International Linear Collider at Stanford Linear Accelerator Center

Overview of the Electron Cloud in the ILC DR and SUPER-B and latest on R&D effort

M. Pivi (SLAC)

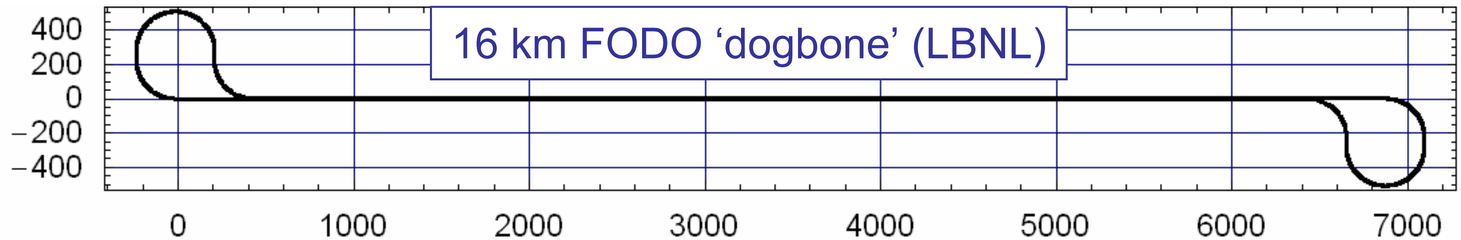
Involved in the ILC:
D. Arnett, Y. Cai, G. Collet, R. Kirby, N. Kurita, B. Mckee, M. Morrison, P. Raimondi, T. Raubenheimer, J. Seeman, G. Stupakov, L. Wang (SLAC), M. Palmer, D. Rubin, D. Rice, L. Schachter, J. Codner, E. Tanke, J. Crittenden (Cornell), U. Van Rienen, G. Pöplau (Rostock Univ.), C. Celata, J.L. Vay, M. Furman (LBNL), K. Ohmi, Y. Suetsugu (KEK), R. Wanzenberg (DESY), F. Zimmermann, E. Benedetto (CERN), A. Wolski (Cockroft Uniiv.), B. Macek (LANL), C. Vaccarezza, S. Guiducci, R. Cimino (Frascati), A. Markovic (Rostock Univ.), et al.

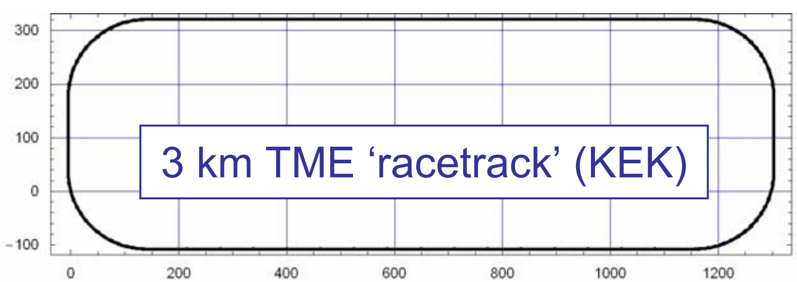
SLAC, June 15, 2006

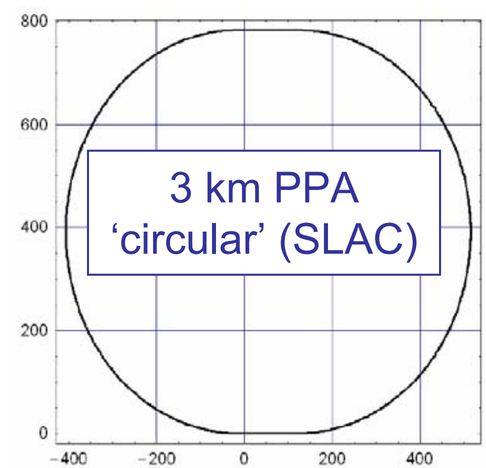
Comparative Study of Possible ILC DRs

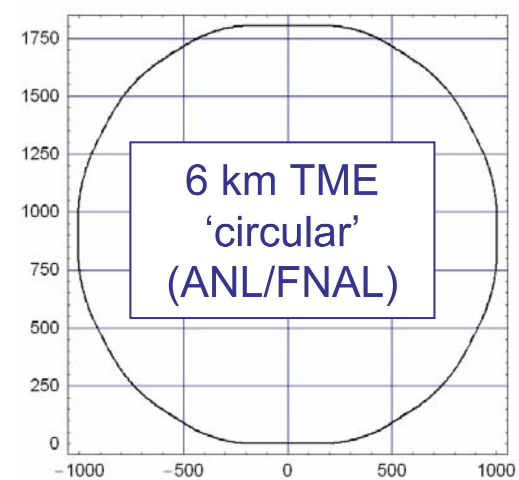
A major activity in 2005

Explore different configuration options (including lattice styles) for the damping rings.









Damping Rings

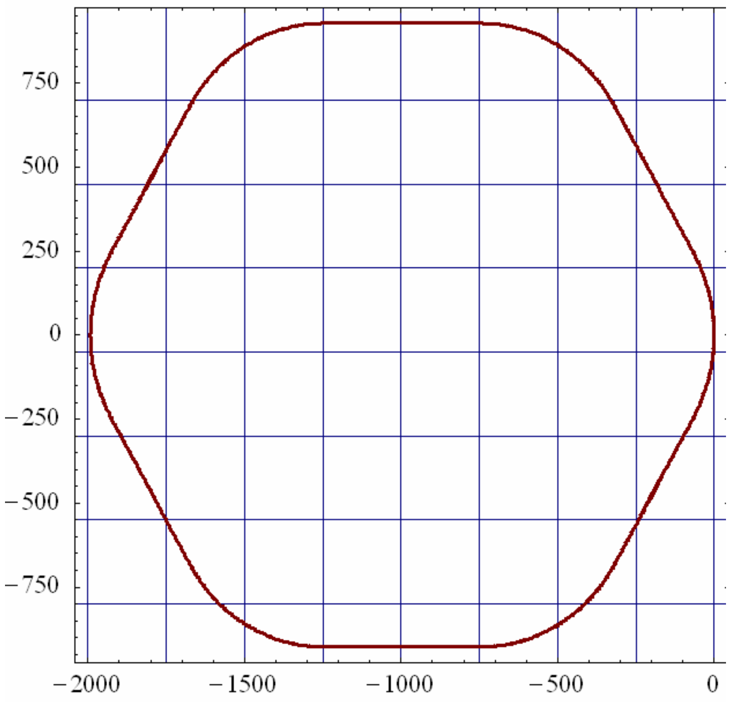
Positrons:

Two rings of ~6 km circumference in a single tunnel

Two rings are needed to reduce e-cloud effects unless significant progress can be made with mitigation techniques

Preferred to 17 km dogbone for:

- Space-charge effects
- Acceptance
- Tunnel layout (commissioning time, stray fields)



Electrons:

One 6 km ring

Damping ring R&D

Extensive program worldwide incl. KEK, UK, Frascati, IHEP

DR component optimization: wigglers, fast kickers; (Cornell) studies of the use of CESR as a DR test facility (in 2008)

Damping Ring Design and Optimization (ANL)

- Lattice design and optimization; studies of ion instability in the APS ring; design of a hybrid wiggler

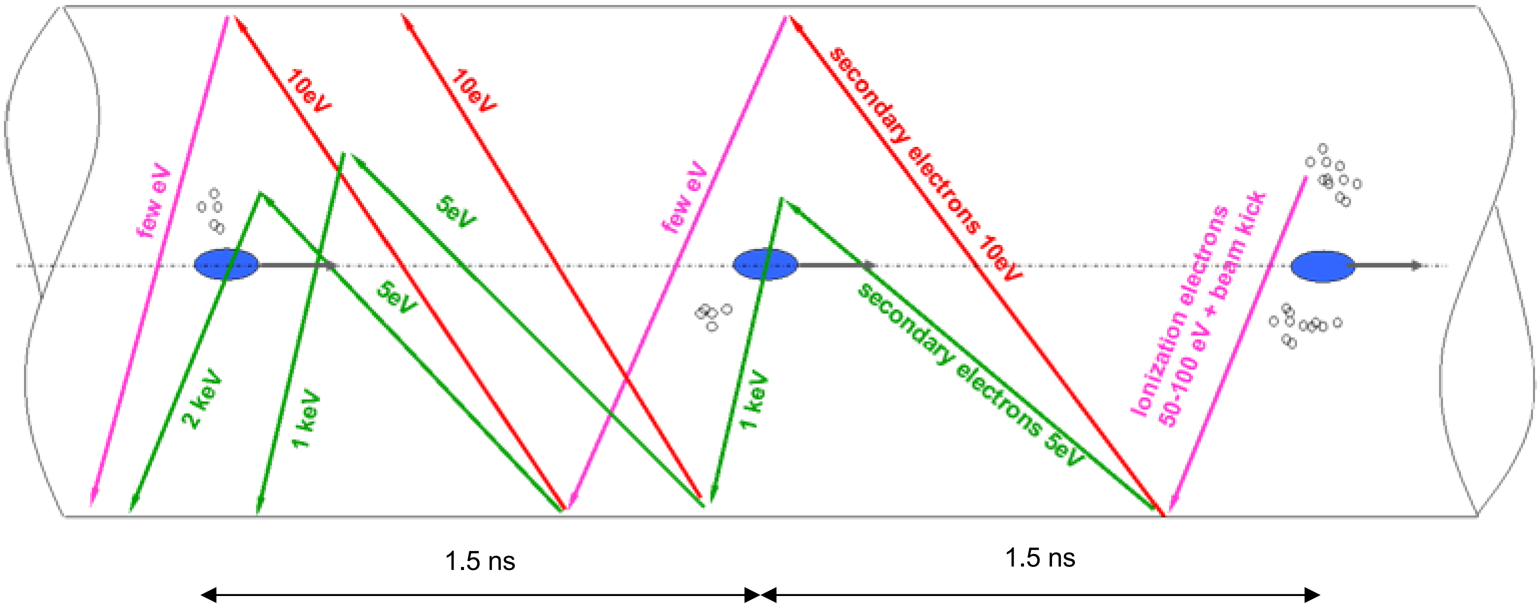
E-cloud, SEY, FII simulations, experiments in PEP-II, KEKB, CESRc and Dafne rings (SLAC, KEK, Cornell, Frascati)

ATF damping ring experiments (SLAC, LBNL, Cornell)

Lattice designs for damping rings and injection/extraction lines; characterization of collective effects; stripline kickers for single-bunch extraction at KEK-ATF (LBNL)

Schematic of electron cloud

Original picture courtesy of F. Ruggiero CERN

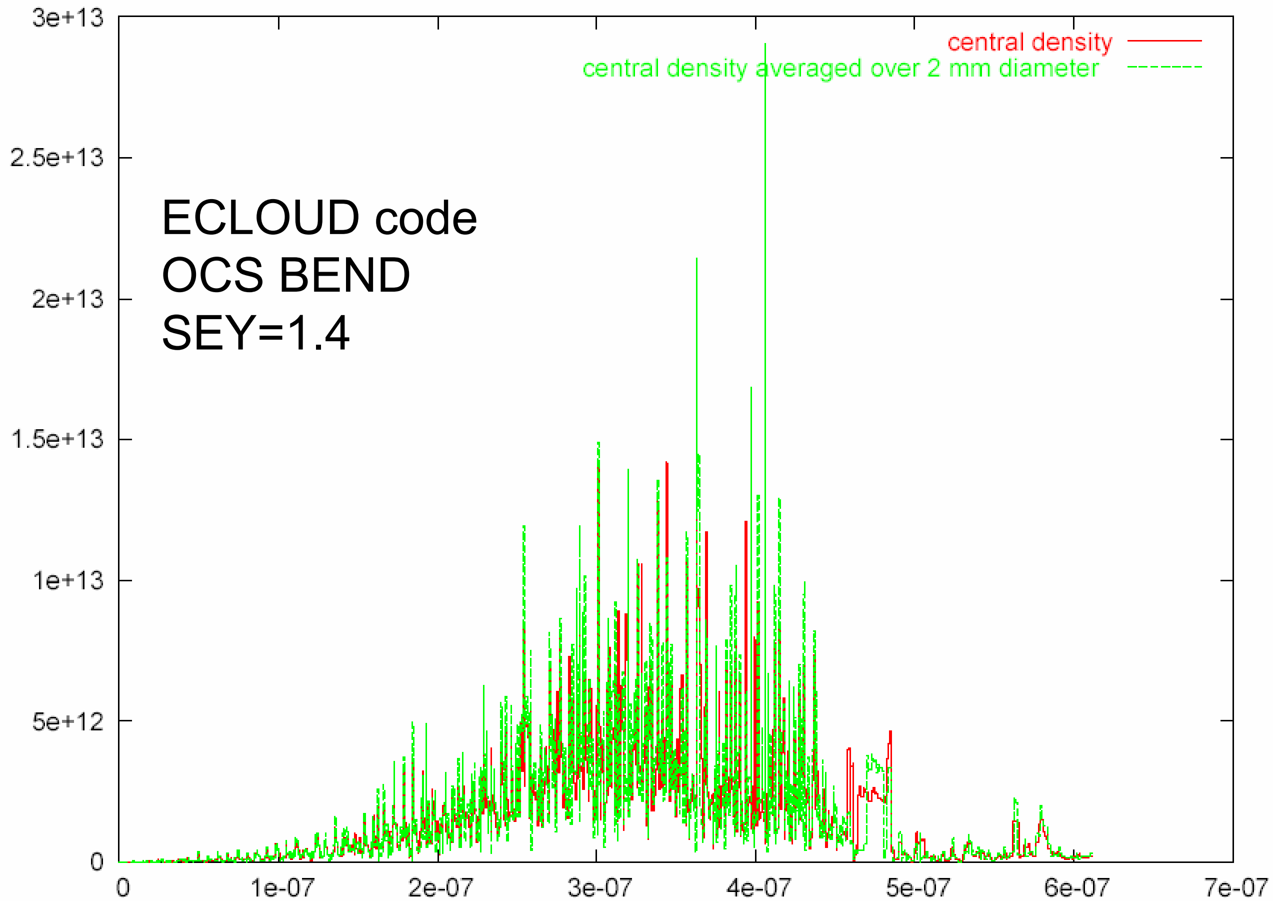


Picture:

Each bunch generates a number of electrons that may grow due to **secondary electron emission** (avg larger than 1) to form a cloud.

