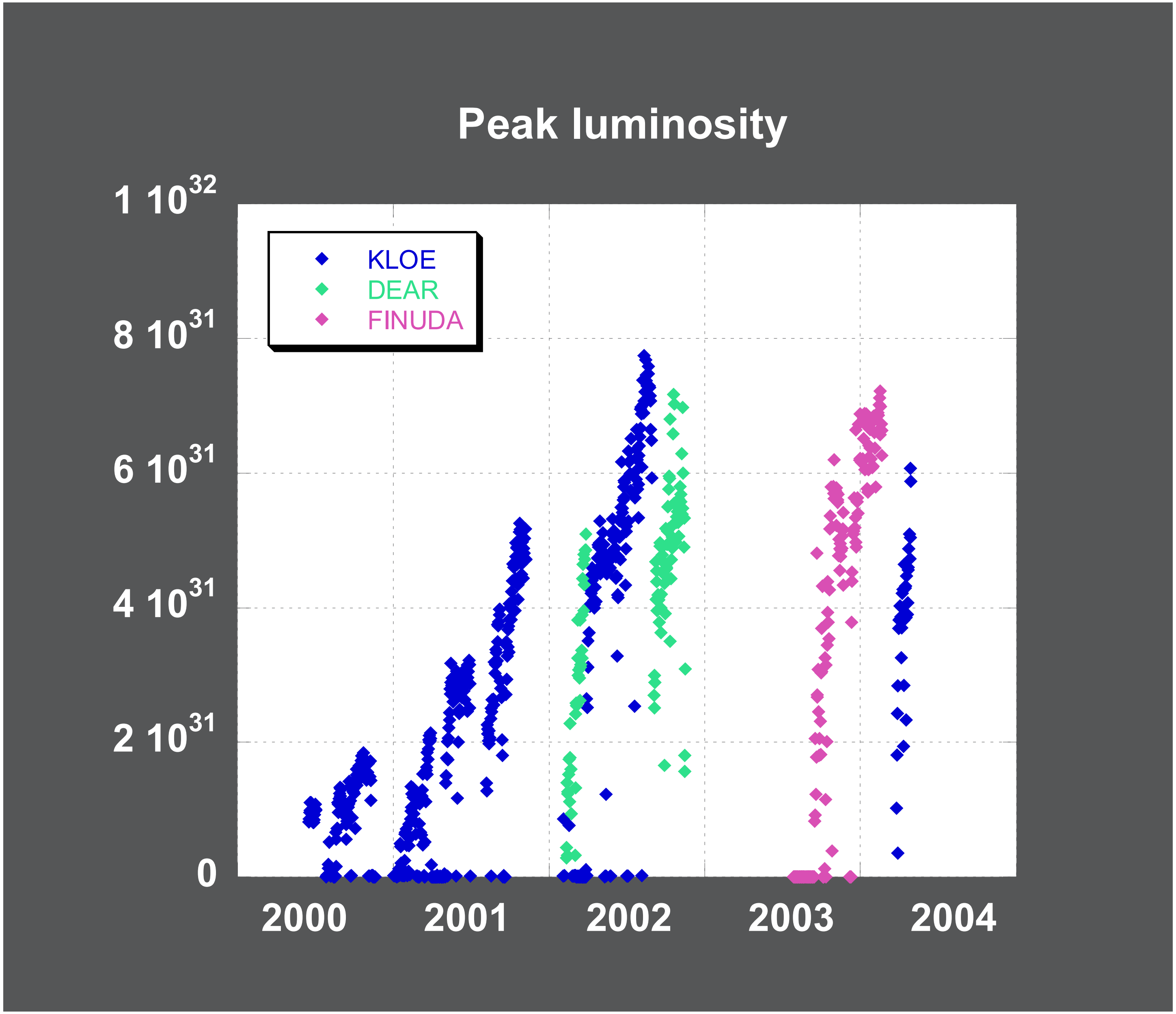
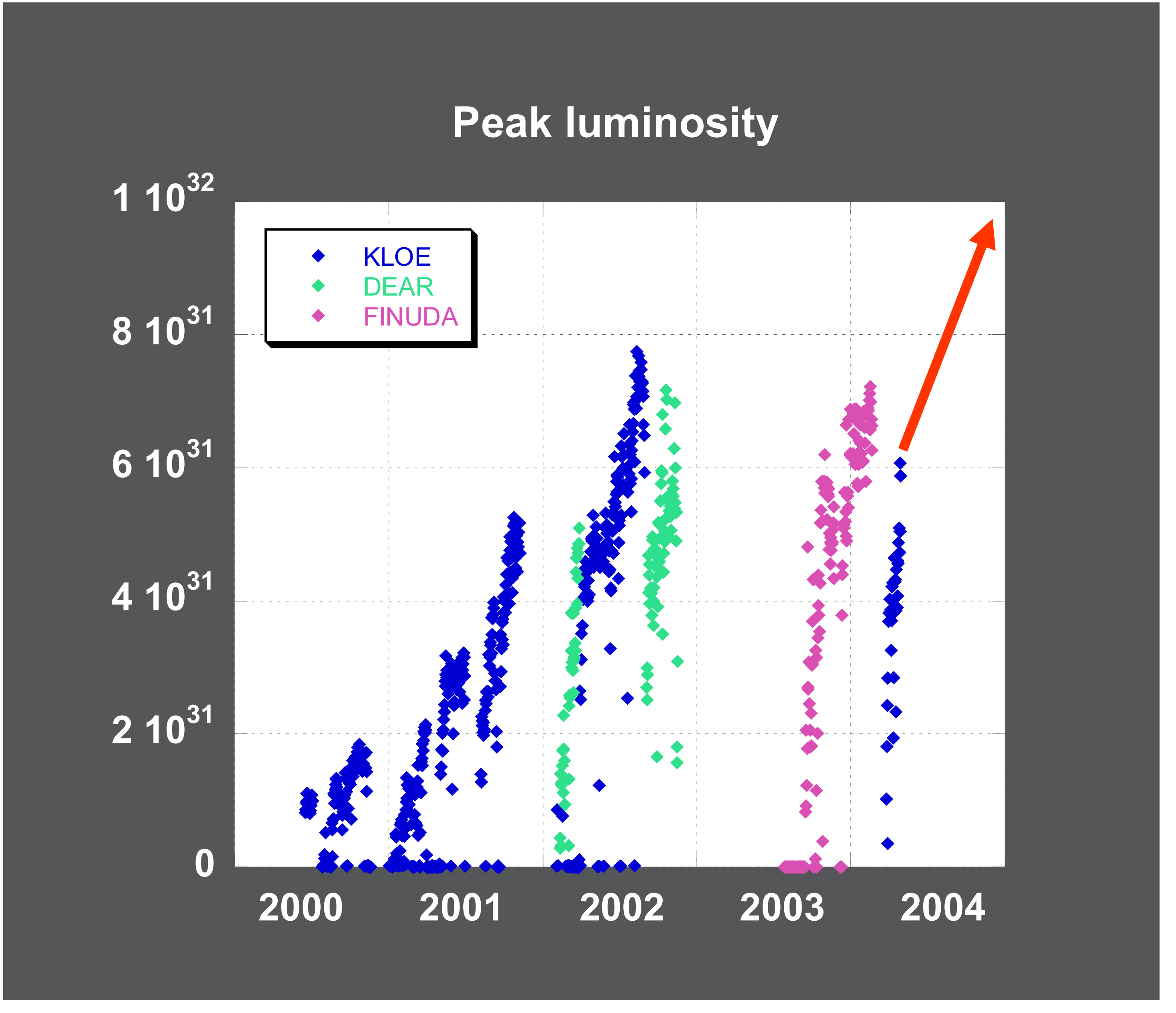
Future of DAΦNE

C. Biscari
for the DAΦNE team

KLOE meeting, June 2004,
Karlsruhe


Peak luminosity
1 10^32
8 10^31
6 10^31
4 10^31
2 10^31
0
KLOE
DEAR
FINUDA
2000
2001
2002
2003
2004


Peak luminosity
1 10^32
8 10^31
6 10^31
4 10^31
2 10^31
0
KLOE
DEAR
FINUDA
2000
2001
2002
2003
2004

From there on

- **No major upgrades**
- **Minimum change for E upgrade**
- **New machine for E upgrade and L > 10^{33}**
- **New machine for L >10^{34}**

Evolution with no major upgrades

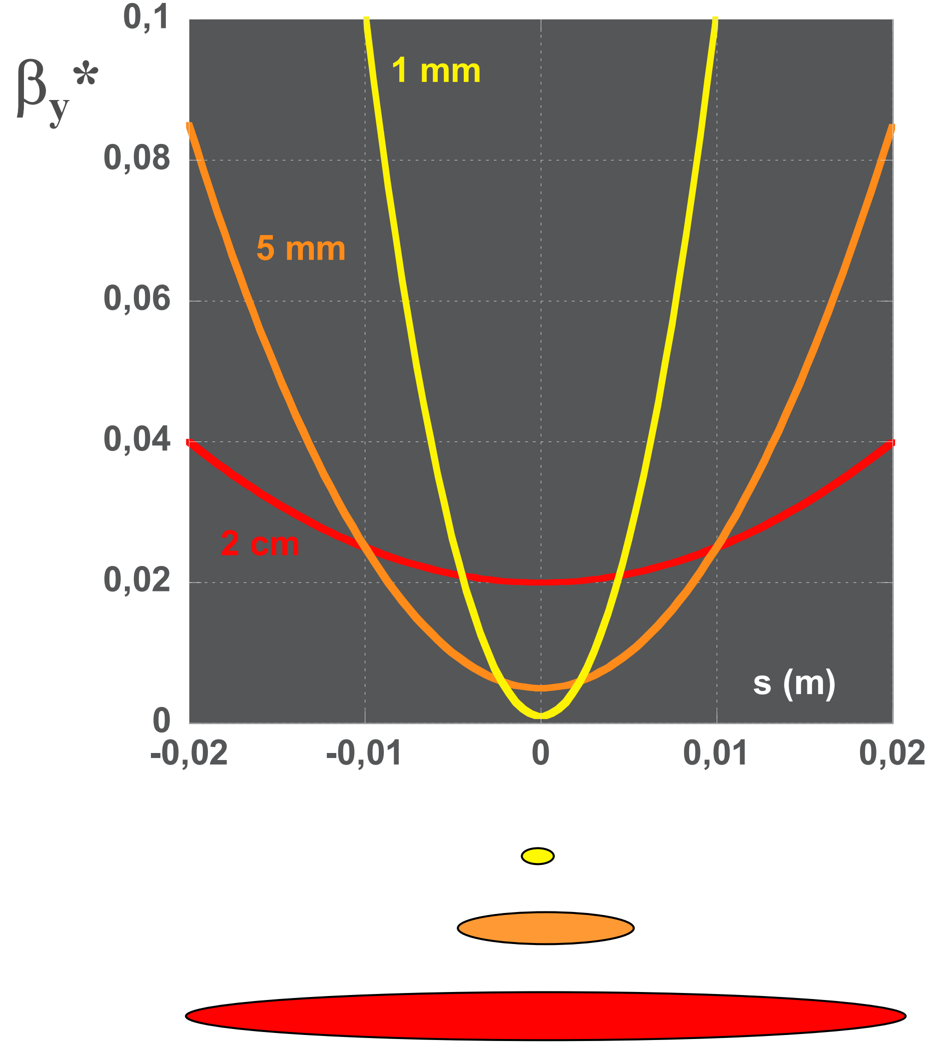
	K Physics	Hyper-nuclei	Exotic atoms		
2004 2006	2 10^{32} >2 fb^{-1}	10^{32} 0.5 fb^{-1}	10^{32} 0.5 fb^{-1}		
2007 2010	>2 10^{32} 10 fb^{-1}	>2 10^{32} >1 fb^{-1}			
2010					
	KLOE	FINUDA	DEAR		

L > 10 ^{32}

- **Negative momentum compaction: shorter bunch**
- **Lower β_y**
- **Reaching 2 A per beam**

“hourglass” effect

Gain in luminosity by squeezing vertical dimensions only if the bunch length is also decreased

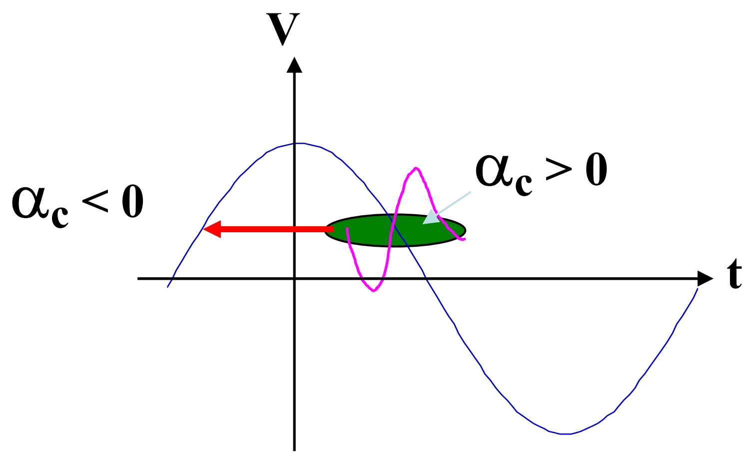


Bunch length

Momentum compaction α_c

relates longitudinal position and energy deviation

$$\Delta l = \alpha_C \frac{\Delta p}{p}$$



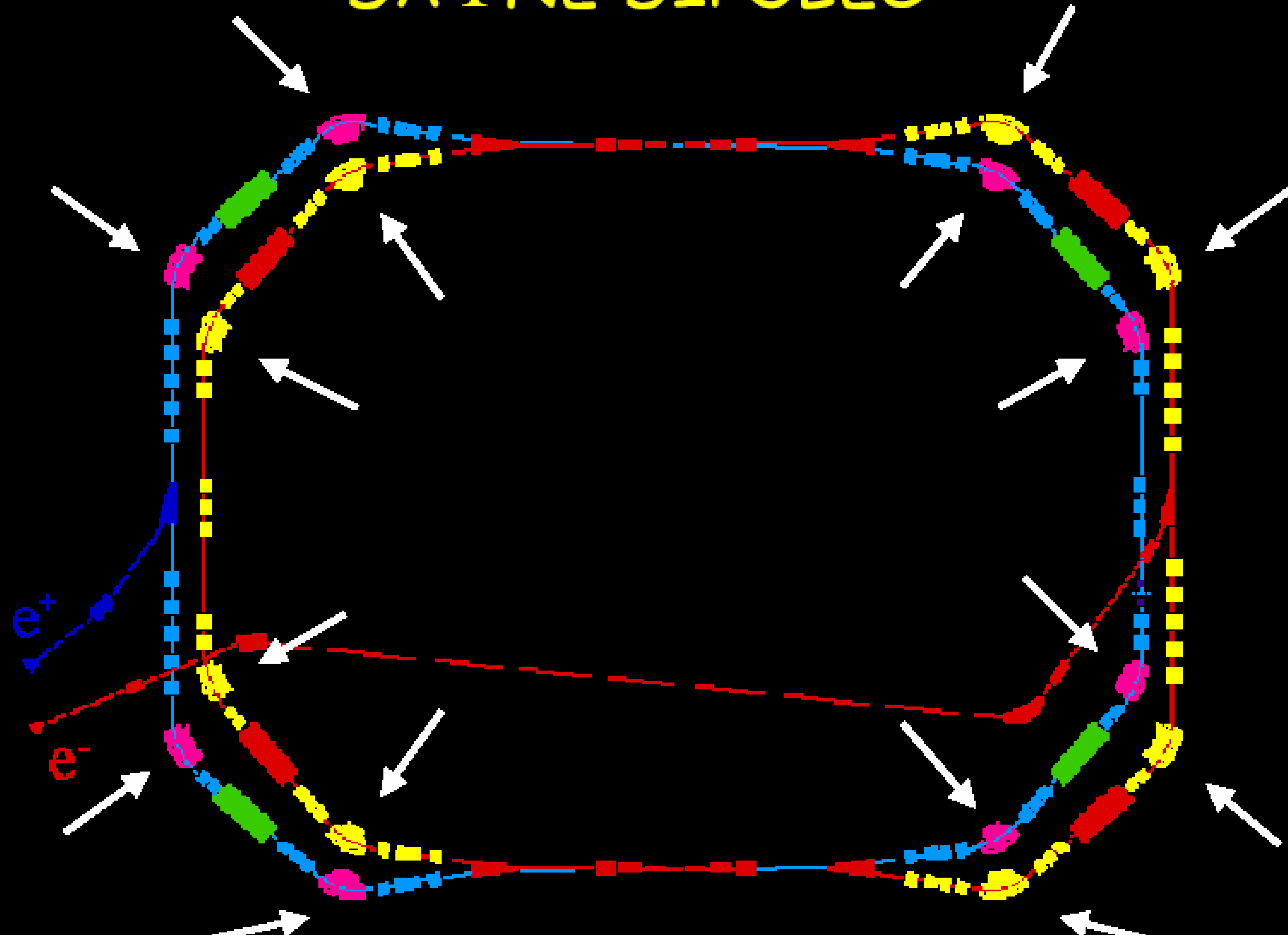
Bunch is shorter with a more regular shape
Longitudinal beam-beam effects are less dangerous
Microwave instability threshold is higher
Sextupoles can be relaxed since head-tail disappears

