SuperB a Super-Flavour-Factory

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on behalf of the SuperB Accelerator Team

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SuperB INFN Istituto Nazionale di Fisica Nucleare

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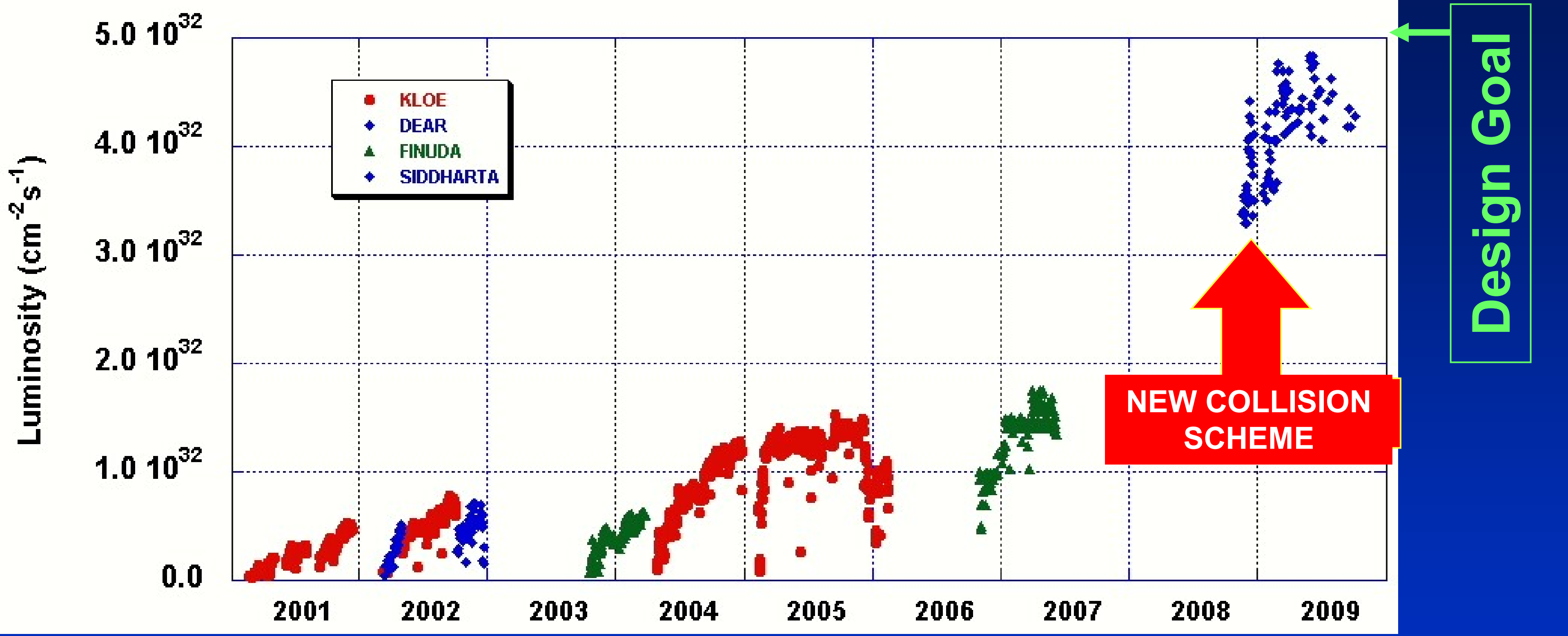
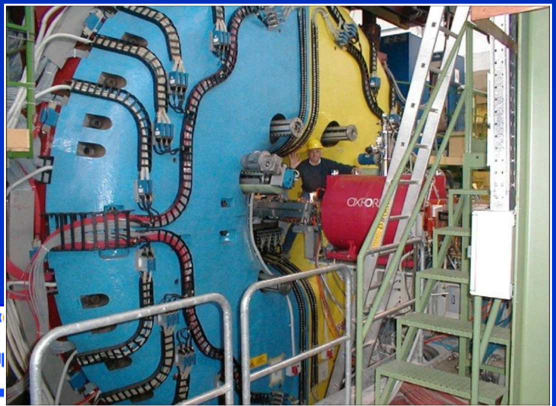
SuperB Accelerator

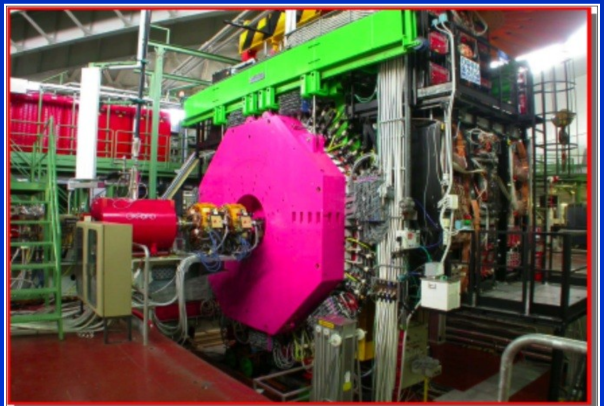
- SuperB is a 2 rings, asymmetric energies (e^- @ 4.18, e^+ @ 6.7 GeV) collider with:
  - large Piwinski angle and "crab waist" (LPA & CW) collision scheme
  - ultra low emittance lattices
  - longitudinally polarized electron beam
  - target luminosity of 10^{36} cm^{-2} s^{-1} at the $\Upsilon(4S)$
  - possibility to run at τ/charm threshold with L = 10^{35} cm^{-2} s^{-1}
- Criterias used for the design:
  - Minimize building costs
  - Minimize running costs
  - Minimize wall-plug power and water consumption
  - Reuse of some PEP-II B-Factory hardware (magnets, RF)
- SuperB can be also a good "light source": there will be some Sinchrotron Radiation beamlines (collaboration with Italian Institute of Technology) → work in progress

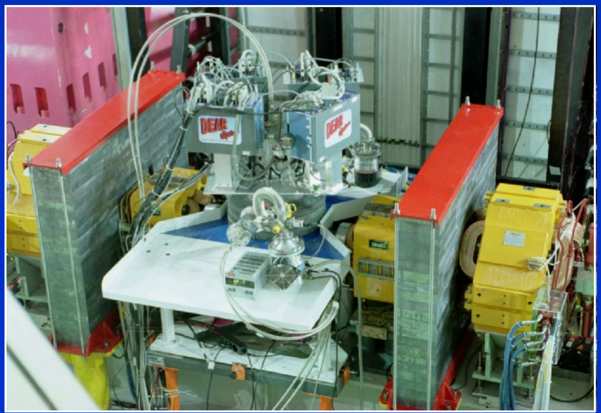
DAΦNE Peak Luminosity

LPA & Crab Waist successfully tested at DAΦNE in 2008-09









SuperB design

- The design requires state-of-the-art technology for emittance and coupling minimization, optics control and modeling, vibrations and misalignment control, e^-cloud suppression, etc...
- SuperB has many similarities with the Damping Rings of ILC and CLIC, and with the latest generation SR sources, and can profit from the collaboration among these communities
- For details see the new Conceptual Design Report (Dec. 2010) on:

http://arxiv.org/abs/1009.6178

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SuperB Parameters

- IP and ring parameters have been optimized based on several constraints. The most significant are:
  - Maintain wall plug power, beam currents, bunch lengths, and RF requirements comparable to past B-Factories;
  - Plan for the reuse as much as possible of the PEP-II hardware;
  - Require 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;
  - Design the Final Focus system to follow as closely as possible already tested systems, and integrating the system as much as possible into the ring design

SuperB Parameters (cont.)

- The machine is also designed to have flexibility for the parameters choice with respect to the baseline:

  1. Low Emittance case relaxes the RF requirements and all the problems related to high current operations (including wall-plug power) but put more strain on the optics and the tuning capabilities
  2. High Current case has the opposite characteristics. The requirements on vertical emittance and IP β-functions are relaxed but the high currents issues are enhanced (instabilities, HOM and synchrotron radiation, wall-plug power,…)

- How?
  - Design horizontal emittance can still be decreased in both rings;
  - 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-II RF units are installed

- Possibility to run at the τ/charm threshold installing damping wigglers, with a Luminosity of 10^{35} cm^{-2} s^{-1}

Parameter Table

		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	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.099	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	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	
Harmonic number		1998		1998		1998		1998	
Number of bunches		978		978		1956		1956	
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0970	0.0971	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Long. 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
σ_E (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 σ_E	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

