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Photon Beam Requirements for E160 and E161

P. Bosted

Abstract

This note summarizes our present understanding of parameters and equipment required for the photon and electron beam lines for E160 and E161. The equipment includes dump magnets and dump for electrons, degraded electron detectors, a toroid current monitor, the diamonds and goniometer, the C24, C37 and D2 collimators, photon beam position monitors, sweep magnets, wire array, roller screens, and Cherenkov, ion chamber, and secondary emission quantameter for photon flux and intensity monitoring. The optics are then presented, along with a study of apertures, beam power, and backgrounds for E160.

1 Design Decision

The physics requirements for E160 and E161 in the context of E.S.A. at SLAC lead to the requirement of a coherent bremsstrahlung beam from a diamond crystal. This basically implies upgrading the facility used in the 1970's to a 50 GeV capability. Alternatives using laser backscattering, ordinary bremsstrahlung, annihilation radiation from a positron beam have previously been investigated, and cannot meet the general design requirements for energy and intensity, as discussed in the E160 proposal in more detail. Since the time the proposal was written, it has become apparent that the linear polarization available with coherent bremsstrahlung will allow for a significant enhancement to the physics output of E160. The asymmetry in open charm photoproduction rates has recently been predicted [1] to be relatively large (about 0.2), and can be measured as a function of A with a statistical error of about 0.02 for the expected luminosity of E160, allowing a powerful test of QCD.

2 Hardware overview

An overview drawing showing the approximate locations of the electron/photon beam line and the equipment discussed below is shown in Fig. 1. The next sections describe the primary beam parameters and equipment, in the order that the items occur along the beam line [from up-beam (west) to down-beam (east)].

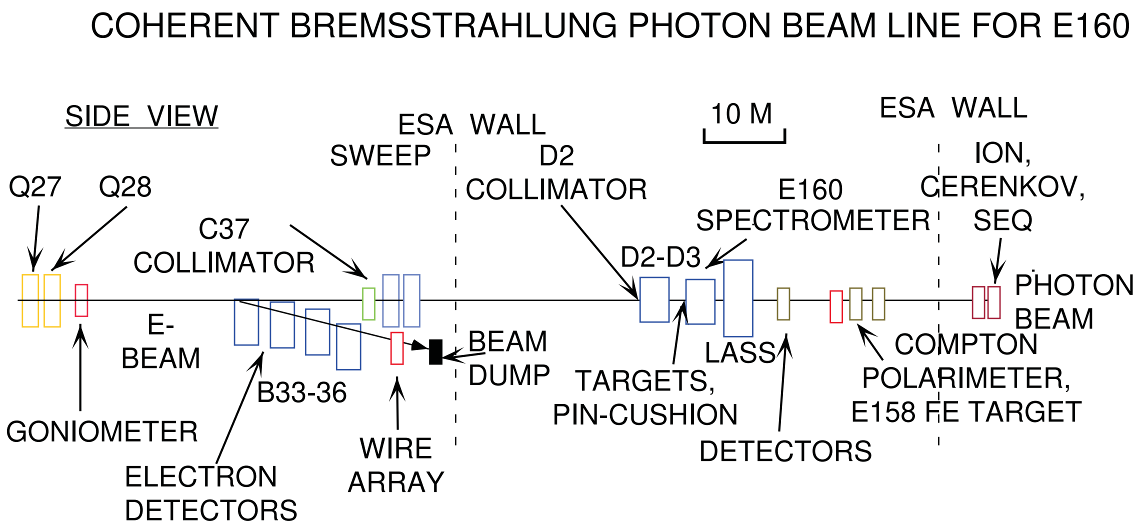

Figure 1: Overview of photon beam components for E160. The layout for E161 differs only in the spectrometer magnets and target.

3 Electron beam

To produce the photons, an electron beam with energies up to 48.3 GeV, intensities up to 6×10^{10} electrons/spill are needed, with emittance characteristics normal for A-line beams. Although SLAC can produce even higher intensities, they probably cannot be used due to radiation and shock damage to the diamond radiators. Simulations show that higher beam currents are not needed in any case, assuming that diamonds up to 1.5 mm thick can be used to obtain the highest possible photon intensity. We assume a repetition rate of 120 Hz for production running. This corresponds to an electron beam power of 55 kW at 48.3 GeV and maximum current.

4 C24 Collimator

The existing C24 collimator (located between the ninth and tenth A-line bend magnets) will be used with no modifications to its current setup. The collimator will be set to approximately ± 2 mm in the vertical direction and about ± 6 mm in the horizontal to ensure that none of the beam hits the Be diamond holder. A simulation of the A-line optics (see below) shows that at most 5% of the beam will hit any of the four jaws under normal running conditions, which is below that 3 kW power capability of each jaw.

5 Goniometer

We plan to use the same goniometer to hold the diamond crystals as was used in previous SLAC experiments. It is presently being re-furbished with new stepping motors and control hardware, electronics, and software.

The goniometer has two diamond holders, mounted on a rocker which puts either one or the other in the beam. One holder is below beam line, the other above. They are made of Be. The vertical distance between the two "in" positions is only a few mm, judging from the drawings. To avoid re-steering the beam for each diamond, we would like this distance to be 6 mm, so the tails of the beam (0.8 mm sigma expected) will not hit the holders. This may require modifying the holder mounts, and a design has been made. Before constructing, the actual current spacing should be verified by a direct survey.

Just up-beam of the goniometer there will be an insertable SEM assembly. It will be possible to select between no SEM, an SEM with a small hole (used for centering the beam on the diamond), and an SEM with a larger hole used for normal running to provide warning if the beam drifts off the standard orbit. This assembly is being re-built, as the original was lost.

A new addition to the goniometer is a plan to continuously anneal the diamonds with ultraviolet light. This requires a light, controls, and a window added to the vacuum vessel.

The current plan is to position the goniometer about 7 m down-beam of the Q28 quadrupole.

