SuperB project status

M.E. Biagini on behalf of *SuperB* Team

PAC09

Vancouver, BC, May 4th, 2009

SuperB Collaboration Team

CDR

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TDR

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A. Chance, O. Napoly (CEA Saclay, France)
F. Bosi, E. Paoloni (Pisa University, Italy)

The *SuperB* accelerator

- *SuperB* exploits new design approaches:
  - large Piwinski angle (LPA) scheme allowing for peak luminosity **$\geq 10^{36}$ cm^{-2} s^{-1}** well beyond the current state-of-the-art, *without a significant increase in beam currents or shorter bunch lengths*
  - "*crab waist*" sextupoles used for suppression of dangerous resonances
  - low currents, with affordable operating costs and fewer detector backgrounds
  - polarized electron beam producing polarized τ leptons, opening an entirely new realm of exploration in lepton flavor physics
- A CDR was published in 2007, a TDR ready by end 2010
- *SuperB* project scrutinized by International Review Committee (chair J. Dainton, 9 members), accelerator by a MiniMachine Advisory Committee (chair J. Dorfan, 10 members)

Both have endorsed the project for Physics program and accelerator feasibility

SuperB main features

- Goal: maximize luminosity while keeping wall power low

- 2 rings (4x7 GeV) design: flexible
- Ultra low emittance optics: 7x4 pm vertical emittance
- Beam currents: comparable to present Factories
- LPA & CW scheme used to maximize luminosity and minimize beam size blow-up

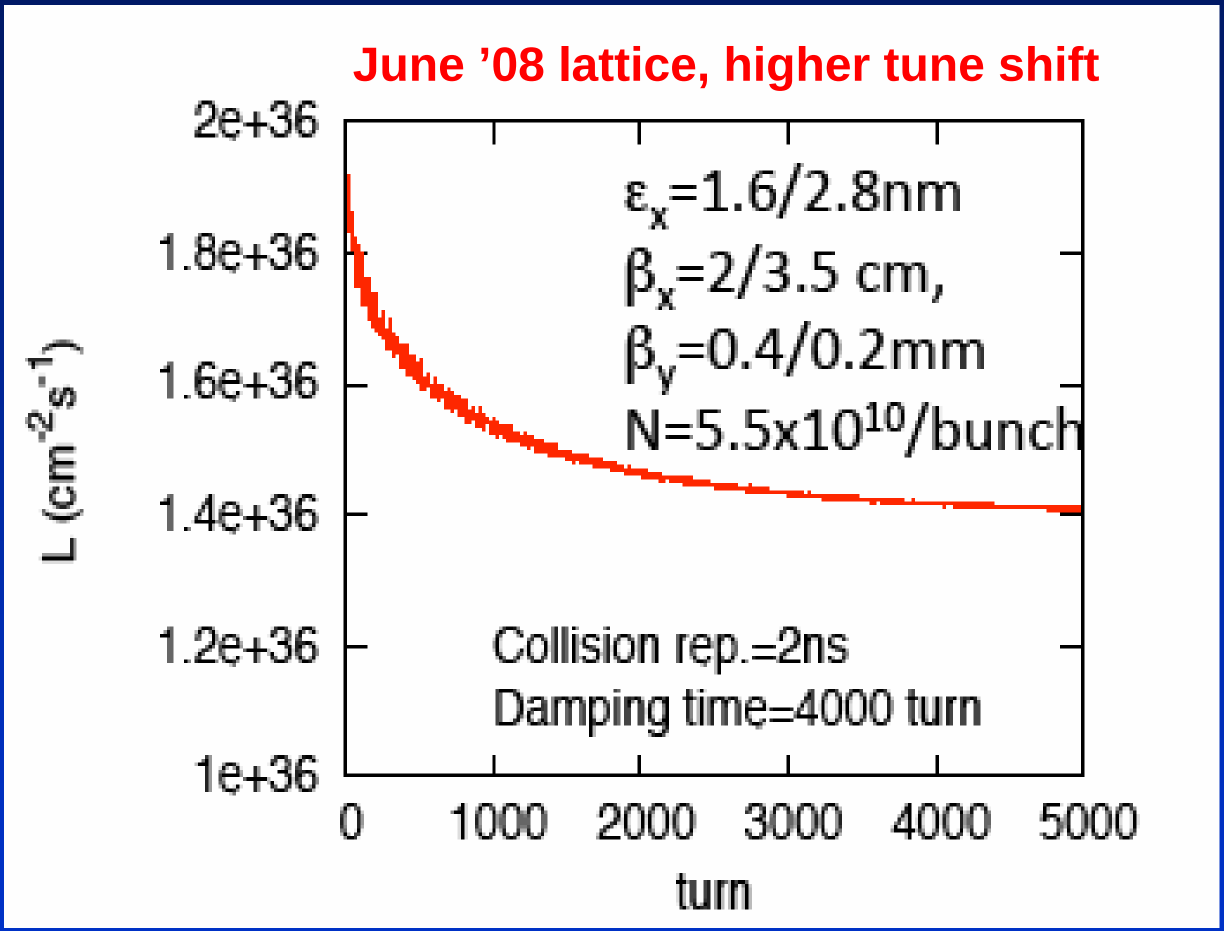
Tested at DAΦNE: see C. Milardi's talk, MO4RAI01

- No "emittance" wigglers used (save power)
- Design based on recycling PEP-II hardware (save costs)
- Longitudinal polarization for e^- in the HER (unique feature)

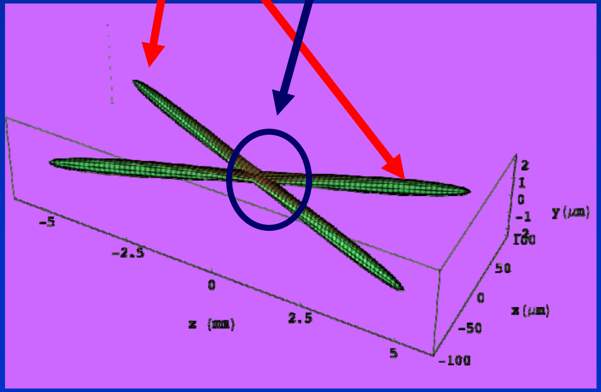
SuperB parameters flexibility

LER/HER	Unit	June 2008	Jan. 2009	March 2009	LNF site
E+/E-	GeV	4/7	4/7	4/7	4/7
L	$cm^{-2}\ s^{-1}$	$1x10^{36}$	$1x10^{36}$	$1x10^{36}$	$1x10^{36}$
I^+/I^-	Amp	1.85 /1.85	2.00/2.00	2.80/2.80	2.70/2.70
N_{part}	$x10^{10}$	5.55 /5.55	6/6	4.37/4.37	4.53/4.53
N_{bun}		1250	1250	2400	1740
I_{bunch}	mA	1.48	1.6	1.17	1.6
$\theta/2$	mrad	25	30	30	30
β_x*	mm	35/20	35/20	35/20	35/20
β_y*	mm	0.22 /0.39	0.21 /0.37	0.21 /0.37	0.21 /0.37
ε_x	nm	2.8/1.6	2.8/1.6	2.8/1.6	2.8/1.6
ε_y	pm	7/4	7/4	7/4	7/4
σ_x	μm	9.9/5.7	9.9/5.7	9.9/5.7	9.9/5.7
σ_y	nm	39/39	38/38	38/38	38/38
σ_z	mm	5/5	5/5	5/5	5/5
ξ_x	X tune shift	0.007/0.002	0.005/0.0017	0.004/0.0013	0.004/0.0013
ξ_y	Y tune shift	0.14 /0.14	0.125/0.126	0.091/0.092	0.094/0.095
RF stations	LER/HER	5/6	5/6	5/8	6/9
RF wall plug power	MW	16.2	18	25.5	30.
Circumference	m	1800	1800	1800	1400

Strong-strong beam-beam simulations



- **Strong-strong modified code (much faster):**
  - **PIC for beams overlap area**
  - **gaussian for beam tails**

