
This is an electronic reprint of the original article.
This reprint *may differ from the original in pagination and typographic detail.*

Author(s): Grigoryev, V. A.; Kaplin, V. A.; Karavicheva, T. L.; Konevskikh, A. S.; Kurepin, A. B.; Loginov, V. A.; Melikyan, A.; Morozov, I. V.; Reshetin, A. I.; Serebryakov, D. V.; Shabanov, A. I.; Slupecki, Maciej; Trzaska, Władysław; Tykmanov, E. M.

Title: Fast timing and trigger Cherenkov detector for collider experiments

Year: 2016

Version:

Please cite the original version:

Grigoryev, V. A., Kaplin, V. A., Karavicheva, T. L., Konevskikh, A. S., Kurepin, A. B., Loginov, V. A., Melikyan, A., Morozov, I. V., Reshetin, A. I., Serebryakov, D. V., Shabanov, A. I., Slupecki, M., Trzaska, W., & Tykmanov, E. M. (2016). Fast timing and trigger Cherenkov detector for collider experiments. In I. Arkhangelskaja, & P. Buzhan (Eds.), ICPPA-2015 : International Conference on Particle Physics and Astrophysics, 5–10 October 2015, Moscow, Russia. Institute of Physics Publishing Ltd.. Journal of Physics: Conference Series, 675. <https://doi.org/10.1088/1742-6596/675/4/042015>

All material supplied via JYX is protected by copyright and other intellectual property rights, and duplication or sale of all or part of any of the repository collections is not permitted, except that material may be duplicated by you for your research use or educational purposes in electronic or print form. You must obtain permission for any other use. Electronic or print copies may not be offered, whether for sale or otherwise to anyone who is not an authorised user.

Fast timing and trigger Cherenkov detector for collider experiments

This content has been downloaded from IOPscience. Please scroll down to see the full text.

2016 J. Phys.: Conf. Ser. 675 042015

(<http://iopscience.iop.org/1742-6596/675/4/042015>)

View the [table of contents for this issue](#), or go to the [journal homepage](#) for more

Download details:

IP Address: 130.234.74.31

This content was downloaded on 09/03/2016 at 10:41

Please note that [terms and conditions apply](#).

Fast timing and trigger Cherenkov detector for collider experiments

V A Grigoryev¹, V A Kaplin^{1,4}, T L Karavicheva², A S Konevskikh², A B Kurepin², V A Loginov¹, Yu A Melikyan¹, I V Morozov², A I Reshetin², D V Serebryakov², A I Shabanov², M Slupecki³, W H Trzaska³ and E M Tykmanov¹

¹ National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe highway 31, Moscow, 115409, Russia

² Institute for Nuclear Research of the Russian Academy of Sciences, V-312, 60-letiya Oktyabrya prospect 7a, Moscow, 117312, Russia

³ University of Jyväskylä, P.O. Box 35, FI-40351 Jyväskylä, Finland

E-mail: kaplinv@mail.ru

Abstract. Analysis of fast timing and trigger Cherenkov detector's design for its use in collider experiments is presented. Several specific requirements are taken into account – necessity of the radiator's placement as close to the beam pipe as possible along with the requirement of gapless (solid) radiator's design. Characteristics of the Cherenkov detector's laboratory prototype obtained using a pion beam at the CERN Proton Synchrotron are also presented, showing the possibility of obtaining sufficiently high geometrical efficiency along with good enough time resolution (50 ps sigma).

1. Introduction

Cherenkov detectors are often used in collider experiments as a tool for timing measurements [1, 2]. As a general trend, requirements to such detectors become stricter. In particular, modern trigger Cherenkov detectors should have as high particle detection efficiency as possible, i.e. such devices should have relatively large area and cover the entire measurement region with no blank spots (including the area in close proximity to the beam pipe).

Even in case of using photomultipliers with large-area photocathodes, it is hardly possible to meet the needs mentioned above, because the photocathode's size is smaller than the external dimensions of the photomultiplier's front surface, and a non-detecting edges would always remain, reducing the detector's homogeneity. Moreover, usage of the square-shaped photomultipliers complicates the coverage of the area around the beam pipe and simple changing the radiators forms and sizes leads to drastic decrease in the signal's amplitudes at certain detector's regions.

In order to solve these problems, we propose to place the Cherenkov detector facing backwards to the beam direction. This could help to greatly improve the detector's homogeneity without the loss in its timing parameters, what is demonstrated by the presented below results of the FIT Cherenkov detector's prototype testing (FIT - Fast Interaction Trigger detector - is currently being developed for the upgraded ALICE experiment).

