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Degraded Electron Detectors for A-line Dump Magnets

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Abstract

The optics for energy-degraded electrons in the A-line dump magnets is presented, along with the projected response of a set of ion chambers located under the vacuum chambers of these magnets.

1 Introduction

As outlined in TN-11, there are four large dipole magnets (B33-B36) that transport the electron beam from the A-line axis to a beam dump. The deflection is downwards, with a bend of about 2 degrees per magnet. Each magnet has a vacuum chamber with a water-cooled, thick copper bottom, designed to absorb most of the power from electrons that have lost energy in the upstream radiator. For E160 and E161, this radiator will be a diamond with a thickness of about 0.015 r.l. A set of ion chambers under these vacuum chambers was designed to measure the flux of degraded electrons along the length of the chambers. This allowed experimenters to observe the position and magnitude of the coherent bremsstrahlung peaks produced in the diamond. Since these ion chambers are highly radiation damaged, new ones will be built for the Real Photon experiments E159-E160.

2 Ray Trace Model

To study the design parameters needed for the ion chambers, an optics model of the dump was made: see ~bosted/aline/adump.c and adump.inp. Each magnet is assumed to have an effective length of 2.91 m, and a field setting of 19.285 kG, corresponding to a 2 deg. bend for 48 GeV electrons. The spacing between B33/B34 is assumed to be 1.25 m, while 1.3 m is assumed for the B34/B35/B36 spacing. The vacuum chambers are assumed to have an opening of ±10 cm, with the upstream ends centered at $y = 1.21$, -8.71, -33.1, and -72.2 cm respectively, and tilt angles of -1, -3, -5, and -7 degrees respectively. These values are subject to more detailed design. They were chosen so that degraded electrons always hit the bottom of one of the vacuum chambers, and not the bellows between the chambers. The magnetic field of each magnet is assumed to vary with the y distance from the central axis of the magnet, according to a correction factor given by $(1 - 0.0044y^2)$ for $y < 6$ cm, and using a look-up table beyond 6 cm (see adump.c, lines 126-132). This table is based on magnetic measurements done when the magnets first were delivered to SLAC, with 3 coils, as they will be used in RPC. However, there are some ambiguities in connecting the two data sets ($<$ 6 cm and $>$ 6 cm) together, so new measurements should be done for the final modeling.

Synchrotron radiation in the magnets is fairly significant at 48 GeV, and is fully taken into account for each step through a magnet.

3 Trajectories

Fig. 1 shows the trajectories of 20 rays, with momenta that are multiples of 48.2/20 GeV (i.. 5% steps). The low momentum particles bend the most, and hit in B33, while higher momenta hit B34-B36. The three rays that do not hit any magnet correspond to $\delta P/P$=0.9, 0.95, and 1. Note that by making a vertical "step" between the chambers of B33 and B34, no particles hit in between, even with tilt angles aligned with the magnet axes. This will require careful thinking about the bellows, however.

Fig. **??** shows the z position where particles hit vacuum chambers, as a function of relative momentum. Note that due to the non-uniform fields, most of the particles hit in either B33 ($0 < \delta P/P < 0.5$) and B34 ($0.5 < \delta P/P < 0.8$). Magnets B35 and B36 only see a 10% range in relative momentum, with the chosen parameters. Note also that z is a monotonic function of $\delta P/P$ up to $\delta P/P = 0.9$ (although it is not linear), which is important because it means that by measuring z, one is also measuring $\delta P/P$ without ambiguities.

Above $\delta P/P = 0.88$, the electrons pass through all four magnets, and hit the beam dump. Fig. 3 shows y versus $\delta P/P$ at the position of a wire array in front of the dump. In this case, there is an ambiguous region around $\delta P/P = 0.91$ For more discussion on the wire array optics, see TN-11.

4 Coherent Bremsstrahlung spectra

To study the response of the ion chambers, we started with highest and lowest photon energy spectra planned for E160. Both have an endpoint energy near 48 GeV, while the primary coherent peaks are located at either 15 GeV or 35 GeV, corresponding to $\delta P/P$ for the electrons at 0.62 and 0.25. For E161, the primary peak will be around 43 GeV, or $\delta P/P = 0.1$. The spectra for E159 will be varied, but all fit in the range $0.1 < \delta P/P < 0.6$, so that detectors are only needed in B33 and B34, and not in B35 and B36.