6 Diamonds

The diamonds should have a height of at least 6 mm, so that after using 1 mm to insert the diamond into the holder, there is a clear 5 mm in the vertical direction for the beam, whose expected vertical size will be 0.8 mm (one sigma). The width should be about 8 to 10 mm to match the beam size. The diamonds should not be wider than 10 mm, in order to maintain a small spot size at the E160 and especially the E161 target. The diamond thickness for E160 should be 1 to 1.5 mm, to obtain the highest possible photon flux. The thickness for E161 is under study.

The diamonds should be cut in the orientation such that coherent peaks from the (022) and $(02\bar{2})$ single points can be obtained with either a horizontal or vertical small-angle rotation of the diamond.

Diamonds are expected to be provided by E160 collaborators from Yerevan and Witts.

7 Dump Magnets

Dump magnets are needed to deflect the electron beam to a dump. Detector backgrounds from the dump should be no larger than those expected from the target, and preferably much smaller (1 background track per beam spill or less is desirable).

The four existing dump magnets are configured for a 12 degree bend, but at full power can only handle up to 25 GeV electrons. Studies by Lew Keller show that if the existing four dump magnets are re-configured to make a total bend of 7 or 8 degrees, the muon flux into E160 or E161 detectors is completely negligible. More recent studies show that a bend angle of 6 degrees may be acceptable, assuming that the concrete blocks under the

E158 D1 to D3 magnets remain in place. These are needed to range out the rare muons that scatter upwards out the End Station A floor. The total bend angle could possibly be reduced by spreading out the magnets, keeping the dump the same distance below the beam line, but this option has been rejected. The baseline design is to raise all but the first magnet in their current beamline z locations to provide the smaller bend angle of 7 to 8 degrees. To make the magnets will work more efficiently, they will be upgraded to three coil pairs (which they are designed for) from the existing two sets of coils per magnet. The radiation damaged coils will be replaced. Some modifications to vacuum chambers will be needed, although much of the existing water-cooled chambers can be re-used.

8 Degraded Electron Detector

To measure the energy spectrum of the electrons that have lost between 25% and 95% of their energy to bremsstrahlung in the diamond, we plan to replace the ion chambers located under the vacuum tanks of the first and second dump magnets. The existing set has seen extensive radiation damage. The new ion chambers and associated cables will be made of more radiation resistant materials. The vacuum chambers will be tilted such that there is continuous coverage of the electron spectrum. For more details, see TN 23. The detectors will require a high voltage supply, a gas supply, and about 60 cables going from the beam switchyard to ADC modules located in the ESA counting house.

Several design compromises were made in the previous detectors to install them under the vacuum chambers after the magnets and chambers were installed in the beam switchyard. To avoid these compromises, the new ion chambers will have to be constructed in time to install them with the vacuum chambers in the assembly shop.

9 Wire Array and Collimator in Beam Switchyard

A wire array, similar to the E158 wire array in the E.S.A. alcove, will be built and installed between the last dump magnet and the dump. I assume it is about 5 m beyond the last dump magnet. It will be used to continuously measure the primary beam position and profile in x and y. This will allow cuts to be placed in the analysis, to reject beam spills where the beam is off energy (due for example to a cycling klystron), or mis-steered. This will require a set of about 96 new cables going from the beam switchyard to the counting house. We plan to use the E158 wire array ADC's to read out this new wire array: on the rare occasions when we wish to use the E158 wire array, the cables will be swapped in the counting house.

Fig. 2 shows the electron beam optics at the wire array location. The optics are calculated by ray-tracing through the magnets using the code bosted/aline/adump.c. Electrons with relative momenta below 0.88 are stopped in the last dump magnet. The field non-uniformity causes a "bump" in the spectrum for P/P_0 between 0.88 and 0.92. Above 0.94, the relationship between P/P_0 and y position at the wire array is monotonic and close to linear, so that for a wire array size of 2.5 cm, there will be no ambiguities in determining electron momentum from y position. This is important, as the radiative tail spectrum can then be used as a check that the beam is passing through a radiator of the correct thickness.

