Light Source design

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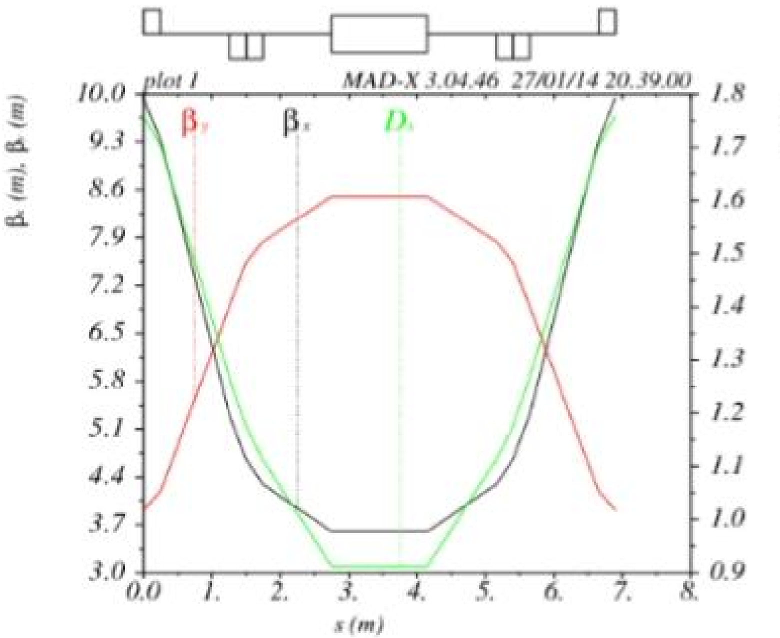
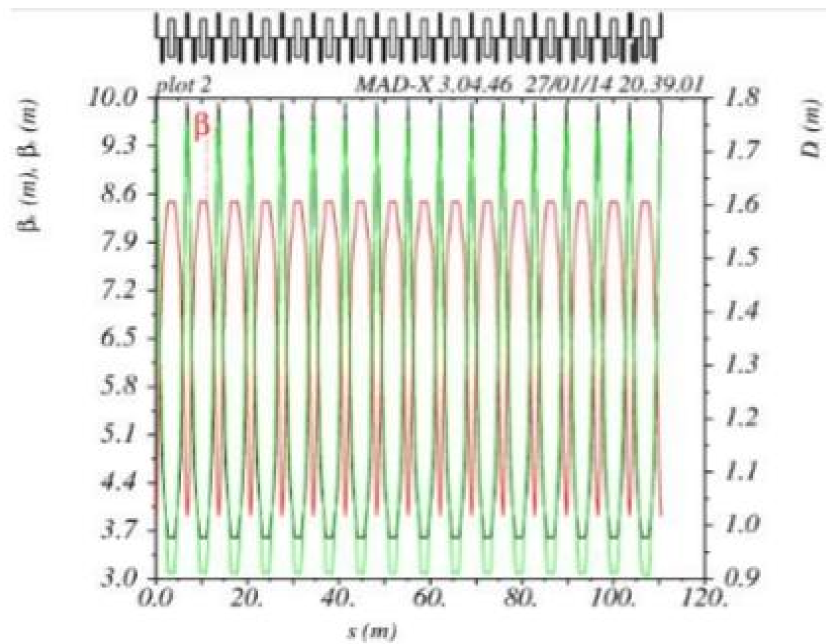
I. ORIGINAL PROBLEM

SR workshop (R. Bartolini)

The goal of the workshop is to design an upgrade of a second generation light source to a third generation light source. The beam energy is 2.5 GeV.

Assume the old lattice looks like





It uses only bending magnets (no long straight sections)

16 bends 1.4 m long. Compute the critical photon energy

SR workshop (R. Bartolini)

We want to create space for IDs and reduce the emittance

The new machine has to fit in the same tunnel, so the circumference is a fixed parameter, say

$$C = 110.4 \text{ m}$$

We want to have 8 long straight sections, say

long drifts 3.5 - 4 m (start with 4 m)

Use a double bend achromat and the previous geometric constraints

SR workshop (R. Bartolini)

What emittance can you achieve?

(check matching conditions, beta_max, tunes, relx Dx = 0)

Can you maintain the same critical energy from the bending magnet?

Find the parameters for the following IDs

fundamental wavelength at 8 keV with a linewidth of 10–4 !

peak flux reaching 20 keV

What RF power is needed for running 400 mA?

Further comments:

Make it symmetric – 8 cells of length 110.4/8 = 13.8 m

Keep the achromatic condition in the ID straights

Make betay small at the ID straight section (beta x can be larger…)

Use symmetry points for matching

Plot (and minimise) the dispersion invariant

Did you compute the emittance correctly?

How would you modify this design to a MBA?

II. LATTICE PROPOSALS

- **Option 1:**
  Keeping same critical energy in bendings.
- **Option 2:**
  Straight sections with low dispersion.
- **Option 3:**
  Dispersion free and low emittance.

Suggestions:
- Use symmetry points for matching
- Beta y small at insertion entrance
- Straights dispersion free

Specifications - lattice

PARAMETER		OPT1	OPT2	OPT3	UNIT
Energy			2.5		GeV
Circumference			110.4		m
Straight sections			8		-
Length of bends		1.4	0.85	1.4	m
Number of bends			16		-
Lattice type		DBA*		DBA	-
Cell length			13.8		m
Emittance	ε_x	0.162		0.074	µm rad
	ε_y	0		0	µm rad
	ε_z	3.53		6.76	µm rad
Bending angle			0.3927		rad

Option 1

Keeping same critical energy in the bendings.

