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Choice of the Readout System Threshold for Light-Tightness Measurements of the Near Detector Modules in New Muon Lab *)

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Abstract

A simple procedure of choosing the readout system threshold in a number of photoelectrons was tested for measurements of the light-tightness in the Near Detector scintillator modules. The most important measurement conditions are described. The absence of light leakage in 5 modules in the nine planes of the Near Detector prototype in the New Muon Laboratory is shown with an accuracy ~ 1 % and with a threshold value ~ 0.1 photoelectron. A preliminary analysis of the main components of the singles rates in the scintillator modules is reported.

Introduction

We have tested a procedure to define a readout system threshold in a number of photoelectrons (phe) for correct measuring the light-tightness in the Near Detector (ND) modules, clear fiber cables and optical connectors. The Ju, Ku, Lu, Mu and Nu modules after a steel plane # 281were investigated in U projection of the nine planes of the ND prototype in the New Muon Laboratory (NML) (see next section). Below we describe the light-tightness measurements and analyses of the main components of the module singles rates.

Choice of the readout system threshold in number of photoelectrons

The readout system for measuring the light-tightness (the same as for the Far Detector (FD), as we know) is shown in Fig.1. The 2" diameter, 12 dynodes PMT EM19839B (#214334) with a "rise tail" type base was used. The clear fiber cable from each investigated module was coupled by an optical connector to a piece (~0.5 m) of a usual clear fiber cable. The opposite end of the extension cable was connected to the PMT photocathode via a plexiglas cookie using an optical grease.

Once the threshold choice has been made, this system is convenient to use with the ratemeter's sound output, but we note that the ratemeter (ORTEC 449-2) has only a rough counting scale. For getting a precise digital measurement of the counting rate we used a scaler and a timer (the latter is not shown in Fig. 1). A capacitor C was introduced to protect the discriminator input from the amplifier output current level. We used one or two amplifiers with a gain equal to 10. The discriminator worked with a minimal threshold value of -300 mV. An effective threshold variation has been produced by changing the PMT gain *G*.

The amplitude of the one-photoelectron-noise signal was observed with the oscilloscope TEKTRONIX 2465B (400 MHz). The dependence of this amplitude on the high voltage (HV) is shown in Fig. 2. The curve describes the dependence of the PMT gain on HV (it will be needed later) and the parameter value of 10.56 characterizes the average number of effective PMT dynodes.

The dependence of the PMT noise on HV is shown in Fig 3. In this measurement, a sheet of black paper was inserted into the optical connector to interrupt light signals from a scintillator module to the PMT photocathode. The one-photoelectron "shoulder "and the thermoelectric dynode noise (rise at HV > 1700 V) are clearly seen. This is the integral characteristic of the PMT noise – the number of noise pulses with amplitude greater than the used threshold (- 300 mV). It is possible to calculate from this the differential characteristic of the PMT noise – the number of noise pulses (Δn), with amplitudes in some amplitude interval (ΔA), i.e. the pulse height noise signal distribution (Δn/ΔA).

First, we transformed the dependence in Fig. 3 into the dependence of the noise-counting rate on the PMT gain (using the fit in Fig. 2). This dependence was then numerically differentiated to obtain Δn/ΔA, where A~1/G is a real noise signal amplitude at a fixed HV. The result of this procedure is shown in Fig. 4 for two measurements, one with the gain equal to 10 and one with the gain equal to 100. For each measurement, the working ranges of HV are shown in the upper part of Fig. 4. The difference of HV values between two neighboring points of the curve is 100 V.

It is possible to see a one-photoelectron noise peak, a "valley" to the left of the peak, and a rise caused by the thermoelectric dynode noise. The amplitude scale was calibrated by the position of this peak to enable the threshold determination in photoelectrons. After this calibration, it is possible to choose the HV value for the needed threshold value in a number of photoelectrons (see arrows in Fig.3).

Reproducible noise counting rate values were successfully achieved over several measurements only under the following conditions:

1. The noise counting rate reached a constant level after the PMT worked continually for 2 - 3 hours.
2. Continuous cooling of the PMT by a fan aided the stabilization.
3. An AC power stabilizer was used.
4. All the measurements were done after working hours (at night) to reduce the light background and the influence of any active electrical equipment on AC power.
5. The duration of the individual rate measurements was 100 s.

