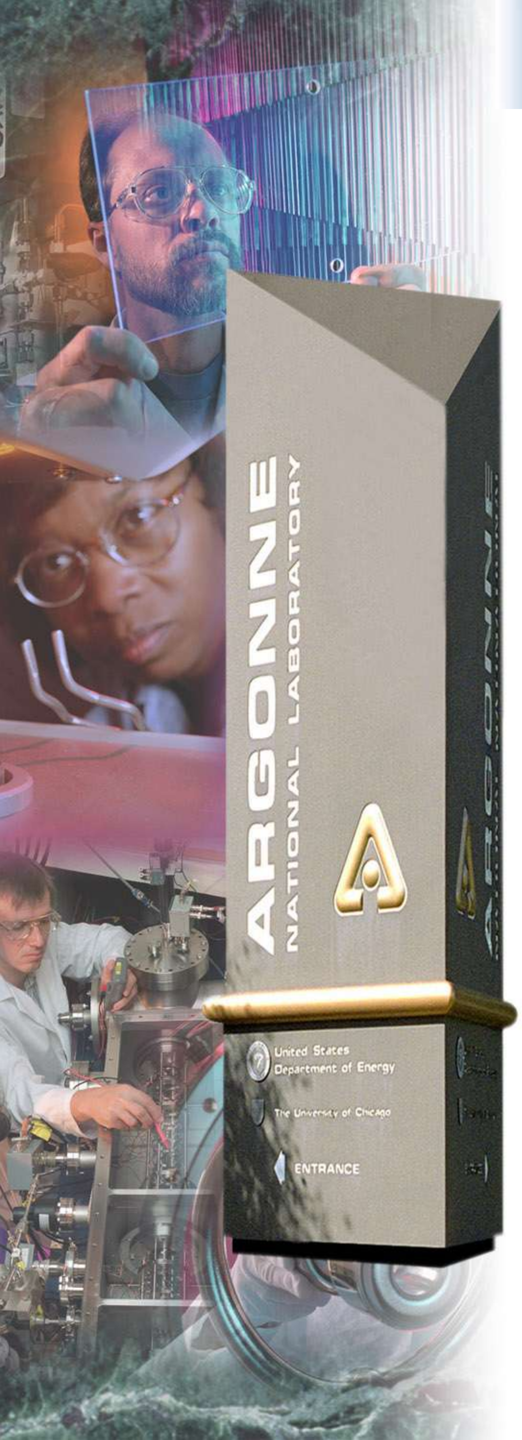

Summary of ILC DR Baseline Configuration

The materials in this presentation come from:

- ***Recommendations for the ILC Damping Rings Baseline Configuration – edited by J. Cao, S. Guiducci, A. Wolski***
- ***Presentation by S. Guiducci at ILC GDE meeting, Frascati, IL***
- ***Presentations at 2nd ILC workshop, Snowmass, USA***

A. Xiao

January 12, 2006

THE UNIVERSITY OF CHICAGO
Office of Science
U.S. DEPARTMENT OF ENERGY

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Nominal Parameters and Performance Specifications

	Baseline	Alternative (I)	Alternative (II)
Bunch train length	2820	5640	
Train repetition rate	5 Hz		
Injected bunch separation	330 ns	165 ns	
Maximum injected normalized betatron amplitude (e^+)[1]	0.09 m-rad		
Injected full-width energy spread (e^+)	1%		
Normalized injected transverse emittance, rms (e^-)	45 μm		
Injected energy spread, rms (e^-)	0.1%		
Injected bunch charge	2×10^{10}	1×10^{10}	
Extracted bunch separation	330 ns	165 ns	
Extracted bunch charge	2×10^{10}	1×10^{10}	
Extracted normalized horizontal emittance	8 μm		
Extracted normalized vertical emittance	0.02 μm		
Extracted rms energy spread	1.4×10^{-3}		
Extracted rms bunch length	6 mm		9 mm
Maximum extracted vertical jitter	0.1σ		

[1] The normalized betatron amplitude is defined as A_x+A_y where:

$$\frac{A_x}{\gamma} = \gamma_x x^2 + 2\alpha_x x p_x + \beta_x p_x^2$$

and similarly for A_y. γ is the relativistic factor, and α_x, β_x, γ_x are the Twiss parameters.

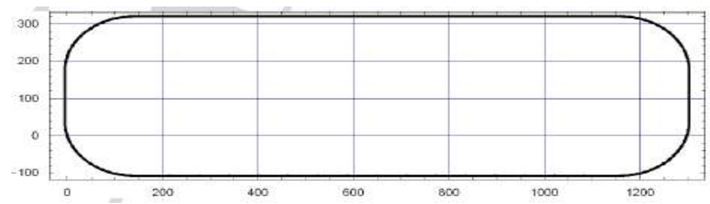
Reference Lattices

NAME	C (km)	E (Gev)	σ_z (mm)	Shape	Cell	Chromatic scheme
OTW	3.2	5	6	Racetrack	TME	Interleaved
PPA	2.8	5	6	Racetrack	PI	Non-interleaved
OCS	6.1	5.07	6	Circular	TME	Interleaved
BRU	6.3	3.74	9	Dogbone	FODO	Interleaved
TESLA	17	5	6	Dogbone	TME	Interleaved
MCH	16	5	9	Dogbone	FODO	Interleaved
DAS	17	5	6	Dogbone	PI	Non-interleaved

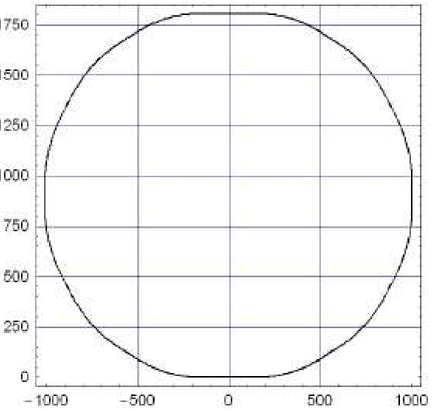
-Seven Reference Lattices have been explored to address various physical and technical issues.

- The goal is NOT to choose a design but to understand of how the various choices affect the performance, cost and operability of the damping rings.

