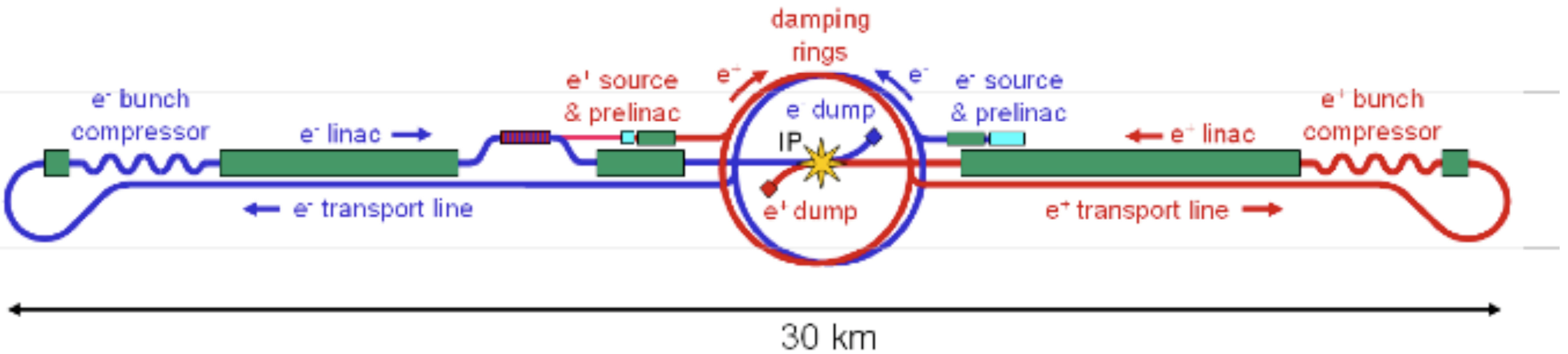
ILC damping rings and common design issues with CLIC

S. Guiducci

CLIC09

October 14, 2009

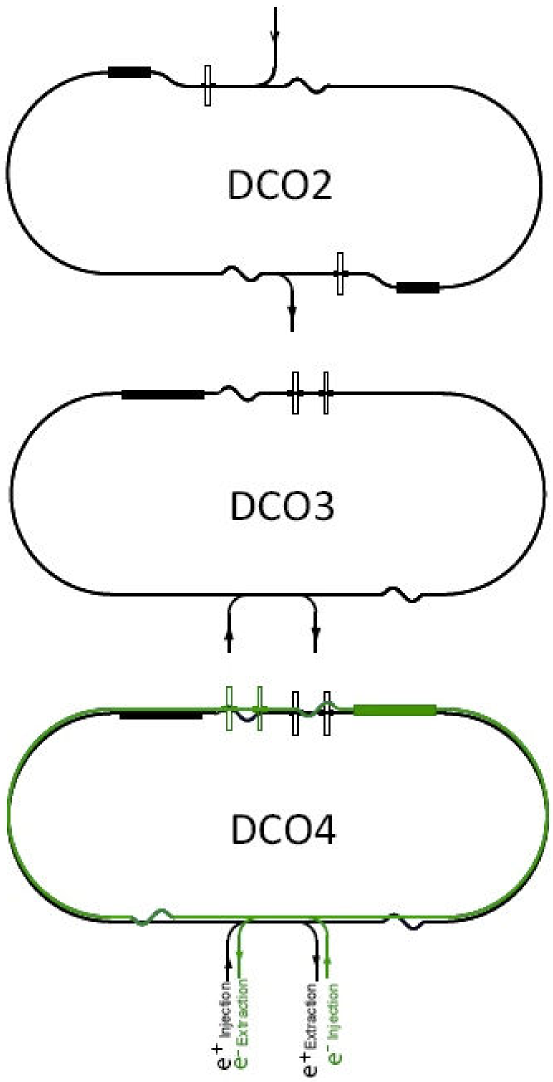
ILC Damping Ring Layout



Two 6.4 km, 5 GeV damping rings are located in a shared tunnel around the interaction region

ILC Reference Design Report (RDR) presented at the Beijing GDE Meeting, IHEP, 4-7 February 2007 (http://www.linearcollider.org/cms/)

RDR Lattice Update



Evolution of the lattice design

Jan 2008: DCO2

- 6.4 km circumference racetrack layout
- FODO - style arc cells
- Injection/extraction in opposite straights
- The left straight section is similar to the write straight section

Mar 2009: DCO3

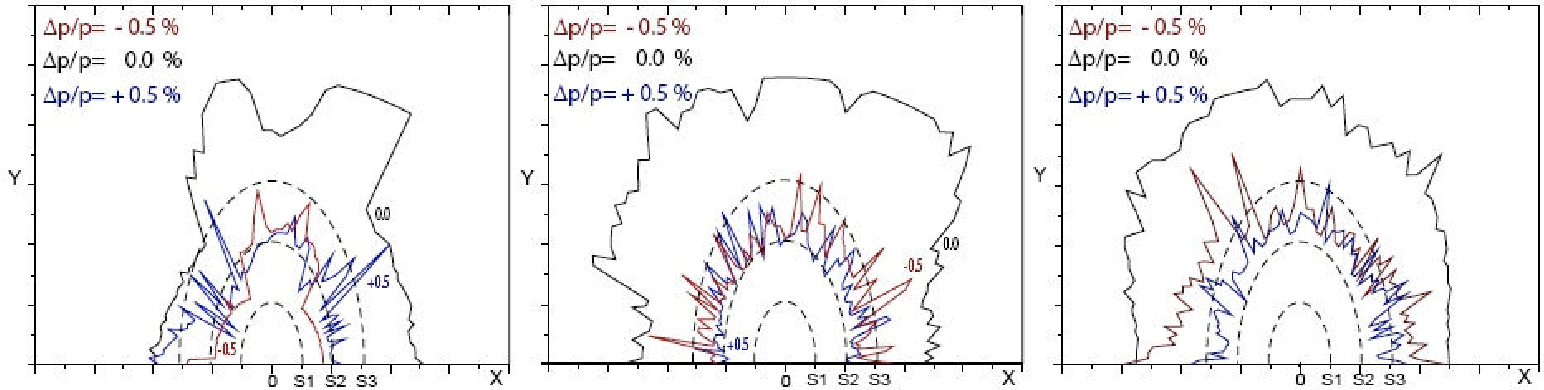
- 6.4 km circumference racetrack layout
- Injection /extraction in one straight
- All wigglers and RF cavities in another straight.

Aug 2009: DCO4

- 6.4 km circumference racetrack layout
- The e+ injection and e- extraction beam lines for both e+ and e- rings are in the same tunnel when two rings are on top of each other.

M. Korostelev

Dynamic aperture of the DCO2, DCO3 and DCO4 lattices at arc cell phase advance close to 72°



DCO2 (nux/nuy=64.12 / 61.41) DCO3 (nux/nuy=61.12 / 61.41) DCO4 ($\nu x/\nu y$ = 61.12 / 60.41)

Dashed ellipses show maximum particle coordinates for injected beam size:

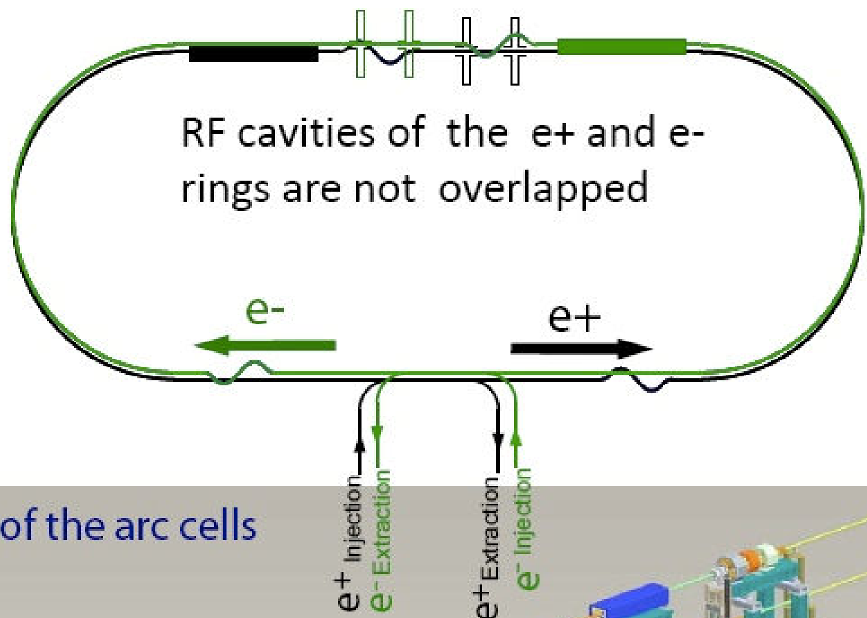
S1 one injected beam size: 25 mm horizontally and 7.4 mm vertically

