RDB S3
Damping Rings R&D

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The Cockcroft Institute, and the University of Liverpool

on behalf of the S3 Task Force

Contents

My emphasis will be on the *process* of developing a coordinated R&D Plan for the damping rings, rather than on the plan itself.

- S3's approach to coordination of damping rings R&D.
- Overview of the damping rings R&D plan.
  - **Example of a damping rings R&D work package.**
- Test facilities.
- Future developments.

S3 Charge

The role of the S3 Task Force is to:

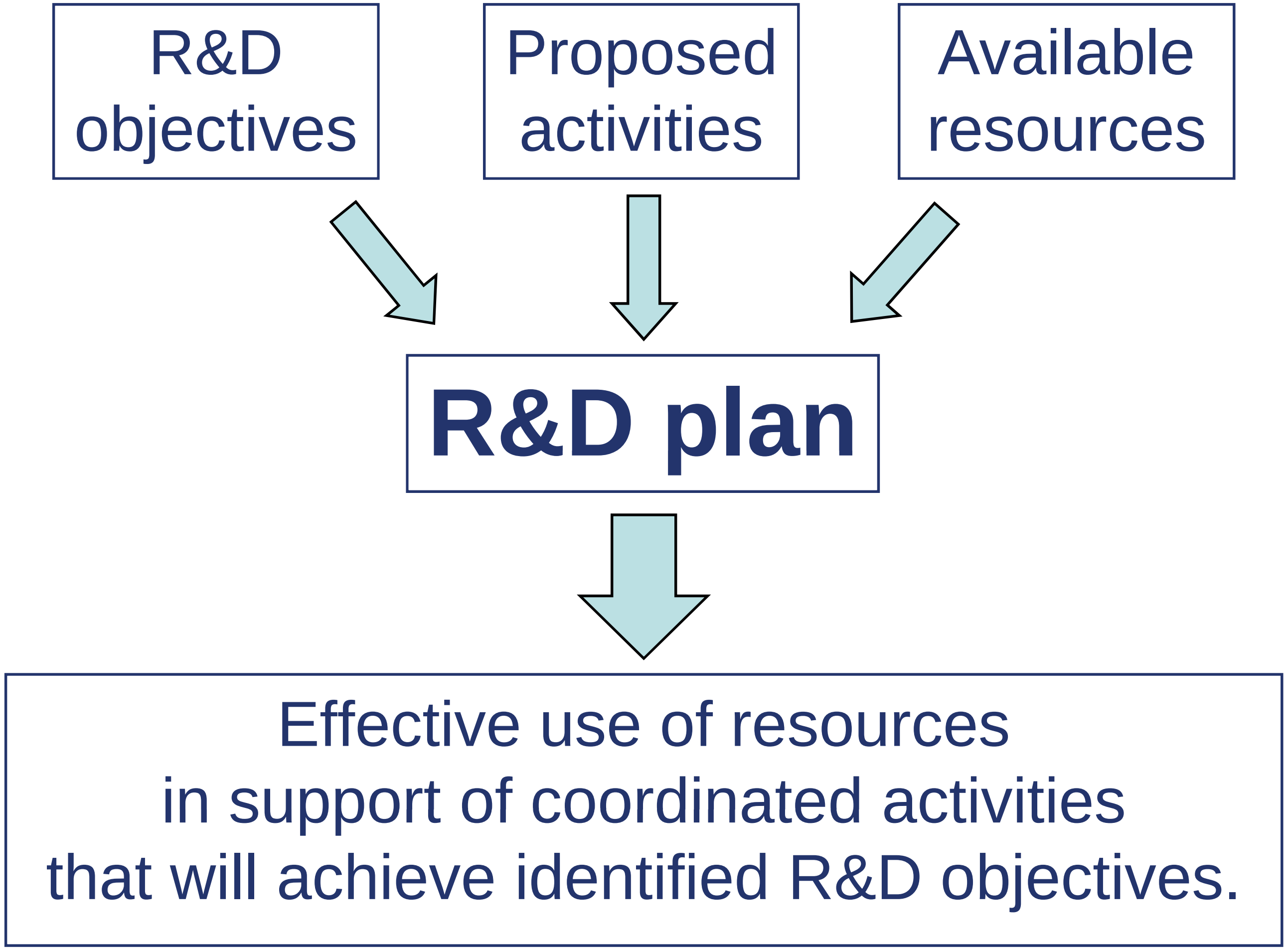
- **advise the RDB on the research and development program for the ILC damping rings;**
- **support the coordination of specific parts of the damping rings research and development program.**

In its advisory role, the Task Force should draw up a coordinated R&D plan for the ILC damping rings, which the Task Force will recommend to the RDB…

