eRHIC Interaction Region Design

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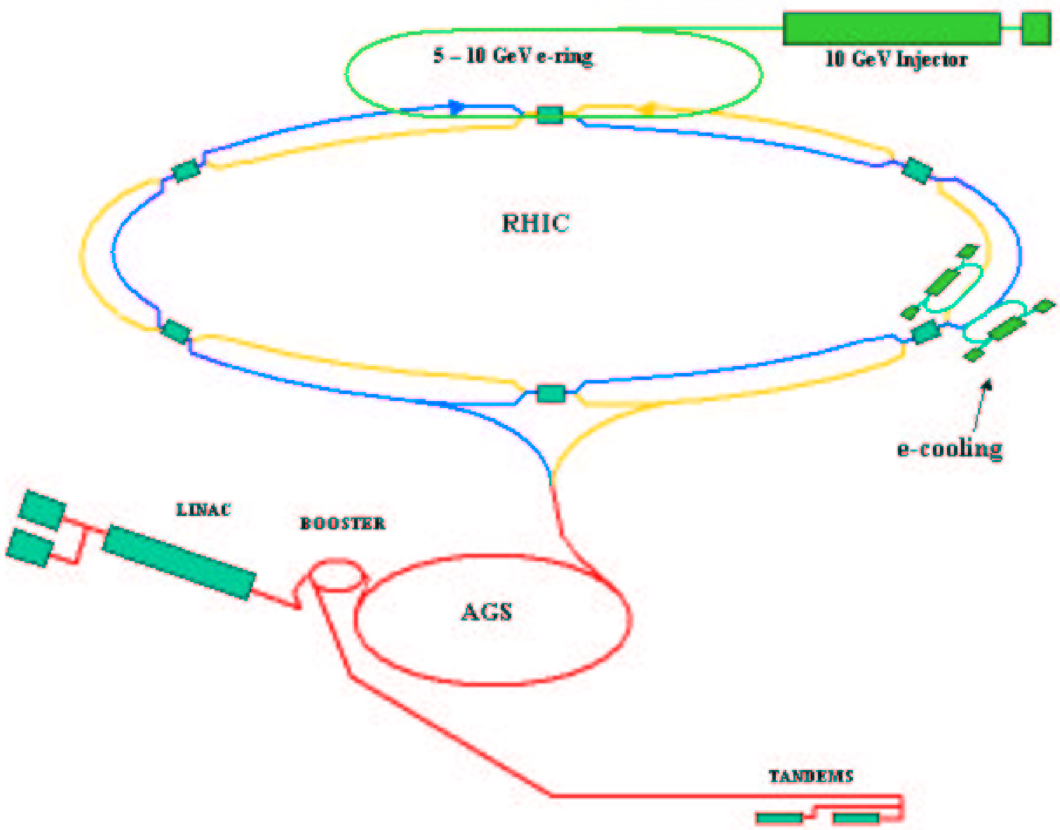


polarized electron-hadron collider

10 GeV $\vec{e}$ vs. 250 GeV $\vec{p}$, or 100 GeV/n Au

flexible beam energies

luminosity goal ($\vec{e} - Au$):
$10^{32} \ldots 10^{33}\,\mathrm{cm}^{-2}\mathrm{sec}^{-1}$

pre-requisite: electron cooling

Constraints:

- zero crossing angle
- proton septum quadrupole starts at 5 m
  → keep horizontal beam sizes at 5 m small to minimize required electron separation angle
- increase horizontal proton β function at IP
- $\beta^*_{y,p}$ limited by proton bunch length
  → resulting luminosity is smaller than for round beams

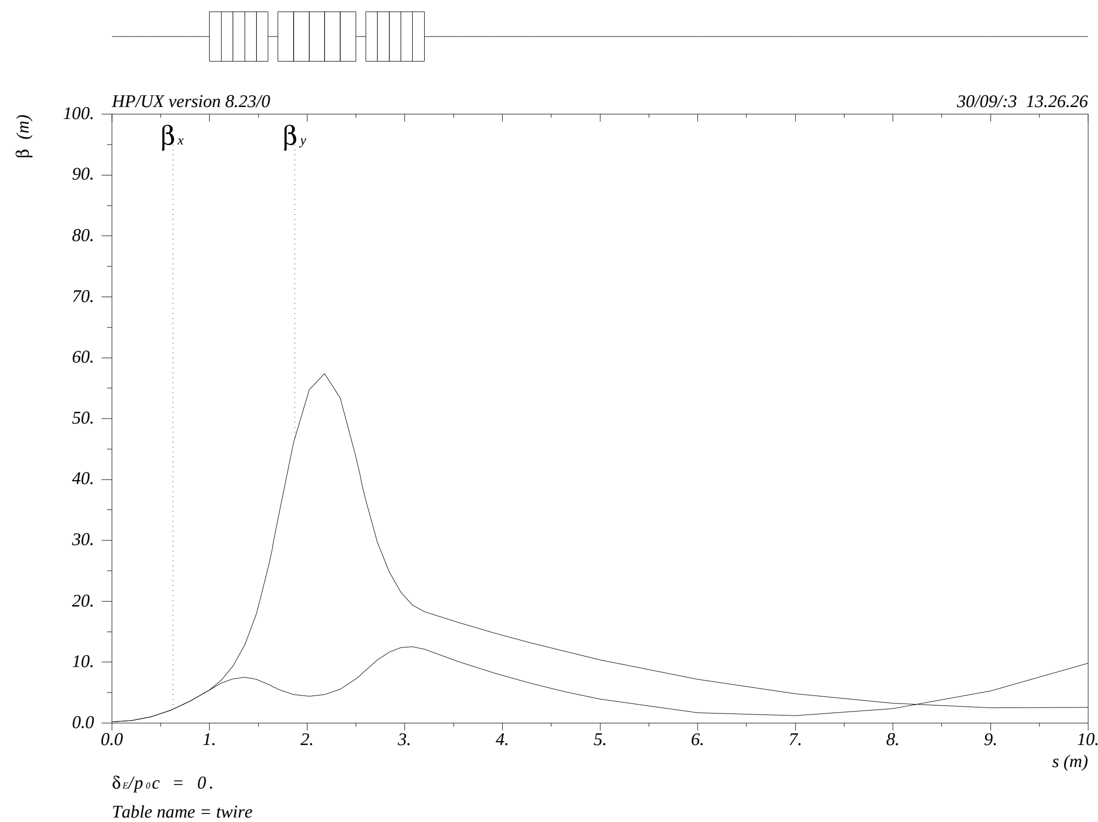
Parameters:

- hadron emittance (geom.): 9 nm
- $\beta_{x,p} = 1.04\,\mathrm{m}$, $\beta_{y,p} = 0.26\,\mathrm{m}$
- $\rightarrow$ low-β doublet (normal conducting)
- electron emittance (geom.): 50 nm hor., 12.5 nm vertical
- $\beta_{x,e} = \beta_{y,e} = 0.19\,\mathrm{m}$
  $\rightarrow$ low-β triplet (superconducting, with dipole coils)
- $N_e = N_p = 1 \cdot 10^{11}$
- electron tune shifts: $\xi_{e,x} = 0.031$,
  $\xi_{e,y} = 0.061$,
- hadron tune shifts: $\xi_{p,x} = 0.0074$,
  $\xi_{p,y} = 0.0037$

Resulting luminosity after intensity reduction to keep tune shifts below $\xi_e = 0.05$, $\xi_p = 0.005$:

$$\mathcal{L} = 2.7 \cdot 10^{32}\,\mathrm{cm}^{-2}\mathrm{sec}^{-1}$$

Electron lattice:

