A study on the stability of the Milagro data and its agreement with the MC from epoch to epoch.

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16th June 2006

Abstract

Milagro reconstructed data of all epochs were analysed and compared with the appropriate Geant4 MC data. The stability of X2, A4 and nfit were also tested vs time by examining their differential, integral and mean value plots. The effects of the 2005 repair on the pond were also examined. Finally, the effects of the baffles (black vs silver vs white) were examined with the MC. The main findings are that the repair had a big effect on the data properties which cannot be explained by the baffles and that as we go back in time the Milagro data exhibit less stability and worse agreement with the MC.

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1 Introduction

The motivation for this study was the absence of reasonable results for the Crab spectral index & flux using the MC and the big differences between the results derived from analysis of each epoch. In my memo[1] I have showed that the MC agrees reasonably well with data taken after the 2005 repair and analysed with the latest calibrations 603. However, most of Milagro data were taken using different calibrations and reconstructions. This memo will try to answer the question if a) the current MC agrees with earlier data and b) if the data properties are stable over time.

From Andy and the log book, I could divide the Milagro data to the following epochs:

Epoch #	Angle & core fitters	Trigger	Start Run #	Start Date	Reconstruction v.	Start F-tape	Comment
1	COM	Multiplicity	2360			20	
2	OFF	Multiplicity	around 2701	12/15/2000	50-56	32	
2.5	OFF	VME	3768	1/25/2002	56-60	71	
3	ORCOM	VME	4817	2/12/2003	61	119	
2.5	OFF	VME	4850	3/3/2003	60	121	
3	ORCOM	VME	4973	5/22/2003	61-63	132	
4	Gaussian 3 Layer	VME	5919	10/8/2004	69, 70	201	
5	Gaussian 2 Layer	VME	6233	4/3/2005	71	221	Pre-repair
5.3	Gaussian 2 Layer	VME	6565	09/22/2005	71	244	Post-repair
5.6	Gaussian 2 Layer	VME	6867	3/18/2006	71	253	Calib 603
5.9	Gaussian 2 Layer	Multiplicity	6903	4/5/2006	71	271	VME trigger died

Table 1: Properties of the various epochs

2 About the analysis

2.1 Analysis of the MC data

Core and angle fitter configuration

The milinda code used for configuring the angle and core fitters for the various epochs can be found at Appendix 1 on page 41.

Trigger configuration

For comparison with data after the last repair the following trigger configuration was used :

```
25
0
110  30  0
77   7   0
36   4   0
30   30  1000
```

This trigger configuration is the one used in my previous MC memo and was created by matching to data run 6662 (November 2005).

For comparison with data before the last repair the default milinda trigger configuration was used:

```
31
0
90   30   0
63   7    0
32   4    0
32   30   1000
```

For comparison with earlier non-VME trigger epochs, a 60PMT trigger was used.

Dead PMTs

In most of the comparisons a MC analysis with no dead PMTs and one with 10% dead PMTs was used. The dead PMTs were selected randomly at the beginning of the analysis.

Pond configuration

There were many different sets of data used for this study:

- For late (after the last repair) data, the MC data used were the ones found at *//data/montecarlo/sim/GEANT4/v2.0/0.99_AbsL30m_ScatL50m_PRO/*. They are produced with g4sim v2.0 and correspond to white baffles, forward mie scattering with asymmetry factor 0.99, 30m Absorption length and 50m Scattering length and no air under the cover. The white baffle material is a diffuse reflector with reflectivity starting at 88% at long wavelengths dropping to 40% at 450nm and 10% shorter than that. The numbers used were the ones measured and reported by David Schmidt[2]. There were about 9.1k VME triggers available for this dataset.
- For earlier (pre-repair) data, the MC data used can be found at */data/montecarlo/sim/GEANT4/Milagro2.1/silverbaffles*. They correspond to g4sim v2.1 with silver baffles, Mie scattering with asymmetry factor 0.99 which is 80% of the times forward and 20% of the times backward, 27m Absorption length, 56m Scattering length and no air under the cover. The silver baffle properties are a guesstimate by me and correspond to specular reflections with flat 80% probability vs wavelength. There were about 19k VME triggers available for this dataset.
- For the MC vs MC comparison, a black baffle configuration was used. This corresponds to g4sim v2.1 with perfectly absorbing baffles, Mie scattering with asymmetry factor 0.99 which is 80% of the times forward and 20% of the times backward, 27m Absorption length, 56m Scattering length and no air under the cover. The data can be found at */data/montecarlo/sim/GEANT4/Milagro2.1/blackbaffles.* There were about 7.8k VME triggers available for this dataset.

PE rescaling

Due to calibration errors (probably a systematic in the filter wheel calibration) the number of pes returned by the pre-603 calibrations is higher than (what we believe is) the correct number of pes. For that reason, Andy and I, added the functionality in milinda to rescale the "real" MC pes up to a number the old calibrations would give. In order to compare the MC with data that were produced with earlier than 603 calibrations, this pe rescaling must be applied. In this study, for all comparisons with epochs earlier than 5.6, the MC pes were rescaled according to $PEs_{rescaled} = PEs_{MC}(1 + 0.18 \cdot log_{10}(PEs_{MC}))$.

2.2 Analysis of the rec data

For this study rec data were used. For each epoch, one every 40 runs was analysed. Each curve produced corresponds to 30million triggers. If a run didn't have enough events then the following runs were used. For example if the run 6000, for some reason, had only 15million triggers then the analysis would continue to run 6001 and so forth.

2.3 About the plots

All the data curves were divided by the duration that corresponded to these 30 million events (about 5.2 hours with a trigger rate of 1.6KHz). So the Y axis of the plots shows the rate in evts/sec. The MC curves were scaled so that their integral is equal to the average integral of the data runs.

One of the most important plots in the X2&nfit bins used by Andy. Plots that show the rate of events in each of those bins (defined in Table 2) are used by Andy for his flux and spectral measurements. For the X2&nfit bits plot, the MC curve is rescaled by hand so that the middle bins match.

Bin #	X2	nfit
1	2.5 - 3.0	20 - 50
2	3.0 - 3.5	50 - 75
3	3.5 - 4.0	75 - 100
4	4.0 - 4.5	100 - 125
5	4.5 - 5.0	125 - 150
6	5.0 - 5.5	150 -175
7	5.5 - ∞	175 - ∞

Table 2: X2 and nfit bins

3 Comparison: data vs data

3.1 Effects of repair on data

The reconstructed data runs analysed correspond to Epochs 5.6 (post repair) and 5.3 (pre repair). These were (epoch 5.3 - black) 6600 to 6840 every 40 runs and (epoch 5 - blue) 6240 to 6480 every 40 runs.