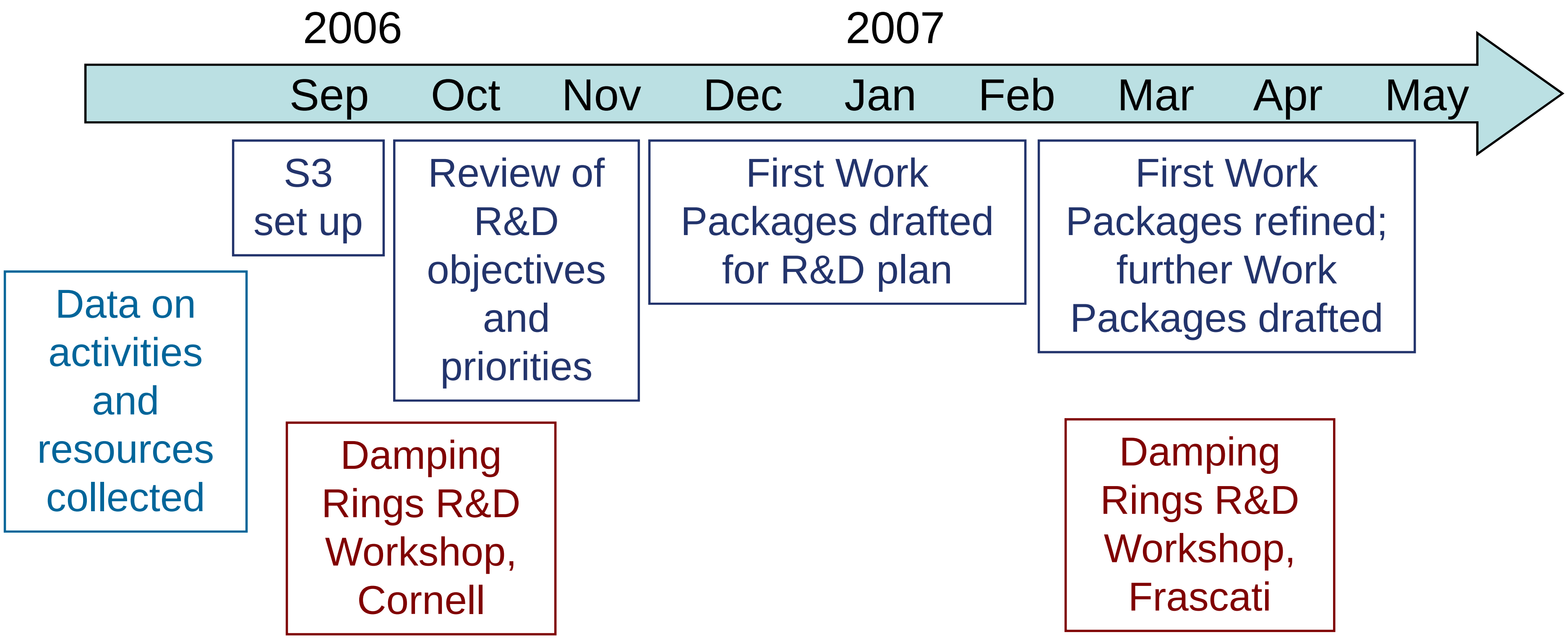
S3 Membership

- Eckhard Elsen
- Jie Gao
- Susanna Guiducci
- Tom Mattison
- Mark Palmer
- Mauro Pivi
- Junji Urakawa
- Marco Venturini
- Andy Wolski
- Mike Zisman

R&D Plan is our key "deliverable"



Development of the DR R&D Plan



Guiding Principles

- R&D objectives should be stated as clearly as possible.
- Priorities to the R&D objectives should be assigned following a systematic procedure. We took into account:
  - **capability of existing technology to meet the specifications;**
  - **impact on performance if the specifications are not met;**
  - **availability and ease of alternatives or work-around solutions;**
  - **potential for cost reductions.**
- The developing R&D plan should have the full involvement and support of the damping rings community.

Classifying the R&D Objectives

1 Parameter optimization

2 Beam dynamics studies

2.1 Single-particle dynamics

2.2 Multi-particle dynamics

2.3 Integrated dynamics studies

3 Technical subsystem or component development

(Including vacuum, magnets, wigglers, kickers, RF, instrumentation and diagnostics, feedback systems, controls, supports and alignment, collimation, dumps)

4 Experimental studies and test facilities

(Includes R&D items required for the test facilities, rather than for the damping rings themselves)

76 Damping Rings R&D Objectives

- 11 Very High Priority Objectives
- 28 High Priority Objectives
- 31 Moderate Priority Objectives
- 6 Low Priority Objectives

Very High Priority R&D Objectives

WP 2.1.1	2.1.1.1 Lattice design for baseline positron ring
	2.1.1.2 Lattice design for baseline electron ring
WP 2.1.4	2.1.4.3 Demonstrate < 2 pm vertical emittance
WP 2.2.1	2.2.1.2 Characterize single bunch impedance-driven instabilities
WP 2.2.3	2.2.3.1 Characterize electron cloud build-up
	2.2.3.2 Develop electron cloud suppression techniques
	2.2.3.3 Develop modelling tools for electron cloud instabilities
	2.2.3.4 Determine electron cloud instability thresholds
WP 2.2.4	2.2.4.1 Characterize ion effects
	2.2.4.2 Specify techniques for suppressing ion effects
WP 3.5.1	3.5.1.1 Develop a fast high-power pulser

The 11 objectives identified as "Very High" priority divide into 6 Work Packages, with each Work Package encompassing those objectives grouped at the third level of the WBS.