Under these conditions, the precision of each counting rate measurement was (1.0-1.5)% that is twice the estimate based on the Poisson statistics.

The light-tightness measurements

Each of the five modules (see [1] and Table 1) after steel plane # 281 was connected with the help of a clear fiber cable [2] to the PMT to measure the dependence of the singles counting rates on HV and on the external light conditions in the New Muon Lab [3] (light "on" or "off" at night). The singles rate is a sum of the real signals from the scintillator modules and of the PMT noise (first component of the "singles" rates). Then signal counting rates for each of the 5 modules were found by subtracting the PMT noise rate from the sum (see, for instance, Fig 3, module Ku).

The average value of the signal counting rate plateau (<Nmod>) in the range 1300 V<HV<1500 V was taken as a characteristic of a module. <Nmod> depends on the module area, its position in the detector (how deep from detector edges), its light-tightness, etc.

The module light-tightness was described by the relative light leakage value R =<Nmod>(light on)/ <Nmod> (light off). Our results are summarized in Table 2. We conclude that there are no light leaks in these 5 modules within the accuracy of the measurements.

Main components of the "singles" rates

It is seen that our measurements were performed with the "null trigger" or" singles". It is known [4] that the two basic configurations of the data acquisition system at the FD are the "plane trigger" and the "null trigger" or "singles". The "plane trigger" configuration is used for the event selection for various physics analyses. The "null trigger" doesn't have such a requirement, so any signal is being read out and recorded. The "singles" data runs have been taken regularly during the FD installation to check functionality of the PMTs and readout electronics, to search for light leaks in the detector planes and optical connections and to monitor the noise levels.

The initial measurements of the singles rates, performed in September 2001 [4], showed that the observed rates were significantly higher than the two main components: natural radioactivity [5] and PMT dark noise. Moreover, these measurements showed that the singles rates were exponentially decreasing with a time constant of ~100 days, consistent with the test stand measurements described in [6]. After the initial decrease, the singles rates stabilized at 4000-6000 events per FD plane per second. That is significantly higher than the sum of the two main components.

We performed an analysis of the data [4, 6] and concluded that the value of the rest singles rates is proportional to the area of the scintillator plane (or module) and it must be seen in the ND modules as well. The origin of these signals may be in mechanical tensions having been "frozen" during the production procedure (extrusion) of the scintillator. The problems with anomalously large noise counting rates appear only when very low threshold values (~ 0.1 phe) are being used.

It is interesting to analyze the main components of <Nmod> for the ND modules under NML conditions. For example, ΔNmod /ΔA, i.e. amplitude distribution of the signals from the Ku module, is shown in Fig. 4 (together with the noise amplitude distribution). One can see the energy deposition peak with amplitude of more than one photoelectron. Cosmic ray muons (~ 5-10 phe) and gamma background (~ 2.5 phe [5]) can produce this amplitude. Some "bump" or "shoulder" is near ~0.1-0.2 phe. Possibly these low light level signals (producing anomalous "singles" rates) have been detected in September 2001 [4] during the Far Detector installation. They look like the signals from the first dynode with a gain of ~ 1/3-1/10 of the signals from the PMT photocathode.

Calculated and measured main components of the singles counting rates for the ND modules in the New Muon Lab after steel plane # 281 are shown in Table 3. Estimates and experimental results are in a good agreement. These results are illustrated in Fig. 5. The data for the Ju module have systematically the largest value, which is due to the greater length of its external edges (see Table 1), as calculations show.

During the measurements, we registered one more source of singles. We noticed that the value of singles rates sharply increase while moving a solid rod (screw-driver) along the gauffer adaptaflex conduit (cover of optical fiber cable) [2]. The singles rate decreases rather quickly. The frequency of signals is proportional to the frequency of acoustical sound. The effect practically disappeared after wrapping the optical clear fibers with black paper inside the adaptaflex conduit. This is some optical-acoustical effect, which should be taken into consideration while using optical clear fibers in the gauffer adaptaflex conduit.

