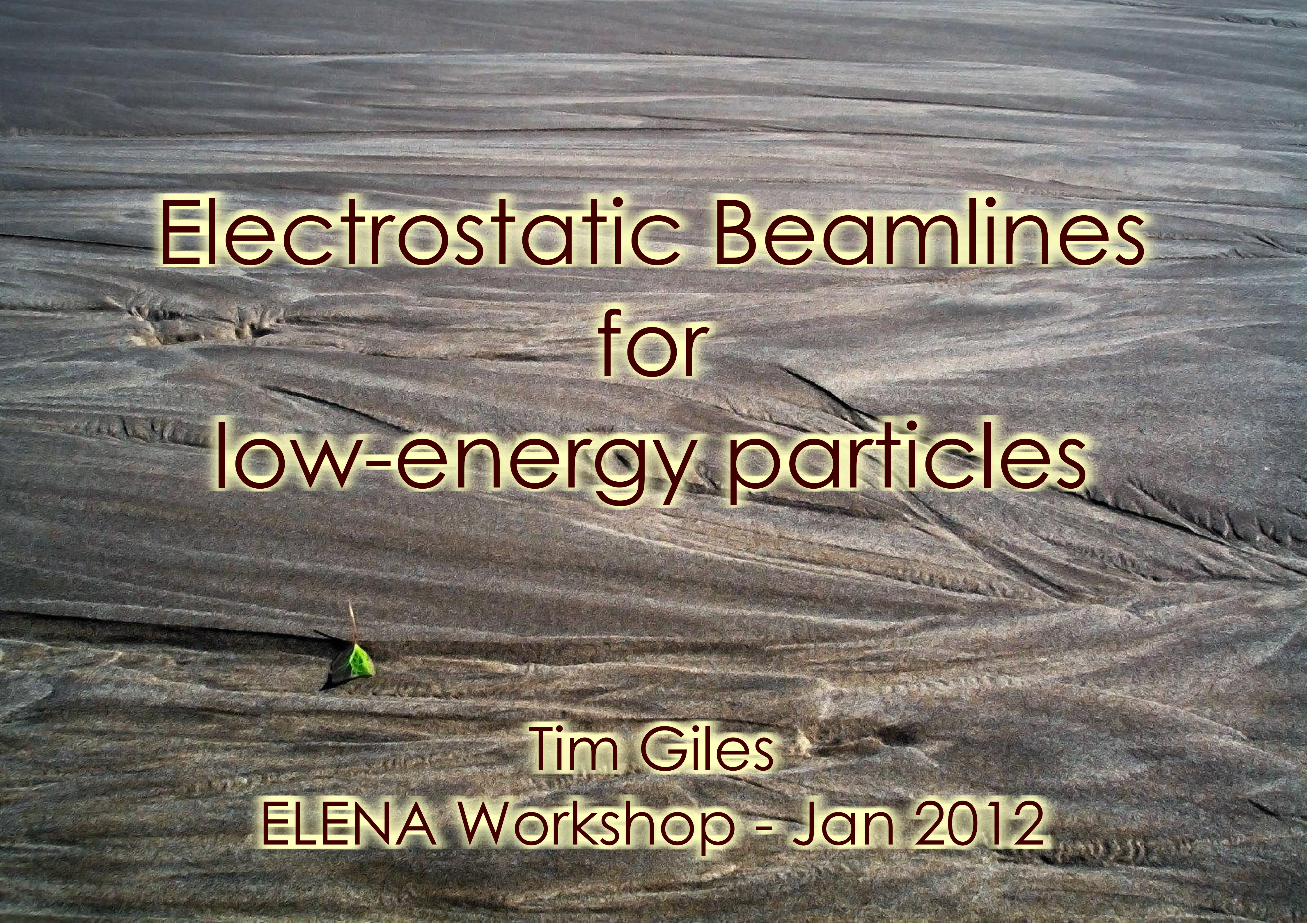


Electrostatic Beamlines
for
low-energy particles

Tim Giles

ELENA Workshop - Jan 2012

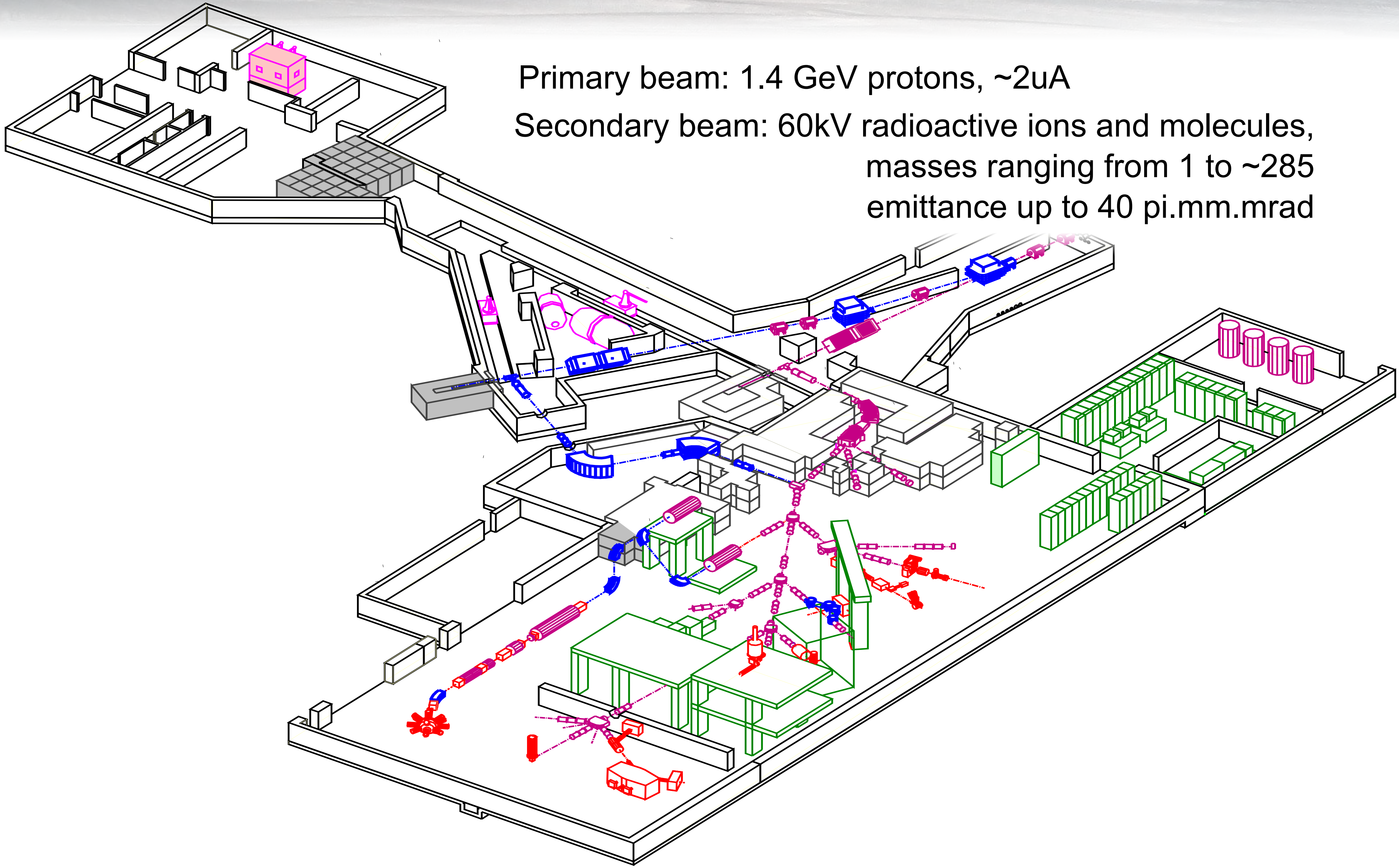
- Beamlines
- Lens Design
- Putting it all together

Tim Giles
ELENA Workshop - Jan 2012

Beamlines

Tim Giles
ELENA Workshop - Jan 2012

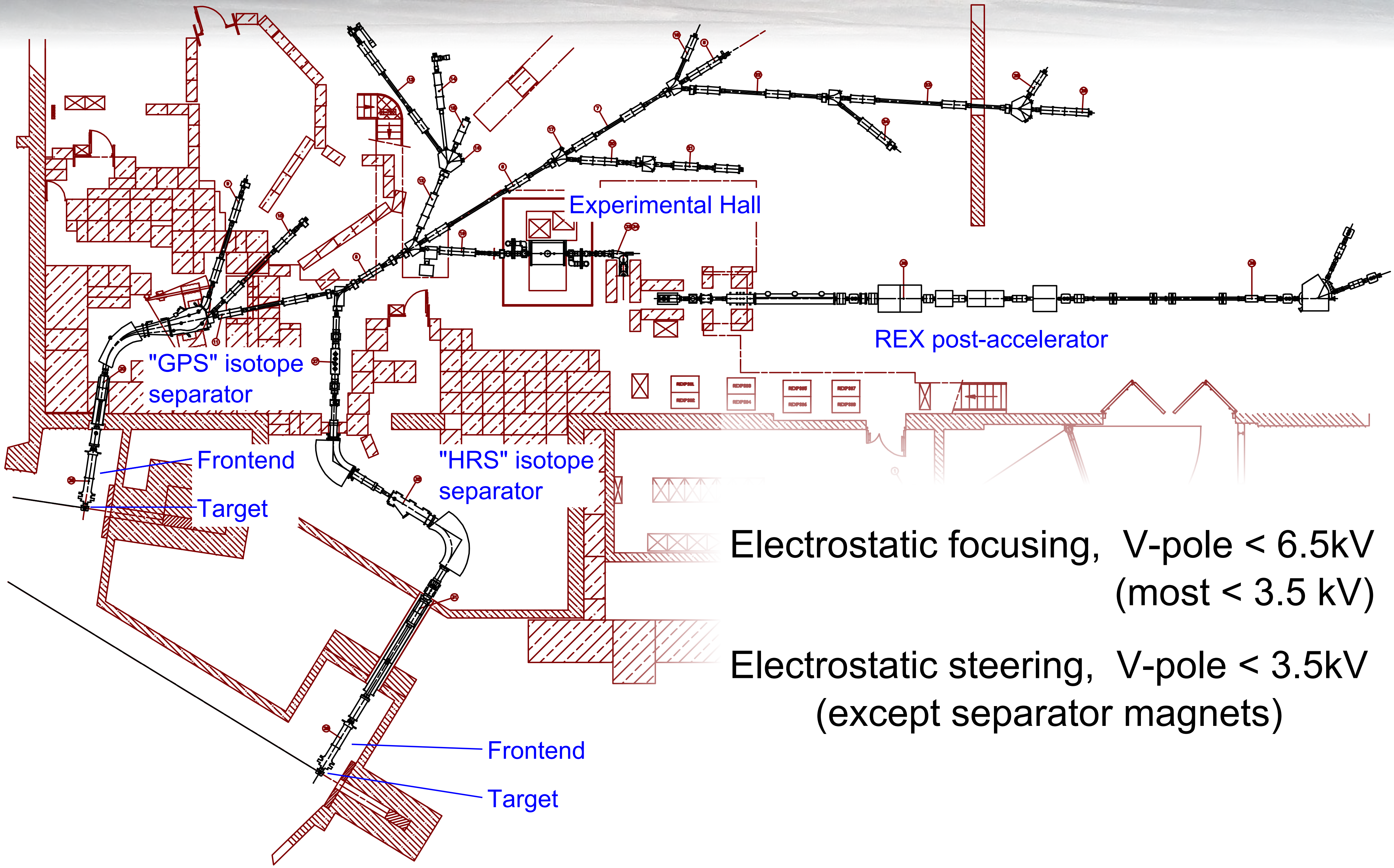
Isolde Layout



Primary beam: 1.4 GeV protons, ~2uA

Secondary beam: 60kV radioactive ions and molecules,
masses ranging from 1 to ~285
emittance up to 40 pi.mm.mrad

