD²

AT mini workshop during 3rd general LOW-ε-RING workshop



Symplectic Tracking based methods

DA, MA separated

DA, MA together

SOLEIL SYNCHROTRON

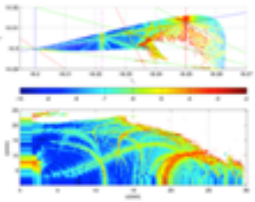
from L. Nadolski, ICFA LowEring, Oxford 7/13

Direct tracking based optimization

GLASS

Analytical based method

Genetic Algorithm MOGA



Lie Algebra/Differential Algebra

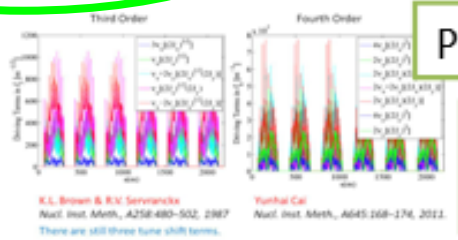
Resonance Driving Terms RDT minimization

Amplitude Tuneshift minimization

Frequency Maps FMA Diffusion factor

Nonlinear "LOCO"

Canceling Sextupole Resonances



Phase advances

Interleaved sextupoles

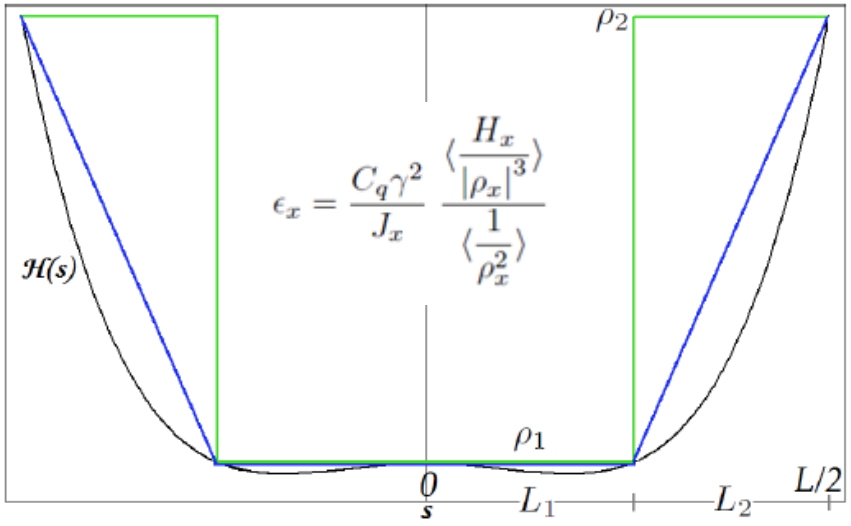
Resonance identification

Robustness to magnetic, alignment errors

Robustness ID configurations

Tracking codes: PTC MADX TRACY AT LEGO OPA ELEGANT

Longitudinally variable bends[1]



$$\rho_{st}(s) = \begin{cases} \rho_1, & 0 < s < L_1 \\ \rho_2, & L_1 < s < L_1 + L_2 \end{cases}$$

$$\rho_{tr}(s) = \begin{cases} \rho_1, & 0 < s < L_1 \\ \rho_1 + \dfrac{(L_1 - s)(\rho_1 - \rho_2)}{L_2}, & L_1 < s < L_1 + L_2 \end{cases}$$

