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IJS Report
IJS - DP - 7615
January 1997

ASD8 Chip Tests with a Hamamatsu Multi-anode PMT

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Abstract

A series of tests was carried out to understand the performance of the outer tracker ASD8 board if coupled to a Hamamatsu multi-anode PMT of the photon detector in the RICH counter of the HERA-B experiment. In addition, some ideas are presented on how to the final mechanical design of the read-out electronics could look like.

1 Apparatus

Both a sixteen (No. 6E23D7) and the four channel (No. 6C27D3) Hamamatsu MA PMTs were mounted in the same apparatus that was used for the light guide tests. On one side of a 500 mm long aluminium tube (painted black) a 1 cm thick quartz window was mounted and used as Čerenkov radiator medium. A strong (1 mCi) Sr beta source provided electrons which, in turn, radiated Čerenkov light in the quartz window [1]. The other side of the tube was closed by a printed board (again painted black) with the PMT socket, base resistor chain and ASD8 board connections.

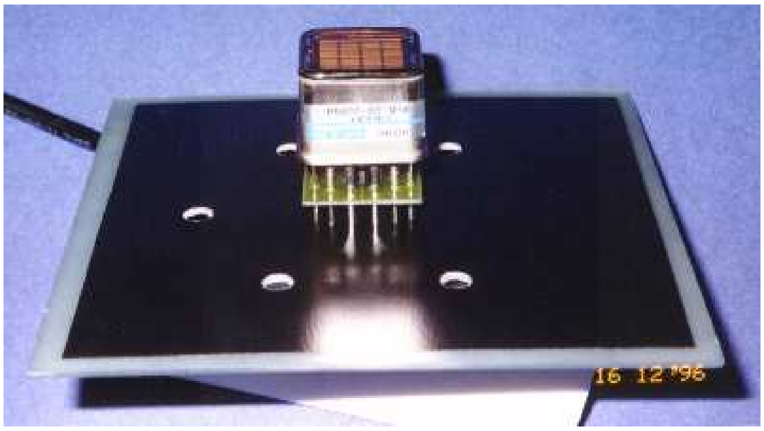

Figure 1: *The PMT and the PMT socket plug in on one side of the board.*

While the PMT socked was on the inner side of the tube (Fig. 1), the resistor chain and the contact pins to the ASD8 board were on the other side (Fig. 3). The bleeder resistor chain was set up in a very much similar way as the mounting presented by S. Korpar at the RICH Week. Such a mounting allowed for an easy exchange of resistors and capacitors in the optimisation studies of the bleeder ratio. The ASD8 board was coupled to the base board using a special interface board (Figs. 5, 6) with a signal splitter.

It is worth mentioning that extensive care was taken of the grounding. A thick copper grounding wire had to be wrapped around the whole system and attached to the low voltage power supply before the noise level became acceptable. In addition, the aluminium tube had to be connected by means of a thick copper wire to the electronics rack, which also housed a HV power supply. As a result, the ASD8 chip could be run with threshold voltage of -200 mV. During the tests it turned out, however, that the ASD8 chip could

