Damping Ring

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AD&I meeting

May 28-29, 2009

Damping Ring Questions

1. **How many bunches?**

Number of bunches and Circumference

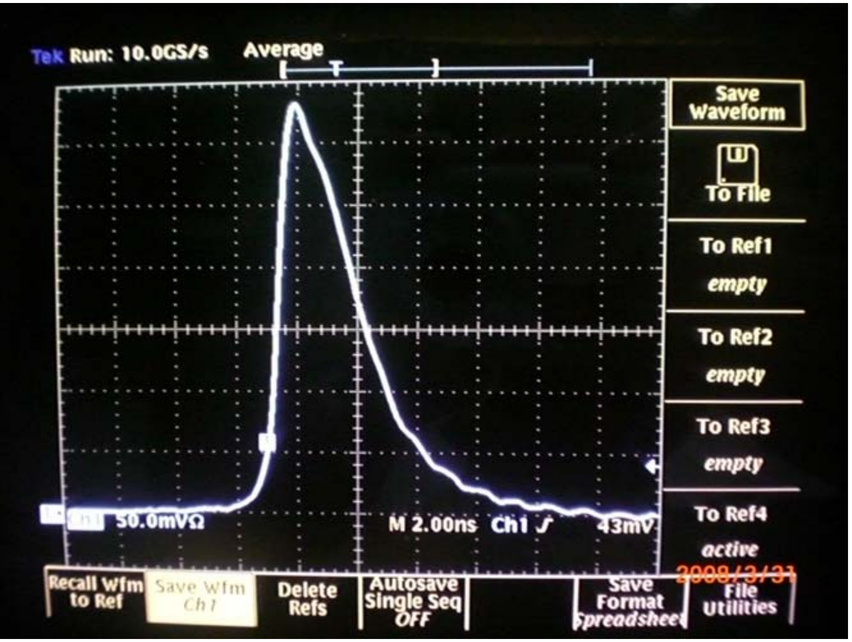
	RDR 2007	TDP TILC08	SB2009	
# of bunches	2684-5412	2610-5265		
Bunch population	$2\text{-}1 \cdot 10^{10}$	$2\text{-}1 \cdot 10^{10}$		
Bunch distance (ns)	6.2-3.1	6.2-3.1		
C (m)	6695	6476		
h	14516	14042		
Kicker frep MHz (1ms linac pulse)	2.8-5.5	2.7-5.4		

Which bunch distance?

e+ Injection kickers

	RDR	
Bunch dist (ns)	3	6
Stripline length (cm)	30	60
Stripline voltage (KV)	± 5	± 5
# of e+ injection striplines	20	10
Kicker frep MHz (1ms linac beam pulse)	5.5	2.8

Pulse source(FID FPG 10-6000KN)