Lattice proposal 1

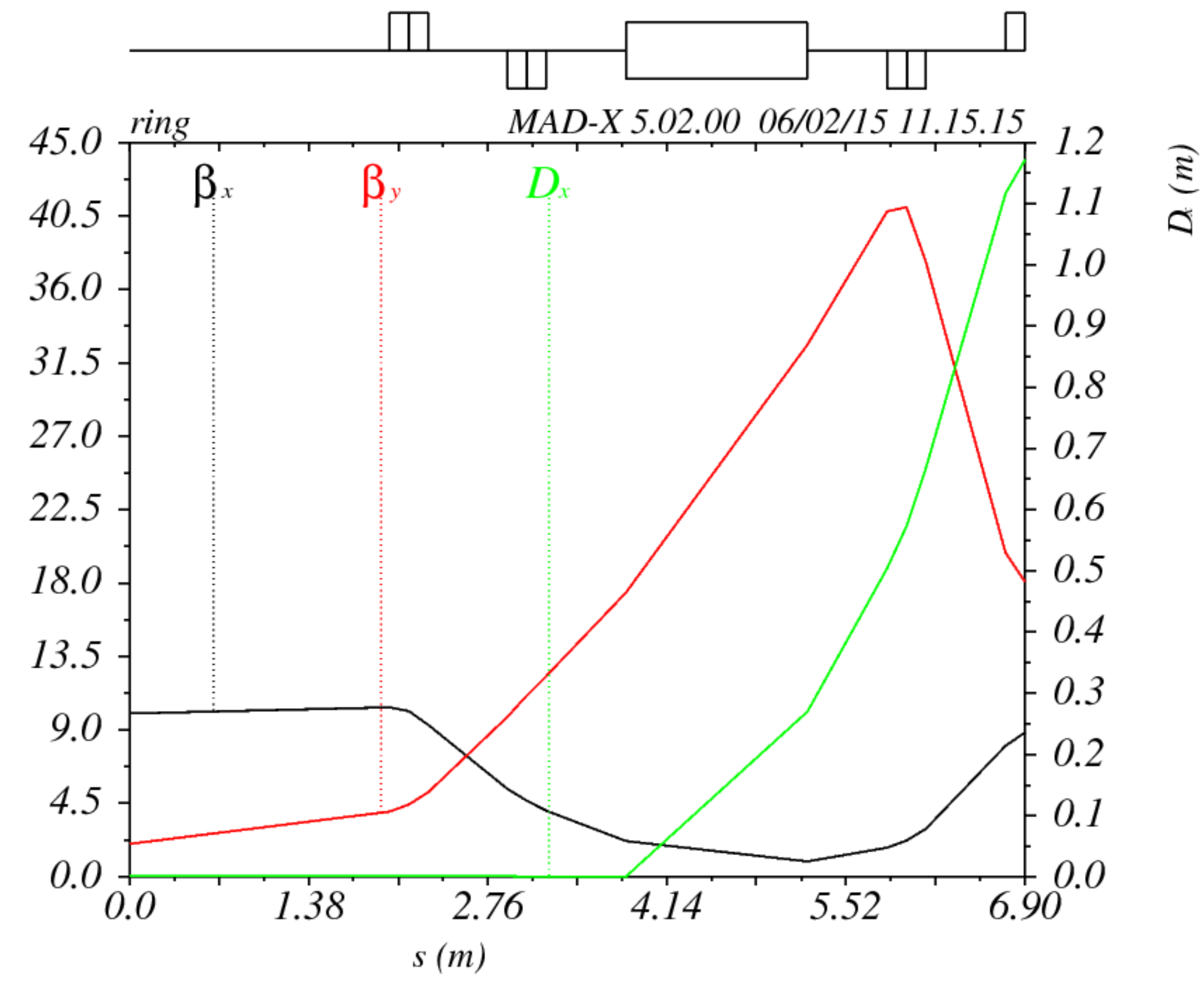
Background

- Unsuccessful matching of a basic **FQ-DQ-Bend-FQ/2** DBA half cell
- New half cell: **FQ-DQ-Bend-FQ-DQ/2**
  - Matching has turned it into **FQ-DQ-Bend-DQ-FQ/2**

- *Main design goal*: keep same critical energy from bend as TME lattice
  - Same bend length
- Emittance not optimized
  - ε_x = 160 nm rad

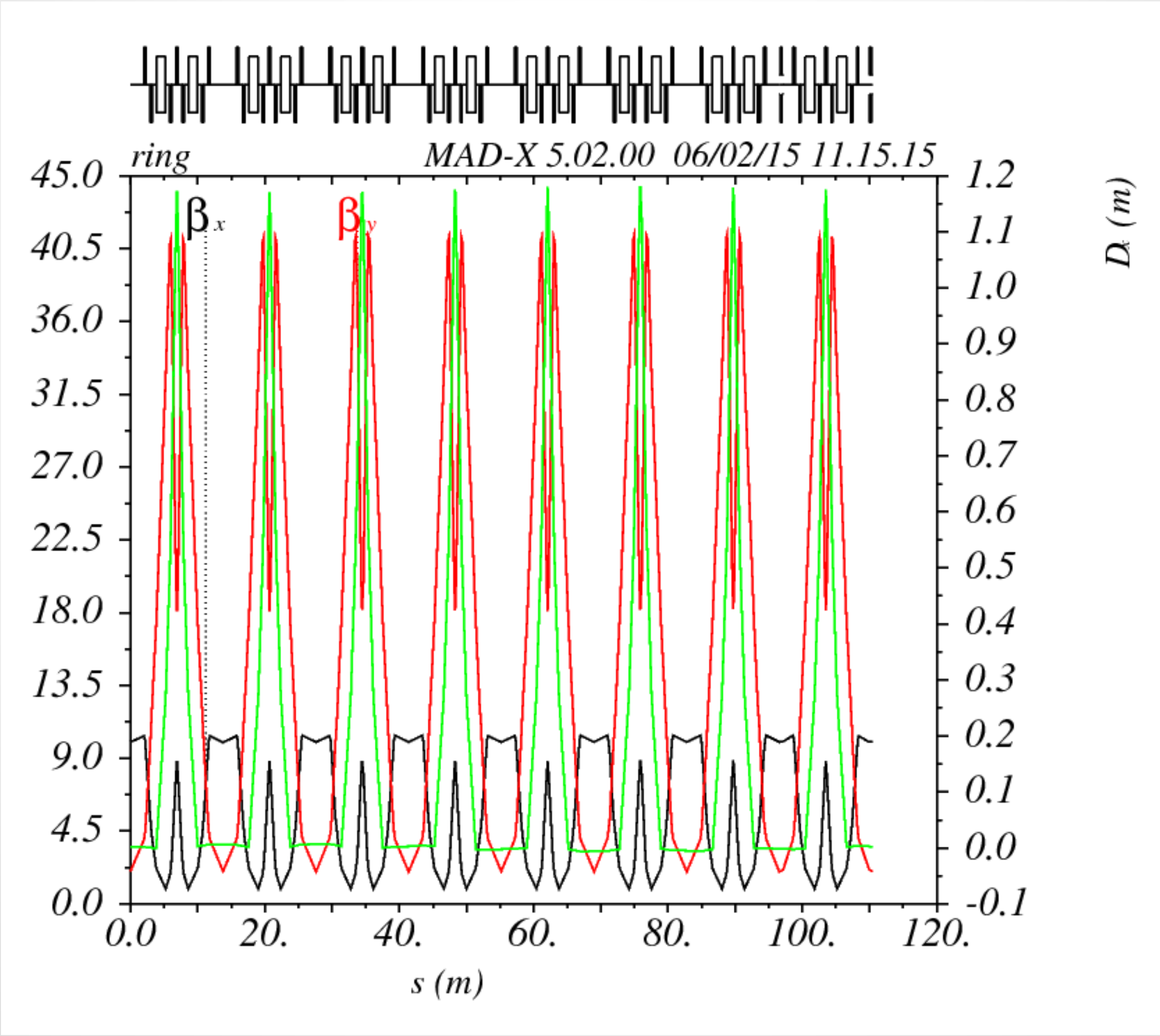
Lattice proposal 1 (2/3)

Optics functions for one half cell



Lattice proposal 1 (2/3)

Optics functions for entire ring (with RF)

