Low emittance rings challenges

Y. Papaphilippou, CERN

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Low emittance rings performance

Colliders (and their injectors)

- Luminosity or brightness

$$\mathcal{L} = \frac{N_1 N_2 f n_b}{4\pi\sigma_x\sigma_y}$$

X-ray storage rings

- Photon brilliance

$$B = \frac{N_p}{4\pi^2 \bar{\epsilon}_x \bar{\epsilon}_y}$$

- Extreme intensity within ultra-low beam dimensions
  - Lattice design, Collective effects, Associated technology

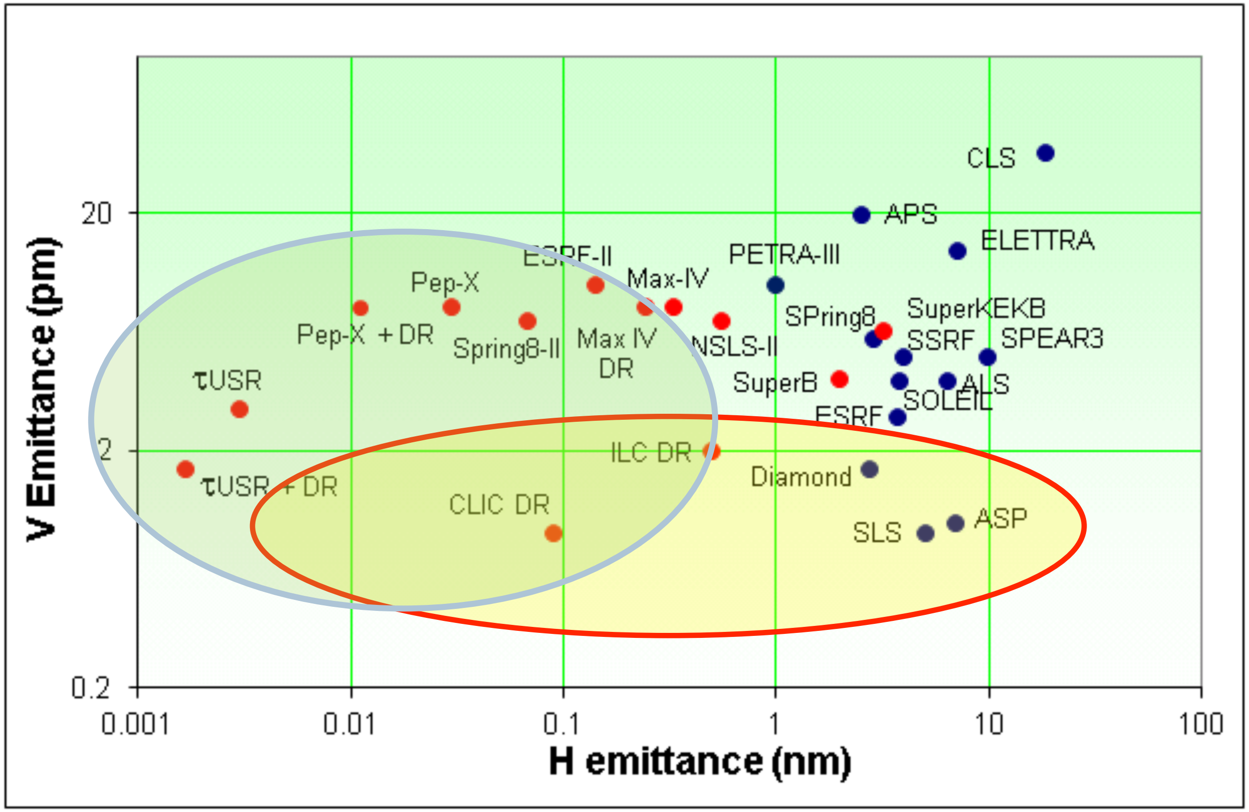
Motivation

$$\varepsilon < \frac{\lambda}{4\pi}$$

- Light sources
  - Diffraction limited operation at 0.1nm requires ~10 pm
- Colliders (e.g B-factories)
  - 10^{36} cm^{-2} s^{-1} requires a few nm as present state-of-the-art light sources
  - Low vertical emittance still a challenge for extreme currents
- Damping rings
  - 500 pm H and 2 pm V (specs for ILC-DR)
  - <100 pm H and 5 pm V (specs for CLIC-DR)

Emittance in X-ray SR, DR and e^+/e^- colliders

Courtesy R. Bartolini



~ 2013

$$\text{brilliance} = \frac{\text{flux}}{4\pi^2 \Sigma_x \Sigma_{x'} \Sigma_y \Sigma_{y'}}$$

$$\Sigma_x = \sqrt{\sigma_{x,e}^2 + \sigma_{ph}^2}$$

$$\Sigma_{x'} = \sqrt{\sigma_{x',e}^2 + \sigma'^2_{ph}}$$

$$\sigma_x = \sqrt{\varepsilon_x \beta_x + (D_x \sigma_\varepsilon)^2}$$

$$\sigma_{x'} = \sqrt{\varepsilon_x \gamma_x + (D'_x \sigma_\varepsilon)^2}$$

$$\sigma_{ph} = \frac{\sqrt{\lambda L_u}}{4\pi}$$

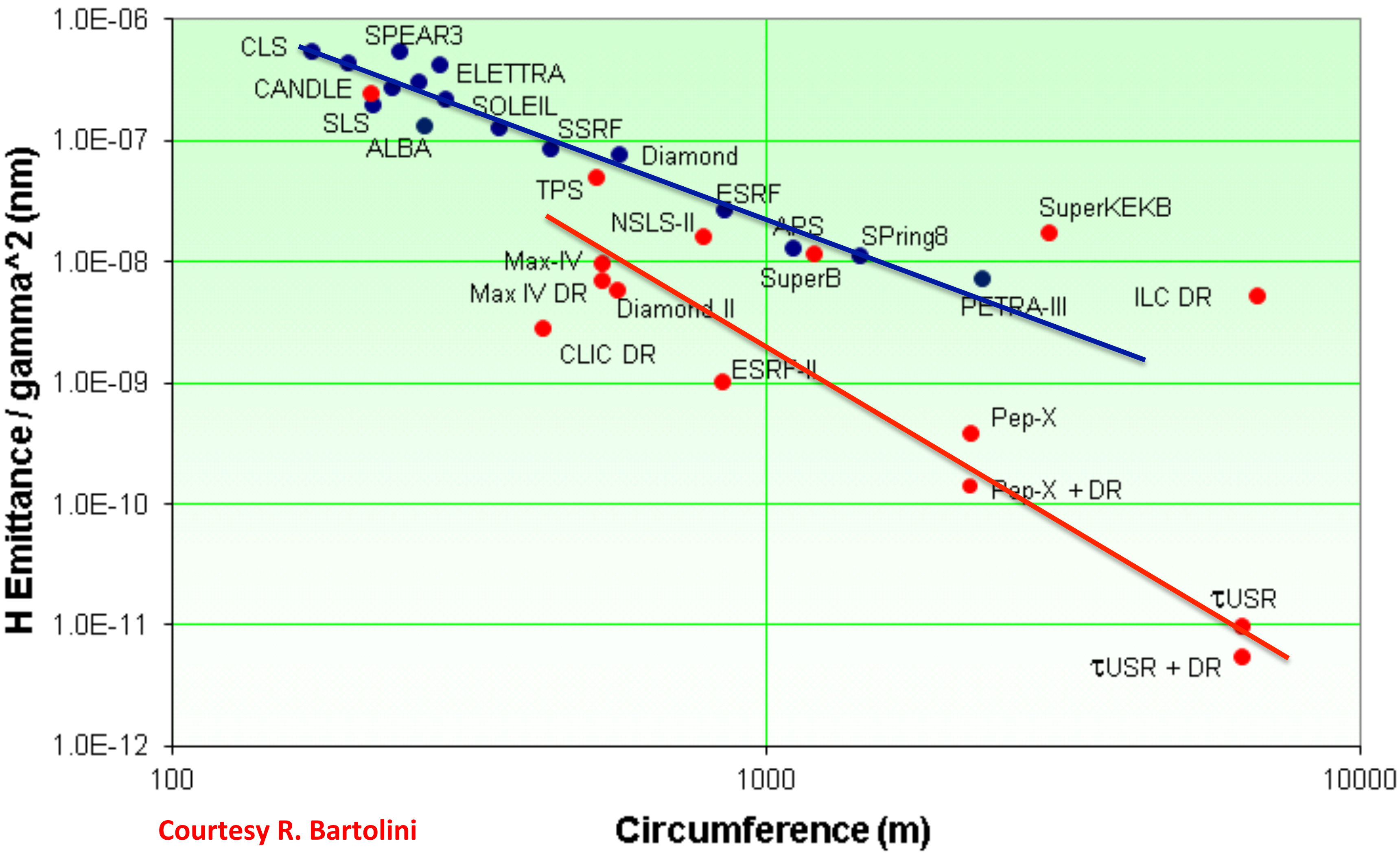
$$\sigma'_{ph} = \sqrt{\frac{\lambda}{L_u}}$$

$$\varepsilon \leq \frac{\lambda}{4\pi}$$

Transverse coherence requires small emittance

Diffraction limit at 0.1 nm requires 8 pm

Present and **Future** Low Emittance Rings

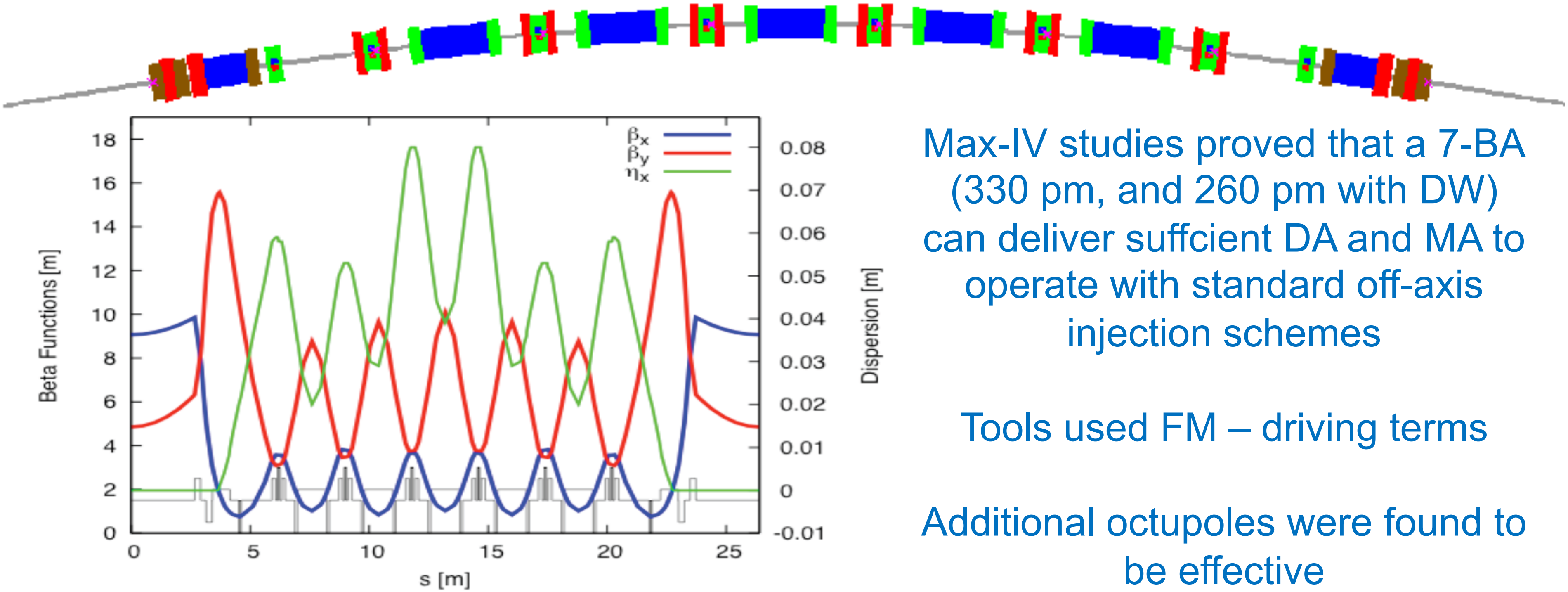


Courtesy R. Bartolini

Low-ε-Ring Lattice Design challenges

- Optics Design of Low Emittance Rings
  - Optics design of multi-bend achromats in conjunction with damping wigglers with large dynamic aperture
  - Use of fancy magnets for reducing emittance (longitudinally variable bends, Robinson wigglers, …)
  - Alternative injection schemes (non-linear pulsed kicker, swap-out injection,…)
  - Design of low momentum compaction factor optics for bunch length reduction and production of coherent synchrotron radiation
  - Reduction of collective effects through optics design
  - Numerical tools (GLASS, multi-objective algorithms) and experimental techniques for linear and non-linear dynamics optimization
- Minimization of Vertical Emittance
  - Obtain ultra-low vertical emittance in high intensity beam conditions (betatron coupling and vertical dispersion)
  - Evaluation of magnetic error tolerances and control of geometric alignment
  - Diagnostics’ requirements for precise beam size, position and emittance measurement as well as on-line correction techniques

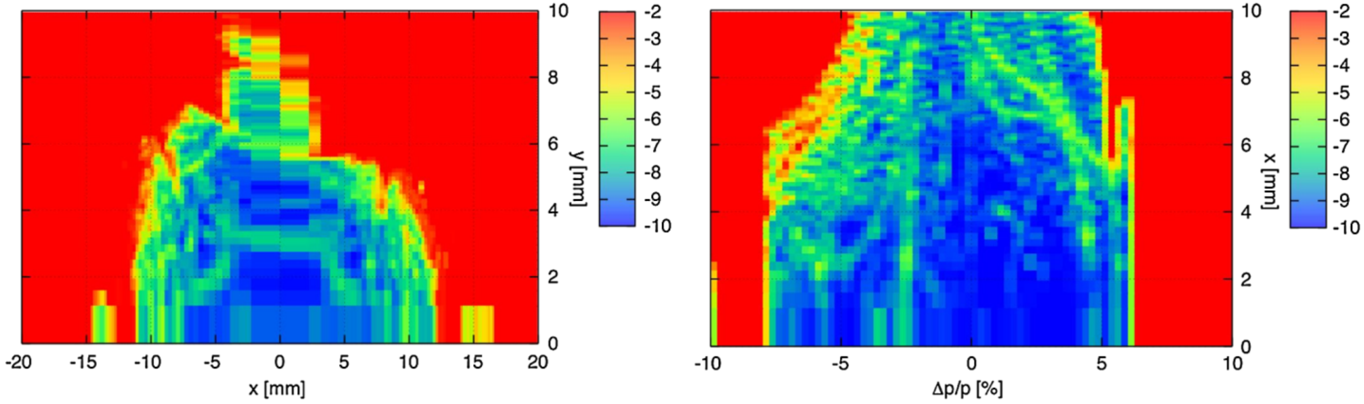
Max-IV 7-BA achromat



Max-IV studies proved that a 7-BA (330 pm, and 260 pm with DW) can deliver suffcient DA and MA to operate with standard off-axis injection schemes