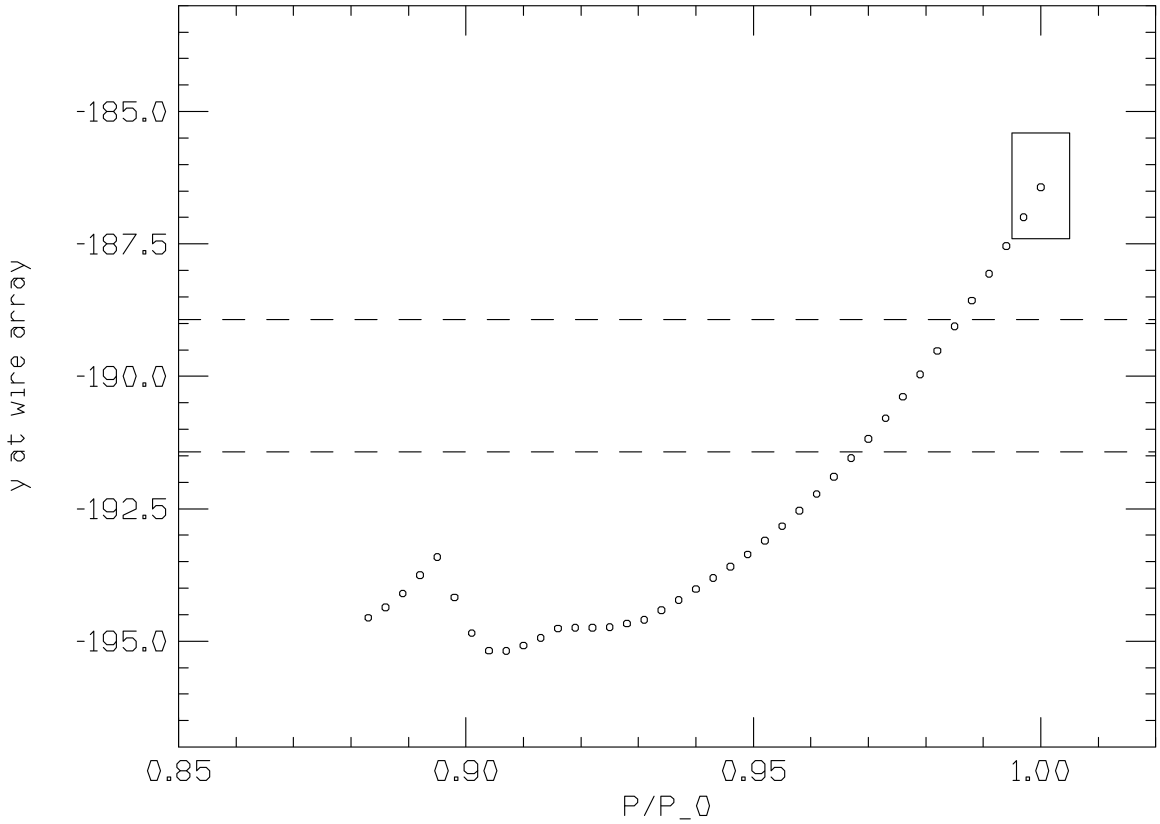

Figure 2: y position of the electron beam 5 m past B36, as a function of relative momentum. The bump around 0.9 is caused by the non-uniformity of the B33-B36 magnetic fields. The rectangle shows the approximate wire array size, and the dashed lines correspond to collimator radii of 2.5 and 5 cm.

A collimator will be placed in front of the wire array. The existing 4-inch inner diameter collimator will probably be augmented with a 2-inch collimator from E155. The outer diameter of the collimator should be at least 10 inches. This is needed to protect the board on which the wires are mounted (and also the toroid). This collimator will require cooling (presumably same water as for the electron beam dump). For the E160 and E161 photon beam spectra, and assuming the thickest possible diamond (1.5% r.l.), I calculated the power into the collimator using the program / bosted/aline/adump.c. As seen in Fig.2, the smallest relative electron momentum into the collimator is 0.88, and the maximum is 0.985 (0.965) for an inner aperture radius of 2.5 cm (5.0 cm). The maximum power therefore is 3 kW (2 kW).

10 Toroid(s)

A beam current toroid will be placed between the wire array and the beam dump. The readout should be available on a pulse-to-pulse basis to both E.S.A. and MCC. It is possible that two toroids will be used, to avoid splitting the output signal (under study). The standard ESA electronics will be used.

11 Dump

The electron beam will be stopped in normal operation in a beam dump mounted close to the wall between the switchyard and ESA. A suitable 60 kW dump has been identified. This will require a radioactive cooling water supply.

12 Primary collimator: C37

A photon collimator is needed to enhance the coherent to incoherent photon flux, and to prevent wide angle photons from hitting the edges of the targets. The collimator aperture should be adjustable in steps of 0.1 mm or less, with a range up to ± 5 mm. The goniometer to collimator distance should be at least 50 m to ensure good coherent enhancement.

The plan is to use the existing C37 collimator for this purpose. It has 30 r.l. of copper and 30 r.l. of W, and was refurbished during the A-line upgrade to 50 GeV. The collimator is located approximately 53 m from the proposed goniometer location. The jaws move in/out in pairs, so in order to center the jaws on the beam, the capability of the entire collimator to move up/down and left/right must be re-established. New stepping motors and controls must be added.

13 Sweep Magnets

Sweep magnets are needed following the collimator. The background level to the detector from the collimator should be small compared to backgrounds from the physics target. The main background is from Bethe-Heitler muons. A detailed simulation was made by Lew Keller, assuming sweep magnets at the location of Q38, just downstream of C37. Comparing vertical and horizontal bends, he finds a vertical bend works better, because the spectrometer magnets bend horizontally, and half of the time will bend muons towards the detectors. He found that for the 6/2001 E160 geometry, an integrated field of 30 kG-m is the minimum needed, yielding a few muon tracks per beam spill, and several muons per spill in each individual hodoscope plane. These values drop to less than 1/spill using 50 kG-m. For the new (12/2001) E160 design, which has larger detectors (up to ± 65 cm in the vertical direction), he again finds that 50 kG-m will be required. The problems mainly occur for the highest momentum muons (above 40 GeV). For typical E160/E161 conditions, there will about 10^8 photons above 40 GeV hitting the C37 collimator. This produces about 2000 muon pairs per spill, of which about 300/spill with have a muon above 40 GeV. Since the distance from the sweep magnets to the detectors is about 50 m, 40 GeV (48 GeV) muons produced at zero degrees will be 125 cm (100 cm) above/below beam line at the detector location, assuming a 33 kG-m sweeping field, and that the poles of D2, D3, and LASS only bend horizontally. In this case, it would seem that 33 kG-m is adequate, even with the nominal 20 cm spread from multiple scattering, and 10 cm from the average production angle ($m_\mu/E \approx 2.5$ mr). But the actual pole fields of D2, D3, and LASS could cause some vertical focusing, and the occasional large angle muon scatters may cause extra problems, leading to the requirement of 50 kG-m.

The E161 spectrometer design is not finished, but will likely have approximately the same detector sizes as E160.

A good choice to obtain 50 kG-m appears to be the D42 magnet presently in ESA and a 26D10 magnet. D42 can go as high as 34 kG-m at 2800 amps. We would probably want to run around 2500 amps so coils do not get too hot. The 26D10 is a smaller magnet and can supply up to 20 kG-m. The present D42 gap appears to be 1.4 inch, or about 1 inch with vacuum chamber. This is still large enough, considering that C37 will be closed to a much smaller size. The weight of D42 is about 5 tons.

Another option is to use one of the spare 3-degree bend magnets. This is presently under investigation.