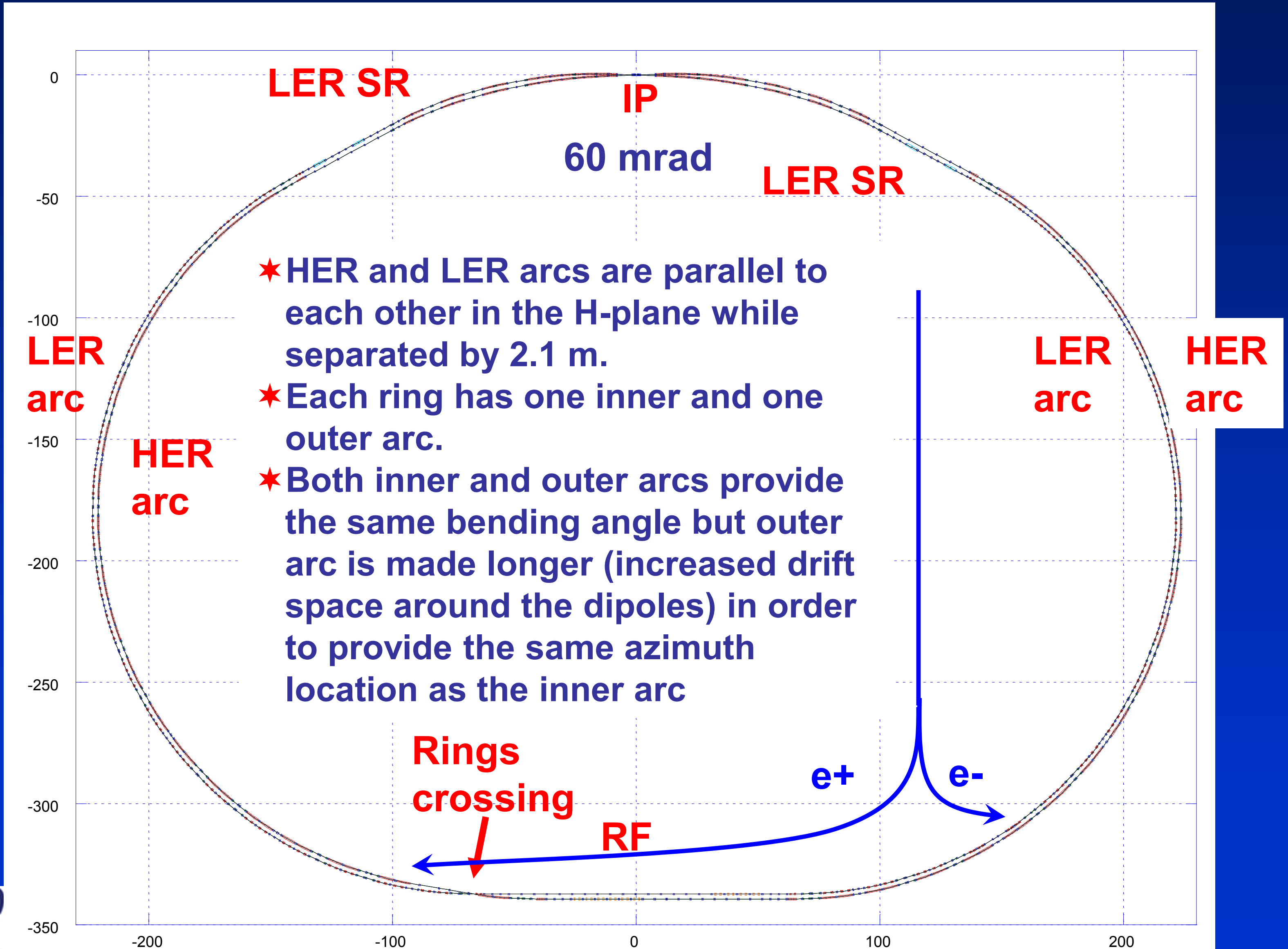
Tau/charm threshold running at 10^{35}

Baseline:
- **Higher emittance due to IBS**
- **Asymmetric beam currents**

2 other options:
- **Lower emittances**
- **Higher currents (twice bunches)**

RF power includes SR and HOM

Layout 2 rings, 1 tunnel

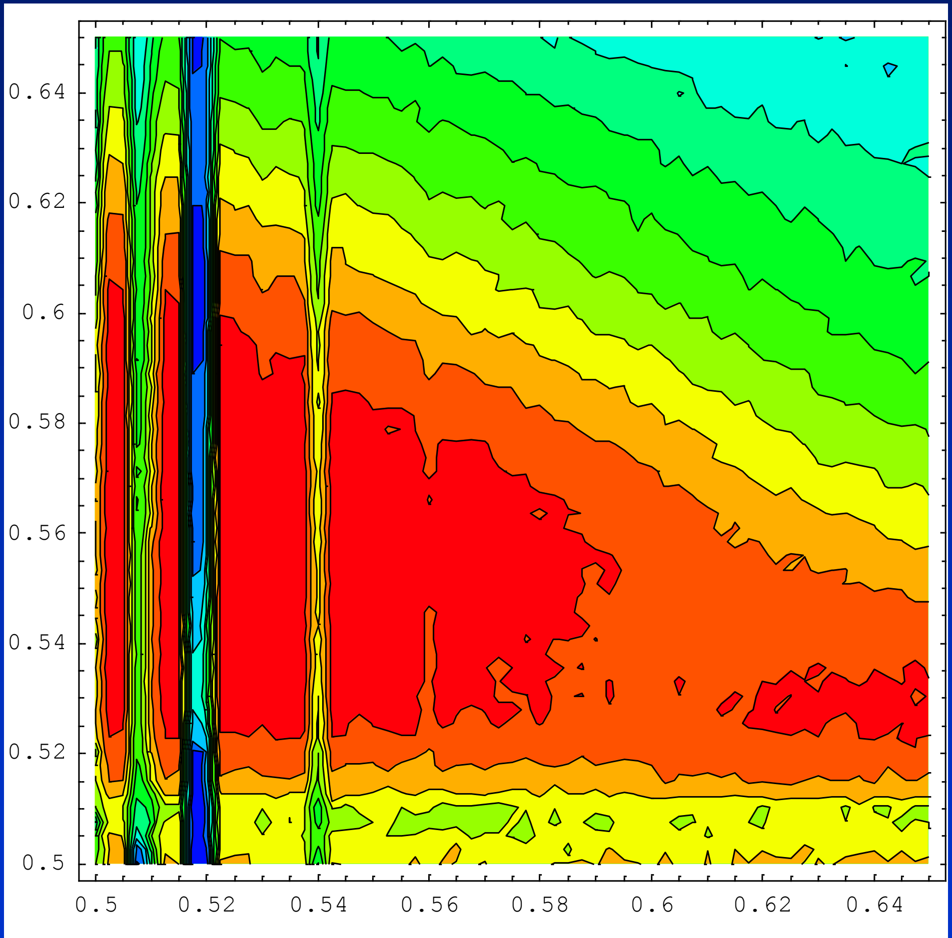


- HER and LER arcs are parallel to each other in the H-plane while separated by 2.1 m.
- Each ring has one inner and one outer arc.
- Both inner and outer arcs provide the same bending angle but outer arc is made longer (increased drift space around the dipoles) in order to provide the same azimuth location as the inner arc

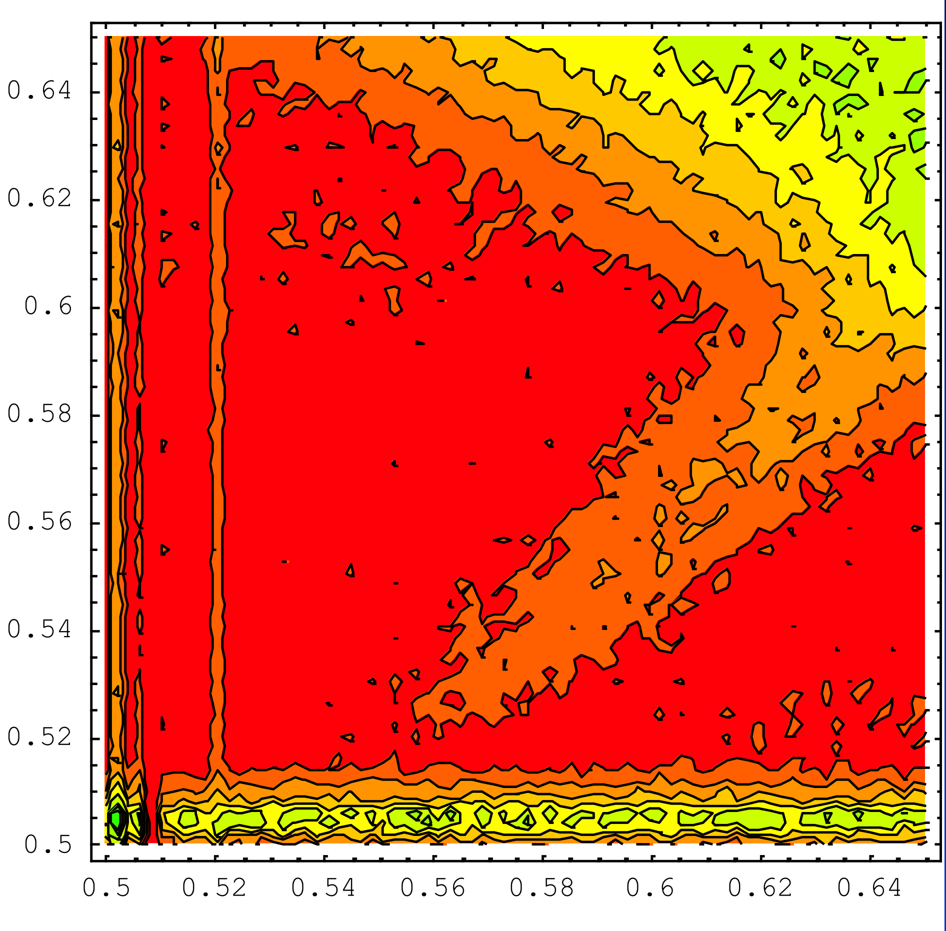
Beam-beam tune scan

D.Shatilov

CDR, $\xi_y = 0.17$



CDR2, $\xi_y = 0.097$



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

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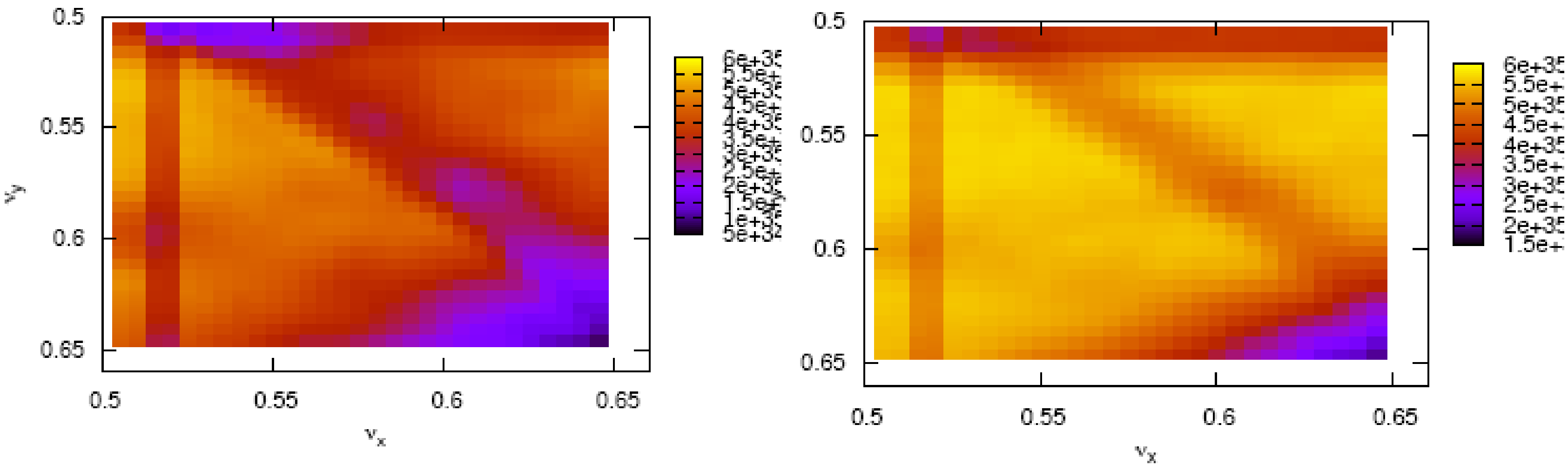
Strong-strong bb

K.Ohmi

Tune scan with/without crab waist

No crab waist | crab waist



- Crab waist gives better performance.
- Synchro-beta resonance is seen in both cases.

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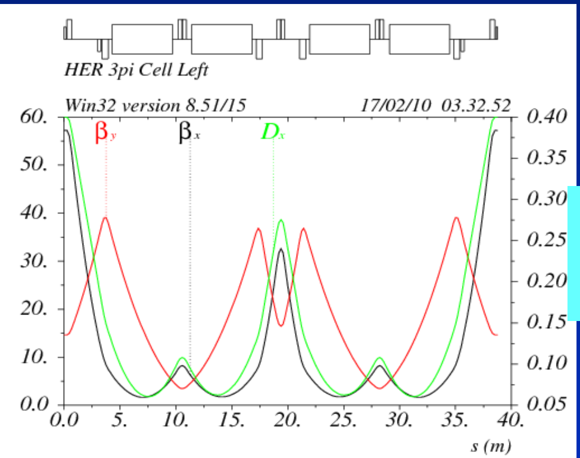
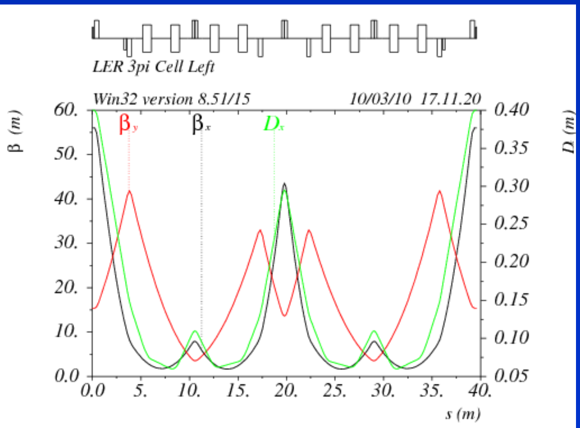
SuperB Arcs

