ILC Damping Rings:
Status and Plans

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ILC 08

UIC, Chicago, 20 November 2008

Program Outline

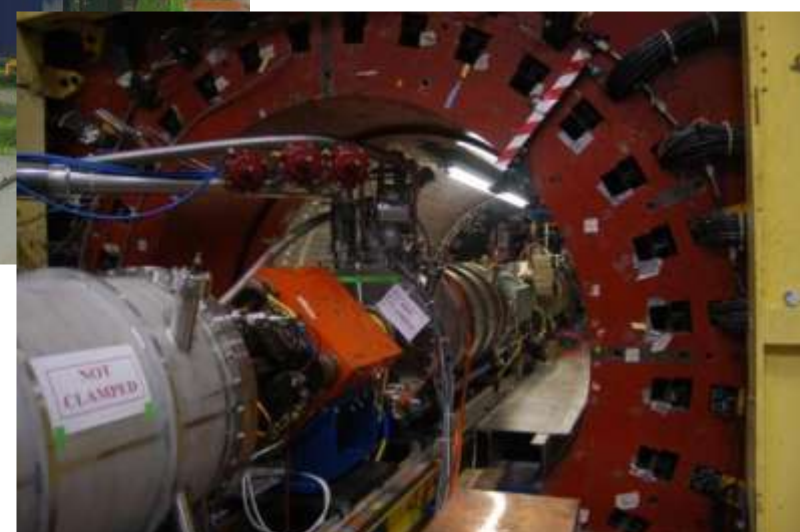
		Minimum Machine	Technical Design, and Costing	Critical R&D
TDP Phase I	2008	Specify tasks.	Specify scope.	Continue critical R&D for cost reduction and risk mitigation: • electron cloud; • fast kickers; • low-emittance tuning.
	2009	Perform studies.	Perform technical design and costing work in support of revising the baseline configuration.	
	Start 2010	Revise baseline configuration.		
TDP Phase II	2010 – 2012		Complete work for TDR (end 2012).	Complete critical R&D.

Critical R&D: Electron Cloud

DAΦNE

KEKB

CesrTA



E-Cloud Collaboration:

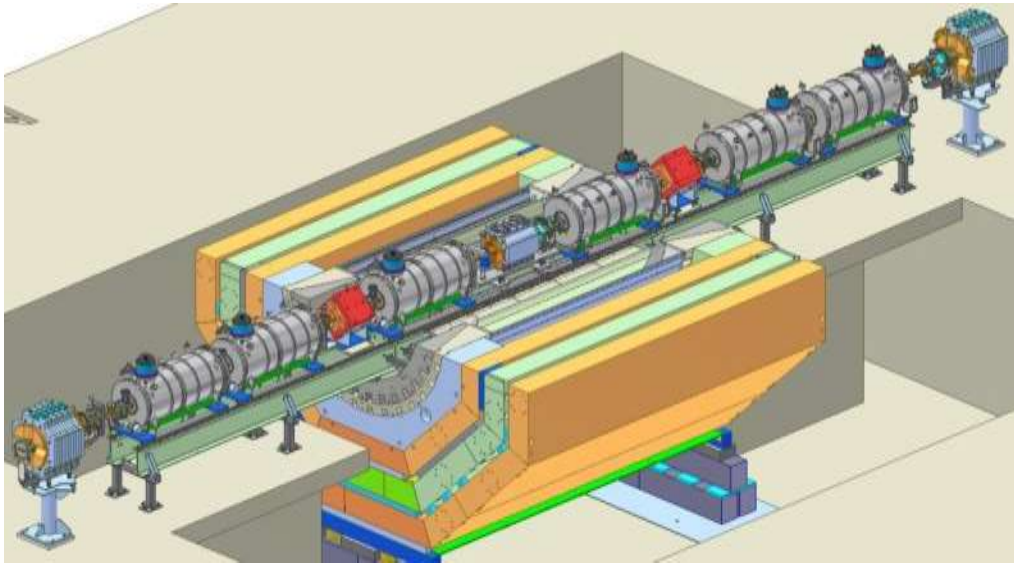
- ANL
- Cornell
- FNAL
- INFN/LNF
- KEK
- LBNL
- SLAC

Electron Cloud: Goals

1. Collect data to validate the simulation codes in the parameter regime of the ILC damping rings.
   - **We need to understand, and be able to predict, build-up of the cloud under a variety of conditions.**
   - **We need to understand, and be able to predict, beam dynamics with e-cloud in ultra-low emittance regime.**
2. Develop effective mitigation techniques.
   - **Mitigation methods needed for drifts, dipoles, wigglers.**
   - **Methods must be demonstrated and adverse consequences understood.**

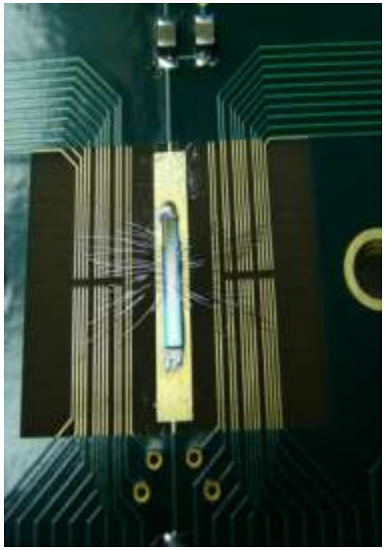
CesrTA E-Cloud Program (1)

- CESR has been reconfigured to allow operation at low horizontal emittance (few nm).
  - **Includes re-locating wigglers at zero-dispersion points in the lattice.**
  - **Commissioning run has just been successfully completed.**



CesrTA E-Cloud Program (2)

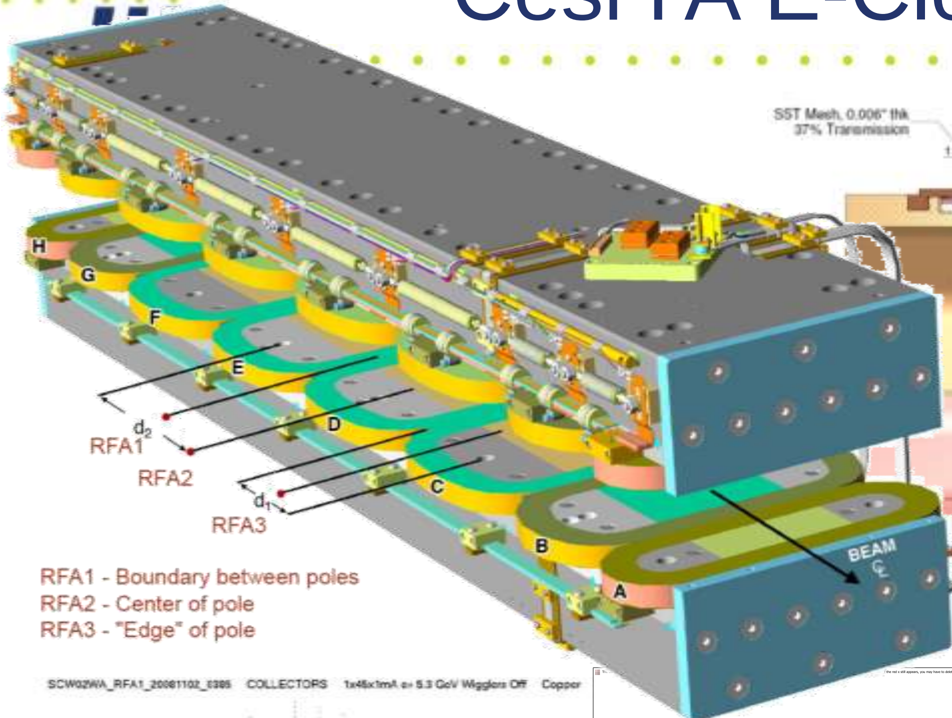
- Instrumentation and diagnostics have been upgraded:
  - **specialised e-cloud diagnostics developed and installed (e.g. retarding field analysers in wiggler vacuum chamber);**
  - **upgraded fast feedback system to maintain beam stability with short bunch separation;**
  - **improved alignment systems and high-performance BPM system to allow tuning for ultra-low emittance;**
  - **fast x-ray monitor (under development) for turn-by-turn beam size measurement with micron resolution.**

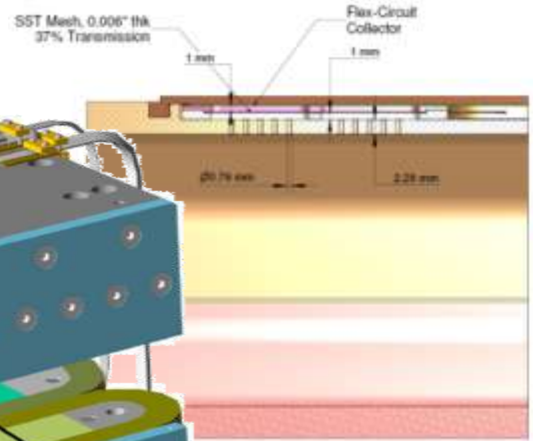


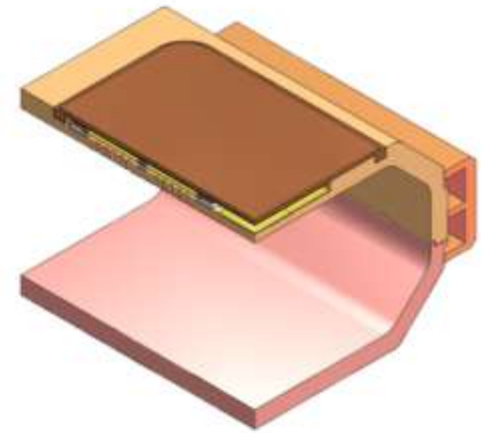
Photodiode array for fast x-ray beam size monitor.

