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Performance study of the fast timing Cherenkov detector based on a microchannel plate PMT

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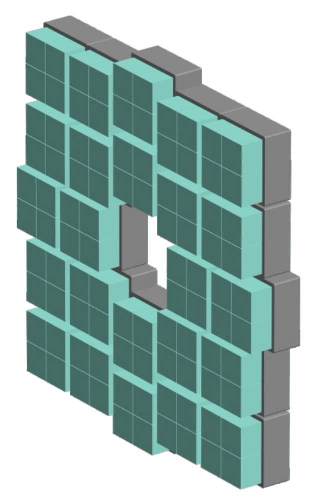
Motivation

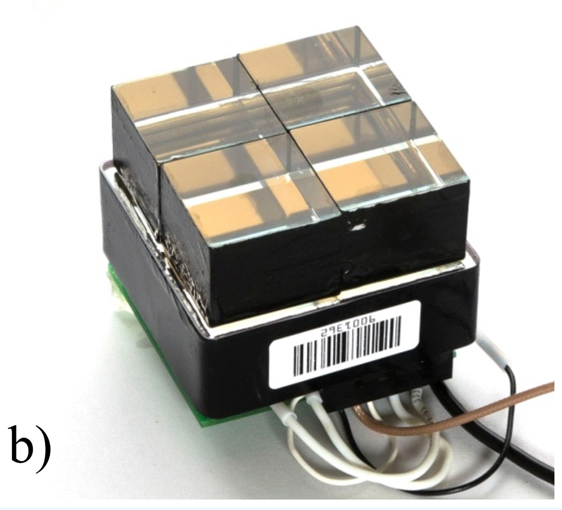
Modern comprehensive detection systems in the field of high-energy physics often require relatively simple subdetectors able to generate trigger signals with best timing as fast as possible. T0 and V0 detectors of the ALICE experiment at LHC are good examples of such subdetectors. They are used for the precise collision time measurement, the earliest trigger generation, online luminosity monitoring and multiplicity determination.

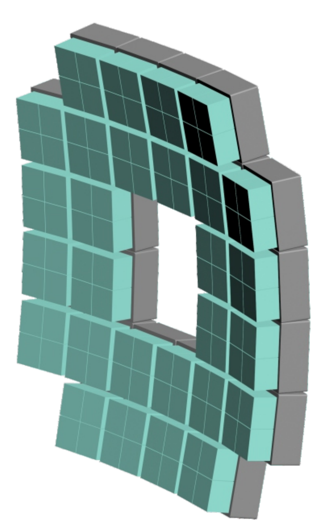
Future HEP projects could require radiation hard trigger detectors of much larger acceptance, smaller size along the beam axis and increased rate capability. ALICE Fast Interaction Trigger (FIT) T0+ subsytem is being developed to meet these needs:

- acceptance **$3.8 \leq \eta \leq 5.4$; $-3.3 \leq \eta \leq -2.2$;**
- thickness **≤10 cm**;
- hadron fluence up to **10^{11} n_{eq}/cm^2**;
- collision rates up to **40 MHz** (periods down to **25 ns**).

