Simulation tools
Optics v tracking

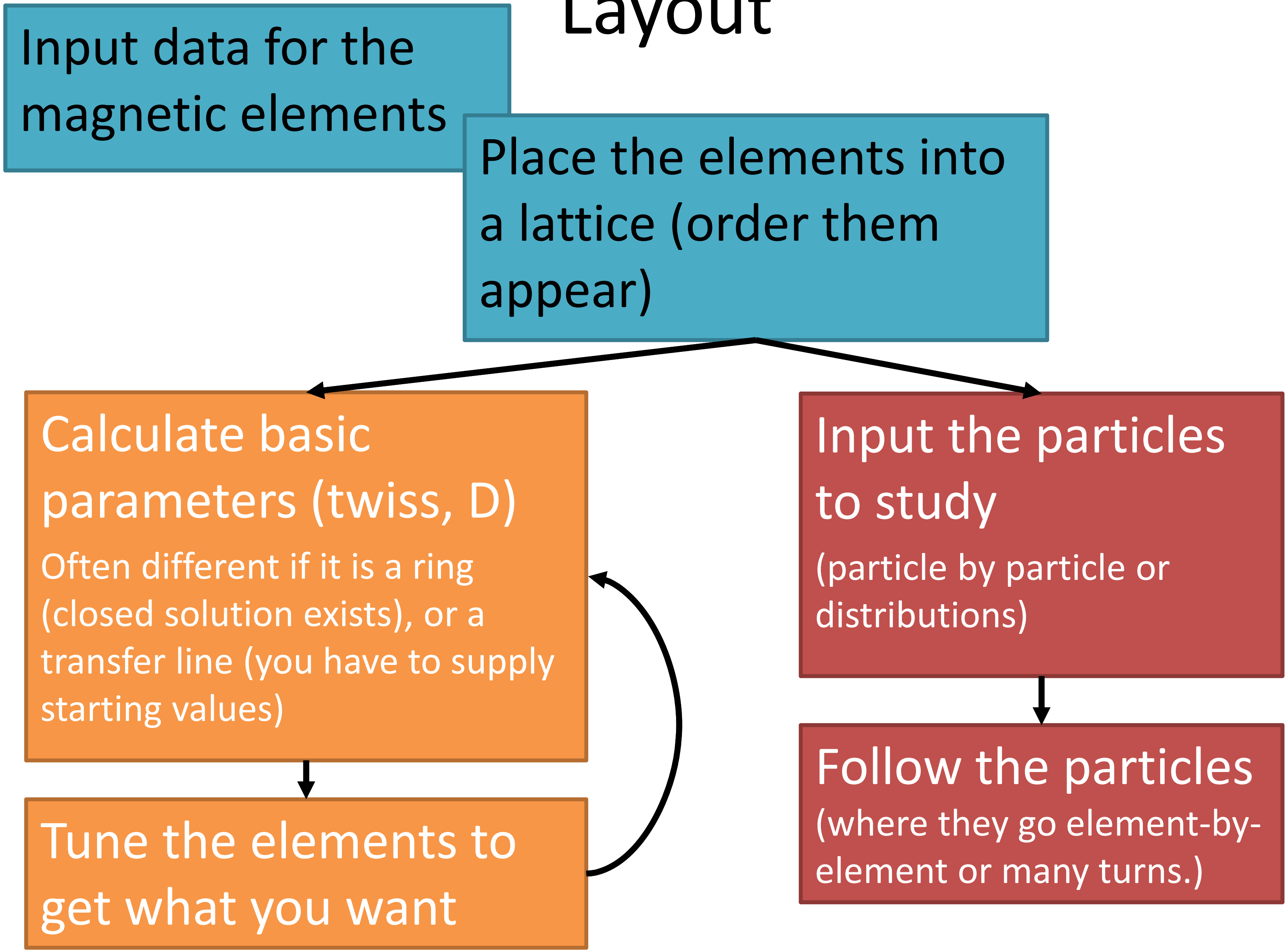
- Matrices, analytical, twiss parameters, tunes, stability, transients -> fast, first designs

v.

