RDB S3: Damping Rings R&D

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for

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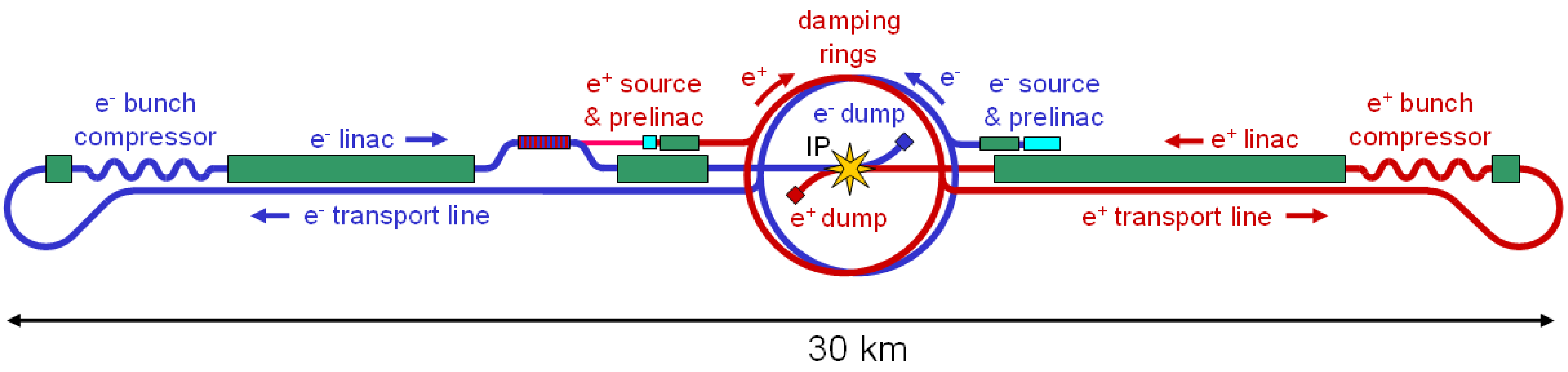
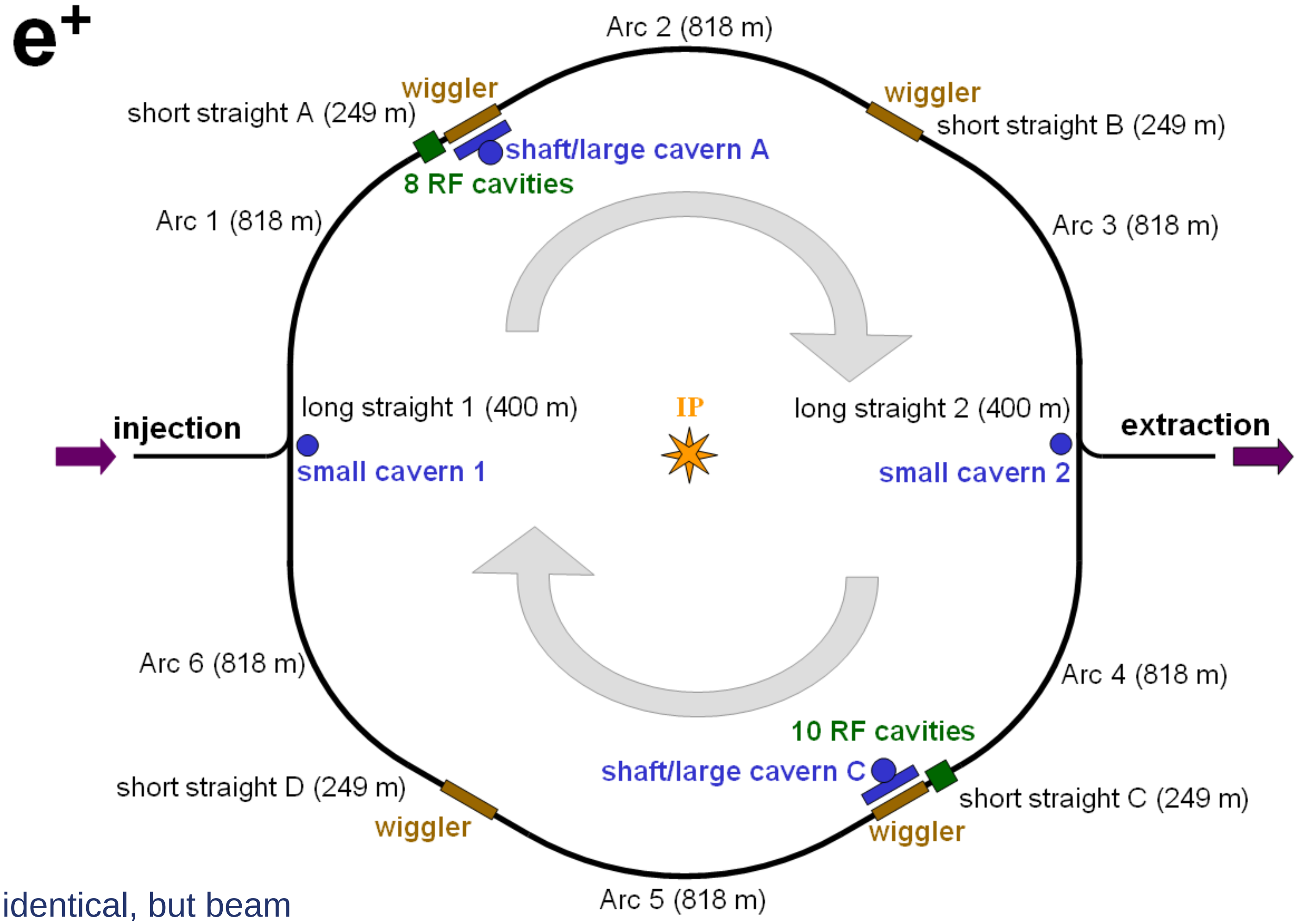
Damping Rings RDR Configuration



