

JUAS

Accelerator workshop

2016

Final presentation

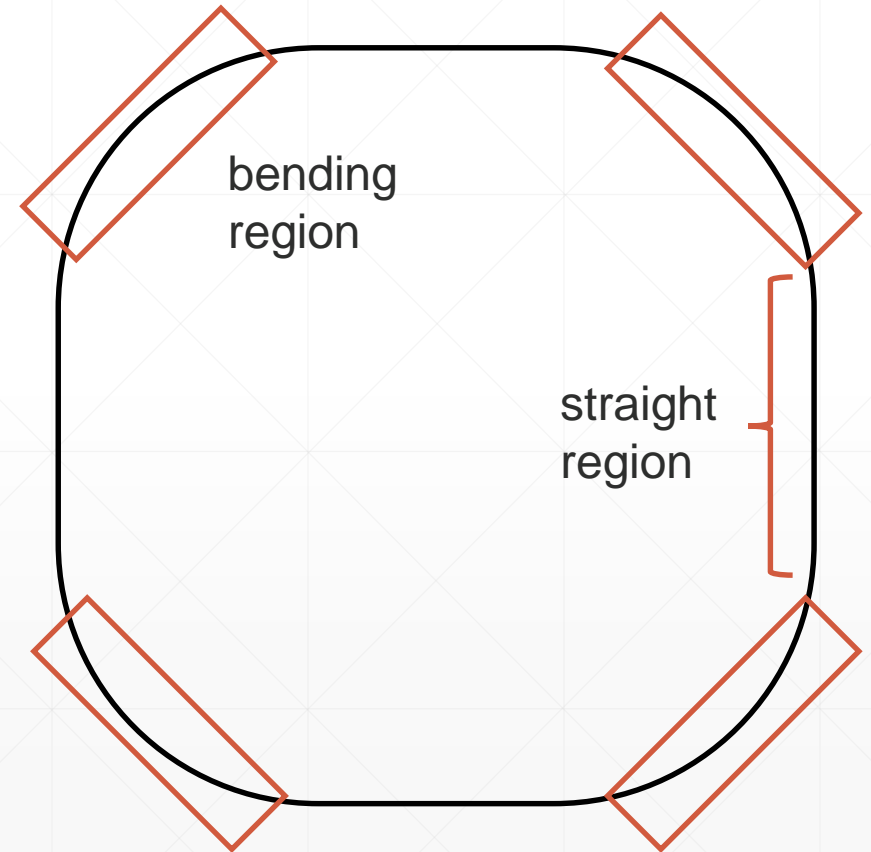
Outlook

- Presentation of the task & introduction of the team
- Lattice design
- RF design
- Collective effects and correction
- Vacuum considerations
- Magnet considerations
- Transition considerations

Presentation of the task & introduction of the team

Presentation of the task and the basic layout

- Replacement for the PS machine at CERN
- Acceleration of protons from a momentum of 3.5 GeV/c to a momentum of 20 GeV/c
- For the basic accelerator lay out a 'rectangular' ring design (with four superperiods) was chosen
 - + Space for beam control, correction and instrumentation
 - + Space for acceleration, injection and extractions
 - + Space for future tasks the accelerator may have to handle



Presentation of the groups

- Design is a 'rectangular' ring (four super periods)
- The project was divided into three main groups
 - Lattice group
 - RF group
 - Collective effects group
- Special attention has been payed to the magnets, the vacuum and the crossing of the gamma transition

Lattice design

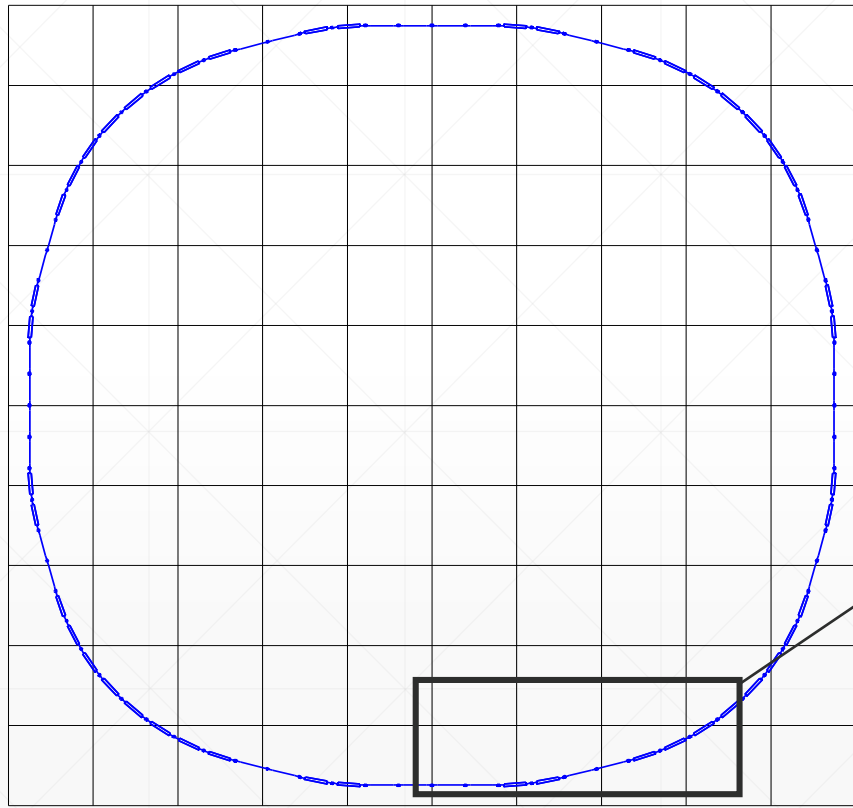
Lattice design – basic parameters

Element	Number	Length
Focusing quadrupoles	40	0,45m
Defocusing quadrupoles	40	0,45m
Bending dipoles	48	8m

$$\rho_d = \frac{L_d}{2\pi/N_d} = 61,12m \quad (R = 150m)$$

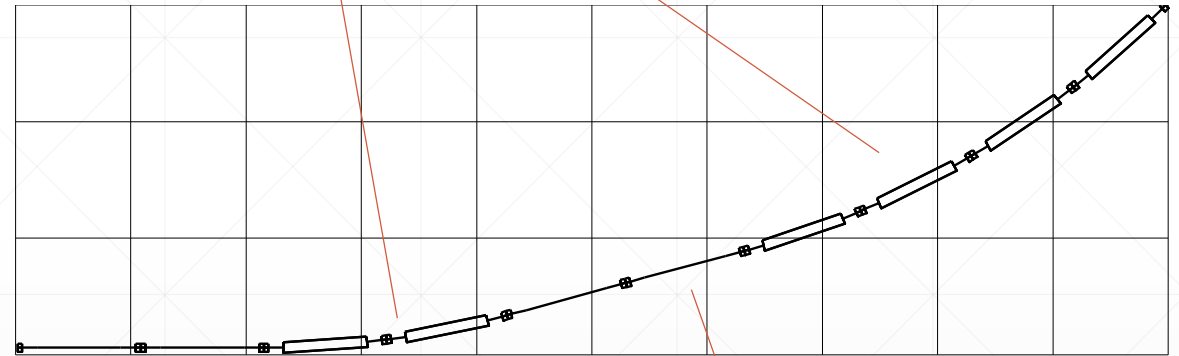
Lattice design - geometry

Horizontal plan view [X-Y plane]



Grid size 30.0000 [m]

