Comments on
What Kind of Test Facility(ies) the ILC Needs

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Test Facility Has to Address Issues Of General Concern:

- Main Linac RF
- Main Linac Emittance Jitter control/FB
- DR beam physics
- e+ source target/capture
- BDS Collimators /stabilization

DR:

- The damping rings perform three functions:
  - reduce the emittances of the beams from the source (by 5 orders of magnitude for the positron beam);
  - produce <u>*highly stable beams*</u> for tuning and operation of downstream systems;
  - delay the beams for operation of feed-forward systems (e.g. to allow compensation of bunch charge variation).
- Baseline specifications:
  - 6.6 km circumference
  - 5 GeV beam energy
  - 2700 – 5400 bunches
  - 430 mA average current
  - 25 ms damping time
  - 0.5 nm × 2 pm emittance ($x \times y$)
  - 6 mm bunch length

DR:

- Beams are stored in the rings for a long time
  - Small (subtle) effects can have a large impact
  - Many novel effects will be important due to small emittances and tight stability requirements
  - Rings are quite different from other operating accelerators

Comments on DR:

There are many important issues that must be addressed:

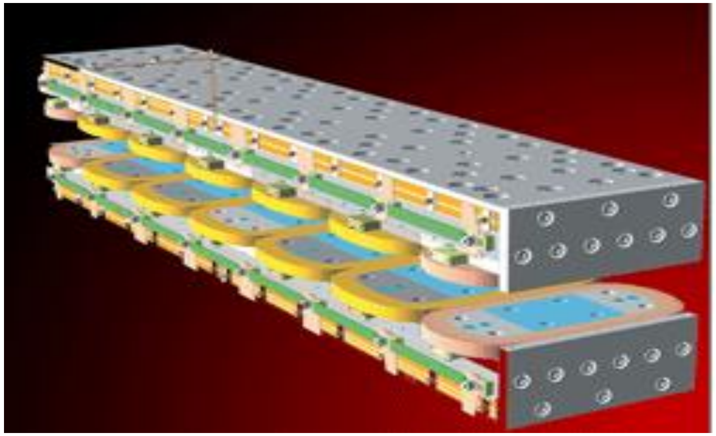
- Average injected beam power is 225 kW: excellent acceptance is needed to capture the large injected positron beam.
- Specified vertical emittance is 2 pm, a factor of two smaller than the lowest vertical emittance achieved in ATF (factor of 1/100 of KEKB)
- A range of collective effects threaten to destabilize the beam:
  - electron cloud in positron rings;
  - ion effects in electron rings;
  - microwave instability;
  - coupled-bunch instabilities…
- Technical subsystems need R&D to demonstrate performance:
  - injection/extraction kickers;
  - bunch-by-bunch feedback systems…

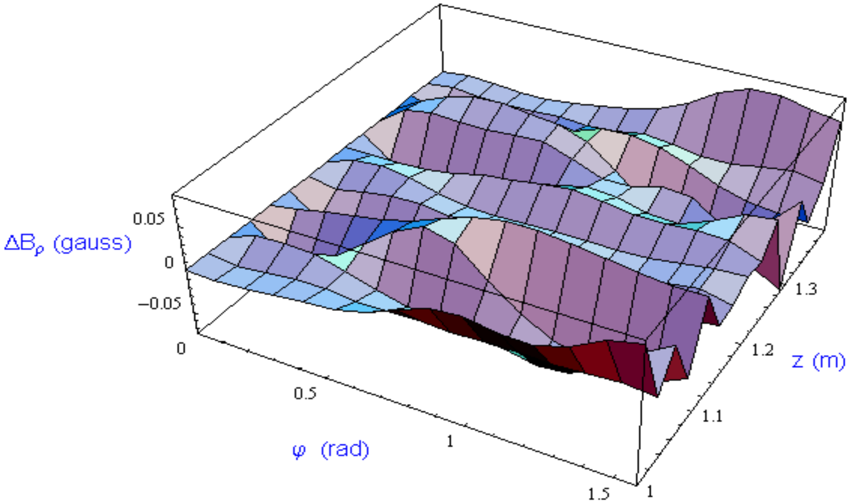
Comments on DR:

- Damping Rings beam dynamics
  - lattice design and optimization
  - theoretical studies of collective effects
  - experimental studies at KEK-ATF, and CESR-c
- Damping Rings technology
  - studies for injection/extraction systems
  - development of techniques for suppressing electron cloud in the positron rings
- Leadership of Damping Rings collaboration
  - organization of studies for configuration recommendation
  - coordination of work for ILC Reference Design Report
- Bunch Compressor studies

Wiggler models → Prototype

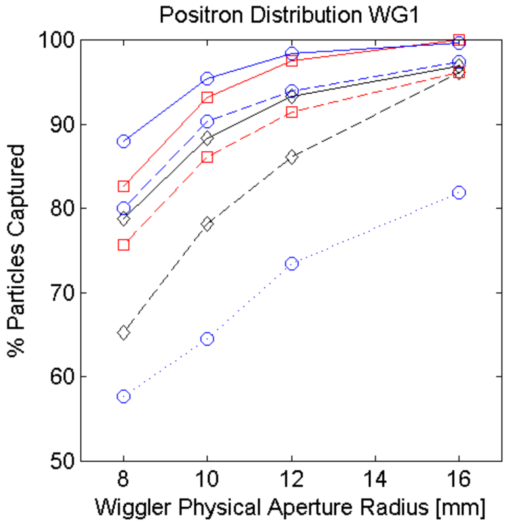
- The wiggler contributes around 80% of radiation loss in damping rings.
- Dynamic aperture can be limited by intrinsic nonlinearities in the wiggler field.

