Beam-stahlung Gamma Detector/ Large Crossing Angle Extraction Beamline Interface Issues

William M. Morse

Brookhaven National Lab, Upton, NY, USA

September 12, 2006

We give here some information on our BNL, DESY Zuethen, Yale ideas about the large crossing angle beam-strahlung gamma detector. First of all, we briefly review why we believe it will be useful to measure the beam-strahlung gammas.

1. Energy. A measurement of the beam-strahlung gamma energy tells us directly what the IP energy loss is. Typically, the beam-strahlung gamma energy is about 2% of the beam energy for the nominal ILC parameters. This measurement will be complementary to the electron and positron energy measurements before and after the IP.

2. Fast Luminosity Measurement. The fast feed-back group requests a signal at 3MHz (the bunch rate) which is effectively proportional to the instantaneous luminosity. We plan to measure the pairs in the BeamCal and the gammas in the GamCal. The pairs are produced mainly through the Bethe-Heitler process [1]. Thus:

$$N_{ee} \propto \frac{\sigma_{BH} N_\gamma N_e}{A} \quad (1)$$

$$\frac{N_{ee}}{N_\gamma} \propto \frac{N_e}{A} \quad (2)$$

The ratio of the pairs to the gammas is thus effectively proportional to the luminosity. This is also true for the ratio of the energies, as the Bethe-Heitler cross-section has only a weak dependence on energy. Simulations have shown that this relationship works remarkably well [1]. Fig.1 shows one plot from ref. 1.

3. Bunch Characteristics. The feed-back group requests information on the bunch characteristics at 5Hz (the train rate). The gammas give complementary information to the pairs on the bunch characteristics [1], ie. compare Fig. 1 with Fig. 2. Another point to make here is that we want to minimize the beam energy radiated into the gammas for physics studies like ee → Zh with the Z decaying to μμ. If the beams are misaligned vertically, then the luminosity is lower and the radiation is higher (see Fig. 2a).

4. Polarization. The spin precession through the intense electro-magnetic fields during the beam crossing is effectively proportional to the Lorentz force [1]. The beam-strahlung

power is proportional to the Lorentz force squared. Although these are different quantities (vector vs. scalar), we believe the beam-strahlung energy measurement will give valuable complementary information of the IP spin precession.
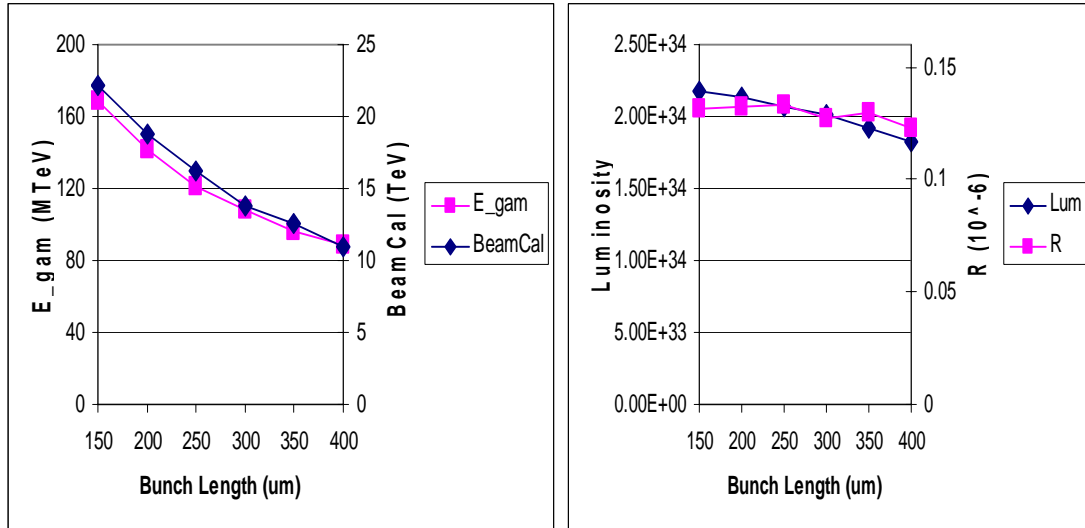

