The Super*B* Project

U. Wienands
Accelerator Systems Division

SLAC DOE HEP Review
July 7 – 9, 2008

SLAC

PPA Particle Physics & Astrophysics

Achievements of PEP-II

* Specified at $3x10^{33}/cm^2/s$ luminosity, PEP-II reached $1.2x10^{34}/cm^2/s$ and delivered about 550/fb of integrated luminosity.
* PEP-II's daily delivery reached 911/pb/day, about 7x the originally anticipated 135/pb/day.
* During its 9 years of physics running PEP-II produced a wealth of results
  – 350 papers total at the average rate of 70 papers/year (last 3 y).
* Proved (together with KEKB) to the world that high-intensity e^+e^- colliders with multi-ampere of beam current can be run, breaking new ground in rf and feedback technology as well as vacuum technology.

Accel. Physics & Engineering Impact of *B*-Factories

* Proof that solenoids are an effective suppressant of e-cloud instability.
* Proof that rf systems dominated by beam loading can be operated relying on cutting-edge feedback loops.
* Demonstration of cutting-edge bunch-by-bunch feedback
  – in all three planes
* New understanding of the interaction of high-current short-bunches with vacuum system & mitigation methods
  – Impedances, HOM heating, HOM-absorber modules
* Benchmark for advanced 3-d beam-beam codes (Ohmi, Cai)
* First e^+e^- IRs successfully operated with multi-ampere beam currents in both beams.

The Physics Case for a High-Luminosity *B*-Factory

* CP asymmetries, and searches for rare branching fractions of quarks and leptons.
* Rare decays not accessible at LHC
* Test of LFV in τ decays
* With polarized electron beams:
  – study CP violation in the lepton sector
  – lepton flavor violating processes
  – attempt at measuring E.D.M. of the τ.
* Physics program will be complementary to LHC*b* and sensitive to new physics unobserved at LHC, at higher mass scales.
* L ≈ 10^{36}/cm^2/s necessary to address physics program

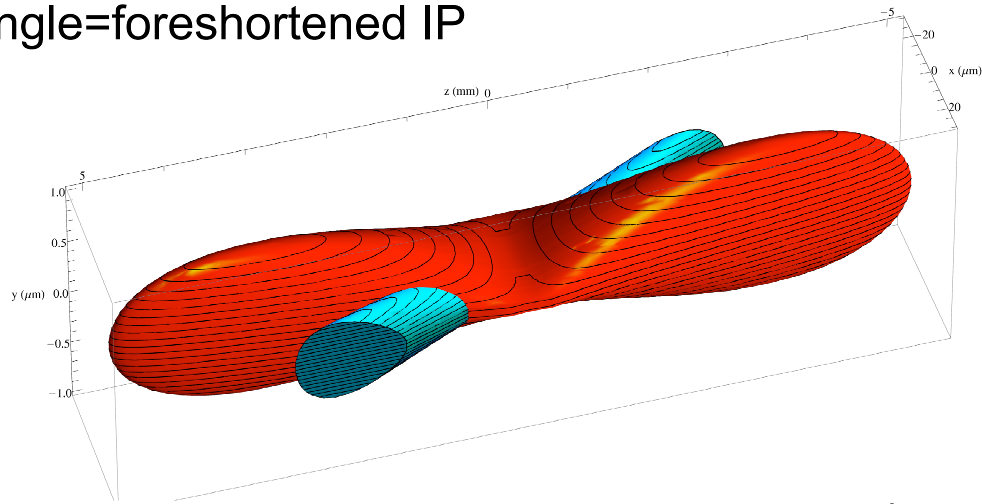
High-Luminosity *B*-Factory Proposals

- SuperKEKB
  - Essentially a phased upgrade of KEKB
    - Higher beam currents up to 9 A (LER)
    - Lower $ß_y^*$ (3 mm)
    - based on crab cavities giving large luminosity enhancement
    - $L_{max} \approx 2 \ldots 4 \times 10^{35}/cm^2/s$
    - in proposal stage, funding uncertain due to J-PARC competition for $$
- Super*B* by INFN with strong input from SLAC & CalTech
  - New facility at University of Rome "Tor Vergata"
  - Crab waist interaction point with crossing angle, very low $ß_y^*$
  - ILC-DR type rings with small emittances
  - Beam currents comparable to PEP-II
  - Polarized electrons designed in from the start.
  - $L_{max} = 10^{36}/cm^2/s$, upgrade potential to $4 \times 10^{36}/cm^2/s$

The Crab Waist Principle

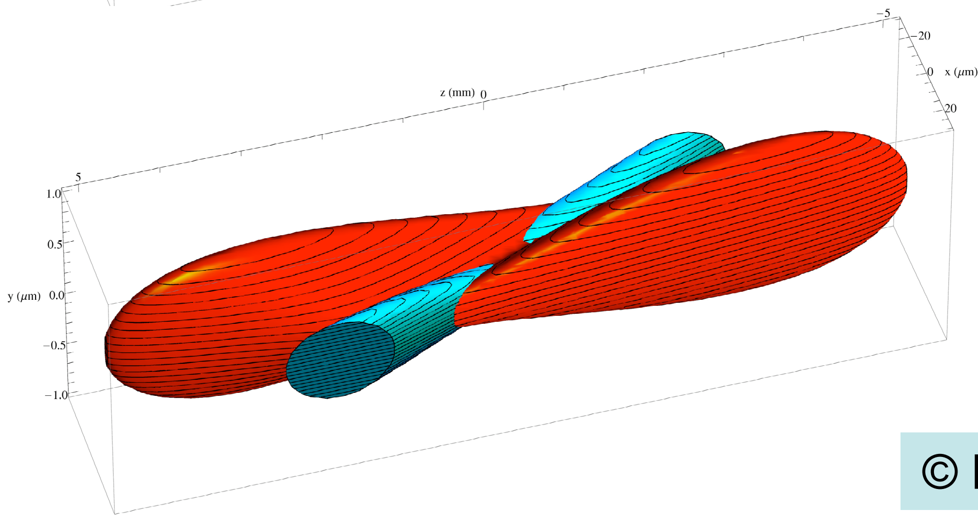
Large “Piwinski” angle=foreshortened IP

Crab sextupoles OFF



waist line is orthogonal to the axis of one bunch

Crab sextupoles ON



waist moves to the axis of other beam

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All particles from both beams collide in the minimum β_y region, with a net luminosity gain

