Technical Evaluation of MiniBooNE Mineral Oil Attenuation

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1 Attenuation Test Setup

The University of Cincinnati oil attenuation test setup consists of a monochromator with deuterium light source, two EMI 9813 photomultiplier tubes (PMTs), two lenses, and a light-tight box containing an oil sample tube. A schematic diagram of the setup is shown in figure 1. The monochromator selects light of a particular wavelength and directs it to an optics box where the beam is split by a borosilicate glass window. Approximately 10 percent of the light is directed to PMT2, the reference PMT, while the other 90 percent is directed toward the oil sample and PMT1. The oil sample is held in a 160 cm long cylindrical lucite tube with borosilicate glass ends. This sample tube is placed in a light-tight box.

The outputs of the photomultiplier tubes are fed into a LeCroy Model 612 amplifier, followed by a LeCroy 821 discriminator, and finally to a LeCroy 2551 scaler. The data are read to a PC via CAMAC. Data consist of recorded scaler counts for PMT1 and PMT2 wavelengths covering the range from 3000 to 5000 Angstroms in steps of 10 Angstroms.

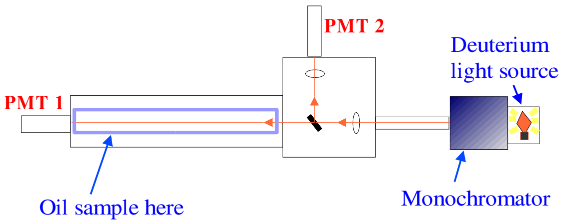

Figure 1: University of Cincinnati oil attenuation tester schematic diagram

The testing procedure is detailed as follows. The lucite sample tube is filled with an oil and allowed to rest overnight in the light-tight box to allow any contaminants in the oil to settle. After the oil has settled, 3 or 4 consecutive runs of that oil are taken without turning off the high voltage or the deuterium lamp. The high voltage is then turned off so that the oil may be emptied from the sample tube; the tube is then returned to the light-tight box for an "empty tube" run. Finally, a run with no tube in the box is taken. Using this procedure, 3 or 4 runs with oil, 1 run with an empty sample tube, and 1 run with no sample tube are obtained on each day of testing.

Data from these runs are plotted as the ratio of light transmitted through the oil sample to the light in the reference beam versus the wavelength. This ratio is divided by the same ratio for a run taken with no oil sample in the light-tight box. For runs taken with an empty sample tube, we expect to see at most only 82 percent of the light transmitted to PMT1 due to the four glass interfaces through which the light must travel (the two faces of each borosilicate glass end on the sample tube). The percentage of light transmitted through the sample tube when it contains oil should be no more than 91 percent, due to two interfaces it must traverse.

2 Oil Tests

We were given 10 samples of previously untested oil, labelled "Jen 1-10." Actual brands of oil were not known until after testing was completed, and one oil had been chosen on the basis of its technical evaluation and price. The testing procedure outlined above was followed

2.1 Jen 1

The Jen 1 (J1) data were collected on 9/09/01. Three runs with oil in the sample tube were taken, as well as one "empty tube" run and one "no tube" run. The runs taken with the J1 sample were very reproducible. This oil exhibited a peak in the wavelength range from 3400 to 3600 Å. The absorption feature at 3600 Åwas not seen in any of the other oils tested. Upon inspection, the oil did not appear to have any visible contaminants that may have caused this strange peaking behavior. Results from the three oil runs are shown in Fig. 2. The mean of these three runs is divided by the mean of all runs taken with no tube in the light-tight box and shown in Fig. 3.

