First results from production testing of 64-channel MaPMT R13742 (1in) and R13743 (2in) for the LHCb RICH Upgrade

New Developments in Photodetection 2017

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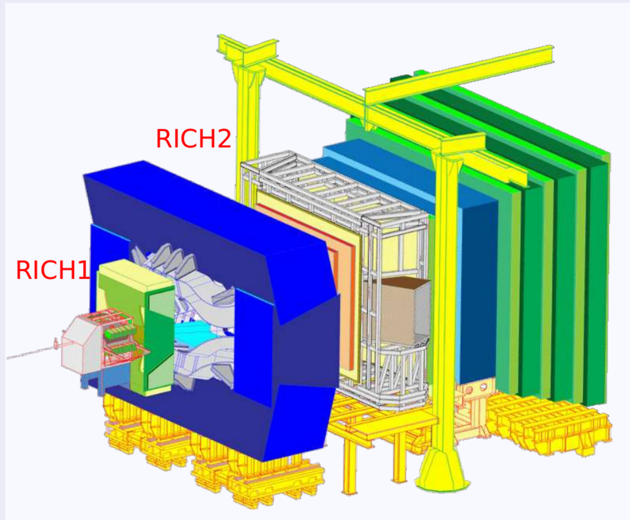
LHCb Detector Upgrade

The LHCb upgrade will take place during 2018 to cope with higher luminosity $2 \times 10^{33}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$[1]

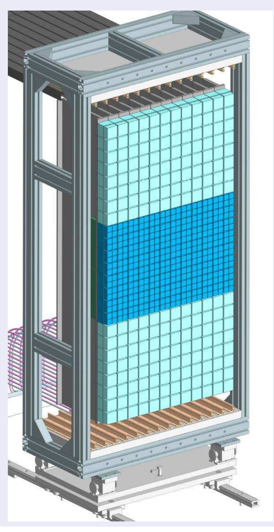


Challenges for the RICH upgrade: 40 MHz readout

- New readout electronics (dead time 25 ns, low power consumption, radiation tolerance)
- New photon detectors (sensitive to single photons between 300 and 700 nm, good spatial resolution, high Quantum Efficiency)
- Significant modifications to RICH1 to reduce peak occupancy (optics to be optimised, mechanics to be redesigned)

Multi-anode Photomultiplier tubes (MaPMT)

Fast, sensitive to single photons, large active area, excellent granularity, radiation hard, from Hamamatsu[2]:



- R13742 (Custom variant of R11265) 1", 64 (8×8) pixels for RICH1 and RICH2
- R13743 (Custom variant of R12699) 2", 64 (8×8) pixels for RICH2 peripheral area only
- MaPMTs are expected to be more reliable than current Hybrid Photon Detectors
- External readout electronics compared to the current built-in one

The Photon Detector Quality Assurance

The aim of the procedure:

- Verify minimal contractual specifications
- Analyse parameters - average gain, uniformity, peak-to-valley ratio, dark count rate
- Assemble MaPMTs in groups of 16 based on performance - common HV operation

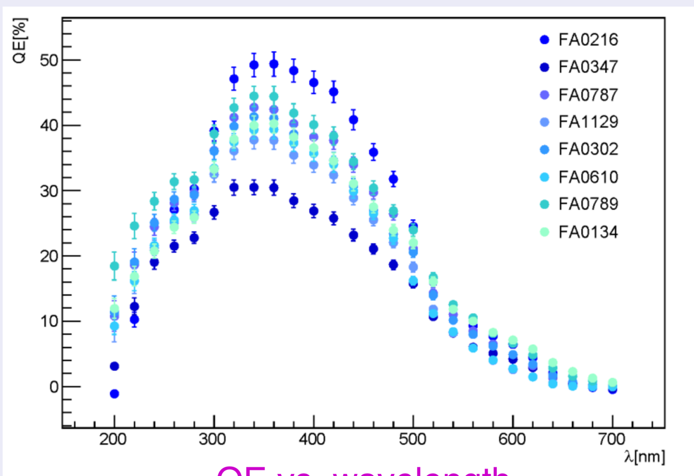
Challenges:

- High-numbers to be tested over two years
- 3100 R13742
- 450 R13743

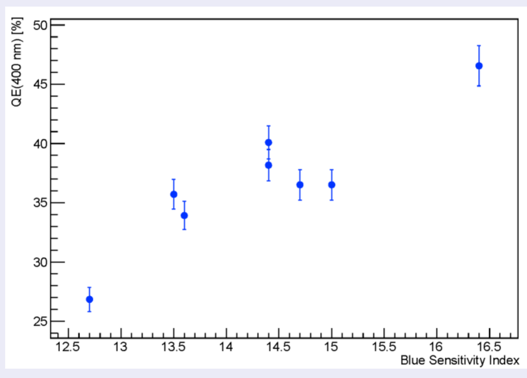
Requirements for testing:

- Reliability
- Redundancy
- Elevated automation

Quantum Efficiency

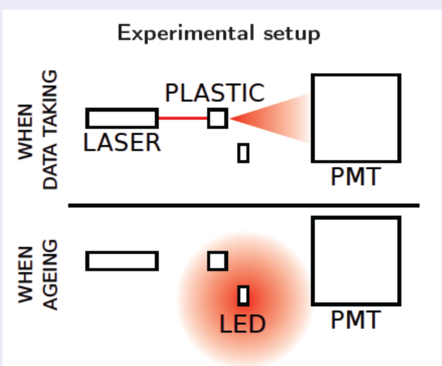


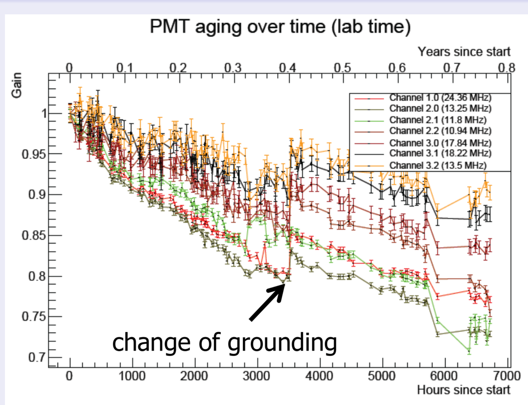
QE vs. wavelength
R13742: pre-series & Batch 1



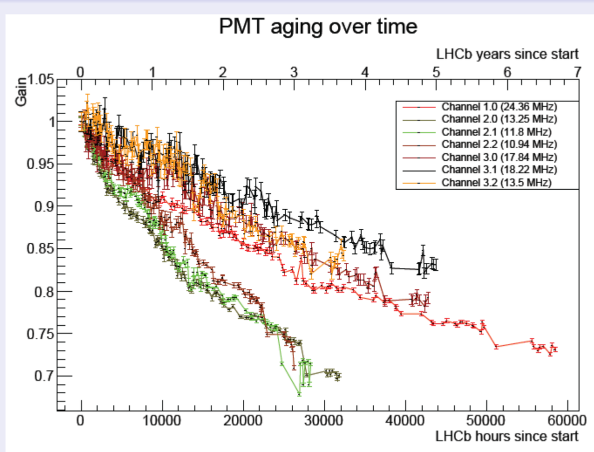
- Tested subset of 1in MaPMTs
- Good correlation with Blue sensitivity
- No need to measure QE for all MaPMTs

MaPMT Ageing



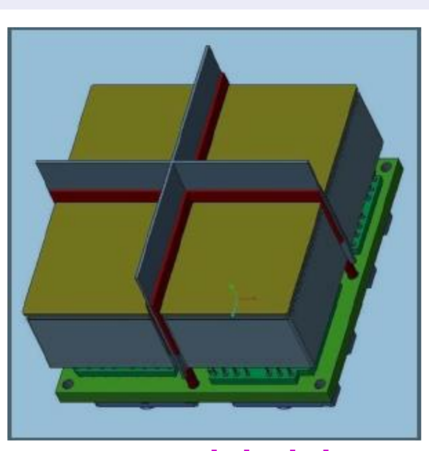


gain vs. laboratory time

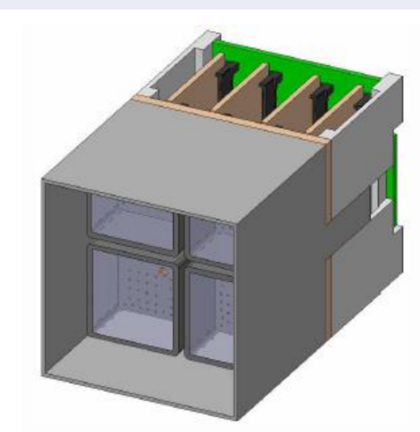


The ageing test procedure is run by a lab in Birmingham. It is performed on R12699 & R13743 MaPMTs types. The setup is a DAQ system with 5GS/s ADCs, where each ADC channel collects 3 time-delayed MaPMT channels and the charge is integrated. The measurement is based on gain degradation. The real operation time is ≈6700hrs, which corresponds to 3-6 LHCb years.