- Matrices, follow (track) particles, errors, non ideal beams, multiple effects -> slow, much data, detailed studies, statistics, study errors, computer power

- … and then combine.

Layout


Input data for the magnetic elements
Place the elements into a lattice (order them appear)
Calculate basic parameters (twiss, D)
Often different if it is a ring (closed solution exists), or a transfer line (you have to supply starting values)
Tune the elements to get what you want
Input the particles to study
(particle by particle or distributions)
Follow the particles
(where they go element-by-element or many turns.)

Codes

Beam dynamics/optics

Accelerator toolbox: MATLAB, MAX IV control system
http://controls.als.lbl.gov/als_physics/portmann/MiddleLayer/

Winagile: CERN, educational code, interface
http://indico.cern.ch/event/162969/contribution/27/attachments/191996/

OPA: Advanced design code, interface
(Mad
http://mad.web.cern.ch/mad/
, Dimad, Dimax…)

Synchrotron light

XOP: radiation and optical elements
Spectra: radiation w beam data
http://radiant.harima.riken.go.jp/spectra/
(Radiation2D: radiation visualisation)

Tracking codes

Elegant: linac optics
Astra: gun/linac optics, space charge
http://www.desy.de/~mpyflo/
Genesis 1.3: FEL
http://genesis.web.psi.ch/
Simplex: FEL, interface
http://radiant.harima.riken.go.jp/simplex/

Other

MATLAB PDE-tool: magnet design
Superfish: magnet design

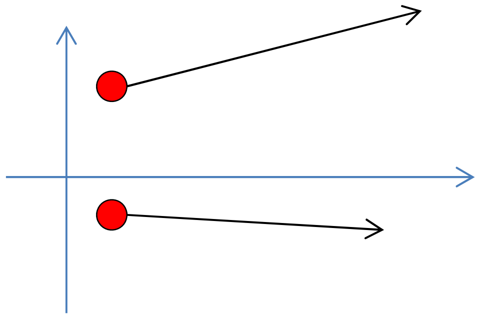
Prepare for the Simulation exercise

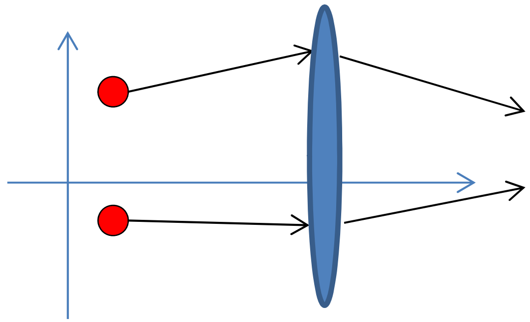
- (Download and install Winagile4) Available on the computers in the computer hall.
- Get the machine info file (.lat) from Teresia. (It is not complete and we will fix it together during the exercise)
- Read/look at chapter 13 in “Accelerator technique”.
- Read the Exercise instructions.
- (Try to run something .)

