TRIUMF Experiment E614
Technical Note 35

Backgrounds due to pions in beam

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Abstract

In the beam entering the M13 beamline, there will be pions present as well as the muons that we are interested in. These pions will travel down the beamline with the muons, and decay to positrons and muons in various parts of the beamline and detector. This report determines the positions of the pion and daughter muon decays, and provides an estimation of background from the positrons produced by these processes.

Pion decays in beamline

The beamline selects particles according to momentum (29.7 MeV/c). Pions around the production target having this momentum will travel or be pulled down the beamline. There will only be such pions around the production target for a short time every cycle, corresponding to the time when the beam from the cyclotron is incident upon the production target. These pions provide a background that we must consider.

For background, we only really need to consider the part of the beamline beyond the last bend. Pion decays upstream of the last bend will primarily produce muons of a different momentum to the rest of the beam and so will not make it around this last bend. Positrons from decay of these pions or decay of the daughter muons will be absorbed by all the metal and concrete surrounding the beamline and few will make it as far as our detector.

An upper bound on the pion flux at the beam focus 150cm upstream of the centre of the detector is about 0.5 percent of the surface muon flux. (This is an estimate based on the TRIUMF Users Handbook, pg. IV-18a). In the rest of this report it is assumed that this ratio was measured at the beamline final focus.

A simulation was carried out with a beam of pions from 300cm upstream of the E614 stopping target; the last bend is about 350cm upstream.

GEANT simulation

Using the RAYS card, a beam of 500000 pions were sent through the simulated detector. The decay branch was set to produce 100 percent muons with spin, and the positions where the pions and muons decayed in the detector were histogrammed in detail. I have not

Region of apparatus	Percentage of pions from -300cm decaying in this region
Decays in flight in beampipe	79.5
Stopping in iron/PVC beampipes	0.07
Stopping in proportional chamber mylar foils	0.6
Stopping in dense stack mylar foils (upstream)	19.6

Table 1: Pion decay statistics

Region of apparatus	Percentage of daughter muons decaying in this region
Muons do not decay within apparatus	2.8
Stopped in beamline pipe material	78.3
Near target (mostly upstream side of target holder)	6.2
Yoke (old design)	1.3
Beamline mylar foils	1.6
Upstream DCs	4.1
Upstream PCs	0.8
Upstream SC	0.6
Downstream DCs	1.6
Downstream PCs	0.6
Downstream SC	0.4

Table 2: Muon decay statistics

simulated the pion to positron direct decay in this simulation as the branching ratio is about 1 percent so the upper limits of the flux relative to the surface muon is a few parts in 10^5.

In addition, the number of pions, muons and positrons entering the detector were counted, if the pion and daughter muon did not pass through the scintillator: i.e. if a pion did pass through the scintillator, it and its daughters are discarded from this background calculation; same if a muon passed through this scintillator (the positron is discarded). The pions and muons which originate from these pions decaying in flight will arrive at a predictable time in the cycle, but the positrons will arrive at any time in the cycle as they mostly originate from stopped muons upstream (more on this later).

Decay distribution of Pions and Muons

The position where the pions and muons decayed were histogrammed, in z and in x-y portions ((Figures 1 and 2). The muon decay distribution is complex so many histograms were needed to see the details. Figure 3 shows that these muons can traverse the entire detector, some eventually stopping downstream, in the chambers and scintillator. Figures 4-7 give the details of the decay positions of these muons. The distribution gives an indication of how and where the decays occur. I have compiled some estimates of the statistics, using the histograms (see tables 1 and 2). I have also listed points relating to the interpretation of some of the data later on in this report.

The figures quoted in Table 1 are percentages of the pions making it around the last bend. This is a greater number than the pions that reach the focus by a factor of 2.5 on account many pions decay between the last bend and the focus. This means that, coming round the bend, pions make up about 1.25 percent of the particles in the beam. Remember that this is a worst case scenario.

