SuperB Design Progress

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for the SuperB Team

Kek, March 20, 2007

Outline

- Basic Concepts (March-Sept,2005)
- Parameters and layout optimization based on a High-Disrupted regime (Nov, 2005)
- Parameters and layout optimization for a Minimal-Disrupted regime (Jan, 2005)
- Layout for a Ring Collider with Linear Collider Parameters (Mar, 2006)
- Optimization of the SuperB design(Nov, 2007)
- Status of the SuperB collaboration
- Where when and how to build the SuperB
- Conclusions

Basic concepts

- SuperB factories based on extrapolationg current machines require:
- Higher currents
- Smaller damping time (weak function ^1/3)
- Shorter bunches
- Higher power
- KeK Proposal based on these concept

SuperB gets very expensive and hard to manage, expecially all the problems related to the high current => look for alternatives

Three factors to determine luminosity:

Stored current:

1.36/1.75 A (KEKB)

→ 4.1/9.4 A (SuperKEKB)

Beam-beam parameter:

0.059 (KEKB)

→ >0.24 (SuperKEKB)

Lorentz factor

$$L = \frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

Classical electron radius

Beam size ratio

Geometrical reduction factors due to crossing angle and hour-glass effect

Luminosity:

0.16×10^{35} cm^{-2}s^{-1} (KEKB)

8×10^{35} cm^{-2}s^{-1} (SuperKEKB)

Vertical β at the IP:

6.5/5.9 mm (KEKB)

→ 3.0/3.0 mm (SuperKEKB)

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)

Scaling laws to optimize the IP parameters

- Disruption:

$$D \approx \frac{N\sigma_z}{(\sigma_x \sigma_y)}$$

Decrease σ_z + decrease N
Increase spotsize

- Luminosity

$$L \approx \frac{N^2}{(\sigma_x \sigma_y)}$$

Increase N
Decrease spotsize

Contraddicting requests!

- Energy spread:

$$\delta_E \approx \frac{N^2}{(\sigma_x^2 \sigma_z)}$$

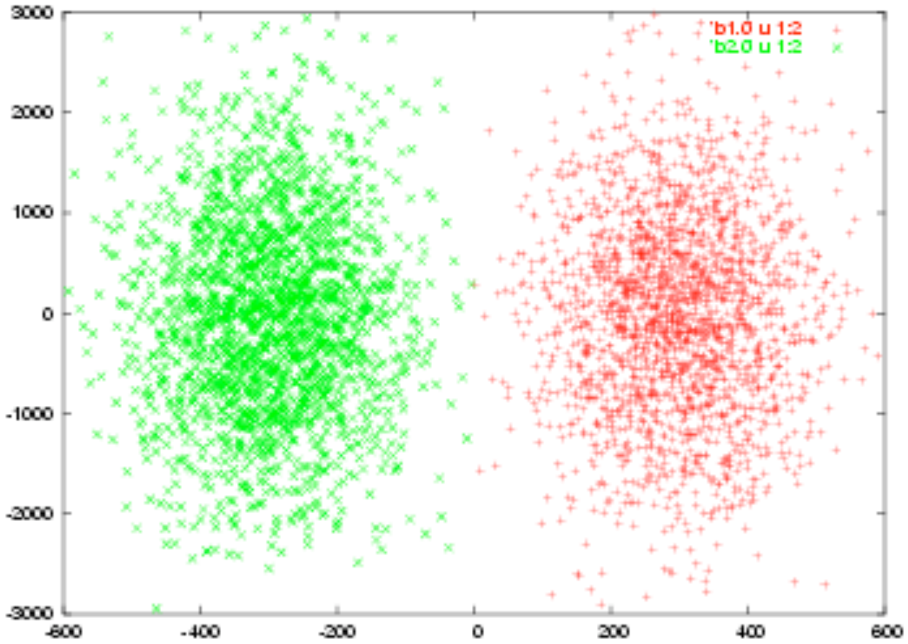
Increase σ_z + decrease N
Increase spotsize

A lot of homework done in collaboration at SLAC and at the LNF for a few months.

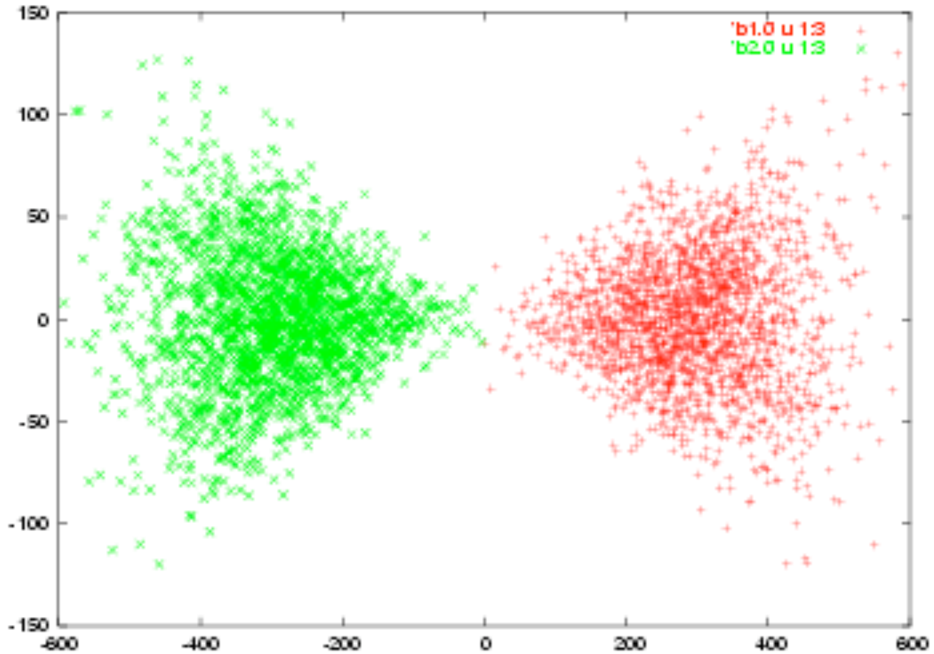
Explored the parameters phase in order to maximize the luminosity per crossing

Laid down all the other possible advantages (e.g. less current through the detector, smaller beams, smaller beam pipe etc)

Leading to a workshop held on Nov,11-12 2005 in Frascati to investigate and optimize the scheme and the feasibility of the different subsystems



Horizontal Collision



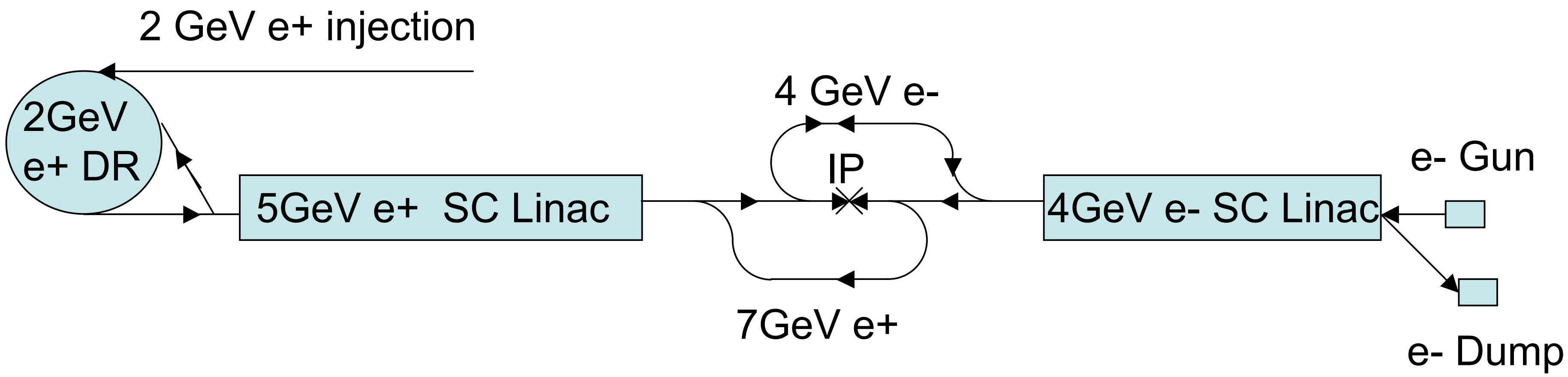
Vertical collision

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

First attempt

Simulation by D.Schulte

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



Overall rings lenght about 6Km, Collision frequency about 120Hz*10000bunch_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

- Use SC linacs 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

Power budget with this schemes

- 4 x 7 GeV
- 10000 bunches at 10^{11} = 6A(e+)/12A(e-)
- Damping ring RFfreq= 500 MHz at 0.6 m spacing
- SC linac for 5 GeV e- with low emittance photo-gun
- 5.5GeV SC linac, frequency = 1300 MHz
- Damping ring for 2 GeV positrons with wigglers
  - 3000 m damping ring at 3.7 msec damping
  - 3000 m damping ring at 4.6 msec damping time
- 120 Hz collisions for 8.3 msec cycle time
- Assume two damping times between collisions →sum 8.3 msec
- Recycle energy for both beams in SC linac structures
- 2GeV ring: 10 MeV/turn, Pwall =100 MW
- Accelerate 10^{11} particles to 5 GeV (e+) and also 4 GeV (e-)
- Without energy recovery, beam generation power = 211 MW
- Assume energy recovery is 99% efficient, needed power = 2 MW
- Cyrogenic power (1W/MeV) Pwall = 5 kW*1000=5MW
- Total power = 110 MW

J. Seeman study

Progress in design optimization after the 1° SuperB workshop

Between December-2005 and March-2006 a lot of studies have been made in order to understand what are the sources of the blow-ups in the collision and how to minimize then.