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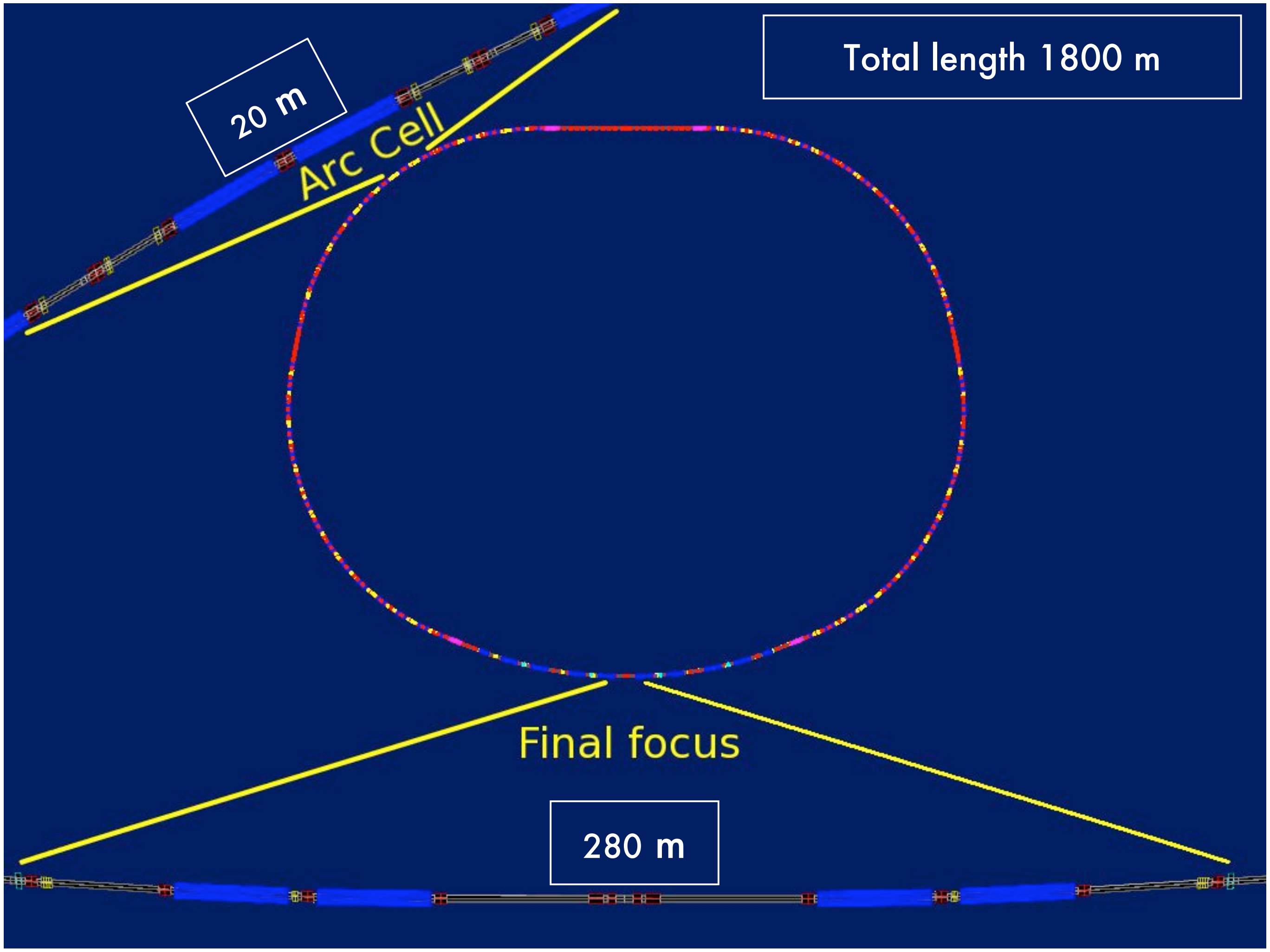
Particle Physics & Astrophysics

Super*B* Parameters

	Nominal		Upgrade		Ultimate	
PARAMETER	LER (e+)	HER (e-)	LER (e+)	HER (e-)	LER (e+)	HER (e-)
Energy (GeV)	4	7	4	7	4	7
Luminosity x 10^{36}	1.0		2.0		4.0	
Circumference (m)	1800	1800				
Revolution frequency (MHz)	0.167					
Eff. long. polarization (%)	0	80				
RF frequency (MHz)	476					
Momentum spread ($x10^{-4}$)	7.9	5.6	9.0	8.0		
Momentum compaction ($x10^{-4}$)	3.2	3.8	3.2	3.8		
Rf Voltage (MV)	5	8.3	8	11.8	17.5	27
Energy loss/turn (MeV)	1.16	1.94	1.78	2.81		
Number of bunches	1251				2502	
Particles per bunch ($x10^{10}$)	5.52				6.78	
Beam current (A)	1.85				3.69	
Beta y* (mm)	0.22	0.39	0.16	0.27		
Beta x* (mm)	35	20				
Emit y (pm-rad)	7	4	3.5	2		
Emit x (nm-rad)	2.8	1.6	1.4	0.8		
Sigma y* (microns)	0.039	0.039	0.0233	0.0233		
Sigma x* (microns)	9.9	5.66	7	4		
Bunch length (mm)	5		4.3			
Full Crossing angle (mrad)	48					
Wigglers (#) 20 meters each	0	0	2	2		
Damping time (trans/long)(ms)	40/20	40/20	28/14	28/14		
Luminosity lifetime (min)	6.7		3.35			
Touschek lifetime (min)	20	40	38	20		
Effective beam lifetime (min)	5.0	5.7	3.1	2.9		
Injection rate pps ($x10^{11}$) (100%)	2.6	2.3	5.1	4.6	10	9.1
Tune shift y (from formula)	0.15		0.20			
Tune shift x (from formula)	0.0043	0.0025	0.0059	0.0034		
RF Power (MW)	17		25		58.2	

