**Hall B at 22 GeV (FFA) with magnet comments re ABC**
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## Abstract

Two variations on a Hall B optics at 22 GeV are presented. The accelerator quads and dipoles are the same. In one (Rev. C) the present layout after the shield wall is preserved, including a triplet at the end of the line. In the second (Rev IV) the 22 GeV Hall C Moller polarimeter concept is placed after the shield wall to show that it fits. Drift from target foil to detectors ~15 m. Diagnostics, including nA BPMs, are not included. Sufficient space has been left for at least two after the shield wall.

## Optics

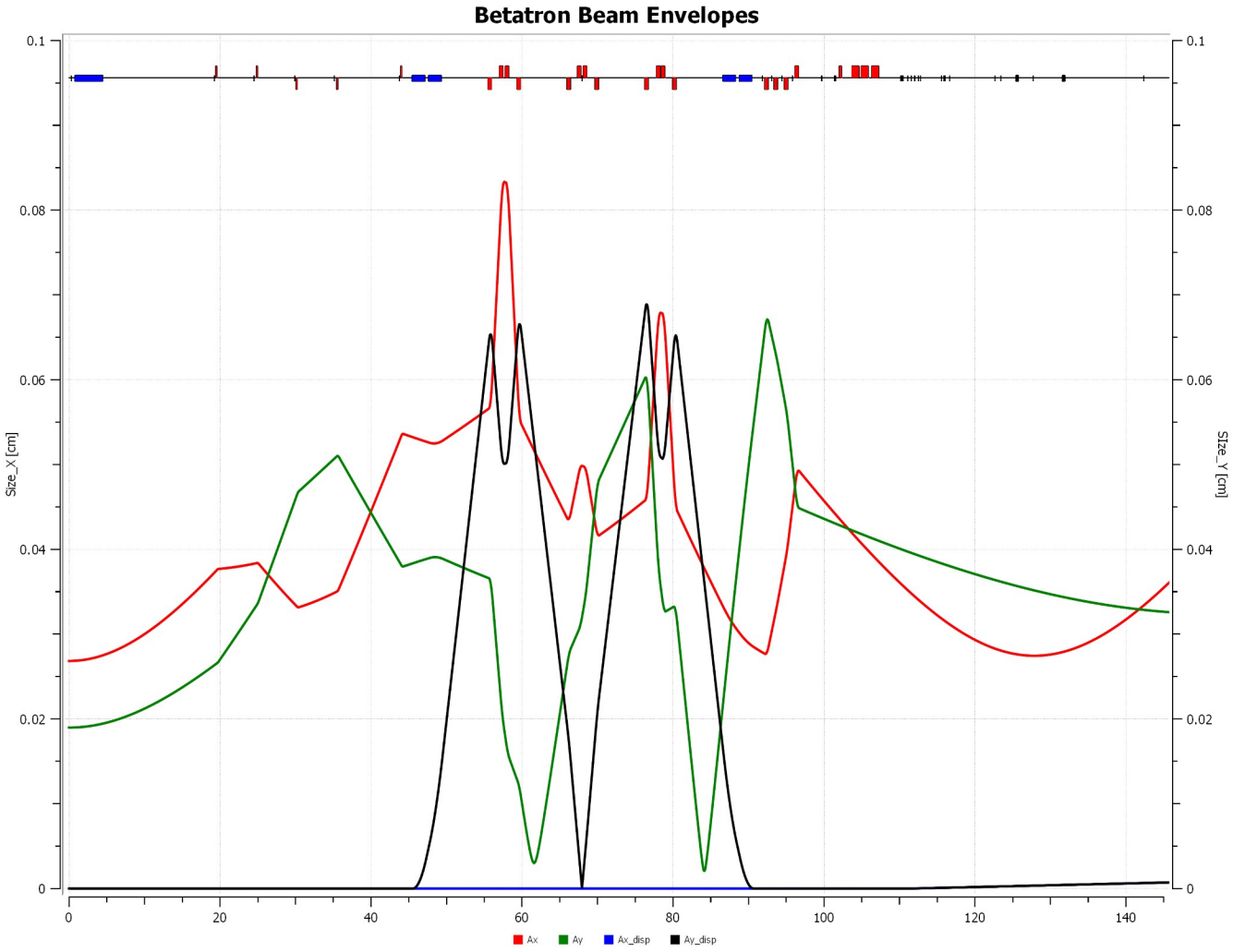


**Figure 1**. Beam envelope assuming nominal 22 GeV entrance emittances and dp/p. Rev IV shown, Rev. C identical as no quads past