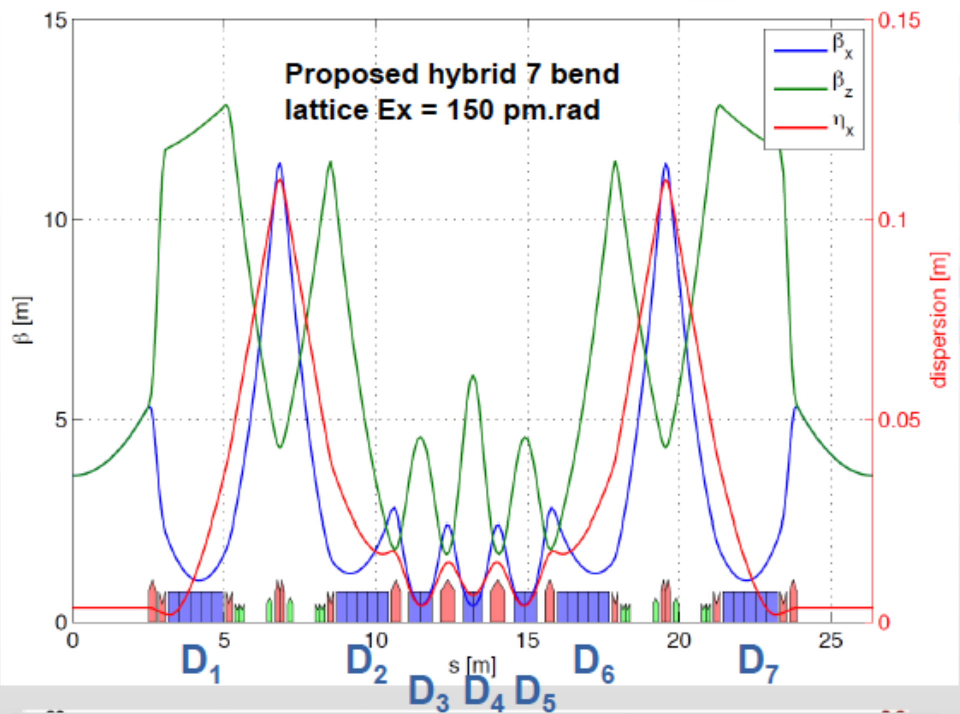
Tools used FM – driving terms

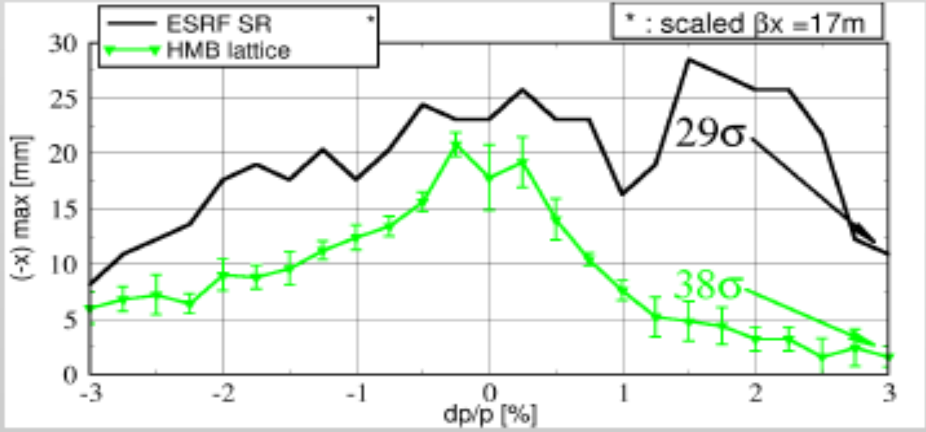
Additional octupoles were found to be effective



Courtesy S. Leemans

ESRFII lattice





@ 7 bending magnets D_{1to7}
➔ reduce the horizontal emittance

@ Space between D_1-D_2 and D_6-D_7
β-functions and dispersion allowed to grow
➔ chromaticity correction
with efficient sextupoles

@ Dipoles D_1, D_2, D_6, D_7
➔ longitudinally varying field to further reduce emittance

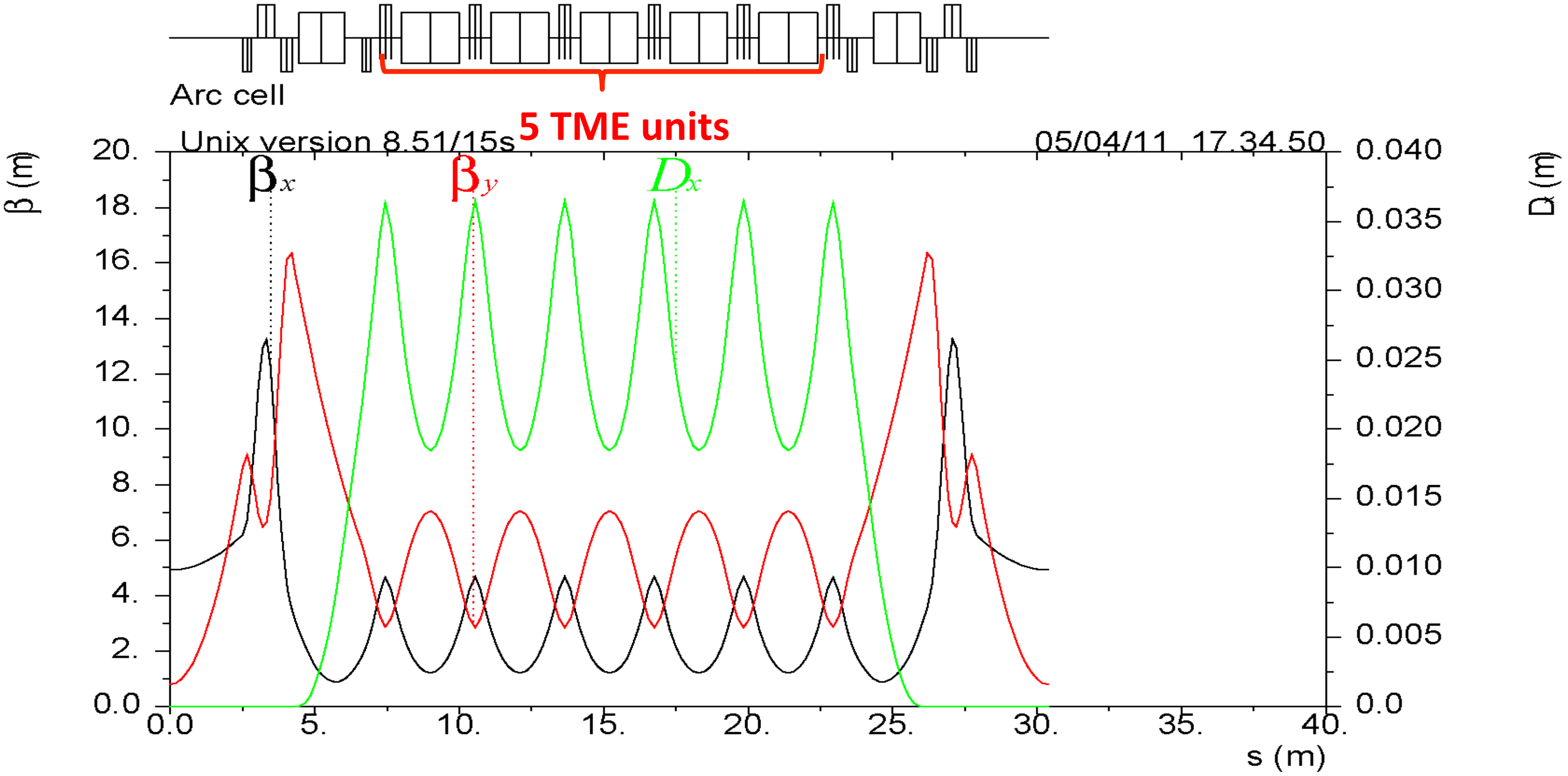
@ Central part alternating
➔combined dipole-quadrupoles$D_{3\text{-}4\text{-}5}$
➔high-gradient focusing quadrupoles

@ D_4 (0.34T) and D_5 (0.85T)
➔Source points for BM beamlines

Courtesy J.-L. Revol

PEP-X 7 bend achromat cell

Natural emittance = 29 pm-rad at 4.5 GeV

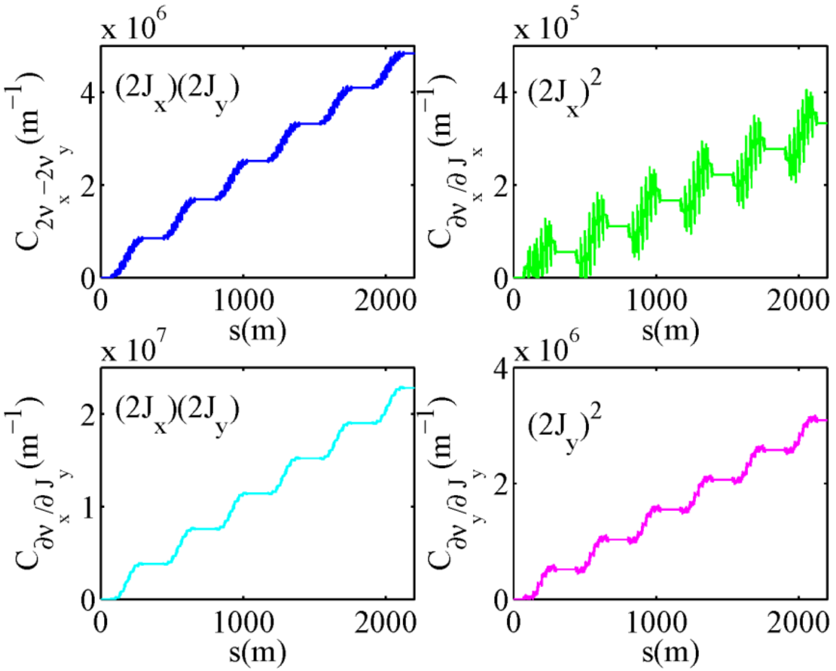


Cell phase advances: $\mu_x=(2+1/8) \times 360^0$, $\mu_y=(1+1/8) \times 360^0$.

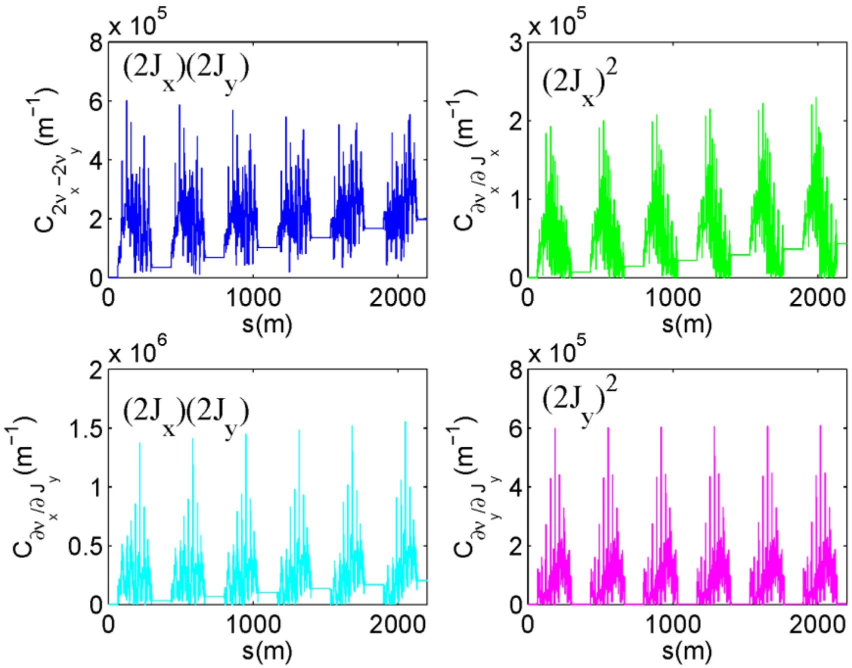
Courtesy B. Hettel, Y. Cai

Harmonic sextupole optimization

Without Harmonic Sextupoles



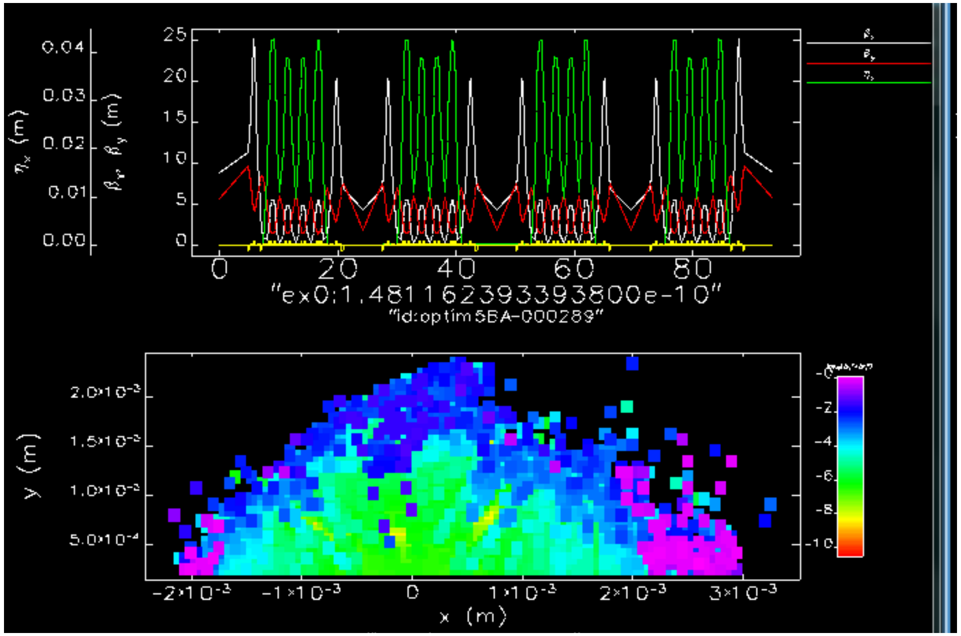
With Harmonic Sextupoles



Optimized with OPA (Accelerator Design Program from SLS PSI)
10 mm DA achieved

Courtesy Min-Huey Wang, B. Hettel, Y. Cai

Lattice optimization using MOGA



2 mm DA

Optimisation just started

Large tuneshift with amplitude to be compensated

Spring8-II, and τ_{USR} have similar DA

It is likely that we have to learn to cope with these small DA

New injection schemes need to be developed

nonlinear pulsed kicker or swap out injection schemes are under investigation

Courtesy R. Bartolini

Parameterization of TME cells

$$f_1 = \frac{s_2(4s_1l_d + l_d^2 + 8D_{xc}\rho)}{4s_1l_d + 4s_2l_d + l_d^2 - 8D_s\rho + 8D_{xc}\rho}$$