R&D Plan Structure and Contents

- The latest version of the damping rings R&D plan contains 6 Work Packages, containing between them the 11 Very High Priority R&D Objectives.
- Each Work Package, led by a named coordinator, contains:
  - **a list of (self-identified) potential investigators;**
  - **a summary of resources required to achieve the stated Objectives;**
  - **a list of the R&D Objectives, with:**
    - a description of the present status, significance for the damping rings design and operation, and the need for R&D;
    - a list of specific tasks that, when completed, will represent achievement of the Objective;
    - a list of the potential investigators, and estimate of the resources needed;
    - the required inputs;
    - identified deliverables.

The Process

- Understanding the resources available was an important preliminary step.
- We collected data on 111 separate activities (in progress or proposed), involving researchers from 28 different institutions. The collected data includes:
  - **brief description of the activity;**
  - **cross-references to the list of R&D Objectives;**
  - **a list of investigators, with a lead investigator identified;**
  - **a summary of resources, and their status.**
- The data collected indicates less-than-perfect coordination. There is some duplication of effort, though there are not many gaps in the programme.

The Process

- Presently, the R&D plan is inclusive.
  - **For example, WP 2.2.3 (Electron Cloud) lists 45 potential investigators. Not all these investigators are likely to get funding for their activities.**
- Coordination and elimination of duplication should happen by communication and agreement.
  - **The specific tasks identified in the R&D plan should form a focus for the discussions that need to take place.**
- The Work Package Coordinator should play a role in ensuring that the necessary discussion happen, and happen constructively.
  - **Difficult decisions may be needed, but holding collaborations together is essential. We need to work positively with each other to achieve the R&D goals.**

Community Input

In the past 7 months, we have held two damping rings R&D workshops:

- Cornell, September 2006 (ILCDR06)
  - **https://wiki.lepp.cornell.edu/ilc/bin/view/Public/DampingRings/ILCDR06/**
  - **Focused on three of the Very High Priority R&D topics:**
    - Electron cloud
    - Injection/extraction kickers
    - Impedance and impedance-driven instabilities
  - **43 participants**
    - 34 from the Americas; 3 from Asia; 6 from Europe
- Frascati, March 2007 (ILCDR07)
  - **http://www.lnf.infn.it/conference/ilcdr07/**
  - **Focused on the remaining three Very High Priority R&D topics:**
    - Lattice design
    - Low-emittance tuning
    - Ion effects
  - **29 participants**
    - 11 from the Americas; 5 from Asia; 13 from Europe

Community Input

- The principal goal of each of the Workshops was to provide a forum for technical presentations and discussions of work related to damping rings R&D.
- **There is real work going on, and real progress being made.**
- The final sessions were devoted to planning future R&D; these sessions provided essential input for the damping rings R&D plan.

- There is a proposal to host the next damping rings R&D workshop in Korea in fall 2007.

Next Steps

- Drafts are in place for 5 of the 6 Work Packages containing Very High Priority R&D Objectives.
- The drafts need to be discussed by those interested or involved in the damping rings R&D, and agreements reached on exactly who will do what.
- These discussions and agreements need to take place in the context of:
  - **an emerging organisational structure for the EDR;**
  - **updated information on resources, reflecting funding situations that have a tendency to change;**
  - **decisions on Test Facilities, that could significantly impact the R&D program;**
  - **potential changes to the baseline configuration.**

Next Steps

- The damping rings R&D plan should be seen as a working document.
- The R&D plan:
  - ***does not*** **lay out a programme that must be adhered to rigidly, but it**
  - ***does*** **provide a snapshot of the present programme and the future direction, which must be flexible to accommodate changing circumstances and project goals and organisation.**
- There is a need to improve communication at all levels, and to establish accountability.
  - **Addressing these issues is one of the goals of the EDR Task Force recently established.**
  - **Regular telephone meetings on particular damping rings R&D topics have been planned, but are yet to get properly off the ground…**

The Damping Rings R&D Plan

S3 WBS	Work Package	S3 WP Coordinator(s)
2.1.1	Lattice Design	Mike Zisman
2.1.4	Low-Emittance Tuning	Andy Wolski
2.2.1	Impedance-Driven Single-Bunch Instabilities	Marco Venturini
2.2.3	Electron Cloud	Mauro Pivi
2.2.4	Ion Effects	Mauro Pivi & Marco Venturini
3.5.1	Fast Injection/Extraction Kickers	Tom Mattison

Estimated required resources, *excluding operational support for test facilities*:

Staff effort (FTE)

S3 WBS	2007	2008	2009	2010
2.1.1	3.0	3.0	1.5	
2.1.4	7.5	7.5		
2.2.1	4.5	4.5		
2.2.3	9.0	9.0		
2.2.4	6.0	4.0	4.0	
3.5.1	8.0?	8.0?		

