Effect of Halo Events on the Measured Luminosity

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1 Introduction

In this note we report on a brief study of halo events in zero bias data which indicates that the fraction of halo events which are actually real interactions can be estimated reasonably well by the naive overlap probability for uncorrelated halo and real interaction events. This suggests that the probability of real interactions should be corrected to

$$P_{real}^{Improved} \simeq P_{real} + P_{real} * (P_{PHALO} + P_{AHALO}) \quad (1)$$
$$P_{PHALO}^{Improved} \simeq P_{PHALO} \quad (2)$$
$$P_{AHALO}^{Improved} \simeq P_{AHALO} \quad (3)$$
$$(4)$$

Where P_{real} is the fraction of zero bias interactions in which the FASTZ bit fired (one or more real interactions occurred) and P_{halo} is the fraction of zero bias interactions in which a proton or anti-proton halo interaction occurred.

This correction is more significant in Run II[1] as such HALO/FASTZ overlaps are no longer vetoed in the L0 trigger as they were in Run I [2] and need to be included in the luminosity estimate.

2 Hypothesis

The Luminosity electronics distinguishes halo from real interactions by the relative timing of the north and south luminosity counters. Proton halo events have an early hit in the North counter while anti-proton halo events have an early hit in the South counter. Events in which both halo and real events occur will have an early hit and are normally counted as halo, while those with both counters in time are classified as FASTZ. This leads to an inefficiency for real interactions. If the electronics behave as expected and halo and real events are fully uncorrelated the relation between the true (improved) rates and the measured rates is given by equations 1-3.

Multiple interactions do not change this relation to first order as n real interactions will be classified as FASTZ unless overlapped by a halo event. In principle, an AHALO PHALO coincidence can fake a FASTZ but the rate is $< 4 \times 10^{-5}$ and can be neglected.

If this hypothesis is true, we can expect that among halo events P_{FASTZ} will actually be real interactions and will resemble them in vertex probability and energy deposition.

3 Data Sample

The data sample used was a set of QCD root-tuples created by Pawel Demine from zero bias skims of runs 151892 to 176308.

The LumByTick method was used to check for lum quality, 9,866 events in the sample were rejected because they did not have good luminosity information, leaving 1.64M events.

3.1 Information from the lum scalers for these events

The luminosity scalers were examined for the lum/tick combination for each event in the sample. For these scalers, the average proton halo rate was 1060/tick/sec, or 2.2% per crossing the anti-proton halo rate was 74/tick/sec or 0.2%.

3.2 Information from the events themselves

If one examines the events themselves, the fraction of events in which PHALO fired was 2.2% while the antiproton fraction was 0.2%, these agree with the numbers from lm_access.

3.3 Cuts

Events were classified based on the AND/OR bits from the luminosity system and on the presence or absence of a vertex. The events were considered to have a vertex if there was at least one vertex with 3 or more tracks attached to it.

The bits were

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North - 0,1
South - 0,1
FASTZ - 0,Z,P,A (nothing, FASTZ, ProtonHalo, AntiProton Halo)
VTX   - 0,1
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For this study only events in which N and S both fired were considered.

Calorimeter energy behind the luminosity monitors was summed and plotted for each end of the detector, cells with energy below a threshold (100 MeV) were not included in the sum.

4 Halo information

We study halo events with and without valid interaction vertices. Figure 1 shows the energy distribution in PHALO events in which no vertex was seen.

Figure 2 shows the energy distributions for PHALO events with a vertex. The energy deposited is much higher. The probability of seeing a vertex in the various samples is:
PHALO events: $19 \pm 1\%$
AHALO events: $24 \pm 5\%$
FASTZ events: $68 \pm 0.3\%$

Figure 3 compares the energy distribution for the North side in PHALO events in which a vertex does occur with real events flagged by FASTZ and a vertex. These energy distributions are very similar and very different from those for events in which PHALO fires and no vertex is seen.

Figures 4,5 show the energy distributions for the small number of anti-proton halo events for completeness.

4.1 Estimate of real event contamination in the Halo sample using vertex information

One can use events with the events with a good vertex with 3 or more tracks to estimate the number of real scattering events in the halo sample. The resemblance between events in with a vertex and halo bit and normal events makes the hypothesis that they are random overlaps of real events and halo is very plausible.