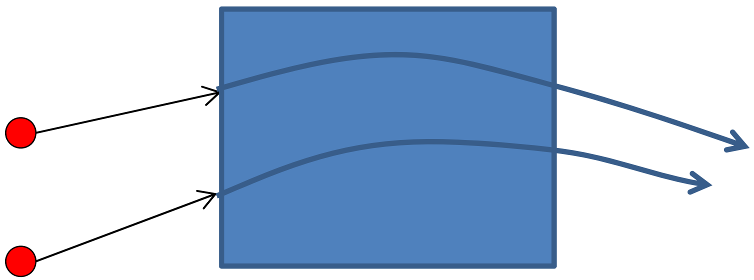
Repetition

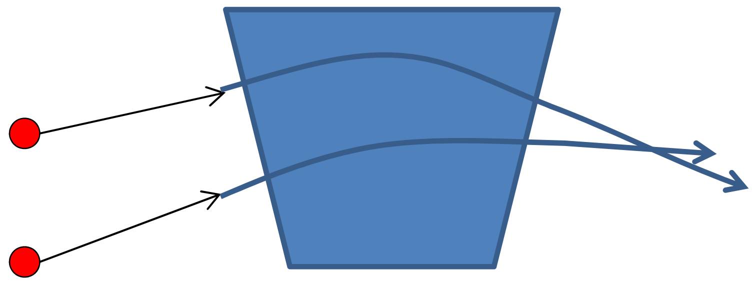
Accelerator simulations tools

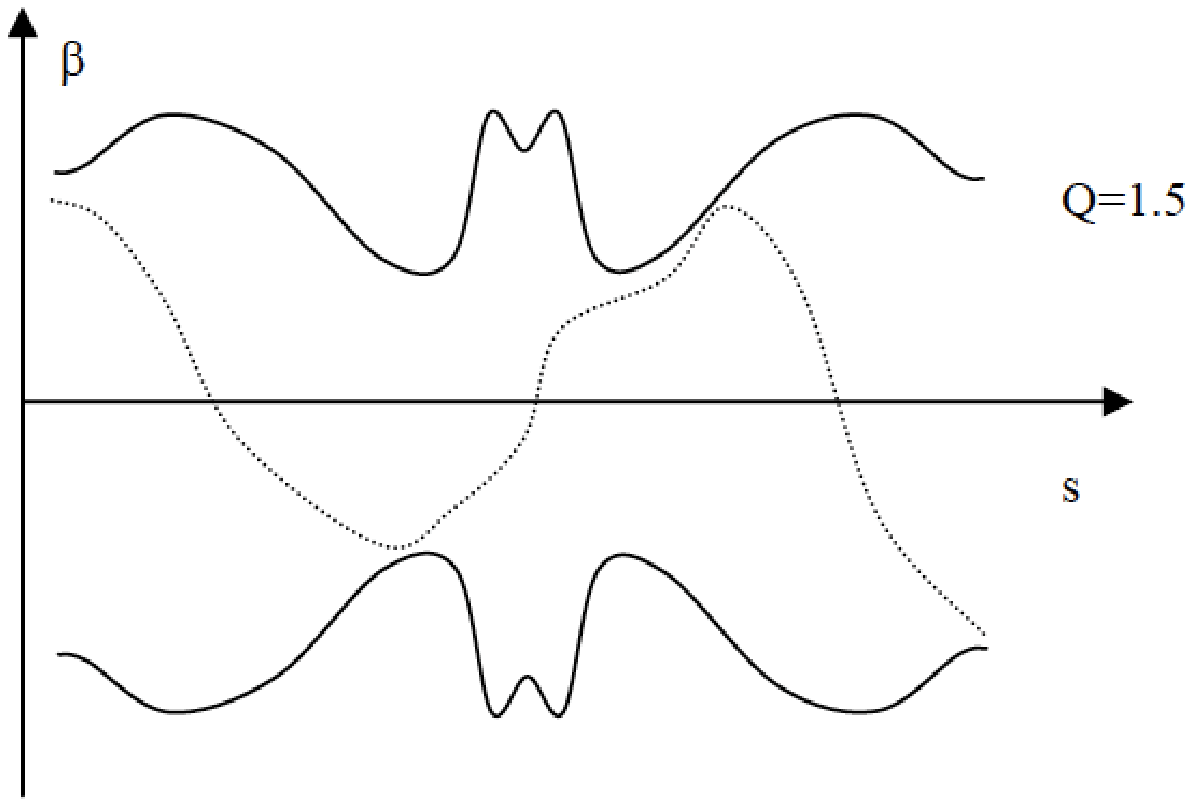
Measurements on accelerators











Betatron function and the path of an individual particle

Phase space and betatron oscillations

The position and angle of any particle around a circular machine can be described

$$\begin{pmatrix} x(s) \\ x'(s) \end{pmatrix} = \begin{pmatrix} \sqrt{\varepsilon}\sqrt{\beta(s)}\cos(\phi(s)-\phi_0) \\ -\frac{\sqrt{\varepsilon}}{\sqrt{\beta(s)}}(\sin(\phi(s)-\phi_0)+\alpha\cos(\phi(s)-\phi_0)) \end{pmatrix}$$