The response of the degraded electron detectors to the two extreme E160 spectra is shown in Fig. 4. The detectors are assumed to cover a z range of 10 cm each in this plot, but in practice a larger size of about 20 cm should be adequate (pairs of bins summed). The lower panel shows the case with no resolution smearing, while the top panel includes a 10 cm Gaussian resolution smearing to roughly account for the showering of the electrons in the copper in the bottom of the vacuum chambers. This should be improved in the future

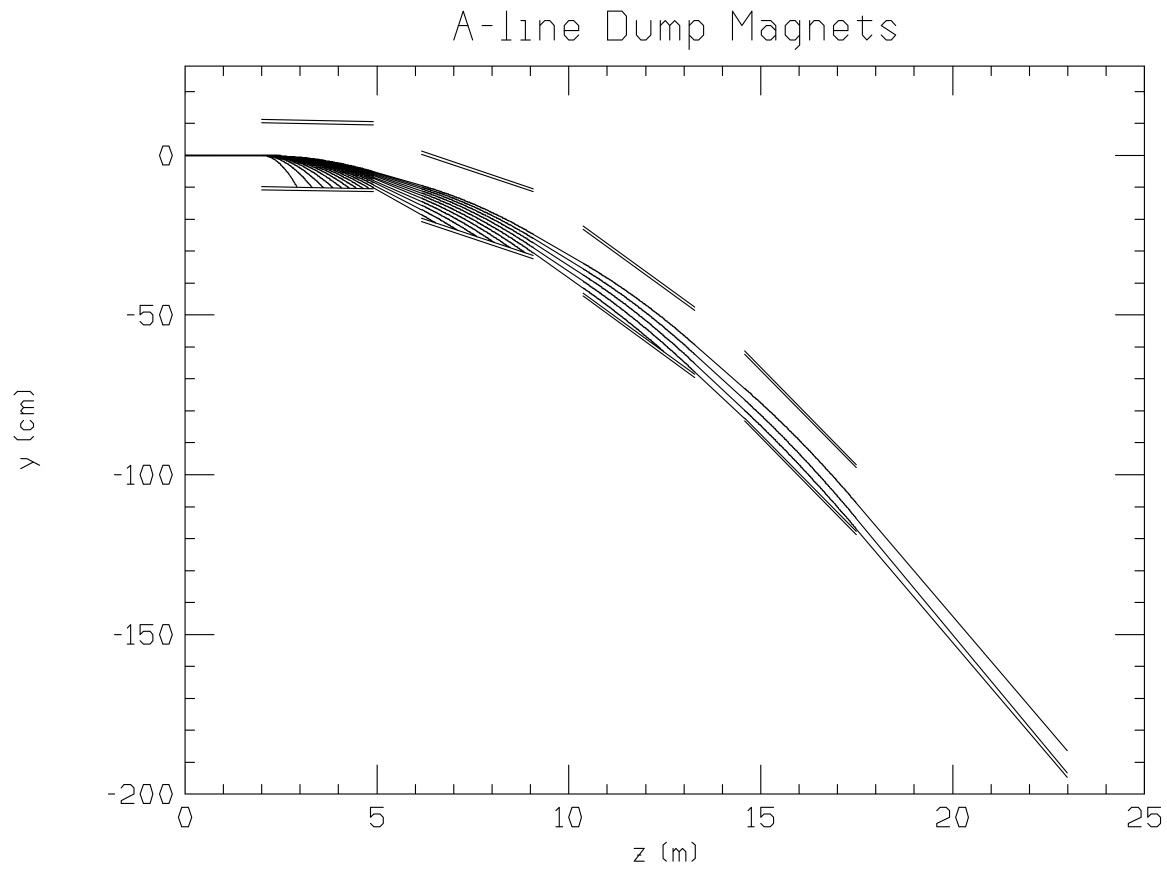

Figure 1: y versus z for electron trajectories in 5% momentum steps in the A-line dump magnets. The primary beam energy is assumed to be 48.2 GeV, and synchrotron radiation and magnet field non-uniformities are taken into account. The four pairs of titled lines correspond to the vacuum chambers of B33 to B36, from left to right.

