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Hall D behind B
or
How an exercise to allow energy measurement in hall B changed into an examination of moving GlueX to the west end of the machine

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1. Abstract

A new optics design for the hall B ramp is presented. Alternate quadrupole settings which move the beam focus 75 m beyond the usual CLAS target are also shown. These and variations on hall A optics are contrasted with the hall D design optics. The advantages and disadvantages of placing hall D behind B are discussed. 12 GeV upgrade project cost savings of order $10M may be possible if D is so located. Four recommendations are made in section 8.

2. Background

In early September 2004 I began looking at alternate designs for the hall B ramp optics. The present optics is by Richard York and consists of two double achromats. Quadrupole and dipole excitations are high relative to those in other hall lines at the same energy. The sextupoles needed for the double achromat are not powered, so that feature isn't used. The dispersion in the ramp is very low, ~25 cm peak, so it is not possible to measure energy variation with time in the B line during electron runs. For photon runs, the 9m dispersion at the tagger dump provides high sensitivity but no way to record or feedback on energy changes. Increasing the dispersion in the B ramp from 25 cm to 75 cm (herein) or 160 cm (likely maximum) would allow real time measurement and feedback. Energy fluctuations were a recent issue in hall B when hall A was frequently turning on and off energy feedback.

In designing the hall D line (TN 03-027) for the GlueX experiment I began with the hall B line as an example and quickly found that high magnet excitations precluded such a design for D. I ended up with simple bends top and bottom and three triplets in the ramp to control envelope and zero dispersion. The design presented here for hall B is similar. It re-orders the eight dipoles and components on 17 girders, 15 before and 2 after the shield wall, into 13 new girders before the shield wall. If the components of one girder can be obtained elsewhere, nothing need be touched after the shield wall, reducing installation cost and time.

3. Standard Hall B optics

Standard hall B optics for normal runs and for g8 (coherent bremsstrahlung) runs are shown on the next two pages. The latter is distinguished by the placement of the tagging radiatior much farther upstream than usual. This allows the incoherent bremsstrahlung cone to increase in radius enough for substantial net polarization of the mix of coherent and incoherent bremsstrahlung photons which make it past the collimators. The same need, in combination with the higher energy, placed the GlueX collimator ~80m from the radiator in the hall D design.

For beam envelopes, standard 4 GeV values are used except in figure 3, where emittances from the 1999 Point Design report at the exit of arc 9 are used. Red and green curves are horizontal and vertical beta functions and sizes. The black line on the beta function plot is dispersion and references the right vertical axis scale, +- 1 m. The line below the figure frame represents the beamline, with, red blocks quads, blue dipoles and black instrumentation or markers.

Dipole field for this optics is 993 G/GeV, well into saturation at 11 GeV. Quadrupole excitation is 465 G/GeV. The return legs of the QA quads saturate at a focusing gradient in these units of 4 kG, so the quads must be extended in length to exceed 8.6 GeV. In the designs that follow I simply shuffle the existing QA quads but explicitly place 7.5 cm gaps on either side of the QAs to provide for a 50% increase in quad length during the 12 GeV upgrade.

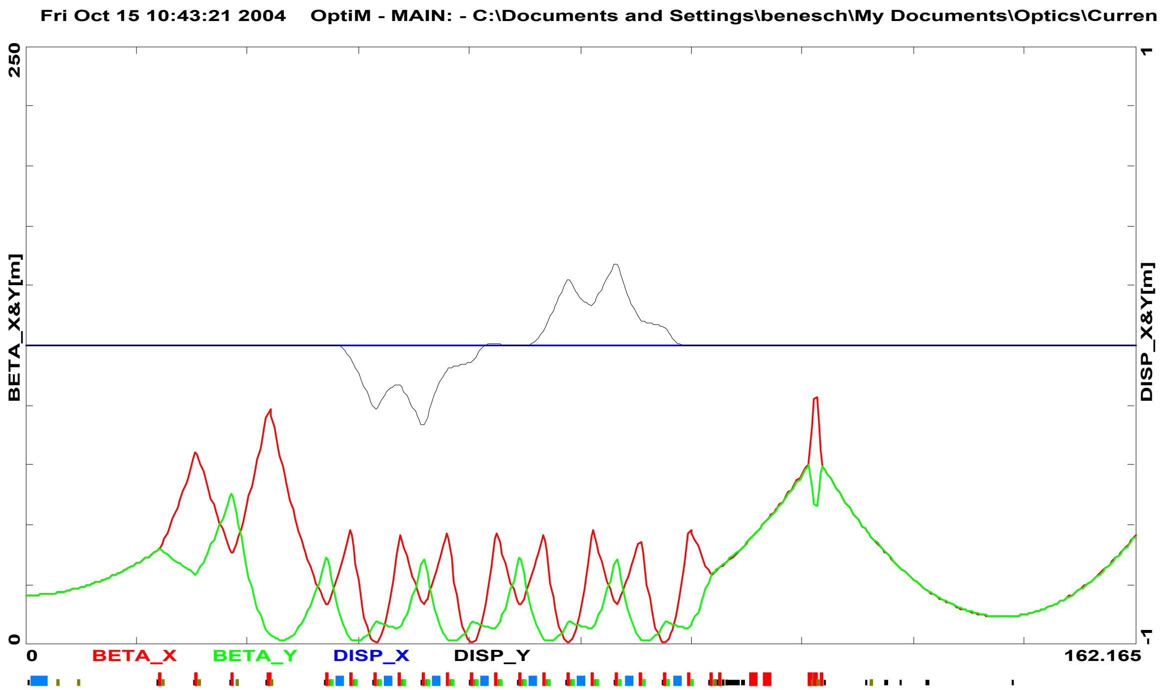

Figure 1. Beta functions and dispersion for standard electron optics, 4 GeV

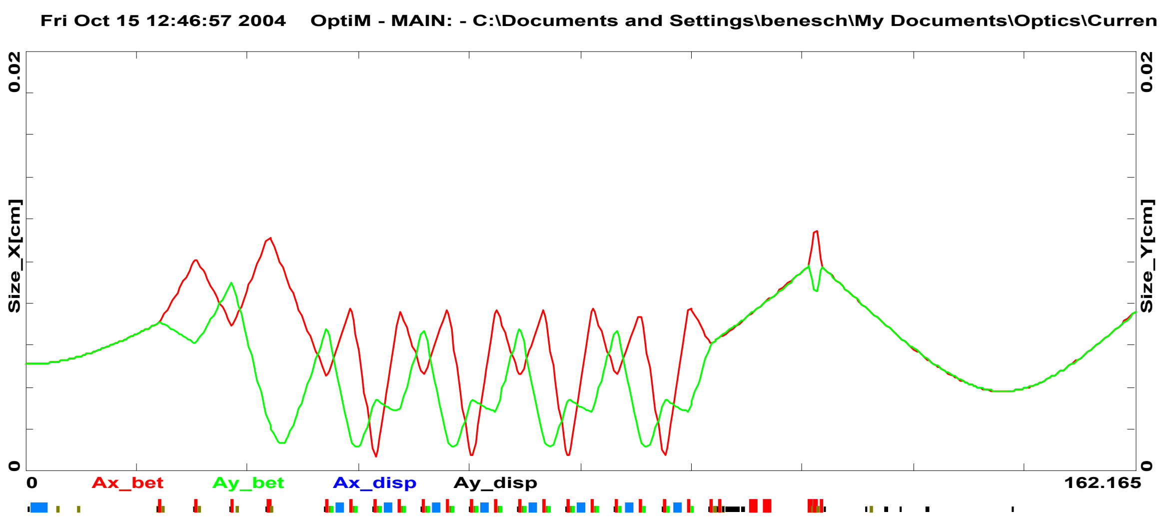

Figure 2. Beam envelopes, 200 micron full vertical scale, 4 GeV

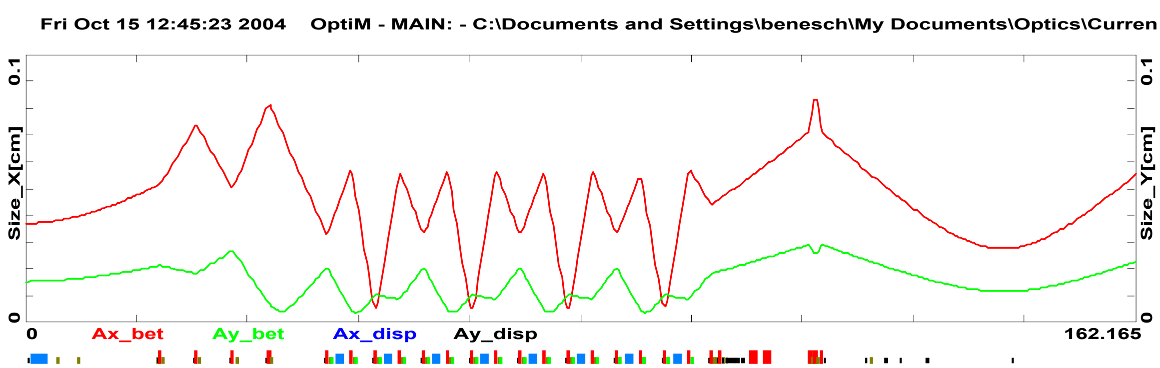

Figure 3. Beam envelopes, 1000 micron full vertical scale, 11 GeV, same optics as above

