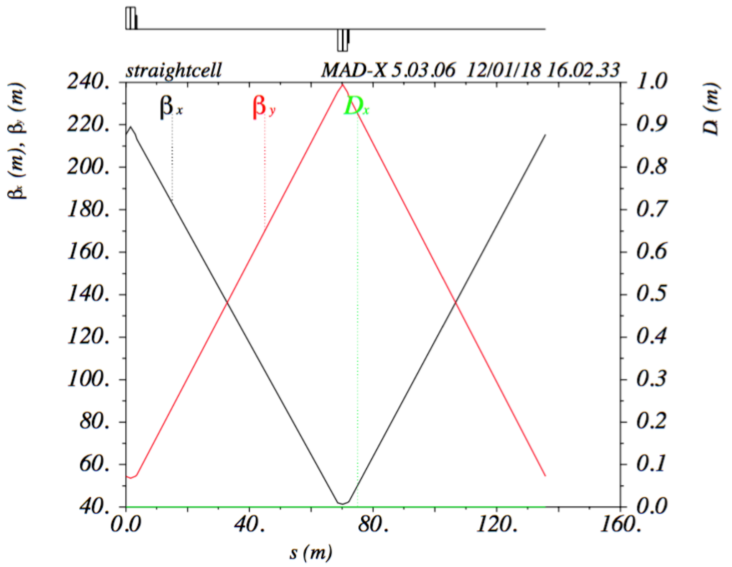
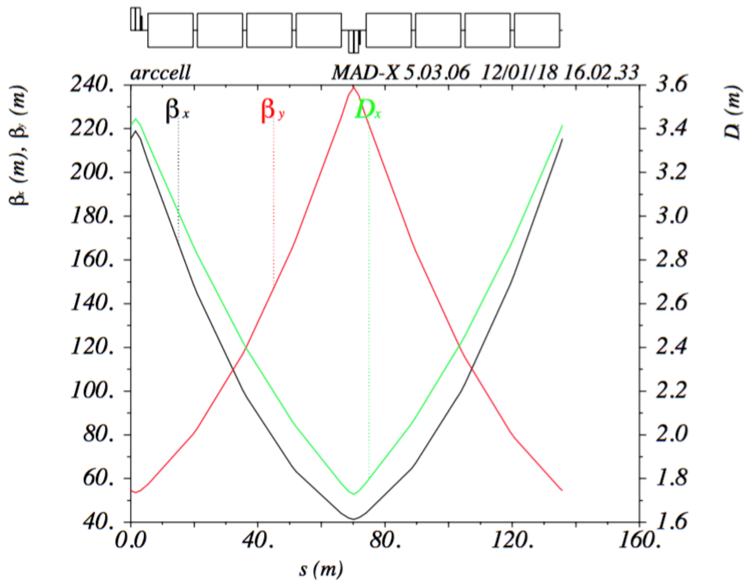
Problem 5.2.a):

The first regular fodo cell in the given lattice sits between 430 and 565 m from IP1. The basic straight cell (no bends) gives is plotted below:



while the regular arc cell is plotted below:



NOTE: the sextupoles following each dipole have been removed from the sequence, since they were OFF.

The source code is attached.

myJob.madx

```
// -------------------------------------------------------------
/*  Eugenio Senes
    JAI Course problem 5.2 a)
    12.01.2018
*/
// User defined variables -- copied from the given macro
nrj = 450.;//Beam energy
emittance_norm = 2.5e-6;
npart = 2.2e11;
bunch_len=0.0755;

//--------------------------------------------------------------
//calculations
gamma_rel=nrj/pmass;
epsx = emittance_norm /gamma_rel;
epsy = emittance_norm /gamma_rel;


call, file="cellSequence.seq";
// call, file="./optics/opt_inj.str";

BEAM, PARTICLE=proton, ENERGY=nrj,EX=emittance_norm/gamma_rel, NPART=1.15E11,
SIGE=4.5e-4*sqrt(450./NRJ), EX:=epsx, EY:=epsy, SIGT:=bunch_len;

USE, SEQUENCE = arcCell;
TWISS;
PLOT , HAXIS=s, VAXIS1=betx,bety, VAXIS2=dx, colour=100;

USE, SEQUENCE = straightCell;
TWISS;
PLOT , HAXIS=s, VAXIS1=betx,bety, VAXIS2=dx, colour=100;

STOP;
```

