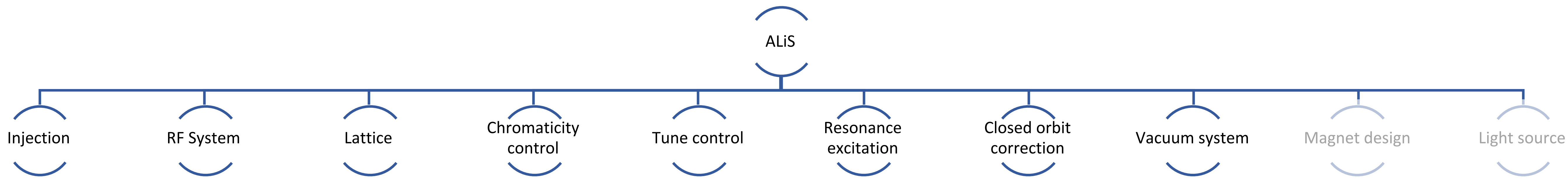
Archamps Light Source

ALiS 4 - Design proposal

CONTEXT

ORGANISATION



Lattice

Injection

RF System

Chromaticity Control

Tune control

Resonance excitation

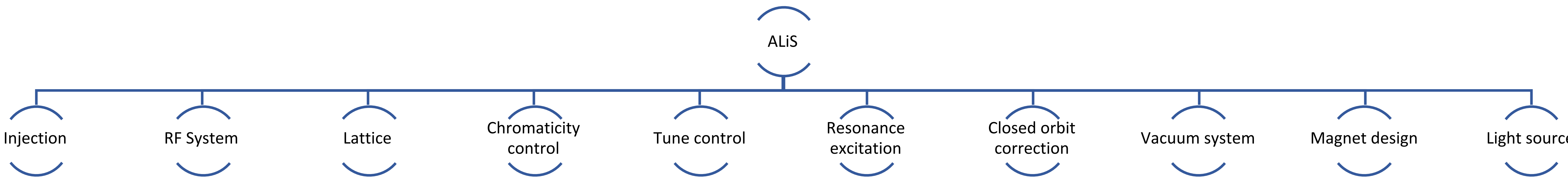
Closed orbit correction

Vacuum system

Magnet design

Light source

ORGANISATION



Lattice

Injection

RF System

Chromaticity Control

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Resonance excitation

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Magnet design

Light source

INJECTION

ALiS

Injection | RF System | Lattice | Chromaticity control | Tune control | Resonance excitation | Closed orbit correction | Vacuum system

Archamps Light Source

ALiS 4 - Injection/Extraction

Considerations

- Dispersion free area
- Low β-functions
- Space for kicker and septum needed
- 180° symmetry for injection/extraction
- 2 GeV → 3 GeV ramping

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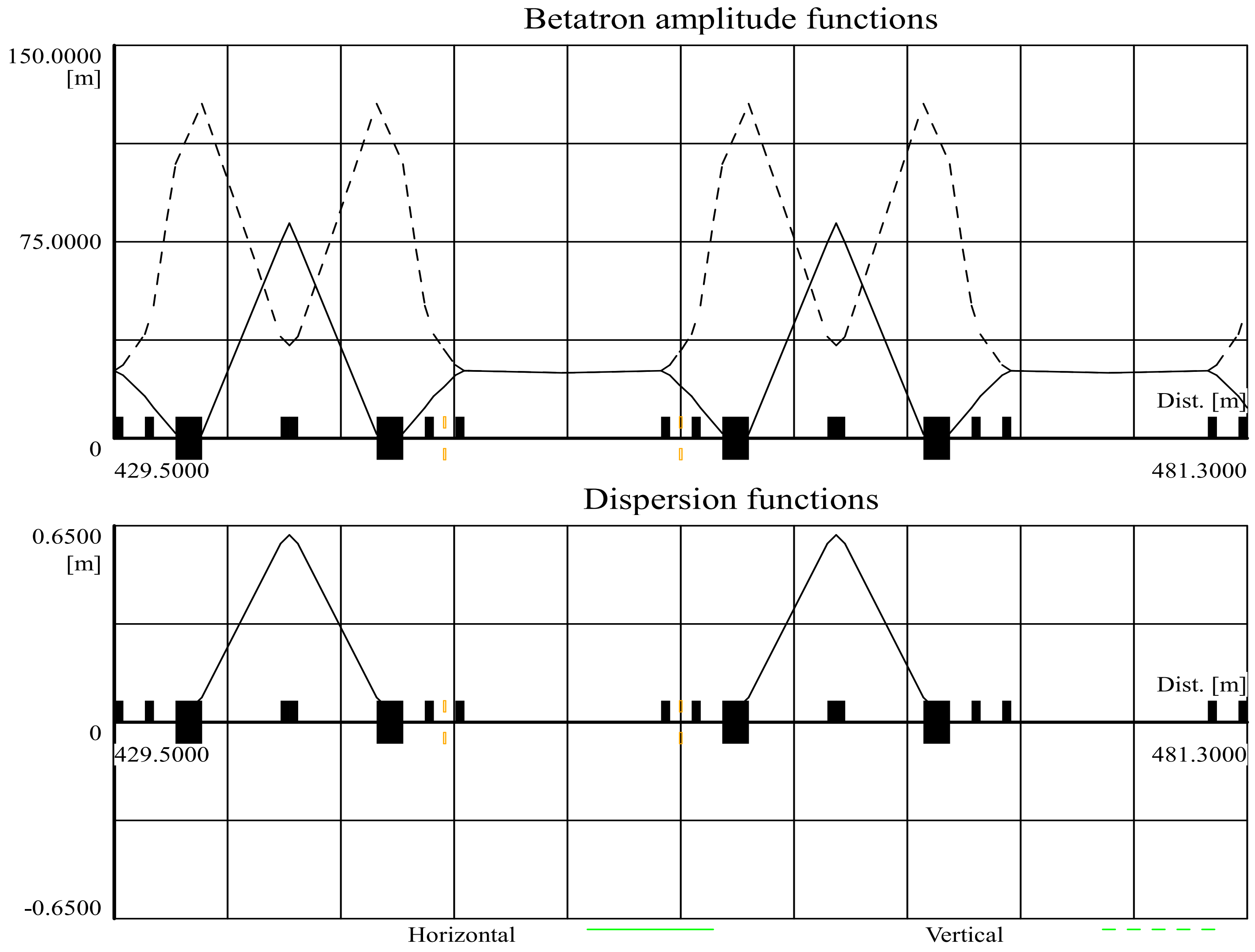

Considerations

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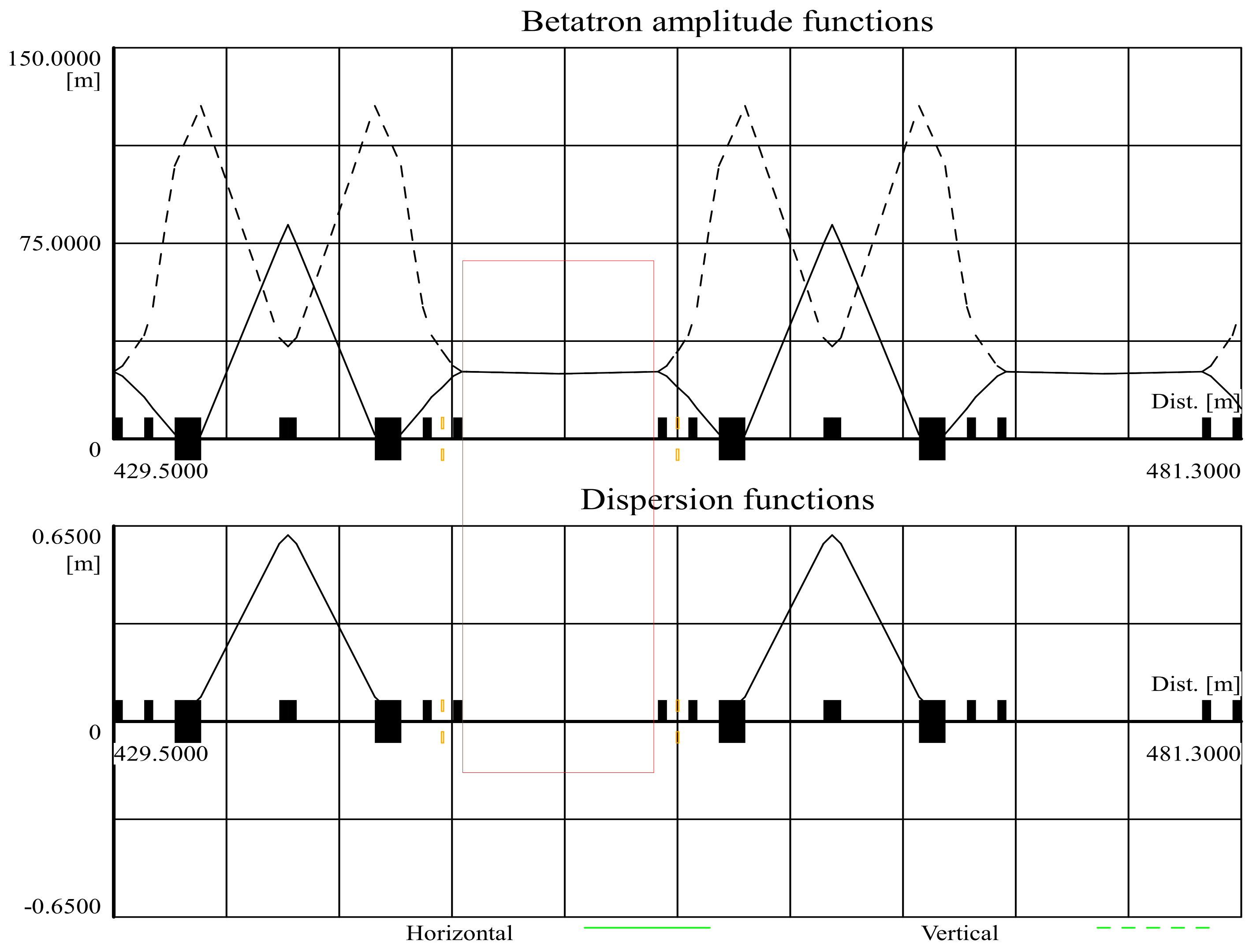
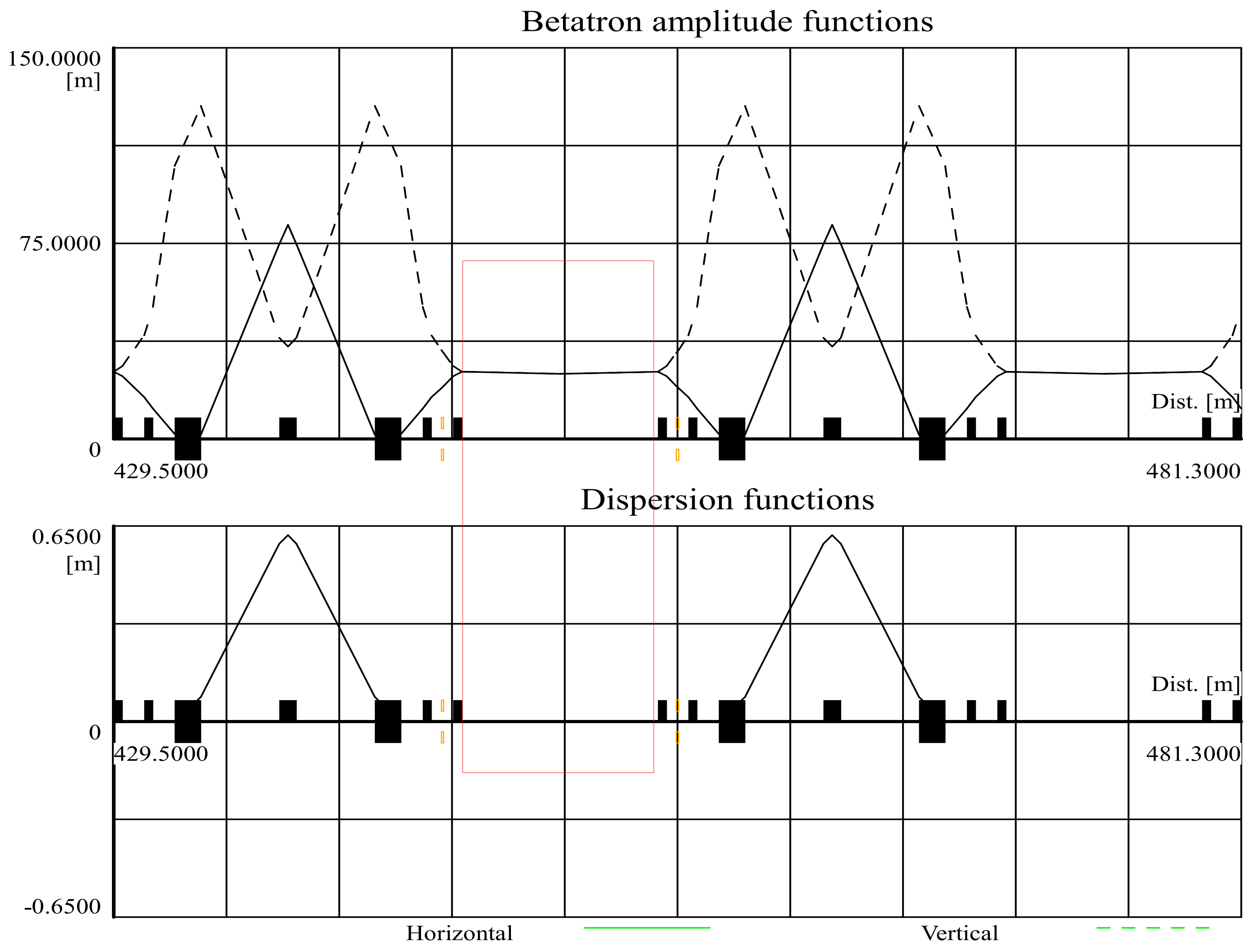
- 2 GeV → 3 GeV ramping



Basic Ring

Input

β_x/β_y	25,74 m
α_x/α_y	0.172 m^{-1}
D_x/D_y	0
dD	0
β_{long}	4.611 m
α_{long}	0.0082 m^{-1}



Extraction - Setup

Input

β_x/β_y	25,74 m
α_x/α_y	0.172 m^{-1}
D_x/D_y	0
dD	0
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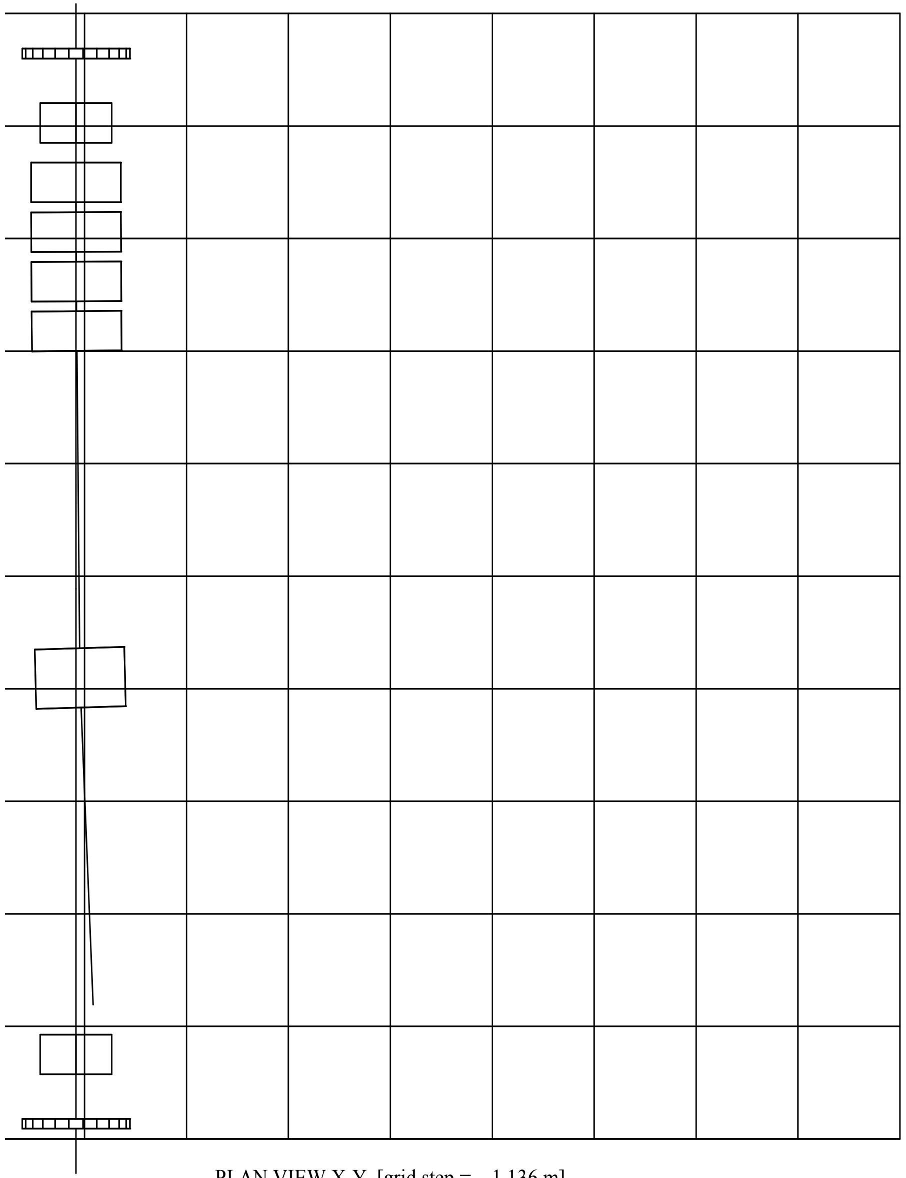

PLAN VIEW X-Y [grid step = 1.136 m]

Extraction - Setup

Input

β_x/β_y	25,74 m
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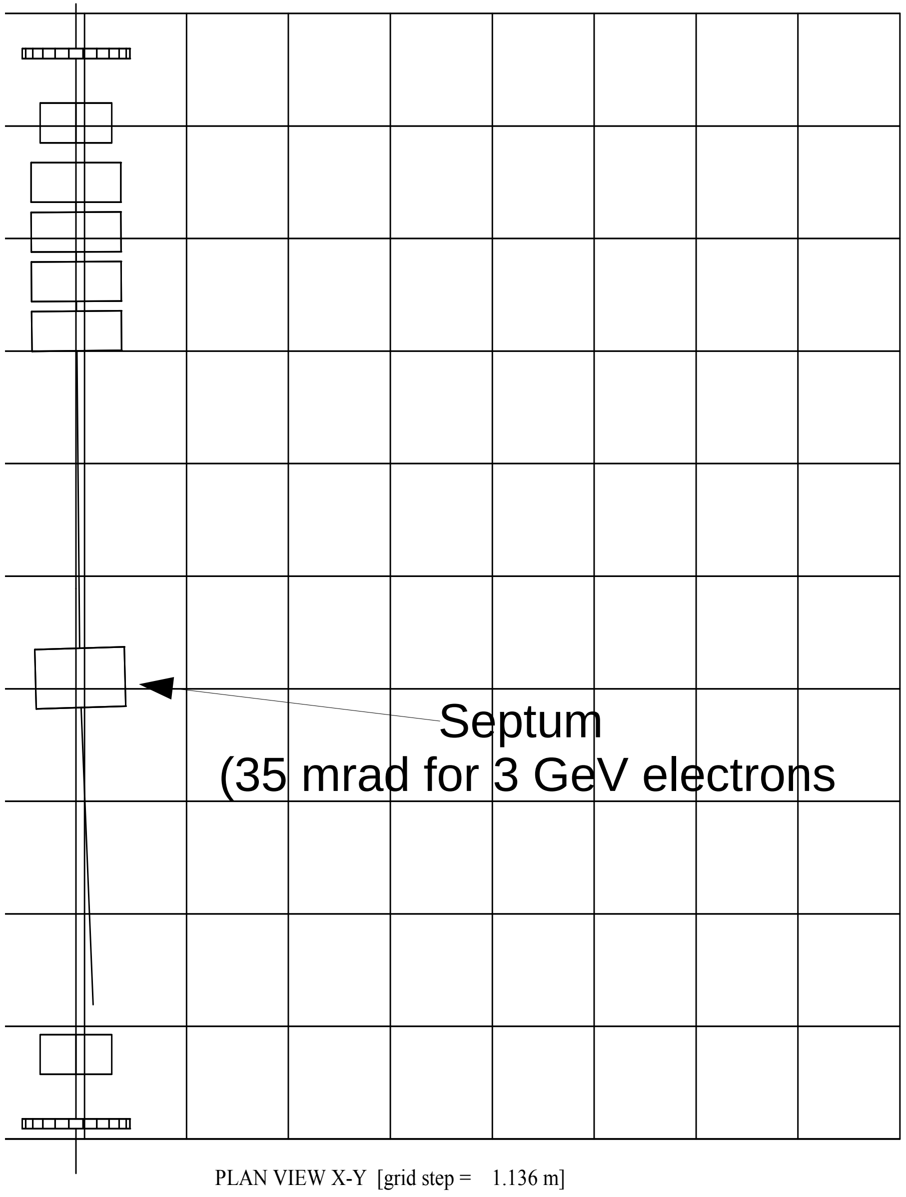

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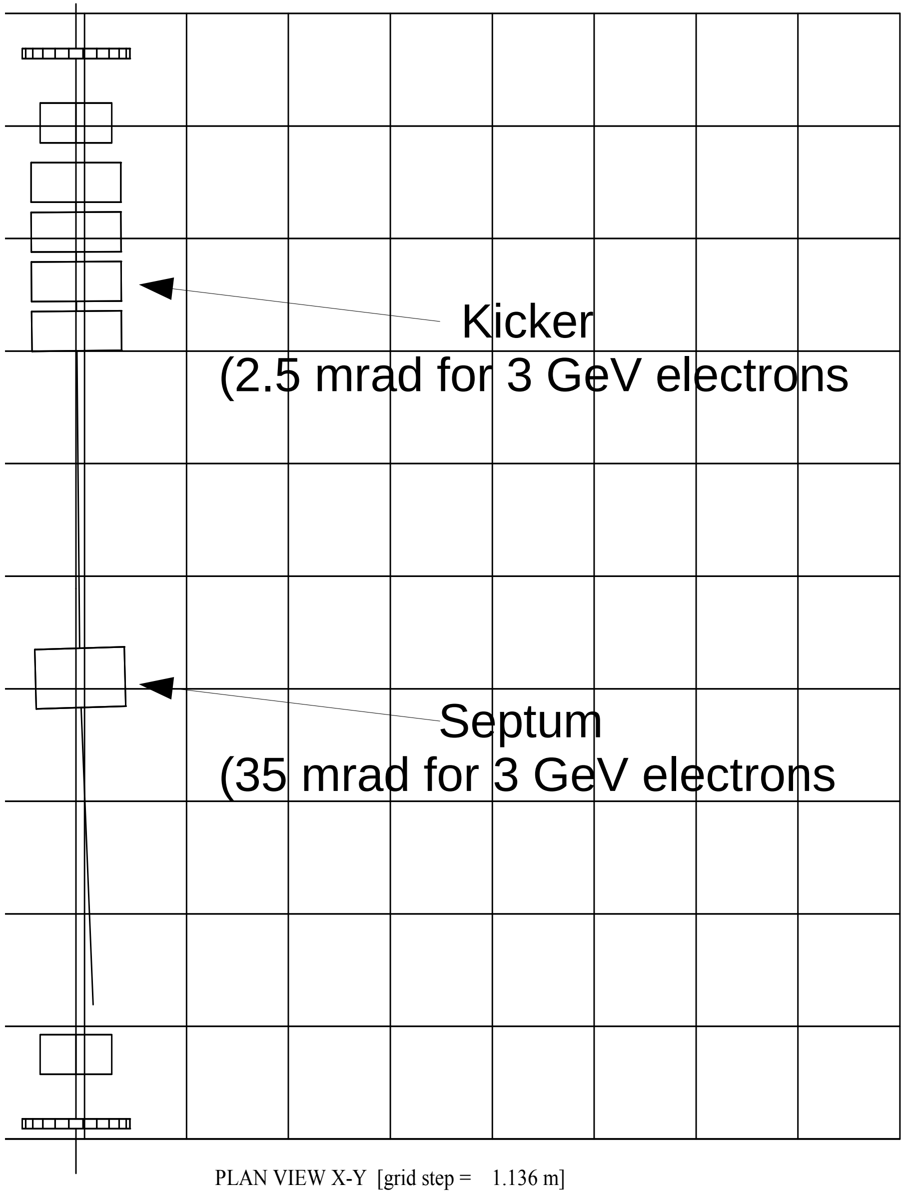

Extraction - Setup

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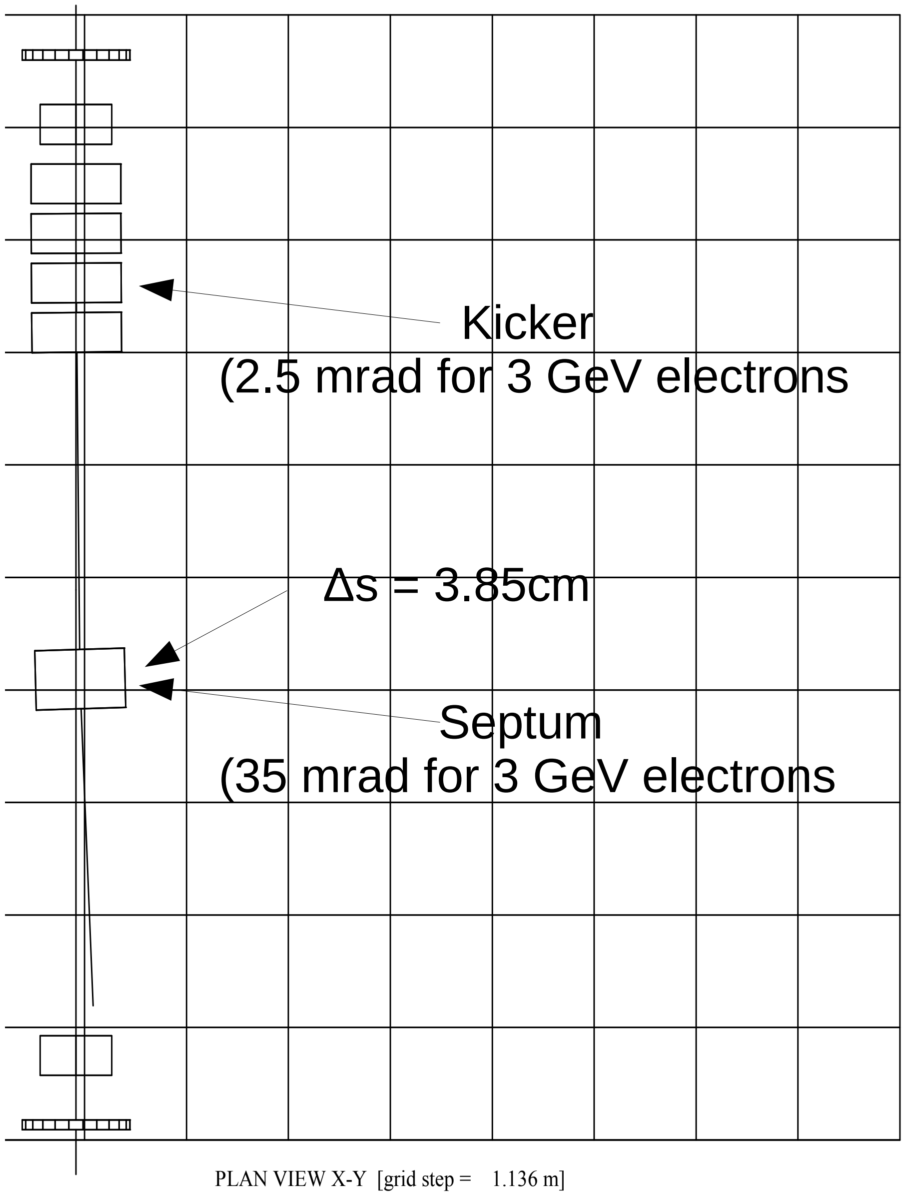