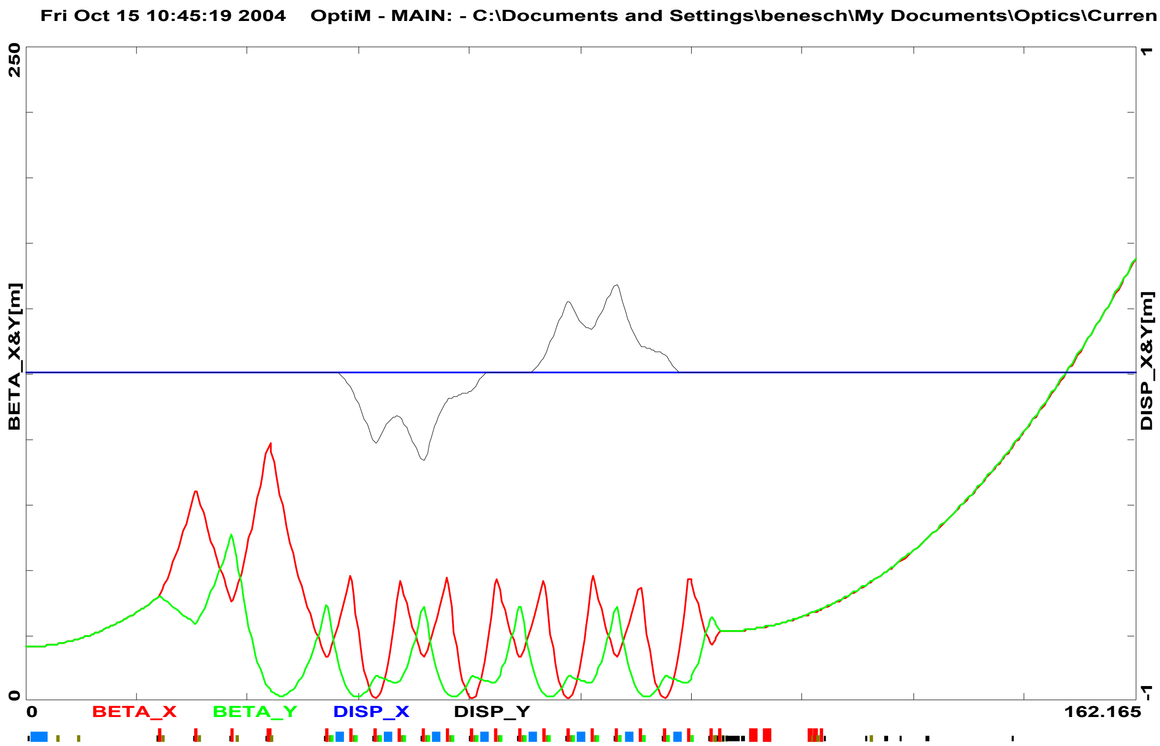

Figure 4. Coherent bremsstrahlung (g8) optics 4 GeV. One of *the* black boxes just above "*the*" in this caption is the goniometer which holds the tagging radiator.

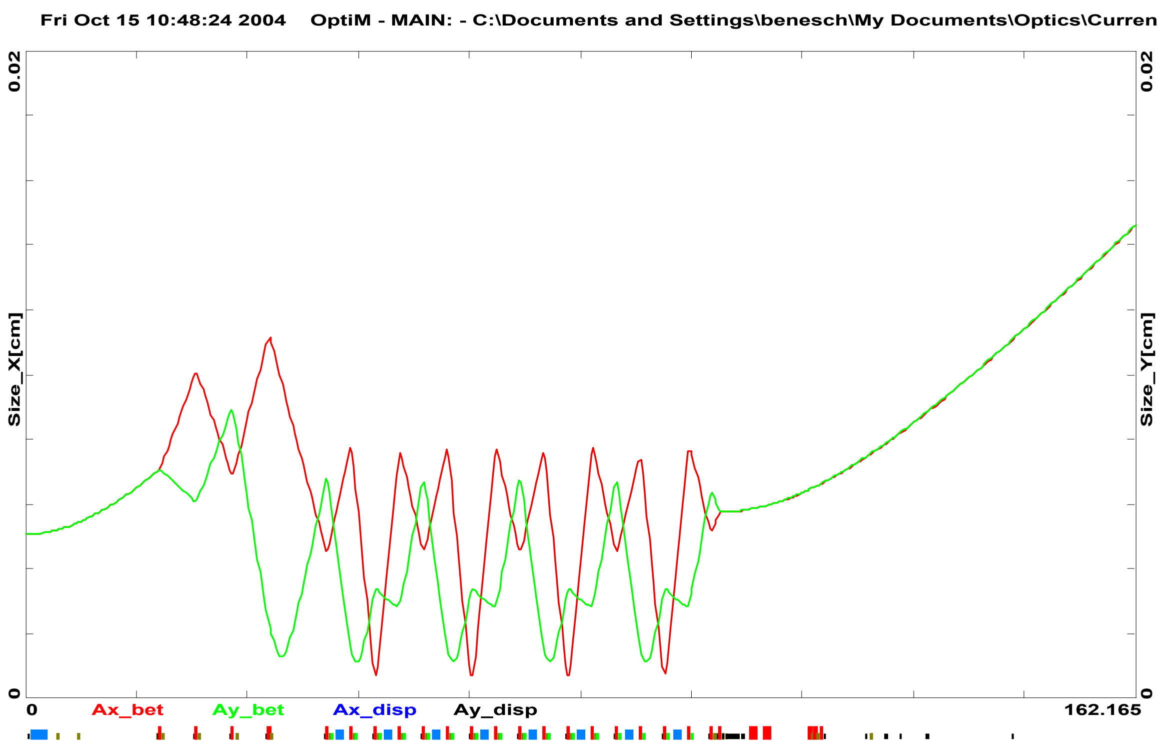

Figure 5. Beam envelopes, 200 micron full scale, coherent bremsstrahlung (g8) optics, 4 GeV

4. Alternate Hall B Optics

The primary goal of the alternate optics design was originally to increase dispersion so energy changes could be observed "real time" in the hall B line, where "real time" is limited by the integration time needed by position measuring instrumentation (BPMs) given the nA currents used in hall B. The simple scheme with dipoles top and bottom and three quad triplets in the ramp allow for peak dispersion approximately one fourth of the vertical displacement. In the optics shown hereafter, peak dispersion is 74 cm. The "nA" cavity BPMs have a resolution of 10 microns with one second integration and 5 nA beam current, corresponding to an energy change of 14ppm. With new software, integrating the SEE BPMs for a second may provide sufficient resolution for 100ppm resolution of energy changes. Only hypernuclear experiments have required energy resolution better than 100ppm; they require ~25ppm.

The first iteration included changes only in the Hall B ramp proper. Six dipoles and fourteen quads were re-located. The first and last dipoles in the ramp were left as is and two quads were removed from the line. The remaining twelve quads were placed in three triplets with the central member of each triplet, with double the field of the ends, consisting of two quads. Because the bend was simple rather than serpentine, dipole excitation went down a third. Quadrupole excitation dropped ~15%. This meant that no dipole changes were needed for even 12 GeV in B and that the longer quadrupoles needed for the higher energy even in this case would run cooler than with the standard hall B optics.

After this design was completed and the layout checked with ME to ensure no interference with concrete, an inquiry was made by a senior staff member from Physics: Could GlueX be accomodated in hall A. I quickly concluded (see section 5) that it was impossible to meet the physics needs of GlueX in hall A. I decided to explore whether the alternate hall B design could be altered to allow GlueX (Hall D) to be placed behind hall B.

The hall D design has σ_x = 1.6mm, σ_y = 0.6 mm at the radiator and both 0.6 mm 80m downstream at the entrance of the 3.4 mm ID collimator. If the distance to the collimator entrance is shorter, its ID must be scaled to preserve the ratio of coherent to incoherent bremsstrahlung photons and thus the polarization. Collimator length is set by energy and is therefore invariant. The electron beam must be steered onto the radiator in such a fashion that the coherent photons are centered on the collimator. The feedback scheme needed for this has not been designed. It is likely to require two well-separated planes of segmented photon detection upstream of the collimator to define angle and center of the incoherent bremsstrahlung cone within which the coherent photons are "hidden". 100 micron location and micro-radian angle accuracy are needed. An 11-12 GeV electron beam is stiff. A long lever arm between pairs of feedback correctors for each plane is desirable. In the hall D design, 13m without focusing elements was allocated. The first iteration of the new hall B design had only ~2.5m before the goniometer for feedback and focusing elements were part of this. Another look was taken.