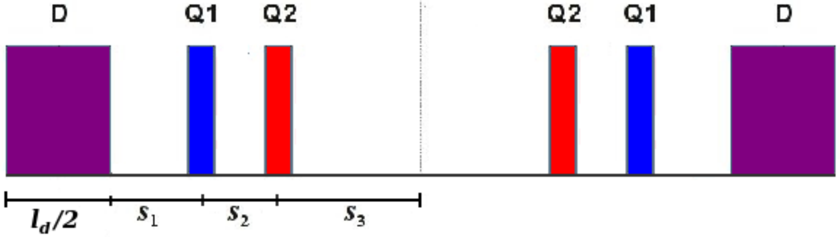
$$= \frac{l_d s_2\left(12s_1 + l_d\left(D_r + 3\right)\right)}{12l_d\left(s_1 + s_2\right) + l_d^2\left(D_r + 3\right) - 24D_s\rho}$$

$$f_2 = \frac{8s_2D_s\rho}{-4s_1l_d - l_d^2 + 8D_s\rho - 8D_{xc}\rho}$$

$$= \frac{24s_2D_s\rho}{12l_ds_1 + l_d^2\left(D_r + 3\right) - 24D_s\rho}$$

$$D_r = \frac{D_{xc}}{D_{xc}^{\min}}, \beta_r = \frac{\beta_{xc}}{\beta_{xc}^{\min}}, \varepsilon_r = \frac{\varepsilon_{xc}}{\varepsilon_{xc}^{\min}}$$

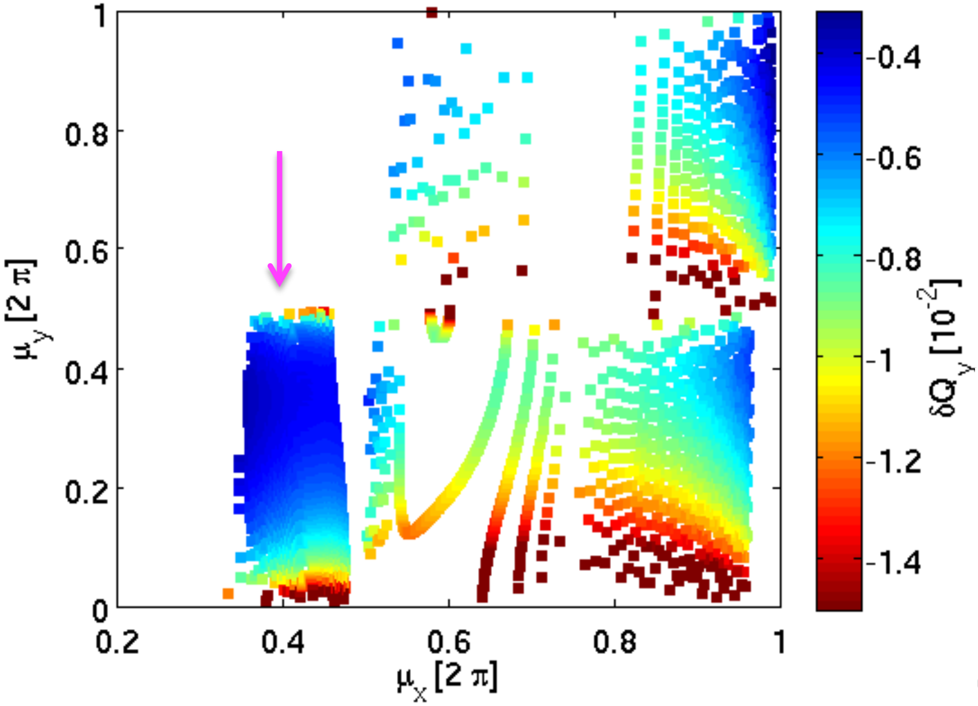
$$D_s = g(s_1, s_2, s_2, l_d, \beta_r, D_r)$$



- Analytical representation of TME quadrupole focal lengths (thin lens)
  - Depending on horizontal optics conditions at dipole center (horizontal emittance) and drift lengths
  - Multi-parametric space for applying optics stability criteria, magnet constraints, non-linear optimization, **IBS reduction**,…

Courtesy F. Antoniou

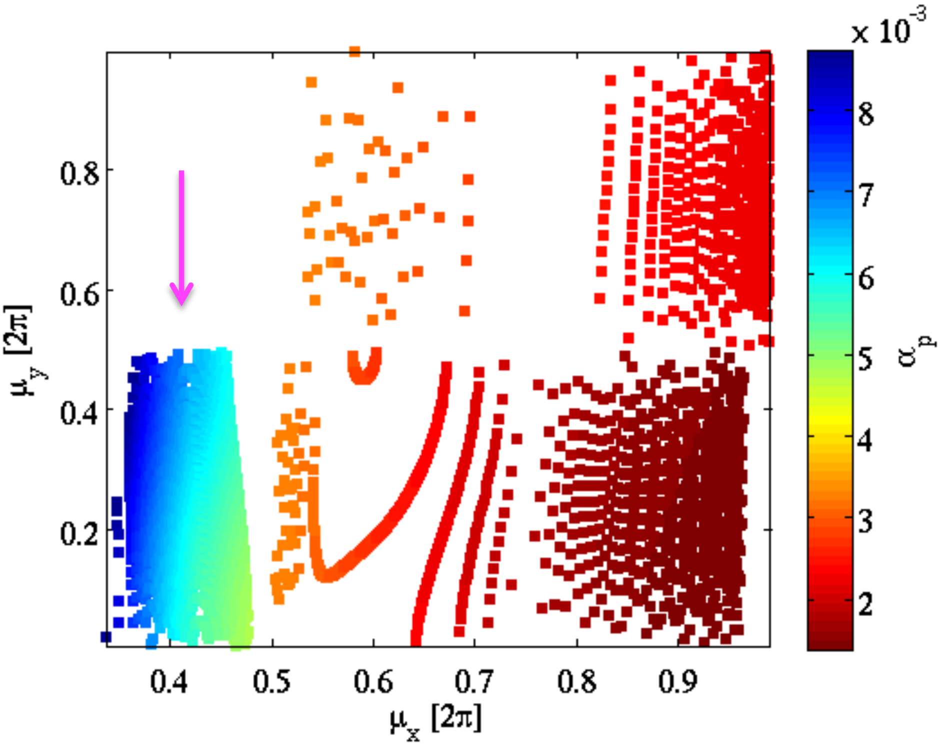
TME optimization for reducing IBS



☐ **Low cell phase advances** can minimize **IBS growth rates**

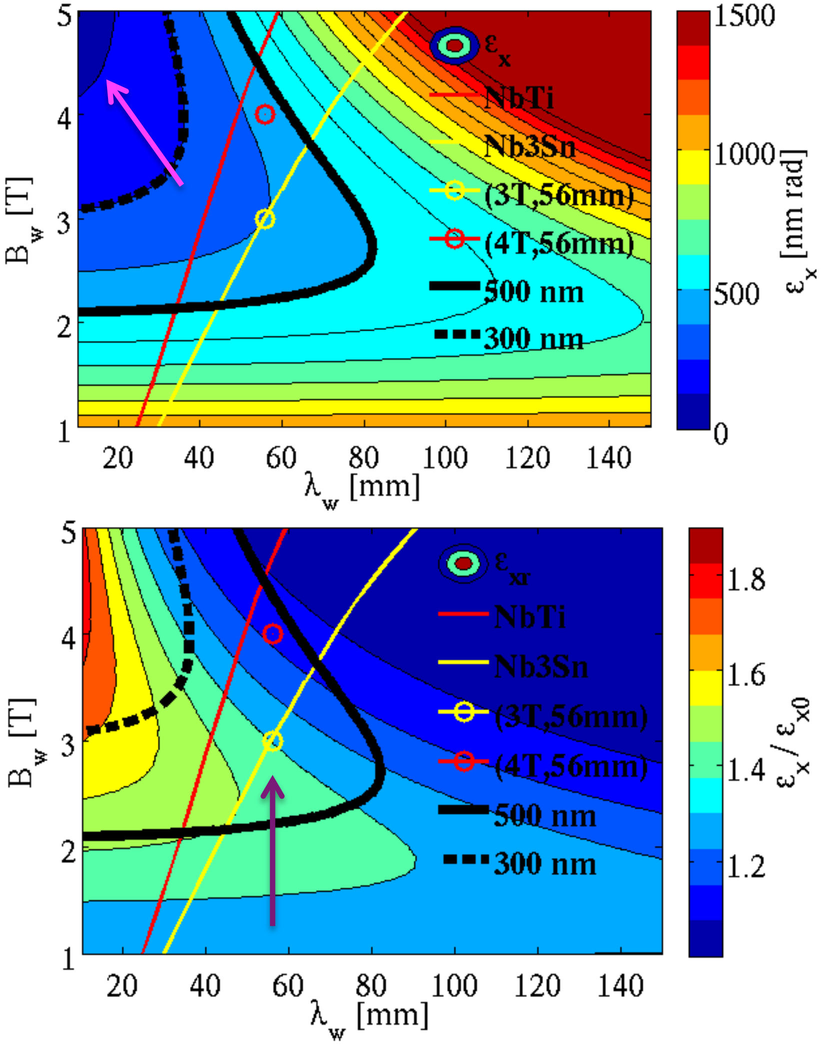
☐ Correspond to large **deviation** from absolute theoretical emittance minimum

☐ Optimal also for minimizing **space-charge** tuneshift and increase **momentum compaction factor**



Courtesy F. Antoniou

Wiggler parameter choice



Courtesy F. Antoniou

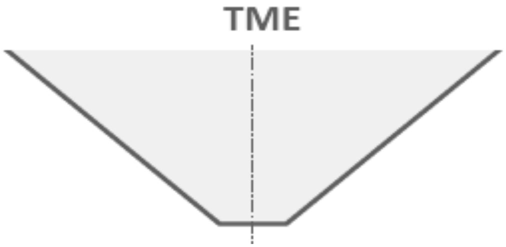
- The **highest field** and **smallest period** provide the smallest emittance
- Lower emittance blow-up due to IBS for **high-field** but **moderate period** (within CLIC emittance targets)
- Wiggler prototype in NbTi with these specs, built at BINP, for installation to ANKA (KIT)
    - Serving X-ray user community but also beam tests
- Development of higher-field short models in Nb3Sn at CERN

D. Schoerling et al., PRST-AB 15, 042401, 2012

Emittance reduction in variable bends

Linearly-ramped bending profile

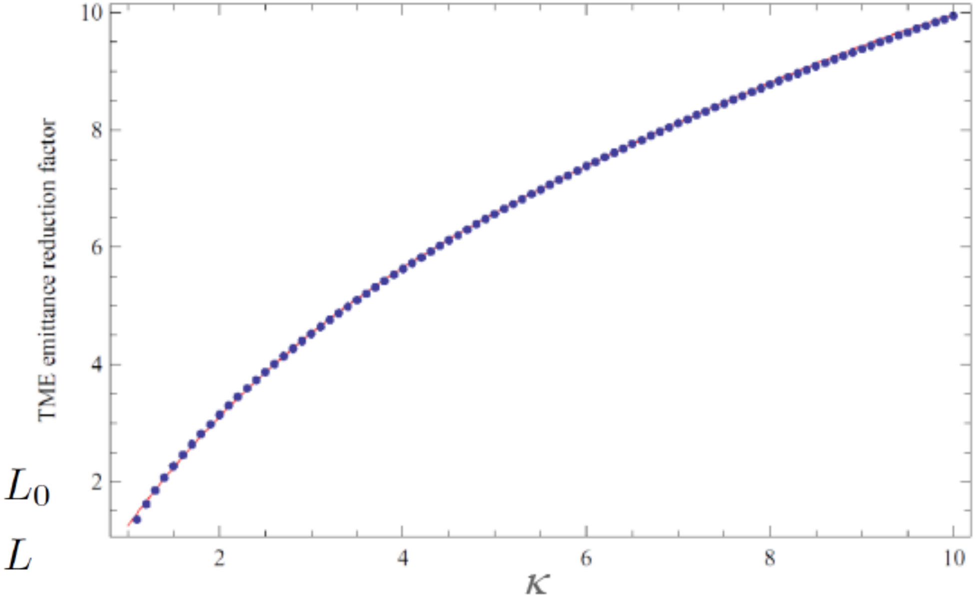
A model sufficiently close to the optimal, yet can be solved analytically



Courtesy C.-X. Wang

See also talk of S. Papadopoulou

improvement in TME emittance



$$\rho(s) = \rho_0 \times \begin{cases} 1 & |s| \le L_0 \\ 1 + g\left(|s|/L_0 - 1\right) & L_0 \le |s| \le L \end{cases}$$

where $g = (r-1)/(L/L_0 - 1)$ and $r \equiv \rho_{\max}/\rho_0$

$$\kappa \equiv \frac{B_{\max}}{B_{\text{ref}}} = \frac{\rho_{\text{ref}}}{\rho_{\min}} = \frac{L}{L_0}\frac{\theta_0}{\theta_{\max}} = \frac{g+r-1}{g+\ln r}$$ is chosen as a given parameter

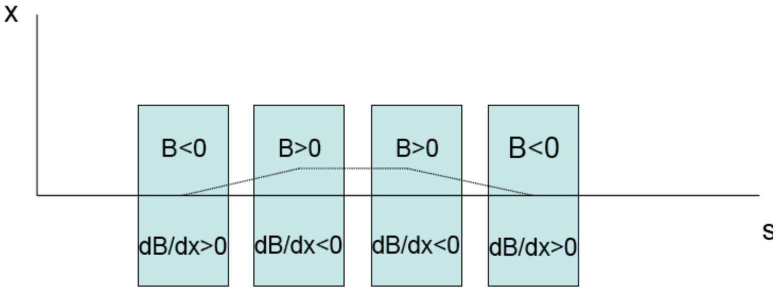
Emittance reduction with Robinson wiggler

PS Robinson wiggler

$$\varepsilon_x = \frac{C_q \gamma^2 \langle H \rangle_{dipole}}{J_x \rho_x}$$

- If we can make $D = -1$ $\Rightarrow$ $J_x = 2$

And the horizontal emittance can be divided by a factor 2!

