Lattice for longitudinal low beta

C. Biscari

LNF, INFN

Alghero, September 2003

Starting point for the study of feasibility of a super Φ factory

Main guidelines for the design
L > 10 [34]

- **Powerful damping**
- **Short bunch at IP**
- **Negative momentum compaction**

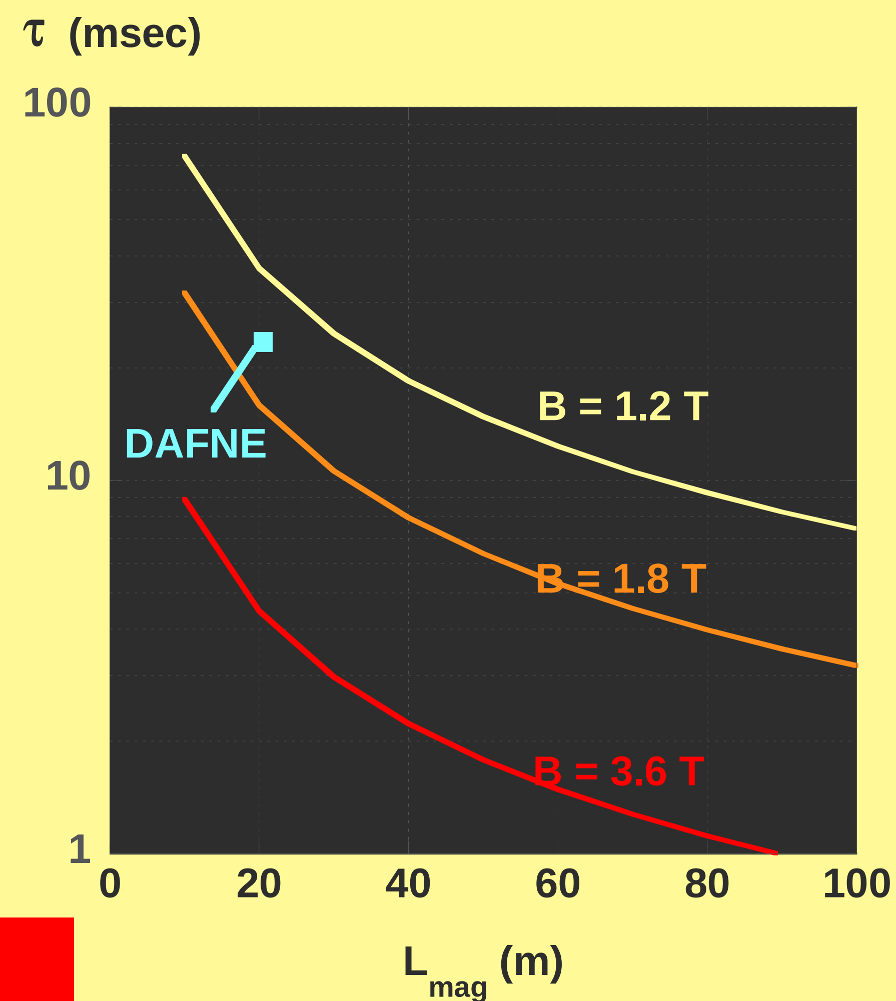
Which kind of collider is possible at Frascati
using present infrastructures?

Damping time on magnetic field

$$\alpha_x \approx \frac{C_\alpha}{C} E^3 I_2$$

For C = 100 m
E = 510 MeV

$$\tau_x(\mathrm{sec}) \approx \frac{\rho^2}{2.8\,L_{dip}}$$

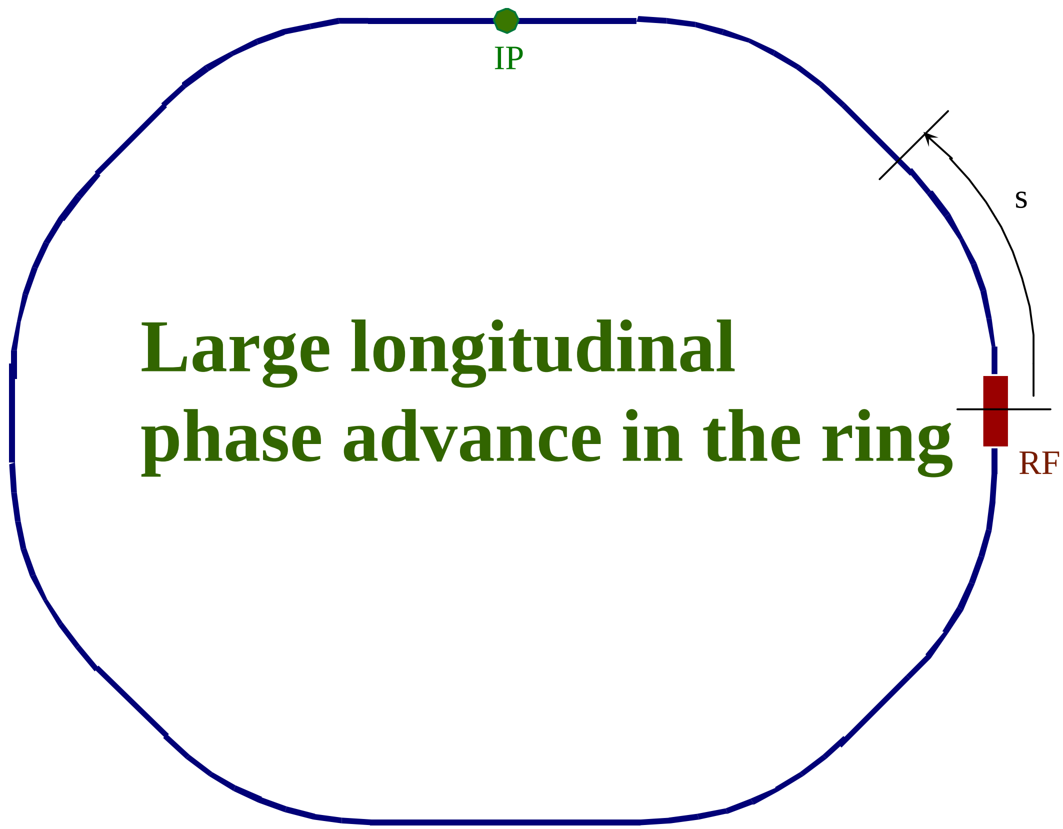


Factor 2 on tuneshift
by factor 10 on damping time

Ring full of dipoles or wigglers
or superconducting magnets with small ρ
(B = 3.6 T => ρ = 0.5 m)