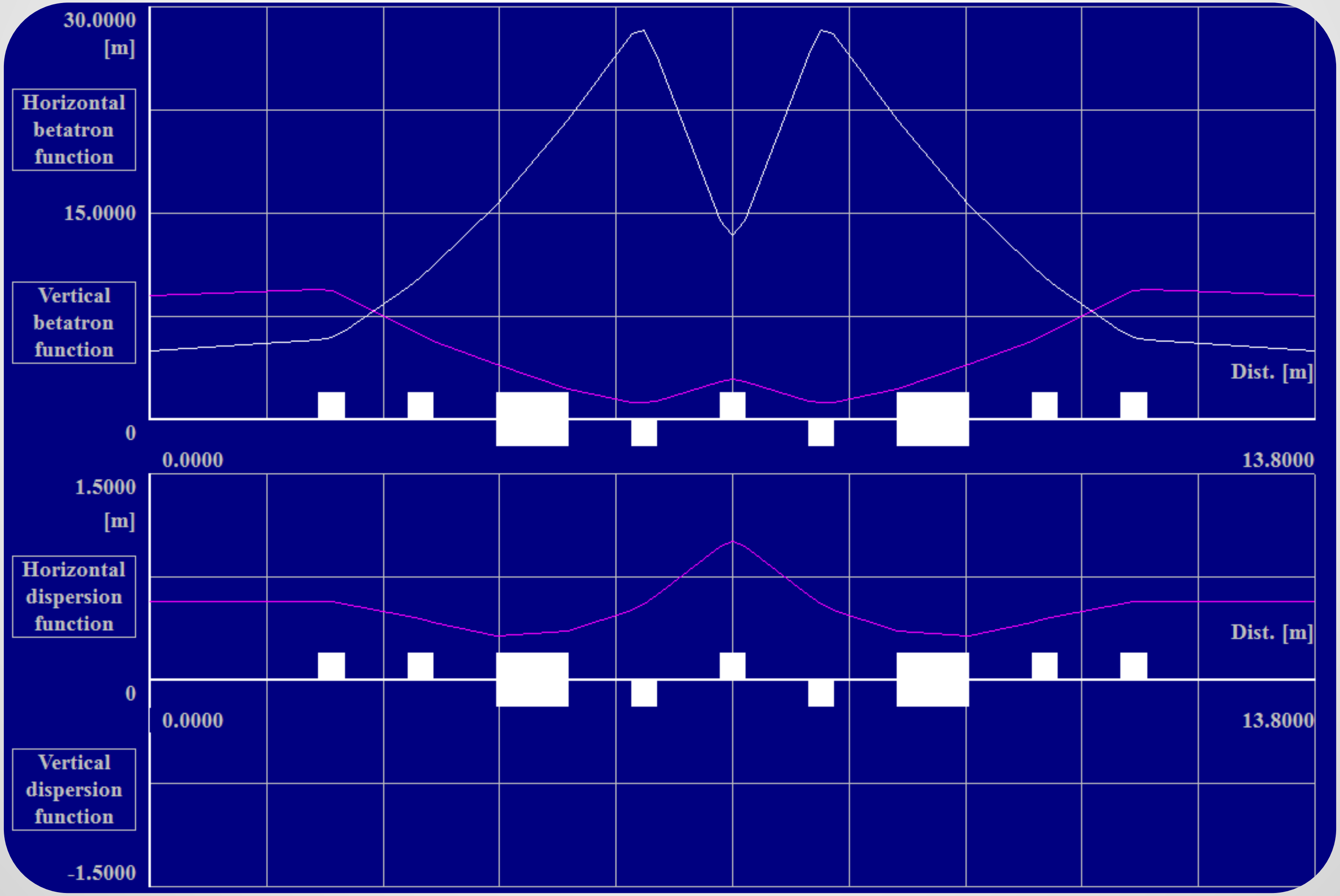


Option 2

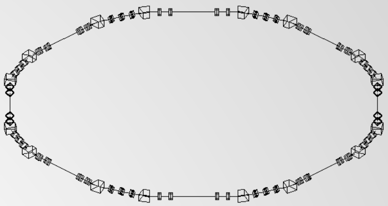
Straight sections with low dispersion.

OPTION 2

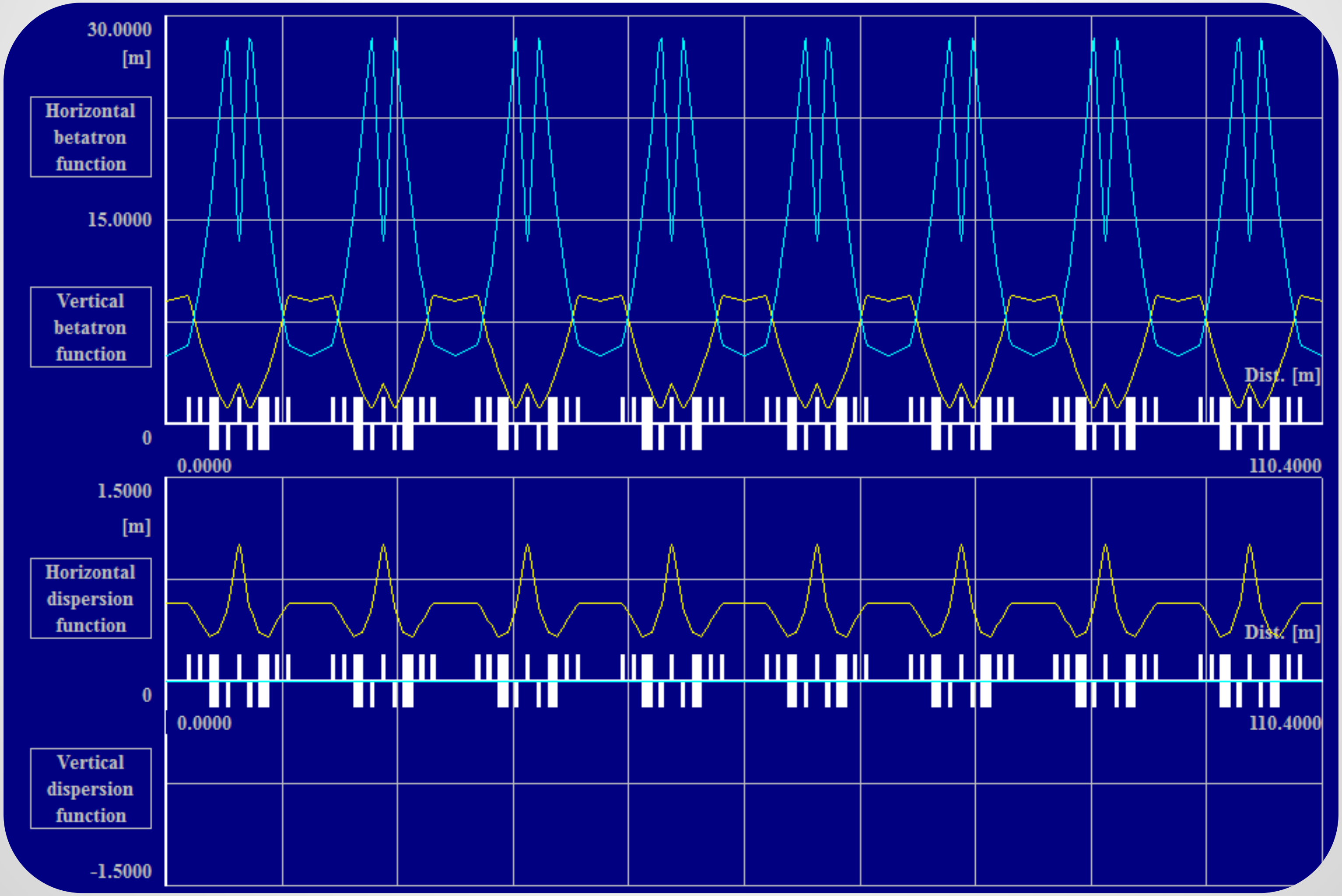
Optic functions in one cell.



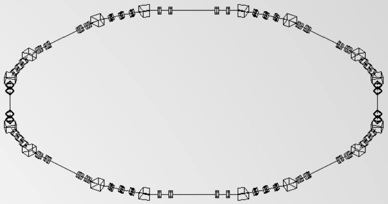
OPTION 2



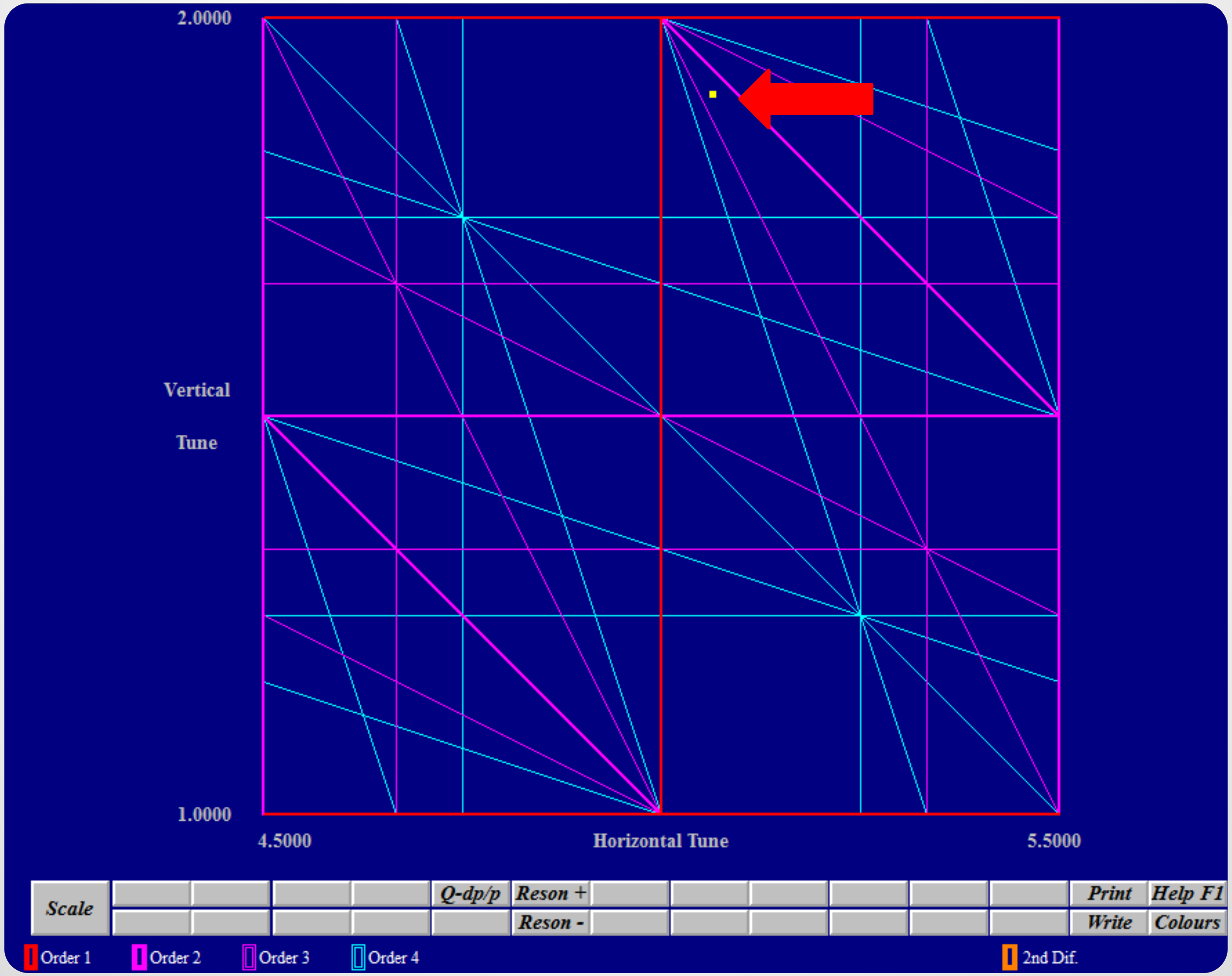
Optic functions in the full ring.



