The TORCH Detector

Time of Internally Reflected Cherenkov Light

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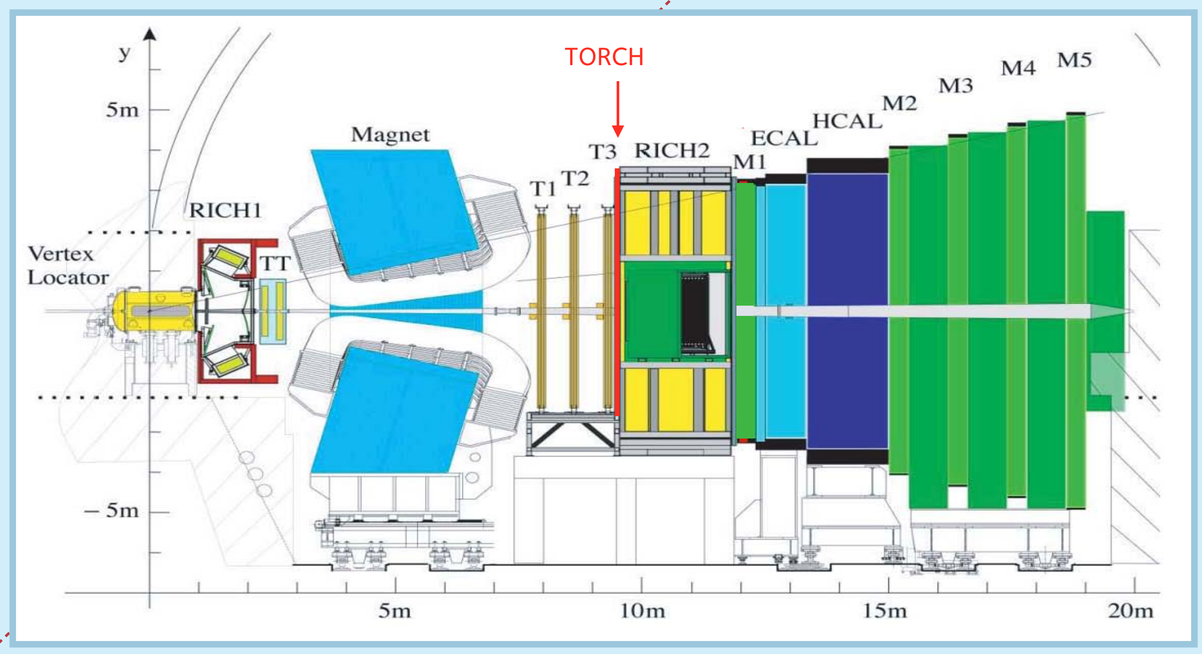
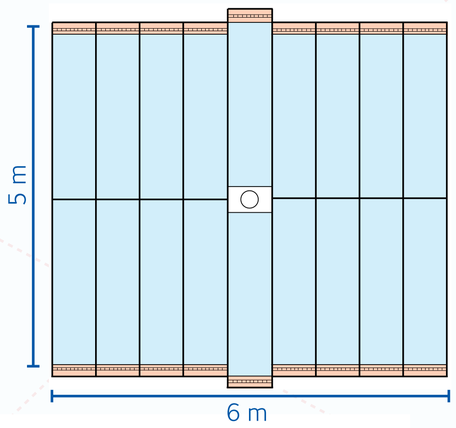
Goals