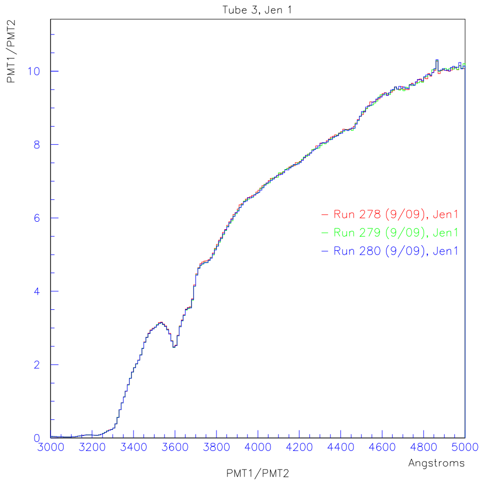

Figure 2: Jen 1 results

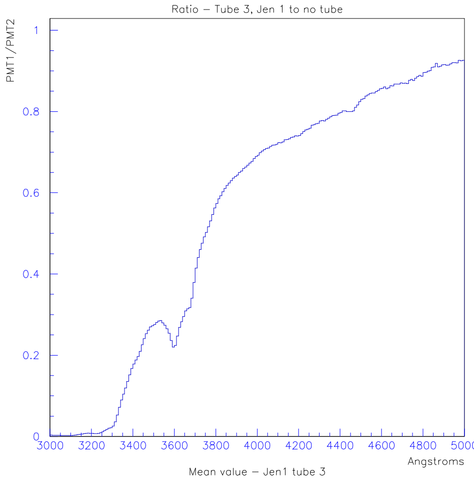

Figure 3: Jen 1 mean/no tube

2.2 Jen 2

The Jen 2 (J2) data were collected on 9/08/01. This oil was also stable during the time tested, but the light begins its rise in transmission at 3600 Å, rather than the 3400 Å with which we are familiar. Three oil runs were taken, followed by an "empty tube" run and a "no tube" run. Results of the J2 runs are shown in Fig. 4 and the ratio of the mean to the "no tube" mean is shown in Fig. 5.

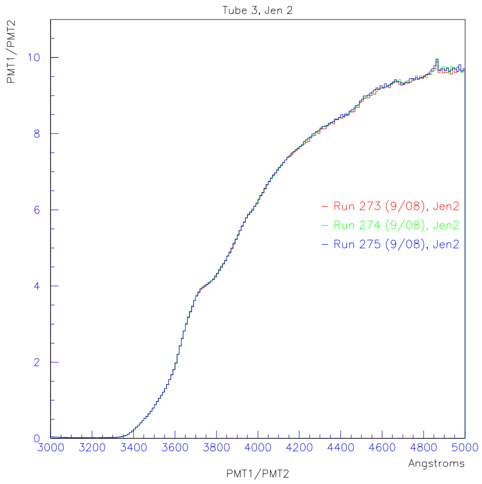

Figure 4: Jen 2 results

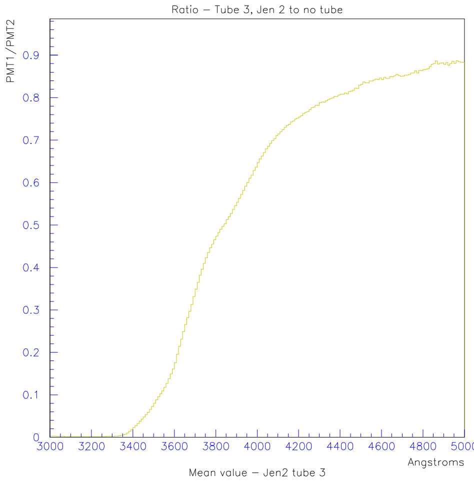

Figure 5: Jen 2 mean/no tube

2.3 Jen 3

The Jen 3 (J3) data were collected on 9/10/01. Three runs were taken with oil in the sample tube, followed by an "empty tube" run and a "no tube" run. This was a yellowish oil; tests of it were saved until the last day of testing so as not to contaminate the system. The oil was stable during testing, but as seen in Fig. 6, very little light was transmitted below 4400 Å. The mean of these runs divided by the mean of "no tube" runs is shown in Fig. 7.