- Two 6.7 km, 5 GeV damping rings.

  One electron ring and one positron ring in a shared tunnel around the interaction region.
- Damping rings area system includes short sections of injection and extraction line, connecting each ring with the sources (upstream) and the RTML (downstream).

Schematic Layout: e^+ Ring



e^- footprint is identical, but beam circulates in opposite direction, and RF cavities are always upstream of the wiggler.

S3 Principal Goal

Our principal goal is to develop a coordinated plan for damping rings R&D, leading up to the start of construction of the ILC, that takes full account of:

- **project needs and priorities;**
- **available (and likely or possible) resources, including the test facilities;**
- **aspirations of participating institutions.**

The R&D plan must be developed in close consultation with the community, to ensure that it has the necessary support.

The large diversity of R&D topics and the extremely wide distribution of very limited resources present significant challenges in developing an effective and realistic R&D plan.

S3 Membership and Responsibilities

- Eckhard Elsen
- Jie Gao
- Susanna Guiducci
  - **Feedback systems**
- Tom Mattison
  - **Kickers**
- Mark Palmer
  - **Normal-conducting magnets**
  - **Superconducting magnets**
  - **Damping Rings RF**
  - **Instrumentation and Diagnostics**
  - **Supports and alignment systems**
  - **Systems integration**
- Mauro Pivi
  - **Multi-particle dynamics**
- Junji Urakawa
  - **Instrumentation and diagnostics**
- Marco Venturini
  - **Multi-particle dynamics**
- Andy Wolski
  - **Vacuum**
- Mike Zisman
  - **Single-particle dynamics**
  - **Vacuum**
  - **Supports and alignment systems**
  - **Systems integration**

S3 Progress

- Convened membership, and identified areas of responsibility.
- Reviewed full list of R&D objectives, including setting priorities.
- Compiled data on R&D resources.
- Organised Damping Rings R&D Meeting at Cornell in September 2006, which provided important input for Very High Priority topics in the R&D plan.
  - **Fast injection/extraction kickers.**
  - **Electron cloud suppression.**
  - **Impedance and impedance-driven instabilities.**
- Initiated "sub-topic" phone meetings to coordinate R&D in very high priority areas across institutions.

