GlueX Requirements for 12 GeV Electron Beam Properties

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Draft 1

Abstract

The electron beam requirements for the GlueX experiment were first published in the GlueX Design Report. The latest version of the design report that was released in November 2002 presents the same list of requirements that were shown at the GlueX Detector Review in October 2004 and at the Lehman Review in July 2005. Considering the time that has passed since these requirements were set and the progress that is now being made in optimizing the design of CEBAF for 12 GeV operation, the GlueX collaboration has been asked to conduct a careful review of its requirements. The purpose of this note is to examine key requirements in a quantitative way and show how the requirements are connected to the ability of the GlueX experiment to reach its ultimate physics goals.

1 Metrics

Making the connection between beam properties and experimental results quantitative requires finding an appropriate set of metrics. ~~The purpose of this section is to explain what~~ metrics ~~have been used to set the beam~~ requirements for GlueX ~~and to argue that the chosen set is both necessary and sufficient~~.

The GlueX experiment requires a photon beam of approximately 9 GeV. The photon beam is generated from an electron beam by the process of coherent bremsstrahlung in a thin diamond crystal. Thus the requirements for GlueX apply most directly to the photon beam and only indirectly to the electron beam, inasmuch as the electron properties determine those of the photons. Of course, photons of 9 GeV require electrons of at least 9 GeV, but photon energy is not the consideration that drives the choice of electron energy. The two properties of the photon beam that drive the electron beam requirements are photon beam polarization and tagged photon intensity. Associated with these two properties are the two metrics that will be the focus of this note, the *polarization figure of merit* and the *tagging efficiency*. ~~The remainder of this section is devoted to explaining the meaning of these two metrics, how they are computed based on electron beam parameters, and the quantitative connections between them and GlueX physics results.~~

The polarization figure of merit is the product of the intensity of the tagged photon beam at the entrance to the GlueX target multiplied by the square of its linear polarization. This well-known metric for polarized beam experiments scales with the inverse of the run time required for an experiment to achieve a given level of statistical precision on a polarization observable. ~~Higher values are better because they indicate that a measurement of a given precision can be achieved with a shorter run~~. The polarization of interest in this context is the linear polarization of the photon beam, which is not dependent on electron beam being polarized. ~~Rather it is produced~~ when the electron scatters from the oriented planes of atoms in the diamond crystal~~, and is connected with the ĕnergy of the electron beam at the radiator.~~ This polarization is significantly enhanced by strictly collimating the bremsstrahlung photons downstream of the radiator, and the ability to effectively collimate is dependent on the low ĕmittance of the electron beam at the diamond radiator.

The photon beam produced through the bremsstrahlung process contains photons of all energies up to the energy of the electron beam. The GlueX experiment can tolerate the presence of all of these photons in the beam, provided that it has some means of distinguishing from ~~the others~~ those ~~that are polarized and have the correct energy to produce the reactions of interest.~~ GlueX plans to do this using the tagging technique in which a coincidence is formed between the products of ~~photoreactions~~ in the GlueX detector and an electron in the tagging spectrometer. An electron which enters the diamond radiator with 12 GeV and radiates a 9 GeV photon as it passes through the crystal exits with only 3 GeV. Instead of being deflected with the 12 GeV electron beam into the dump it is bent into an array of detectors called tagging counters. A hit in the tagging counter at 3 GeV amounts to a a prediction that a 9 GeV photon is on its way toward the GlueX target. Of course, not all 9 GeV photons that exit the radiator actually arrive at the target. The tagging efficiency is defined as the ratio of the number of photons of the energy of interest that reach the experimental target ~~divided by~~ the number of electrons ~~seen~~ in the corresponding tagging counter.

Tagging efficiency is a critical parameter for the GlueX experiment~~s~~ because the tagging counters must operate at a very high aggregate rate in order not to limit the rate capabilities of the GlueX detector and trigger. At such high rates there is a significant number of accidental tags in which a false association between a beam photon event and a tagger electron hit ~~is formed because they accidentally~~ occur in the same beam bucket. The rate of experimental triggers scales linearly with photon beam intensity, whereas the accidentals rate scales with the product of the photon beam intensity and the rate of electrons in the tagger, or in other words the photon beam intensity squared divided by the tagging efficiency. An upper bound on the operating beam intensity that is compatible with tagging is obtained by requiring that the rate of accidental tags be some small fraction of the total tagged event rate. For example, the maximum rate of 10^8 tagged photons on target per second at which GlueX is designed to run was obtained by limiting the accidental tagging fraction to ~~one third~~ under nominal beam conditions.

The accidental tagging fraction itself is not suitable as a beam performance metric because its value is a choice, not a given, and the choice of an appropriate value depends on a balance of event rate and background considerations which depend in turn on the physics emphasis during a given run period. What one would like to do is to fix the tagged photon event rate and then obtain as low an accidental fraction as possible. This the equivalent to maximizing the tagging efficiency.

