SuperB design progress and Dafne Upgrade

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for the LNF-DA Team

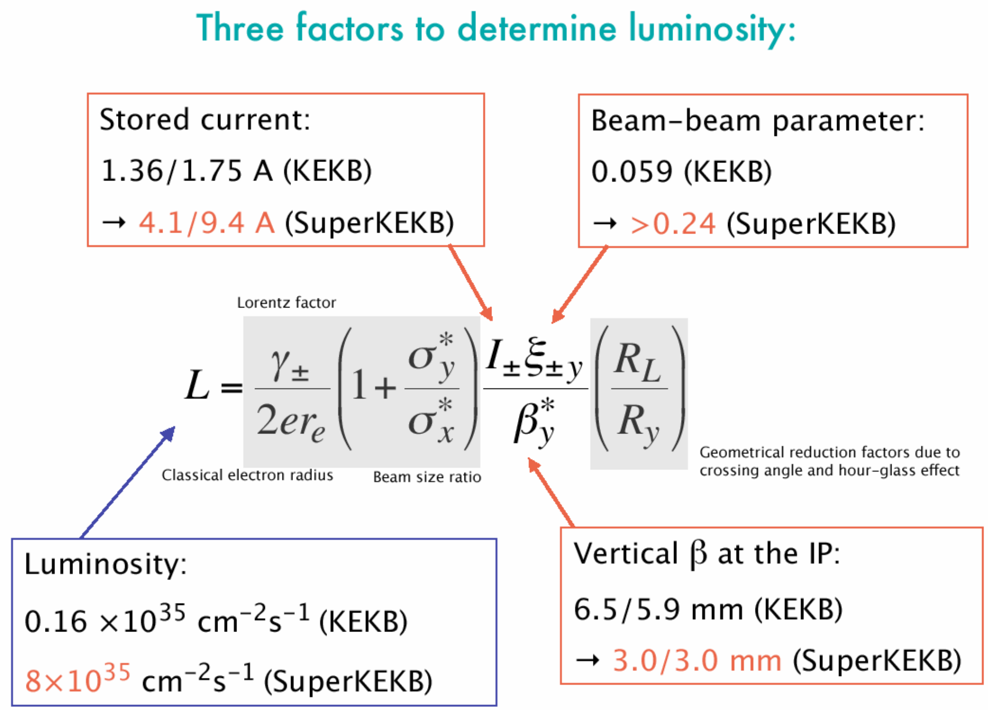
PAC, June 25, 2007

Outline

- Basic Concepts (March-Sept,2005)
- Parameters and layout optimization based on a High-Disrupted regime (Nov, 2005)
- Layout for a Ring Collider with Linear Collider Parameters
- Optimization of the SuperB
- Status of the SuperB collaboration
- Where when and how to build the SuperB
- Conclusions

Basic concepts

- B-factories reachs already very high luminosity (~10^{34} s^{-1} cm^{-2}). To increase of ~ two orders of magnitude (KeKB-SuperKeKB) it is possible to extrapolate the requirements from the current machines:



Parameters :

- Higher currents
- Smaller damping time (f(exp1/3))
- Shorter bunches
- Crab collision
- Higher Disruption
- Higher power
- SuperKeKB Proposal is based
- on these concepts

Increase of plug power ($$$$$..) and hard to operate (high current, short bunches)

look for alternatives keeping constant the luminosity

=> new IP scheme: Small beams, ILC-like

Large Piwinsky Angle and CRAB WAIST

Summary from Oide's talk at 2005 2nd Hawaii SuperBF Workshop

- Present design of SuperKEKB hits fundamental limits in the beam-beam effect and the bunch length (HOM & CSR).
- Higher current is the only way to increase the luminosity.
- Many technical and cost issues are expected with a new RF system.
- **We need a completely different collider scheme.....**

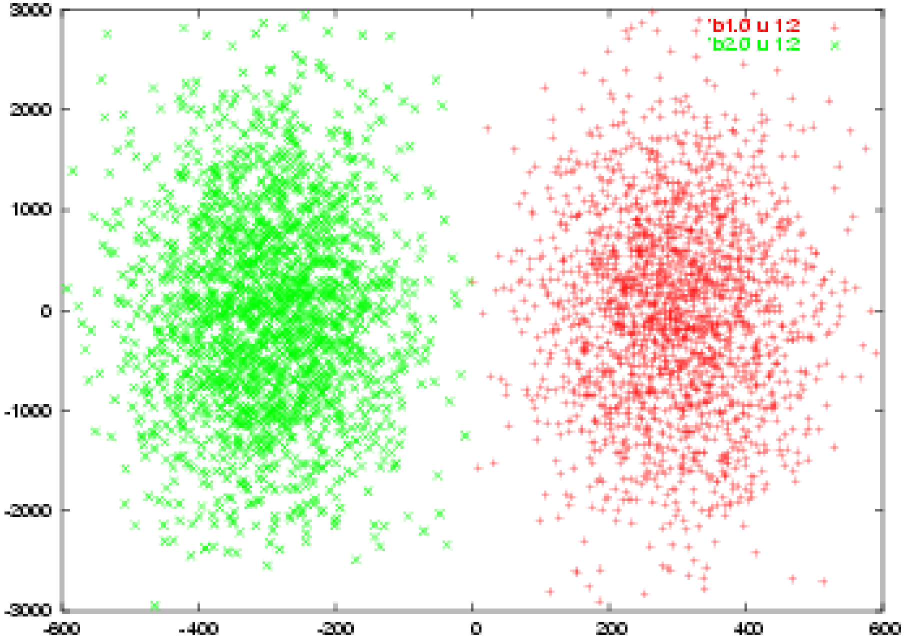
- **Basic Idea comes from the ATF2-FF experiment**

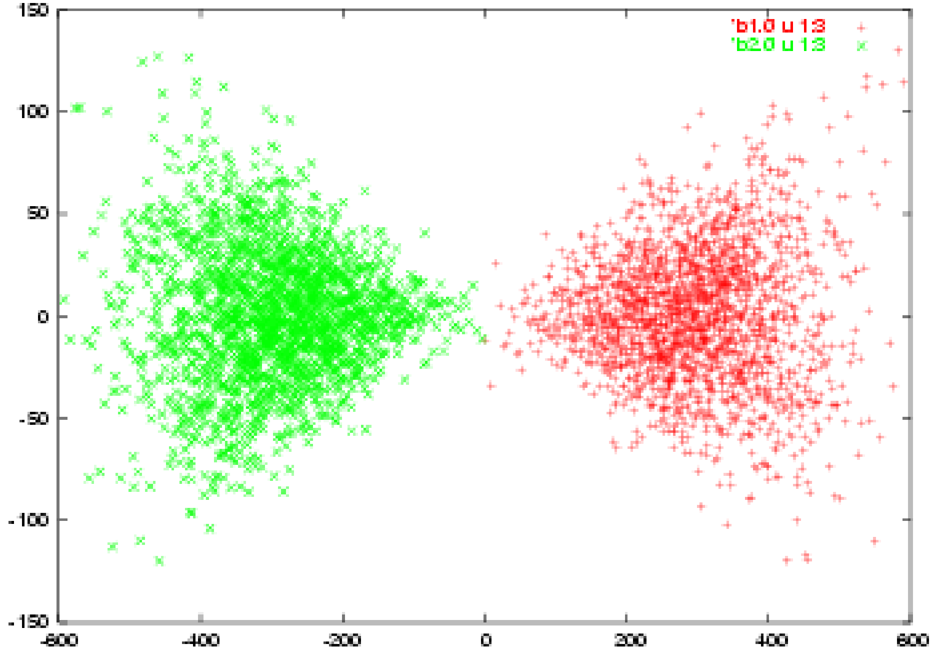
  In the proposed experiment it seems possible to acheive spot sizes at the focal point of about 2μm*20nm at very low energy (1 GeV), out from the damping ring

- **Rescaling at about 10GeV/CM we should get sizes of about 1μm*10nm =>**

- **Is it worth to explore the potential of a Collider based on a scheme similar to the Linear Collider one**

Idea presented at the Hawaii workshop on Super-B factory on March-2005 (P.Raimondi)





Horizontal Collision

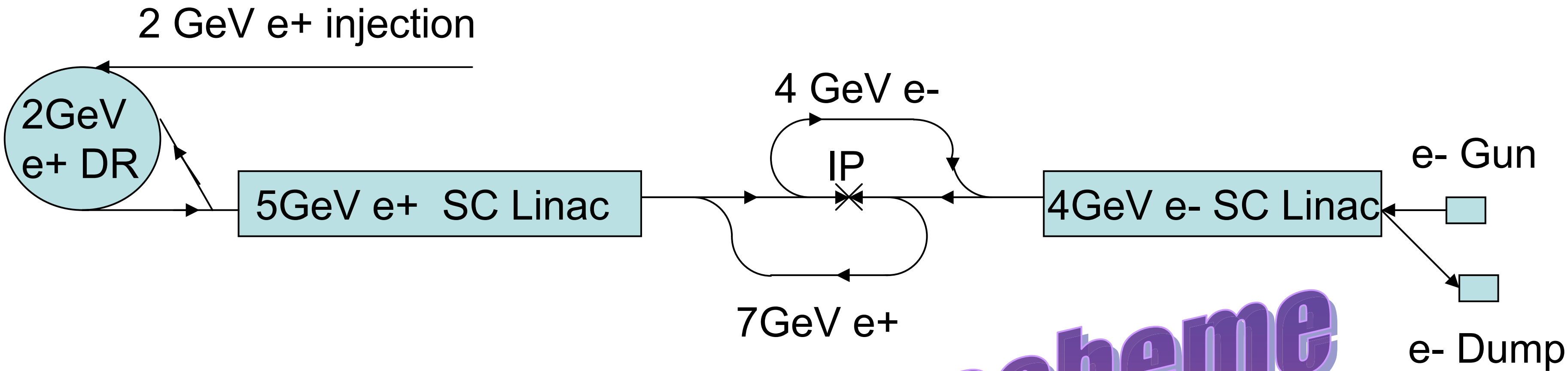
Vertical collision

Effective horizontal size during collision about 10 times smaller, vertical size 10 times larger

First attempt to collide small beams

Simulation by D.Schulte

Linear Super B schemes with acceleration and energy recovery, to reduce power



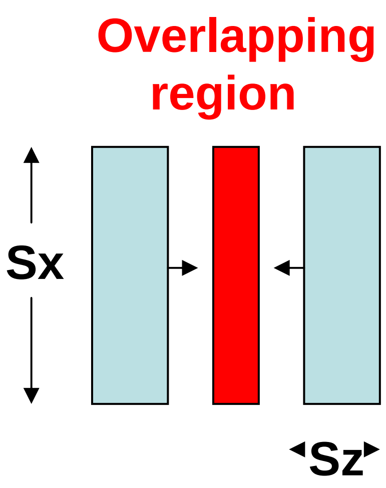
First collider scheme

Overall rings lenght about 6Km
Collision frequency abo...
120Hz*1000... ...trains=1.2
00MHz

Bunch train stays in the rings for 8.3msec, then is extracted, compressed and focused. After the collision is reinjected in its ring

- ...e S... ...acs to recover energy
- Use lower energy damping rings to reduce synchrotron radiation
- No electron damping ring
- Make electrons fresh every cycle
  - Damping time means time to radiate all energy
  - Why not make a fresh beam if storage time is greater than 1 damping time

Crossing angle concepts

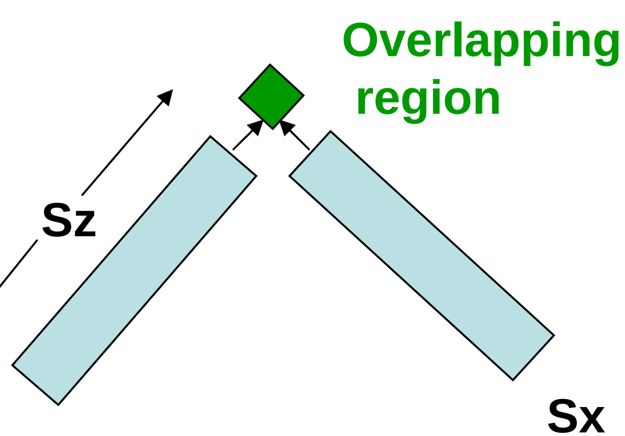


1) Standard short bunches

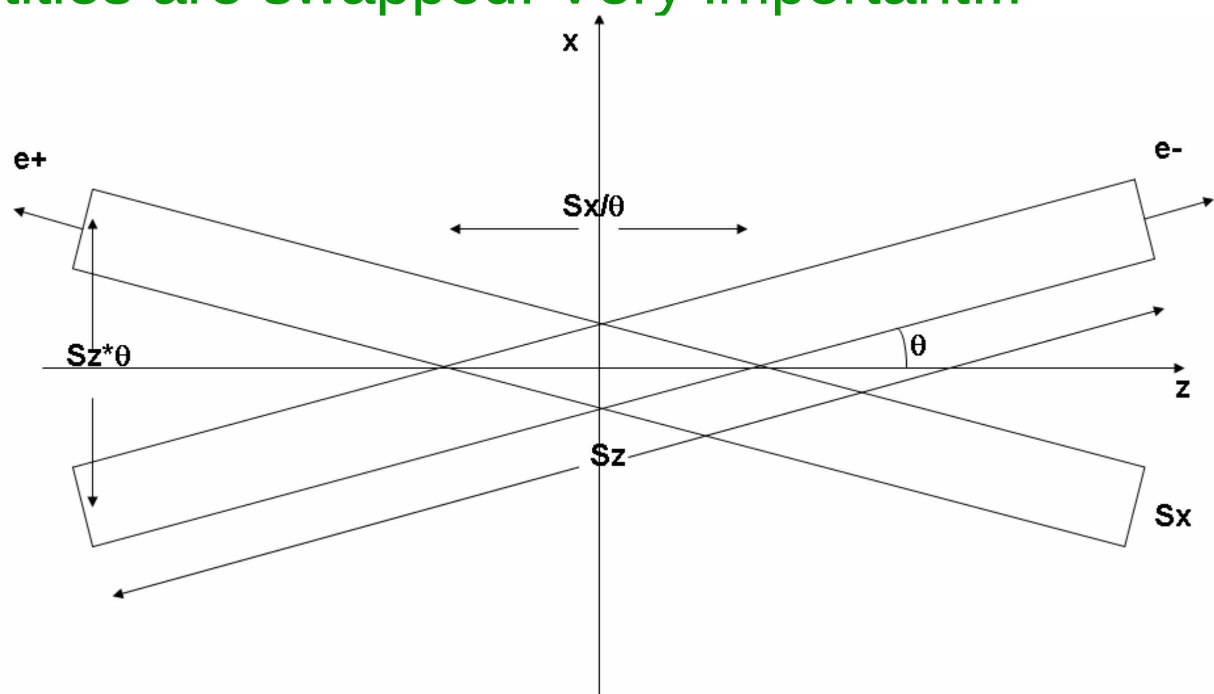
All colliders do need short bunches to decrease the hourglass effect and the beams disruption

Both cases have the same luminosity, (2) has longer bunch and smaller σ_x

With large crossing angle X and Z quantities are swapped: Very important!!!