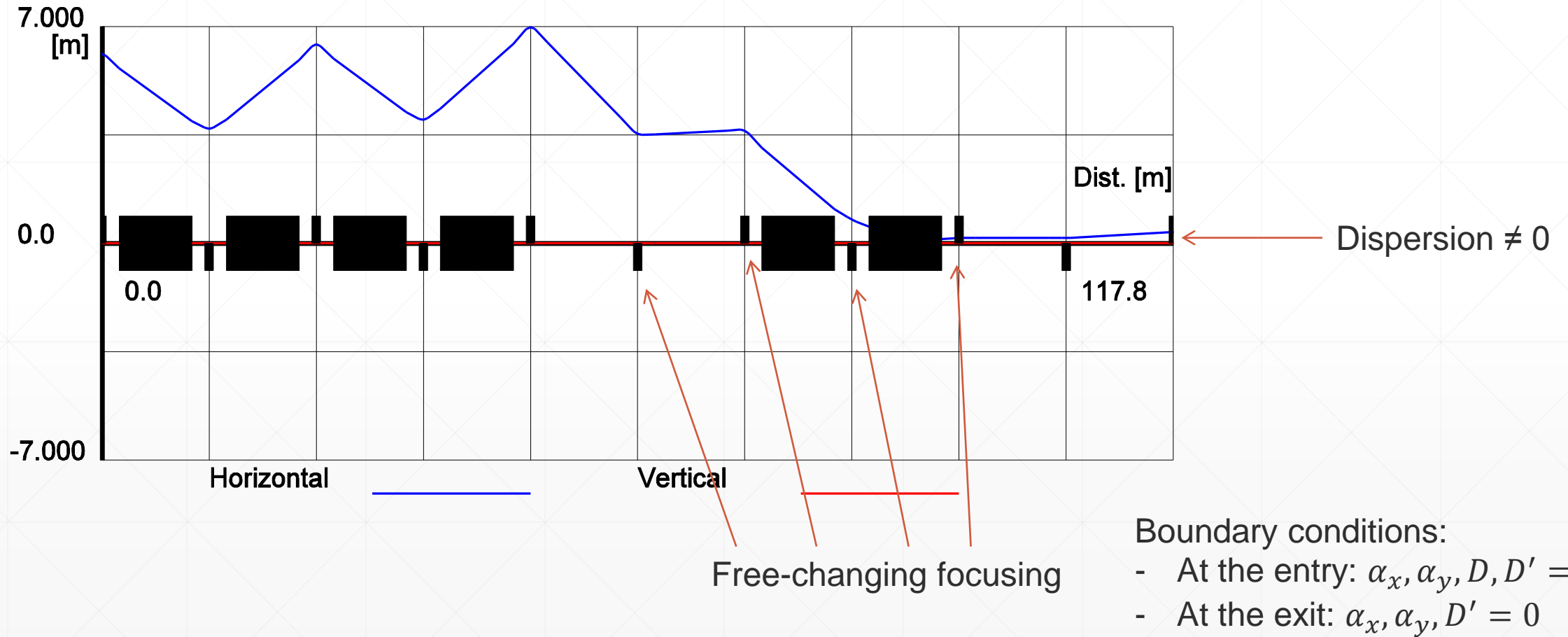
Bending dipoles



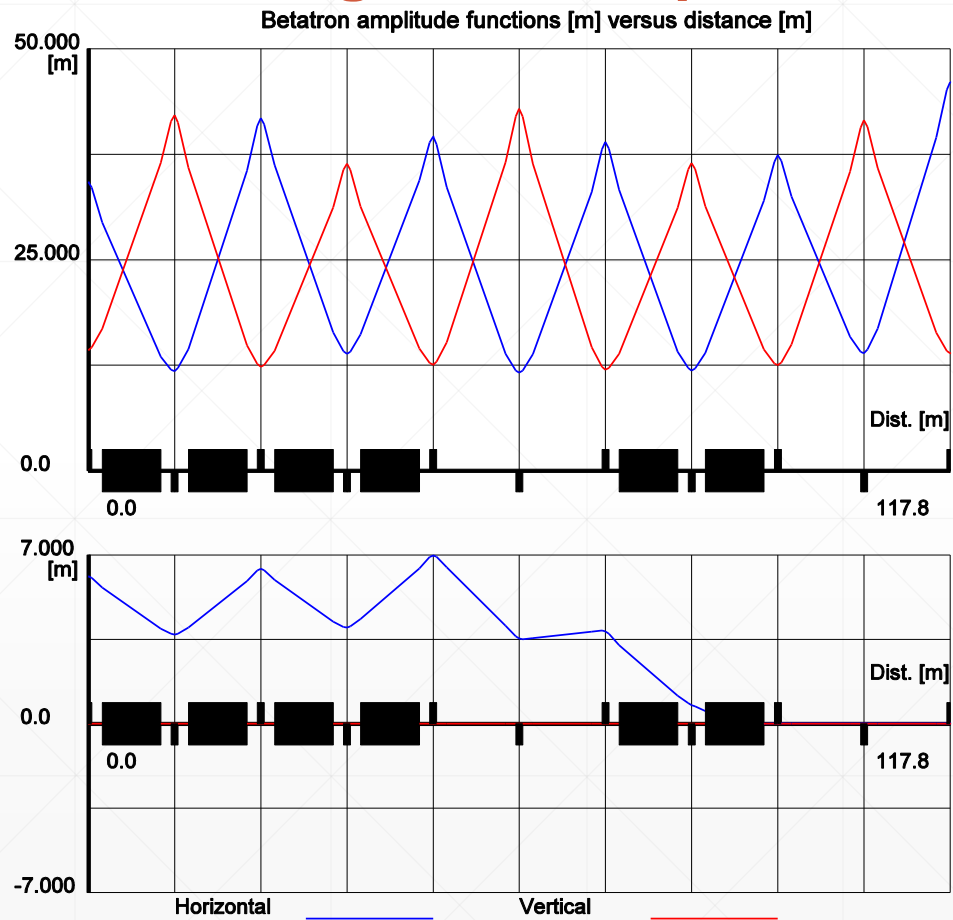
0-dispersion zone

Dispersion suppressor

Lattice design – lattice optimization



Lattice design – Twiss parameters



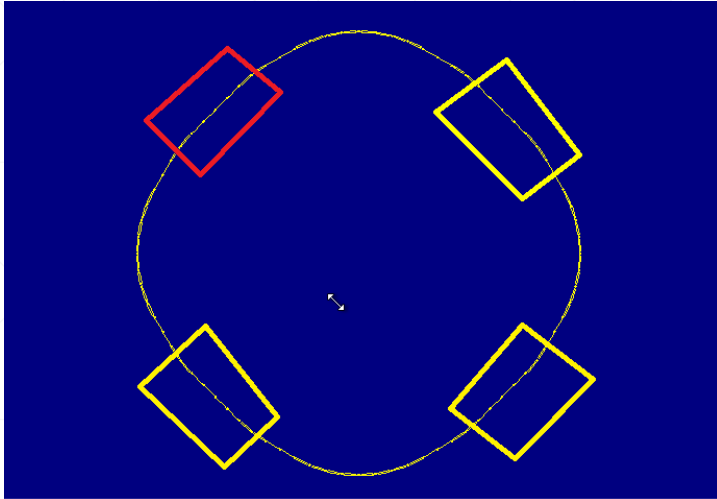
Average transversal dimension of the beam

$$\sigma_x = \sqrt{\varepsilon_x \cdot \beta_x} = 16.4 \text{ mm}$$

$$\sigma_y = \sqrt{\varepsilon_y \cdot \beta_y} = 11.6 \text{ mm}$$

RF design

What we need Vs What we have:



$$\gamma_{\text{transition}} = 6.36$$

$$\text{Free Space} = \frac{256}{4}$$

For R.F = 64 m

Objectives for the RF:

- . Get to 20 GeV/c.
- . Get the intensity of 3×10^{13} Protons/Beam.
- . Preserve the beam from the booster.
- . Try not to blow things up

$$\Delta E = 16.4 \text{ GeV}$$

$$T_{REV(\text{Inj})} = 3.25 \times 10^{-6} \text{ s}$$

$$T_{REV(\text{Ext})} = 3.14 \times 10^{-6} \text{ s}$$

$$\rho = 61.115 \text{ m (Bending Radius)}$$

$$\frac{dB}{dt} = \frac{B_{\text{ext}} - B_{\text{inj}}}{T} = 3.6 \text{ [T/s]}$$

Circunference (m)	982.48
Number of protons per pulse	3E13
Cycling frequency (Hz)	3.125
Momentum at injection (GeV/c)	3.5
Momentum at extraction (GeV/c)	20
Gamma at Injection	3.86
Gamma at Extraction	21.35

$$h = \frac{\text{Number of proton /pulses wanted}}{\text{Number of proton /pulses from booster}} = 20$$

$$\begin{aligned} \epsilon &= 0.1 \pi \text{ eV} \cdot \text{s} \\ \Delta t &= 51.2 \text{ ns} \\ \Delta E &= 3.9 \text{ MeV} \end{aligned}$$

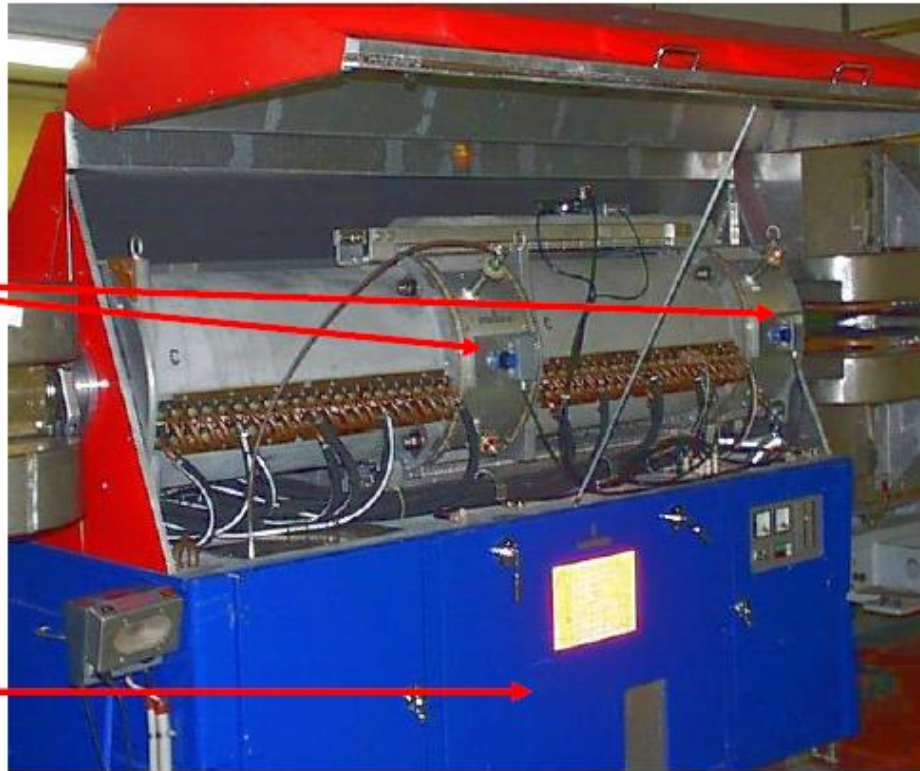
Booster:	Number of rings	4		
(fast cycling)	Average radius	37.5	Circumference [m]	235.619449
	Dipole occupation [fraction]	0.28	Length [m]	65.97344573
	Extraction momentum [GeV/c]	3.5	Top field [T]	1.111866667
			Gamma at extraction	3.862040361
			Beta at extraction	0.965895958
			Extraction kinetic energy [GeV]	2.685323679
			Rigidity at extraction [Tm]	11.674600
			Extraction revolution period [s]	8.186139E-07
	Harmonic number	4	RF frequency [Hz]	4.886309E+06
	Bunching factor (peak/average)	5.66	Bunch lgth/RF period	0.249861053
			Extracted bunch lgth [s]	5.12E-08
			Gap for kicker [s]	1.54E-07
	Kicker rise or fall time [s]	1.00E-07		
	Assume multi-turn injection with 20 turns with 50% efficiency after bunching giving 6.E12 particles/ring			
	Particles per ring	6.00E+12	Particles/bunch	1.50E+12
	Norm. H emit. [π mm mrad]	40	Geom. H. emit.[π mm mrad]	10.72291429
	Norm. V emit. [π mm mrad]	20	Geom. V. emit.[π mm mrad]	5.361457143
	Longitudinal emittance [eV s]	0.1		

