January 17, 2001

Study of the light yield from plastic scintillator with green fibers using green extended tubes.

C. Milsténe

I) Introduction

We have tested plastic scintillator paddles of Bicron BC404 with green wave shifting fibers BCF92 for the Veto Systems of CKM. A study has been made of the light yield of various kind of green extended Photo-Multiplier tubes connected to those fibers. It was then compared to the light yield of the Phillips tubes 2232, used in KTeV, The signal was provided by high energy cosmic μs, above $\simeq 4$ GeV. The setup is described below, the same setup was used this summer in a study done with Belinka Gonzales, Bob Tschirhart and myself and which has been described in the ckm note CKM_55.ps.gz which will become a Fermilab note. One prototype paddle is used to check separatly each one of the tubes under study.

II) Setup

We are measuring the mean number of counts triggered by a high energy muon into our reference scintillator, which is of the type of the prototype paddle 10cm$\times$ 10cm$\times$ 0.5cm of BC404 with double-cladding fibers. The fibers are BCF92 1mm diameter fibers and have a total length of 67 cm. One end of the fibers is an aluminized mirror. There are 10 fibers located 1cm apart of each other.

The telescope has 3 paddles of plastic scintillator. We require a coincidence between the signals in all three of them. The lower paddle is located under 54cm of steel and insure that we are triggering only on high energy muons ($\geq$ 4GeV). Both the lower and higher paddles are 15cm$\times$ 15cm$\times$ 0.5cm and are distant 95cm apart. In between a middle paddle of the size of the prototype paddle tested defines the opening angle of the muon of the trigger. The middle paddle of the trigger stands on the prototype tested paddle. A picture of the telescope is shown below. In this study the so called "Test", has been replaced by a smaller paddle 10cm×10cm×0.5cm the size of the small paddle sitting right on top of it. It is the size of the paddle adopted for the prototype. This note follows an inclusive study of the light response done in summer 2000 with B. Gonzalez, R. Tschirgart and myself which is the object of another note and from which the Figure 1 was taken

Our measurements are done using the same Camac crate and ADC2249.

III) Measurement of the Gain of the tubes as a function of the High Voltage

The gain of the tubes has been measured as a function of the hight voltage and is tabulated further.

Two PMT's were connected in parallel to the ADC2249A by 8 ns cables for each PMT. The Gate was generated by the negative output of the same Pulse generator used for the LED (positive output). It went through a Discri LeCroy 821 with a threshold at -50mV and a 100ns width and then through a Dual gate generator (LRS 222). This was done to be "gentle" on the computor and "retime " the signal, with a hold of 10ms for the start and of of 1microsec for the end followed by a 32ns cable to the ADC 2249A gate. In order to be as closed as possible to the signal of one single phot-electron the Quantum Efficiency has been kept as low as 3with a High Voltage of 2300 volts The signal was well separated from the Pedestal to make sure we deal with the signal. This was confirmed at higher voltage points were the separation Signal-Pedestal kept increasing. A printout of the bin content per channel was done consistantly. For the Pedestal alone without LED light, one got a huge signal in one bin and almost nothing elswhere whereas for the signal+Pedestal the huge Pedestal signal focused in one bin was followed by a distribution of counts among more than 7 bins. The use of a magnetic shield did contribute to provide a very stable signal.

In Table 1 we have reported only the statistical error while running with 20000 triggers. This error is negligible comparatively to the systematic error which is ≃10 times bigger. The overall error is reported while using Peter Cooper's Landau fitting method below.

In Figure 2 and Figure 3 are represented the data from the hight voltage table in a double-log plots.

IV) The measurements of the light yield using the Telescope with a Prototype paddle

The tubes tested were all extended green tubes, the formerly EMI type 9954 or 9813 provided by BNL and the small Russian tubes marked as 25 and 32.

We have first given an identity number to the 2 BNL bases as BNL1 and BNL2 and renamed the tubes BNLA(29053) and BNLB(33362).

1. We have tested BNLA(29053) connected to BNL1
2. BNLB(33362) connected to BNL2

We have given an identity number to the 2 small bases as Yuri1 and Yuri2.

1. We have tested PMT25 connected to Yuri1
2. PMT32 connected to Yuri2

Taking into account the recommandations of Jim Frank for the BNL tubes and of Yuri Kudenko for his tubes (confirmed by our own gain studies) we ran around 2300 Volts with the BNL tubes and 1900 Volts with Yuri's tubes.

This corresponds to:

1. $\simeq$15$\pm$1.1 counts/pe for the combination BNL1-BNLA(29053)
2. $\simeq$10.$\pm$1.8 counts/pe BNL2-BNLB(33362)
3. $\simeq$10.pm7.5 counts/pe for the combination Yuri2-PMT32
4. $\simeq$3.$\pm$0.25 counts/pe for the combination Yuri1-PMT25

Remarks:

As already mentionned, the statistical errors are shown in the tables and are negligible comparativly to the systematics. Here too, the overall error has been taken from the Landau fits made using Peter Cooper's routine and shown in Figure 9 and Figure 10 for the BNL tubes and Figure 11 and Figure 12for Russian small tubes.

1. 1) BNL2-BNLB(33362) is around 10 counts/pe we were getting with the PMT2232

2. 2) In each case there is a gain difference between the tubes/bases of the same kind

3. 3) Putting the shieldings to the tubes make a big difference when the tubes are not verticals

The results are shown in the figures below and summarized in a table. In Figure 4 is represented the signal pedestal subtracted for the base-tube BNL1-BNLA(29053) and in Figure 5 for the base-tube BNL2-BNLB(33362). In each of the 4 cases our tube has been connected to the prototype paddle of reference, a 10cm$\times$10cm$\times$0.5cm plastic scintillator with 10 fibers 1cm apart from one another. The trigger came from high energy μ ($\geq$4GeV μ) which had to hit both an upper paddle and a lower paddles located under 54cm of steel while going through a small paddle the dimensions of the prototype and standing on it. The upper and lower paddles dimensions were 15cm$\times$15cm$\times$0.5cm.

The study of the response of tube BNL2-BNLB(33362) as a function of the voltage shows that for a High-Voltage of 2260 Volts one gets $\simeq$10counts/pe. A similar study done with Erik Ramberg for the Phillips PMT2232 has shown that at 1760 Volts the number of counts/pe is comparable, namely $\simeq$ 10counts/pe. The signal obtained on the cosmic ray test with the same prototype paddle is shown in Figure 6for the phillips PMT2232. One notices that the light yield is better with the green extended tubes.

In Figure 7 and Figure 8 are represented the same signal but using the small Russian extended green tubes provided by Yuri kudenko.