The design presented here increases the dipole field to 9 kG at 12 GeV from that used in the first (unshown) iteration, still in the linear regime of the steel. This is still well below the 11.9 kG needed for 12 GeV with the standard hall B optics. . This change frees room for a grouping of four quads to allow full control of transverse parameters and 8m between corrector pairs without focusing elements for final feedback. If still more "throw" is needed between feedback correctors, the upstream pair may be located near complementary quads 12 and 10 m upstream of the final pair. The final layout will include at least three fast feedback correctors in each plane.

This design requires the relocation of 7 dipoles, 17 quads and associated elements. It affects the line downstream of the first dipole and upstream of viewer 2C20. This viewer, the 2C20 nA BPM and the g8 goniometer are not moved. The Moller spectrometer is shown in its present configuration but will have to be altered to deal with higher beam energy. The final quad triplet is shown in the figures below but is unused. It can be removed to provide space for Moller and tagger spectrometer expansions.

The two figures below can be compared to figures 1 and 3 above. Input emittances are the same. Note that the vertical scale for the beta functions is now 500m, not 250m, and that for the envelopes is 1.2mm, not 1mm as in figure 3. A round beam at the CLAS target can be achieved, but only at ~0.35 mm sigma. In other words, the author and the Optim minimizer can't make further progress with σ_x. Vertical envelope can be adjusted. The beam pipe for QA quads is 22mm ID, ~20*σ_x(peak)..

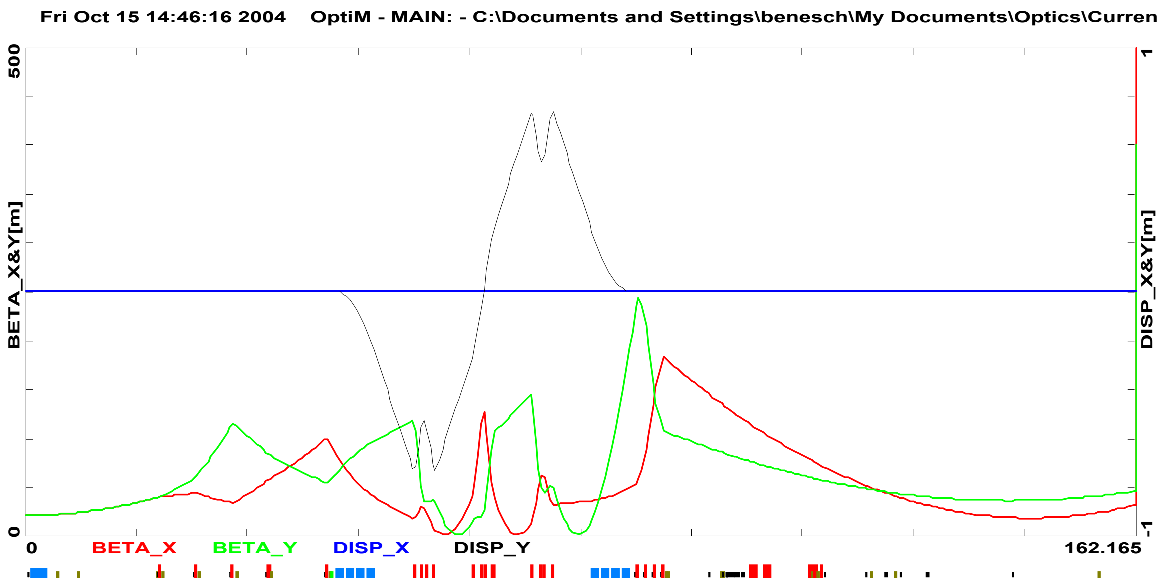

Figure 6. Beta functions and dispersion for revised hall B optics, 11 GeV.

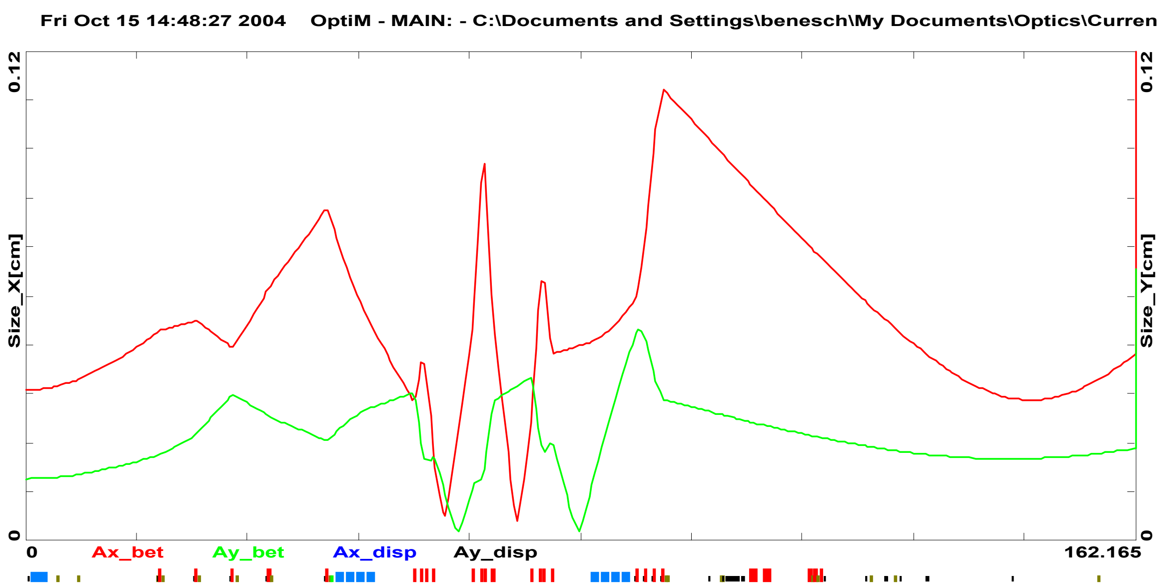

Figure 7 Beam envelopes for revised hall B optics, 11 GeV, 1.2 mm full vertical scale

The figure below shows beam envelopes for the same layout with slightly modified quads before and after the ramp and 12 GeV input beam energy. Input emittances are those from the exit of arc 10 in the Point Design Report PDR): Emittance: ex[cm]=10e-07 ey[cm]=2e-07 DP/P=5e-04 (Optim input format). Beam is round with σ ~0.5 mm at the CLAS target.

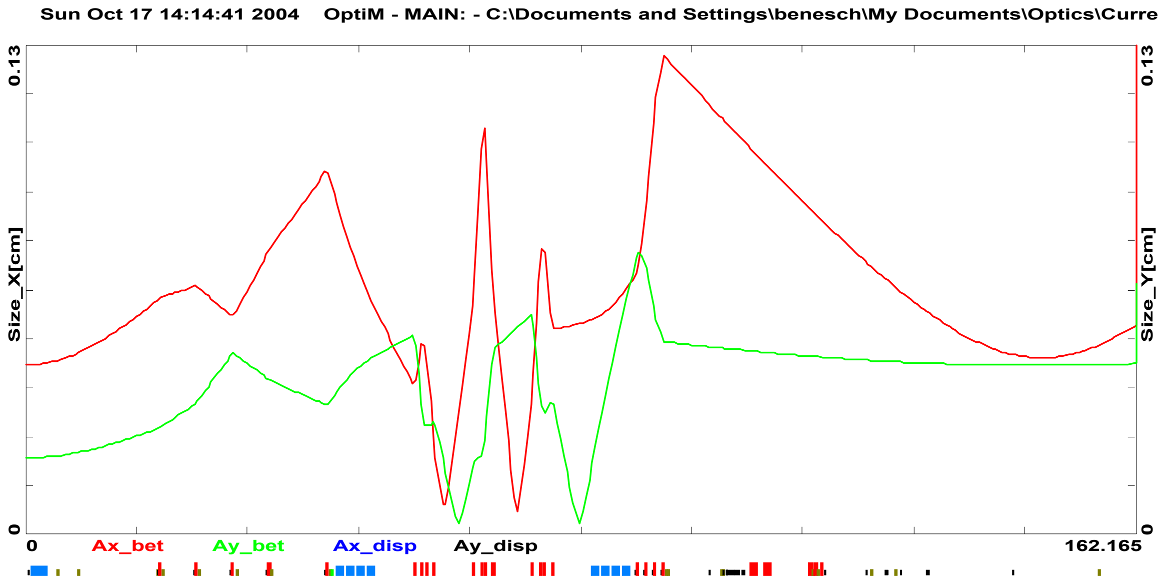

Figure 8 – approximate beam envelopes for 12 GeV in hall B. Full vertical scale 1.3mm.