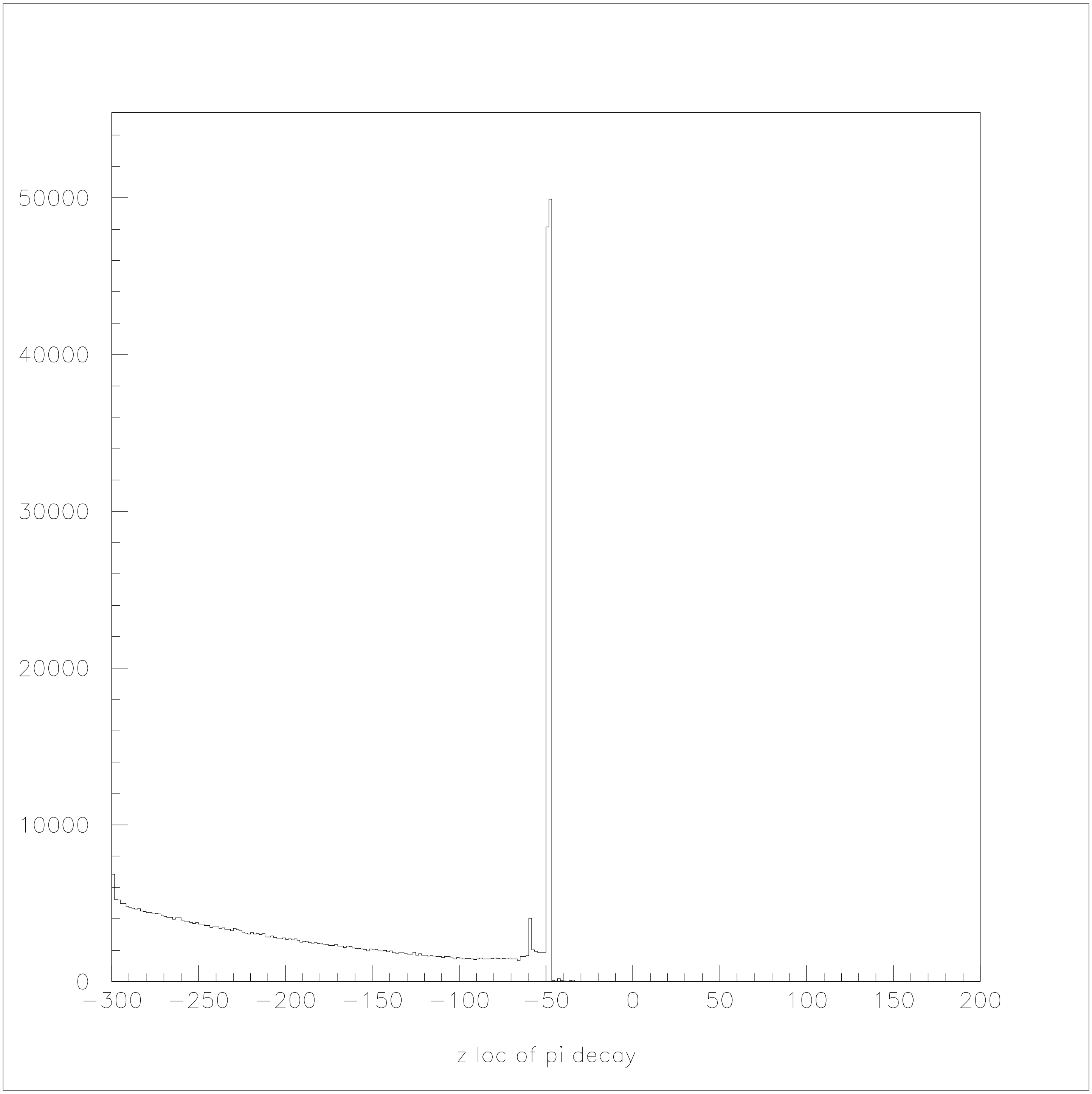

Figure 1: Pion decay positions

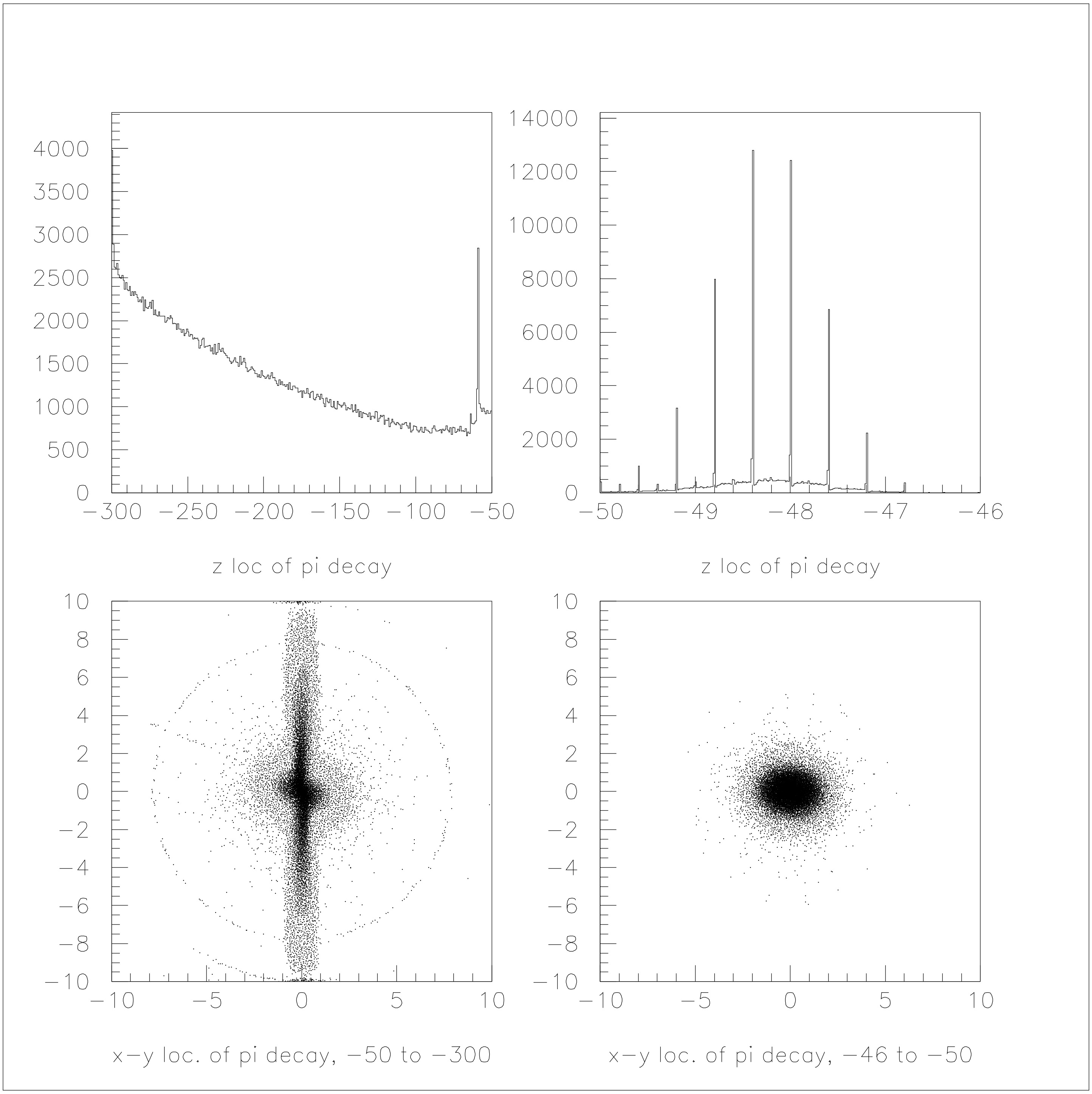

Figure 2: Details of pion decay positions

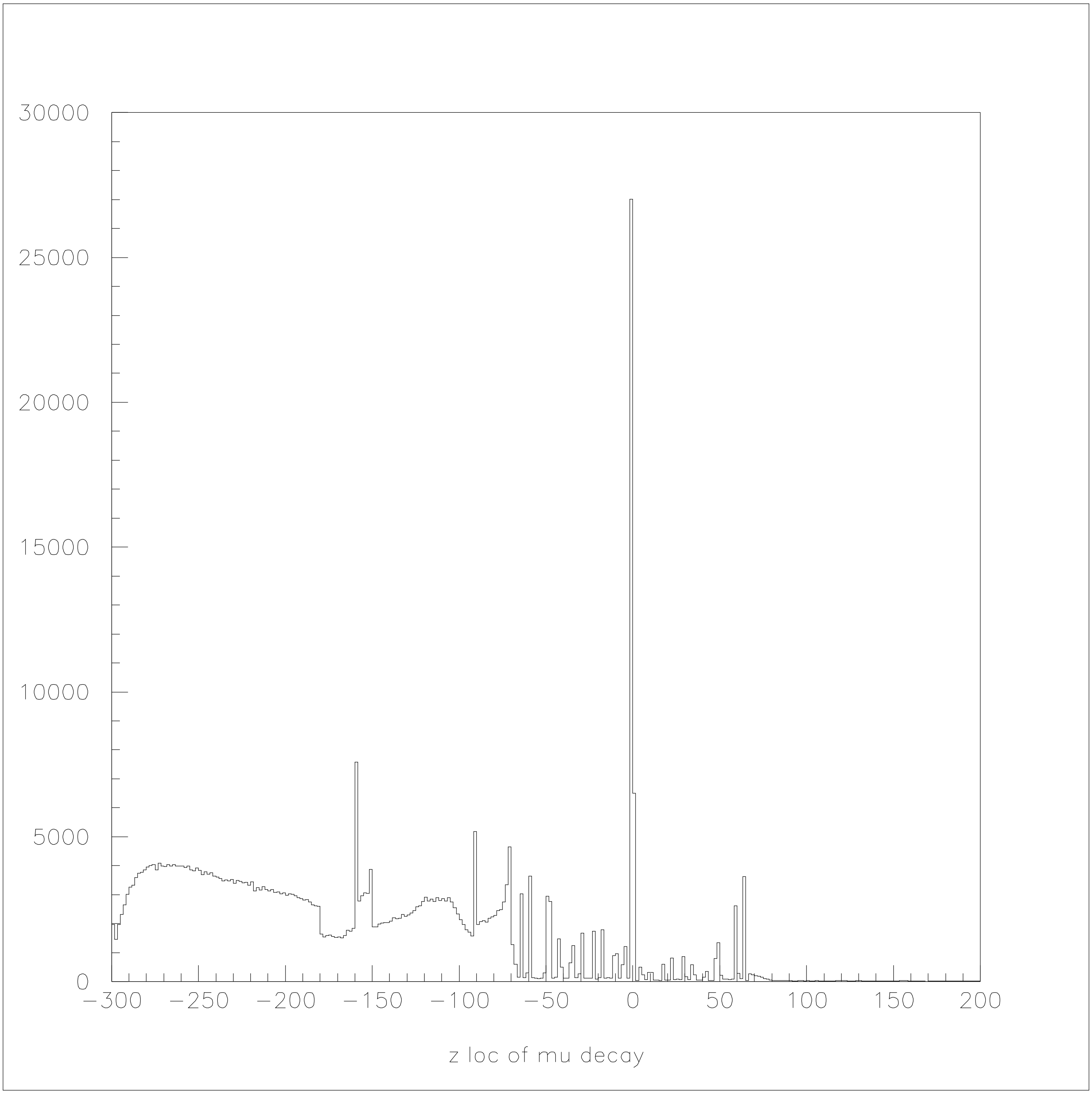

Figure 3: Muon decay positions

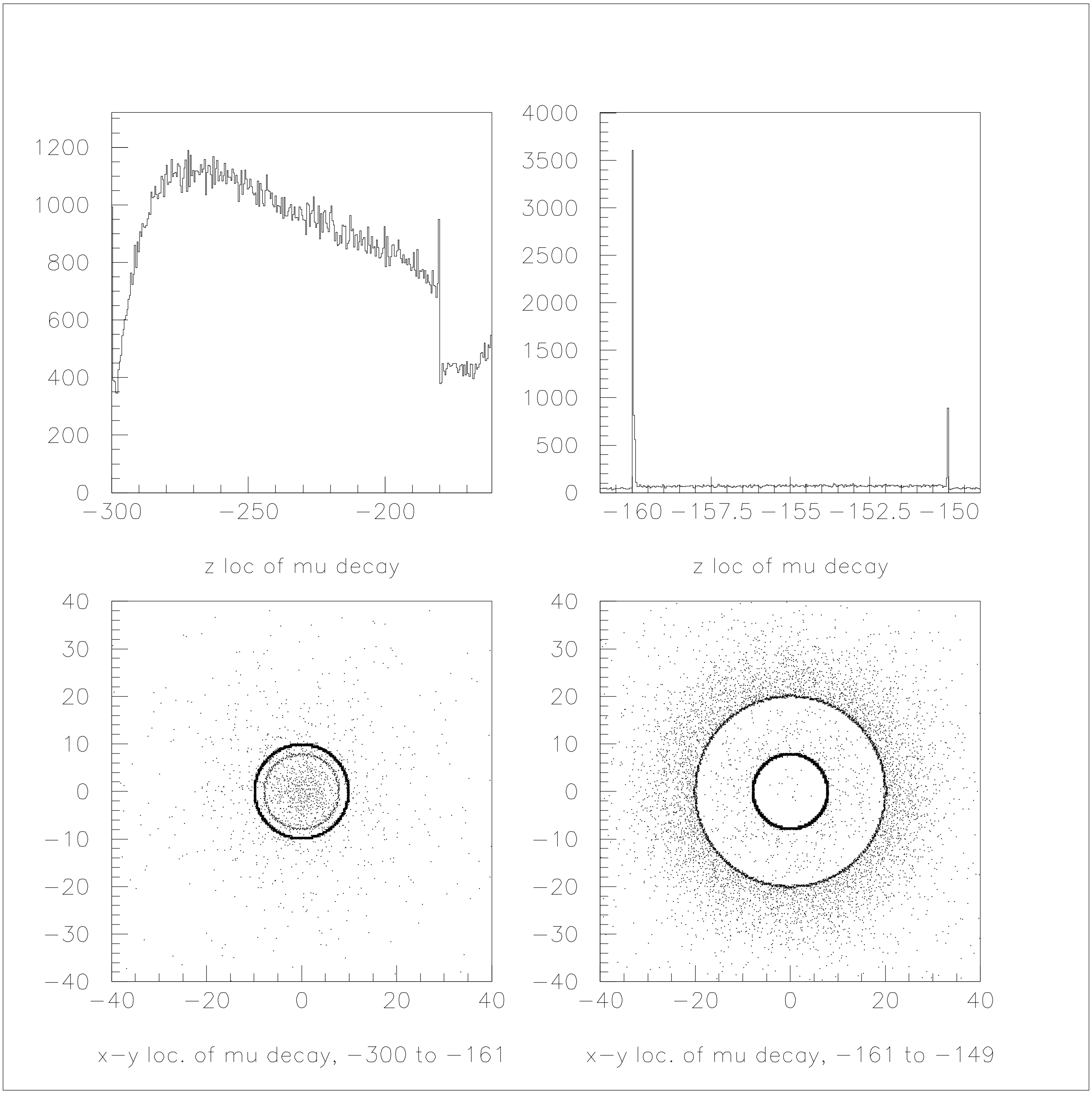

Figure 4: Details of muon decay positions

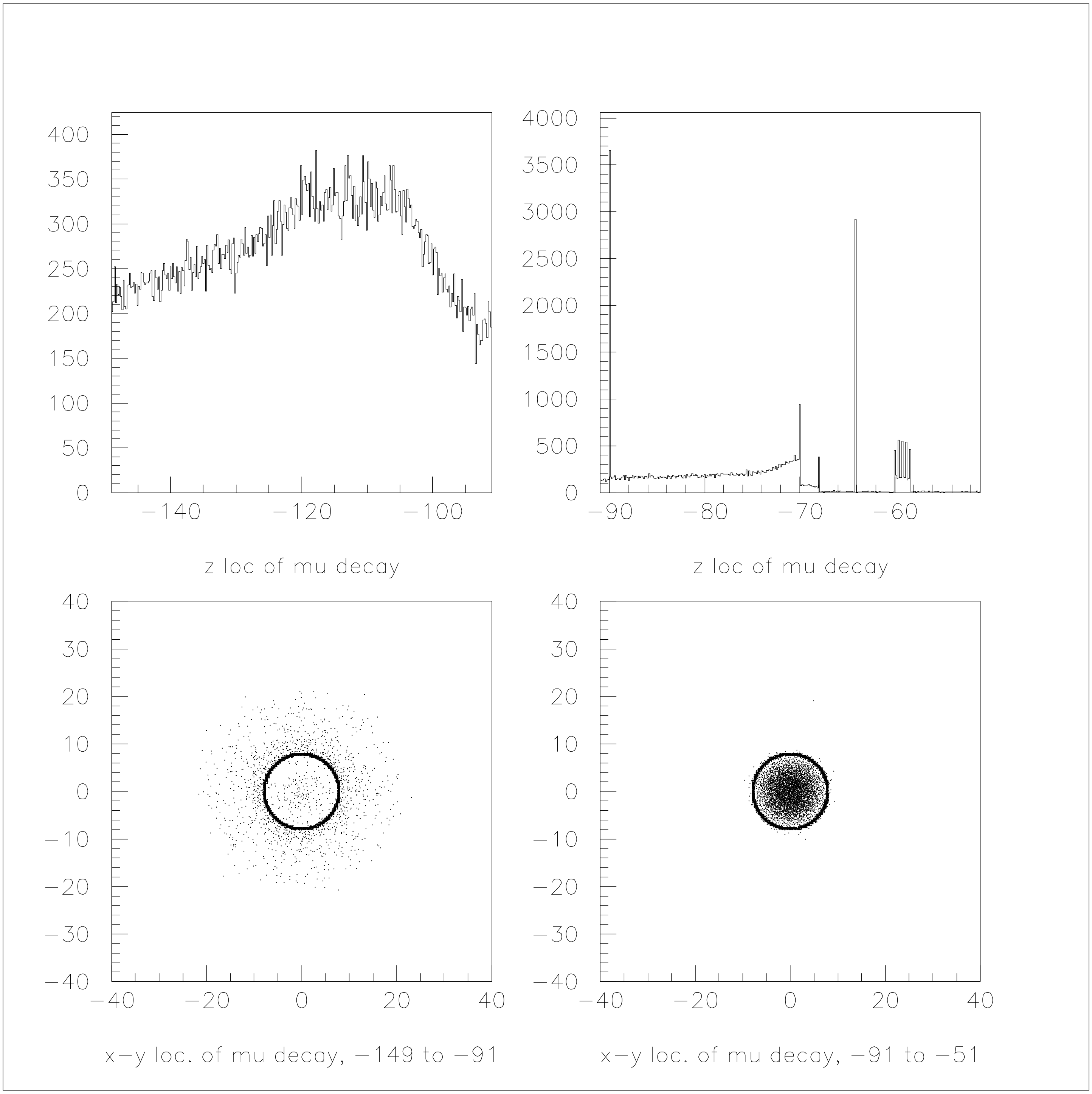

Figure 5: Details of muon decay positions

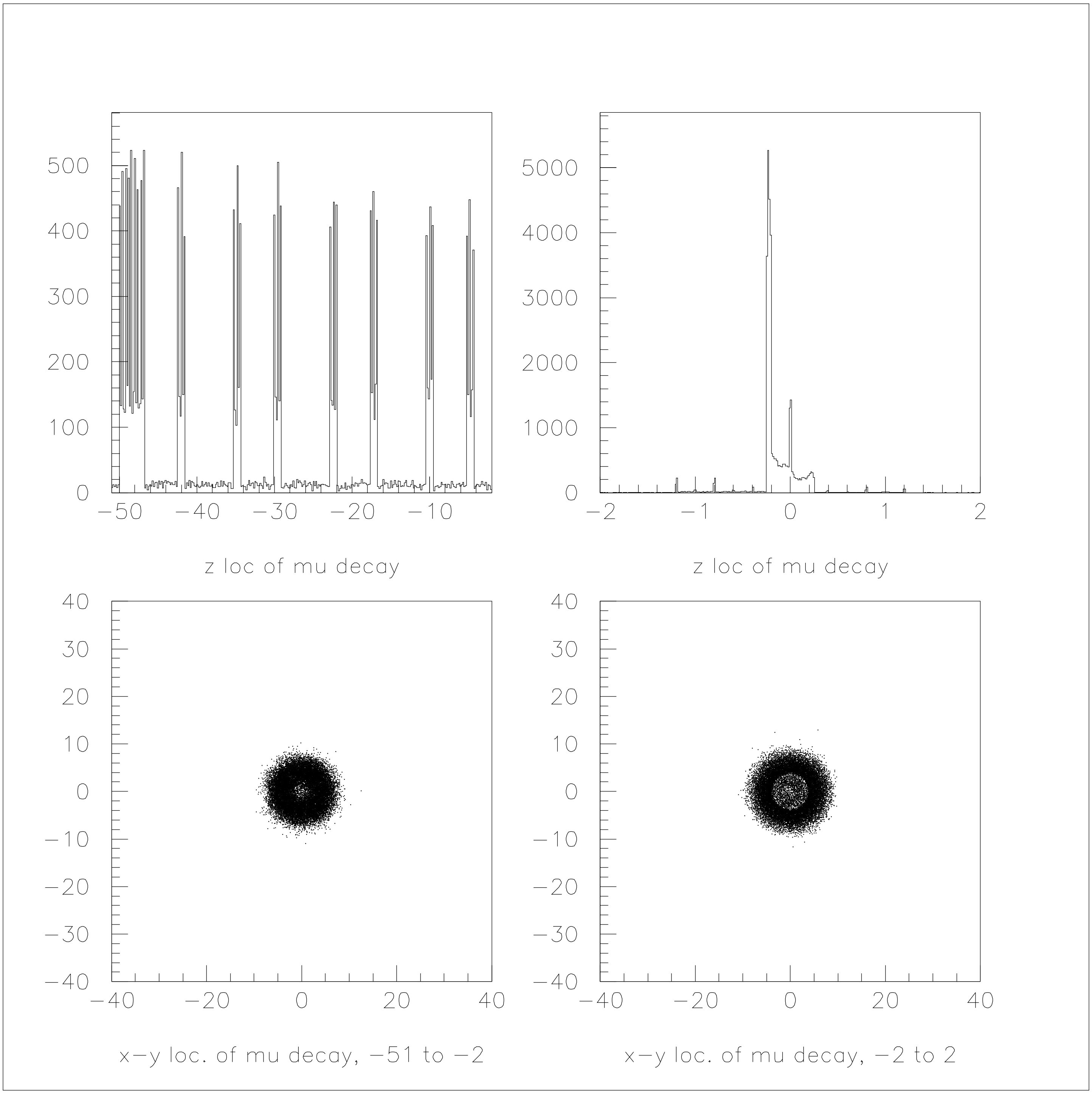

Figure 6: Details of muon decay positions

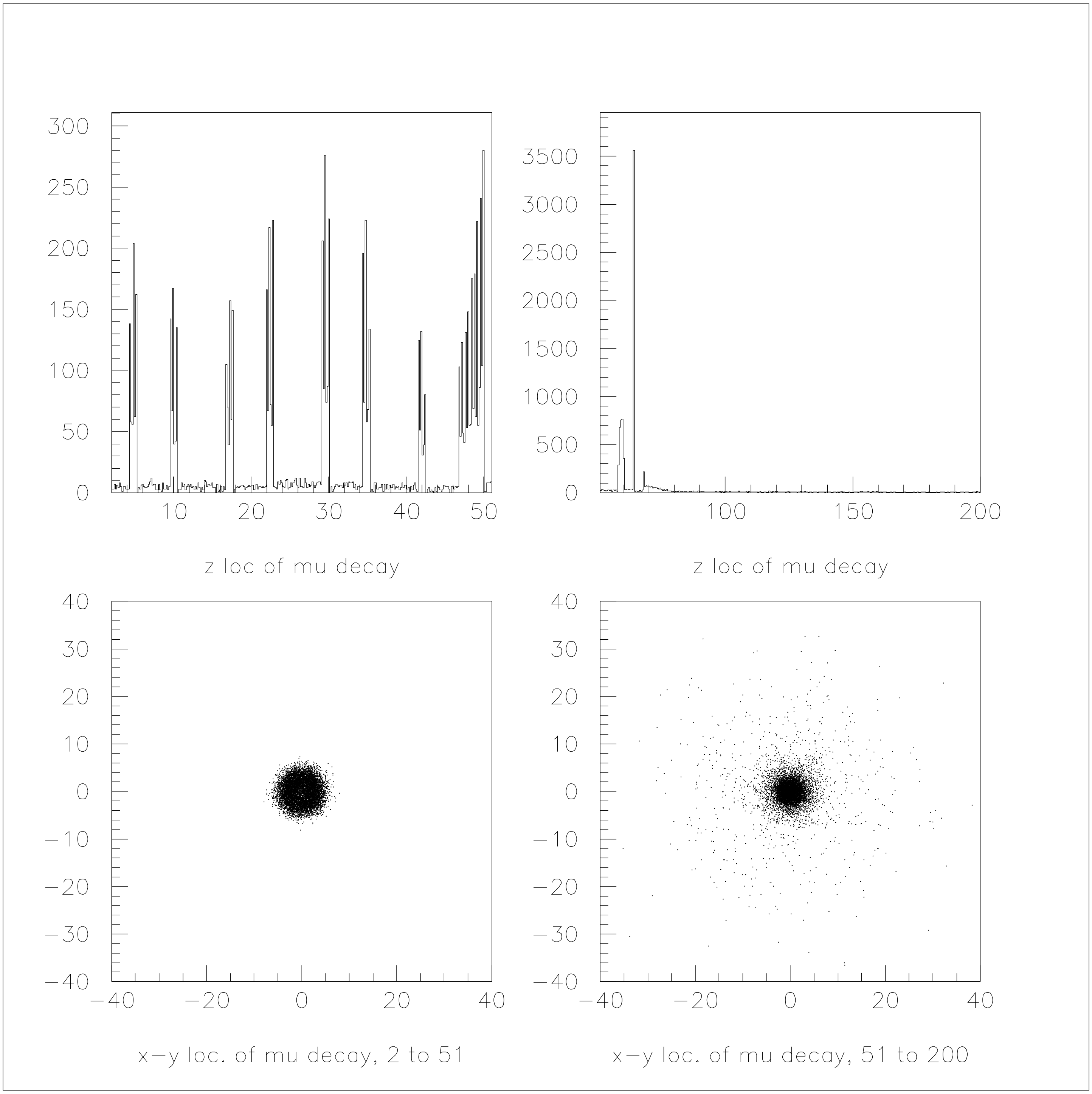

Figure 7: Details of muon decay positions

Notes on interpretation of Decay Distributions

