# Chapter 7

# Methods for recreating ILC backgrounds: Method C

Three methods of creating a beam to use in conjunction with the FONT module were developed as described in section 5.1 and table 5.1. In this chapter, Method C is described.

## 7.1 Methods for creating spray: C

### 7.1.1 Overview

In the ILC simulations, the particles that hit the BPM striplines came from particles that hit the low-Z mask (figure 3.26) and went on to shower in the material of the BeamCal (figure 3.18). Method C was developed to reproduce the energy density and number density of particles that hit the low-Z mask in the ILC simulations at ESA.

To illuminate the whole low-Z mask with impacting particles as at the ILC, it was planned to use a beampipe-filling spray. This could be produced using a thick target in the beam switchyard (BSY) [108]. The magnets in the beamline between the BSY and ESA (called the A-line) could be tuned to deliver a momentum bite of the spray with 2% spread to ESA.

The flux of the spray beam could be controlled using adjustable slits (SL10) and the beam charge. The energy could be controlled with different momentum settings for the A-line. By adjusting these together, the average number density and energy density of particles hitting the low-Z mask in the module could be matched to the ILC conditions.

### 7.1.2 Thick Target Simulations

A beryllium target exists in the SLAC BSY. It is 42.7% of a radiation length thick (figure 7.1). This was modeled in GEANT3. The model for this stage was very simple: a disc of beryllium, 15.24 cm long in the beam direction. Using the random number generator incorporated in Matlab and the expected emittances [96] at the point of the target, an incident bunch of $10^5$

electrons was generated. Beam energies of 7 GeV, 10 GeV, 15 GeV, 20 GeV and 30 GeV were used[1].

The particles were recorded as they left the target. Due to the creation of low energy electrons and the multiple scattering of the incident beam, the beam after the beryllium target contains particles with energies from 0 to the incident beam energy (figure 7.2).

The incident beam at the BSY is small in $\sigma_x$ and $\sigma_y$ (as stated in table 5.1). After the beryllium target, the beam fills the beampipe (figure 7.3).

The use of the beryllium target therefore provides a beampipe-filling spray beam of containing particles with energies from 0 to the energy of the incident beam.

### 7.1.3 Tracking in the A-line

The spray from the beryllium disc is produced at the end of the linac in the Beam Switch Yard and then passes through the B2 magnet which selects a certain momentum slice for transport down the A-line. Particles that are not bent by the magnet into the A-line proceed to the D10 dump (calculations indicate that the dump will be able to deal with the particle fluxes required for this experiment well within the safety margin [108]). The electrons that are bent into the A-line continue through the beam line (as described in the A-line configuration for E-158 [109]) comprising of various elements including slits (SL10) that can be opened or closed, thereby allowing variation of the flux of particles that are allowed through.

To track the electrons generated in the spray down the A-line and into the End Station, MatMerlin [110] (Merlin [111] within the Matlab environment) was used. It constructs a model of an accelerator from a MAD generated file [112] and uses MerlinC++ libraries to track particles. MatMerlin does not deal with particles hitting targets and then scattering or producing more particles, so collimation needed to be dealt with separately. The tracking was done step-by-step, initially tracking a bunch without any collimation then chopping the beam at the relevant positions and with the relevant aperture as if each collimator was a 100% absorber. Ideally the beam would be tracked to the collimator and GEANT used to find how the bunch interacts with it. The output from GEANT would be used to continue tracking. This was not performed in the preliminary investigation. Synchrotron radiation needed to be turned off as tracking with this method failed otherwise. It is not expected to affect the result as synchrotron radiation is negligible at these low energies [113].

Using the results of the spray generation from the GEANT3 model, the bunch of electrons was tracked from the position of the beryllium target to the position of the FONT module in ESA. The magnets in the beamline can be tuned within MatMerlin to transport a particular energy so only a section of the spray electrons are successfully transported; the rest are not deflected along the beamline and are removed via the 100% collimation routine. The spray beam, once it is transported to the final position, is a couple of centimetres wide and would fill the beam pipe at the ILC (see figure 7.4). The rectangular shape of the spray beam in figure 7.4 is due to upstream collimation at the rectangular entrance (D10) to ESA. This

[1]The SLAC linac can deliver up to 50 GeV beams.

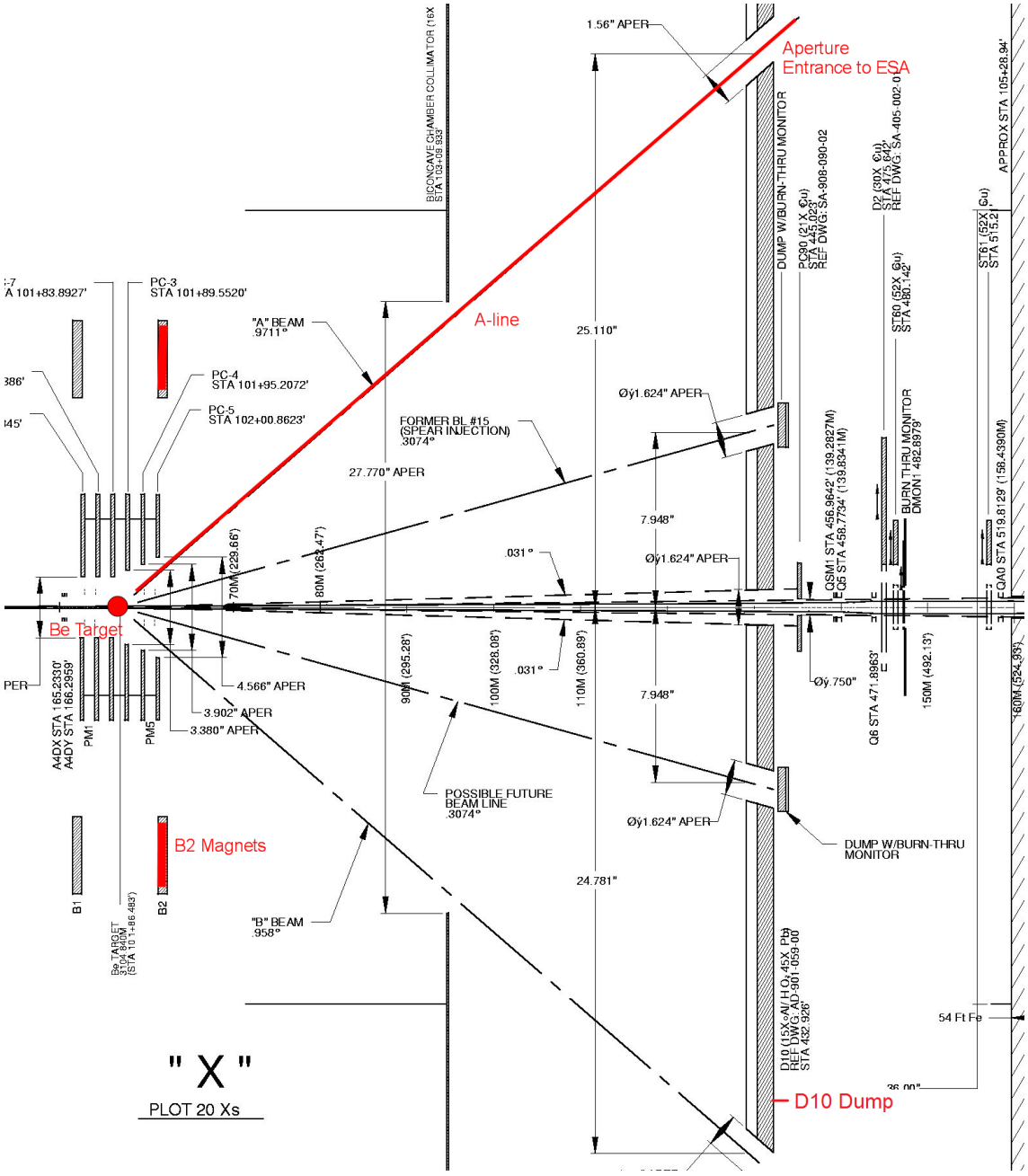



Figure 7.1: Layout of the Beam Switch Yard (BSY) and A-line [108]. The beryllium target is shown (labeled Be Target) and also magnets (labeled B2 Magnets) to deflect the beam from the linac to the A or B line. The entrance to the End Station is a 1.56 inch rectangular aperture (labeled Aperture) in the D10 dump.

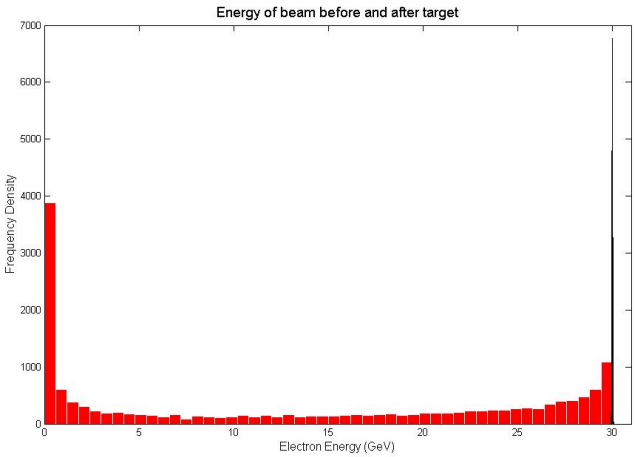



Figure 7.2: The electron energy distribution for a 30 GeV beam (±0.2% energy spread) incident on the beryllium target (black) and the electron energy distribution of the beam after the beryllium target (red).

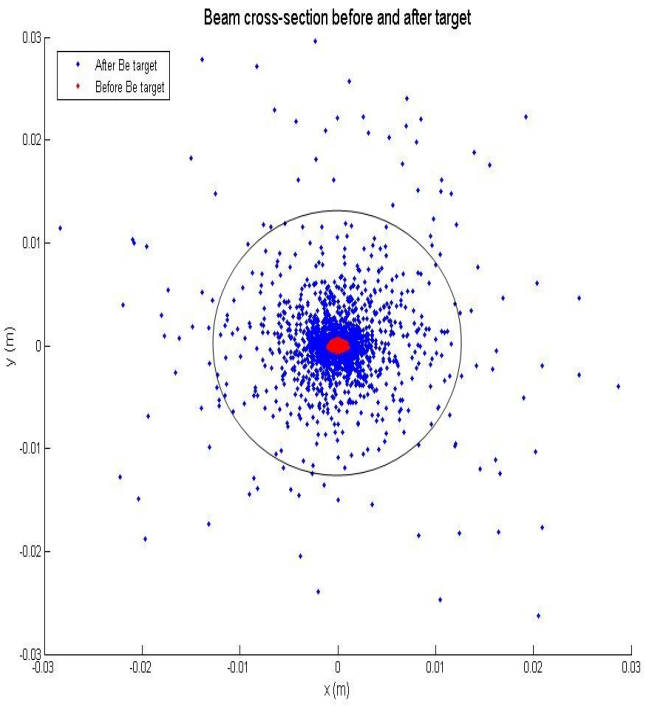



Figure 7.3: The x-y distribution of the incident beam of 30 GeV electrons (red) and the spray generated from the target (blue).

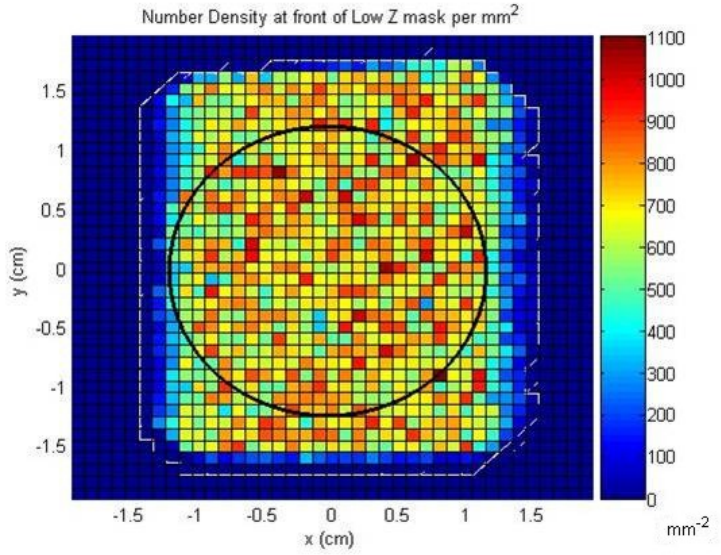



Figure 7.4: The number density (per mm$^2$) of the spray at the position of the FONT module. The inner radius of the low-Z mask is marked as a black circle.

wide spray beam is a closer match to the spatial distribution at the ILC of the low energy background pairs on the low-Z mask (see figure 3.25) than Method A (see figure 5.1) or Method B (see figure 6.1).

The tracking from the target to ESA was repeated with the beamline tuned to various acceptance energies and also for different incident beam energies hitting the target. The fraction of electrons that survive to the position of the FONT module was recorded and plotted against the momentum setting of the A-line for different energies of the electrons incident on the beryllium target (figure 7.5). This graph allows estimation to be made of the fluxes expected at ESA given the energy at which the linac is running, the momentum setting of the A-line and the beam charge.

## 7.2 Simulating the experiment: Method C

As before, it was checked through simulations that these conditions were not dissimilar to those at the ILC with regards to the hits on the BPM striplines. $1 \times 10^6$ 28.5 GeV electrons were used as the beam incident on the beryllium target. The A-line momentum was set at 4 GeV/c. The output from the A-line tracking was used as input to a GEANT3 simulation of the module. The energies of the charges that hit the striplines were recorded. Figure 7.6 shows both the energy distribution from the ILC GEANT3 simulations [87] and this Method C simulation. The distributions are similar as anticipated as the module materials match the IR materials.

Such simulations were repeated with different tuned momentum selection in the A-line with different beam charges to demonstrate that for a fixed linac energy (in these simulations, 28.5 GeV) any ILC scheme could be matched in both energy and number density of charged particle hits on the low-Z mask. The results are shown in figure 7.7. In this figure, data

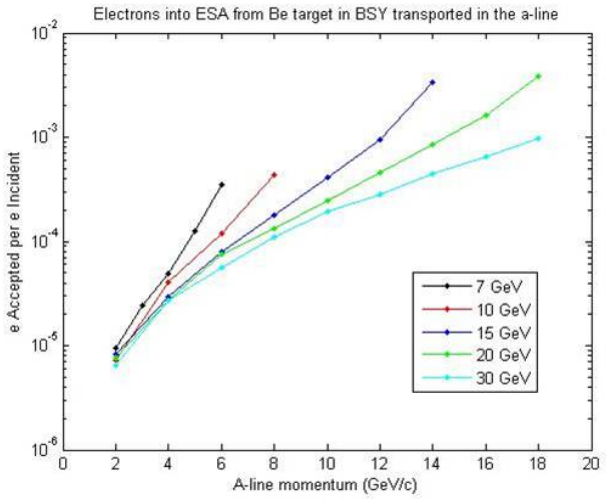
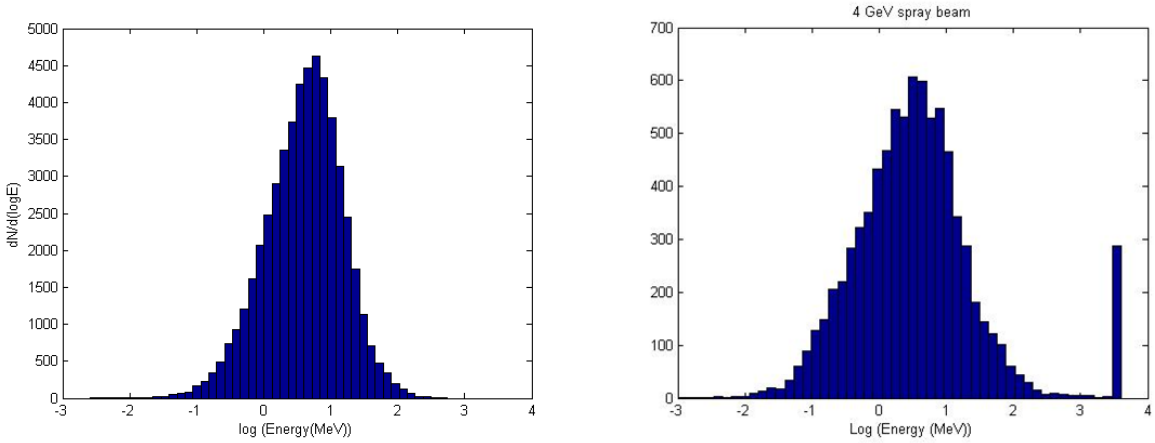


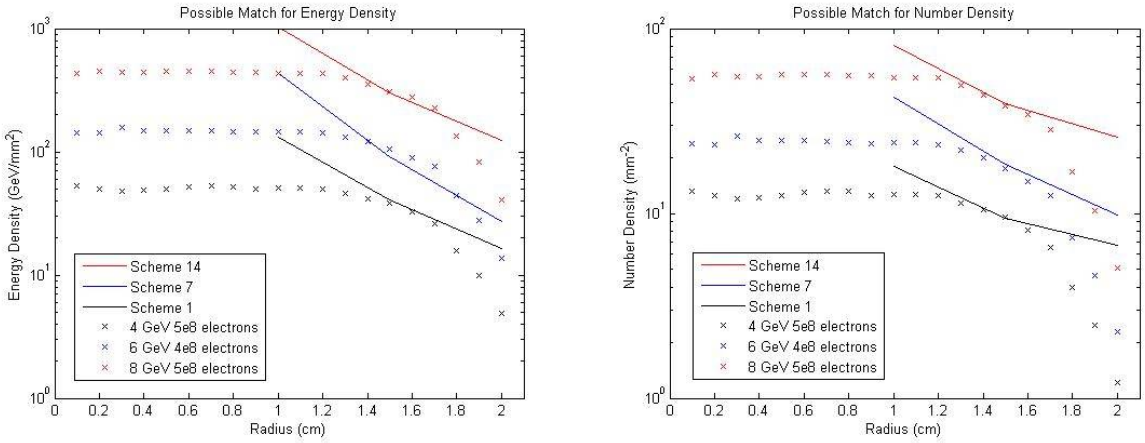

Figure 7.5: The number of electrons per electron incident on the beryllium target that reach the FONT module depending on the momentum setting of the A-line (x axis) for different linac energies (7 GeV in black, 10 GeV in red, 15 GeV in blue, 20 GeV in green and 30 GeV in cyan).




(a) ILC Scheme 14, 14 mrad crossing angle. 10% of the full simulation.

(b) Method C (as described in the text).

Figure 7.6: The energy distribution of particles that hit the striplines in GEANT3 simulations.




(a) Energy density

(b) Number density

Figure 7.7: The average energy and number density of the particles versus radius. ILC schemes (full lines) are compared to the average energy and number density of the particles in Method C (crosses).

are shown from simulations of the ILC with the 20 mrad crossing angle and pairs from the beam-beam interaction of three schemes: 14, 7 and 1 (that is, the 1 TeV high luminosity scheme, the 500 GeV high luminosity scheme and the 500 GeV TESLA scheme as described in tables 1.2 and 1.3). The number density and energy density of the charged particles hitting a plane at z = 3.12 m, just in front of the low-Z mask, are shown as lines. These densities are the values to be matched at ESA since previous studies (figure 3.26) indicated that the particles that hit the low-Z mask are the ones to cause hits on the striplines. The figure shows the Method C produced background densities that are close to matching those of the ILC schemes. For example, $5 \times 10^8$ electrons of energy 28.5 GeV incident on the beryllium target and an A-line momentum setting of 8 GeV can match the number and energy densities of the charged particles hitting the low-Z mask at the ILC with the scheme 14 accelerator parameter set.

It seems unlikely from the results of the other methods that this method would produce any signal at all on the striplines unless the ILC conditions were exceeded rather than matched. By using the maximum beam charge at ESA of $2 \times 10^{10}$, the Method C set-up with the incident 28.5 GeV electrons on the beryllium target and the A-line momentum setting 8 GeV exceeds ILC Scheme 14 conditions by a factor of 40.

## 7.3 Summary to Method C

Method C was developed to more closely match the number and energy density of particles hitting the low-Z mask, previously shown to be the sources for showers in the BeamCal that create the backgrounds at the stripline location. This method involves creating a spray beam of electrons that fills the beampipe. The existing beryllium target in the beam switch yard at SLAC is suitable for this purpose and produces a wide beam of energies from 0 to the incident beam energy. The energy to be transported to the end station can be selected

by tuning the magnets of the A-line to transport a momentum bite of this spray, the rest going to a dump. By carefully choosing the initial beam energy, the initial beam charge and the momentum setting for the A-line, simulations using a combination of GEANT3 and MatMerlin show that both the energy and number density of primaries on the low-Z mask can be matched between ILC and ESA. Increasing the beam charge could make the conditions worse.

This method requires instrumentation capable of measuring very low beam charge (see also Method A section 5.2.3). Matching ILC conditions for ILC accelerator scheme 1 requires $5 \times 10^8$ 28.5 GeV electrons incident on the beryllium target and a 4 GeV/c A-line momentum setting (figure 7.7). The studies of the A-line acceptance (figure 7.5) indicate that the beam charge in the end of the A-line will be $\sim 10^4$ electrons per bunch.

Methods A and B were easier to implement in terms of the instrumentation equipment required and commissioning for radiation safety. The results from Methods A and B indicated that Method C, which is capable of producing backgrounds only 40 times worse than scheme 14 ILC backgrounds, would not have seen any effect on the striplines. Method A produced backgrounds ∼800 times worse and Method B, ∼1000 times worse, with only very small effects from the secondary backgrounds. Therefore, Method C was not used.