# Background Rejection for Gamma Ray Bursts

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**Abstract**

In previous memos and meeting notes I have demonstrated the use of both compactness (X2) and a MARS type cut to reject the cosmic ray background in Milagro. The same analysis also shows that these standard cuts tend to remove the low energy gamma ray events from the sample. For an analysis of gamma ray bursts this behavior could well remove the only signal present in the data. For this reason I have developed an alternative cut that preferentially keeps only the low energy gamma ray events. The cut is developed using the MARS algorithm and the same four parameters: *nTop, nBottom, sumPEsbottom, and nBottom > 8 PEs*, as in the "standard" MARS analysis. Using as my signal sample only gamma ray events with energies less than 200 GeV that reconstruct within 1.2 degrees of the source, I obtain a quality factor of 1.4.

## Introduction:

The observation of optical counterparts to gamma ray bursts has proven that the great majority of bursts (at least the long bursts) are of cosmological origin, with typical redshifts greater then 0.4. It is well known that the intervening IR field absorbs higher energy gamma rays over such vast distances. In Figure 1 (from Jay Norris) I show the measured redshift distribution of the gamma ray bursts with optical counterparts. Figure 2 shows the attenuation as a function of energy for high-energy gamma rays.

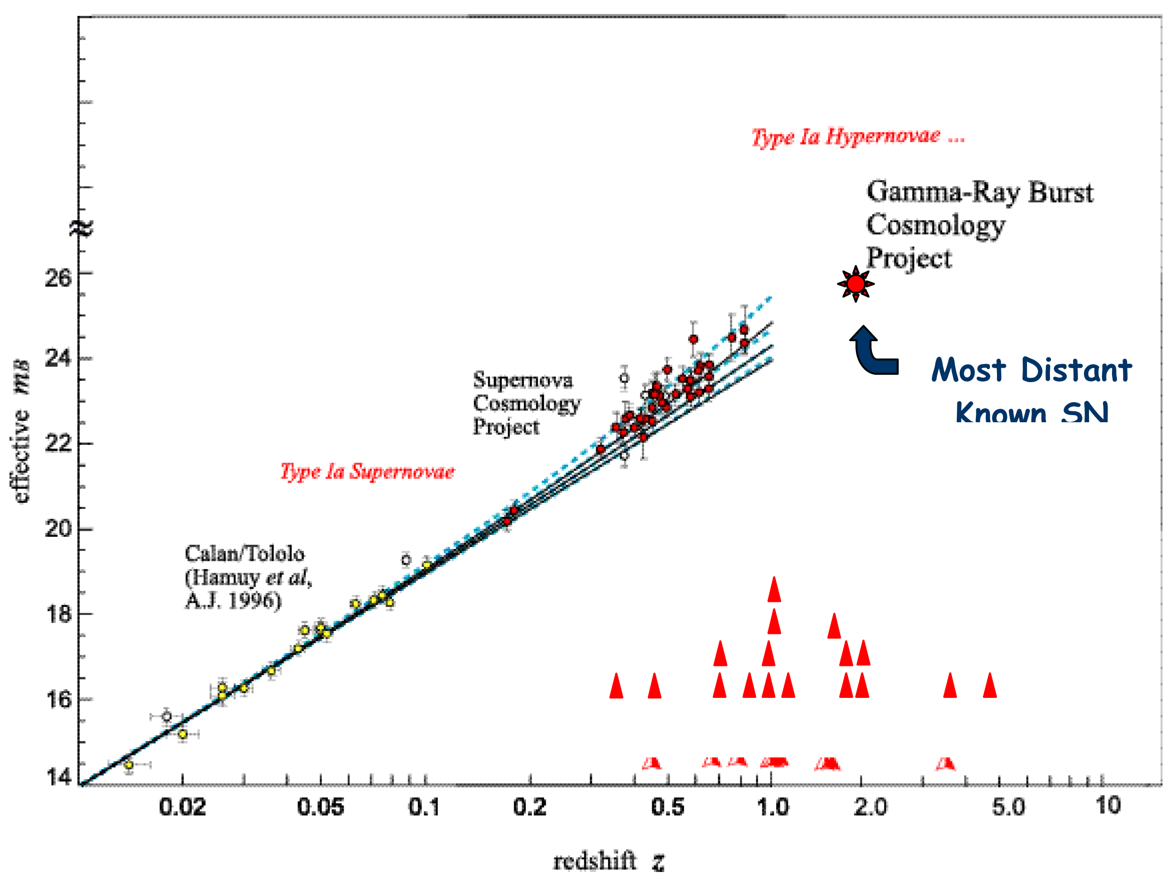