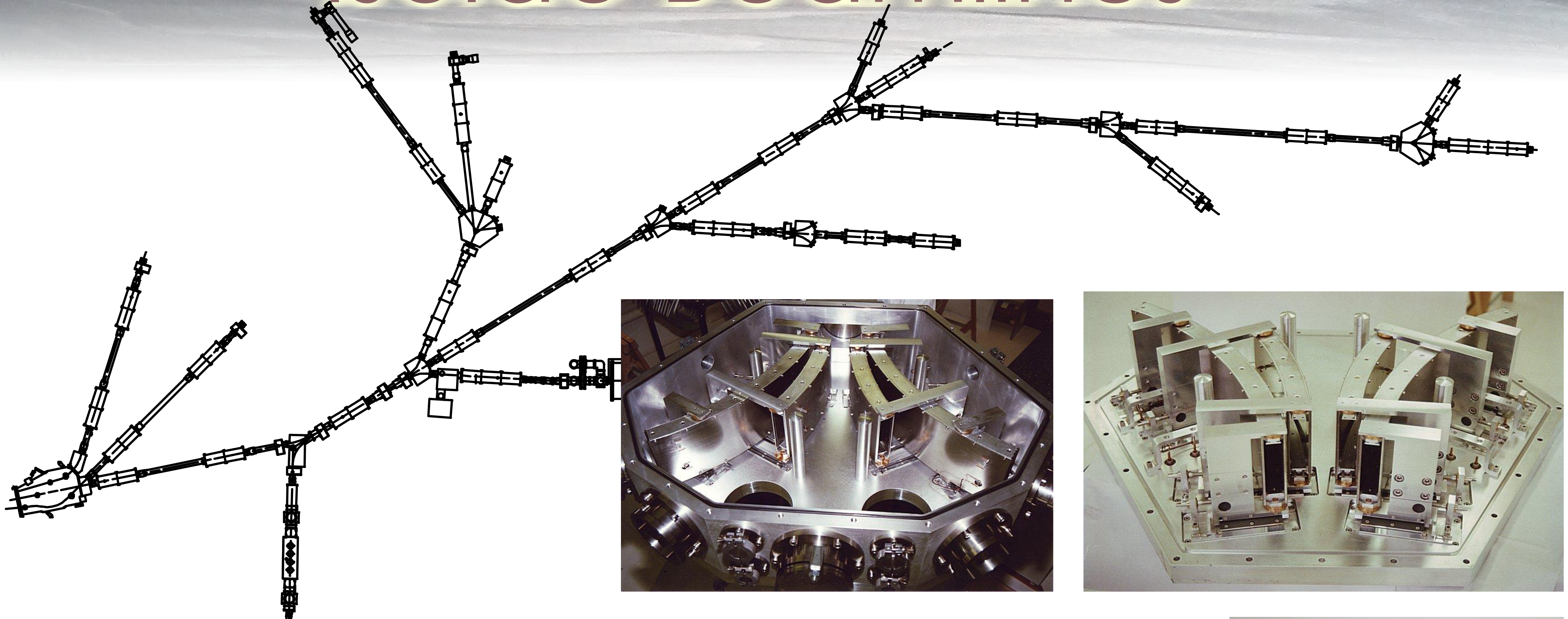
Isolde Beamlines

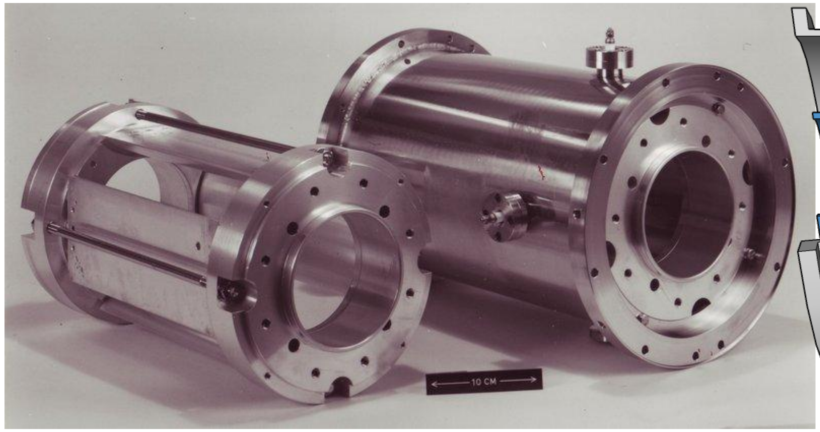


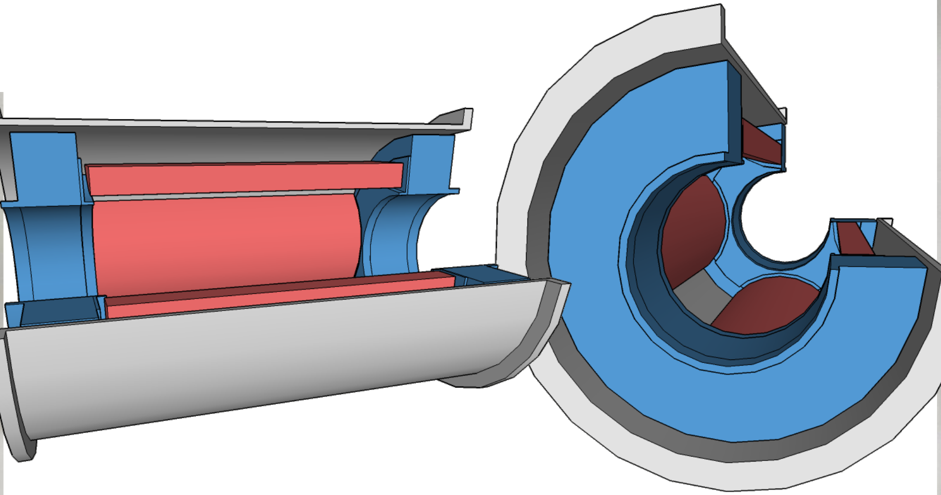
Electrostatic focusing, V-pole < 6.5kV (most < 3.5 kV)

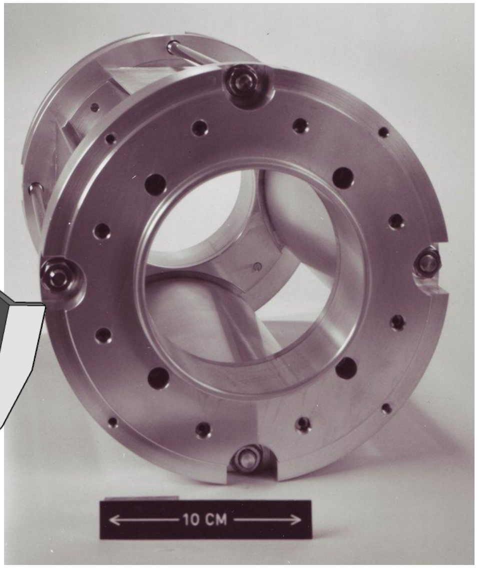
Electrostatic steering, V-pole < 3.5kV (except separator magnets)