14 Muon absorbers

A study by Lew Keller shows that putting extra shielding between the sweep magnets and the alcove wall actually increases backgrounds, (due to multiple scattering) rather than decrease them (due to energy loss), so this idea has been dropped.

15 Wire Array in E.S.A.

The E158 wire array may be used to measure the electron beam profile when tuning the accelerator. This can check the steering of the beam, the Q27 and Q28 settings, and the spot size, although normally this will be done with the other wire array in th switchyard. A proposal to add an insertable piece of tungsten in front of the wire array to measure the photon beam profile has been dropped because the shower will be much wider than the expected photon beam width.

16 Pin-cushion Beam Monitor

The purpose of this pin-cushion tungsten SEM photon flux monitor is to measure the photon flux in each of four quadrants, with a central hole of ± 7 mm. A similar device was used in the previous SLAC experiments, but apparently was discarded, so a new device is needed. Originally, we thought the pin-cushions should be mounted on the jaws of C37, but we now think it would be more useful to be positioned near the 3DC2 collimator. A possible location is the E158 solid target table. The construction will be very similar to the previous design. Each quadrant has a single cable readout to an ADC to measure the charge.

The scenario for centering the photon beam will be to open the C37 jaws to a wide setting, put in a thick diamond (which spreads out the photon beam due to multiple scattering), and steer the electron beam until the rates in the left/right and up/down quadrants are equalized. This will ensure that the photon beam is centered on the target. At the same time, the spent electron flux will be maximized to ensure that the beam is centered on the diamond. The goniometer SEM can also be used for this purpose (minimizing the signal). Then, the C37 jaws will be closed to about ± 4 mm and the entire C37 assembly moved with the stepping motors until the quadrants are again equalized. Finally, C37 jaws will be set to their operating point (about ± 2 mm for E160), at which point the pin-cushion quadrants should read all read very small values (less than 0.1% of full flux in each quadrant). A final check of photon beam alignment will be made with the "hole" target.

17 Secondary collimator and D2

Secondary collimators are needed following the main collimator to clean up halo. The current plan is to use the existing 3DC2 collimator in the E158 D2 magnet, for the E160 run. It's radius of 7 mm is matched to that of the pin-cushion monitor, which will be located just up-beam of 3DC2. The polarity and magnitude of the field in the D2 magnet will be adjusted to minimize backgrounds in the E160 detectors. A simulation (see ~bosted/E160/simul/d3spect.inp and d3spect.f) of the Bethe-Heitler muon rate (the dominant background) was done assuming that the effective thickness of the collimator is 1 r.l., and that 0.1% of the beam photons hit the collimator. The singles rates in the second hodoscope plane are shown as function of D2 field setting in Fig. 3, where positive polarity means the same polarity as D3 and LASS. Note the log scale: the rates vary dramatically with D2 setting. There is a minimum in the rates near 8 kG, and these rates are small compared to calculated backgrounds from the E160 targets (about 10/spill). The optics simulation with a 5 mm wide diamond and a ± 2.5 mm opening for C37 predicts 0.03% of the beam will hit the D2 collimator (see ~bosted/aline/spect.c using spect.inpe160), but the actual rates might be quite a bit higher due to misalignments and scattering from the edges of the C37 collimator. With the optimum D2 setting, it appears that we could tolerate as much as 1% of the beam hitting the collimator before the rates start to become a significant problem. The rates for pion and kaon decays were also evaluated, and are about a factor of five smaller than for the Bethe-Heitler background from the collimator.

Ray traces in the horizontal plane for muons originating in D2 collimator are shown in Fig. 4, for a setting of 8 kG. Muons around 8 GeV are bent out by the field of D2, then bent back in by the return flux of D3, then travel straight (outside the wedge) through LASS, to mostly hit the back hodoscope plane, missing the front plane. There are also some very high momentum muons that bend out through all three magnets, and make tracks by hitting both planes. The acceptance for J/ψ particles is small at 8 kG for events originating from