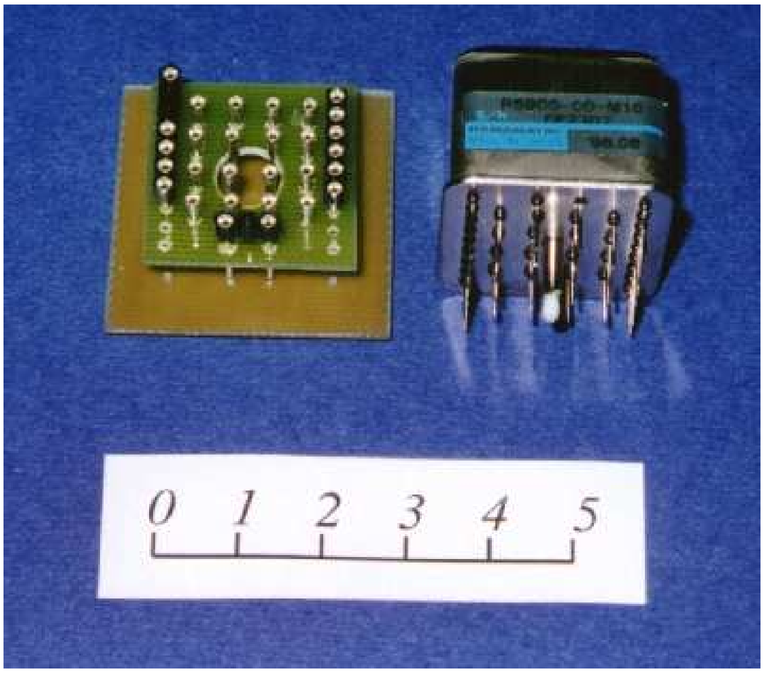

Figure 2: *The M16 socket.*

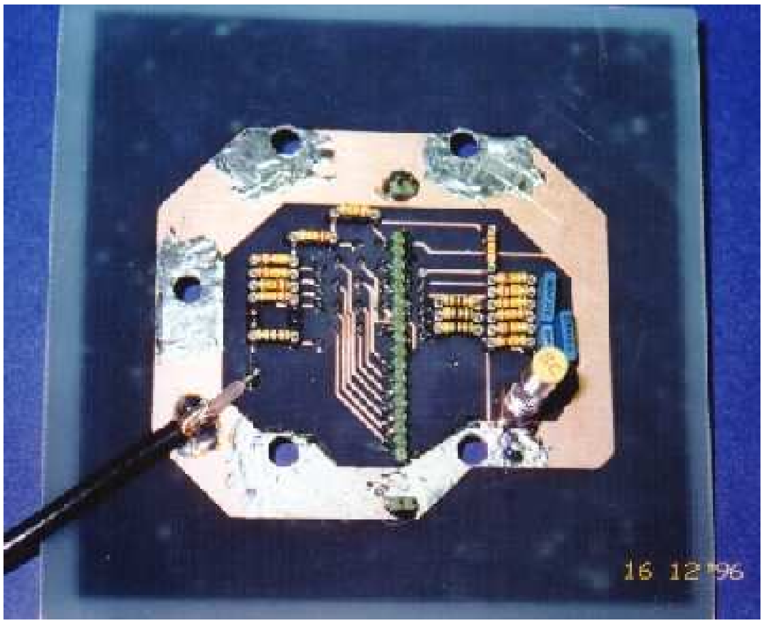

Figure 3: *The bleeder chain with easily exchangeable resistors and capacitors.*

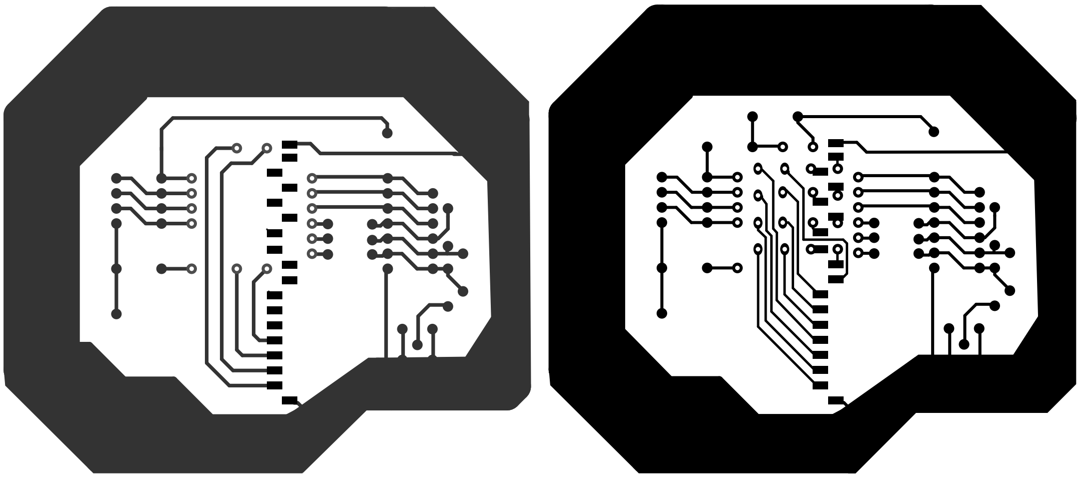

Figure 4: *Layout of the test base board: M4 design (left) , M16 design (right). Some signal lines are longer on purpose to study the cross-talk between the channels.*

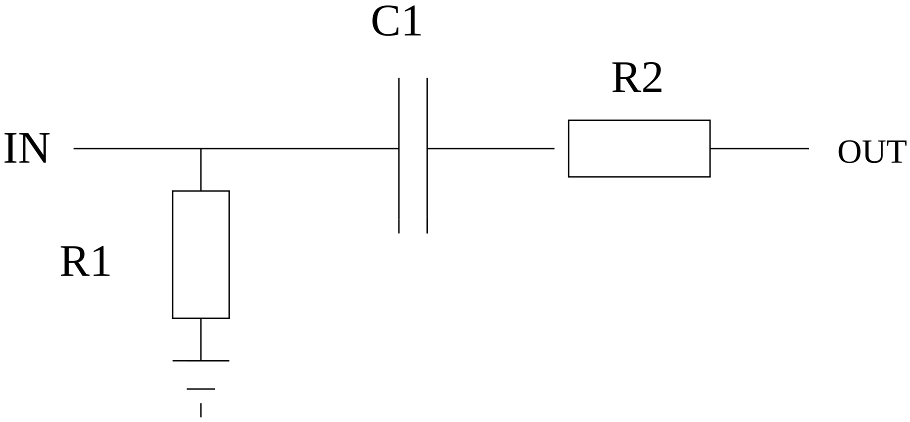

Figure 5: *The interface board between the base board and the ASD8 board. We have studied the response of the PMT for various values of R1 (50 Ω , 100 Ω, 200 Ω), while keeping R2=1 kΩ and C1= 10 nF.*

be run with no loss of efficiency even if the threshold was set to values around -1 V, a typical value used in the presented measurements.

In the first set of measurements, the four channel PMT was read-out in the following way. The ASD8 board (serial number SN96070242, with one dead channel - 13) was plugged in directly onto the printed board with PMT base and socket. The four PMT channel were fed into the channels 10, 11, 14 and 15 of the ASD8 board. The analog output (the amplified channel 15) from the ASD8 chip was led to an EGG Ortec 574 timing amplifier, where it was amplified twice and then led to a PS774 analog fan-in/fan-out unit, which provided the signal and its inverse with an adjustable pedestal. Both signals were then led to a CAMAC ADC unit (EGG Ortec AD811). The pedestal was, in turn, adjusted in such a way that the signals fitted well into the linear regime of the ADC.

While the positive digital outputs of those four ASD8 board channels, that were connected to the photomultiplier, were terminated by a 50 Ω resistor, the negative digital outputs were fed into a leading edge discriminator CF8000 which then provided NIM signals. These signals were then led to a CAMAC TDC unit (Silena ADC4418/T) where the time of arrival was digitized. The same signals were also fed into a coincidence unit LF4000 which provided a trigger decision. The trigger was provided by the channel 15 of the ASD8 board, i.e. the same channel that was monitored by the analog output of the chip.

The data were collected by a data acquisition program which runs on an HP RT VME controller and is very similar to the program used in the test beam measurements at DESY. The output, an ntuple with six variables, analog signal, inverted analog signal and four digital signal arrival times, was offline analyzed in PAW.

For the measurements using M16 PMT, a somewhat different measurement scheme was used. A socket was constructed which holds the PMT 17 mm above the base board and allows an easy plug in (Figs. 3, 2). In this case, another ASD8 board was used (serial number SN96081101, one of the channels (nr. 9) with a high offset).

The digital signals from ASD8 chips were converted to the ECL level using the LeCroy MVL407 comparator (Fig. 7). The ECL signals were then split in the ECL-NIM converter EGG-ESN EC 1600. The ECL signals were counted in the 16 channel CAMAC scaler CAEN C257. The NIM signals were plugged in the EGG-ESN LF400 unit to form OR of all the signals. The OR signal and OR signal of width of up to 1 μs were counted by a CAMAC BORER quad scaler.

The data were recorded by a Lab Windows data acquisition program which runs on PC and controls the applied high voltage (on CAEN N470 programmable HV supply via the CAENET) and the ASD8 threshold level. The output, ASCII files with 18 variables (16 PMT channels, OR and extended OR) versus high voltage or ASD8 threshold were again analyzed in PAW.

2 Cross talk

2.1 Cross talk measurements with M4

By varying the high voltage of the PMT a series of pulse height spectra was recorded (Fig. 8) of the analog signals. The origin of the peak at small pulse heights was investigated by studying the correlations of pulse heights and times of arrival of the digital signals (Fig. 9). We attribute the left peak at smaller arrival times to the case where the original signal appeared on the neighbouring channel, and the signal of the trigger channel is a consequence of cross-talk (Fig. 8).

To further study the nature of these cross-talk signals, we have plotted the measured rate as a function of high voltage. Both the raw measured rate and the rate after having applied the time-of-arrival cuts are shown in Fig. 10.