3-10 MHz

**Gaps,
10 kV/gap**

About 2 m long

Tetrode



CERN PS cavity

$$f_{rev(inj)} = 307\text{KHz}$$

$$f_{rev(ext)} = 318\text{KHz}$$

$$f_{RF(inj)} = 6.14\text{MHz}$$

$$f_{RF(ext)} = 6.36\text{MHz}$$

$$\frac{\Delta f_{RF}}{f_{RF}} = 3.6\%$$

$$\Delta E_{Bucke_t} = 7 G(\phi_s) \text{ MeV}$$

$$G(\phi_s) \geq 0.55$$

From the booster:

$$\epsilon = 0.1 \pi \text{ eV} \cdot \text{s}$$

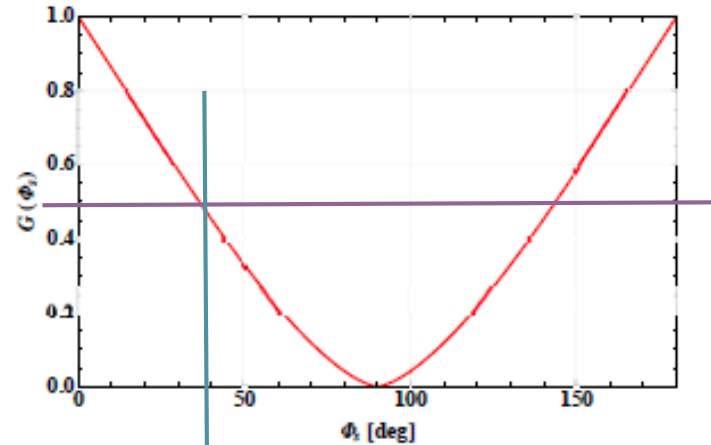
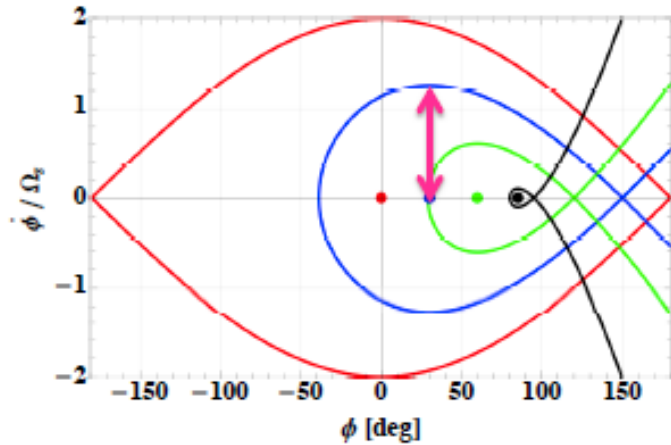
$$\Delta t = 51.2 \text{ ns}$$

$$\Delta E_{Bunch} = 3.9 \text{ MeV}$$

$$\Delta E_{\max}^{\text{sep}}(\phi_s) = \sqrt{\frac{2 \beta_s^2 E_s e \hat{V}_{RF}}{\pi h \eta}} G(\phi_s)$$

with

$$G(\phi_s) = \frac{\sqrt{2 \cos \phi_s - (\pi - 2 \phi_s) \sin \phi_s}}{\sqrt{2}}$$



- $\phi_s = 0^\circ$
- $\phi_s = 30^\circ$
- $\phi_s = 60^\circ$
- $\phi_s = 85^\circ$

$$\phi_s < 40^\circ$$

$$\phi_s = 30^\circ$$

$$N(\text{number of cavities}) = 20$$

$$\frac{dB}{dt} = \frac{V_{rf} N \sin(\phi_s)}{C \rho}$$

Free space left = 24 m

$$20 * 2 (\text{Length of the cavity}) = 40 \text{ m}$$

Consideration for Transition:

$$\gamma_{transition} = 6.36$$

$$\phi_s(\textit{After Transition}) = \pi - 30^\circ$$

Some Numbers:

$$Q_{inj} = 8.29 \times 10^{-4}$$

$$Q_{ext} = 2.265 \times 10^{-4}$$

$$\textit{Ramp Time} = 0.25 \textit{ second}$$

$$(\Delta E)_{gain} = 200 \textit{ KeV}$$

$$\textit{Number of Turns} = 72500 \textit{ turn}$$

Group photo



Collective effects and corrections

Eleonora Belli, Rodrigo Varela, Jay Kalinani

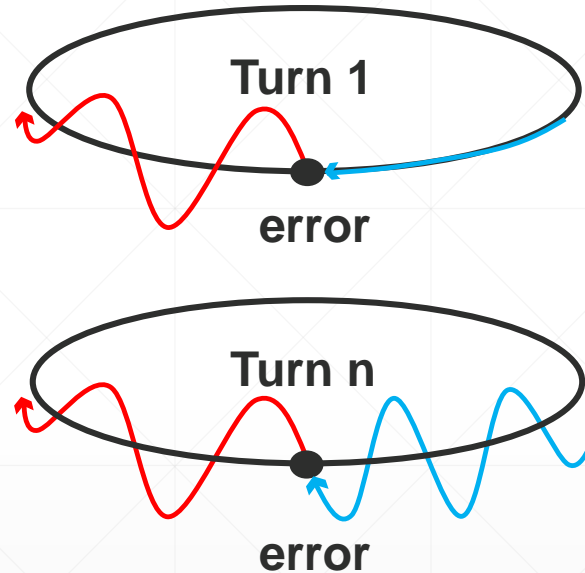
1. Tune control

Remind: the tune is the number of oscillations per turn

Avoid resonance conditions (integer tune)

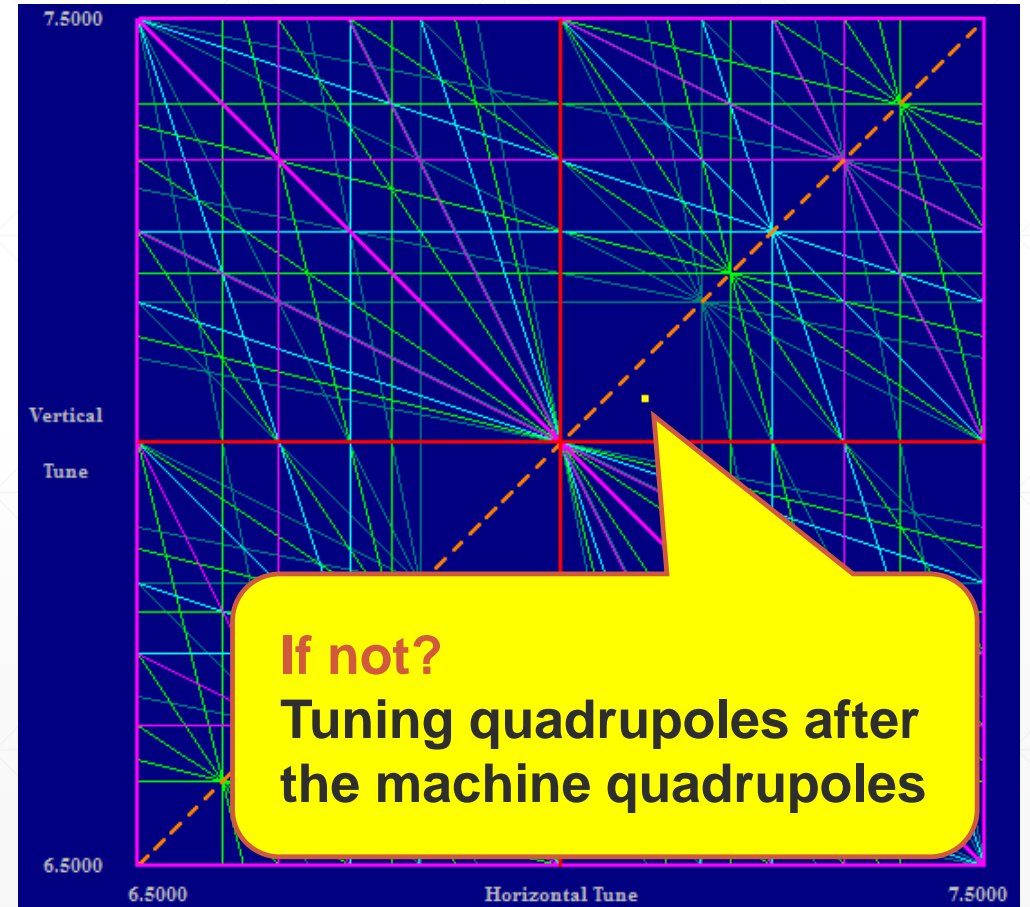
$$Q = \frac{1}{2\pi} \oint \frac{ds}{\beta(s)} = \frac{\mu}{2\pi}$$

