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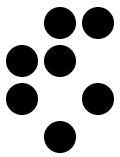

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Quality assessment tests of Hamamatsu M16 and M4 photomultipliers

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Abstract

The second group of delivered M16 photomultipliers (185 in total) and the first group of delivered M4 photomultipliers were tested in the quality assessment test setup for the photon detector of the HERA-B experiment. The sample tuned out to be homogeneous and confirmed the results of our previous tests.

1 Motivation

The RICH photon detector of the HERA-B experiment at DESY, Hamburg, will be build of 1000 16-channels multianode PMTs and 750 4-channels PMTs. The quality assessment test is therefore needed to check their quality and to provide the relevant PMTs characteristic data. The optimal value of high voltage as well as plateau count rate of all the PMT channels should be provided for further analysis. This data are important for an appropriate assignment of tubes to groups with equal high voltage.

While designing the setup for testing, we should bear in mind the stability of the photon source, the easy exchangeability of the PMTs, a relative easy data analysis and a small time consumption for a single test. The setup has been constructed and is described in the following section.

2 The multianode PMT quality assessment set-up

Four M16 PMTs are mounted in a PMTs base board (painted black) with the PMT socket, base resistor chain and ASD8 board connections (Fig. 1). The board is fastened by screws to the steel plate. The plate is covered at the PMT side by a cylindrical aluminum box. To prevent light leaks into the test volume, the steel plate is attached to the cylindrical Al box via channels (see Fig.2) which allows an easy exchange of the PMTs. On one side of the 100 mm long aluminum box (painted black) a 1 cm thick quartz window is incorporated and used as Čherenkov radiator medium. The exit window of the quartz crystal is 80 mm from the PMTs cathode layer. A strong (0.1 mCi) Sr beta source provides electrons which, in turn, radiates Čherenkov light in the quartz window. Inbetween the crystal and the Sr source incorporated into removable aluminum stick there is a black mylar foil of thickness 0.5 mm. To make the box light tight the foil is attached to the box using a black O ring.

While the PMT socket is on the inner side of the testing volume, the resistor chain and the contact pins to the ASD8 board are on the other side [2]. The bleeder resistor chain values are 1M:1M:1M:680k:680k:...:680k for both M16 and M4 case.

The serial numbers of the readout boards are 96081093, 96081111, 96060970 and 96081095 for the M16 setup. For the M4 setup we have used the ASD8 readout board without serial number.. The analog output (the amplified channel 15) are enabled on all the boards used, so that it is always possible to control one of PMT channels on the scope.

Negative digital outputs of the ASD8 are fed into an ASD8 to ECL converter (using LeCroy MVL comparator) in the same way as in the previous M16 and M4 tests [2]. The

ECL outputs are connected to ECL-NIM-ECL converters. Further on ECL output plug into the scalers (Le Croy 32 ch. scaler) while NIM outputs are are connected to the OR logic unit to form OR signals. The OR signals are connected to the scalers (CAEN 16 ch. scaler). The OR signals are connected also to the coincidence unit() to form extended OR. The duration of the output signals is adjusted to 1μs. The outputs are then plugged into the the scalers (CAEN 16 ch. scaler)

The HV for the PMTs is supplied by the CAEN programmable high voltage controller while the ASD8 threshold is controlled by a DAC CAEN CAMAC unit. The data are collected by a LabWindows data acquisition program which runs on the Windows 95 platform. The same program controls the applied high voltage and the ASD8 threshold level. The PC is connected to the HV Controller through a PC CAENET card and to the CAMAC via a GPIB interface. The gate for the scalers is given by the CAMAC gate generator unit.

The output, ASCII files with 18 variables (the HV value/ threshold value, time of measurement and the count rates of 16 PMT channels) for each photomultiplier, is analyzed in PAW.

3 Expected illumination

Since the illumination of the tubes in the set-up is slightly inhomogeneous, we determined the expected distribution of photons on the cathode layer of the PMTs using a MC simulation program [1]. In the simulation Sr electrons are generated. They are propagated to the quartz crystal, where ionization losses are calculated for small enough steps. The Čherenkov photons are emitted and propagated to the output window of the quartz and further on to the cathode layer of the PMTs. Multiple scattering of electrons in the quartz is taken into account as well as total photon reflection and absorption in the crystal. The procedure is repeated until the electron energy is under the threshold for Cherenkov radiation.

The result of the simulation, the distribution of the hits on the PMT pads, turns out to be quite uniform with maximum variation of 8% from the average value (Fig. 4).

4 The testing procedure

To check the stability of the tests one of the four PMTs remained as a reference PMT in the setup for the whole time of measurement and will be kept there to the end of the Q.A. test.

The procedure is straightforward: First the three PMTs are plugged into the PMT sockets. The testing plate is then covered with the aluminum box and left for about 15 minutes. This time is, according to our experience with tested M16s, considered to be sufficient for reducing the noise, since the background rate always drops to a few Hz at 700 V after some minutes in the darkness, and the measured rate is around 1 kHz.

The high voltage curve and threshold curve are then measured. After the test the high voltage is automatically set to zero and the threshold for ASD8 to -2 V. The procedure is repeated with the next three PMTs.

5 Results

In total, a set of 191 M16 PMTs and 54 M4 was tested. They are all quite homogeneous. From the first set of measurement (March 1997) we added to the test background measurement (measurement of background rate versus applied high voltage). It was proved that nearly all the pmt cool down to darkness rate $\approx$5 Hz per channel at 700 V in 15 minutes. For each of the PMTs three curves were measured. The rates with and the rates without Sr source from all the channels were measured and recorded for different high voltages at fixed ASD8 threshold. To check the stability of the ASD8 boards the rates with the source were measured for different thresholds at fixed high voltage.

The raw data are kept in ASCII files and then collected in the hbook ntuple.

To account for the slight inhomogeneity of the illumination of chamber as discussed in section 2, we have corrected the measured rates by using the distribution of photons as determined from the simulation (Fig. 4). The correction factor ranged from 0.9 to 1.1 for the pads closest and furthest from the source.

For each channel and for each photomultiplier we determined various characteristic values during analysis:

- RQE as relative efficiency of the channel and of the PMT. For M16 photomultipliers this is just corrected rate measured in 0.1 s, for M4 photomultipliers this is just corrected rate measured in 0.1 s and then divided by 4 (surface factor). For the whole PMT, mean RQE is averaged over all the channels.

- characteristic HV as the voltage at which the RQE 40 (M16) and 120 (M4) is reached. This value is in the range at which the slope of the high voltage scan curve is the highest.

- we defined the recommended HV 100 V above the characteristic HV

- gain uniformity : spread of the characteristic HV on one PMT.

We have compared our characteristic values to the data from the HAMAMATSU test sheet:

- EBB : voltage at which the gain 3×10^5 is reached

- SK : cathode luminous sensitivity (μA/Lm)

5.1 M16 analysis

For the M16 photomultipliers some high voltage scans can be seen on the Fig.6. A distribution of RQE at 750V is on the Fig.7. The distribution for the PMTs is more sharp than the one for all the channels. Anyhow there is not much to worry about as this is in both cases small enough FWVM=$20\% - 30\%$ of the mean value.

Some lego plots of the RQE can be seen on Fig. 8. It is obvious that the outermost pads are slightly more sensitive than the central one.

As expected there wasn't any important changes during the whole time of tests. The rates on the both reference photomultipliers (Fig.9 and Fig.18) remained constant ($\pm 5\%$). The distribution of the recommended HV (Fig.10) shows that the majority of the photomultipliers can be operated at HV=725 V and the interval extends from 650 V to 850 V.

When operating at recommended HV the RQE distribution is of course sharpened (Fig. 11). The FWVM is $10\% - 20\%$ which is evidently a factor of 2 better in comparison to RQE distribution at 750 V (Fig. 7). Our characteristic values are in good agreement with the HAMAMATSU data (Fig. 13).

