Contents

Energy (GeV)	σ_x (mm)	σ_y (mm)
1.1	0.250-0.300	<0.040
2.2	0.250-0.300	<0.040
6.6	0.250-0.300	<0.040

Table 1: HPS beam energies and beam size on target requirements.

Energy (GeV)	ε_x (nm)	ε_y (nm)	dp/p (%)
1.1	0.44	0.44	0.003
2.2	0.22	0.22	0.003
6.6	0.28	0.21	0.005

Table 2: The expected electron beam emittance and momentum spread for the three HPS beam energies.

1 HPS Test Run

The Heavy Photon Experiment (HPS) in the Hall-B endstation requires three different beam energies and a ribbon beam incident on their target. The ribbon beam specification with a very narrow vertical and larger than nominal horizontal profile is off normal for CEBAF. The beam energies and required beam size are found in Table 1.

1.1 Hall-B Beam Parameters for HPS

The Heavy Photon Experiment (HPS) test run requires three different beam energies, 1.1,2,3 and 6.6 GeV. The beam parameters, emittance (ε) and momentum spread ($\frac{dp}{p}$) at the entrance to the B transport line for the three beam energies are in Table 2. Note that at the 6.6GeV energy the emittance growth due to synchrotron radiation is comparable to (larger than) the damping due to the energy gain in the vertical (horizontal) plane.

2 Deck provenance

The Hall-B beamline definition originated with the elegant lattice, HALLB.lte, and command, HALLB.ele, files corresponding to eDeck release: 12GeV1-3

2.1 Comments

The sextapole magnets have non-zero K2 values in these decks. Some of the locations of elements downstream of the tagger appear to be incorrect. The songsheet drawings are used to estimate the distances of the elements in the Hall proper.

3 Drawings

Drawing ACC-000-2845-0034 Rev. 5 is used to provide checks on the elegant decks for the region from just upstream of the green shield wall to the Tagger magnet.

Drawing 2845-E-0037 is used to provide approximate distances for elements in Hall-B.

Drawing JL0008001 of the HPS template is used to provide the location of the diagnostics immediately upstream of HPS (2H03 elements) and the HPS target.

3.1 Comment

The drawings of the B beamline, 2845-0034 do not appear to reflect the removal of the goniometer. The girders that hold 2C22, 2C23, 2C24 quadrupole magnets and the 2C24A nA BPM girder are shown in their 6GeV positions. These elements are to moved for 12GeV Hall-B, the work for the design and movement of these elements will not take place until after Oct. 2014. It is assumed that this work will take place **after** the HPS test run.

The locations for elements in the Hall proper as defined by the elegant decks do not agree very well with the ME drawings. For this study locations as determined by scaling the drawings are used and the decks are updated with these values.

4 Design approach

The HPS beam size requirements are used as optimization targets and the `elegant` function `optimize` is used to adjust quadrupole settings to achieve the desired beam size. A vertical target of 20μm is used to establish some headroom in achieving the desired beamsize. Quadrupole magnet ranges are restricted to be within the operating range of the quadrupole magnet.

The elegant optimization target commands are as follows:

```
&optimization_term
weight=1,
term="ETA2HHPS#1.Sx 300e-6 5e-6 segt",
&end
&optimization_term
```

Energy	QA	QK	QR
	K max	K max	K max
(GeV)	(1/m)	(1/m)	(1/m)
1.1	7.0	11.5	14.6
2.3	3.3	5.5	7.0
6.6	1.2	1.9	2.4

```
weight=1,
term="ETA2HHPS#1.Sx 275e-6 5e-6 selt",
&end
&optimization_term
weight=1,
term="ETA2HHPS#1.Sy 40e-6 5e-6 segt",
&end
&optimization_term
weight=1,
term="ETA2HHPS#1.Sy 35e-6 5e-6 selt",
&end
&optimization_term
weight=1,
term="ETA2HHPS#1.alphay sqr",
&end
&optimization_term
weight=0.5,
term="tagger.max.betax 500 5 segt",
&end
&optimization_term
  weight=0.5,
  term="tagger.max.betay 500 5 segt",
&end
```

4.1 Quad limits

Quadrupole magnets of different capabilities are used in the B line. During optimization it is important to restrict the range of the quadrupole to its allowed range. The following ranges were used in this design.

5 Element Layout

A two-quad girder based on the design of the Arc8 recombiner 8R04 quad girder is placed between the tagger magnet and the nA BPM (IPM2H01). This girder is tentatively assigned the name 2H00. The only change is that the required focusing strength allows for the QK quadrupole magnets to be replaced with QA style magnets. Which is not actually a change in magnet style, but reflects a change in powering requirements (20A for QK versus 10A for QA magnets). For reference the 8R04 lattice definition as found in `ARC8.lte` is as follows:

```
IPM8R04: MONITOR, L=0
MQK8R04:KQUAD,  L=0.3, K1=-1.083362749609911, TILT=0, ISR=1, SYNCH_RAD=1
MQK8R04A:KQUAD,  L=0.3, K1=-1.083362749609911, TILT=0, ISR=1, SYNCH_RAD=1
MBC8R04H: HKICK,  L=0, KICK=0,TILT=0
MBC8R04V: VKICK,  L=0, KICK=0,TILT=0
```

5.1 Girders

5.1.1 2H00

This girder will support a BPM, two quadrupole magnets and two corrector magnets. A direct copy of the 8R04 girder is used to provide element order and relative locations in the optics design. No reason to reinvent the wheel. The location of this girder can be shifted downstream, upstream shifts are to be avoided and will require confirmation from the optics designer.

5.1.2 2H02

This girder will support a BPM and two corrector magnets. The precise location this girder is not fixed by the optics design.

5.2 Magnets

5.3 Quadrupole Magnets

HPS configuration adds two quadrupole magnets, tentative named MQA2H00 and MQA2H00A. Spare QA magnets will be used in this HPS test run and returned to the spare pool when the test run is completed.

5.4 Corrector Magnets

HPS configuration add four corrector magnets, tentative named MBD2H00H, MBD2H00V, MBD2H02H and MBD2H002V. Spare MBD/MBC corrector magnets

Element Name	Distance to Start (m)	Distance to Center of Hall (m)	Owner	Comment
MQR2C20	98.92856	-44.27891		
IPM2C21	101.76391	-41.44356		
MQR2C21	102.13825	-41.06922		
MQA2C21A	103.56545	-39.64202		
IHA2C21	104.37045	-38.83702	Hall-B:	
IPM2C21A	105.56825	-37.63922		
IPM2C22	116.34875	-26.85872		
MQK2C22	116.69875	-26.50872		
MQK2C23	117.44023	-25.76724		
MQK2C24	118.30841	-24.89906		
IPM2C24A	118.66841	-24.53906		
IHA2C24	121.15381	-22.05366	Hall-B:	
ATAGGER	125.5601	-17.64737		
COLA	127.9221	-15.28537		
IPM2H00	130.9221	-12.28537	Eng.	New
MQA2H00	131.29675	-11.91072	Eng.	Spare
MQA2H00A	131.59675	-11.61072	Eng.	Spare
MBD2H00H	131.93990	-11.26757	Eng.	Spare
MBD2H00V	132.13599	-11.07148	Eng.	Spare
ITV2H01	135.16210	-8.04537	Eng.	Existing nA stand
IPM2H01	135.16210	-8.04537	Eng.	recommission
CENTEROFHALL	143.20747	0		
IPM2H02	155.20747	12. ?	Eng:	New
MBD2H02H	155.20747	12. ?	Eng.	New, precise
MBD2H02V	155.20747	12. ?	Eng:	New, location TBD
IPM2H03	157.27529	14.06782	Eng:	New
IHA2H03	157.27529	14.06782	HPS:	Moved 2H00 Harp
ETA2H03	157.68647	14.47900	HPS:	Collimator
ETA2HHPS	160.23815	17.03068	HPS:	
IFY2D00	170.23815	27.03068	HPS:	

Table 3: Hall-B and HPS Beamline elements between the MQR2C20 quadrupole and the Faraday Cup. The s column is the distance from the start of the Hall-B line and the center of the element. Distances to the Center-Of-Hall-B are given for convenience.

or equivalent will be used in this HPS test run and returned to the spare pool when the test run is completed.

5.5 Beam Position Monitors

5.5.1 nA Beam Position Monitors

The three nA BPM systems in Hall-B, IPM2C21A, IPM2C24A and IPM2H01, will be used by HPS and need to be functional for the HPS run.

5.5.2 Stripline Beam Position Monitors

The HPS configuration add three new stripline BPMs to the beamline, tentatively named IPM2H00, IPM2H01, IPM2H02. The BPMs along with the associated electronics will need to be fabricated and installed.

5.6 Vacuum Valves

Location of vacuum valves, pump out port and gauges has not been included in the design. This needs to be done.

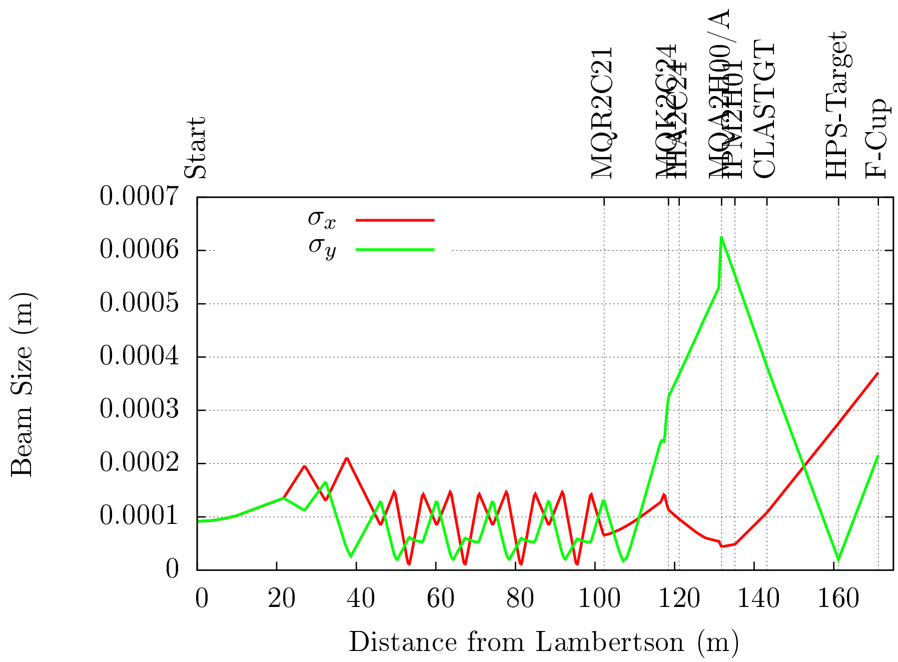
6 Optimized quad values

Table XXX lists the quadrupole values needed to achieve $250 \leq \sigma_x \leq 300\mu$m and $\sigma_y \leq 20\mu$m.

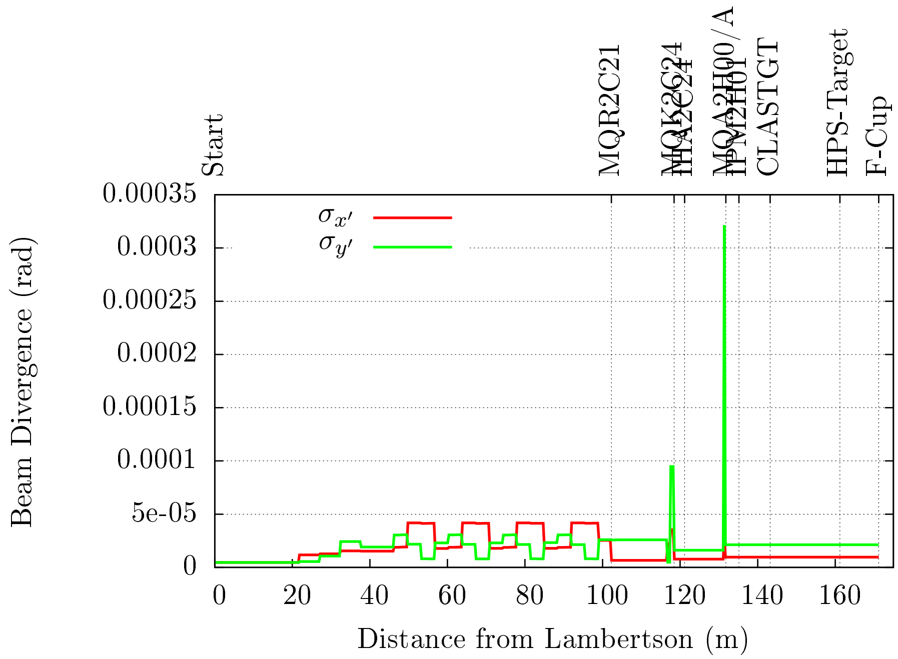
	Unit	1.1GeV	2.3GeV	6.6GeV
σ_x	(mm)	0.275	0.287	0.289
σ_y	(mm)	0.020	0.020	0.021
MQR2C20.K1	(1/m)	1.5636	1.7226	1.7213
MQR2C21.K1	(1/m)	-1.3080	-0.2544	-0.2566
MQA2C21A.K1	(1/m)	-0.0010	-0.0009	-0.0010
MQK2C22.K1	(1/m)	-0.4168	-0.4984	-0.4951
MQK2C23.K1	(1/m)	1.3485	1.3454	1.3550
MQK2C24.K1	(1/m)	-0.8219	-0.8327	-0.8605
MQA2H00.K1	(1/m)	1.8614	0.9666	0.9934
MQA2H00A.K1	(1/m)	-1.8723	-0.9985	-0.9995

7 1.1 GeV plots

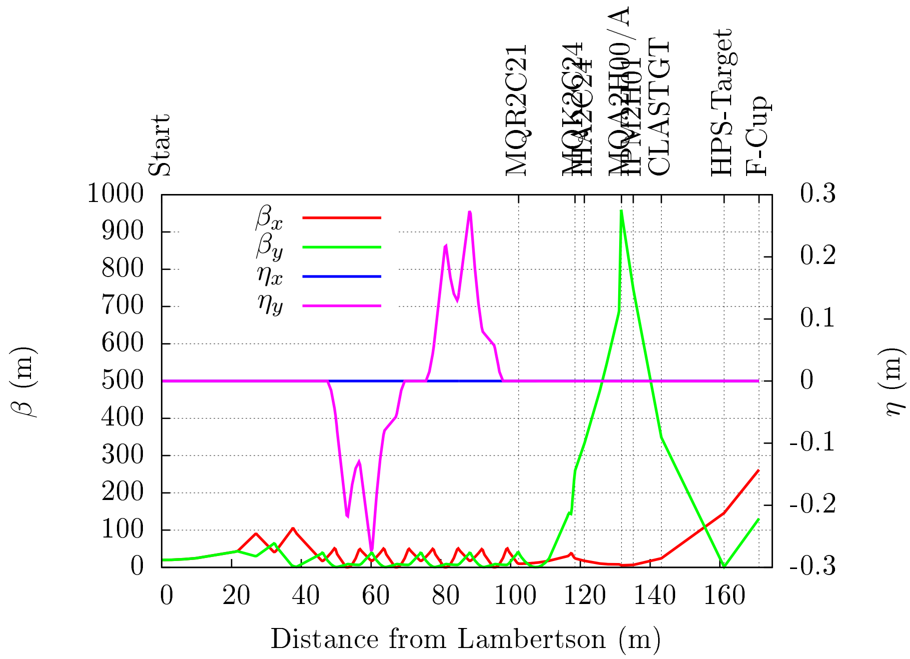
7.1 Beam Sizes



7.2 Beam Divergence

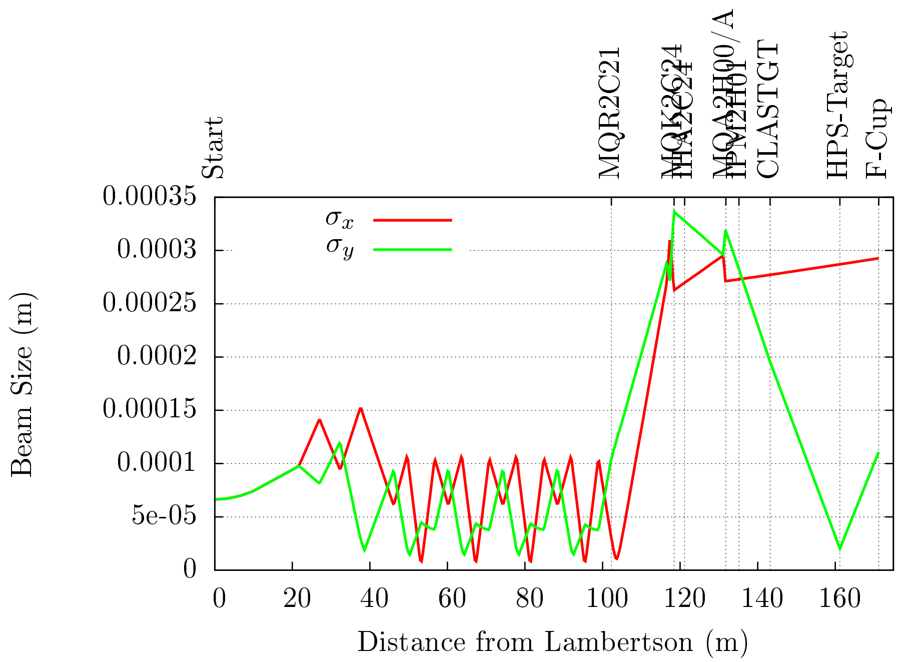


7.3 β, η

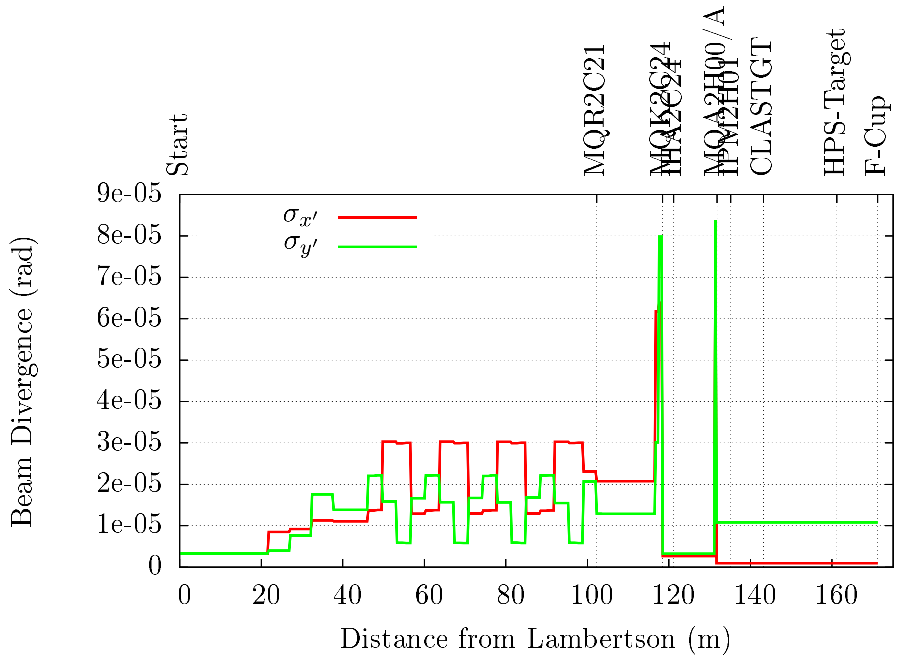

Start
MQR2C21
MQK2C24
MAS2C24
MQA2H00/A
IPM2H01
CLASTGT
HPS-Target
F-Cup
β_x
β_y
η_x
η_y
β (m)
η (m)
Distance from Lambertson (m)
1000
900
800
700
600
500
400
300
200
100
0
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
0
20
40
60
80
100
120
140
160

8 2.3 GeV plots

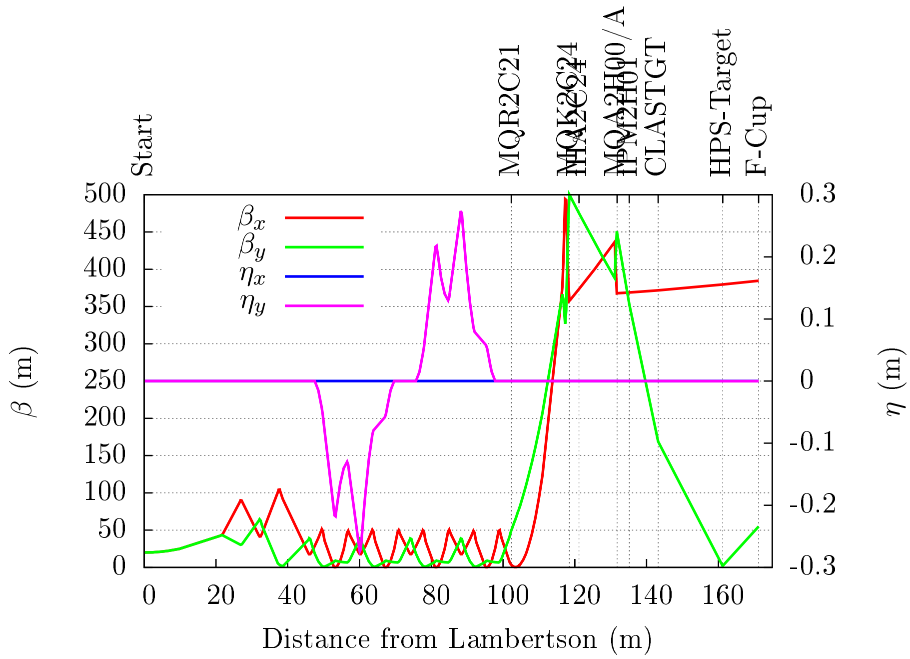
8.1 Beam Sizes



8.2 Beam Divergence

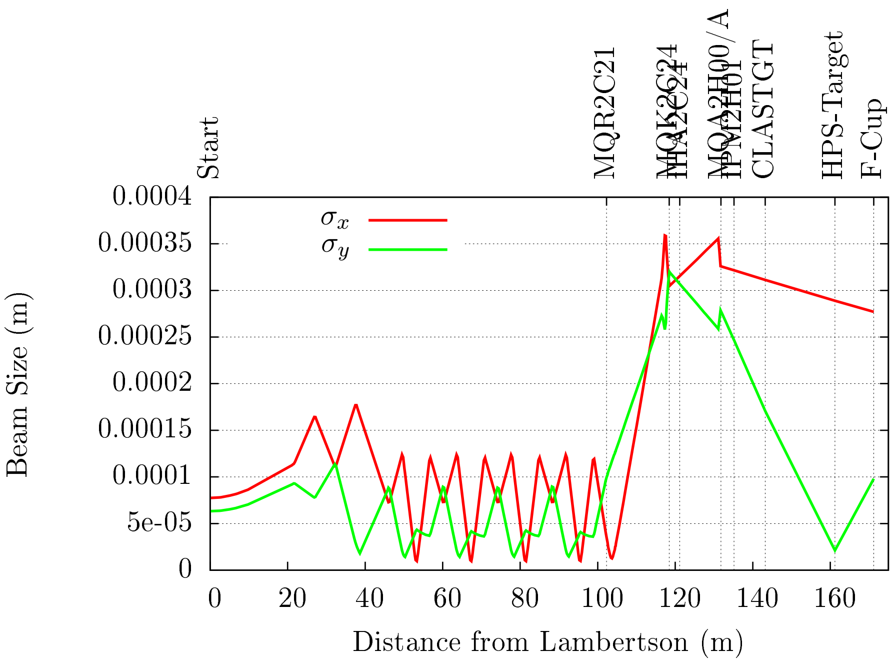


8.3 β, η

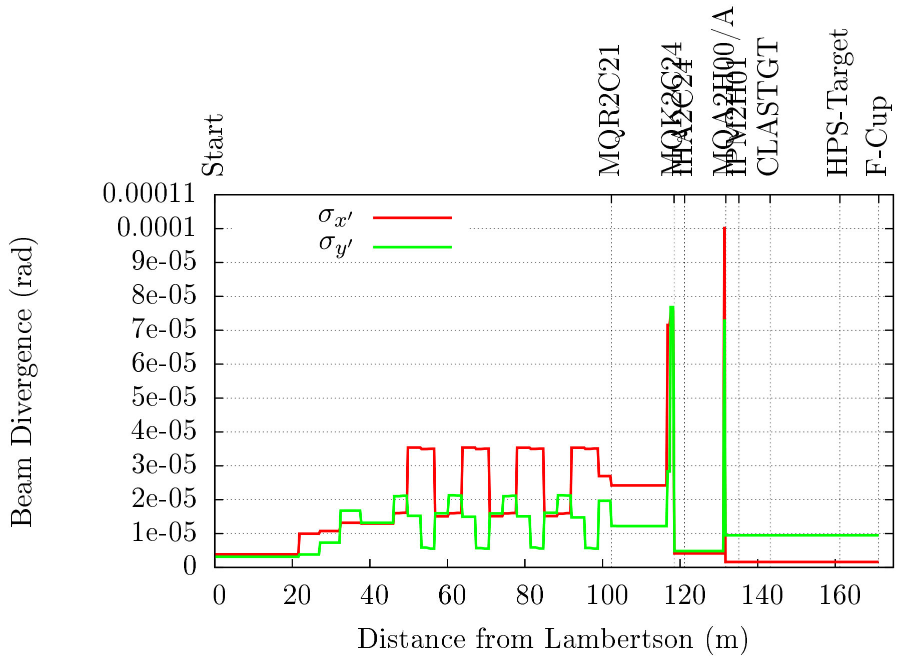

Start
MQR2C21
CLASTGT
HPS-Target
F-Cup
β_x
β_y
η_x
η_y
β (m)
η (m)
Distance from Lambertson (m)
500
450
400
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
0.3
0.2
0.1
0
-0.1
-0.2
-0.3

9 6.6 GeV plots

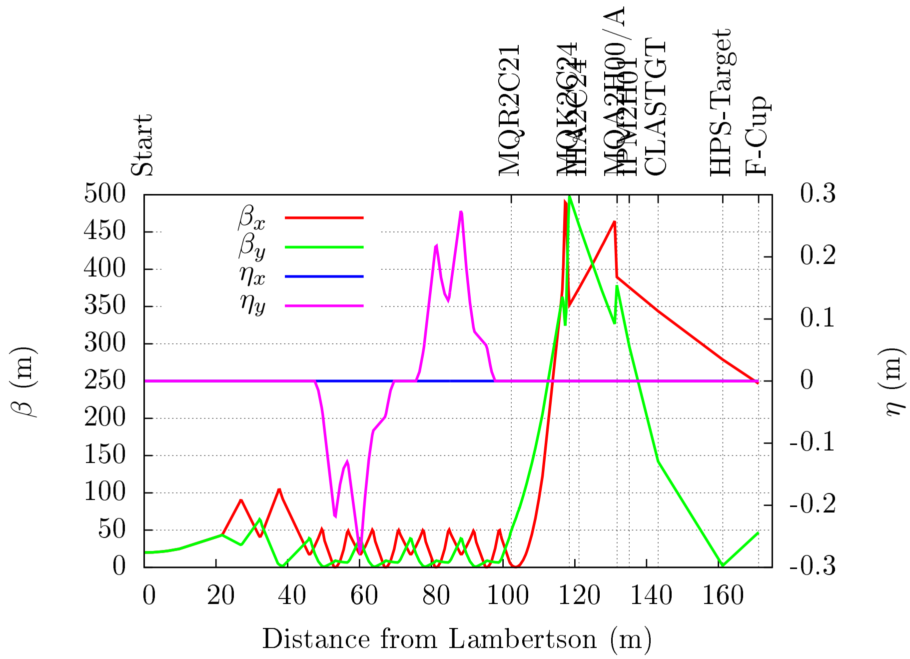
9.1 Beam Sizes



9.2 Beam Divergence



9.3 β, η



Start
MQR2C21
MQK2C24
MHA2C24
MQA2H00/A
IPM2H01
CLASTGT
HPS-Target
F-Cup
β_x
β_y
η_x
η_y
β (m)
η (m)
Distance from Lambertson (m)