To check whether the cross-talk originates from the cross talk between the channels in the chip itself, we have performed a separate measurement in which only one of the neighbouring channels was fed by signals from PMT, and two remaining neighbours had no signal input. At the output of the latter two channels there was practically no signal rate. From the time evolution and polarity of the signal we conclude that most of the cross-talk is caused by the coupling between the last dinode and the anodes.

2.2 Cross talk measurements with M16

The measurement of cross talk in the M16 case showed that there is much less cross talk between the channels than in the four anode PMT, and was in good agreement with the results obtained in spring last year [1]. The difference can be understood if we assume that the cross talk originates from the capacitive coupling between the last dinode and the anodes, which are four times smaller in the M16 case. This type of cross talk was further reduced by using the capacitor in the stage of the voltage divider. Once this type of cross talk with opposite polarity is reduced, another cross talk, pulses of same polarity, becomes noticeable, most probably due to the cross talk between the signal lines.

3 Setting the threshold voltage

By using a CAMAC DAC, a threshold voltage scan was made, and the output rate recorded. Very little variation of rate can be seen below 1.6 V (Fig. 11). The high voltage applied to the M16 PMT was 800 V.

4 Signal splitting

To test the influence of reduced signal height upon the system performance, we have added between the base board and the ASD8 board an interface board with a signal splitter (Fig. 5), as discussed in the first section of this report. The high voltage scan was made for three different values of the resistor R1, as well as without using the interface board (Fig. 12). Within a few percent the saturated rate does not depend on whether the signal was split or not. The plateau, however, is somewhat wider if this interface board is used, partly due to filtering and partly due to a reduction of the PMT based cross talk.

To show the channel to channel uniformity, we also plot the high voltage scan for each individual channel (Fig. 16).

5 High rate operation

For both multipliers M4 and M16 no influence of high rate operation on the pulse height spectra could be observed up to 10 MHz per channel. At this rate we observed a baseline shift of 10mV, which is one half of the pulse height, caused rather by ASD8 board than by the PMT itself. In a high voltage scan, the count rate plateau is reached at roughly the same high voltage as in the low rate tests (Fig. 14).

To check what is the lowest acceptable base current, high voltage scans were made by using a uniform bleeder chain with resistors values of 430 kΩ, 1 MΩ and 4.7 MΩ. As expected, the base with highest current performs somewhat better than the other two (Fig. 15).

6 Optimisation of the bleeder chain

In the following step we have tried to optimize the bleeder chain for M16. The base was built of 1 MΩ and 560 kΩ resistors. Their saturation rates show no significant deviations (Fig. 16) and are within few percent equal. There might be a slight preference for a 2:2:2:1:....:1 chain.

7 Ideas for the final design

While working on the test set-up, we got some ideas on how the final version of the read-out electronics/base board could look like, in particular the mechanics parts. Some of the ideas are presented below. Note that for most of them autocad drawings exist, but are still in a very rough stage, and are being worked on. Comments are welcome.

7.1 Board and cable connection

We have made a preliminary PMT module design using AutoCad (Fig. 18). The PMT modul consists of a base board (72 mm$\times$72mm) for four PMTs to which four ASD8 boards are plugged in. The modul is covered by metallic plate of the same planar dimensions as base board. The holes on the plate allows connecting cables to easily plug in the ASD8 board outputs. Three separate “vertically” oriented lines collect cables from the super-module (Fig. 19). To leave space between the lines, the cables are collected in two levels. The signal cables are led to the both upper and the lower side of the super-module, from where they are led to the electronics racks at the left and right side of the photon detector. In this scheme the distance between the collecting line and modules is about 20 cm, and allows individual testing and access to the modules. For a better access we have also foreseen that the lines are movable to the left and to the right (Fig. 19) like windows.

7.2 Base design

The base optimisation tests carried out so far suggest that the bases can be used with only one (or even none) capacitor for the M16 case, and two (or even only one) capacitor for the M4 PMT (Fig. 17). At the moment we are considering a bleeder chain built of three 1 MΩ resitors (first stages) and 10 560 kΩ resitors.

If the ASD8 board is only slightly modified (signal lines in one input row, in two groups of eight lines), one could use a two-layer board with elements on one side only (Fig. 20).

7.3 ASD8 Board Modifications

From the measurements we have performed, it is clear that the ASD8 chip serves excellently the purpose. The OTR ASD8 board we have used, needs some rather simple modifications, part of which are similar to the ones taken into account in the latest upgrade:

1. The filter and signal splitter (Fig. 5), now housed on the interface board, have to become part of the board.
2. The input signals lines have to be aligned in a single row.
3. In order to simplify the base board (see above), the input signal lines should be grouped in two groups of eight.
4. The analog (test point) output of one of the channels has to have a normal pin connector, which nicely fits in the output connector row. The output will serve only as diagnostics tool, and will not be read out.

Points 1 to 3 need a next, rather trivial iteration, similar to the latest upgrade. Point 4 simply requires a connector line longer by a pin pair, and a slight modification of output lines.

7.4 PMT Test Set Up

The test set up is under construction. The test module is designed in such a way that can easily plug in the detector panel of the test beam T24 in DESY as well as in the test light source in the Ljubljana laboratory (Fig. 21). The black painted module support consists of holes for 9 modules of the proposed design (Figs. 18, 20). The material for the 10 mm thick support is transformer steel with high μ to shield PMTs against magnetic fields.

The module (Figs. 18) is under construction as well, and it is expected that a few (maybe 4) of these will be ready for the test beam measurements in February.

References

[1] P. Križan et al., Test of a Multianode PMT for the HERA-B RICH, submitted to NIM A.

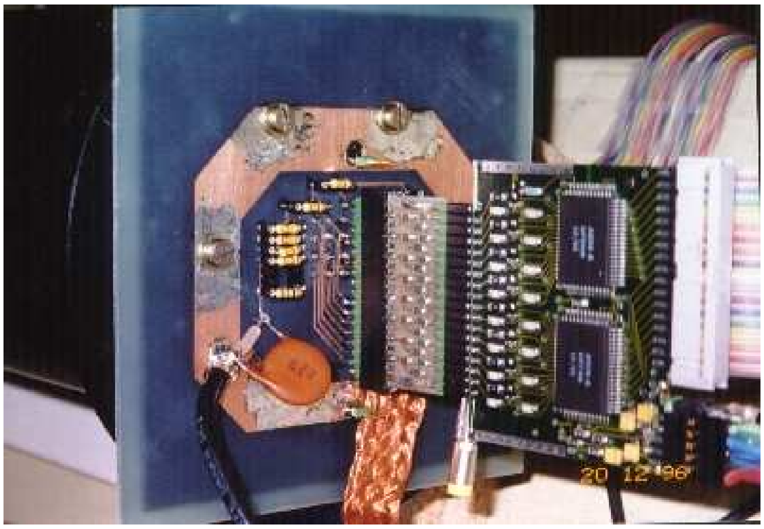

Figure 6: *The ASD8 board as coupled to the base board via the interface board (Fig. 5).*