Both of these two metrics have a similar straight-forward interpretation as the rate at which the experiment is making progress towards its scientific goals. In general it is best to treat them separately because each is sensitive to different combinations of electron beam parameters and they affect the experimental results in different ways. However the two metrics are coupled in that the polarization figure of merit is proportional to the tagged beam intensity, and the tagging efficiency is one of the factors that determines the upper bound on usable beam intensity. In cases where variations in a single beam parameter significantly degrade both the tagging efficiency and the polarization, the metrics are combined by taking the tagging efficiency to limit the rate that goes into the polarization figure of merit. In cases where the two metrics are considered individually, care is taken to avoid double-counting by using a criterion other than tagging efficiency to define the rate that goes into the polarization figure of merit.

2 Electron Beam Parameters

Two different categories of electron beam properties were considered in this study, intrinsic and extrinsic. Intrinsic properties like beam energy and emittance are determined by the accelerator, while extrinsic properties like beam dispersion and transverse size are dependent on the intrinsic properties and the optics of the beam delivery system. GlueX photon beam properties depend on both. The focus of this note is on the intrinsic properties ~~because they are the most difficult and expensive to change, and eventually are subject to fundamental limits. How resources are spent in trying to approach these limits must be motivated by their connections to the physics goals of the experiments that will make use of the 12 GeV beam.~~ In the following sections five intrinsic beam properties of relevance to GlueX are examined and their implications for the experiment quantified in terms of the metrics described above. A discussion of extrinsic properties follows, showing how the results for intrinsic properties can be used to derive the sensitivity to optics parameters.

2.1 electron energy

Electron beam energy is ~~the most~~ important beam property for achieving the physics goals of GlueX. The tagging efficiency for 9 GeV photons is essentially independent of electron beam energy, but the polarized beam intensity and polarization are strongly affected. Beam intensity is controlled by electron beam current, so the reader may wonder how this is coupled to the beam energy. The reason for this is tied to the presence of all of the low-energy photons that are present in the photon beam together with the tagged photons are 9 GeV. At the low-energy end of the photon beam spectrum the spectral intensity scales like $1/k$ where k is the photon energy, so in terms of photon count the beam is dominated by low-energy photons. These low-energy photons undergo both electromagnetic and hadronic interactions in the target which are the primary source of background in the detector. The GlueX detector and trigger are designed to operate in the presence of these backgrounds and ignore them, but there ~~is~~ are limits on how high a rate ~~of these~~ is acceptable.

Independent of what those exact limits will be, it is possible to compute a relative figure of merit as a function of electron beam energy. The results are shown by the upper curve in Fig. 1. This curve was generated by computing the square of the average polarization in the GlueX collimated photon beam multiplied by the flux of tagged photons between 8.4 and 9 GeV divided by the total hadronic interaction rate in the target. The curve is a smooth interpolation between points at several discrete energies over the range 9 - 13 GeV. Normalizing to the total electromagnetic rate instead of the hadronic rate would produce essentially the same result. The lower curve in the figure corresponds to the photon beam without any collimator in place. It is included to show ~~how~~ the improvement in the beam polarization figure of merit in going from a 9 GeV ~~electron beam~~ to 12 GeV is almost entirely achieved through collimation. This fact is relevant in considering the role played by electron beam emittance, to be discussed next.

2.2 transverse emittance

The definition taken here for the transverse emittance of the electron beam is the product of the half-axes of the 1-sigma beam ellipse in transverse coordinates, (x, α_x) for the horizontal and (y, α_y) for the vertical, in a coordinate system where the z axis defines the nominal beam direction. The emittance ~~values used to compute metrics are those that would be measured~~ just upstream of the GlueX crystal radiator.

Having a small-emittance electron beam is what makes it possible to use strict collimation to significantly enhance the photon beam 9 GeV flux and polarization. Both the tagging efficiency and the polarization figure of merit are sensitive to emittance. The tagging efficiency is plotted versus horizontal beam emittance in Fig. 2. The polarization figure of merit is shown in Fig. 3, under different assumptions for the way operating beam current is adjusted to compensated for variations in the emittance. Because increasing the emittance increases the photon spot size on the collimator, the photon intensity at the GlueX target tends to decrease with increasing emittance for fixed electron beam current. This decrease can be compensated by increasing the electron beam current up to a point, depending on what experimental conditions are used to determine the optimum operating current. If the rate-limiting factor is background rate in the detector and trigger then it makes sense to recompute the beam current at each value of the emittance so as to keep the background rate constant in the detector, similar to the way Fig. 1 was produced. This result is shown by the dashed curve in Fig. 3. Under these conditions, the tagging efficiency and polarization figure of merit effects and independent and separate. When the two effects are combined, the result is that shown by the solid curve in Fig. 3. The procedure for how the two metrics are combined is presented next.