Concern for Luminosity in future colliders with high intensity beam

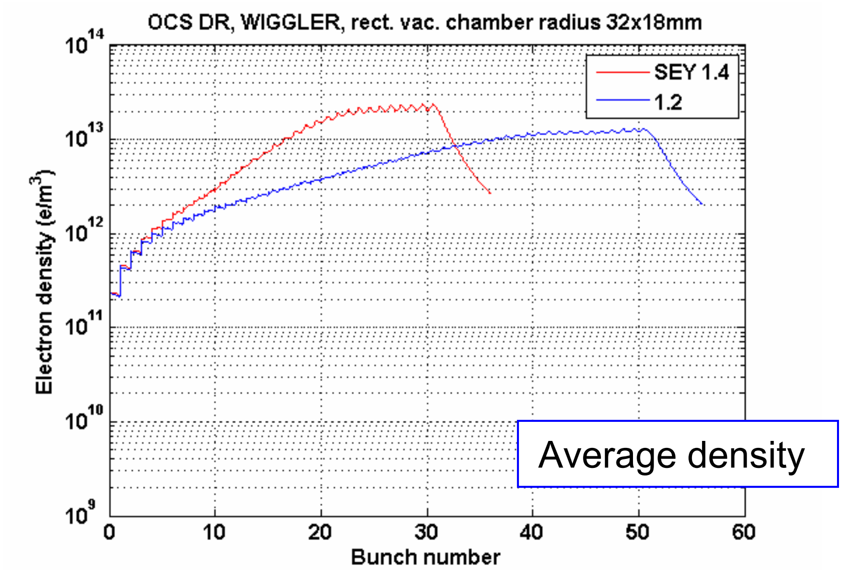
OCS BEND

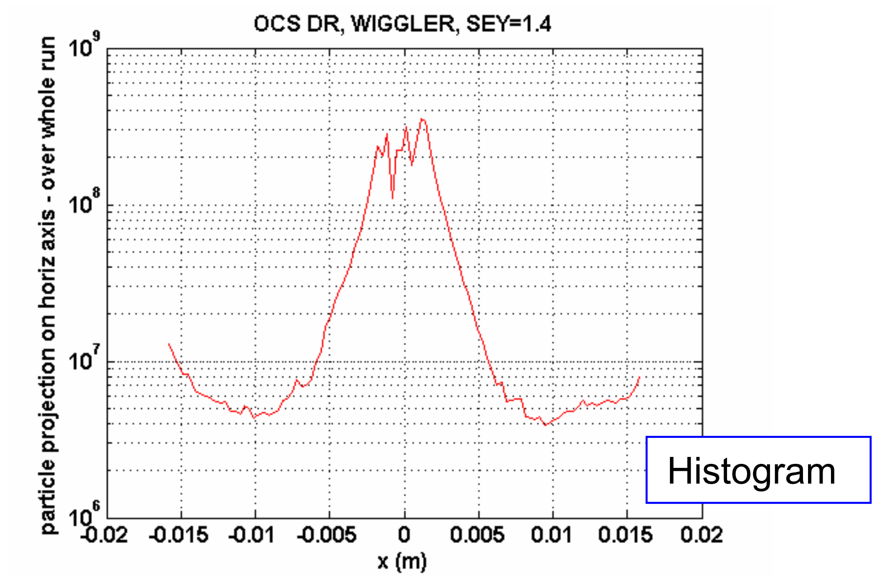


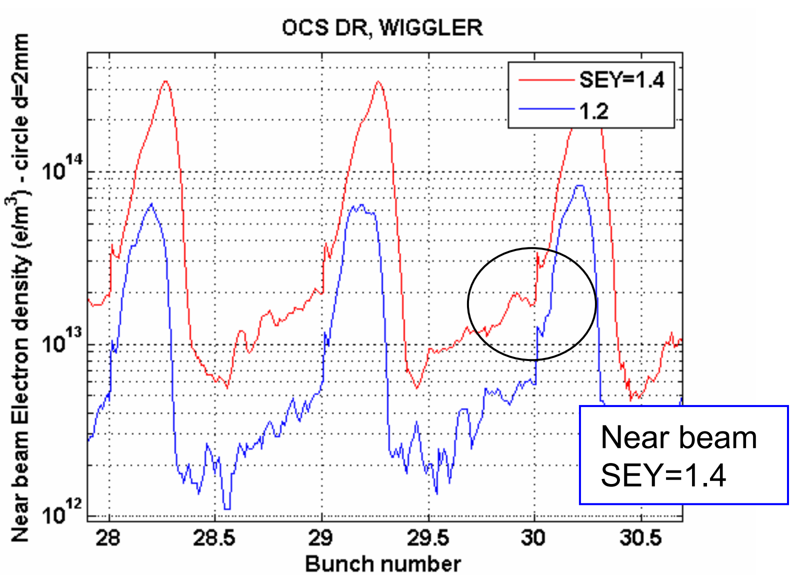
By Frank Zimmermann. Note: saturation not reached yet. Need to consider cloud density before bunch-cloud interaction. See also R. Wanzenberg DESY, next presentation benchmarking with ECLOUD.

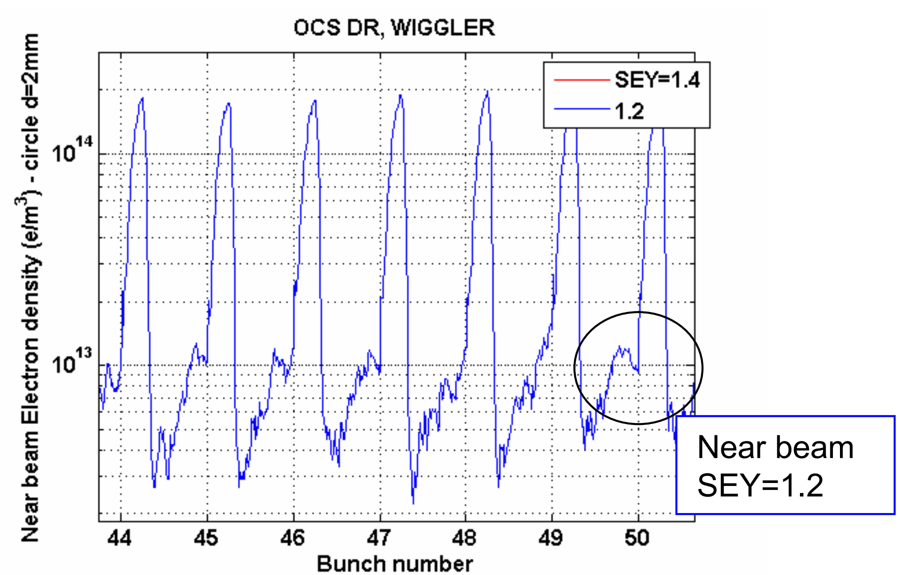
Single 6 km DR WIGGLER simulations

POSINST code
Note: Photon reflectivity R=80%





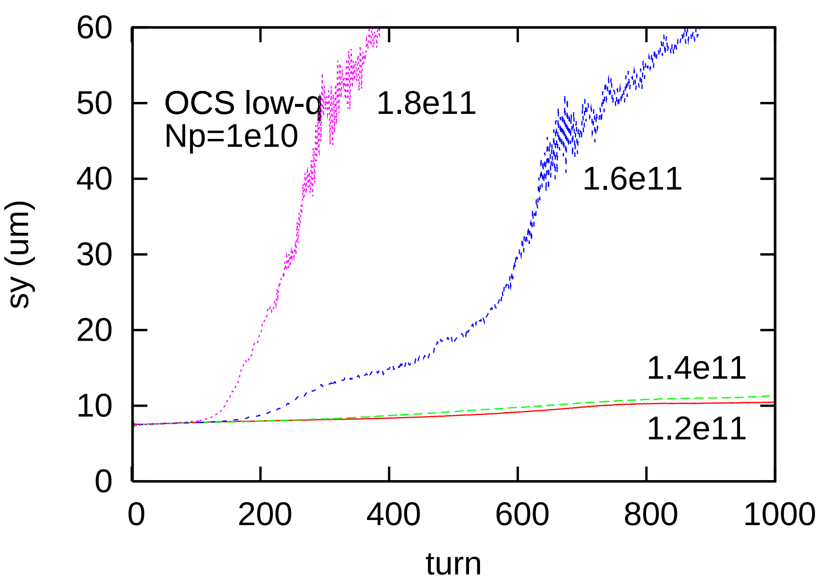


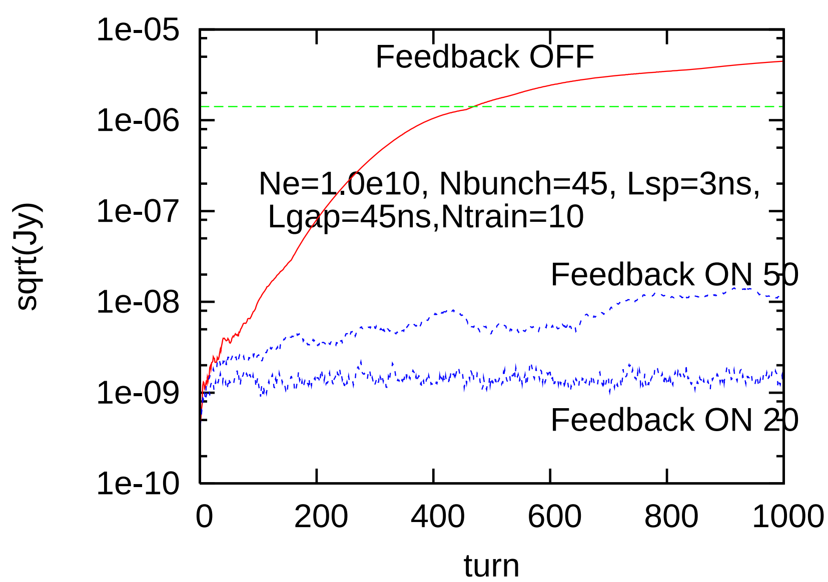


Recent results for low Q ($N=1x10^{10}$)

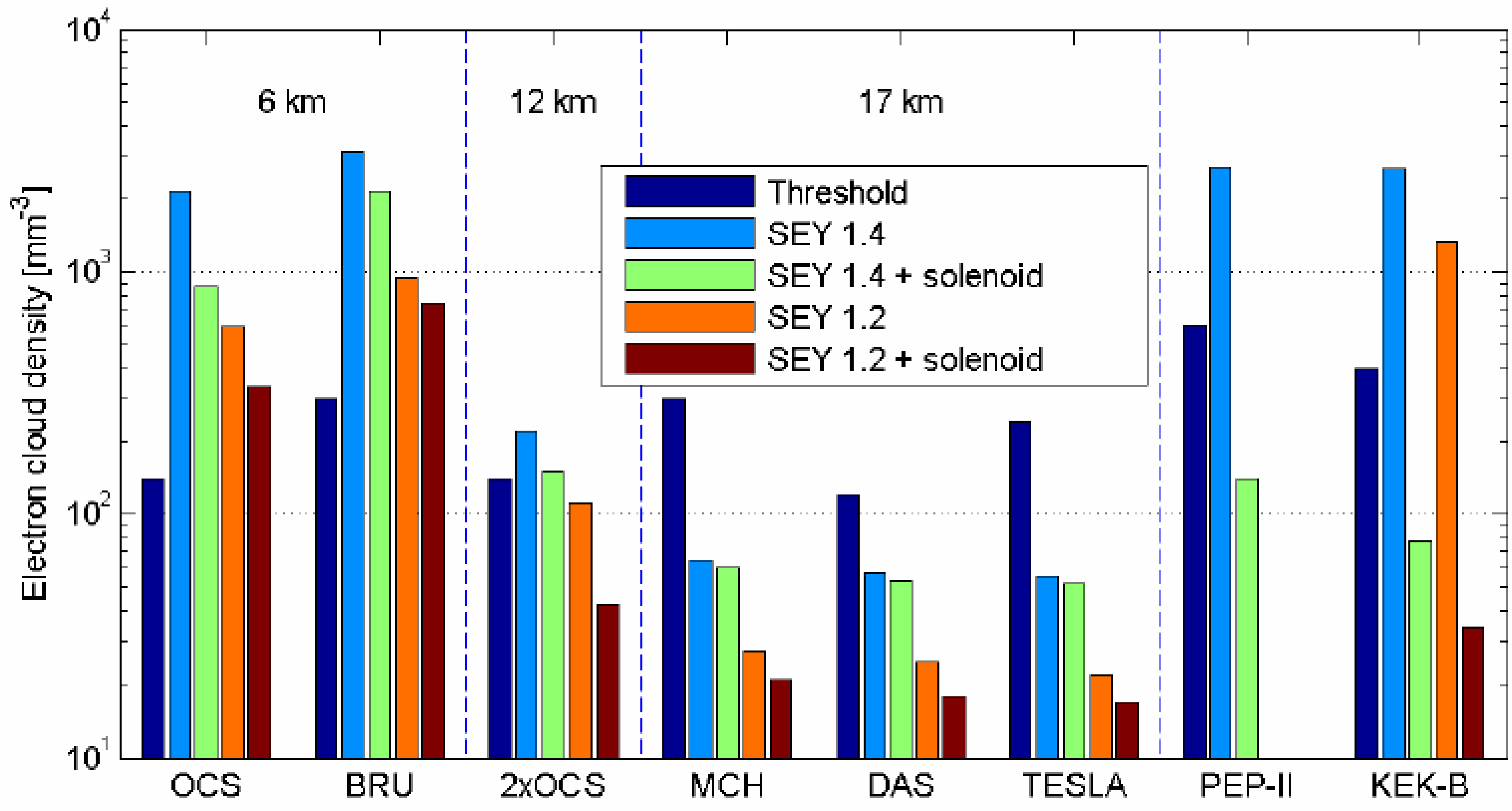
K.Ohmi (KEK)

- Ecloud: Threshold of electron cloud, $1.4x10^{11}$ m^{-3}.
- Ion: Feedback system can suppress for 650 MHz (3ns spacing), number of bunch in a train 45, and gap between trains 45ns..