to take into account the energy and angle of incidence of the electrons. The figure shows that even with 10 cm resolution, the "edge" corresponding to the coherent peaks can readily be measured with high precision; monitoring this quantity corresponds to monitoring the angle of the diamond with respect to the electron beam. The height of the "steps" are all quite well measured: this is a measure of the coherent to incoherent bremsstrahlung ratio, and monitors the quality of the diamond. The relative coherent peak height is expected to deteriorate with time due to radiation damage, and must be taken into account in the data analysis.

Finally, the absolute magnitude of the ion chamber response will be a measure of the radiator thickness. This can be calibrated with an amorphous radiator. A sudden decrease in detector response will be a useful way to find out if a diamond has cracked and broken off (as has happened in th past).

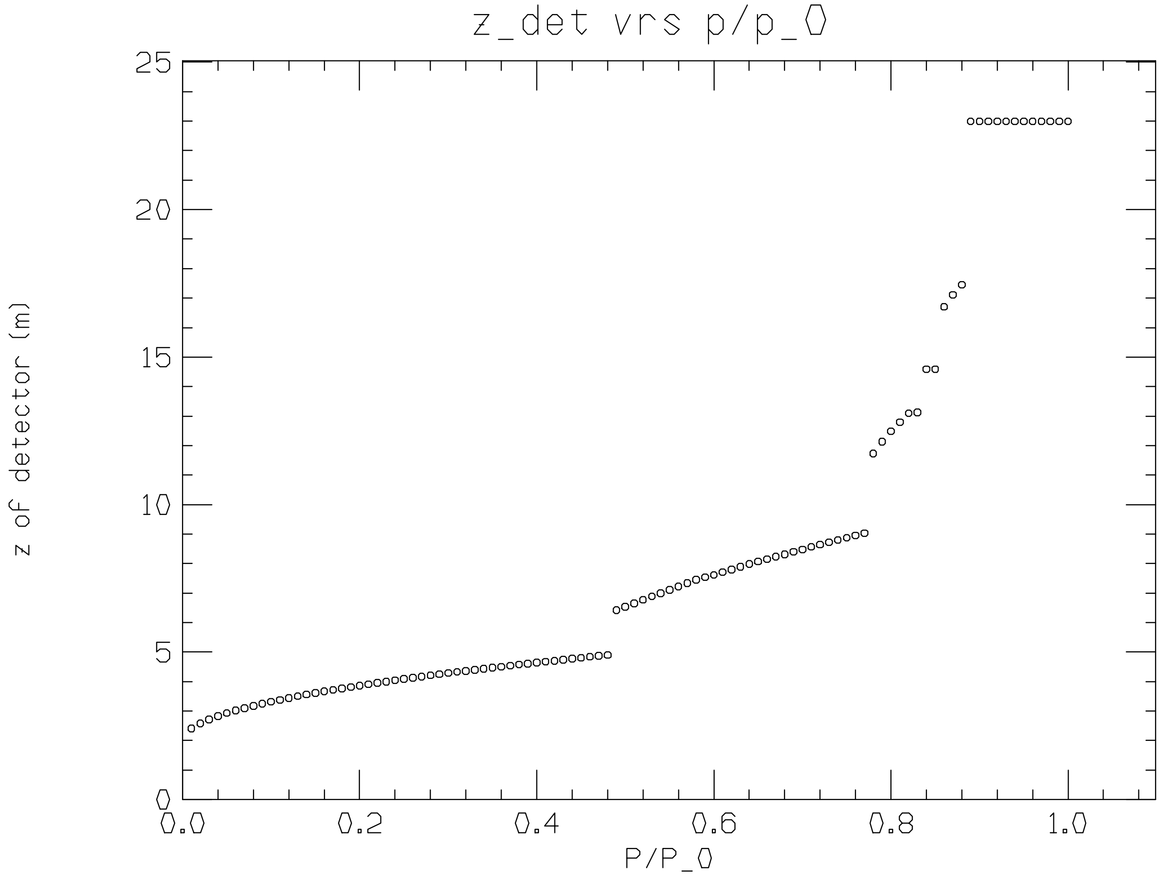

Figure 2: z of where a particle hits a vacuum chamber versus $\delta P/P$ for electrons in the A-line dump. The upper right circles miss the vacuum chambers and hit the wire array.