In the discussion above it was pointed out that background rates are a key consideration that places an upper bound on the photon beam intensity that is acceptable to GlueX. A second consideration that must be taking into account in setting the operating intensity is the tagging accidentals rate, which depends upon the tagging efficiency. It is the more restrictive condition which takes precedence over the other. If one takes a fixed accidentals rate to set the beam current instead of background rates then the intensity factor that appears in the definition of the polarization figure of merit must decrease with increasing emittance instead of increasing. Quantitatively, this intensity scaling factor is just the tagging efficiency shown in Fig. 2. Hence the solid curve in Fig. 3 is simply the product of the tagging efficiency with the polarization figure of merit at constant electron beam current.

2.3 energy spread

The energy spread of the electron beam determines the ultimate energy resolution on the photon beam that is possible to achieve with the tagger. Knowing the energy of the photon that caused an event provides an important constraint that GlueX needs in order to optimize its momentum and mass resolution in reconstructing exclusive final states. The energy resolution determines to what degree it will be possible to eliminate reconstructed events with missing particles in the final state, and to reconstruct final states with neutrons or other neutral particles that are not seen in the detector by exploiting energy and momentum conservation from the initial state.

The following general argument can be made to estimate the required photon beam energy resolution for GlueX. The way that initial state energy is applied to final state reconstruction is through momentum conservation, requiring the sum of the momenta of all final state particles, seen and unseen, to equal the momentum of the initial state. The momentum of at least one final-state particle must be measured in the detector and, even in cases where missing particles are allowed, typically at least 50% of the total energy in the final state comes from particles whose momentum is measured. If one takes a final state with several charged tracks, each with an optimum momentum resolution of 2% in the GlueX tracking detectors, and let their energies sum up to 5 GeV then the uncertainty on the sum of their energies is roughly $100/\sqrt{n}$ MeV, where n is the number of tracks. These energies are compared with the initial state energy when the constraint of momentum conservation is applied, so improving the resolution on the initial-state photon below something of order 50 MeV produces diminishing returns. This argument leads to an upper bound on the energy spread of the electron beam of roughly 50 MeV.

This estimate was checked using reconstructed Monte Carlo events for the reaction $\gamma p \rightarrow K^+K^-\pi^+\pi^-\pi^0 p$ where the final π^0 was missing from the reconstructed event. One way to detect the presence of a missing particle in a reconstructed event is to plot the missing mass, a measure of the mismatch between the total momentum of the initial and final states. The missing-mass resolution of the detector + beam combination provides a useful metric for gauging the relative effect of varying the tagged photon energy resolution on the physics capabilities of GlueX. In Fig. 4 is shown the missing-mass resolution for the above reaction with a missing π^0 as a function of the r.m.s. error on the energy of the initial photon. This simulated reaction contains five reconstructed charged particles and one neutral. Not all charged particles are measured with the optimum 2% precision and not all events in this reaction have 50% missing energy, but at the level of a factor-of-two estimate the above analytic formula agrees with the data. Optimum missing-mass resolution in the GlueX detector can be obtained with an electron beam energy spread of A tagger energy resolution of 0.5% or better.

Clearly the energy spread from CEBAF at 12 GeV will be better than this by about an order of magnitude, as will the resolution of the tagger. The intrinsic resoluton of the tagging spectrometer is on the order of a few MeV, and the full width of individual tagging channels in the tagger microscope array is 8 MeV, with segmentation driven by rate considerations. All of this means that the intrinsic energy resolution of the Hall D photon beam will be much better than what is required for the GlueX physics program, as currently envisioned. It is never a bad thing to exceed physics requirements in a beam parameter, provided that it does not require significant special expenditures to obtain it.

2.4 beam tails

Transverse emittance reflects the r.m.s. widths of the transverse position and angle distributions of electrons in the beam. These distributions follow a Gaussian profile, typically over several orders of magnitude. Beyond some radius, however, the distribution begins to fall more slowly than the Gaussian profile or even becomes relatively flat. These tails (or halo) contain relatively few particles relative to the central core of the beam, but can be important because they can interact with the dense materials surrounding the beam line and target and produce background. In the case of GlueX, the distance of order 100 m from the electron beam to the target (with the photon collimator in between) prevents such off-axis electrons from producing background in the GlueX detector. The same is not true of the tagging counters, however.

Photons produced by halo electrons have essentially zero chance of getting through the photon collimator. The reason for this is that they are produced by bremsstrahlung in materials that are orders of magnitude thicker than the crystal radiator, otherwise their photon yield would be negligible by reason of the low intensity of halo electrons relative to the core of the beam. Electrons passing through such a thick radiator undergo so much multiple scattering that the photon spot that they produce projected out to the distance of the collimator plane is orders of magnitude larger than the collimator aperture. By contrast, the probabilities are somewhat higher that the degraded halo electron might find its way into one of the tagging counters. Beam particles which create hits in the tagging counters but no corresponding photon in the photon beam inflate the tagging efficiency. To make a quantitative estimate of this effect a model is needed for the distribution of materials in the vicinity of the beam axis upstream of the tagger and a spatial and momentum distribution for the halo particles.

