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DE L'ACCÉLÉRATEUR
LINÉAIRE

SuperB

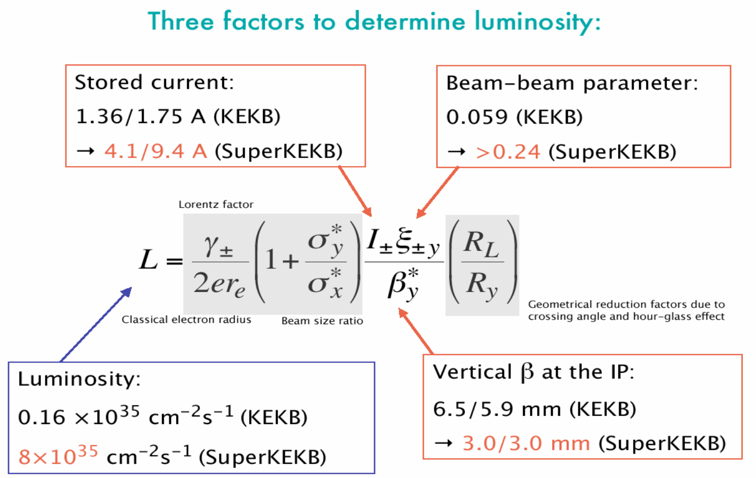
A.Variola
Group SuperB

Context

- Next generation lepton colliders for the flavor physics
- WHAT IS THE CHALLENGE ? Luminosity (~ brillance….)& $$$$$$$
- The barrier is given by the beam-beam effect. (1st order = extremely strong focusing 2D QUAD) => Tune shift & resonances

Basic concepts

- B-factories already attain very high luminosity (~10^{34} s^{-1} cm^{-2}).
- To increase it by ~ 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

Proposal to push at the limits all the parameters (also money). Increase in plug power ($$$$$..) and hard to operate (high current, short bunches)

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SUPERB approach

Look for alternatives keeping constant the luminosity => new IP scheme: CRAB WAIST (P.Raimondi)

If f_{rep} is required to increase the luminosity, the 'circular' ring solution has to be analysed:

Let's assume we have no/little collision angle. From the formulas (see following transparencies), to attain high luminosity one has to provide

swap

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

In a ring:

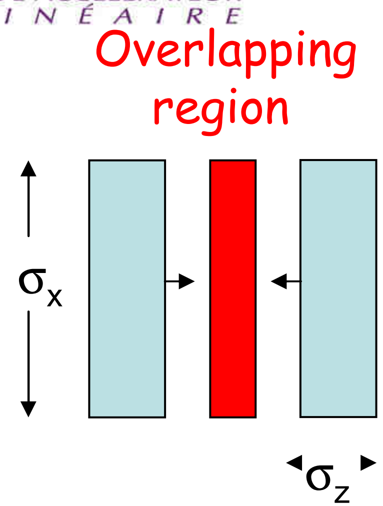
- Easy to have small horizontal emittance and horizontal size
- Vertical emittance scales with H (coupling)
- Very difficult to have short bunches (HOM, CSR..)

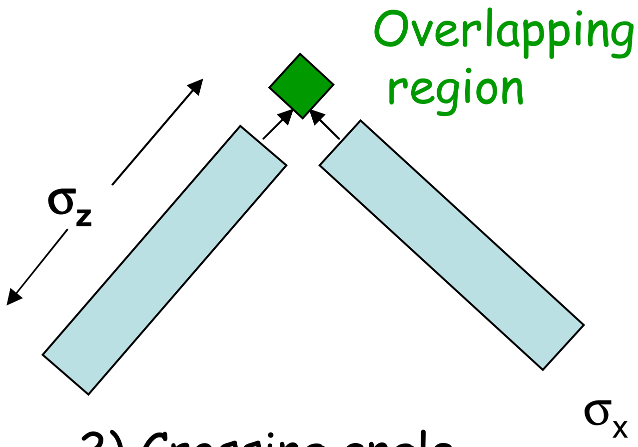
So=> First basic IDEA: Swap the X with Z requirements with a crossing angle, so the high luminosity requirements are naturally met.

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

Crossing angle concepts

1) Standard short bunches

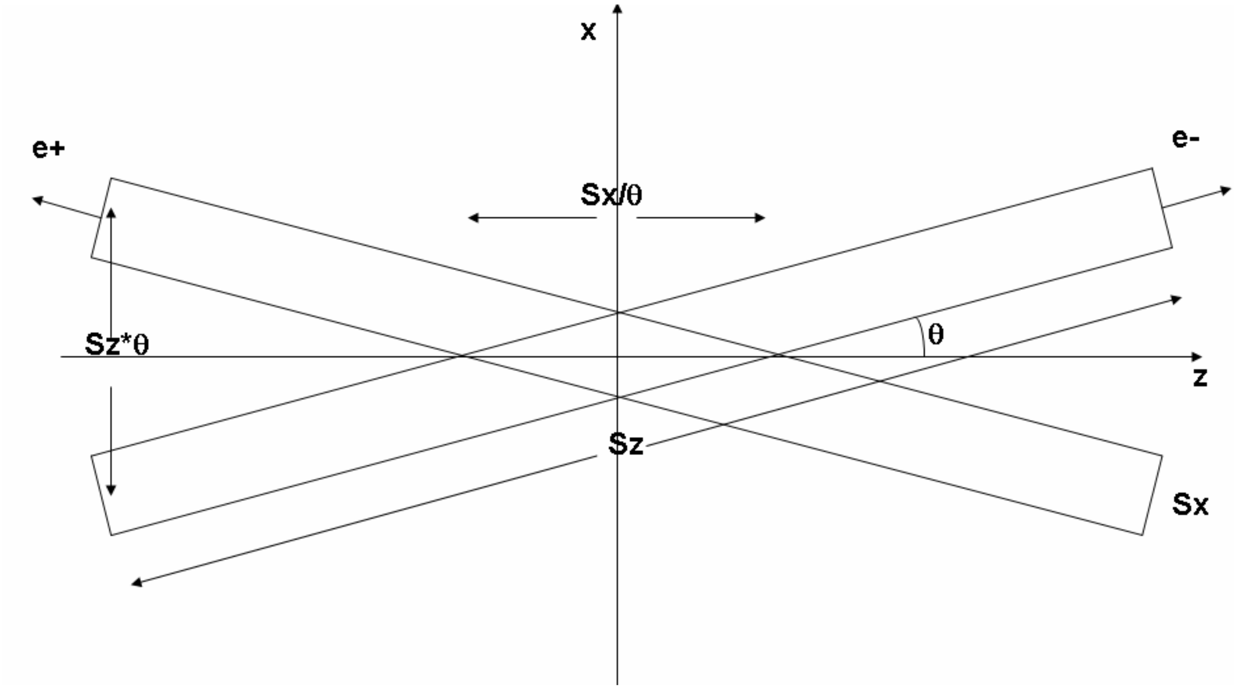




2) Crossing angle

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

With large crossing angle X and Z requirements are swapped:



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But not only crossing angle……

Large Piwinski angle $\Phi = \frac{\sigma_z}{\sigma_x} tg(\frac{\vartheta}{2})$ => (so long bunches and little H emittances).

