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# Pico-second Precise Photo-detectors for Particle Identification and Photon Vertex Identification (12' + 3')

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High precision, large area time of flight detectors could be a key element in strategies for coping with the extreme pile-up conditions expected in the high luminosity LHC. Very high precision (O(10ps)) timing information could be used to associate photons with the correct primary interaction vertex amongst the many present in the each bunch crossing. Such systems are being developed, originally for particle identification. In this presentation, the novel TORCH time of flight detector concept will be introduced, which is designed to achieve ~15ps time resolution over areas of tens of $m^2$. Results from prototype tests in a test-beam will be presented alongside laboratory measurements of the key technology making such detectors possible: extremely fast, highly granular photon detectors and electronics. Placing a thin sheet of high Z material in front of the TORCH detector would result in high energy photons converting into electron positron pairs which then produce Cherenkov photons in a quartz radiator. Use of this combination to associate each high energy photon with its primary vertex is discussed.

The TORCH concept has been proposed for particle identification by time-of-flight (ToF). One possible application is as an upgrade to the LHCb experiment to complement the particle identification capabilities of its RICH detectors. TORCH aims for a time of flight resolution better than 15ps and is designed for large-area coverage, up to $30m^2$. TORCH has a DIRC-like construction with 10mm thick synthetic amorphous fused-silica plates as a radiator. Cherenkov photons propagate by total internal reflection to the periphery and plate edges and there are focussed onto an array of position-sensitive photo-detectors. The construction of a prototype TORCH detector and test beam measurements in a 2-10GeV mixed beam of kaons, pions and protons will also be presented.

Micro-channel plate photo multipliers MCP-PMT are being developed in collaboration with industry. The anode structure is a resistive sea, capacitively coupled to readout electrodes with a segmentation of 64 x 64. For TORCH the anodes are combined to give a segmentation of 8 x 64. The resistive sea gives precisely controlled charge sharing, resulting in an effective spatial resolution of 8 x 128. The micro-channel plates have an atomic layer deposition (ALD) coating which gives an order of magnitude increase in lifetime compared to previous MCP based PMTs. Timing resolution for individual detected photons is $\sigma_t$ < 25ps. Laboratory tests of the MCP-PMT developed for TORCH and its readout electronics are also presented.

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