The summary is reported in Table 2

Then using the Landau fitting method developped by Peter Cooper the 3rd parameter of the fit being the ncount/pe is shown is Figure 9 and Figure 10 for the BNL tubes and similar figures have been done for the Russian tubes as well. The fit results for the BNL tubes is 17.91 $\pm$1.06 counts/pe and 12.61$\pm$1.82 counts/pe. In the Figure 12 and Figure 11the fit results were for the small green-extended Russian tubes, 10.58$\pm$7.56 counts/pe for the PMT(32) and 3.$\pm$0.25 for the PMT(25).

In the Figure 11 and Figure 12 the fit results are displayed for the small green-extended Russian tubes. There Landau fit results were 3.$\pm$0.25 for the

PMT(25) and 10.58±7.56 counts/pe for the PMT(32). The small Russian tubes are more sensitive to shorter times light exposure than the BNL tubes and they need a longer time to recover. During the recovery time the tubes are more noisy and instable than the BNL tubes.

IV) Conclusion

For the BNL tubes, a comparison of the gain obtained by Jim Frank at Brookhaven and the gain obtained by the direct method (as a function of the High Voltage) at FNAL as well as the gain obtained by the Landau fit has been made and the results are in excellent agreement considering that three very different methods have been used.

List of Figures

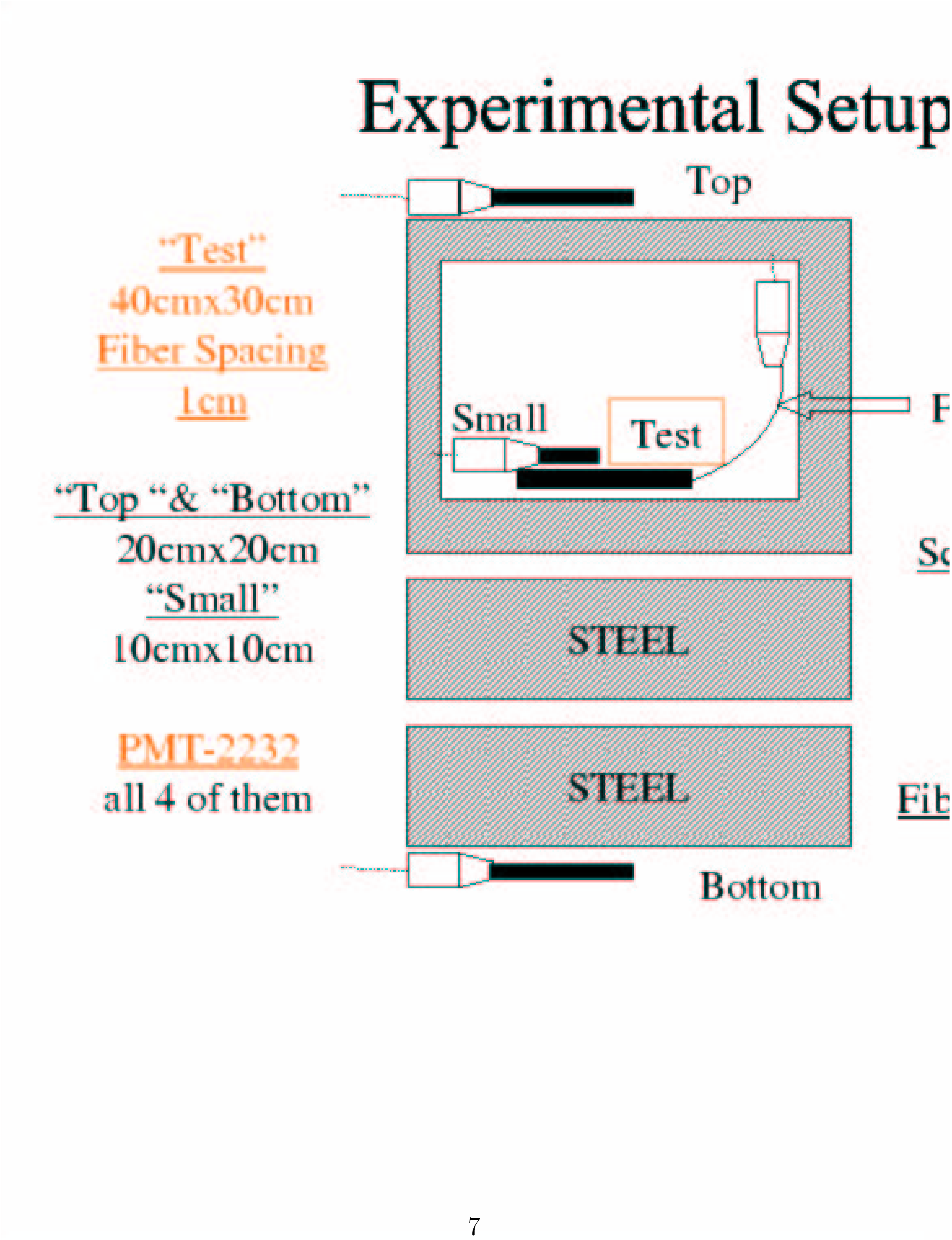

Figure 1: Telescope

HV	PMT	ncounts/pe (Stat. errors)	Gain (Stat. errors)
2200	PMTBNLA-baseBNL1	9.66 ±0.22	$(15.0698 \pm 0.33529)E^{+06}$
	PMTBNLB-baseBNL2	8.02 ± 0.11	$(12.5114 \pm 0.17254)E^{+06}$
2250	PMTBNLA-baseBNL1	12.44± 0.25	$(19.3978 \pm 0.3887)\ E^{+06}$
	PMTBNLB-baseBNL2	8.77 ± 0.12	$(13.6864 \pm 0.1807)E^{+06}$
2300	PMTBNLA-baseBNL1	14.94± 0.26	$(23.3079 \pm 0.4012)E^{+06}$
	PMTBNLB-baseBNL2	9.70± 0.12	$(15.1368 \pm 0.19222)E^{+06}$
2350	PMTBNLA-baseBNL1	17.28±0.32	$(26.9599 \pm 0.49245)E^{+06}$
	PMTBNLB-baseBNL2	11.52± 0.17	$(17.9721 \pm 0.2656)E^{+06}$
2400	PMTBNLA-baseBNL1	21.00± 0.37	$(32.756 \pm 0.58123)E^{+06}$
	PMTBNLB-baseBNL2	13.06± 0.19	$(20.376 \pm 0.29501)E^{+06}$
2450	PMTBNLA-baseBNL1	24.19± 0.42	$(37.7319 \pm 0.6522)E^{+06}$
	PMTBNLB-baseBNL2	15.70± 0.25	$(24.488 \pm 0.3843)E^{+06}$
2500	PMTBNLA-baseBNL1	29.52± 0.59	$(46.0434 \pm 0.9181)E^{+06}$
	PMTBNLB-baseBNL2	17.68 ± 0.29	$(27.5767 \pm 0.4569)E^{+06}$
2550	PMTBNLA-baseBNL1	35.74± 0.64	$(55.7496 \pm 0.99058)E^{+06}$
	PMTBNLB-baseBNL2	21.15 ± 0.33	$(33.0095 \pm 0.5210)E^{+06}$
2600	PMTBNLA-baseBNL1	41.14 ± 0.71	$(64.1698 \pm 1.1062)E^{+06}$
	PMTBNLB-baseBNL2	24.51± 0.38	$(38.2276 \pm 0.5899)E^{+06}$
2650	PMTBNLA-baseBNL1	47.73± 0.64	$(74.4509 \pm 1.38207)E^{+06}$
	PMTBNLB-baseBNL2	33.11 ± 0.52	$(51.6518 \pm 0.813959)E^{+06}$
2700	PMTBNLA-baseBNL1	55.73 ± 1.01	$(86.9373 \pm 1.57994)E^{+06}$
	PMTBNLB-baseBNL2	33.11 ± 0.52	$(51.6518 \pm 0.813959)E^{+06}$