OPTION 2



Tune diagram of the complete ring



OPTION 2

- Low Dispersion
- Horizontal Betatron function < 30m
- Add RF

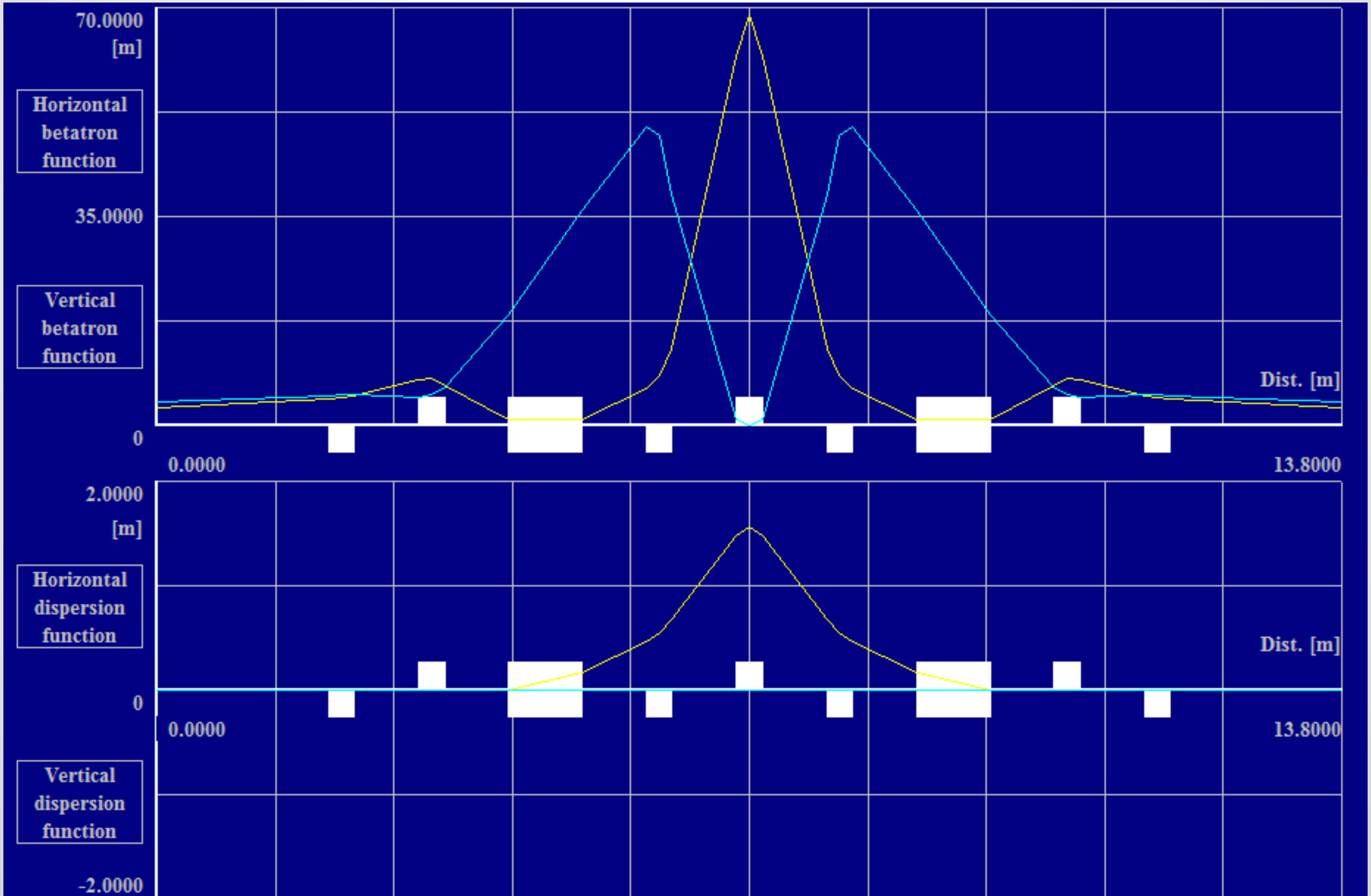
- Compute the emittance

Option 3

Dispersion free and low emittance

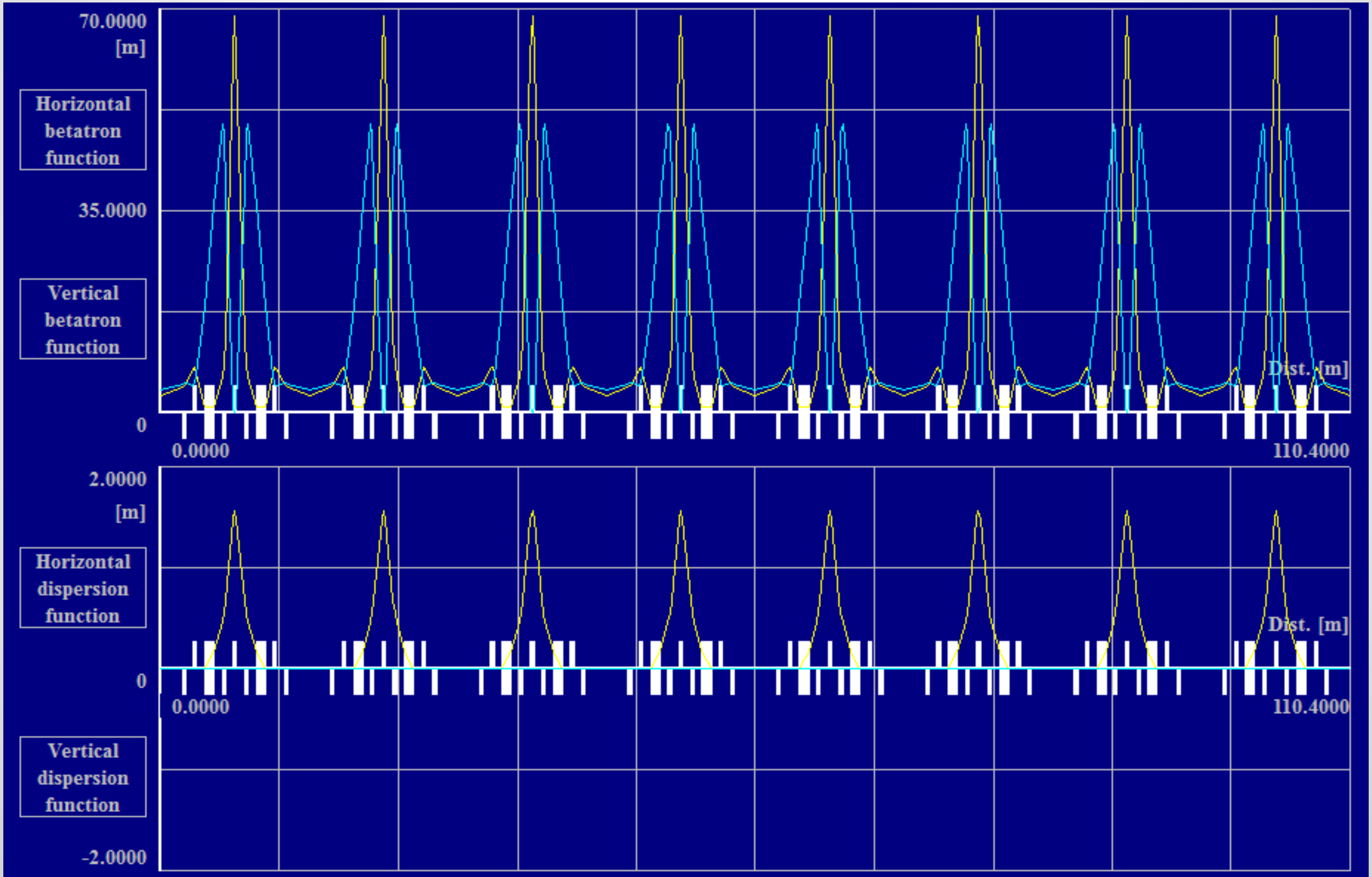
OPTION 3 - WinAgile

Optic functions in one cell.