2) Crossing angle



High luminosity requires:

- **short bunches**
- **small vertical emittance**
- **large horizontal size and emittance to mimimize beam-beam**

For a ring:

- **easy to achieve small horizontal emittance and horizontal size**
- **Vertical emittance goes down with the horizontal**
- **Hard to make short bunches**

Crossing angle swaps X with Z, so the high luminosity requirements are naturally met:

Luminosity goes with $1/\varepsilon_x$ and is weakly dependent by σ_z

Crab Waist Advantages

1. Large Piwinski's angle

$$\Phi = tg(\theta)\sigma_z/\sigma_x$$

→

a) Geometric luminosity gain

b) Very low horizontal tune shift

2. Vertical beta comparable with overlap area

$$\beta_y \approx \sigma_x/\theta$$

→

a) Geometric luminosity gain

b) Lower vertical tune shift

c) Vertical tune shift decreases with oscillation amplitude

d) Suppression of vertical synchro-betatron resonances

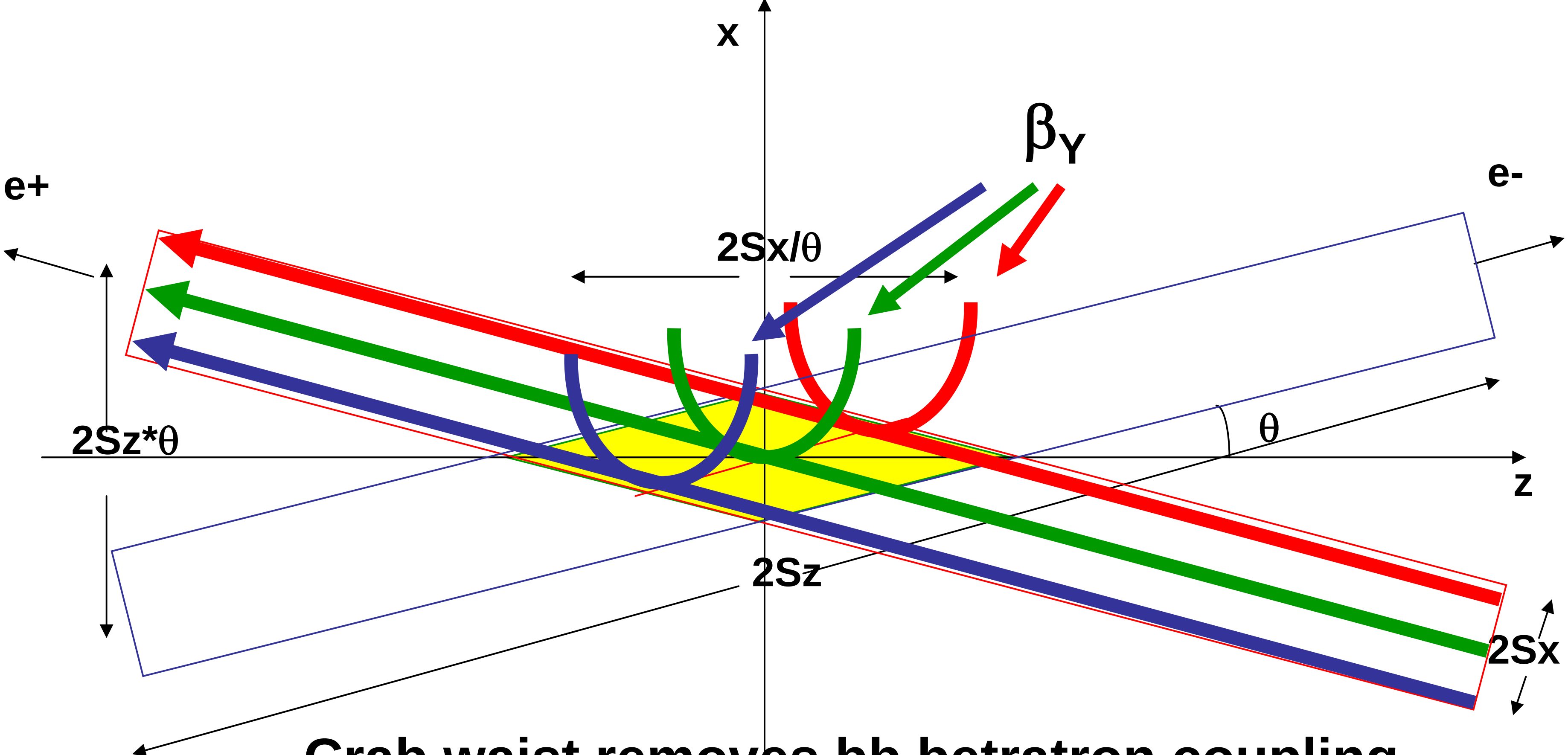
3. Crabbed waist transformation

$$y = xy'/(2\theta)$$

→

a) Geometric luminosity gain

b) Suppression of X-Y betatron and synchro-betatron resonances



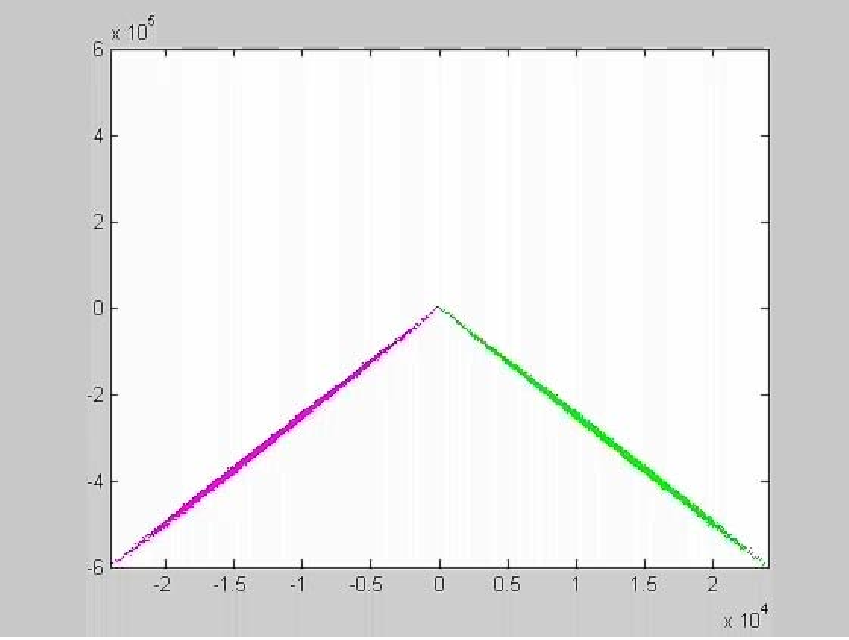
Crab waist removes bb betratron coupling Introduced by the crossing angle

Vertical waist has to be a function of x:

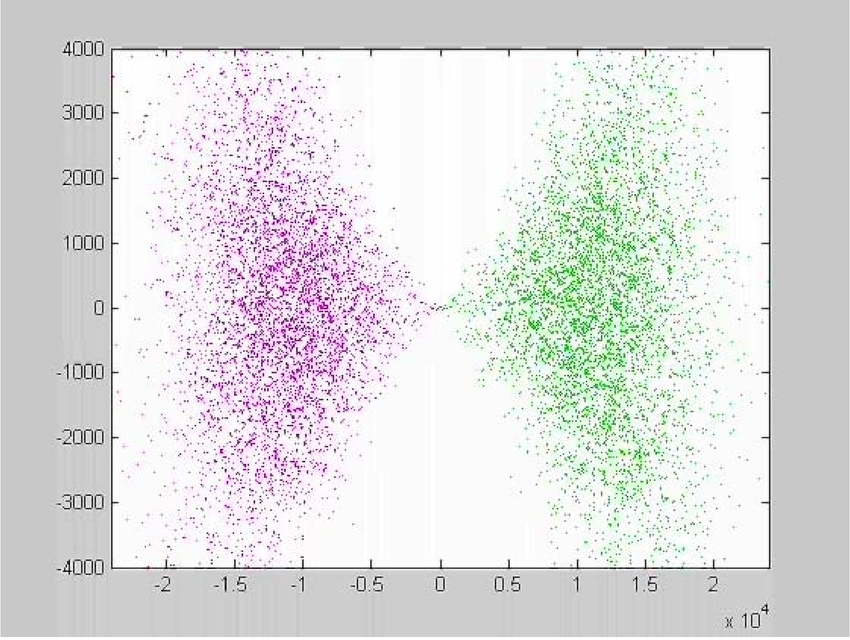
Z=0 for particles at $-\sigma_x$ ($-\sigma_x/2\theta$ at low current)

Z= σ_x/θ for particles at + σ_x ($\sigma_x/2\theta$ at low current)

Crab waist realized with 2 sextupoles in phase with the IP in X and at $\pi/2$ in Y



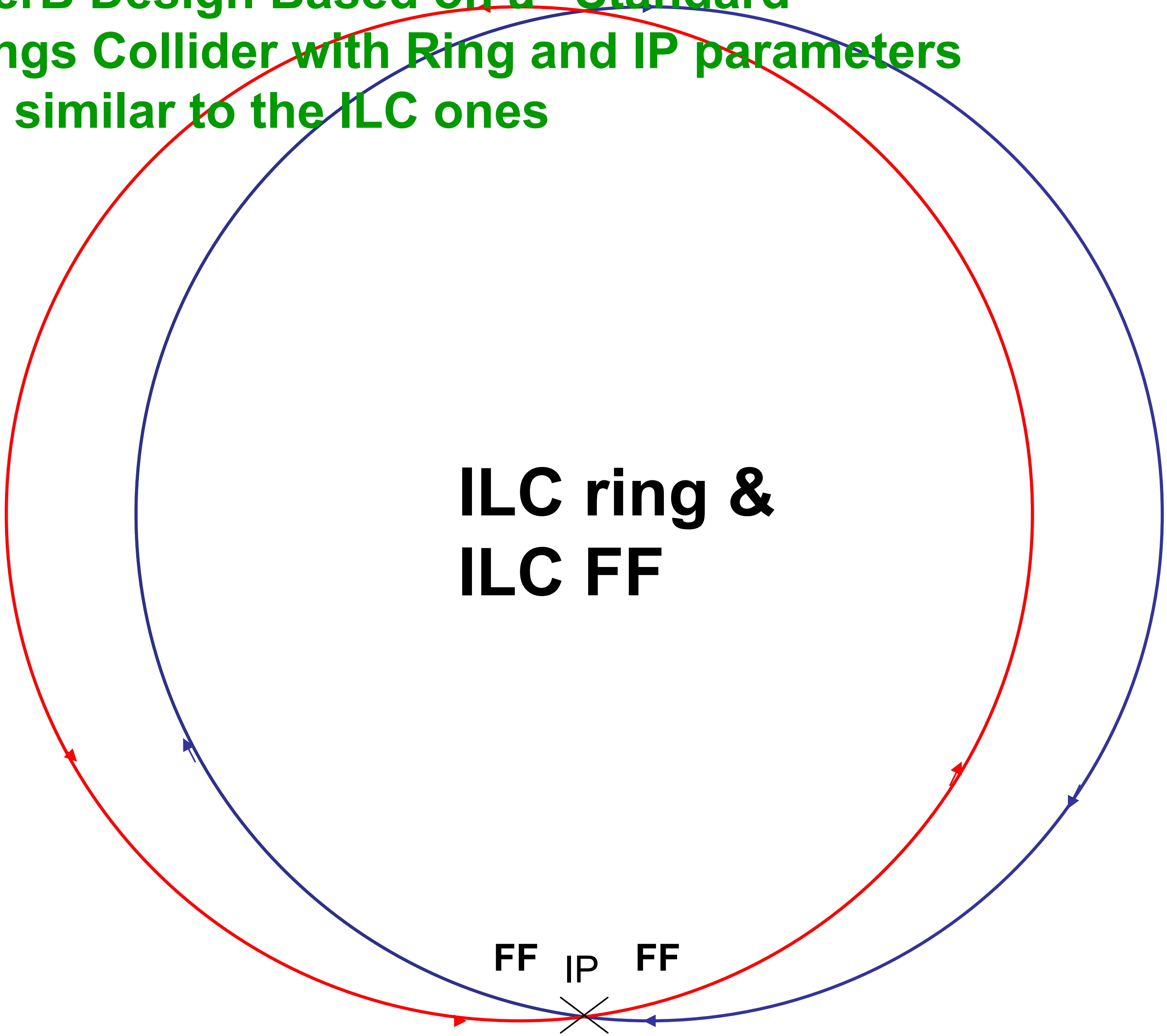
Horizontal Plane



Vertical Plane

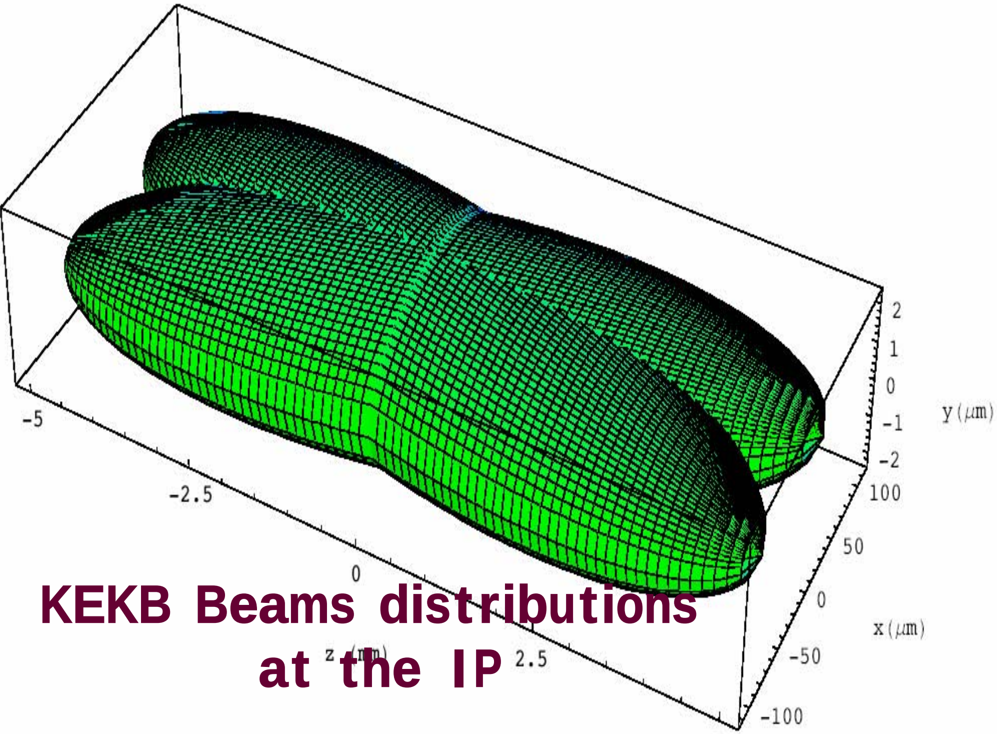
Collisions with uncompressed beams
Crossing angle = 2*25mrad
Relative Emittance growth per collision about $1.5*10^{-3}$
$\varepsilon_{yout}/\varepsilon_{yin}=1.0015$