Table 1: Gain of the EMI extended tubes of BNL as a function of the HV with Statistical Errors only

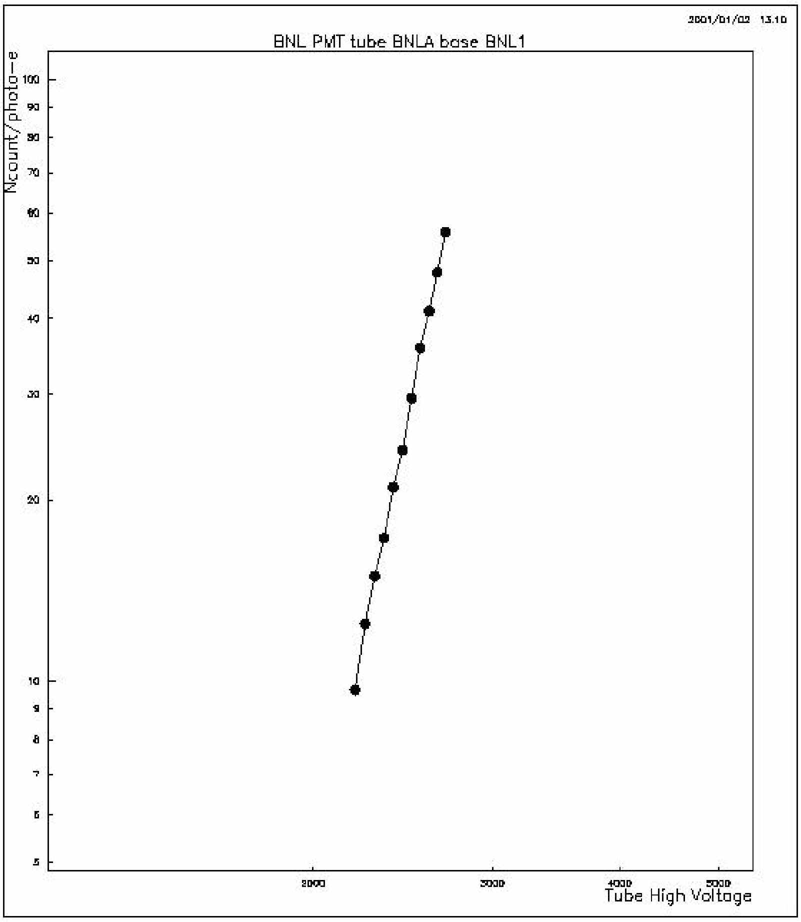

Figure 2: The double log plot of the HV data for the tube BNL1-BNLA(29053)

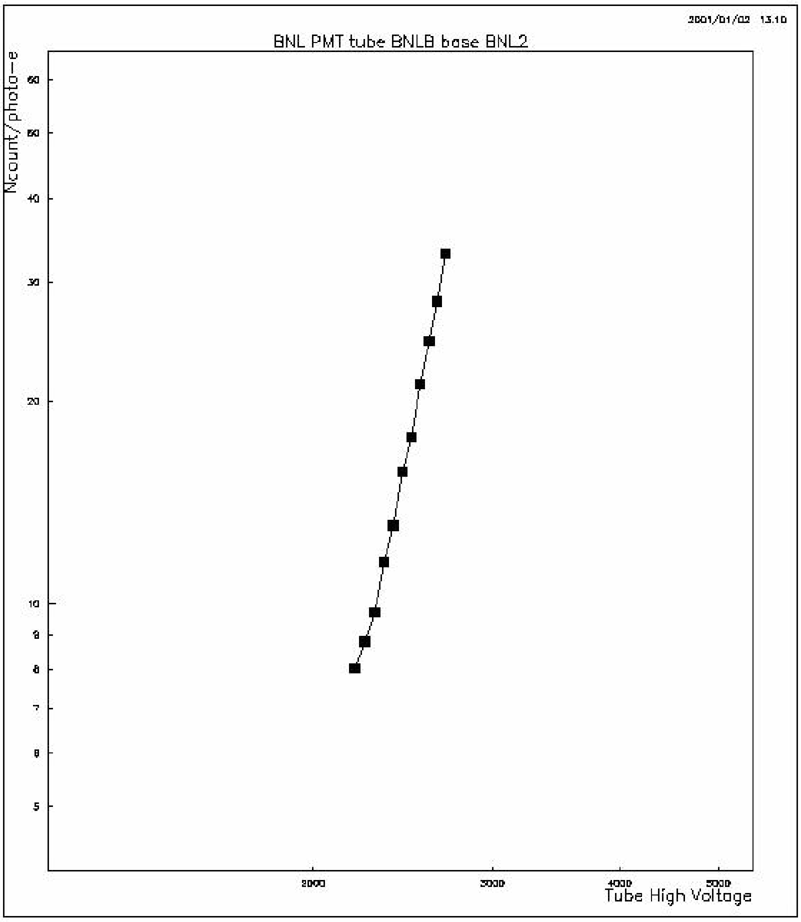

Figure 3: The double log plot of the HV data for the tube BNL2-BNLB(33362)