Errors will sum-up in consecutive turns



➤ Check your **working point**, i.e. the position of the tunes in the resonance diagram

$$Q_x = 7.1 \quad Q_y = 7.05$$



1. Tune control (cont.)

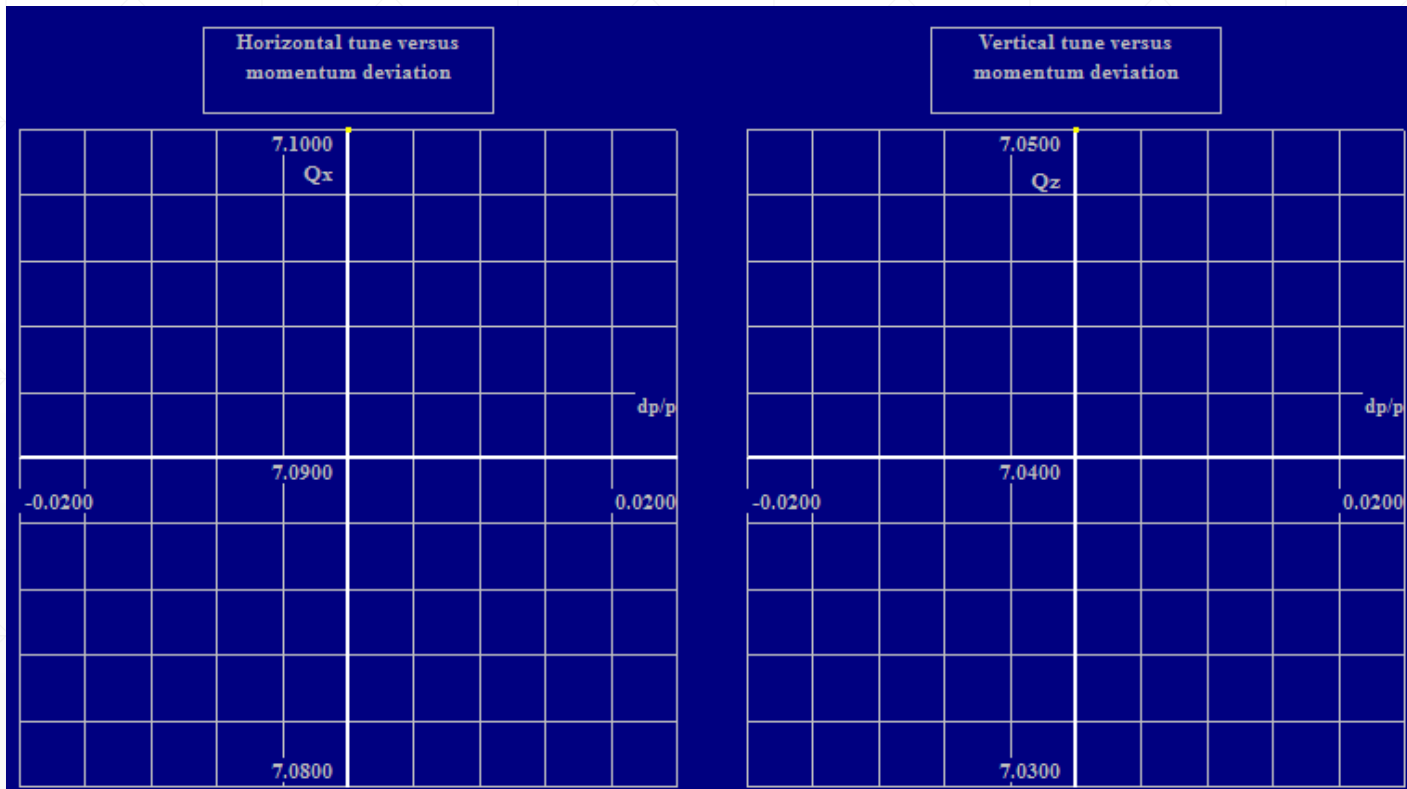
The **tune shift** is induced by

- Errors in quadrupole strength

$$\Delta Q = \frac{1}{4\pi} \oint_{quad} \Delta k(s) \beta(s) ds$$

- Coherent and incoherent space charge effects

$$\Delta Q_{x,y} = -\frac{1}{2} \frac{Nr_0}{\beta^2 \gamma^3 (2\epsilon_{x,y})} \frac{1}{1 + \frac{b}{a}}$$



1. Coherent space charge
2. Incoherent space charge with $\frac{\Delta p}{p} = 10^{-3}$ @ 3.5GeV
3. Incoherent space charge with $\frac{\Delta p}{p} = 10^{-1}$ @ 3.5GeV
4. Incoherent space charge with $\frac{\Delta p}{p} = 10^{-3}$ @ 20GeV

3. Closed orbit prognosis and correction

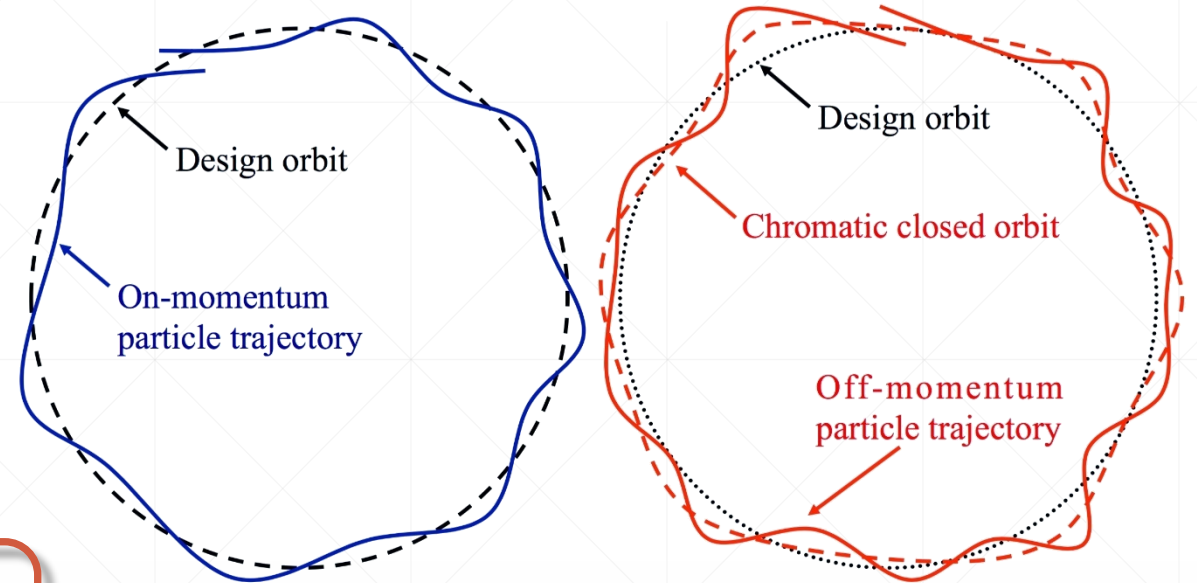
- On-momentum particle → design orbit
- Off-momentum particle → closed orbit