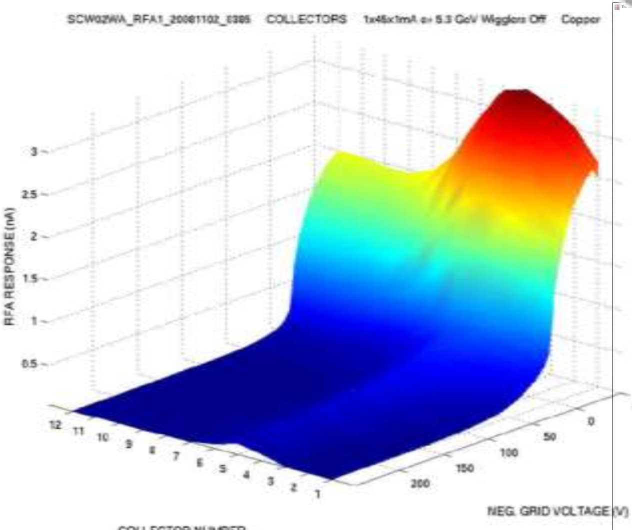
Retarding field analysers for electron cloud measurements in wiggler chambers.

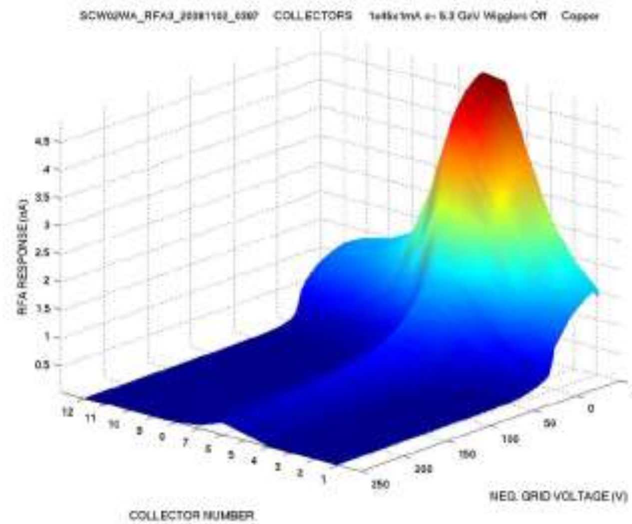
CesrTA E-Cloud Program (3)





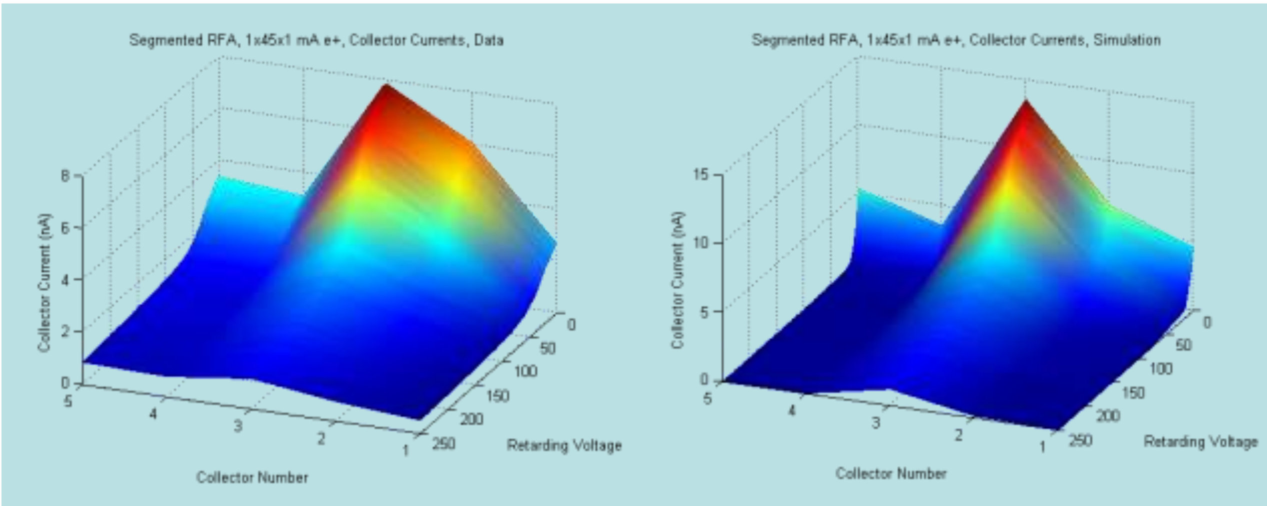






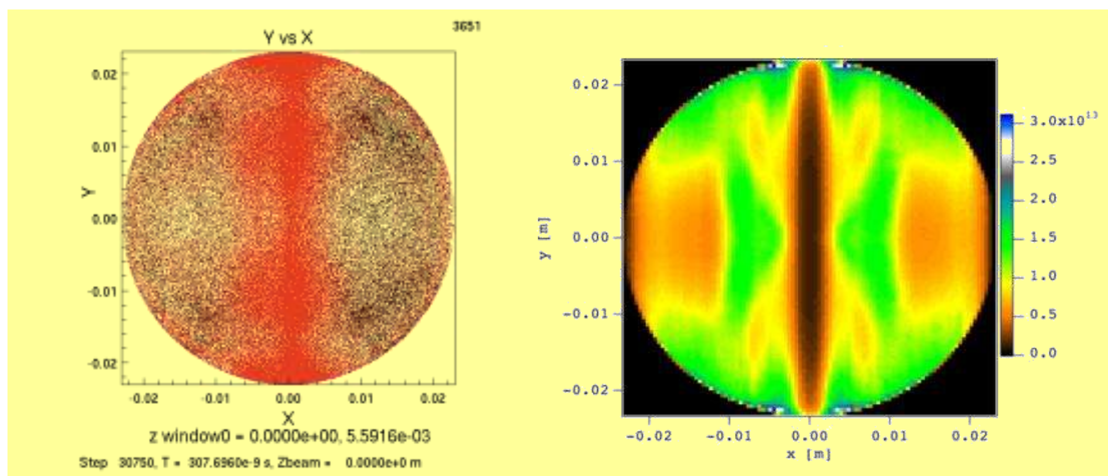
CesrTA E-Cloud Program (4)

Simulation studies aim to validate modelling tools.

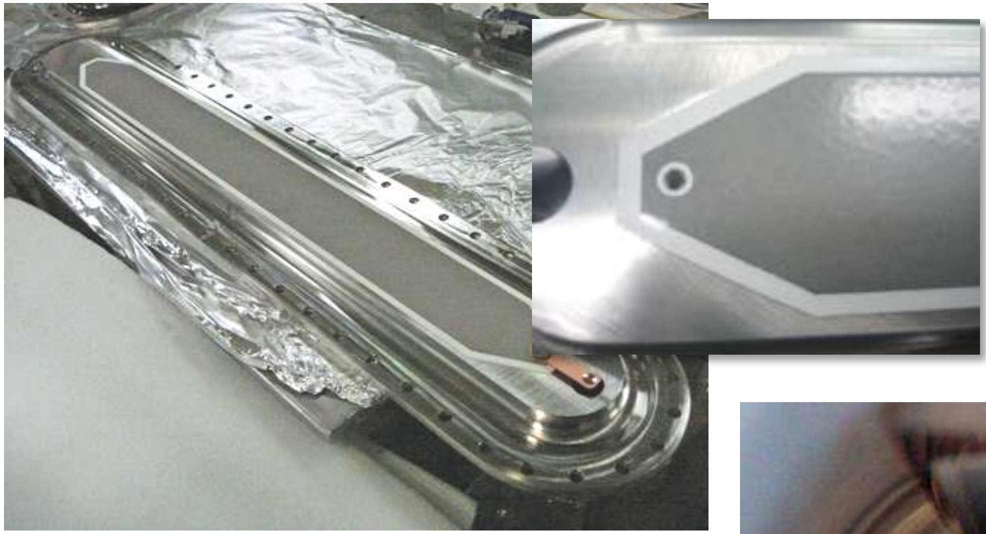


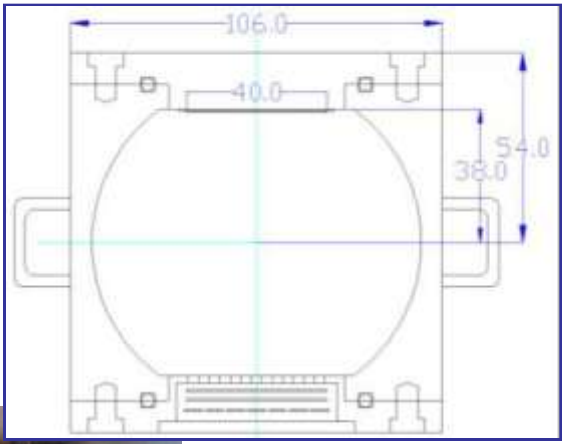
Simulation of RFA signal (right) compared to data (left).

