The status and prospects of Low Energy Factories

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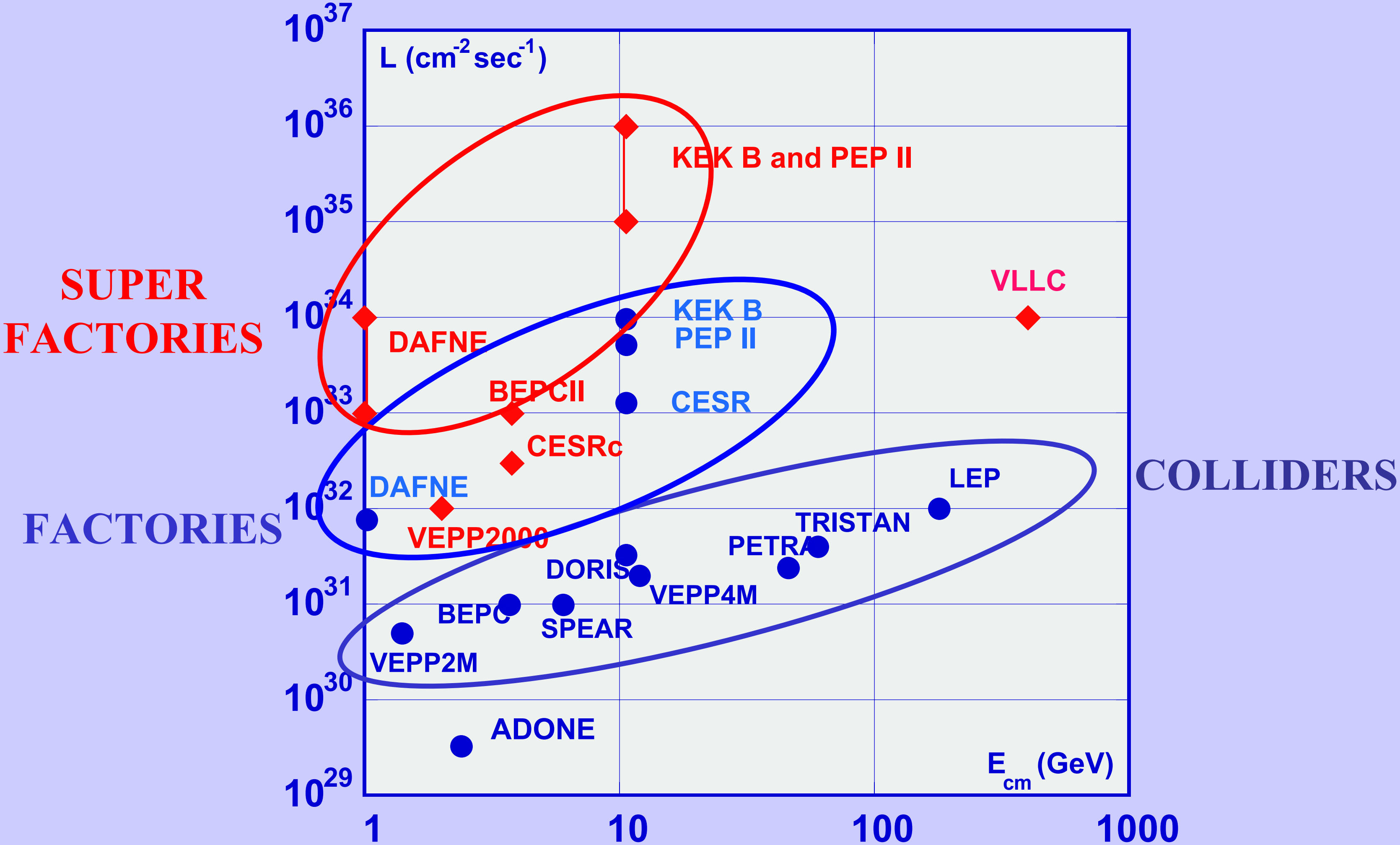
LNF - INFN

Forty years of lepton colliders – May 15-17, 2004 - Novosibirsk

PAST, PRESENT AND FUTURE



- Physics below τ-charm energy is worth before and during LHC and LC era

- Costs and investments fits national laboratory size and possibilities

- Accelerator physics issues equally or more interesting than at higher energies: benchmark for future facilities

	E_{cm} GeV	logged $\int L$	New physics at $\int L$	Operating In construction	Design studies
τ	3.9	$< 1\ fb^{-1}$	$> 100\ fb^{-1}$	CESRc BEPC - II	VEPP 5
light quarks	2	$< 10\ pb^{-1}$	$500\ pb^{-1}$	VEPP 2000	DAFNE2
Φ	1	$1\ fb^{-1}$	$> 100\ fb^{-1}$	DAΦNE	DAΦNE-II

Single ring – few bunches	*CESR c*
Double ring – multibunches high currents	*DAΦNE BEPC-II*
Round beam	*VEPP 2000*
Strong rf focusing Strong radiation damping Negative momentum compaction	*DAΦNE-II*

In operation

	E_{cm} GeV	logged $\int L$	New physics at $\int L$	Operating In construction	Design studies
τ	3.9	1 fb^{-1}	> 100 fb^{-1}	CESRc	
light quarks	2	< 10 pb^{-1}	500 pb^{-1}		
Φ	1	1 fb^{-1}	> 100 fb^{-1}		

CESR-c

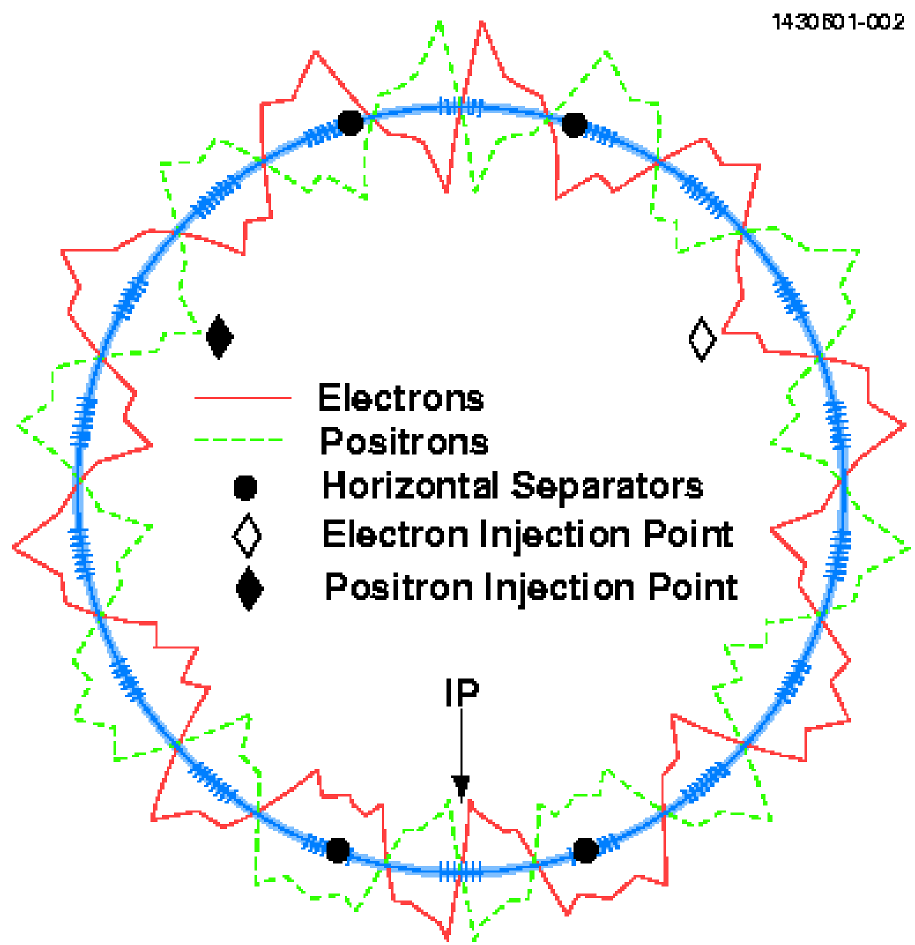
Energy reach 1.5-6GeV/beam
(768m circumference)

Electrostatically separated e+e- orbits accomodate counterrotating trains

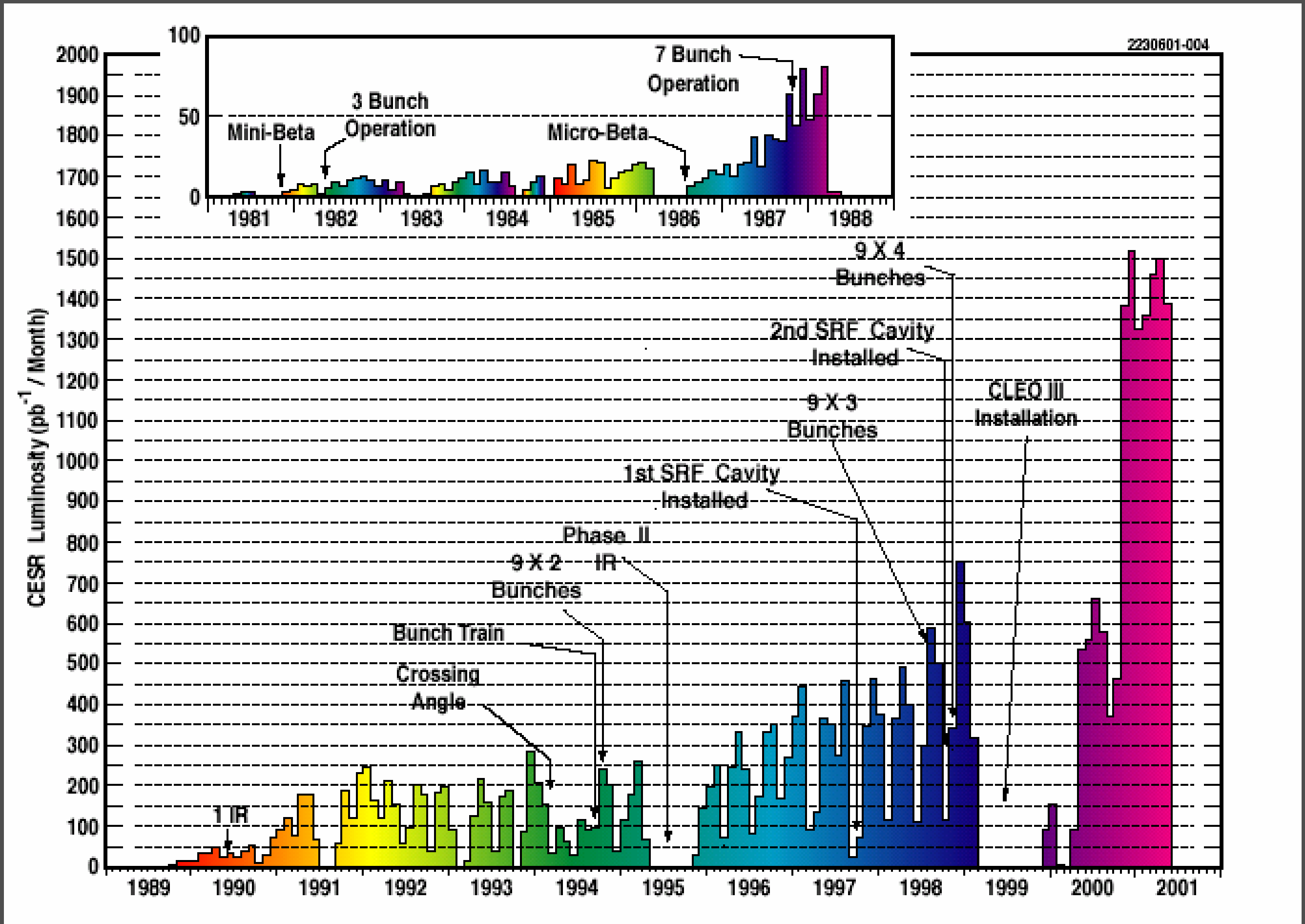
First use of SC rf in a storage ring (1982)

First use of permanent magnet quads in micro-beta IR

First successful use of many bunches, bunch trains, and crossing angle in e+e- storage ring



CESR luminosity in 20 years



CESR-c Energy dependence

Beam-beam effect

- In collision, beam-beam tune shift parameter ~ I_b/E
- Long range beam-beam interaction at 89 parasitic crossings ~ I_b/E (for fixed emittance) (and this is the current limit at 5.3GeV)

Single beam collective effects, instabilities

- Impedance is independent of energy
- Effect of impedance ~I/E

CESR-c Energy dependence

Radiation damping

In CESR at 5.3 GeV, an electron radiates ~1MeV/turn

~> τ ~ 5300 turns (or about 25ms)

SR Power ~ $E^2B^2 = E^4/\rho^2$ at fixed bending radius

$1/\tau \sim P/E \sim E^3$

so at 1.9GeV, τ ~ 500ms

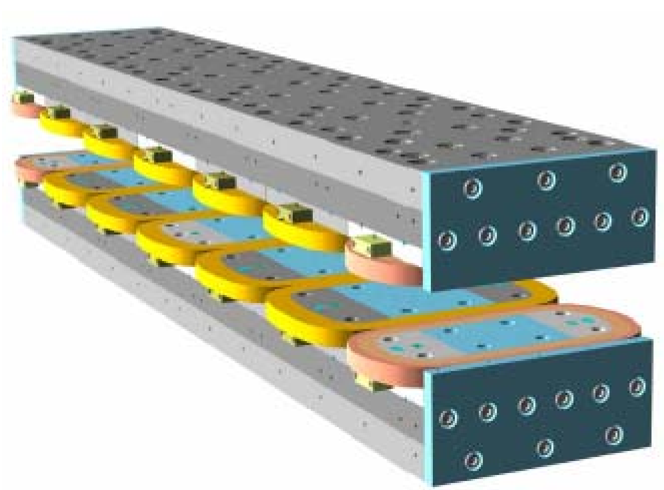
Longer damping time

- Reduced beam-beam limit
- Less tolerance to long range beam-beam effects
- Multibunch effects, etc.
- Lower injection rate