**Figure 1 Redshift distribution of measured gamma ray bursts. From J. Norris.**

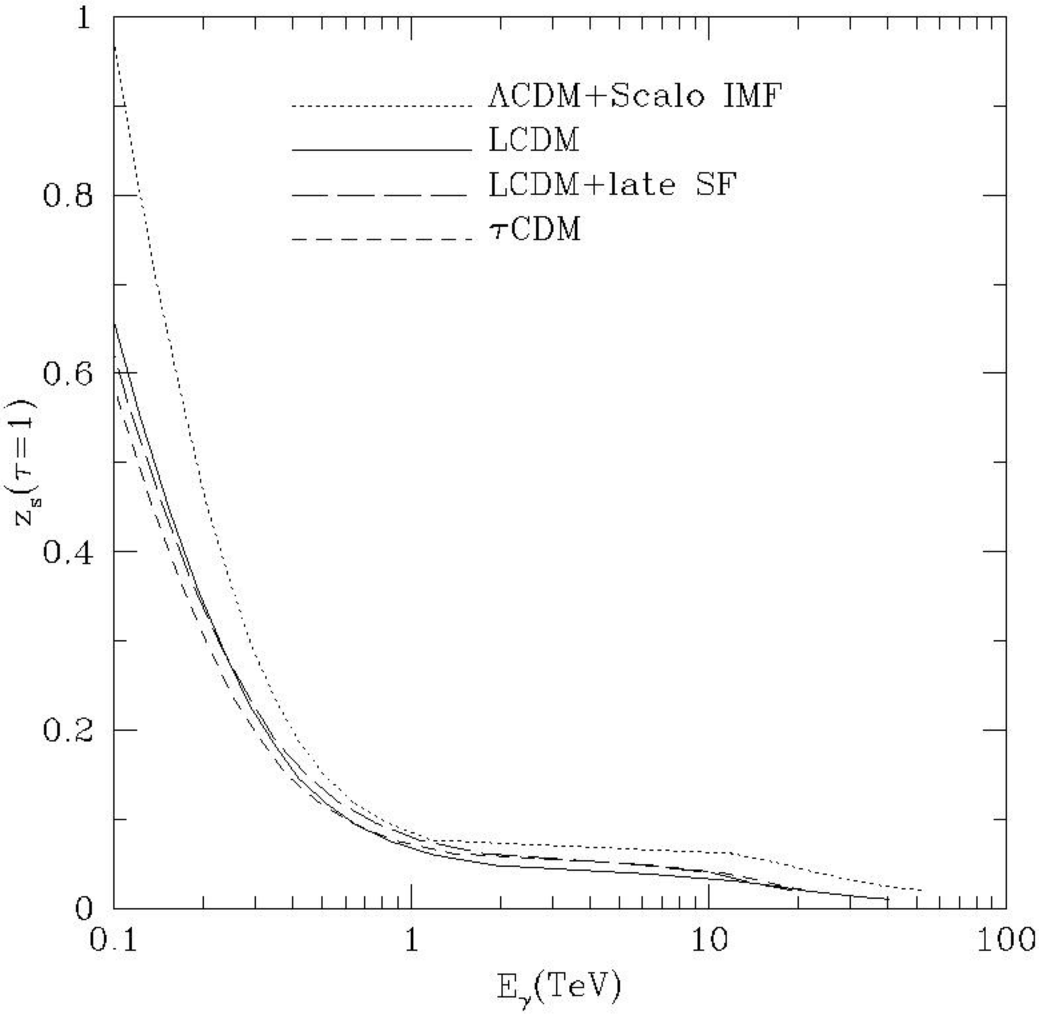



**Figure 2 Redshift at which the optical depth is unity as a function of photon energy. From Primack. The different curves correspond to different cosmologies.**

From Figure 2 we can see that the optical depth is ~1 for a 200 GeV photon traveling from z=0.4 to earth. For the analysis below I optimize on retaining all photons with energies below 200 GeV.

## The Monte Carlo Data Set

I use version 31 of the proton simulation and version 30 of the gamma simulations. Remember that V31 has the incorrect baffle geometry. The trigger criterion is 50 PMTs. There are a total of 12259 protons and 13618 gammas that passed the trigger. In Figure 3 I show the energy distribution of the triggered events. There are few gamma ray (292) events below 200 GeV and this may limit the interpretation of this memo. There are no gamma ray triggers below 100 GeV; this is a limitation of our computer power, not an inherent cutoff in the instrument. In 10 figures appended to the end of this memo I demonstrate the validity of the Monte Carlo. There I show plots of all four parameters and the seven possible couplings of the parameters for data, Monte Carlo protons, and Monte Carlo gammas. Though the agreement is not perfect (possibly due to the baffle geometry issue) it is quite good in most of the parameters.

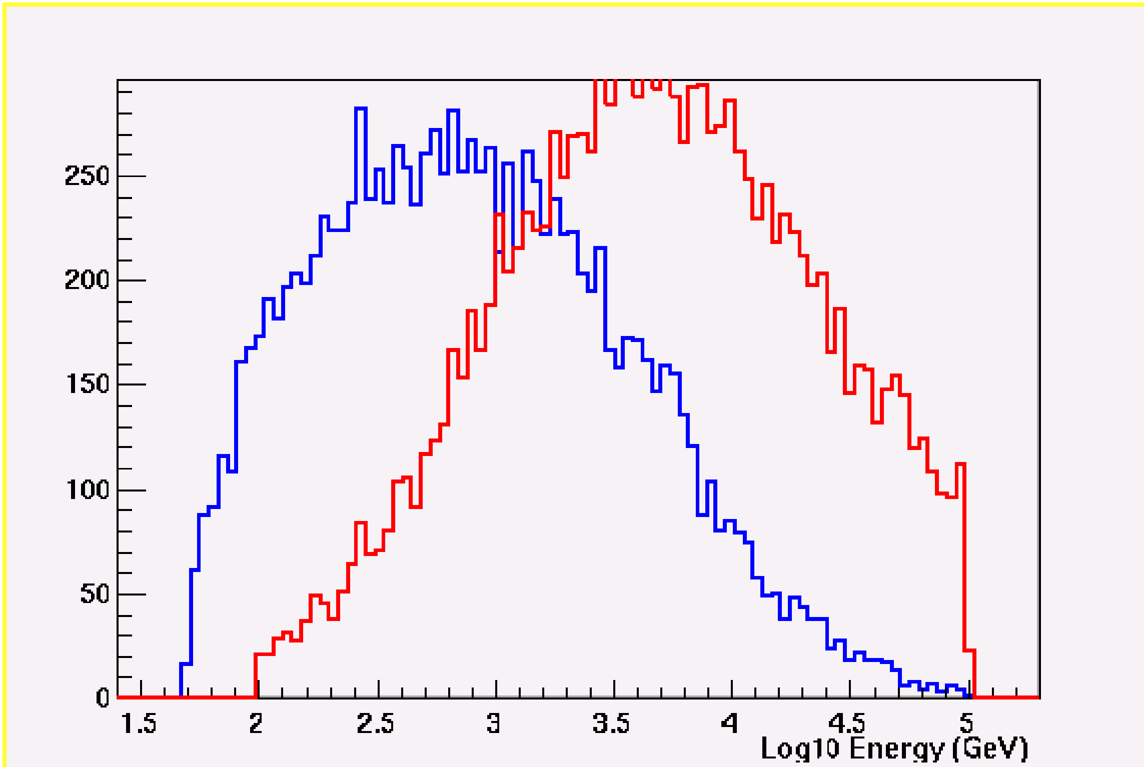



**Figure 3 Energy distributions of triggered events. The blue line corresponds to proton events and the red line to gamma ray events.**