Isolde Beamlines

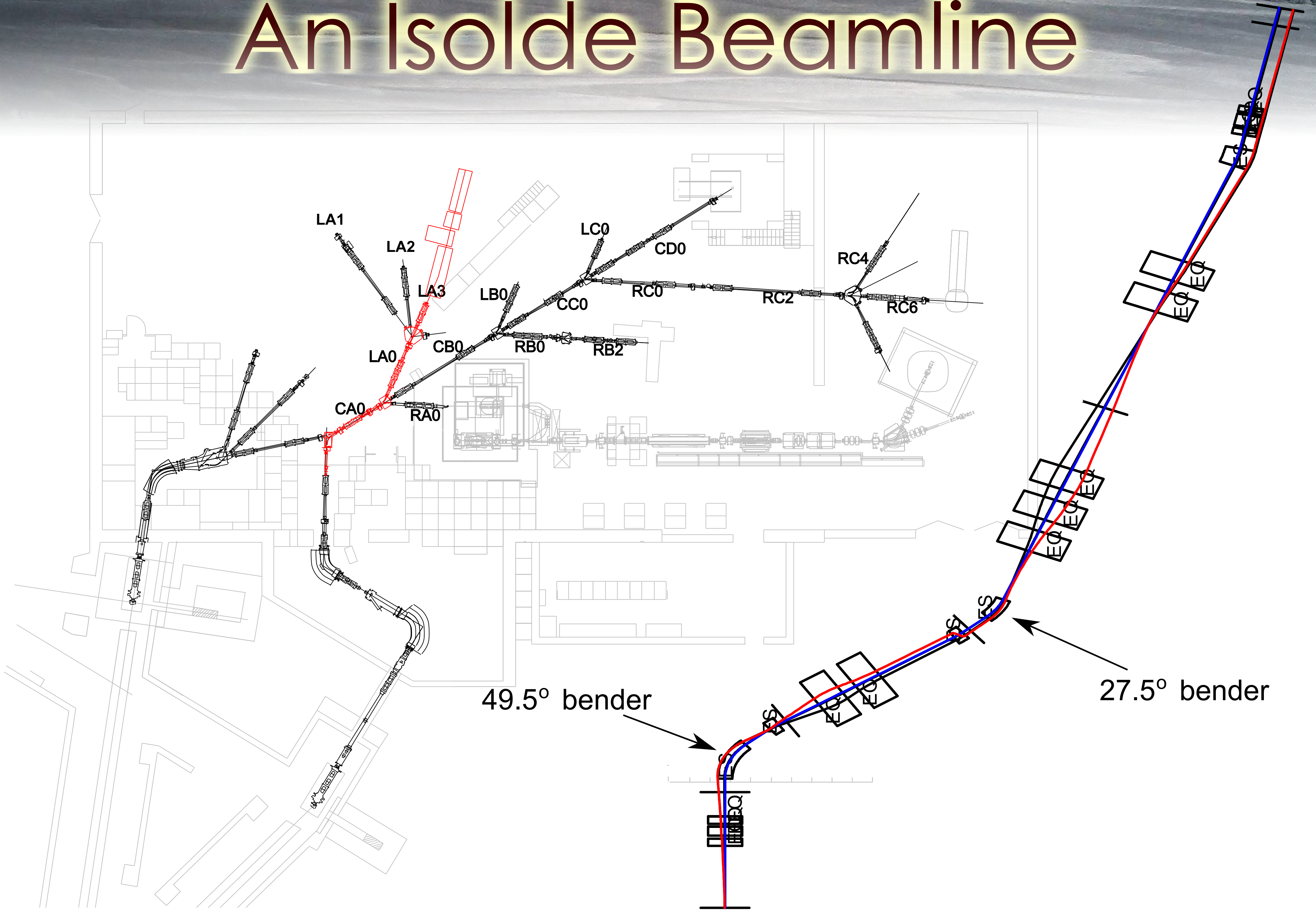








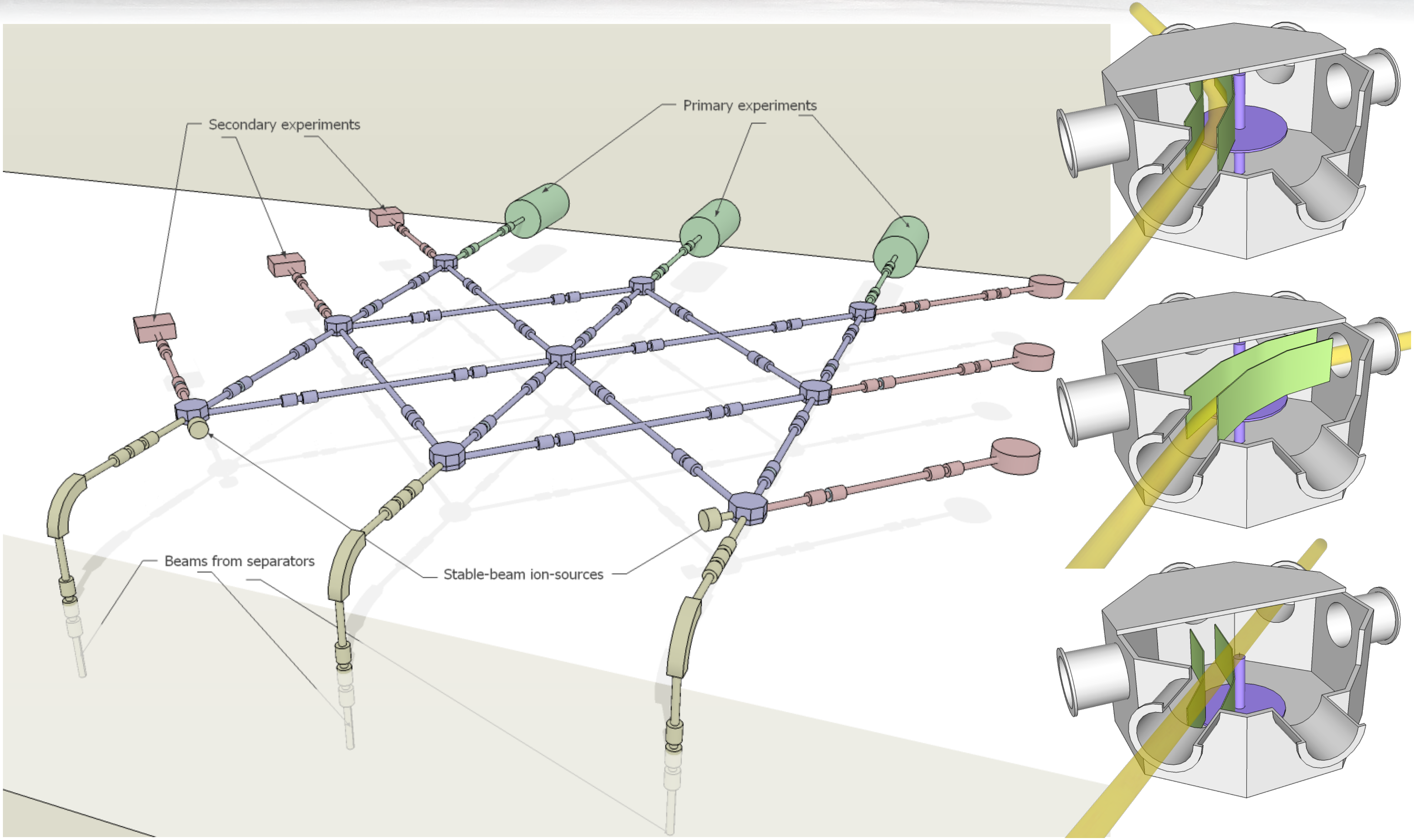
An Isolde Beamline



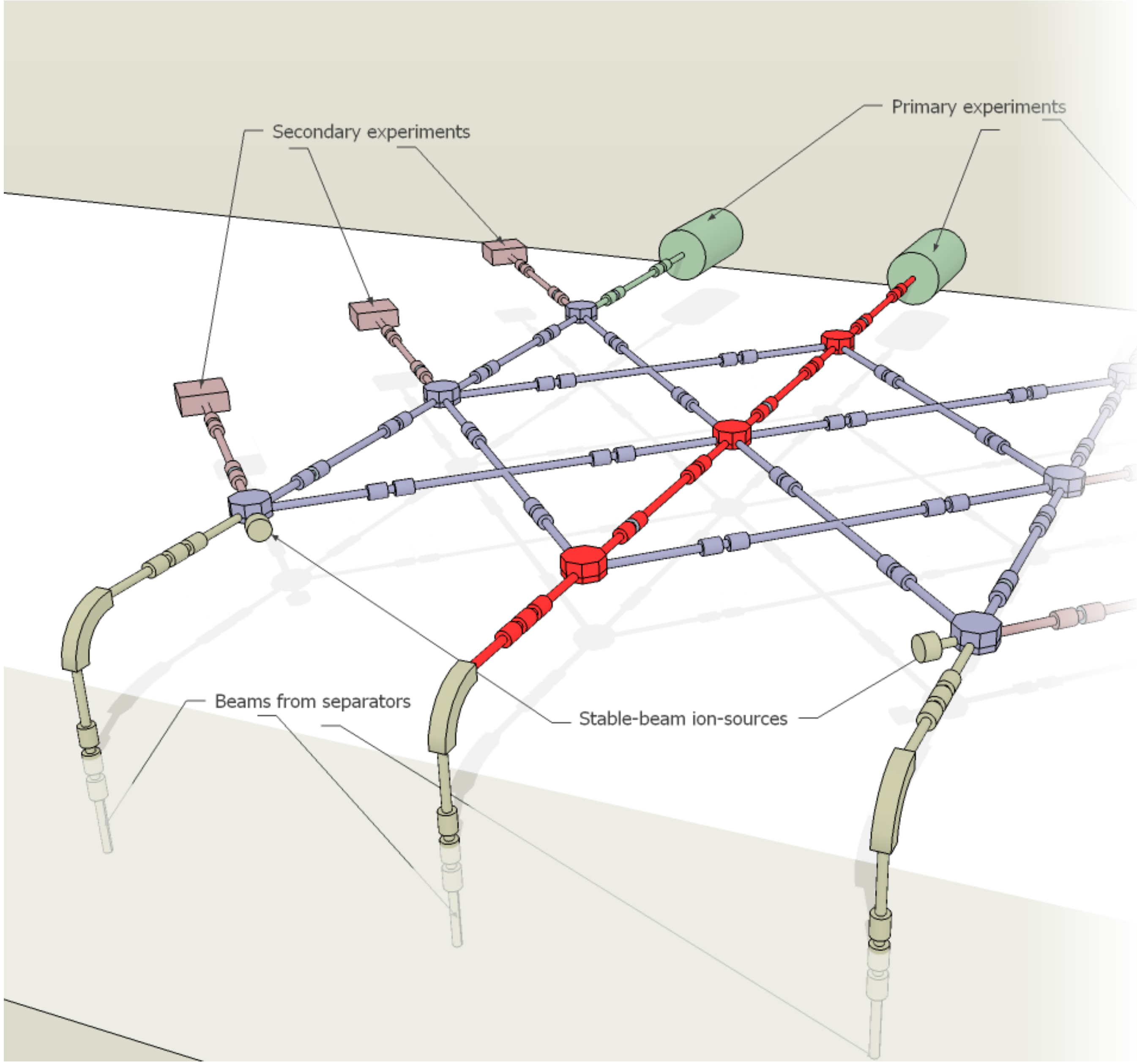
49.5° bender

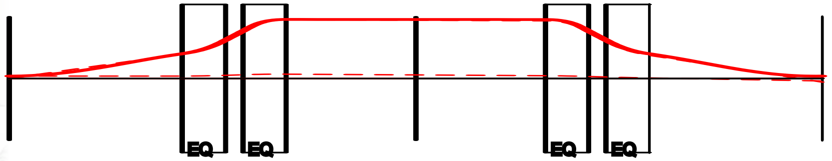
27.5° bender

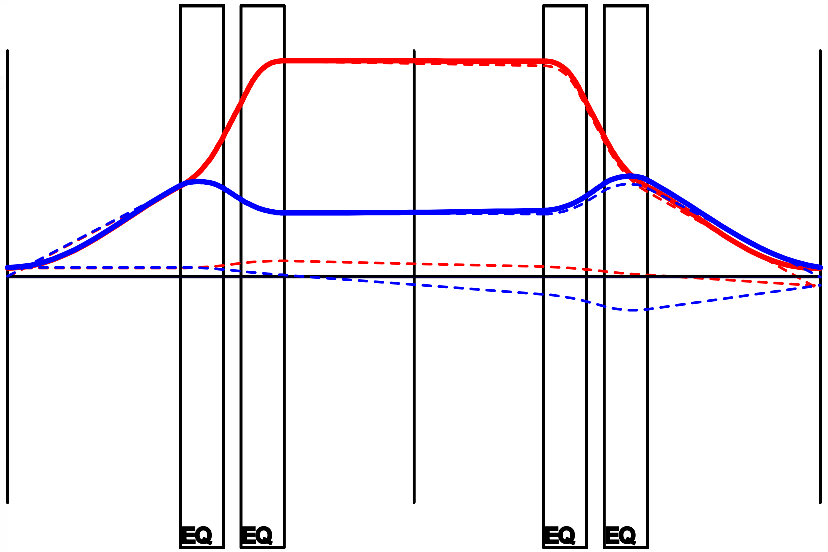
Better Beam Distribution



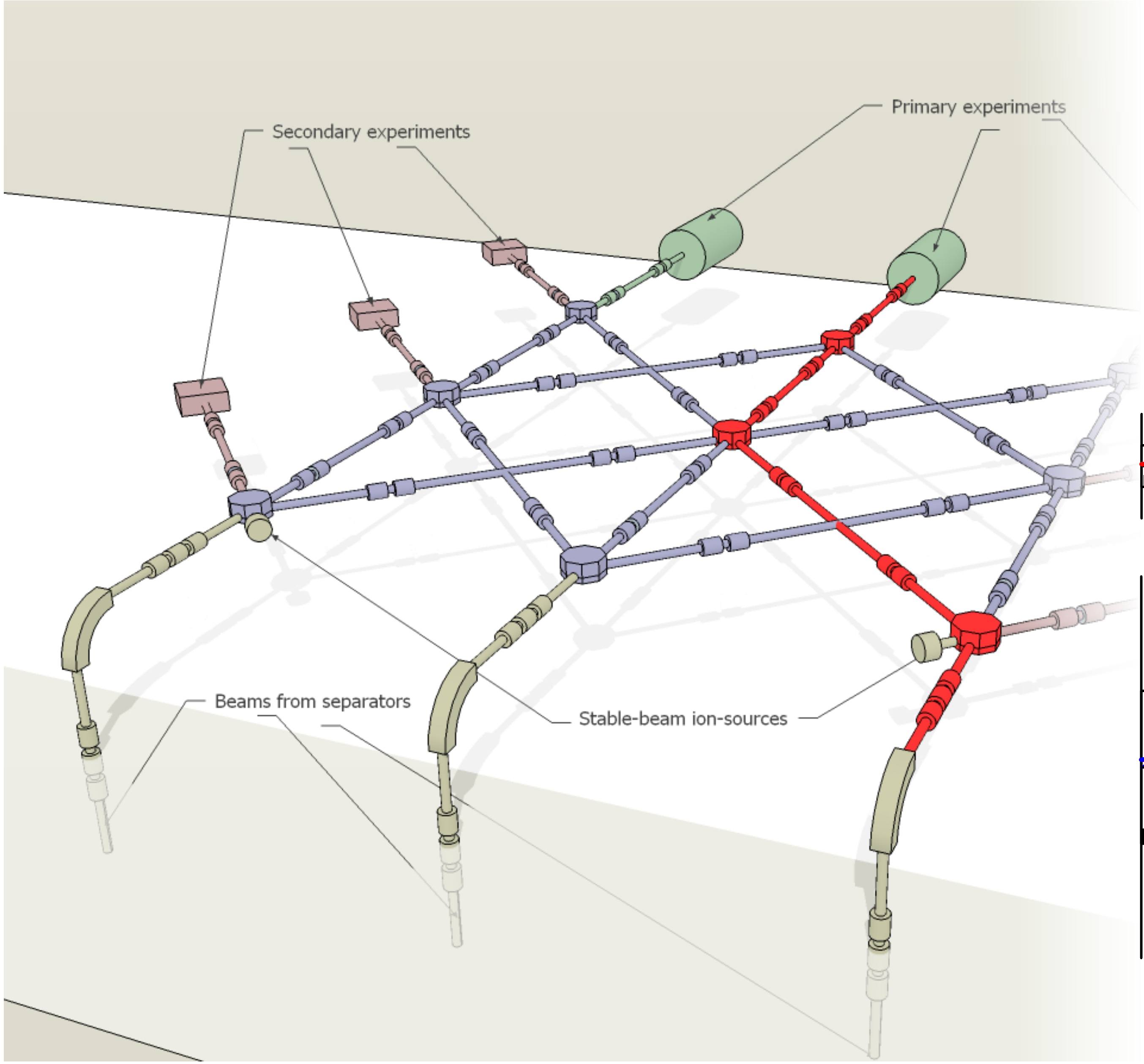
Better Beam Distribution

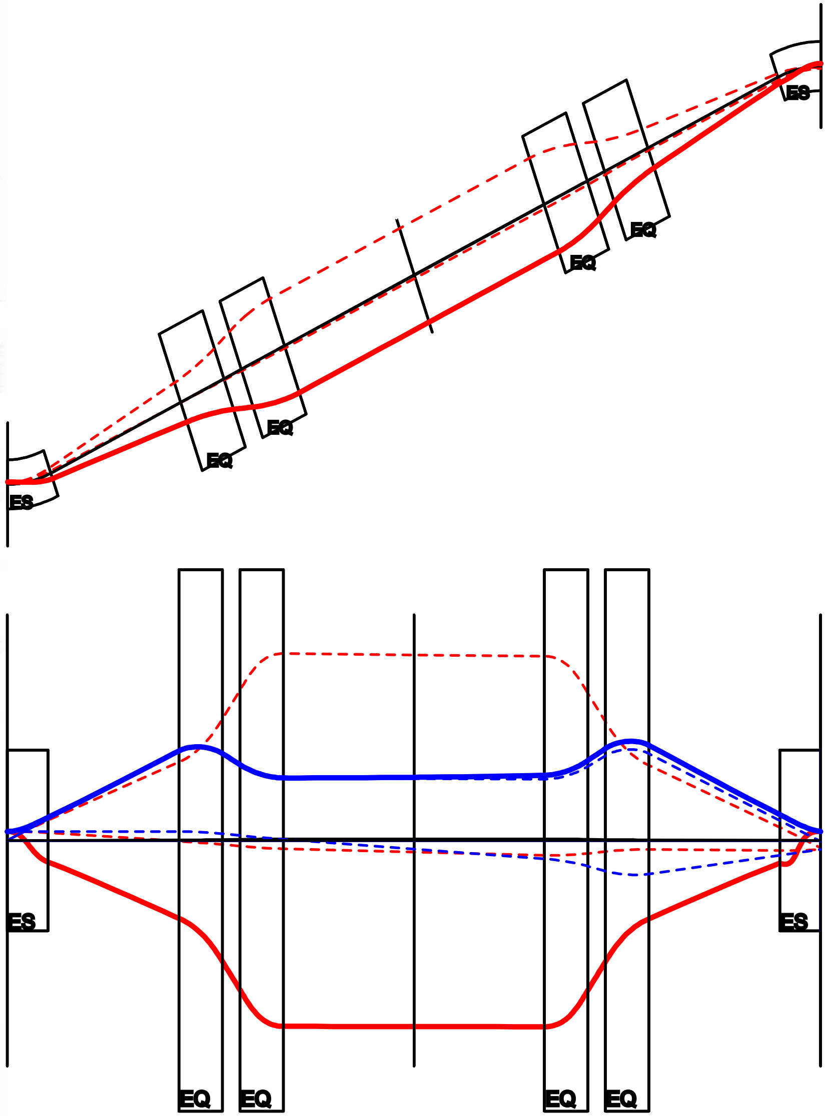






Better Beam Distribution



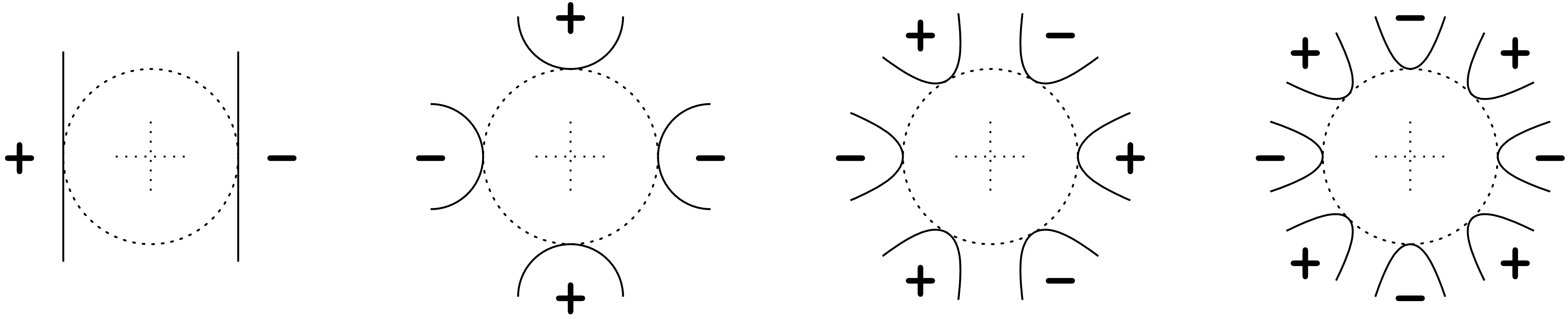


Lens Design

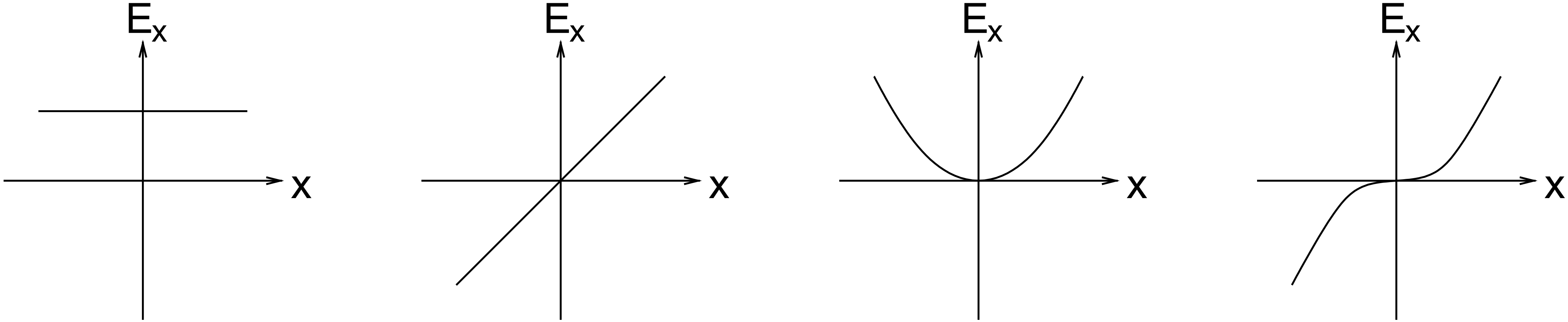
Tim Giles
ELENA Workshop - Jan 2012

Multipoles vs. Order

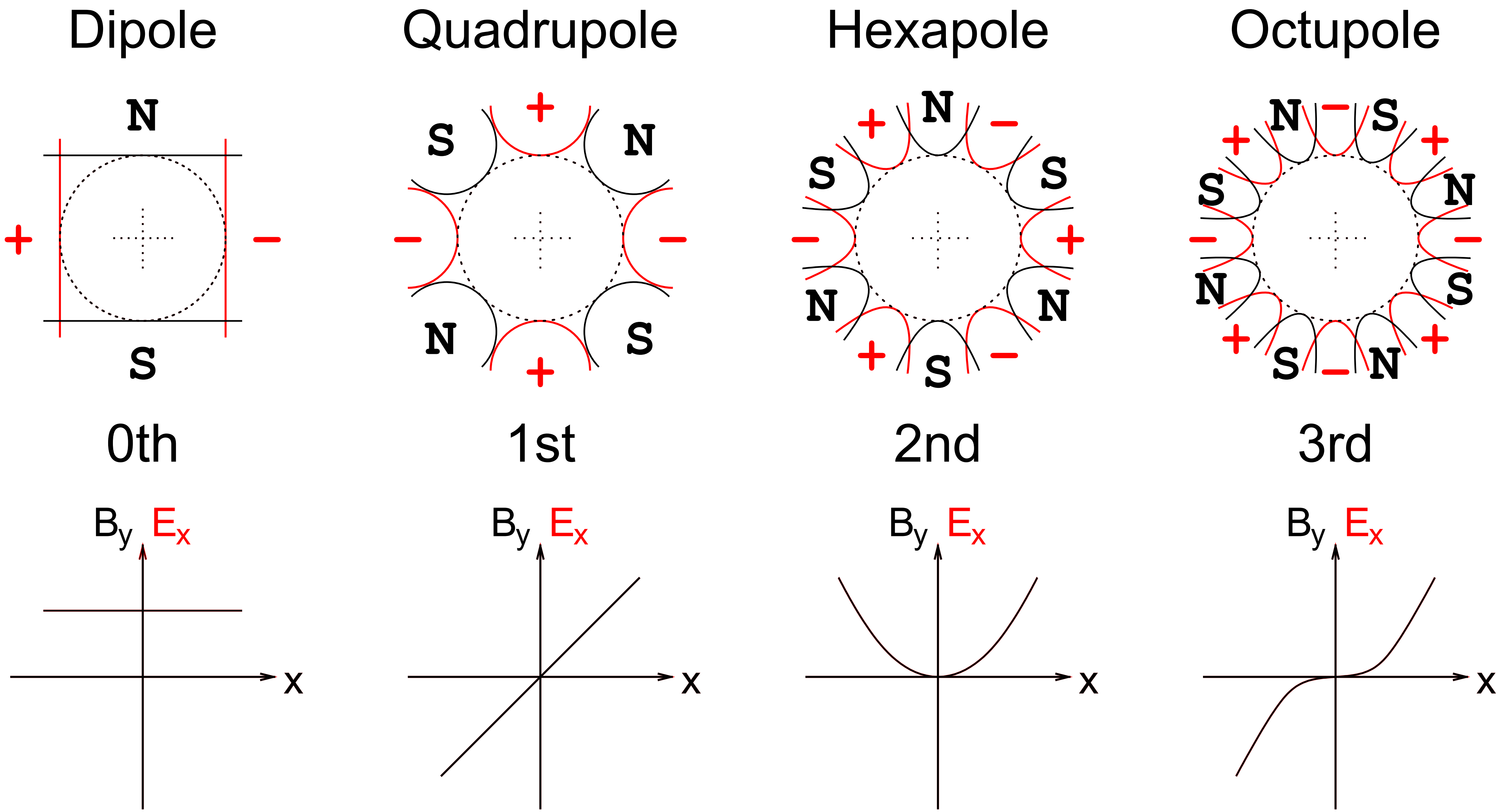
Dipole Quadrupole Hexapole Octupole



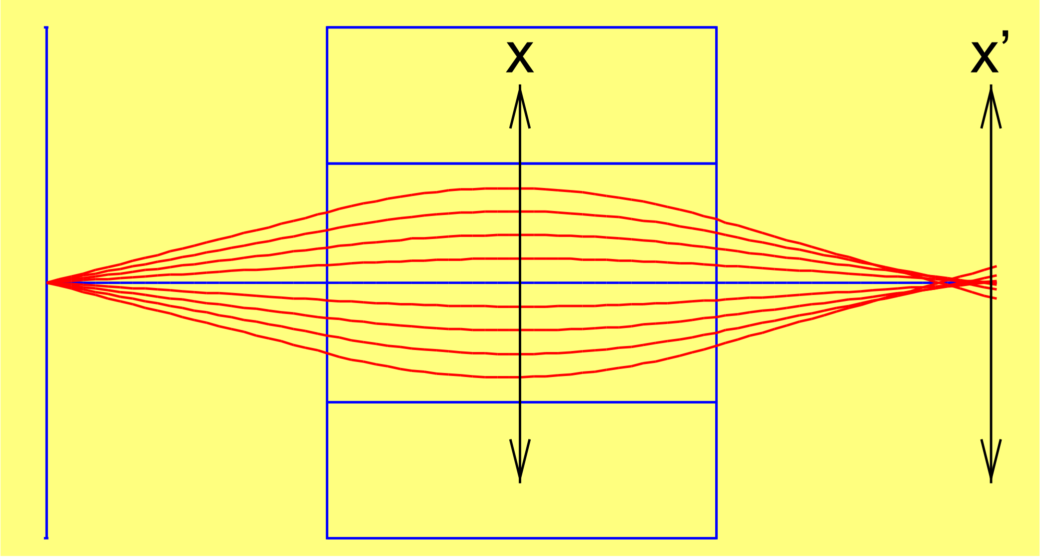
0th 1st 2nd 3rd

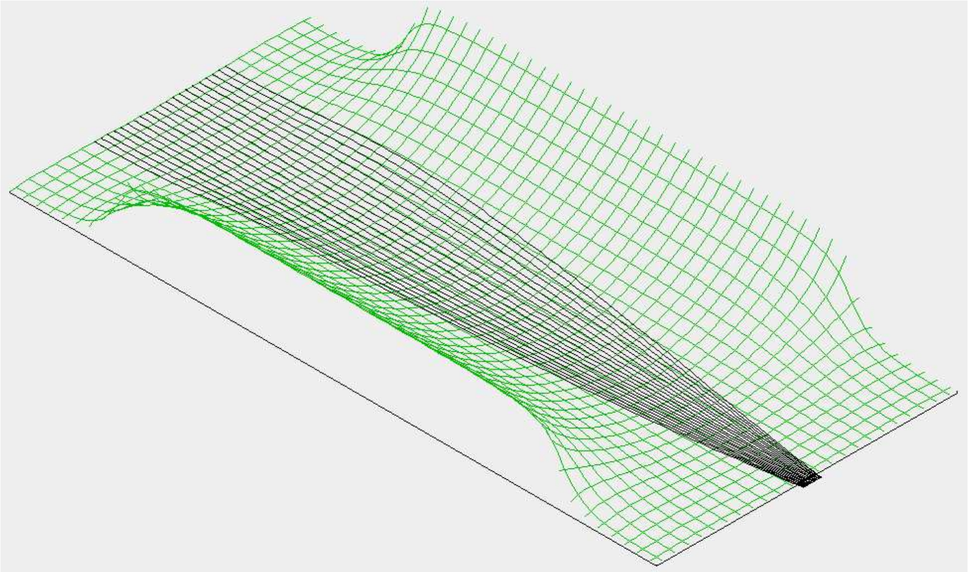


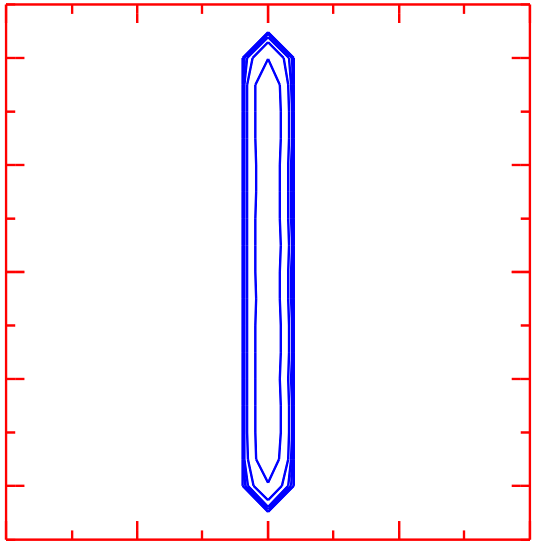
Multipoles vs. Order