shield wall are powered. See next two figures for an explanation of the differences. IPM2C21, just after the shield wall, is the tick mark at the top just before 100 m. Hall Center is at 142.5 m on the horizontal axis, where the red (x) and green (y) lines cross, the rightmost tick mark at the top. Black is size due to vertical dispersion given dp/p = 0.001. There is space after the last ramp triplet where betaY is small and vertical dispersion still large. A nA BPM placed here would be sensitive to energy variation. 1 mm full vertical scale.

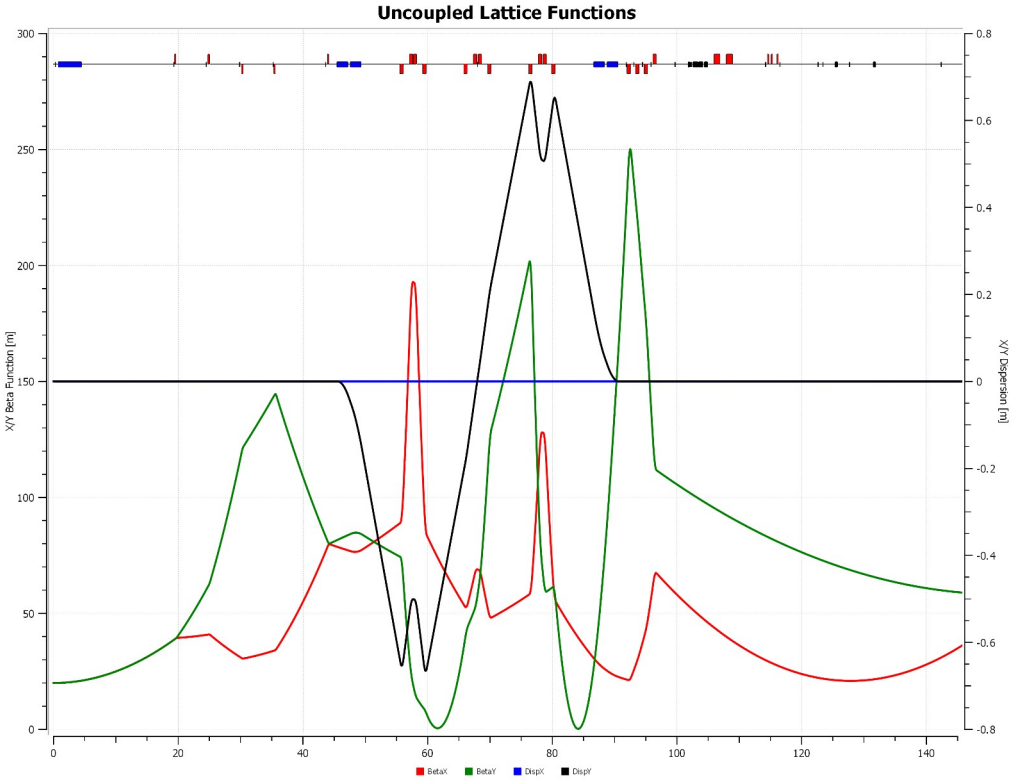


**Figure 2**. Rev. C beta functions. IPM2C1 is the tick mark just before S=100 m. The two versions are identical to that point. After 100 m the existing Moller polarimeter and final triplet are shown, all quads set to zero.

