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COMPUTERLAB, EXERCISE 1.2.1-2, SOLUTION

Abstract

Turn separation at extraction from cyclotron. Limitation in energy.

Contents

1 1.2.1-2 - Acelerate to extraction **2**

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The input data file is given in page 4, a gnuplot script to plot the accelerated trajectory is given page 5.

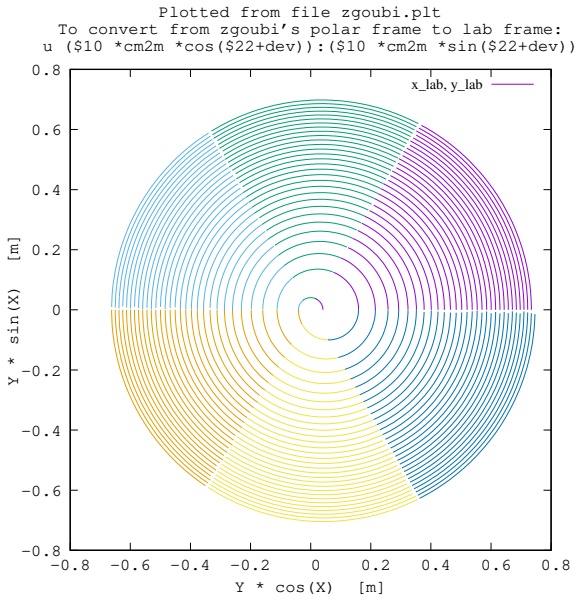

Figure 1: Accelerated trajectory, over 30 turns. In this simulation, there are two accelerating gaps, 100 kV each, located along a diameter. Injection energy is 20 keV, 6.02 MeV is reached in 30 turns.

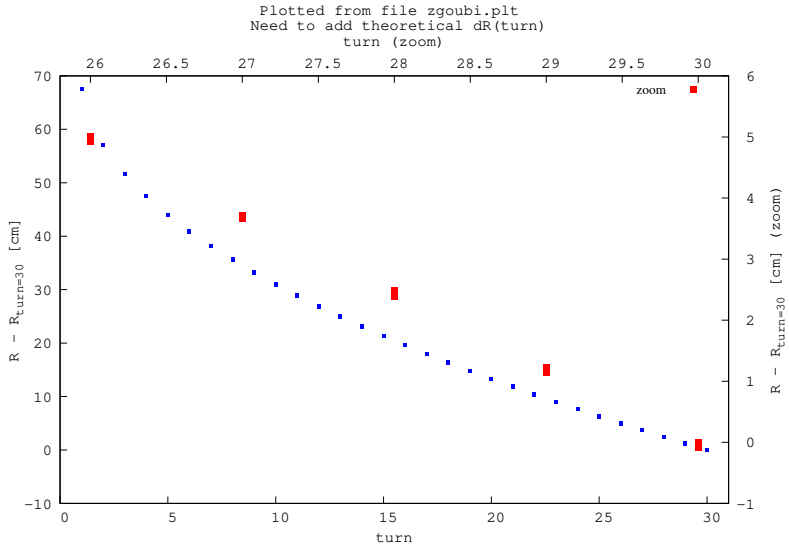

Figure 2: Distance to last turn, as a function of turn number (a zoom in, in red, top horizontal and right vertical axes). The distance between the last two turns is 1.2 cm, proper to the installtion of a septum for beam extraction. This distance decreases with energy, which sets a limit to the maximum energy which can be extracted from a cyclotron.

Optical sequence in zgoubi, separation at extraction

```
Cyclotron, classical. Acceleration to 6.02 MeV.
 'OBJET'
64.62444403717985                  ! Reference: 200keV proton.
2                                  ! Generate a
1 1                                ! single particle.
4.087013 0. 0. 0. 0. 0.3162126 'o' ! p[MeV/c]=  6.126278, Brho[kG.cm]= 20.435064, kin-E[keV]=  20
1
 'PARTICUL'            ! This is required only because we want to get the time-of-flight
PROTON

! DIPOLE appears 3 times as a dipole is a 60 deg deviation
'INCLUDE'
1
60degSector.inc[#Start:#End]
 'FAISCEAU'
'INCLUDE'
1
60degSector.inc[#Start:#End]
 'FAISCEAU'
'INCLUDE'
1
60degSector.inc[#Start:#End]
 'FAISCEAU'
 'CAVITE'
3                                  ! dW = qVsin(phi_s), independent of time
0. 0.
100e3  1.57079632679

'INCLUDE'
1
60degSector.inc[#Start:#End]
 'FAISCEAU'
'INCLUDE'
1
60degSector.inc[#Start:#End]
 'FAISCEAU'
'INCLUDE'
1
60degSector.inc[#Start:#End]
 'FAISCEAU'
 'CAVITE'
3                                  ! dW = qVsin(phi_s), independent of time
0. 0.
100e3  1.57079632679

 'REBELOTE'             ! K = 99 : coordinates at end of previous pass are used as initial
29  1.1 99              ! coordinates for the next pass ; idem for spin components.

 'FAISCEAU'
 'SYSTEM'
6
cp gnuplot_zgoubi.plt.cmd gnuplot_zgoubi.plt_temp.cmd
sed -i 's@pause 2@pause 0@g' gnuplot_zgoubi.plt_temp.cmd
gnuplot < gnuplot_zgoubi.plt_temp.cmd
mv -f gnuplot_zgoubi.plt_XYLab.eps gnuplot_zgoubi.plt_XYLab_dRRSeparation.eps
okular gnuplot_zgoubi.plt_XYLab_dRRSeparation.eps &
rm -f gnuplot_zgoubi.plt_temp.cmd
 'END'
```