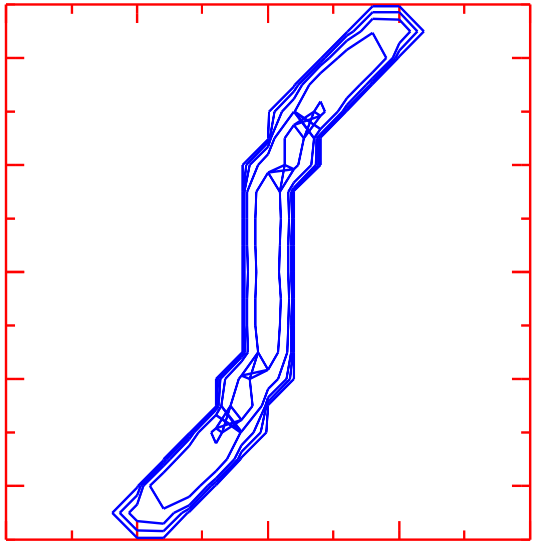


Intrinsic Distortions





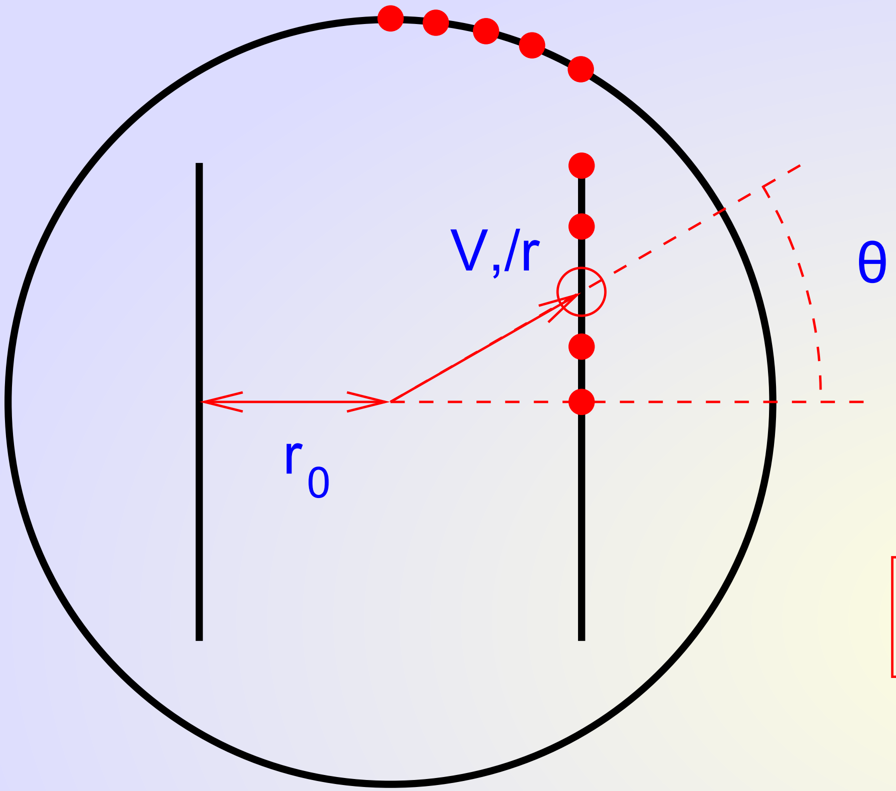




$$f = f_0 \left(/1/- \frac{k/x^2}{Q_0} \right)$$

$$x' = - \frac{k/x^3}{Q_0}$$

Multipole Distortions



$$V = V_0 \sum_n a_n \frac{r^n}{r_0^n} \cos(n\,\theta)$$

For a dipole, n = 1, 3, 5 ...

For a quadrupole, n = 2, 6, 10 ...

Emittance growth $\varepsilon' = \varepsilon(1 + tol)$

Dipole

$$\frac{\varepsilon}{x_0 . tol} = \delta A_1 . \frac{a_n}{a_1} . n . \frac{x_0^{(n-1)}}{r_0^{(n-1)}}$$

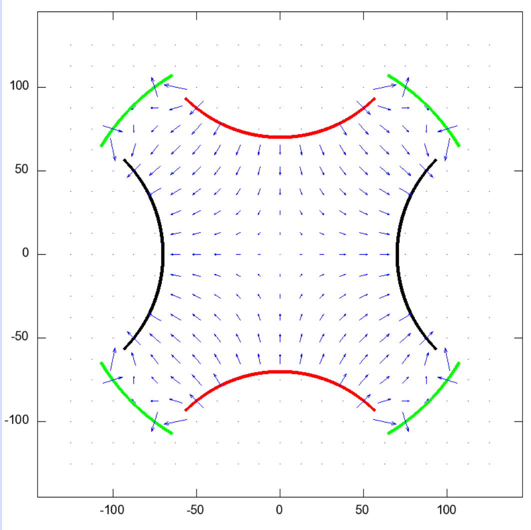
deflection angle

Quadrupole

$$\frac{\varepsilon}{x_0 . tol} = \delta A_2 . \frac{a_n}{a_2} . n . \frac{x_0^{(n-2)}}{r_0^{(n-2)}}$$

x_0 / focal length

Transverse Fields in Quadrupole Lenses



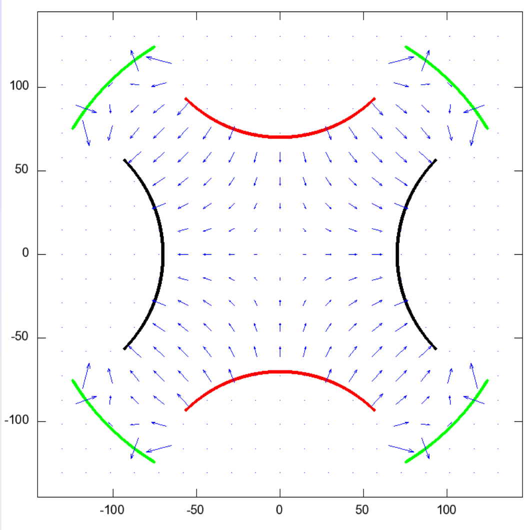
Beamline Quadrupole

$a_2 = +1.004$

