Damping Rings Summary

S. Guiducci, INFN, M. Palmer, Cornell,

Y. Papaphilippou, CERN, J. Urakawa, KEK

IWLC , Geneva 22 October 2010

DR Agenda – Wednesday 20

Opening session, Chaired by M. Palmer		
9:00	Working group organisation	Y. Papaphilippou, CERN
9:15	Design progress for the ILC Damping Rings	S. Guiducci, INFN/LNF
9:45	Conceptual design of the CLIC Damping Rings	Y. Papaphilippou, CERN
10:15	ATF status	J. Urakawa, KEK

Lattice design and Low emittance tuning, Chaired by R. Bartolini		
11:15	Update of 3.2 km ILC DR design	J. Gao, IHEP
11:40	Low emittance tuning at CERTA	J. Shanks, Cornell
12:05	ASLS low-emittance tuning progress	E. Tan, R.Dowd, ASLS

X-ray storage rings and kickers, Chaired by S. Guiducci		
14:00	DIAMOND status	R. Bartolini, JAI/DIAMOND
14:30	ATF fast kicker progress (Webex)	T. Naito, KEK
14:55	Update on fast pulser design/prototyping for the ILC kickers (Webex)	C. Burkhart, SLAC
15:20	CLIC extraction systems (common WG6, 7, 8,)	M. Barnes, CERN

RF systems (Common WG8 and 4), Chaired by A. Grudiev		
16:00	Introduction	S. Guiducci, INFN
16:10	Transient beam loading correction at ILC DR	K. Kubo, KEK
16:35	RF system issues due to pulsed beam in ILC DR	S. Belomestnykh, Cornell
17:00	Conceptual design of the CLIC DR RF system	A. Grudiev, CERN
17:25	Discussion on 50% duty cycle operation of the ILC DR and synergies with CLIC DR RF design	ALL

DR Agenda – Thursday 21

Instabilities, Chaired by J. Urakawa		
9:00	Collective instabilities simulations for the CLIC damping rings	E. Koukovini-Platia, CERN
9:30	Observations and Analysis of Fast Beam-Ion Instabilities at SOLEIL	R. Nagaoka, SOLEIL
10:00	Coherent synchrotron radiation for damping rings: theory and experimental proposal	F. Zimmermann, CERN

E-cloud, Chaired by G. Rumolo		
11:00	Electron Cloud instability measurements	M. Billing, Cornell
11:30	Electron cloud mitigation at CESRTA	M. Palmer, Cornell

IBS, Chaired by Y. Papaphilippou		
14:00	Simulation of Intrabeam scattering	A. Vivoli, CERN

Wigglers (Common with WG8), Chaired by H. Schmickler		
16:00	Design and prototyping of Nb3Sn wigglers for the CLIC damping rings	D. Schörling, CERN
16:20	Short period NbTi wiggler prototype for CLIC damping ring	A. Bragin, BINP
16:40	Progress on the superconducting undulator for ANKA and on the instrumentation for R&D	S. Casalbuoni, ANKA

Closing session, Chaired by Y. Papaphilippou		
17:00	Recommendation on ILC DR EC mitigation (webex)	M. Pivi, SLAC
17:30	Discussion on future R&D planning, experimental program and LER collaboration	

ILC DR - 6.4 km Lattice

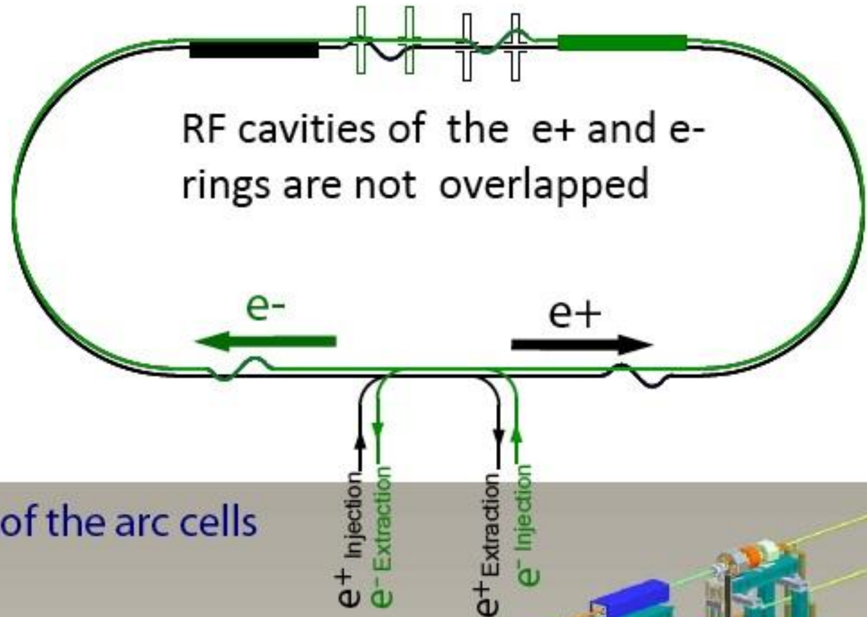
- Lattice for the 6.4 km is mature
  - **Racetrack layout optimal for CFS**
  - **Flexible momentum compaction ($2.9\ 10^{-4} \div 1.3\ 10^{-4}$)**
  - **DA large enough for injection acceptance**
- *Technical design is in progress for*:
  - **Arc layout**
  - **Wigglers**
  - **vacuum system**
- Vacuum chamber Impedance including bpms with bellows and wiggler SR absorbers has been evaluated