Power requirements could be greatly reduced if collision is less disruptive

Search for a trade off between luminosity delivered in one collision and power spent for each collision

Search for the simplest and more economic solution

A lot of study done to find a solution that meets the "Small Disruption requirements":

small σ_z

big σ_x

small σ_y (for luminosity) and β_y

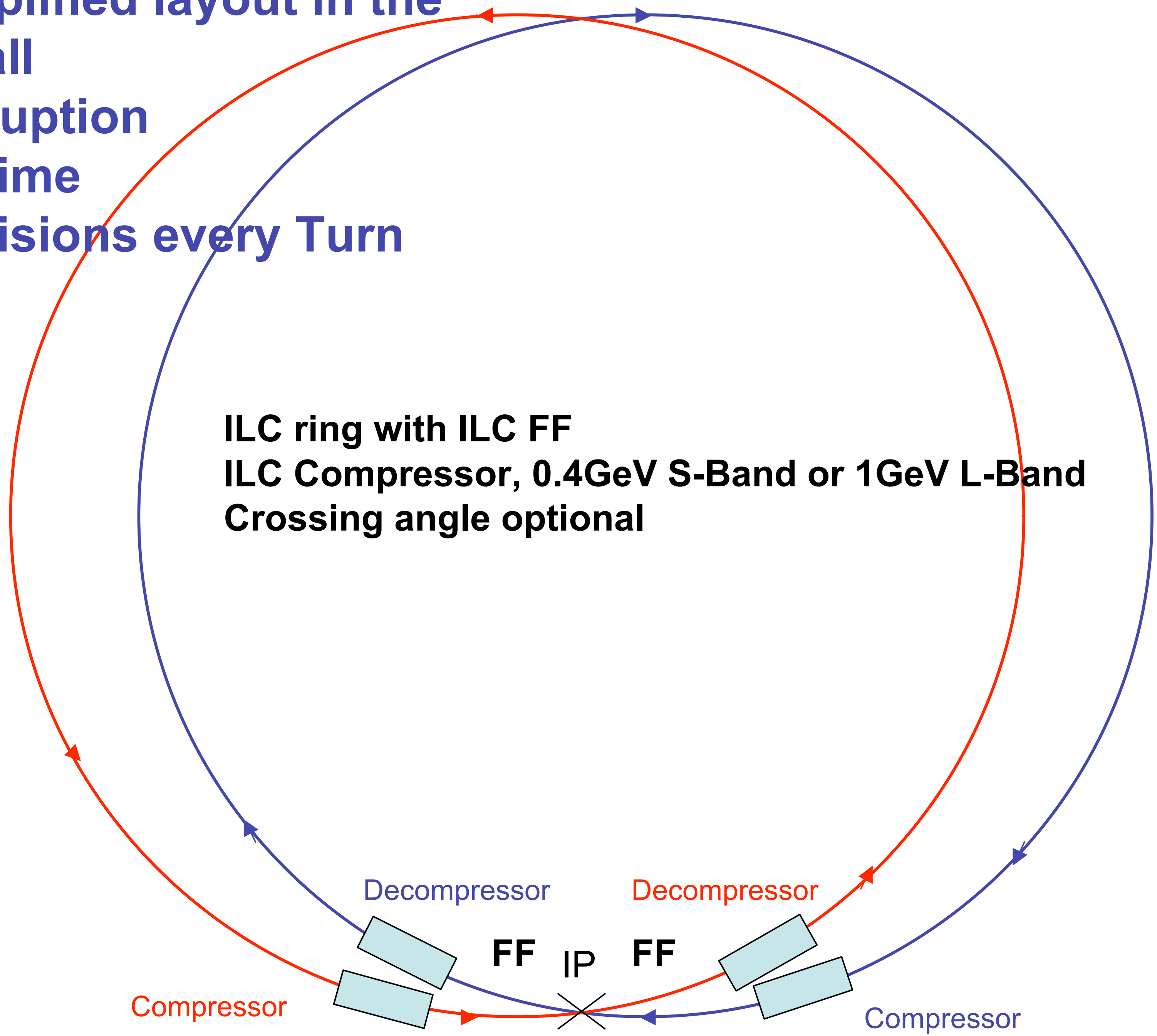
- **Best luminosity always obtained with collision in the ring, ILC-colliding scheme ruled out:**

  higher collision rep-rate

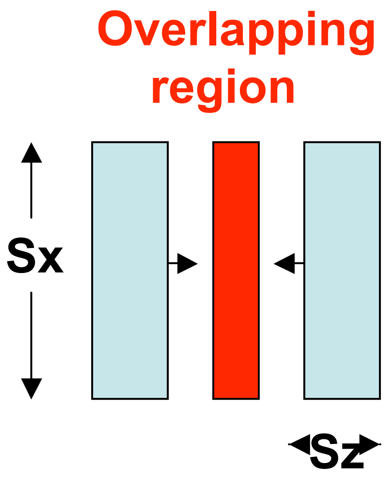
  lower current

  lower beam-blowup
- Flat beams compressed colliding in the rings
- Flat beams, uncompressed colliding in the rings, BB-compensation with Crab-Waist

Simplified layout in the Small Disruption Regime Collisions every Turn



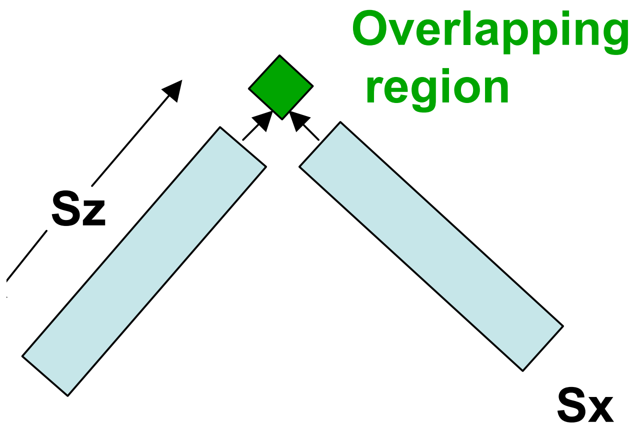
Crossing angle concepts



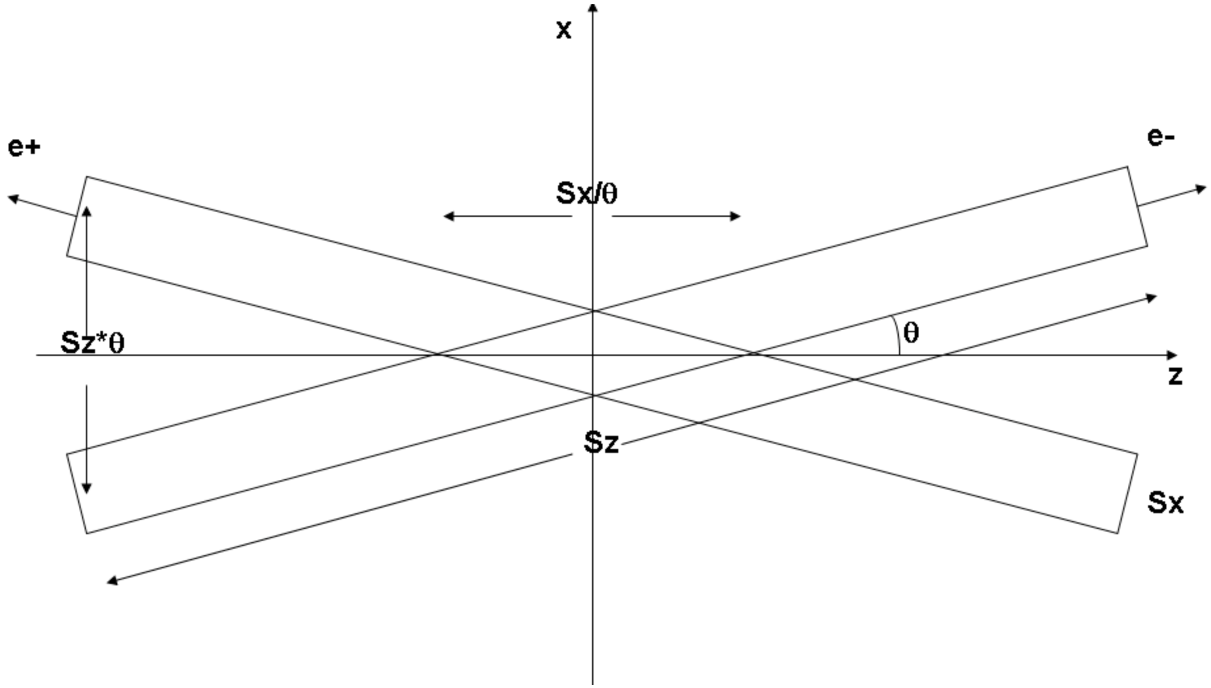
1) Standard short bunches

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:

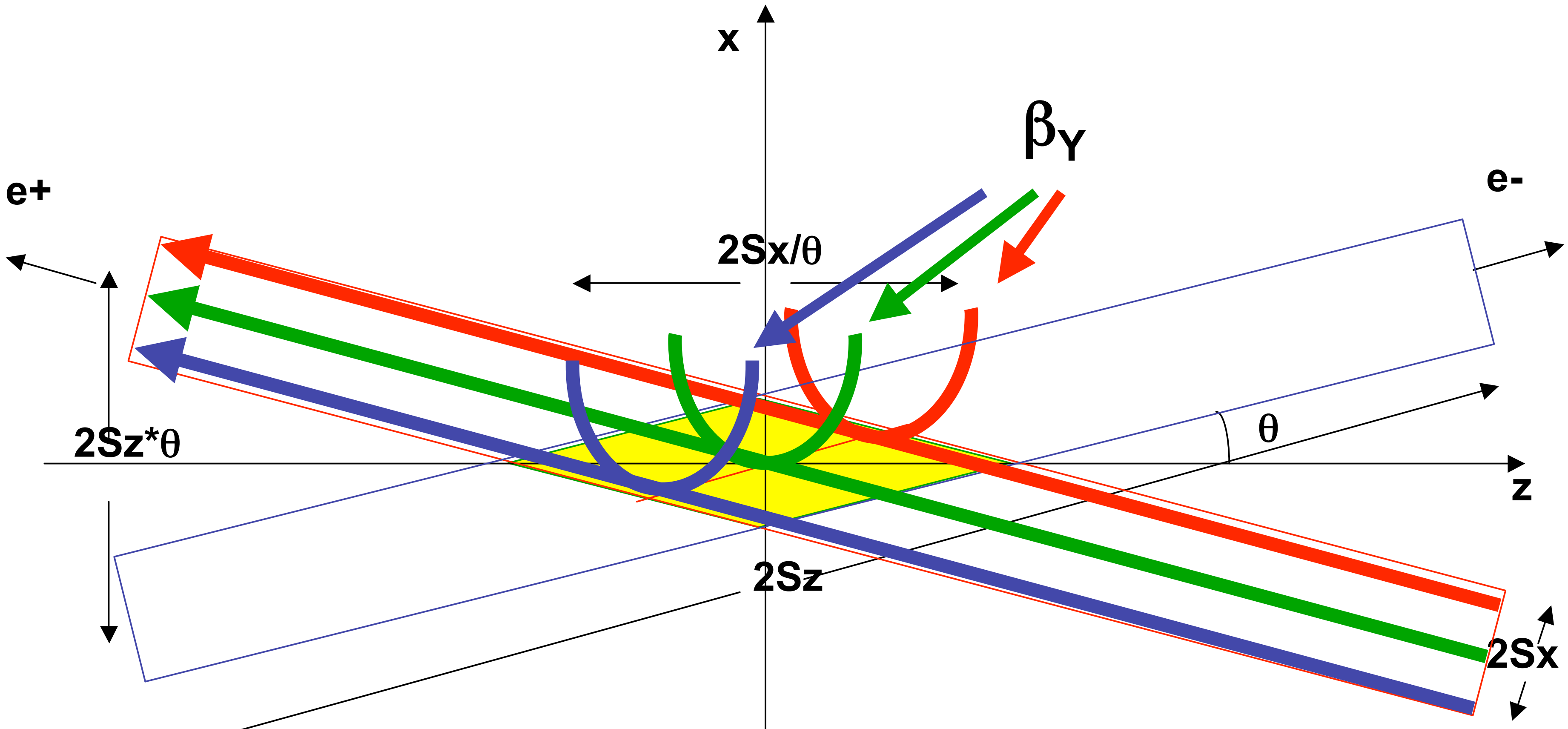
- short bunches
- small vertical emittance
- large horizontal size and emittance to mimimize beam-beam