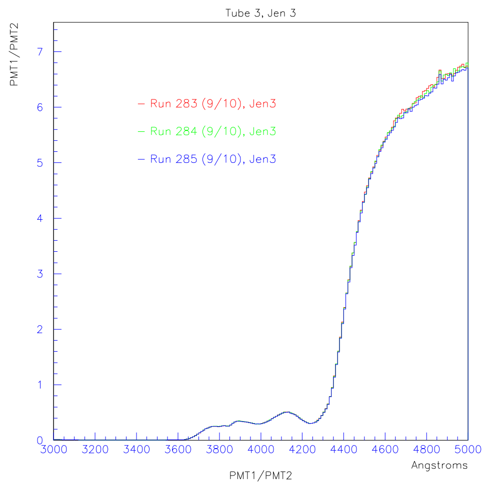

Figure 6: Jen 3 results

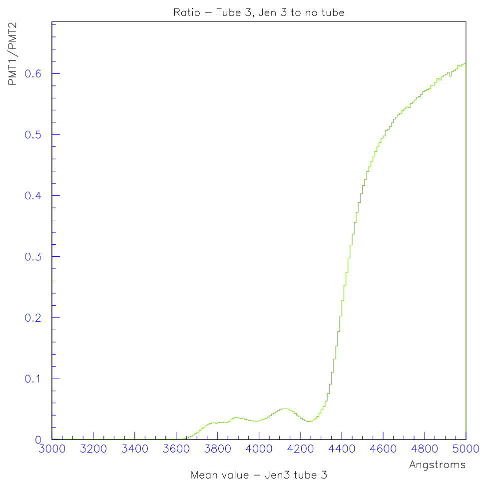

Figure 7: Jen 3 mean/no tube

2.4 Jen 4

The Jen 4 (J4) data were collected on 9/07/01. The three oil runs taken seemed stable, and are shown in Fig. 8. There is a small downward dip just below 3400 Å. Some absorption is seen between 3600 and 4200 Å. Fig. 9 shows the mean value divided by the "no tube" mean. The three oil sample runs were followed by an "empty tube" run and a "no tube" run.

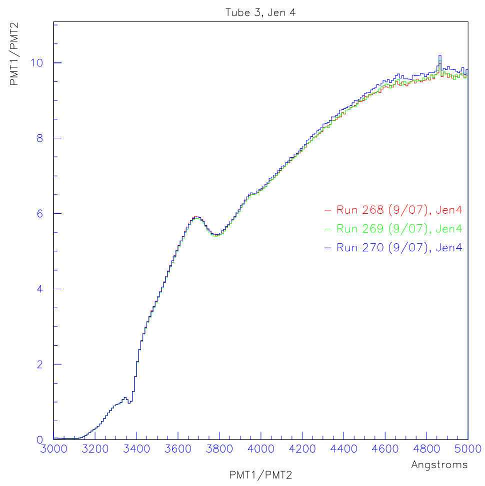

Figure 8: Jen 4 results

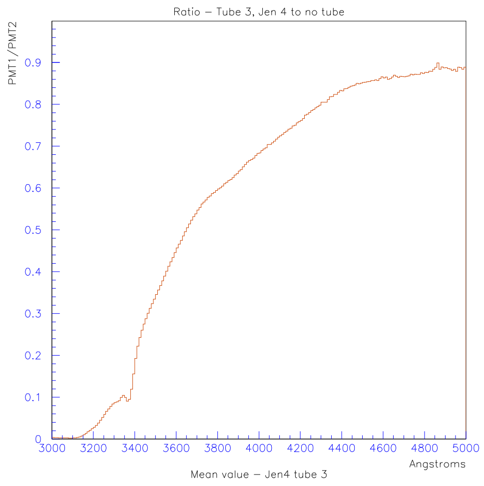

Figure 9: Jen 4 mean/no tube

2.5 Jen 5

The Jen 5 (J5) runs were taken on 9/06/01. Like J4, this oil also exhibited a small amount of absorption between 3600 and 4200 Å. Three fairly stable oil runs were taken, and are shown in Fig. 10. Fig. 11 shows the ratio of the mean value to the “no tube” mean value. As usual, the three oil sample runs were followed by an “empty tube” run and a “no tube” run.