SuperB Design Based on a "Standard" 2 Rings Collider with Ring and IP parameters very similar to the ILC ones

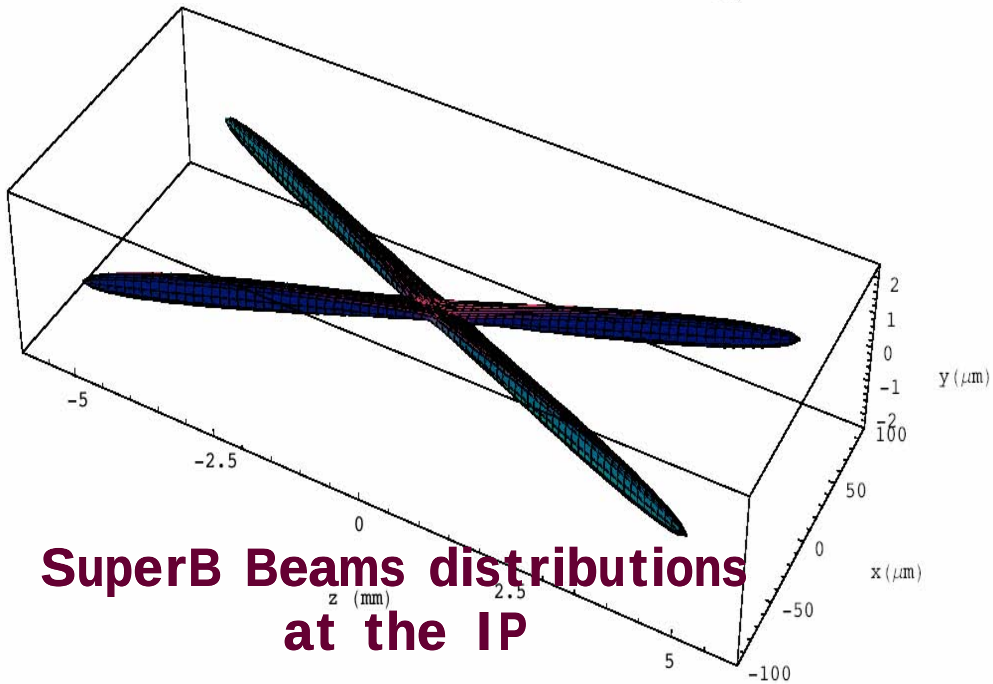


Where is the real gain?

	PEPII	KEKB	SuperB
current	2.5 A	1.7 A	2.3 A
betay	10 mm	6 mm	0.3 mm
betax	400 mm	300 mm	20 mm
Emitx (sigmax)	23 nm (~100μm)	~ the same (~80μm)	1,6 nm (~6μm)
y/x coupling (sigma y)	0,5-1 % (~6μm)	0.1 % (~3μm)	0,25 % (0,035μm)
Bunch length	10 mm	6 mm	6 mm
Tau l/t	16/32 msec	~ the same	16/32 msec
ζ_y	0.07	0.1	0.16
L	$1.2\ 10^{34}$	$1.7\ 10^{34}$	$1\ 10^{36}$



KEKB Beams distributions at the IP



SuperB Beams distributions at the IP

Beams are focused in the vertical plane 100 times more than in the present factories, thanks to:

- **small emittances**
- **small beta functions**
- **large crossing angle**
- **Crab waist**

Tune shifts and longitudinal overlap greatly reduced

	KEKB	SuperB
current	1.7 A	2.3 A
betay	6 mm	0.3 mm
betax	300 mm	20 mm
sigmax	~80μm	~6μm
sigma y	~3μm	0,035μm
Sigma z	6 mm	6 mm
L	$1.7\ 10^{34}$	$1\ 10^{36}$

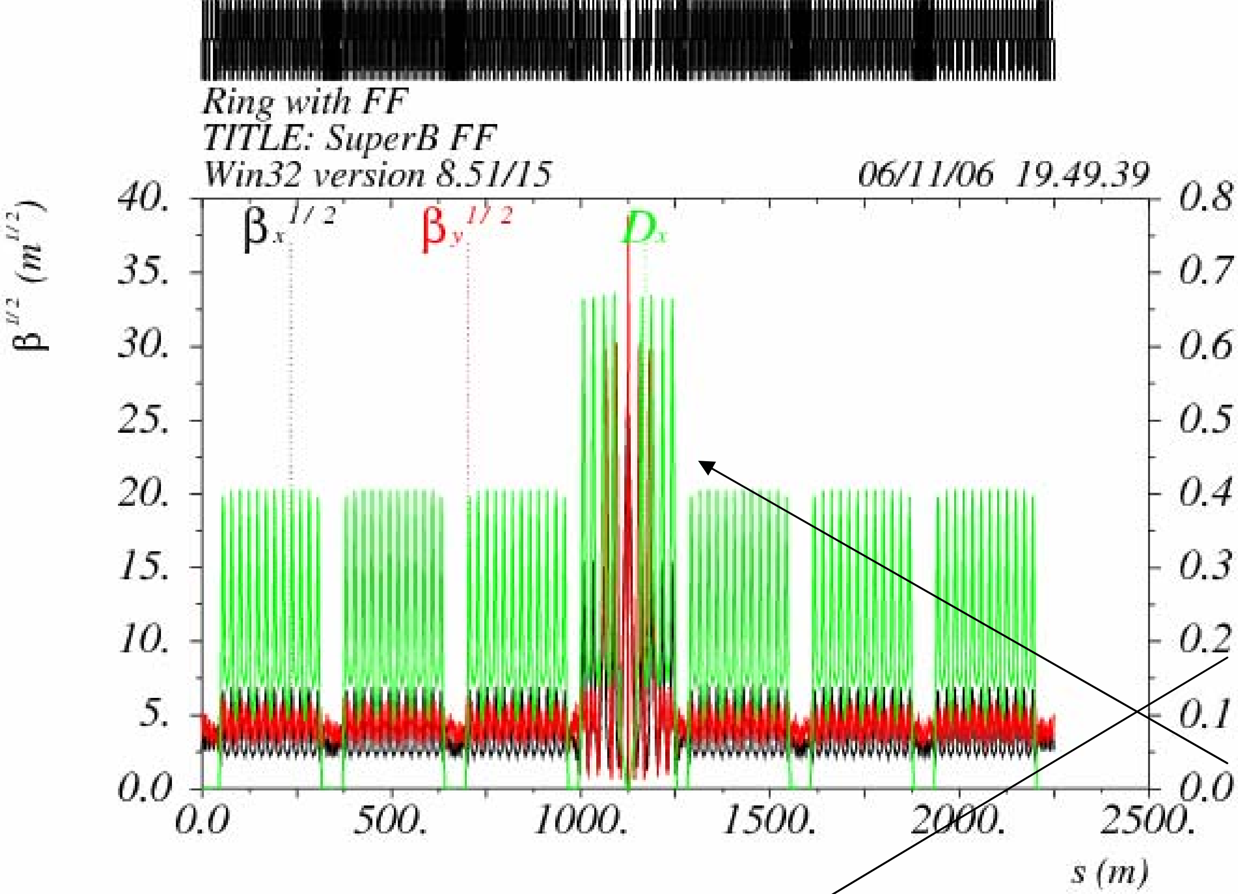
Parameters Optimization

- Relaxed damping time, now chosen like the PEP one: 10msec=>16msec
- Relaxed y/x IP βs: 80μm/9mm => 300μm/20mm
- Relaxed y/x IP σs: 12.6nm/2.67μm => 20nm/4μm
- Possible to increase bunch length: 6mm => 7mm
- Possible increase in L by further β's squeeze
- Possible to operate with half of the bunches and twice the bunch charge (same current), with relaxed requirements on ε_y: 2pm => 8pm (1% coupling)
- Possible to operate with half of the bunches and twice the bunch charge (same current), with twice the emittances
- **Possible to have two interaction points**

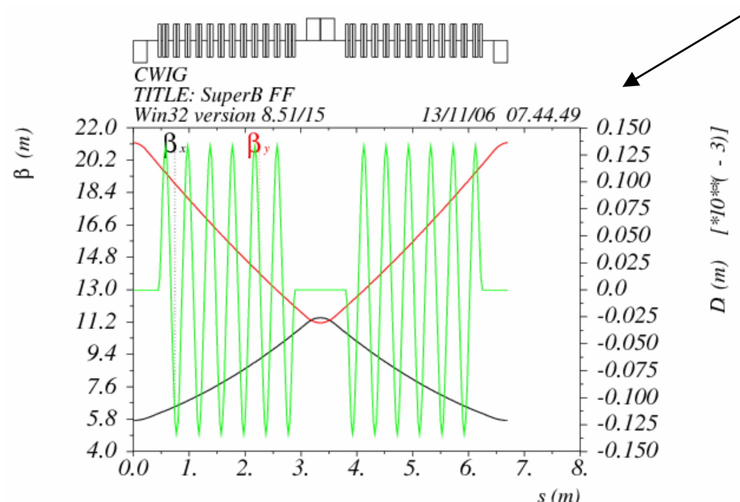
Luminosity x 10^{36}	1		2,4		3,4	
Circumference (m)	2250	2250	2250	2250	2250	2250
Revolution frequency (MHz)	0,13	0,13	0,13	0,13	0,13	0,13
Eff. long. polarization (%)	0	80	0	80	0	80
RF frequency (MHz)	476	476	476	476	476	476
Harmonic number	3570	3570	3570	3570	3570	3570
Momentum spread	8,4E-04	9,0E-04	1,0E-03	1,0E-03	1,0E-03	1,0E-03
Momentum compaction	1,8E-04	3,0E-04	1,8E-04	3,0E-04	1,8E-04	3,0E-04
Rf Voltage (MV)	6	18	6	18	7,5	18
Energy loss/turn (MeV)	1,9	3,3	2,3	4,1	2,3	4,1
Number of bunches	1733	1733	3466	3466	3466	3466
Particles per bunch $x10^{10}$	6,16	3,52	5,34	2,94	6,16	3,52
Beam current (A)	2,28	1,30	3,95	2,17	4,55	2,60
Beta y* (mm)	0,30	0,30	0,20	0,20	0,20	0,20
Beta x* (mm)	20	20	20	20	20	20
Emit y (pmr)	4	4	2	2	2	2
Emit x (nmr)	1,6	1,6	0,8	0,8	0,8	0,8
Sigma y* (microns)	0,035	0,035	0,020	0,020	0,020	0,020
Sigma x* (microns)	5,657	5,657	4,000	4,000	4,000	4,000
Bunch length (mm)	6	6	6	6	6	6
Full Crossing angle (mrad)	34	34	34	34	34	34
Wigglers (#)	4	2	4	4	4	4
Damping time (trans/long)(ms)	32/16	32/16	25/12.5	25/12.5	25/12.5	25/12.5
Luminosity lifetime (min)	10,4	5,9	7,4	4,1	6,1	3,5
Touschek lifetime (min)	5,5	38	2,9	19	2,3	15
Effective beam lifetime (min)	3,6	5,1	2,1	3,4	1,7	2,8
Injection rate pps (100%)	4,9E+11	2,0E+11	1,5E+12	5,0E+11	2,1E+12	7,2E+11
Tune shifts (x/y) (from formula)	0.004/0.17	0.004/0.17	0.007/0.16	0.007/0.16	0.009/0.2	0.009/0.2
RF Power (MW)	17		35		44	

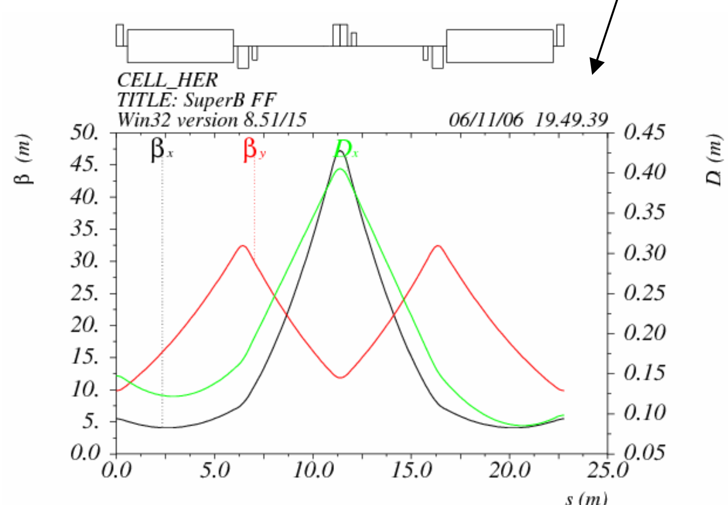
Possible site in the Tor Vergata University close to the Frascati Lab

HER Ring Lattice



6 Arc with 12 Cells each
4 Wigglers section
1 Straight section
1 300m long
Final Focus Section





Ring optimization

- Shorten the arcs by using less cells with smaller intrinsic emittance:

  TME: mux=0.375, muy=0.14 =>

  pi/pi2: mux=0.5, muy=0.2
- Other benefits:

  - smaller natural chromaticity: qx’ from -80 to -55

  qy’ unchanged

  - better dynamic aperture?