Bending radii ratio

$$\rho = \frac{\rho_1}{\rho_2}$$

Lengths ratio

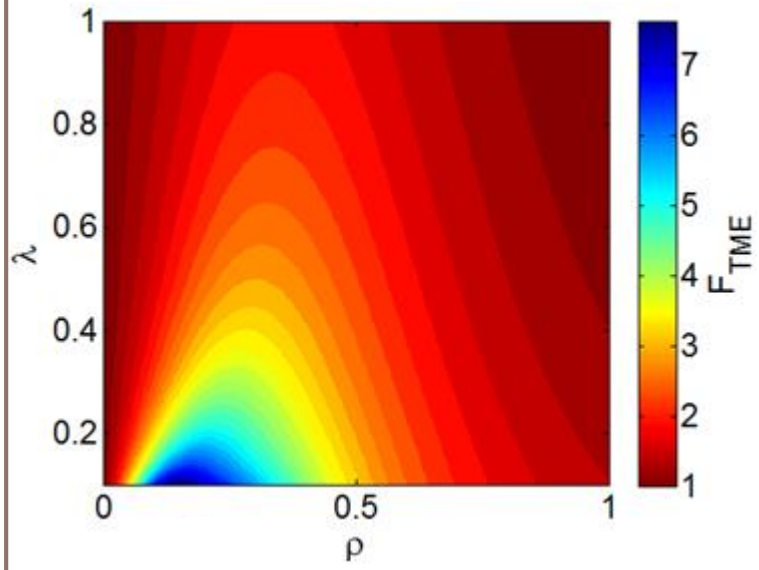
$$\lambda = \frac{L_1}{L_2}$$

Emittance reduction factor

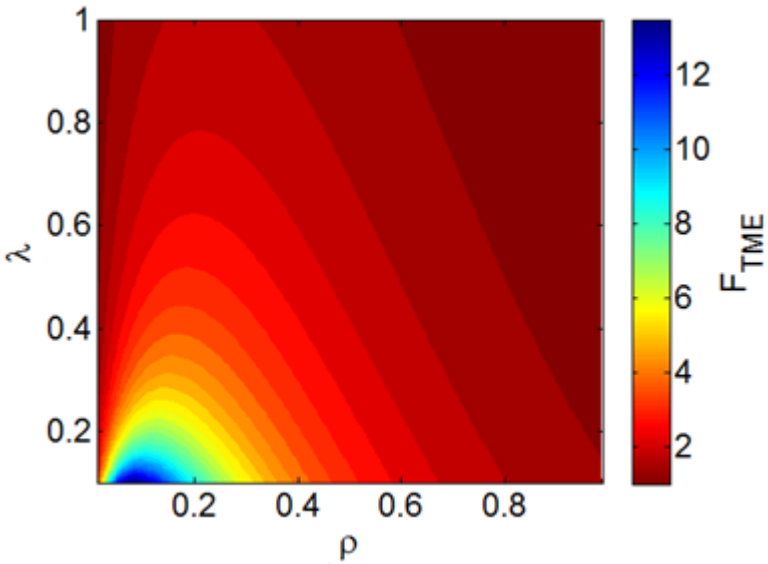
$$F_{TME} = \frac{\epsilon_{TME_{uni}}}{\epsilon_{TME_{var}}}$$