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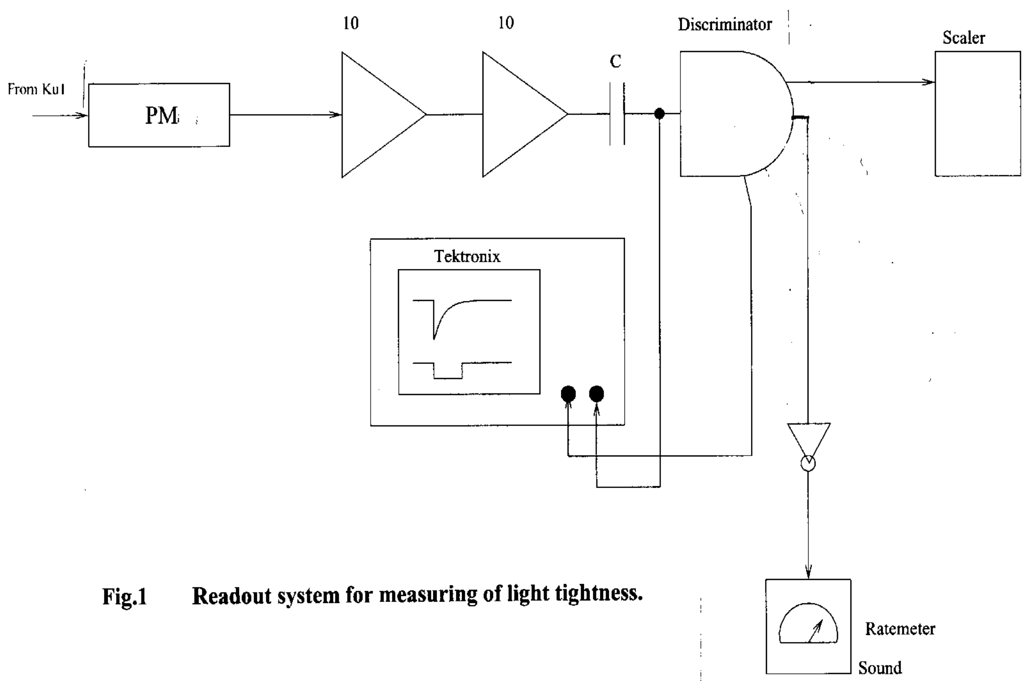
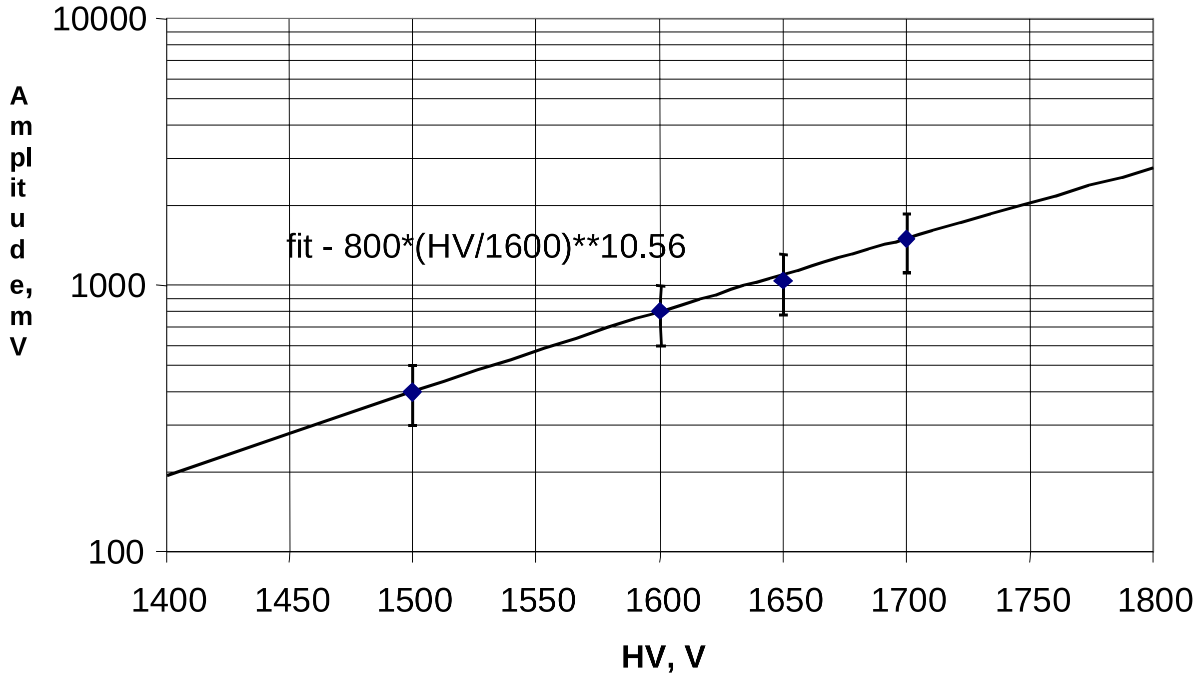


Fig.1 Readout system for measuring of light tightness.