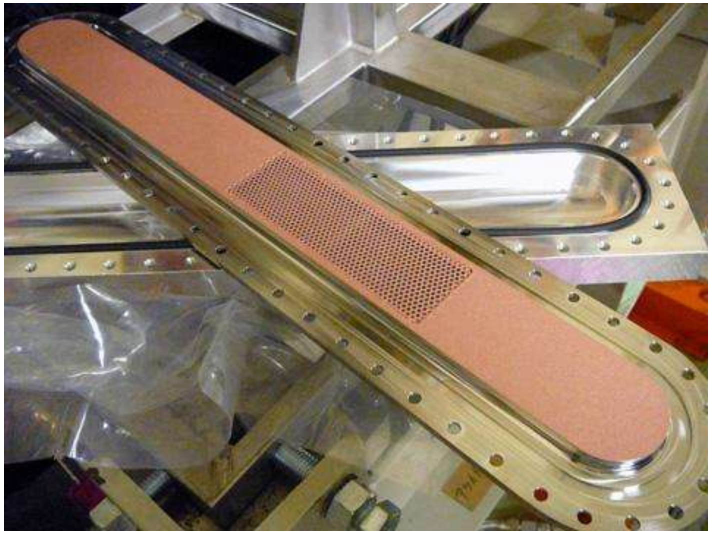
Simulation of electron cloud distribution in 2D field (right) and 3D field (left).

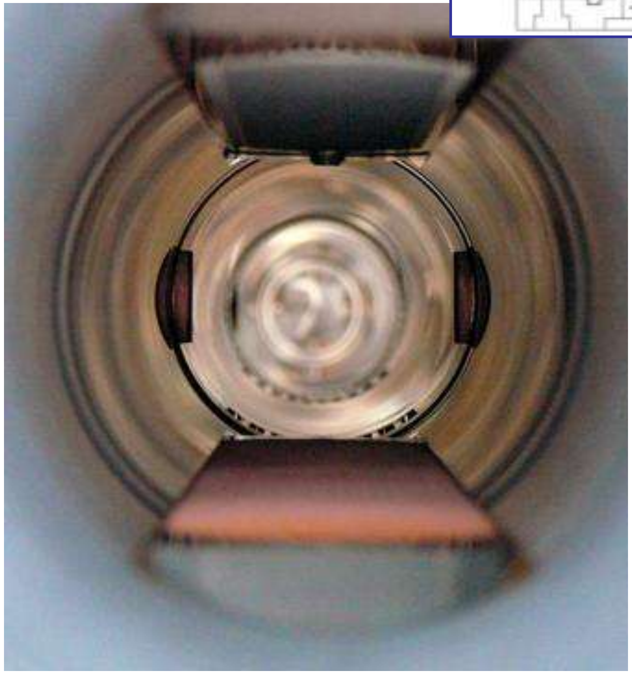


E-Cloud Studies at KEKB (1)





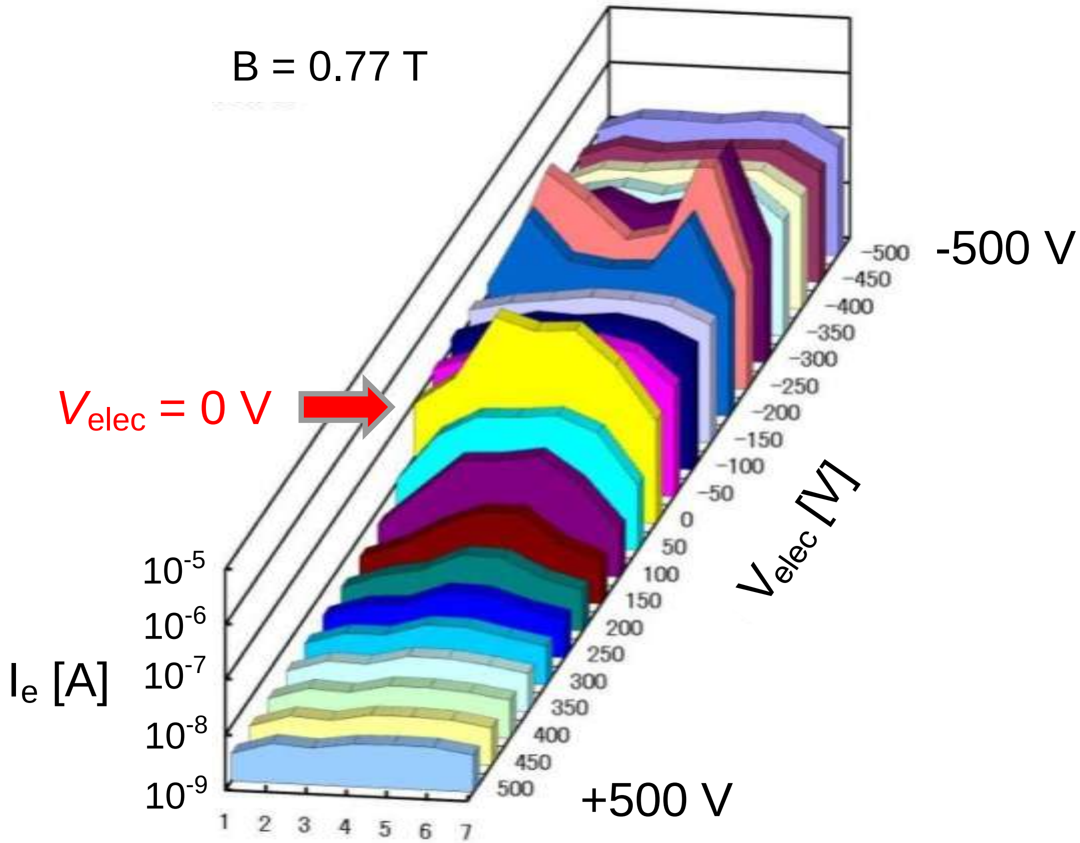




Clearing electrode for mitigation in magnetic field, with RFA.

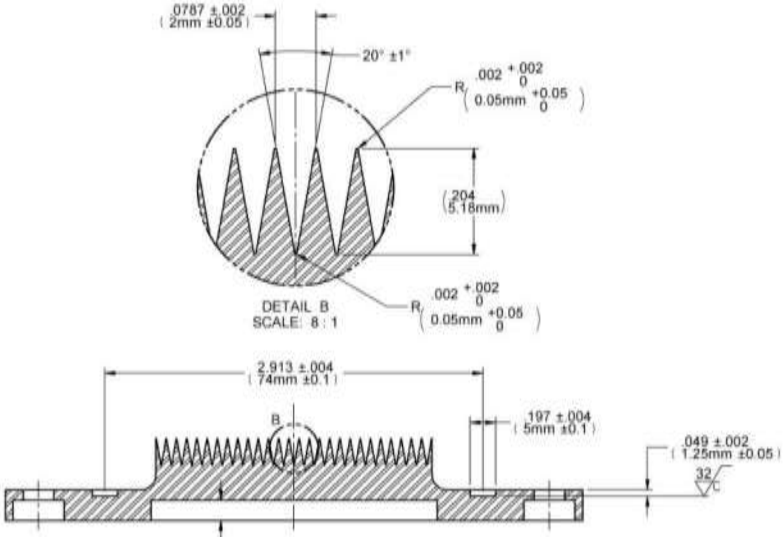
E-Cloud Studies at KEKB (2)

Application of voltage on clearing electrode leads to a dramatic reduction in electron cloud density.



