

SuperB design and needs

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SuperB design

- SuperB is a 2 rings, asymmetric energies (e^- @ 4.18, e^+ @ 6.7 GeV) collider with:
 - large Piwinski angle and “crab waist” resonance compensation
 - ultra low emittance lattice
 - longitudinally polarized electron beam
 - **target luminosity of $10^{36} \text{ cm}^{-2} \text{ s}^{-1}$**
 - possibility to run at τ /charm threshold with $L = 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$
- There will be also some SR beamlines in parasitic or dedicated running
- The design requires state-of-the-art technology for emittance and coupling minimization, vibrations and misalignment control, e^- -cloud suppression, etc...
- The design has many similarities with the Damping Rings of ILC and CLIC, and with latest generation SL sources → common problems
- For details see the new Conceptual Design Report (Dec. 2010) on:

<http://arxiv.org/abs/1009.6178>

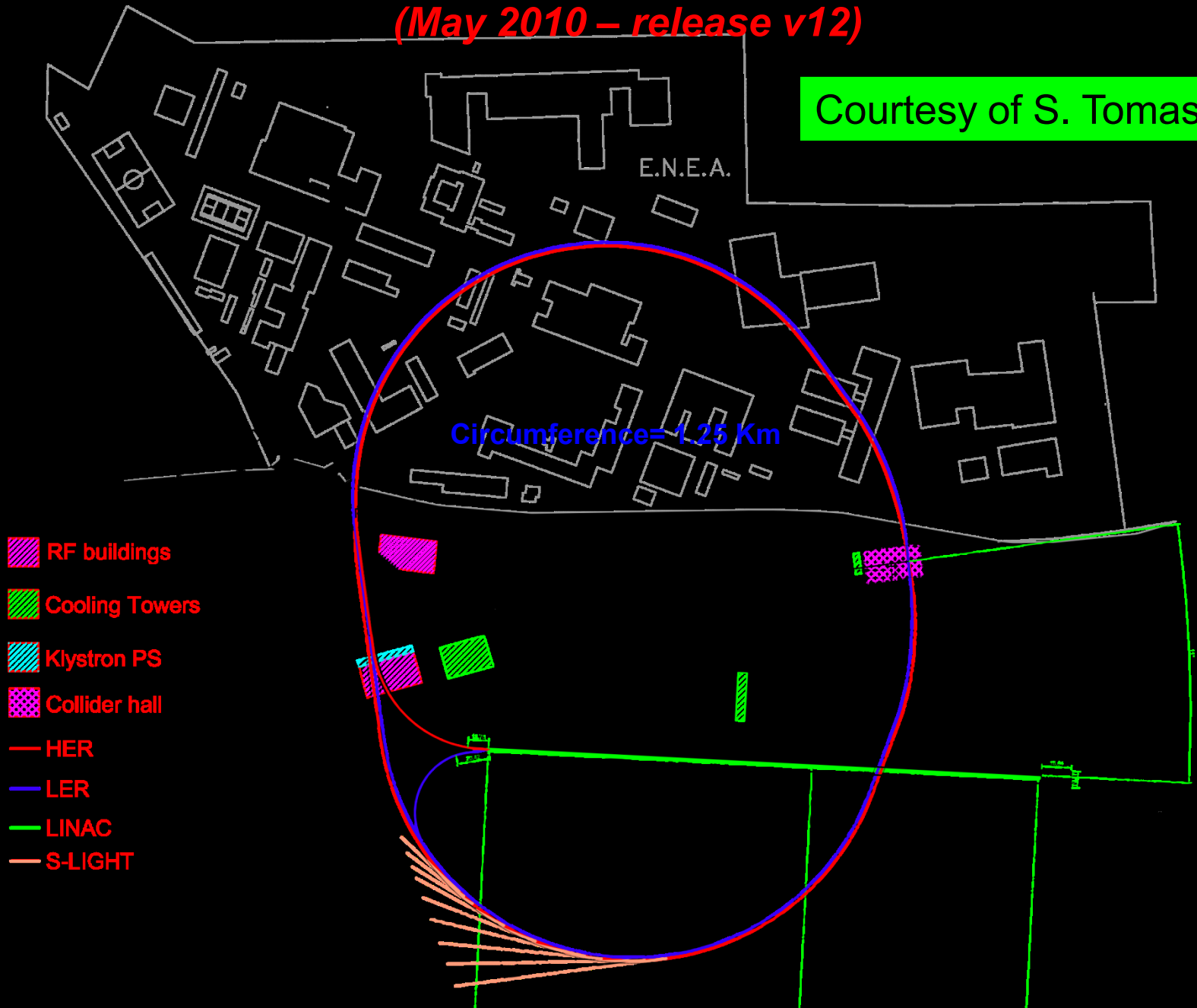


Site choice

- Site choice is the present main issue
- Frascati Lab is a possibility, however space available is small, and there may be conflicts with other future infrastructures
- Tor Vergata University may be the optimal choice (seems available now) due to “green field” status and vicinity to the LNF
- Other sites (North and South Italy) have been proposed and will be evaluated

(May 2010 – release v12)

Courtesy of S. Tomassini



SuperB footprint at LNF

SuperB parameters

- IP and ring parameters (see Table) have been optimized in order to:
 - Maintain wall plug power, beam currents, bunch lengths, and RF requirements comparable to past B-Factories
 - Reuse as much as possible of the PEP-II hardware
 - Have ring parameters as close as possible to those already achieved in the B-Factories, or under study for the ILC Damping Ring or achieved at the ATF ILC-DR test facility
 - Simplify IR design as much as possible. In particular, reduce the synchrotron radiation in the IR, reduce the HOM power and increase the beam stay-clear
 - Eliminate the effects of the parasitic beam crossing;
 - Relax as much as possible the requirements on the beam demagnification at the IP
 - Design the FF system to follow as closely as possible already tested systems, and integrating the system as much as possible into the ring design

(Bold: Computed Values)		Base Line		Low Emittance		High Current		Tau/Charm (prelim.)	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	cm⁻² s⁻¹	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
β _x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β _y @ IP	cm	0.0252	0.0206	0.0179	0.0146	0.0292	0.0238	0.0658	0.0536
Coupling (low current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
Emittance x (without IBS)	nm	1.97	1.82	0.97	0.9	1.97	1.82	1.97	1.82
Emittance x (with IBS)	nm	2.00	2.41	1.00	1.21	2.00	2.41	5.20	6.3
Emittance y	pm	5	5.8	2.5	2.9	10	12.05	13	15.75
Bunch length (zero current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
Bunch length (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2410	1465	1860	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Revolution frequency	Hz	2.38E+05		2.38E+05		2.38E+05		2.38E+05	
Harmonic number	#	1998		1998		1998		1998	
Number of bunches	#	978		978		1956		1956	
N. Particle/bunch	#	5.08E+10	6.46E+10	3.93E+10	4.99E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
σ _x @ IP	microns	7.211	8.782	5.099	6.223	10.060	12.243	18.749	22.895
σ _y @ IP	microns	0.035	0.035	0.021	0.021	0.054	0.054	0.092	0.092
σ _{x'} @ IP	microrad	277.4	274.4	196.1	194.5	198.8	196.8	277.4	275.2
σ _{y'} @ IP	microrad	140.9	167.8	118.2	140.9	185.1	225.0	140.6	171.4
Piwinski angle	rad	22.88	18.79	32.36	26.52	14.43	11.86	8.80	7.21
σ _x effective	microns	165.22	165.29	165.14	165.18	145.60	145.77	166.12	166.64
Σ _x	microns	11.363		8.045		15.846		29.592	
Σ _y	microns	0.050		0.030		0.076		0.130	
Σ _x effective	microns	233.35		233.35		205.34		233.35	
Hourglass Reduction Factor		0.950		0.950		0.950		0.950	
Tune shift x		0.0021	0.0033	0.0016	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0978	0.0978	0.0901	0.0901	0.0689	0.0689	0.0914	0.0915
Longitudinal damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.166
Momentum compaction		4.36E-04	4.05E-04	4.36E-04	4.05E-04	4.36E-04	4.05E-04	4.36E-04	4.05E-04
Energy spread (zero current)	dE/E	6.31E-04	6.68E-04	6.31E-04	6.68E-04	6.31E-04	6.68E-04	6.31E-04	6.68E-04
Energy spread (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM energy spread	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Energy acceptance	dE/E	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
SR power loss	MW	3.99	2.08	3.09	1.61	6.53	3.46	0.55	0.29
Touschek lifetime	min	35	16	17	8	70	32	17	8
Luminosity lifetime	min	4.82	6.14	3.72	4.72	7.85	10.14	34.60	44.77
Total lifetime	min	4.24	4.44	3.05	2.97	7.05	7.70	11.40	6.79
RF Wall Plug Power (SR only)	MW	12.15		9.40		19.98		1.68	
Total RF Wall Plug Power	MW	17.08		12.72		30.48		3.11	

