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TEST OF LONG SCINTILLATION COUNTERS FOR LARGE SUPERCOLLIDER DETECTORS

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1 Introduction

All designs of general-purpose detectors for the future hadron supercolliders, LHC and SSC, require fast detector to signal traversing muons. These counters play a decisive role in the so-called "level 0" trigger. Given the fact that surface of a muon trigger layer may reach hundreds of m^2 and that the detector must operate for dozens of years, the problem of ensuring they stability and full efficiency all-along their useful life is potentially serious. One excellent candidate for such a muon detector is an array of plastic scintillators seen by photomultipliers. These counters have been used extensively in the past. However the need of employing long scintillators bars, of using cheap components, of requesting full efficiency through many years complicate the issue considerably. We have investigated light yield and attenuation length of a new plastic scintillator of Ukraine production (UPS 923A) and compared it to a well known western product (NE 114). Counters employing 3 *m* long, 30 *cm* wide, 2 *cm* thick scintillators were found to be very efficient on traversing cosmic muons over their entire length, the light yield being about 25% more for UPS 923A. The adopted method and the results in term of absolute light yield and attenuation length are described in this paper. The measurements of time stability are in progress.

2 Detail on Counters and Measurement

The quality of scintillator counters is determined primarily by the quality of the scintillating material used by the manufacturer. The basic scintillator parameters are light output and light attenuation length. We carried out a comparison of these basic characteristics of NE 114 and UPS 923A.

For this purpose two long counters were built. The first counter used NE 114 which is based on polyvinyltoluene (PVT). The scintillator itself was a bar with dimensions $200 \times 30 \times 2$ cm^3. At one end a lightguide was glued to it by means of the optical cement NE 581. The second end was painted black to suppress light reflection. In addition, an identical but 3 m long counter using UPS 923A was also built and tested.

The light guide was a standard one made of plexiglass and assembled with two parts glued together with "TENSOL" cement $N^0 70$. The first part was a 2 *cm* thick trapezoidal plexiglass bar with bases 30 and 15 *cm* and height 20 *cm*. The second part had a conic form with the base 15×2 *cm* ending into a cylinder with the diameter of 4.6 *cm* and length 7 *cm*. To this cylinder the photomultiplier (PM) was joined. The full length of the lightguide was 38 *cm*. The counter was wrapped in aluminized paper and isolated from light. The second counter was

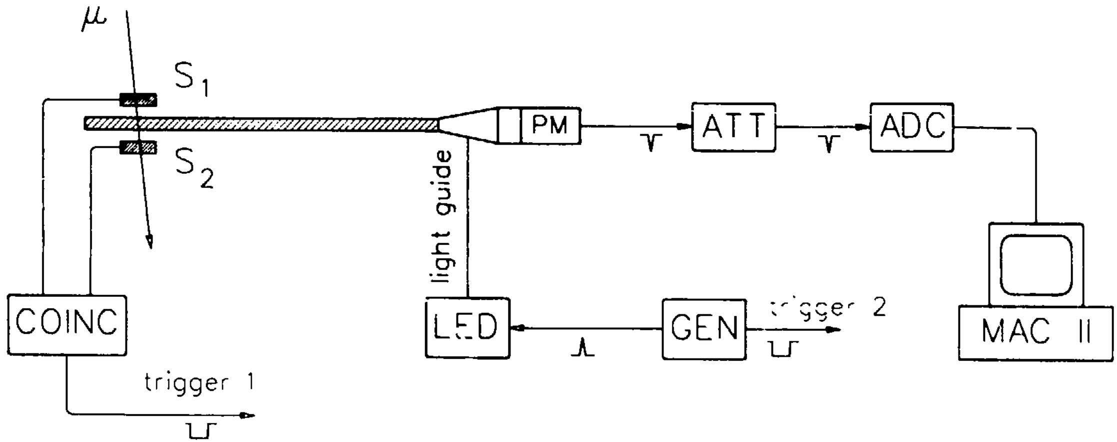

Fig. 1 Block diagram of the measuring setup.

identical, but used a UPS 923A scintillator. This scintillator has a polystyrene (PS) base (97.95%) and contains in addition paraterphenyl (2%), POPOP (0.03%) and a stabilizer (0.02%).