Our present choice:
Normal conducting dipoles at 1.8T

Short bunch at the IP



Large longitudinal phase advance in the ring

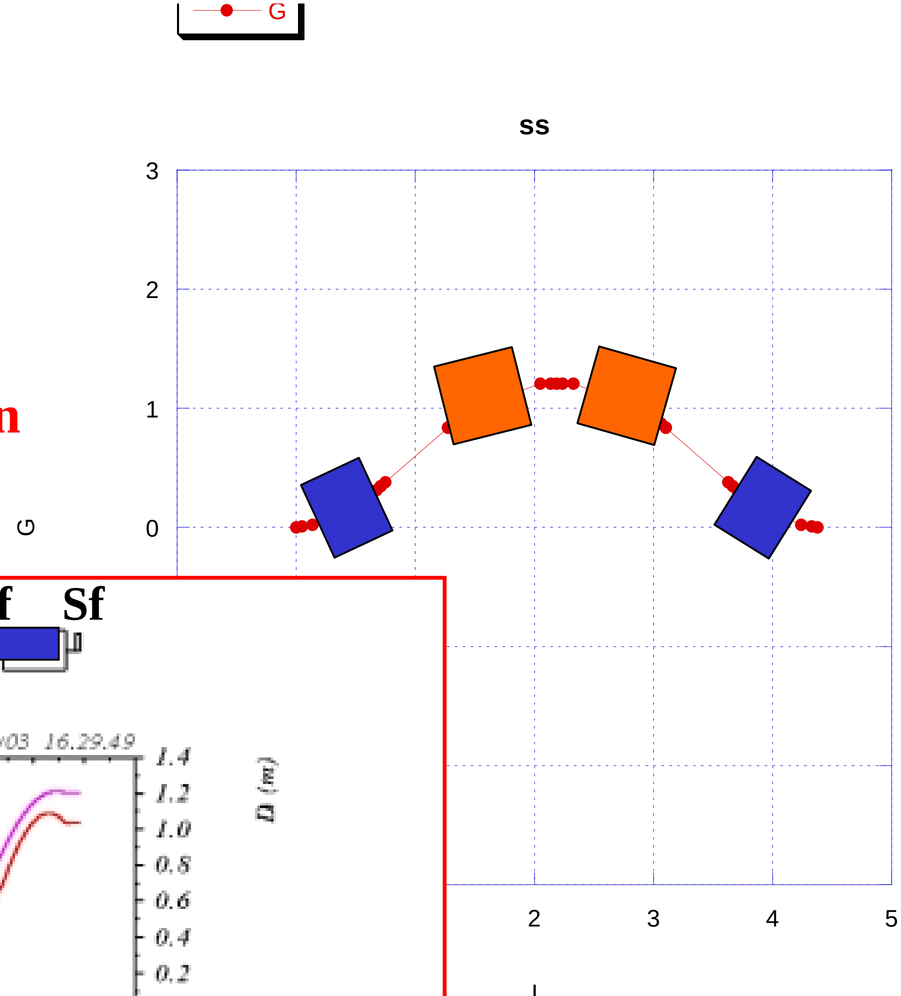
High voltage RF

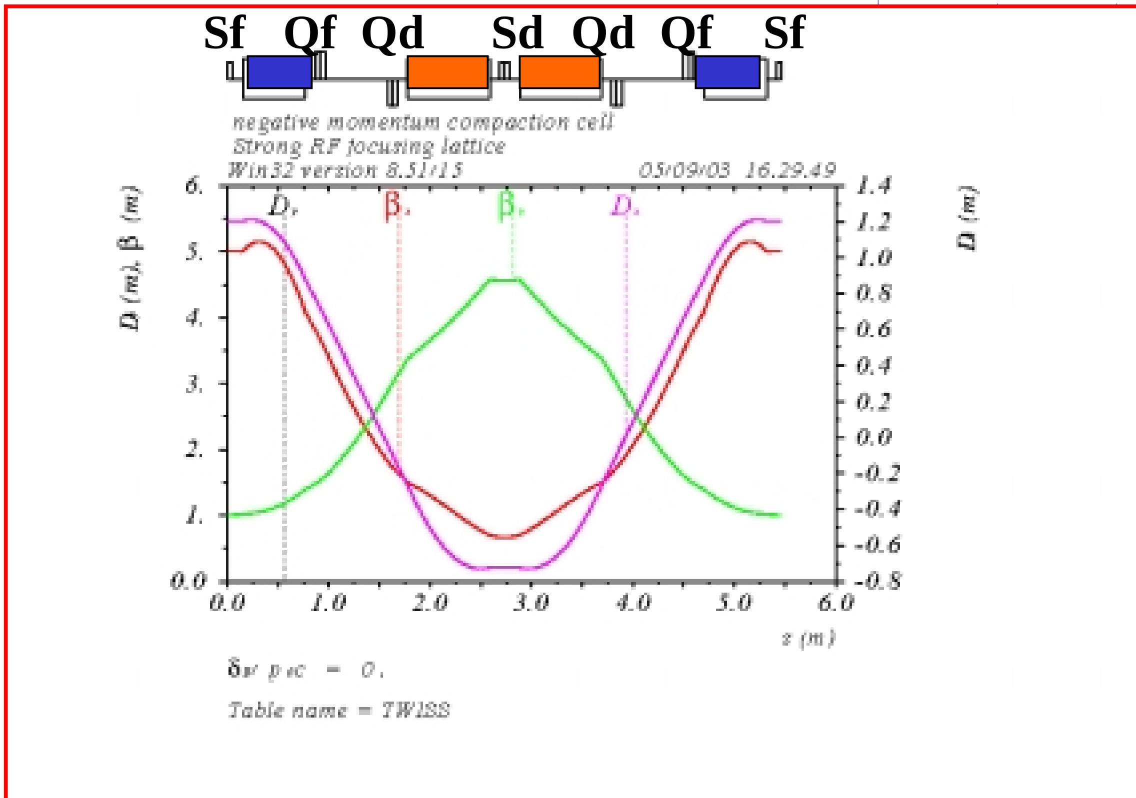
$$\cos\mu = 1 - \pi \frac{\alpha_c L}{\lambda_{rf}} \frac{V_{rf}}{E/e}$$

High |momentum compaction|
+ high Voltage

HIGH and NEGATIVE MOMENTUM COMPACTION

strong RADIATION emission





Alternating positive and negative bending dipoles

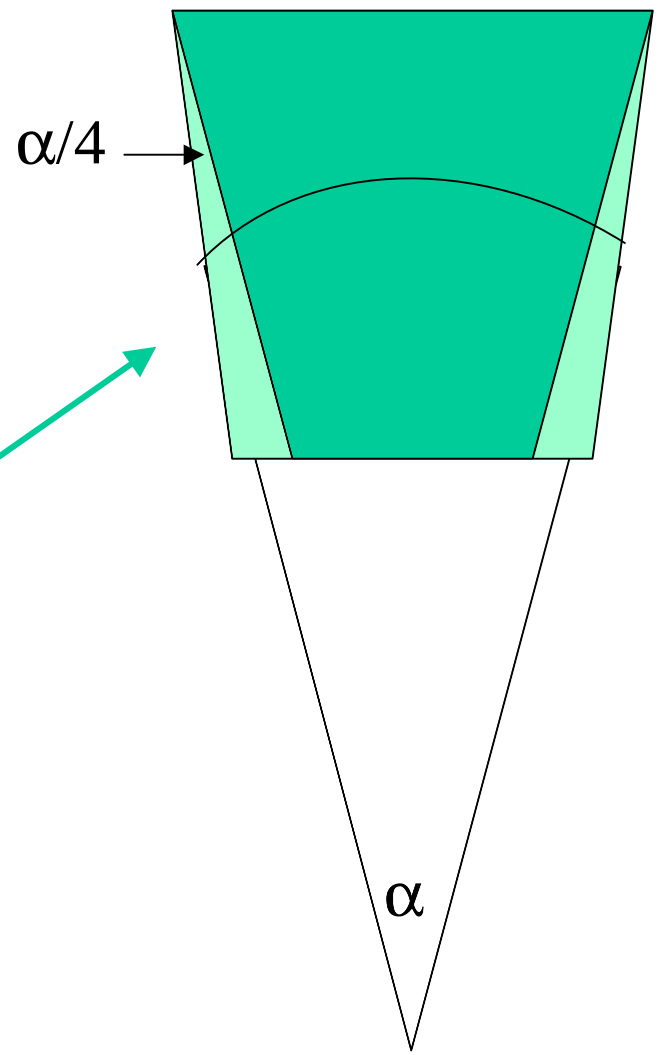
(proposed by Raimondi)

