

Simulation of injection into EMMA, injection section

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Abstract

Principles, methods and examples for the simulation of injection into EMMA, using Zgoubi, are described.

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1 Introduction

Injection into EMMA is simulated, using Zgoubi and hard edge magnets.

For 10, 15 and 20 MeV, the septum field is given 3 different values (two correspond to extreme trajectories or extreme kicker fields, one is taken in between). For each one of these 3 septum values, the kickers are varied so to get ring closed orbit conditions downstream of the second one.

2 Working hypothesis

- The 070221b lattice is considered : the geometrical and magnetic parameters of the cell are those found on EMMA web site
- All elements, QF, QD, kickers as well as septum are hard edge, here
- The geometry in the injection region (septum and first two cells) corresponds to the scheme in Fig. 1, with particular quadrupole shifts (070221b lattice)
 - $x_d = +3.404834122312866$ cm
 - $x_f = +0.7513707181808552$ cm
 - The geometry in the injection septum region (septum positioning, entrance coordinates, etc.) is drawn from the plot in Fig. 2
 - A template zgoubi.dat file, comprised of the septum and first three cells, including FIT input data for kicker matching, is given in App. A. This template can be extended to include fringe fields if desired.
 - Closed orbits at various energies, right upstream of the $2\pi/42$ axis break, and periodical optical functions at 10, 15 and 20 MeV right downstream of a corner of the polygon (a template data file for matrix calculation is given in App. B), are as follows :

E (MeV)	x (cm)	x' (mrad)	p/p_0	alpha_x	beta_x	alpha_y	beta_y
10	-5.5476E-02	3.8184E+01	6.772144E-01	0.01539	0.06331	-3.07452	0.70422
11	-1.2486E-01	3.1597E+01	7.417895E-01				
12	-1.5911E-01	2.5148E+01	8.063534E-01				
13	-1.5936E-01	1.8836E+01	8.709087E-01				
14	-1.2674E-01	1.2661E+01	9.354571E-01				
15	-6.2390E-02	6.6227E+00	1.000000E+00	0.27705	0.17960	-1.52145	0.58389
16	3.2587E-02	7.1897E-01	1.064538E+00				
17	1.5710E-01	-5.0507E+00	1.129072E+00				
18	3.1009E-01	-1.0687E+01	1.193604E+00				
19	4.9050E-01	-1.6193E+01	1.258133E+00				
20	6.9734E-01	-2.1569E+01	1.322659E+00	0.35772	0.27705	-1.28959	0.72273

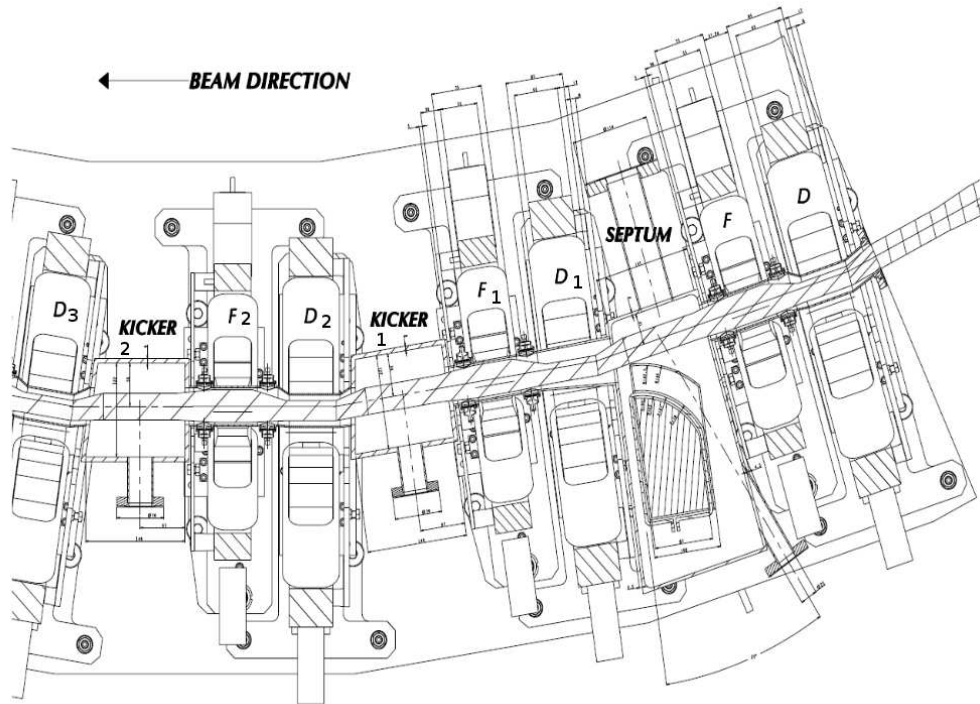


Figure 1: EMMA injection region [2] and notations used in the text.

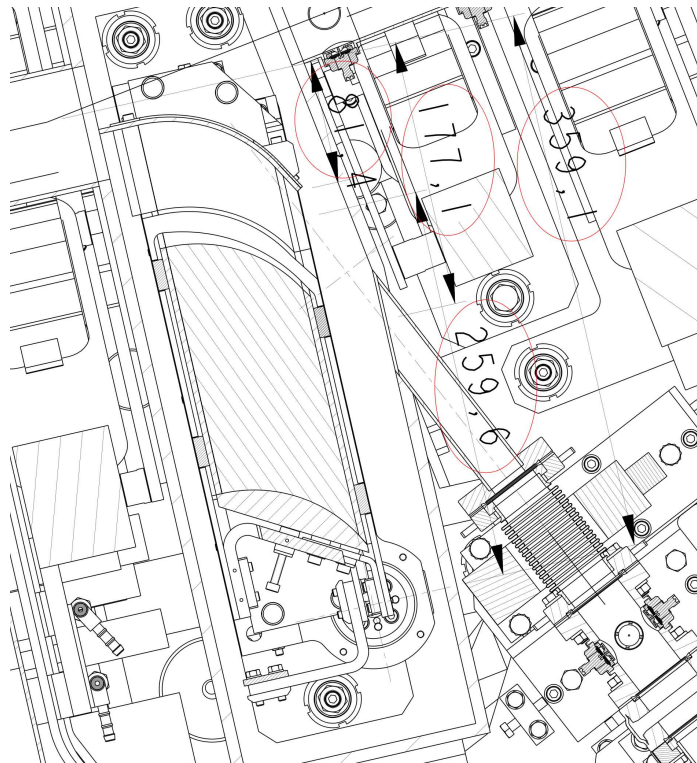


Figure 2: EMMA injection septum region, with distances [2].