S1 - one injected beam size
S2 - double injected beam size
S3 - triple injected beam size

Positioning of the e+ and e- DR rings

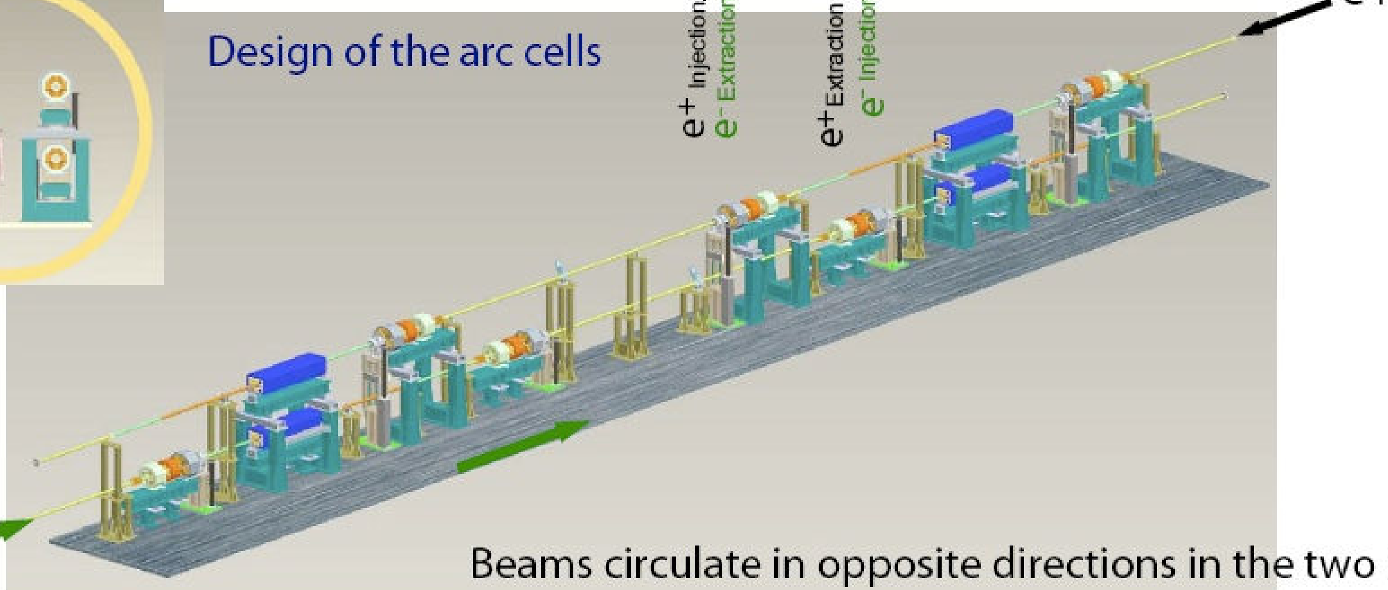
e- Damping Ring
e+ Damping Ring

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



Tunnel

Design of the arc cells



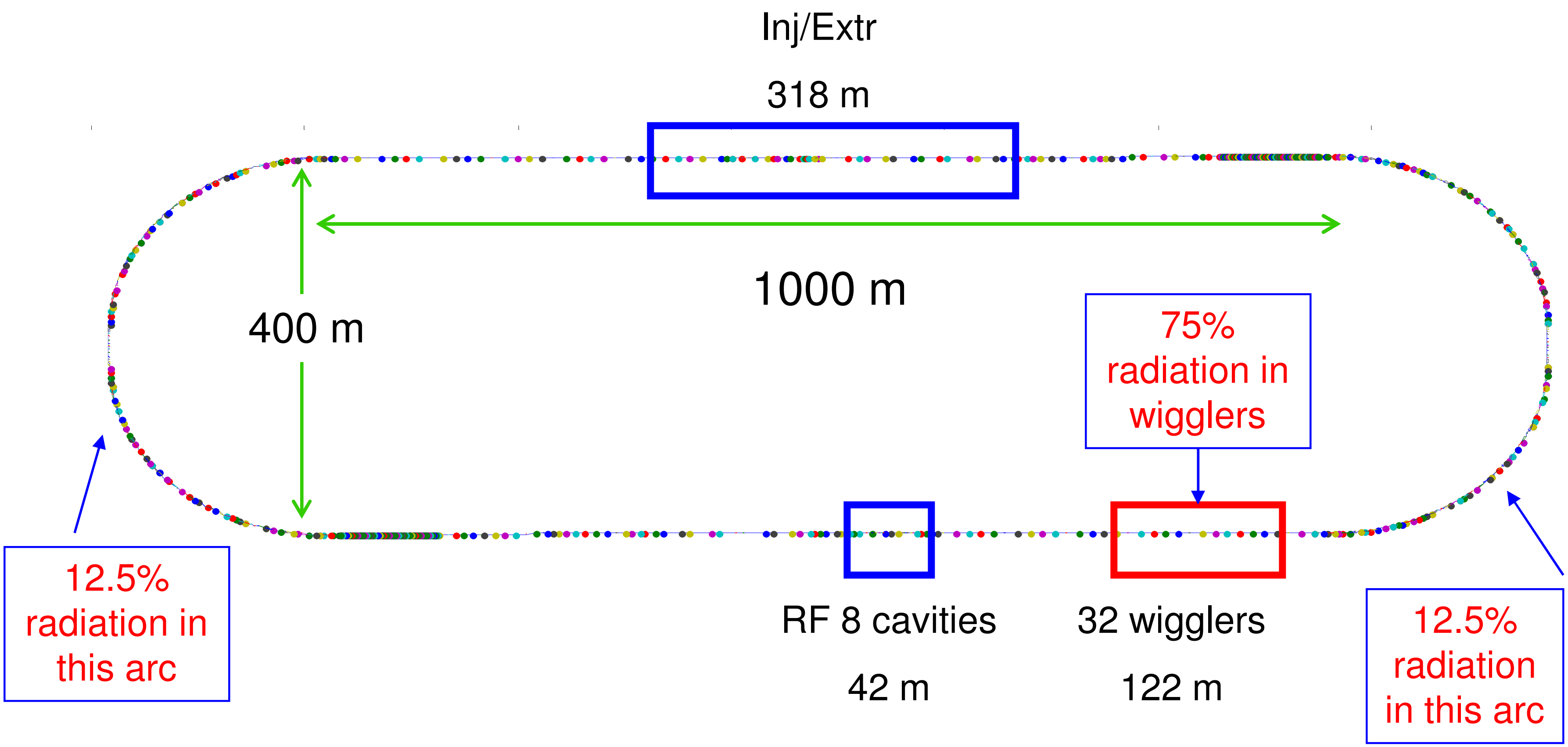
Beams circulate in opposite directions in the two rings.

New Baseline SB2009

- **DR circumference 6.4 ⇒ 3.2 km**
- **N bunches 2600 ⇒ 1300**
- **Reducing circumference and number of bunches by keeping the same current keeps the same DR performance and reduces costs**
- **Technical work done for 6 km ring can be applied to 3 km,**
  - similar layout
  - Nearly same straight sections as DCO4
  - arcs based on SuperB-like cells

SB2009 - DSB3 LATTICE

STRSECI: INJ/EXTRACTION



STRSECR: RF AND WIGGLERS

ILC/CLIC DR Parameters 2008

	ILC	CLIC
Energy (GeV)	5	2.4
Circumference (m)	6476	365
Bunch number	2700 - 5400	312
N particles/bunch	$2\text{x}10^{-10}$	$3.7\text{x}10^{-9}$
Damping time τ_x (ms)	21	1.5
Emittance $\gamma\varepsilon_x$ (nm)	4200	381
Emittance $\gamma\varepsilon_x$ (nm)	20	4.1
Momentum compaction	$(1.3 - 2.8)\text{x}10^{-4}$	0.80^{-4}
Energy loss/turn (MeV)	8.7	3.9
Energy spread	$1.3\text{x}10^{-3}$	$1.4\text{x}10^{-3}$
Bunch length (mm)	9.0 - 6.0	1.53
RF Voltage (MV)	17 - 32	4.1
RF frequency (MHz)	650	2000