This is an ellipse in the phase space coordinates x(s) and x'(s)

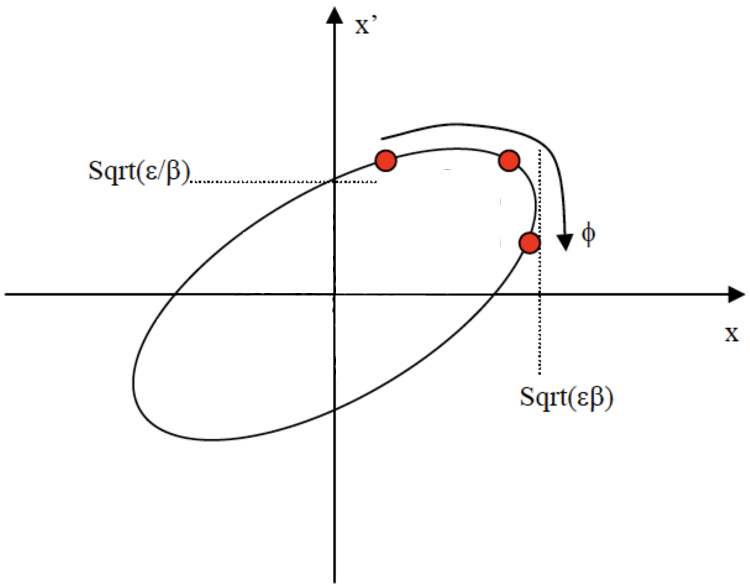
The amplitude of the oscillation is given by $(\varepsilon\beta(s))^{1/2}$

ε is a constant called emittance

β varies around the machine

The phase of the oscillation around the accelerator is given $\phi(s)$

ϕ_0 defines the position on the ellipse for the particle at a certain s



$$Area = \pi\sqrt{\varepsilon}\sqrt{\beta(s)}\frac{\sqrt{\varepsilon}}{\sqrt{\beta(s)}} = \pi\varepsilon$$

The area of the ellipse is constant and it is independent of s.

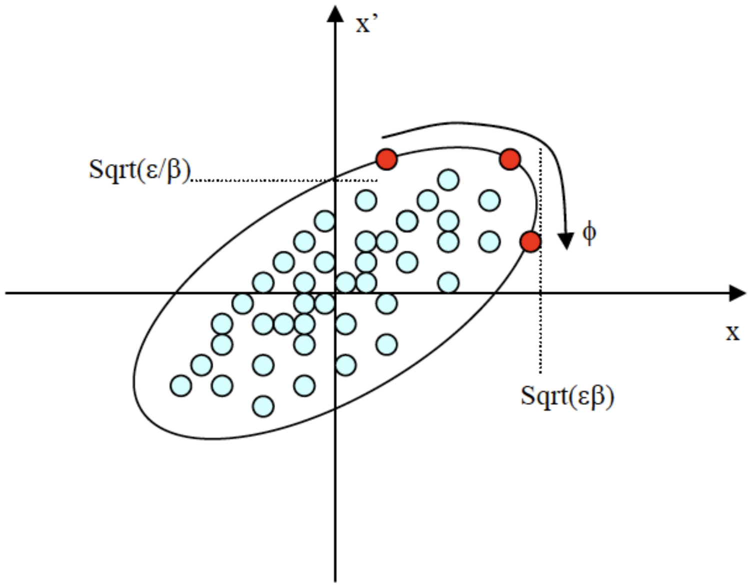
This is called Liouville's theorem.

Phase space ellipse of a beam consisting of many particles

The emittance of the individual particles of the beam in an electron storage ring have a Gaussian distribution.

The phase ellipse of the beam is drawn around the ensemble particles in the beam. Usually the emittance of the beam is defined as one standard deviation of the emittance distribution among the beam particles.