M&S (US$k)

S3 WBS	2007	2008	2009	2010
2.1.1	0	0		
2.1.4	350	350	100	100
2.2.1	0	0		
2.2.3	762	782		
2.2.4	200?	200?		
3.5.1	1,000?	1,000?	1,000?	

The Damping Rings R&D Plan

S3 WBS	Work Package	S3 WP Coordinator(s)
2.1.1	Lattice Design	Mike Zisman
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2.2.1	Impedance-Driven Single-Bunch Instabilities	Marco Venturini
2.2.3	Electron Cloud	Mauro Pivi
2.2.4	Ion Effects	Mauro Pivi & Marco Venturini
3.5.1	Fast Injection/Extraction Kickers	Tom Mattison

Required or possible test facilities:

S3 WBS	
2.1.1	None required
2.1.4	CesrTA, ATF, ALS, APS
2.2.1	None required
2.2.3	CesrTA, PEP-II, KEKB, DAΦNE, (LHC)
2.2.4	CesrTA, ATF
3.5.1	ATF, FNAL-A0, DAΦNE, (CesrTA)

Resource Situation 2007/08

Staff effort (FTE)

Excluding support for test facilities

Estimated requirements

S3 WBS	2007	2008
2.1.1	3.0	3.0
2.1.4	7.5	7.5
2.2.1	4.5	4.5
2.2.3	9.0	9.0
2.2.4	6.0	4.0
3.5.1	8.0?	8.0?

Actual approved*

S3 WBS	2007	2008
2.1.1	2.5	2.5
2.1.4	8.3	10.0
2.2.1	0	0
2.2.3	5.8	0.7
2.2.4	5.1	2.3
3.5.1	7.9	3.9

M&S (US$k)

Excluding support for test facilities

Estimated requirements

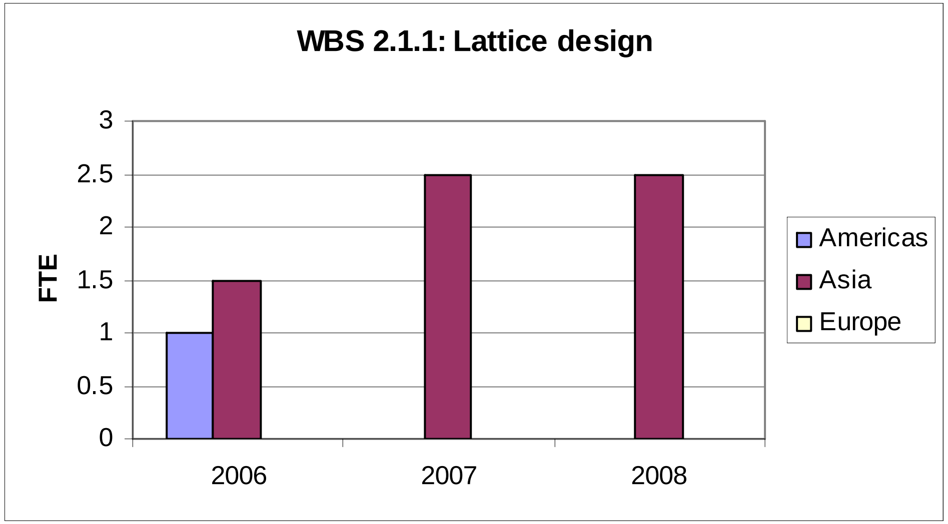
S3 WBS	2007	2008
2.1.1	0	0
2.1.4	350	350
2.2.1	0	0
2.2.3	762	782
2.2.4	200?	200?
3.5.1	1,000?	1,000?

