Damping Rings in the Engineering Design Phase

Andy Wolski

Cockcroft Institute/University of Liverpool

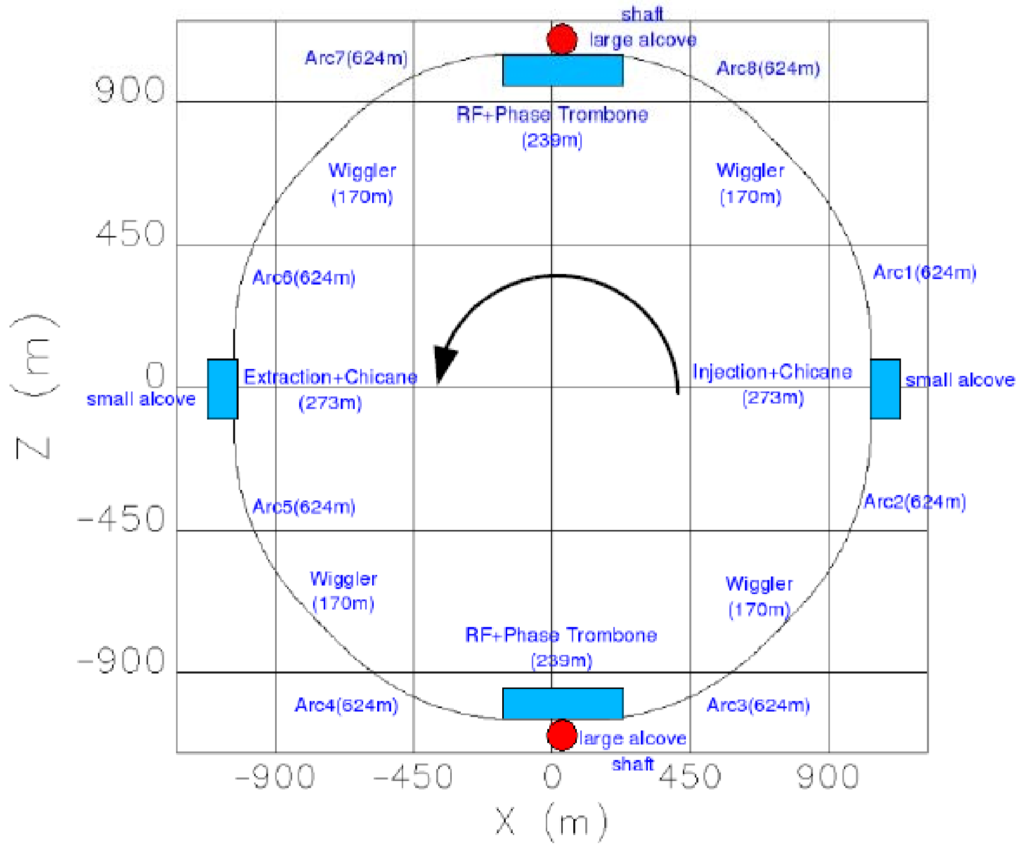
Contents

- Overview of technical presentations during the Damping Rings parallel (Thursday).
  - **Lattice design**
  - **Electron cloud and vacuum system**
  - **Fast ion instability**
  - **Impedance and impedance-driven instabilities**
  - **Fast injection/extraction kickers**
  - **Low-emittance tuning**
  - **Instrumentation and diagnostics**
  - **Polarisation**
  - **Cornell program/CesrTA**
  - **LBNL program**
- Outcome of discussions on Damping Rings organisation and milestones for the Engingeering Design Phase (Friday).

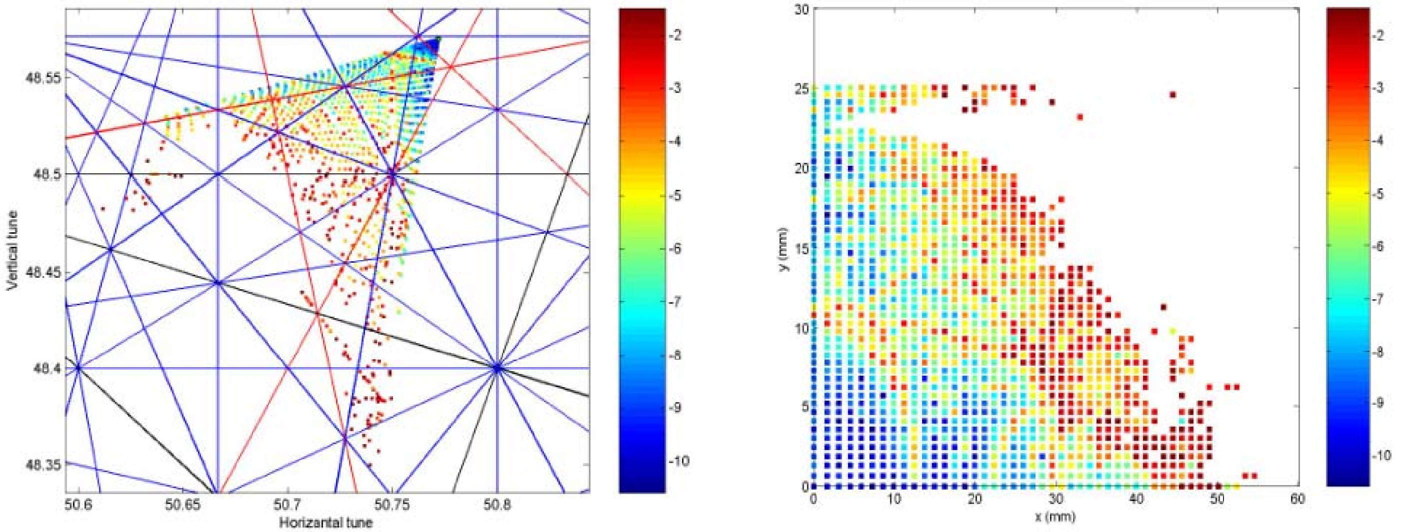
Lattice Design: Louis Emery/Aimin Xiao

OCS8 Ring Layout

- Positron and electron rings on top of each other
- Rings are counter-rotating
- Injection and extraction lines on each side would be in same tunnel
- SC RF cavities from different rings don't interfere with each other



Frequency map analysis (on momentum)



FMA analysis for on momentum particles: (Left) footprint; (Right) Dynamic aperture with FMA.

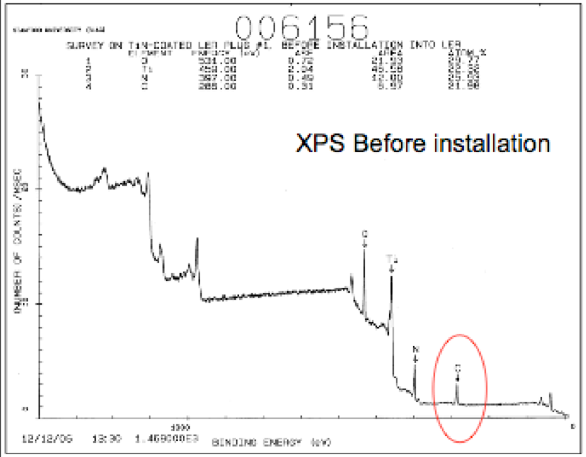
2500 particles distributed in the range of seven times the injected bunch size are tracked for 1024 turns.

Yi-Peng Sun et al. ILC DR Alternative Lattice Design 18

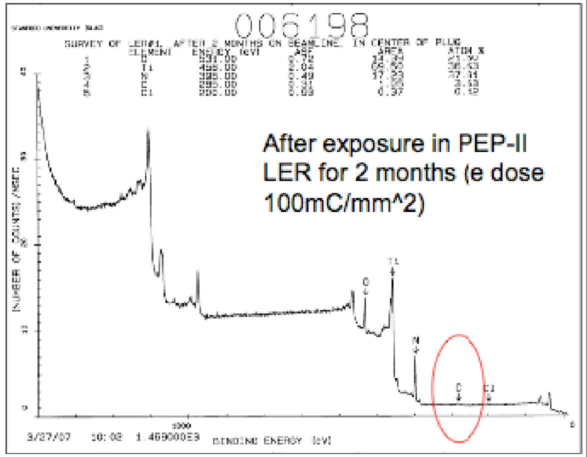
Electron Cloud: Roberto Cimino

New results from M. Pivi @ e^-cloud 07

Surface analysis: Carbon content decrease



LER#1 →



Different from electron conditioning in laboratory setup where carbon crystals grows!

Carbon is strongly reduced if exposed to beam. Same for LER #1 and #2 samples.