We also investigated the efficiency on cosmic rays of a prototype trigger counter with an identical UPS scintillator with the far end of counter not blackened.

Our measurements were carried out using cosmic muons. The block scheme of the measurement setup is shown in Fig. 1. The photomultiplier was an EMI 9814B joined to the lightguide by an optical grease. The amplitude of the output signal was measured by a LeCroy ADC 2249A charge-to-digital converter. The gate to the ADC had a width 80 ns. To the increase of dynamical range an attenuator (ATT) was included in the spectrometric channel. The ADC was readout by a Macintosh II. We operated in two different regimes. Trigger 1, to measure the cosmic muon spectra, and trigger 2 for calibration of the spectrometric channel. Trigger 1 was generated by a telescope consisting of two small ($\sim 4 \times 10\ cm^2$) scintillation counters (S_1,S_2) in coincidence sandwiching the scintillator to be tested. Moving the telescope along the counter we were able to measure the dependence of light yield on distance from the PM. Trigger 2 was provided by a pulse generator and was used for the measurement of the light emission diode (LED) spectra. The average number of photons incident on the PM photocathode was varied by changing the amplitude of the LED driving voltage. The LED spectra were used to determine the channel parameters and to monitor its time drift. For this purpose measurements of LED spectra were carried out both before and after each cosmic muon measurement.

3 Calibration of the Spectrometric Channel

The spectrometric channel was calibrated by measuring, in absolute units, the distribution of the number of photoelectrons generated in a cosmic muon passage. The calibration was done by means of a LED, using light flashes of low intensity. The knowledge of light output in absolute units - numbers of photoelectrons created on the PM photocathode and collected by the first dynode - is very important as it enables not only to find the efficiency of the system but also to check its stability, and to compare parameters of different detectors. The LED spectra are deconvoluted in terms of various detector parameter and some of the deconvoluted parameters are used as calibration and monitoring means. The choice of the correct PM response function is a crucial point of the method.

We constructed this function on the base of a simplified but realistic PM model. The detail of this model can be found in reference [1]. We will report here only the final result. The function that we have used to describe the PM response has 7 free parameters. Three of them describe the part of spectrum corresponding the real input signal (not pedestal, not noise):

- Q_1 - the average charge at the PM output corresponding to one electron collected by the dynode system, i.e. the gain coefficient of the PM;
- σ_1 the standard deviation of the output charge distribution corresponding to one input electron;
- μ the average number of photoelectrons collected from the PM photocathode in the measurement being considered;

From these 3 parameters one (μ) characterizes the intensity of the light source and the two remaining ones (Q_1 and σ_1) characterize the response of the PM. It should be noted that μ characterizes not only the light source but also the quantum efficiency of the PM photocathode and the collecting capability of the dynode system.

Q_1 can be used as a calibration means. It can also serve for checking the stability of the spectrometric channel, supposing the photocathode quantum efficiency to be stable. As already mentioned, calibration measurements were carried out before and after each cosmic muon measurement. From each calibration spectrum the parameter Q_1 was extracted and a calibration coefficient was found as an average of the two Q_1 values before and after the muon measurement. A typical deconvoluted LED spectrum is shown in Fig. 2. It corresponds to an average of 1.9 photoelectrons collected from the PM photocathode. The solid line shows the PM response function, with fitted parameters as given in the figure. The dashed curves represent the exponential PM noise, and the partial charge distributions for $n = 1, 2, 3...$ photoelectrons collected by the photocathode. The maximum number of photoelectrons handled by the fitting procedure was $n_{max} = 9$. The asymmetry of the partial charge distributions is caused by the convolution of the ideal distributions with the background and decreases with increasing n. From Fig. 2 we see that the experimental spectrum is well fitted and $Q_1(channel/ph.e.)$ is determined with high accuracy ($< 1\%$). The errors were found by Minuit Minos analysis. For illustration we present in Fig. 3 the time dependence of Q_1 during our entire set of measurements. The local discontinuities in the same day can be readily explained by the temperature changes during the day. The global increase of Q_1 was traced to a drift of the PM high voltage supply during the