Positioning of the e+ and e- DR rings

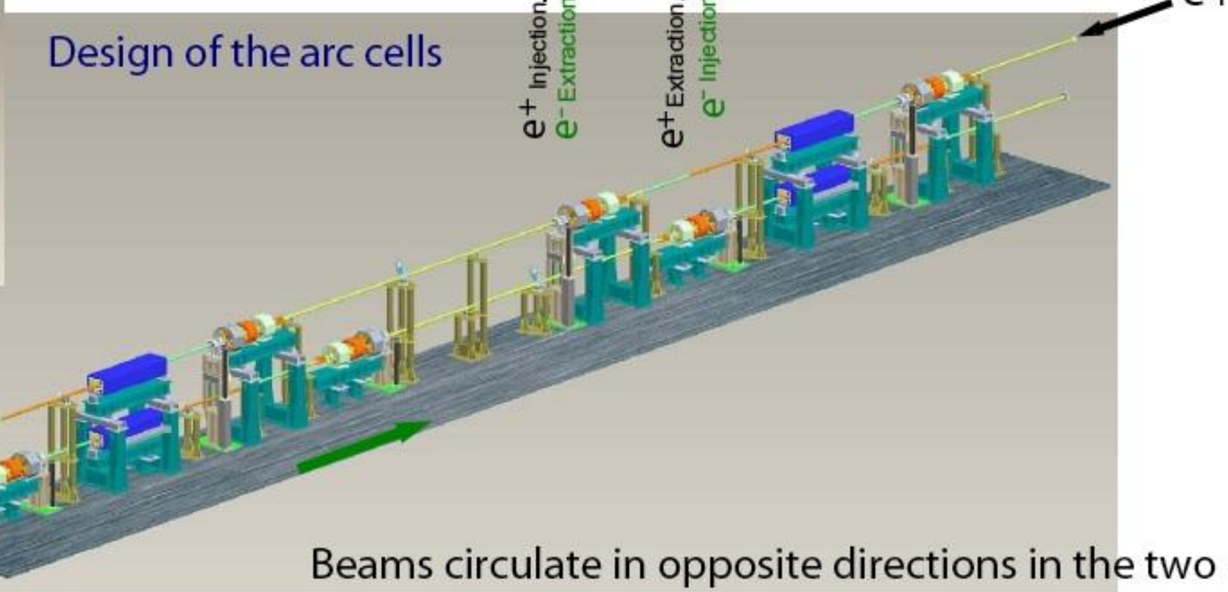
e- Damping Ring

e+ Damping Ring

The lattice of e- DR is identical to the lattice of the e+ DR.



Tunnel

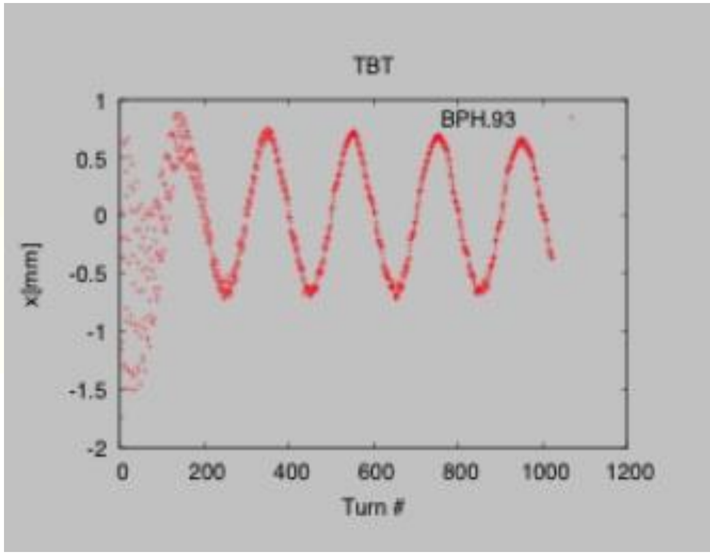


Beams circulate in opposite directions in the two rings.

A. Wolski et al. **Damping Rings Design Work at the Cockcroft Institute,** ILC10 Beijing

BPM Circuit upgrade (FNAL)

Able to measure Injection TBT, Narrowband Orbit, Narrowband Calibration , and Last Turn on every injection



Upgrade of Beam Instruments

- DR BPM readout (FNAL digitizer)
- EXT Strip-line BPM readout (SLAC-LCLS digitizer)
- Multi-OTR monitors

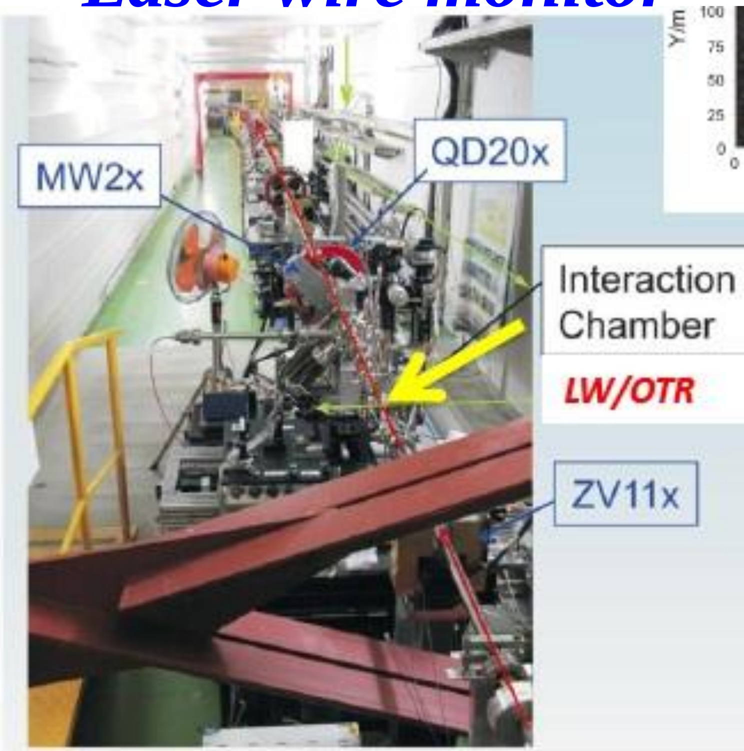
Upgrade of Accelerator

- Two LINAC klystron Modulators
- EXT corrector PS

R&D

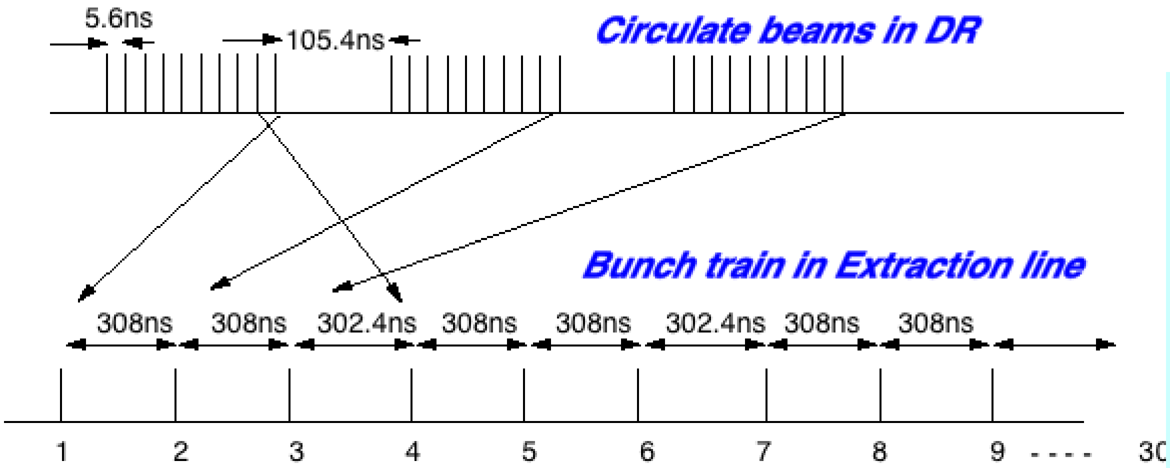
- Fast Kicker
- EXT Laser Wire
- 4-mirror optical cavity installation
- Cold BPM
- Single- and Multi-bunch instability