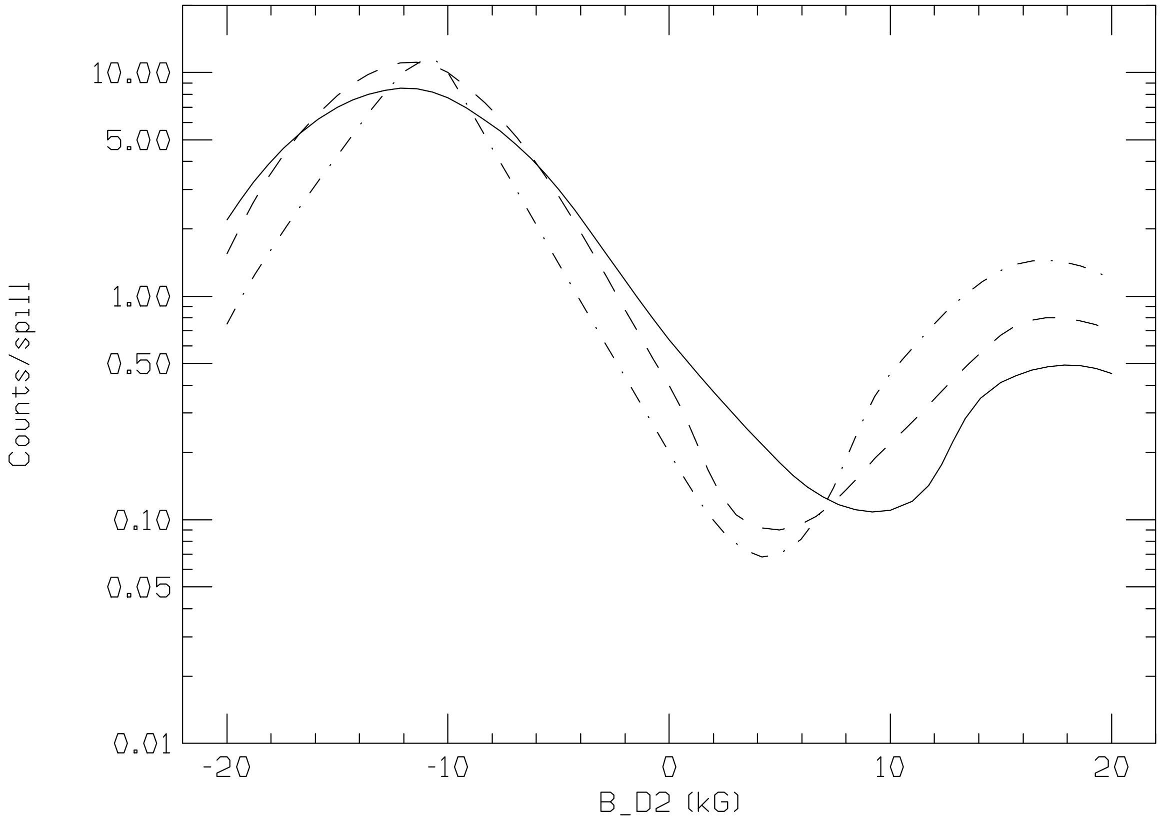

Figure 3: Rate of muons/spill hitting the second hodoscope plane of the E160 spectrometer, from the pin-cushion and D2 collimator, assuming they absorb 0.1% of the beam. The dot-dash, dash, and solid curves refer to the photon beam spectra with coherent peaks at 15, 25, and 35 GeV, respectively.

the D2 collimator, less than 10% of the acceptance from the normal target at 35 GeV, and they will be reconstructed to the wrong invariant mass.

18 Roller Screen and PR3 Screen

The roller screen in the alcove should be kept in place. It should be possible to see the photon beam on it, since it is more sensitive than the PR screens. We would like to keep the E158 PR3 screen in place also, to examine the photon beam spot size and position down-beam of the collimators in D2 and D3. The screen will need to be replaced with zinc-sulfide to make it sensitive enough for photons. Both the roller screen and PR2-4 will also be used for tuning up a low power electron beam.

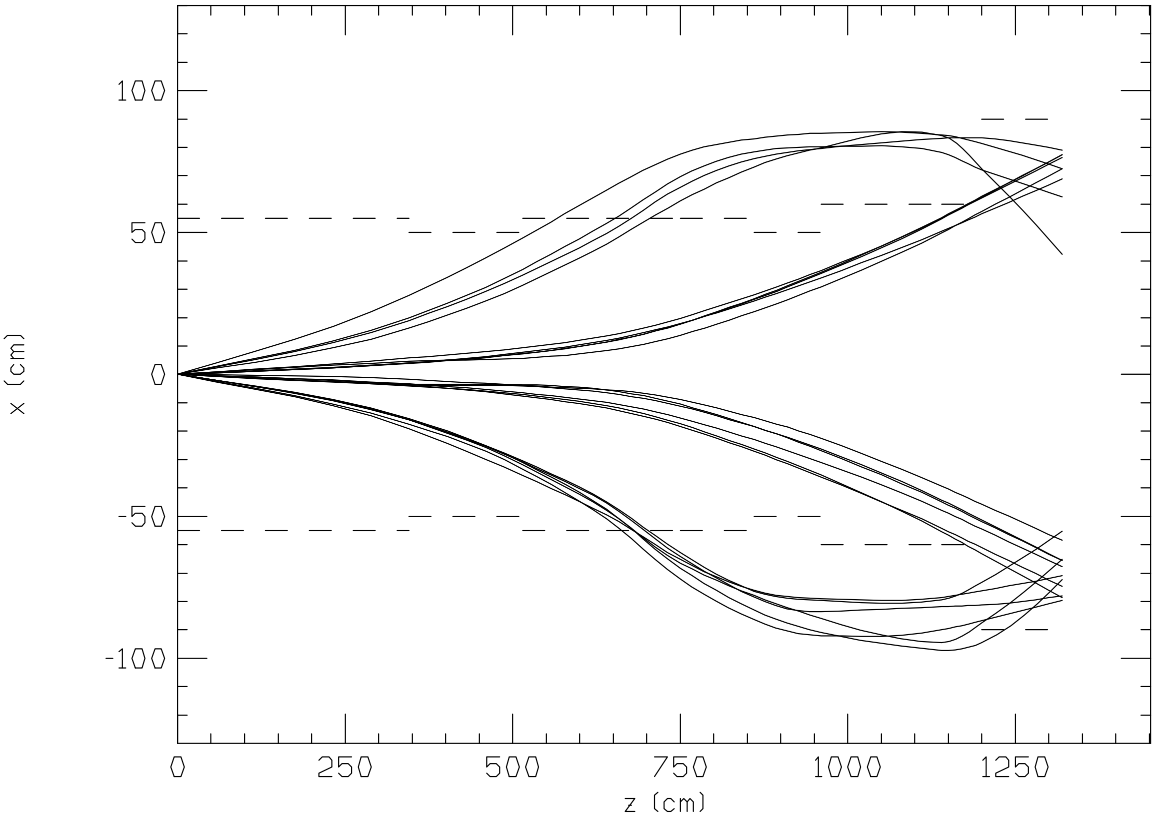

Figure 4: Ray trace of Bethe-Heitler muons originating in the D2 collimator, passing through D2, D3, LASS, and the front and back hodoscopes (indicated by the dashed lines).

19 Compton Polarimeter

A Compton Polarimeter is needed to measure the circular polarization of the beam for E159 and E161. Although there is sensitivity to linear polarization, it is very weak, and this process is not suitable for E160 linear polarization measurements. However, the Compton polarimeter will be very useful for measuring the photon spectrum directly, and therefore should be in place for E160 and well as E159 and E161. The polarimeter consists of an 18D36 magnet and a set of about 100 lead glass block detectors (to be provided by Yerevan collaborators), and possibly a small hodoscope array. Design is in progress. This would be located approximately where the Q4 magnet is in E158. The E158 Moller foil target would need to be moved to a location just up-beam of the magnet, but probably no other changes are needed.