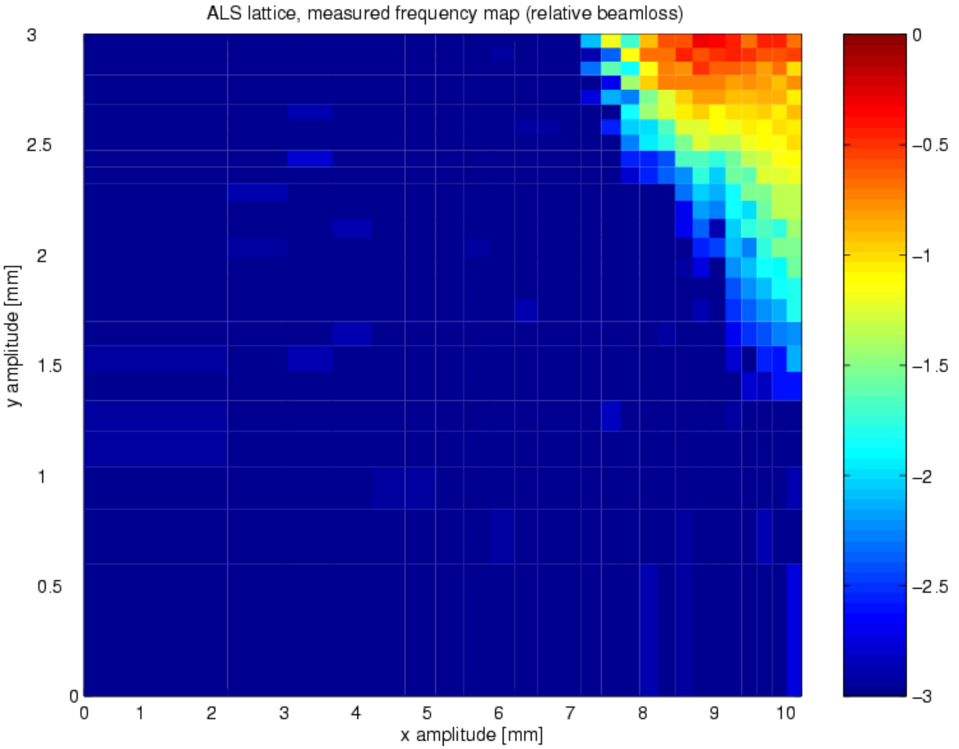


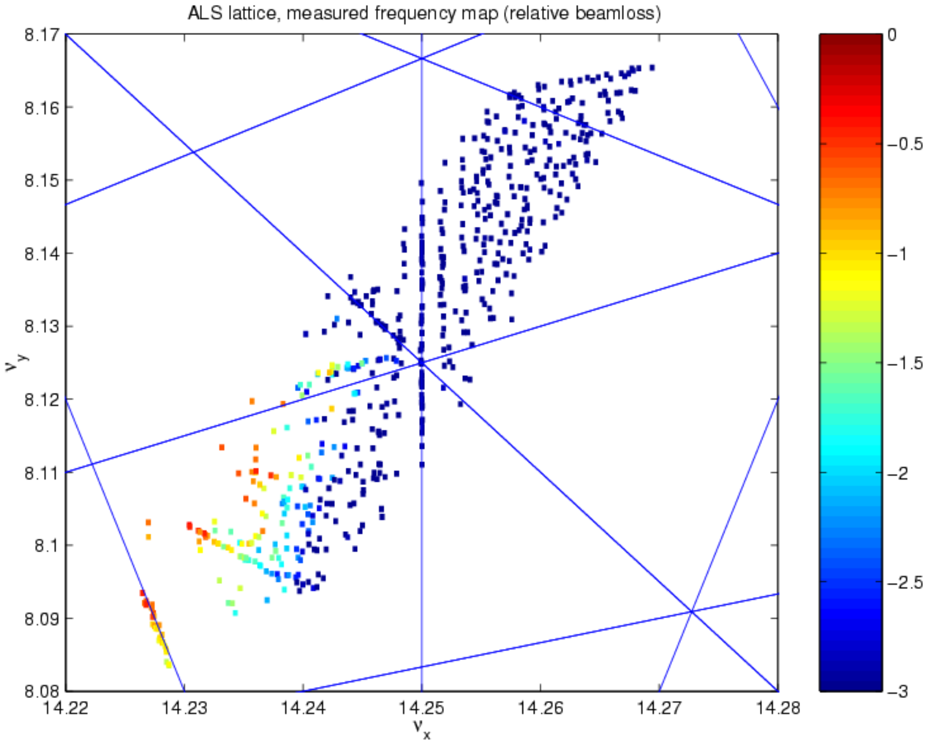
Type	B(T)	g (mm)	dB/dx (T/m)
Out-vacuum	1.4	11	140
In-vacuum	1.0	5.5	182

- How to reach such very high gradient?

Courtesy L. Nadolski

Measured Frequency Map/Beam Loss





- Partial Beam Loss mostly if particles have to pass (radiation damping) through resonance intersection
- Isolated resonances not dangerous.
- Spectra contain more information than just fundamental frequencies – other resonance lines – resonance strength versus amplitude (see R. Bartolini, et al.).

Courtesy C. Steier

New injection schemes

Multipole kicker schemes

- still off-axis: it requires ~5 mm DA (MAX IV data)
- some R&D still needed
- but excellent perspective at BESSY-II (**BESSY-II data**)

Swap out injection

- kick in - on axis - a new bunch and kick out the depleted bunch
- requires a small emittance injector – can work with 2 mm DA
- no top up – but fractional replacement of current
- the injector and the achievable fill pattern limit the total stored current (0.5 nC/bunch) - with a booster or linac

Courtesy R. Bartolini

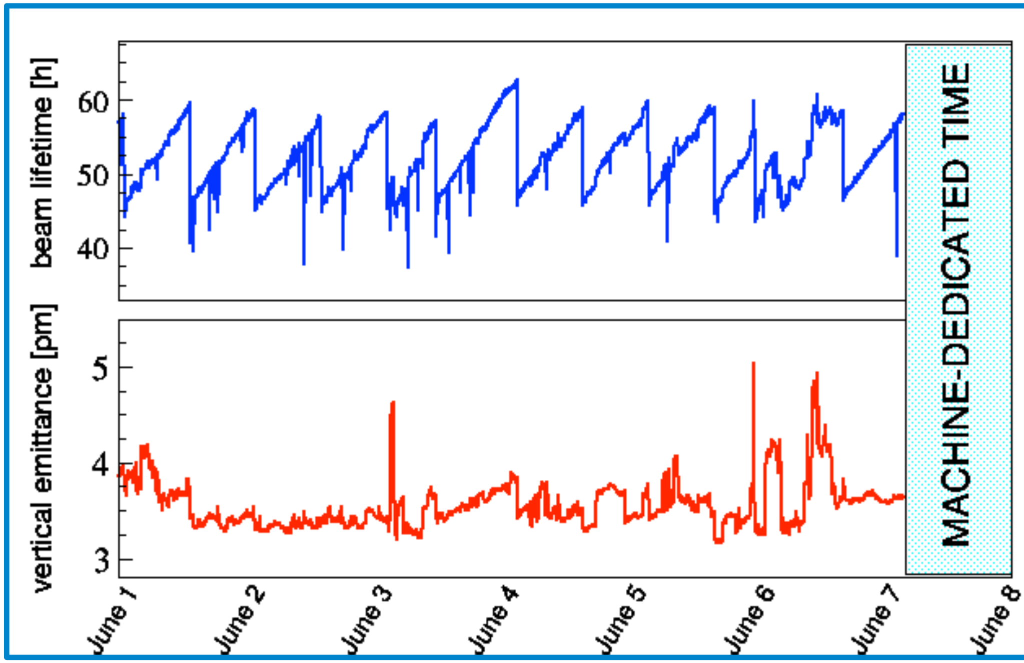
Survey of ultra-low emittance lattices

MAX IV	7BA	3 GeV	320 pm	500 mA	SS length 5m	DA 7mm w/errors
Sirius	5BA w/ superbend	3	280	500	5m & 6m	5 mm w/errors
Spring-8	6BA	6	67.5	300	4.5m & 27m	3 mm w/errors
APS	7BA	6	147	100		
Pep-X	7BA	4.5	11	200	5 m	10 mm w/errors
ESRF Phase II	7BA	6	130	200	5m	10 mm
SOLEIL	QBA w/longit.. gradient dipole	2.75	980 (220)	500		Robins. Wiggler + beam adapter
Diamond	mod. 4BA, 5BA, 7BA	3	45-300	300	5m & 7 m	2 mm
ALS	5BA - 7BA	2	50-100	500	5 m	2-3 mm
BAPS	7BA-15BA	5	50	150	10m & 7m	10 mm w/errors
τ_{USR}	7BA	9	3	100	TEV tunnel	0.8 mm

Coupling correction at ESRF

- The Resonance Driving Terms (RDT) formalism allows a straightforward linear correction algorithm.
- Applications in the ESRF storage ring led to vertical emittance of ε_y = 2.6 ± 1.1 pm, a record low for this machine (ε_x=4.2 nm => $\varepsilon_y/\varepsilon_x \approx$ 0.06%, a factor 10 lower than in the past).
- Preserve small vertical emittance during beam delivery: as of spring 2011 stable ε_y = 3.2-4.5 pm delivered to users (lifetime of 45 hours after refilling @ 200 mA, 10 hours less than in the past only).

2011, with 64 skew quad correctors

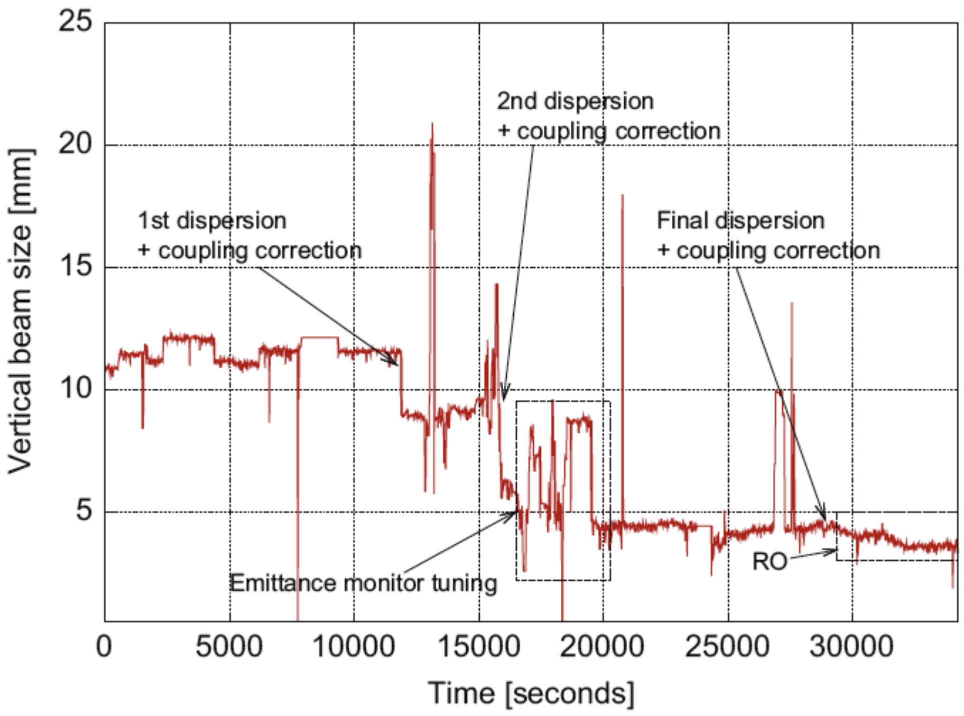


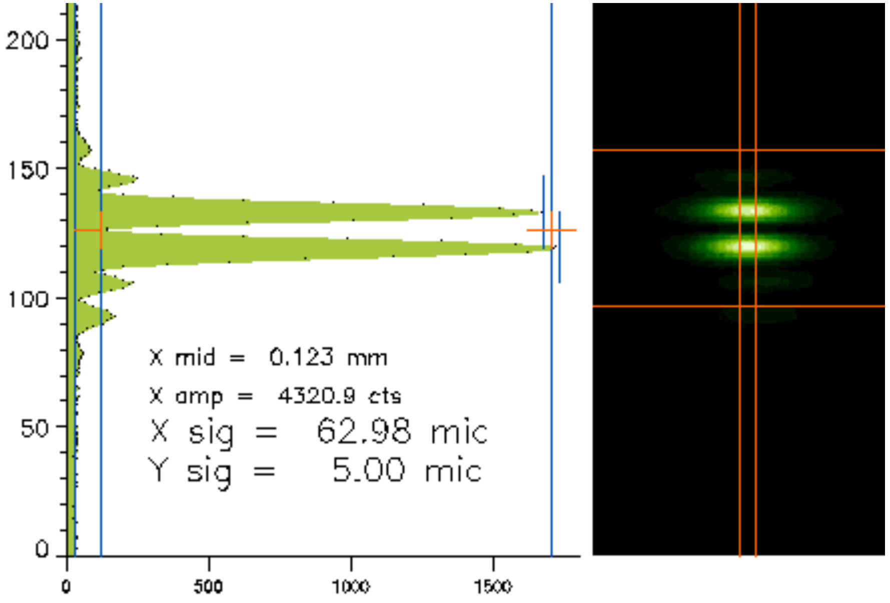
Courtesy A. Franchi

Ultra-low vertical emittance at SLS

- SLS achieved ε_y of **0.9 ± 0.4pm** (confirmed with different techniques)
- New emittance monitor for resolutions below 3μm (vertical polarized light) recently installed

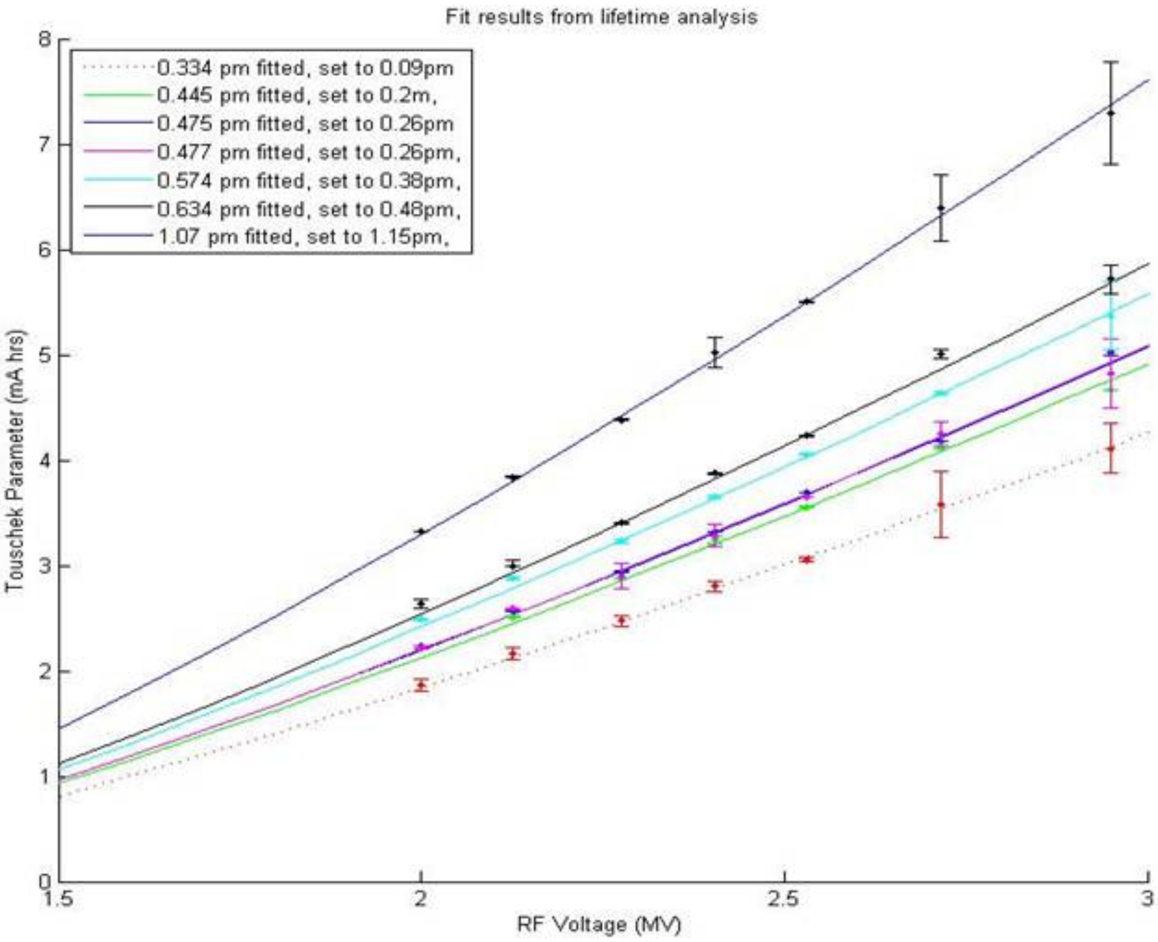
Courtesy M. Aiba, et al.