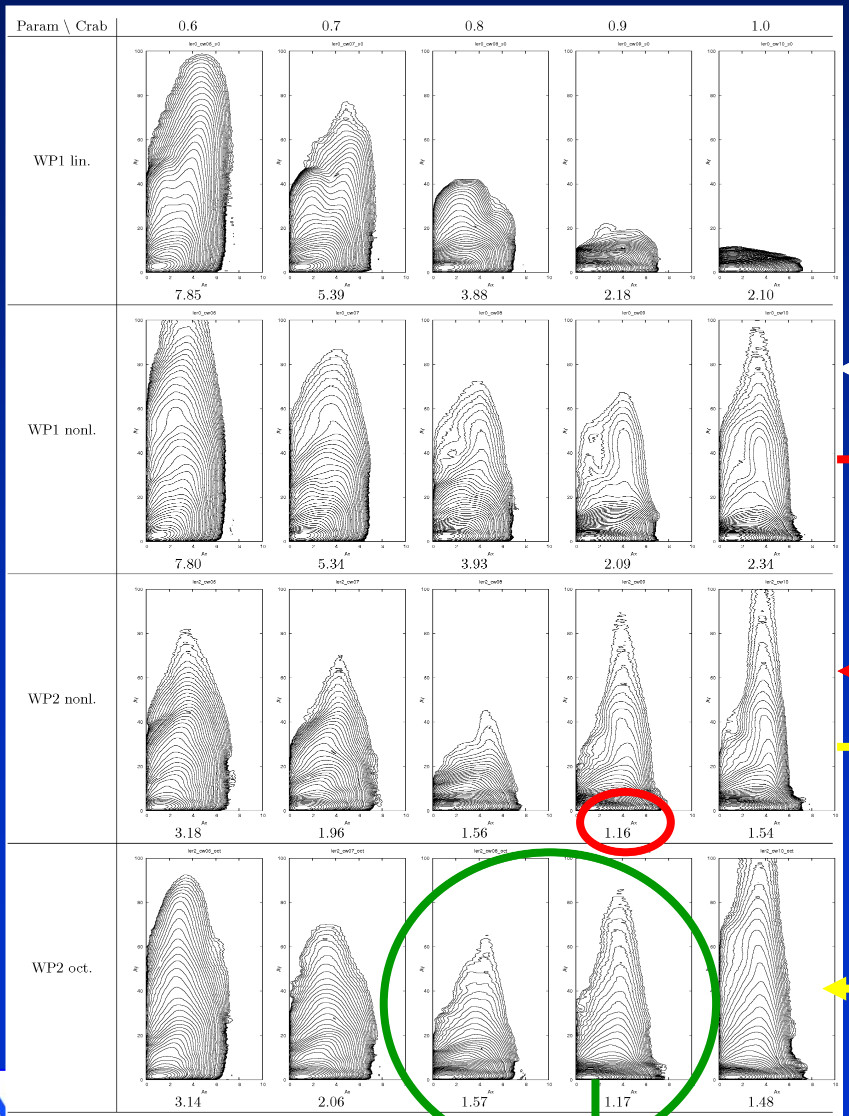


K. Ohmi

Luminosity of 10^{36} can be reached

BB optimization with lattice nonlinearities (weak-strong Lifetrack code)

Piminov, Shatilov, Zobov



Nonlinear elements included: longer tails affect the lifetime

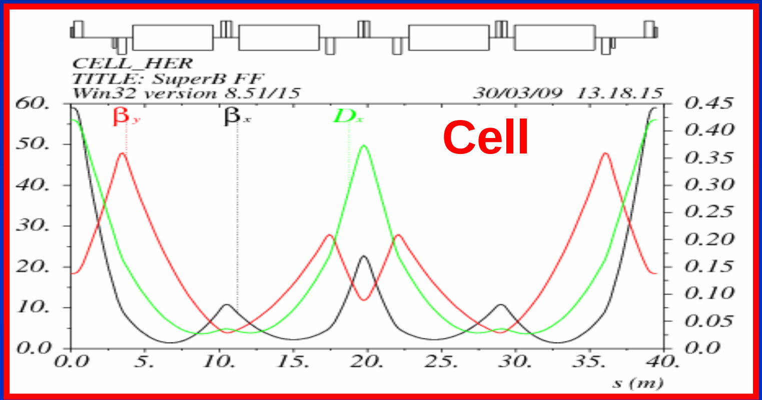
Change of the working point: emittance blow up almost disappears

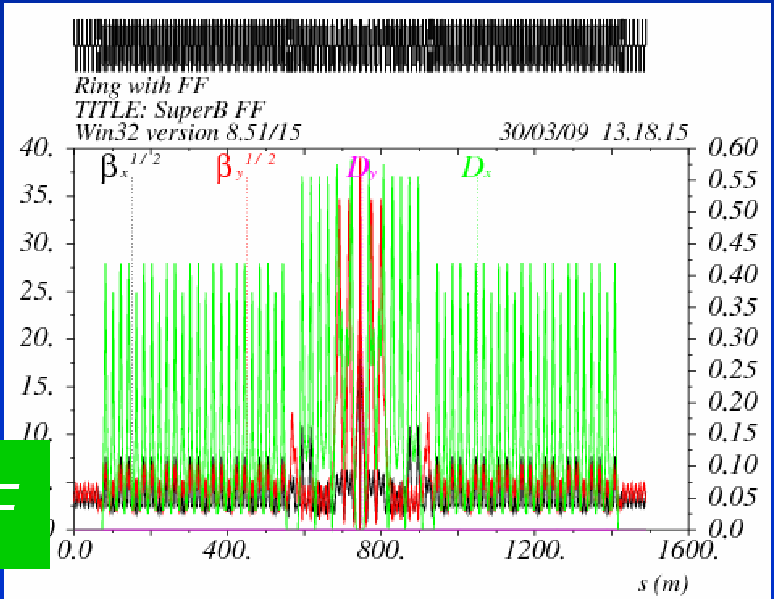
Changing the octupole strength: lifetime increased by a factor of 3-4 for CW strength → 0.8 and 0.9

Lifetime 30 min

Arcs Lattice

- Arc cell flexible: solution is based on decreasing the natural emittance by increasing μ_x/cell, and simultaneously adding weak dipoles in the cell drift spaces to decrease synchrotron radiation
- All cells have: μ_x=0.75, μ_y=0.25 → about 30% fewer sextupoles
- Just 2 Arcs left with 21 Cells each (was 4 Arcs with 14 cells), decreased length
- Better DA since all sextupoles are at –I in both planes (although x and y sextupoles are nested)
- Distances between magnets compatible with PEP-II hardware
- All quads-bends-sextupoles in PEP-II range
- Straights in the middle of the Arcs are now missing, not required for optics properties, but can be added if needed (for RF, Injection etc…)



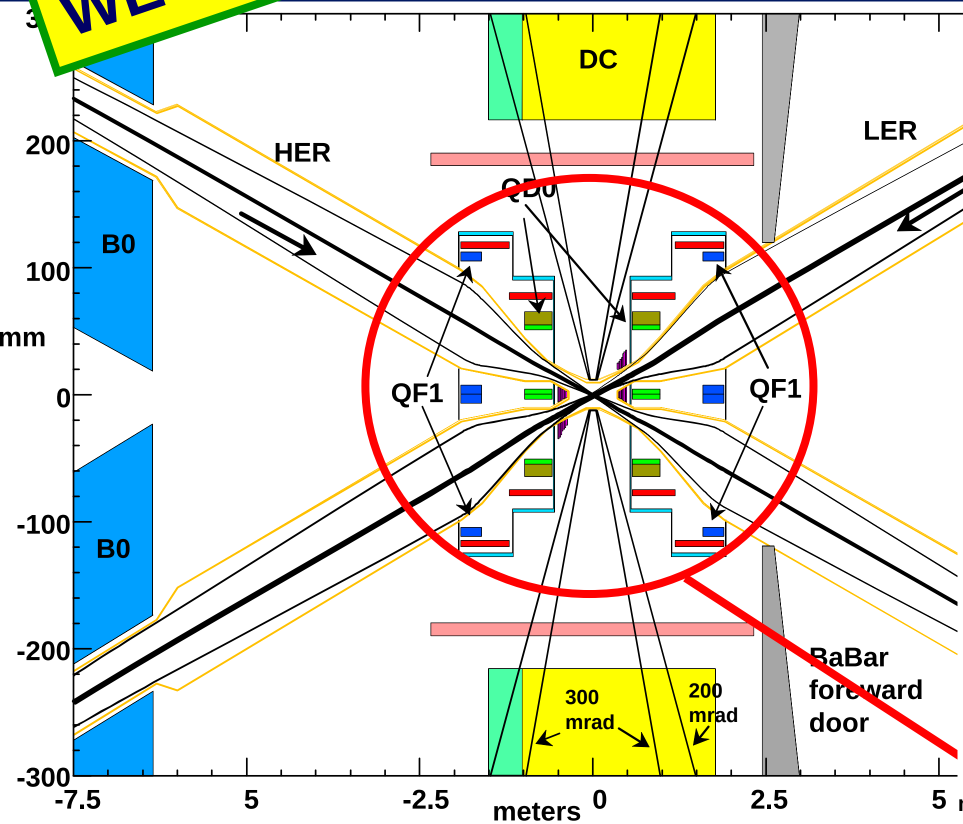


Arcs & FF

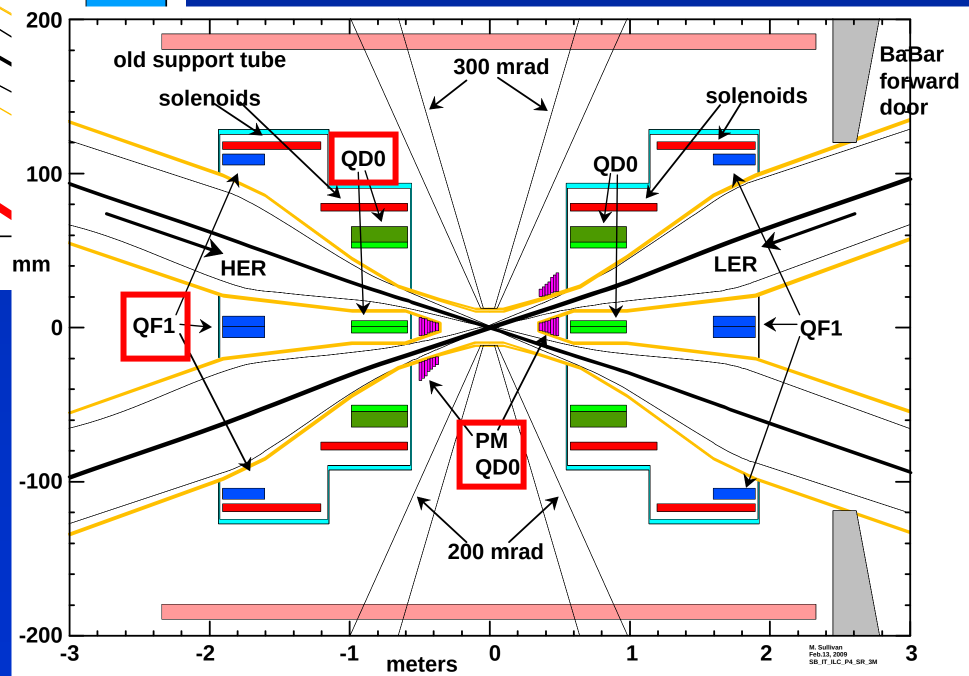
New IR design

M. Sullivan

WE6PFP051



With a larger crossing angle (60 mrad total) beams are far enough apart at 0.35 m from the IP to have enough space to install a PM, in front of QD0, for LER which needs more focusing