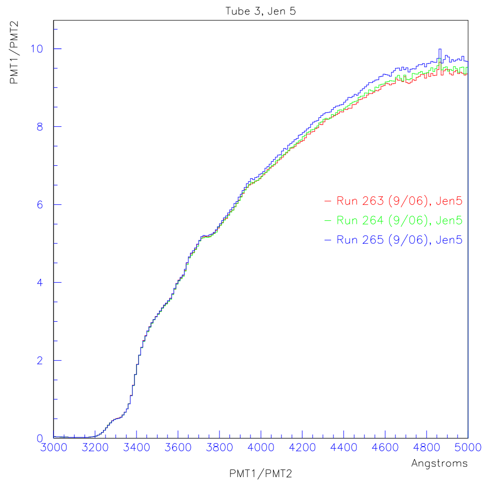

Figure 10: Jen 5 results

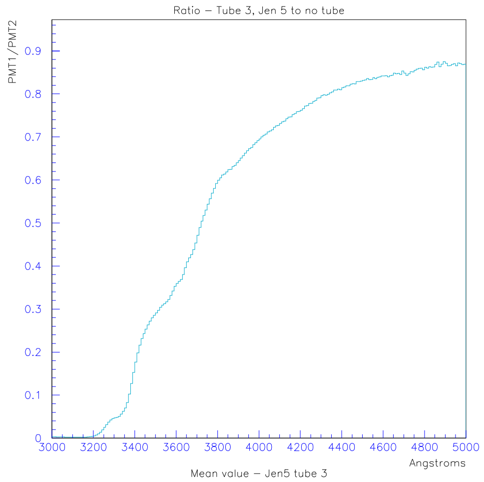

Figure 11: Jen 5 mean/no tube

2.6 Jen 6

The Jen 6 (J6) runs were taken on 9/05/01. The transmission of light through this oil dropped off at a much higher wavelength than we see in “typical” oils. The drop-off starts around 4200 Å, and a small peak is seen near 3600 Å. This excessive absorption of light in the wavelengths of interest to MiniBooNE seem to indicate this would not be a good oil choice for the experiment. The three oil runs taken seemed stable, and are shown in Fig. 12. Fig. 13 shows the ratio of the mean value to the “no tube” mean value. The three oil sample runs were followed by an “empty tube” run and a “no tube” run.

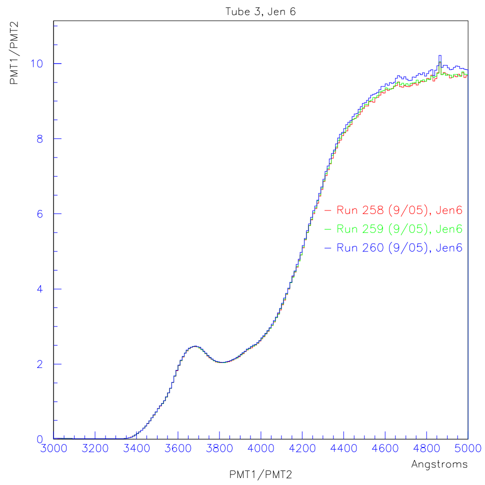

Figure 12: Jen 6 results

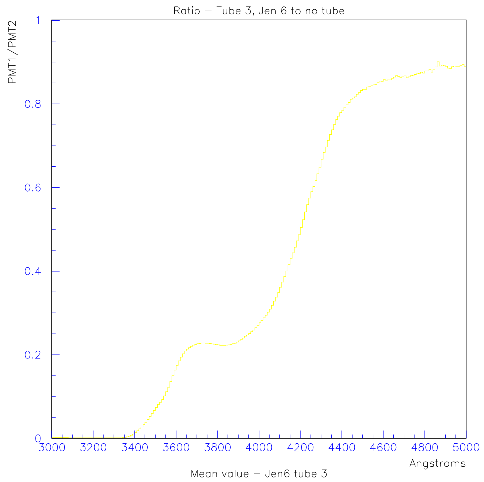

Figure 13: Jen 6 mean/no tube

2.7 Jen 7

The Jen 7 (J7) data were collected on 9/04/01. This oil also shows excessive absorption in the wavelength range between 3600 and 4200 Å. Three reproducible runs were taken with oil in the sample tube. These are shown in Fig. 14. An "empty tube" run and a "no tube" run were also taken. The mean value divided by the "no tube" mean value is shown in Fig. 15.