Minimum modifications for E & Φ upgrade

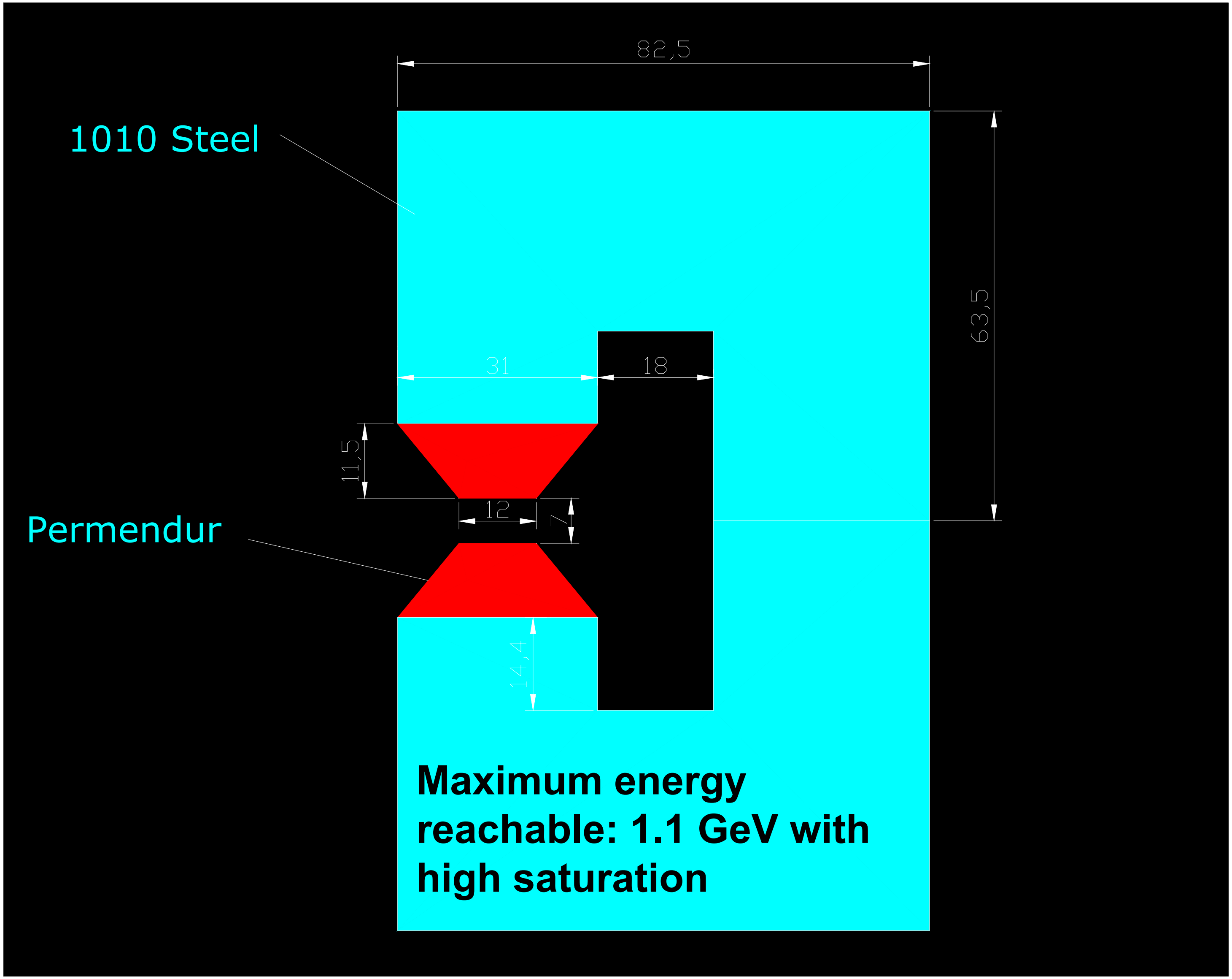
	K Physics	Hyper-nuclei	Exotic atoms	1 to 2.2 GeV physics	>3 Gev
2004 2007	$2\ 10^{32}$ $>2\ fb^{-1}$	10^{32} $0.5\ fb^{-1}$	10^{32} $0.5\ fb^{-1}$		
2008 2010	$2\ 10^{32}$ $3\ fb^{-1}$	$2\ 10^{32}$ $1\ fb^{-1}$		10^{32} $1\ fb^{-1}$	
	KLOE	FINUDA	DEAR	n-nbar…	J/Ψ, τ...
Cost (M€)				10 Accel 10 Linac	

DAΦNE DIPOLES

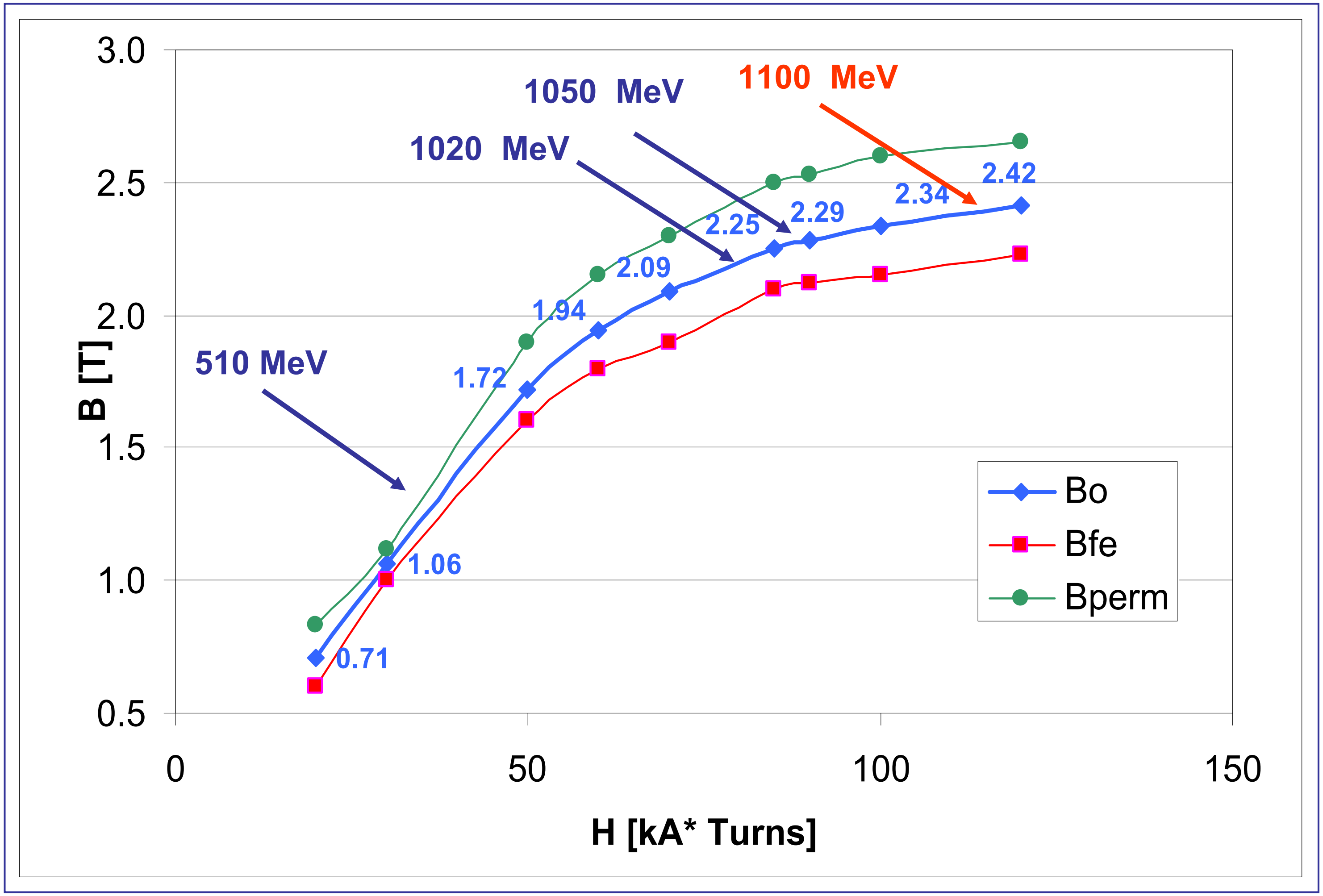
B=1.2 T



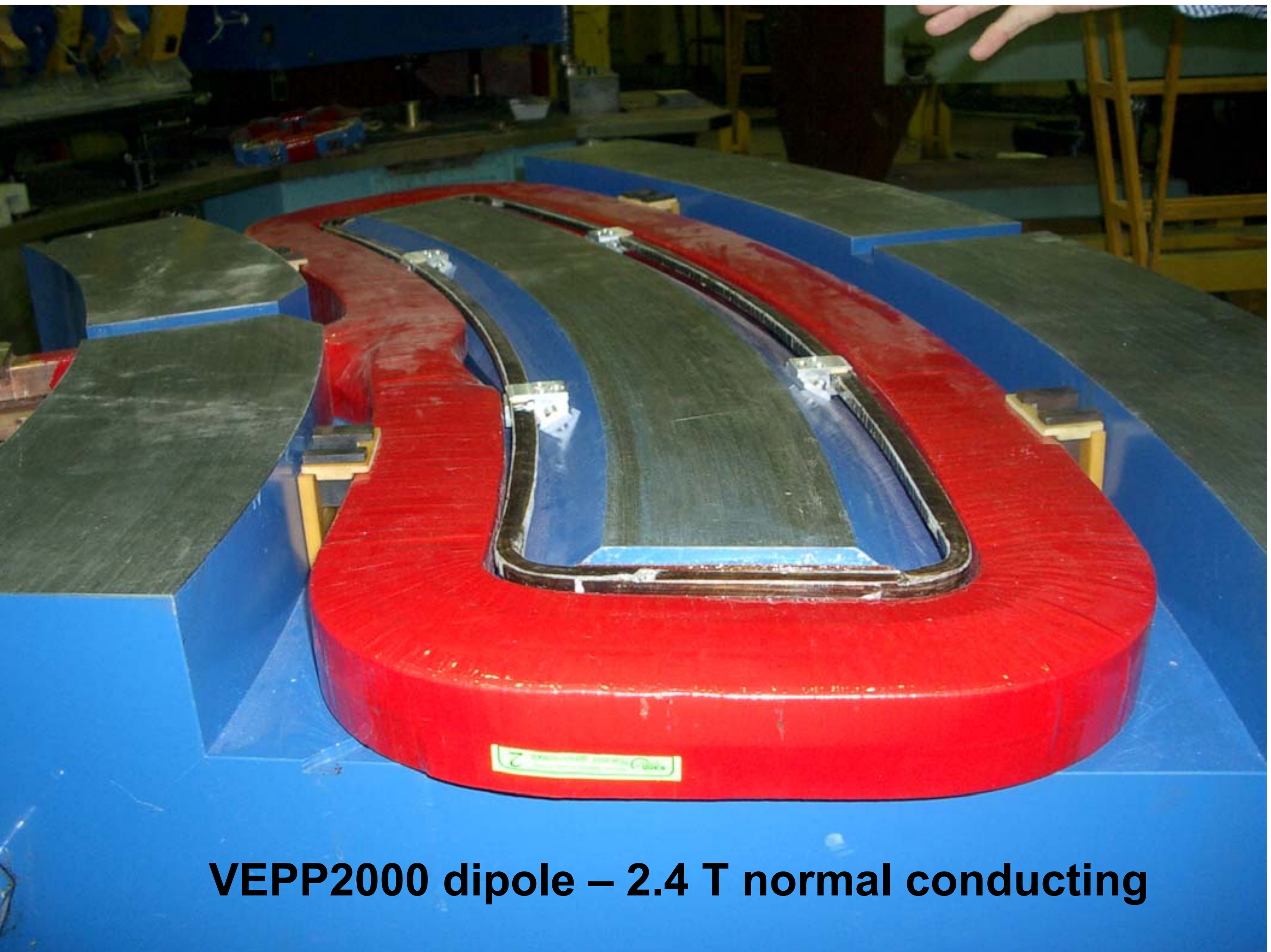
Dipole Section – preliminary design



Magnetization curve



Collaboration with BINP
(may 2004)



VEPP2000 dipole – 2.4 T normal conducting

Pavel Vobly looking at the possibility of designing a higher magnetic field dipole fitting our vacuum chamber and space constraints

Φ and n-nbar sharing DAFNE

Energy (GeV)	0.51	1.1
Current (A)	1 - 2	0.5
Luminosity (10^{32})	2	1
N bunches	100	30
I/bunch (mA)	10-20	17
τ damping (msec)	70/40	11/9
Uo (keV)	4.3 / 9.3	64 / 84
τ (h)	<1	> 4

SC DAFNE for upgrade E & L @ Φ

	K Physics	Hyper-nuclei	Exotic atoms	1 to 2.2 GeV physics	>3 Gev
2004 2006	2 10^{32} 4 fb^{-1}	10^{32} 0.5 fb^{-1}	10^{32} 0.5 fb^{-1}		
2008 2012	10^{33} 10 fb^{-1}	10^{33} 1 fb^{-1}		>10^{32} >1 fb^{-1}	>10^{32} >1 fb^{-1}
	KLOE	FINUDA	DEAR	n-nbar…	J/Ψ, τ...
Cost (M€)				50 Accelerat 10 Linac	

Damping time vs energy

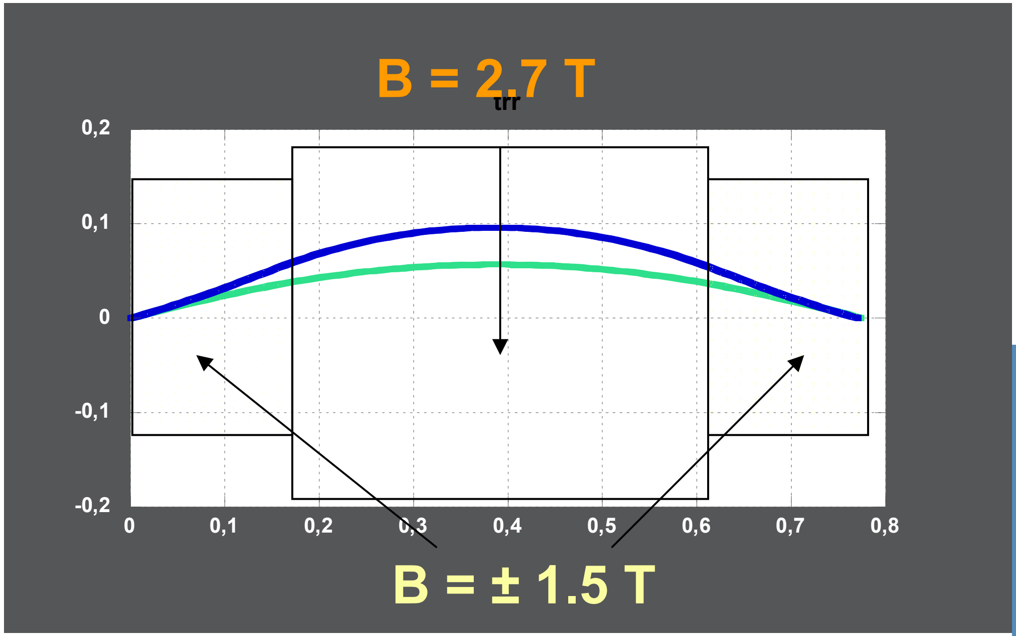
$$I_2 = \int_{dipoles} \frac{ds}{\rho^2}$$

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

$$U_o = C_\gamma \frac{E^4}{2\pi} I_2$$

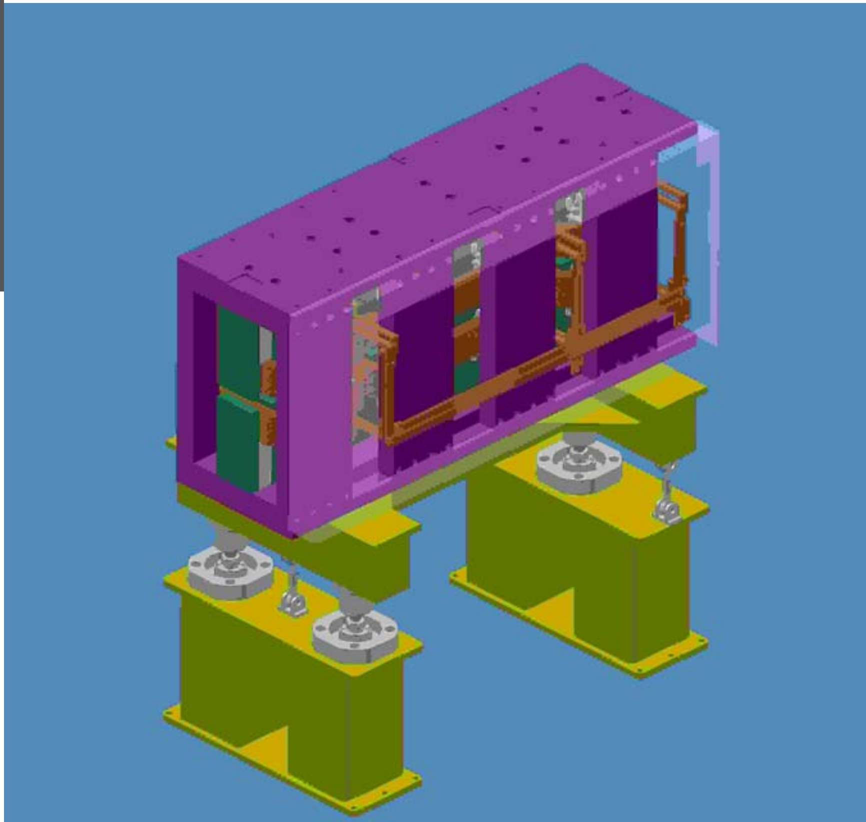
Optimization of luminosity at low energy by increasing I_2