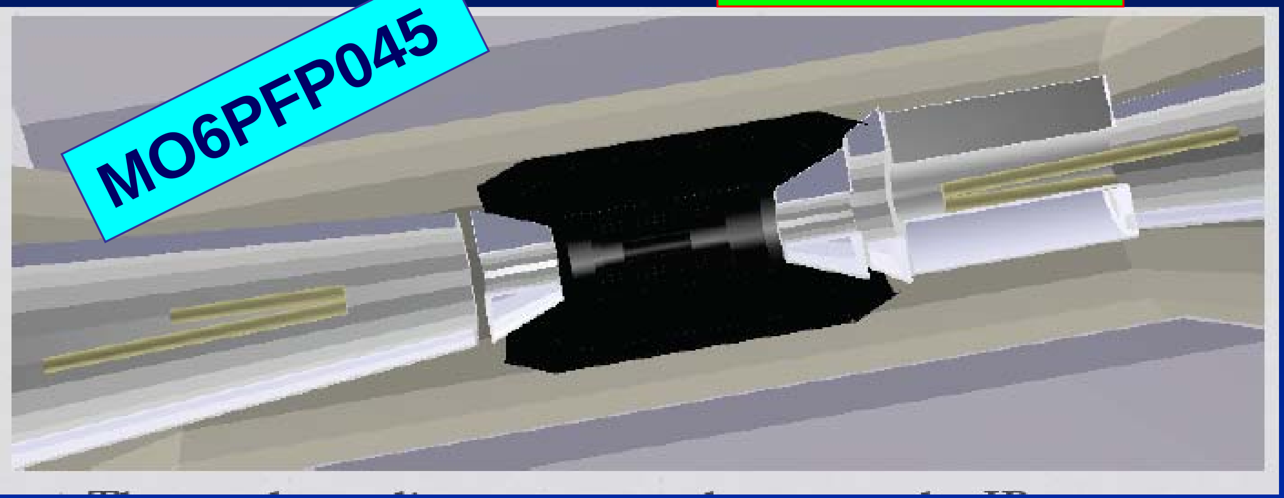


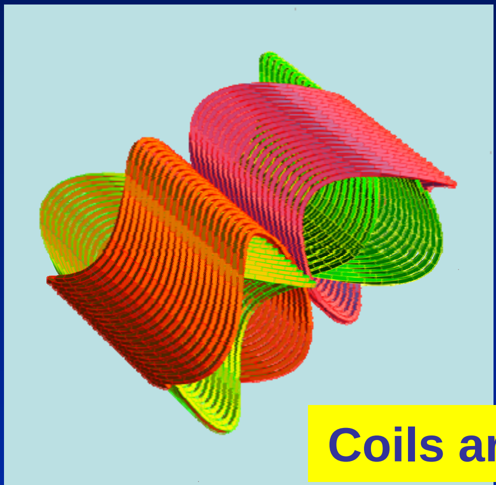
- New QD0 design
- QD0 & QF1 are SC and share same cryostat
- Compensating solenoids were included

R&D on SC Quadrupoles at the IP

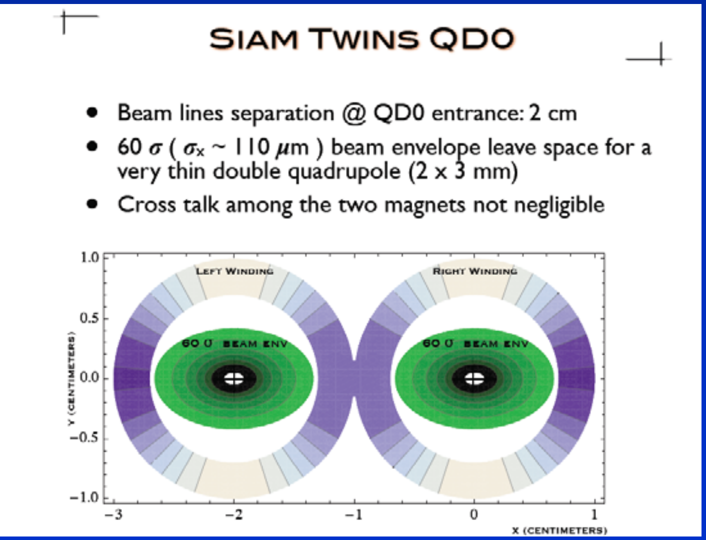
Bettoni, Paoloni

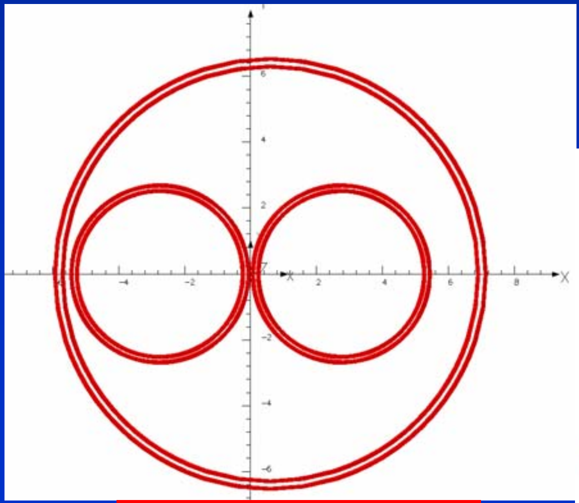
MO6PFP045





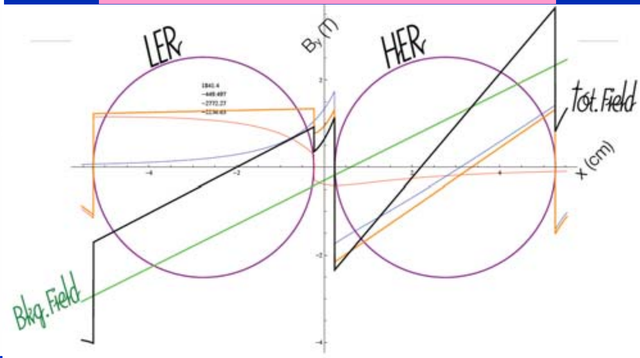
Coils array





Latest design: Q & qq

Total field in black



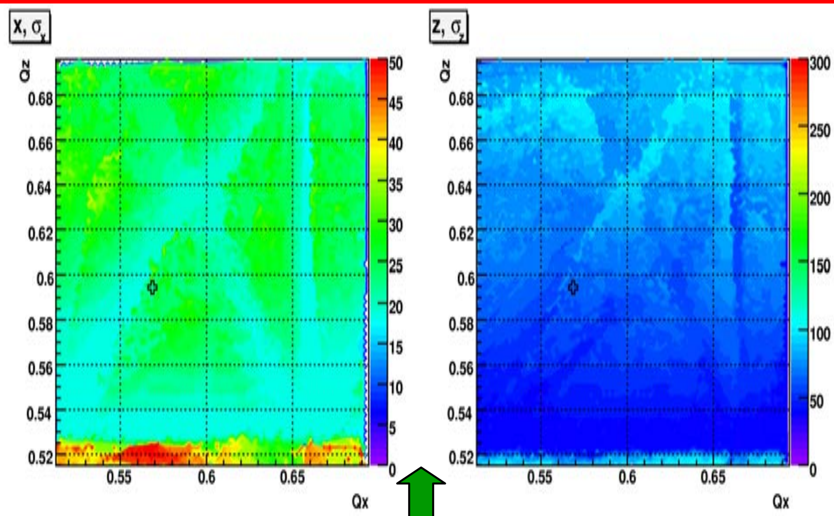
SuperB

LER Dynamic Aperture tune scan

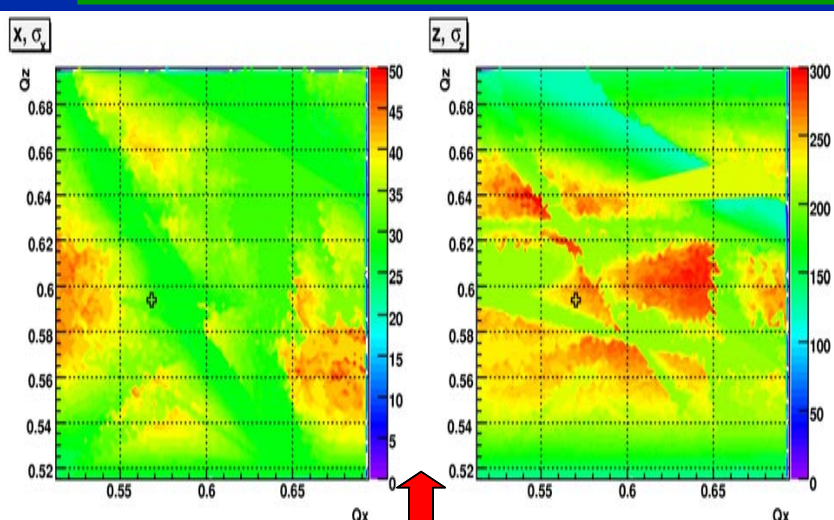
TH6PFP092

Levichev, Piminov

Strong sextupoles (mainly vertical) in IR are the major source of DA limitation, due to –I phase advance detuning for "long" sextupoles → DA recovered by adding weak correction sextupoles (strength <10% of the main ones)