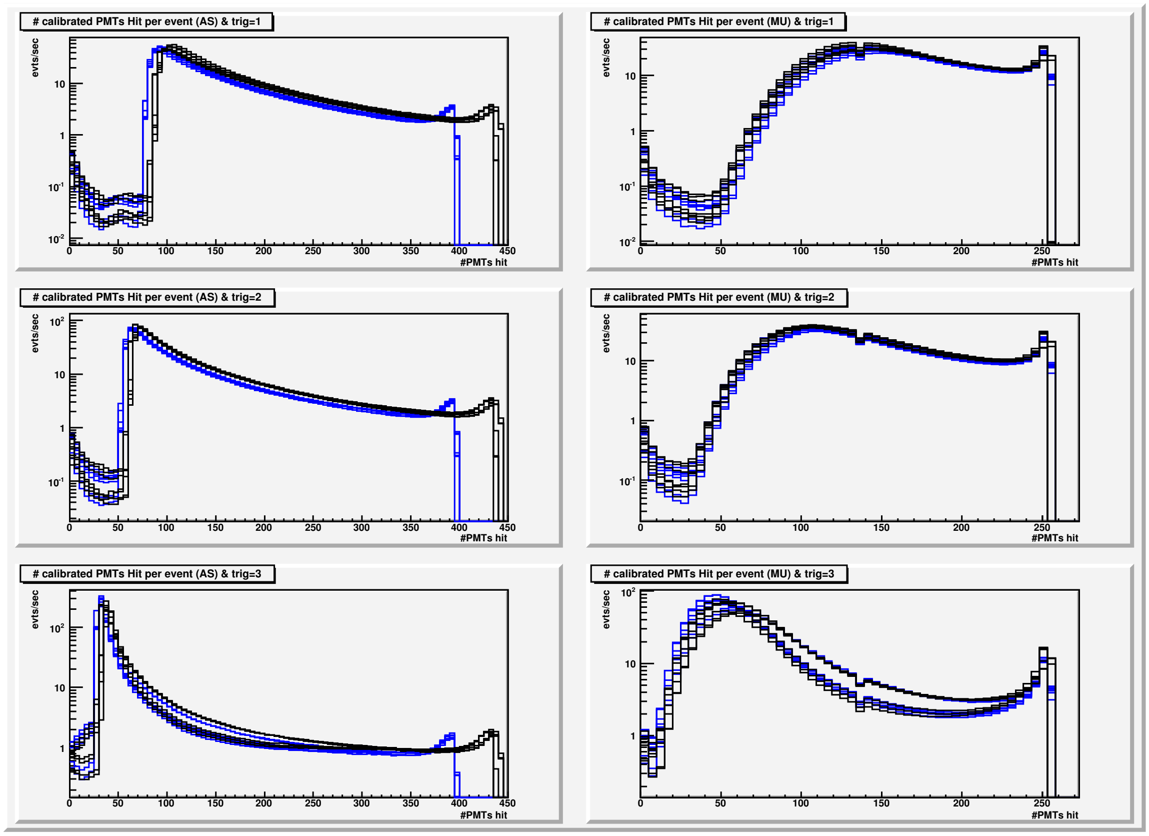

Figure 1: nPMTs hit vs trigger

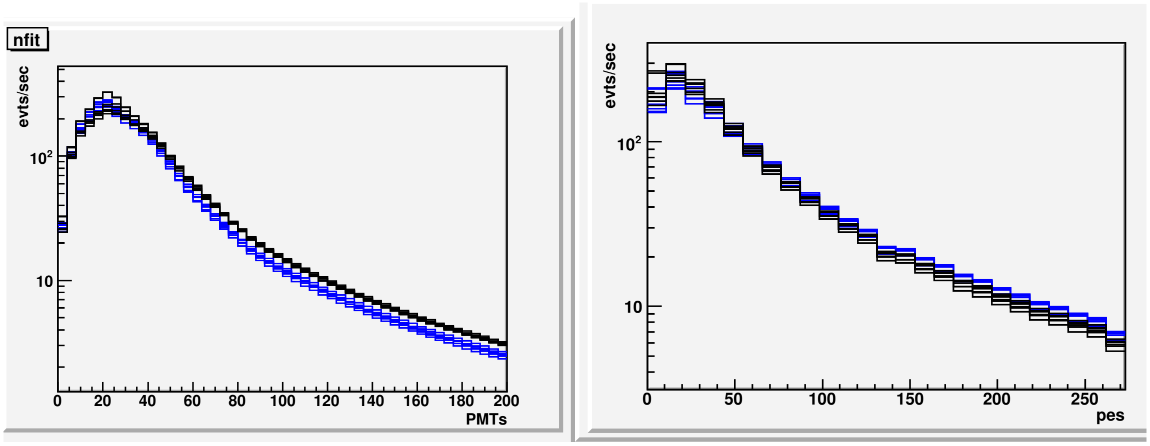

Figure 2: nfit & mxPE

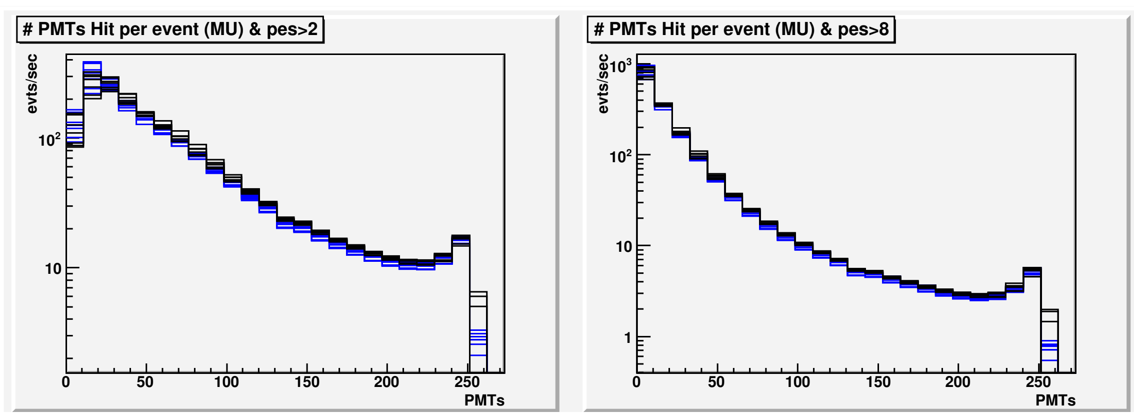

Figure 3: nb2 and nb8

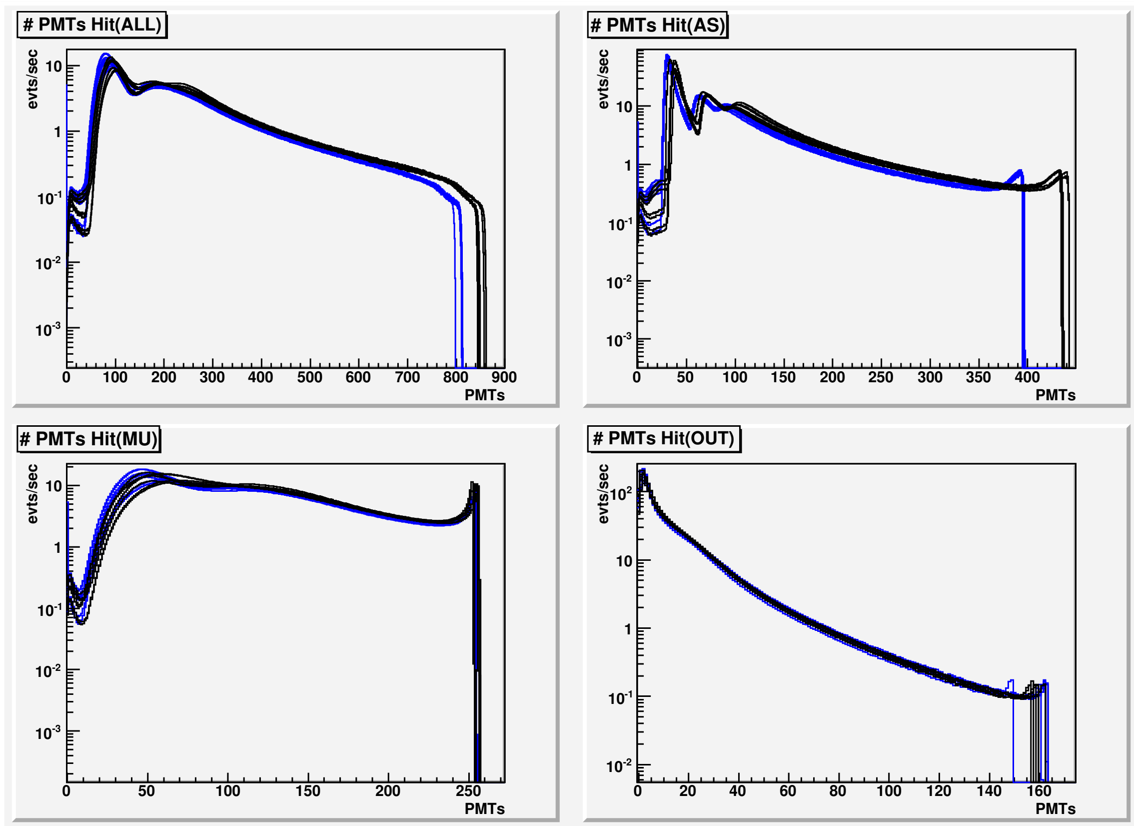

Figure 4: nPMTs hit per event

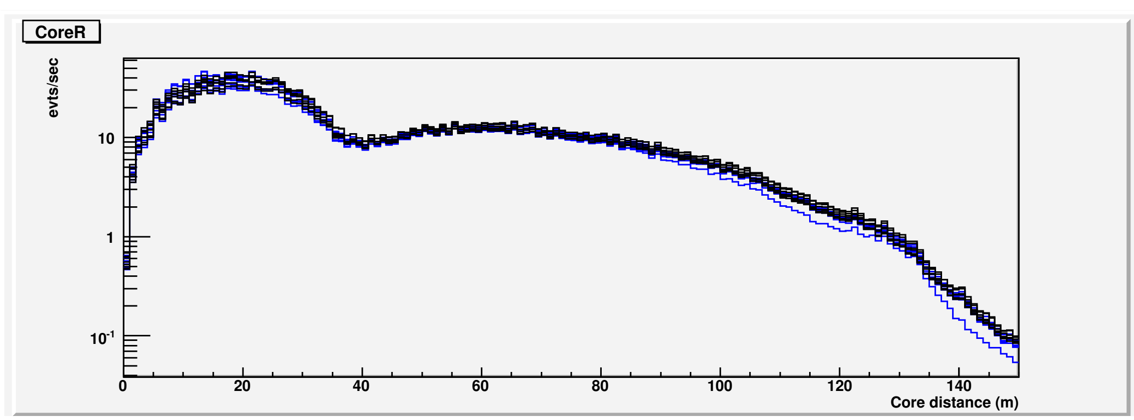

Figure 5: Core distance

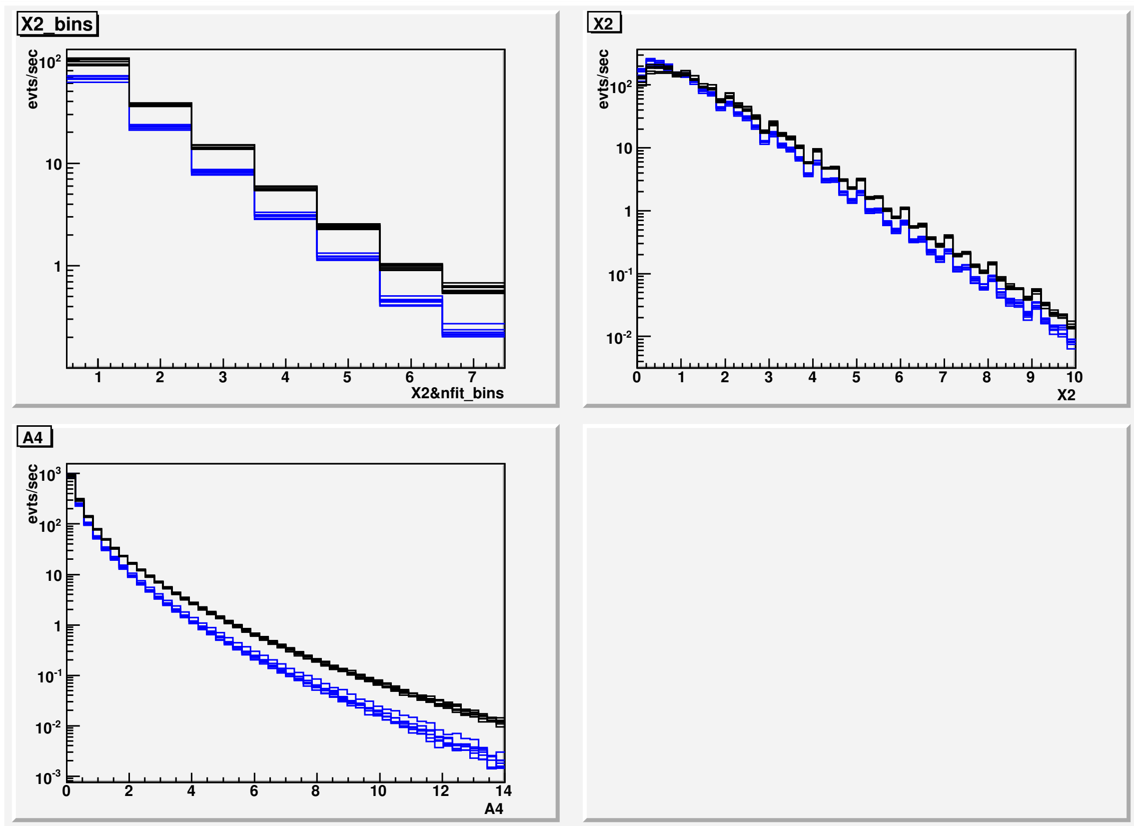

Figure 6: X2 & A4

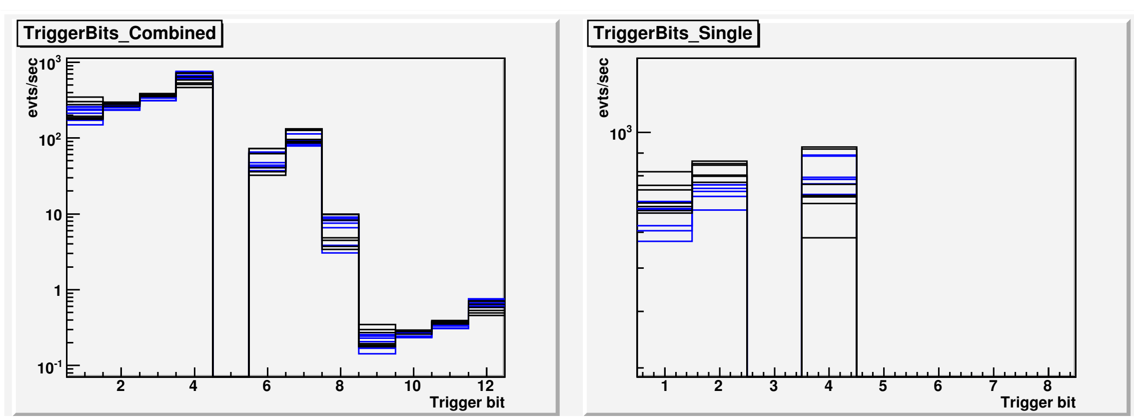

Figure 7: Trigger data

3.2 Stability of data vs time

The stability of X2, A4 and nfit was tested for all Milagro data. One every 40 runs from Epoch 1 (run 2400) until recently (run 6940) were analysed.For A4, no analysis could be made for runs earlier than run 4840, since no outrigger data were saved in those rec files (A3 is used for that era). Also for Epoch 4 (3 layer fitter) no analysis was made for A4 and nfit data, since I don't currently know a reliable way to make a 3-layer to 2-layer fit conversion.

Differential and integral plots for X2, A4 and nfit were made. A gaussian fit was made on the peaks of the X2 and nfit distributions for each run. There wasn't such a fit for A4, since it doesn't have a peak like the other two parameters. The locations of these peaks vs run number was plotted. Lastly, the average of X2,A4 and nfit was plotted vs run number. These plots can be found in figures 8, 9 and 10 . In figures 11 and 12 the event rate over some X2 and A4 value are plotted vs runnumber. Each epoch corresponds to a different color: EP 1, 2, 2.5, 3, 4, 5, 5.3, 5.6 (dark green)

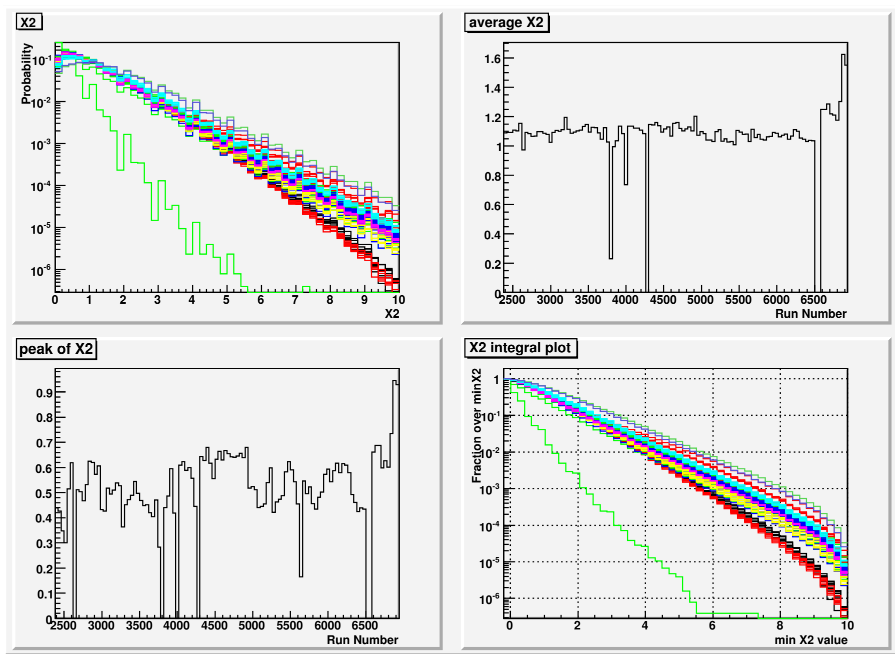

Figure 8: Stability of X2

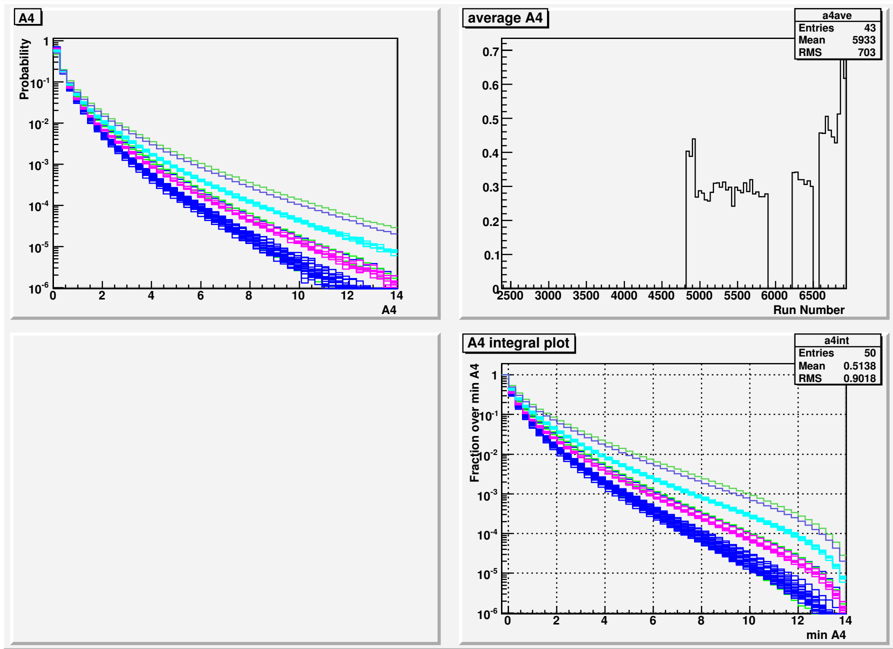

Figure 9: Stability of A4

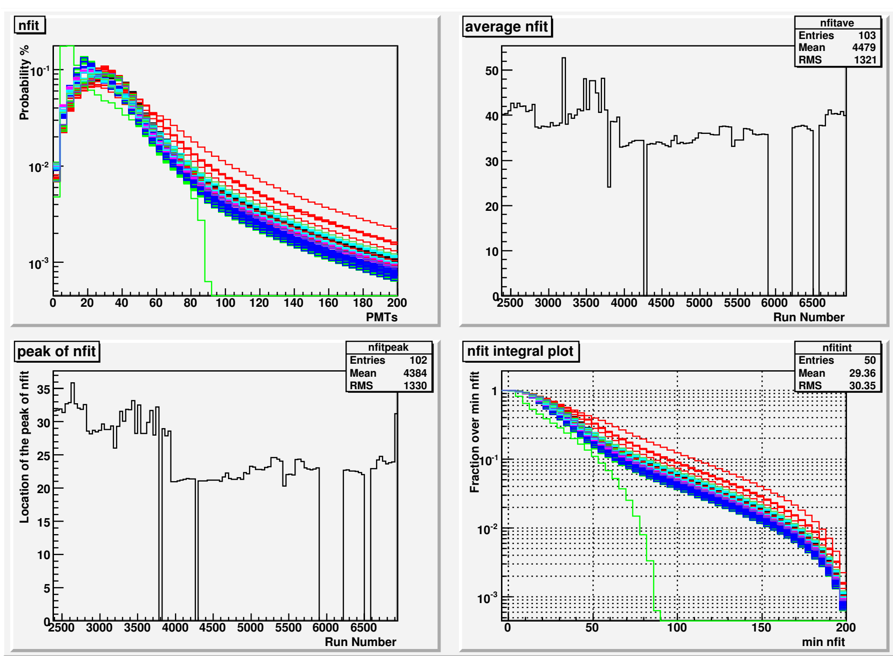

Figure 10: Stability of nfit

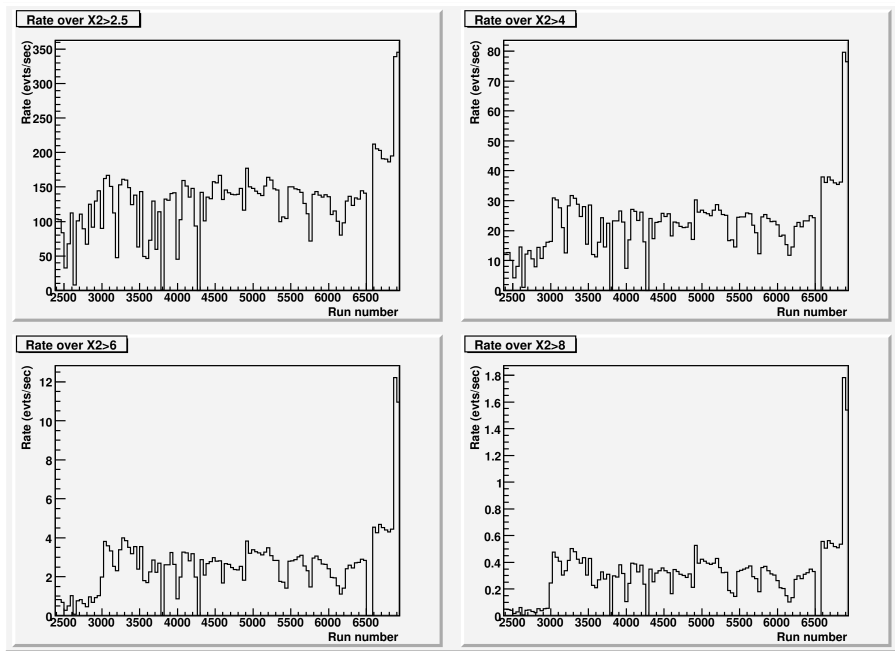

Figure 11: Event rates for different minX2 cuts

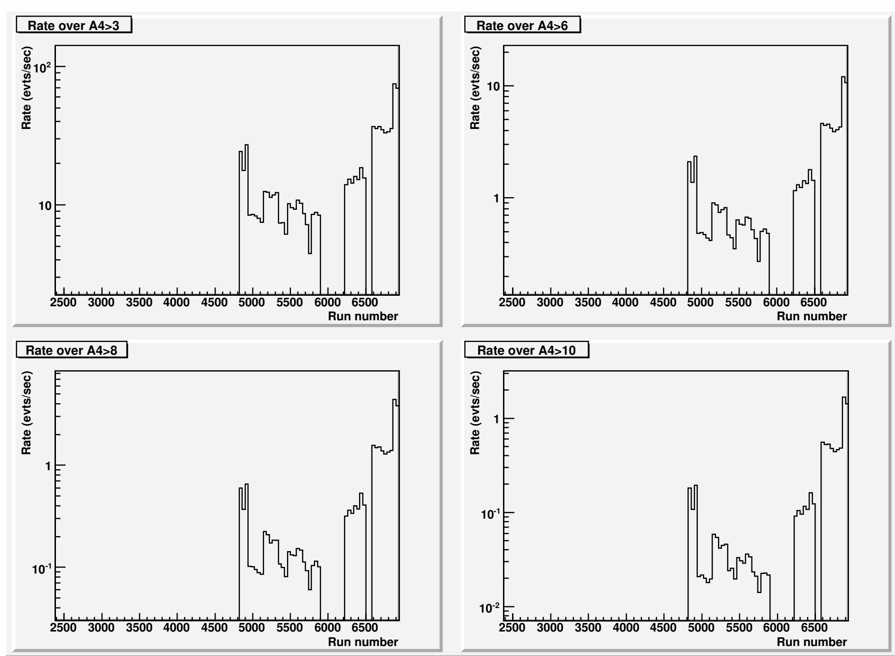

Figure 12: Event rates for different minA4 cuts

4 Comparison: MC vs MC

Only the effect of baffles on the MC was examined in this study. There are some data with air under cover but they are not enough to have good statistics. In the future I will prepare a more extensive memo examining the effects of more parameters.

4.1 Effect of baffles on the MC

Three MC configurations and a data run were compared. Black is data run 6660 (post repair 501 - calibrations). Red is MC with black baffles, green is white baffles and blue is silver baffles.