E-Cloud Studies at KEKB (3)

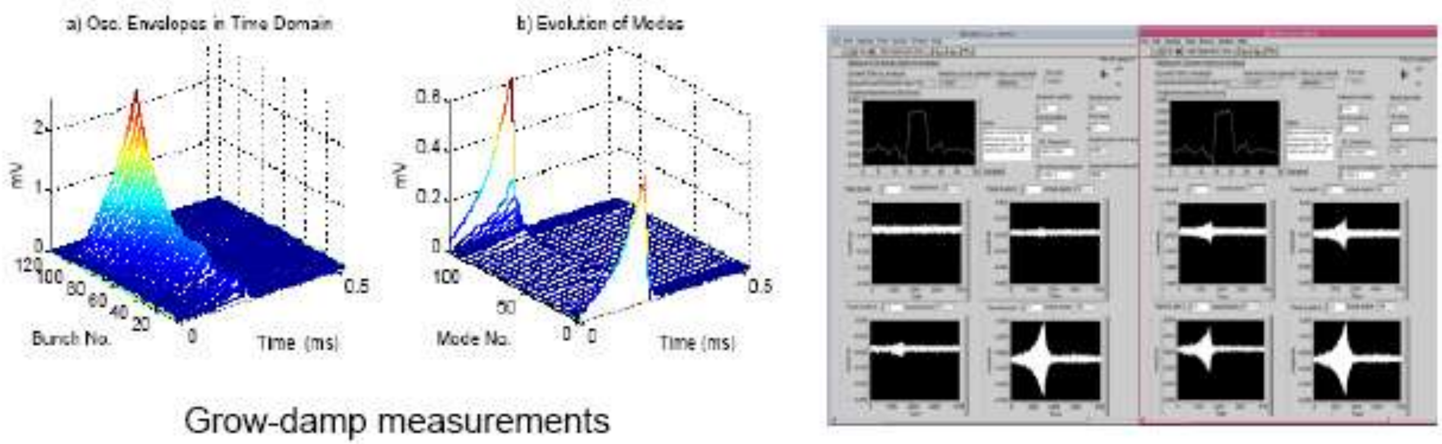
Grooved chambers (manufactured by SLAC) are presently being tested.



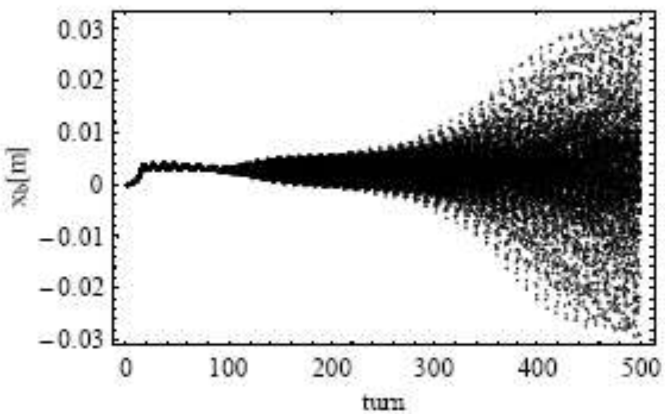
E-Cloud Studies at DAΦNE

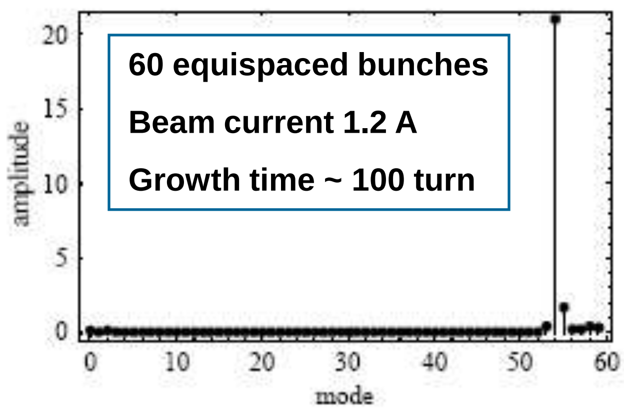
Multibunch instability caused by electron cloud.

Simulations consistent with main observations.



Grow-damp measurements





Fast Kicker R&D

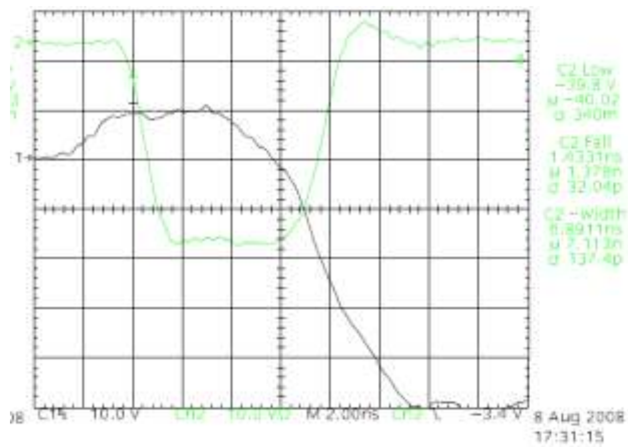
- The goal is to develop and demonstrate a high-reliability fast kicker that meets the ILC specifications for damping ring injection and extraction.

Pulse amplitude	10 kV
Bunch spacing	3 ns
Pulse repetition rate	6.6 MHz
Pulse stability	~ 0.1%

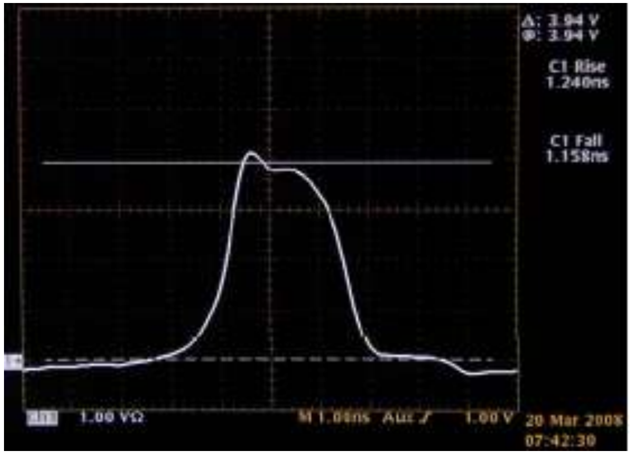
- R&D program includes activities at SLAC, INFN/LNF and KEK.

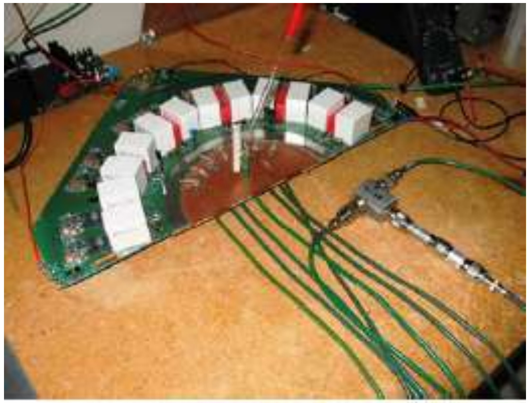
Fast Injection/Extraction Kickers: SLAC

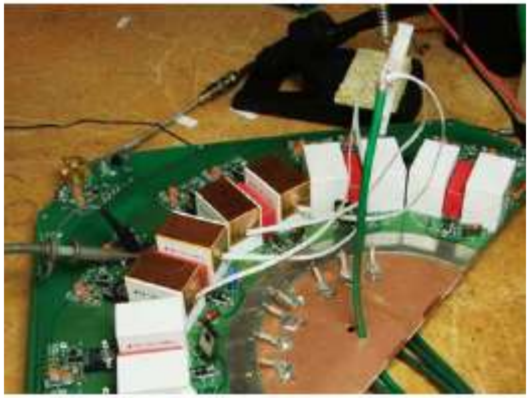
- Researchers at SLAC are investigating two possible technologies: MOSFET array, and DSRD fast switch.
- Both technologies provide attractive characteristics.
- A hybrid pulser may be the best solution.