Before the IR sextupoles optimization

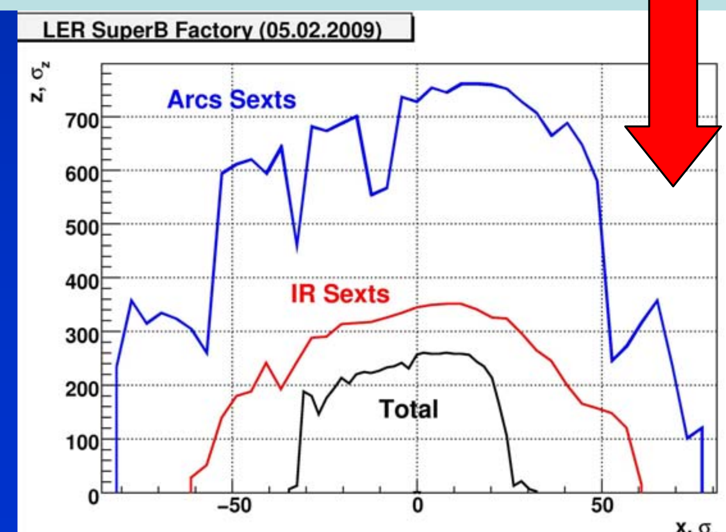


After the IR sextupoles optimization

Blue – arc sextupoles alone

Red – IR sextupoles optimized

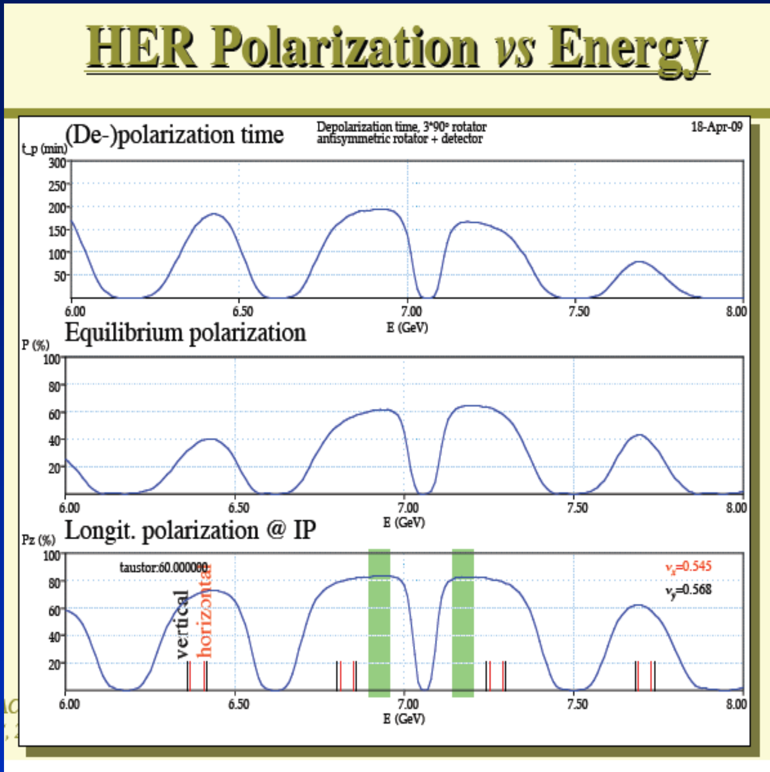
Black – arc and optimized IR sextupoles together. Additional optimization is necessary



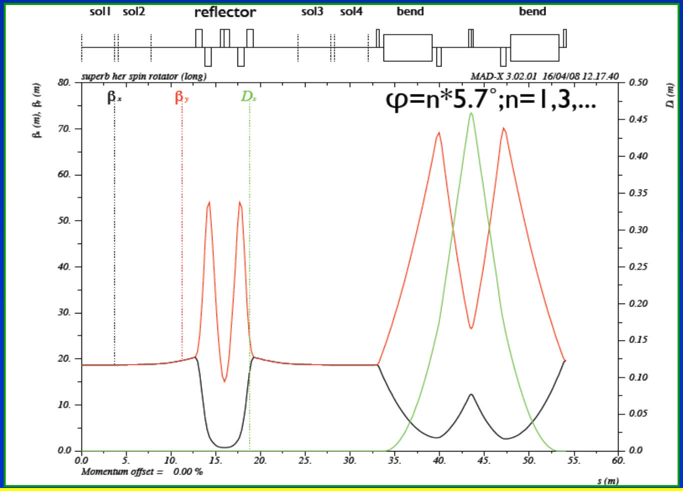
Polarization in HER

U. Wienands

- Polarization of one beam is included
  - either energy beam could be polarized
  - LER less expensive, HER easier (HER was chosen)
- Longitudinal polarization times and short beam lifetimes indicate a need to inject vertically polarized electrons
  - plan is to use SLC polarized e^- gun
- There are several possible IP spin rotators:
  - solenoids look better (vertical bends give unwanted vertical emittance growth)



Expected longitudinal polarization at IP ~ 85%(inj) x 95%(ring) = 80%(effective)