Luminosity & IP parameters for a circular collider (beam re-used)

$$L \propto \frac{N\xi_y}{\beta_y}$$

+ crossing angle and beam-beam

$$L \propto D \frac{f_r N^2}{(\sigma_x \sigma_y)} \frac{1}{\sqrt{1+\Phi^2}}$$

$$\Phi = \frac{\sigma_z}{\sigma_x} tg(\frac{\vartheta}{2})$$

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

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

As usual contradictory requests!!!
Multiparameter Optimization needed

$$\xi_y \propto \frac{N}{(\sigma_x \sigma_y)} \frac{\beta_y}{\sqrt{1+\Phi^2}}$$

$$\xi_x \propto \frac{N}{\varepsilon_x (1+\Phi^2)}$$

from Hourglass effect $\Rightarrow \beta^*_y \geq \sigma_z$

- So the first assumption for CW scheme is to collide with large Piwinski angle

1) Large Piwinski angle - high σ_z and collision angle. (slight L decrease)

⇒ allows point (2) & decreases the disruption due to the effective z overlap & minimises parasitic collision. The ring stability profits from long bunches (CSR, HOM…) but

Introduces B-B and S-B resonances (strong coordinates coupling).

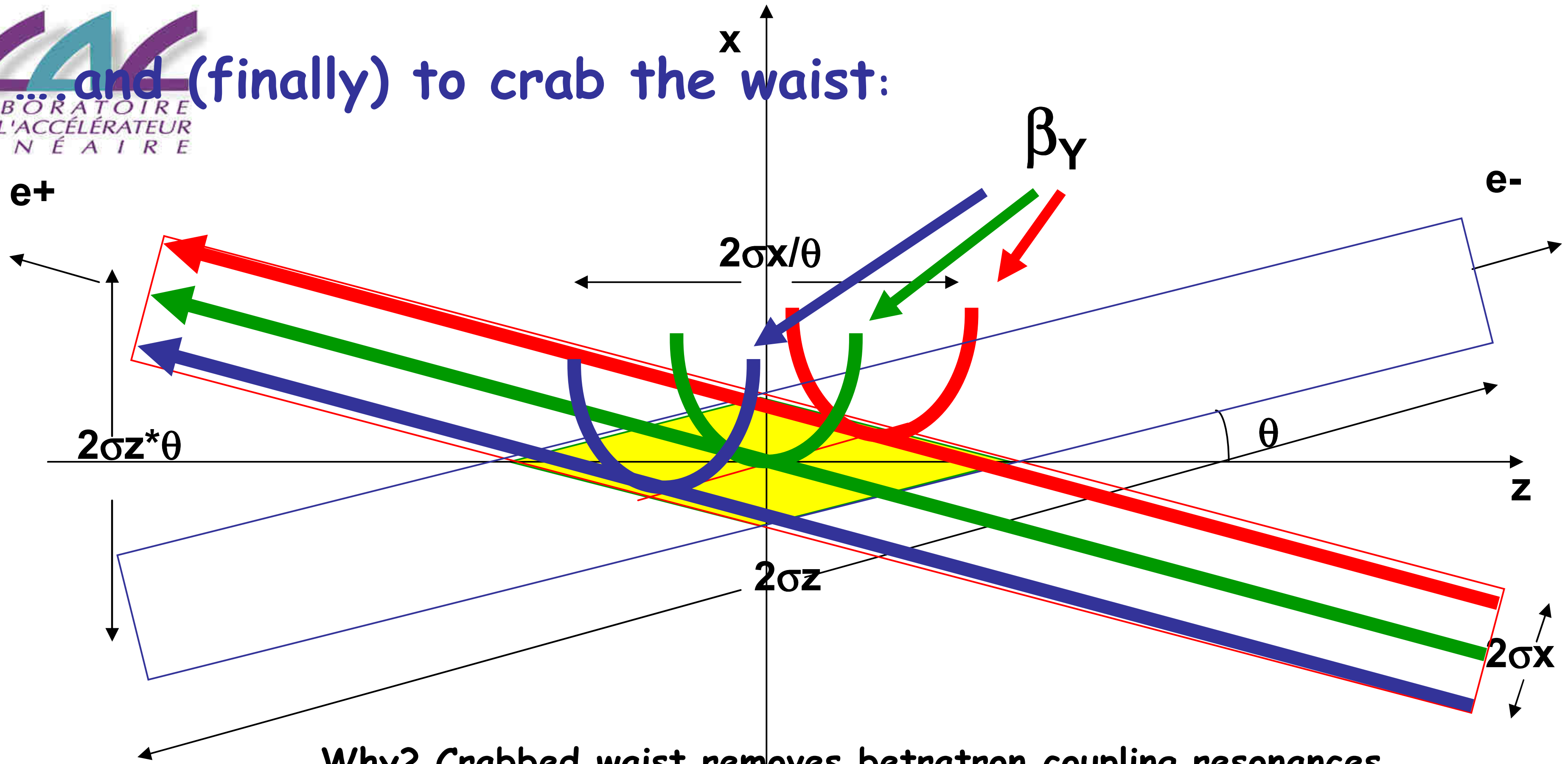
2)Extremely short β^*_y (300 μm) so little σ^*_y (35 nm - high L gain…)

3)Large angle scheme already allows to reduce S-B resonances (small overlap)

4)Small horizontal emittance (horizontal tune compensated by large Piwinski angle)

5) Small disruption (or same D increasing N) without luminosity loss. The beam can be re-utilised in an accumulation ring => High repetition frequency and charge per bunch (High L gain)