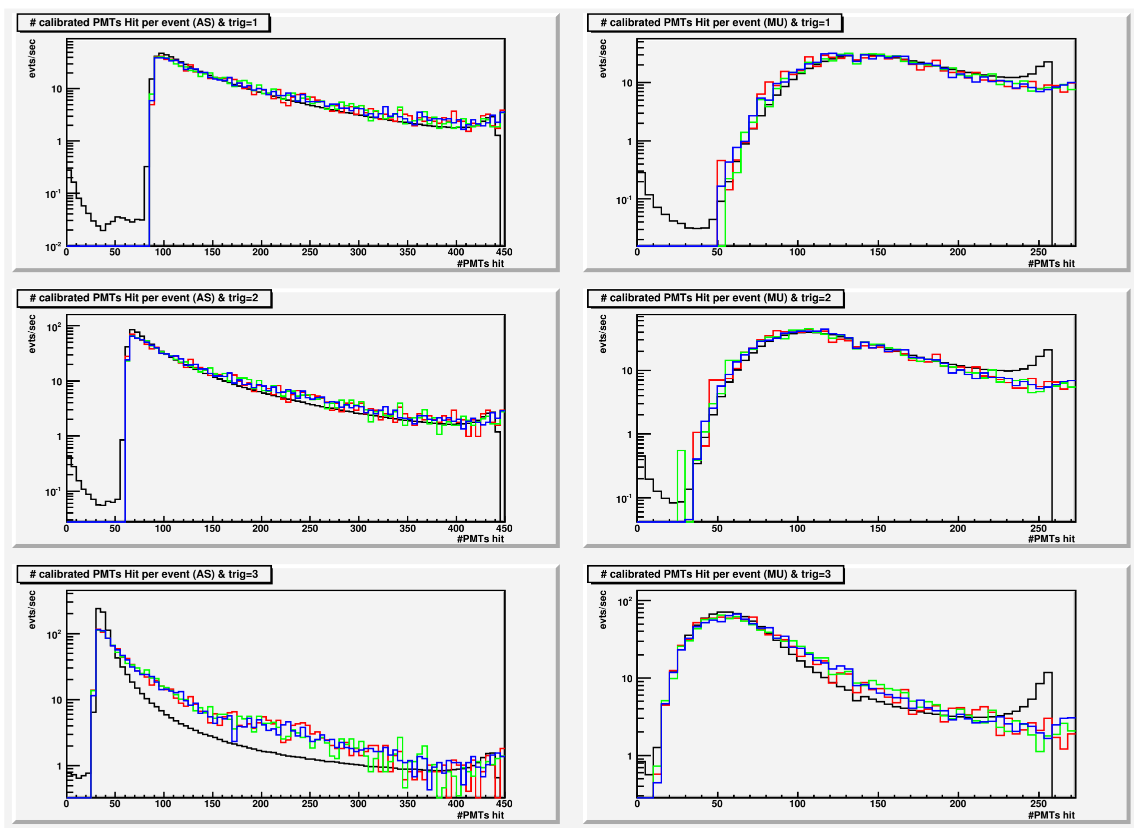

Figure 13: nPMTs hit vs trigger

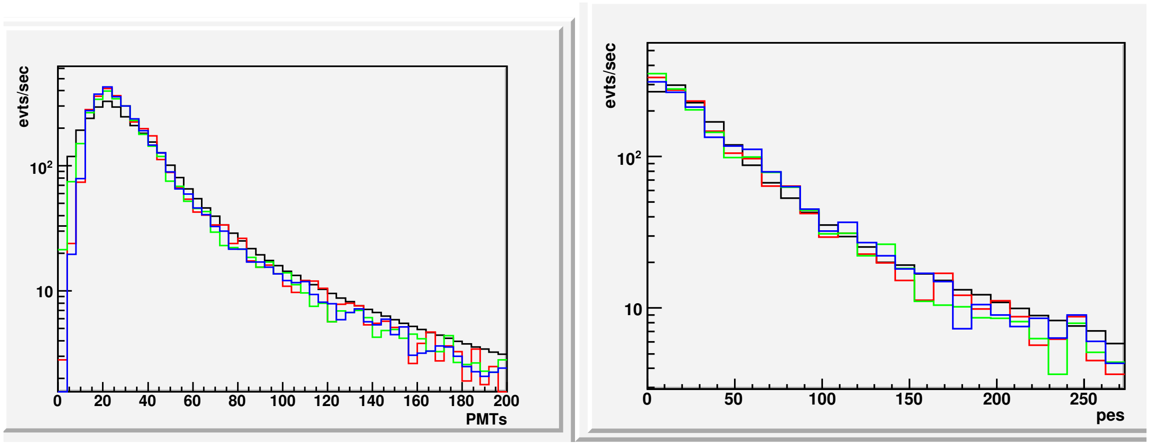

Figure 14: nfit & mxPE

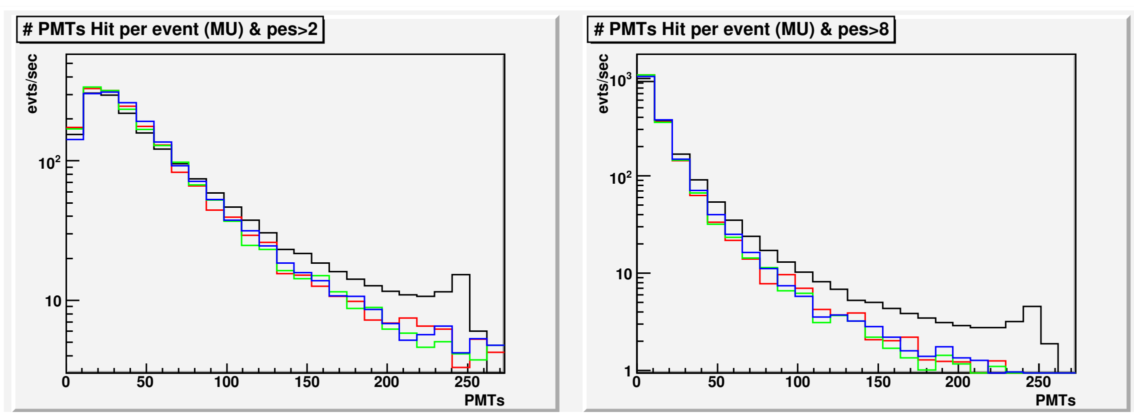

Figure 15: nb2 and nb8

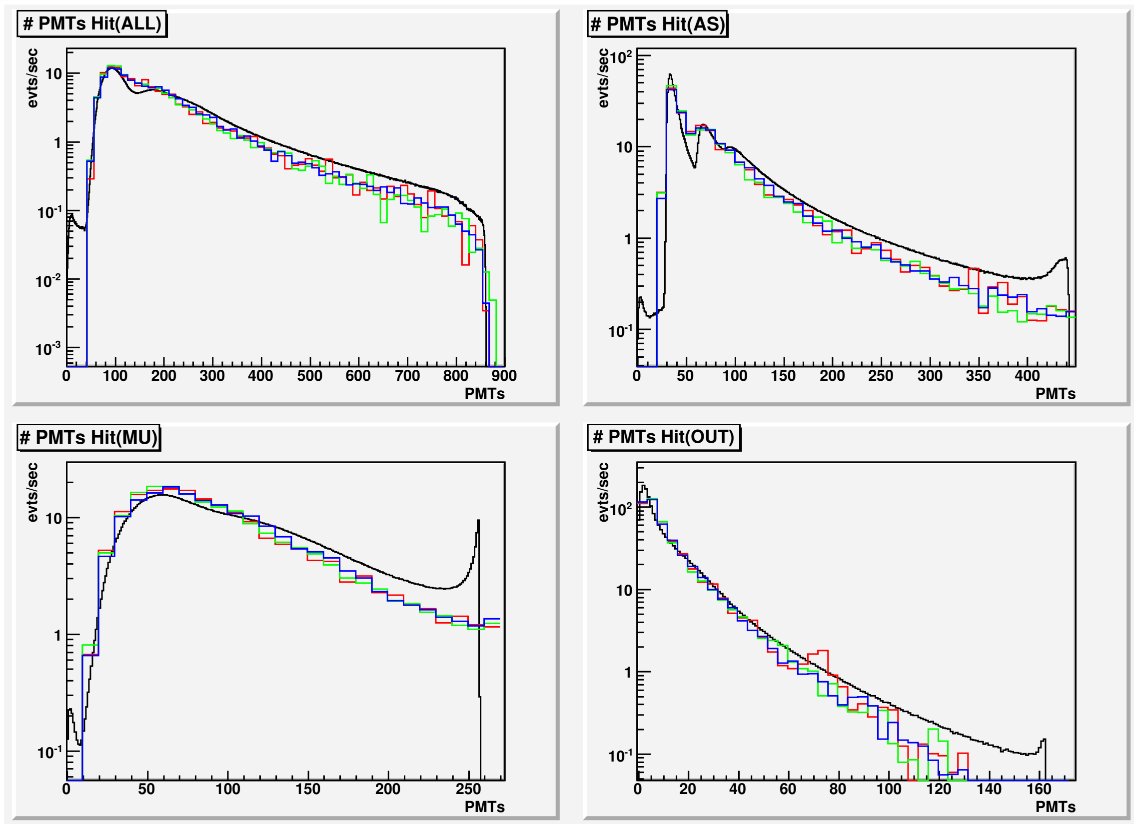

Figure 16: nPMTs hit per event

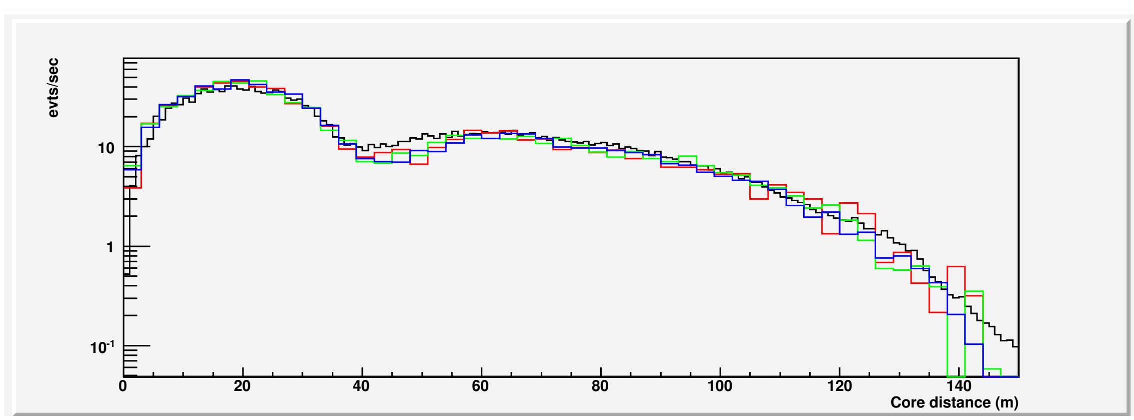

Figure 17: Core distance

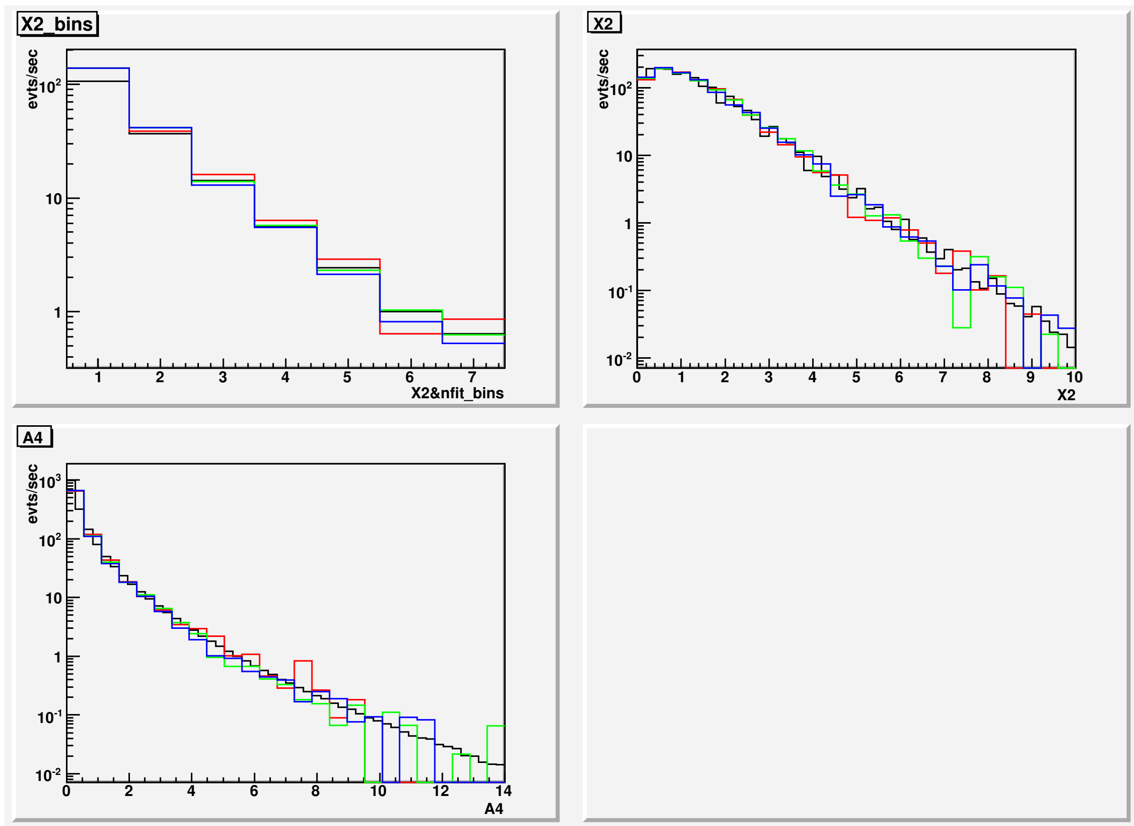

Figure 18: X2 & A4

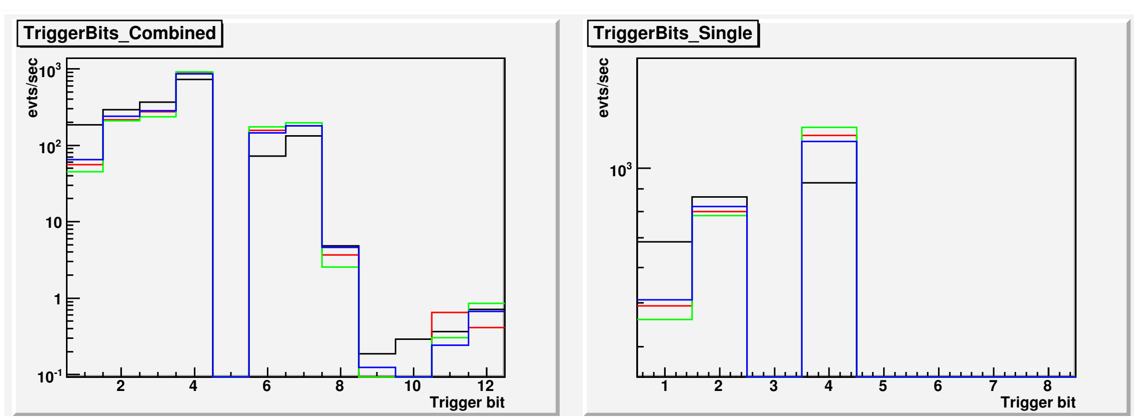

Figure 19: Trigger data

5 Data vs MC

5.1 Epoch 5.3 - Gaussian 2 layer - Post repair - Pre 603 calibs

The reconstructed data runs analysed (black lines) were 6600 to 6840 every 40 runs. The red and green curves correspond to silver baffles MC (see chapter 2.1) with no dead PMTs and 10% dead PMTs correspondigly.