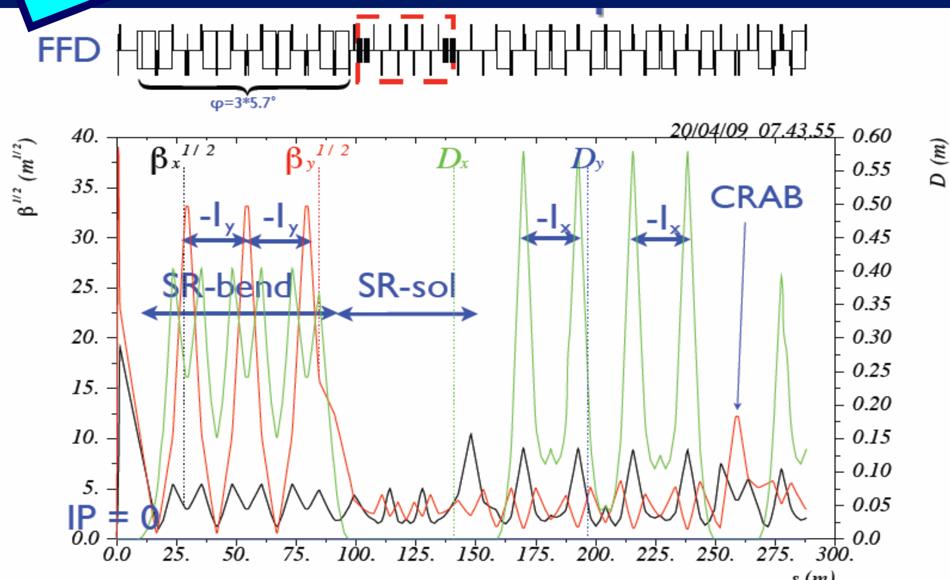


Spin rotator with solenoids and plane twister bends

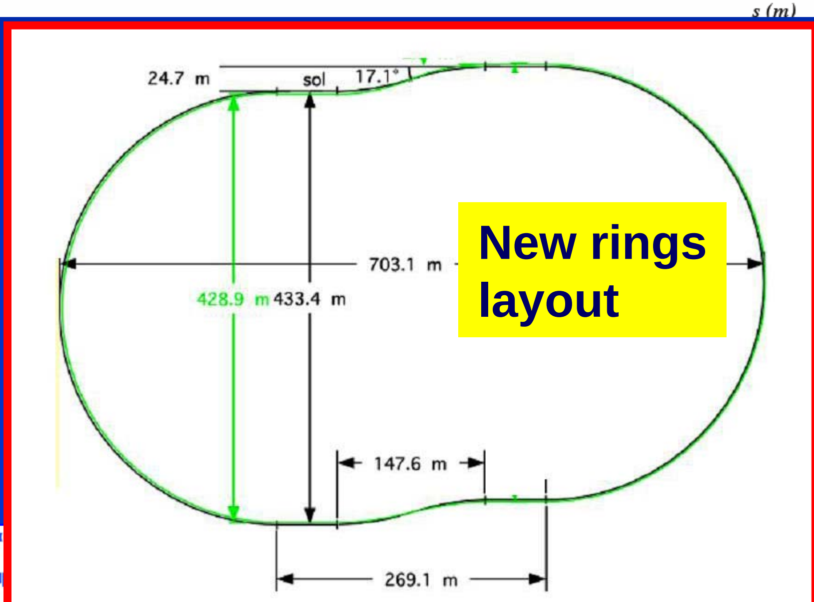
WE6PFP054

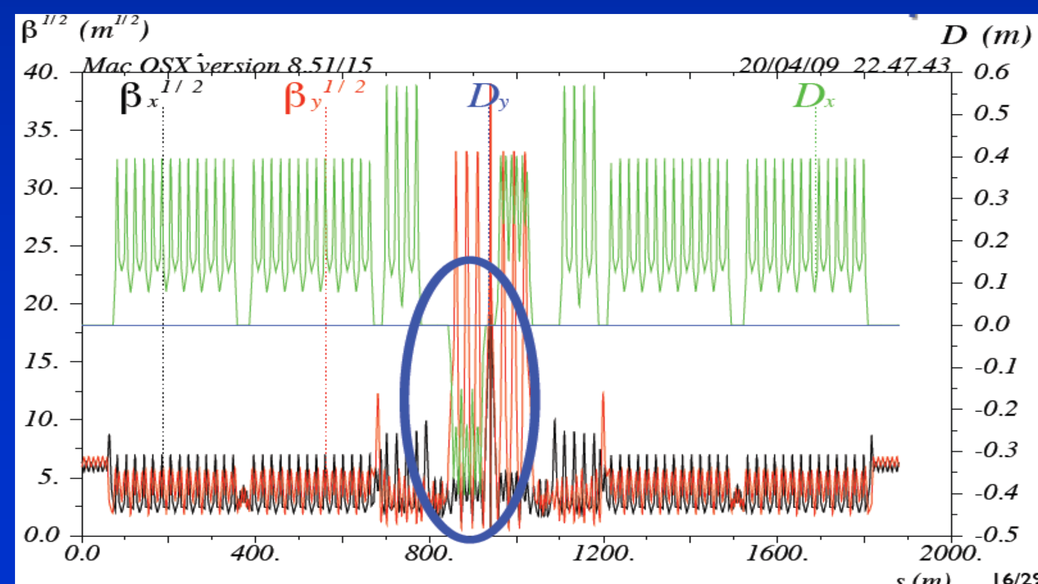
HER with spin rotator

W. Wittmer



- Introduced spin rotators on both sides of IP in HER to provide longitudinal polarized electrons at IP and maintain the chromatic characteristic of the original design necessary for the crab waist scheme, band width and dynamic aperture
- Bends have opposite sign w.r.t. IP for spin transparency condition

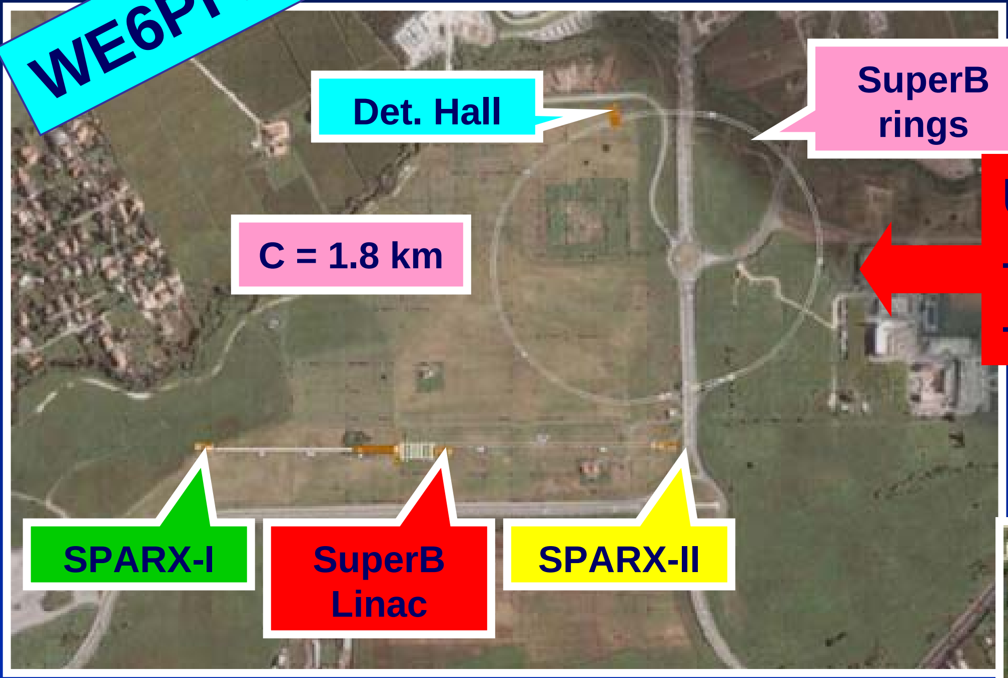




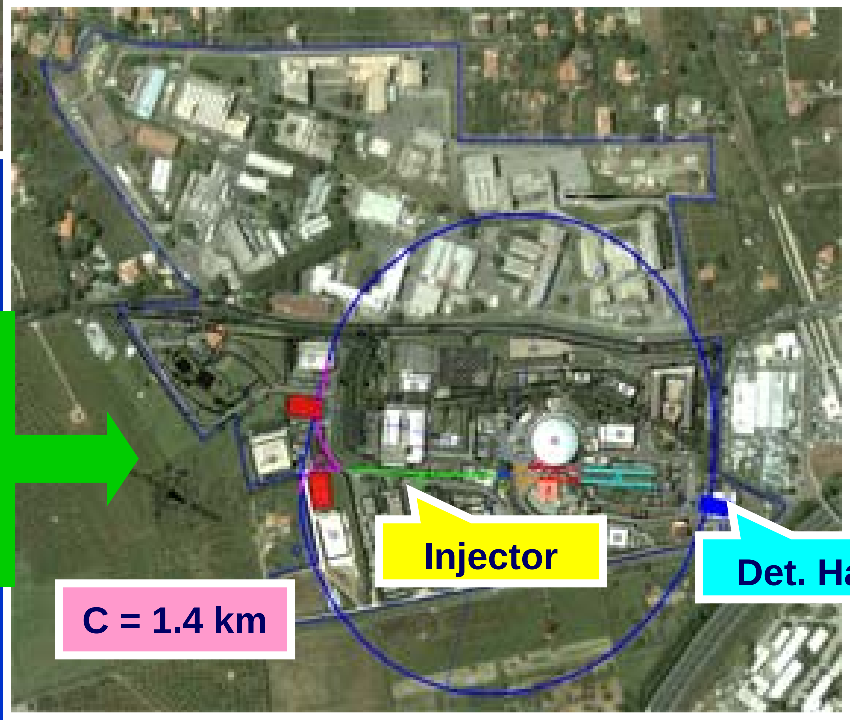
WE6PFP047

SuperB site choices

S. Tomassini



University of Tor Vergata Campus:
- green field
- synergy with SPARX-FEL project



Frascati National Laboratories:
- infrastructures
- synergy with SPARX-FEL project still possible

Conclusions

- ***DAΦNE tests have shown that the LPA&CW scheme works !***
- ***SuperB*** **parameters are being optimized around 1 x 10^{36} cm^{-2} s^{-1}**
- **Mini-MAC has endorsed the machine design: *"Mini-MAC now feels secure in enthusiastically encouraging the SuperB design team to proceed to the TDR phase, with confidence that the design parameters are achievable" (April 2009)***
- **Good progresses have been made in the IR design**
- **IR spin rotators have been added to the HER lattice. Polarization has changed the geometrical layout**
- **Beam-beam and dynamic aperture calculations are in progress, preliminary strong-strong simulations are encouraging**
- **Beam loading, RF parameters, have been studied and look acceptable**
- **Injector as well as feedback designs are in good shape**
- **Planning for a Technical Design Report for the end of 2010 has started**
- **Areas for further concentration:**
  - **Lattice low emittance tuning and dynamic aperture studies**
  - **Vibration measurements and active damping for the IR**
  - **Polarization geometry and tolerances**
  - **IR engineering**
  - **Next round of beam-beam interaction studies**

Backup slides

A new idea for collisions (LPA & CW)

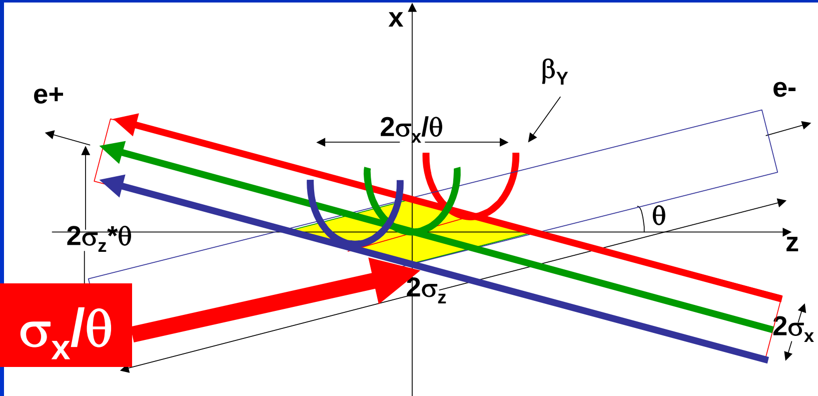
P.Raimondi, 2° SuperB Workshop, March 2006