Vacuum and Ecloud: Oleg Malyshev

ASTeC Accelerator Science and Technology Centre

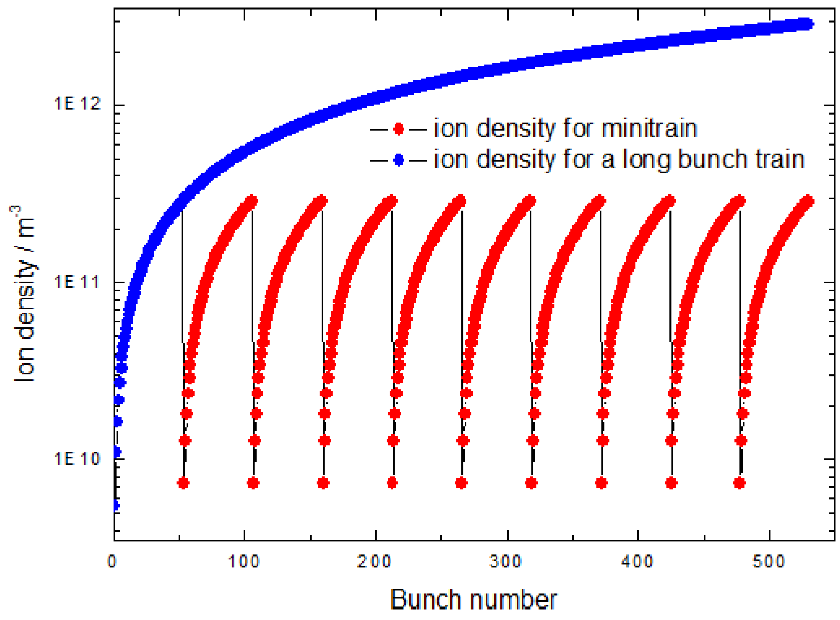
Conclusions

- An ante-chamber is not needed for vacuum (electron and positron DRs)
- A KEKB-type ante-chamber is required to suppress e-cloud in positron DR
  - in wigglers and, possibly, dipoles
  - the straight are to be studied
- Multipacting electrons in positron DR will cause the pressure increase comparable or larger than due to photons – to be considered in vacuum design
- Ion induced pressure instability might be a problem at ILC DR
  - Large distributed pumping speed required
  - TiZrV coated vacuum chamber has a sufficient safety margin

30/05-03/06/2007 LCWS2007 and ILC2007, DESY Hamburg, Germany O.B. Malyshev

Fill patterns

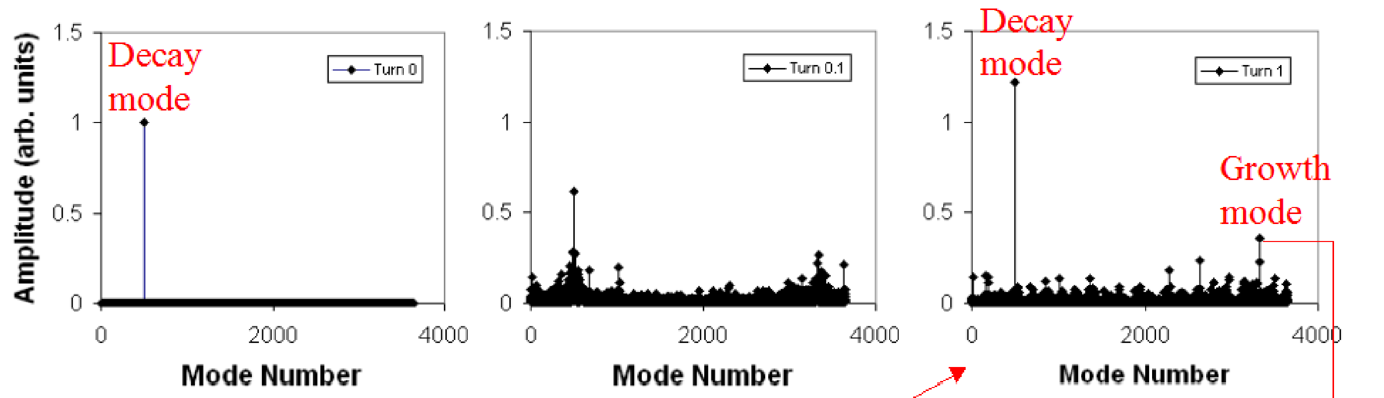
- For case C, the ion density like this



Ion density for 10 bunch trains for case C. n_b= 4346, N_0= 1.29E10, N_{train}= 82. There are 53 bunches per train. Bunch spacing =2 RF buckets= 3.08 ns. Gap between trains= 71 RF buckets. Partial pressure of CO is 1 ntorr.

Coupled Bunch Instability: Kai Meng Hock

Decay modes grow because …



$$\ddot{\tilde{y}}_\mu(t) + \overline{K}\tilde{y}_\mu(t) = \sum_{n=1}^{\infty} b_n e^{i\frac{2\pi n\mu}{M}} \tilde{y}_\mu(t-n\tau) - \frac{1}{M}\sum_{\mu'=0}^{M-1} \tilde{k}_{\mu-\mu'}(t)\tilde{y}_{\mu'}(t)$$

Mode Coupling

?

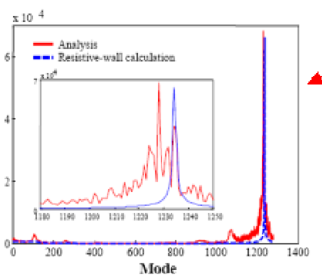
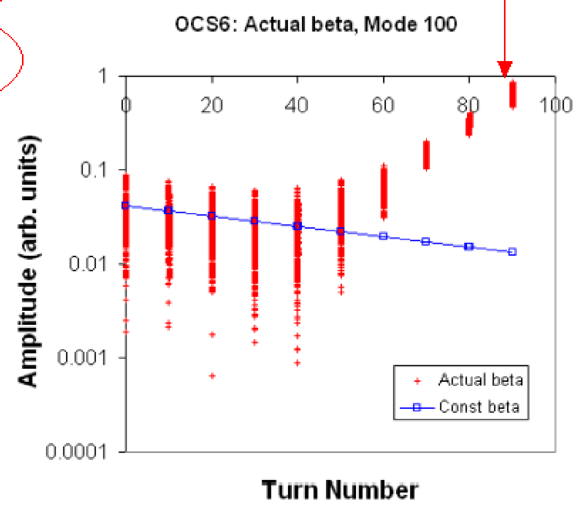
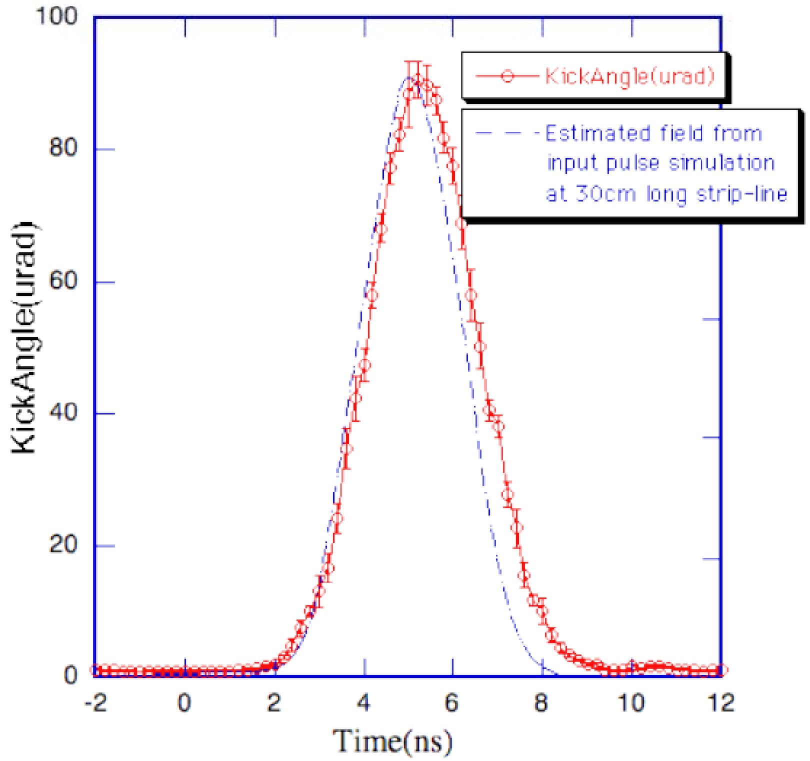


Fig. 1 The horizontal mode distribution of HER at 700 mA



Injection/Extraction Kickers: Takashi Naito

Timing scan of the kick pulse



Kick angle is estimated from the amplitude of the betatron frequency of the FFT signal.

Beam kick profile

The timing of the kick pulse is scanned for the timing of the beam with 200ps steps. The kick angle is estimated from the beam oscillation amplitude.

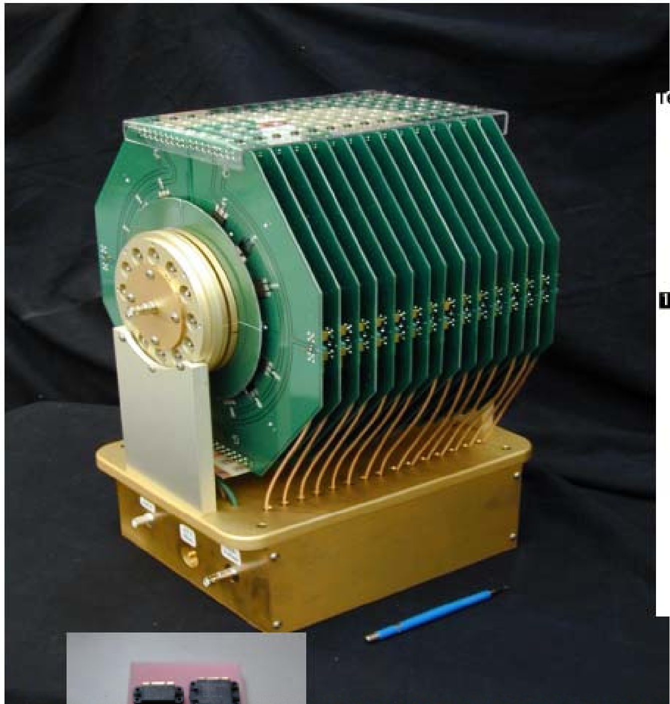
Rise time = 3.2ns
(1%~100%)
Fall time = 4.0ns
(100%~1%)