The RMS bunch size and divergence of the beam is hence given by :



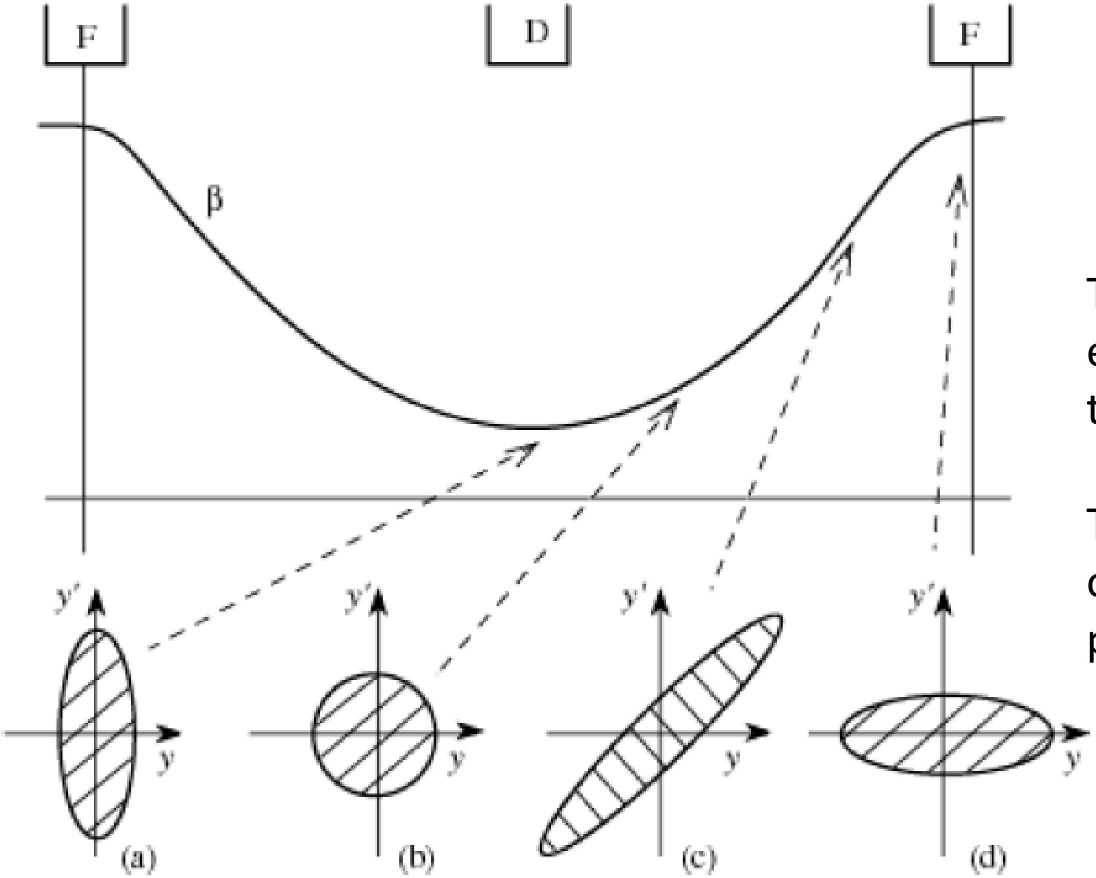
$$\sigma_x = \sqrt{\varepsilon\beta(s)}$$

$$\sigma_x' = \sqrt{\frac{\varepsilon}{\beta(s)}}$$

Large values of β(s) gives a large and parallel, non divergent beam
Small values of β(s) gives a small and divergent

Phase space ellipse variation with the beta function β(s)