Laser wire monitor

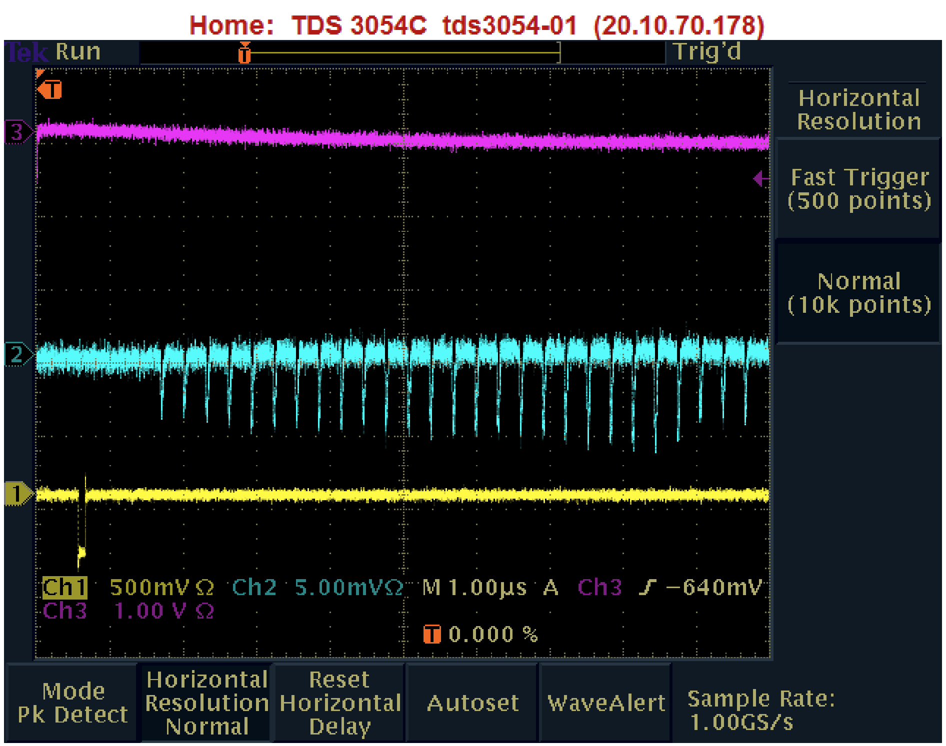


JAI(RHUL,Oxford) / KEK

Multi-bunch beam extraction by the Fast kicker



- *Kick angle was stable as $4x10^{-4}$ < ILC requirement.*
- *A pulse train delay circuit will be installed to stabilize the HV pulser for multi-bunch extraction.*



in DR:

- 3 Trains,
- 9(max 10) bunches/train with 5.6 nsec spacing

Extracted:

- 27(max 30) bunches with 308 ns spacing
- bunch-by-bunch profile follows that in the DR.
- bunches were extracted from the last bunch to the first bunch.

SB2009 Studies

- Low-power option (1312 bunches) → Smaller circumference damping ring (6.4 km → 3.2 km)
- 2 lattices with the same racetrack layout as the DCO4 and similar straight sections are at present under study
  - **FODO arc cells with variable momentum compaction $2.8 \cdot 10^{-4} \div 6.2 \cdot 10^{-4}$** (D. Wang, J. Gao and Y. Wang, IHEP)
  - **SuperB-like arc cells, low momentum compaction $1.3 \cdot 10^{-4}$** (M. Biagini, S. Guiducci, INFN)
- Different configuration options
  - **Low power: 1312 bunches, 5 Hz repetition rate**
  - **Low power: 1312 bunches, 10 Hz repetition rate**
  - **High power: 2625 bunches, 5 Hz repetition rate**

Main DR issues for BAW2 (SLAC 18-21st Jan. 2011):

- ECLOUD evaluations
  - **Comparison of 6.4km ring (2600 bunches) and 3.2km ring (1300 bunches)**
    - Both ring configurations exhibit similar performance for single bunch instability threshold
    - 3.2km ring is an acceptable baseline design choice
  - **Recommendation for mitigation techniques**
  - **Characterization of electron cloud at different bunch spacing in 3.2km ring: 6ns (1300 bunches) and 3ns (2600 bunches)**
- RF issues for 50% duty cycle DR operation

  (discussion at RF session, common WG2, WG8, WG4, Wednesday 16÷18)

EC Working Group Baseline Mitigation Plan

Mitigation Evaluation conducted at satellite meeting of ECLOUD`10 (October 13, 2010, Cornell University)

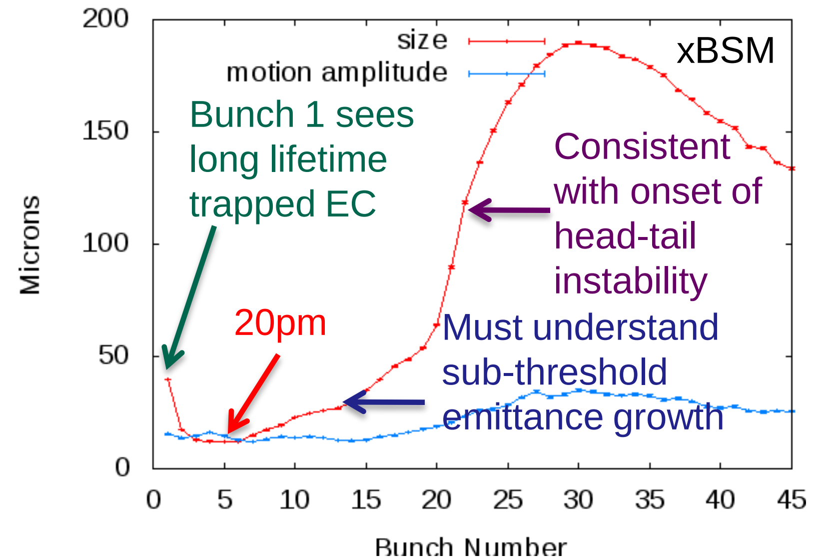
EC Working Group Baseline Mitigation Recommendation				
	Drift*	Dipole	Wiggler	Quadrupole*
Baseline Mitigation I	TiN Coating	Grooves with TiN coating	Clearing Electrodes	TiN Coating
Baseline Mitigation II	Solenoid Windings	Antechamber	Antechamber	
Alternate Mitigation	NEG Coating	TiN Coating	Grooves with TiN Coating	Clearing Electrodes or Grooves

