because it can lead to charge misassignment, but it contributes less than 0.01% to the the total energy loss [39].

Photonuclear interactions account for about 5% of the total energy loss of high-energy muons in iron, and for about 2% in uranium [47]. The losses are concentrated in rare, relatively hard events.

These radiative cross sections are expressed as functions of the fractional energy loss ν. The bremsstrahlung cross section goes roughly as $1/\nu$ over most of the range, while for the pair production case the distribution goes as ν^{-3} to ν^{-2} (see Ref. 48). "Hard" losses are therefore more probable in bremsstrahlung, and in fact energy losses due to pair production may very nearly be treated as continuous. The momentum distribution of an incident 1 TeV/c muon beam after it crosses 3 m of iron is shown in Fig. 10.12. The most probable loss is 9 GeV, or 3.8 MeV $\mathrm{g^{-1}cm^2}$. The full width at half maximum is 7 GeV/c, or 0.7%. The radiative tail is almost entirely due to bremsstrahlung; this includes most of the 10% that lost more than 2.8% of their energy. Most of the 3.3% that lost more than 10% of their incident energy experienced photonuclear interactions. The latter can exceed nominal detector resolution [49], necessitating the reconstruction of lost energy. Electromagnetic and hadronic cascades in detector materials can obscure muon tracks in detector planes and reduce tracking efficiency [50].

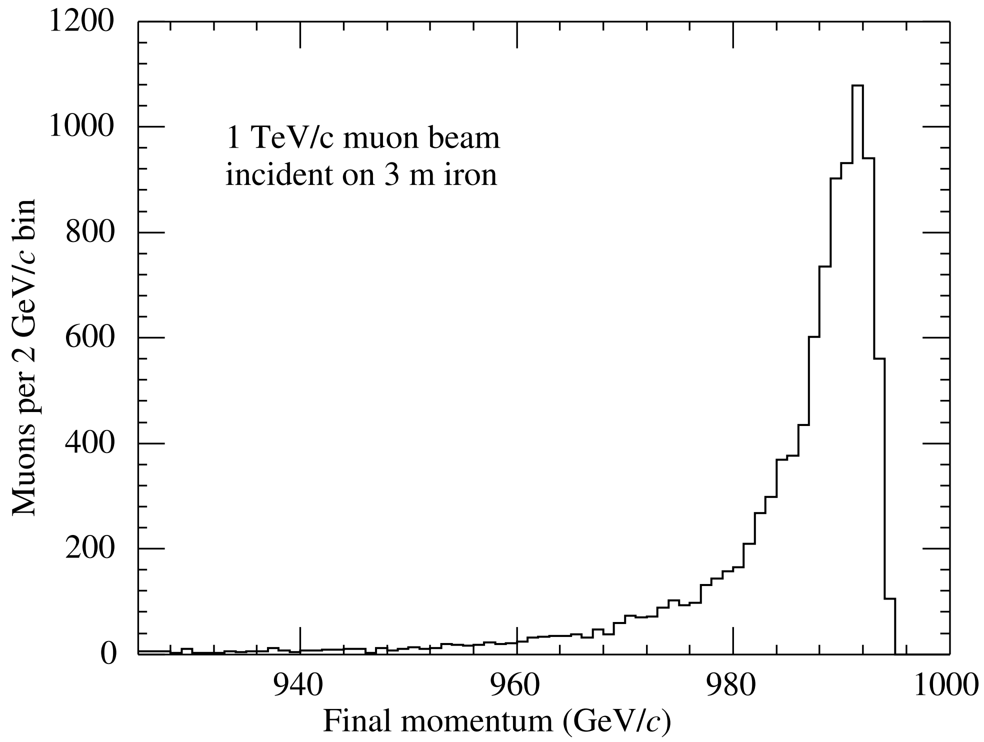

Figure 10.12: The momentum distribution of 1 TeV/c muons after traversing 3 m of iron, as obtained with Van Ginniken's TRAMU muon transport code [48].