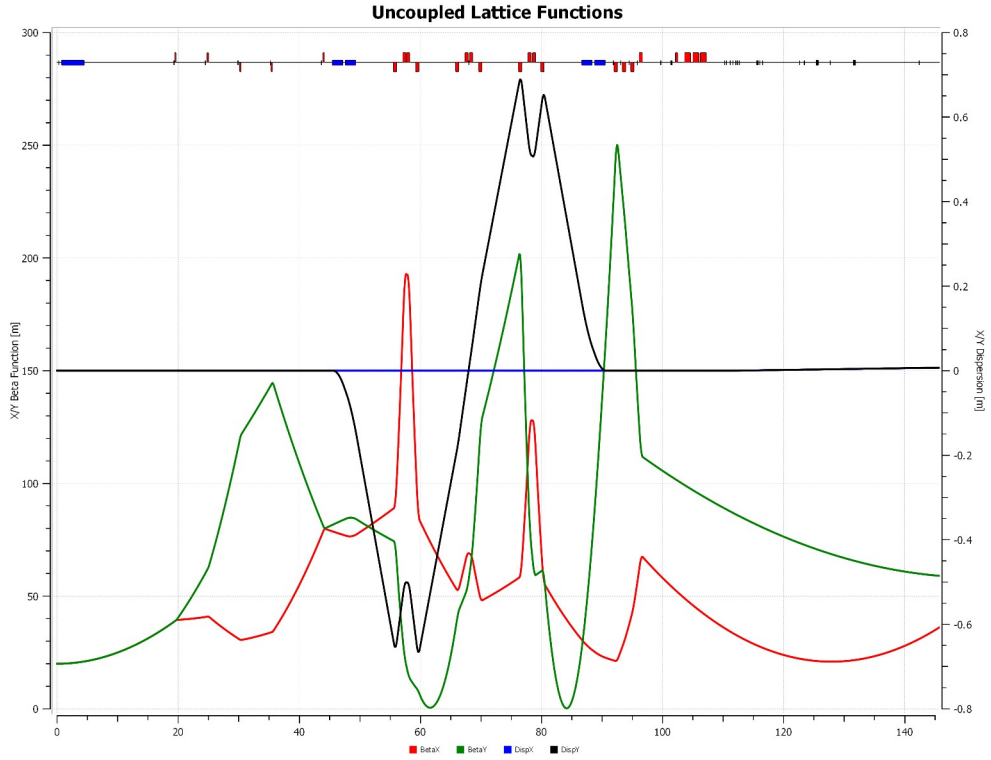


**Figure 3**. Rev. IV After 100 m there is a gap for a nA BPM and then the Hall C Moller polarimeter. There is a box with three cavities at the end of that insertion which would be a second nA BPM.

**Magnets**

One of the goals of my 22 GeV Hall line design effort is commonality of magnets to reduce production costs. As work on all three lines and a sample splitter dipole progressed, it became clear that I could reduce the number of magnet types.

Dipoles
Hall A and C arcs: 380 cm dipoles with 50 cm square section, TN 23-016, instead of larger section
Halls A and C Comptons, Lambertson shunt and Hall B ramp, 180 cm dipoles 50 cm square section
Scaling my 2004 B line design suggested 200 cm dipoles for B which were optimized away

Quadrupoles
Scaling my 2004 B line design suggested 52 cm long quads with QR profile, 5.3 kG/cm focusing, would be required. The design presented above requires only 42 cm length with that profile including 4% adjustment margin. There are four quads in the A and C lines which require a 50 cm quadrupole to have 3% adjustment margin. All the other quads in the A and C line which are above existing quad capability will accept the 42 cm length of the B design. Two new quad lengths, 16.5" = 41.9 cm and 20"=50.8 cm might be more cost effective than ordering only 20" units. Then again, perhaps not.

All of the quads in the Hall B design files are still labeled QA. Lengths were increased to 52 cm where I expected to need extra focusing. I have not gone through the tedious exercise of reducing quad lengths while maintaining center location so as to maintain the optics to first order. This is left as an exercise for my successor.

**Relevant TNs**

The MCG and MCH correctors JLAB-TN-21-033
Hall A and C dipoles for higher energy (re FFA) JLAB-TN-21-051 (380 cm, old section)
Extended Lambertson for FFA JLAB-TN-22-041
180 cm Dipoles for Hall Line Use at 22 GeV (FFA) JLAB-TN-23-008 (old section)
Hall C line at 22 GeV (FFA) TN-23-009
First Look at Hall A Beam Line at 22 GeV (FFA) TN-23-011
Conventional Dipole for FFA Splitters TN-23-016 (50 cm square section)
C magnet to allow 11 GeV FFA tests in BSY dump line TN-23-017 (300 cm, 50 cm square section)
Variations on the 104 mm quad for FFA and other uses TN-23-018 (Moller polarimeters)

**Comments**

This is by no means a final conceptual design. There should be a standard BPM and a pair of correctors after the final dipole in the ~140 cm gap before the shield wall. [oD37, 305.6 cm, includes the 140 cm shield wall. See spreadsheet.] A nA BPM should follow the standard IPM2C21 in the lattice. A similar installation is required just before the tagger, along with a nA BPM. These elements are included in Rev. IV between the legs of the Moller polarimeter but are not explicit in Rev. C lattice. Two pair of correctors are needed for the final orbit lock. Nevertheless it's a solid start and sufficient to place at the end of a full FFA model.

