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Simulation of Interactions in the HARP Target Support

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Abstract

A target, together with the support and insertion tube, were modelled using GEANT3, in order to study interactions of the beam halo with the support material. Some interactions were observed, but their rate is several orders of magnitude less than that in the air inside the support tube. It is therefore concluded that the extra engineering work required to taper down the *inside* of the support tube is probably not worthwhile.

1 Introduction

At the HARP collaboration meeting on the 13th June, the question was raised as to whether beam halo particles would interact with the target support at a significant rate. If this was the case, it could cause problems, for example due to a build-up of ionisation in the TPC. The current design of the target insertion tube has a long aluminium section composed of a collar of external radius 43 mm near the support flange, followed by a tube which tapers down on the *outside* from 35 mm radius to 25 mm where it joins on to the 0.2 mm thick final support near the target. The inner radius of the insertion tube is constant at 21 mm. The interaction rate of beam halo particles with the insertion tube would be less if the taper was on the *inside*, with the outer radius being held constant. Such a construction, however, would present many more engineering problems, and should only be adopted if it prevents a serious problem. GEANT3 was therefore used to simulate both the intended target support and the expected beam profile within the HARP experiment.

2 The Target and Support

A geometrical description was provided of one of the standard targets – a 2% interaction length copper cylinder – and the current design of the insertion and support material. The latter is aluminium, varying in thickness from 22 mm where it passed through the magnet flange to 0.2 mm for the last 148 mm before the target. A view of the material is provided in figure 1, and in cross-sectional form in figure 2.

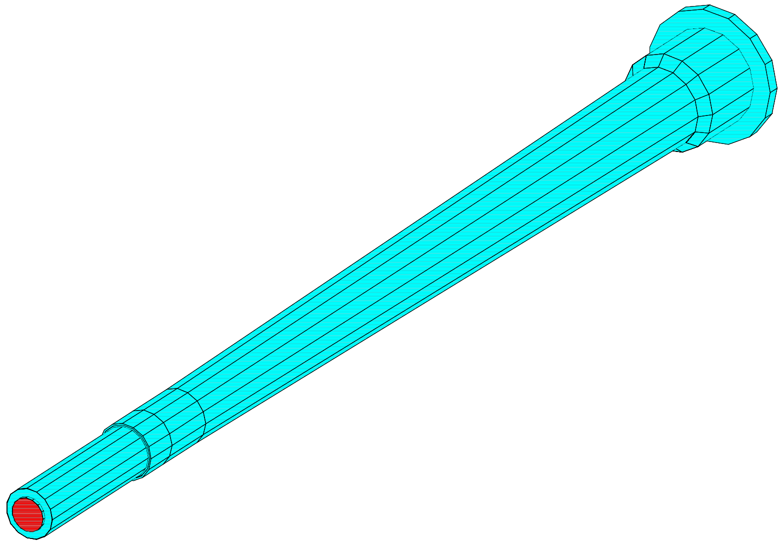

Figure 1: *View of the target and its support, as simulated in GEANT3.*

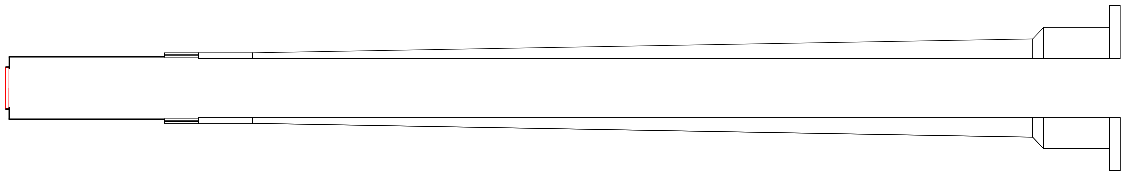

Figure 2: *Cross section through the target and its support.*

3 The Beam

Parameters of the beam were obtained from the proposed configuration for the t9 testbeam dated 17/4/2000, and are summarised in table 1. The beam converges to a focus which is in fact 0.6 m downstream of the position of the target (nominally called "focus B"). The beam is therefore much bigger on entry to the TPC solenoid structure, where the support material is also much thicker. (This is therefore the area where halo interactions are most likely to cause a problem.)