$$F_{TME} > 1$$

Step profile

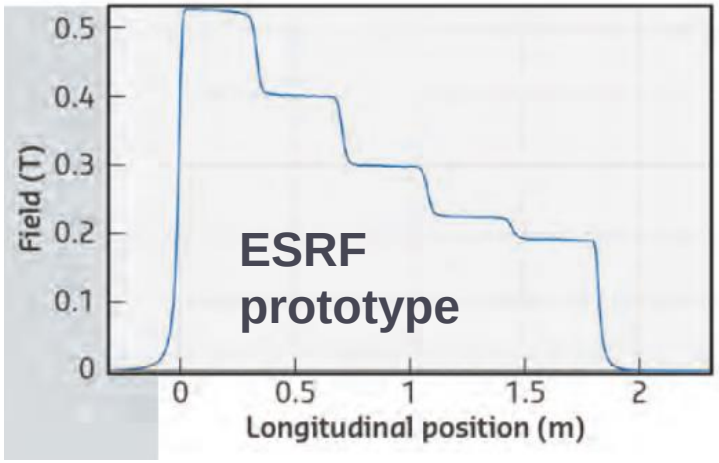


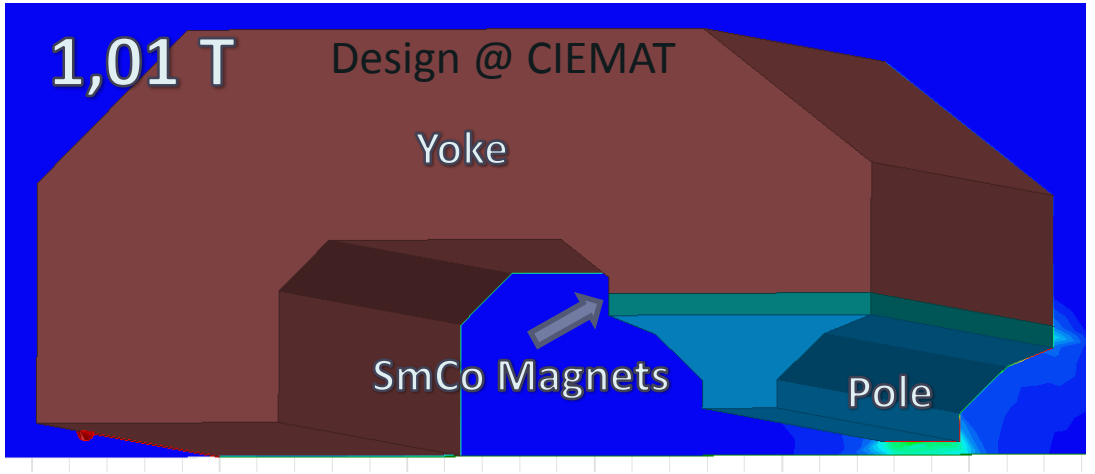
Trapezium profile

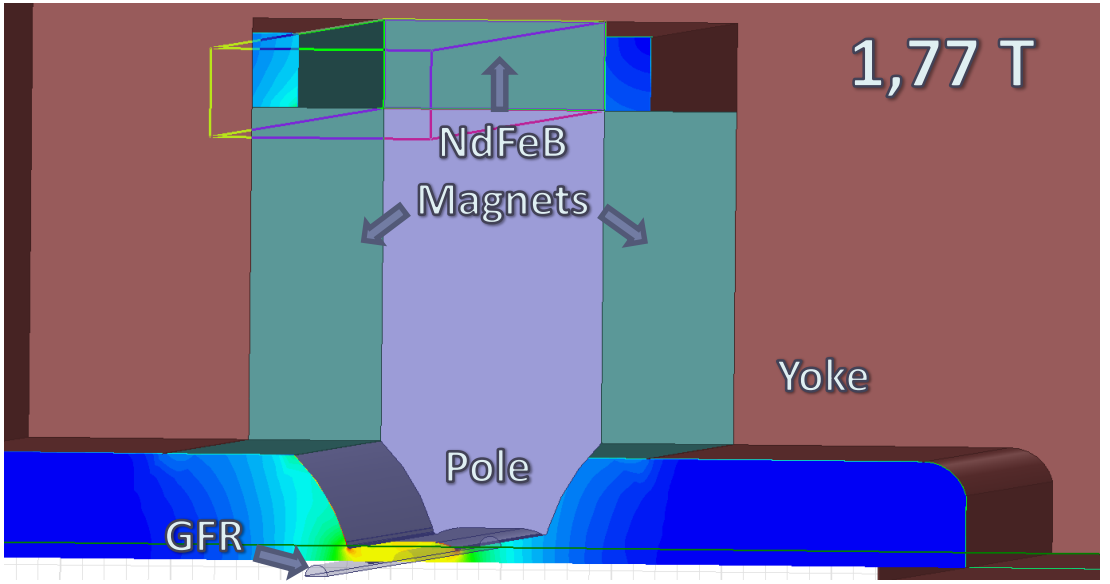


The parameterization of the emittance reduction factor F_{TME} with the bending radii ratio ρ and the lengths ratio λ, always for λ>0.1.