  - fewer elements: 6 arcs with 12 cells =>

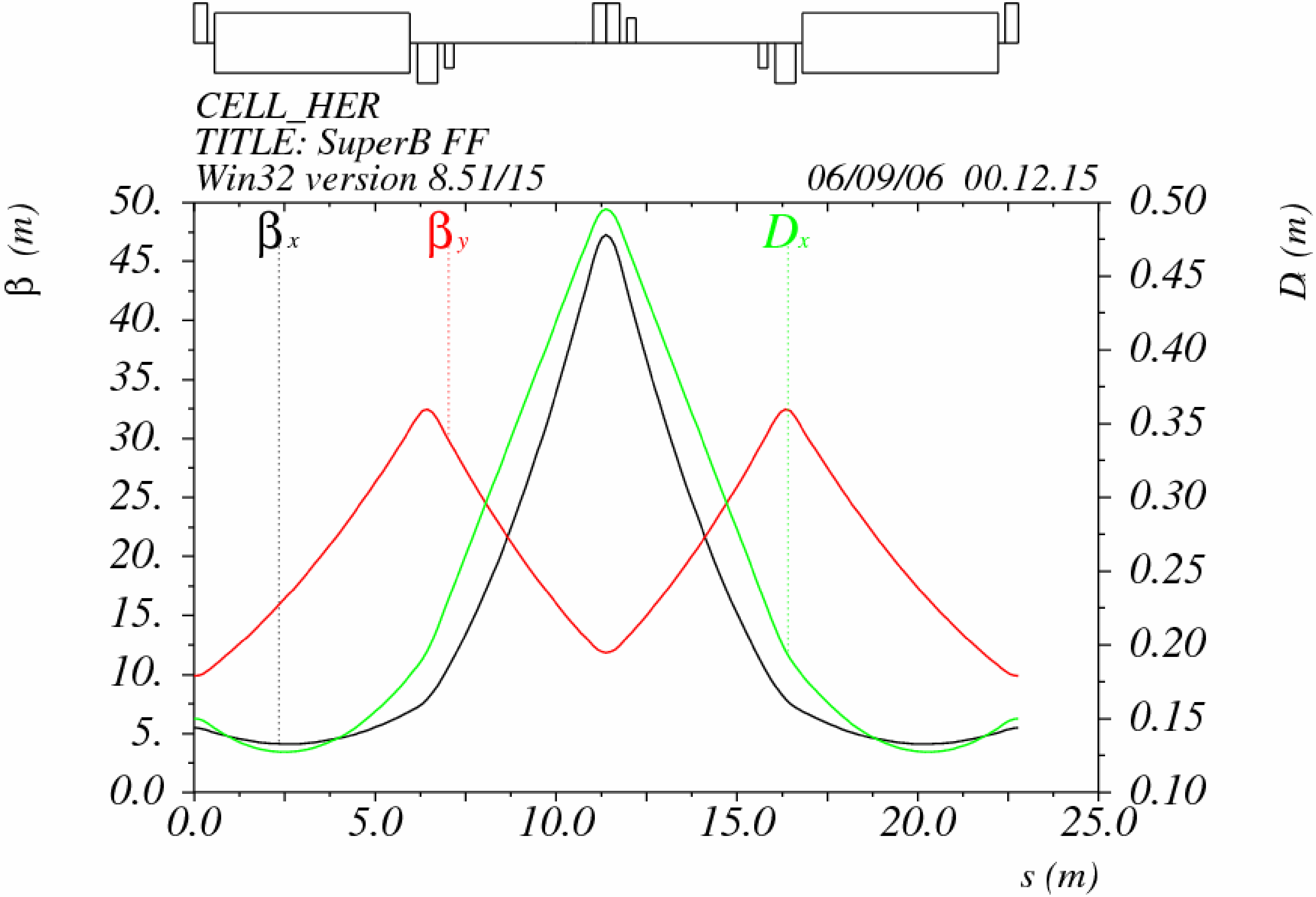
  120 5.4m long bends + 16 5.4m long bends for the FF

  - arcs 250m long

  - overall ring lenght 2.2Km

  - optimized phase advance between arcs (pi/3) to get best performances

  emix_x =1nm (from 0.8nm) sigma_z = 6mm (from 7mm)

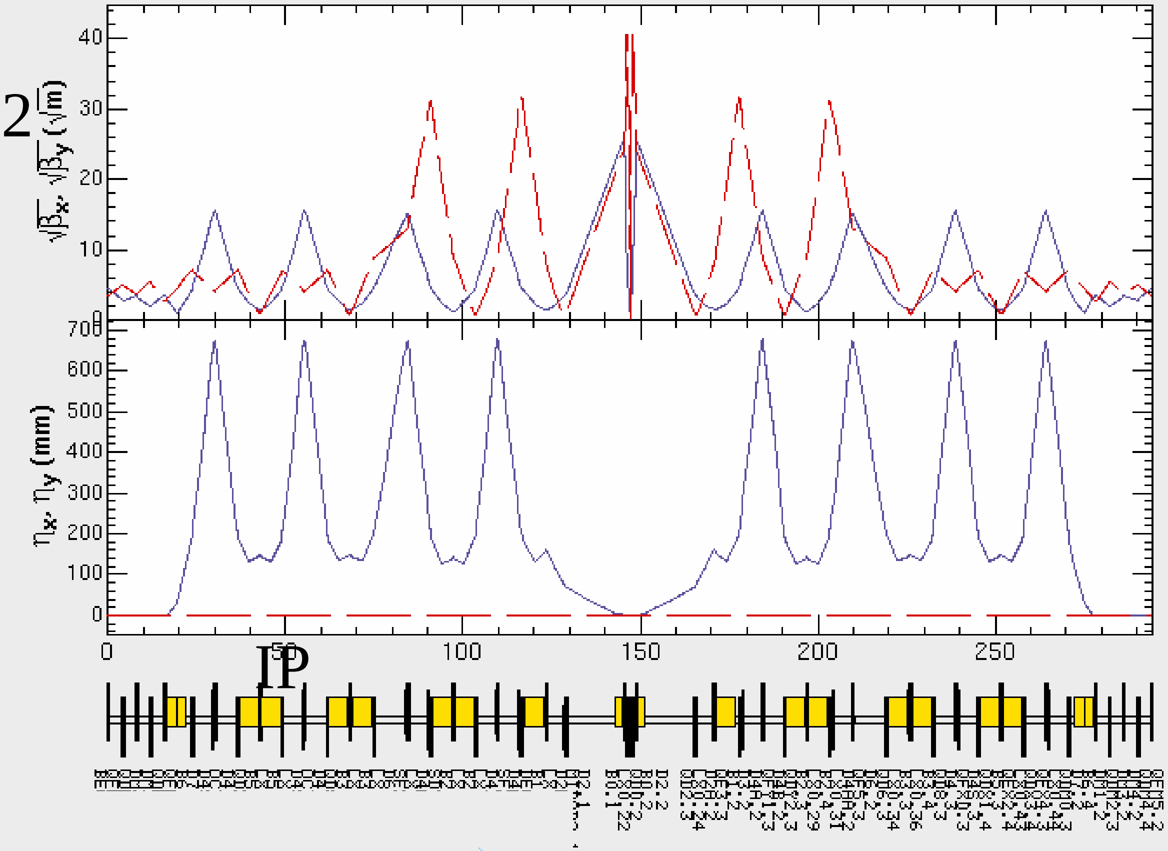


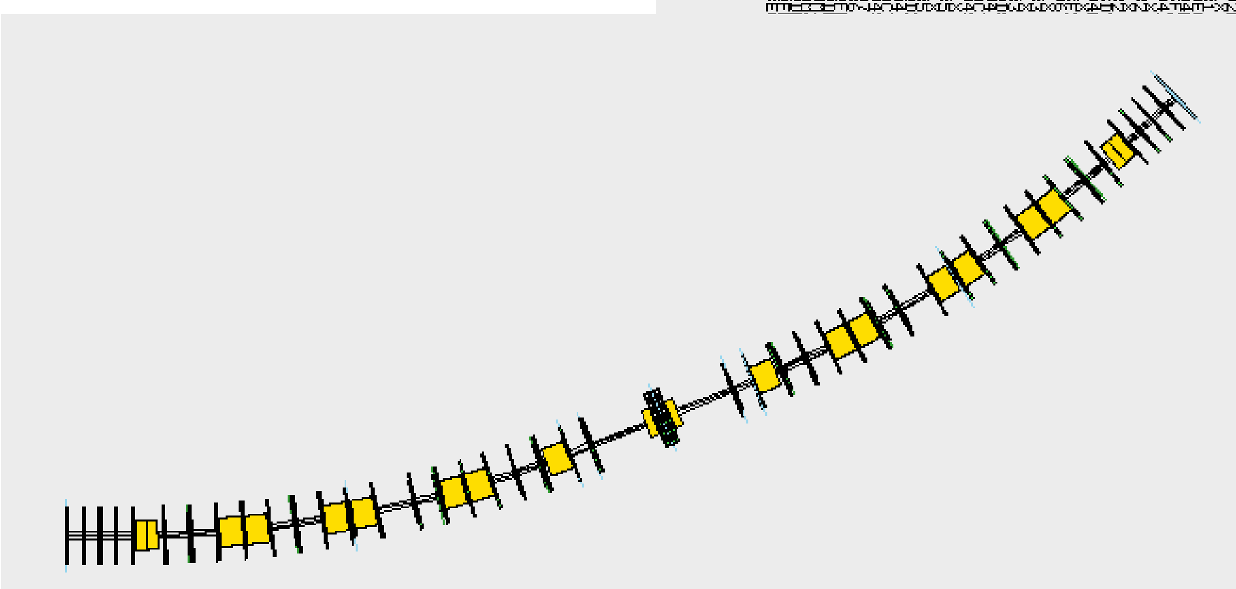
CELL_HER
TITLE: SuperB FF
Win32 version 8.51/15
06/09/06 00.12.15
β (m)
D (m)
βx
βy
Dx
50.
45.
40.
35.
30.
25.
20.
15.
10.
5.
0.0
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.0
5.0
10.0
15.0
20.0
25.0
s (m)

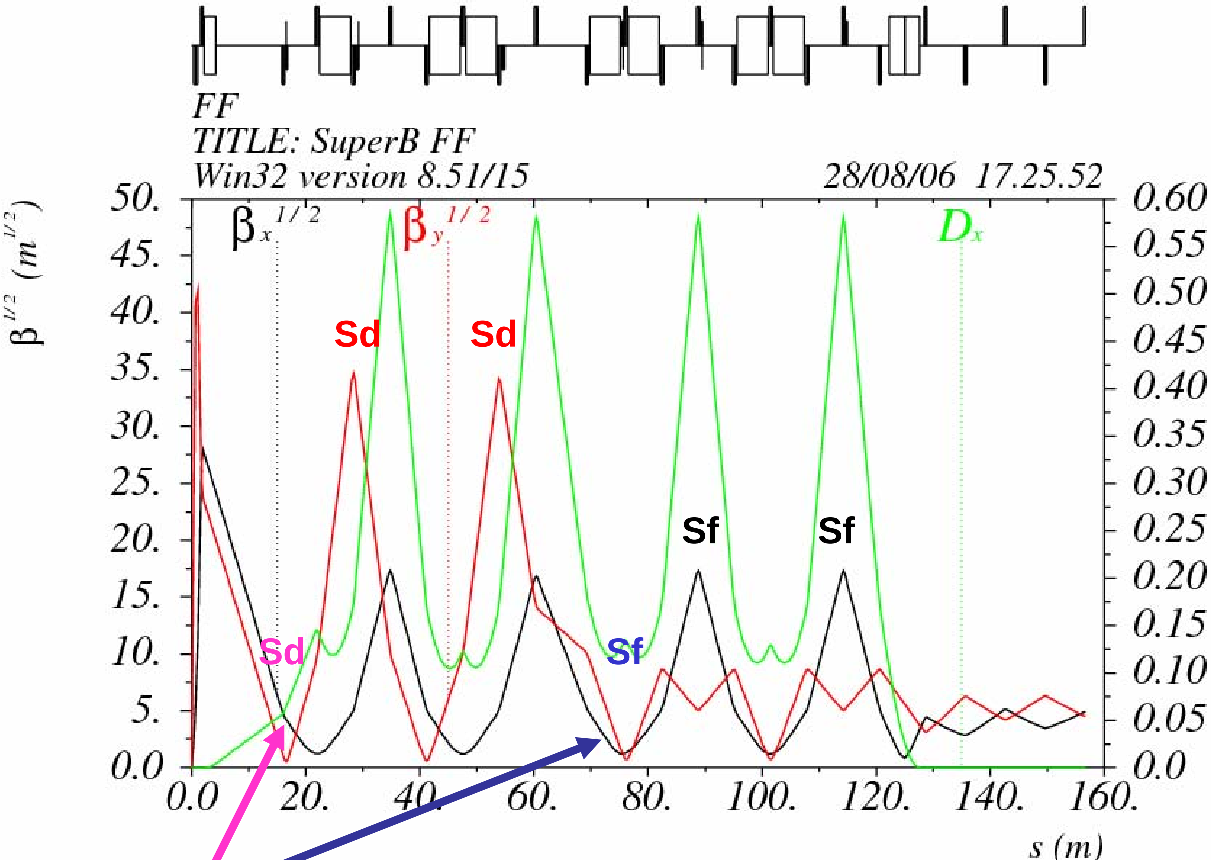
Pi/Pi/2 cell

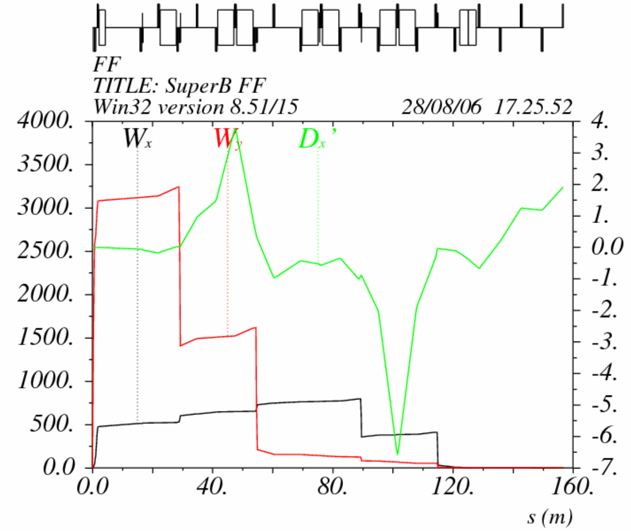
SuperB: sb70_ff_linepro12

Y. Ohnishi



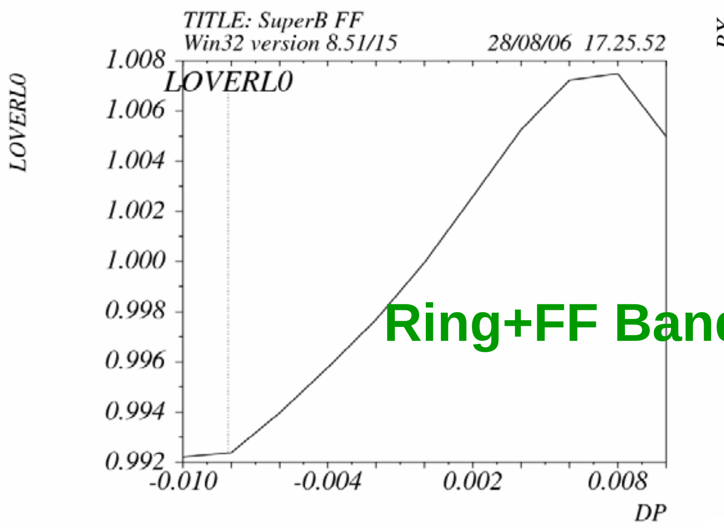




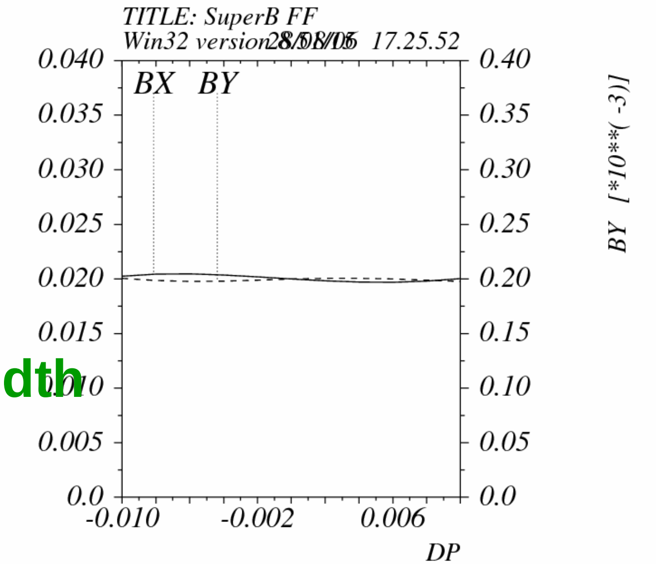


FFTB-stile Final Focus

IP phase sexts



Ring+FF Bandwidth



- SuperB requirements different from the ILC:

  - Needs geometric aberrations small, sextupoles should be uninterleaved.