Fig. 2 One photo electron noise signal amplitude vs HV
(or dependence of PMT Gain vs HV)



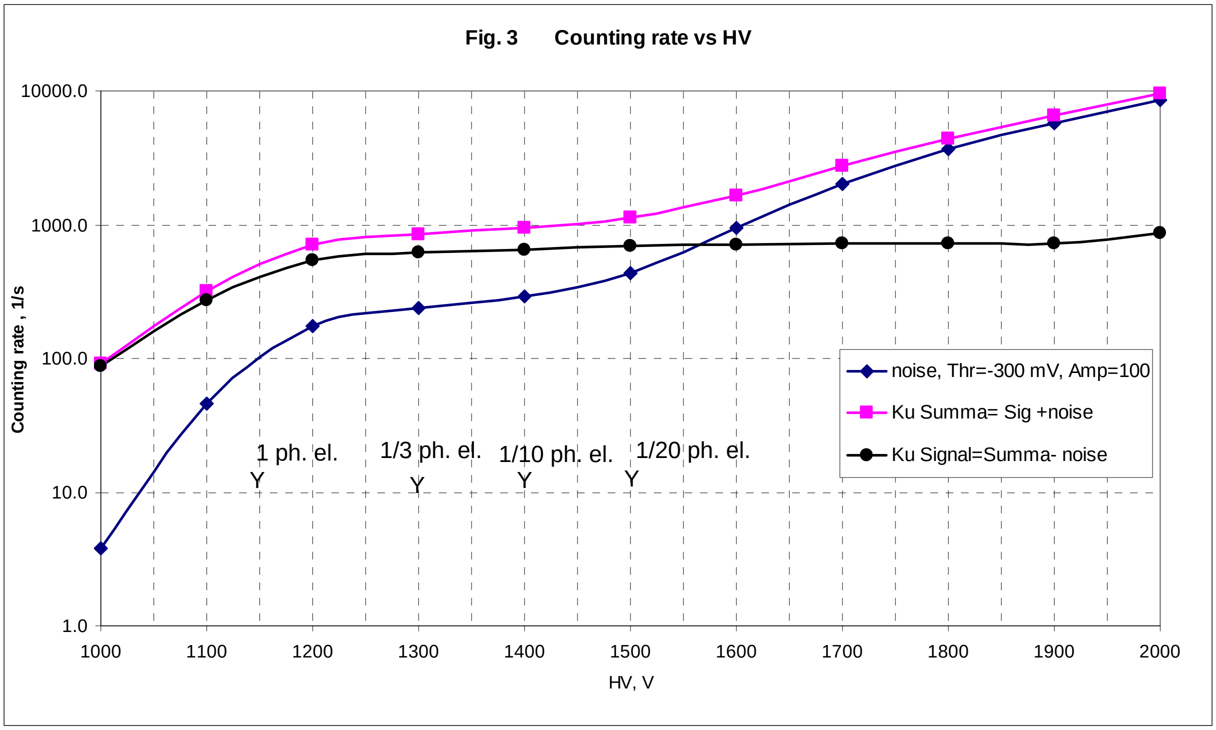


Fig. 3 Counting rate vs HV
Counting rate , 1/s
10000.0
1000.0
100.0
10.0
1.0
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
HV, V
1 ph. el.
1/3 ph. el.
1/10 ph. el.
1/20 ph. el.
noise, Thr=-300 mV, Amp=100
Ku Summa= Sig +noise
Ku Signal=Summa- noise