Dipoles

Sector magnet:
horizontal focusing

Rectangular magnet:
Vertical focusing

In between:
(H + V)/2 focusing



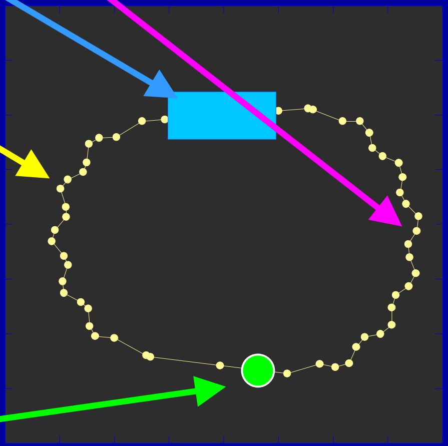
Layout similar to present DAΦNE rings:

One IR

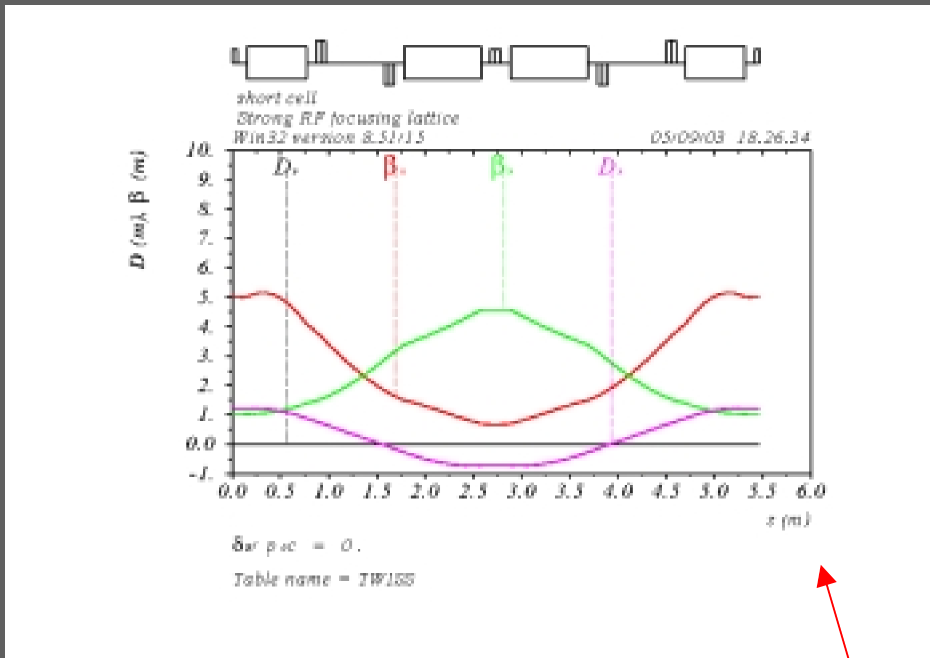
Second crossing for injection, rf, diagnostics

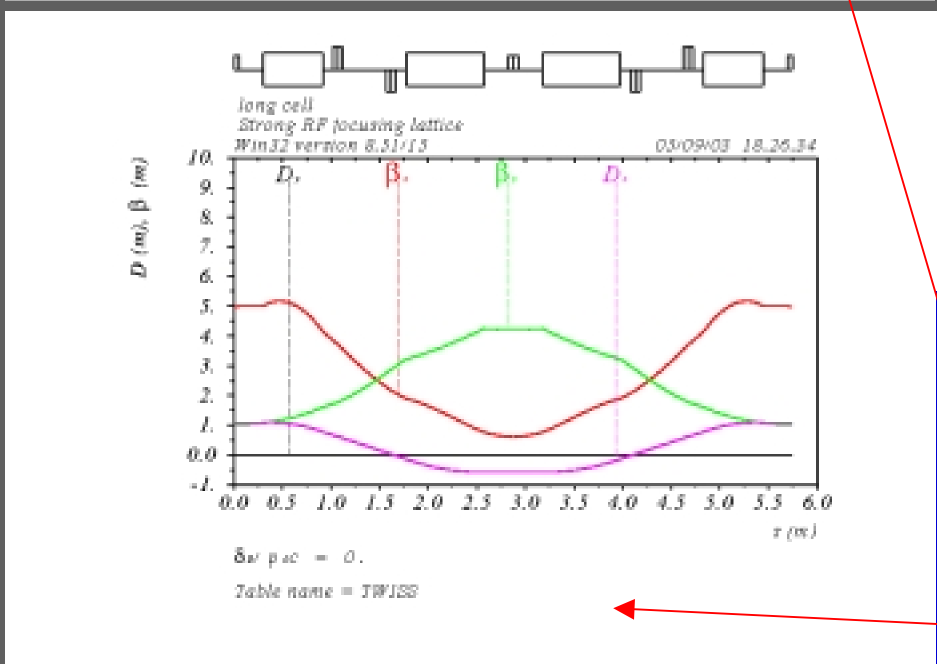
Short inner arc and long outer arc with the condition of equal longitudinal phase advance between cavity and IP in both directions