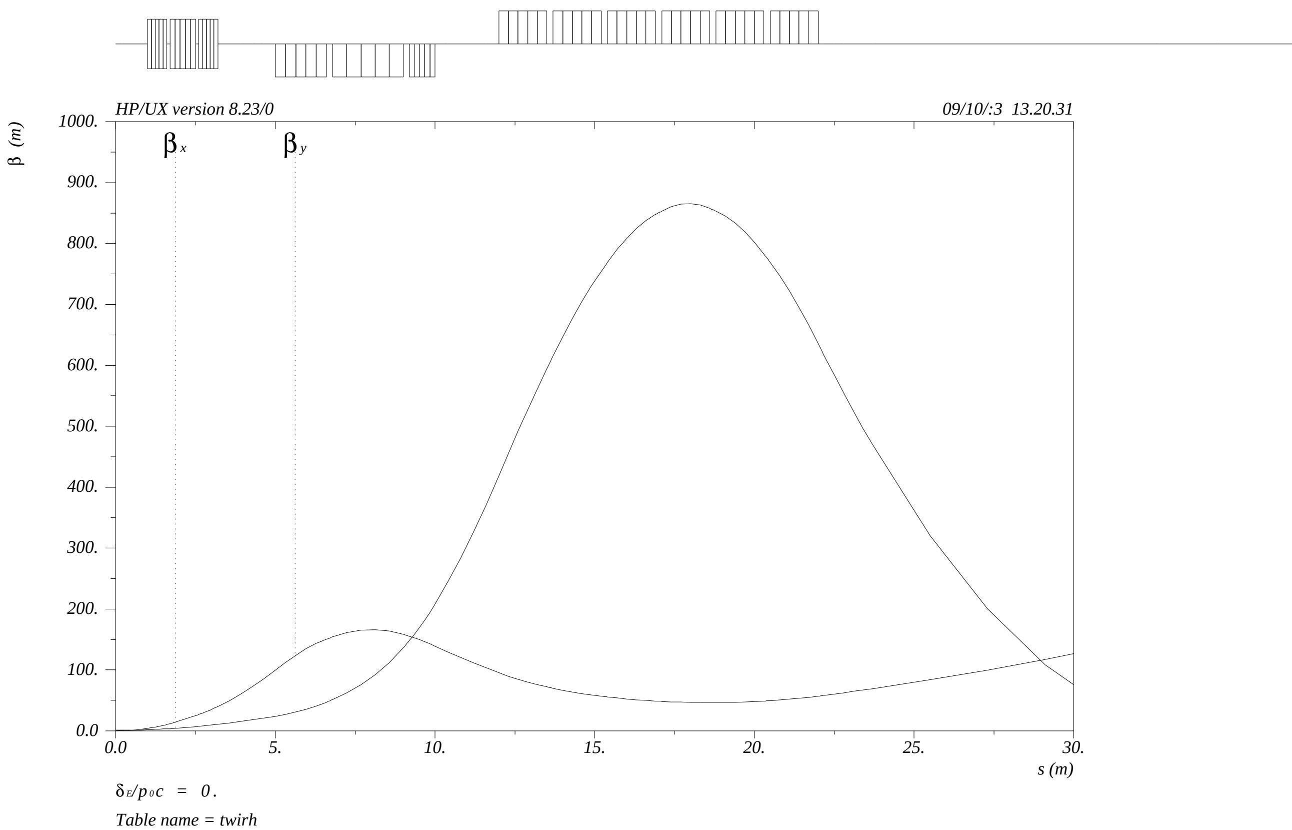


Q2 needs aperture of 34 mm to accomodate

$20\sigma_{e,y}$ at $\beta_y = 60\,\mathrm{m}$

consistent with synchrotron radiation issues

Hadron lattice (store):



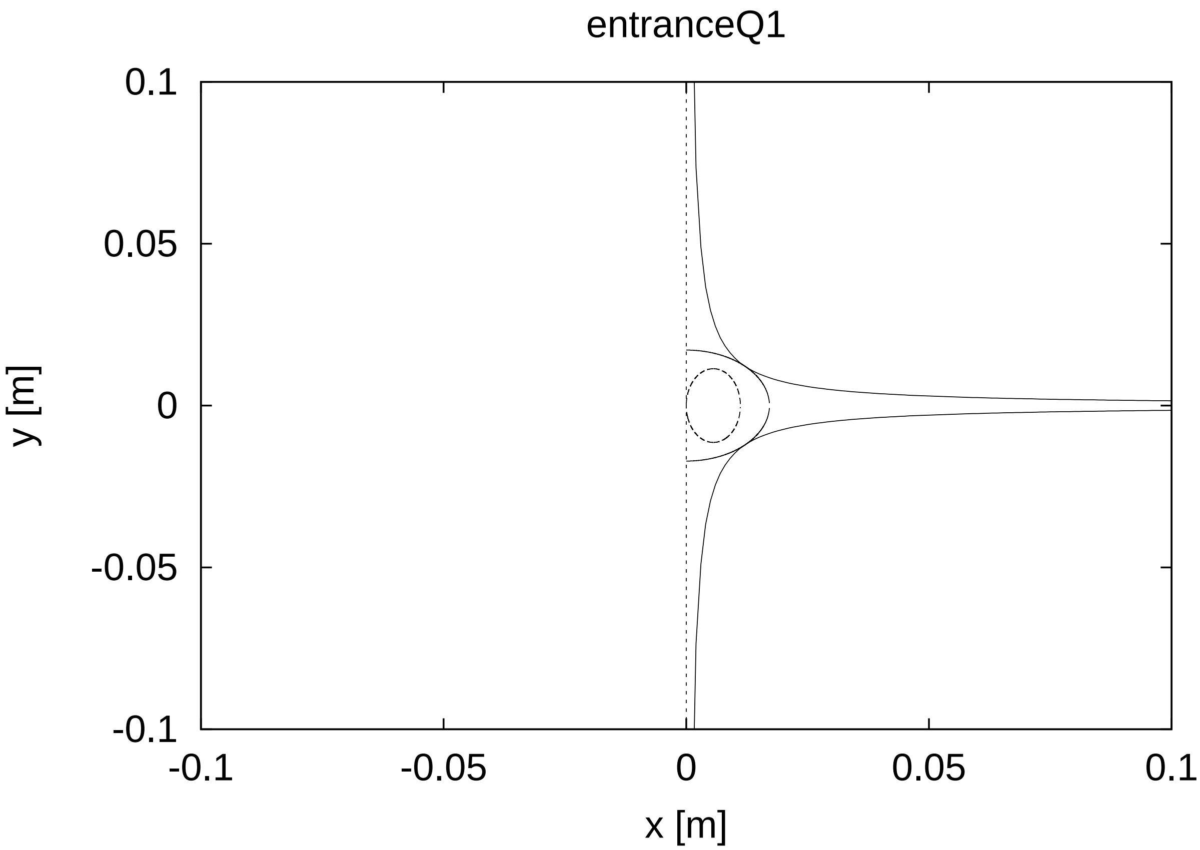
Pole tip fields: 1.0 Tesla

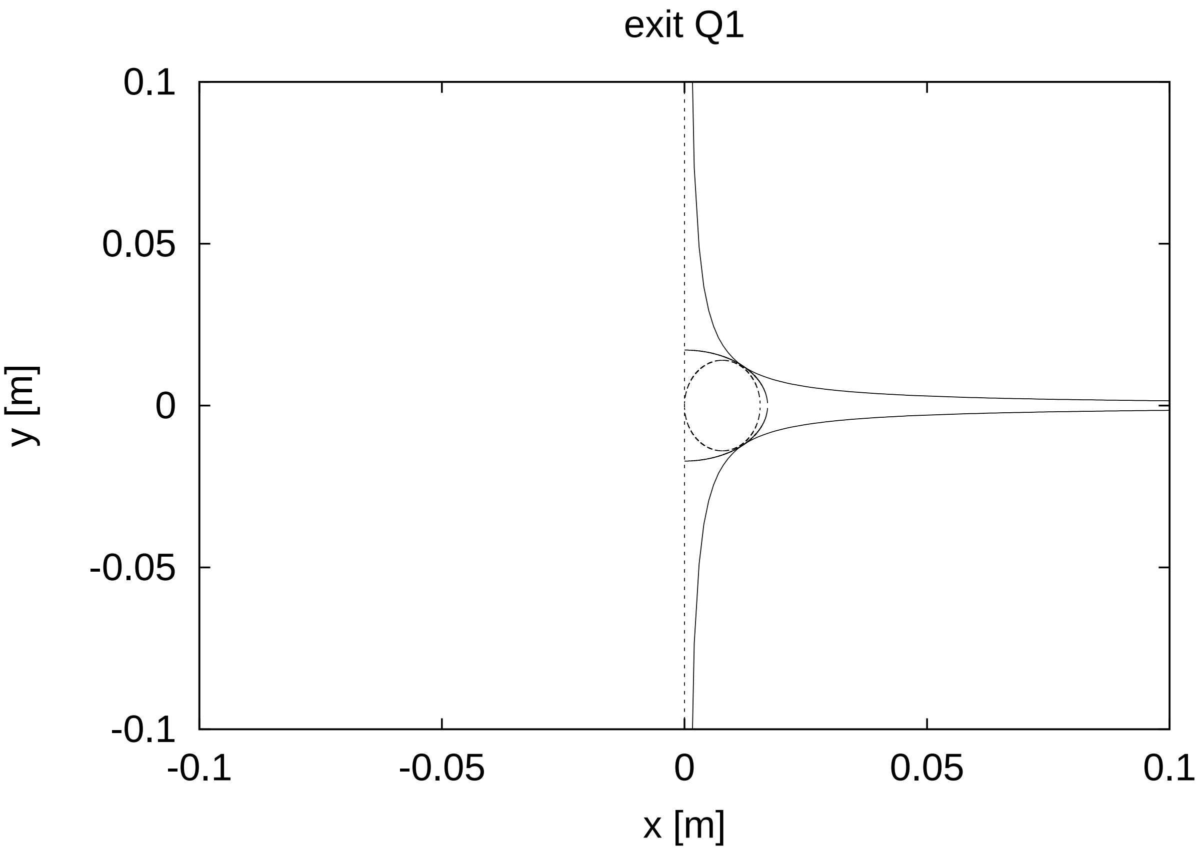
$\epsilon_n = 6\pi\,\mu\text{m}$, $\gamma = 107$ (Au, cooled)