  - Bends not needed to be weak (smaller synchrotron radiation)

  - Bends should all have the same sign, to avoid chicanes

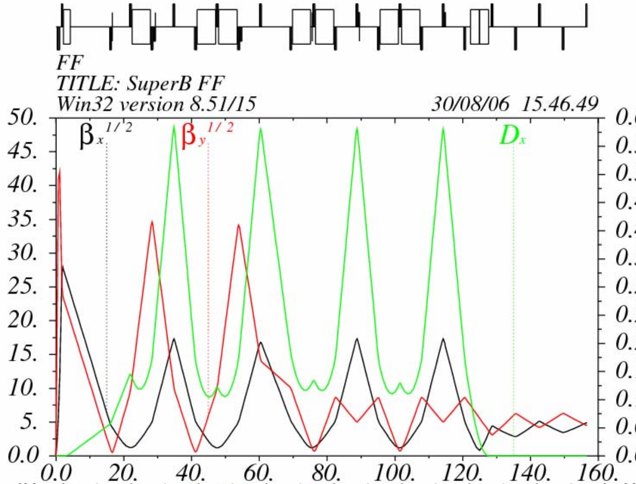
- Studied an FFTB-OLD_NLC stile solution: two sextupoles pairs (x and y) at -I

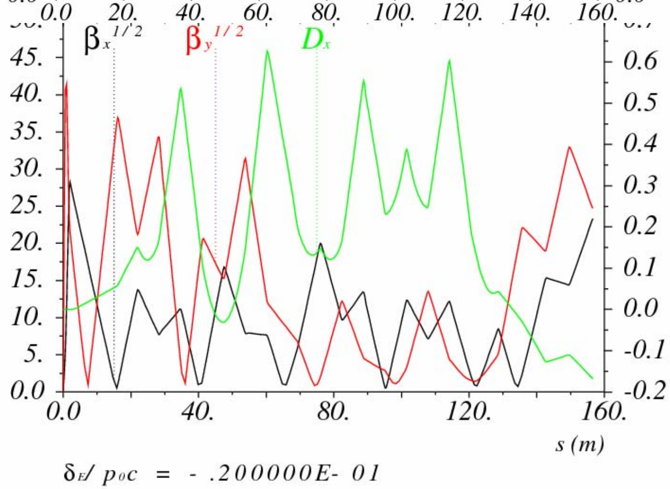
  Non local chromatic correction limits the bandwidth:

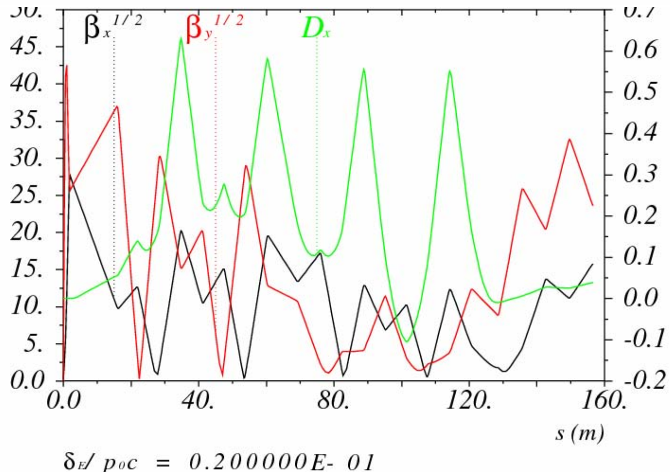
  strong 3rd order chromaticity (V12666 and V34666 in transport notation, T126 and T346 is the “natural” chromaticity)

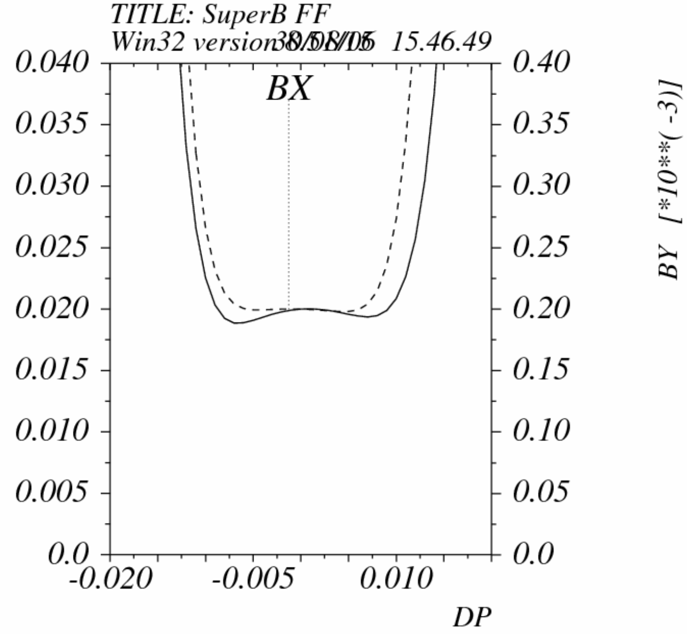
  Two additional sextupoles at the IP phase cancel these aberration providing an excellent bandwidth, since they are placed at a minimum betas location, they do not reduce the dynamic aperture