$$x = D \frac{\Delta p}{p}$$

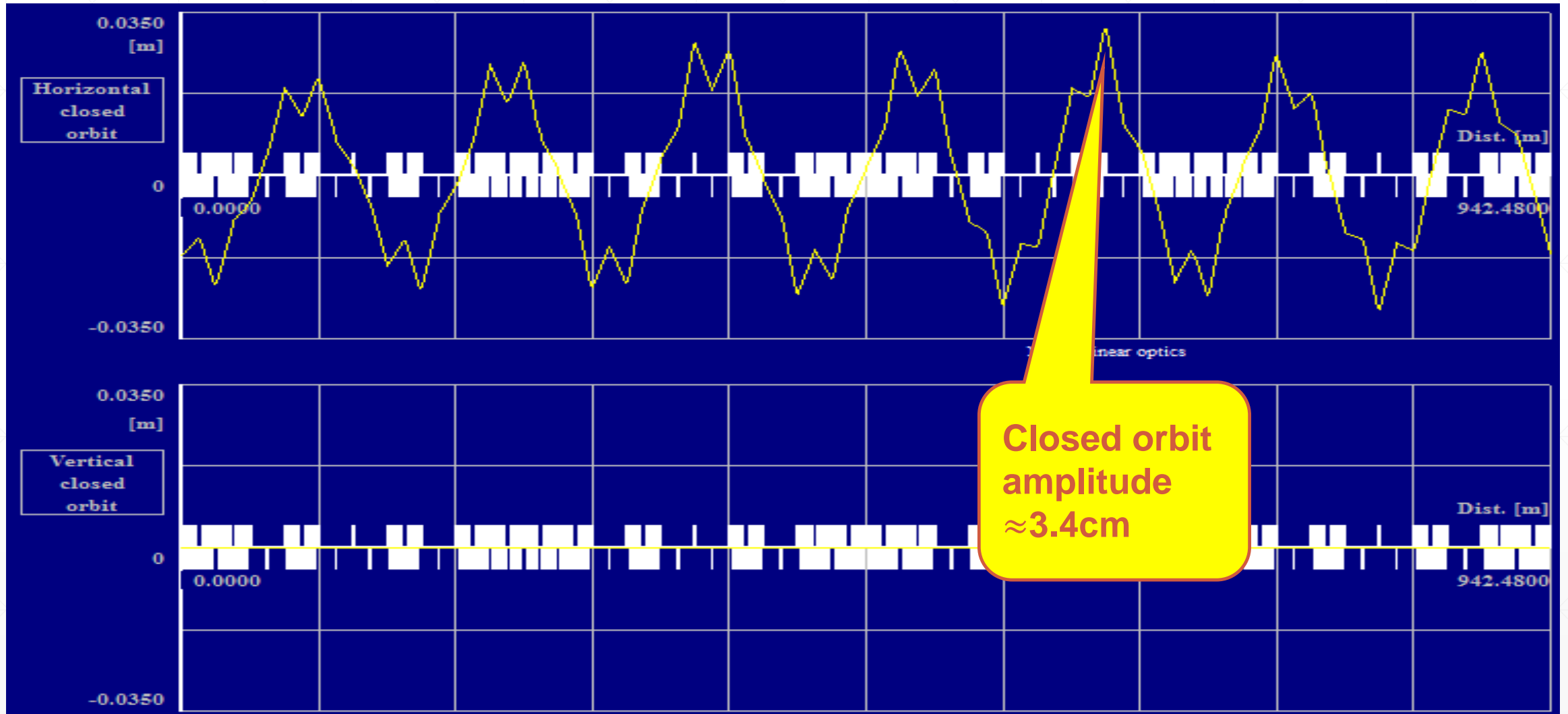
Distortion of the closed orbit

$$\langle \Delta z^2(s) \rangle^{1/2} = \frac{\overline{\beta_z(s)}}{2\sqrt{2}|\sin \pi Q|} [\sum_n \langle \delta_n^2 \rangle]^{1/2}$$

- **Dipole misalignments (1mm)**
- Dipole rolls
- **Quadrupole misalignments (1mm)**



3. Closed orbit prognosis



3. Closed orbit correction

CHOOSE PLANE :

- Correct HORIZONTAL plane
- Correct VERTICAL plane

CHOOSE MONITOR OPTION :

- Use elements of types HPO, VPO, HVPO
- Use entries to quadrupoles for positions (backup mode)

CHOOSE CORRECTOR OPTION :

- Use elements of types HCORR, VCORR, HVCOR
- Use entries to quadrupoles for positions (backup mode)

Edit monitor and/or corrector lists

NO. OF CORRECTORS TO BE USED :

Enter min. no. of correctors to be used

Enter max. no. of correctors to be used

Total no. of monitors available =

Total no. of correctors available =

COMPUTATIONAL METHOD :

- Least Squares Fit + Gauss-Jordan (fast)
- Singular Value Decomposition Fit (safe)
- Least Squares Fit + Householder Trans. + Tri-diag.

Compute **Add a corrector**

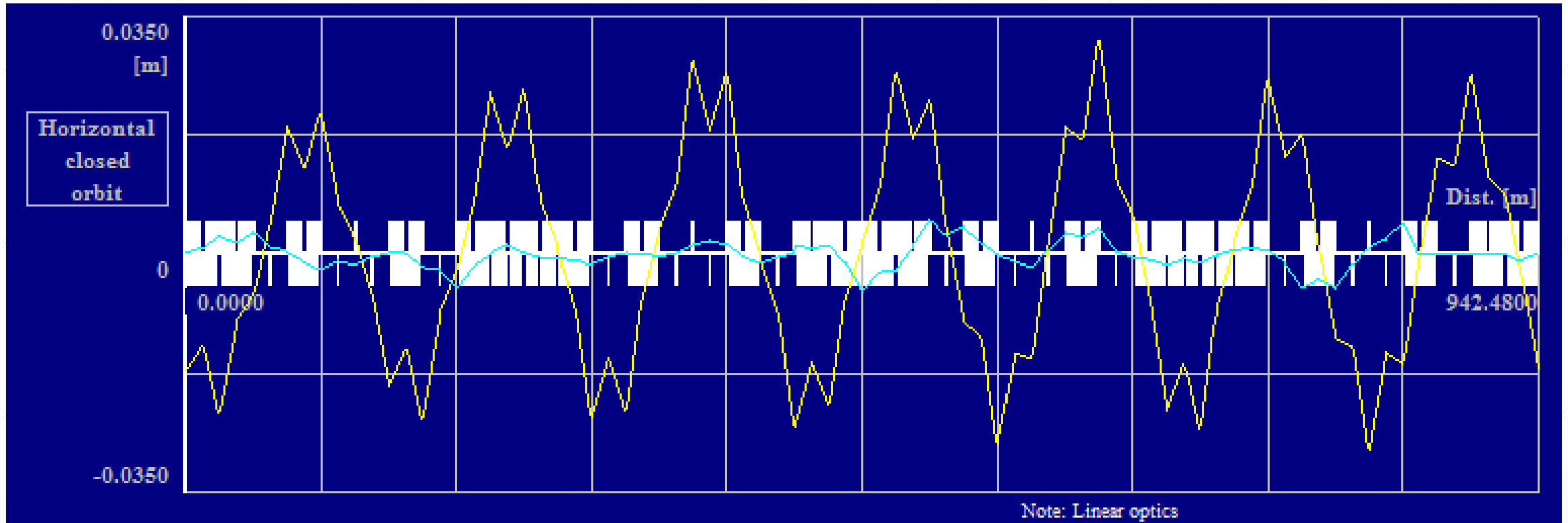
# corr	Pk-Pk [m]	Mean [m]	RMS [m]
0	0.060406	-0.000089	0.016453
6	0.012841	-0.000246	0.002396
7	0.012801	-0.000284	0.002335
8	0.012812	-0.000179	0.002277
9	0.011170	-0.000089	0.002162
10	0.011060	-0.000050	0.002135
11	0.011031	-0.000024	0.002117
12	0.011004	-0.000008	0.002123
13	0.010987	-0.000016	0.002120
14	0.010635	-0.000061	0.002069
15	0.010475	-0.000089	0.002044

SELECT ONE SOLUTION IN THE LIST BOX THEN CLICK OK

OK **Cancel**

15 correctors
Expected closed orbit amplitude $\approx 1\text{cm}$

3. Closed orbit correction (cont.)



Pk-Pk amplitude $\approx 1\text{cm}$

Vacuum consideration

Vacuum considerations

The screenshot shows a software window titled 'MAIN WINDOW' with a menu bar containing 'Options', 'File', 'Calculations', 'Aids', 'Tables', 'Graphs', 'Output', and 'Help'. The 'Aids' menu is open, listing several options, with 'Vacuum design aid...' circled in orange and an arrow pointing to it. Other menu items include 'Conventional magnet design aid', 'Conventional magnet cost aid', 'Eddy current calculator...', 'Water-cooled coil design aid...', 'RF cavity performance aid...', 'RFQ period performance aid...', 'Halo collimation design aid...', 'Emittance growth calculator...', 'Relativistic data calculator...', and 'Analytic matching...'. The 'Selection:' box displays 'Center Arc'. Below it, there are fields for 'File name : bas...', 'Treated as:', and 'User title: Qu...'. A table titled 'LATTICE ELEMENTS (On-Axis)' is visible, with columns for 'Unit no.', 'Element', 'Hor. Mbend [rad]', 'Vert. Mbend [rad]', and 'Edge ang [rad]'. The table contains 8 rows of data. On the left side, there are buttons for 'Quit', 'Grid', and 'Field', and a 'Unit no.' column with values 1 through 8.

Unit no.	Element	Hor. Mbend [rad]	Vert. Mbend [rad]	Edge ang [rad]
1	Center	0.0000	0.000000	0.0
2	((0.0000	0.000000	0.0
3	((0.0000	0.000000	0.0
4	QF1 QUADR	0.4500	0.000000	0.0
5	s0 DRIFT	1.4405	0.000000	0.0
6	Dip1 SBEND	8.0000	0.130900	0.0
7	s0 DRIFT	1.4405	0.000000	0.0
8	QD1 QUADR	0.4500	0.000000	0.0

VACUUM SYSTEM DESIGN AID

INTRODUCTION:
 Equilibrium pressure calculation for an infinite array of uniformly spaced vacuum pumps connected to a vacuum pipe of circular or elliptical cross-section

INPUT:

Pump separation [m] = 10

Pump speed [l/s] = 50

Major half-width of pipe [m] = 0.04

Minor half-width of pipe [m] = 0.07

Specific surface area 'seen' by vacuum [cm²/m] = 35

Specific out-gassing rate (enter #.#E##) [Torr l/s/cm²] = 10.E-12

Absolute temperature [K] = 300

Molecular weight of residual gas = 28

OUTPUT:

Maximum pressure [Torr] = 1.01E-0010

Average pressure [Torr] = 9.13E-0011

Minimum pressure [Torr] = 7.00E-0011

Conductance of pipe (over separation lgth) [l/s] = 13.72

Specific conductance of pipe [l m/s] = 137.19

Buttons: COMPUTE, QUIT, Copy data to clipboard, Copy data to notebook, Paste time stamp, Load from notebook

NOTES:

- The specific surface area 'seen' by vacuum should be increased to account for shields, screens, bellows etc.
- Some typical outgassing rates are:

Stainless steel baked for 24 hour at 300 deg. C	= 1 E -12
Stainless steel, unbaked after 100 hour pump-down	= 2 E -9
Copper after 10 hour pump-down	= 5 E -9
Brass after 10 hour pump-down	= 2.5 E -8
Teflon and aluminium after 10 hour pump-down	= 1 E -7
Araldites B, D and F after 10 hour pump-down	= 8 E -7, 5 E -7, and 4 E -7
Nylon after 10 hour pump-down	= 4.5 E -6
- Molecular weights: 2(H₂), 28(N₂), 32(O₂).

