# Single Cherenkov photon measurements with multi-anode photomultipliers for performance studies of the CBM-RICH photodetector

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In November 2010 the CBM-RICH group together with other CBM groups took part in a test beam time at the CERN PS target area T10. We report on first results from the analysis of the obtained data.

## Overview and goals

Our goal for this beamtime was to further study the Cherenkov photon detection with Hamamatsu H8500 multi-anode PMTs using a proximity focusing test setup. This test provided valuable experience for the preparation of a full-scale gas Cherenkov prototype setup [1] to be tested at CERN in autumn 2011.

## Setup and data analysis

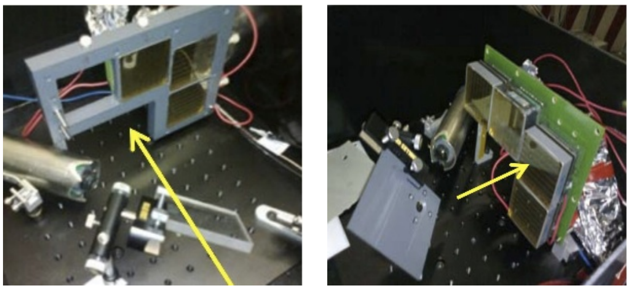

Figure 1: Proximity focusing setup with Plexiglas radiator (left) and quartz radiator with pin hole mask (right)

The experiment was set up inside a light-tight box, similar to earlier tests at GSI [2]. This time, 4 MAPMTs were mounted in a L-shaped arrangement in front of a Cherenkov radiator, covering roughly 25% of the generated Cherenkov cone. Two alternative kinds of radiator were used: an 8 mm thick Plexiglas sheet and a 4 mm thick quartz radiator. Both were oriented such that the plane normal pointed towards the PMTs in order to minimize ring distortion due to refraction at the radiator surface. Two different kinds of PMT mountings were tested (see Fig. 1): During the first runs, the PMTs were hold by a plastic frame and connected directly via ribbon cables to the readout electronics. Later, the PMTs were plugged on a special PCB board, allowing for a better positioning and good shielding of the PMTs. Such a solution is foreseen to be used for the full detector and was tested here for the first time. Each pair of two PMTs was connected via attenuator boards to individual nXYTER frontend boards (FEB) each providing 128 readout channels.

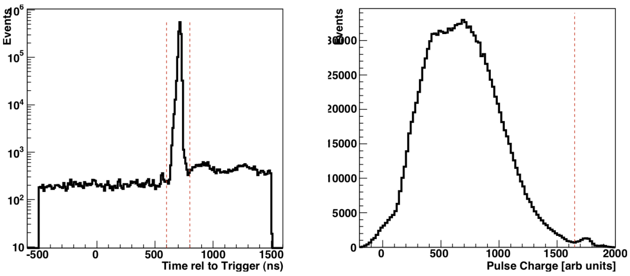

Figure 2: Time and amplitude distributions for individual hits. The dotted lines visualize cuts applied in the further data analysis.

A secondary beam of mixed pions and electrons in the momentum range between 1 and 6 GeV/$c$ was used for the experiment, entering the box through a light-tight entrance window. After crossing the radiator, it passed the PMT plane with the beam centre a few cm away from the PMT cathodes. The Cherenkov cone at these momenta has a nearly fixed opening angle of 46.6° for both radiators. The projected ring image, however, is smeared out because of the large beam spot of several cm. A pinhole mask of $\approx$1 cm diameter on top of the radiator was used in some of the runs to limit the origin area of photons in order to nevertheless obtain a sharp ring image.

A coincidence condition of several scintillating finger detectors before and behind the setup provided a trigger signal used for normalization of the data. All obtained data, together with the trigger signal and data from the silicon tracking station (STS) in front of our setup, were synchronized and stored in ROOT trees for later analysis.

## Results

First results from the data analysis are shown in Fig. 2 and Fig. 3. The time distribution of MAPMT hits in relation to the trigger (Fig.2 left) shows a clear coincidence peak with background below the peak on the permille level. A cut on these coincident hits is applied for all later analysis. The amplitude sum spectrum (Fig. 2 right) is dominated by the peak corresponding to single photon response, a small peak around ADC values of 1700 is induced by signal overflow. These high amplitudes are mainly caused by direct hits of charged beam particles.