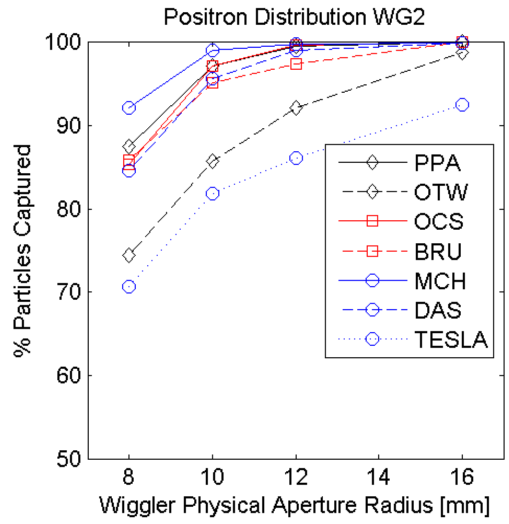


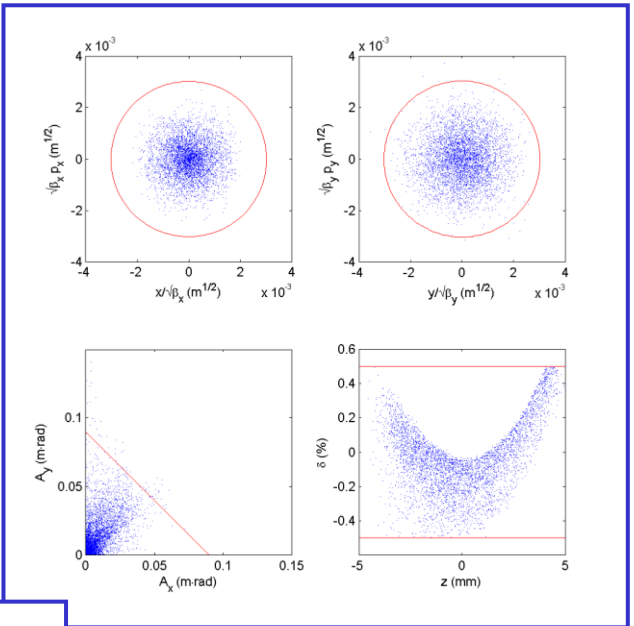


Field model based on CESR-c superferric wigglers used in ILC damping rings studies.

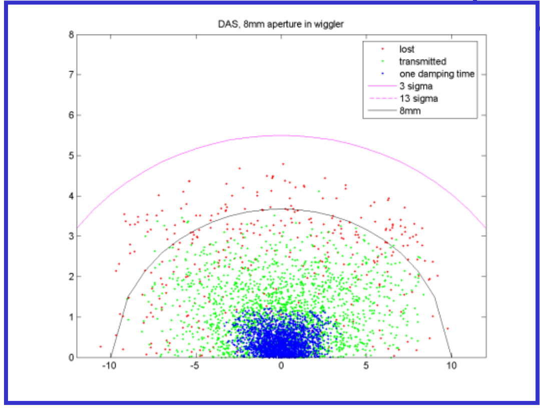
From Tracking a ‘realistic’ distribution → DA studies by blowing up the beam by noise





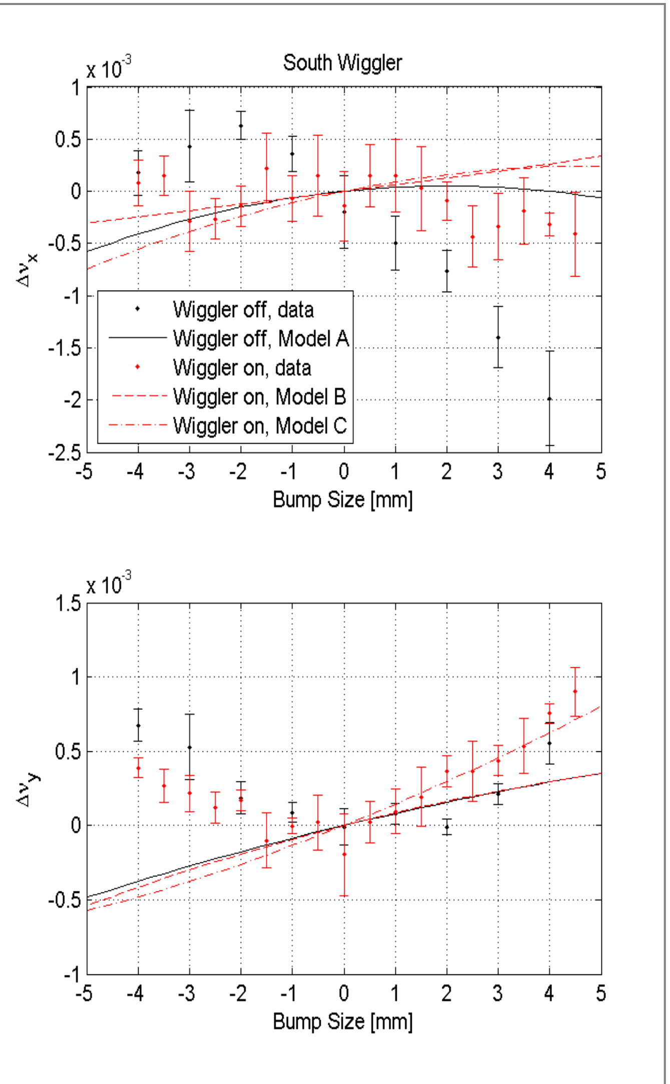


A physical aperture of at least 16 mm radius is needed in the wiggler, to ensure adequate injection efficiency. The average injected beam power is 226 kW.