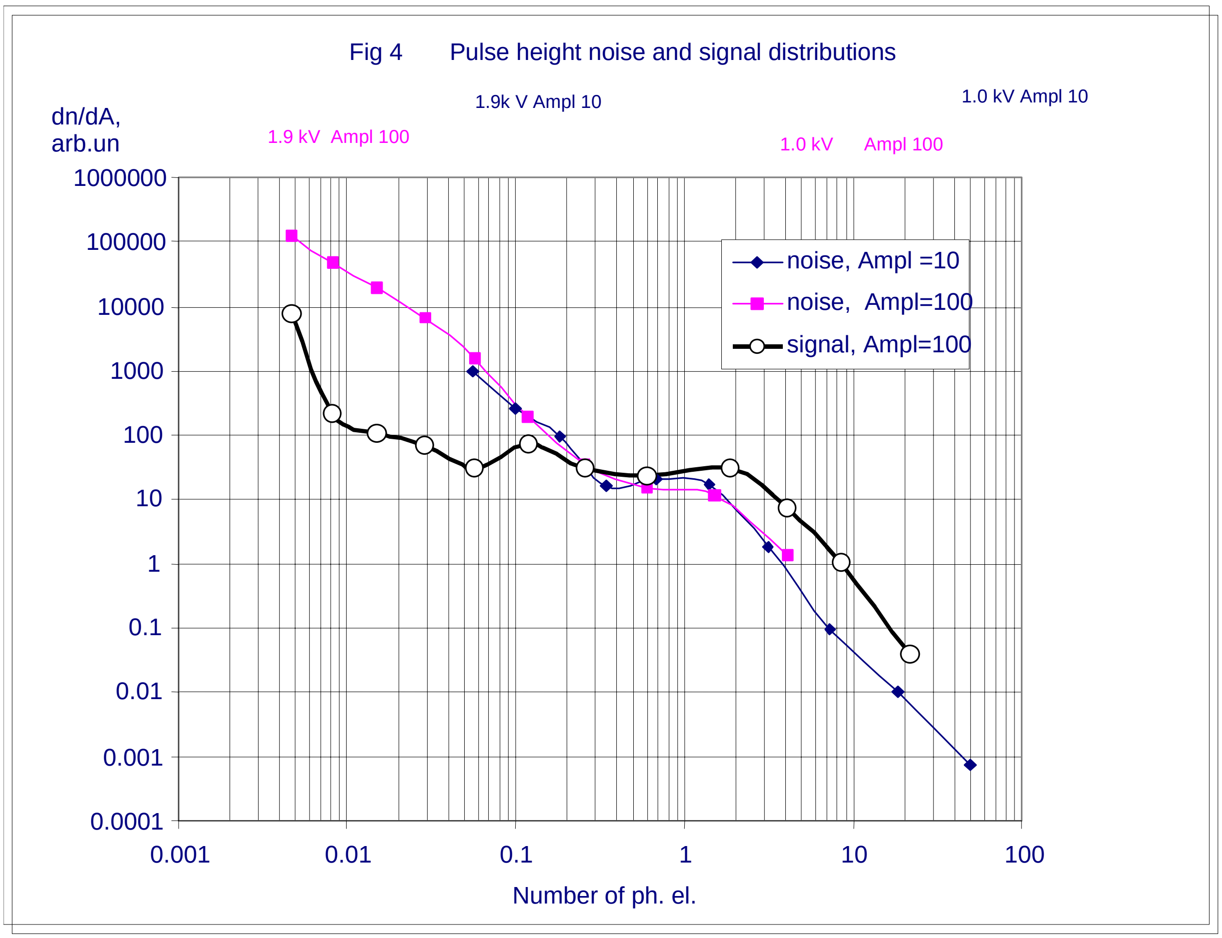


Fig 4 Pulse height noise and signal distributions
dn/dA, arb.un
1.9k V Ampl 10
1.0 kV Ampl 10
1.9 kV Ampl 100
1.0 kV Ampl 100
1000000
100000
10000
1000
100
10
1
0.1
0.01
0.001
0.0001
0.001
0.01
0.1
1
10
100
Number of ph. el.
noise, Ampl =10
noise, Ampl=100
signal, Ampl=100