SuperB Layout

Note: Spin rotators need to be included



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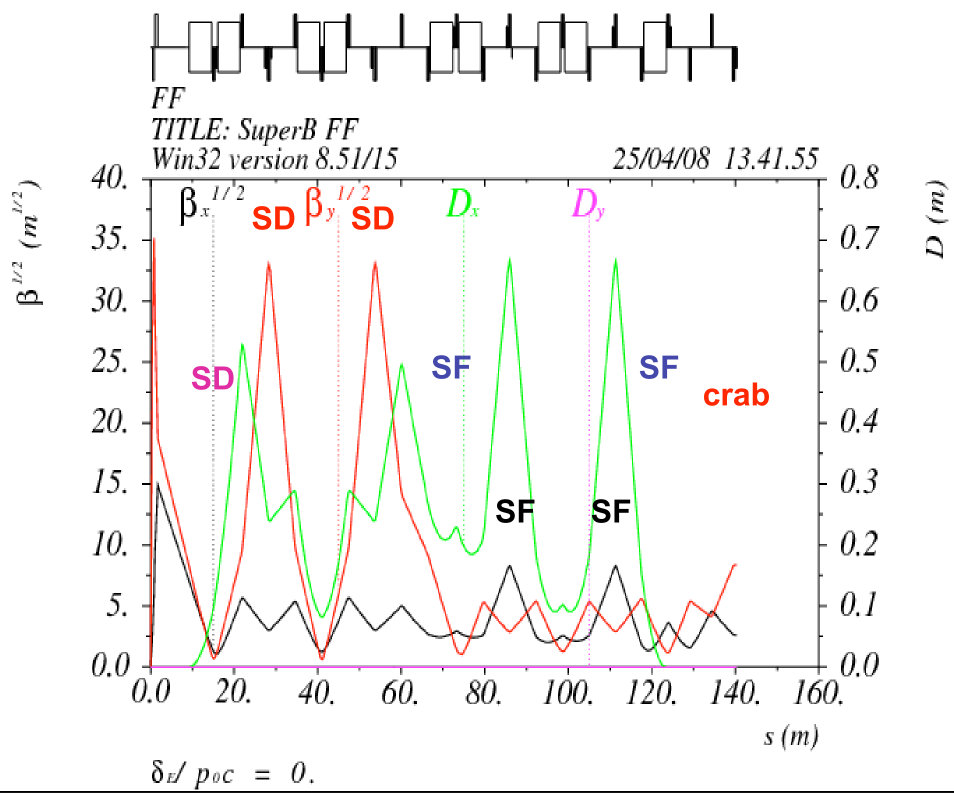
IR Design

IR Optics (NLC-FF Style)



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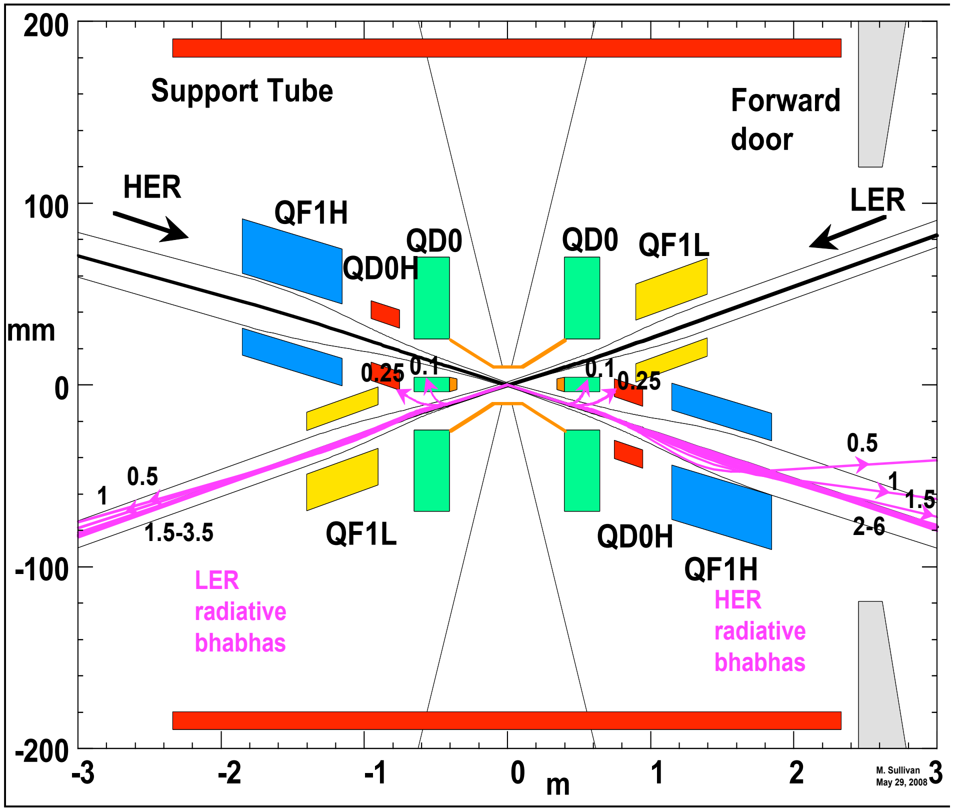
IR Layout (dual-bore QD0)