S3 Progress (continued)

- Agreed a template for R&D Plan Work Packages.
- Prepared initial drafts of three Work Packages:
  - **Fast injection/extraction kickers.**
  - **Electron cloud suppression.**
  - **Impedance and impedance-driven instabilities.**
- Agreed date and focus topics for next R&D Meeting.
  - **Frascati, 5-7 March 2007.**
  - **The meeting will focus on Very High Priority topics not covered at Cornell:**
    - Lattice design.
    - Low-emittance tuning.
    - Ion effects.
  - **The meeting will provide invaluable input for the parts of the R&D plan covering these topics.**

Damping Rings R&D Issues

- The RDB S3 group has reviewed 76 R&D objectives for the damping rings, and identified 11 as "Very High Priority". These fall into the categories of:
  - **injection/extraction kickers;**
  - **electron cloud effects;**
  - **impedance and impedance-driven instabilities;**
  - **lattice design (for good dynamic aperture, etc.);**
  - **tuning and maintaining low vertical emittance;**
  - **ion effects.**

  (First three: Cornell R&D Meeting, September 2006; last three: Frascati R&D Meeting, March 2007)
- Development of a detailed R&D plan is in progress, detailing objectives, resources, milestones and timescales.
  - **So far, draft work packages have been produced for the fast injection/extraction kickers; electron cloud studies; studies of impedance and impedance-driven instabilities.**
- The R&D program at present test facilities (notably, KEK-ATF) could be strengthened by future test facilities (e.g. CESR-ta and HERA-DR).
- With over 25 institutions and 150 people interested or already involved, coordination of R&D efforts is a significant issue.

R&D Meeting at Cornell, 26-28/9/2006

- The meeting focused on three "Very High Priority" topics:
  - **Injection/extraction kickers.**
  - **Electron cloud.**
  - **Impedance and impedance-driven instabilities.**
- There was a special session devoted to discussion of the proposed test facilities:
  - **CESR-TA.**
  - **HERA-DR.**
  - **damping ring studies at KEKB.**
- 46 participants attended the meeting.
- All talks are posted on the Damping Rings wiki page:
  - **https://wiki.lepp.cornell.edu/ilc/bin/view/Public/DampingRings/**
- The three summary talks gave a "first pass" on coordinated R&D plan work packages, including milestones, resources, personnel etc.

Kicker Specifications

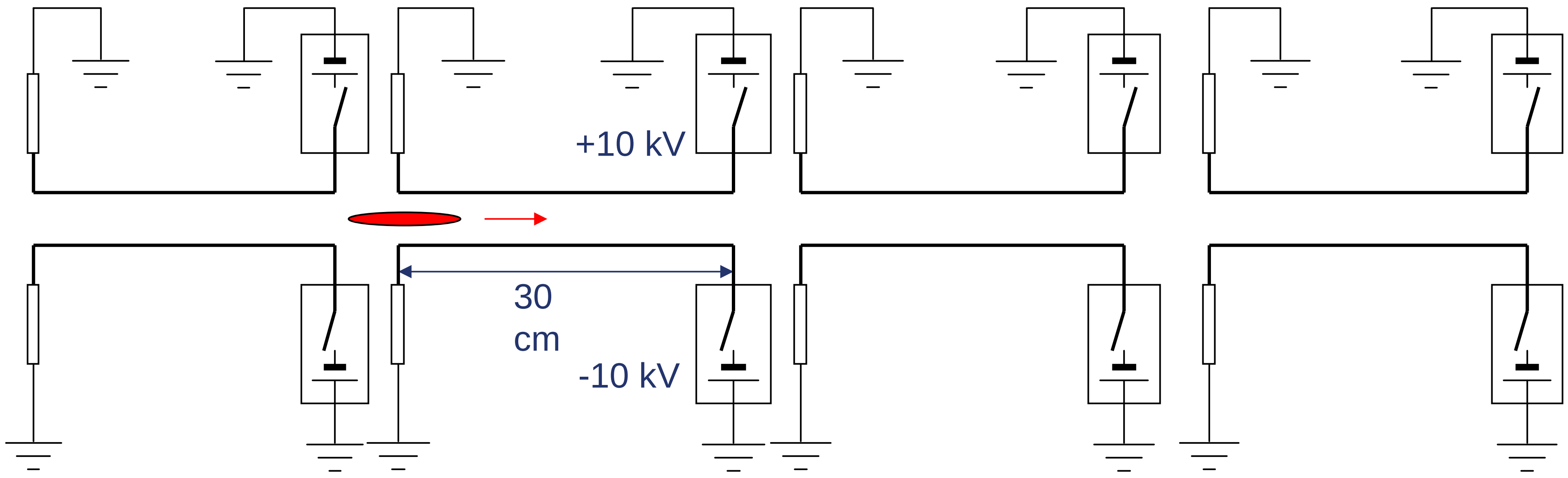
The kickers will consist of strip-lines fed by ultra-fast, high-voltage pulsers. The integrated voltage required is determined by the acceptance specification:

$$V \times L = \frac{2}{k} \frac{A_{x,\max}}{\gamma} \frac{E}{e}$$

where V is the voltage between the strip-lines, L is the strip-line length, k is a geometry factor (~ 0.7) determined by the strip-line shape, $A_{\max}$ (~ 0.09 m for injected positrons) is the maximum betatron amplitude, E is the beam energy and γ is the relativistic factor.