20 Cherenkov

A simple Cherenkov counter using air at atmospheric pressure will be used for flux measurements. This probably needs to be a new device, as the one from E78 [2] has not been located. It would be positioned just up-beam of the Ion chamber, and down-beam of PR4 and the E158 Lumi detector, which can remain in place (it may be useful for measuring halo). The ESA vacuum line can end just up-beam of the Cherenkov. A thin aluminum window should be used.

21 Ion Chamber

An ion chamber is also needed for flux measurements. This will be similar to the one used in E78 [2], and positioned just up-beam of the SEQ and down-beam from the Cherenkov.

22 SEQ Quantameter

A quantameter is needed for intensity measurements. This marks the end of the photon beam line. Adequate shielding and distance is needed so that back-splash does not generate high background levels in the spectrometer detectors. A calculation by Stan Mao shows that at least 1 m of concrete shielding is needed between the SEQ and the physics detectors, for a 30 m separation. A suitable SEQ quantameter [3] from E78 [2] is presently located in ESA. It needs cooling water, a high vacuum pump and high voltage to operate. It may need some re-furbishing, but may be fine to use as is. It can handle up to 10 kW, far above the maximum 600 W planned for E160. The location should be near the 3PC3 collimator, about 6.5 m beyond the E.S.A. wall.

23 Radiation Safety

The largest radiation source will be the electron beam dump, which will absorb an average of 40 kW (assuming a beam-on efficiency of 65%). To calculate total doses, we assume 2 months of data taking for each experiment (E160, E161, and E159). The next largest source of radiation is the C37 collimator, which for the nominal E160 settings (see below) will absorb between 0.6 and 2 kW of power, for an average of about 1 kW. The power for E161 will likely be similar, but an accurate estimate requires the final spectrometer design.

In the End Station, the pin-cushion and D2 collimators will absorb about 10 W, and the E160 and E161 targets will absorb less than 1 W. We plan to leave the big concrete bunker from E158 in place, which should be adequate for these power levels, which are far below the E158 values. The largest radiation source from the photon beam, by far, is the SEQ., just beyond ESA. The E160 nominal beam settings have power levels of 1750 W, 920 W, and 680 W for the spectra with coherent peaks at 15, 25, and 35 GeV, respectively. Assuming equal running times for each setting, at 65% efficiency, this amounts to an average power level of about 1 kW. The power level in E161 will likely be similar. Local lead shielding on the north side and above the quantameter of about 50 cm thickness should be adequate (similar to the present local shielding around the E158 Lumi detector), but this needs more study. This assumes that the sand bags placed for E158 can remain in place. The beam dump East tunnel beyond 3PC3 is not needed in its present form, but protection is needed against the muons generated in the quantameter. If the tunnel is taken down, a new PPS door would have to be installed for access to the SEQ, Ion, and Cherenkov detectors.

For E160, the E158 walls can remain in place, along with the BTM's, and probably provide adequate protection against accident scenarios in E.S.A. In normal mode of running, the maximum power in the photon or electrons beams is 2 kW. All dipole magnets would be turned off when running electrons (since they are meant to be stopped by the quantameter). Burn-through monitors will be needed to protect against the accident case of a sweeping magnet, the D2 or D3 dipole, or the Compton polarimeter magnets being on when there is an electron beam.

24 Electron Running

To calibrate the quantameter, provision should be made to run low power (up to 2 kW) electron beams straight ahead into the quantameter. The E158 wire array will be used to measure the electron beam spot size in this mode. The Roller screen, PR3, and PR4 will be used to align the electron beam. The E158 toroid will be used to measure the electron beam current. We will probably want to calibrate the SEQ at 15, 25, 35, and 45 GeV, for about 4 hours each.

25 Photon Beam optics

A study of the electron and photon beam optics was made using bosted/aline/spect.c and spect.inpe160. The goal of the study was 1) to find out if the C24 collimator is suitable to collimate the electron beam; 2) what diamond dimensions are desirable; 3) see if beam can be focused using only Q27 and Q28, since Q30 will be down-beam of the diamonds; 4) determine spot size at the E160/E161 targets; 5) see how many photons would hit the E158 collimators in the D2 magnet.

Since synchrotron radiation causes a large emittance growth in x, increasing as E^5, I studied the case of 45 GeV, close to the highest that we will run, and a beam current of 5×10^{10} electrons per spill, at 120 Hz. I assume the linac emittance is 1.4 mm-μrad in y (± 0.14 mm in y and ± 10 μrad in dy, uncorrelated at the "swivel point"). It doesn't matter what I assume in x, since the synchrotron radiation blows it up immediately upon entering the A-line. The y beam parameters are from wire scan measurements and the linac optics model, and reproduce beam spot sizes observed in E158 quite well.

I assume an energy spread of 0.3% (one sigma) and SL10 slits set to ± 40 mm (intercepting about 1% of the beam power). I set C24 to ± 3 mm in x and ± 2.2 mm in y to prevent less than 0.03% of the electrons from hitting the vertical diamond holder, and less than 0.01% from hitting in x where there is steel at about ± 1.1 cm. I find that the beam size at C24 is 1.1 mm (sigma) in x and 1.3 mm in y, and about 10% of the electrons hit the collimator (or 2.5 kW each on the upper and lower jaws, close to the rated power of 5 kW).

I choose the Q27 and Q28 settings to roughly focus in both x and y at the position of the E160 target, in order to minimize the number of photons that can hit the D2 collimators (just up-beam). The exact settings aren't too important for thick (> 0.001 r.l.) diamonds, as long as the divergence is significantly smaller than the multiple scattering in the diamond. The setting I used at 45 GeV are -133 for Q27 and 137 for Q30.