ILC/CLIC DR Parameters 2009

	ILC	CLIC
Energy (GeV)	5	2.9
Circumference (m)	3238	493
Bunch number	1300	312
N particles/bunch	$2\mathrm{x}10^{10}$	$4.1\mathrm{x}10^{9}$
Bunch distance (ns)	6.2	0.5
Average current (mA)	387	125
Bunch peak current (A)	25	21
Damping time τ_x (ms)	24	1.6
Emittance $\gamma\varepsilon_x$ (nm)	5300	390
Emittance $\gamma\varepsilon_x$ (nm)	20	4.9
Momentum compaction	$1.3\ \mathrm{x}10^{-4}$	$0.6\ \mathrm{x}10^{-4}$
Energy loss/turn (MeV)	4.4	5.8
Bunch length (mm)	6.0	1.4
RF Voltage (MV)	7.5	7.4
RF frequency (MHz)	650	2000
Natural chromaticity x/y	-100 / -63	-149 / -79

Common issues

- Low Emittance Tuning
- Collective effects:
  - **e-cloud**
  - **Fast ion**
  - **IBS**
  - **Impedance related effects**
- Wiggler dominated ring

Objectives

Attain sufficiently low vertical emittance to enable exploration of

- dependence of electron cloud on emittance
- emittance dilution effect of e-cloud

- Design/install low emittance optics ($1.5 < E_{beam} < 5.0$ GeV)
  - Exploit damping wigglers to reduce damping time and emittance
- Develop beam-based techniques for characterizing beam position monitors
  - BPM offsets, Gain mapping, ORM and transverse coupling measurements ==> BPM tilt
- Also for measuring and minimizing sources of vertical emittance including
  - Misalignments
  - Orbit errors
  - Focusing errors
  - Transverse coupling
  - Vertical dispersion
- Develop single bunch/single pass measurements of vertical beam size
- Characterize beam current dependence of lifetime in terms of beam size
- Measure dependencies of beam size/lifetime on
  - Beam energy
  - Bunch current
  - Species

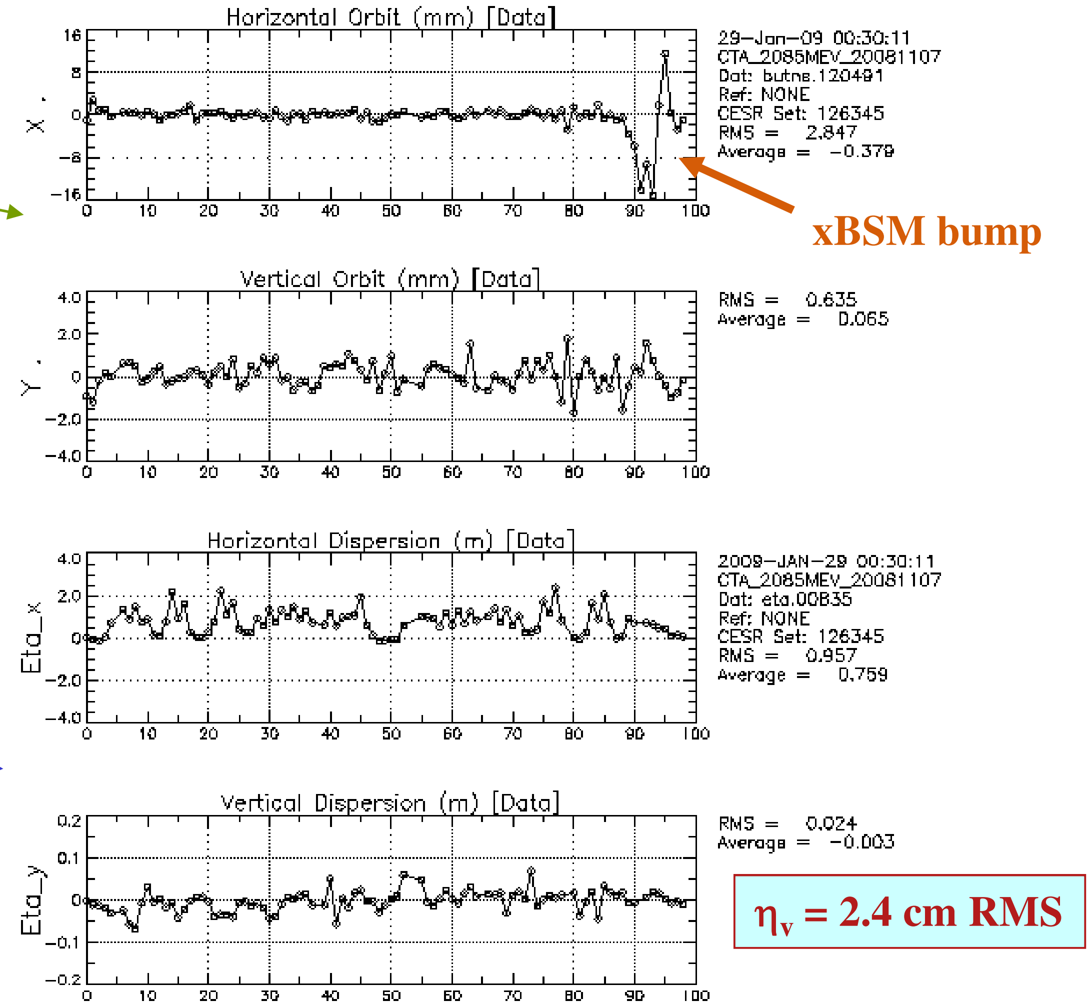
CesrTA
Low emittance tuning

Orbit

A feature of the orbit is the closed horizontal bump required to direct xrays onto x-ray beam size monitor

-Measure and correct vertical dispersion using skew quads (14) and vertical steering magnets (~60)

Residual vertical dispersion
RMS ~ 2.4cm - Signal or systematic?
Accuracy of dispersion measurement is limited by BPM systematics



Measured with older *relay* BPM system!!

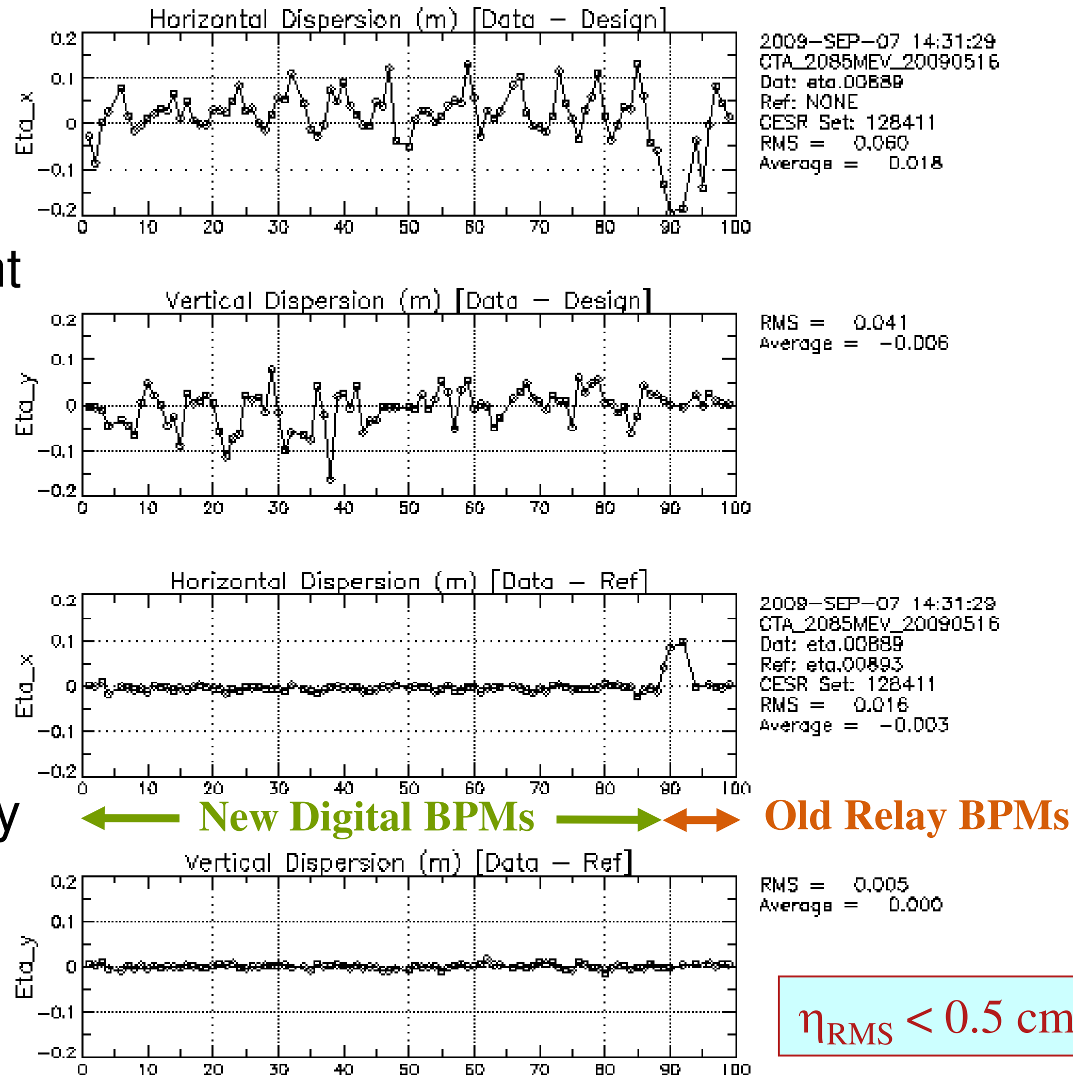
Note: Residual vertical dispersion 1 cm, corresponds to ε_v ~ 10pm