CESR-c

2003 - 12 wigglers installed for Run @ 3 GeV

CESR-c will run until 2008 at three energies between 3.1 and 4.1 GeV



. Table 1: Parameters with and without wigglers (1.9 GeV)

Parameter	**No Wigglers**	**18m 2.1T wigglers**
ε_X	30	220 nm-rad
Damping time	570	55 ms
σ_E/E_0	2×10^{-4}	8×10^{-4}

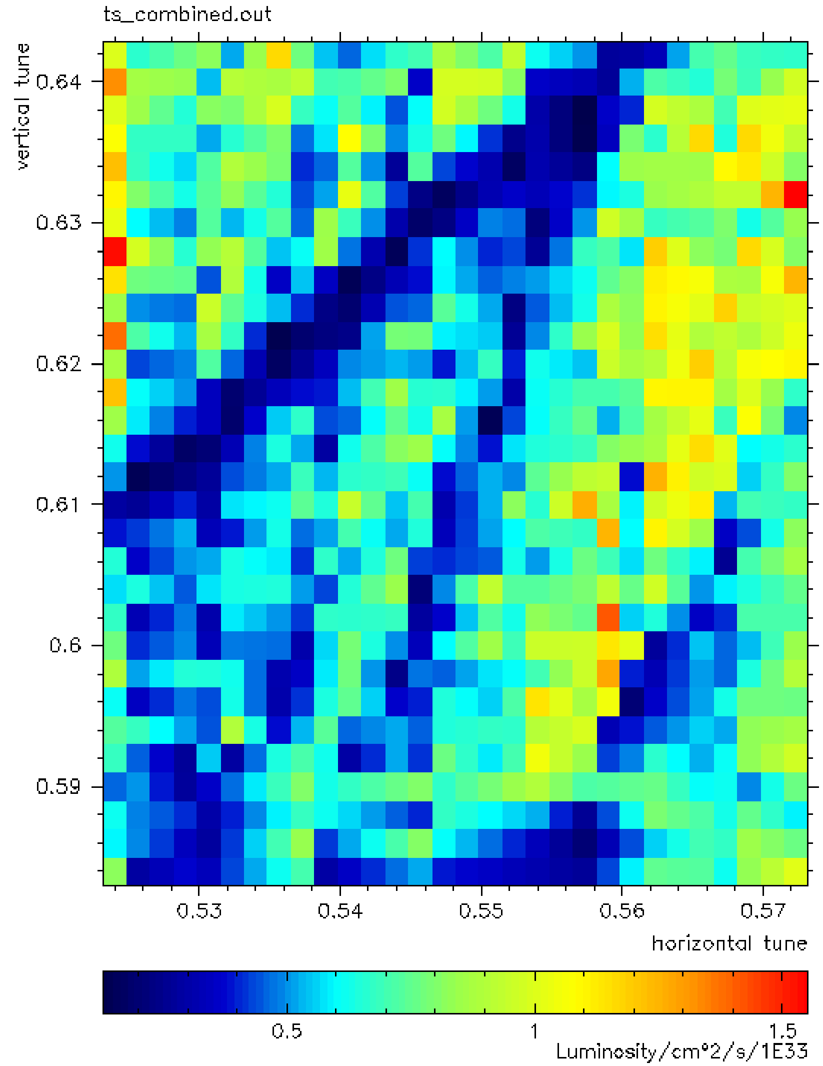
Table 2: CESR-c Parameters

$\mathbf{E_0}$ [GeV]	**1.55**	**1.88**	**2.5**	**5.3**
Luminosity [$\div 10^{30}$ cm^{-2}-sec^{-1}]	150	300	500	1250
i_b [mA/bunch]	2.8	4.0	5.1	8.2
I_{beam} [mA/beam]	130	180	230	360
ξ_y	0.035	0.04	0.04	.06
ξ_x	0.028	0.036	0.034	.028
σ_E/E_0 [$\times 10^3$]	0.75	0.81	0.79	0.67
$\tau_{x,y}$ [ms]	69	55	52	22
B_W [Tesla]	2.1	2.1	1.75	0
β_y^* [cm]	1.0	1.0	1.0	1.8
ε_x [nm-rad]	230	220	215	205

Simulation

- Machine model includes:
  - Wiggler nonlinearities
  - Beam beam interactions (parasitic and at IP)
  - Synchrotron motion
  - Radiation excitation and damping

- Weak beam
  - 200 particles
  - initial distribution is gaussian in x,y,z
  - track ~ 10000 turns

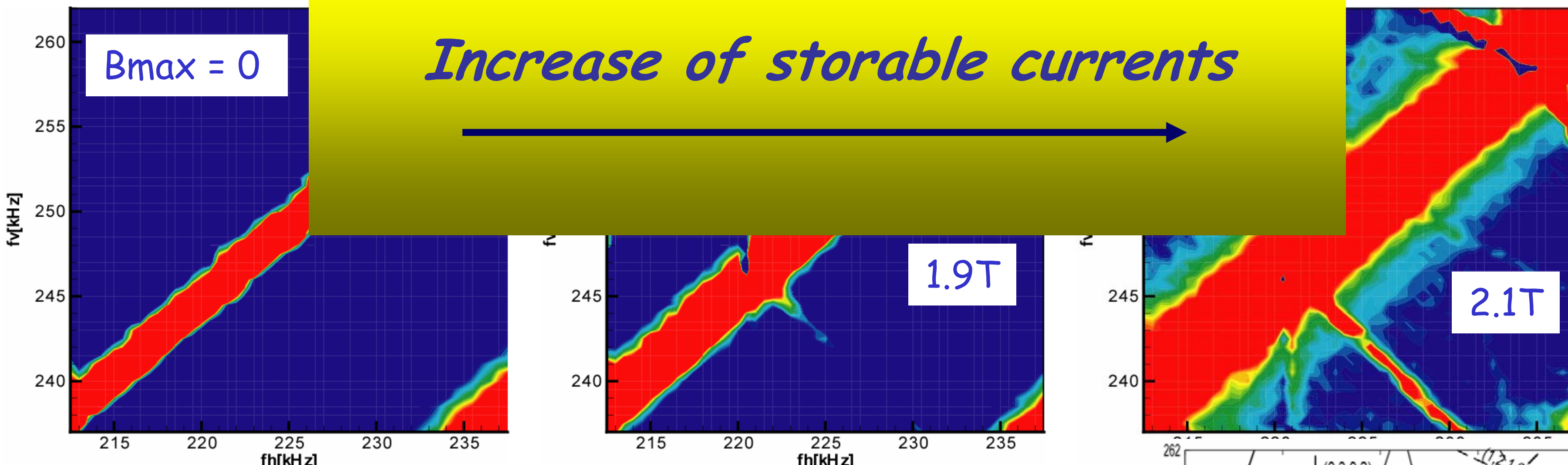


Rubin, September 03, Alghero

Beam based characterization: Nov 2002, one wiggler optics, wiggler#1 (7p)

3) 2D tune scan: vertical beam versus tune, evaluation with wiggler field

Increase of storable currents →

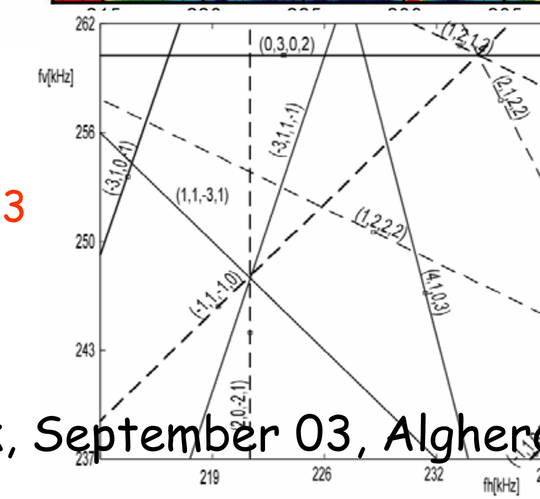


Oct. 14 2002, Optics: 1843MeV_1WIG_R3_OT, fs = 25kHz

Observed resonances

Wiggler OFF: -fh+fv = 0, -fh+fh-fs=0, fh+2fv + fs = 2f0, Pmax = 3

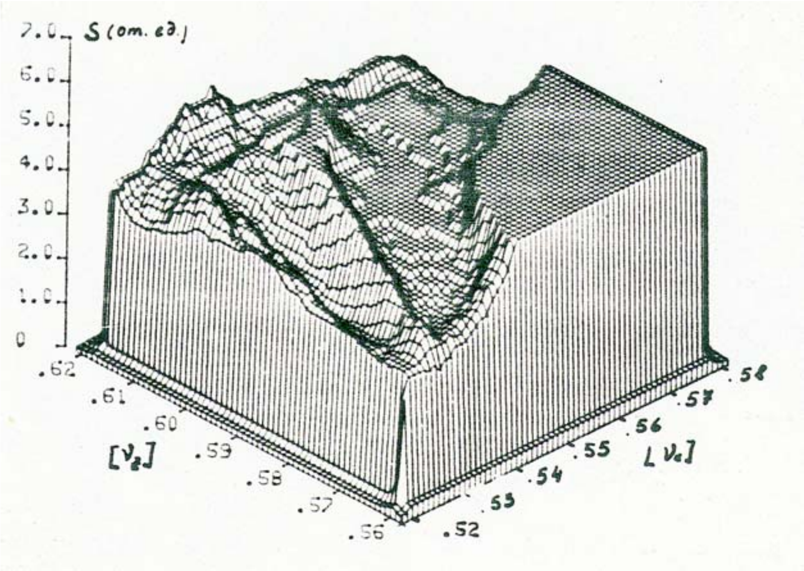
Wiggler ON: -3fh+fv= -f0, fh+fv-3fs=f0, 3fv=2f0, fh+2fv+2fs=2f0, 4fh+fv=3f0, 2fh+fv+2fs=2f0, 2fh-2fs=f0 and -3fh+fv+fs=-f0, Pmax = 5



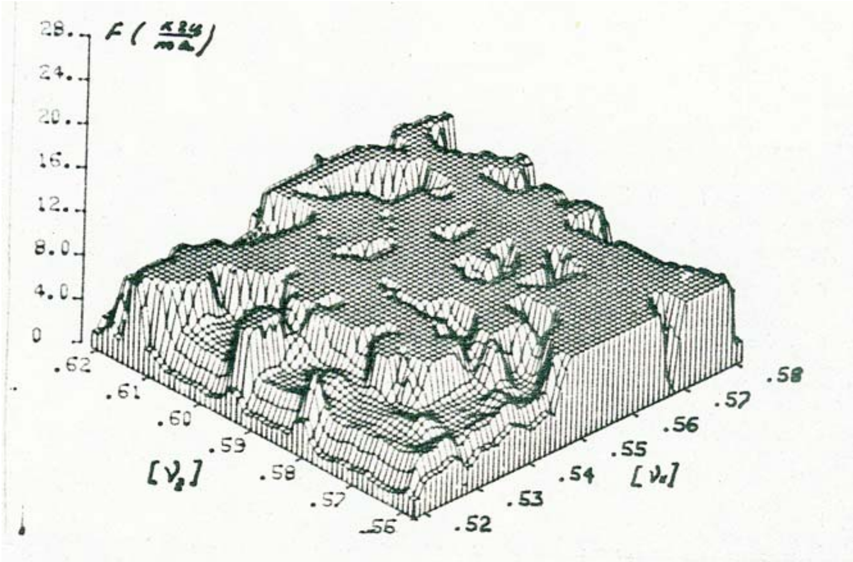
Temnick, September 03, Alghero

Tune plane appearance: beam-beam interaction

Vertical beam size from luminosity (r.u.)