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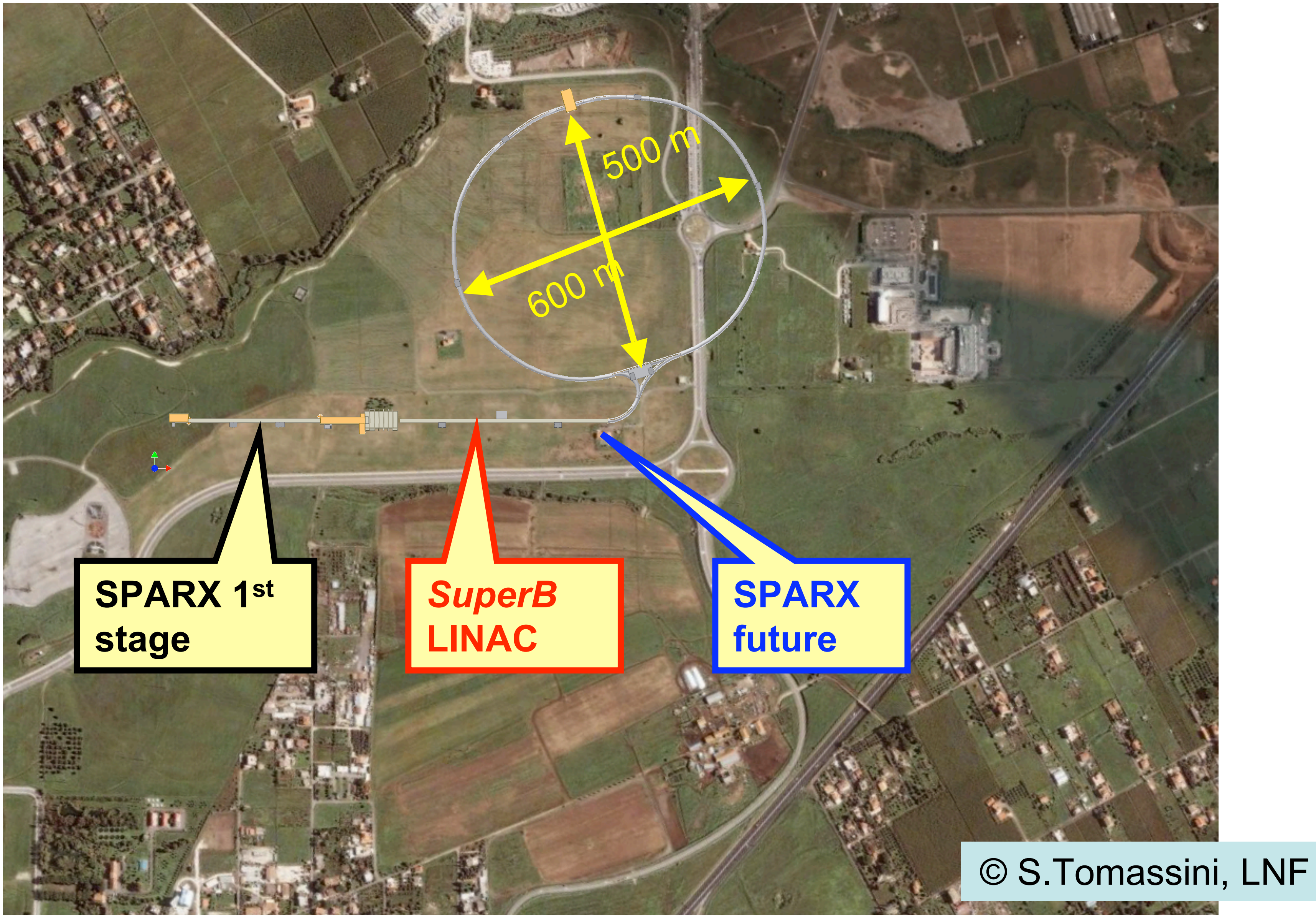
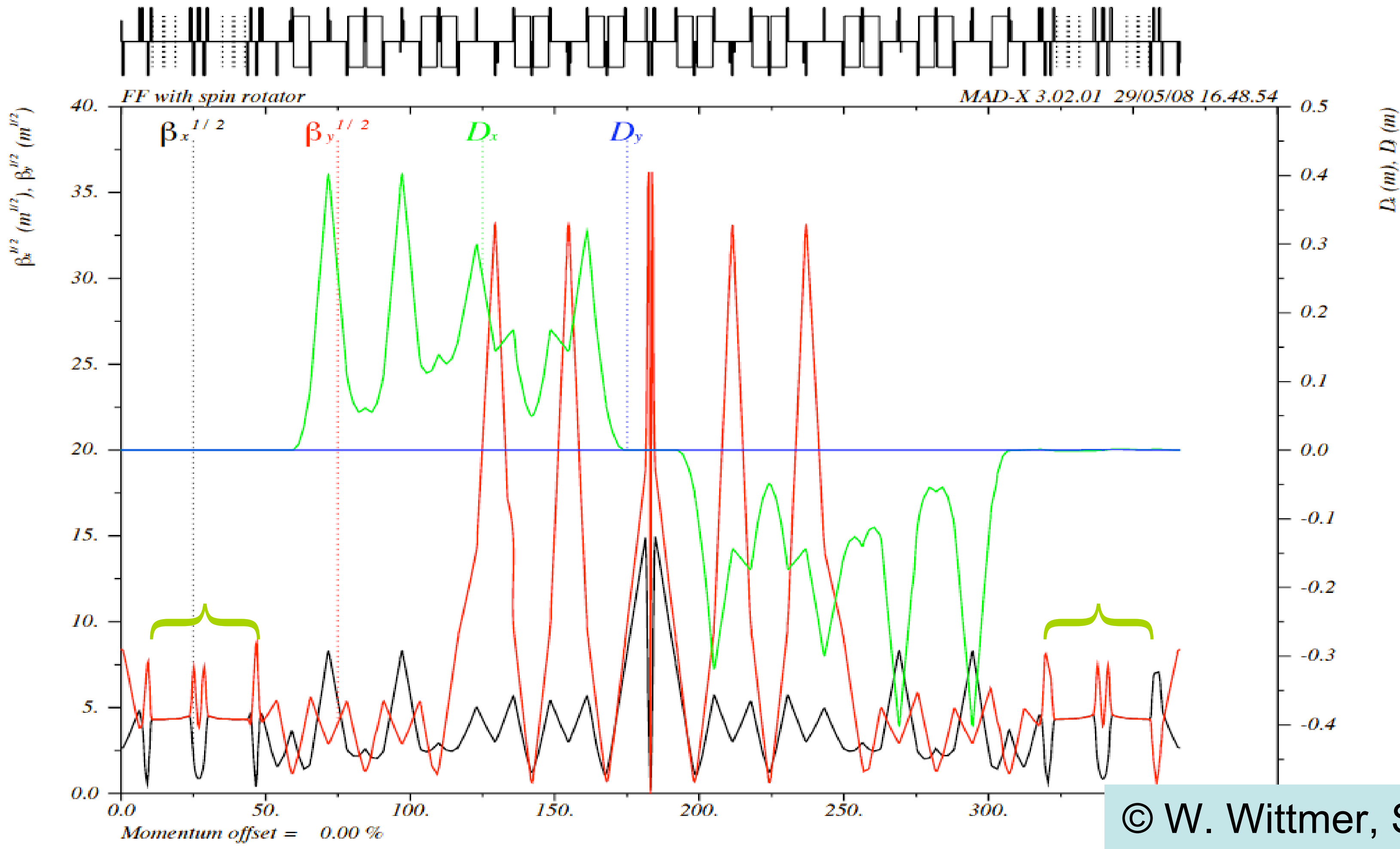
SuperB Site Layout (preliminary) @ Tor Vergata