CBPM II Modules: V Dispersion

After Installation of 80+ CBPM II modules

Dispersion Measurement

Reproducibility



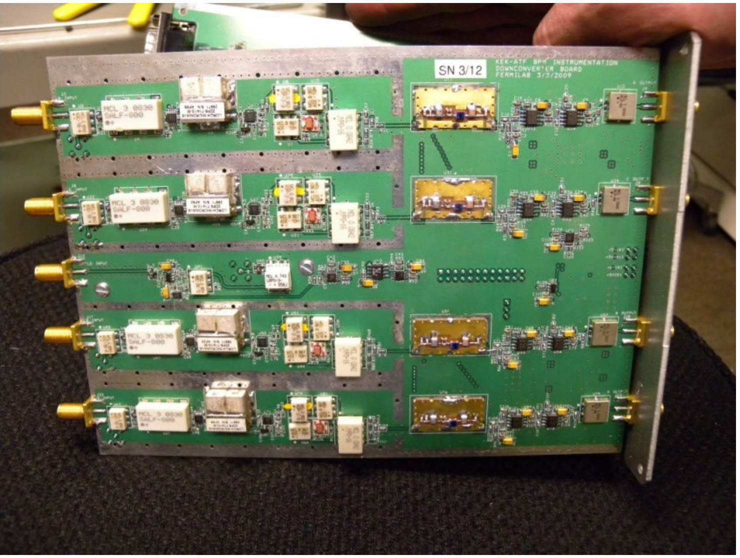
$\eta_{RMS} < 0.5$ cm

Present $\varepsilon_v \leq 40$pm
Will pursue 20pm with new BPM system during Nov-Dec Experimental run

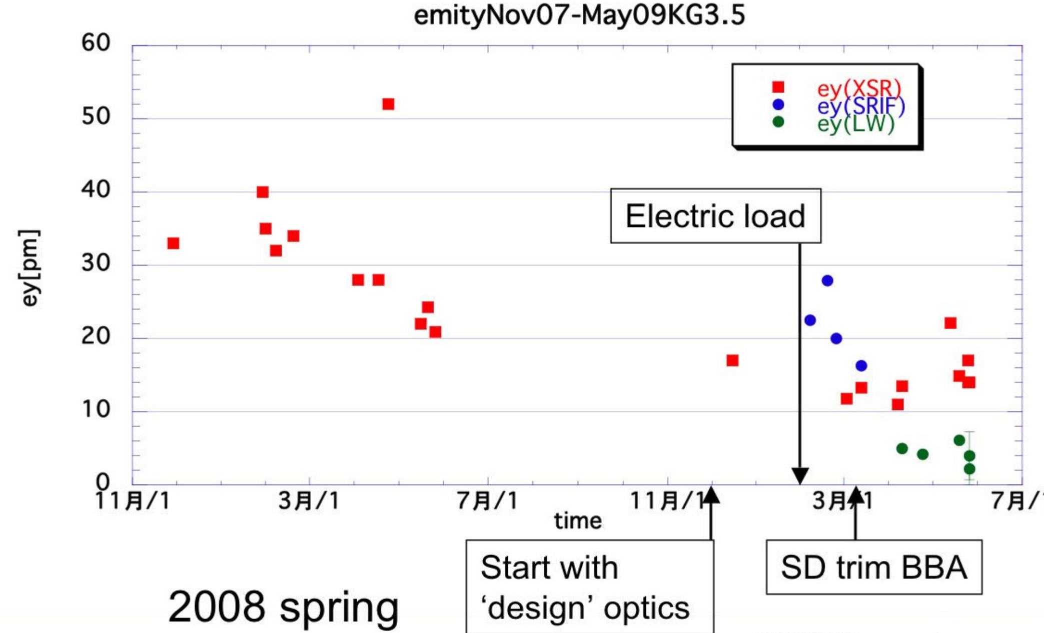
LCWA09 M. Billing

ATF Low Emittance Tuning

- **Necessary: a state-of-the-art BPM system, utilizing**
  - **a broadband turn-by-turn mode (< 10 μm resolution)**
  - **a narrowband mode with high resolution (~ 100 nm range)**



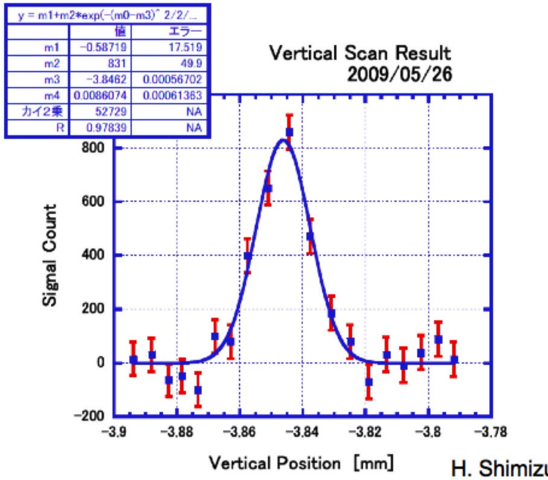
Measured Emittance



2009 spring
$I=5\text{-}6\times10^9$

Example of DR Laser Wire measurement

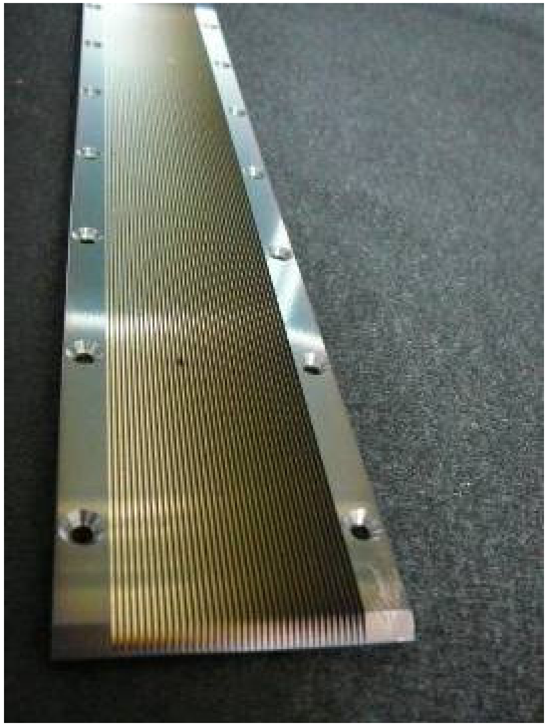
s = 8.6 mm (convolution of beam size and laser size)



H. Shimizu

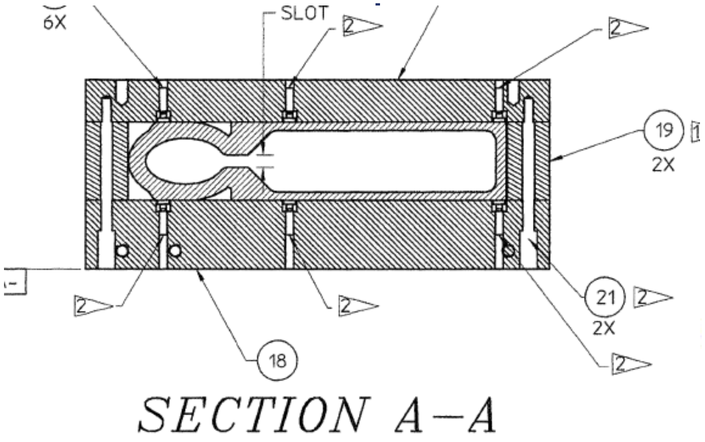
e-cloud mitigation

5mm groove tests in KEKB: reduction up to one order of magnitude less cloud current