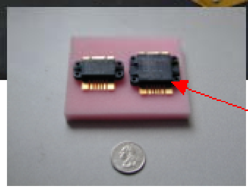
2007/6/2

20

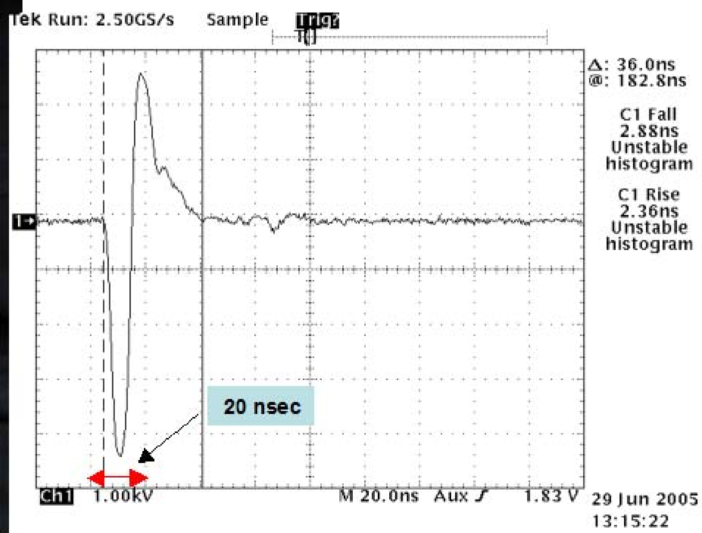
Injection/Extraction Kickers: Mark Palmer

Original Prototype Tested at KEK





Integrated Driver & Power MOSFET



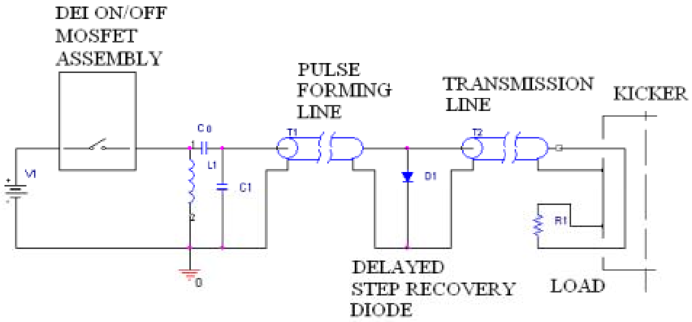
Pulse needs faster Tr, Tf, tail compensation

E. Cook LLNL

Global Design Effort

Injection/Extraction Kickers: Mark Palmer

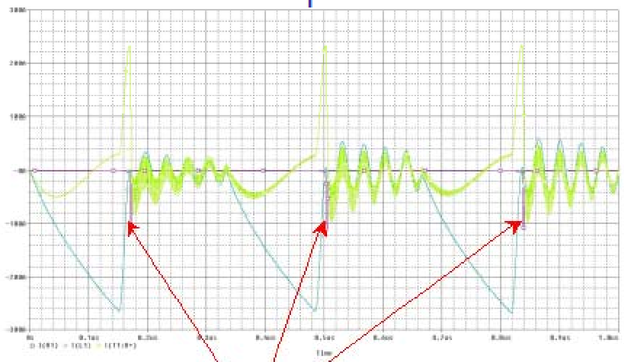
DSRD Detailed Circuit Behavior

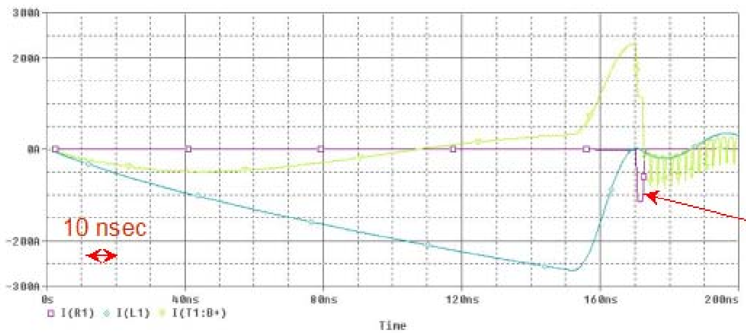


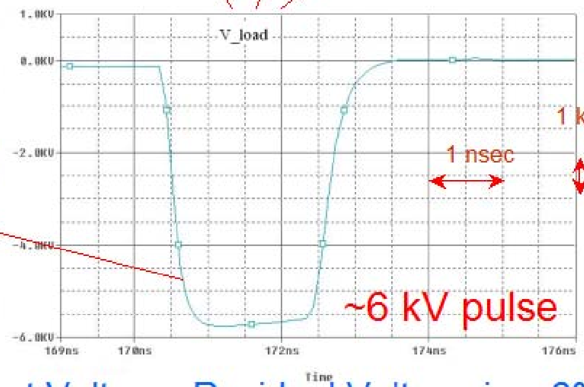
L=40 nH, C_o=30 nF, C_1=1.5 nF,

t_{on}=150 nsec, t = 1 nsec

3 MHz Rep Rate







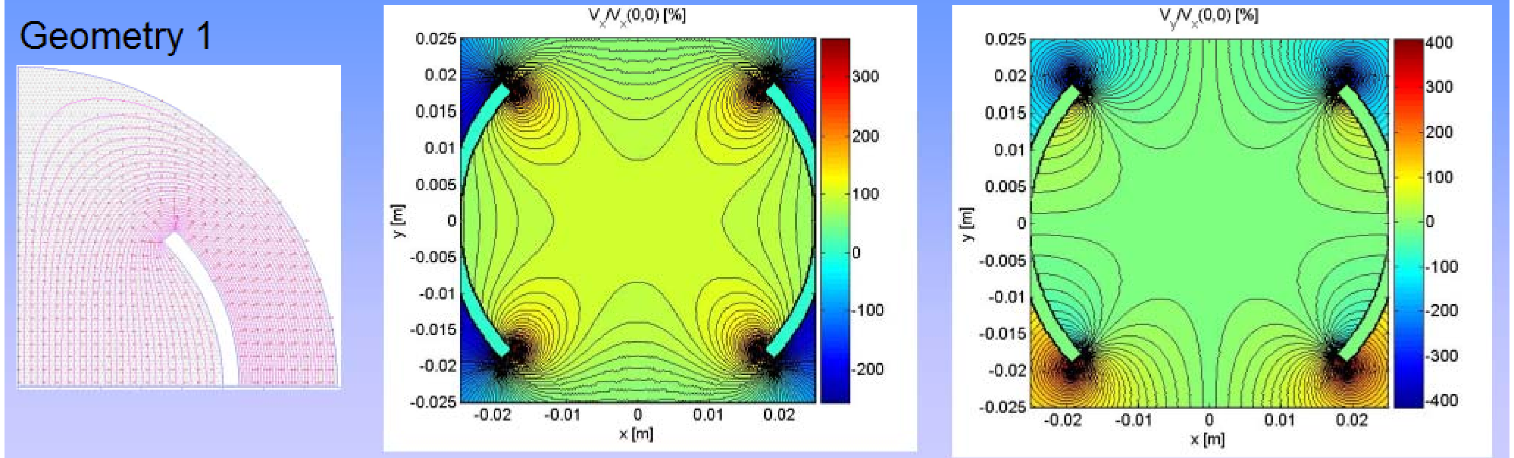
Currents vs. time for one cycle

Output Voltage, Residual Voltage is ~ 2%

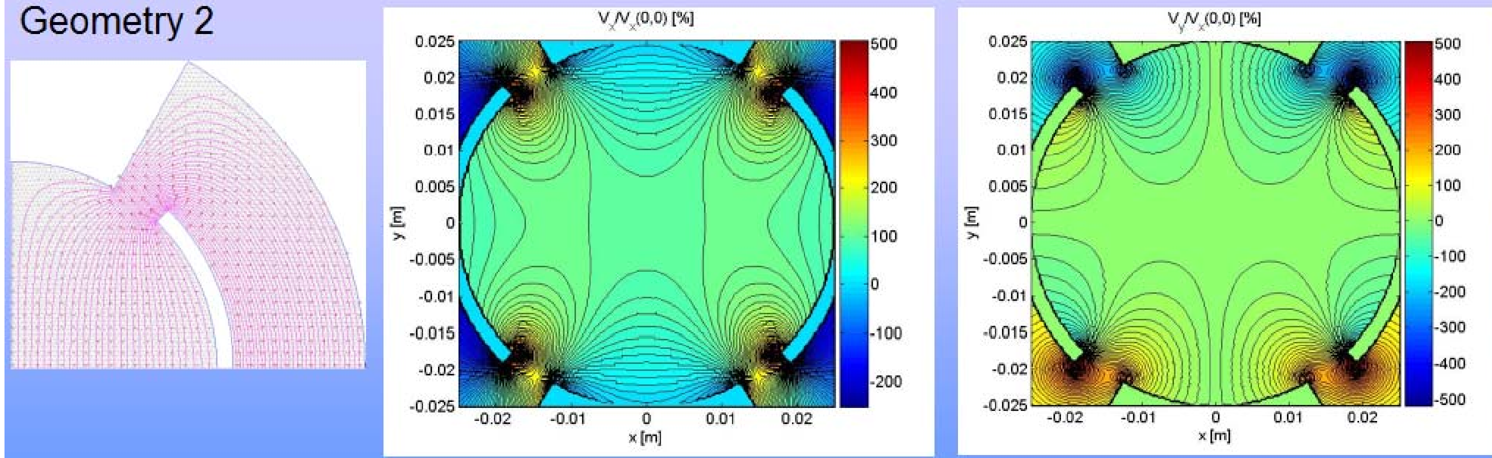
Injection/Extraction Kickers: David Alesini

ILC kickers: uniformity of the deflecting field (2/2)