Principle: thigher focus on beams at IP + "large" crossing angle (LPA) + a couple of sextupoles/ring to "twist" the beam waist at the IP (CW)

- Ultra-low emittance
- Very small β^* at IP
- Large crossing angle
- "Crab Waist" transformation

- Small collision area
- Lower β^* is possible
- NO parasitic crossings
- NO x-y-betatron resonances

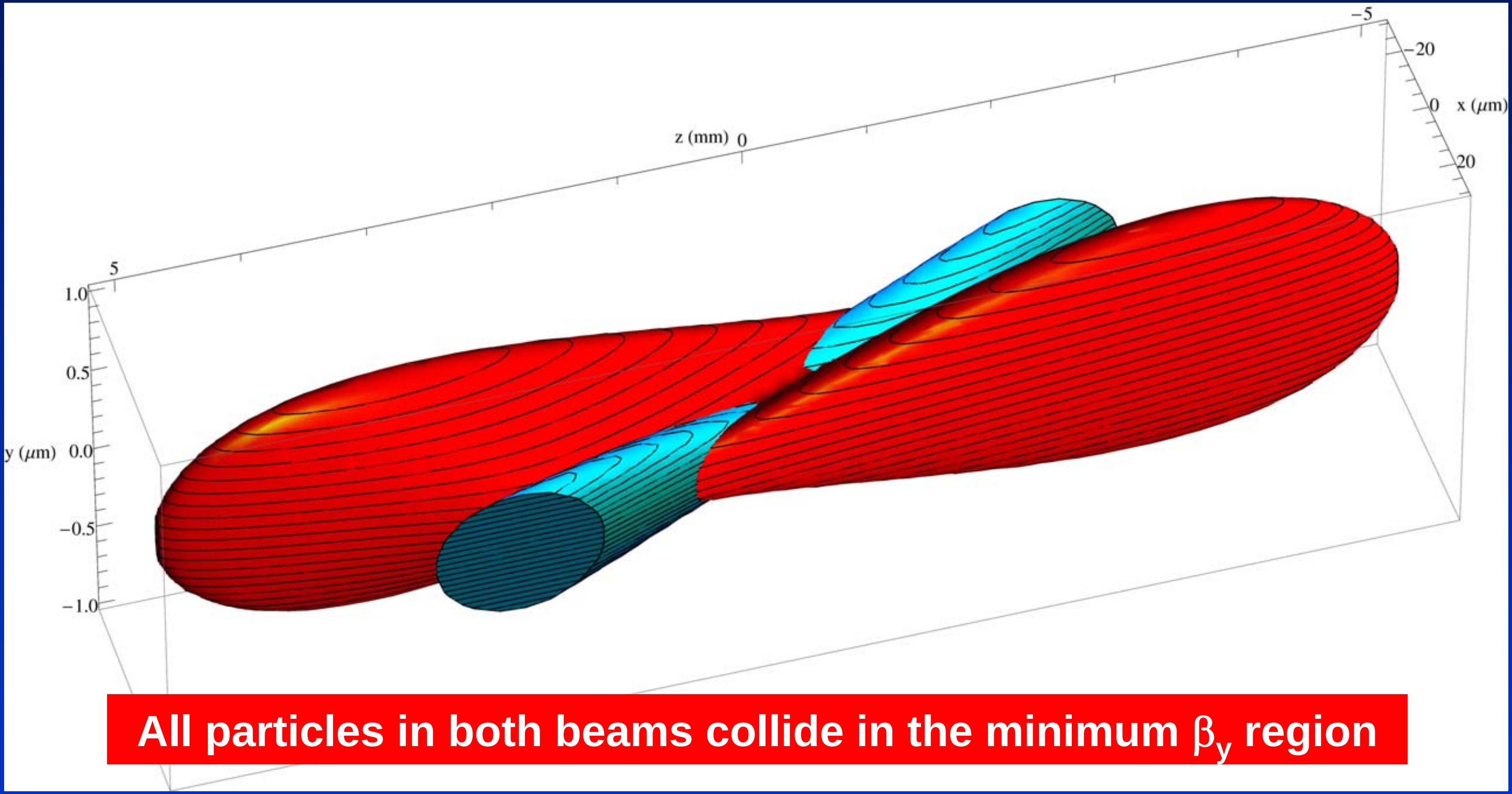
Tested at DAΦNE
Milardi's talk: MO4RAI01



Small collision area: σ_x/θ

How CW works

Crab sextupoles OFF: Waist line is orthogonal to the axis of other beam



All particles in both beams collide in the minimum β_y region

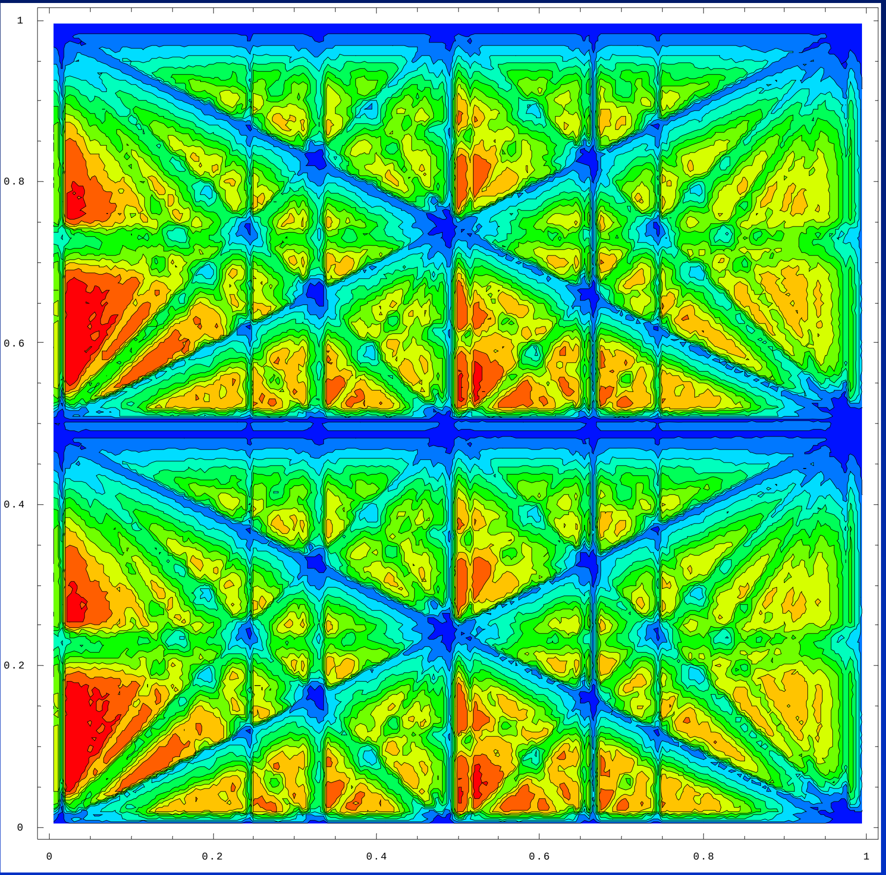
Crab sextupoles ON: Waist moves parallel to the axis of other beam: maximum particle density in the overlap between bunches

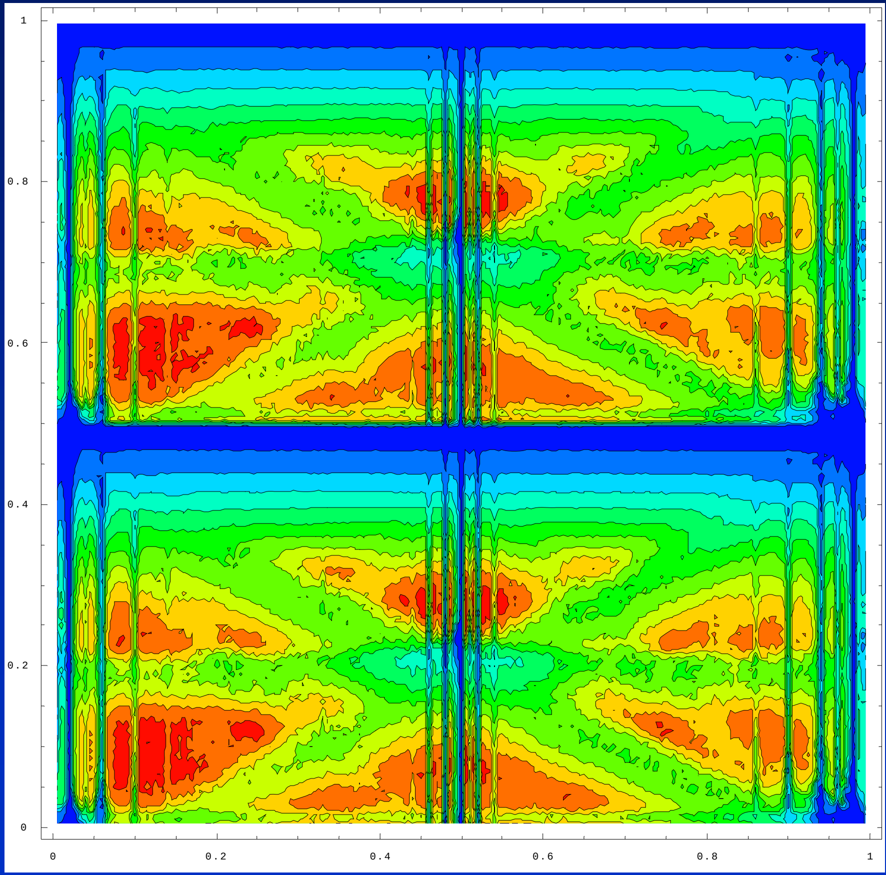
Plots by E. Paoloni

x-y resonance suppression in LPA&CW

D.Shatilov's (BINP), ICFA08 Workshop

Much higher luminosity!