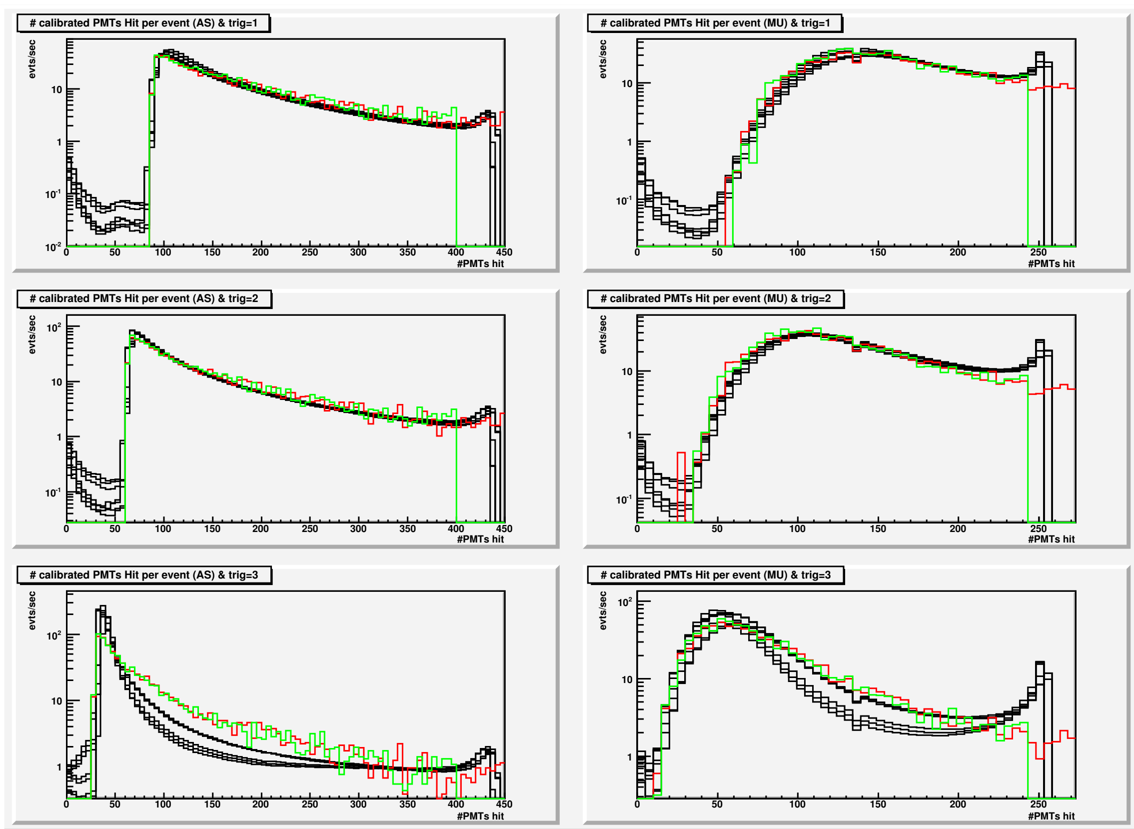

Figure 20: nPMTs hit vs trigger

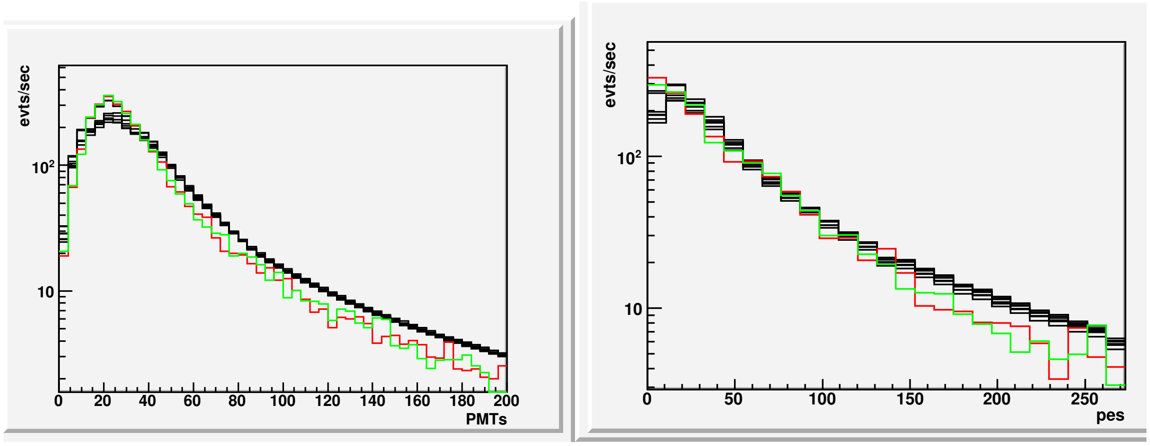

Figure 21: nfit & mxPE

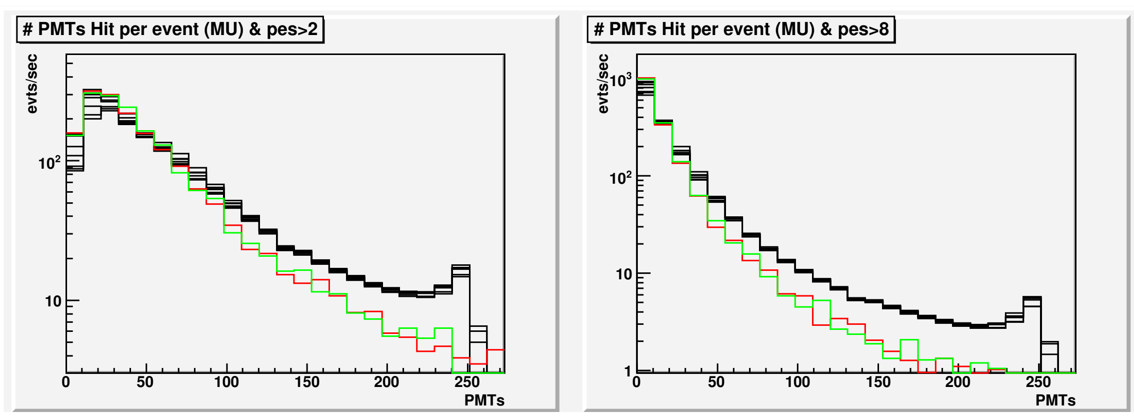

Figure 22: nb2 and nb8

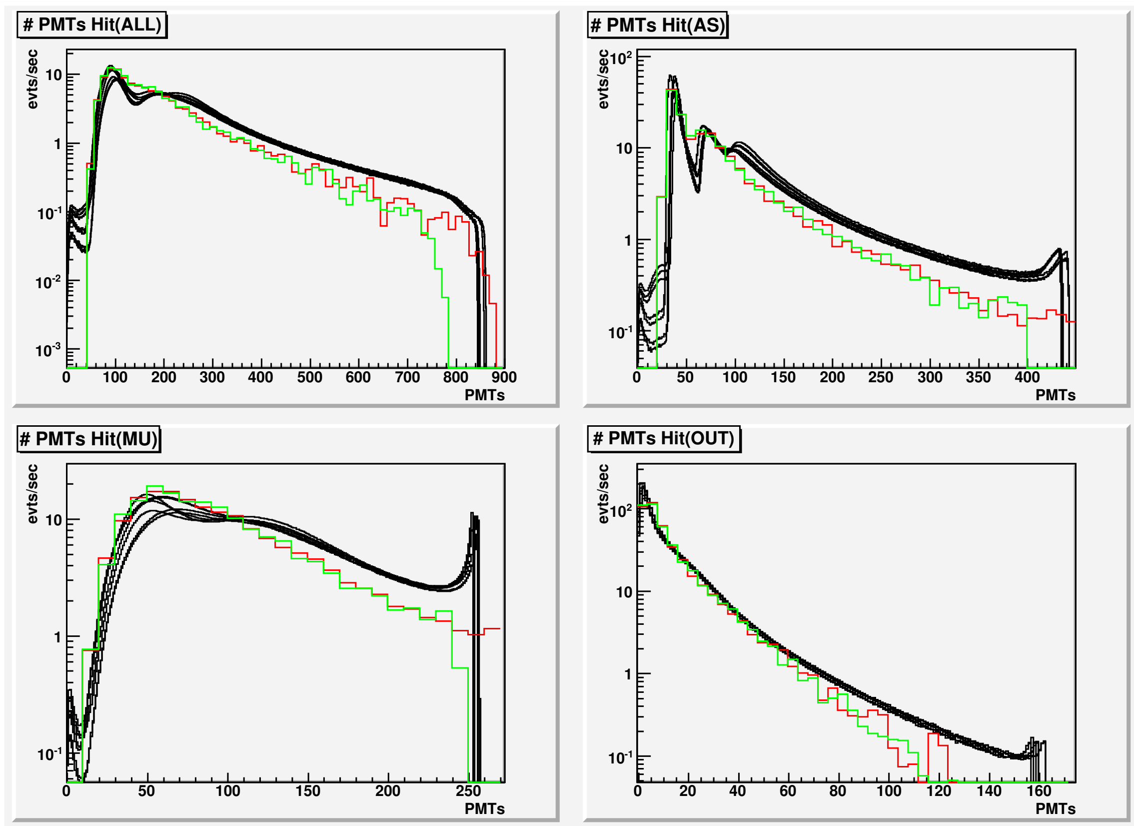

Figure 23: nPMTs hit per event

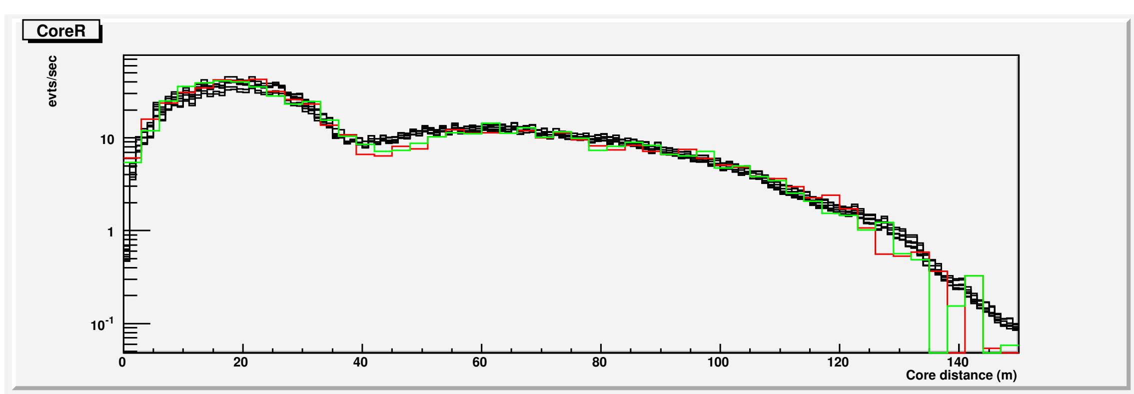

Figure 24: Core distance

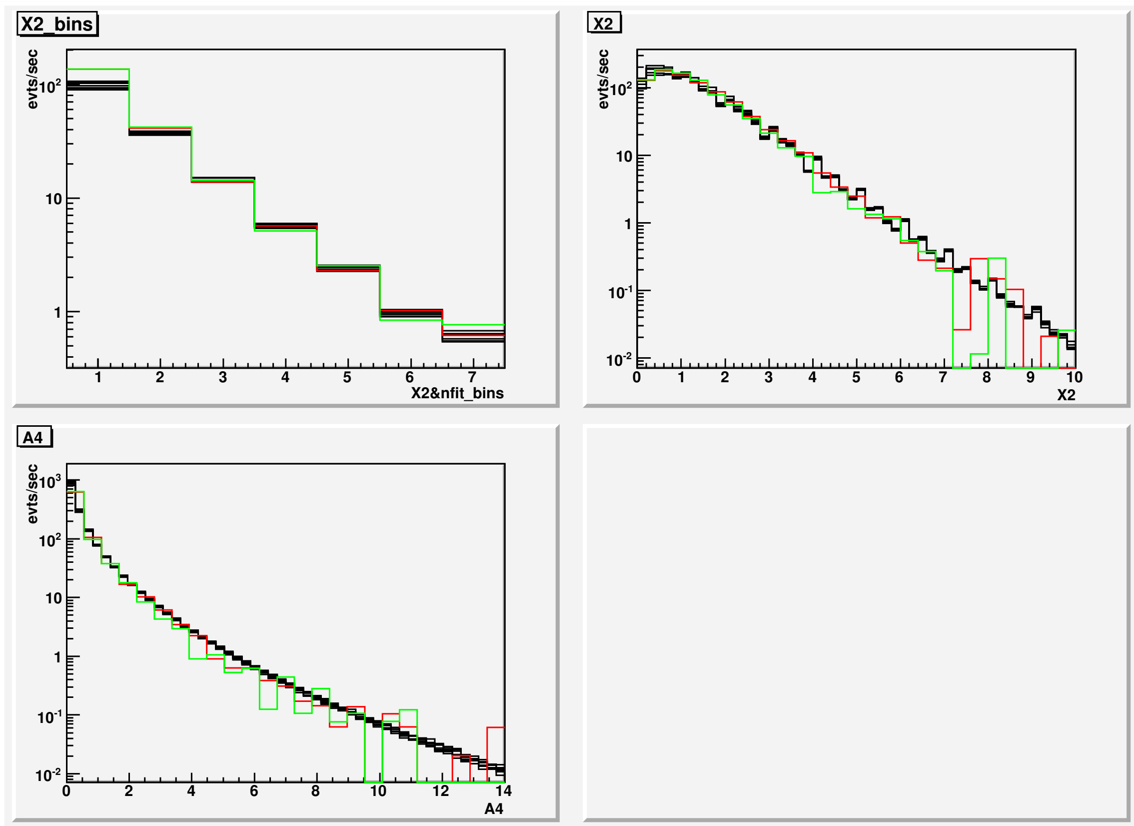

Figure 25: X2 & A4

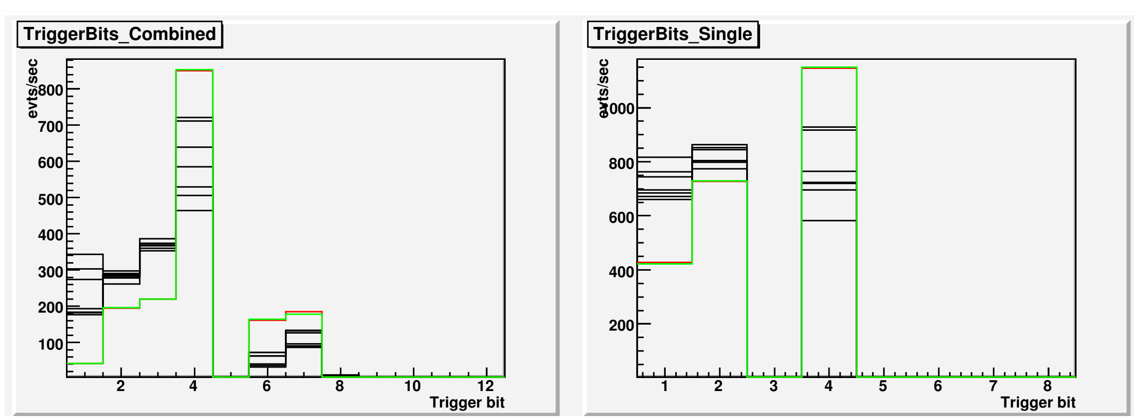

Figure 26: Trigger data

5.2 Epoch 5 - Gaussian 2 layer - Pre repair - Pre 603 calibs

The reconstructed data runs analysed were 6600 to 6840 every 40 runs. The red and green curves correspond to silver baffles MC (see chapter 2.1) with no dead PMTs and 10% dead PMTs correspondigly.