Integrated voltage	> 132 kV-m
Rise and fall times	< 3 ns
Repetition rate	5.5 MHz
Pulse length	970 µs
Stability	< 0.1%

Kicker Systems

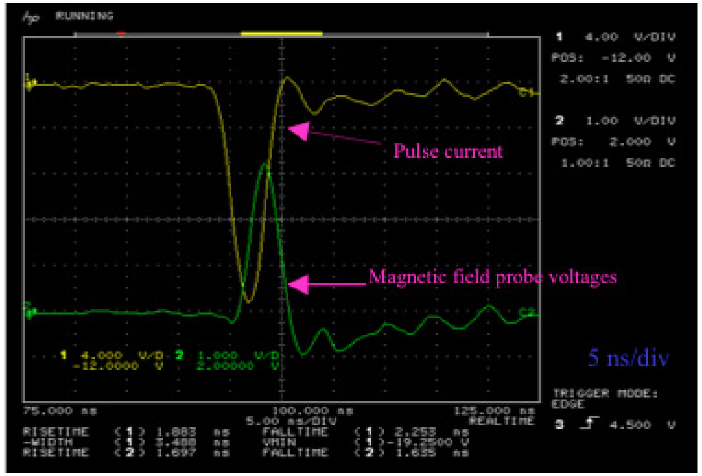


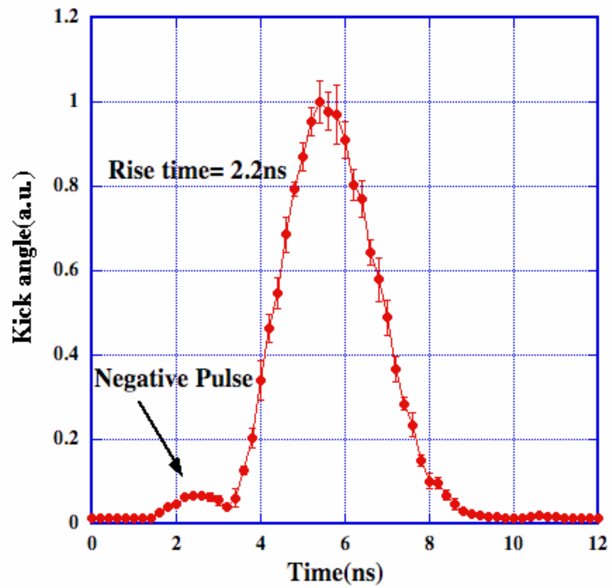
- The length of each strip-line is limited by the rise and fall time specifications: the maximum length is **approximately 30 cm**.
- Each strip-line is driven by two pulsers operating at **±10 kV**, providing a voltage between the electrodes of 20 kV.
- A "complete" kicker is made up of **22 such units**.

Kicker Systems

- There is a continuing R&D program to develop a pulser that meets the specifications for amplitude, rise and fall time, repetition rate, and stability.
- Several technologies look promising, including:
  - **fast ionization dynistor (FID);**
  - **drift step recovery diode (DSRD);**
  - **"inductive adder" (MOSFET).**
- There is a commercial FID device available that comes close to meeting the specifications.
  - **A prototype with modified architecture, which could meet most of the ILC specifications, is in development; a version for bench testing is expected by the end of April 2007.**
- Modification of ATF extraction system to allow fast extraction of individual bunches from a train is planned for late 2007.

