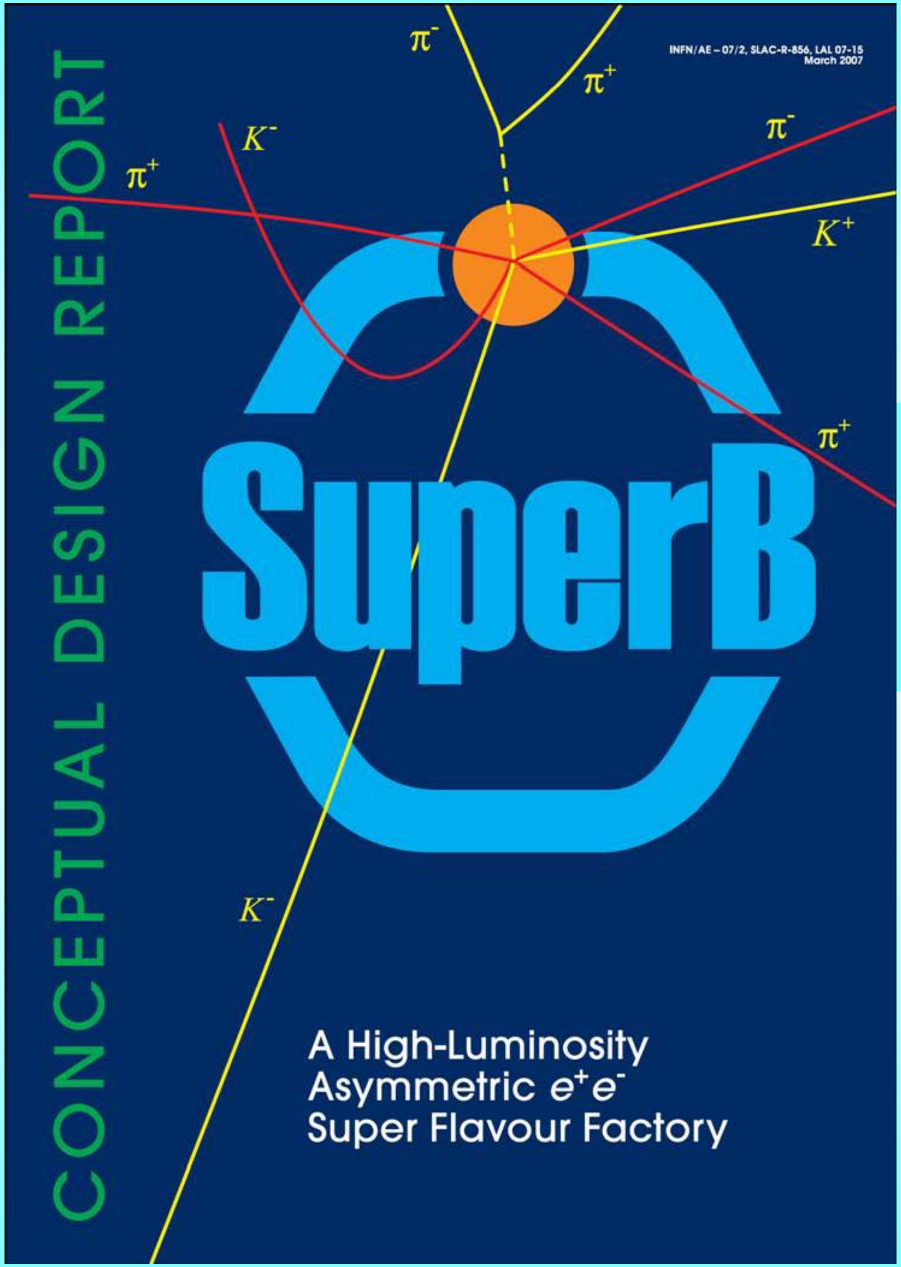


-Factory

M. Biagini, LNF-INFN

on behalf of the SuperB Team

CARE-HHH

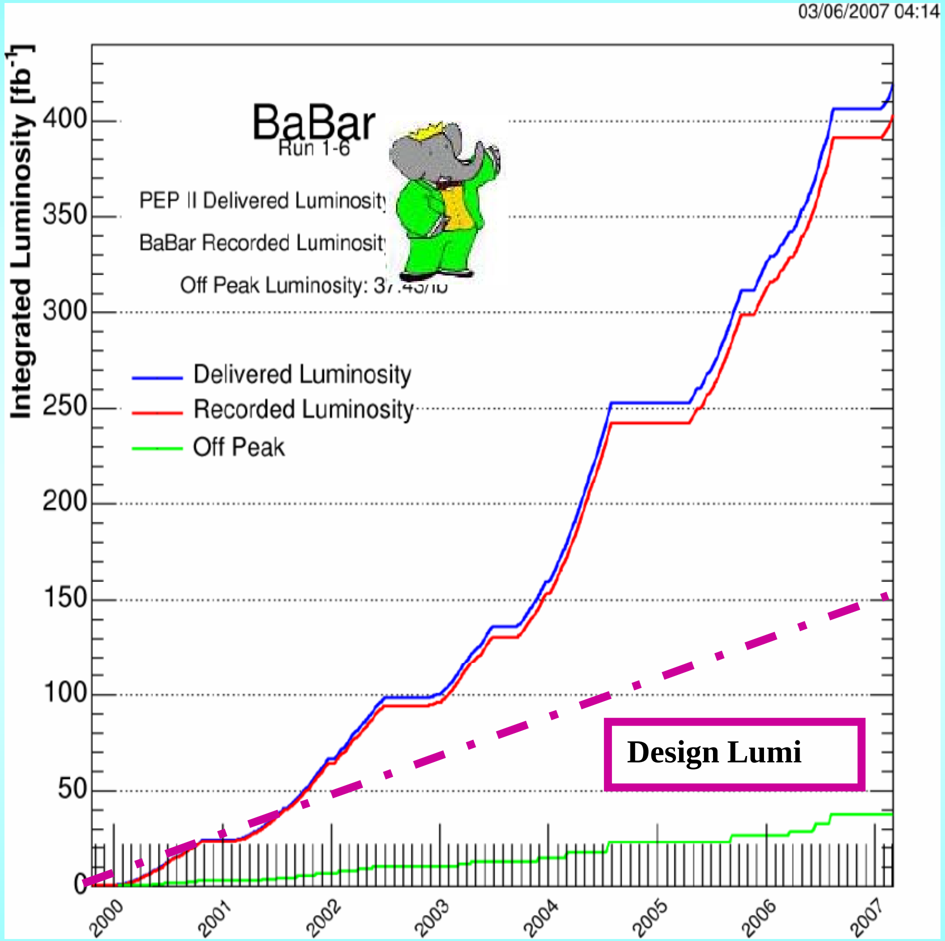
Frascati, Nov. 7th, 2007

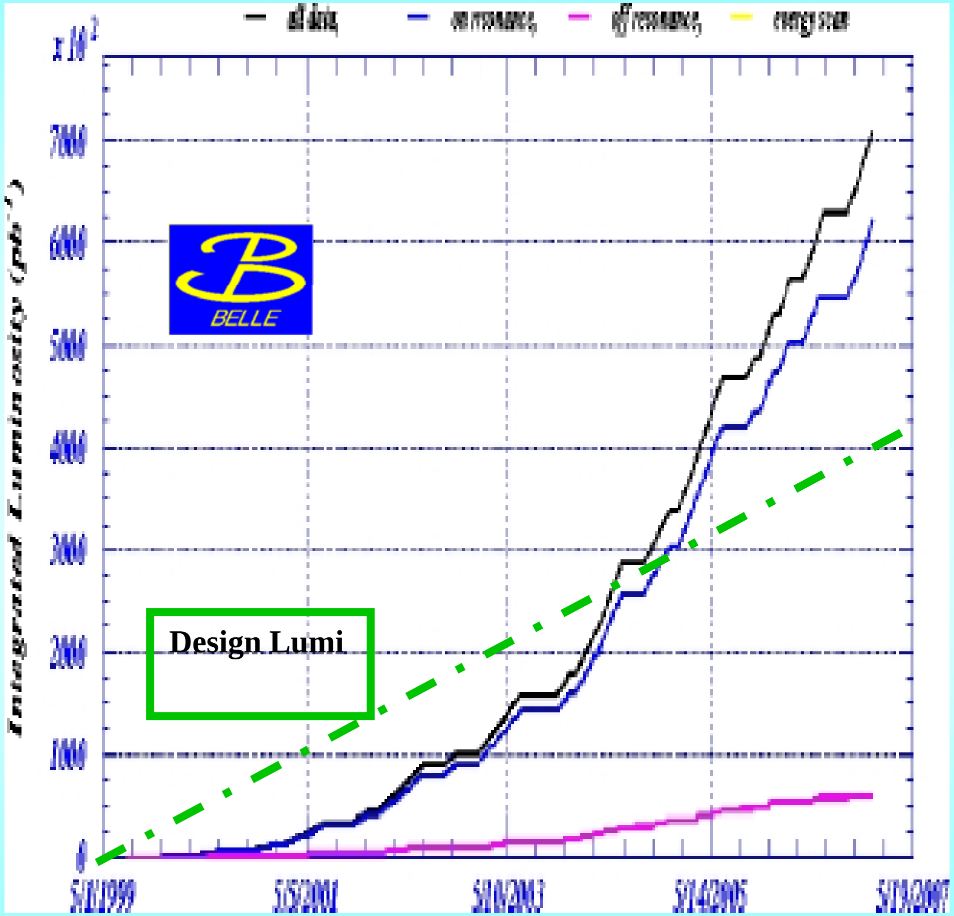
Why a SuperB-Factory?

- B-factories (PEP-II and KEKB) have exceeded their design goals, both in peak and integrated luminosity
- High operation reliability and performances represent a success for all factories (at lower energy too: DAΦNE)
- Upgrade of an order of magnitude and more in Luminosity is highly desirable for investigation on Physics beyond the Standard Model

Goal is $L \geq 1 \times 10^{36}$ cm^{-2} s^{-1}

Extraordinary success of B-Factories





PEP-II (BaBar), 400 fb^{-1}

KEKB (Belle), 710 fb^{-1}

Total > 1.1 ab^{-1}

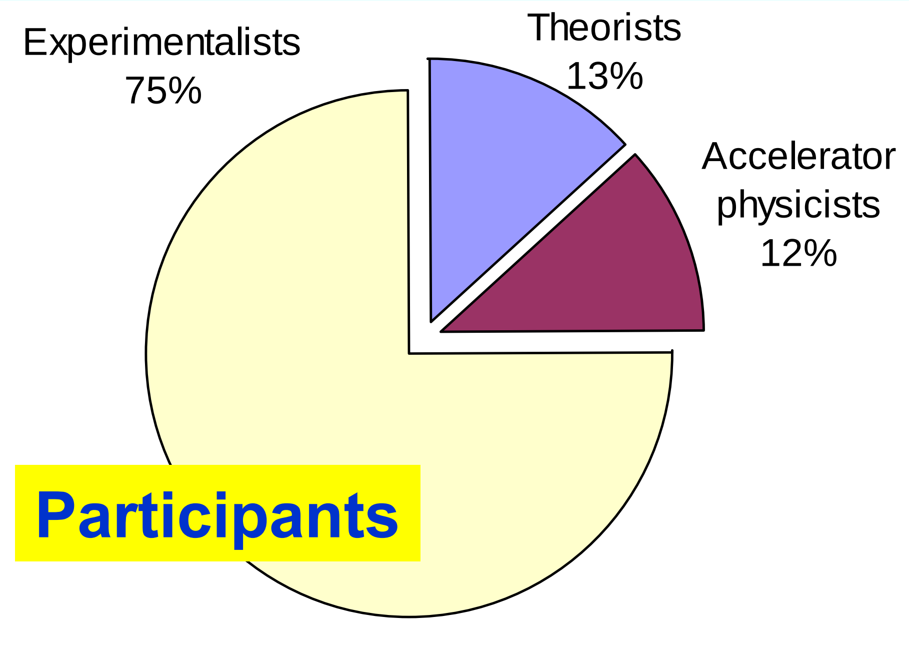
The SuperB Process

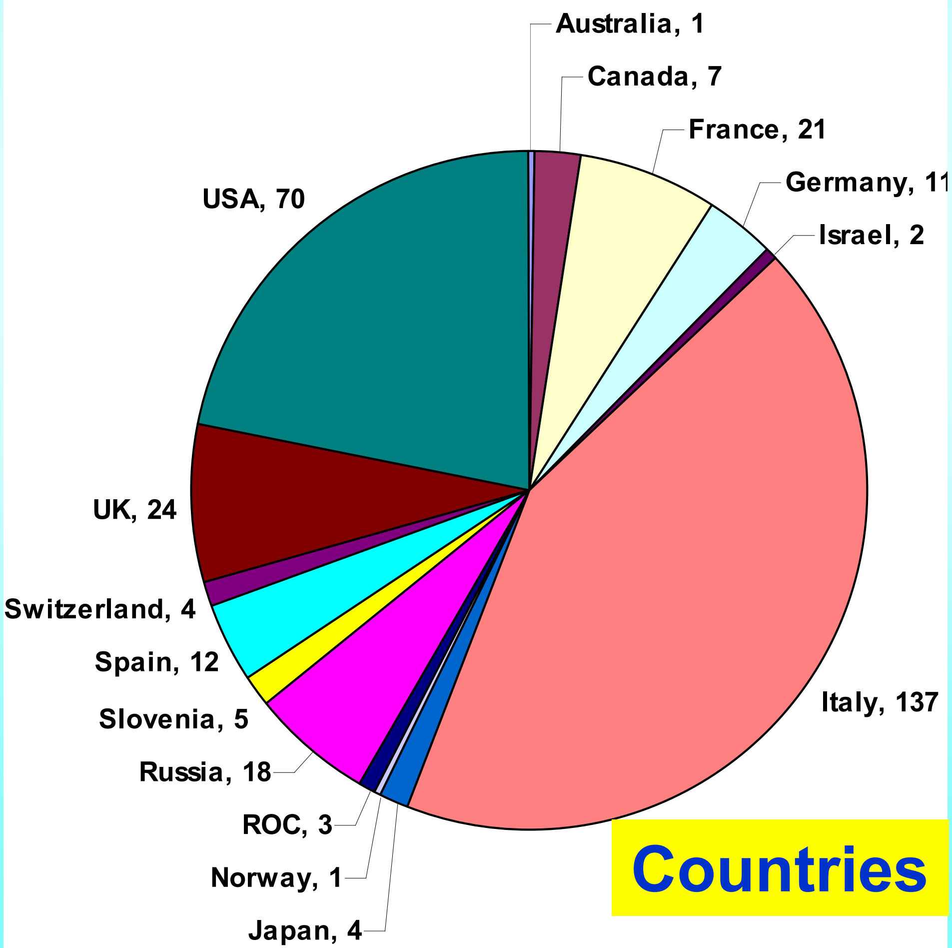
- International SuperB Study Group on:
  - Physics case, Machine, Detector
- International steering committee established with members from:
  - Canada, France, Germany, Italy, Russia, Spain, UK, USA