The detector design

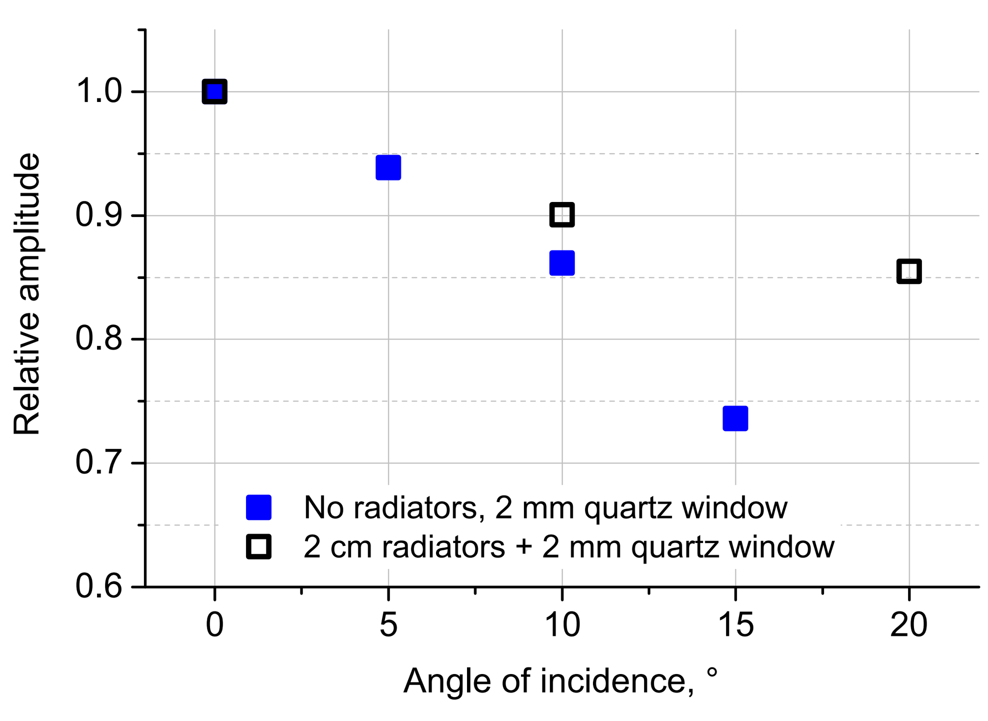

a)


b)


c)

a, c - proposed layout of FIT T0+ subdetector for ALICE side-A and side-C;
b - photo of a single Cherenkov detector module based on Planacon XP85012 microchannel plate PMT (MCP-PMT) and 2 cm-thick quartz radiators;

The reason for the concave (R=80 cm) T0+C design is that it would be located at the distance of **80 cm** from the Interaction Point (IP). If the detector assembly was flat, particles would hit the radiators at the angles of up to **12.6°**. It leads to a significant variation of the detector's amplitude characteristics:



A set of unknown/variable parameters act here:

- Q.E. variation for oblique photons;
- unclear reflectivity of PhC-window border;
- quartz transparency for VUV-light at short distances, etc.

T0+A would be located 3.6 m away from the IP - no need for the concave design.

MCP-PMT modernization

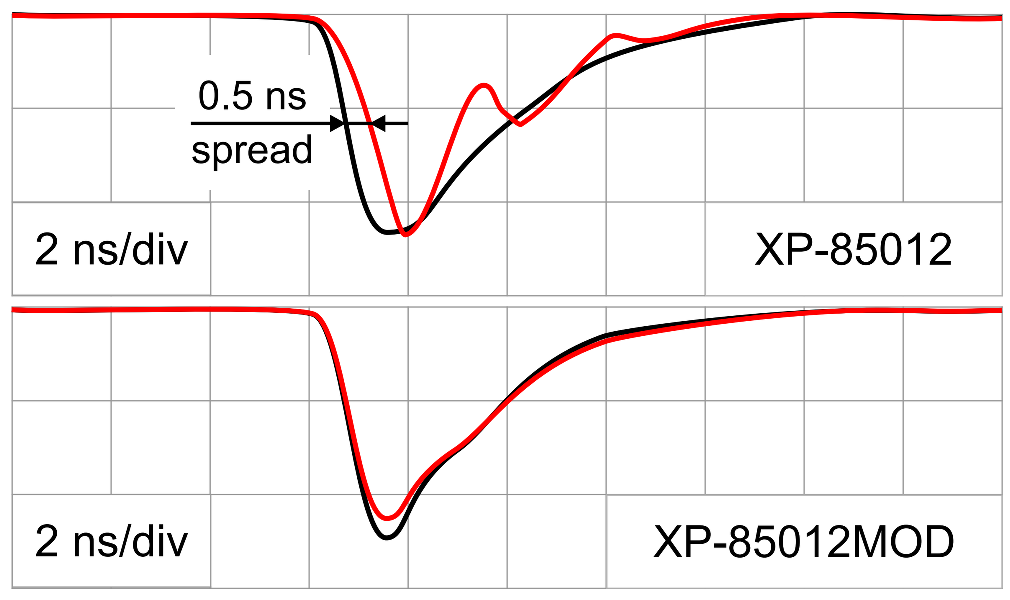
XP-85012 MCP-PMT with the default readout PCB is not optimized for precise timing measurements under intense illumination. Main drawback - positive crosstalk between readout channels via the common readout connection, resulting in signal distortion if more than one channel is fired.

