Strategy and Automation of the Quality Assurance Testing of MaPMTs for the LHCb RICH Upgrade

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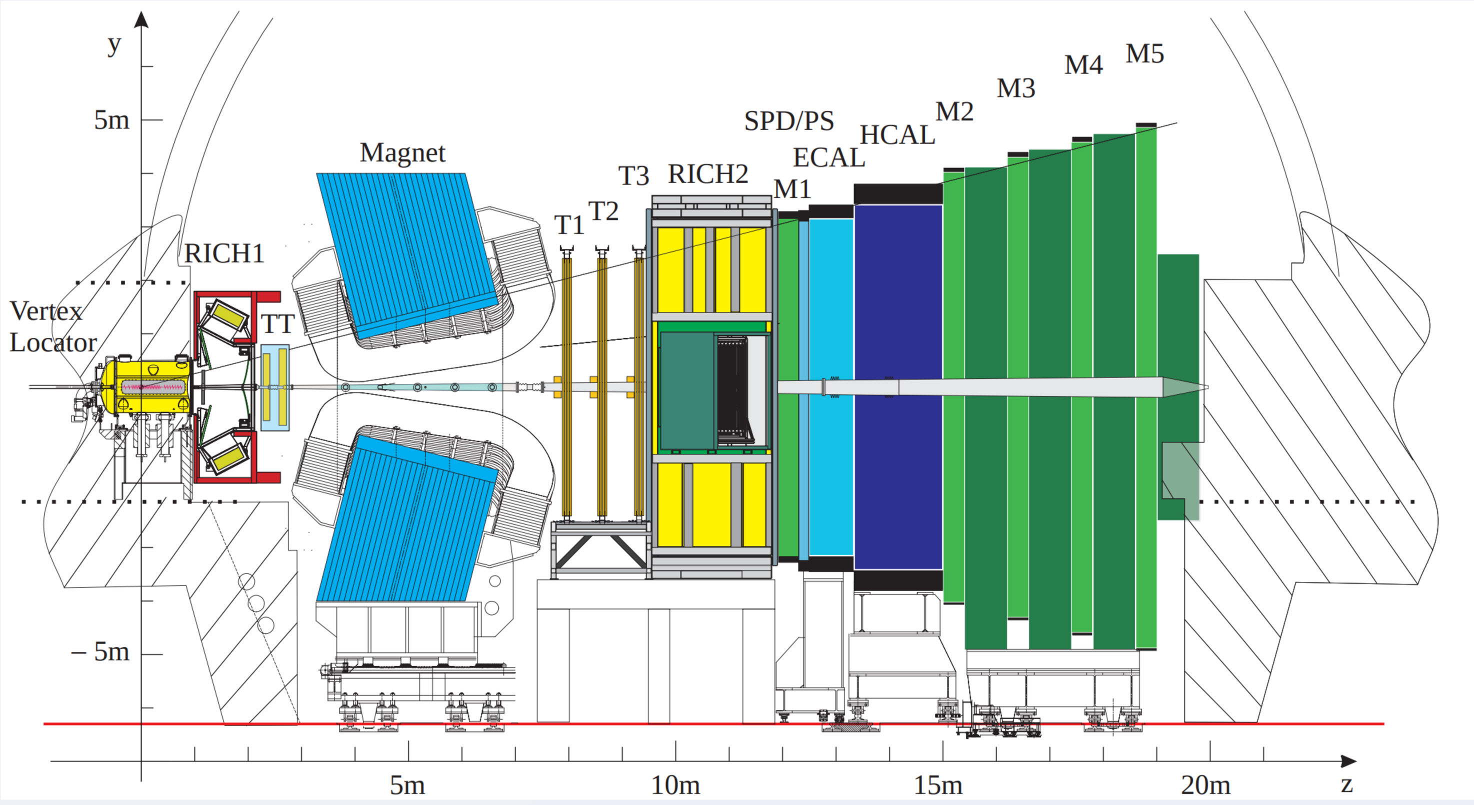
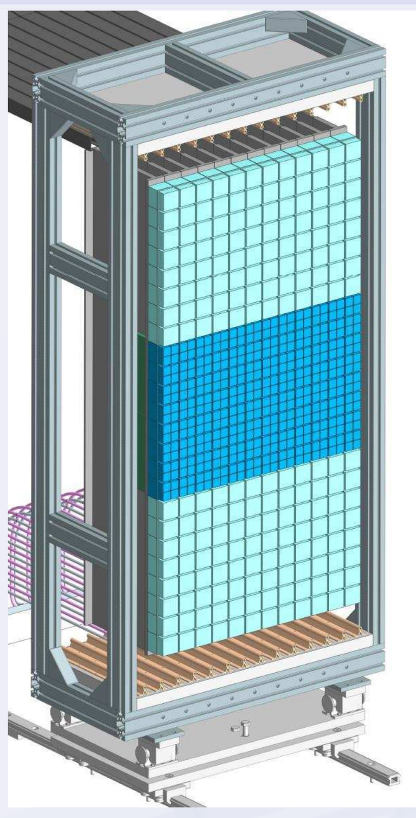
LHCb Detector Upgrade & Challenges