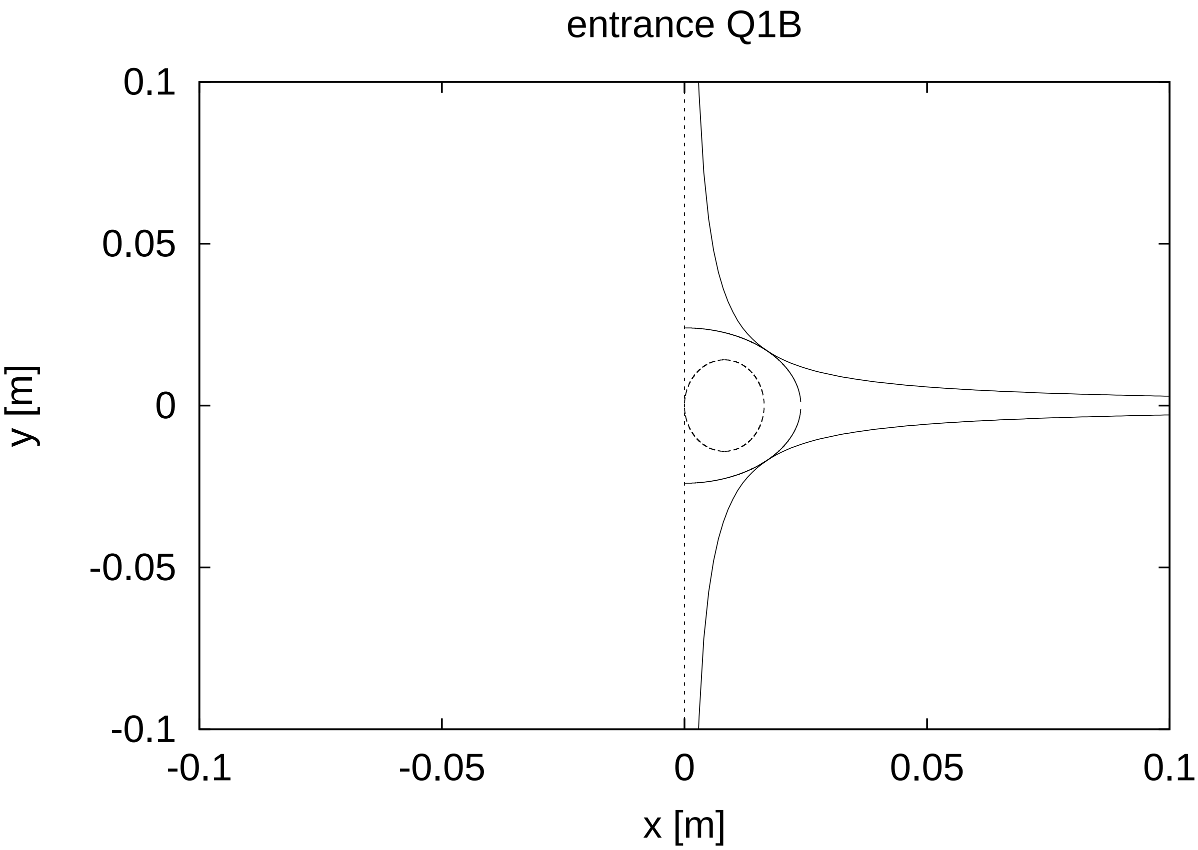
$\epsilon_n = 14.5\pi\,\mu\text{m}$, $\gamma = 250$ (p)

Minimum aperture for cooled beam: $12\sigma_p$

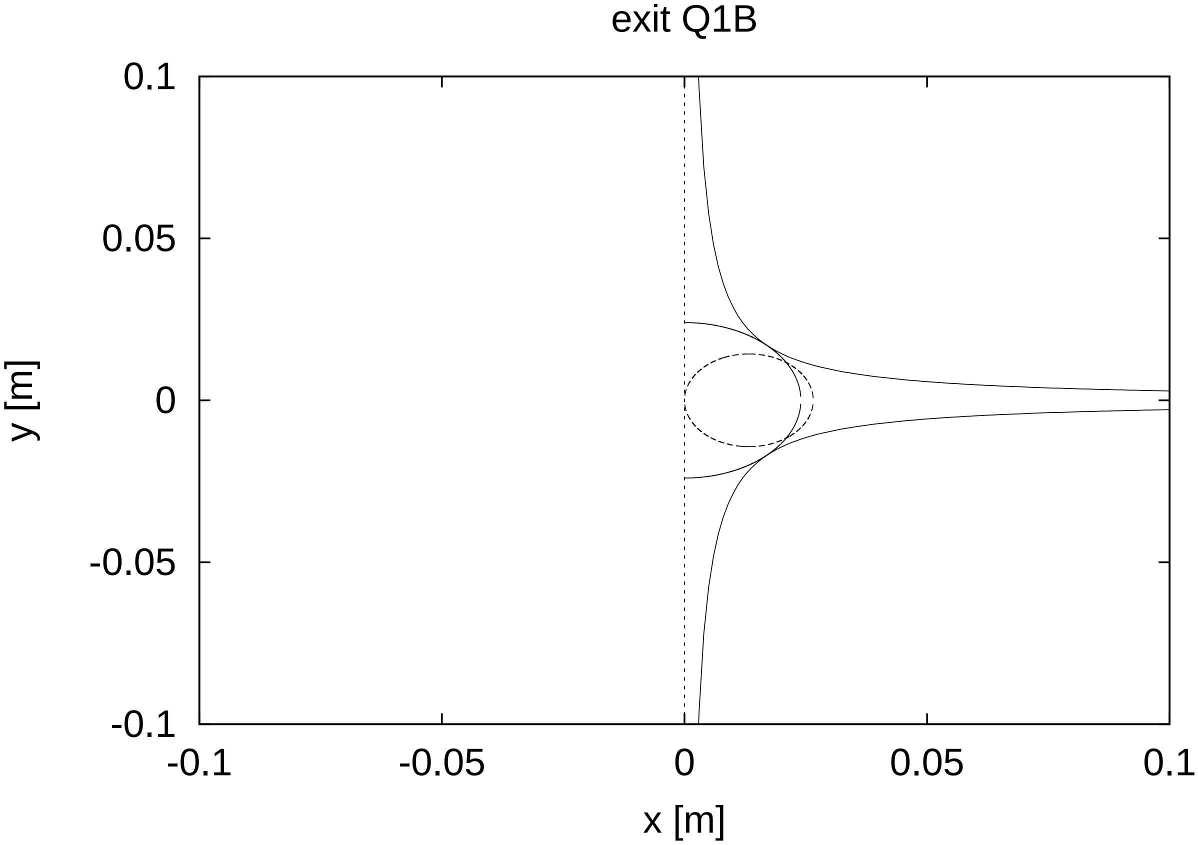
Minimum aperture for uncooled Au beam: $8.8\sigma_p$

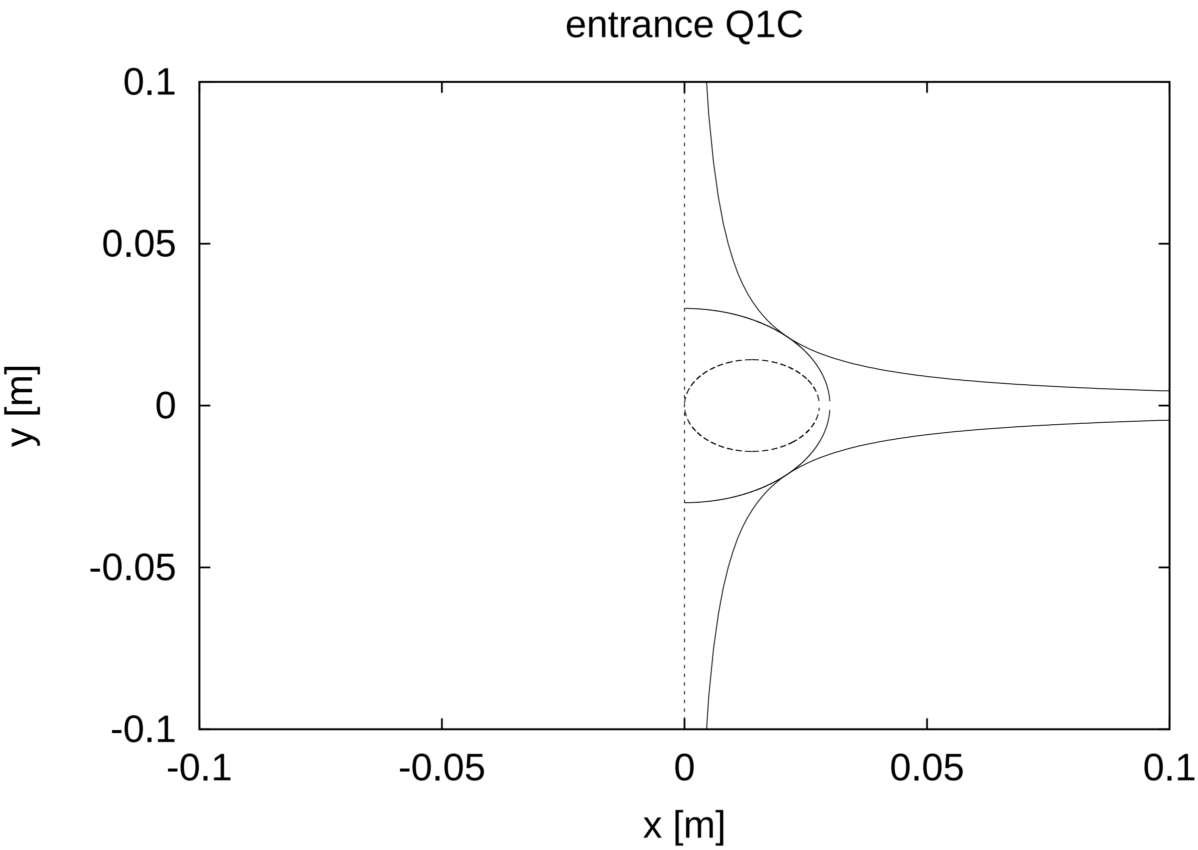

entranceQ1
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]