Typical case (KEKB, DAΦNE):

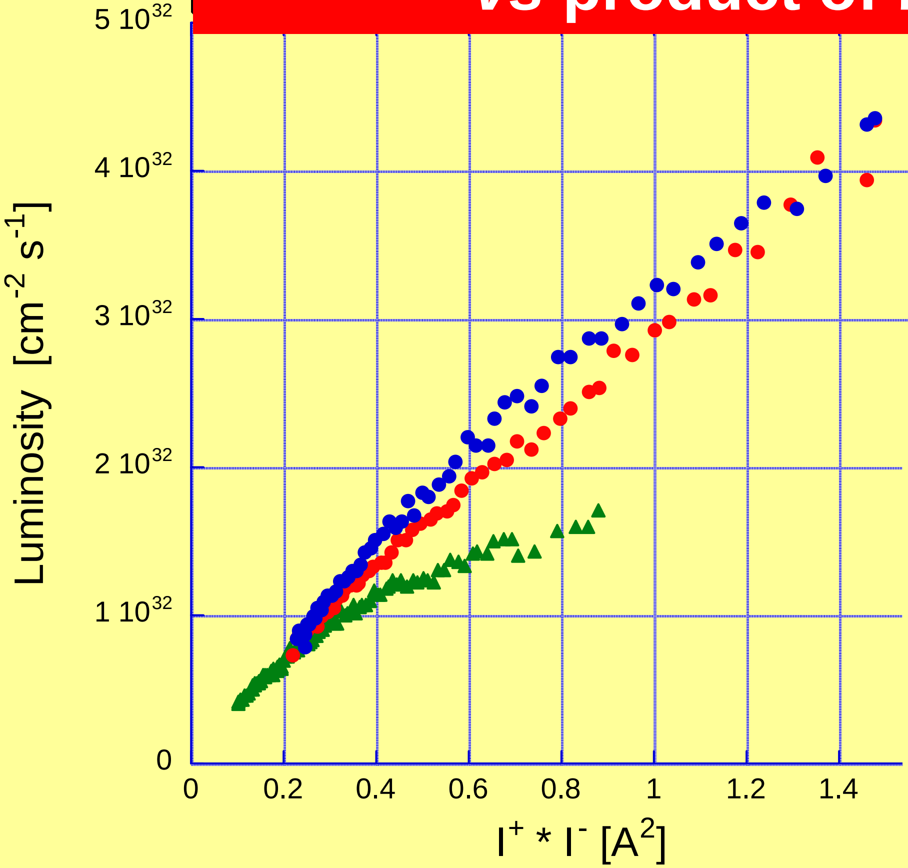
1. low Piwinski angle $\Phi < 1$
2. β_y comparable with σ_z

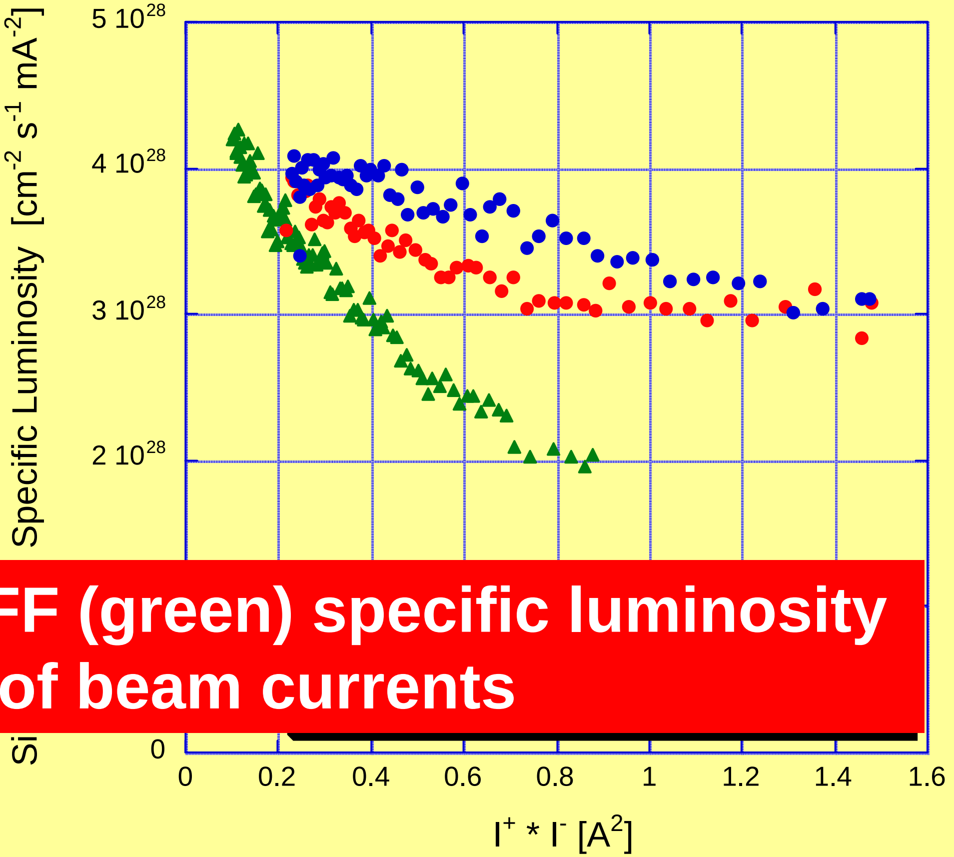
Crab Waist On:

1. large Piwinski angle $\Phi >> 1$
2. β_y comparable with σ_x/θ

DAΦNE Results

Crab ON (blue, red) & OFF (green) luminosity *vs* product of beam currents

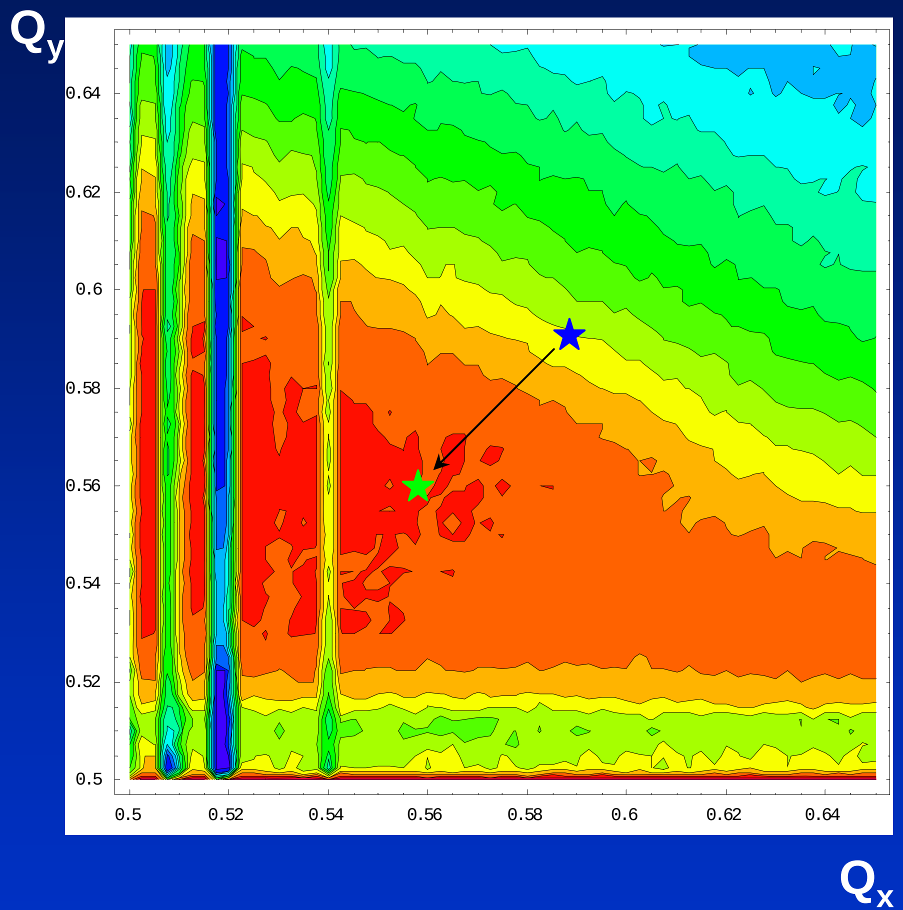


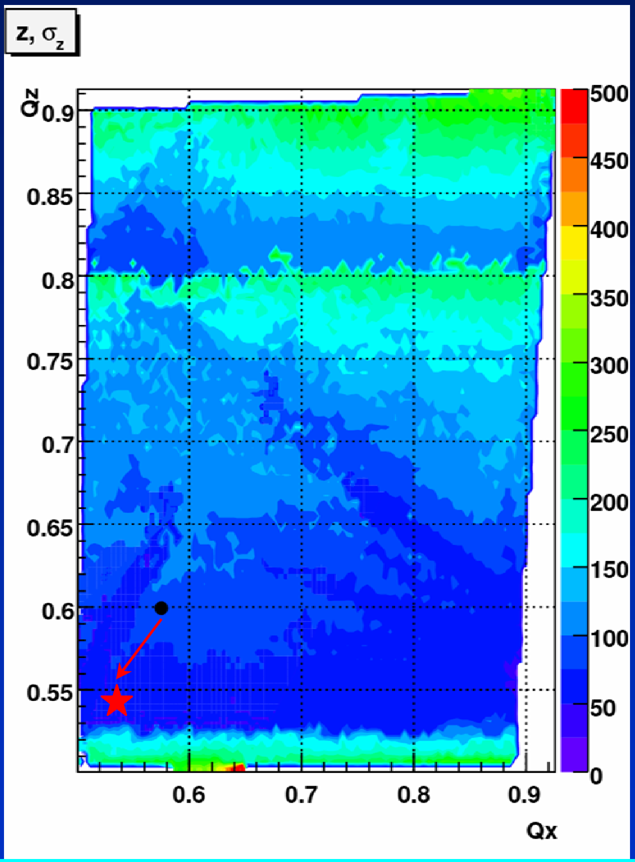


Crab ON (blue, red) & OFF (green) specific luminosity *vs* product of beam currents

Luminosity and Dynamic Aperture Scans

Piminov, Shatilov, Zobov





Beam-beam simulations taking into account nonlinear lattice elements have indicated that further dynamic aperture optimization is required in order to increase the beam lifetime (in progress)

Tune point optimization should be done together with bb simulations and luminosity/lifetime optimization

RF issues

- SLAC PEP-II RF stations (modulators, klystrons and cavities) showed high performance in achieving very high power level, which is needed for successful operation of *SuperB* project

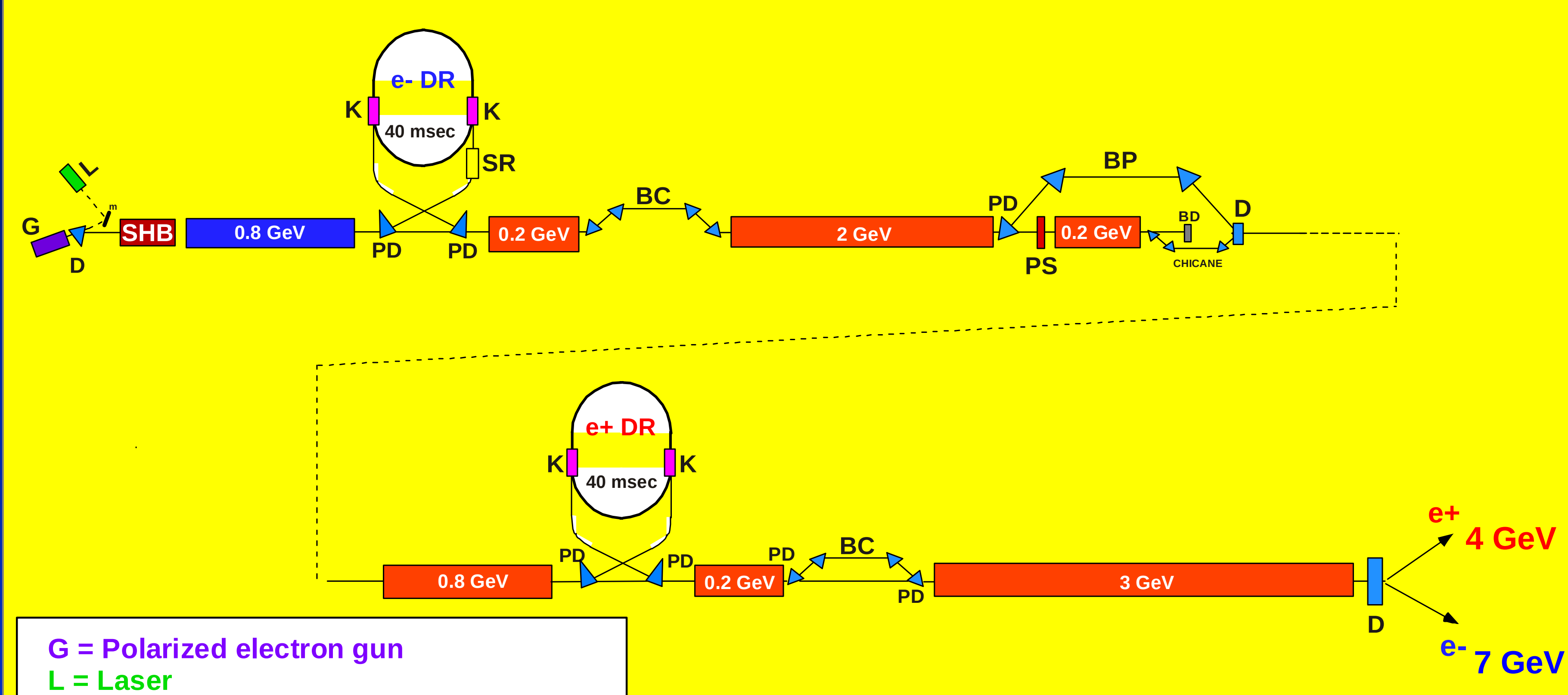
- Small momentum compaction of the *SuperB* requires smaller impedance of the rings in order to avoid large bunch lengthening and single bunch instabilities and all other current dependant effects

- Wake field studies showed that impedance can be reduced by changing materials of the chamber walls, avoiding open ceramic absorbing tiles in IR and other regions, smoothing chamber geometry, using symmetrical collimators, developing new BPMs. At this low level of impedance we have to consider other effects, which were ignored at “higher” impedance machines. For example, CSR wake fields may give noticeable effect

- Final wake field analysis should be included in engineering design of every beam chamber element

SuperB Injector layout

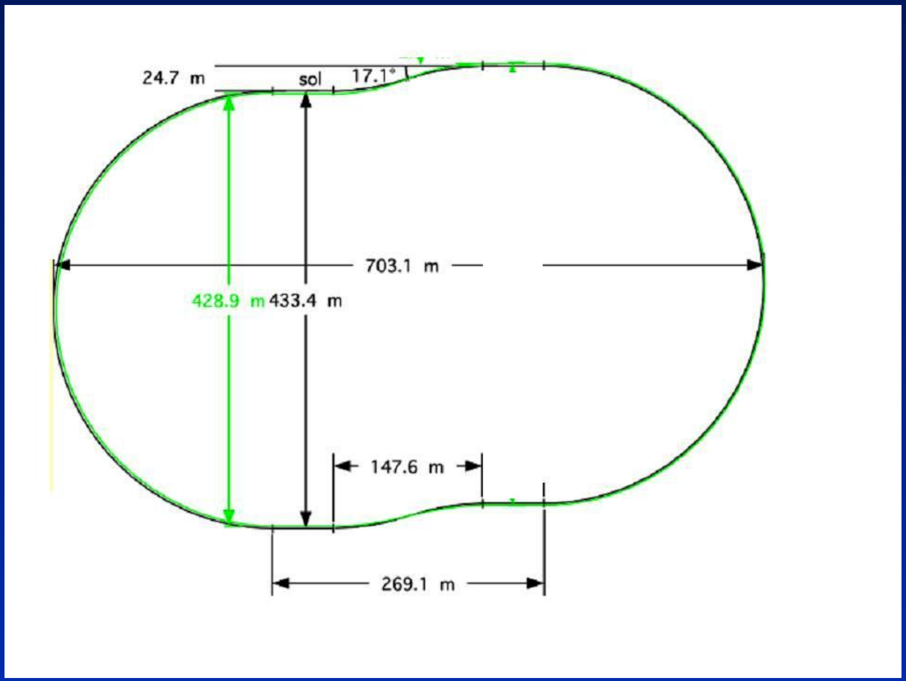
R. Boni



G = Polarized electron gun
L = Laser
SHB = Sub-Harmonic Buncher
PD = Pulsed Dipole
D = DC Dipole
K = Injection/Exctraction Kicker
SR = Spin Rotator
BC = Bunch Compressor
PS = Positron Source
BP = By-Pass Line
BD = e- Beam Dumper

F_{LINAC} = **2856 MHz**

Layout: PEP-II magnets reuse



Available | **Needed**

Dipoles

L_{mag} (m)	0.45	5.4
PEP HER	-	194
PEP LER	194	-
SBF HER	-	130
SBF LER	224	18
SBF Total	224	148
Needed	30	0

Quads

L_{mag} (m)	0.56	0.73	0.43	0.7	0.4
PEP HER	202	82	-	-	-
PEP LER	-	-	353	-	-
SBF HER	165	108	-	2	2
SBF LER	88	108	165	2	2
SBF Total	253	216	165	4	4
Needed	51*	134	0	4	4

Sexts

L_{mag} (m)	0.25	0.5
PEP HER/LER	188	-
SBF Total	372	4
Needed	184	4

All PEP-II magnets can be used, dimensions and fields are in range

RF requirements are met by the present PEP-II RF system