DAFNE upgrades

C. Biscari

15 novembre 2002

present	next future
• L_{max} = 0.8 10^{32} cm^{-2} sec^{-1}	1.5 10^{32}
• L_{int}/day = 4.5 $pbarn^{-1}$	8
• I^+ = 1.2 A	2
• I^- = 0.9, 1.4 A	2
• N bunches = 50 , 100	100

Upgrades – future future

- **Higher E** $\sim 10^{31}$ @ 1 + 1 GeV
- **Higher L** $> 10^{33}$ @ 510 + 510 MeV
- **BOTH with the same machine ?**

Higher E $\sim 10^{31}$ @ 1 + 1 GeV

Rinaldo Baldini will give us a talk (december 2002) on Fenice2 and other measurements at this energy

Riunione alla SIF (fine settembre 02)
Bini, Zallo, Filippi
Files pdf disponibili

FENICE experiment @ ADONE

$\langle L \rangle = 5\ 10^{28}\ cm^{-2}\ sec^{-1}$

$L_p = 10^{29}\ cm^{-2}\ sec^{-1}$

$L_{int} = 0.48\ pb^{-1}$

With ~ 100 pb^{-1} answers to open questions on FF

Higher L $> 10^{33}$ @ 510 + 510 MeV

Fabio Bossi and Gino Isidori
will gave us a talk before before the end of the year
on the physics motivation for this request

Concerns @ DAFNE design

- High currents
- 120 bunches - feedbacks
- Impedance
- Vacuum
- Crossing angle - parasitic crossings
- Coupling - beam sizes

DAFNE experience

Not critical

- **Feedbacks: challenging but ok**
- **Crossing angle**
- **Coupling**
- **IP β^***

Critical

- **Damping time still long**
- **Non linearities**
- **2 IPs**
- **Beam lifetime and background: Touschek**

1) Higher E

1) Easy accelerator physics
- Hardware
- Costs
- Injection/ramping

2) Higher L

Challenging
- flat/round
- high current
- more damping
- …

3) 1) + 2)

Possible scenarios

- Minimum modifications to increase the energy

- Change as much as needed to increase the luminosity
- and include what needed to increase the energy

Higher Energy : 2 GeV (1+1)