The remaining Halo sample can be assumed to consist of overlays of halo with real events in which no vertex was found (which happens 32% of the time for real events) and of pure halo events.

For normal FASTZ events the fraction with a good vertex is 68%. We can take this to be the vertexing efficiency for good events.

For PHALO events the fraction with a good vertex is 19%. If we assume that these events which do have vertices are real FASTZ events which were overlaid by PHALO, that the vertexing probability is the same for these events as for normal FASTZ events and that pure halo events never have a good primary vertex we can estimate that $27 \pm 2\% = 19\%/0.68$ of PHALO events are actually real events and should have been classified as FASTZ.

4.2 What we would expect in the random coincidence model

The probability we would expect for such overlap can be estimated from the measured probabilities of FASTZ and HALO events. 29.2% of all zero_bias events had FASTZ fire, we would thus expect the fraction of PHALO events which are actually real events simultaneous with PHALO events to be 29.2% (actually a bit larger as the true real event rate should include these overlaps). This is very consistent with the 27% derived from the vertex information.

This indicates that the halo electronics are behaving as expected and that we can use equations 1-3 to correct the rates from the electronics with reasonable accuracy.

For the sample considered here, this the improved FASTZ rate is on average 2.4% higher than the level measured from the scalers.

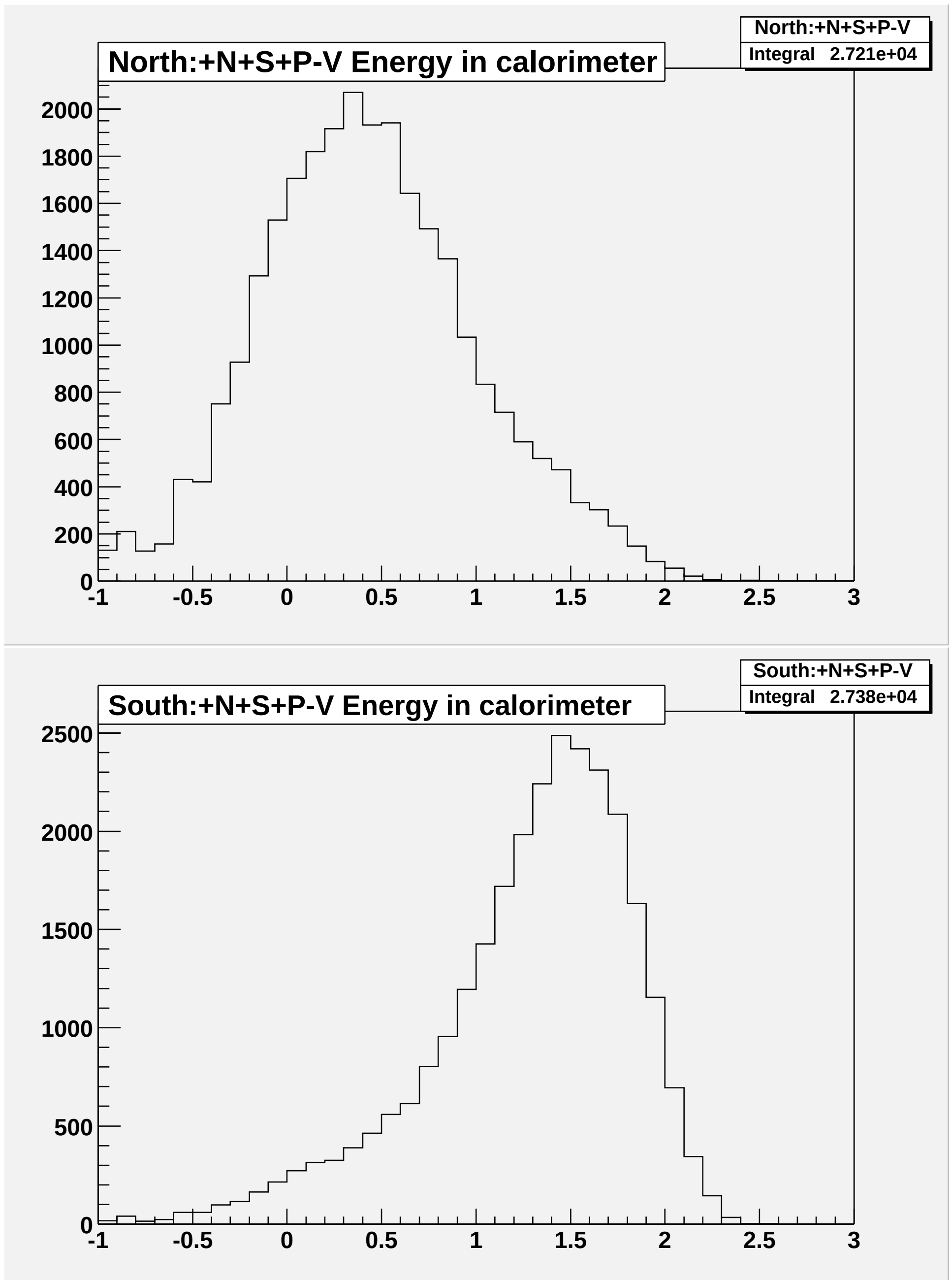


Figure 1: Energy distributions for Proton Halo Events without vertices. Top: North side, South: South side

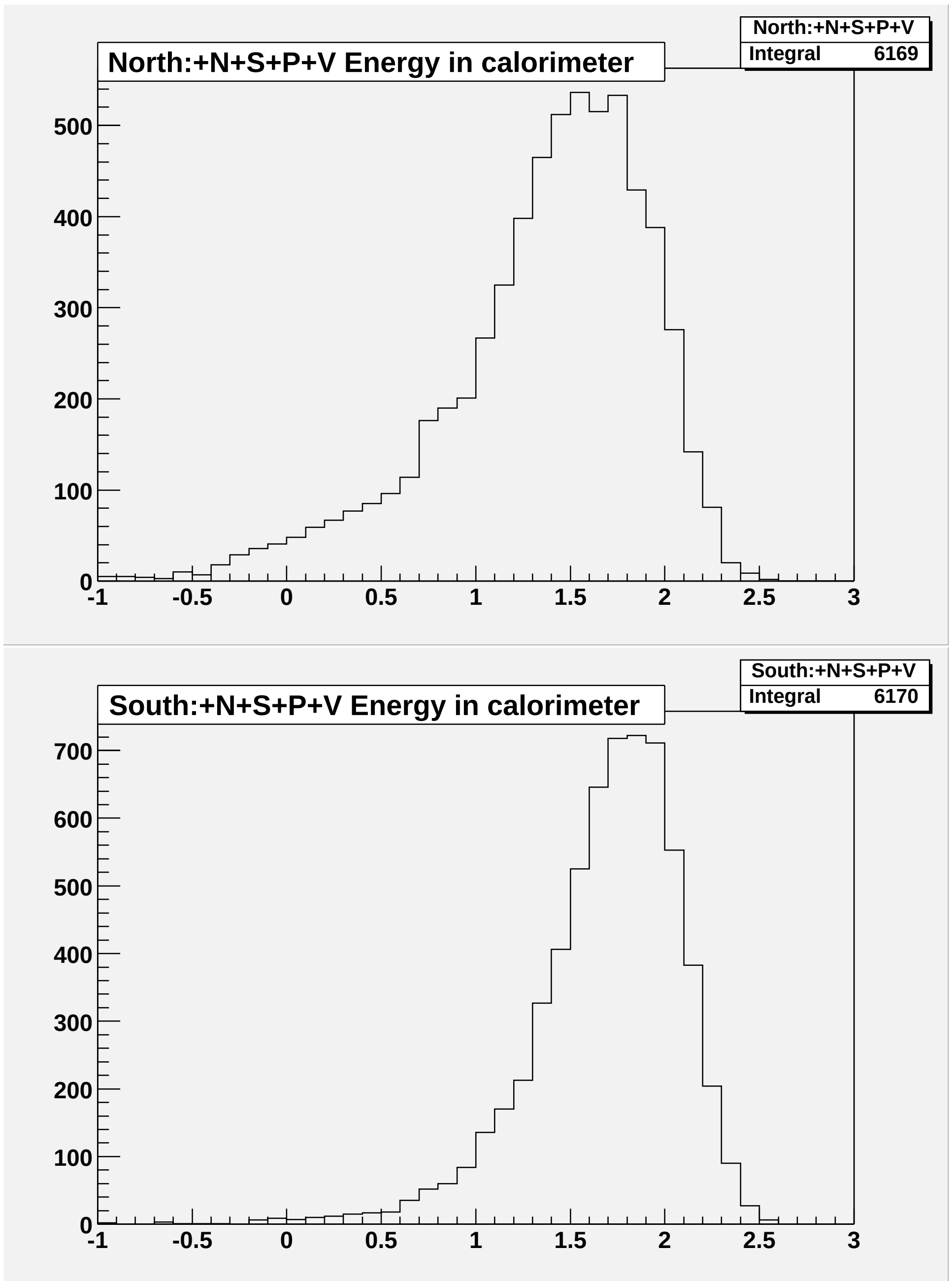


Figure 2: Top: North side energy and south side energy distributions for proton halo events with a vertex.