If the FFA collaboration is unable to come up with a way to extract beam to Hall D, there's about 50 m span from a possible goniometer position to Hall B center in Rev. IV. Polarized photons were generated in Hall B in the 6 GeV era. Lock correctors and final BPMs will cut this to ~48 m.

To get a feel for how this optics would work at energies below 22 GeV, hence smaller emittances and dp/p, I went to a 2020 spreadsheet with measured beam properties at 121/1031/1031 (Inj/NL/SL) and extracted values at energies close to those of the lower passes of the FFA. See Table. The figures below show beam sizes (sigmas) with the estimated emittances and dp/p 2E-4. I did not rematch to deal with the fact that emitY is **not** half of emitX as expected at 22 GeV. With rematch, average X and Y sizes by eye.

**Table: Emittances measured 7/1/2020 setup and derived FFA low pass estimates**

| | Energy | Measured | | Energy | Estimates | |
|---|---|---|---|---|---|---|
| Pass | 07/01/20 | emitX (m) | emitY (m) | FFA_low_pass | emitX (m) | emitY (m) |
| 1 | 1152 | | | 1750 | | |
| 2 | 2183 | | | 2850 | 4.00E-10 | 3.00E-10 |
| 3 | 3214 | 3.726E-10 | 2.894E-10 | 3950 | | |
| 4 | 4245 | | | 5050 | 2.00E-10 | 4.00E-10 |
| 5 | 5276 | 2.177E-10 | 3.989E-10 | 6150 | | |
| 6 | 6307 | | | 7250 | 5.00E-10 | 4.00E-10 |
| 7 | 7338 | 4.972E-10 | 3.504E-10 | 8350 | | |
| 8 | 8369 | | | 9450 | 1.30E-09 | 6.00E-10 |
| 9 | 9400 | 1.310E-09 | 8.997E-10 | 10550 | | |
| 10 | 10431 | | | 11650 | 3.50E-09 | 1.80E-09 |
| 11 | 11462 | 3.470E-09 | 1.798E-09 | 12750 | | |