Anyhow we observed that some of the PMTs does not respond in a way it was expected from Hamamatsu data-sheet. We found the PMTs with the following serial numbers were dead: 6K30R7, 6L06C8, 7A10L3, 7A09LA, 7A17L4 and 7A13L7. We didn't observe any measured output signals at all. This is probably because the PMT pins were damaged either during packaging or transportation. We have also observed that in some PMTs (serial numbers 7A09C3,7A14L4,6L07C1 and 7A13RC) some channels behave strange. Their response is not in accordance with the response of the other channels on the same PMT but is for a factor three or four higher. We marked such PMTs as the ringing ones.

5.2 M4 analysis

Up to now we have only tested 54 PMTs. On the Fig. 15 there are some HV scans for the M4 PMTs. We observe cross talk arising at HV higher than 800 V. This is in agreement with previous M4 measurements. On the Fig. 16 RQE distribution at 750 V can be seen. In comparison to the M16s, M4 are more sensitive (+70%) . This was expected knowing that M16s have normal glass windows while the M4s have UV extended windows.

The RQE is uniform over the whole surface as can be seen on the Fig. 17. The range for the optimal high voltage is nearly the same as for the M16 case, i.e. 650 V-850 V. This allows us to combine M4 and M16 modules in the same row of the photon detector and use the same daisy chain HV.

The RQE distribution at optimal high voltage is on the Fig. 20. There is slightly worse correlation between our characteristic values and the Hamamatsu data (Fig. 22) We found one channel dead on one PMT (serial number 6M17C3). The rest were all good without any strange behavior.

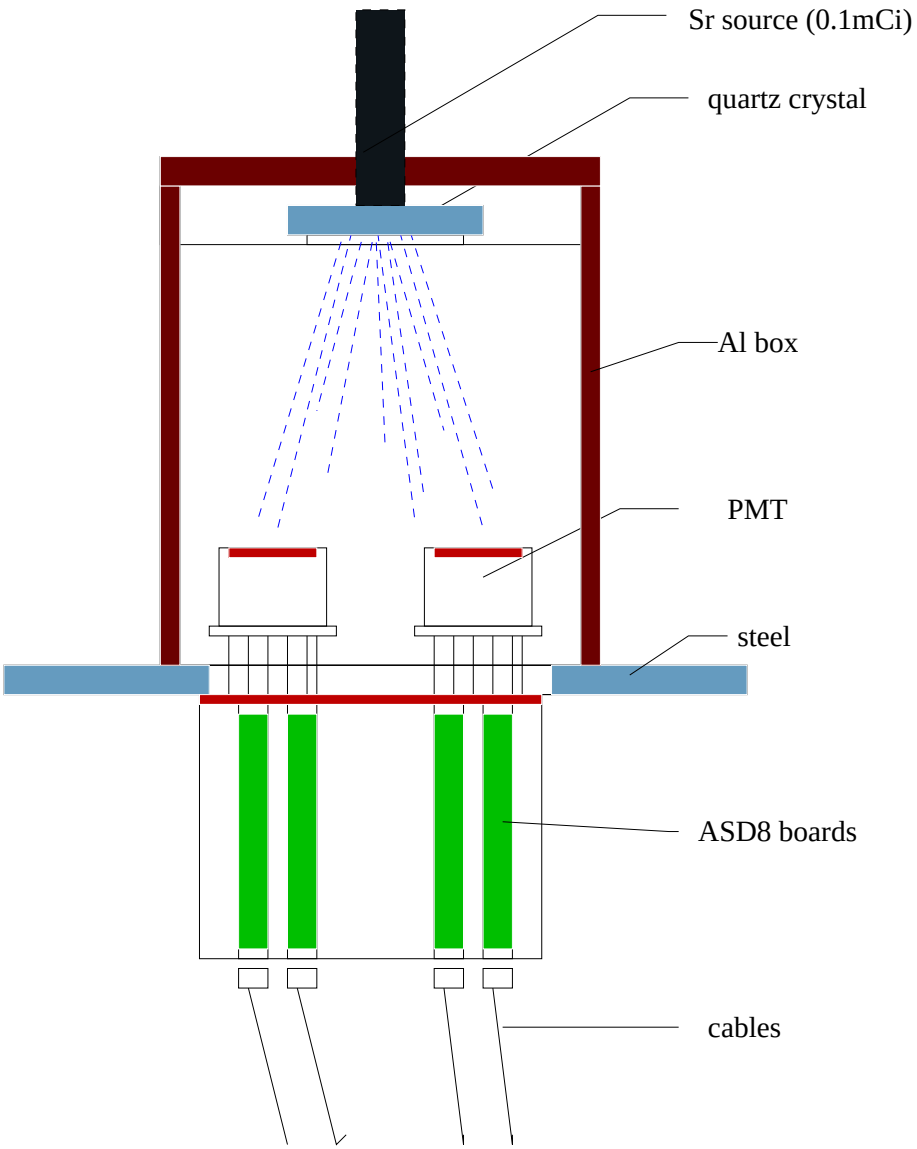

Figure 1: *The experimental setup.*

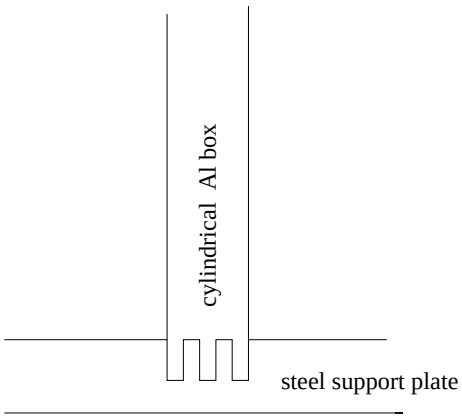

Figure 2: *The connection between the metal plate and the aluminum box.*

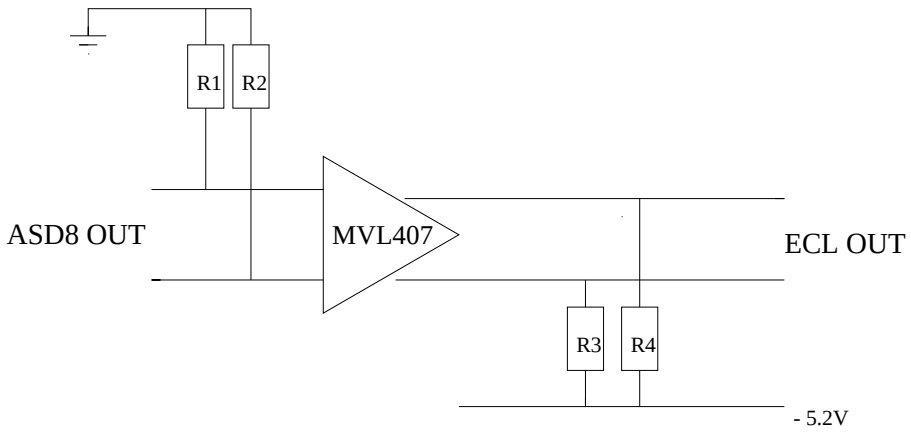

Figure 3: *ASD8 logical output to ECL converter (R1=R2=50Ω,R3=R4=500Ω, MVL407= LeCroy MVL407).*