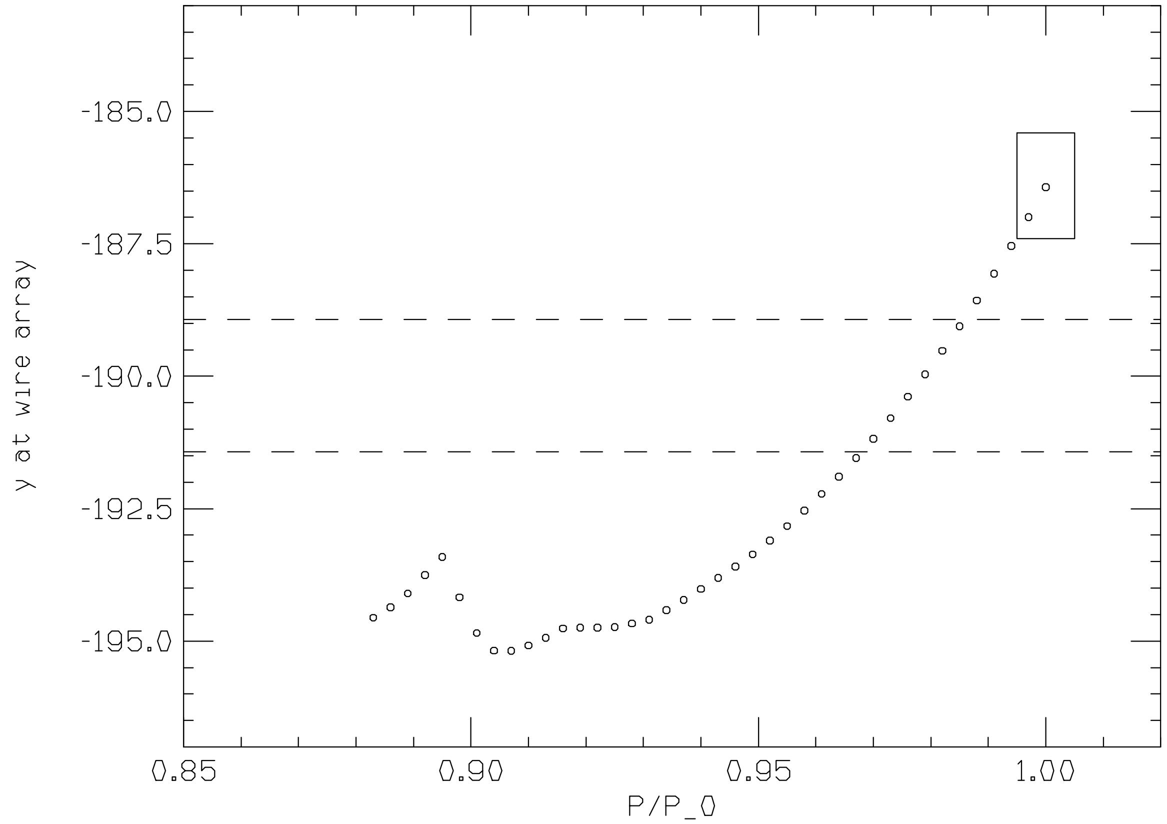

Figure 3: y position of the electron beam 5 m past B36, as a function of relative momentum. The bump around 0.9 is caused by the non-uniformity of the B33-B36 magnetic fields. The rectangle shows the approximate wire array size, and the dashed lines correspond to collimator radii of 2.5 and 5 cm.