Wiggler – dipole

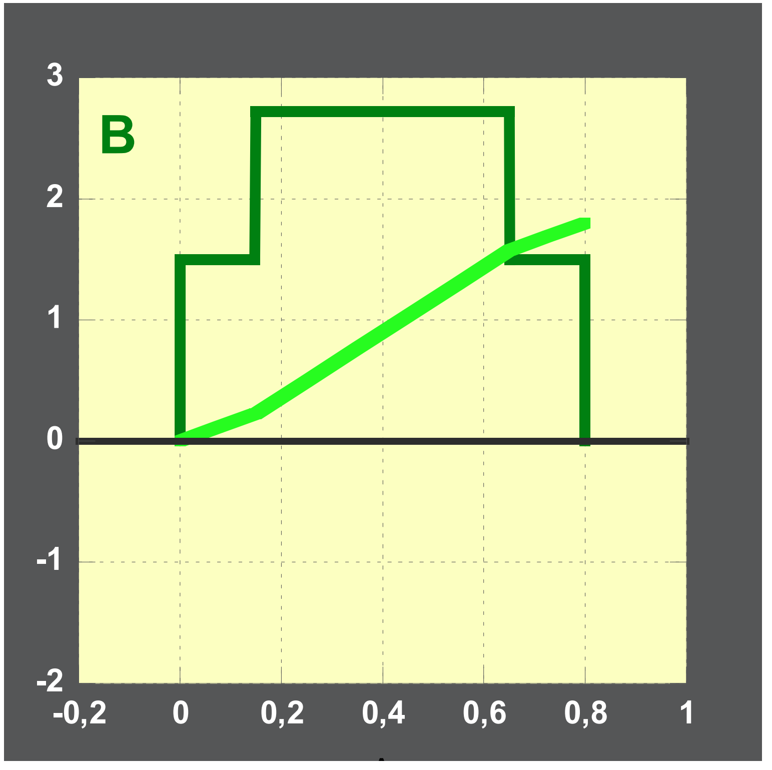


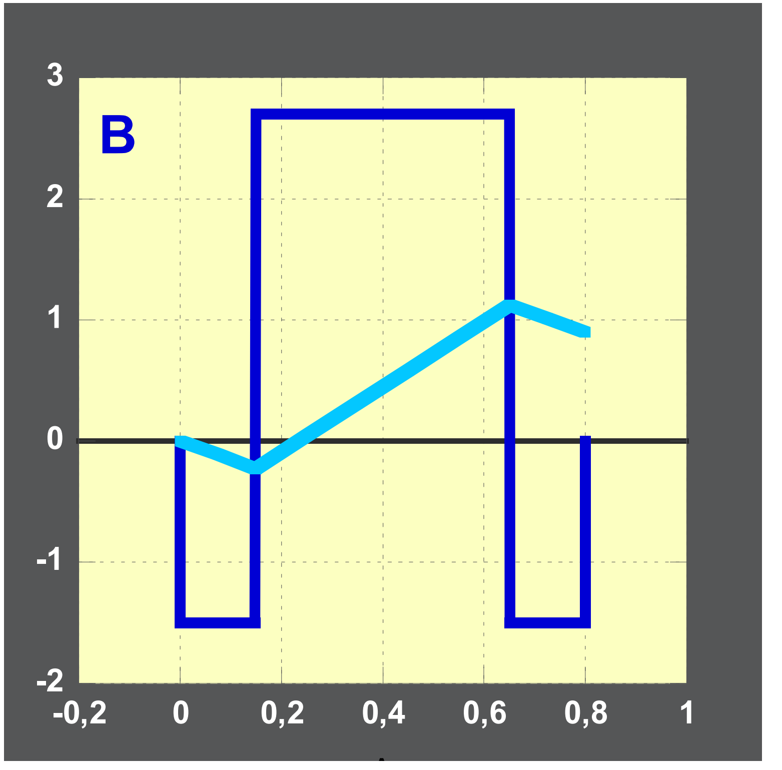
$$\theta = \frac{1}{B\rho}\oint B\,dl = 2\pi$$