Easier luminosity

Naturally increase radiation damping and lifetime

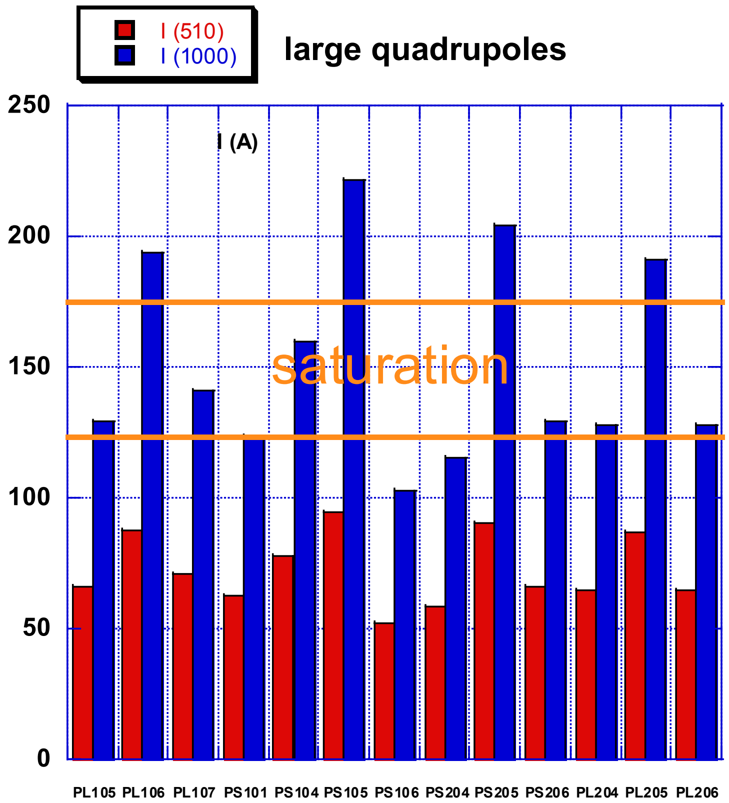
But

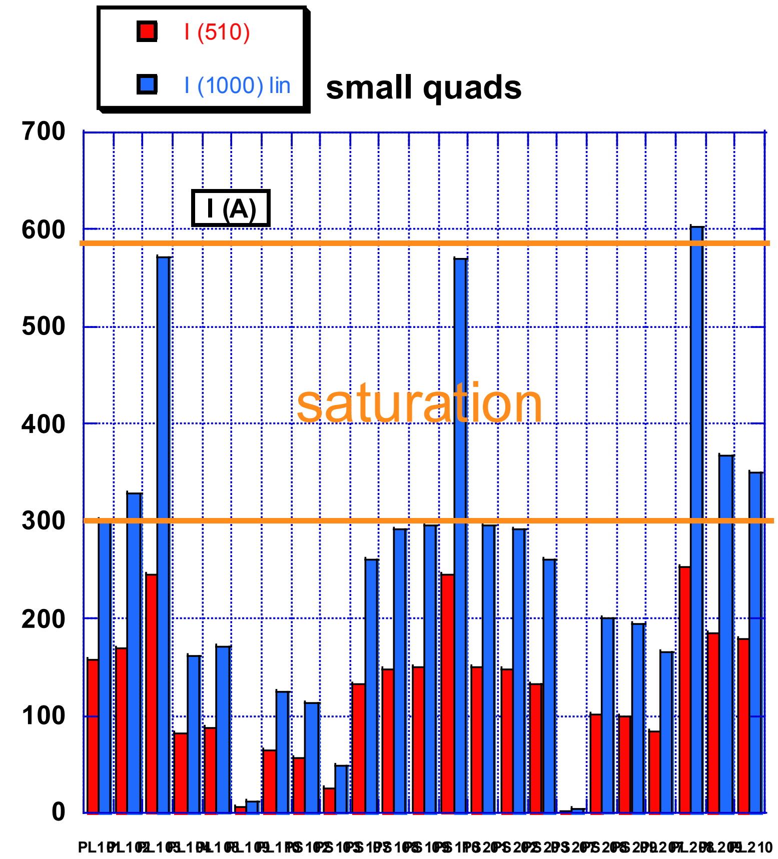
hardware, costs, injection

QUADRUPOLES

510 MeV

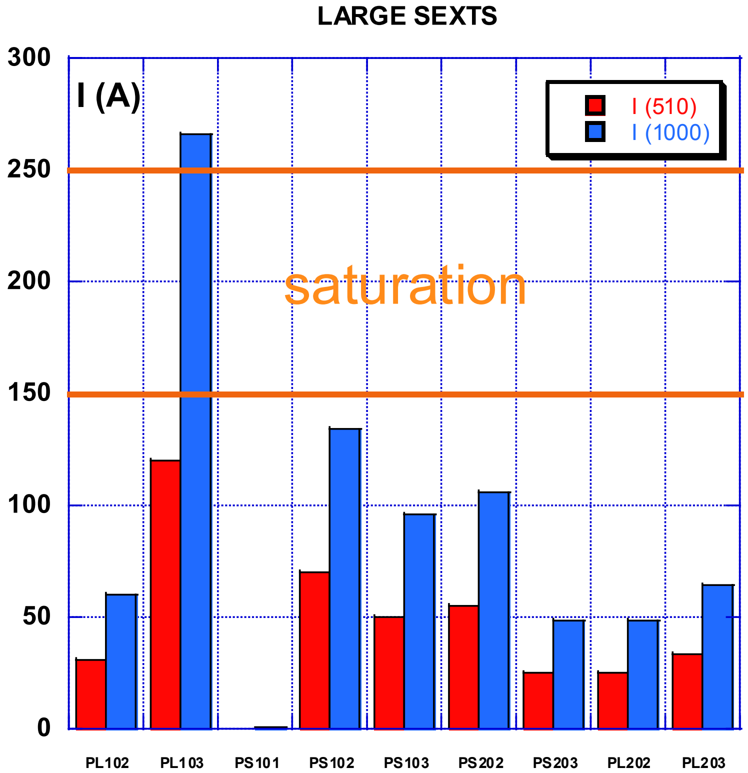
1 GeV

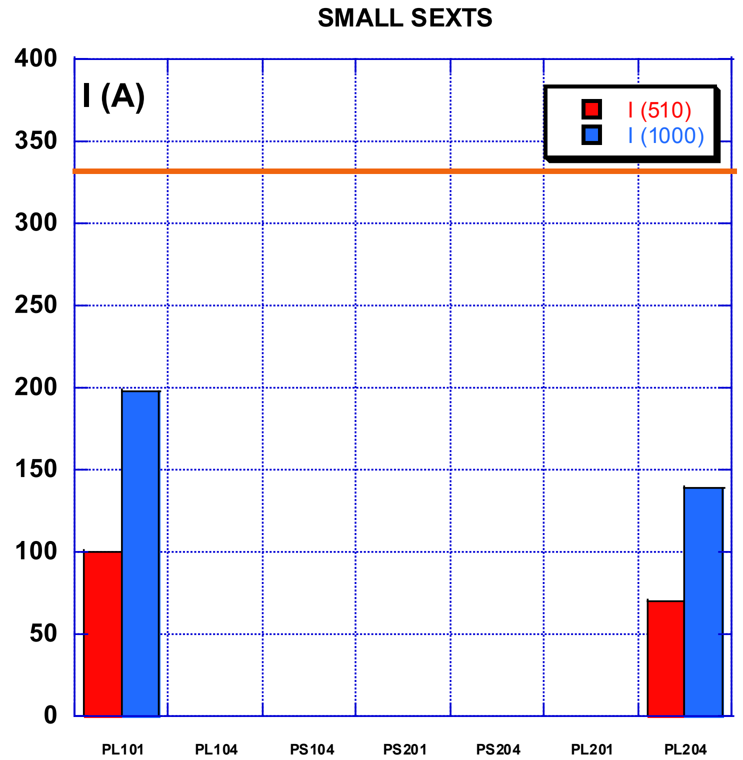


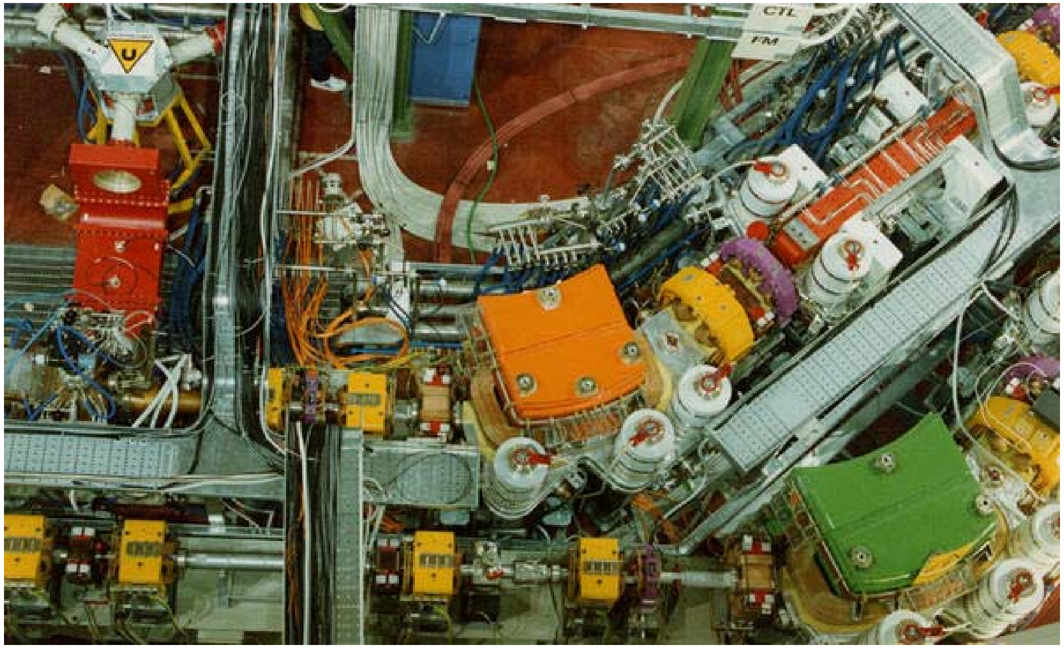


SEXTUPOLES

510 MeV
1 GeV



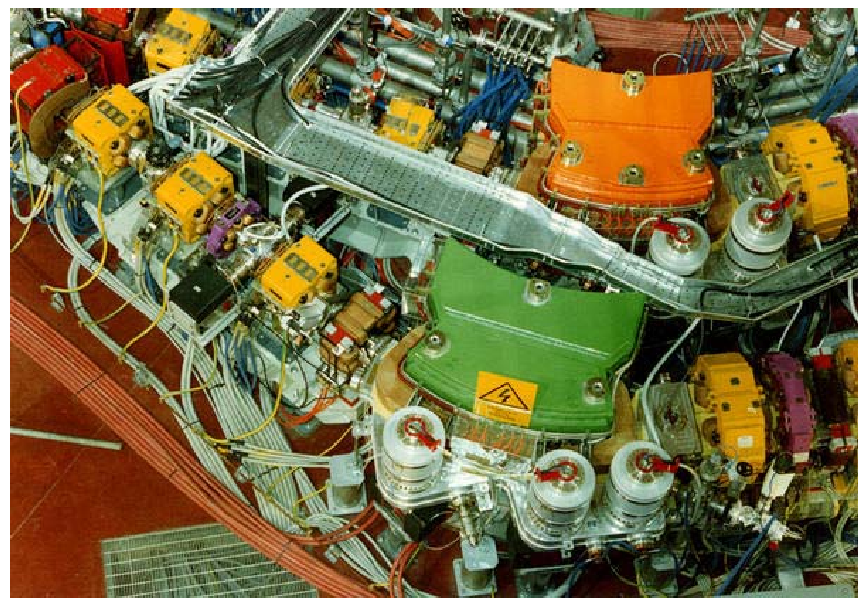


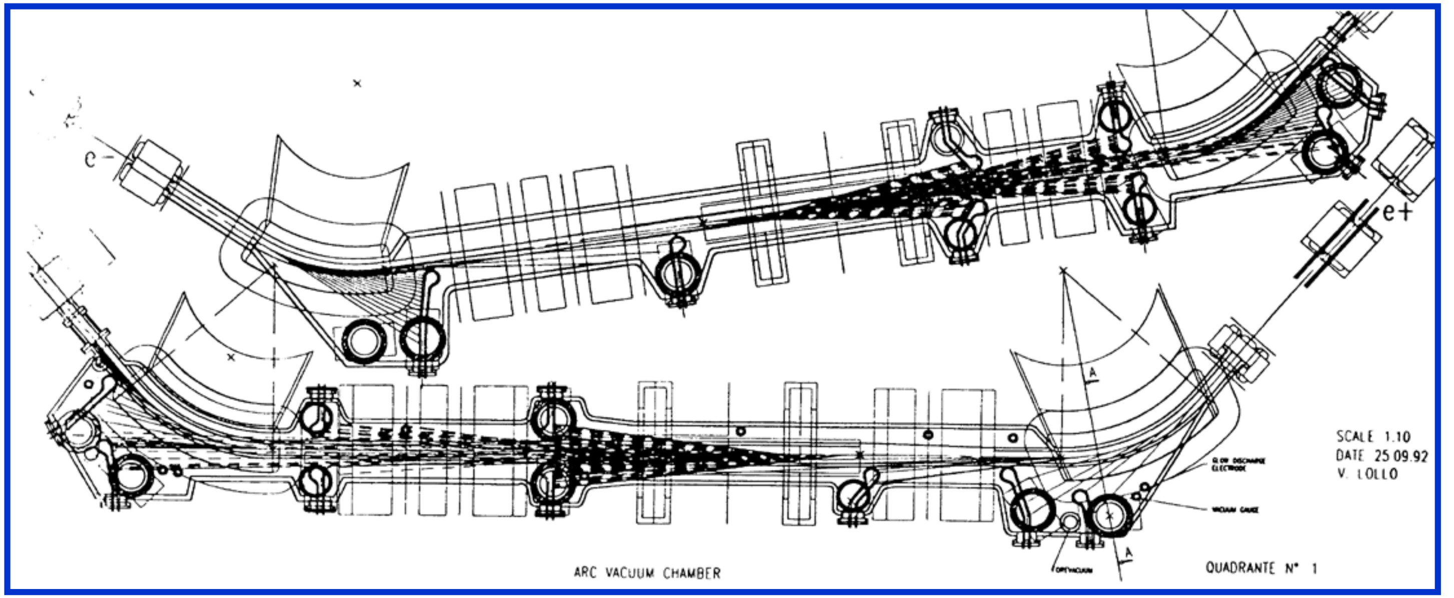


DIPOLES

Long: L =1.21m
Short: L = 0.99 m
ρ = 1.4 m
L_T = 8.8 m
B = 1.2 T

B = 1.76 T @ 1 GeV
α = 245 °
Missing 115 ° = 2.8m





Substitute with SC dipoles, same total dimension

saving vacuum chamber

Add adyacent dipoles (pm, sc, …) simmetrically around each dipole, needed > 3 T to fit in the spaces

Modify layout, substitute with normal conducting dipoles, change arc vacuum chamber

SPLITTERS **Maximum current : 750 A**
Now 420 - 460

Compensators **o.k. - Compensate the detector field**

Wigglers **o.k. – larger ρ, but still more radiation**

Others: correctors, skews, octupoles,….
Can be adapted…

Low beta: control if combinations of KLOE + FINUDA quads can be used to design a new low-beta

Energy lost per turn

$$U_o = 1.88\ 10^{-15}\ \gamma^3\ E\ I_2\ \ (m^{-1})$$

U_o (keV) ~ I_2 (m^{-1}) @ 510 MeV

U_o (keV) ~ 15 I_2 (m^{-1}) @ 1 GeV

Now : $I_2 = 9.8\ m^{-1}$ -> $U_o = 9.4$ keV

1GeV

same ρ_d, same wigglers:

$I_2 = 7.2\ m^{-1}$ $U_o = 108$ keV

increasing ρ_d, same wigglers:

$I_2 = 5.6\ m^{-1}$ $U_o = 85$ keV

Luminosity $5\ 10^{31}\ \mathrm{cm}^{-2}\ \mathrm{sec}^{-1}$

$I = 1A$

$N_b = 50$

$f_{coll} = 153\ \mathrm{MHz}$

$I_b = 20\ \mathrm{mA} = 4\ 10^{10}$ part/bunch

$\sigma_x\ \sigma_y = 4\ 10^{-8}\ \mathrm{m}^2$

$\sigma_x = 2\ \mathrm{mm}$

$\sigma_y = 20\ \mu$

Rf …

… easy

Feedbacks …

Vacuum …

L estimation at 2 GeV

Peak L should not decrease as the energy increases

Now: **$L_{av} = 0.7\ L_{peak} \sim 5\ 10^{31}$**

Injection at lower energy ~ factor 2 below:
$L_{av} = 0.35\ L_{peak}$

Feasible to achieve the request of $1pb^{-1}/day = 10^{31}$ average

Higher luminosity at the Φ energy

“Conservative” L upgrade

- Add damping: sc wigglers and/or sc dipoles
- Increase crossing angle: increase rf frequency and n. of buckets -> bunches
- Increase V for lifetime
- Eliminate 2nd IP
- Minimize β^* and bunch length
- Background estimation and shielding
- 2 independent injection chains

Damping

Radiated energy per turn $$U_o \propto E^4 \; I_2 \qquad I_2 = \int \frac{ds}{\rho^2}$$

Damping time:

few tens of ms

$$\frac{1}{\tau} \propto \frac{E^3 \; I_2}{T_o}$$

Wigglers

NOW

--->

4 wigglers/ring
$\rho = 0.94$ m
$B = 1.8$ T
$L_{TOT} = 8$m
$I_2 \sim 5.7$ m^{-1}

4 SC wigglers/ring
$\rho = 0.34$ m
$B = 5$ T
$L_{TOT} = 10$m
$I_2 \sim 60$ m^{-1}

Damping increased by a factor 10...