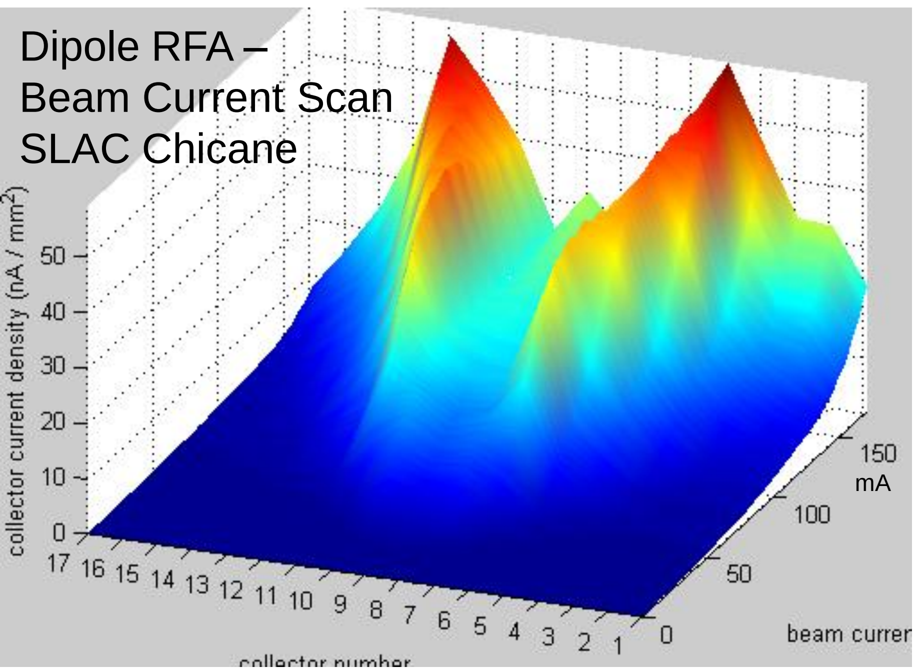
*Drift and Quadrupole chambers in arc and wiggler regions will incorporate antechambers

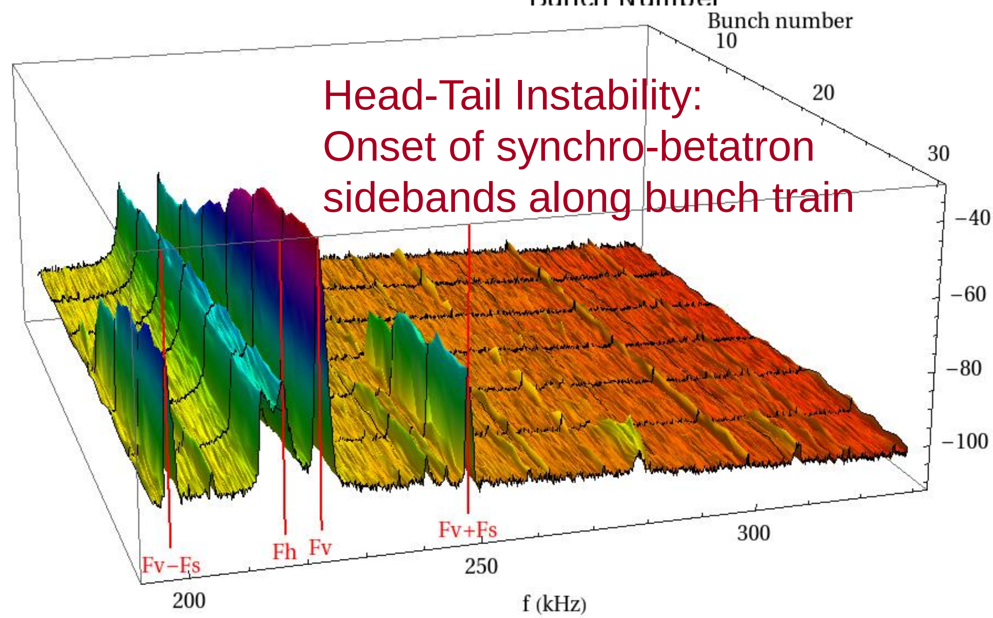
- Preliminary CESRTA results and simulations suggest the presence of *sub-threshold emittance growth*
  - Further investigation required
  - May require reduction in acceptable cloud density ⇨ reduction in safety margin
- An aggressive mitigation plan is required to obtain optimum performance from the 3.2km positron damping ring and to pursue the high current option

S. Guiducci, M. Palmer, M. Pivi, J. Urakawa on behalf of the ILC DR Electron Cloud Working Group

- The final run in Phase I of the CESRTA program concluded on September 30, 2010
- Program Highlights
  - Achievement of ε_y = 20pm target
  - Tests of a range of EC mitigations
  - Beam dynamics studies
  - Inputs for the ILC DR baseline design







ILC Damping Ring RF system 50% Duty Cycle

- e^- linac runs at 10 Hz alternating:
  - **1 pulse for positron production and injection into e^+ DR**
  - **1 pulse for collisions at 5 Hz**
- e^+ DR is empty half of the time (100 ms):
  - **Beam injected in ~1ms**
  - **Beam stored for 100 ms for damping**
  - **Beam extracted in ~1 ms**
- Main Concern:
  - **large beam loading variation in a very short time (1 ms)**
  - **implications on RF system and beam stability**
- WG2 RF Session, Wednesday 16:00: Discussion to get advice from RF experts in preparation of BAW2 meeting, SLAC 18-22 Jan 2011
  - **Feasible? Needs more R&D? Cost implications?**

Option #1: lower overvoltage factor

Alessandro Gallo (DAFNE RF system, LNF) performed further analysis and derived

$$\tan\psi_{\max} \approx -\frac{(R/Q)Q_{ext}I_{b_{\max}}}{V_c}\sin\varphi_0 = \frac{(R/Q)Q_{ext}I_{b_{\max}}}{V_c}\sqrt{1-\frac{1}{\eta^2}} \underbrace{=}_{eq.2} \sqrt{\eta^2-1}$$

$$P_{FWD}(I_b=0) = P_{beam_{\max}}\left[\frac{1}{4}+\frac{\tan^2\psi_{\max}}{4}\right] = \left(\frac{\eta}{2}\right)^2 P_{beam_{\max}}$$

where η is the overvoltage factor. One can see that for $\eta \le 2$ the cavities can be operated at fixed detuning while the power demand for zero beam current does not exceed the maximum beam power.