Reaching Quantum Limit of Vertical Emittance at the Australian Synchrotron

- Touschek parameter as a function with RF voltage
- Curve fit by varying only emittance ratio
- Bottom curve fit corresponds to **ε_y = 0.33pm** (Quantum limit @ 0.35pm)

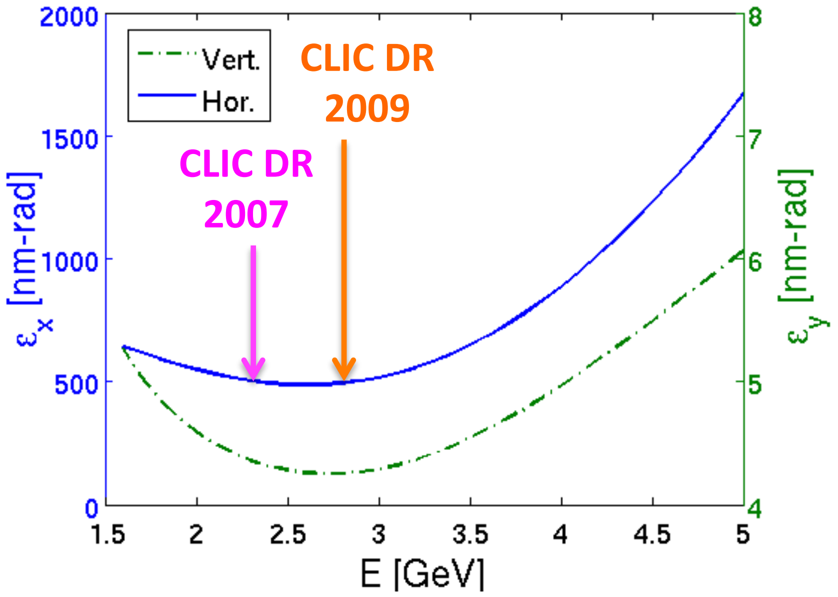


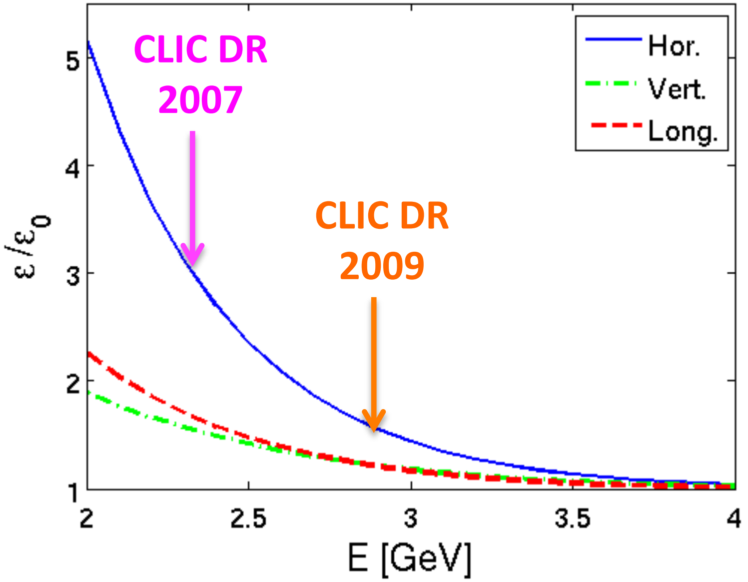
Courtesy R. Dowd

Collective Effects

- Impedances and Instabilities
  - Single and multi-bunch instabilities for ultra-high brightness, short bunches
  - Estimation and optimization of components' impedance in the presence of coating
- Two-Stream Instabilities (e-cloud, ions)
  - Numerical and experimental methods to estimate impact of two-stream instabilities, including code-benchmarking
  - Choice of most appropriate cures, including vacuum and feedback systems and their impact to impedance budget
  - Vacuum methods including laboratory tests and impedance degradation leading to heating, pressure rise and ion instabilities
- Particle Scattering (IBS and Touschek)
  - Scattering theory and numerical tools for non-Gaussian beams
  - Benchmarking with simulations and experiments
- Coherent Synchrotron Radiation Instabilities
  - Theory and simulation comparison of micro-bunching instability thresholds with experiments

Optimal energy for IBS reduction

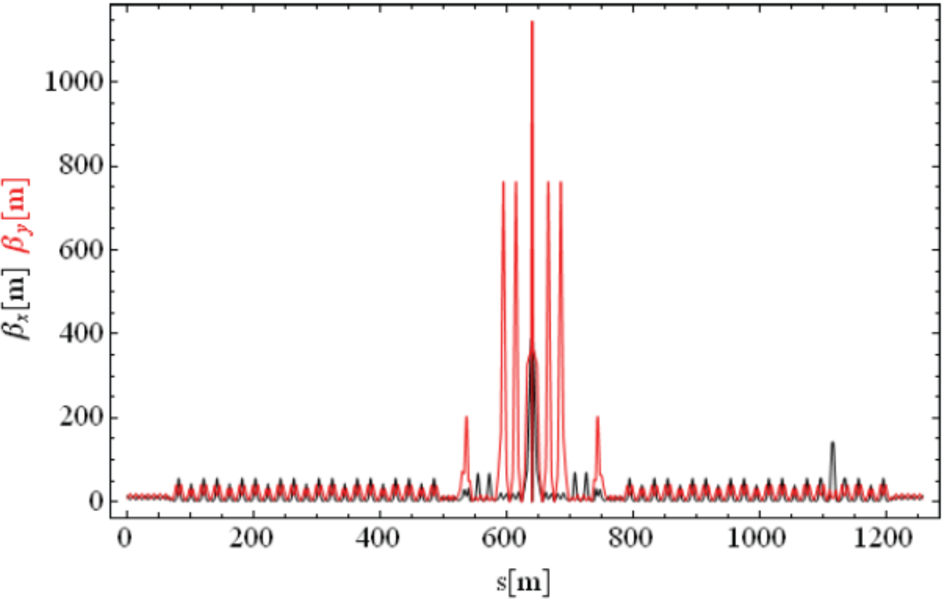




- Steady state emittance as a function of the energy (including IBS)
- Broad minimum at around 2.5 GeV
- Strong horizontal beam blow-up for lower energies
- Increased energy from **2.42** to **2.86** GeV resulted in reduction of horizontal emittance blow-up by a **factor of 2**

Courtesy F. Antoniou

IBS evaluation in SuperB



SuperB V12 LER lattice (~1800IPs)

σ_z=5.0*10^{-3} m

δp=6.3*10^{-4}

e_x=1.8*10^{-9} m

e_y=0.25/100*e_x

ppb= 5.7 10^{12}

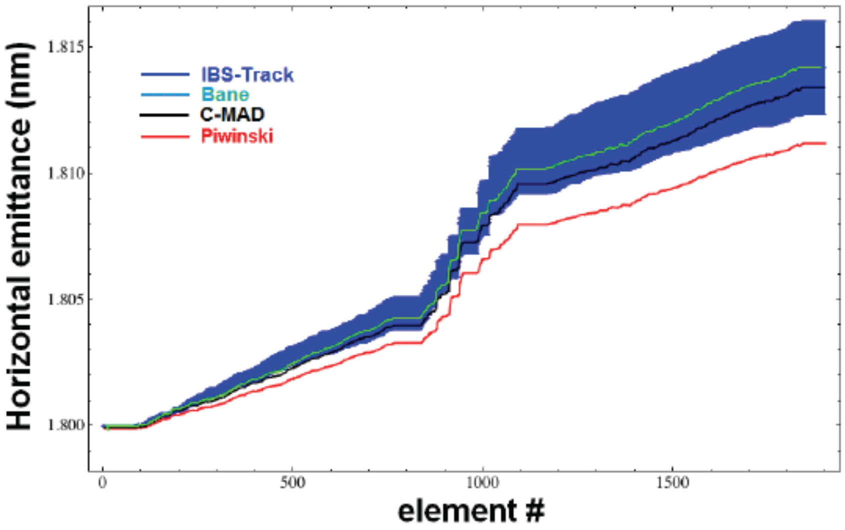
MacroParticleNumber=3 x 10^5

Grid size = $10\sigma_y$ x $10\sigma_x$

cells = 64 x 64

slices = 64

processors for this run = 64



Theoretical models compared with simulations for Super-B, using IBS-Track and C-MAD codes: one turn evolution of emittance with Intra-beam scattering.

Courtesy T. Demma and M. Pivi

Two-stream instabilities

Positron machines

- Primary electrons (mainly photoemission)
- Acceleration and secondary electron production

- Multi-bunch electron cloud build up
- Detrimental effects
- Mitigation/suppression needed

Electron machines

- Ions generation (mainly gas ionization)
- Acceleration and trapping

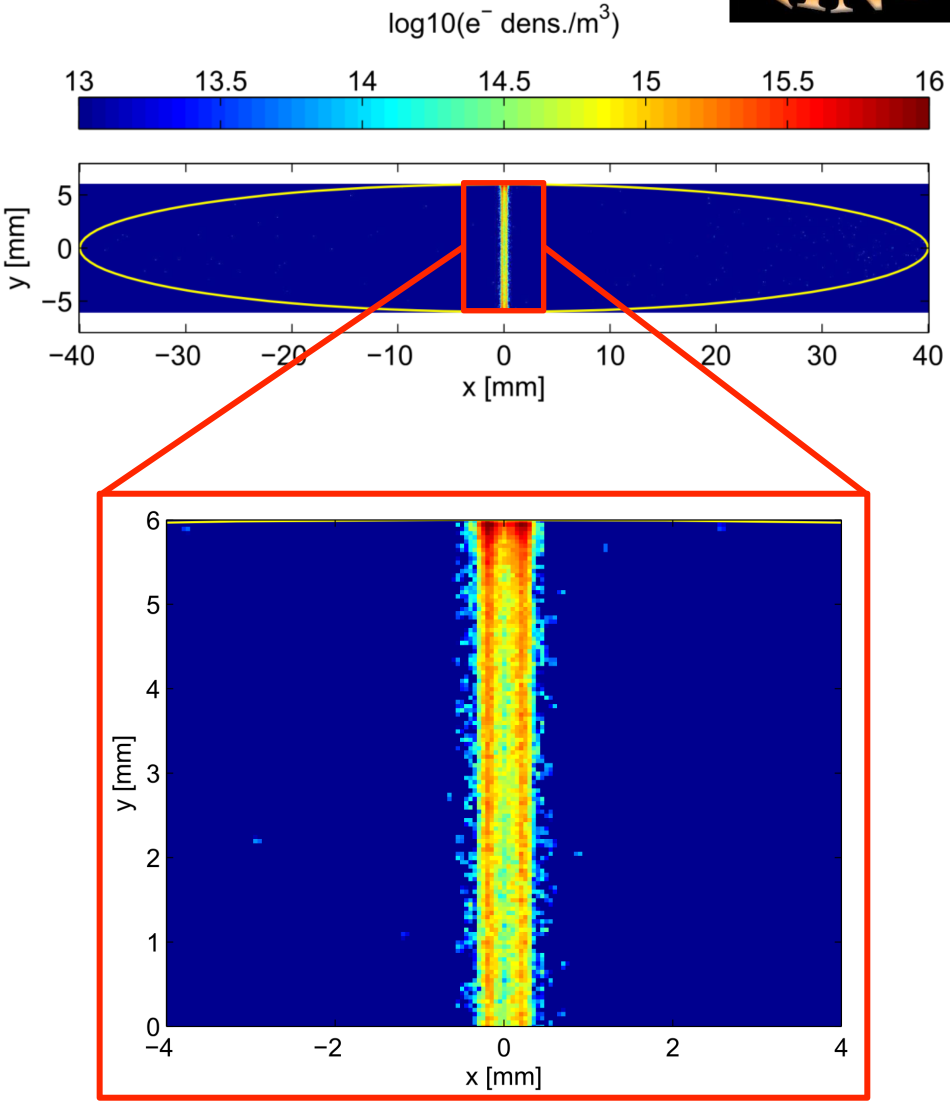
- Multi-bunch accumulation
- Beam instability
- Very good vacuum and vacuum composition needed

Courtesy G. Rumolo

e-cloud built-up

⇒ Challenging simulation scenario

- Short bunches → Short time step
- Small emittance → Beam size 10^4 smaller than chamber size
- In the cases of **wigglers and dipoles** e^- in a **narrow stripe** close to the beam → Fine grid needed for Poisson solver