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



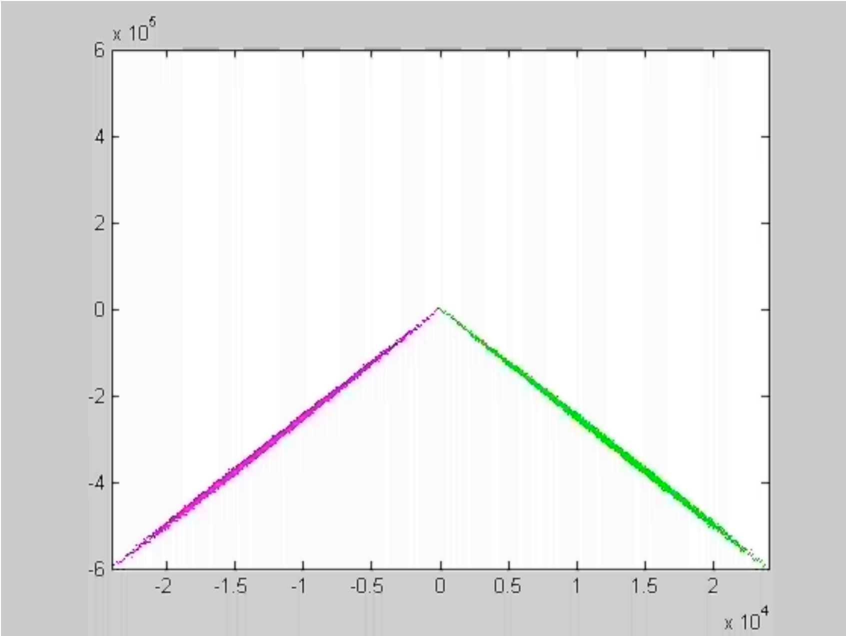
Crabbed waist removes bb betratron coupling Introduced by the crossing angle

Vertical waist has to be a function of x:

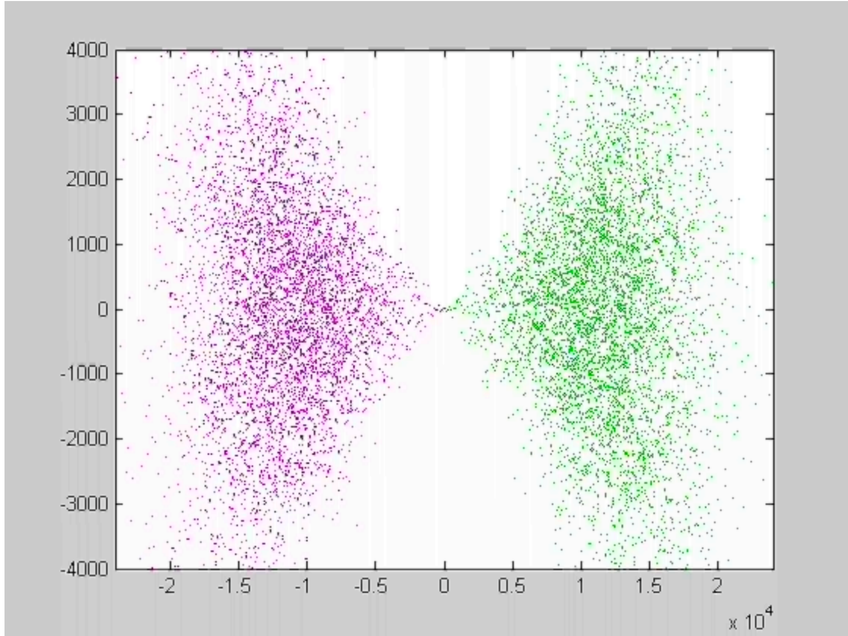
Z=0 for particles at $-\sigma_x$ ($-\sigma_x/2\theta$ at low current)

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

Crabbed waist realized with a sextupole 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

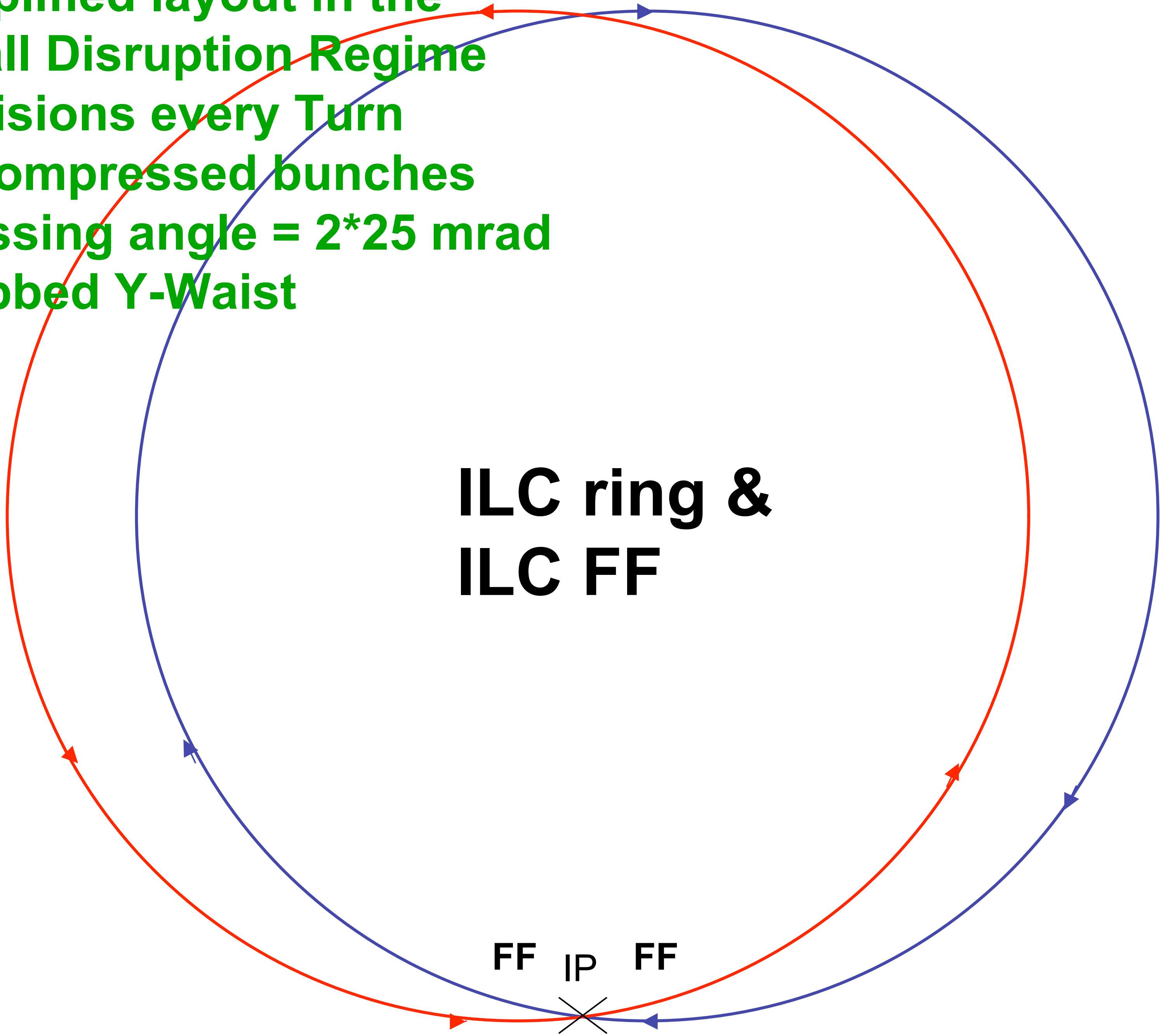
Simplified layout in the Small Disruption Regime

Collisions every Turn

Uncompressed bunches

Crossing angle = 2*25 mrad

Crabbed Y-Waist



During the last year we have optimized design and parameters based on:

Large (piwinski) crossing angle and crab-waist concept

Small horizontal emittance, vertical beta and beam size

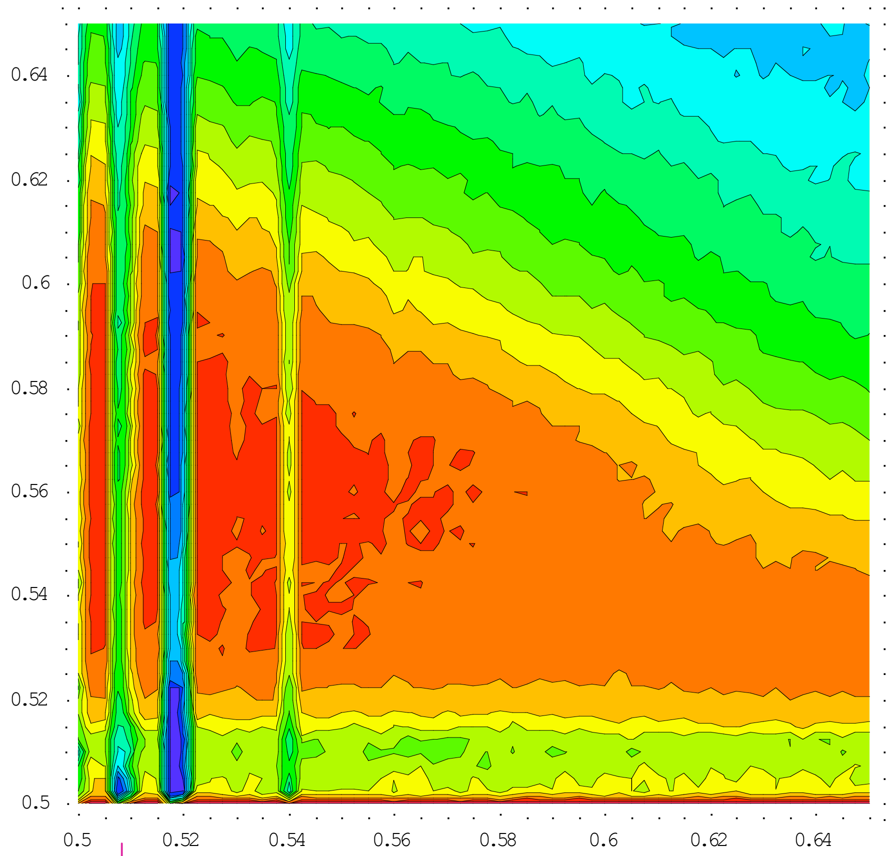
Reuse of all the PeP hardware

Reoptimization of the ring parameters in 6 months studies

- 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
- Relaxed crossing angle: 2*25mrad => 2*17mrad
- 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 $\times 10^{10}$	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	