In order to simulate beam particles with the correct distributions of positions at the target and of divergence, parameters were first calculated at the true focus. Gaussian distributions were generated in x and y with appropriate variances. Independent angles (in the horizontal and vertical planes) were then also generated from further Gaussian distributions, and the particles were extrapolated back upstream a distance 3.27 m from focus B. (The generated beam profiles were plotted in x and y at both $z = -3.27$ m and the target for all runs, and their standard deviation checked against the tabulated values.)

For the tests described in this note, protons were generated with a momentum of $10\,\mathrm{Ge}V/c$ and beam parameters as described above. These then propagated down to the target, possibly interacting

Position	Horizontal σ (mm)	Vertical σ (mm)
Nominal focus B	2.25	1.75
1.25 m upstream	2.75	4.75
3.27 m upstream	4.25	9.5

Table 1: *Beam size at various points near the focus. (N.B. These values are a factor of 4 less than the "2 sigma diameters" quoted on the distributed plots labelled 17/4/2000.)*

in the support structure on the way. The coordinates of the (first) interaction vertex – if the particle interacted at all – were recorded and displayed in histograms.

4 Results of Simulations

Ten million protons were generated with the beam parameters described in the previous section. Figure 3a) shows that about 200,000 interactions occured close to $z = 0$, that is inside the target. This is in agreement with a target 2% of an interaction length thick. On the linear scale, no vertices are visible upstream, corresponding to the material of the support structure. However, when viewed on a logarithmic scale in figure 3b), 2 vertices are visible just over a metre upstream. This corresponds to the position of the support collar which passes through the upstream magnet yoke.