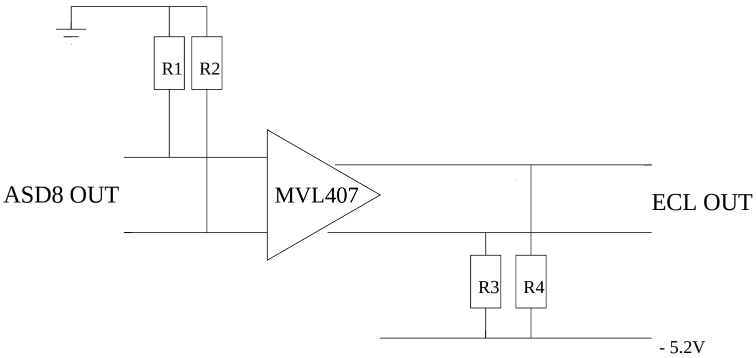

Figure 7: *ASD8 logical output signal to ECL converter (R1=R2=50Ω,R3=R4=500Ω).*

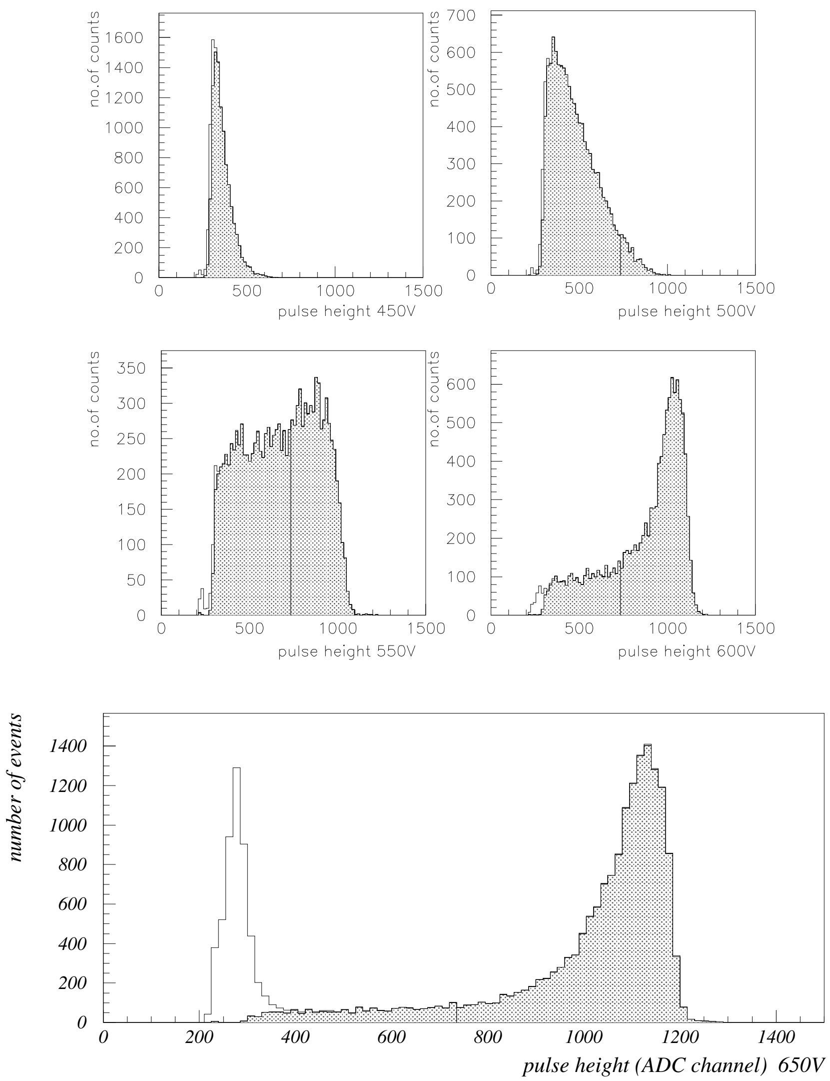

Figure 8: M4: Pulse height spectra of the analog output for high voltages of 450 V, 500 V, 550 V and 600 V in the case of a uniform resistor chain (upper four figures), and at the high voltage of 650 V for a resistor chain 1.95:1.95:1.95: :1.95:1:1:1 (bellow). Also shown are the pulse height distributions after the time of arrival cuts were applied (hatched).

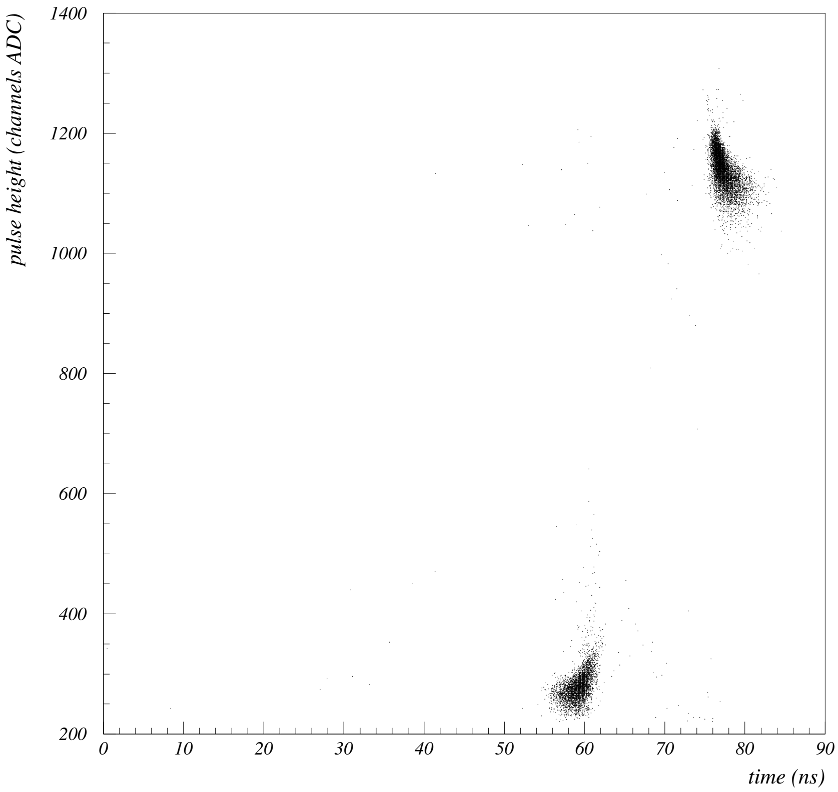

Figure 9: Scattered plot of the observed pulse height versus time of arrival for the M4 PMT. Events coming earlier than the trigger pulse can easily be distinguished from the others.