Scan above Half Integers



In the first order in perturbation

nQx + mQy + kQs = integer

m should be even

(n + k) should be even

$Q_s = 0.02$

$L_{max} = 1.21 \times 10^{36}\ cm^{-2}s^{-1}$

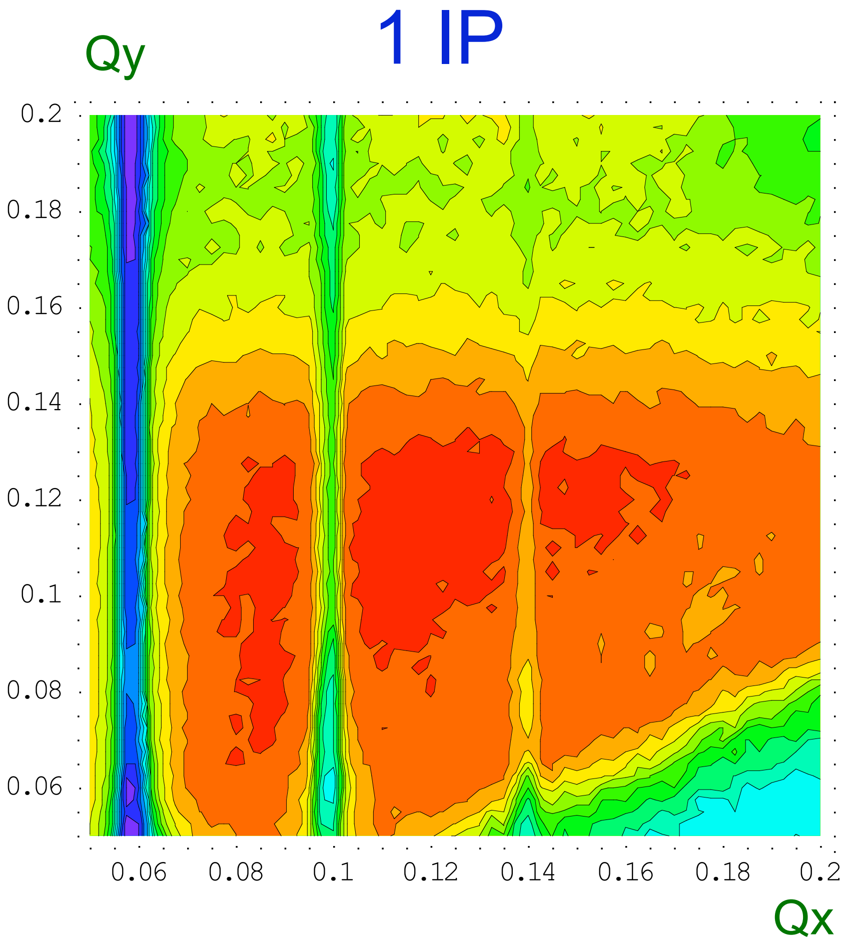
2Qx – 4Qs (first order)

2Qx – 2Qs (first order)

2Qx – 1Qs (higher order)
4Qx – 2Qs (first order) ?