Gradient Dipoles for ESRF and CLIC DR







Experimental control of beam optics

- Excellent control of the electron optics proven at many light sources

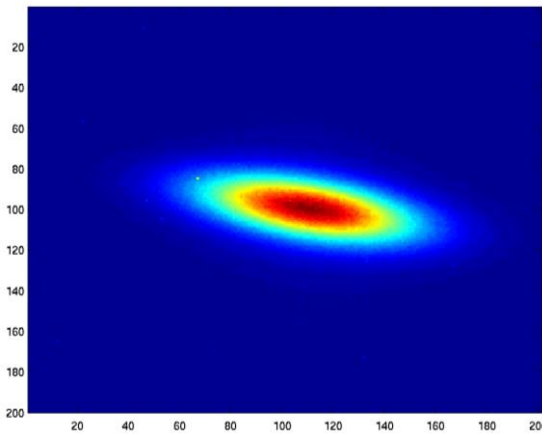
  Proven correction strategies

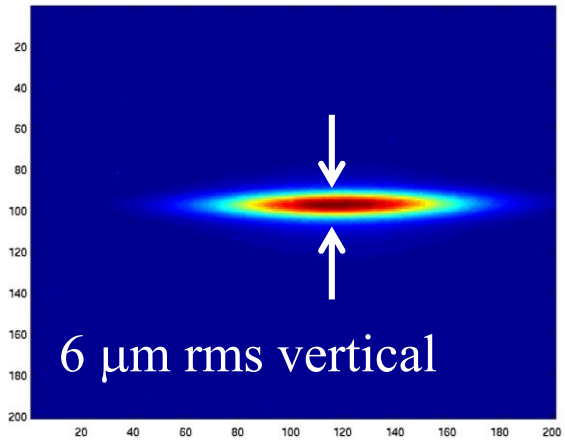
  beam based tuning techniques

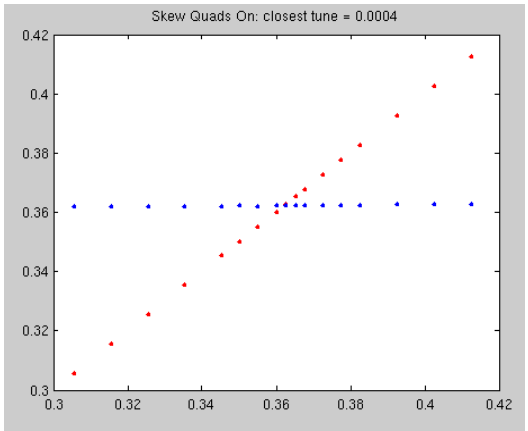
  (better instrumentation: diagnostics, power supplies, …)

e.g. Diamond operates with a very good control of the beam optics

- Optics deviation **(beta-beating) reduced to 1% level** with **LOCO and equivalent ORM based** methods
- Emittance [2.78 - 2.74] (2.75) nm
- Energy spread [1.1e-3 - 1.0-e3] (1.0e-3)
- Emittance coupling ~0.08% achieved → vertical emittance ~ 2.0 pm (2009 WR)

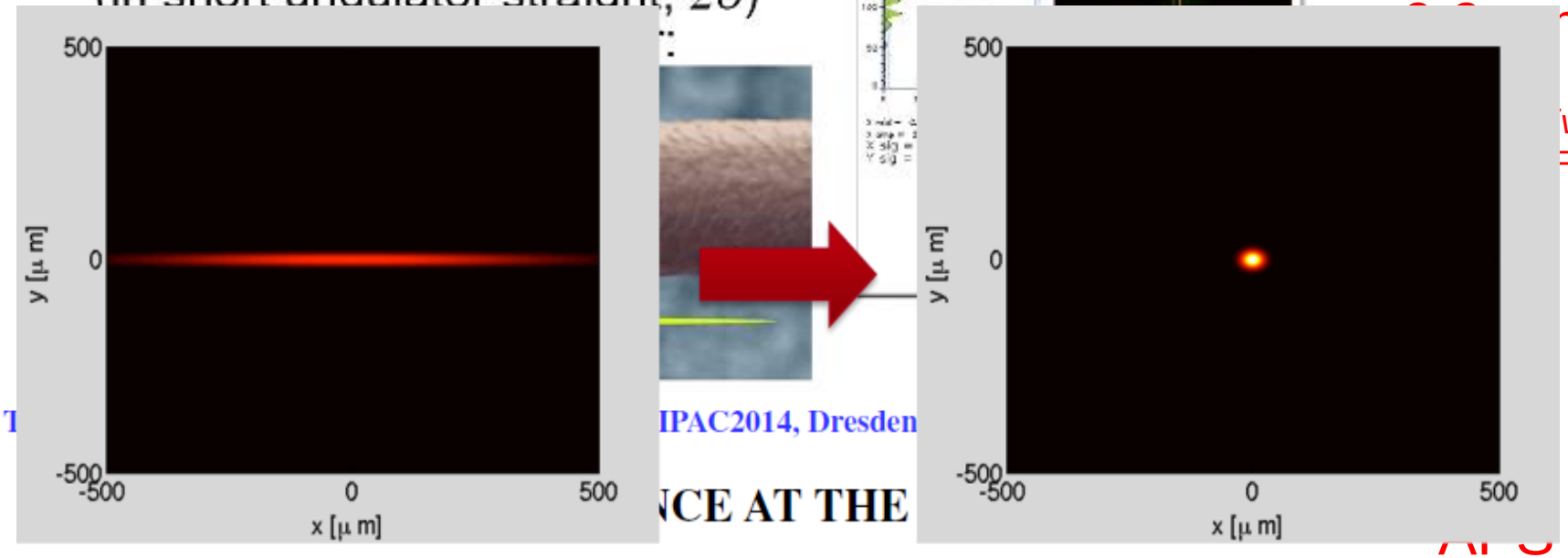






Experimental control of beam optics

- Beam size 3.6 ± 0.6 μm
- Emittance 0.9 ± 0.4 pm
- SLS beam cross section (in short undulator straight, 2σ)