$a_6 = -0.0044$

$a_{10} = -0.0057$

$a_{14} = -0.0003$



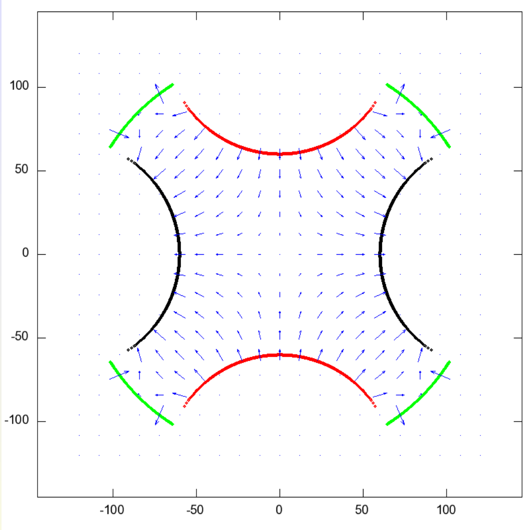
Frontend Quadrupole (old)

$a_2 = +1.008$

$a_6 = +0.0062$

$a_{10} = -0.0012$

$a_{14} = -0.0000$



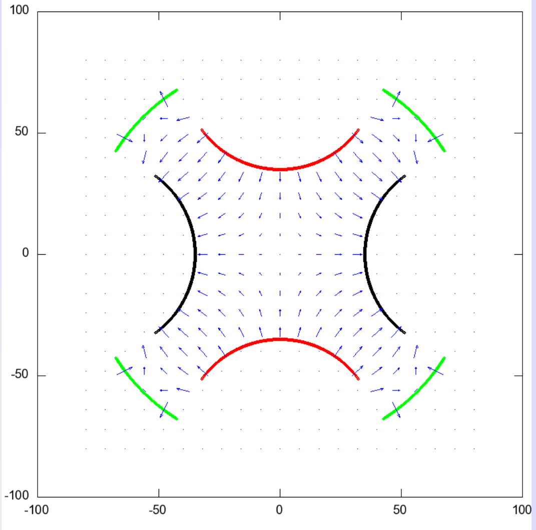
Frontend Quadrupole (new)

$a_2 = +1.003$

$a_6 = +0.0012$

$a_{10} = -0.0019$

$a_{14} = -0.0001$



Compact Lens for RFQ Matching

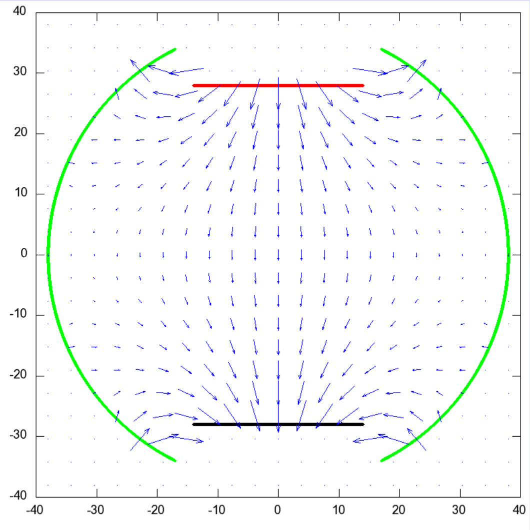
$a_2 = +1.009$

$a_6 = +0.0076$

$a_{10} = -0.0004$

$a_{14} = -0.0000$

Transverse Fields in Deflectors



Wide Aperture

a_1 = +0.699

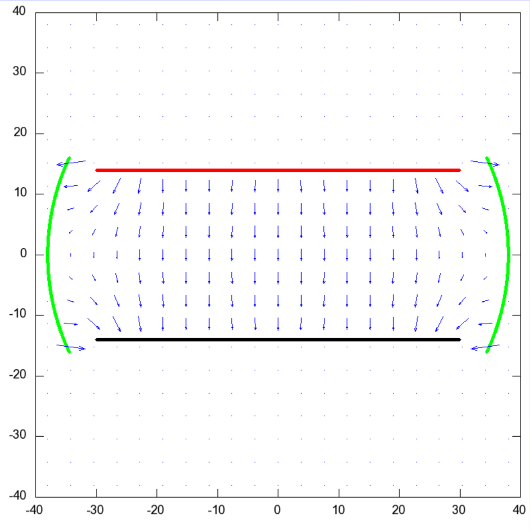
a_3 = +0.311

a_5 = +0.113

a_7 = +0.031

a_9 = +0.005

a_{11} = -0.001



Narrow Aperture

a_1 = +1.000

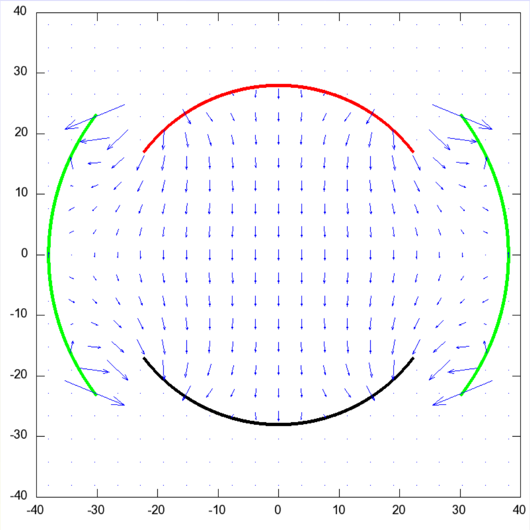
a_3 = +0.012

a_5 = +0.007

a_7 = +0.003

a_9 = +0.000

a_{11} = +0.000



Compact Curved
(new frontend)