Wigglers added to optimize L at lower energies

For example:

LEPP, Cornell University (Laboratory for Elementary-Particle Physics)

Optimization of luminosity performance of the 768 m circumference **e+e- collider CESR** at 1.9 GeV is a critical objective of the CESR-c conversion project. In order to achieve a reasonable damping rate at the low energy approximately **18 m of 2.1 Tesla peak field wigglers** will be installed. 90% of the synchrotron radiation power in the ring will be produced in the wigglers. The non-linear properties of the wigglers are a concern for high luminosity operation.

A SUPERCONDUCTING 3.5 T MULTIPOLE WIGGLER FOR THE ELETTRA STORAGE RING

A.Batrakov, V.Jurba, S.Khrushchev, G.Kulipanov, E.Kuper, M.Kuzin, A.Medvedko, N.Mezentsev,
V.Shkaruba, *BINP, Novosibirsk,Russia;*
D.Zangrando, B.Diviacco, R.P.Walker1 , *Sincrotrone Trieste, Trieste, Italy*
Proceedings of EPAC 2002, Paris, France

Abstract

The superconducting 3.5 T wiggler was designed and fabricated for the ELETTRA storage ring (Italy) for thegeneration of synchrotron radiation with critical energy of
9.3 keV. The presented wiggler is a 49 polesuperconducting magnet with maximum field of 3.5 Teslainserted into a special liquid helium cryostat. The wigglerdesign and main parameters are presented in this article.
Results of magnetic field measurements and wiggler testing in different modes of operation are discussed.. The general view of the magnet isshown in Fig.1.
The main goal of the wiggler design was to obtain a magnetic field of 3.5 Tesla while keeping the period of the magnet structure as short as possible. The wiggler period is 64 mm. The shape of the central pole is elliptical with axes 140 mm and 7 mm. The 45 central coils consist of two different sections which are wound one over another. Each section is energised by different currents in order to obtain the optimal field-current characteristics

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ELETTRA wiggler – 3.5T

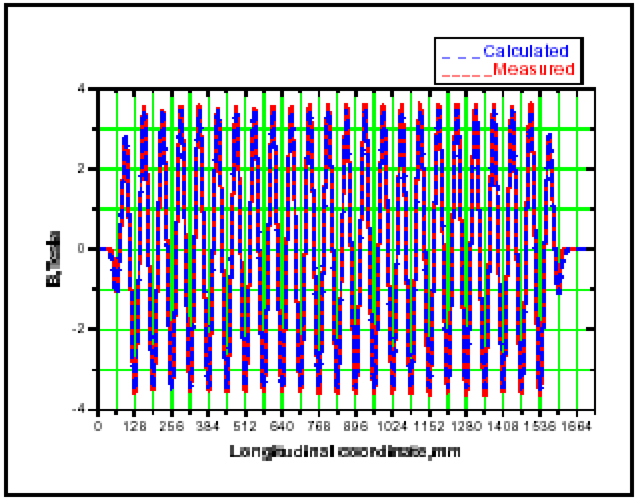

Fig.3. Computed and measured longitudinal distribution of the vertical magnetic field.

Table 1: Main parameters of wiggler.

Maximum field on beam axis:	
Central 45 poles (T)	3.5
Side 2-nd and 48-s poles (T)	2.8
Side 1-st and 49-s poles (T)	1.0
Pole gap (mm)	16.5
Period length (mm)	64
Stored energy (kJ)	240
Total weight of cooled parts (Kg)	1000
Working temperature (K)	4.2
Crytical photon energy at 2 GeV (keV)	9.3
Total radiated power at 2 GeV, 100 mA (kW)	4.6

A SUPERCONDUCTING 7T MULTIPOLE WIGGLER FOR BESSY II: MAIN CHALLENGES AND FIRST FIELD MEASUREMENTS*

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E. Weihreter, BESSY, Einsteinstraße 15, 12489 Berlin, Germany
N. Mezentsev, V. Shkaruba, BINP, Acad. Lavrentiev prospect 11, 630090 Novosibirsk, Russia
Proceedings of EPAC 2002, Paris, France

Abstract

To provide high flux hard X-ray beams with a critical energy of 16.8 keV for material research, a 17 pole superconducting 7T wiggler has been built for the BESSY II ring.

The scope of this paper is to describe the magnetic layout and the main technological challenges of this unique insertion device. Secondly we will report on first tests of the magnet at high fields including the quenching behaviour. Magnetic fields were measured using Hall-probes to determine the on-axis field distribution as well as the lifetime in the persistent current mode and the remanent field strength.

A first evaluation of the measured fields including a comparison with 3D-field calculations indicates that the specified field quality could be met.

BESSY wiggler – 7T

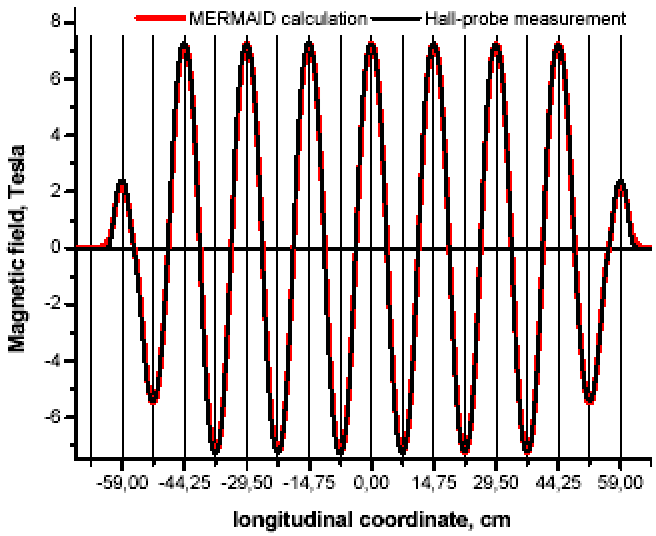


Figure 7: Longitudinal field distribution measured with a hall probe and calculated with MERMAID

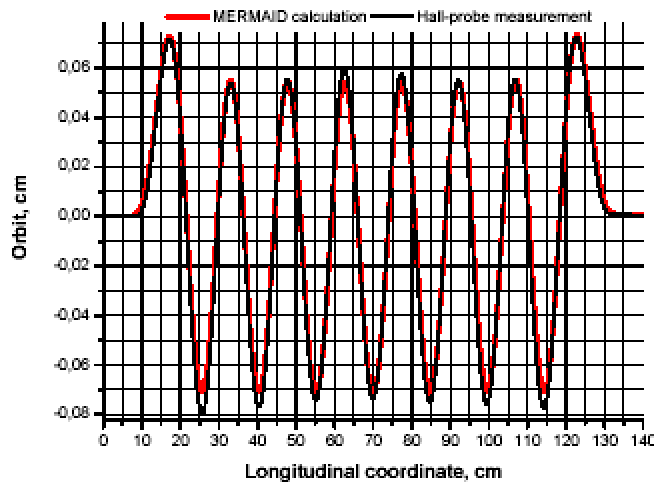


Figure 8: Horizontal electron orbit calculated from the measured and calculated fields

Increase rf frequency

Present: 369 MHz
$C = 98$ m $h = n_{max} = 120$

Distance between bunches:
$D = 0.8$ m

Going to 500 MHz
$C = 100$ m $h = n_{max} = 160$

$D = 0.6$ m

↓

Decrease bunch length

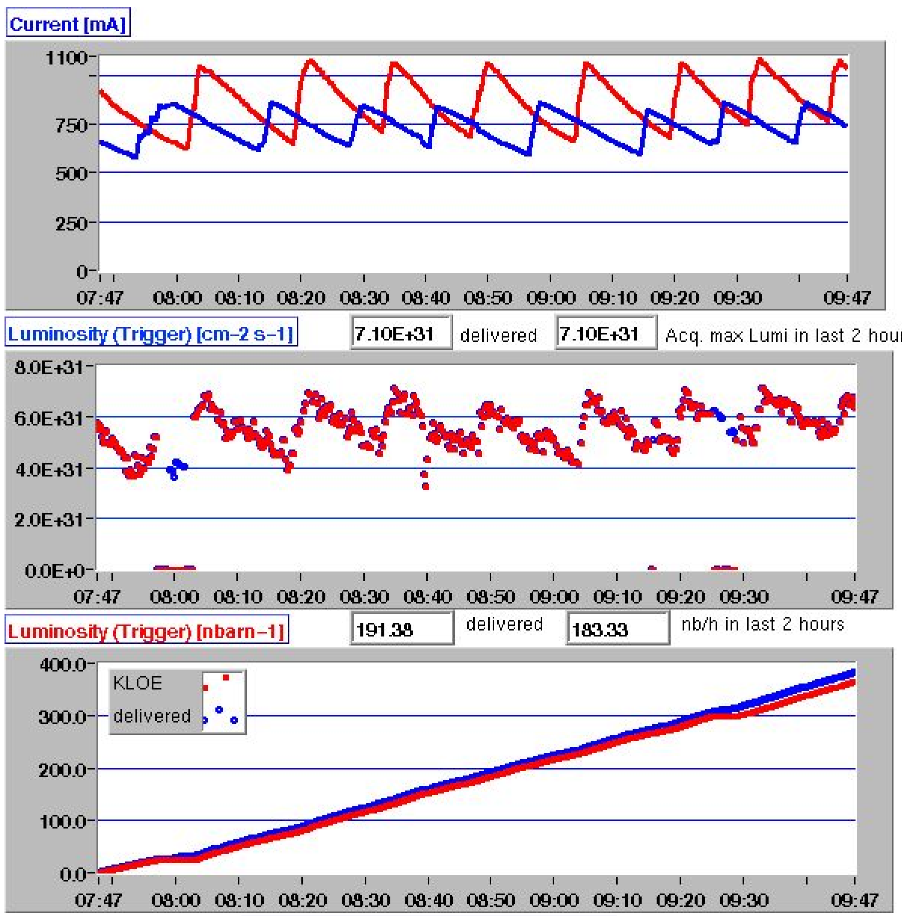
↓

Increase f_{coll}

2 independent injection chains

Ratio between integrated and peak luminosity depends on:

- **Beam lifetime**
- **Injection efficiency**



KLOE runs

Luminosity 10^{33} cm^{-2} sec^{-1}

$I = 5A$

$N_b = 140$

$f_{coll} = 467$ MHz

$I_b = 36$ mA $= 7\ 10^{10}$ part/bunch

$\sigma_x\ \sigma_y = 1.8\ 10^{-8}\ m^2$

$\sigma_x = 1$ mm

$\sigma_y = 18\ \mu$

Ring for two energies

Energy (GeV)	0.5	1.0
$B\rho$ (T m)	1.7	3.3
Dipoles	ρ_o	ρ_o
Wigglers	ρ_w	$2\ \rho_w$
Energy lost per turn	U_{oD} - U_{oW}	16 U_{oD} -4U_{oW}
Damping time	τ_{oD} - τ_{ow}	τ_{oD} / 8 - τ_{ow} / 2

ρ constant
B ramping

B constant

$$\frac{1}{\tau} \propto \frac{E^3\ I_2}{T_o}$$

… ideas for higher L

- **Round beam (Novosibirsk style)**
- **Round beam + 2 IPs (H / V)**
- **AWM**

Round beam (Novosibirsk style)

1.7 ϕ—фабрика

В проекте ϕ—фабрики для достижения высокой светимости предполагается использовать столкновение так называемых "круглых пучков".

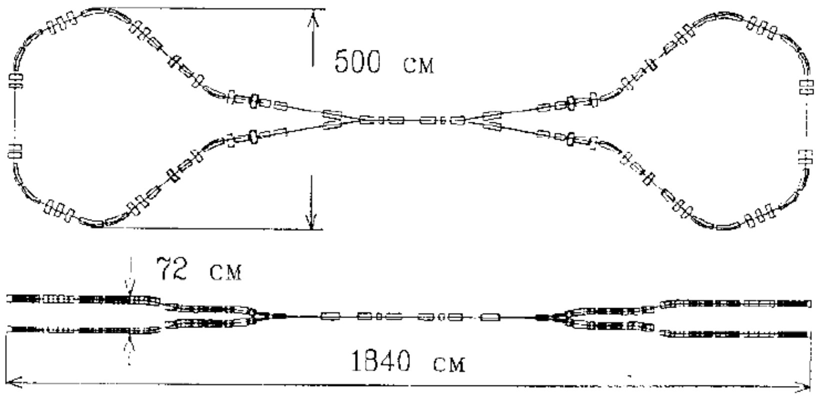


Рис. 1.2: ϕ—фабрика.

From a seminar by Valishev @ KEK, march 2002

Increasing the Luminosity

1. **Number of bunches**
2. **Bunch-by-bunch luminosity**

$$L = \frac{\pi \gamma^2 \xi_y \xi_x \epsilon_x f}{r_e^2 \beta_y^*} \cdot (1 + \frac{\sigma_y}{\sigma_x})^2$$

Round beams:

- **Geometric factor**
- **Beam-beam limit enhancement**

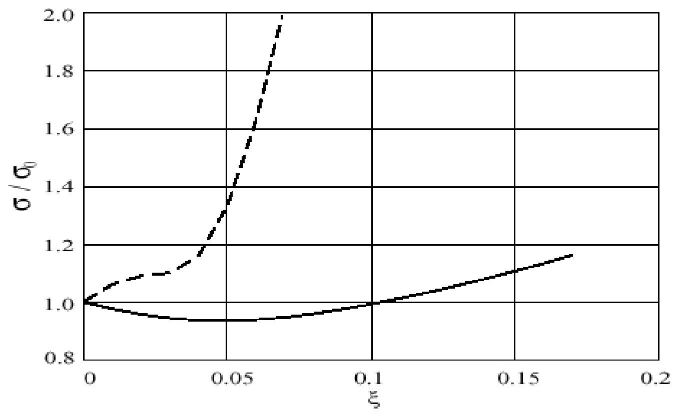
- **Round cross-section of beams at IP**
- **Machine optics has rotational symmetry**

$\rightarrow$ **Motion in central field with additional integral of motion**

reduces the transverse oscillations from 2D to 1D!

V.V.Danilov and E.A.Perevedentsev, Frascati Physics Series Vol. X (1998), p.321

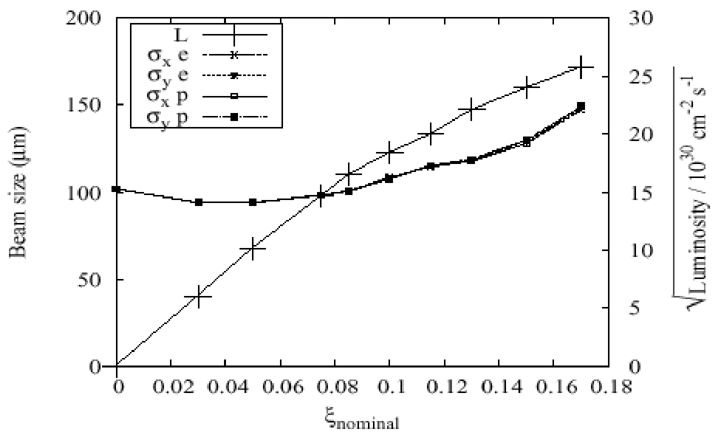
Weak-strong simulation for VEPP-2M



Vertical beam size vs. the beam-beam parameter. Solid line - round beam, dashed line - flat

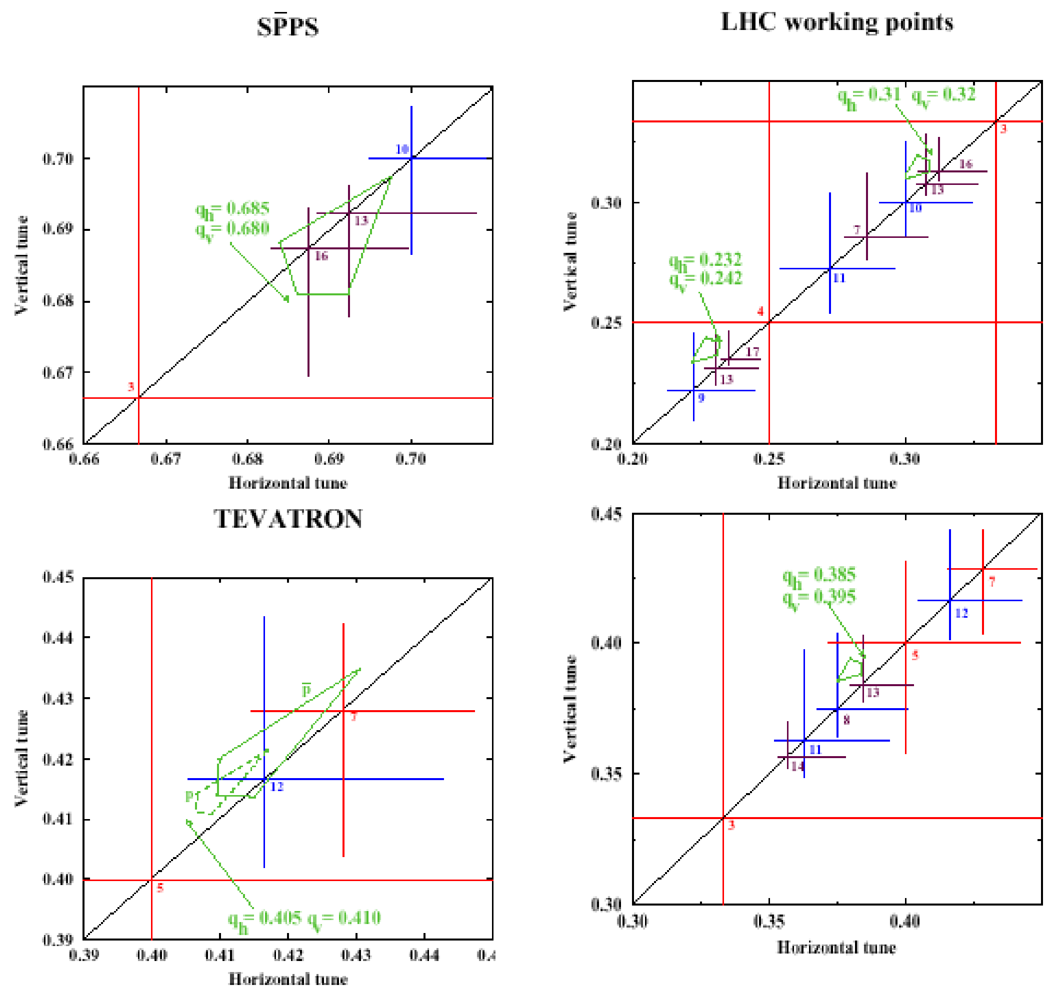
Strong-strong simulation for VEPP-2000

Code by K.Ohmi



Beam size and $\sqrt{L}$ vs. the beam-beam parameter.