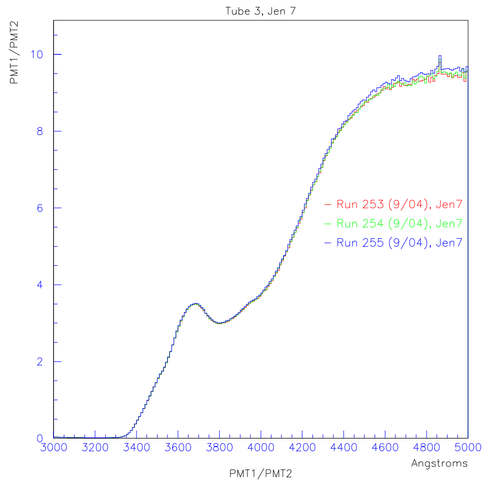

Figure 14: Jen 7 results

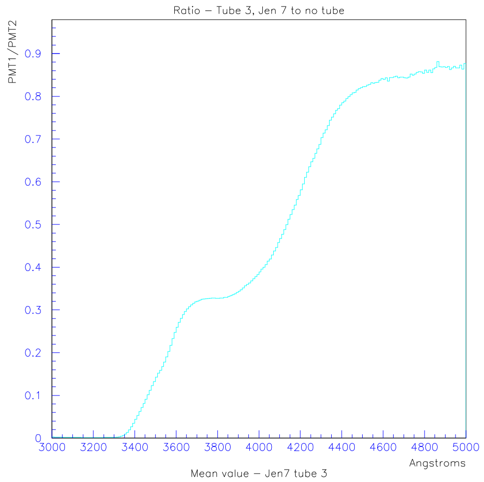

Figure 15: Jen 7 mean/no tube

2.8 Jen 8

The Jen 8 (J8) data were taken on 9/02/01. This is a typical "good" oil – it shows no excessive absorption in the range of wavelengths that are of interest to MiniBooNE. Three reproducible oil runs were taken, shown in Fig. 16, followed by the usual "empty tube" and "no tube" runs. Fig. 17 is the ratio of the J8 mean to the "no tube" mean.

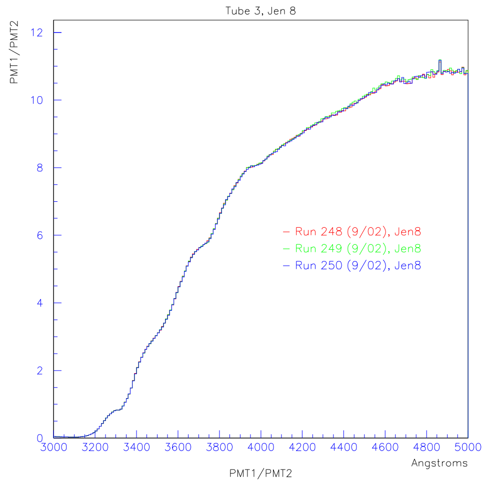

Figure 16: Jen 8 results

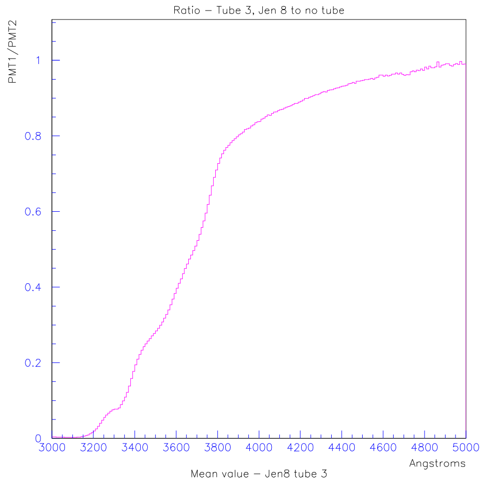

Figure 17: Jen 8 mean/no tube

2.9 Jen 9

The Jen 9 (J9) data were collected on 9/01/01. This is also a typical “good” oil, having the same general shape as J8 in the range from 3000 to 5000 Å. The three oil runs were taken, followed by two “empty tube” runs (because they were lower than other “empty tube” runs taken) and a “no tube” run. The oil runs are shown in Fig. 18. Fig. 19 shows the mean value of these runs divided by the mean of the “no tube” runs.