Geometry 1

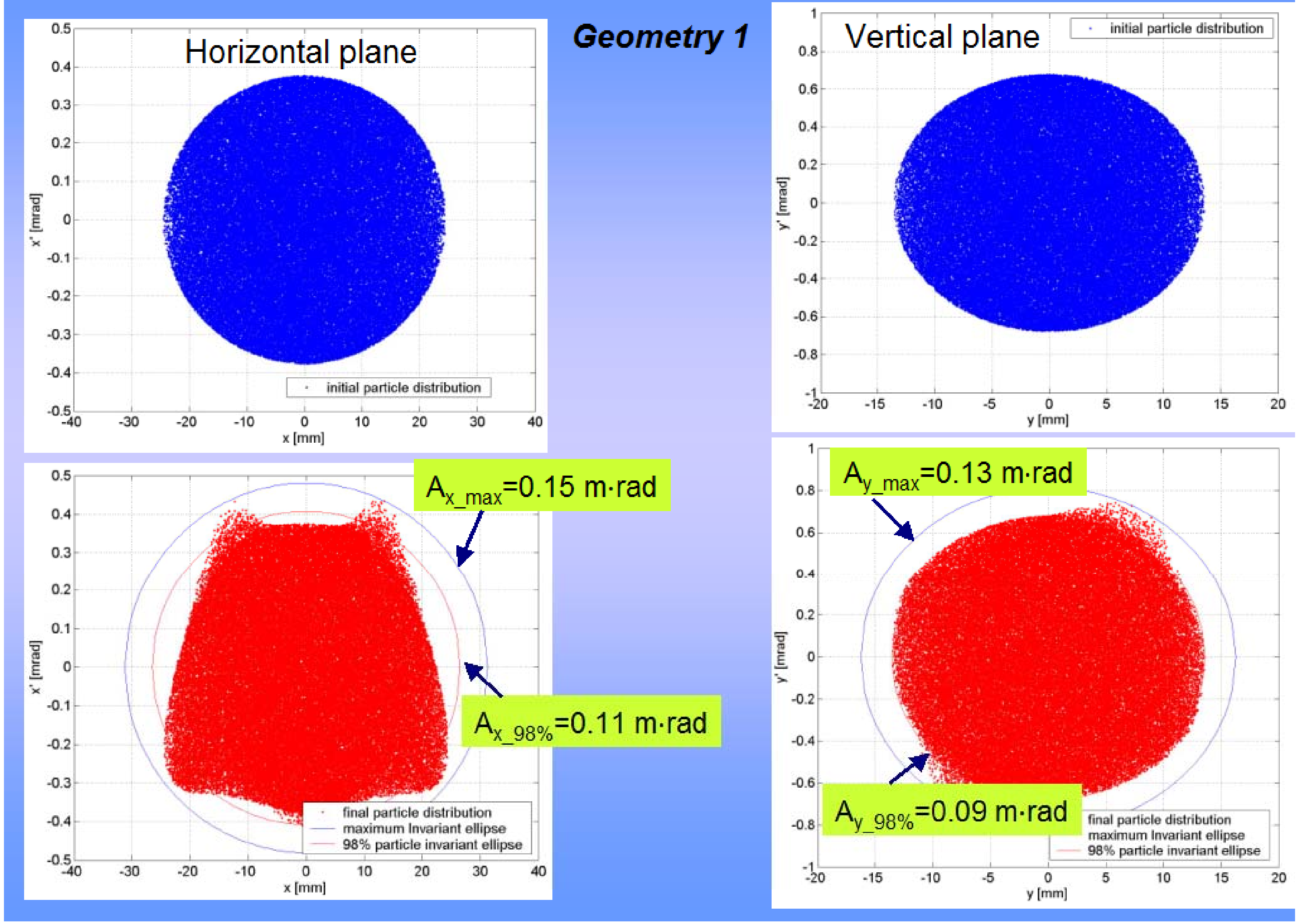


Geometry 2



Injection/Extraction Kickers: David Alesini

ILC kickers: effect of the uniformity of the deflecting field on beam invariant



Hard disk drive write head technology for use in a damping ring extraction kicker?

We always think about spatially fixed devices and moveable beams.

BUT could one build an extraction kicker that was a sort of hard disk write head on steroids?

Hard disk write head (from discussions with Hitachi):

- 1 T field strength
- field direction can be changed at 1 GHz (soon 2 GHz)
- field volume is small, ~120 μm^3 including flux return
- head positioning is accurate to a few nm

Extraction kicker needs 1 T·cm field integral. Can HDD head be scaled up?

Probably not: requires too much power!

Physics Illinois

George Gollin, *LCWS07, DESY May 31, 2007* 12

Low-Emittance Tuning: Kiyoshi Kubo

For lower emittance

We did some improvements to achieve ~5 pm emittance.

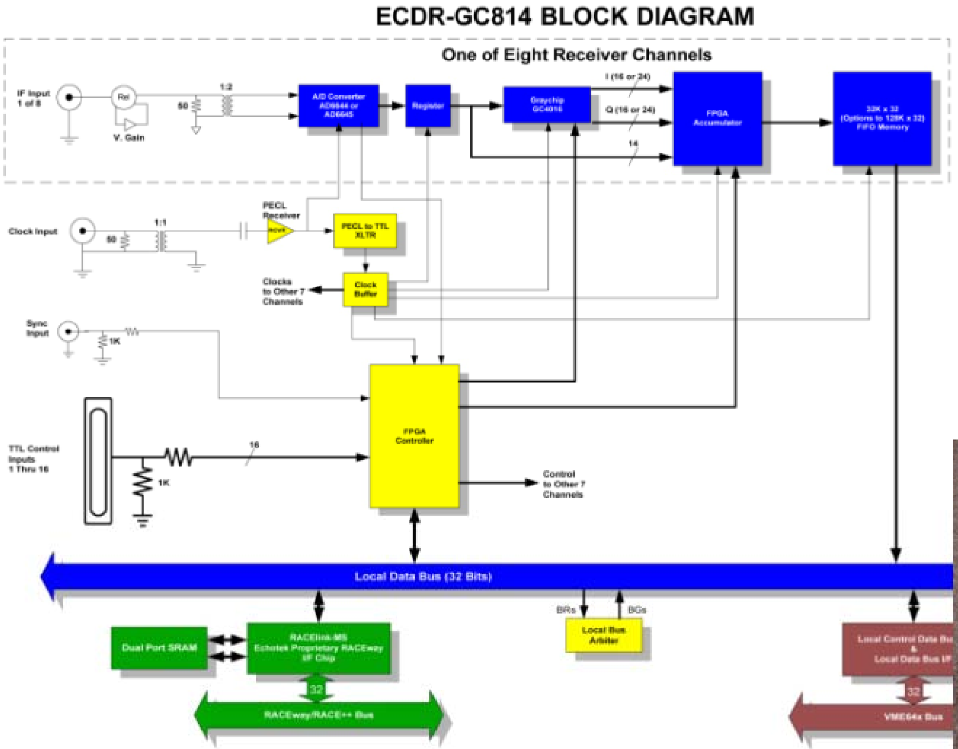
- Reduction of BPM offset error wrt. nearest magnet
- Reduction of optics error (magnet strength error)

Now, we need more improvement for ~2 pm.

- Further reduction of BPM offset error will be the first priority.
- New BPM electronics, is being tested.
- Better resolution and stability. Then,
  - Reduce BPM offset error w.r.t. magnets from improved data for Beam Based Alignment.
  - Reduce optics error from improved response matrix data
- Better BBA has been demonstrated for a few (? one) quadrupole magnet- BPM pairs, recently.
- But,detailed simulations of BBA and Optics Test have not done yet.

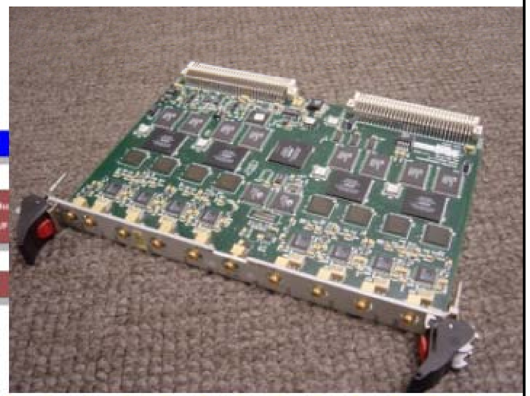
Instrumentation: Manfred Wendt

Digital Signal Processing



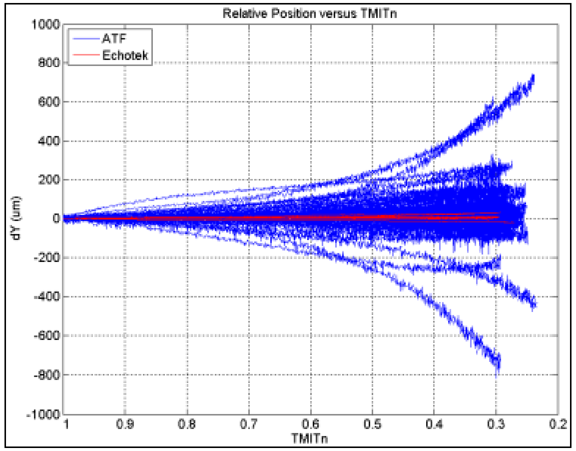
***Echotek* digital receiver:**

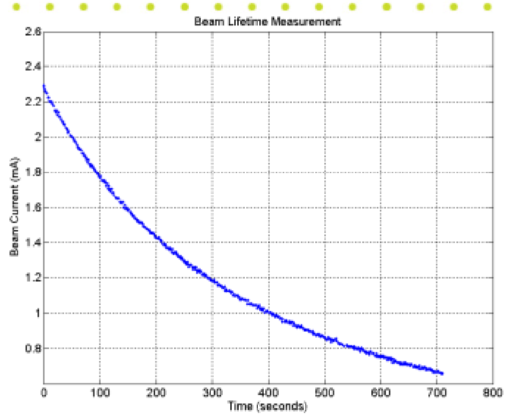
- 8-ch VME 64x module
- *Analog Devices* 14-bit 105 MS/s AD6645
- Each channel: *Texas Instruments* 4-ch GC4016 “Graychip” digital downconverter