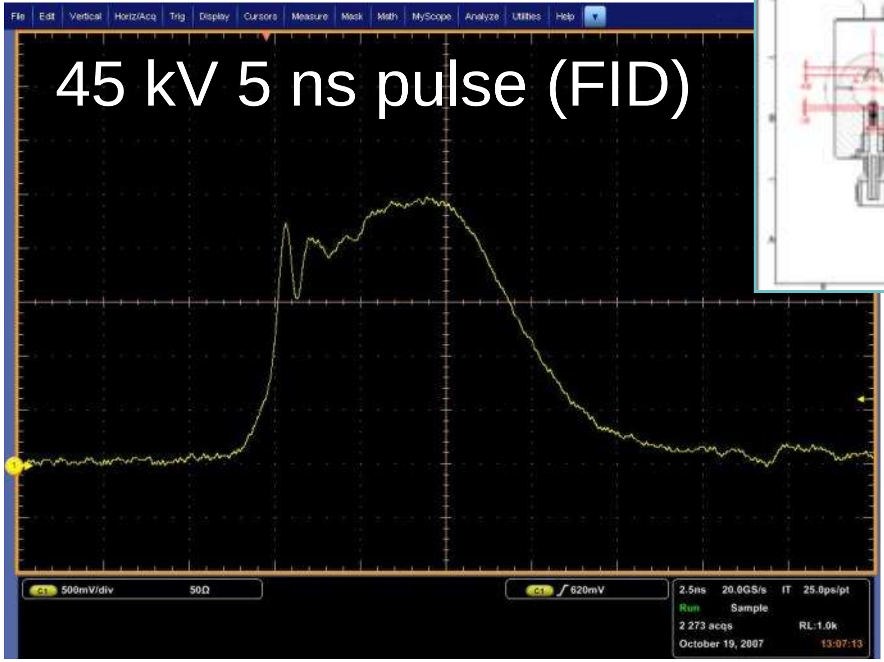
V_{DS}=1kV, R_{Load}=10 ohm, I_D=68 A

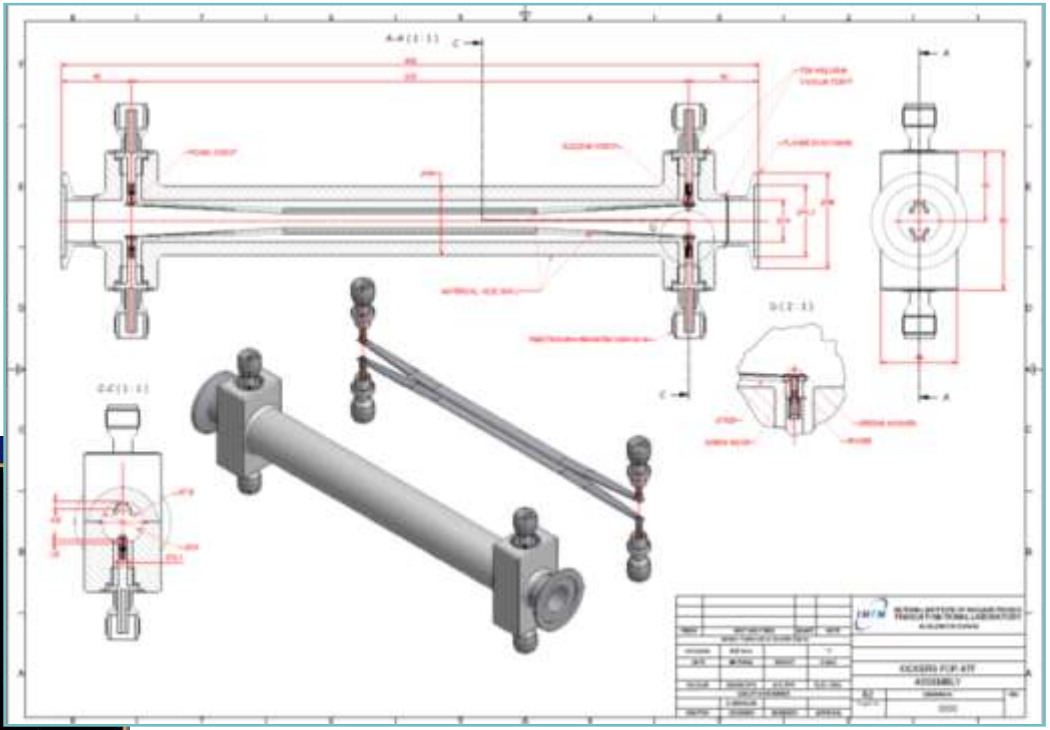






Fast, high-power pulsers approaching ILC DR specifications are being tested as part of DAΦNE upgrade program.

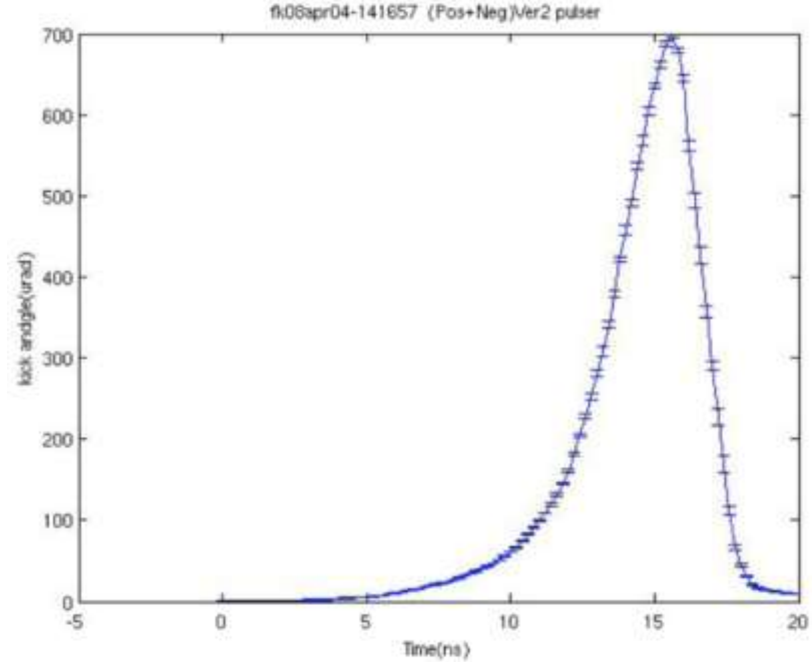


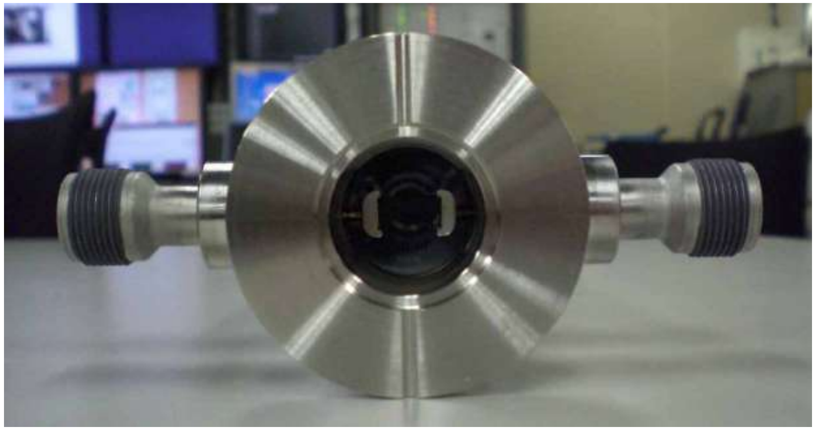


DAΦNE stripline kicker designs are being modified for devices to be installed for testing in ATF.

Fast Injection/Extraction Kickers: KEK

- Goal is to achieve single-bunch extraction from ATF DR for ATF2, demonstrating ILC damping ring performance specifications.
- Fast (FID) pulsers have10 kV peak output, rise time around 2 ns.
- Strip line kickers have been manufactured and show good impedance characteristics.



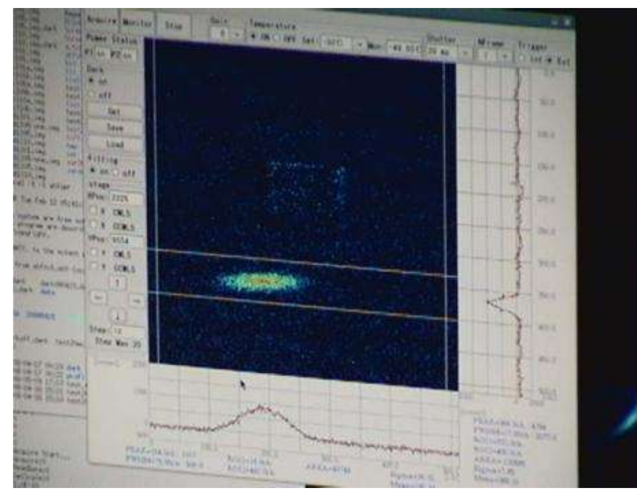


Low-Emittance Tuning

- ILC damping rings are specified to operate with 2 pm vertical emittance.
- Swiss Light Source has recently achieved 3 pm.
- Low-emittance tuning program includes work at:
  - **ATF: motivated by ATF2, studies of fast ion instability, and demonstration for ILC damping rings;**
  - **CesrTA: motivated by studies of electron cloud in ultra-low emittance regime;**
  - **Cockcroft Institute: in support of ATF and CesrTA programs, and ILC damping rings design.**
- Issues include: alignment and stabilisation specifications; diagnostics and instrumentation functionality and performance; design of coupling correction system; development of effective tuning techniques...

