Preliminary considerations on the RCS option for the beta beam neutrino facility

A.Tkatchenko
IPN Orsay, CNRS/IN2P3

Programme

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- General features of RCS's
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- Rate of rise of the dipole magnetic field
- Accelerating voltage and RF frequency
- Examples of possible lattices
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Baseline scenario (low energy beam)

- 60 GHz ECR source, 20 μs to 100 μs pulses of fully stripped ions (^{6}He , ^{18}Ne)
- Eurisol post accelerator linac, acceleration to ~100 MeV/u
- Low energy ring, multiturn injection, bunching, acceleration to ~300 MeV/u and fast transfer to the PS
- Source and low energy ring are operated at a repetition rate of 16(8) Hz to fill 16(8) PS buckets in one second
- Beta Beam task starts at the exit of the EURISOL post accelerator

Recent evolution

- Dedicated accelerator for He and Ne ions under consideration. EURISOL LINAC designed for CW acceleration of low intensity beams (300µA max.), peak intensity of He beam is 8mA. Energy of this new post-accelerator could be lower than 100 MeV/u (50 or 75MeV/u).
- Higher injection energy into the PS is desirable in order to relax space charge problems and to reduces decay losses.

$\Rightarrow$ increased energy range from injection to extraction

$\Rightarrow$ more demands on the low energy ring

General features of Rapid Cycling Synchrotrons (RCS's)

Compared to slow cycling synchrotrons of the same Bρ, RCS's have larger circumferences (348m for the 3Gev proton, 25Hz, J-Parc RCS, 106m for the 0.3Hz, 3GeV Saturne synchrotron).

Extra length due to arcs whith bending fields limited to ~1T in order to maintain dB/dt to acceptable values and to long dispersion free straight sections needed to accommodate numerous RF cavities.

$$V \sin\varphi_s = C.\rho.dB/dt$$

V=450 kV for the J-Parc RCS, V=15 kV for Saturne

Large rate of rise of B induces intense eddy currents in solid metal vacuum chambers

⇒thin metallic chambers reinforced with ribs or ceramic chambers

Examples of RCS parameters

	$B\rho_{max}$ (T.m)	F_{rep} (Hz)	R(m)	ρ(m)	R/ρ
Saturne	12.8	0.3 to 1	16.8	6.34	2.65
Soleil e- (APD)	8.33	12	22.76	8.33	2.75
AGS booster	7.51	7.5	32.15	12.2	2.63
ISIS	4.88	50	26	7	3.7
J-Parc booster	12.8	25	55.4	12.58	4.41

In the absence of other constraints, R/ρ is a function of the repetition rate and of the maximum beam energy.

For a 8 to 10 T.m rigidity, 16 Hz RCS, a R/ρ value close to 3 seems reasonable

Rate of rise of the dipole magnetic field

Resonant network, sinusoidal excitation

$B = 1/2(B_{MAX} + B_{mim}) – 1/2(B_{MAX} – B_{min})\cos(2\pi Ft)$

$[dB/dt]_{MAXIMUM} = \pi FB_{MAX} [1-(B\rho)_{min}/(B\rho)_{MAX}]$

ISIS 50Hz (~80T/s) J-Parc booster 25Hz (~60T/s)

Programmable power supply, linear ramp

$B \sim B_{min} + 2(B_{MAX} - B_{min})Ft$

$[dB/dt] \sim 2FB_M[1 – (B\rho)_{min})/(B\rho)_{MAX}]$

AGS booster 7.5Hz (~10T/s)

Accelerating voltage and RF frequency

Assumed conditions:

$R/\rho \sim 3 \Rightarrow C = 2\pi R = 6\pi\rho = 6\pi(B\rho)_{MAX}$ if $B_{MAX} \sim 1T$

RF parameters assessment for ^{6}He ions (most demanding case)