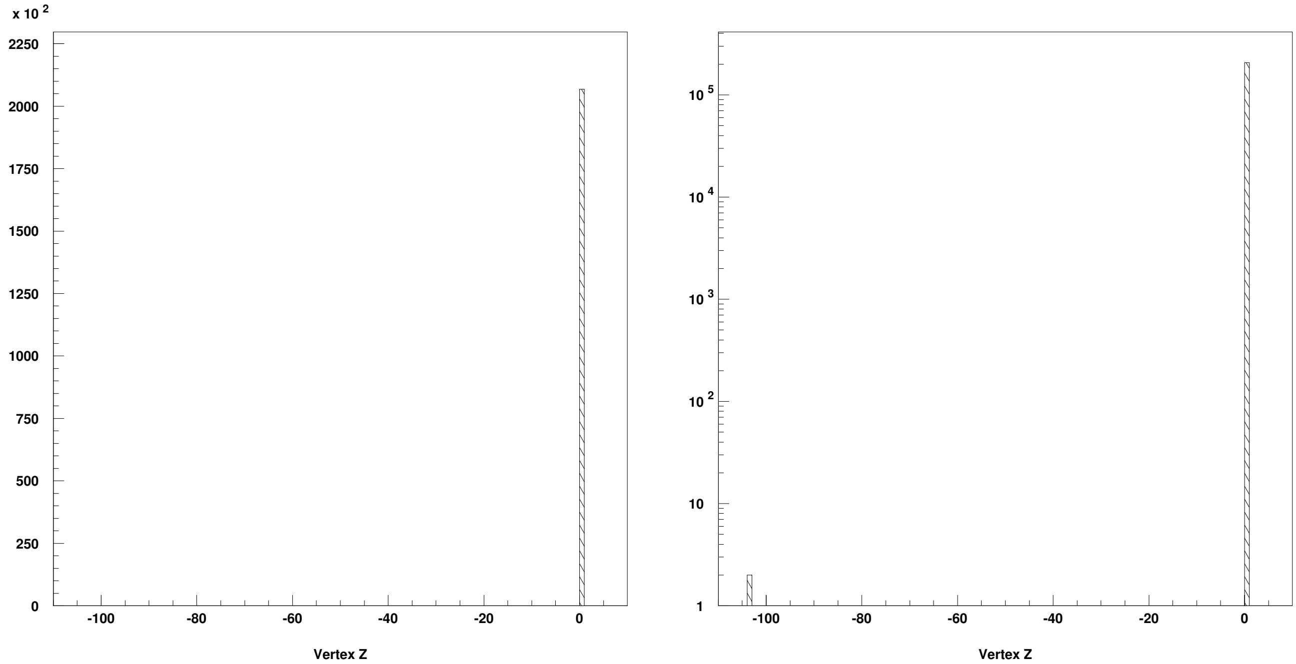

Figure 3: *z coordinate of interaction vertices; a) linear scale, b) logarithmic.*

The first simulation clearly does not provide enough statistics to study interactions in the support in any detail. Since it took a few hours of computer time, it is evident that running long enough simulations of this type to get high statistics for interactions in the upstream material is not practical. For this reason, it was decided to generate events from a broader distribution of beam positions and angles, and then weight them such that the weighted distributions corresponded to the original distribution of particles. For each of the 4 x and y, position and angular distributions, a value was chosen from a Gaussian distribution with a width twice as great as previously. In each case, the probability of the value having been drawn from the original Gaussian was calculated, and the product of these values used to weight the event in all plots. (Once again, the x and y beam profiles were examined, and their standard deviations agreed with the required values.)

A million beam protons were generated in this way, and their average weight found to be 0.062. Figure 4 shows the z profile of the interaction vertices. A weighted number of 1303 particles interacted within the target (consistent with 2% of an interaction length and an equivalent weighted total number of particles of 62,395). The weighted number of particles interacting in the support structure is 0.009. The profile shows that, as expected, the interactions are concentrated upstream where the beam is larger and the material is thicker. Figure 5 shows the x and y distributions of the interaction vertices. The much larger size of the beam in y (the vertical plane) is apparent. (The target and support are axially symmetric).

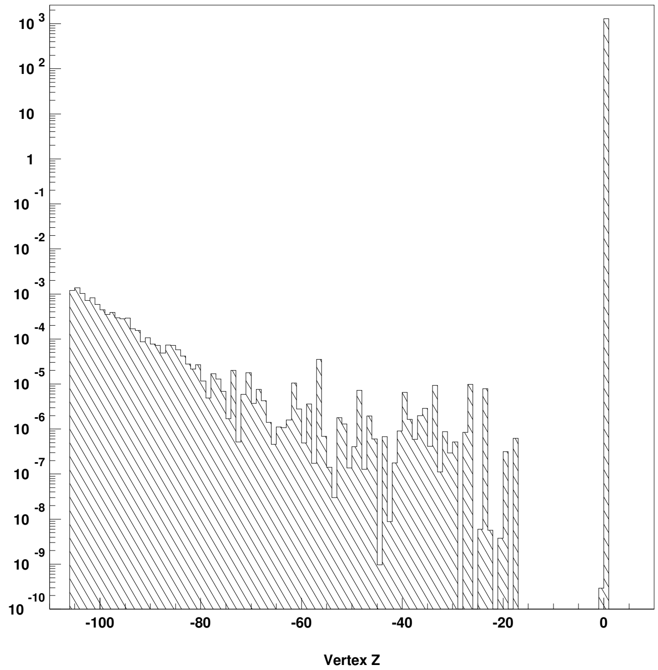

Figure 4: *z coordinate of interaction vertices, from weighted run.*

In order to make a judgement as to whether the interaction rate in the support material is a problem, it was decided to repeat the simulation with the support tube filled with air. (In the previous runs, the tube was empty, i.e. effectively evacuated.) A similar weighted run was performed, and new vertex profiles generated. Figure 6 shows the z profile of this run (empty histogram) superimposed on the previous distribution (shaded). It can be seen that there is an interaction rate of just below 1 event per cm, throughout the simulated region. (This is entirely consistent with having 62,395 particles passing through air with an interaction length of 746.9 m, from which 0.84 cm^{-1} is expected.) The interaction rate in air is thus about 4 orders of magnitude greater than that in the target support structure.