cellSequence.seq

```
// -----------------------------------------------------------
/*  Eugenio Senes
    JAI Course problem 5.2 a)
    12.01.2018
    Sequence file
*/
//-------------------------------------------------
// Magnets definitions
//strengths
kqf = 0.00672058135316;
kq12.r1b1 = -0.00601678958300;
ksf = 0.02541420325915;
ksd = -0.05229014955827;

// bends
b: sbend,l:= 14.18000000000000,angle:= 0.00490873852123,e1:= 0.00000000000000,e2:= 0.00000000000000;
// quads
qfh: quadrupole,l:= 1.55000000000000,k1:=kqf ;
mq.12r1.b1: qfh,k1:=kq12.r1b1 ;
// sextupoles
ms: sextupole,l:= 0.36900000000000;
ms.11r1.b1: ms,k2:=ksf ;
ms.12r1.b1: ms,k2:=ksd ;
//-------------------------------------------------
// Sequence definitions
// arc cell
arcCell: SEQUENCE, l = 564.52885466731368 + 1.55 - 430.31563529613766;
qfh, at = 430.31563529613766 + 0.775  - 430.31563529613766;
qfh, at = 431.86563529613761 + 0.775  - 430.31563529613766;
ms.11r1.b1, at = 432.98513529613757 + 0.775  - 430.31563529613766;
b, at = 442.08904037053810 + 0.775  - 430.31563529613766;
b, at = 457.62954106186726 + 0.775  - 430.31563529613766;
b, at = 473.17004175319636 + 0.775  - 430.31563529613766;
b, at = 488.71054244452552 + 0.775  - 430.31563529613766;
mq.12r1.b1, at = 498.93394751892595 + 0.775  - 430.31563529613766;
mq.12r1.b1, at = 500.48394751892590 + 0.775  - 430.31563529613766;
ms.12r1.b1, at = 501.60344751892586 + 0.775  - 430.31563529613766;
b, at = 510.70735259332639 + 0.775  - 430.31563529613766;
b, at = 526.24785328465543 + 0.775  - 430.31563529613766;
b, at = 541.78835397598459 + 0.775  - 430.31563529613766;
b, at = 557.32885466731364 + 0.775  - 430.31563529613766;
ENDSEQUENCE;

// straight cell
straightCell: SEQUENCE, l = 564.52885466731368 + 1.55 - 430.31563529613766;
qfh, at = 430.31563529613766 + 0.775  - 430.31563529613766;
qfh, at = 431.86563529613761 + 0.775  - 430.31563529613766;
ms.11r1.b1, at = 432.98513529613757 + 0.775  - 430.31563529613766;
mq.12r1.b1, at = 498.93394751892595 + 0.775  - 430.31563529613766;
mq.12r1.b1, at = 500.48394751892590 + 0.775  - 430.31563529613766;
ms.12r1.b1, at = 501.60344751892586 + 0.775  - 430.31563529613766;
ENDSEQUENCE;

// NOTE1 on the distances: at = (position in the HE-LHC model V.0.2) + (length of a half qfh) - (position of the first qfh in the HE-LHC model)
// NOTE2: all the sextupoles after the dipoles ms.xxxx.b1 are OFF! --> so have been removed
```

EX 5.2.b)

Maximum energy:

$\rho = 3$ Km
$B = 16$ T $\rightarrow \frac{p}{e} = B\rho \rightarrow p = 3\times10^3\,m \times 16T \times e \times 3\times10^8 \frac{m}{s} = 14,4 \frac{TeV}{c}$

and so the energy is $\boxed{E = 14,4\ TeV}$

Synchrotron radiation:

$\gamma(14,4\,TeV) = 15,3\times10^3$

now the magority of the photons is emitted at the criticall energy

$$\boxed{\epsilon_c = \hbar\omega_c = \hbar\frac{2}{3}\frac{c}{\rho}\gamma^3 = 158,5\ eV}$$

So in the UV.

The energy lost per turn by one proton is:

$$\boxed{U_0(KeV) = 6,03\frac{E^4(TeV)}{\rho(m)} = 86,4\ KeV}$$

this means that for an 1 A beam the power irradiated is

$$\boxed{P(KW) = U_0^{(KeV)}\cdot I(A) = 86,4\ KW}$$

So this means:

- the vacuum is stressed a lot by the synchrotron emission, the beam pipe will probbably need proper conditioning. Also the working of getters and ion pump. has to be verified carefully because ad- and ab-sorbtion of gases is reduced by radiation. (smaller capture time on the surfaces of the residual gas)

- the RF system has to be designed to transfer to the beam at least 86,4 KW of power. And ~~at top~~ ~~and~~ this just to maintain the energy at flattop.

Compared to the LHC at 7TeV, where just 3.7 KW are irradiated per beam [1], this means to require a much higher performance of the RF system.

[1] LHC project report 316, 1.12.1999

- In general such high radiation level is stressing for all the instrumentation, in particular the electronics.

Question 5.2.c):

on the accelerator side, there is no particular advantage in choosing between the two racetracks while retaining 4 interaction points. In both cases, dispersion suppressor cells are required for the interaction points and the RF.
On the detector side it is a complete different story. Having two detectors on the same line might lead to detector noise, fake tracks and pileup. This is because the forward physics of one detector can propagate to the second one. A consistent part of the collision debris can be stopped by collimators, but this is not possible for low interacting particles such as muons.