SLS

0.35 pm

IPAC2014, Dresden

R. Dowd, Y-R. E. Tan, Australian Synchrotron, Clayton, Australia
K. P. Wootton, University of Melbourne, Parkville, Australia

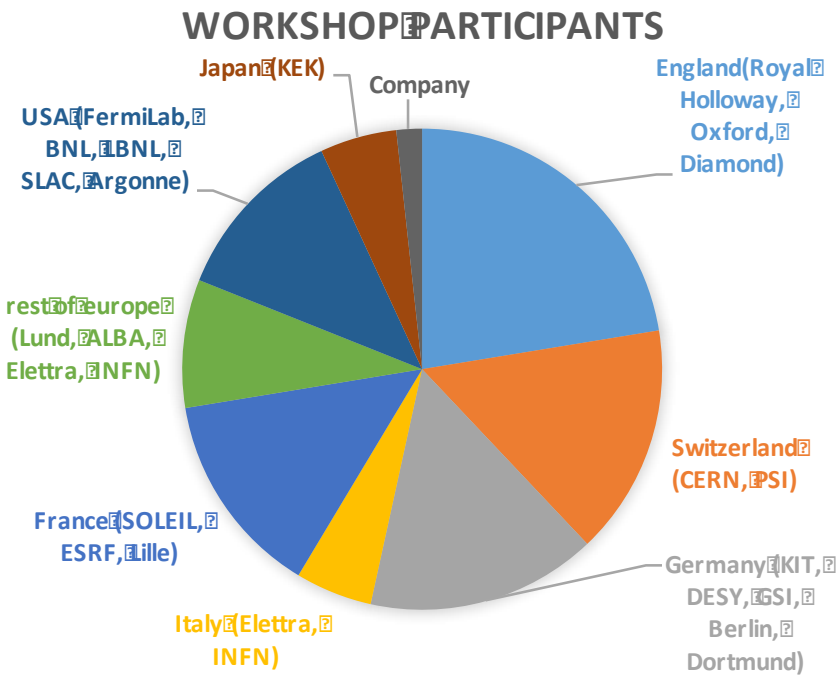
Running for the "Quantum LOVE prize" at the next topical/general workshop

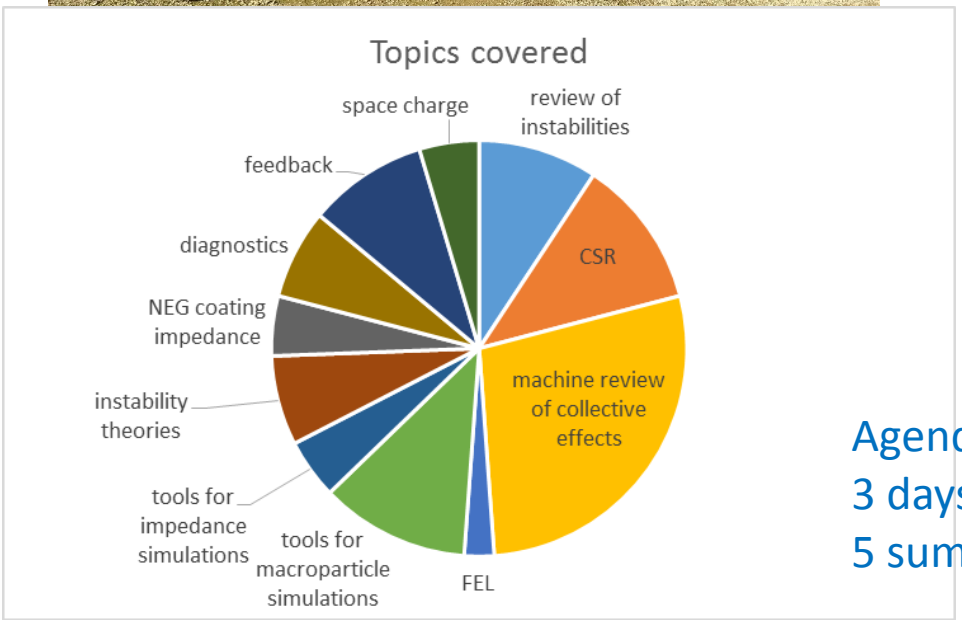
6.3. Instabilities, Impedances and Collective Effects (IICE)
Objectives and Results