Particle loss rate from positron beam

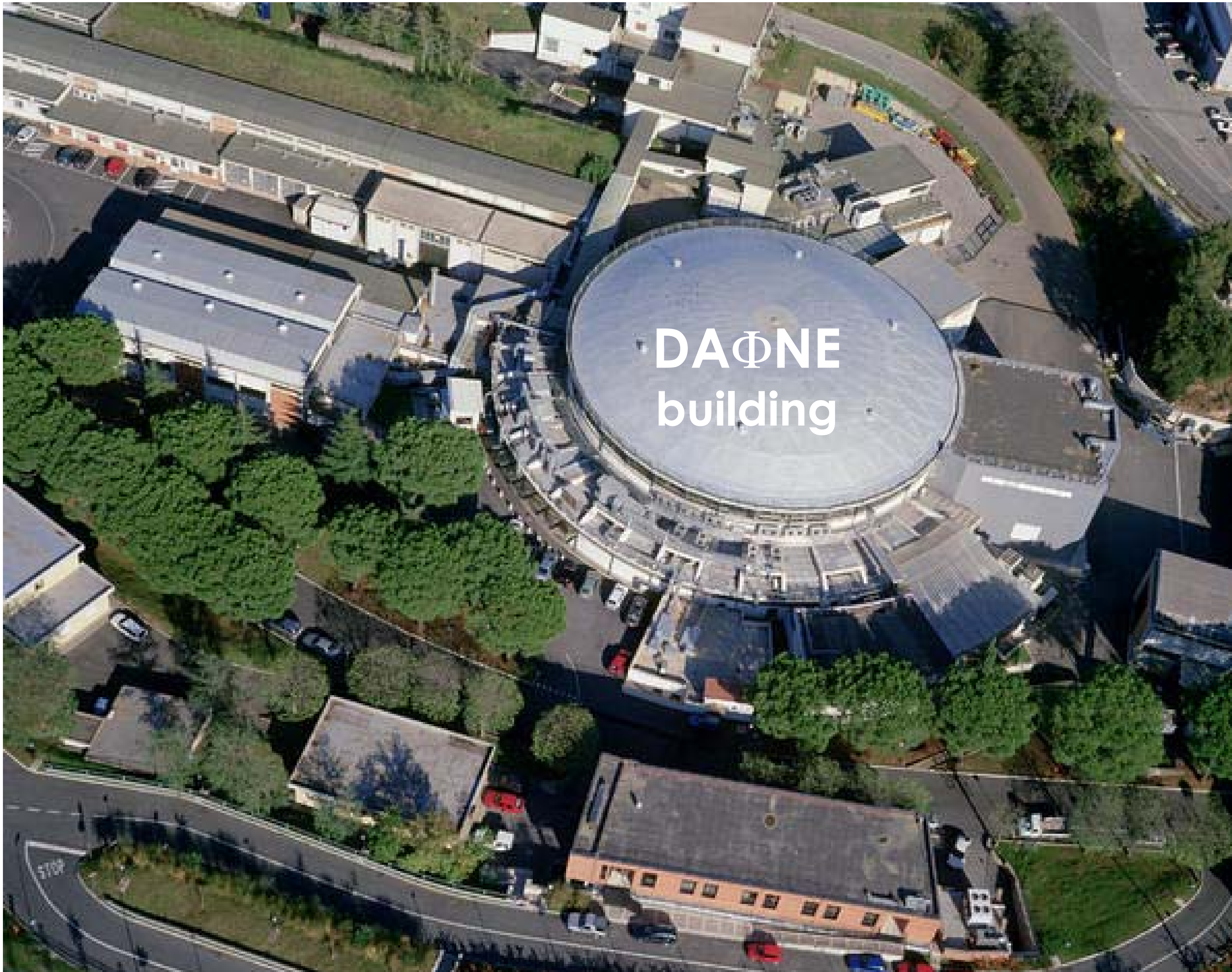


I+ ~ 6.2 mA, I- ~ 10.2 mA
$\xi x = 0.015$, $\xi y = 0.060$

Temnick, September 03, Alghero

CESR c will run until 2008

	E_{cm} GeV	logged $\int L$	New physics at $\int L$	Operating In construction	Design studies
τ	3.9	1 fb^{-1}	> 100 fb^{-1}	CESRc	
light quarks	2	< 10 pb^{-1}	500 pb^{-1}		
Φ	1	1 fb^{-1}	> 100 fb^{-1}	DAΦNE	