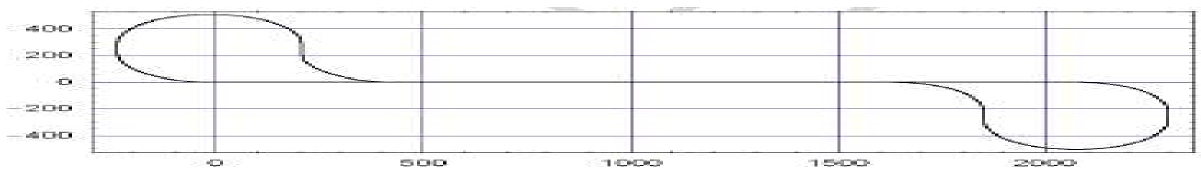
Lattice Layout



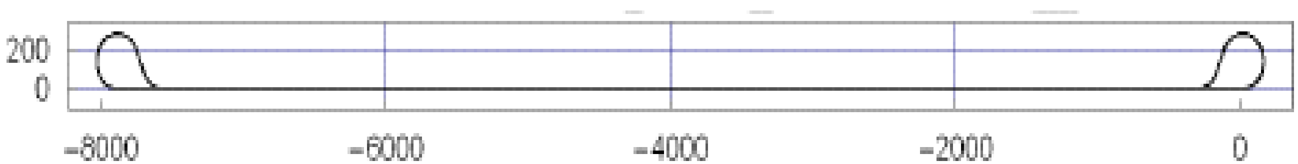
OTW



OCS (PPA)



BRU (DAS, MCH)