Questions:

- □ Is it possible to reduce the overvoltage factor?
- □ How it was chosen in the first place?

The 3.2 km ring has
$\eta \le 2$
for all the configurations

Summary

- 10 Hz operation of the ILC Damping Ring RF system seems to be feasible.
- We have presented four different options. Each of them however have challenges.
- Option #3 is the most attractive as the RF power demand is minimal under it. However, it requires extensive R&D.

(Option #3 Fast frequency tuner)

- Option #1 would be the most easily implementable if the overvoltage factor can be lowered to 2.

Common concerns & studies needed (in addition to those listed for individual options):

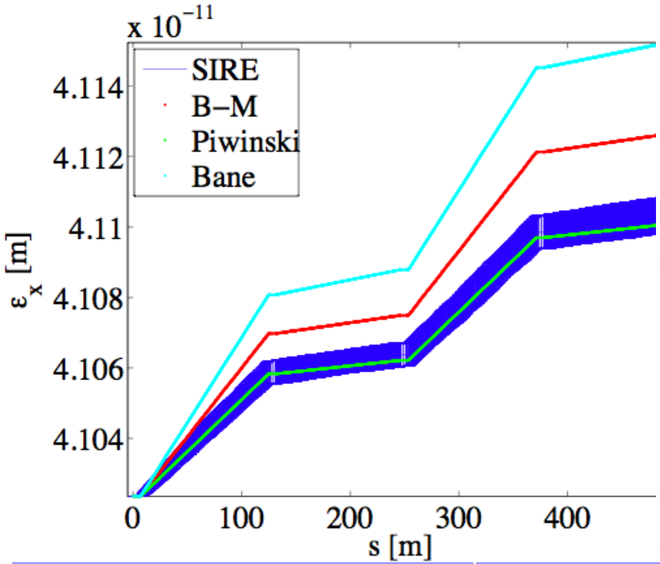
- RF window/coupler power handling with full reflection (except option #3)
- Feedforward to mitigate transients during beam injection/extraction
- Pulsed operation of the RF system is worth considering as it will save power and reduce thermal load on RF window/coupler. Two options here: (i) pulsed RF and klystron mod anode; (ii) pulsed klystron HV.

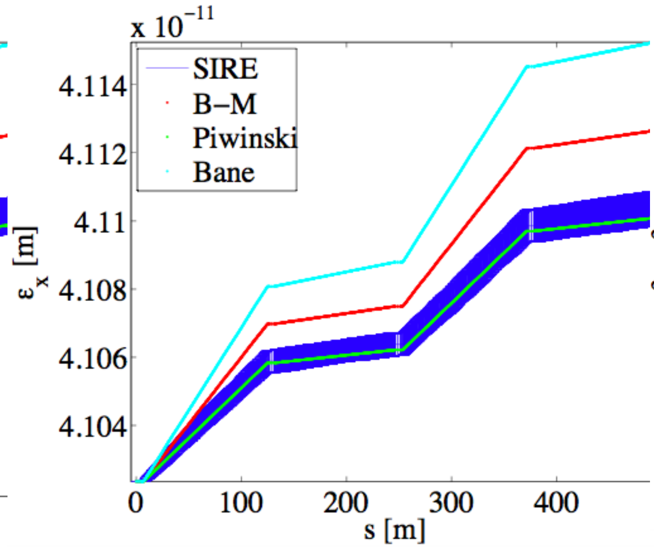
CLIC DR parameter optimization

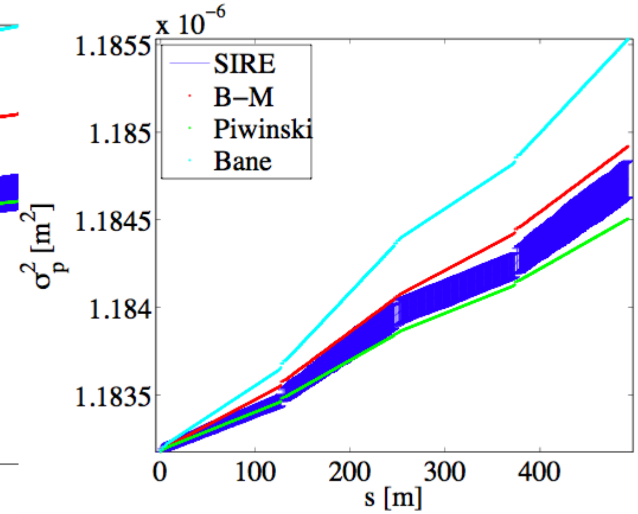
- Reasonable magnet strengths (magnet models already studied) and space constraints
- DA significantly increased
- TME optics with gradient in the bend and energy increase reduces IBS growth factor to 1.4 (as compared to 5.4 in original DR design)
- Reduction of space charge tune-shift with combined circumference reduction and bunch length increase
- Further optics optimization with respect to IBS and tracking code for comparaison with analytical theory

Parameters	Value
Energy [GeV]	2.86
Circumference [m]	420.56
Coupling	0.0013
Energy loss/turn [MeV]	4.2
RF voltage [MV]	4.9
Natural chromaticity x / y	-168/-60
Momentum compaction factor	8e-5
Damping time x / s [ms]	1.9/ 0.96
Dynamic aperture x / y [σ_{inj}]	30 / 120
Number of dipoles/wigglers	100/52
Cell /dipole length [m]	2.36 / 0.43
Dipole/Wiggler field [T]	1.4/2.5
Bend gradient [$1/m^2$]	-1.10
Max. Quad. gradient [T/m]	73.4
Max. Sext. strength [kT/m^2]	6.6
Phase advance x / z	0.452/0.056
Bunch population, [10^9]	4.1
IBS growth factor	1.4
Hor./ Ver Norm. Emittance [nm.rad]	400 / 4.5
Bunch length [mm]	1.6
Longitudinal emittance [keVm]	5.5

IBS tracking code







	1/Tx (s^{-1})	1/Ty (s^{-1})	1/Tz (s^{-1})
MADX (B-M)	1476.7	952.9	1010.6
Bjorken-Mtingwa (Martini)	1579.4	739.1	968.5
SIRE (compressed)	1224.6	732.5	815.6
SIRE (not compressed)	1181.1	691.8	802.0
Mod. Piwinski	1299.5	625.7	775.2