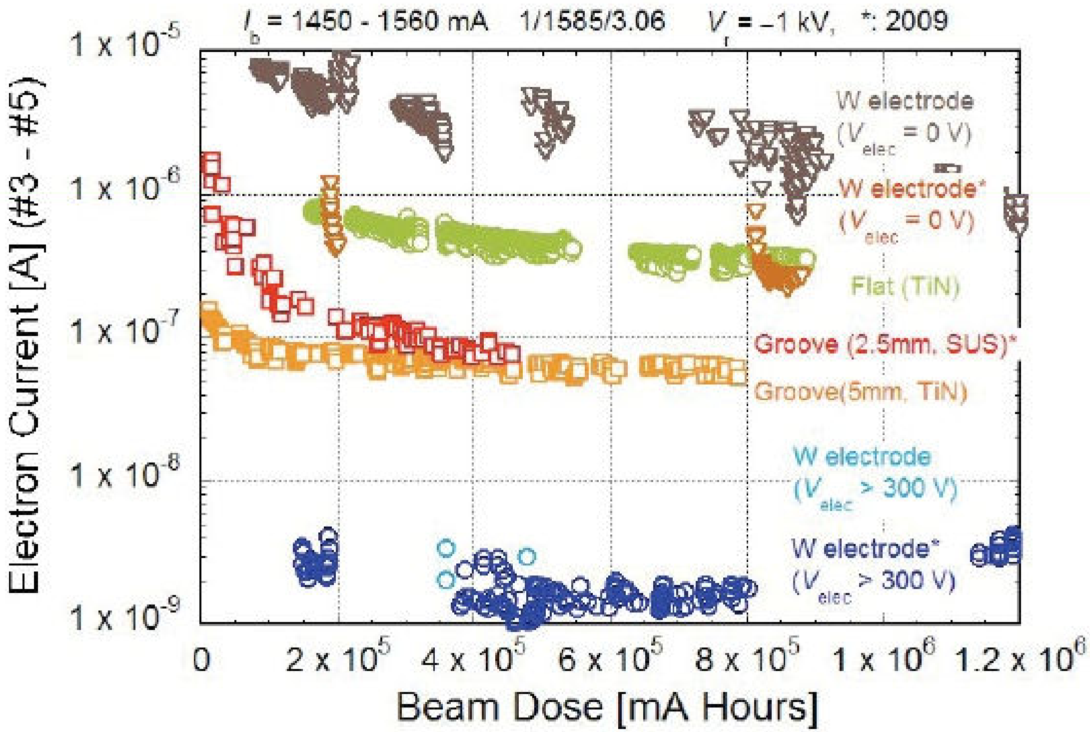
New 2mm groove manufactured at KEK. SLAC-KEK design.

SLAC: PEP-II chamber analysis of TIN surface after 10 years



Groove and Clearing electrode

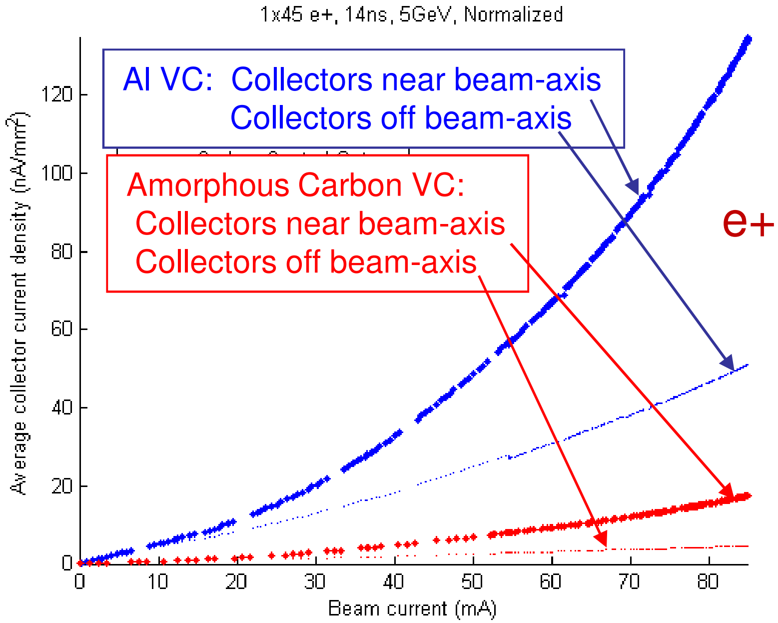
- Compared to the case of TiN-coated flat surface;
  - Clearing electrode (> +300 V): 1/100~1/500
    - ~1/50 of groove structure



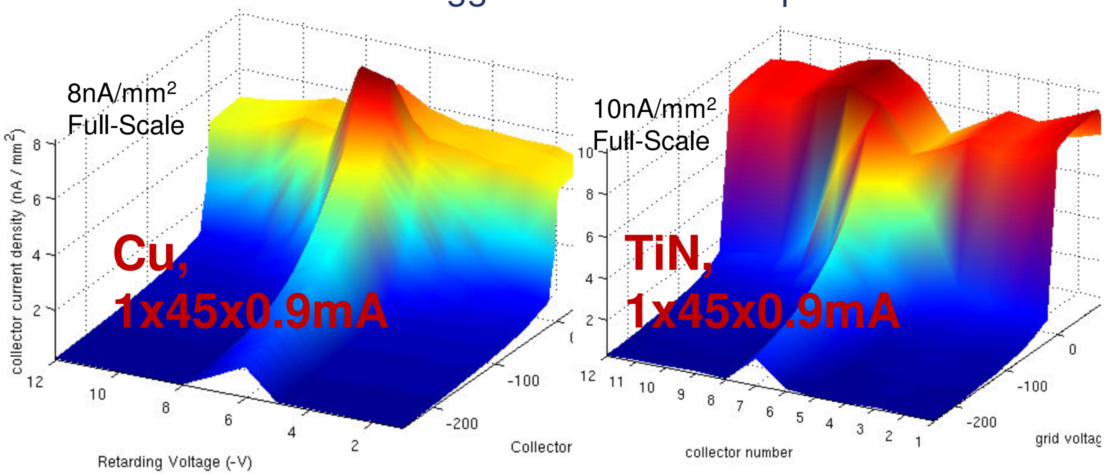
Suetsugu

Mitigation Studies

- Comparisons of EC mitigations:
  - **Environments: Drift, Wiggler**
  - **Chamber Surfaces: Al, Cu, TiN coating, amorphous carbon coating,**