$F_{rep} = 16$ Hz, $h = 1$ (one bucket), sinusoidal magnetic field excitation

$V\sin\varphi s = C\rho dB/dt$ with $\sin\varphi_s \sim 0.5$

Accelerating voltage and RF frequency

E_{INJ} MeV/u	E_{EXT} MeV/u	$(B\rho)_{min}$ T.m	$(B\rho)_{MAX}$ T.m	$V\sin\varphi_s$ kV	V kV	$(f_{HF})_{min}$ MHz	$(f_{HF})_{MAX}$ MHz
100	300	4.44	8.1	28	56	0.84	1.28
100	400	4.44	9.54	46	92	0.71	1.19
75	400	3.84	9.54	52	104	0.63	1.19
50	400	3.09	9.54	58	116	0.52	1.19
50	500	3.09	10.92	81	162	0.46	1.10

ISIS 50 Hz,C=163m, V=140kV, h=2 , f=1.34 to 3.1 MHz, 6 cavities (3m long)
J-Parc RCS 25Hz, C=348m, V=450kV, h=2, f=1.23 to 1.67 MHz, 12 cavities (2m long)

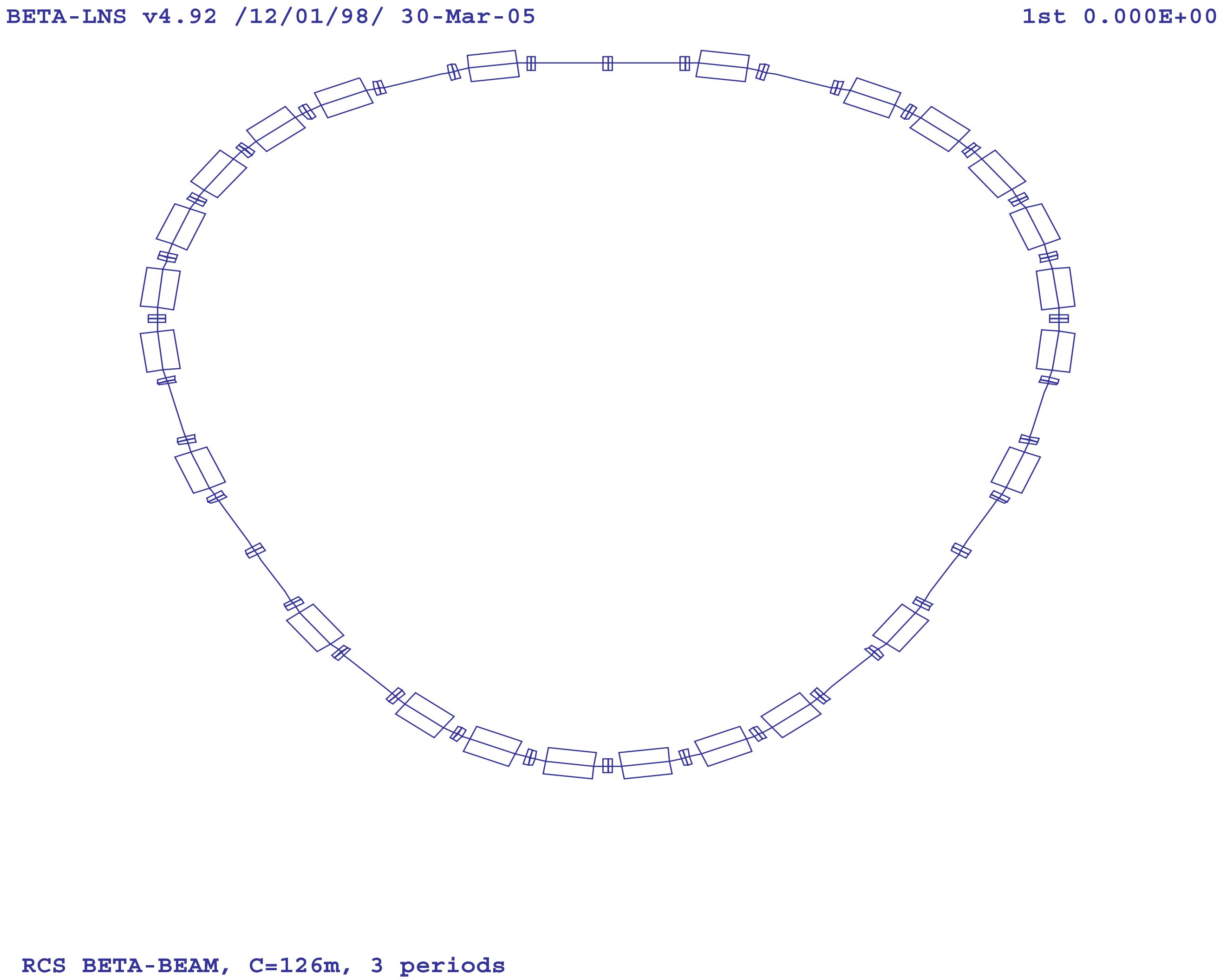
Examples of possible lattices

Proposed lattices are based on FOFO cells with missing dipoles to suppress dispersion in straight sections.

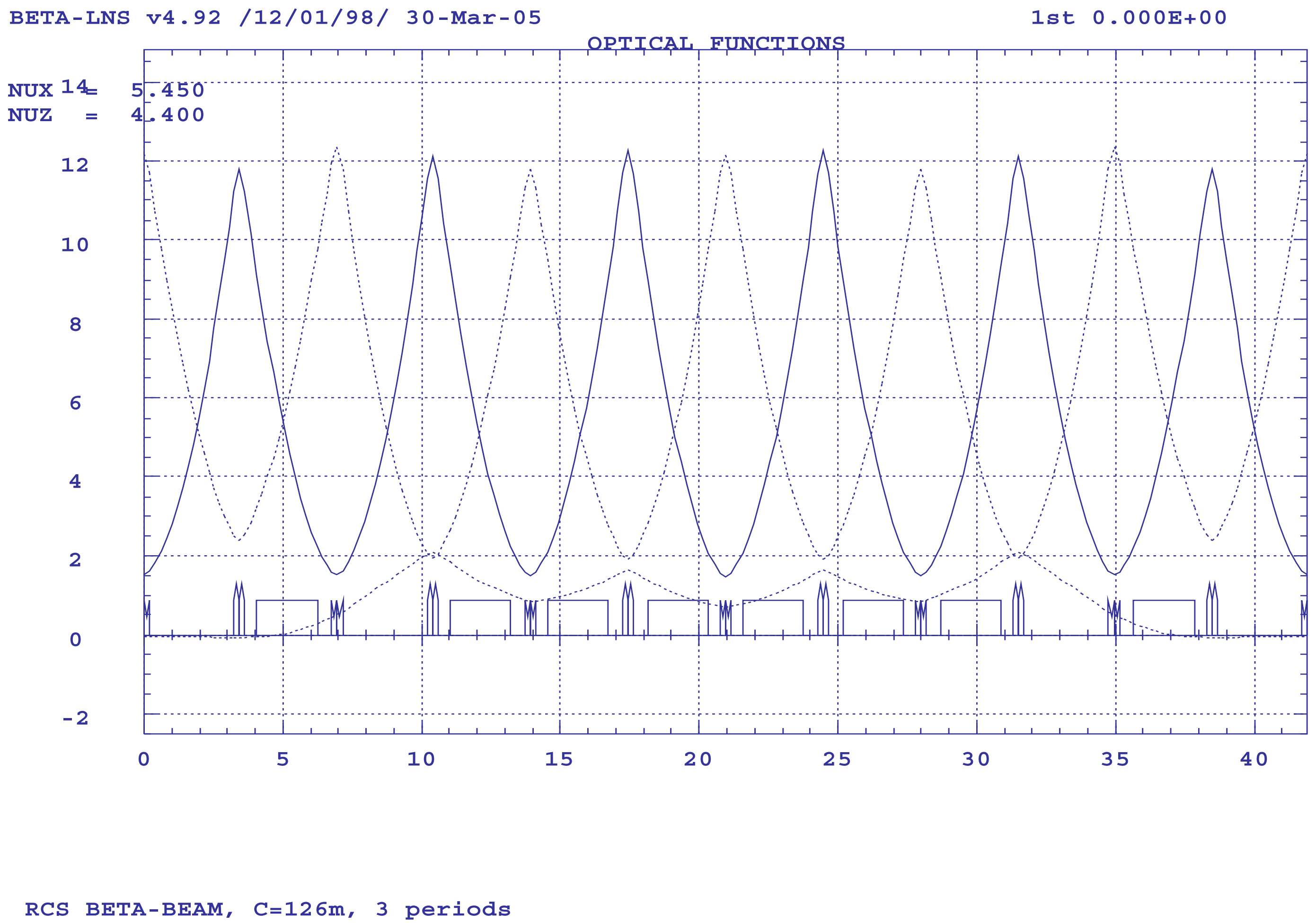
In the following examples, the ring has 3 or 4 symmetric periods comprising 24 dipoles and short or long straight sections. The dipole bending radius is ~8m.

The betatron phase advance per cell has been chosen to obtain a working point located far from low order systematic resonances and to cancel the dispersion function with only 2 quadrupole families.

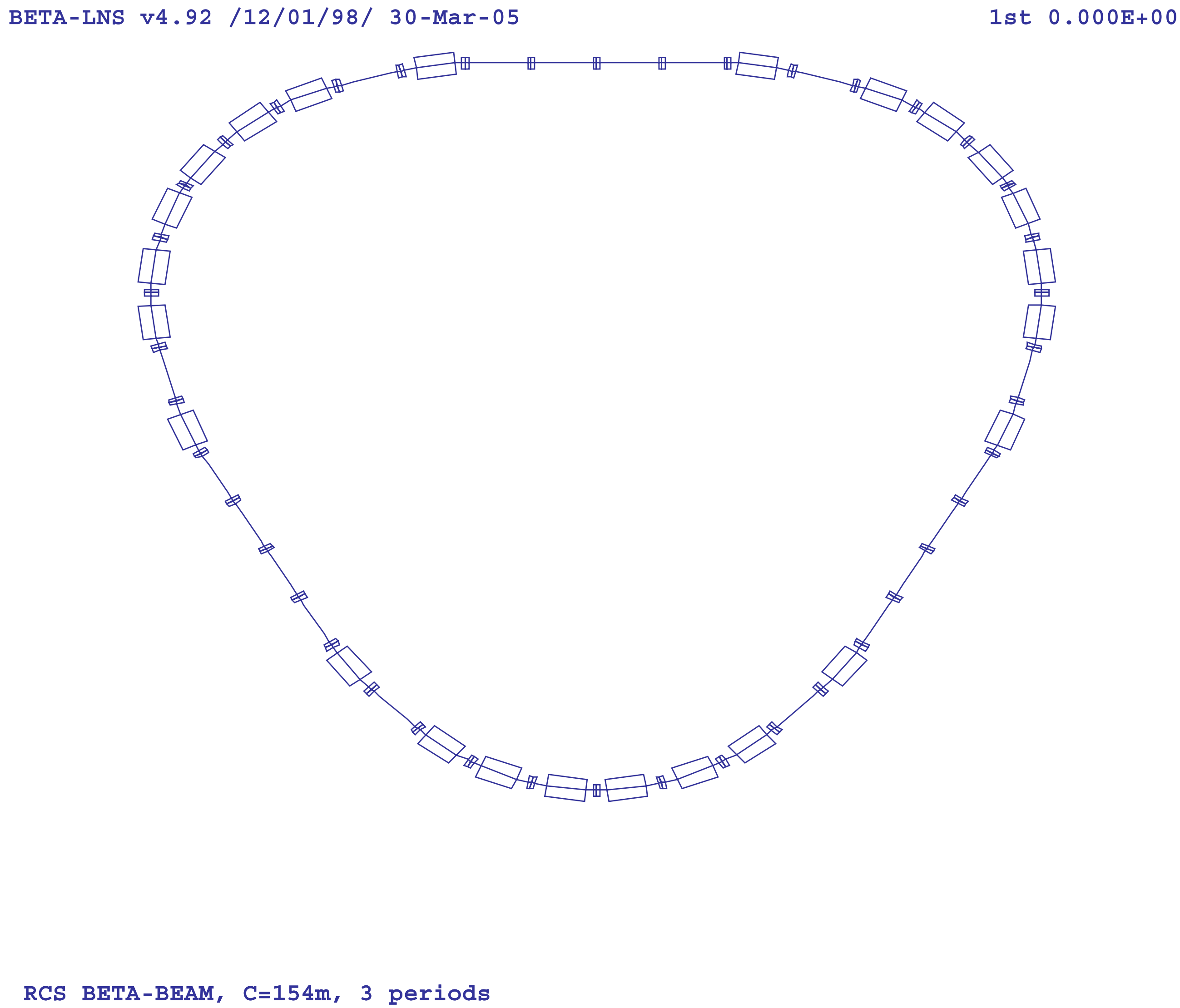