- Focus on methods to evaluate impact of impedances and instabilities in LER
- Promote methods to estimate impact of two-stream instabilities and techniques to cure them
- Enable Intrabeam Scattering community to improve theory and simulations through experimentation
- Provide a forum to help achieve Coherent Synchrotron Radiation, avoiding micro-bunching instabilities

Topics/Issus in collective effects (task 6.3)

2nd Topical Workshop on Instabilities, Impedance and Collective Effects (TWIICE -II) organized at Oxford:





Agenda in https://indico.cern.ch/event/459623/

3 days, 61 delegates, 41 talks + 2 introductions and 5 summaries

Topics/Issus in collective effects (task 6.3)

2nd Topical Workshop on Instabilities, Impedance and Collective Effects (TWIICE -II) organized at Oxford:

A large number of contributions went **beyond** the strict problematic of low emittance rings

- Intense effort in all machines to identify **impedance sources**, minimize them and build an impedance model
- **Benchmark codes** with measurements of beam observables (collaboration among different laboratories)

6.4. Low Emittance Rings Technology (LERT)
Objectives and Results

Promote interactions concerning insertion devices, magnets and alignment in low emittance rings
Establish contacts within low emittance rings diagnostics specialists for common studies
Exchange experiences of low impedance strip-line kickers and high voltage pulsers
Coordinate design efforts and experimental tests in RF cavity design for various bunch structures

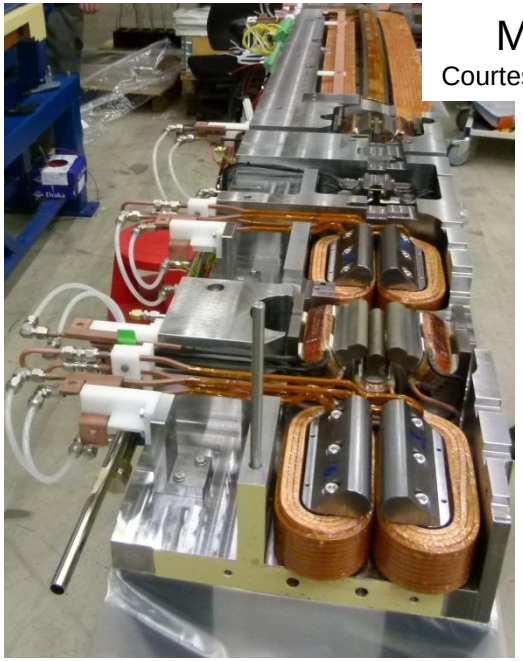
- Key enabling technologies appears to be mature

Vacuum (task 6.4)

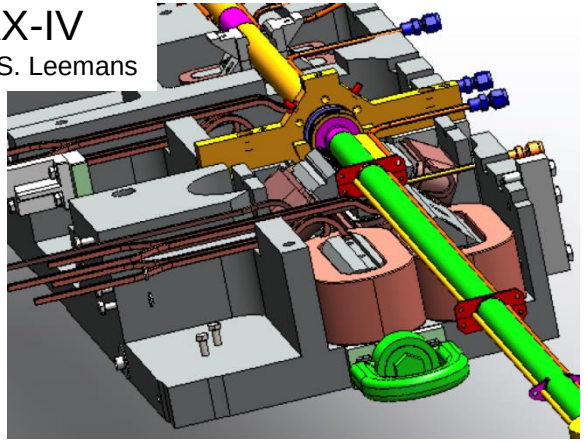
Vacuum technology

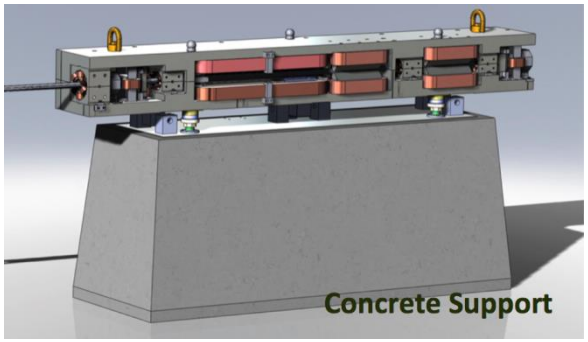
- NEG-coated vacuum chambers enable small apertures to enable high magnet gradients