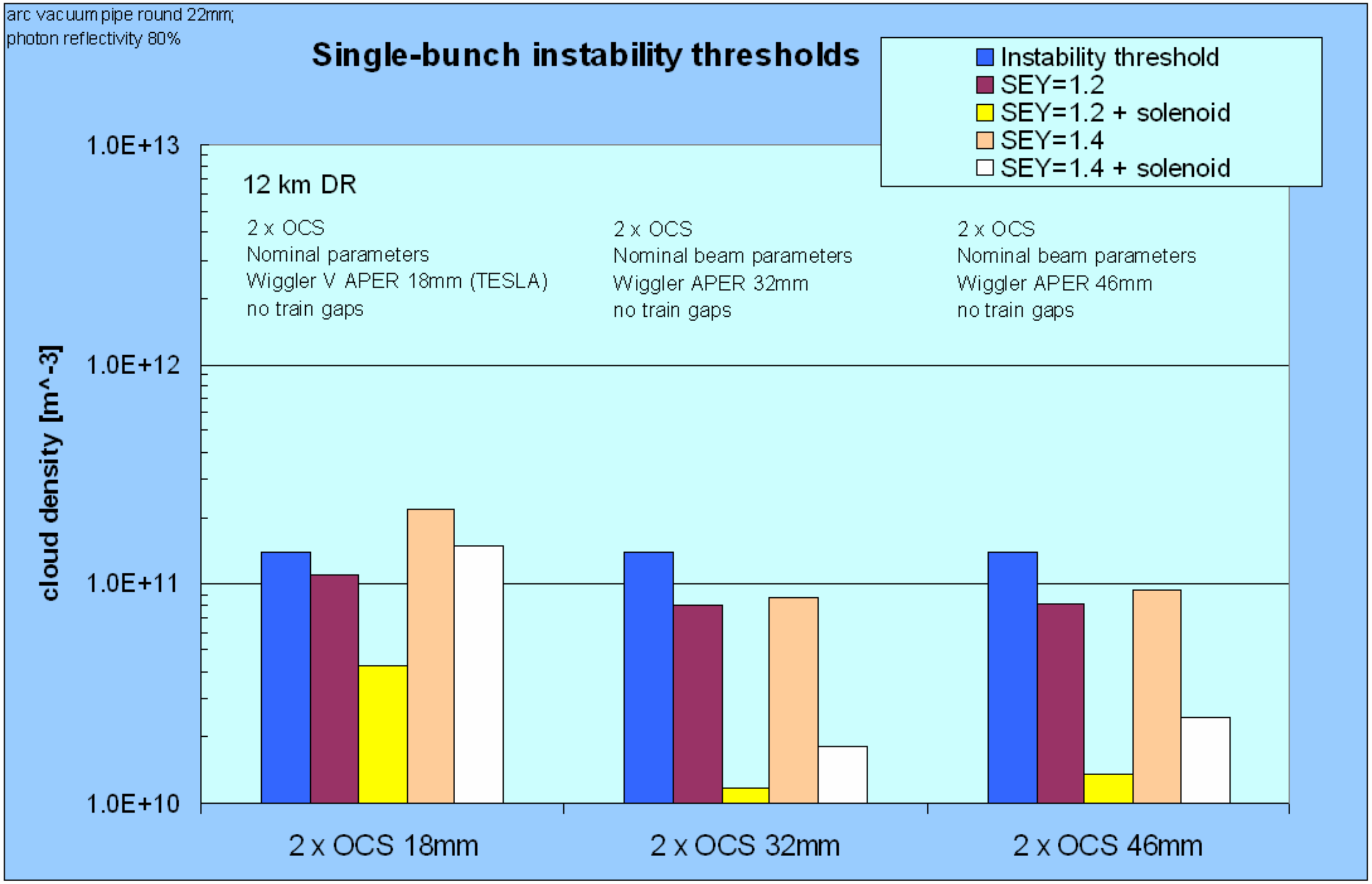


Damping ring R&D



Single bunch instability threshold and simulated electron cloud build-up density values for a peak SEY=1.2 and 1.4.

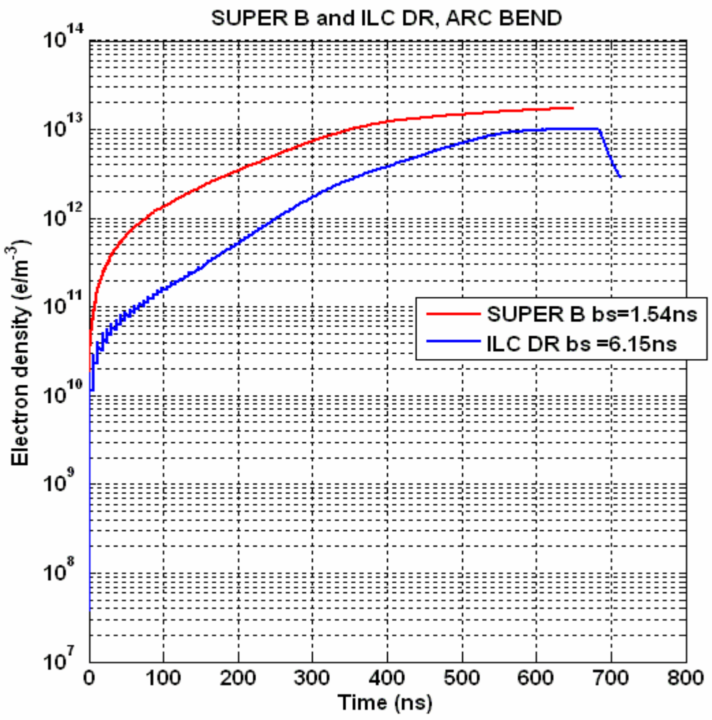
Wiggler aperture increase

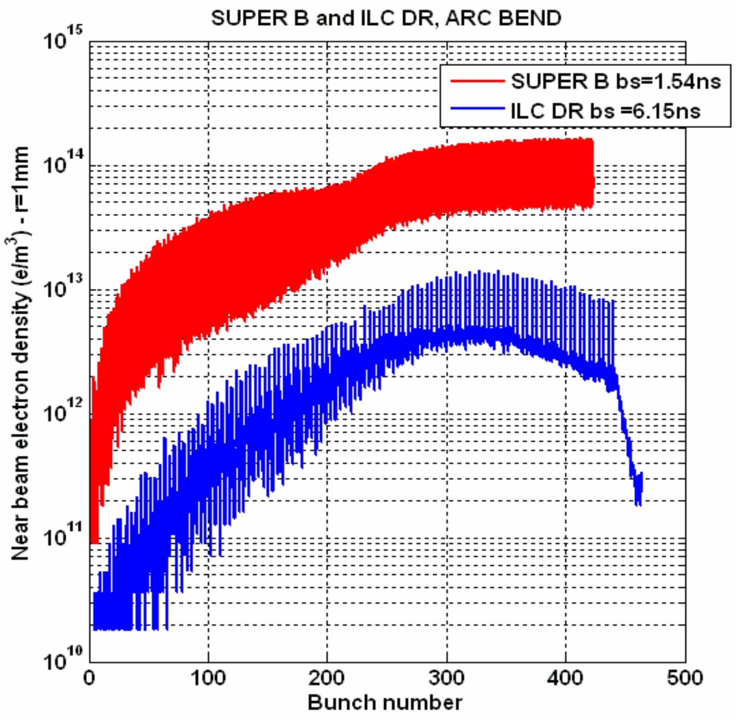


2 x 6km DR: Beneficial effect of increasing the wiggler chamber aperture.

Selected ILC 2 x 6km DR positron with increased wiggler aperture is safe from single-bunch instability !

SuperB and ILC DR





Lattice	SUPERB	OCS
Circumference [m]	6114	6114
Energy [GeV]	5.066	5.066
Harmonic number	13256	13256
Bunch charge [10^{10}]	2.0	2.0
Bunch Spacing [ns]	1.54	6.154
Mom. comp. [10^{-4}]	1.62	1.62
Bunch length [mm] sigz	6.0	6.0
Sigx, sigy in BEND [μm]	620, 8	620, 8
Energy spread [10^{-3}]	1.29	1.29
Synchrotron Tune [10^{-2}]	3.37	3.37

Compare electron cloud in SuperB and ILC (assuming 1 single ring 6 km DR instead of the actual two). Only difference is bunch spacing 1.5 ns versus 6.15 ns

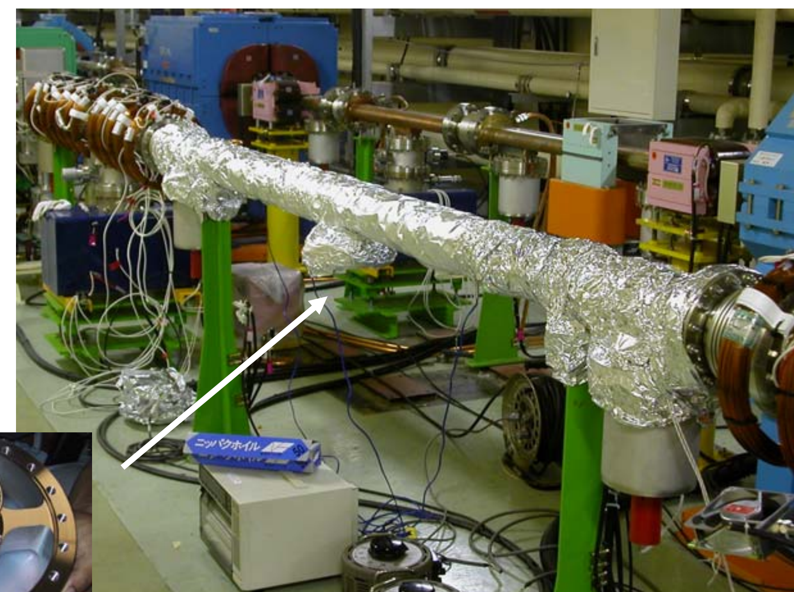
Motivations for electron cloud studies and R&D

- For ILC Damping Ring:
  - If the Secondary electron yield (SEY) can be reduced in magnets, a smaller positron (6 km) ring can be feasible
  - promising cures in magnet regions as thin micro-fins and clearing electrodes need further R&D and full demonstration in accelerators
- For Super B factory:
  - Higher currents shorter bunch spacing
- For KEKb:
  - KEKb Annual Report 2005: "The electron cloud effect still remains the major obstacle to a shorter bunch spacing, even with the solenoid windings " [1].
- For LHC

[1] http://www-kekb.kek.jp:16080/pukiwiki/index.php?Documents

At the KEKB Positron Ring

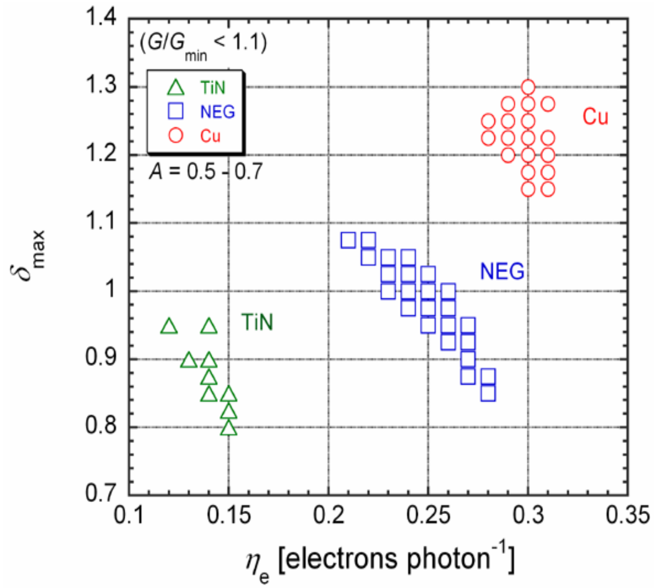
- Test chambers (Cu, TiN-coated and NEG-coated) were installed in the KEKB positron ring.
  - 3.5 GeV positron, stored beam current ~1.7 A.
- Number of electrons near the beam orbit was measured using a special electron monitor.
- SR of 1×10^{16} photons/s/m/mA was irradiated at side wall.
- Incident angle ~8 mrad.

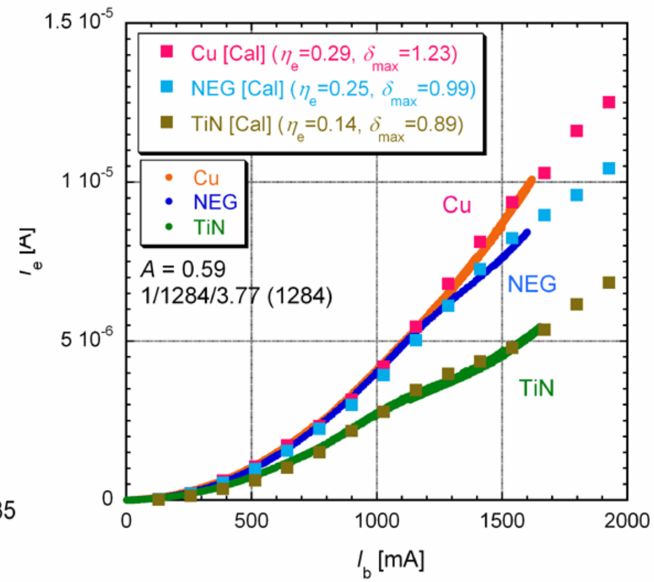


Electron monitor

Estimated η_e and δ_{max} (SEY)

- Curve fitting by scanning η_e ($0.1 \leq \eta_e \leq 0.4$) and δ_{max} ($0.8 \leq \delta_{max} \leq 2.0$).





3.77 bucket spacing
1293 bunches
Repeller -30V

	η_e	δ_{max}
Cu	0.28-0.31	1.1-1.3
NEG	0.22-0.27	0.9-1.1
TiN	0.13-0.15	0.8-1.0

- TiN coating seems better from view points of low δ_{max} and small η_e.
- δ_{max} of NEG is lower than Cu, but not so clear due to high η_e.
- The δ_{max} of Cu, NEG and TiN is near to those measured in laboratory after sufficient electron bombardment.

Electron Cloud and SEY R&D Program at SLAC

An electron cloud generates if the metal surface secondary electron yield (SEY) is high enough for electron multiplication.

In the ILC Damping Ring an electron cloud develop mostly in BENDS and WIGGLERS.