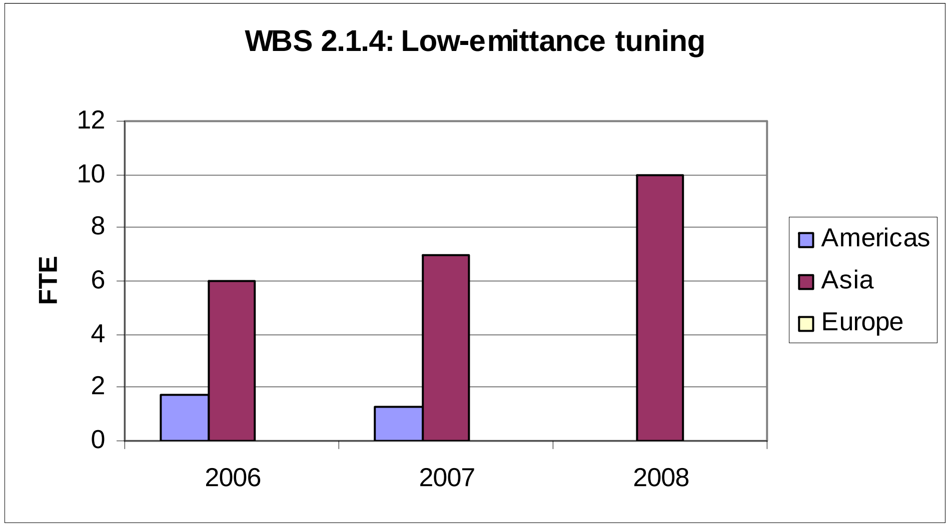
Actual approved*

S3 WBS	2007	2008
2.1.1	0	0
2.1.4	280	300
2.2.1	0	0
2.2.3	60	0
2.2.4	20	20
3.5.1	205	160

*Last updated: September 2006

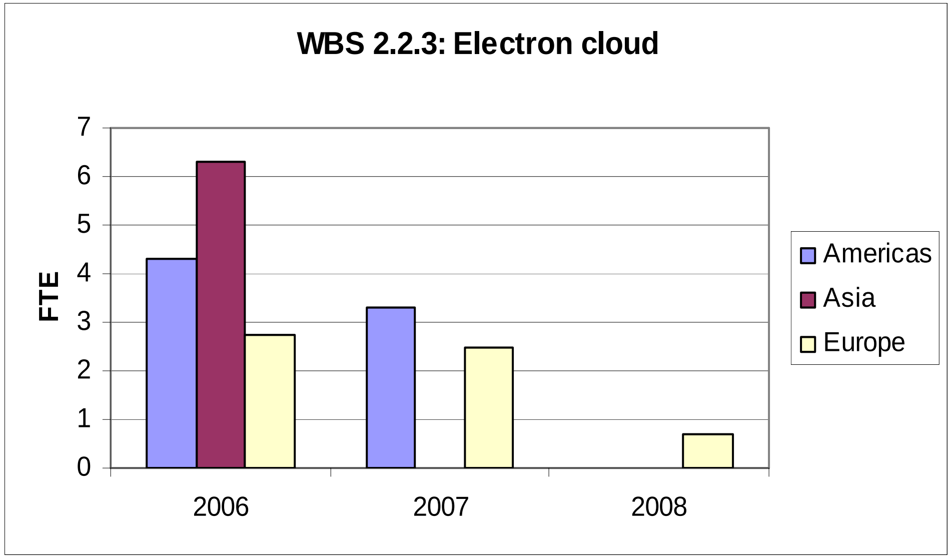
Resource Distribution*

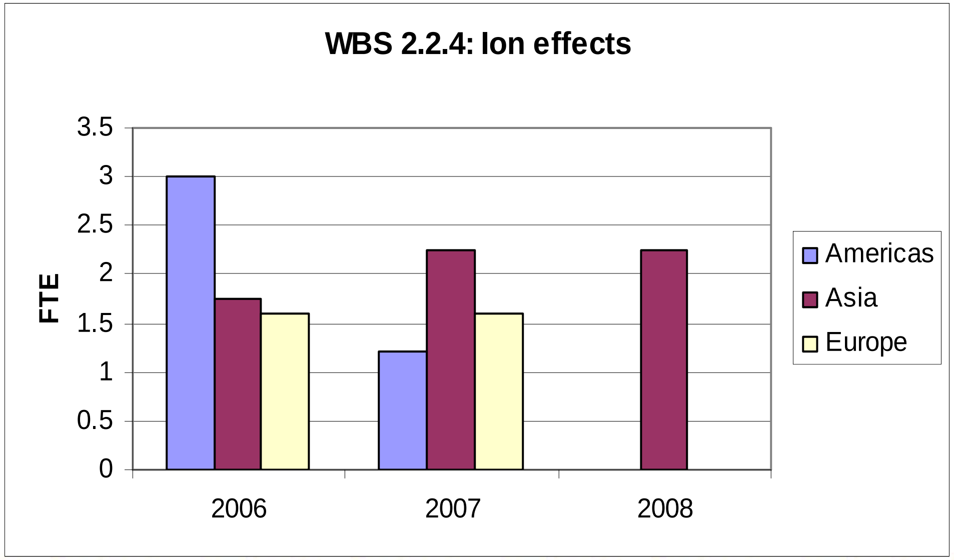




*Last updated: September 2006

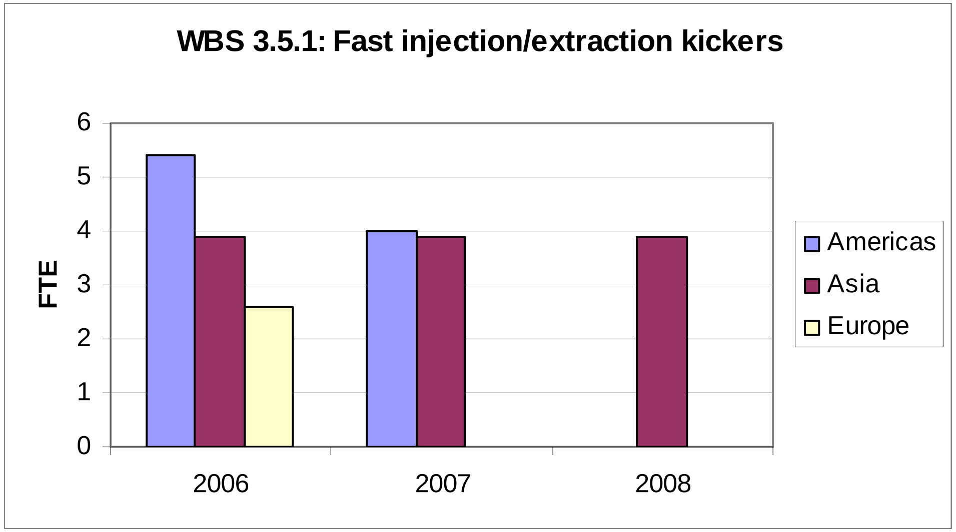
Resource Distribution*





*Last updated: September 2006

Resource Distribution*



*Last updated: September 2006

Example: WP 2.2.3 (e-cloud)

- Potential Investigators
- Summary of Required Resources (by Objective)
  - **Staff effort**
  - **M&S**
  - **Travel**
  - **Facilities**
- Objectives
  - **Priority**
  - **Description: explanation, discussion, motivation**
  - **Tasks**
  - **Investigators**
  - **Resources**
  - **Timescale (milestones)**
  - **Input**
  - **Deliverables**
  - **Impact**

Example: WP 2.2.3 (e-cloud)

Potential Investigators

CERN
Warner Bruns
Fritz Caspers
Daniel Schulte
Frank Zimmermann
Cockcroft Institute
Oleg Malyshev
Ron Reid
Andy Wolski
Cornell
Jim Crittenden
Mark Palmer
DESY
Rainer Wanzenberg
FNAL
Panagiotis Spentzouris
INFN-LNF
David Alesini
Roberto Cimino
Alberto Clozza
Pantaleo Raimondi
Cristina Vaccarezza
KEK
John Flanagan
Hitoshi Fukuma
Ken-ichi Kanazawa
Kazuhito Ohmi
Kyo Shibata
Yusuke Suetsugu

LANL
Bob Macek
LBNL
John Byrd
Christine Celata
Stefano de Santis
Art Molvik
Gregg Penn
Marco Venturini
Mike Zisman
PAL
Eun-San Kim
Rostock University
Aleksander Markovik
Gisela Poplau
Ursula van Rienen
SLAC
Karl Bane
Bob Kirby
Alexander Krasnykh
Brett Kuekan