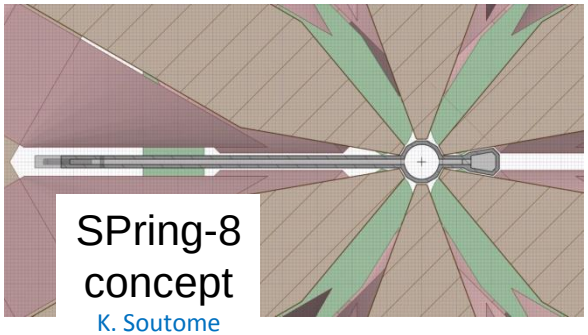
  Pioneered at CERN, used extensively at Soleil, and adopted for MAX-IV and Sirius MBA lattices



MAX-IV
Courtesy S. Leemans







SPring-8
concept
K. Soutome

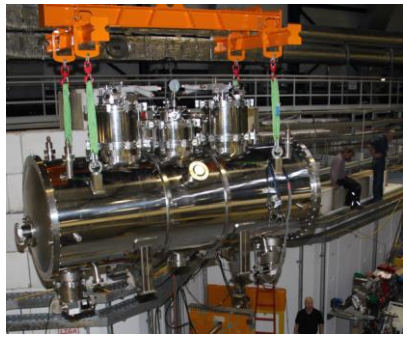
Not all designs have adopted a full neg-coated chamber approach

Collaboration between colliders and light sources

- High-field (~3T), low period (~5cm) **super-conducting** NbTi **damping wiggler** (BINP-KIT/ANKA –CERN)
  - Prototype under commissioning at ANKA SR for heat-load (cooling concept) and beam dynamics measurements
  - Ultimately serve the SR user community
- Low-impedance, stringent field homogeneity **stripline kicker** and ultra-stable **pulser**
  - Stripline produced by Spanish industry, under laboratory tests at CERN, to be measured with beam at ALBA SR
  - Inductive adder achieving pulse jitter tolerances ~5.10^{-4} to be tested with the prototype stripline and beam (ALBA, ATF DR)
- Correction **methods** and beam **instrumentation** for achieving and measuring **ultra-low emittances** (beam size of ~1µm)
  - Novel measuement methods using vertical undulator at the Australian Light Source (reaching the **quantum limit** of vertical emittance ~0.4pm.rad)

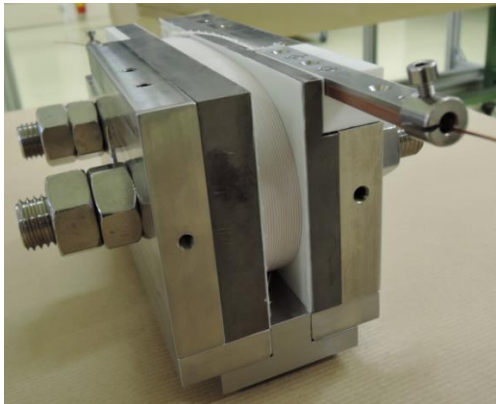
Prototype inductive adder

NbTi wiggler lowered in the ANKA SR



Stripline licker laboratory tests

Nb_3Sn short model winding



Enabling technologies (task 6.4)

Advanced Low Emittance Rings Technology (ALERT) 2016 Workshop

14-16 September 2016
Trieste, Italy
Europe/Rome timezone

- Overview
- Scientific Programme
- Timetable
- Contribution List
- Registration
- Participant List
- Venue
- Accommodation

Trieste | 14-16 September 2016

A workshop on Advanced Low Emittance Rings Technology (ALERT 2016) is organized by ELETTRA on the 14th and 16th of September 2016, as a series of the Low Emittance Rings (LOWεRING) Workshops, supported by the EUCARD2 project.

This will be the 2nd workshop on Low Emittance Rings technology after the one organized in the 2014 in Valencia.