Specification

Maximum output voltage + 10 kV
- 10 kV

Rise time @ 10-90% level - < 1 ns

Rise time @ 5-95% level - < 1,2 ns

Pulse duration @ 90% - 0,2-0,3 ns

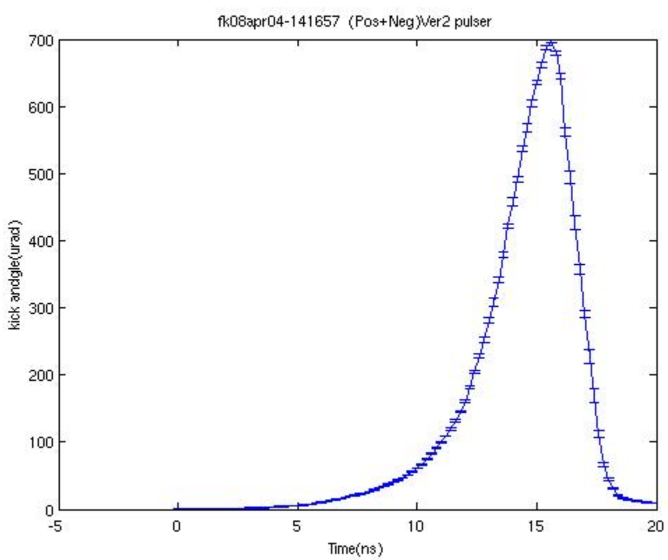
Pulse duration @ 50% - 1,5-2 ns

Output pulse amplitude stability - 0,5-0,7%

Maximum PRF in burst - 6,5 MHz

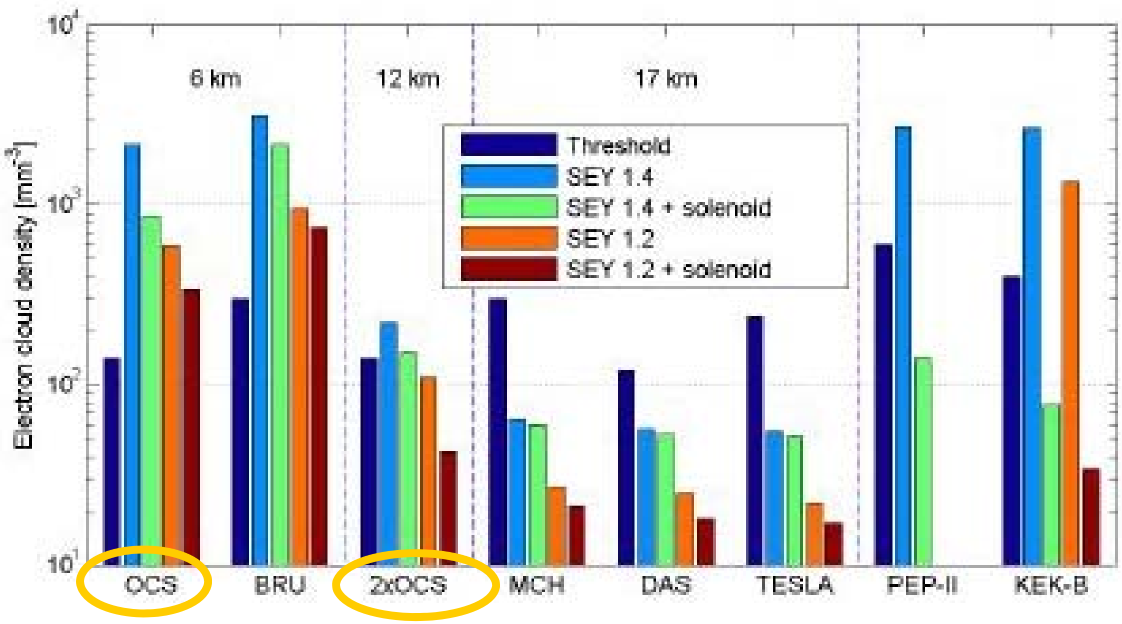
Number of pulses in burst - up to 110

PRF of bursts - up to 5 Hz



Beam kick profile from the beam oscillation amplitude

Bunch distance and e-cloud



OCS 6 ns

2xOCS 12 ns

2 10^{10} part./bunch

Figure 3.94: Electron cloud densities in the reference lattices and the B-Factories, compared with the estimated instability thresholds.

Increasing the bunch spacing (OCS and 2xOCS) strongly reduces the e-cloud density (Configuration recommendation Feb. 2006)

At present a 3.1ns bunch distance seems feasible with proper choice of mitigation techniques