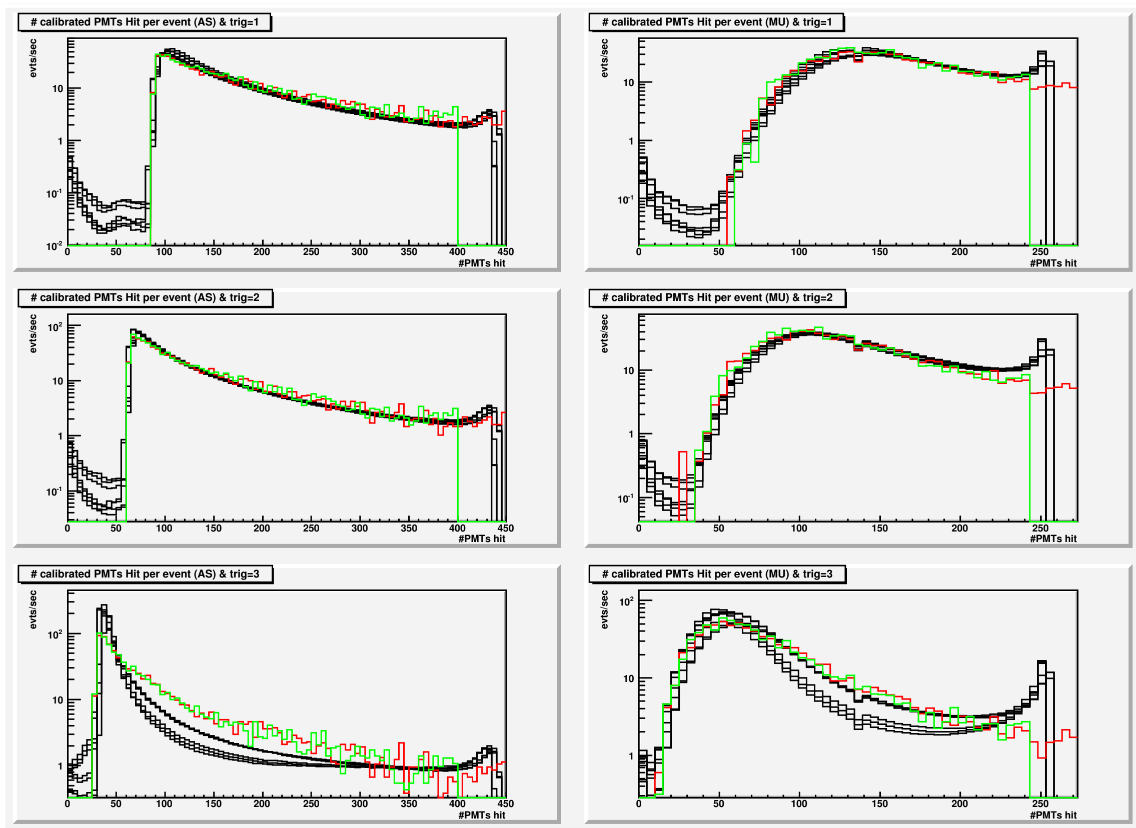

Figure 27: nPMTs hit vs trigger

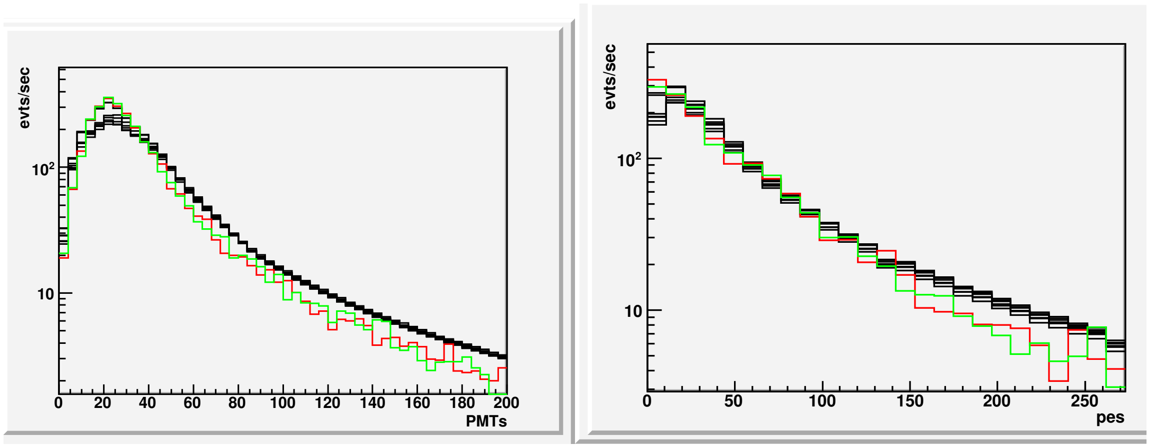

Figure 28: nfit & mxPE

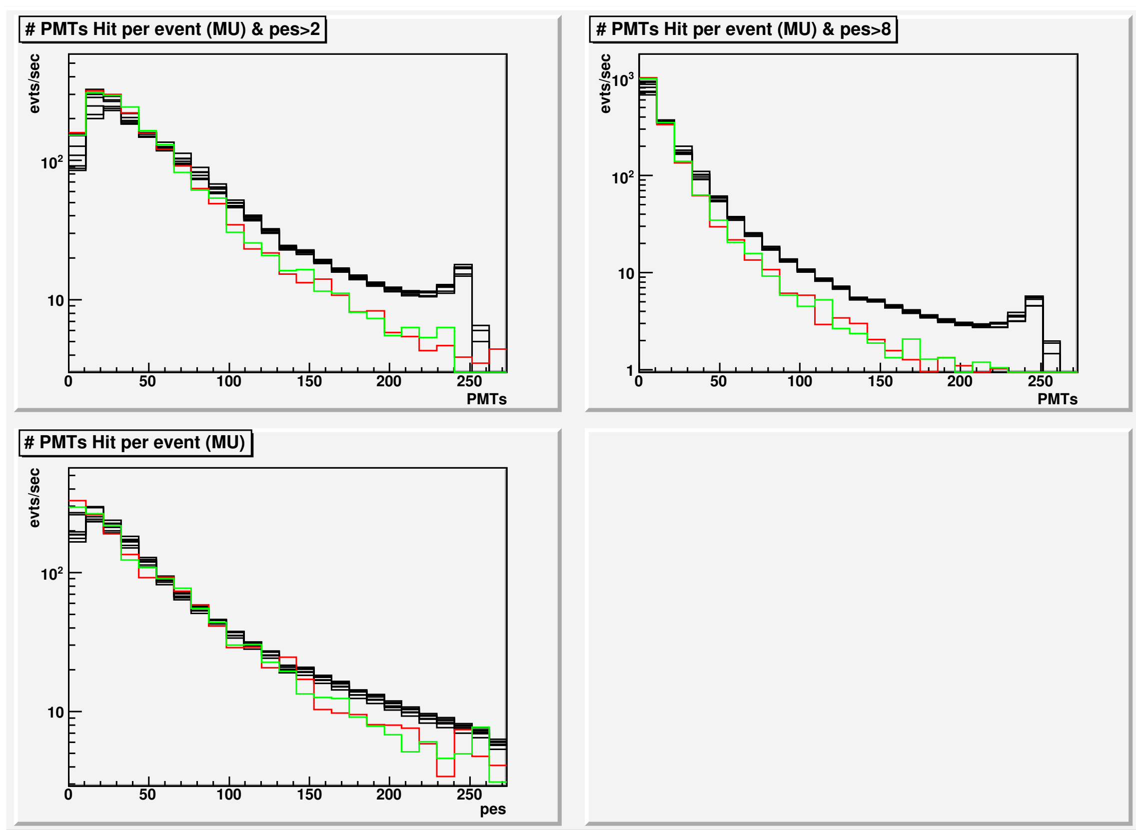

Figure 29: nb2 and nb8

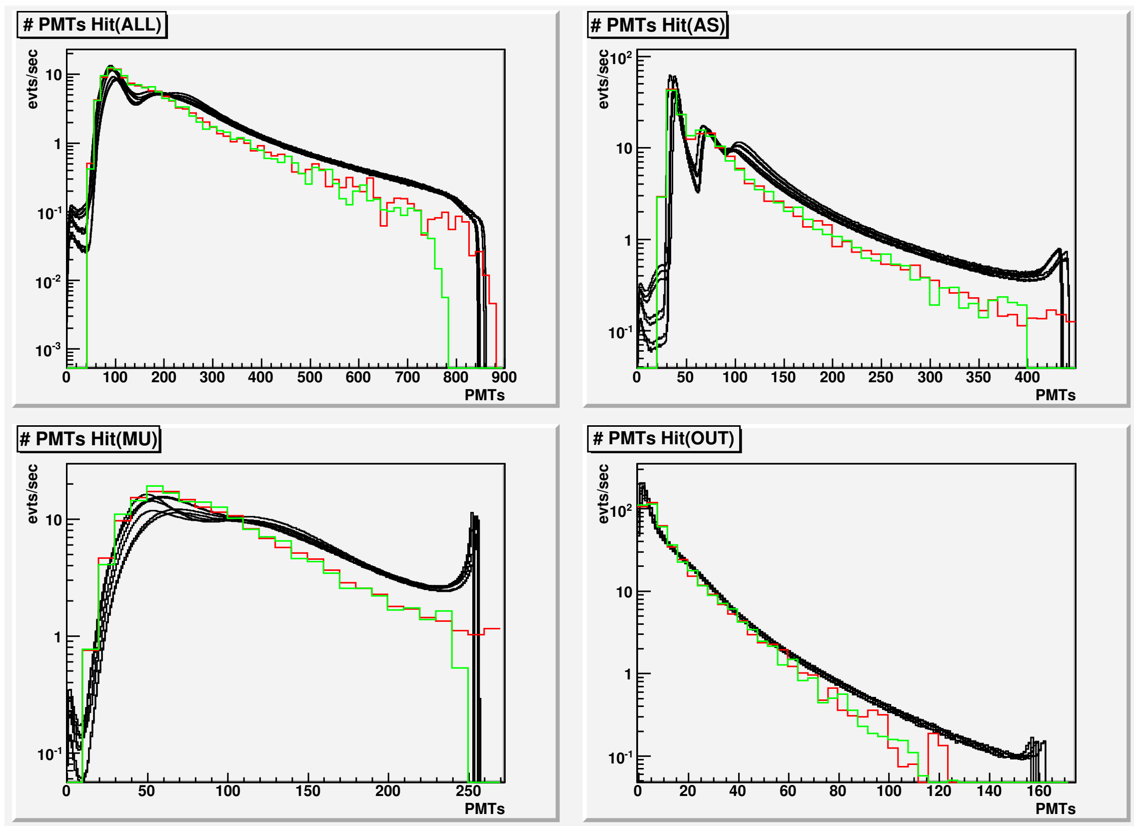

Figure 30: nPMTs hit per event

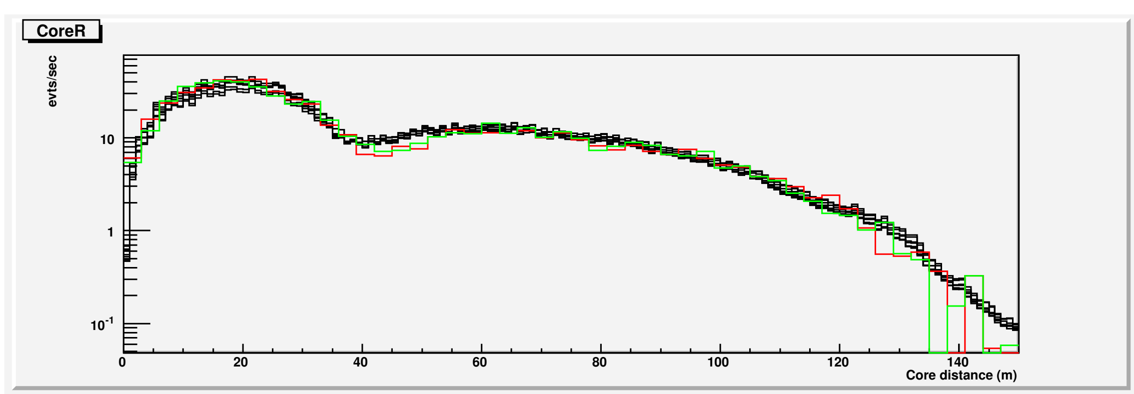

Figure 31: Core distance

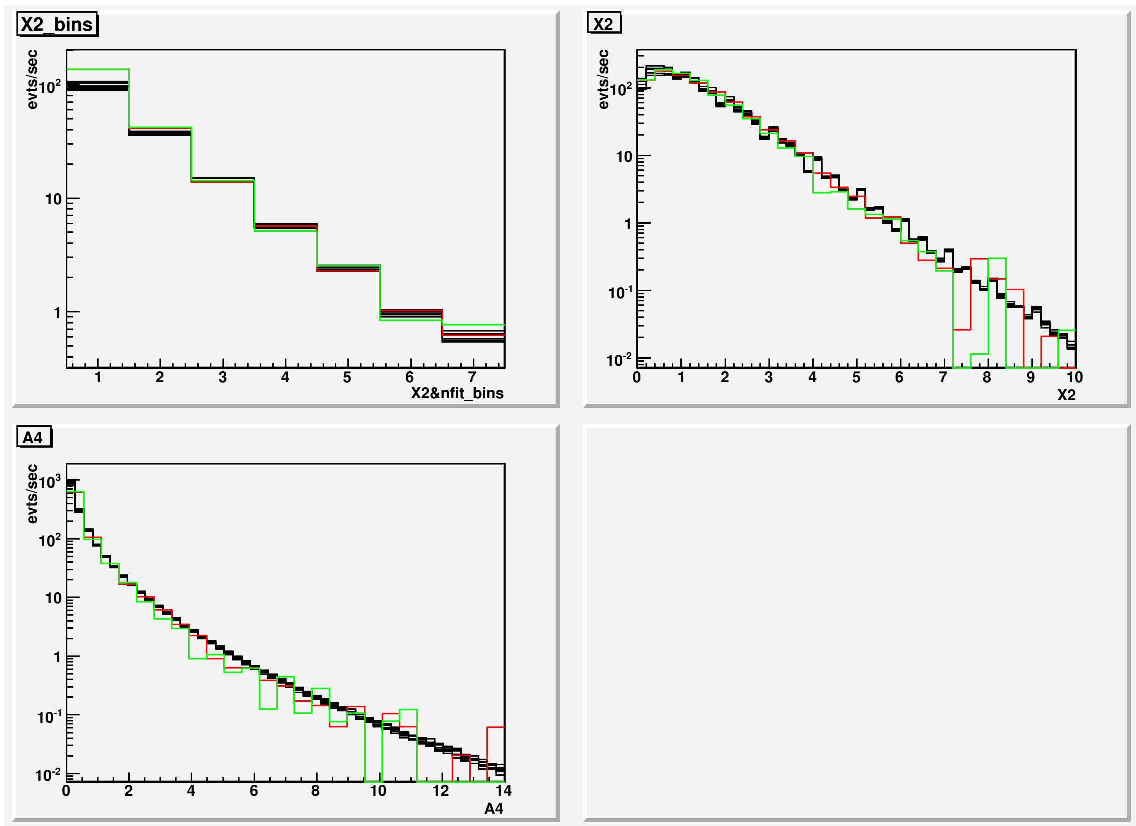

Figure 32: X2 & A4

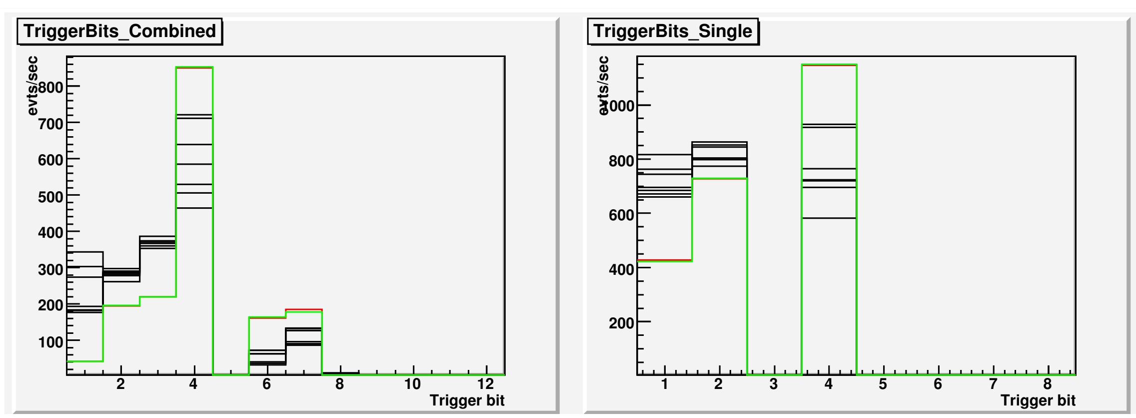

Figure 33: Trigger data

5.3 Epoch 4 - Gaussian 3 layer - Post repair

The reconstructed data runs analysed were 5090 to 6160 every 40 runs. The red and green curves correspond to silver baffles MC (see chapter 2.1) with no dead PMTs and 10% dead PMTs correspondigly.