Courtesy G. Iadarola

Mitigation – Suppression Techniques

Courtesy G. Rumolo

Possible Solutions

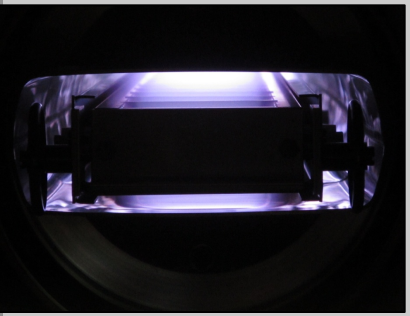
Clearing electrodes installed along the vacuum chambers (only local, impedance)

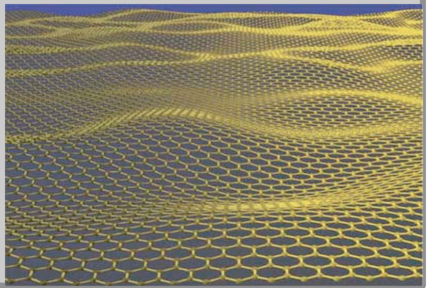
Solenoids (only applicable in field-free regions)

Tolerate e-cloud but damp the instability: feedback system

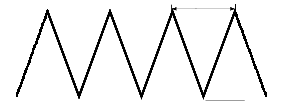
Machine scrubbing during operation
- Limited by reachable SEY
- Depends on e- energy
- Relies on surface graphitization

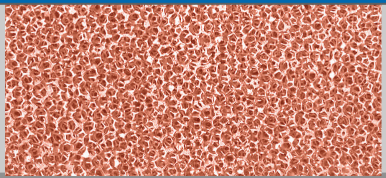
Applying on the wall thin films with intrinsically low SEY
- NEG coating (helps vacuum)
- C coating (no activation)

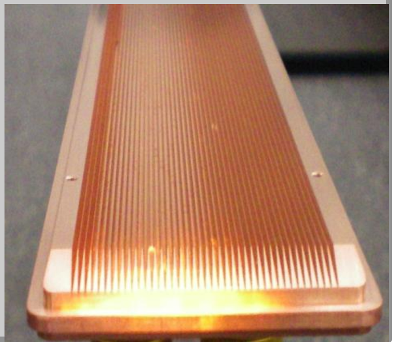




Surface roughness to stop secondary electrons
- Grooves
- Rough material coating
- Sponges

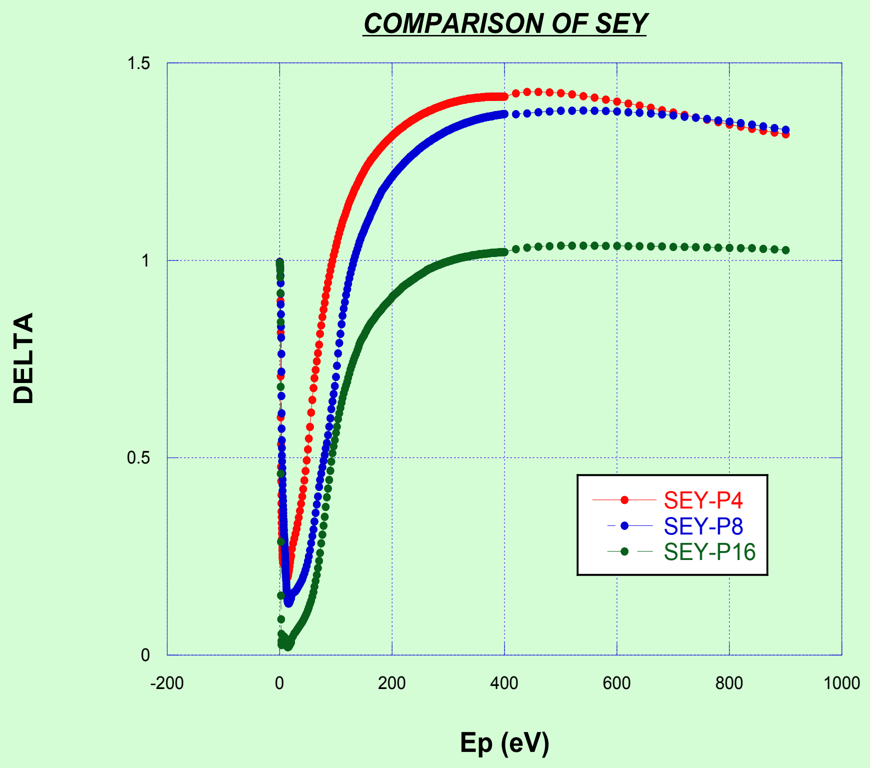


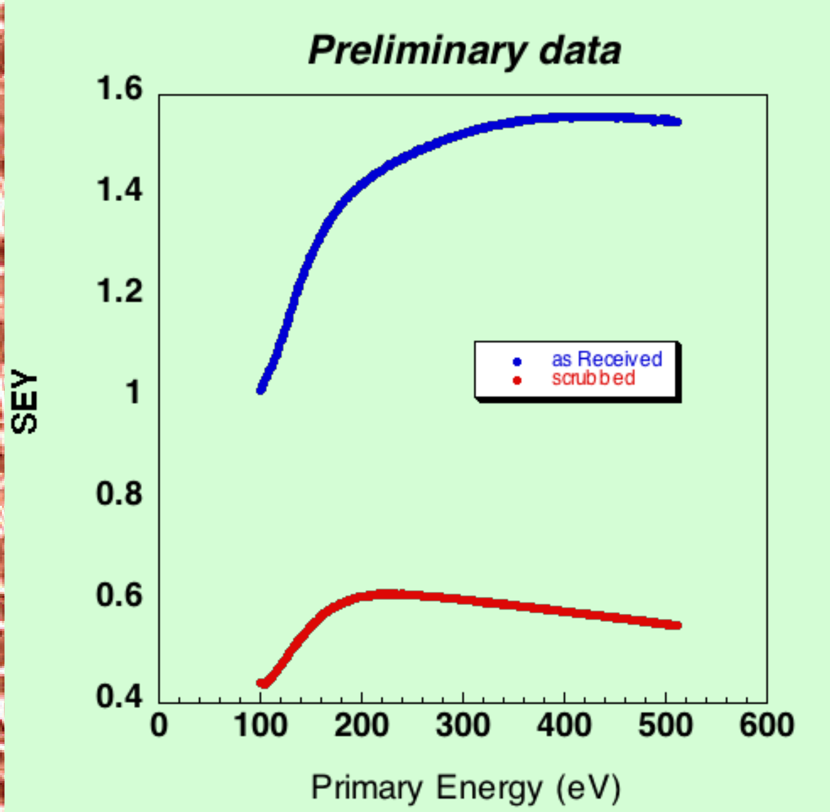




Mitigation – Suppression with sponges

Courtesy R. Cimino



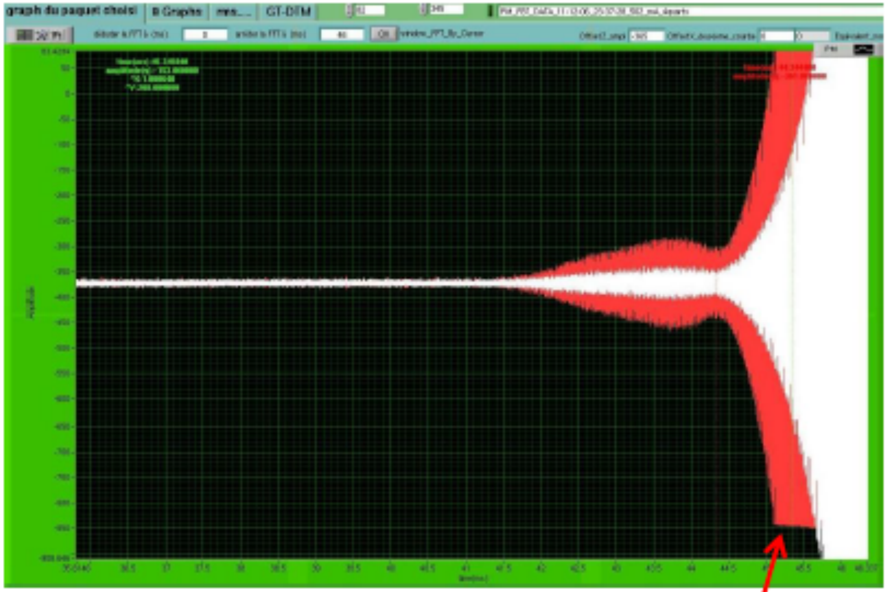


Impedance impact, vacuum behaviour, desorption properties are still under study

→ **seems very promising**

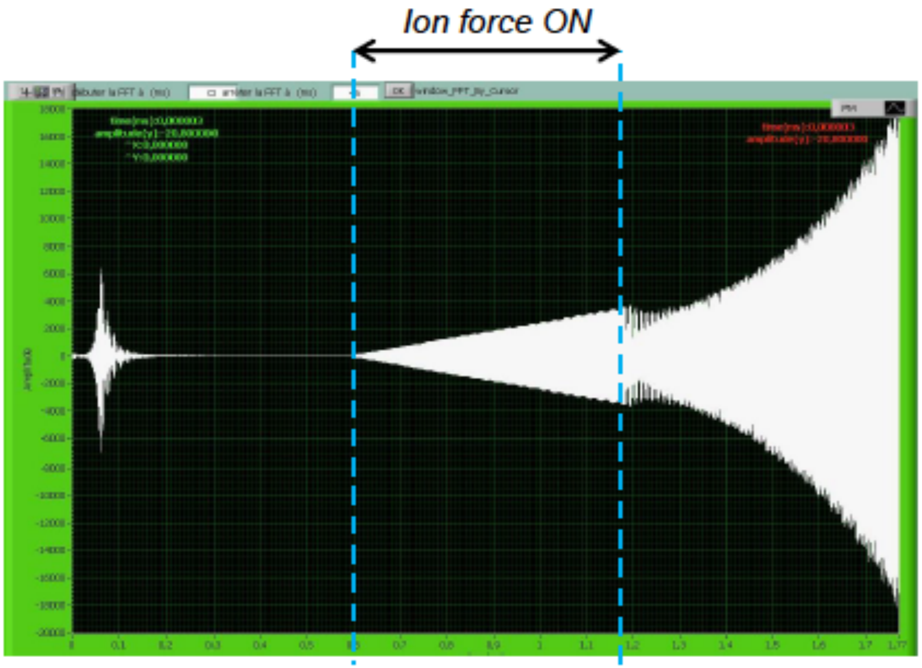
Ion instabilities

- Usually less severe than predictions, stabilizing effects not included in existing models ?
- Ions enhanced by local heating (outgassing) seem to trigger some recently observed high current instabilities @ SSRF and SOLEIL
- mbtrack simulations suggest that SOLEIL instability results from an intriguing interplay between resistive wall, ion effect and transverse feedback



Measured beam loss at 500 mA
White: Beam, *Red: TFB kick*

feedback saturation



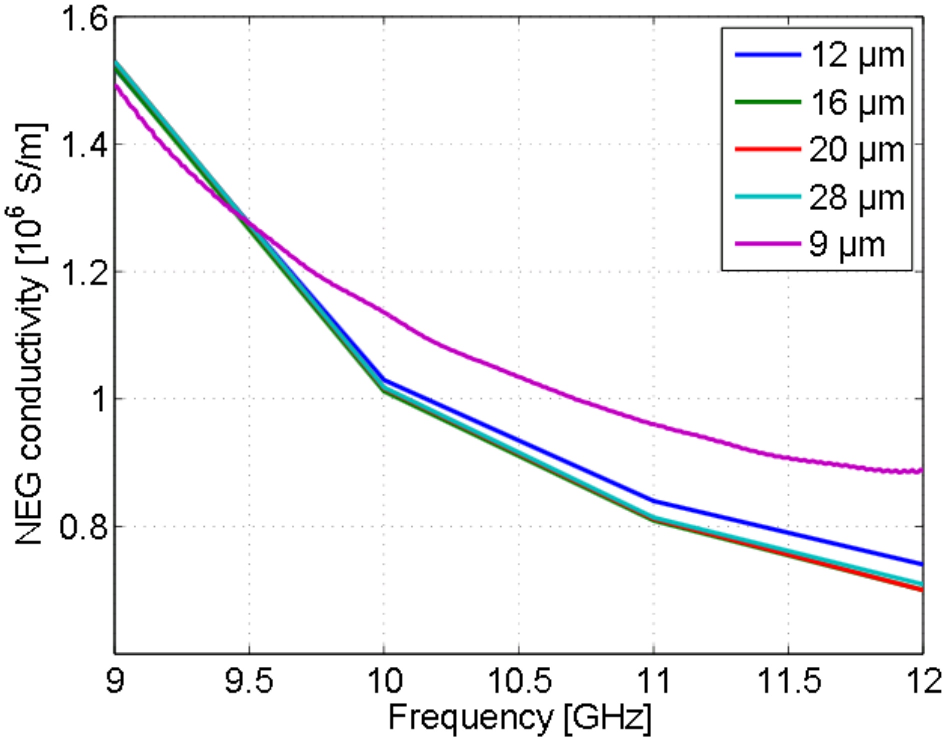
Ion force ON

Simulation: RW with temporal “shaker” excitation at F_{ion}

Courtesy R. Nagaoka

Coating and impedance

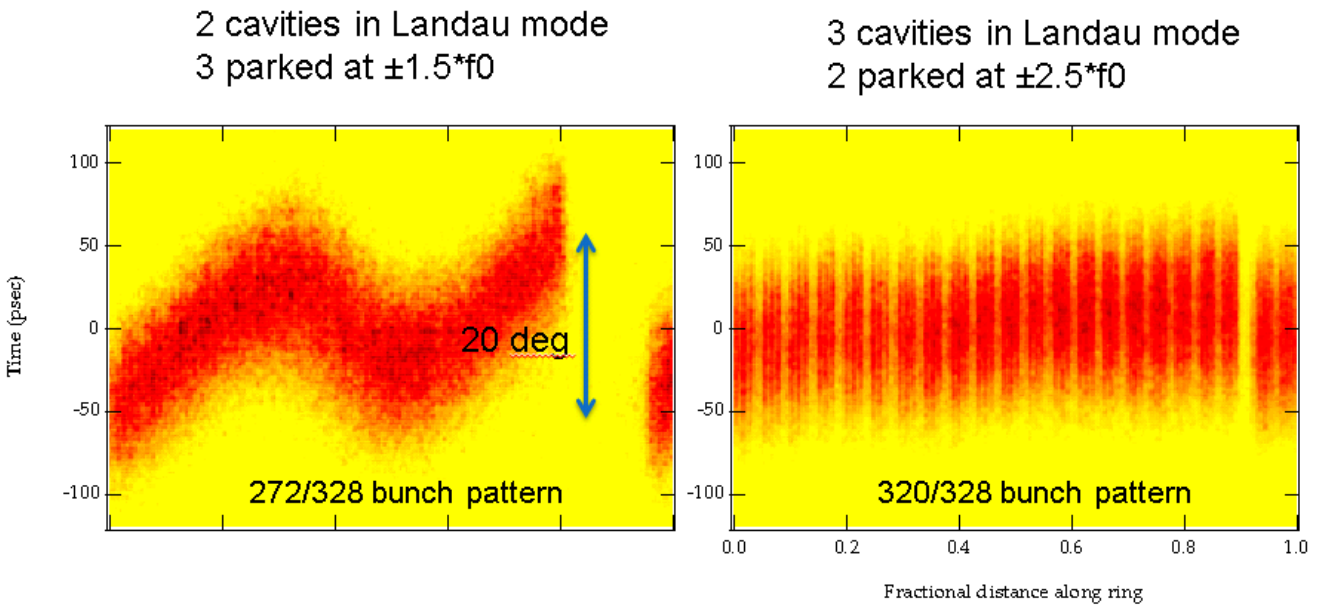
- Measurement of NEG conductivity with waveguide method
- Very important input for resistive wall impedance and instability thresholds, as skin depth is very small in the frequency range excited by the ultra-short bunch (CLIC DR parameters)