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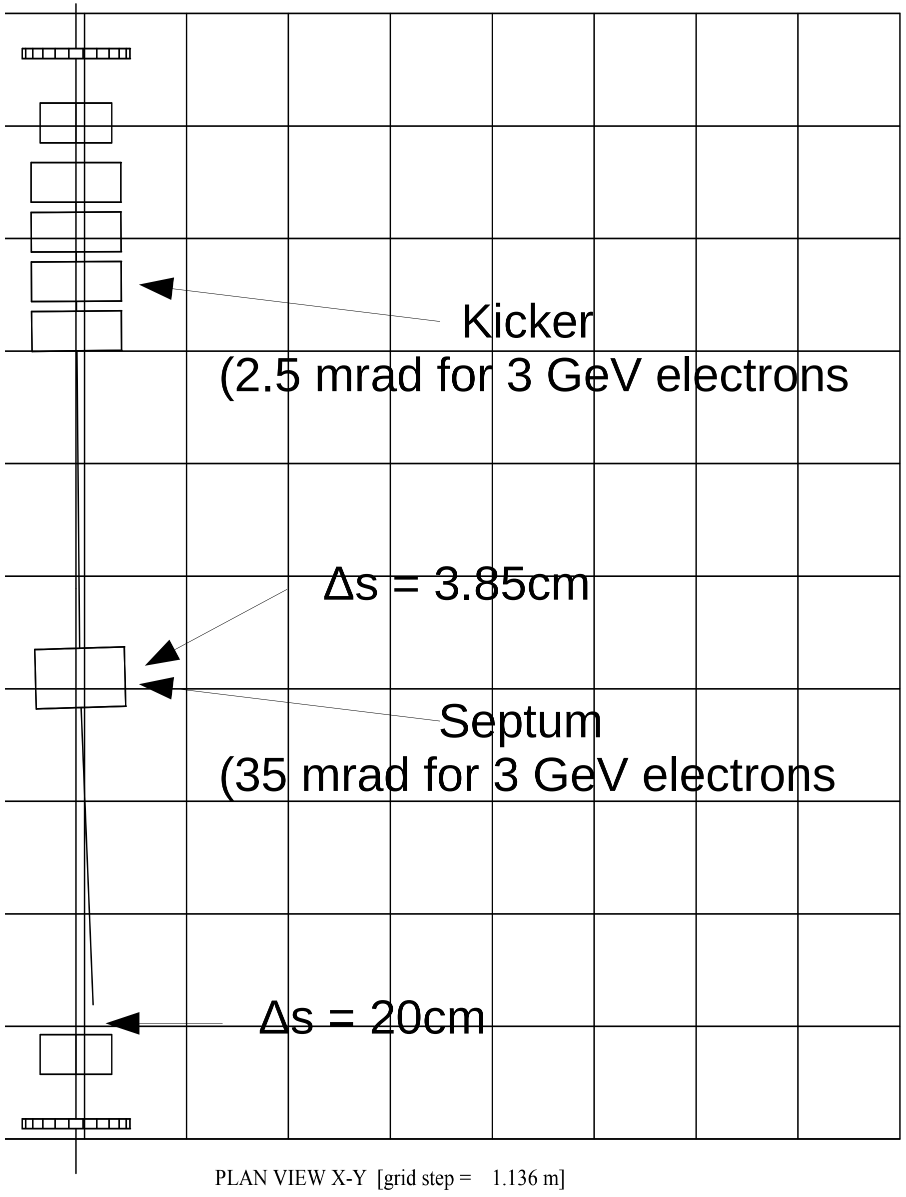
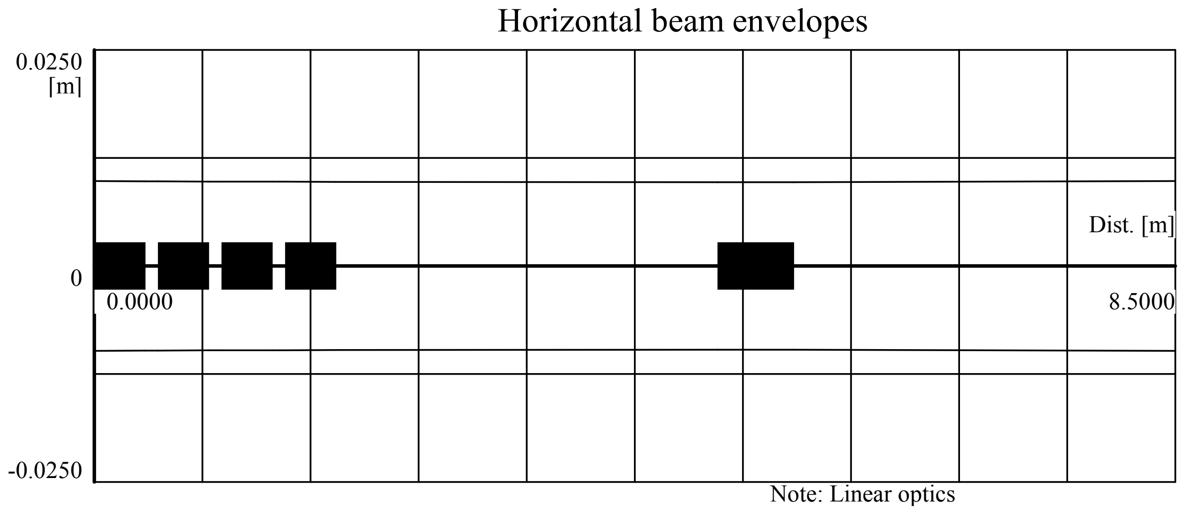
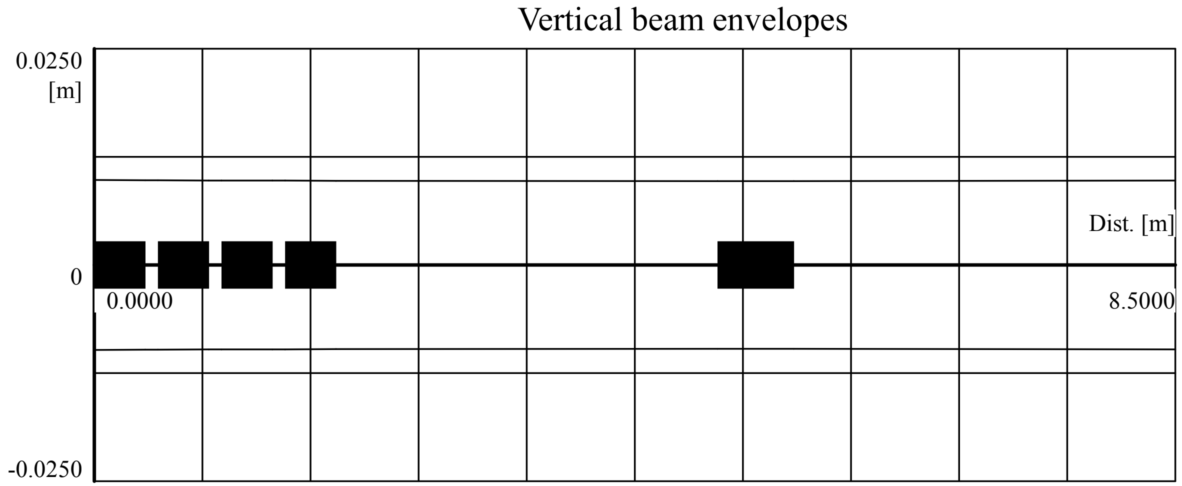


Extraction - Performance

Output

β_x/β_y	25.7/25.3 m
α_x/α_y	0.17/0.1 m^{-1}
D_x/D_y	0.191/0 m
dD_x/dD_y	0.045/0 m
β_{long}	-
α_{long}	-





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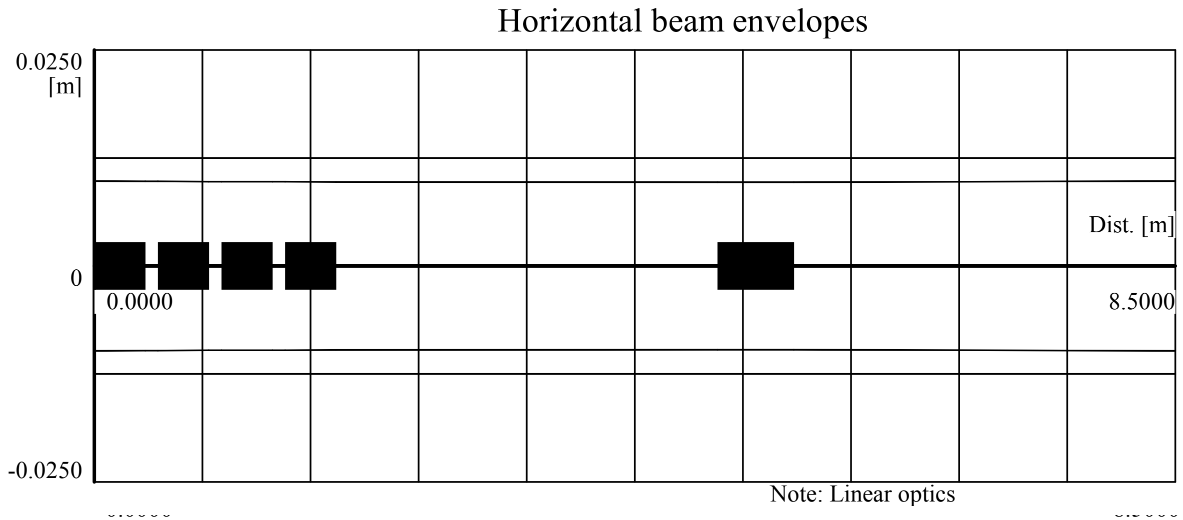
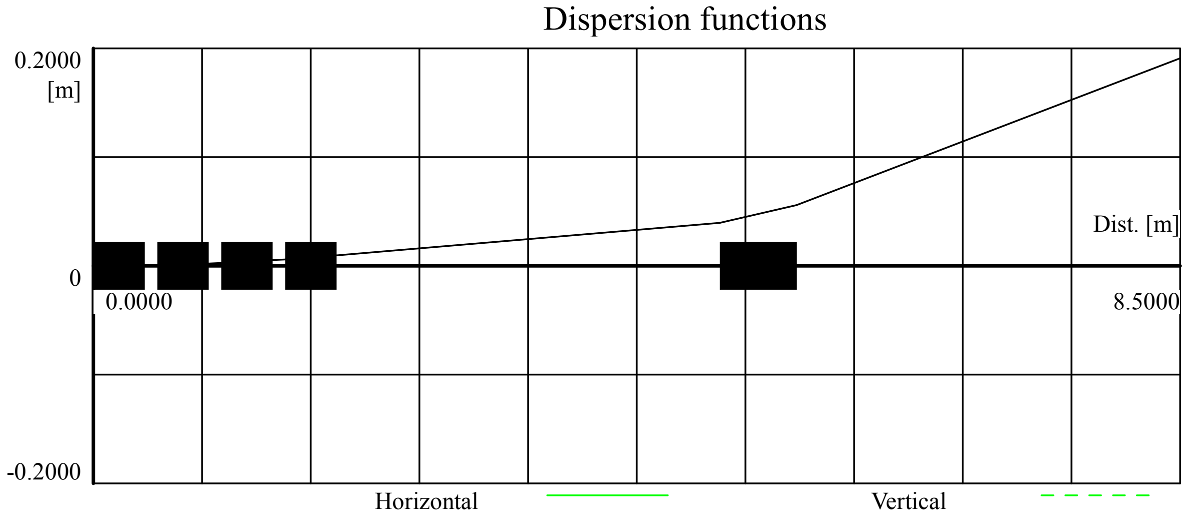
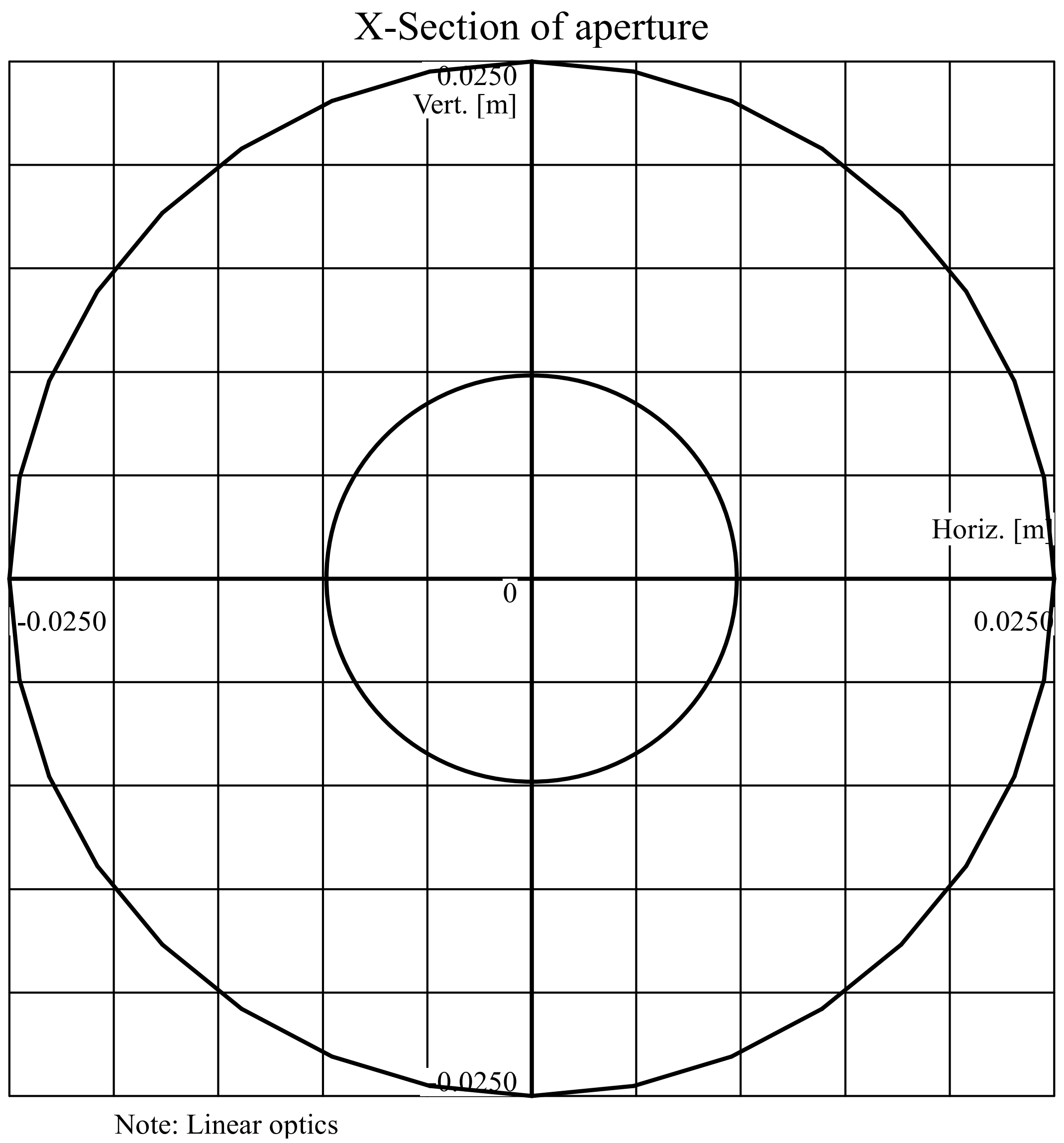


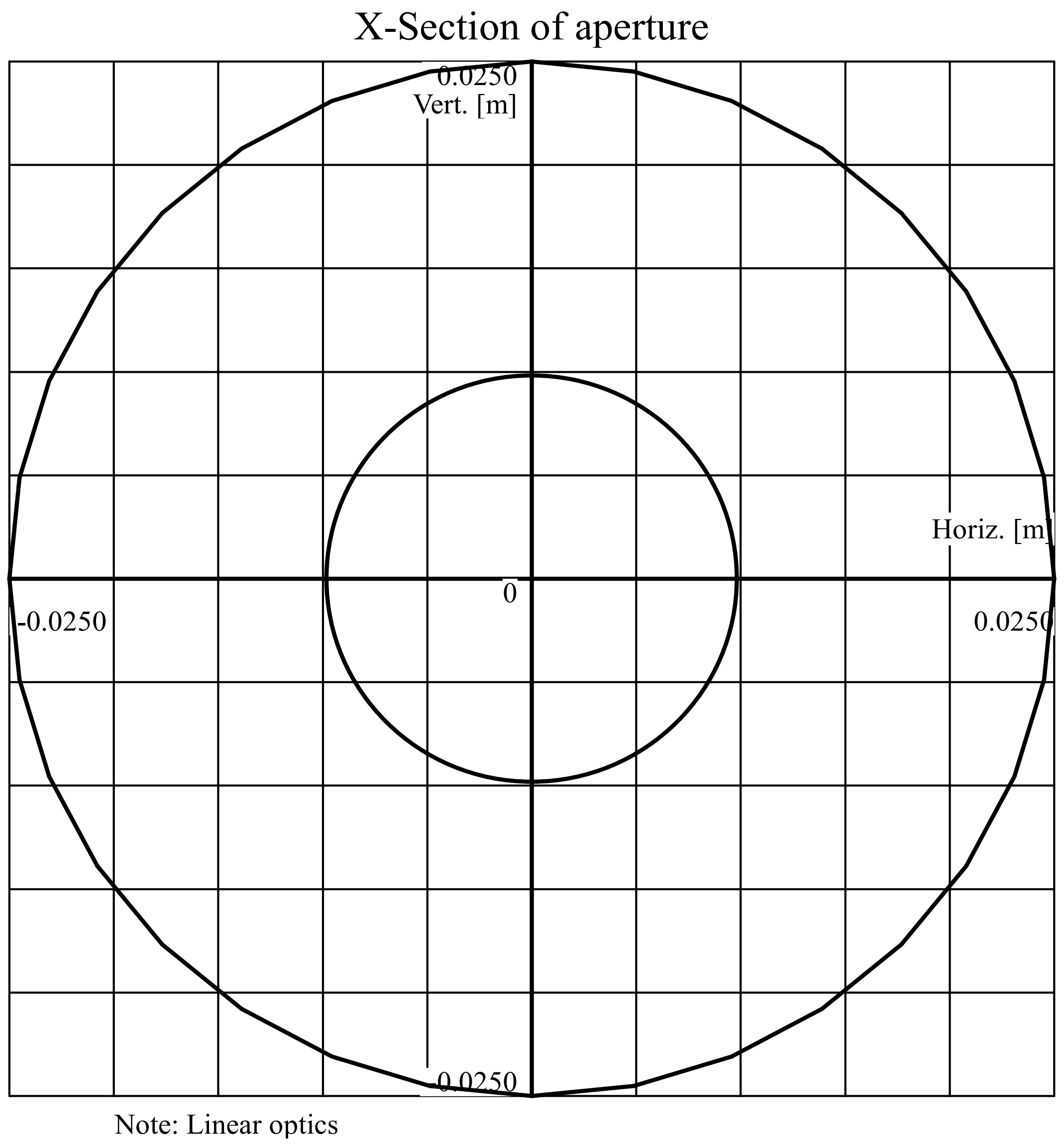


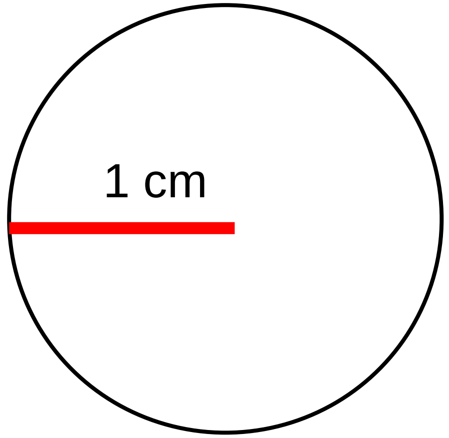
Septum



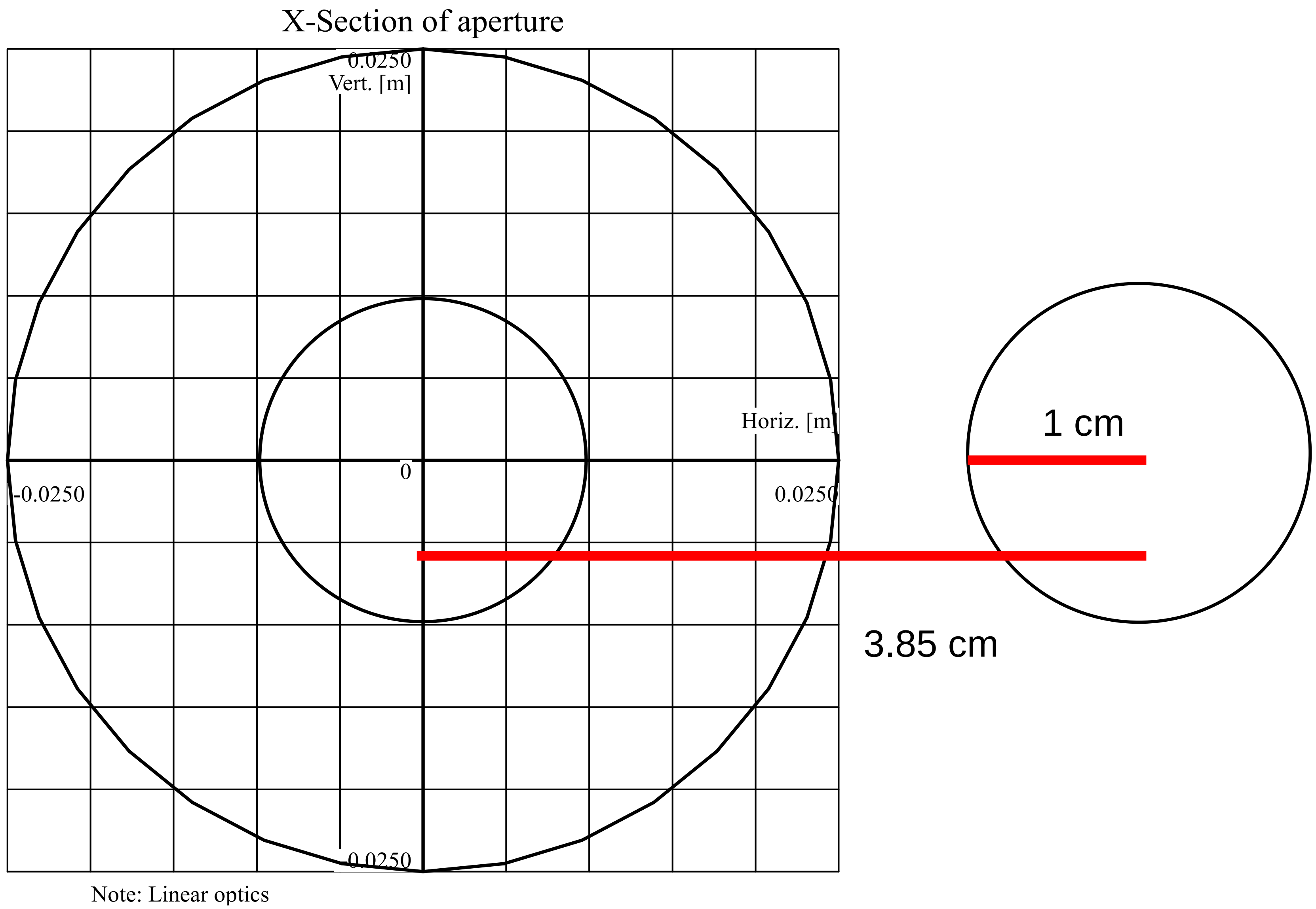
X-Section of aperture
0.0250
Vert. [m]
Horiz. [m]
0
-0.0250
0.0250
-0.0250
Note: Linear optics

Septum

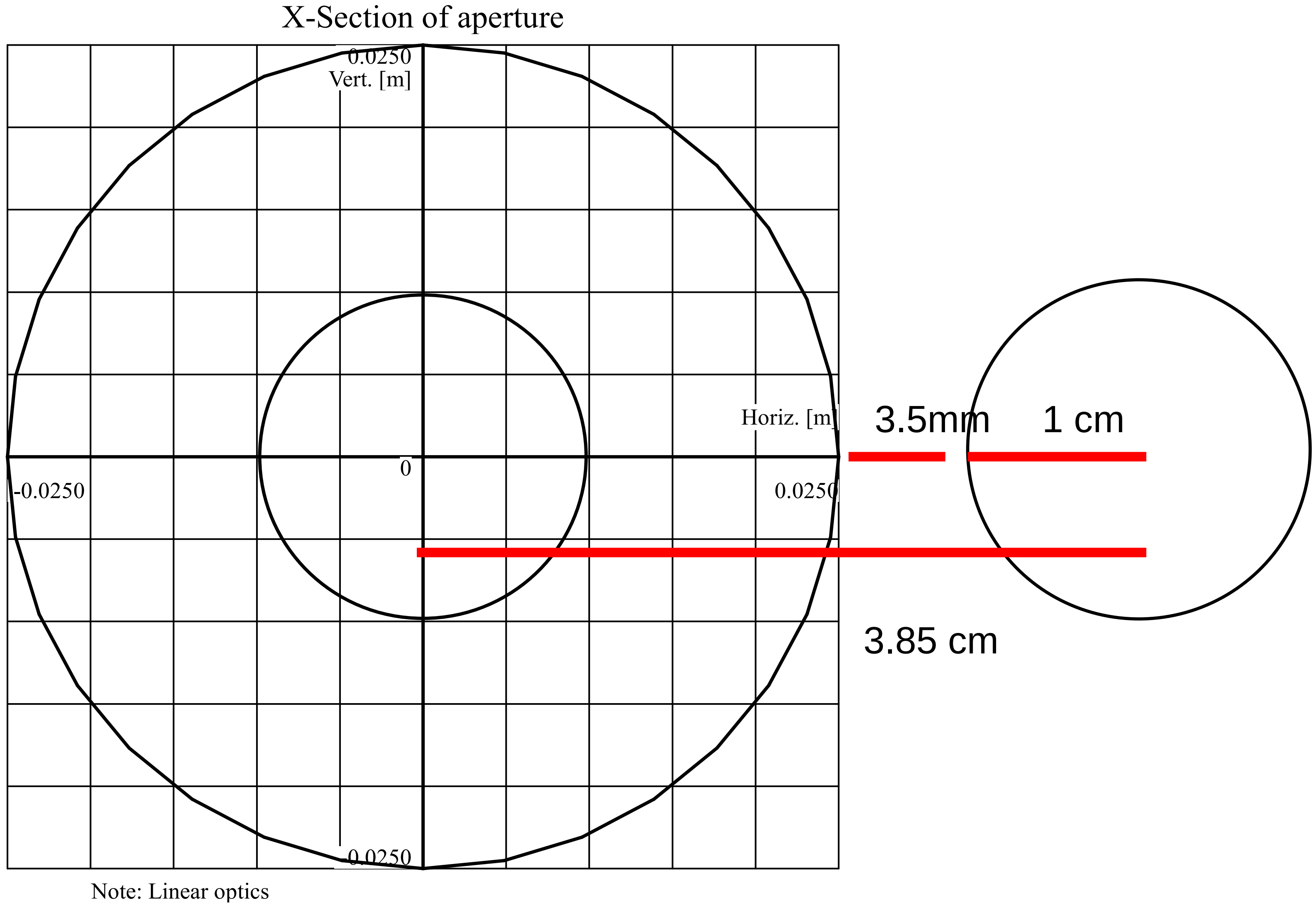

X-Section of aperture
0.0250
Vert. [m]
Horiz. [m]
0
-0.0250
0.0250
-0.0250
Note: Linear optics


1 cm

Septum


X-Section of aperture
0.0250
Vert. [m]
Horiz. [m]
0
-0.0250
0.0250
-0.0250
Note: Linear optics
1 cm
3.85 cm

Septum



X-Section of aperture
0.0250
Vert. [m]
Horiz. [m]
0
-0.0250
0.0250
-0.0250
Note: Linear optics
3.5mm
1 cm
3.85 cm

Injection

Output – Beginning of Ring

β_x/β_y	25,74 m
α_x/α_y	- 0.172 m^{-1}
D_x/D_y	0
dD	0
β_{long}	4.611 m
α_{long}	0.0082 m^{-1}