$$R_{56}(rf \rightarrow IP) = R_{56}(IP \rightarrow rf)$$



rf

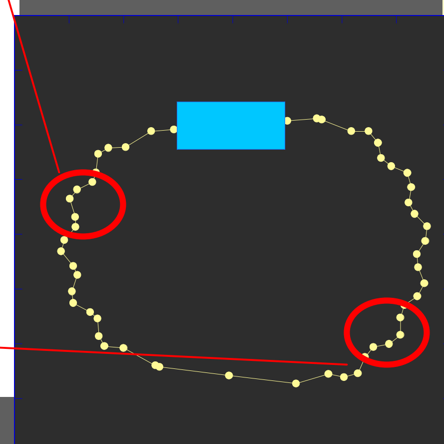




Long arc : 6 cells
Short arc : 5 cells

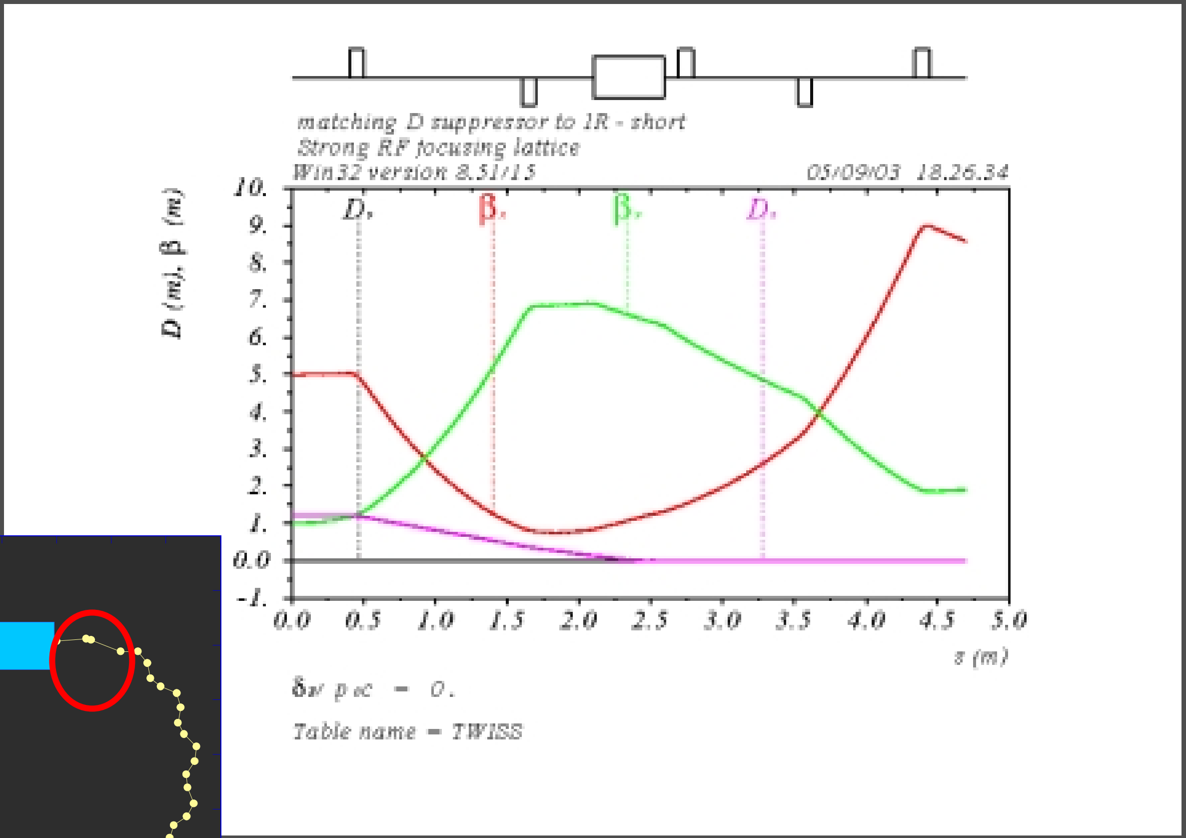
Same magnetic elements
Different drifts and quads settings

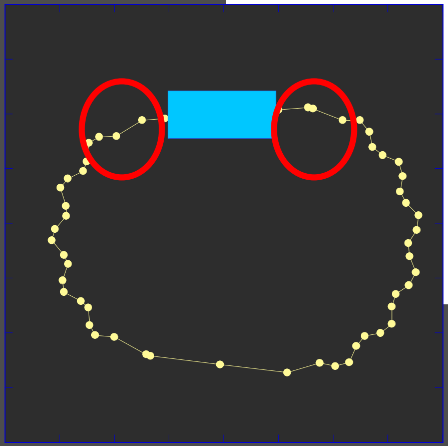
R_{56} (5 SHORT CELLS) =
R_{56} (6 LONG CELLS)



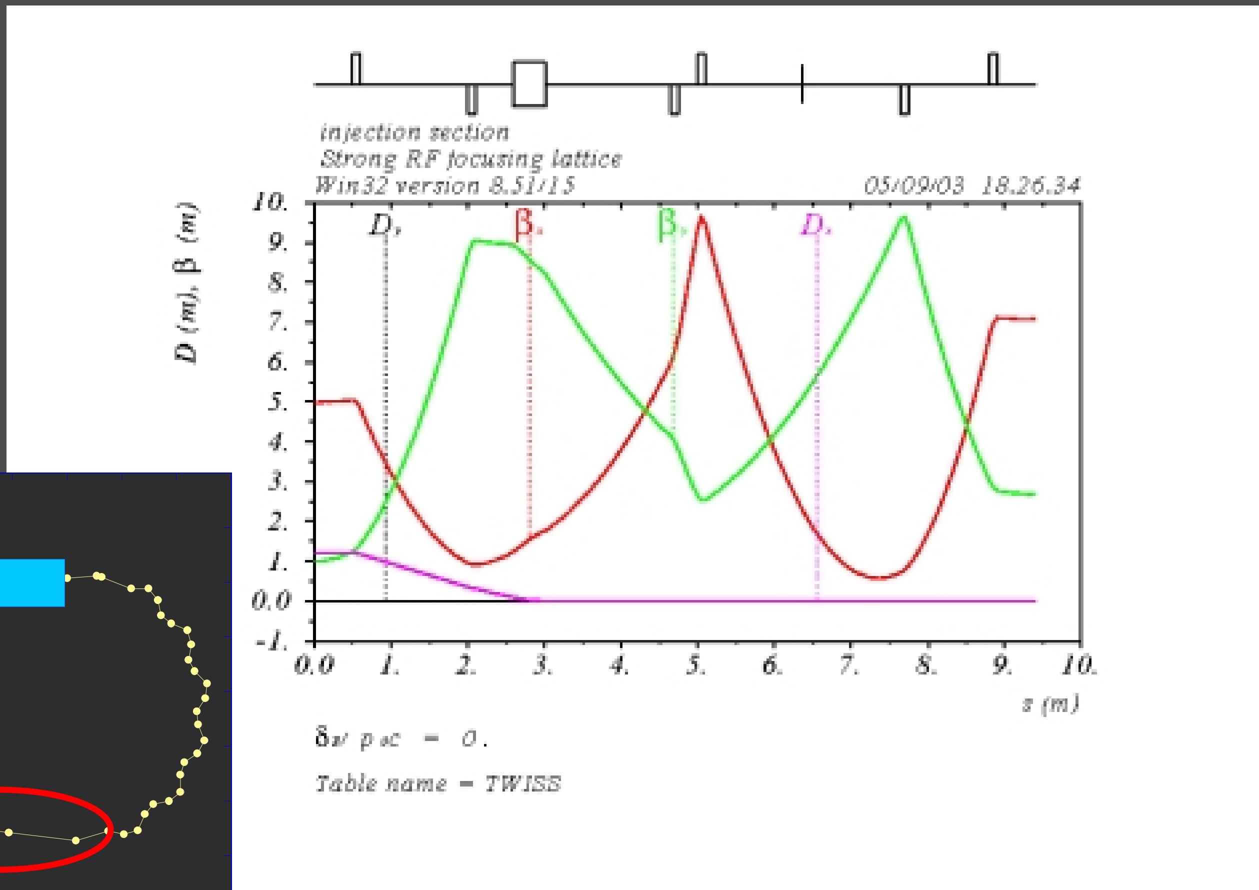
$$\int_{RF}^{IP} \frac{\eta}{\rho} ds = \int_{IP}^{RF} \frac{\eta}{\rho} ds$$