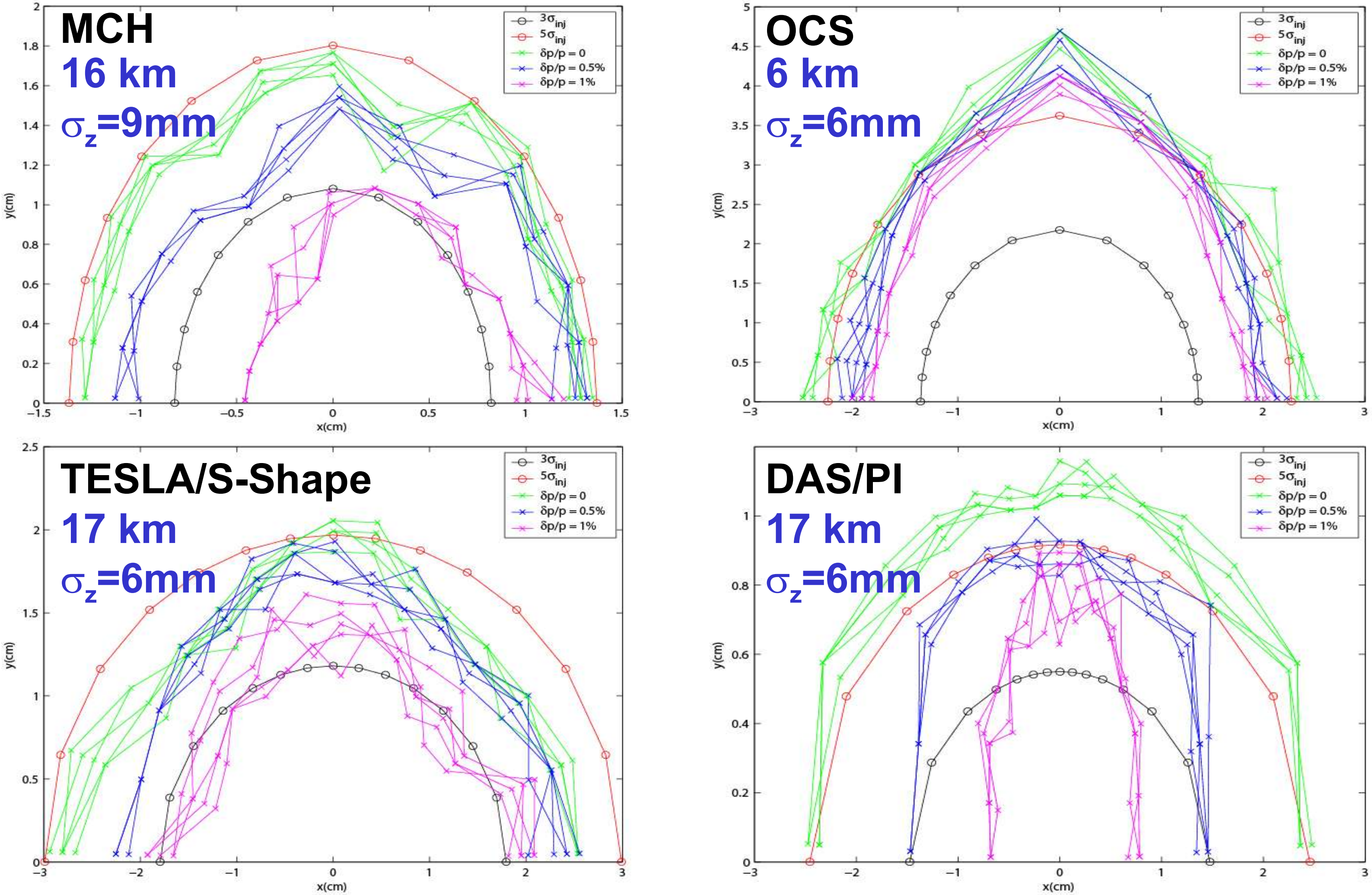


TESLA

3 or 6 km rings can be built in independent tunnels

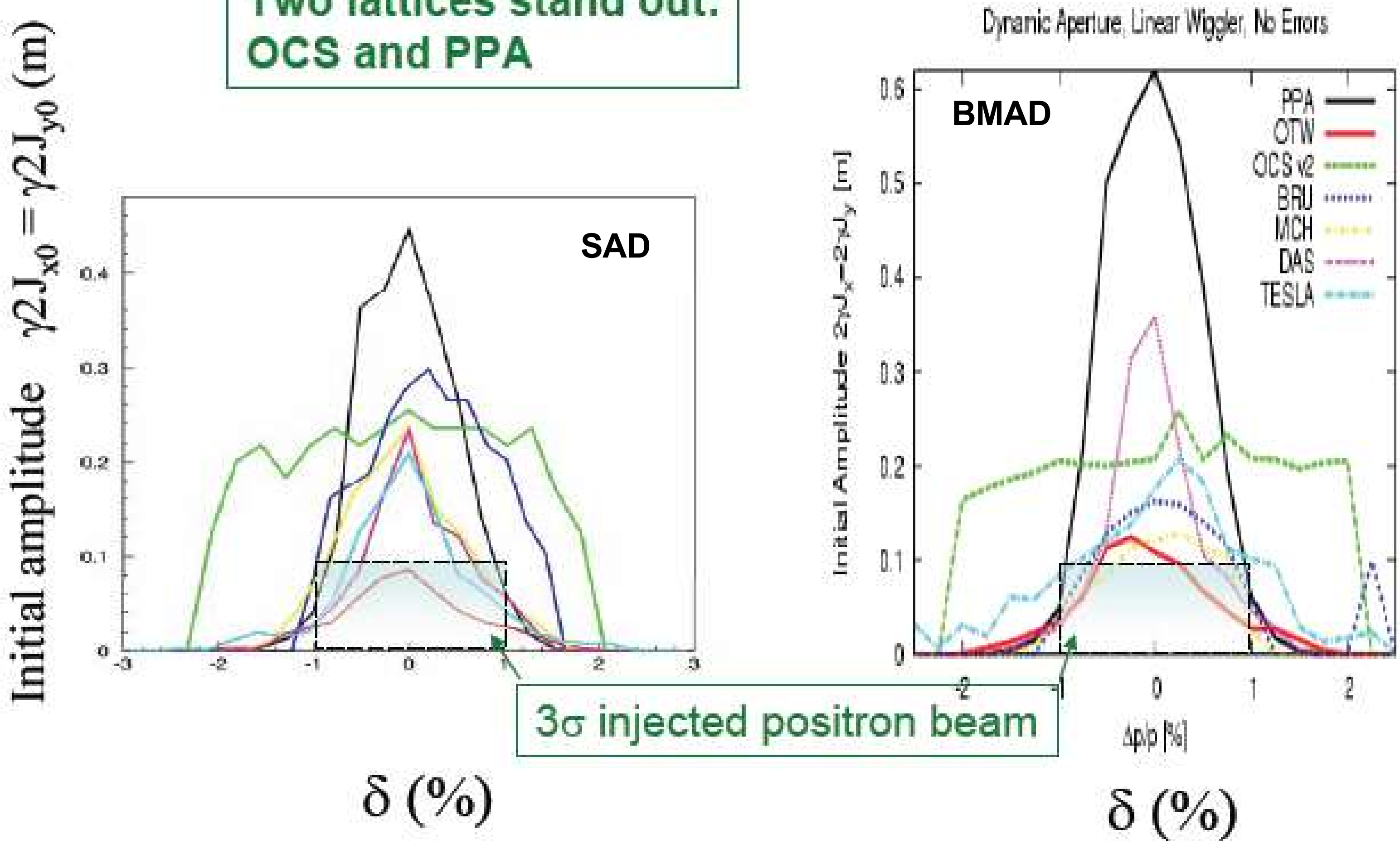
“dogbone” straight sections share linac tunnel

Acceptance: Dynamic Aperture with Multipole Errors and Single-Mode Wigglers



Acceptance: Longitudinal for Ideal lattice

Two lattices stand out: OCS and PPA



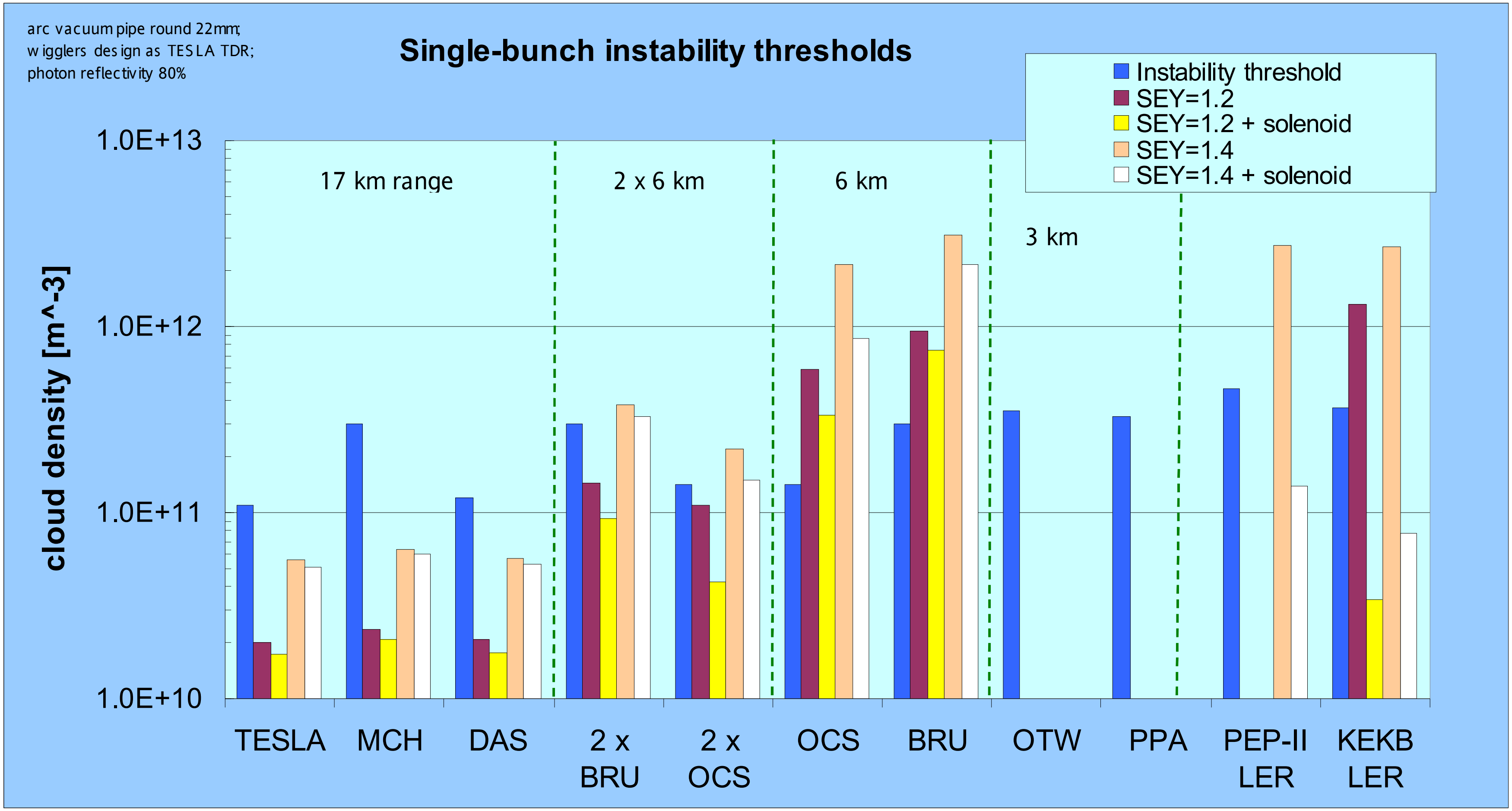
3σ injected positron beam

Short and circular type lattice with more super periods structure has advantage on getting better dynamic aperture.