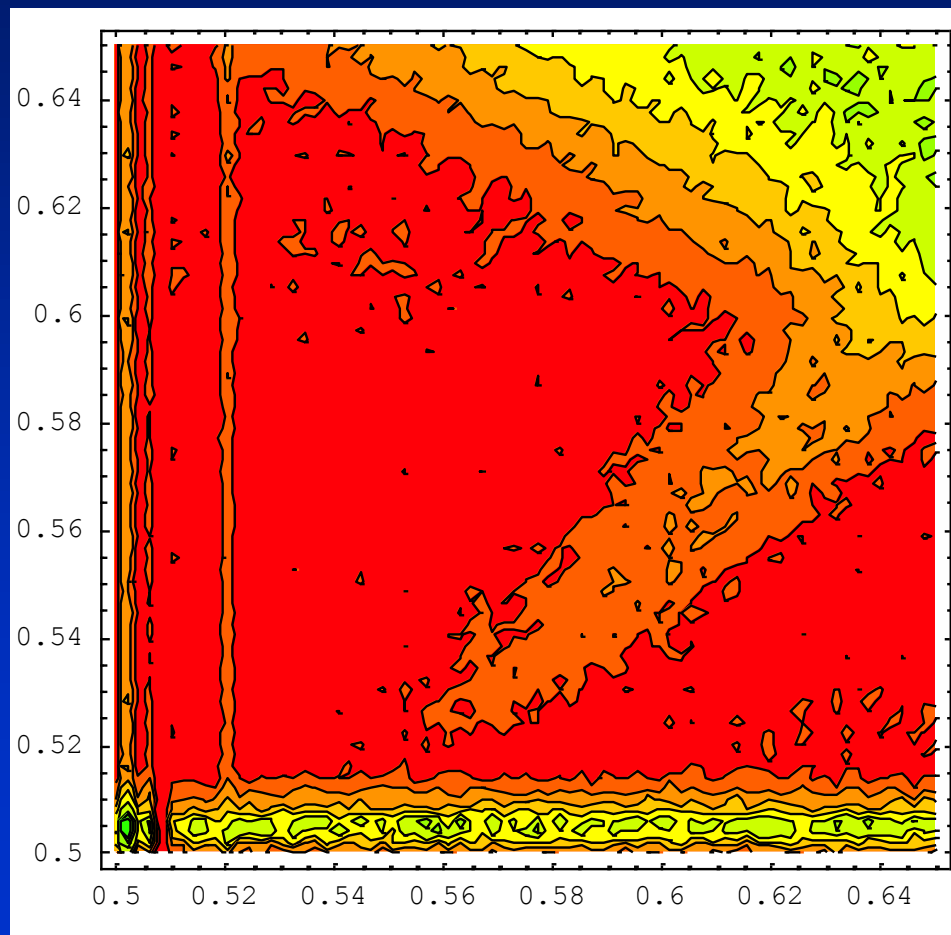
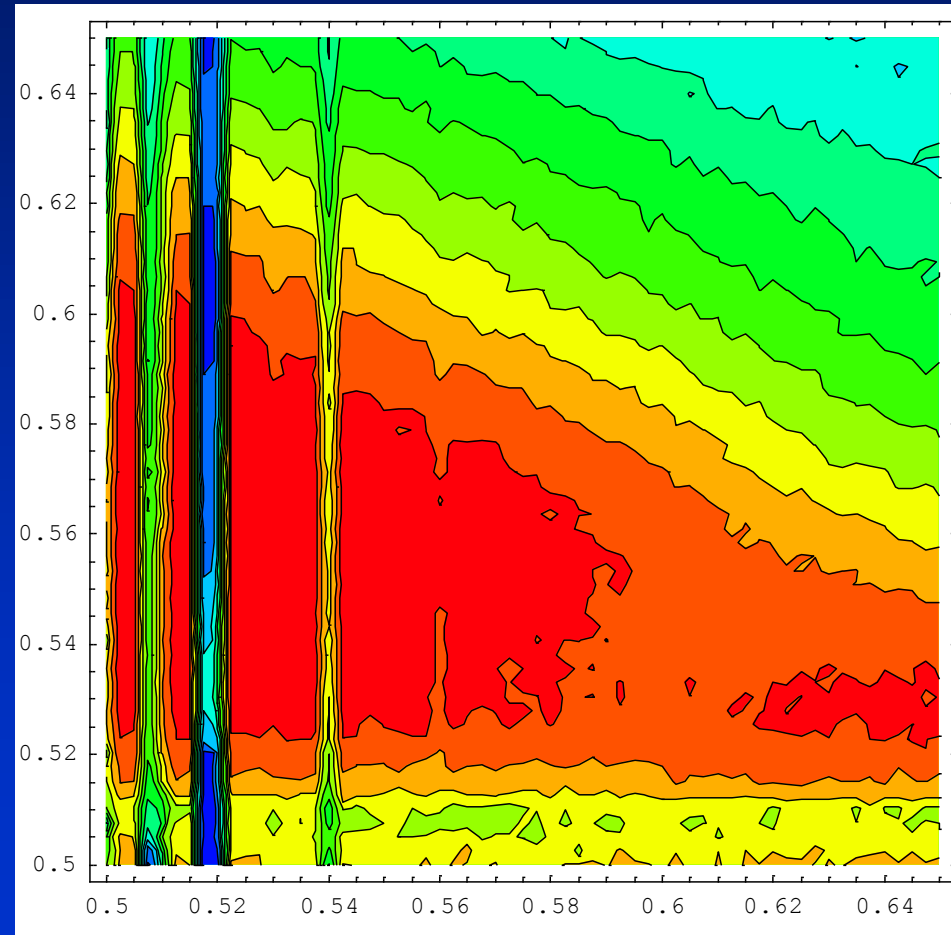


Beam-beam tune scan

Courtesy of D. Shatilov

CDR, $\xi_y = 0.17$

CDR2, $\xi_y = 0.097$



L (red) = $1 \cdot 10^{36}$

SuperB flexibility

- ❑ Rings are designed to have flexibility for the parameters choice with respect to the baseline. In particular:
 - horizontal emittance can be decreased by about a factor 2 in both rings by changing the partition number (by changing the RF frequency [LEP] or the orbit in the ARCS) and the natural ARC emittance by readjusting the lattice functions
 - Final Focus system as a built-in capability of about a factor 2 in decreasing the IP beta functions
 - RF system will be able to support higher beam currents (up to a factor 1.6) than the baseline ones, when all the available PEP RF units are installed
- ❑ “Low Emittance” set relaxes the RF requirements and all the problems related to high current operations (including wall-plug power) but put more strain on optics and tuning capabilities
- ❑ “High Current” set has the opposite characteristics: requirements on vertical emittance and IP beta functions are relaxed but the high currents issues are enhanced (instabilities, HOM and synchrotron radiation, wall-plug power etc...).
- ❑ In all sets several parameters are kept as much constant as possible (bunch length, IP stay clear etc...), in order to reduce their impact on Detector backgrounds, HOM heating, etc...