- R&D Goals
  - Reduce and stabilize the surface SEY below electron cloud threshold in the ILC damping ring. Challenge: SEY ≤ 1.2.
- Approaches
  - Electron and photon conditioning
  - Metal surfaces with fins (grooves) profile
  - Clearing electrodes
- Plan:
  - Measure the SEY of samples directly exposed to PEP-II LER synchrotron radiation and electron conditioning.
  - Test new structure concepts with very low effective SEY < 1:
  - grooved surfaces in PEP-II LER
  - clearing electrodes in PEP-II LER

Projects

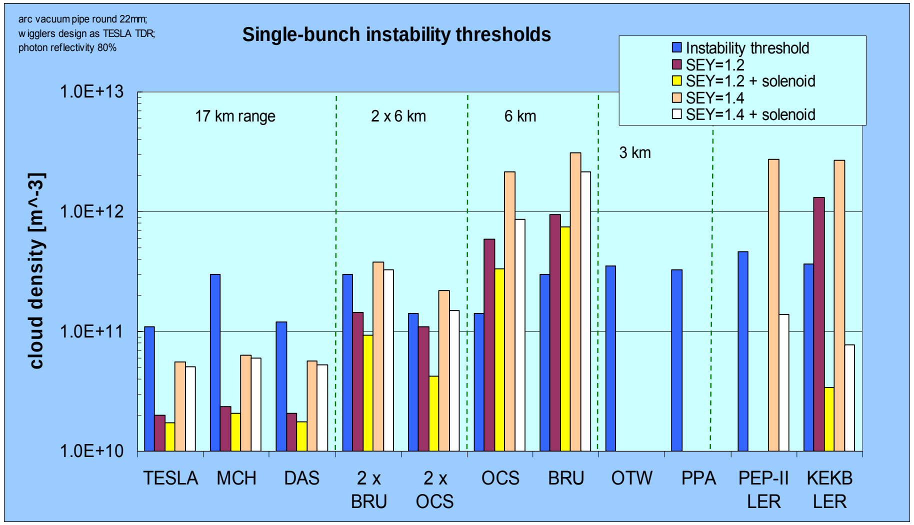
Ongoing chamber projects at SLAC:

	TEST in	LOCATION	Ready for INSTALLATION	Status
SEY TESTS TiN and NEG	STRAIGHT	PEP-II LER VACP-PR12-3101	October 2006	Pre-operation tests undergoing
LARGE FINS	STRAIGHT	PEP-II LER PR12	October 2006	Ordered chamber extrusion

Next chamber projects:

CLEARING ELECTRODES	BEND / WIGG	PEP-II LER ARC	2007	Drawings
MICRO-FINS	BEND / WIGG	PEP-II LER ARC	2007	Drawings

SLAC: E-cloud R&D Program



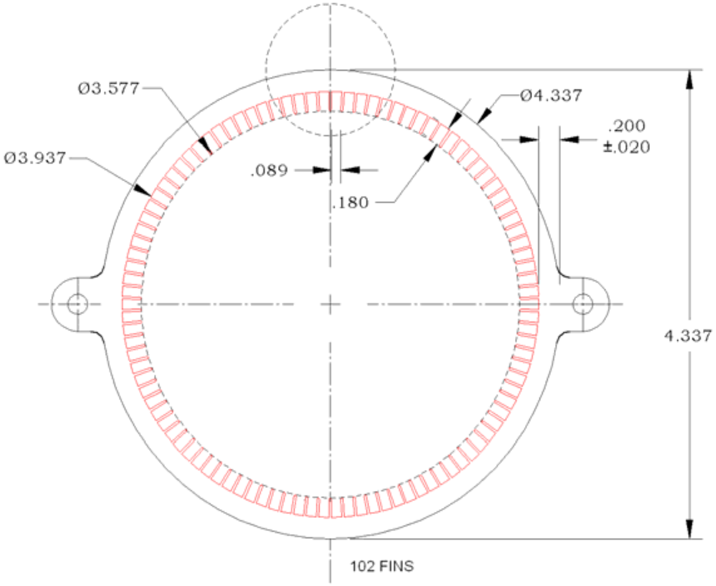
Multi-pronged program

Simulations (SLAC, KEK, LBNL)

Secondary Yield studies

Test sample chamber in PEP-II

Chambers with fins to trap e-

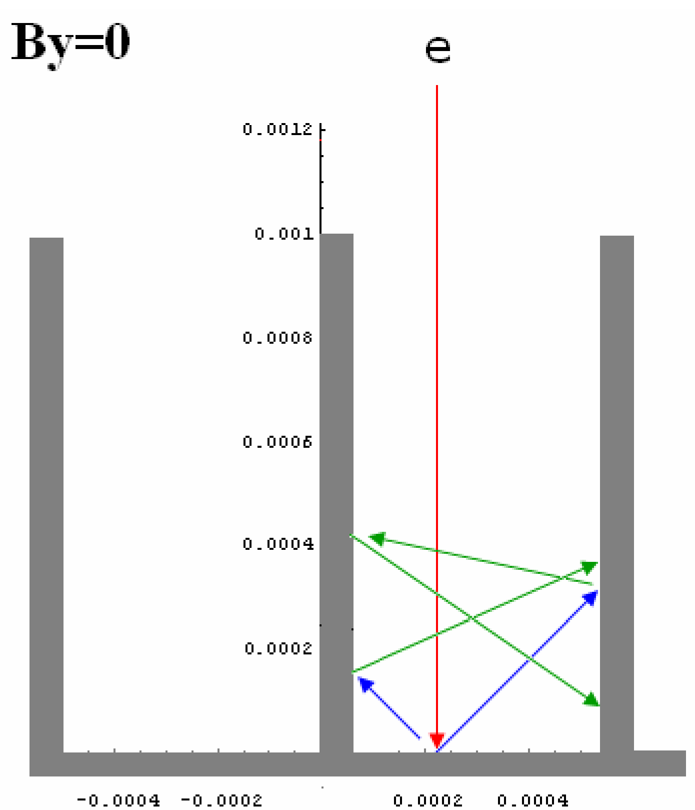


Rectangular Grooves to Reduce SEY

Rectangular grooves can reduce the SEY without generating geometric wakefields.

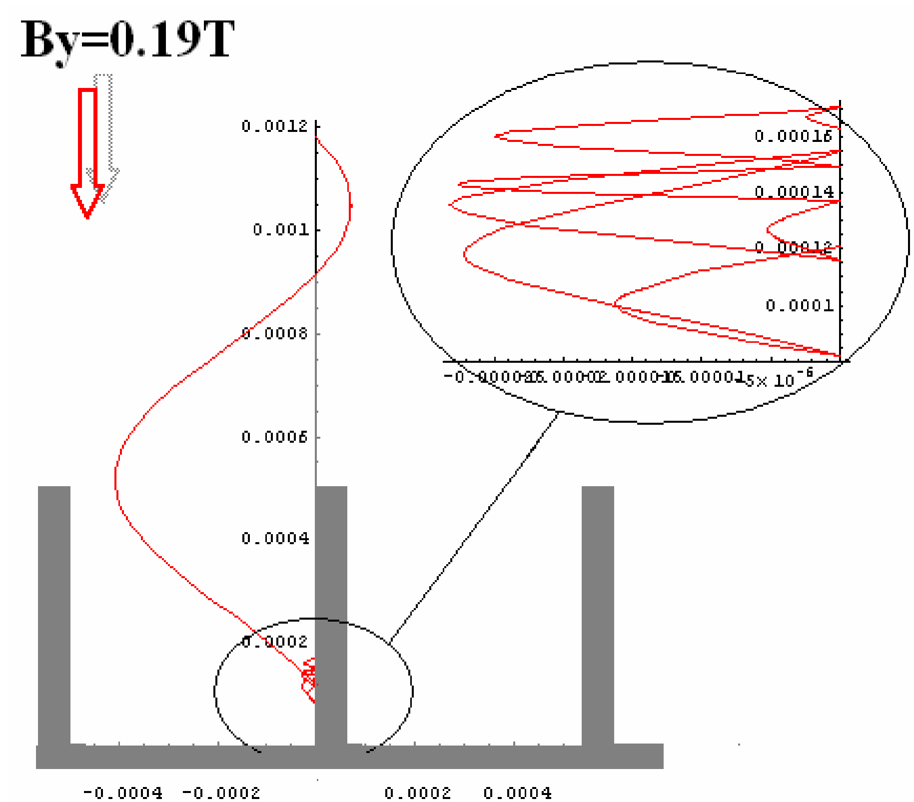
Macro fins (mm scale)

USE IN STRAIGHT
Without B field

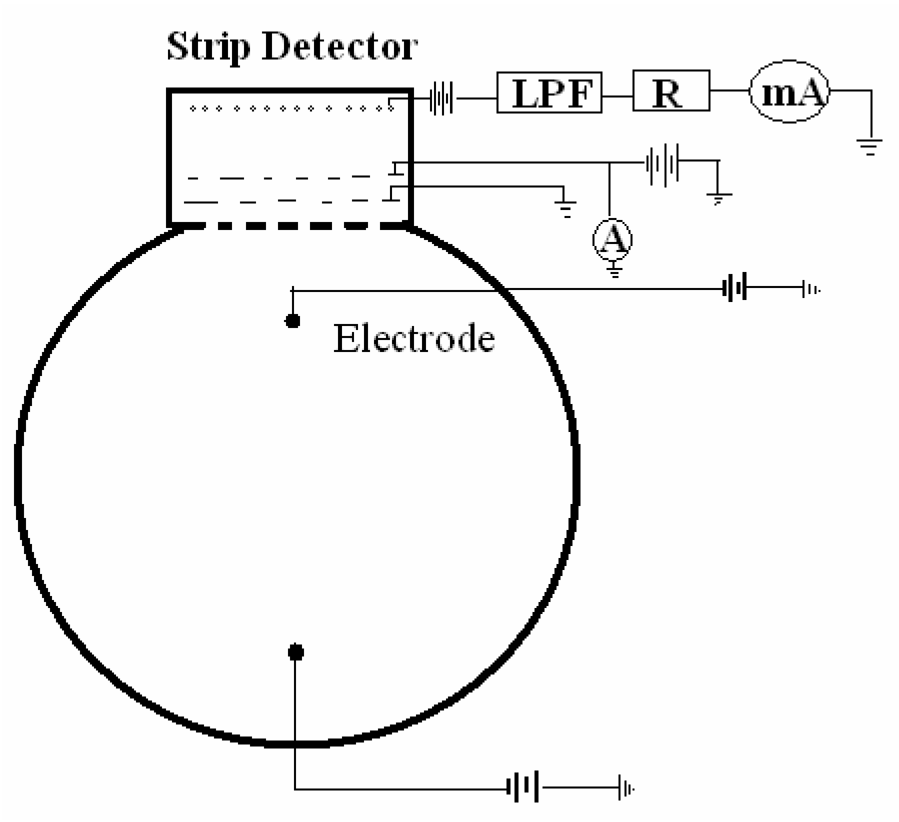


Micro fins (μm scale)

USE IN BEND, WIGG, QUAD
With B field



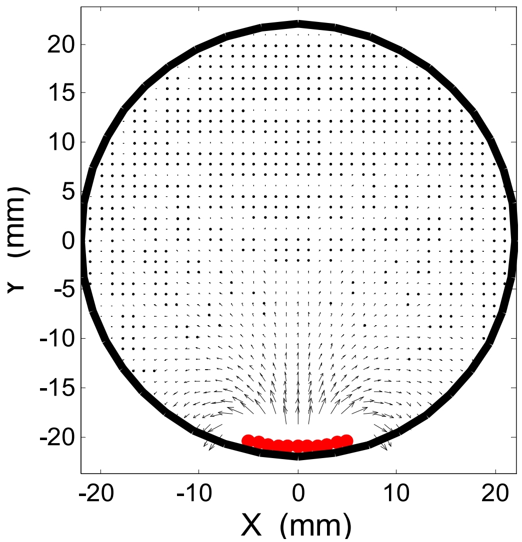
Wire Type electrode



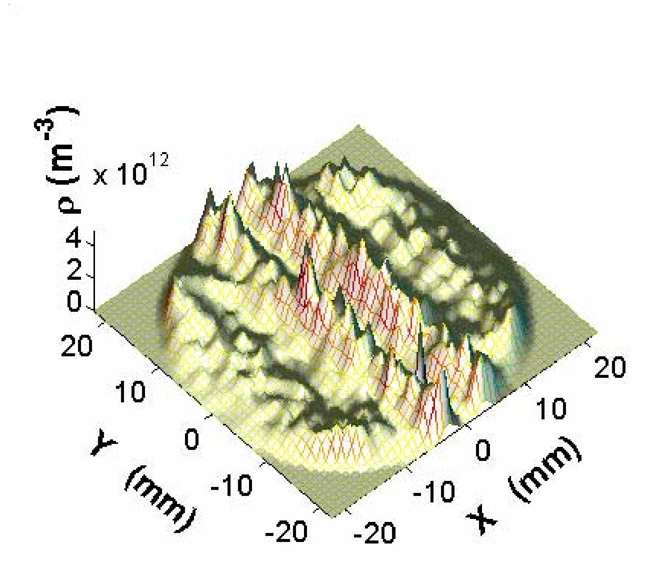
- **Its effect is perfect**
- **easy to apply inside long wiggler and short dipole**
- **Support?**

Clearing of electron cloud in ILC dipole magnet

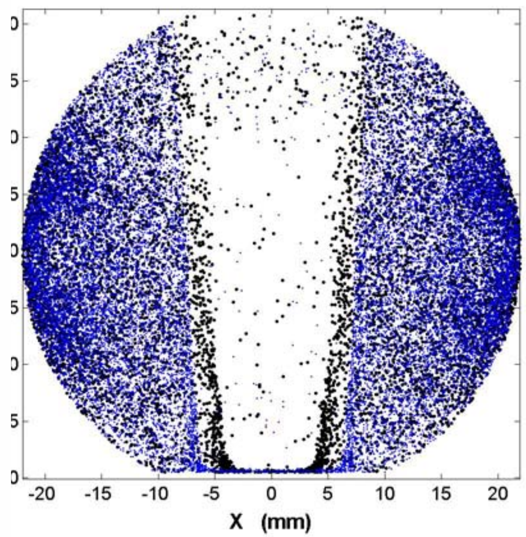
The width of low electron density region increases with the size of the electrode.