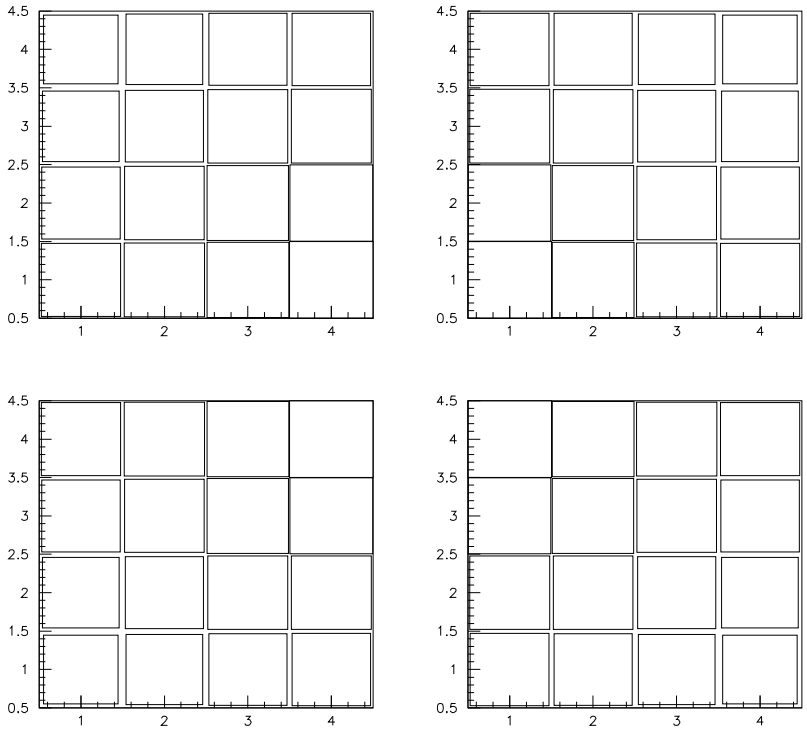

Figure 4: *The expected distribution of photons on the cathode layer of the PMTs.*

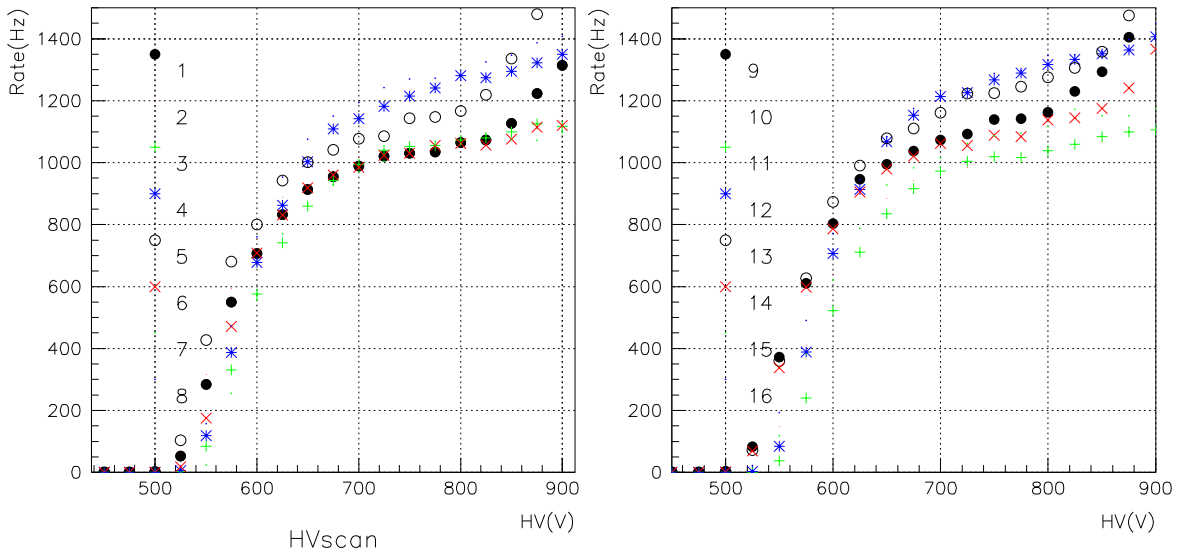

Figure 5: *High voltage scan for the reference M16 PMT.*

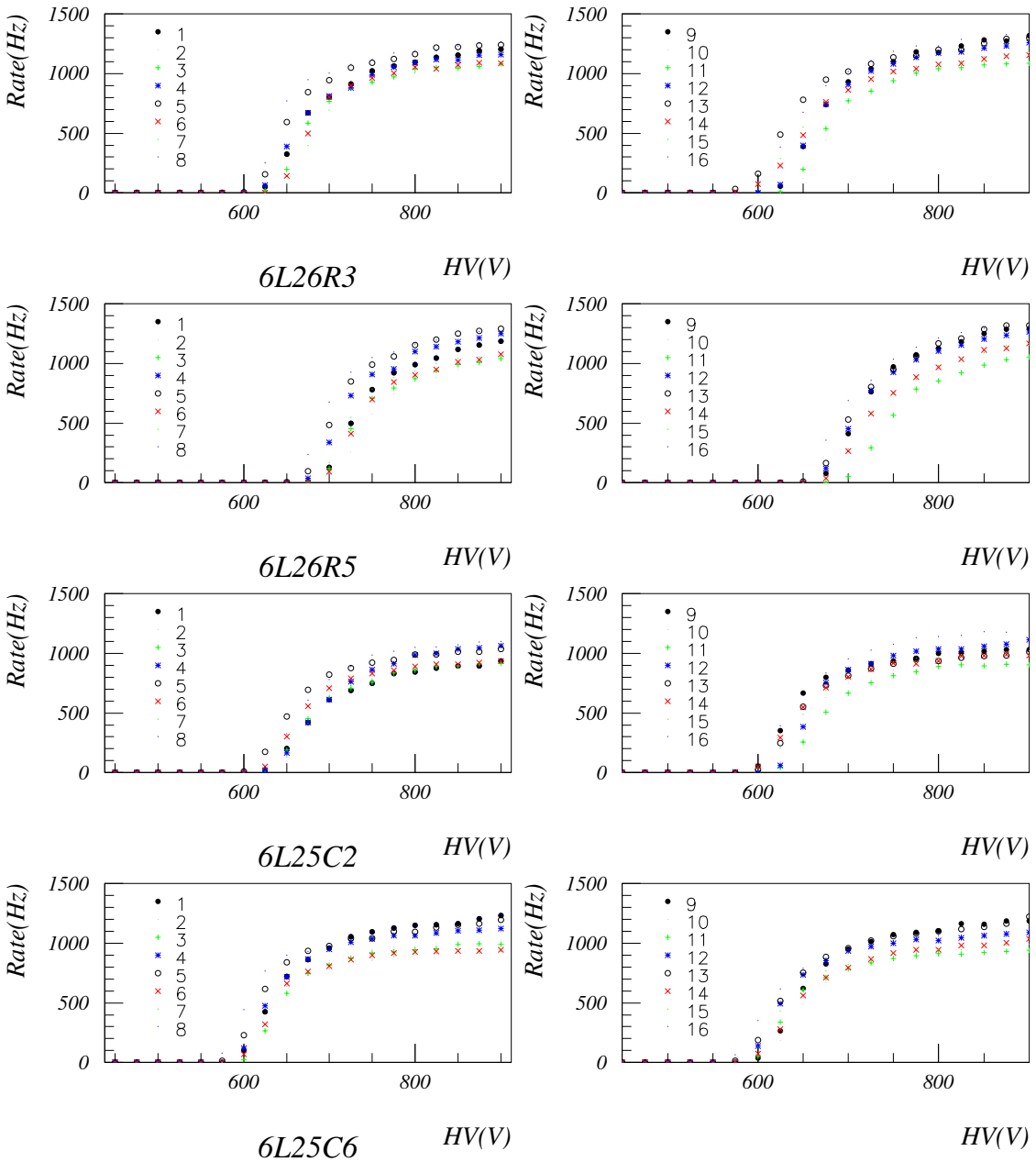

Figure 6: *High voltage scans for the M16 PMT serial numbers: 6L26R3, 6L26R5, 6L25C2 and 6L25C6.*