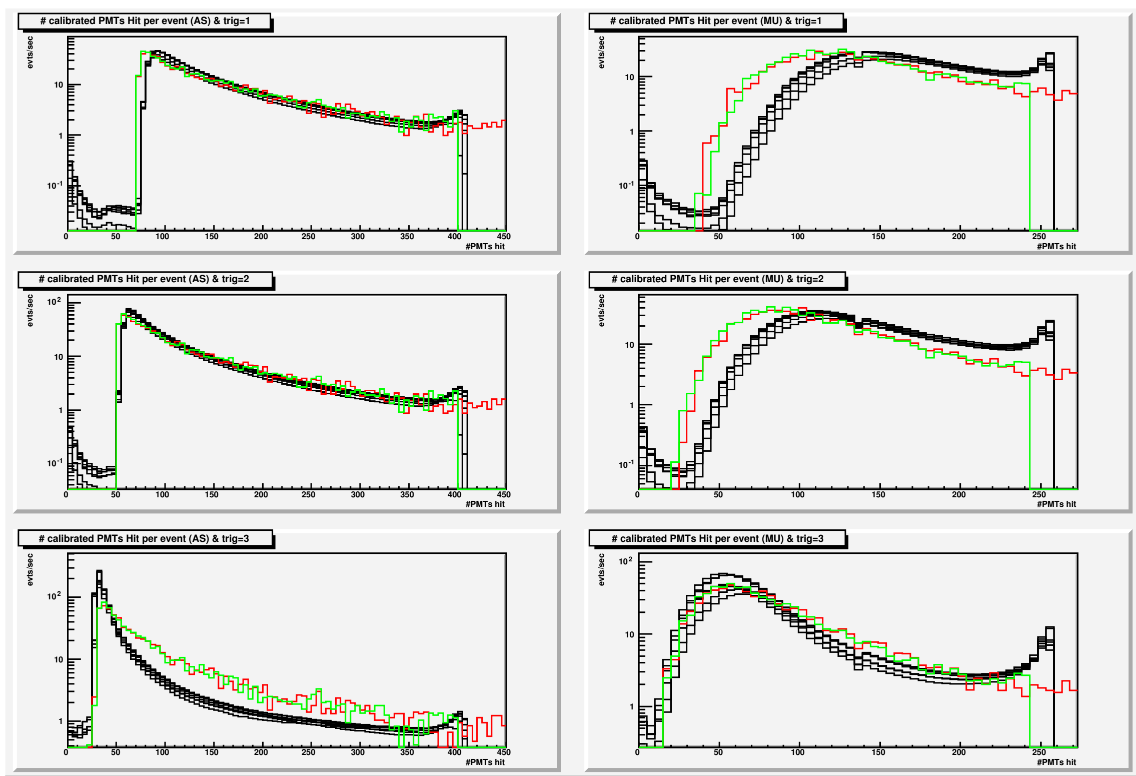

Figure 34: nPMTs hit vs trigger

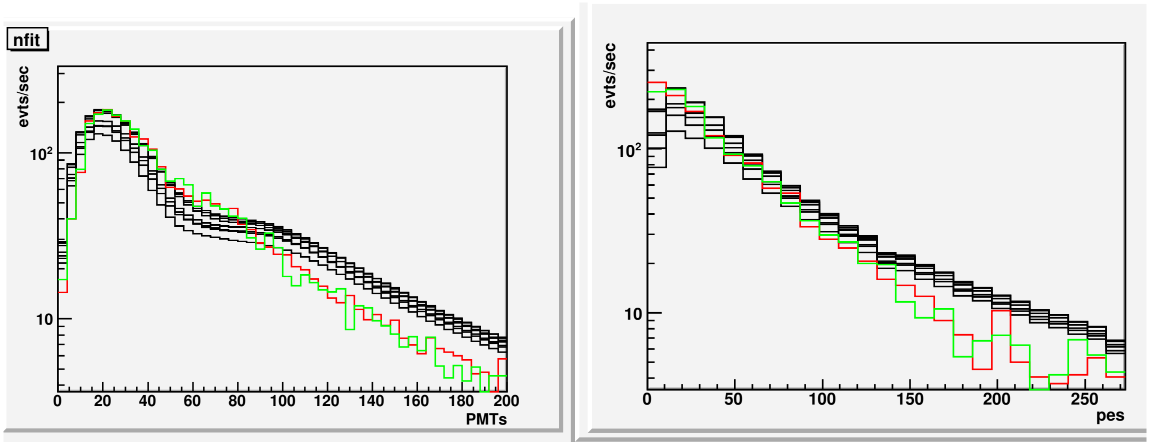

Figure 35: nfit & mxPE

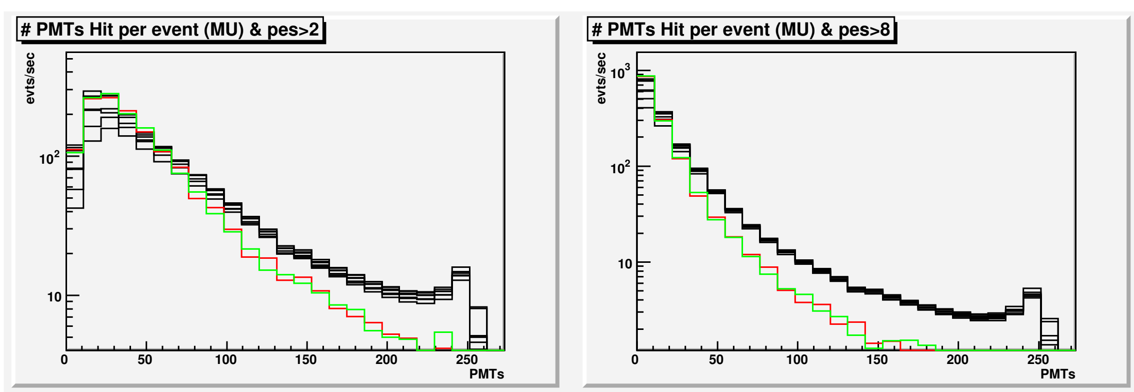

Figure 36: nb2 and nb8

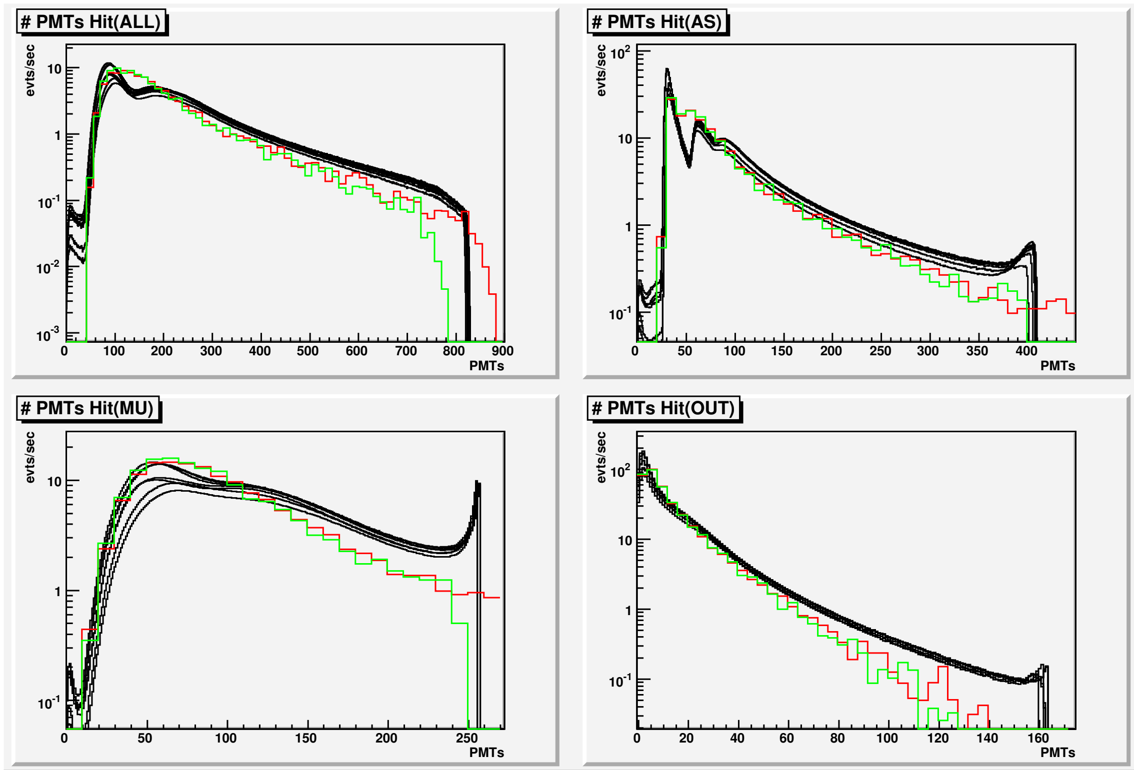

Figure 37: nPMTs hit per event

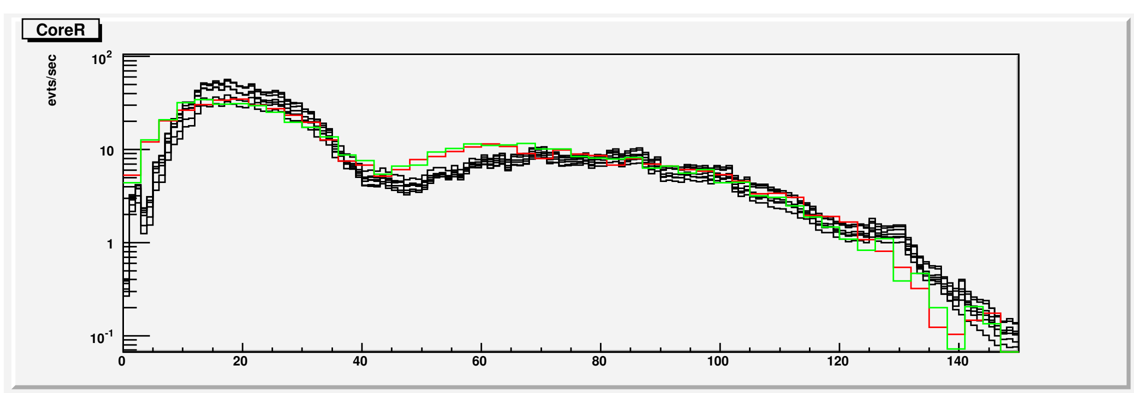

Figure 38: Core distance

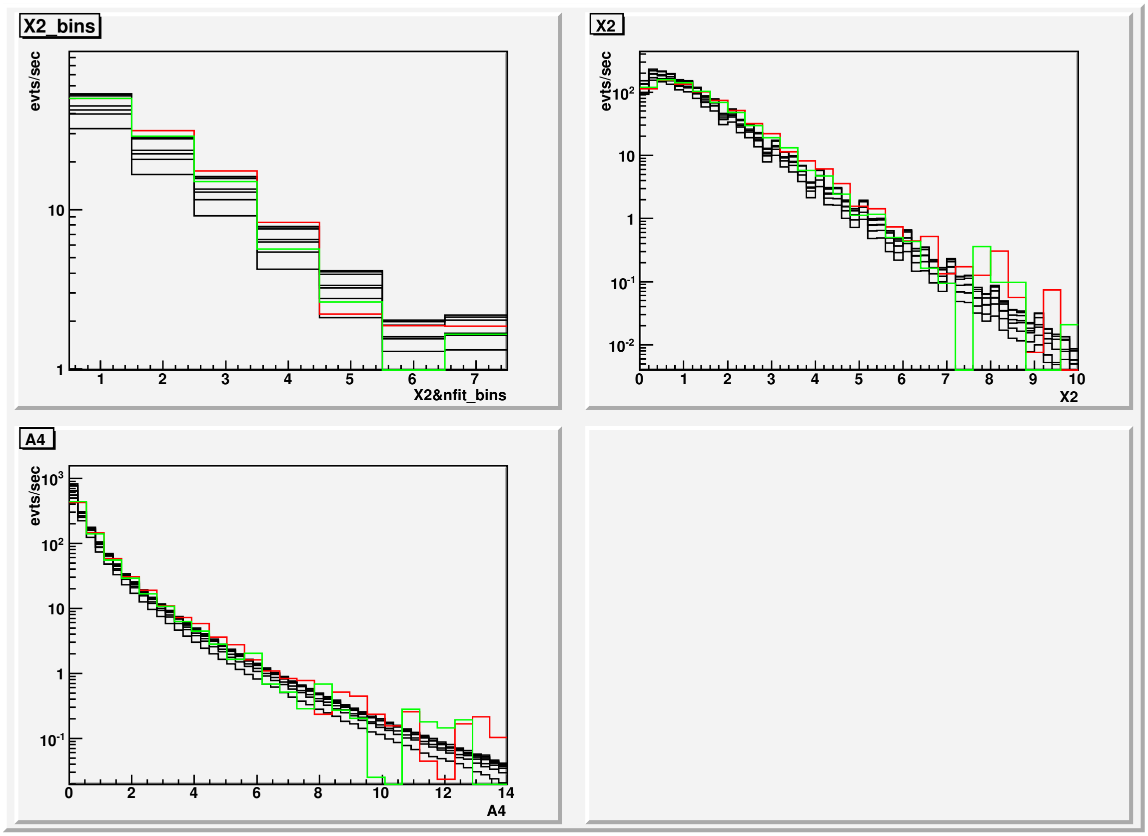

Figure 39: X2 & A4

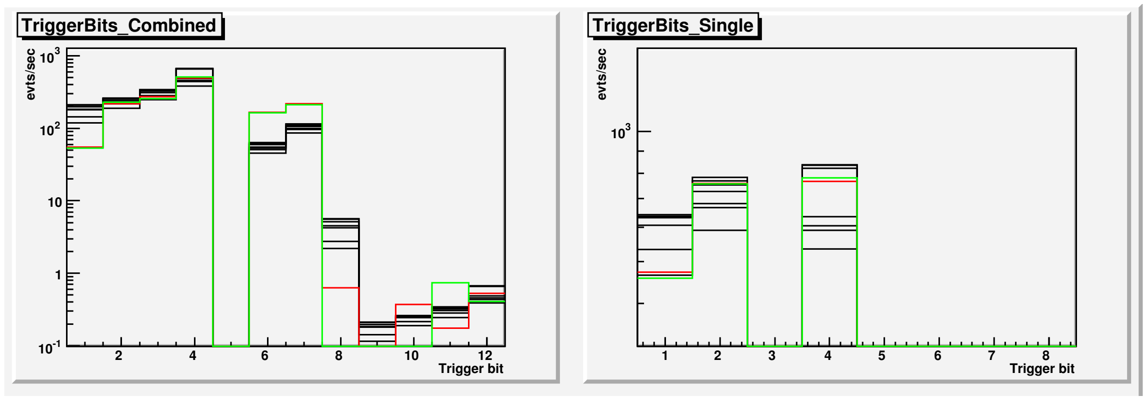

Figure 40: Trigger data

5.4 Epoch 3 - ORCOM fitter

The reconstructed data runs analysed were 5040 to 5900 every 40 runs. The red and green curves correspond to silver baffles MC (see chapter 2.1) with no dead PMTs and 10% dead PMTs correspondigly.