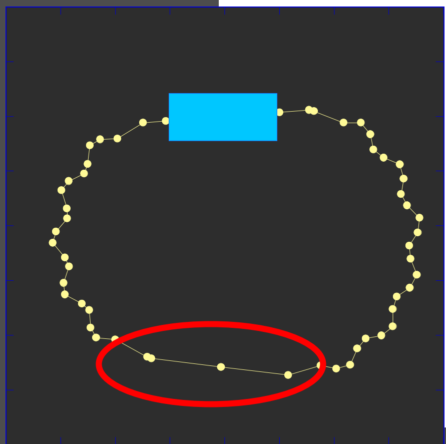
ARCS to IR : Dispersion suppressors

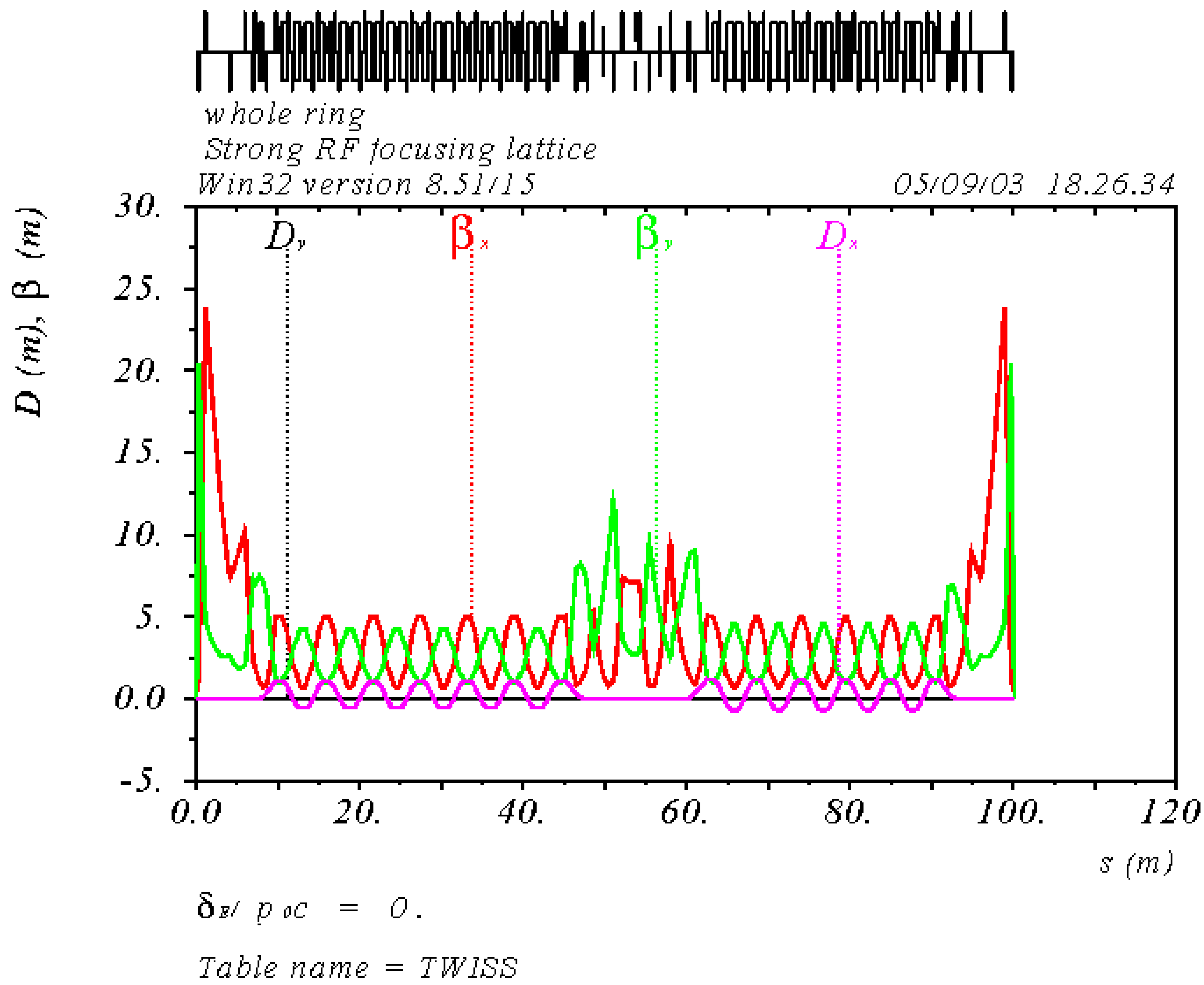




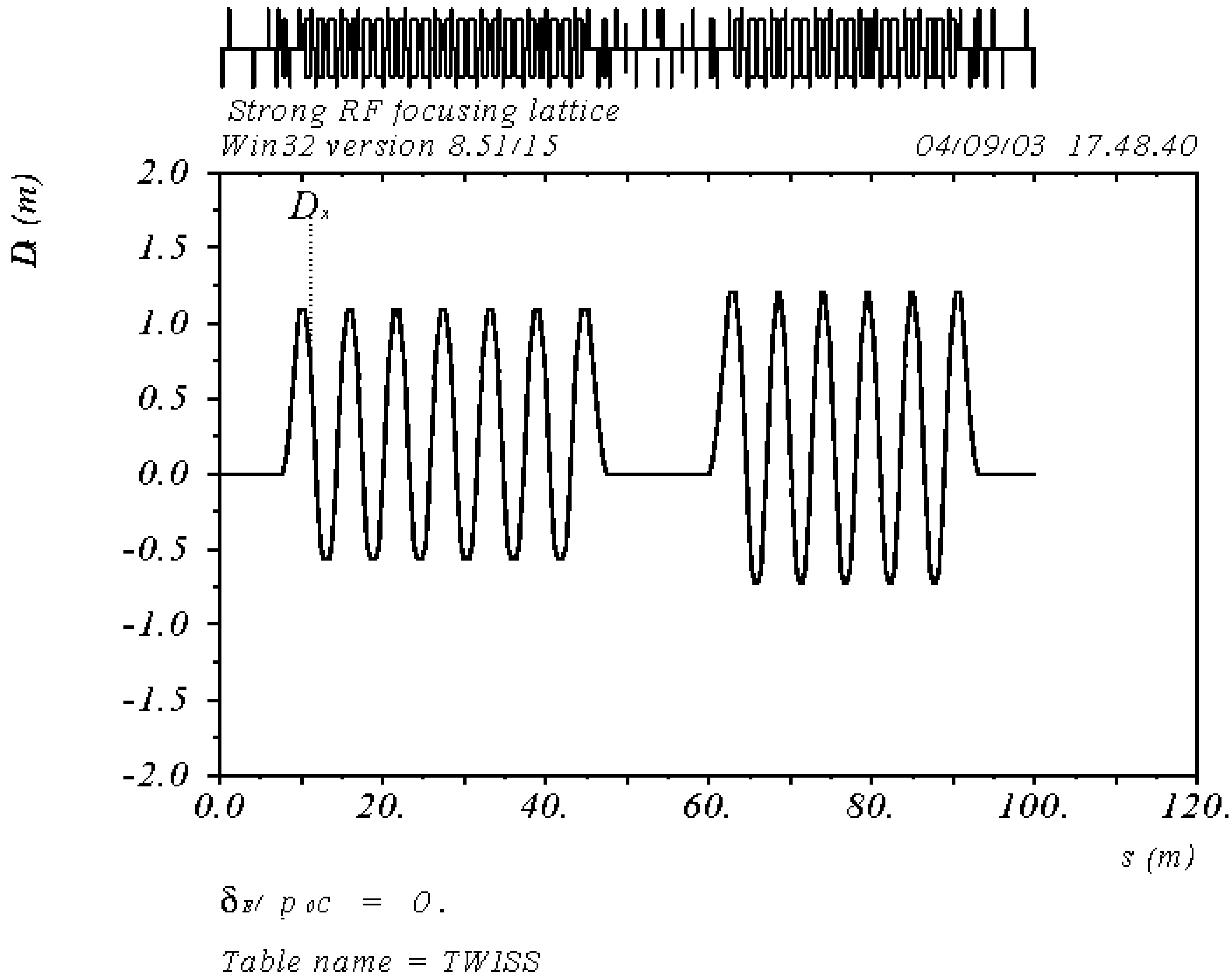
ARCS to Injection and rf section, with D suppressor