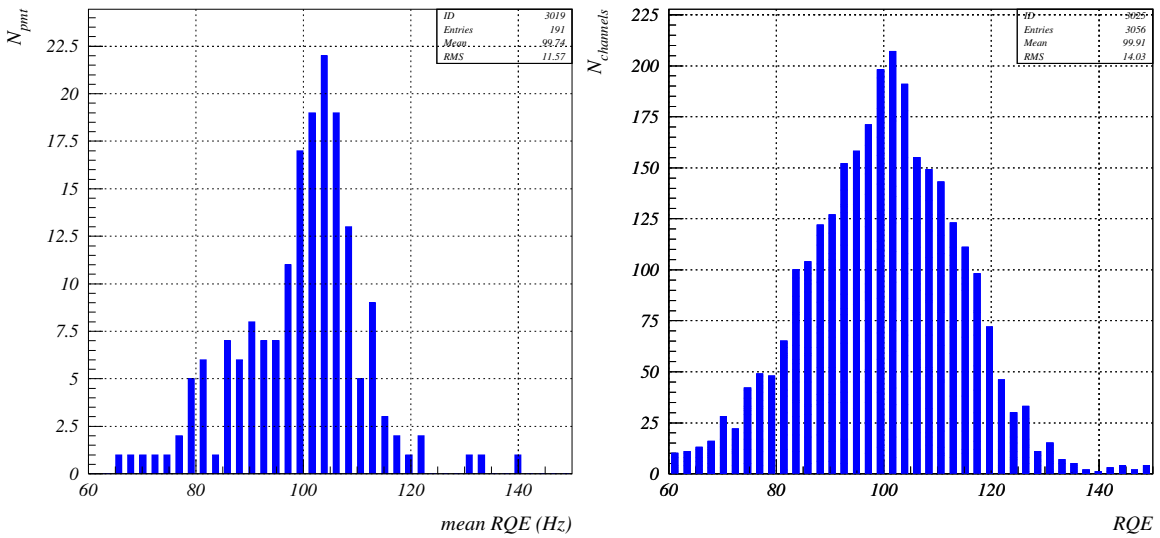

Figure 7: *Distribution of M16 RQE for the PMTs (left) and for all the channels (left) at 750 V, ASD8 threshold was set to -1.2 V .*

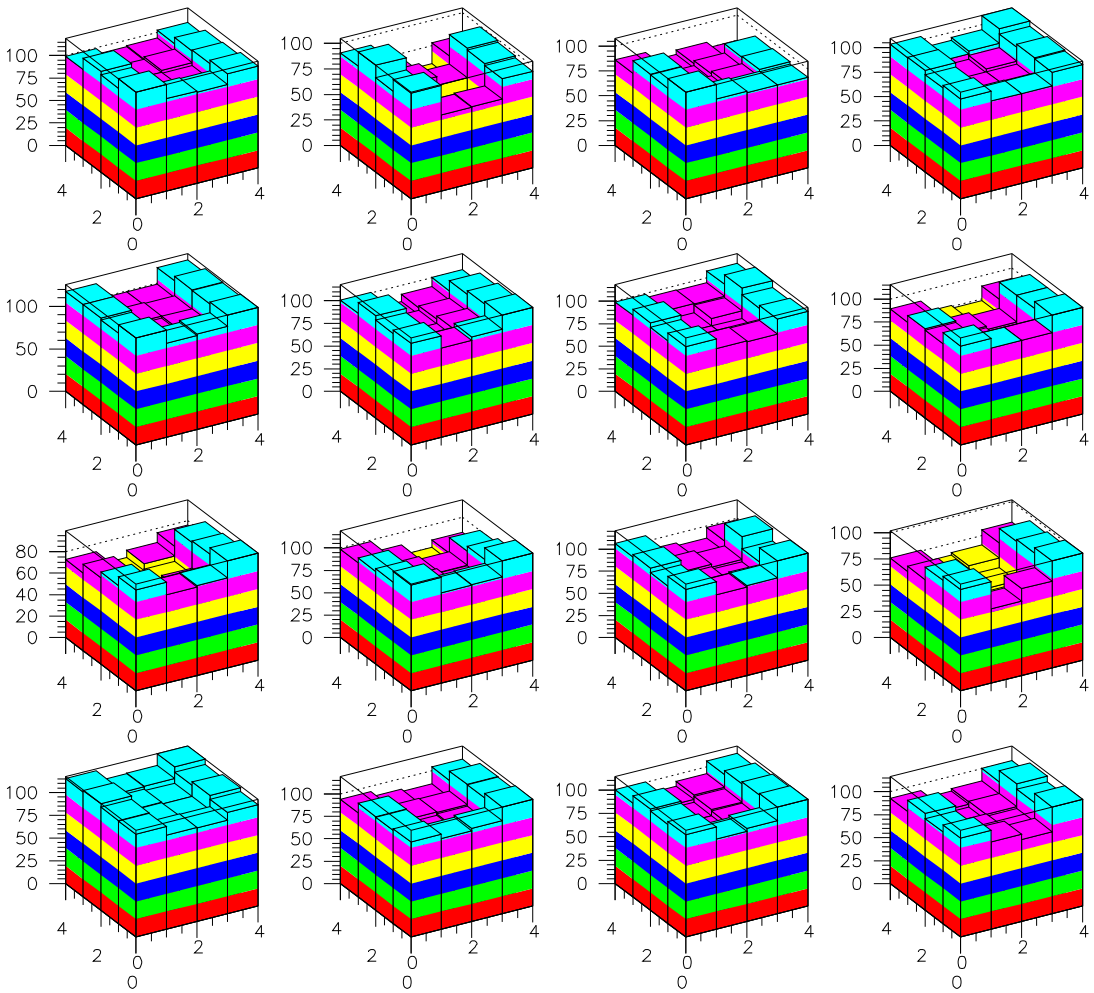

Figure 8: *RQE for several M16 PMTs at 750 V, ASD8 threshold was set to -1.2 V .*

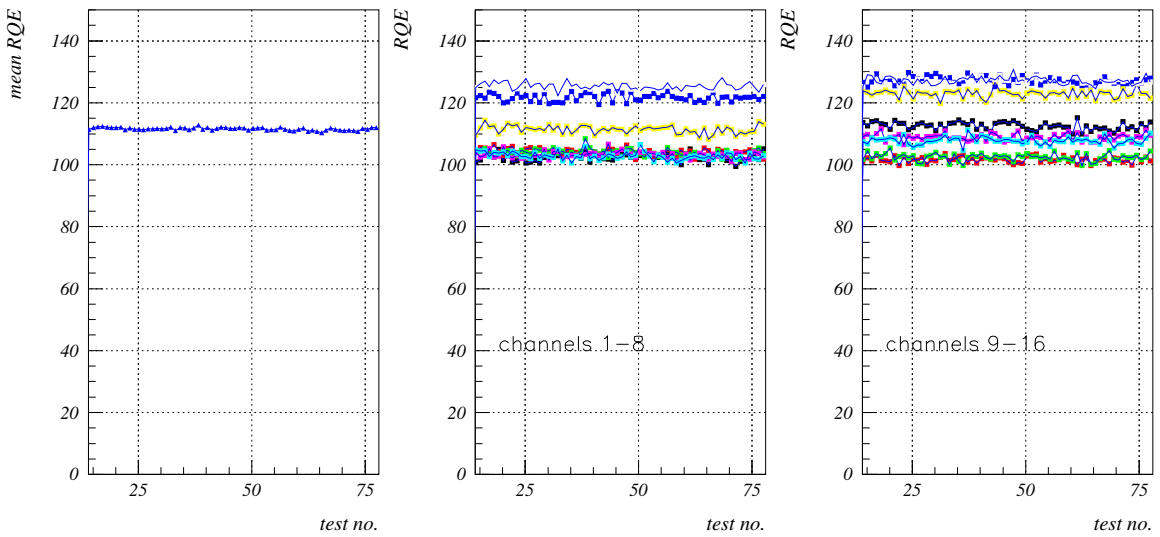

Figure 9: *Reference M16 PMT stability: mean rate per channel for the whole PMT (left) and rate for all the channels (right,middle) as function of test number. High voltage was set to 750 V, ASD8 threshold was at -1.2 V.*