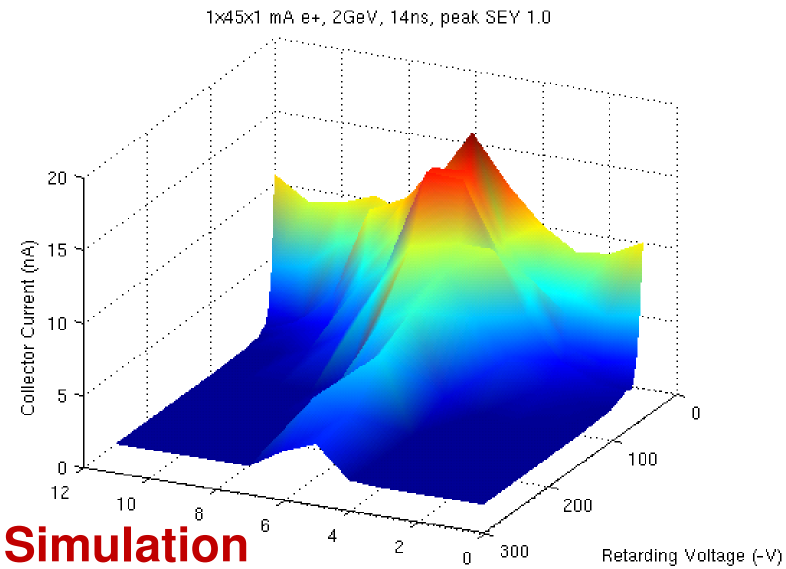


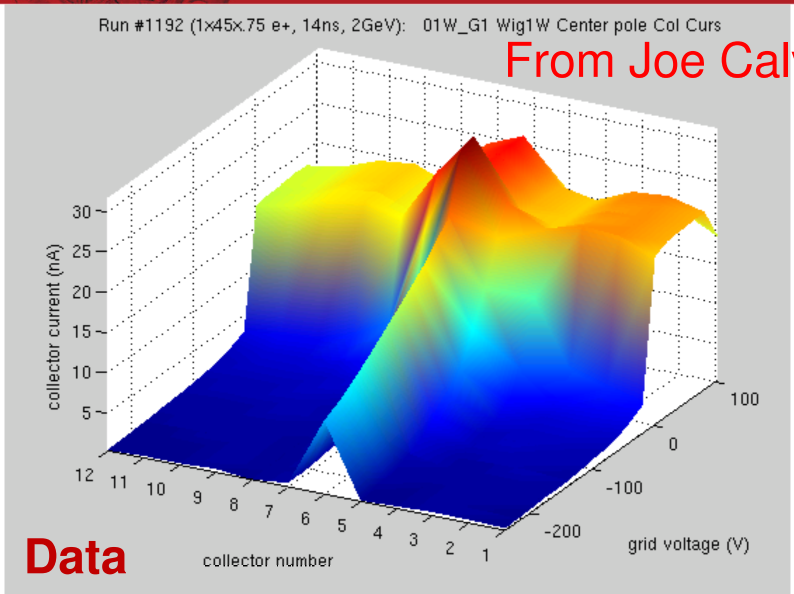
Cu and TiN-coated Wiggler Chamber Comparisons



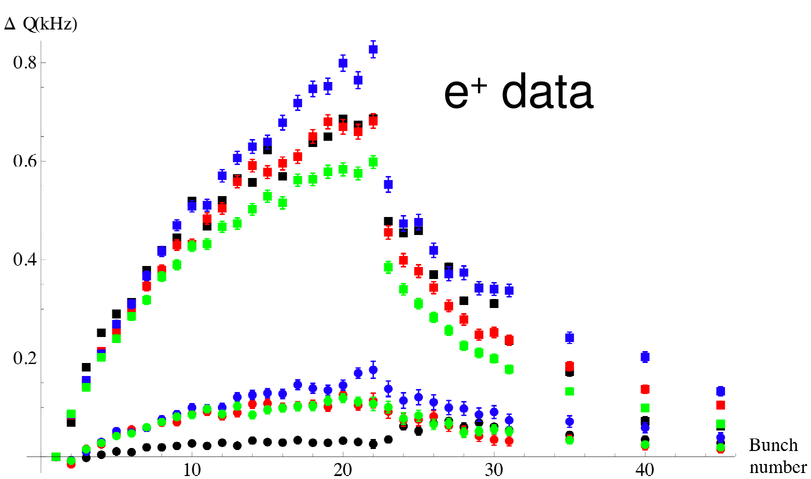
Measurements at CesrTA

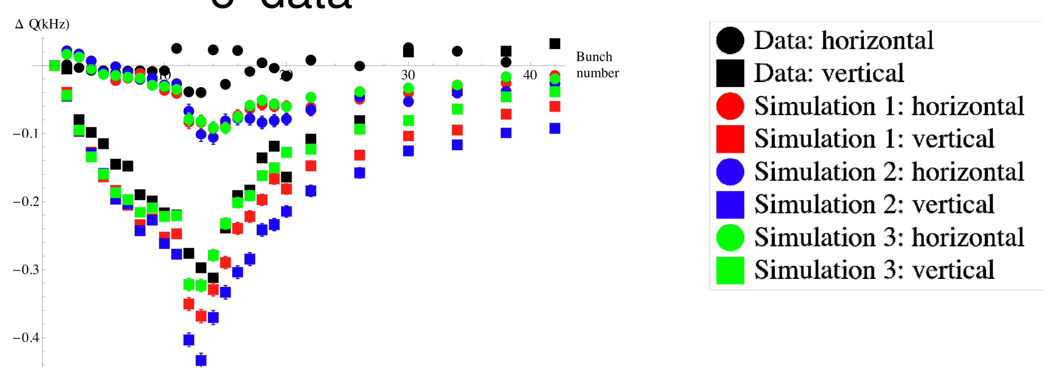
Wiggler: ECLOUD RFA Model





Coherent tune shift vs. bunch number

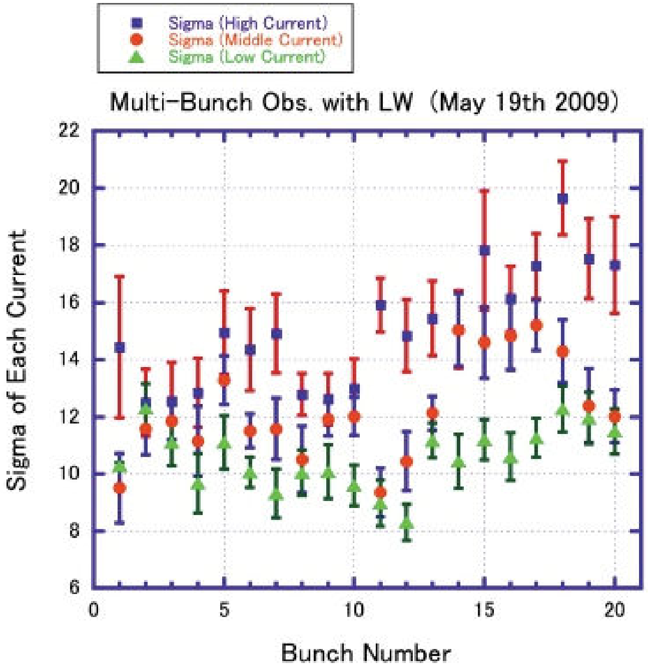




E-cloud Working Group Charges

- To evaluate electron cloud mitigation techniques, simulations and code benchmarking for the Damping Ring. In particular, evaluate the differences between mitigations as grooves clearing electrodes, coating (TiN, TiZrV NEG and amorphous Carbon) regarding their feasibility, effectiveness, impact on the vacuum system, on the beam impedance and on costs, for different regions of the DR as drifts, arc magnets and wigglers.
- To recommend a baseline solution for the electron cloud mitigations in the 6.4km (RDR) and 3.2km (SB2009) DR.
- Evaluate the 'upgrade' potential from the SB2009 proposed 1312 bunches back to the current RDR nominal value of 2623 (doubling the current) immediately identified bottlenecks.
- Evaluate the current limits due to e-cloud for the 3.2 km DR.

Fast Ion studies at ATF



0.4x10^{10}/bunch

0.3x10^{10}/bunch

0.1x10^{10}/bunch

We observed a beam-size growth of 50%.
It becomes clear than the result of 2007.
Emittance growth in 2004 was much bigger.
Is the emittance really small now?
Improve the LW measurement.

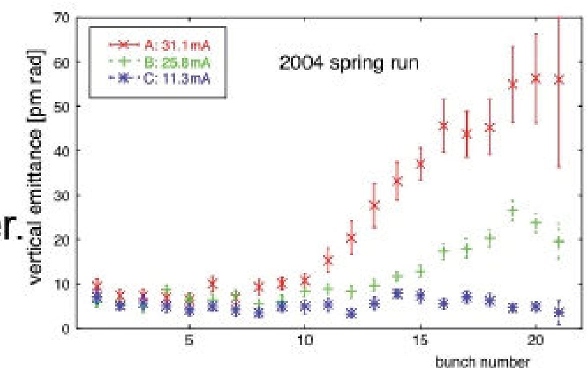
DR vertical emittance is almost recovered ~< 10 pm. Multi-bunch beam should be well tuned just before the FII study.

First step: Re-confirmation of the 2004 results.