3 Results

3.1 Orbits, 10, 15 and 20 MeV

Figs. 3- 5 show the injection paths at 10, 15 and 20 MeV. Starting coordinates at entrance to septum magnet are imposed, namely (Fig. 2),

- distance to the downstream cell axis : 9.95 cm
- angle with the downstream axis : 65 degrees.

Final coordinates at exit of kicker-2 are the closed orbit ones, given above.

In the present case the matching is obtained by varying the two kicker fields, after having imposed a particular field value in the septum. So obtained septum and kicker-1, kicker-2 field values are as follows (at precision better than 0.1 kG ; the extreme septum field values correspond to matching possibility limits) :

	septum	kicker 1	kicker 2	alpha_x	beta_x	alpha_y	beta_y
	-	all	-				
		kGauss					
20 MeV	-6.6	-0.21758111	-0.42981206				
	-6.35	-0.41770027	-0.23296494				
	-6.1	-0.62339113	-0.03374165				
15 MeV	-5.2	-0.49527236	-0.55337050				
	-5	-0.54316511	-0.40024658	1.8588	0.13168	-2.9618	0.12743
	-4.8	-0.60216170	-0.24450914				
	-4.7	-0.63422516	-0.16564778				
10 MeV	-2.9	-0.55891419	0.17631857				
	-2.65	-0.21565199	0.38042719				
	-2.4	0.38562793	0.53921695				

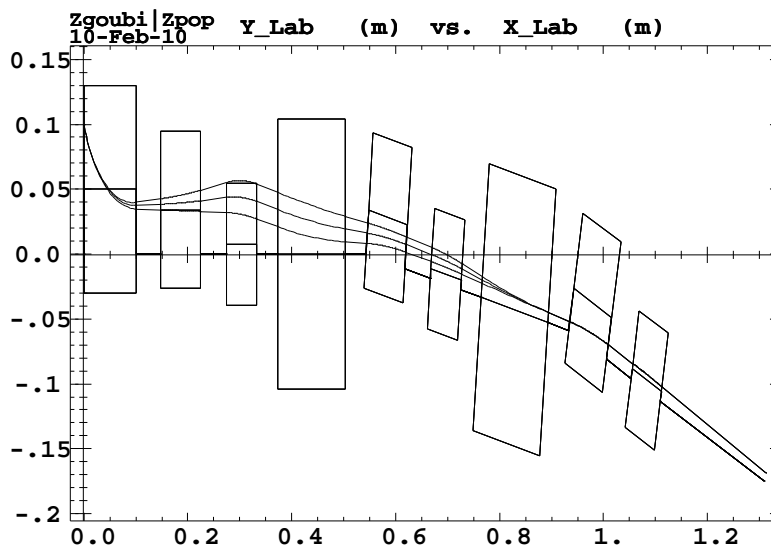


Figure 3: 20 MeV trajectories for septum field = -6.6 kG (upper traj.), -6.35 kG (middle traj.), -6.1 kG (lower traj.).

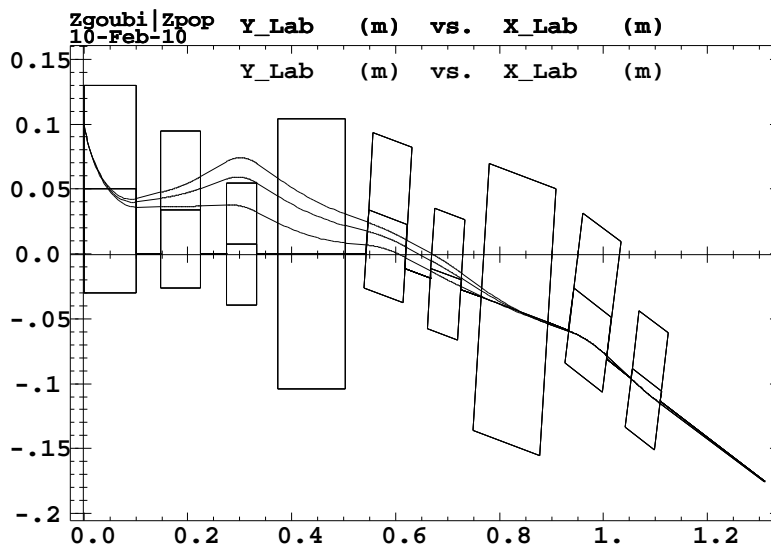


Figure 4: 15 MeV trajectories for septum field = -5.2 kG (upper traj.), -5 kG (middle traj.), -4.7 kG (lower traj.).

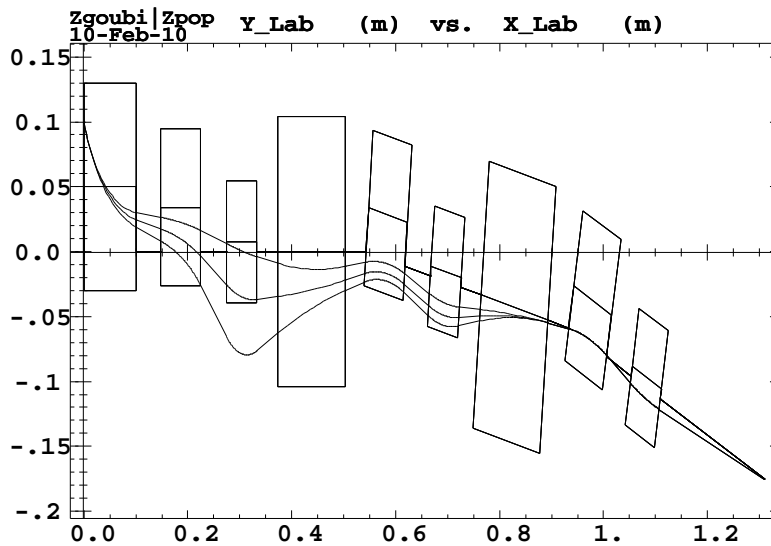


Figure 5: 10 MeV trajectories for septum field = -2.9 kG (upper traj.), -2.65 kG (middle traj.), -2.4 kG (lower traj.).

3.2 Focusing, 15 MeV

The values of periodical functions at polygon corner are given in the table in Section 2. They correspond to the optical functions at septum entrance as given in the table in Section 3.1.

Figs. 6, 7 shows the beam tube from septum entrance to QD3 entrance. Invariants at septum entrance are taken at 9.95 cm from the polygon side in a plane at right angle to the incoming beam direction (65 degrees from polygon side).

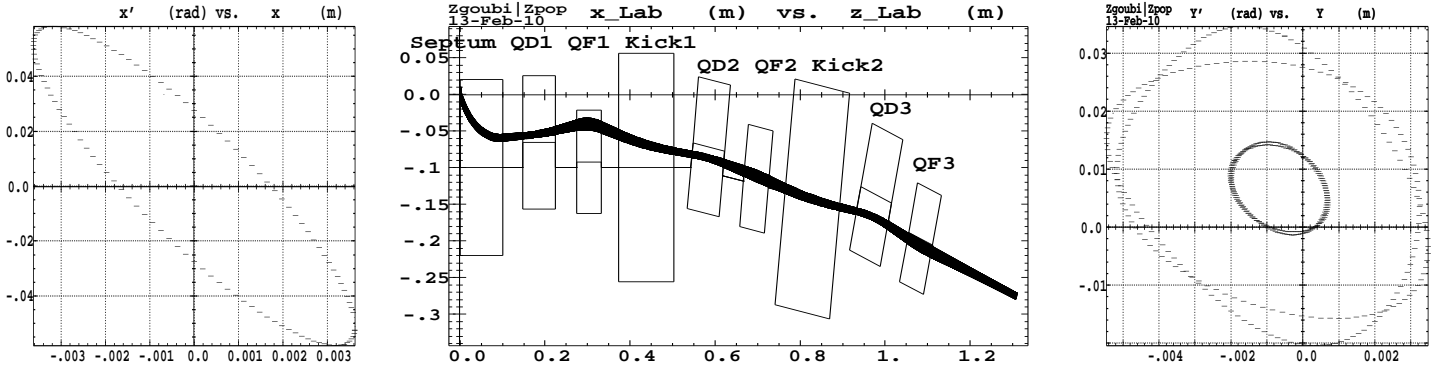


Figure 6: Central plot : horizontal beam (the numbering of the magnets refers to Fig. 1). Left : $\epsilon_x = 100 \pi \text{mm.mrad}$ injected invariant, at entrance to septum. Right : shape of the $100 \pi \text{mm.mrad}$ invariant at entrance to QD2 and QD3, assuming periodical paraxial optical functions. A 10 times smaller injected invariant yields quasi-identical, quasi-ellipse shapes at QD2, QD3 entrance.

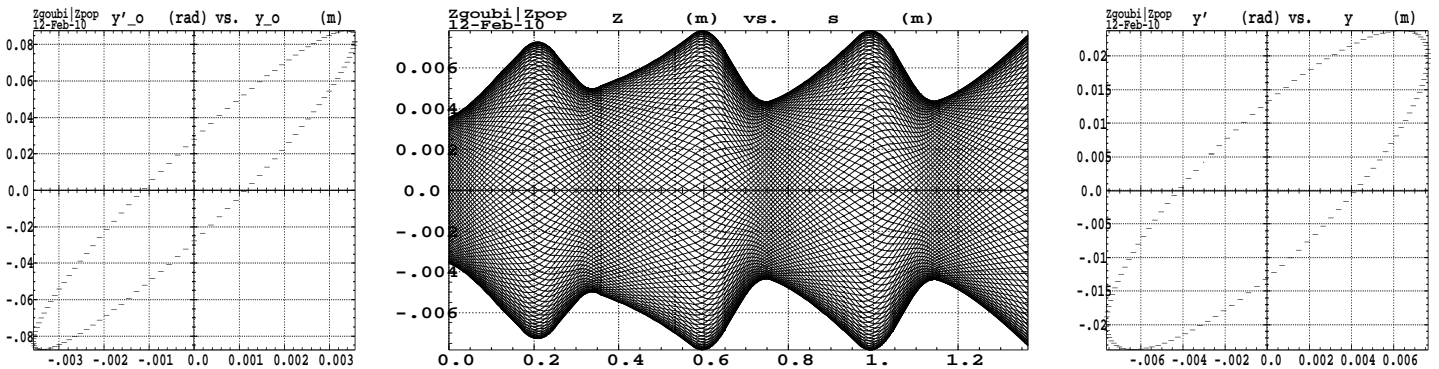


Figure 7: Central plot : vertical beam. Left : $\epsilon_y = 100 \pi \text{mm.mrad}$ injected invariant, at entrance to septum ; right : periodic invariant at entrance to QD.


```

4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 0. 0. 0. 0. 0.00e+00 0.00e+00 0.00e+00 0.00e+00
#320|59|320
2 0.00e+00 0.7513707181808552 0.
'DRIFT' ld 23
4.
'MULTIPOL' kicker2 24
0020 .plt
13. 10. -0.4002337332 0. 0. 0. 0. 0. 0. 0. 0. 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 0. 0. 0. 0. 0.00e+00 0.00e+00 0.00e+00 0.00e+00
#320|20|320
2 0.00e+00 0. 0.00e+00
'DRIFT' ld 26
4.
'MARKER' BPM1 off 17
'CHANGREF' 18
0.00e+00 0.00e+00 -8.571428571429e+00
'MULTIPOL' QD3 19
0020 .plt
7.569871747666486 5.30e+00 0. -2.49324632276342185 0. 0. 0. 0. 0. 0. 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 0. 0. 0. 0. 0.00e+00 0.00e+00 0.00e+00 0.00e+00
#320|76|320
2 0.00e+00 3.404834122312866 0.
'MARKER' BPM2 off 20
'DRIFT' sd 21
5.00e+00
'MULTIPOL' QF3 22
0020 .plt
5.878241131662439 3.70e+00 0. 2.47708182137912441 0. 0. 0. 0. 0. 0. 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 0. 0. 0. 0. 0.00e+00 0.00e+00 0.00e+00 0.00e+00
#320|59|320
2 0.00e+00 0.7513707181808552 0.
'DRIFT' ld 23
21.
'MARKER' #E .plt 27
'END'

'FIT2' 29
2
14 4 0. [-.7, .7] kicker 1
24 4 0. [-.7, .7] kicker 2
2
3 1 2 28 -6.239026E-02 1. 0. position at entrance of Cell (before 2pi/42 angle)
3 1 3 28 6.622761E+00 1. 0. angle at entrance of Cell (before 2pi/42 angle)
'END' 30

```

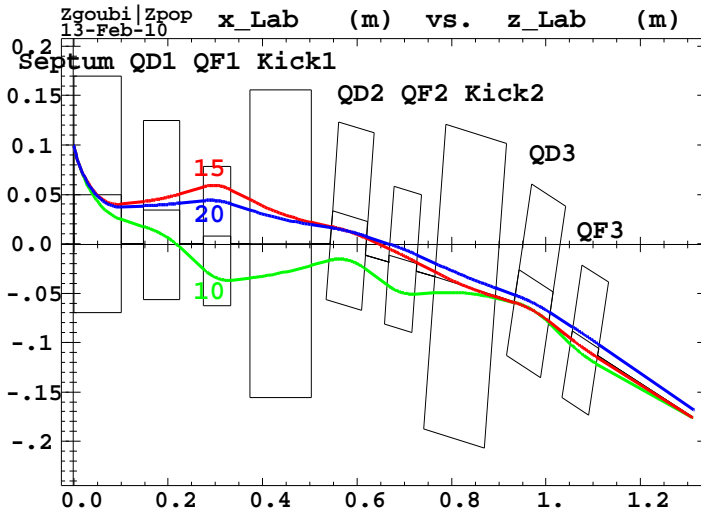
B Zgoubi data file, computation of optical functions

```

Data generated by searchCO
'OBJET' 1
5.171103865922e+01
5.03
.001 .001 .001 .001 0. .001
-5.547658E-02 3.818484E+01 0.0E+00 0.0E+00 0.0E+00 6.77214420E-01 'i' 10.000000 MeV
-6.239091E-02 6.622761E+00 0.0E+00 0.0E+00 0.0E+00 1.00000000E+00 'i' 15.000000 MeV
6.973487E-01 -2.156973E+01 0.0E+00 0.0E+00 0.0E+00 1.32265940E+00 'i' 20.000000 MeV
'PARTICUL' 2
5.10998920e-01 1.602176487e-19 1.159652181100e-03 0.00e+00 0
'FAISTORE'
b_zgoubi.fai
1
'CHANGREF' 18
0.00e+00 0.00e+00 -8.571428571429e+00
'MULTIPOL' QD 19
002 .plt
7.569871747666486 5.30e+00 0. -2.49324632276342185 0. 0. 0. 0. 0. 0. 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 0. 0. 0. 0. 0.00e+00 0.00e+00 0.00e+00 0.00e+00
#320|76|320
2 0.00e+00 3.404834122312866 0.
'DRIFT' sd 21
5.00e+00
'MULTIPOL' QF 22
002 .plt
5.878241131662439 3.70e+00 0. 2.47708182137912441 0. 0. 0. 0. 0. 0. 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 1.00 1.00 1.00 1.00 1.00 1. 1. 1. 1.
4 .1455 2.2670 -.6395 1.1558 0. 0. 0.
0. 0. 0. 0. 0. 0. 0.00e+00 0.00e+00 0.00e+00 0.00e+00
#320|59|320
2 0.00e+00 0.7513707181808552 0.
'DRIFT' ld 23
21.
'MATRIX'
1 11
'END'

```

C Trajectory coordinates, 10, 15 and 20 MeV



Coordinates of the three trajectories in the plot above are listed below. They are taken with respect to the polygon side containing the 'QD1 QF1' cell (the very line wrt. which QD and QF are shifted by respectively $x_d = +3.404834122312866$ cm, $x_f = +0.7513707181808552$ cm).

10MeV injected orbit, Septum with 2.65kG field

3.061515884556E-18	9.950000000000E-02
7.096445910000E-03	8.629397963649E-02
1.564300150000E-02	7.397671914840E-02
2.552966990000E-02	6.270674551808E-02
3.662920670000E-02	5.262910681954E-02
4.879875730000E-02	4.387350540451E-02
6.188169590000E-02	3.655262859273E-02
7.570964090000E-02	3.076069835105E-02
9.010462230000E-02	2.657225862728E-02
1.000000000000E-01	2.468692300011E-02
1.501321074400E-01	1.709813304343E-02
1.530829532400E-01	1.662775156849E-02
1.560304370600E-01	1.613674567474E-02
1.589743138000E-01	1.562455911324E-02
1.619143216000E-01	1.509061386725E-02
1.648501803000E-01	1.453430985533E-02
1.677815907000E-01	1.395502465044E-02
1.707082326000E-01	1.335211321942E-02
1.736297640000E-01	1.272490768727E-02
1.765458189000E-01	1.207271713154E-02
1.794560063000E-01	1.139482741242E-02
1.823599082000E-01	1.069050110449E-02
1.852570775000E-01	9.958977120600E-03
1.881470367000E-01	9.199471285502E-03
1.910292753000E-01	8.411175784862E-03
1.939032476000E-01	7.593259582360E-03
1.967683708000E-01	6.744868565584E-03
1.996240223000E-01	5.865125849042E-03
2.024695371000E-01	4.953132187644E-03
2.053042050000E-01	4.007966514790E-03
2.081272679000E-01	3.028686620612E-03
2.109379167000E-01	2.014329987365E-03
2.137352879000E-01	9.639148006096E-04
2.165184607000E-01	-1.235588435050E-04
2.192864529000E-01	-1.249107512698E-03
2.220382175000E-01	-2.413762770664E-03
2.238618404767E-01	-2.538916834826E-03
2.266054394467E-01	-2.657497242860E-02
2.293716083467E-01	-2.770711949035E-02
2.321599947067E-01	-2.878337690867E-02
2.349700960767E-01	-2.980158135803E-02
2.378012618767E-01	-3.075964836879E-02
2.406526961767E-01	-3.16558205350E-02
2.435234619767E-01	-3.248748489265E-02
2.464124860767E-01	-3.325356746334E-02
2.493185658767E-01	-3.395215799034E-02
2.522403764767E-01	-3.458171159687E-02
2.551764795767E-01	-3.514081913226E-02
2.581253329767E-01	-3.562821545623E-02
2.610853013767E-01	-3.604278706385E-02
2.640546675767E-01	-3.638357894232E-02
2.670316448767E-01	-3.664980056000E-02
2.700143903767E-01	-3.684083089898E-02
2.730010179767E-01	-3.695622245613E-02
2.759896128767E-01	-3.699570415205E-02
2.789782453767E-01	-3.695918310379E-02

6.319649856767E-01	-3.684674523396E-02
3.791332865433E-01	-3.418765847449E-02
3.985906012933E-01	-3.289989486622E-02
4.180310497933E-01	-3.137858200288E-02
4.374518287933E-01	-2.962393925112E-02
4.568501380933E-01	-2.763621962274E-02
4.762231807933E-01	-2.541570973817E-02
4.955681617933E-01	-2.296272978522E-02
5.026442517933E-01	-2.200641818336E-02
5.420783043961E-01	-1.660247777579E-02
5.450473589470E-01	-1.626602788198E-02
5.480225445806E-01	-1.598896688885E-02
5.510026105801E-01	-1.577054727352E-02
5.539863587028E-01	-1.561006312328E-02
5.569726376326E-01	-1.550685171997E-02
5.599603378113E-01	-1.546029488474E-02
5.629483864888E-01	-1.546982008468E-02
5.659357422457E-01	-1.553490121196E-02
5.689213905381E-01	-1.565505928939E-02
5.719043389774E-01	-1.582986292640E-02
5.748836121434E-01	-1.605892851052E-02
5.778582478090E-01	-1.634192043059E-02
5.808272920033E-01	-1.667855095465E-02
5.837897945931E-01	-1.706858002446E-02
5.867448051832E-01	-1.751181494294E-02
5.896913685454E-01	-1.800810983969E-02
5.926285205630E-01	-1.855736506574E-02
5.955552839018E-01	-1.915952639820E-02
5.984706637014E-01	-1.981458409783E-02
6.013736433899E-01	-2.052257183013E-02
6.042631802251E-01	-2.128356538441E-02
6.071382011567E-01	-2.209768127186E-02
6.099759586171E-01	-2.296507513264E-02
6.128402257470E-01	-2.388593986481E-02
6.1564617545198E-01	-2.478839821490E-02
6.184361380519E-01	-2.5744400665690E-02
6.2121836634008E-01	-2.67433812794325E-02
6.2400377306277E-01	-2.7784270432924E-02
6.2679076194417E-01	-2.8875107319275E-02
6.2957925391988E-01	-2.99918696875E-02
6.3236916347853E-01	-3.122431772668E-02
6.3516039924166E-01	-3.25636129969E-02
6.3795286469909E-01	-3.39991717250E-02
6.4074645882798E-01	-3.55346279168419E-02
6.4354107690792E-01	-3.71626098736E-02
6.4633661122550E-01	-3.887281328020E-02
6.4913295187639E-01	-4.0660228060974E-02
6.5192998753645E-01	-4.2523461404526E-02
6.5472760630084E-01	-4.4460988437061E-02
6.5752569642272E-01	-4.6472828204924E-02
6.6032414714933E-01	-4.85479011677455E-02
6.63122284944732E-01	-5.0709581631354E-02
6.6592169679495E-01	-5.294592493994E-02
6.6872058587256E-01	-5.524110123715E-02
6.7151941724955E-01	-5.768211545886E-02
6.74318269426404E-01	-6.0264358641076E-02
6.771173829055E-01	-6.298770901405E-02
6.79916763848165E-01	-6.584489214312E-02
6.8271676824142E-01	-6.8831506525206E-02
6.8551625296421E-01	-7.1940897250895E-02
6.883160921877304E-01	-7.516229317286469E-02
6.9111579289123E-01	-7.849220522010E-02
6.9391526332269E-01	-8.19223056005E-02
6.96714676824142E-01	-8.544652305811E-02
6.99513608085E-01	-8.907285779572E-02
7.0231295187639E-01	-9.279201952063205E-02
7.051124230201018E-01	-9.6606586224085E-02
7.079114145260E-01	-1.005127637427E-02
7.1071032105394E-01	-1.0446167519942216E-02
7.135091247987803E-01	-1.08411009869E-02
7.1630805350897E-01	-1.12362897760E-02
7.1910694866959E-01	-1.163170178955E-02
7.2190561216507E-01	-1.20271969590E-02
7.247042908760207E-01	-1.24228565741880E-02
7.27502958027376E-01	-1.2818560113410832E-02
7.303016865266394E-01	-1.32143233195682E-02
7.331003568450734E-01	-1.36101200239E-02
7.35899147388E-01	-1.400597332918E-02
7.3869782816042E-01	-1.440189305266001E-02
7.414965443551E-01	-1.480786012369374E-02
7.4429521266427E-01	-1.5213829645350E-02
7.470939479090E-01	-1.561980056575E-02
7.4989267110196E-01	-1.60257705678535E-02
7.526914089780004E-01	-1.6431744053453E-02
7.55490146052666E-01	-1.6837719794058E-02
7.5828883182912E-01	-1.7243724263494E-02
7.61087571424127E+00	-1.764971939014E-02
7.6388621402416E+00	-1.805571340352E-02
7.6668485175123E+00	-1.84617061653E-01
7.6948351862719E+00	-1.886771915256E-01
7.722821561313E+00	-1.927373053506E-01
7.750808057308E+00	-1.96797429547E-01
7.7787945107799E+00	-2.008575631558E-01
7.80678107799E+00	-2.049176599367E-01
7.8347676379835E+00	-2.089777822220E-01
7.862754219469945E+00	-2.13037842100E-01
7.890740724578444E+00	-2.17097939177E-01
7.918727238969202E+00	-2.2115804143385E-01
7.94671382482683E+00	-2.25218149487822E-01
7.97470037966E+00	-2.29278263451172E-01
8.002686834136E+00	-2.33338396921E-01
8.0306733057308E+00	-2.373985430521E-01

1.096743853532E+00	-1.186038708904E-01	6.990472897052E-01	-1.232556140488E-02
1.099609888648E+00	-1.194521144658E-01	7.019534887616E-01	-1.302394910719E-02
1.102483691755E+00	-1.202736562826E-01	7.048587796526E-01	-1.372610501576E-02
1.105364985918E+00	-1.210685273250E-01	7.077632289618E-01	-1.443173431524E-02
1.309511285127E+00	-1.755997246898E-01	7.106669051560E-01	-1.514053841846E-02
# 15MeV injected orbit, Septum with 5kG field		7.135698785334E-01	-1.585221531011E-02
3.061515884556E-18	9.950000000000E-02	7.164722213691E-01	-1.656645992338E-02
7.301256900000E-03	8.641193348885E-02	7.193740070714E-01	-1.728296437040E-02
1.641745750000E-02	7.451652580817E-02	7.222753107217E-01	-1.800141838396E-02
2.715717240000E-02	6.406356638723E-02	7.251762085271E-01	-1.872150959735E-02
3.929488040000E-02	5.527255495446E-02	7.653339698576E-01	-2.870772115331E-02
5.257570400000E-02	4.832809230539E-02	7.842924160817E-01	-3.327062584926E-02
6.672076180000E-02	4.337600390496E-02	8.033175666690E-01	-3.75468883190E-02
8.143302420000E-02	4.05202772603E-02	8.224050881909E-01	-4.153553606755E-02
9.640355130000E-02	3.982088062548E-02	8.415506326002E-01	-4.523565897457E-02
1.491573034580E-01	4.296159410720E-02	8.607498390030E-01	-4.864641474808E-02
1.521395444200E-01	4.314872890487E-02	8.799983339486E-01	-5.176702644592E-02
1.551213132600E-01	4.334324103410E-02	8.930336508974E-01	-5.371149346787E-02
1.581025810500E-01	4.354528694886E-02	9.325331959009E-01	-5.939780077146E-02
1.610833172000E-01	4.375502908032E-02	9.354887716834E-01	-5.983745017543E-02
1.640634896000E-01	4.397263595587E-02	9.384401288307E-01	-6.030458229669E-02
1.670430639000E-01	4.419828232209E-02	9.413870687127E-01	-6.079881738097E-02
1.700220042000E-01	4.443214927143E-02	9.443293985544E-01	-6.131979665814E-02
1.730002725000E-01	4.467442437277E-02	9.47269306570E-01	-6.186718215169E-02
1.759778284000E-01	4.492530180569E-02	9.501994814513E-01	-6.244065642450E-02
1.789546294000E-01	4.518498249854E-02	9.531268708017E-01	-6.303992239213E-02
1.819306305000E-01	4.545367427072E-02	9.560489210639E-01	-6.366470305196E-02
1.849057842000E-01	4.573159197582E-02	9.589654566991E-01	-6.431474137721E-02
1.878800402000E-01	4.601895765530E-02	9.618763030297E-01	-6.498979994067E-02
1.908533451000E-01	4.631600068665E-02	9.647812859518E-01	-6.568966082950E-02
1.938256429000E-01	4.662295794179E-02	9.676802311704E-01	-6.641412540970E-02
1.967968738000E-01	4.694007394626E-02	9.705729631486E-01	-6.716301400031E-02
1.997669751000E-01	4.726760104207E-02	9.734593049180E-01	-6.793616581154E-02
2.027358802000E-01	4.760579955378E-02	9.763390773147E-01	-6.873343870552E-02
2.057035184000E-01	4.795497307575E-02	9.792120981205E-01	-6.955470892746E-02
2.086698155000E-01	4.831529305326E-02	9.820781816819E-01	-7.039987098457E-02
2.116346926000E-01	4.868715013885E-02	9.849371379553E-01	-7.126883734880E-02
2.145980662000E-01	4.907080318768E-02	9.877887723159E-01	-7.216153839626E-02
2.175598482000E-01	4.946655502769E-02	9.906328845074E-01	-7.307792208248E-02
2.205199454000E-01	4.987471752266E-02	9.934692684501E-01	-7.401795388399E-02
2.234782589000E-01	5.029561175503E-02	9.962977109986E-01	-7.498161641675E-02
2.24848283537E-01	5.774578842344E-02	9.991179921320E-01	-7.596890949760E-02
2.278127685867E-01	5.812695034498E-02	1.001929883328E+00	-7.697984964643E-02
2.807841485867E-01	5.844998727435E-02	1.004733147850E+00	-7.801447017808E-02
2.837613171767E-01	5.871440325133E-02	1.052739040068E+00	-9.615129191972E-02
2.867431390767E-01	5.891979054235E-02	1.055536647869E+00	-9.720349103903E-02
2.897284558767E-01	5.906583132909E-02	1.058337505477E+00	-9.824700855178E-02
2.927160913767E-01	5.915229903500E-02	1.061141654634E+00	-9.928164824244E-02
2.957048579767E-01	5.917905927659E-02	1.063949131513E+00	-1.003072235943E-01
2.986935622767E-01	5.914670742969E-02	1.066759966891E+00	-1.013235580880E-01
3.016810113767E-01	5.905338380529E-02	1.069574185921E+00	-1.023304853641E-01
3.046660183767E-01	5.890114343283E-02	1.072391808243E+00	-1.033278494757E-01
3.076474088767E-01	5.868985854345E-02	1.075212848209E+00	-1.043155051636E-01
3.106240265767E-01	5.841903712905E-02	1.078037314930E+00	-1.052933180585E-01
3.135947387767E-01	5.808991547734E-02	1.080865212130E+00	-1.062611648107E-01
3.165584425767E-01	5.770272554641E-02	1.083696538577E+00	-1.072189333825E-01
3.195140697767E-01	5.725805834596E-02	1.086531287856E+00	-1.081665231188E-01
3.224605921767E-01	5.675658845569E-02	1.089369448711E+00	-1.091038449809E-01
3.253970265767E-01	5.619907133403E-02	1.092211005302E+00	-1.100308217351E-01
3.283224391767E-01	5.558634035327E-02	1.095055936897E+00	-1.109473879489E-01
3.312359503767E-01	5.491930358927E-02	1.097904218415E+00	-1.118534902375E-01
3.726442517933E-01	4.465440466761E-02	1.100755820608E+00	-1.127490873763E-01
3.916174181933E-01	4.015377569368E-02	1.103610709952E+00	-1.136341503094E-01
4.106787832933E-01	3.604268502642E-02	1.106468848830E+00	-1.145086622309E-01
4.298203503933E-01	3.232285737430E-02	1.108410666720E+00	-1.150962309841E-01
4.490340888933E-01	2.899585330078E-02	1.309490906522E+00	-1.756657905046E-01
4.683119383933E-01	2.606306857006E-02	# 20MeV injected orbit, Septum with 6.35kG field	
4.876458107933E-01	2.352573356064E-02	3.061515884556E-18	9.950000000000E-02
5.026442517933E-01	2.183393492600E-02	7.263935790000E-03	8.639001079993E-02
5.462526696759E-01	1.726403153063E-02	1.627737940000E-02	7.441527012452E-02
5.492233272237E-01	1.694159696360E-02	2.686580640000E-02	6.380764107836E-02
5.521925254649E-01	1.660598961446E-02	3.882419640000E-02	5.477251581732E-02
5.551602164924E-01	1.625730537402E-02	5.192100290000E-02	4.748483860533E-02
5.581263522589E-01	1.589562965146E-02	6.590263600000E-02	4.208571842416E-02
5.610908845609E-01	1.552103742467E-02	8.049837560000E-02	3.867969672497E-02
5.640537646393E-01	1.513359334207E-02	9.542560720000E-02	3.733272322533E-02
5.670149430458E-01	1.473335177803E-02	1.491589119710E-01	3.842404384707E-02
5.699743697958E-01	1.432035683903E-02	1.521462382400E-01	3.849235344115E-02
5.729319935807E-01	1.389464250504E-02	1.551335008700E-01	3.856339156351E-02
5.758877621658E-01	1.345623258588E-02	1.581206962800E-01	3.863720176944E-02
5.788416219962E-01	1.300514079063E-02	1.611078208000E-01	3.871382931081E-02
5.817935178016E-01	1.254137079060E-02	1.640948704000E-01	3.879332116340E-02
5.847433926952E-01	1.206491620162E-02	1.670818410000E-01	3.887572605526E-02
5.876911881720E-01	1.157576057492E-02	1.700687285000E-01	3.896109449609E-02
5.906368434144E-01	1.107387748608E-02	1.730555282000E-01	3.904947880771E-02
5.935802952888E-01	1.055923051338E-02	1.760422355000E-01	3.914093315557E-02
5.965214787371E-01	1.003177315037E-02	1.790288454000E-01	3.923551358134E-02
5.994603254862E-01	9.491448965584E-03	1.820153527000E-01	3.93327803661E-02
6.023967649315E-01	8.938191428280E-03	1.850017522000E-01	3.943428641773E-02
6.053307232404E-01	8.371923996390E-03	1.879880379000E-01	3.953860060173E-02
6.082621235420E-01	7.792560034527E-03	1.909742041000E-01	3.964628448345E-02
6.111908853249E-01	7.200002845320E-03	1.939602443000E-01	3.975740401379E-02
6.141169247248E-01	6.594145560822E-03	1.969461522000E-01	3.987202723918E-02
6.170401538211E-01	5.974871177250E-03	1.999319206000E-01	3.999022434226E-02
6.199604808236E-01	5.342052450038E-03	2.029175425000E-01	4.011206768376E-02
6.699224609180E-01	-5.610477285461E-03	2.059030103000E-01	4.023763184560E-02
6.728408525981E-01	-6.256020218785E-03	2.088883158000E-01	4.036699367535E-02
6.757578122492E-01	-6.908003583468E-03	2.118734509000E-01	4.050023233189E-02
6.786733791412E-01	-7.566187357148E-03	2.148584066000E-01	4.063742933236E-02
6.815875957102E-01	-8.230324684208E-03	2.178431738000E-01	4.077866860048E-02
6.845005073339E-01	-8.900162140498E-03	2.208277427000E-01	4.092403651625E-02
6.874121626625E-01	-9.575440088718E-03	2.2381211032000E-01	4.107362196688E-02
6.903226130588E-01	-1.025589290617E-02	2.248569532227E-01	4.366831388848E-02
6.932319125608E-01	-1.094124929759E-02	2.278432391567E-01	4.379382129234E-02
6.961401183285E-01	-1.163123268678E-02	2.808306888767E-01	4.388762712088E-02

2.838189675567E-01	4.394963880484E-02	1.056384104873E+00	-8.433428205951E-02
2.868077374767E-01	4.397979510492E-02	1.059242881415E+00	-8.520671243945E-02
2.897966588767E-01	4.397806622747E-02	1.062100496527E+00	-8.608293956430E-02
2.927853918767E-01	4.394445388090E-02	1.064956943884E+00	-8.696296606522E-02
2.957735969767E-01	4.387899127239E-02	1.067812218127E+00	-8.784679122786E-02
2.987609366767E-01	4.378174304509E-02	1.070666315108E+00	-8.873441106530E-02
3.017470764767E-01	4.365280515606E-02	1.073519231417E+00	-8.962581817577E-02
3.047316863767E-01	4.349230469558E-02	1.076370964897E+00	-9.052100190705E-02
3.077144417767E-01	4.330039964889E-02	1.079221514606E+00	-9.141994835280E-02
3.106950247767E-01	4.307727860161E-02	1.082070880429E+00	-9.232264024569E-02
3.136731253767E-01	4.282316039032E-02	1.084919063454E+00	-9.322905708942E-02
3.166484424767E-01	4.253829370043E-02	1.087766065973E+00	-9.413917517561E-02
3.196206847767E-01	4.222295661308E-02	1.090611891277E+00	-9.505296754473E-02
3.225895722767E-01	4.187745610378E-02	1.093456543847E+00	-9.597040406782E-02
3.255548367767E-01	4.150212749526E-02	1.096300029341E+00	-9.689145147210E-02
3.285162230767E-01	4.109733386720E-02	1.099142354588E+00	-9.781607336944E-02
3.314734897767E-01	4.066346542614E-02	1.101983527387E+00	-9.874423022866E-02
3.344242517933E-01	4.025896378542E-02	1.104823556973E+00	-9.967587955700E-02
3.3739297457933E-01	3.984335302536E-02	1.107662453528E+00	-1.006109757895E-01
3.4036242118933E-01	3.9432160304830E-02	1.110500228363E+00	-1.015494703875E-01
3.433319102933E-01	3.90262980930310E-02	1.112395326749E+00	-1.021782804435E-01
3.4630130970933E-01	3.862410517978611E-02	1.114285326749E+00	-1.028570326749E-01
3.49270740243933E-01	3.822214315849243E-02	1.1161730279887E+00	-1.036459230628E-01
3.522401887969407933E-01	3.7826041231267180E-02		
3.552106442517933E-01	3.7432051132655E-02		
3.581801460725639399E-01	3.7038160813926E-02		
3.611505490517103726E-01	3.6644158498479165E-02		
3.6412100098822E-01	3.62500796622300E-02		
3.6709074349088E-01	3.585554580670E-02		
3.700602579839586479E-01	3.5469271048631E-02		
3.73030695549940E-01	3.5084181957584046E-02		
3.760001984498E-01	3.47091453625115041E-02		
3.7897078638966E-01	3.4334283948594E-02		
3.819405266999E-01	3.3959343773792E-02		
3.8491021625190E-01	3.35842613669301E-02		
3.87880227471152E-01	3.32093302110563E-02		
3.90850787922567533E-01	3.2834297016967785E-02		
3.9382018176672184E-01	3.2459262765524517E-02		
3.96790279548098E-01	3.2084227554466145E-02		
3.9976040953570E-01	3.17091389897923E-02		
4.0273090647182E-01	3.1334277340354E-02		
4.05700228384876E-01	3.0959116221736234E-02		
4.086705853918013E-01	3.058407722455901E-02		
4.11640466995376E-01	3.0209037298296256E-02		
4.1461025067362211E-01	2.9834096473839641E-03		
4.175804654756291E-01	2.94590476828365E-03		
4.20550228910900E-01	2.90840119309905032E-03		
4.23520113789551881E-01	2.87090868289437341E-03		
4.2649043336398631E-01	2.833405237225175146E-03		
4.29460172869160151E-01	2.7959128321312848E-03		
4.32430202387539991E-01	2.7584176414777E-03		
4.3540066654423847E-01	2.7209165664814E-04		
4.383703610840660E-01	2.6834172598097276E-03		
4.41340765651975394E-01	2.64591658871349282E-03		
4.44310795127590936E-01	2.6084154464813409E-03		
4.47280424587467501E-01	2.570912659329799207E-03		
4.5025013404899E-01	2.53341073409513157E-03		
4.53220883459220086E-01	2.495913696639073934E-03		
4.5619012870751821E-01	2.45841228945642802E-03		
4.591602265859876E-01	2.42091770248479765E-03		
4.621301644424920E-01	2.383415320459017764E-03		
4.651001006351364E-01	2.345915879480989089E-03		
4.6807030351566241E-01	2.30841447210499540E-03		
4.7104059680020043E-01	2.27091303536139614E-03		
4.7401088991687562E-01	2.233417608339102775E-03		
4.76980118286570685E-01	2.195918201493340433E-03		
4.79950147564693274E-01	2.15841802865604441E-03		
4.82920176826108891E-01	2.12091412315689913E-03		
4.85890206070895660E-01	2.08341002969649067E-02		
4.88860235299156059E-01	2.04591065485413541E-02		
4.9183011022638E-01	2.00841128762821928E-02		
4.94800666339500410E-01	1.970912008291617802E-02		
4.97770856966359574E-01	1.933412418932673471E-02		
5.007401861756450E-01	1.895912816903473100E-02		
5.03710239017270633E-01	1.858413202186461634E-02		
5.06680430424467281E-01	1.820913574764639274E-02		
5.09650262074905026E-01	1.783413934621573593E-02		
5.12620813960124097E-01	1.745914281741381800E-02		
5.15590340788215E-01	1.708414508371792704E-02		
5.18560347913097626E-01	1.670915207717543249E-02		
5.2153037343280457E-01	1.633415259428836192E-02		
5.24500406744703548E-01	1.595915312751087307E-02		
5.27470436116888067E-01	1.558415367661140372E-02		
5.3044046549372509E-01	1.520915424136824538E-02		
5.33410494771709512E-01	1.483415482156938646E-02		
5.36380524053466507E-01	1.445915541701247374E-02		
5.393504218418E-01	1.408415602750453000E-02		
5.42320523551840E-01	1.370915665286202624E-02		
5.4529011711055636E-01	1.333415729291053674E-02		
5.48260866328734E-01	1.295915794748492598E-02		
5.5123066998967846E-01	1.258415861642891825E-02		
5.54200969078572393E-01	1.220915929959519973E-02		
5.57170728134742718E-01	1.18341599684513609E-02		
5.6014075157073534E-01	1.145916070804942493E-02		
5.6311045156905E-01	1.10841613308634522E-02		
5.66080815098578538E-01	1.070916217184340281E-02		
5.6905044016917887E-01	1.033416292421639632E-02		
5.72020899744432E-01	9.95916369010944774E-02		
5.749901746617763E-01	9.58416446943497363E-02		
5.7796057083840E-01	9.20916526211354117E-02		
5.8093030677934E-01	8.83416606807393335E-02		
5.8390066917994E-01	8.45916688725292235E-02		
5.868701001676530758E+00	8.08416771959534057E-02		
5.89840542533110E+00	7.70916856505391885E-02		
5.9281007404645389E+00	7.33416942358927513E-02		

References

- [1] The ray-tracing code Zgoubi, Users' guide, <http://sourceforge.net/index.php>.
- [2] Data communicated by Y. Giboudot, C. Hill, N. Bliss.