Hadron’s colliders:
working point near the main coupling resonance



Ruggiero – Zimmermann (*CERN*)
2 Ips – H/V

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS, VOLUME 5, 061001 (2002)

Luminosity optimization near the beam-beam limit by increasing bunch length or crossing angle

F. Ruggiero and F. Zimmermann
CERN, SL Division, AP Group, CH-1211 Geneva 23, Switzerland
(Received 21 February 2002; published 18 June 2002)

We discuss the choice of bunch length and crossing angle near the beam-beam limit in a storage-ring collider. First, we derive expressions for the tune shifts of either bunched or continuous round beams which are induced by a single collision with arbitrary crossing angle and bunch length and for the associated luminosities. Then, considering two collision points with alternating planes of crossing, we demonstrate that, if the total beam-beam tune shift is held constant, the collider luminosity increases as a function of bunch length and crossing angle. This implies a corresponding increase in the bunch intensity. As an illustration, we present numerical examples for a Large Hadron Collider upgrade and for the Very Large Hadron Collider.

The beam-beam effect between the horizontal and the vertical crossing is compensated

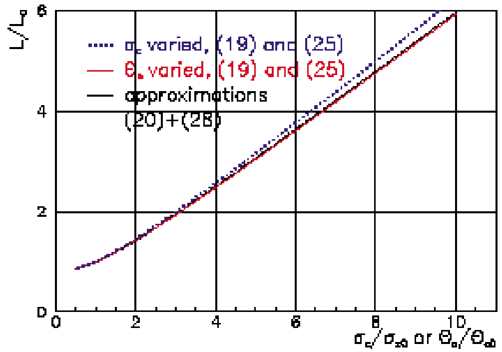


FIG. 2. (Color) Relative increase in LHC luminosity as a function of the relative increase of the product of rms bunch length and crossing angle, $(\sigma_z\theta)$, starting from a nominal bunch length $\sigma_z = 7.7$ cm and crossing angle $\theta = 300$ μrad [11], and maintaining a constant total beam-beam tune shift for two collisions with alternating crossing. The transverse rms beam size is $\sigma^* = 16$ μm and the interaction-point beta function $\beta^* = 0.5$ m. The subindex "0" refers to the nominal initial parameters listed above.

The luminosity increases with crossing angle and bunch length

AWM: All Wiggler Machine

LABORATORI NAZIONALI DI FRASCATI DELL'INFN

DIVISIONE MACCHINE - MEMORANDUM INTERNO

DATA 28/5/1980

Gruppo e Numero G-34

TITOLO AWM - 6 PERIODS AND 4 PERIODS.- (ESRF - 93)

NOME S. Tazzari, F.H. Wang

1) General remarks

a) The magnetic field in the bending magnets is no longer related to the desired critical wavelength, λ_c, the latter being determined by the operating energy and the field in the wiggler. The bending radius is therefore a free parameter. We assume the wiggler field is sinusoidal and given by

$$B_w = B_0 \sin\frac{s}{\lambda} \qquad 1)$$

s being the coordinate along the unperturbed trajectory.

Since the critical wavelength is given by:

$$\lambda_c = \frac{K}{B_w E^2} \qquad K = 18.63\ \text{Å}\cdot\text{T}\cdot\text{GeV}^2 \qquad 2)$$

if we define a useful field region

$$B_0 \geq |B| \geq .8\,B_0, \qquad 3)$$

the critical wavelength will satisfy the condition

$$\frac{K}{.8\,B_0 E^2} \geq \lambda_c \geq \frac{K}{B_0 E^2} \equiv \lambda_{c_0}.$$

λ_{c_0} will be obtained in the forward direction.

b) The angle through which the beam is bent in each wiggler pole (useful field region) is usually very small, and effectively determines the angular aperture of the emitted beam, ϑ_w

$$\vartheta_w = .2\,\frac{\lambda_w}{\varrho_{w_0}} = 6\,10^{-2}\,\frac{\lambda_w B_0}{E} = 1.118\,\frac{\lambda_w}{\lambda_{c_0}^{(\text{Å})} E^3} \quad (*) \qquad 4)$$

λ_w has to be small enough that the amplitude of the trajectory oscillation does not become too large, but large enough that the desired field (for a given gap) can be obtained. The value $\lambda_w = .17$ was used.

c) In the proposed designs[(1),(2)] the wiggler length is of the order of 1 m, so that the source is longitudinally extended over the same distance.
Source dimensions in the radial plane are also affected by the trajectory in the wiggler;

(*) Unless otherwise specified, energies are always in GeV, magnetic fields in T, and lengths in m.

cartografica baioni s.n.c. - frascati

LABORATORI NAZIONALI DI FRASCATI DELL'INFN

DIVISIONE MACCHINE - MEMORANDUM INTERNO

DATA 4/11/80

Pag.

Gruppo e Numero G-36

TITOLO Formulario AWM

NOME Rapa Tazzari

1. Generali per luce di sincrotrone

$$\omega_c = \tfrac{3}{2}\, c\, \gamma^3/\rho \qquad 1)$$

$$\varepsilon_c = \frac{3}{4\pi}\,\frac{\Lambda_{ce}}{\rho}\, mc^2\, \gamma^3 \qquad 2)$$

$$\Lambda_{ce} = \frac{h}{mc} = 2.427\times10^{-12}\ \text{m}$$

$$\boxed{\lambda_c = \frac{4\pi}{3}\,\frac{m_0 c}{e}\,\frac{1}{\gamma^2 B} = 7.14\times10^{-3}\,\frac{1}{\gamma^2 B}\ \ \text{MKS}} \qquad 3)$$

$$\rho = \frac{m_0 c\,\gamma}{e B} \qquad 4)$$

potenza totale emessa in un anello di accumulazione

$$P_B = \frac{e}{3\varepsilon_0}\,\frac{\gamma^4 I}{\rho} = \frac{e^2}{3\varepsilon_0 m_0 c}\,\gamma^3 B I = \frac{4\pi e}{9\varepsilon_0}\,\frac{\gamma I}{\lambda_c} \qquad 5)$$

2. Wiggler

$$B = B_0 \sin(s/\lambda_w) \qquad 6)$$

$$x(s) = \frac{\lambda_w^2}{\rho_0}\,\sin(s/\lambda_w) \qquad 7)$$

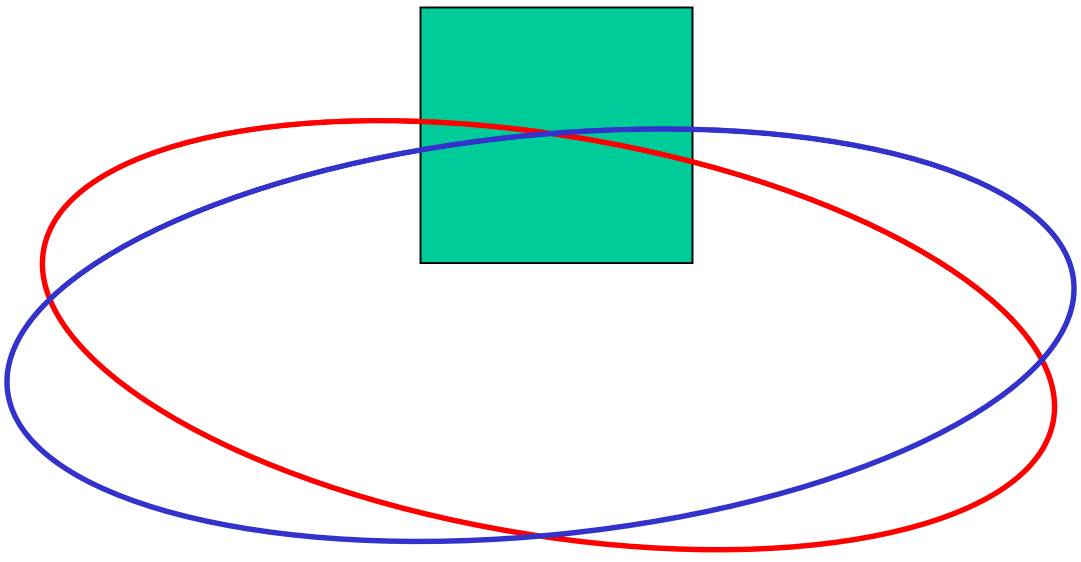
$$x'(s) = \frac{\lambda_w}{\rho_0}\,\cos(s/\lambda_w) \qquad 8)$$

$$\boxed{\theta_{w_0} = 2x'_0 = 2\,\frac{\lambda_w}{\rho_0} = \frac{e}{\pi m_0 c}\,\frac{B_0\lambda_w}{\gamma} = 186.8\,\frac{\lambda_w B_0}{\gamma}} \qquad 9)$$