a_1 = +1.096

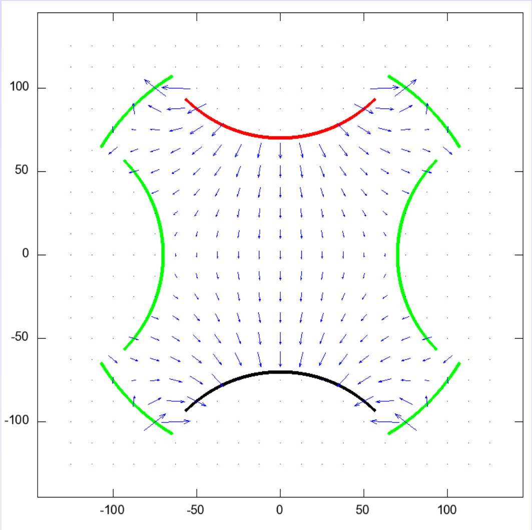
a_3 = -0.002

a_5 = -0.149

a_7 = +0.016

a_9 = +0.053

a_{11} = +0.018



Quadrupole as
Deflector

a_1 = +0.784

a_3 = +0.240

a_5 = +0.023

a_7 = +0.007

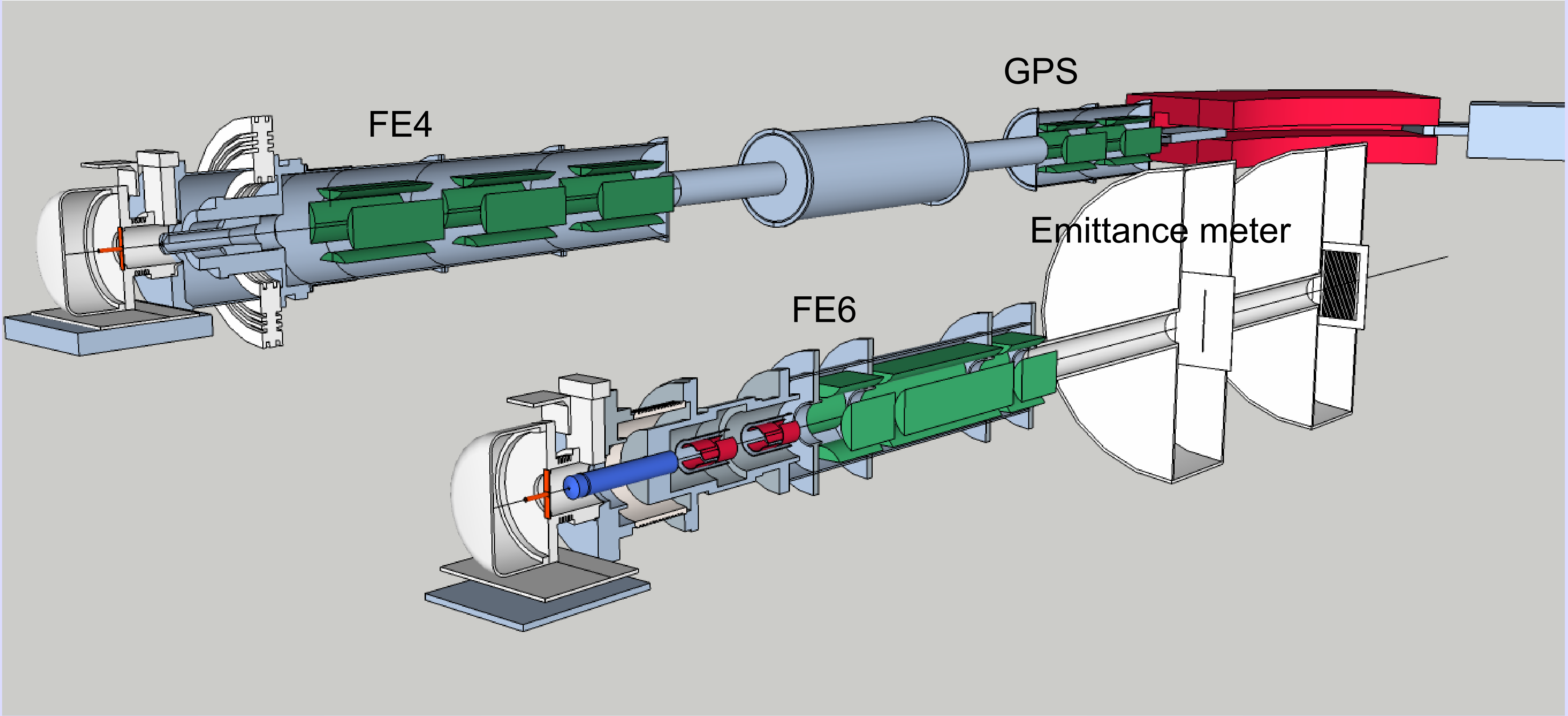
a_9 = -0.001

a_{11} = -0.000

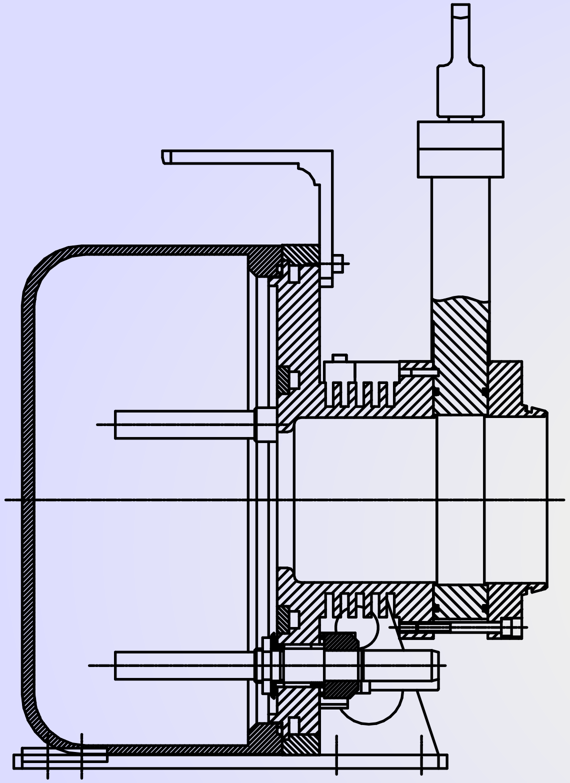
Putting it all together

Tim Giles
ELENA Workshop - Jan 2012

Tune testing method

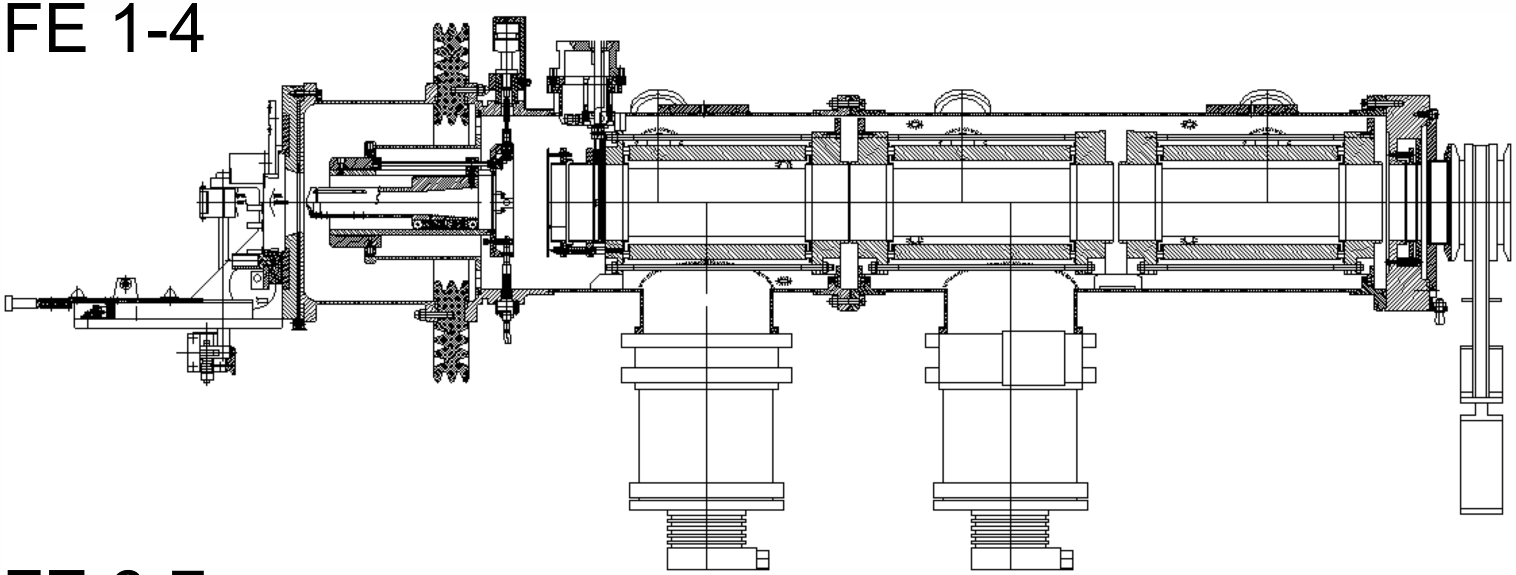


The Isolde Frontends

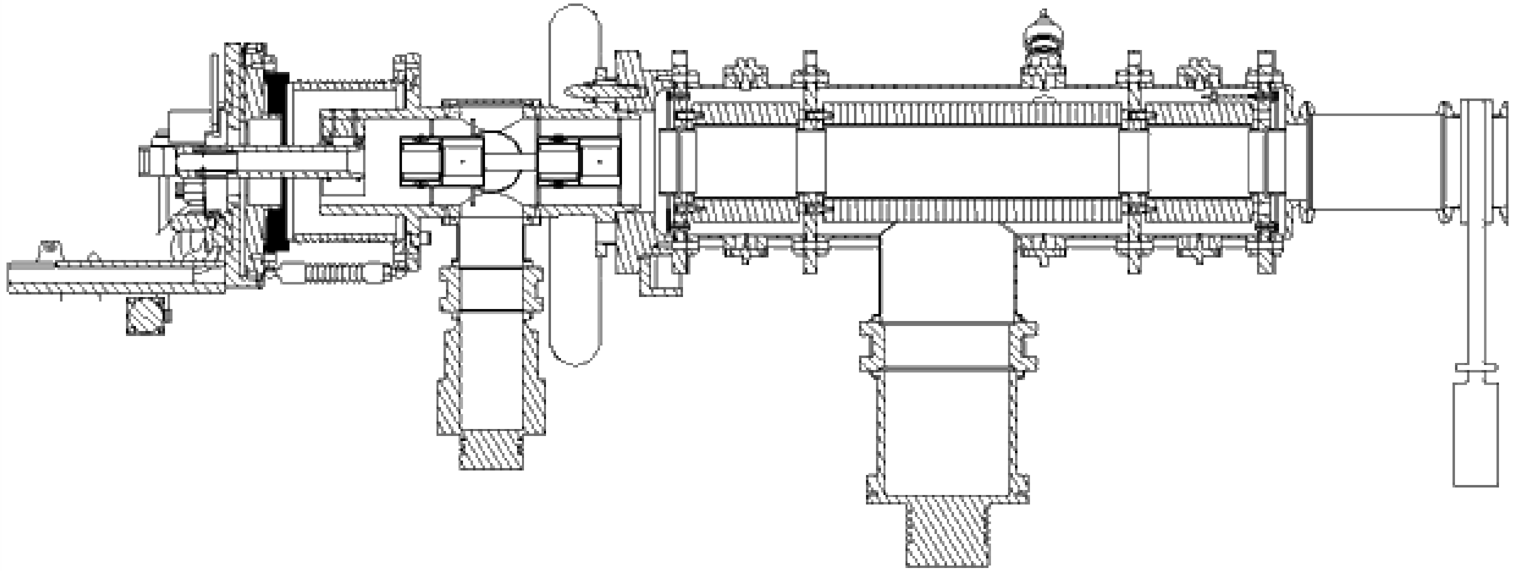


Target unit
x2.5

FE 1-4



FE 6-7



FE6 test setup

Quadrupole triplet

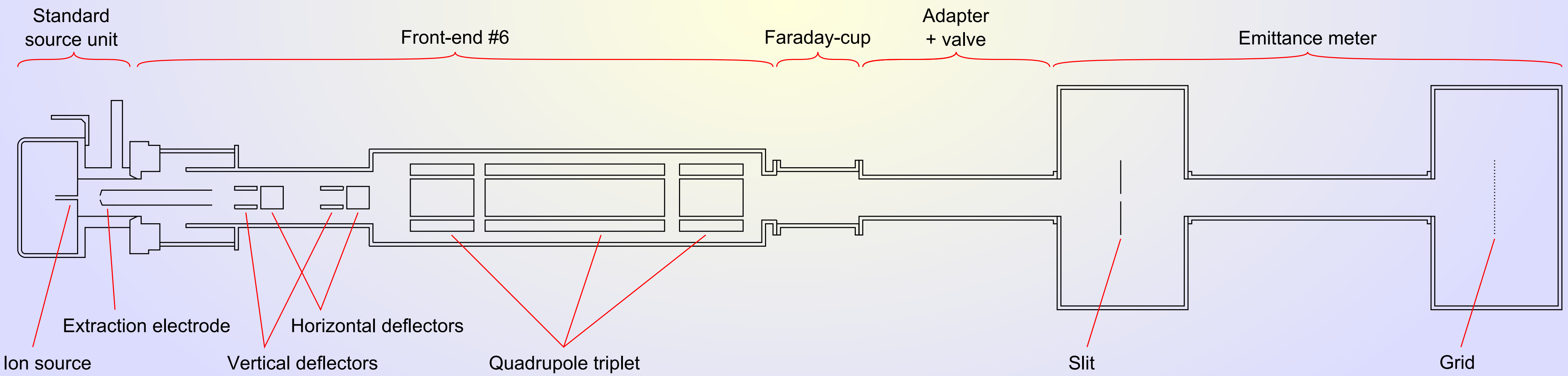
Test beam-tunes matched to GPS and HRS separators