Clearing field



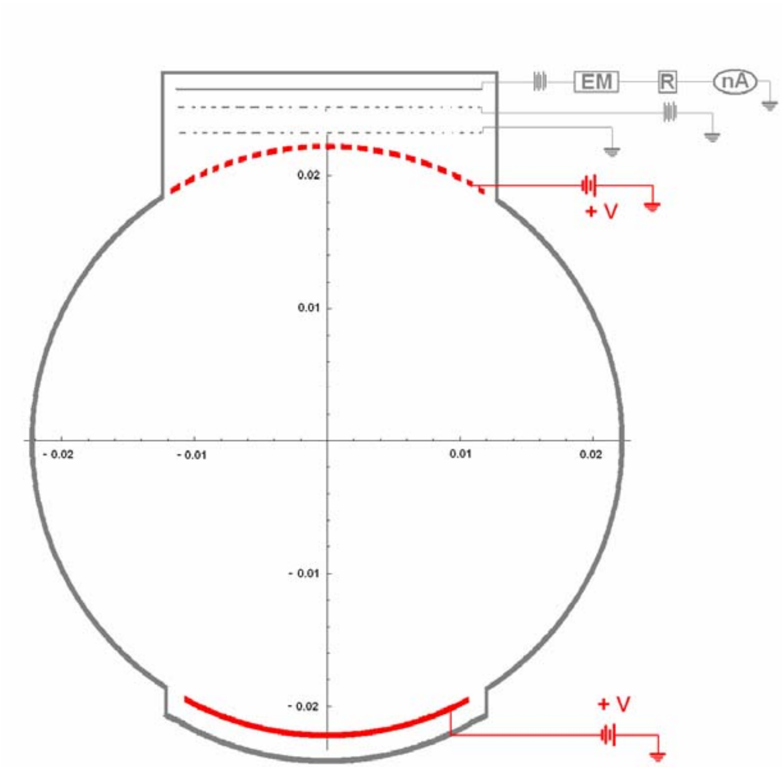
0 Voltage



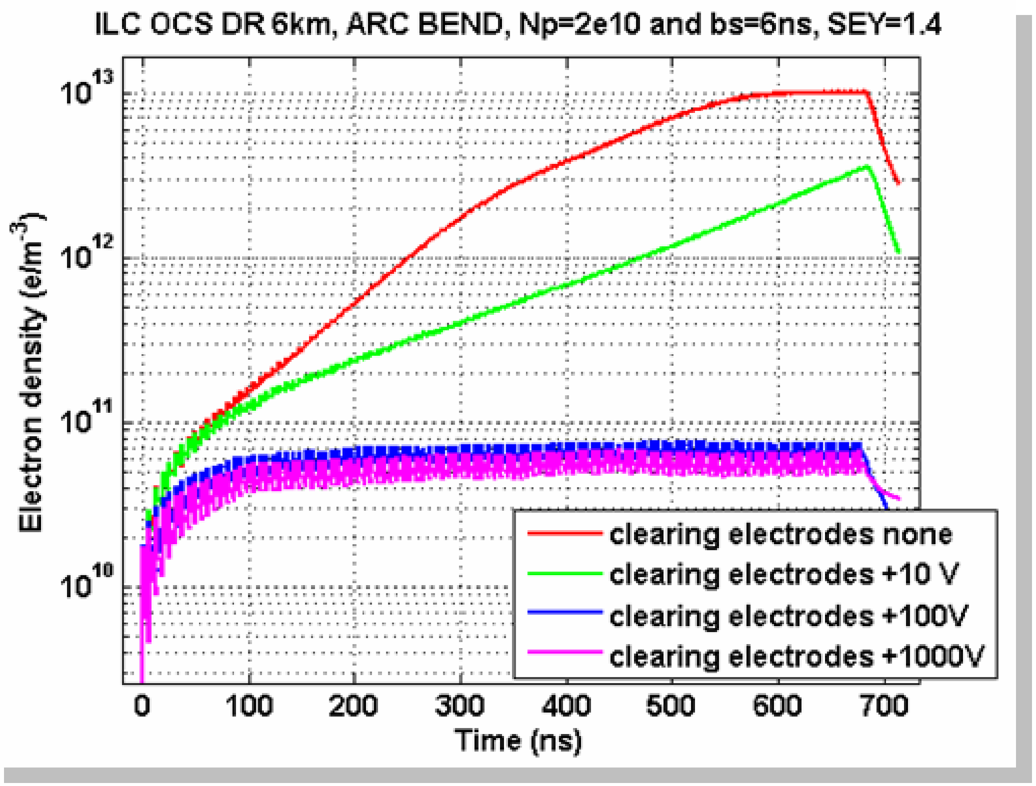
100 Voltage

Clearing field (left) and effect (right) of a **traditional stripline type of electrode**. The red color in (left) shows the electrode. The blue and black dots in right plot show the electrons with different size of electrode.

Curved clearing electrodes: simulations



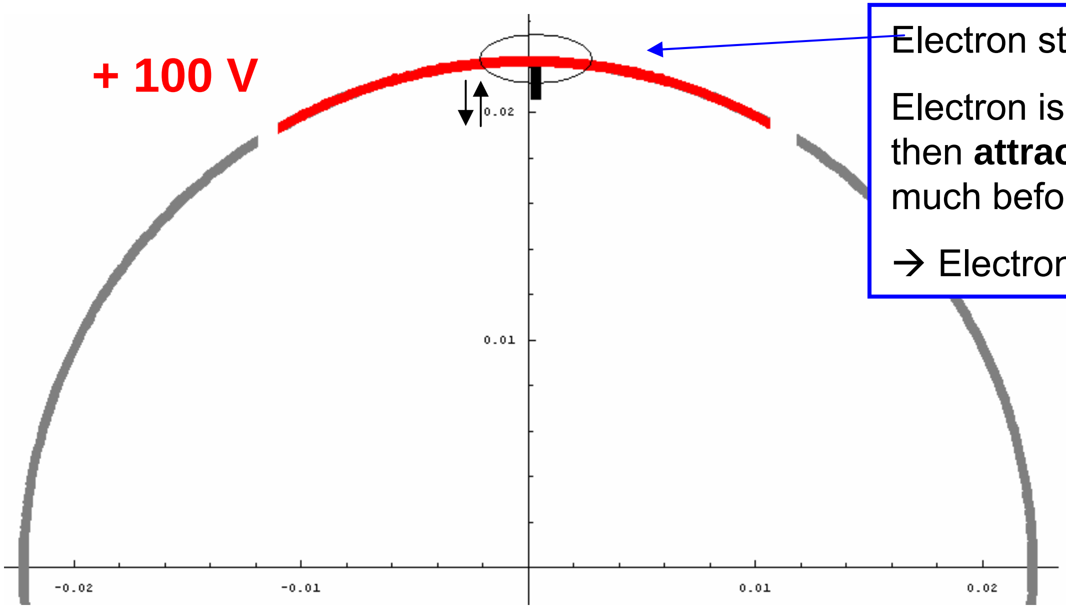
BEND chamber with curved clearing electrodes



Simulation unsing POSINST code of electron cloud build-up and suppression with clearing electrodes. ILC DR positron: assuming one single 6 km ring.

M. Pivi – P. Raimondi, L. Wang, T. Raubenheimer SLAC, Mar 2006

Curved clearing electrodes effect



Electron starts at rest near wall.

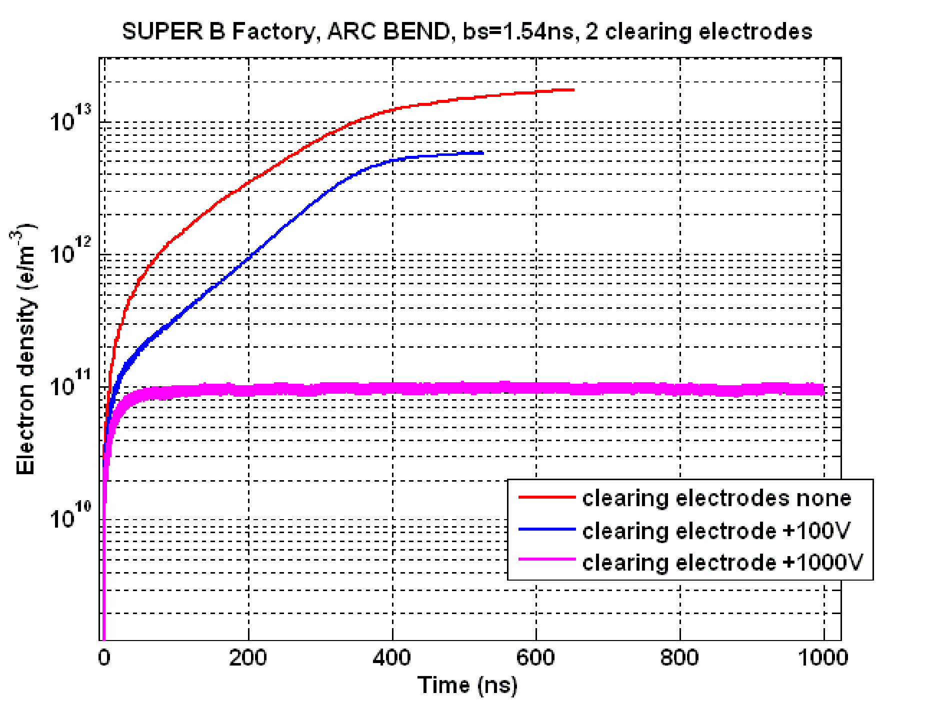
Electron is first accelerated to the center by the **beam** and then **attracted back by the +100V electrode,** after 3 ns much before the next bunch passage.

→ Electron cloud is strongly suppressed !

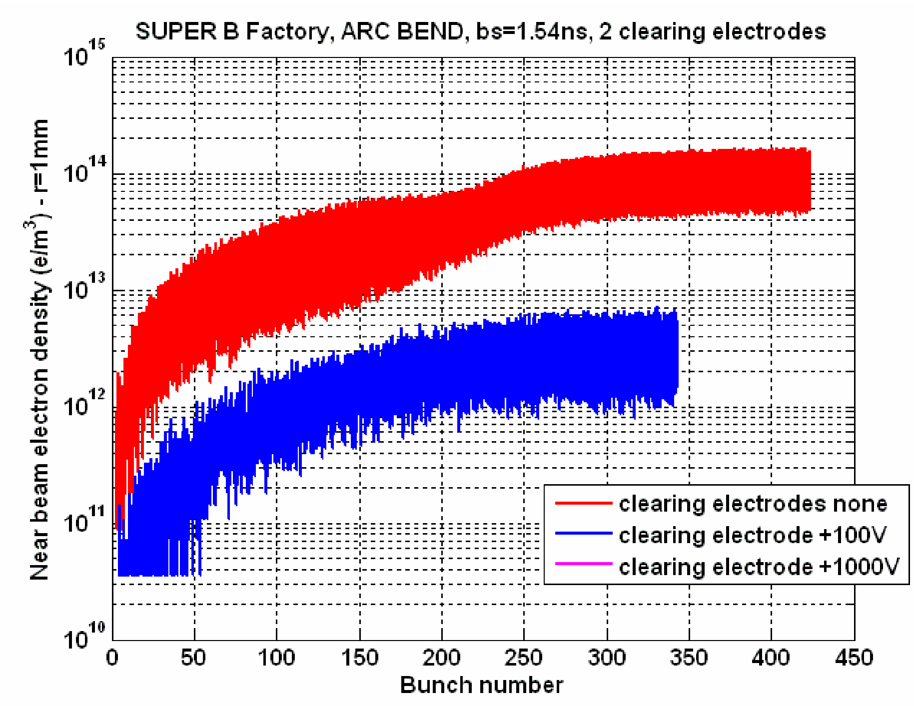
$$V_{CE} = +100 \text{ V}$$
$$E_{CE} \approx 2000. \text{ V/m}$$
$$m\ddot{x} = -e(2000[V/m] + v \times 0.2[T])$$

electron back to the wall in ~ 3 ns

SUPERB bends clearing electrodes



E-cloud build-up and suppression with/without clearing electrodes in bends of SUPERB factory (bs=1.54ns)

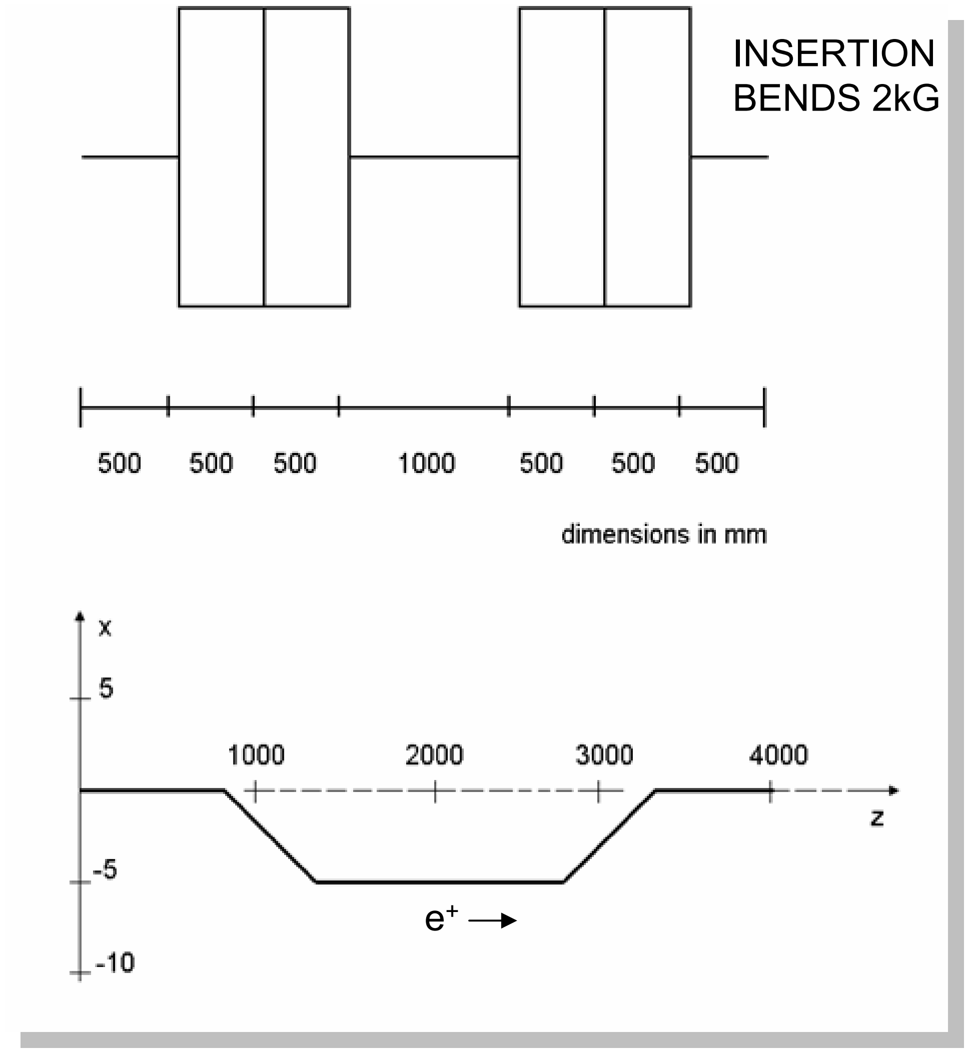


Near beam electron cloud density.