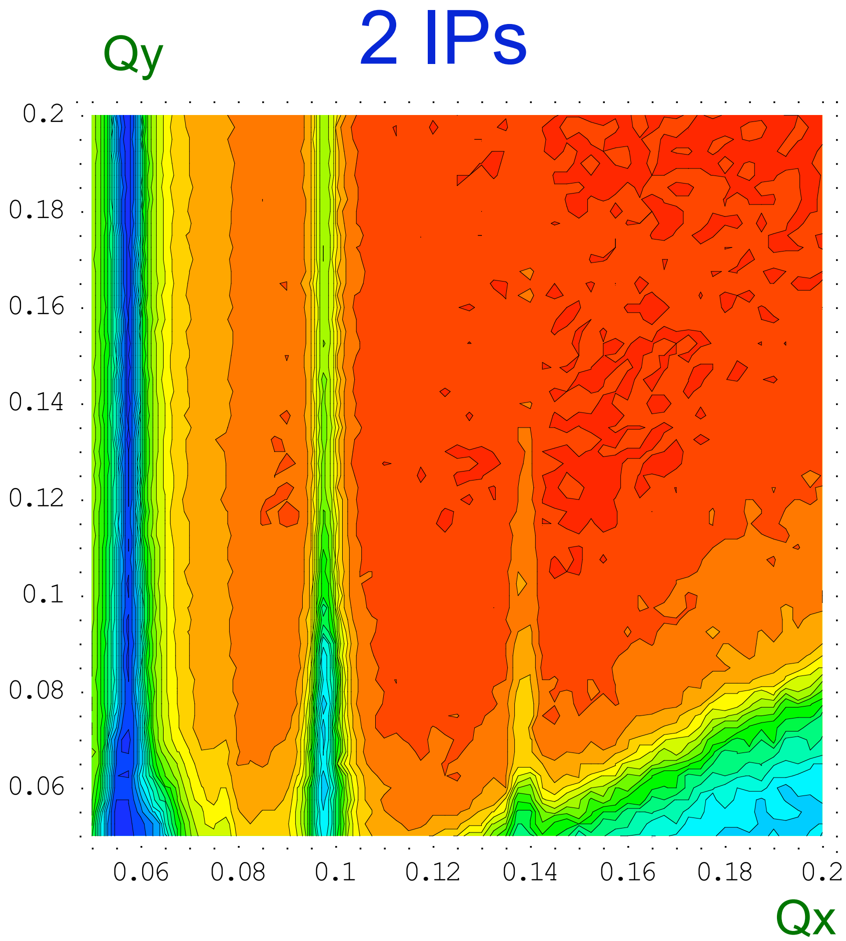
M.Zobov, D.Shatilov

Luminosity Tune Scan



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

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

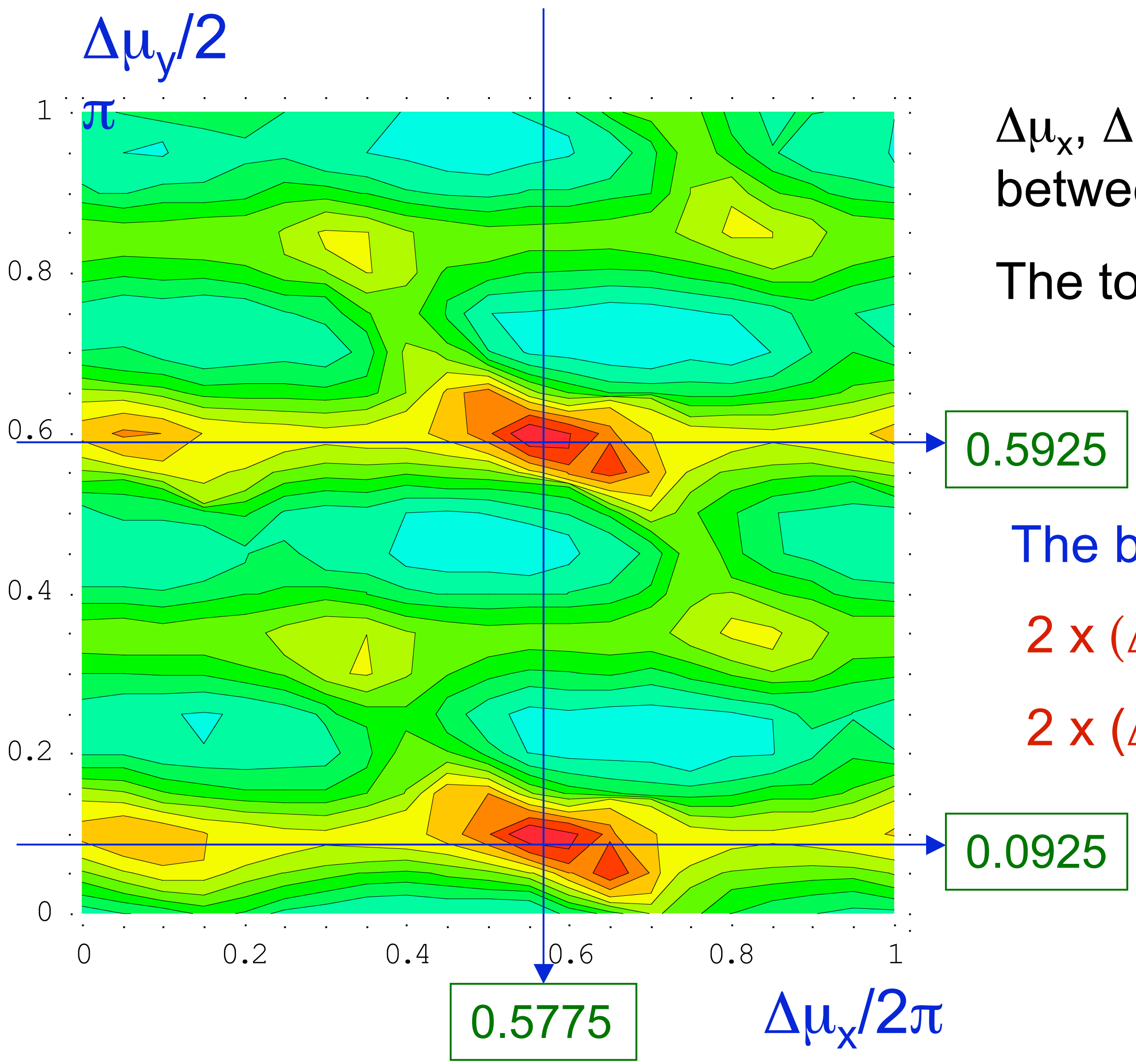


$Lmin = 3.37 \times 10^{34}\ cm^{-2}s^{-1}$

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

M.Zobov, D.Shatilov

Double Phase Advance Scan



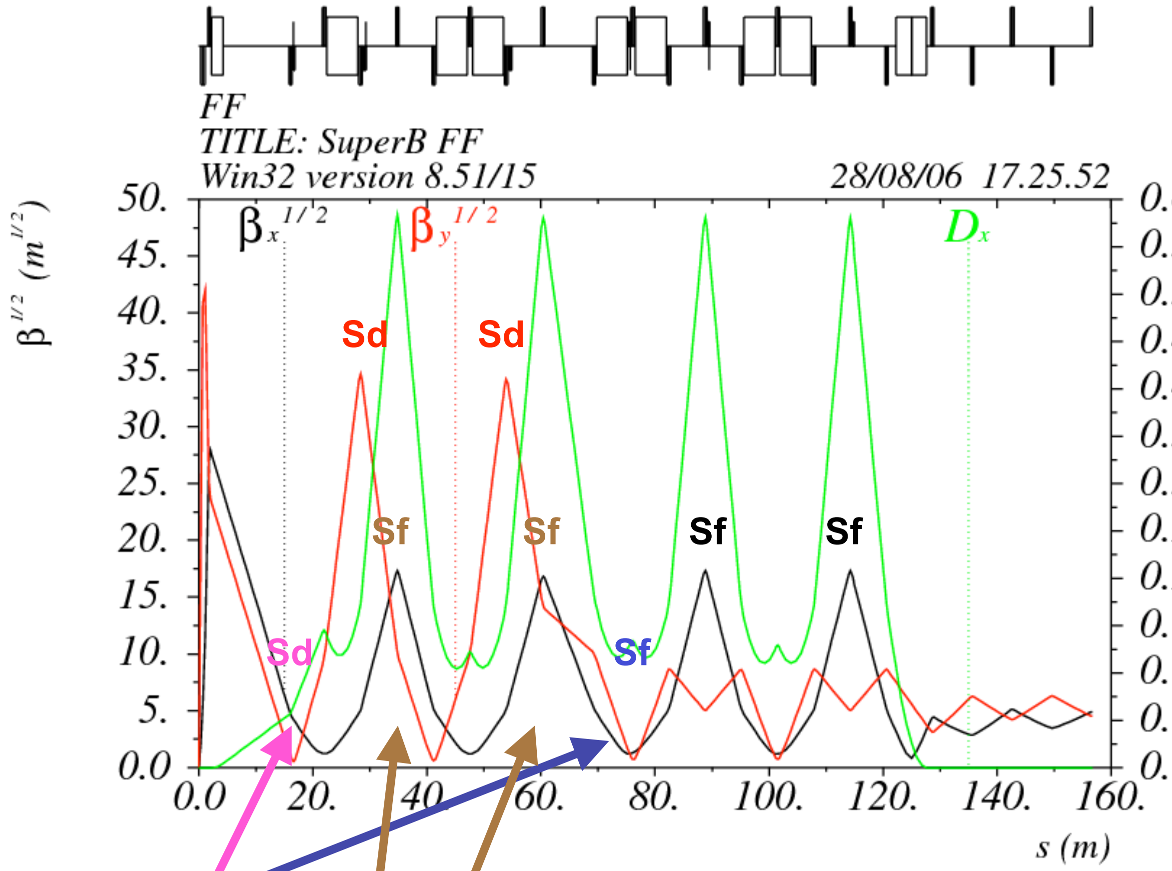
$\Delta\mu_x$, $\Delta\mu_y$ are phase advances between IP_1 and IP_2

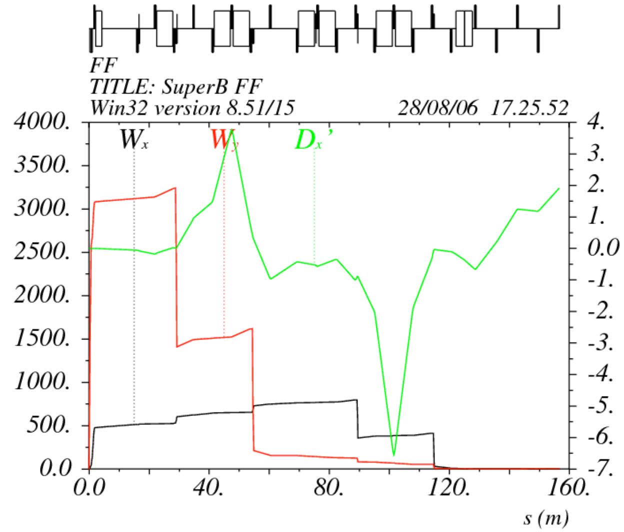
The total tune (0.155, 0.185)