Then measurements by changing the ionization condition (beam intensity, ion pump ON/OFF, Gas injection, …)

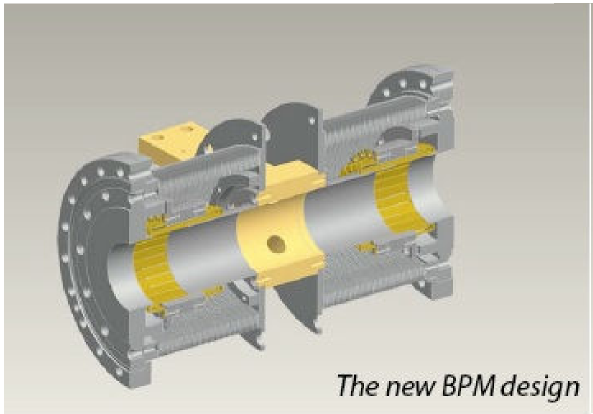
Table 2: vacuum pressure in 2004

ion pump status	11mA	26mA	31mA
normal	4.0×10^{-6} Pa	6.0×10^{-6} Pa	6.5×10^{-6} Pa

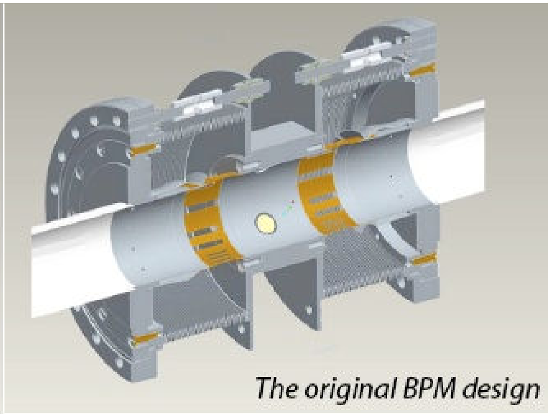


Bunch lengthening

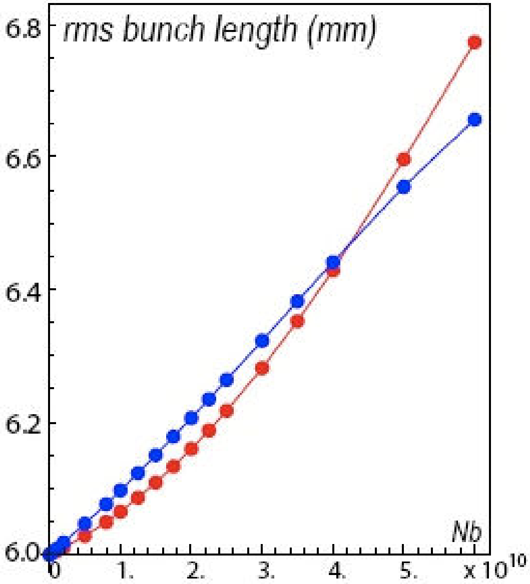
To estimate bunch lengthening for the calculated wake functions, the Haissinski equation have been solved using a numerical iterative technique.

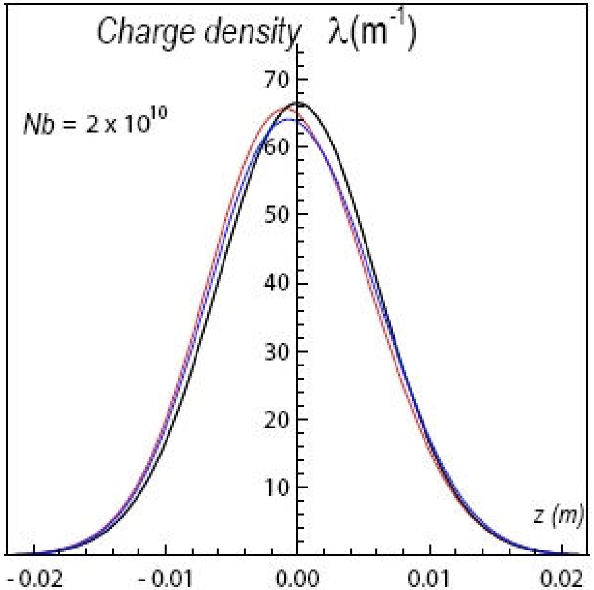


The new BPM design



The original BPM design





A Gaussian bunch of rms length 6mm deforms to shapes with rms length of 6.15 mm with the new BPMs (red), and 6.21 mm with the original BPMs (blue)

There is a possible instability threshold just above the nominal bunch population of 2.0×10^{10} particles: this needs more careful study

M. Korostelev

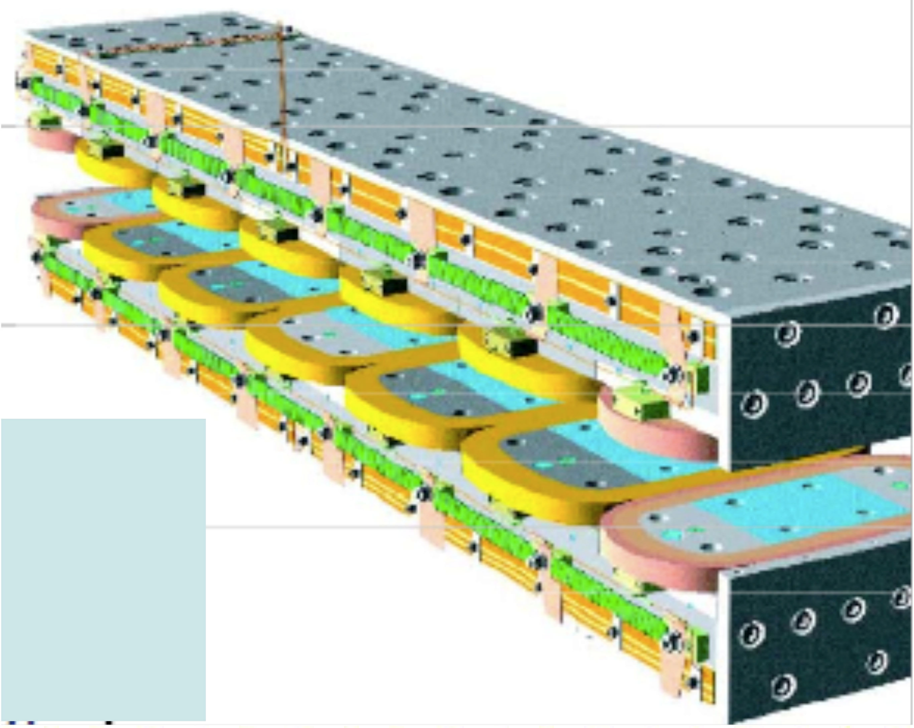
ILC DR wigglers

•Extensively used to reduce damping time and emittance and to mitigate IBS effect

•CESR-c type superconducting wiggler: good aperture, very good field quality and proven performance.

- Number of wigglers 88
- Peak field 1.6 T
- Period 0.40 m
- Unit length 2.45 m
- Vertical aperture 5 cm

•Pole width 20 cm

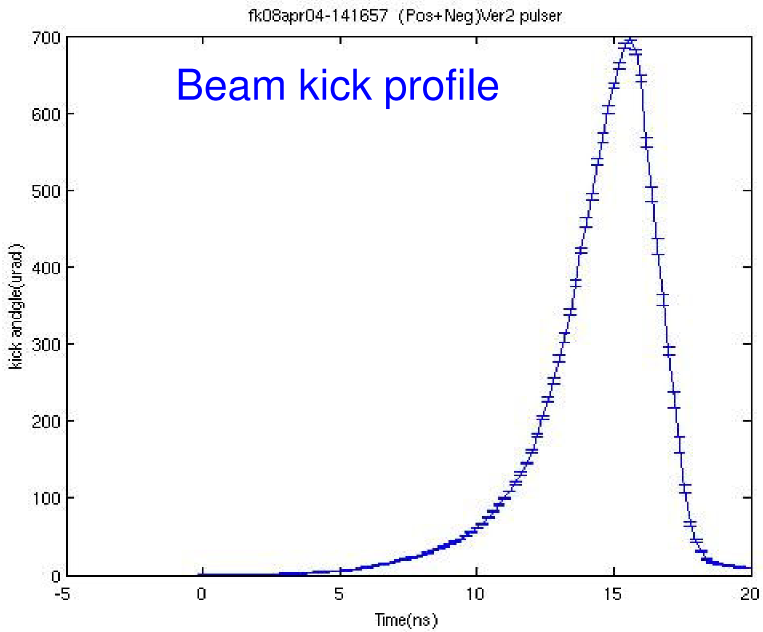


ILC/CLIC wigglers

	ILC RDR	ILC SB2009	CLIC BINP	CLIC CERN
B_{peak} [T]	1.6	1.6	2.5	2.8
L_w [mm]	400	400	50	40
Beam aperture full gap [mm]	50	50	13	13
Total wiggler length [m]	216	78	152	152
Energy radiated/turn in wigglers [MeV]	9.2	3.4	5.0	5.0