A portion of this material was presented at the beam transport team meeting Tuesday, Oct. 12. Andrew Hutton suggested that an emittance rotator installed in an appropriate location would mitigate the horizontal and vertical asymmetry shown above and lower the peak envelope size. Some numerology was done with the emittance values in PDR table 5-2.4. With emittance rotators in both 7E and 9E, the only locations with ample room, emittances are reduced in the horizontal and increased in the vertical so their ratio is ~1.7:1. This produces, after re-optimization, beam envelopes shown in Figure 9 below. The beam is slightly smaller at the CLAS target than in figure 8 and the peak beam size is less than 1mm, significant improvement.

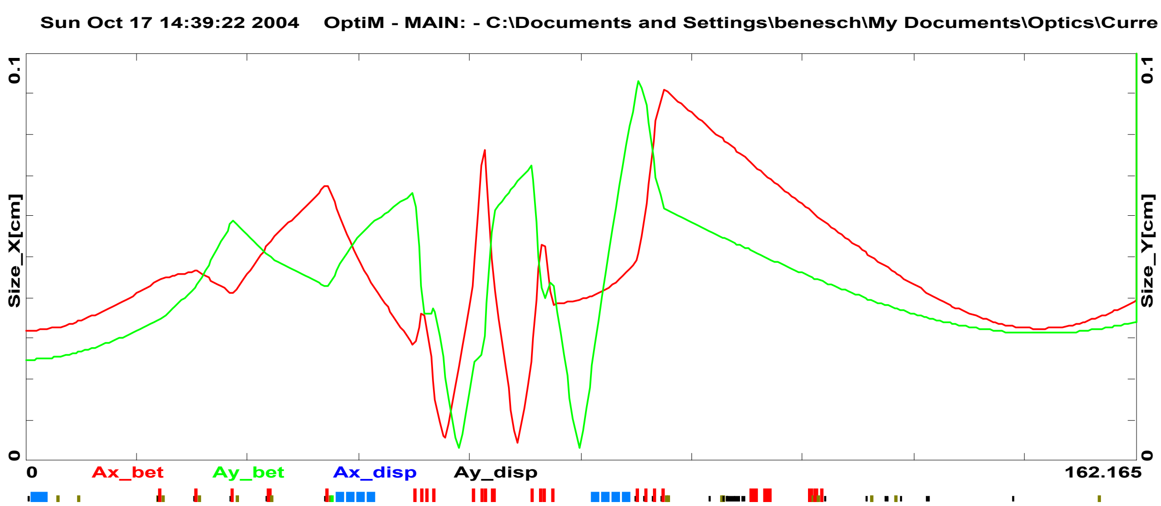

Figure 9. Beam envelope estimate with emittance rotators in 7E and 9E, 11 GeV. 1mm full vertical scale.

It is likely that a similar reduction in peak beam envelope and in size at CLAS target can be achieved at 12 GeV with two rotators, but to quote actual values would go well beyond the uncertainty of the assumptions made in calculating the benefits for fifth pass beam at 11 GeV to hall B. Relatively detailed optics development, including calculation of emittance growths in the NE spreader where the need to match into the NL force high beta functions in dispersive regions, are needed to determine what gain would really be obtained with emittance rotators in 7E and 9E.

An emittance rotator is likely to be similar to the beam property rotator recently installed in the FEL and consist of eight skew quadrupoles. 7E and 9E, which are sparsely occupied because they mirror the real beam extraction regions optically, are the obvious locations for such rotators. 8E, with two beams already separated, is not a good choice. Location of such rotators before or after the doglegs will have to be modeled. Note that the 7E rotator, by rounding the beam at 8E, allows one to maintain horizontal separation there and eliminates the need for a new set of dogleg magnets with larger pole separation. Thus adding such a rotator provides for a cost savings in excess of $250K just in dogleg magnets and elimination of a new Lambertson magnet.

The 1999 Point Design did not consider all the implications of the large horizontal emittances and the dipole magnet good field region on spreader and recombiner magnets where the large axis of the ellipse is perpendicular to the pole face. CASA is still working on a revised dipole good field specification. Adding both 7E and 9E emittance rotators will ease the requirements on the new S/R/R dipoles under any specification. This cost savings cannot now be quantified. Eight skew quads, associated diagnostics, and power supplies are likely to cost <=$240K.

Recommendation: Add skew quad groups to 7E and 9E to exchange x and y emittances and maintain the beam substantially closer to circular than in the 1999 Point Design.

5. GlueX in Hall A

In September I was asked by a member of the Physics Division to look at putting the GlueX experiment in hall A. Another member had noted that if the radiator could be placed immediately after the shield wall about half the planned drift space between the radiator and the collimator could be achieved while keeping the GlueX detector contained in hall A. I assumed that the optics of the arc proper would remain unchanged and attempted to use the matching region before the arc to prepare the beam for the goniometer. I was unable to find a solution under these conditions which did not have too large a beam in the arc. Even with a cm σ_x allowed in the arc, half the beam pipe diameter, the beam size at the collimator was too large for adequate polarization. Beam preparation and steering is thus needed after the arc under the assumption that its optics remains unchanged. The following two figures show the best solution I was able to arrive at. The collimator is 20m after the radiator. $\sigma_x = \sigma_y = 0.18$ mm. Collimator ID of 0.9mm would be required to maintain polarization. Maintaining electron beam angle and position on the radiator to keep the coherent bremsstrahlung properly located through the collimator would be very difficult. I concluded that putting GlueX in hall A was not desirable.

Recommendation: Ask someone more skilled in optics to examine whether GlueX can be accomodated in hall A if the arc optic is redesigned.

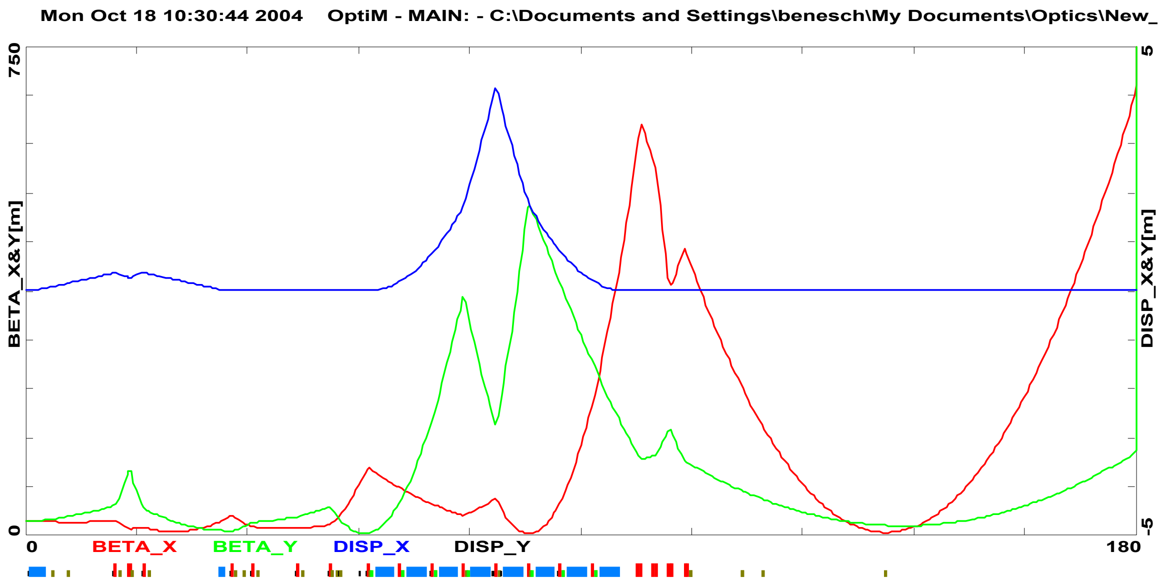

Figure 10. Beta functions and dispersion for GlueX in hall A at 12 GeV. Collimator is at minimum in horizontal beta function (red). Right axis (-5,5)m is for the blue dispersion curve.