Fig. 1a) Pair energy as measured in the BeamCal and the beam-strahlung gamma energy vs. bunch length; 1b) Ratio of BeamCal energy to the beam-strahlung gamma energy and luminosity vs. bunch length.
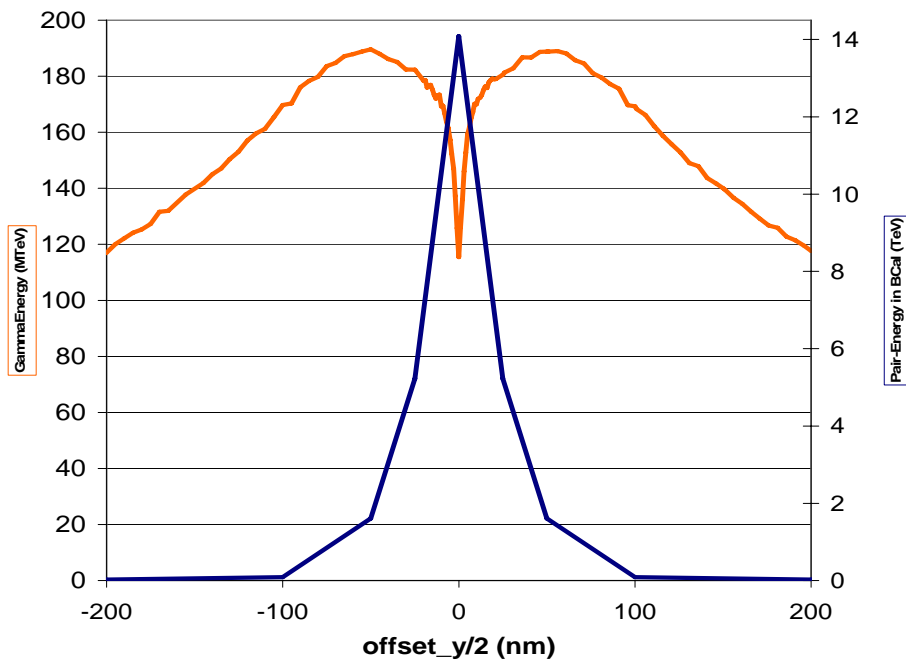

Fig. 2a. Pair energy as measured in the BeamCal and the beam-strahlung gamma energy vs. bunch vertical offset.
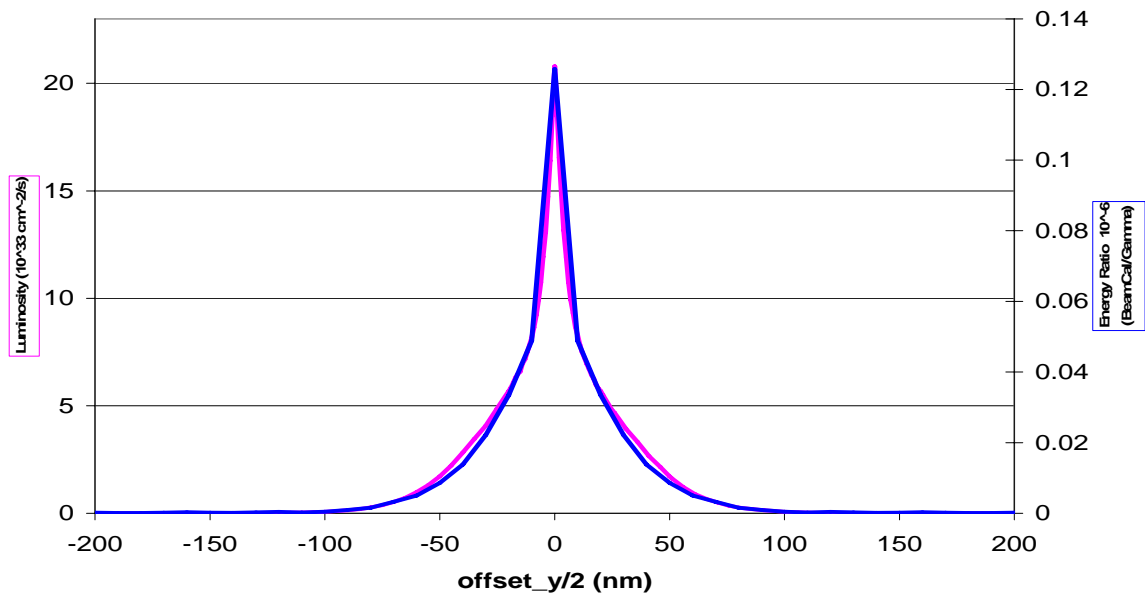
Fig. 2b.) Ratio of the pair energy as measured in the BeamCal to the beam-strahlung gamma energy and luminosity vs. bunch vertical offset.

A plot from the fast feed-back talk at Vancouver is shown below. During the first 100 bunches, the beams are brought into collision using the beam-beam deflections as measured by the pick-up electrodes. Then using the signal proportional to luminosity, scans are performed. Finally, the remaining 2.5K bunches are run with optimal luminosity.

Intra-train y + y' IP feedback simulations
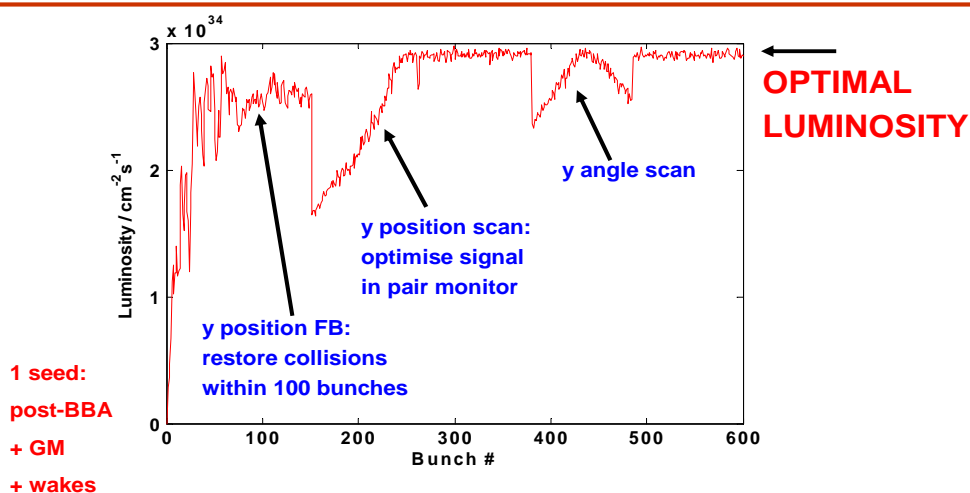
P.N. Burrows

We would like the GamCal to be close to the position and angle kickers. However, we may have to place the GamCal after the energy and polarization detectors to avoid creating backgrounds for these detectors. The polarization detector is at z=175m. If we place the start of the GamCal at z=185m, then even if there is background, it will arrive at the polarimeter detector out of time by 60ns.

It takes the beam 0.55μs to get from the IP to z=185m, and another 0.55μs for the GamCal signal to get back to the IP location on an air core cable, although the kickers are closer than the IP. This is ≈1.1μs × 3MHz = 3-4 bunch crossings. This is unpleasant, but perhaps acceptable, since the scans over one hundred bunches in Fig. 3 are pretty linear. Another way to look at it is that if the bunch characteristics change a lot over 0.33μs, then fast feed-back wouldn't work at all! Our request to the BDS team is to be as close as possible to the position and angle kickers.

The next unfortunate feature of the large crossing angle extraction beam-line is that the electron and gamma beams largely overlap each other. Table 1 shows the beam sizes at z ≈ 185m.

Table 1. Approximate width and height of electron and beam-strahlung distributions at z ≈185m for perfect collisions. The centroids are at 0.

	Hor core	**Hor edge**	**Vert core**	**Vert edge**
Electron	±2cm	±5cm	±0.3cm	±1.5cm
Gamma	±4cm	±7cm	±0.9cm	±1.8cm

For non-perfect collisions, the horizontal distributions don't change much, but the vertical gamma distribution grows to approximately match the horizontal. The vertical electron distributions grow much less. Of course, we would like for the BDS group to separate the gamma and electron beams for all collision cases. However, in case this proves difficult, we have investigated a GamCal detector for the Table 1 parameters.

The basic idea is a gas jet which converts ≈10[-6] of the gammas, followed by a magnet which separates the "wrong sign" particles from the beam. One would guess that the backgrounds from the electron beam interacting with the gas jet would be large. However, we have found that they are small (see ref. 2). Briefly, this is because:

1. There are more beam-strahlung gammas than electrons, and

2. We have designed the system to maximize our acceptance for the signal and minimize it for the backgrounds.

We have calculated the necessary vacuum pressure to keep polarimeter detector backgrounds sufficiently low in the polarimeter chicane (<10[-6] Torr, see ref. 2). This should be achievable, although we don't have a gas target/vacuum design now, but would come up with a design as part of our R&D efforts. A sketch of the detector is shown in Fig. 3. This has not been optimized, and we look forward to give and take with the BDS team.
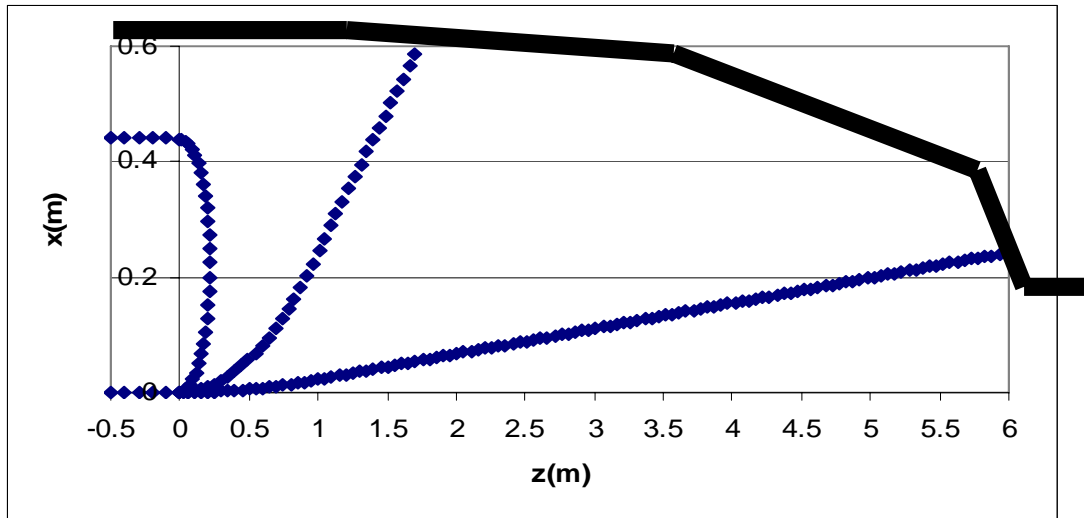
Fig. 3. Gas jet followed by a 1m long 1.5T dipole magnetic field. Trajectories of positrons of momentum 0.1, 1, and 10 GeV/c are shown. We are interested in the energy range ≈1-10 GeV positrons (in the electron extraction beamline). Calorimeters would be distributed in z outside the vacuum chamber (solid black line).

References

1. W. Lohmann, W. Morse, and M. Ohlerich, to be submitted as an ILC Note.

2. W. Morse, GamCal R&D Note.