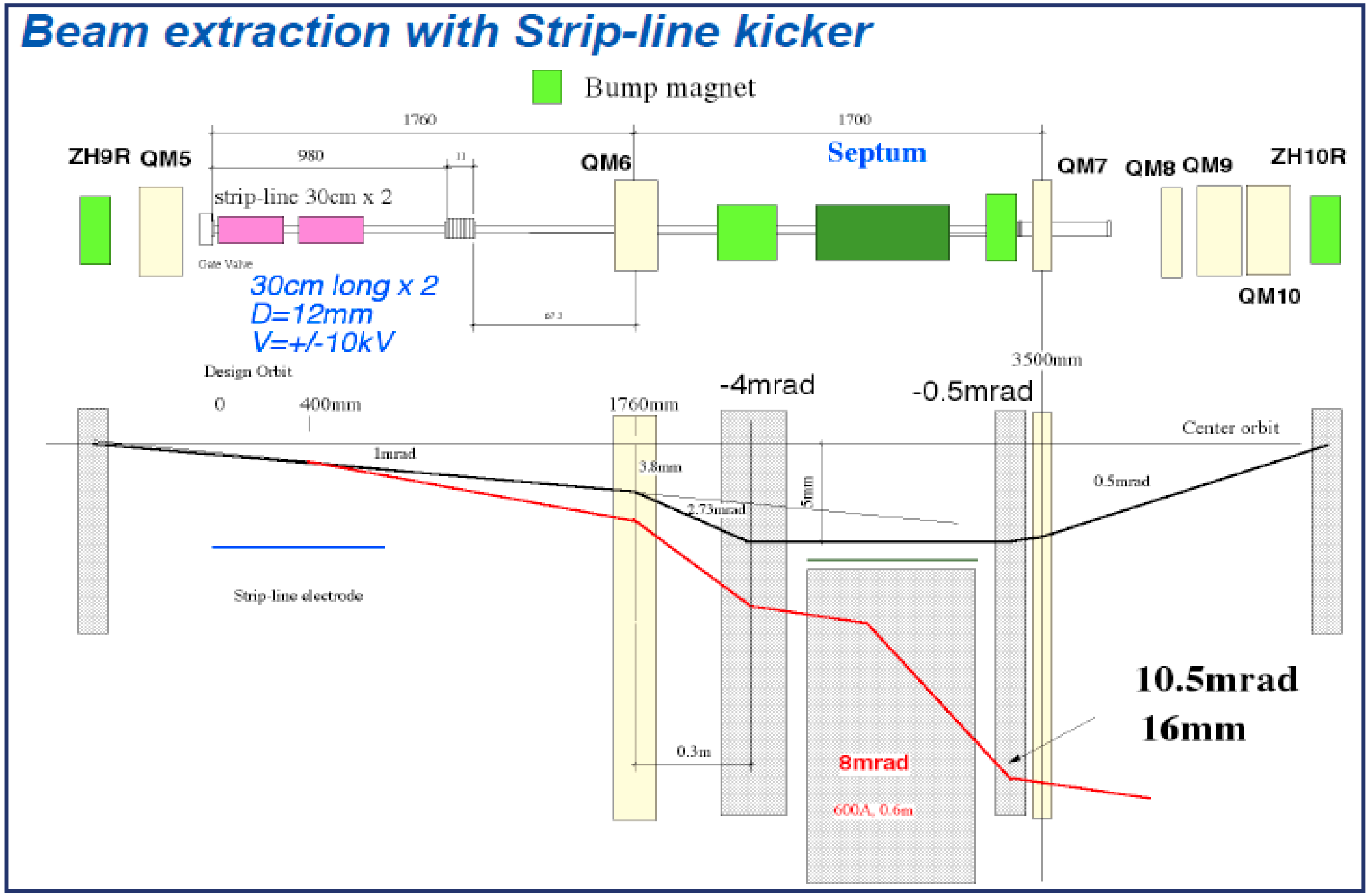
Tests of FID Pulser at Low Amplitude in ATF





Future Kicker Tests at ATF

New septum and a "slow" orbit bump would allow fast extraction using two 30 cm strip lines, driven by ±10 kV pulsers.