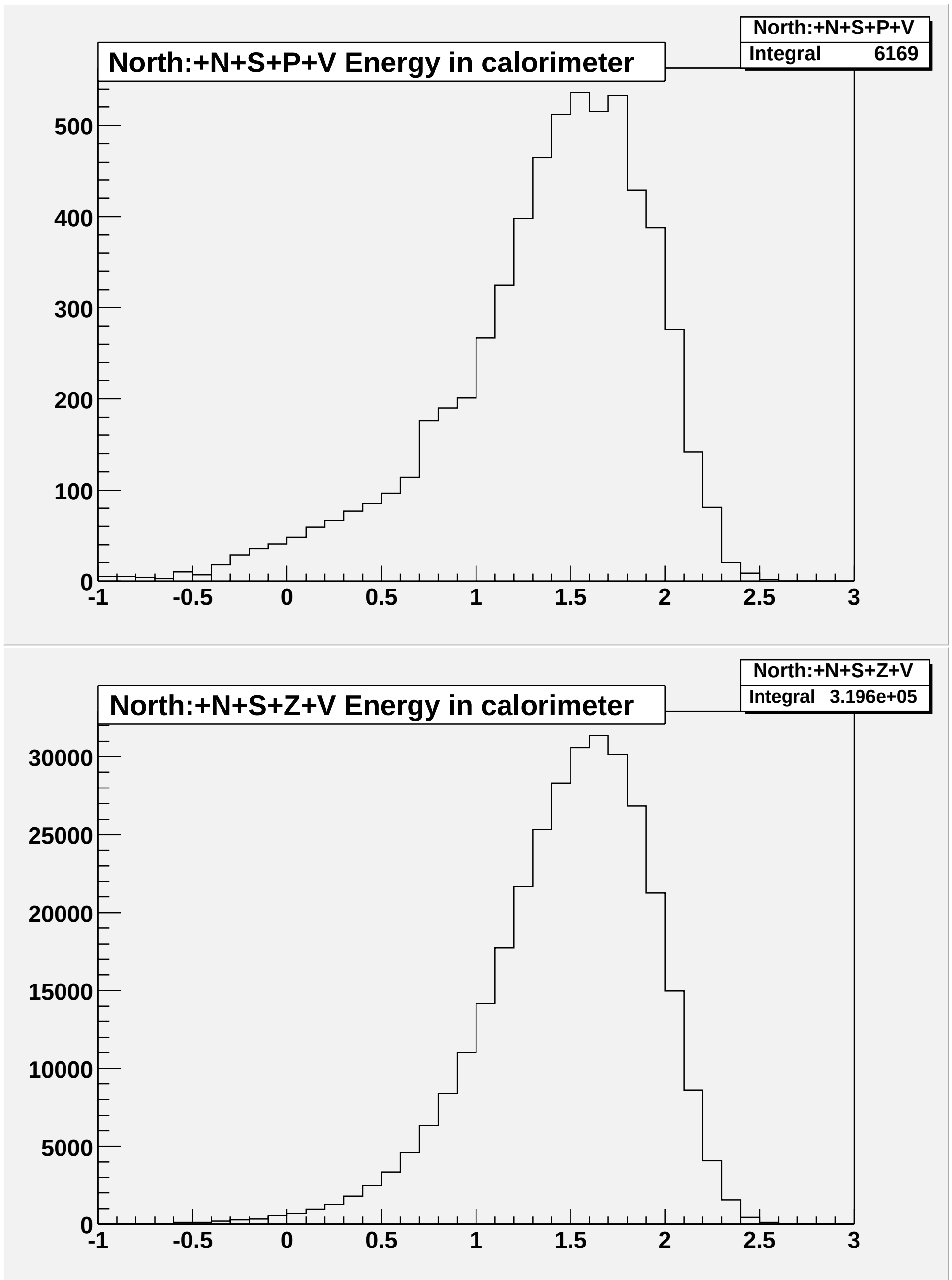
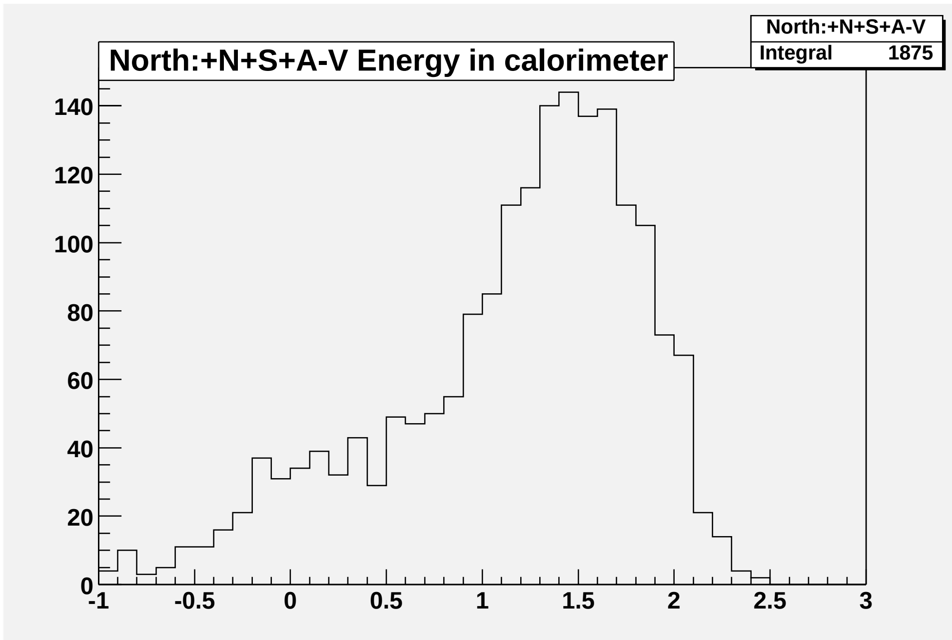