τ /charm running

- In order to operate at τ /charm threshold (about 3.8 GeV) with minimal modifications to the machine, the beam energies will be scaled, maintaining the nominal energy asymmetry ratio used for operation at the center-of-mass energy of the Y(4S)
- All magnet currents will be rescaled accordingly
- In order to provide the necessary damping at low current wigglers will be installed in the straight sections (dispersion free) and in the ARCs, in a relative number matched to achieve the desired beam parameters (emittance etc...). About 15-20m of wigglers will be needed, their total lengths depends from the field in the wigglers (to be studied). The permanent magnets in the IR will be replaced with weaker versions
- Main differences in the ring properties will be:
 - lower energy by a factor of about 2.6-2.8 per ring
 - longer damping time by a factor of about 2.0 per ring
 - decreased Touschek lifetime by a factor of 3-6
 - increased sensitivity to collective effects

τ /charm running

- ❑ Luminosity should scale linearly with energy, however damping times and collective effects will result in a further decrease the luminosity. In general, the luminosity dependence is less then linear with respect to the damping times (about $\tau^{-0.3}$ in beam-beam limit regime).
- ❑ Given all factors, we expect that operations at lower energy will require a decrease of the beam current and an increase of the beam emittance
- ❑ It is thus reasonable to expect a luminosity about 10 times smaller than that at 10.58 GeV

Latest lattice studies

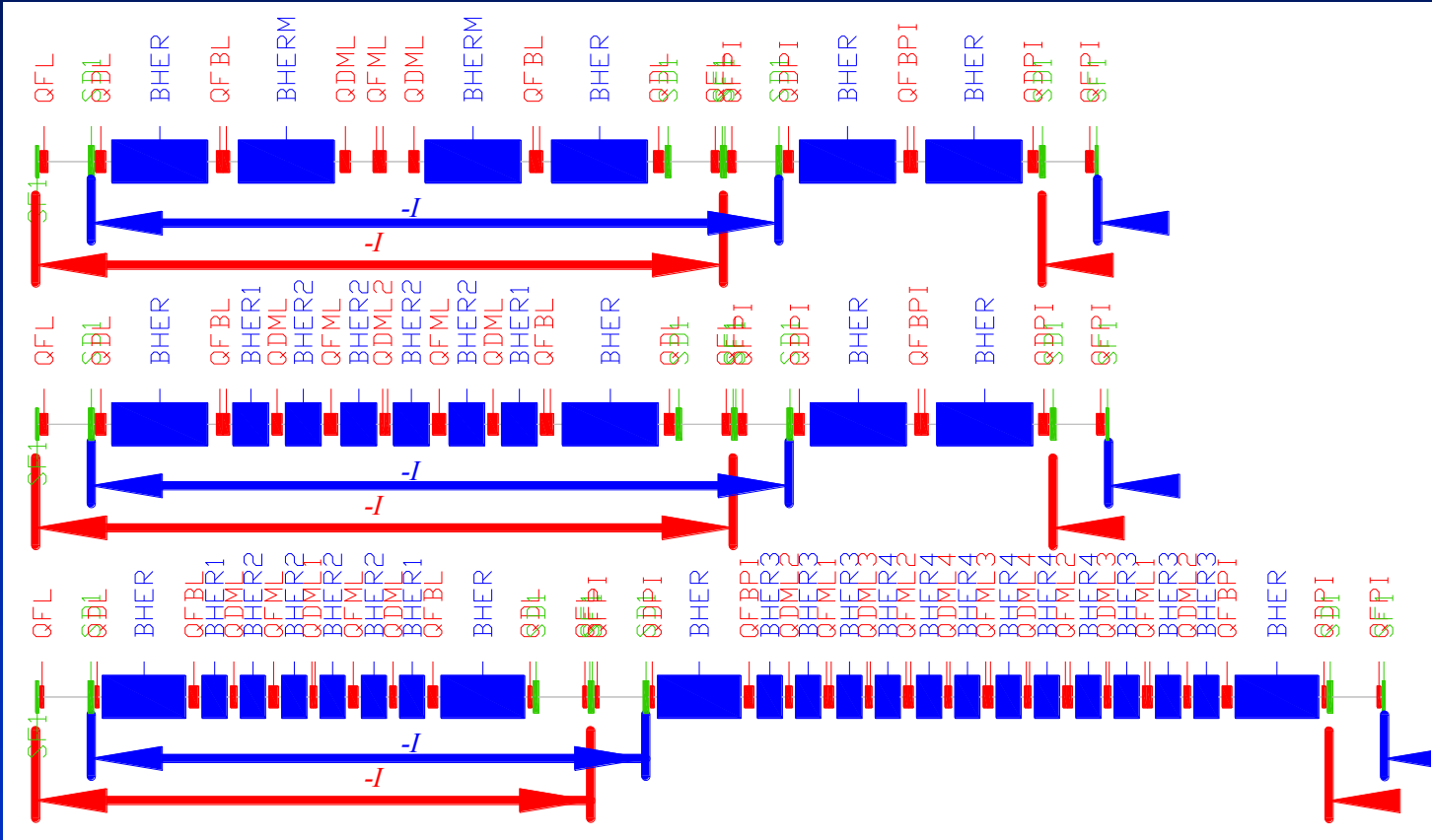
- Modified V12 (CDR2) 3π ARC cell lattice with alternating long and short arc cells → V13
- Modified Final Focus design for better performances
- Near-IP lattice with detector solenoids and compensation of coupling Some studies also performed for a shorter Ring (V14)
- Lattice design is still in evolution, at present we are studying the possibility to have different length rings (LER half of HER) → needs bb simulations for possible dangerous resonances (see Keil-Hirata)

Layout of HER arcs (Sep.'10)

V12

V13

V14



V12 = CDR2 lattice
V13 = modified V12 (new arcs)
V14 = shorter ring (on hold)

Courtesy of S. Sinyatkin



SuperB lattices parameter list

(Bold: computed values)		V12		V13		V14	
Parameter	Units	HER [e-]	LER [e-]	HER [e-]	LER [e-]	HER [e-]	LER [e-]
LUMINOSITY	cm⁻² s⁻¹	1.00E+36		1.10E+36		1.1E+36	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18
Circumference	m	1258.4		1263.5		1159.5	
X-Angle (full)	mrad	66		60		50	
β _x @ IP	cm	2.6	3.2	2.6	3.2	2.6	3.2
β _y @ IP	cm	0.0253	0.0205	0.0253	0.0205	0.0253	0.0205
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.25	0.25
Emittance x (without IBS)	nm	1.97	1.82	2.09	1.93	1.90	1.82
Emittance x (with IBS)	nm	2.07	2.37	2.19	2.51	2.00	2.37
Emittance y	pm	5.17	5.92	5.49	6.27	4.99	5.92
Bunch length (zero current)	mm	4.69	4.29	4.8	4.4	4.53	4.29
Bunch length (full current)	mm	5	5	5	5	5	5
Beam current	mA	1892	2447	1930	2470	1892	2447
Buckets distance	#	2		2		2	
Ion gap	%	2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08	
Revolution frequency	Hz	2.38E+05		2.37E+05		2.59E+05	
Harmonic number	#	1998		2006		1841	
Number of bunches	#	978		982		901	
N. Particle/bunch	#	5.08E+10	6.56E+10	5.18E+10	6.63E+10	5.08E+10	6.57E+10
σ _x @ IP	microns	7.334	8.701	7.554	8.960	7.262	8.701
σ _y @ IP	microns	0.036	0.035	0.037	0.036	0.036	0.035
σ _x ' @ IP	microrad	282.1	271.9	290.5	280.0	277.0	271.9
σ _y ' @ IP	microrad	143.0	169.9	147.3	174.9	140.4	169.9
Piwinski angle	rad	22.50	18.96	19.86	16.74	20.93	17.24
σ _x effective	microns	165.22	165.29	150.24	150.31	150.22	150.30
Σ _x	microns	11.379		11.719		11.295	
Σ _y	microns	0.050		0.052		0.050	
Σ _x effective	microns	233.35		212.13		212.13	
Hourglass reduction factor		0.950		0.950		0.950	
Tune shift x		0.0021	0.0033	0.0026	0.0040	0.0026	0.0040
Tune shift y		0.0989	0.0955	0.1067	0.1041	0.1089	0.1070
Longitudinal damping time	msec	13.4	20.3	13.6	20.6	11.6	20.3
Energy Loss/turn	MeV	2.11	0.865	2.08	0.88	2.24	0.865
Momentum compaction		4.36E-04	4.05E-04	4.69E-04	4.35E-04	4.60E-04	4.05E-04
Energy spread (zero current)	dE/E	6.31E-04	6.68E-04	6.30E-04	6.68E-04	6.52E-04	6.68E-04
Energy spread (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.64E-04	7.34E-04
CM energy spread	dE/E	5.00E-04		5.00E-04		5.11E-04	
Energy acceptance	dE/E	0.01	0.01	0.01	0.01	0.01	0.01
SR power loss	MW	3.99	2.12	4.01	2.17	4.24	2.12
Touschek lifetime	min	33	16	33	16	33	16
Luminosity lifetime	min	4.81	6.22	4.48	5.73	3.99	5.16
Total lifetime	min	4.20	4.48	3.94	4.22	3.56	3.90
RF Wall Plug Power (SR only)	MW	12.22		12.38		12.71	
Total RF Wall Plug Power	MW	17.08					