A. Vivoli, F. Antoniou, et al.

	γεx (m)	γεy (m)	εz (eV m)
Injection	74e-6	1.8e-6	130589
Extraction	498e-9	4.3e-9	3730
Equilibrium (NO IBS)	254e-9	3.7e-9	2914

- Developed Monte-Carlo tracking code for IBS including synchrotron radiation damping and quantum excitation (SIRE, based on MOCAC)
- Agreement between analytical emittance growth and the mean values obtained by 20 SIRE runs
- Final emittances obtained by SIRE are just within the CLIC DR budget but for lower longitudinal emittance

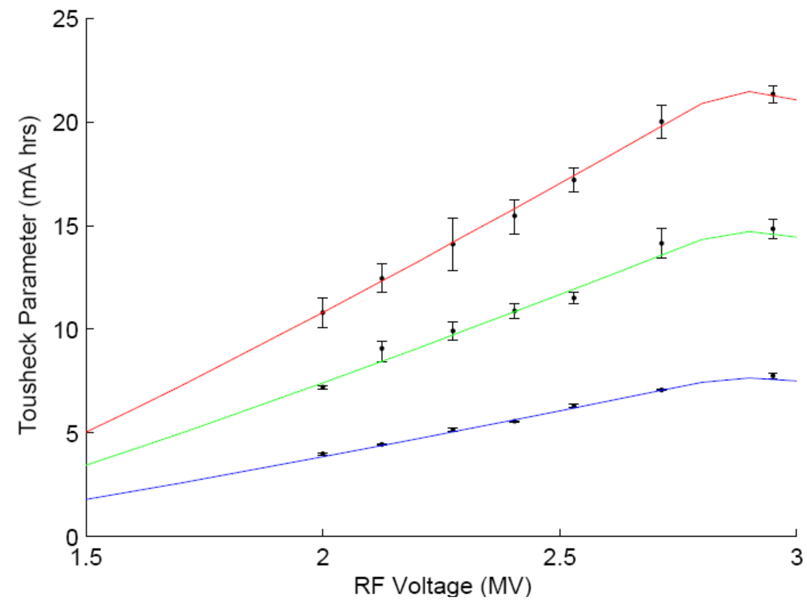
Reaching Quantum Limit Of Vertical Emittance

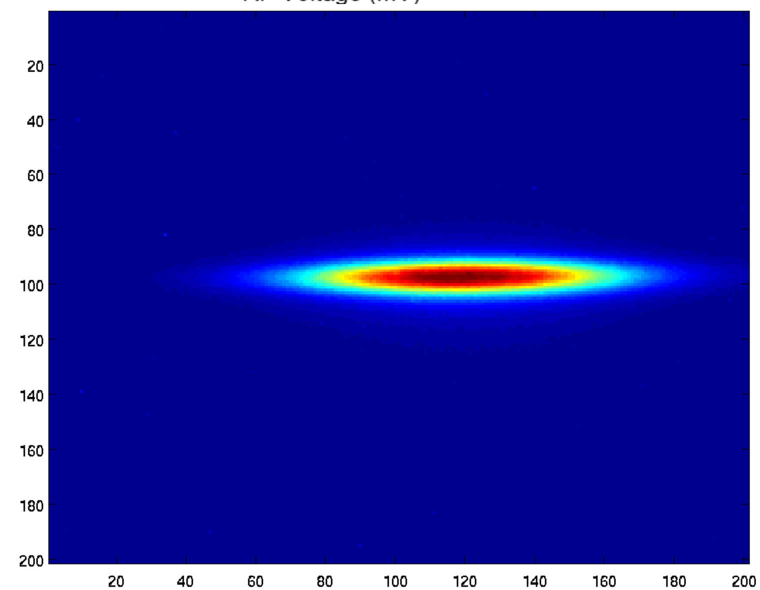
Set ϵ_y/ϵ_x (%)	Fitted ϵ_y/ϵ_x (%)	Fitted ϵ_y (pm)	Fit χ^2/dof
0.01	$0.012^{+0.003}_{-0.002}$	$1.2^{+0.3}_{-0.2}$	0.69
0.06	$0.043^{+0.013}_{-0.008}$	$4.5^{+1.3}_{-0.8}$	0.42
0.10	$0.092^{+0.025}_{-0.012}$	$9.4^{+2.6}_{-1.2}$	0.01

- Tousheck component variation with RF voltage in ASLS
- Blue curve fit corresponds to

  ε_y = 1.24 ± 0.3 pm
- Beam size measurement in Diamond after coupling correction
- V beam size at source point 6 μm
- Emittance coupling 0.08% →