Nadine Kurita
Cho Ng
Alexander Novokhatski
Mauro Pivi
Tor Raubenheimer
John Seeman
Lanfa Wang

Example: WP 2.2.3 (e-cloud)

S3 WBS	Objective	Priority
2.2.3.1	Characterize electron-cloud build-up	Very High
2.2.3.2	Develop electron-cloud suppression techniques	Very High
2.2.3.3	Develop modelling tools for electron-cloud instabilities	Very High
2.2.3.4	Determine electron-cloud instability thresholds	Very High

Staff effort (FTE)

S3 WBS	2007	2008	2009	2010
2.2.3.1	2.0	2.0		
2.2.3.2	3.0	3.0		
2.2.3.3	2.0	2.0		
2.2.3.4	1.5	2.0		

Travel, at US$10k/FTE (US$k)

S3 WBS	2007	2008	2009	2010
2.2.3.1	20	20		
2.2.3.2	30	30		
2.2.3.3	20	20		
2.2.3.4	15	20		

M&S (US$k)

S3 WBS	2007	2008	2009	2010
2.2.3.1	35	0		
2.2.3.2	700	755		
2.2.3.3	7	7		
2.2.3.4	20	20		

Example: WP 2.2.3 (e-cloud)

Facilities

CesrTA would provide a unique facility for studies of electron cloud under a range of conditions close to those expected in the damping rings. In particular, CesrTA would allow detailed studies of electron cloud build-up in wigglers (Objective 2.2.3.1) and tests of a range of mitigation techniques (Objective 2.2.3.2). Experimental data from several machines (CesrTA, PEP-II, KEKB, DAΦNE, LHC) will be needed for proper completion of all the Objectives. Tests of grooved chambers for suppression of electron cloud are underway in PEP-II. It is possible that the KEKB positron ring could be tuned for low natural emittance (1 nm by reducing the energy from 3.5 GeV to 2.3 GeV), and some time could be available over the next few years for dedicated electron cloud studies.