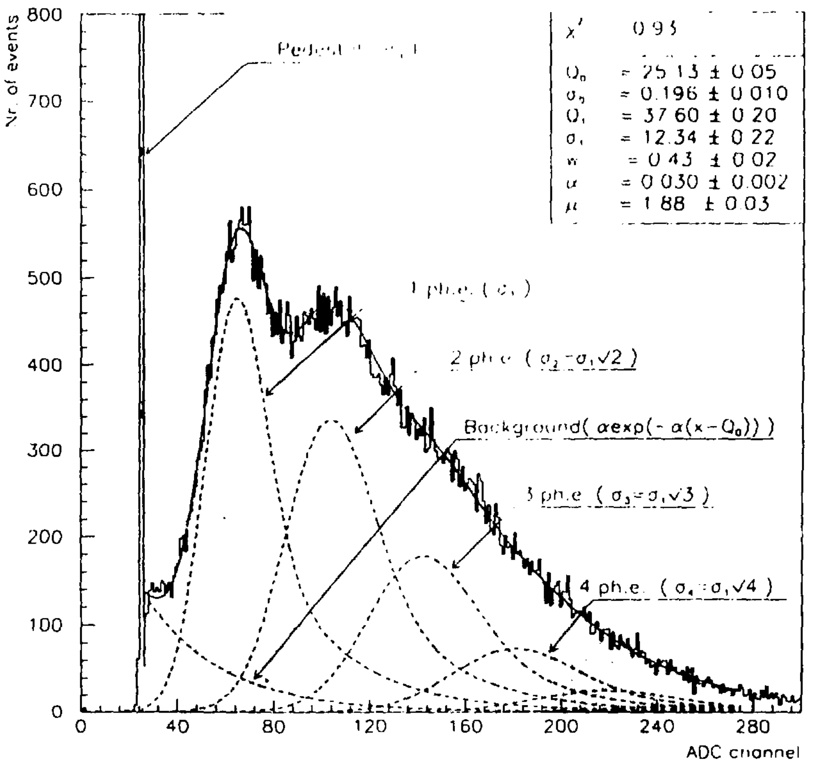

Fig. 2 A typical deconvoluted LED spectrum (EMI - 9814B photomultiplier).

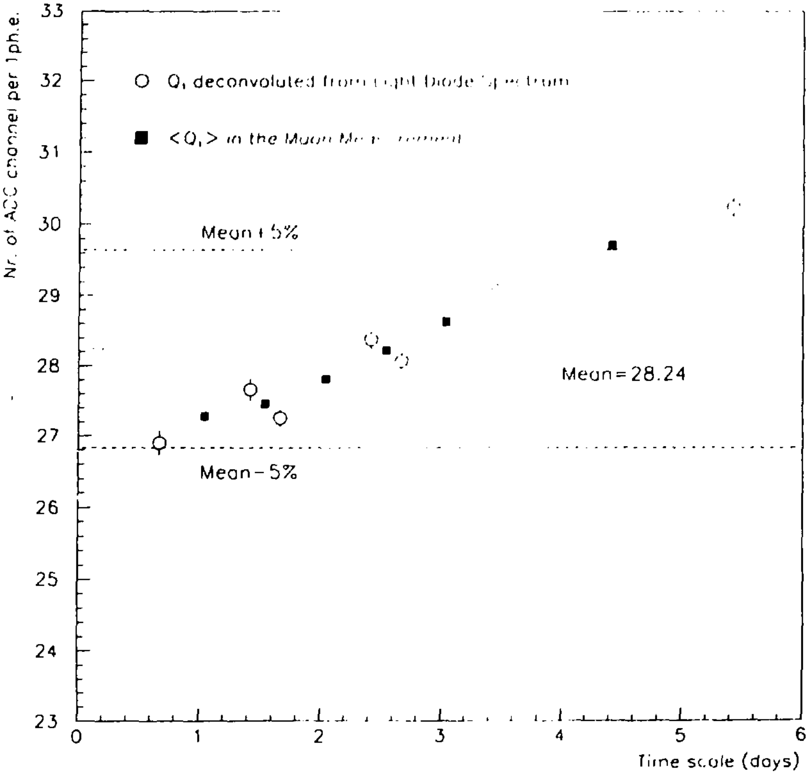

Fig. 3 *Time shift of the* Q_1 *calibration coefficient during the measurement of the* 3 *m long counter;* $< Q_1 >$ is the average of Q_1 before and after a measurement.

measurements. A correction for these small effects (a few percents) was applied to the results.