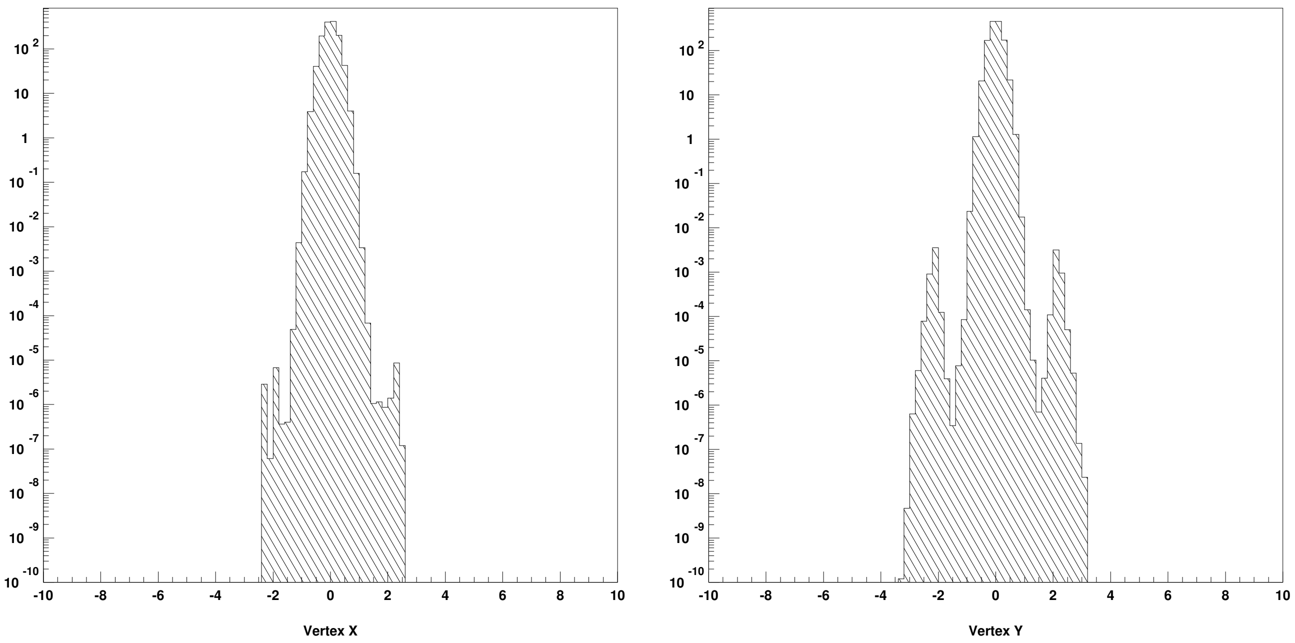

Figure 5: *x and y coordinates of interaction vertices.*

5 Conclusions

The expected HARP beam profile has been simulated, and interactions in the target support structure examined. It is found that the interaction rate in the support, as currently designed, is about 5 orders of magnitude less than that in a "thin" target (2% of an interaction length). Further, the rate of interactions in the air, which are unavoidable, is almost 4 orders of magnitude greater than that in the support.

It is therefore concluded that the complicated extra engineering required to reduce the amount of material close to the beam is not worthwhile. (It should also be pointed out that tapering the support from the inside has most effect closest to the target, where the beam is already more focussed and interactions are less likely.) Interactions in the air will occur at about 7% of the rate at which they occur in thin targets, and this should be borne in mind for future calculations of background rates.

Finally, it must be observed that the present simulations have assumed that any non-Gaussian tail in the beam profile will be negligible. This is apparently what is expected, but until real beam profiles have been measured this will remain an assumption which, if wrong, could have a serious impact on all the conclusions!