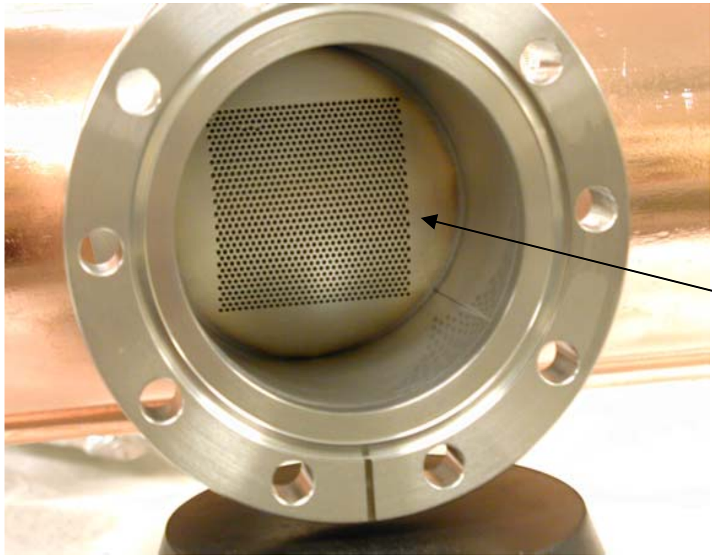
Electron Cloud

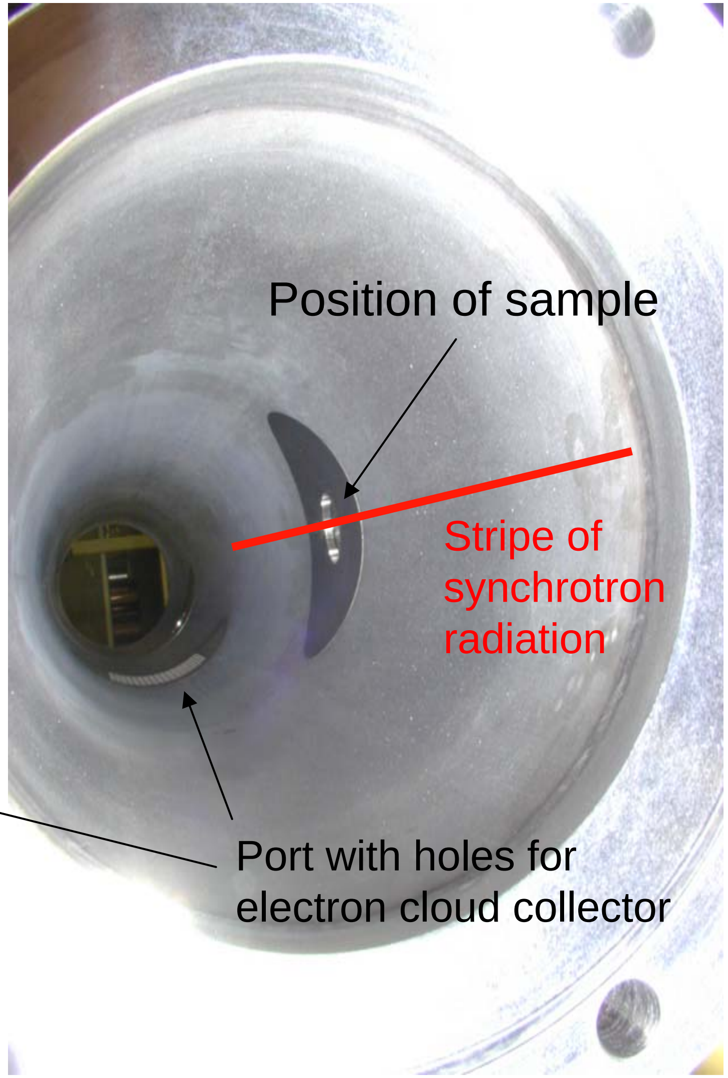
- Electron cloud could drive instabilities in the positron beam, if allowed to develop to a sufficiently high level.
- The goal is to reduce the peak secondary electron yield (SEY) to below 1.2 in straights, bends and wigglers.
  - **Benchmarked simulations indicate this will be sufficient to prevent the electron cloud reaching a density that would make the beam unstable.**
- Several techniques are under investigation for suppressing the electron cloud build-up:
  - **Solenoid windings in straights (demonstrated at the B factories).**
  - **Coating with low-SEY material, e.g. TiN or TiZrV (NEG): shown to be effective in lab studies, machine experience is needed.**
  - **Use of grooved chambers: shown to be effective in lab studies, machine experience is needed.**
  - **Clearing electrodes: simulation results look promising, experimental studies are needed.**

Electron Cloud

- A draft of a detailed R&D plan has been prepared, specifying goals and milestones for a range of activities, including:
  - **Improved modelling of electron cloud build-up.**
  - **Improved modelling of beam instabilities driven by electron cloud.**
  - **Continued laboratory investigations of a range of mitigation techniques.**
  - **Tests of mitigation techniques in operating machines.**
- The R&D plan takes account of resources that are, or are likely to be, available.
- The present draft is still being discussed by S3: a public version should be available soon.
- Many R&D activities are already in progress…

Electron Cloud: Tests in PEP-II LER





Electron Cloud: Tests in PEP-II LER

Extruded aluminum beam pipe with "fins" and coating.