## <u>The New MARS Cut</u>

For the standard analysis the MARS algorithm is fed a list of all triggered events, both protons and gammas. Gammas are given a code of 1 and protons a code of 0. The algorithm then proceeds to differentiate the two samples based on the parameters given for each event. In both the standard case and in this case I use the four parameters: *nTop, nBottom, nBottom8, sumPE(Bottom),* where *NBottom8* is the number of PMTs in the bottom layer with more than 8 PEs. To maintain the validity of the model as PMTs die in the pond I use the ***fraction*** of PMTs (not the absolute number) of the first 3 parameters. Also the natural logarithm of the sum of the PEs is used. Unlike the standard analysis gamma events are only given a code of 1 if the primary energy is less than 200 GeV (and they are reconstructed with 1.2 degrees of the source).

The results are shown in Figures 4-6. In Figure 4 I show the MARS distribution for data (blue), proton Monte Carlo (red) and gamma Monte Carlo (black), where the gammas shown are only those with energy less than 200 GeV and that are reconstructed with 1.2 degrees of the source position. The cut on the angular reconstruction reduces the number of gamma rays from 292 to 148. The MARS algorithm was optimized on these gammas. Figure 5 is identical to Figure 4 only the 3 distributions have been normalized.

Though the data and the proton simulation do not match perfectly, I think given the nature of this plot (correlations between four measured parameters) the agreement is quite good. The sharp right edge is correctly characterized as is the long tail to the left. There is a region between MARS -5.0 and MARS -10.0 where the agreement is not so good.

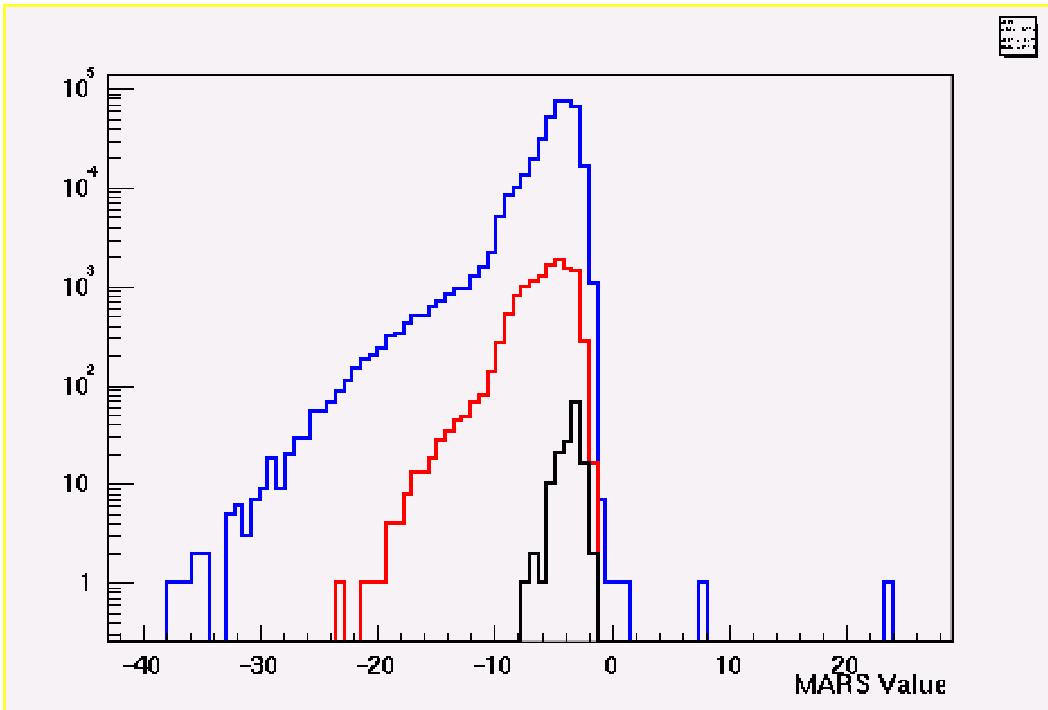



**Figure 4 The MARS distribution for data (blue), proton MC (red) and gamma MC (black). The gammas shown are only those with E<200 GeV and that reconstruct within 1.2 degrees of the source.**

In Figure 6 I show the resulting quality (Q) factor as a function of MARS cut. The Q factor is shown on the right-hand axis. On the left axis I show the fraction of protons and gammas (Monte Carlo) retained as a function of the MARS cut. The optimal cut value is MARS>-3.5. This keeps 25% of the protons and 70% of the gammas for a Q factor of 1.4. Note that unlike in the standard analysis (no energy cut) the proton and gamma distributions are not well separated. There is a class of low energy protons that look just like the low energy gammas, this is demonstrated in Figure 7 where I show the MARS distributions for protons and gammas both with E<200 GeV. Note the bump in the proton distribution just at the location of the gamma rays.

**Conclusions**

Gamma ray bursts are typically distant objects. The absorption of high-energy photons through interactions with the IR fields ensures that the gamma rays that make it to the Earth are of low energy. The standard MARS algorithm (and also the X2 cut) tends to preferentially remove these low energy gamma rays from the data. In this memo I have tailored the background rejection to keep the low energy events. In contrast to the higher-energy gamma rays, these low energy gammas are not well separated from the proton distributions. The algorithm developed retains 70% of the gammas while rejecting 75% of the protons and has a Q factor of 1.4. More low energy simulations are needed to test this result. Also I have found reasonable agreement between the data and the proton simulations. The differences maybe due to the incorrect baffle geometry used in the current proton simulations. These are being re-run and I will test the new simulations once they are complete.