4 Results

We carried out measurements on three muon scintillation counter prototypes. Two of them (2 m and 3 m long) emploied UPS 923A scintillator and the third one emploied NE 114. As always mentioned, the 2 m long prototypes had the counter rear edge blackened. The results are summarized in the following table and figures. The typical muon pulse height spectrum is shown in Fig. 4. In this figure we see the pulse height spectrum for a 2 m long counter using UPS 923A, for muons crossing at the distance 295 cm from the light guide edge of the counter. From such a spectrum the average light yield, expressed as number of photoelectrons, was found as :

$$N_{pe} = \frac{< Q > - Q_0}{< Q_1 >}$$

where:

- N_{pe} is the average number of photoelectrons captured by first dynode;
- $< Q >$ is the average amplitude of the pulse hight spectrum;
- Q_0 is the pedestal position;
- $< Q_1 >$ is the (average) calibration parameter, giving the output charge per input photoelectron.

As can see in Fig. 4 the dynamical range of the ADC was not sufficient to cover the whole spectrum. In order to handle correctly the overflow we supposed the spectrum tail to decrease exponentially. The contribution of the tail to the average pulse heigh was thus obtain by fitting an exponent to the measured tail in the linear ADC range. In Fig. 5 and Table 1 we give the light yield as a function of distance from light guide edge for three different counters. To compare the 2 m long counters (UPS 923A versus NE 114) we fitted the corresponding light outputs with a single exponential function ($A\ exp(-x/\lambda)$). The effective attenuation lengths are found to be 130 and 115 cm, respectively, with errors of a few cm [1].

[1] In ref. [2], Fig. 6 shows the same attenuation factor over the same distance for a 2 cm thick-bar It should be noted that the apparently different attenuation length which is found there (Ls = 192 cm) is due to a different definition of Ls, which includes reflections, relative to our "effective" λ.

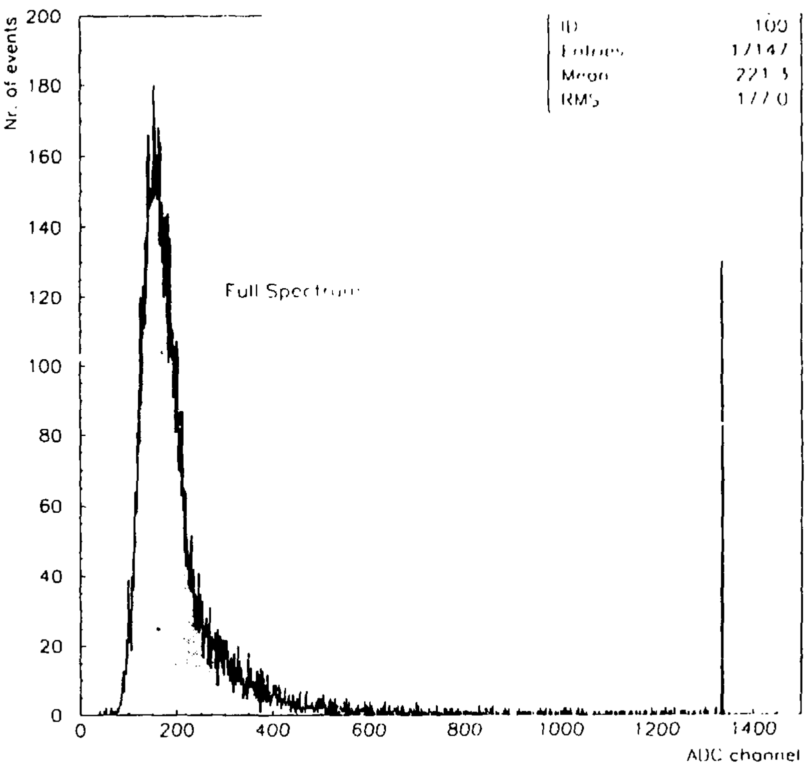

Fig. 4 A typical cosmic muon spectrum.