  V emittance 2.2 ± 0.4 pm





E.Tan, R. Dowd, R. Bartolini

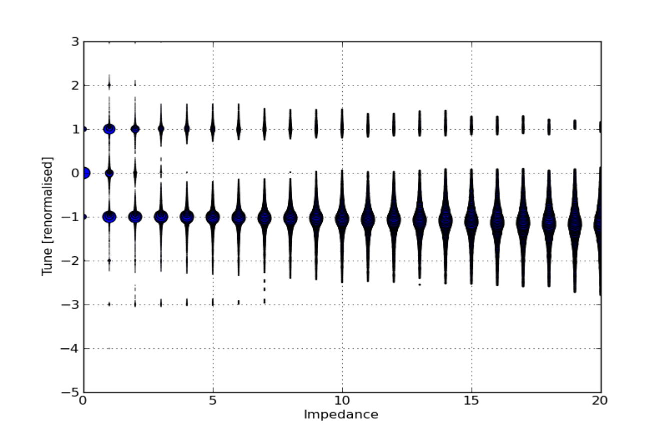
CLIC Damping Rings TMCI simulations

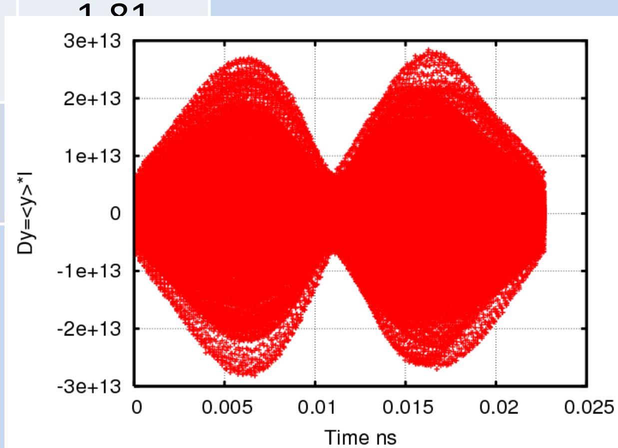
Results for round chamber

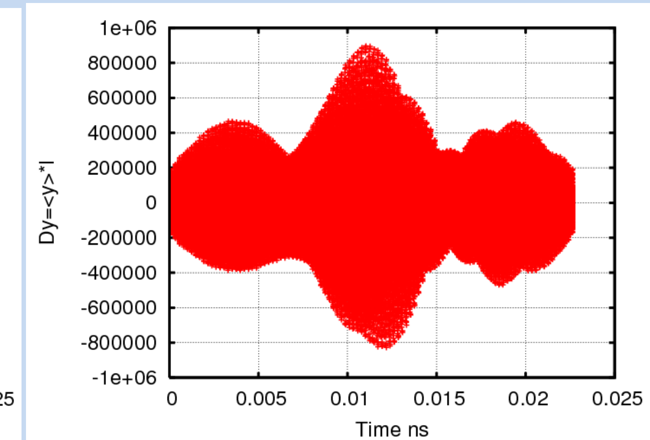
E. Koukovini-Platia, G. Rumolo

	x	y	x	y
Chromaticity H/V	Threshold [MΩ/m]		Rise time (ms) τx=1.88, τy=1.91	
0/0	10	11	0.38	0.49
9.2/1.9	16	3	1.92	2
18.4/3.8	stable	6	stable	1.81
27.6/5.7	stable	13	stable	1.81

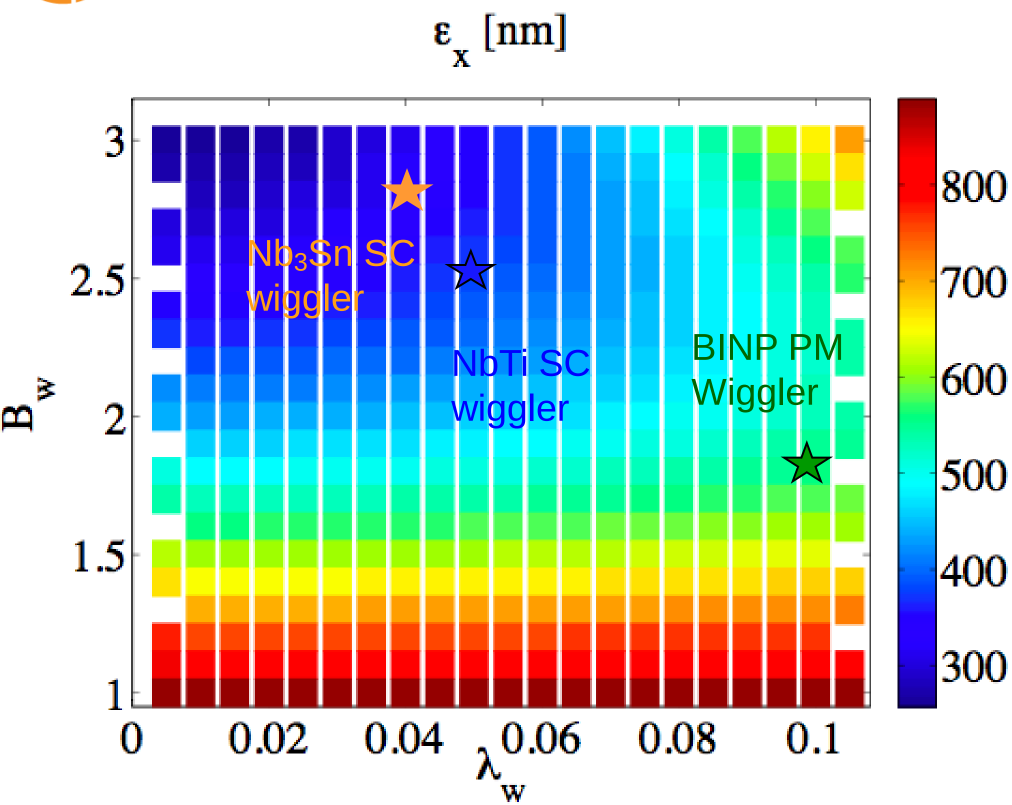
- For chromaticity 0, the TMCI threshold is at 10 and 11 MΩ/m for x,y respectively
- For positive chromaticity, there is no TMCI but another instability occurs.
- As the chromaticity is increased, higher order modes get excited, less effect, move to higher instability thresholds







Wigglers' effect with IBS

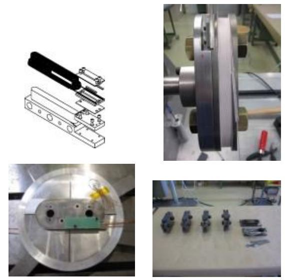


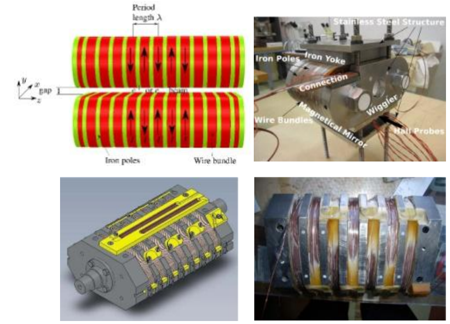
Parameters	BINP	CERN
B_{peak} [T]	2.5	2.8
λ_W [mm]	50	40
Beam aperture full gap [mm]	13	
Conductor type	NbTi	Nb_3Sn
Operating temperature [K]	4.2	

- Stronger wiggler fields and shorter wavelengths necessary to reach target emittance due to strong IBS effect
- Current density can be increased by different conductor type
- Nb_3Sn can sustain higher heat load (potentially 10 times higher than NbTi)
- Two wiggler prototypes
  - 2.5T, 5cm period, built and currently tested by BINP
  - 2.8T, 4cm period, designed by CERN/Un. Karlsruhe
- Mock-ups built and magnetically tested
- Prototypes to be installed in a storage ring for beam measurements