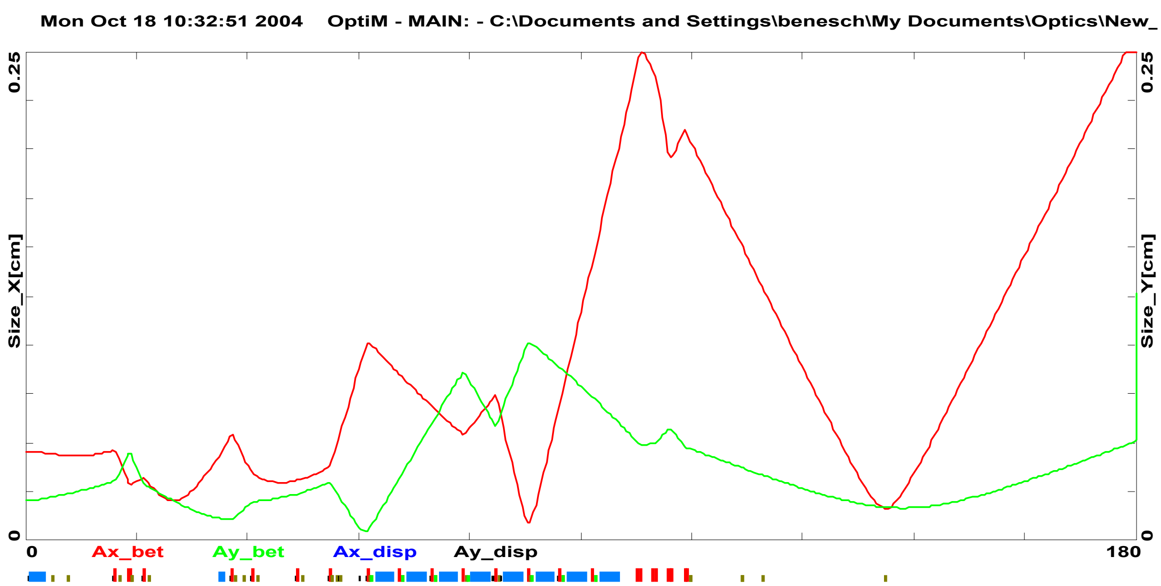

Figure 11. Beam envelopes for optics above. 2.5mm full scale vertical. A new quad type accepting 35 mm ID beam pipe would likely be needed for the last quad in the arc and the final quadruplet.

6. Hall D behind Hall B

As discussed above in section 4 and shown in section 5, it quickly became clear that putting hall D behind hall B was a better location if one must locate GlueX at the west end of the machine. In the figures below, I show what can be done by asking Optim to fit particular Twiss parameters at various locations using the four quads at the end of the line and two immediately before the ramp. The first pair of figures were required to have minimum beta functions 73.85m from the goniometer. This is 50' from the back of the alcove which itself is 20' deep into the back wall of hall B. This is the closest location that the collimator for GlueX might be located and would require removal of a very large mass of un-reinforced concrete at the end of the hall B dump tunnel.

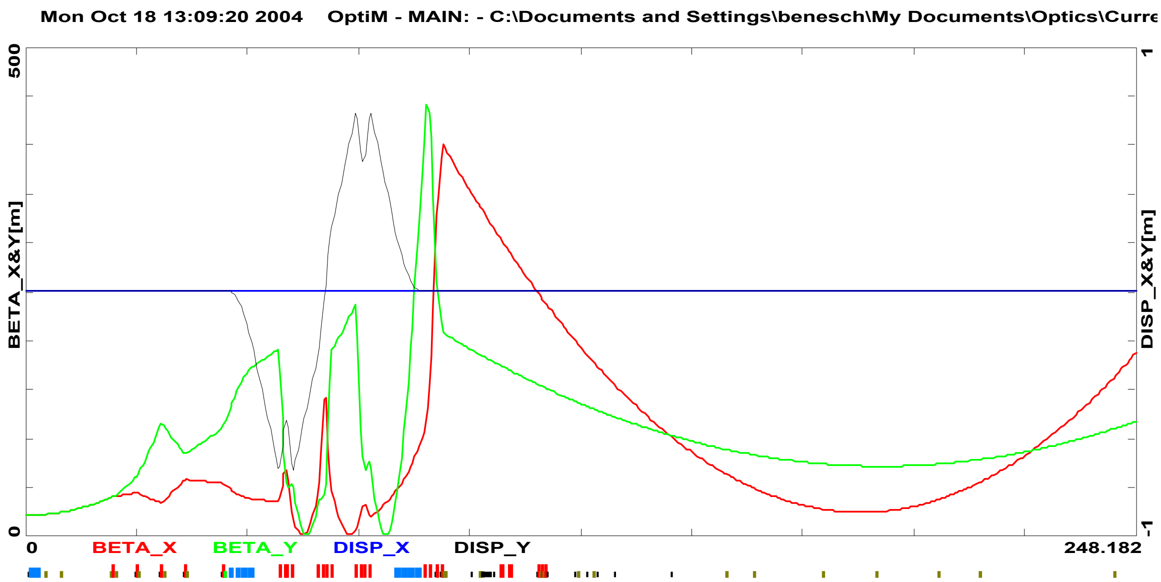

Figure 12. GlueX collimator beginning 70' behind back wall of hall B, 12 GeV

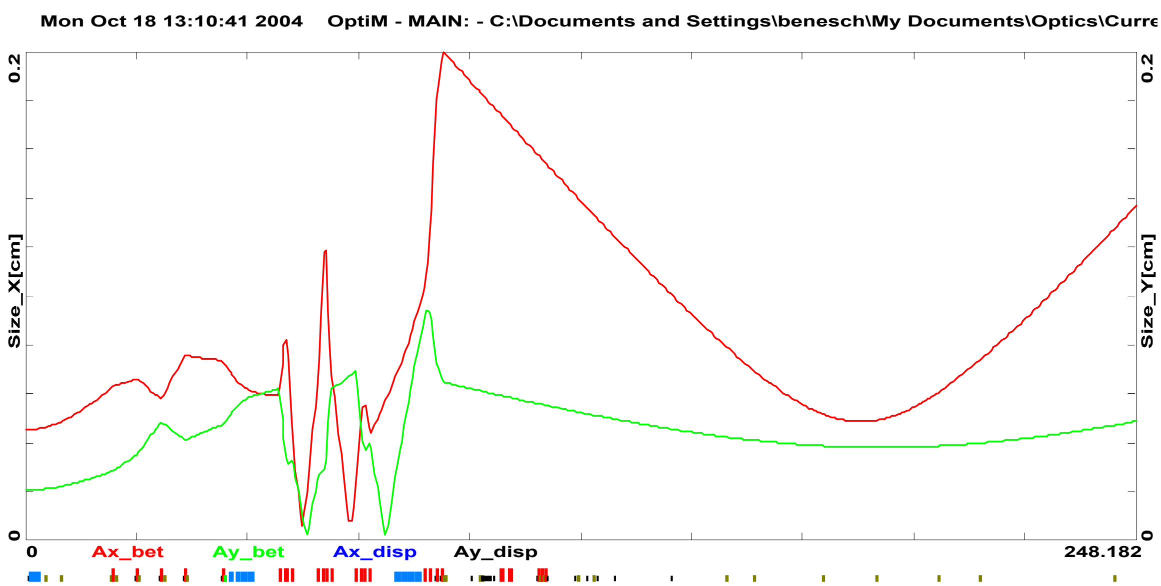

Figure 13. Beam envelopes for optics above, 12 GeV input parameters from PDR, 2mm full vertical scale

The next pair of figures locates the 10m collimator within the large mass of concrete at the end of the hall B dump tunnel, the region with 15' thick concrete walls. Placing the collimator here would increase the distance between the end of the collimator and the beginning of the detector proper from that in the GlueX experiment proposal. It is assumed that the collimated beam is conducted through the 15' of concrete in a beam pipe located in a core-drilled hole with sufficient diameter to handling settling of hall D after construction. The distance from the goniometer to the start of the collimator is 85m in this case.

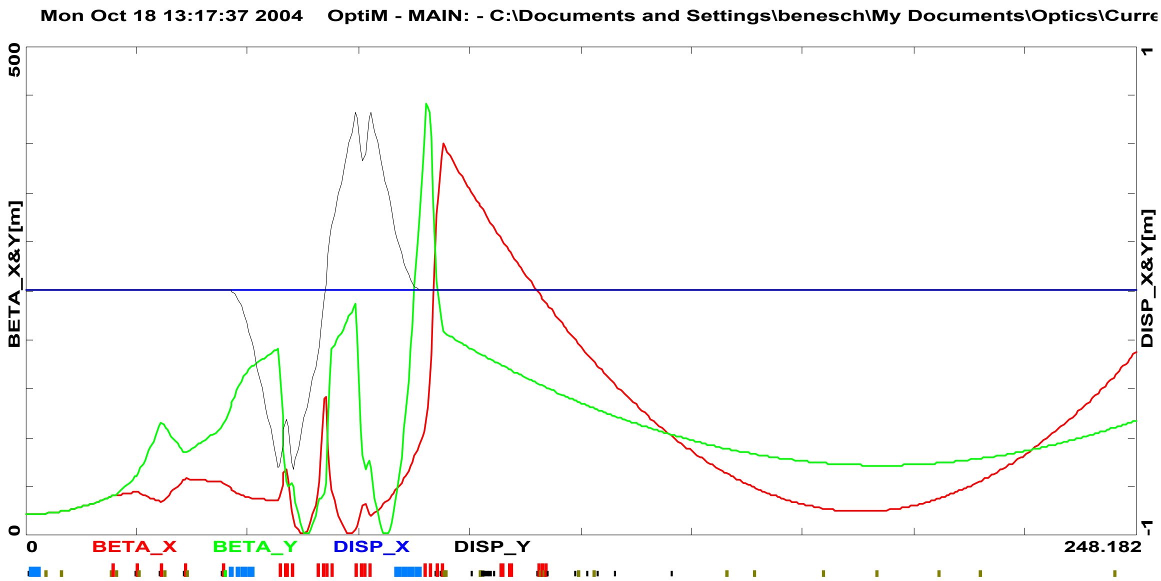

Figure 14. Collimator located at end of hall B dump tunnel.