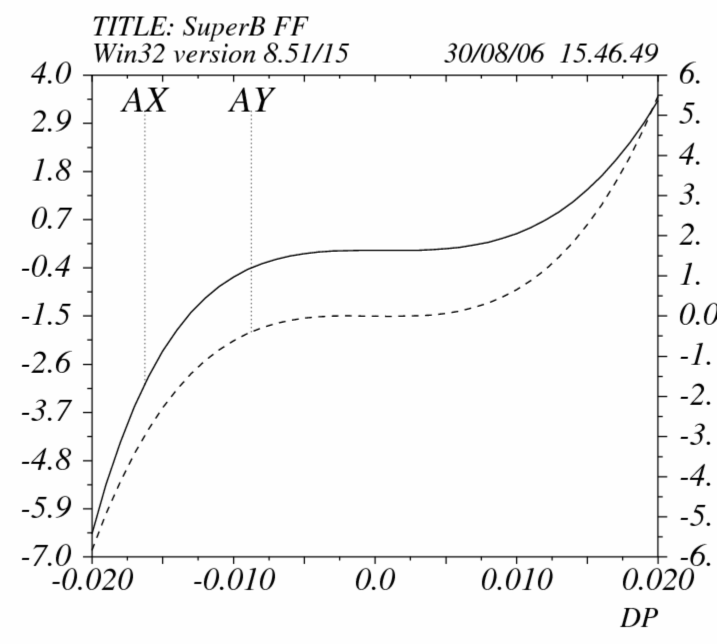
FF without IP-phase sexts



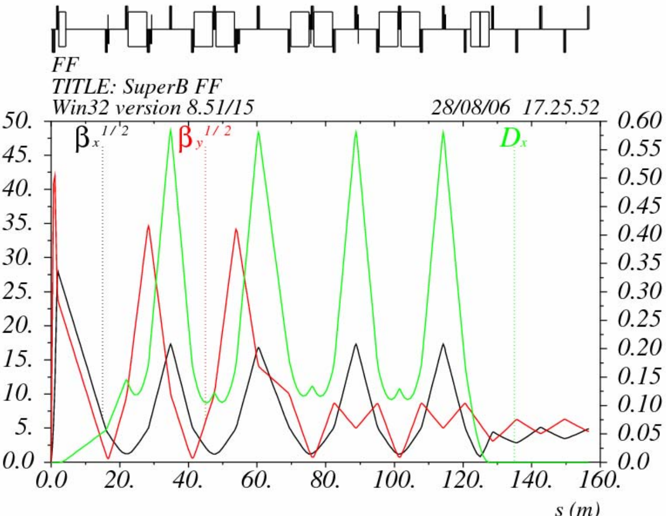


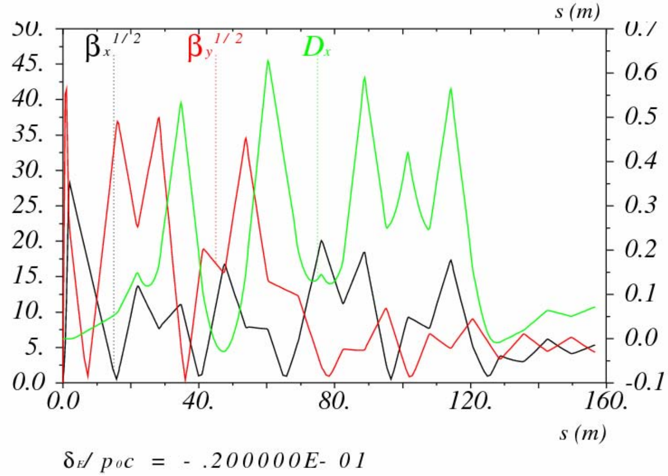


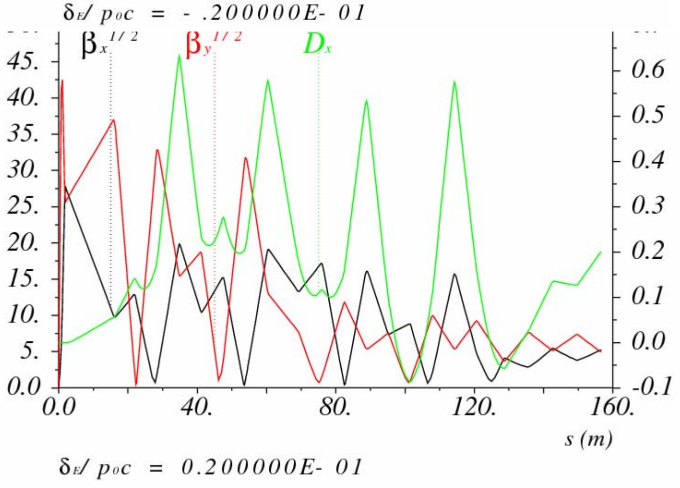


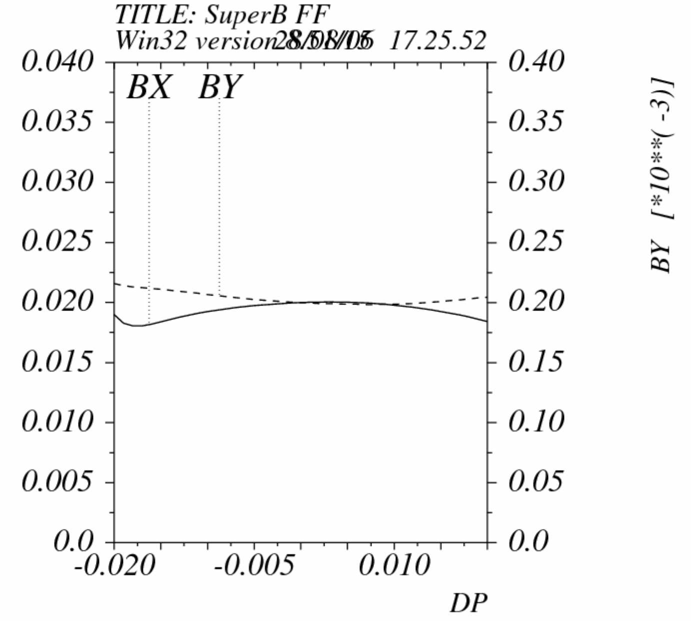


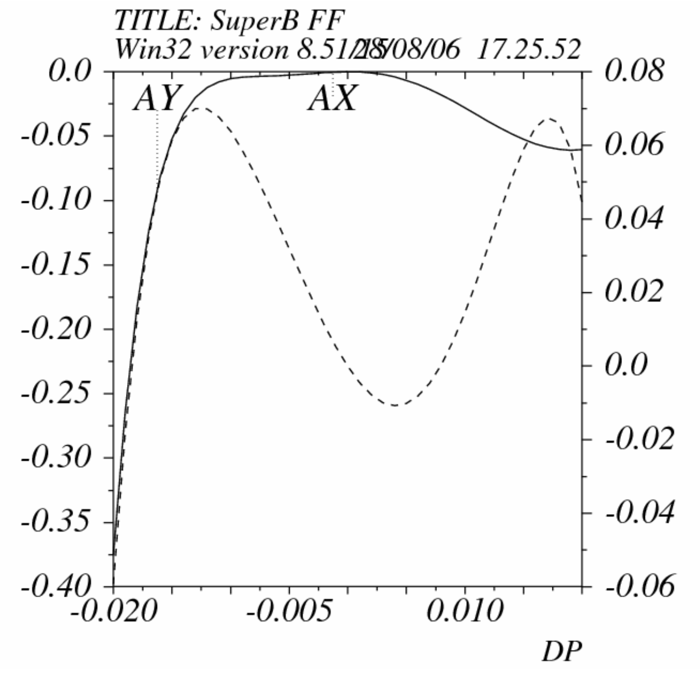
FF with IP-phase sexts



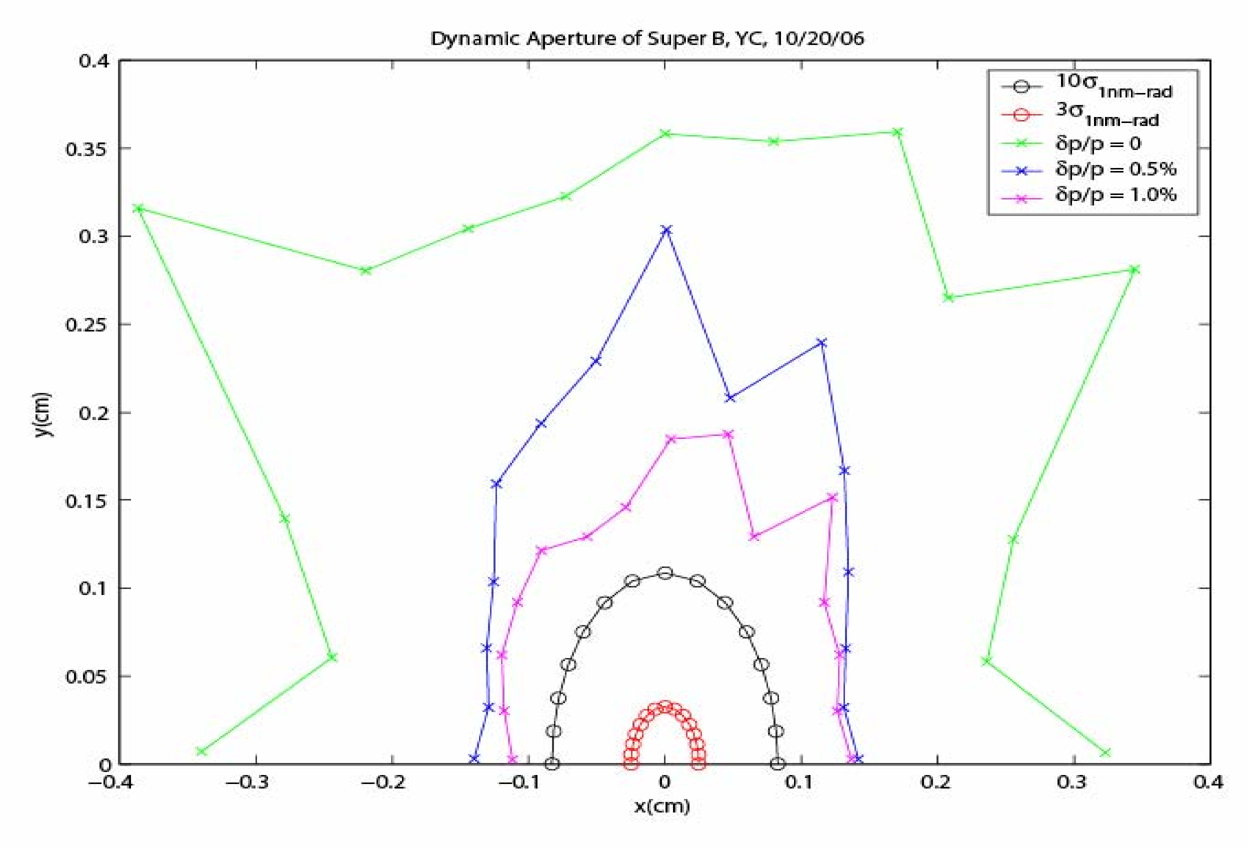








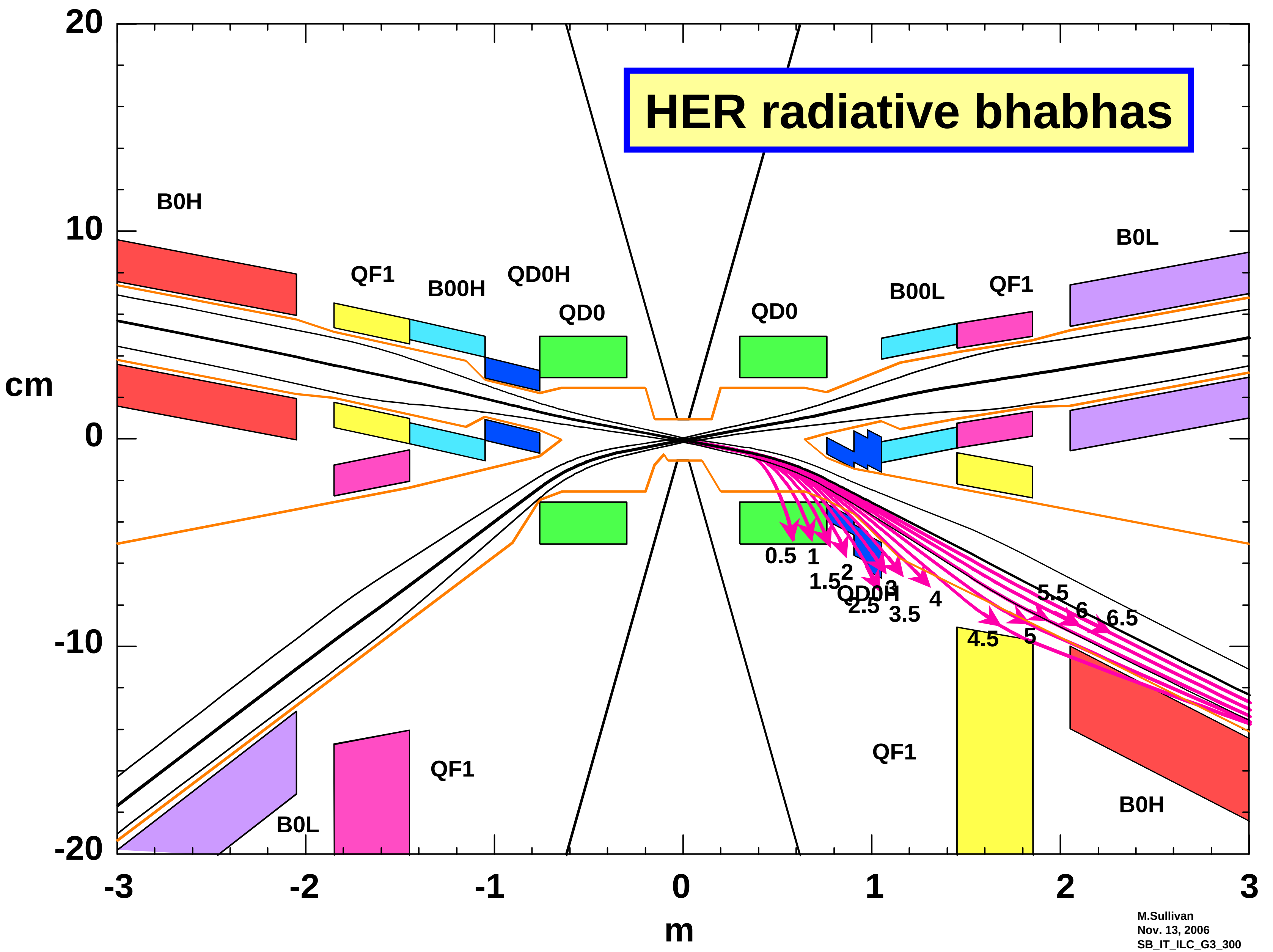
Dynamic aperture of ideal lattice with final focus and octupoles



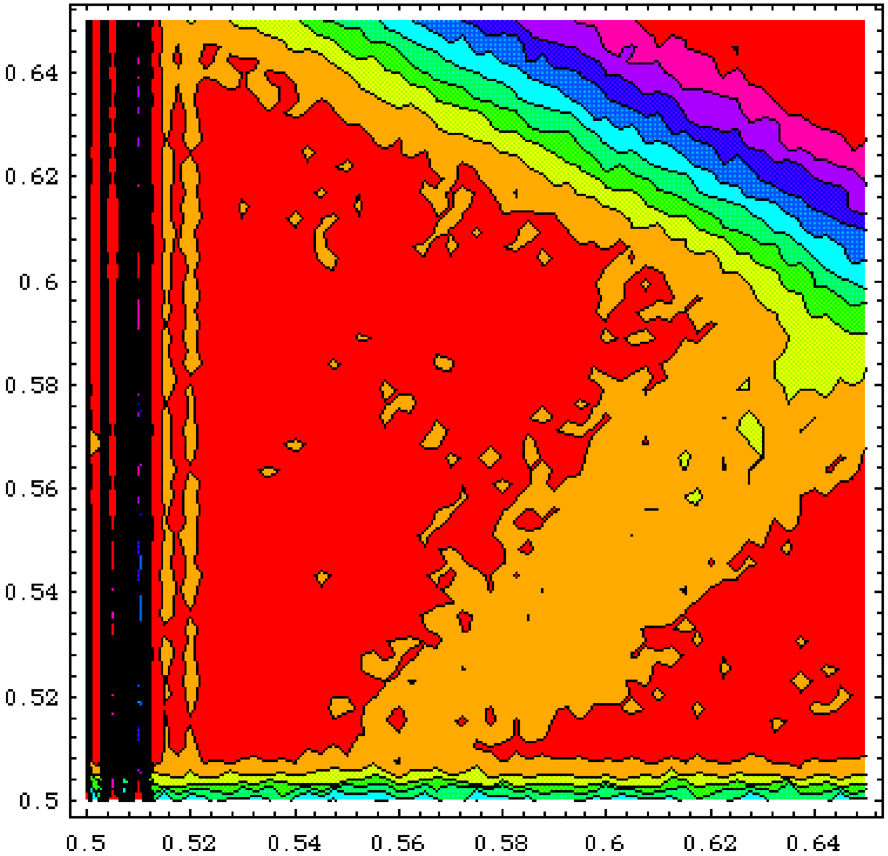
Including higher-order terms (beyond the paraxial approximation) in the quadrupoles:

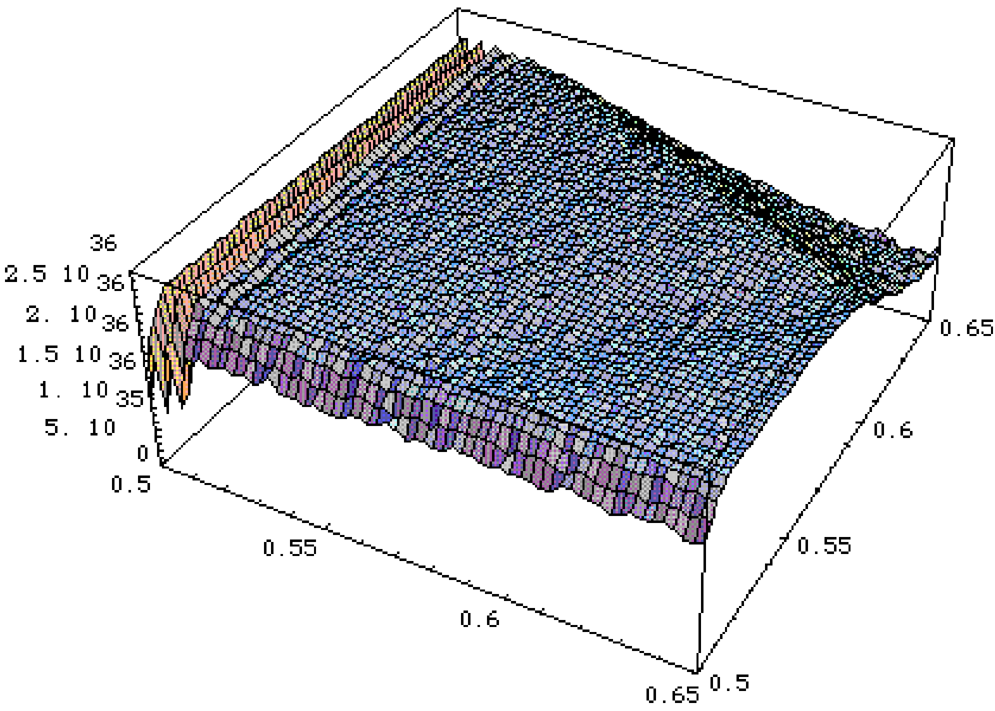
$$H = \frac{p_x^2 + p_y^2}{2(1+\delta)}\left[1 + \frac{p_x^2 + p_y^2}{4}\right]$$

SuperB Interaction Region



SuperB Luminosity Tune Scan
(crab=0.8/θ, σ_z = 7 mm; 3x10^{10} particles)