Polarized e^- in Super*B*

- SuperB will be have polarization capability designed in
  - Spin rotators, polarized e^- source



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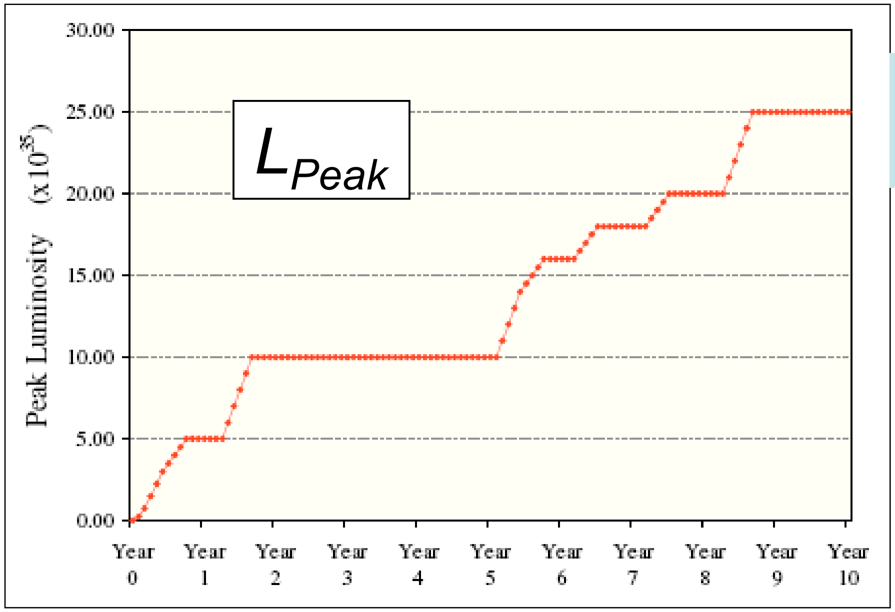
Super*B* Rf Power

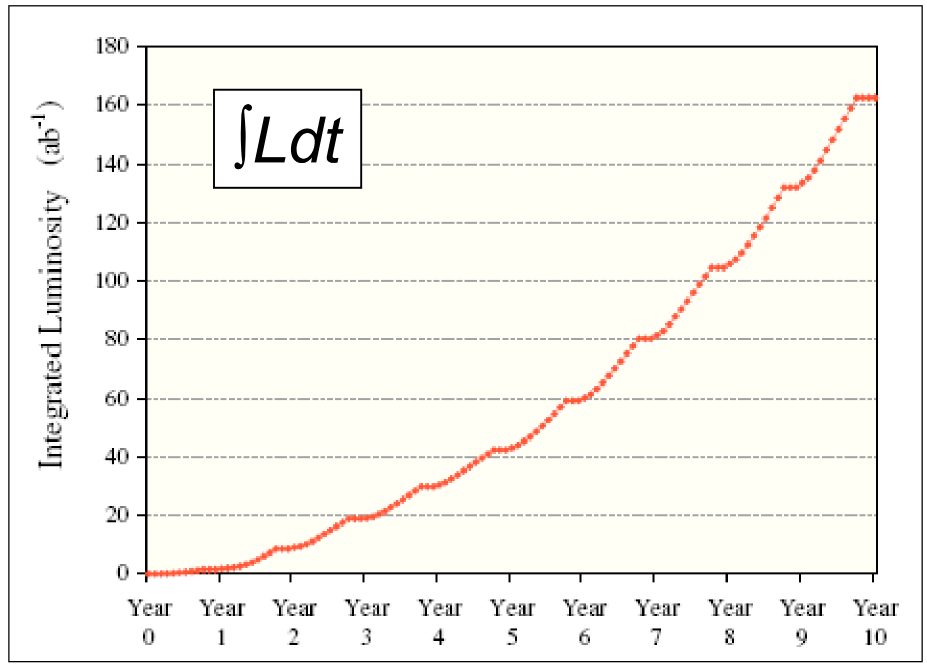
HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER	HER+
			S.R. energy			Total	Zero I		Max				Total	Total	Total	Power for	LER
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	Numbe	S.R.	HOM	cavity	reflected	forward	one	Total
	energy	curren	per turn	um com-	tum	voltag	length	spacing	er cavit	of	power	power	loss	power	power	cavity	forward
	GeV	A	MeV	paction	spread	MV	mm	nsec	MV	cavities	MW	MW	MW	MW	MW	MW	MW
1E+36	7	1.85	1.95	3.8E-04	5.8E-04	8	5.1	4.2	0.65	12	3.6075	0.3303	0.702	0.4349	5.07	0.42	8.10
2E+36	7	1.85	2.81	3.8E-04	8.0E-04	12	5.7	4.2	0.65	18	5.1985	0.3201	1.053	0.5014	7.07	0.39	11.67
4E+36	7	3.7	2.81	3.8E-04	1.0E-03	22	5.2	2.1	0.6	36	10.397	0.9772	1.769	1.7783	14.92	0.41	25.03

LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	LER	HER+ LER
			S.R. energy			Total	Zero I		Max				Total	Total	Total	Power for	Supply
Lumi	Beam	Beam	loss	Momen-	Momen-	RF	Bunch	Bunch	voltage	Numbe	S.R.	HOM	cavity	reflected	forward	one	Power
	energy	curren	per turn	um com-	tum	voltag	length	spacing	er cavit	of	power	power	loss	power	power	cavity	eff.~50%
	GeV	A	MeV	paction	spread	MV	mm	nsec	MV	cavities	MW	MW	MW	MW	MW	MW	MW
1E+36	4	1.85	1.13	3.2E-04	8.0E-04	6	5.6	4.2	0.65	10	2.0905	0.2744	0.474	0.1846	3.02	0.30	16.20
2E+36	4	1.85	1.78	3.2E-04	9.0E-04	8	5.5	4.2	0.65	12	3.293	0.2971	0.702	0.3027	4.59	0.38	23.33
4E+36	4	3.7	1.78	3.2E-04	1.0E-03	12	4.9	2.1	0.6	20	6.586	0.8073	0.947	1.7635	10.10	0.51	50.05

SuperB luminosity profile



Luminosity upgrade to 2.5×10^{36} after 5 years of running



160 ab^{-1} in ten years
~100 x combined
BABAR + Belle data sample

(SuperKEKB: 57 ab^{-1} by 2028)

SuperB vs SuperKEKB

Notes:

SuperB length w/o spin rotators.

SuperKEKB luminosity assumes x2 gain from crab cavities.

SuperB luminosity arises from small emittance & small *ß** compared to SuperKEKB

	Super*B*	SuperKEKB
Circumference (m)	1800	3016
Energy (GeV) (LER/HER)	4/7	3.5/8
Current (A)/beam	1.85	9.4/4.1
No. bunches	1251	5018
No. part/bunches	5.5×10^{10}	$12/5 \times 10^{10}$
θ (rad)	2x24	2x15
ε_x (nm-rad) (LER/HER)	2.8/1.6	24
ε_y (pm-rad) (LER/HER)	7/4	180
β_y^* (mm) (LER/HER)	0.22/0.39	3
β_x^* (mm) (LER/HER)	35/20	200
σ_y^* (μm) (LER/HER)	0.039	1
σ_x^* (μm) (LER/HER)	10/6	50
σ_z (mm)	5	3
L ($cm^{-2}s^{-1}$)	$1.x10^{36}$	$4.x10^{35}$

Super*B* Most Important Questions

* Will the Crab Waist work?
  – Crab waist running @ DAFNE,
  – ongoing MD program & Super*B* simulation work
* Will the low emittances be achievable?
  – Requirements in line with ILC DR => Synergy SuperB <=> ILC DR
  – ATF experience is valuable
* Will the low *ß** be achievable with reasonable acceptance?
  – Acceptance simulations indicate yes, ongoing work needed
* Will the short beam lifetimes be tolerable?
  – "Trickle Charge" was established operationally at PEP-II
    • SLC-type sources sufficient for Super*B* beam lifetimes & currents
  – First look at Touschek losses: should be able to handle the loss rate