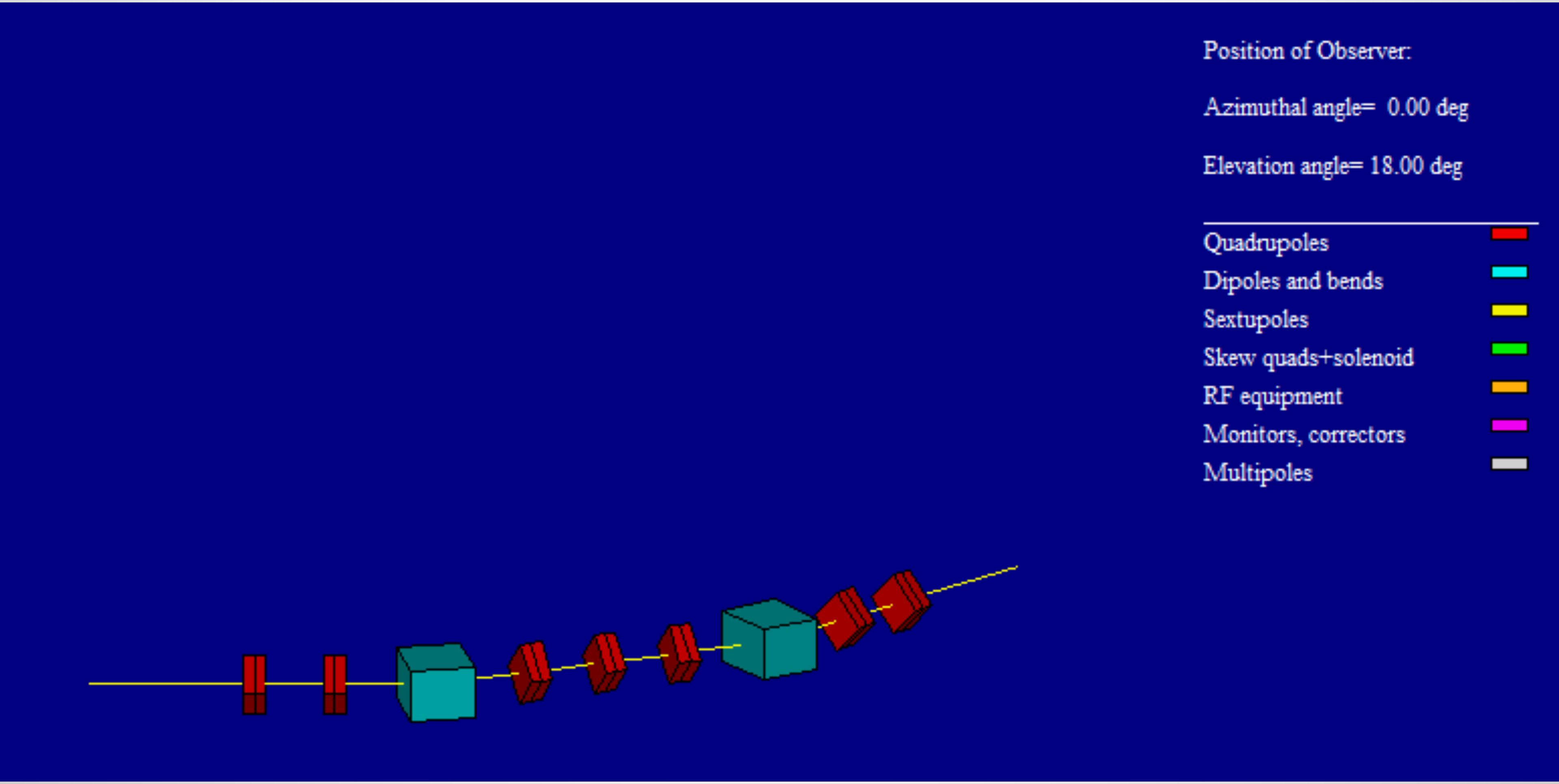
OPTION 3 - WinAgile

Optic functions in the full ring.



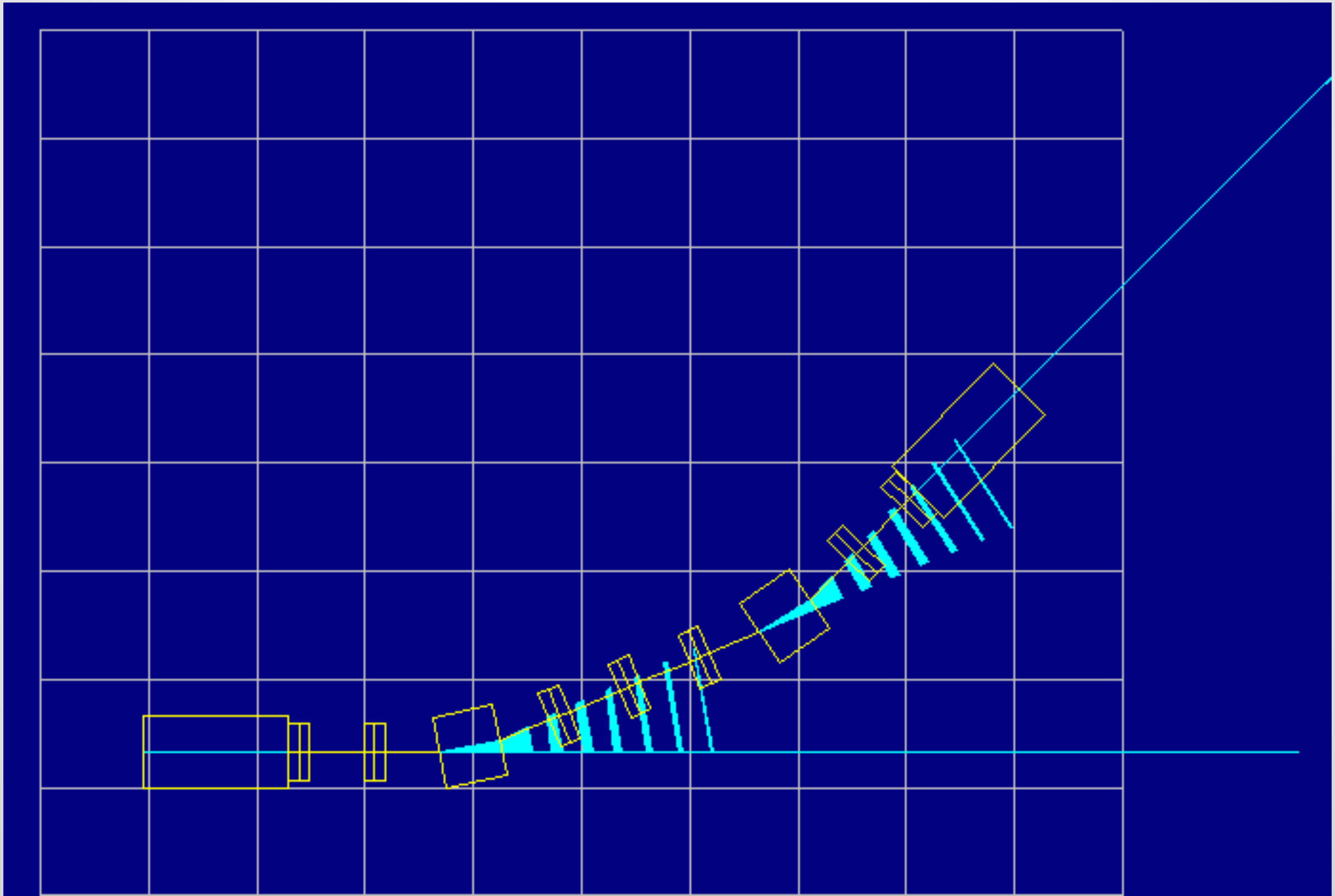
OPTION 3 - WinAgile

One cell geometry.