Courtesy E. Koukovini-Platia

Harmonic cavities and collective effects

- Harmonic cavities to control bunch shape and landau damping
- Transient beam loading (filling with large gap) may be a problem
- Effect in single and multi-bunch thresholds still in question (see work of T. Argyropoulos at CERN)



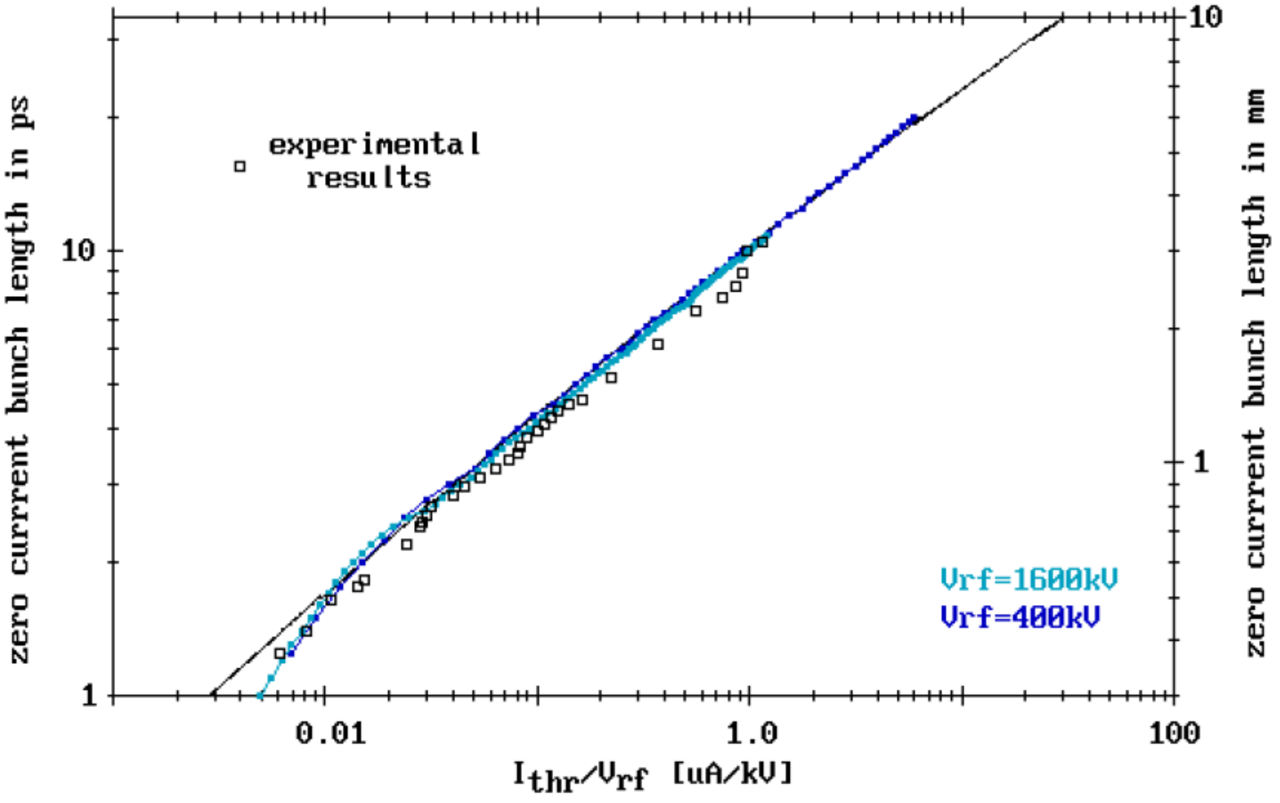
Unequal fill or gap of 20-25% (users' demand) aggravates this problem.

This result was NOT expected and not reported in prior literature. We began an investigation to understand the effect.

Courtesy J. Byrd

Coherent Synchrotron Radiation

- Good agreement between measurements in several storage rings and models
- If bunch length is known we can estimate shielding parameter or normalized resonance frequency and predict the threshold and manifestation of instability



Solid black line: K.L. Bane, et al., Phys. Rev. ST-AB **13**, 104402 (2010)

Courtesy P. Kuske

Low Emittance Ring Technology

- Insertion Device, Magnet Design and Alignment
  - Insertion devices with new super-conducting materials
  - Cryogenic and vacuum technology in the presence of synchrotron radiation heat loads
  - Novel measurement techniques for estimating magnetic errors
  - Beam based alignment technologies for low emittance and long-term stability
- Instrumentation for Low Emittance
  - BPM systems for submicron orbit feedback and vertical dispersion control of a few mm
  - Monitors for measuring ultra-low beam sizes and bunch lengths
  - Wideband feedback systems able to for multi-bunch instabilities with fast rise times
- Design of Kicker Systems
  - Low impedance fast strip-line kickers with tight field tolerances
  - Fast high voltage pulsers with good amplitude stability and high reliability.
- Vacuum technology
  - Design and manufacturing of ultra-low gap vacuum chambers with complex geometries including coatings for low pressure and/or secondary electron yield
- RF Design
  - RF powering, super-conducting RF technology, and low level RF system design (including harmonic cavities)

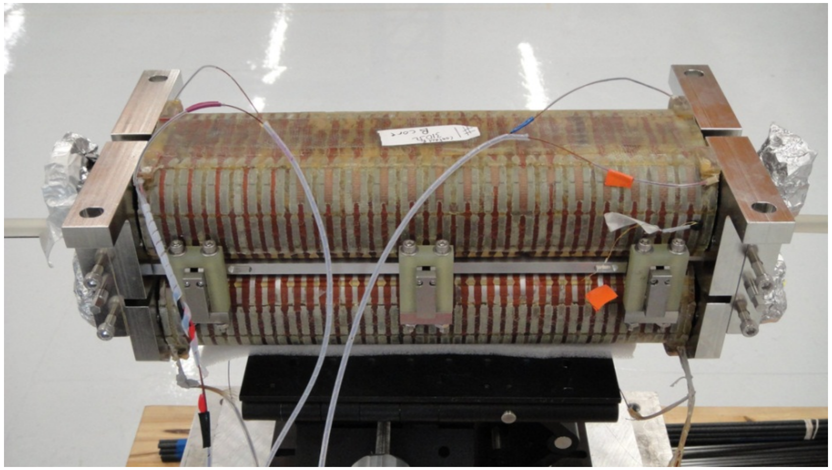
Insertion Device Technology

Courtesy J. Chavanne, J. Barth

- ID impact with new low emittance lattice
  - Beam dynamics: will need FF tables correction
  - Photon quality:
    - rms phase errors 2-3 degree is adequate
    - Energy spread will become the dominant effect to higher harmonics
  - Heat load:
    - no major changes as the size of the photon beam is weakly dependent on emittance (mostly depends on K)
- CMPUs vs SCUs
  - CPMU mature design;
  - SCU higher field for periods above 10 mm
  - SCU have big potential; CMPU still compatible with users application in the next 5-10 years due to flexibility, fast tuning, reproduclbility

SCU in APS

- SCU has been built at the APS
- Beff = 0.64 T at 500 A
- 21 periods of 16 mm
- **Installation December 2012**

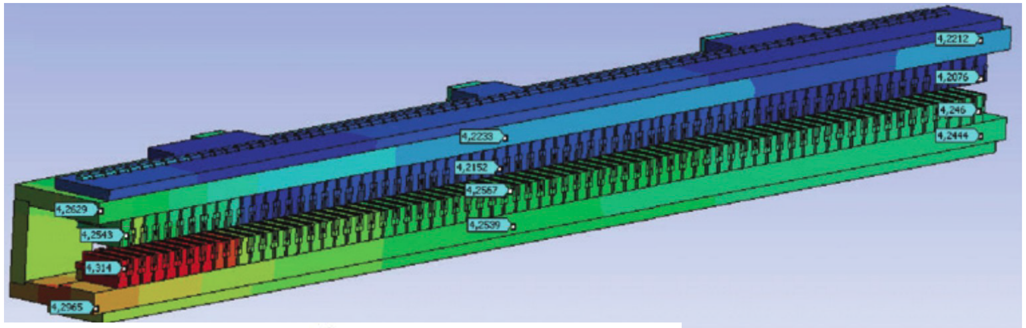


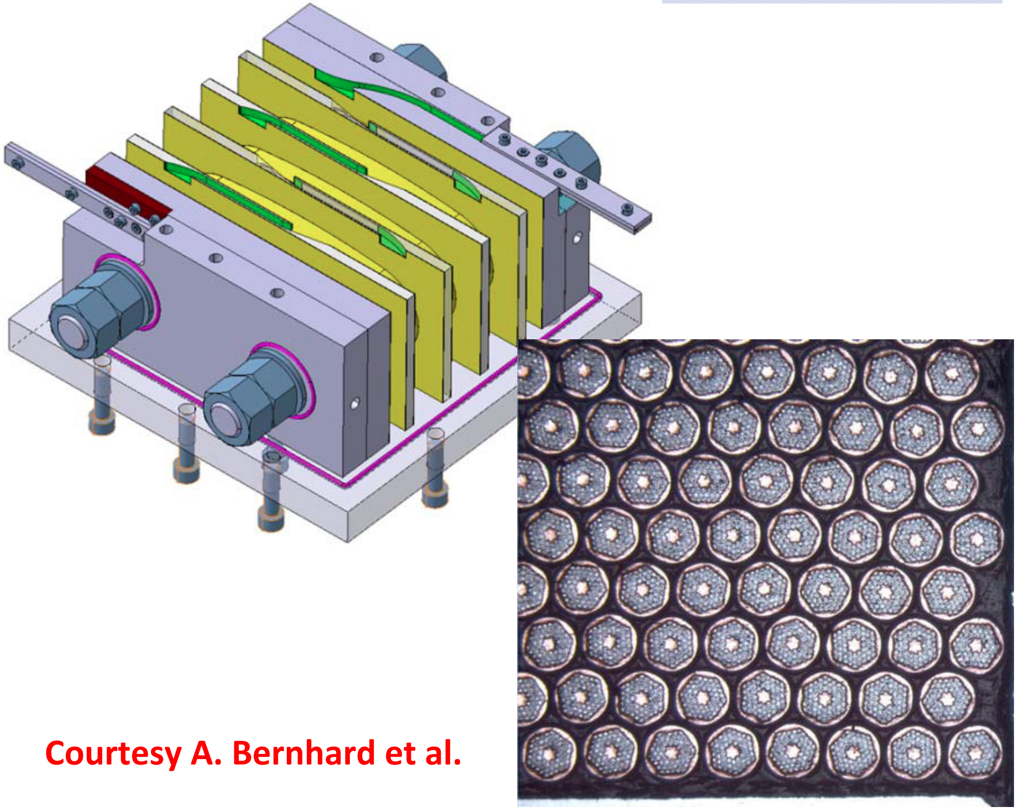
Completed magnet assembly

Fit test of cold mass and current lead assemblies in cryostat

Courtesy M. Jaski et al.

SC wiggler development for CLIC DR





Courtesy A. Bernhard 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 soon installed in ANKA for beam tests
  - Operational performance, field quality, cooling concept
- First Nb_3Sn vertical racetrack magnet (3-period) tested in 2011
  - Reached 75% of max. current
  - Limited by short coil-to-structure (insulation)
  - New short model under development (optimised impregnation,

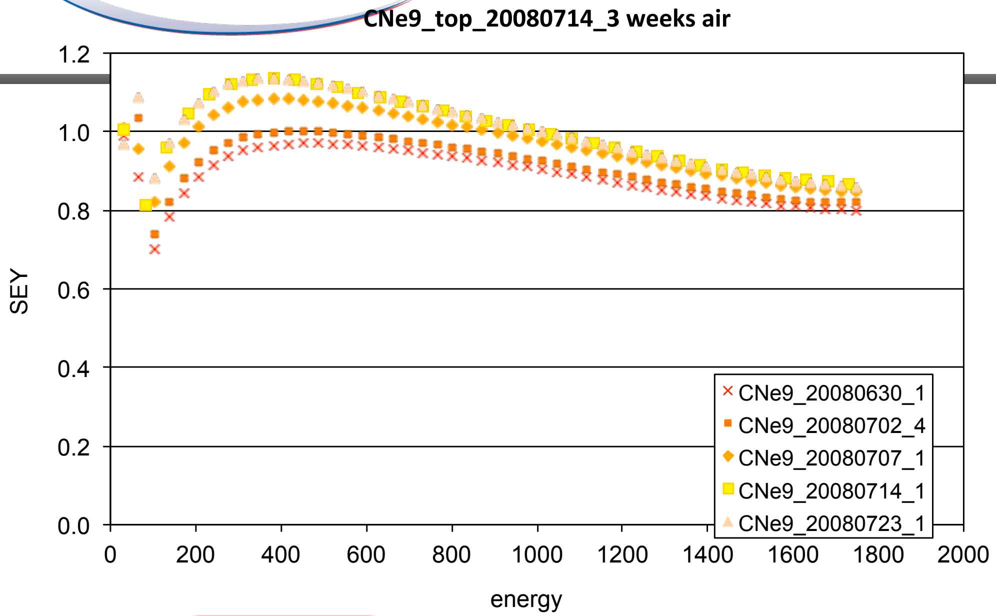
Magnets R&D

Diffraction limited emittance requires magnets with unprecedented strength in storage ring. High gradient and high precision required