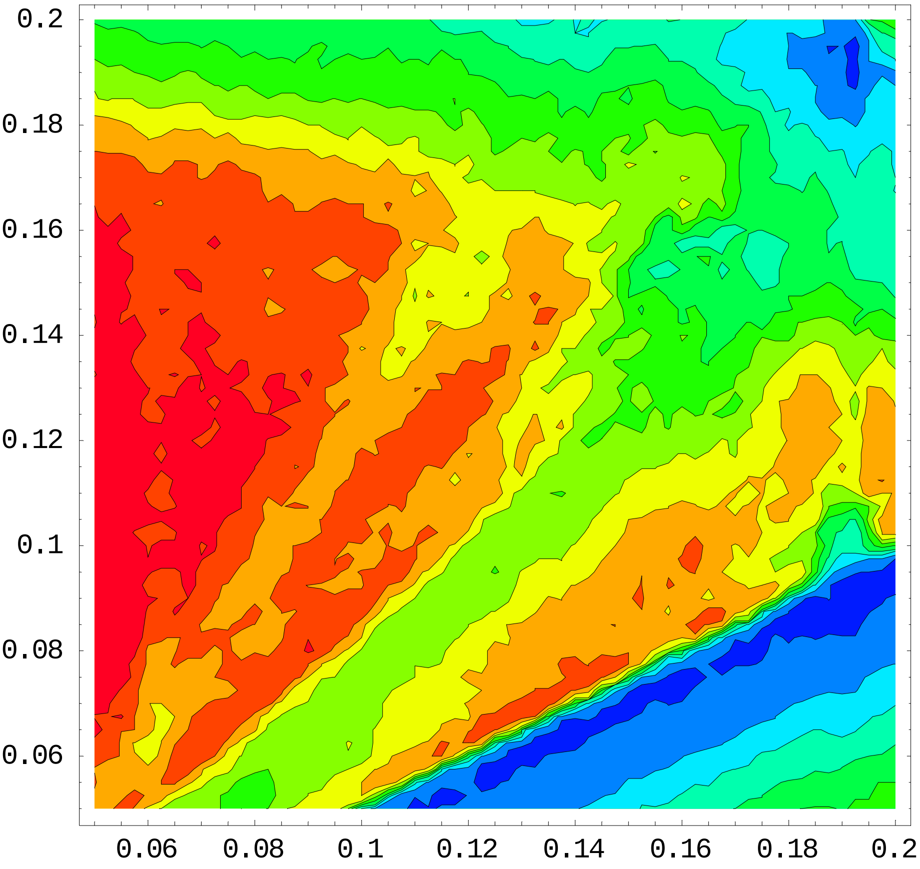




L_{max} = 2.2x10^{36} cm^{-2} s^{-1}

Dafne Upgrade IR Luminosity Scan

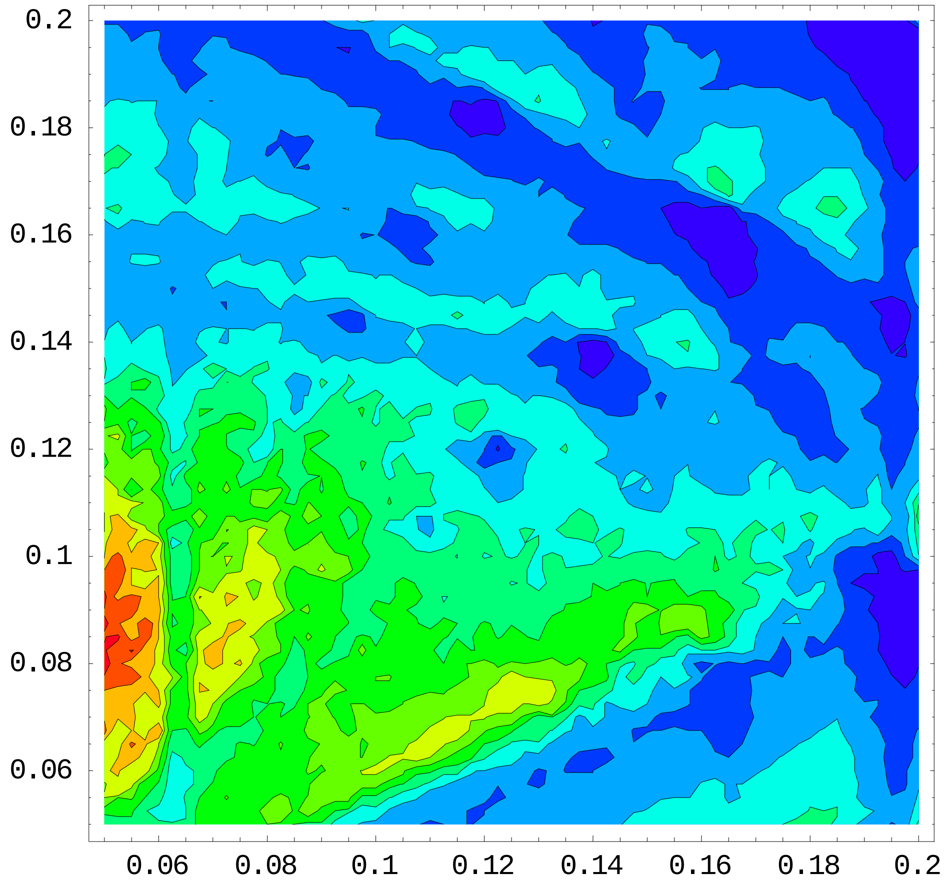
Crab On --> 0.6/θ



$L_{max} = 2.97 \times 10^{33}\ cm^{-2}s^{-1}$

$L_{min} = 2.52 \times 10^{32}\ cm^{-2}s^{-1}$

Crab Off, 60% luminosity

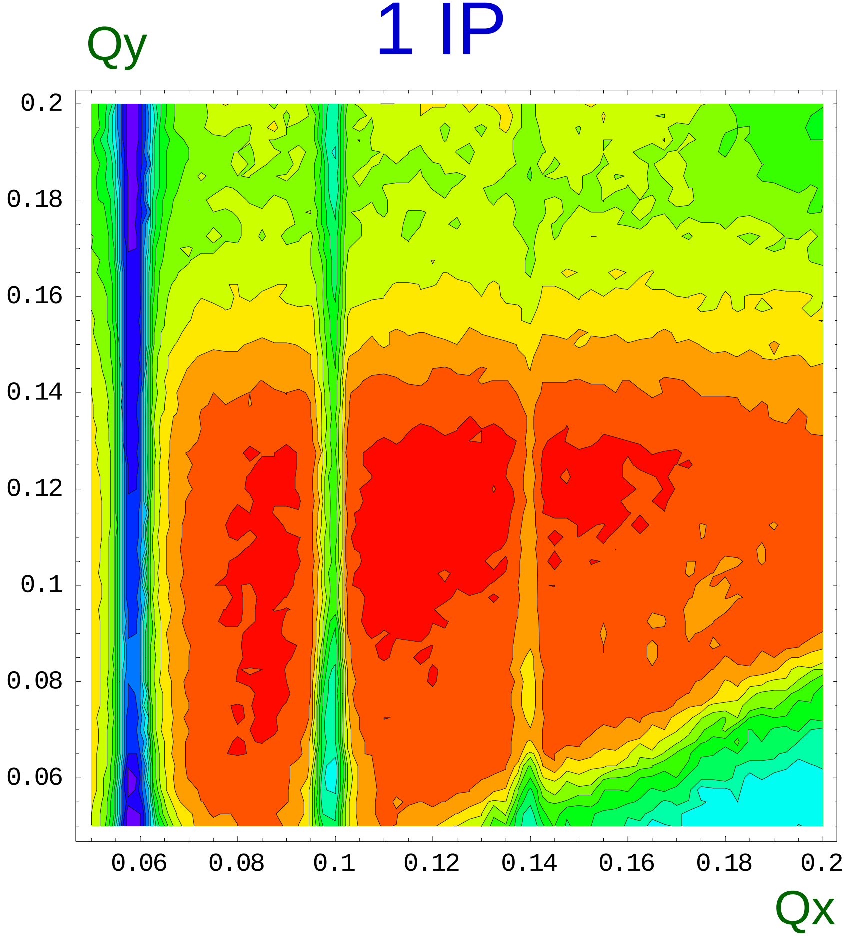


$L_{max} = 1.74 \times 10^{33}\ cm^{-2}s^{-1}$

$L_{min} = 2.78 \times 10^{31}\ cm^{-2}s^{-1}$

Luminosity Tune Scan

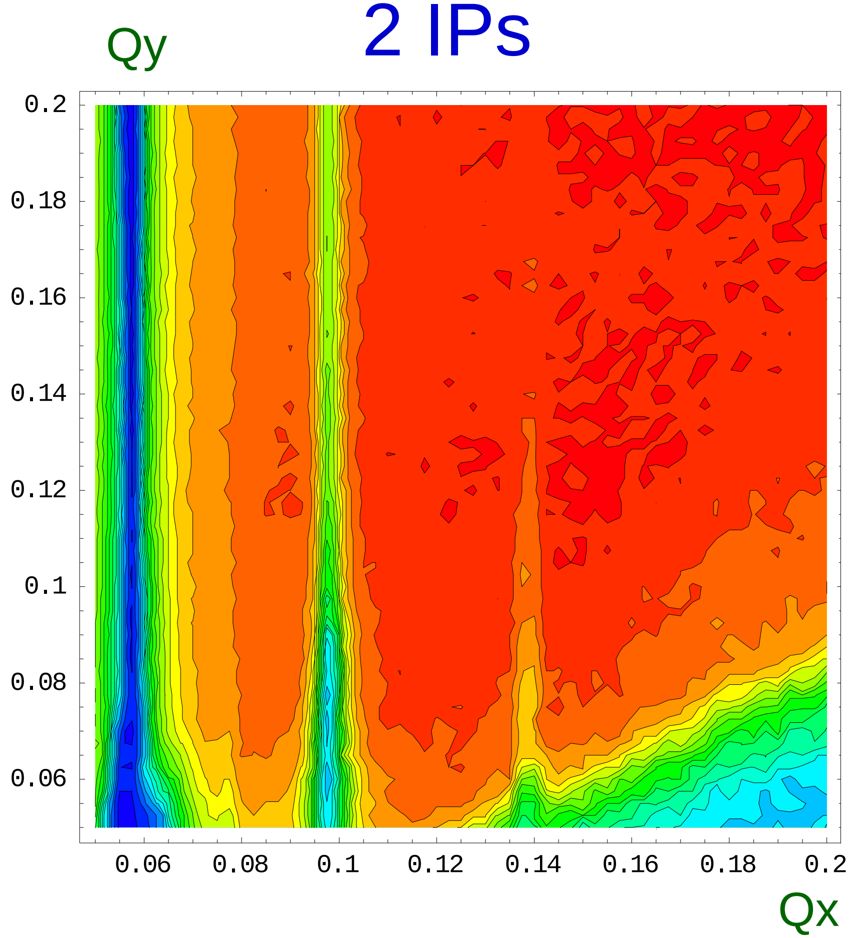
1 IP



L_{min} = 3.95 x 10^{34} $cm^{-2}s^{-1}$

L_{max} = 1.02 x 10^{36} $cm^{-2}s^{-1}$

2 IPs

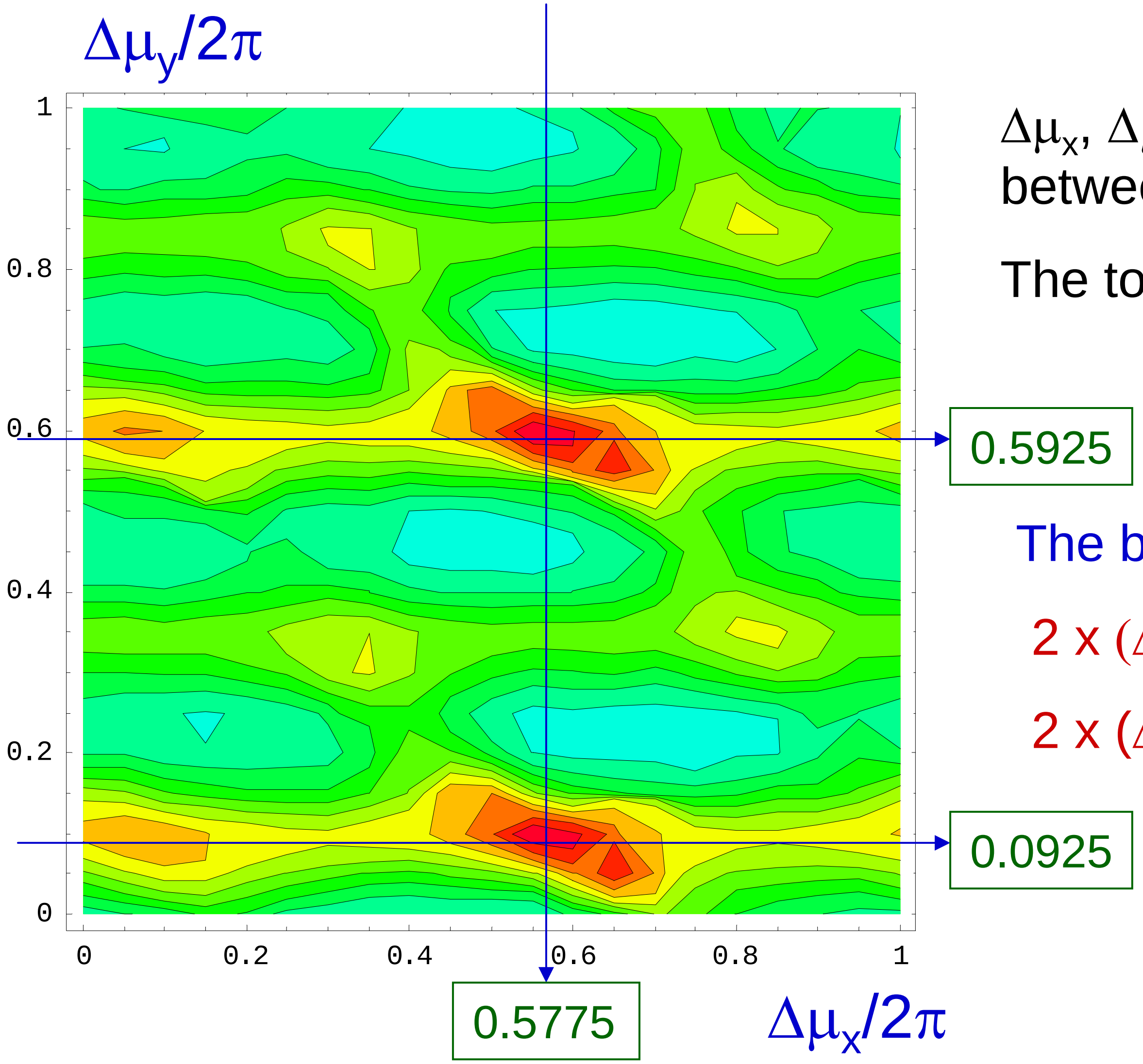


Lmin = 3.37 x 10^{34} $cm^{-2}s^{-1}$

Lmax = 1.00 x 10^{36} $cm^{-2}s^{-1}$

M.Zobov, D.Shatilov

Double Phase Advance Scan



$\Delta\mu_x$, $\Delta\mu_y$ are phase advances between IP_1 and IP_2

The total tune (0.155, 0.185)

The best choice is symmetric

$2 \times (\Delta\mu_x/2\pi) = 0.155 + \text{integer}$

$2 \times (\Delta\mu_y/2\pi) = 0.185 + \text{integer}$

- We have proven the feasibility of small emittance rings using all the PEP-II magnets, modifying the ILC DR design
- The rings have circumference flexibility
- The FF design complies all the requirements in term of high order aberrations correction, needs to be slightly modified for LER to take care of energy asymmetry
- All PEP-II magnets are used, dimensions and fields are in range
- RF requirements are met by the present PEP-II RF system

Dipoles Summary

L_{mag} (m)	0.45	5.4	2	0.75
PEP HER	-	192	8	-
PEP LER	192	-	-	-
SBF HER	-	160	2	-
SBF LER	144	16	2	144
SBF Total	144	176	4	144
Needed	0	0	0	144

- 160 (144 in Arcs+16 in FF) “PEP-II HER” dipoles are used in SuperB HER
- 16 dipoles are used in FF for SuperB LER
- 144 “PEP-II LER” dipoles are used in SuperB LER → need to build 144 new ones, 0.75 m long