$$I_2 = \int_{dipoles} \frac{ds}{\rho^2} = \int \frac{|B|^2}{(B\rho)^2} ds$$



Wiggler for CTF3 – in construction





E = 1.1 GeV

$\int Bds$ = 1.8 Tm

Bending angle = 30°

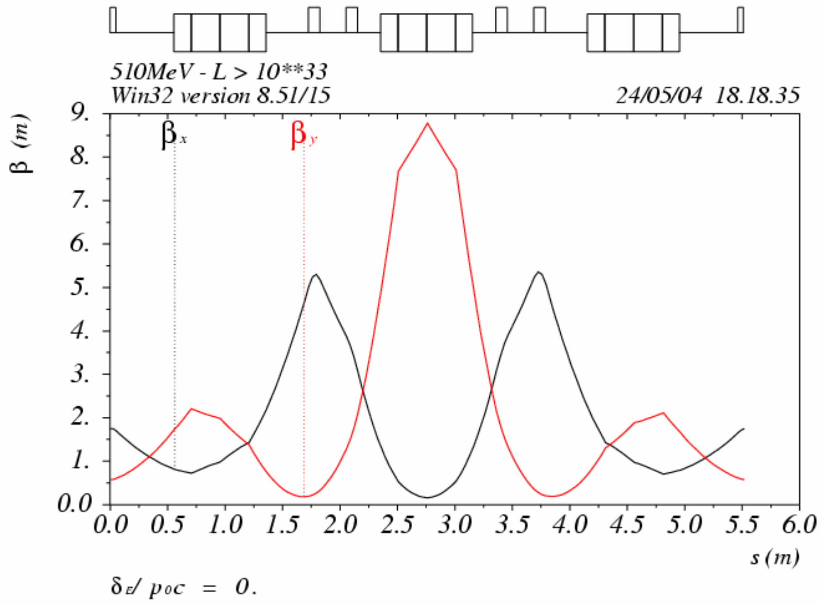
I_2 = 0.38 m^{-1}

E = 0.5 GeV

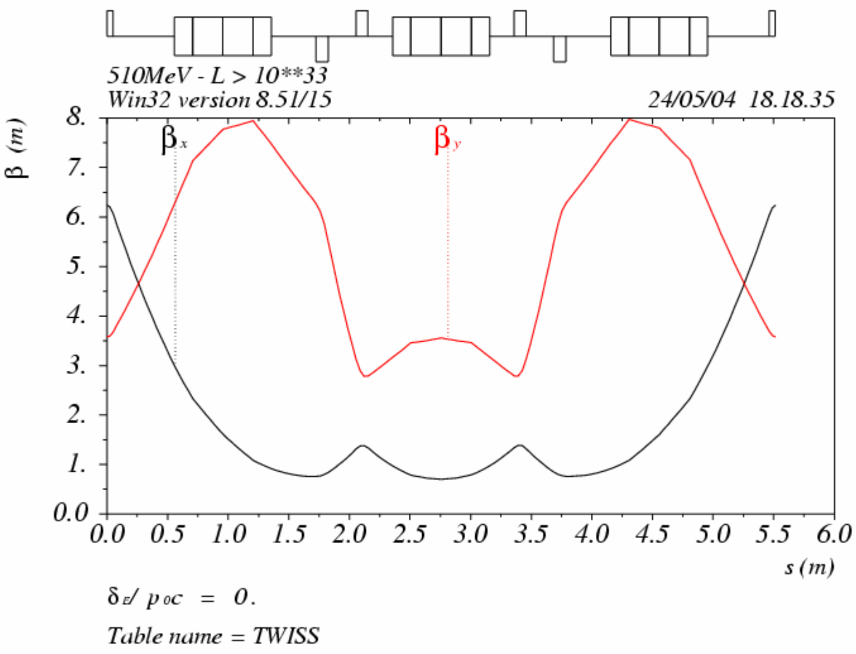
$\int Bds$ = 0.9 Tm

Bending angle = 30°

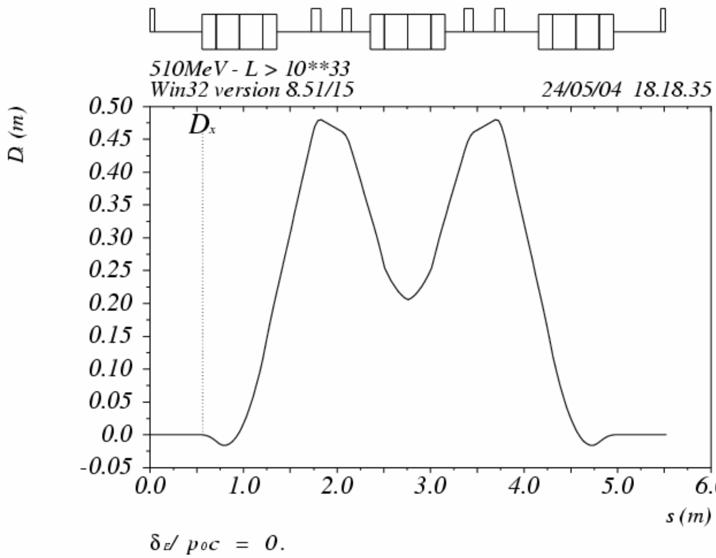
I_2 = 1.46 m^{-1}

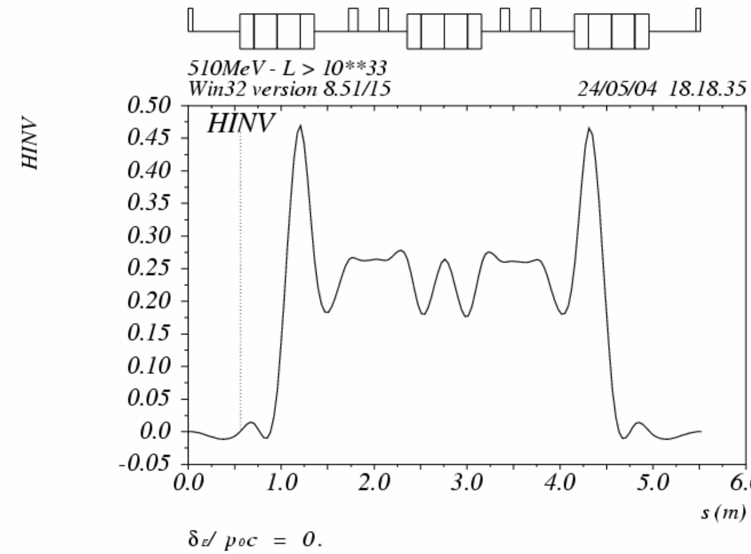


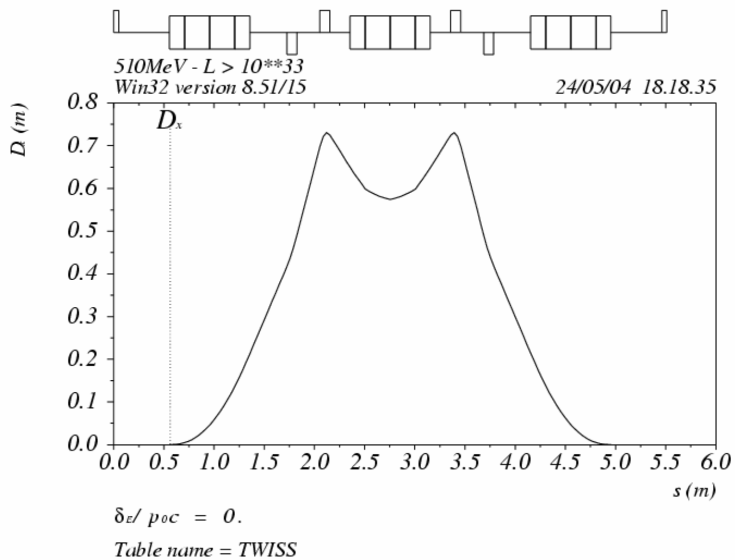
E = 0.5 GeV

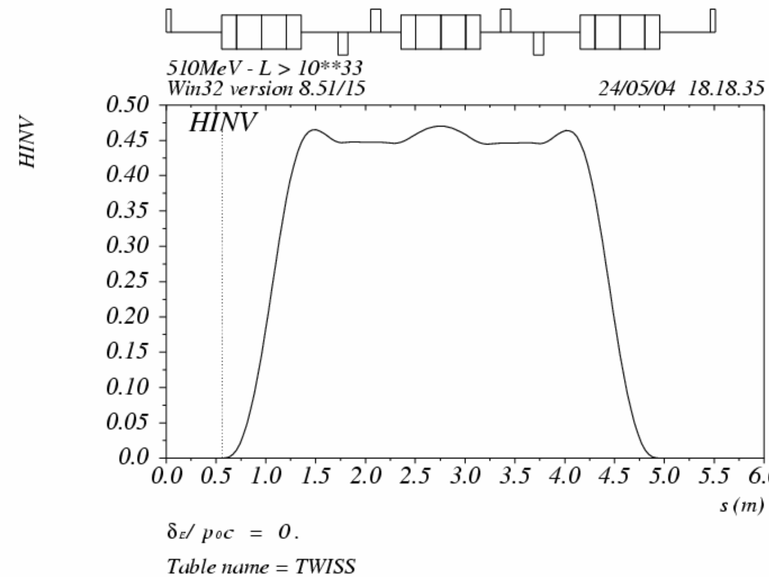


E = 1.1 GeV





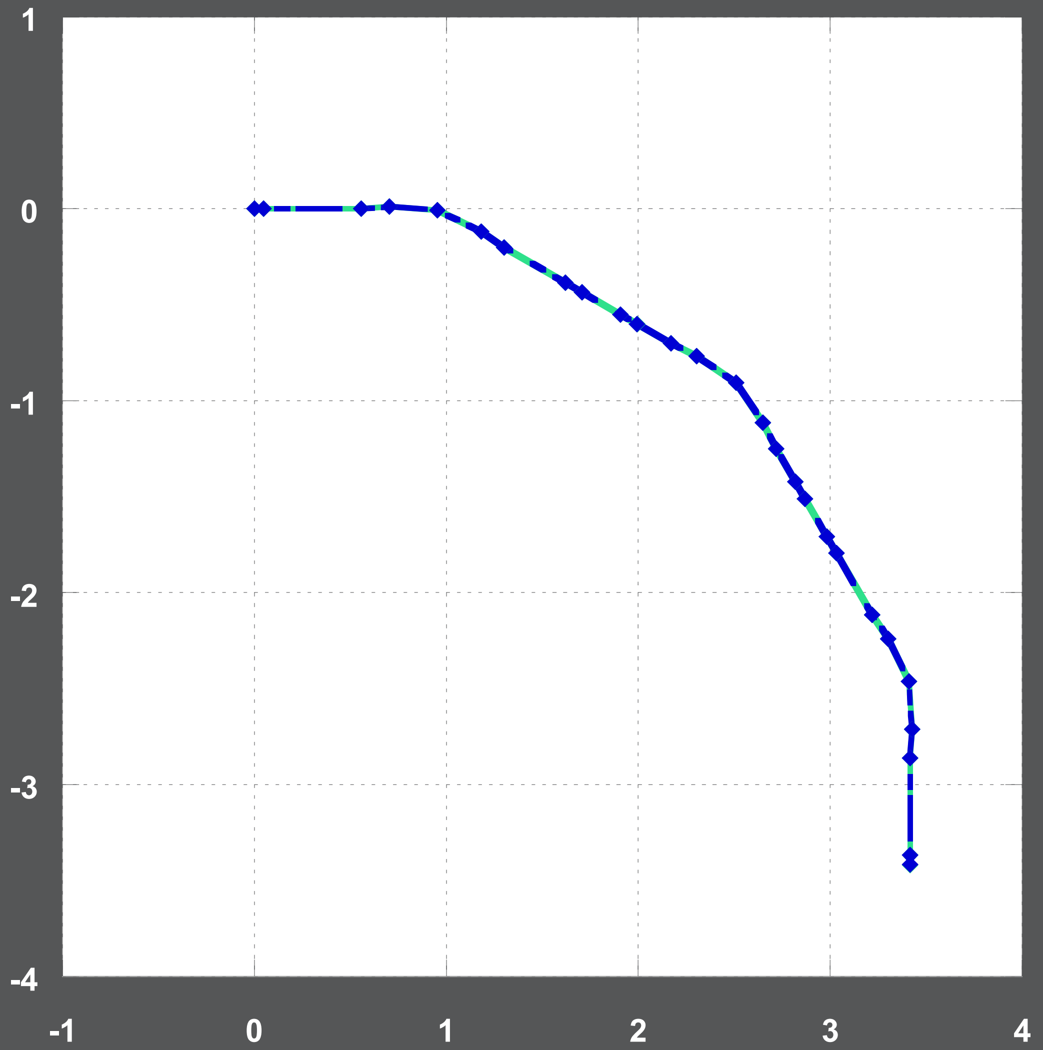




Dispersion in one arc

Emittance invariant

Total length of arcs – 20 m



Total ring < 90 m

Φ and n-nbar sharing new DAFNE

very preliminary considerations

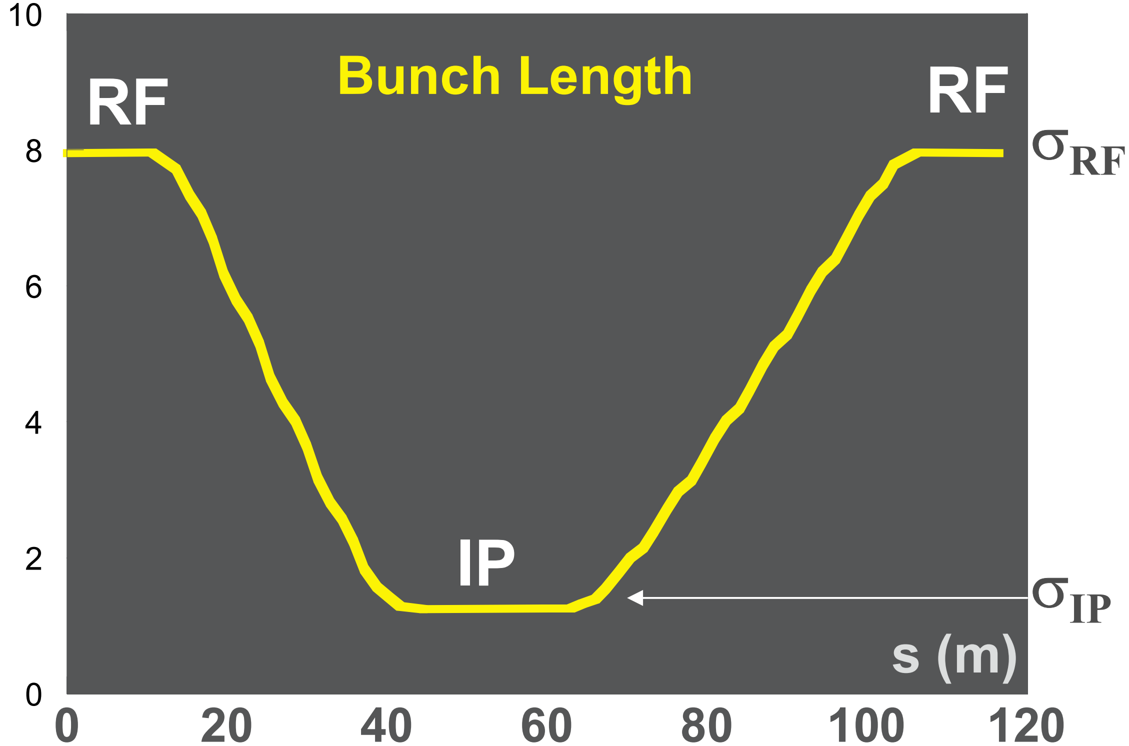
Energy (GeV)	0.51	1.1
Current (A)	3	1
Luminosity (10^{32})	10	5
N bunches	100	50
I/bunch (mA)	>20	20
τ damping (msec)	6	3

Luminosity Upgrade @ Φ

	K Physics	Hyper-nuclei	Exotic atoms		
2004 2007	$2\ 10^{32}$ 4 fb^{-1}	10^{32} 0.5 fb^{-1}	10^{32} 0.5 fb^{-1}		
2008 2014	10^{33} to 10^{34} 100 fb^{-1}	10^{33} >1 fb^{-1}			
	KLOE	FINUDA	DEAR		
Cost (M€)	60 Accelerator				

Strong RF Focusing (SRFF)

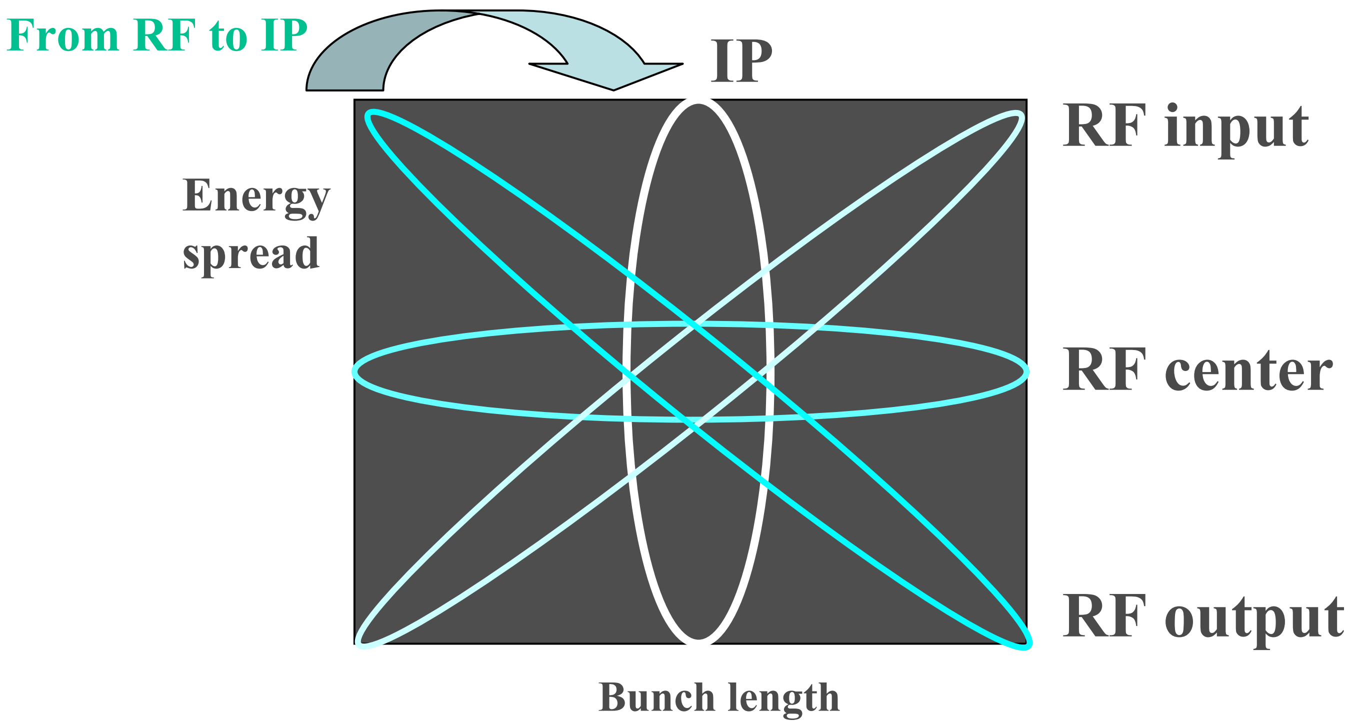
Modulation of bunch length along the ring with a minimum at the IP



Allows very small vertical β* (few mm)

High rf voltage
+
Magnetic lattice which correlates longitudinal position with energy deviation (high momentum compaction)

Longitudinal phase space

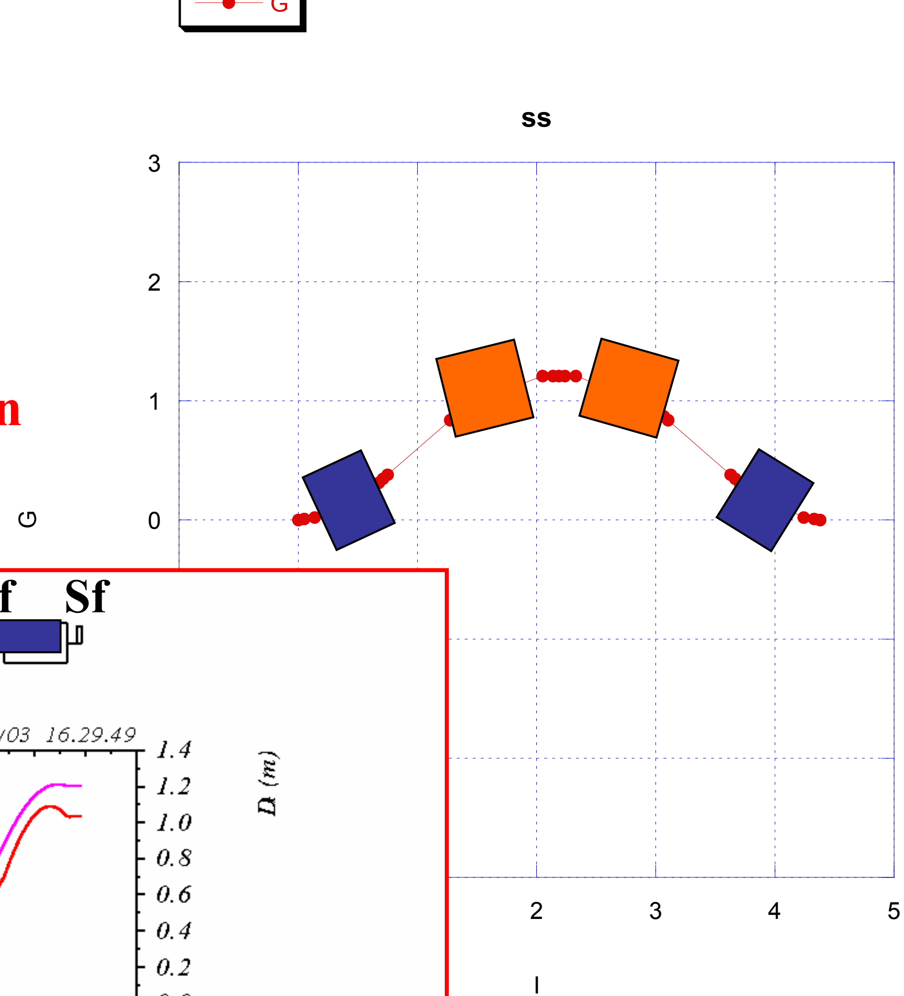


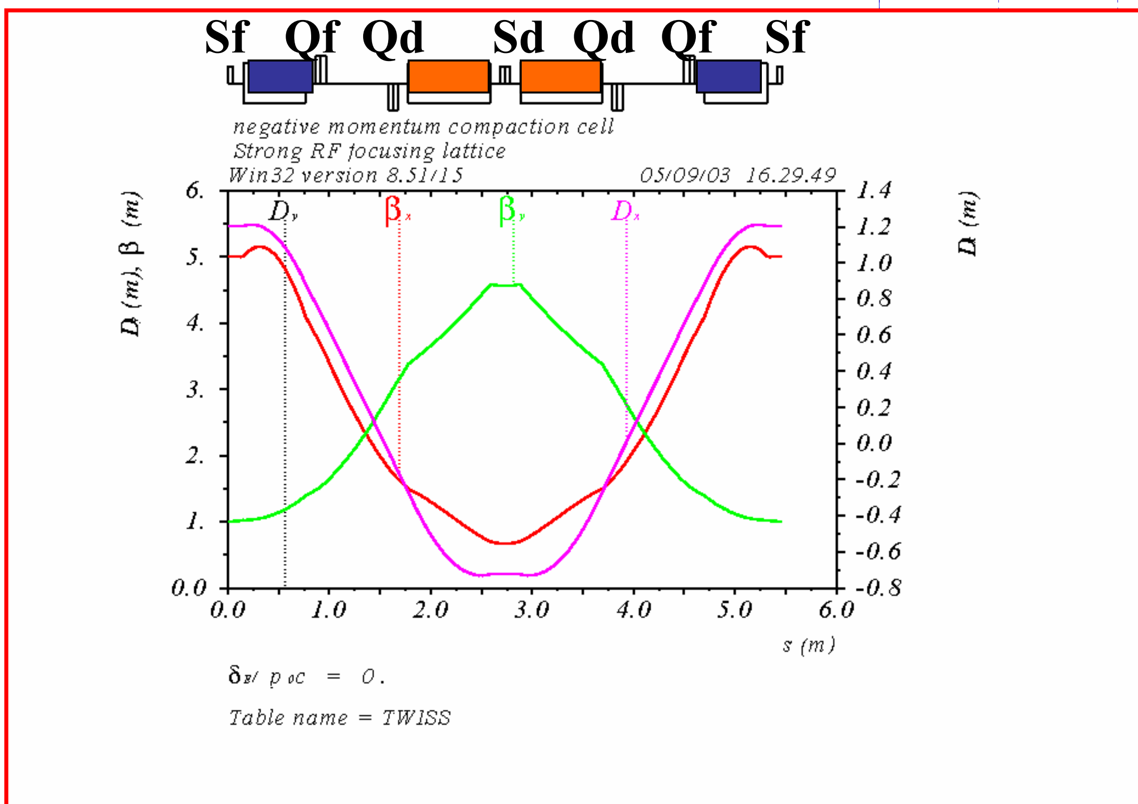
$$\cos\mu = 1 - \pi \frac{\alpha_c L}{\lambda_{rf}} \frac{V_{rf}}{E/e}$$

High |momentum compaction|
+ high Voltage

HIGH and NEGATIVE MOMENTUM COMPACTION

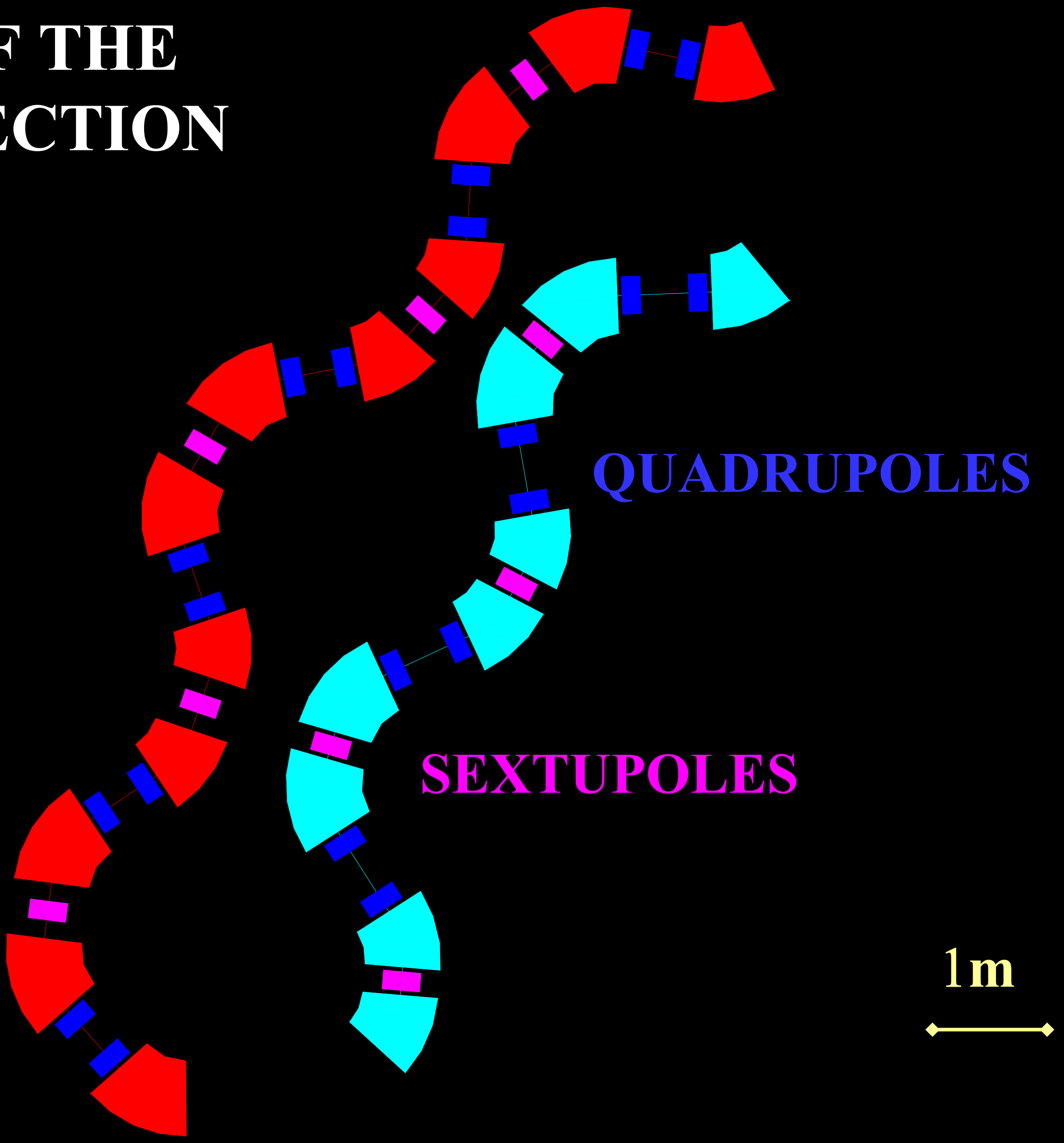
strong RADIATION emission





Alternating positive and negative bending dipoles

ZOOM OF THE RINGS SECTION



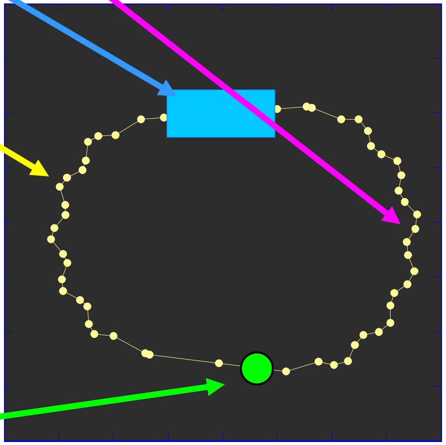
Layout similar to present DAΦNE rings:

One IR

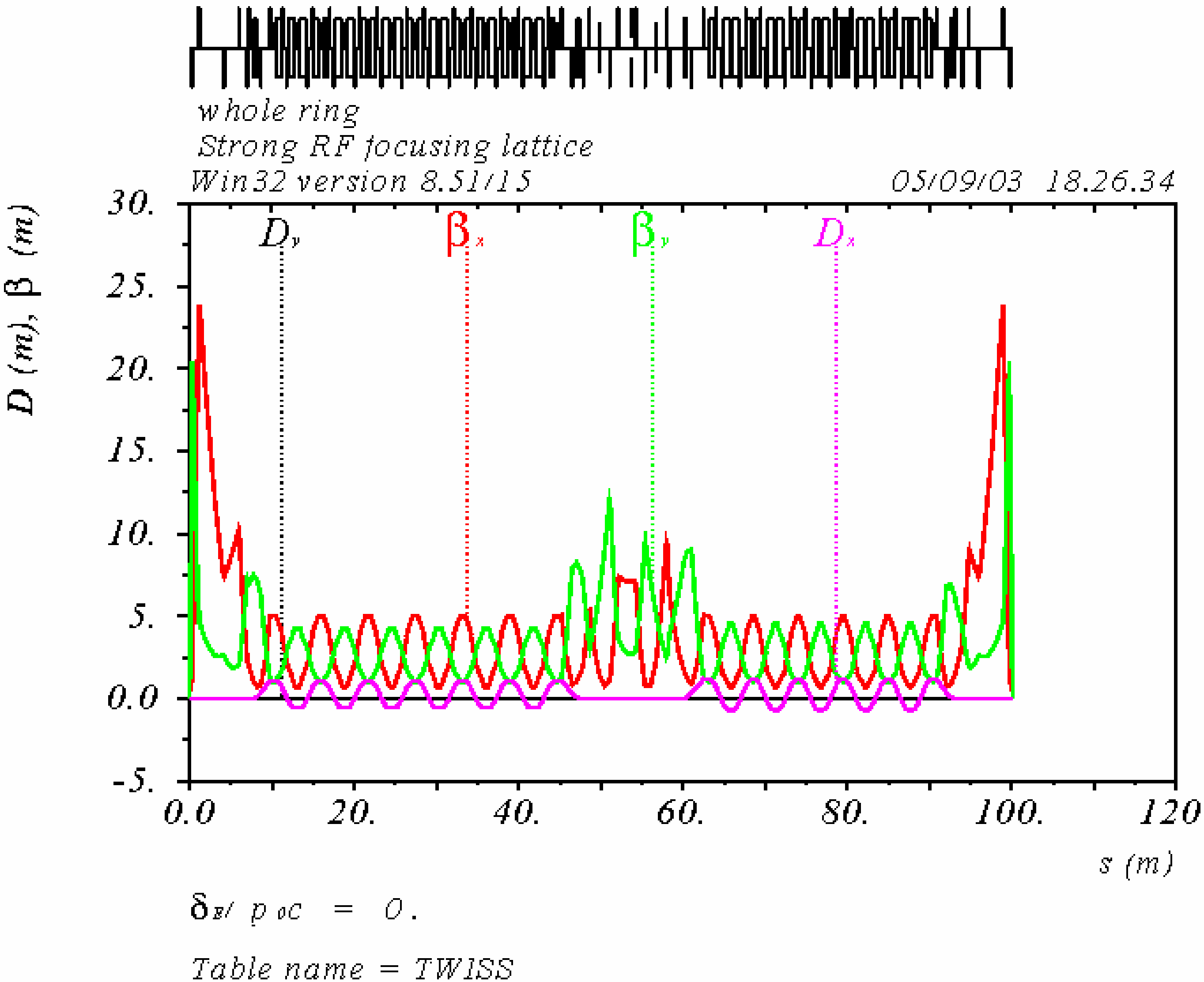
Second crossing for injection, rf, diagnostics

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

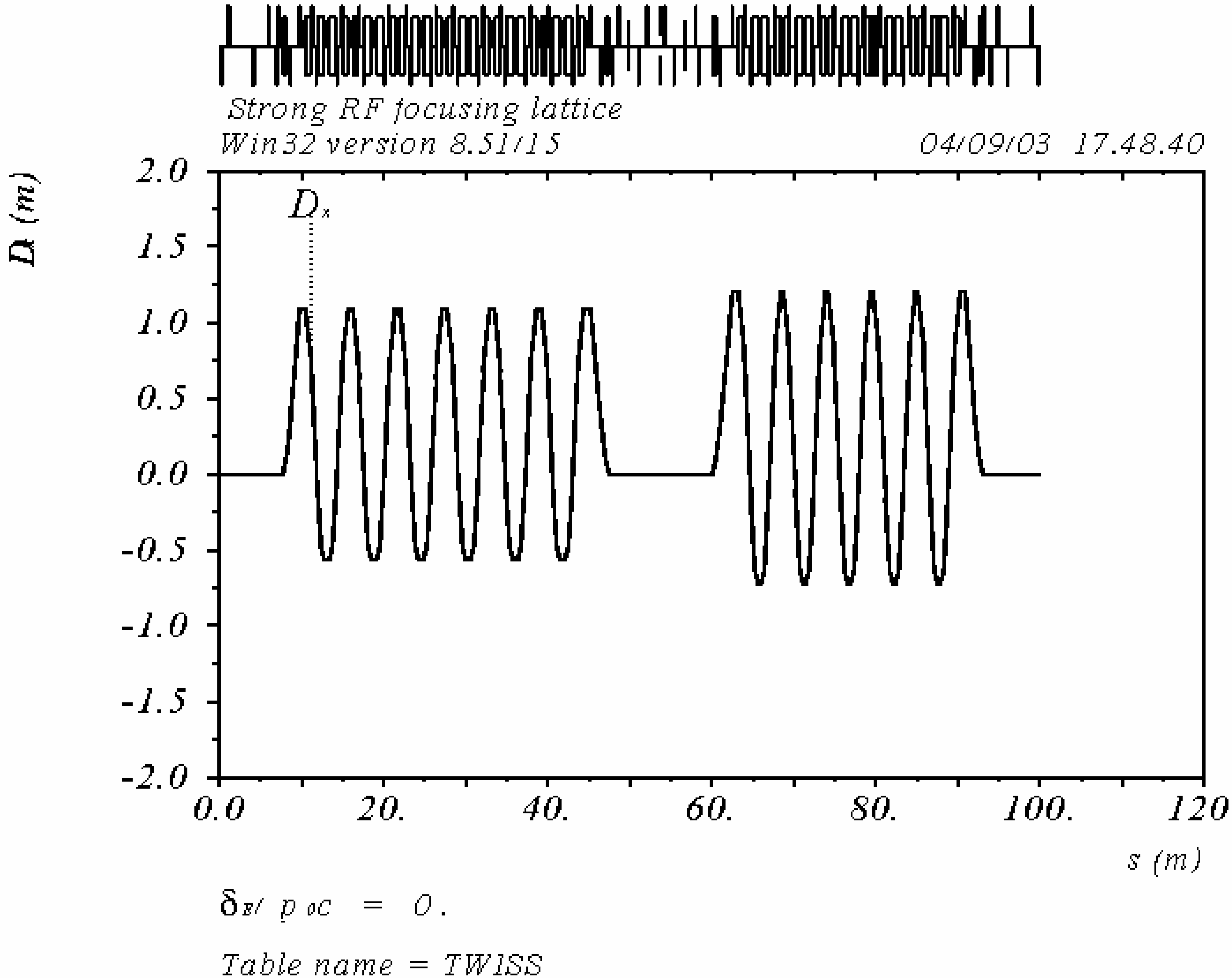
$$R_{56}(rf \to IP) = R_{56}(IP \to rf)$$



rf



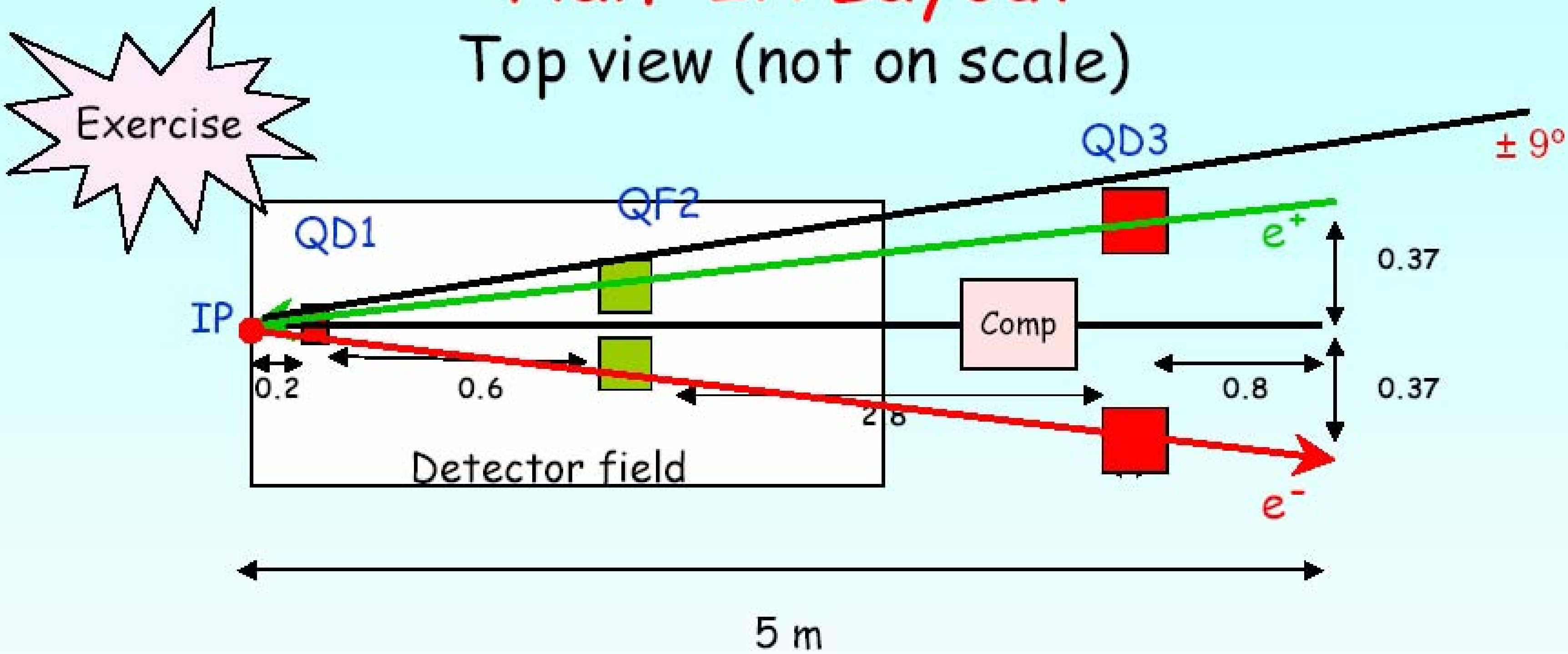
whole ring
Strong RF focusing lattice
Win32 version 8.51/15
05/09/03 18.26.34
D (m), β (m)
s (m)
D_y
β_x
β_y
D_x
30.
25.
20.
15.
10.
5.
0.0
-5.
0.0
20.
40.
60.
80.
100.
120.
δ_E / p_0c = 0.
Table name = TWISS



Strong RF focusing lattice
Win32 version 8.51/15
04/09/03 17.48.40
D (m)
D_x
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)
δ_E/p_0c = 0.
Table name = TWISS

Half-IR Layout

Top view (not on scale)



With ± 10σ_x clearance, ± 9° cone, ±30 mrad angle:

QD1: L= 20 cm, pole radius = 1.5 cm, R_{ext} = 3 cm, pm thickness= 1.5 cm small

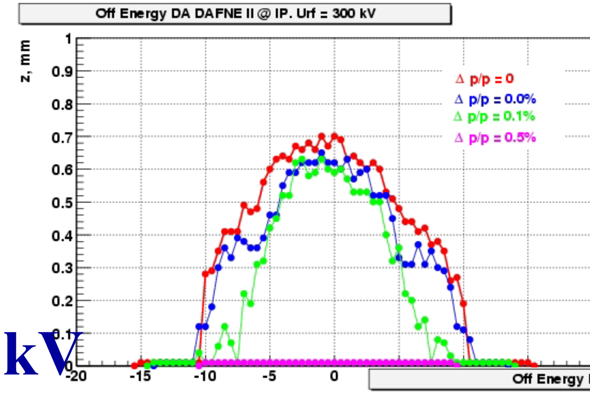
QF2: L= 20 cm, pole radius = 11 cm, R_{ext} = 16 cm, pm thickness= 1.5 cm, 4 cm space between 2 quads

QD3: L= 20 cm, pole radius = 15 cm , R_{ext} = 63 cm, 25 cm space between 2 quads

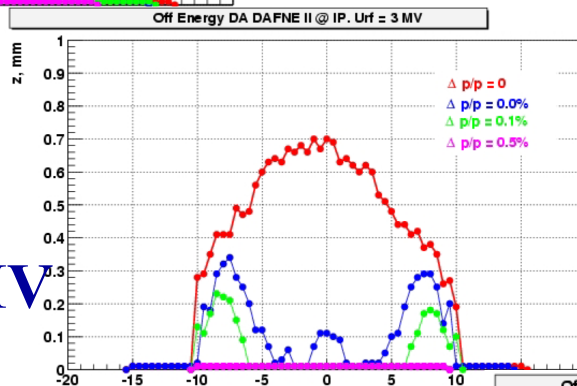
First evaluation by *E.Levichev, P.Piminov**)

BINP, Lavrentiev 13, Novosibirsk 630090, Russia

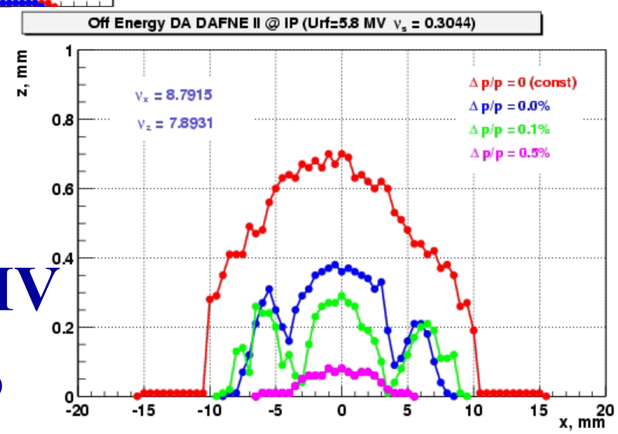
----- no synchr oscill
----- Dp/p = 0
----- Dp/p = 0.1%
----- Dp/p = 0.5%