The best choice is symmetric

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

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

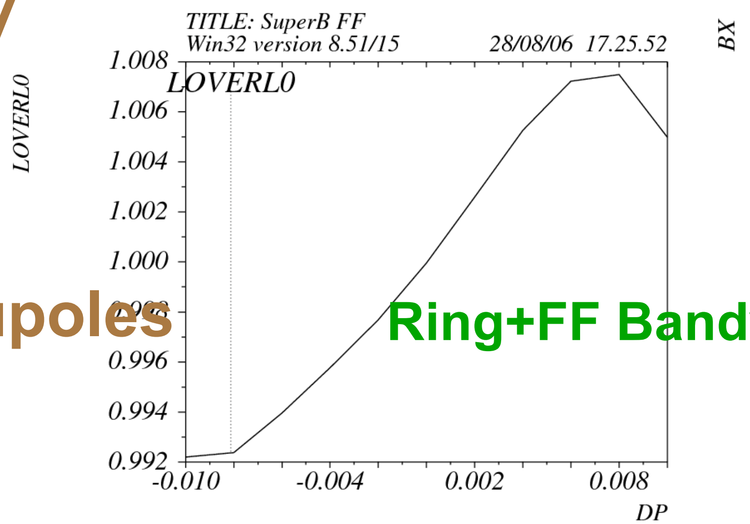




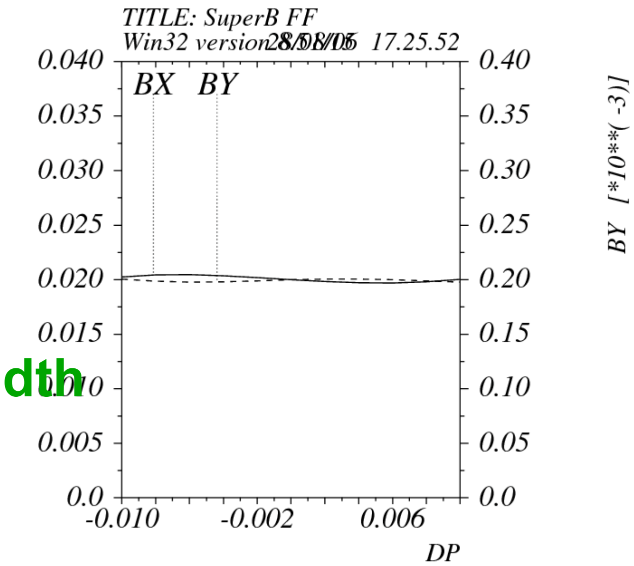
FFTB-stile Final Focus

IP phase sexts

-I restoring "weak" sextupoles

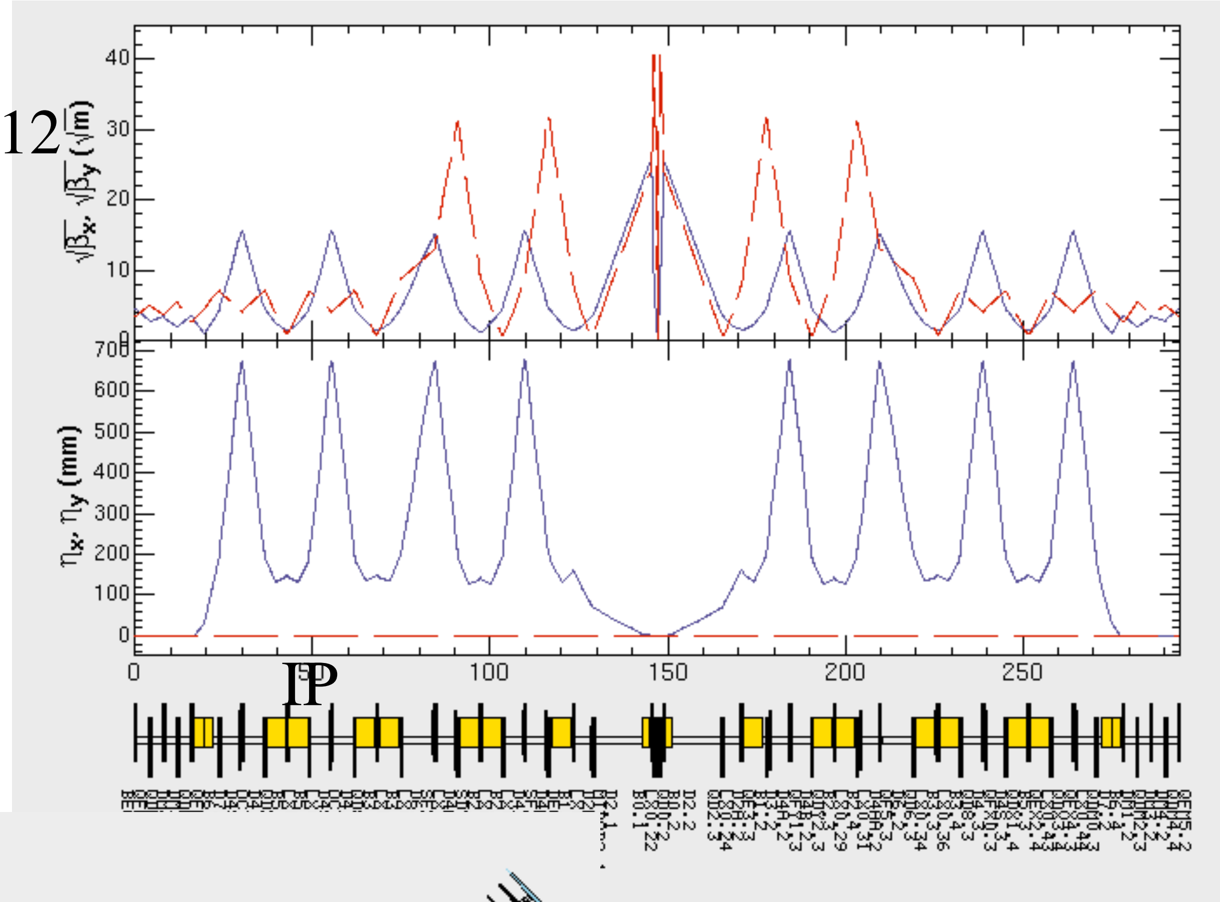


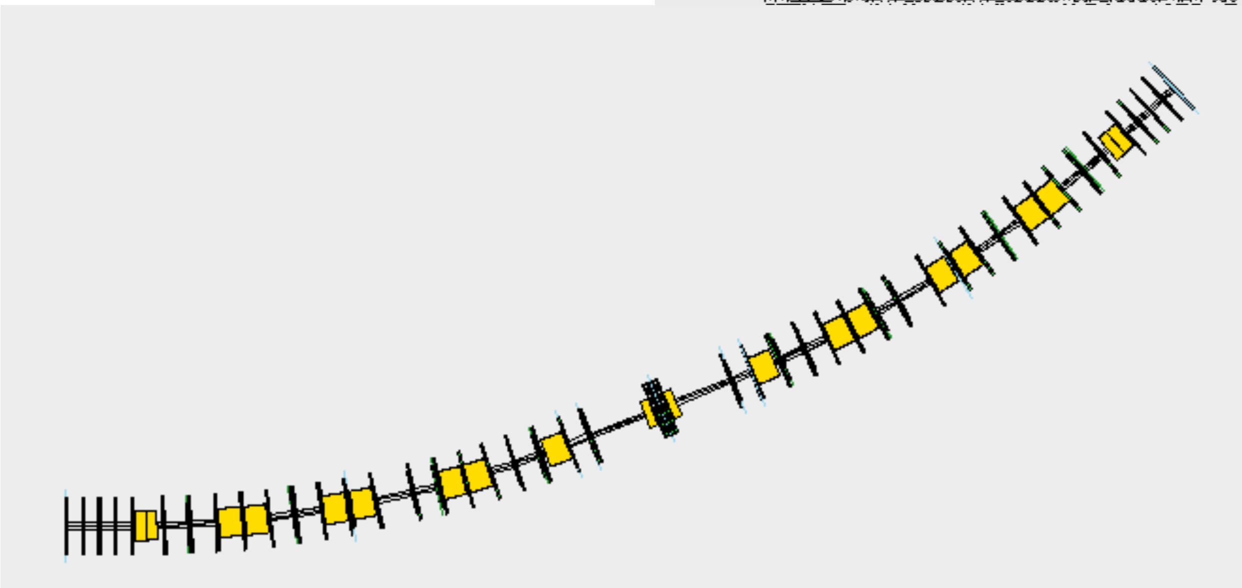
Ring+FF Bandwidth



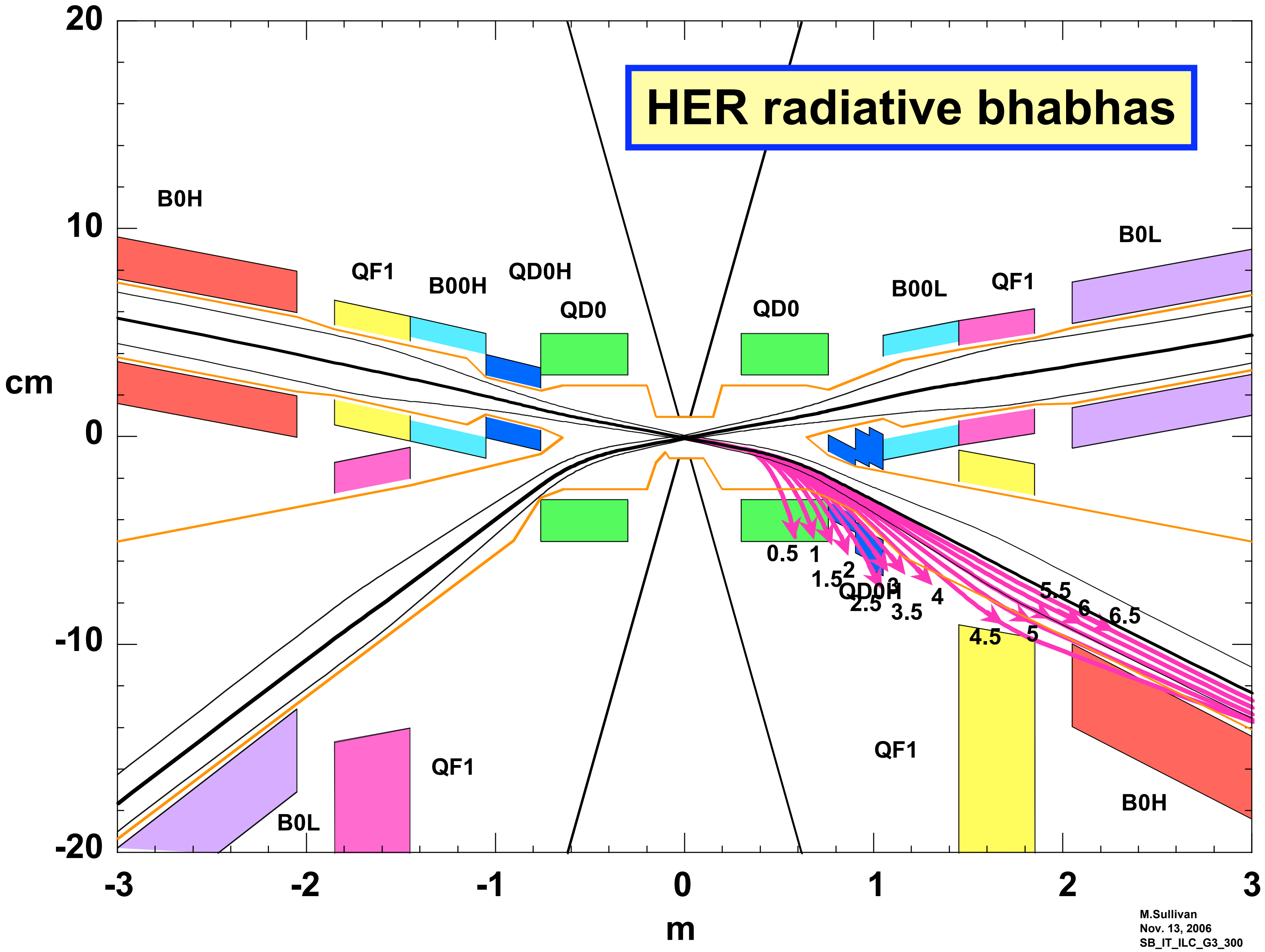
SuperB: sb70_ff_linepro12

Y. Ohnishi



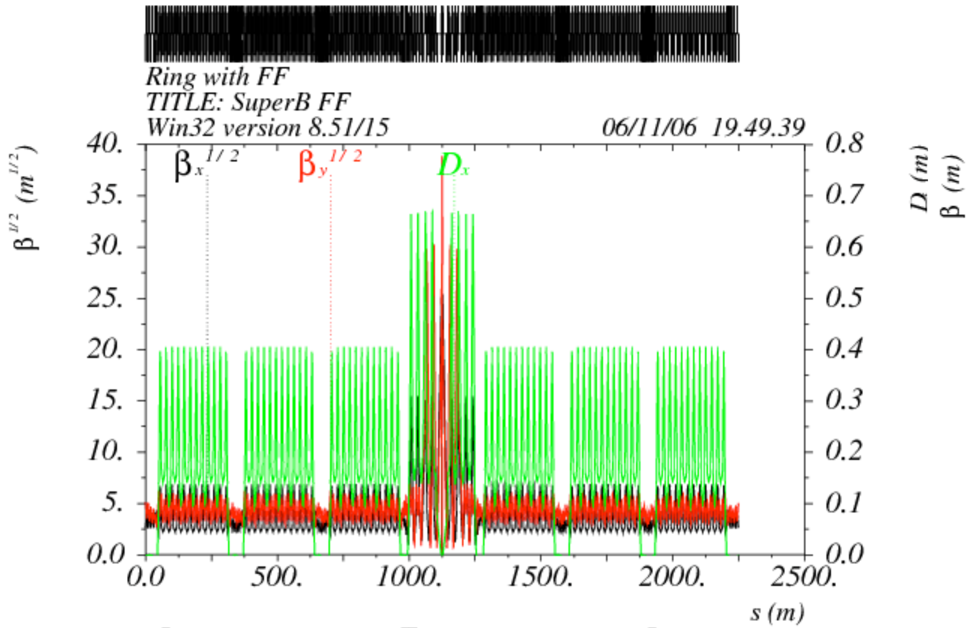


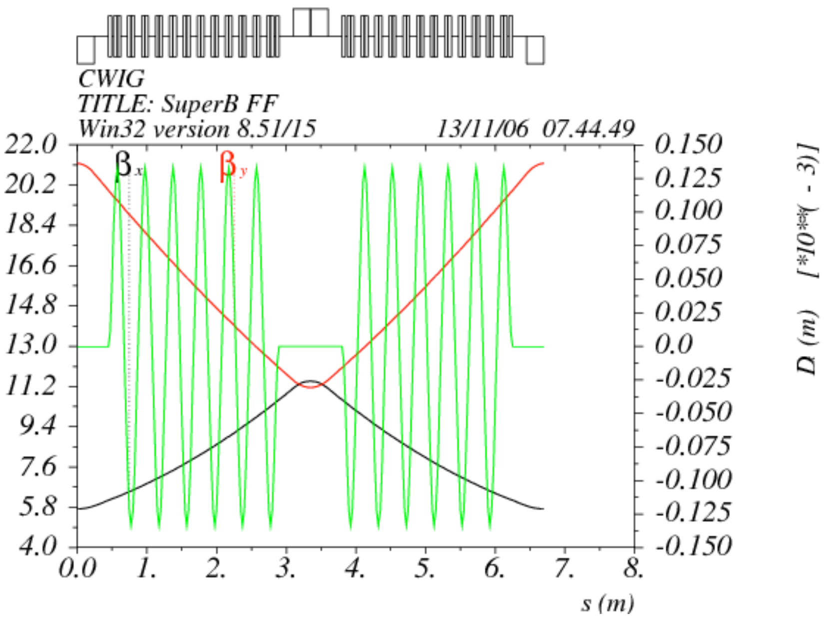
SuperB Interaction Region

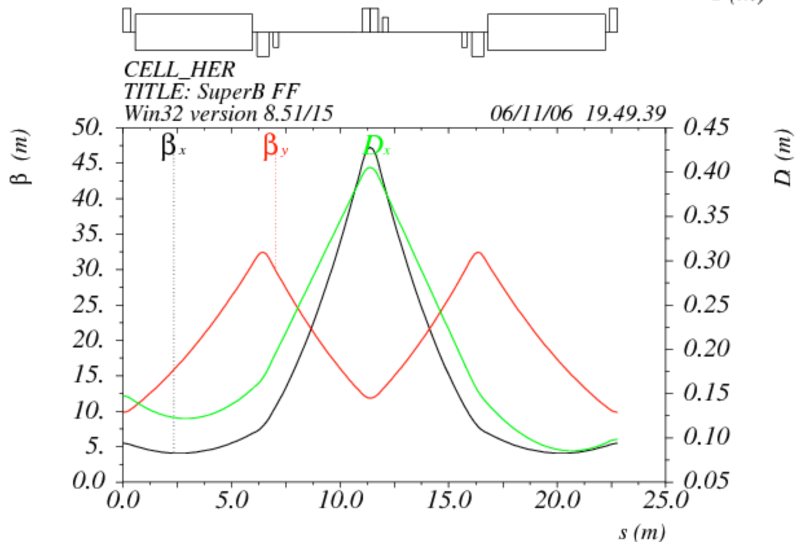


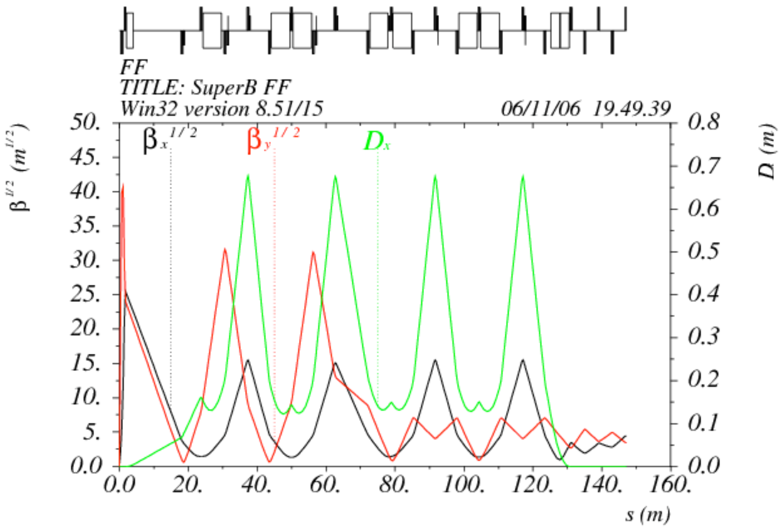
M.Sullivan
Nov. 13, 2006
SB_IT_ILC_G3_300

HER Ring Lattice









- 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
- Now that the lattice is in its “final” state, is time to have a look seriously at the hardware needs (RF locations, space for diagnostics, vacuum pumps, etc...)