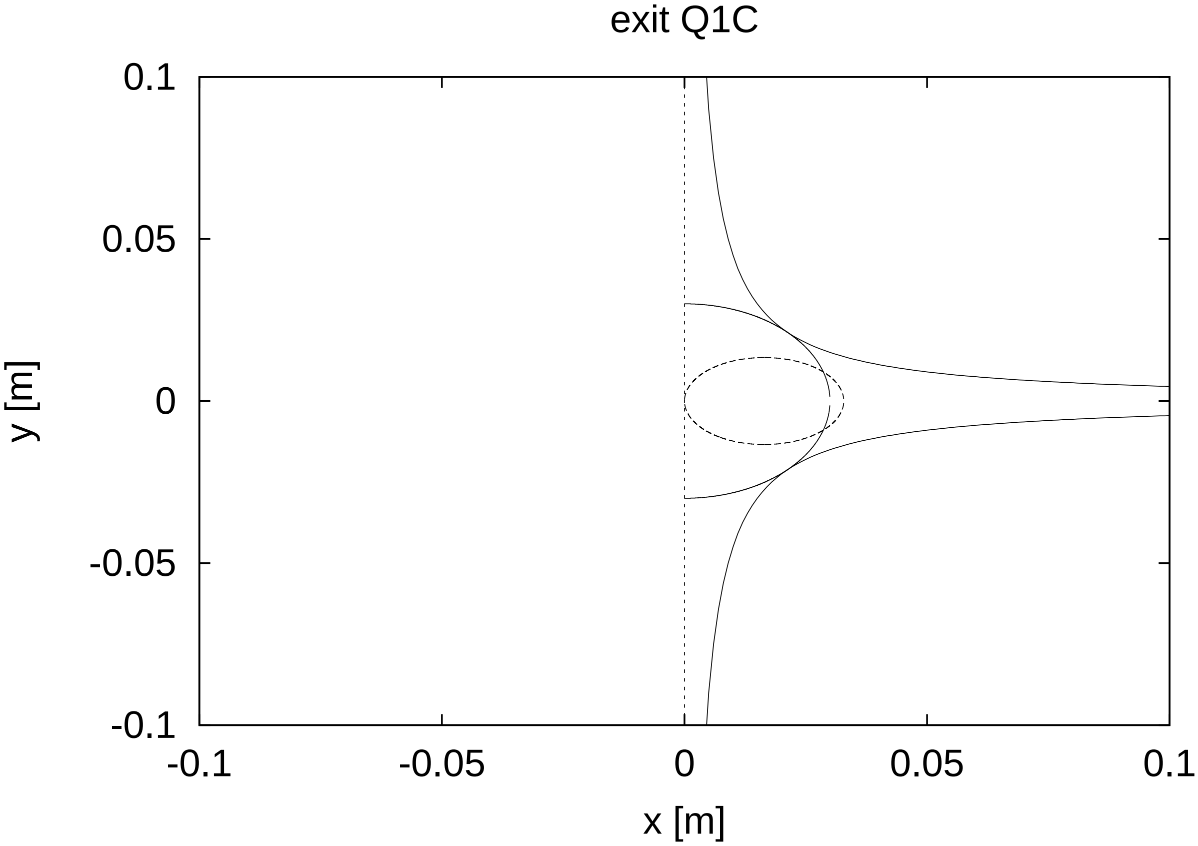

exit Q1
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]

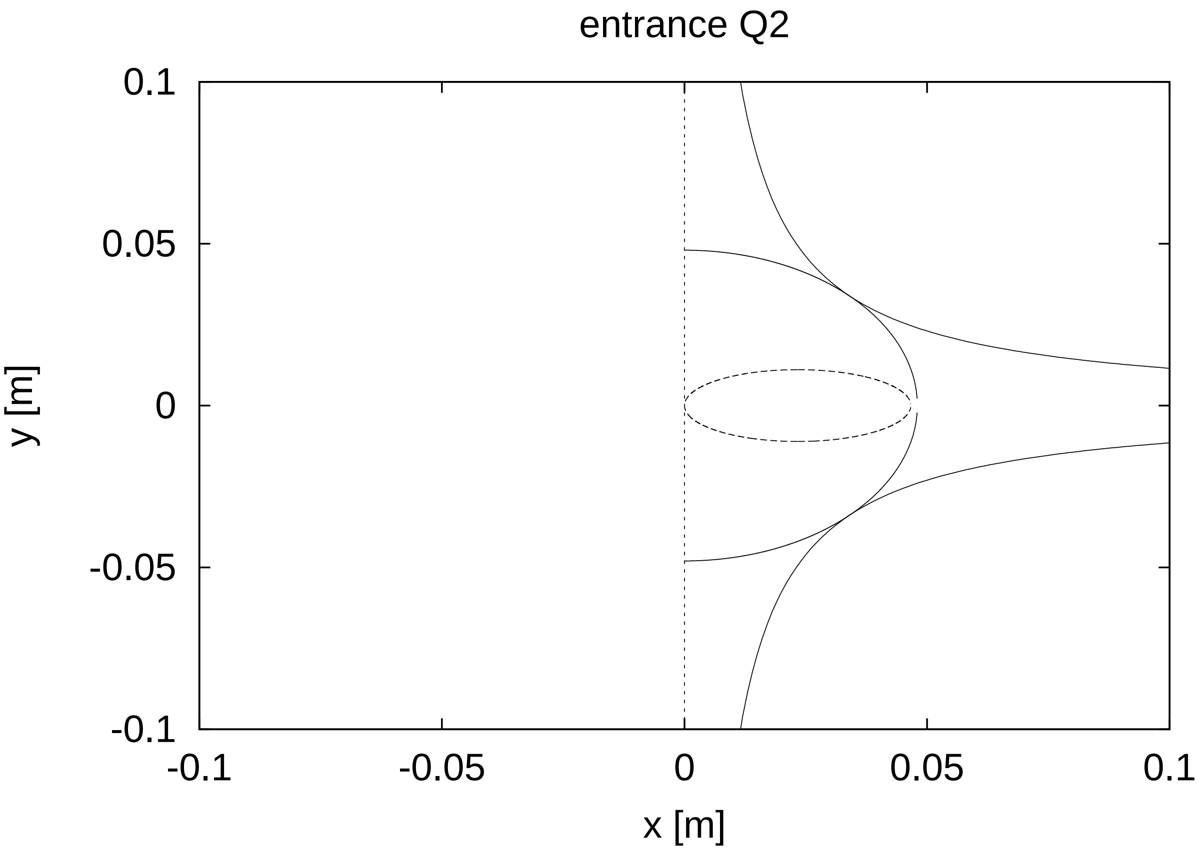


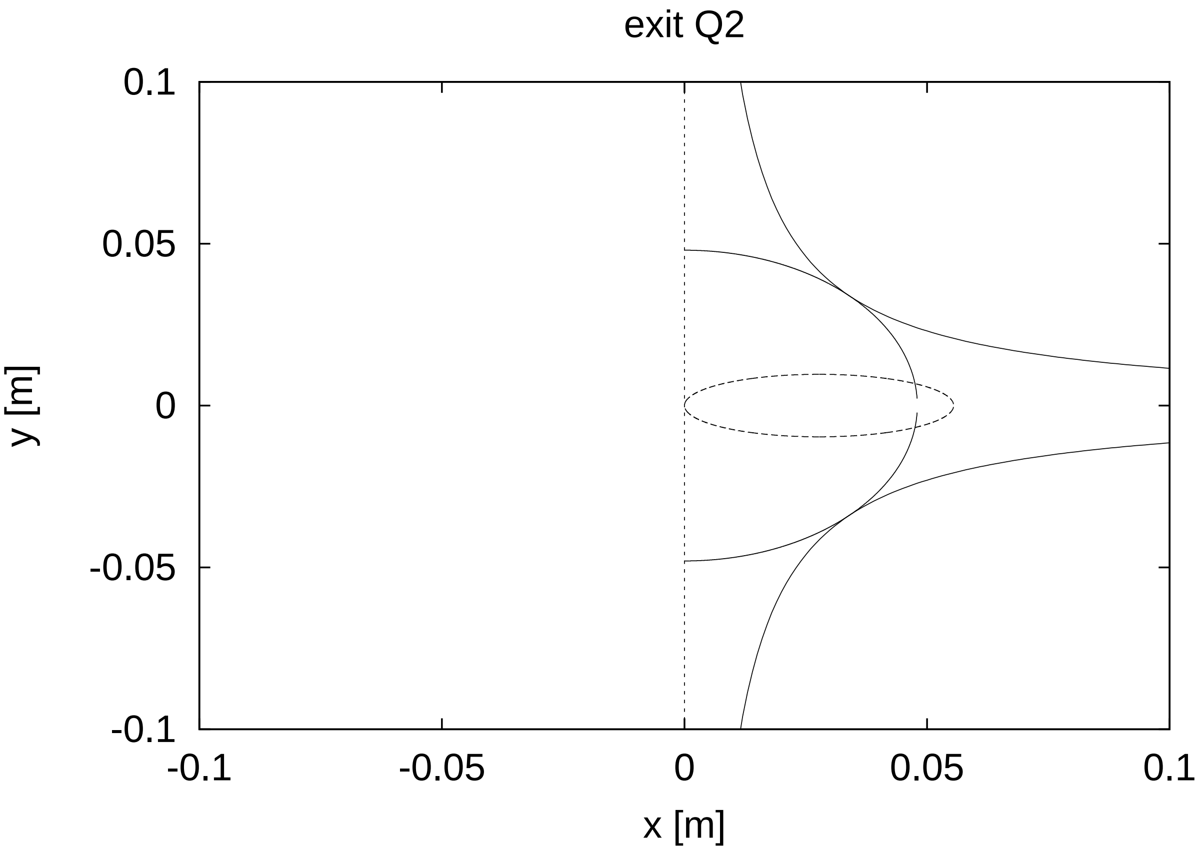
entrance Q1B
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]