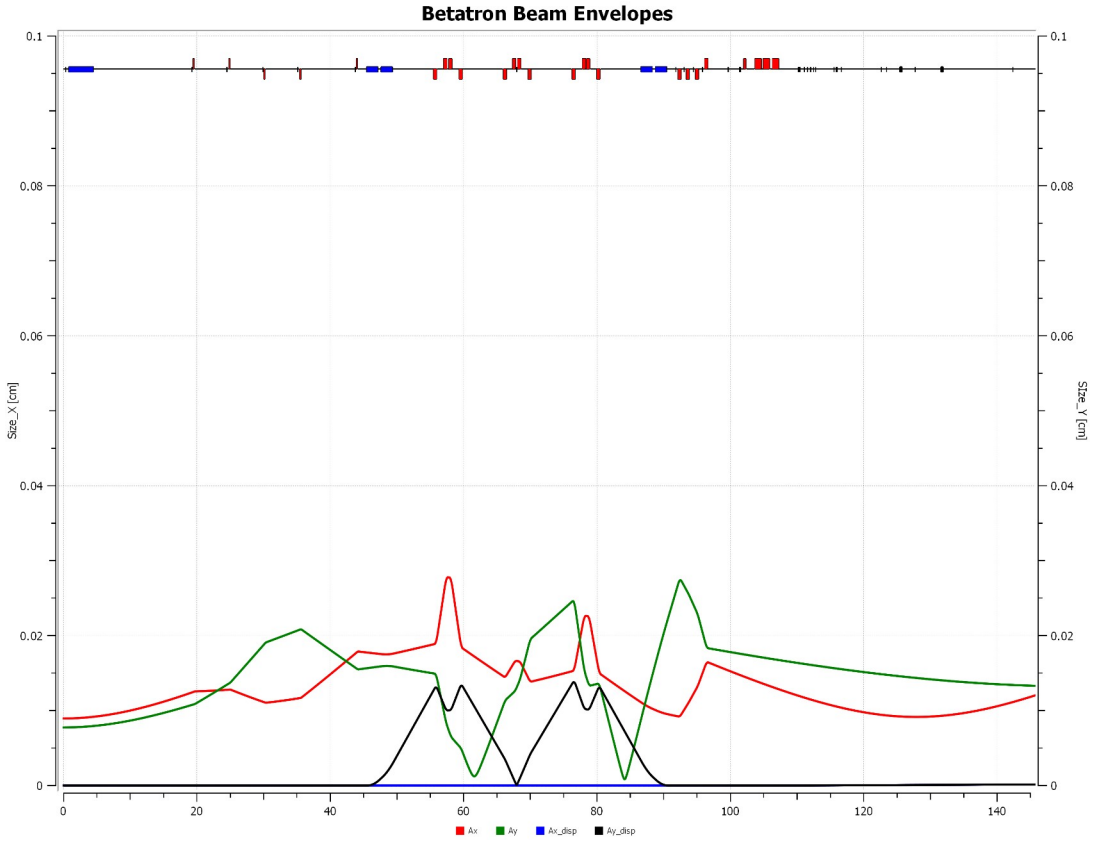


**Figure 4**. Beam sizes with 2850 MeV emittance estimates from Table.

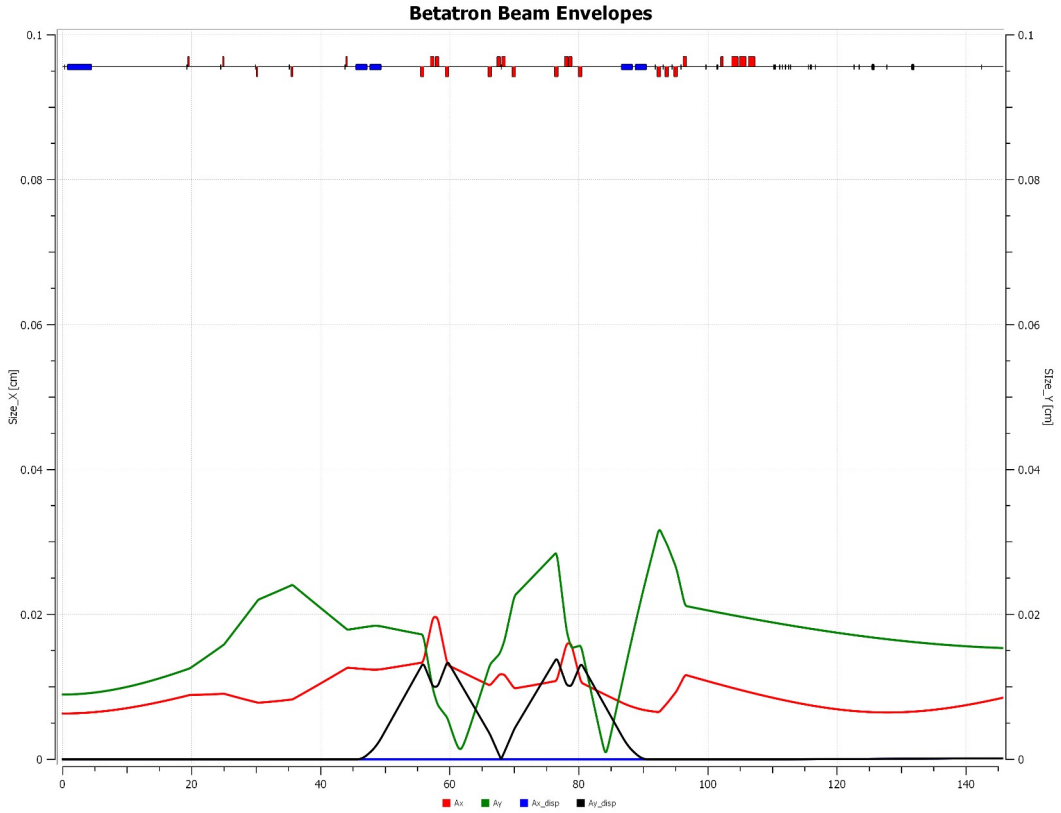


**Figure 5**. Beam sizes with 5050 MeV emittance estimates from Table.

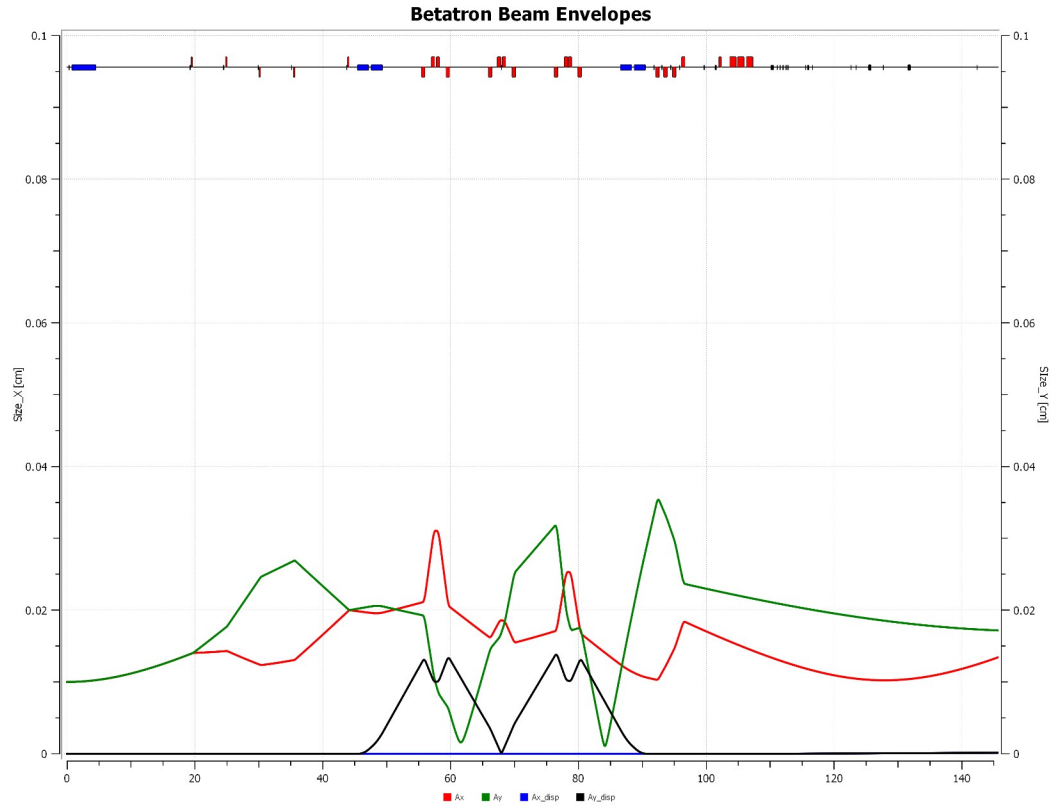