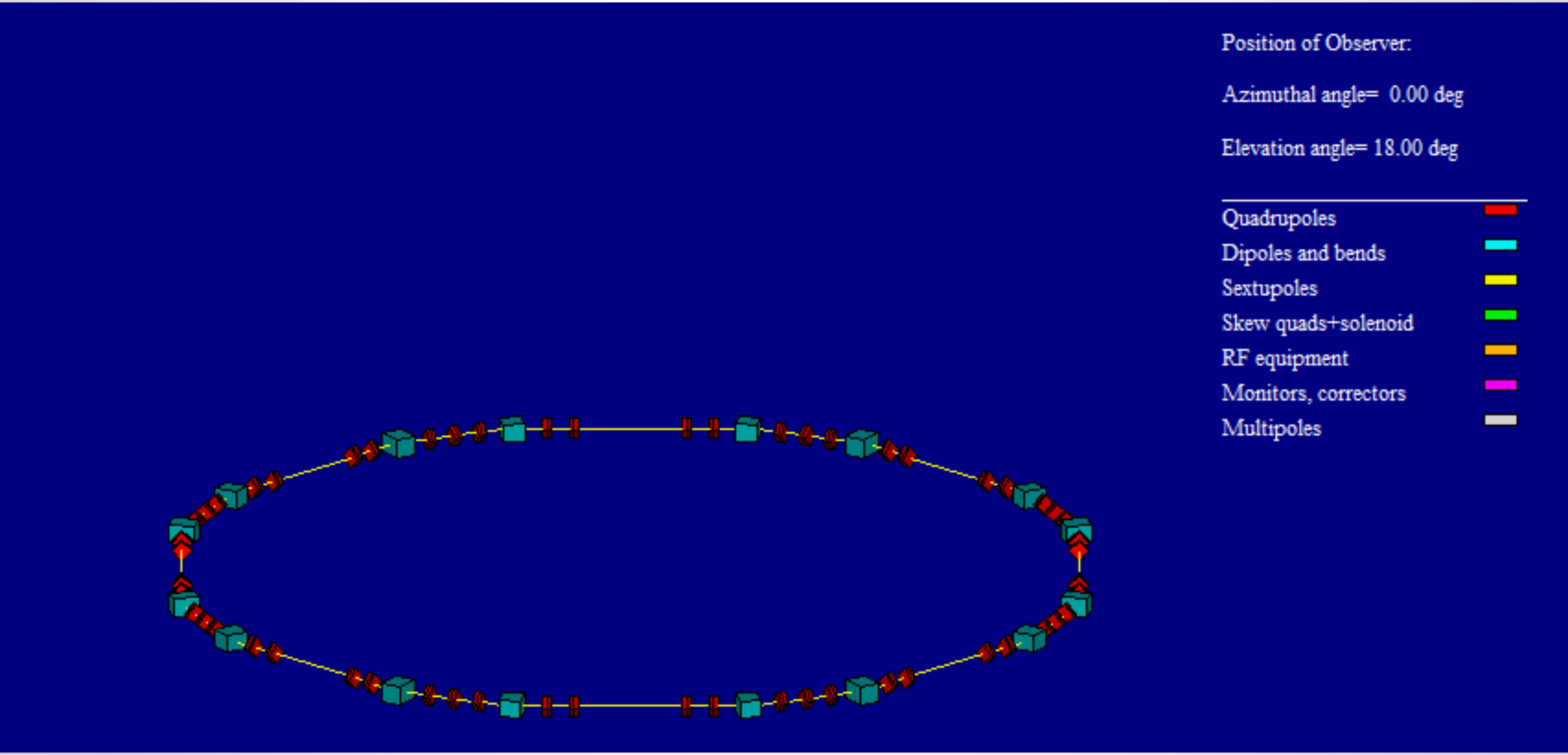
OPTION 3 - WinAgile

Synchrotron radiation fans in one cell.



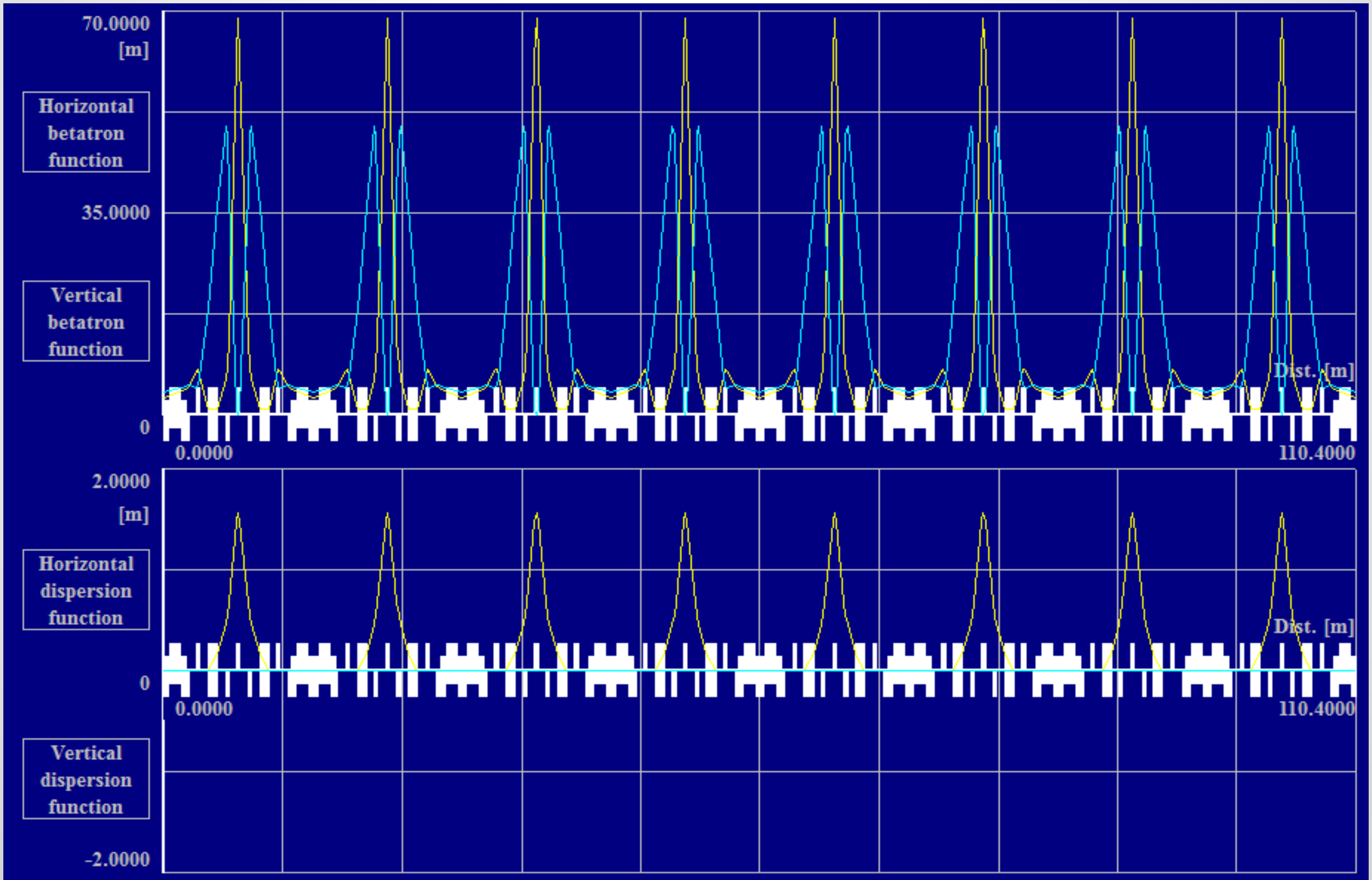
OPTION 3 - WinAgile

Full ring geometry.