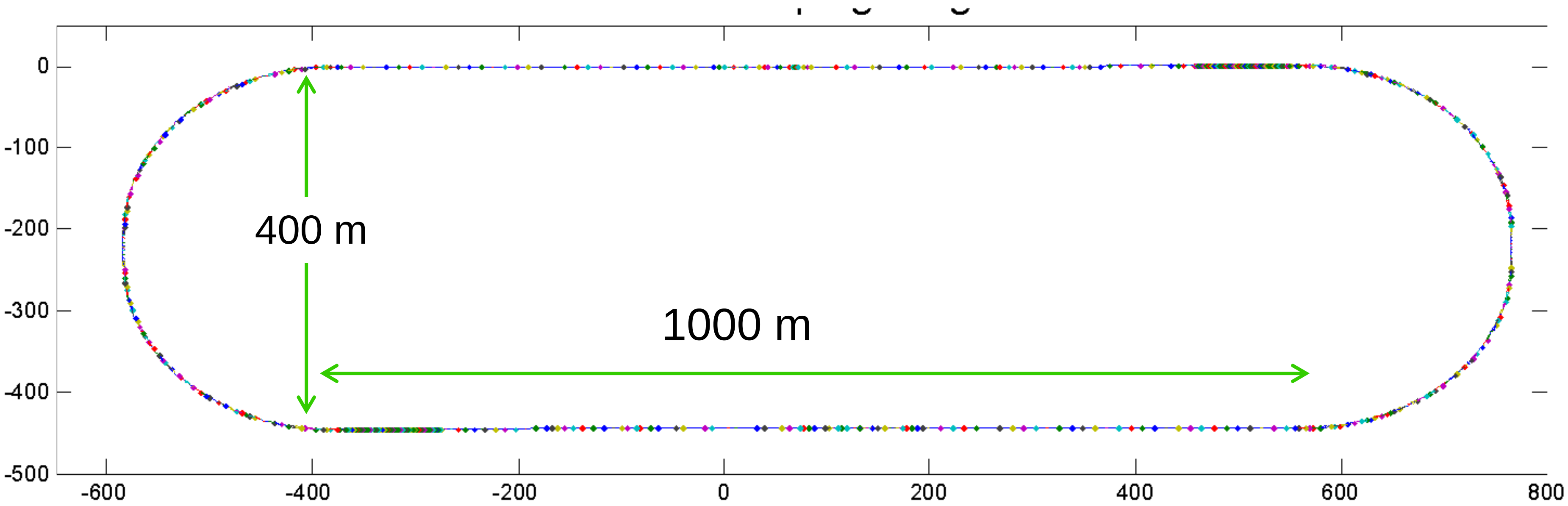
Number of bunches and Circumference

	RDR 2007	TDP TILC08	SB2009	?
# of bunches	2684-5412	2610-5265	1305-2632	**1300**
Bunch population	$2\text{-}1 \cdot 10^{10}$	$2\text{-}1 \cdot 10^{10}$	$2\text{-}1 \cdot 10^{10}$	$2 \cdot 10^{10}$
Bunch distance (ns)	6.2-3.1	6.2-3.1	6.2-3.1	3.1
C (m)	6695	6476	3238	**1600**
h	14516	14042	7021	3500
Kicker frep MHz (1ms linac pulse)	2.8-5.5	2.7-5.4	1.4-2.7	1.4

Number of bunches and Circumference

- For 1300 bunches one could design a very short ring, as the SuperB one (~1600 m) **without wigglers**
- Wigglers give the main contribution the e-cloud density
- Cost would be reduced by ~1/4