  - Close collaboration with Japan, although not formalized
- Regular workshops
  - Five workshops held at SLAC, Paris, Frascati
  - SuperB Meeting at Daresbury
  - 2 accelerator “retreats” at SLAC (2006, 2007)
- Conceptual Design Report
  - Published in March 2007
  - Describes Physics case, Accelerator, Detector, including costs
  - International Review Committee: 12-13 November 2007 at LNF
- More informations: www.pi.infn.it/SuperB

The SuperB Effort

"Conceptual Design Report" (450 pp), March 2007
INFN/AE-07/2,SLAC-R-856, LAL 07-15
www.pi.infn.it/SuperB/?q=CDR

- 320 CDR signatures
- 85 Institutions
- 239 Experimentalists





A new idea for L increase

P. Raimondi's: to focus more the beams at IP and have a "large" crossing angle → large Piwinski angle

- Ultra-low emittance (ILC-DR like)
- Very small β^* at IP
- Large crossing angle
- "Crab Waist" scheme

- Small collision area
- Lower β is possible
- NO parasitic crossings
- NO synchro-betatron resonances due to crossing angle

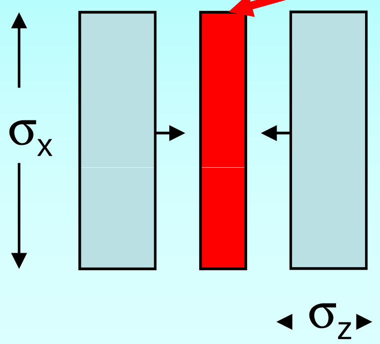
Tested at DAΦNE from this month !!!