Instrumentation: Manfred Wendt

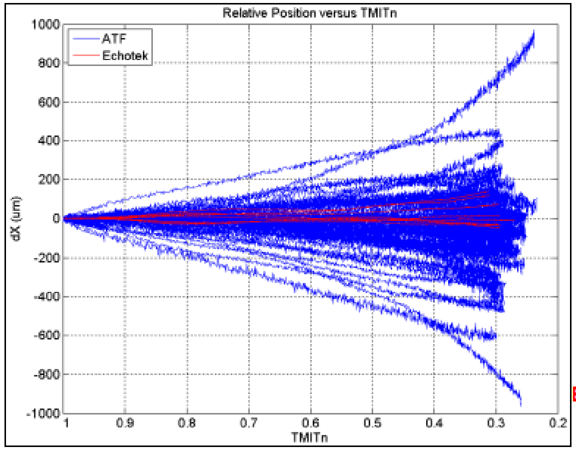
First Results (February 2006)

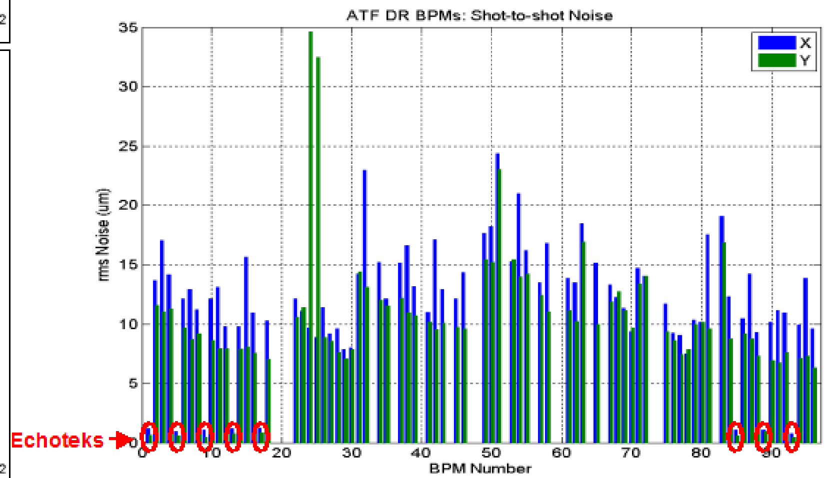




Accomplishments:

- Improved observed resolution (~10 -> ~1 μm)
- Reduced intensity dependence





Cornell Program: Mark Palmer

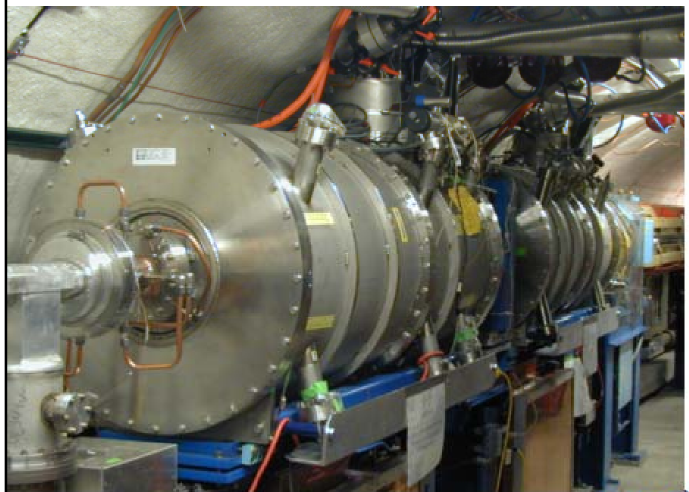
Outline

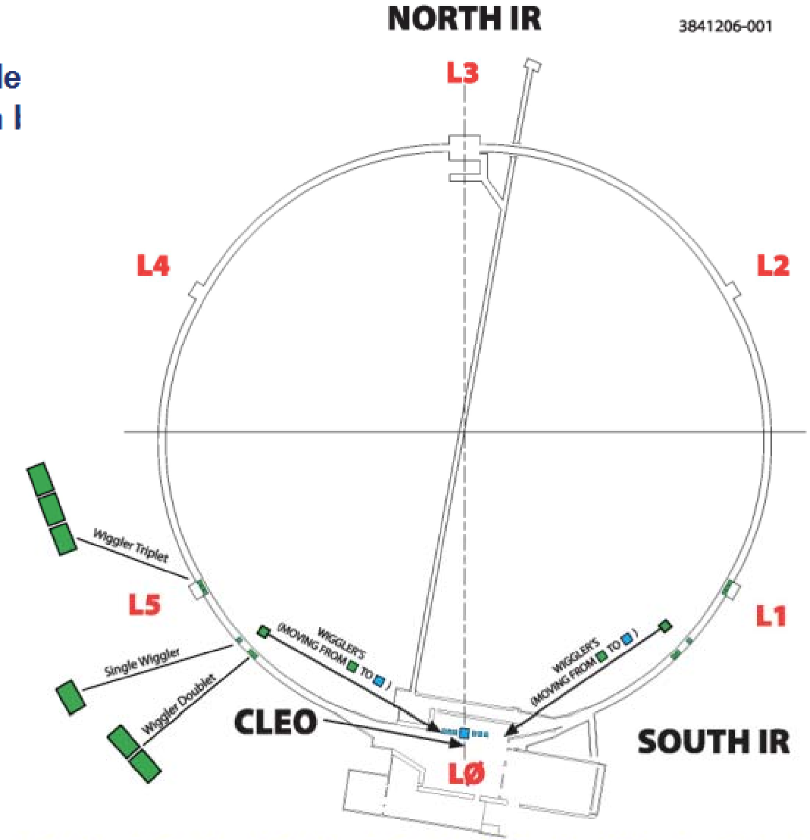
- Overview of the Cornell Program
  - **Recent efforts**
  - **Goals for EDR phase**
- Review Highlights of Recent Activities
  - **Wiggler optimization**
  - **Bypass line options to relax kicker requirements**
  - **Electron cloud studies**
  - **CesrTA design and planning**
  - **Diagnostics development**
- Conclusion

CesrTA: Mark Palmer

CESR Modifications

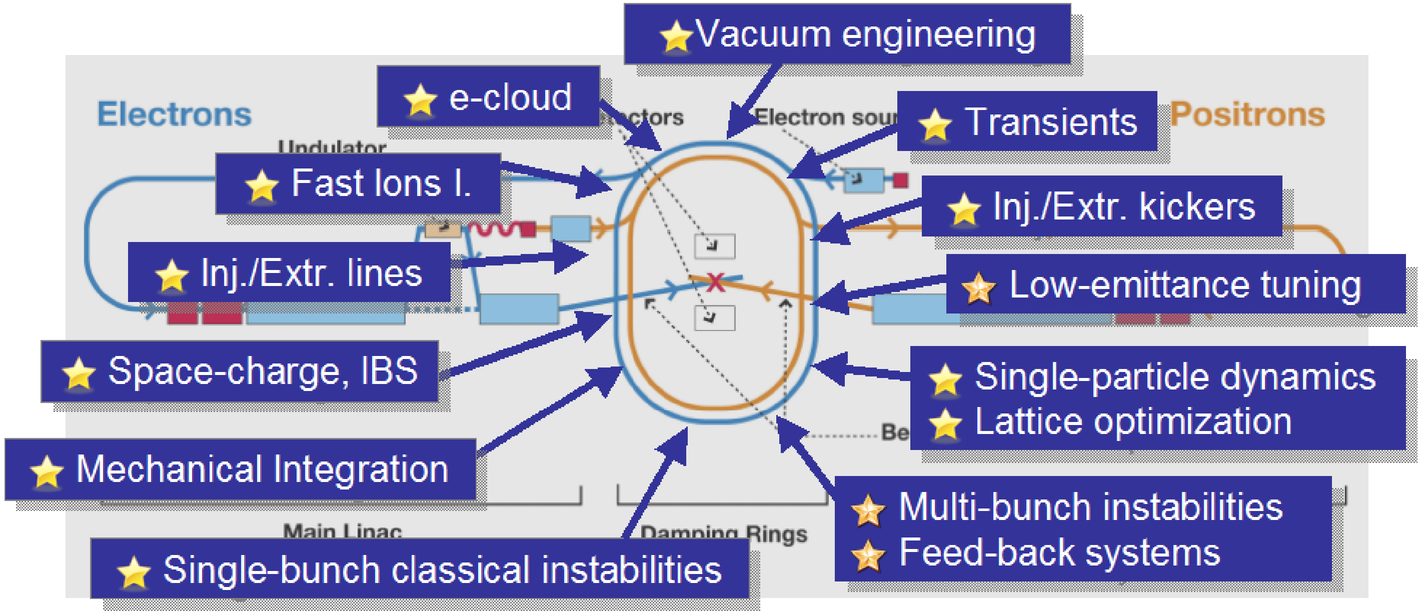
- Move 6 wigglers from the CESR arcs to the South IR (zero dispersion region)
  - **Cryogenics support available**
  - **Zero dispersion regions can l created locally around the wigglers left in the arcs**
- Make North IR available for insertion devices and instrumentation
- Instrumentation and feedback upgrades





LBNL Program: Mike Zisman

Overview of Activities



Other ILC activities

- Leadership/coordination within DR community
- Involvement in ILC-related R&D at other facilities (PEP-II/SLAC, ATF/KEK, CESR/Cornell)
- Generic development of diagnostics, instrumentation