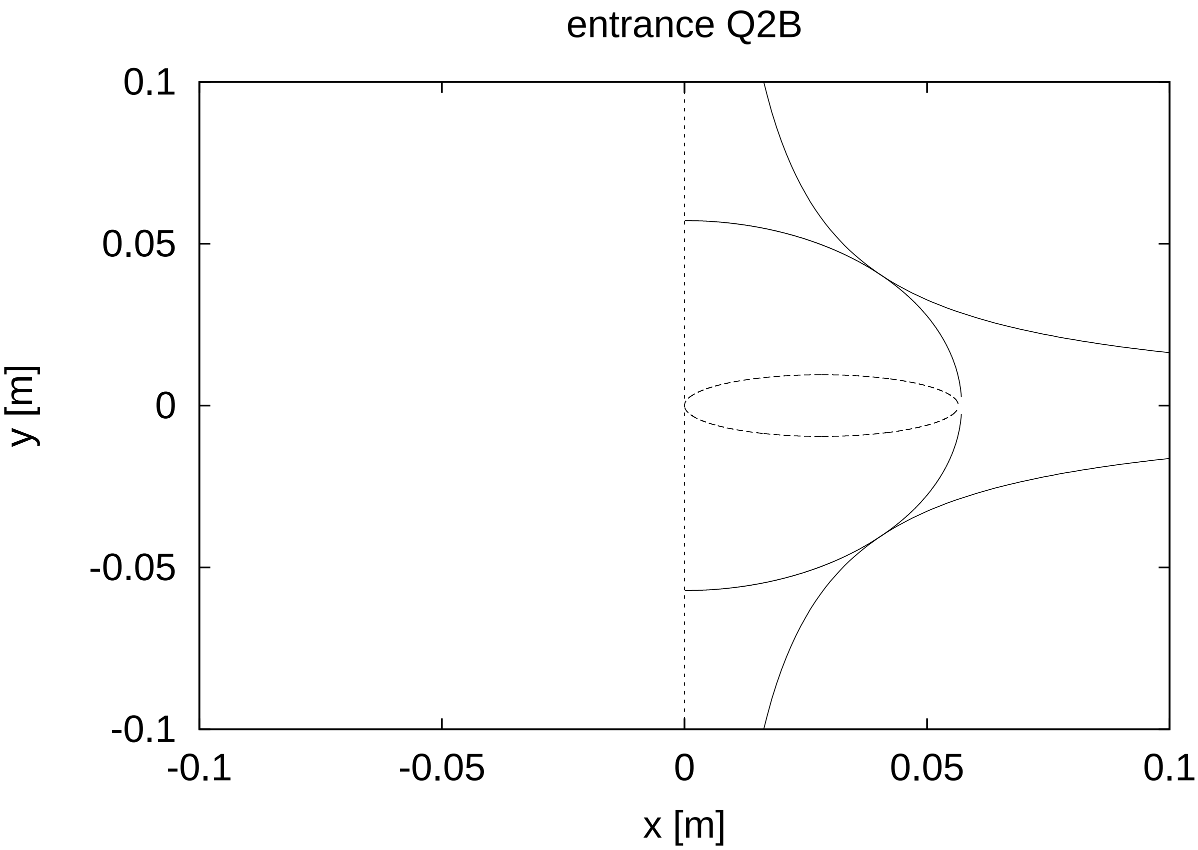

exit Q1B
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]

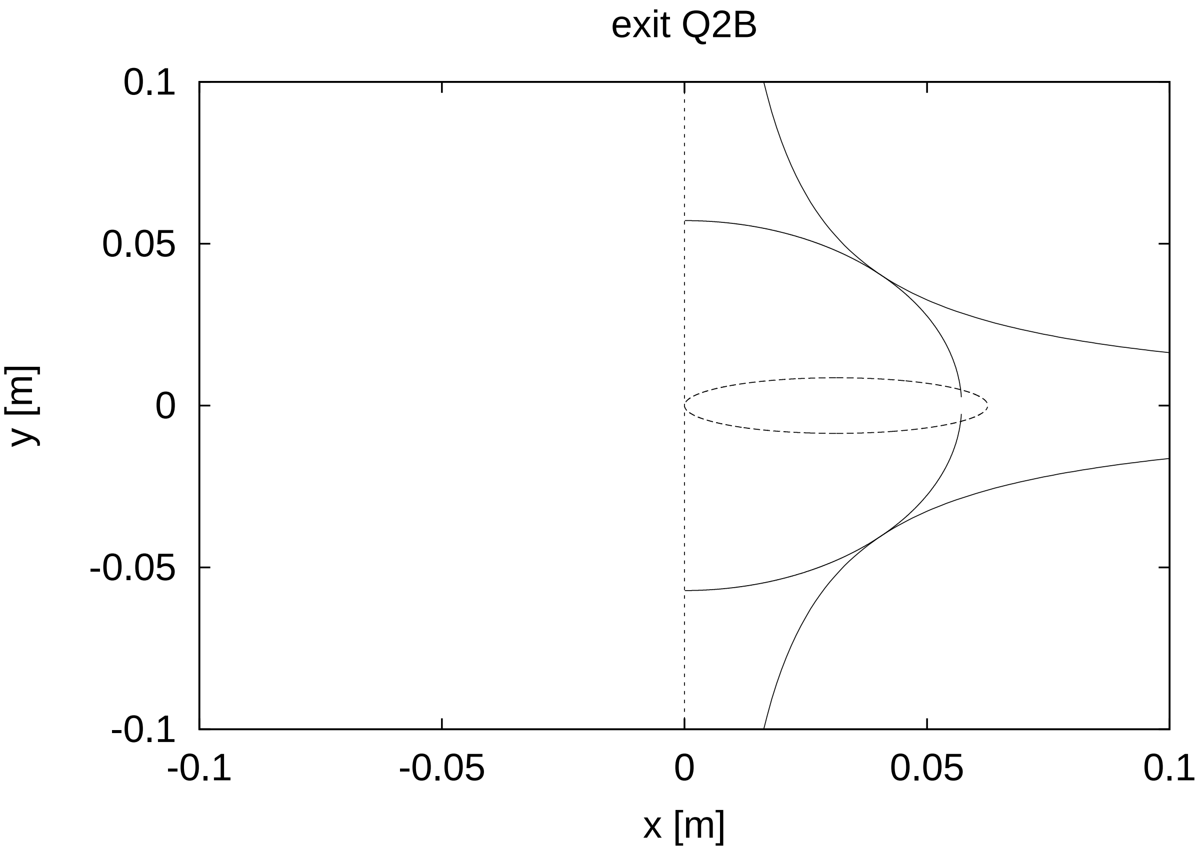

entrance Q1C
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]


exit Q1C
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]

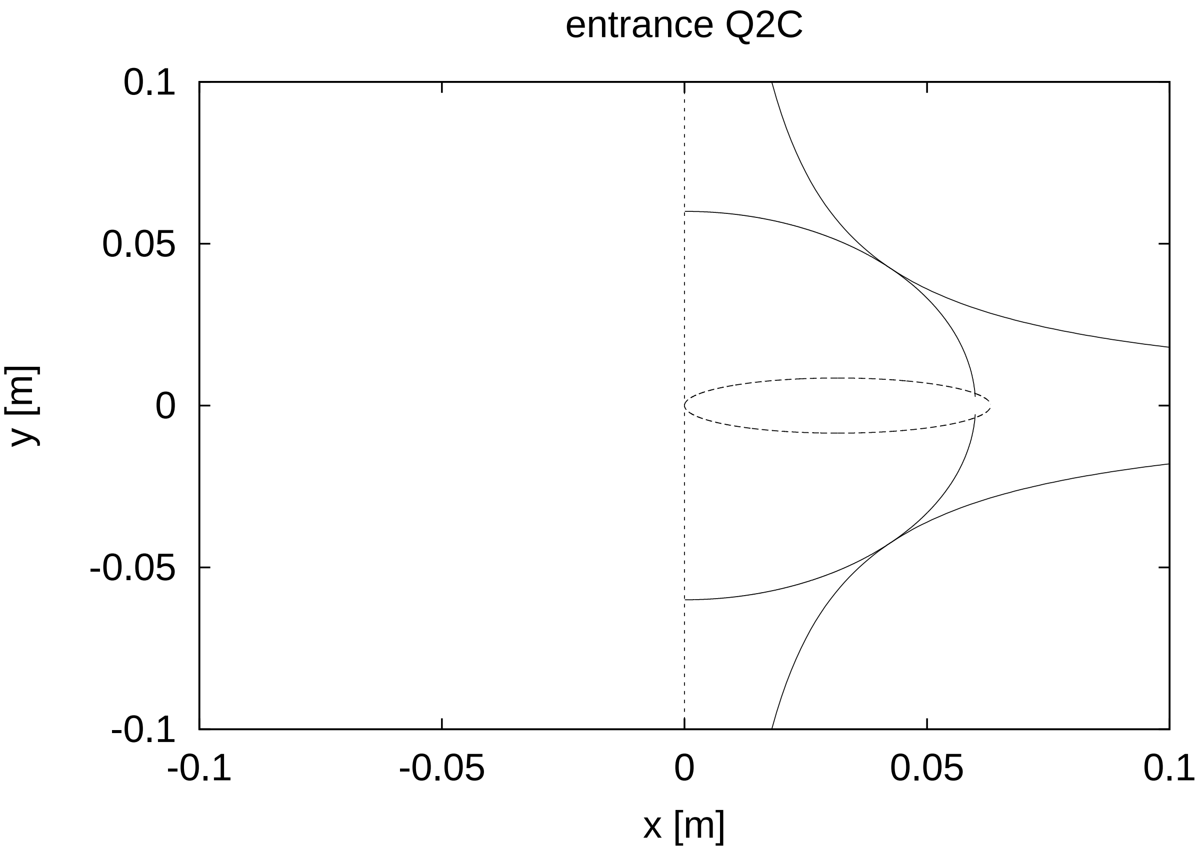

entrance Q2
0.1
0.05
0
-0.05
-0.1
-0.1
-0.05
0
0.05
0.1
x [m]
y [m]