Large crossing angle, small x-size

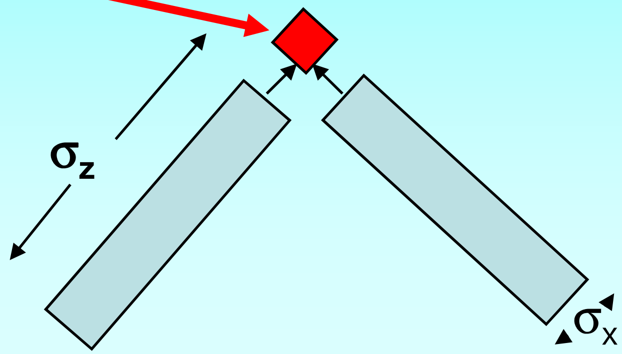
**1) Head-on,
Short bunches**

Overlap region

**2) Large crossing angle,
long bunches**



(1) and (2) have same Luminosity, but (2) has longer bunches and smaller σ_x



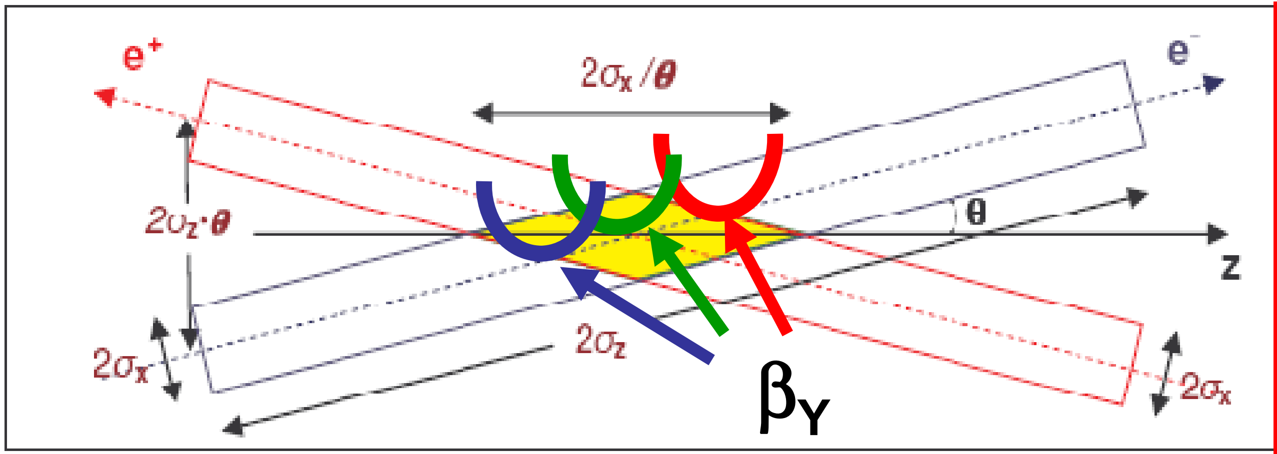
Vertical waist has to be a function of x:

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)

Large Piwinski angle:

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



y waist can be moved along z with a sextupole on both sides of IP at proper phase

"Crab Waist"

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

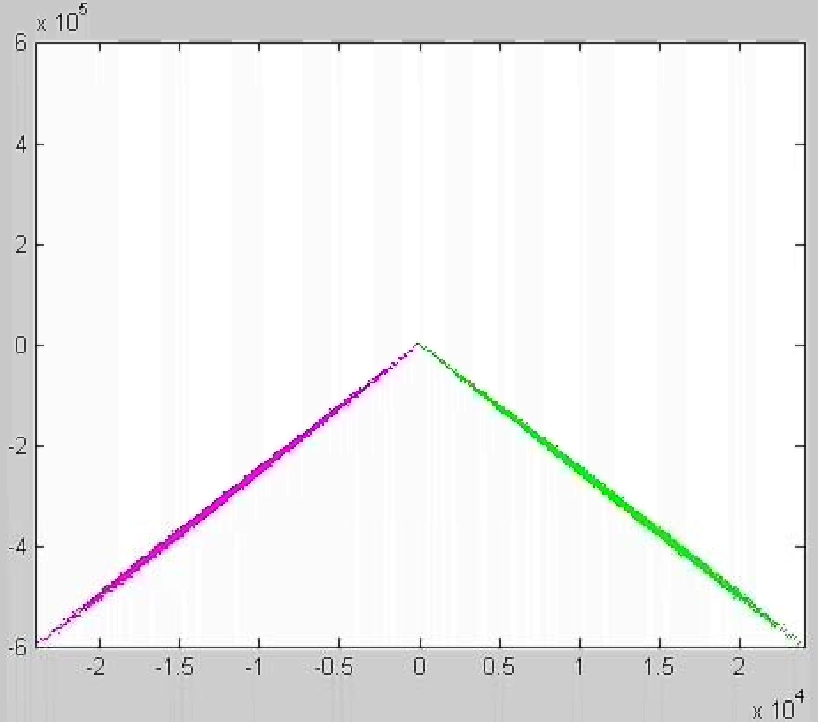
b) Suppression of X-Y betatron and synchro-betatron resonances

... and ...

- Higher luminosity with same currents and bunch length:
  - Beam instabilities are less severe
  - Manageable HOM heating
  - No coherent synchrotron radiation of short bunches
  - No excessive power consumption

- Lower beam-beam tune shifts
- Relatively easier to make small σ_x w.r.t. short σ_z
- Parasitic collisions becomes negligible due to higher crossing angle and smaller σ_x

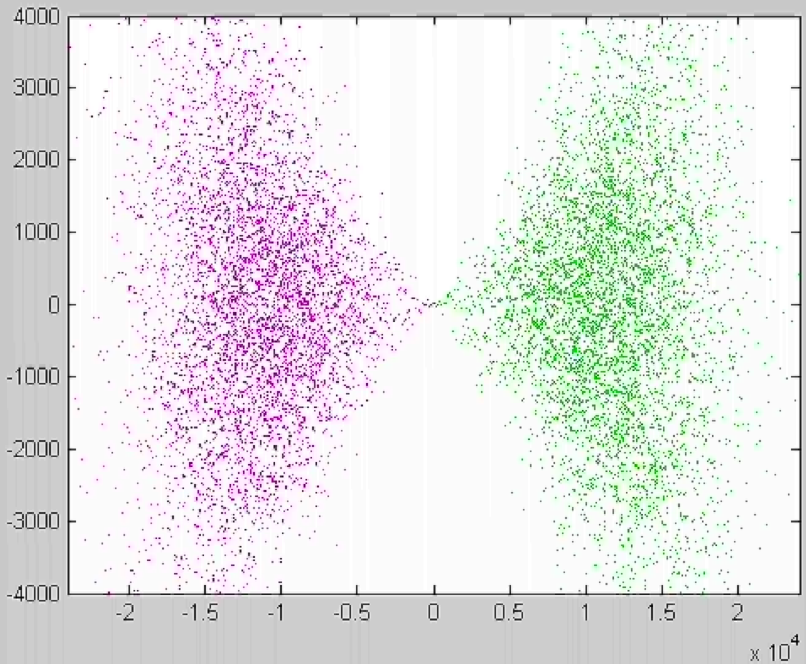
Crossing angle = 2*25mrad
Relative Emittance growth per collision about 1.5*10^{-3}, $\varepsilon_{yout}/\varepsilon_{yin}$=1.0015