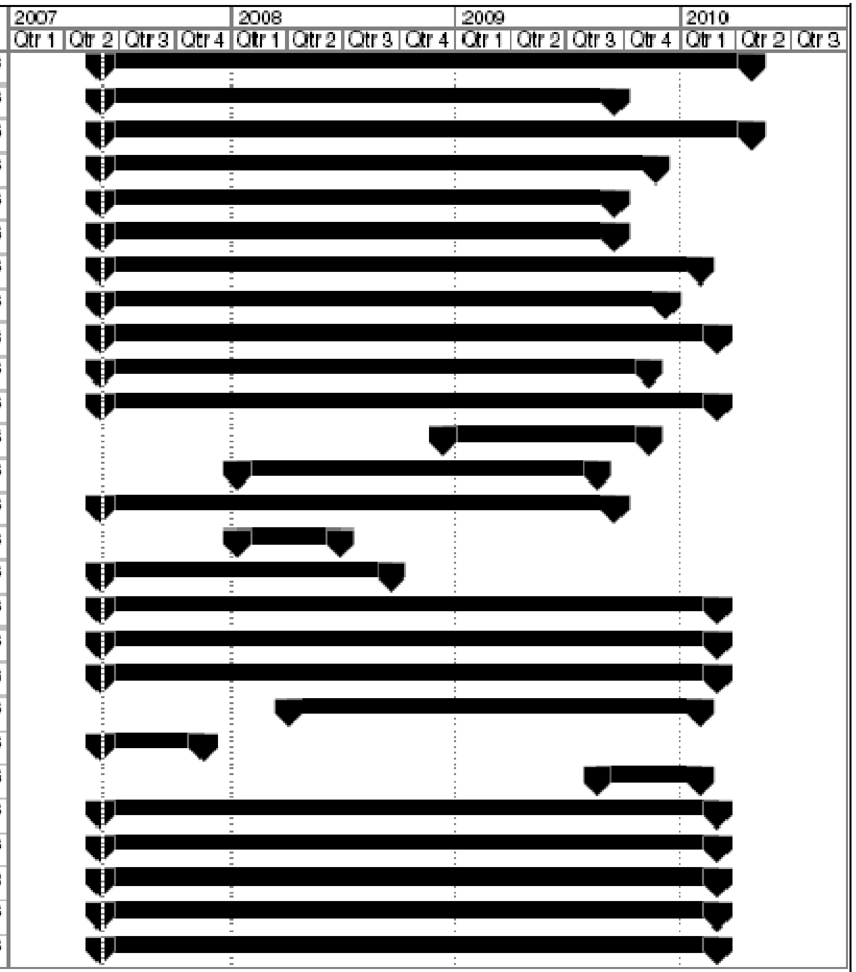
May 31, 2007-Hamburg (Zisman) Global Design Effort 3

Tentatively suggested Work Packages

- Lattice design
- Impedance and impedance-driven instabilities
- Electron cloud
- Ion effects
- Acceptance
- Orbit, optics and coupling correction
- Vacuum system
- Magnets and magnet supports
- Power systems
- 650 MHz RF system
- Injection and extraction systems
- Fast feedback systems
- Abort systems
- Instrumentation and diagnostics
- Systems integration
- ATF
- CesrTA…

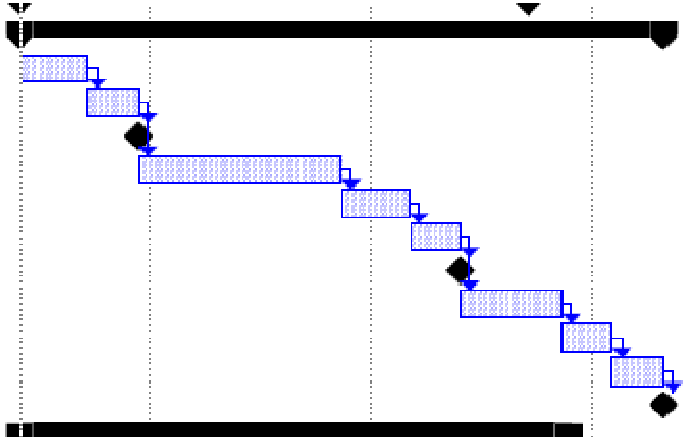
Planning the Engineering Design Phase

ID	Task Name	Duration
1	Optics and beam dynamics	760 days
2	Lattice design	600 days
14	Impedance and impedance-driven instabilities	760 days
26	Electron cloud	648 days
39	Ion effects	600 days
41	Other collective effects	600 days
47	Acceptance	700 days
58	Orbit, optics and coupling correction	660 days
69	Technical subsystems	720 days
70	Vacuum system	640 days
80	Magnets and supports	720 days
96	Power systems	240 days
100	650 MHz RF system	420 days
107	Injection and extraction systems	600 days
112	Fast feedback systems	120 days
117	Abort systems hardware	340 days
122	Instrumentation and diagnostics	720 days
124	Systems integration	720 days
126	Global(?) systems	720 days
127	Conventional facilities	480 days
131	Control systems	120 days
134	Cryogenics systems	120 days
137	Survey and alignment	720 days
139	Commissioning plan	720 days
141	Test facilities	720 days
142	ATF	720 days
146	CesrTA	720 days



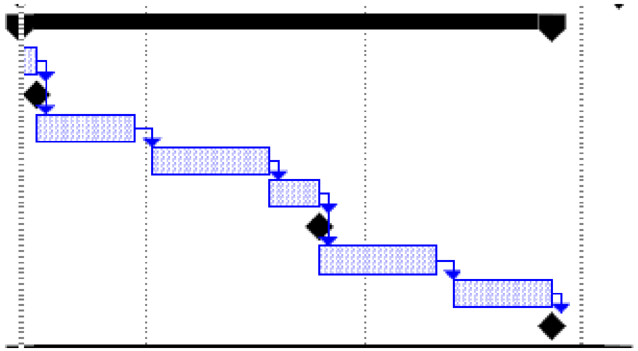
Work Package: Impedance

14	**Impedance and impedance-driven instabilities**	760 days
15	Construct impedance model from scaled component designs	4 mons
16	Model instabilities using preliminary impedance model	3 mons
17	Make instability estimates based on preliminary impedance model	0 days
18	Refine and improve impedance models and instability calculations	12 mons
19	Construct impedance model using real technical designs	4 mons
20	Understand impact of single-bunch and coupled-bunch instabilities, and injection/ext	3 mons
21	Specify improvements to lattice and vacuum designs	0 days
22	Refine and improve impedance models and instability calculations	6 mons
23	Finalise impedance model	3 mons
24	Characterise instabilities using detailed impedance model	3 mons
25	Predict instability characteristics and thresholds	0 days
26	**Electron cloud**	648 days



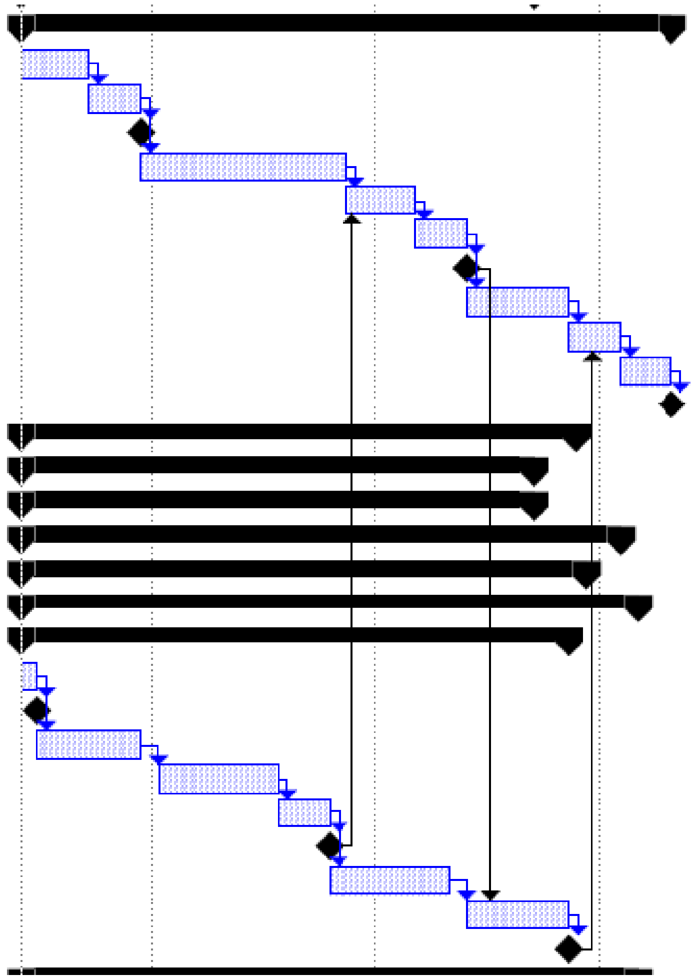
Work Package: Vacuum

70	**Vacuum system**	640 days
71	Preliminary vacuum system specifications	1 mon
72	Set baseline specifications for vacuum system (subject to ecloud studies)	0 days
73	Prepare initial technical designs of vacuum system components	6 mons
74	Develop initial technical designs of vacuum system components	7 mons
75	Finalise technical designs of vacuum system components	3 mons
76	Technical designs of vacuum system components	0 days
77	Optimise vacuum system for cost and technical performance	7 mons
78	Make essential modifications to technical designs of vacuum system components	6 mons
79	Vacuum system technical design finalised, documented and costed	0 days



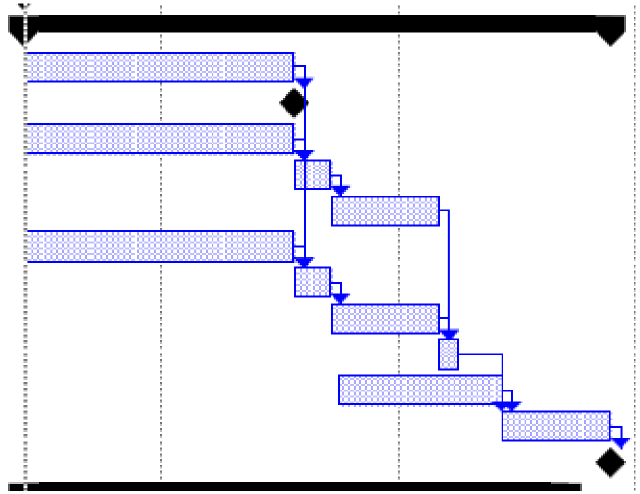
“Critical Information Exchange” example 1