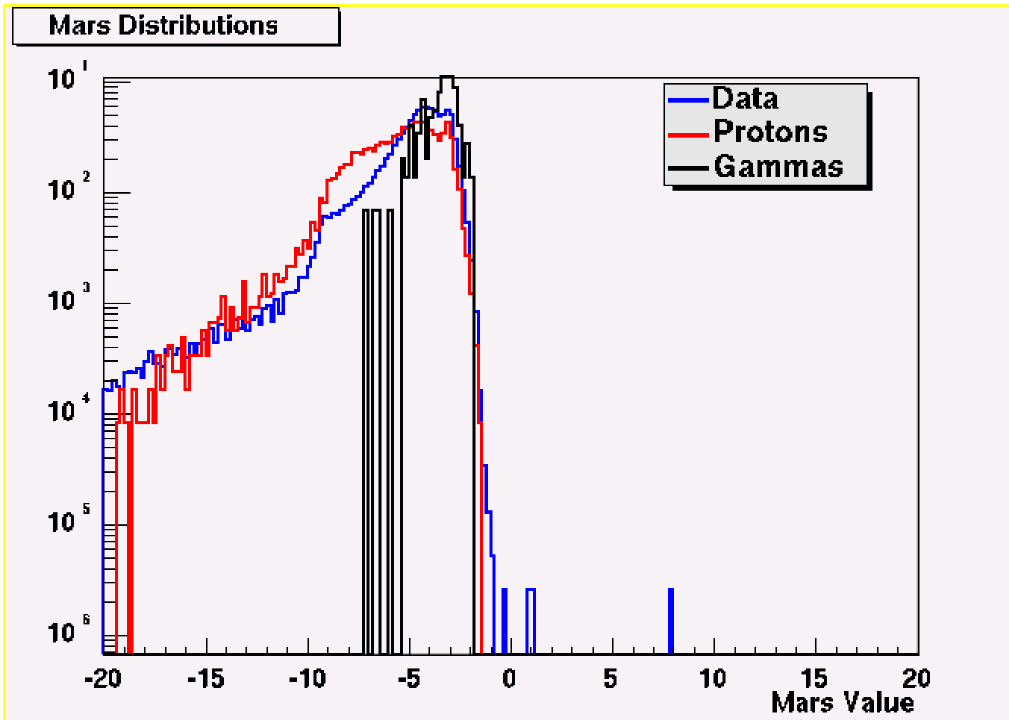



**Figure 5 Same as Figure 4 but the distributions have been normalized.**

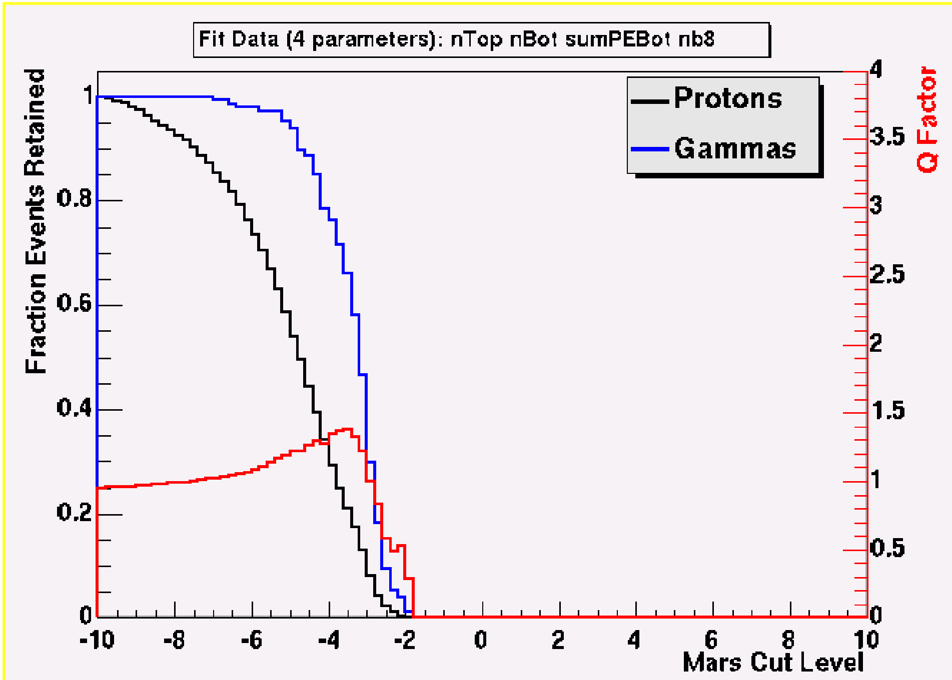



**Figure 6 Quality factor as a function of MARS cut (rhs) and proton and gamma retention as a function of MARS cut (lhs).**