A zeroth-order estimate for a safe upper limit for beam halo intensity is obtained as follows. Fit the transverse beam position distribution to a Gaussian function and subtract this distribution from the full beam population. The remaining particles, described as the halo population, are spread out over a relatively large spot compared to the original Gaussian radius. Assume that all of the halo beam particles end up striking some vacuum, support or magnetic element on their way through the tagger and that they all either scatter into a tagging counter themselves or produce secondaries that do. Under these assumptions, one may ask what fraction of the original beam may belong to the halo population without degrading the tagging efficiency by more than 1%. Under these somewhat perverse assumptions, the upper limit on the halo integral is 10^{-6}.

If this halo level were easy to guarantee coming from CEBAF at 12 GeV then our work would be done. However we have been assured that it is not. To make progress in refining this estimate, more information regarding the distribution of materials around the beam and the halo phase space distribution is needed. Experience with CEBAF at 6 GeV has shown that the latter can be difficult to predict and sometimes to control. On the other hand, we can configure the beamline elements to minimize the amount of material in the region upstream of the tagger which may cause the electron beam tails to scrape and produce background in the tagging counters. The following preliminary description of the region surrounding the beam in the region of the radiator has been studied using a GlueX tagger Monte Carlo simulation.

- A square aluminum frame with an inner cutout region of dimensions 1.5×1.5 cm^2, outer dimensions 3×3 cm^2 and thickness 3 mm.
- A stainless steel beam pipe leading through the tagger quadrupole from the radiator housing to the tagger vacuum box of outer diameter 3.8 cm and thickness 3 mm.
- A pressure of 10^{-4} Torr in the tagger vacuum.
- A 3 cm gap between the poles of the tagger dipoles.

In order to estimate the background in the tagging spectrometer, particles were generated uniformly in a disk of radius 2.5 cm at the position of the Hall D radiator. This is a very pessimistic model for what might emerge from a 1.5 inch beam pipe coming from the tunnel, so the results can be taken as a conservative estimate for the expected halo rates in the tagger.

Using this model, 10^6 halo events were tracked through the tagger geometry with magnetic field simulation and full shower generation. Fig. 5 shows the transverse profile at the position of the radiator of all electrons in this sample which produced hits in the tagging counters. Clearly visible are the outlines of the radiator crystal holder and steel beam pipe between the radiator and the tagger.

In this sample a total of 9480 hits were observed leaving energy more than 200 keV in the tagging microscope counters. One million beam particles represents 50 ns of real time under full-intensity running conditions of 10^8 tagged γ/s on the GlueX target. Hence if 10^{-5} of the total electron beam population were in the halo then the halo rate in the tagging counters would be 10k per 5 ms or 2 MHz, which corresponds to a inflation factor of 1% in the tagging efficiency. From this it follows that an upper bound of 10^{-5} on the halo fraction is sufficient to insure that its effect on the tagging efficiency is negligible. The only part of the halo that contributes significantly to the background in the tagging counters is what lies between the radii of 1.0 and 1.5 cm.

In addition to the tagger microscope counters, there is also an second array of tagging counters which covers a much broader range in photon beam energy is more coarsely segmented. This broad-band array is not used for tagging during polarized photon running, but it is extremely important for monitoring the quality and stability of the photon beam. It is also needed to align the crystal at the beginning of each run period. The simulation showed that a 10^{-5} halo creates a hit rate below 1% of the tagged photon rate across most of the counters, with the exception of the very low-energy electron end of the spectrum. The broad-band array extends up to 95% of the bremsstrahlung end-point, which means that it sees electrons of only 600 MeV energy at the extreme end. This end of the array is also the closest to the radiator, which means that the solid angle of these counters relative to sources in the radiator region is the greatest in the same place where the bremsstrahlung spectral intensity is at its minimum. Fig. 6 shows the fraction of the total hits in each of the counters in the broad-band array that would be generated by a halo with a beam fraction of 10^{-5}. Maintaining a 1% upper bound on the halo contribution to the count rate in the tagger at the high-energy photon end of the broad-band array would push the requirement on the total halo fraction down to 10^{-6}.

2.5 electron beam polarization

Up to this point, the beam polarization has referred to the linear polarization of the photon beam that is produced through the coherent bremsstrahlung process and enhanced by collimation. In this section we consider the degree of freedom of electron beam polarization and its implications for GlueX physics. Any non-zero polarization in the electron beam is transferred by the bremsstrahlung process onto the circular polarization of the photon beam. More precisely, it is the projection of the electron polarization onto the electron momentum axis that is transferred to the circular polarization of the radiated photon. This transfer is quite efficient, more than 90% for a 12 GeV electron radiating a 9 GeV photon. Circular polarization is not required for the GlueX physics program but it does have an effect on the results, so if it is present then that fact must be known so that it can be taken into account in the analysis.

The simplest scenario for GlueX is if the electron beam is unpolarized. The beam in the LEP ring was naturally polarized to a high degree by the process of synchrotron radiation, but the relaxation time for that process was on the order of hours, whereas the CEBAF beam spends only microseconds circulating in the machine. On that basis it appears unlikely that the beam can acquire a significant spontaneous polarization during acceleration, so the polarization of the beam delivered to Hall D should be controlled at the source. The GlueX requirement for the precision with which we know the average degree of linear polarization in the photon beam is 1-2% absolute. Knowing that the polarization of the electron beam is zero at a similar level of precision should be sufficient.