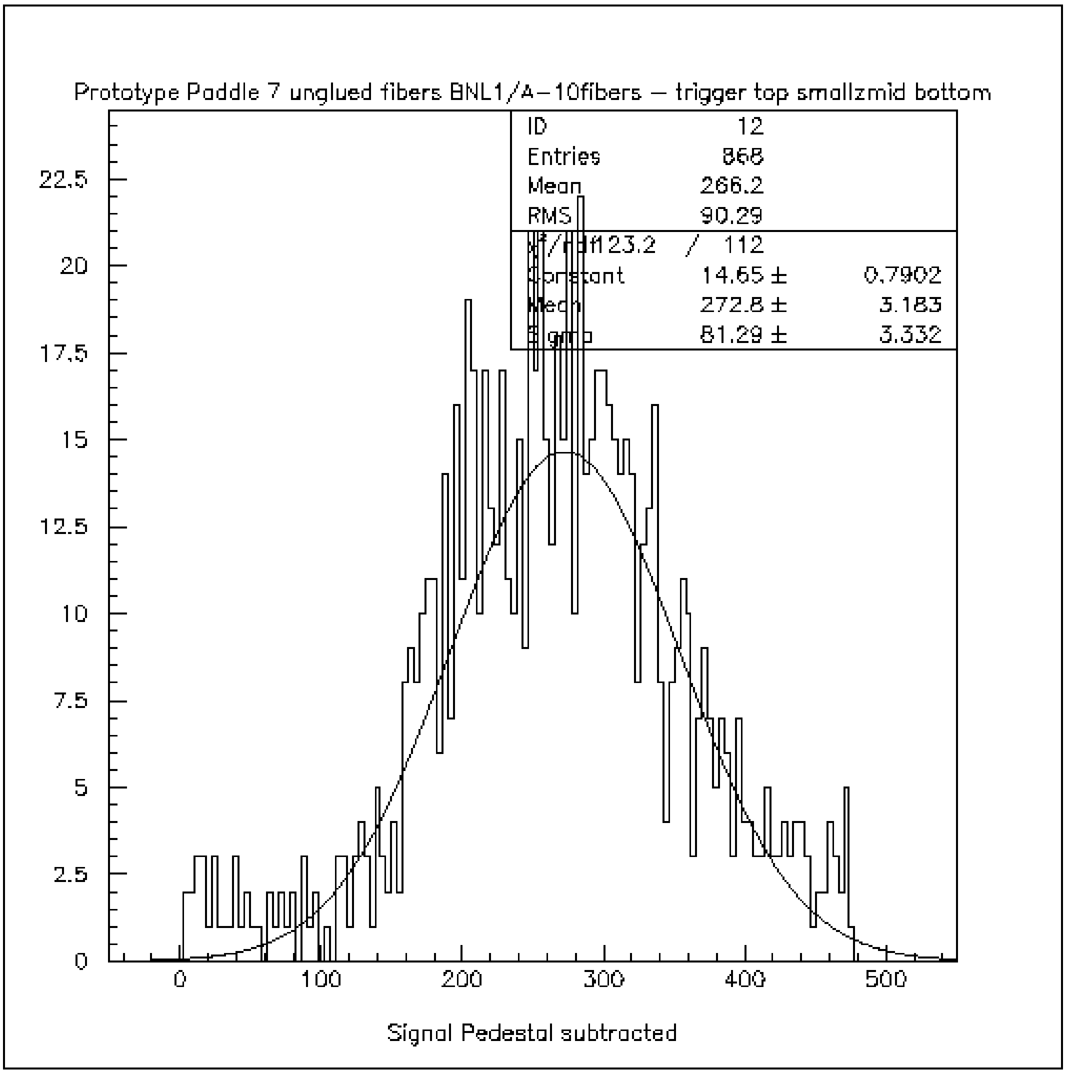

Figure 4: The Signal obtained using the extended green tube BNL1-BNLA(29053) the prototype paddle- 266.2±3.07counts Pedestal Sub.

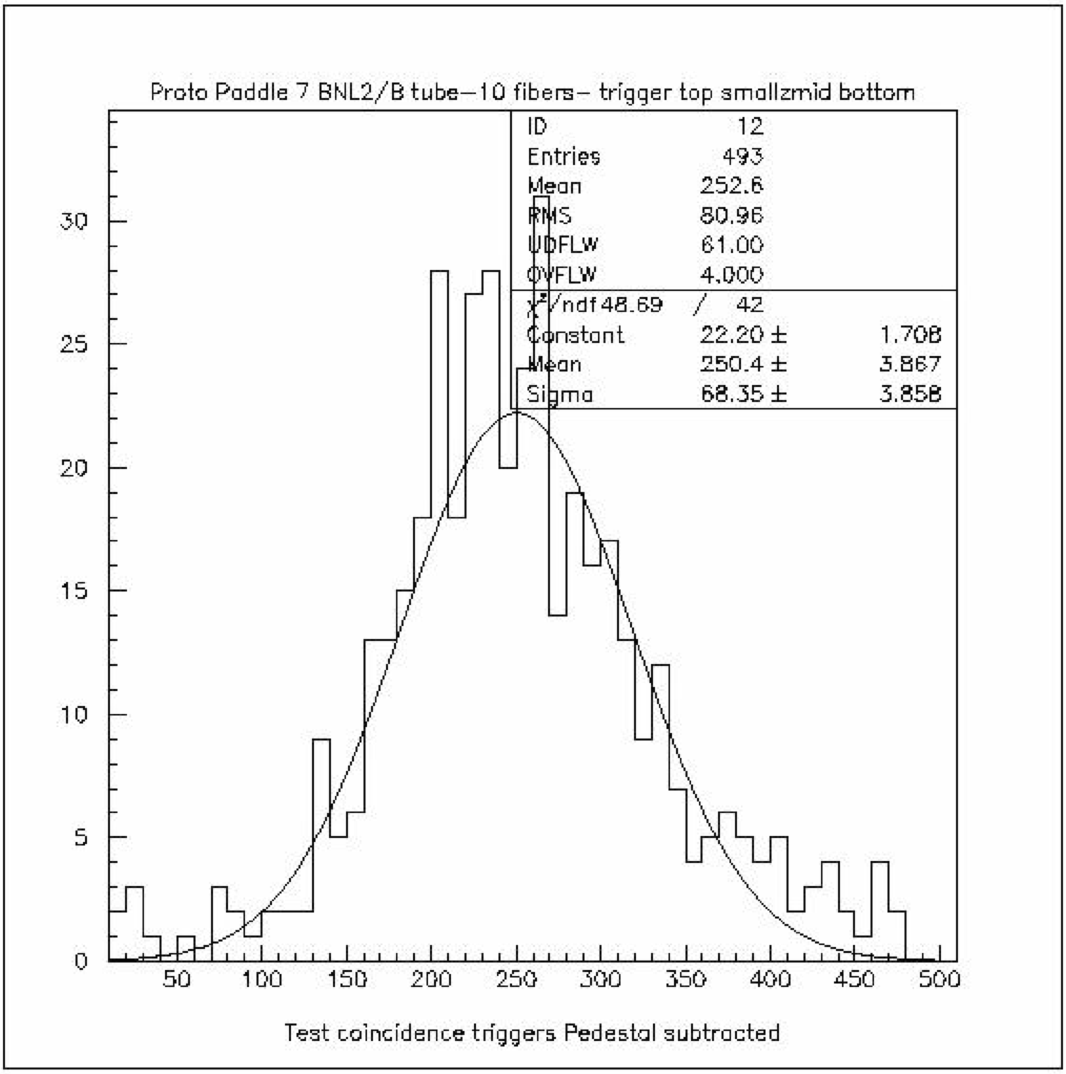

Figure 5: The Signal obtained using the extended green tube BNL2-BNLB(33362) the prototype paddle- 249.4±5.0 counts Pedestal Sub.