Zona utile: $.8\,B_0 \leq B \leq B_0$

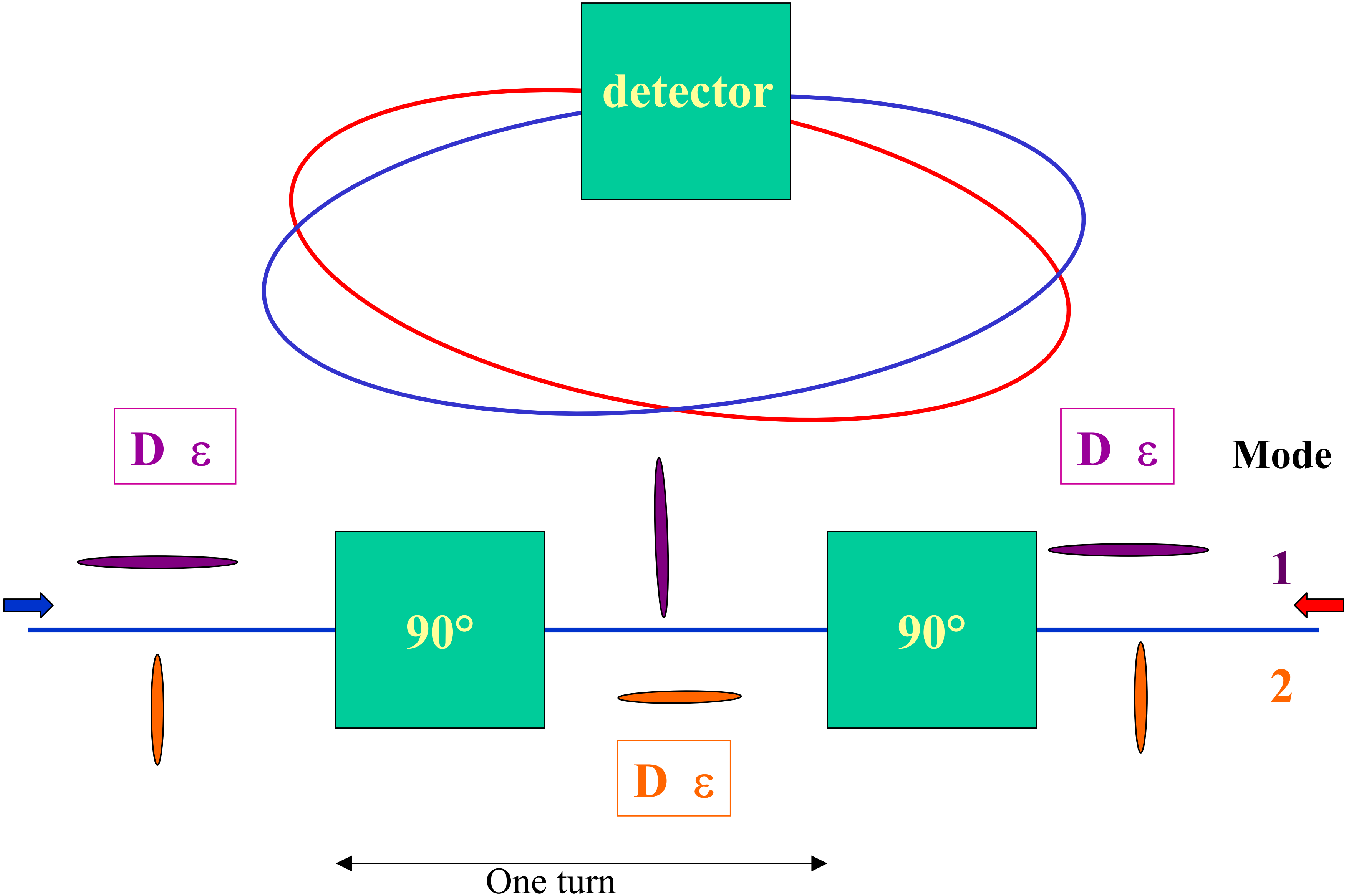
$$\boxed{\theta_{wu} = .6\,\theta_{w_0}} = f_\theta\,\theta_{w_0} \qquad 10)$$

Starting point

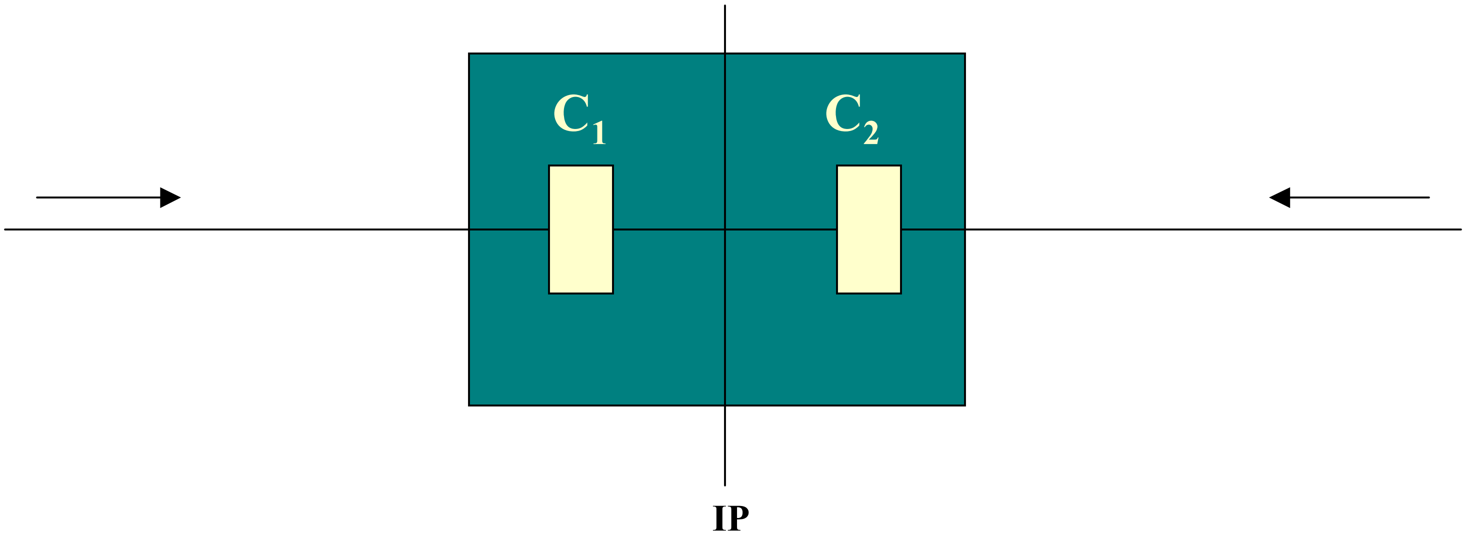


Two rings, multibunch
Only 1 IP, 1 detector
Add SC wigglers / dipoles

Round beam = no coupling



Interaction Region for flat and round beam



$\Theta_d = B_d\, L_d / 2B\rho = 45°$

FLAT beam: $\Theta_{C1} = \Theta_{C2} = -22.5°$ $\qquad \Theta_{tot} = 0$

ROUND beam: $\Theta_{C1} = \Theta_{C2} = 22.5°$ $\qquad \Theta_{tot} = 90°$

Example:

(90° = 5.3 Tm @ 510 MeV)

Detector: 45°

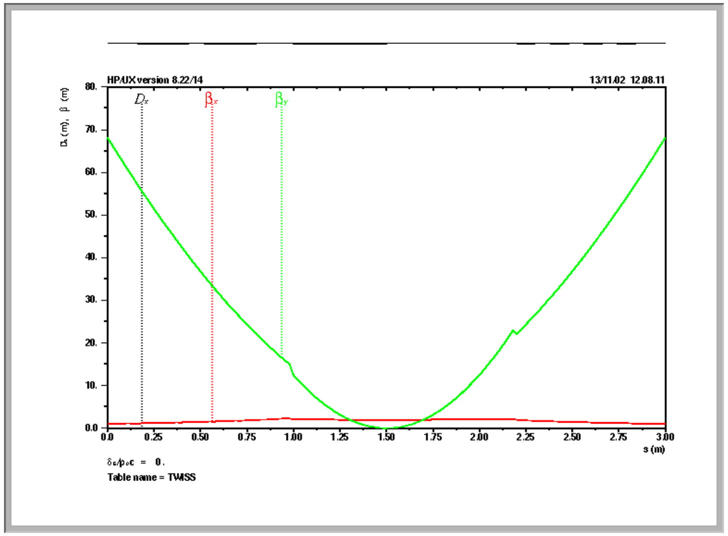
L_d = 3m -> B_d = 0.89 T

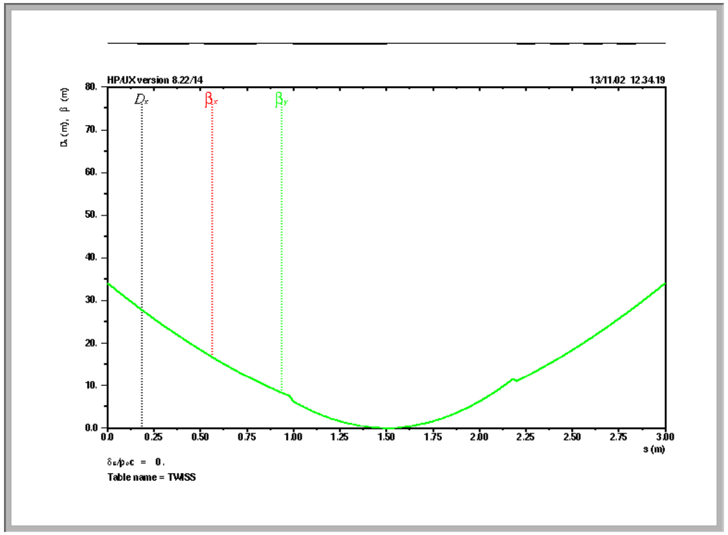
Compensators: 45°/2

L_c = 20 cm -> B_c = 6.6 T

Superconducting compensators inside the detector
(Bassetti, Biscari, Milardi, 1993, L-11
***Alternative Interaction Region Design*)**