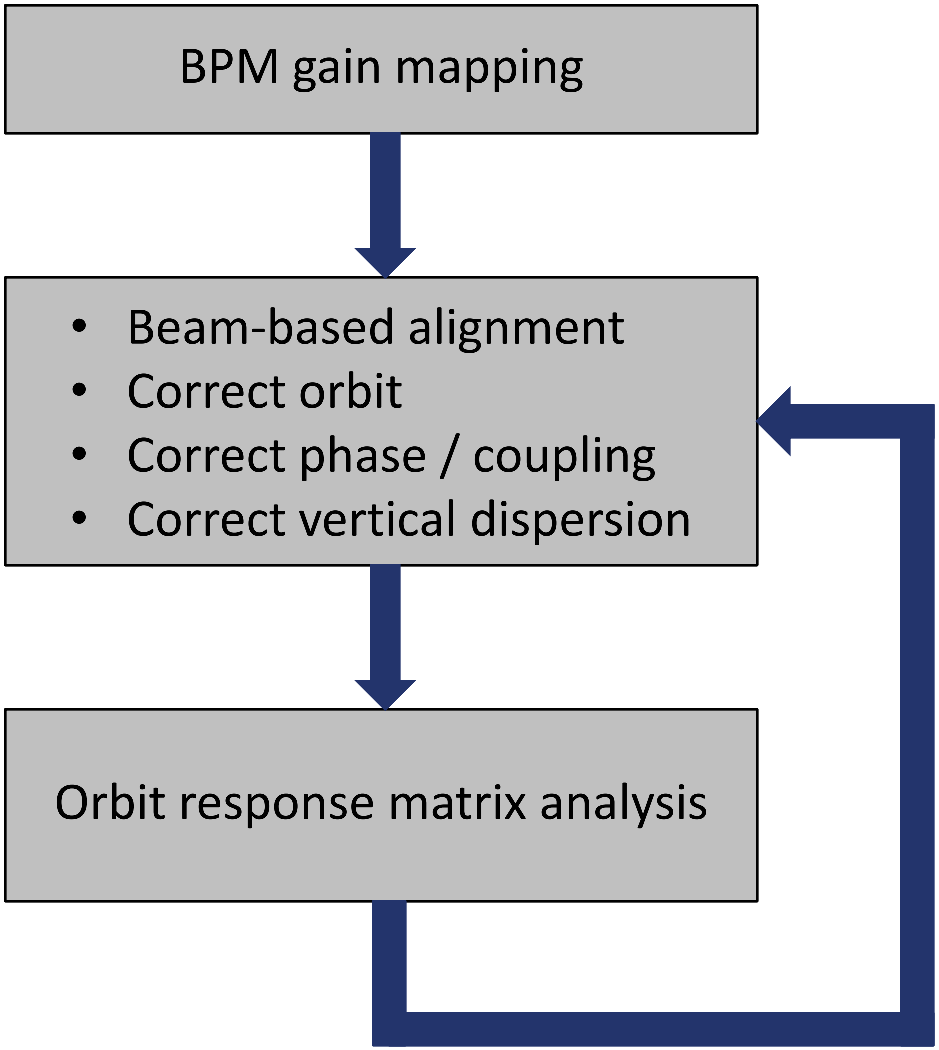
Low-Emittance Tuning: KEK

Remote participation in machine studies is made effective by use of Control Room Web Cam and Skype.

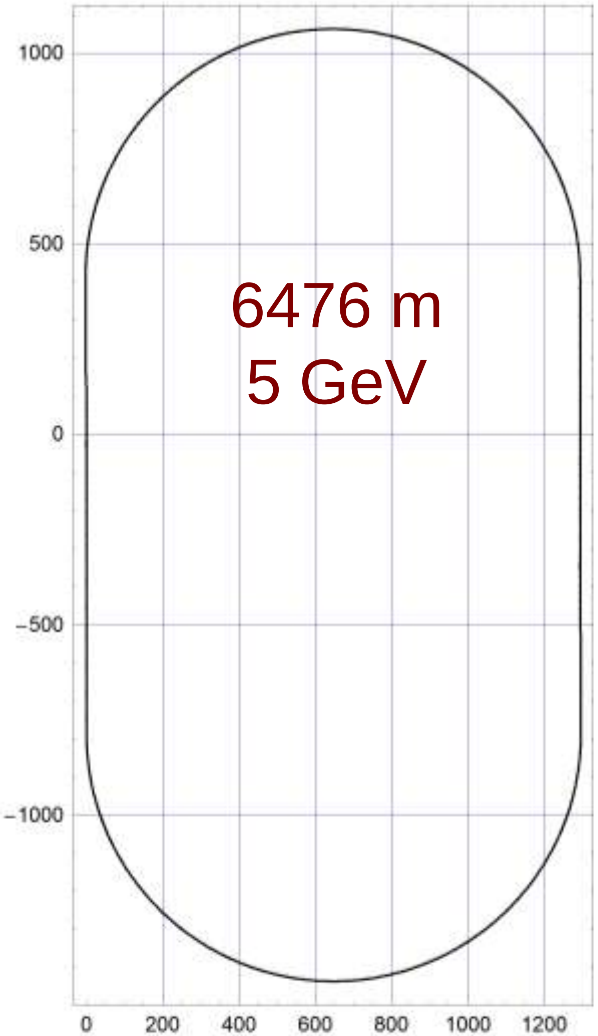


Low-Emittance Tuning: CesrTA

- Determine BPM gain errors.
- Apply sequence of corrections.
- Further characterise BPM and coupling errors.



Damping Rings Design and Costing (1)

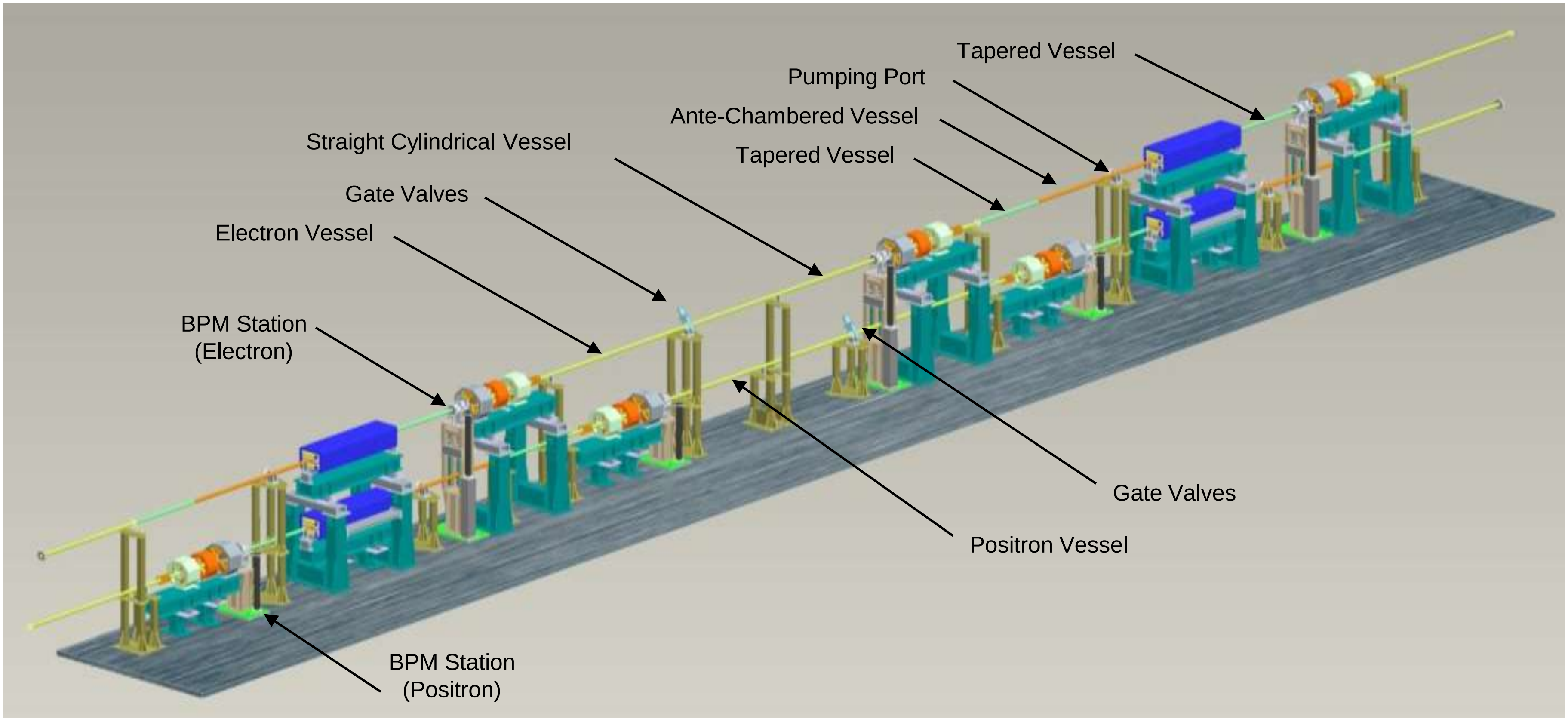


Present baseline: DCO lattice

- Arcs consist of a total of 192 FODO cells
- Flexibility in tuning momentum compaction factor, given by phase advance per arc cell:
  - **72° phase advance: α_p=2.8×10^{-4}**
  - **90° phase advance: α_p=1.7×10^{-4}**
  - **100° phase advance: α_p=1.3×10^{-4}**
- No changes in dipole strengths needed for different working points.
- Racetrack structure has two similar straights containing:
  - **injection and extraction in opposite straights**
  - **phase trombones**
  - **circumference chicanes**
  - **rf cavities**
  - **"doglegs" to separate wiggler from rf and other systems**
  - **wiggler**

Damping Rings Design and Costing (2)

Significant progress is being made with a CAD model for the present baseline lattice.