60degSector.inc file

```
Cyclotron, classical. Acceleration to 6.02 MeV.
 'OBJET'
64.62444403717985                  ! Reference: 200keV proton.
2                                  ! Generate a
1 1                                ! single particle.
4.087013 0. 0. 0. 0. 0.3162126 'o' ! p[MeV/c]=  6.126278, Brho[kG.cm]= 20.435064, kin-E[keV]=  20
1
'MARKER'  #Start
'DIPOLE'
2
60. 50.
30.  5. 0. 0. 0.
0.  0.                                     ! EFB 1  hard-edge
4  .1455   2.2670  -.6395  1.1558  0. 0.  0.
30. 0.  1.E6  -1.E6  1.E6  1.E6
0.   0.                                    ! EFB 2
4  .1455   2.2670  -.6395  1.1558  0. 0.  0.
-30. 0.  1.E6  -1.E6  1.E6  1.E6
0. 0.                                      ! EFB 3
0  0.      0.      0.      0.      0. 0.  0.
0. 0.  1.E6  -1.E6  1.E6  1.E6 0.
4   10.
1.                  ! The smaller, the better the orbits close.
2  0. 0. 0. 0.      ! Could also be, e.g., 2 50. 0. 50. 0. with Y0 amended accordingly in OBJET
'MARKER'  #End
'END'
```

Plot trajectories, using gnuplot

```
set title "Plotted from file zgoubi.plt  \n To convert from zgoubi's \
polar frame to lab frame: \n u ($10 *cm2m *cos($22+dev)):($10 *cm2m *sin($22+dev)) " font "sans, 14"

set key maxcol 1
set key t r

set xtics mirror font  "sans, 14"
set ytics mirror font  "sans, 14"

set xlabel 'Y * cos(X)  [m]' font  "sans, 14"
set ylabel 'Y * sin(X)  [m]' font  "sans, 14"

cm2m = 0.01
MeV2eV = 1e6
am = 938.27203
c = 2.99792458e8
pi = 4. * atan(1.)

NOEL_1 = 4   #   number of 1st TOSCA in zgoubi,plt (col. 42)
NOEL_2 = 8   #   number of 2nd TOSCA in zgoubi,plt (col. 42)
NOEL_3 = 12   #   number of 3rd TOSCA in zgoubi,plt (col. 42)
NOEL_4 = 17   #   number of 4th TOSCA in zgoubi,plt (col. 42)
NOEL_5 = 21   #   number of 5th TOSCA in zgoubi,plt (col. 42)
NOEL_6 = 25   #   number of 6th TOSCA in zgoubi,plt (col. 42)

dev = 2.*pi/6.

set size ratio -1

plot  \
   'zgoubi.plt' u ($42==NOEL_1 ? $10 *cm2m *cos($22) :1/0):($10 *cm2m *sin($22)) w l tit 'x\_lab, y\_lab' ,\
   'zgoubi.plt' u ($42==NOEL_2 ? $10 *cm2m *cos($22+   dev) :1/0):($10 *cm2m *sin($22+   dev)) w l notit ,\
   'zgoubi.plt' u ($42==NOEL_3 ? $10 *cm2m *cos($22+2.*dev) :1/0):($10 *cm2m *sin($22+2.*dev)) w l notit ,\
   'zgoubi.plt' u ($42==NOEL_4 ? $10 *cm2m *cos($22+3.*dev) :1/0):($10 *cm2m *sin($22+3.*dev)) w l notit ,\
   'zgoubi.plt' u ($42==NOEL_5 ? $10 *cm2m *cos($22+4.*dev) :1/0):($10 *cm2m *sin($22+4.*dev)) w l notit ,\
   'zgoubi.plt' u ($42==NOEL_6 ? $10 *cm2m *cos($22+5.*dev) :1/0):($10 *cm2m *sin($22+5.*dev)) w l notit

    set terminal postscript eps blacktext color  enh  "Times-Sans" 12
      set output "gnuplot_zgoubi.plt_XYLab_dRRSeparation.eps"
      replot
      set terminal X11
      unset output


pause 2   # don't change this: needed for proper running of sector180deg
exit
```