Since the decay distributions are quite convoluted I have compiled a list of the main features of each histogram and what they show.

Figure 2: Pions

Top left: This decay-in flight distribution looks exponential as expected.

Peak near -60 : proportional chambers

Peak at -300 : end of beampipe (some pions hit end-on - the simulation places them right next to the end of the pipe and they stop on the end wall). Whether this is actually present in reality or not is unclear, it could just be a bad beam extrapolation.

Top right: Peaks correspond to the mylar foils of the dense stack.

Bottom left: Ring corresponds to a few pions stopping in pipe. Propellor shape is shape of beam as it is being focussed. Most decays occur near centre of beampipe.

Bottom right: All decays in mylar foils occur near the main axis.

Figure 4: Muons

Top left: The decay distribution falls off towards -300. This is because the simulation does not simulate pions before -300cm, so there are no muons produced before -300cm, which means there are less muons stopping in the beampipe around -300cm.

Peak at -300cm : end of beampipe, as above. Maybe the stopped pions just here produce muons which immediately stop.

Discontinuity at -180 corresponds to the end of one pipe and start of another.

Top right: Peaks correspond to the inner and outer faces of the yoke. Muons will hit the side of the yoke and be stopped. Please note that this corresponds to an old model for the yoke: the newest model locates these peaks at -158cm and -140cm.

Bottom left: Two rings correspond to the two pipes (one downstream of the other).

Bottom right: Inner ring is PVC pipe; outer ring the start of the yoke. Quite a few muons decay in the yoke as you can see.

Figure 5: Muons

Top left: More muons stopping in pipe in a complicated spectrum; the peak is probably due to being beyond the pion focus.

Top right: Peaks at -90, -70 and -68 are mylar foils.

Peak at -64 is the scintillator.

Peaks at -60 are proportional chambers mylar foils.

Beampipe stops at -70; downstream of this there is no longer the continuous spectrum of muons stopping in the pipe.