The modernized PCB has equalized electric contacts length and no common readout channel.

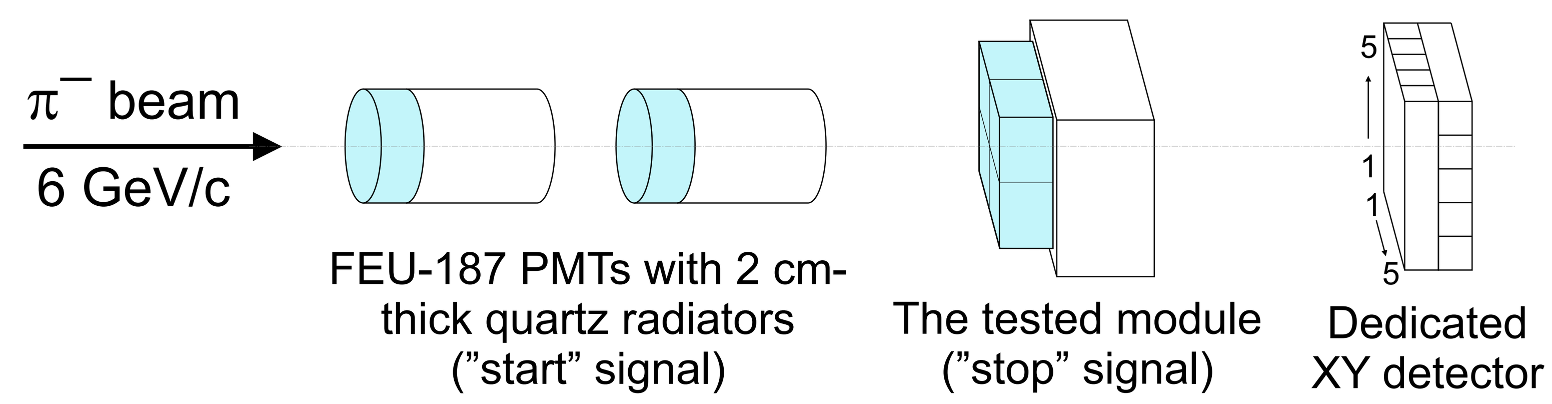
Averaged MCP-PMT signal waveforms before and after the readout PCB modernization ⇨

— one MCP-PMT quadrant under illumination;

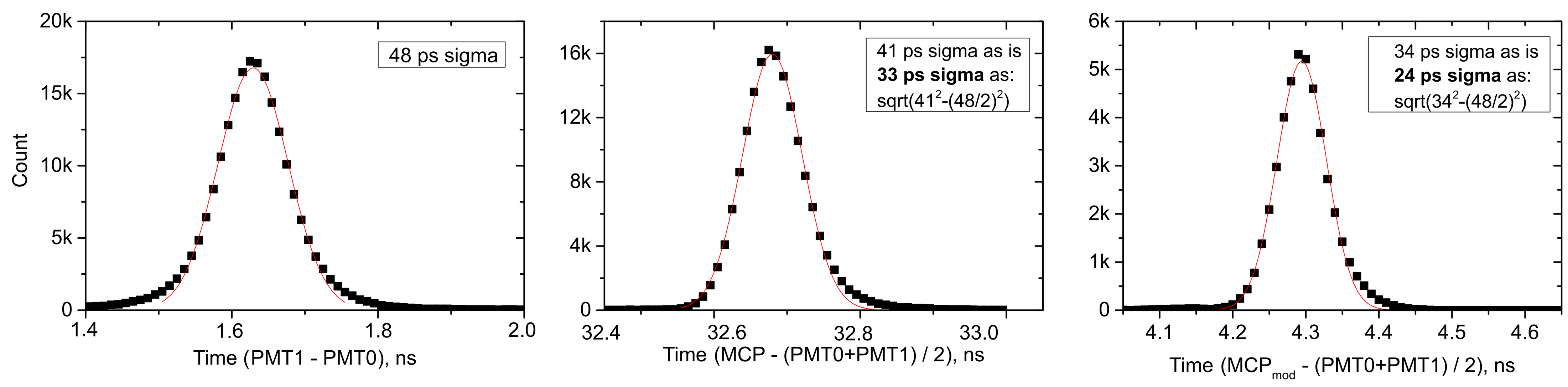
— all MCP-PMT quadrants under illumination.