Distribution of injected positrons in phase space (top) and coordinate space (left). *W. Gai, ANL.*

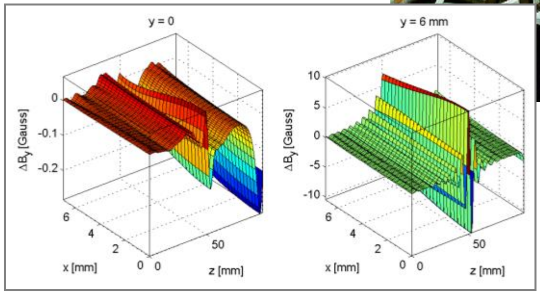
Wiggler studies at KEK-ATF show some surprises

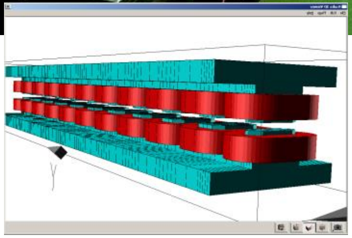


- KEK-ATF is a prototype damping ring, and the world's largest linear collider test facility.
- Four electromagnetic wigglers have recently been commissioned, and their effects on the beam dynamics are being studied closely.

Right and top: ATF wiggler and residuals of fit to a field model.

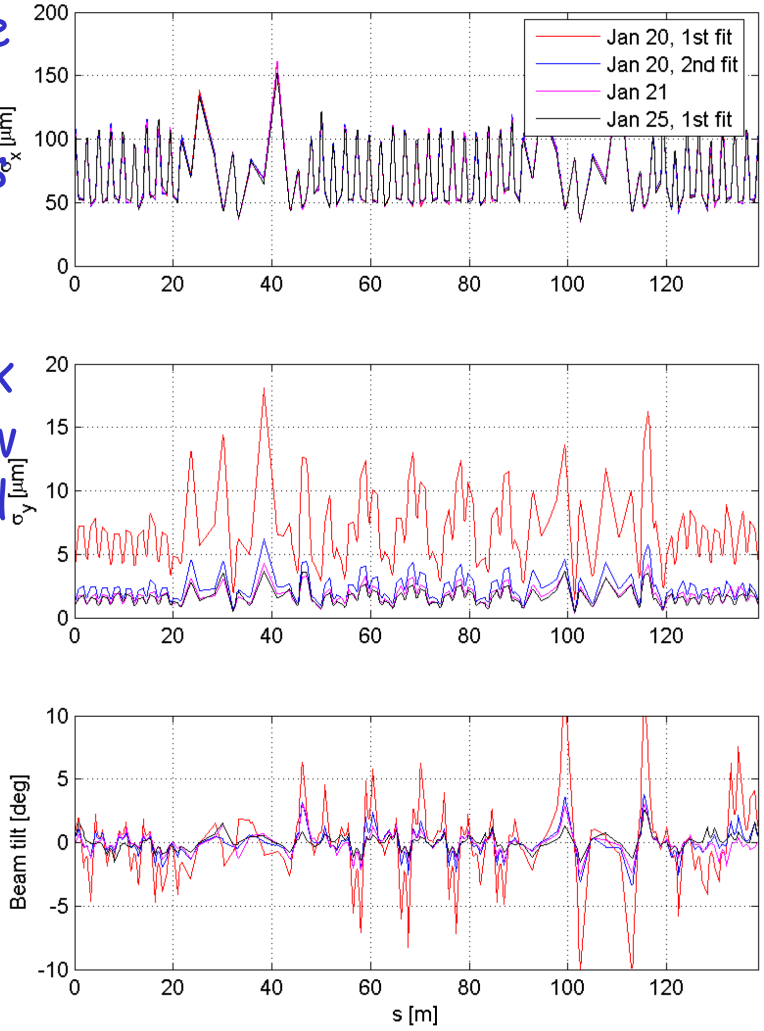
Left: Tune-shift measurements compared to model.