It is important to emphasize that it is only the time-averaged electron beam polarization that is of interest to GlueX. A beam with a high degree of electron polarization would be acceptable to GlueX if it were reversed frequently and had a zero time-averaged value over a time scale of several hours.

2.6 optics

In the preceding sections, the metrics of tagging efficiency and polarization figure of merit were shown to be sensitive to the electron beam energy and transverse emittance. The validity of these results relies upon two assumptions, that the beam line optics that were assumed in the design of the GlueX photon beam can actually be achieved, and that no way can be found to produce the same photon beam properties under relaxed electron beam conditions. Examining these assumptions requires a closer look at the optics for Hall D.

In what follows, the beam energy is considered to be fixed at 12 GeV and the beam emittance is a variable that is within an order of magnitude of 10 mm$\cdot\mu$r. The angle between the electron direction and the direction of the radiated photon is random, but its scale is set by the characteristic angle m/E which is about 40 μr. A typical photon trajectory intersects the front surface of the collimator about 3 mm away the linear projection onto the same plane of its electron's trajectory at the point of radiation. The collimator is located 75 m downstream of the radiator. While all photons from a coherent bremsstrahlung source have this characteristic angular spread, the ones near the maximum of the coherent peak (that carry the enhanced polarization) are the ones that land the closest to their associated projected electron impacts. This statement is correct regardless of the emittance of the electron beam. The electrons are dumped far upstream of the collimator, however, so the only way these low-angle photons can be distinguished from the others at the collimator is by their proximity to the center of the photon spot. The center of the spot is only as well defined as the electron beam emittance allows it to be.

The optics that optimizes this angular collimation are those which create a virtual electron beam focus at the collimator position, while keeping the size of the beam at the radiator within the limits of the crystal dimensions. A solution for the Hall D beam line that achieves these goals in the horizontal direction and keeps the virtual spot circular at the position of the collimator has been found and been subjected to one or two optimizing iterations. So far no scheme has been found which is able to exploit a given electron beam emittance to produce a collimated photon beam with significantly higher values for the metrics in Figs. 1-3.

3 Graduated Requirements

The physics goals of GlueX will be achieved over a period of time. Likewise it is foreseen that the ultimate performance of CEBAF at 12 GeV will be achieved in a series of steps. Without attempting to predict what the limiting factors in 12 GeV accelerator operations will be, a graded schedule for achieving certain performance figures for critical beam properties is presented that would insure that GlueX can make optimal progress toward achieving its scientific objectives. Based on the results presented in the previous section, a graduated set of electron beam requirements for GlueX are given in Table 1.

Listed in Table 2 are the operating parameters for the GlueX photon beam, based on our best estimates for the 12 GeV electron beam properties at Hall D. This is a copy of Table 4.3 from the GlueX Design Report and have been presented a number of times over the last two-year period. The values in this table are best estimates and are expected to change over time, as more is learned about the electron beam properties and the design for the upgrade moves forward. They are provided here for reference only, not to be confused with requirements, which are listed in Table 1.

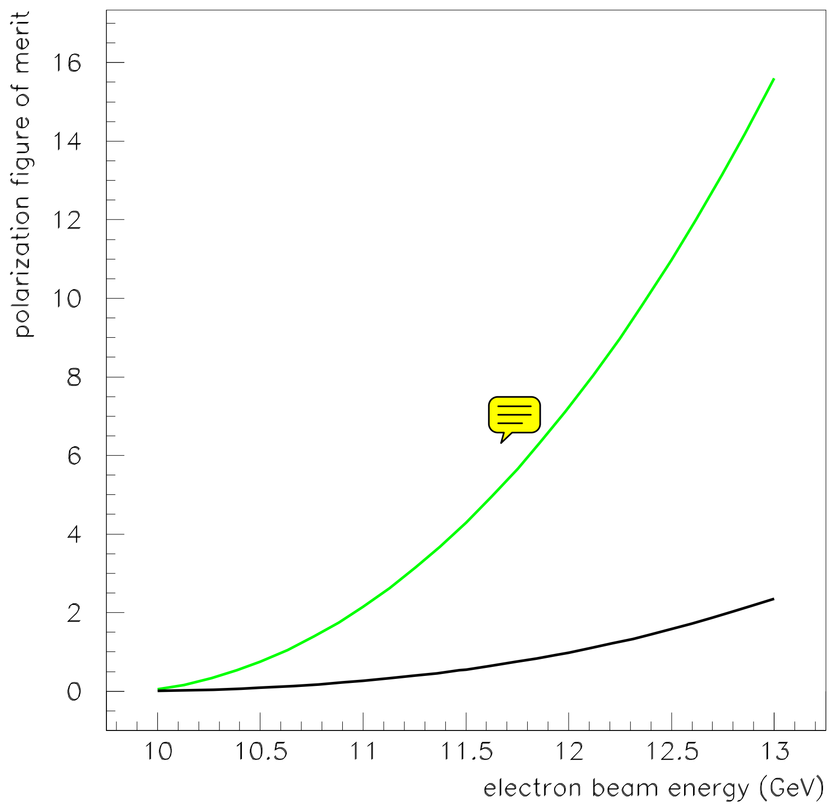

Figure 1: Polarization figure of merit (arb. units) as a function of electron beam energy with (upper curve) and without (lower curve) photon beam collimation. The collimator is the nominal 3.5 mm diameter circular aperture located 75 m downstream from the radiator. An electron beam emittance of 10 mm·μr is assumed.