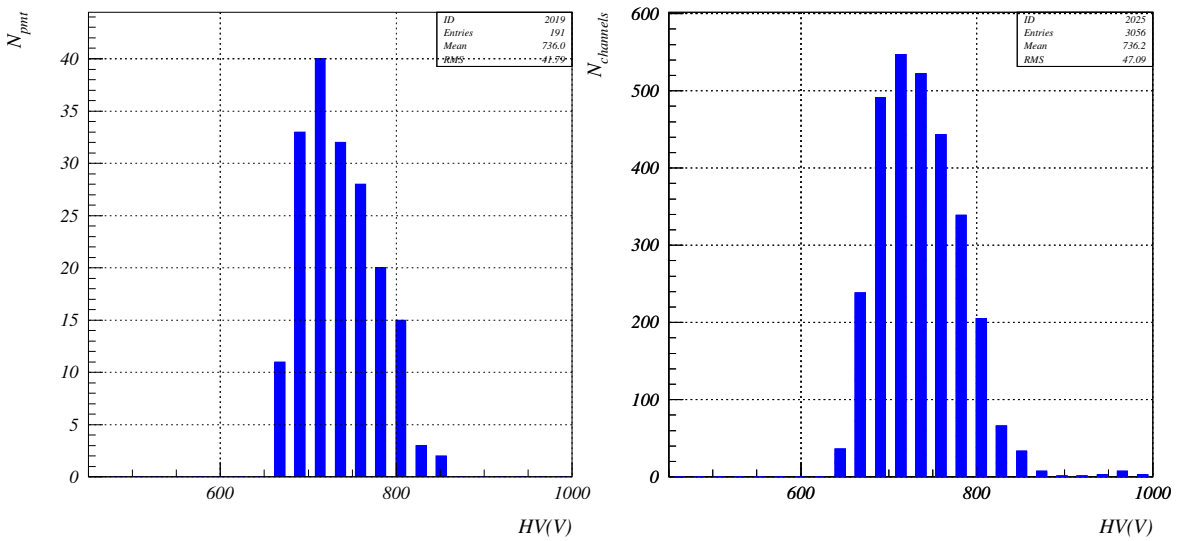

Figure 10: *Gain uniformity: Distribution of recommended voltages (voltages at which threshold level 500 Hz per channel is reached +100V): for the average over PMT (left) and for separate channels (right) for the M16 PMTs.*

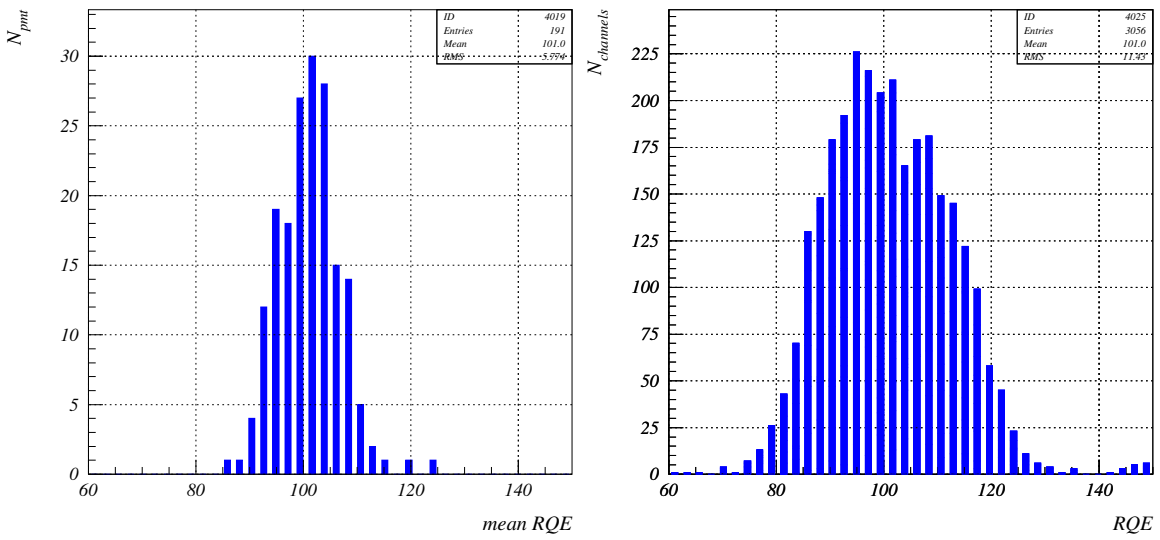

Figure 11: *Distribution of RQE for the M16 PMTs (left) and for all the channels (right) at recommended HV, ASD8 threshold was set to -1.2 V .*

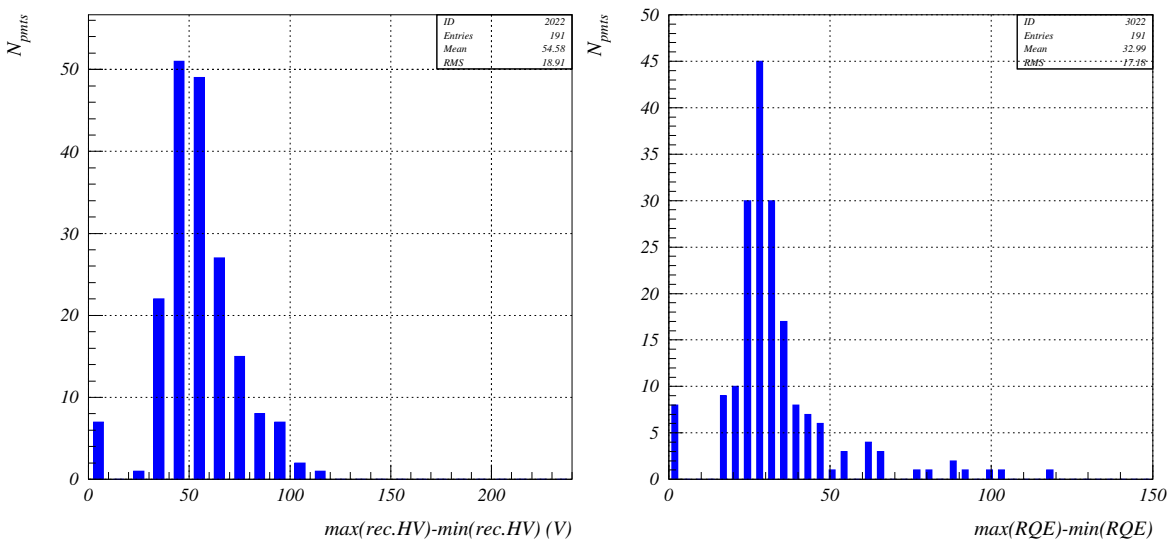

Figure 12: *Distribution of the maximum spread of the recommended HV and the RQE on the PMT for the M16 PMTs.*

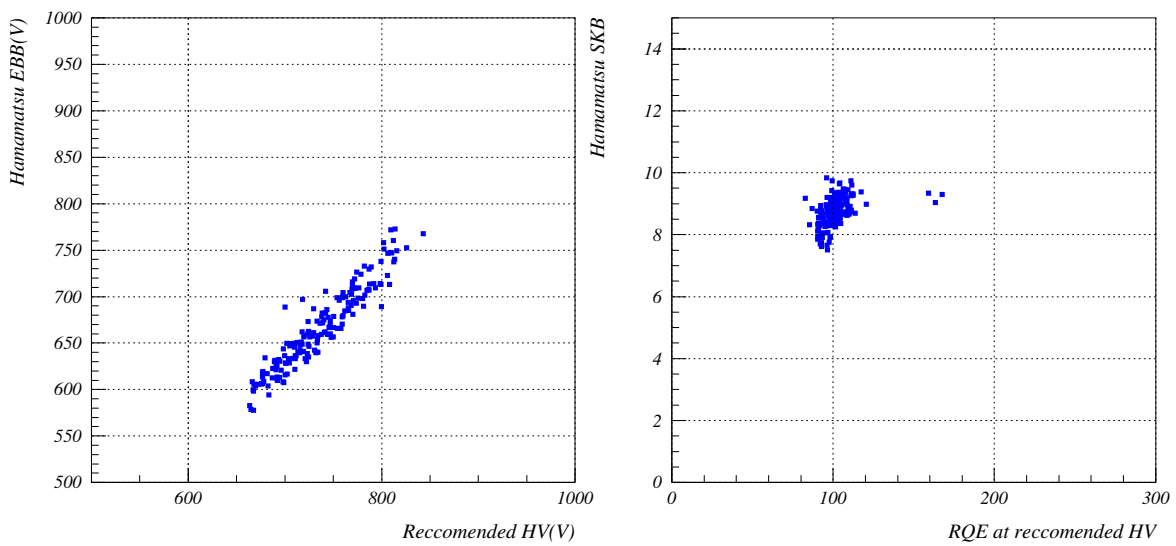

Figure 13: *Correlation between our recommended HV and HAMAMATSU EBB (voltage at gain* 3×10^5*) for the M16 PMTs. Note that the dead photomultipliers have RQE 0 and are not included in the correlation. We observed some of the PMTs have better characteristic than expected and they fall out of the main cluster (right figure).*