V12 = CDR2 lattice
V13 = modified V12 (new arcs)
V14 = shorter ring (on hold)

Intra Beam Scattering

- Effect of IBS on transverse emittances about 30% in LER and less than 5% in HER, still reasonable if applied to lattice natural emittances values
- Interesting aspects of the IBS such as its impact on damping process and on generation of non Gaussian tails may be investigated with a multi-particle code being developed:
 - Benchmarking with conventional IBS theories gave good results
- Preliminary FORTRAN (faster!) version of the code produced:
 - Remaining features are going to be included very soon
 - Started collaboration with M. Pivi (SLAC) to include the IBS in CMAD (parallel, faster)
- Started studies on full lattice (including coupling and errors)

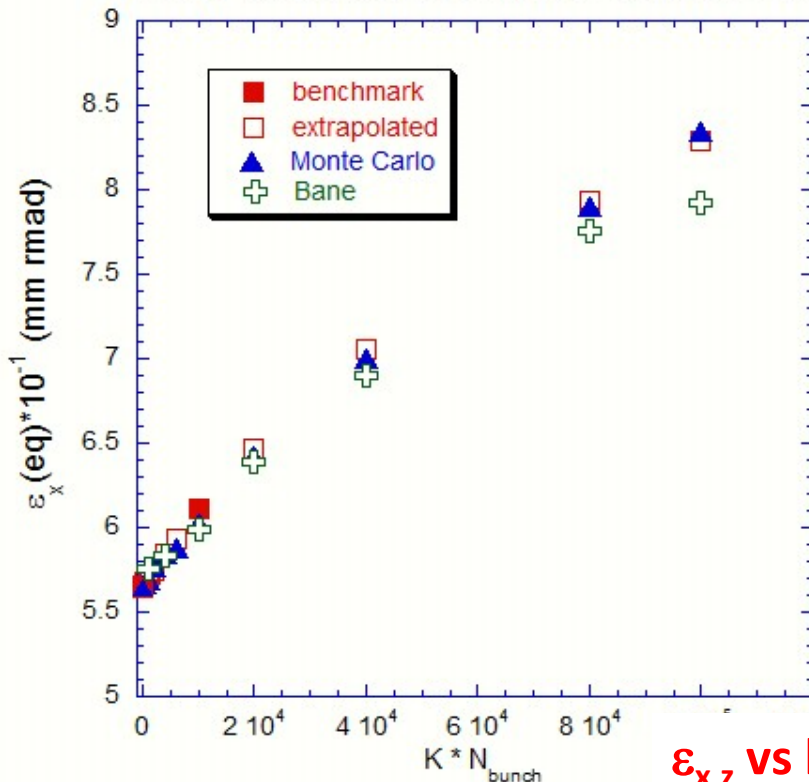
IBS evaluation methods comparison

Courtesy of T. Demma

3 methods used, all in good agreement:

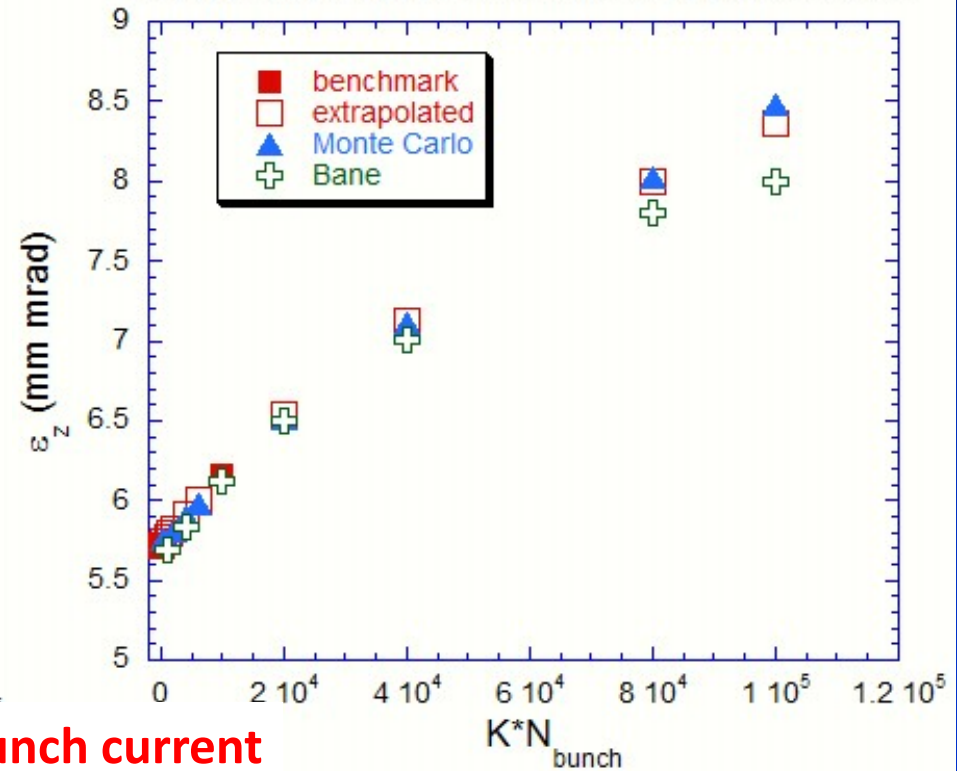
- **Bane** (theoretical), allows for emittance growth rates estimate
- **Chao** (theoretical), allows for emittance time evolution estimate
- **6D MonteCarlo** → more accurate, all of above, will include non-gaussian tails, soon to be translated from Mathematica to Fortran for speed and precision reasons (collaboration with M. Pivi, SLAC)