X/Y deflectors

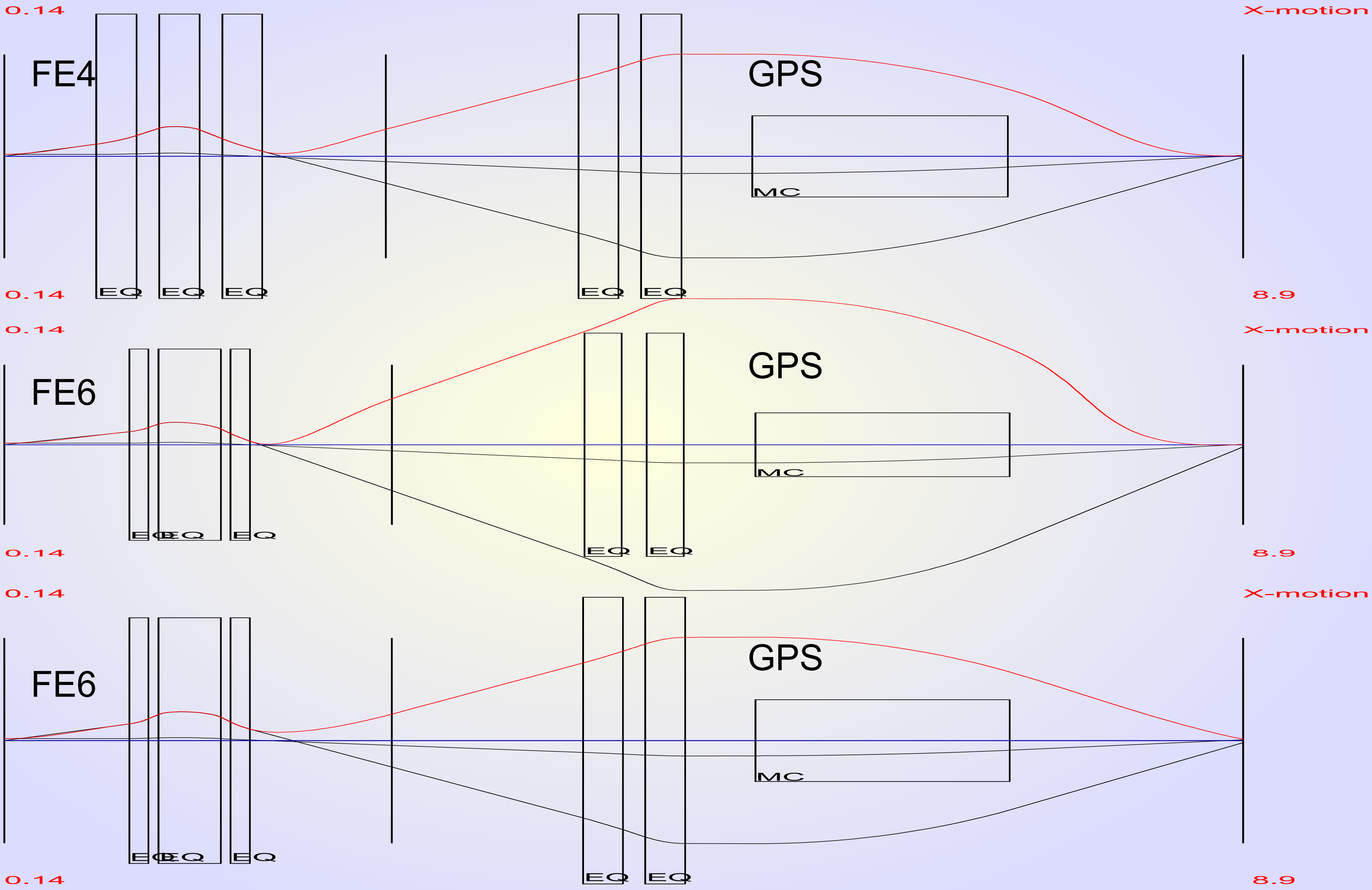
Extraction electrode

Ion beam

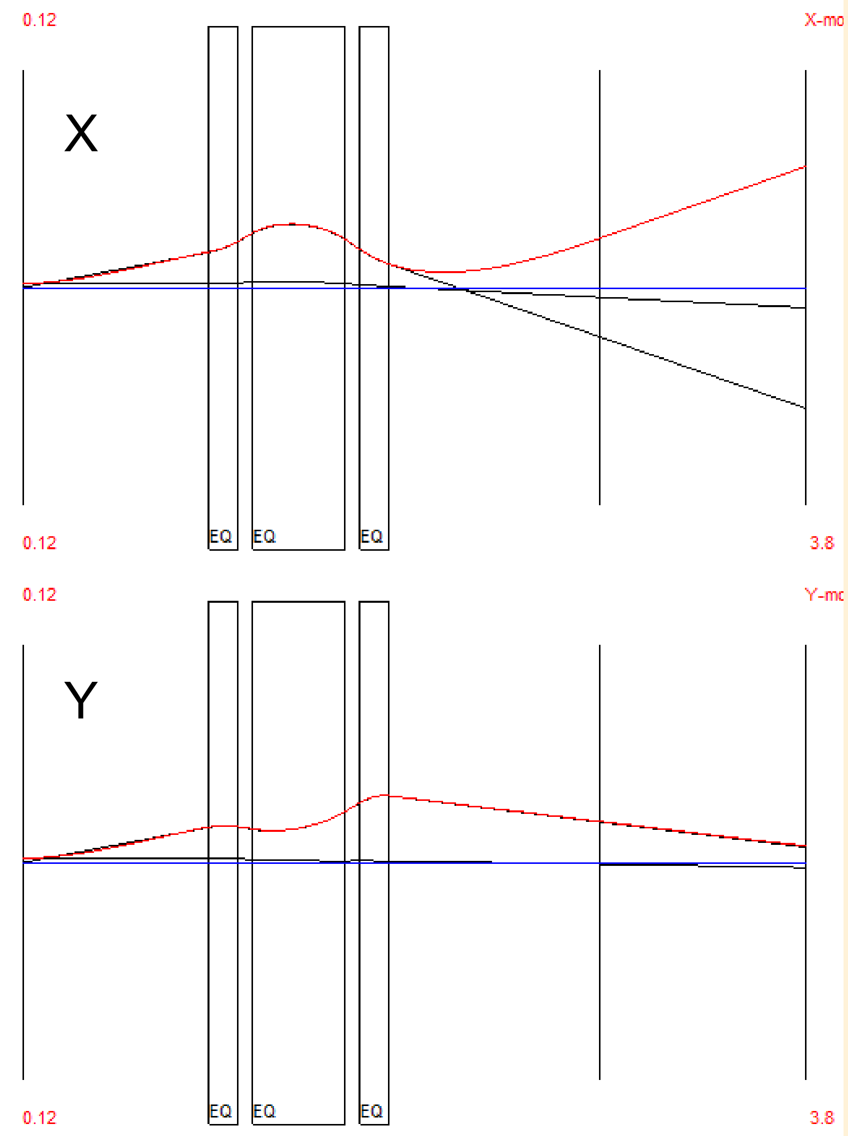
Ion source



Tune testing method



GPS tune #1



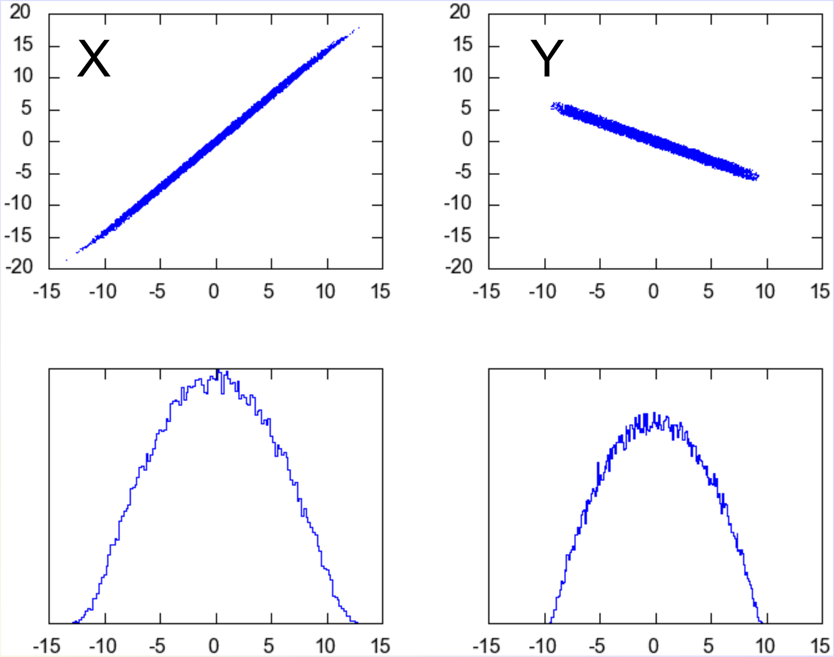
Simulation

$\alpha_x = -20.9$
$\beta_x = 14.5$
$\gamma_x = 30.2$

$\Theta_x = -2.4$
$\rho_x = 59$

$\alpha_y = 6.0$
$\beta_y = 9.9$
$\gamma_y = 3.8$

$\Theta_y = -2.2$
$\rho_y = 24$



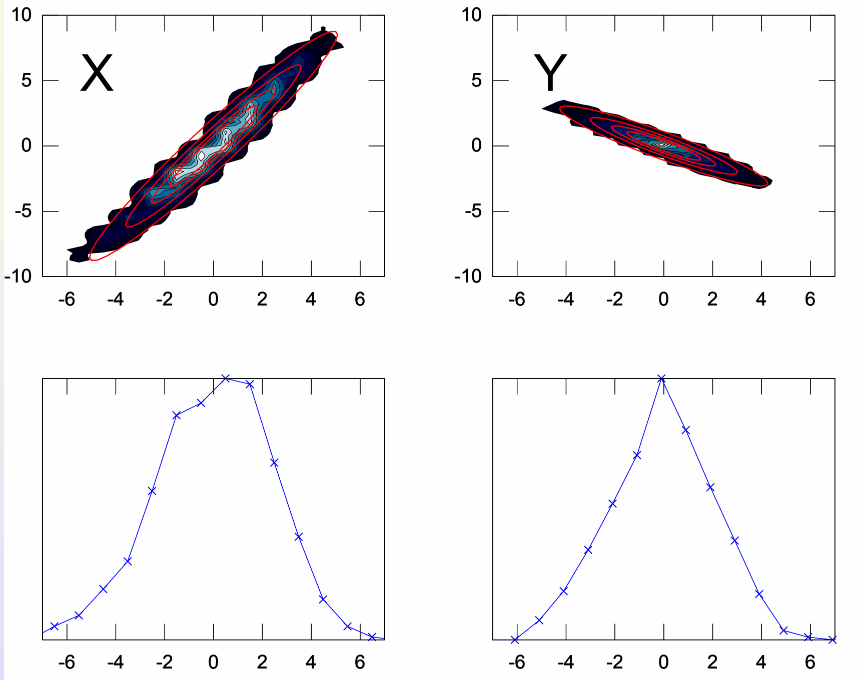
Measurement

$\alpha_x = -4.0$
$\beta_x = 2.4$
$\gamma_x = 7.1$

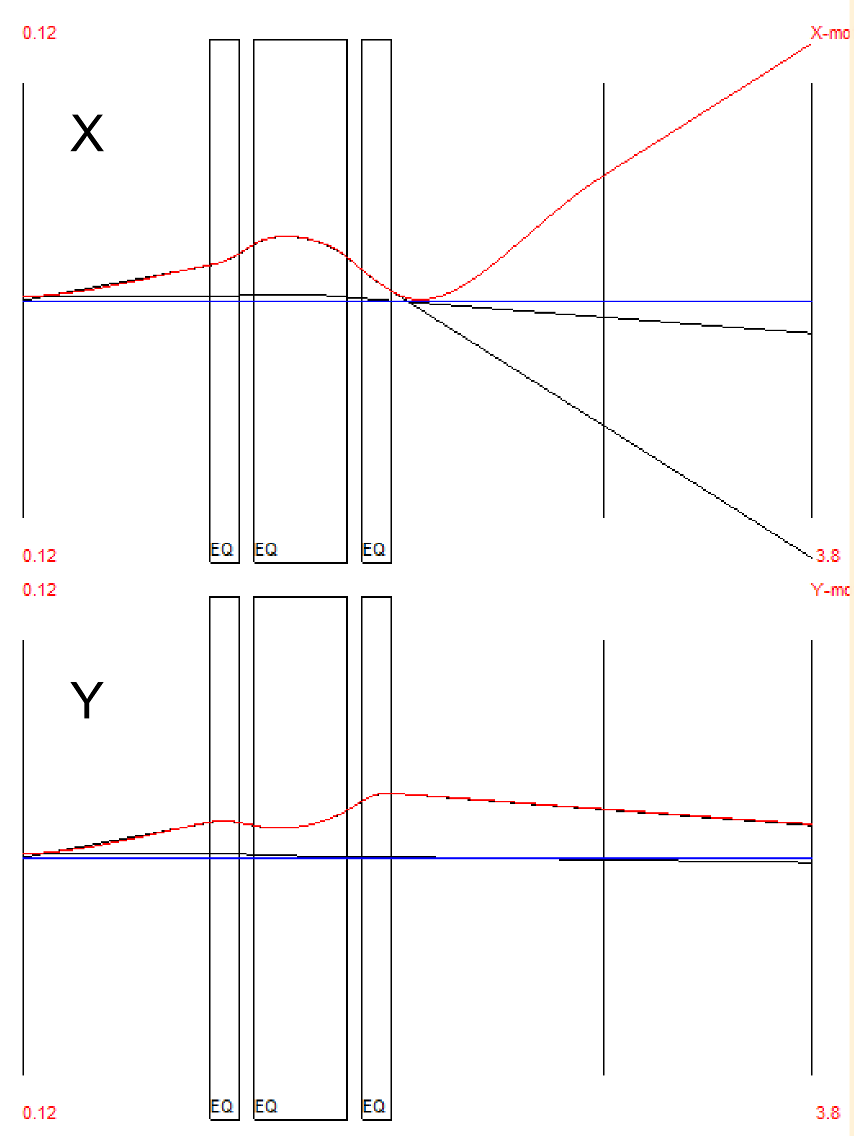
$\Theta_x = -2.1$
$\rho_x = 12$

$\alpha_y = 2.6$
$\beta_y = 3.9$
$\gamma_y = 2.0$

$\Theta_y = -2.5$
$\rho_y = 10$



GPS tune #2



Simulation

$\alpha_x = -97$

$\beta_x = 92$

$\gamma_x = 102$

$\Theta_x = -3.0$

$\rho_x = 287$

$\alpha_y = 4.4$

$\beta_y = 13.9$

$\gamma_y = 1.5$

$\Theta_y = -1.2$

$\rho_y = 29$

Measurement

$\alpha_x = -25$

$\beta_x = 23$

$\gamma_x = 28$

$\Theta_x = -2.9$

$\rho_x = 74$

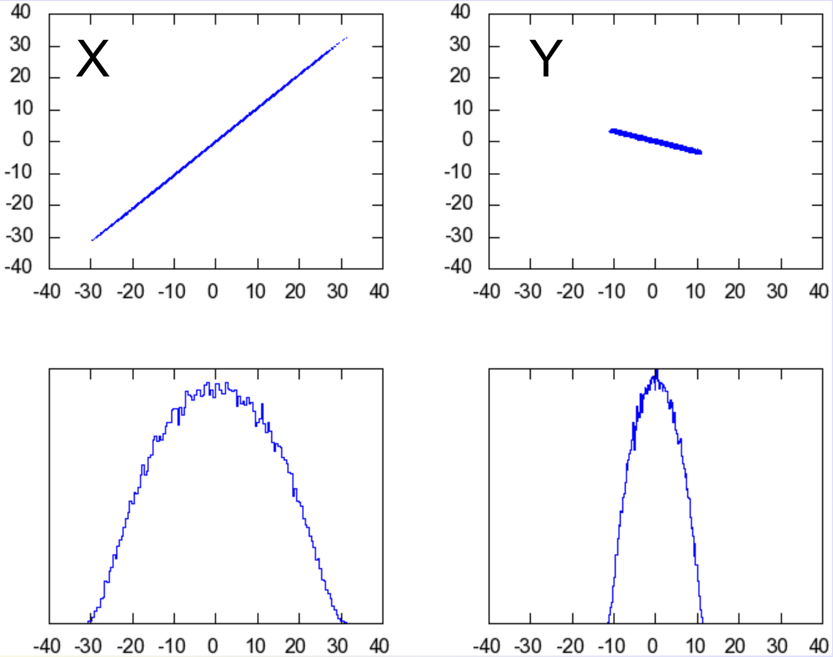
$\alpha_y = 1.8$

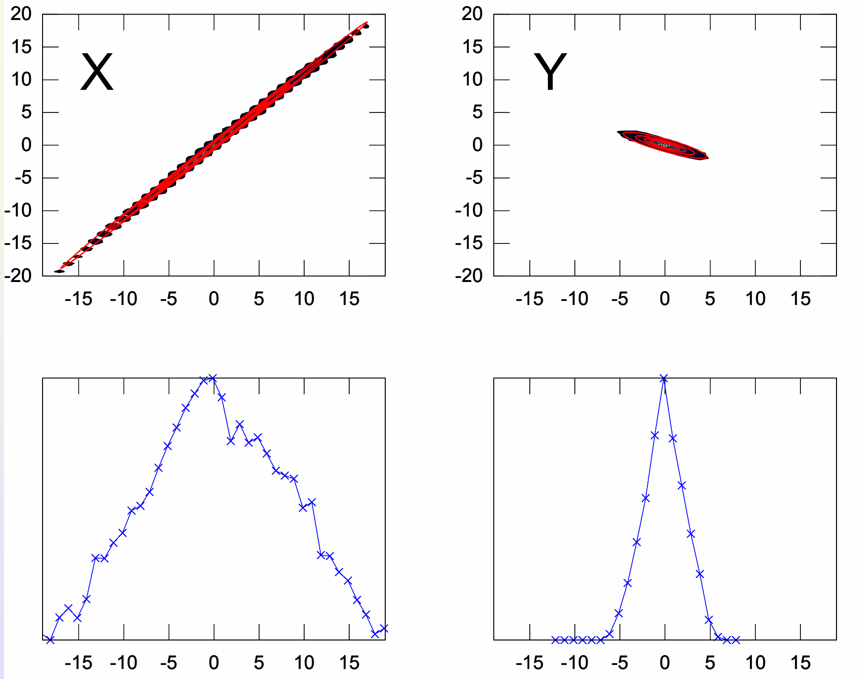
$\beta_y = 4.7$

$\gamma_y = 0.9$