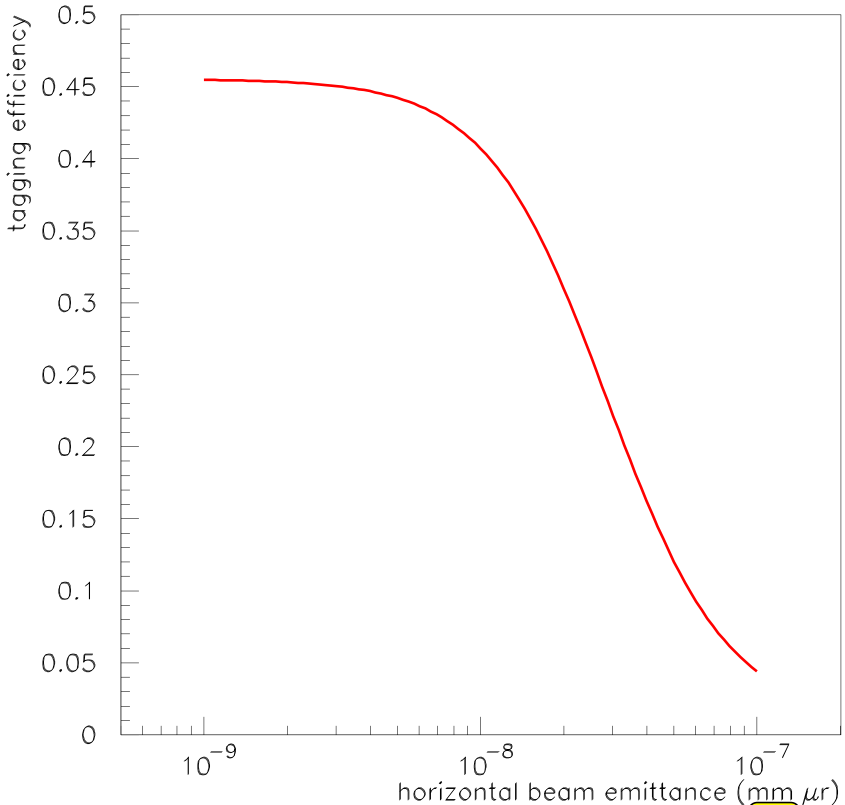

Figure 2: Tagging efficiency as a function of horizontal electron beam emittance under nominal conditions for the Hall D photon beam collimator. The electron beam energy is 12 GeV. The primary coherent photon peak is at 9 GeV, with the tagger set to tag photons between 8.4 and 9 GeV.