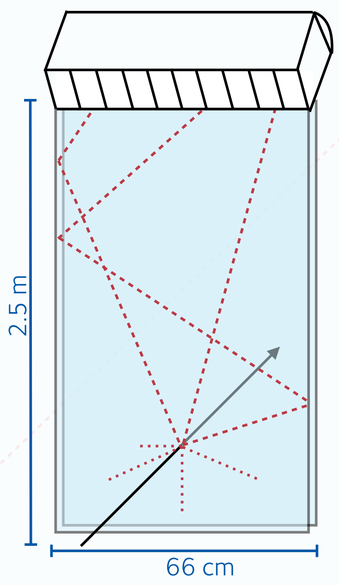
- TORCH is a time of flight detector which gives positive Particle Identification (PID) for low momentum particles between **2-10 GeV/c** (pions, kaons and protons) over a 10m flight path.
- It is proposed for the **LHCb Upgrade II.** It must cope with high occupancy & large amounts of pile up.
- PID is essential for CP violation measurements, exotic spectroscopy and particle tagging.
- Aim to measure individual photons with **~70 ps** time resolution. With 30 detected photons, this gives 15 ps per track.

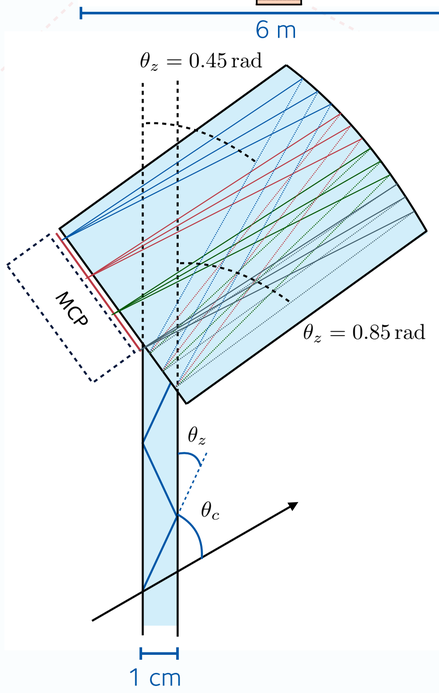


Design

- TORCH forms a time of flight wall of area 5 x 6 m², 10m from the interaction region.
- Total area is split into **18 modules.**
- **Cherenkov radiation** is emitted in 1 cm thick quartz plates.
- Photons reach top of the plate via **total internal reflection.**
- Photons are then **focussed** onto the photon detector plane.



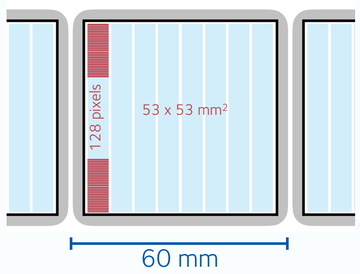


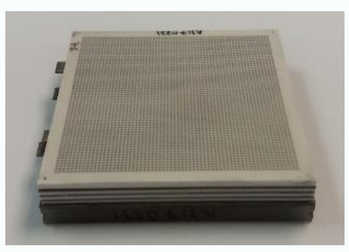


- **Micro-channel plate** photo multiplier tubes (MCP-PMTs) detect Cherenkov photons. The MCP-PMTs are developed in collaboration with Photek Ltd, see poster ID107, James Milnes.

Micro-channel plate PMTs

- To achieve required timing performance, ~1 mrad angular resolution is required for each photon in both longitudinal and transverse projections.
- Hence, each detector needs **128x8** effective granularity over **53x53mm²** active area , with 11 MCP-PMTs per module.

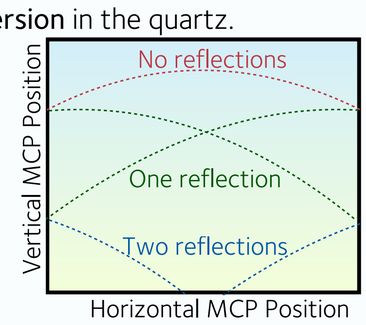




- The MCP-PMTs pixels are 64x64 and grouped to readout with 64x8 granularity. Charge sharing is used to give required granularity in vertical direction.
- To survive the LHC environment, MCPs are required to withstand an integrated charge of **5 C/cm²** (ALD coating used).
- MCP-PMTs read out with **NINO and HPTDC electronics,** developed for theTOF detector of the ALICE collaboration.