V = 300 kV
$Q_s = 0.059$



V = 3 MV
$Q_s = 0.2$

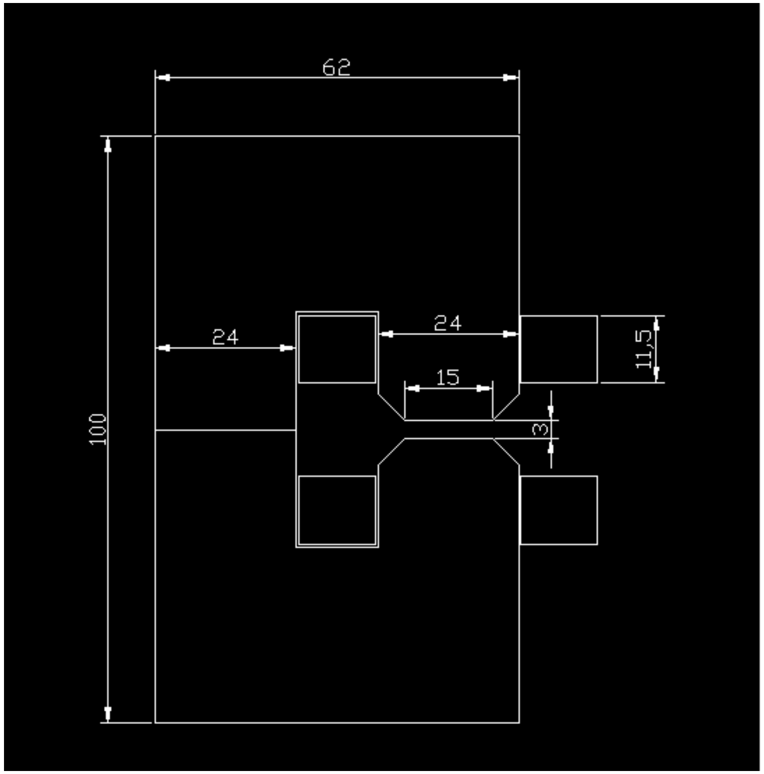


V = 5 MV
$Q_s = 0.3$

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

Dipole parameters

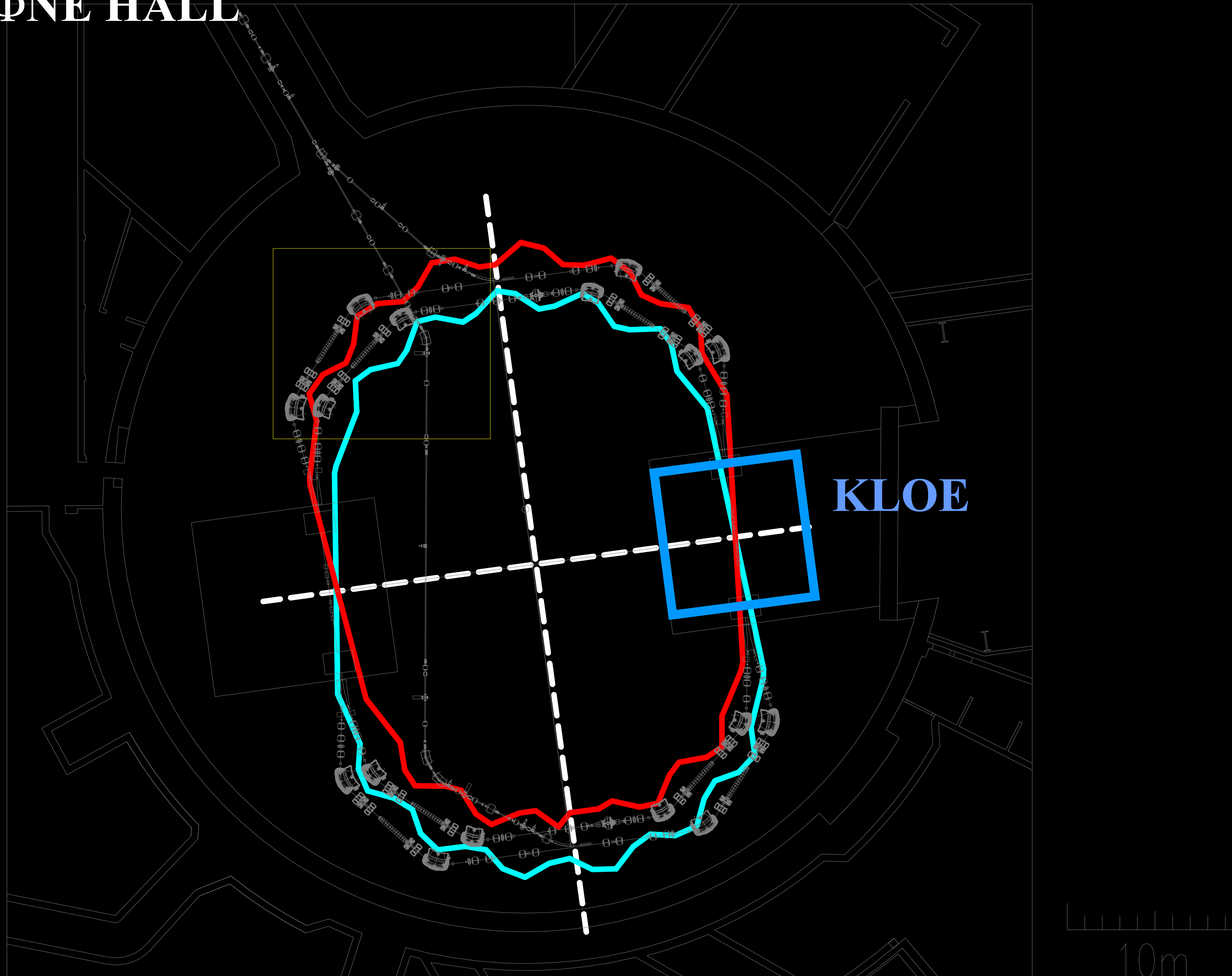
Type	A	B	C
N	22	22	4
Alfa [rad]	0.6545	0.8528	0.5236
Chord [m]	0.607	0.781	0.489
Sagitta [m]	0.050	0.085	0.032
Mag lenght	0.618	0.805	0.494
Vol Fe [mc]	0.282	0.362	0.227
Vol Cu [mc]	0.041	0.047	0.037
Weight Fe [kg]	2222	2859	1789
Weight Cu [kg]	359	410	324
Total Weight [kg]	2581	3269	2113
Power [W]	7234	8260	6537



NI [A]	26350
J[A/mmq]	3.2
Total power [kW]	370

Cost evaluated: 1600 k€

DAΦNE HALL

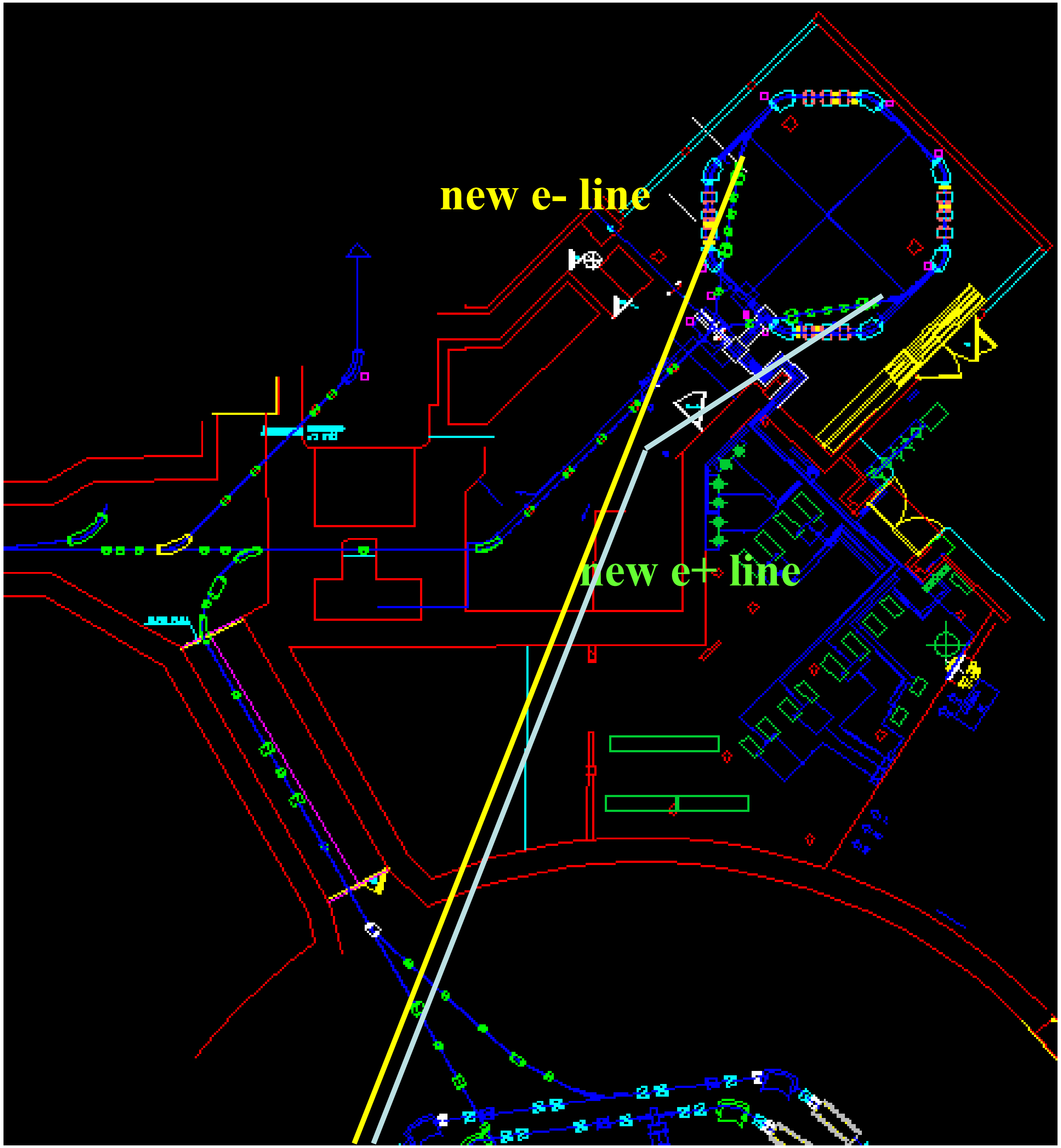


F. Sgamma

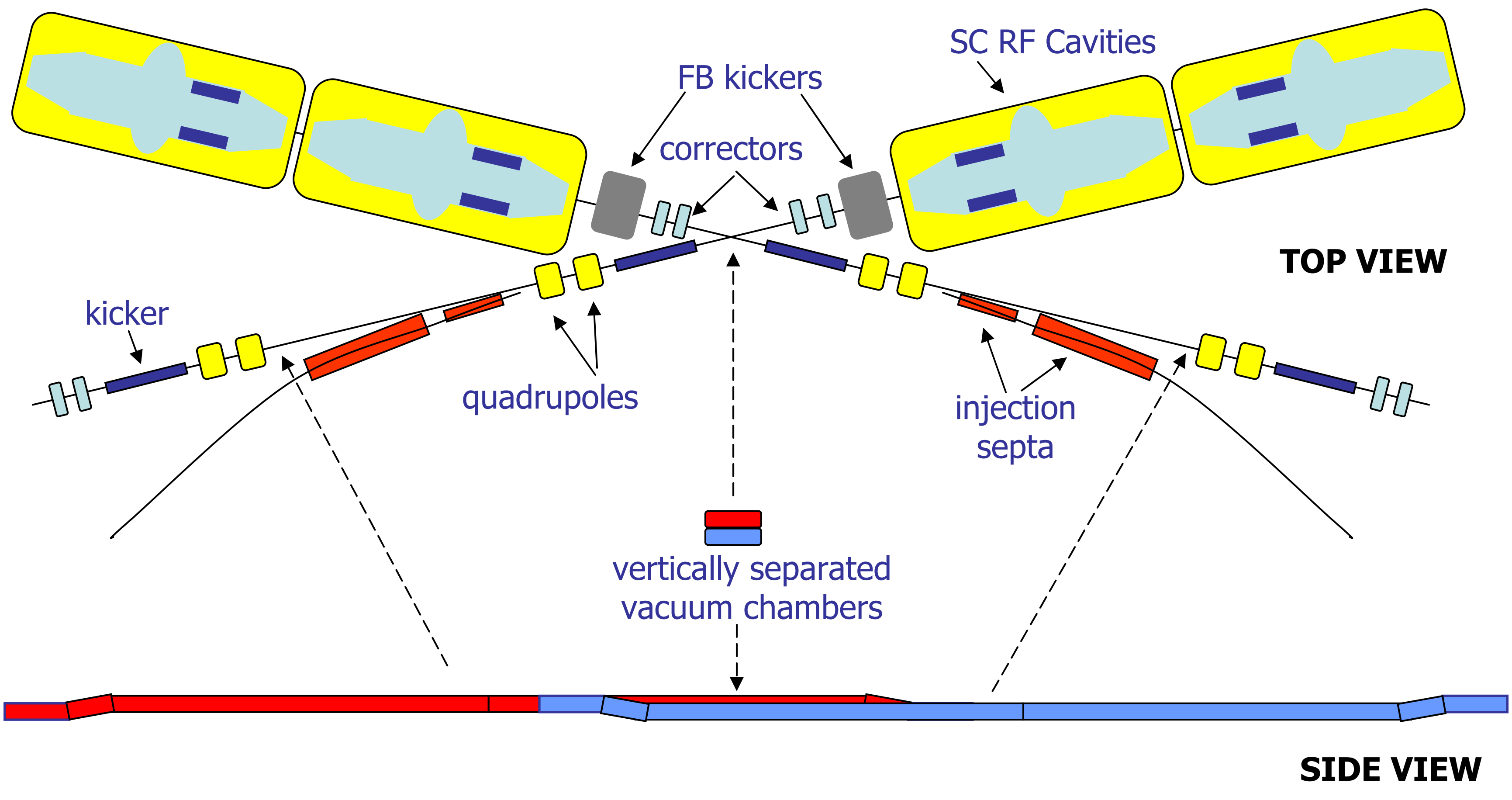
Injection system upgrade

- The proposed transfer lines pass in existing controlled area

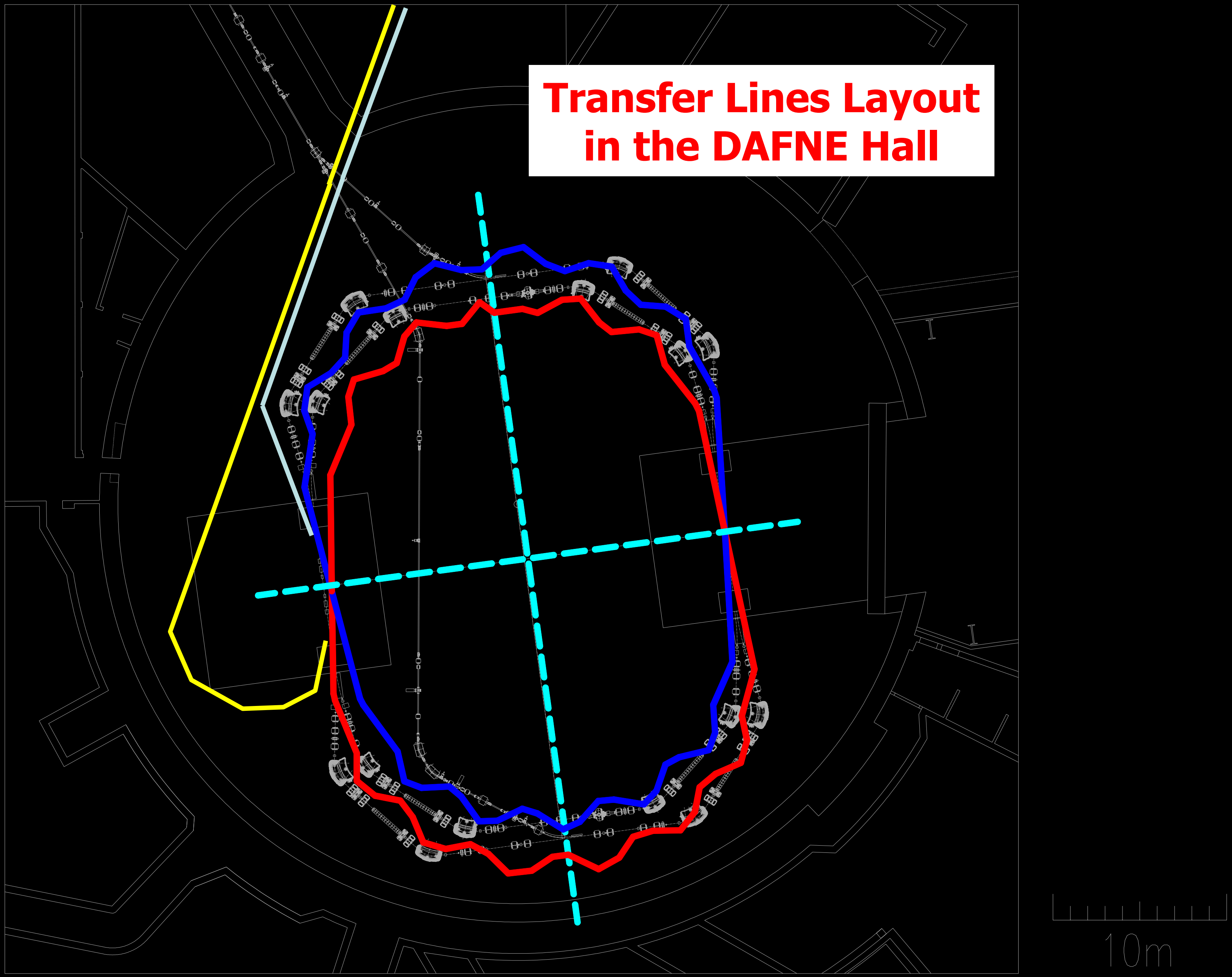
- Additional shielding needed in the area between the accumulator and DAFNE buildings