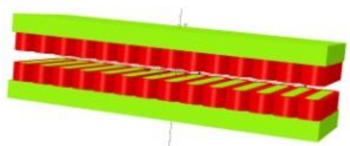
Nb_3Sn Technology

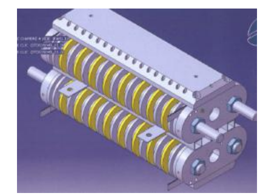
Nb-Ti Technology



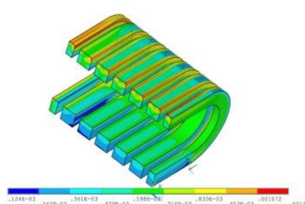


CDR





SCU14 in ANKA



TDR

D. Schoerling, S. Russenchuck, A. Bragin et al.

Conceptual Design of CLIC DR RF system

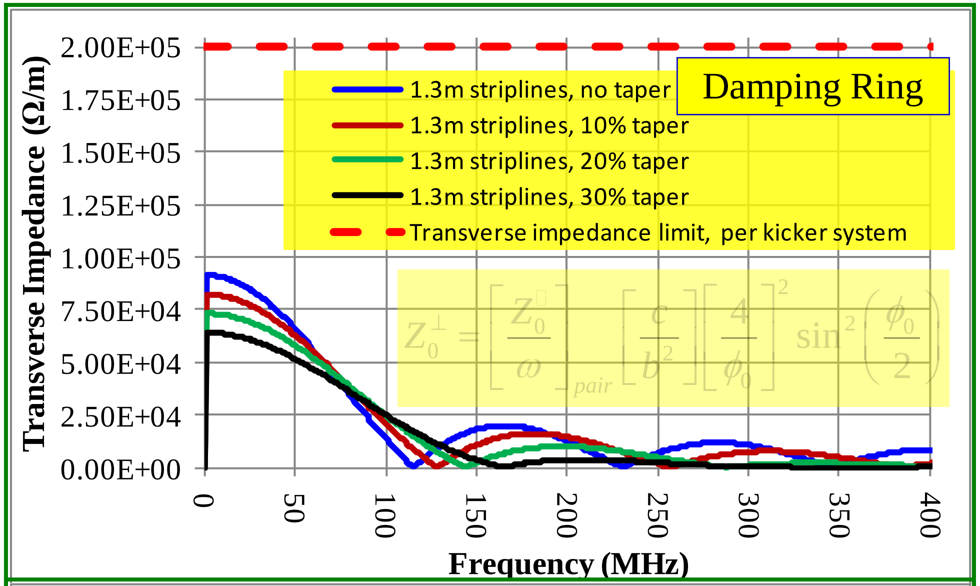
All 3 options seems to be feasible but have different issues summarized below

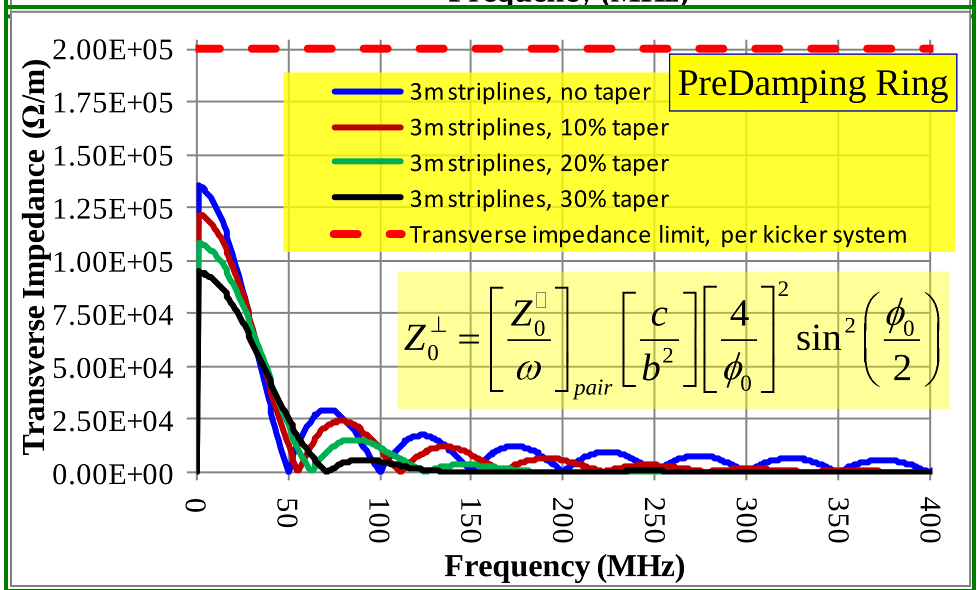
	"A la linac"		ARES		SC	
Train length [ns]	156	312	156	312	156	312
Total stored energy [J]	0.3		77	154	77	154
Shunt impedance R [MΩ]	36		1.9	0.95	20000	10000
Total rf power [MW]	6 (3)		6	~12	0.6	1.2
Total length [m]	10 (5)		~50	~50	~20	~40
Klystron bandwidth [%]	> 1		< 0.1		< 0.1	
Voltage modulation	Strong: Phase + amplitude		No, or very small phase	Could be stronger	No, or very small phase	Could be stronger
Strong HOM damping	demonstrated		demonstrated		demonstrated in single cell	
Transverse impedance	Highest		Lower		Lowest	
Cryogenic power [MW]	0		0		>0.5	
Main Challenge	Voltage modulation for transient compensation, Low efficiency		Low efficiency Big size		Low R/Q, Rf design both for fundamental and for HOM	

ϕ_s reduction will help a lot here

A. Grudiev

Main Beam: Transverse Beam Impedance of CLIC DR and PDR Striplines





Allowable transverse broad band beam impedance, in the CLIC PDR & DR, is 10MΩ/m. Maximum transverse impedance per kicker system is assumed to be 2%, i.e. 200kΩ/m.

Calculated transverse impedance, for 1.3m long striplines, is less than 200kΩ/m, for all frequencies, with or without tapers.

Calculated transverse impedance, for 3m long striplines, is less than 200kΩ/m, for all frequencies, with or without tapers.
For longitudinal impedance reasons, two sets of striplines with individual length of 1.5m may be used.
Transverse impedance of two sets of 1.5m striplines would be slightly greater than twice that shown for 1.3m striplines. Thus each PDR kicker system would meet the transverse impedance specification.

Striplines will be prototyped under the Spanish Program “Industry for Science”.

M. Barnes

CLIC 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 or 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 system

- Experimental program set-up for measurements in storage rings and test facilities
  - ALBA (Spain), ANKA (Germany), ATF (Japan), Australia Synchrotron (Australia), CESRTA (USA), DIAMOND (UK), SOLEIL (France),…

Low Emittance Rings collaboration

- Initiated by the ILC-CLIC working group on damping rings
- Workshop organized in January 2010 at CERN identifying items of common interest among the low emittance rings community (synchrotron light sources, linear collider damping rings, b-factories)
- Low emittance rings working groups formed
- **EU network proposal is being prepared**
- **Next workshop to be organized during summer 2011**

	Working groups
1	**Low emittance cells design**
2	**Non-linear optimization**
3	**Minimization of vertical emittance**
4	**Integration of collective effects in lattice design**
5	**Insertion device, magnet design and alignment**
6	**Instrumentation for low emittance**
7	**Fast Kicker design**
8	**Feedback systems (slow and fast)**
9	**Beam instabilities**
10	**Impedance and vacuum design**