whole ring
Strong RF focusing lattice
Win32 version 8.51/15
05/09/03 18.26.34
D (m), β (m)
30.
25.
20.
15.
10.
5.
0.0
-5.
0.0
20.
40.
60.
80.
100.
120.
s (m)
D_y
β_x
β_y
D_x
δE/ p0c = 0.
Table name = TWISS


Strong RF focusing lattice
Win32 version 8.51/15
04/09/03 17.48.40
D (m)
Dx
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
0.0
20.
40.
60.
80.
100.
120.
s (m)
δE/ p0c = 0.
Table name = TWISS

Maximum bunch length at cavity
Minimum bunch length at IP

$$\sigma_z(Cav) = \frac{\alpha_c L}{\sin\mu}\left(\frac{\sigma_E}{E}\bigg|_0\right)\sqrt{\frac{2+\cos\mu}{3}}; \quad \sigma_z(IP) = \alpha_c L\left(\frac{\sigma_E}{E}\bigg|_0\right)\sqrt{\frac{2+\cos\mu}{6\,(1-\cos\mu)}}$$

α_c = - 0.23

L = 100 m

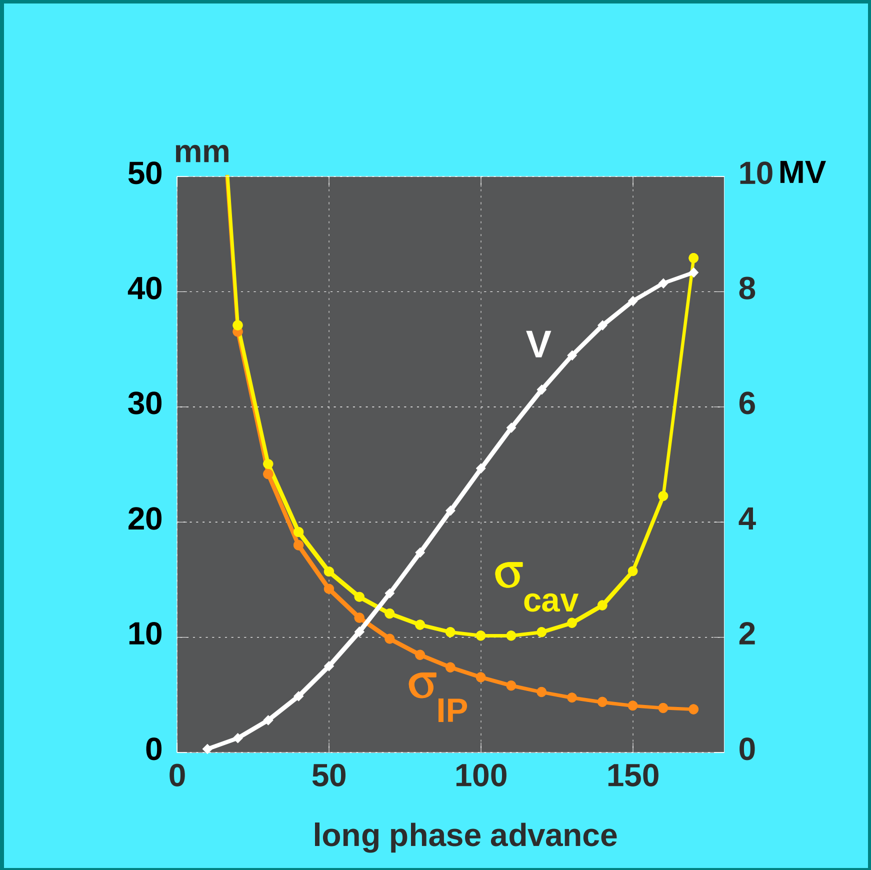
$\sigma_e/E|_o = 5\ 10^{-4}$

V = 8.2 MV

$\mu = 165^o$

σ_{cav} = 30 mm

σ_{IP} = 3.8 mm



Synchrotron radiation

$B\rho$ = 1.7 Tm
B = 1.8 T
ρ = 0.94 m
$2\pi = 11\ \theta_{cell} + \theta_{DS}$

$\theta_{cell} = 2 * 48.86^o - 2 * 37.5^o = 22.72^o$

$|\theta_{rad}| = 2 * 48.86^o + 2 * 37.5^o = 172.72^o$

$L_{rad} = \rho\ (11\ |\theta_{rad}| + \theta_{DS}) = 5.6\ (2\pi\ \rho) = 33$ m

Radiation Integrals

$$I_1 = \oint \frac{\eta}{\rho} ds = -23.2m$$

$$I_2 = \oint \frac{ds}{\rho^2} = 37.1m^{-1}$$

$$I_3 = \oint \frac{ds}{|\rho|^3} = 39.3m^{-2}$$

$$I_4 = \oint \frac{\eta}{|\rho|^3} ds = -26.0m^{-1}$$

$$I_5 = \oint \frac{H}{|\rho|^3} ds = 44.4m^{-1}$$

Damping times

$$U_o = \frac{C_\gamma}{2\pi} E^4 I_2 = 35\, keV / turn$$

$$A_i = A_{i,o}\, e^{-\alpha_i t}$$

$$\alpha_x = \frac{C_\alpha}{C} E^3 (I_2 - I_4)$$

$$\alpha_y = \frac{C_\alpha}{C} E^3 I_2$$

$$\alpha_s = \frac{C_\alpha}{C} E^3 (2I_2 + I_4)$$

Usually : $0 < I_4 << I_2$

$\alpha_x = \alpha_y$

Here $I_4 < 0$

Shorter horizontal damping time

$$\tau_x = 5.6\, \mathrm{msec}$$

$$\tau_x = 9.6$$

$$\tau_s = 7.4$$

Transverse plane parameters

	X	Y
Q	8 + δQ	7 + δQ
Q'	-8.	-20.