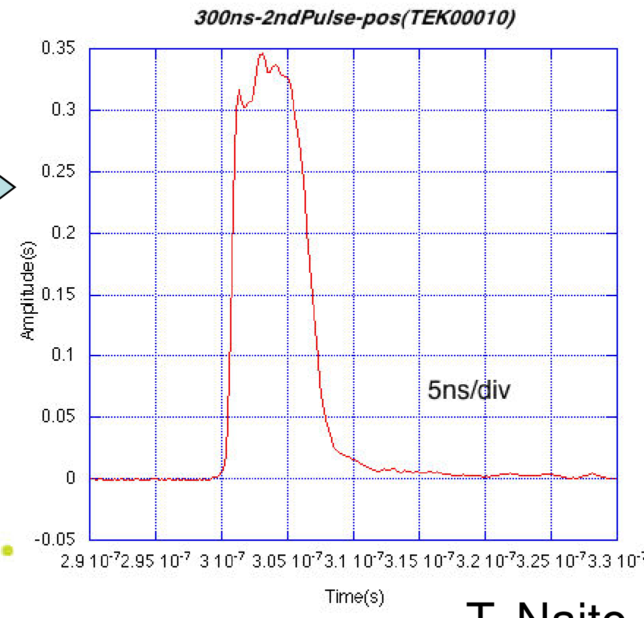
Fast kicker Experiment at ATF

Pulse source(FID FPG 10-6000KN)
Maximum output voltage ±10 kV
Rise time @ 10-90% level - < 1 ns
Rise time @ 5-95% level - < 1.2 ns
Pulse duration @ 90% - 0.2-0.3 ns
Pulse duration @ 50% - 1.5-2 ns
Output pulse amplitude stability – 0.5-0.7%



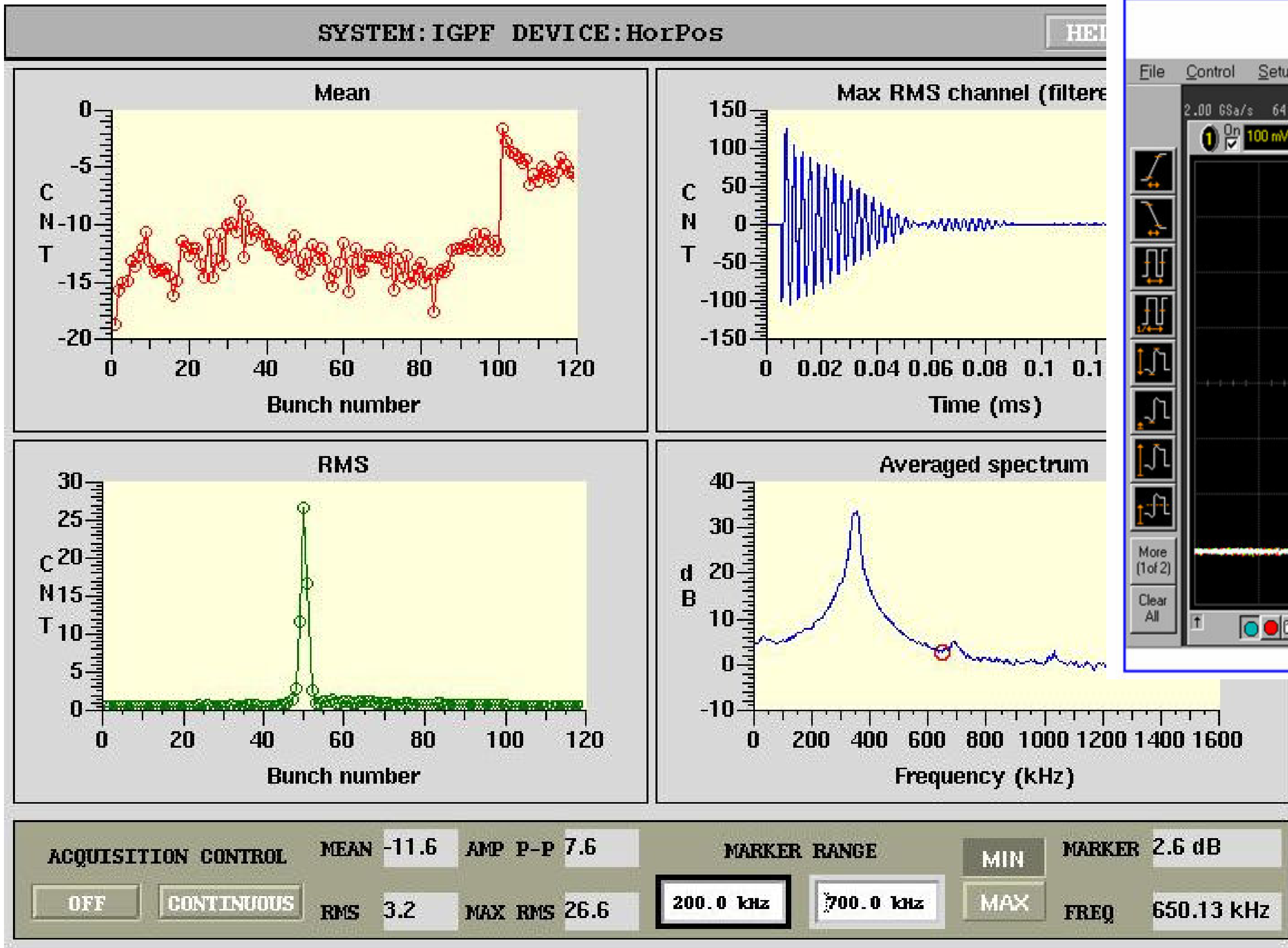
June beam extraction tests: everything ok but the kick angle was lower than design.
To increase the kick angle, we ordered 4ns pulse width pulsers (FPG10-3000N2G) to FID. The total kick angle of two pairs of strip-line is 3.6mrad, enough to extract the beam.

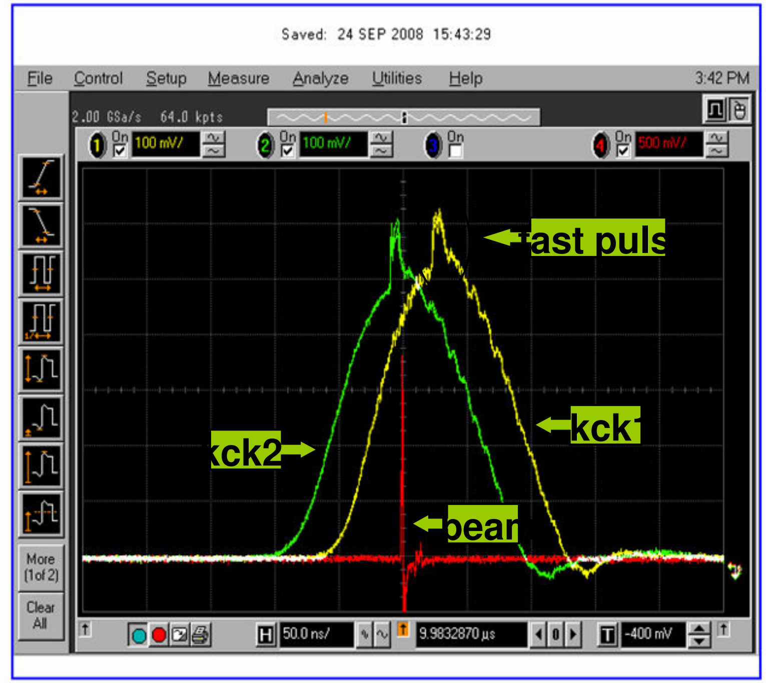
Next beam test is scheduled,
2009 Oct. 2weeks(10/19~, 10/26~)



T. Naito

Fast kickers in operation at DAFNE





hybrid configuration with long and short pulsers

e+ beam oscillation with fast kick at DAΦNE (bunch distance 2.7 ns)

Measured by diagnostics of the horizontal digital feedback system. 100, of 120, stored bunches with kicker pulse centered on bunch 50

Conclusions

- For the ILC DR main issue is e-cloud mitigation:
  - **different tecniques have been demonstrated or are being sperimented**
  - **We have setup a working group to apply the results of the R&D to the DR design and make recommendations**
- ILC DR nominal vertical emittance (2pm) has been demonstrated at Diamond. R&D is needed:
  - **to specify alignment tolerance and stability, and diagnostics requirements.**
  - **to demonstrate low emittance at nominal current, taking into account collective effects.**
- For e-cloud and low emittance issues ILC and CLIC DR have common R&D objectives.
- Collaboration on some technical aspects of systems like wigglers, kickers, feedbacks could be useful.
- January 12-15 we will have a joint ILC/CLIC DR workshop