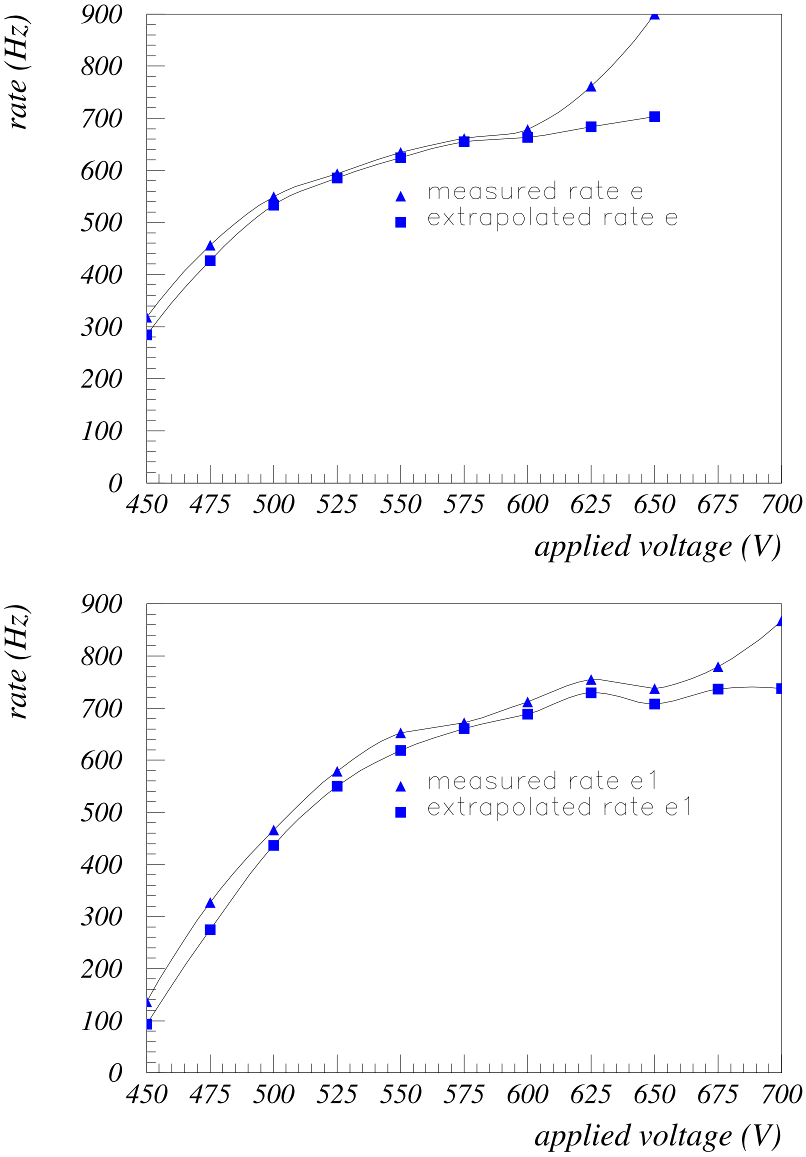

Figure 10: *Rate of the observed channel before (triangles) and after (squares) the cuts were applied for two resistor chains: 1:1:1: :1 (above) and 1.95:1.95:1.95:1.95:1.95: :1:1:1 (bellow)*

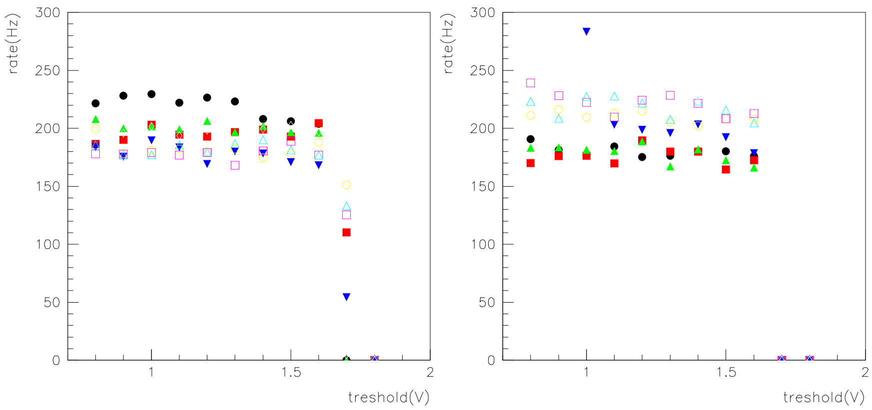

Figure 11: *Threshold voltage scan at a high voltage of 800 V for the sixteen channels of the M16. Inverted triangles: the channel with a high offset.*

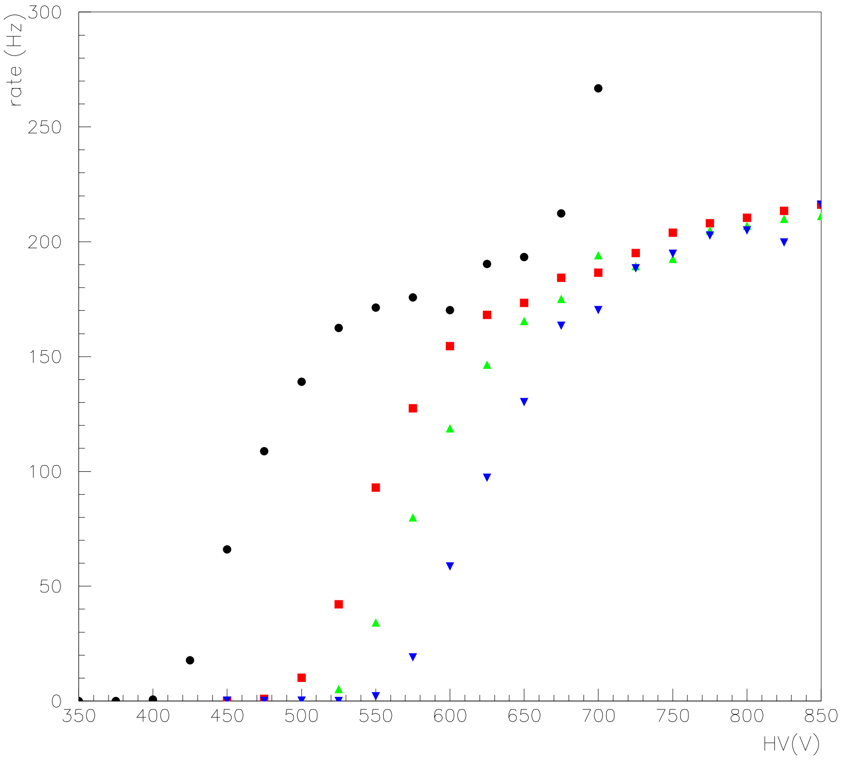

Figure 12: Influence of signal splitting in the case of M16: R1=50 Ω (inverted triangles), 100 Ω (triangles), 200 Ω (squares), no splitting (circles).

