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DAFNE2: LATTICE for a 2 GeV ELECTRON COLLIDER

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DAFNE2

DAFNE2 (**D**ouble **A**nnular **F**rascati e^+ e^- factory for **N**ice **E**xperiments at **2** GeV) is the upgrade of DAΦNE from the present energy of 1.02 GeV c.m. up to the neutron-antineutron threshold, about 2 GeV c.m., using the existing systems and structures.

The luminosity required by the experiments for a «light quark factory» is of the order of few 10^{31} cm^{-2} s^{-1}, easily achievable in the particle factory era.

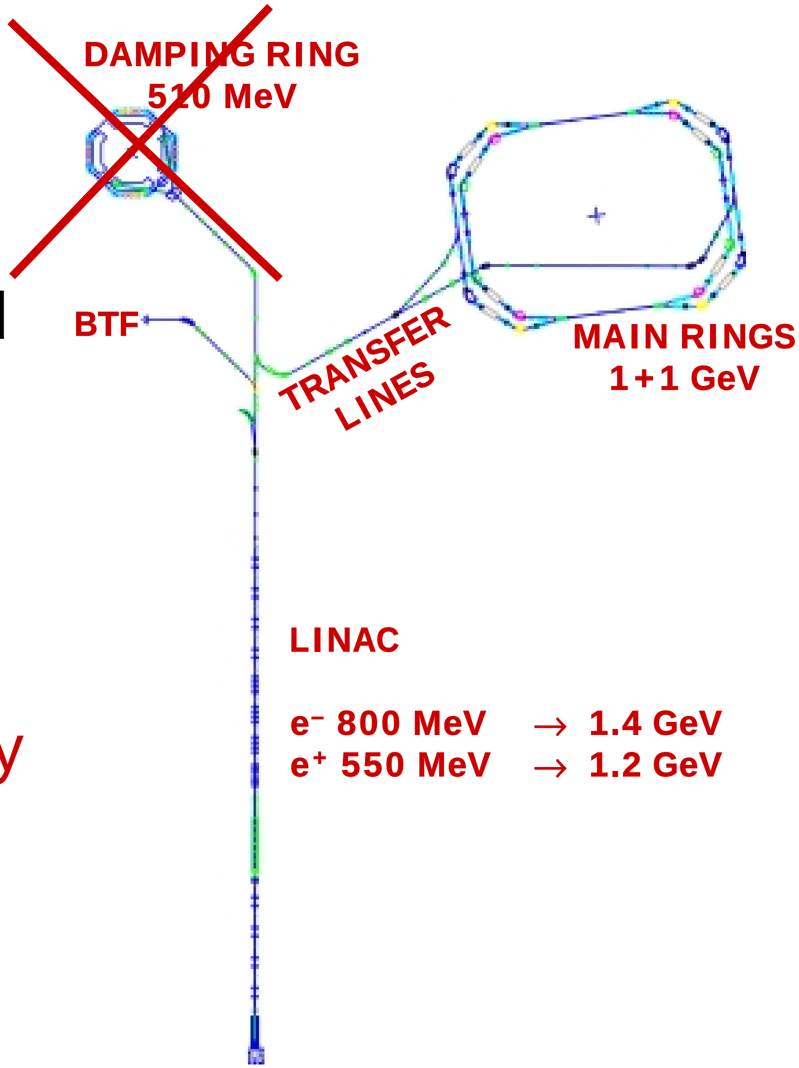
ENERGY UPGRADE: from 1.02 to 2-2.4 *GeV* c.m.

Two options:

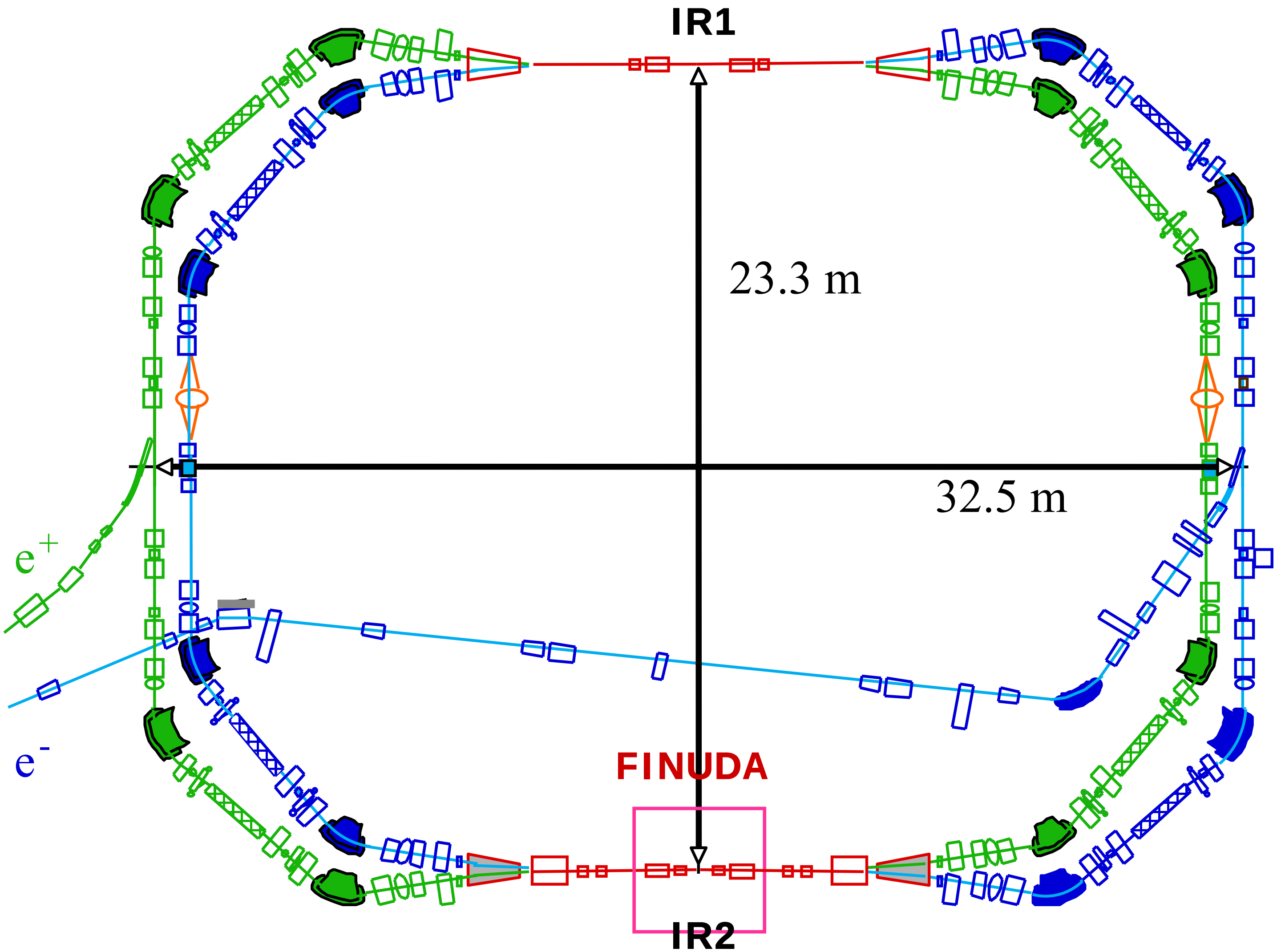
1) DAFNE2 can use the existing injection system (linac and damping ring) at 0.51 *GeV* and reach 1–1.1 *GeV* per beam performing an energy ramping in the main Rings [C. Milardi]

or:

2) We can inject directly on energy adding new accelerating structures to the linac [R. Boni]



DAFNE2 MAIN RING LAYOUT

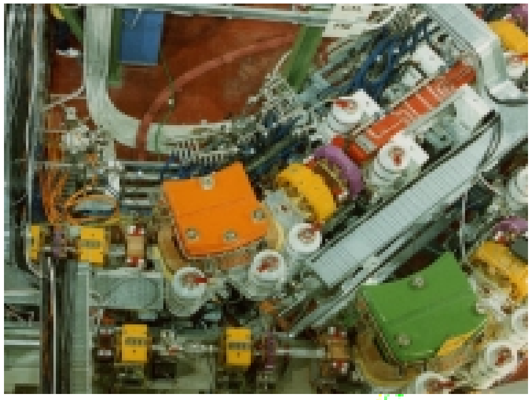


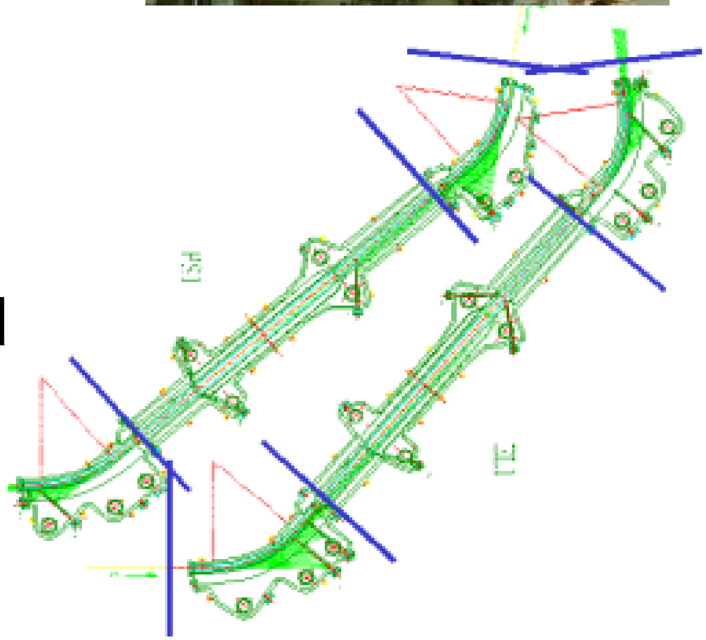
WHAT CAN BE USED FROM DAΦNE

- DAFNE2 can exploit DAΦNE hardware:
  - vacuum chamber
  - all quads and sexts
  - RF cavity
  - Feedback, diagnostics, vacuum system…
- But needs new:
  - stronger bending dipoles
  - 4 SC quads in IR2