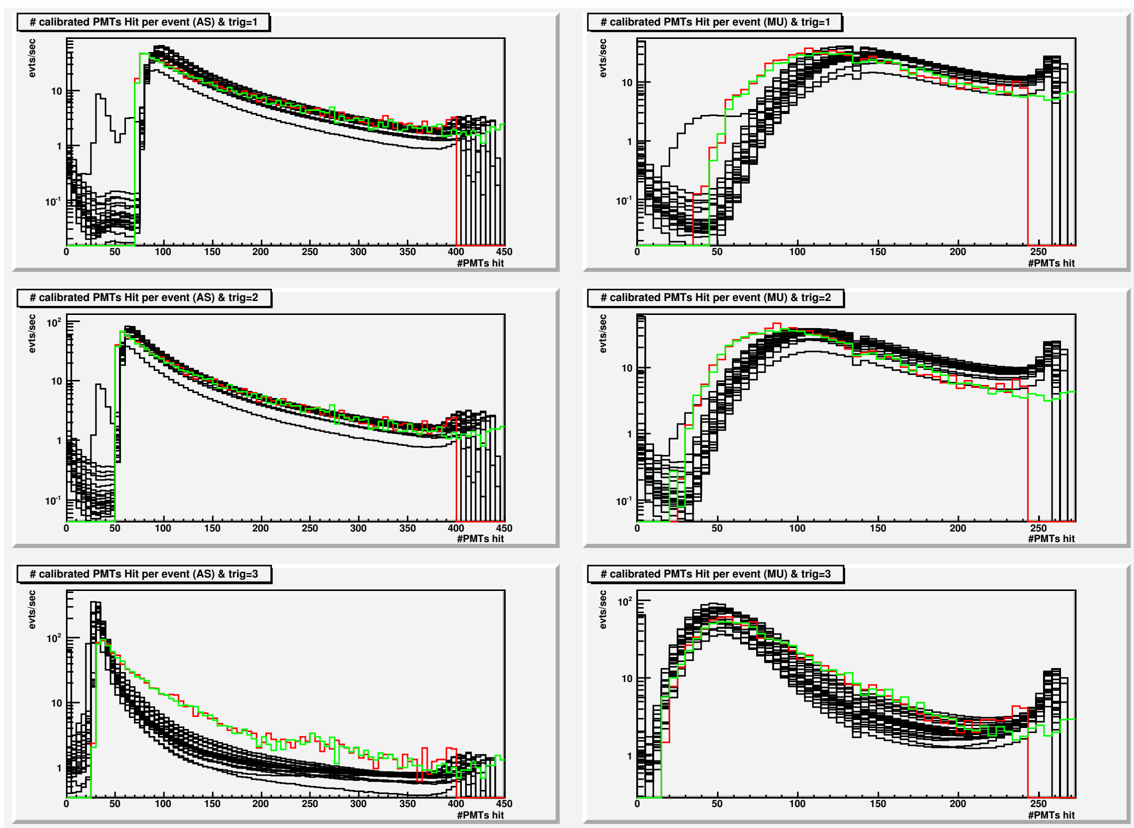

Figure 41: nPMTs hit vs trigger

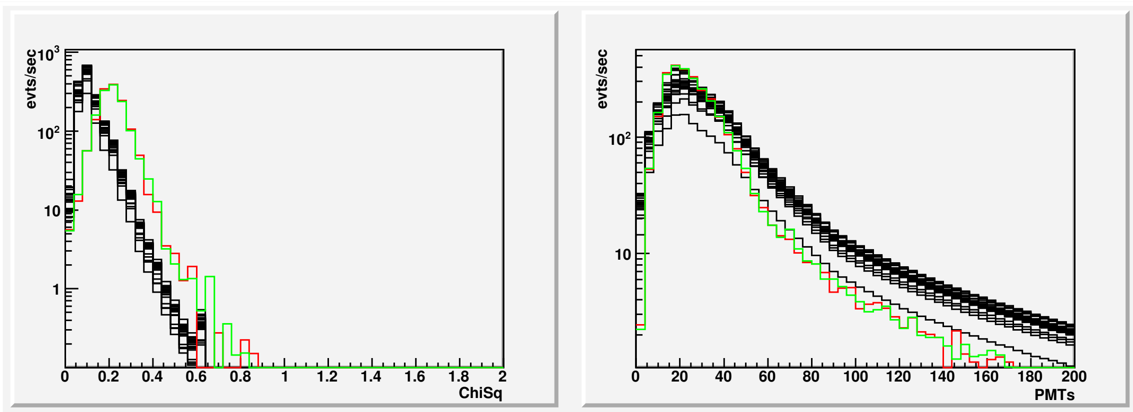

Figure 42: ChiSq & nfit

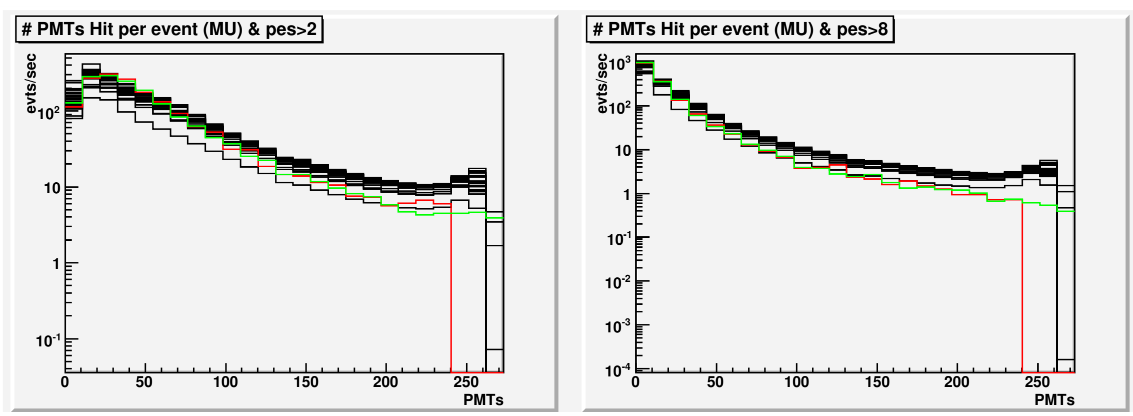

Figure 43: nb2 and nb8

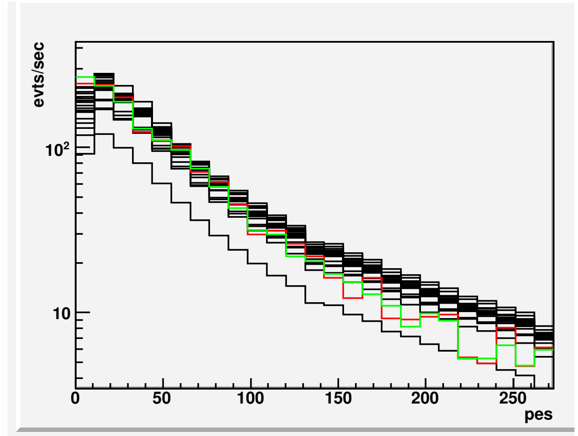

Figure 44: mxpe

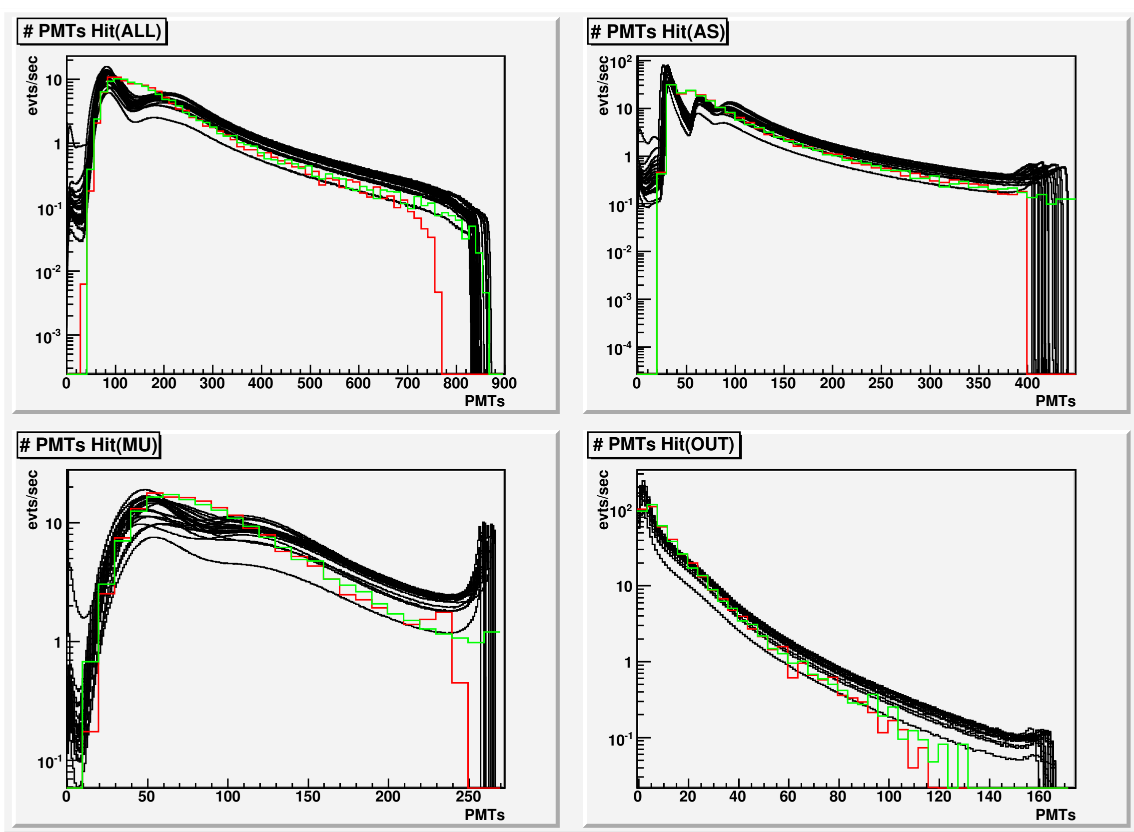

Figure 45: nPMTs hit per event

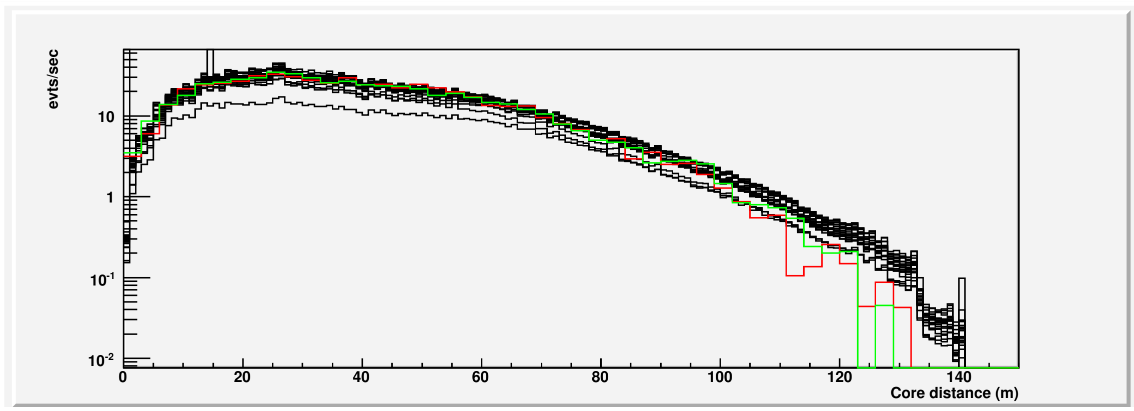

Figure 46: Core distance

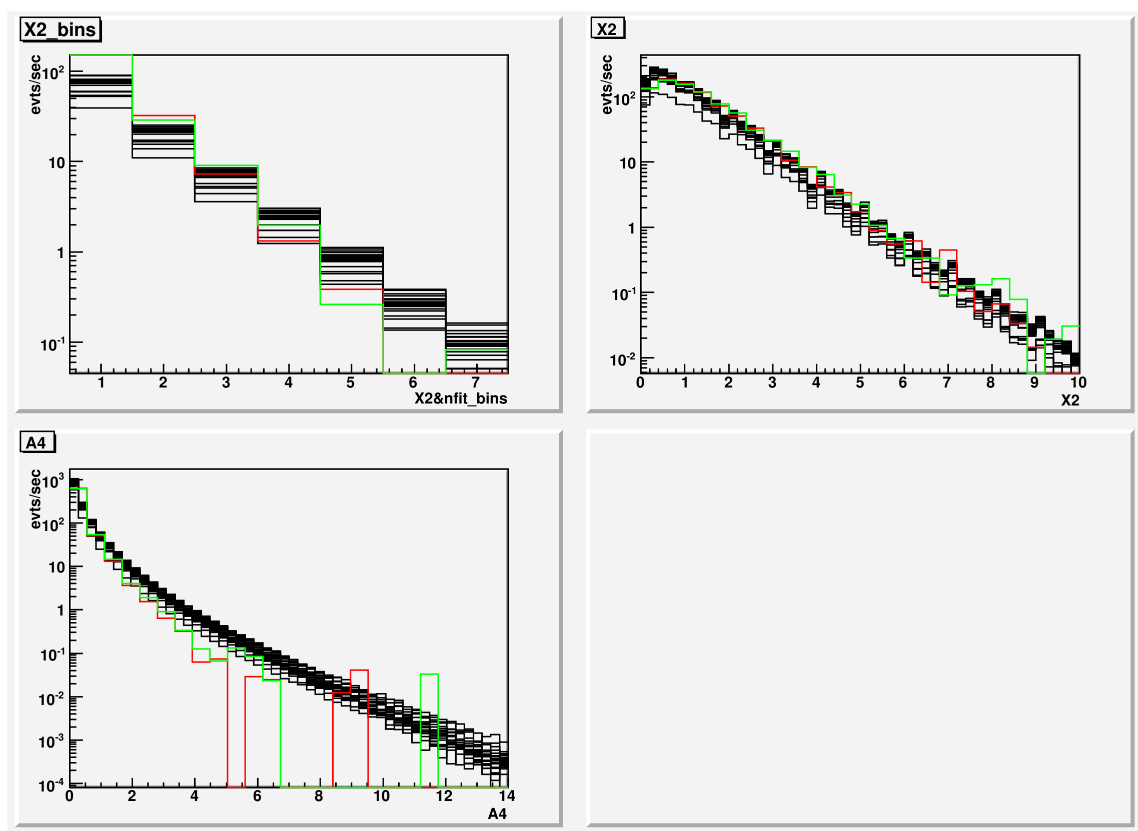

Figure 47: X2 & A4

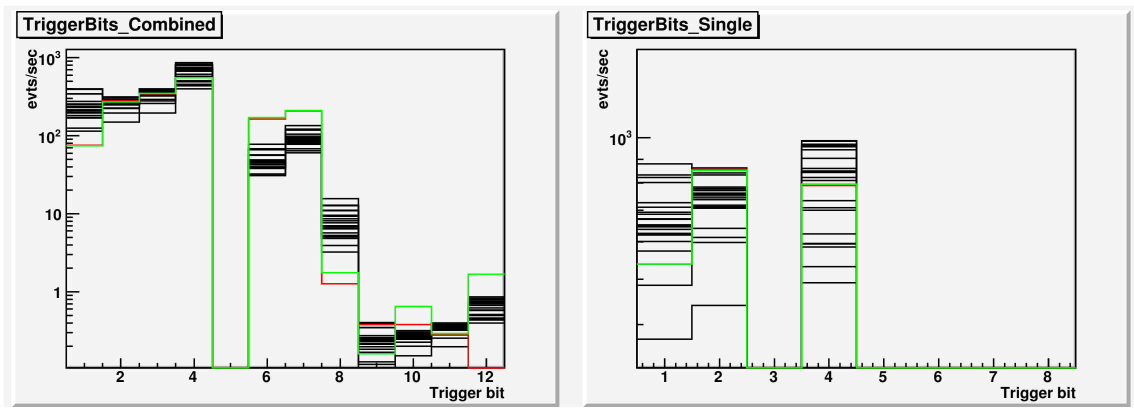

Figure 48: Trigger data

5.5 Epoch 2.5 - OFF fitter & VME Trigger

There were two sets of data analysed: before and after the short ORCOM fitter intermission (see Table 1 on page 2). The black lines correspond to an analysis of every 40 runs from runs 3920 to 4810. The blue lines correspond to an analysis of every 40 runs from runs 4880 to 4980. The red and green curves correspond to silver baffles MC (see chapter 2.1) with no dead PMTs and 10% dead PMTs correspondigly.

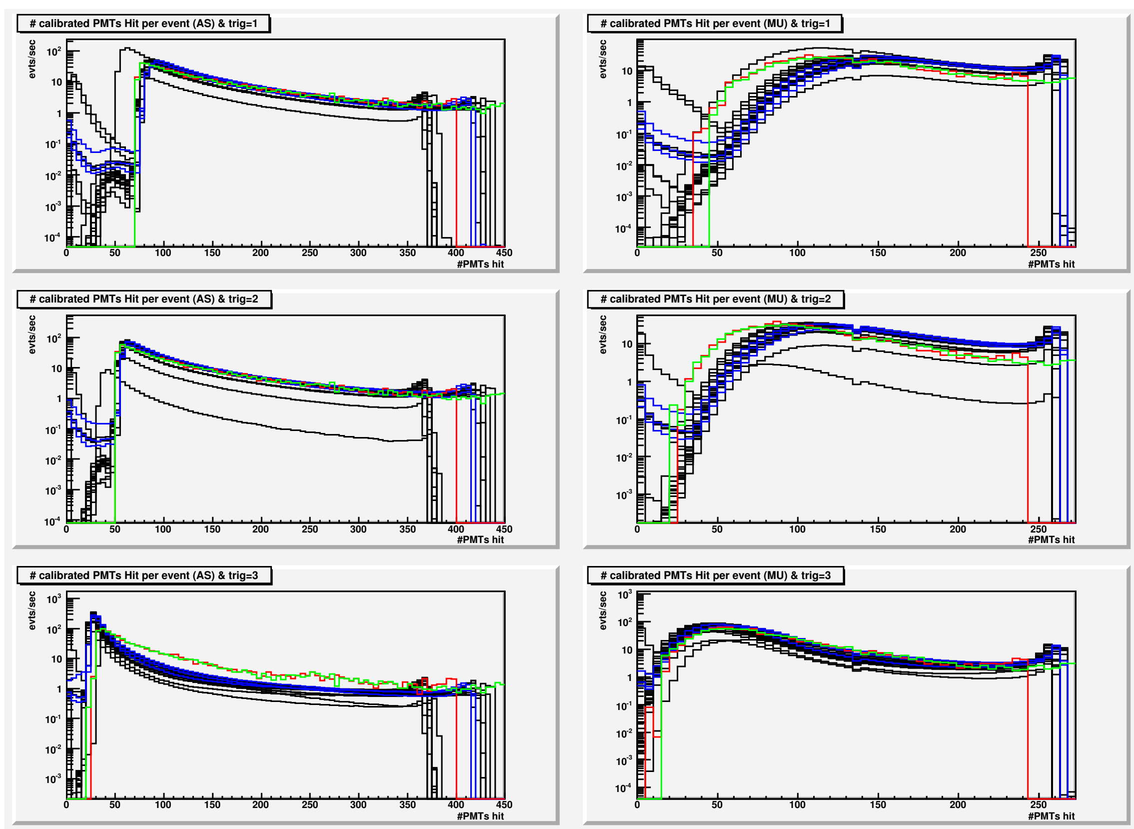

Figure 49: nPMTs hit vs trigger

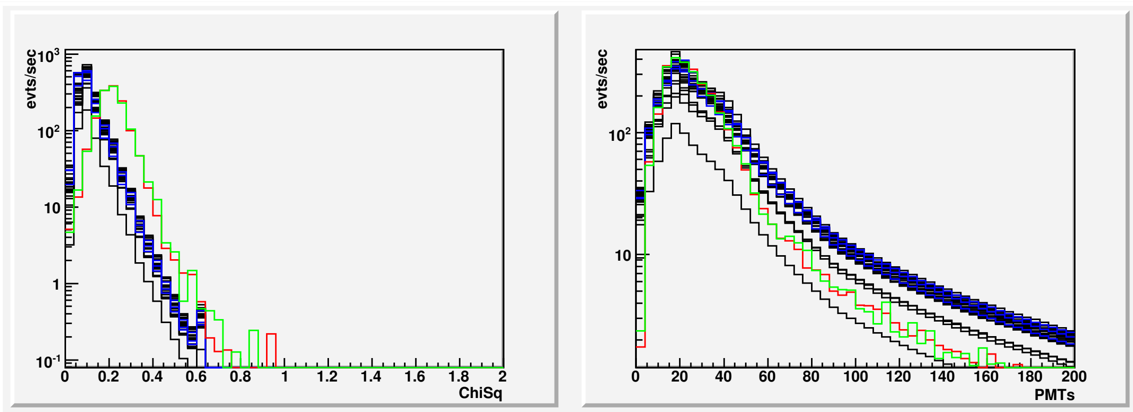

Figure 50: ChiSq & nfit

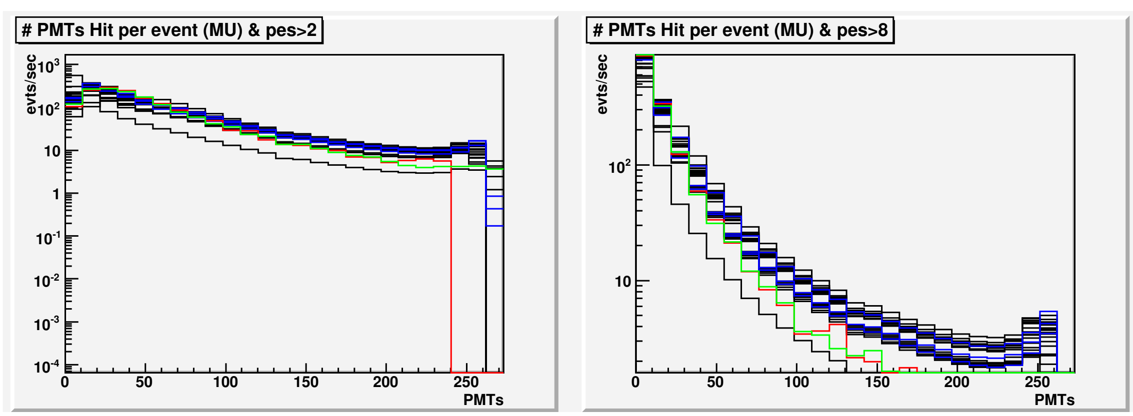

Figure 51: nb2 and nb8

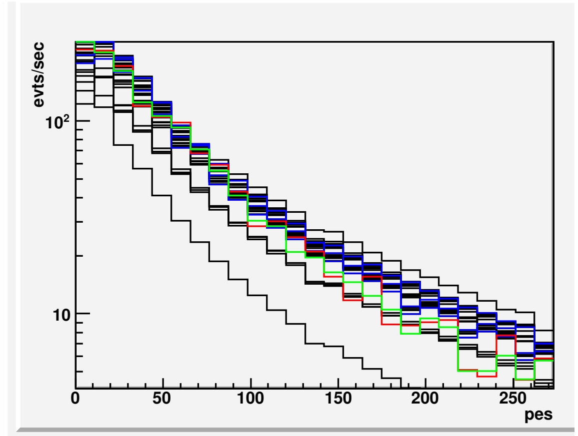

Figure 52: mxpe

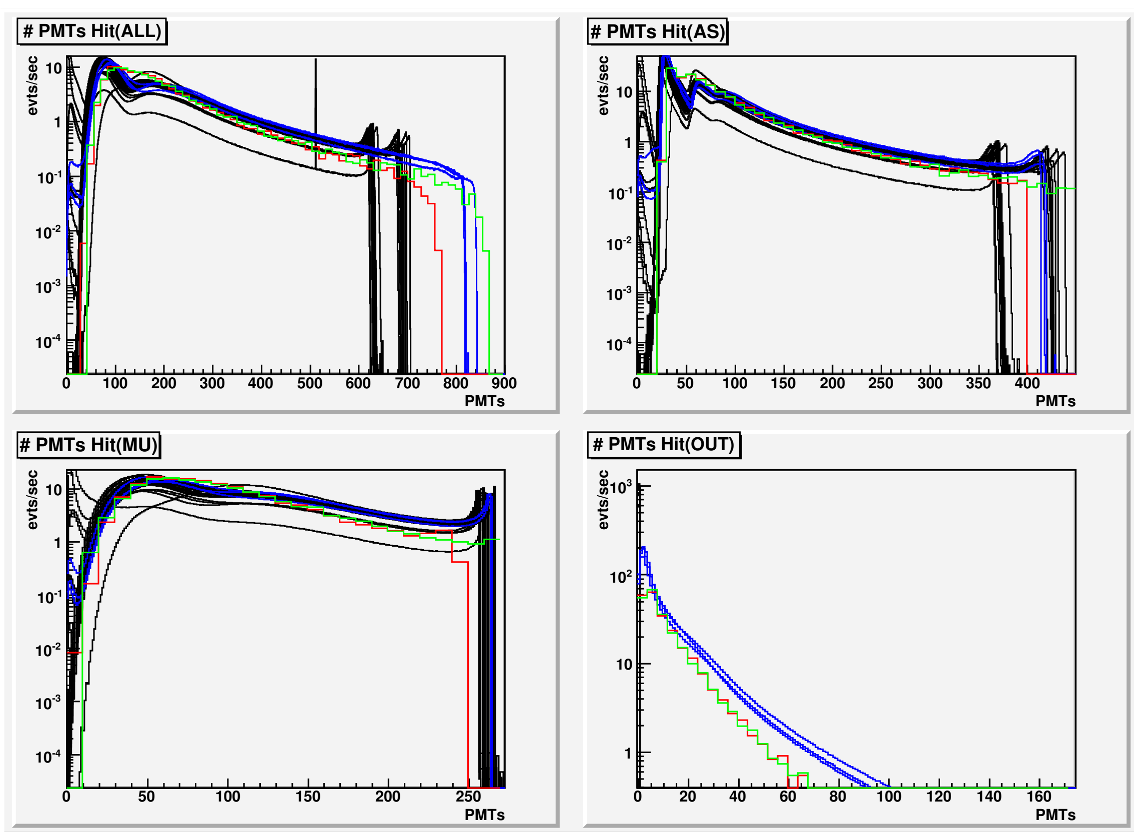

Figure 53: nPMTs hit per event

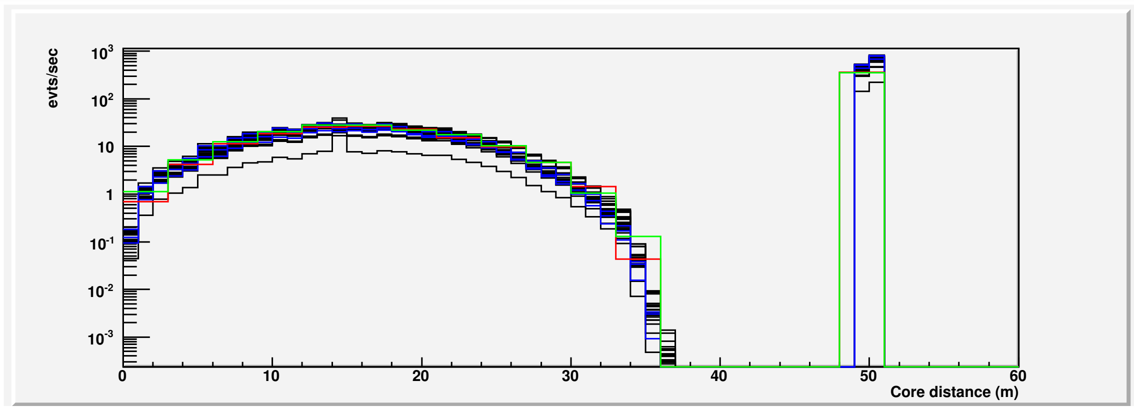

Figure 54: Core distance

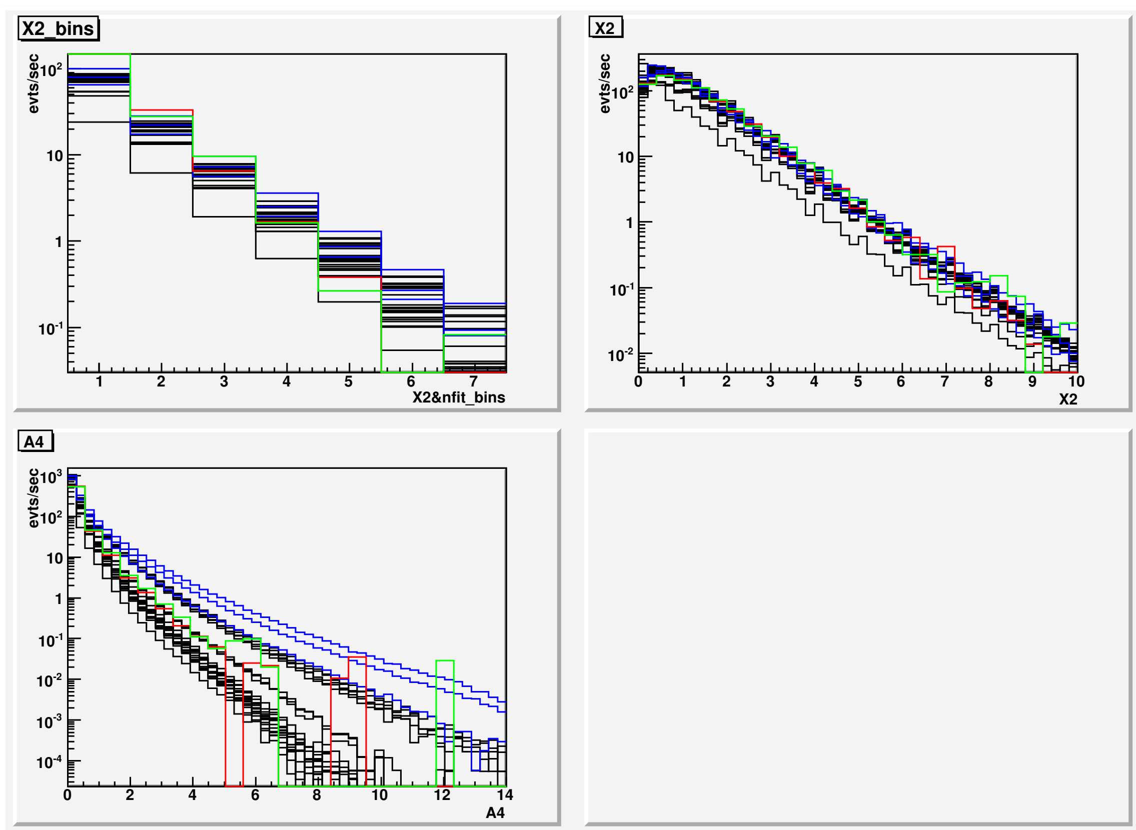

Figure 55: X2 & A4

Please ignore the black A4 curves. There weren't any outrigger data saved in the rec files that time, so A4 couldn't be calculated.