14	**Impedance and impedance-driven instabilities**	760 days
15	Construct impedance model from scaled component designs	4 mons
16	Model instabilities using preliminary impedance model	3 mons
17	Make instability estimates based on preliminary impedance model	0 days
18	Refine and improve impedance models and instability calculations	12 mons
19	Construct impedance model using real technical designs	4 mons
20	Understand impact of single-bunch and coupled-bunch instabilities, and injection/ext	3 mons
21	Specify improvements to lattice and vacuum designs	0 days
22	Refine and improve impedance models and instability calculations	6 mons
23	Finalise impedance model	3 mons
24	Characterise instabilities using detailed impedance model	3 mons
25	Predict instability characteristics and thresholds	0 days
26	**Electron cloud**	648 days
39	**Ion effects**	600 days
41	**Other collective effects**	600 days
47	**Acceptance**	700 days
58	**Orbit, optics and coupling correction**	660 days
69	**Technical subsystems**	720 days
70	**Vacuum system**	640 days
71	Preliminary vacuum system specifications	1 mon
72	Set baseline specifications for vacuum system (subject to ecloud studies)	0 days
73	Prepare initial technical designs of vacuum system components	6 mons
74	Develop initial technical designs of vacuum system components	7 mons
75	Finalise technical designs of vacuum system components	3 mons
76	Technical designs of vacuum system components	0 days
77	Optimise vacuum system for cost and technical performance	7 mons
78	Make essential modifications to technical designs of vacuum system components	6 mons
79	Vacuum system technical design finalised, documented and costed	0 days



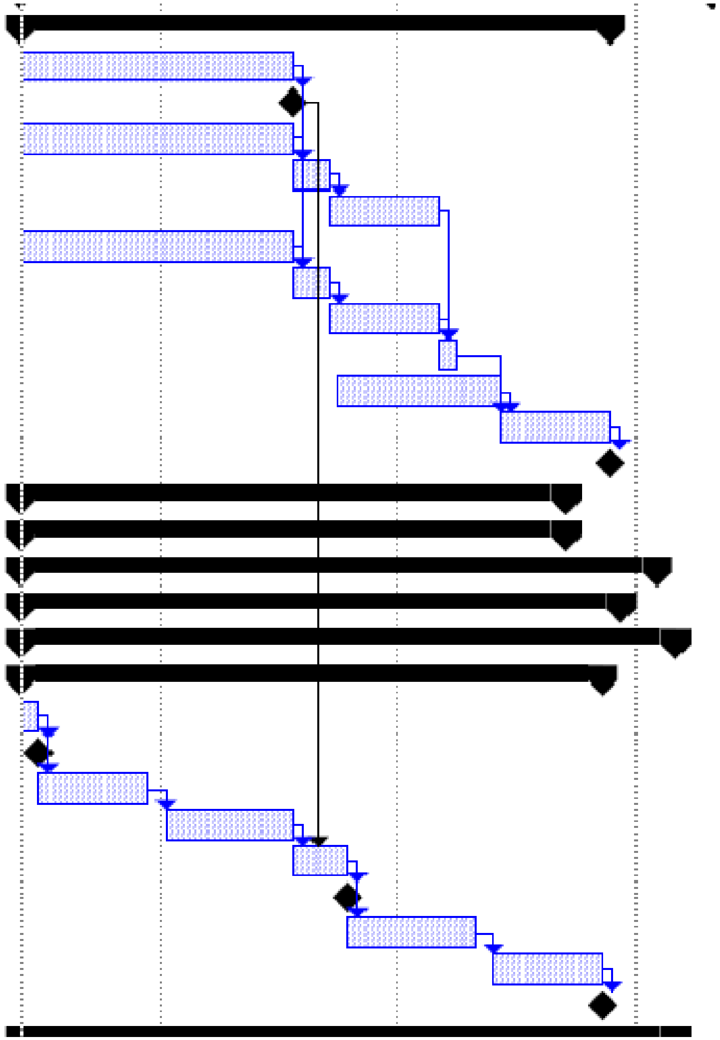
Work Package: Electron Cloud

26	**Electron cloud**	648 days
27	Evaluate electron cloud mitigation techniques	15 mons
28	Specify baseline ecloud mitigation techniques	0 days
29	Start construction of test dipole chamber	15 mons
30	Finalise construction of test dipole chamber	2 mons
31	Test ecloud mitigation techniques in dipole chamber	6 mons
32	Start construction of test wiggler chamber	15 mons
33	Finalise construction of test wiggler chamber	2 mons
34	Test ecloud mitigation techniques in wiggler chamber	6 mons
35	Model ecloud build-up with baseline mitigation techniques	1 mon
36	Benchmark electron cloud instability codes	9 mons
37	Model electron cloud instabilities	6 mons
38	Validate design for ecloud mitigation, and predict ecloud instability safety margins	0 days
39	**Ion effects**	600 days



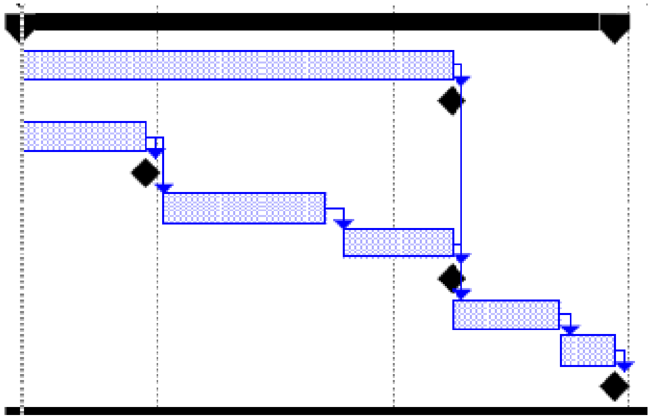
“Critical Information Exchange” example 2

26	**Electron cloud**	648 days
27	Evaluate electron cloud mitigation techniques	15 mons
28	Specify baseline ecloud mitigation techniques	0 days
29	Start construction of test dipole chamber	15 mons
30	Finalise construction of test dipole chamber	2 mons
31	Test ecloud mitigation techniques in dipole chamber	6 mons
32	Start construction of test wiggler chamber	15 mons
33	Finalise construction of test wiggler chamber	2 mons
34	Test ecloud mitigation techniques in wiggler chamber	6 mons
35	Model ecloud build-up with baseline mitigation techniques	1 mon
36	Benchmark electron cloud instability codes	9 mons
37	Model electron cloud instabilities	6 mons
38	Validate design for ecloud mitigation, and predict ecloud instability safety margins	0 days
39	**Ion effects**	600 days
41	**Other collective effects**	600 days
47	**Acceptance**	700 days
58	**Orbit, optics and coupling correction**	660 days
69	**Technical subsystems**	720 days
70	**Vacuum system**	640 days
71	Preliminary vacuum system specifications	1 mon
72	Set baseline specifications for vacuum system (subject to ecloud studies)	0 days
73	Prepare initial technical designs of vacuum system components	6 mons
74	Develop initial technical designs of vacuum system components	7 mons
75	Finalise technical designs of vacuum system components	3 mons
76	Technical designs of vacuum system components	0 days
77	Optimise vacuum system for cost and technical performance	7 mons
78	Make essential modifications to technical designs of vacuum system components	6 mons
79	Vacuum system technical design finalised, documented and costed	0 days
80	**Magnets and supports**	720 days



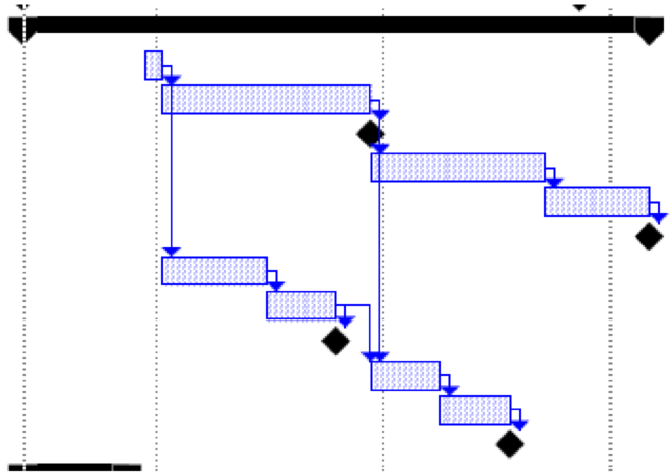
Work Package: Coupling Correction

58	**Orbit, optics and coupling correction**	660 days
59	Experimental studies of orbit and coupling correction	24 mons
60	Demonstrate 2 pm vertical emittance	0 days
61	Make initial estimates of alignment sensitivities in baseline lattice	7 mons
62	Initial estimates of alignment sensitivities	0 days
63	Specify and evaluate possible orbit and coupling correction schemes	9 mons
64	Evaluate impact of ground vibration and long-term motion	6 mons
65	Initial estimate of impact of ground vibration and long-term motion	0 days
66	Optimise orbit and coupling correction scheme	6 mons
67	Finalise orbit and coupling correction scheme	3 mons
68	Correction systems documented and costed	0 days