Example: WP 2.2.3 (e-cloud)

Objective 2.2.3.2: Develop electron-cloud suppression techniques

Very High Priority

Actions to suppress the electron cloud are required for the positron damping ring. The B-factories have implemented external solenoid fields to mitigate electron cloud in field-free regions, which constitute a large fraction of the PEP-II and KEKB positron rings [1, 2]. Notably, the electron cloud effect in KEKB remains a major obstacle to shorter bunch spacing and higher luminosity, even with solenoid windings [3]. In the ILC damping rings, beam instability can occur even if electron cloud is present only in the wigglers and dipoles, where external solenoid fields are not effective in preventing build-up of the cloud. Therefore, R&D is required into techniques that can be applied in regions of strong magnetic fields to prevent build-up of electron cloud.

Preliminary studies (mostly based on simulations, but supported by some laboratory measurements) suggest that techniques such as grooves in the wall of the vacuum chamber, or the use of clearing electrodes, could be effective at suppressing the electron cloud in regions of strong wiggler or dipole fields [4, 5]. On the basis of these studies, a single 6 km positron damping ring has now been adopted in the baseline configuration for the ILC. However, a demonstration of the effectiveness of possible suppression techniques is required to validate this choice; an (expensive) alternative is to use two positron damping rings to reduce the beam current. Any technique used to mitigate build-up of electron cloud must be consistent with stringent requirements for large aperture and low impedance in the damping rings.

Example: WP 2.2.3 (e-cloud)

Achieving the objective of developing suppression techniques for the electron cloud will involve the following tasks:

1. **Study coating techniques, test the conditioning of coated surfaces and characterize their performance *in situ* in CesrTA, PEP-II and KEKB.**
2. **Test clearing electrode concepts by installing chambers with clearing electrodes in existing machines and in magnetic field regions in CesrTA, PEP-II, KEKB, LHC and HCX (LBNL). Characterize the impedance seen by the beam, the generation of higher order modes (HOMs), and the power deposited in the electrodes.**
3. **Test "groove" concepts by installing chambers with grooved or finned surfaces in existing machines, including bend and wiggler sections in CesrTA and PEP-II. Characterize the impedance and HOMs.**

Example: WP 2.2.3 (e-cloud)

Potential Investigators on these tasks will be:

David Alesini
Fritz Caspers
Alexander Krasnykh
Bob Macek
Art Molvik
Cho Ng
Mark Palmer
Mauro Pivi
Yusuke Suetsugu
Lanfa Wang

A total effort of 3 FTE per year for two years will be required. Work includes mainly experimental studies with support of simulations.

An M&S budget of $730k in 2007, and $920k in 2008 is required.

Work on these tasks should start now. The goal is to complete all three tasks by the end of 2008 as input for the Engineering Design Report (EDR).

Example: WP 2.2.3 (e-cloud)

The required input includes:

- **Experimental data from machines including CesrTA, PEP-II, KEKB, LHC. Data should include detailed comparison of electron cloud density with beam in sections with mitigation techniques implemented (grooved and/or coated surfaces, clearing electrodes, etc.) compared with the electron cloud density in sections without mitigating techniques.**

The deliverables will include:

- **Technical specifications for techniques to be used to suppress build-up of electron cloud in the positron damping ring, consistent with aperture and impedance requirements.**
- **Guidance for the design of the vacuum chamber material and geometry (Objective 3.1.1.1), and for the technical designs for principal vacuum chamber components (Objective 3.1.1.2).**

Example: WP 2.2.3 (e-cloud)

If electron cloud mitigation techniques are not developed and demonstrated to be sufficiently effective for the proposed baseline positron 6 km ring, then two 6 km rings or a single ring of much larger circumference are possible alternatives. If the electron cloud density is not reduced below the threshold level for beam instabilities, then the positron damping ring will be unable to provide a beam meeting the specifications for quality, stability and intensity; this will have a potentially significant impact on the luminosity of the ILC.

Test Facilities

- Experimental studies will form an essential part of the damping rings R&D programme.
- Key areas requiring experimental study include:
  - **electron cloud;**
  - **low-emittance tuning;**
  - **ion effects;**
  - **fast injection/extraction kickers.**
- Use of test facilities requires particularly careful evaluation and planning, since they tend to be expensive to operate.