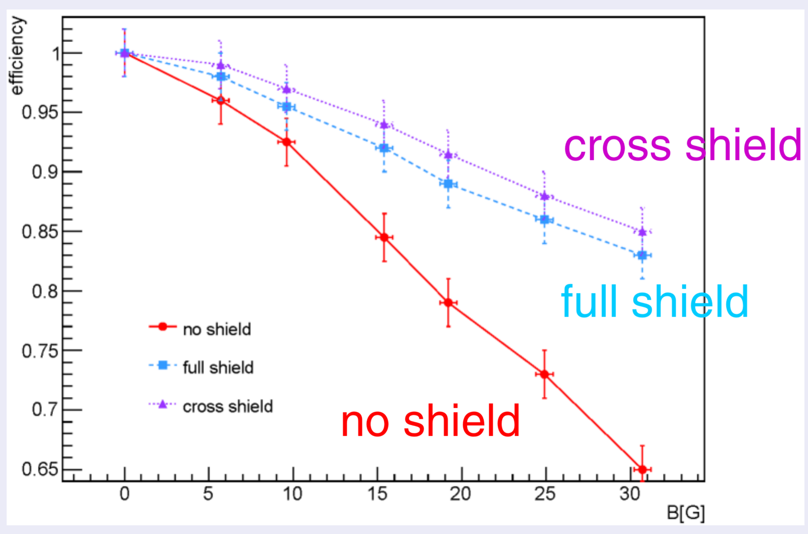
Magnetic Shield



cross-shield



full shield



The MaPMTs will operate in a residual field of 30 Gauss. The magnetic field reduces gain and photodetection efficiency. To counteract this effect, we have tested two types of EM shielding - a full shield and cross shield. The cross shield appears as effective as full shield, but will have the advantage of simpler assembly and less reduction on active area.

References

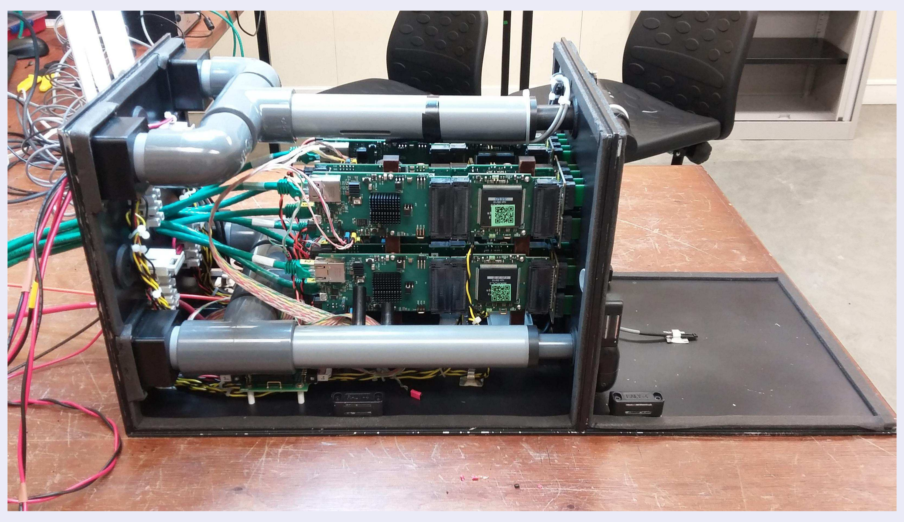
3. Gambetta et al., *First results from Quality Assurance Testing of MaPMTs for the LHCb RICH Upgrade*. Sep 2016. In: 9th International Workshop on Ring Imaging Cherenkov Detectors

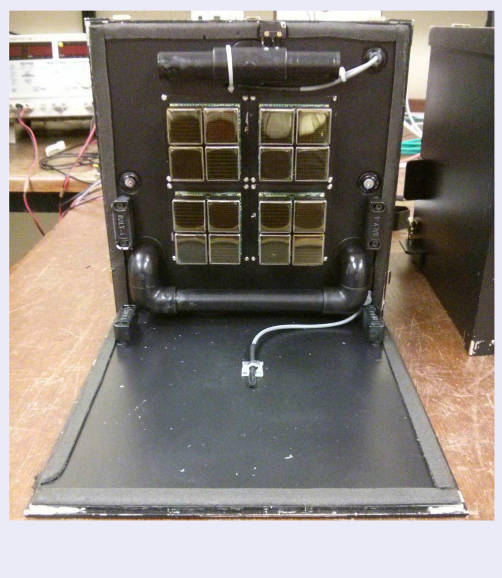
1. LHCb Collaboration et al., *LHCb PID Upgrade Technical Design Report*. 2013. url: http://cds.cern.ch/record/1624074