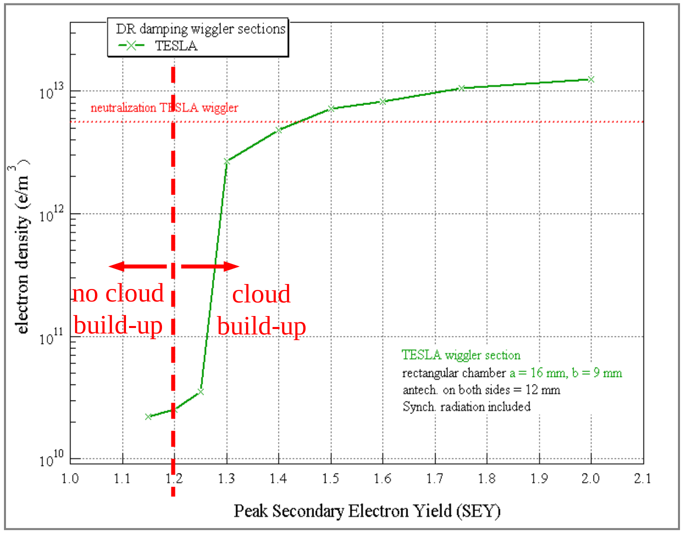


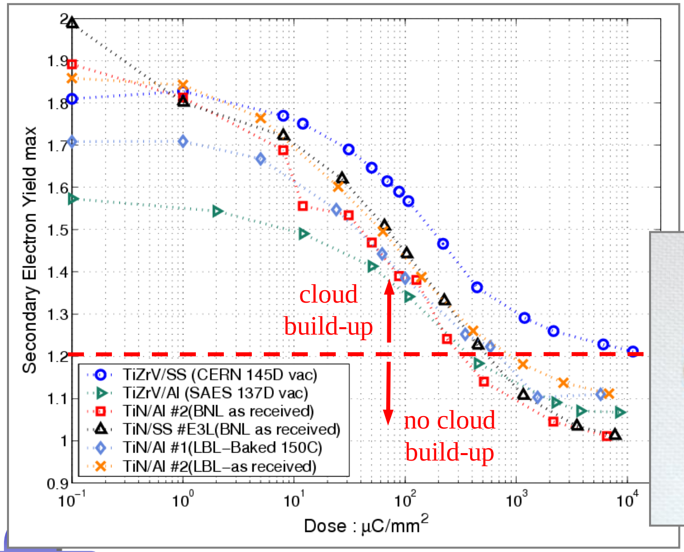
Low-emittance tuning at KEK/ATF – many things to learn

- ILC specifies 2 pm vertical emittance in the damping rings.
- Lowest achieved vertical emittance is 4.5 pm, in KEK-ATF.
- effectiveness of Beam-Based Alignment and Orbit Response Matrix Analysis techniques for tuning for low emittance at ATF have demonstrated
- New BPM electronics will be installed and tested in ATF in February 2006.
- hope to achieve ε_y ~ 2 pm within a year.