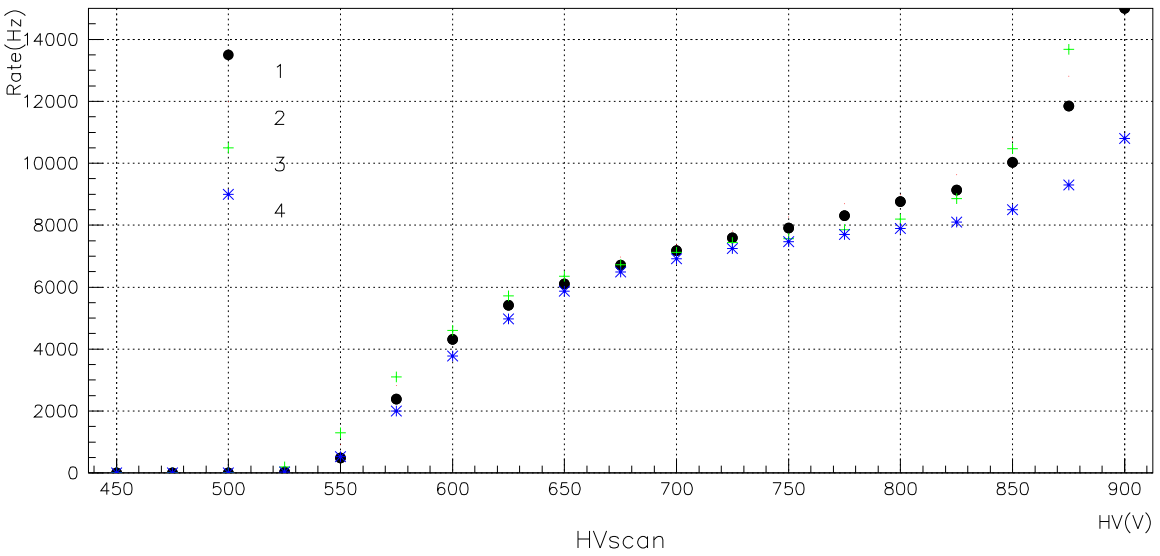

Figure 14: *High voltage scans for the reference M4 PMT.*

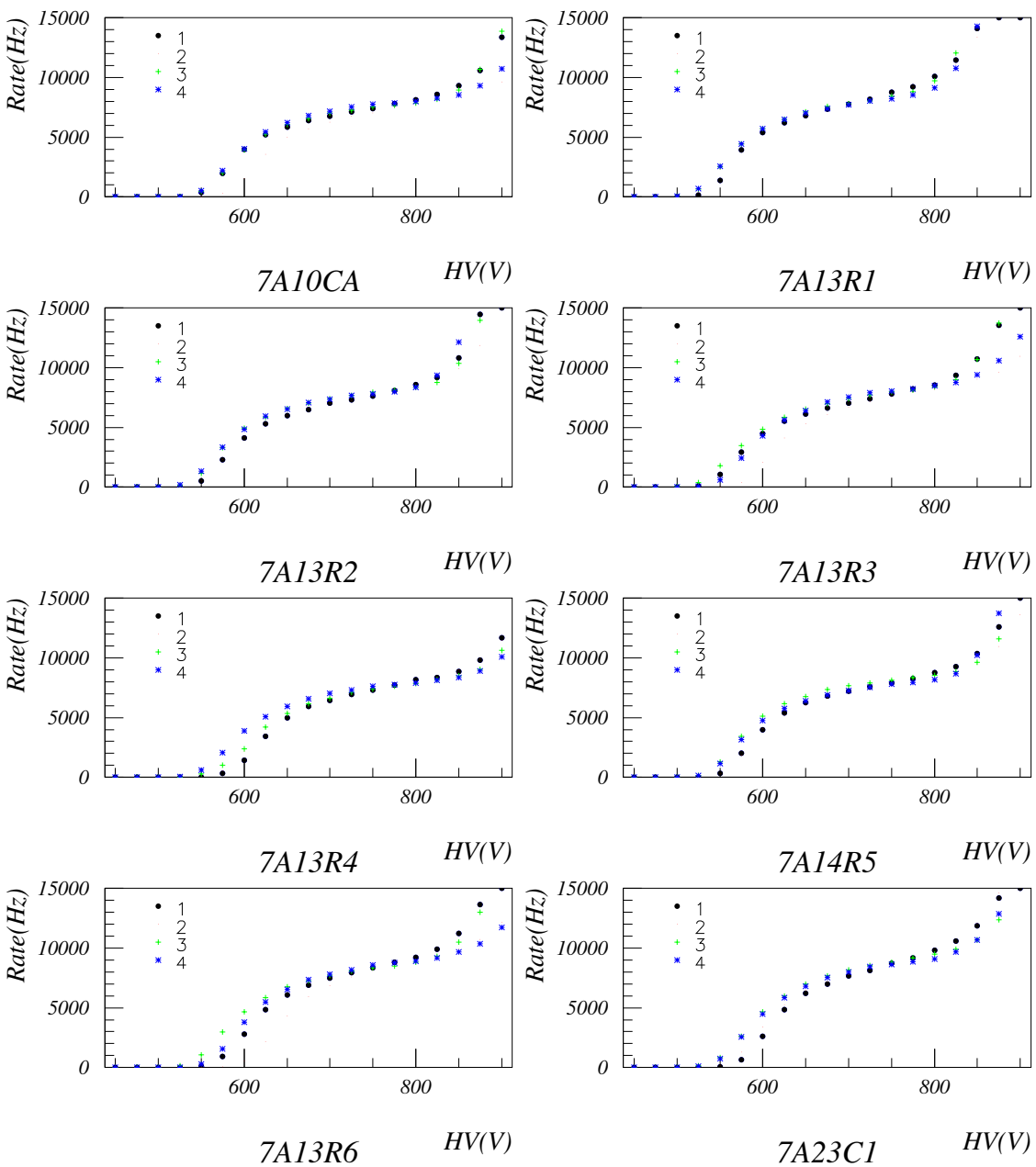

Figure 15: *High voltage scans for the PMT serial numbers: 7A10CA, 7A13R1, 7A13R2, 7A13R3, 7A13R4, 7A14R5, 7A13R6 and 7A23C1.*

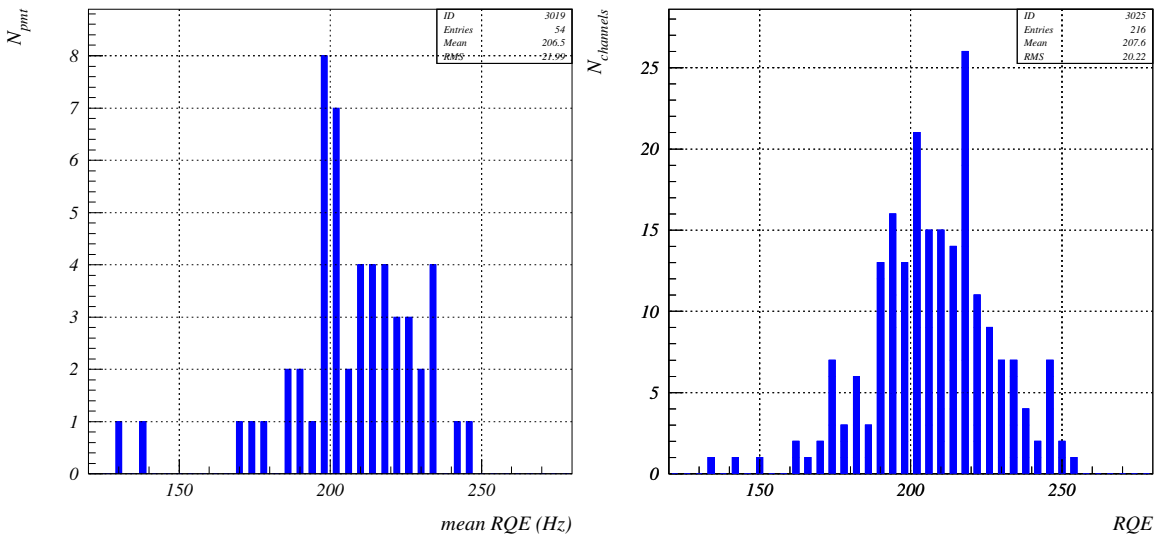

Figure 16: *Distribution of RQE for the M4 PMTs (left) and for all the channels (left) at 750 V, ASD8 threshold was set to -1.2 V .*