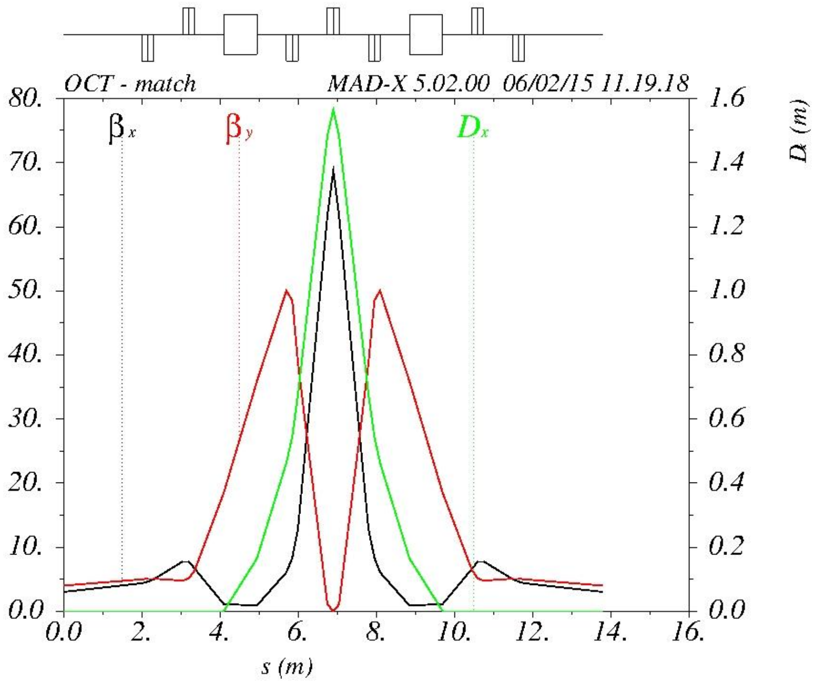
OPTION 3 - WinAgile

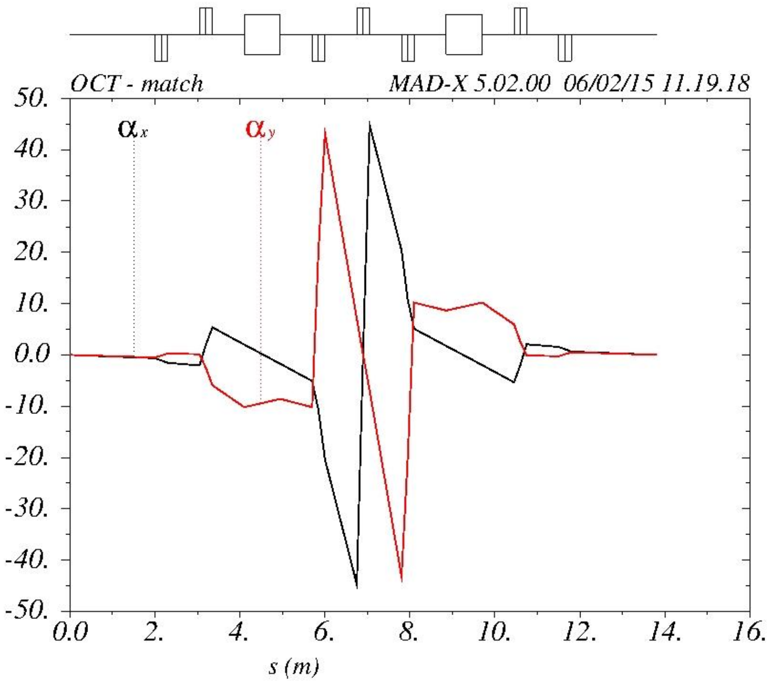
Optic functions in the full ring with wigglers.



OPTION 3 - MAD-X

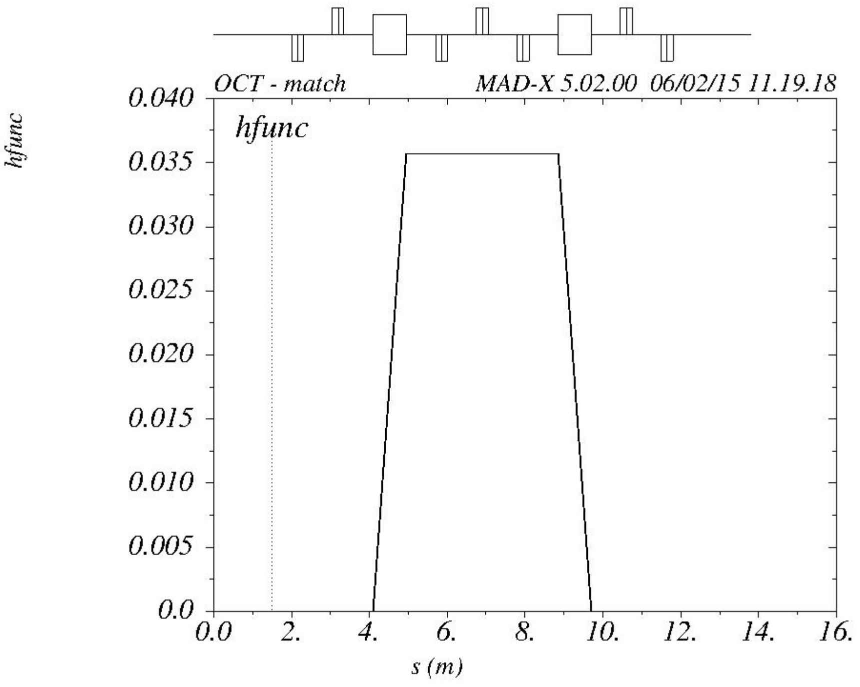
Optic functions in one cell.

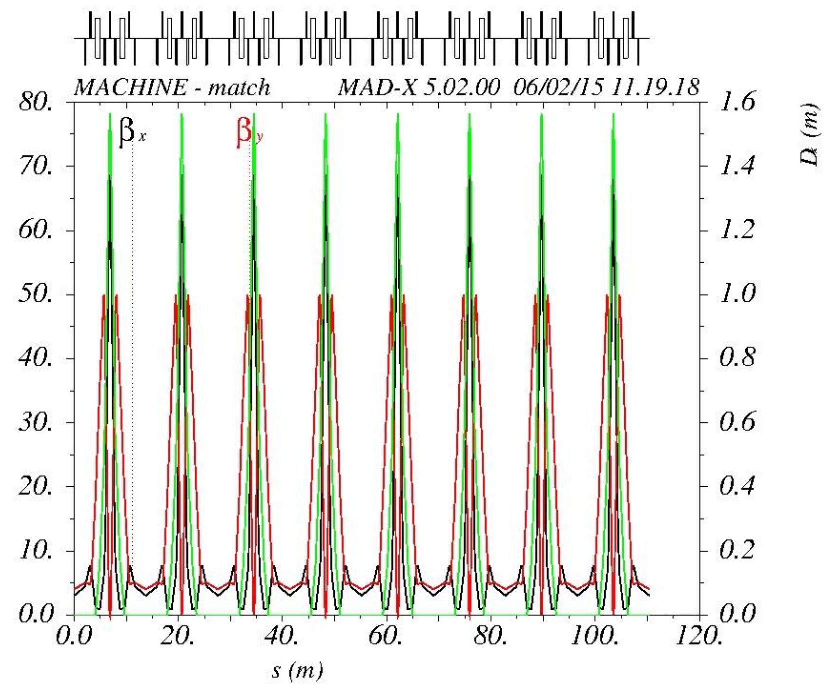




OPTION 3 - MAD-X

Optic functions in the full ring.