Crab Waist Results from DAFNE

e^- sextupoles on

LUMINOMETERS

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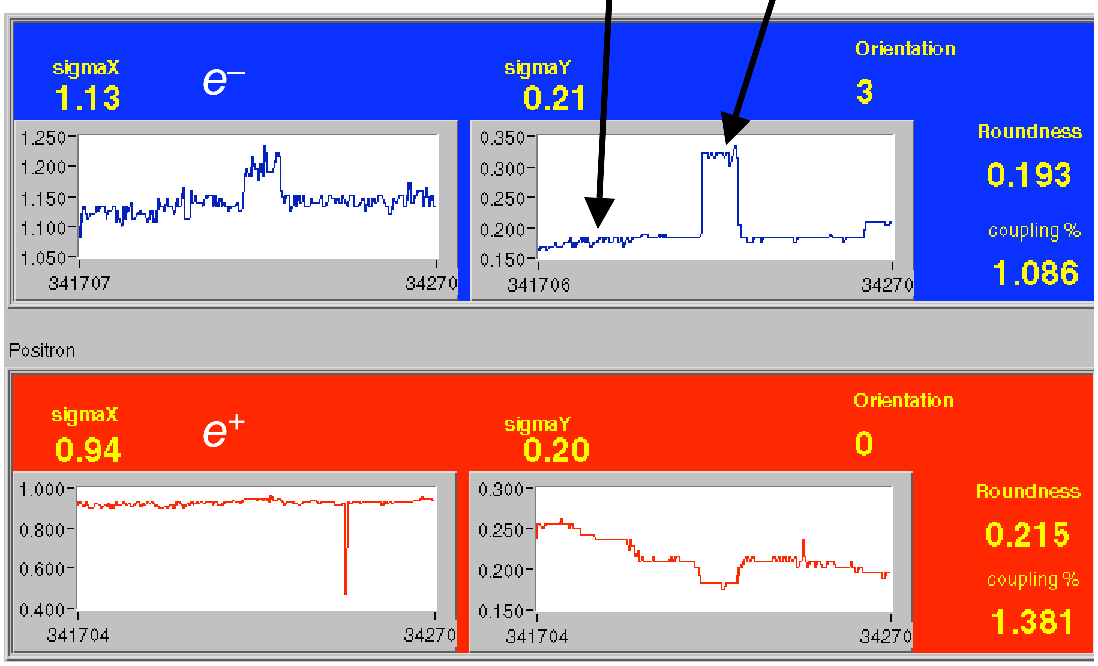
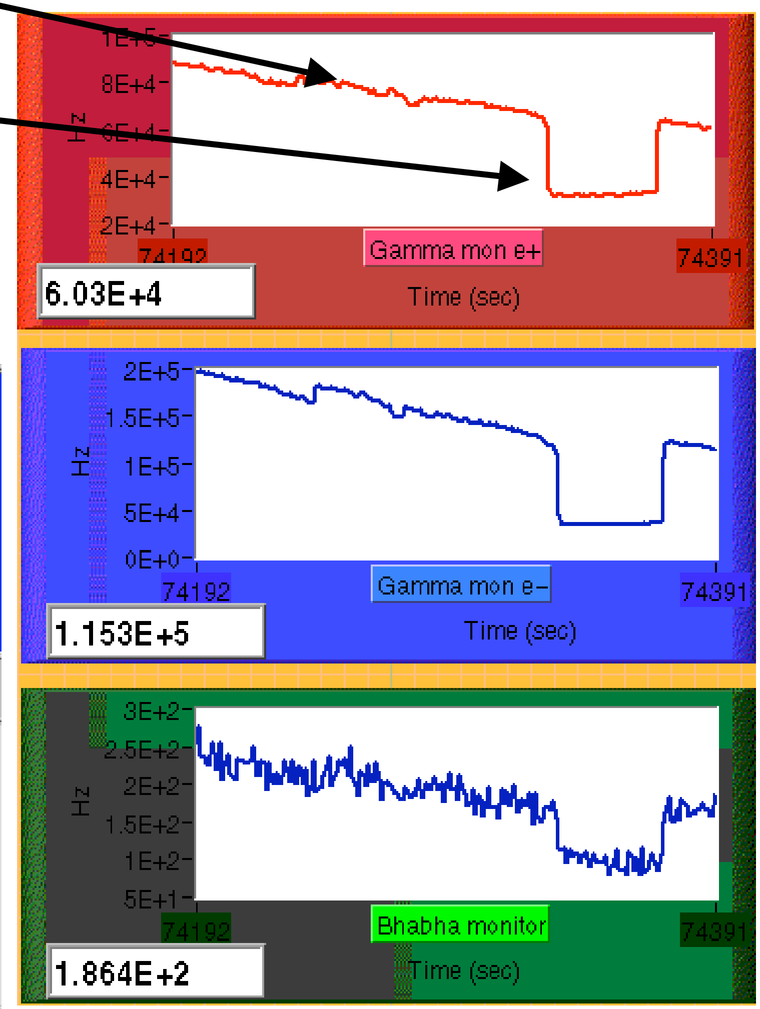
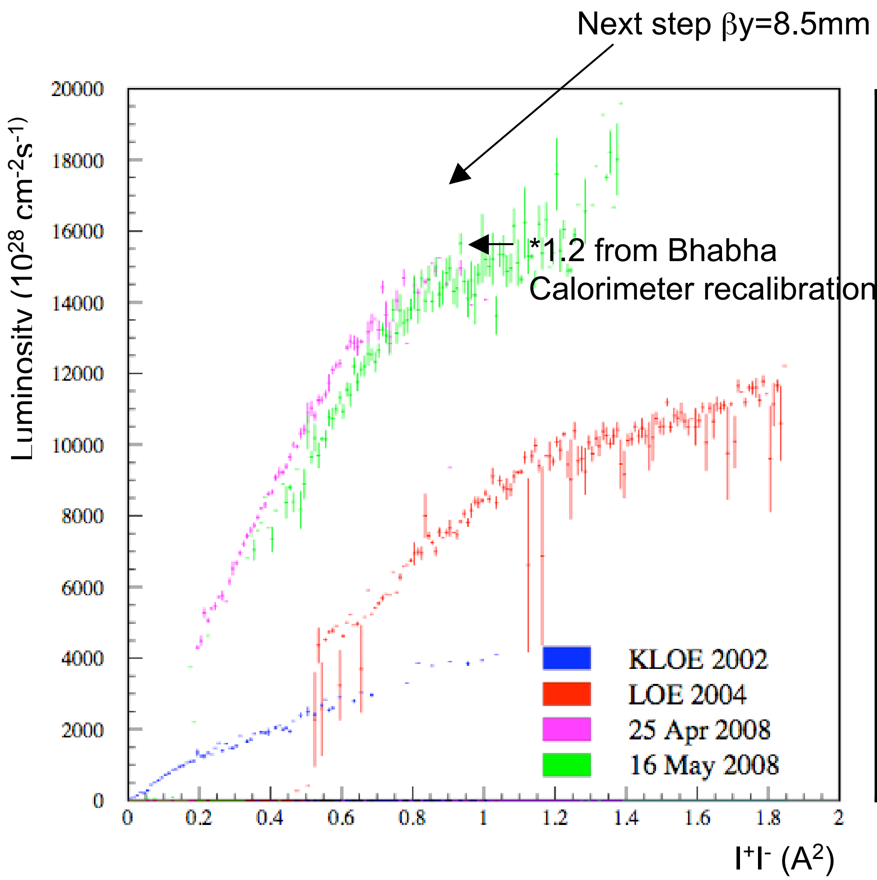
e^- sextupoles off

Transverse beam sizes at Synchrotron Light Monitors





DAFNE Luminosity

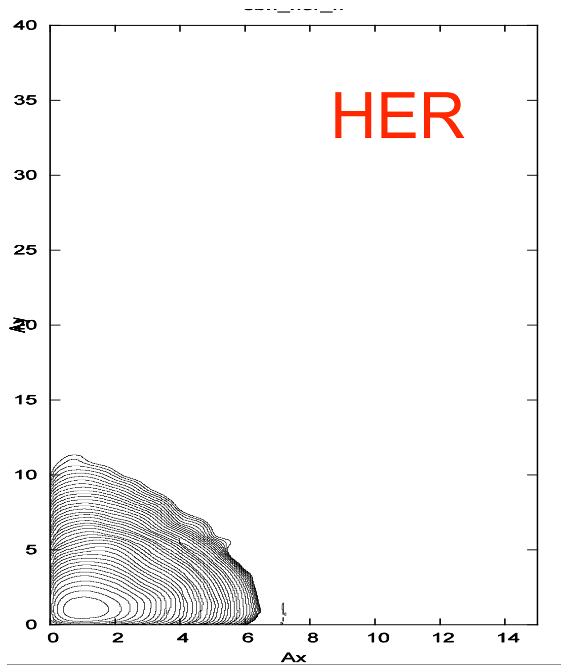


	electrons achieved	positrons achieved
emittance (mm.mrad)	0.25	0.25
β_x @IP (m)	0.27	0.24
β_y @IP (m)	0.0106	0.0096
coupling (%)	≈0.7	≈0.7
σ_x @ IP (mm)	0.26	0.25
σ_y @ IP (μm)	4.0	4.0
Piwinski angle (10mA)	1.6	1.7