2. LHCb Collaboration et al., *Characterization of the Hamamatsu R11265-103-M64 multi-anode photomultiplier tube for the LHCb RICH upgrade*. 2014. DOI: 10.1088/1748-0221/9/06/P06021

The PDQA Test Bench

Fully intergrated Front End readout with Data Acquisition and Environment Control:



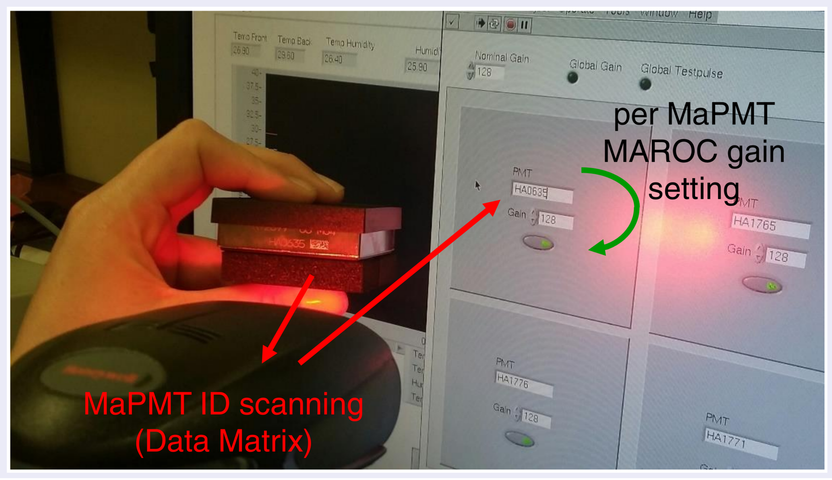


- Front-End - MAROC3 ASIC 8bit ADC
- FPGA Data acquisition boards
- Fully automated Control Station
- Power and Cooling

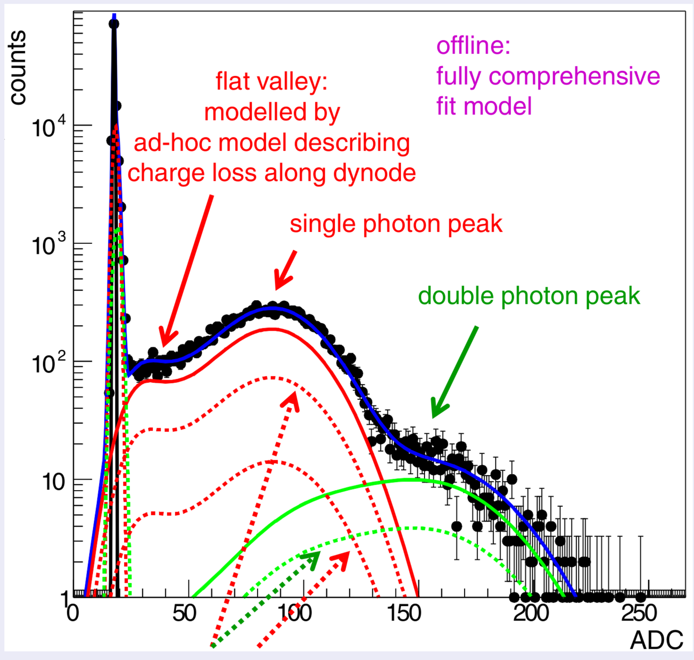
Fully Automated System

In the coming two years, the testing will involve a strict schedule and highly standardised procedure[3]. An essential part of this effort is the system that will handle the photon detector quality assurance of sevaral thousand MaPMTs. 4 test stations for the RICH upgrade PDQA have been developed and equipped in 2 different test facilities - Edinburgh, UK and Padua, Italy.

- FPGA firmware on Chimaera DAQ boards
- C++ API to send & receive data between DAQ hardware & Linux DAQ PC
- C++ API layer – libraries to interface to Labview
- XML files to configure DAQ hardware
- LabView GUI to log and sequence
- ROOT & C++ for data analysis