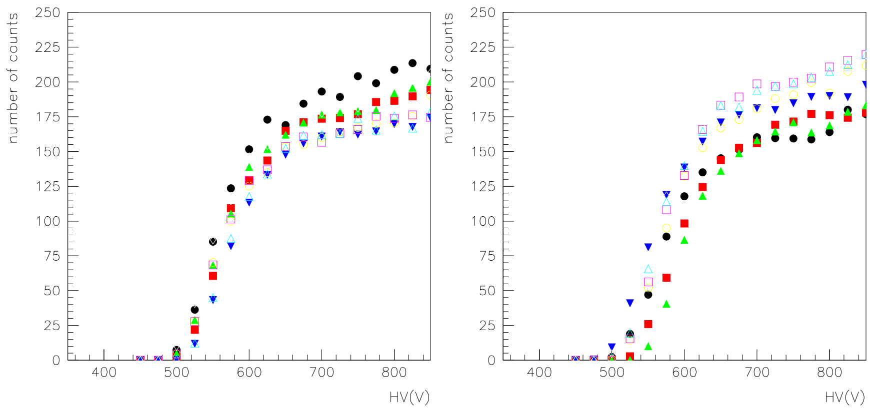

Figure 13: M16: Channel-to-channel uniformity for the interface resistor R1=200 Ω.

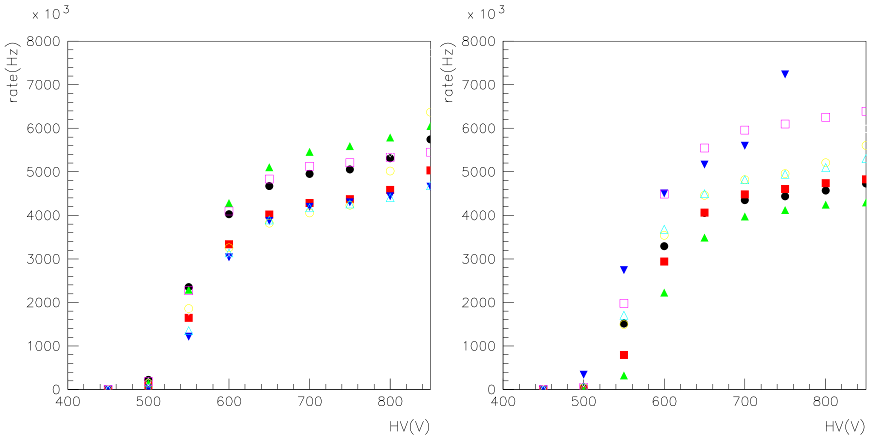

Figure 14: *High rate operation: high voltage scan for all sixteen channels of M16. Inverted triangles: the channel with a high offset.*

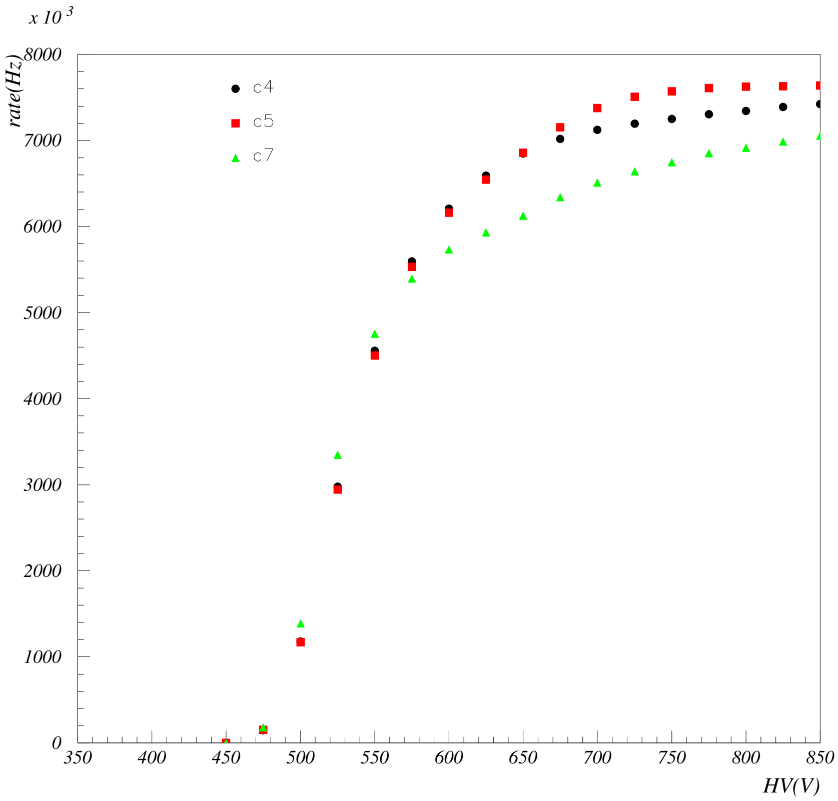

Figure 15: *Influence of the bleeder resistor value on the high rate performance: high voltage scan for one of the channels of the M16 PMT with a uniform base built of 560 kΩ resistors (c5), 1 MΩ (c4) and 4.7 MΩ (c7), without a capacitor. The interface resistor was R1=500 Ω.*