Minimum Machine: New 3 Km layout

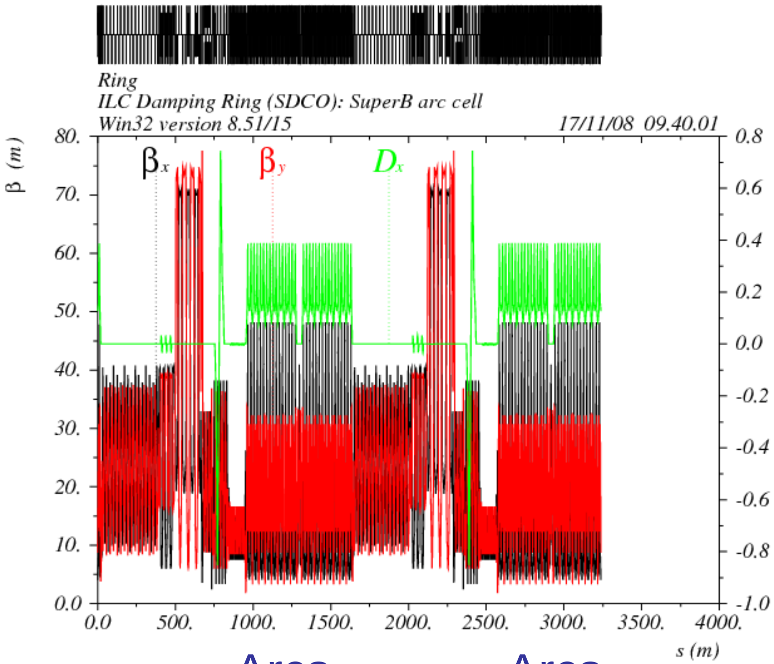


Arcs based on SuperB-like cells

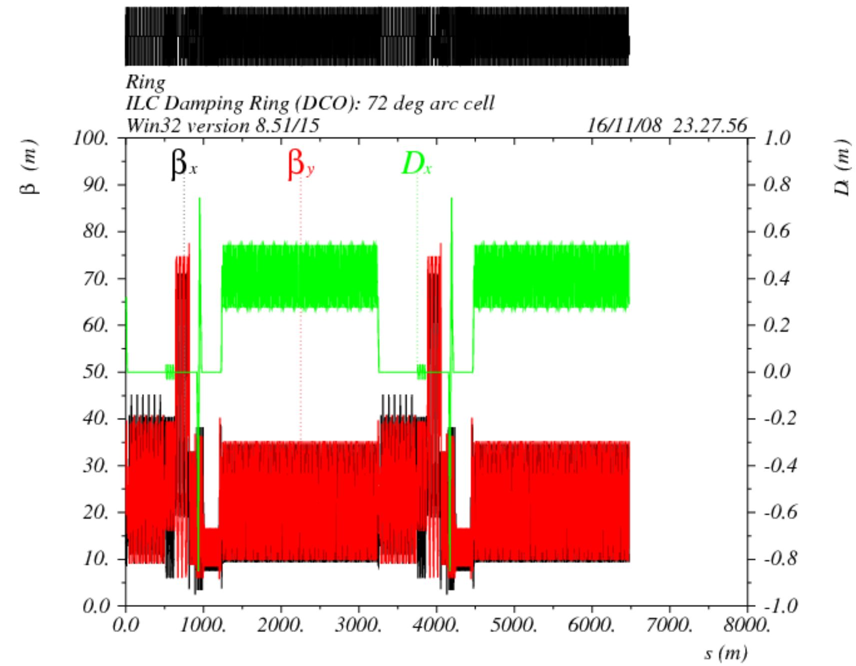
Same straight sections as the 6 km ring

Cost estimate for TDP-2: straight sections scale directly from the 6 km ring, for the arcs use information from the SuperB TDR