Offline Data Analysis

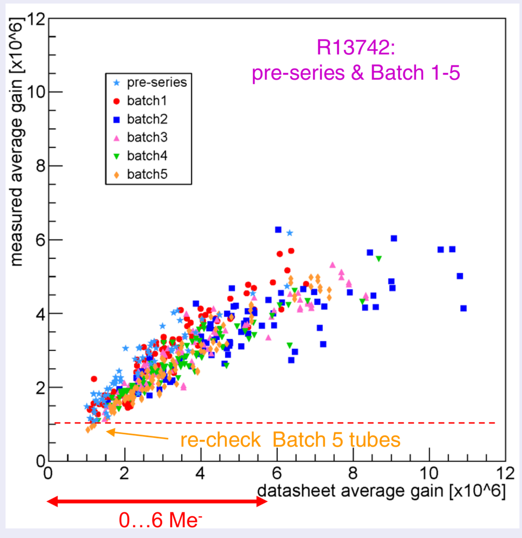


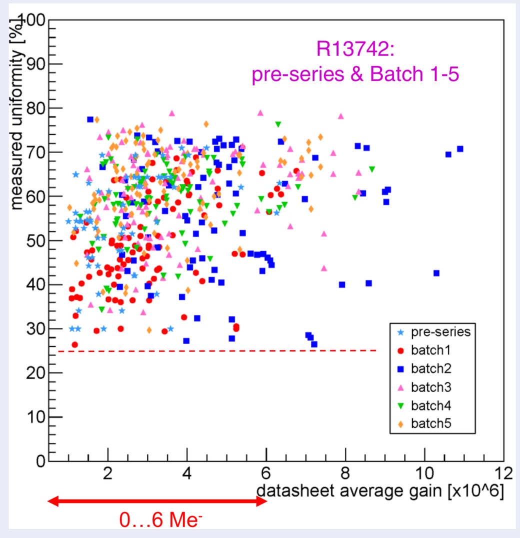
Signal + Contribution needed to describe right side of pedestal

Gaussian model for pedestal and photon signal peaks

- Unprecedented resolution
  - Resolves second photon peak
  - Resolves flat valley
- with light the pedestal is asymmetric
  - Developed phenomenological description
- Comprehensive fit model
  - Including all these features
  - Fit time: O(1 s)/spectrum
  - Robust - less than 1 per mill fit failure

Gain and Uniformity

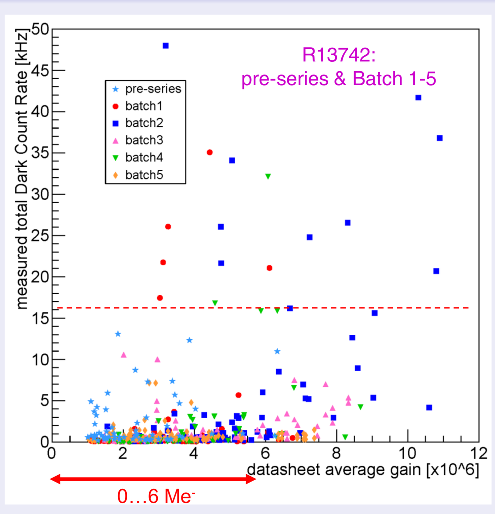


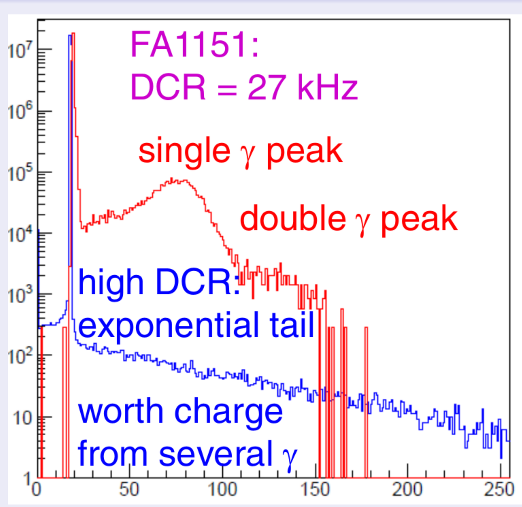


Comparing Hamamatsu datasheet values for gain (left) and uniformity (right).

The average gain and uniformity (ratio of highest to lowest pixel gain in a PMT) are two of the most important parameters. We require a gain of at least a 1M electrons and that the uniformity remains less than 1:4. This will ensure that PMTs operate as single units and they could achieve uniform efficiency over the photodetector plain.

Dark Count Rate (DCR)





The RICH DAQ will depend on binary hit readout and the DCR metric will help determine if an MaPMT has sufficient signal-to-noise ratio - $< 16\,\mathrm{kHz}$. So far almost all units pass successfully. We have observed a steady signal-to-noise ratio and also its correlation to increase in average PMT gain. In the rare cases where tubes were found to be above threshold, the problem has been discussed and resolved with Hamamatsu.

Acknowledgements

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Conclusion

The QA is in production mode and 18%/15.5% (474/20) of total number of 1in/2in MaPMTs have been fully tested. The initial results are promising, showing excellent gain, uniformity and single photon resolution. Only <2.2% of 1in MaPMTs show a higher than expected DCR, but this is being addressed through exceptional communication with Hamamatsu.