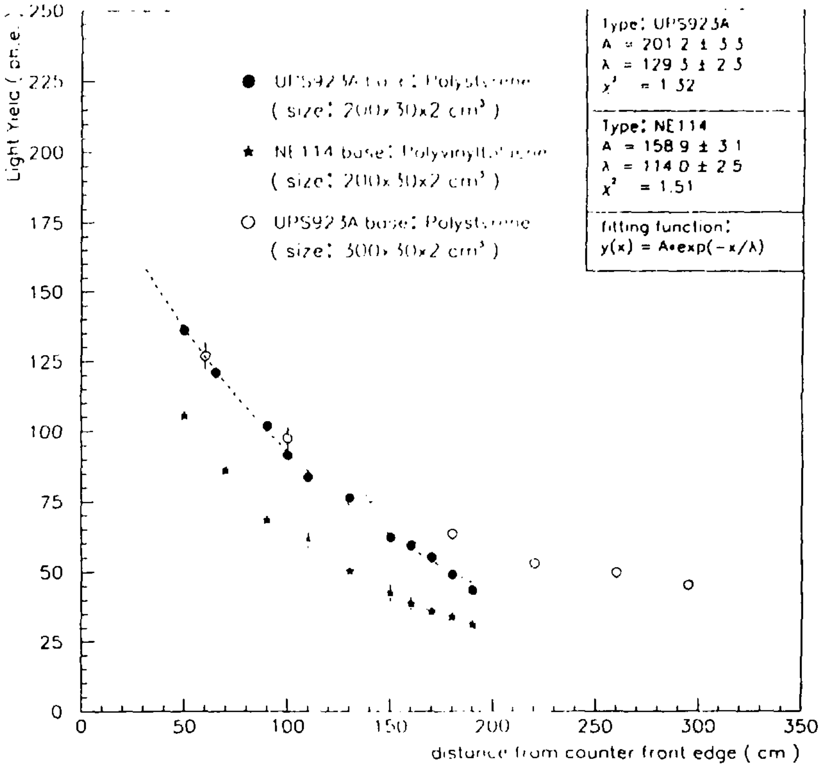

Fig. 5 Light yield of the three counter prototypes versus distance from the front end of scintillator.

Table 1 The measured light yield (in photoelectrons) vs distance for three different counters: 2 *m* long NE 114; 3 *m* and 2 *m* long UPS 923A. The rear edge of the 2 *m* long counters were blackened to reduce reflection.

Table 1: Light Yield (*ph.e.*) vs Distance for Different Counters			
distance (*cm*)	NE 114 (2 *m*)	UPS 923A* (2 *m*)	UPS 923A (3 *m*)
50	105.5 ± 1.8	136.3 ± 2.0	-
60	-	121.7 ± 2.0	126.9 ± 4.7
70	86.0 ± 1.1	120.1 ± 2.0	
90	68.3 ± 1.1	102.1 ± 1.8	
100		91.8 ± 1.5	97.6 ± 2.1
110	61.2 ± 3.1	83.8 ± 2.2	-
130	50.4 ± 1.4	76.4 ± 1.7	-
140	-	-	76.6 ± 3.5
150	42.7 ± 3.3	62.3 ± 1.7	-
160	39.0 ± 2.6	59.7 ± 1.2	-
170	36.0 ± 0.9	55.4 ± 1.2	-
180	34.2 ± 1.1	49.3 ± 1.3	63.6 ± 2.5
190	31.3 ± 1.7	43.8 ± 1.3	-
220	-	-	53.2 ± 2.0
260	-	-	50.1 ± 2.0
295	-	-	45.6 ± 1.8

* The composition of UPS 923A is: polystyrene 97.95%, paraterphenyl 2%, POPOP 0.03% and stabilizer 0.02%.