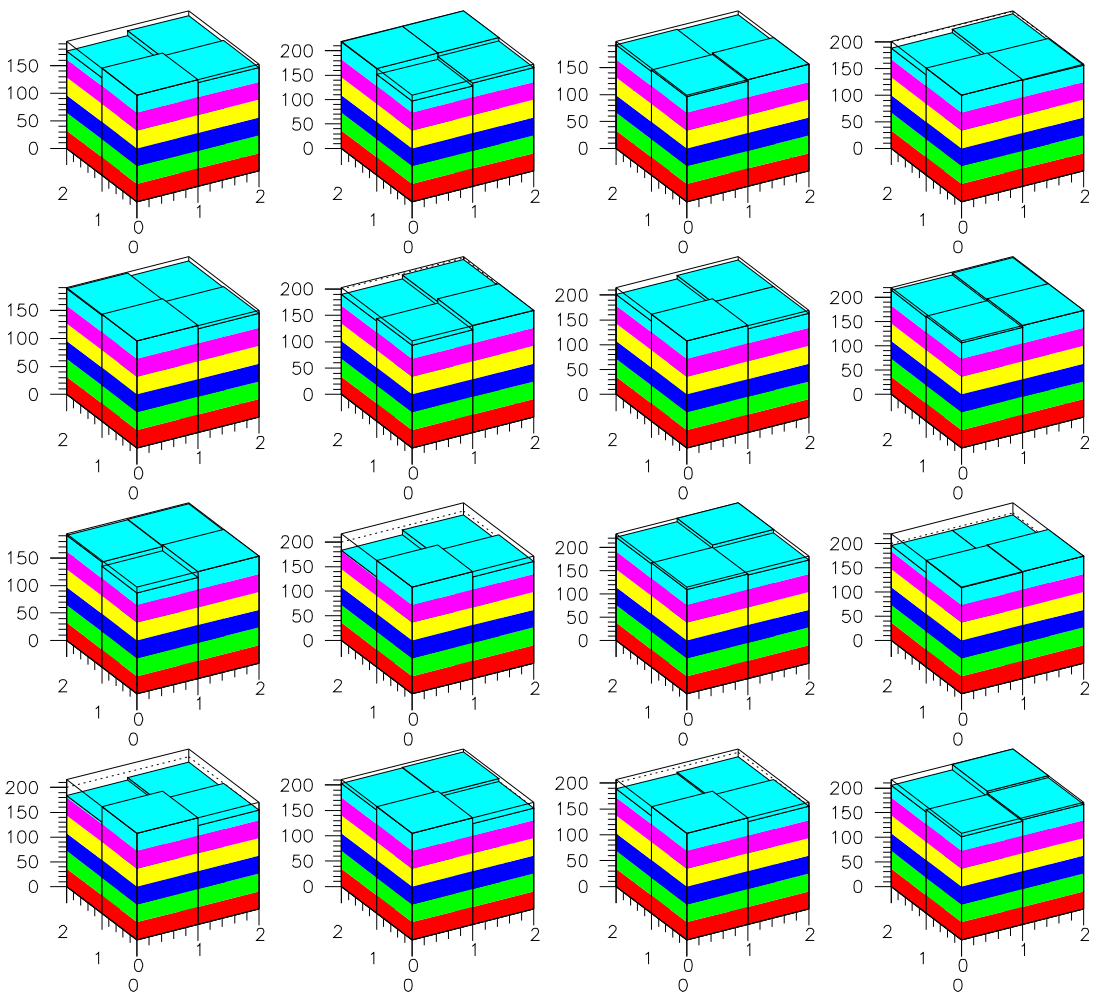

Figure 17: *RQE for several M4 PMTs at 750 V, ASD8 threshold was set to -1.2 V .*

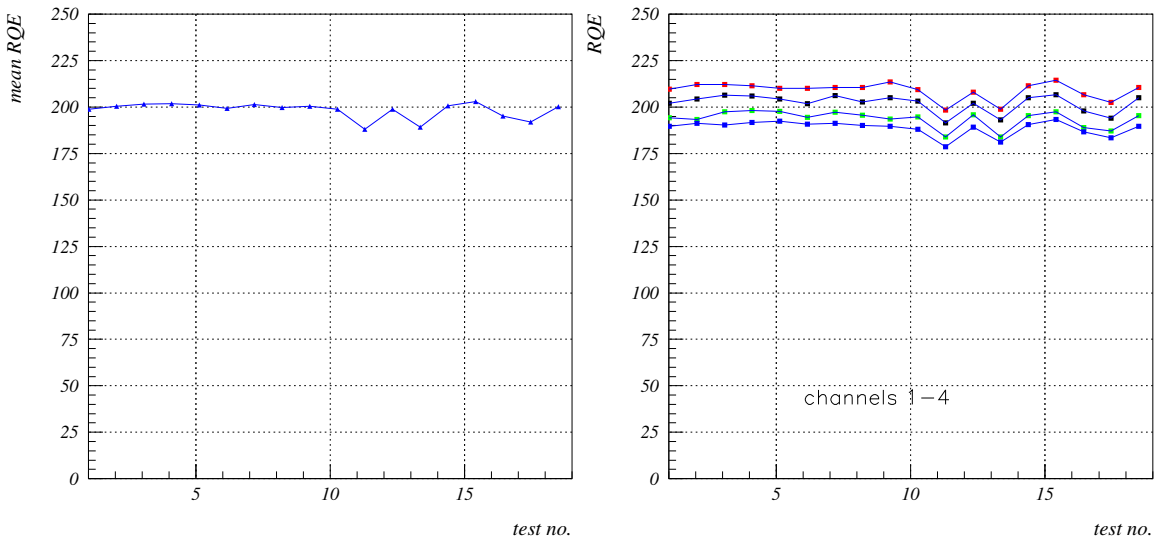

Figure 18: *Reference M4 PMT stability: mean rate per channel for the whole PMT (left) and rate for all the channels (right,middle) as function of test number. High voltage was set to 750 V, ASD8 threshold was at -1.2 V.*

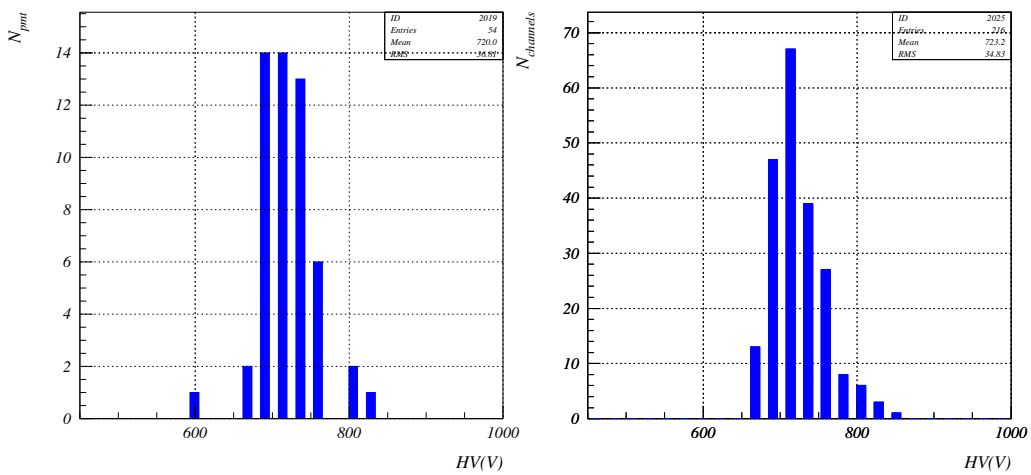

Figure 19: *Gain uniformity: Distribution of recommended voltages (voltages at which threshold level 5 kHz per channel is reached +100V): for the average over M4 PMT (left) and for separate channels (right).*