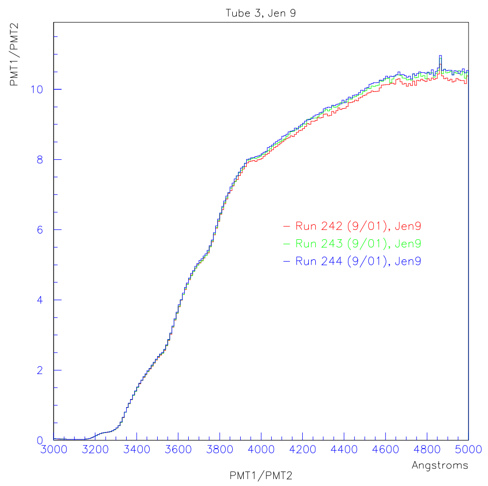

Figure 18: Jen 9 results

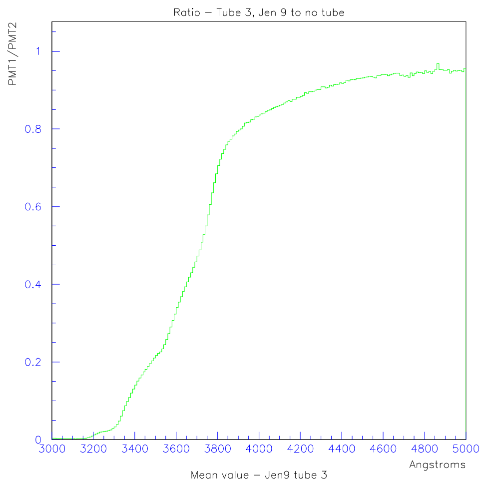

Figure 19: Jen 9 mean/no tube

2.10 Jen 10

The Jen 10 (J10) data were collected on 8/29/01 and 8/31/01. Four oil runs, one “empty tube” run and one “no tube run” were taken on each day of testing. This is a very interesting oil – it transmits light at much lower wavelengths than any of the previous oils tested. The total of 8 oil runs taken are shown in Fig. 20. The mean value of these runs divided by the “no tube” mean are shown in Fig. 21.

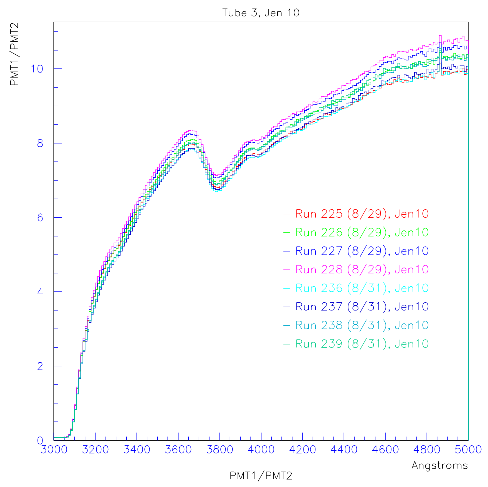

Figure 20: Jen 10 results

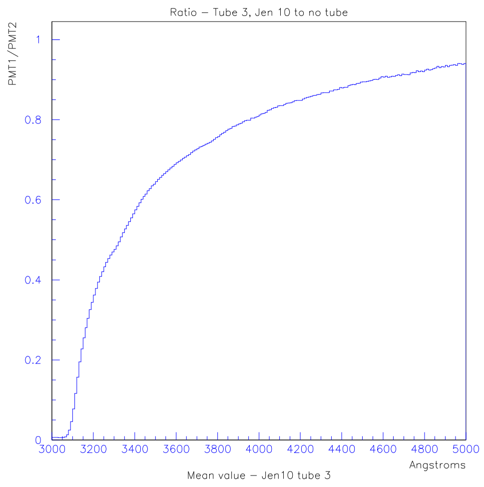

Figure 21: Jen 10 mean/no tube

2.11 Comparisons

The "no tube" runs for the eleven days of testing were consistent within less than 5 percent variation. The runs taken with no tube in the light-tight box are shown in Fig. 22. The "empty tube" runs show much more variation over the course of testing. These are shown in Fig. 23. The two empty tube runs associated with J9 (Runs 245 and 246) are lower than those associated with all other oil samples. The reason for the large variation in runs is not known at this time.

