Characterization of the Hamamatsu R11265 multi-anode photomultiplier tube with single photon signals

L. Cadamuro[b], M. Calvi[a,b], A. Giachero[a,b], C. Gotti[a,c,*], M. Maino[a,b], C. Matteuzzi[a,b], G. Pessina[a,b]

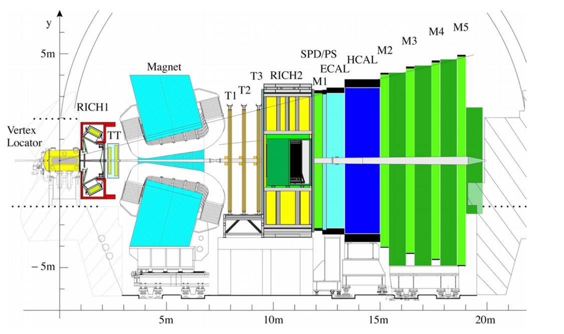
a - INFN, sezione di Milano Bicocca, I-20126 Milano, Italy
b - Dip. di Fisica, Università di Milano Bicocca, I-20126 Milano, Italy
c - Dip. di Elettronica e Telecomunicazioni, Università di Firenze, I-50125 Firenze, Italy
* E-Mail: claudio.gotti@mib.infn.it

The LHCb RICH upgrade

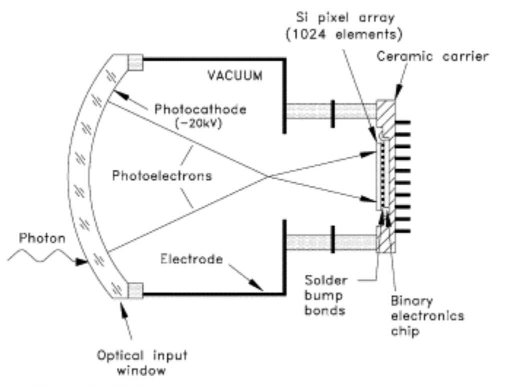
LHCb is an experiment devoted to the study of B physics in proton-proton collisions at the Large Hadron Collider (LHC) at CERN.
Two RICH detectors provide particle identification through the measurement of the Cherenkov angle of photons produced by the particles in the RICH radiators.

The Cherenkov photons are currently detected by hybrid photodetectors (HPDs) coupled to a readout chip integrated in the vacuum envelope of the tube.
The readout speed is limited to 1 MHz by the readout chip.

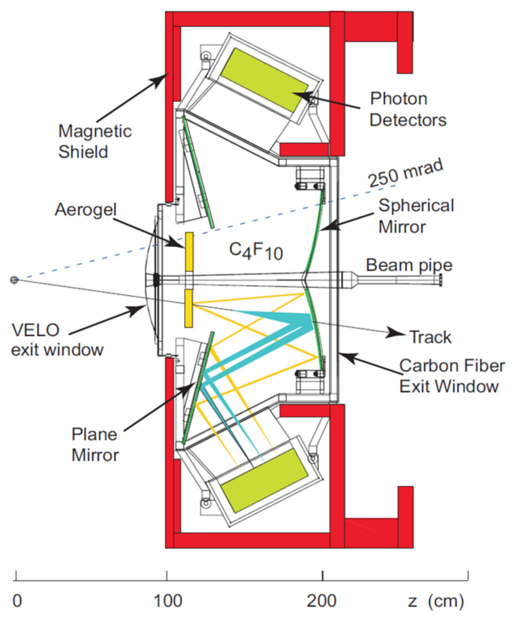
The upgrade planned for the next years aims to increase the luminosity by a factor of ten.
To cope with the higher occupancy, the electronics must withstand a full 40 MHz readout speed, to match the bunch crossing rate of the LHC.
In the case of the RICH subdetectors, the baseline for the upgrade is to replace the HPDs with multi-anode photomultiplier tubes.



The LHCb detector



The HPDs with embedded readout chip currently employed in LHCb



The current layout of the RICH1

Ma-PMTs for the LHCb RICH

For the LHCb RICH upgrade, we characterized three Ma-PMTs from Hamamatsu: the H9500, the R7600 and now the R11265.
As indicated by Hamamatsu, the R7600 is more suitable than the H9500 for single photon counting applications such as RICH detectors. In particular, in the H9500 we found a significant amount of crosstalk at the single photoelectron level, which is negligible in the R7600.
The R7600 was extensively characterized and found compliant with the requirements of the LHCb RICH, but the inactive border of the device would call for the use of a lens in front of the device to increase its active area.
The R11265, recently made available by Hamamatsu, has a larger active area and overcomes this limitation. Its characteristics are currently being measured, but are expected to be very similar to those of the R7600.