⁴ To whom any correspondence should be addressed.



2. The experimental setup

A Cherenkov detector module based on the XP85012 multianode (8x8 anodes array) microchannel plate photomultiplier is going to be used as a basic element of the FIT detector. The first testing procedures carried out under laboratory conditions showed that the photomultiplier is suitable for the use in the FIT detector [3].

One of the distinctive features of this photomultiplier is its relatively large size ($53 \times 53 \text{ mm}^2$ sensitive area). This fact must be taken into account while creating a timing detector with $\sim 50 \text{ ps}$ time resolution, because there could be problems with the signal delay time variability depending on the point of the particle hitting. In order to study the detector's characteristics in the backward configuration and in case of oversized radiators usage a special research was made at the CERN PS (Proton Synchrotron) relativistic pion beam employing an additional coordinate-sensitive detector, specially developed for this purpose.

To increase the detector's granularity, it was planned to use four independent quartz radiators with a single MCP-PMT. A photo of the tested Cherenkov detector module with XP85012 photomultiplier and four radiators is shown in figure 1. The readout could be done from the common output and from individual "quadrant's" output (one quadrant stands for a square of 16 interconnected anodes).



Figure 1. The Cherenkov detector module.

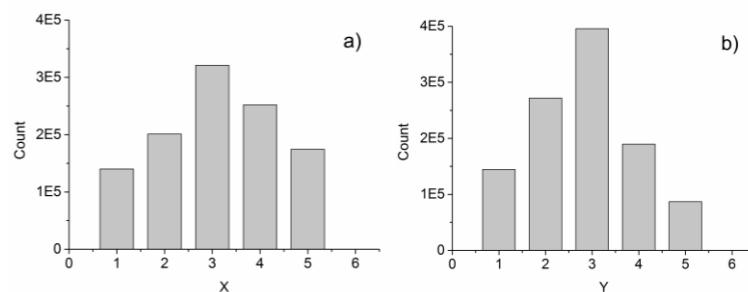


Figure 2. X-dimension (a) and Y-dimension (b) of the beam profile, measured by the specially developed coordinate-sensitive detector.

The measurements were done in a wide beam – the detection of the XY-position of the particle penetration through the tested Cherenkov module was provided by an additional coordinate-sensitive scintillation detector, employing two identical arrays of 5 plastic scintillator strips each with silicon photomultiplier readout. Such detector with the sensitive area equal to the area of the tested detector allows one to detect the position of a particle's penetration with $\sim 1 \text{ cm}$ accuracy. In figure 2a,b the beam profile measured with the described XY-detector is shown.

For the data-acquisition system triggering, two auxiliary Cherenkov counters based on FEU-187 PMTs were used. During the off-line data-processing the timing reference for all signals was set to the level of 50% of amplitude (virtual analogue of a constant fraction discriminator). In figure 3a the spectrum of time intervals between the moments of triggering of the two start Cherenkov counters is shown, in figure 3b – a similar spectrum is shown for the time intervals between the tested MCP-PMT signal coming from a common output and the averaged start detectors' moment of triggering.

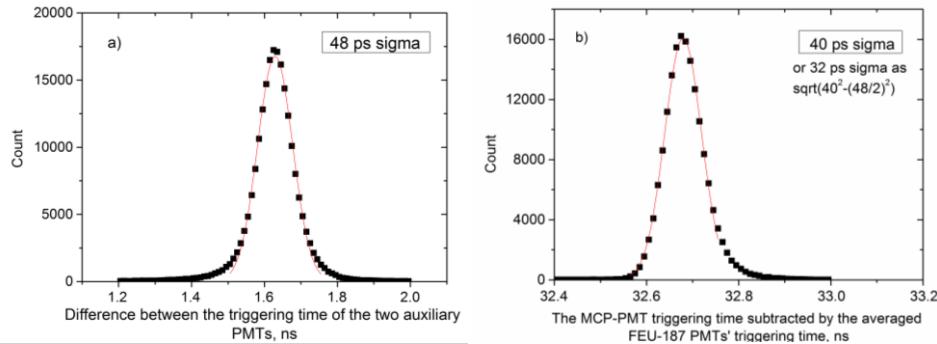


Figure 3. Time spectra, representing the auxiliary Cherenkov counters' combined time resolution (a) and an example time spectrum of the tested MCP-PMT (b).