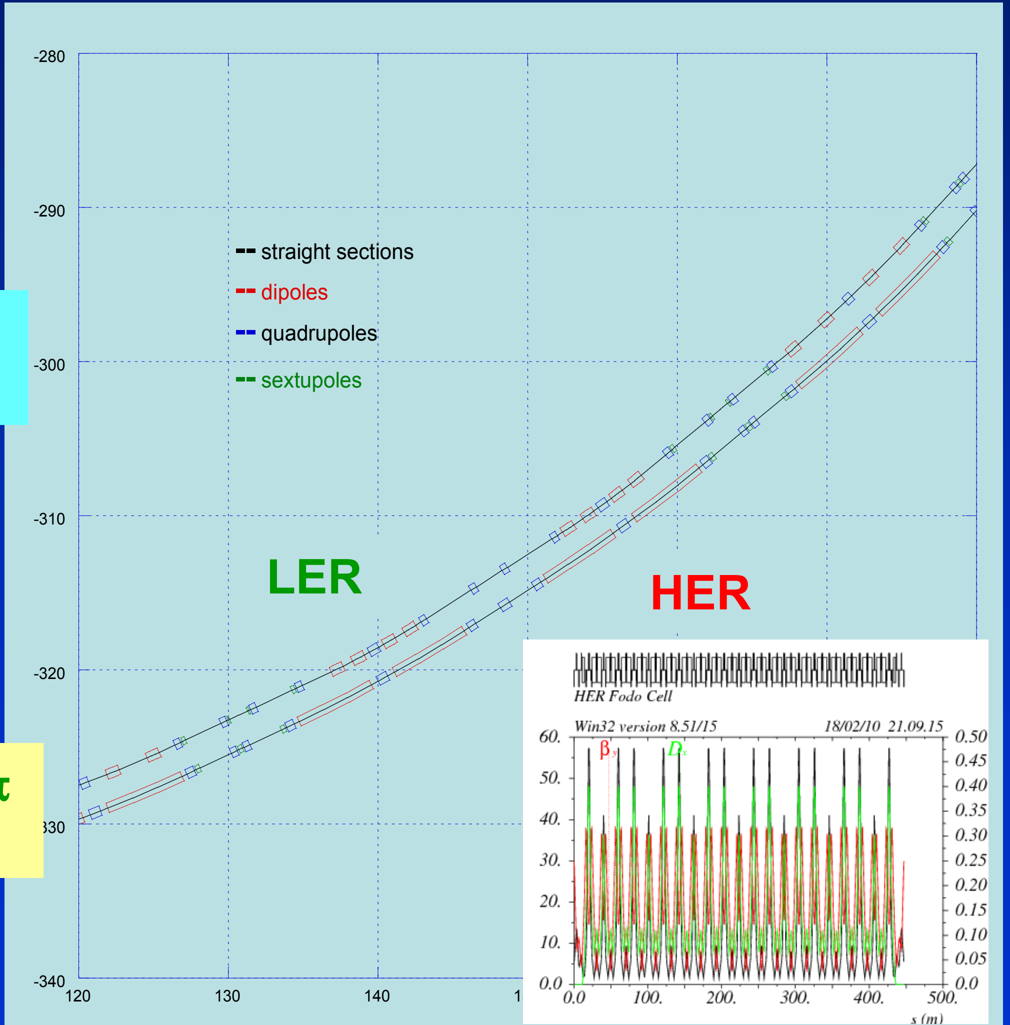
- HER and LER arcs have conceptually the same lattice. LER arc dipoles are shorter (bend radius about 3 times smaller) than in the HER in order to match the ring emittances at the asymmetric beam energies



$\mu_x = 3\pi$, $\mu_y = \pi$
Cell in HER

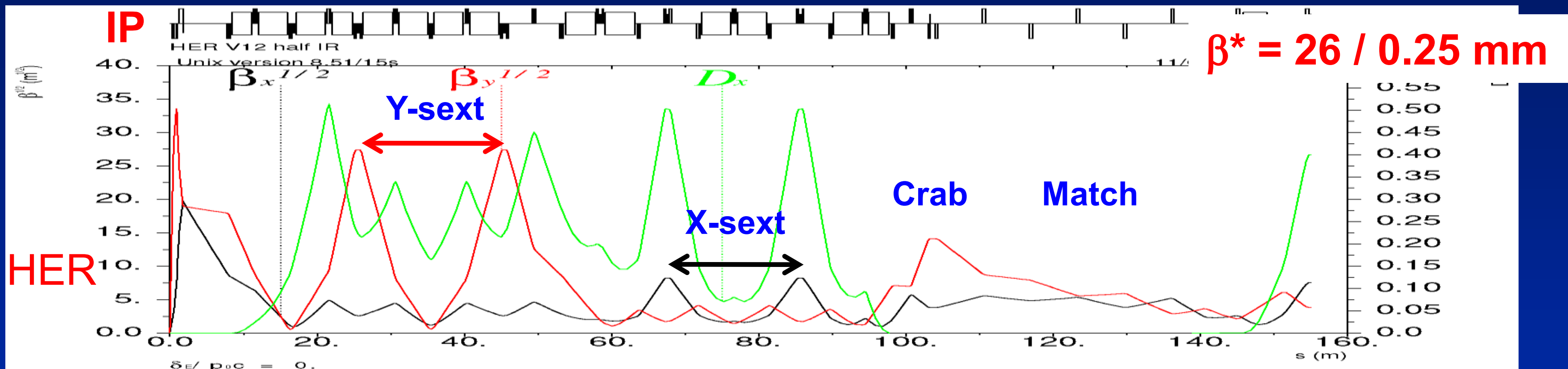


$\mu_x = 3\pi$, $\mu_y = \pi$
Cell in LER

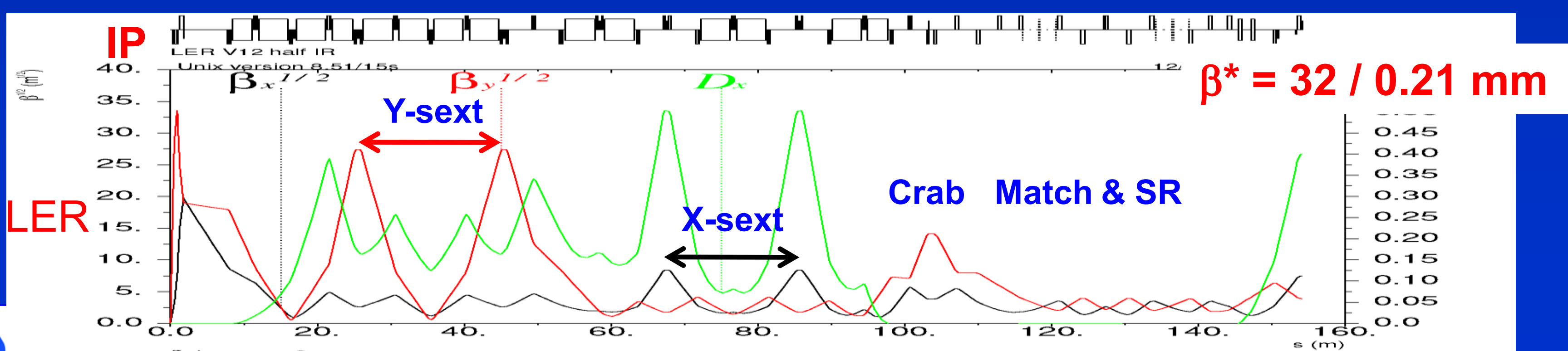


FF optics

- "Spin rotator" optics is replaced with a simpler matching section



- Matching section is shorter than HER to provide space for spin rotator optics.
- ±30 mrad bending asymmetry with respect to IP causes a slight spin mismatch between SR and IP resulting in ~5% polarization reduction.



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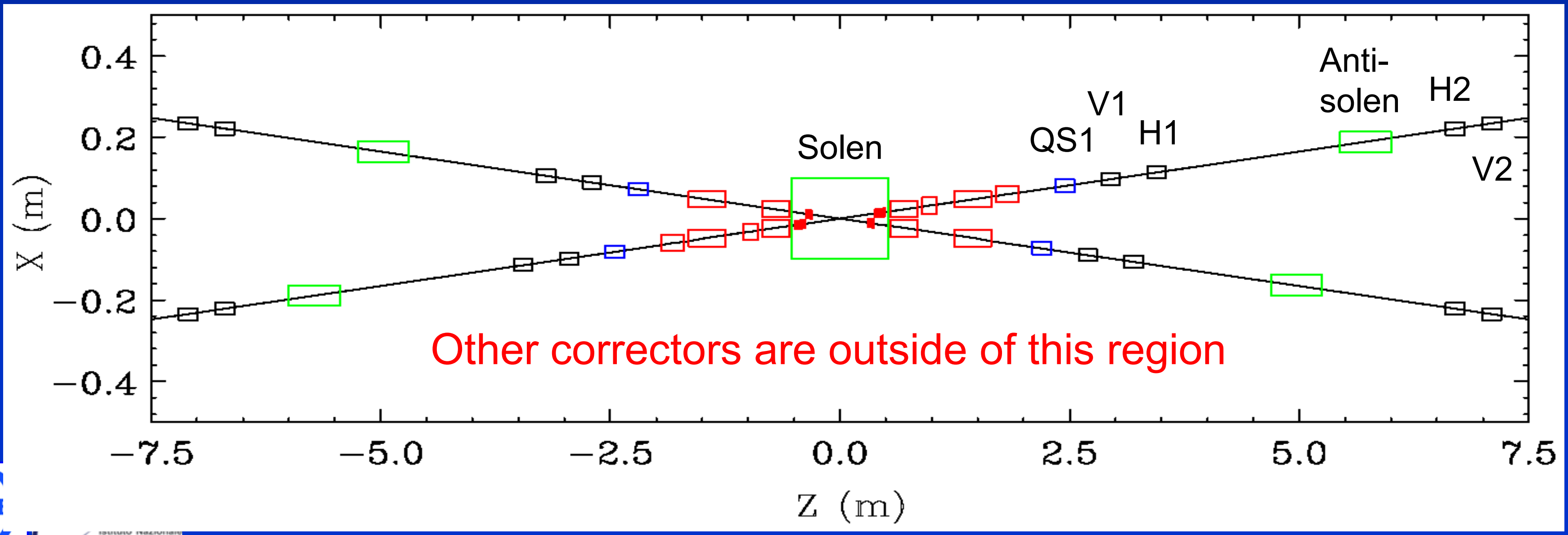
Coupling correction with detector solenoid ON

Nosochkov

The designed correction system compensates each half-IR independently and contains on each side of IP:

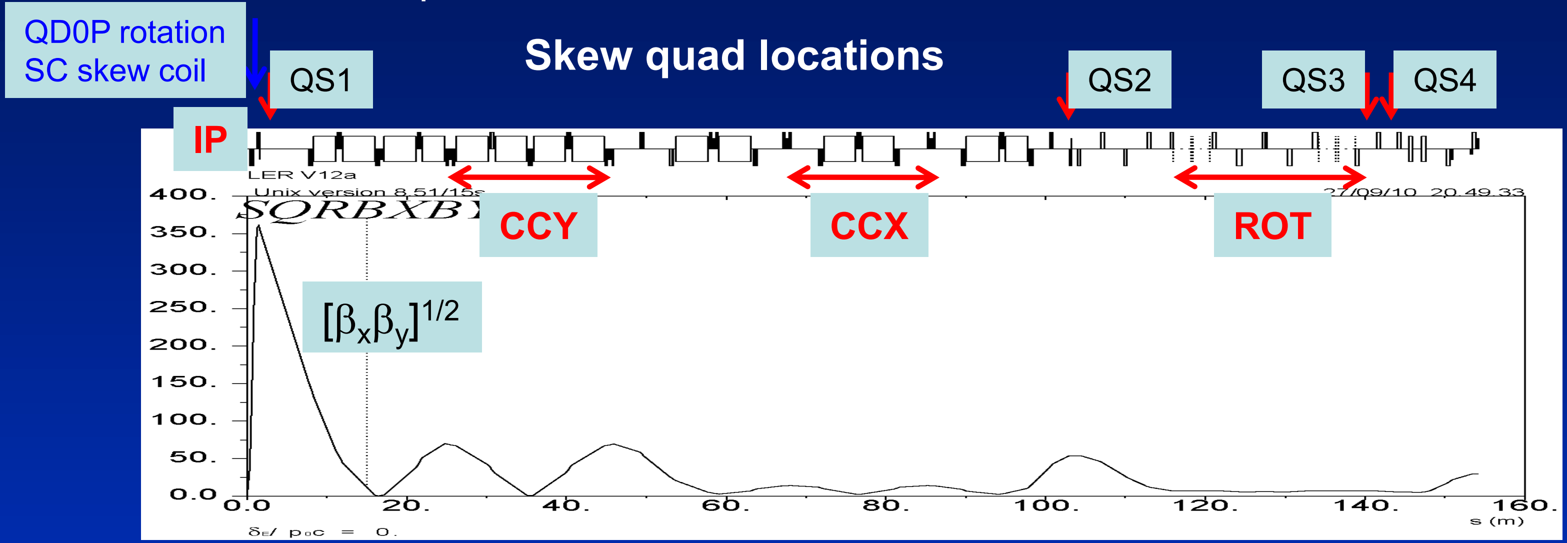
- Rotated permanent quads
- Skew winding on SC quads to simulate rotation
- SC anti-solenoid of strength 1.5T x 0.55 m aligned with the beam axis
- 2 vertical and 2 horizontal dipole correctors for orbit correction
- 4 skew quads at non-dispersive locations for coupling correction
- 2 skew quads at dispersive locations for correction of vertical dispersion and slope
- The nominal FF quads are used to rematch the Twiss functions and horizontal dispersion



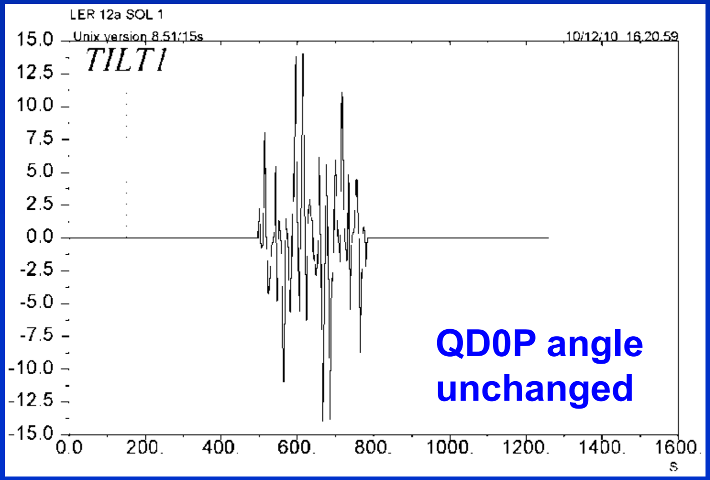
Coupling correction with detector solenoid OFF

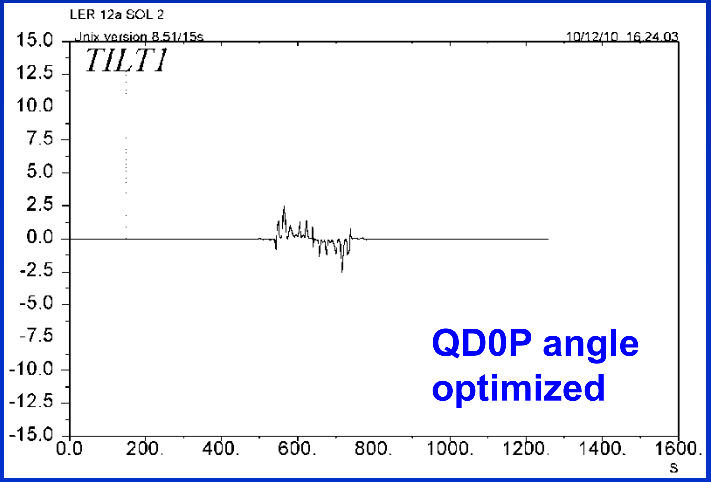
Assumptions: 1) detector solenoid, bucking solenoids and anti-solenoid are OFF; 2) SC skew quad coil is ON; 3) Permanent quad QD0P rotation angle is adjustable. Correction is done using QS1,QS2, QS3,QS4 skew quads

Skew quad locations



Coupling angle after correction



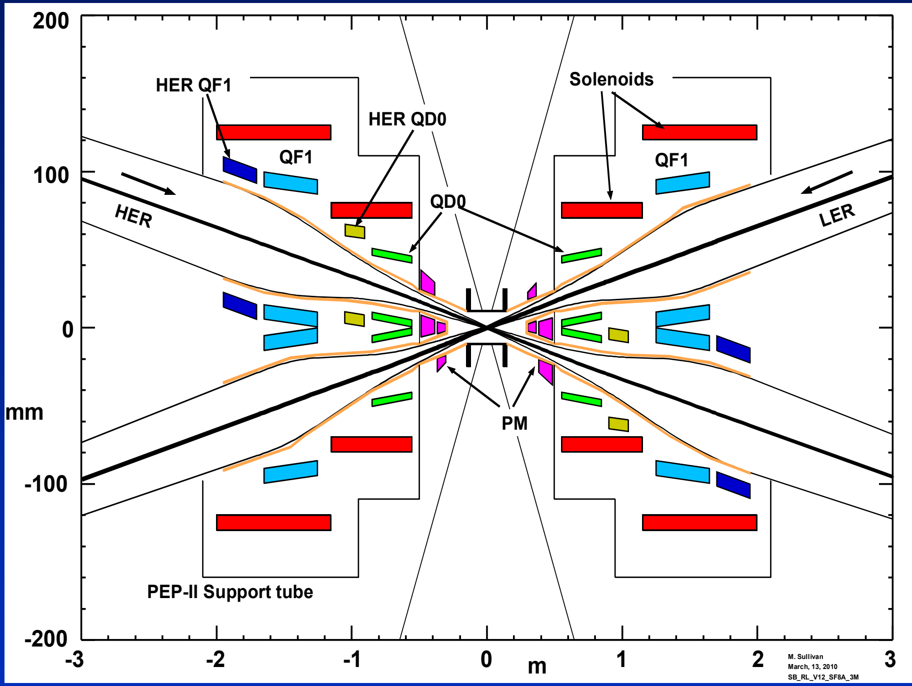


Nosochkov

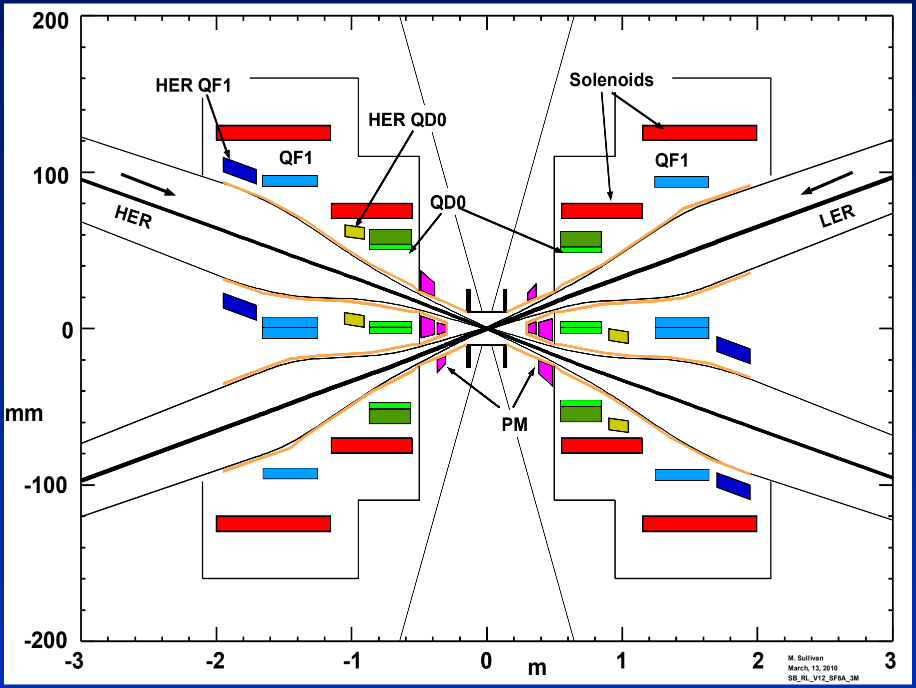
IR design

- Two designs possible that are flexible and have good:
  - SR backgrounds
  - Lattice functions
  - Beam apertures
- They are:
  - Vanadium Permendur “russian” solution for QD0 and QF1
  - Parallel air-core dual quads “italian solution” for QD0 and QF1 (prototype in progress)
    - Both designs include additional vanadium permendur Panofsky quads on HER
- These IR design demonstrates initial robustness
  - Two separate QD0 designs work
  - The direction of the beams can be either way with a weak preference for the incoming beams to be from the outside rings due to the location of the SR power on the cryostat beam pipe

QD0 Design: 2 possible choices



Vanadium Permendur "Russian" Design



Air core "Italian" QD0, QF1 Design

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QD0 DESIGN OPTIONS

"Italian" Design

Field generated by 2 double helix windings in a grooved Al support

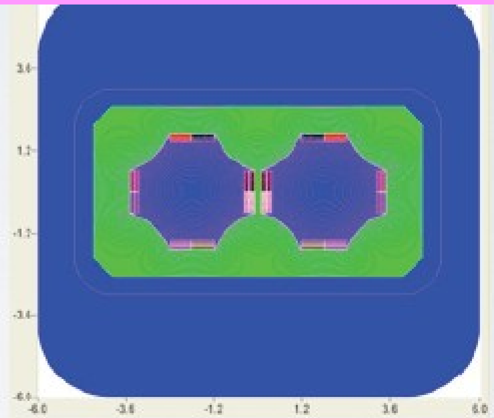
E. Paoloni ,
P. Fabbricatore,
R. Musenich,
S. Farinon ,
S. Bettoni