H9500 (16x16)

R7600 (8x8)

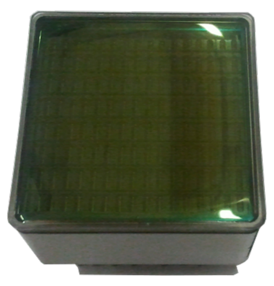
R11265 (8x8)

The Hamamatsu R11265

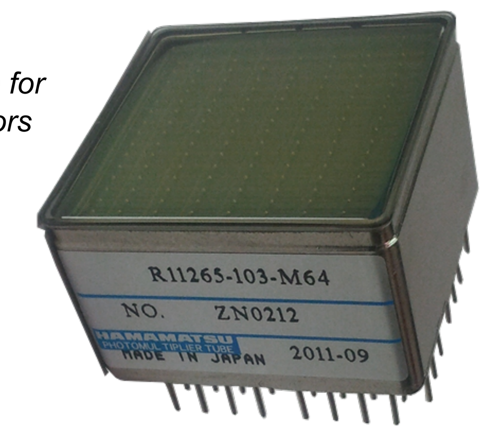
The table summarizes the main characteristics of the R11265.

	R11265
Spectral Response Range	185-650 nm
Window Material / Thickness	UV glass / 0.8 mm
Geometrical Dimensions	26.2 x 26.2 mm²
Photocathode Minimum Effective Area	23 x 23 mm² (>80%)
Number of Pixels / Dimensions	64 / 2.9 x 2.9 mm²
Photocathode Material	Super Bialkali
Number of Dynodes	12
Maximum Supply Voltage	1100 V
Gain	1 x 10⁶ at 1000V
Anode Dark Current (Each anode)	0.4 nA
Rise / Transit Time	0.6 / 5.1 ns
Uniformity Between Each Anode	1 : 3

very attractive for RICH detectors

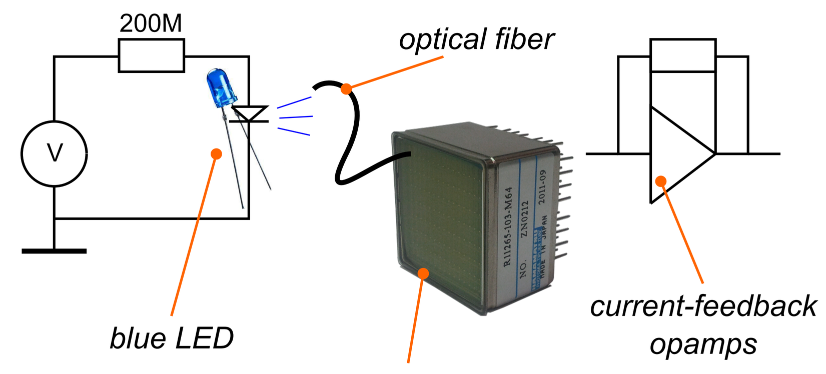


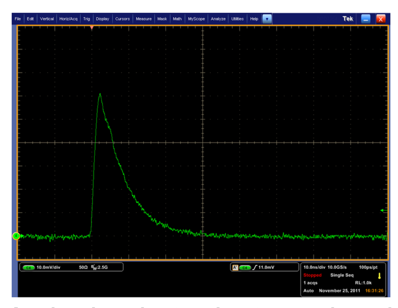
The standard socket from Hamamatsu



Tools for characterization

The Ma-PMT is illuminated by a commercial blue LED faintly biased at DC with a current of the order of a few nA. The LED emits thousands of photons per second, randomly distributed in time. An optical fiber to a PMT pixel is placed at the side of the LED (where less photons are emitted).
The anodes are read out with fast current feedback operational amplifiers. Being the rise and fall times of the output signal of the order of a few nanoseconds, single photon signals can be easily resolved.





A single photoelectron signal from the R11265

This method allows to characterize the single photon response of the Ma-PMT with just a few commercial components.
The spectra obtained with this method match the spectra obtained with Cherenkov photons produced by low energy electrons in crystals faced to the PMT, confirming that the LED can be a source of single photons.