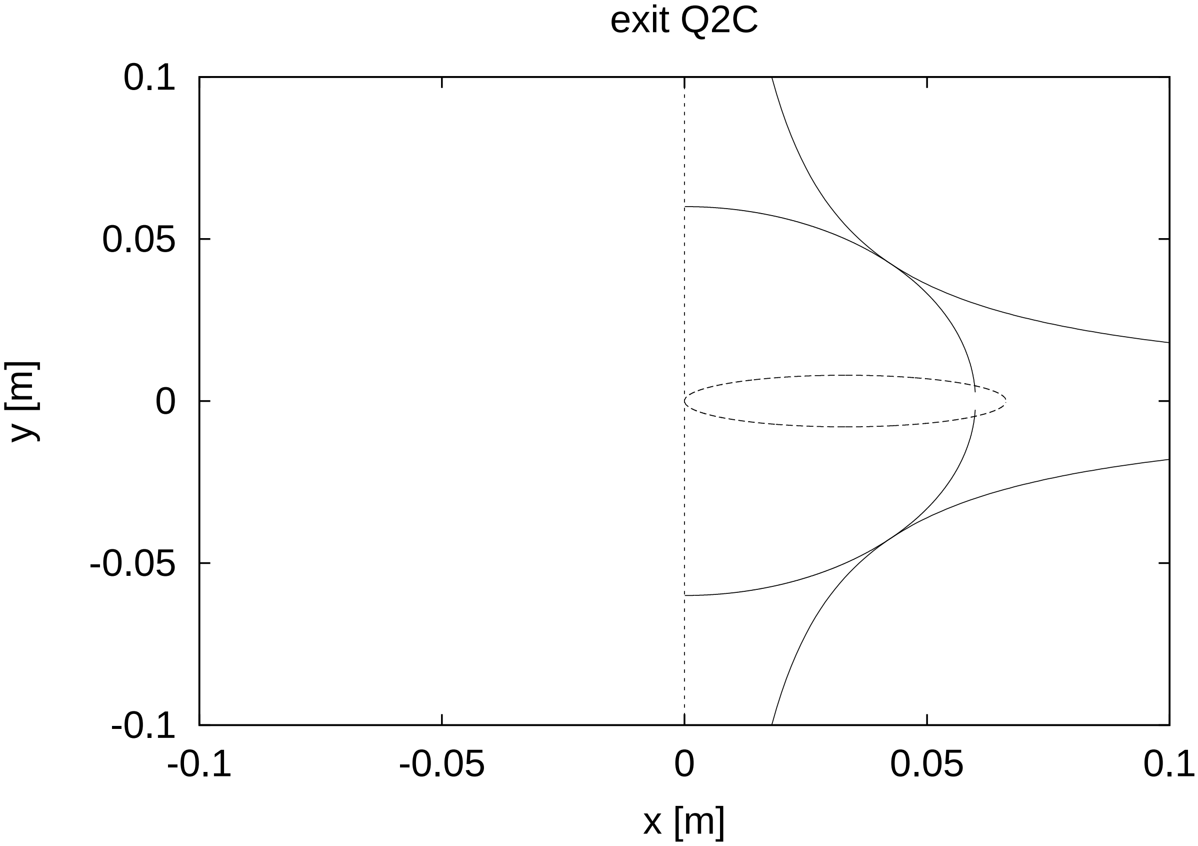

exit Q2
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]

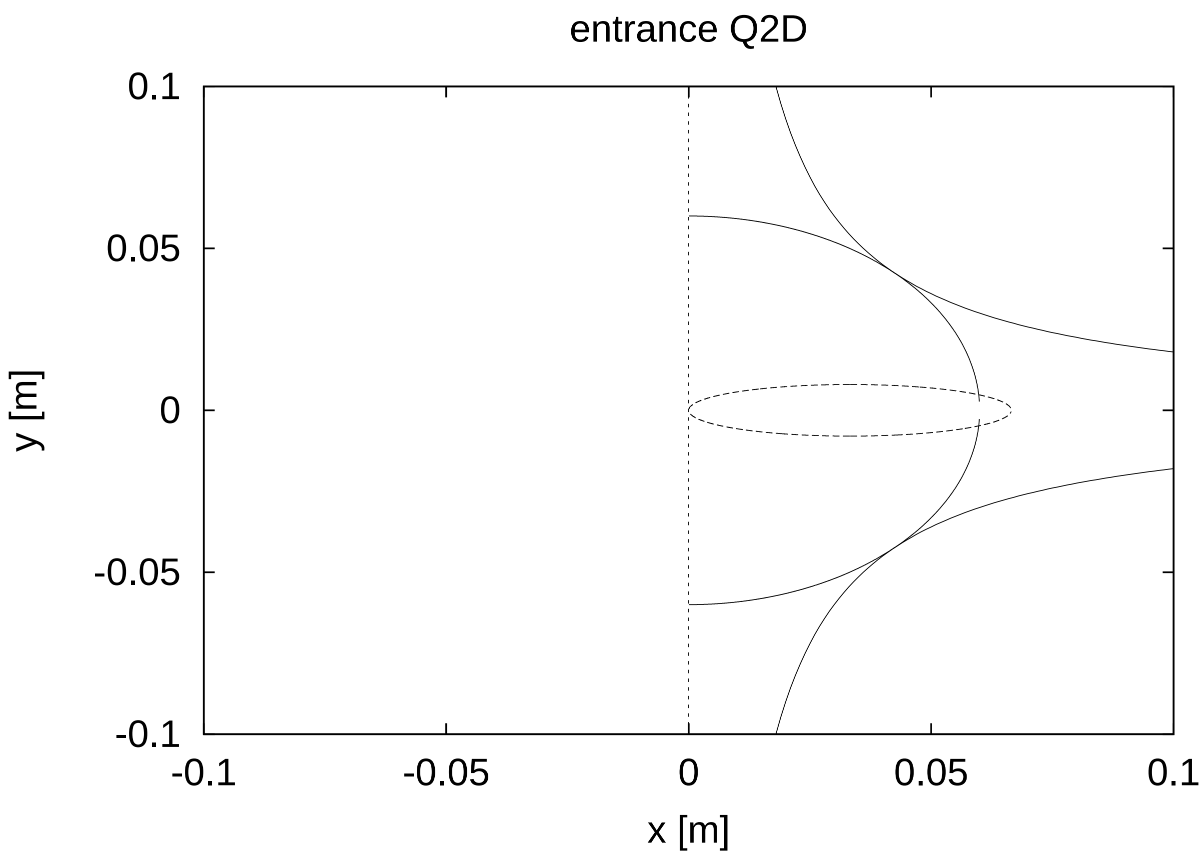

entrance Q2B
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]



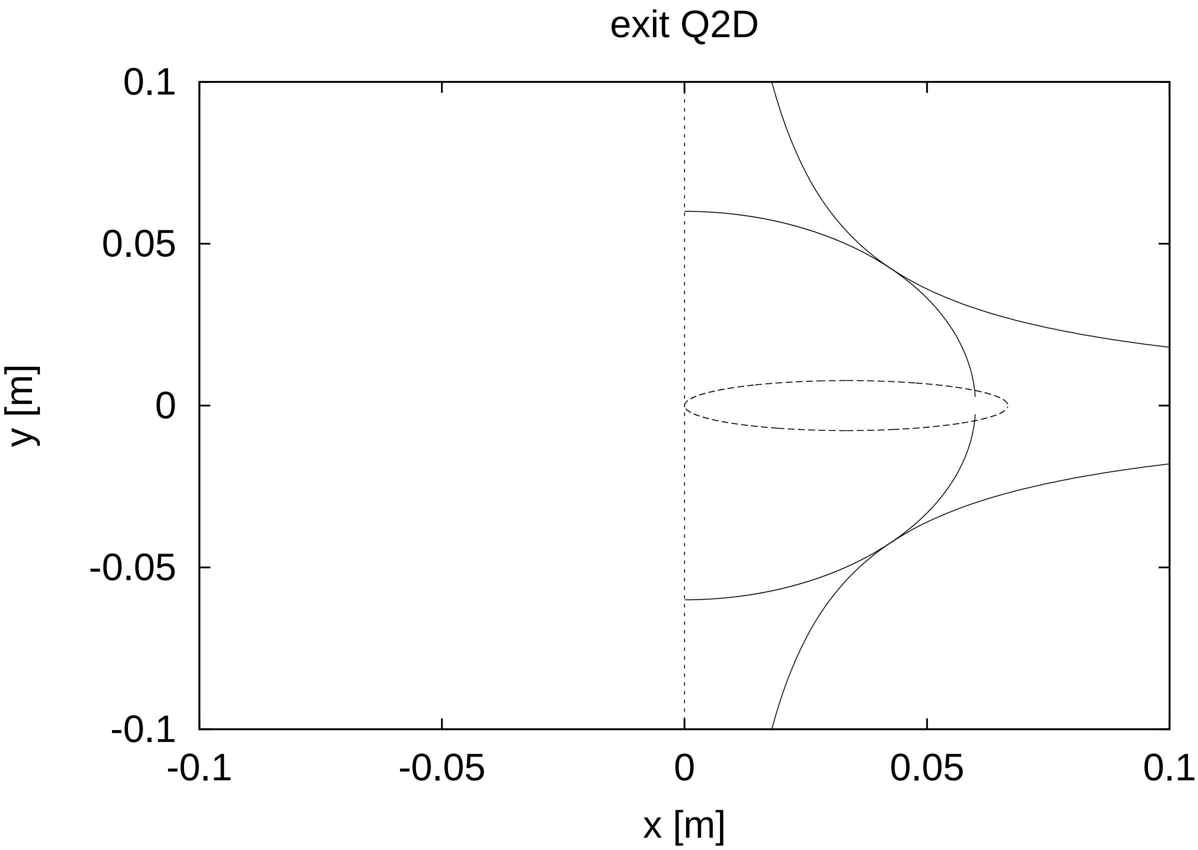
exit Q2B
0.1
0.05
0
-0.05
-0.1
-0.1
-0.05
0
0.05
0.1
y [m]
x [m]