Summary on Acceptance

- Based on what we have learned so far
- Pick 6 km ring with “circular” shape
  - more symmetric
  - better chromatic property, large moment aperture
  - large dynamic aperture with multipole errors and wigglers
  - More space in arcs, potentially leads more flexible lattice, emittance, momentum compaction factor, bunch length
- Not yet to recommend any particular type of cell because we would like to have a lattice that achieve the maximum flexibility.

Electron Cloud Effects – positron ring



M. Pivi, K. Ohmi, F. Zimmermann, R. Wanzenberg, L. Wang, T. Raubenheimer, C. Vaccarezza, X. Dong

Suppressing e- cloud in magnetic field regions

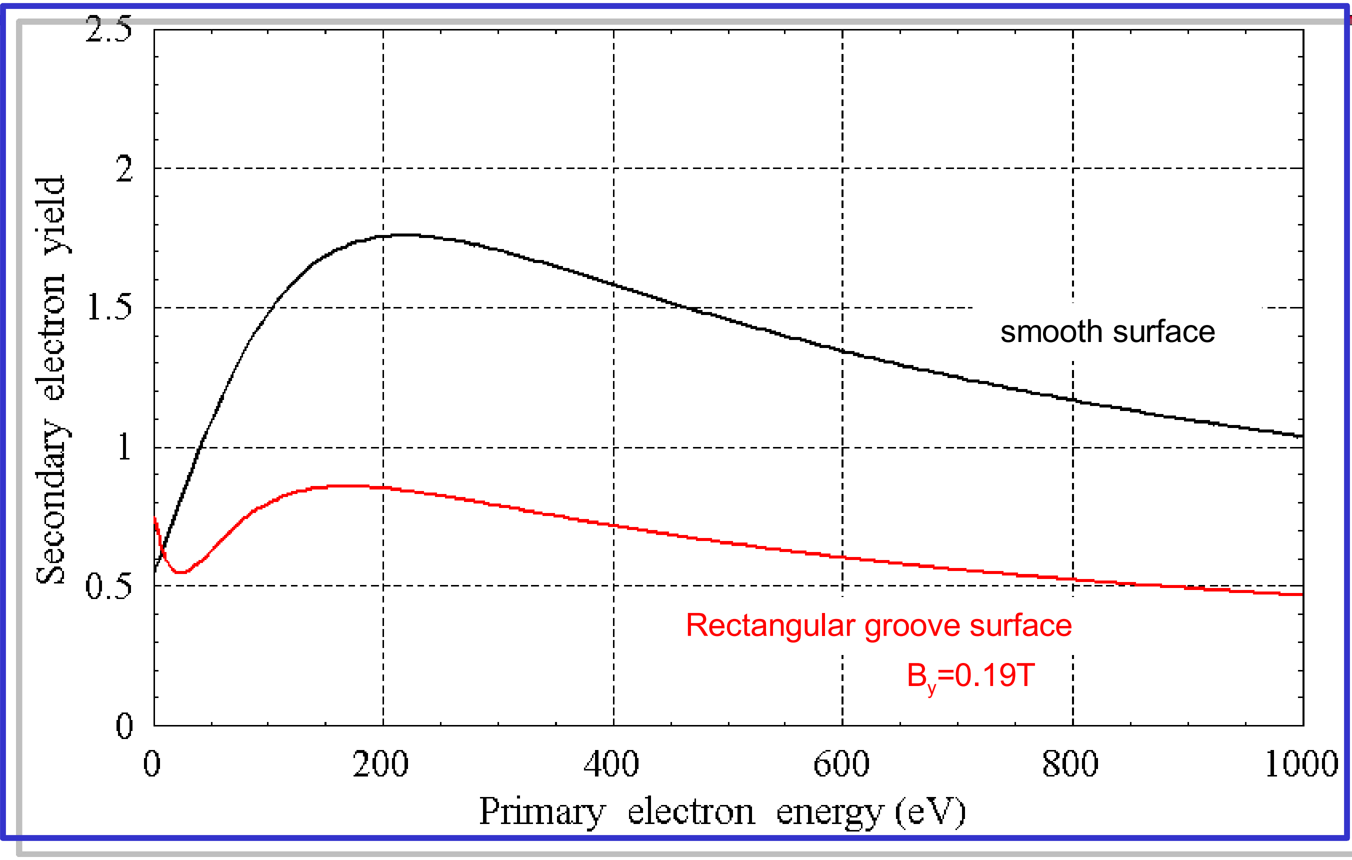
- Microgrooves.
  Groove spacing comparable with e- Larmor radius.
  R&D status: laboratory tests at SLAC very successful in magnetic free regions, measured reduction to SEY < 0.7. Building chamber for installation in dipole region in PEP-II.

- Clearing electrodes: simulations show that likely electrodes can suppress electron cloud in magnetic field regions, but need further R&D and studies (Impedance, support …).
  R&D at KEKb.

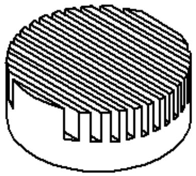
- Photon absorbers to reduce reflectivity

*

Rectangular grooves in BEND: SEY



Parameters
rectangular groove:
period = 250 um
depth = 250 um
width = 25 um



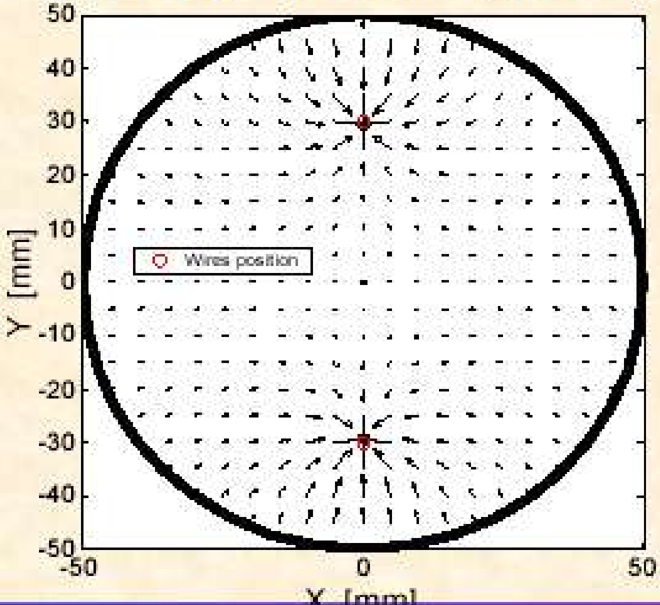
Simulated secondary yield of a rectangular grooved surface in a dipole field compared with a smooth surface (field free reference).