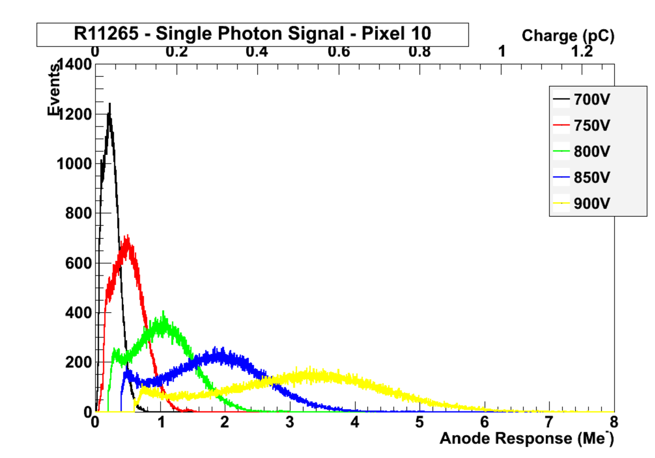
Gain and uniformity

The single photolectron gain of the device was measured with the standard HV bias ratio from Hamamatsu. The mean signal for pixel 10 is about 1.9 Me^- at 850 V.

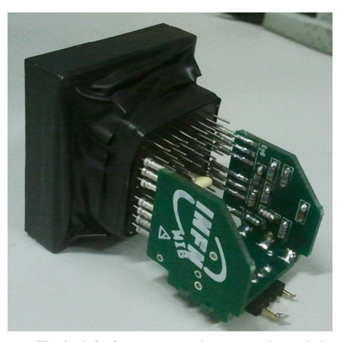
Voltage Distribution Ratio and Supply Voltage

Electrodes	K	Dy1	Dy2	Dy3	Dy4	Dy5	Dy6	Dy7	Dy8	Dy9	Dy10	Dy11	Dy12	G.R	P
Ratio	2.3	1.2	1	1	1	1	1	1	1	1	1	1	1	0.5	

Supply Voltage : 1000 V   K : Cathode   Dy : Dynode   G.R : Guard Ring   P : Anode



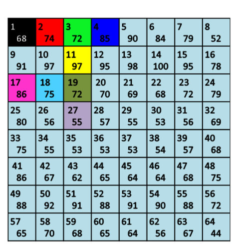
Single photon spectra at different HV values

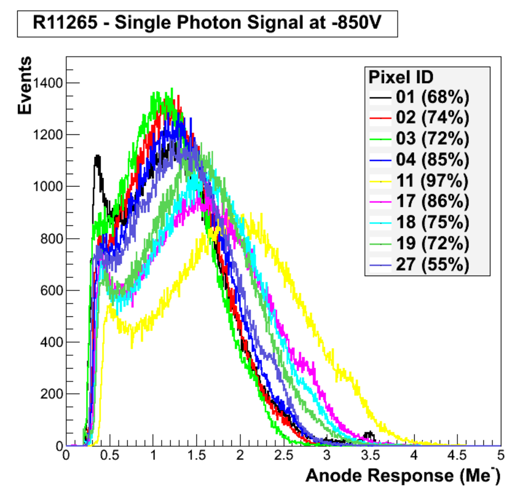


The R11265 equipped with the custom bias PCBs

Custom PCBs for HV bias were designed, as an alternative to the Hamamatsu socket. This will allow to test other HV bias ratios, to find the optimal values for our application.
Moreover, in this way the capacitance between anodes can be minimized (good to eliminate crosstalk in the readout electronics).

The gain uniformity of the device was measured at the single photoelectron level, and found compliant with the Hamamatsu specifications, which are given for continuous light.
The mamimum gain spread between pixels is 2.3, a very good figure.





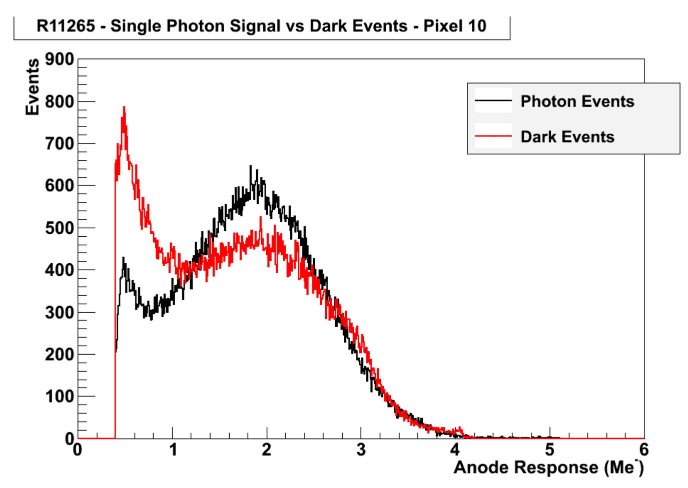
Gain uniformity between pixels

Dark counts

The dark current was evaluated by counting events above threshold (200 ke- at 850 V), to simulate false counts in the RICH.
Groups of four pixels were put in parallel, and the following rates were observed:

-Pixels 1+2+3+4: rate of 5.2 Hz (65 hours)
-Pixels 9+10+11+12: rate of 4.5 Hz (44 hours)
-Pixels 17+18+19+20: rate of 3.7 Hz (41 hours)

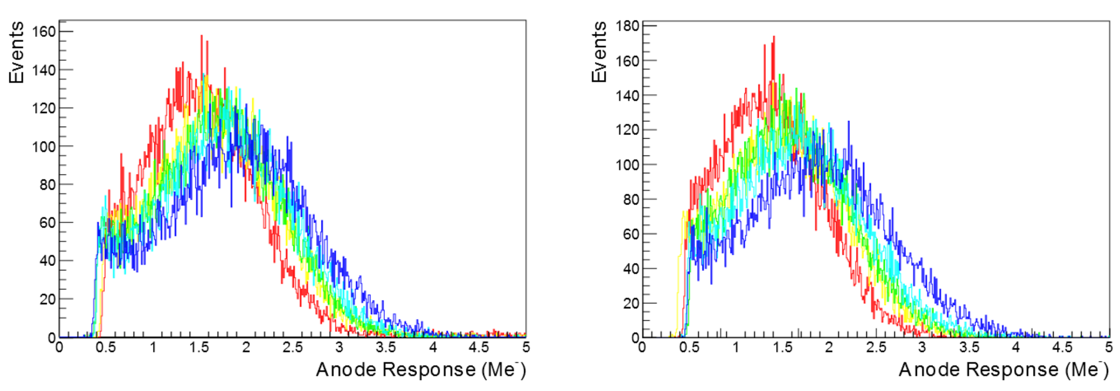
The average dark count rate per pixel is about 1 Hz.



Comparison between the single photon spectrum and the spectrum of dark counts

Gain vs temperature

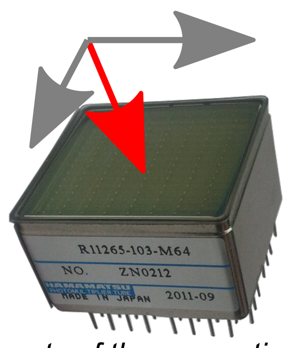
The single photon response of the PMT was tested at different temperatures in a Votsch 4018 environmental chamber, from -30° to 50°.
The measurements show a gain decrease with increasing temperature. The gain is roughly proportional to 1/T (where T is the absolute temperature).
The measurements will be completed with a measurement of the variation of dark count rate, which is expected to increase at higher temperatures.



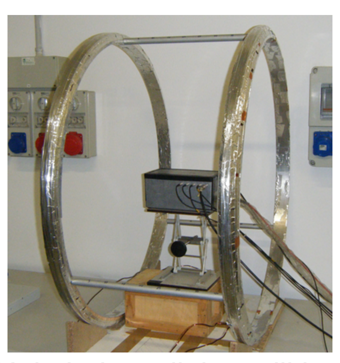
Spectra at different temperatures for two PMT pixels. (blue: -30°, to red, 50°, in steps of 20°)

Plans for tests in a magnetic field

The devices in the RICH must operate in the presence of the residual magnetic field from the LHCb magnet, up to 30 G for the RICH1, less for the RICH2.
It is known that magnetic field causes gain decrease in such devices. The gain decrease is expected to be proportional to the axial component of magnetic field with respect to the PMT. The other components are expected to cause negligible effects. The maximum gain decrease is expected in the pixels at the border of the PMT.



Components of the magnetic field: the axial component is shown in red



The Helmholtz coil that will be used for characterization

Future characterization

The study of the device will proceed with:

- measurement of dark count rate vs temperature
- characterization in magnetic field
- crosstalk measurement
- investigation on the optimal bias voltage ratio
- aging of the device

In particular, aging may be a delicate issue for the LHCb RICH. The current estimates for event rates in the hottest regions of the RICH detectors can reach 10 MHz per pixel: in these conditions, a noticeable aging is expected in a few months of operation. This may indicate the need to operate the devices with the lowest possible bias voltage, to mitigate the aging effects.

PhotoDet 2012 - International Workshop on New Photon-Detectors   June 13-15, 2012, LAL Orsay, France