DAΦNE
building


E = 500 MeV/beam
C = 98 m

DAΦNE

Double ring

Multibunch

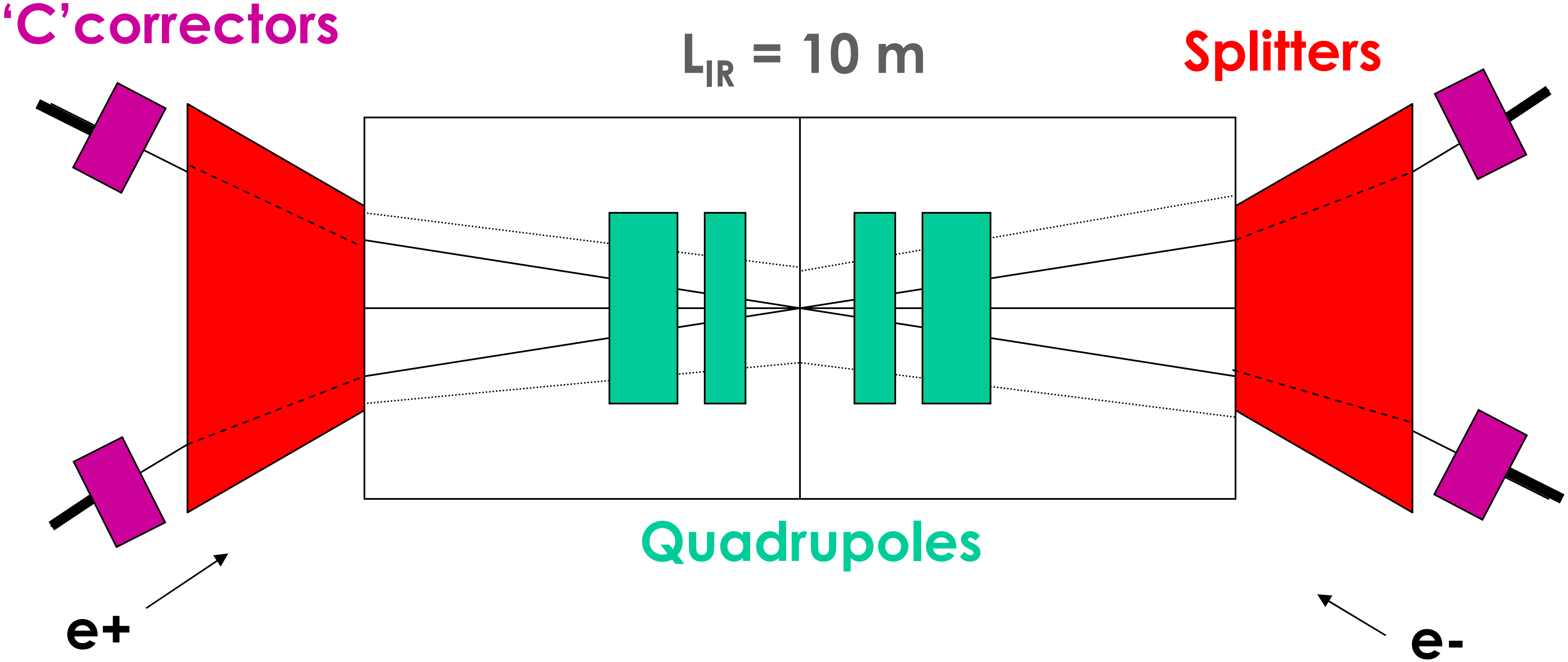
Flat beams

Two IRs

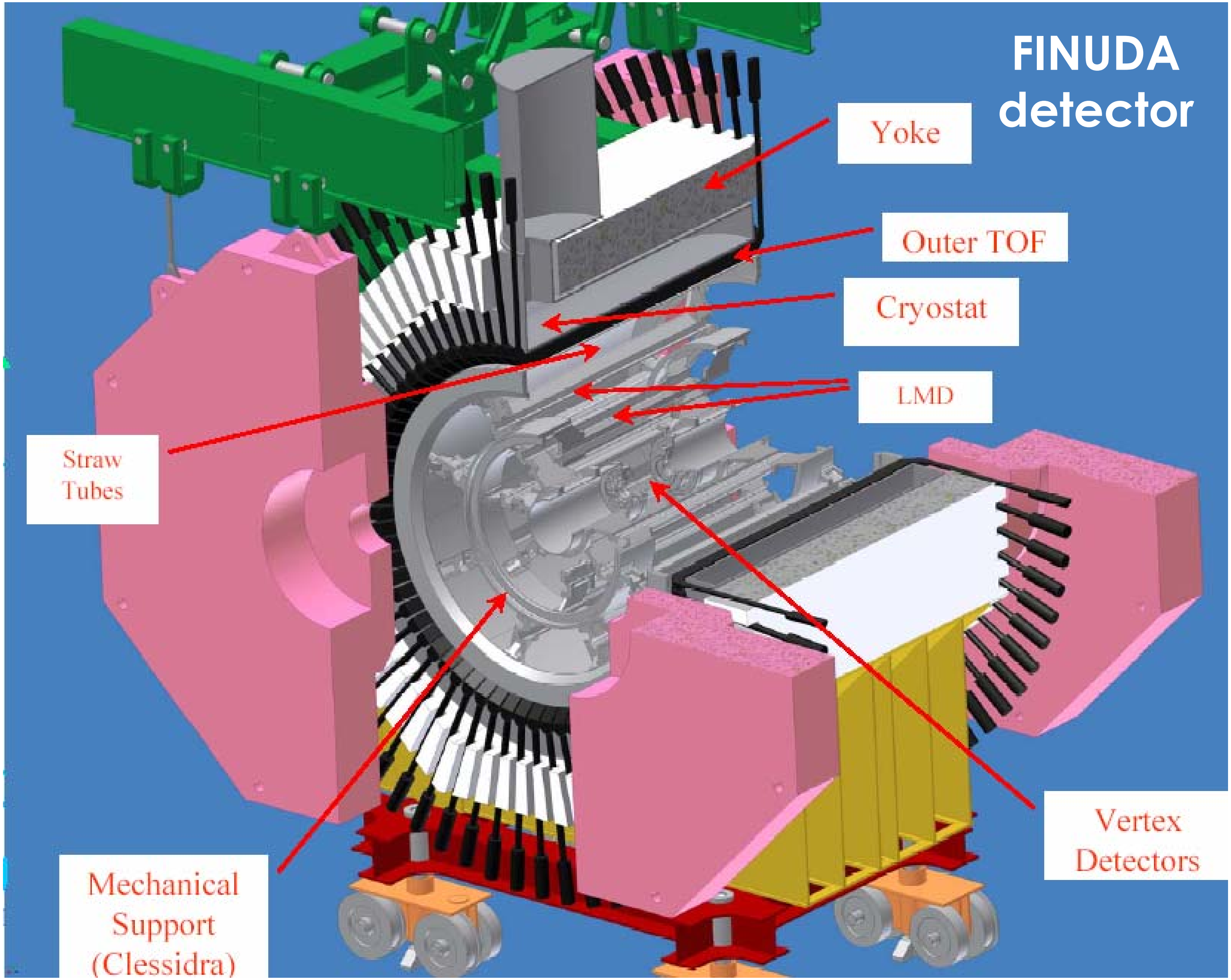
Damping wigglers

Interaction Regions

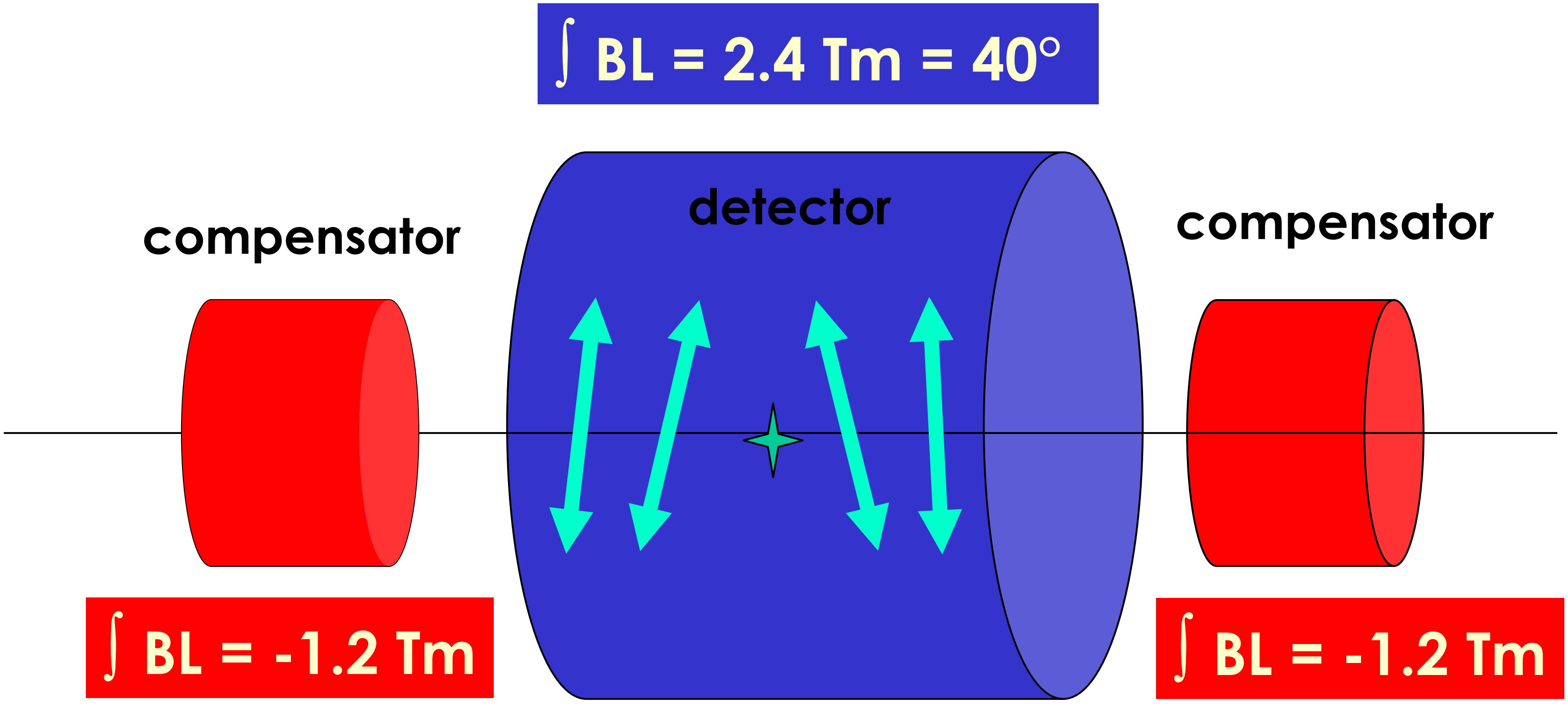
Tunable crossing angle



In operation: 10-20 mrad

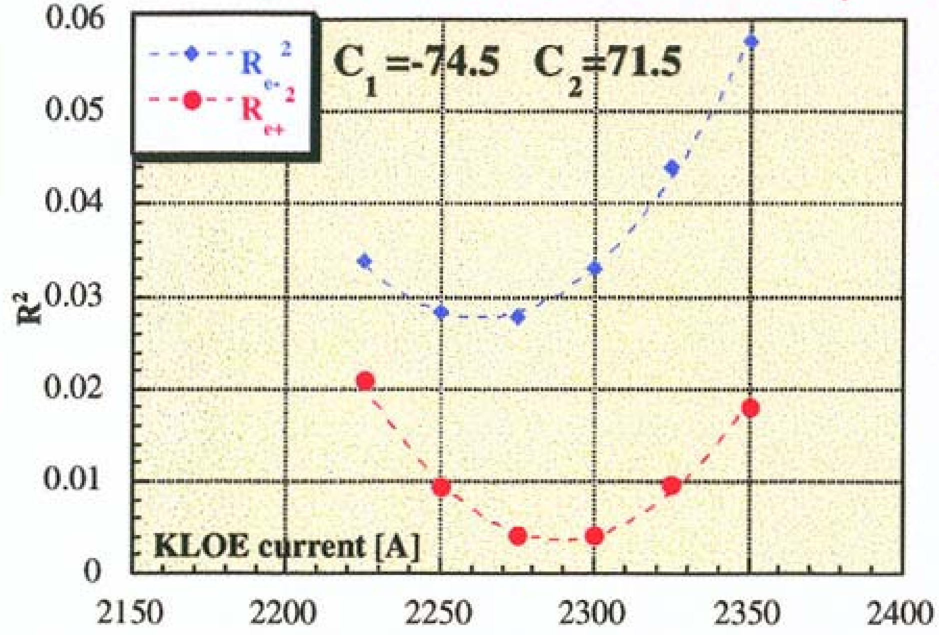

FINUDA
detector
Yoke
Outer TOF
Cryostat
LMD
Straw
Tubes
Vertex
Detectors
Mechanical
Support
(Clessidra)

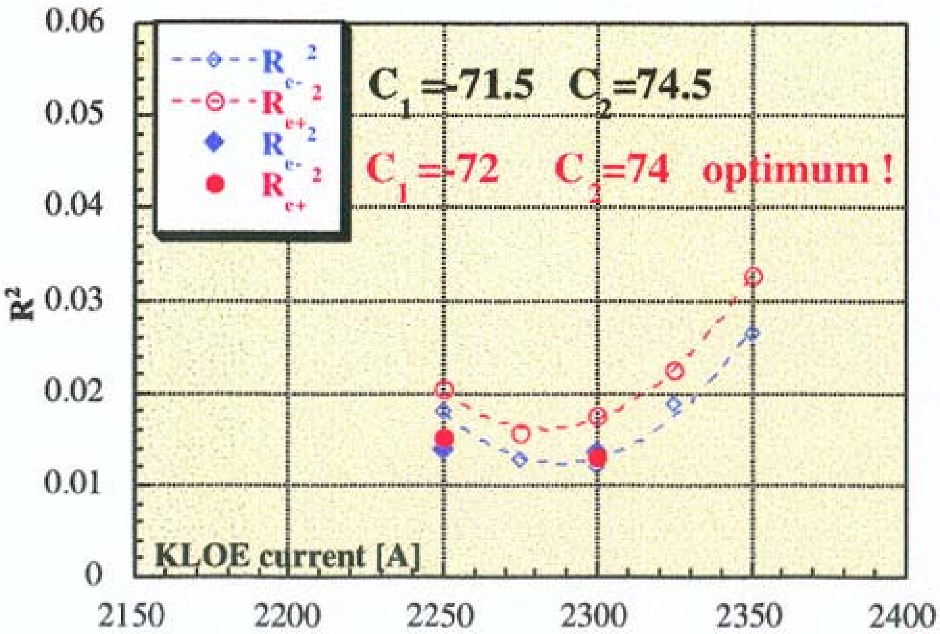
Solenoid compensation



Quads tilted by $$\frac{1}{2B\rho}\int_{IP}^{s_q} Bds + \delta\theta_q$$

Detuned Lattice, Coupling Correction

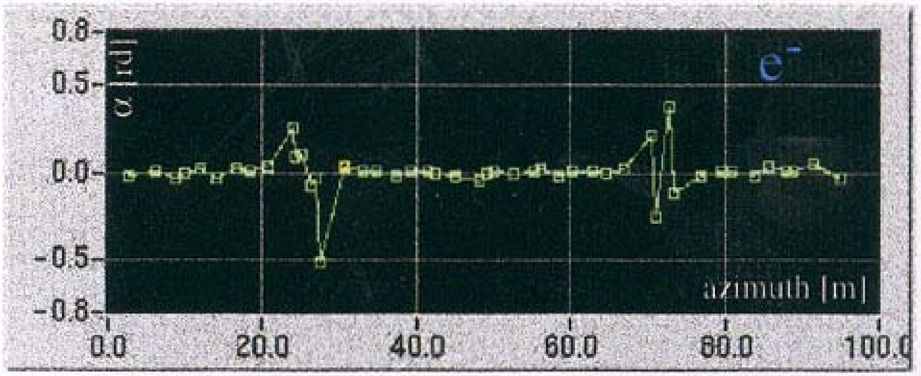


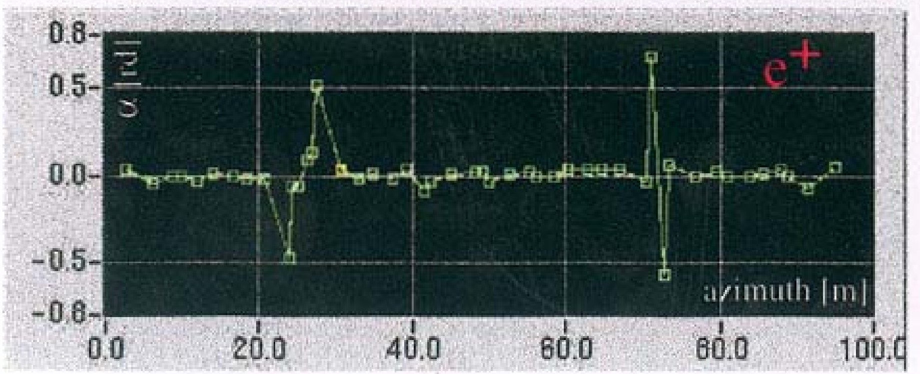


- **R** is the beam aspect ratio as measured at the SLM
- α is the measured amount of Horizontal oscillation transferred to the Vertical plane

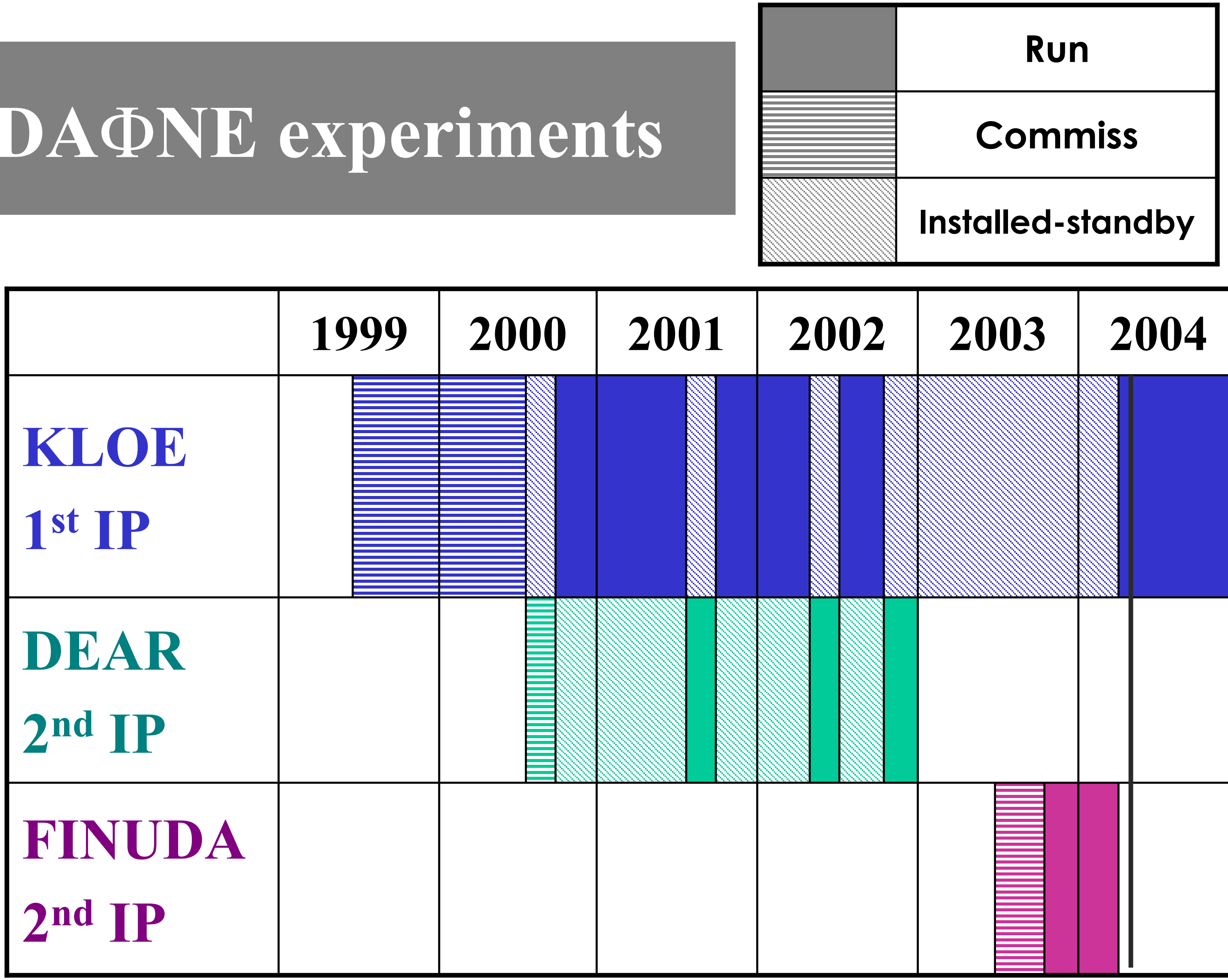
$\alpha \longrightarrow 0$ **means no coupling !**

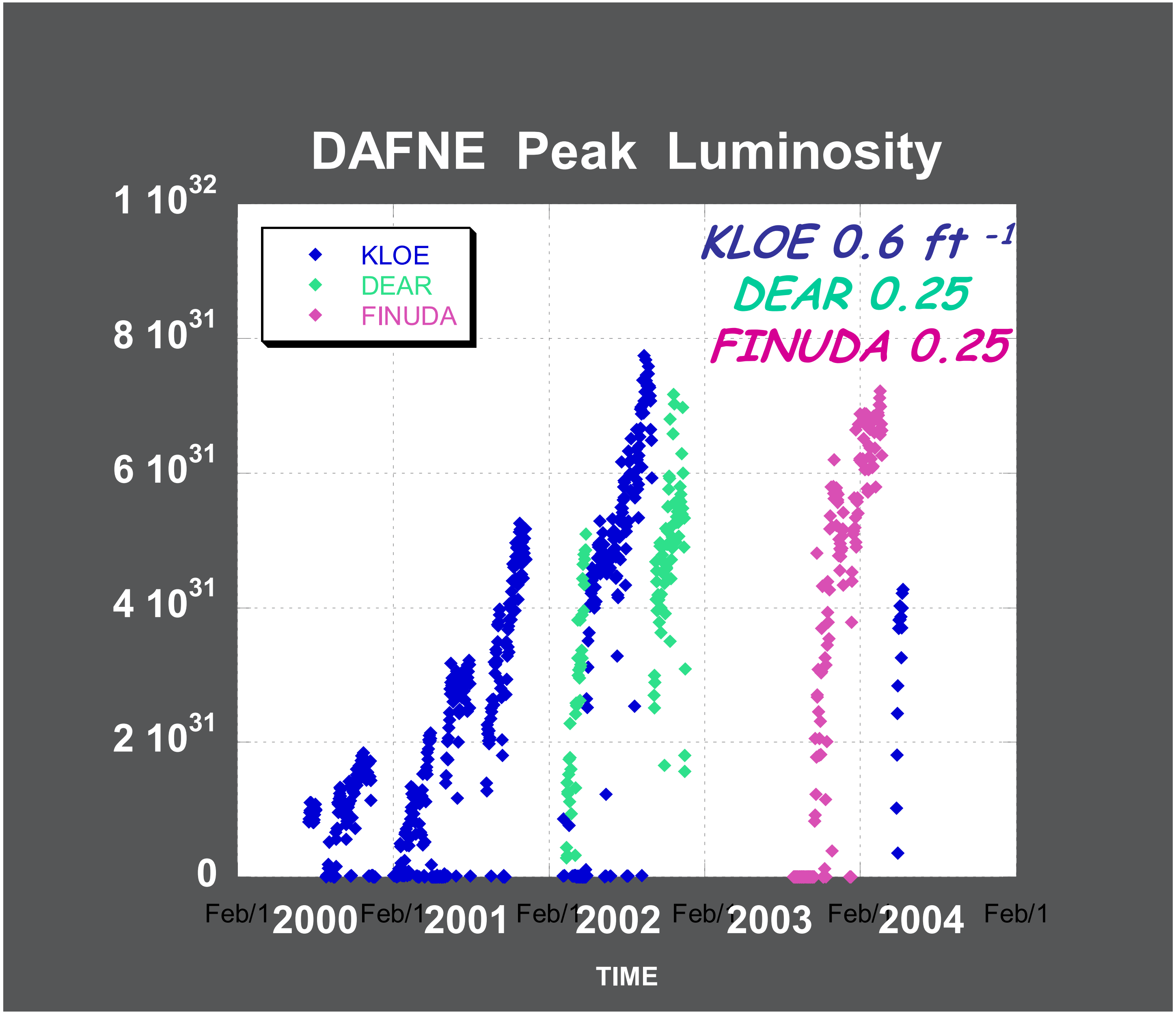
$\kappa < 0.2\%$





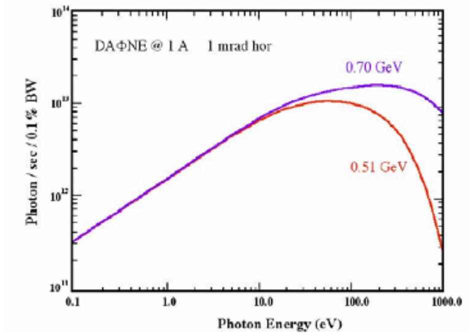
DAΦNE experiments





DAFNE Peak Luminosity
KLOE
DEAR
FINUDA
KLOE 0.6 fb -1
DEAR 0.25
FINUDA 0.25
1 10^32
8 10^31
6 10^31
4 10^31
2 10^31
0
Feb/1
2000
2001
2002
2003
2004
TIME