Time resolution of the interval between the two start Cherenkov detectors is equal to 48 ps or a twice smaller value – 24 ps - in case of the offline averaging of the timing parameters of the both counters' signals. After the subtraction of the averaged start detectors' contribution, the resulting time resolution of the tested MCP-PMT is 32 ps for the typical case, presented in figure 3b.

3. The edge effects influence

In order to study the effects which occur in case of a particle's penetration through the MCP-PMT's window edges, which are not sensitive to light, two sets of radiators were produced. The first set includes four $21.5 \times 21.5 \times 20 \text{ mm}^3$ radiators which could cover the total $53 \times 53 \text{ mm}^2$ MCP-PMT's sensitive area, when combined. The second set of four $54.5 \times 54.5 \times 20 \text{ mm}^3$ radiators could cover the whole $59 \times 59 \text{ mm}^2$ area of the MCP-PMT window.

Figure 4 shows amplitude spectra measured from the individual quadrant's readout channels and the common output channel for the MCP-PMT with the first set of radiators, covering the MCP-PMT's photocathode area only. The left plot (a) is for the front beam conditions, while the right plot (b) is for the backward beam. Both plots show reasonably good amplitude resolution for all curves and no odd peaks. Figure 5 shows similar amplitude spectra for the case of usage of the second set of radiators, covering the whole area of the MCP-PMT window. As one could see from the presented data, the amplitude spectra measured for the case of the front beam (a) are far from being satisfactory because of an odd low-amplitude peak, induced by particles hitting the MCP edge. At the same time, the backward beam spectra (b) are characterized by acceptable amplitude resolution, loosing only one-thirds of typical signal amplitude.

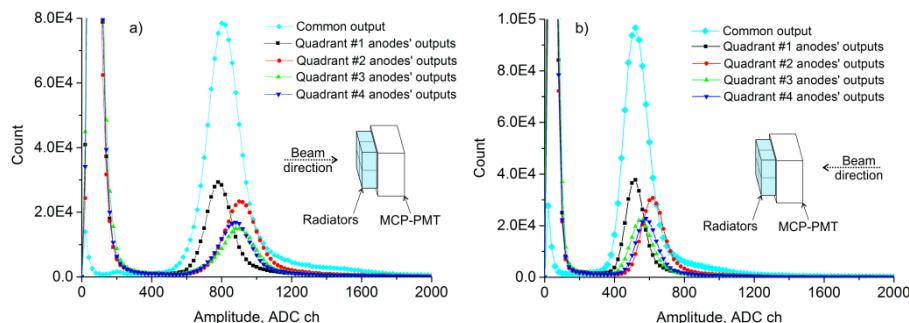


Figure 4. Amplitude spectra of different readout channels of the MCP-PMT with the set of radiators, which covers only the photocathode's area ($53 \times 53 \text{ mm}^2$ in total) for the front (a) and backward (b) beam direction.

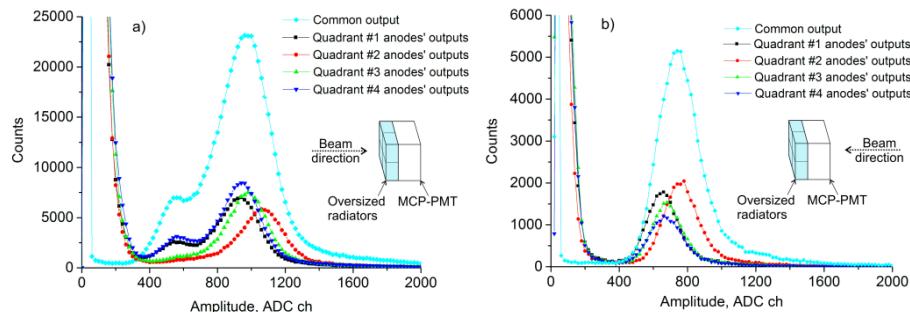


Figure 5. Amplitude spectra of different readout channels of the MCP-PMT with the set of radiators, covering the whole MCP-PMT window's area for the front (a) and backward (b) beam direction.

The timing parameters for all the configurations described are acceptable for the requirements of the experiment: the time resolution for the quadrant's timing readout is ~ 30 ps, or ~ 50 ps in the case of the common output readout (because of much larger readout area).