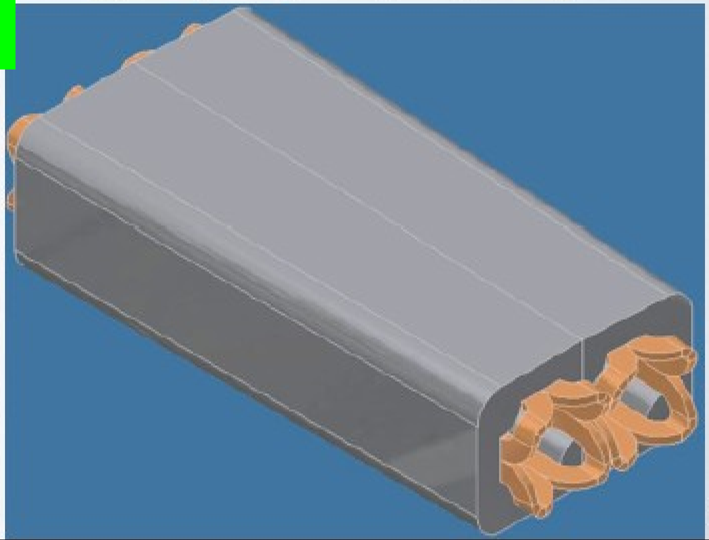
Conceptual sketch

"Russian" Design

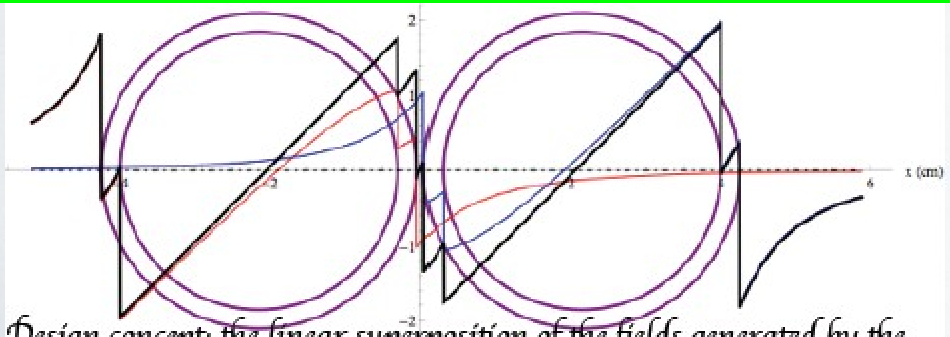
I. Okunev, V. Syrovatin, A. Bragin, P. Vobly

Prototype in progress at BINP



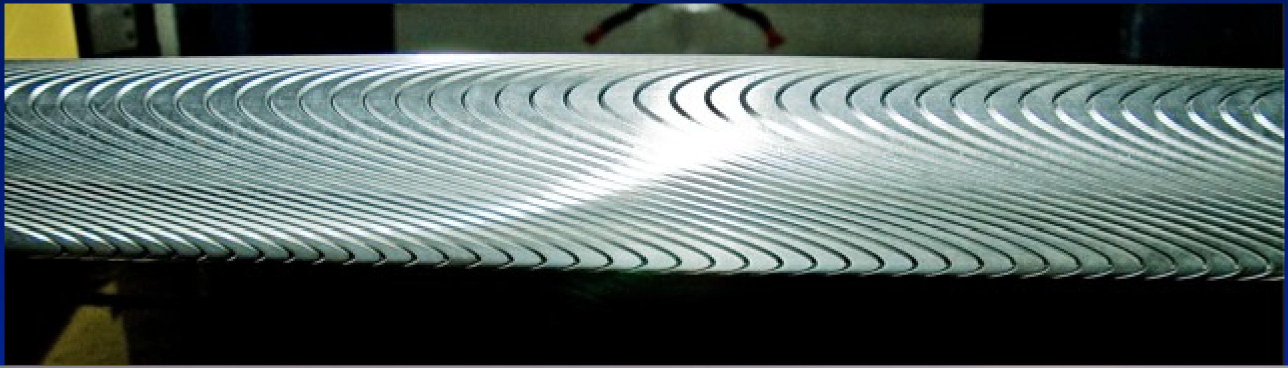


Air-core QD0 is a SC iron free septum double quad

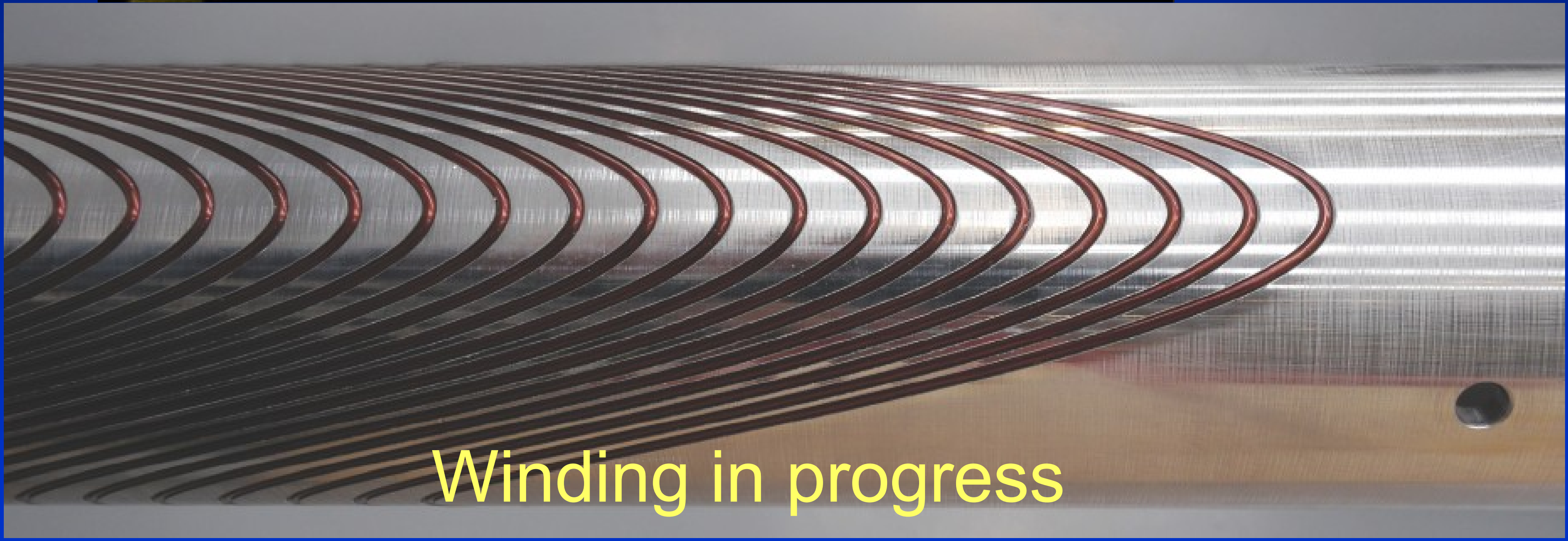


Design concept: the linear superposition of the fields generated by the left coil (in red) and by the right one (in blue) produces the needed quadrupolar field (in black).

The actual QD0



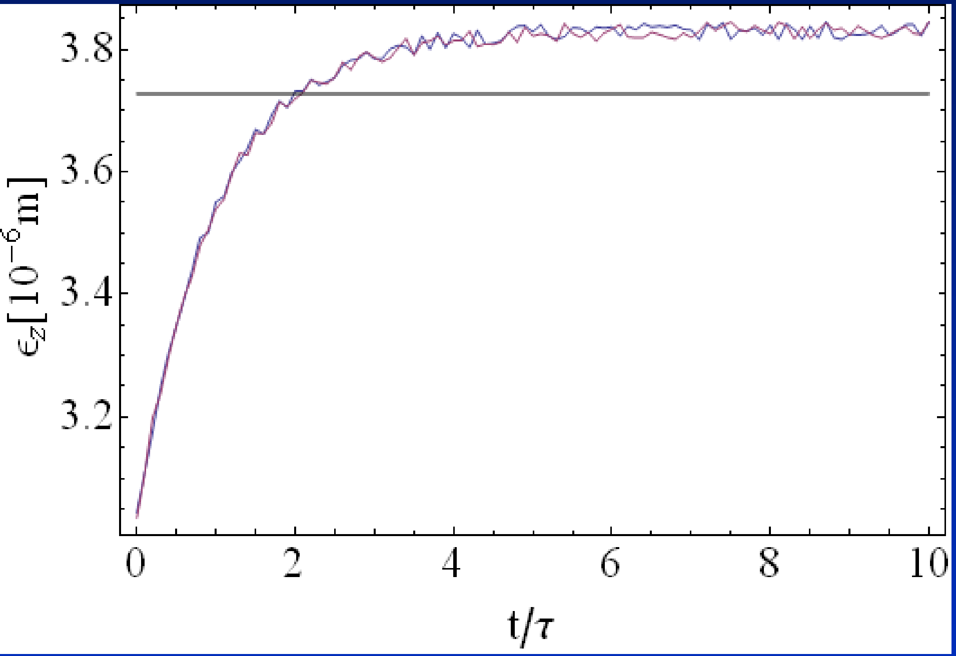
Grooved Al support

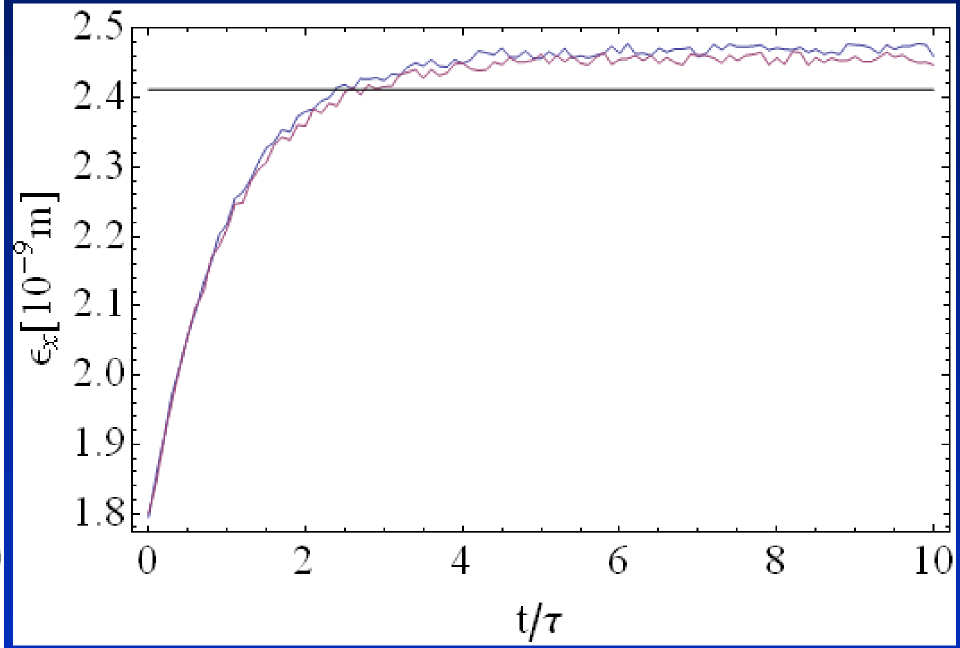


Ready this Summer for tests and field measurements @ CERN

Multi-particle tracking of IBS in LER

The effect of IBS on the transverse emittances is about 30% in the LER and less then 5% in HER