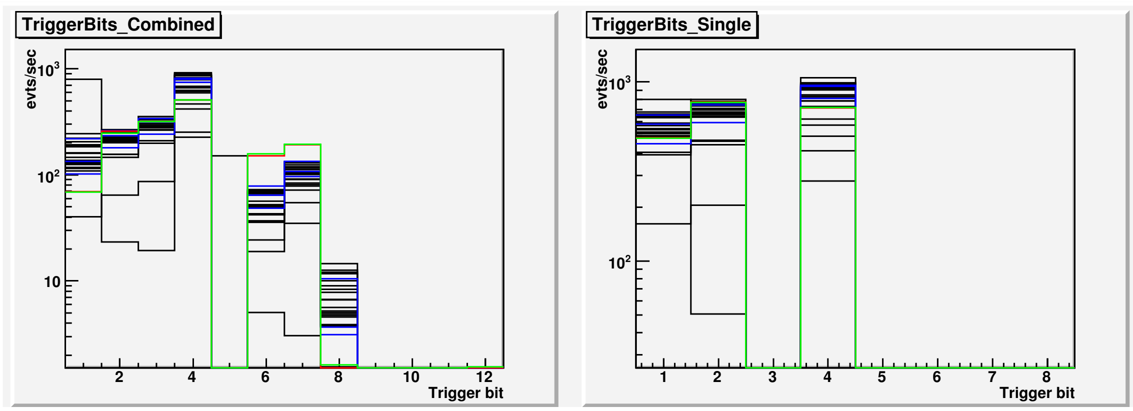

Figure 56: Trigger data

5.6 Epoch 2 - OFF fitter & Multiplicity trigger

The reconstructed data runs analysed were 2720 to 3880 every 40 runs. The red and green curves correspond to silver baffles MC (see chapter 2.1) with no dead PMTs and 10% dead PMTs correspondigly.

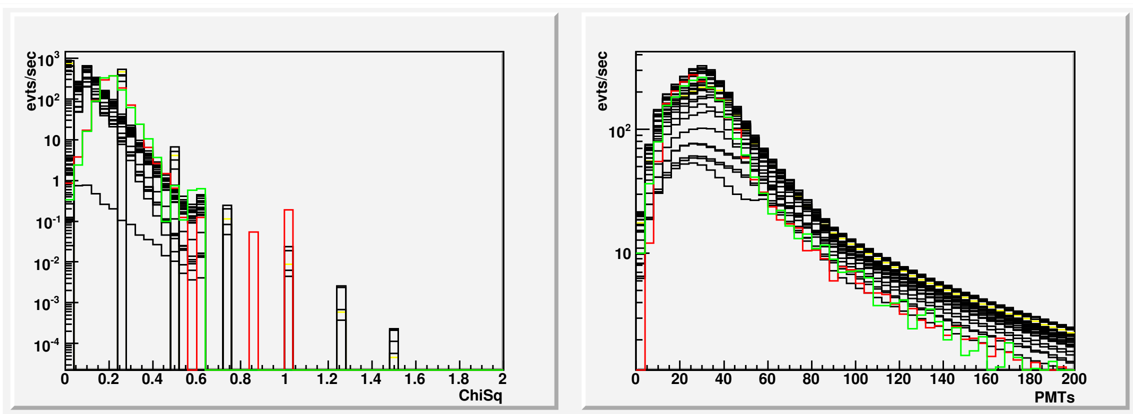

Figure 57: ChiSq & nfit

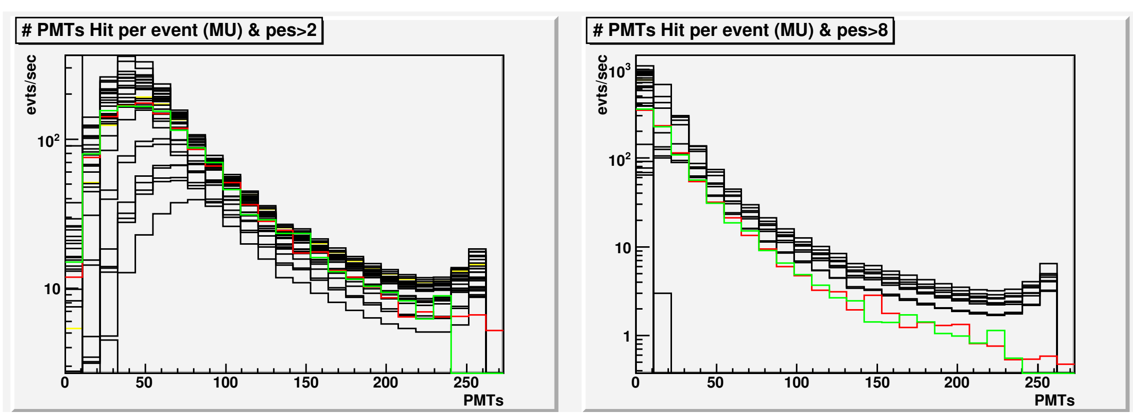

Figure 58: nb2 and nb8

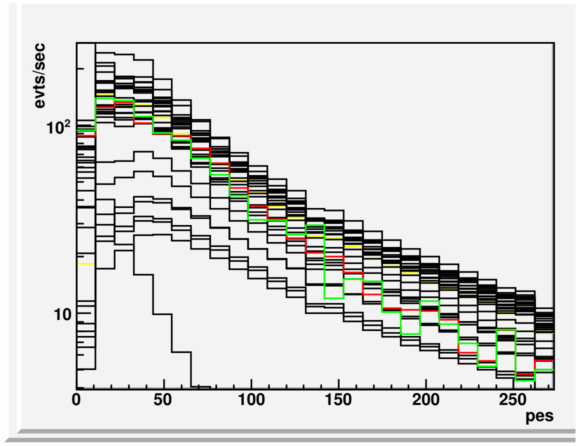

Figure 59: mxpe

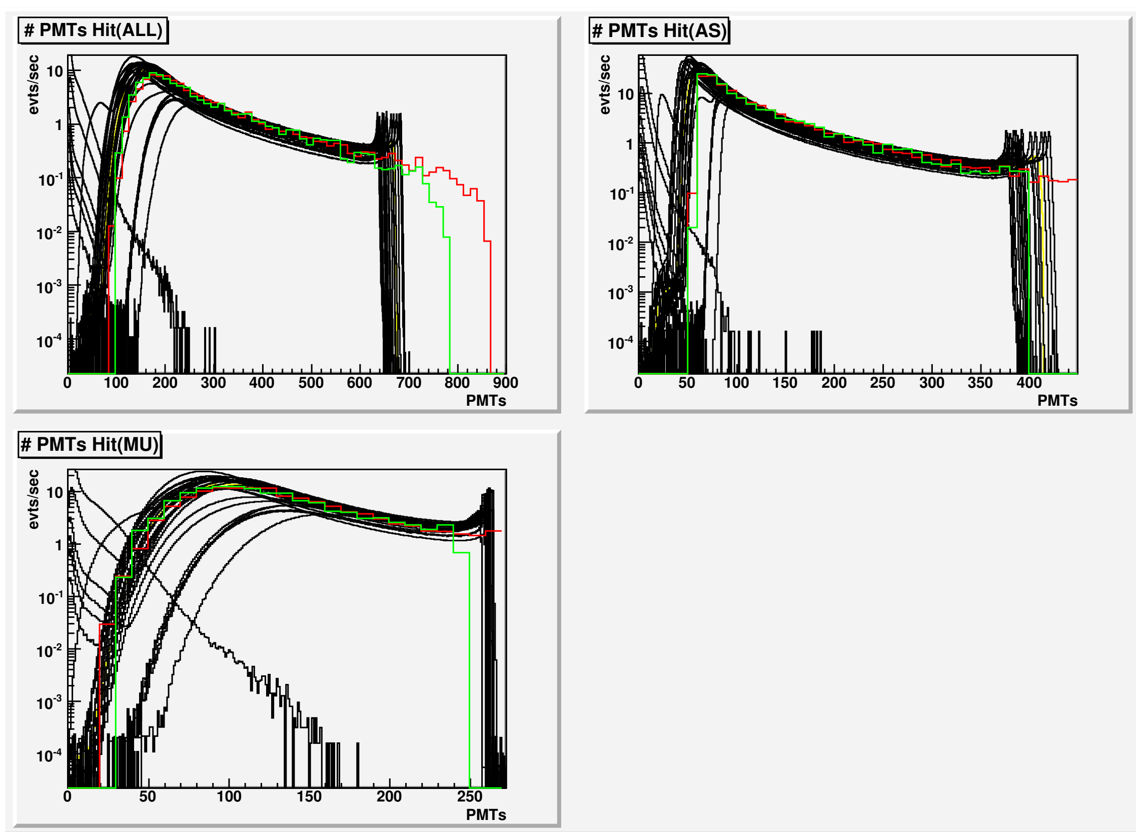

Figure 60: nPMTs hit per event

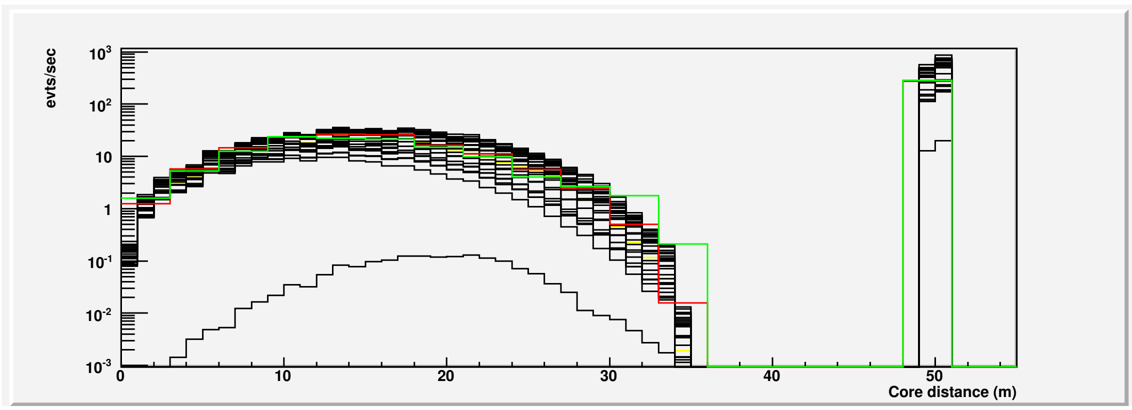

Figure 61: Core distance

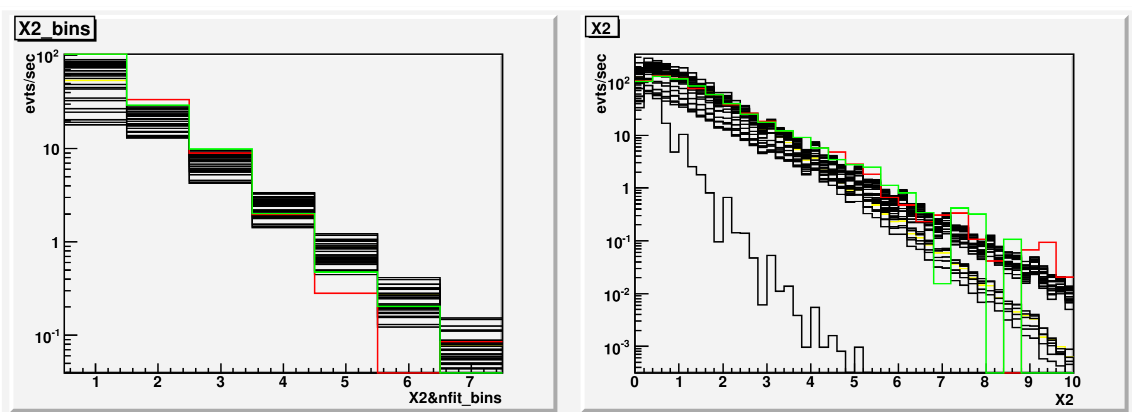

Figure 62: X2 & A4

6 Discussion - conclusion

The main conclusion derived from this study is that the division of the Milagro dataset into separate epochs is essential. There is a wide variation of the data properties from epoch to epoch. The current MC with the current set of available configurations can't match the properties of all epochs. As shown in my last memo[1] and from chapters 5.2 and 5.1 the MC has fairly good agreement with data from Epoch 5[1]. For earlier epochs the data don't show good stability. This can be either from physical changes in the detector or from minor changes in the reconstruction software. The first case isn't very probable (unless something major happened) because these changes should also be present in the last stable Epoch 5. If these effects are caused by different calibrations or minor differences in the reconstruction software, a finer division of these epochs may be needed.

The effect of the last repair was also examined. There were evident changes in most of the data properties. The effect on X2, A4 and the X2&nfit bins was very big. The following changes could have happened during the repair:

[1]Take note that this claimed agreement is just in the context of this study. The MC doesn't agree with the data in terms of crab and trigger rates for Epoch 5.

- Baffles
- Accumulation of air under cover
- Contamination of the water from people and boats going in
- Change in the trigger card
- Cleaning of the PMTs
- More PMTs available

From Chapter 4.1 it is shown that the optical properties of the baffles have almost no effect on the detector. So the baffles can't be the factor responsible for this change.

The data after the repair are fairly stable and different from the ones before the repair. This shows that it wasn't a change in the water quality or the accumulation of air under the cover, because these effects are transient and would improve over time. It also couldn't be that the extra repaired PMTs was the cause, since from the MC, even with 10% dead PMTs, such a big effect can't be reproduced.

The PMTs were dirty before the repair, probably because of the aluminum oxide particles sitting on their surfaces. I was there and I saw that the PMTs weren't that dirty. I estimate at most 5-10% of the light would be absorbed by that dirt. Such a small effect can't cause such a big change in the rates.

If I remember correctly, the trigger card was broken before the repair: some patches weren't contributing to the analog sum. David Williams went and fixed that during the repair. If this is correct, then how do we know that the repair of the trigger card didn't cause that big change?

This study shows that more studies are needed if we want to understand our data. What we are doing now, is that we are using the epoch-5-matching MC for all of Milagro data. This is not correct. The variety of different results vs epoch from Andy and Aous and this study shows that we (I) must find the MC/analysis configurations that match each sub epoch and use them appropriately. All the changes in the detector and software configuration must be detected and a maximum set of epochs must be created. MC data with extreme values of detector properties must be created (like what was done for the baffles) in order to detect the most important detector parameters. The VME trigger card must be simulated more accurately (rise time issues) in milinda.

7 Appendix 1: Milinda code to configure the core and angle fitters for each epoch

// Settings for standard analysis before Outriggers, but with COM fitter

```
if (epoch==1) {
  ActivateMethod(&Milinda->Steer.CoreList,"CoreFit_COM",DEFAULT);
  Milinda->Reco.Control.AngleControl.layer                 = 1;
  Milinda->Steer.SamplingMethod                            = SamplingCorrection1;
  Milinda->Steer.CurvatureMethod                           = CurvatureCorrection1;
  Milinda->Reco.Control.AngleControl.SigmaFunction         = Sigma5;
  Milinda->Reco.Control.AngleControl.relax_method          = RELAX2;
  Milinda->Reco.Control.AngleControl.PE_SIG_cuts_method    = CUTS4;
  Milinda->Reco.Control.CoreControl.CoreControlGauss.layer = 5;
}
// Settings for standard analysis before Outriggers, but with OFF fitter
if (epoch==2) {
  ActivateMethod(&Milinda->Steer.CoreList,"CoreFit_OFF",DEFAULT);
  Milinda->Reco.Control.AngleControl.layer                 = 1;
  Milinda->Steer.SamplingMethod                            = SamplingCorrection1;
  Milinda->Steer.CurvatureMethod                           = CurvatureCorrection1;
  Milinda->Reco.Control.AngleControl.SigmaFunction         = Sigma5;
```

```
  Milinda->Reco.Control.AngleControl.relax_method          = RELAX2;
  Milinda->Reco.Control.AngleControl.PE_SIG_cuts_method    = CUTS4;
  Milinda->Reco.Control.CoreControl.CoreControlGauss.layer = 5;
}
// Settings for standard analysis before Outriggers, but with ORCOM fitter
if (epoch==3) {
  ActivateMethod(&Milinda->Steer.CoreList,"CoreFit_ORCOM",DEFAULT);
  Milinda->Reco.Control.AngleControl.layer                 = 1;
  Milinda->Steer.SamplingMethod                            = SamplingCorrection1;
  Milinda->Steer.CurvatureMethod                           = CurvatureCorrection1;
  Milinda->Reco.Control.AngleControl.SigmaFunction         = Sigma5;
  Milinda->Reco.Control.AngleControl.relax_method          = RELAX2;
  Milinda->Reco.Control.AngleControl.PE_SIG_cuts_method    = CUTS4;
  Milinda->Reco.Control.CoreControl.CoreControlGauss.layer = 5;
}
//Use Tony's new fitter (bottom layer included)
if (epoch==4) {
  ActivateMethod(&Milinda->Steer.CoreList,"CoreFit_Gauss",DEFAULT);
  Milinda->Reco.Control.AngleControl.layer                 = 7;
  Milinda->Steer.SamplingMethod                            = SamplingCorrectionNull;
  Milinda->Steer.CurvatureMethod                           = CurvatureCorrection2;
  Milinda->Reco.Control.AngleControl.SigmaFunction         = Sigma6;
  Milinda->Reco.Control.AngleControl.relax_method          = RELAX3;
  Milinda->Reco.Control.AngleControl.PE_SIG_cuts_method    = CUTS5;
  Milinda->Reco.Control.CoreControl.CoreControlGauss.layer = 5;
}
//Use Tony's new fitter (bottom layer not used)
if (epoch==5) {
  ActivateMethod(&Milinda->Steer.CoreList,"CoreFit_Gauss",DEFAULT);
  Milinda->Reco.Control.AngleControl.layer                 = 5;
  Milinda->Steer.SamplingMethod                            = SamplingCorrectionNull;
  Milinda->Steer.CurvatureMethod                           = CurvatureCorrection2;
  Milinda->Reco.Control.AngleControl.SigmaFunction         = Sigma6;
  Milinda->Reco.Control.AngleControl.relax_method          = RELAX3;
  Milinda->Reco.Control.AngleControl.PE_SIG_cuts_method    = CUTS5;
  Milinda->Reco.Control.CoreControl.CoreControlGauss.layer = 5;
}
```

References

[1] "Results from the Geant4 MC simulation", Vlasios Vasileiou, Milagro Memo 4/15/06

[2] "Results of Reflectivity Measurements for the Muon Layer", David Schmidt, Milagro Memo 09/22/94