I find the spot size at the diamond to be about 2.7 mm in x and 0.8 mm in y (depending on linac emittance) (these are one sigma values). With 10,000 trials, none of the electrons hit the thick holder at ± 10.3 mm in x, and two hit the holder on the bottom on the diamond, assumed to be 2.5 mm below the center. Increasing this distance to 3 mm allows less power on C24. I assume there is empty space above the diamond and to each side. I chose a diamond width of ± 4 mm, since that is the size the S. African synthetic diamonds come in, and find that about 13% miss the diamond on either side. This is an acceptable loss rate. With ± 5 mm, the loss is reduced to 8%. although longer tails of the beam distribution at the target are generated. Many of the beam parameters are listed in Table 1.

Electron Energy (GeV)	45.0	45.0	48.3
Electron Current (10^{10}/spill)	5.0	5.0	5.0
Peak Photon Energy (GeV)	14.8	26.5	35.2
Diamond angle (μrad)	305	888	1587
C37 opening (mm)	± 2	± 2	± 2
Photon Beam Power (kW)	1.7	0.9	0.7
Diamond thickness (mm)	1.5	1.5	1.5
Linear Polarization	0.91	0.68	0.47
J/ψ/day total	78K	124K	132K
J/ψ/day in Peak	11K	45K	48K
J/ψ goal per target	7K	30K	30K
days (at 100% efficiency)	2.6	2.6	2.5

Table 1: Summary of the beam parameters, J/ψ rates, and running time needed for each of the three beam energies, assuming average 0.7 b^{-1} target thickness, and the D3/LASS spectrometer acceptance. The linear polarization value is at the main coherent peak. The photon beam power is after C37. The J/ψ rates only include quasi-elastic production.

I then examined what setting of the C37 collimator is needed to obtain a reasonably small spot size at the E160 target. With an opening of ± 2 mm in both x and y, about half of the photons hit the collimator for a 0.015 r.l. diamond. This is a power of 1 to 2 kW. Out of the 5000 remaining photons, none of them hit the inside of the 0.7 cm radius photon collimator in the D2 magnet, while 70 of them (about 1.4%) are between 0.5 and 0.7 mm, and would hit the holder of the E161 polarized target. It is therefore crucial to minimize the amount of material in this area. The spot size at the target is about 2.1 mm in x by 1.8 mm in y. Using bosted/E160/simul/d3spect.f, I compared the mass resolution compared to a point beam spot: the change is negligible.

Note that the spot size is for electrons: photons are spread out by an additional angle of $m/E \approx 10$ μrad. Since this is small compared to the 35 μrad average multiple scattering angle, the spot size for photons will only be slightly larger than for the electrons that created them.

Fig. 5 shows the trajectories of the particles in the A-line for a 0.015 r.l. diamond and the quad and collimator settings discussed above.

The linear polarization values are pretty good for the 15 and 25 GeV settings, but only about 0.5 at 35 GeV. This is still good enough, for 10,000 clean inelastic J/ψ particles, as the asymmetry error will be about 0.02, while the expected physics asymmetry is about 0.2.

26 Photon Energy Spectra

Using the program bosted/jpsi/bremdia.f, I calculated three photon spectra that will give the desired physics errors in about one fourth of the proposal running time, assuming an average target thickness of 0.7 inverse barns. All use a 1.5% r.l. diamond and ± 2 mm square C37 collimator opening. The lower running time is due to the new spectrometer design which allows high luminosity with less background than the proposal design. This should allow more statistics to be gained than in the proposal, or additional energy settings and targets to be run.

Fig. 6 shows in the top panels the intensity of photons (flux times energy) as a function of energy for settings that give primary (022) peaks at 15, 25, and 35 GeV. The angle of the crystal with respect to the beam axis in the y direction is given in Table 1. These spectra assume a large angle in the x direction, so only the (022), (044), and (066) lattice points contribute with significant strength (these correspond to photon peaks of increasing energy but decreasing strength). The dashed lines show the incoherent bremsstrahlung. The middle figures show the flux of J/ψ particles per day assuming the E160 spectrometer acceptance given in TN 24, while the bottom panels show the linear polarization.

References

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[2] W. Kaune *et al.,* Phys. Rev. D 11 (1975) 478.