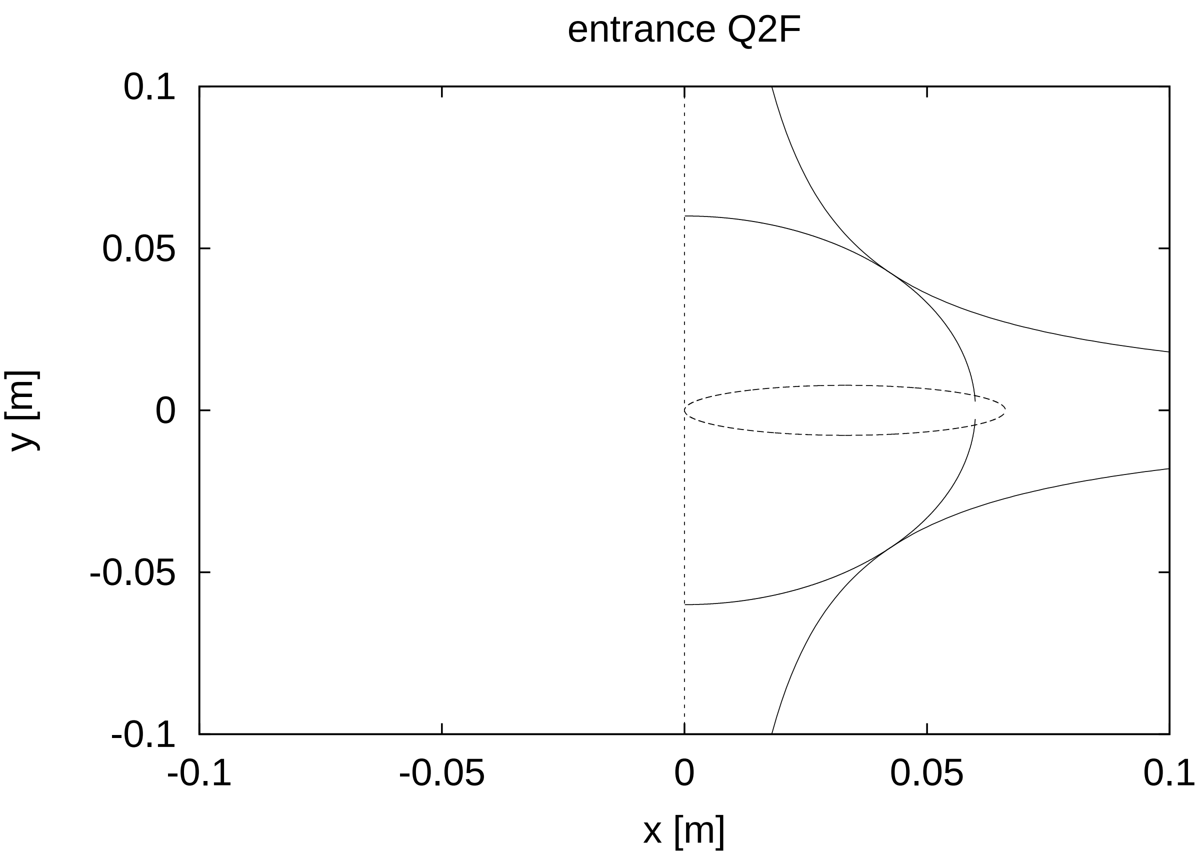

entrance Q2C
0.1
0.05
0
-0.05
-0.1
-0.1
-0.05
0
0.05
0.1
y [m]
x [m]

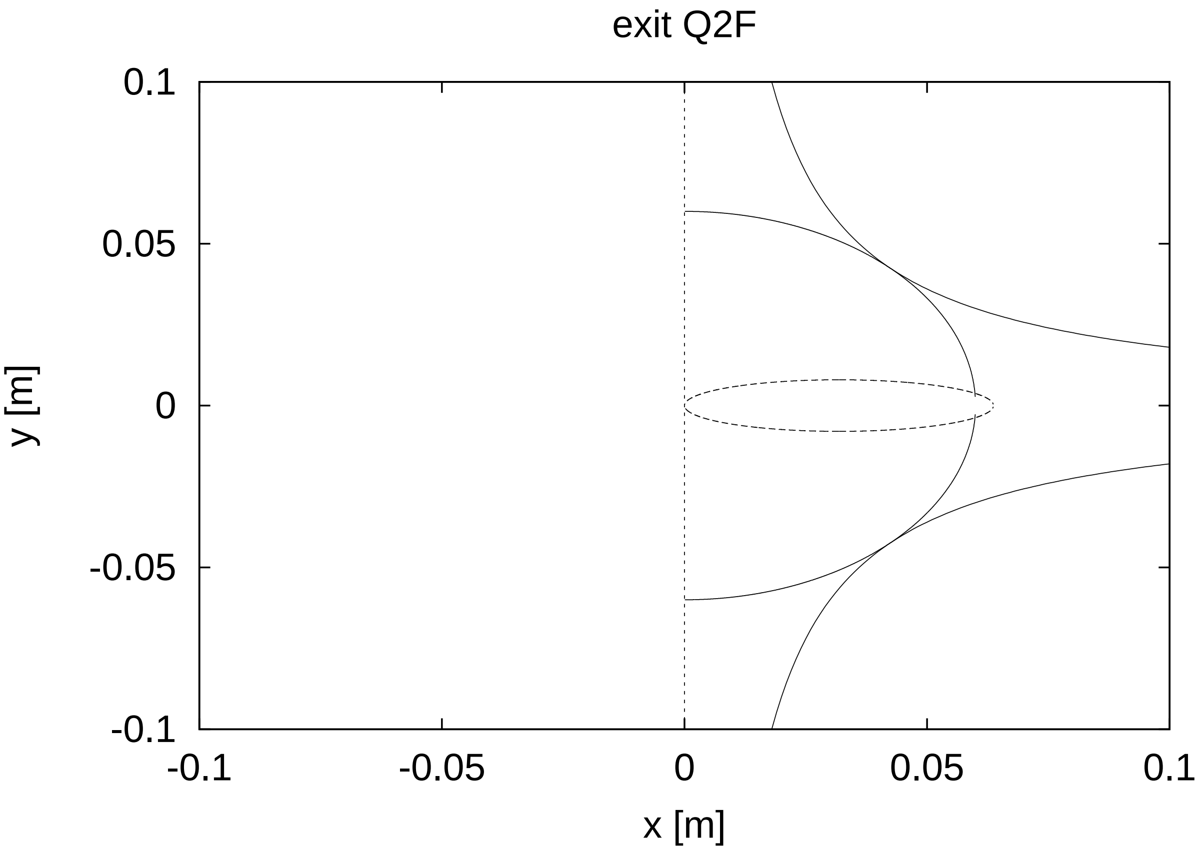

exit Q2C
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]