Three-fold symmetry, C = 126 m



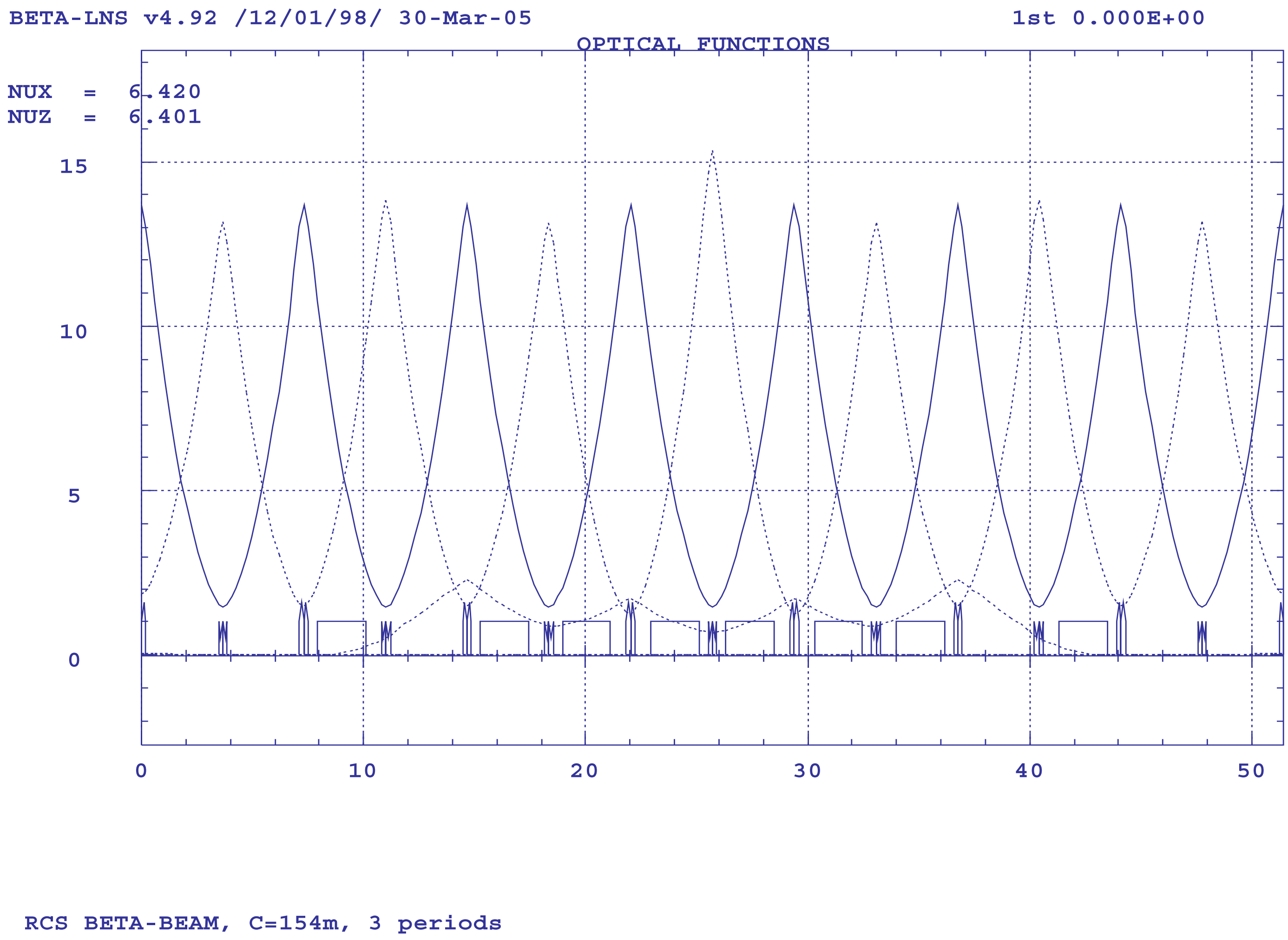
Three-fold symmetry, C = 126m



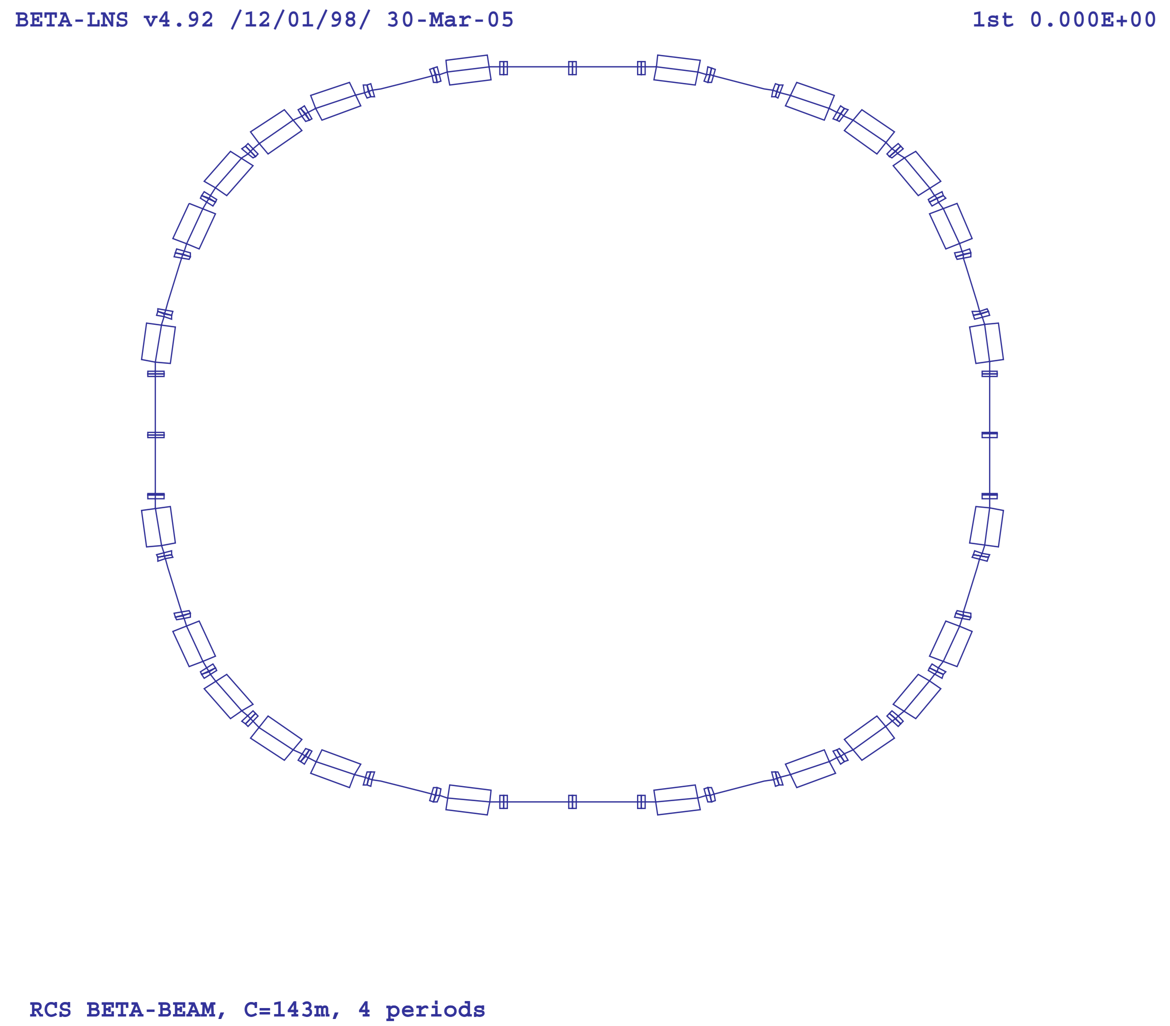
Three-fold symmetry, C = 154 m



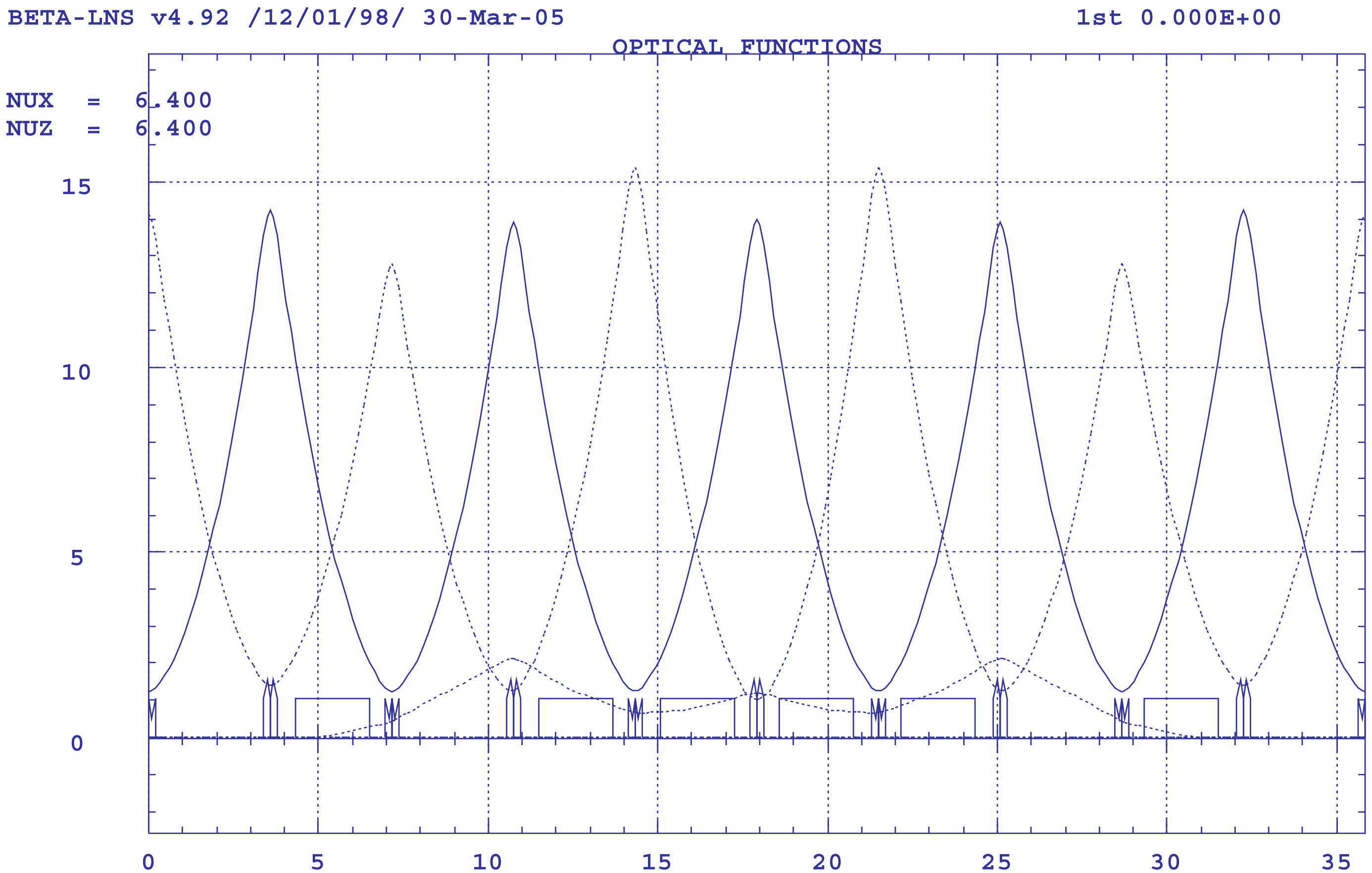
Three-fold symmetry, C = 154 m



Four-fold symmetry, C = 143 m



Four-fold symmetry, C = 143 m



RCS BETA-BEAM, C=143m, 4 periods

Conclusion

Main characteristics of Rapid Cycling Synchrotrons are strongly influenced by the repetition rate and by the energy range of the acceleration cycle.

$\Downarrow$

It is essential to fix these parameters to start a realistic study of the ring lattice.

Beam characteristics at the post accelerator exit and at injection into the PS are also required to study a multiturn injection scheme.