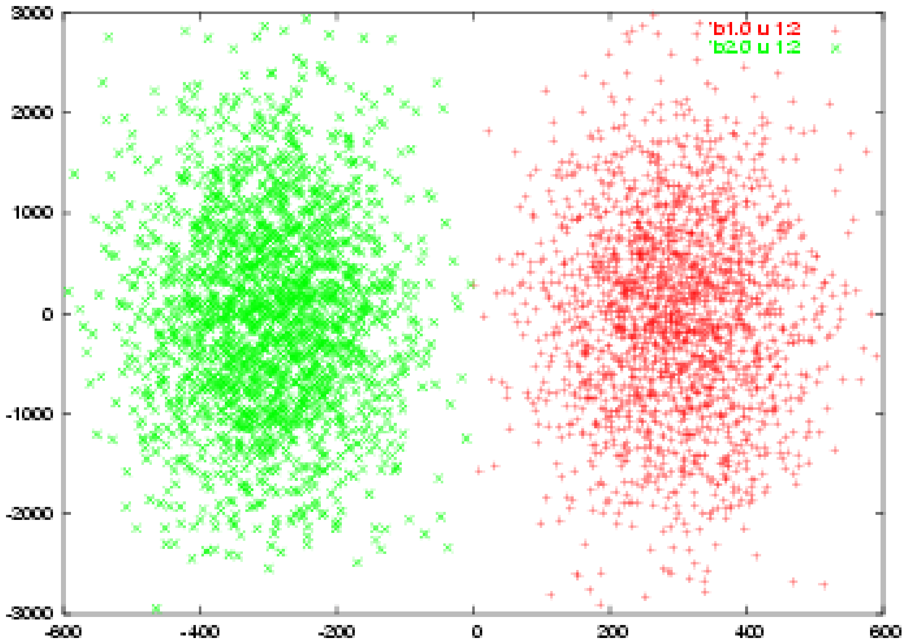
…. and (finally) to crab the waist:



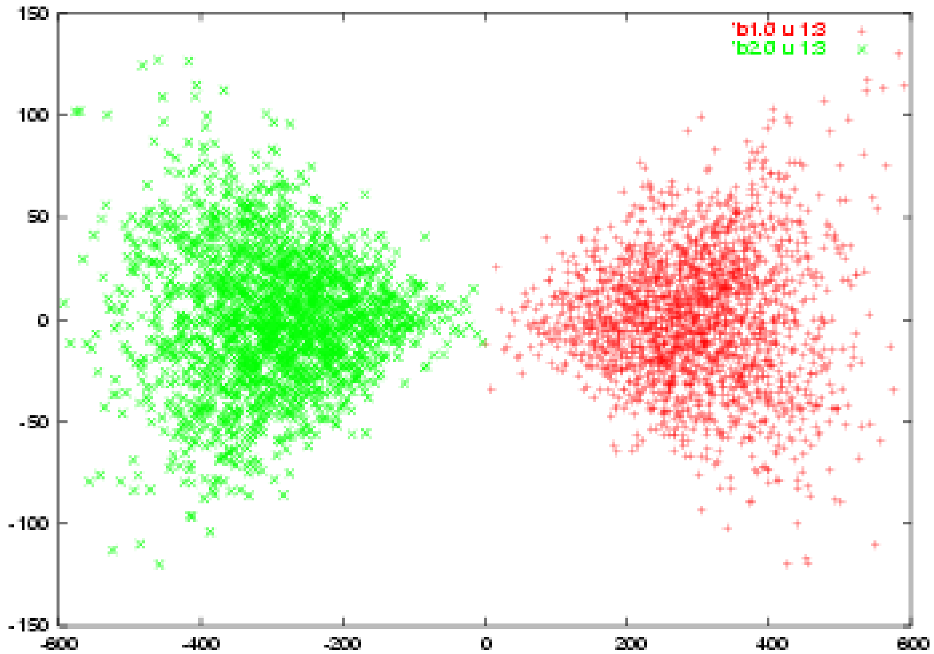
Why? Crabbed waist removes betratron coupling resonances introduced by the crossing angle (betatron phase and amplitude modulation)

Vertical waist has to be a function of x:

Crabbed waist realised with a sextupole at $\pi/2$ in Y……. slight luminosity increase.