Figure 3: Top: North side energy distributions for proton halo events with a vertex. The same for FASTZ events with a vertex



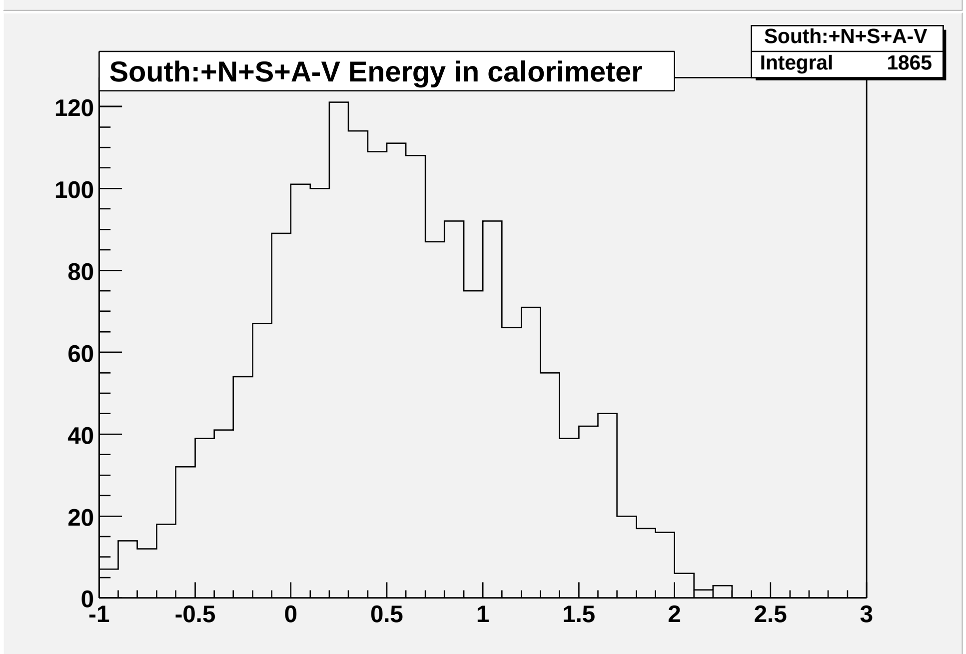


Figure 4: Energy distributions for Anti-proton Halo Events without vertices. Top: North side, bottom: South side