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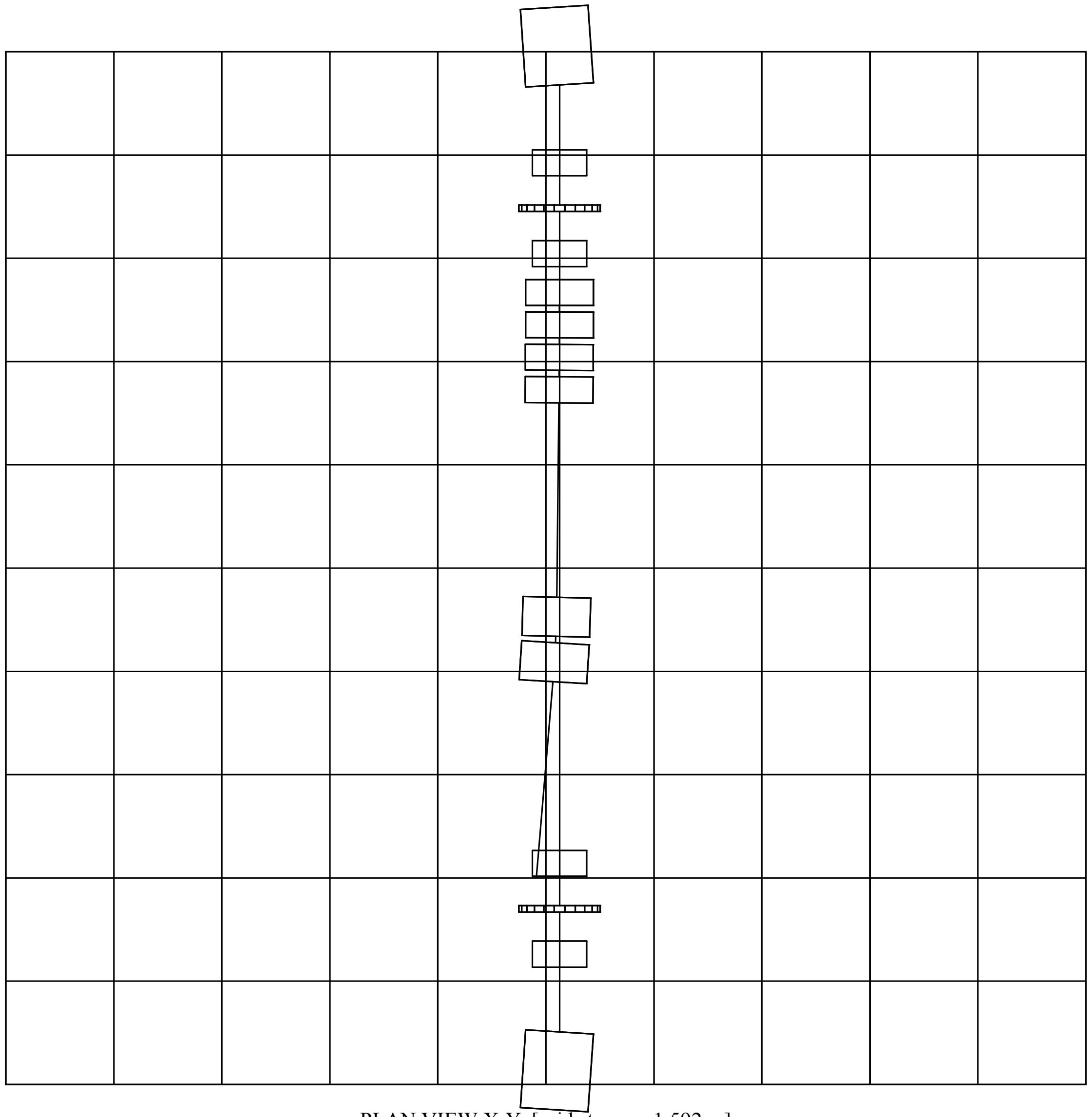
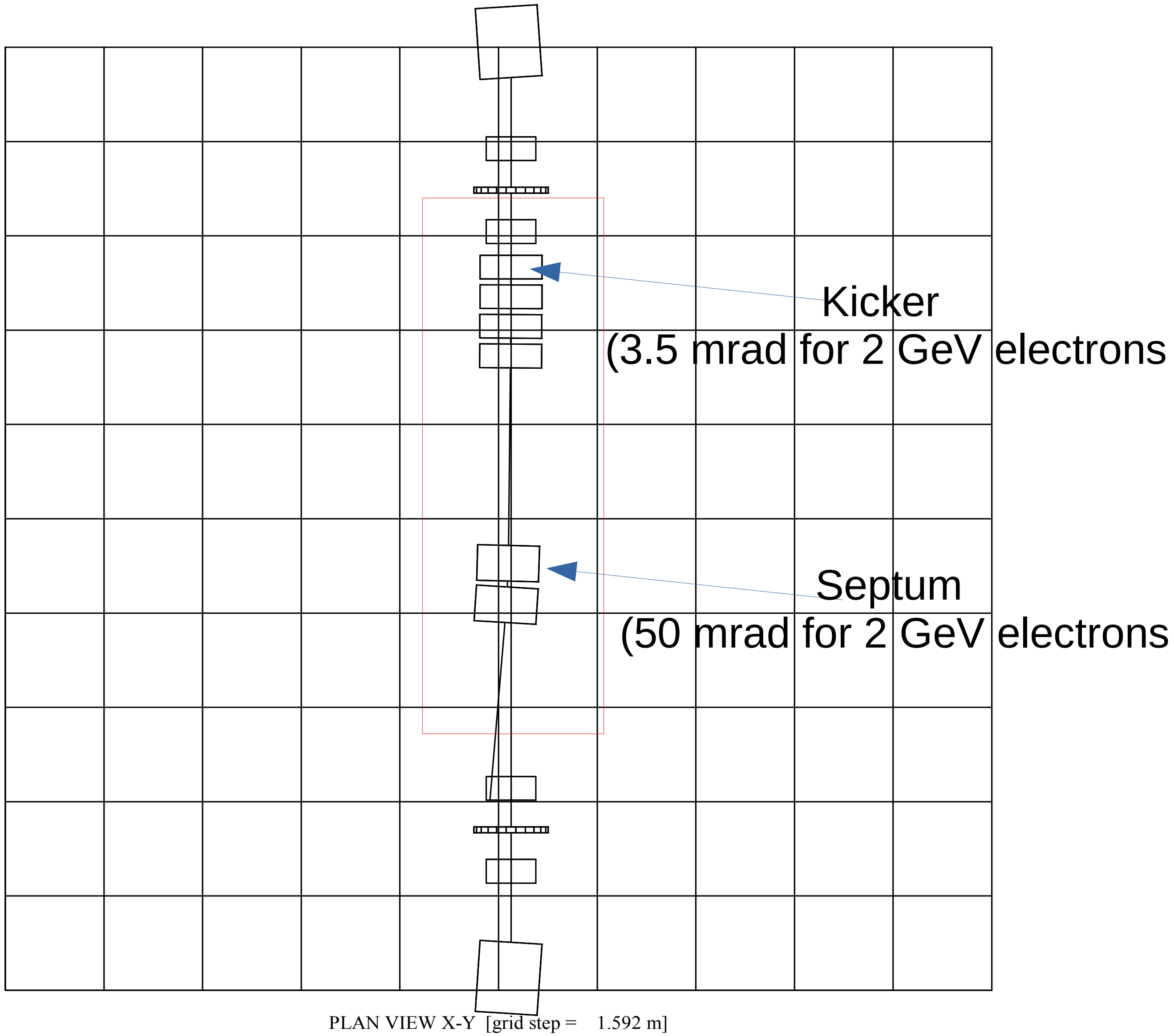


PLAN VIEW X-Y [grid step = 1.592 m]

Injection

Output – Beginning of Ring

β_x/β_y	25,74 m
α_x/α_y	- 0.172 m^{-1}
D_x/D_y	0
dD	0
β_{long}	4.611 m
α_{long}	0.0082 m^{-1}



Injection

Output – Beginning of Ring

β_x/β_y	25,74 m
α_x/α_y	- 0.172 m^{-1}
D_x/D_y	0
dD	0
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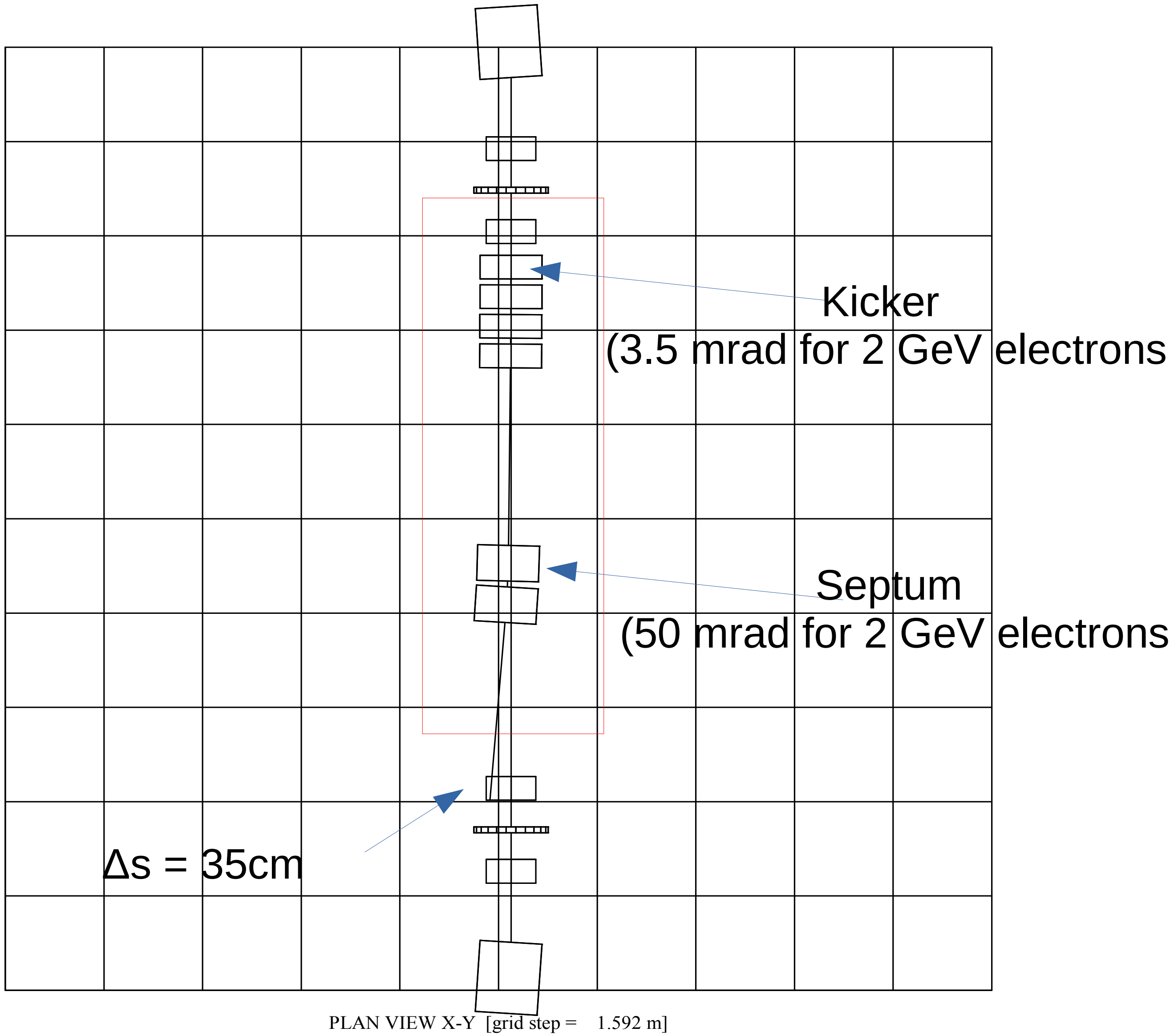
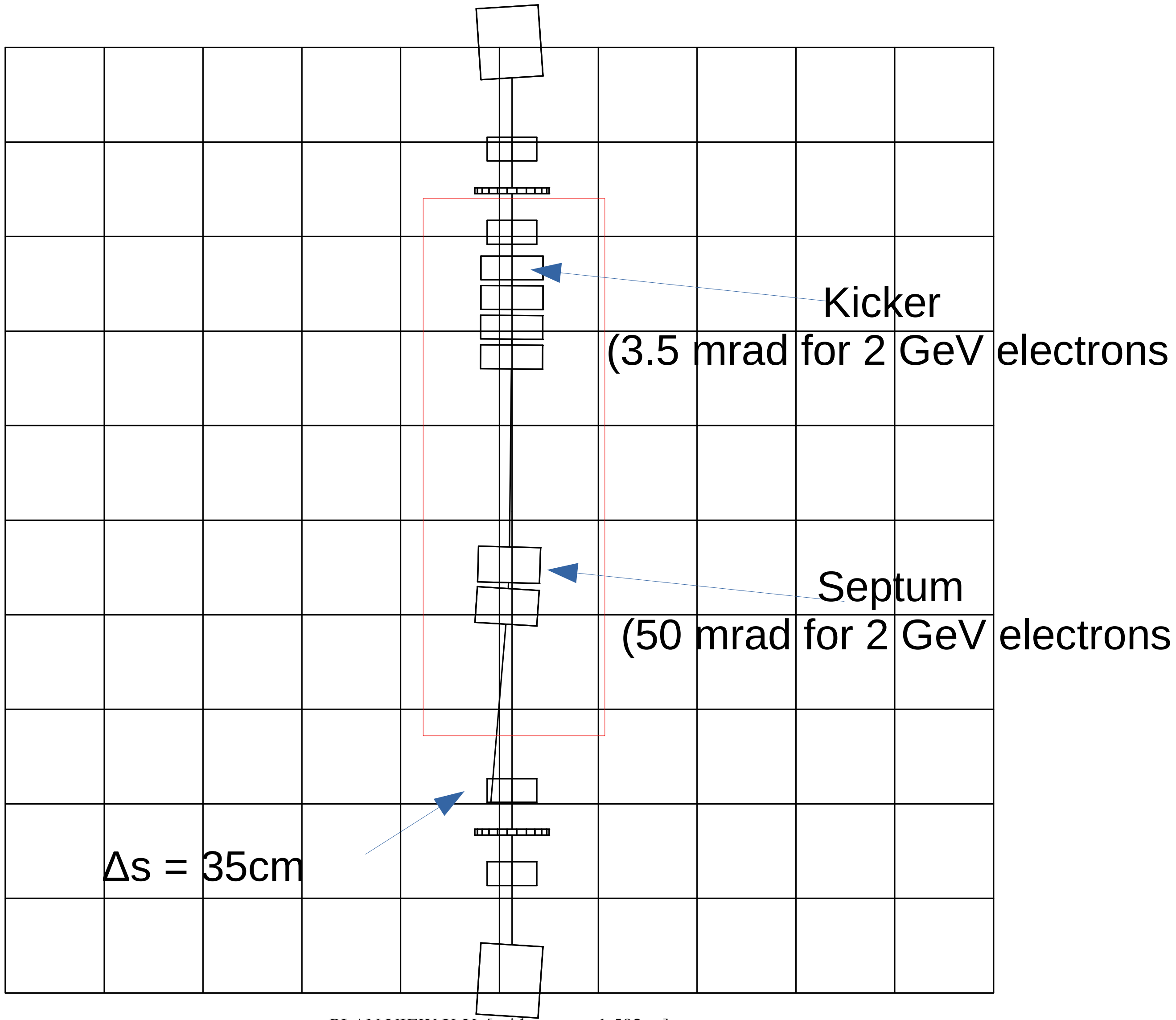


Injection

Input – Beginning of Injection

β_x/β_y	25,96/25.2 m
α_x/α_y	0.20/0.10 m^{-1}
D_x/D_y	0.338/0 m
dD	-0.08/0 m
β_{long}	-
α_{long}	-



PLAN VIEW X-Y [grid step = 1.592 m]

Injection - Performance

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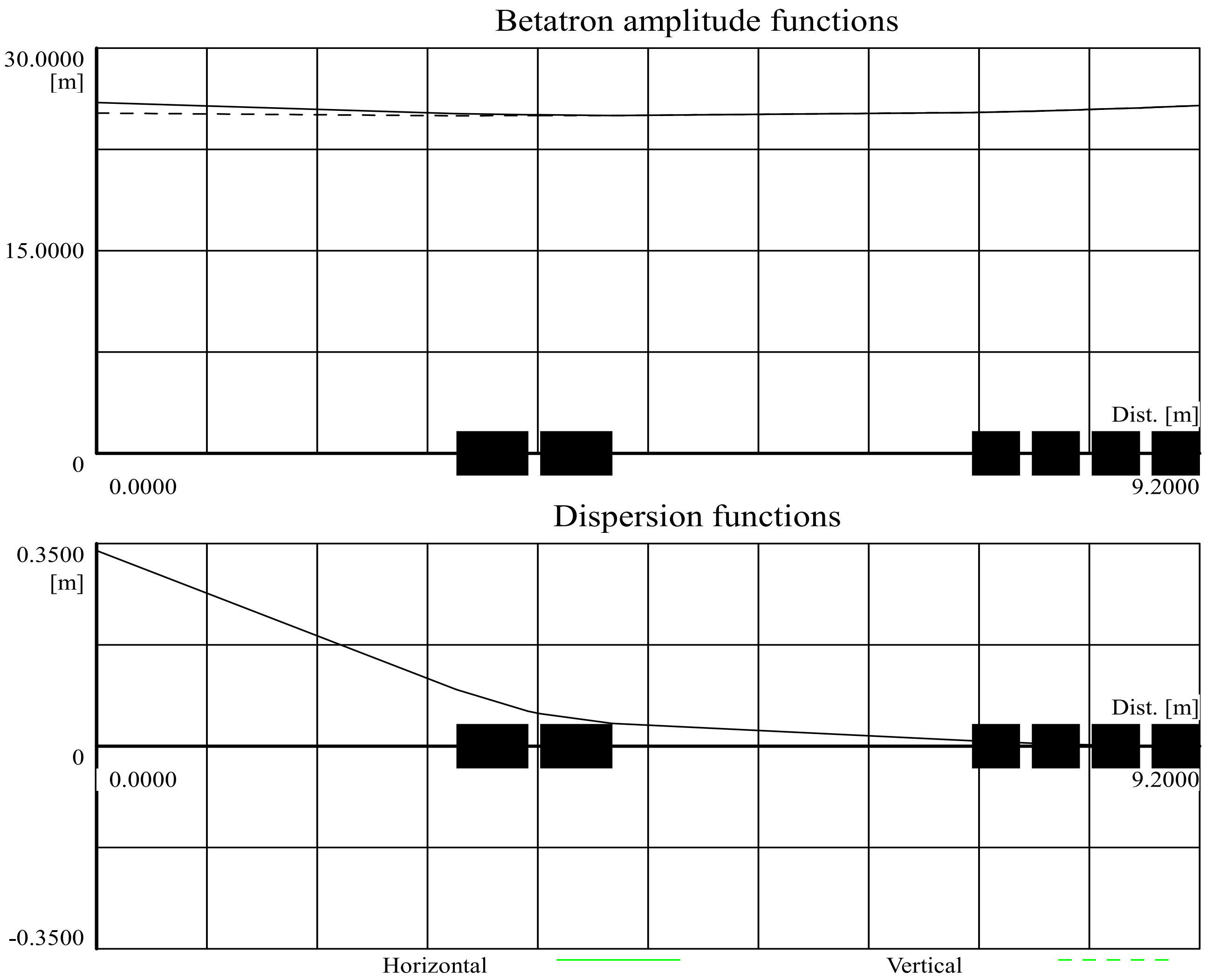


Outlook

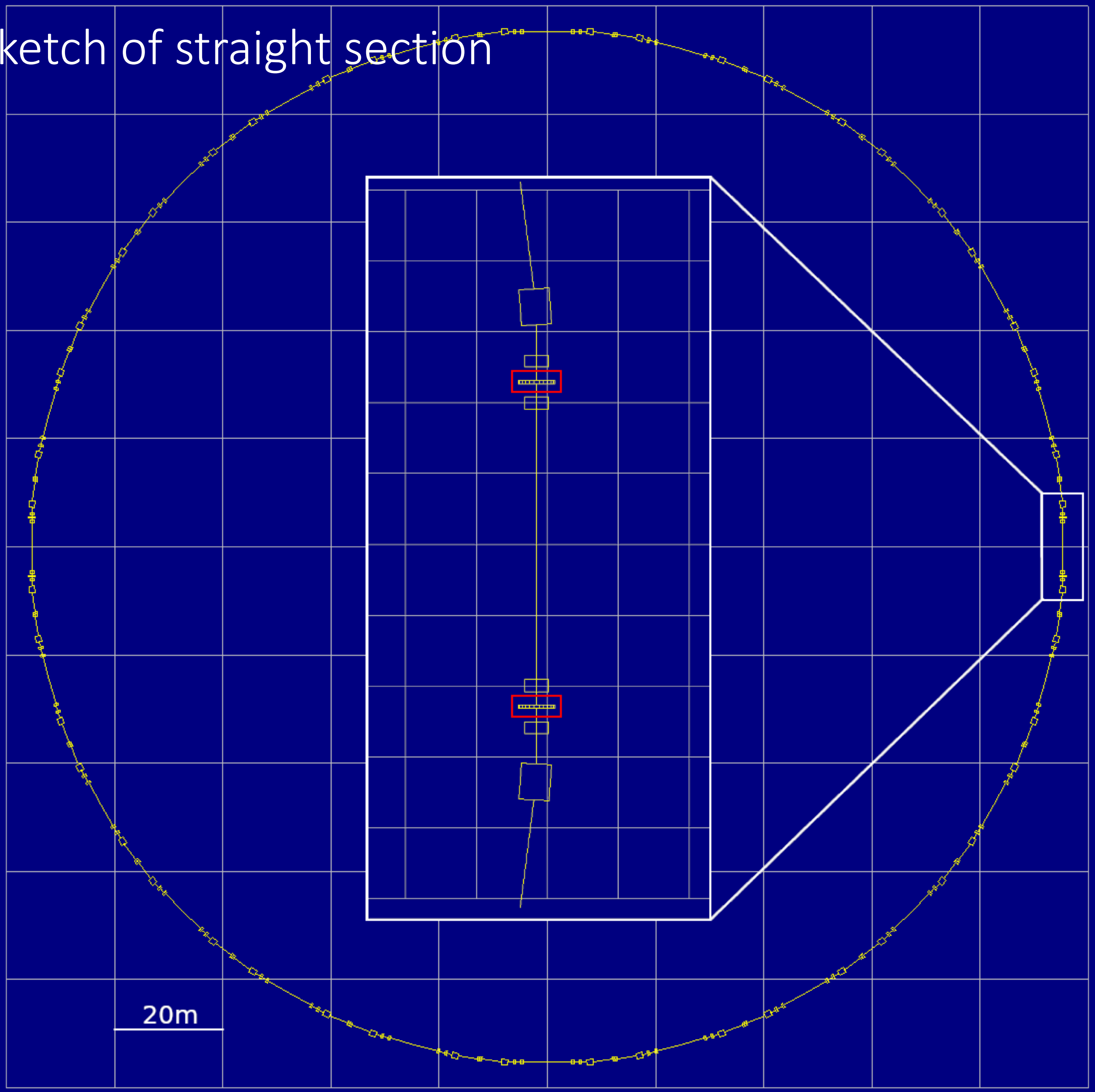
- Extraction-line needs 4 Kickers → probably less Kicker for Injection
- 3.5mm thickness for blade of septum (Extraction)
- 15 cm distance between extraction-vacuum pipe and quadrupole
  → second septum for higher bending angle
- Injection-twiss parameter calculated (without considering focusing optics)
- Beam-dumping can be easily realized

RF SYSTEM

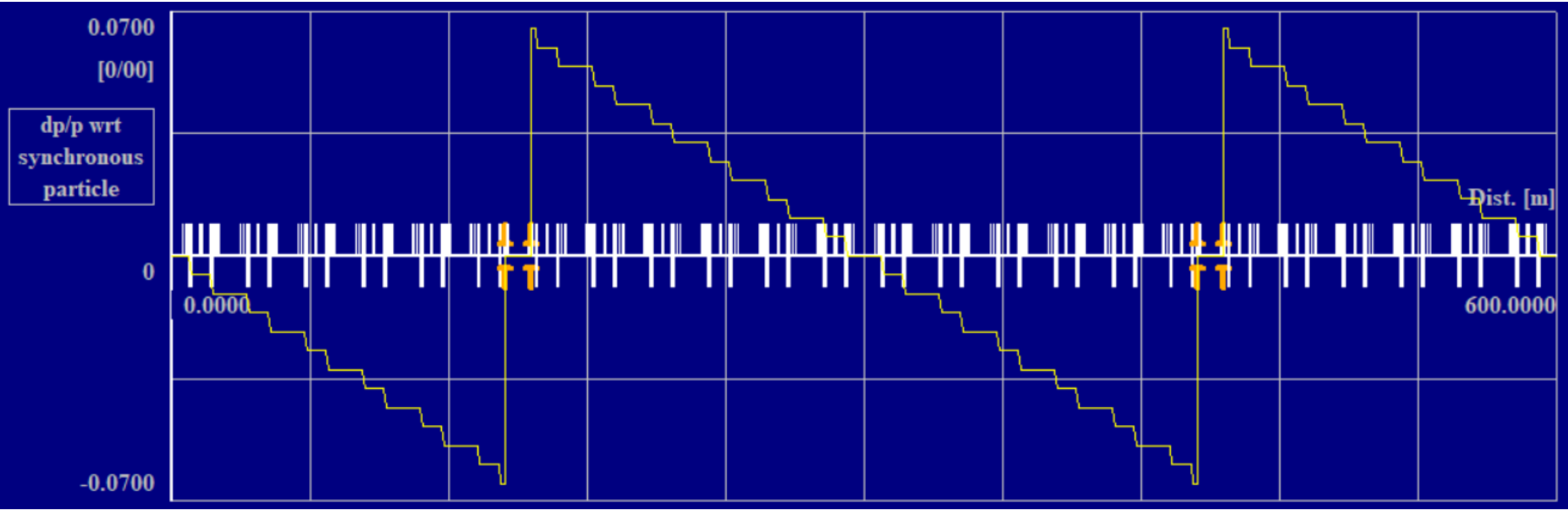
ALiS

Injection | RF System | Lattice | Chromaticity control | Tune control | Resonance excitation | Closed orbit correction | Vacuum system

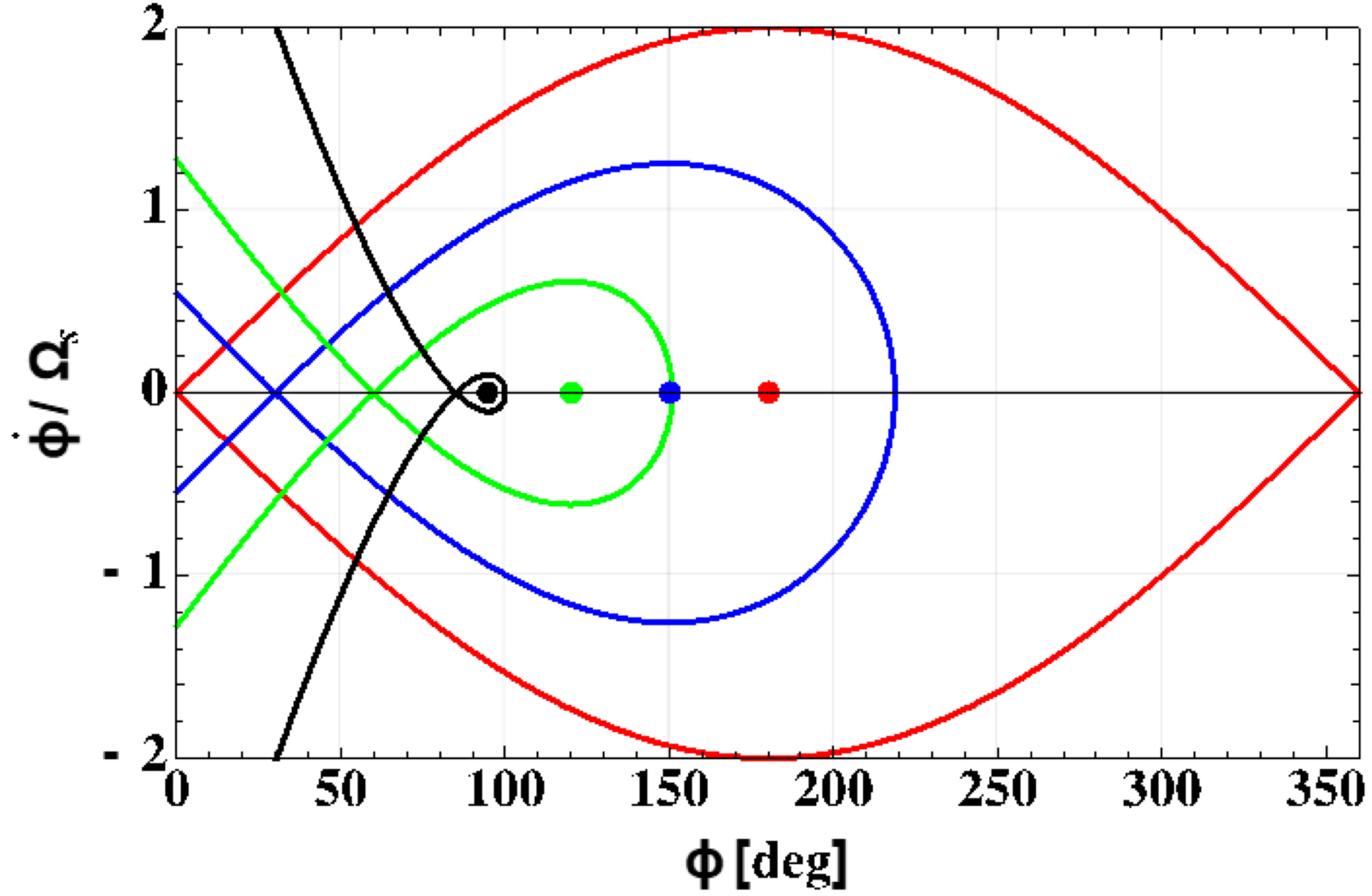
Sketch of straight section



Tracking an electron



u Above transition

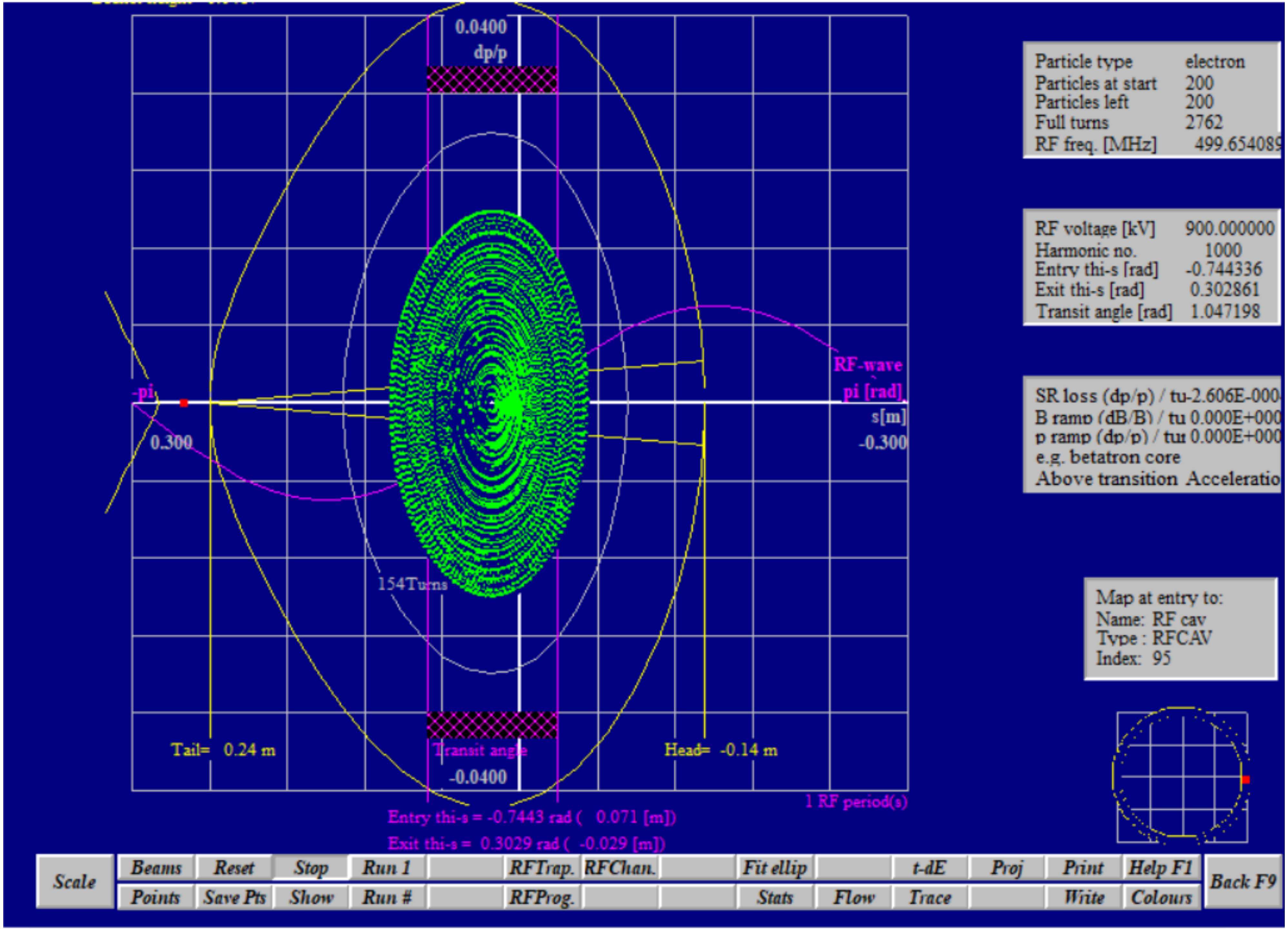


Compromise:
Want good acceleration & low beam losses

=> Goal : $\emptyset_s \approx \pi - 45° = 135°$

$\phi_s \Rightarrow \pi - \phi_s$

$\phi_s = 180°$ $\phi_s = 150°$
$\phi_s = 120°$ $\phi_s = 95°$



0.0400
dp/p
-pi
RF-wave
pi [rad]
s[m]
0.300
-0.300
154Turns
Tail= 0.24 m
Transit angle
-0.0400
Head= -0.14 m
1 RF period(s)
Entry thi-s = -0.7443 rad (0.071 [m])
Exit thi-s = 0.3029 rad (-0.029 [m])
Particle type electron
Particles at start 200
Particles left 200
Full turns 2762
RF freq. [MHz] 499.654089
RF voltage [kV] 900.000000
Harmonic no. 1000
Entry thi-s [rad] -0.744336
Exit thi-s [rad] 0.302861
Transit angle [rad] 1.047198
SR loss (dp/p) / tu-2.606E-000
B ramp (dB/B) / tu 0.000E+000
p ramp (dp/p) / tu 0.000E+000
e.g. betatron core
Above transition Acceleratio
Map at entry to:
Name: RF cav
Type : RFCAV
Index: 95
Scale
Beams
Reset
Stop
Run 1
RFTrap.
RFChan.
Fit ellip
t-dE
Proj
Print
Help F1
Back F9
Points
Save Pts
Show
Run #
RFProg.
Stats
Flow
Trace
Write
Colours

ps	dps/dt	RF-voltag	Ey-geom p	Ey-norm p	# of	Time	Mid. thi-	gamma	Ts	RF freq	Pk bea	Pk Buck	Head	Tai
[GeV/c]	[GeV/c/s	[kV]	[mm mrad	[mm mrad	sigma	[ms]	[rad]		[GeV]	[MHz]	[dp/p]	[dp/p]	[m]	[m
2	0.2	50	0.06	234.83	2.200	0.000	-0.056	3913.8	1.99	499.65	0.000	0.046	-0.16	0
2.2	2	100	0.05	234.83	2.200	1000.0	-0.083	4305.2	2.19	499.65	0.000	0.044	-0.16	0
2.4	2	200	0.05	234.83	2.200	1100.0	-0.113	4696.6	2.39	499.65	0.000	0.042	-0.16	0
2.6	2	300	0.05	234.83	2.200	1200.0	-0.150	5088.0	2.59	499.65	0.000	0.040	-0.15	0
2.8	0.2	800	0.04	234.83	2.200	1300.0	-0.171	5479.4	2.79	499.65	0.000	0.043	-0.16	0
3	0	900	0.04	234.83	2.200	2300.0	-0.220	5870.8	2.99	499.65	0.000	0.041	-0.16	0