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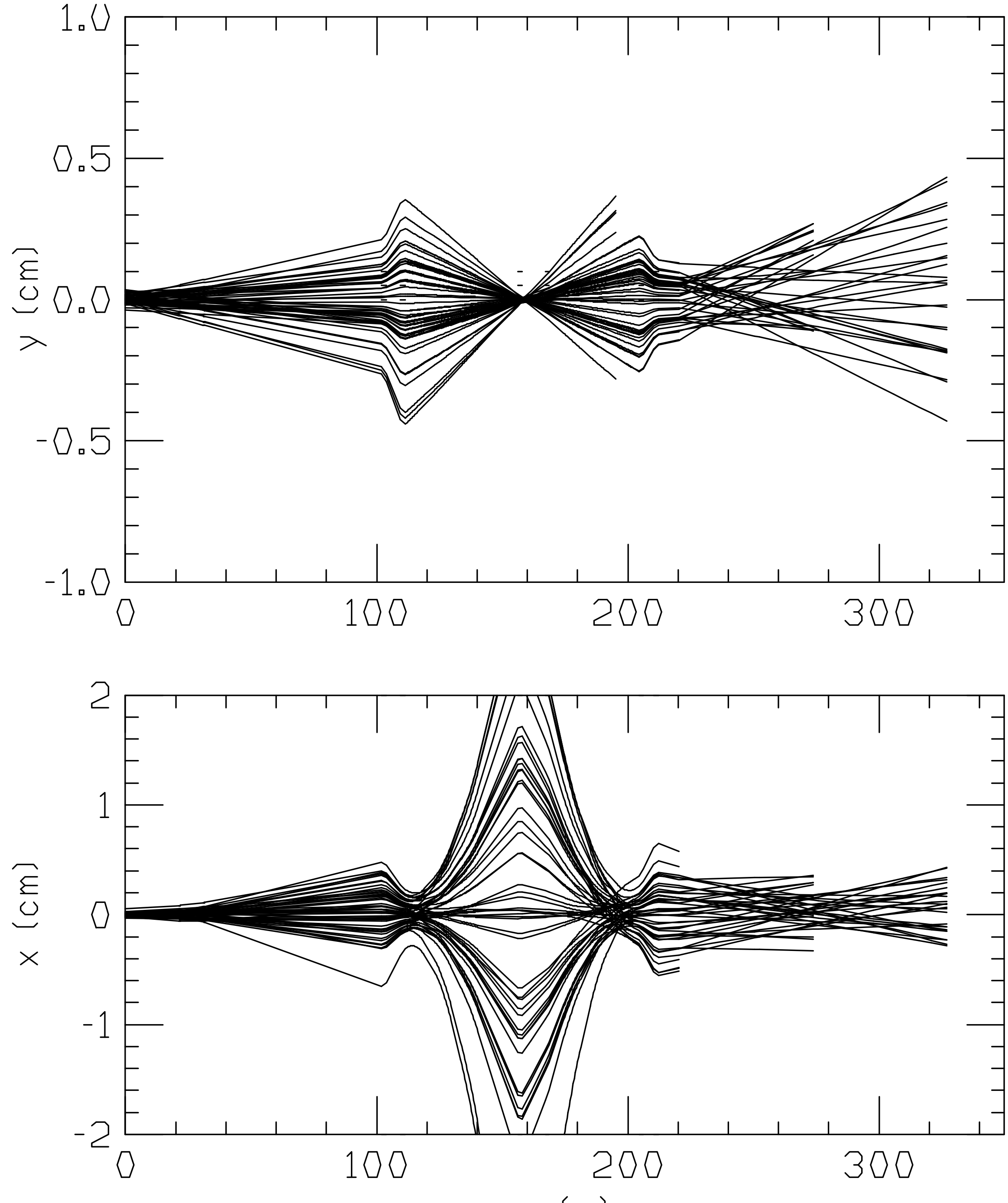

Figure 5: Optics that electrons would have in the A-line with the quad and collimator settings given in the text, for a 0.015 r.l. 8 mm wide diamond located near $z = 220$ m. The C37 collimator is near $z = 270$ m, while the target is at the end of the trajectories.

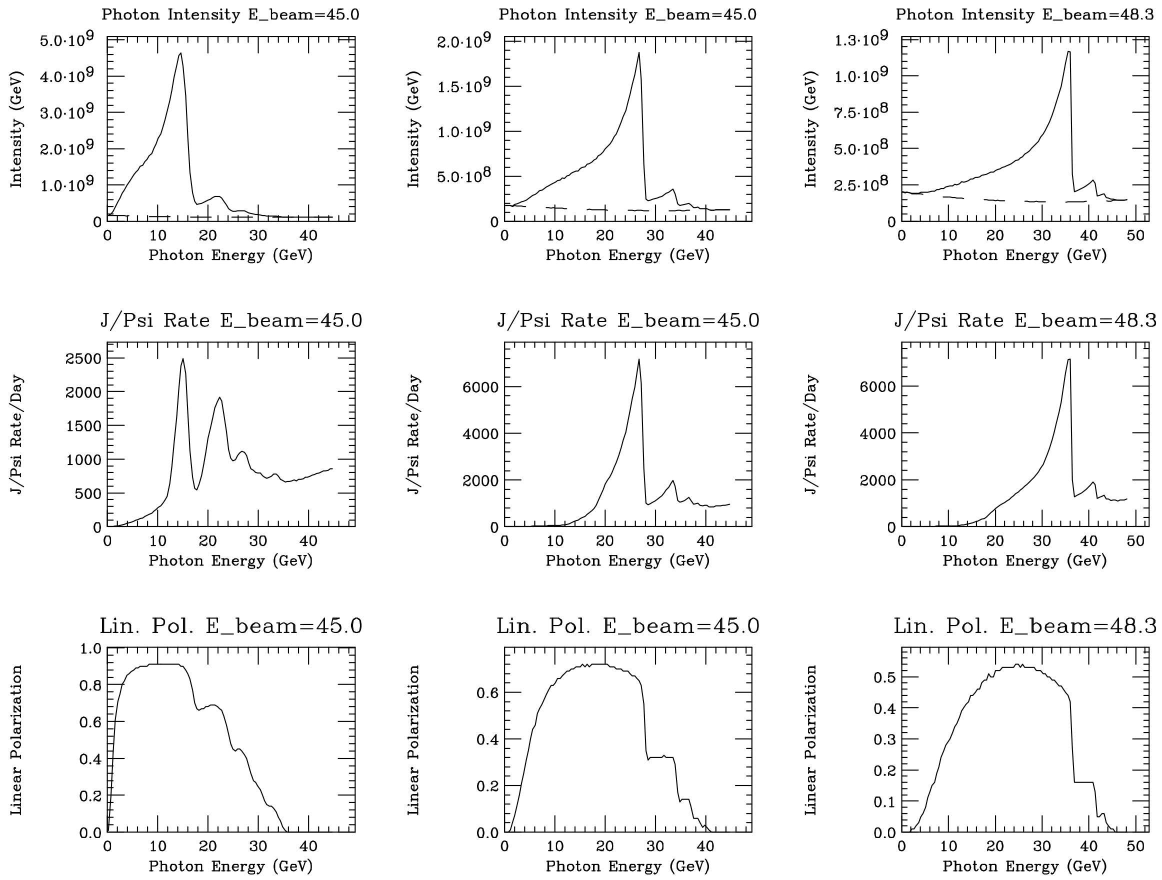

Figure 6: Photon intensity spectra, J/ψ rates, and linear polarization as a function of photon energy, for three diamond orientations listed in Table 1.