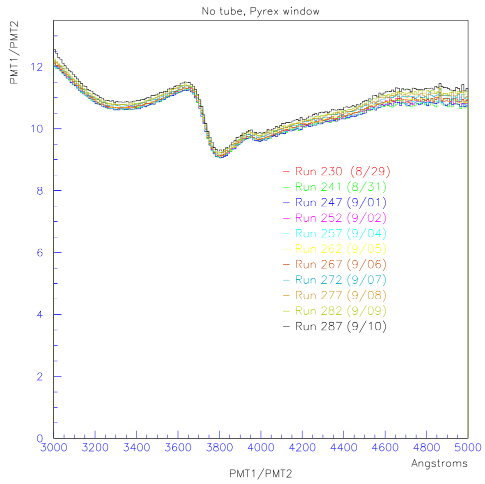

Figure 22: No tube runs

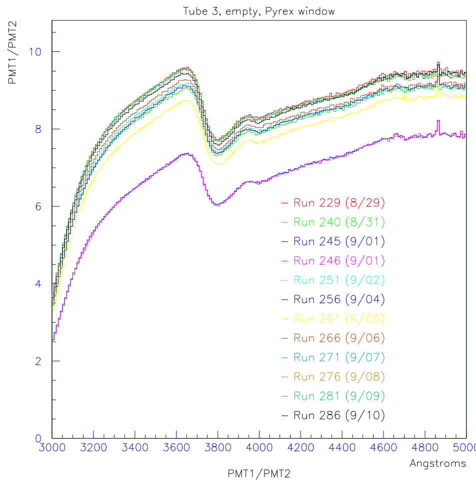

Figure 23: Empty tube runs

The mean values of runs taken with each oil sample are divided by the mean value of the "no tube" runs and shown in Fig. 24. We can see from this plot that the J3, J6, and J7 samples are definitely worse than the others. We also see that the J8, J9, and J10 samples are better than others.

The J1 sample has a strange absorption feature just above 3600 Å, decreasing its standing in the oil rankings. Because J2 absorbs almost all light below 3600 Å, rather than 3400 Å like other oils, it also has a lower ranking. As stated before, J3 is a yellow oil which absorbs almost all light below 4400 Å. It therefore has the lowest ranking of all the oils tested, and should be rejected. J4 and J5 are "okay" oils – they have typical shapes over the wavelength range, but absorb more light than some of the other oils tested. The J6 and J7 samples should be rejected on the basis of their excessive absorption of light in the range of 3600 to 4200 Å. Samples J8 and J9 "very good" oils. They have similar shapes, and both transmit more light between 3800 and 5000 Å than other oils tested. The J10 sample transmits much more light from 3100 to 3800 Å than any other oil tested. While this is a very interesting feature, it has not been seen before, so much more testing would need to be done on this particular sample if it were chosen for use in the MiniBooNE detector.

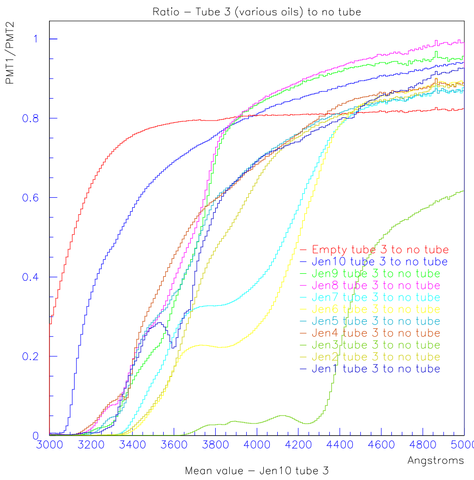

Figure 24: Ratio of oil samples to empty tube

2.12 Unblinding Oil Vendors

This section was written after above results were compiled with results from the "Alabama Tester" and results from the index of refraction tester. The collaboration chose J9, based on the results of all oil tests. The table below translates oil types from the blind J1-J10 to the vendors and actual oil names.

Oil	Oil Name	Manufacturer	Vendor	Date Tested	Comments
J1	Witco	Witco	Witco	09/08/01	Feature at 360 nm
J2	Superla 7	Chevron	Parent Petrol.	09/09/01	Rise at 360 nm
J3	Telura 622	Exxon/Mobil	Boncosky	09/10/01	Yellow oil
J4	Duoprime 70	Lyondell	Lyondell Lubr.	09/07/01	Some absorp. 360-420 nm
J5	Marcol 10	Exxon/Mobil	Boncosky	09/06/01	Some absorp. 360-420 nm
J6	Duoprime 90	Lyondell	Precision Lubr.	09/05/01	Much absorp. 360-420 nm
J7	Duoprime 90	Lyondell	Lyondell Lubr.	09/04/01	Much absorp. 360-420 nm
J8	Marcol 9	Exxon/Mobil	Boncosky	09/02/01	Typical “good” oil
J9	Marcol 7	Exxon/Mobil	Boncosky	09/01/01	Typical “good” oil
J10	Parol 80 HP-C	Penreco	Penreco	08/29,31/01	Strange, cutoff at 310 nm