Impedance-Driven Instabilities

- Demanding specifications on extracted beam stability lead to concerns over the impedance of the vacuum chamber.
- Growth times for resistive-wall instability of the order of 20 turns are expected.
  - **Growth times are within the range of modern digital bunch-by-bunch feedback systems.**
  - **Large chamber apertures and good conductivity (aluminum) are desirable.**
  - **Higher-order modes in cavities must be well damped.**
- Vacuum chamber must be carefully designed and fabricated for low impedance, to allow reasonable margin for operating below single-bunch instabilities.

Impedance: Outline from ILCDR06 (Cornell)

1. Produce initial technical designs for:
   (a) vacuum system (~ 2 years for ~ 2 FTEs), and
   (b) RF cavities (> 2 years).
2. Produce preliminary impedance model based on general specifications and scaling from existing machines/designs. (~ 1 year time frame for 1 FTE).
3. Make preliminary estimates of thresholds, growth rates, HOM heating etc. based on preliminary impedance model. (~ 1 year time frame).
4. Construct detailed impedance model based on initial technical designs for vacuum system and RF cavities. (as information from milestone 1 becomes available; ~ 1 year).

4½. Specify feedback system model.

5. Characterize the impedance-related collective effects. (follows 4; ~ months).
6. Specify revised design parameters, and produce optimized technical designs (low risk and cost) for vacuum system and RF cavities. (following TDR).
7. Produce revised impedance model and updated characterization of impedance-related collective effects. (following TDR).
8. Prototyping and testing (in parallel with 6 and 7).

Other Very High Priority R&D Items

- **Lattice design.** The present lattice is satisfactory for the RDR but can be improved:
  - **Change in circumference to optimise timing scheme.**
  - **Improve the dynamic aperture.**
  - **Reduce the sensitivity to alignment errors.**
  - **Reduce the number of magnets to reduce the cost.**
  - **Reduce the momentum compaction factor (or design a tunable lattice) to reduce RF costs.**
- **Low emittance tuning.** Requires investigation of different techniques and experimental studies to demonstrate < 2 pm vertical emittance.
- **Fast ion instability.** Requires experimental studies (being planned for ATF this year) to collect data for benchmarking modelling codes. A good understanding of this effect is needed to specify vacuum system, feedback system, and safe operating conditions.

Who's Planning What? (An incomplete list…)

	ANL	CI	Cornell	DESY	FNAL	IHEP	KEK	LBNL	LNF	SLAC
kickers			•		•		•	•	•	•
e-cloud			•	•	•		•	•	•	•
impedance	•	•						•		•
lattice design	•				•	•		•		•
low-ε_y	•	•					•	•		•
ions				•			•			•
vacuum		•				•		•		
acceptance	•		•					•		•
RF system			•							
RF controls								•		•
align/support			•					•		
mech.integration								•		
instrumentation	•		•				•	•		
feedback system								•	•	•
wiggler			•	•					•	
main magnets						•		•		

Future Test Facilities

- There are possibilities for several test facilities that could play an important role in damping rings R&D:
  - **KEK-ATF: in operation for several years. Has already made many important contributions: low-emittance tuning, development of instrumentation and diagnostics, test of fast kickers, fast ion instability studies…**
  - **PEP-II: now being used for electron cloud studies.**
  - **KEKB: planned R&D program for the damping rings, including electron cloud studies.**
  - **CESR-TA: proposed test facility. Could study a range of beam dynamics issues in wiggler-dominated regime, including low-emittance tuning, electron cloud…**
  - **HERA-DR: 6 km ring that could eventually be developed into one of the ILC damping rings.**
- The developing R&D plan must take full account of the possibilities afforded by these facilities to address critical issues.