Betatron functions inside the detector





Flat

$\beta_x{}^* = 1\mathrm{m}$

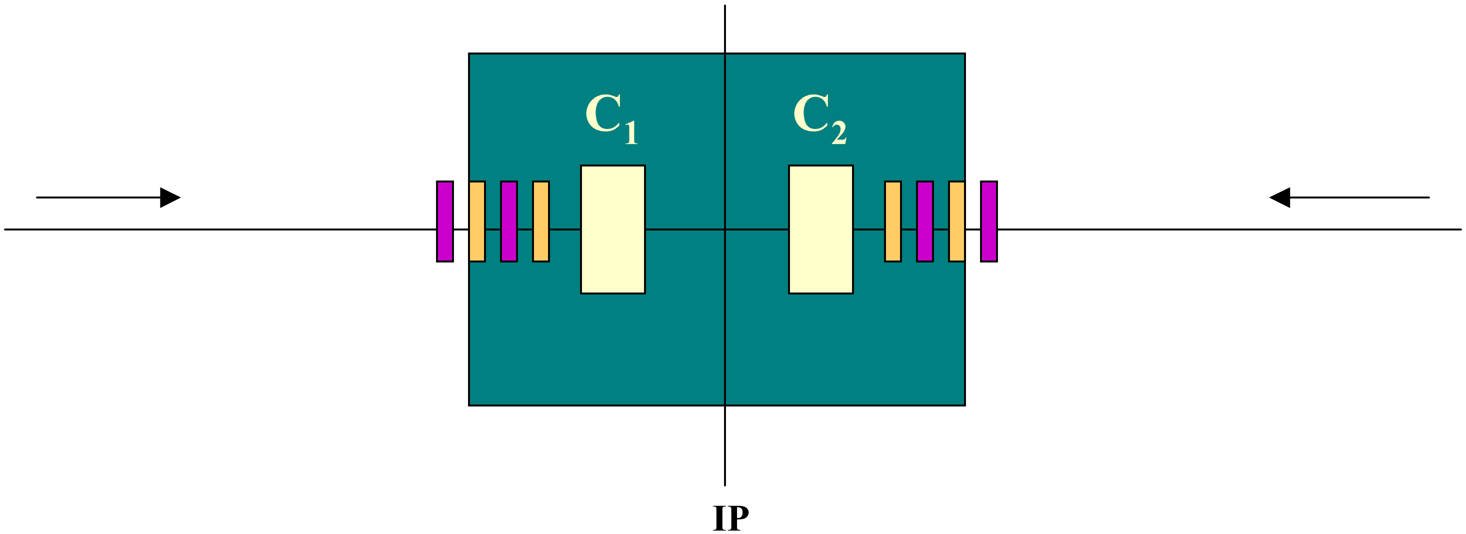
$\beta_y{}^* = 2\mathrm{cm}$

Round

$\beta_x{}^* = 4\mathrm{cm}$

$\beta_y{}^* = 4\mathrm{cm}$

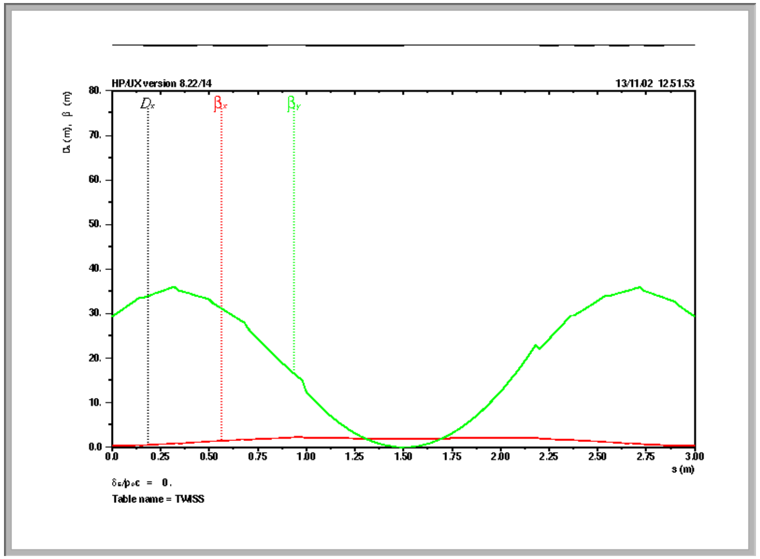
Add focusing with ‘wiggling sc solenoids’

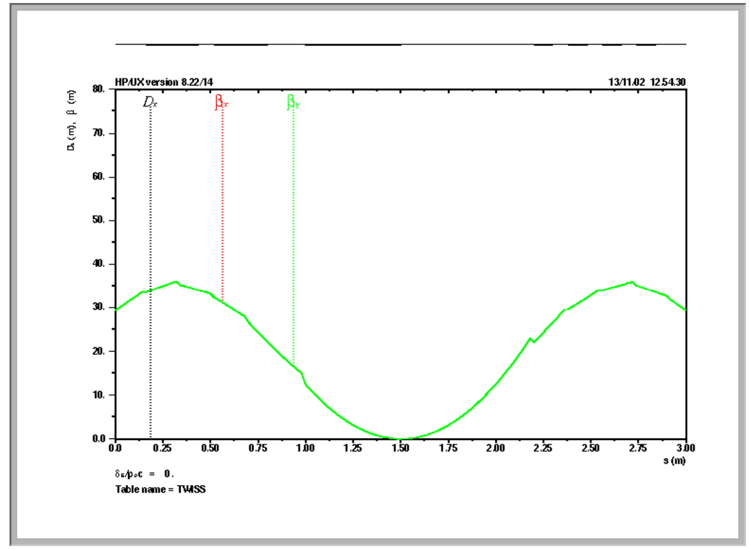


Positive B_s + Negative B_s = 0

$C_1 + C_2 + B_d = 0$ FLAT
$C_1 + C_2 + B_d = 90°$ ROUND

Betatron functions inside the detector





Flat

$\beta_x^* = 1\mathrm{m}$

$\beta_y^* = 2\mathrm{cm}$

Round

$\beta_x^* = 2\mathrm{cm}$

$\beta_y^* = 2\mathrm{cm}$

Can we make an experiment on DAFNE?

Round beam with Finuda?