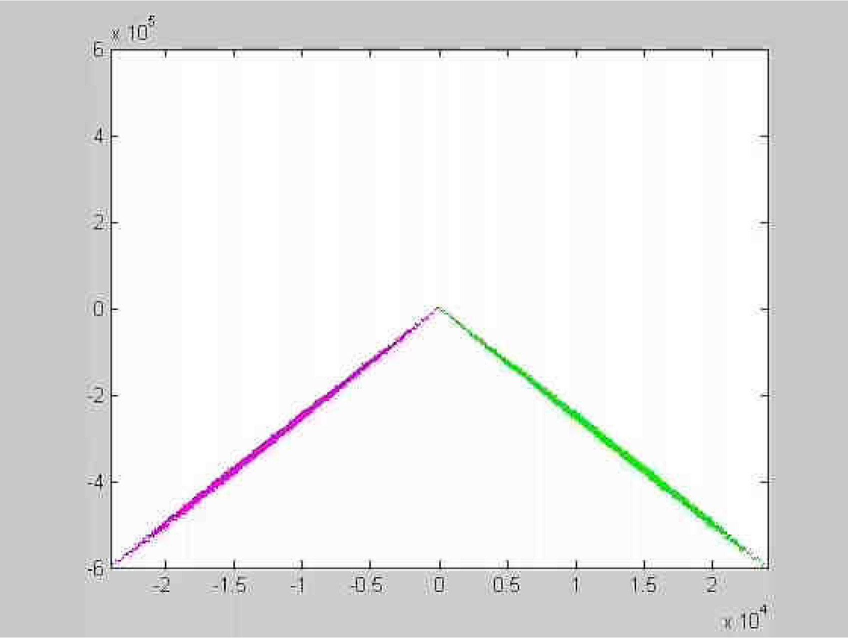


Horizontal Collision

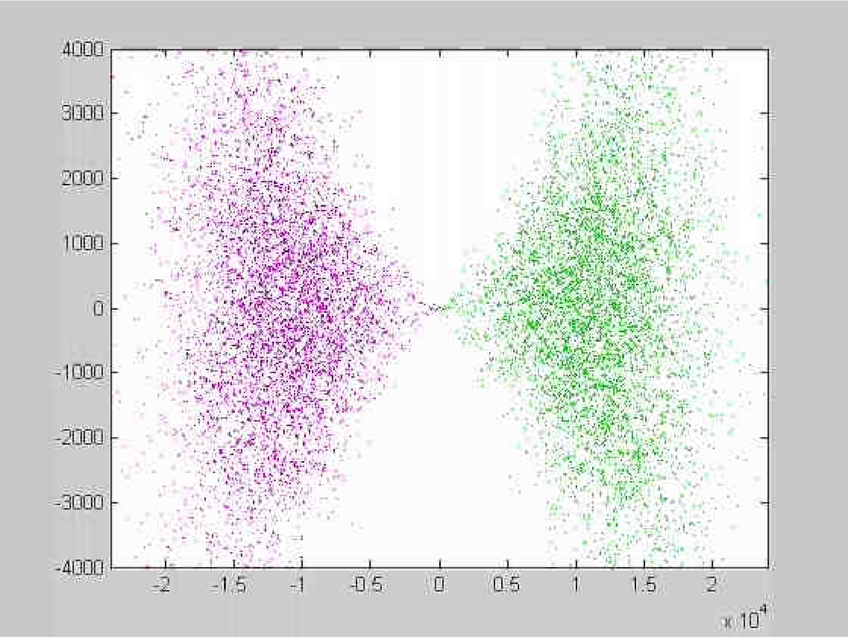


Vertical collision

First attempt without crab waist.
Relative Emittance growth per collision about 2.5*10-3
$\varepsilon_{yout}/\varepsilon_{yin}$= 200y/10x



Horizontal Plane



Vertical Plane

Another example: Collisions with uncompressed beams
Crossing angle = 2*25mrad.
Relative Emittance growth per collision about $2.5*10^{-3}$
$\varepsilon_{yout}/\varepsilon_{yin}=1.0025$

Usual Accelerator parameter table……….

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	

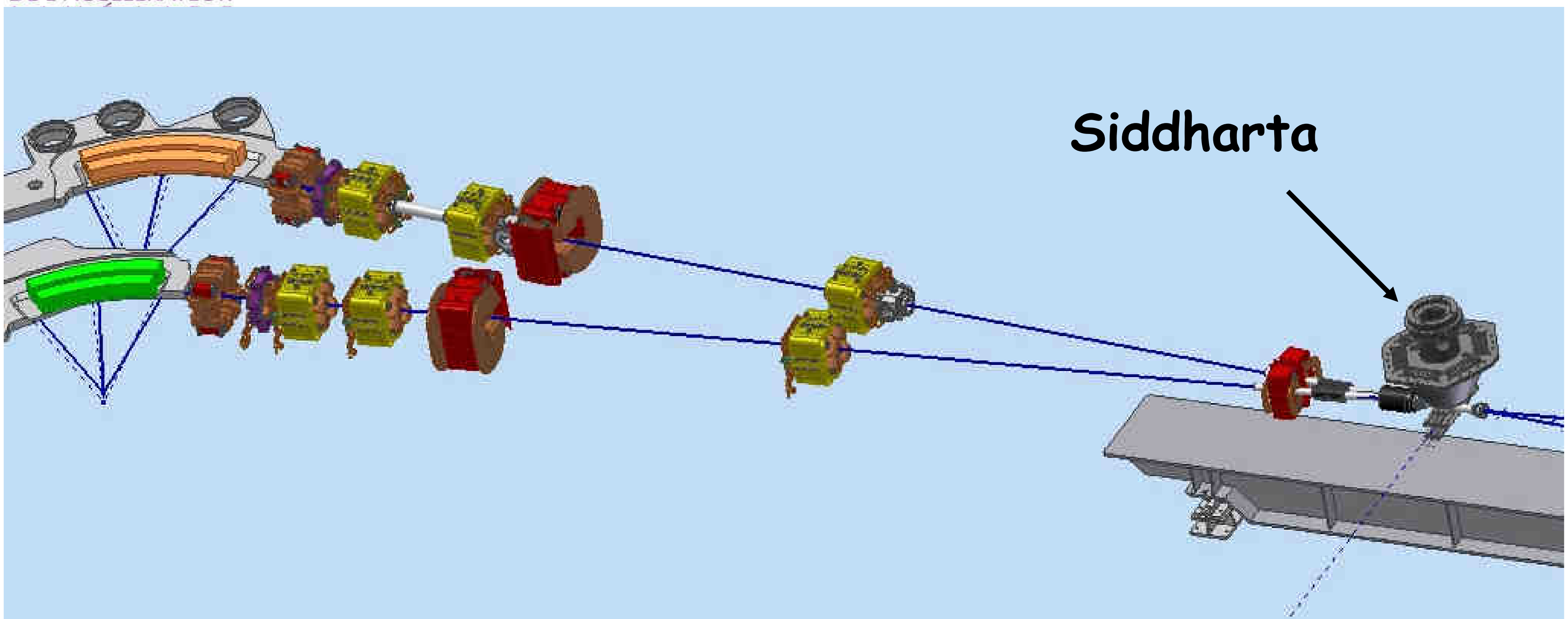
•Possibility of energy scaling to work at the τ/charm center of mass with an estimated luminosity loss of an order of magnitude.

•But 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)	~ 20 nm (~80μm)	1,6 nm (~6μm)
y/x coupling (sigma y)	0,5-1 % (~6μm)	0.25 % (~2μm)	0,25 % (0,035μm)
Bunch length	10 mm	6 mm	6 mm
Tau l/t	16/32 msec	16/32 msec	16/32 msec
ζy	0.07	0.1	0.16
L	1.2 10^{34}	1.7 10^{34}	1 10^{36}

Where to build it? Possible site: Tor Vergata University close to the Frascati Lab

DAFNE test



View of the modified IR1 region
Similar modifications will be made in the IR2,
without the low-beta insertion
In addition in IR2 the two lines will be Vertically Separated

Results

- Sextupoles on and off
- Effect on beam blow up evident
- 2 sext on => same luminosity with ~ 6 times less current
- 1 sext on => beam blow up
- 1 sext on + 1 beam on => no effect

- Crab waist is working!!!!!!!

SuperB & LAL

- At present we participate in Dafne in the luminometry and in the luminosity feedback
- If crab waist ok, and SuperB $ ok we
- are surely interested in have a strong
- Participation in designing and operating the machine.
- Possible fields : Positron source, polarization transport, beam-beam interaction & background etc etc…..