DAFNE2 DIPOLES

- B_0 must go from 1.2 *T* (DAΦNE dipoles) to 2.2 *T* at 1 *GeV* [C. Ligi, R. Ricci]
- the existing vacuum chamber impose constraints on the dipole geometry
- new dipoles are 10% longer and they are all Sector magnets
- bending radius ρ from 1.40 *m* (old dipoles) to 1.54 *m*



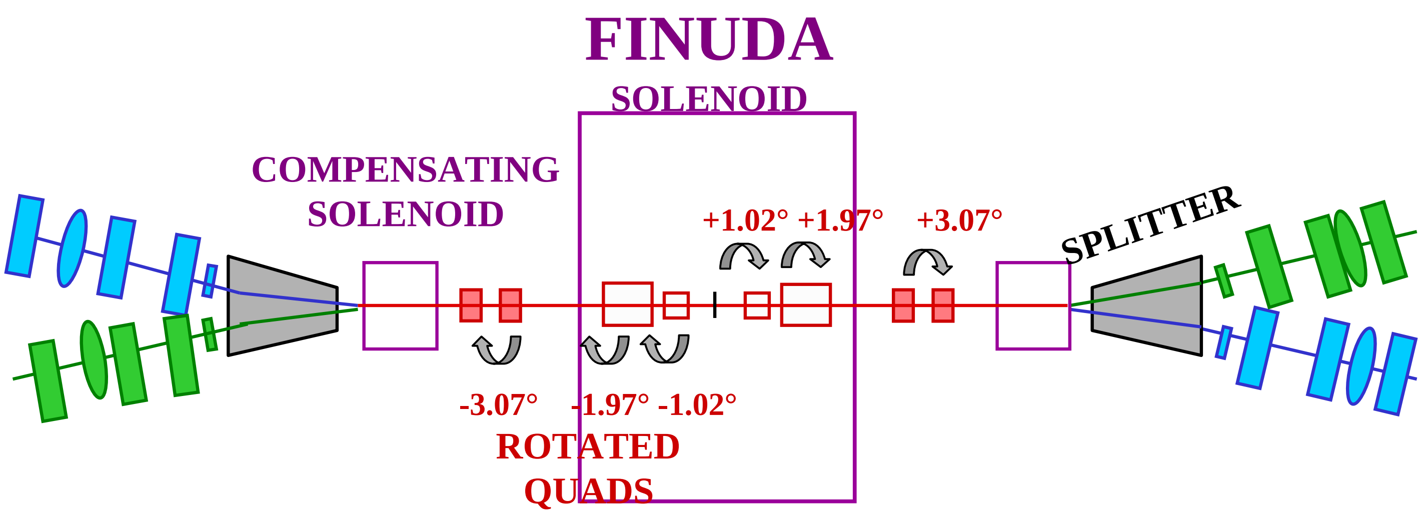


DAFNE2 DIPOLES

Position	#/ring	Type	L (*m*)	B_0 (*T*)	Angle	Radius (*m*)
Long Section	4	Sector	1.32	2.4	49.5 º	1.54
Short Section	4	Sector	1.12	2.4	40.5º	1.54

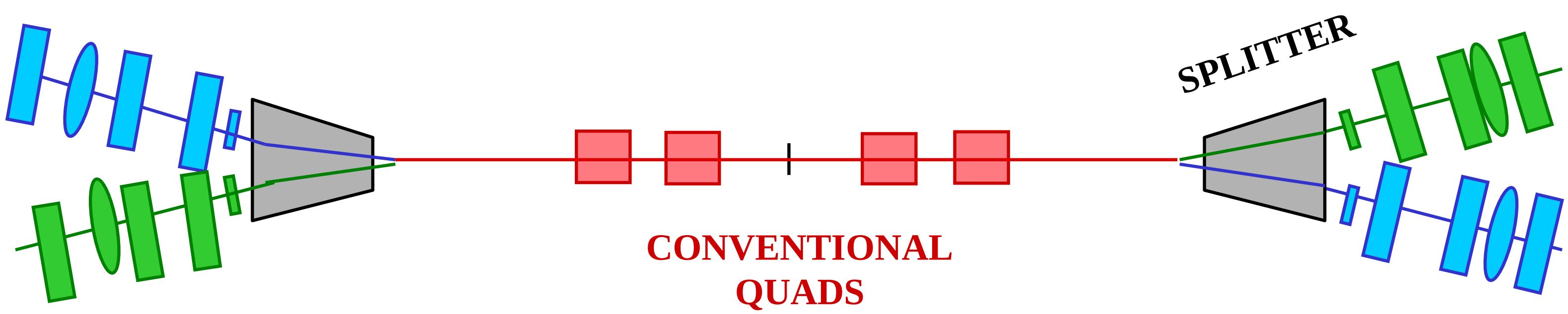
IR2: FINUDA FIELD COMPENSATION

- FINUDA Solenoid integrated field 0.3 *T* x 2.4 *m*
- 4 SC Quads inside the detector + 4 conventional quads outside
- Coupling at IP2 is corrected rotating each quadrupole following the rotation of the beam
- 2 Compensating Solenoids 0.36 *T* x 1 *m* provide cancellation of coupling outside IR2