TO CREATE RF PROGRAMME:

- RED COLUMNS. Enter the momentum and its ramp rate at key points along the ramp in chronological order. Note ps is directly proportional to B in the dipole.
- PURPLE COLUMN. Enter the estimated RF voltage.
- GREEN COLUMNS. Enter EITHER Ey-geom. OR Ey-norm. Only one value needs to be entered for the whole table. Re-entering an emittance value updates whole table.
- Click 'Re-Calculate ROW' and follow any instructions. To modify the RF Programme adjust the RF volltage or the momentum ramp rate and re-calculate. If search fails re-calculate 2 or 3 times.
- If needed, 'Write Data' to a file and load into EXCEL for additional calculations.

TO EDIT RF PROGRAMME:

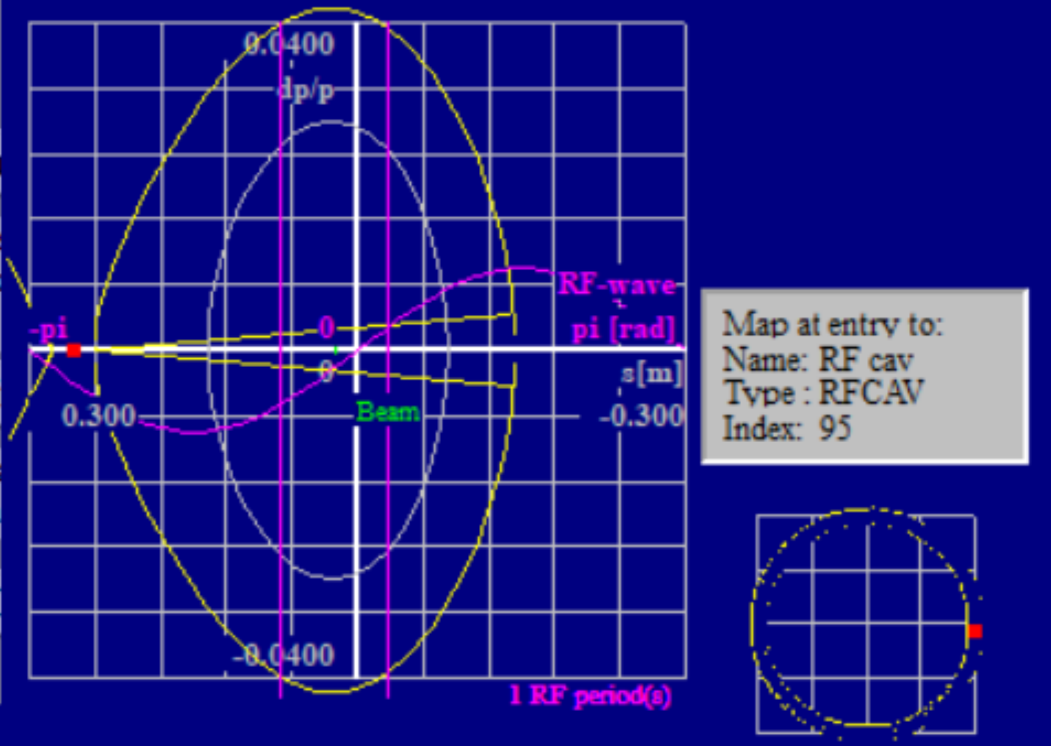
Re-Ca

Calculate
by curs

W

Write dat
(comm

FI



ps [GeV/c]	dps/dt [GeV/c/s	RF-voltag [kV]	Ey-geom p [mm mrad	Ey-norm p [mm mrad	# of sigma	Time [ms]	Mid. thi- [rad]	gamma	Ts [GeV]	RF freq [MHz]	Pk bea [dp/p]	Pk Buck [dp/p]	Head [m]	Ta [m
2	0.2	50	0.06	234.83	2.200	0.000	-0.056	3913.8	1.99	499.65	0.000	0.046	-0.16	0
2.2	2	100	0.05	234.83	2.200	1000.0	-0.083	4305.2	2.19	499.65	0.000	0.044	-0.16	0
2.4	2	200	0.05	234.83	2.200	1100.0	-0.113	4696.6	2.39	499.65	0.000	0.042	-0.16	0
2.6	2	300	0.05	234.83	2.200	1200.0	-0.150	5088.0	2.59	499.65	0.000	0.040	-0.15	0
2.8	0.2	800	0.04	234.83	2.200	1300.0	-0.171	5479.4	2.79	499.65	0.000	0.043	-0.16	0
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Re-Ca

Calculate by curs

W

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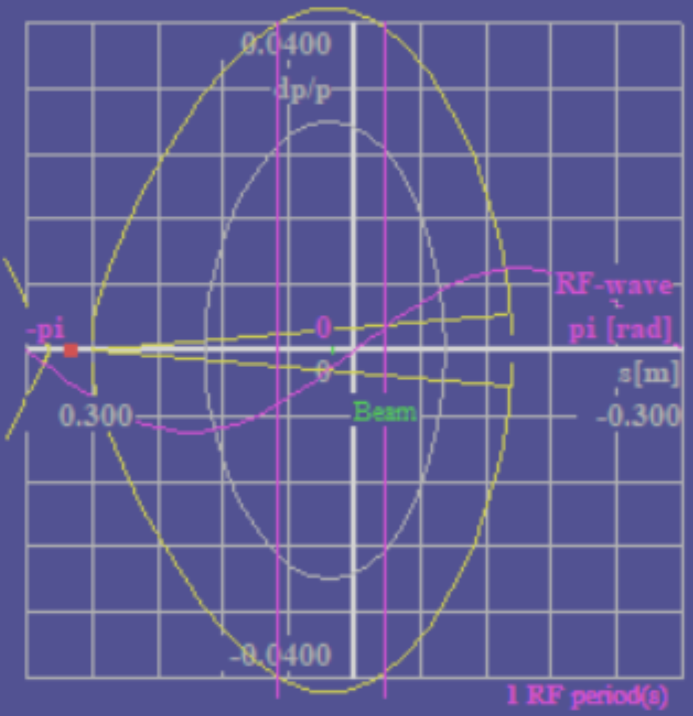
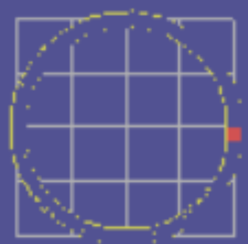
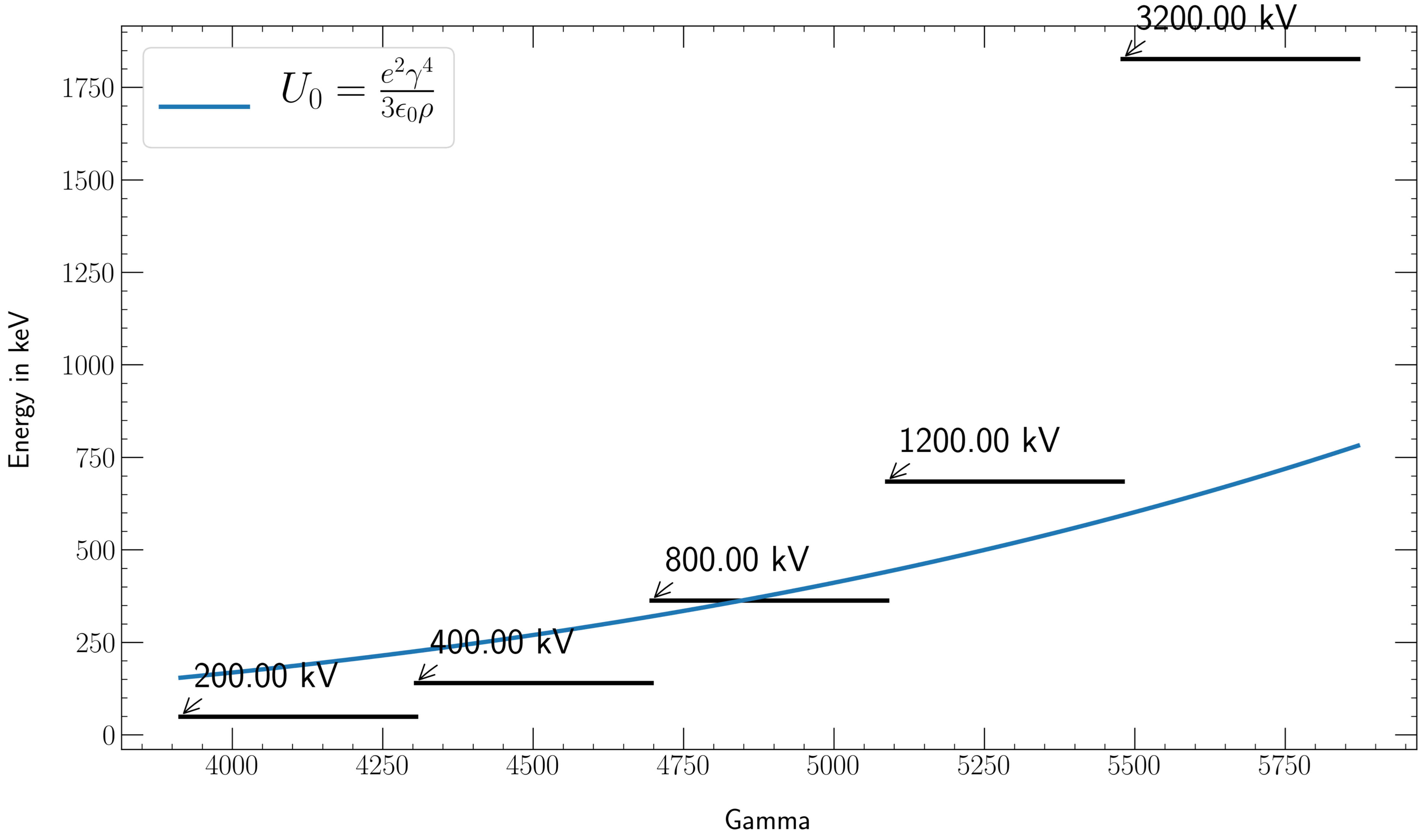
FI



Map at entry to:
Name: RF cav
Type : RFCAV
Index: 95





$U_0 = \frac{e^2\gamma^4}{3\epsilon_0\rho}$
3200.00 kV
1200.00 kV
800.00 kV
400.00 kV
200.00 kV
Energy in keV
Gamma
0
250
500
750
1000
1250
1500
1750
4000
4250
4500
4750
5000
5250
5500
5750

LATTICE

ALiS

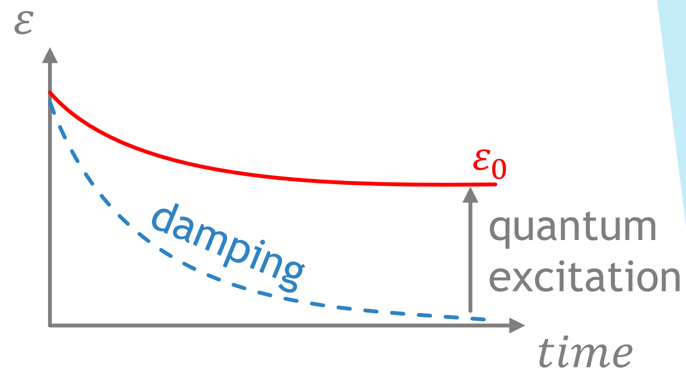
Injection | RF System | **Lattice** | Chromaticity control | Tune control | Resonance excitation | Closed orbit correction | Vacuum system

Optimize a light source

Goal: increase brilliance → keep emittance as low as possible

Radiation damping suppresses the injected emittance
but
quantum excitation tackles damping, especially for ε_x

→ convergence at a **«natural» emittance ε_0**



Natural emittance and lattice

$$\varepsilon_0 = C_q \gamma^2 \frac{I_2}{j_x I_5}$$

$C_q \approx 3.832 \cdot 10^{-13}$ m is constant (for e)

I_2, I_5 are the radiation integrals

j_x is the horizontal partition number

Depend only on the lattice!

$$\varepsilon_0^{min} \approx \frac{1}{12\sqrt{15}} \cdot \left(\frac{M+1}{M-1}\right) C_q \gamma^2 \vartheta^3 \qquad (*)$$

M number of dipoles per cell

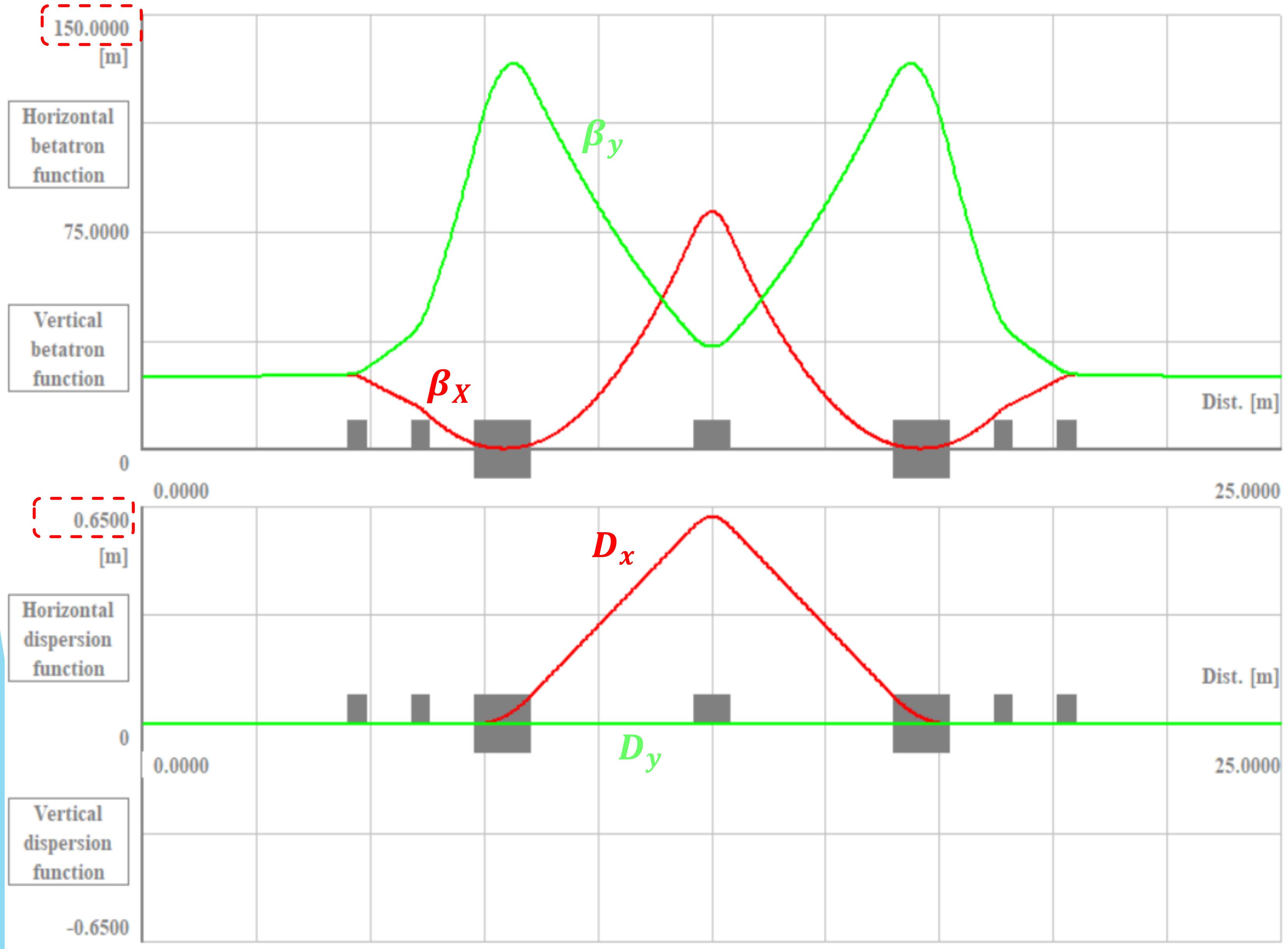
ϑ bending angle per dipole

→ **as many dipoles as possible!**

*valid if $j_x \approx 1$

Reference: A. Wolski, *Low emittance storage ring*, CAS.

ALiS 3.0: a DBA

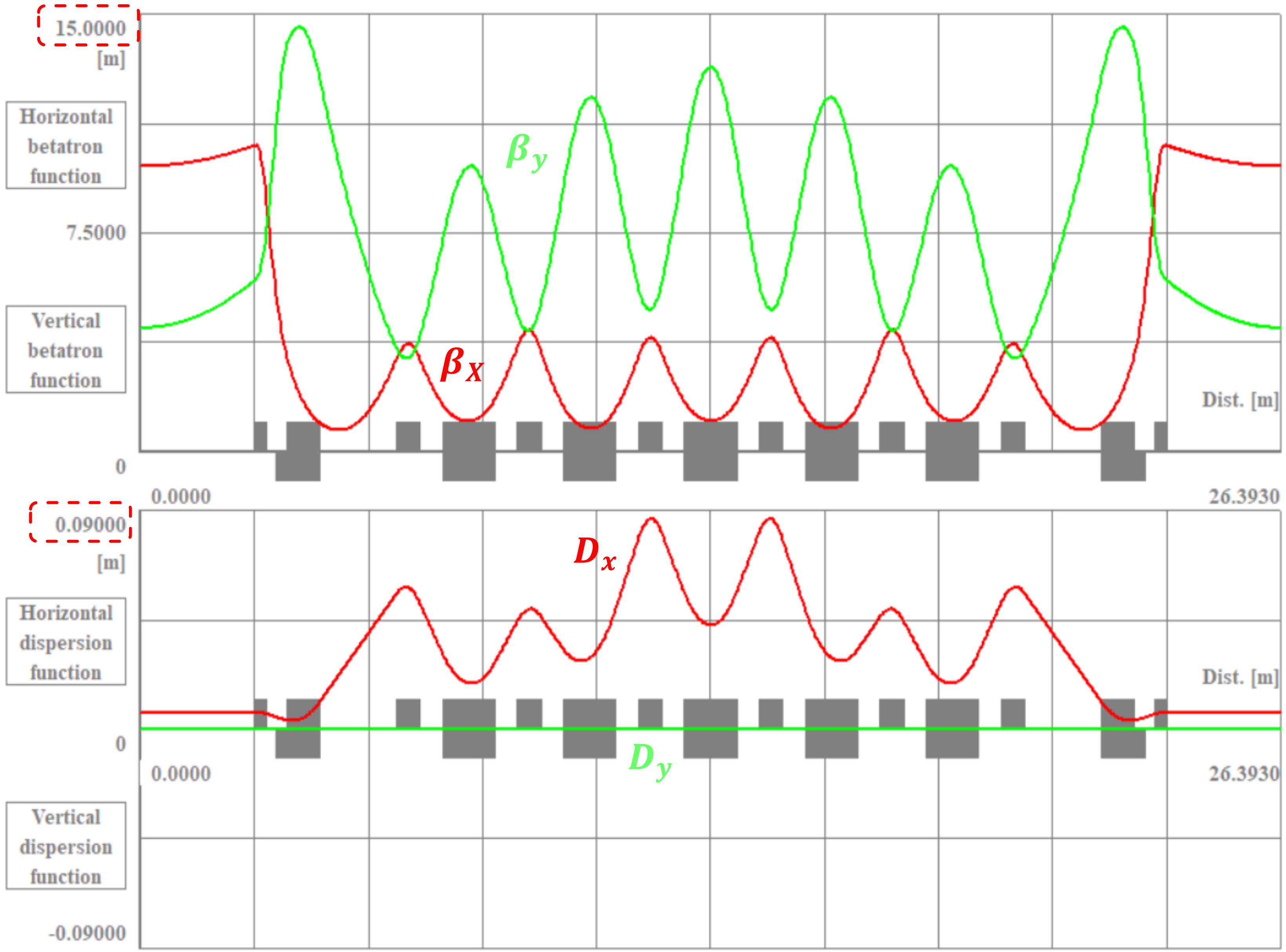


$M = 2$
$N_{cell} = 24$
$\vartheta = 7.5°$

Theoretical natural emittance:
$\varepsilon_0^{min} \approx 1.91$ nm rad

Computed natural emittance:
$\varepsilon_x \approx 3.15$ nm rad

MAX IV: a 4th generation 7BA



$M = 7$
$N_{cell} = 20$
$\vartheta = 2.6°$

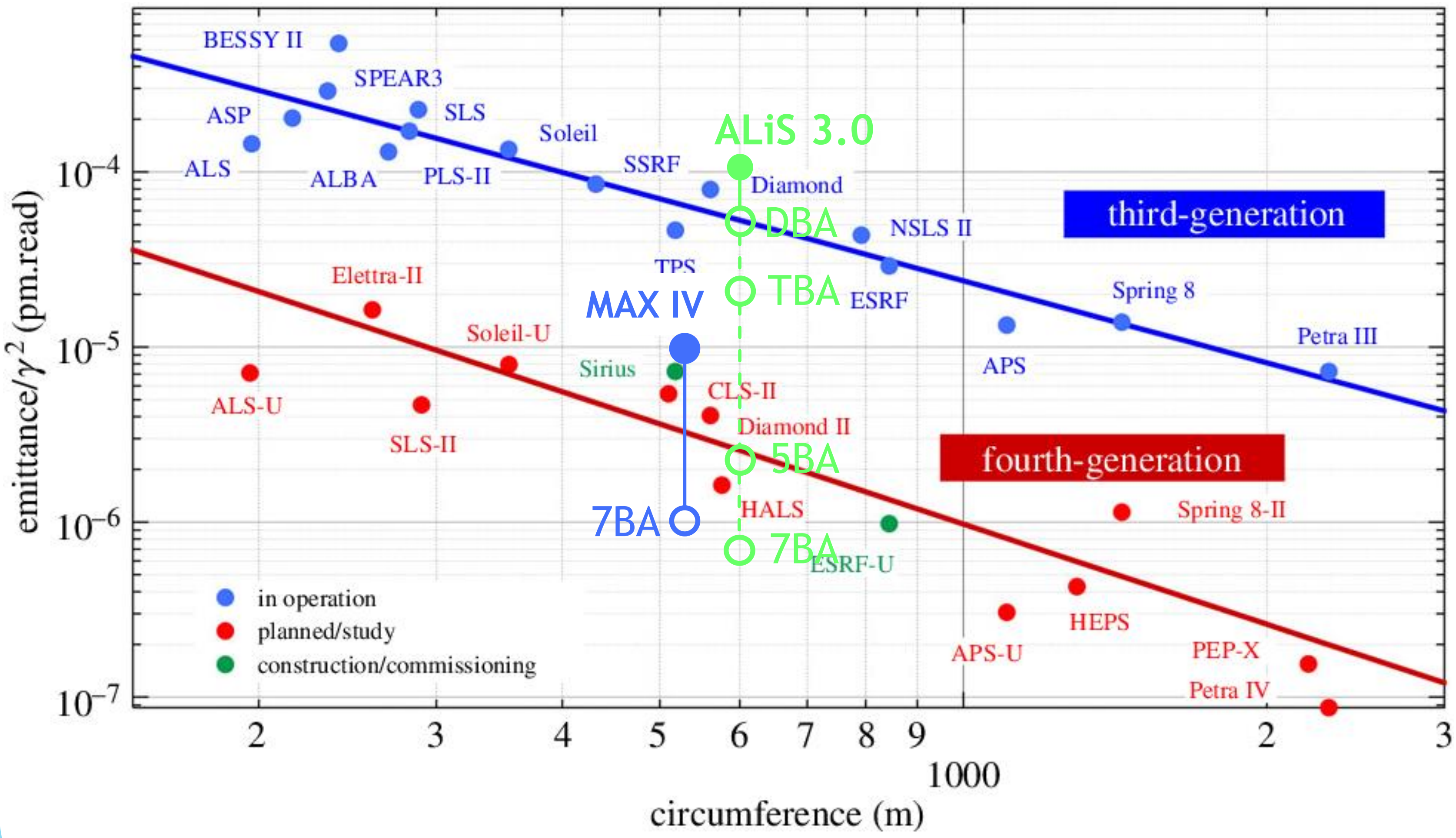
Theoretical natural emittance:
$\varepsilon_0^{min} \approx 0.034$ nm rad (vs 1.91)

Computed natural emittance:
$\varepsilon_x \approx 0.282$ nm rad (vs 3.15)

How does it work?