Bottom left: Ring is the PVC pipe

Bottom right: Ring is the pipe, decays in mylar foils are near axis though.

Figure 6: Muons

Top left: Spikes are mylar foils of drift chambers.

Top right: Large peak is at upstream side of target holder. Smaller peak is at target.

Bottom left: Decays are centred in a region of about radius 10cm.

Bottom right: More muons decay in the target holder than the actual target itself.

Figure 7: Muons

Top left: Mylar foils of the downstream DCs.

Top right: Peaks correspond, from left to right, to the proportional chambers, scintillator and a mylar foil.

Bottom left: Near axis.

Bottom right: More diffuse. The magnetic field is less uniform in this region, this may scatter the muons.

Estimation of Backgrounds

The number of particle (by type) entering the detector from this pion beam source where the pions or muons have not been seen by the scintillator are as follows. The percentage is relative to the number of pions at the focus (100 percent corresponds to 0.5 percent of the surface muon flux)

Pions: 0.36 percent (about 0.09 particles/sec)

Muons: 6.4 percent (about 1.6 particles/sec)

Positrons: 10.1 percent (about 2.5 particles/sec)

These figures are assuming a surface muon flux of 5000 particles/sec.

The histograms above show only a very few pions stopping in the pipe (of the order of a few parts in 10^{-3} in the total pion flux) so it seems a good assumption that the daughter muons from upstream pion decays will arrive at the same point in the cycle as the pions. However the positrons seem to originate from stopped muons (in the pipe and elsewhere) so their arrival will be delayed by the muon lifetime, in effect we will have a continual background of such positrons when the beam is incident on the apparatus.

There is a possibility of calibration of parts of the detector system using these daughter muons and positrons; this is yet to be looked into.

References

[1] GEANT Version 3.21, CERN, Geneva 1993.

[2] TN-29 E614 GEANT user's guide