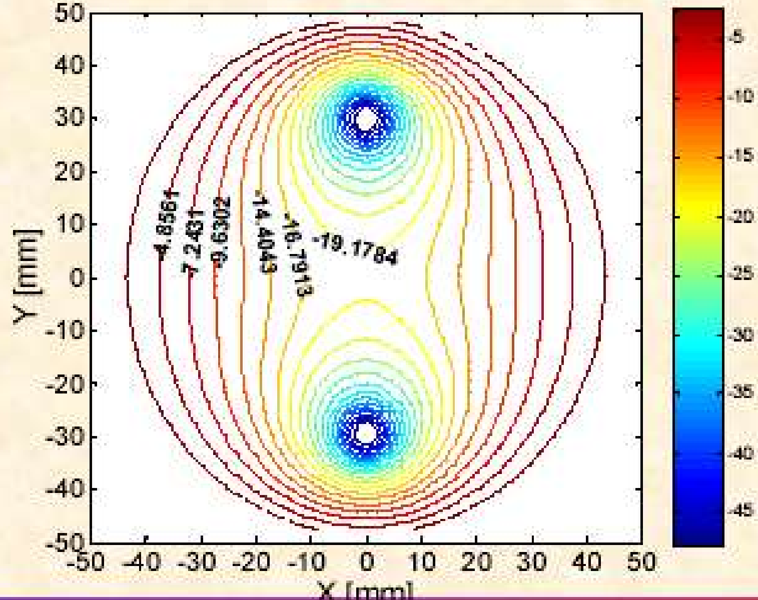
Groove dimensions in wiggler ~10-100 um. 1cm wide stripe with grooves.

- Possible solution: need laboratory and accelerator tests in dipole field

Clearing electrodes for Dipole Magnet

- *Inside the strong dipole magnets, crossed-field and gradient drifts couldn't eliminate the electrons. Therefore, the electric field must be along the magnetic field line in order to effectively repel the electron. This conclusion hold for other strong magnetic fields*
- *The wire electrodes must have negative potential relative to the grounded chamber!!!*
- *The field is perfect!!! (very weak field at chamber center, strong vertical field around both the top and bottom of the chamber, where multipacting could happen.*





ILC DR Task Force 6 Recommendation Summary

- The instability limit is more likely to be exceeded in smaller rings.
- Larger bunch spacing Damping Rings with a larger synchrotron tune and/or momentum compaction are preferable.
- In order of preference: **MCH, DAS, TESLA, BRUx2, OCSx2, BRU, OCS**.

- It's a technical challenge to stably reduce the SEY below 1.1-1.2
  - Redflag: KEKB Annual Report 2005 "The electron cloud effect still remains the major obstacle to a shorter bunch spacing, even with the solenoid windings" [1].
- If the SEY can be reduced in magnets, the 6 km BRU and OCS can be feasible.
- Promising cures as microgrooves and clearing electrodes need further R&D and full demonstration in accelerator.
- Larger wiggler apertures may be helpful to reducing the cloud density below threshold in 6km rings
- In the short bunch spacing 3 km DR, multipactoring arises even at low SEY~1, developing the highest cloud densities (see Snowmass 05 talks) therefore should be discarded as possible candidates.

M.Pivi, K. Ohmi, R. Wanzenberg, Zimmermann, SLAC, Nov 2005

Space Charge Effects

- Linear space charge tune shift for uncoupled lattice:

$$\Delta\nu_x = -\frac{1}{4\pi}\frac{2\lambda r_e}{\beta\gamma^3}\int_0^C \frac{\beta_x}{\sigma_x(\sigma_x+\sigma_y)}ds; \quad \Delta\nu_y = -\frac{1}{4\pi}\frac{2\lambda r_e}{\beta\gamma^3}\int_0^C \frac{\beta_y}{\sigma_y(\sigma_x+\sigma_y)}ds$$

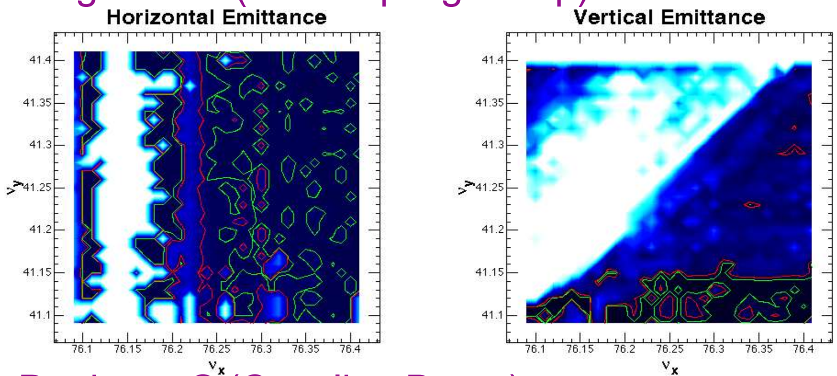
lattice	C (Km)	ε_x (nm)	ν_{xo}	ν_{yo}	$\Delta\nu_x$	$\Delta\nu_y$
MCH w/o b.	15.9	0.68	75.783	76.413	-0.014	-0.270
MCH w/ b.	15.9	0.68	75.783	76.413	-0.014	-0.089
OCS	6.1	0.56	50.84	40.80	-0.006	-0.127
PPA	2.8	0.43	47.81	47.68	-0.004	-0.064

$$\varepsilon_y = 2\text{ pm}, \ \sigma_z = 6\text{ mm (assumed uniform)}, \ N = 2\times10^{10}\text{ part./bunch}$$