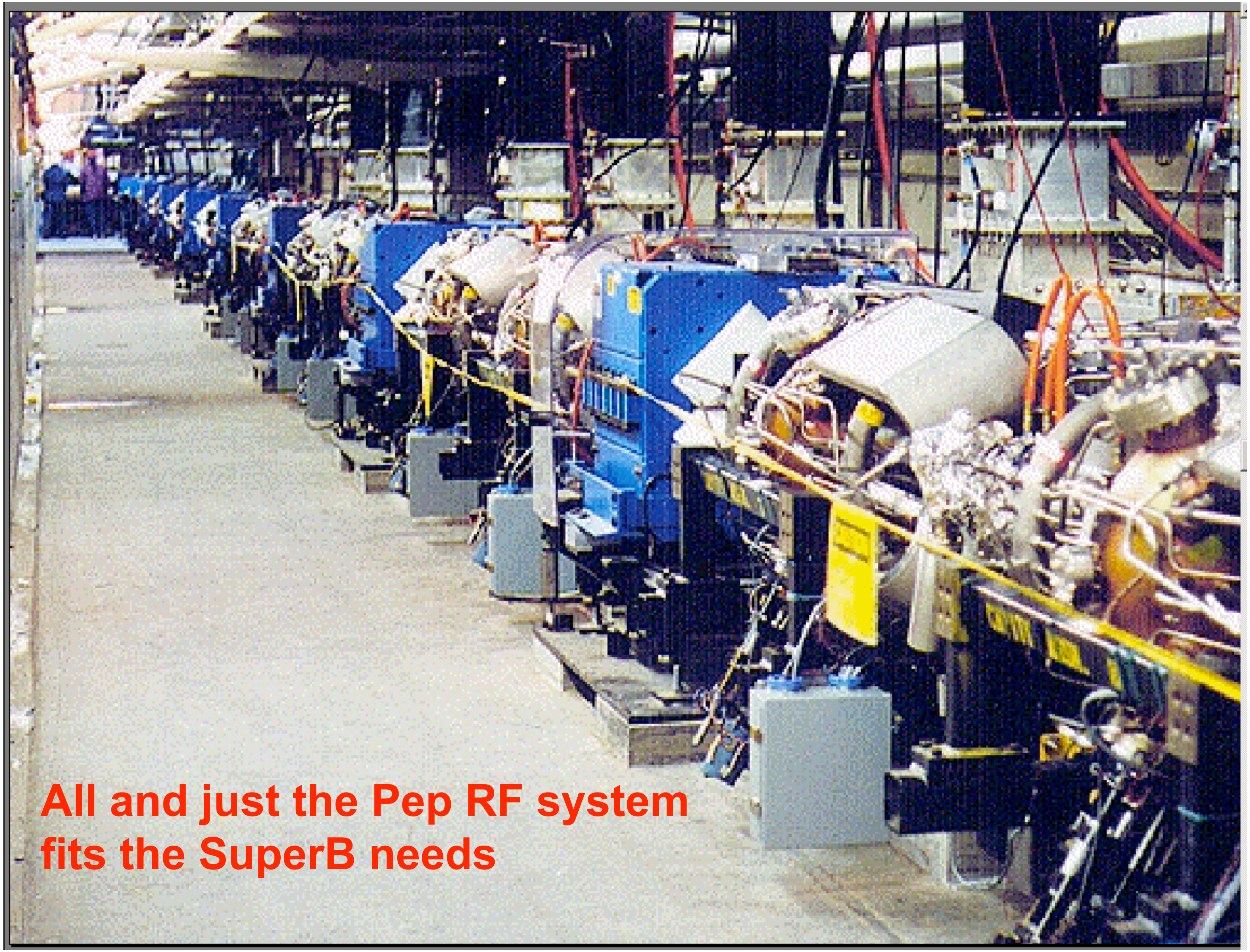
Dipoles Summary

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

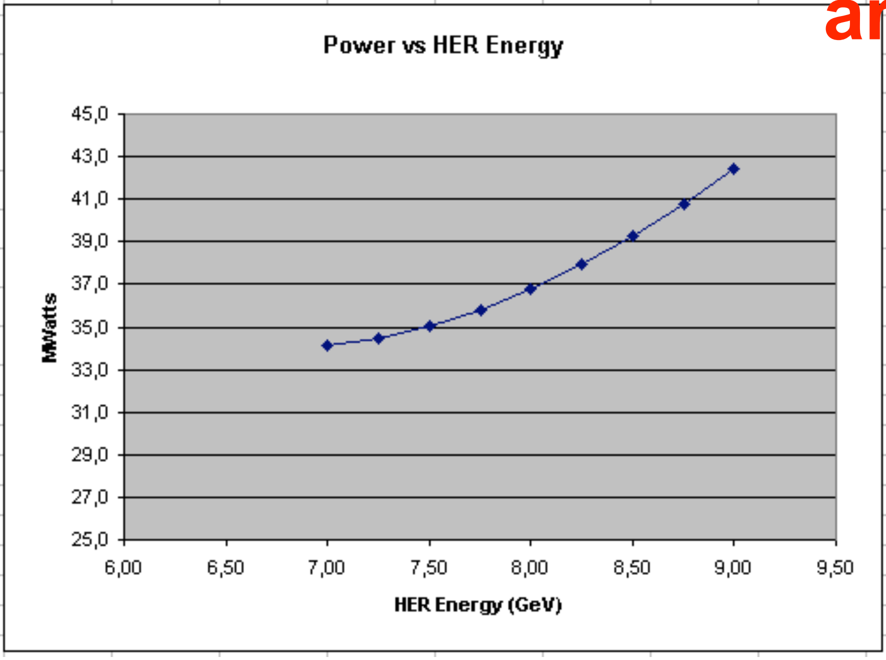
We have excess of:
- **48 bends 0.45 m long**
- **16 bends 5.4 m long**
- **4 bends 2. m long**


All and just the Pep RF system
fits the SuperB needs

HER Energy GeV	LER Energy GeV	HER Loss per turn MeV	LER loss per turn MeV	HER Current Amp	LER Current Amp	HER RF power MW	LER RF power MW	HER magne power MW	LER magne power MW	Cooling H2O Power MW	Control power MW	Injector Power MW	Lights and HVAC MW	Total power MW
7,00	3,99	3,30	1,89	1,30	2,28	8,6	8,6	4,0	3,0	2,4	0,5	4,0	3,0	34,1
7,25	3,85	3,80	1,64	1,26	2,36	9,5	7,8	4,3	2,8	2,4	0,5	4,1	3,0	34,5
7,50	3,72	4,35	1,44	1,21	2,45	10,6	7,0	4,6	2,6	2,5	0,5	4,3	3,0	35,0
7,75	3,60	4,96	1,26	1,17	2,53	11,6	6,4	4,9	2,4	2,5	0,5	4,4	3,0	35,8
8,00	3,49	5,63	1,11	1,14	2,61	12,8	5,8	5,2	2,3	2,6	0,5	4,6	3,0	36,8
8,25	3,38	6,37	0,98	1,10	2,69	14,0	5,3	5,6	2,1	2,7	0,5	4,7	3,0	37,9
8,50	3,28	7,17	0,87	1,07	2,77	15,4	4,8	5,9	2,0	2,8	0,5	4,9	3,0	39,3
8,75	3,19	8,06	0,77	1,04	2,85	16,8	4,4	6,3	1,9	2,9	0,5	5,0	3,0	40,8
9,00	3,10	9,02	0,69	1,01	2,93	18,2	4,1	6,6	1,8	3,1	0,5	5,1	3,0	42,4

Beam current scales inversely with beam energy.
Assumes RF power is 50% efficient.
Assumes water power to remove other generated power is equal to 10% of removed power.
Magnet power scales as the square of the energy.
Radiation power scales as the 4th power of the energy.

Wall Plug Power around 30 MWatt



3 Super-B Accelerator

CDR ready

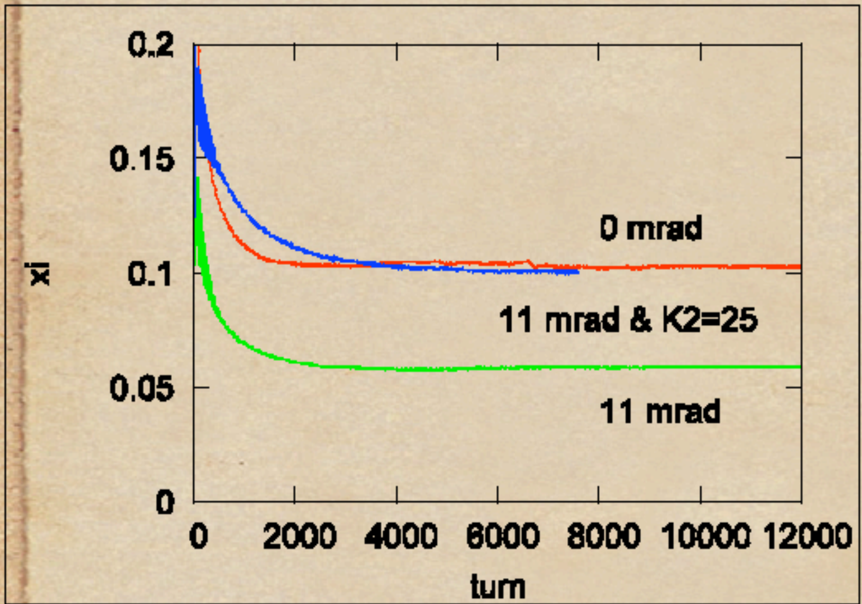
Possible site in the Tor Vergata University close to the Frascati Lab

Toward a cost estimate

- Rings rebuild by reusing about 90% of Pep (300Meuro), 90 Meuro
- Ring tunnel and collider hall 40Meuro
- Injector system 90Meuro
- Convetional facilities 50Meuro
- Total about   270Meuro

- Possible fall back on the existing factories
- The crabbed 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

Crab Waist for present KEKB



$H = K_2 \, x \, p_y^2$

- Crab waist may improve the luminosity of present KEKB as powerful as the crab crossing.
- Actual lattice design is going on.
- Another term proportional to x^3 arises if only one pair of sexts is used. Its effect will be studied.
- Can be tested after the crab cavity test.