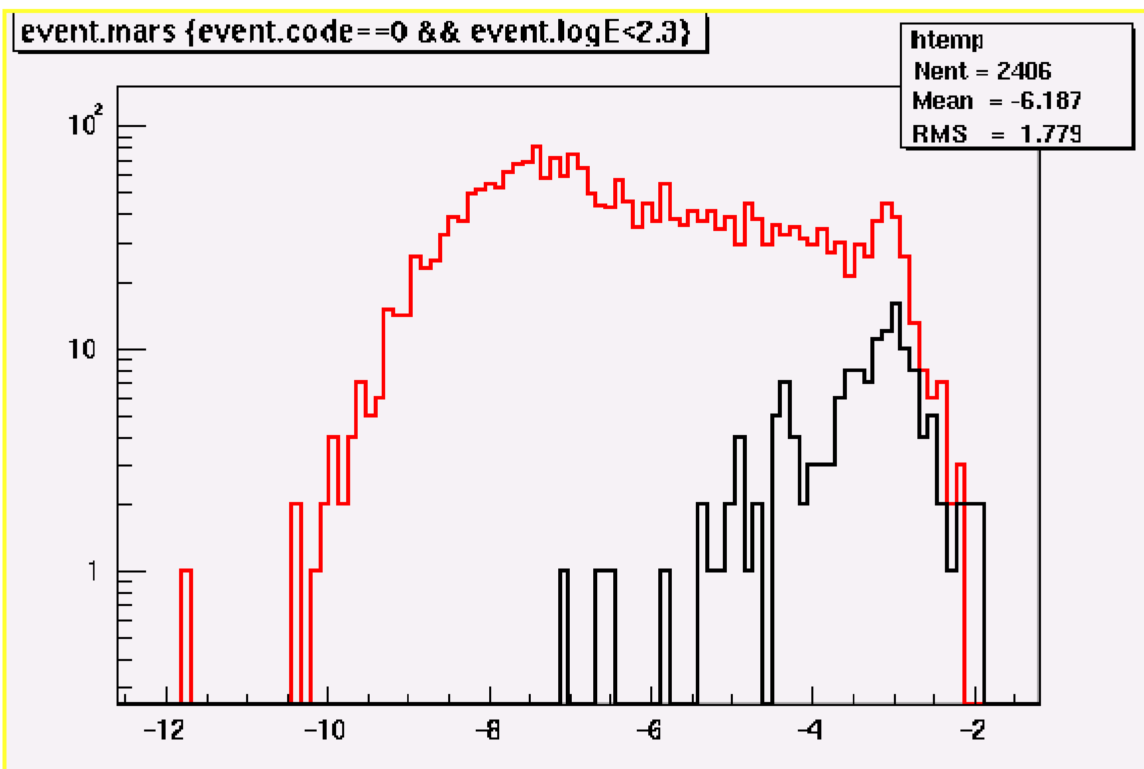



**Figure 7 MARS distribution for low energy protons (red line) and low energy gammas (black line). Low energy corresponds to primaries with E<200 GeV.**

# Appendix

Some plots comparing the Monte Carlo and the data for the four parameters used in the above analysis. Also shown for comparison are the distributions for gamma rays.

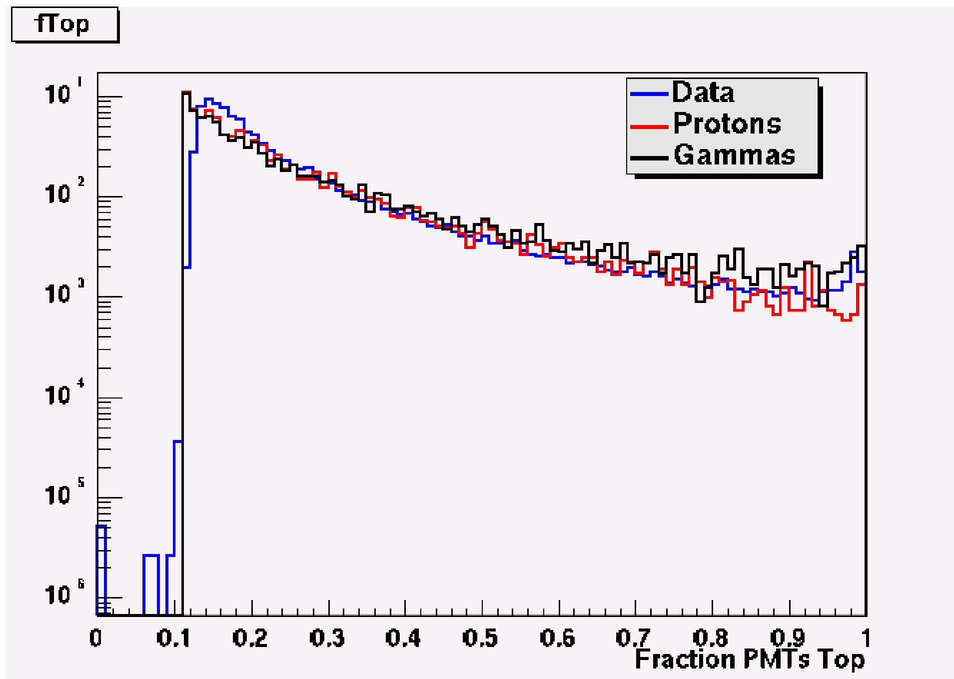
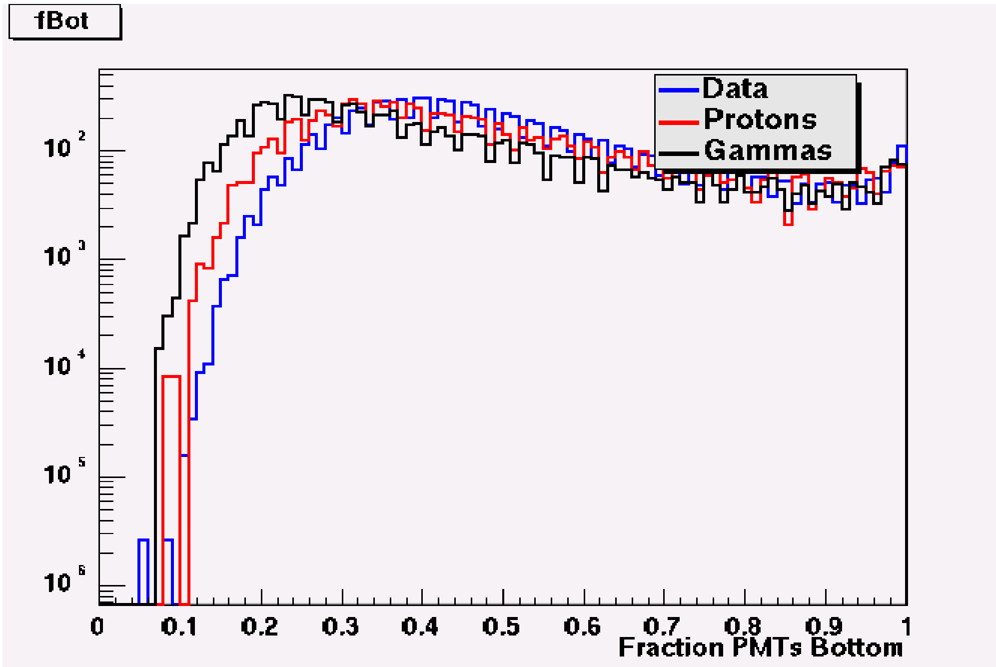



**Figure 8 Distribution of fTop: fraction of PMTs hit in the top layer. See legend for color code. All histograms normalized to 1.**