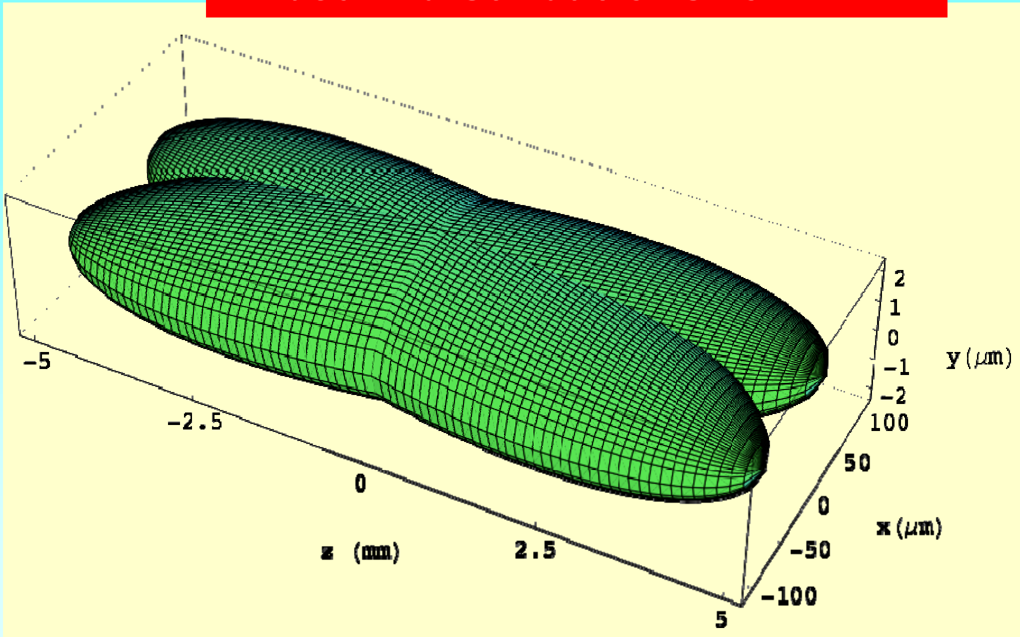
Horizontal

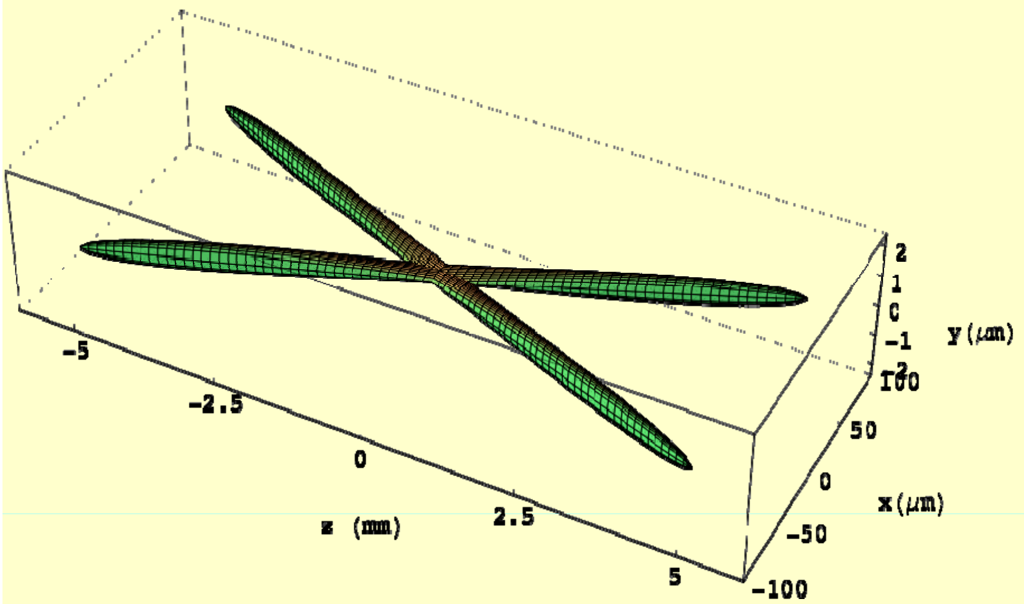
Simulation with GuineaPig by D. Schulte

Vertical



IP beam distributions for KEKB





IP beam distributions for SuperB

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 are greatly reduced

	KEKB	SuperB
I (A)	1.7	2.
β_y^* (mm)	6	0.2
β_x^* (mm)	300	39
σ_y^* (μm)	3	0.039
σ_x^* (μm)	80	6
σ_z (mm)	6	5
L ($cm^{-2}s^{-1}$)	1.7×10^{34}	$1. \times 10^{36}$

Here is Luminosity gain

Transparency condition

- Due to the large crossing angle, new conditions are possible, different from asymmetric currents, for having equal tune shifts with asymmetric energies
- LER and HER beams can have different emittances and β* and equal currents

$$\xi^+ = \xi^- \Leftrightarrow \frac{N^+}{N^-} = \frac{E^-}{E^+}$$

Present B-factories

⇔

$$\xi^+ = \xi^- \Leftrightarrow \frac{\beta_y^+}{\beta_y^-} = \frac{E^+}{E^-}$$

SuperB

$$\xi^+ = \xi^- \Leftrightarrow \frac{\beta_y^+}{\beta_y^-} = \frac{E^+}{E^-}$$

$$\Leftrightarrow$$

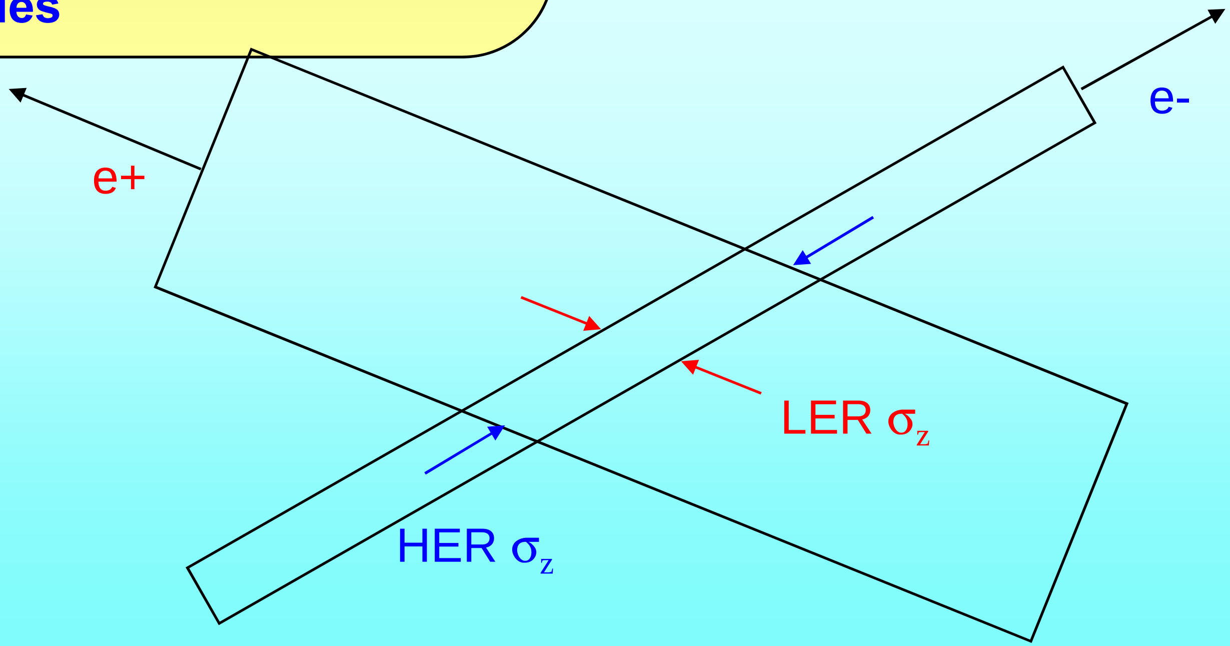
$$\sigma_y^+ = \sigma_y^- \Leftrightarrow \beta_y^+ = \frac{E^+}{E^-}\beta_y^-$$

$$\varepsilon_y^+ = \frac{E^-}{E^+}\varepsilon_y^-, \quad \varepsilon_x^+ = \frac{E^-}{E^+}\varepsilon_x^-$$

$$\sigma_x^+ = \frac{E^-}{E^+}\sigma_x^-$$

LER beam:

- **sees a shorter interaction region, (4/7 of the HER one)**
- **has a smaller β_y^*, easier to achieve in the FF w.r.t. HER**
- **has larger emittance: better for Touschek lifetime, and tolerance for LER instabilities**

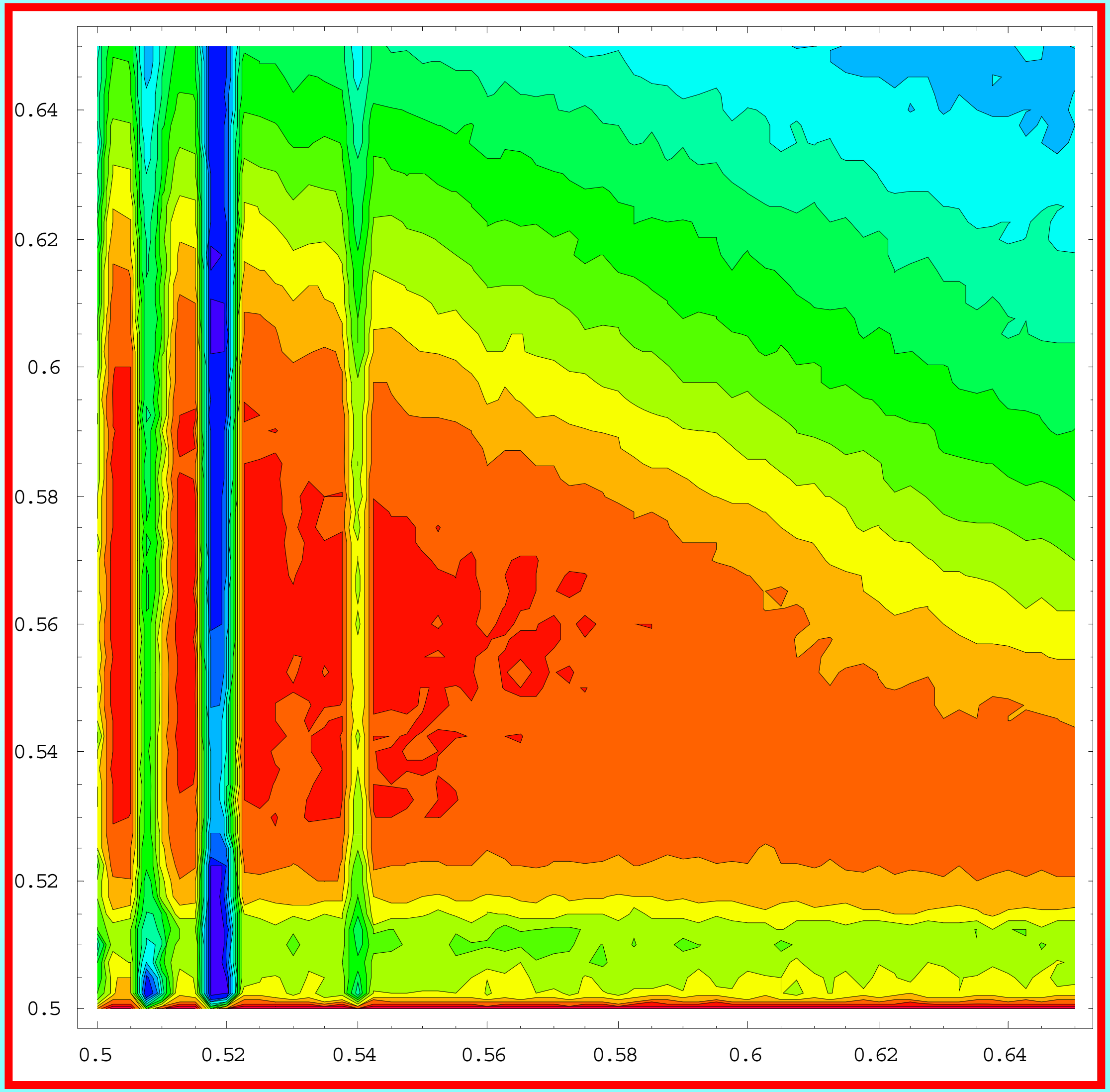


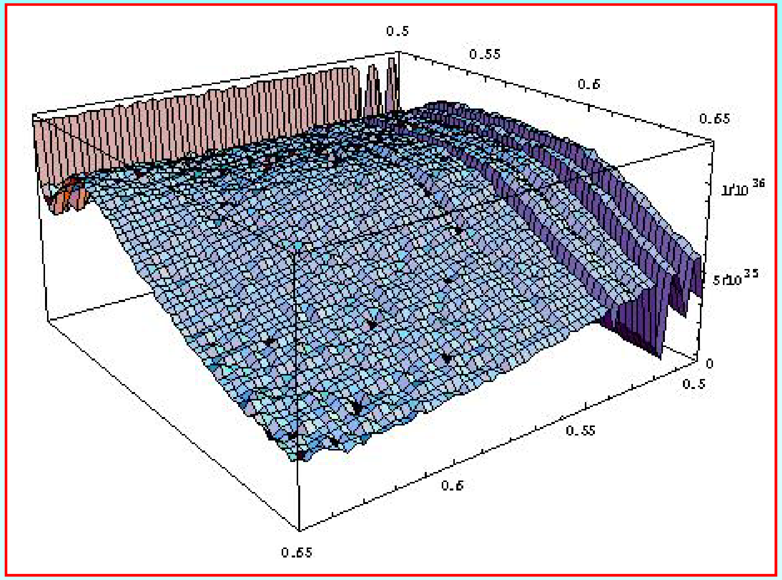
SuperB Parameters

Circumference (m)	1800.
Energy (GeV) (LER/HER)	4/7
Current (A)/beam	2.
No. bunches	1342
No. part/bunches	5.5×10^{10}
θ (rad)	2x24
ε_x (nm-rad) (LER/HER)	2.8/1.6
ε_y (pm-rad) (LER/HER)	7/4
β_y^* (mm) (LER/HER)	0.22/0.39
β_x^* (mm) (LER/HER)	35/20
σ_y^* (μm) (LER/HER)	0.039
σ_x^* (μm) (LER/HER)	10/6
σ_z (mm)	5
RF Power (MW)	17
L ($cm^{-2}s^{-1}$)	**$1. \times 10^{36}$**

Luminosity vs tunes scan

P. Raimondi, D. Shatilov, M. Zobov



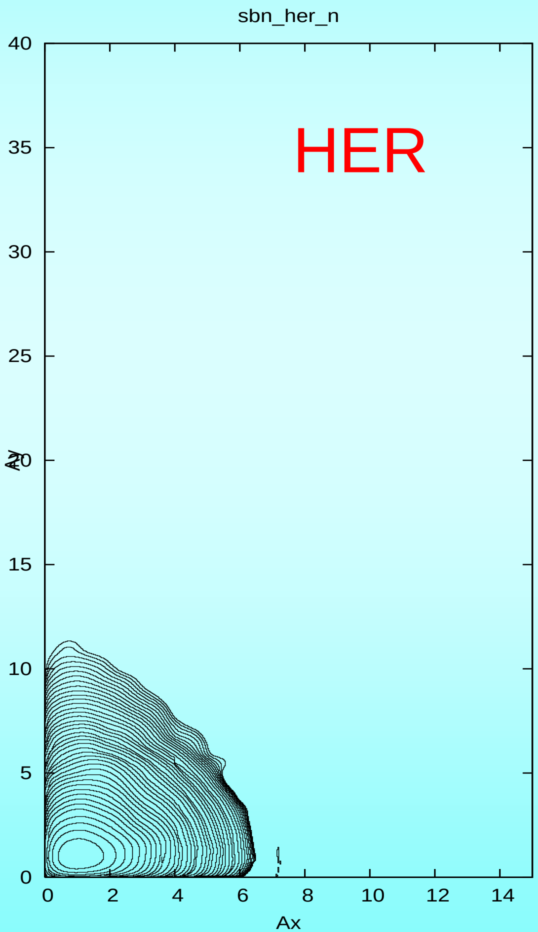


- Individual contours differ by 10% in luminosity
- Design luminosity can be obtained over a wide tune area