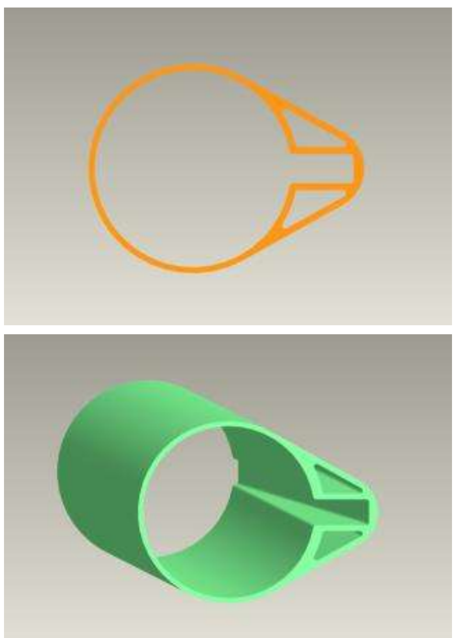


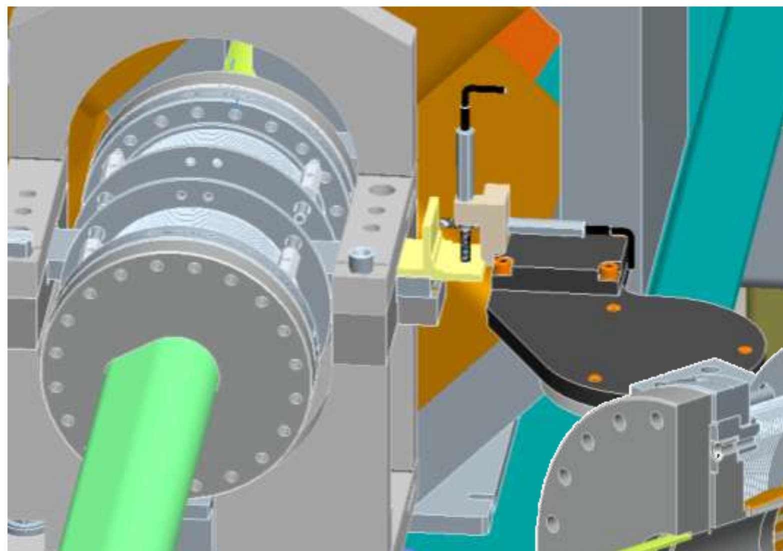
Damping Rings Design and Costing (3)

Development of the CAD model provides essential information for:

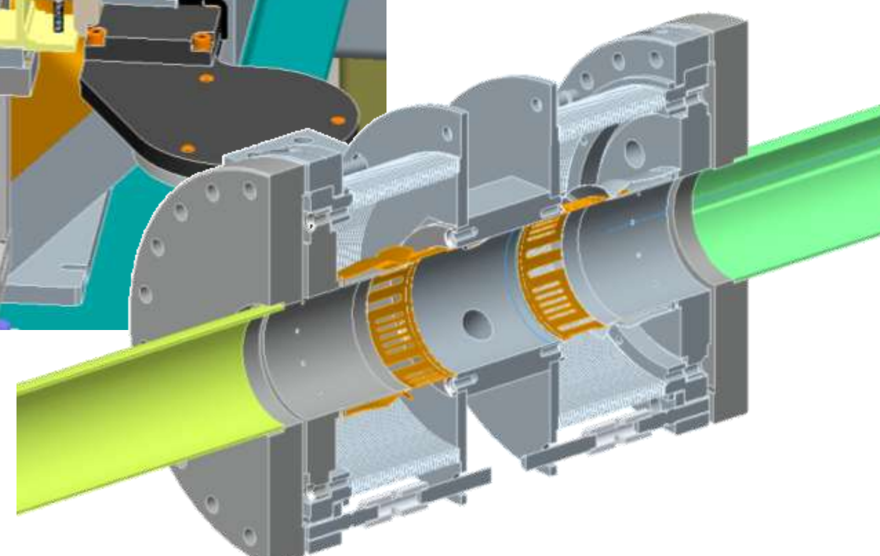
- technical systems development (vacuum, conventional facilities...);
- costing and value engineering;
- beam dynamics studies (low emittance tuning, e-cloud...)

Vessel with antechamber for e-cloud mitigation.



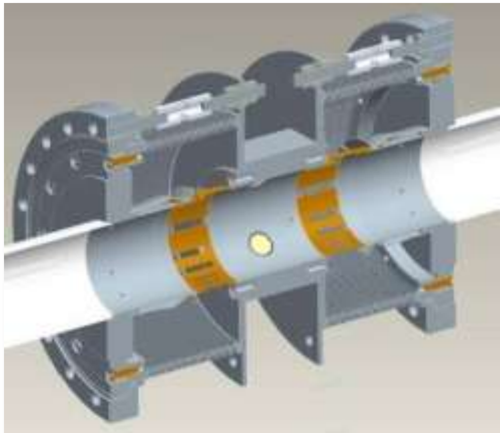


BPM chamber with position encoders.



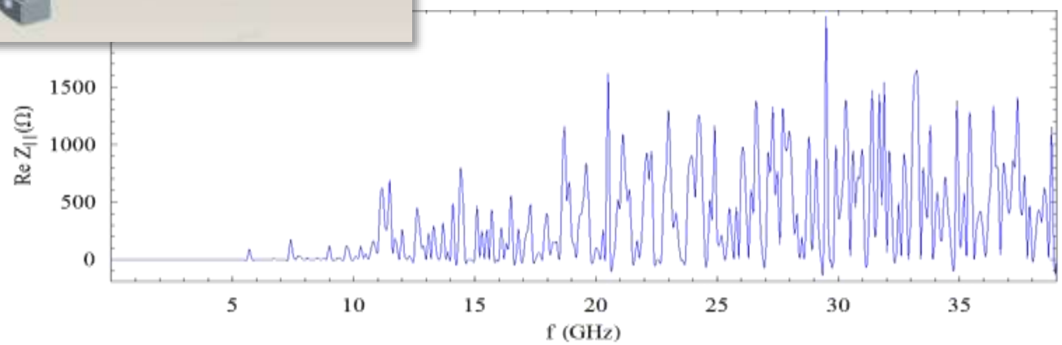
BPM/bellows will contribute to machine impedance.

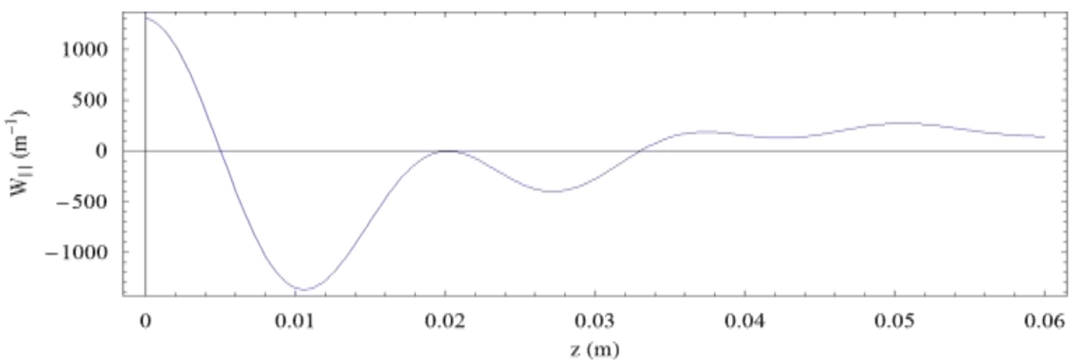
Impedance Model: BPM/bellows/tapers

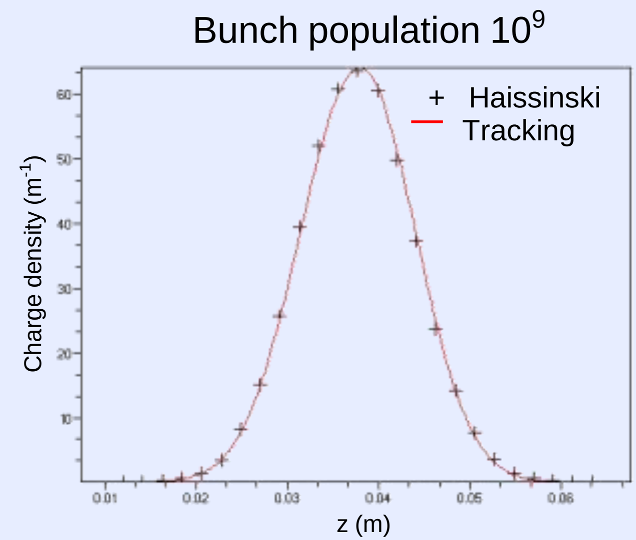


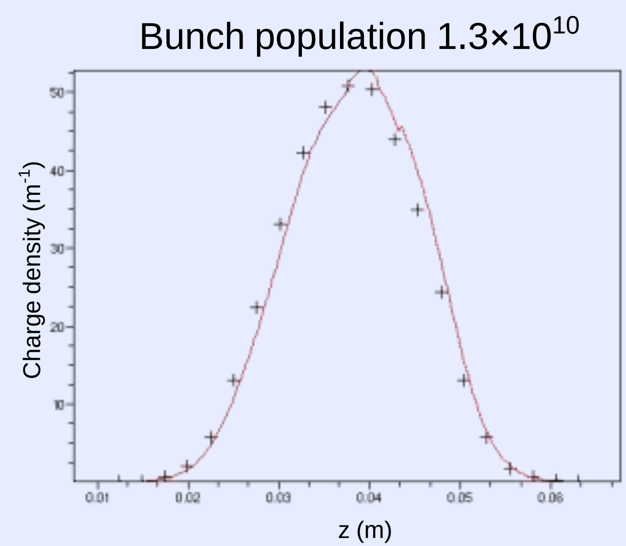
From the impedance model we can evaluate:

- potential well distortion;
- HOM heating;
- instability thresholds.