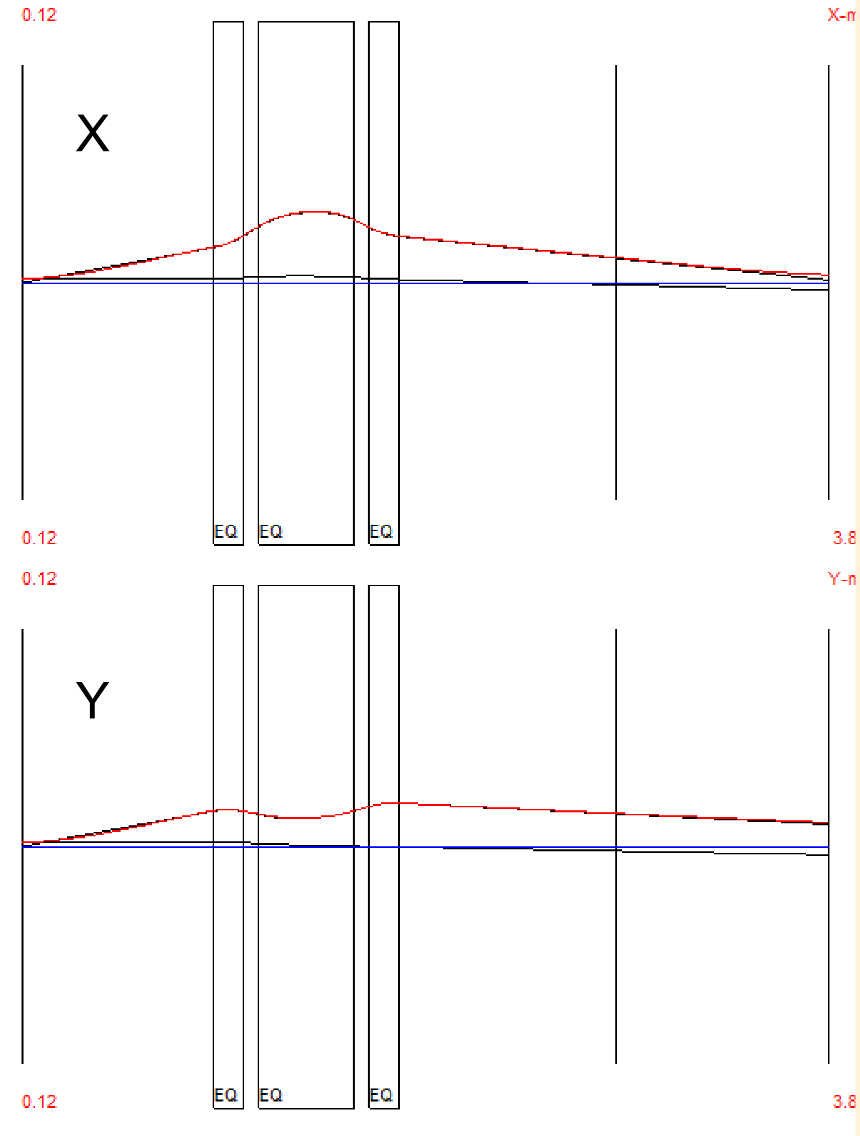
$\Theta_y = -1.5$

$\rho_y = 10$





HRS tune



Simulation

$\alpha_x = 3.0$
$\beta_x = 3.6$
$\gamma_x = 2.8$

$\Theta_x = -2.9$
$\rho_x = 10$

$\alpha_y = 1.9$
$\beta_y = 6.4$
$\gamma_y = 0.7$

$\Theta_y = -1.2$
$\rho_y = 13$

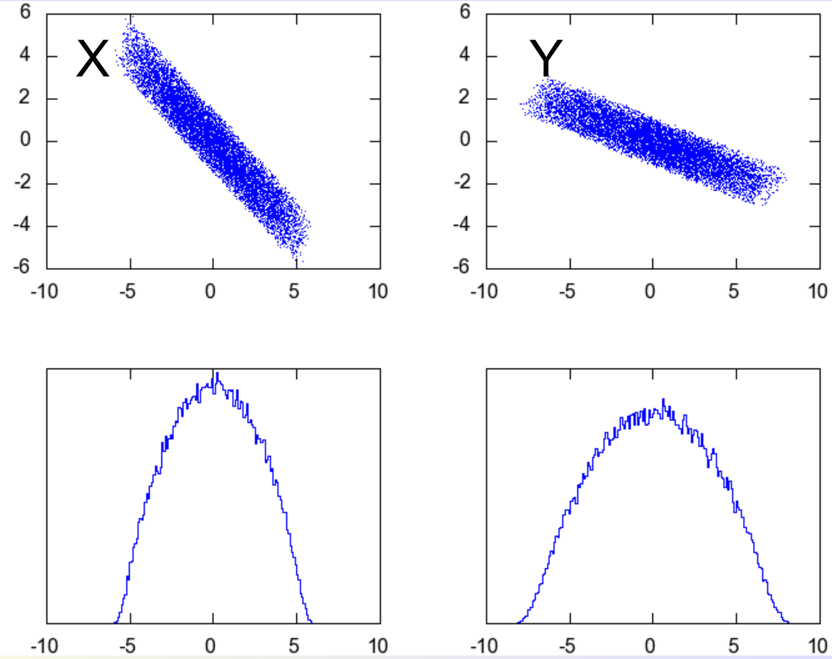
Measurement

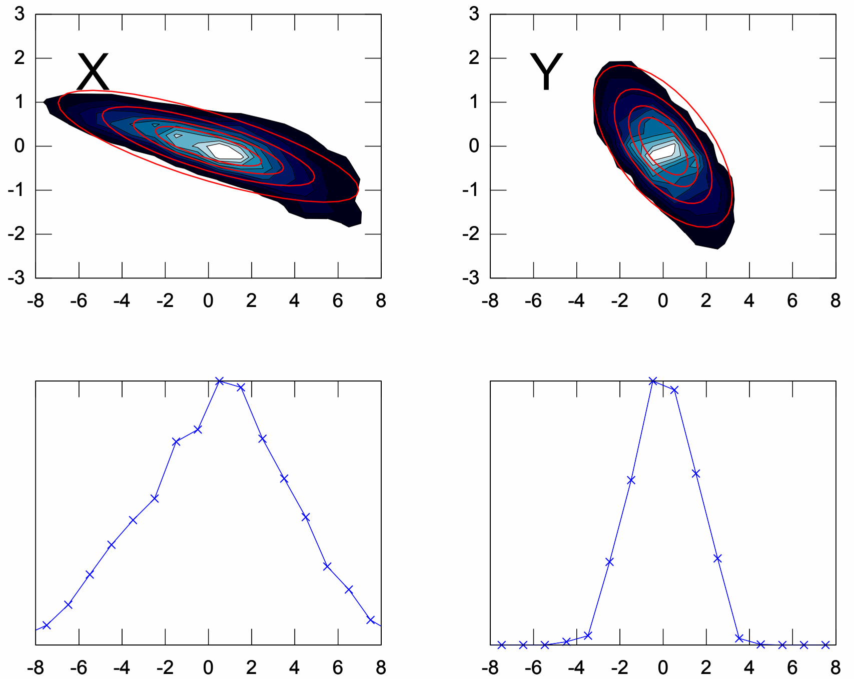
$\alpha_x = 1.2$
$\beta_x = 8.8$
$\gamma_x = 0.3$

$\Theta_x = -0.6$
$\rho_x = 18$

$\alpha_y = 0.7$
$\beta_y = 2.2$
$\gamma_y = 0.7$

$\Theta_y = -1.6$
$\rho_y = 5$





Summary

Pros & Cons of electrostatic beamlines

- Cheap power supplies and cabling
- Mass-independent
- No hysteresis (easy to operate)
- No power used (no cooling)
- Transverse field shape easy to optimise

- Difficult to measure field shape (esp. effective length)
- Large internal surface area (outgassing)
- Vulnerable to dirt inside vacuum
- Bad connections can cause beam movement
- Difficult to diagnose bad connections
- Must be interlocked with vacuum (arcing + safety)
- Repairs require opening vacuum
- Limited choice of vacuum-compatible insulators