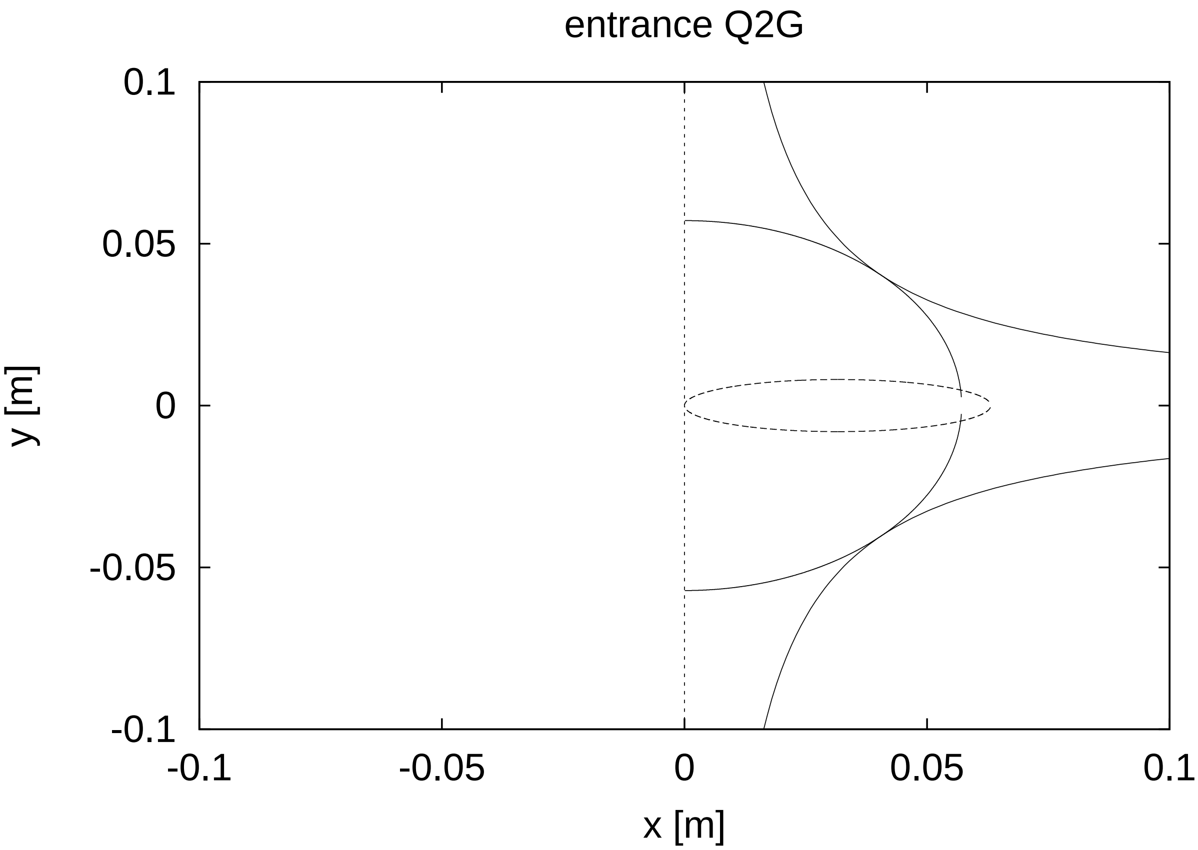


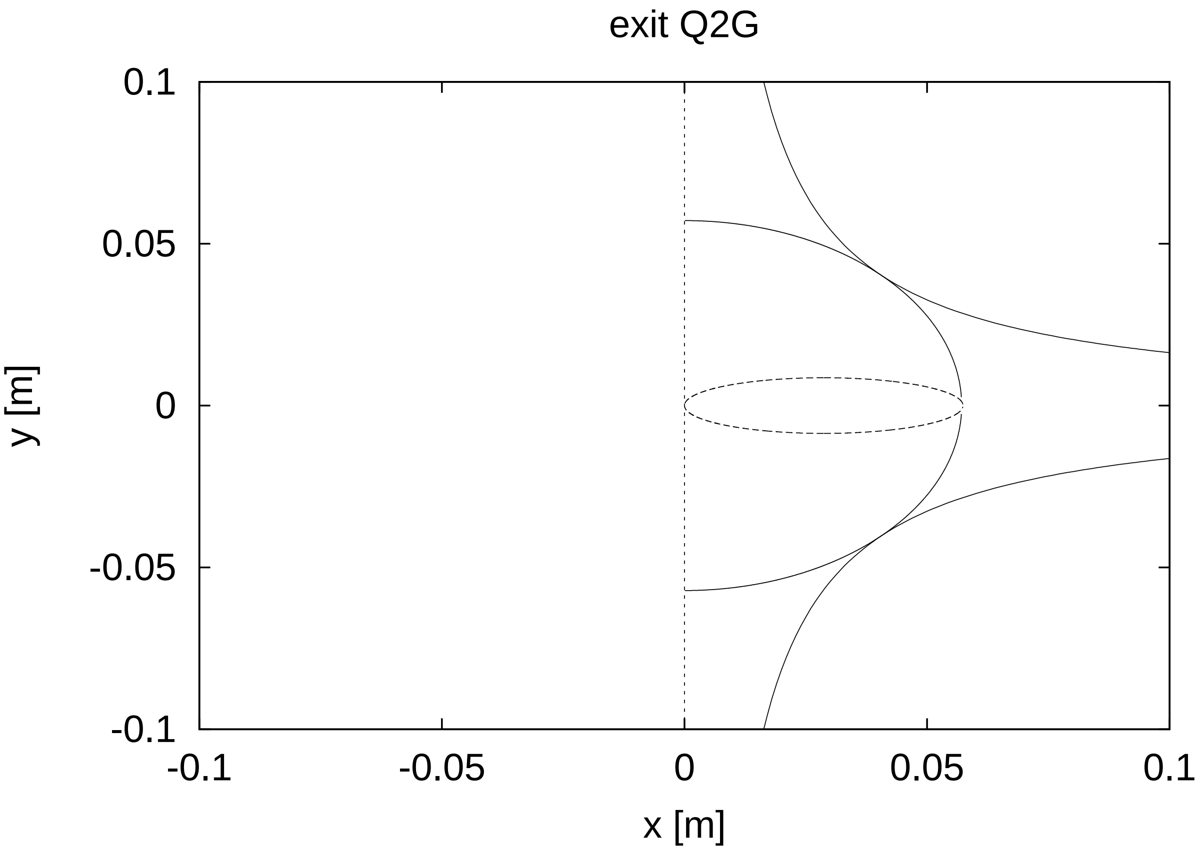
entrance Q2D
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]


exit Q2D
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]

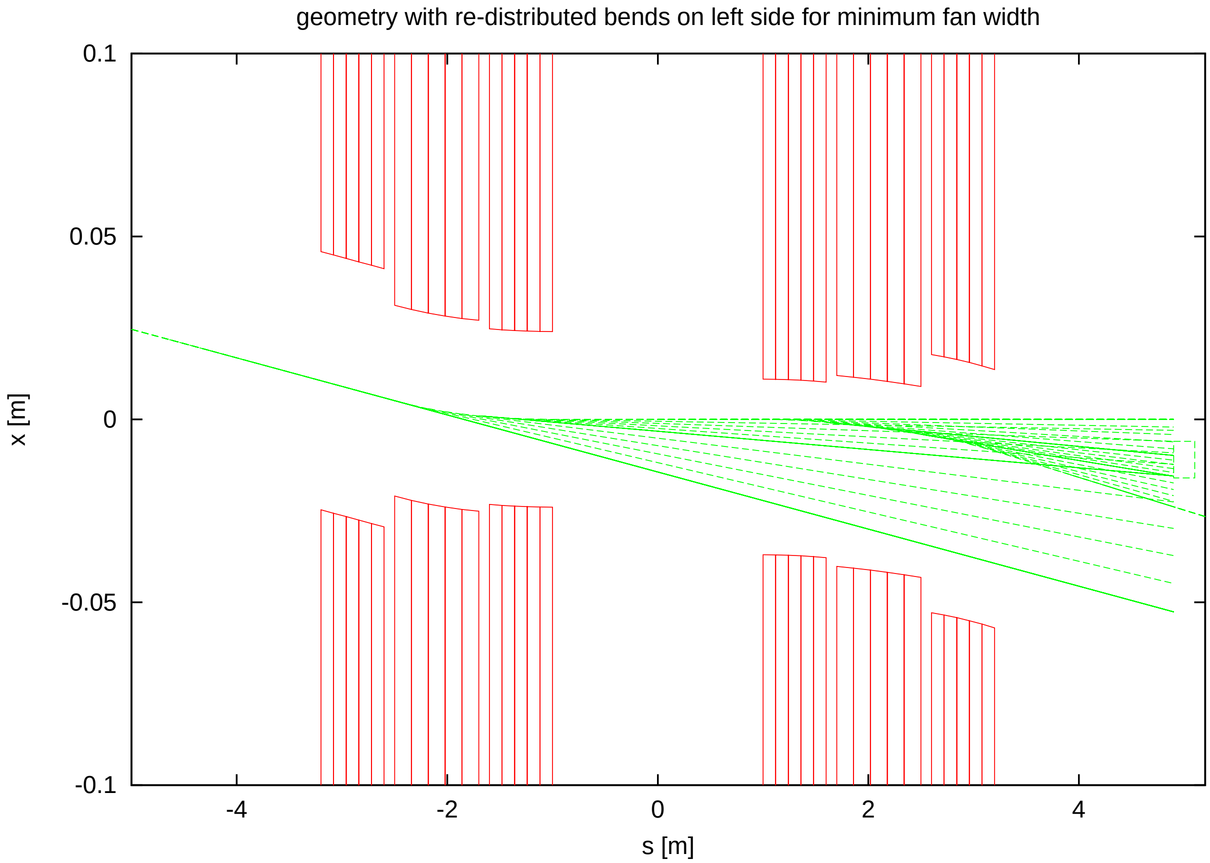

entrance Q2F
0.1
0.05
0
-0.05
-0.1
-0.1
-0.05
0
0.05
0.1
y [m]
x [m]


exit Q2F
0.1
0.05
0
-0.05
-0.1
y [m]
-0.1
-0.05
0
0.05
0.1
x [m]


entrance Q2G
0.1
0.05
0
-0.05
-0.1
-0.1
-0.05
0
0.05
0.1
y [m]
x [m]


exit Q2G
0.1
0.05
0
-0.05
-0.1
-0.1
-0.05
0
0.05
0.1
x [m]
y [m]

Synchrotron radiation fan (top view):



Q3 magnet at about 3 m from the IP needs inner diameter of some 60 mm

Synchrotron radiation hitting the septum, with optimized bends:

$$
\begin{aligned}
P_{\mathrm{total}} &\approx 1.0\,\mathrm{kW} \\
E_{\mathrm{critical}} &\leq 11\,\mathrm{keV}
\end{aligned}
$$

Beam-beam simulations with reduced proton current: