Technical Note
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The Bremsstrahlung Cone Profile as Measured by RadPhi with a Scanning Scintillator

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Abstract

Situated almost 40m downstream from the bremsstrahlung radiator in Hall B, the RadPhi experiment relies upon good collimation properties of the photon beam to ensure that the beam is essentially contained within the 2.5cm diameter target, and that the tails extending into the acceptance of the calorimeter and charge-particle veto are small. Using a small piece of thin scintillator mounted on the movable target platform at the nominal target position, scans of counting rate versus horizontal position were performed during the May 1997 run. These results are compared with what would be expected, based upon the bremsstrahlung cross section, for an ideal electron beam (zero emittance) to look for sensitivity of the photon beam profile to electron beam tune. Some evidence for electron beam effects are present; however it appears that these are minor and that, under the conditions of the May run, the self-collimation of the bremsstrahlung process is sufficient for the needs of this experiment.

The bremsstrahlung cone profile was measured by scanning a small scintillator through the beam at the position of the *RadPhi* target. Scans were performed during the May 97 run both at 1.4GeV and 4.0GeV electron beam energy, hereafter called endpoint. The angular distribution of photons from a thin bremsstrahlung target is described approximately by the following equation, after averaging over outgoing electron momentum and photon polarization.

$$\frac{dN_\gamma}{d\Omega} = \frac{1}{\left(\theta^2 + \frac{m^2}{p^2}\right)^2} \left(\frac{1}{q_{min}}\right)^4 \frac{p-k}{pk}$$

Here p is the electron beam energy, k is the photon energy, and q_{min} is the momentum transfer to the recoil nucleus in the bremsstrahlung target when all scattering angles are 0. The normalisation is arbitrary. Except for photon energies within 20% of the endpoint, last two terms are approximately constant across the photon beam, and the profile is given by the first term.

To describe the results of the beam scan, a two-dimensional image of above distribution was formed, and then integrated over the surface covered by the scintillator, assumed to by $2.54x2.54\text{cm}^2$. The results for a 1.4GeV endpoint are shown below, overlayed with the data points. To convert to cm, angles were multiplied by 3960cm, which is the distance from the centre of the radiator box at the tagger to the *RadPhi* target according to the drawing of Hall B. By comparing the solid and dotted curves, one can see how the bremsstrahlung cone shrinks somewhat as one approaches the endpoint. But the scintillator is sensitive mainly to the low-energy component of the photon beam, so the solid curve is the relevant one for this comparison.

It appears that the calculation actually overestimates the size of the photon beam. The same exercise was carried out again at 4.0GeV endpoint, with the following results

The original data for these figures were taken from the file `beamscan3.ps` pointed to from the *RadPhi* online web page. The measured points in these figures were shifted by +0.5cm to centre them at zero; other than that there are no adjustable parameters in this comparison. Again at 4.0GeV the measurements are narrower than the calculation. But here the edges of the measured peak are narrower than the nominal size of the scintillator! I conclude that the dimensions of the scintillator must be smaller than 1in. I went down to the hall and discovered two things, that the scintillator is only 1.9 ± 0.1cm wide, and it is oriented diagonally to the scan direction. The two figures above are repeated below with the curve recomputed under these new conditions.

There are no adjustable parameters used in calculating the curve in these figures, except the height of the peak, which was scaled to match the data. An excellent description of the data is obtained, indicating that the beam spread due to the electron beam emittance is very small. The asymmetric shape of the peak in Fig. 4 I take to be a consequence of an asymmetric electron beam spot at the tagger radiator. No collimator effects are evident in these data. In Fig. 5 is shown the calculated photon beam profile as it would be seen by scanning with a 1mm x 1mm scintillator, to show the actual photon beam profile at our radiator.

At energies very near the endpoint the spot is actually somewhat smaller. The shaded curve in Fig. 5 is for photons at 90% endpoint, adjusted to have the same area as the solid curve, which applies to the bulk of the bremsstrahlung flux. The thought occurs to me that we might make use of this fact by making our target small and picking out only the central part of the beam. It is one of the disadvantages of the tagging technique that you cannot throw away any more than the fringes of the beam because collimation hurts the tagging efficiency, defined as the number of usable photons on target per count in the tagger. Keeping our tagging efficiency above 90% in the upper 20% of the bremsstrahlung spectrum fixes a minimum *RadPhi* target diameter of about 1cm at a 4.0GeV endpoint. Using a target much larger than that makes alignment less critical, but generates somewhat more untagged background in our detectors, although the difference is not huge.

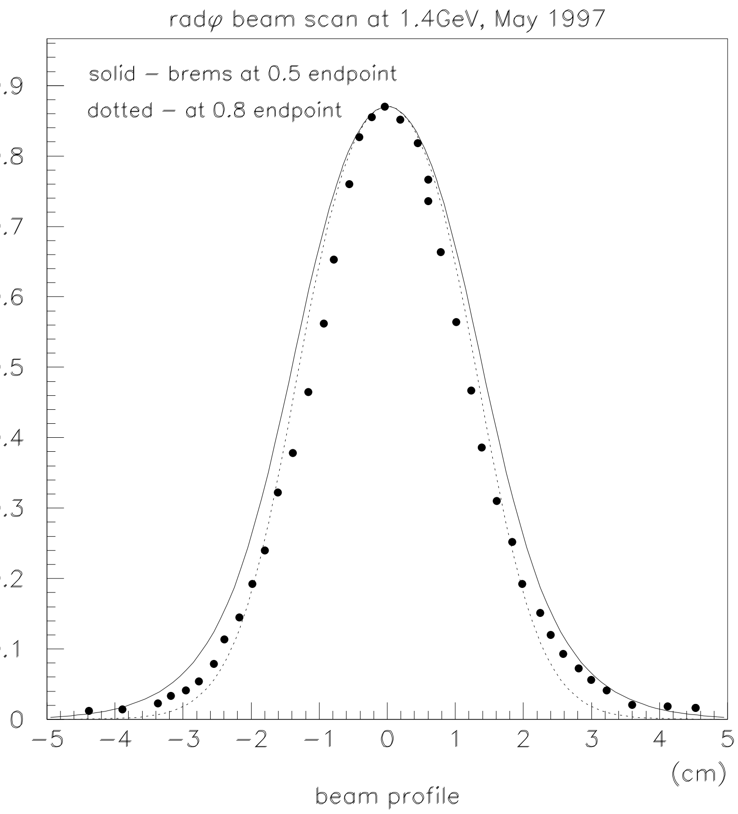

Figure 1: Solid curve is probability that a photon with a 1.4GeV endpoint bremsstrahlung distribution will hit the scintillator *vs* displacement. The data points are measured beam counter rates with a 1.4GeV electron beam, which have been overall normalized to the vertical scale of the curve.