SuperB Magnets Shopping list

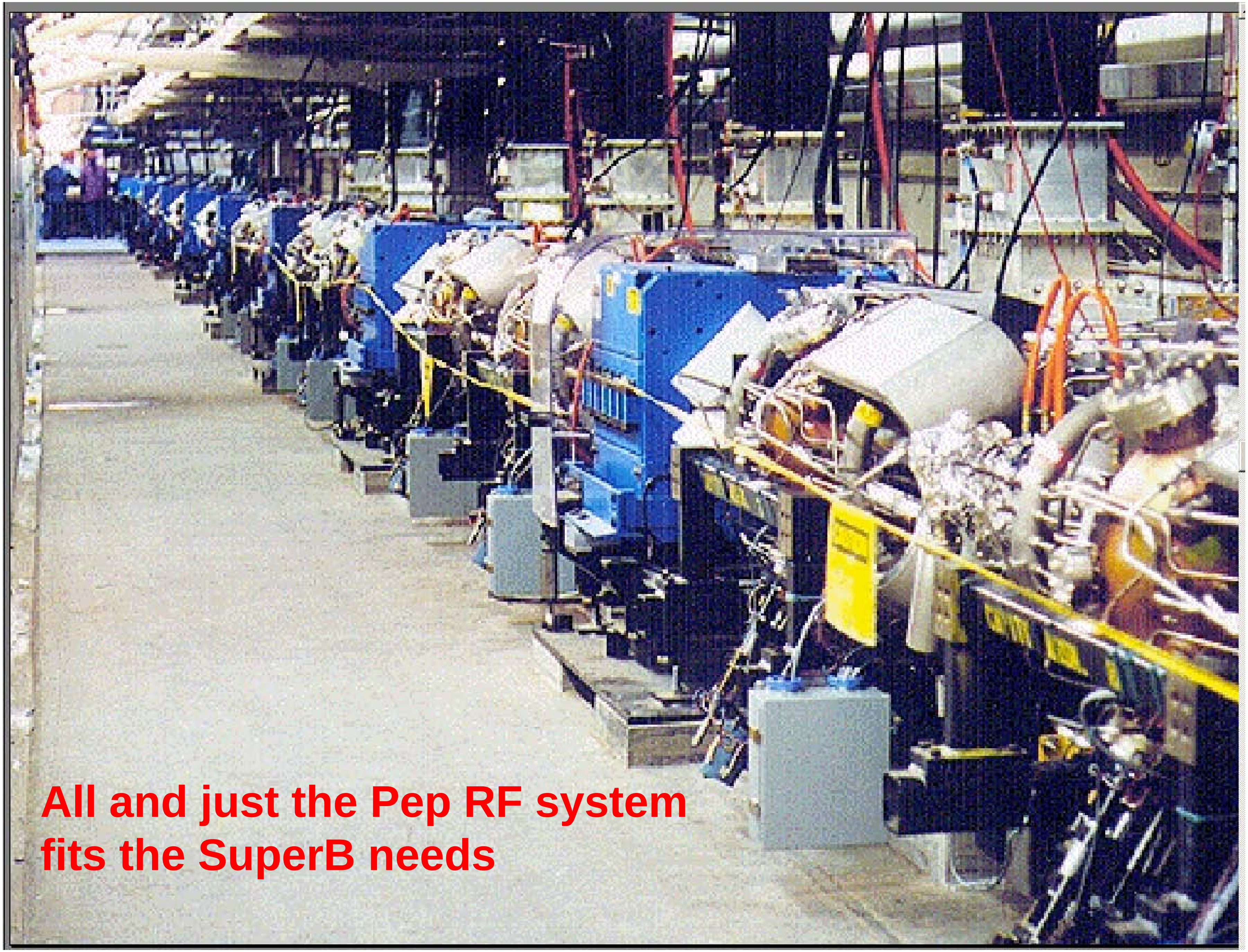
We have excess of:
- **48 bends 0.45 m long**
- **16 bends 5.4 m long**
- **4 bends 2. m long**

Quadrupoles Summary

L_{mag} (m)	0.56	0.73	0.5	0.43	0.75	0.4	0.45	1.0
PEP HER	94	82	-	-	-	-	70	22
PEP LER	-	-	-	282	-	-		16
SBF HER	248	138	36	-	2	2	-	-
SBF LER	44	-	36	302	2	2	70	-
SBF Total	292	138	72	302	4	4	70	0
Needed	198	56	72	20	4	4	0	0

We need 354 quads:
- **198 quads 0.56 m long**
- **56 quads 0.73 m long**
- **20 quads 0.43 m long**
- **72 quads 0.5 m long**
- **4 quads 0.75 m long**
- **4 quads 0.4 m long**

We have excess of:
- **38 quads 1. m long**



All and just the Pep RF system fits the SuperB needs

3 Super-B Accelerator

3.1 Accelerator overview (Seeman+Raimondi)
- 3.1.1 History of B-Factories
- 3.1.2 Key issues for a Super-B Factory (Raimondi)
  - Key items:
    - Luminosity
    - Crossing angle/crab waist/ip
    - Beam lifetime and injection
    - Backgrounds
    - Beam emittances and stability
    - Polarization
    - Power
    - Costs
- 3.1.3 Site requirements

3.2 Parameters (Seeman)
- 3.2.1 Nominal parameters for 1 x 1036 at the 4S
- 3.2.2 Upgrade parameters at 2.4 x 1036 at the 4S
- 3.2.3 Luminosity at the Psi' (3.8 GeV cm)
- 3.2.4 Yearly integrated luminosity
- 3.2.5 Energy asymmetry (Raimondi)

3.3 Layout
- 3.3.1 HER (Biagini)
- 3.3.2. LER (Biagini)
- 3.3.3 Interaction region (Sullivan)
- 3.3.4 Injector (Seeman+Raimondi)

3.4 Interaction region (Sullivan)
- 3.4.1 Geometry
- 3.4.2 Beam trajectory
- 3.4.3 Magnets
- 3.4.4 Vacuum chambers
- 3.4.5 Synchrotron radiation
- 3.4.6 Lost particles (detector)
- 3.4.7 Backgrounds (detector)
- 3.4.8 Vacuum profile

3.5 Magnet lattice and optics
- 3.5.1 LER lattice (Biagini)
- 3.5.2 HER lattice (Biagini)
- 3.5.3 Interaction region (Raimondi)
- 3.5.4 Detector solenoid compensation (Biagini+Raim
- 3.5.5 Dynamic aperture (Cai, Wolski)

3.6 Imperfections and errors
- 3.6.1 Tolerances and errors (Cai)
- 3.6.1 Vibrations and stability (Seeman,Seryi)
- 3.6.1 Low emittance tuning (Wolski)
- 3.6.1 Final Focus tuning (Raimondi,Seryi)

3.7 Intensity dependent effects
- 3.7.1 Beam-beam interaction (Shatilov)
- 3.7.2 Lifetimes (Boscolo+Wienands+Paoloni)
- 3.7.3 Intra Beam Scattering (Wienands+Wolski)
- 3.7.4 Electron cloud instability (Heifets, Pivi)
- 3.7.5 Fast ion instability (Heifets,Wang)
- 3.7.6 Space charge (Heifets)
- 3.7.7 Higher order modes (Novokhatski)
- 3.7.8 Single bunch impedance effects (Heifets)
- 3.7.9 CSR (Agoh)
- 3.7.10Multi-bunch instabilities (Wienands)

3.8 Magnet systems (Wienands+Yocky+Biagini)
- 3.8.1 LER dipoles
- 3.8.2 LER quadrupoles
- 3.8.3 LER sextupoles
- 3.8.4 LER octupoles
- 3.8.5 HER dipoles
- 3.8.6 HER quadrupoles
- 3.8.7 HER sextupoles
- 3.8.8 HER octupoles
- 3.8.9 Correction magnets
- 3.8.9 Damping wigglers (Koop →Levichev)
- 3.8.10 Interaction region magnets (Ecklund)

3.6 RF systems (Wienands+Seeman)
- 3.7.1 RF parameters
- 3.7.2 RF cavities
- 3.7.3 Klystrons
- 3.7.4 Power supplies
- 3.7.5 RF controls
- 3.7.6 RF feedback
- 3.7.7 High current beam loading

3.7 Vacuum system (Wienands,...)
- 3.8.1 Arc vacuum system
- 3.8.2 Straight section vacuum system
- 3.8.3 Expansion bellows
- 3.8.4 Collimation

3.8 Instrumentation and controls (Fisher)
- 3.9.1 Beam position monitors (Fisher)
- 3.9.2 Beam size monitors (Fisher)
- 3.9.4 Longitudinal feedback (Drago)
- 3.9.5 Transverse feedback (Drago)
- 3.9.6 IP feedback (Sullivan+Decker)
- 3.9.7 Beam abort system (Fisher)
- 3.9.8 Temperature monitor (Ecklund)
- 3.9.9 Temperature control (Ecklund)
- 3.9.10 Control system (Fisher, Stecchi)

3.11 Injection system (Vaccarezza+Seeman)
- 3.11.1 Requirements
- 3.11.2 Layout
- 3.11.3 Components
- 3.11.4 Timing

3.12 Polarization (Koop)
- 3.12.1 Geometry
- 3.12.2 Spin rotators
- 3.12.3 Spin transport
- 3.12.4 Measurement

3.13 Site and Utilities
- 3.13.1 Tunnel (Seeman)
- 3.13.2 AC Power (Seeman)
- 3.13.3 Cooling system (Seeman)
- 3.13.4 Air conditioning (Seeman)

3.14 References

SuperB CDR ready

Preliminary cost estimate

- Rings rebuild by reusing about 90% of Pep (220Meuro), 90 Meuro (130Me recycle value)
- Ring tunnel and collider hall 40Meuro
- Injector system 90Meuro
- Convetional facilities 50Meuro
- Total about 270Meuro

Working progress

- A lot of studies to understand the effects of the crab sextupoles done (Ohnishi, KEK)
- A preliminary solution now exists

- Very long to do list to for the ring design optimization:

Include the injection section, the tunes trombone and the chicane in the ring

Optimize the ARC cell

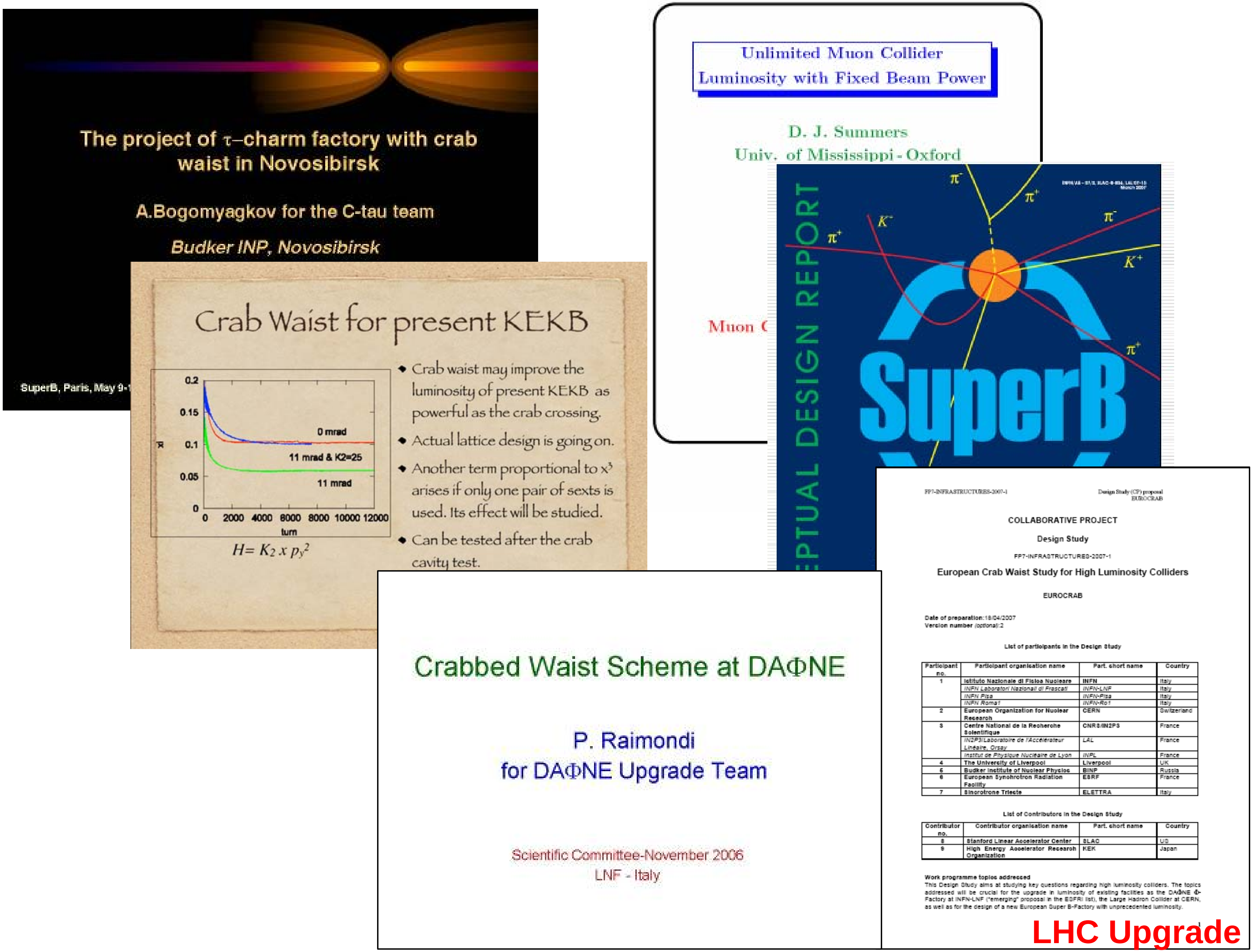
Optimize the wigglers

Improve the Dynamic Aperture (Mostly FF and Crab Waist Optics optimization)

Design the Injection System

Optimize Length, cost and minimize power

- Possible fall back on the existing factories
- The crab waist seems to be beneficial also for the current factories
- Potential to simultaneously boost the performances of the existing machines and do SuperB R&D



FP7-INFRASTRUCTURES-2007-1 Design Study (CP) proposal EUROCRAB

COLLABORATIVE PROJECT

Design Study

FP7-INFRASTRUCTURES-2007-1

European Crab Waist Study for High Luminosity Colliders

EUROCRAB

Date of preparation:18/04/2007
Version number *(optional)*:2

List of participants in the Design Study

Participant no.	Participant organisation name	Part. short name	Country
1	Istituto Nazionale di Fisica Nucleare	INFN	Italy
	INFN Laboratori Nazionali di Frascati	*INFN-LNF*	Italy
	INFN Pisa	*INFN-Pisa*	Italy
	INFN Roma1	*INFN-Ro1*	Italy
2	European Organization for Nuclear Research	CERN	Switzerland
3	Centre National de la Recherche Scientifique	CNRS/IN2P3	France
	IN2P3/Laboratoire de l'Accélérateur Linéaire, Orsay	*LAL*	France
	Institut de Physique Nucléaire de Lyon	*INPL*	France
4	The University of Liverpool	Liverpool	UK
5	Budker Institute of Nuclear Physics	BINP	Russia
6	European Synchrotron Radiation Facility	ESRF	France
7	Sincrotrone Trieste	ELETTRA	Italy

List of Contributors in the Design Study

Contributor no.	Contributor organisation name	Part. short name	Country
8	Stanford Linear Accelerator Center	SLAC	US
9	High Energy Accelerator Research Organization	KEK	Japan

Work programme topics addressed
This Design Study aims at studying key questions regarding high luminosity colliders. The topics addressed will be crucial for the upgrade in luminosity of existing facilities as the DAΦNE Φ-Factory at INFN-LNF ("emerging" proposal in the ESFRI list), the Large Hadron Collider at CERN, as well as for the design of a new European Super B-Factory with unprecedented luminosity.

1

Conclusions

- SuperB studies are already proving useful to the accelerators and particle physics community
- We have a preliminary “Conceptual Design Report”, based on the reuse of all the Pep hardware, that might fit in one of the existing facilities, or in a new (and avalaible) site near Frascati
- The INFN will push any solution but particularly the last one, expecially if the Dafne upgrade (SuperB based) proves successful. A decision to ask for fundings to the Italian Government might happen already next year (About 200MEuros, mostly for the injector and the conventional facilities)
- We hope to gather in the enterprise as many labs and institutions as possible (See the CDR for the ones already involved)