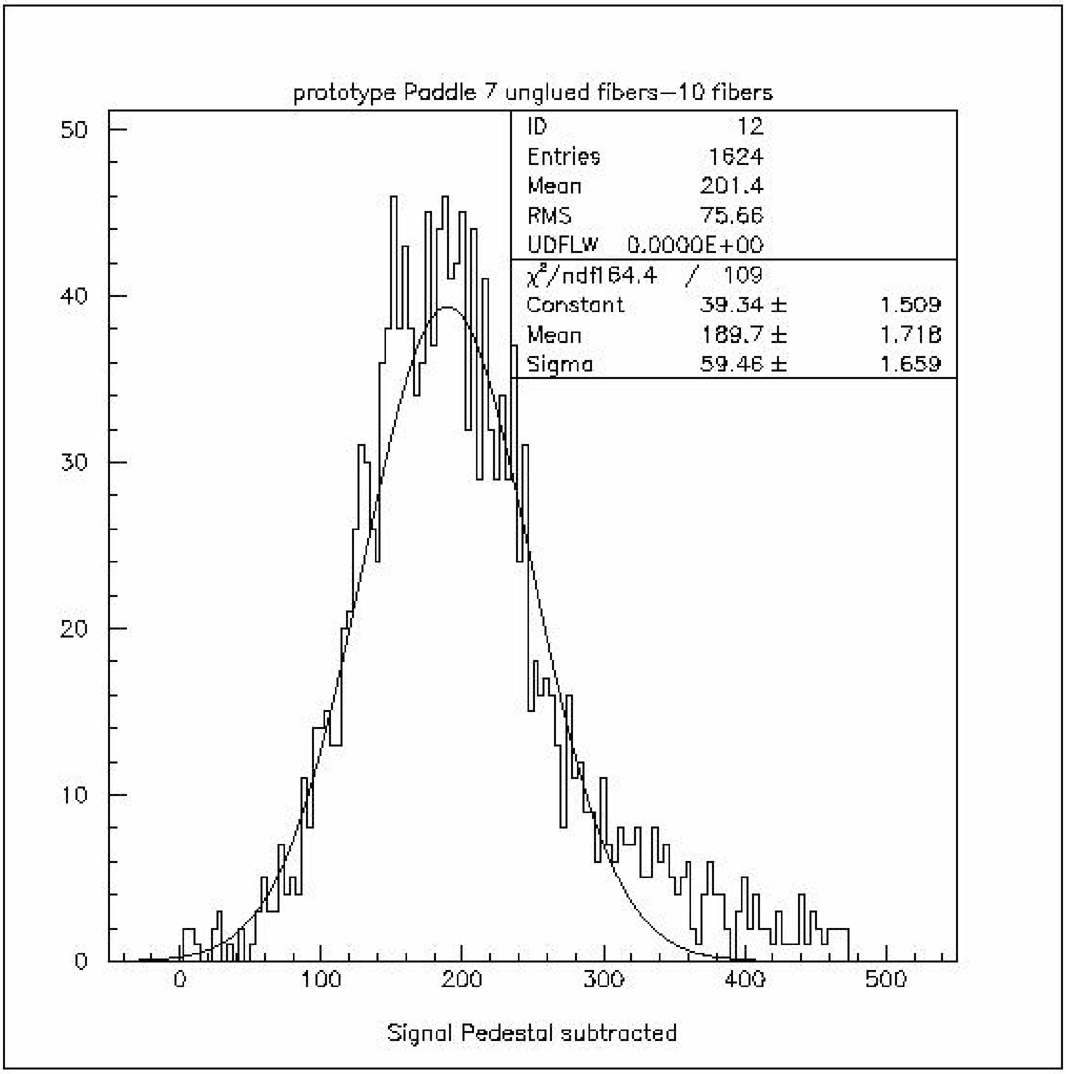

Figure 6: The Signal obtained using the KTeV tubes Phillips PMT2232 and the same prototype paddle- 200.1±5.0 counts Pedestal Sub.