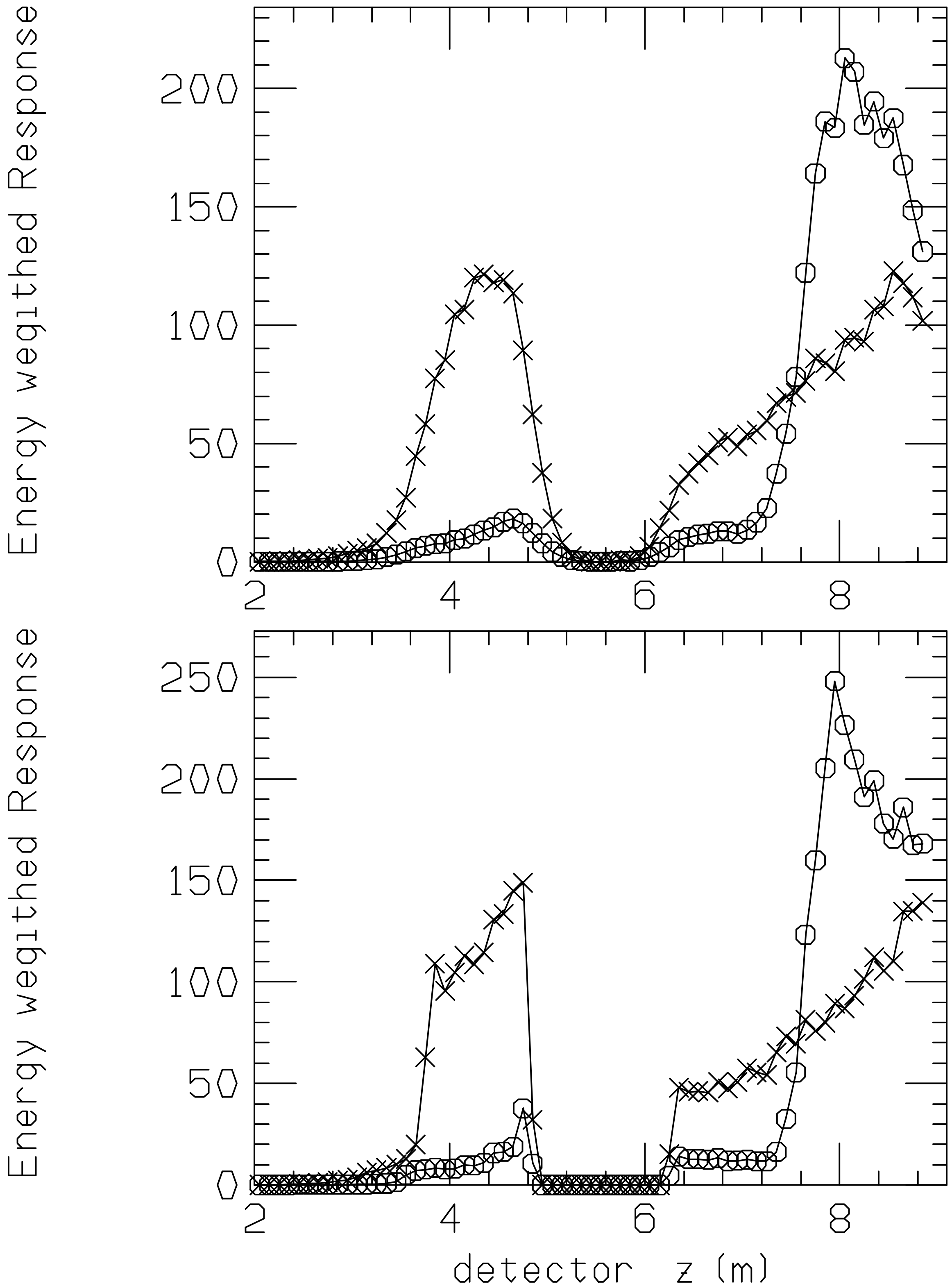

Figure 4: Response of ion chamber detectors as a function of z. The regions of no response correspond to the gaps between the magnets. The crosses (circles) are for E160 photon spectra with coherent photon peaks at 35 (15) GeV. The top panel includes 10 cm resolution smearing.