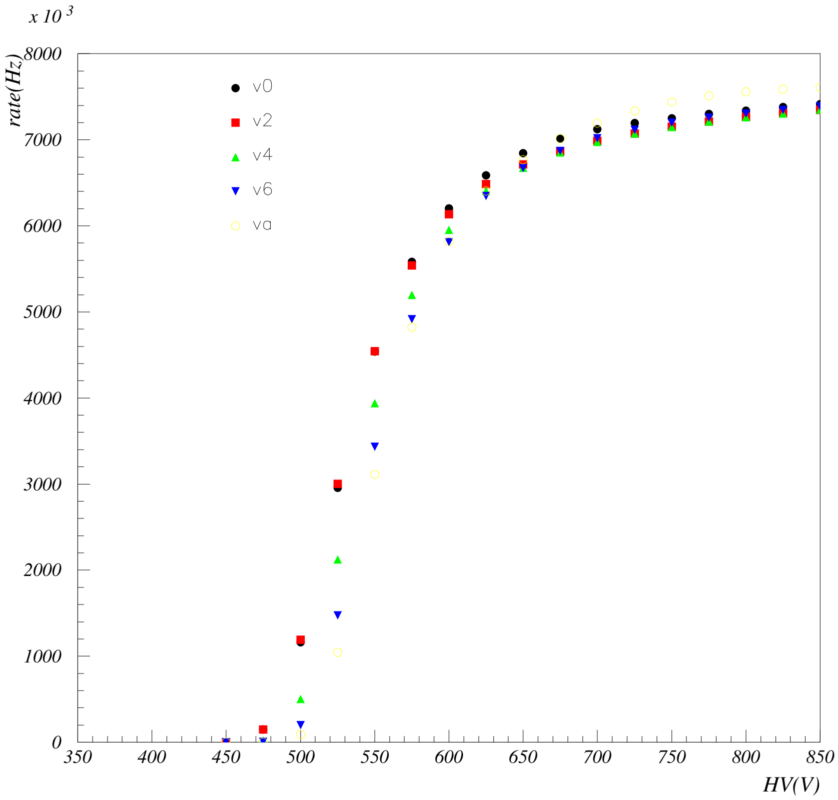

Figure 16: *Influence of bleeder composition on the high rate performance: high voltage scan for one of the channels of the M16 PMT with a base built of 13 1 MΩ resistors (v0), 11 1 MΩ and 2 560 kΩ resistors (v2), 9 1 MΩ and 4 560 kΩ resistors (v4), 7 1 MΩ and 6 560 kΩ resistors (v6), 5 1 MΩ and 8 560 kΩ resistors (v8), 3 1 MΩ and 10 560 kΩ resistors (va). A capacitor of 10 nF was used in in the last stage. The interface resistor was R1=500 Ω.*

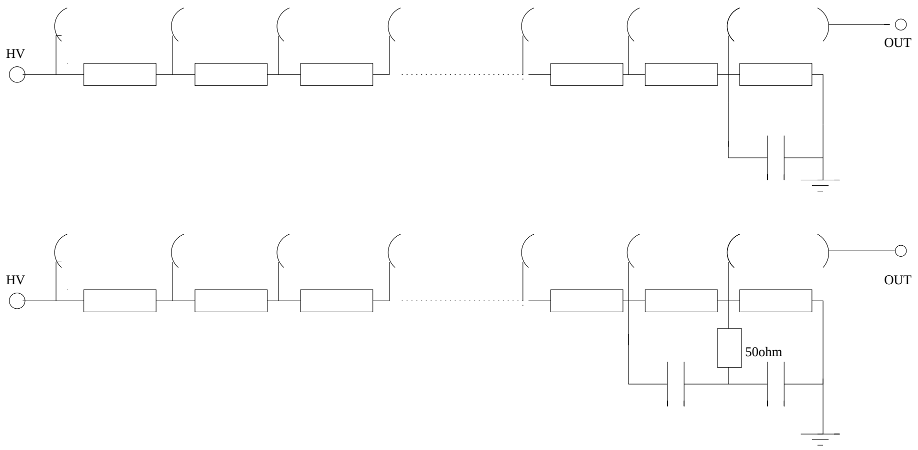

Figure 17: Proposed resistor chain for the M16 (above) PMT and M4.

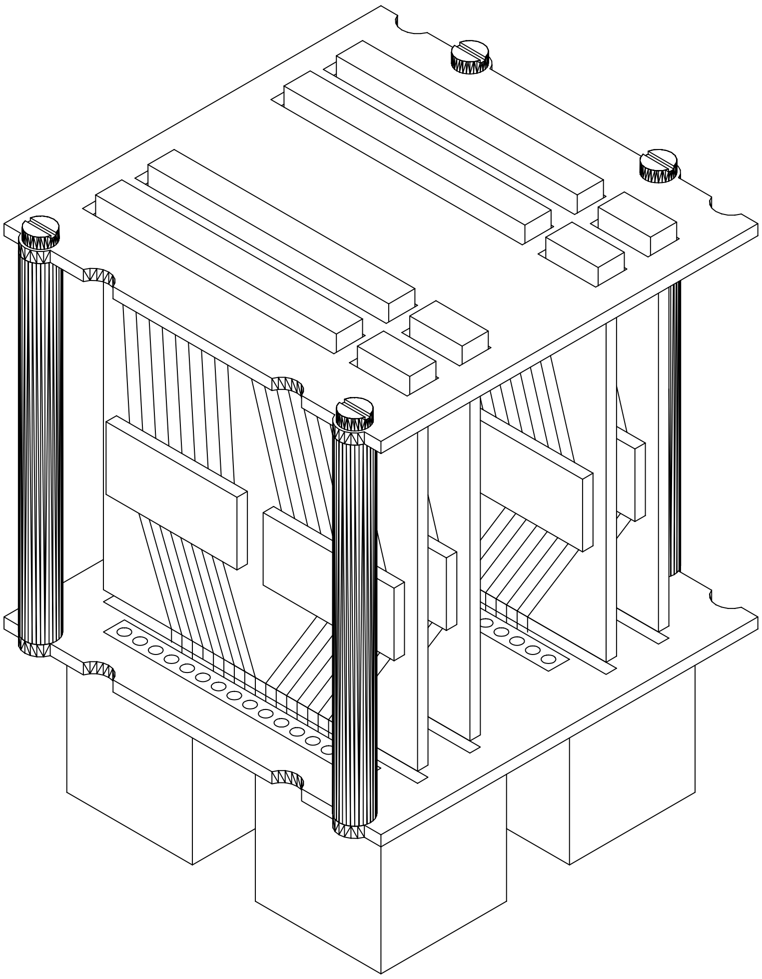

Figure 18: *Layout of the PMT module.*

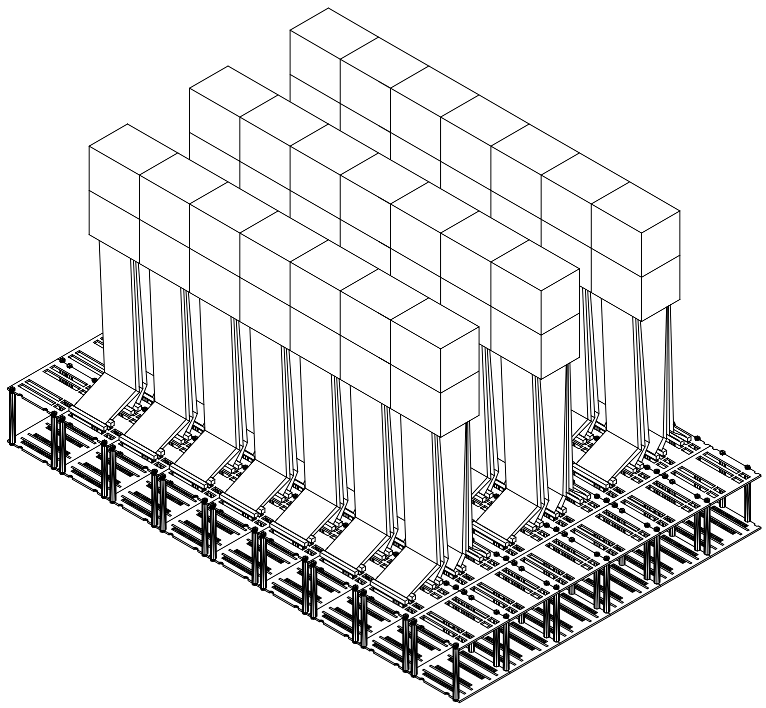

Figure 19: *Schematic layout of a part of the super-module and the cable lines (above) and the rear view showing two level wiring.*