$$\varepsilon_x = C_q \frac{\gamma^2}{J_x} \frac{I_5}{I_2} = 0.26 \mu rad$$

$$\varepsilon_y < 0.2\,10^{-2} \mu\, rad \quad \Leftrightarrow \kappa < 0.8\%$$

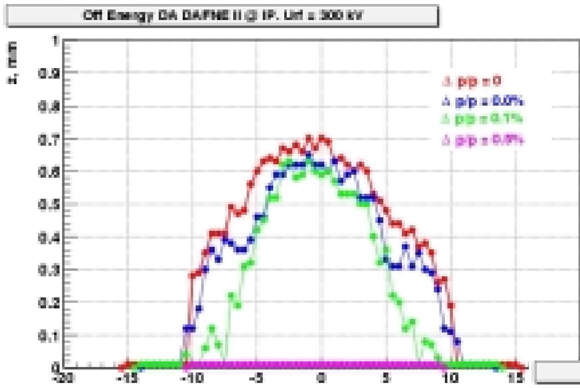
Dynamic aperture

First evaluation by
E.Levichev, P.Piminov[*)]
BINP, Lavrentiev 13, Novosibirsk 630090, Russia

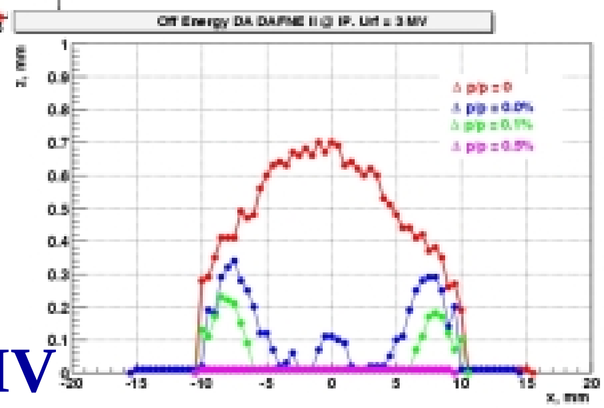
ACCELERATICUM computer code [*]
Symplectic 6-D tracking for transversely and longitudinally coupled magnetic lattice

[*] Tracking code ACCELERATICUM, VEPP-4M Internal Note, BINP, Novosibirsk, 2003.

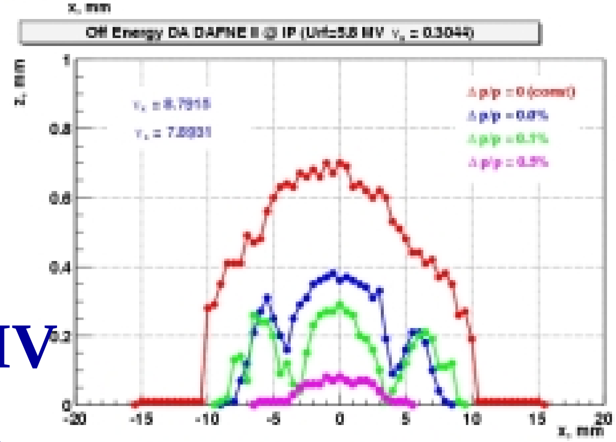
----- no synchr oscill
----- Dp/p = 0
----- Dp/p = 0.1%
----- Dp/p = 0.5%



V = 300 kV
Q_s = 0.059



V = 3 MV
Q_s = 0.2



V = 5 MV
Q_s = 0.3

Strong dependence on V
but specially on Q_s
=> Resonances in 3D

Resonant condition for the tune-amplitude dependence expressions in presence of synchrotron oscillation:

$$m_x\left(\nu_{xo}+C_{xx}A_x^2+C_{xz}A_z^2\right)+m_z\left(\nu_{zo}+C_{zx}A_x^2+C_{zz}A_z^2\right)+k\nu_s=n$$

Now suppose that at every point of the dynamic aperture curve we have some particular betatron resonance that limits the stable area in this point. Then the synchrotron motion generates a set of satellite resonances, which are represented by lines at the amplitude plane .

Considering for example only the horizontal resonance and main (strongest) satellite (k=1, m_z =0) , the horizontal position of the satellite resonance line can be deduced:

$$A_x=A_{xo}\sqrt{1-\frac{\nu_s}{m_s\delta}}$$

where δ is the distance from the resonance and A_{xo} the position of the original (ν_s = 0) betatron resonance on the amplitude plane.

1. **More detailed investigation of the satellite behaviour for the weak, strong and intermediate RF focusing, including the satellites amplitude values.**
2. **Dependence of dynamic aperture in the case of the strong RF focusing on the tune point is to be explored (in other words, more accurate choosing of the betatron and synchrotron tunes). It seems that all the three tunes are important now.**
3. **As the satellites resonances location depends of the detuning coefficients, it is necessary to check if it possible to control it by octupole magnets.**