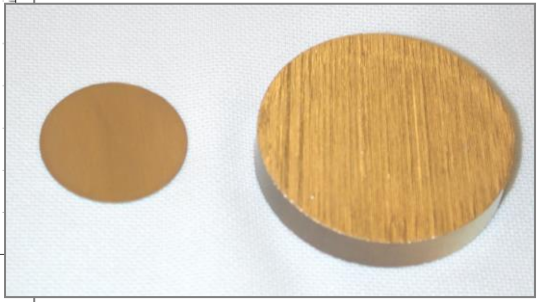


Electron-cloud needs a solution



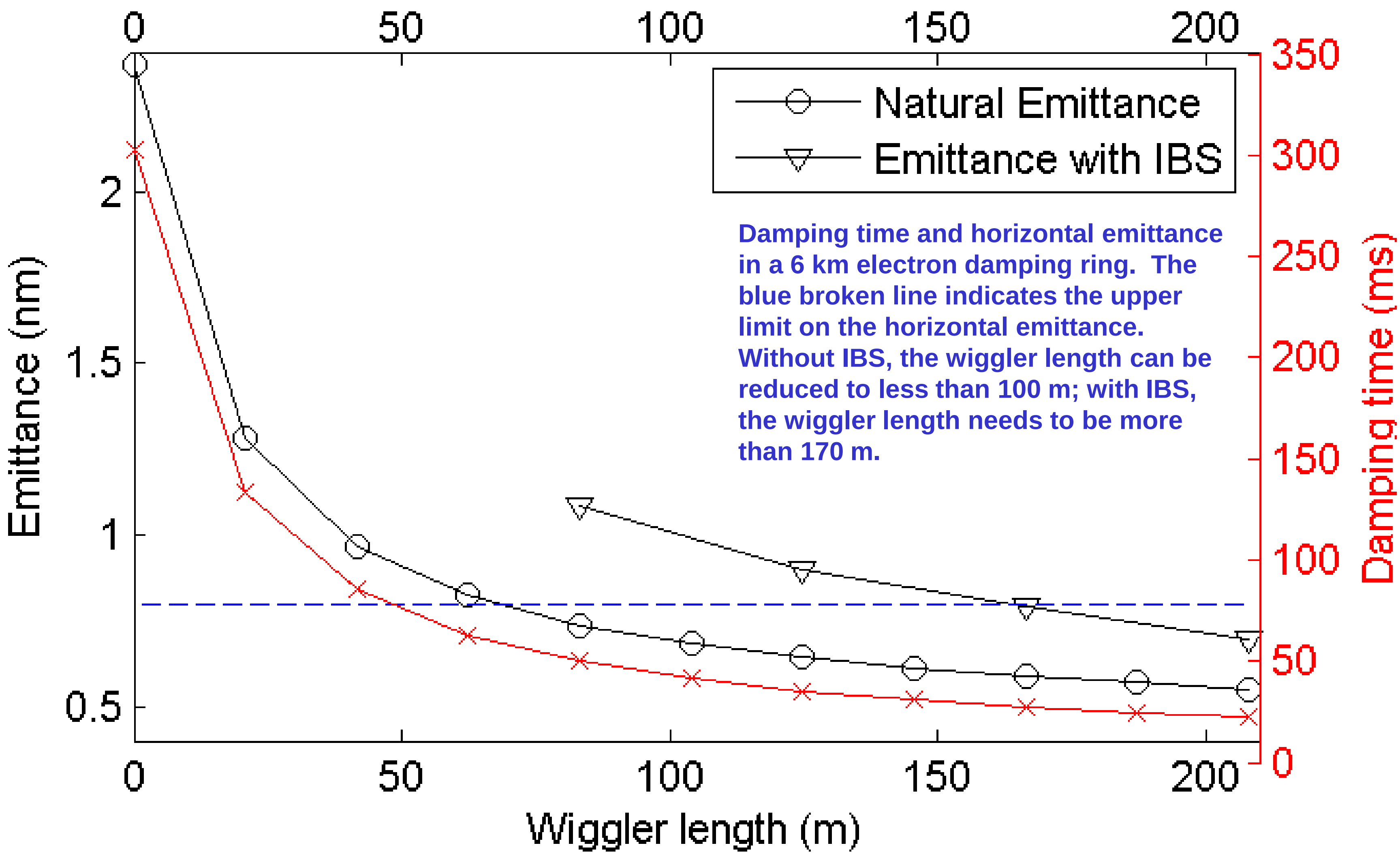


- Electron cloud is observed in many proton and positron rings.
  - Secondaries are released when electrons, accelerated by the beam, hit the chamber
  - A build-up of electrons (electron cloud) drives beam instabilities.
  - Treating the chamber surface reduces the number of secondaries, and prevents build-up of the electron cloud.
- LBNL and SLAC are investigating a number of possible treatments:
  - TiN coating
  - TiZrV coating (NEG – can also improve vacuum)
  - Grooved chamber surface
- FNAL/LHC and TexA&M are looking into clearing electrodes along entire beampipe



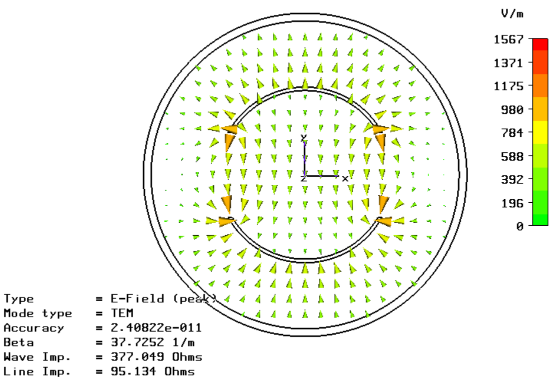
TiN coatings prepared at LBNL and measured at SLAC.

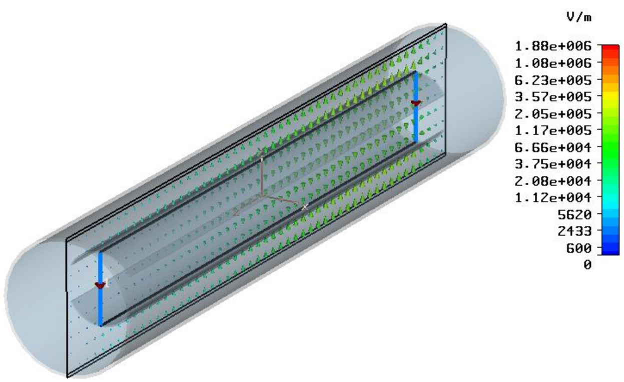
Intrabeam Scattering: One'd think it's slow – it's not for ILC DR



Fast Injection/Extraction Kickers and effects of injected/extracted bunches

- Fast kickers are a critical component of ILC damping rings.
  - Challenging parameters: rise/fall times < 3 ns; repetition rate 6 MHz.
- Such kickers can be built
- There are effects of the kickers which can not be studied without beams:
  - What will happen with circulating bunches when one bunch is injected/extracted
  - Longitudinally? (beam loading)
  - Transversely (impedances and clouds)





Left: 2D model kicker for impedance optimization.