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Conclusion: as far as the accelerator physics is concerned this is an impressive idea and an extremely exciting machine.

This talk has widely profited from the help and material provided by P.Raimondi, M.Biagini and S.Guiducci.

- Thanks for your attention

- Back-up Transparencies

ILC & SuperB Synergies

- From ILC effort (ATF): It is possible to collide nanometric beam at the interaction point. The SuperB project is based on this assumption since the main gain in luminosity is given by the small betay function at the IP!!!!!
- All the R&D carried out in the ILC framework has a great impact :

1) Magnet alignments (IP stabilisation) and orbit and coupling corrections
2) Very low emittances lattices
3) Damping rings (dynamic aperture and injection stability, lifetime)
4) Final focus design & commissioning
5) Diagnostics

- The SuperB project is closely linked with the technology developed in the ILC framework.
- The polarised positron source (upgrade of SuperB)
  could be an incredible test for the ILC one (1/100 intensity).

The SuperB is an ILC without LINAC !!!!!!!!!!

Reoptimization of the ring parameters in different studies: it is possible to have a L=10^{36} machine whose parameters are similar to the ones of present factories. In this analysis the re-use of the PEP hardware was taken into account. Furthermore....

- Possible to increase bunch length: 6mm => 7mm
- Possible to increase 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**

Rough cost estimate

- Rings rebuilt by re-using about 90% of Pep, (250) add 90 Meuro
- Ring tunnel and collider hall 50 Meuro
- Injector system 100 Meuro
- Conventional facilities 50 Meuro
- Total about 290 Meuro

(J.Seeman)

Polarisation & Sources

- Electron beam is polarised
- Positron beam could be polarised :

  At the same luminosity the event rate is proportional to the effective polarisation. Positron polarisation => same physics, reduced luminosity or more physics, same luminosity

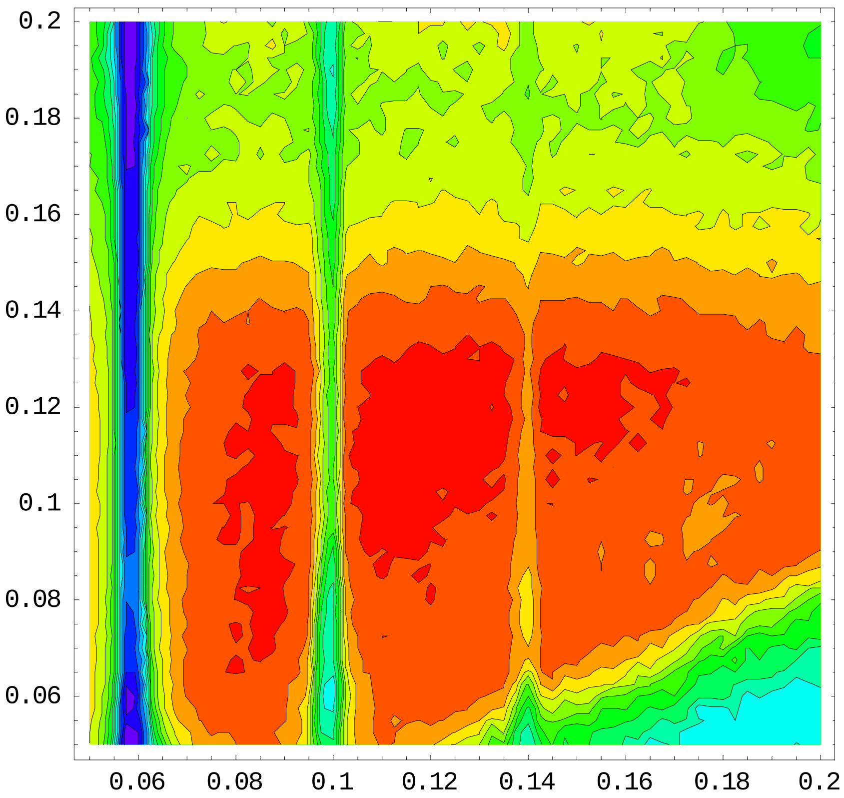
Possibility to implement (as un upgrade) a Compton based polarised source (strong correlation with the ILC). The average required flux is ~2 10^{12} e^{+}/sec.

Taking into account the present ILC R&D, with a set of Fabry Perot cavities at G=10^4, 200W/30-50 MHz pump lasers and an impinging electron 1.5 nC bunch = > less than 10^6/sec injection needed

This could be an amazing test facility for the ILC solution and a first attempt at having an extremely high brightness gamma factory.