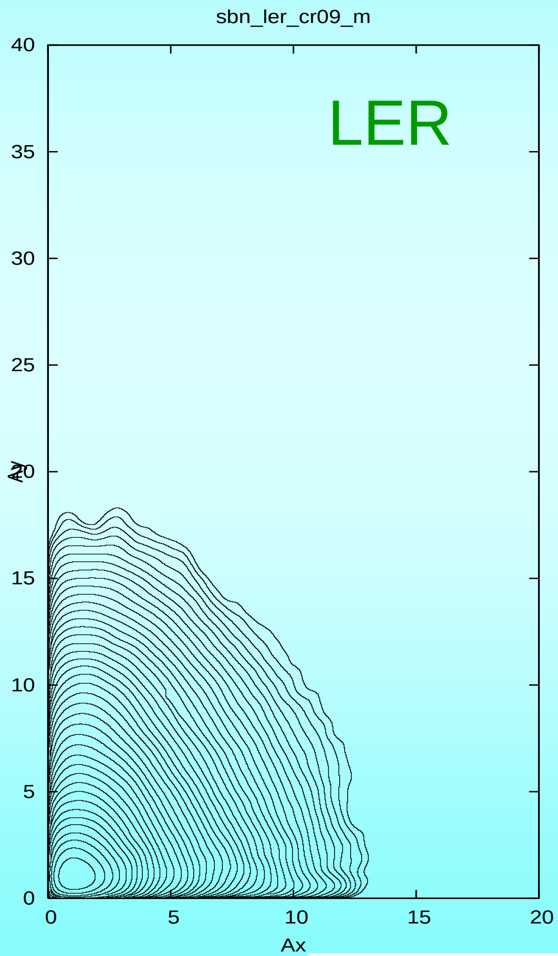
(horizontal axis - ν_x from 0.5 to 0.65; vertical axis – ν_y from 0.5 to 0.65)

Beam-beam blow up
(weak-strong simulations)

Crab=0.8Geom_Crab



Crab=0.9Geom_Crab



No blow up is seen for HER, 1-3% for LER, but some more optimization is still possible: tunes, crabbing etc...

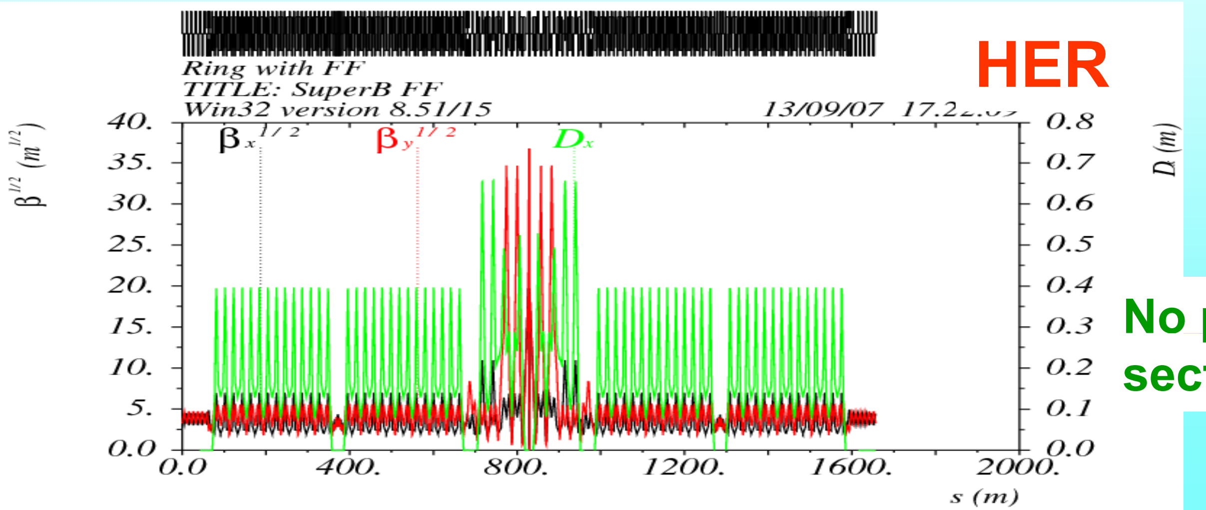
$L=10^{36}\ cm^{-2}\ s^{-1}$

D. Shatilov

The Rings

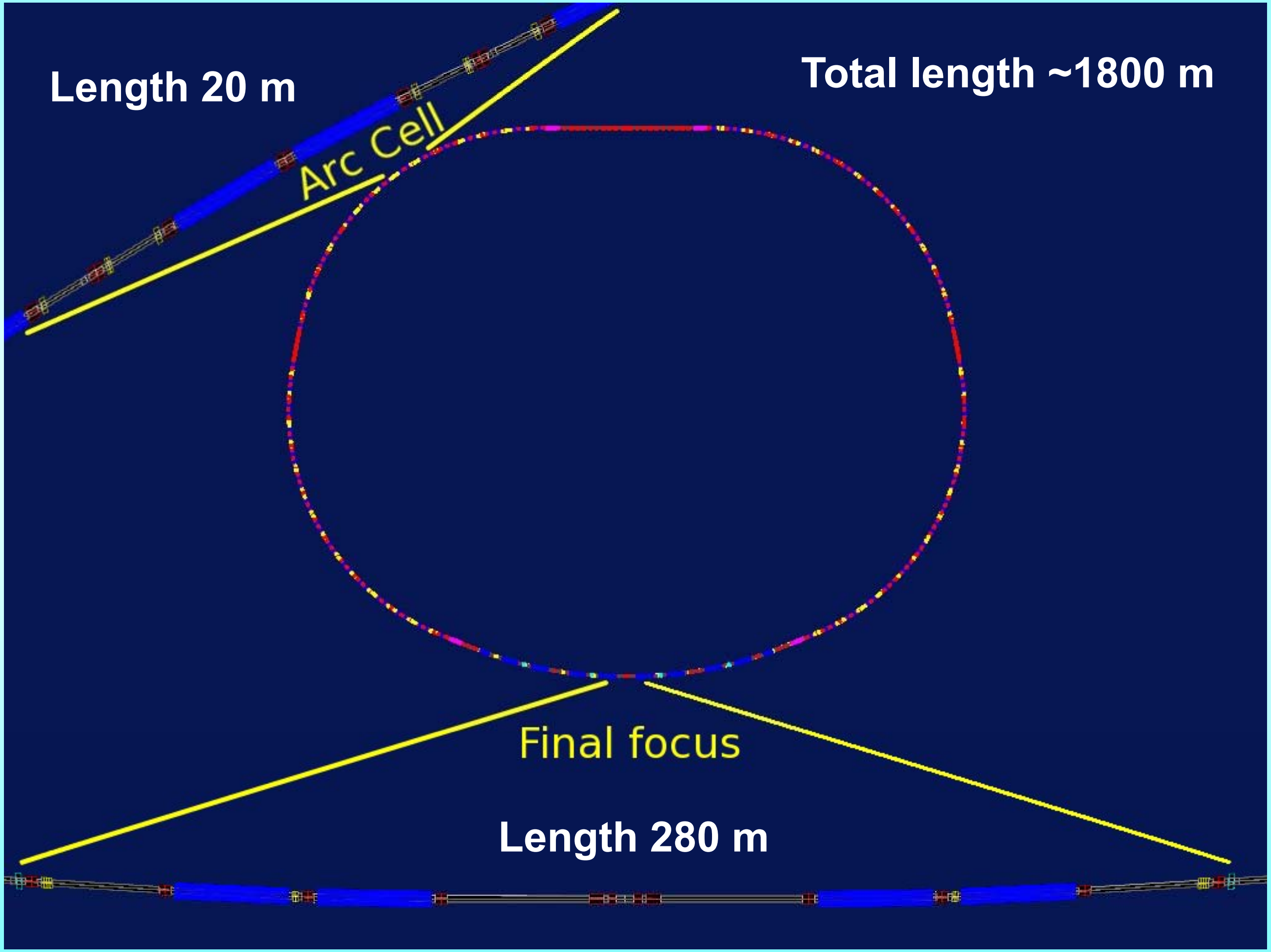
- Two rings @ 4 and 7 GeV with one Interaction Region where Super-BaBar detector will be installed
- Ring characteristics similar to ILC Damping Rings → synergy
- Polarization of electrons is desirable