Fig 5. The relative "singles" counting rates of the ND modules vs their Area

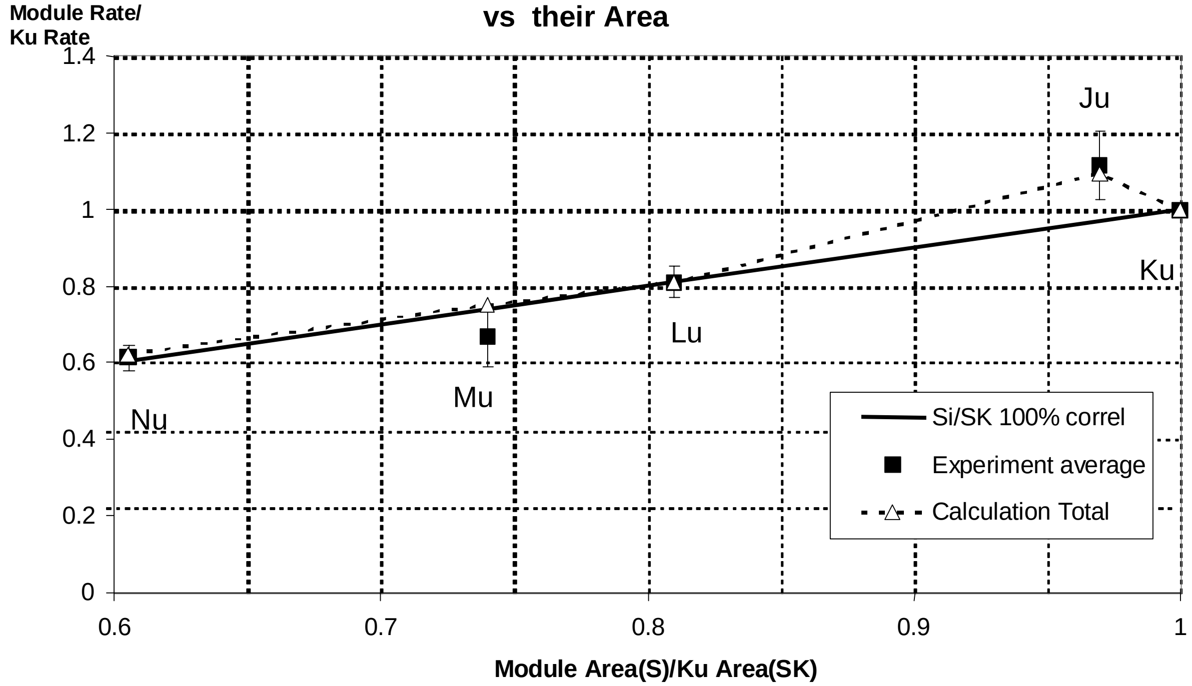


Table 1 Some geometric characteristics of ND and FD modules and planes

Modules	S, m*m	S/Sk	N strips	External edges length m
Ju	2.99	0.97	28	4.64
Ku	3.07	1.00	20	0.82
Lu	2.50	0.81	16	0.66
Mu	2.28	0.74	16	0.95
Nu	1.86	0.61	16	0.95
All mod/ND plane#281	12.70		96	8.01
FD	50.24		192	25.12
FD/ND	3.96		2	3.14

Table 2 Relative LIGHT LEAKAGE in 5 modules

Relation	##	Ju	Ku	Lu	Mu	Nu	All modules
ON/OFF	1	1.016	0.967	1.029	0.981	0.987	
ON/OFF	2	0.931	1.043			1.056	
ON/OFF	3		1.029				
mean		0.973	1.005	1.029	0.981	1.022	1.002
Standard Deviation		0.060	0.054			0.049	0.025
Standard Error		0.031	0.038	0.031	0.025	0.035	0.011

Table 3 Main components of the "singles" counting rates (Hz) for ND modules in New Muon Lab after steel plane # 281.

Modules	Anomalous*	Sum of G**	Cosmic***	Total	Experiment	Ratio Calc/Exp
Ju	231.9	330.8	259.0	821.7	809.8	1.01
Ku	239.1	244.3	267.0	750.4	759.3	0.99
Lu	193.7	198.3	216.3	608.2	583.9	1.04
Mu	176.9	189.6	197.6	564.1	489.6	1.15
Nu	144.6	158.8	161.5	465.0	447.0	1.04
mean						1.05
RMS						0.06

Notes:

Anomalous* - The rest singles rates is calculated [6] from the FD as It is proportional to the area of the scintillator plane (or module)

Sum of Gamma** - Sum of external and internal gammas rates, calculated for the ND modules from FD [5] (with factor 1/ 1.45, defined for New Muon Lab experimentally)

Cosmic*** - Muon cosmic rate (hard component), measured in special Run with two small modules (~ 0.9 m*m) in coincidence and normalized on module area