New designs under consideration foresee magnets whose strength exceed even the most aggressive existing designs and distance is of the order of the gap

quadruple gradient			MAX IV has 40.0 T/m
	ESRF – Diamond-II	100 T/m	
	Spring8-II	80 T/m	
	BAPS	50 T/m	
	τ USR	90 T/m	
quadrupoles in dipoles			MAX IV has 9 T/m
	ESRF – Diamond-II	30 T/m	
sextupoles			MAX IV has 2*2200 T/m2
	ESRF-Diamond -τUSR	7000 T/m^2	
	Spring-8 II	13000 T/m^2	
	BAPS	7500 T/m^2	
space between magnets (hard edge)		10 cm	MAX IV has 7.5 cm
Apertures = 20-26 mm diameter in arcs			MAX IV inner diam. 22 mm

Vacuum technology



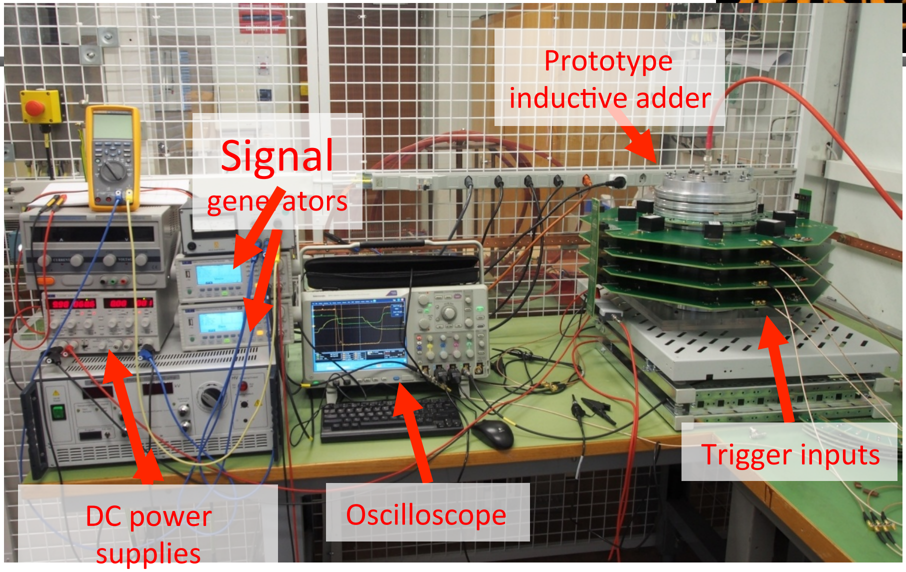
- Amorphous-C coating shows maximum SEY starting from below 1 and gradually growing to slightly more than 1.1 after 23 days of air exposure
  - Peak of the SEY moves to lower energy
- Experimental tests
  - Huge amount of data at SPS
  - Run with 5 GeV positrons at CESRTA, for different intensities and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

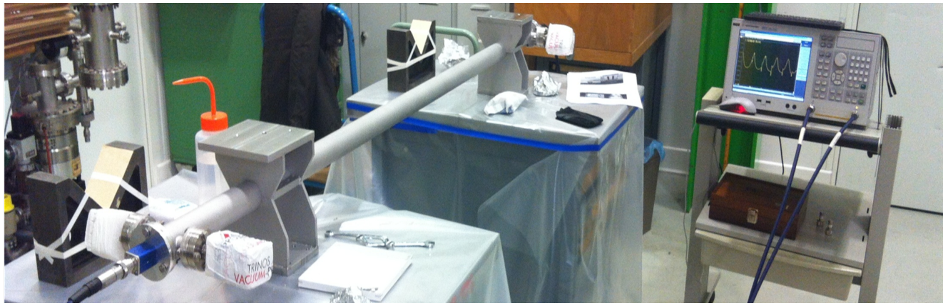
NEG coatting of exotic vacuum chambers, for MAXIV

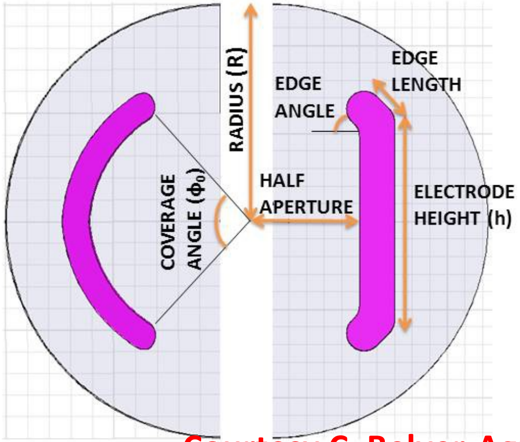
Courtesy S. Calatroni et al.

Extraction kicker design

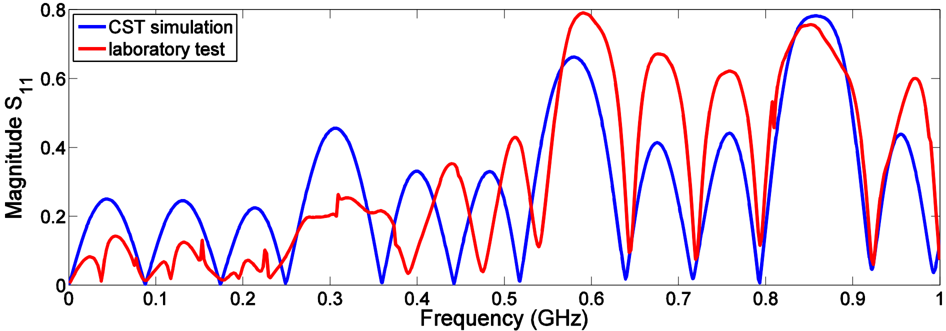
- Kicker jitter tolerance ~ few 10^{-4}
- Striplines required for achieving low longitudinal coupling impedance
  - Prototyped under the Spanish Program “Industry for Science”
  - Now, at CERN for laboratory tests (very good
- Significant R&D done for pulser
  - First 5-layer inductive adder prototype under tests at CERN), second one to be assembled during this month
- Collaboration is set-up with ALBA synchrotron and ATF for beam tests







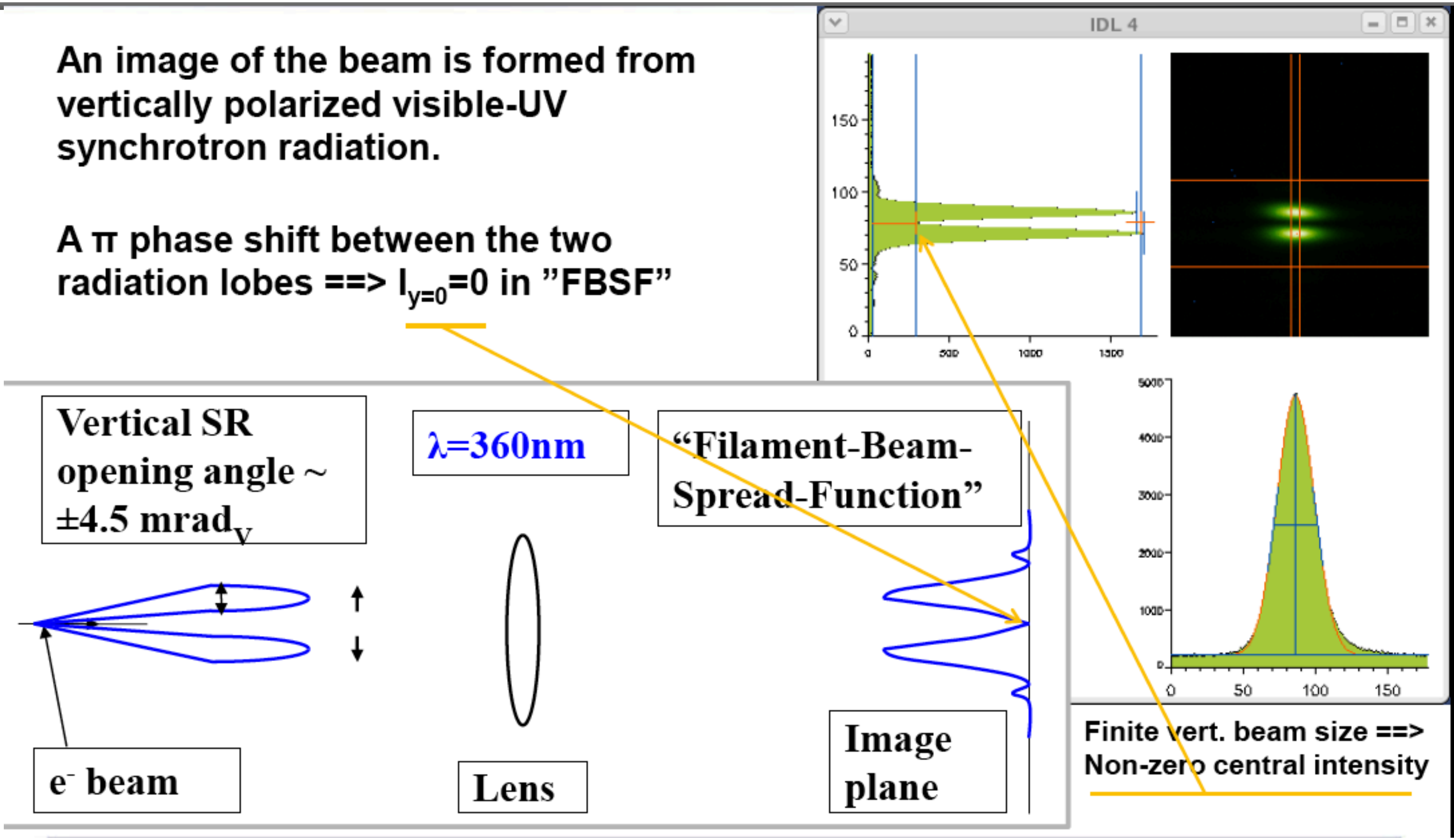
Courtesy C. Belver-Aguilar et al.



π-polarization method

An image of the beam is formed from vertically polarized visible-UV synchrotron radiation.

A π phase shift between the two radiation lobes ==> $I_{y=0}=0$ in "FBSF"



Vertical SR opening angle ~ ±4.5 mrad_V

λ=360nm

"Filament-Beam-Spread-Function"

e^- beam

Lens

Image plane

Finite vert. beam size ==> Non-zero central intensity

Courtesy A. Andersson

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

- 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

Organisation

- 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)

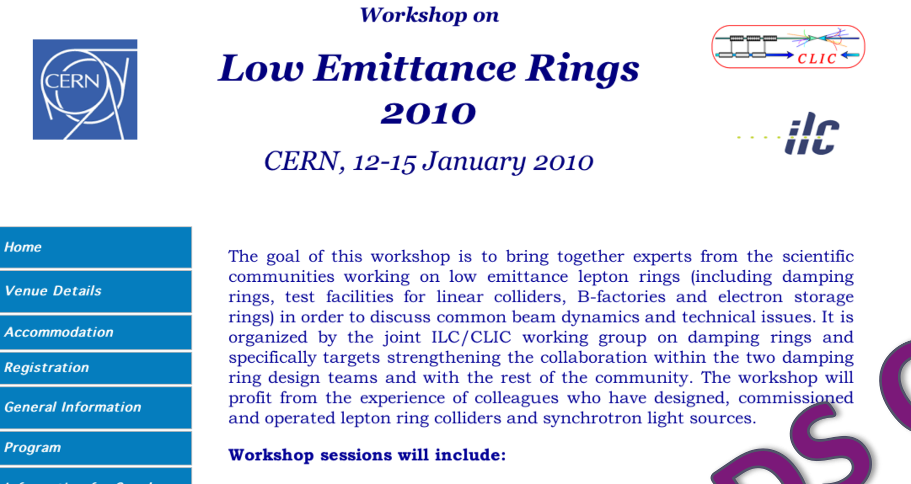
Representing “Ultimate-storage ring” community and damping ring test facilities

  - Task coordinators: M. Böge (PSI), R. Nagaoka (Soleil), H. Schmickler (CERN)
- Organize Low Emittance Rings’ general and topical workshops
  - Already organized 4 general (2 within EUCARD2 and 2 topical)

EuCARD²

Low Emittance Rings workshops

TOWARDS COMMON R&D



Workshop on

Low Emittance Rings 2010

CERN, 12-15 January 2010

- Home
- Venue Details
- Accommodation
- Registration
- General Information
- Program
- Information for Speakers
- Program Advisory Committee
- Organising Committee

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 sessions will include:

- **Low Emittance Design and Tuning**
- **Collective Effects (electron cloud, f**
- **Low Emittance Ring Tech instrumentation, etc.)**

3-5 Oct 2011
Heraklion, Crete, Greece

- Home
- Venue Details
- Directions
- Registration
- Accomodation
- General Information
- Program
- Informati eake
- Prog Advisory Com ee
- Orga Committ
- Local Org Committee

Be n ics Mini Workshop on Lo Emittance Rings 2011

The goal of the worksh to b together erts from the scientific communities working on low emittance lepton rings. This includes damping rings, test fa for r colli , B-factories and electron storage rings. The theme will be common beam dynamics and technology challenges p ucin trolling ultra-low emittance beams and the participants will benefit from the experience of colleagues ave d gne ommissioned and operated such rings. This is the second in a series of workshops initiated in 2010 (http://le cer h), he joint CLIC/ILC working group on damping rings. During the 1st workshop and subsequent dis ions, wa hat e state of the art in the design of accelerator systems in X-ray storage rings approaches the goals of li llider mpin s and future e+/e- circular collider upgrade projects. This workshop specifically targets the strengthening of int s wi the lo emittance ring community by forming a LOWεRING collaboration network.

Wor op ons will include:

Low ittance optics design and tuni

- Low emittance cells design
- Non–linear optimization
- Minimization of vertical emittance
- Collective effects reduction through la

Collective Effects and beam instabiliti

- Electron cloud effect and fast ion insta
- Intrabeam Scattering
- Impedances
- Coherent Synchrotron Radiation

Low Emittance Rings workshop

LOWεRING 2014

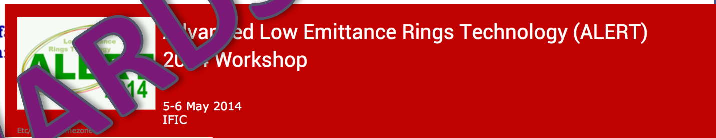
INFN Istituto Nazionale di Fisica Nucleare

LNF-INFN, Frascati
17-19 September 2014

Goal of the workshop is to bring together experts from the scientific communities working on low emittance lepton rings

Workshop sessions

- Low emittance lattice design and tuning
- Collective effects
- Low emittance ring technology



Advan ed Low Emittance Rings Technology (ALERT) 20 4 Workshop

5-6 May 2014
IFIC

Low emittance ring 2013 workshop

- Main Page
- Agenda
- Register
- Delegates list
- Registration payment
- Transport
- Local Facilities
- Contact

TWIICE 2014

Topical Workshop on Instabilities, Impedances and Collective Effects

Synchrotron SOLEIL, 16-17 January 2014

EuCARD^2

THANK YOU
for your
attention