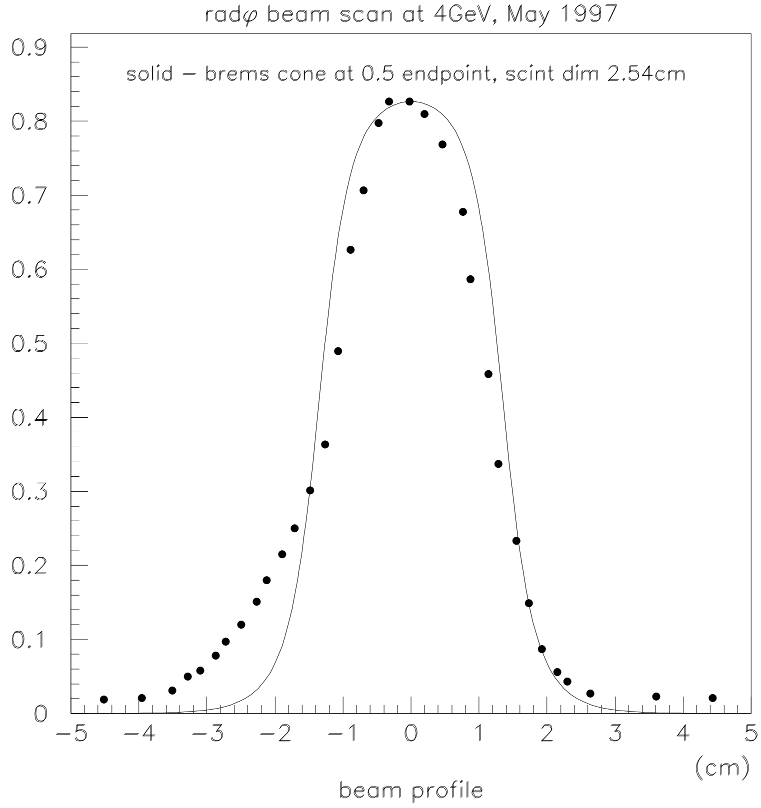

Figure 2: Solid curve is probability that a photon with a 4.0GeV endpoint bremsstrahlung distribution will hit the scintillator *vs* displacement. The data points are measured beam counter rates with a 4.0GeV electron beam, which have been overall normalized to the vertical scale of the curve.

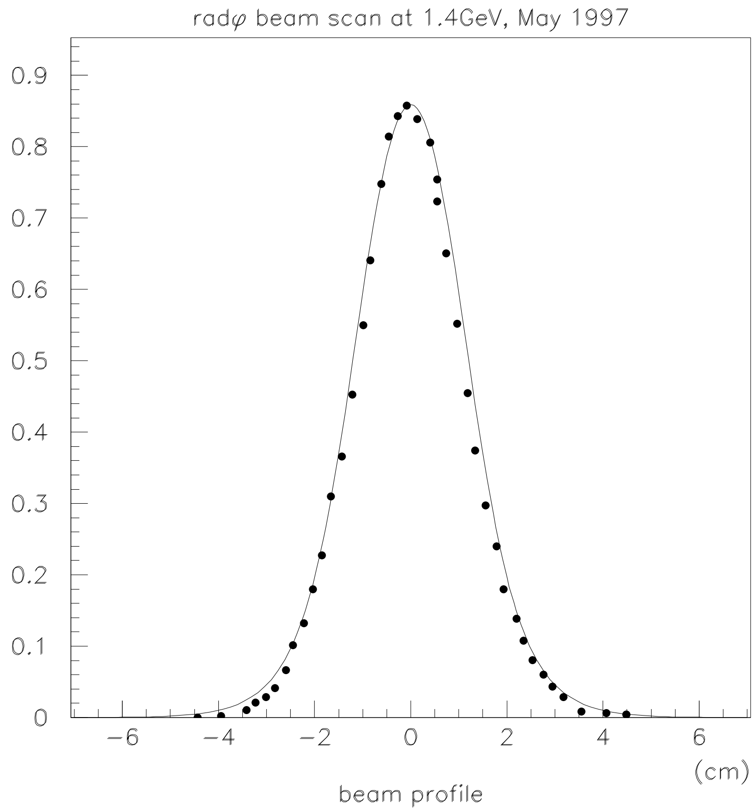

Figure 3: Same as Fig. 1 except that the curve has been recalculated with corrections for the actual geometry of the scintillator.