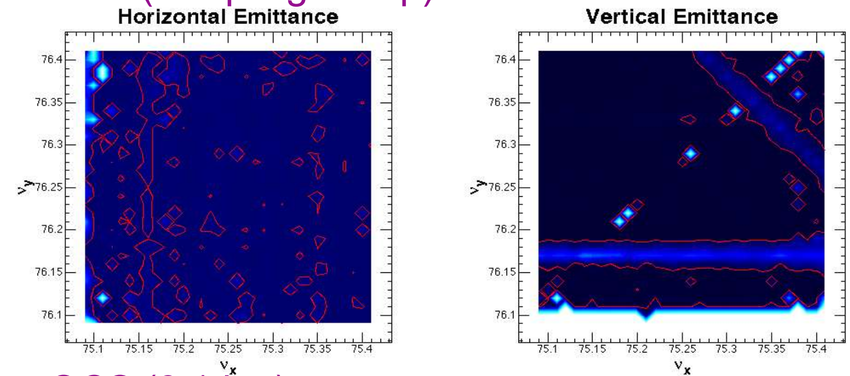
Space Charge –Emittance Growth vs. tune

By K. Oide and Y. Ohnishi

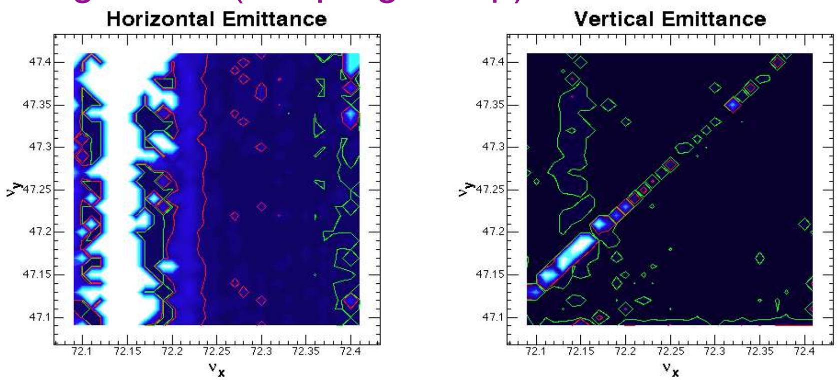
Dogbone-S (No Coupling Bump)



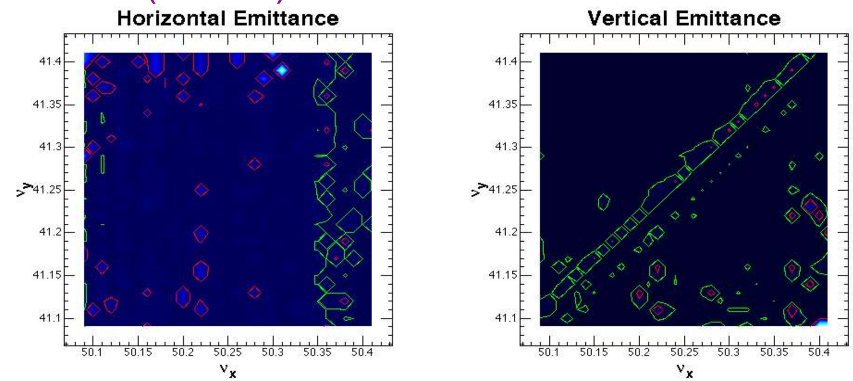
MCH (Coupling Bump)



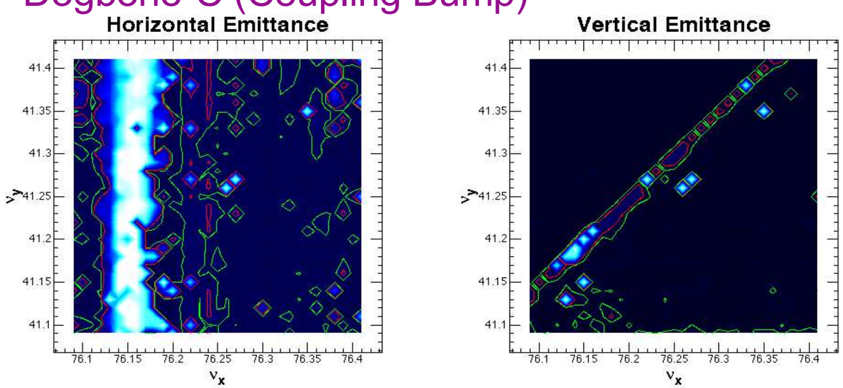
Dogbone-S (Coupling Bump)



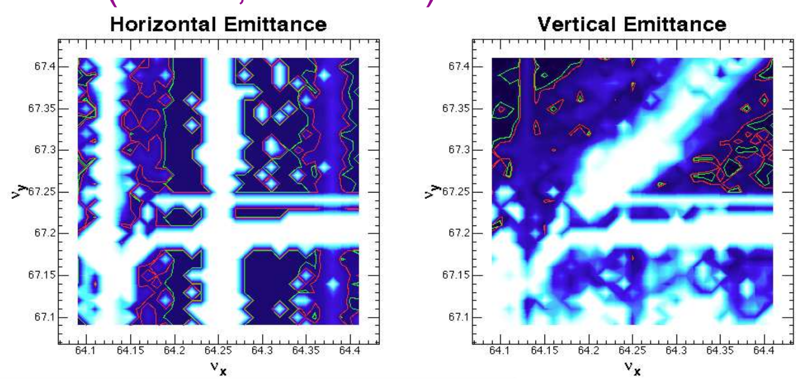
OCS (6.1 km)

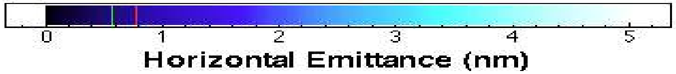


Dogbone-C (Coupling Bump)



BRU (6.4 km, 3.74 GeV)