- "Final Focus" section FFTB/ILC-like
- Design based on recycling all PEP-II hardware, magnets, and RF system
- Total power: 17 MW, lower than PEP-II
- No wigglers for Phase I
- Circumference ~1800 m (with polarization section)



No polarization section here

Layout (1)



Length 20 m
Arc Cell
Total length ~1800 m
Final focus
Length 280 m

Layout (2)

- HER: ε_x = 1.6 nm, τ_s = 20 msec
- LER: ε_x = 2.8 nm, τ_s = 20 msec
- HER cells host 2 x 5.4 m long PEP-II dipoles
- LER cells host 4 x 0.45 m long PEP-II dipoles
- Final Focus sections have 18 HER-type bends
- 2 straights between cells can host wigglers if needed
- 2 new sections, about 200 m long, will be added for the polarization scheme (not included in present lattice)
- Total length ~ 1800 m

Arcs Lattice

- Alternating sequence of two different cells: $\mu_x = \pi$ cell, that provides the best dynamic aperture, and $\mu_x = 0.72$ cell with much smaller intrinsic emittance which provides phase slippage for sextupoles pairs, so that one arc corrects all phases of chromaticity. Then:

  - chromatic function $W_x < 20$ everywhere

  - β and α variation with particle momentum are close to zero

  - larger dynamic aperture

- Cell #1: L=20 m, $\mu_x = 0.72$, $\mu_y = 0.27$
- Cell #2: L=21 m, $\mu_x = 0.5$, $\mu_y = 0.2$
- New cell layout (double-cell wrt CDR lattice):

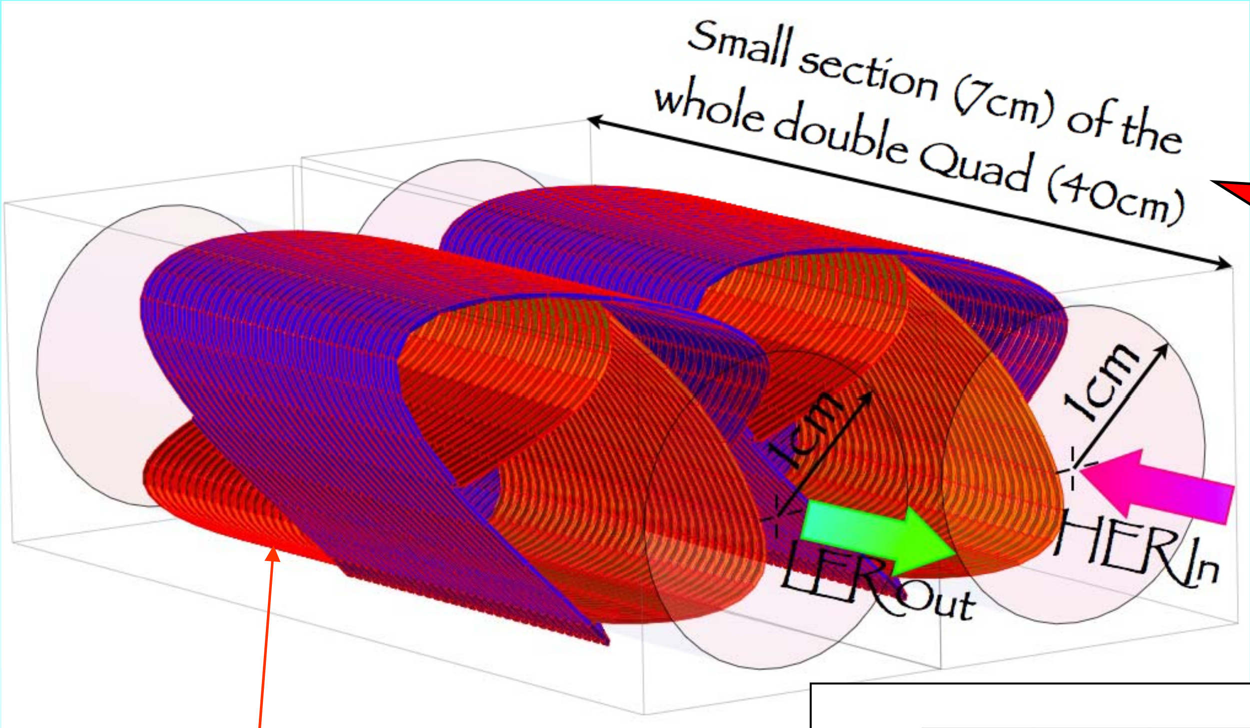
  QF/2-QD-B-B-QF-B-B-QD-QF/2

Final Focus

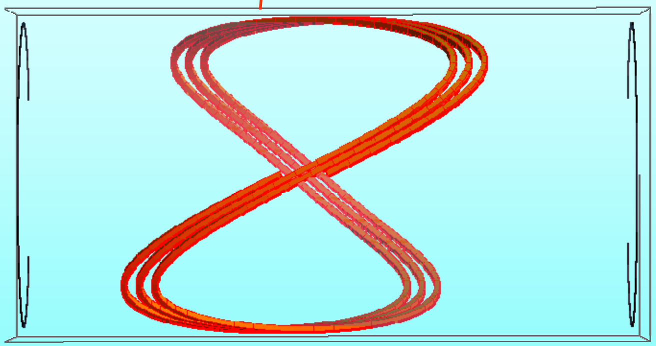
- Crossing angle to 2*25 mrad, L*=0.4 m
- Local chromaticity correction
- Horizontal beam separation at QD0: 2 cm, about 180 σ_x
- A possible solution with a septum QD0 is being studied:

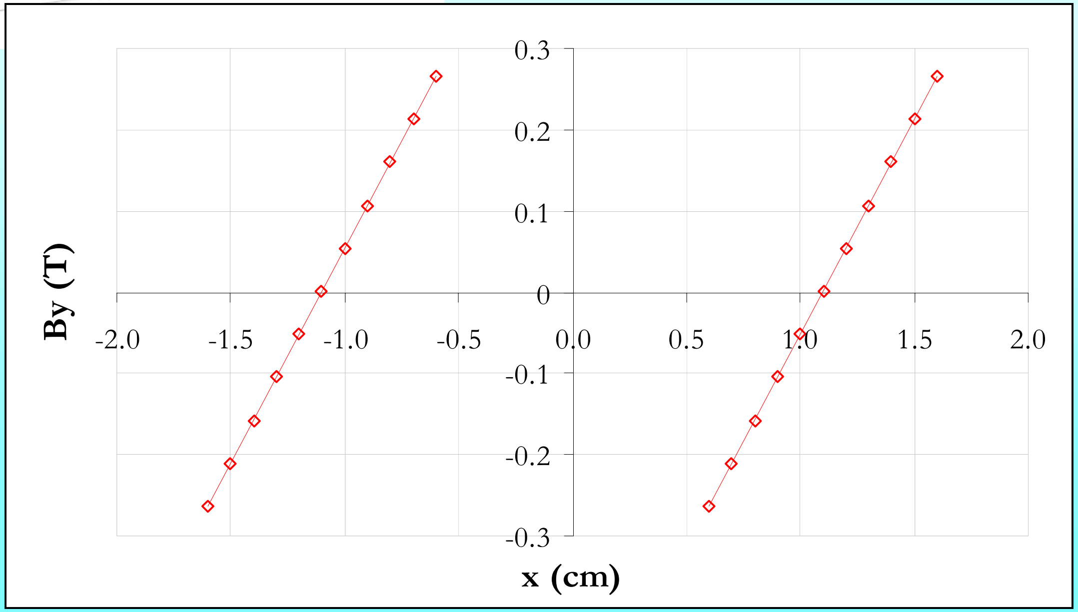
a Super Conducting array of wires placed in the middle of QD0 to shift the magnetic center, opposite for the 2 beams, to get no net steering from QD0 (Bettoni, Paoloni design). Overall thickness ~ 8mm, leaving about 60 σ_x of beam stay-clear