steady-state horizontal emittance vs bunch current



$\epsilon_{x,z}$ vs bunch current

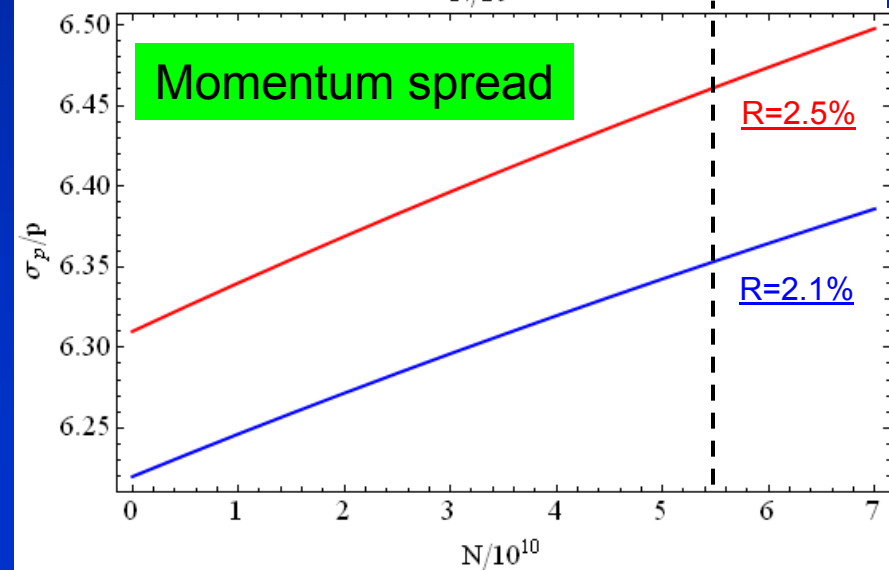
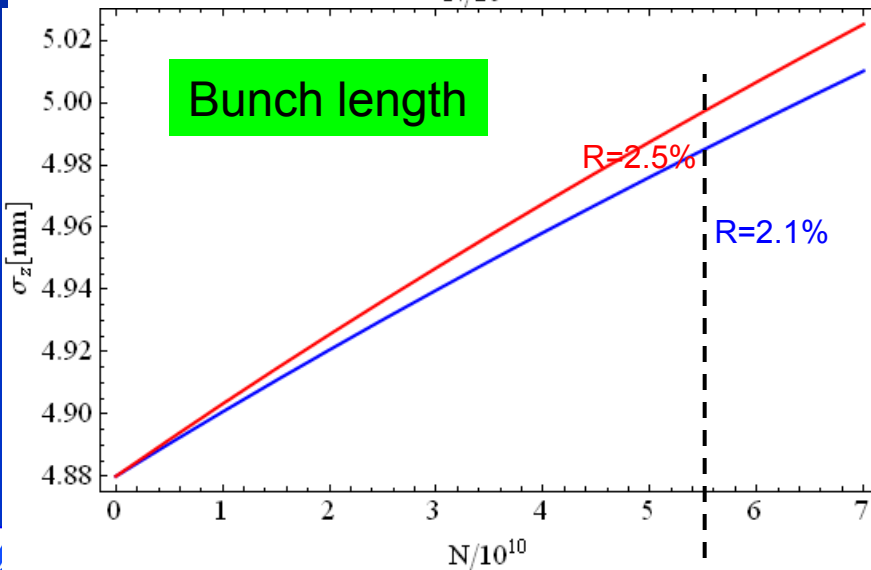
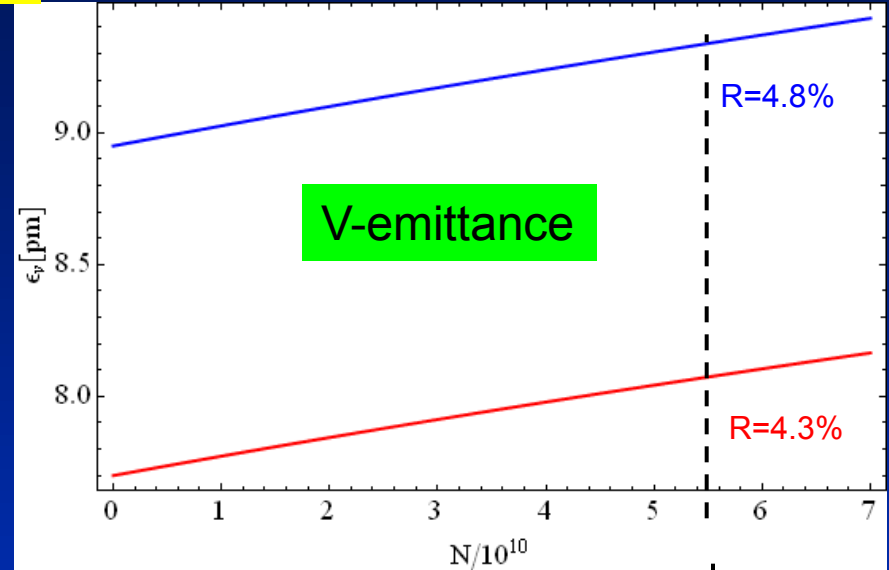
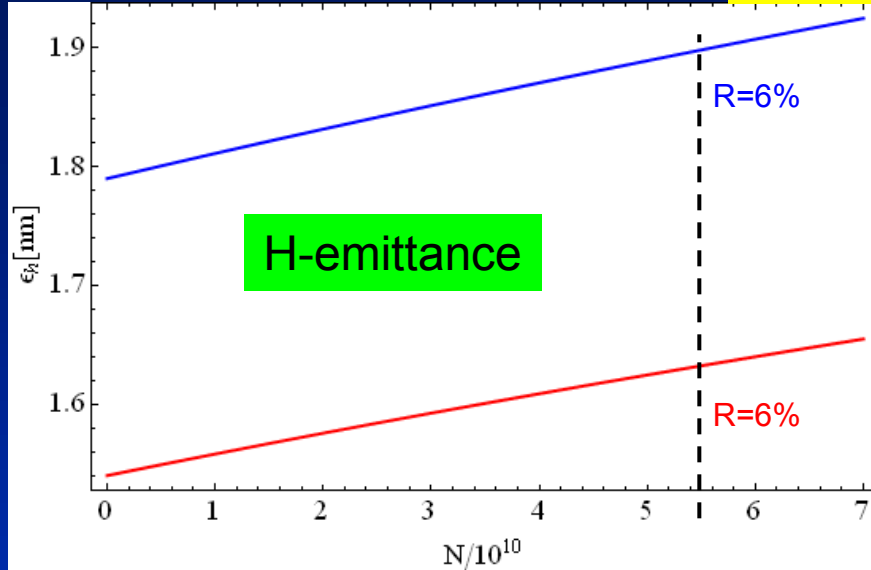
steady-state longitudinal emittance vs bunch current



IBS in SuperB HER ($\tau_h = \tau_v = 2$ $\tau_s = 40$ ms)

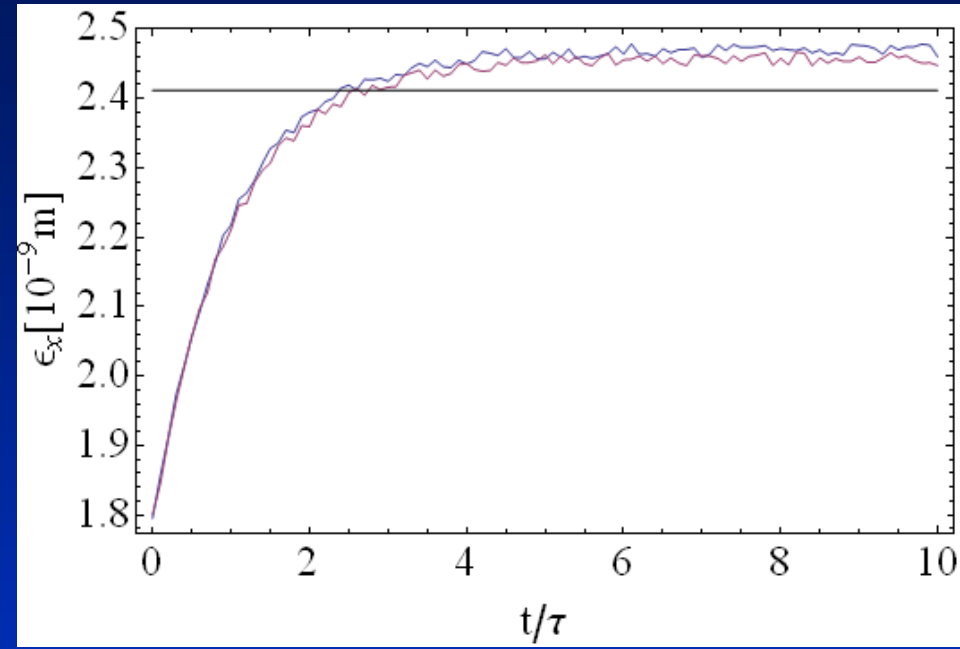
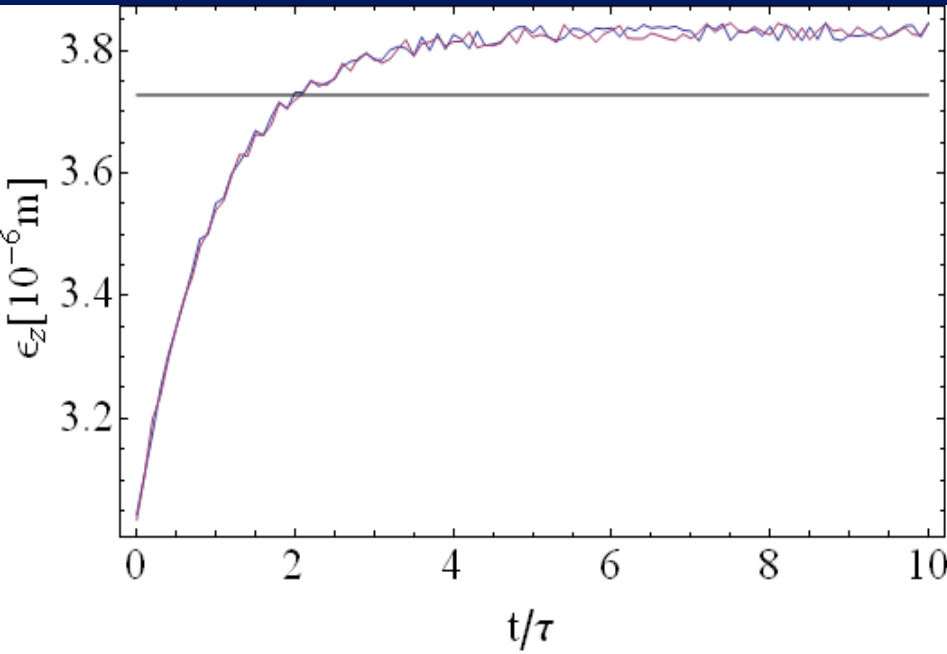
V13 vs V12

Courtesy of T. Demma



Multi-particle tracking of IBS in LER

Courtesy of T. Demma



MacroParticleNumber=10000

NTurn=10000 (≈ 10 damping times)

$$\sigma_z = 5.0 \cdot 10^{-3} \text{ m}$$

$$\delta p = 6.3 \cdot 10^{-4}$$

$$\epsilon_x = 1.8 \cdot 10^{-9} \text{ m}$$

$$\epsilon_y = 0.25/100 \cdot \epsilon_x$$

$$\tau_x = 100^{-1} \cdot 0.040 \text{ sec}$$

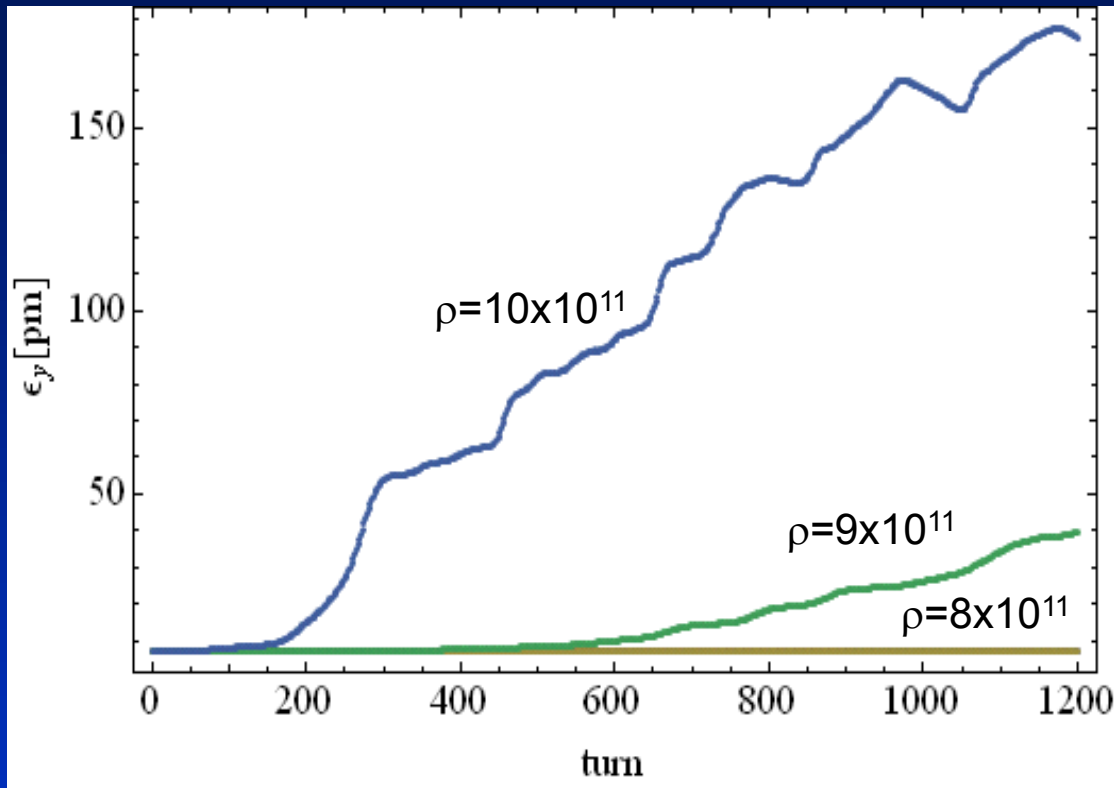
$$\tau_y = 100^{-1} \cdot 0.040 \text{ sec}$$

$$\tau_s = 100^{-1} \cdot 0.020 \text{ sec}$$

Mathematica vs Fortran implementation of the IBS multi-particle tracking code. The Fortran version is more than 1 order of magnitude faster!



Emittance growth due to head-tail instability



Input parameters for CMAD

Beam energy E[GeV]	6.7
circumference L[m]	1200
bunch population N_b	5.06×10^{10}
bunch length σ_z [mm]	5
horizontal emittance ϵ_x [nm rad]	1.6
vertical emittance ϵ_y [pm rad]	4
hor./vert. betatron tune Q_x/Q_y	40.57/17.59
synchrotron tune Q_z	0.01
momentum compaction α	4.04×10^{-4}

Taking into account the effect of solenoids in drifts, the interaction between the beam and the cloud is evaluated only in the magnetic regions of the SuperB HER (V12) for different values of the electron cloud density.

The threshold density is determined by the density at which the growth starts:

$$\rho_{e,th} = 9 \times 10^{11} \text{ m}^{-3}$$

Courtesy of T. Demma

Low Emittance Tuning for LER

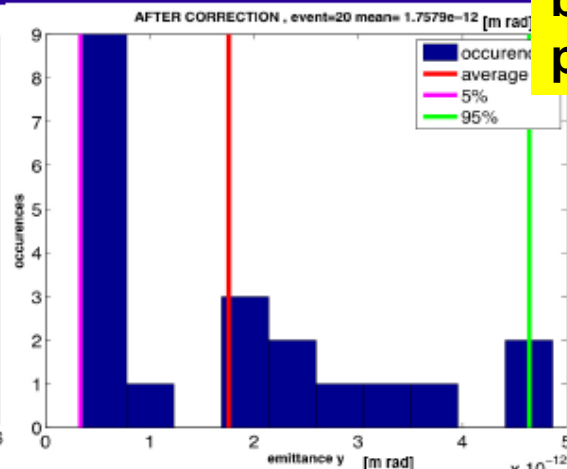
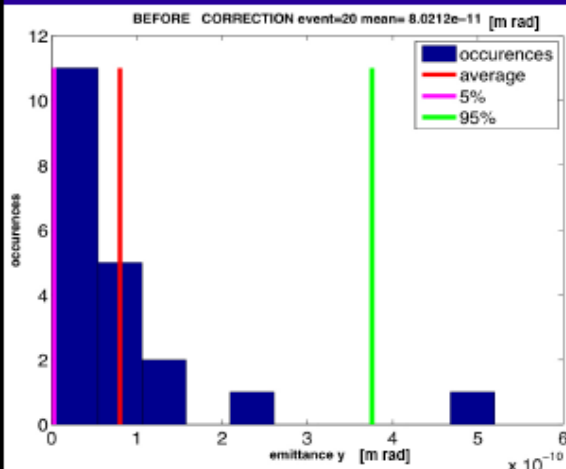
LER

Elements From QF1R to QF1L are considered as a single element.

109-ARCS+60-FF

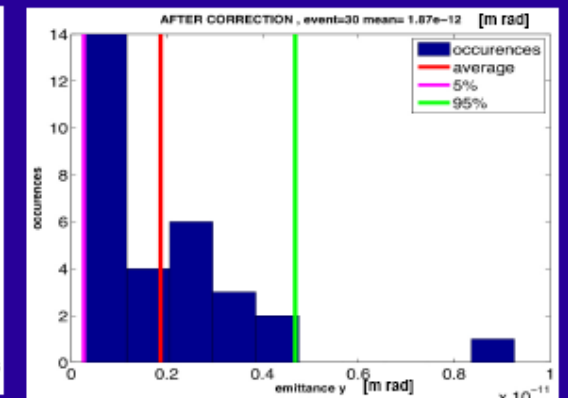
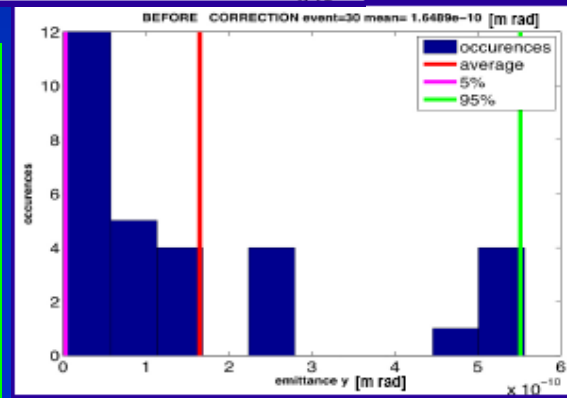
Misalignment	Tolerated value	
	ARC	FF
Quadrupole H and V	50 μm	20 μm
Quadrupole Tilt	50 μrad	20 μrad
Sextupole H and V	50 μm	20 μm
BPM resolution	1 μm	1 μm
BPM Offset	50 μm	20 μm

LER ARC's tolerances evaluated using a Response Matrix technique that optimizes orbit, in order to recover the design values for Dispersion, Coupling and Beta-beating, and obtain the lowest possible vertical emittance



Misalignment	Value	
	ARC	FF
Quadrupole H and V	50 μm	00 μm
Quadrupole Tilt	50 μrad	00 μrad
Sextupole H and V	50 μm	00 μm
BPM resolution	1 μm	0 μm
BPM Offset	50 μm	00 μm

Different sets of correctors tested, may be reduced to 109. Final Focus introduces stringent restrictions on alignment of both FF and ARCS (even for no errors in FF)



The introduction of the Final Focus In the lattice defines more stringent tolerances also in the arcs



Courtesy of S. Liuzzo

IR Summary

Courtesy of M. Sullivan

- ❑ Crossing angle back to 60 mrad
 - This removes some of the space for the PM slices as well as the dual quad super-conducting magnets
 - Presently the dimensions of these elements are “snug” but acceptable at this stage (actual engineering requirements will no doubt alter the design again)

- ❑ We have two designs that work for SR backgrounds
 - Vanadium Permendur (with Holmium as an option)
 - Parallel air-core dual quads + vanadium permendur Panofsky quads on the HER

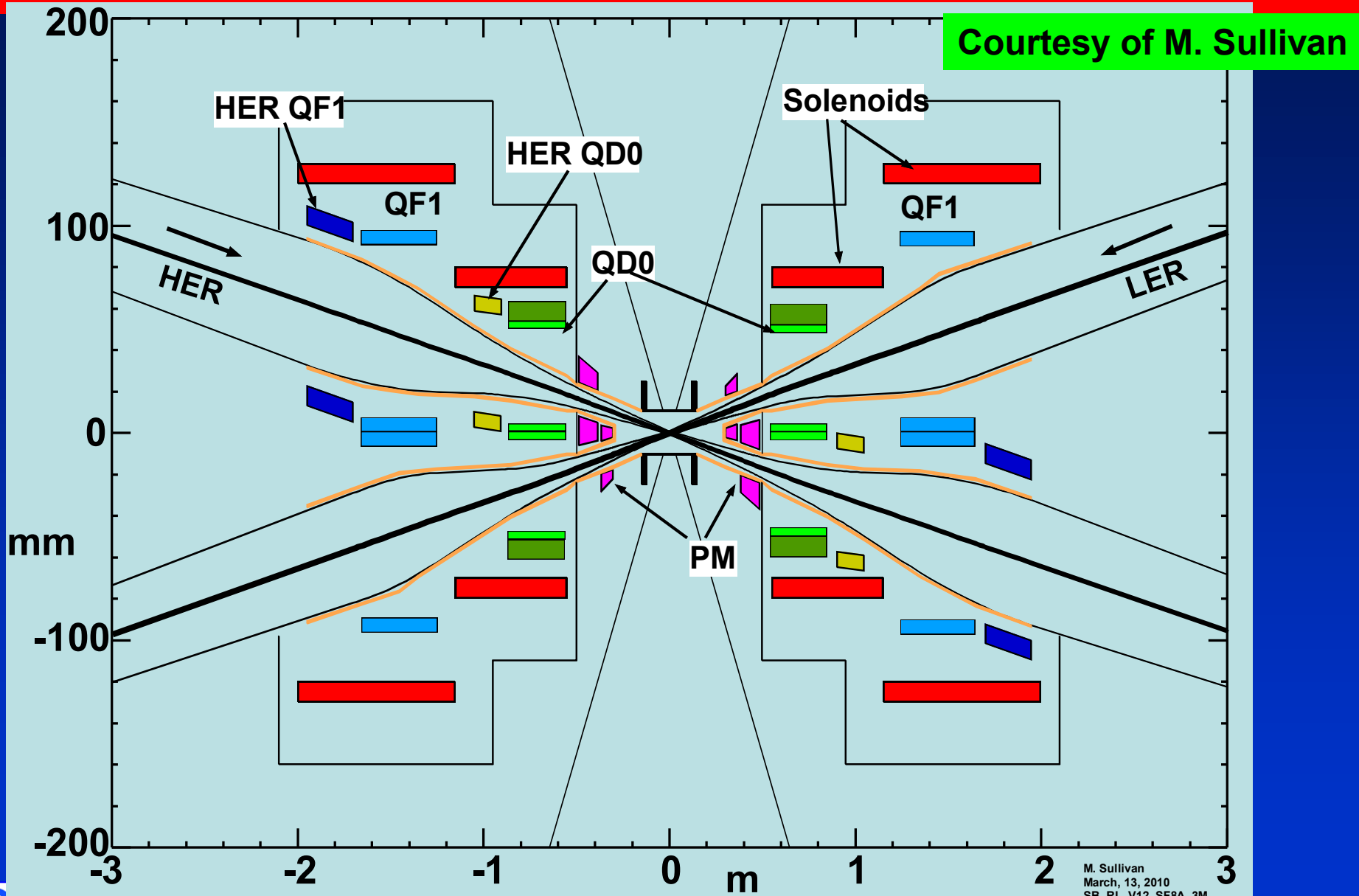
- ❑ Good progress is being made on the design of the QD0
 - The engineering details for the “Italian” SC design are being studied
 - A prototype Panofsky style QD0 is planned for the BINP C-tau design

- ❑ An overall vibration control design is being developed for the FF magnets

- ❑ We have a first look at correcting the effects of the detector solenoid in hand

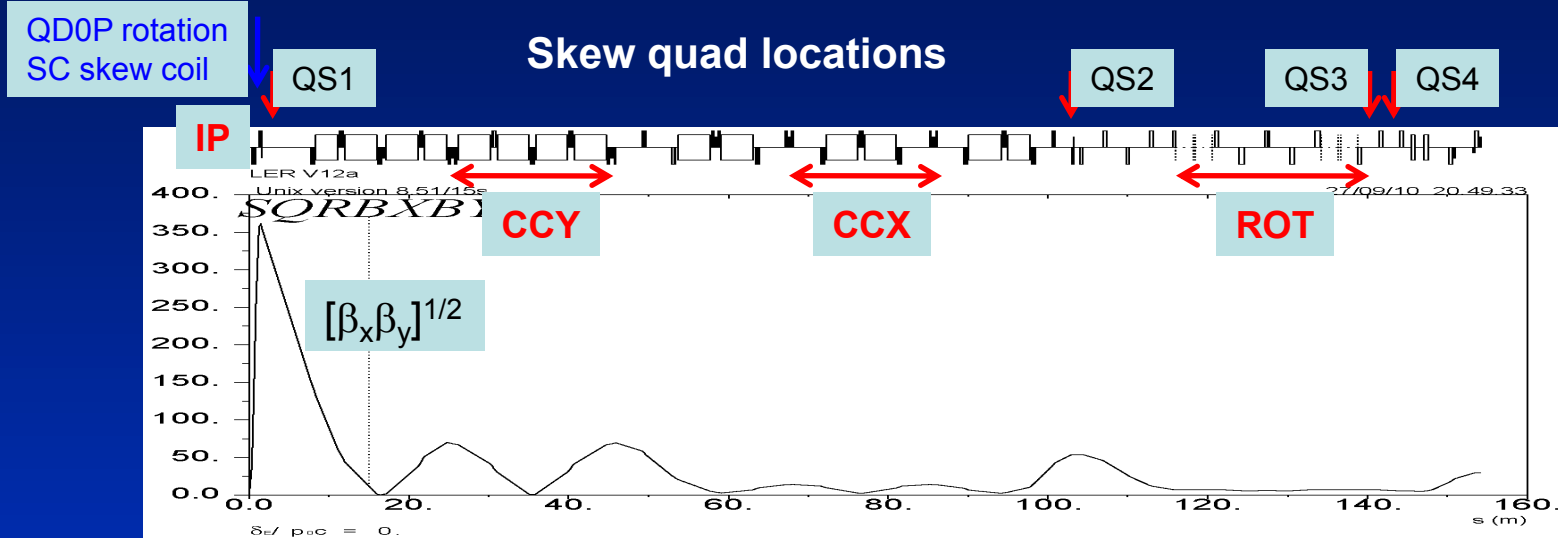
- ❑ The polarimeter design is being studied to enable measuring transverse polarization

Air core "Italian" QD0, QF1

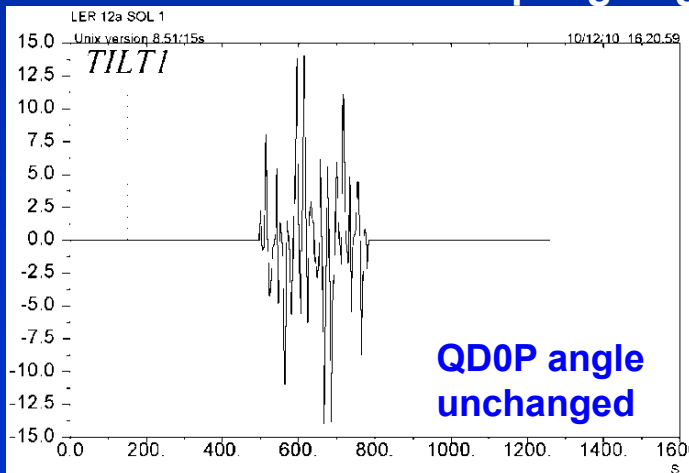


Coupling correction with detector solenoid OFF

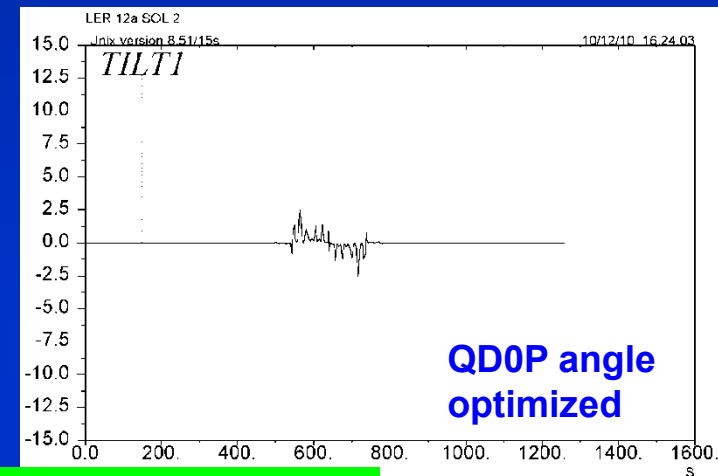
Assumptions: 1) detector solenoid, bucking solenoids and anti-solenoid are OFF; 2) SC skew quad coil is ON; 3) Permanent quad QD0P rotation angle is adjustable. Correction is done using QS1, QS2, QS3, QS4 skew quads.



Coupling angle after correction



QD0P angle unchanged



QD0P angle optimized

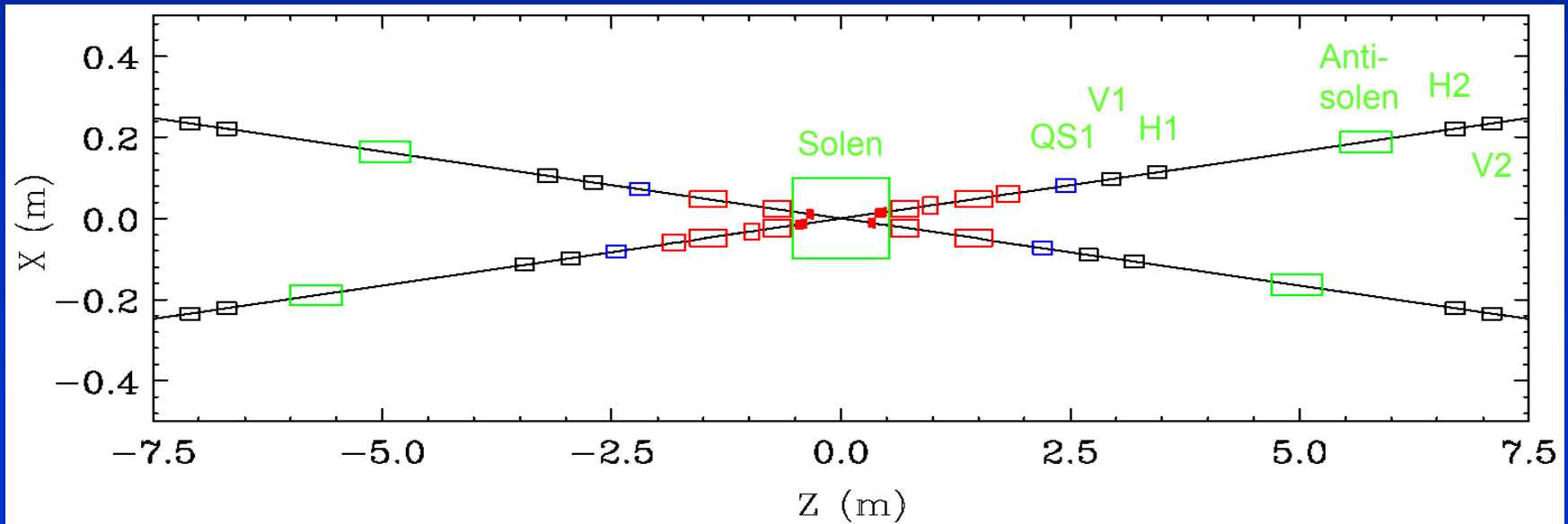
Courtesy of Y. Novokhatski



Coupling correction with detector solenoid ON

- The model assumes that the compensating solenoids in the cryostats zero out the detector field everywhere except ± 0.55 m from the IP
- First “linear” correction: as things become more stable a more sophisticated model and correction scheme can be developed that includes the non-linear terms
- The designed correction system compensates each half-IR independently and contains on each side of IP:
 - Rotated permanent quads
 - Skew winding on SC quads to simulate rotation
 - SC anti-solenoid of strength $1.5\text{T} \times 0.55$ m aligned with the beam axis
 - 2 vertical and 2 horizontal dipole correctors for orbit correction
 - 4 skew quads at non-dispersive locations for coupling correction
 - 2 skew quads at dispersive locations for correction of vertical dispersion and slope
 - nominal FF quads are used to rematch the Twiss functions and horizontal dispersion

Courtesy of Y. Novokhatski



Other correctors are outside of this region

Vibrations studies

Courtesy of K. Bertsche

- Measured ground motion at LNF (possible site?)
- Must keep quad motion below $1\ \mu\text{m}$
 - Cantilevered cryostat should be designed for low vibration
 - Damp resonances and push $> 10\ \text{Hz}$
 - Support cryostat on both sides of detector door
- Must keep cryostat rotation below $2\ \mu\text{rad}$
 - Avoid building torques into magnet supports
- Beam feedback should extend to $> 100\text{Hz}$, provide $> 10\text{x}$ vibration reduction at LF
 - But we may not even need beam feedback during quiet parts of day
- Vibration should not be a problem for SuperB at LNF, even at rush hour, need to be evaluated for other sites

What we would like to achieve with SVET

- ❑ To learn on emittance measurement diagnostics
- ❑ To apply and check Simone's LET tools to SLS to achieve minimum emittance and coupling and detect misalignments
- ❑ To collaborate in studies and simulation of IBS (most for the τ /charm running)
- ❑ To study coupling control methods to optimize SuperB design
- ❑ To participate to MD shifts
- ❑ All this with very few resources... (11.5 p-m, 9 keuro for 3 years) !