Crossing point section schematic layout



Transfer Lines Layout in the DAFNE Hall



MAIN PARAMETERS	
C (m)	105
E (MeV)	510
f_{rf} (MHz)	497
V (MV)	10
ε_x (μ rad)	0.26
ε_y (μ rad)	0.002
α_c	- 0.165
β_x^* (m)	0.5
β_y^* (mm)	2.0
N / bunch	5 e10
h	180
L /bunch (cm^{-2} sec^{-1})	$9\ 10^{31}$
L tot (cm^{-2} sec^{-1})	$\sim 10^{34}$

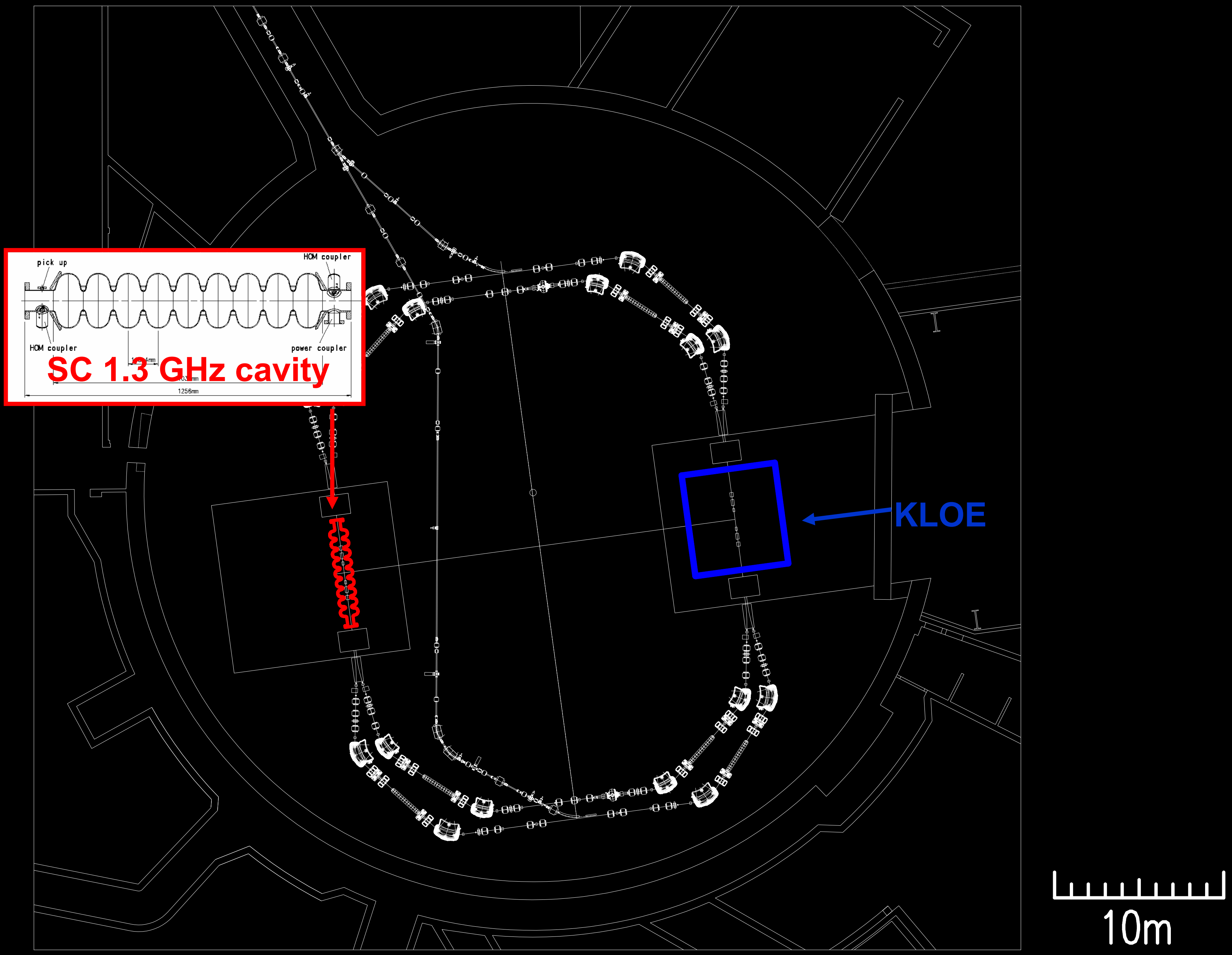
SRFF at DAΦNE

Experiment for the first time the strong RF focusing concept:

- Study the single bunch dynamics (effects of the distributed wake on the bunch length)
- Study the multibunch dynamics at very large synchrotron tunes
- Study of the 3D coupled dynamics
- Collisions of short bunches (with β_y ~1 cm)
- Study of CSR

What is needed

- New rf sc-cavity with cryostat
- High momentum compaction lattice – feasible with present hardware
- Criogenic system modification from FINUDA line to rf cavity.
- Few days of MD in 2004, 2005
- One-two monthes in 2006 for installation and experiment

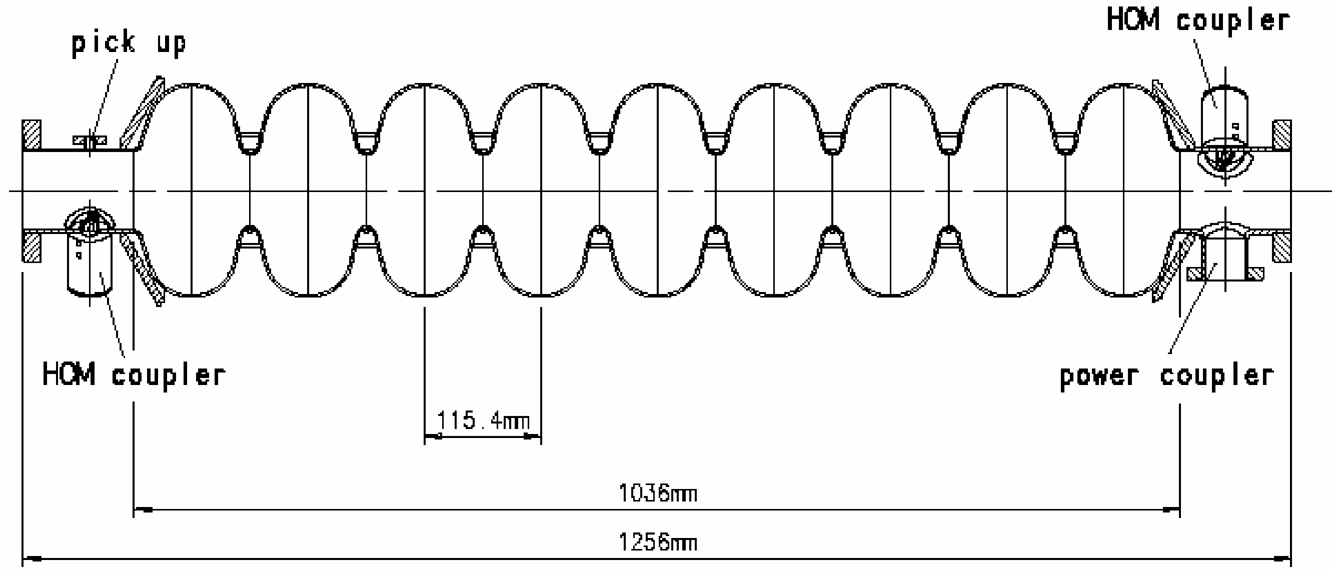


pick up
HOM coupler
HOM coupler
power coupler
SC 1.3 GHz cavity
1256mm
KLOE
10m

Parameter List for a Strong RF Focusing Experiment at DAFNE

Momentum Compaction	α_c	**0.07 - 0.1**
RF Frequency	f_{RF}	**1288.973 MHz**
RF Voltage	V_{RF}	**8 - 5.8 MV**
Harmonic Number	**h**	**420 (= 3.5 x 120)**
Longitudinal Phase Advance	μ_l	**120°**
Natural Energy Spread	$\left.\frac{\sigma_E}{E}\right\|_0$	**5 • 10^{-4}**
Energy Spread @ μ_l = 120°	$\frac{\sigma_E}{E}$	**9 • 10^{-4}**
Bunch Length	σ_z	**1.3 - 2.5 mm** **3 - 5.0 mm**
RF Acceptance (waist/cavity)	$\left.\frac{\Delta E}{E}\right\|_{\max}$	**7 • 10^{-3}/ 5 • 10^{-3}**

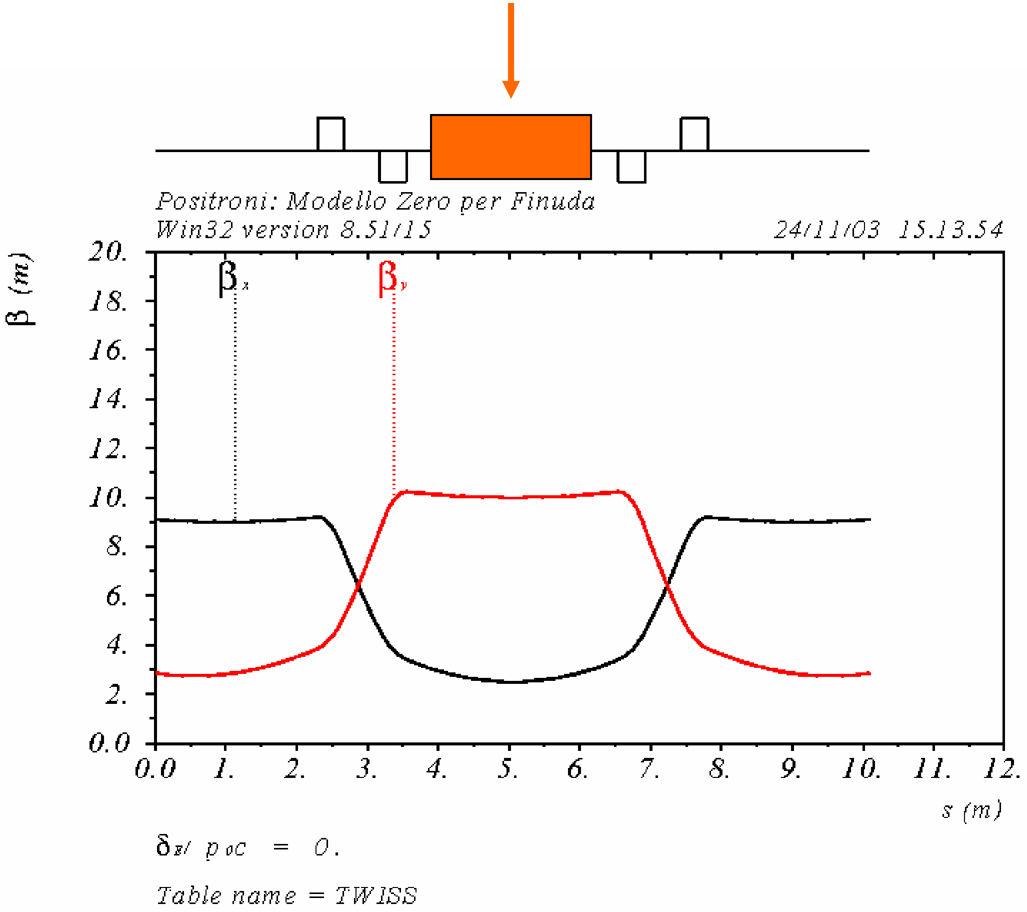
RF Cavity Parameter List

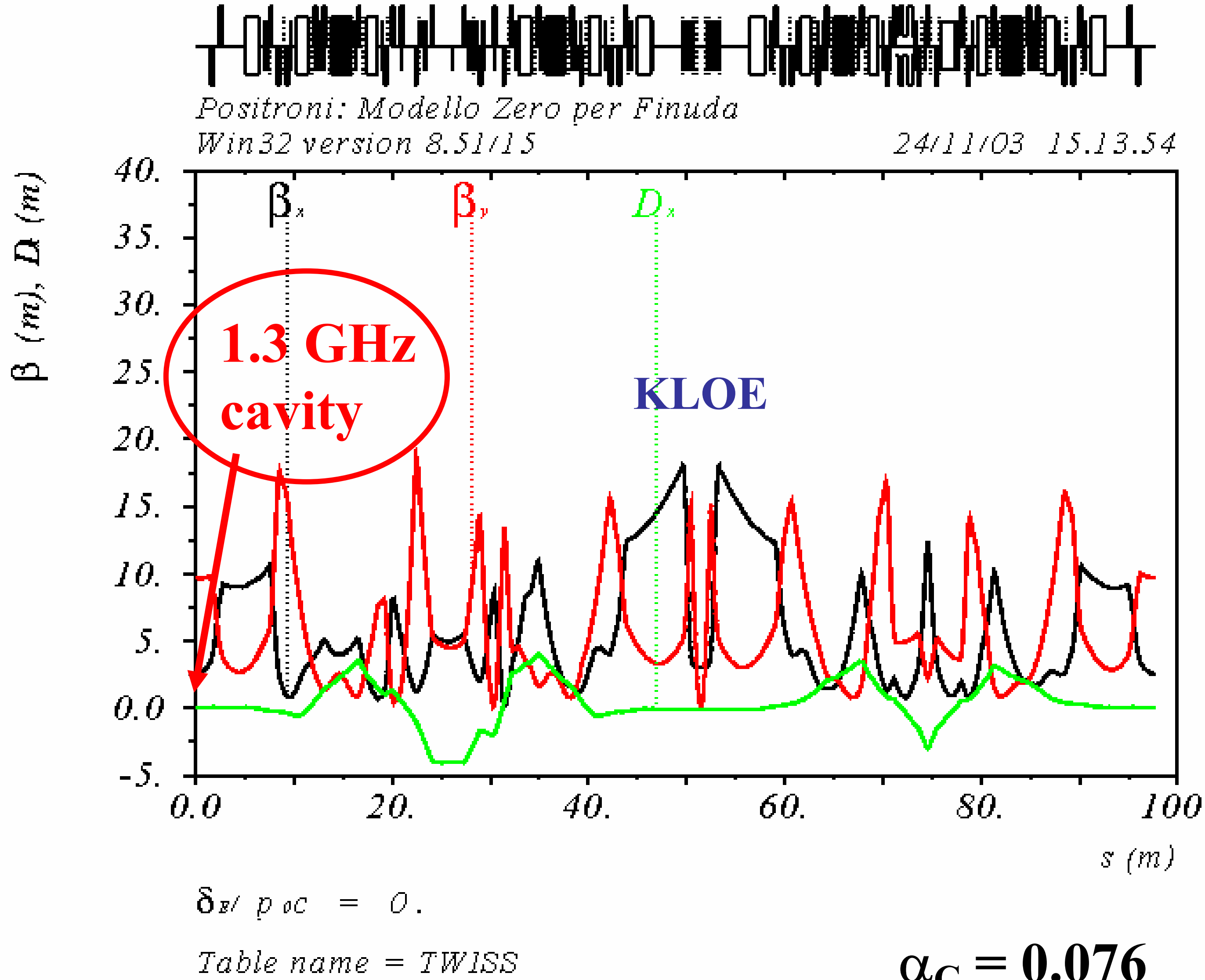


Cavity type		SC TESLA like, 9 cells
RF frequency	f_{RF}	1288.973 MHz (-0.85 %)
RF voltage	V_{RF}	5.8 MV
R/Q geometric factor	R/Q	500 Ω
Quality factor (@ 4.2 °K)	Q_0	$5 \cdot 10^8$
Cavity wall power	P_{cav}	68 W
Loaded quality factor	Q_L	$2 \cdot 10^7$
RF generator power	P_{cav}	420 W
Cavity length	L_{cav}	1 m