MacroParticleNumber=10000 **NTurn=10000 (≈10 damping times)**

σ_z=5.0*10^{-3} m
δp=6.3*10^{-4}

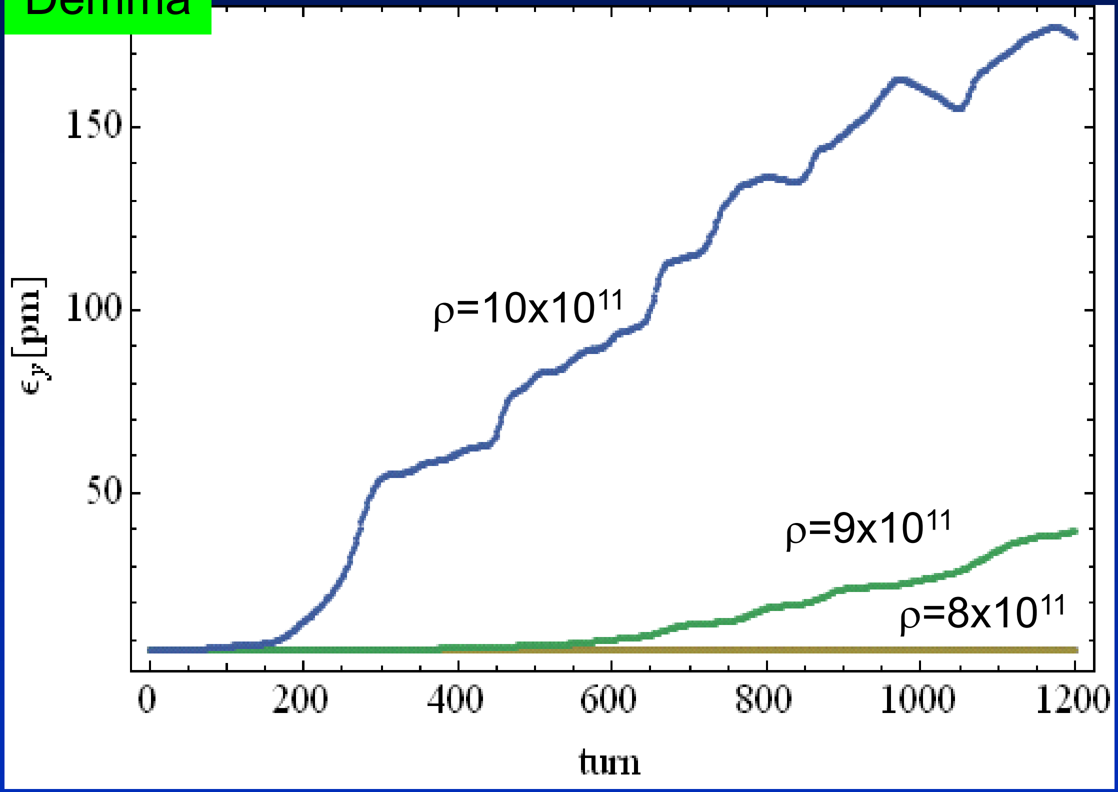
ϵ_x=1.8*10^{-9} m
ϵ_y=0.25/100*ϵ_x

τ_x = 100^{-1} * 0.040 sec
τ_y = 100^{-1} * 0.040 sec
τ_s = 100^{-1} * 0.020 sec

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

Emittance growth due to head-tail instability

Demma



Input parameters for **CMAD**

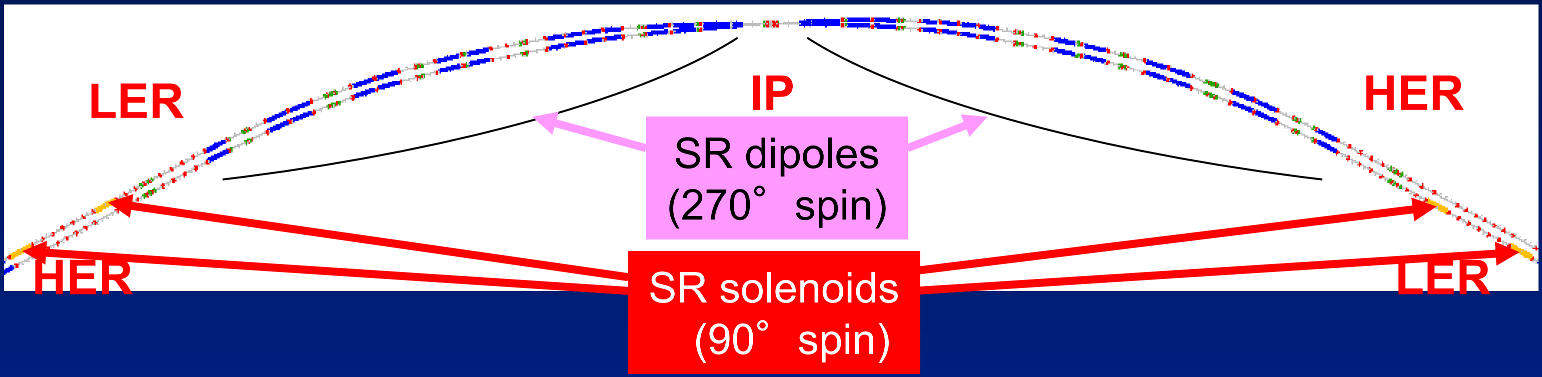
Beam energy E[GeV]	6.7
circumference L[m]	1200
bunch population N_b	5.06×10^{10}
bunch length σ_z [mm]	5
horizontal emittance ε_x [nm rad]	1.6
vertical emittance ε_y [pm rad]	4
hor./vert. betatron tune Q_x/Q_y	40.57/17.59
synchrotron tune Q_z	0.01
momentum compaction α	4.04e-4

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.

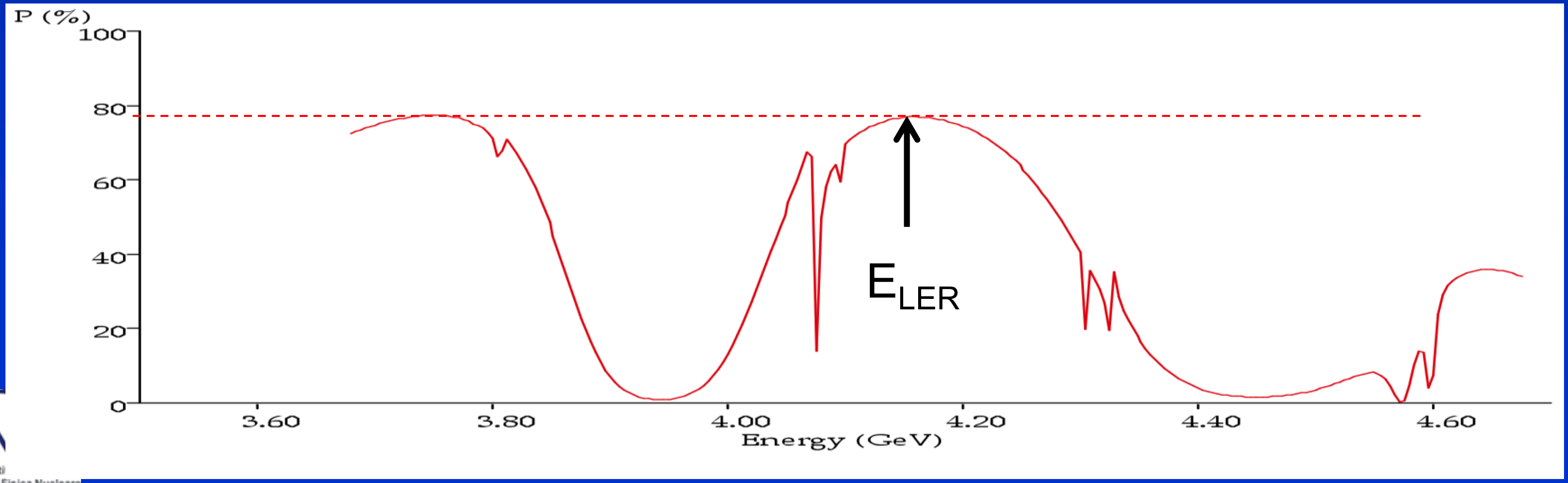
The threshold density is determined by the density at which the growth starts:

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

Polarization in LER



- 90° spin rotation about *x* axis: 90° around *z* (solenoids) followed by 90° around *y* (dipoles)
- Solenoids are split & decoupling optics added
- SR optics matched to the Arcs and a similar (void) insertion added to HER
- Beam polarization resonances do constraint the beam Energy choice
- Beam polarization computed assuming
  - 90% beam polarization at injection
  - 3.5 minutes of beam lifetime (luminosity limited)



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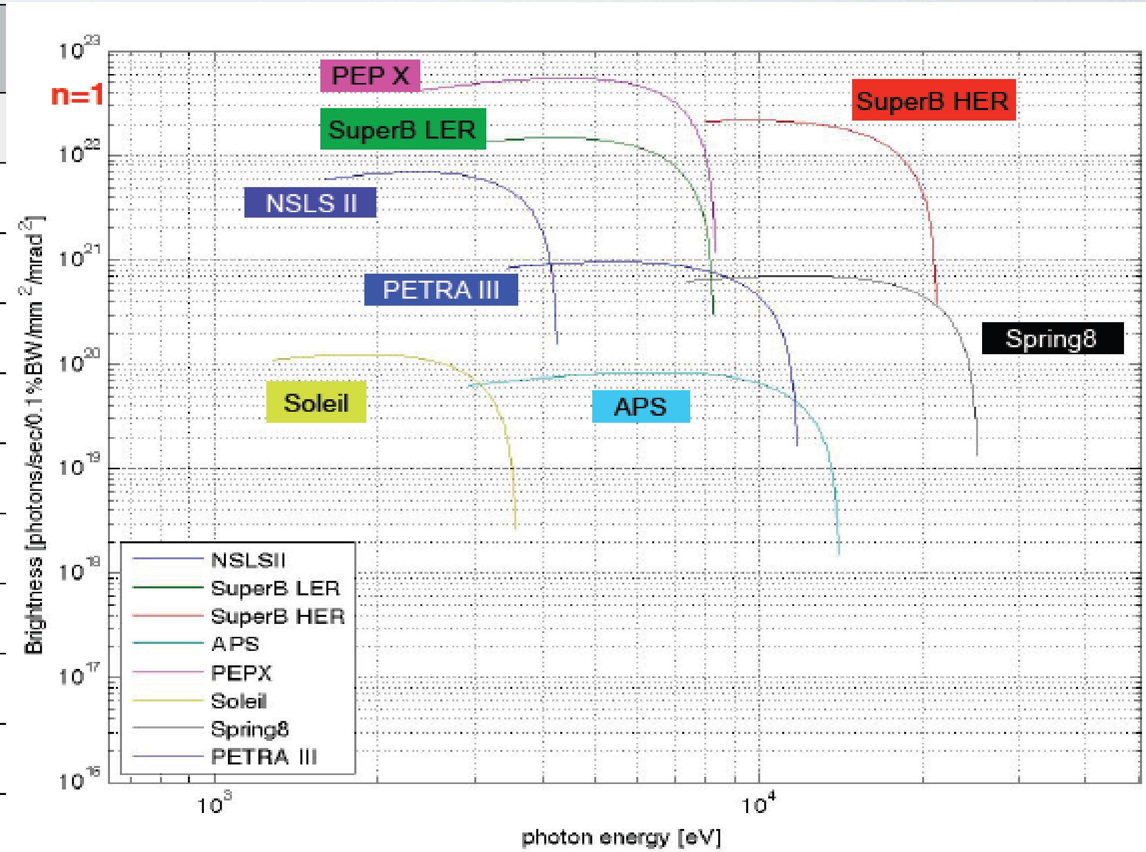
Synchrotron light options @ SuperB

- Comparison of brightness from undulators for different dedicated SR sources & SuperB HER and LER
- Assumed undulators characteristics as NSLS-II
- Light properties from undulators still better than most SR, slightly worst than PEP-X (last generation project)