“Minimum Machine” Studies

	Nom. RDR	Low P RDR	new Low P
E_{CM} (GeV)	500	500	500
Particles per bunch, N ($\times 10^{10}$)	2.0	2.0	2.0
Bunches per pulse, n_b	2625	1320	1320
Pulse repetition rate (Hz)	5	5	5
Peak beam power, P_b (MW)	10.5	5.3	5.3
$\gamma\varepsilon_x$ (μm)	10	10	10
$\gamma\varepsilon_y$ (nm)	40	36	36
β_x (cm)	2.0	1.1	1.1
β_y (mm)	0.4	0.2	0.2
Traveling focus	No	No	Yes
σ_x (nm)	640	474	474
σ_y (nm)	5.7	3.8	3.8
σ_z (μm)	300	200	300
Beamstrahlung* $\delta E/E$	0.023	0.045	0.036
Luminosity* ($\times 10^{34}$ cm^{-2}s^{-1})	2.0	1.7	1.9

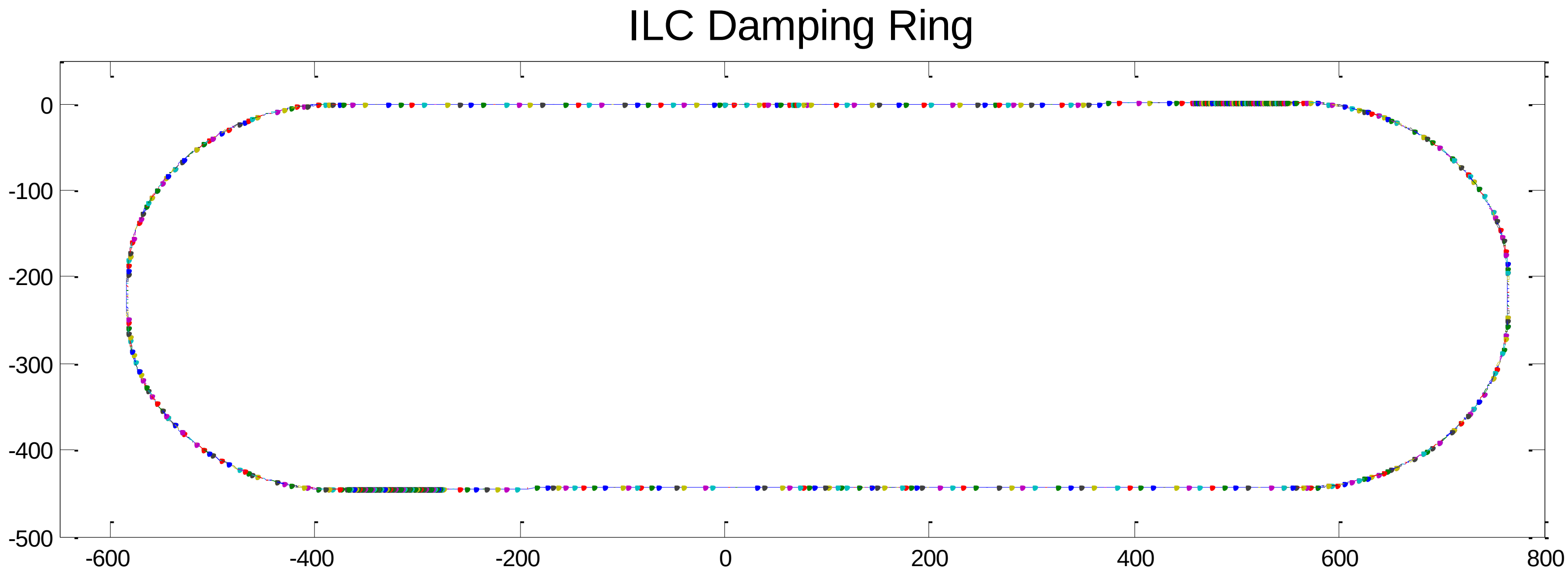
N.J. Walker, PAC Meeting, October 2008

“Minimum Machine” Studies

- Main implication for the damping rings is that the “low power” parameter set makes a 3 km circumference feasible.
  - **Number of bunches in the ring is halved.**
  - **Average current and bunch separation remain constant.**
- Reducing the circumference makes it possible to contemplate also reducing the beam energy.
  - **Maybe reduce from 5 GeV to 4.6 GeV, or 4.2 GeV.**
  - ☺ **Reduces longitudinal emittance, with benefits for the bunch compressors.**
  - ☺ **Reduces amount of wiggler, rf, magnet power, etc.**
  - ☹ **Injected beam sizes becomes larger.**
  - ☹ **Beam becomes less robust against collective effects.**

"Minimum Machine" Studies

- We have two lattices that can be used as a basis for 3 km damping ring studies...
- ...one of them produced by replacing the arc cells in the present baseline lattice, with cells based on those used in SuperB.



Plans for TDP-I/Minimum Machine

1. Continue critical R&D:
   - electron cloud; fast kickers; low emittance tuning.
2. Produce technical evaluation and cost comparison of 6 km and 3 km damping ring options, by end 2009, to support possible new baseline.
3. Continue technical design and costing work for TDR.

Task	Responsibility
Modify/develop 3 km damping ring lattice design.	Korostelev/Biagini
Evaluate dynamics in 3 km damping ring.	Korostelev/Biagini
Develop lattice designs for injection/extraction lines.	Guiducci
Continue to develop impedance model.	Korostelev/Marcellini
Develop and maintain CAD models.	Lucas
Update and maintain cost estimates.	Lucas
Specify and cost power distribution system.	Palmer/Bellomo

LC Damping Rings Collaboration

- Differences in linac technologies drive damping rings to different configurations in ILC and CLIC, however...
- ...there are a number of high-priority issues that are common for both projects:
  - **electron cloud mitigation;**
  - **ultra-low emittance tuning and preservation.**
- A first step toward closer collaboration has already been taken, in coordinating CLIC and ILC damping rings WebEx meetings.
- A joint working group on damping rings is now being established, convened by Yannis Papaphilippou and Mark Palmer.

	ILC	CLIC
Energy (GeV)	5	2.4
Circumference (m)	6476	365
Bunch number	2700-5400	312
Particles/bunch (10^{10})	2.0-1.0	0.37
Damping time τ_x (ms)	21	1.5
Emittance $\gamma\varepsilon_x$ (nm)	4200	381
Emittance $\gamma\varepsilon_y$ (nm)	20	4.1
Momentum compaction (10^{-4})	1.3-2.8	0.80
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

LC Damping Rings Collaboration

The CLIC-ILC working group on damping rings will:

- develop synergies and collaborate in beam dynamics and technical issues of common interest in damping ring design;
- promote the use of common research approaches and studies when possible, including numerical tools;
- enable researchers to take advantage of existing test facilities or storage rings and participate in a common experimental program;
- trigger communication, establish links between the two communities, share knowledge and document common work.

A more detailed mandate is being drafted.

Final Words

- The goals for the damping rings R&D program are clearly defined:
  1. **Demonstrate performance specifications in the critical areas of electron cloud, fast kickers, and low-emittance operation.**
  2. **Produce technical performance and cost comparisons of present baseline (6 km) and possible "minimum machine" (3 km) damping ring configurations.**
  3. **Develop design and costs information in support of the Technical Design Report.**
- There is more activity and progress than I would have thought possible given the recent funding situation.
- Steps are being taken to establish closer collaboration between CLIC and ILC damping ring groups, and thereby get maximum benefit from limited resources.

Thanks and apologies to...

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Yulin Li
John Lucas
Oleg Malyshev
Fabio Marcellini

Dawn Munson
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Toshiaki Okugi
Kosmas Panagiotidis
Yannis Papaphilippou
Mauro Pivi
David Rubin
David Sagan
Stefano de Santis
Jim Shanks
Yusuke Suetsugu
Tao Tang
Nobuhiro Terunuma