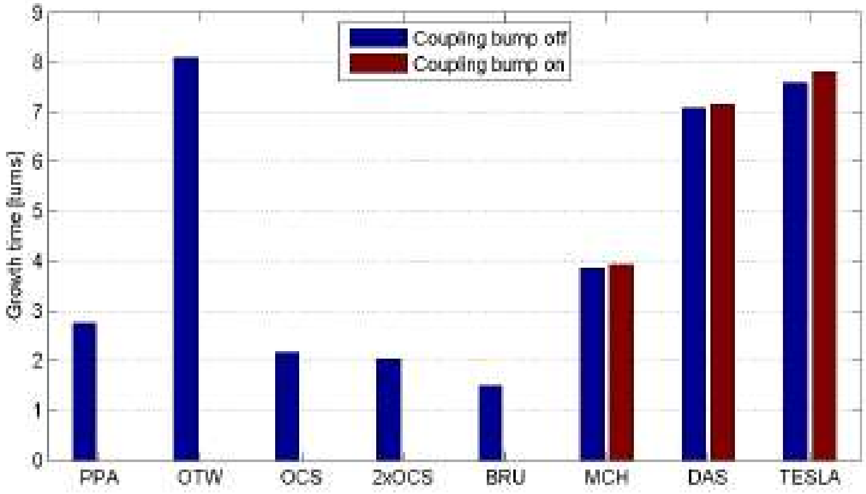




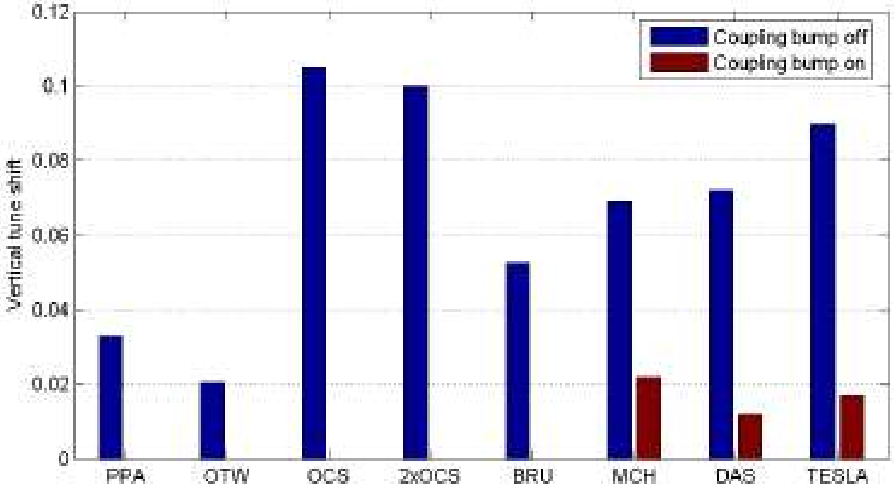
Space Charge Summary

- Dogbones (17 km) and MCH (16 km) look safe for the space charge with the "round" coupling bump.
- OCS (6.1 km) is the safest.
- BRU at 3.74 GeV, the tune space with safe emittance growth is very small. Dogbone without the coupling bump too.
- The structure resonances should be avoided.
  - C or S-shape of Dogbone is not critical for space charge if good working point can be chosen, respectively.
- The detail of the lattices, such as the way how to change the tunes, may affect the strengths of the resonances.
- Need more study with lattice errors, etc.

Ion Effects – electron ring



Growth rate due to FII



Tune shift due to FII

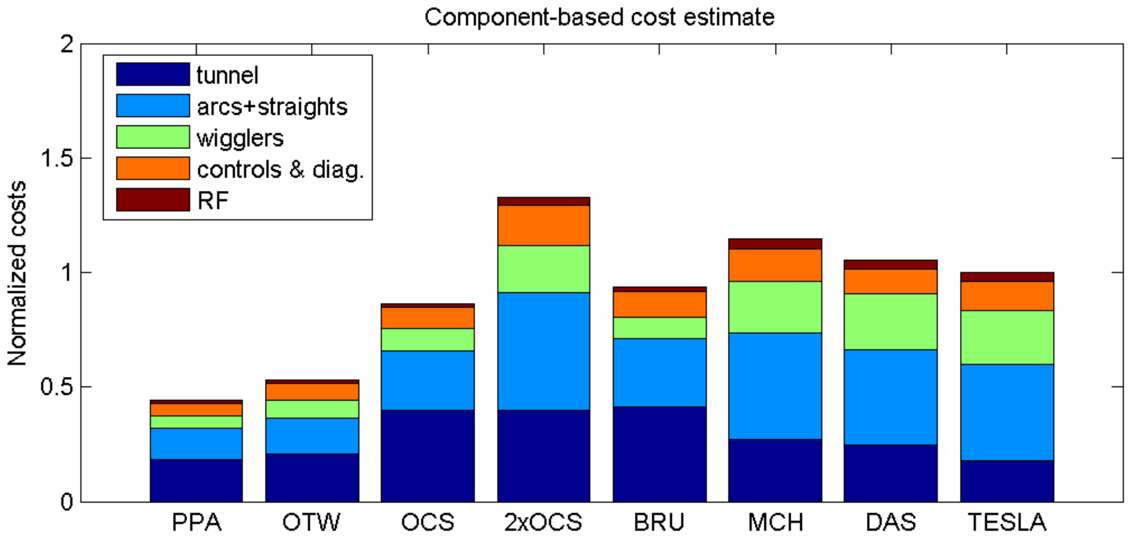
Mini-gap is required and it can reduce the growth rate of FII and tune-shift up to a factor of 10~20

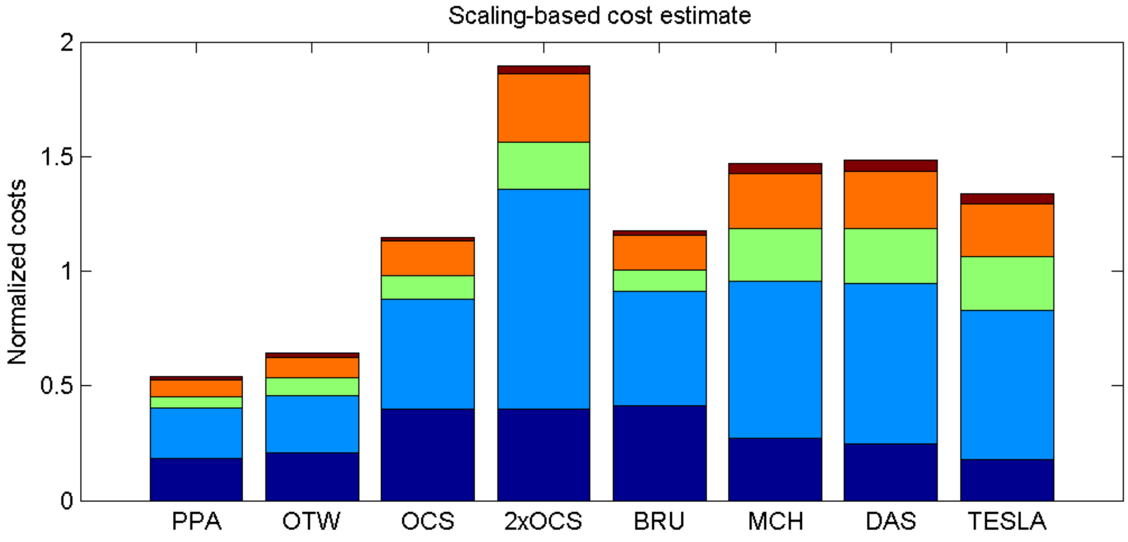
Ion-density reduction factor (IRF) depends on fill-pattern, optics and the time during the damping. Need a detailed lattice design for electron ring

Kick Technology

- Three different type of fast pulsers have been tested on a strip line kicker at ATF(KEK).
- All of them have very short rise/fall time (~3ns) and fulfil nearly all of the requirements for the damping ring injection.
- R&D programs are in progress in various laboratories both on the pulser and on the electromagnetic design of the electrode.
- The task force participants are confident that:
  - kickers for a 6 Km (i.e. 6 ns bunch spacing) are a “low risk” issue
  - kickers for the 3 Km (i.e. ~3ns bunch spacing) ring are considered at present a high risk.

Preliminary Cost Estimated





A 3 km ring would have rather a lower cost than 6 km or 17 km rings.

Two 6 km rings in a single tunnel is a higher cost than a 17 km ring.