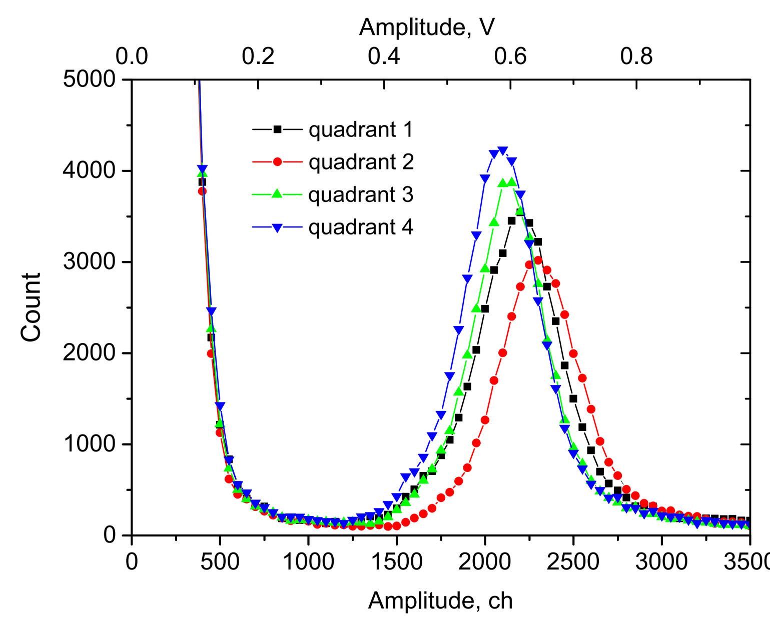


Beam tests: basic time and amplitude characteristics



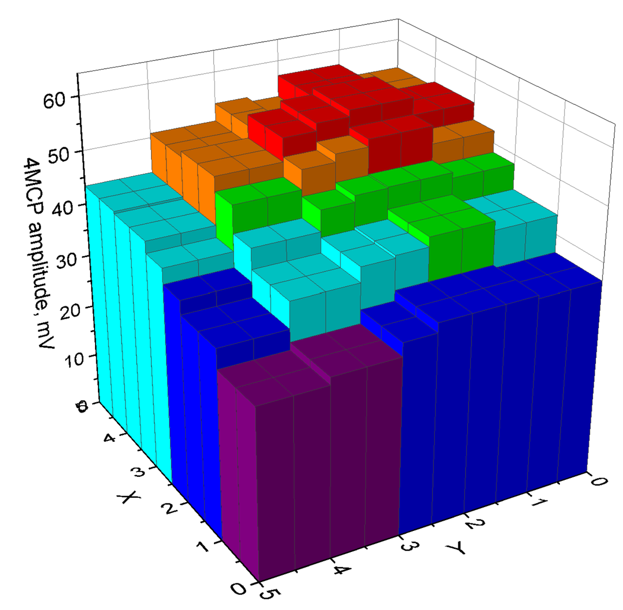
⇦ The experimental setup at CERN PS (Proton Synchrotron) to study time and amplitude characteristics of the Cherenkov detector module.