Lower β_x
+
much lower D_x
=
q. excitation suppressed

Light source brilliance



ALiS 3.0 is already an average 3rd light source

DBA is theoretically limited to 3rd gen. performance

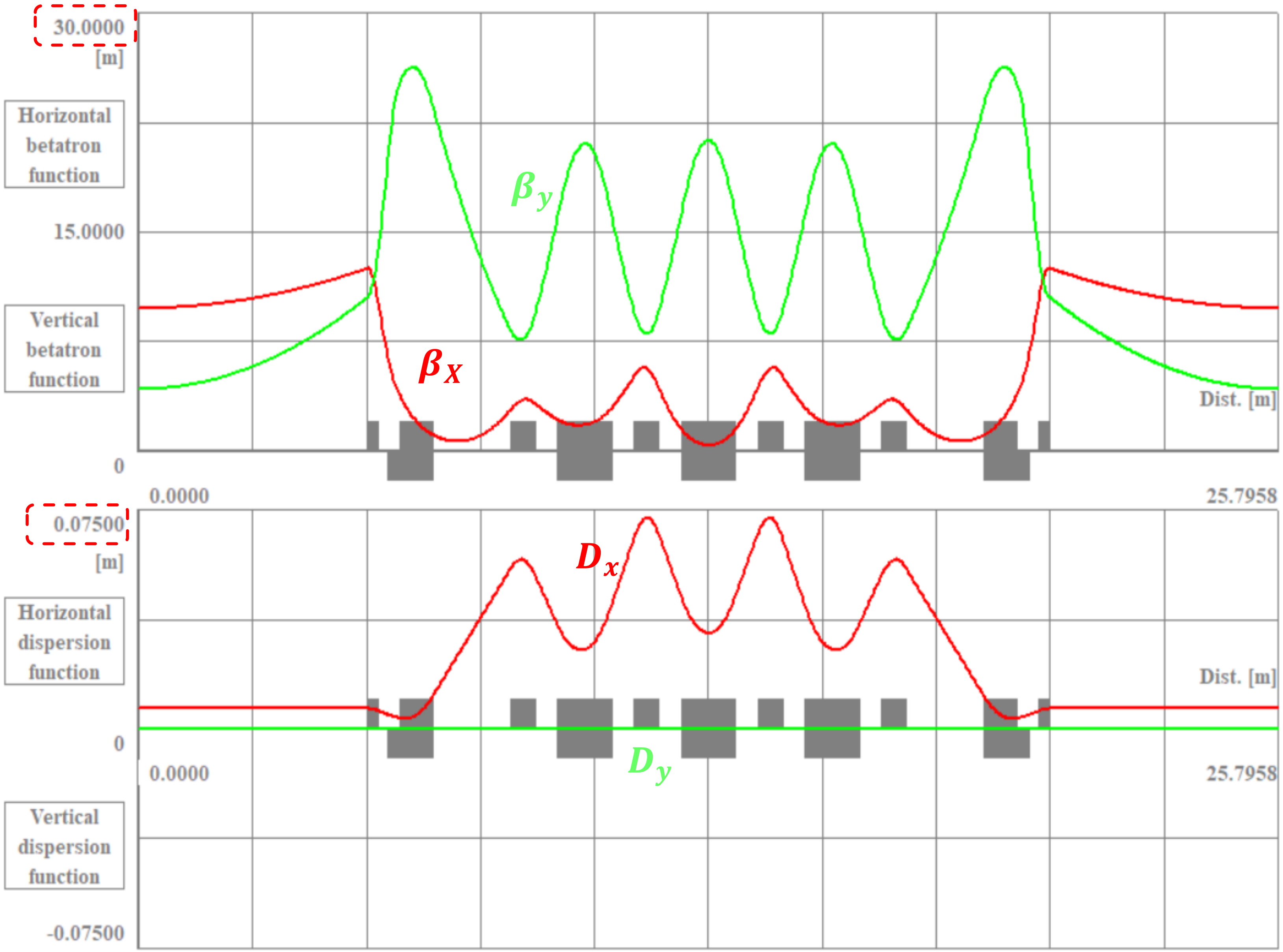
5BA should in principle reach 4th gen. performances but, as MAX IV shows, at lower ε it is difficult to reach the theoretical value

● current emittance

○ theoretical natural emittance for a MBA

NB: we fixed N_{cell} to keep the remaining facilities as they are

ALiS 4-0: first attempt with 5-BA

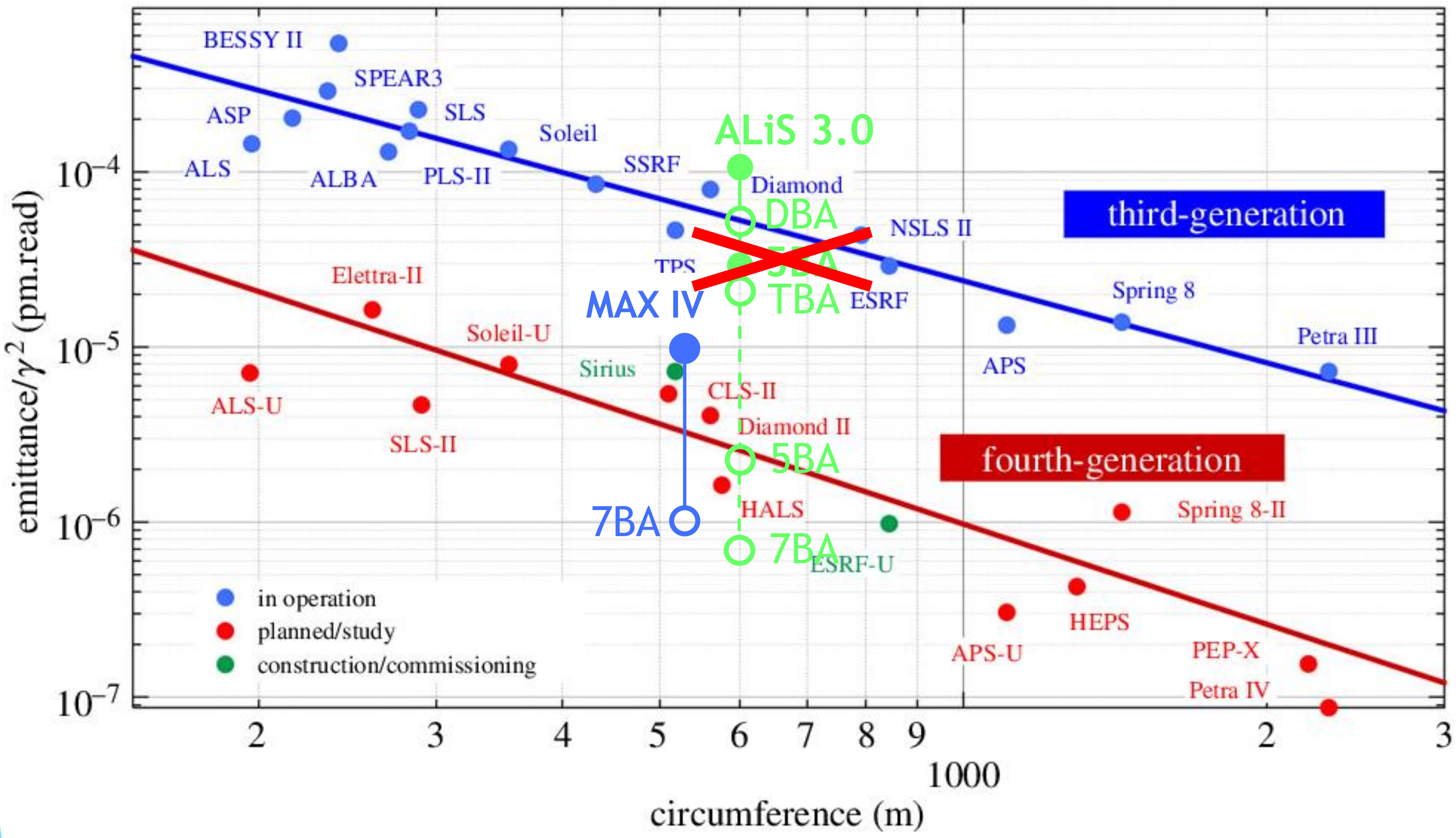


$M = 5$
$N_{cell} = 24$
$\vartheta = 3°$

Theoretical natural emittance:
$\varepsilon_0^{min} \approx 0.062$ nm rad

Computed natural emittance:
$\varepsilon_x \approx 0.690$ nm rad

Where are we?



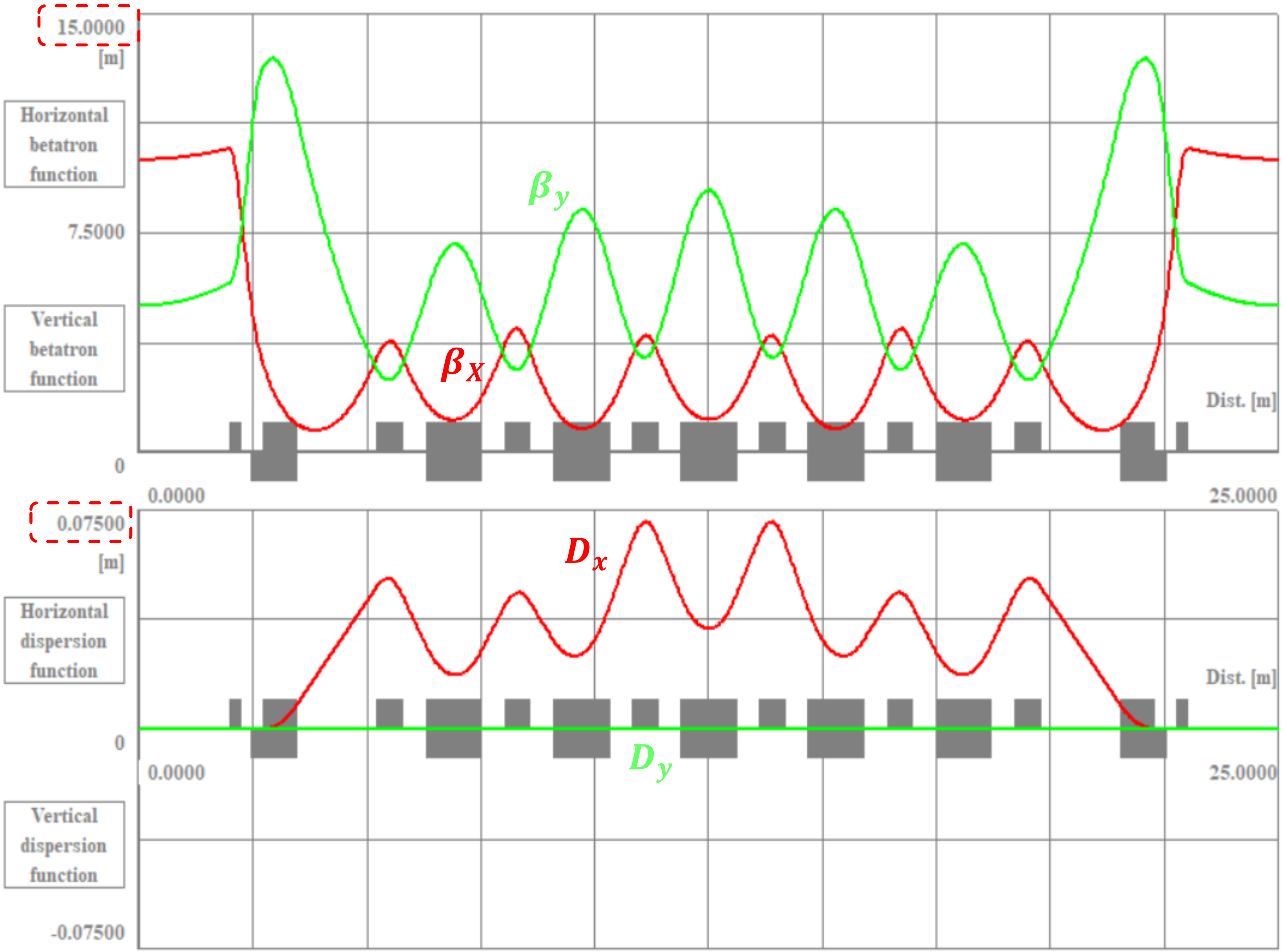
5BA is not able to bring ALiS to 4th performances!

● current emittance

○ theoretical natural emittance for a MBA

NB: we fixed N_{cell} to keep the remaining facilities as they are

ALiS 4-0: 7-Bend Achromat

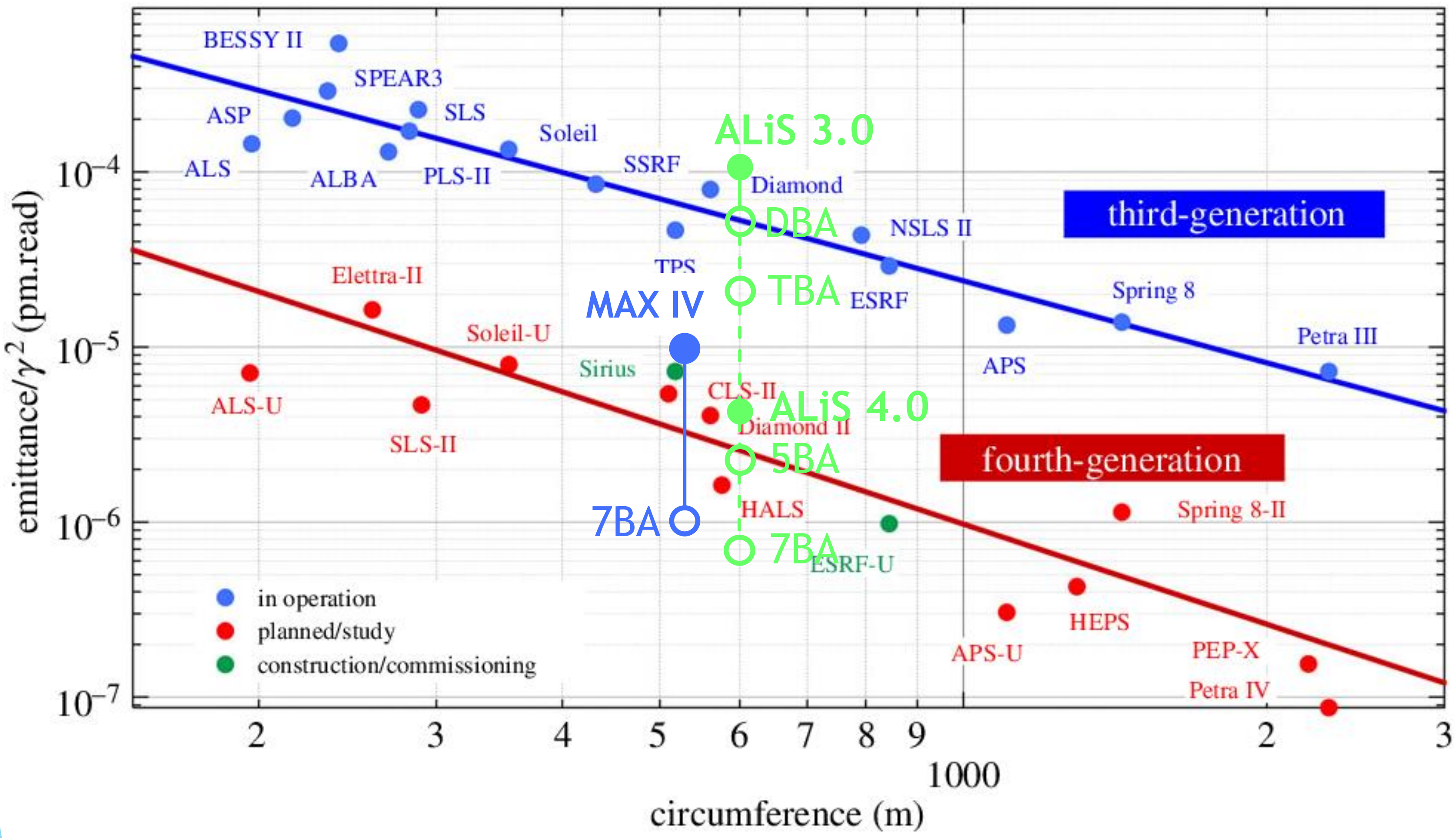


$M = 7$
$N_{cell} = 24$
$\vartheta = 2.14°$

Theoretical natural emittance:
$\varepsilon_0^{min} \approx 0.019$ nm rad

Computed natural emittance:
$\varepsilon_x \approx 0.161$ nm rad

Where are we?

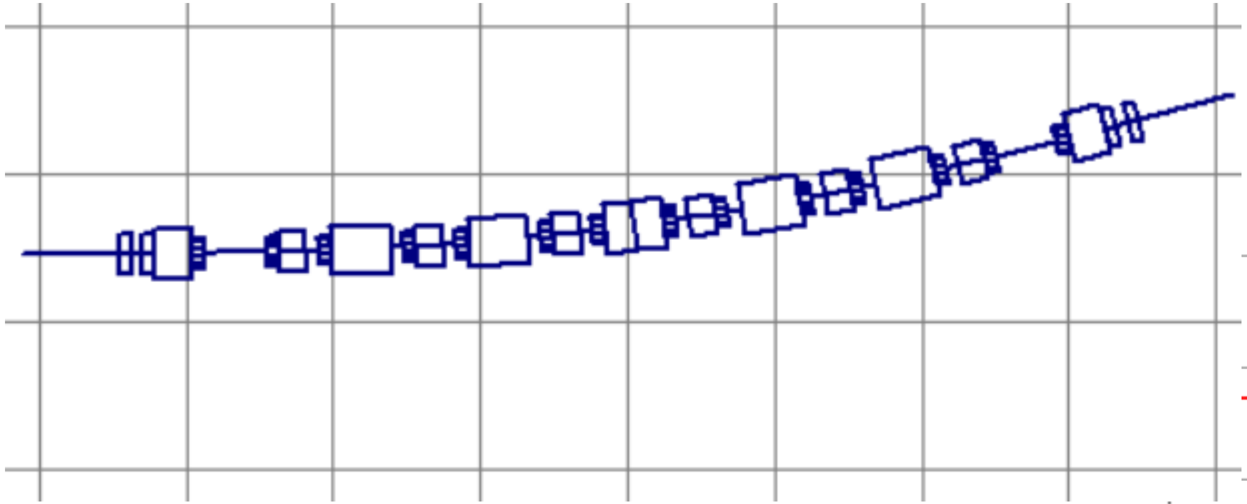


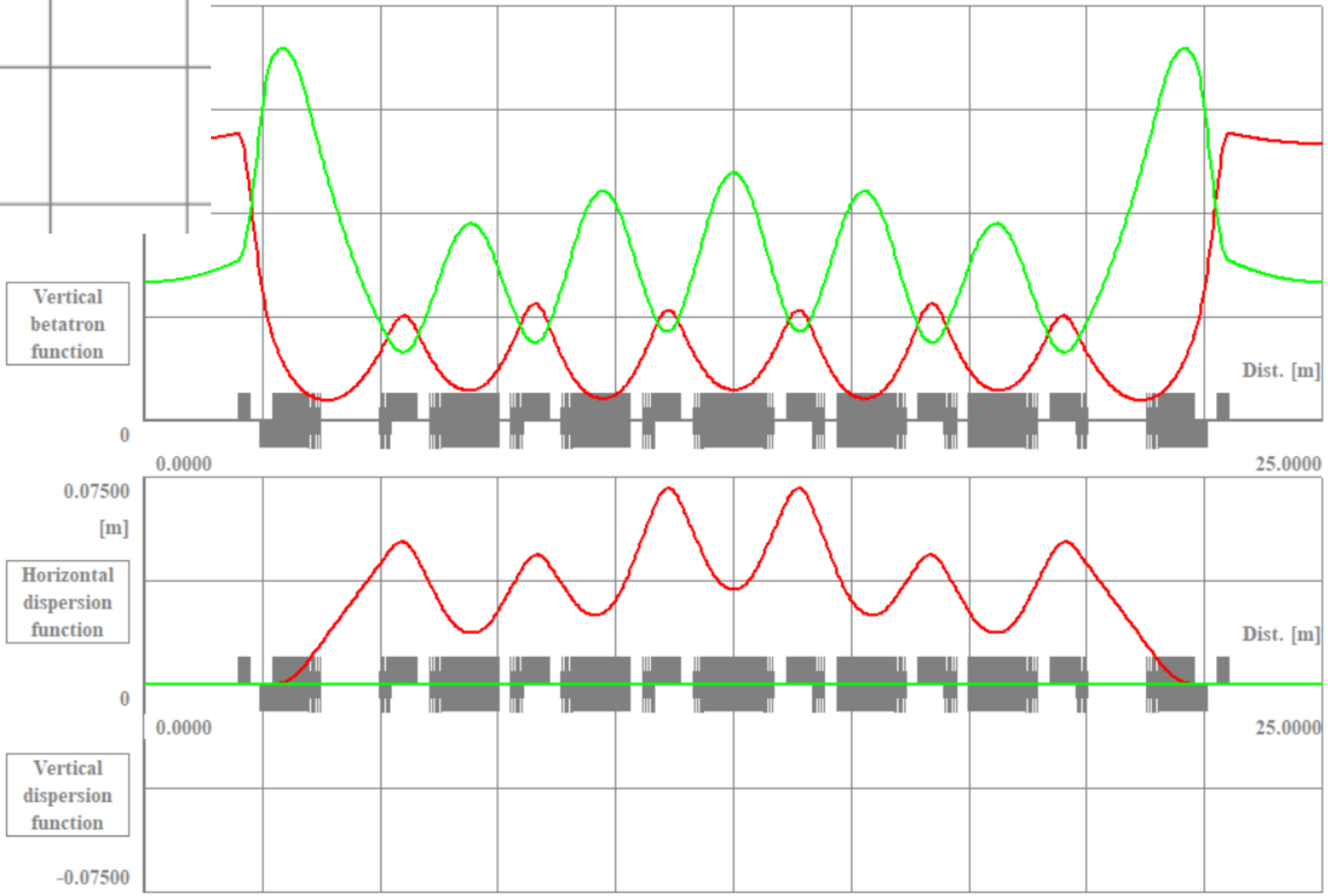
With the 7BA we enter the domain of 4th generation

- ● current emittance
- ○ theoretical natural emittance for a MBA

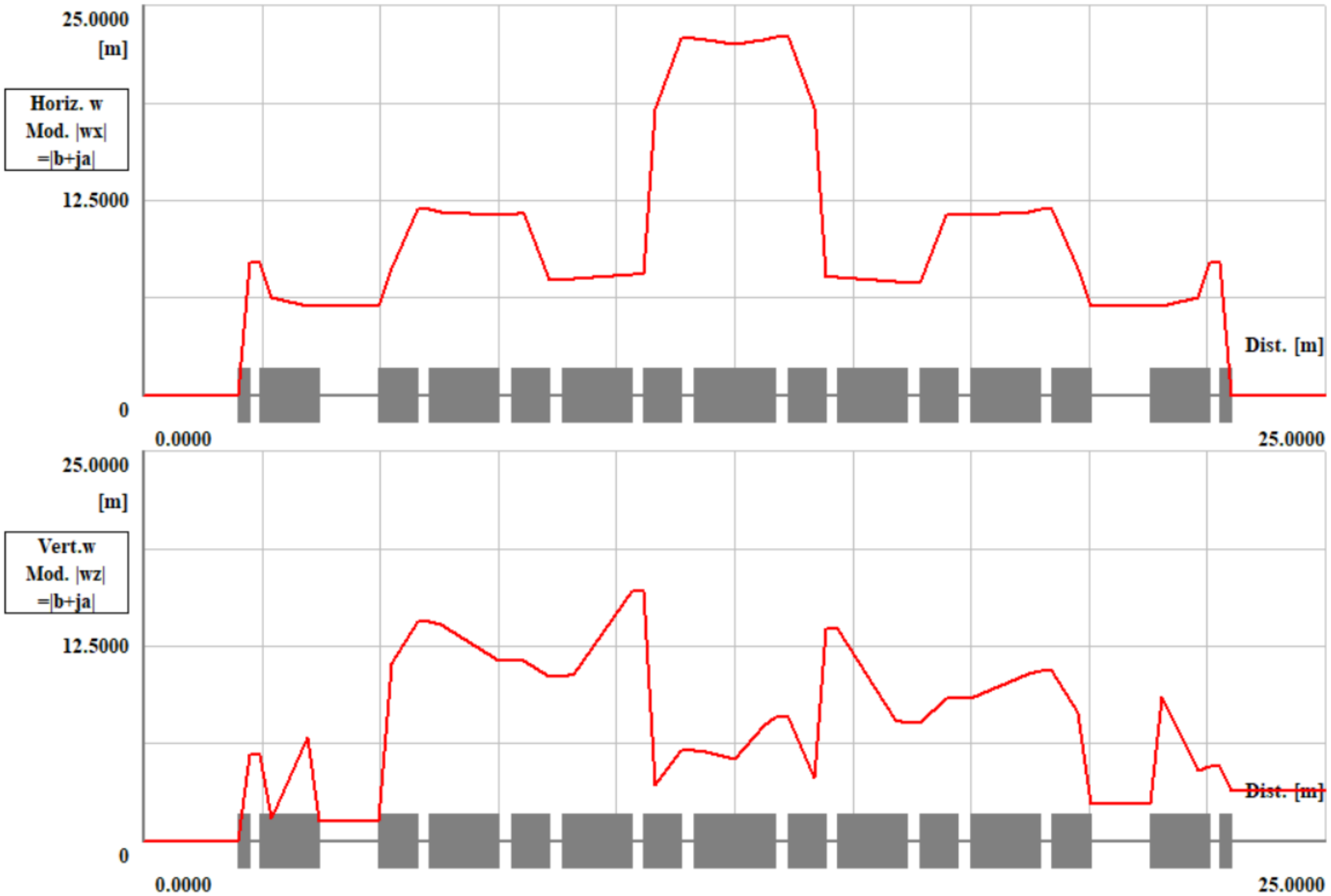
NB: we fixed N_{cell} to keep the remaining facilities as they are

Chromaticity correction





Chromaticity correction

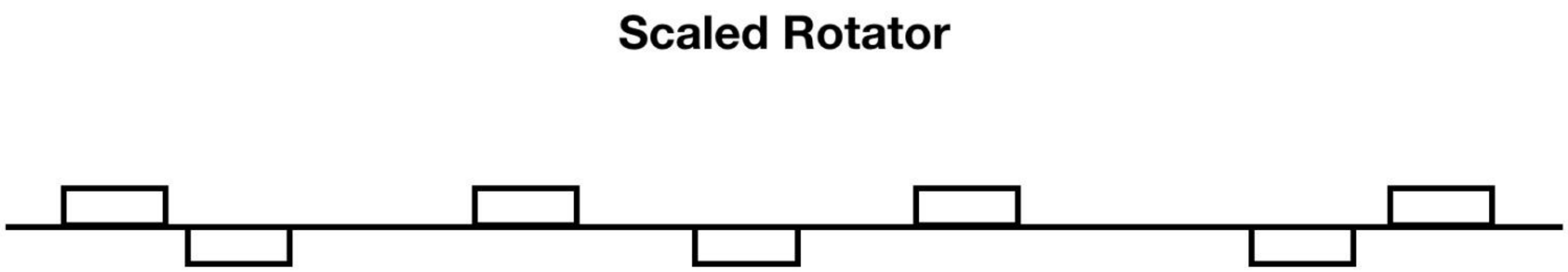


CHROMATICITY & TUNE CONTROL

ALiS

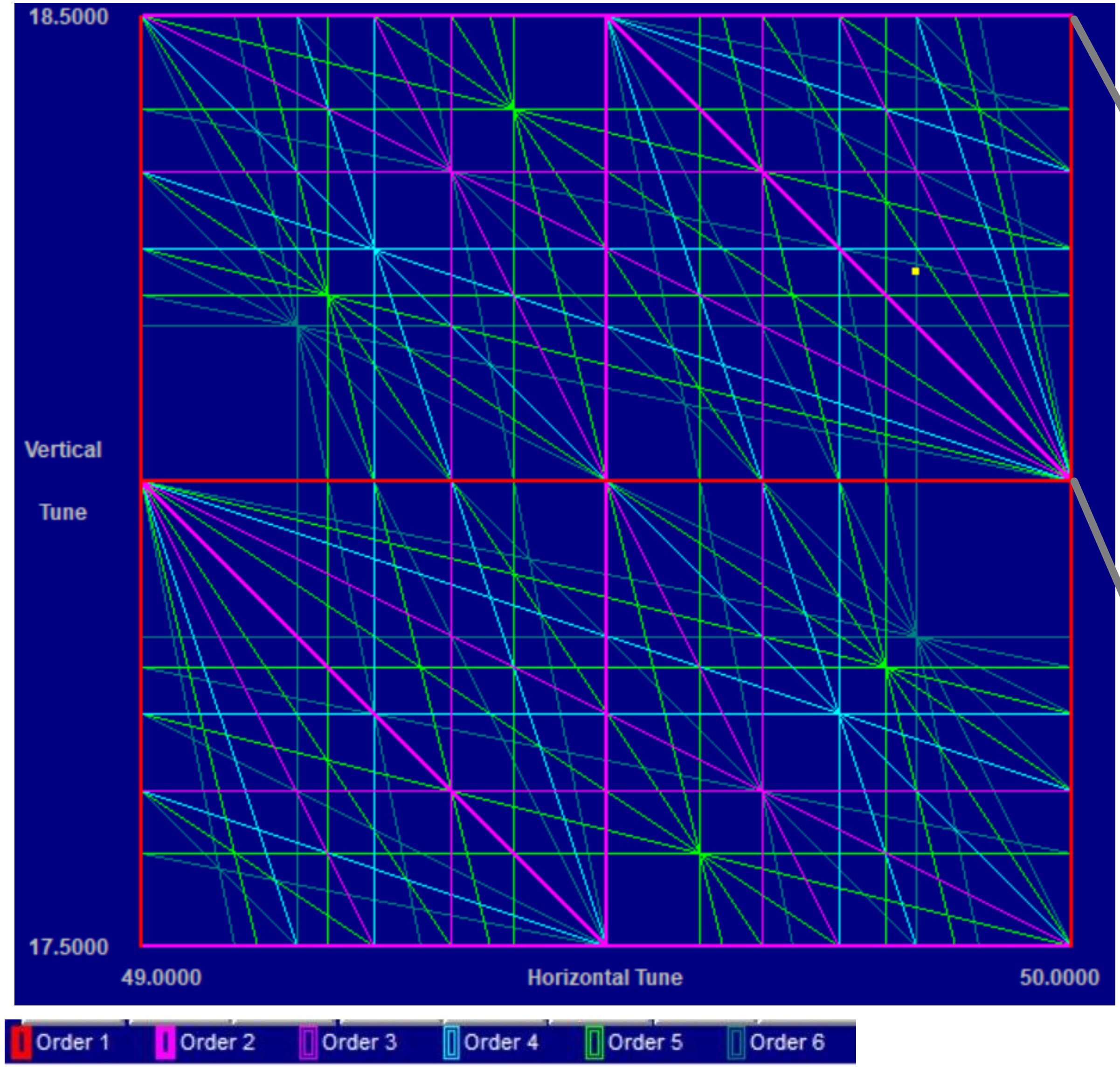
- Injection
- RF System
- Lattice
- Chromaticity control
- Tune control
- Resonance excitation
- Closed orbit correction
- Vacuum system

Tune control - strategy



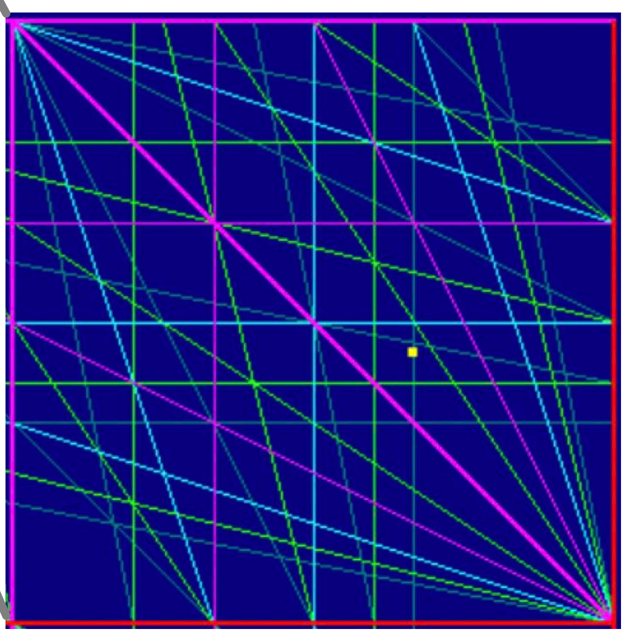
6 : Twiss parameters
1 : Matching

Tune control

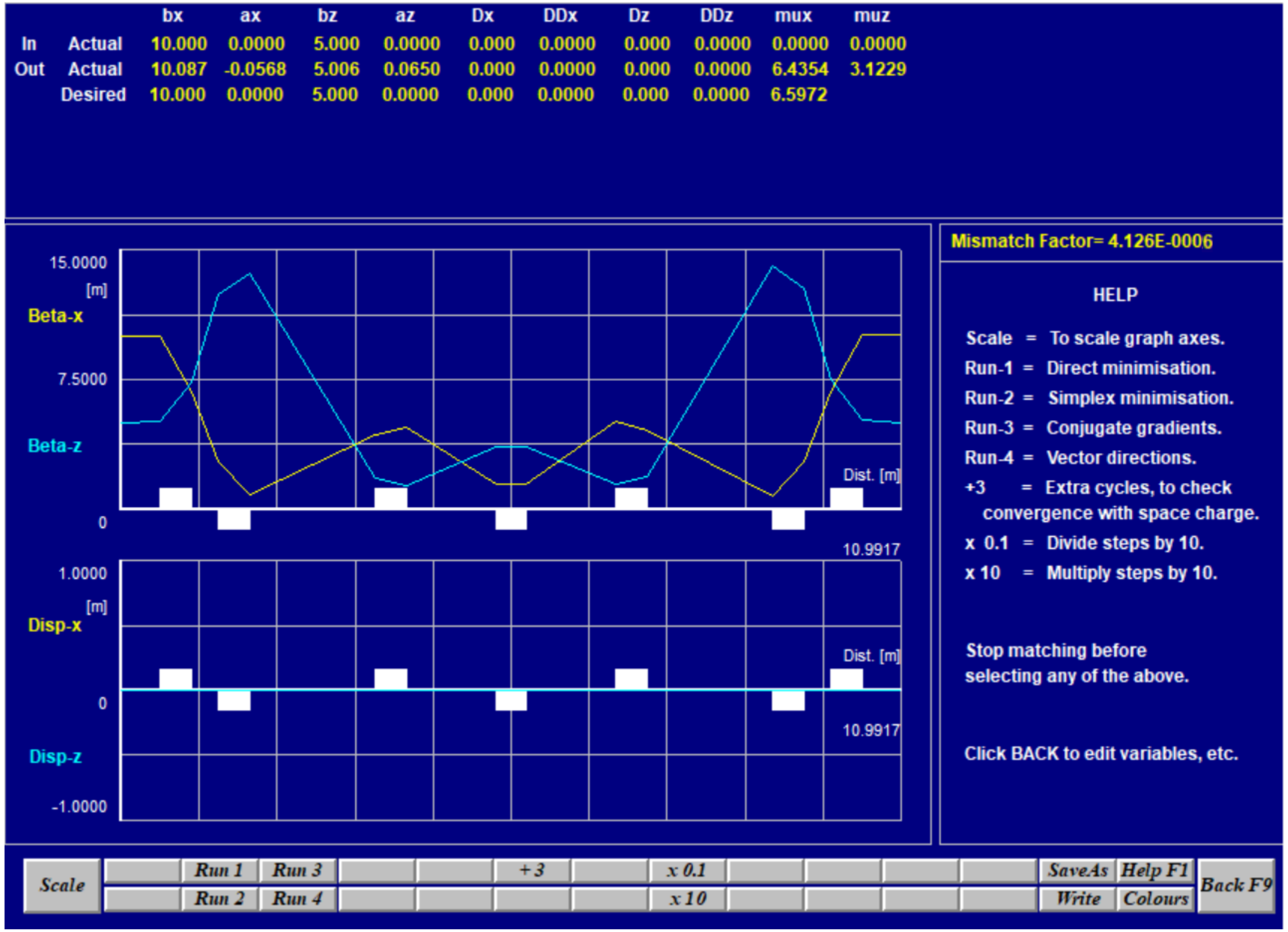


Q_x = 49.83
Q_y = 18.22

According to the lattice requirements, a tune shift in the horizontal plane δQ_x ~ 0.12 is needed to avoide resonances.

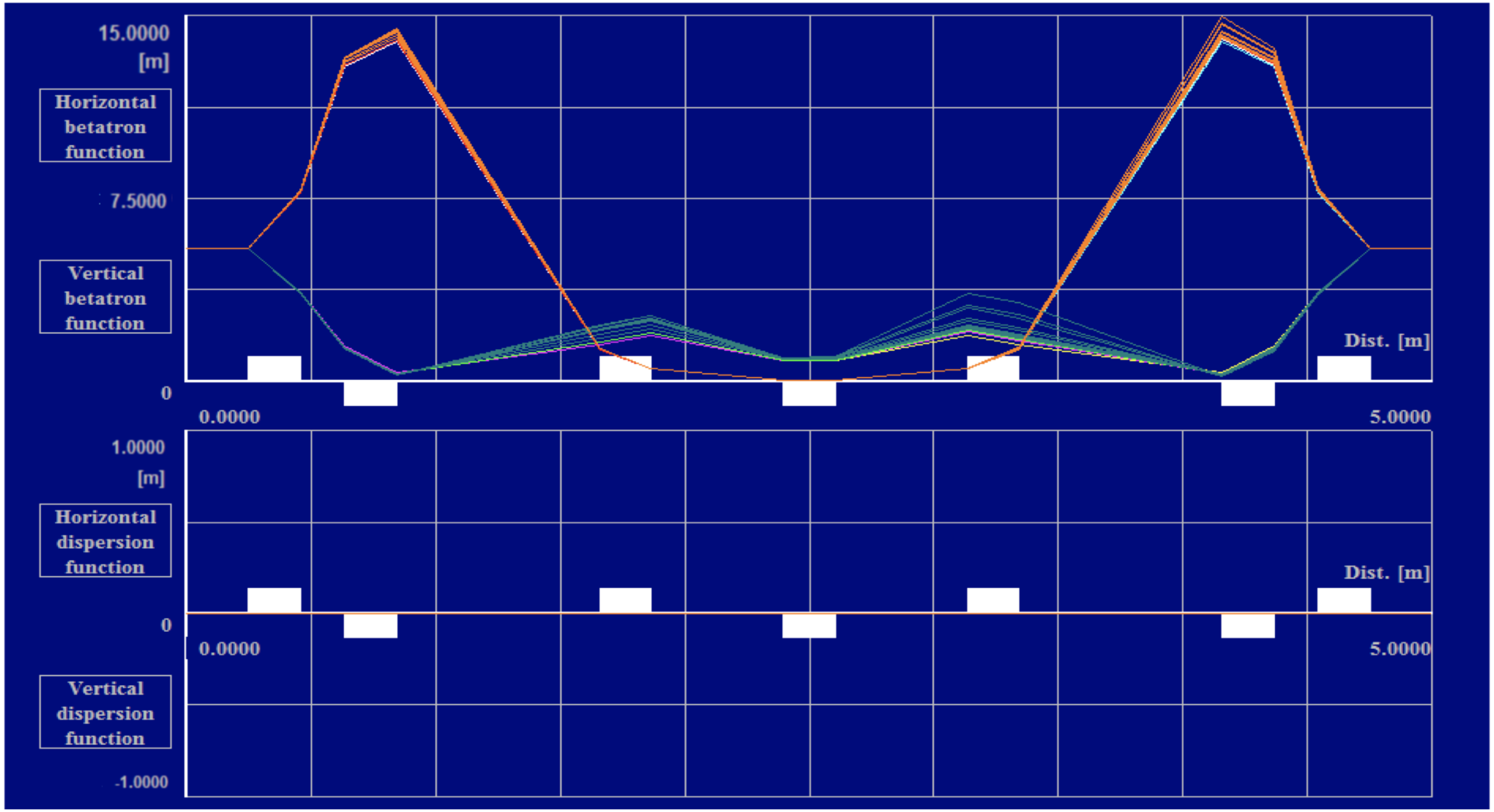


Matching



Parameters:
K(Q41)
Drift lenght

Achievable phase advance



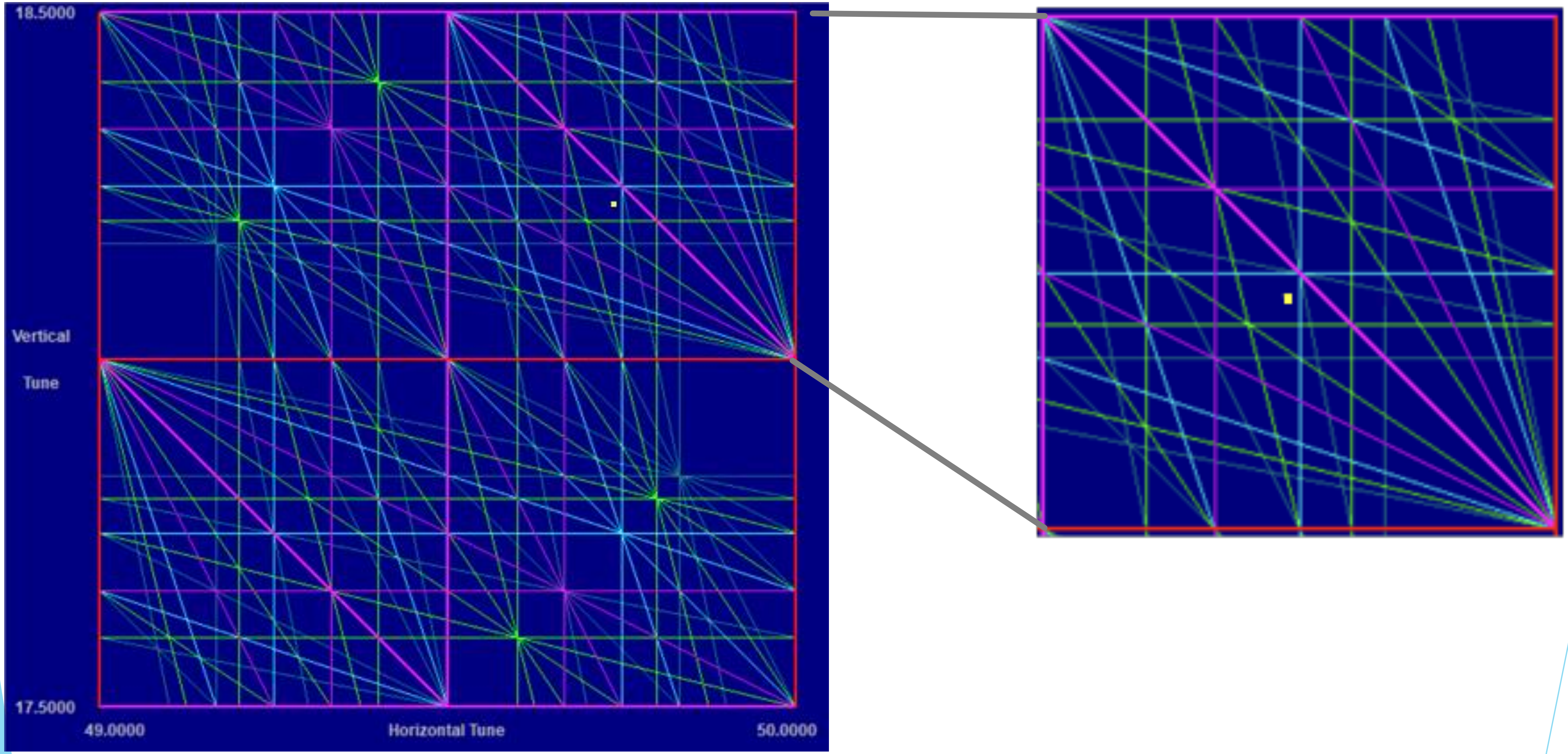
Final solution: $\mu_x: 2\pi \rightarrow 2\pi + 0.15$

$\mu_y: \pi \rightarrow \pi$

Tune options

Q_x = 49.81
Q_y = 18.22

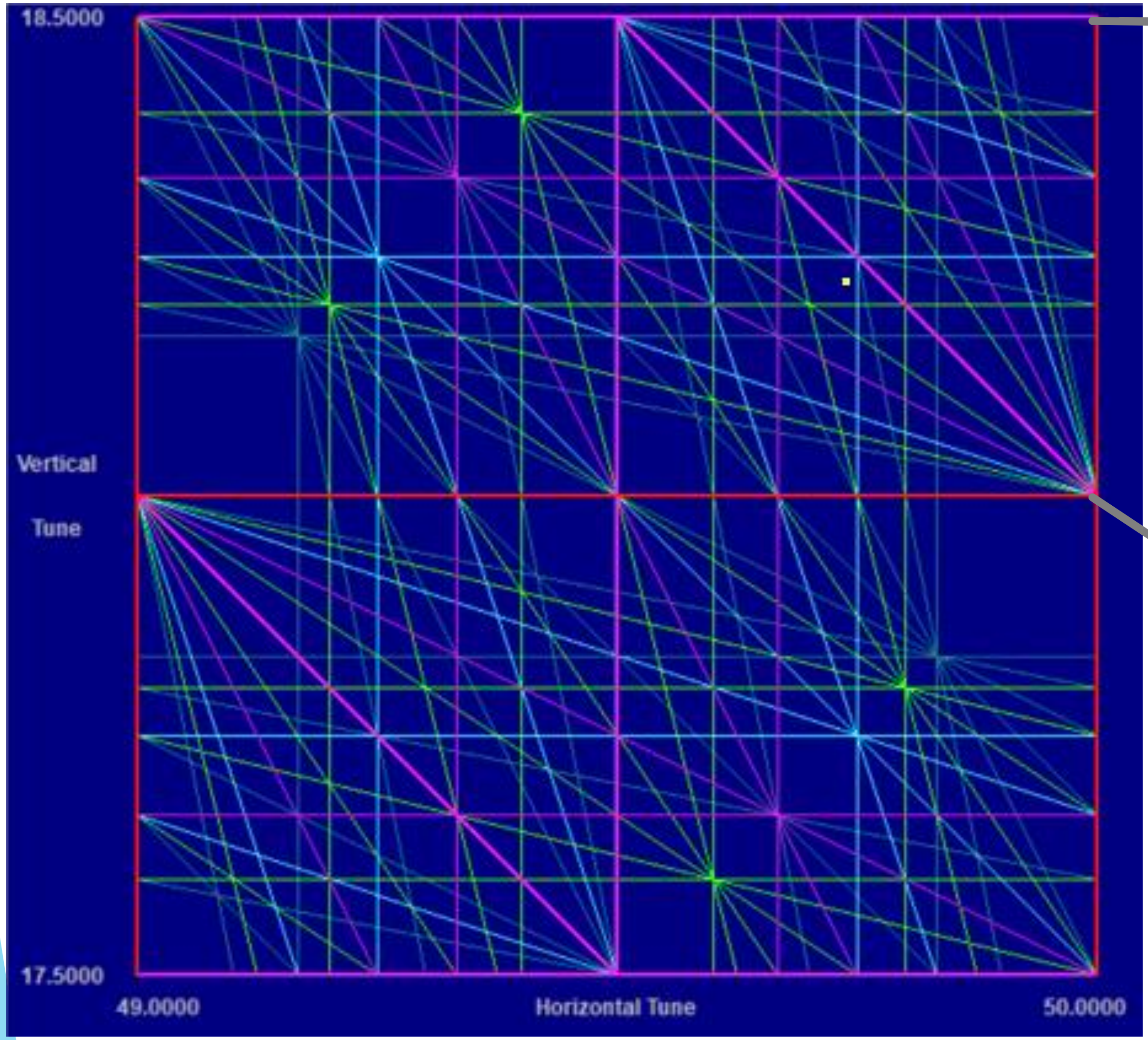
Q_x = 49.85
Q_y = 18.22

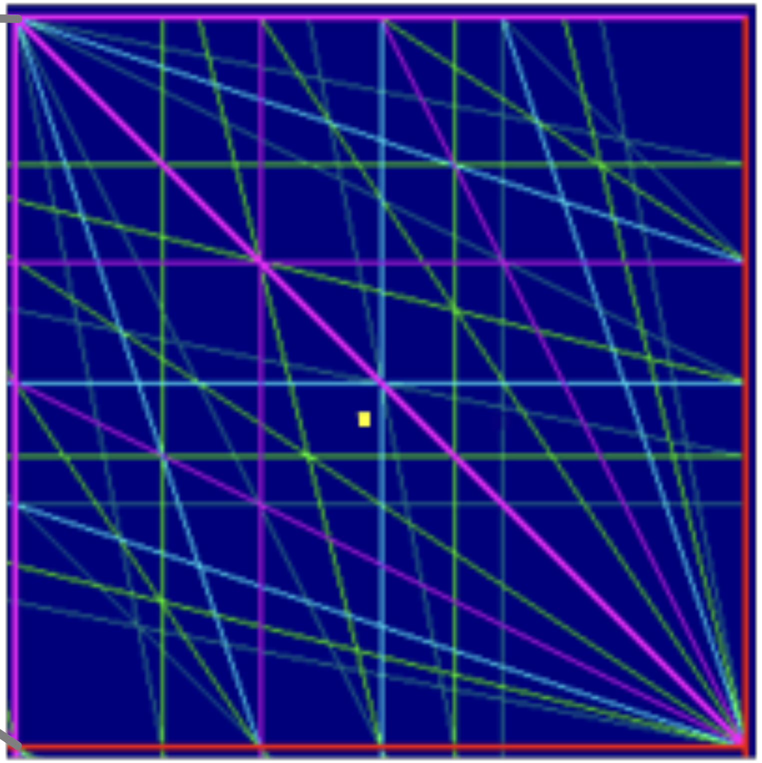


Tune options

$Q_x = 49.81$
$Q_y = 18.22$

$Q_x = 49.85$
$Q_y = 18.22$





CLOSED ORBIT

ALiS

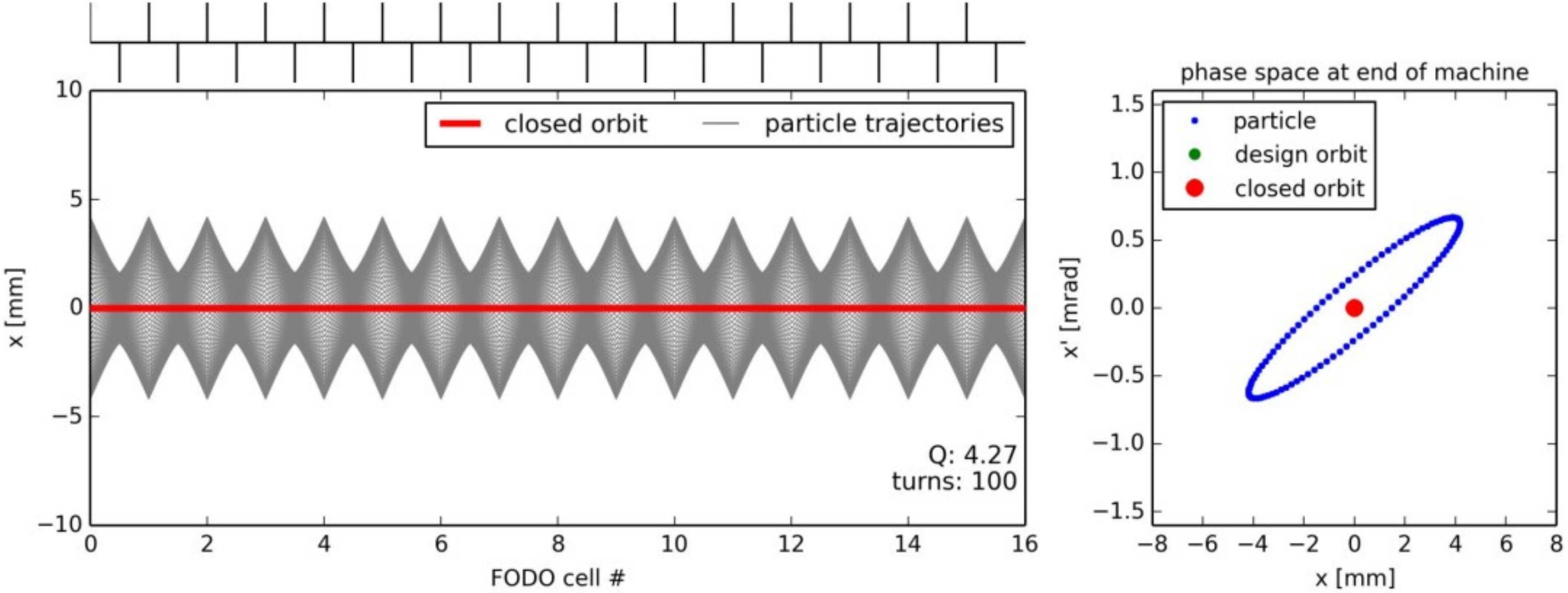
Injection | RF System | Lattice | Chromaticity control | Tune control | Resonance excitation | **Closed orbit correction** | Vacuum system

Closed Orbit and Closed-Orbit Correction

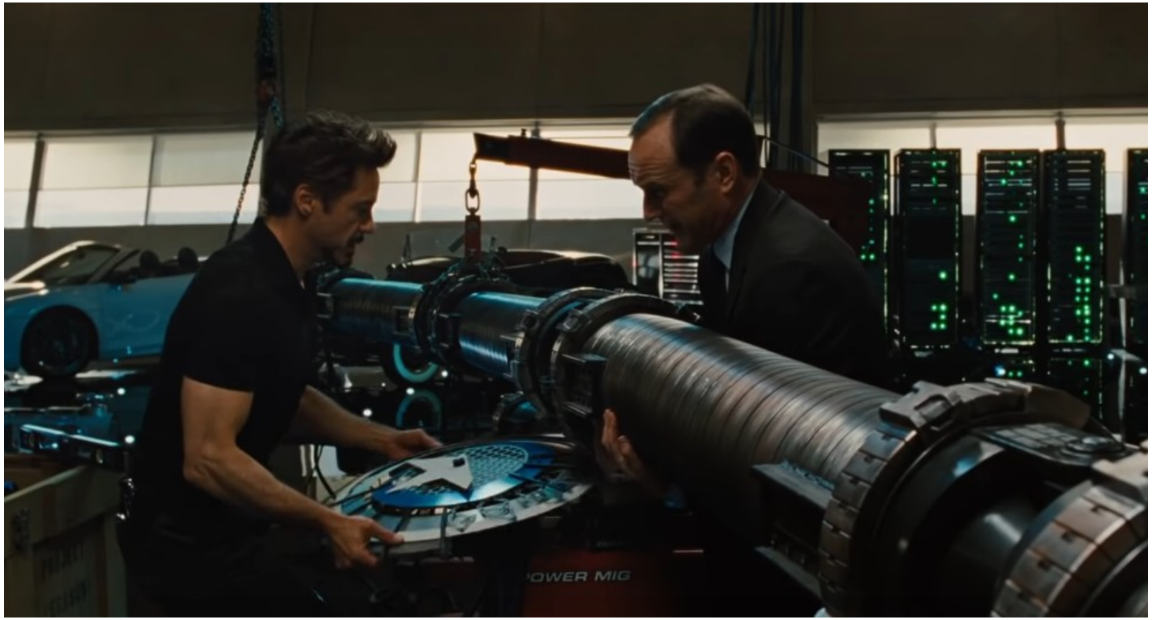
Maxim Saifulin, Vivek Maradia

JUAS 2020 Mini-Workshop

Perfect Closed Orbit



Hannes Bartosik. Linear Imperfections. JUAS 2020

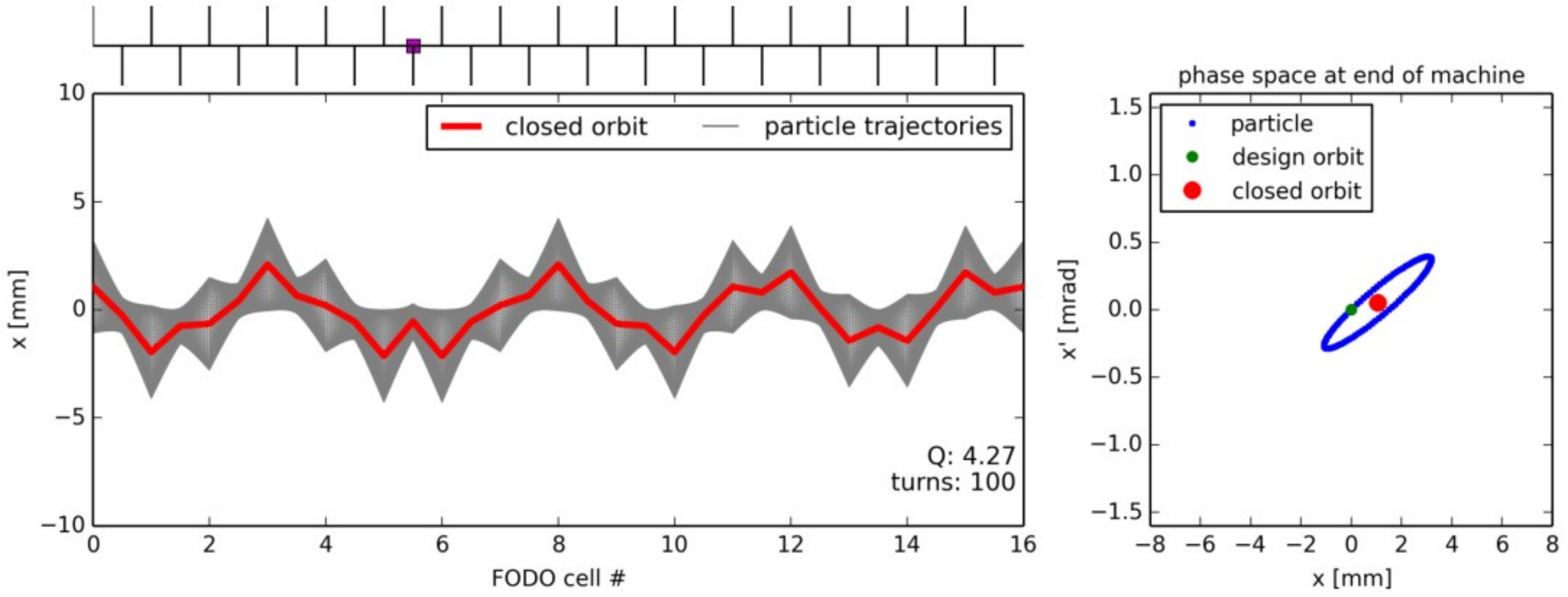

POWER MIG


PERFECT!!!

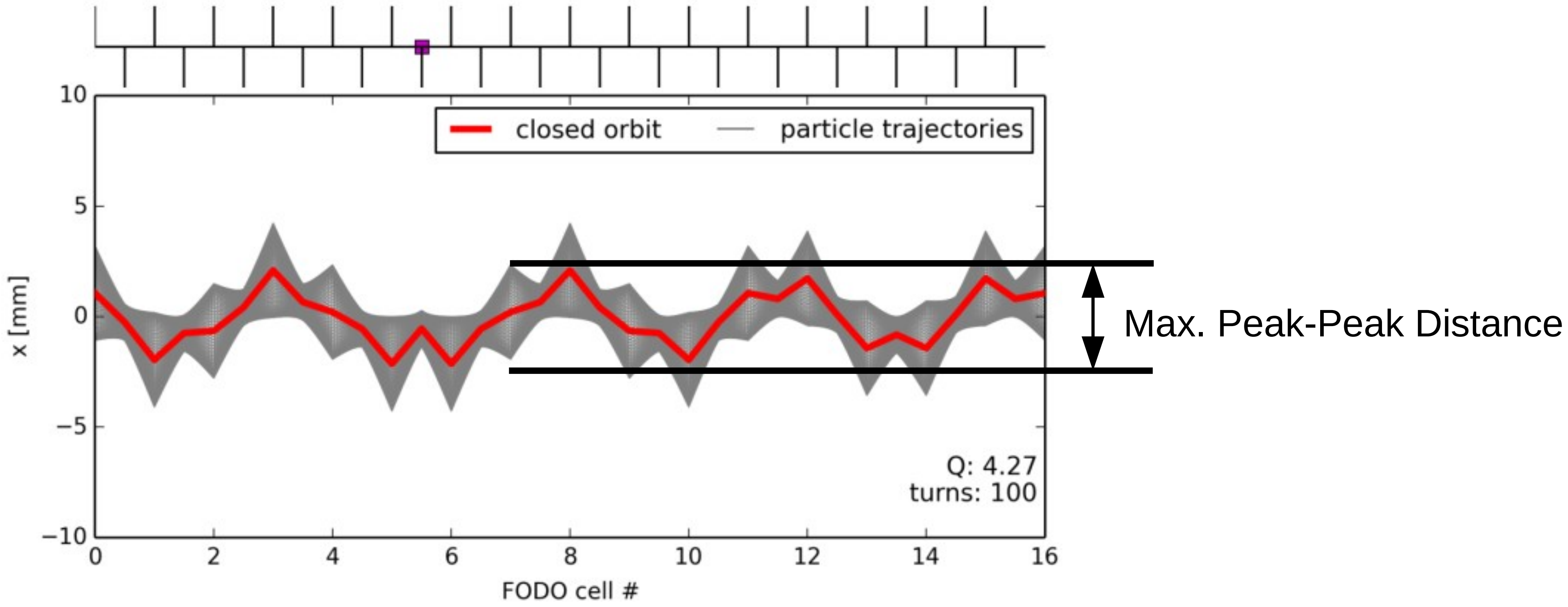
Possible Errors

- **Long term (years - months):** ground settling, season changes
- **Medium term (days - hours):** sun and moon, day-night variations (thermal), rivers, rain, wind, refills and start-up, sensor motion, drift of electronics, local machinery, filling patterns
- **Short term (minutes - seconds):** ground vibrations, power supplies, experimental magnets, air conditioning, refrigerators/compressors

Distorted Closed Orbit



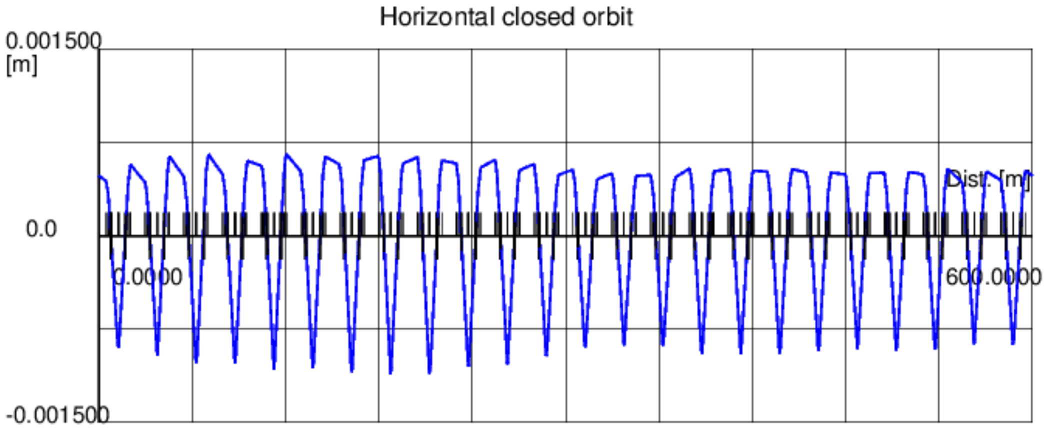
Distorted Closed Orbit

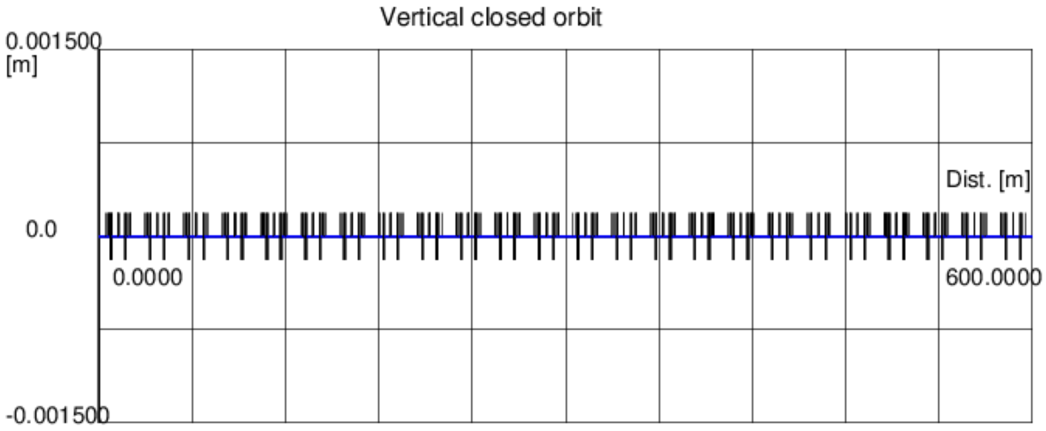


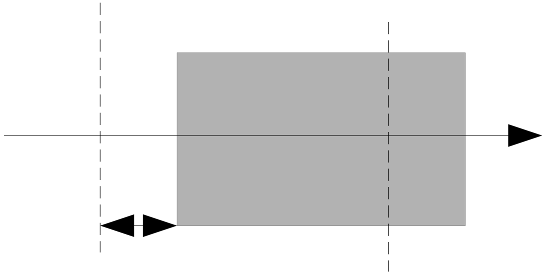
Alignment Errors:

- Random Axial Shifts of ALL dipoles
- Random Tilt of ALL dipoles
- Random Transverse Horizontal Shift of ALL quadrupoles
- Random Transverse Vertical Shift of ALL quadrupoles

Random Axial Shifts of ALL dipoles

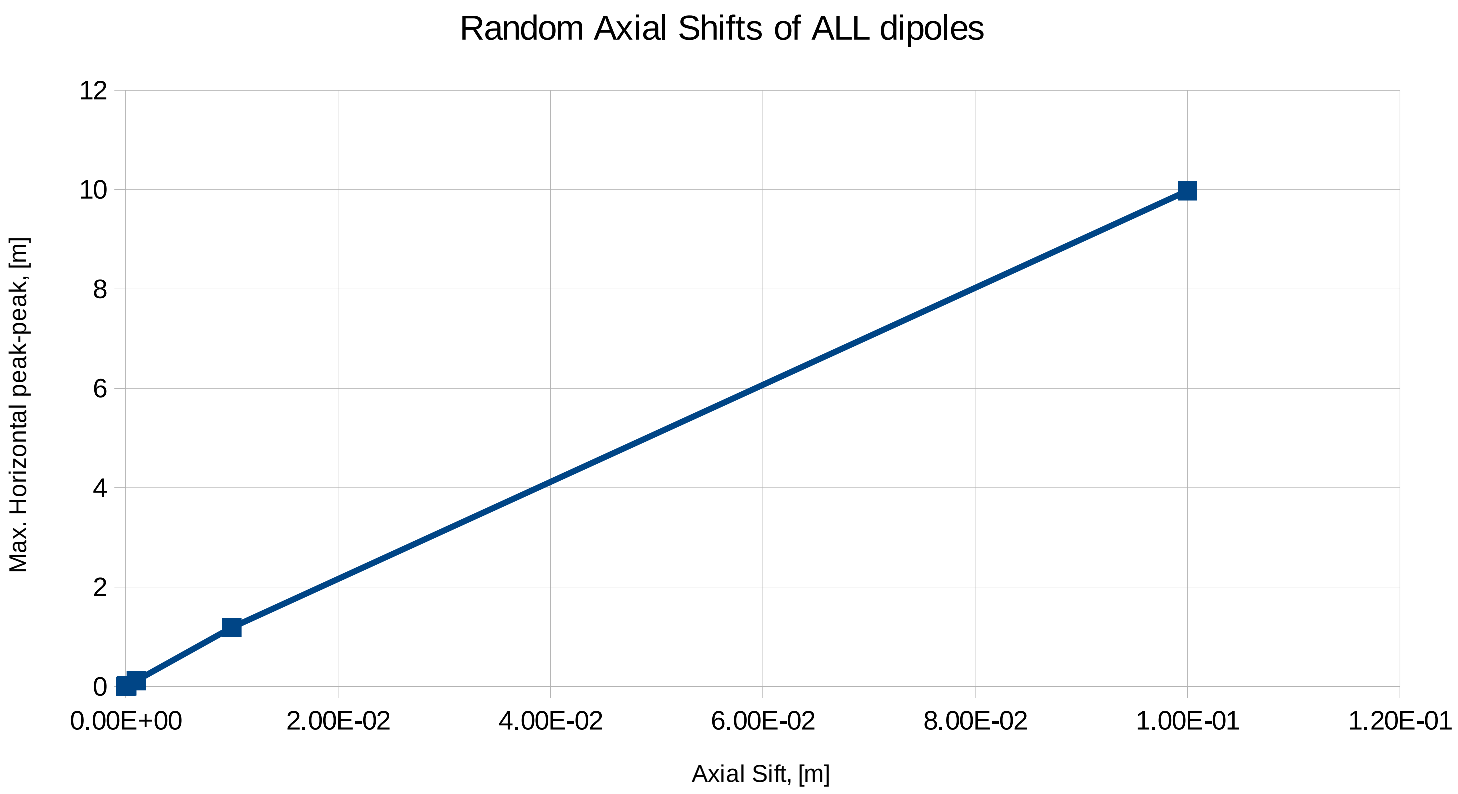


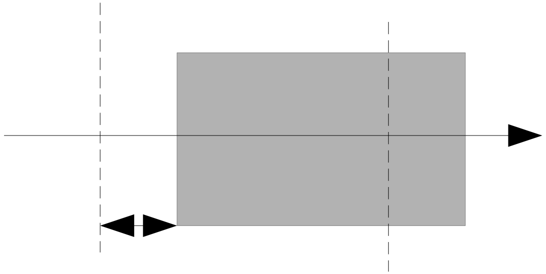




Axial Shift

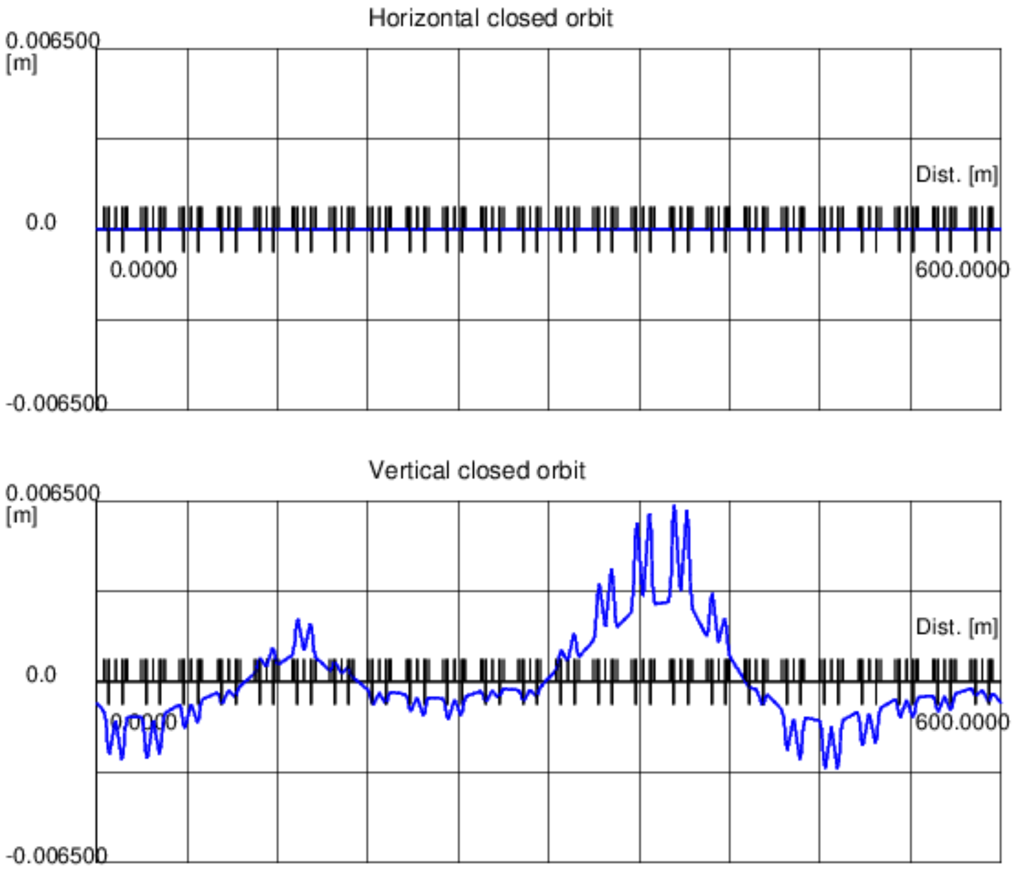
Random Axial Shifts of ALL dipoles

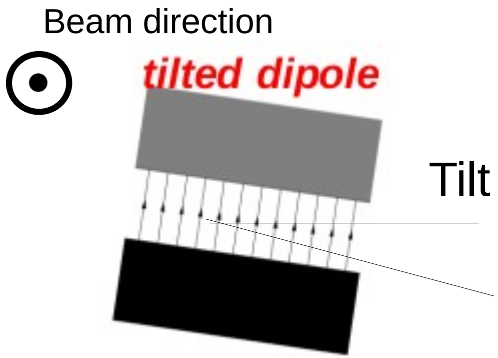




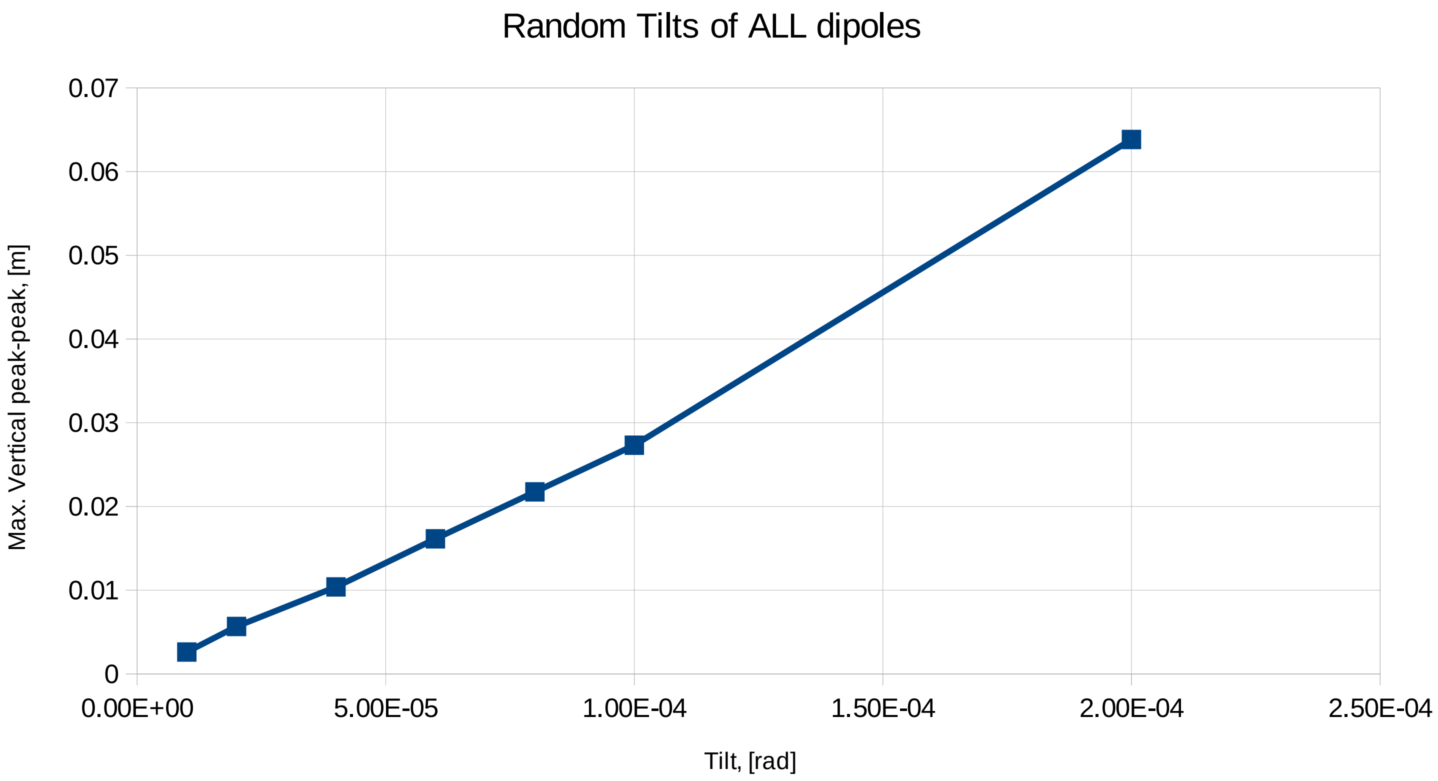
Axial Shift

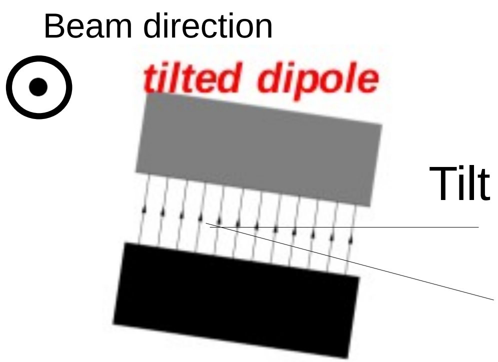
Random Tilt of ALL dipoles



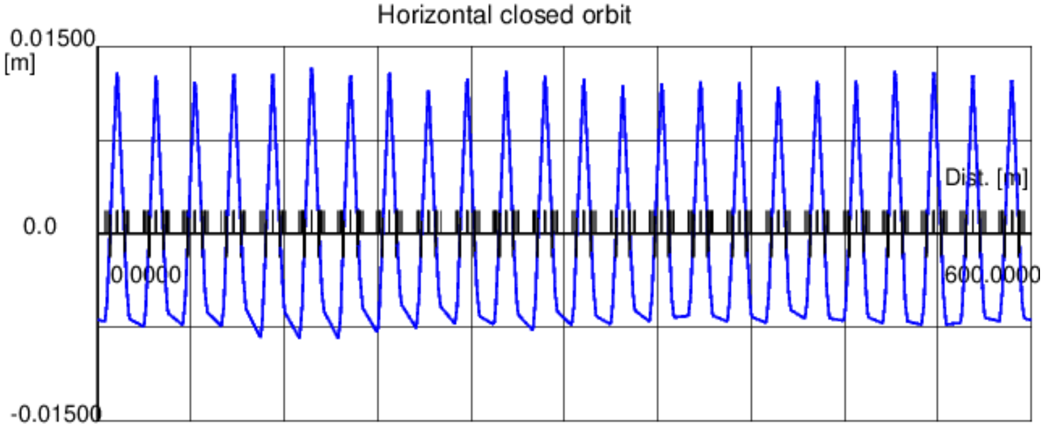


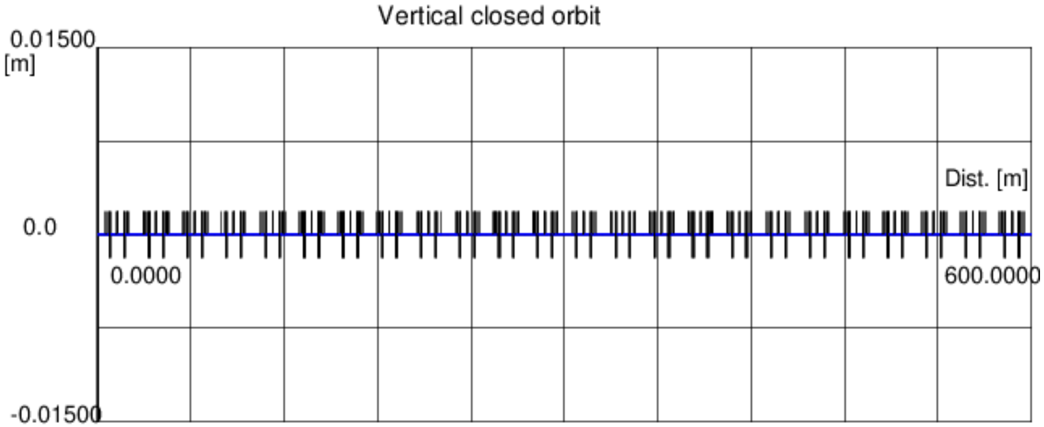
Random Tilt of ALL dipoles

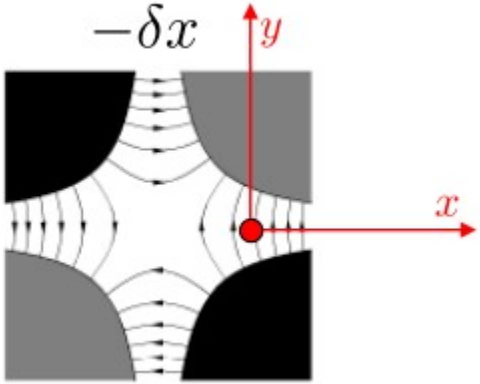




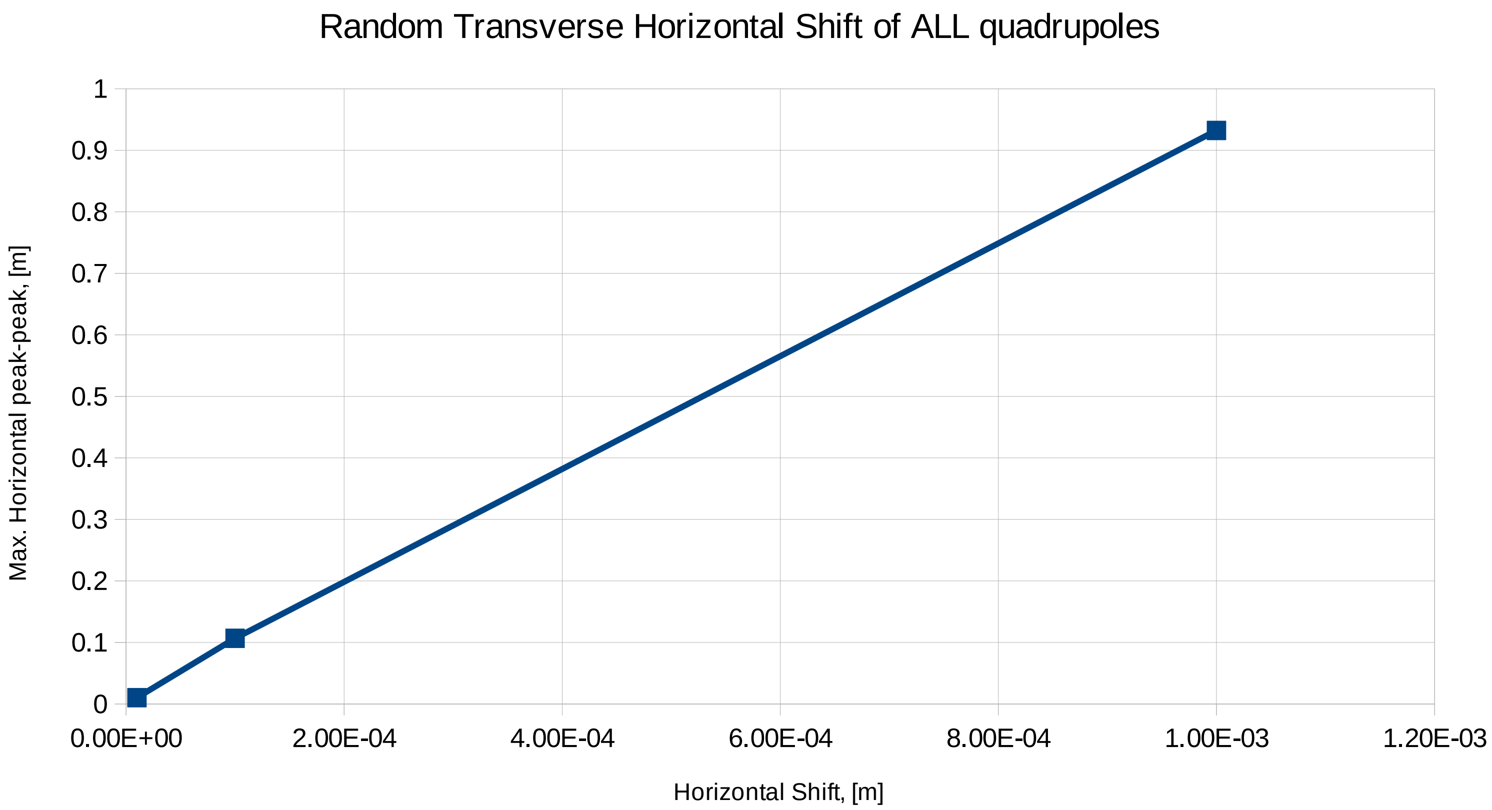
Random Transverse Horizontal Shift of ALL quadrupoles

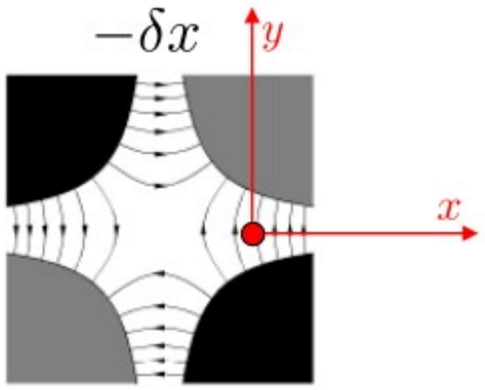




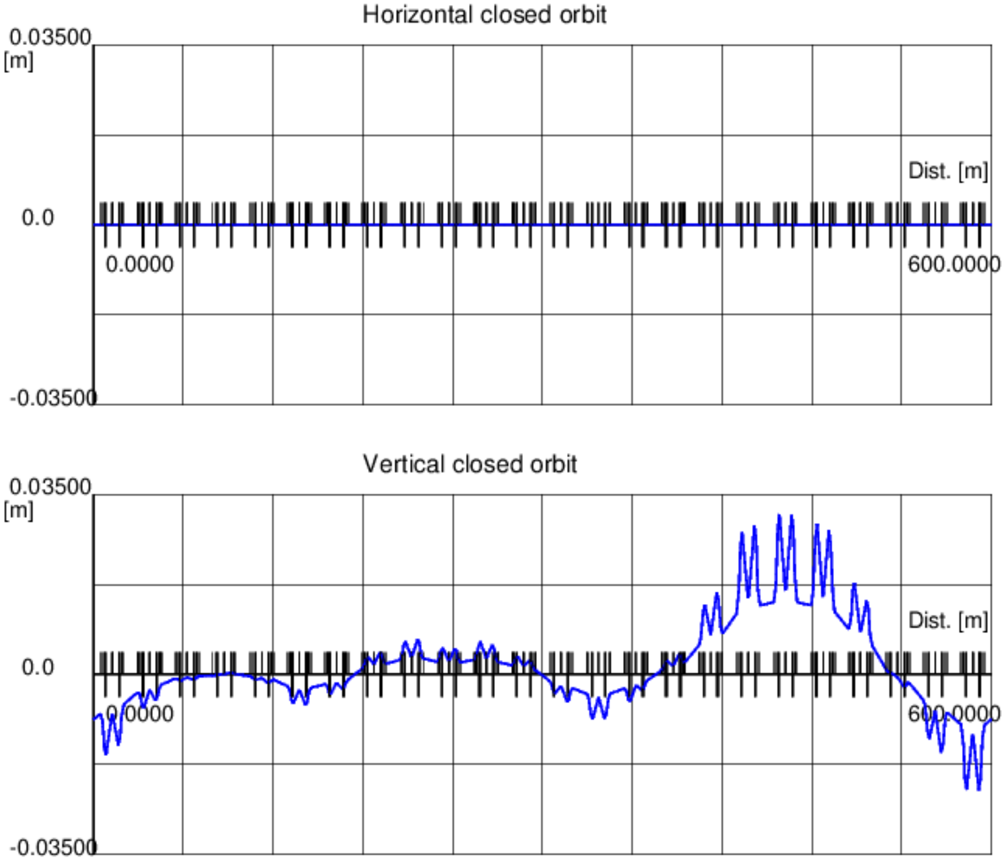


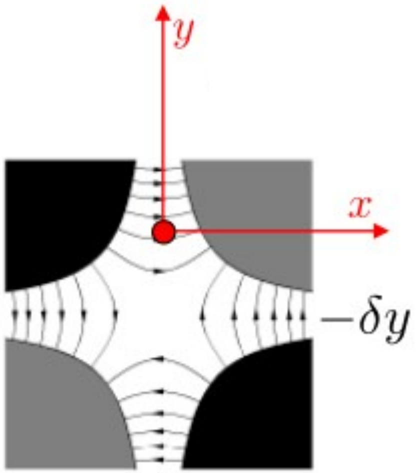
Random Transverse Horizontal Shift of ALL quadrupoles



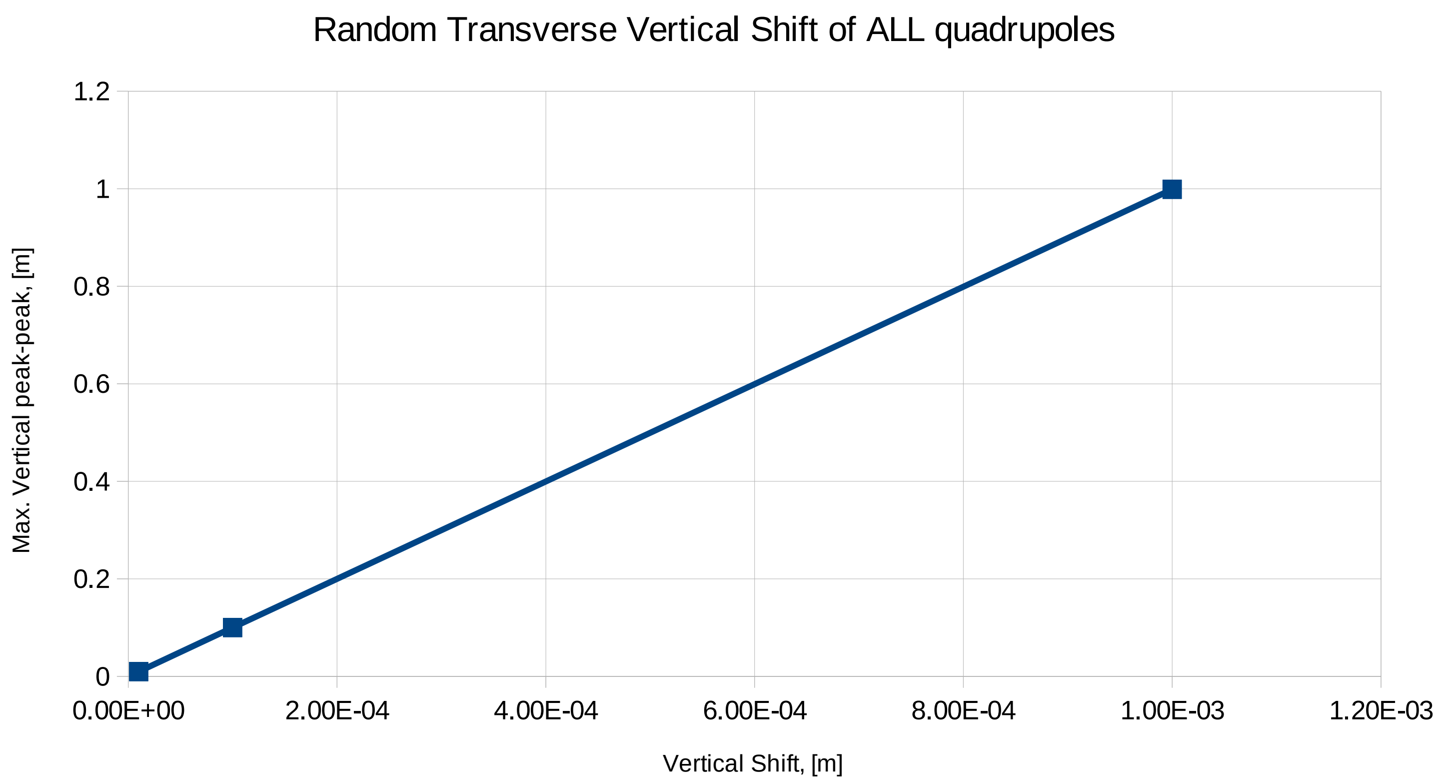


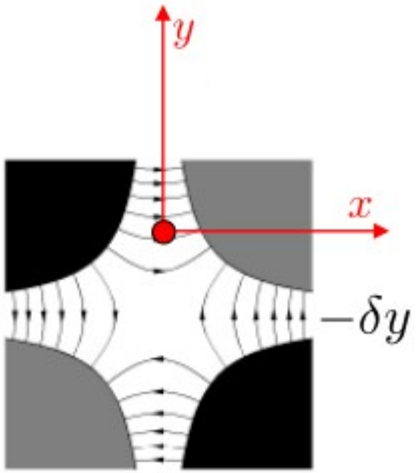
Random Transverse Vertical Shift of ALL quadrupoles

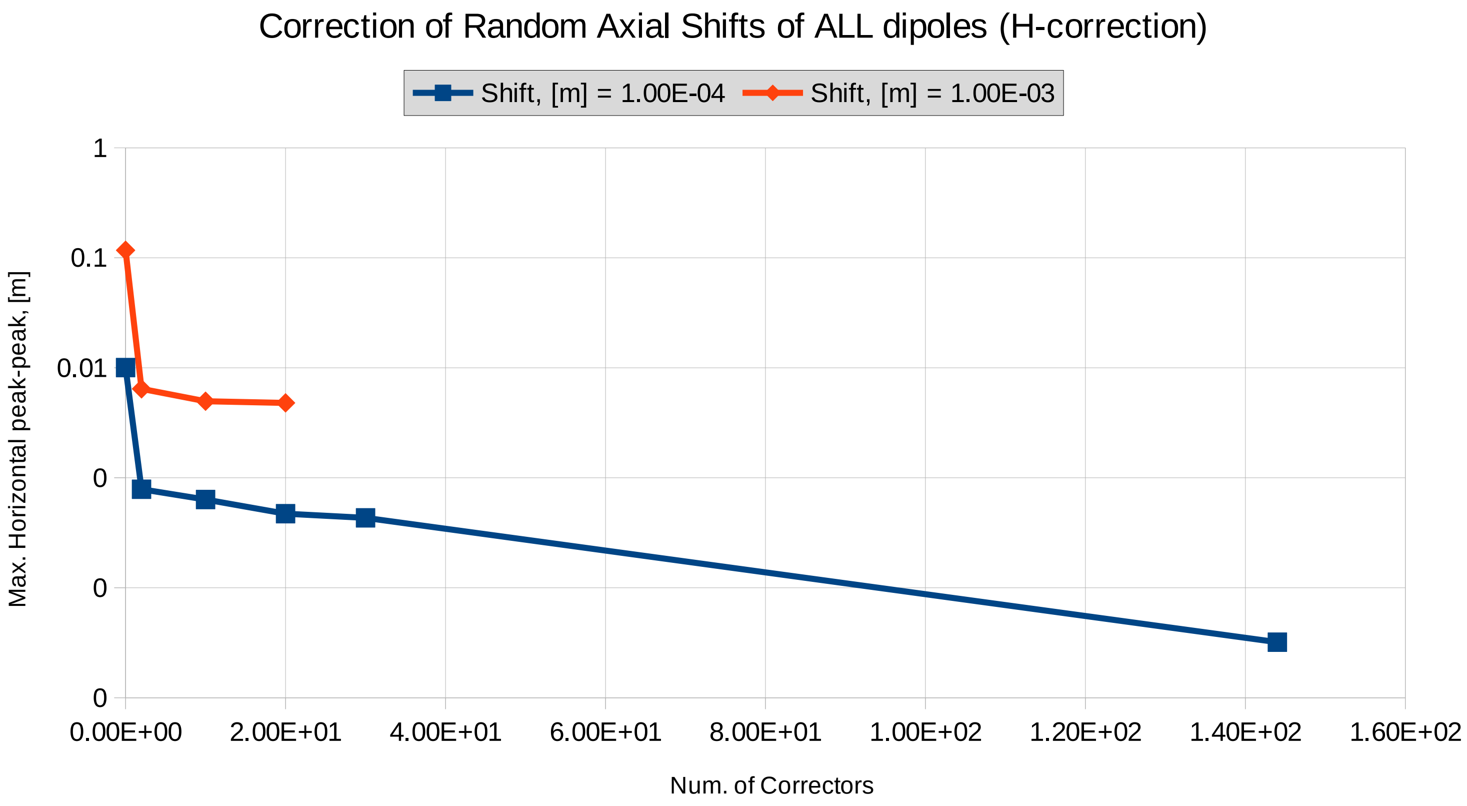


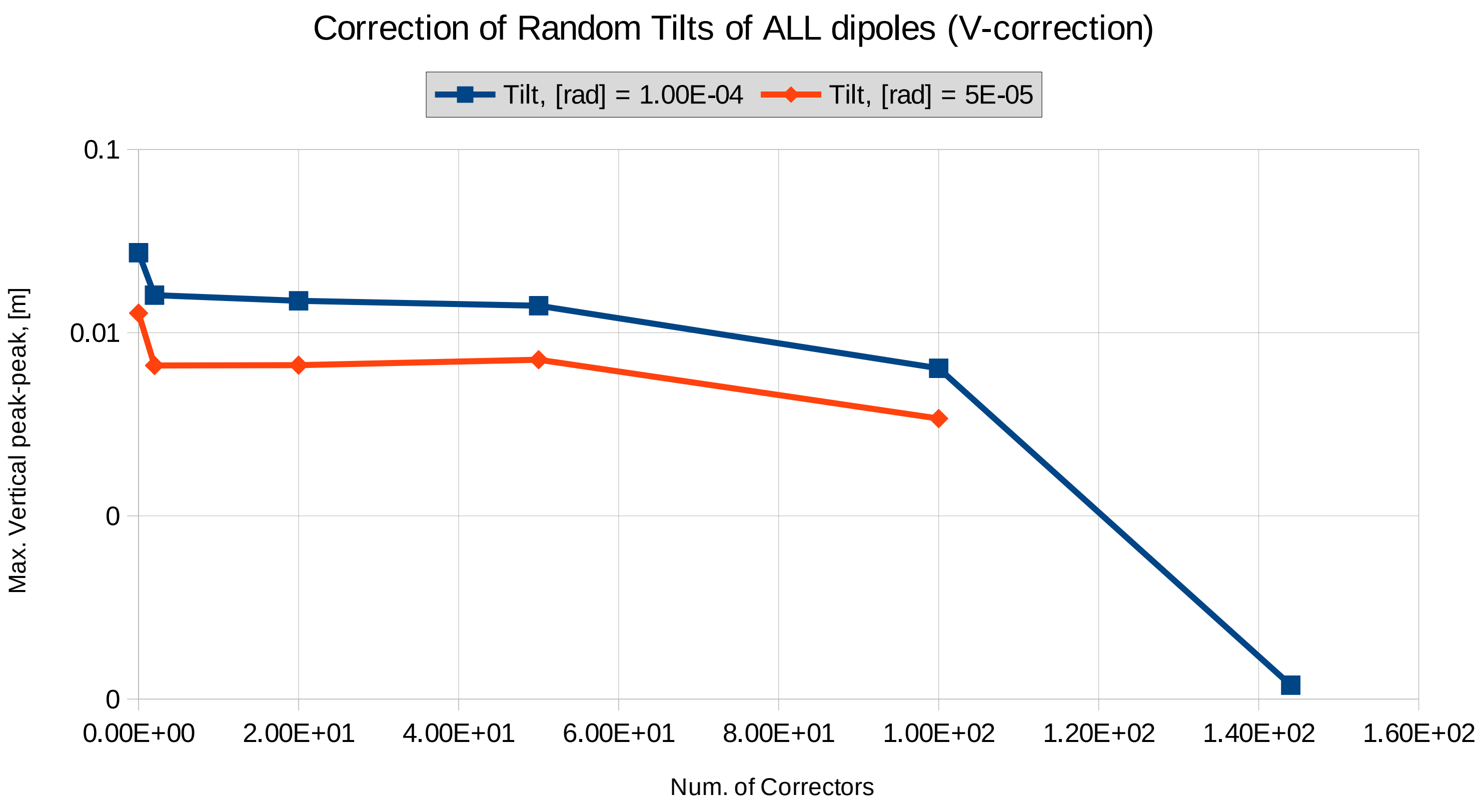


Random Transverse Vertical Shift of ALL quadrupoles

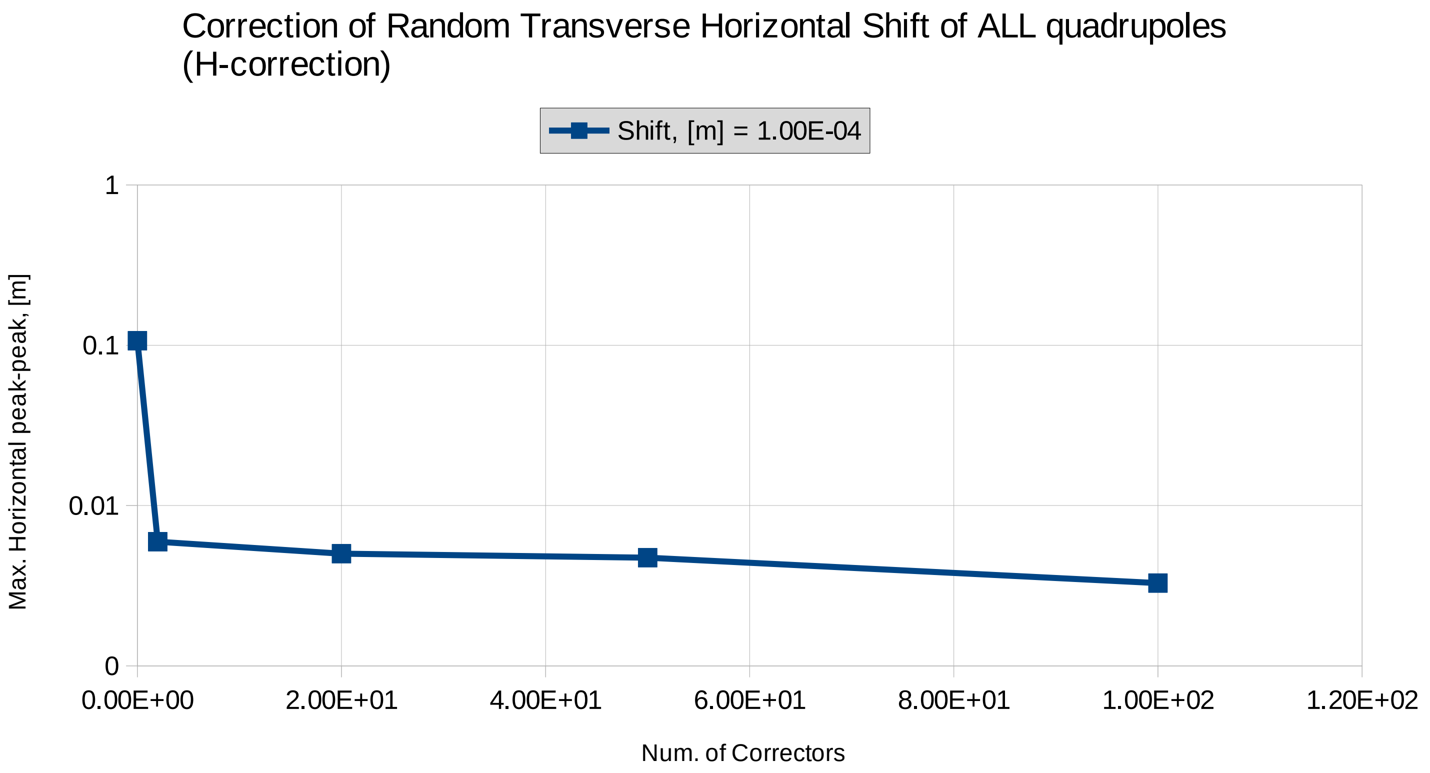





Correction of Random Axial Shifts of ALL dipoles (H-correction)
Shift, [m] = 1.00E-04
Shift, [m] = 1.00E-03
1
0.1
0.01
0
0
0
Max. Horizontal peak-peak, [m]
0.00E+00
2.00E+01
4.00E+01
6.00E+01
8.00E+01
1.00E+02
1.20E+02
1.40E+02
1.60E+02
Num. of Correctors



Correction of Random Tilts of ALL dipoles (V-correction)
Tilt, [rad] = 1.00E-04
Tilt, [rad] = 5E-05
0.1
0.01
0
0
Max. Vertical peak-peak, [m]
0.00E+00
2.00E+01
4.00E+01
6.00E+01
8.00E+01
1.00E+02
1.20E+02
1.40E+02
1.60E+02
Num. of Correctors

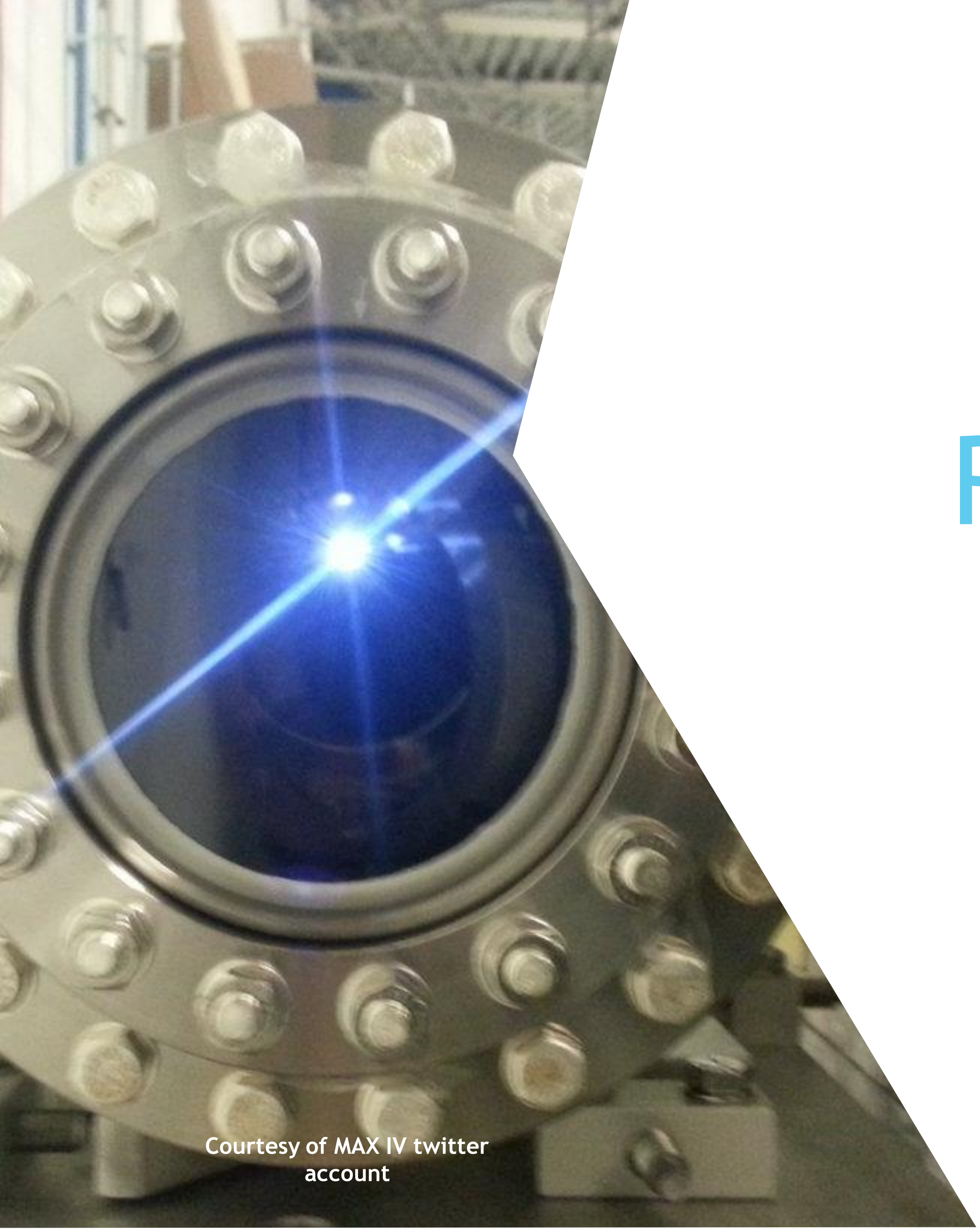

Correction of Random Transverse Horizontal Shift of ALL quadrupoles
(H-correction)
Shift, [m] = 1.00E-04
Max. Horizontal peak-peak, [m]
1
0.1
0.01
0
0.00E+00
2.00E+01
4.00E+01
6.00E+01
8.00E+01
1.00E+02
1.20E+02
Num. of Correctors

VACUUM SYSTEM & SYNCROTRON RADIATION

ALiS

Injection | RF System | Lattice | Chromaticity control | Tune control | Resonance excitation | Closed orbit correction | **Vacuum system**

Synchrotron Radiation and Vacuum



Armando Novelli
Emanuela Carideo
Chiara Antuono

Synchrotron Radiation:Input Parameters

Overall Input Parameters	Value
Beam Energy (GeV)	2 (Injection Energy) 3 (Top Energy)
Number of cells	24 (7 Bend Achromat)
Number of undulators	22
Average Beam Current (mA)	250 (from MAX IV data)
Relativity Gamma Factor	3913,9 (Injection) 5870,85 (Top Energy)
Axial Magnetic Field (inner dipole magnets) (T)	3,5
Axial Magnetic Field (outer dipole magnets) (T)	0,28
Axial Magnetic Field/Tip Field (undulator) (T)	1/1.14
Undulator Length (m)	3,5
Undulator Period (cm)	0,3
Number of periods	1167

Synchrotron Radiation: Performance of the beam

Assumptions:

- Only first harmonic (n=1) is taken in account for Brilliance determination inside the undulators;
- SR is considered at top energy of the beam (3 GeV), the variation during acceleration is not taken in account;

Outer Bending Magnet

Critical Frequency: ω_c =2,634 $* 10^{18}$ rad/s

Critical energy: ϵ_c =1,73 keV

Photon Flux: $\dot{N}$= 5,7 $* 10^{15}$ photons/s/(0.1% BW)

Inner Bending Magnet

Critical Frequency: $\omega_c = 3,25 * 10^{19}$ rad/s

Critical energy: ϵ_c =21,39 keV

Photon Flux: $\dot{N}$= 4,2 $* 10^{15}$ photons/s/(0.1% BW)

Undulator

Undulator Parameter: K=0,233 T*cm

Photon wavelength: λ=7,3 nm

Photon Flux, $\dot{N}$ =4,51 $* 10^{16}$ photons/s/(0.1% BW)

Brillance: B=1,02* 10^{20} photons/s/(0.1% BW)*mm*mrad

Overall Parameters (some from WinAGILE)

SR divergence: θ=0,00017 rad

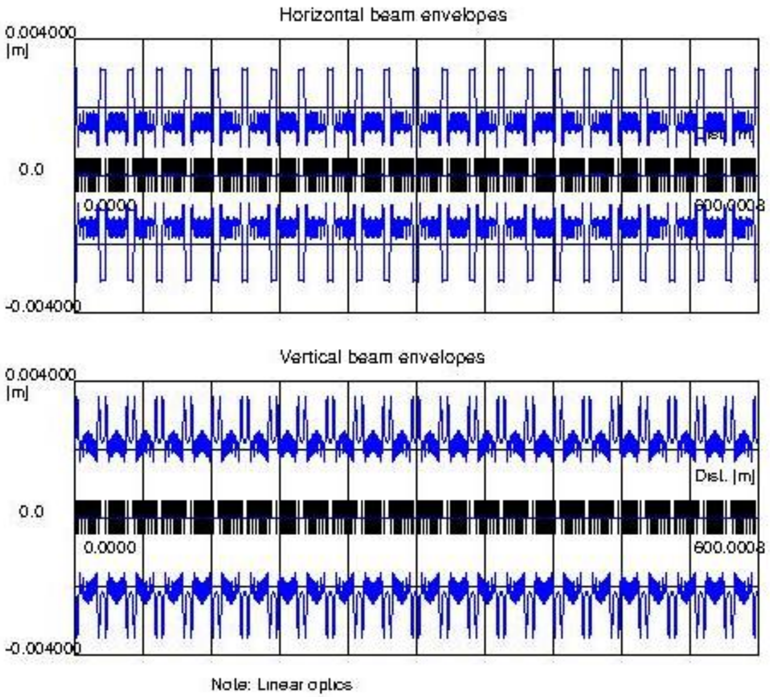
Energy Loss: U_0 = 247.8 keV/electron/turn

Horizontal Damping Time: τ_x = 24,25 ms

Longitudinal Damping Time: τ_s = 48,44 ms

Vertical Damping Time: τ_y= 48,33 ms

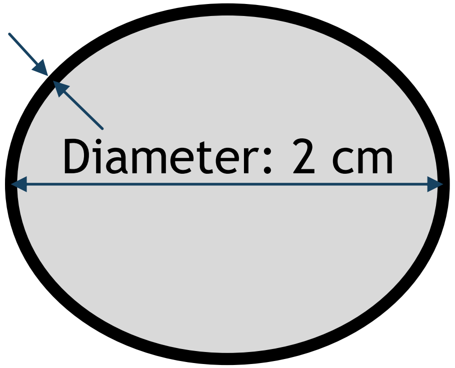
Vacuum: Chamber dimensioning



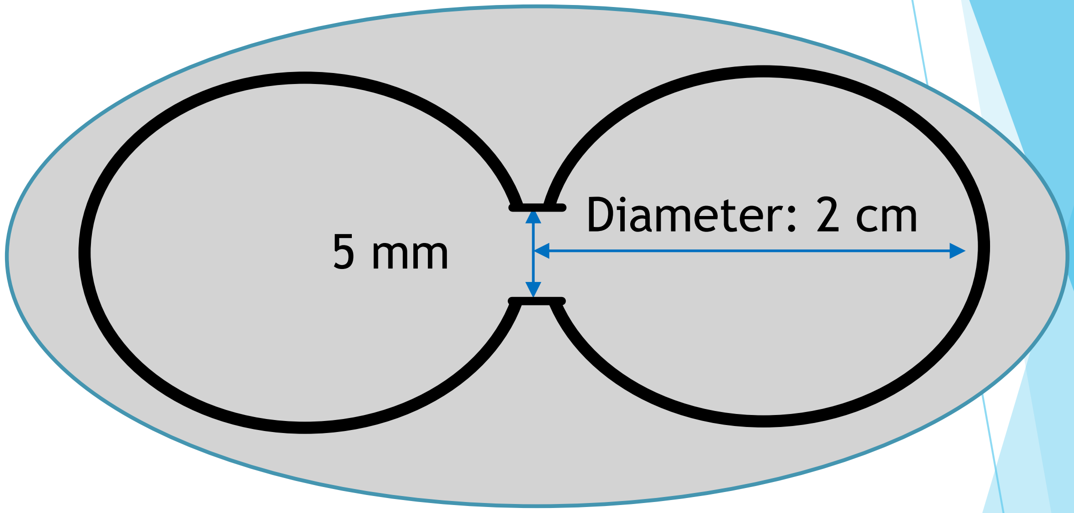
Vacuum Chamber Type: E (Circular)
(after injection point)

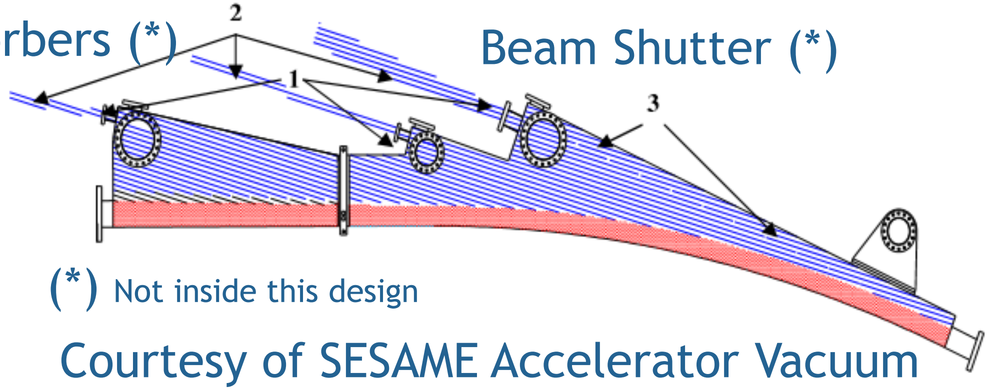
Thickness: 1 mm

Material:
Stainless Steel
(316 L)



Vacuum Chamber Type: Double E (Circular)
SR generation and extraction zone





(*) Not inside this design

Courtesy of SESAME Accelerator Vacuum

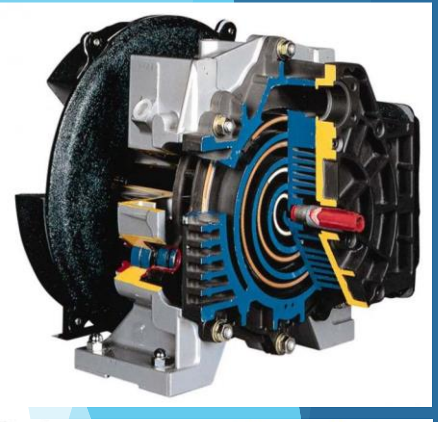
Vacuum: Pumping design

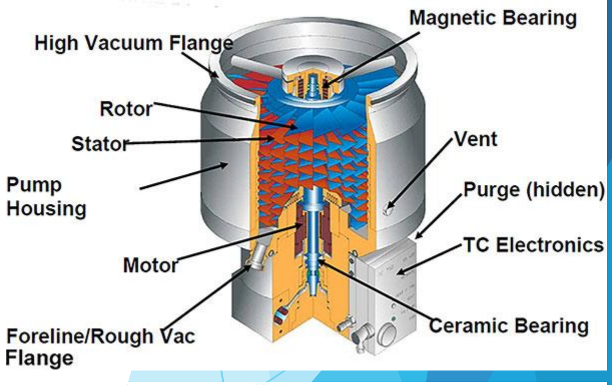
Assumptions:

- Desorption Surface is assumed to be the sum of a couple of cylinders with a 2cm diameter;
- We consider as desorption rate: 1*10^{-11} Torr*l/s/ cm^2 ;
- From experimental data most of gases that comes from synchrotron interaction are carbon monoxide (CO) and dioxide (CO2) so we have consider two cases
- We're considering 100 pumping line for the storage ring

Vacuum Pump type:

- Scroll (LV level)
- Turbomulecular (HV and UHV Level)
- Ionic (UHV level)





INPUT	Values	OUTPUT	Values
Pump Separation (m)	6	Max Pressure (Torr)	4,7*10^-9
Pump Speed (l/s)	200	Average Pressure (Torr)	3,2*10^-9
Specific Area (cm2)	628,31	Min Pressure (Torr)	1,9*10^-10
Outgassing Rate(Torr*l/cm2)	1*10^-11	Conductance (l/s)	1,05
Temperature (K)	293,15	Specific Conductance (l/s/m)	6,29
Molecular mass (amu)	44	/	/

INPUT	Values	OUTPUT	Values
Pump Separation (m)	6	Max Pressure (Torr)	4,47*10^-9
Pump Speed (l/s)	200	Average Pressure (Torr)	3*10^-9
Specific Area (cm2)	628,31	Min Pressure (Torr)	1,8*10^-10
Outgassing Rate(Torr*l/cm2)	1*10^-11	Conductance (l/s)	1,10
Temperature (K)	293,15	Specific Conductance (l/s/m)	6,6
Molecular mass (amu)	40	/	/

Vacuum: Possible Improvements

Improvements for Vacuum:

- Neg strips or Neg coatings;
- Titanium Sublimation Pump;
- Low SEY Surfaces (LASE or coatings);