Luminosity 10^{34}

$$N^{+,-} = 5\ 10^{10}$$

$$\beta_x = 0.5\,m$$

$$\beta_y = 4\,mm$$

$$\varepsilon_x = 0.26\,\mu rad$$

$$\kappa = 0.6\%$$

$$n_b = 150$$

$$I_b = 24\,mA$$

$$I_{tot} = 3.7\,A$$

challenges

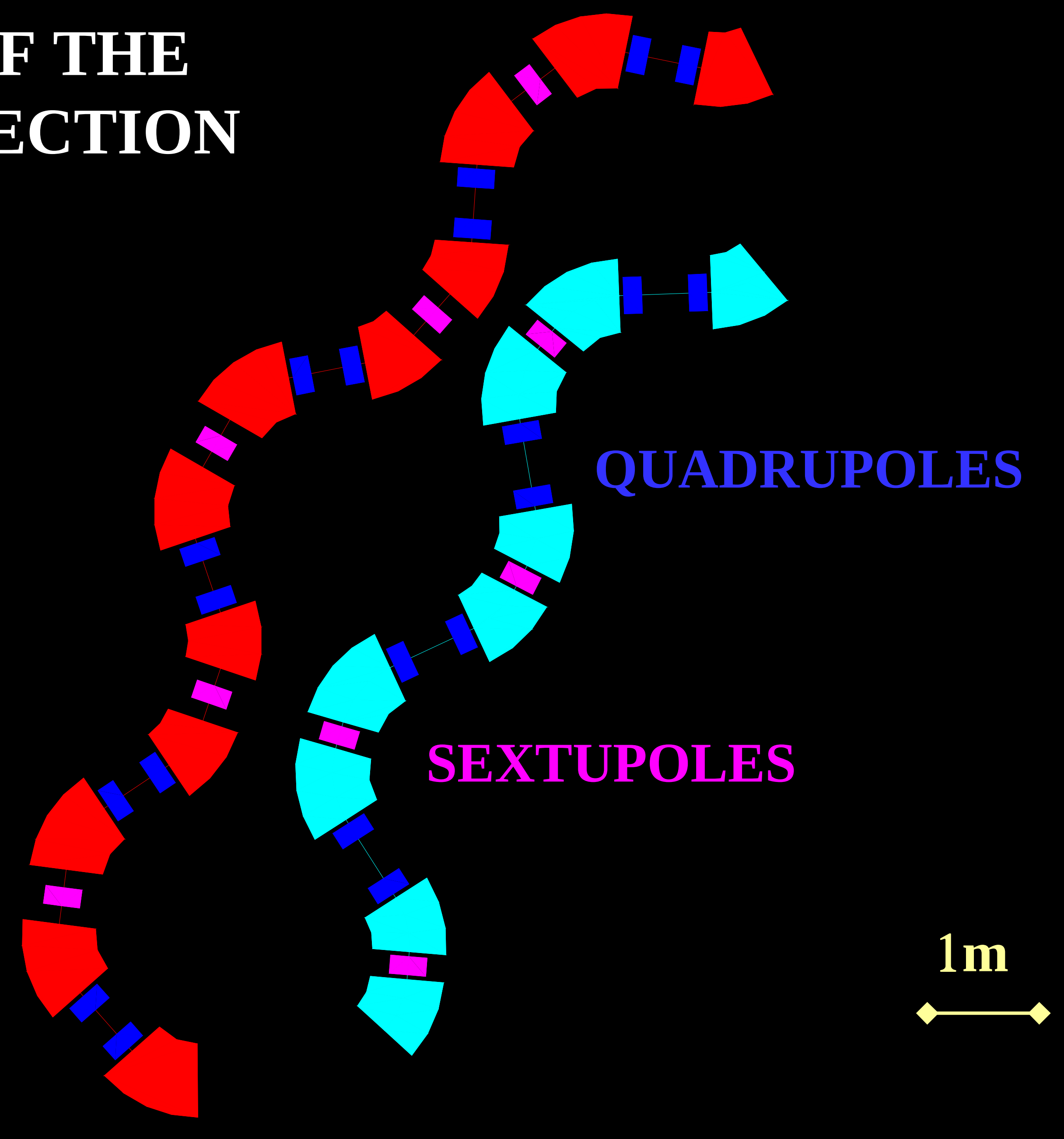
MAIN PARAMETERS	
C (m)	100
E (MeV)	510
f_{rf} (MHz)	503
V (MV)	8.2
ε_x (μ rad)	0.26
ε_y (μ rad)	0.002
α_c	- 0.23
β_x* (m)	0.5
β_y* (mm)	4.0
N / bunch	5 e10
h	168
L /bunch (cm^{-2} sec^{-1})	6 10^{31}
L tot (cm^{-2} sec^{-1})	10^{34}

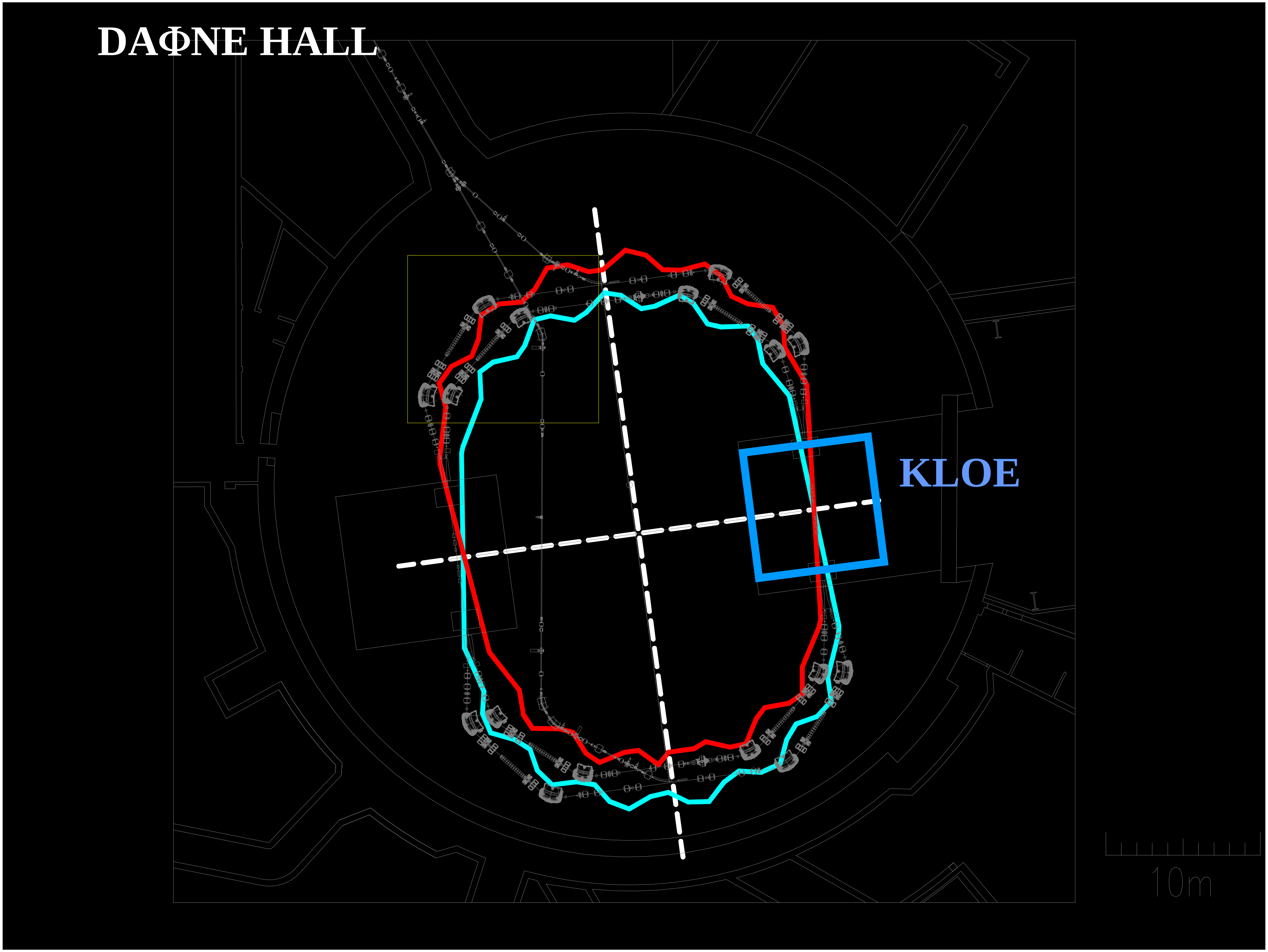
MAGNETS

	N/ring	characteristics
DIPOLES	48	B = 1.8 T Alfa = 30, -37.5, 48
QUADRUPOLES	66 (26)	K_1L_{max} = 1. m^{-1}
SEXTUPOLES	44 (4)	K_2L_{max} = 10 m^{-2}

Minimum independent power supplies

ZOOM OF THE RINGS SECTION




DAΦNE HALL
KLOE
10m

For the discussion

M.Serio, A. Ghigo, J.Fox

Possibility of testing the strong RF focusing in an existing machine ?

PEP2, KEK-B , CESR