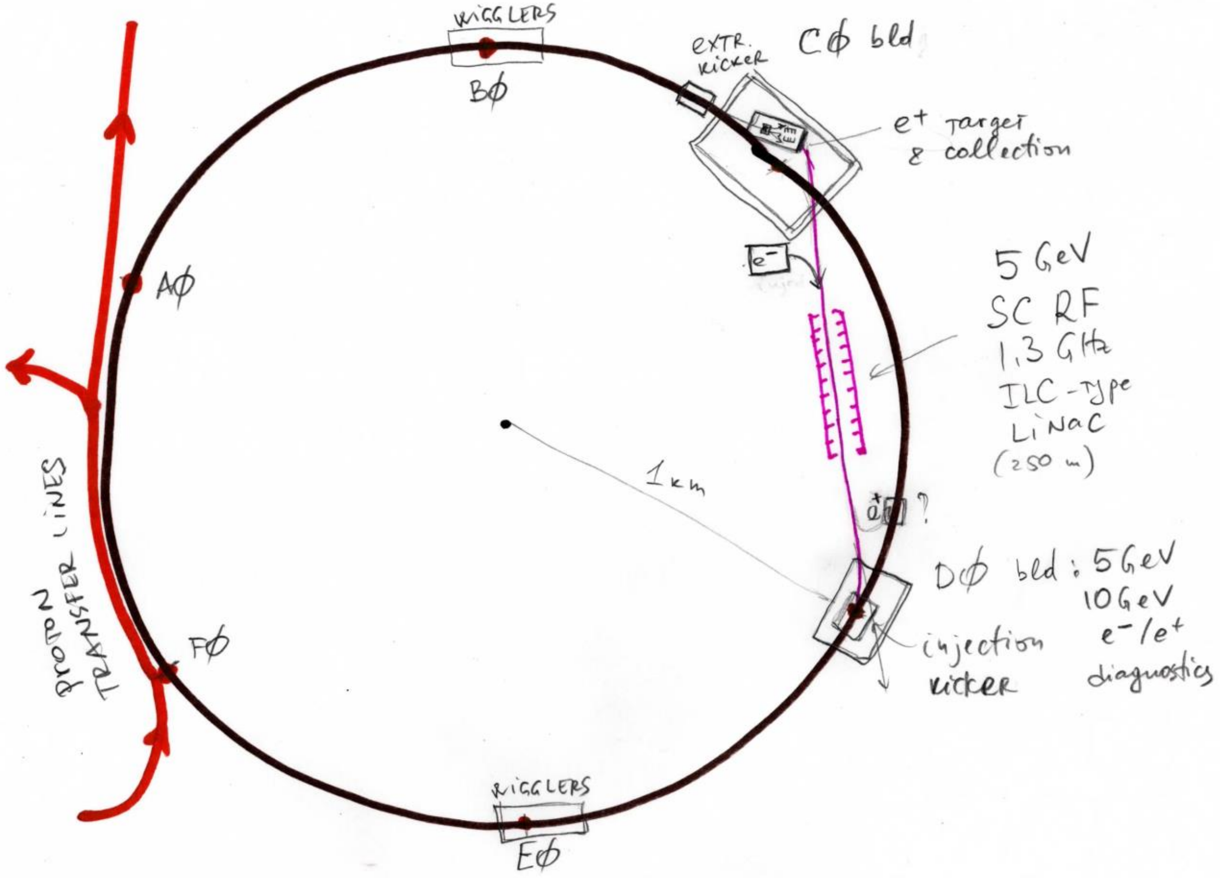
Right: 3D transients analysis.

Proposal: HERA-e DR in the Tevatron tunnel

- HERA operation to end in mid-2007
- Magnets, part of RF, vacuum pipes and possibly ion pumps to be stored for 2 years either in Germany or at Fermilab
- US/FNAL to build magnet bus PSs, supports, controls
- International/other-than FNAL contributions:
  - Injection lines
  - Injection/extraction kickers
  - Diagnostics
  - Wigglers
- Total cost of DR in the Tev tunnel ~40M$ (over ~4 years):
  - Shipping 5M$
  - Build new stuff 20M$ (PSs, supports, wigglers, etc)
  - Installation 10M$
  - Operations 5M$ over 1-2 years

Proposal: HERA-e DR in the Tevatron tunnel

5GeV SC Linac / 5 GeV DR ILC /
e-/e+ production / energy up to 5-10 GeV



5GeV Linac and TeV-DR Test Facility

- Unambiguous answers to:
  - e- beam production and quality
  - e+ targetry, collection, transport and acceleration
  - SC RF technology, operations, beam effects and diagnostics
  - 5 GeV=2% ILC Linac model and upto 10GeV=4% of ILC beam energy
  - All DR issues with full intensity e- beam
  - Large emittance e+ acceleration and damping
  - ILC DR Injection/extraction
- Plus, many possibilities for expansion : high intensity e+, 8GeV proton, etc

HERA-e:

HERA-e as back-bone ILC DR:

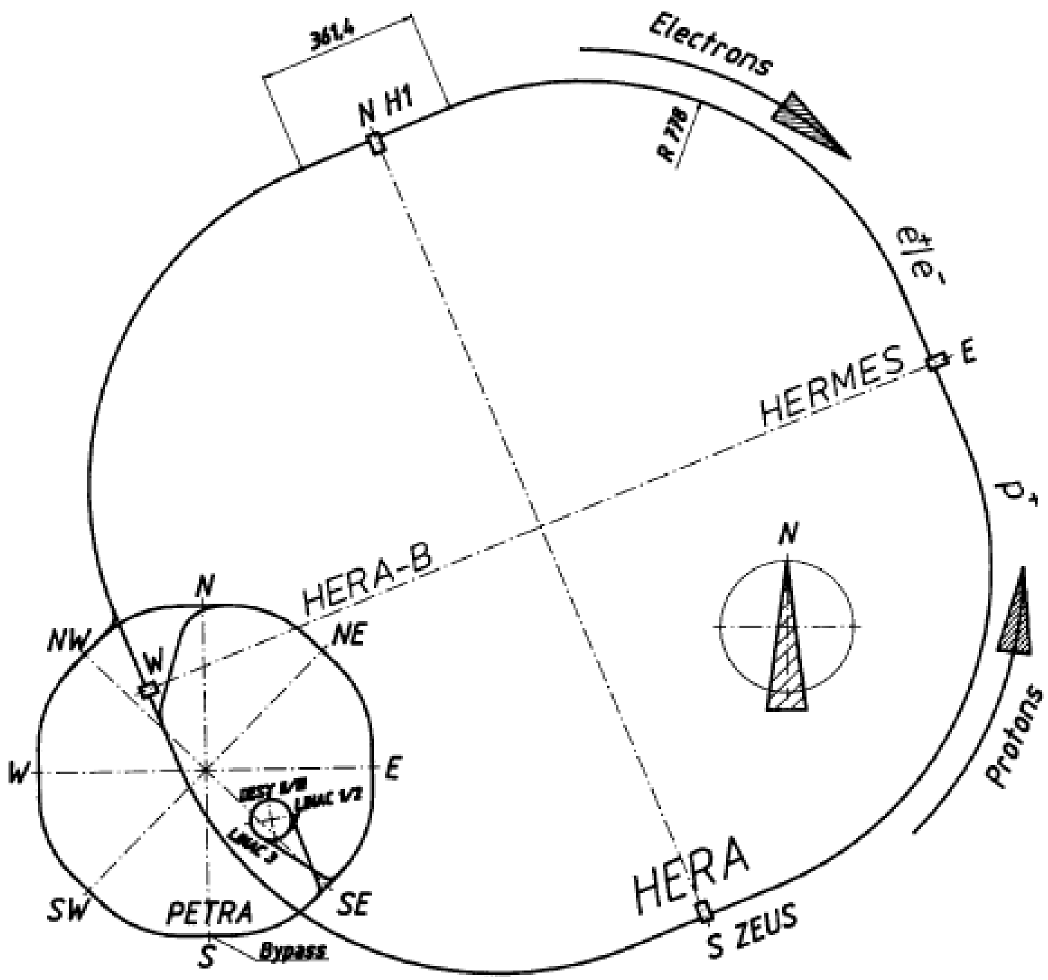


Figure 1: Layout of the electron proton collider HERA.

	e^+ / e^-
Circumference C	6335.82 m
Injection momentum $p_0 c$	12 GeV
Design momentum pc	30 GeV
Number of bunches N	210
Number of buckets N_B	220
Average beam current I	58 mA
Length of straight sections L	4×361.4 m
Length of a half cell l	11.755 m
Length of the dipole yoke l_D	9.135 m
Length of the quadrupole yoke l_Q	0.76 m

Table 1: Main parameters of HERA electron machine.

The magnets of one half cell of the electron machine are assembled in a module [2]. The four arcs consist of four hundred modules. They have been prepared outside of the tunnel, including the vacuum system. A single vacuum chamber spans the total module length. The chamber is brazed of various 4 mm profiles made of the copper alloy CuSn2 [3]. The water-cooled chamber walls absorb synchrotron light more efficiently than aluminium and therefore the radiation shielding problem is reduced. Any additional lead shielding needs no special cooling arrangement. The vacuum system is mainly pumped by integrated ion sputter pumps that use the field of the dipole and quadrupole magnets. The beam pipe has a cross section of 80 mm × 40 mm.

HERA-e Vacuum Pipe:

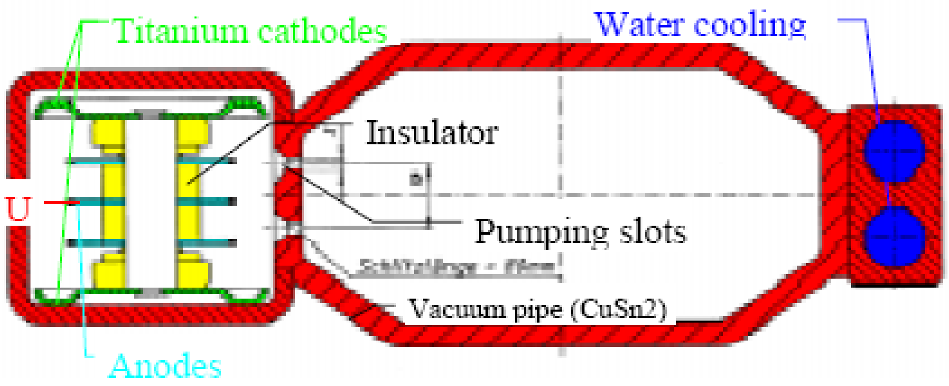


Figure 2: Cut through a HERA dipole vacuum chamber with an integrated ion sputter pump.

BEFORE 1996

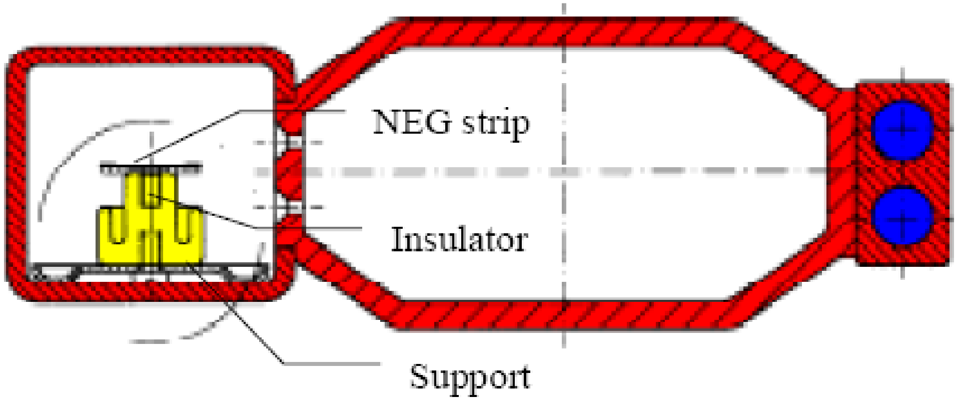


Figure 6: Cut through a HERA dipole vacuum chamber with an integrated Non Evaporable Getter-pump.