IP2

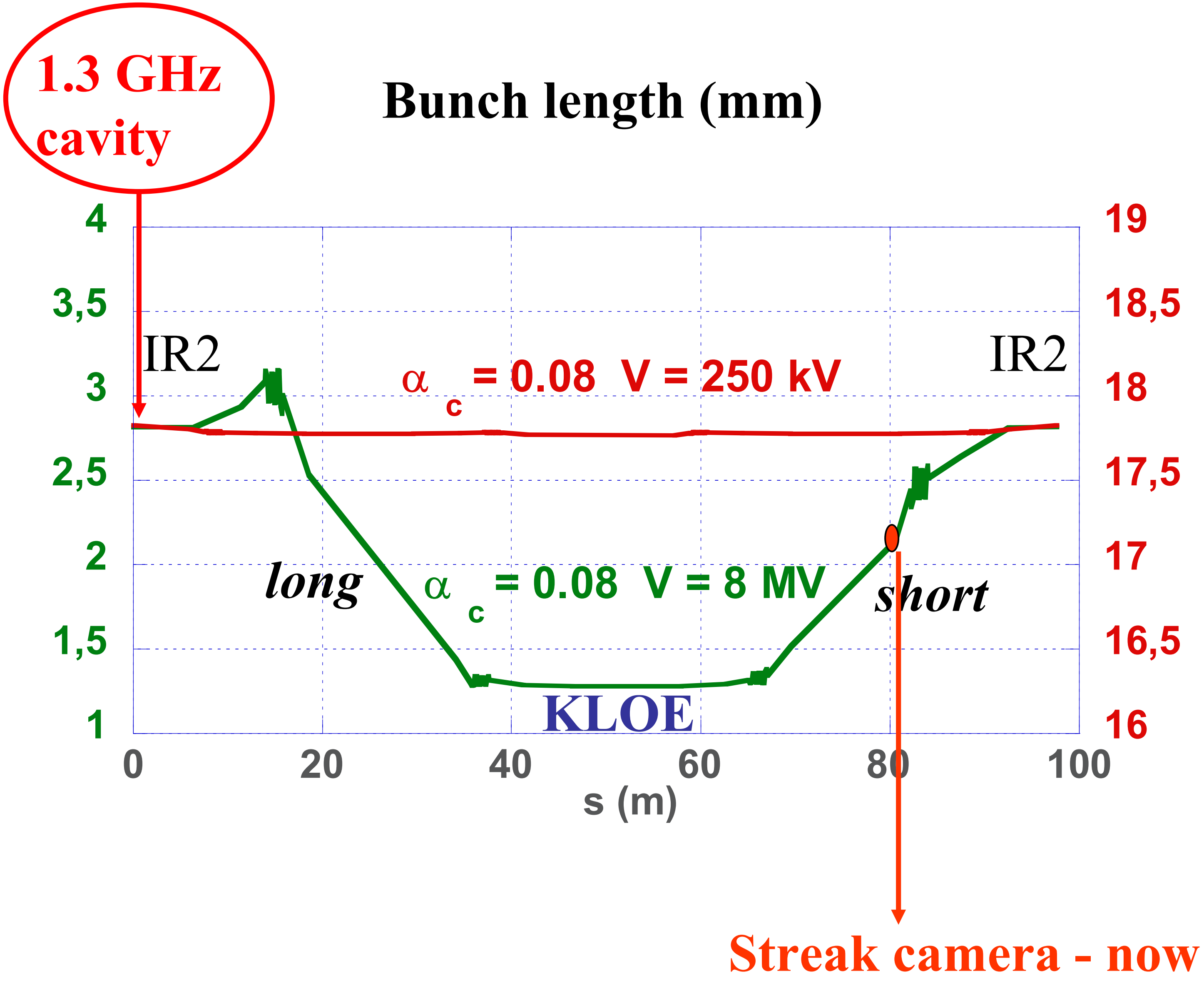
RF cavity - 1.3 GHz



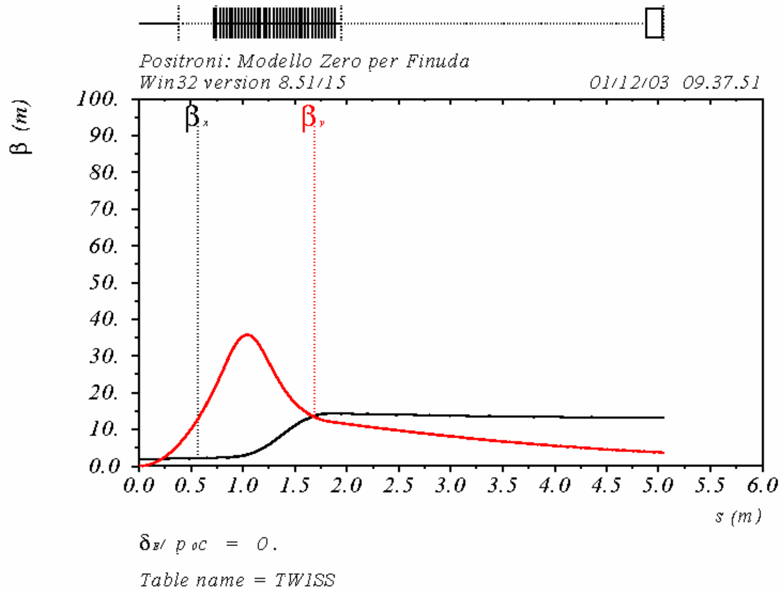


Positroni: Modello Zero per Finuda
Win32 version 8.51/15
24/11/03 15.13.54
β (m), D (m)
βx
βy
Dx
1.3 GHz
cavity
KLOE
40.
35.
30.
25.
20.
15.
10.
5.
0.0
-5.
0.0
20.
40.
60.
80.
100.
s (m)
δE/ p0c = 0.
Table name = TWISS

$\alpha_C = 0.076$



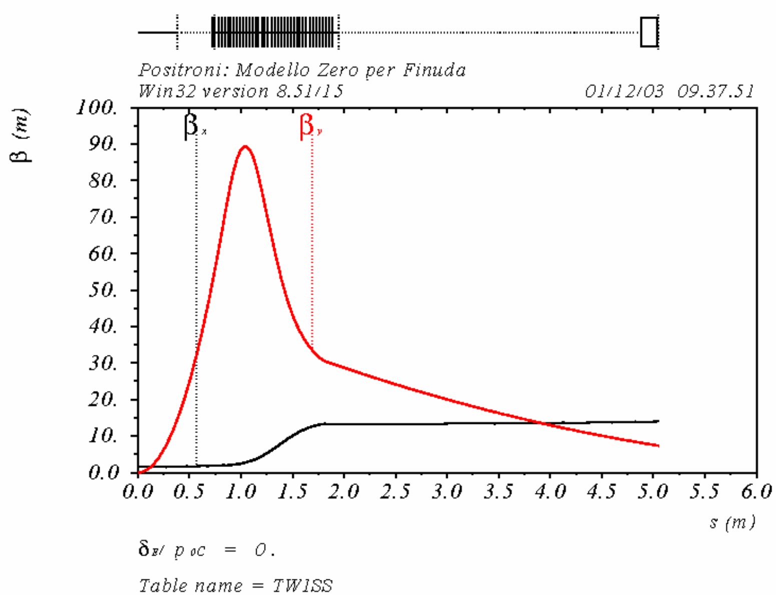
1.3 GHz cavity
Bunch length (mm)
IR2
IR2
αc = 0.08 V = 250 kV
αc = 0.08 V = 8 MV
long
short
KLOE
4
3,5
3
2,5
2
1,5
1
19
18,5
18
17,5
17
16,5
16
0
20
40
60
80
100
s (m)
Streak camera - now



KLOE now

$\beta_x^* = 2$ m

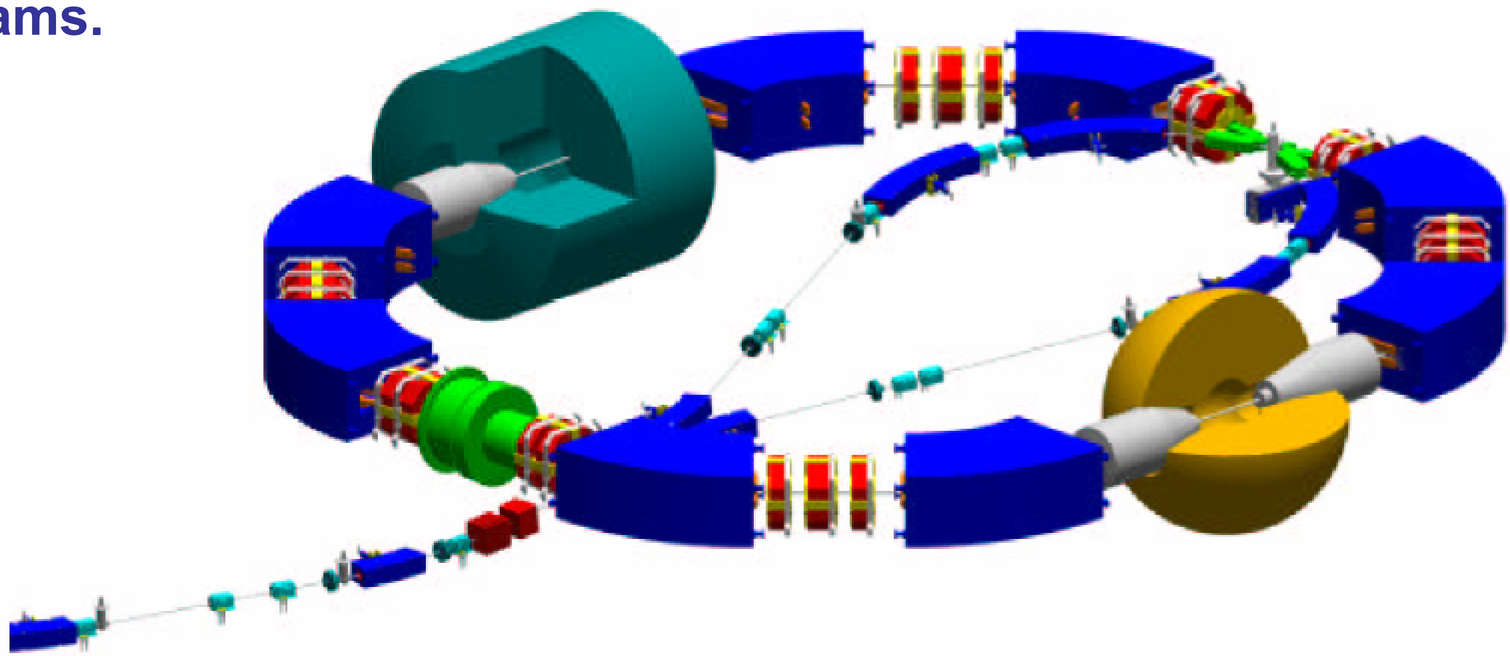
$\beta_y^* = 2.5$ cm

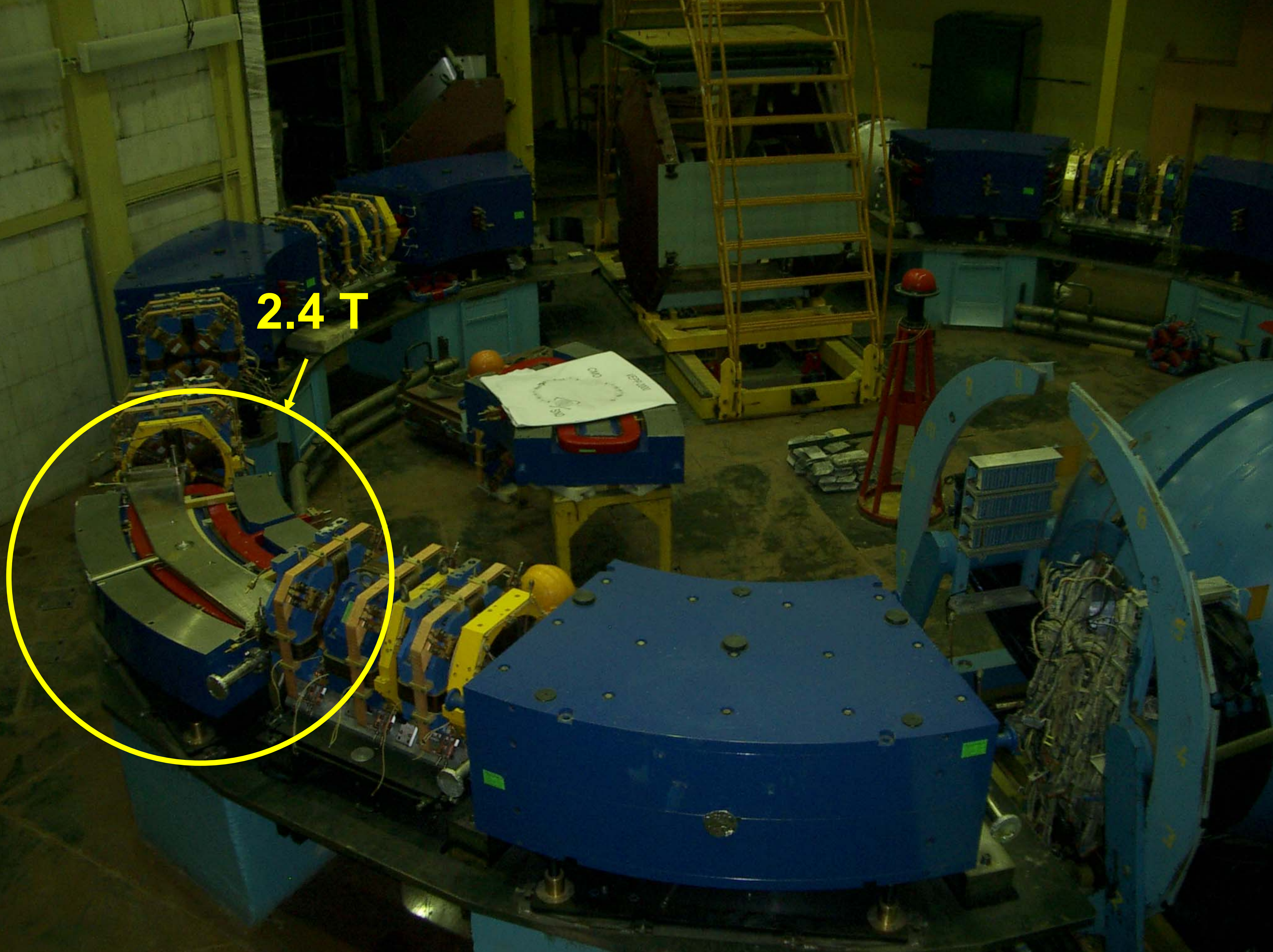


$N_{bunches}$	60
β_y^*	1 cm
β_x^*	1.5 m
ε_x	1 μ rad
ε_y	0.005 μ rad
I/beam	< 0.5 A
L	< 10^{32}

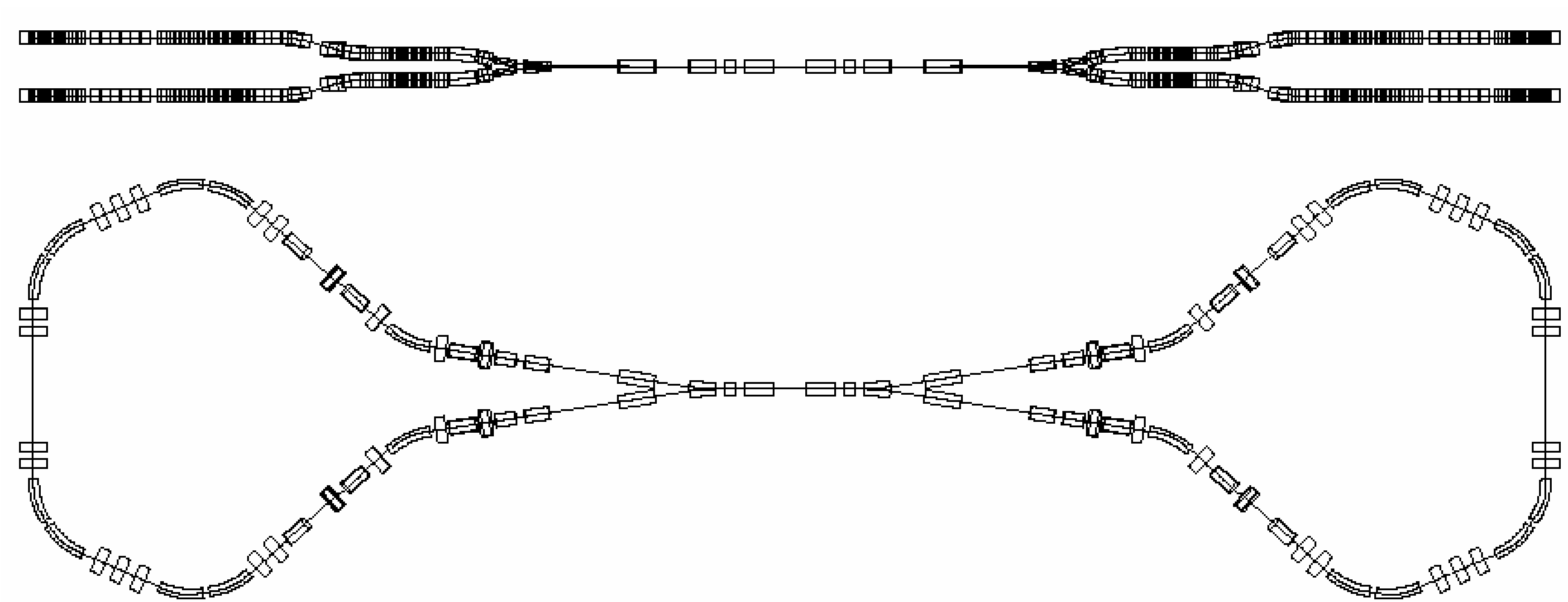
View of the VEPP-2000 collider

Experimental testing of RCB should verify predictions on extremely high attainable space charge parameters for the round beams.




2.4 T

Round beam Novosibirsk Φ – Factory: Four wings



Shatunov: if RCB @Vepp2000 : tune shifts >0.1 -> L @phi >10^{34}

Answer in 2005

conclusions

- **No major upgrades**
- **Minimum change for E upgrade**
- **New machine for E upgrade and L > 10^{33}**
- **New machine for L >10^{34}**

Increasing
Challenge, cost, time, FTE
scientific interest