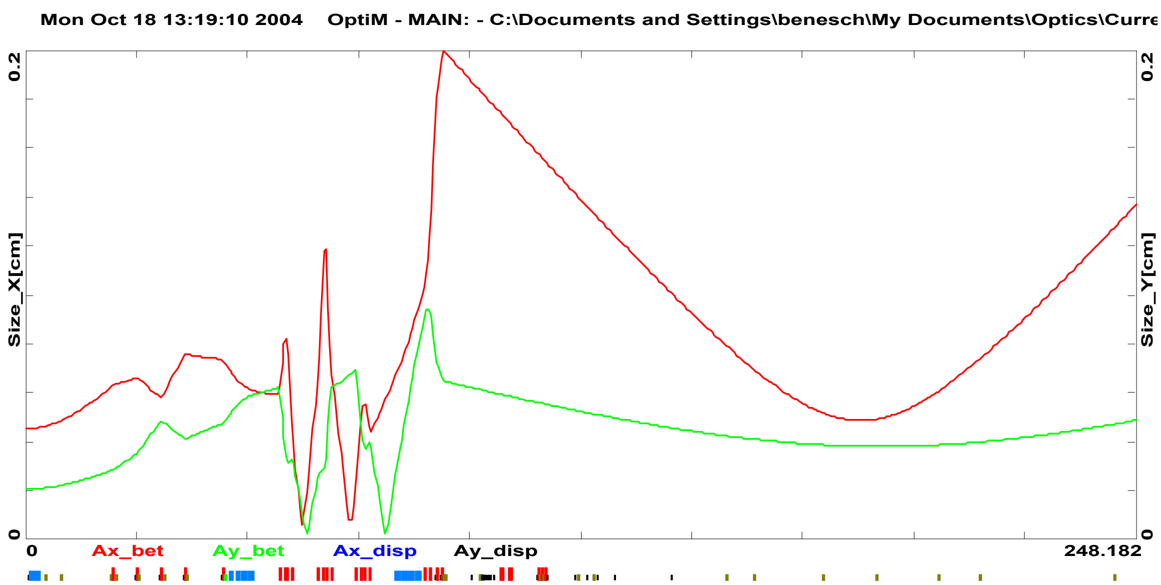

Figure 15. Beam envelopes for optics in figure 14. 12 GeV PDR inputs

The final pair of figures in this section places the collimator start 30’ beyond the end of the 15’ concrete. The 30’ provides the needed construction allowance for the pit in which hall D will be built. Hall D can just be built within the existing service road in this case. Beam height is about 3.5m below grade. If additional shielding is needed for the photon dump or skyshine, it will have to be in the form of a berm on the other side of the service road, between the road and the fence.

The collimator begins 109m from the goniometer in this case. The best minimum I was able to achieve was at the end of the concrete proper, not 30’ from it, as seen in the two figures following. Acceptable polarization is still available. The difficulty of pointing the beam increases linearly, of course.

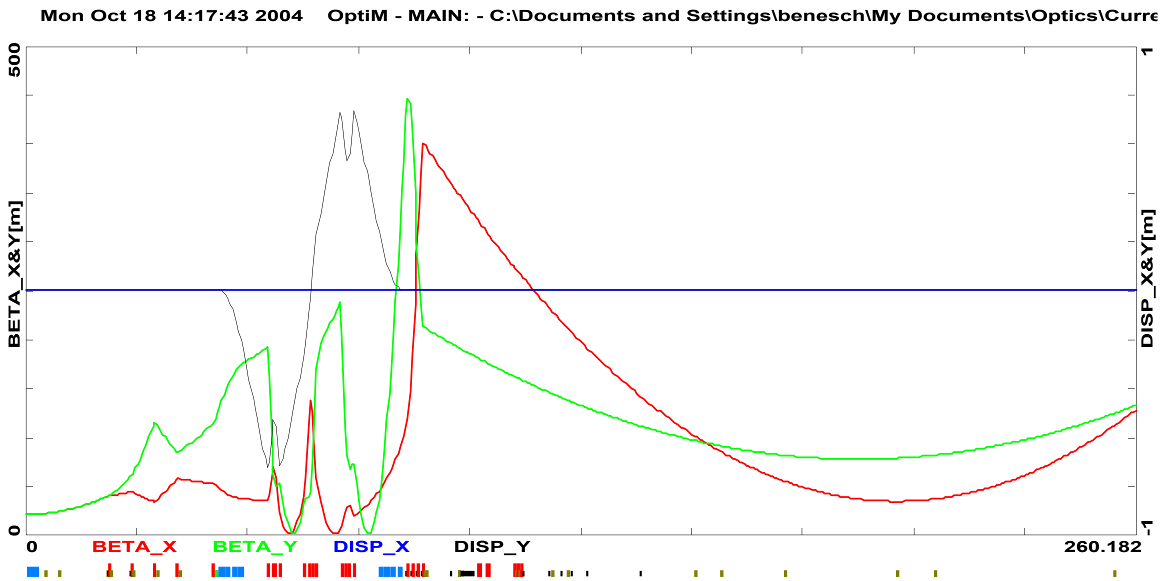

Figure 16. Collimator begins 30’ after end of 15’ concrete surrounding B dump tunnel

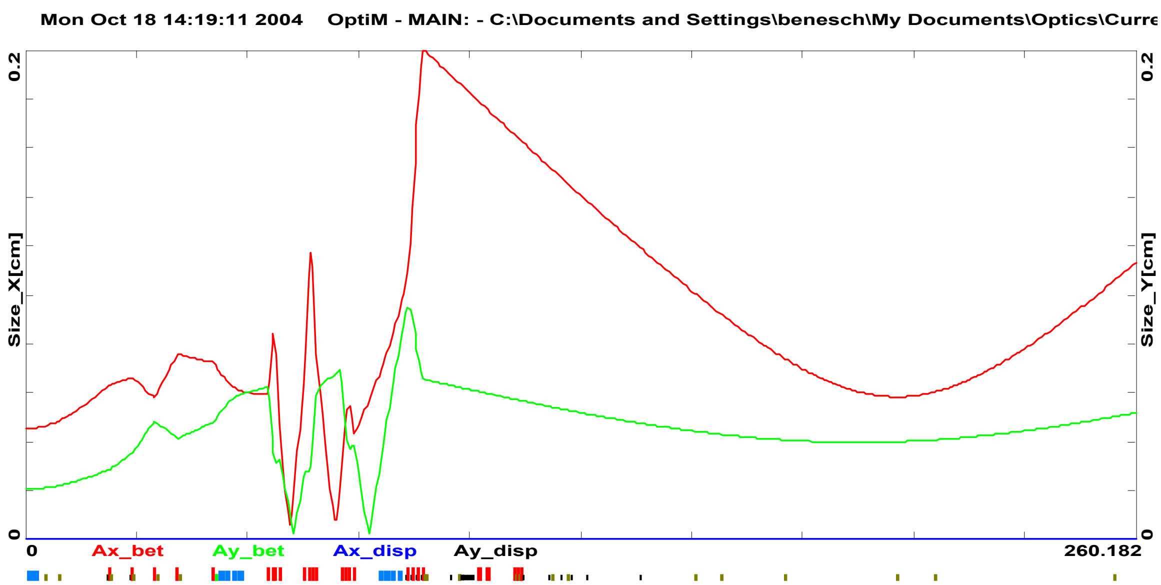

Figure 17. Beam envelopes for optics above

In all cases the virtual beam at the collimator entrance can be made rounder at a cost of moderately increased horizontal dimension and substantial increase in the vertical. Only quad fields need be changed.

This section shows that it is possible to use the alternate optics proposed for hall B to serve GlueX located in a new hall behind hall B. The location shown in figures 14 and 15, with the GlueX collimator in the existing end-vault of the hall B dump tunnel, seems best to me.