Finuda detector: **BL = 2.6 Tm => 44 °**

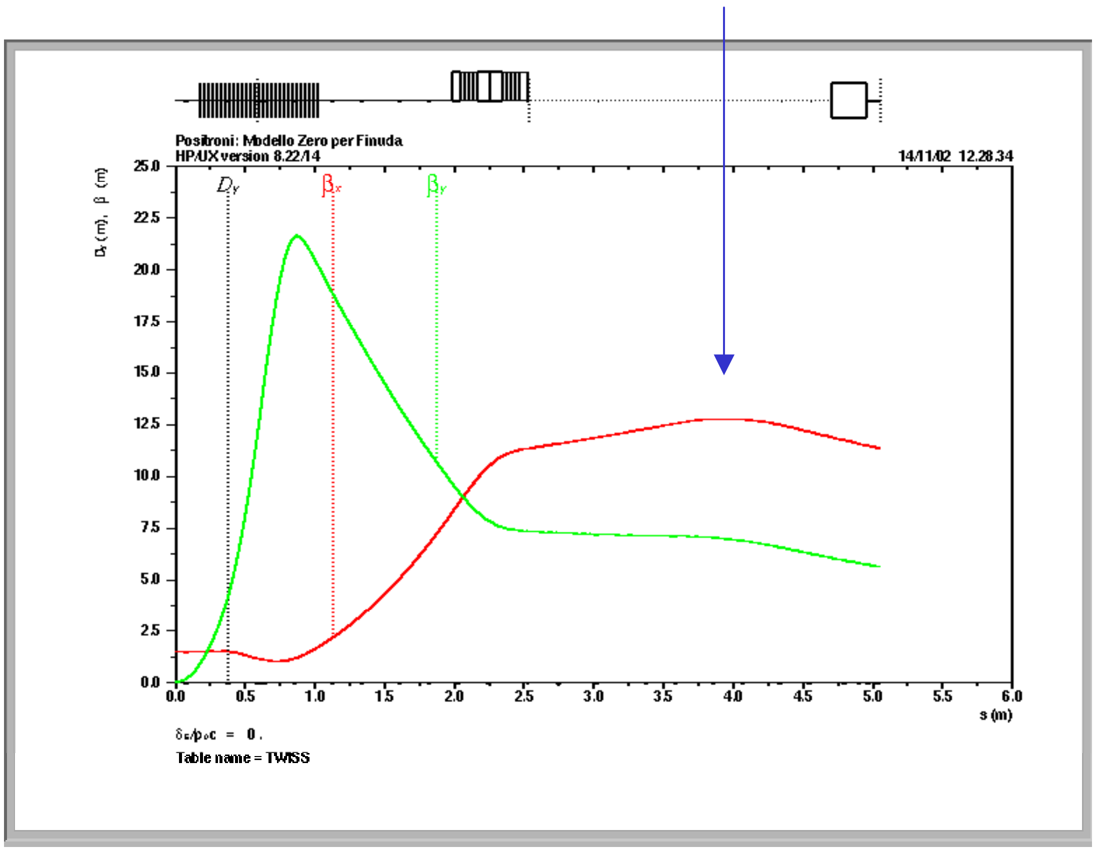
+

Compensators: **22° + 22 °**

Almost 90°

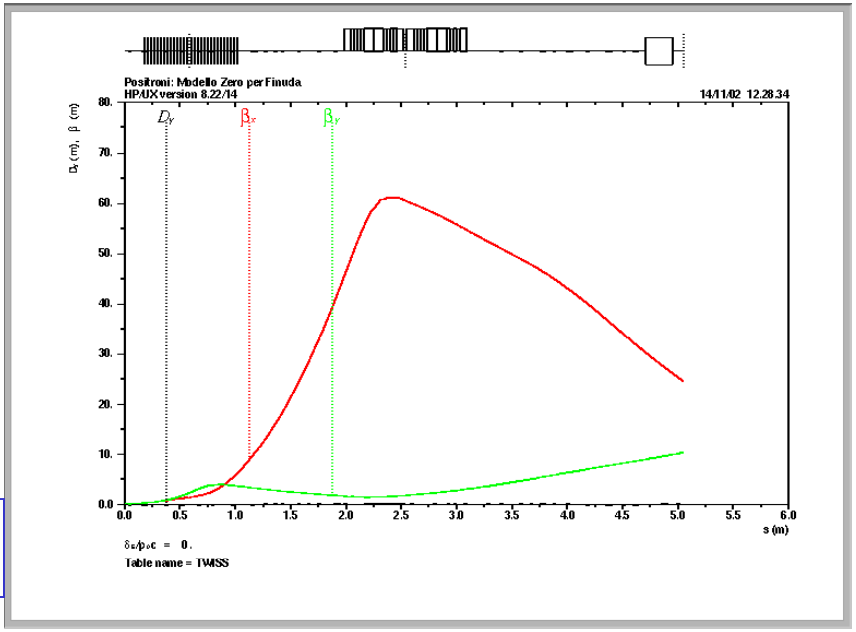
FINUDA IR - now

compensator

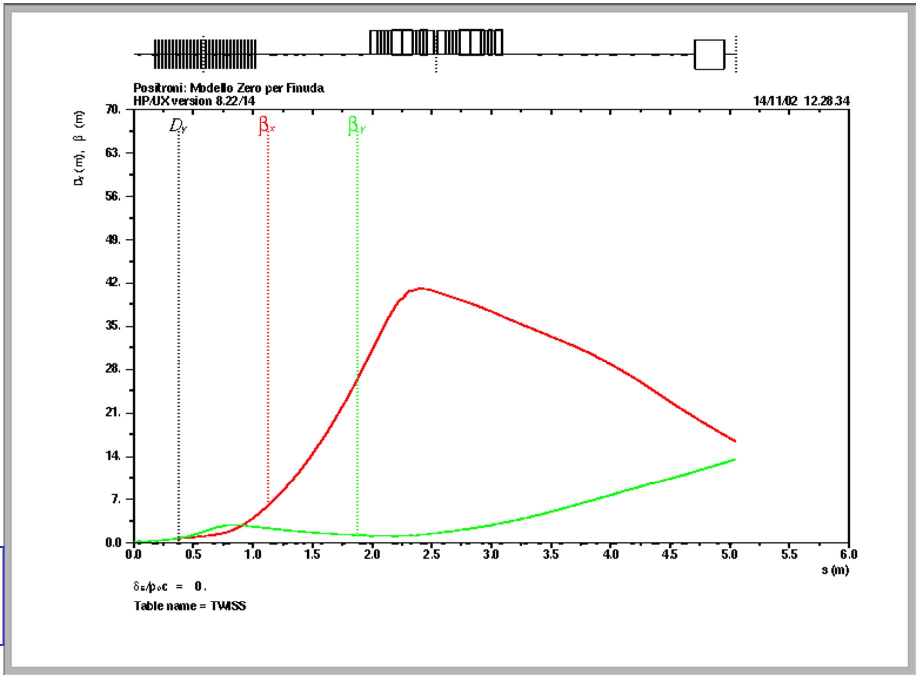


FINUDA IR
with equal β*

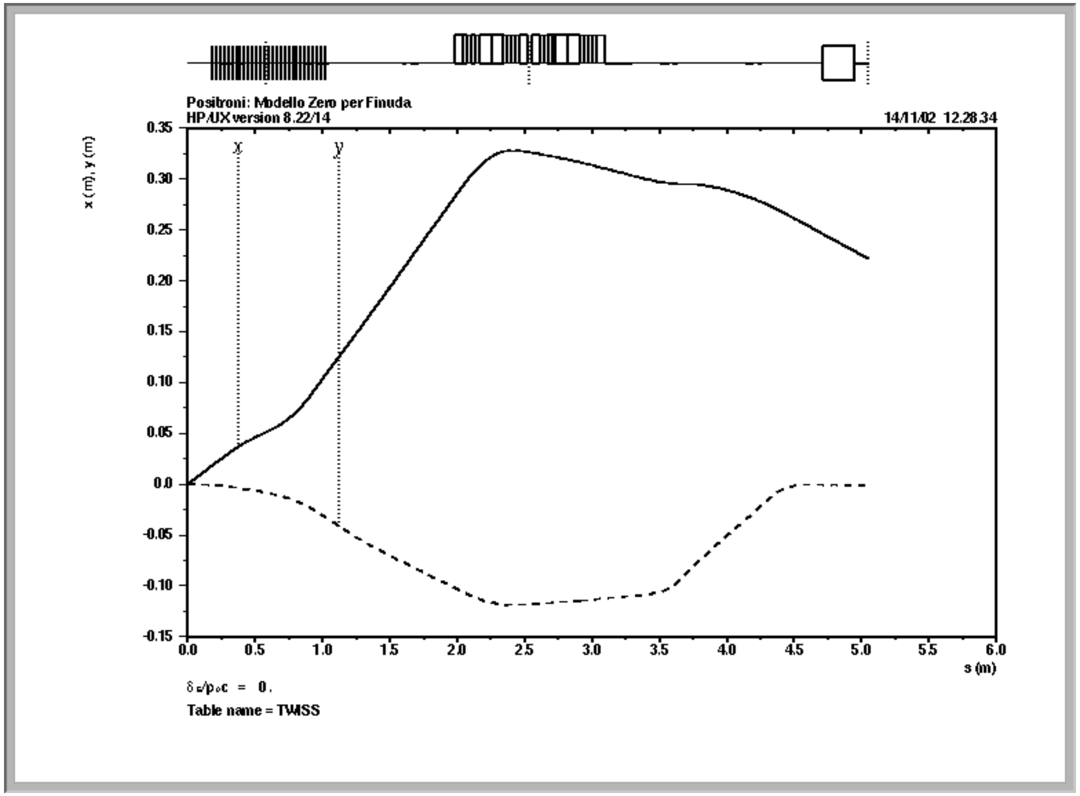
$\beta^*_1 = \beta^*_2 = 20\text{cm}$



$\beta^*_1 = \beta^*_2 = 30\text{cm}$



But trajectory off-axis + rotation of 90°
transform the horizontal separation into vertical



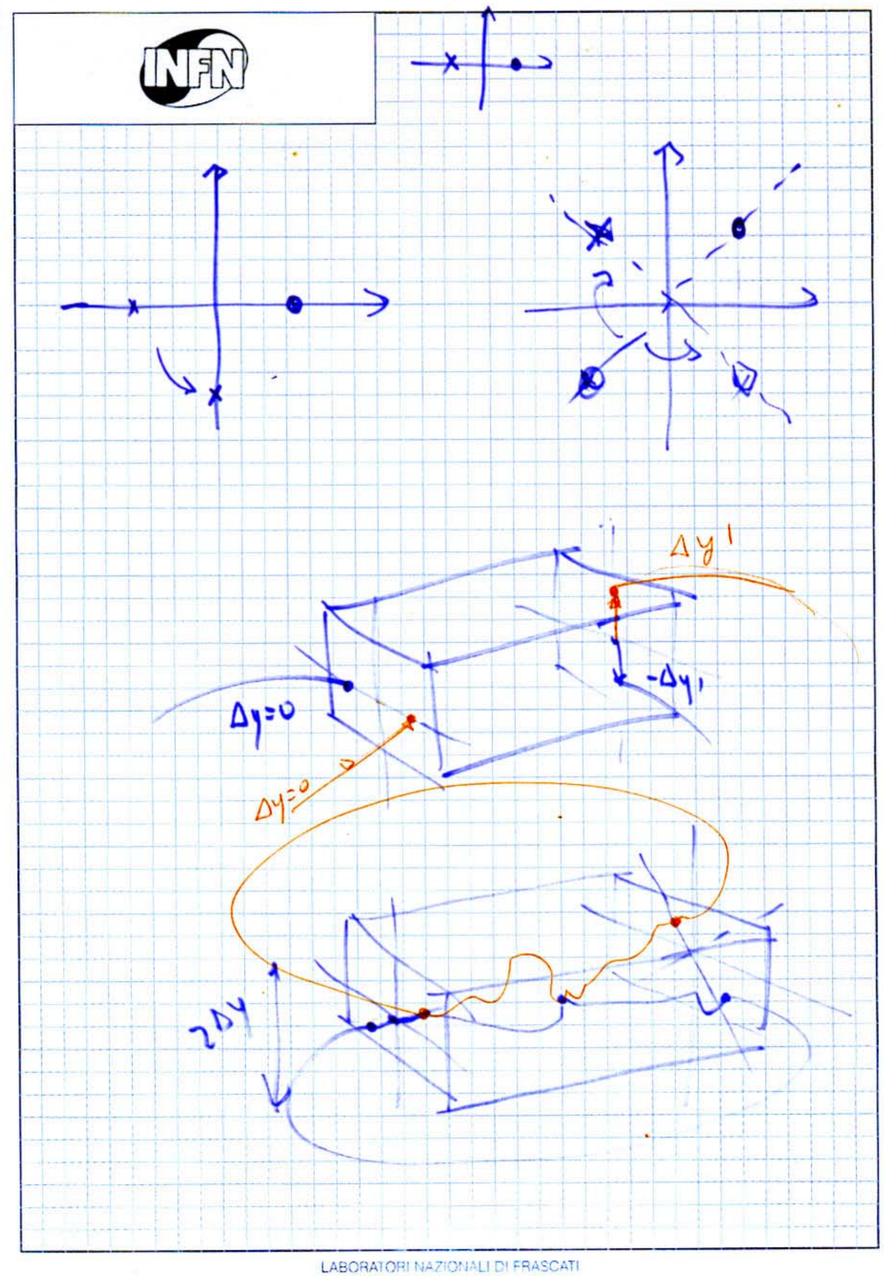
Off-axis + 90 °:

Two equal rings vertically separated

Round beam

Multibunch

Only 1 crossing point



When?

Present schedule:

2002 : KLOE + DEAR

2003 : shutdown for FINUDA, KLOE, ...

FINUDA + KLOE runs

2004: FINUDA + KLOE runs

2005 - on

Some of the items to be studied

Higher energy

- **Ring structure (ε, τ, rf, bunch length,….)**
- **Interaction region**
- **New magnets design**
- **Magnet Ramping with injection @ 510**
- **Diagnostics**
- **Cost estimation**

Higher luminosity… everything

Flat/round beam => Ring structure

- Wigglers
- Rf
- IR
- Background
- Injection system
- …

Next appointments

- **Seminar bossi/isidori**
- **Seminar baldini**
- **Workshop @ Thuile (march 2003) – to be organized**
- **Workshop @ Alghero (june 2003) – to be organized**