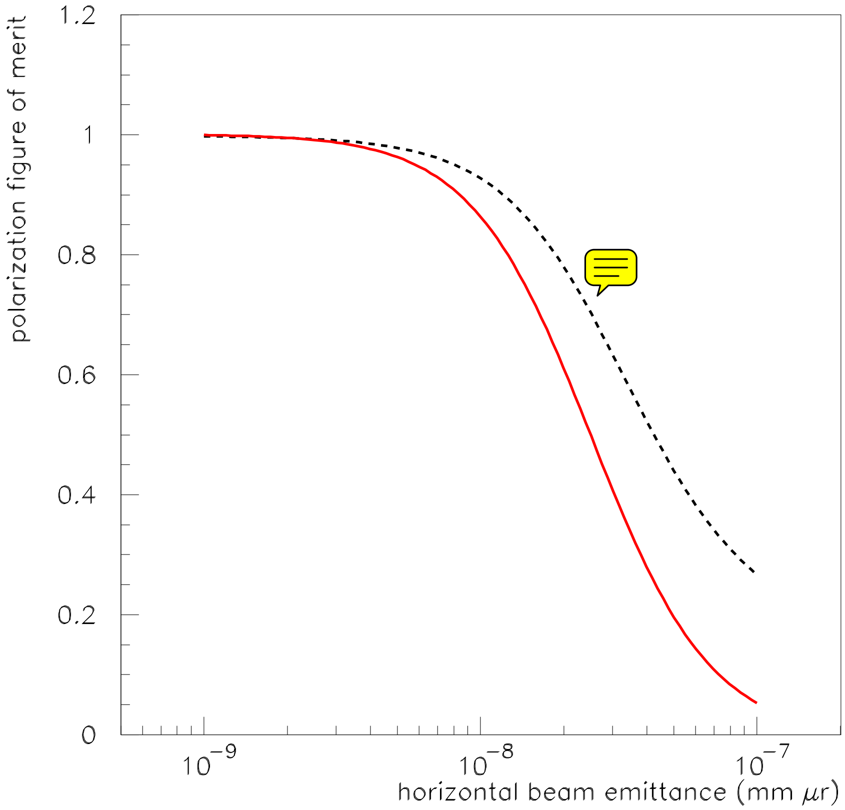

Figure 3: Polarization figure of merit as a function of horizontal electron beam emittance, under nominal conditions for the Hall D photon beam collimator, assuming that the operating current is determined by the background rate (dashed curve) or tagging accidentals rate (solid curve). The electron beam energy is 12 GeV. The primary coherent peak is at 9 GeV, with the tagger set to tag photons between 8.4 and 9 GeV.

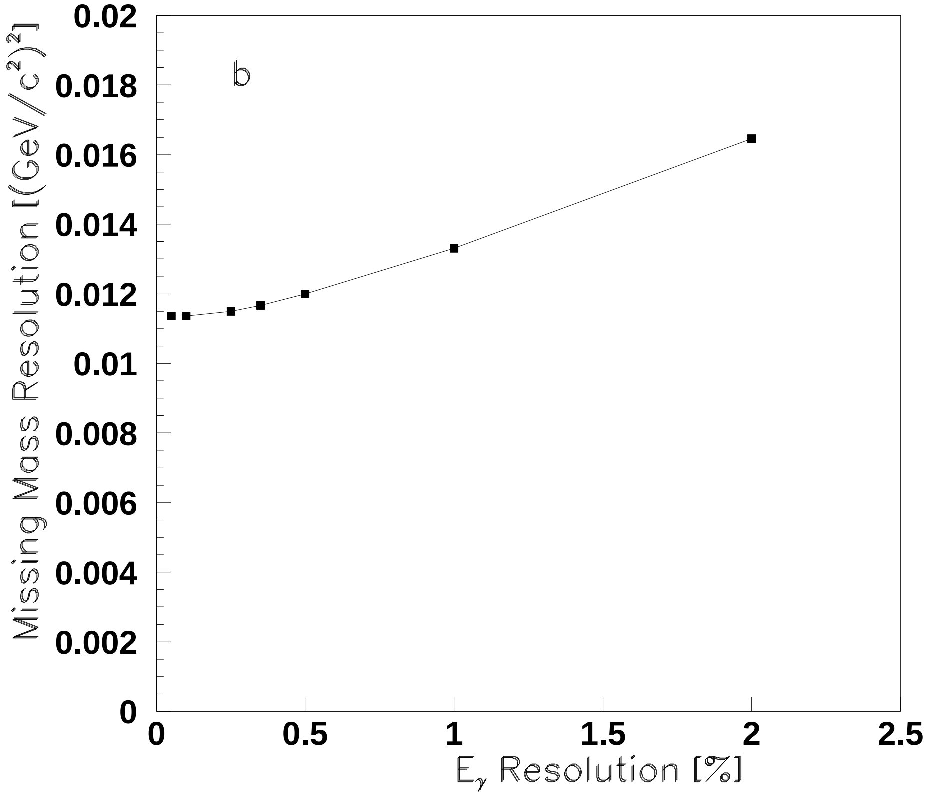

Figure 4: Missing mass resolution as a function of the uncertainty on the initial state photon energy measured by the tagger. The reaction used for this study was $\gamma p \rightarrow K^+K^-\pi^+\pi^-\pi^0 p$ where the π^0 is undetected and must be reconstructed using missing momentum. The incident photon energy energy is 9 GeV.