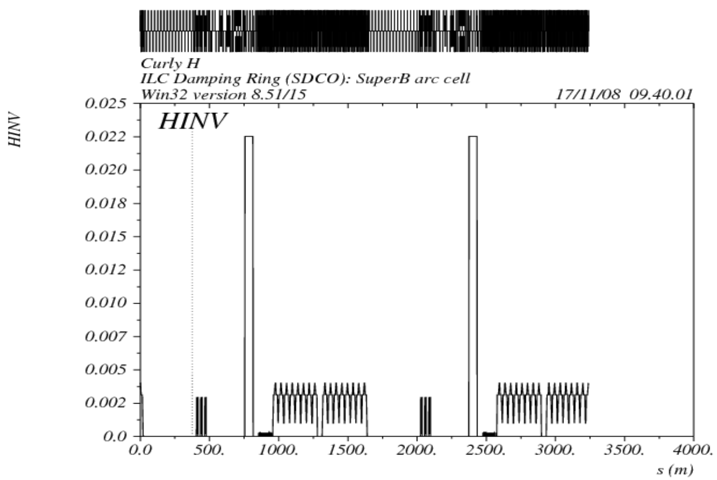
Ring



Arcs Arcs



Original, 6Km

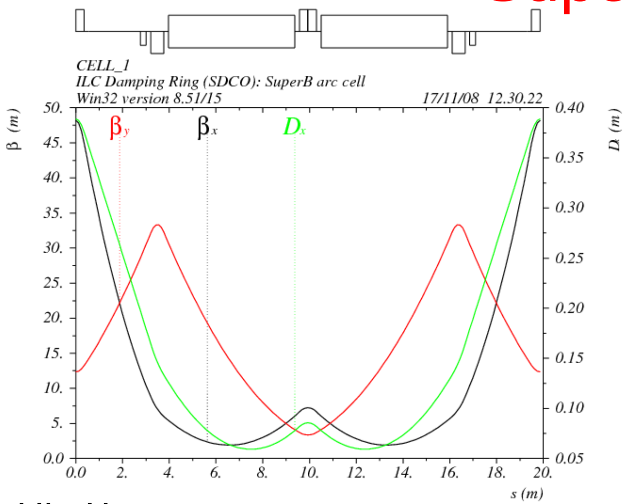


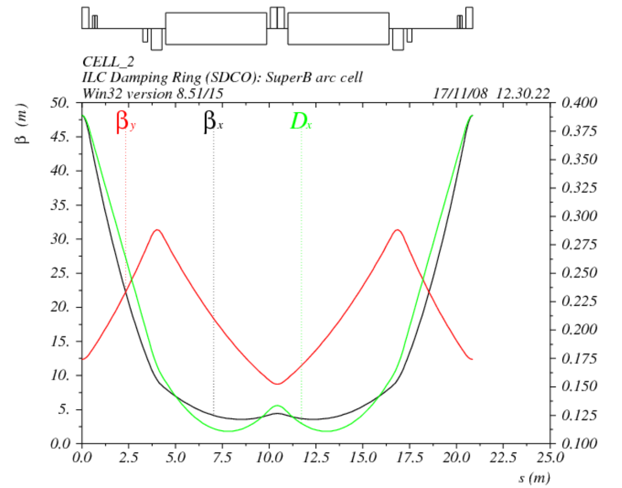
Curly H

Features

- Arcs contain alternating cells with different phase advances:
  - cell #1: L=20 m, $\mu_x = 0.72$, $\mu_y = 0.27$
  - cell #2: L=21 m, $\mu_x = 0.5$, $\mu_y = 0.2$
- Emittance can be tuned by changing the x-phase advance/cell in cell#1
- Same is true for momentum compaction

SuperB-like cells

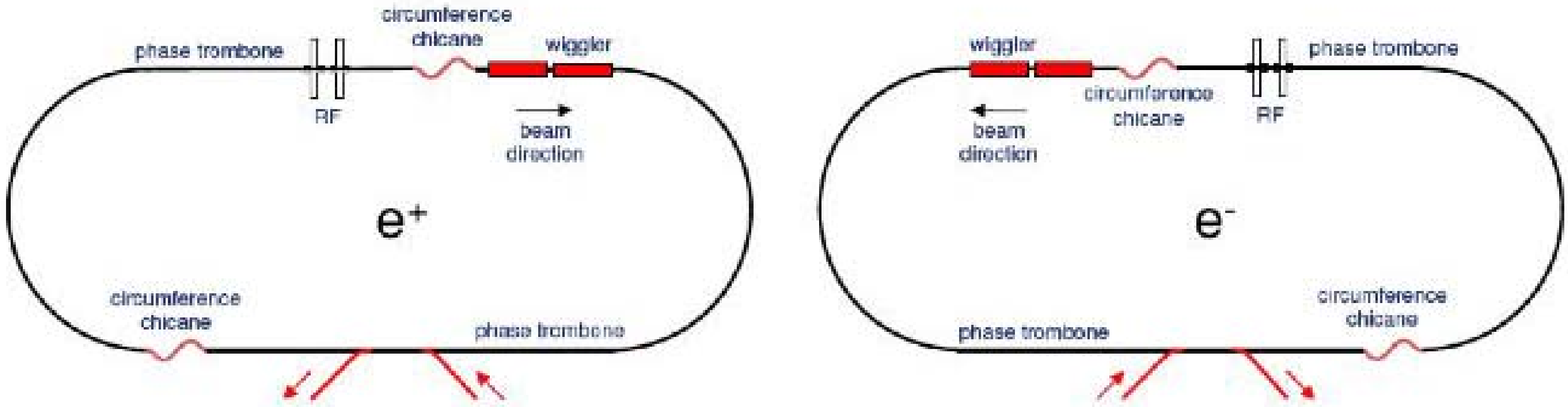




Lattice and Dynamic Aperture optimization in progress

Lattice Design at CI (6 km)

(apply also to 3 km)



Modifications have been made to the straight sections according to the requirements for the central injector integration scheme proposed for the "Minimum Machine":

Injection and extraction are now in a single straight in each ring

Beams circulate in opposite directions in the two rings

A. Wolski, ILC DR Webex, 4 March 09

What changes with the number of bunches

Assuming:

- Same bunch distance
- Same charge/bunch
- Same damping time

} same current

What changes with the number of bunches

	EDR	SB2009
	DCO	DSB
Energy (GeV)	5	5
Circumference (m)	6476	3238
Bunch number	2610 - 5265	2610 - 1305
N particles/bunch	2x10e10	2x10e10
Damping time tx (ms)	21	21
Emittance ex (nm)	0.48	0.37
Emittance ey (pm)	2.0	2.0
Momentum compaction	1.7x10-4	1.8x10-4
Energy loss/turn (MeV)	10.3	5.3
Energy spread	0.0013	0.0013
Bunch length (mm)	6	6
RF Voltage (MV)	21	11
RF frequency (MHz)	650	650
B wiggler (T)	1,6	1,6
Lwig total	215,6	107,8
Number of wigglers	88	44