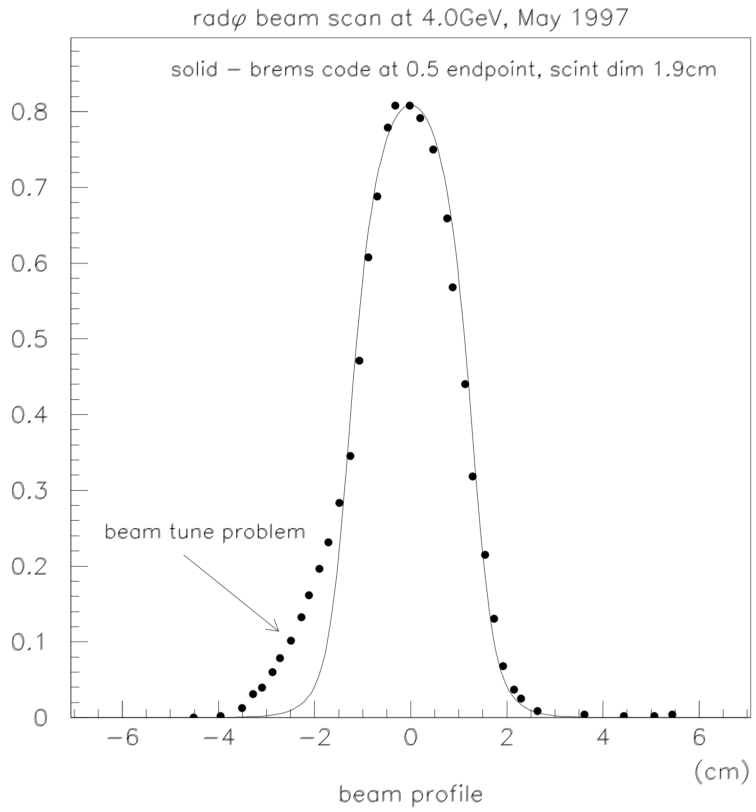

Figure 4: Same as Fig. 2 except that the curve has been recalculated with corrections for the actual geometry of the scintillator.

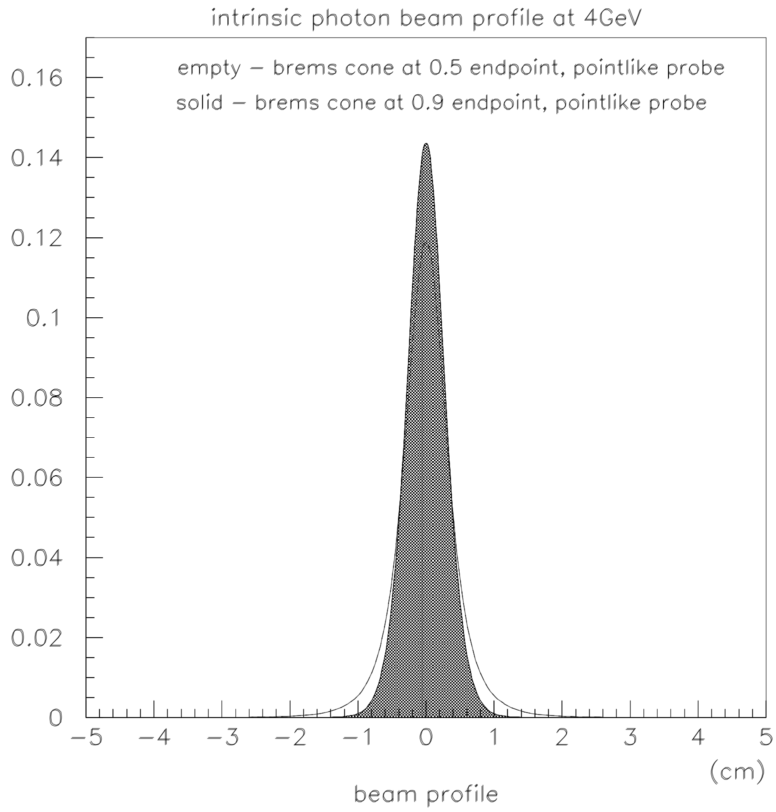

Figure 5: Probability that a photon with a 4.0GeV bremsstrahlung distribution would hit a small scintillator 1mm x 1mm *vs* displacement, to show the intrinsic beam spot size with negligible distortion from the size of the scanning scintillator. The open curve is the profile for the bulk of the bremsstrahlung spectrum, while the shaded curve applies to photons at 90% of the endpoint.