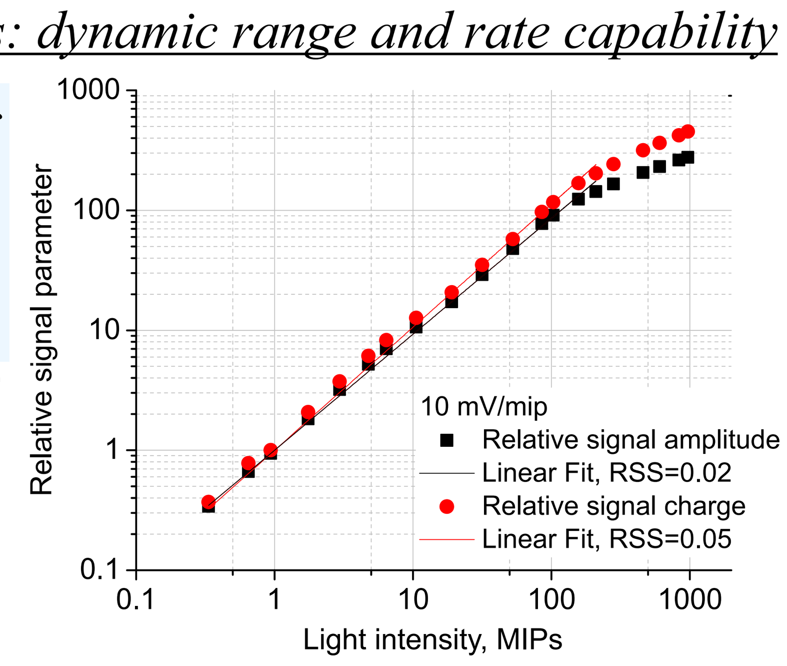
⇦ 1 MIP amplitude spectra for each quadrant of the Cherenkov detector module;

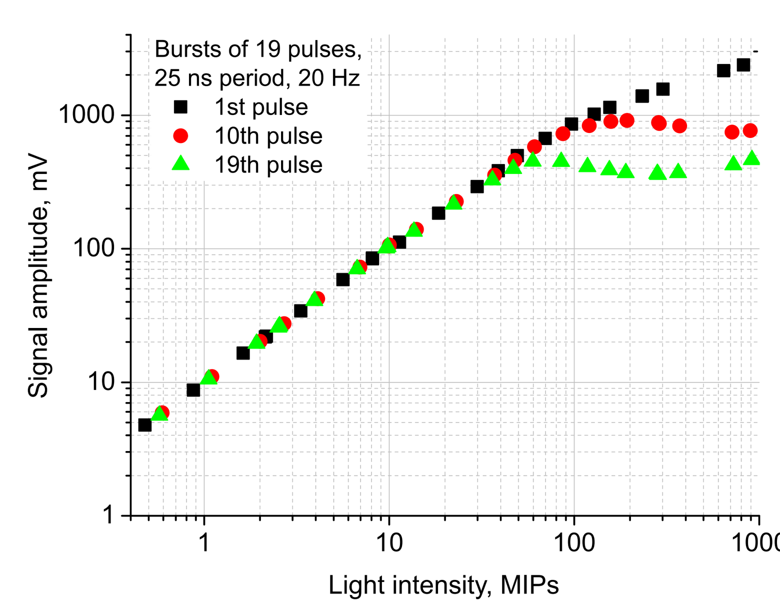
Signal amplitude variation across the MCP-PMT surface as measured without radiators (2 mm quartz window acting as the radiator) ⇨



Results of the laboratory tests: dynamic range and rate capability

Amplitude dynamic range of the MCP-PMT for single pulses and **bursts of 19 pulses** with **25 ns** period ⇨





According to the results of the special measurements, the MCP-PMT gain is stable within 5% for the average anode currents of up to **0.1 uA**. For the gain 1.5*10^5 (10 mV/mip) it ensures stable detection of **1 mip** pulses at **~150 kHz** rate or **100 mip** pulses at **~1 kHz** rate.

Conclusion

- The possibility to build a compact high-precision timing detector for a high-energy and high-luminosity collider experiment is confirmed;
- The tested Cherenkov detector module is based on **Planacon XP85012 MCP-PMT** with the modernized readout PCB, providing **~24 ps** time resolution (1 MIP) and at least **1:400** amplitude dynamic range for single events (**0.5...200 MIPs**);
- The detector can cope with the bursts of up to **10 signals** with **100 MIP** amplitude at reasonable gain (1.5*10^5, 10 mV/mip);
- Particle hits at oblique angles significantly deteriorate amplitude resolution - modular detector structure enables the concave detector geometry appropriate when placed close to the IP.