Example from a FODO cell. FODO = Focusing+Drift+Defocusing+Drift



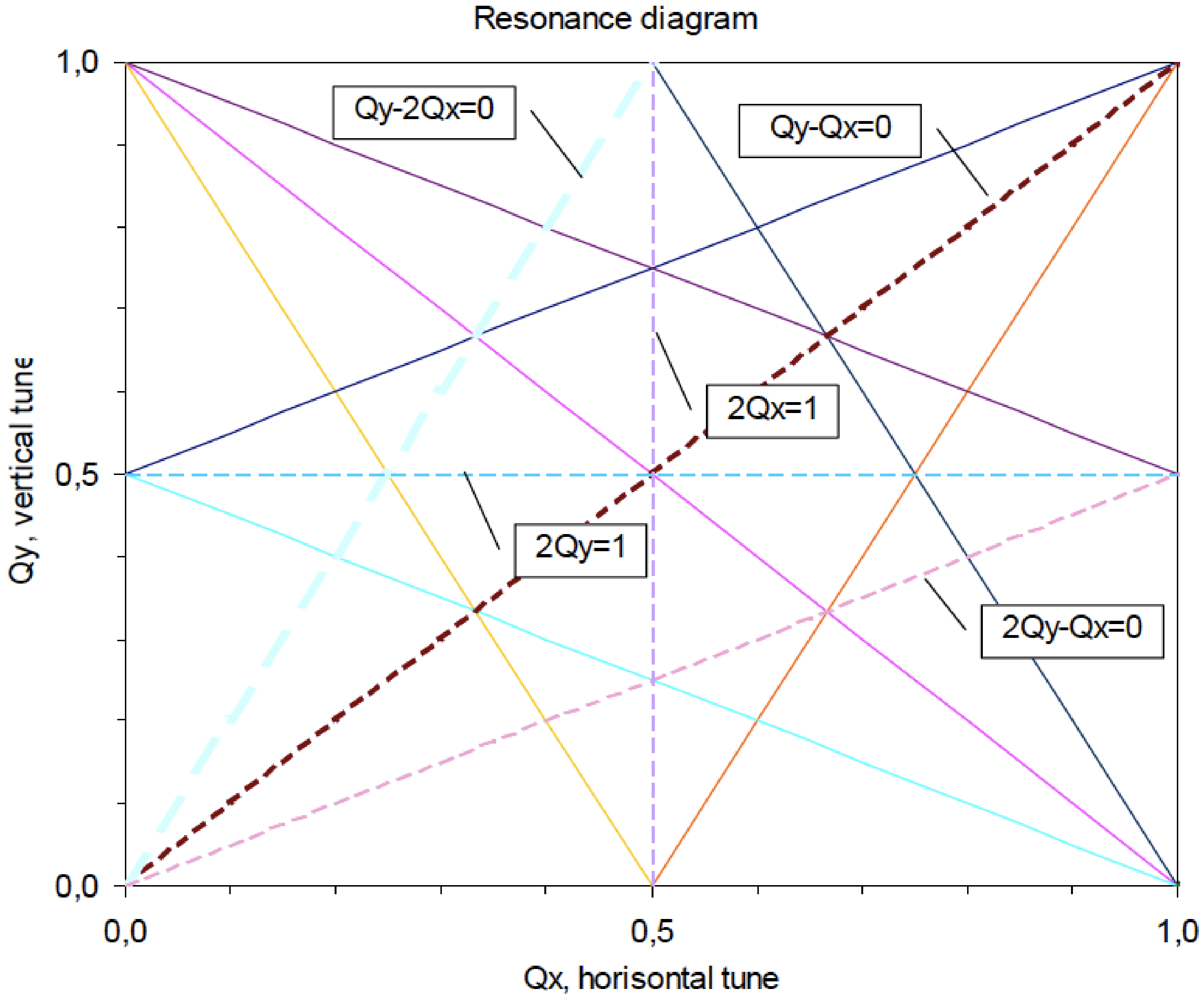
The tilt of the phase ellipse is given by the α-parameter.

The α-parameter is one of the Twiss parameters.

Large values of β(s) gives a large and parallel, non divergent beam
Small values of β(s) gives a small and divergent

Tune diagram

The tune diagram shows which Q, or betatron tunes, that give resonances



The operating point of the machine should be far from any resonances.