What if we add an interaction point ?
Luminosity Tune Scan

Qy 1 IP

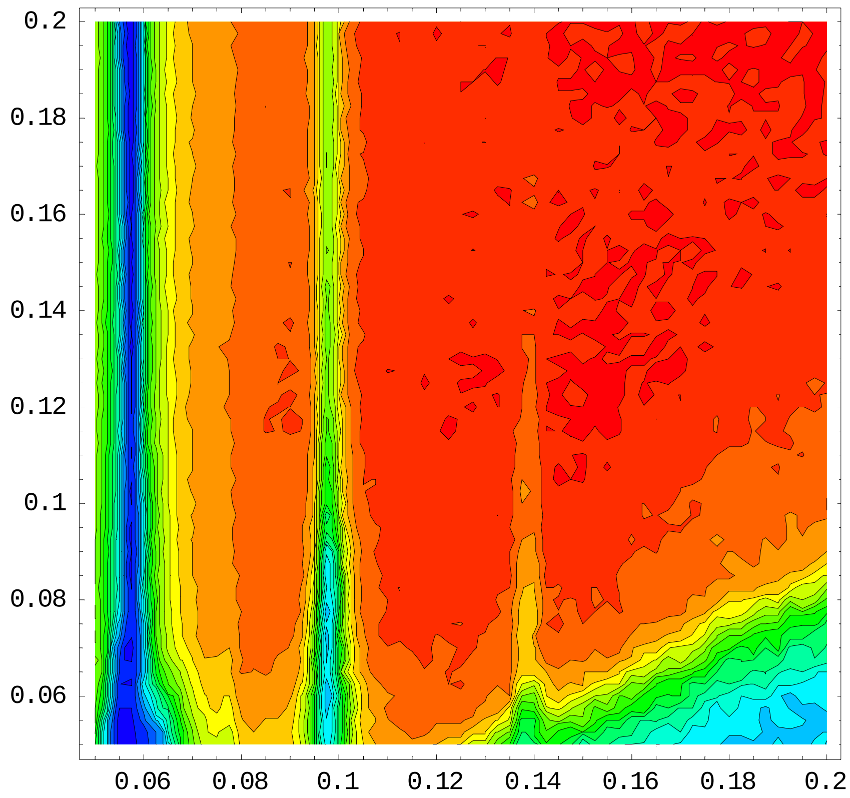


L_{min} = 3.95 x 10^{34} $cm^{-2}s^{-1}$

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

Qx

Qy 2 IPs



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

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

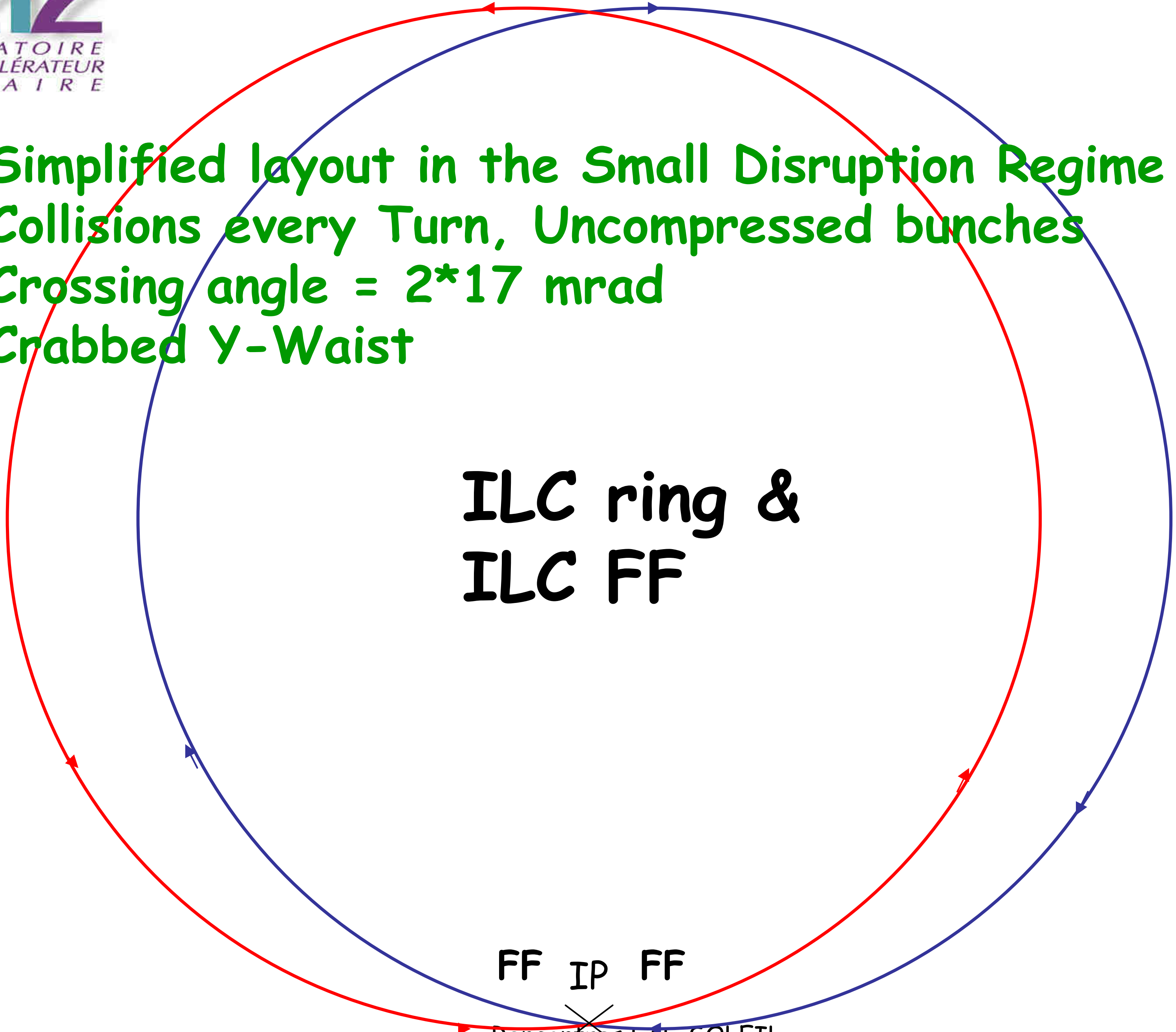
Qx

Simplified layout in the Small Disruption Regime

Collisions every Turn, Uncompressed bunches

Crossing angle = 2*17 mrad

Crabbed Y-Waist



Power budget with these schemes

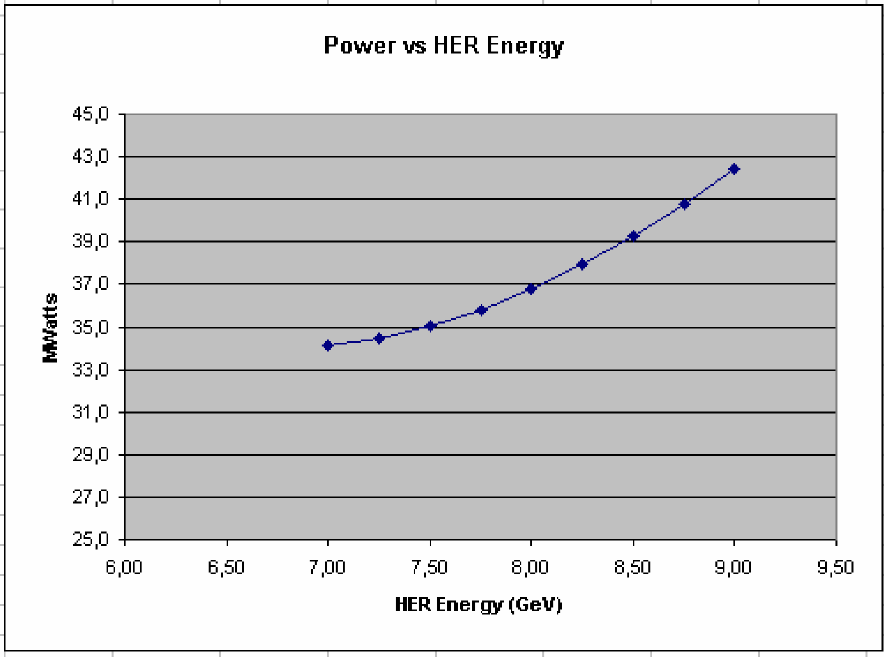
- 4 x 7 GeV
- 10000 bunches at 10^{11} = 6A(e+)/12A(e-)
- Damping ring RFfreq= 500 MHz at 0.6 m spacing
- SC linac for 5 GeV e- with low emittance photo-gun
- 5.5GeV SC linac, frequency = 1300 MHz
- Damping ring for 2 GeV positrons with wigglers
  - 3000 m damping ring at 3.7 msec damping
  - 3000 m 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