Highest e- current



90 bunches stable beam

Next 2 - 3 years at DAΦNE

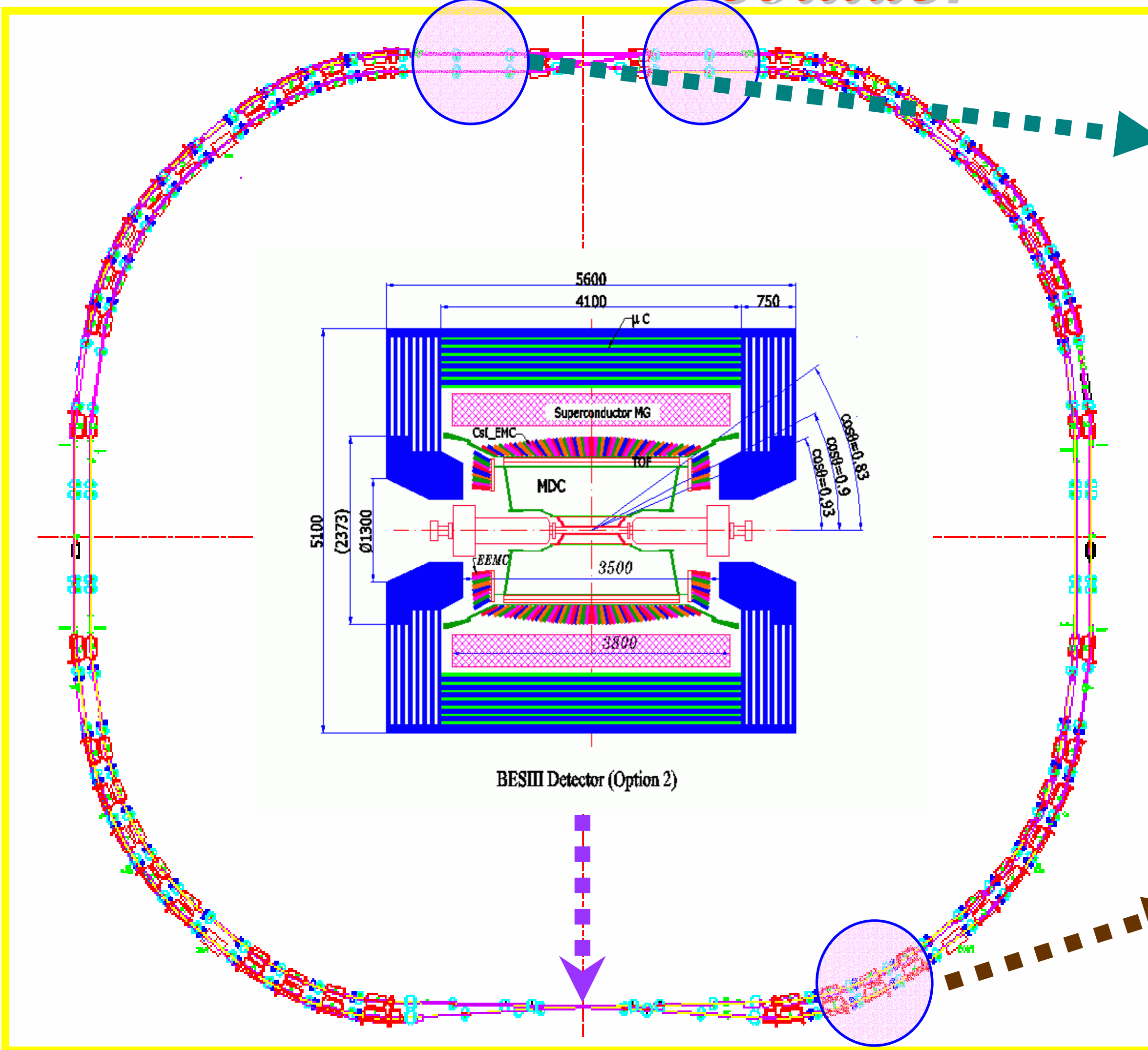
- KLOE ~ 2 fb^{-1}
- SIDDHARTA ~ 0.5 fb^{-1}
- FINUDA ~ 0.5 fb^{-1}

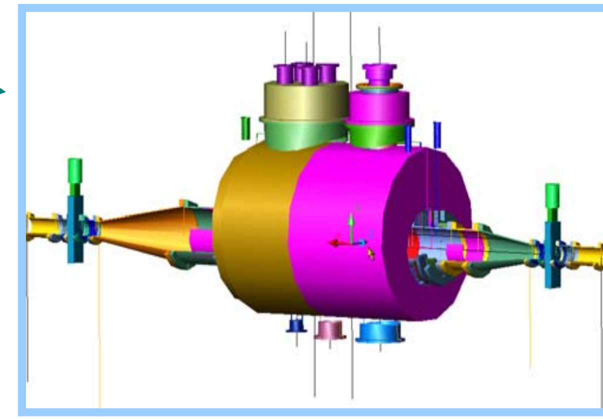
In construction

	E_{cm} GeV	logged $\int L$	New physics at $\int L$	Operating In construction	Design studies
τ	3.9	1 fb^{-1}	> 100 fb^{-1}	CESRc BEPC - II	
light quarks	2	< 10 pb^{-1}	500 pb^{-1}		
Φ	1	1 fb^{-1}	> 100 fb^{-1}	DAΦNE	

BEPC - II

BEPCII: *a high luminosity double–ring collider*

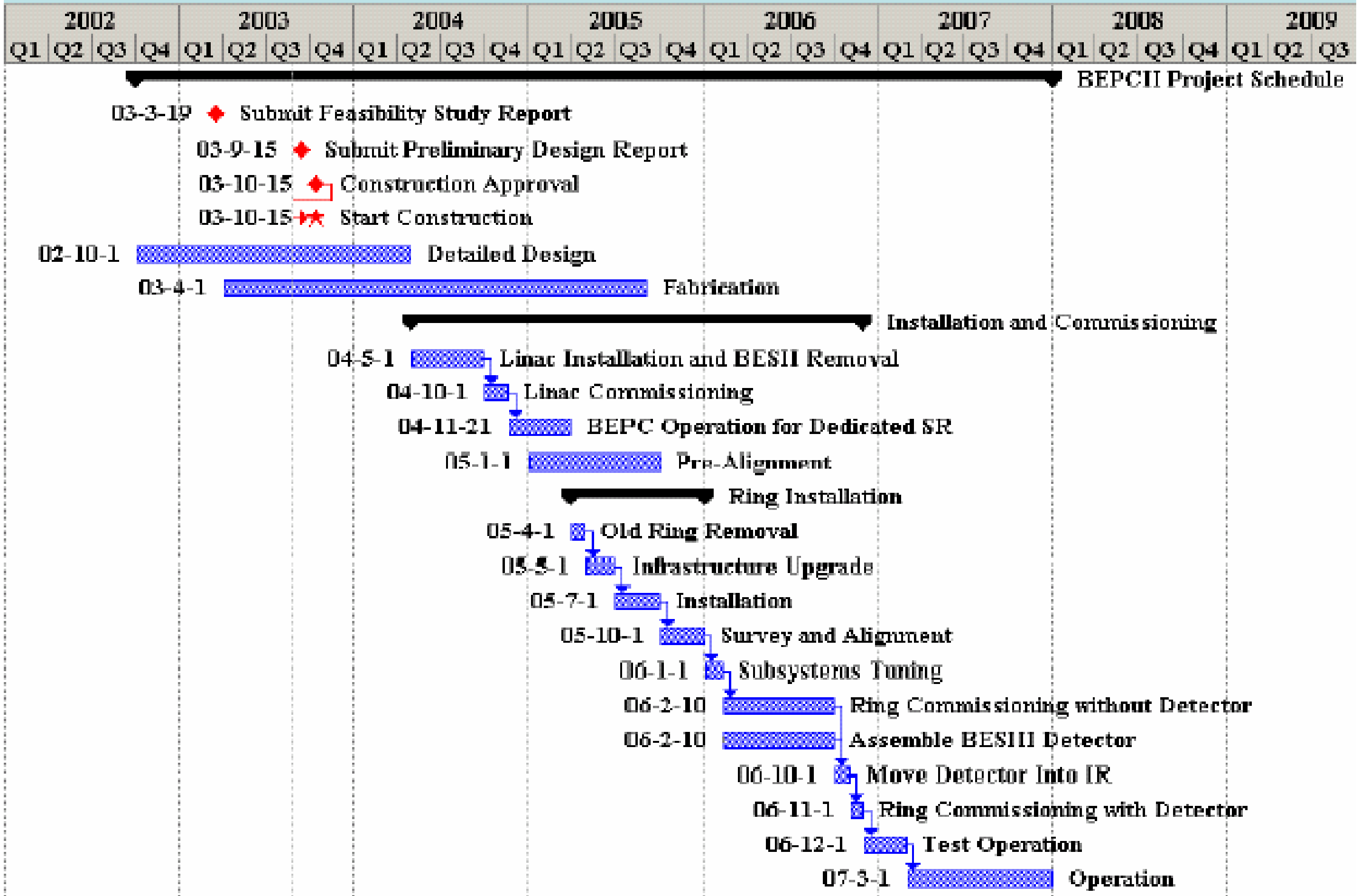




τ-charm factories

Collider	CESRc[2]	BEPC II [3]
status	operating	in construction
E (GeV)	1.88	1.89
C (m)	768	237.5
L (10^{32} $cm^{-2}s^{-1}$)	3	10
rings	1	2
IPs	1	1
β* (m) (h / v)	0.7/ 0.011	1 / .015
ε (μ rad) (h / v)	0.22	0.17 / 0.002
θ (mrad)	±2.8	± 11
ϕ (rad)	0.07	0.4
σ_z (cm)	1.0	1.5
N_b (10^{10})	6.4	4.8
ξ (h / v)	0.03 / 0.03	0.04 / 0.04
N bunches	45	93
I (A)	.18	0.91
f_{RF} (MHz)	500.0	499.8
V (MV)	10	1.5