**Figure 6**. Beam sizes with 7250 MeV emittance estimates from Table.

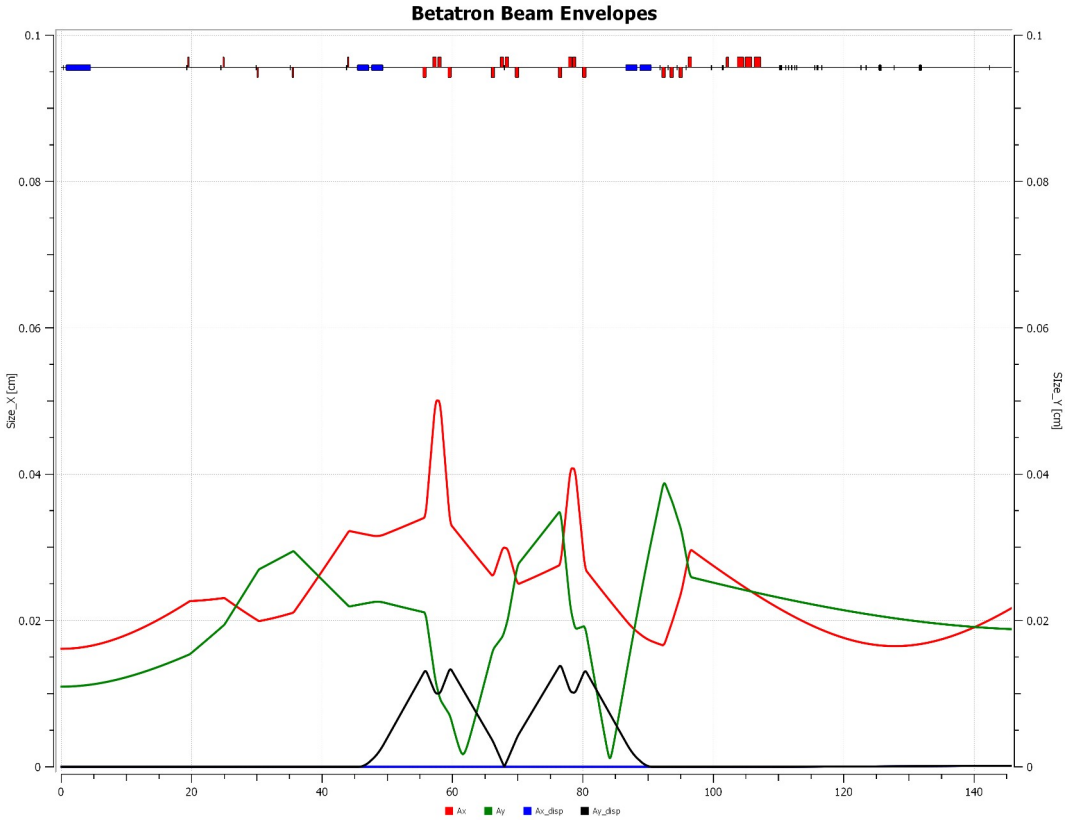


**Figure 7.** Beam sizes with 9450 MeV emittance estimates from Table.

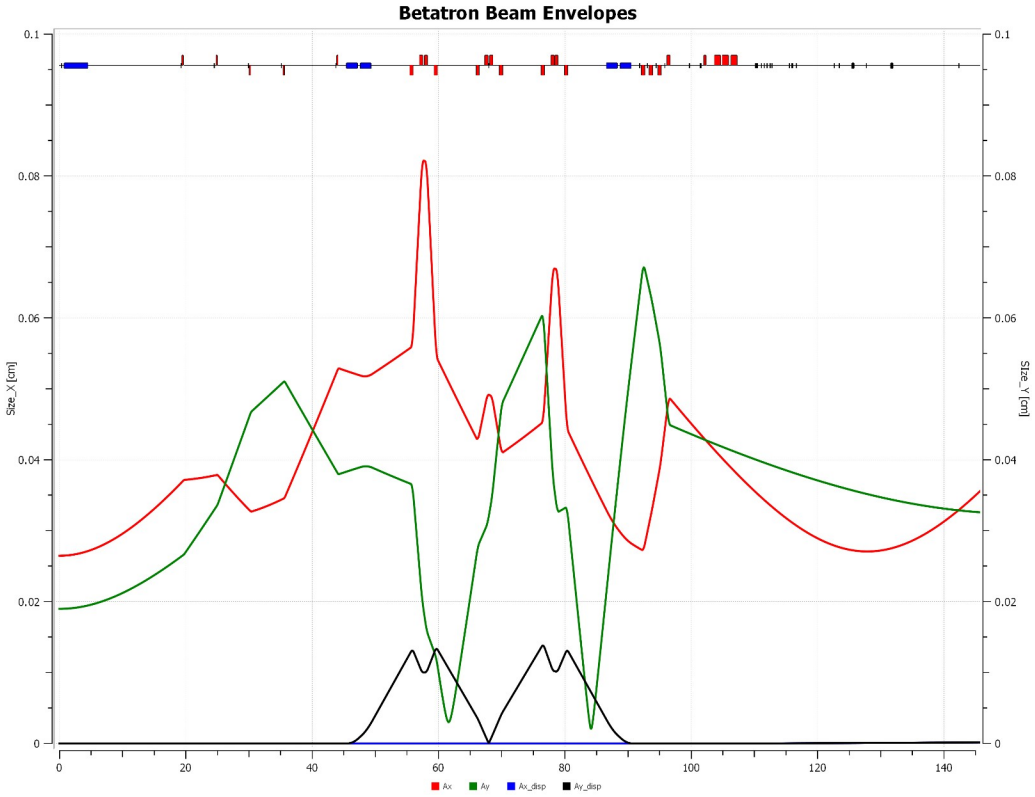


**Figure 8.** Beam sizes with 11650 MeV emittance estimates from Table.

Finally, if one uses the triplet at the end of Rev. C in addition to the quadruplet after the last dipole, beam size may be reduced. Whether the reduction in length available for the Moller polarimeter by retaining this triplet is a desirable trade-off is a topic for the Hall B collaboration.