7. Disadvantages and advantages of placing hall D behind B

Disadvantages

1. placing hall D behind B has one major disadvantage, reduced utilization of hall B. Assuming nine months of simultaneous operation of three halls per calendar year, the four hall scheme has 6.75 months of operation and 5.25 months of installation per hall each year. In this scheme, hall B has 4.5 months of operation and 1.5 months of installation each year. Hall D has 4.5 months of operation and 7.5 months of installation each year. Halls A and C each gain a third in utilization and B and D lose a third.
2. requires more cryomodules be refurbished under AIP funds to reach 12 GeV after five passes.
3. requires altered magnets in arcs 3, 6 and 9. These might be obtained either by adding 10% length to all these dipoles in situ or by moving arcs 6 and 9 up and buying 32 new 3.5m dipoles for arc 9. Adding length to existing magnets is likely cheaper due to otherwise-required mechanical support changes. Moving the magnets up would lower synchrotron radiation forced emittance growth.

Advantages

1. eliminates arc 10, dogleg 10 and transport line to hall D, eliminating36 4m dipoles and ~55 girders with quads, correctors, BPMs, etc. Dogleg 10 hasn't been designed and it's an issue.
2. simplifies injector modifications immensely because arc 10 doesn't interfere
3. simplifies spreader/recombiner redesign immensely because three (SW, NW, NE) don't need to deal with sixth pass beam.
4. provides 12 GeV to all halls
5. allows three way split at fifth pass energy of 12 GeV
6. requires more cryomodules to be refurbished under AIP, dropping fault rate for 6 and 12 GeV CEBAFs
7. improved hall B tagger system for use by CLAS collaboration
8. utilizes existing instrumentation in hall B line rather than duplicating it
9. eliminates ~100m of new tunnel from North Stub to Hall D
10. eliminates need for new cryo and utility placement in exchange for upgrade of old
11. hall D counting room might be on second floor of existing counting house rather than an entirely new building adjacent to hall
12. eliminates construction traffic past linacs while CEBAF is operating. Microphonic disturbances driven by heavy trucks have been a problem in the past.
13. no significant change in lab appearance from Jefferson Ave. Hall D will simply appear to be an extension of the existing mound behind hall B unless additional shielding is needed in the form of a berm just inside the fence.
14. no need for SURA or NN to transfer land to DOE
15. no holding ponds need be dug
16. construction laydown area exists already as boneyard just inside gate
17. Hall B personnel can assist in hall D work when B is down, decreasing number of new staff
18. *cost savings associated with all the items above except 6, hence TPC reduction.*

8. Recommendations

1. **Change the baseline design for the 12 GeV upgrade to locate hall D behind hall B.**
2. **Add skew quad groups to 7E and 9E to exchange x and y emittances and maintain the beam substantially closer to circular than in the 1999 Point Design.**
3. **Ask someone more skilled in optics to examine whether GlueX can be accomodated in hall A if the arc optic is redesigned.**
4. **Ask someone more skilled in optics to examine whether it is possible to obtain ~1.5m of dispersion in the B ramp with a different optics. The author was unable to get a stable solution with unipolar dispersion. If such a solution is available, energy resolution would double from that given in section 4.**

9. Summary

An alternate optic for hall B has been presented which allows for 11 or 12 GeV operation of hall B with energy monitoring and allows GlueX to be located behind hall B at a substantial savings in total project cost. Another change in the 1999 accelerator point design is discussed and a recommendation made. This will result in absolute cost savings.

Appendix 1 – Lattice for hall B optics shown in figures 14 and 15. Other figures were generated by changing values in six quads.

N	Name	S[cm]	L[cm]	B[kG]	G[kG/cm]	S[kG/cm/cm]	Tilt[deg]	Tilt_out
1	oD4000	44.539	44.539					
2	iITV2C00	44.539	0					
3	oD4001	79.989	35.45					
4	bMLA2C02	309.989	230	0	0	0	0	0
5	oD4002	461.709	151.72					
6	kMBD2C00V	461.709	1e-06	0	0	0	90	
7	oD4003	779.386	317.677					
8	kMBD2C00H	779.386	1e-06	0	0	0	0	
9	oD4004	1914.81	1135.42					
10	kMBC2C01H	1914.81	1e-06	0	0	0	0	
11	oD4005	1934.12	19.315					
12	iIPM2C01	1934.12	0					
13	oD4006	1956.59	22.465					
14	qMQA2C01	1986.59	30	0	0.235406	0	0	
15	oD4005	2005.9	19.315					
16	kMBC2C01V	2005.9	0	0	0	0	90	
17	oD4007	2464.12	458.22					
18	iIPM2C02	2464.12	0					
19	oD4006	2486.59	22.465					
20	qMQA2C02	2516.59	30	0	0.477046	0	0	
21	oD4005	2535.9	19.315					
22	kMBC2C02H	2535.9	1e-06	0	0	0	0	
23	oD4007	2994.12	458.22					
24	iIPM2C03	2994.12	0					
25	oD4006	3016.59	22.465					
26	qMQA2C03	3046.59	30	0	-1.1	0	0	
27	oD4008	3085.51	38.924					
28	kMBC2C03V	3085.51	1e-06	0	0	0	90	
29	oD4009	3524.12	438.611					
30	iIPM2C04	3524.12	0					
31	oD4006	3546.59	22.465					
32	qMQA2C04	3576.59	30	0	0.683748	0	0	
33	oD4005	3595.9	19.315					
34	kMBC2C04H	3595.9	1e-06	0	0	0	0	
35	oD4010	4378.66	782.76					
36	iIPM2C05	4378.66	0					
37	oD4011	4398.59	19.925					
38	qMQA2C05	4428.59	30	0	0.49056	0	0	
39	oD4005	4447.9	19.315					
40	kMBC2C05V	4447.9	1e-06	0	0	0	90	
41	oD4012	4463.08	15.182					
42	SMSA2C05	4478.08	15	0	0	-0.0248177	0	
43	oD4013	4554.59	76.503					
44	gMBE2C01	4554.59	0	8.98568	Angle[deg]=0.853071	Eff.Length[cm]=0		

Tilt[deg]=-90
45 bMBE2C01 4654.59 100 8.98568 0.0364757 0 -90 -90
46 GMBE2C01 4654.59 0 8.98568 Angle[deg]=0.853071
Eff.Length[cm]=0 Tilt[deg]=-90
47 oD4201 4704.59 50
48 gMBE2C03 4704.59 0 8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0
Tilt[deg]=-90
49 bMBE2C03 4804.59 100 8.98568 0.0364757 0 -90 -90
50 GMBE2C03 4804.59 0 8.98568 Angle[deg]=0.853071
Eff.Length[cm]=0 Tilt[deg]=-90
51 oD4201 4854.59 50
52 gMBE2C05 4854.59 0 8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0
Tilt[deg]=-90
53 bMBE2C05 4954.59 100 8.98568 0.0364757 0 -90 -90
54 GMBE2C05 4954.59 0 8.98568 Angle[deg]=0.853071
Eff.Length[cm]=0 Tilt[deg]=-90
55 oD4201 5004.59 50
56 gMBE2C07 5004.59 0 8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0
Tilt[deg]=-90
57 bMBE2C07 5104.59 100 8.98568 0.0364757 0 -90 -90
58 GMBE2C07 5104.59 0 8.98568 Angle[deg]=0.853071
Eff.Length[cm]=0 Tilt[deg]=-90
59 oD4204 5664.09 559.5
60 oD4206 5671.59 7.5
61 qMQA2C31 5701.59 30 0 -5 0 0
62 oD4206 5709.09 7.5
63 oD4203 5779.09 70
64 oD4206 5786.59 7.5
65 qMQA2C32 5816.59 30 0 4.668 0 0
66 oD4206 5824.09 7.5
67 oD4205 5839.09 15
68 oD4206 5846.59 7.5
69 qMQA2C32A 5876.59 30 0 4.668 0 0
70 oD4206 5884.09 7.5
71 oD4203 5954.09 70
72 oD4206 5961.59 7.5
73 qMQA2C33 5991.59 30 0 -5 0 0
74 oD4206 5999.09 7.5
75 oD4202 6526.09 527
76 oD4206 6533.59 7.5
77 qMQA2C34 6563.59 30 0 -5 0 0
78 oD4206 6571.09 7.5
79 oD4203 6641.09 70
80 oD4206 6648.59 7.5
81 qMQA2C35 6678.59 30 0 5 0 0
82 oD4206 6686.09 7.5
83 oD4205 6701.09 15
84 oD4206 6708.59 7.5