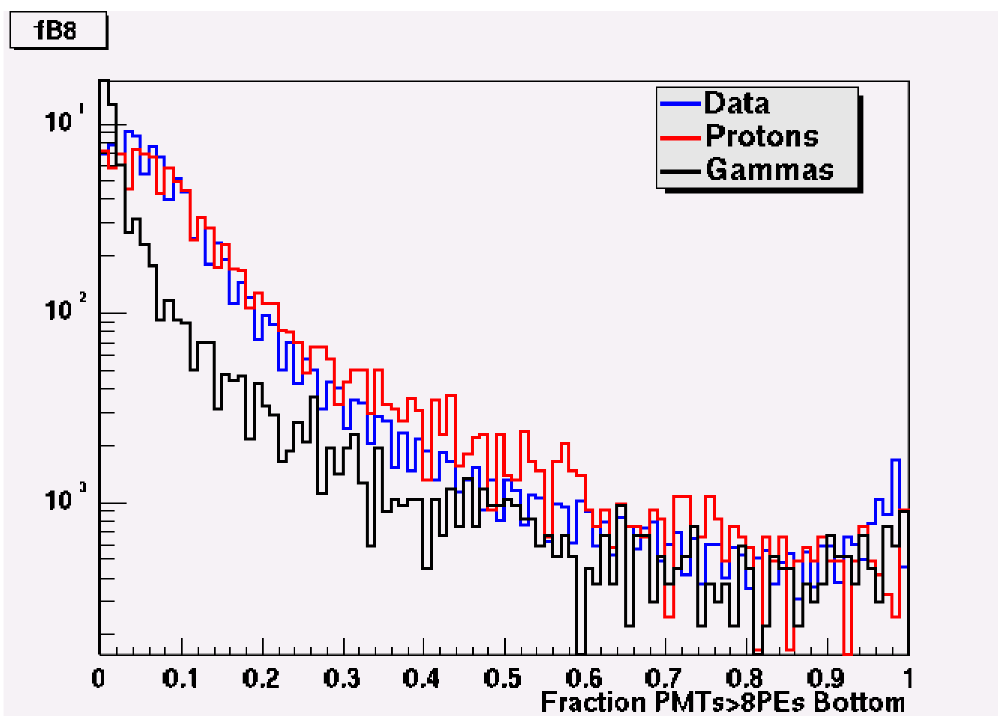




**Figure 10 Fraction of PMTs in bottom with > 8 PEs**

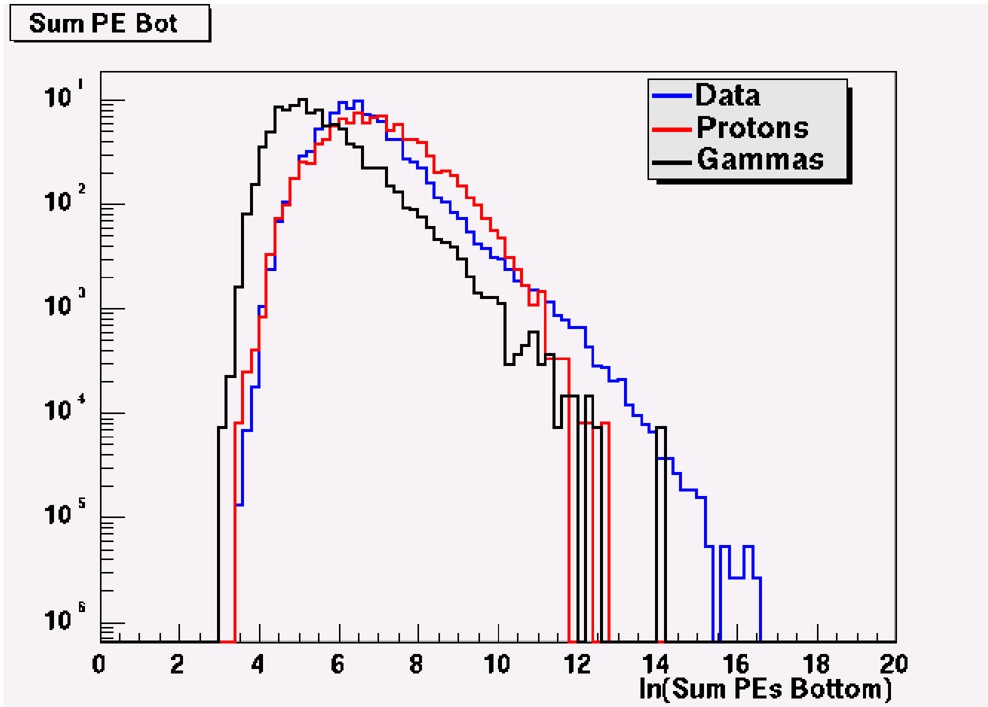



**Figure 11 ln of sum PEs in bottom.**

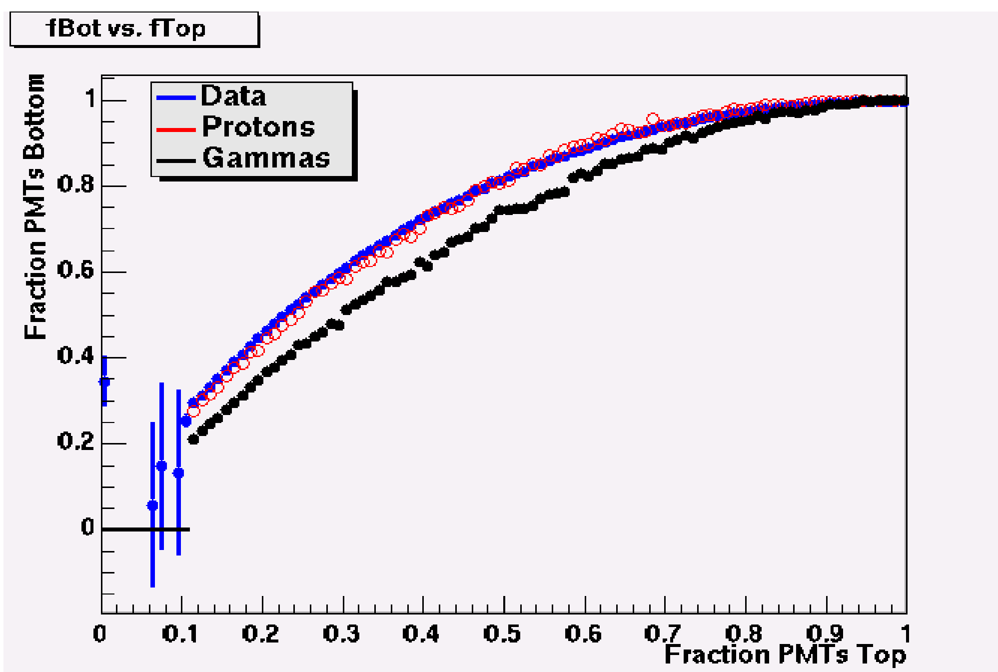