IR1: NO DETECTOR

- four FDDF quadrupoles allow to separate the e^{+} e^{-} beam trajectories with a vertical bump of ±1 *cm*



DESIGN PARAMETERS

- Luminosity requirements not critical for DAFNE2
- horizontal crossing angle at IP2 $\theta_x = \pm 15$ *mrad* : Piwinsky angle $\phi = \theta_x \sigma_L^* / \sigma_x^* = 0.22$ already exceeded in existing factories
- linear tune shift is ξ_x / ξ_y = 0.014 / 0.024, below the limit achieved in DAΦNE
- 30 bunches we can inject out of collision and collide with a fast RF phase jump
- $L = 1 \cdot 10^{32}$ s^{-1} cm^{-2} is straightforward to achieve with a total current of 0.45 A

Energy E_0	1.0 GeV
Luminosity L	$1 \cdot 10^{32}$ s^{-1} cm^{-2}
Circumference C	97.69 *m*
Emittance ε	$0.5 \cdot 10^{-6}$ *rad m*
Coupling $\kappa = \varepsilon_x / \varepsilon_y$	0.009
Beta functions at IP β_x^* / β_y^*	1.5 / 0.025 *m*
Crossing angle at IP θ_x^*	±15 *mrad*
Bunch width at IP σ_x^* / σ_y^*	0.95 / 0.008 *mm*
Bunch natural length σ_z	13.9 *mm*
Linear tune shift ξ_x / ξ_y	0.014 / 0.024
Betatron tunes ν_x / ν_y	5.15 / 5.21
Momentum compaction α_c	0.012
Number of bunches	30
Harmonic number *h*	120
Beam current I_{tot}	450 *mA*

WIGGLER OFF/ON: SYNCHROTRON RADIATION

Synchrotron radiation loss per turn depends on the energy as:

$$U_0 = C_\gamma \frac{E^4}{2\pi} \oint \frac{ds}{\rho^2}$$

In the Wiggler ON option, the wiggler field has to be kept constant from 0.51 to 1 *GeV*, since in the 0.51 *GeV* lattice it is already near saturation and at 1 *GeV* the synchrotron radiation is high enough to improve damping times

without / with Wigglers		0.51 GeV	1 GeV
U_0	(*keV/turn*)	4.3 / 9.3	64.0 / 83.5
τ_x	(*ms*)	68 / 40	11 / 8.6
τ_E	(*ms*)	41/ 31	5.0 / 3.5

Synchrotron radiation and damping times

EMITTANCE

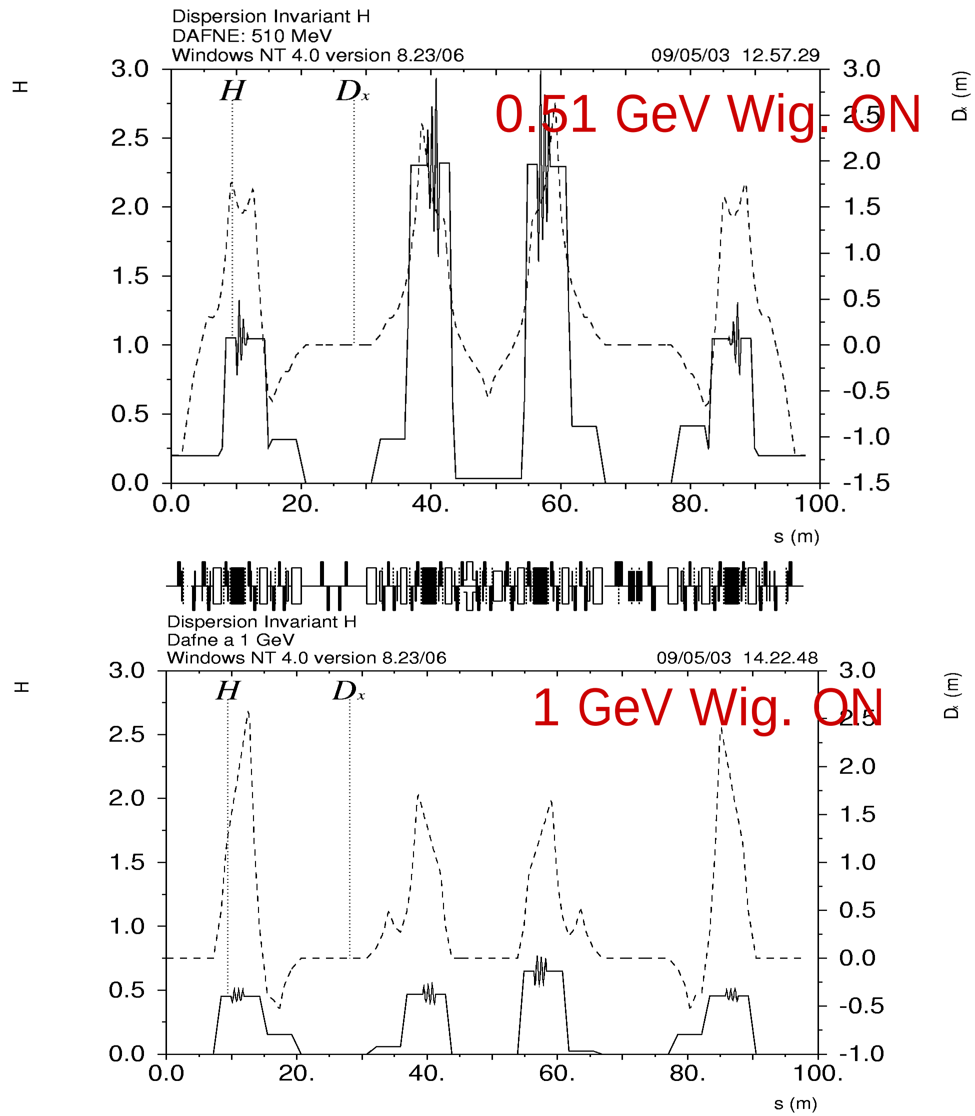
The emittance in electron storage rings depends on the energy as:

$$\varepsilon = C_q \gamma^2 \frac{< H / |\rho|^3 >}{J_x < 1/\rho^2 >}$$

and to have constant emittance from 0.51 to 1 GeV the dispersion invariant *H*:

$$H = \gamma_x D^2 + 2\alpha_x D D' + \beta_x D'^2$$

in both cases (wiggl. OFF/ON) is lowered by changing the Twiss parameters at the dipoles



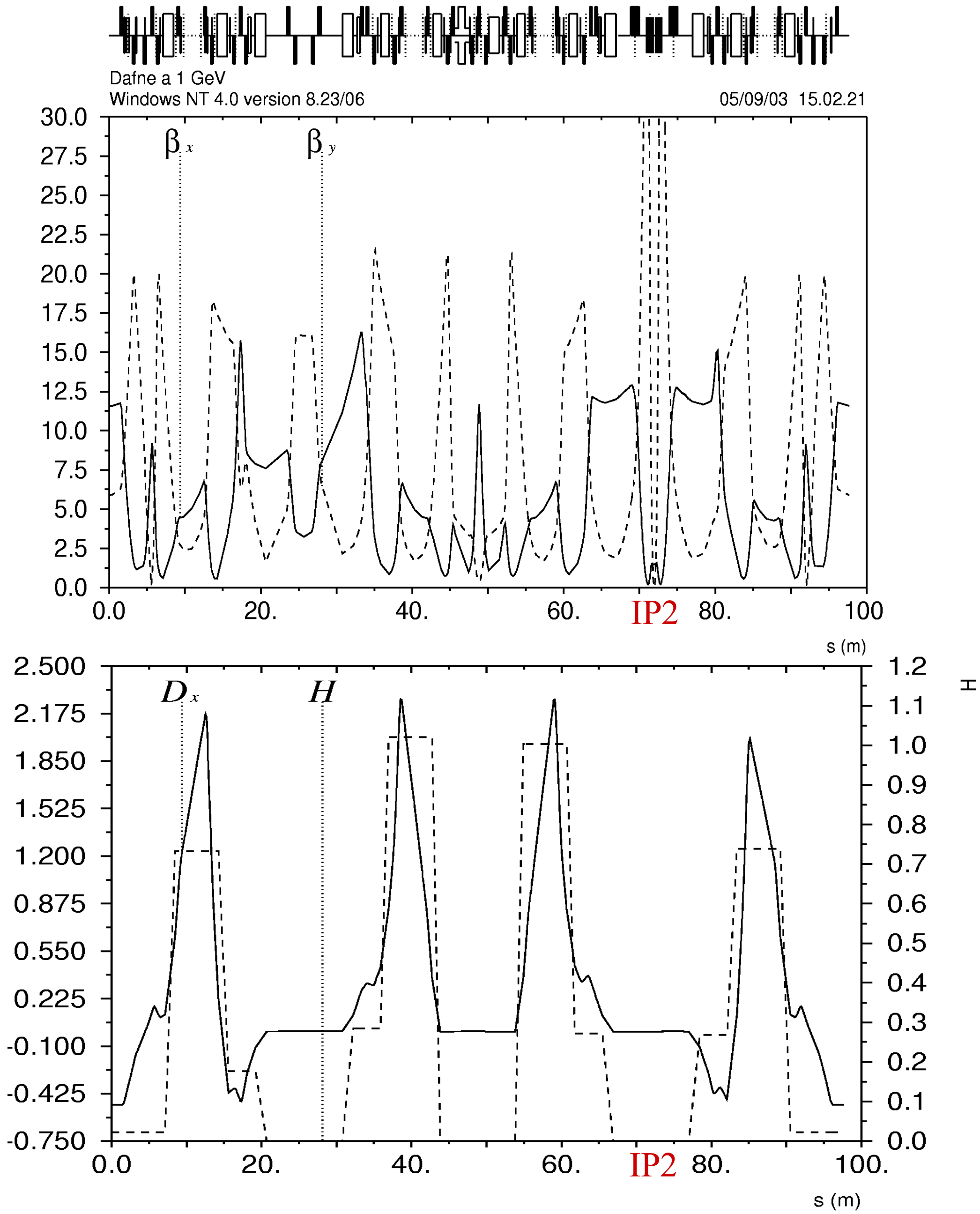
INJECTION ON/OFF ENERGY and WIGGLERS

- First option: injection on energy
  - Wiggler OFF: at 1 GeV no need for damping times
- Second option: inject. off energy and ramping
  - Wiggler OFF: better to control non-linearities and resonances during ramping
  - Wiggler ON: better for damping times at low energy