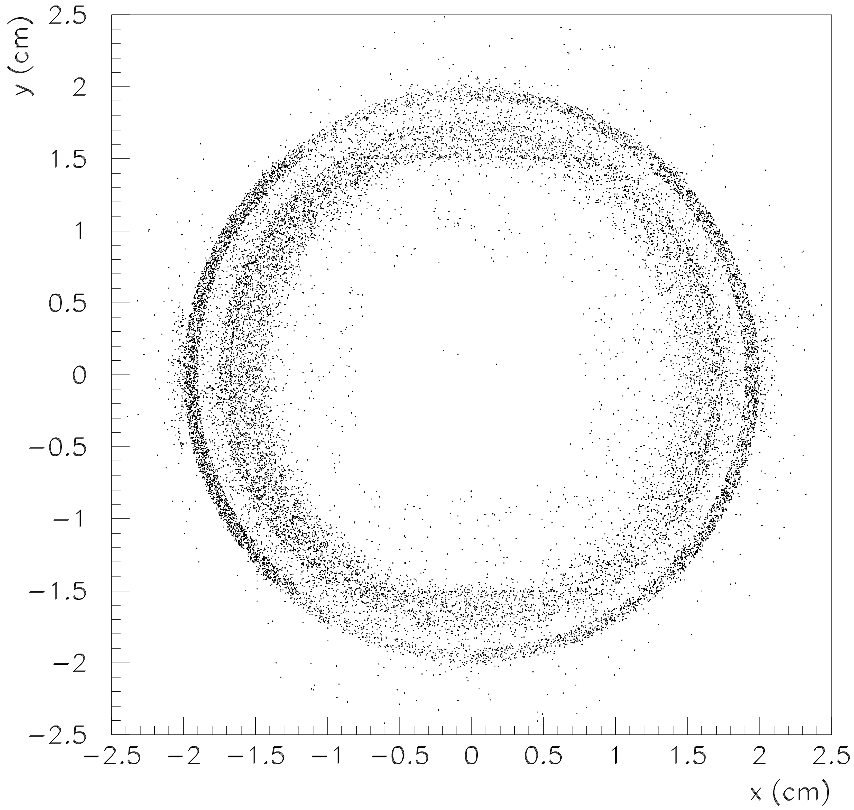

Figure 5: Transverse profile at the radiator of particles in the beam halo that went on to create hits in the tagger focal plane counters. Each point is the intersection of an electron track with the plane containing the radiator. The crystal radiator is in the center of the frame, but is invisible in this image because it is so thin that relatively few electrons interact in it.

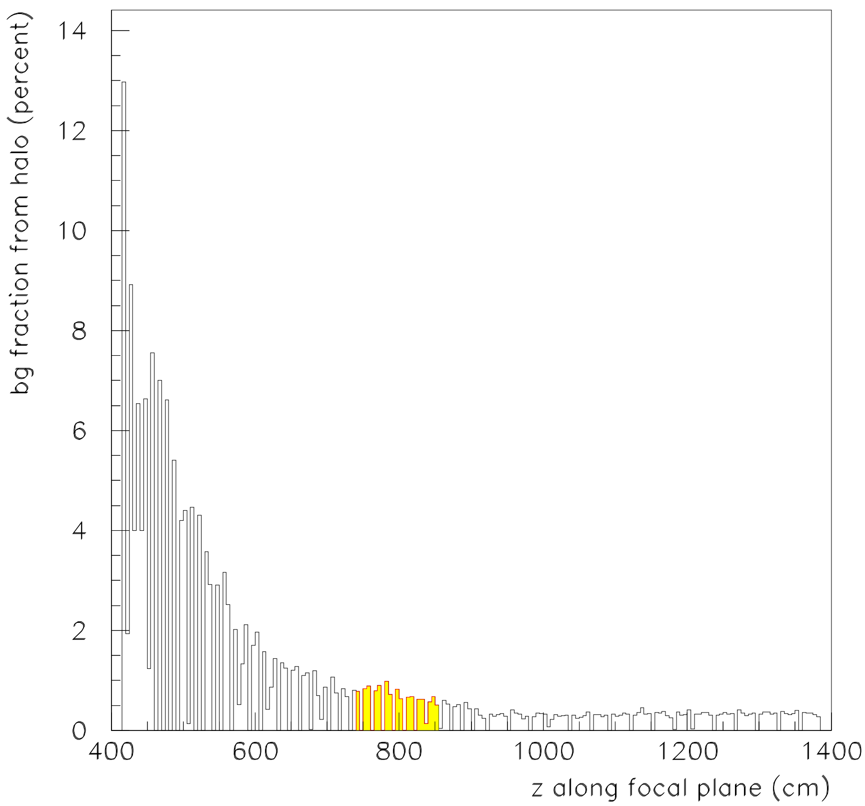

Figure 6: Percentage of hits in the broad-band tagging counters that are generated from electron beam halo particles, assuming a beam halo fraction of 10^{-5}. The electron beam energy scale is roughly linear in the z coordinate, varying from 600 MeV at the left end of the plot to 9 GeV at the right. The shaded region indicates the coverage of the microscope.

Table 1: Values for 12 GeV electron beam requirements at various stages in the commissioning and execution of the GlueX experimental program. The specification for the electron polarization refers to a time-averaged value.

	first 6 months	months 6-12	year 2 and following
beam energy	10 GeV	11 GeV	12 GeV
horizontal emittance	50 mm·μr	20 mm·μr	10 mm·μr
energy spread	$< 0.5\%$		
halo intensity	10^{-4}	10^{-5}	
electron polarization	-	-	$< 1\%$

Table 2: Electron beam parameters that are actually used by GlueX in the design and simulation of the photon beam. The table is reproduced from Table 4.3 in the GlueX design report.

parameter	design value
energy	12 GeV
electron polarization	0
minimum useful current	100 pA
maximum useful current	3 μA
r.m.s. energy spread	7 MeV
transverse x emittance	10 mm·μr
transverse y emittance	2.3 mm·μr
x-dispersion at radiator	0
y-dispersion at radiator	0
x spot size at radiator	1.55 mm r.m.s.
y spot size at radiator	0.55 mm r.m.s.
x image size at collimator	0.54 mm r.m.s.
y image size at collimator	0.52 mm r.m.s.
distance radiator to collimator	75 m
position stability	$\pm 200\ \mu$