OPTION 3 - MAD-X

EMIT command results (with RF):

```
C                     110.4 m        f0              2.715511338 MHz
T0             0.3682547688 musecs   alfa         0.003113197967
eta          0.003113156188          gamma(tr)       17.92241919
Bcurrent                  0 A/bunch  Kbunch                1
Npart                     0 /bunch   Energy                    2.5 GeV
gamma            4892.37817          beta           0.9999999791
guess:          0                 0                  0
    U0              1.596476 [MeV/turn]

                                               M o d e   1        M o d e   2        M o d e   3
Fractional tunes            undamped            0.29163816         0.08677774         0.01694909
                            damped              0.29163791         0.08677738         0.01694884

beta* [m]                   x               0.29973574E+01     0.18836656E-37     0.91573745E-04
                            y               0.45077767E-34     0.41527008E+01     0.85775804E-31
                            t               0.30016120E-04     0.85181803E-31     0.32350415E+01

gamma* [1/m]                px              0.33362902E+00     0.84937989E-40     0.14326237E-07
                            py              0.99059248E-35     0.24125145E+00     0.63360666E-31
                            pt              0.60931232E-05     0.38410062E-33     0.30959624E+00

beta(max) [m]               x               0.69034068E+02     0.18776803E-36     0.39996412E-01
                            y               0.17219661E-30     0.52312416E+02     0.88865226E-31
                            t               0.84926909E+00     0.84911142E-30     0.32391926E+01

gamma(max) [1/m]            px              0.32585394E+02     0.17777772E-36     0.14326237E-07
                            py              0.81322237E-31     0.50426265E+02     0.63529496E-31
                            pt              0.40076778E+00     0.80393392E-30     0.30959624E+00
```

OPTION 3 - MAD-X

EMIT command results (with RF):

Damping partition numbers	0.97476117	1.00000430	2.02525243
Damping constants [1/s]	0.84516653E+03	0.86705358E+03	0.17559948E+04
Damping times [s]	0.11831988E-02	0.11533313E-02	0.56947776E-03
Emittances [pi micro m]	0.74211330E-01	0.36518744E-30	0.67646363E+01

RF system:

Cavity	length[m]	voltage[MV]	lag	freq[MHz]	harmon
rfc	0.5	3.6	0.48	1216.54908	448

III. SYNCHROTRON RADIATION

Bending Magnets

PARAMETERS	TME Lattice	DBA Lattice
Circumference	110.4 m	110.4 m
Bending radius ρ	3.57 m	2.16 m
Magnetic field	2.33 T	3.86 T
Critical energy ε_c	9.7 keV	16 keV

With a different bending radius (magnetic fields) we don’t achieve the same critical energy in TME start lattice and in DBA upgraded lattice

Bending Magnets

PARAMETER	VALUE	UNIT
Beam current	400	mA
Dipole field	3.86	T
Number of electrons $N_{electrons}$	$9.25*10^{11}$	-
Bending radius ρ	2.16	m
$P^u_{rad\ tot} = P^u_{rad\ per\ electron} * N_{electrons}$	2	MW
P^{dip}_{rad}	40	kW
Critical energy ε_c	16	keV

$$P = \frac{e^4}{6\pi\epsilon_0 m^4 c^6} E^2 B^2 L = 633 E^2[GeV] B^2[T] I_{beam}[A] L_w[m] \ with \ B = B_0/2$$

Insertion Devices

Specification values

PARAMETER	VALUE	UNIT
Energy 1st harmonic	8	keV
$\Delta\lambda/\lambda$	10^-3	-
Peak flux	20	keV

Insertion Devices

Design and results

PARAMETER	FIRST HARMONIC	THIRD HARMONIC
$L = 4$ m	$\varepsilon = 8$ keV	$\varepsilon = 20$ keV
$\lambda_u = 4$ mm	$B_0 = 3.4$ T	$B_0 = 4.1$ T
$N_u = 10^3$	$K = 1.23$	$K = 1.565$
$\Delta\lambda/\lambda = 10^{-3}$		
$P_{undulator} = 2$ MW		

Superconductive wiggler!!!

Insertion Devices

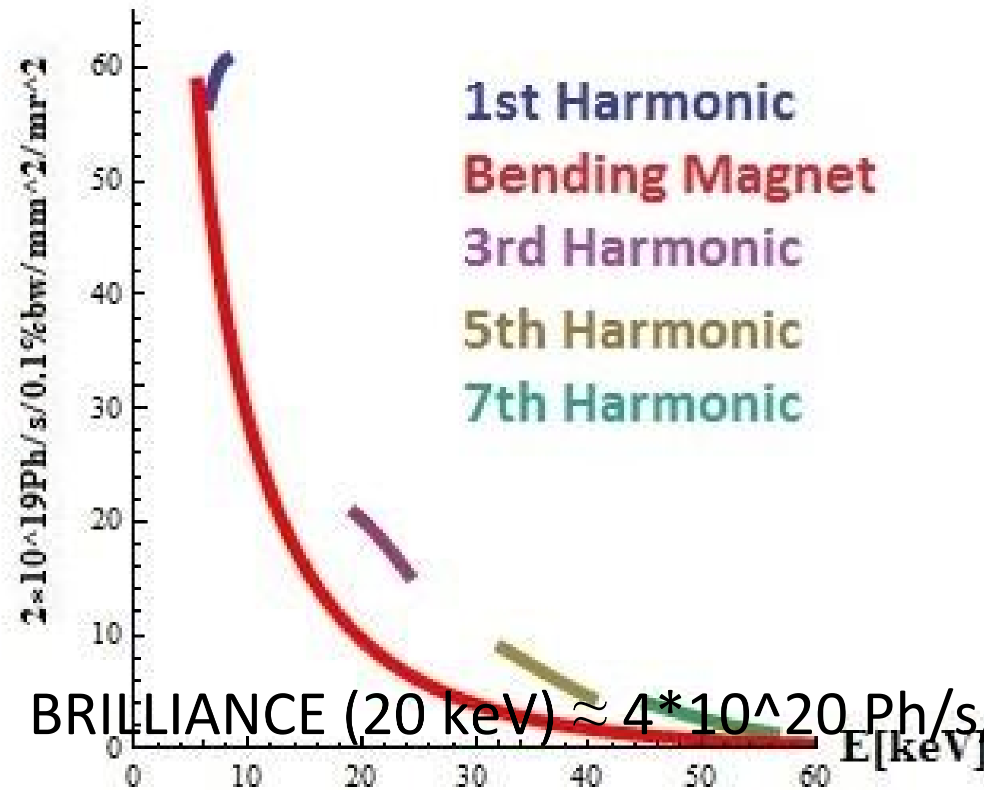
PARAMETERS
Bu = 3.4 T
Bdip = 3.86 T
$N_{electrons}$ = 9.25 * 10^{11}
$\rho = 2.16$ m
$P^{u}_{rad\ per\ electron}$ =436.5*10^{-8} W
P^{dip}_{rad} = 40 kW
P_{tot} = Ndip * P^{dip}_{rad} + $P^{u}_{rad\ tot}$ * Nu = 16.64 MW
ε_c =16 keV

$$P = \frac{e^4}{6\pi\epsilon_0 m^4 c^6} E^2 B^2 L = 633 E^2[GeV] B^2[T] I_{beam}[A] L_w[m] \ with\ B = B_0/2$$

Brilliance

$$\frac{dN}{dE} = \int\int_{4\pi} \frac{d^3I}{d\omega d\Omega} d\Omega = \frac{\sqrt{3}e^2}{4\pi\epsilon_0 c\omega_C\hbar}\gamma \int_{\frac{\omega}{\omega_c}}^{\infty} K_{5/3}(x)dx$$

$$\frac{d^3N}{d\Omega dE} = \frac{e^2\gamma^2N^2}{\omega 4\pi\epsilon_0 c\hbar} L\left(N\frac{\Delta\omega}{\omega_{res}(\theta)}\right) F_n(K,\theta,\phi) \;\; with \;\; \Delta\omega = \omega - n\omega_{res}(\theta)$$



$1.23 \leq K \leq 1.565$

$3.4\ T \leq B_0 \leq 4.1\ T$

$\varepsilon x = 75\ nm$

$\varepsilon y = 1.3\ nm$

BRILLIANCE (20 keV) $\approx$ 4*10^20 Ph/s/0.1%bw/mm^2/mr^2

Thank you for your attention!