Integrated hit distributions are shown in Fig. 3 for three different setups, together with their corresponding hit multiplicity distributions. Data obtained with the Plexiglas radiator without pinhole mask show a broad structure be-

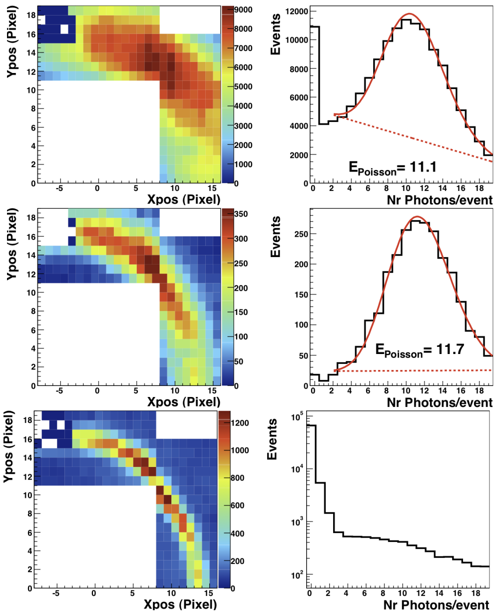

Figure 3: (Top row) Integrated image of Cherenkov ring and hit multiplicity for data with Plexiglas radiator without pin hole. (Middle row) Same data including an additional cut on $\geq$1 hit in STS. (Bottom row) Data obtained with quartz radiator using 1 cm pin hole. The full line in the multiplicity distributions represent a Poisson fit plus a linear background.

cause of the large size of the beam. Applying a coincidence condition on $\geq$ 1 hit in the STS limits the acceptance range significantly and leads to a less smeared ring image. Missing hits in the upper left corner are caused by a broken cable. In both cases, the hit multiplicity nicely reflects a Poisson-shaped distribution on some linear background. A $\chi^2$ fit yields an average multiplicity of 11-12 Cherenkov photons per event. In case of the quartz radiator with pinhole mask, the observed ring image is well focused. However, the acceptance area is now much smaller than the trigger corridor, which causes many events without Cherenkov photons. The multiplicity distribution in this case is dominated by background and does not show any Poisson-shaped peak structure, probably because of partial shadowing by the pinhole mask. An average photon number cannot be extracted for this configuration so far; a full Monte Carlo simulation is being prepared to understand this distribution quantitatively.

## Expected photon yield

The total number $N$ of produced Cherenkov photons per incident charged particle is

$$N = \int_{\lambda_1}^{\lambda_2} \frac{1}{\lambda^2}\, d\lambda \cdot L \cdot 2\pi\alpha \cdot z^2 sin^2\theta_C \qquad (1)$$

with the low wavelength end of the radiator transmission $\lambda_1$, the high wavelength end of the photocathode quantum efficiency $\lambda_2$, the radiator length $L$, the fine-structure constant $\alpha$, the charge of the incident particle $z$ in units of the electron charge, and the Cherenkov angle $\theta_C$. The number of expected Cherenkov photons in the photodetector is lower than the number of produced photons. Limiting factors are the finite transmittance of the radiators (80% above 390 nm for Plexiglas, 85% above 200 nm for quartz), the geometrical coverage of the MAPMTs (89% for the H8500 series), the wavelength-dependent quantum efficiency of the MAPMTs, and the geometrical acceptance of the photodetector. Considering refraction of photons at the radiator-air interface and dead MAPMT pixels due to the broken cable leads to a geometrical acceptance of 21.5 % for the Plexiglas radiator and 20 % for the quartz according to a simple geometry simulation shown in Fig. 4. For the above analyzed runs, MAPMTs with bialkali photocathode and UV glass window were used. The number of photons detected by the photodetector is then expected to be 8.0 for the Plexiglas radiator and 15.5 for the quartz.

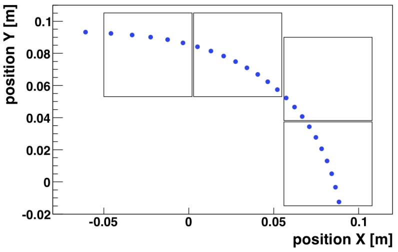

Figure 4: Geometrical acceptance of the photodetector. The dots display the expected position of Cherenkov photons on the photodetector plane. The ring is distorted because of refraction.

## Summary and conclusion

For data taken with the Plexiglas radiator, the measured number of Cherenkov photons per event exceeds the theoretical expectation of 8 photons/event significantly. This might be partly attributed to crosstalk between neighbouring pixels (see [3]), which would increase the observed hit multiplicities. Another possible contribution could be an underestimation of the transmittance of Plexiglas for UV photons. In any case, the high photon yield demonstrates the good single-photon detection capabilities of H8500 PMTs. A full Monte Carlo simulation of the setup is being prepared to further improve the quantitative understanding of the data.

## References

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