Pattern Recognition

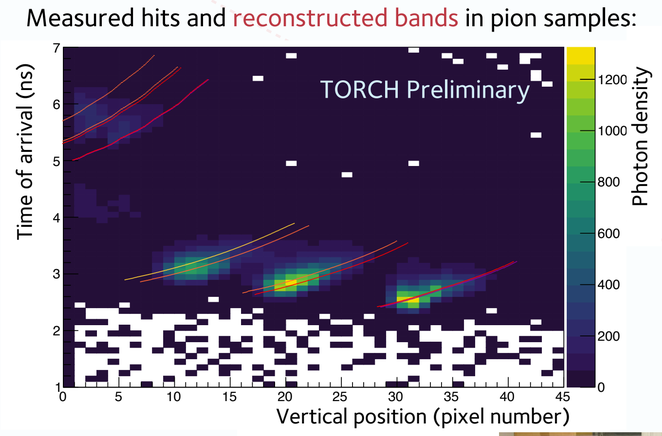
- Photon patterns are reconstructed. Position information from the LHCb spectrometer is used to define track entry point in the radiator.
- Corrections are made to account for **Chromatic dispersion** in the quartz.
- Bands are formed due to reflections from quartz sides.
- Expected distributions for p/K/π hypotheses are compared to the measured MCP hits.
- The patterns and timing information distinguish different particle species.



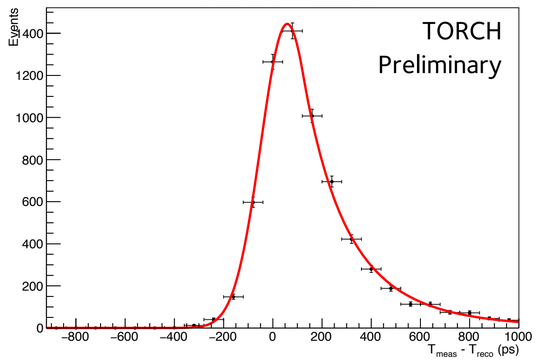
Ongoing R&D

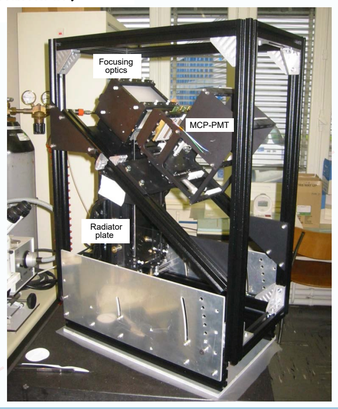
- A small-scale TORCH demonstration module tested in CERN PS 5 GeV pion-proton beam (Nov 2017) with a single MCP-PMT.
- Patterns show characteristic reflections.
- Resolution of **~100 ps** achieved.
- Tails caused by imperfect timewalk correction

Measured hits and reconstructed bands in pion samples:



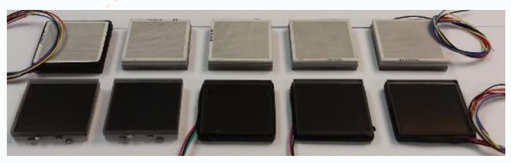
Time Resolution

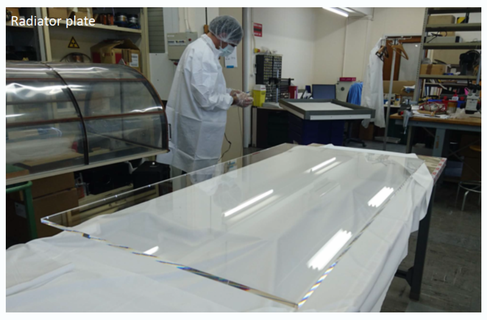




Future plans

- Half length module with 10 MCPs being constructed.
- Test-beam planned for the end of this year.





125 x 66 x 1 cm³ quartz plate