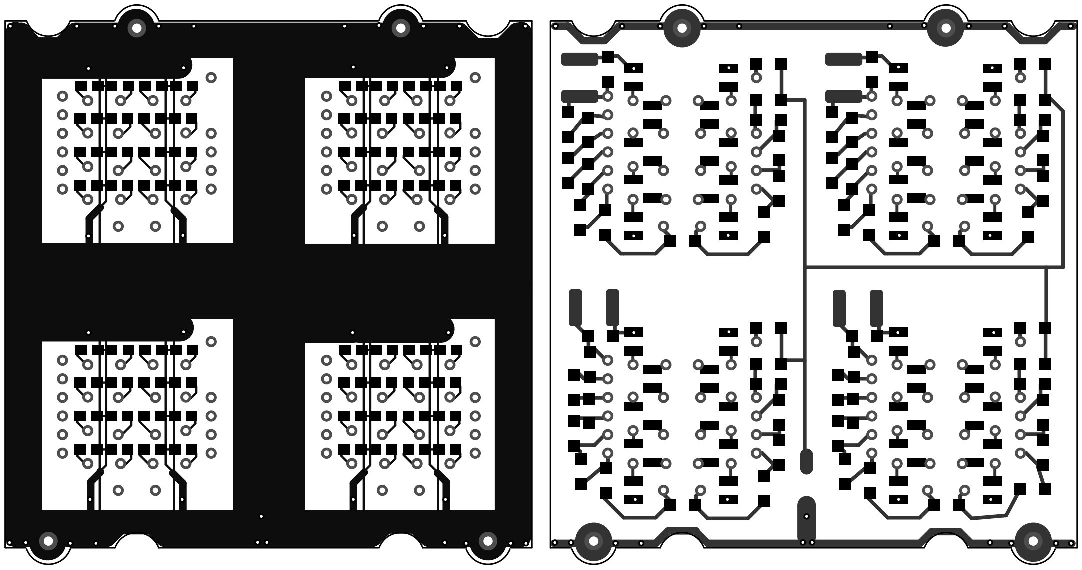

Figure 20: *Layout of the proposed base board: inner (PMT) side (left), outer (read out) side (right).*

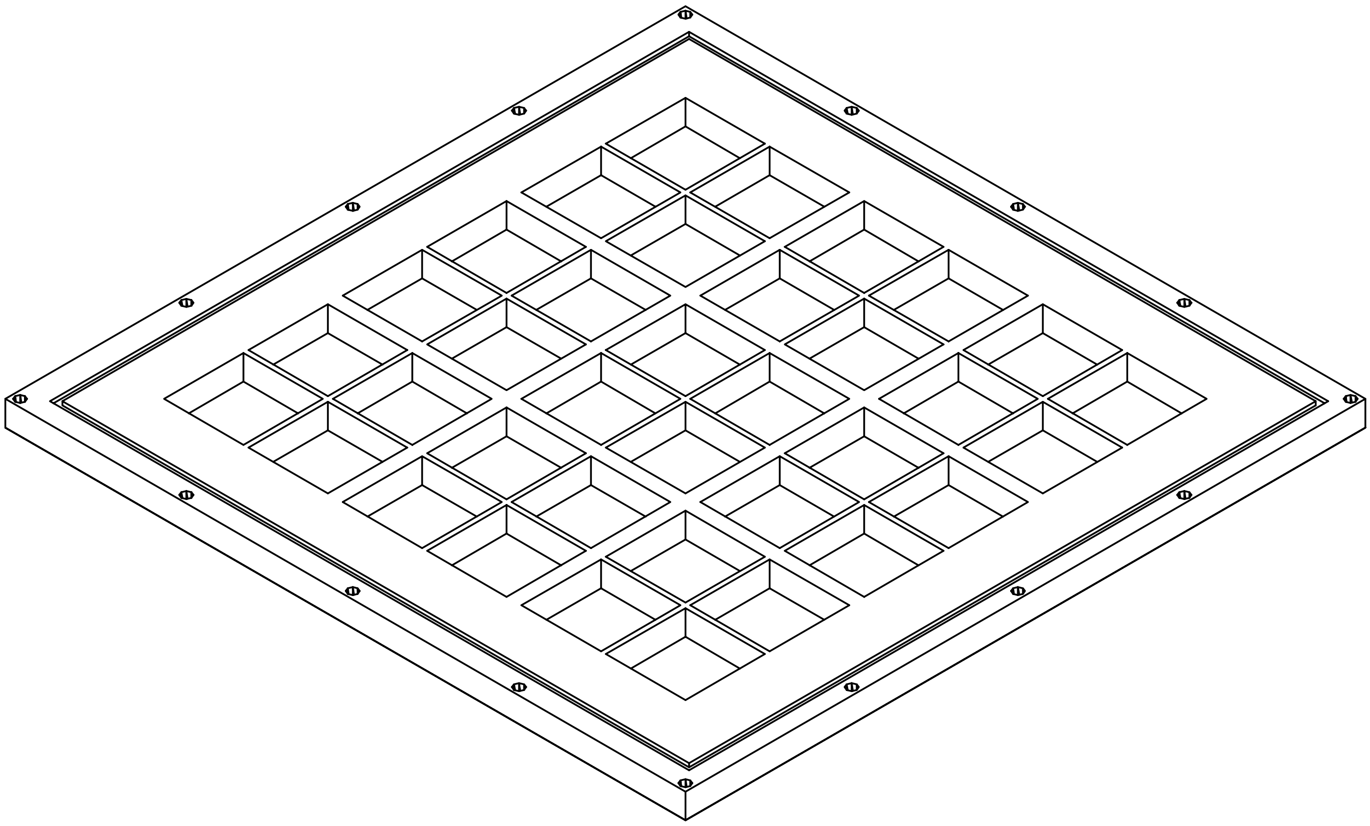

Figure 21: *The PMT test module support to fit on the test beam vessel.*