K. Ohmi

DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, Sept. 25, 2006

Note: G-xx

DAΦNE UPGRADE FOR SIDDHARTA RUN

DAΦNE Team, LNF-INFN
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1. Introduction

The Siddharta experiment will be ready to be installed in DAΦNE by mid-2007. It seems very feasible to install an Interaction Region suitable to exploit the "Large crossing angle" and "crabbed waist" concept. This new scheme for luminosity increase in e^+e^- colliders has been extensively studied, for example it has been presented at the 2nd Frascati Workshop on SuperB-Factory, March 2006 [1]. A combination of large crossing angle, together with very small beam sizes at the IP, and the "crabbed vertical waist", should in theory give us the possibility of reaching a luminosity of the order of 10^{33} cm^{-2} s^{-1}, with very little modifications of the machine, with beam currents similar to ones reached during the KLOE run [2]. This scheme does not need to have very short bunches in the rings (very expensive and difficult), in order to have very low β-functions and little hourglass effect.

Other improvements will be the installation of fast stripline kickers, as the ones that will be used in the ILC damping rings. This should increase the injection efficiency from 50% to100%, with consequent background reduction and possibly higher beam currents, with a further gain in peak and integrated luminosity.

Wigglers poles will also be modified in order to improve the dynamic aperture, with benefits in beam lifetimes and background.

Ti Coating in the positron wiggler vacuum chambers will hopefully ameliorate the e-cloud instability threshold and should allow us to further increase the current.

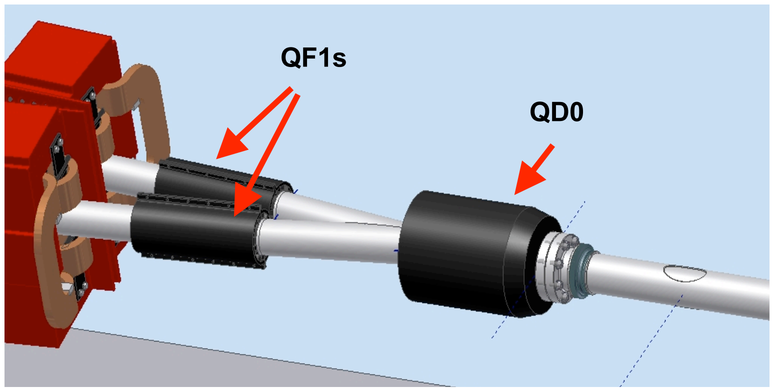
This paper will review the principle of the new collision scheme and present a summary of the beam-beam studies performed in order to estimate the luminosity gain. Moreover a description of the lattice and hardware modifications needed for its implementation will be given.

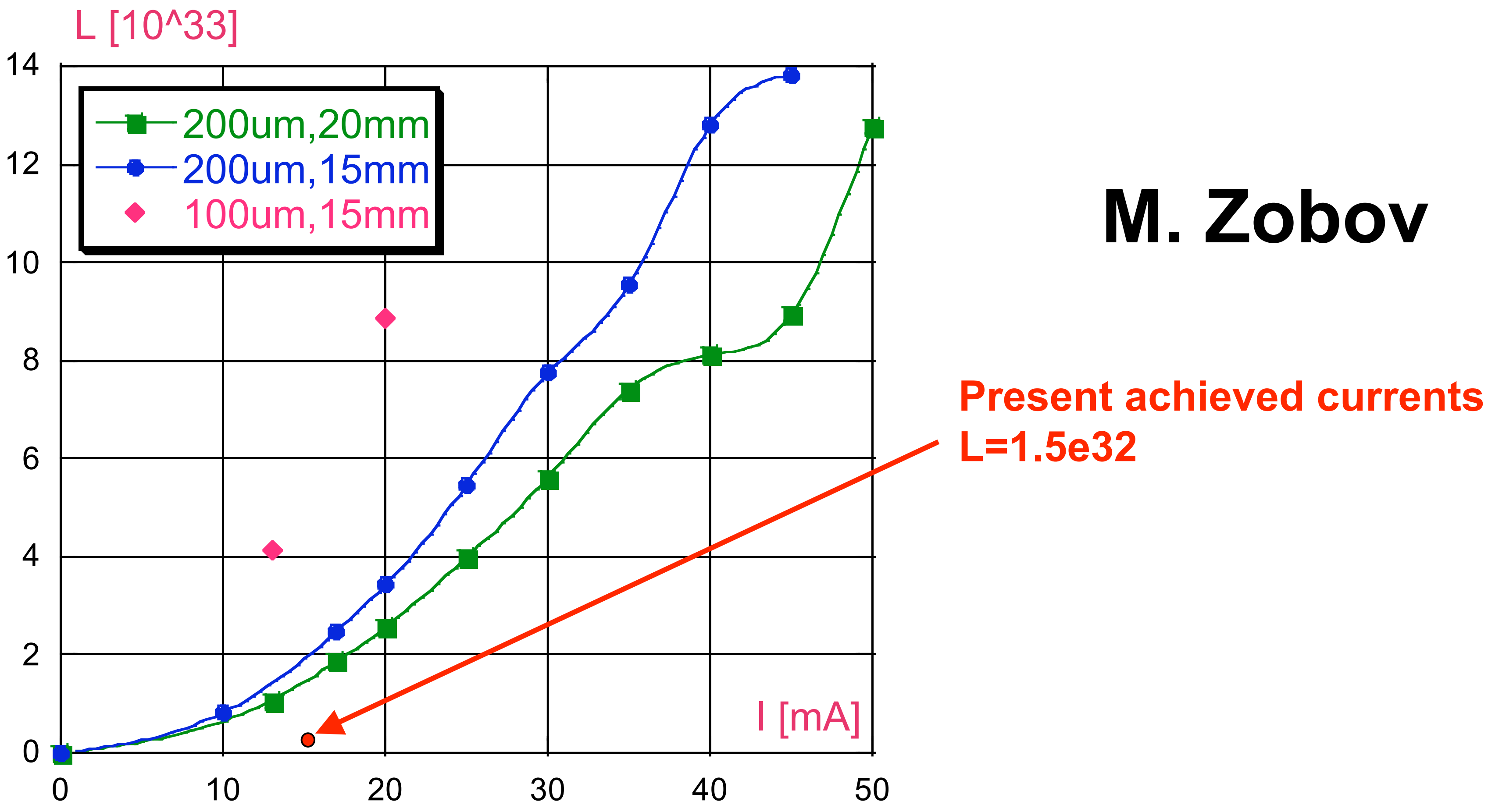
2. The large crossing angle and crab waist concepts

In high luminosity colliders one of the key points is to have very short bunches, since this allows to decrease β_y^* at the IP. This values cannot indeed be much smaller than the bunch-length without incurring in the "hourglass" effect. Moreover high luminosity requires a small vertical emittance and large horizontal size and emittance to minimize the beam-beam effect. Unfortunatley for a ring it is relatively easy to achieve small horizontal emittance and horizontal size and it is very hard to shorten the bunch length σ_z.

Novosibirsk is designing a tau-charm factory based On The Crab-Waist

Large piwinski angle and Crab Waist will be used in the Dafne run next fall to try to improve the luminosity by a factor > 3

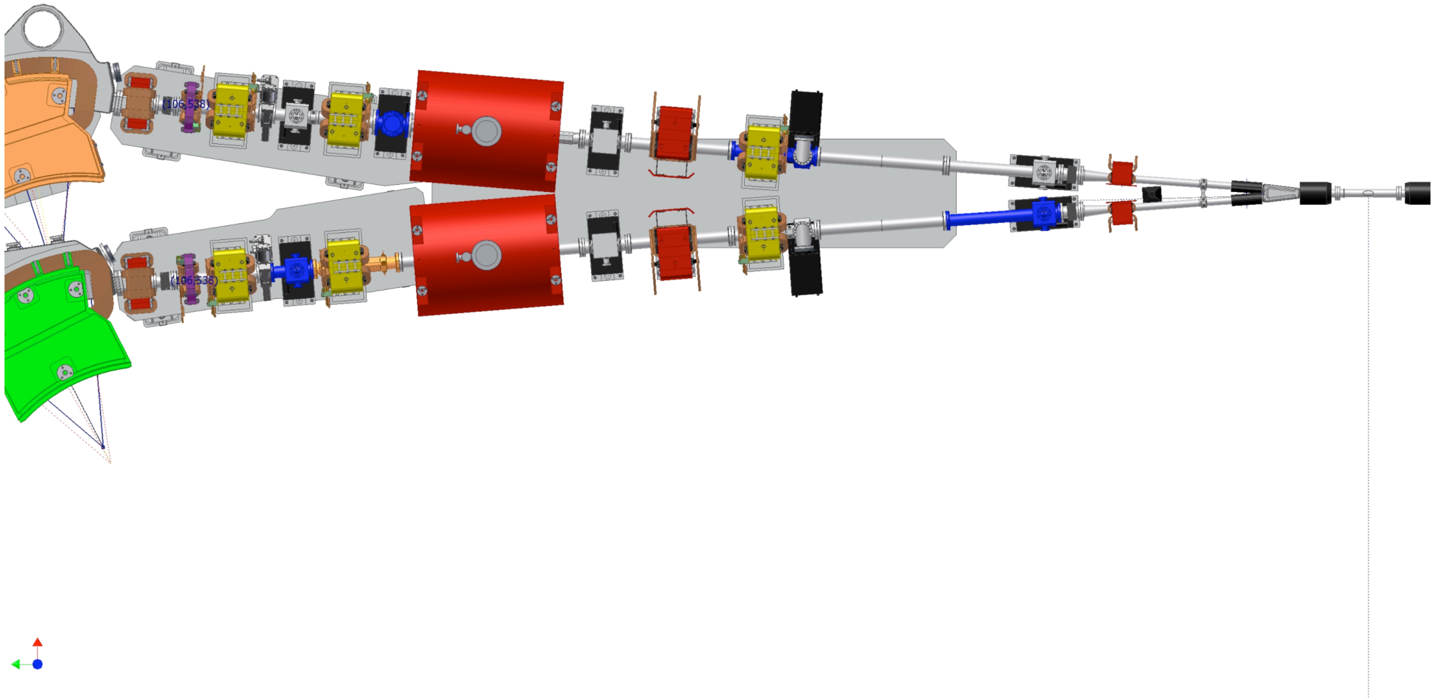




M. Zobov

With the present achieved beam parameters (currents, emittances, bunchlenghts etc) a luminosity in excess of 10^{33} is predicted.
With 2Amps/2Amps more than $2*10^{33}$ is possible
Beam-Beam limit is way above the reachable currents

Siddharta (Kloe) side



Cost estimate

	Kilo-Euros
PM quads	**400**
IR1 vacuum chambers	40
IR2 vacuum chambers	30
Kickers pulsers	140+100
Kickers	60
Matching chambers for kickers	30
Vacuum pumps and components	60
New wigglers poles	200
External labor	90
Contingency+extras	150
Total	1300

Time schedule

- Final design ready
- PM quads, the most critical component, delivered by June
- Bids for Vacuum chambers started at the end of january, orders by end of february, 3 months for delivery
- Orders for Kickers and ½ of the pulser under way, 3-4 months for delivery
- Wiggler poles will not be done (budget cuts)

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)