Other Beam Dynamics Issues

- Low-Emittance Tuning
- Beam Jitter
- Collective Effects
  - Intrabeam Scattering
  - Touschek Lifetime
  - Classical Single (Couple) Bunch Instability
- Polarization

Beam is more stable at higher energy in general

Primary studies show that these effects are moderate and can be handled for all reference lattices They mostly depend on detail lattice parameter (like tune, etc.) than lattice type.

Need to be detailed in future studies

Other Technical Issues

- Wiggler
  - CESR-C superconducting wiggler demonstrates good field quality with large physical aperture. Normal-conducting electromagnetic and hybrid wiggler need to show similar quality within reasonable efforts and cost.
- Vacuum System
  - The size of vacuum chamber is decided to accommodate injected positron beam and to reduce electron cloud effects.
  - No decision has been made on material and other issues.
- RF System
  - 500 MHz RF system has been chosen since it’s a standard technology; other options would require R&D.
  - Superconducting system requires fewer cavities, with advantages for keeping cost and HOMs low.

Significance and Risk

Rank	Meaning
A	This issue: • is critical to the corresponding item in the configuration decision; • has significant technical, operational or cost implications associated with it; • is likely to be a key consideration in choosing between the various options.
B	This issue is important for the corresponding item in the configuration decision, but should not be considered a decisive factor.
C	This issue has only a minor impact on the corresponding item in the configuration decision.

Rank	Meaning
1	The performance requirements of this option have been demonstrated, or studies indicate little risk.
2	R&D required to demonstrate performance requirements, but with a likelihood of successful outcome; *or* low technical risk, and practical fix will likely be found in event that a problem occurs.
3	Significant R&D required to demonstrate performance requirements; *or* high technical risk, with likelihood to cause ongoing problems.
4	There is unlikely to be an acceptable technical solution.

Significance and Risk – cont.

Issues Ranking

Issue	Significance	Risks			
		3 km	6 km	2×6 km	17 km
Electron cloud (positron ring)	A	4	3	2	2
Kickers	A	3	2	2	2
Acceptance	A	2	1	1	2
Cost	A	1	2	3	3
Ion effects (electron ring)	B	3	2	2	2
Space-charge	B	1	1	1	2
Tunnel layout	B	1	1	1	2
Availability	C	1	1	1	1
Classical collective effects	C	2	2	2	2
Low-emittance tuning	C	2	2	2	2
Polarization	C	1	1	1	1

Recommendation on Circumference and Layout

- The critical choice for the DR is the circumference and layout. It has strong impact on beam dynamics, technology choice and cost.
- Based on intensively studying on seven reference lattice:
  - The positron ring shold be 2 of 6 km in a single tunnel
  - The electron ring can be a single 6 km ring
- The ring will be roughly circular to obtain better acceptance.
- Alternatives:
  - If techniques are found that can sufficiently suppressing the electron cloud, a single 6 km, or possibly smaller, ring can be used for positron ring
  - If electron cloud effects can not solved sufficiently, then a 17 km ring is a possible alternative. Space-charge effects and acceptance issues need to be addressed in this case.

Recommendation on Beam Energy

- The damping ring energy should be approximately 5 GeV
  - Lower energy increase the risks from collective effects and requirement on ring's acceptance.
  - Higher energy makes harder to tune for low emittance.

Recommendation on Injection/Extraction Kicker Technology

- The damping ring kickers should be based on "conventional" strip-line kickers driven by fast pulsers without use of RF separators. The basic technology is available, and is close to a demonstration of most of the performance specifications.
- Alternative:
  - RF separators maybe required for more bunches inside the ring
  - Fourier pulse-compression kickers provide a very different approach, it's worthwhile continuing studies to develop a more complete understanding of the benefits and limitations of these systems.

Summary of Recommended Baseline Configuration

Item	Baseline	Alternatives
Circumference	(e^+) 2×6 km (e^-) 6 km	1. (e^+) 6 km 2. (e^+/e^-) 17 km
Beam energy	5 GeV	
Injected emittance and energy spread	A_x+A_y<0.09 m-rad $\|\delta\|<1\%$	A_x+A_y<0.045 m-rad $\|\delta\|<2\%$
Train length @ bunch charge	2800 @ 2×10^{10}	>2800
Extracted bunch length	6 mm - 9 mm	
Injection/extraction kicker technology	Fast pulser/stripline kicker	1. RF separators 2. Fourier pulse compressor
Wiggler technology	Superconducting	1. Normal-conducting 2. Hybrid
Main magnets	Electromagnetic	Permanent magnet
RF technology	Superconducting	Normal conducting
RF frequency	500 MHz	
Vacuum chamber diameter, arcs/wiggler/straights	50 mm/46 mm/100 mm	
Vacuum system technology	…	

Proposed ILCDR study activity at ANL

- Lattice optimization: 1) Detail positron ring design. 2). Design a suitable electron ring. 3) Search design variable space with multi-objective evolutionary algorithms.
- Simulation Tools: Add to tracking code elegant space charge forces (done), vertical emittance with synchrotron radiation, SVD for orbit correction.
- Develop an algorithm and scheme on vertical emittance and coupling correction.
- Study single bunch limits with particle tracking with wakefields modeled from 3D codes.
- Study ion instability on APS ring. Once we observed ion instability only when a vacuum leak occurred.
- Design a hybrid wiggler which would meet the field quality tolerance of the OCS reference lattice design. This is for cost estimation.

List of comments, interests, and planned activities from some of our damping ring colleagues

- http://www.hep.uiuc.edu/LCRD/ILCDR.html

ILCDR Configuration Study Task Forces and Coordinators

- 1: Acceptance Issues - Y. Cai and Y. Ohnishi
- 2: Vertical Emittance Tuning - J. Jones and K. Kubo
- 3: Classical Instabilities - K. Bane, S. Heifets, G. Stupakov
- 4: Space-Charge Effects - K. Oide and M. Venturini
- 5: Electron-Cloud Effects - K. Ohmi and M. Pivi
- 6: Fast-Ion Effects - E.-S. Kim, D. Schulte, F. Zimmermann
- 7: Polarization - D. Barber
- 8: Kicker Technology - M. Ross and T. Naito
- 9: Cost Estimates - S. Guiducci, J. Urakawa and A. Wolski
- 10: Availability - J. Nelson

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More Information

- ILC
  - http://www.linearcollider.org/
- ILC Baseline Configuration Document
  - http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd_home
- ILC Damping Ring
  - http://www.desy.de/~awolski/ILCDR/Menu.htm
- ILCDR BC Recommendation Detail Report
  - http://www.desy.de/~awolski/ILCDR/DRConfigurationStudy_files/DRC