RICH 2 Array of MaPMTs

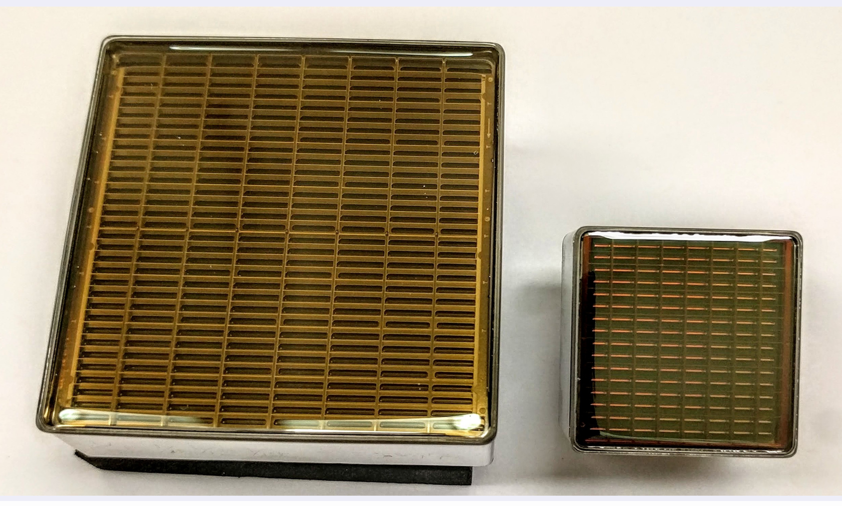
Challenges for the **RICH Upgrade**: *[CERN-LHCC-2013-022]*

- Higher luminosity $\mathcal{L} = 2 \times 10^{33}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$
- 40 MHz readout
- **New photon detectors** (sensitive to single photons between **300** and **700 nm**, good spatial resolution, high Quantum Efficiency)
- **New readout electronics** (**dead time 25 ns**, low power consumption, radiation tolerance)
- Significant **modifications to RICH 1** to reduce peak occupancy (optics to be optimised, mechanics to be redesigned)

LHCb Upgrade 1a taking place during 2019-20

Multi-anode Photomultiplier tubes (MaPMT)

Fast, sensitive to single photons, large active area, excellent granularity, radiation hard, from Hamamatsu: *[arXiv:1403.3215]*



- **R13742** (Custom variant of R11265) 1 in, 64 (8 $\times$ 8) pixels for RICH 1 and RICH 2
- **R13743** (Custom variant of R12699) 2 in, 64 (8 $\times$ 8) pixels for RICH 2 peripheral area only
- External readout electronics

The Photon Detector Quality Assurance

The aim of the procedure:

- **Verify** minimal contractual specifications
- **Characterise** - average gain, uniformity, peak-to-valley ratio, dark count rate
- **Organise** MaPMTs in groups of 16 based on common HV performance

Challenges:

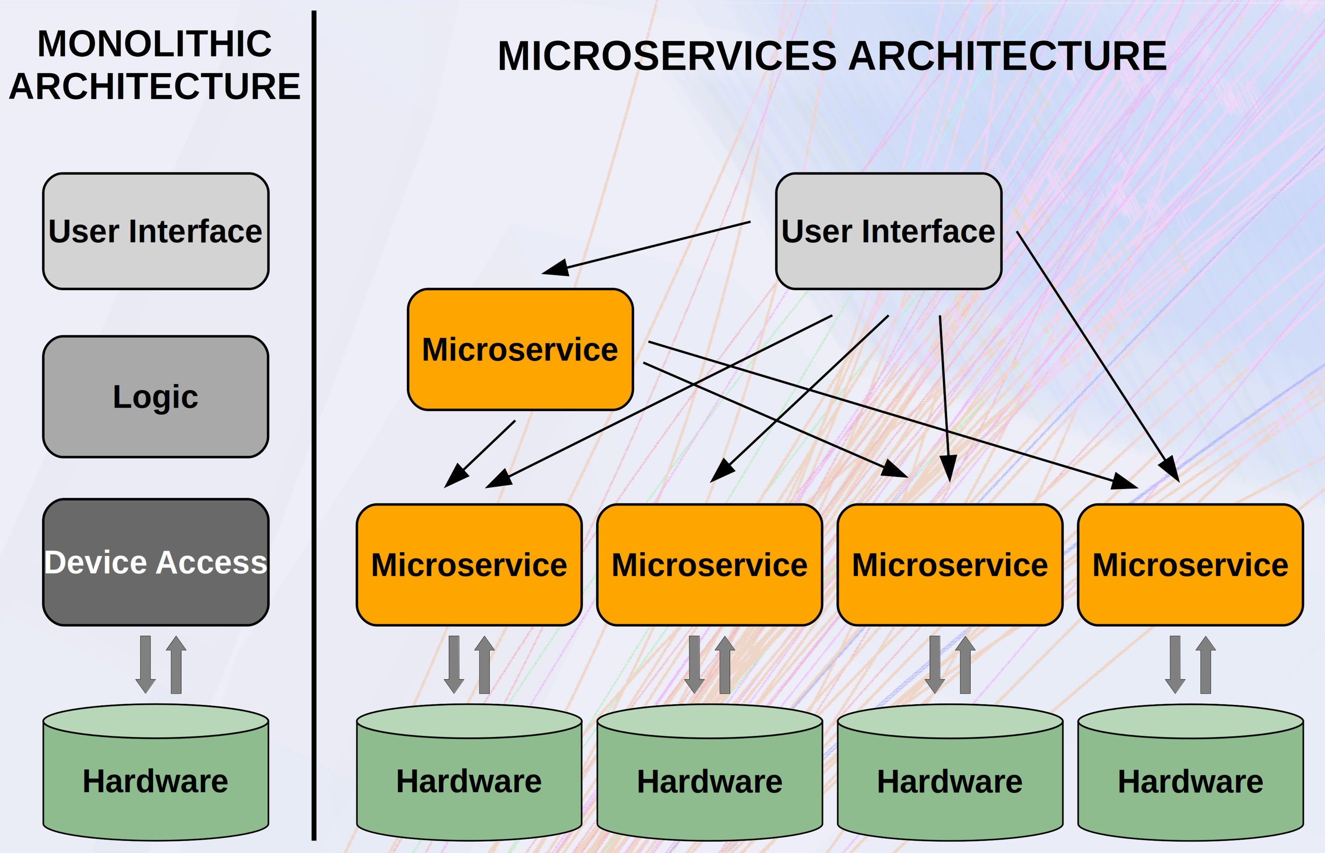
- High-numbers to be tested over two years
- **3100** $\times$ **R13742**
- **450** $\times$ **R13743**

Requirements for testing:

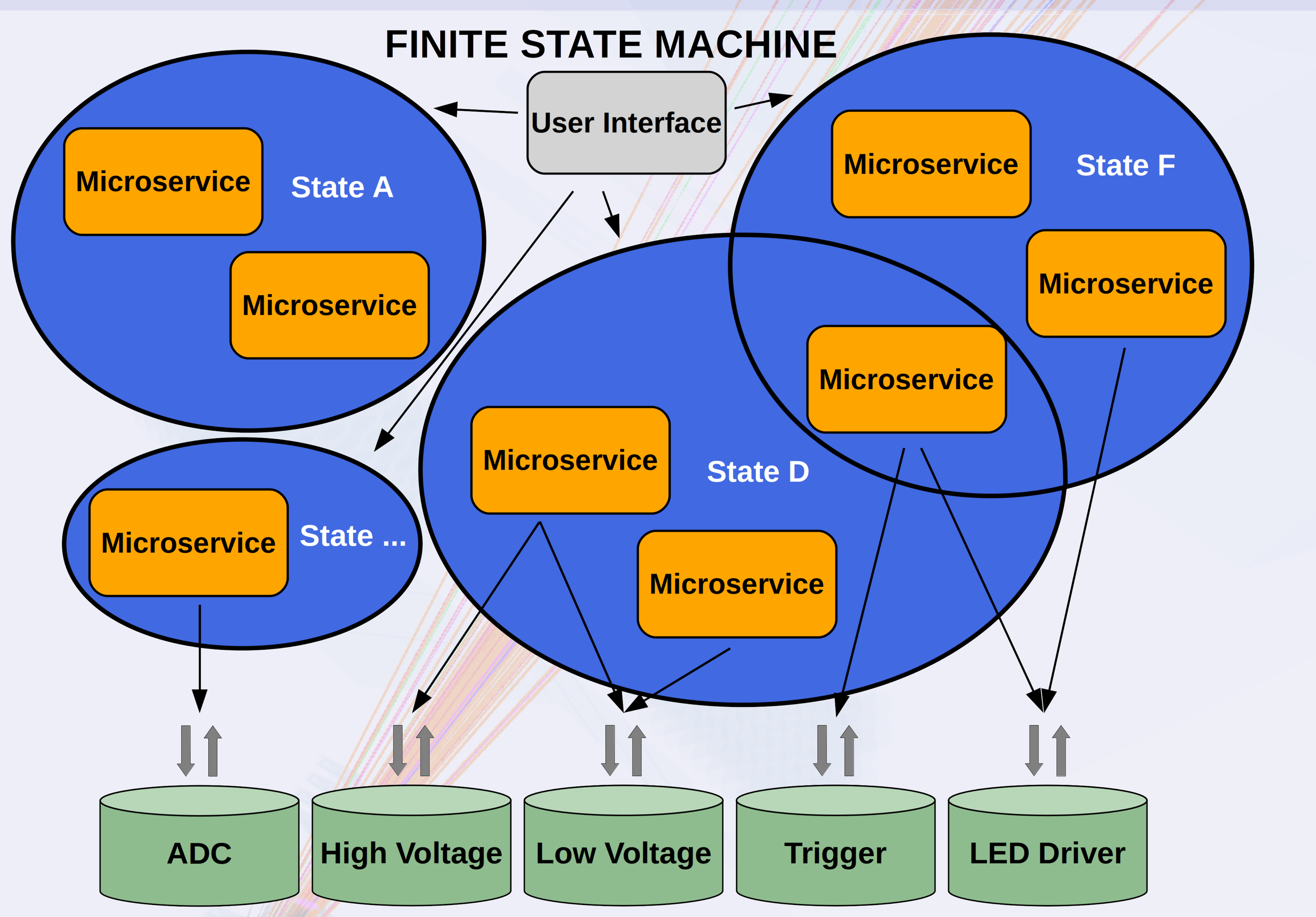
- Reliability
- Redundancy
- Elevated automation

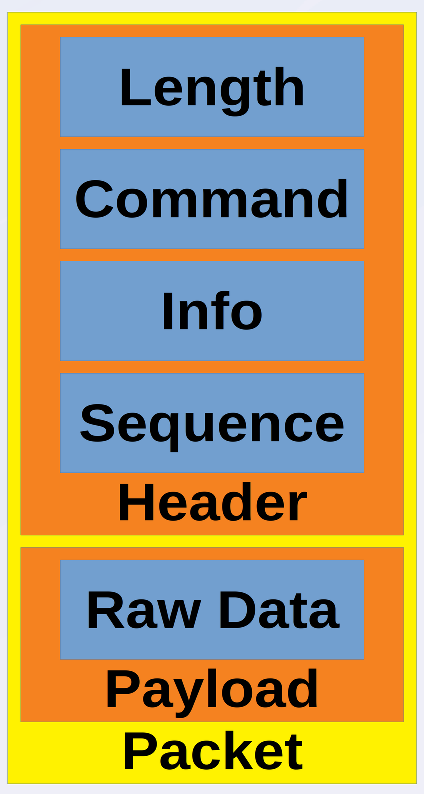
Microservice Architecture

Design was chosen to ensure reliability and high availability. The architecture provisions **independent auto-recoverable microservices** and native **multi-threaded operation**.