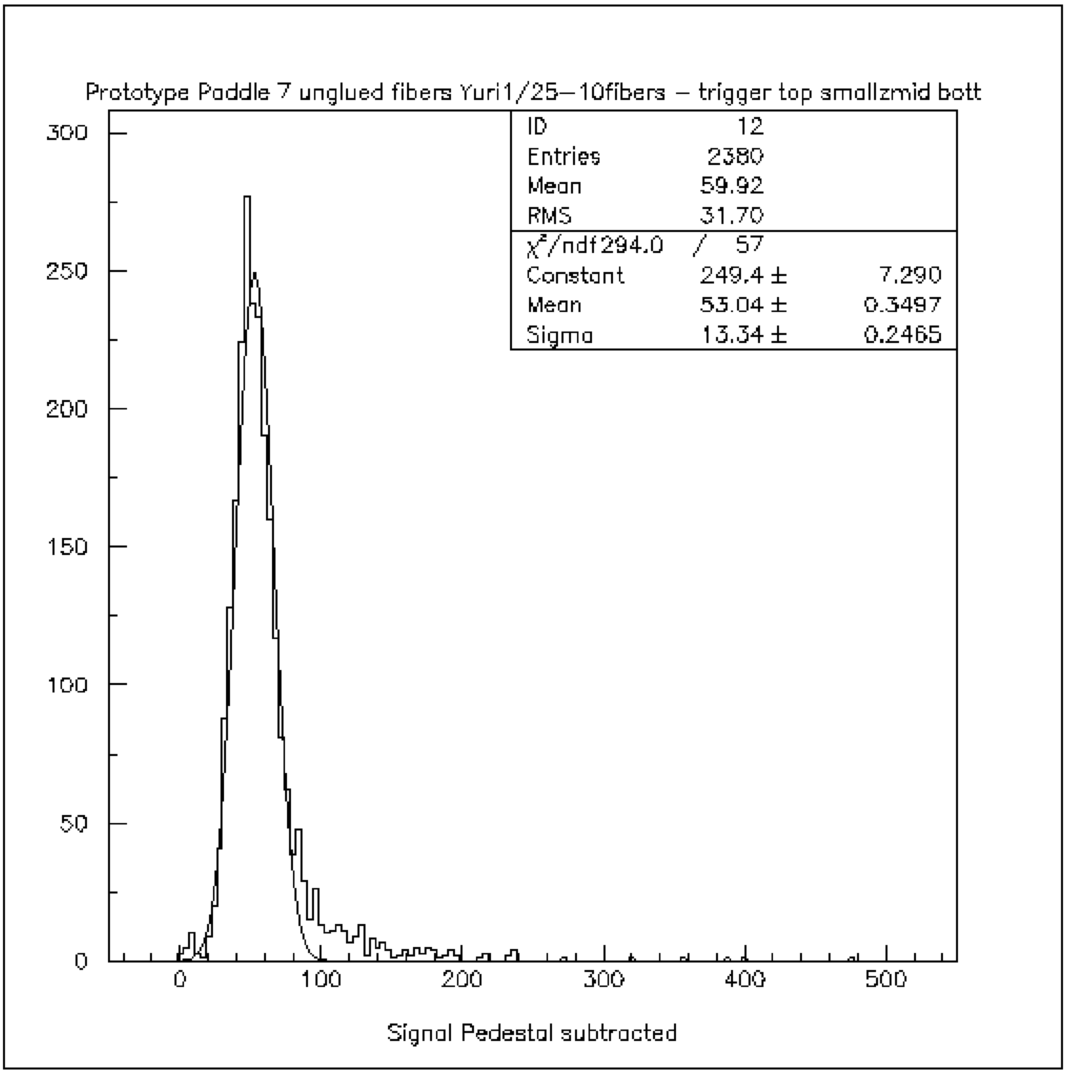

Figure 7: The Signal obtained using the extended green tube yuri1-25 the prototype paddle- $\simeq$60.$\pm$0.7 counts Pedestal Sub.

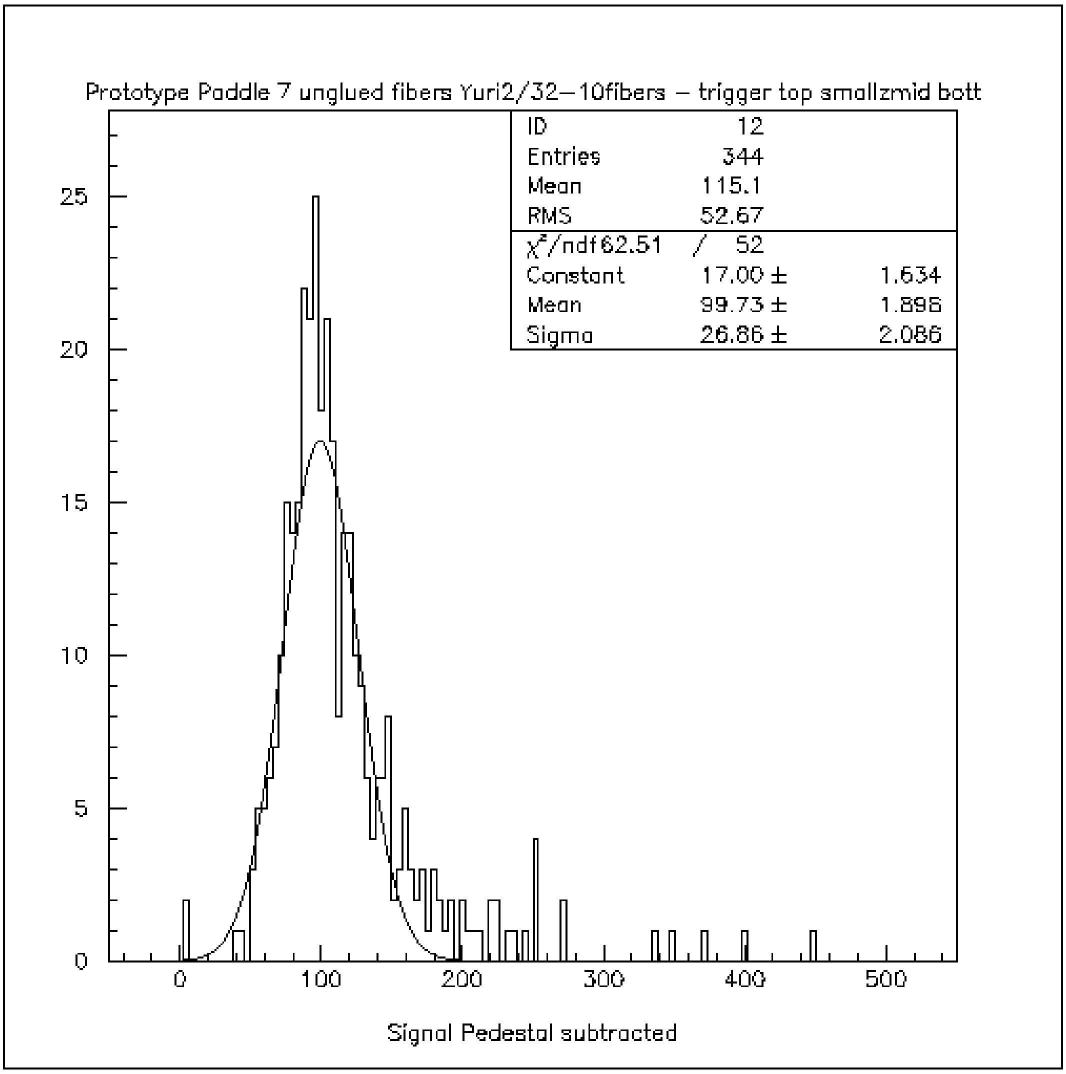

Figure 8: The Signal obtained using the extended green tube yuri2-32 the prototype paddle- 115.1±2.2 counts Pedestal Sub.

Coincidences	Base+PMT	Emean and Ped. numb. of Counts	RMS Ped. Sub.	Fitted Mean
Total=20000 Signal= 810 Ped= 8482	PMT2232	Sig= 237.8± 2.69 Sig(Ped. Sub.)=201.4±1.87 Ped= 35.50	76.66	190±1.72
Total=20000 Signal=868 Ped= 7201	BNL1-BNLA	Sig= 302.2± 3.07 Sig(Ped. Sub.)=266.2 ± 3.07 Ped= 35.09	90.29	273±3.18
Total=10000 Signal=493 Ped= 9507	BN21-BNLB	Sig= 285.4± 5.0 Sig(Ped. Sub.)=252.6 ± 3.65 Ped= 33.91	80.96	250.4±3.87
Total=20000 Signal=344 Ped= 19589	YURI2-32	Sig= 151.1± 2.2 Sig(Ped. Sub.)=115.1 ± 2.2 Ped= 35.5	52.67	99.73±2.
Total=20000 Signal=2380 Ped= 17401	YURI1-25	Sig= 95.92± 0.3 Sig(Ped. Sub.)=59.95 ± 0.7 Ped= 35.09	31.70	53.0±0.35