INPUT:

Pump separation [m] = 10

Pump speed [l/s] = 50

Major half-width of pipe [m] = 0.04

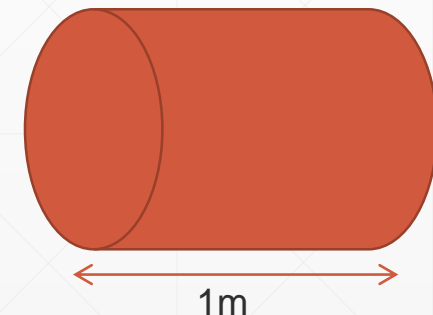
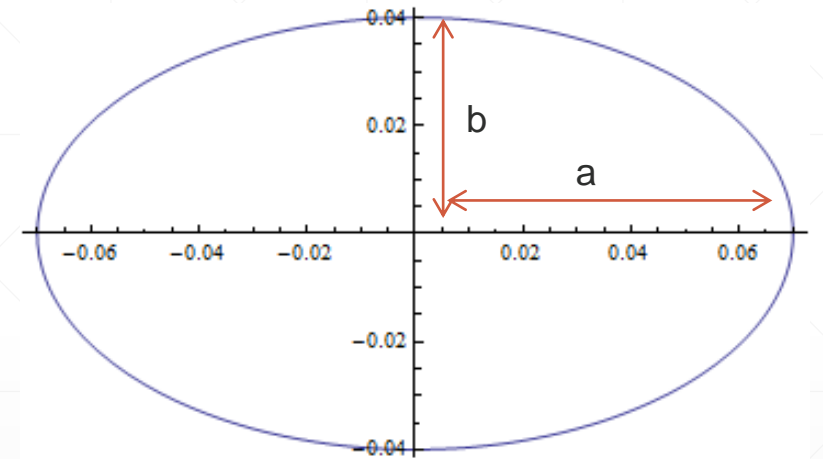
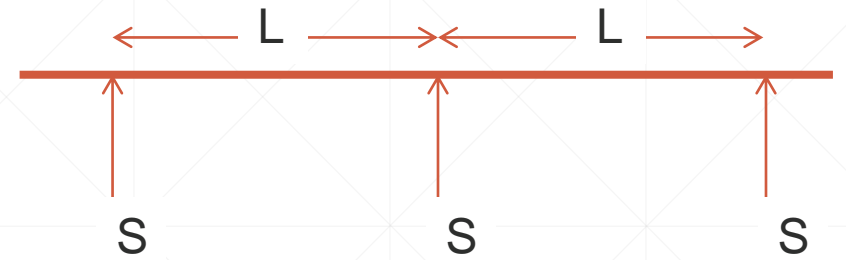
Minor half-width of pipe [m] = 0.07

Specific surface area
'seen' by vacuum [cm²/m] = 35

Specific out-gassing rate
(enter #.#E##) [Torr l/s/cm²] = 10.E-12

Absolute temperature [K] = 300

Molecular weight of residual gas = 28



OUTPUT:

Maximum pressure [Torr] = **1.01E-0010**

Average pressure [Torr] = **9.13E-0011**

Minimum pressure [Torr] = **7.00E-0011**

**Conductance of pipe
(over separation lgth)** [L/s] = **13.72**

**Specific conductance
of pipe** [l m/s] = **137.19**

Pressure can be transformed to
particle density:

$$P.V = N.k.T$$

10^{-10} Torr ~ 3 million particles/cm³

(1mbar ~0.75 Torr)

Datei Start Einfügen Seitenlayout Formeln Daten Überprüfe						
D25 f_x						
	A	B	C	D	E	F
1	11:59:30					
2	VACUUM SYSTEM DESIGN: INPUT- can be reloaded, do not re-format					
3	Pump separation [m] =5					
4	Pump speed [l/s] =50					
5	Major half-width of pipe [m] =0.04					
6	Minor half-width of pipe [m] =0.07					
7	Specific surface area 'seen' by vacuum [cm ² /m] =35					
8	Specific out-gassing rate [Torr l/s/cm ²] =10E-12					
9	Absolute temperature [K] =300					
10	Molecular weight of residual gas =28					
11						
12						
13	VACUUM SYSTEM DESIGN: OUTPUT					
14	Maximum pressure [Torr] = 4.30E-0011					
15	Average pressure [Torr] = 4.03E-0011					
16	Minimum pressure [Torr] = 3.50E-0011					
17	Conductance of pipe (over separation lgth) [l/s] = 27.44					
18	Specific conductance of pipe [l m/s] = 137.19					
19						
20						

Output can be saved in an EXEL-file

Summary of vacuum system design parameters:

- Conductance of pipe (over separation lgth) [l/s] = 27.44
- Specific conductance of pipe [l m/s] = 137.19

Buttons: Copy data to clipboard, Copy data to notebook, Load from notebook

Additional parameters: shields, screens, bellows etc. eg. C = 1 E -12, temp-down = 2 E -9

$$P(x) = A_0 \left\{ \frac{Lx - x^2}{2\omega} + \frac{L}{S} \right\}$$

$$P_{\max} = A_0 \left\{ \frac{L^2}{8\omega} + \frac{L}{S} \right\}$$

$$P_{\text{av}} = A_0 \left\{ \frac{L^2}{12\omega} + \frac{L}{S} \right\}$$

$$P_{\text{av}} = A_0 / S_{\text{eff}} \quad \text{where } S_{\text{eff}} = \left(\frac{L^2}{12\omega} + \frac{L}{S} \right)^{-1}$$

(2)

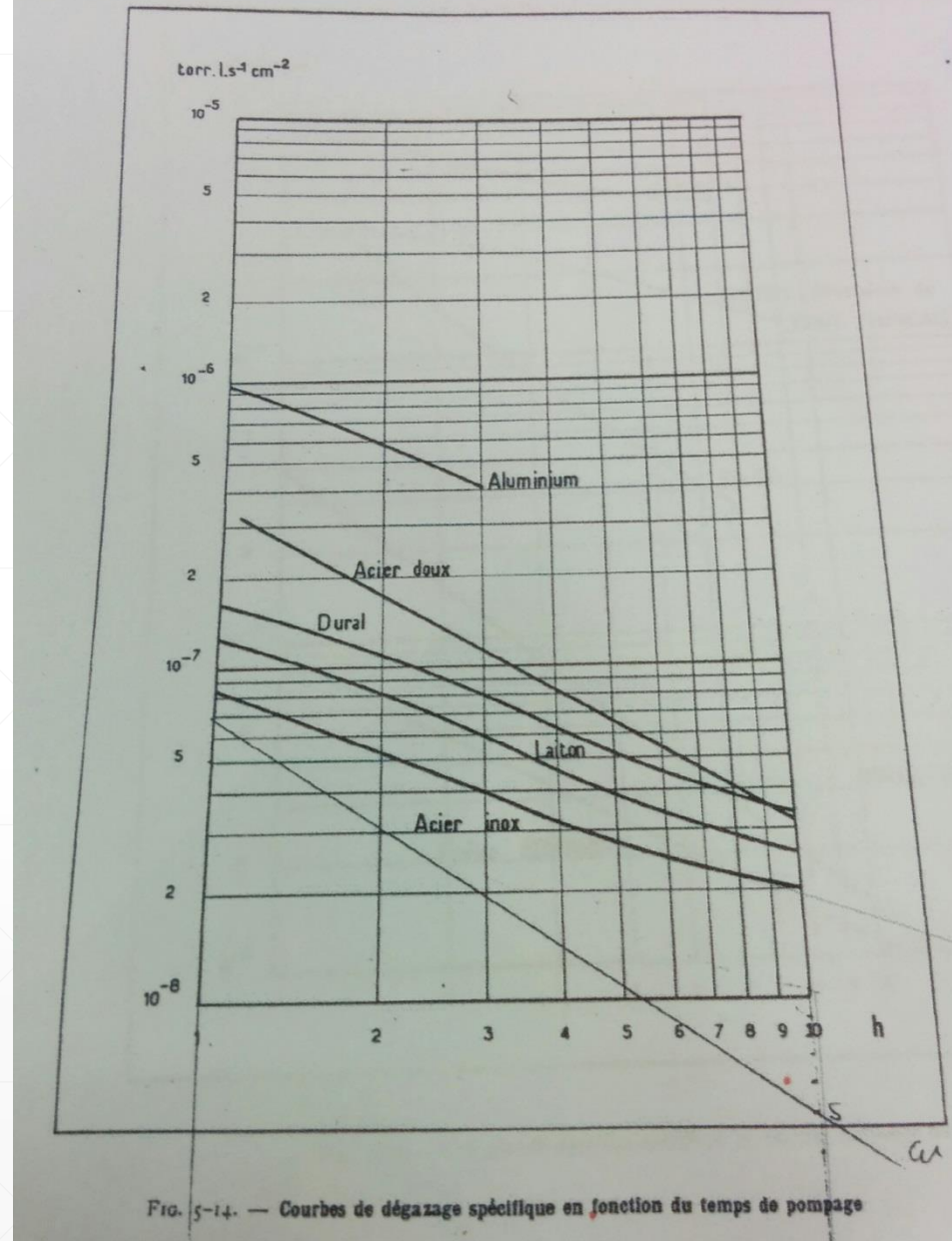


FIG. 5-14. — Courbes de dégazage spécifique en fonction du temps de pompage

Magnet consideration

Dipoles

MAIN SPECIFICATIONS

Bmax [T]	1.09
Bending Radius [mm]	61500
Bending Angle [°]	7,44
Magnet lenght [mm]	8000

IRON YOKE SPECIFICATIONS

Pole iron gap [mm]	100
L overall [mm]	8270
L iron [mm]	7870
Pole width [mm]	500
Overall width [mm]	1400
Overall height [mm]	1100

COIL SPECIFICATIONS

Number of turns	220
Nominal current [A]	393
Conductor type	Hollow
Conductor dimensions [mm]	14 x 14
Hole diamater [mm]	8,5

WATER-COOLED COIL DESIGN AID...