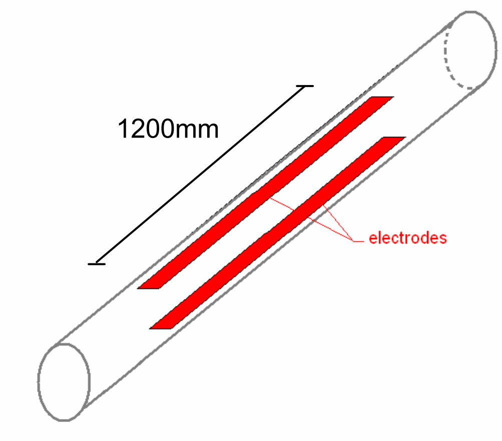
POSINST code

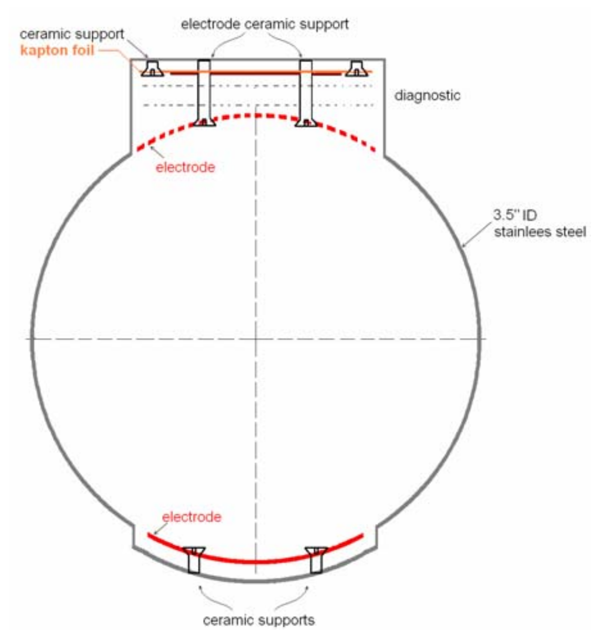
M. Pivi – P. Raimondi, L. Wang, T. Raubenheimer SLAC, Mar 2006