Test Facilities: KEK-ATF

- 140 m, 1.28 GeV electron storage ring with full-energy injection linac, and extraction line.
- Operating several years as a DR test facility. Still the largest linear collider test facility in the world.
- Has enabled significant progress in:
  - **instrumentation and diagnostics (laser wire, nano-BPM, OTR/ODR, FONT…);**
  - **beam dynamics, including studies on intrabeam scattering, fast ion instability, beam-based alignment, low-emittance tuning (holds world record for low emittance, at 4.5 pm);**
  - **technology (fast kickers).**
- From 2008, focus of effort will switch from damping rings to ATF2.

Test Facilities: CesrTA

- Cesr-c is a wiggler-dominated electron-positron collider.
- The proposed development of CESR into CesrTA would allow a unique opportunity for electron cloud studies at a dedicated test facility, operating in a parameter regime directly relevant for the ILC damping rings.
  - **Requires relocation of wigglers to allow tuning for low natural emittance; upgrade of instrumentation for tuning for low vertical emittance; installation of instrumented test chambers in wigglers.**
- A range of other important studies will also be possible (e.g. low-emittance tuning, development of instrumentation for fast beam-size measurements of ultra-low emittance beams).
- Presently, there are serious funding uncertainties…

Test Facilities: HERA-DR

- More than just a test facility: the proposed development of HERA into HERA-DR would actually provide one of the damping rings for the ILC.
- Staged program over several years:
  - **2007 – 2009: installation of new injection line, replacement of NC RF, re-commissioning as test facility;**
  - **2009 – X: test facility programme, including demonstration of operational performance in key areas;**
  - **X – (X+7): ILC project start, procurement and installation of new DR components, further DR tests, de-installation and transport to ILC site, re-installation and commissioning.**
- Initial studies show this plan to be an interesting possibility.

Test Facilities: KEKB

- Electron cloud effects have already been studied extensively at KEKB, but not in the same low-emittance parameter regime in which the damping rings will operate.
- Solenoid fields in the straight sections have been effective at suppressing electron cloud effects in the B factories; but recent interest in a SuperB factory motivates further research.
- Tests of grooved and coated chamber surfaces for suppressing e-cloud are already underway at PEP-II, but studies of suppression techniques in wigglers with low emittance beams will require other facilities.
- KEKB LER could be tuned for ~ 1 nm emittance by reducing the energy from 3.5 GeV to 2.3 GeV.
- For the next two years, the priority for KEKB will be to continue to provide luminosity for BELLE. However, there may be some limited opportunity for electron cloud studies for ILC in that time, if the operational (power) costs of the machine are provided.

Other Test Facilities

- DAΦNE
  - **electron cloud**
  - **fast injection/extraction kickers**
- FNAL-A0
  - **fast injection/extraction kickers**
- Third-generation synchrotron light sources, e.g. LBNL-ALS, ANL-APS
  - **low emittance tuning**
  - **fast ion effects**
- LHC
  - **electron cloud**

Test Facility Funding

- Use of test facilities needs to be evaluated against a number of criteria, including:
  - **technical capability: can studies be performed (perhaps with specified upgrades) that will resolve issues for the ILC damping rings?**
  - **availability: does the time available on the test facility allow studies to be completed in time for the EDR?**
  - **resources: what impact will it have on other parts of the ILC program if resources have to be diverted to operate the test facility?**
- After initially appearing promising, the future for CesrTA recently became less certain. The RDB was asked to make a recommendation on the role of CesrTA in the ILC R&D programme.

Test Facility Funding

- The S3 Task Force has collected information on CesrTA and on the use of KEKB for ecloud studies. Briefly, we find that:
  - **CesrTA is a realistic project only if funding at the level of $0.5M is found to support the program in FY08, $7M in FY09 and $12M in FY10 and FY11.**
  - **The program would directly address (in time for the EDR) several critical R&D areas for the ILC damping rings, including electron cloud, low-emittance tuning, ion effects, and beam instrumentation.**
  - **Without the understanding that would be gained by tests at CesrTA (or equivalent tests elsewhere) and demonstration of effective suppression techniques, electron cloud must be considered a serious risk to damping rings performance given the present baseline configuration.**
  - **KEKB could offer some opportunities for electron cloud tests as an alternative to CesrTA, but the program has not been developed to the same level of detail, some additional funding would be needed, and the studies would have to defer to BELLE operation.**
  - **Without tests at CesrTA, serious consideration would have to be given to the acceptability of the risk in the present baseline configuration.**

Future Goals

1. Complete the present draft of the R&D plan, to include all Work Packages that contain Very High Priority R&D Objectives. (early May)
2. Discuss the R&D plan with the community, and collect up-to-date information on participation and resources. (May-June)
3. Review the R&D plan, taking into account the updated information on participation and resources, and in the context of the emerging organization for the EDR. (July-August)