Half circumference

Half RF cavities

Half wigglers

Magnet counts

	DSB (3km)	DCO (6km)
Arc dipole length	5.4 m	2.0 m
Arc dipole field (2 types)	0.178/0.243 T	0.273 T
Number of arc dipoles	128	192
Number of 2 m dipoles	4	8
Number of 1 m dipoles (in chicanes)	36	48
Total number of quadrupoles	502	690
Maximum quadrupole gradient	7.5 T/m	12.0 T/m
Total number of sextupoles	192	384
Maximum sextupole gradient	145 T/m^2	215 T/m^2

Number of magnets reduced by 0.5÷0.7

Half cable lenght

What changes with the number of bunches

- Lattice and DA
  - **Different lattices can fulfill the requirements in both cases**
- LET
  - **Reevaluate for the different lattice**
  - **We expect ~ half bpms and correctors**
- Space charge incoherent tune shift

$$\Delta Q_y \approx \frac{r_e N C}{(2\pi)^{3/2}\sqrt{\gamma\varepsilon_x \gamma\varepsilon_y}\,\sigma_z \gamma^2}$$

~ half

- E-cloud and other instabilities
  - **Depend on bunch distance, peak and average current ~ same results**
- Fast ion
  - **Shorter gaps between trains**
  - **Reconsider the fill patterns**

What changes with the number of bunches

CFS:

- Half tunnel length
- Half space for RF and wigglers
- Same number of shafts (1 for RF and wigglers, 1 for injection/extraction)

Risk analysis

RDR

Concern		RISK	COST	r*C	MITIGATION
(1) Secondary Emission Yield too high. >1.2	Q	High	200	100	Return to two e+ ring design after extensive R&D programs
(2) Vacuum system design not robust		Med	20	5	Redesign vacumm system with more distributed pumping
(3) High impedance of vacuum chamber components		Med	10	3	More engineering design or DR re optimization
(4) RF Margin	Q	Med	50	13	Increase klystron/cavity system by 50%
(5) Combination of concerns with RF and Wiggler layouts	Q	Med	100	25	Increase in number of shafts and alcoves
(6) Plan for having room for future double ring, later decision	Q	Low	20	2	Increase tunnel diameter and include above (5)
(7) General concern with injection/extraction kicker performance		Med	20	5	Increase no of kicker units and/or restrict parameter ranges

Concern	COMMENTS/NOTES	UPDATES	
(1) Secondary Emission Yield too high. >1.2	Assumes CF&S designs have been changed to allow this possibilty. Ref JMP 3/27/07	Mitigation Techniques can lower e-cloud density below instability threshold. Effect of MT on vacuum system design, cost and impedance not yet evaluated, see 2,3.	Very low
(2) Vacuum system design not robust	Early decision is less expensive and less impact on other systems Ref JMP 3/27/07	Present vacuum system design includes antechamber in dipoles (1) and more pumping speed. Cost will be available in few weeks.	High
(3) High impedance of vacuum chamber components	Could be input to review of design parameter range Ref JMP 3/27/07	recent estimates indicate that nominal parameters are below the thresholds for microwave and other instabilities	Very low
(4) RF Margin	Coupled with items,5,6, has large impact on CF&S Ref JMP 3/27/07	Not needed since momentum compaction has been reduced	Very low
(5) Combination of concerns with RF and Wiggler layouts	CF&S impact coupled with 4,6 Ref JMP 3/27/07	risk of 4,6 is reduced	Med
(6) Plan for having room for future double ring, later decision	Ref JMP 3/27/07	double ring is unlikely	Very low
(7) General concern with injection/extraction kicker performance	Ref JMP 3/27/07	kickers satisfy most specifications but still there are concerns on the reliability. The cost per unit should be lower.	Med