Resources

- Nearly 40 FTEs and $1100k M&S on damping rings R&D in 2006.
- To meet laboratories' desires in 2008, we would need roughly a factor of 2 increase in FTEs, and a factor of 4 increase in M&S.
- Laboratories' desires provide guidance in developing R&D plan; but represent proposals that have not been effectively coordinated.
- Final version of R&D plan will estimate the level of resources required to achieve the specified goals and milestones, with proper coordination of activities.

Future Goals of S3

- Continue the telephone meetings to coordinate activities on specific R&D topics.
- Organise the next Damping Rings R&D Meeting.
  - **The meeting will be held at Frascati, 5-7 March 2007.**
  - **The meeting will focus on three very high priority topics:**
    - Lattice design and dynamic aperture.
    - Low-emittance tuning.
    - Ion effects.
  - **The meeting will provide essential input for the developing R&D plan.**
- Complete a draft of the coordinated R&D Plan.
  - **Database information needs to be updated.**
  - **We hope to complete the first draft of the R&D plan, consisting of those Work Packages that include Very High Priority R&D Objectives, in the next two or three months.**
  - ***How do we ensure consistency with the new organization being discussed by the GDE Executive Committee?***

Contributors

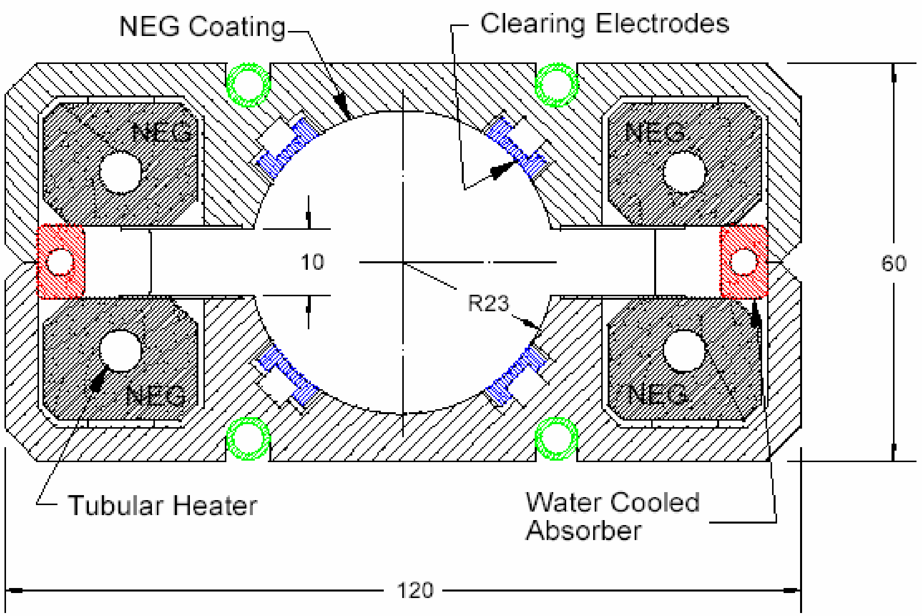
ANL	FID	LLNL
ASTeC	FNAL	LNF
CERN	IHEP	UBC
Cockcroft Inst.	KEK	U. Maryland
Cornell	KNU	U. Minnesota
DESY	LANL	SLAC
Efremov Inst.	LBNL	U. Illinois UC
		YerPhI

R&D Points for EDR (from my view points)

- First, we have to select the lattice design which satisfies many constraints, especially dynamic aperture of positron DR and β function at beam injection/extraction to make enough kick angle.
- Consider the BPM one-pass resolution (3μm (r.m.s.)) to make 2pm-rad vertical emittance beam.
- Consider the impedance and electron cloud issues to make the stable flat multi-bunch beam.
- Super Conducting 650MHz RF system to make 9mm bunch length beam and Super Conducting Wiggler system to make small damping time (20msec).
- Confirm beam quality by a lot of beam simulation.

Wiggler Design

- Baseline design based on Cornell SC wiggler (Urban)
  - **permits high field with large aperture**
    - alternative designs still being examined (PM or resistive)
  - **vacuum chamber concept to handle heat load and provide adequate pumping developed (Marks, Plate)**



Material: welded Al, NEG coated

P_{CO} = 0.7 nTorr

Power density: 3 W/mm^2

Power: 26 kW/wiggler (13 kW each absorber)