Option 1: four magnets chicane



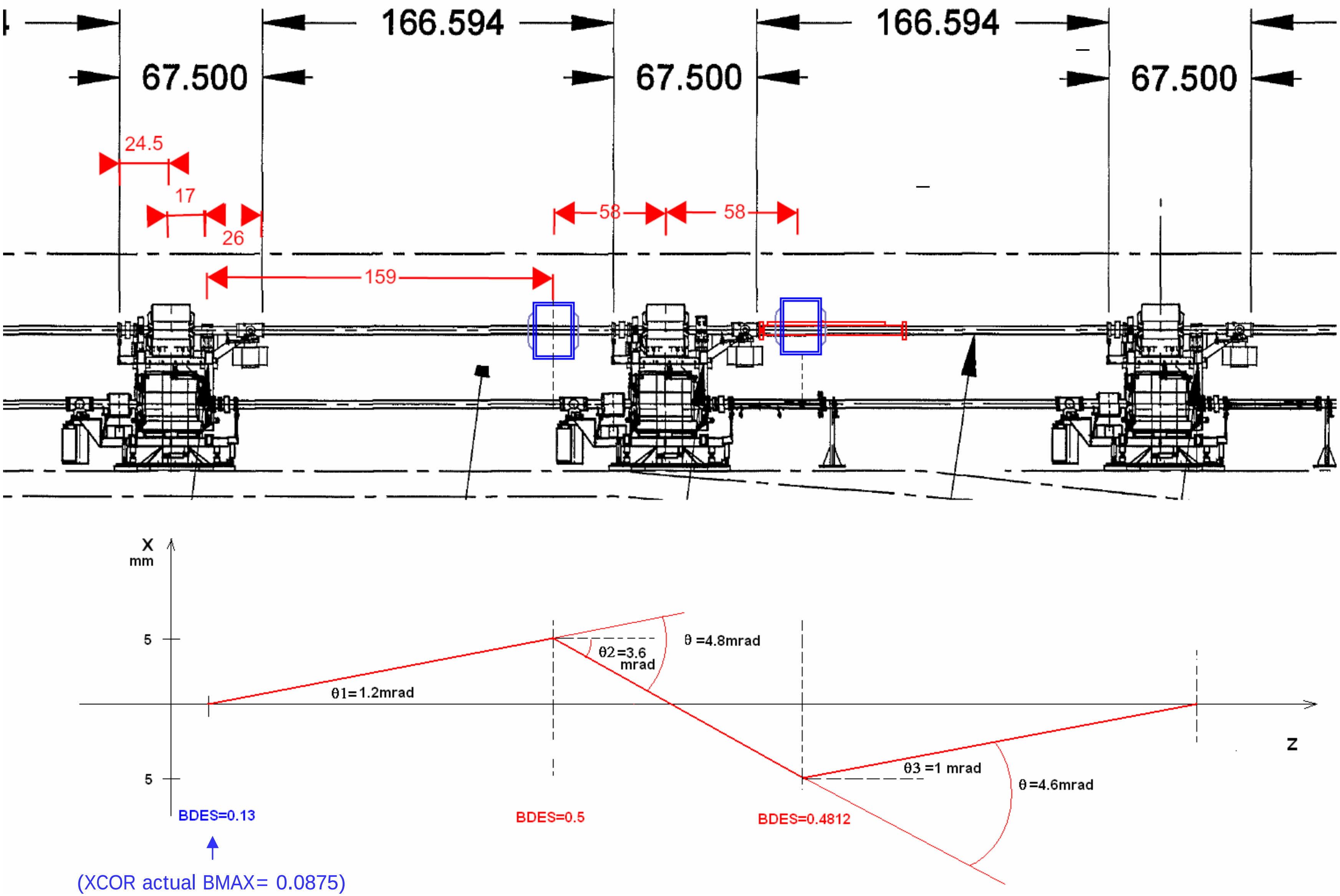
Layout PEP-II installation, PR12 LER

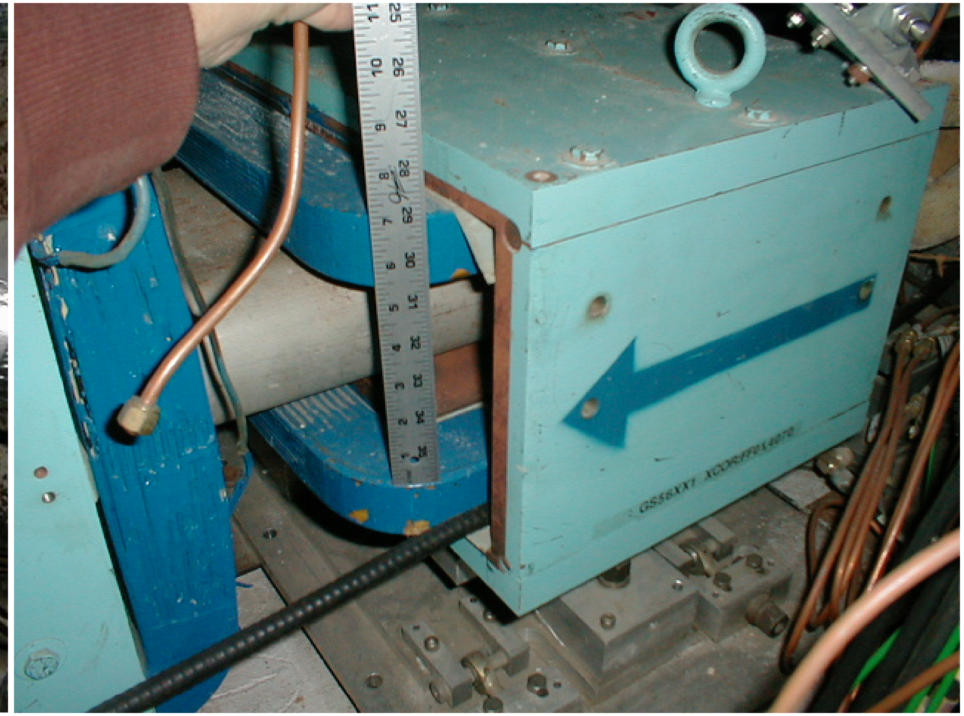


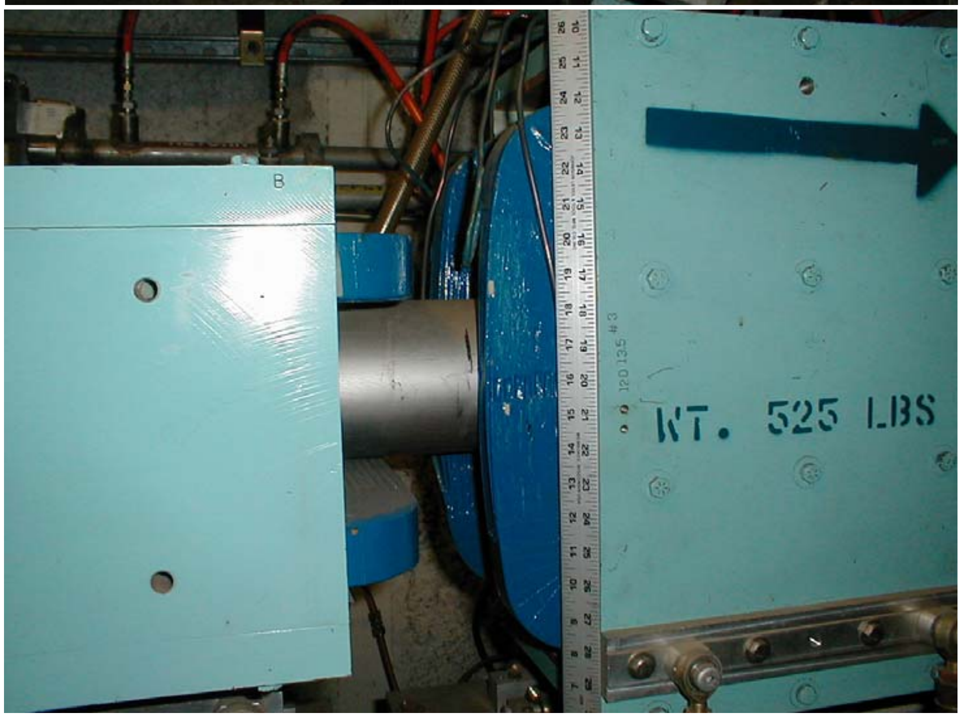


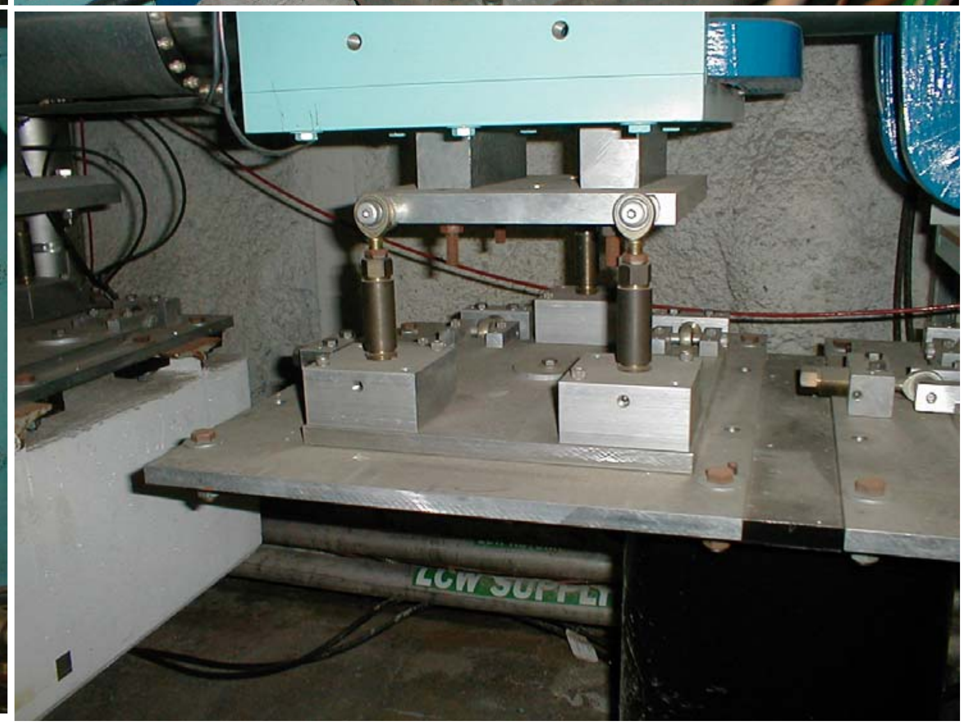
Chamber layout PEP-II

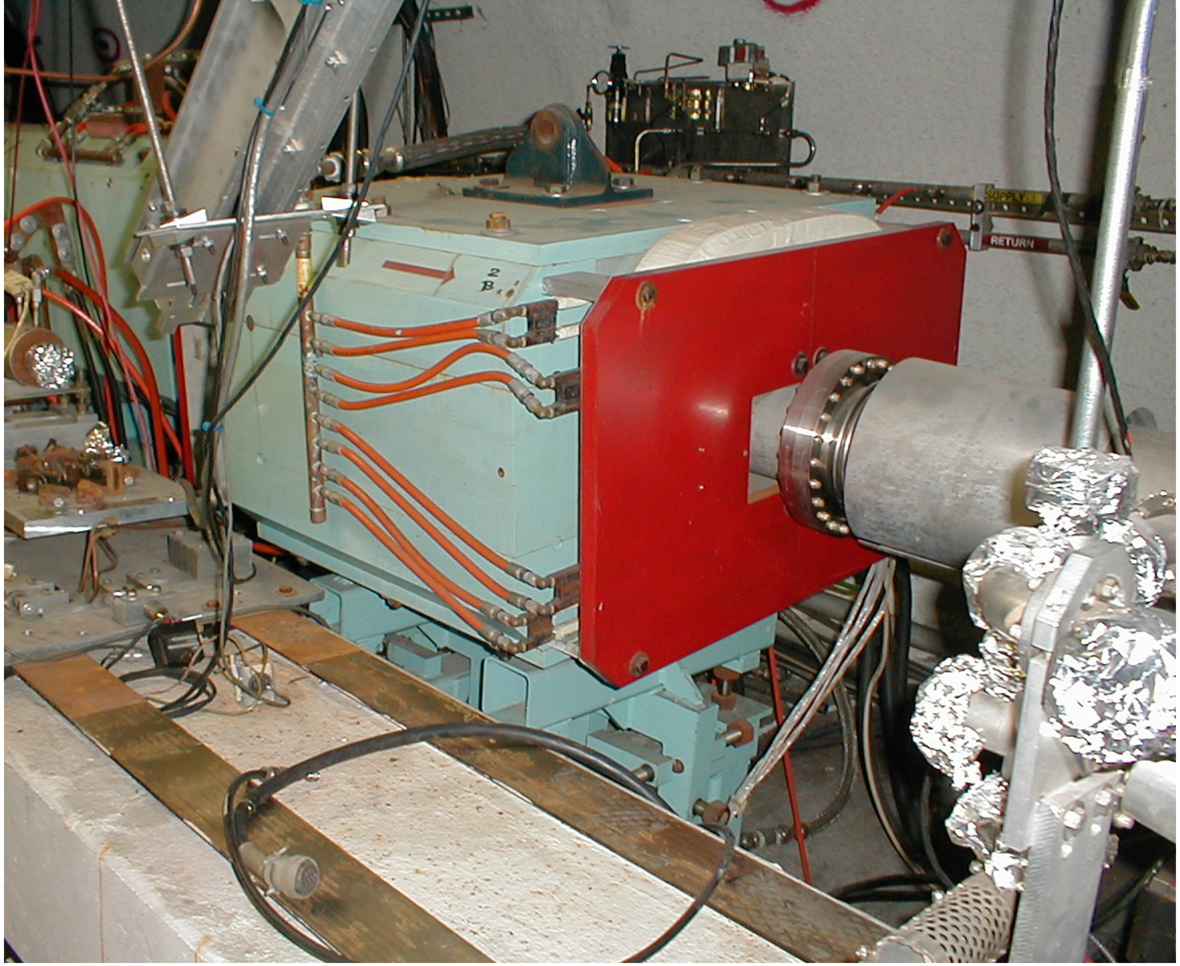
Option 2: two magnets chicane






WT. 525 LBS



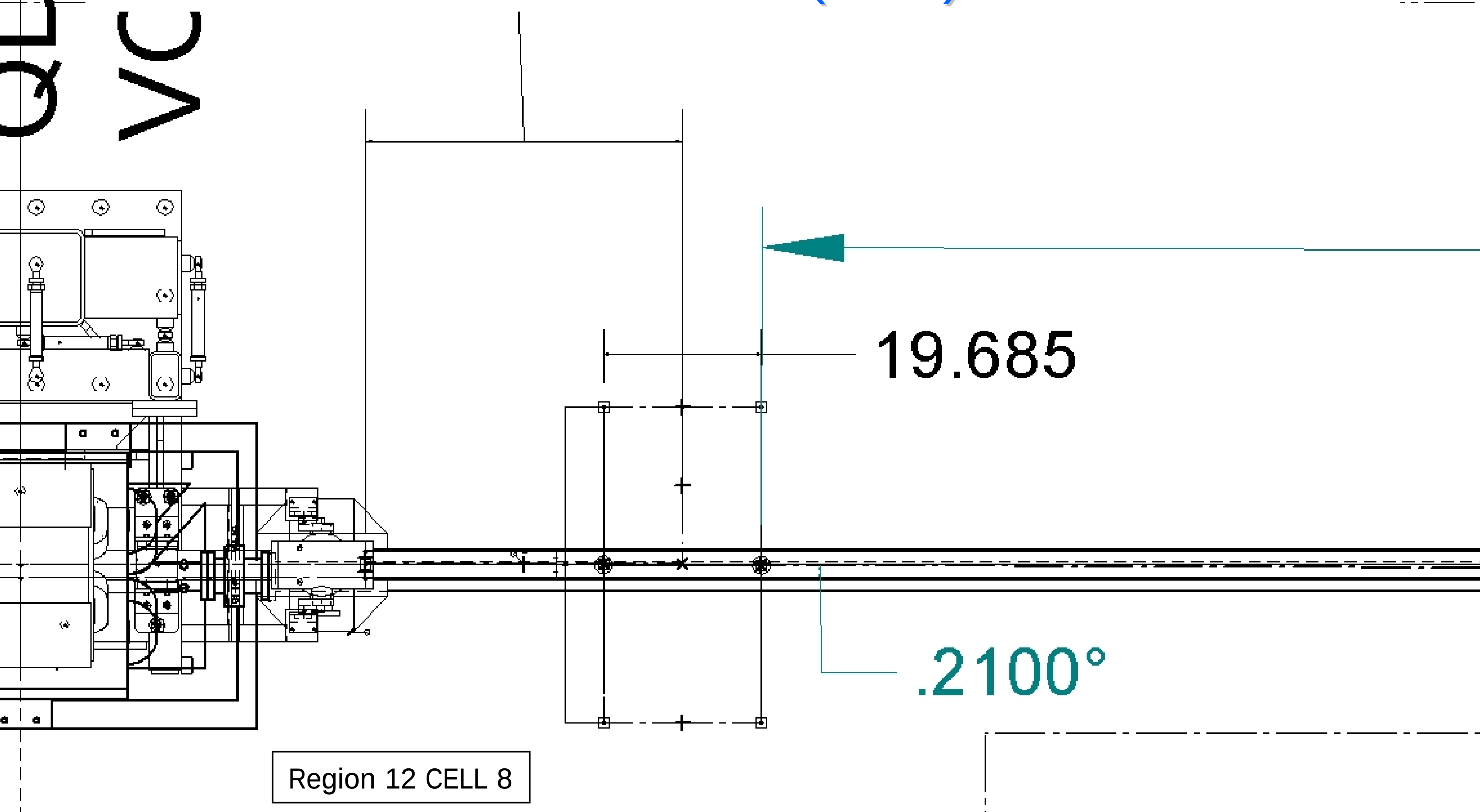


B33 LGPS16	SLC South FF damp, en. spectrometer	28” long	6” aperture

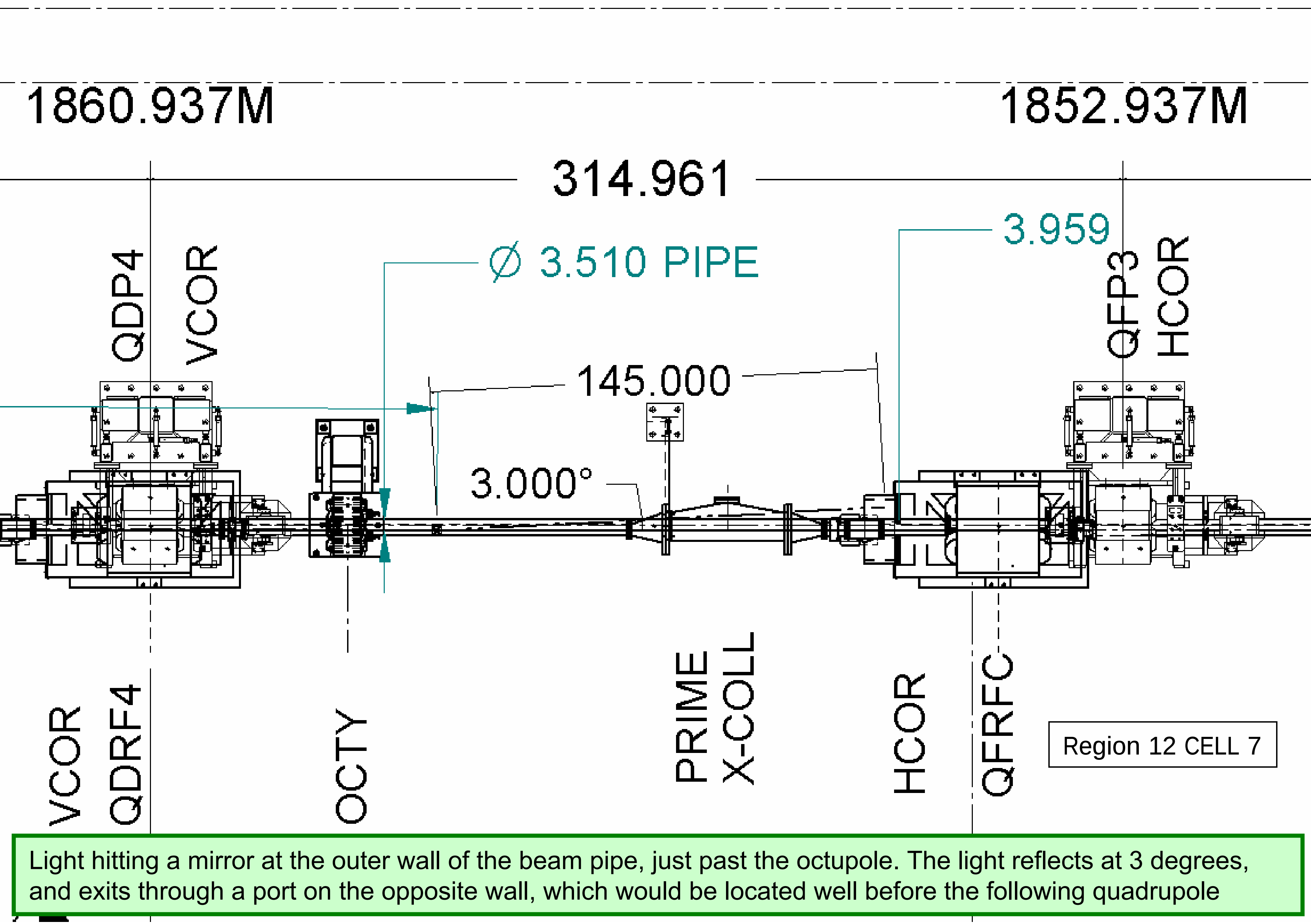
SLC final focus correctors and magnets	Location, note	length	aperture	BMAX on SCP (BdL=KG-m)
B33 LGPS16	South FF damp, en. spectrometer	28”	6”	36.81
YCOR: FF01, 2280	South FF, orange	15”	4”	0.406
XCOR: FF01, 2270	South FF, orange	15”	4”	0.406
YCOR: FF01, 4080	**South FF, blue**	**13.5”**	**5 ¼”**	**0.143**
XCOR: FF01, 4070	**South FF, blue**	**13.5”**	**5 ¼”**	**0.27**
YCOR: FF01, 5180	**South FF, blue**	**13.5”**	**5 ¼”**	
XCOR: FF01, 5170	**South FF, blue**	**13.5”**	**5 ¼”**	
YCOR: FF01, 5340	**South FF, blue**	**13.5”**	**5 ¼”**	**0.264**
XCOR: FF01, 5330	**South FF, blue**	**13.5”**	**5 ¼”**	**0.25**
YCOR: FF11, 5340	**North FF, blue**	**13.5”**	**5 ¼”**	
XCOR: FF11, 5330	**North FF, blue**	**13.5”**	**5 ¼”**	
YCOR: FF11, 5180	**North FF, blue**	**13.5”**	**5 ¼”**	
XCOR: FF11, 5170	**North FF, blue**	**13.5”**	**5 ¼”**	
YCOR: FF11, 4080	**North FF, blue**	**13.5”**	**5 ¼”**	
XCOR: FF11, 4070	**North FF, blue**	**13.5”**	**5 ¼”**	
“CN84BD1”	North FF damp, en. spectrometer ?!	36”	4”	

Water cooling line would allow to reach 2 kG

ADVANTAGE: SYNCHROTRON-LIGHT BEAM SIZE MONITOR LER (HER) BUILT-IN



Sketch showing the source point, in the first magnet of the chicane. The light is taken after the beam bends through 3.6 (sketches by D. Arnett).



Light hitting a mirror at the outer wall of the beam pipe, just past the octupole. The light reflects at 3 degrees, and exits through a port on the opposite wall, which would be located well before the following quadrupole

Clearing electrodes chamber

- Suppress the electron cloud in BEND and WIGGLER (QUAD) section. Perfect !

- DESIGN: optimized, kicker stripe line concept
- LOCATION: PEP-II LER PR12 Straight CELL 8, in a dedicated 4 (2) BENDS chicane (bump).
- MATERIAL: SLC FF correctors + one chamber with electrodes and diagnostics.
- ADVANTAGES: extra SR monitor LER (HER) come at low cost

- Alternative location: existing BCC4L BEND in PR02
- Manufacturing should start as soon as possible (!)

ILC and PEP-II, collaboration; Cornell, KEK (?!)