Risk analysis

SB2009

Concern		RISK	COST	r*C	MITIGATION
(1) Secondary Emission Yield too high. >1.2	Q	High	200	100	Return to two e+ ring design after extensive R&D programs
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		COMMENTS/NOTES	UPDATES		
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(2) Vacuum system design not robust		Early decision is less expensive and les impact on other systems Ref JMP 3/27/07	Present vacuum system design includes antechamber in dipoles (1) and more pumping speed. Cost will be available in few weeks.	High	20?
(3) High impedance of vacuum chamber components		Could be input to review of design parameter range Ref JMP 3/27/07	recent estimates indicate that nominal parameters are below the thresholds for microwave and other instabilities	Very low	10
(4) RF Margin	Q	Coupled with items,5,6, has large impac on CF&S Ref JMP 3/27/07	Not needed since momentum compaction has been reduced	Very low	50
(5) Combination of concerns with RF and Wiggler layouts	Q	CF&S impact coupled with 4,6 Ref JMP 3/27/07	Space for RF and wigglers is half	very low	100
(6) Plan for having room for future double ring, later decision	Q	Ref JMP 3/27/07	double ring is unlikely	Very low	20
(7) General concern with injection/extraction kicker performance		Ref JMP 3/27/07	kickers satisfy most specifications but still there are concerns on the reliability. The cost per unit should be lower.	Med	20?

Plans

- R&D in progress is useful for both
- Beam dynamics: repeat evaluation for the new lattice
- TD and Cost evaluation
  - **Work done for the 6 km ring straight sections can be used for the 3 km**
  - **Work done for the arcs has to be updated (using SuperB information)**
- Schedule a webex meeting to update DR plan and prepare for discussion at Albuquerque

Conclusions

- CONS
  - **Half bunches**
- PROS
  - **Half cost**

Damping Rings Fill Pattern

Sendai 2008 RDR 2007

Damping Rings Fill Pattern		Nominal EDR Circumference						RDR Circumference				
DR bunch spacing	DR RF buckets	2	2	2	2	4	4	2	2	2	3	4
Pattern repetition factor	p	117	90	78	65	58	32	123	118	82	71	61
Bunches per even-numbered minitrain	f2	0	0	0	0	23	23	0	0	0	22	22
Gaps per even-numbered minitrain	g2	0	0	0	0	30	126	0	0	0	37	32
Bunches per odd-numbered minitrain	f1	45	45	45	45	22	23	44	44	44	22	22
Gaps per odd-numbered minitrain	g1	30	66	90	126	30	122	30	35	89	34	28
Linac average current	**milli-amps**	**9**	**9**	**9**	**9**	**9**	**5**	**9**	**9**	**9**	**9**	**9**
Derived Parameters												
Ring harmonic number		**14042**	**14042**	**14042**	**14042**	**14042**	**14042**	**14516**	**14516**	**14516**	**14516**	**14516**
DR circumference	meters	6476	6476	6476	6476	6476	6476	6695	6695	6695	6695	6695
DR average current	milli-amps	405	405	405	405	401	226	396	396	396	393	393
Total number of bunches		5265	4050	3510	2925	2610	1472	5412	5192	3608	3124	2684
Bunch population	1,00E+10	1,04	1,35	1,56	1,87	2,07	2,07	1,02	1,06	1,53	1,75	2,04
Extraction kicker interval	DR RF buckets	120	156	180	216	240	432	118	123	177	203	236
Linac bunch spacing	Linac RF buckets	240	312	360	432	480	864	236	246	354	406	472
Linac bunch spacing	nanoseconds	184,62	240,00	276,92	332,31	369,23	664,62	181,54	189,23	272,31	312,31	363,08
Linac pulse length	**microseconds**	**971,82**	**971,76**	**971,72**	**971,67**	**963,32**	**977,65**	**982,30**	**982,30**	**982,21**	**975,34**	**974,14**
Average injected power	kW	219	219	219	219	217	122	221	221	221	220	219
Total population of damping ring	1,00E+13	5,46	5,46	5,46	5,46	5,41	3,05	5,52	5,52	5,52	5,48	5,47
Linac bunch spacing (buckets) mod 6		0	0	0	0	0	0	2	0	0	4	4
Linac bunch spacing (buckets) mod 12		0	0	0	0	0	0	8	6	6	10	4
Linac bunch spacing (buckets) mod 24		0	0	0	0	0	0	20	6	18	22	16