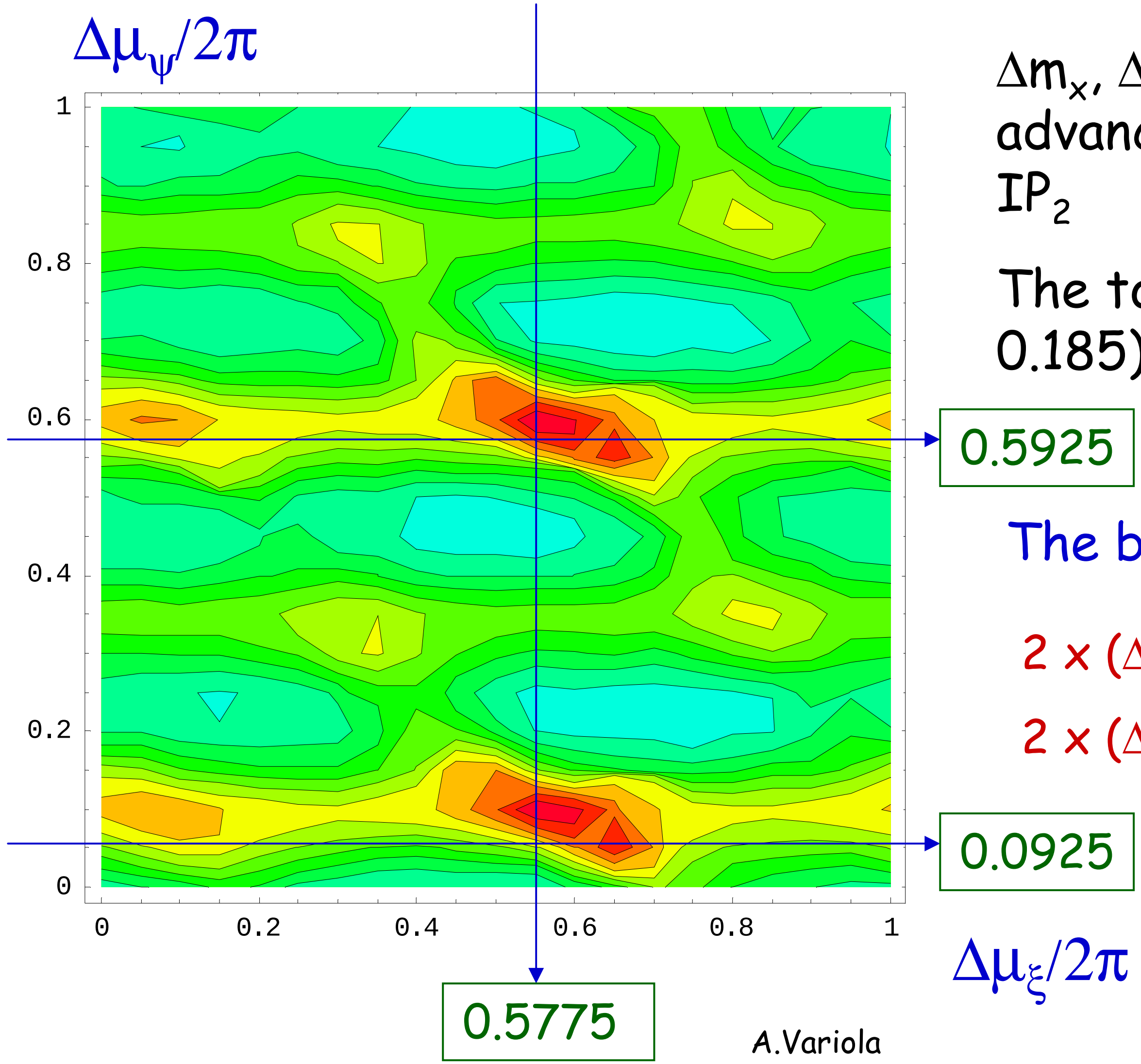
HER Energy GeV	LER Energy GeV	HER Loss per turn MeV	LER loss per turn MeV	HER Current Amp	LER Current Amp	HER RF power MW	LER RF power MW	HER magne power MW	LER magne power MW	Cooling H2O Power MW	Control power MW	Injector Power MW	Lights and HVAC MW	Total power MW
7,00	3,99	3,30	1,89	1,30	2,28	8,6	8,6	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