**Figure 12 Fraction bottom vs. fraction top**

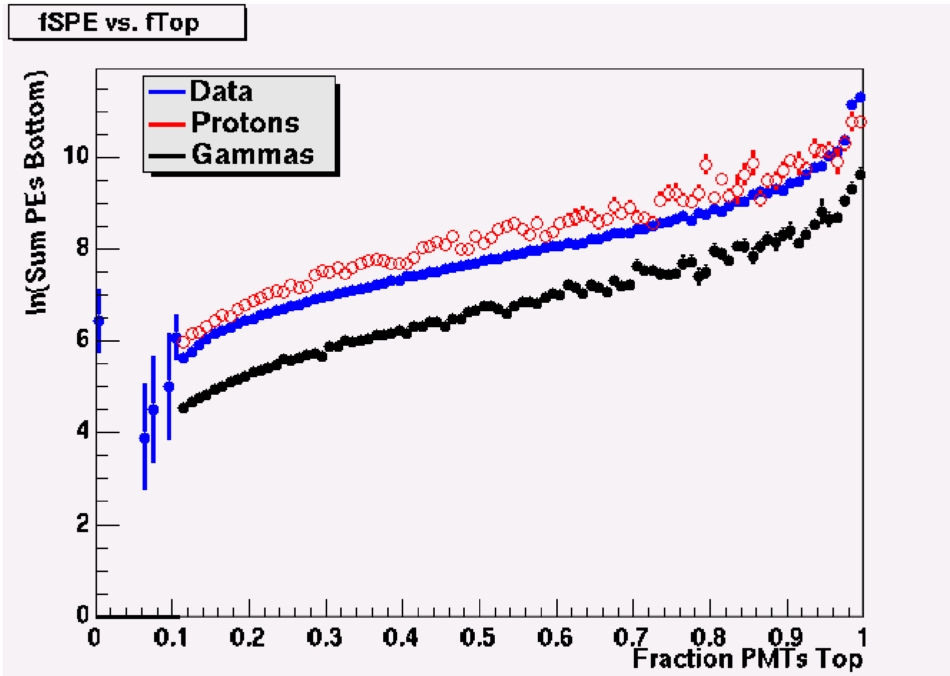



**Figure 14 Sum PEs (ln) bottom vs. fTop**

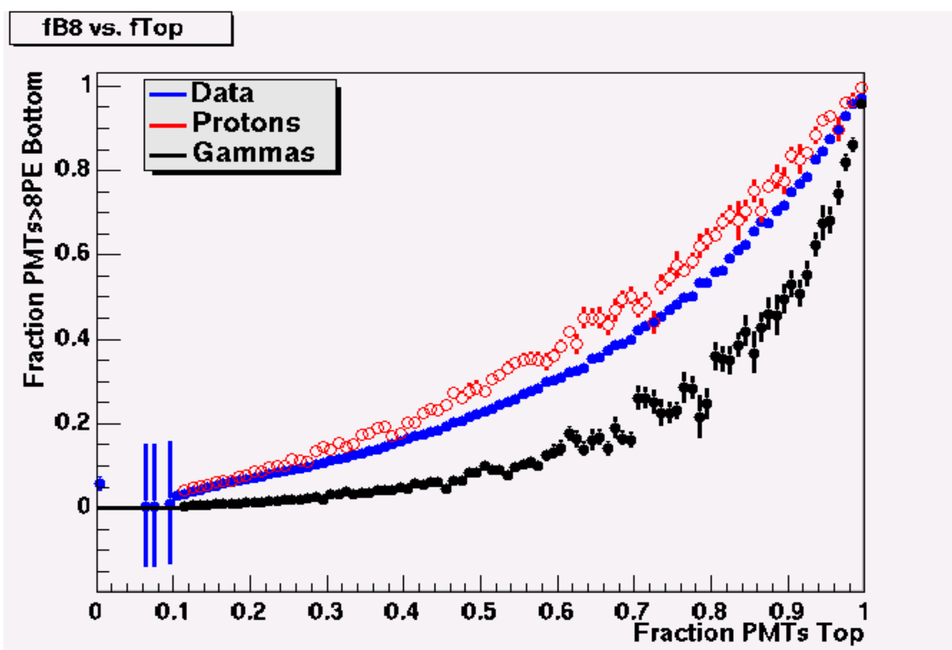



**Figure 13 Fraction > 8 PEs bottom vs. fraction top.**

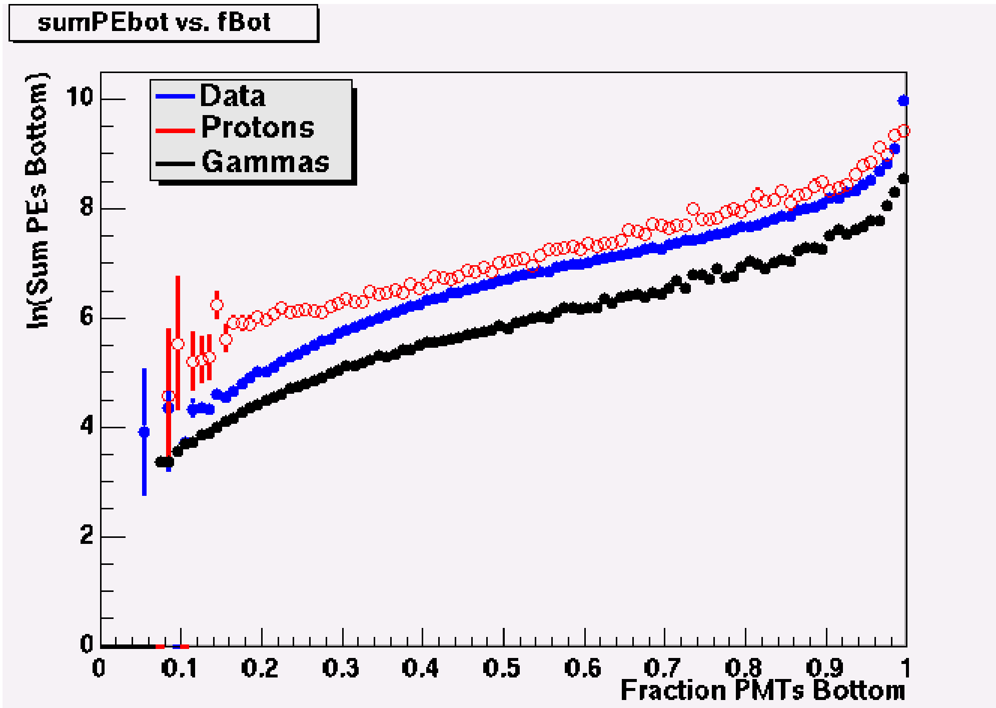