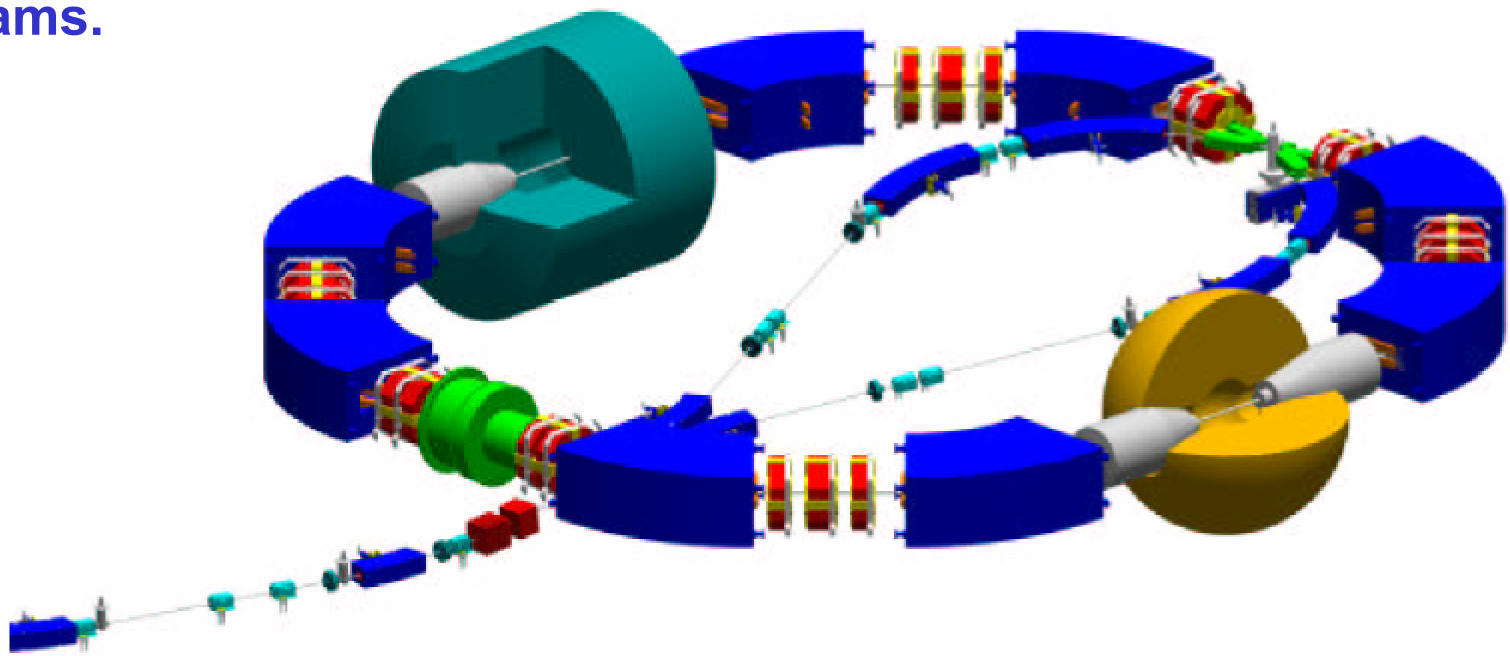
BEPCII Schedule



	E_{cm} GeV	logged $\int L$	New physics at $\int L$	Operating In construction	Design studies
τ	3.9	1 fb^{-1}	> 100 fb^{-1}	CESRc BEPC - II	
light quarks	2	< 10 pb^{-1}	500 pb^{-1}	VEPP2000	
Φ	1	1 fb^{-1}	> 100 fb^{-1}	DAΦNE	

View of the VEPP-2000 collider

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



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Φ	1	1 fb^{-1}	> 100 fb^{-1}	DAΦNE	

DAFNE2 (2 GeV, Frascati)

Feasibility study

"Easier" luminosity than at Φ

Naturally increase radiation damping and lifetime

b-b tune shifts / 2

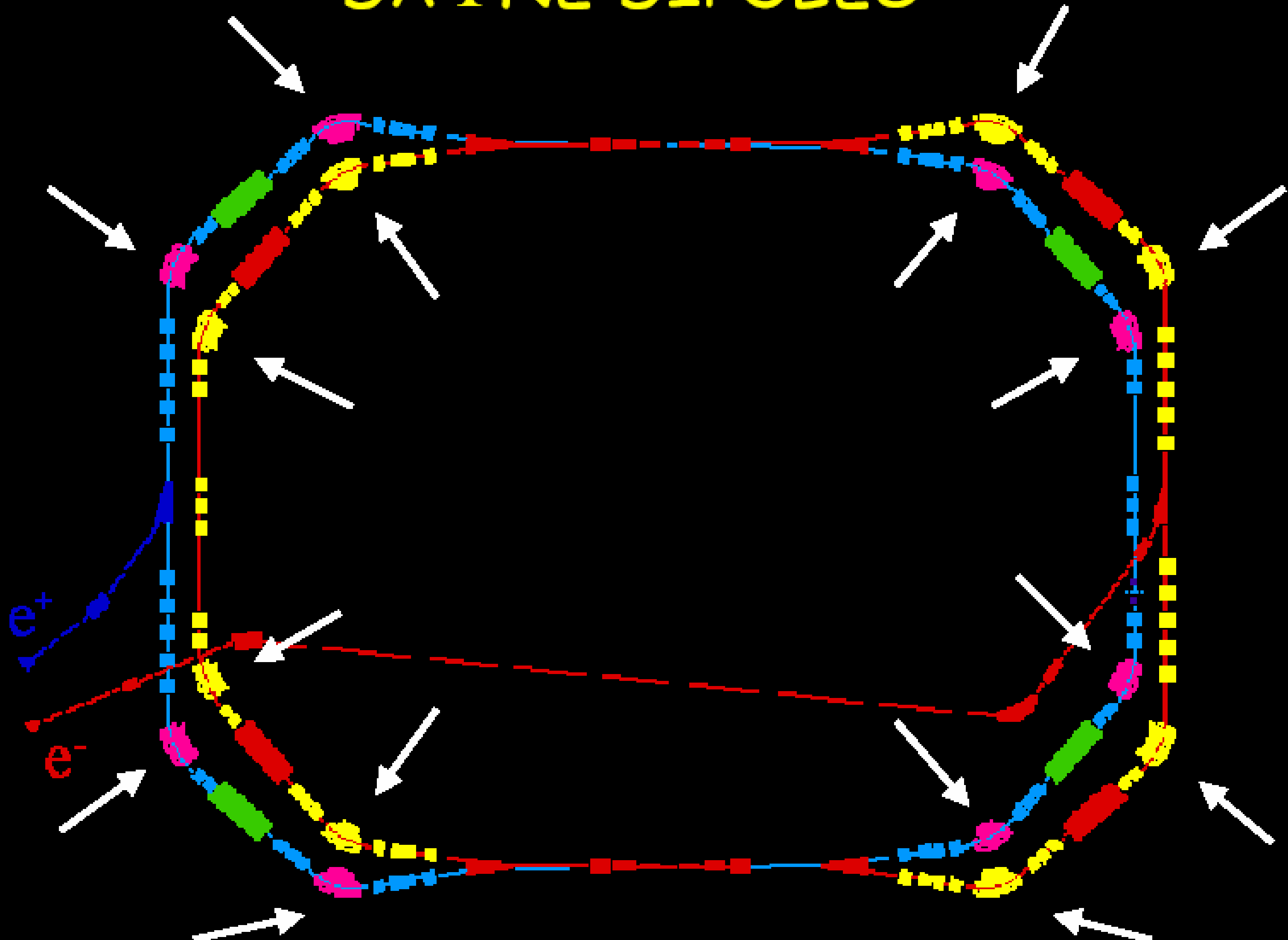
shorter bunch length (I_{thrs} *10) -> lower β_y

roughly same L with I/2 and N_b = 3/5

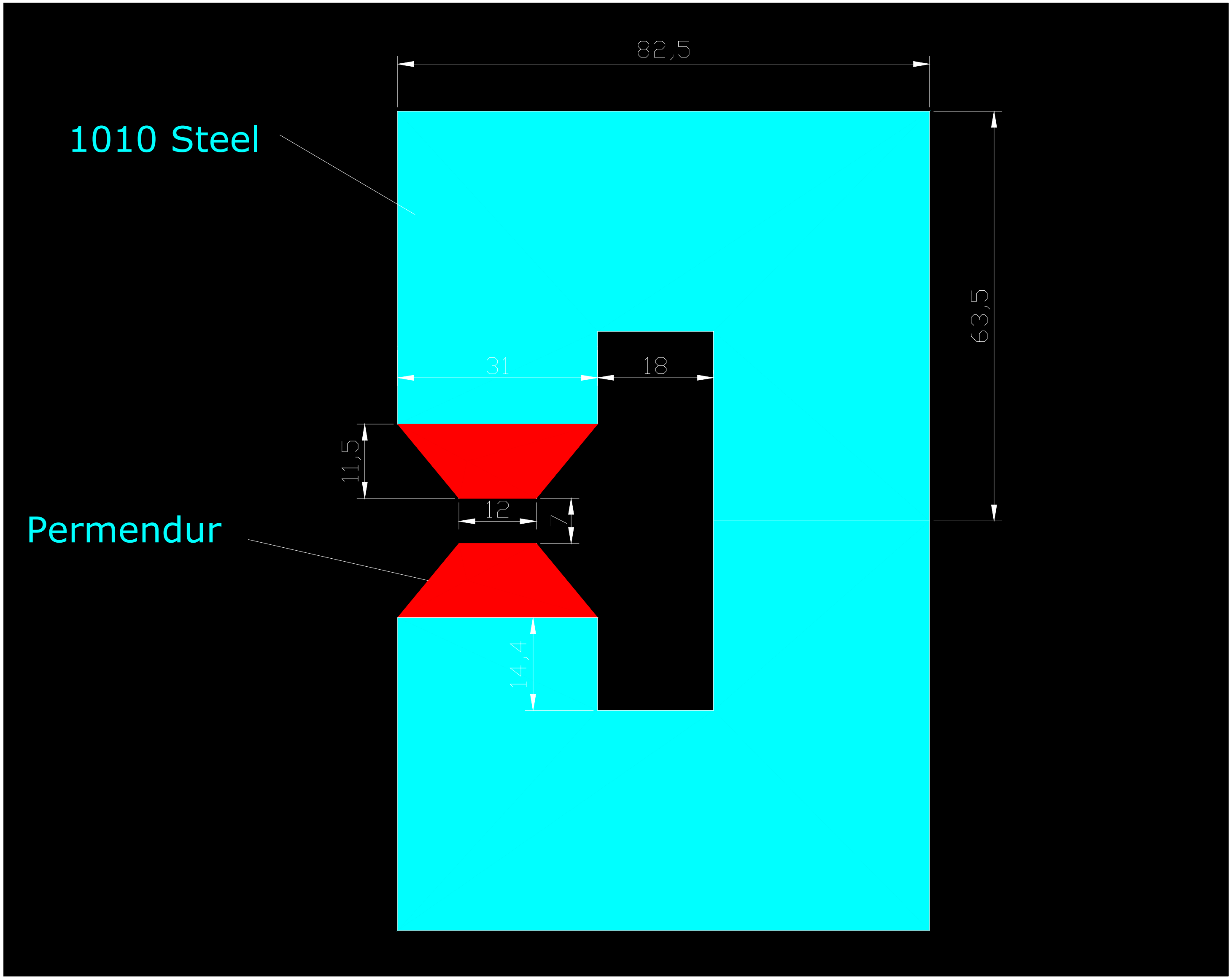
hardware: dipoles, splitters, 20% of quads, IR

DAΦNE DIPOLES

B=1.2 T



Dipole Section



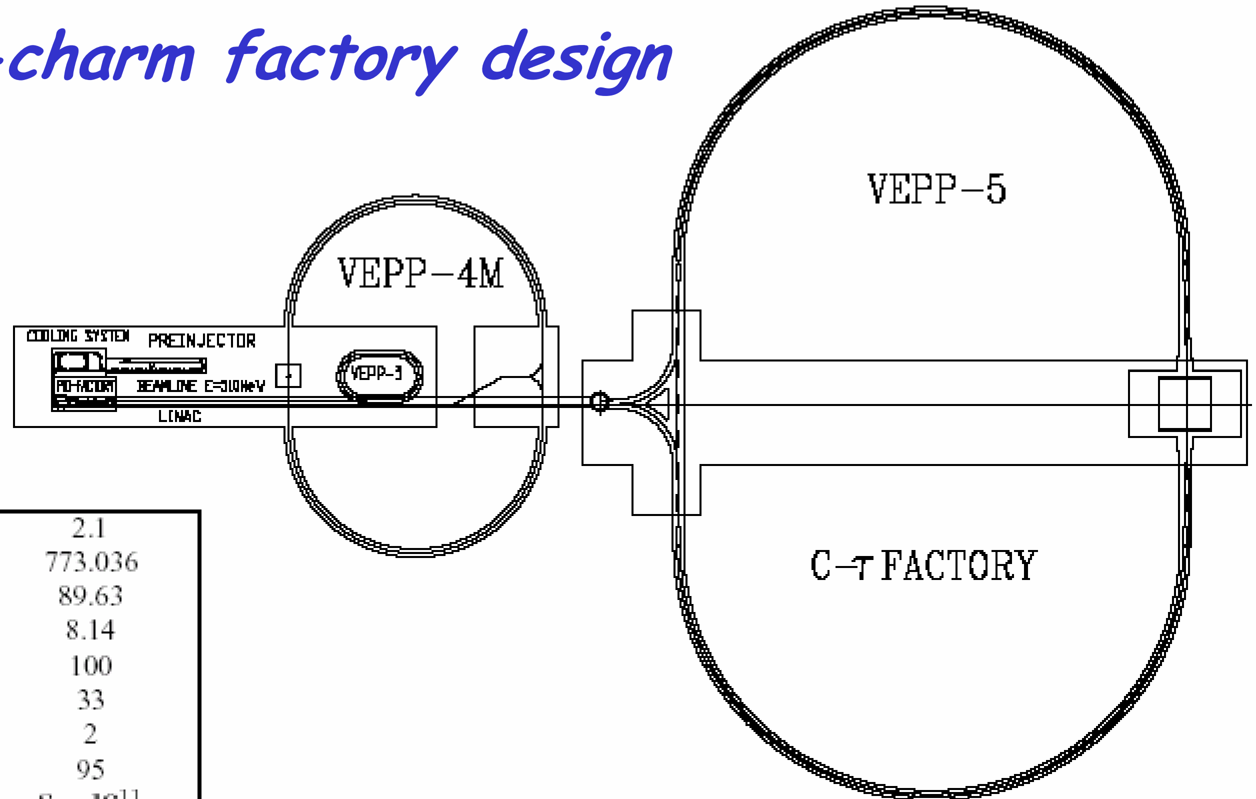
Light Quark Factories

Collider	VEPP2000	DAFNE 2
status	in construction	design study
E (GeV)	1.	1.
C (m)	24	97
L (10^{32} $cm^{-2}s^{-1}$)	1	1
IPs	2	1
β^* (m) (h / v)	0.1 / 0.1	1.5 / 0.025
ε (μ rad) (h / v)	0.136 / 0.136	0.5 / 0.0025
θ (mrad)	0	± 15
ϕ (rad)	0	0.26
σ_z (cm)	3	1.1
N_b (10^{10})	10	3
ξ (h / v)	0.1 / 0.1	0.014 / 0.024
N bunches	1	30
I (A)	0.20	0.45
f_{RF} (MHz)	172	368.3
V (MV)	0.12	0.25