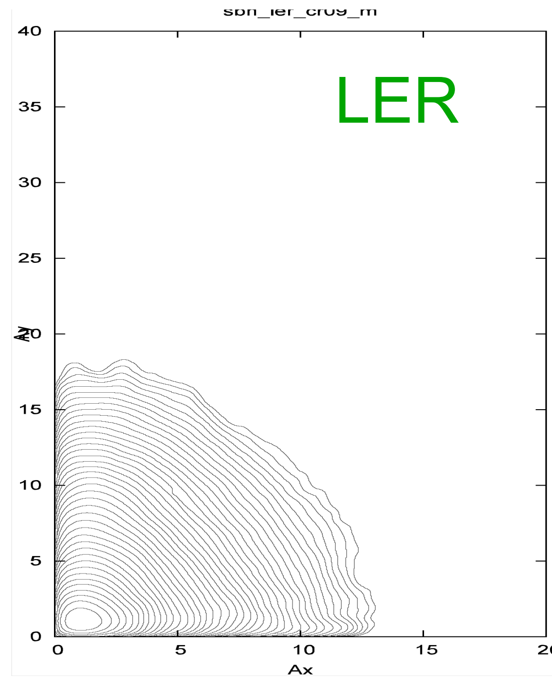
Beam-Beam Emittance Growth

* L = 10^{36} /cm^2/s
* No blow up is seen for HER, 1-3% for LER

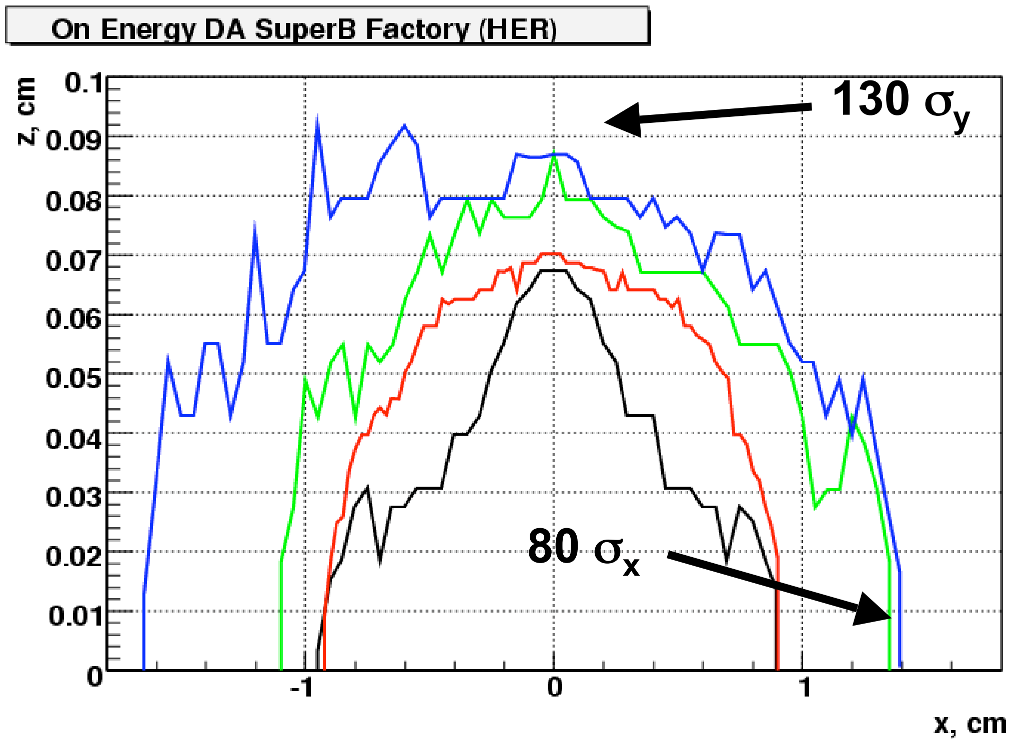
Crab=0.8Geom_Crab



Crab=0.9Geom_Crab



SuperB HER Dynamic Aperture



Black: original DA at WP (.575/.595)
Red: optimized at WP (.575/.595)
Green: DA for the new WP (.569/.638), same sextupoles
Blue: DA re-optimized in the new WP (.569/.638)

Super*B* Reviews & Verdicts

- Two IRC reviews (International Review Committee, Dainton) (mostly physics, some accelerator)
  - “So far there has been no ‘showstopper’; rather there have emerged a number of innovative and noteworthy developments at the cutting-edge of contemporary technique in accelerator physics and detector technology…”.
  - “We recommend strongly that work towards the realisation of a Super*B* continues”.
- P5 Report (Baltay)(Physics)
  - “The physics reach of a super flavor factory is well motivated and grounded in the very rich suite of measurements produced by the current generation of B factories.”
  - “The maturity of the field of B physics supports a strategy of significant US investment in a single next-generation overseas facility.”
- “MiniMAC” Review scheduled for July 17, 18 (accelerator)

Super*B* at SLAC

* SLAC ASD and BP had major impact on design.
  – CDR design mostly based on SLAC/PEP-II (+ ILC-DR) experience.
    • Compatible with PEP-II components & systems, esp. magnets & rf.
  – SLAC BP provided initial acceptance estimate.
  – SLAC provided initial Touschek lifetime estimate.
  – SLAC is leading the polarized-beam effort.
  – SLAC provided power estimates, cost & schedule estimates for CDR.
  – SLAC ASD & BP wrote good fraction of accelerator part of CDR
    • Rf, IR, Magnets, Vacuum, beam dynamics, cost & schedule,…
* SLAC is playing a leading role in planning for the TDR
* Last not least, PEP-II components can fulfill a significant fraction of Super*B* needs
  – rf: almost 100%, Magnets: ≈ 70%

Conclusion

* With the recent developments and the support by INFN, P5 & the IRC, Super*B* has gained significant momentum.
* Excitement about the physics case is building up.
* SLAC would be an essential player & natural lead laboratory for US involvement in this project
  – The Super*B* rings will be a cutting-edge challenge for accelerator physics and engineering.
  – There is significant synergy between the Super*B* rings and linear-collider damping rings.
  – The project provides a timely bridge between now and a linear collider for both experimentalists and accelerator physicists/engineers.
* Best opportunity to leverage investment in PEP-II.

End of Presentation