R&D Status Summary

- SEY test chamber: chamber ready, tunnel supports manufacturing, thermal and transferring sample tests, installation 2006
- Fins chambers: extruded chambers arrive mid-June, installation 2006

- Clearing electrodes chambers: decision on chicane layout, need detailed drawings → installation downtime 2007 (?!)
- Thin micro-fins: analyzing first samples, feasibility

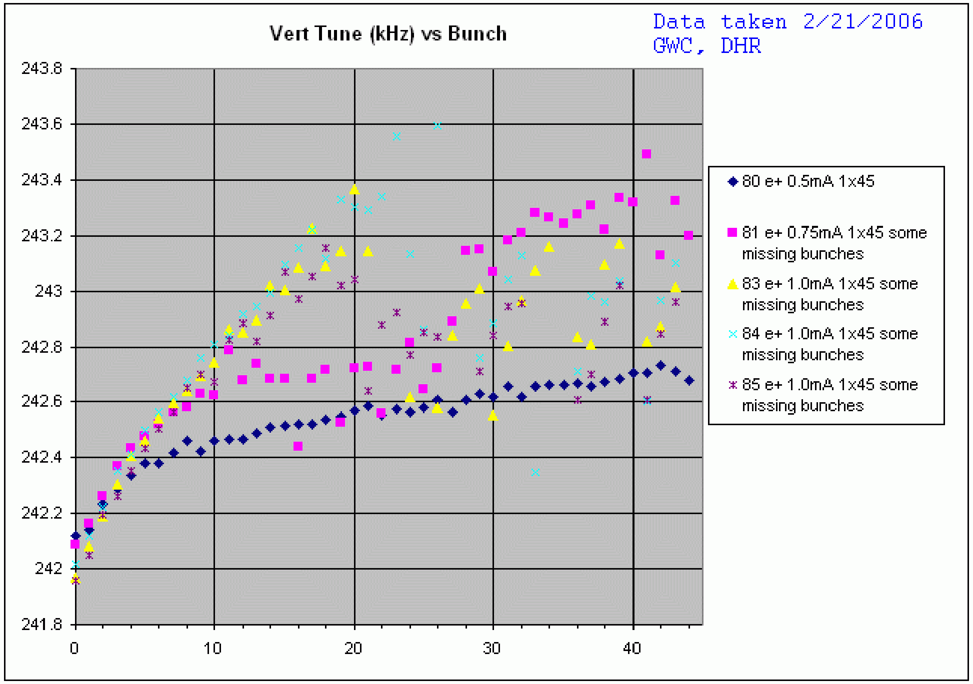
- Collaborations: ILC, PEP-II, LBNL, KEK, Frascati, CERN, LANL.
- Collaborators: T. Raubenheimer, M. Pivi, J. Seeman.
- Thanks ! D. Arnett, D. Blankenship, B. Bigornia, N. Kurita, M. Pivi, M. Morrison, G. Stupakov, K. Bane, B. McKee, R. Kirby, G. Collet, K. Jobe, T. Smith, M. Ross, L. Wang, P. Raimondi.

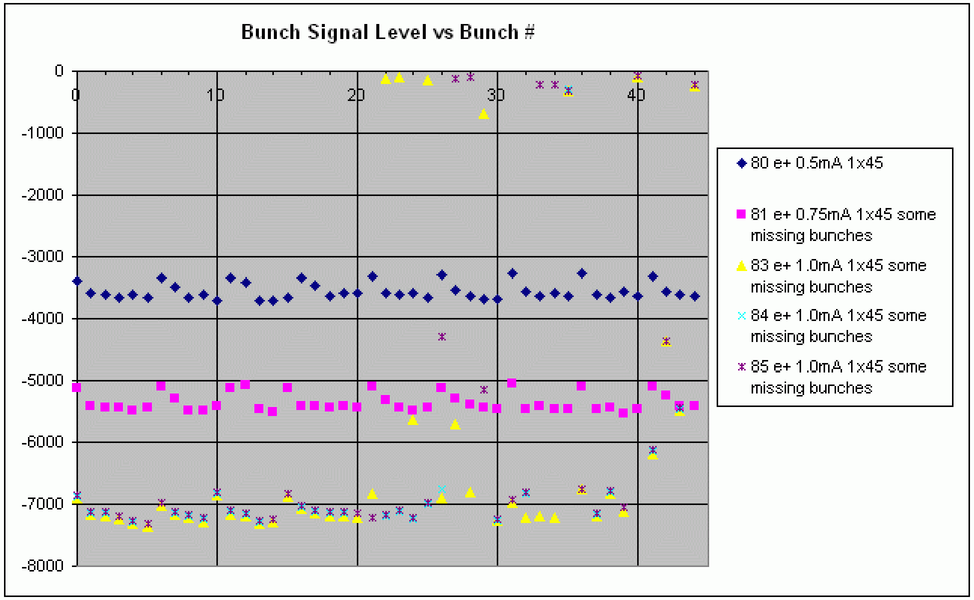
Electron Cloud Studies at CESR

- Recent Measurements at CESR
  - Observed large e^+ emittance among other indicators
  - Also interesting from ILC DR perspective
  - New instrumentation coming on line (CESR-c and ILC driven)
- Key CESR Parameters
  - Circumference: 768.44 m
  - Revolution frequency: 390.13 kHz
  - RF frequency: 499.76 MHz
  - Harmonic number: 1281
    - 1281/7 = 183 bunches
  - Spacing between bunches in train: 14 ns
- Instrumentation
  - Bunch-by-bunch tune monitor
    - Capable of sampling up to 366 bunches in parallel
    - Used for measurements on the following pages
  - Bunch-by-bunch beam size monitor
    - New capability just coming on line for multi-bunch operation
    - First measurements made and being analyzed ⇨ expect updates soon!

Positron Measurements

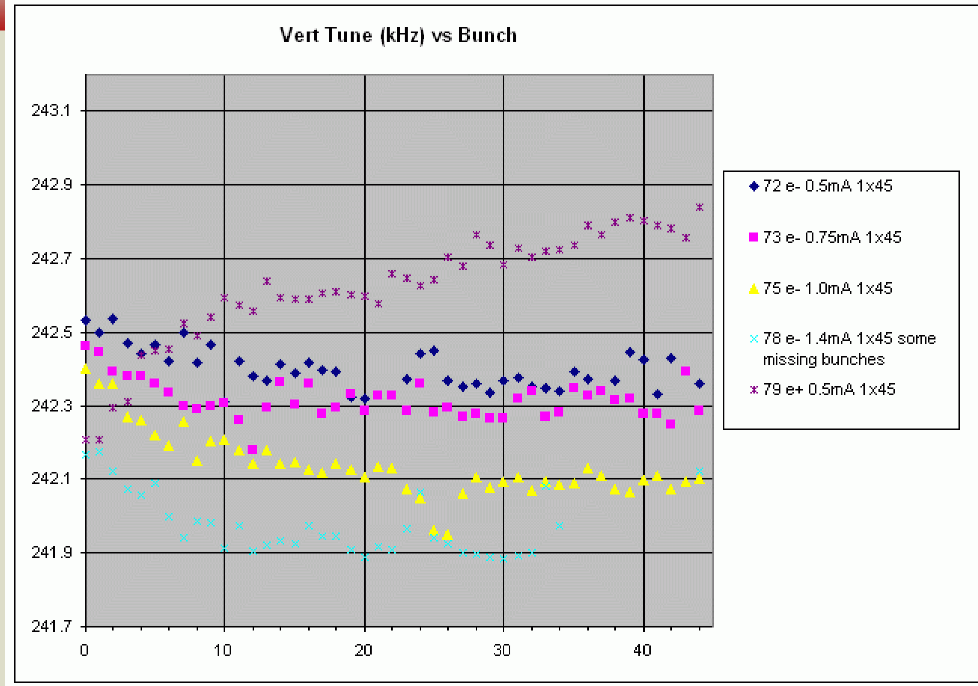
- Positrons @ 5.3 GeV
- Single train of 45 bunches with 14 ns spacing
  - NOTE: at highest bunch currents, filling of bunches > #20 no longer uniform
- Plots
  - Top: Bunch Tune (kHz) vs Bunch
  - Bottom: BPM ADC level vs Bunch (note missing bunches at high bunch currents)

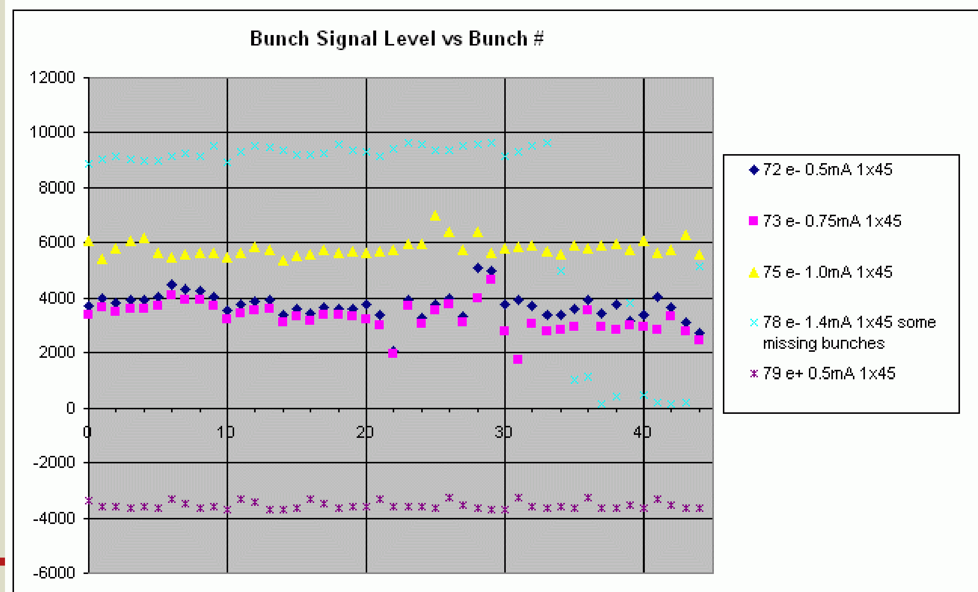




Electron Measurements

- Electrons @ 5.3 GeV
- Single train of 45 bunches with 14 ns spacing
  - NOTE: Filling generally more uniform than for e^+
  - Also includes reference plot of positrons from previous page (0.5 mA/bunch)
  - Smaller effect observed than for e^+
  - Opposite sign of tune variation consistent with ECE for *both* species

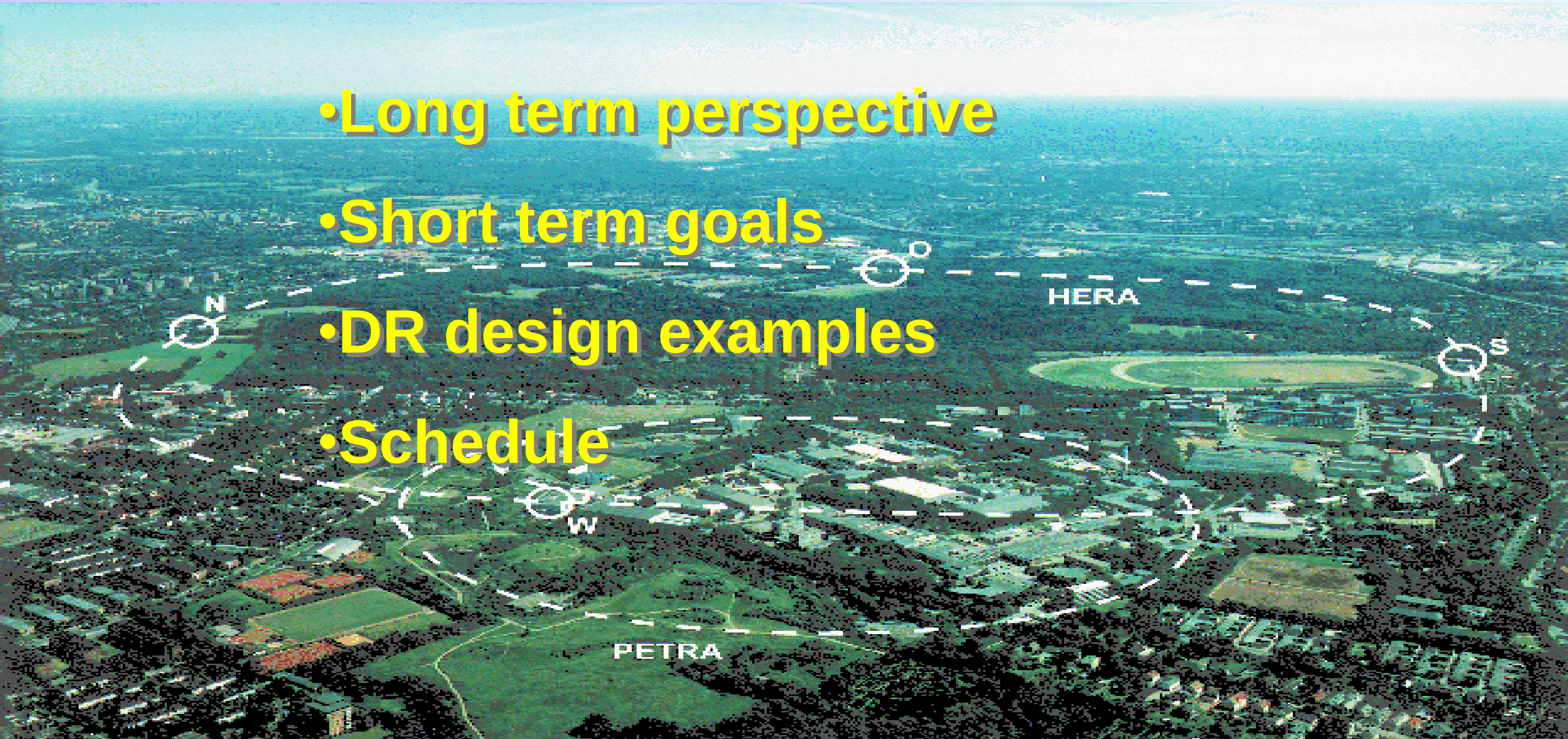




The use of the HERA Electron Ring in Conjunction with ILC Damping Rings

Damping Ring Collaboration Meeting May9, 2006

F. Willeke, DESY



- Long term perspective
- Short term goals
- DR design examples
- Schedule

ILC Damping Ring & HERA

Damping Ring Collaboration has concluded that the optimum circumference for the ILC damping rings is about 6km

it turns out, there exists one accelerator ring which matches almost perfectly the major design parameters of the ILC damping ring.

The HERA Electron Ring

- circumference of 6.36 km.
- magnets with good field quality
- large aperture
- sophisticated beam diagnostics,
- superconducting RF,
- a well conditioned copper vacuum pipe,
- build-in beam-based alignment capabilities

in addition

outstanding expertise of dealing with large electron rings

strong interest in low emittance lattice.

No plans for any other use of HERA

This is a remarable constellation!

How make we make best use of it?

Possible Not-too-Far-Term DR Studies in HERA

ISSUE	Additional Equipment Needed
• Storage of 250mA of positron with a bunch-spacing of 6-16 ns, • study of electron-cloud issues, testing of remedies	• De-install n.c. 500MHz cavities, RF feedbacks, 250MHz bandwidth MB damper improved HOM couplers at SCC
• Demonstration of 1pm vertical emittance • Demonstration of effective bba procedures	•Improved BPM electronics Additional BPMs Additional BBA circuitry Low ε Measurement equipment
• Polarization test measurements	

To be discussed and closely co-ordinated with GDE and DR collaboration!