We have simulatated the optics at 1 GeV for both options…

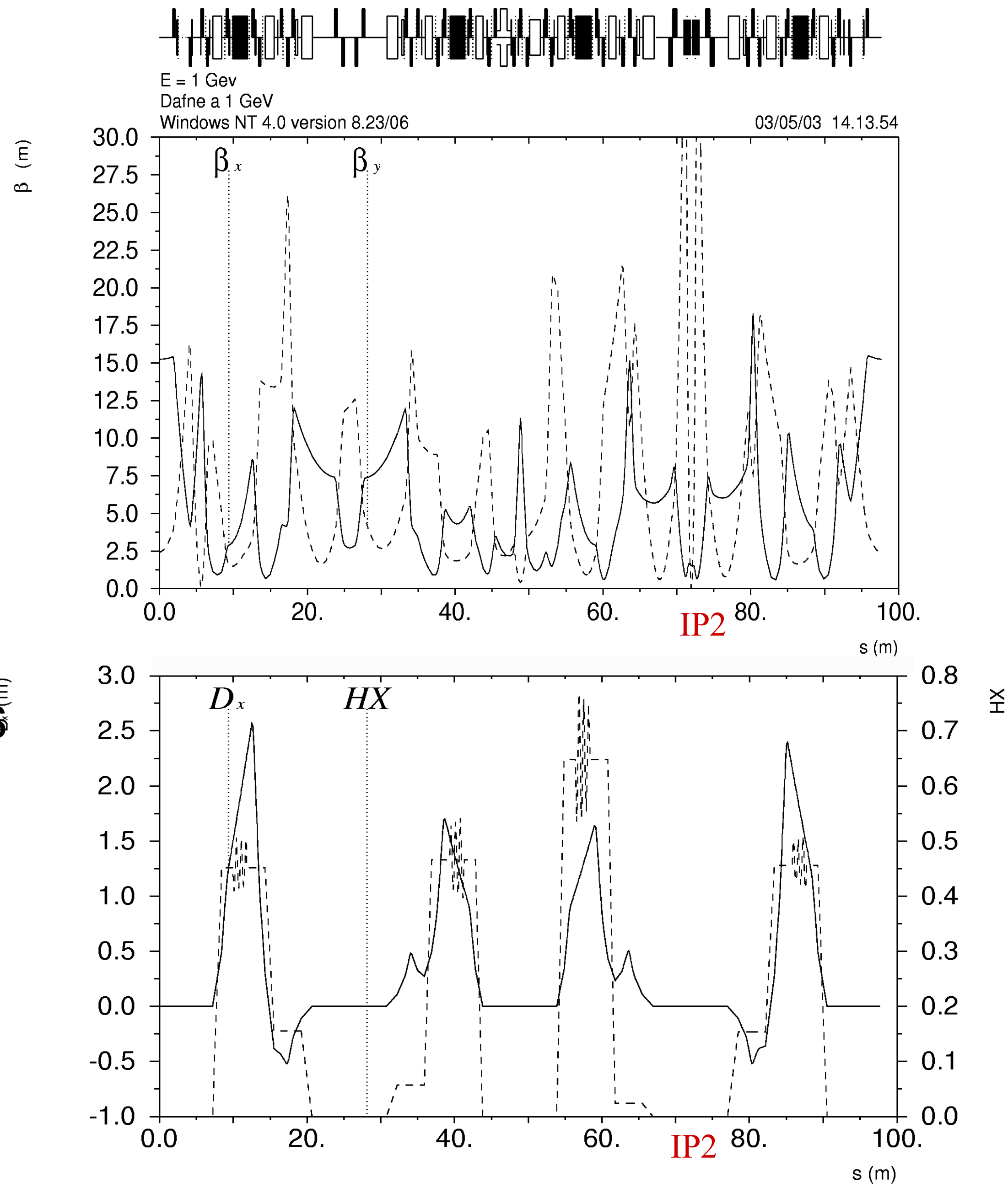
OPTICS AT 1 GeV WIGG. OFF

- β_x and β_y in the four achromat arcs, where D_x is higher, are separated to correct both horizontal and vertical natural chromaticity with chromatic sextupoles



OPTICS AT 1 GeV WIGG. ON

- Very similar to the Wiggler OFF optics
- β_x and D_x at the dipoles are shaped so that the natural emittance ε does not change