Example of QD0 design

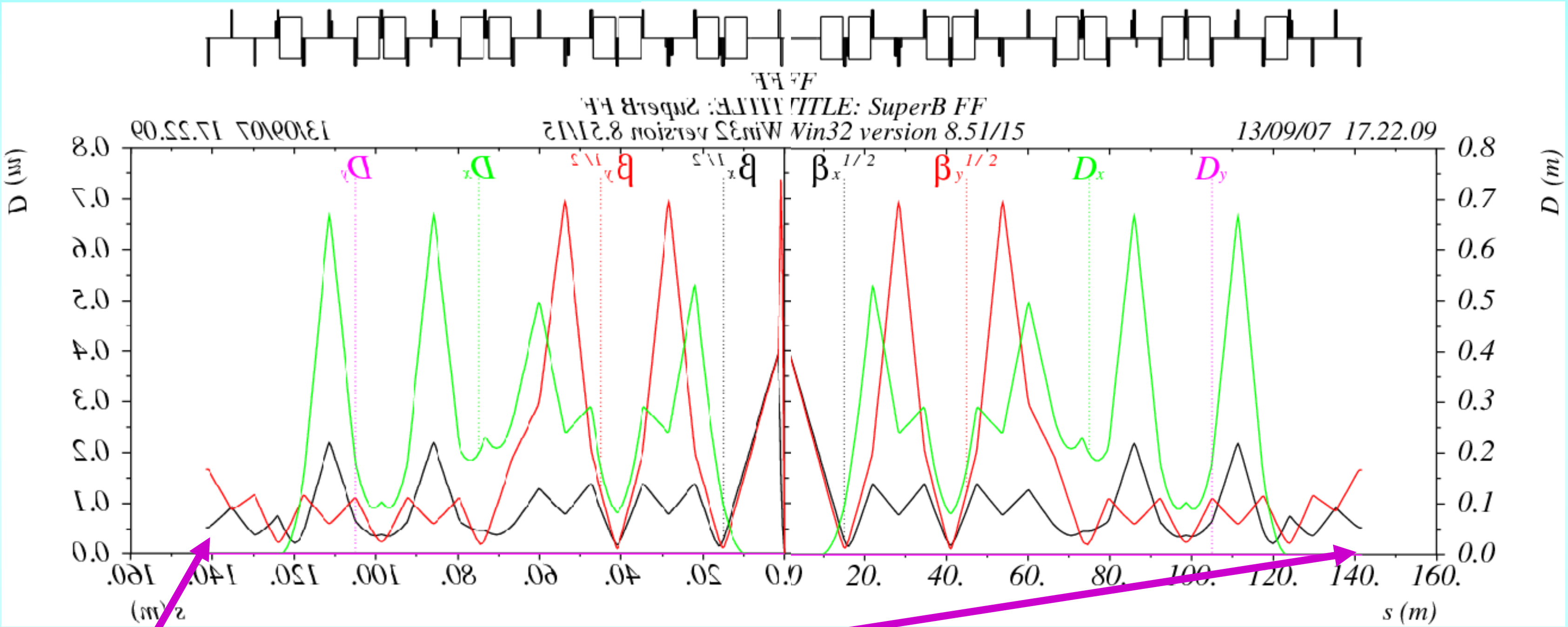


S. Bettoni, E. Paoloni
Work in progress





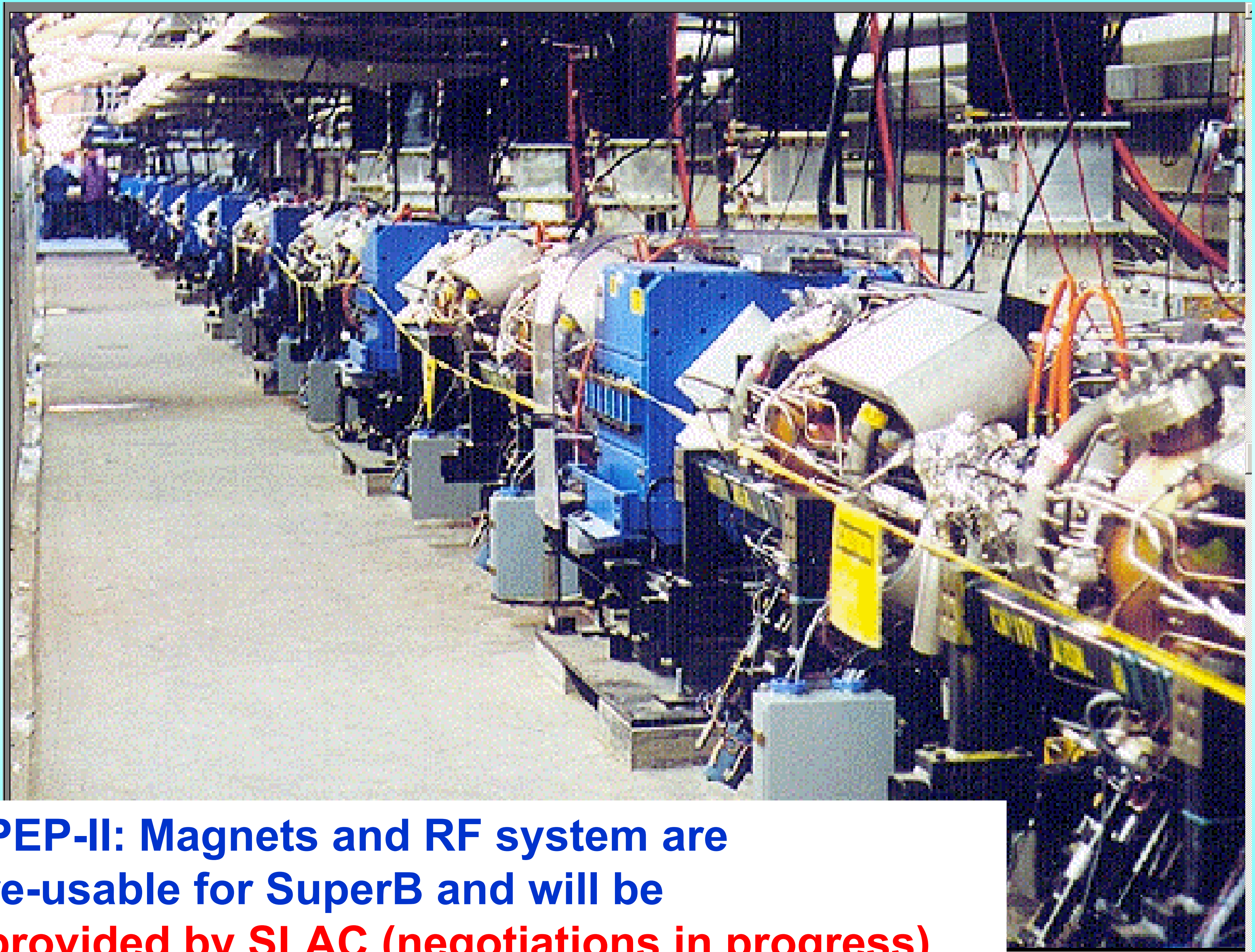
Final Focus



Crab sextupoles

LER: β_x^* = 35 mm, β_y^* = 220 μ

HER: β_x^* = 20 mm, β_y^* = 390 μ



PEP-II: Magnets and RF system are re-usable for SuperB and will be provided by SLAC (negotiations in progress)

Conclusions (1)

New large Piwinski angle scheme will allow for peak luminosity ≥ **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

- Use of "*crab waist*" sextupoles will add a bonus for suppression of dangerous resonances
- Test at DAΦNE will help in discovering possible issues

Conclusions (2)

- There is a growing international interest and participation
- R&D is proceeding on various items

- A CDR is ready for review by the International Review Committee
- A TDR will be ready by 2010
- Next issues are: **site, money**