Table 2: Data from the prototype Paddle using Extended green tubes

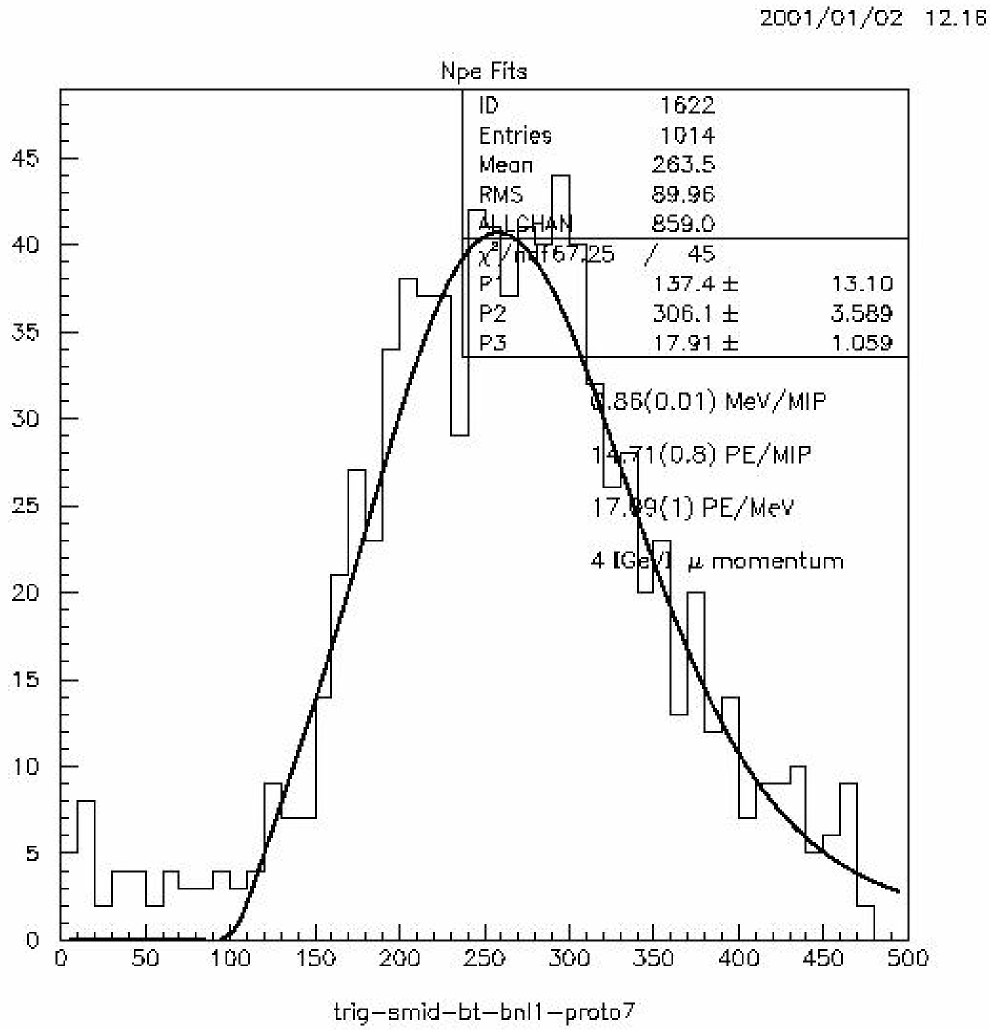

Figure 9: The Landau fit to the signal from the extended green BNL1-A tube the prototype paddle of reference-the trigger being high energy μ

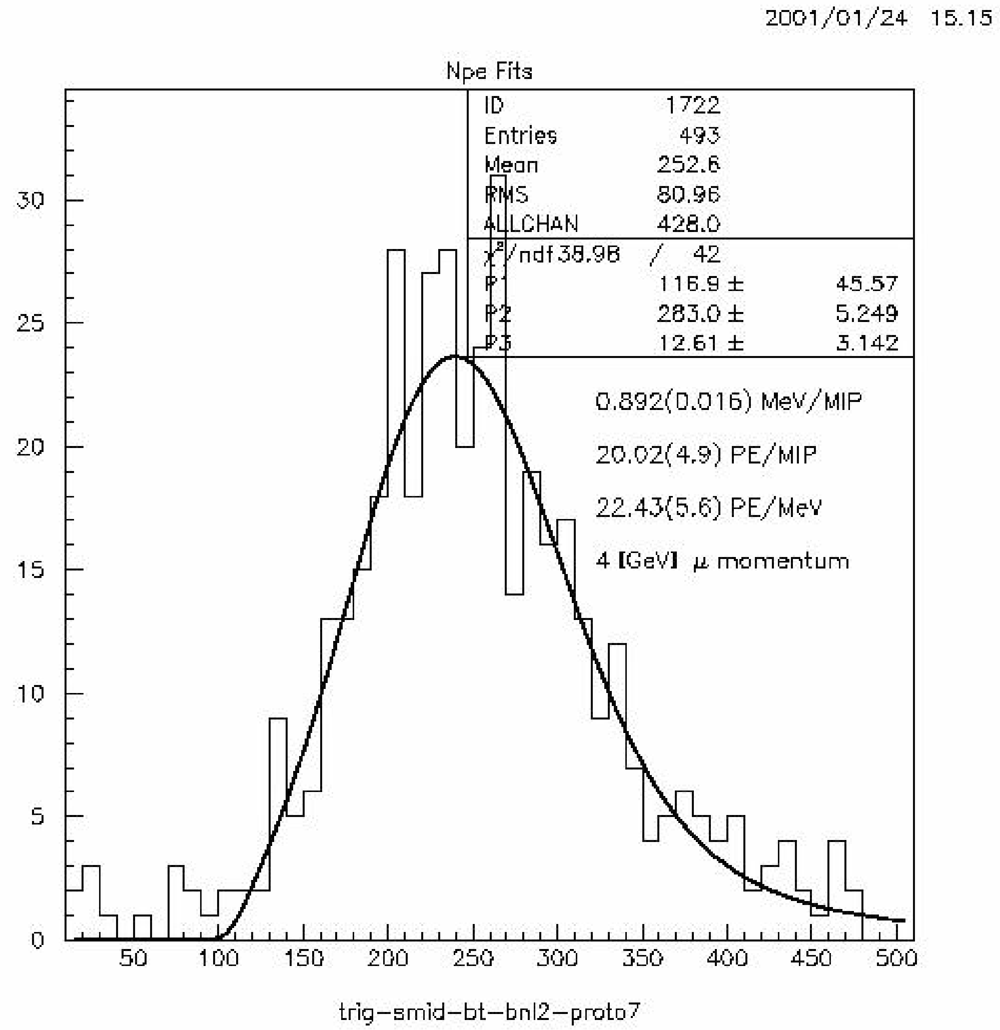

Figure 10: The Landau fit to the signal from the extended green BNL2-B tube the prototype paddle of reference-the trigger being high energy μ