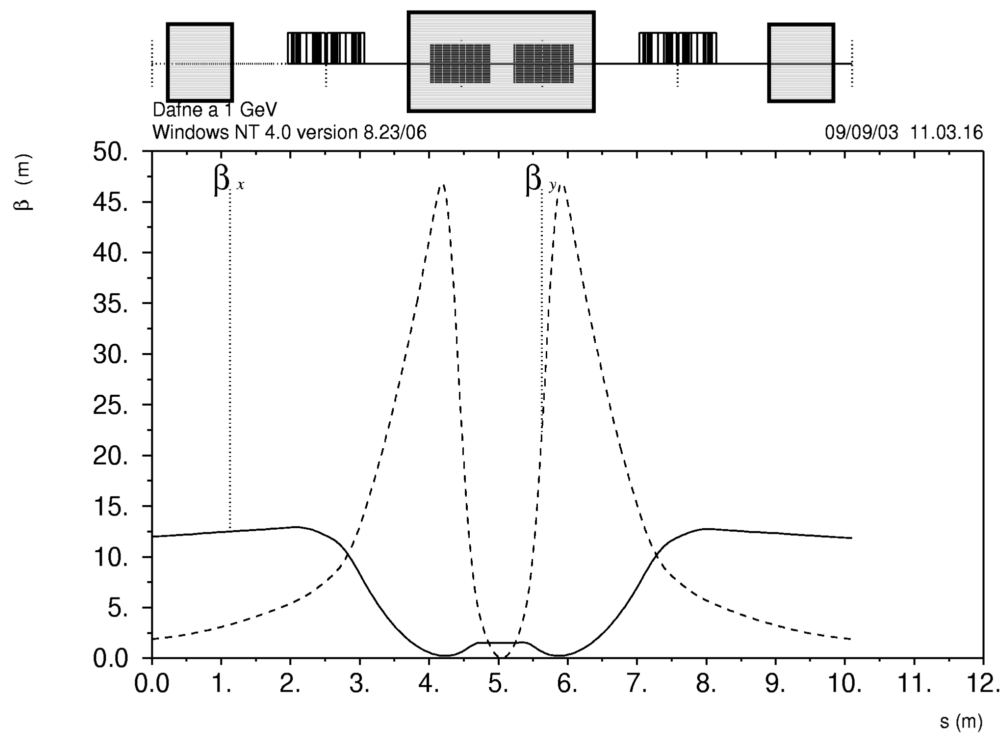


IR2 BETA FUNCTIONS

- β_x*=2.5 *m* and β_y*=2.5 *cm*, already achieved at DAΦNE
- FF DFFD FF quad sequence
- the inner SC quads have integrated grad:

Q1 → 8.0 *T*

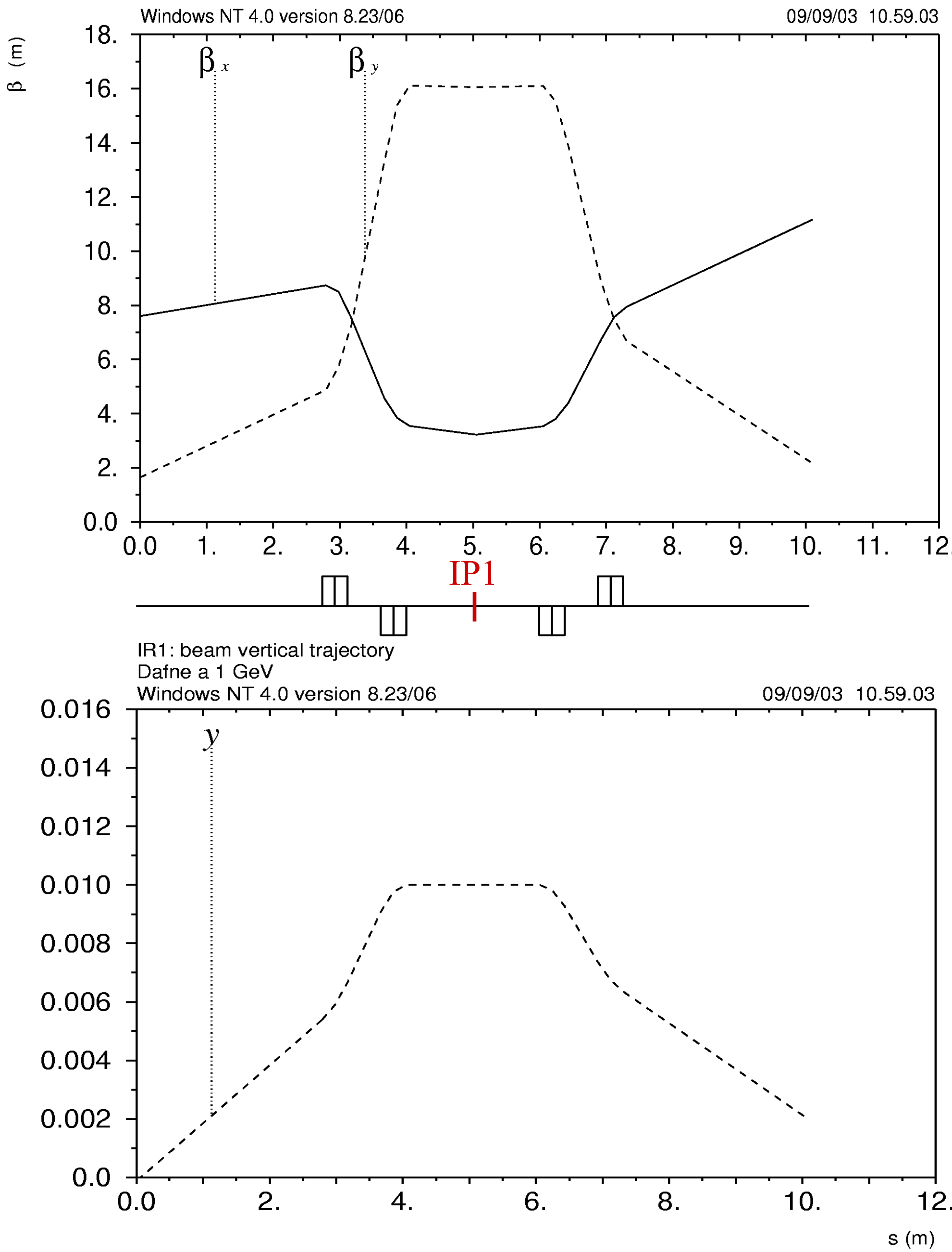
Q2 → 7.5 *T*



IR1 BETA FUNCTIONS and TRAJECTORY

- β_y* is detuned (16 *m* @IP1)

- 4 quads FDDF allow to separate the beam trajectories with a vertical bump of ±1 *cm*



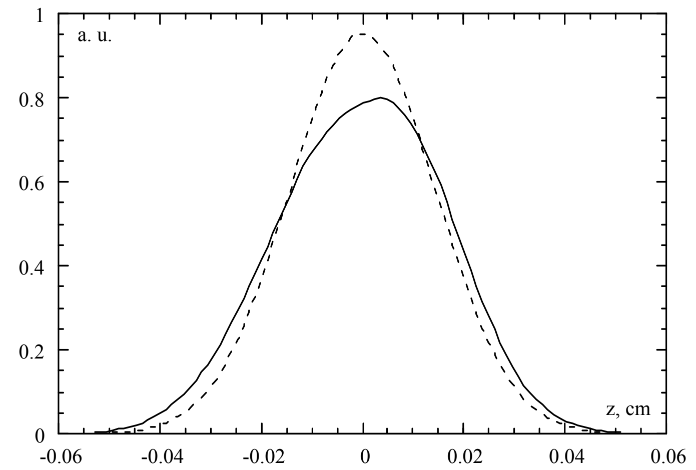
LIFETIME AND BACKGROUND

- Background and beam lifetime at DAΦNE (0.51 *MeV*) are strongly dominated by Touschek scattering
- At the higher energy (1 *GeV*) and RF voltage of DAFNE2 it will be less critical than at the present energy
- with the DAFNE2 parameters τ_{tou} comes out to be 650 *min* as calculated by MAD, with longitudinal acceptance dominated by RF
- Further quantitative simulations will be done with the programs already used for DAΦNE

BUNCH LENGTHENING

- Using the impedance and wake fields of the present vacuum chamber in the turbulent microwave threshold calculations, performing a multiparticle tracking (M. Zobov) the rms bunch length increases from the natural value of 13.9 *mm* to only 15.9 *mm* at 15 *mA/ bunch*

- energy spread constant $\rightarrow$ the microwave instability threshold is not reached



Charge density bunch distribution at zero current (dashed line) and at 15 mA/bunch (solid line)

RF SYSTEM

	DAFNE2	max value
RF peak voltage V_{RF}	250 *kV*	350 *kV*
RF frequency f_{RF}	368.26 *MHz*	
Energy loss $U_{rad}+U_{paras}$	83.5 +6.5 *KeV/turn*	
RF power $P_{beam}+P_{wall}$	40.5 + 17.5 *kW*	150 *kW*
Synchr. frequency f_{syn}	11.7 *kHz*	

- The existing RF system is completely compatible with the required specifications

FINAL CONSIDERATIONS ON SYSTEMS

- Present vacuum system can withstand the new configuration. In DAFNE2 (I_{tot}=0.45 *A*) synchrotron radiated photon flux is 1.8·1020 phot/s corresponding to a power of 38 kW, while the existing vacuum chamber is designed for a synch. radiation power of 50 kW [A.Clozza]
- Transverse feedback needs no change if the betatron tunes stay constant during the ramping
- Longitudinal feedback can follow the synch. freq. variation in a large range with 8 synchronizable filters. Timing is not critical with a synchronous RF phase up to 100 ps (RF phase is 70 ps at 250 kV)

CONCLUDING:
WHAT MAX ENERGY DAFNE2 CAN REACH?

- Preserving present vacuum chamber, energy is limited by iron saturation in dipoles (we can guarantee 1 *GeV, 1.1 GeV* seems already critical...)
- many of the present quads (about 25%) are near or in saturation in a lattice at 1.2 *GeV*
- with a new vacuum chamber layout (more dipoles or longer dipoles) we could for sure reach more than 1.2 *GeV*