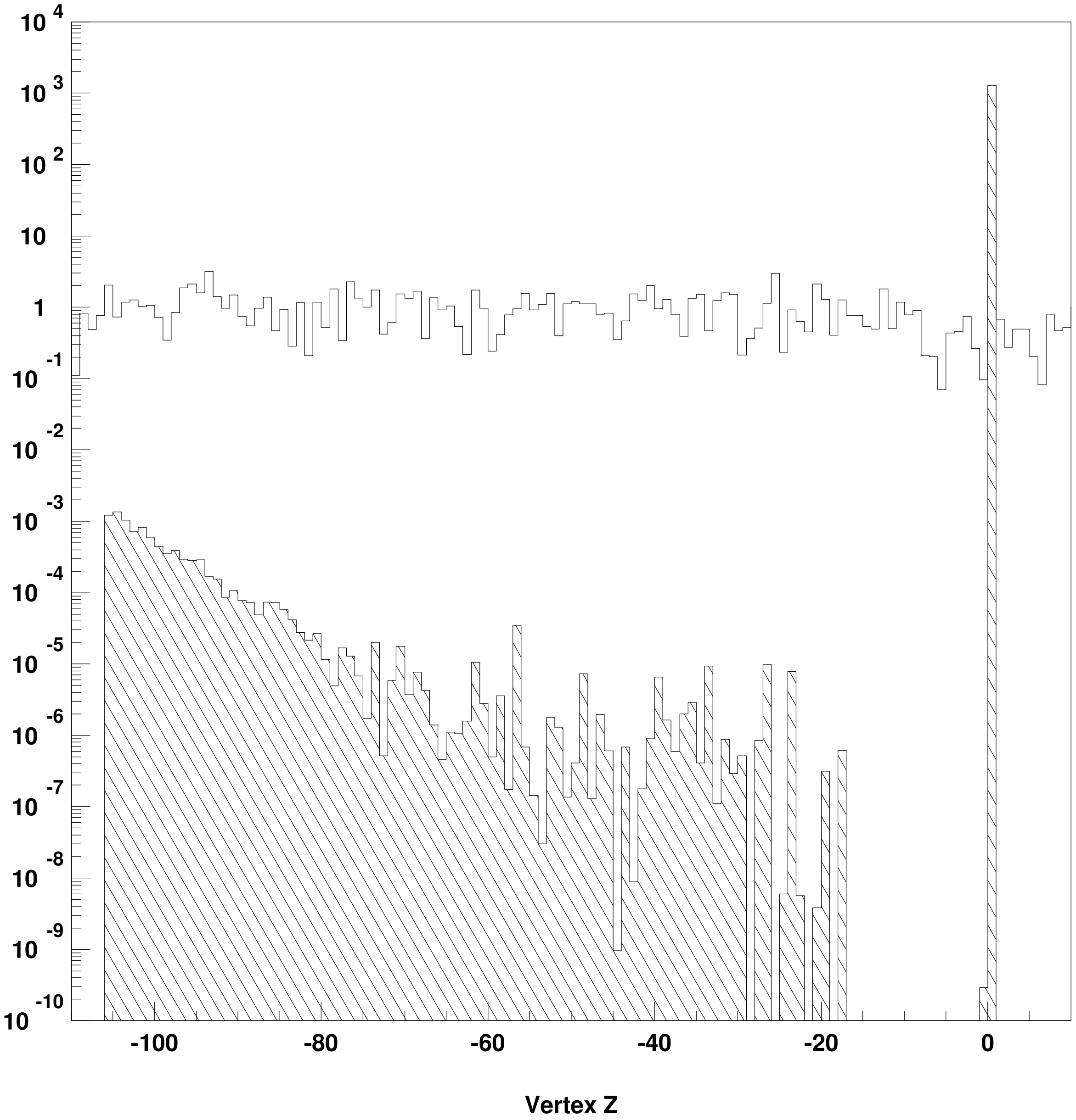

Figure 6: *z coordinate of interaction vertices: open histogram with air in tube, shaded histogram without.*