FUTURE

	E_{cm} GeV	logged $\int L$	New physics at $\int L$	Operating In construction	Design studies
τ	3.9	1 fb^{-1}	> 100 fb^{-1}	CESRc BEPC - II	VEPP 5
light quarks	2	< 10 pb^{-1}	500 pb^{-1}	VEPP 2000	DAFNE2
Φ	1	1 fb^{-1}	> 100 fb^{-1}	DAΦNE	

Novosibirsk τ-charm factory design



Energy (Gev)	2.1
Circumference (m)	773.036
Ring radius (m)	89.63
Interbunch distance (m)	8.14
Straight section lenght (m)	100
Beam radius at IP (μ m)	33
Number of rings	2
Number of bunches per beam	95
Number of particle per bunch	2×10^{11}
b-function at IP (cm)	1
Beams emittance ($\epsilon_x = \epsilon_y$) (cm/rad)	10^{-5}
RMS bunch length (cm)	0.8
Compaction factor	$0.001 \div 0.0017$
Betatron tune ν_x	29.077
Betatron tune ν_y	31.077
Vertical damping time (s)	0.11
RF voltage (kV)	1000
RF frequency (MHz)	700
Energy loss per turn (keV)	100
Energy spread	5×10^{-4}
Harmonic Number	1805
Tune shift parameter $\xi_x = \xi_y$	0.1
Design Luminosity ($cm^{-2}s^{-1}$)	10^{34}

	E_{cm} GeV	logged $\int L$	New physics at $\int L$	Operating In construction	Design studies
τ	3.9	1 fb^{-1}	> 100 fb^{-1}	CESRc BEPC - II	VEPP 5
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Φ	1	1 fb^{-1}	> 100 fb^{-1}	DAΦNE	DAΦNE-II

Main guidelines for the design
$L \sim 10^{34}$ at Φ energy

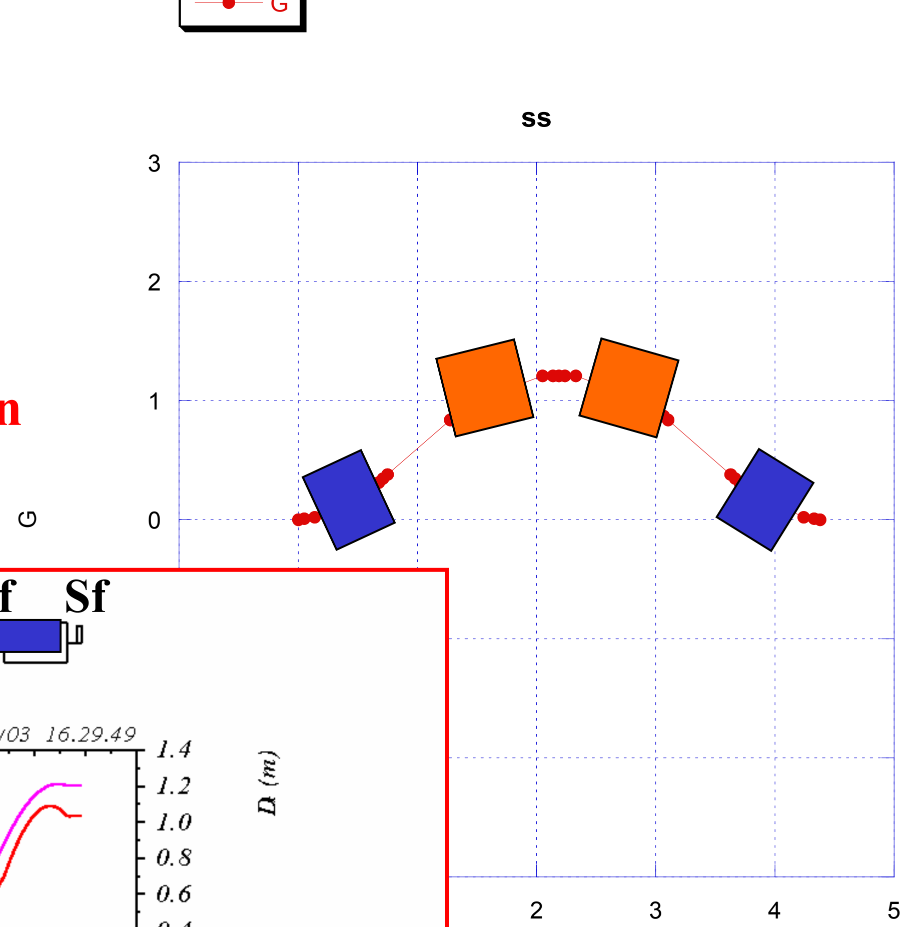
Double ring
Multibunch operation
Flat beam

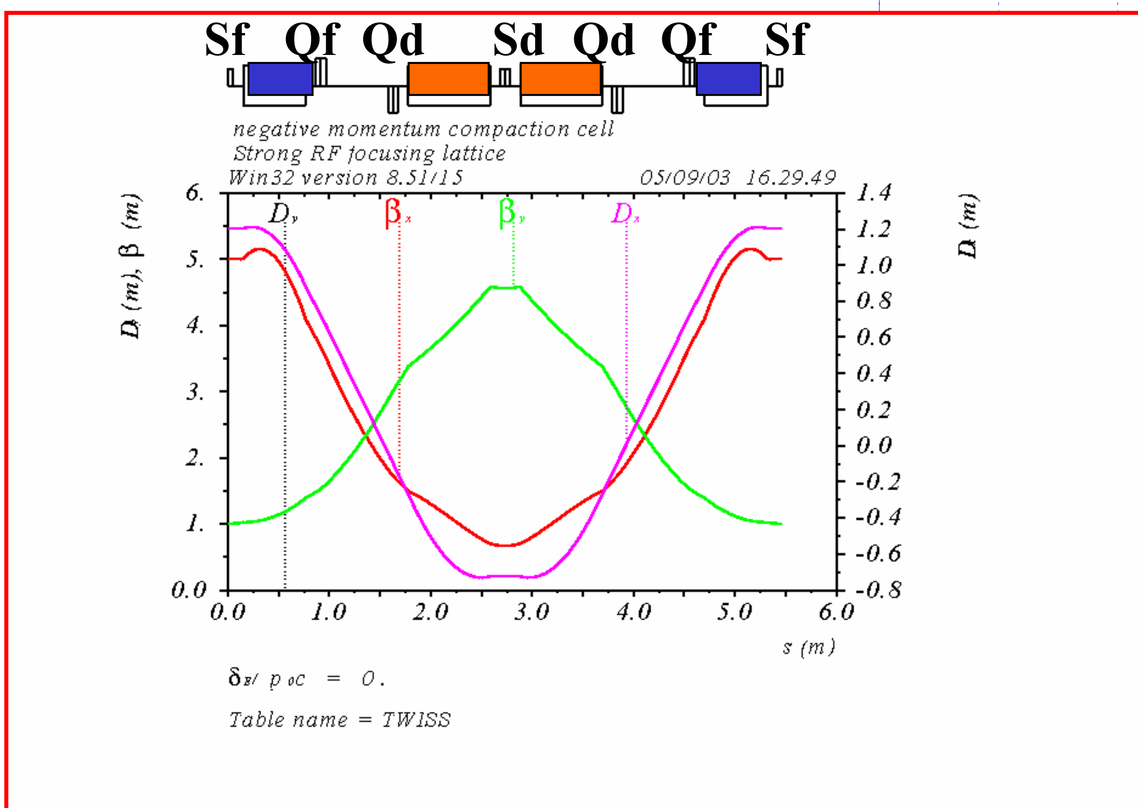
+

- **Powerful damping**
- **Negative momentum compaction**
- **Very short bunch at IP**

HIGH and NEGATIVE MOMENTUM COMPACTION

strong RADIATION emission

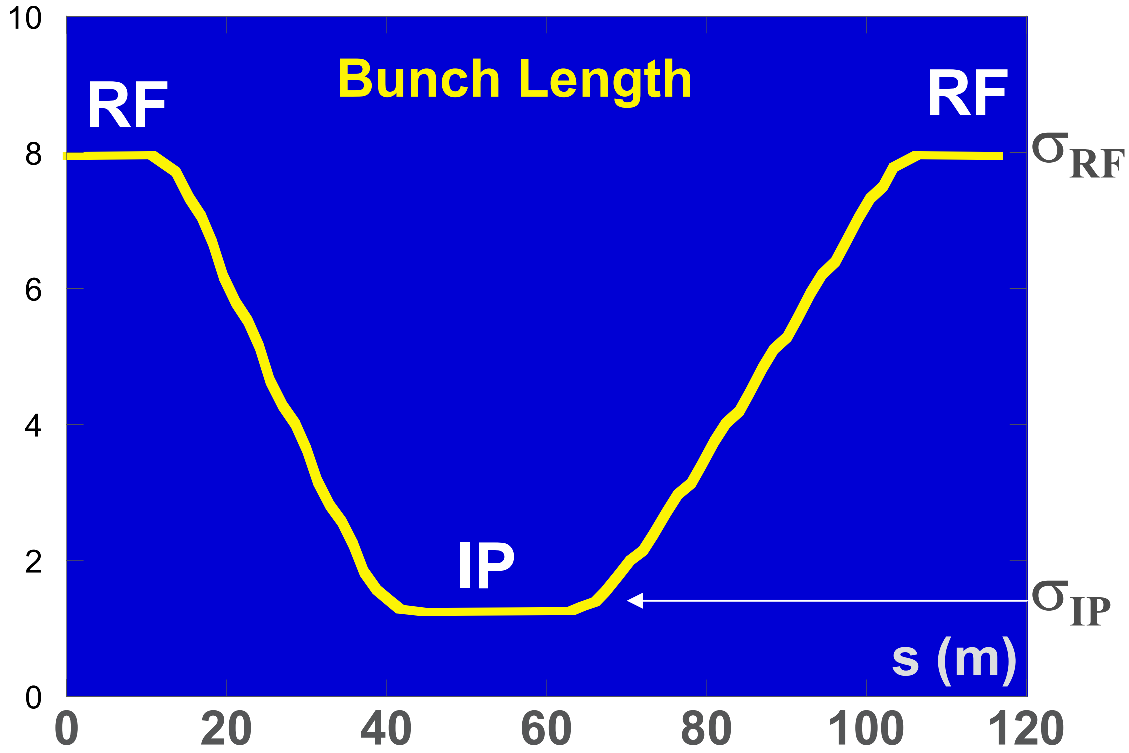




Alternating positive and negative bending dipoles

Strong RF Focusing (SRFF)