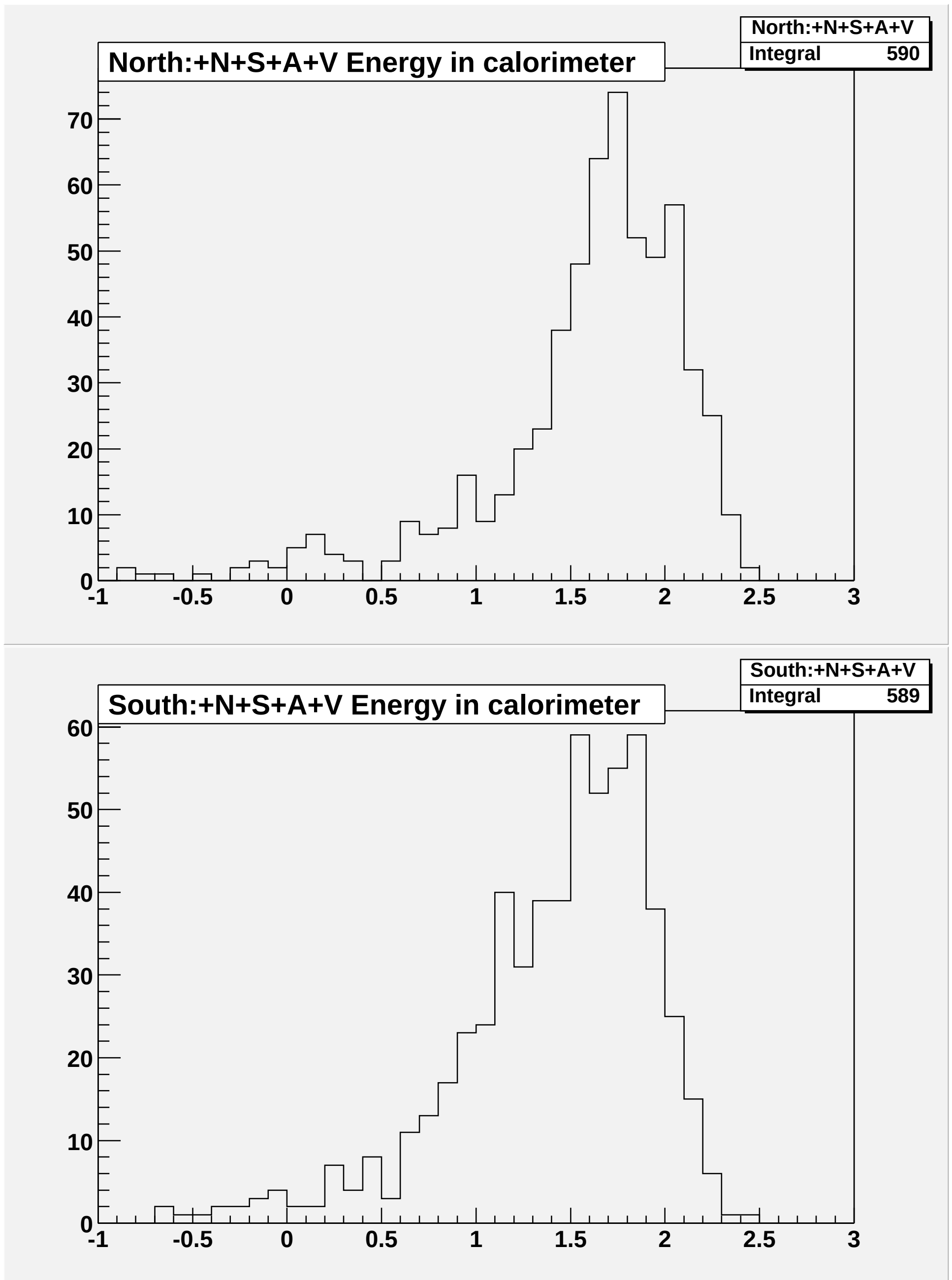


Figure 5: Top: North side energy and south side energy distributions for anti-proton halo events with a vertex.

References

[1] M. Begel *et al.*, D0 notes 3970,3972, 3973.

[2] J. Bantly, J. Krane, D. Owen, R. Partridge and L. Paterno, FERMILAB-TM-1995