Double Phase Advance Scan



Δm_x, Δm_y are phase advances between IP_1 and IP_2

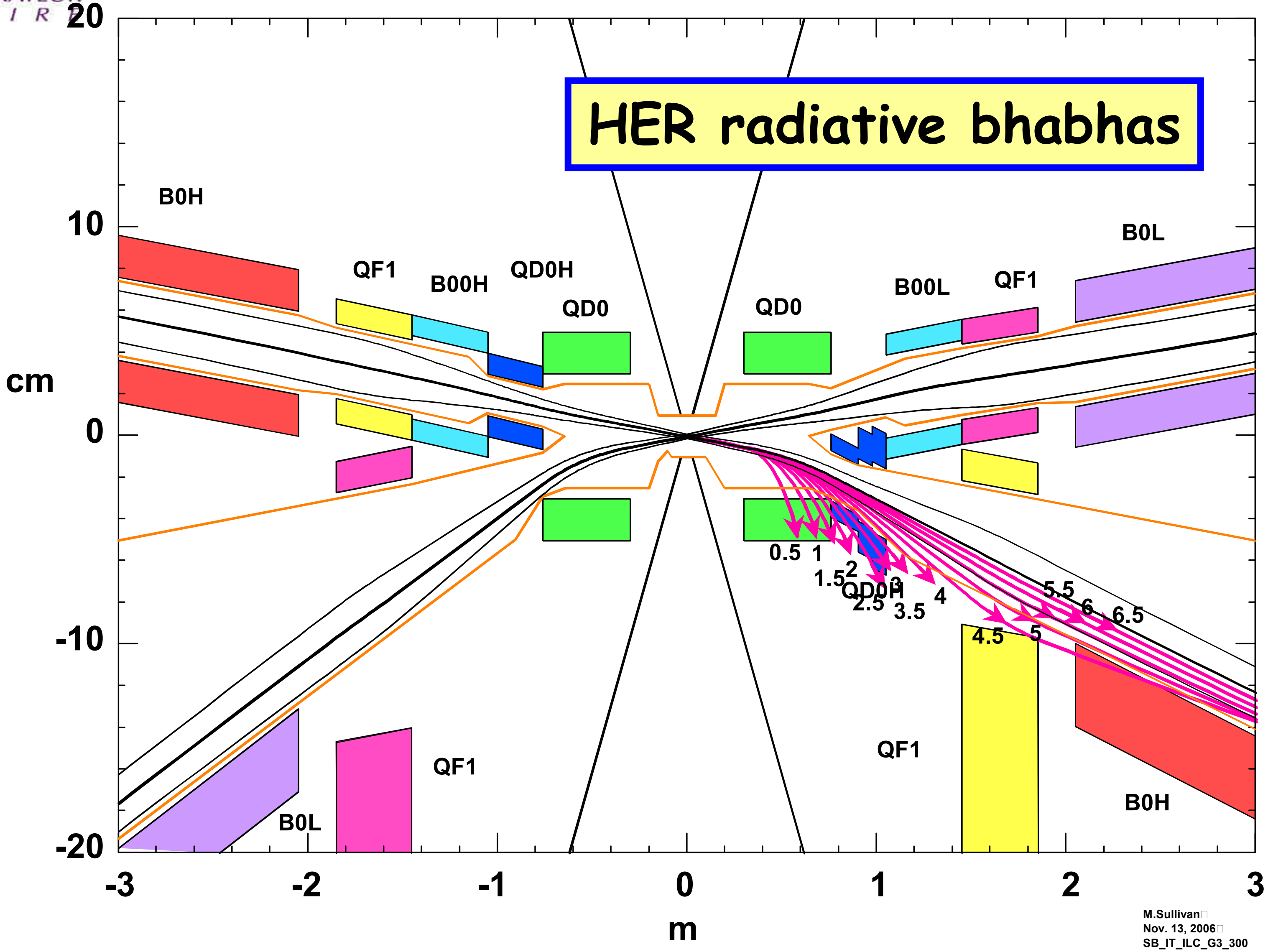
The total tune (0.155, 0.185)

The best choice is symmetric

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

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

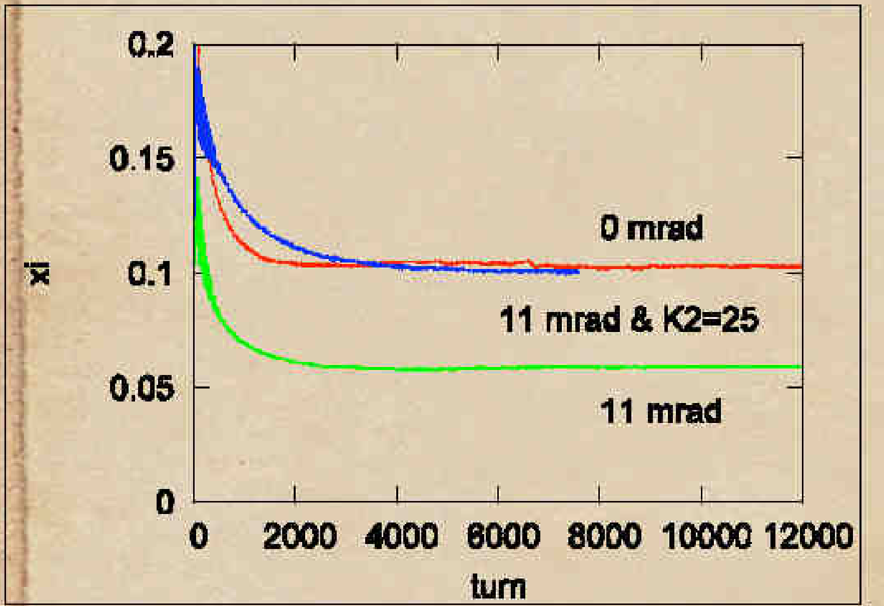
SuperB Interaction Region



- 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...)

- 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
D. Shatilov, I.A.Koop, BINP

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.

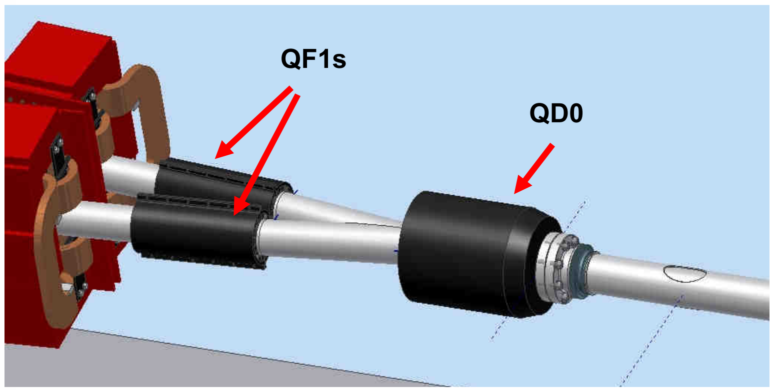
This paper will review the principle of the new collision scheme and present a summary of the beam-beam studies performed in order to estimate the luminosity gain. Moreover a description of the lattice and hardware modifications needed for its implementation will be given.

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



Parameters used in simulations

Horizontal beta @ IP	0.2 m (1.7 m)
Vertical beta @ IP	0.65 cm (1.7 cm)
Horizontal tune	5.057
Vertical tune	5.097
Horizontal emittance	0.2 mm.mrad (0.3)
Coupling	0.5%
Bunch length	20 mm (32mm,24mm)
Total beam current	2 A (2.4A, 1.4A)
Number of bunches	110 (110)
Total crossing angle	50 mrad (25 mrad)
Horizontal beam-beam tune shift	0.011
Vertical beam-beam tune shift	0.080

$L \Rightarrow 2.2 \times 10^{33}\ cm^{-2}\ s^{-1}$