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

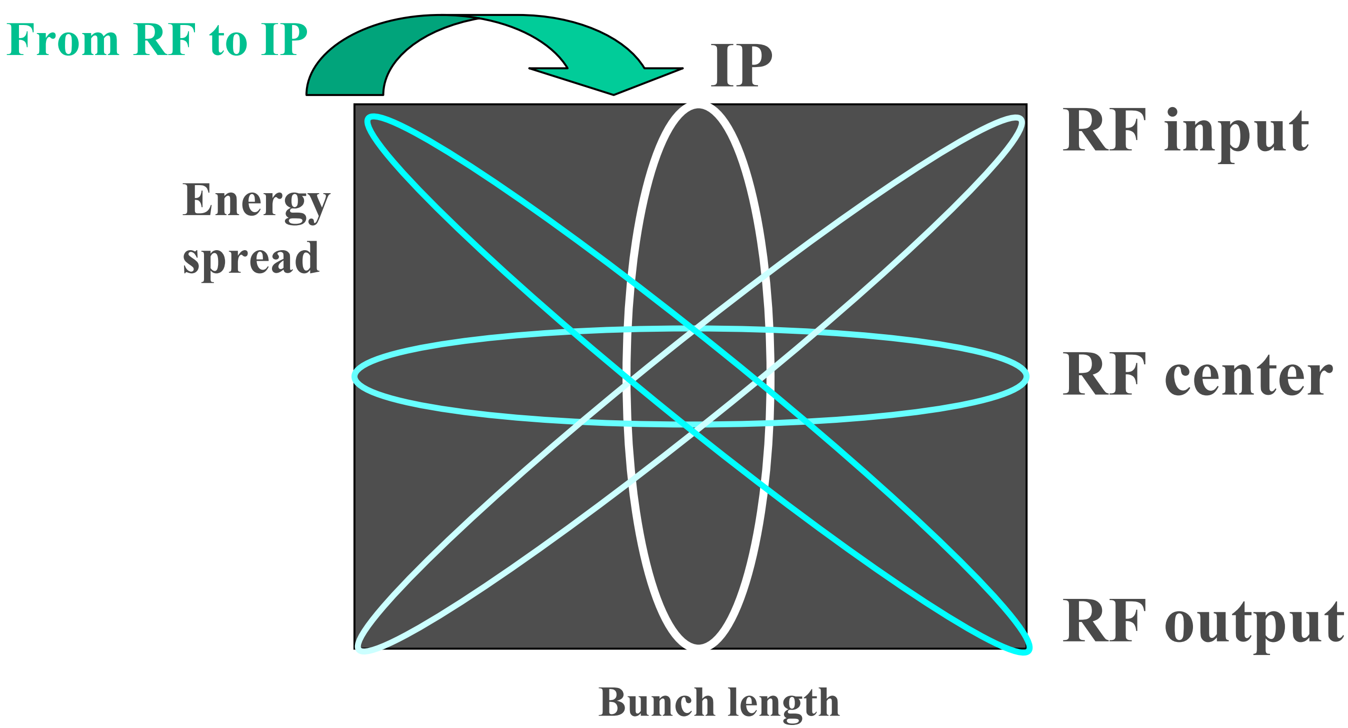


High rf voltage

+

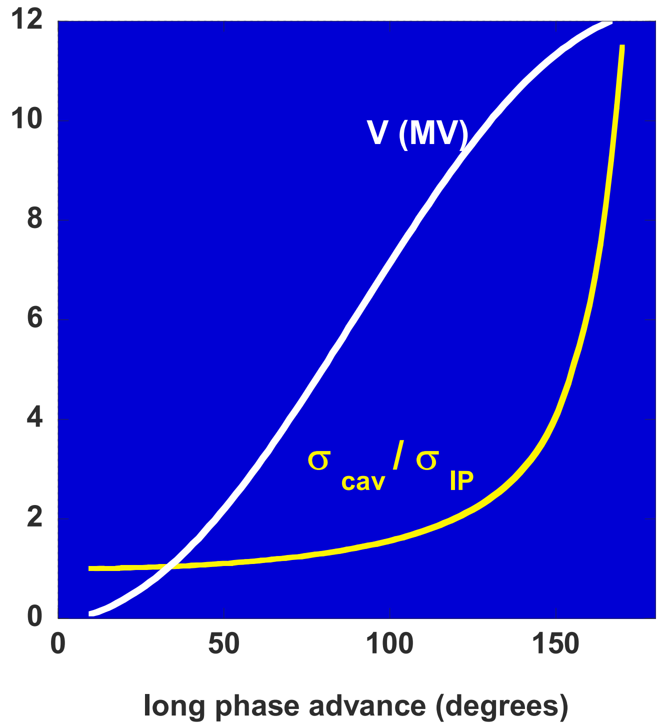
Magnetic lattice which correlates longitudinal position with energy deviation (high momentum compaction)

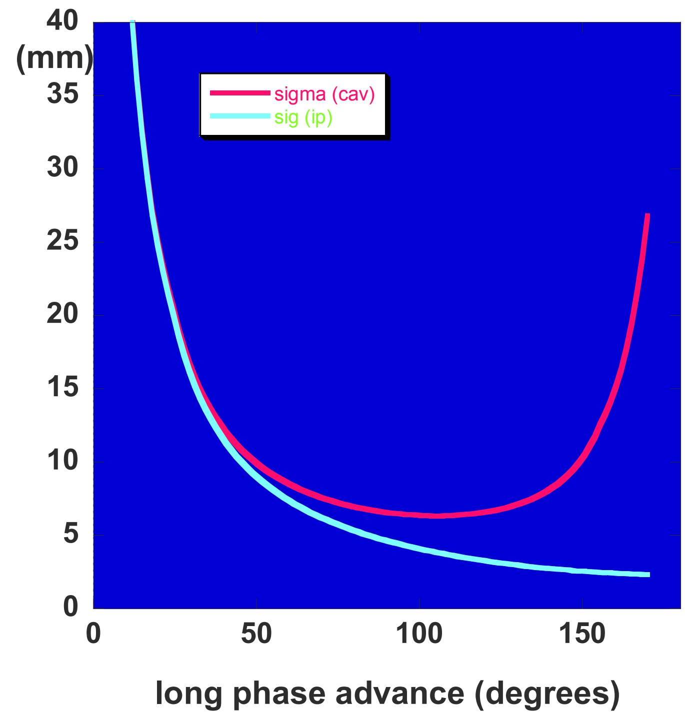
Longitudinal phase space



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

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





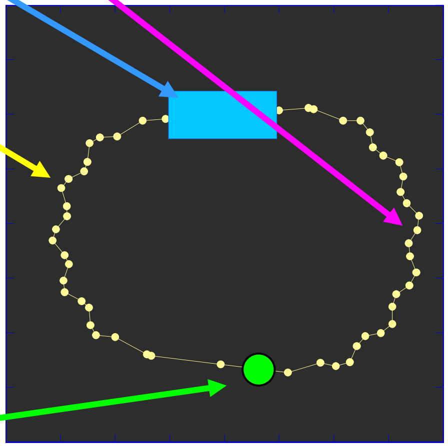
Layout similar to present DAΦNE rings:

One IR

Second crossing for injection, rf, diagnostics

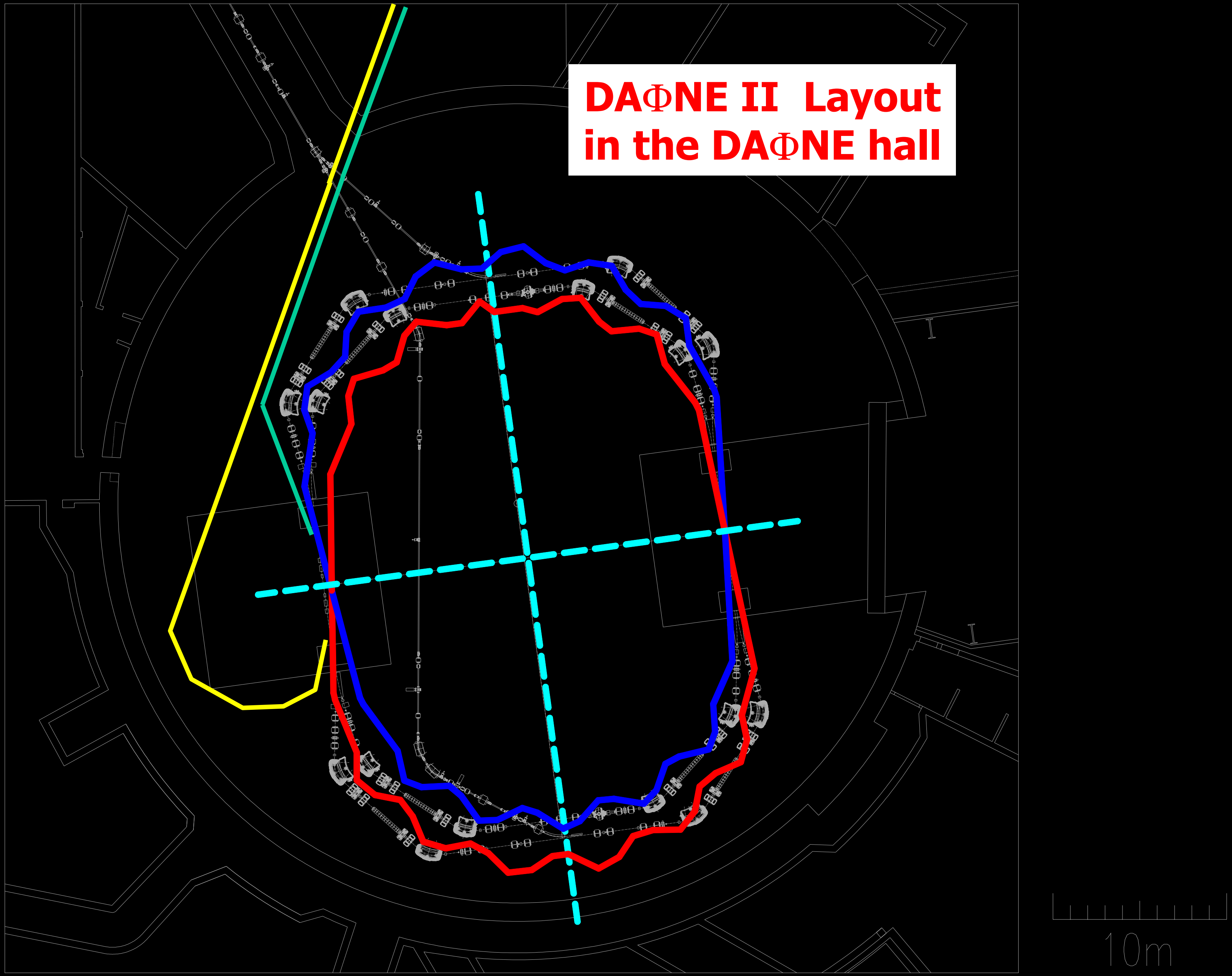
Short inner arc and long outer arc with the condition of equal longitudinal phase advance between cavity and IP in both directions

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



rf

DAΦNE II Layout in the DAΦNE hall



Light Quark Factories

Collider	DAΦNE II
status	design study
E (GeV)	0.51
C (m)	100
L (10^{32} cm^{-2}s^{-1})	100
IPs	1
β^* (m) (h / v)	0.5 / 0.0025
ε (μ rad) (h / v)	0.2 / 0.0025
θ (mrad)	± 15
σ_l (cm)	1.4 – 0.2
Qs	0.4
α c	- 0.16
N bunches	150
I (A)	3
f_{RF} (MHz)	500
V (MV)	10

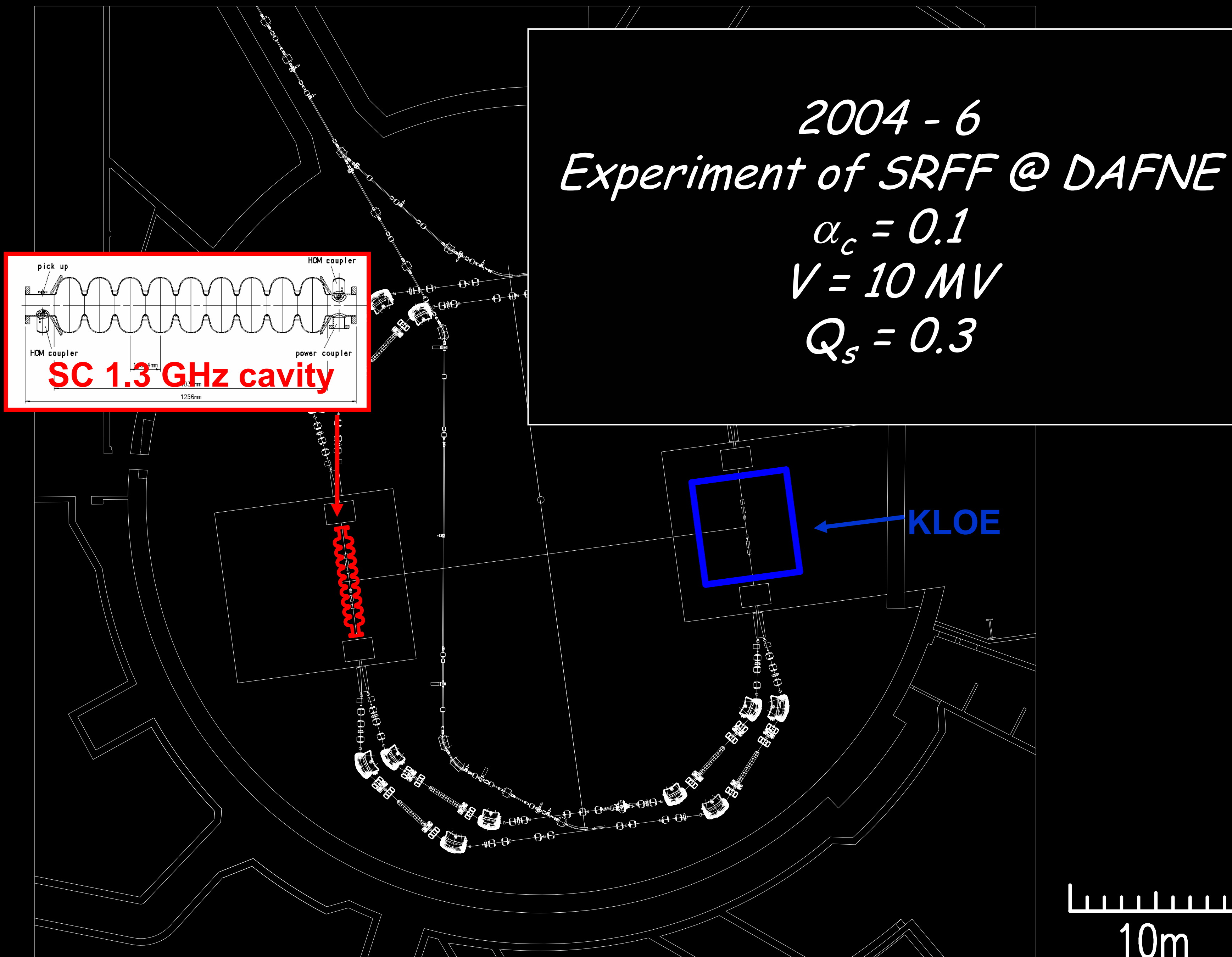
2004 - 6

Experiment of SRFF @ DAFNE

$\alpha_c = 0.1$

$V = 10$ MV

$Q_s = 0.3$



	E_{cm} GeV	logged $\int L$	New physics at $\int L$	Operating In construction	Design studies
τ	3.9	1 fb^{-1}	> 100 fb^{-1}	CESRc BEPC	VEPP 5
light quarks	2	< 10 pb^{-1}	500 pb^{-1}	VEPP 2000	DAFNE2
Φ	1	1 fb^{-1}	> 100 fb^{-1}	DAΦNE	DAΦNE-II