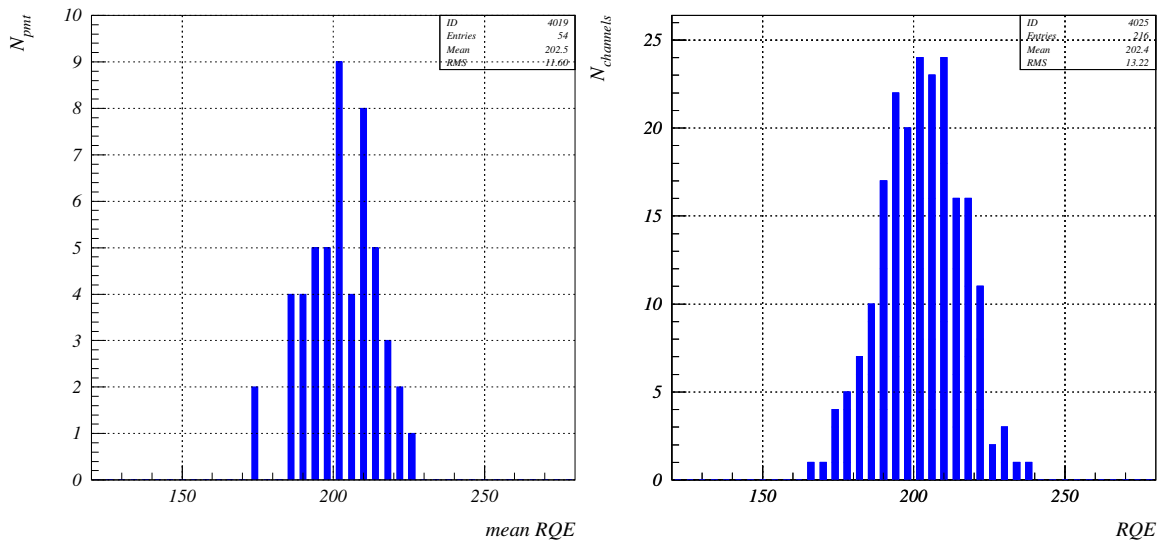

Figure 20: *Distribution of counts (RQE) for the M4 PMTs (left) and for all the channels (right) at recommended HV, ASD8 threshold was set to -1.2 V .*

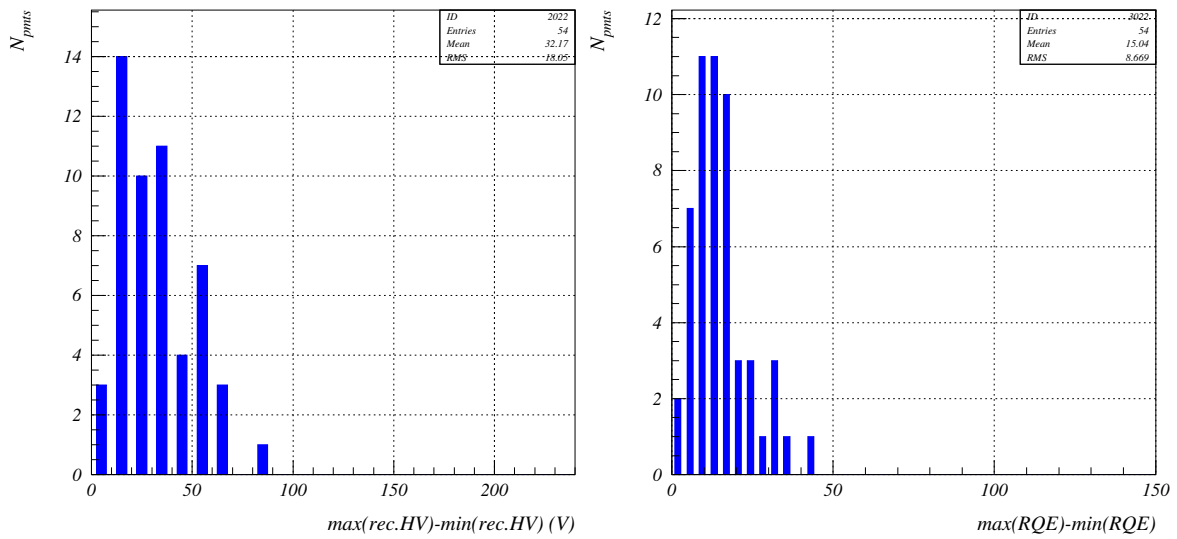

Figure 21: *Distribution of the maximum spread of the recommended HV and the RQE on the PMT for the M4 PMTs.*

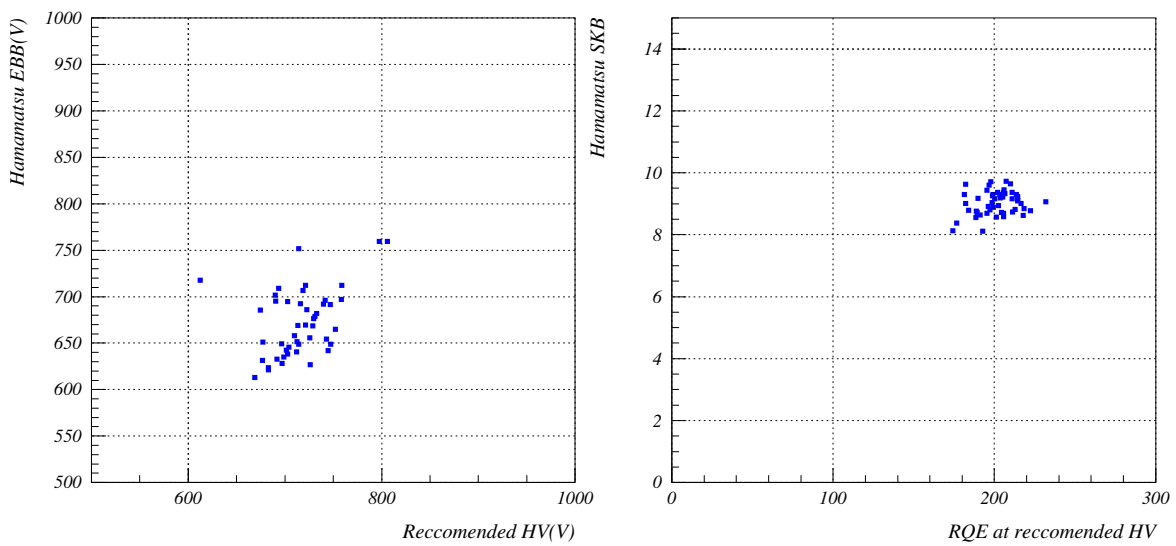

Figure 22: *Correlation between our recommended HV and HAMAMATSU EBB (voltage at gain* 3×10^5*) for the M4 PMTs. Note that the dead PMT is not included in the correlation.*

6 Conclusions

To summarize, we note that:

- the Q.A. set-up performed well
- the performance of the tubes was in agreement with required specs except for a few tubes which were most probably damaged during packaging or transportation.

A database has been set up that includes all we have learned about each tube, and will be further used for assigning to each tube the proper position on the photon detector.

References

[1] P. Križan et al., Test of a Multianode PMT for the HERA-B RICH, to be published in NIMA.

[2] P. Križan et al., ASD8 Chip Tests with a Hamamatsu Multi Anode Photomultiplier, IJS DP-7615.