85 qMQA2C35A 6738.59 30 0 5 0 0
86 oD4206 6746.09 7.5
87 oD4203 6816.09 70
88 oD4206 6823.59 7.5
89 qMQA2C36 6853.59 30 0 -5 0 0
90 oD4206 6861.09 7.5
91 oD4202 7388.09 527
92 oD4206 7395.59 7.5
93 qMQA2C37 7425.59 30 0 -5 0 0
94 oD4206 7433.09 7.5
95 oD4203 7503.09 70
96 oD4206 7510.59 7.5
97 qMQA2C38 7540.59 30 0 4.65342 0 0
98 oD4206 7548.09 7.5
99 oD4205 7563.09 15
100 oD4206 7570.59 7.5
101 qMQA2C38A 7600.59 30 0 4.65342 0 0
102 oD4206 7608.09 7.5
103 oD4203 7678.09 70
104 oD4206 7685.59 7.5
105 qMQA2C39 7715.59 30 0 -5.0049 0 0
106 oD4206 7723.09 7.5
107 oD4204 8282.59 559.5
108 gMBE2C09 8282.59 0 -8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0 Tilt[deg]=-90
109 bMBE2C09 8382.59 100 -8.98568 0.0364757 0 -90 -90
110 GMBE2C09 8382.59 0 -8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0 Tilt[deg]=-90
111 oD4201 8432.59 50
112 gMBE2C11 8432.59 0 -8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0 Tilt[deg]=-90
113 bMBE2C11 8532.59 100 -8.98568 0.0364757 0 -90 -90
114 GMBE2C11 8532.59 0 -8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0 Tilt[deg]=-90
115 oD4201 8582.59 50
116 gMBE2C13 8582.59 0 -8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0 Tilt[deg]=-90
117 bMBE2C13 8682.59 100 -8.98568 0.0364757 0 -90 -90
118 GMBE2C13 8682.59 0 -8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0 Tilt[deg]=-90
119 oD4201 8732.59 50
120 gMBE2C15 8732.59 0 -8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0 Tilt[deg]=-90
121 bMBE2C15 8832.59 100 -8.98568 0.0364757 0 -90 -90
122 GMBE2C15 8832.59 0 -8.98568 Angle[deg]=0.853071 Eff.Length[cm]=0 Tilt[deg]=-90
123 oD4208 8903.09 70.5
124 iIPMgen 8903.09 0

125	**oD4209**	**8925.59**	**22.5**				
126	**oD4206**	**8933.09**	**7.5**				
127	**qMQA2C40**	**8963.09**	**30**	**0**	**-1.47119**	**0**	**0**
128	**oD4206**	**8970.59**	**7.5**				
129	**oDcorr**	**8989.89**	**19.3**				
130	**oDcorr**	**9009.19**	**19.3**				
131	**oD4210**	**9025.59**	**16.4**				
132	**iIPMgen**	**9025.59**	**0**				
133	**oD4209**	**9048.09**	**22.5**				
134	**oD4206**	**9055.59**	**7.5**				
135	**qMQA2C41**	**9085.59**	**30**	**0**	**-2.18659**	**0**	**0**
136	**oD4206**	**9093.09**	**7.5**				
137	**oDcorr**	**9112.39**	**19.3**				
138	**oDcorr**	**9131.69**	**19.3**				
139	**oD4210**	**9148.09**	**16.4**				
140	**iIPMgen**	**9148.09**	**0**				
141	**oD4209**	**9170.59**	**22.5**				
142	**oD4206**	**9178.09**	**7.5**				
143	**qMQA2C42**	**9208.09**	**30**	**0**	**1.65849**	**0**	**0**
144	**oD4206**	**9215.59**	**7.5**				
145	**oDcorr**	**9234.89**	**19.3**				
146	**oDcorr**	**9254.19**	**19.3**				
147	**oD4210**	**9270.59**	**16.4**				
148	**iIPMgen**	**9270.59**	**0**				
149	**oD4209**	**9293.09**	**22.5**				
150	**oD4206**	**9300.59**	**7.5**				
151	**qMQA2C43**	**9330.59**	**30**	**0**	**1.35164**	**0**	**0**
152	**oD4206**	**9338.09**	**7.5**				
153	**oDcorr**	**9357.39**	**19.3**				
154	**kMBD2C43H**	**9357.39**	**1e-06**	**0**	**0**	**0**	**0**
155	**oDcorr**	**9376.69**	**19.3**				
156	**kMBD2C43V**	**9376.69**	**1e-06**	**0**	**0**	**0**	**90**
157	**oD4210**	**9393.09**	**16.4**				
158	**oD4016**	**9976.59**	**583.501**				
159	**iIPM2C21**	**9976.59**	**0**				
160	**oD4017**	**9999.02**	**22.434**				
161	**oD4211**	**10139**	**140**				
162	**oDcorr**	**10158.3**	**19.3**				
163	**kMBD2C43AH**	**10158.3**	**1e-06**	**0**	**0**	**0**	**0**
164	**oDcorr**	**10177.6**	**19.3**				
165	**kMBD2C43AV**	**10177.6**	**1e-06**	**0**	**0**	**0**	**90**
166	**oD4212**	**10187.6**	**10**				
167	**iTV_BV**	**10217.6**	**30**				
168	**oD4108**	**10226.6**	**9**				
169	**iDharp**	**10241.6**	**15**				
170	**iIHA2C21**	**10241.6**	**0**				
171	**iDharp**	**10256.6**	**15**				
172	**oD4021**	**10268.1**	**11.5**				

173	**iIPM2C21A**	**10358.1**	**90**				
174	**igon**	**10428.1**	**70**				
175	**oD4105**	**10458.1**	**30**				
176	**iMollTarg**	**10508.1**	**50**				
177	**oD4106**	**10598.1**	**90**				
178	**qMQE2M01**	**10698.1**	**100**	**0**	**0**	**0**	**0**
179	**oD4023**	**10798.1**	**100**				
180	**qMQE2M02**	**10898.1**	**100**	**0**	**0**	**0**	**0**
181	**oD4024**	**11436.2**	**538.05**				
182	**iIPM2C22**	**11436.2**	**0**				
183	**oD4025**	**11456.2**	**20**				
184	**qMQA2C22**	**11486.2**	**30**	**0**	**0**	**0**	**0**
185	**oD4018**	**11505.2**	**19**				
186	**kMBC2C22H**	**11505.2**	**1e-06**	**0**	**0**	**0**	**0**
187	**oD4026**	**11530.3**	**25.148**				
188	**qMQA2C23**	**11560.3**	**30**	**0**	**0**	**0**	**0**
189	**oD4027**	**11574.3**	**14**				
190	**kMBC2C23V**	**11584.3**	**10**	**0**	**0**	**0**	**90**
191	**oD4028**	**11617.1**	**32.818**				
192	**qMQA2C24**	**11647.1**	**30**	**0**	**0**	**0**	**0**
193	**oD4029**	**11668.1**	**21**				
194	**iIPM2C24A**	**11668.1**	**0**				
195	**oD4030**	**12268.1**	**600**				
196	**iIHA2C24**	**12268.1**	**0**				
197	**oD4031**	**12357.3**	**89.169**				
198	**kaTAGGER**	**12357.3**	**0**	**0**	**0**	**0**	**0**
199	**oD4101**	**12553.5**	**196.2**				
200	**iColA**	**12593.5**	**40**				
201	**oD4111**	**12692.5**	**99**				
202	**kfrontwall**	**12692.5**	**1e-06**	**0**	**0**	**0**	**0**
203	**oD4112**	**12784.1**	**91.6**				
204	**iPH2H00**	**12784.1**	**0**				
205	**oD4103**	**13168.1**	**384**				
206	**iColB**	**13208.1**	**40**				
207	**oD4104**	**14417.1**	**1209**				
208	**ITARGET**	**14417.1**	**0**				
209	**oD4034**	**15679.2**	**1262.1**				
210	**kbackwall**	**15679.2**	**1e-06**	**0**	**0**	**0**	**0**
211	**oD4035**	**16289.2**	**610**				
212	**kalcoveend**	**16289.2**	**1e-06**	**0**	**0**	**0**	**0**
213	**oD4036**	**17813.2**	**1524**				
214	**kcollim50f**	**17813.2**	**1e-06**	**0**	**0**	**0**	**0**
215	**oD4043**	**19032.2**	**1219**				
216	**kcollim40f**	**19032.2**	**1e-06**	**0**	**0**	**0**	**0**
217	**oD4044**	**20404.2**	**1372**				
218	**kcollim45f**	**20404.2**	**1e-06**	**0**	**0**	**0**	**0**
219	**oD4040**	**21318.2**	**914**				
220	**kcollim30f**	**21318.2**	**1e-06**	**0**	**0**	**0**	**0**

221	**oD4042**	**24318.2**	**3000**				
222	**kbackwall**	**24318.2**	**1e-06**	**0**	**0**	**0**	**0**
223	**oD4039**	**24818.2**	**500**				