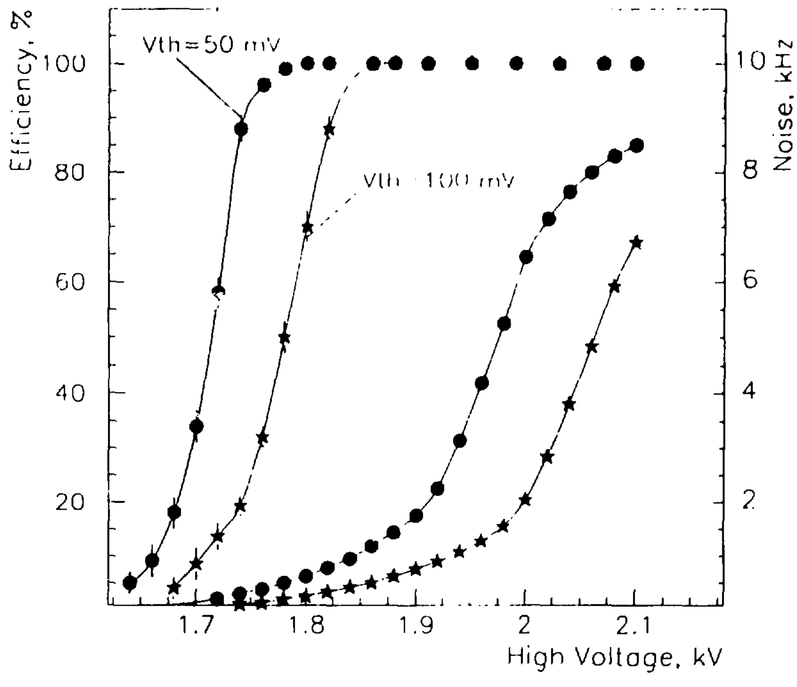

Fig. 6 HV plateau curves of the 3 m long counter for two threshold values, 50 mV and 100 mV. The characteristics were taken with muons traversing at the far end of the counter.

One can see that the light yield of the UPS 923A counter is higher than that of NE 114 by approximately 25%. This fact is not a surprise, since NE 114 contains 50% anthracene and UPS 923A more than 60%. One may note that usually it is beleived that a scintillator based on PVT should have a light output larger than one based on PS. However, the light output depends not only on polymer base, but also on the polymer supermolecular structure and on the distribution of dopands, which in turn depends on the monomer polymerisation conditions. For example, the PS-based SCSN 81 scintillator also has a light output (more than 60% from anthracene) which is comparable with the scintillators based on PVT. As can be seen from Fig. 5 the effective attenuation lengths of the 2 m long counters are comparable. In this figure the light yield for 3 m long prototype is also shown. In this case we have more 40 photoelectrons from the far end of the counter. This value is much larger than the minimum needed for 100% efficiency of muon registration. We estimated that even taking into account Landau fluctuation, 10 photoelectrons would be sufficient for an essentially 100% efficiency. We note that the light yield for the 3 m long counter is higher than that for the 2 m long ones. This is due to the contribution of the light reflected from the rear edge, which was made reflecting in the 3 m long counter. In Fig. 6 we present the efficiency and noise of the 3 m counter for two values of threshold 50 mV and 100 mV, as a function of voltage. For this measurement, the muons were traversed at the far end of the counter. The noise was a few kHz and was caused by external radioactivity and by PM noise.

5 Conclusions

The measurement performed on some long scintillator counter prototypes have shown that the light output of UPS 923A is about 25% higher than that of NE 114. The effective attenuation length for the 2 m long counters based on the UPS 923A and NE 114 scintillators were found to be approximately 130 cm and 115 cm respectively. The light yield from the far end of 3 m long UPS 923A counter was found to be more than 40 photoelectrons, while 10 photoelectrons would be sufficient for full efficiency on a m.i.p.

References

[1] E.H.Bellamy et al.,JINR Preprint **E13-93-295**, Dubna, 1993.

[2] G. Kettenring, NIM 131 (1975), 451.

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