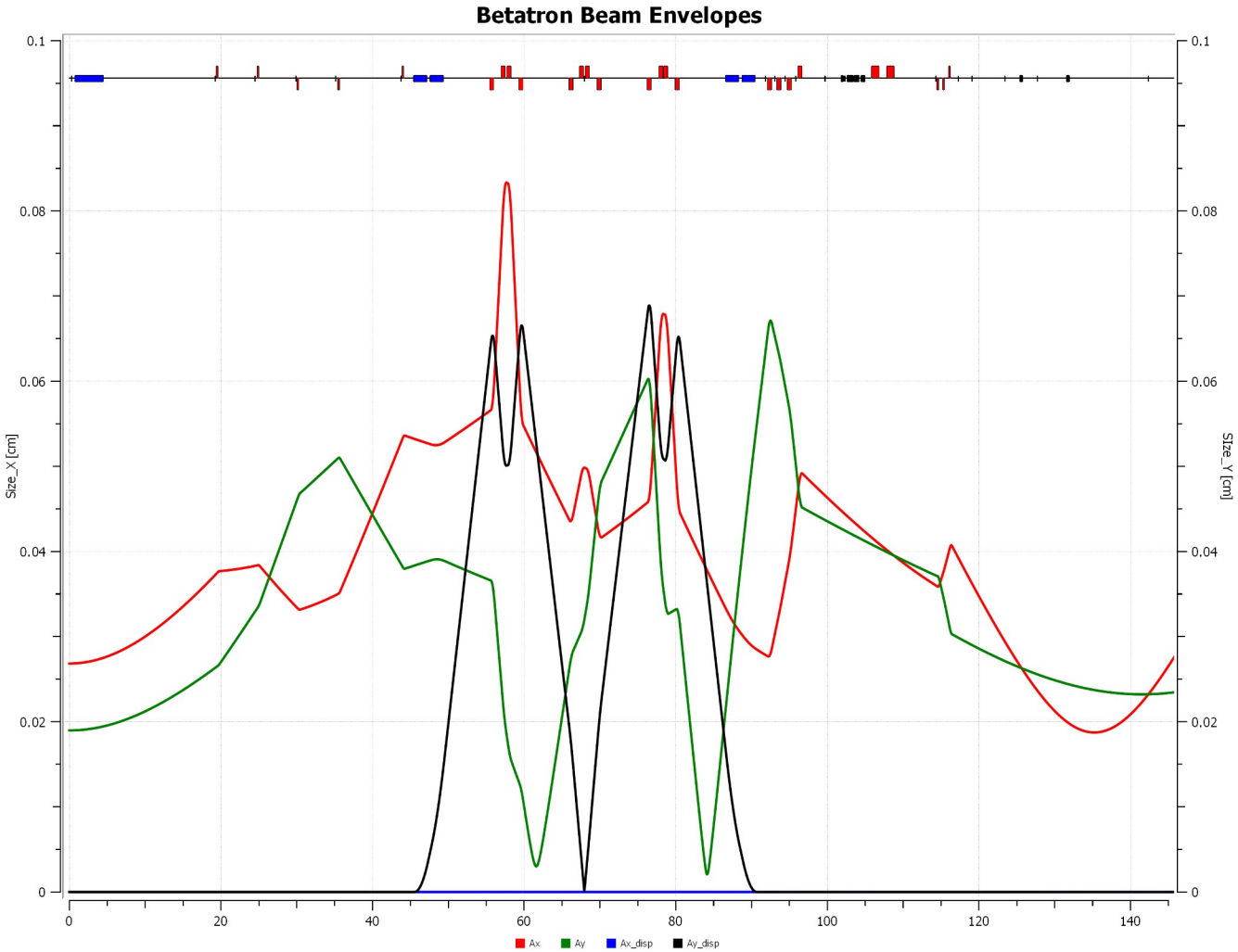


**Figure 9** Seven accelerator quads after the last dipole used to reduce spot size. Compare to Figure 1 or Figure 8 just above as Fig. 8 is almost identical to Fig. 1.