INTRODUCTION:

- Parameters are for a SINGLE water circuit.
- It is left to the user to combine water circuits in series/parallel to get the overall temperature rise, power consumption, etc.
- For circular conductors, set conductor height = width and the rounding radius = 0.5*width.

INPUT:

Conductor height [mm] = 17.15

Conductor width [mm] = 17.15

Diameter of water hole [mm] = 10.6

Radius of edge rounding [mm] = 3

Conductor length in a single water circuit [m] = 50

Available water pressure for a single circuit [bar] = 4

Input water temp. [deg C] = 18

Current [A] = 393

Conductor material: Copper Aluminium

OUTPUT FOR SINGLE WATER CIRCUIT:

Water speed [m/s] = 2.61263

Water flow [l/min] = 13.83346

Water flow (turbulent/laminar) TURBULENT

Water temp. rise [deg C] = 0.67739

Power dissipation [watt] = 652.822

Resistance (hot) [ohm] = 0.004227

Current density [A/mm²] = 1.98335

Conductor mass [kg] = 88.50347

RESPONSE TIME:

If the cooling water is cut off, then the temperature will rise at the rate of ; 0.019 [deg C/s]

COMPUTE

Load from notebook Paste time stamp QUIT Copy data to clipboard Copy data to notebook

NOTES:

- Typical values for lattice magnets: turbulent water flow at 3-5 m/s; current density 3-5 A/mm²; pressure drop 4-8 bar; temperature rise 10-30 deg C. For air cooling, keep below 2 A/mm².
- For septa, parameters are more extreme: try not to exceed a current density of 50 A/mm² (abs. max. 90 A/mm²); try not to exceed a water velocity of 10 m/s; try to use a square conductor to facilitate bends in both planes.
- For high current densities, check the rate of temperature rise if the water stops and be sure the temperature interlock is fast enough to cut the current.
- The maximum length of conductor without a braze is limited by the maximum billet size for drawing (120 kg approx. for Cu).

Qadrupoles

MAIN SPECIFICATIONS

Maximum gradient [T/m]	6,6
Magnet lenght [mm]	450

IRON YOKE SPECIFICATIONS

Aperture diameter[mm]	100
L overall [mm]	500
Liron [mm]	450
Overall Width [mm]	400

COIL FEATURES

Number of turns per pole	36
Nominal current [A]	183
Conductor type	Hollow
Conductor dimensions [mm]	9,4 x 9,4
Hole diamater [mm]	5,83

WATER-COOLED COIL DESIGN AID...

INTRODUCTION:

- Parameters are for a SINGLE water circuit.
- It is left to the user to combine water circuits in series/parallel to get the overall temperature rise, power consumption, etc.
- For circular conductors, set conductor height = width and the rounding radius = 0.5*width.

INPUT:

Conductor height [mm] = 9.4

Conductor width [mm] = 9.4

Diameter of water hole [mm] = 5.86

Radius of edge rounding [mm] = 3

Conductor length in a single water circuit [m] = 6

Available water pressure for a single circuit [bar] = 4

Input water temp. [deg C] = 18

Current [A] = 183

Conductor material: Copper Aluminium

OUTPUT FOR SINGLE WATER CIRCUIT:

Water speed [m/s] = 5.74642

Water flow [l/min] = 9.29894

Water flow (turbulent/laminar) TURBULENT

Water temp. rise [deg C] = 0.09670

Power dissipation [watt] = 62.645

Resistance (hot) [ohm] = 0.001871

Current density [A/mm²] = 3.41010

Conductor mass [kg] = 2.87629

RESPONSE TIME:

If the cooling water is cut off, then the temperature will rise at the rate of ; 0.057 [deg C/s]

COMPUTE

Load from notebook Paste time stamp QUIT

Copy data to clipboard Copy data to notebook

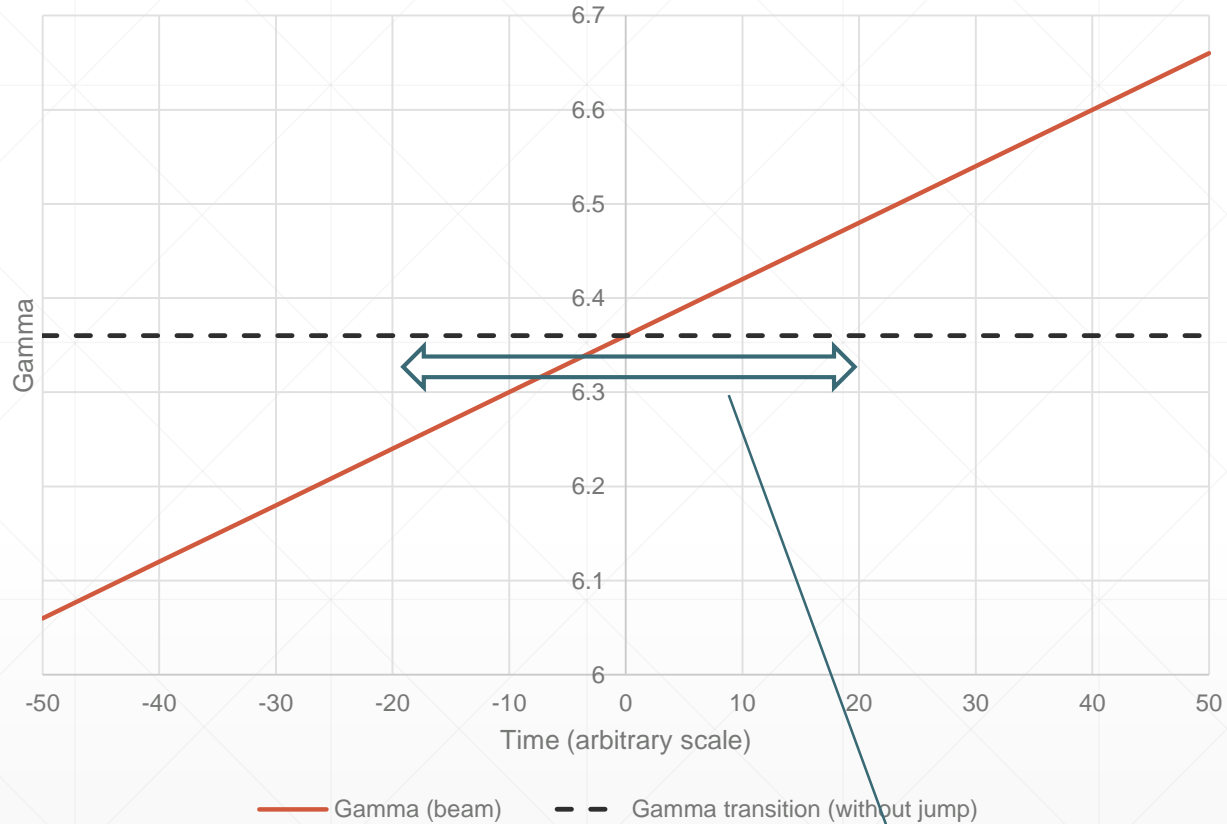
NOTES:

- Typical values for lattice magnets: turbulent water flow at 3-5 m/s; current density 3-5 A/mm²; pressure drop 4-8 bar; temperature rise 10-30 deg C. For air cooling, keep below 2 A/mm².
- For septa, parameters are more extreme: try not to exceed a current density of 50 A/mm² (abs. max. 90 A/mm²); try not to exceed a water velocity of 10 m/s; try to use a square conductor to facilitate bends in both planes.
- For high current densities, check the rate of temperature rise if the water stops and be sure the temperature interlock is fast enough to cut the current.
- The maximum length of conductor without a braze is limited by the maximum billet size for drawing (120 kg approx. for Cu).