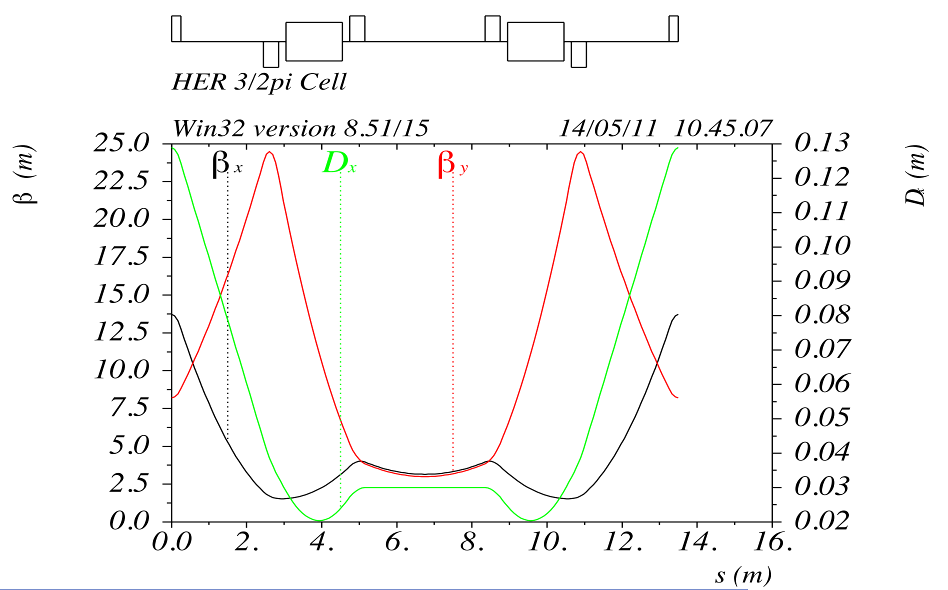
Parameters *	SuperB HER	SuperB LER	NSLS II
	IVU20	IVU20	IVU20
E [GeV]	6.7	4.18	3
I [mA]	1892	2447	500
σx [mm]	60.0 E-3	66.5 E-3	33.3 E-3
σy [mm]	2.4 E-3	2.6 E-3	2.9 E-3
σx' [mrad]	33.3 E-3	37.0 E-3	16.5 E-3
σy' [mrad]	2.1 E-3	2.7 E-3	2.7 E-3
N [1]	148	148	148
λu [mm]	20	20	20
Kmax [1]	1.83	1.83	1.83
Kmin [1]	0.1	0.1	0.1

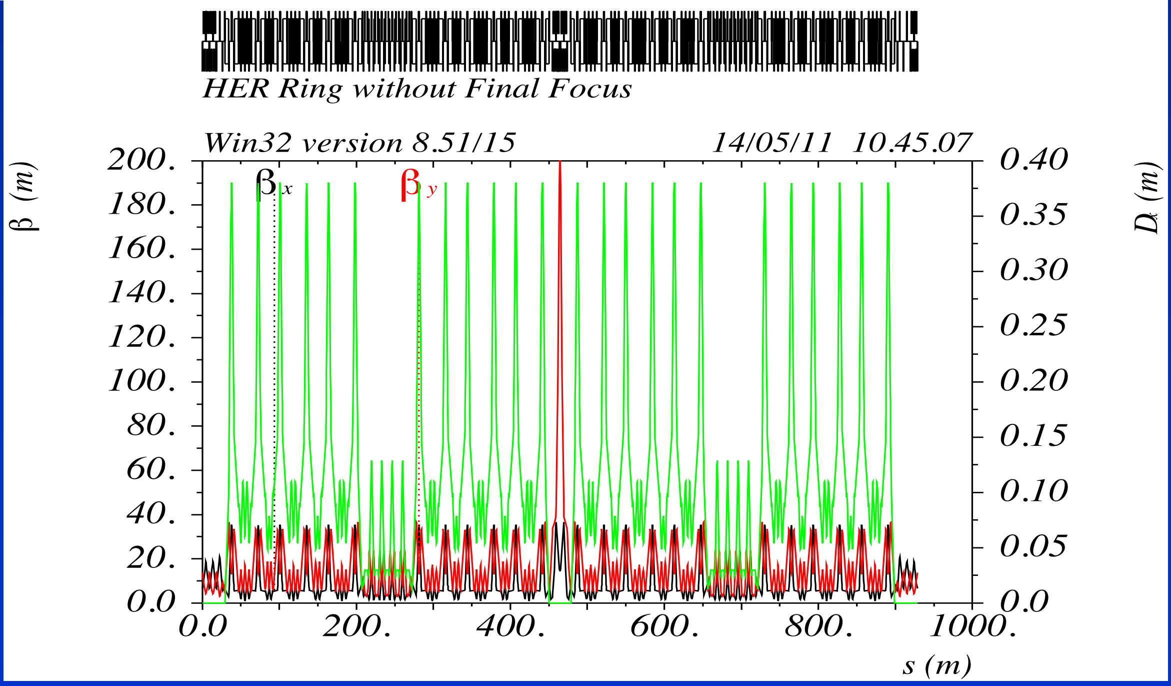


Insertions for SR Undulators

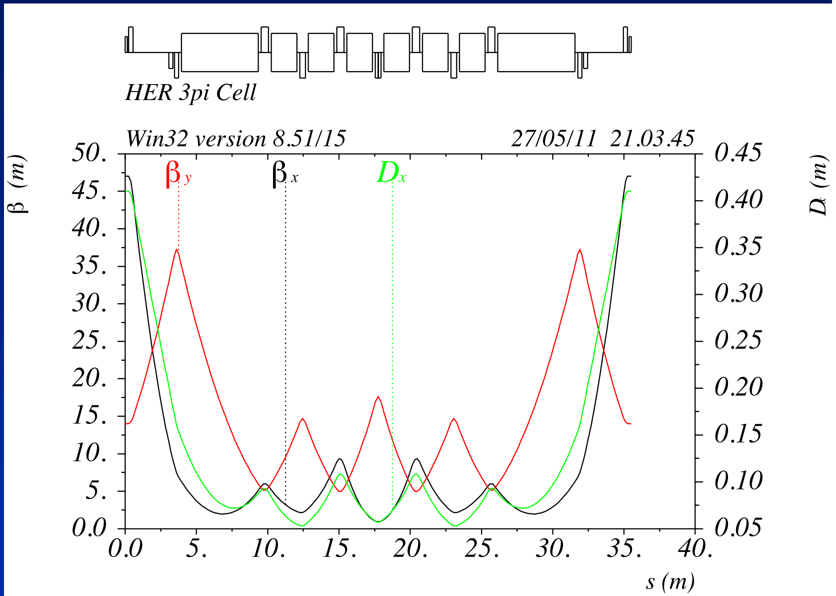
- Design of HER insertions in progress
- LER might as well have the same optic and layout
- At the moment two possible solutions:
  - 2 sections with 5 insertions in a row in the middle of the arcs. 10 beamlines total
  - 6 insertions in the μ_x=0.75 cell distributed along the Arcs. 12 beamlines total

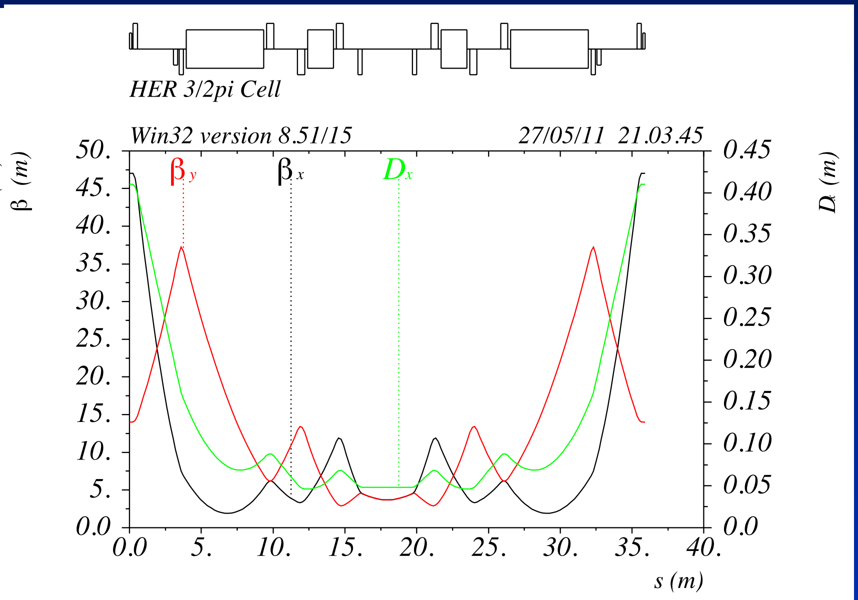
5 consecutive cells





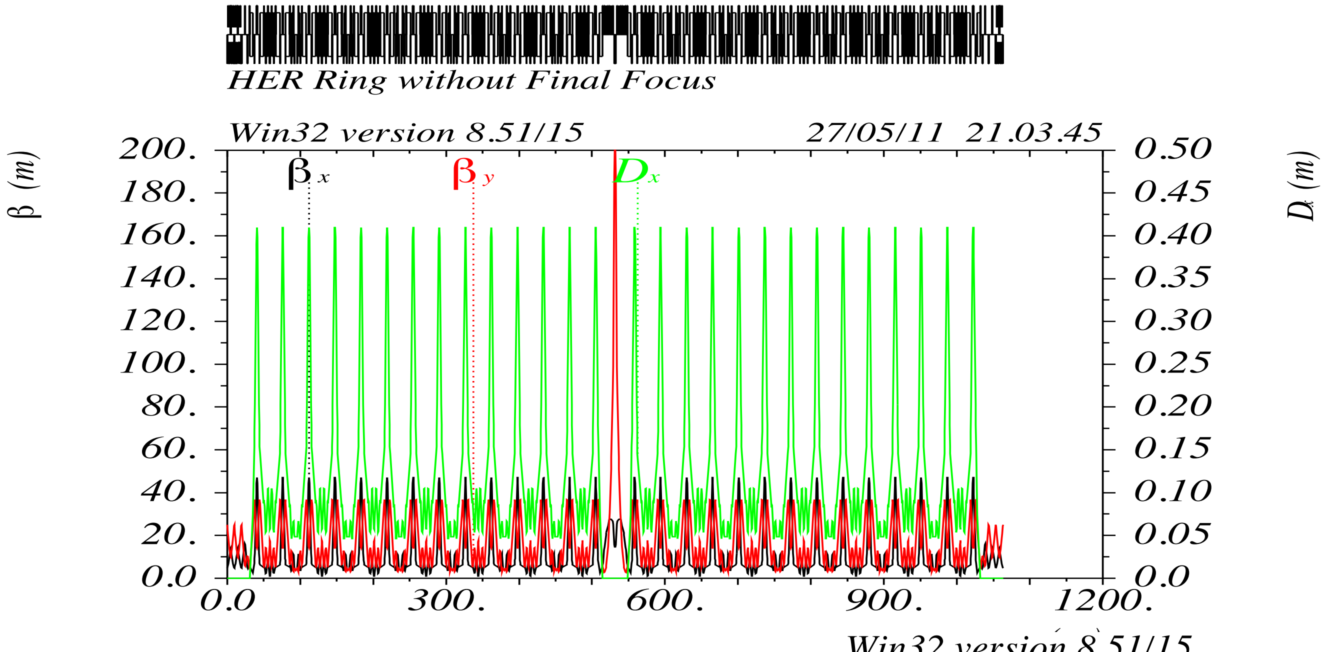
6 distributed insertions

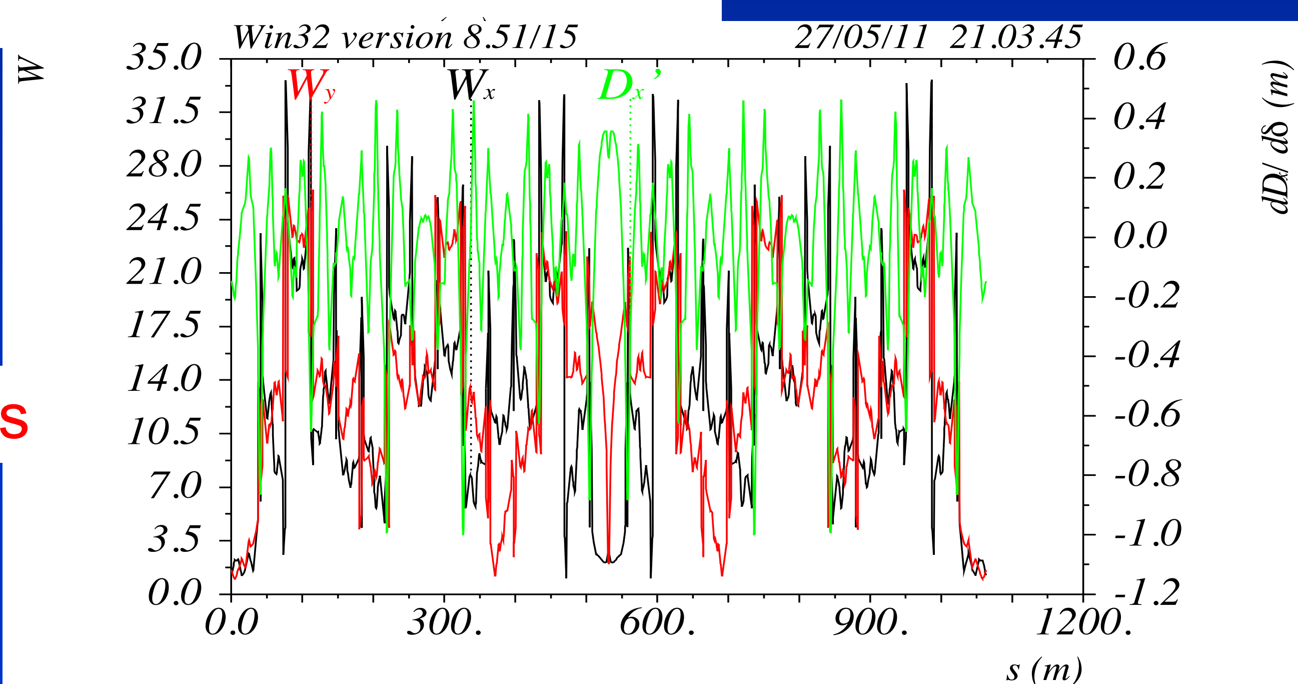




- Alternating sequence of:
  - Cell1 μ_x = 1.5, μ_y =0.5
  - Cell2 μ_x = 1.215, μ_y =0.688
- Undulator insertions: length = 3.5 m, $\beta_{x,y}$ = 3.2 m
- Optics flexible to change β and μ

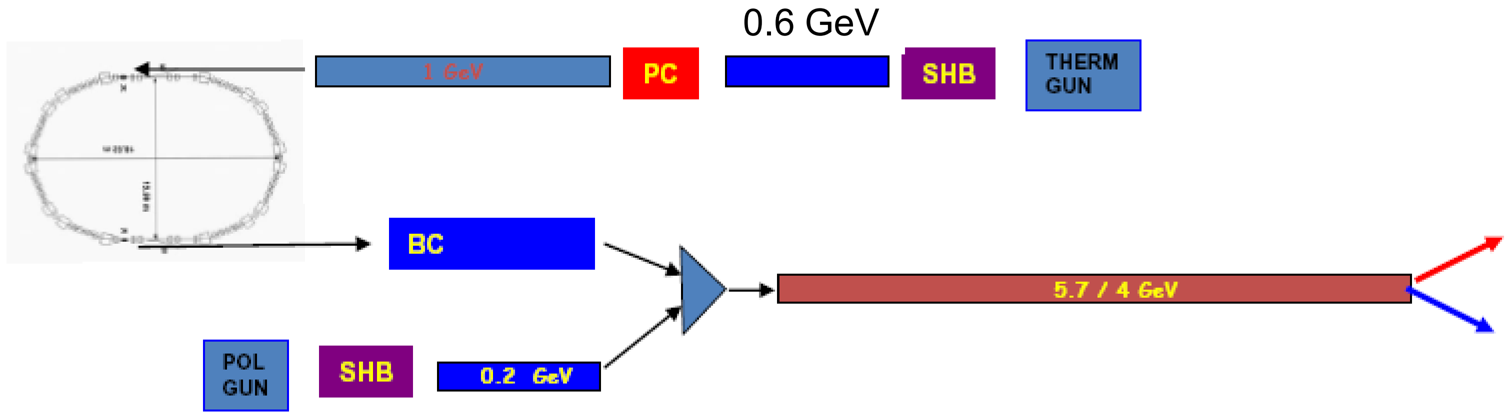
6 distributed insertions





Chromatic functions

Injection system (new proposal)

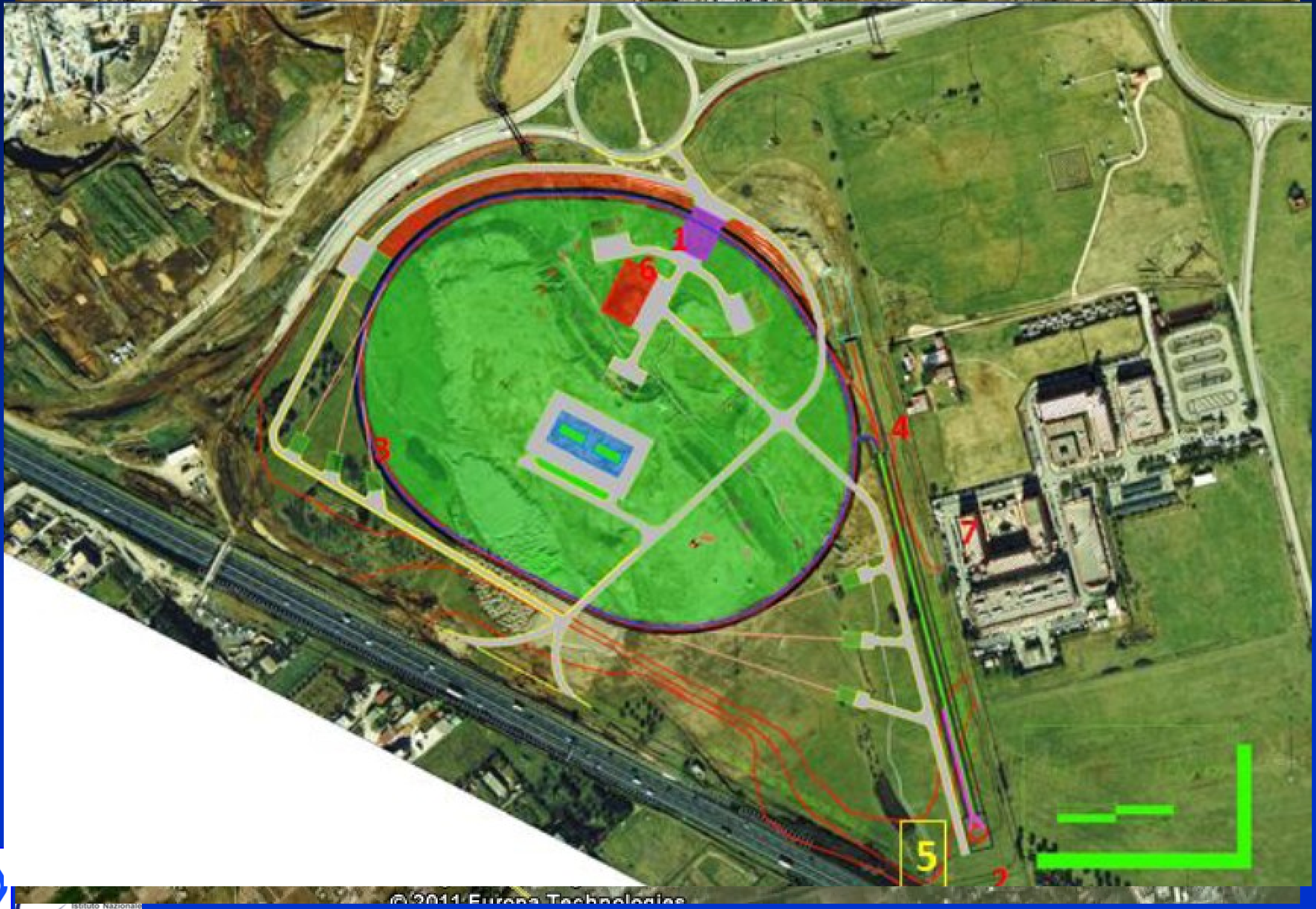


- Only the **e+ beam** is stored in the DR
- S band linac at 100 Hz
- Injection in each ring at 50 Hz
- 2 electron guns
  - a "high current" gun for positron production
  - a "low emittance" polarized gun for electron injection
- Additional 200 MeV linac for e^-
- Reduced transfer lines and kickers for DR injection/extraction
- Conversion e^-/e^+ at low energy 0.6 GeV as in CDR2

Layout, Site

- The rings footprint is 2 rings in same tunnel, about 1250 m long
- The insertion of synchrotron beamlines, with their impact on the layout and lattice is being studied
- Site chosen is in Tor Vergata University campus (green field)
- Preliminary ground measurements have been performed at Tor Vergata in mid-April, showing that the site is very stable, in spite of the presence of the highway
- The layout of the rings with beamlines and injection system will be adjusted to fit the site to further optimize the system performances

Tor Vergata University campus



Ground motion @ Tor Vergata

B. Bolzon, G. Deleglise, A. Jeremie, S. Tomassini

✓ Main source of vibrations of Tor Vergata Site: the highway

✓ However, vibrations well damped near the highway (just below the bank) thanks to the very soft floor of this site

✓ Moreover, the Super B will be built at a minimum of 100m from the highway where vibrations are very low

➔ In the 3 axes: Amplitude varies from 8nm to 30nm for all the points above 1Hz (and from 30nm to 60nm above 0.2Hz)

➔ For the interaction point: a road is planned to be made soon near this point but since there is also a high bank, vibrations should be well damped

➢ INFN site: too close to main roads and the floor does not damp vibrations like it does at the Tor Vergata site

➔ Vibrations can be huge in the INFN site during the day and especially during traffic time contrary to the Tor Vergata site

➔ Tor Vergata seems to be a very good site for the Super B project compared to the INFN site where the only choice is to build a tunnel in underground

Conclusions

- Accelerator design is converging
- Lattice and parameters optimization is continuing, for better performances and more flexibility
- Synchrotron Light beamlines are being considered
- A possible new layout is being studied, with special IDs insertions
- Work is in progress on more subtle beam dynamics issues (IBS, FII, CSR, e-cloud, beam-beam, feedbacks,…)
- Components and lattice tolerances with corrections are being studied
- The site has been chosen: Tor Vergata campus
- Ground motion mesurements look very good even in the vicinity of highway
- An International collaboration is forming, work is being organized in Work Packages
- We are collaborating with other Labs (ex. SLAC, LAL/LAPP, BINP, CERN, PSI, DIAMOND, IHEP, Cornell,…) to solve common issues

From the WS programme…

- *Introduce the planned upgrades and future projects new challenges for optics modeling and beam instrumentation?*
- *Are the optics challenging enough?*

SuperB for sure it is !!!!!!

SuperB

INFN Istituto Nazionale di Fisica Nucleare