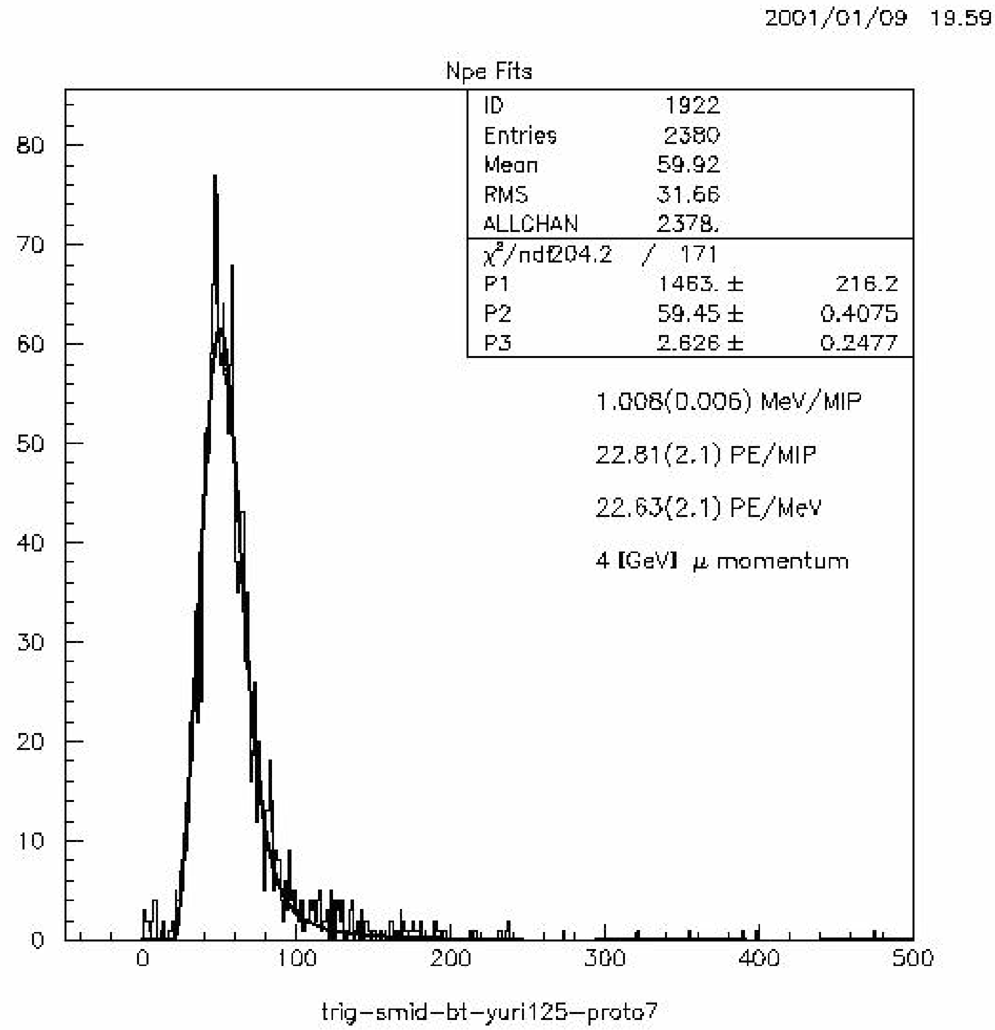

Figure 11: The Landau fit to the signal from the extended green YURI-PMT25 tube the prototype paddle of reference-the trigger being high energy μ

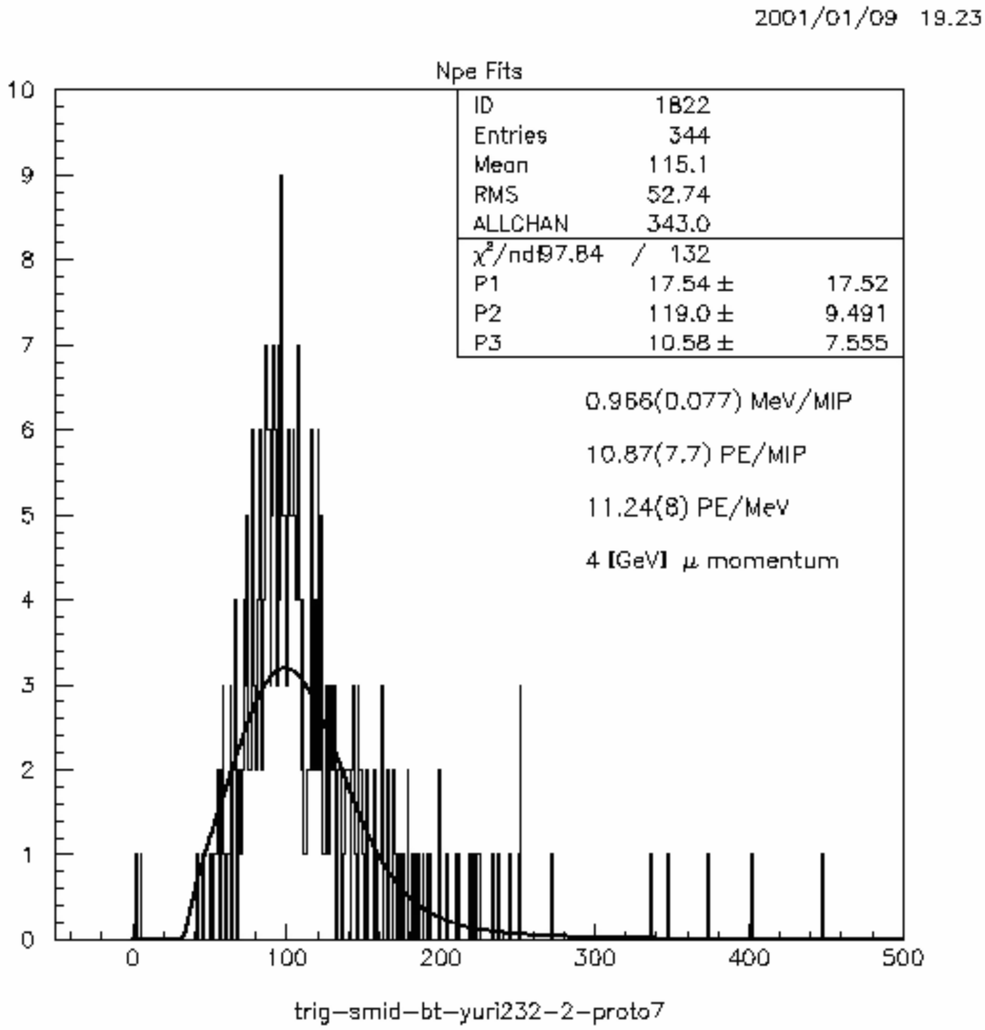

Figure 12: The Landau fit to the signal from the extended green YURI2-PMT32 tube the prototype paddle of reference-the trigger being high energy μ