**Figure 16 Sum PEs (ln) bottom vs. fraction bottom.**

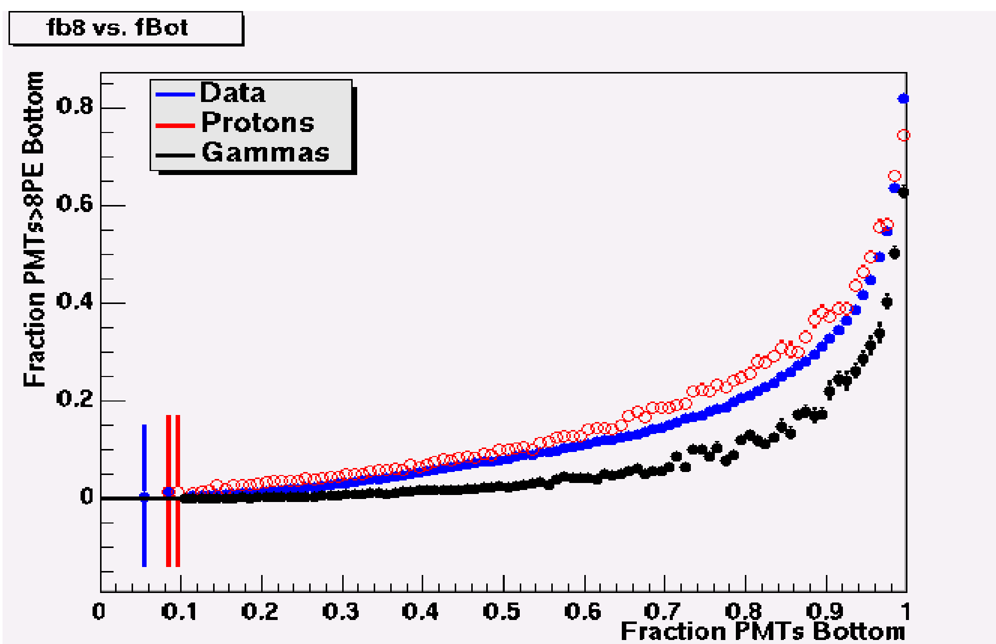



**Figure 15 Fraction > 8 PEs bottom vs fraction bottom.**

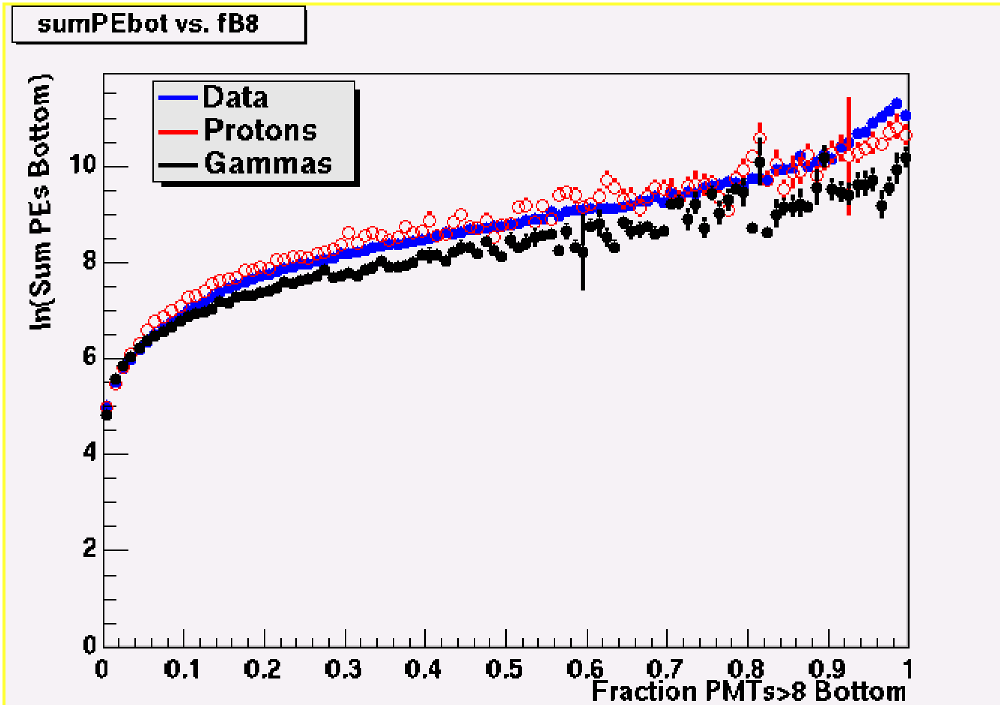



**Figure 17 Sum PE (ln) bottom vs. fraction bottom > 8 PEs.**