4. Study of a Cherenkov detector parameters with an oversized radiator

In order to study the possibility to use oversized radiators which protrude from the MCP-PMT borders a single $53 \times 53 \times 20$ mm³ radiator was produced and placed on the MCP-PMT window shifted sideways. Figure 6 shows amplitude spectra obtained for a front beam hitting the center of the radiator (a) and its edge (b), which protrudes for 5 mm from the edge of the MCP-PMT's sensitive area. For this configuration, the mean amplitude is decreased twice. In figure 7 a summary of the results of similar measurements is shown for the backward beam.

In the case of the backward beam, amplitude decreases insignificantly even for 15 mm radiator's shift. The time resolution of the device worsens from 36 to 41 ps (σ) while shifting the radiator from 5 to 15 mm – all of these values are acceptable for the projected purpose.

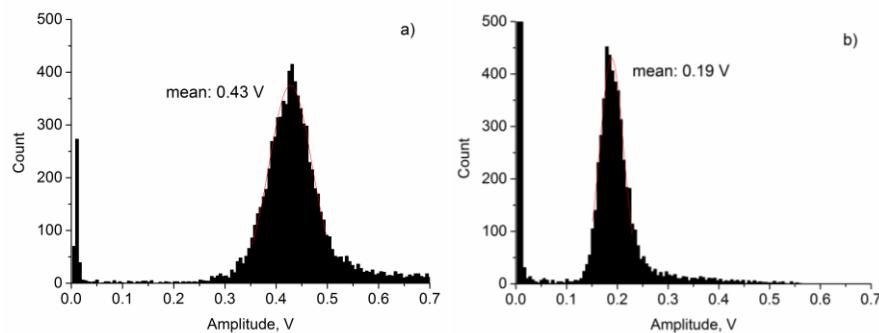


Figure 6. Amplitude spectra, obtained for a front beam hitting the center of the radiator (a) and its edge (b), which protrudes for 5 mm from the border of the MCP-PMT's sensitive area.

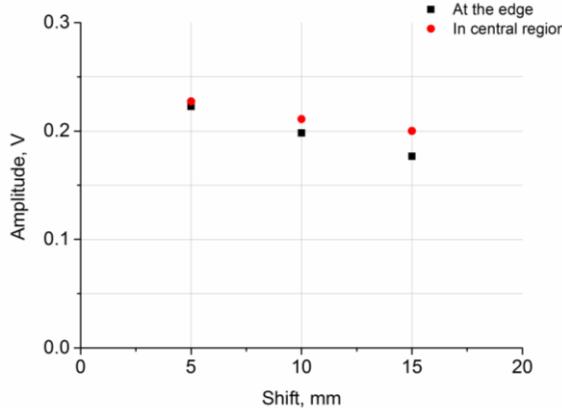


Figure 7. Summary of the results of measurements of average signal's amplitude measured with the common output for the backward beam while the radiator was shifted. Error bars lie within the data points size.

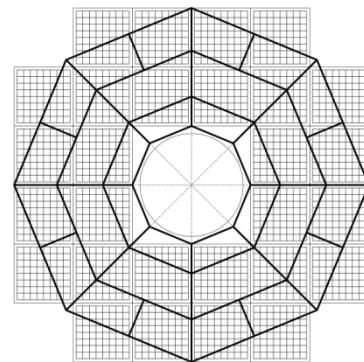


Figure 8. Possible configuration of a Cherenkov detector for a collider experiment. Thick lines – separate radiators' borders, thin lines – separate MCP-PMTs with indicated 8x8 anodes subdivision.

5. Conclusion

The results obtained show that turning the Cherenkov detector backwards to the beam direction might improve the homogeneity of the detector's amplitude parameters without any significant deterioration of its timing properties. Backward Cherenkov detector configuration also allows using oversized radiators, which could cover the unavoidable non-sensitive regions at the photodetectors' edges. These facts could help one to develop a highly effective detector that could cover the whole area required. For example, in the case of the collider experiments the resultant detector configuration could look like presented in figure 8.

Acknowledgments

This work was performed within the framework of the Fundamental Research and Particle Physics Center supported by NRNU MEPhI Academic Excellence Project (contract № 02.a03.21.0005, 27.08.2013) and Russian state grant RFMEFI61014X0003.

References

- [1] Ikematsu K *et al.* 1998 *Nucl. Instrum. Methods A* **411** 238-48
- [2] Yurevich V I 2013 *Physics of Particles and Nuclei Letters* **10** 258-68
- [3] Abelev B *et al.* CERN-LHCC-2013-019 / LHCC-TDR-015