AFTER 1996

HERA-e

Daten der Elektronen / Positronen -HF-Systeme **Parameters of the electron / positron rf systems**

Beschleuniger	Accelerator	Units	HERA-e-Daten	
Energie	**Energy**	**GeV**	**12**	**27,5**
Anzahl der Bunche	**Number of bunches**	-	**220**	**220**
Bunchabstand	**Bunch spacing**	**ns**	**96**	**96**
Dämpfungszeit der Synchrotronschwingung	Synchrotron damping time	s	7,74E-02	6,43E-03
Energieabweichung, maximale stabile	Energy deviation, maximum stable	MeV	307,98	218,42
Energieabweichung, mittlere	Energy deviation, average	MeV	5,00	26,26
Energieverlust pro Umlauf	Energie loss per turn	MeV	3,17	87,38
Harmonischenzahl	Harmonic number	-	10560	10560
HF-Frequenz	**RF frequency**	**MHz**	**499,667**	**499,667**
Ladung pro Bunch	Charge per Bunch	nAs	5,76	5,76
Momentum-Compaction-Faktor	Momentum compaction factor	-	6,87E-04	6,87E-04
Senderinduzierte Spannung	Generator induced voltage	MV	78	220
Strahlinduzierte Spannung	Beam induced voltage	MV	83	106
Strahlstrom	**Beam current**	**mA**	**60**	**60**
Strom pro Bunch	Bunch current	mA	0,27	0,27
synchrone Phase	**Synchronous phase angle**	**Grad**	**1,9**	**44,3**
synchrone Phase	Synchronous phase angle	radian	0,033	0,774
Synchrotronfrequenz	**Synchrotron frequency**	**kHz**	**4,52**	**2,90**
Teilchen pro Bunch	Particles per Bunch	-	3,60E+10	3,60E+10
Umfangspannung	**Circumference voltage**	**MV**	**95**	**125**
Umlauffrequenz	**Revolution frequency**	**kHz**	**47,317**	**47,317**

Sender	Transmitter		HERA-e-Daten	
Anzahl Cavities pro Sender	Number of cavities per transmitter	-	1*10, 6*12, 1*16	1*10, 6*12, 1*16
DC-Leistungsaufnahme	DC input power	kW	1000	2190
Klystrons, Anzahl	Klystrons, number of	-	16	16
Nennleistung pro Sender	Nominal transmitter power	kW	1400	1400
Sender, Anzahl	**Transmitters, number of**	-	**8**	**8**
Senderbetriebsspannung	Transmitter supply voltage	kV	71	71
Senderleistung für Nennstrahlstrom	**Transmitter power for nominal beam current**	**kW**	**244**	**1160**
Senderstrom	Transmitter supply current	A	14	31
Verluste im Hohlleitersystem	Power loss of wave guide system	%	8	8

HERA-e

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DC-Leistungsaufnahme	DC input power	kW	1000	2190
Klystrons, Anzahl	Klystrons, number of	-	16	16
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HERA-e RF:

Super-B with L=1e36:

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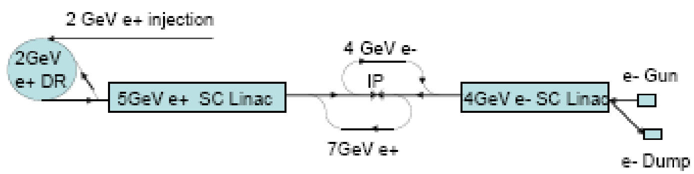

FIG. 13: Linearly colliding Super-B Factory layout

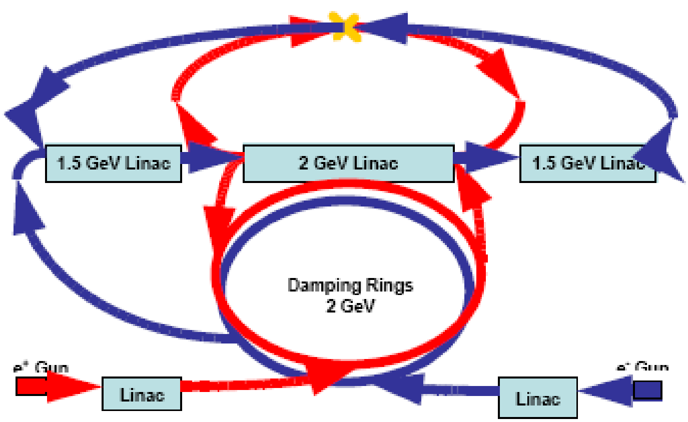

FIG. 14: Linearly colliding Super-B Factory layout

TABLE VI: Preliminary Super-B Factory collision parameters.

Parameter	LEB	HEB	Compared to ILC
Beam Energy (GeV)	4	7	
Number of bunches	10000	10000	× 2-4
Collision freq/bunch (Hz)	120	120	× 24
IP energy spread (MeV)	5	7	
Particles /bunch $\times 10^{10}$	10	10	× 5-10
Time between collisions (msec)	8.3	8.3	
by* (mm)	0.5	0.5	
bx* (mm)	22	22	
Emittance (x/y) (nm)	0.7/0.0016	0.7/0.0016	× 0.8
sz (mm)	0.35	0.35	
Lumi enchancement Hd	1.07	1.07	
Crossing angle(mrad)	0	0	
IP Horiz. size (mm)	4	4	
IP Vert. size (mm)	0.028	0.028	
Horizontal disruption	1.7	0.9	
Vertical disruption	244	127	
Luminosity (x1034/cm2/s)	100	100	