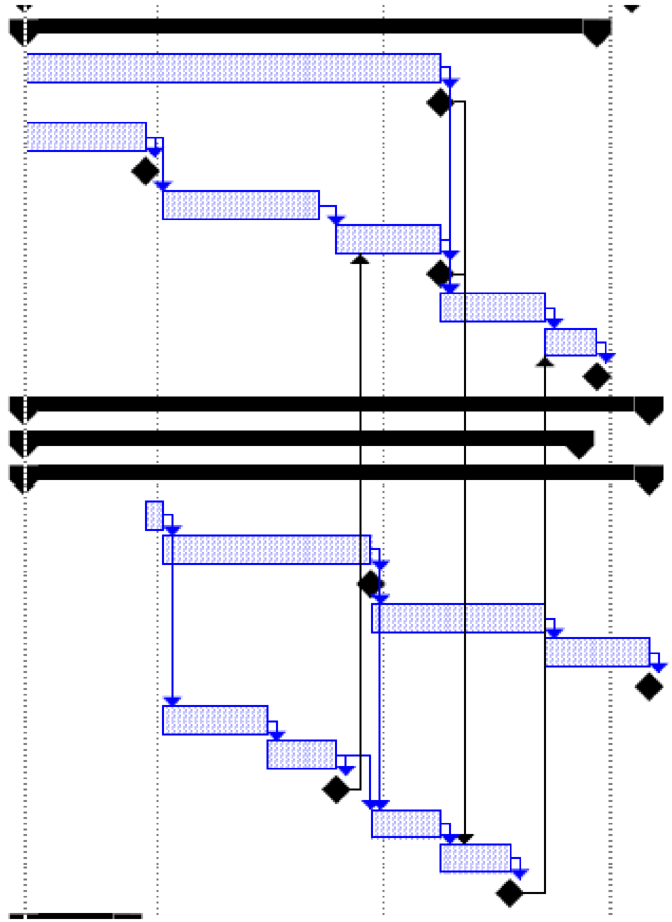
Work Package: Magnets and Supports

80	**Magnets and supports**	720 days
81	Specify magnets	1 mon
82	Develop technical designs for main magnets	12 mons
83	Technical designs for main magnets	0 days
84	Optimise magnet designs for cost and performance	10 mons
85	Finalise designs of main magnets	6 mons
86	Magnet designs documented and costed	0 days
87	Develop technical designs for magnet supports	6 mons
88	Model magnet supports response to vibration and long-term stability	4 mons
89	Characterisation of magnet supports response to vibration and long-term stability	0 days
90	Optimisation of design of magnet supports	4 mons
91	Finalise design of magnet supports	4 mons
92	Magnet supports documented and costed	0 days



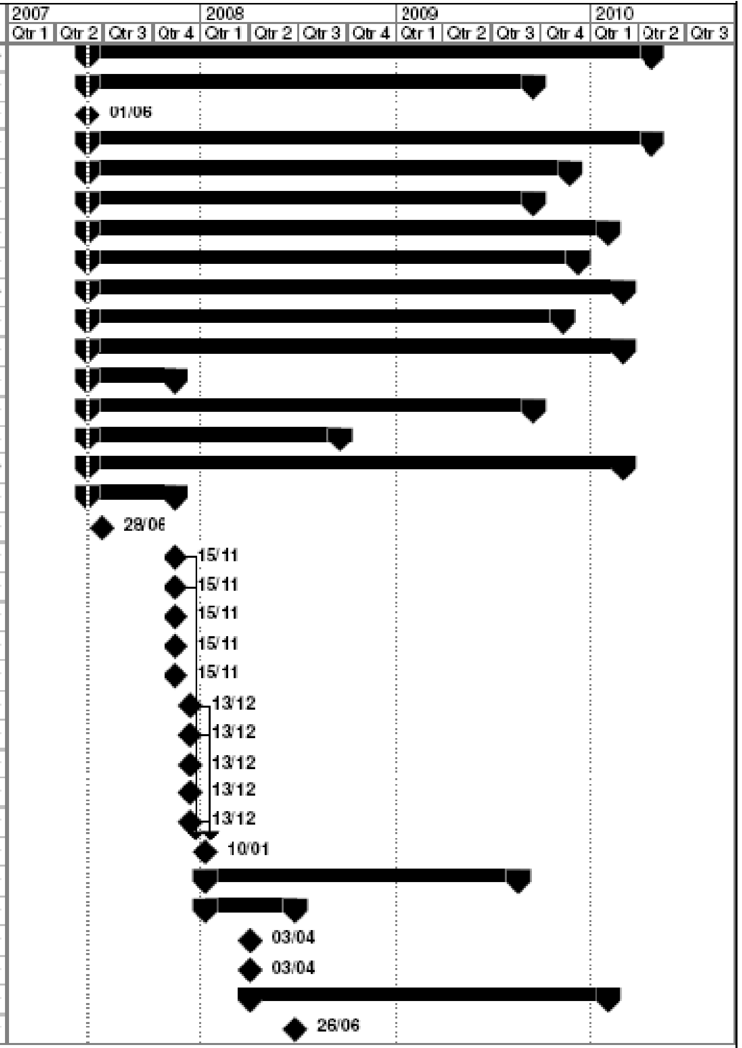
“Critical Information Exchange” example 3

58	**Orbit, optics and coupling correction**	660 days
59	Experimental studies of orbit and coupling correction	24 mons
60	Demonstrate 2 pm vertical emittance	0 days
61	Make initial estimates of alignment sensitivities in baseline lattice	7 mons
62	Initial estimates of alignment sensitivities	0 days
63	Specify and evaluate possible orbit and coupling correction schemes	9 mons
64	Evaluate impact of ground vibration and long-term motion	6 mons
65	Initial estimate of impact of ground vibration and long-term motion	0 days
66	Optimise orbit and coupling correction scheme	6 mons
67	Finalise orbit and coupling correction scheme	3 mons
68	Correction systems documented and costed	0 days
69	**Technical subsystems**	**720 days**
70	**Vacuum system**	640 days
80	**Magnets and supports**	720 days
81	Specify magnets	1 mon
82	Develop technical designs for main magnets	12 mons
83	Technical designs for main magnets	0 days
84	Optimise magnet designs for cost and performance	10 mons
85	Finalise designs of main magnets	6 mons
86	Magnet designs documented and costed	0 days
87	Develop technical designs for magnet supports	6 mons
88	Model magnet supports response to vibration and long-term stability	4 mons
89	Characterisation of magnet supports response to vibration and long-term stability	0 days
90	Optimisation of design of magnet supports	4 mons
91	Finalise design of magnet supports	4 mons
92	Magnet supports documented and costed	0 days



Milestones…

ID	Task Name	Duration
1	Optics and beam dynamics	760 days
2	Lattice design	600 days
3	Set lattice specifications	0 days
15	Impedance and impedance-driven instabilities	760 days
27	Electron cloud	648 days
42	Other collective effects	600 days
48	Acceptance	700 days
59	Orbit, optics and coupling correction	660 days
70	Technical subsystems	720 days
71	Vacuum system	640 days
81	Magnets and supports	720 days
94	Wiggler	120 days
108	Injection and extraction systems	600 days
118	Abort systems hardware	340 days
127	Global(?) systems	720 days
132	Control systems	120 days
73	Set baseline specifications for vacuum system (subject to ecloud studies)	0 days
45	Initial estimates of intrabeam scattering	0 days
47	Initial estimates of Touschek lifetime	0 days
96	Wiggler design documented and costed	0 days
120	Technical design for abort dumpt	0 days
134	Control systems documented and costed	0 days
18	Make instability estimates based on preliminary impedance model	0 days
50	Preliminary estimates of dynamic aperture	0 days
51	Specify magnet field quality	0 days
52	Specify physical apertures	0 days
63	Initial estimates of alignment sensitivities	0 days
5	Select and "freeze" baseline lattice design	0 days
101	650 MHz RF system	420 days
113	Fast feedback systems	120 days
7	"Freeze" baseline design of injection/extraction lines	0 days
9	"Freeze" baseline design of abort line	0 days
128	Conventional facilities	480 days
115	Longitudinal fast feedback systems documented and costed	0 days



Page 1

Milestones… (continued)

ID	Task Name	Duration	
117	Transverse fast feedback systems documented and costed	0 days	26/06
29	Specify baseline ecloud mitigation techniques	0 days	24/07
122	Abort systems documented and costed	0 days	18/09
77	Technical designs of vacuum system components	0 days	16/10
90	Characterisation of magnet supports response to vibration and long-term stability	0 days	16/10
104	Technical design of RF cavities	0 days	13/11
84	Technical designs for main magnets	0 days	11/12
97	Power systems	240 days	
55	Understand acceptance limitations using technical designs of magnets	0 days	05/03
61	Demonstrate 2 pm vertical emittance	0 days	02/04
66	Initial estimate of impact of ground vibration and long-term motion	0 days	02/04
22	Specify improvements to lattice and vacuum designs	0 days	28/05
93	Magnet supports documented and costed	0 days	23/07
107	RF system documentation and costing	0 days	20/08
135	Cryogenics systems	120 days	
14	Lattice designs finalised and documented	0 days	17/09
111	Demonstrate injection and extraction system performance	0 days	17/09
112	Complete costing and documentation for injection and extraction systems	0 days	17/09
80	Vacuum system technical design finalised, documented and costed	0 days	12/11
100	Power systems documented and costed	0 days	12/11
39	Validate design for ecloud mitigation, and predict ecloud instability safety margins	0 days	24/11
69	Correction systems documented and costed	0 days	10/12
58	Confirm acceptance margin on injected beam	0 days	04/02
131	Conventional facilities documented and costed	0 days	04/02
137	Cryogenics systems documented and costed	0 days	04/02
87	Magnet designs documented and costed	0 days	04/03
26	Predict instability characteristics and thresholds	0 days	29/04

How to define a Work Package?

The plan has evolved from an original version that was clearly unmanageable, to one that "feels" manageable.

The characteristics that make it feel manageable are:

1. **Each Work Package contains one or more (fairly) continuous activities (though not necessarily at a constant level of effort).**
2. **The number of parallel activities within each Work Package is minimised; ideally, there is only one activity going on within each Work Package at any given time.**
3. **The number of points of "Critical Information Exchange" is minimised.**

Note: there is no explicit distinction made between activities on different points of the scale from basic R&D (e.g. electron cloud mitigation) to design of relatively-straightforward components (e.g. quadrupoles).

Next Steps

- Complete the list of Tasks and Milestones, filling in all the dependencies and connections.

- Match the Resources to the Work Packages.
  - **This will provide a reality check.**
  - **Information on Damping Rings resources and activities has recently been updated: we have (most of) the information that we need.**

- Meanwhile: discuss all this with the EDR Task Force…