The state of the art in the design of accelerator systems in light source storage rings has today many challenges and issues in common with those of linear collider damping rings and future e+/e- circular

- Next topical workshop scheduled for September 2016 in Trieste
- Organising session involving industry in collaboration with WP2

EuCARD² Student prize

- Sponsor trip to a major accelerator conference for presenting work related to low emittance rings
- Selection procedure:
  - Poster presentations in general Low-ε-ring workshops
- And the first three winners are…
  - LOWERING2013 workshop: **Eirini Koukovini Platia** (CERN/EPFL), **Simone Liuzzo** (ESRF/Un. Of Rome)
  - LOWERING2014 workshop: **Tobias Goetsch** (HZ Berlin)
  - LOWERING2015 workshop: **Panos Zisopoulos** (CERN) and **Stefania Papadopoulou** (CERN)





Deliverables

- One interim per task (all achieved on M18 or 19)

Delive-rable Number [61]	Deliverable Title	Lead benefi-ciary number	Estimated indicative person-months	Nature [62]	Dissemi-nation level [63]	Delivery date [64]
D6.1	Low Emittance Ring Design interim report	19	2.00	R	PU	18
D6.2	Instabilities, Impedances and Collective Effects interim report	9	2.00	R	PU	18
D6.3	Low Emittance Ring Technology interim report	1	2.00	R	PU	18

Future Deliverables

- One final report per task (all in year 4)

Delive-rable Number [61]	Deliverable Title	Lead benefi-ciary number	Estimated indicative person-months	Nature [62]	Dissemi-nation level [63]	Delivery date [64]
D6.4	Low Emittance Ring Design final report	30	3.00	R	PU	46
D6.5	Instabilities, Impedances and Collective Effects final report	9	3.00	R	PU	46
D6.6	Low Emittance Ring Technology final report	1	3.00	R	PU	46

Milestones

- 3 topical and 3 general workshops (dates had to be slightly advanced-delayed)
- A 4th workshop will be also organized by the network

Milestone number [59]	Milestone name	Lead benefi-ciary number	Delivery date from Annex I [60]	Achieved month
MS41	First workshop of Collective effects in Low Emittance Rings	9	6	12
MS42	First workshop of Low Emittance Rings Technology	1	9	15
MS43	Annual LOW-e-RING workshop, first year	40	12	6
MS44	First workshop of Low Emittance lattice design	30	18	24
MS45	Annual LOW-e-RING workshop, second year.	40	24	18
MS46	Second workshop of Collective effects in Low Emittance Rings	9	30	imminent
MS48	Annual LOW-e-RING workshop, third year.	40	36	36

Future Milestones

- 2 topical ones remaining (initially in year 3 but delayed to year 4)
- An additional general workshop decided
  - 26th to the 28th October 2016, SOLEIL, Paris

Milestone number [59]	Milestone name	Lead benefi-ciary number	Delivery date from Annex I [60]	Achieved month
MS47	Second workshop of Low Emittance Rings Technology	1	33	41
MS49	Second workshop of Low Emittance lattice design	30	36	45

SAC recommendation and reply

- "Today, almost all synchrotron light sources are pursuing low emittance efforts. MAX-IV (near to commissioning) and ESRF (constructing an upgrade) will be real tests of low emittance advances. We recommend that WP6 members consider participating in these"

- Reply: Already several colleagues have participated to the commissioning of MAXIV (especially from SOLEIL). We foresee to strongly support this, also in the future.

Conclusion

The LOWεRING community sponsored by EuCARD2 is playing a **leadership** role in fostering the world-wide development of low emittance rings

- ICFA Low Emittance Rings Workshops (LowERing, 2010, 2011)
- XDL 2011 Workshops for ERLs and DLSRs, Cornell, June 2011
- Beijing USR Workshop, Huairou, October 2012
- DLSR Workshop, SPring-8, December 2012
- Low Emittance Ring Workshop, Oxford, July 2013
- SLAC DLSR Workshop, SLAC, December 2013
- Workshop on collective effects (TWIICE), Paris, 2014
- Workshop on Low Emittance Rings Technology (ALERT), Valencia, 2014
- Low Emittance Rings Workshop (LowERing2014), Frascati, September 2014
- DLSR Workshop, Argonne, November 2014
- Workshop on Low emittance ring design, Barcelona, April 2015
- Low Emittance Rings Workshop (LowERing2015), Grenoble, September 2015
- 2nd Workshop on Instabilities, Impedance and Collective Effects (TWIICE -II), Oxford, February 2016

EuCARD²

ARIES

RUL

Rings with Ultra-Low Emittance

THANK YOU for your attention