Transition considerations

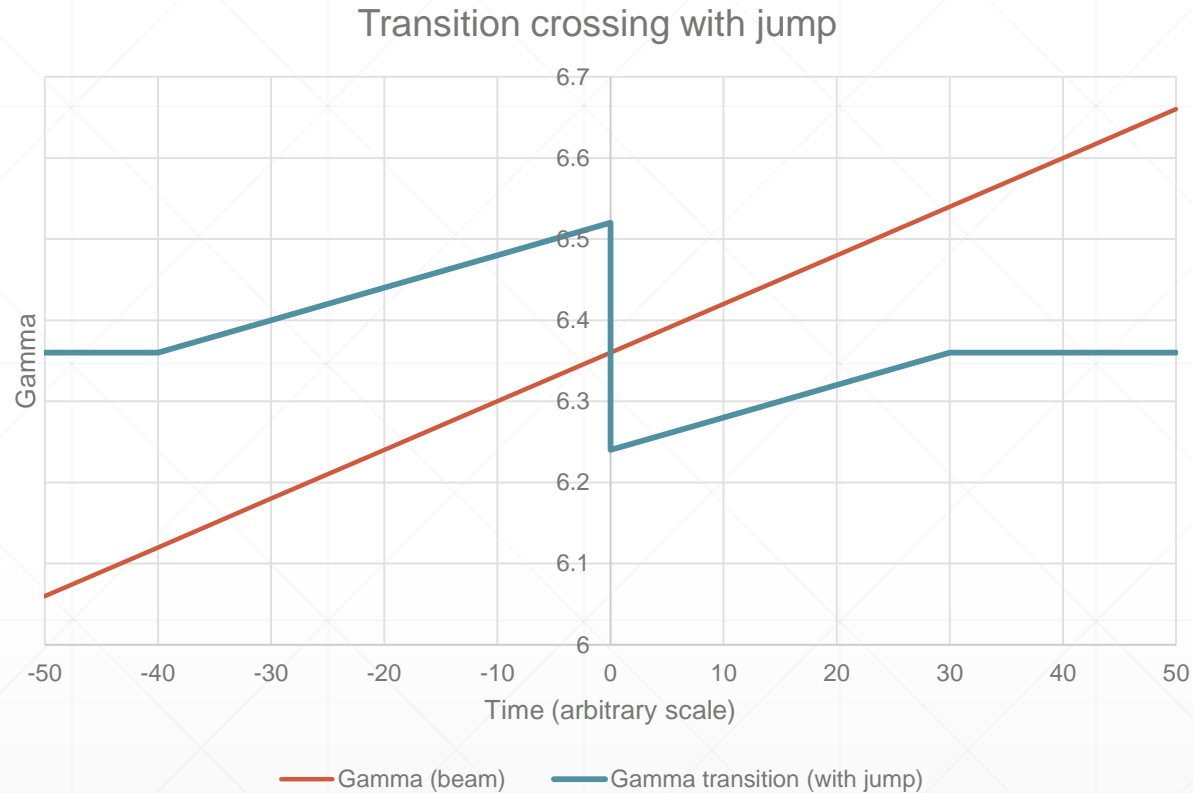
Gamma transition crossing I

Transition crossing without jump



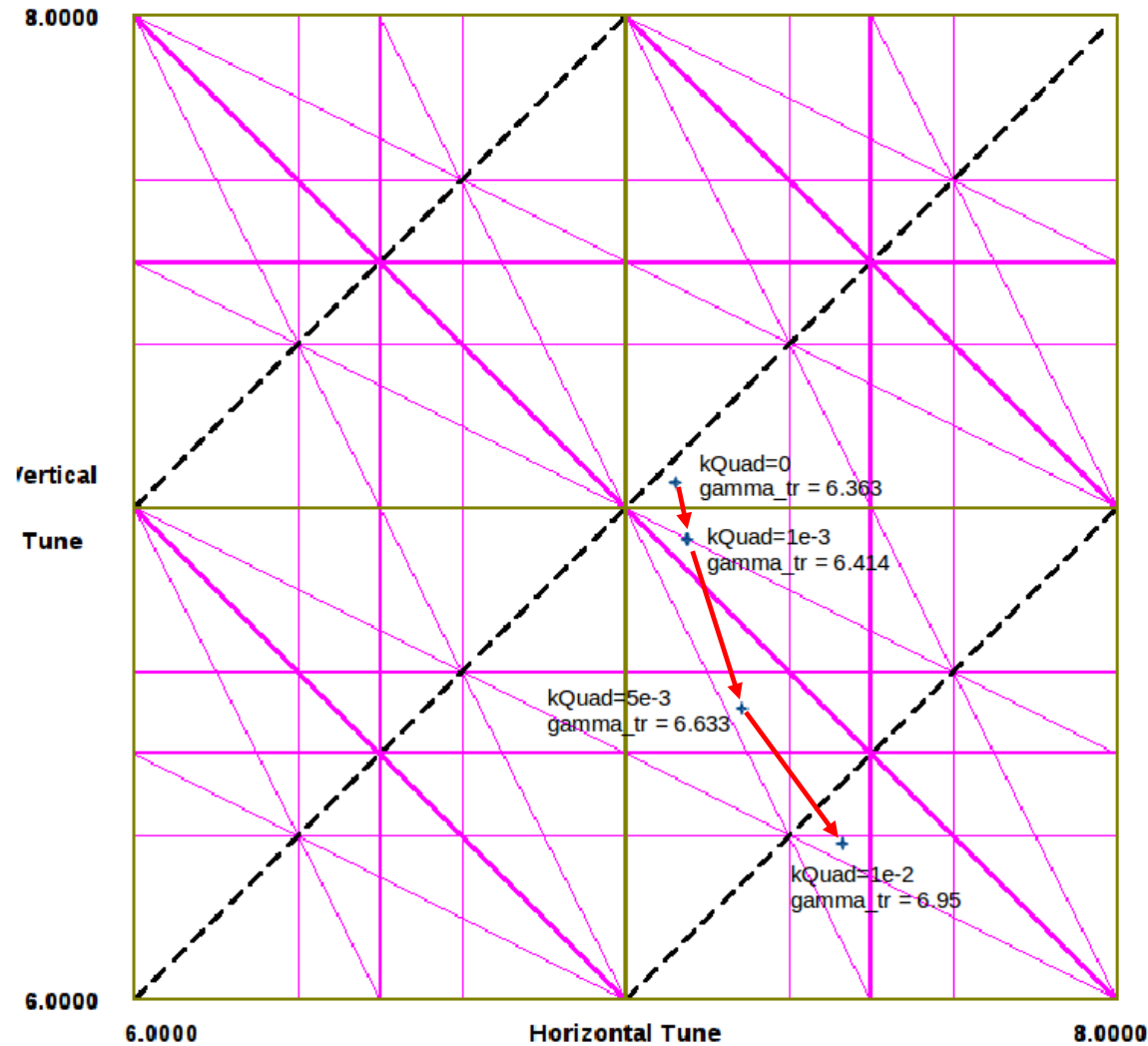
- Non adiabatic theory needed
- At transition, bunch length \searrow and momentum spread \nearrow
- Main risk: losses in the beam

Gamma transition crossing II



- Solution: create a jump in γ_{tr}
- How to: add quadrupoles to change the momentum compaction factor
- Problem: adding quadrupole changes the tune

Gamma transition crossing III



- Switch on the quadrupoles:
 - γ_{tr} increases
- Switch off or invert the polarity of the quadrupoles at the right time
 - γ_{tr} decreases suddenly
 - You have crossed transition
- The tune changes
 - You may cross resonances
 - To avoid it, one may want to change the tune before the gamma jump and reestablished it afterward

Gamma transition crossing

- Do we have time to do this gamma jump?
- Assume a 30kV RF cavity, a $\dot{B} = 3,6 T/s$ and a $\gamma_{tr} = 6,36$
- Therefore $\Delta E = 10 MeV/turn$
- A $\Delta\gamma = 0,27$ means an increase in energy of $\Delta E = 250 MeV$ so we would need approximately 10 turns to operate the quadrupoles (about 300 μ s)

Thanks for your attention

Spare slides

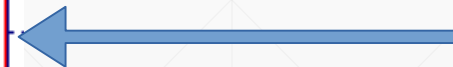
Chromaticity correction

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Chromaticity correction I

- In order to correct the chromaticity 2 sextupoles were added, one focusing and one defocussing
- The sextupoles were placed next to the defocussing quadrupoles
- WinAGILE calculated the closed orbit parameters (without sextupoles):

CENTRAL ORBIT			
Circular machine			
Circumference	[m] =		943.0480
Horizontal tune	Qx =		7.104830
Vertical tune	Qz =		7.054848
Horizontal chromaticity	dQx/dp/p =		-8.513
Vertical chromaticity	dQz/dp/p =		-3.349
Gamma transition	gamma tr =		6.36840



Chromaticity correction II

- To steps to find the strength of the sextupoles are:
 - Go into calculations menu
 - Select correct chromaticity
 - In the menu select the desired chromaticity, e.g. 0.
 - Click on recompute, and it will display the strength needed
- After getting the values, it is recommended that you check it is feasible within technological restrictions.

1. ENTER DESIRED CHROMATICITIES:
Horizontal, $dQ_x/dp/p =$
Vertical, $dQ_z/dp/p =$

2. CHOOSE FROM INVENTORY:
EITHER click on unit in inventory
OR enter directly below the indices and increments to be used

2	__	QF1
4	__	SD
6	__	Dip1
8	__	QD1
28	__	QUADD1
33	__	QUADF1
38	__	QUADD2
43	__	QUADF2

3. UNITS/SERIES AND STEP-SIZES TO BE USED:
Index of 1st unit or unit in 1st series
Index of 2nd unit or unit in 2nd series
Step-size for 1st unit/series =
Step-size for 2nd unit/series =

(Re-) Compute

STATUS:

	$dQ_x/dp/p$	$dQ_z/dp/p$
Desired values =		
Obtained values =		
Residual errors =		

OK - accept new values **Reset original values**