System Model & Communication



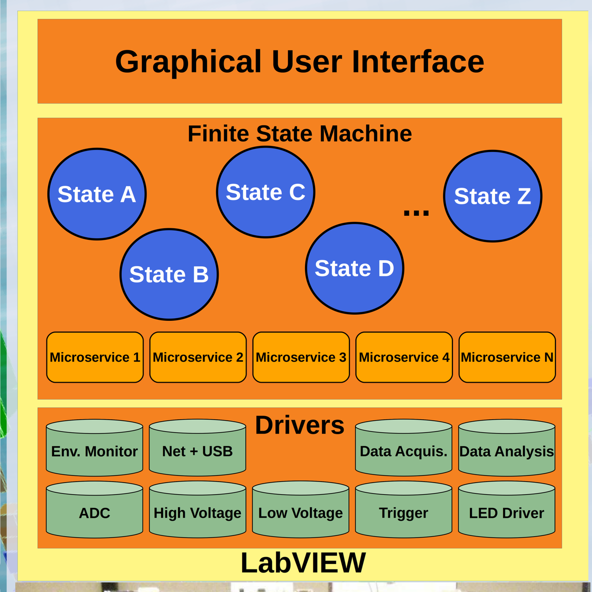


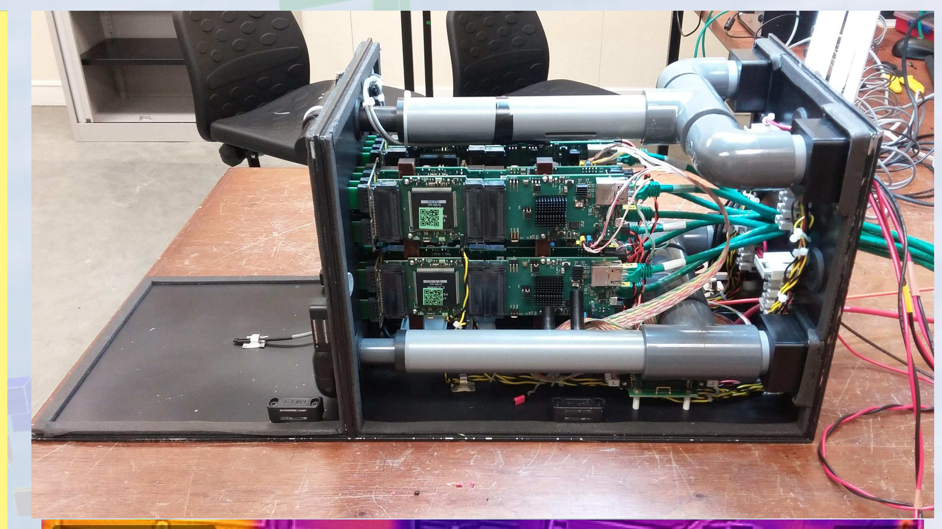
Communication Protocol

The system is designed as an **FSM with independent and self-sufficient states**. **Each state can communicate with several microservices** to accomplish tasks. State transitions occur when a state calls another and exits. States determine internal logic based on successfully performing their tasks. Communication is parallel and messages are verified.

The PDQA Test Bench

Fully integrated FE readout with Data Acquisition and Environment Control:





FE:
MAROC3 ASIC 8bit ADC

DAQ:
Chimaera FPGA boards

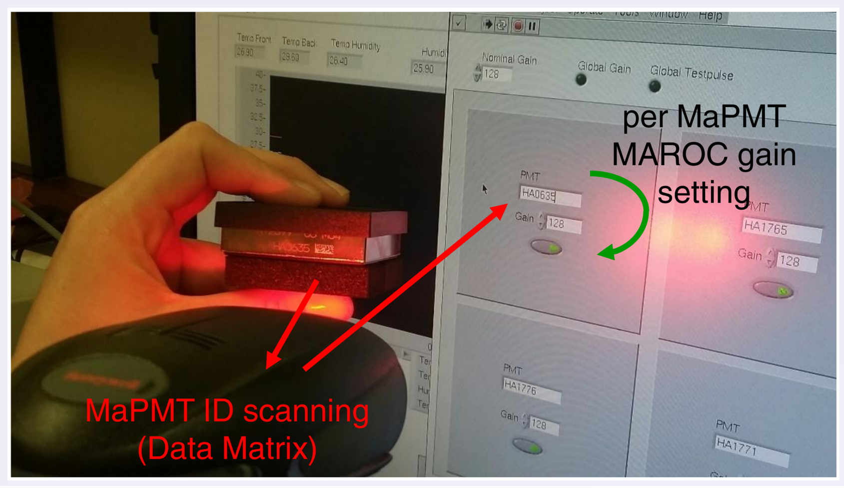
Box:
Automated Control Station

Power & Cooling

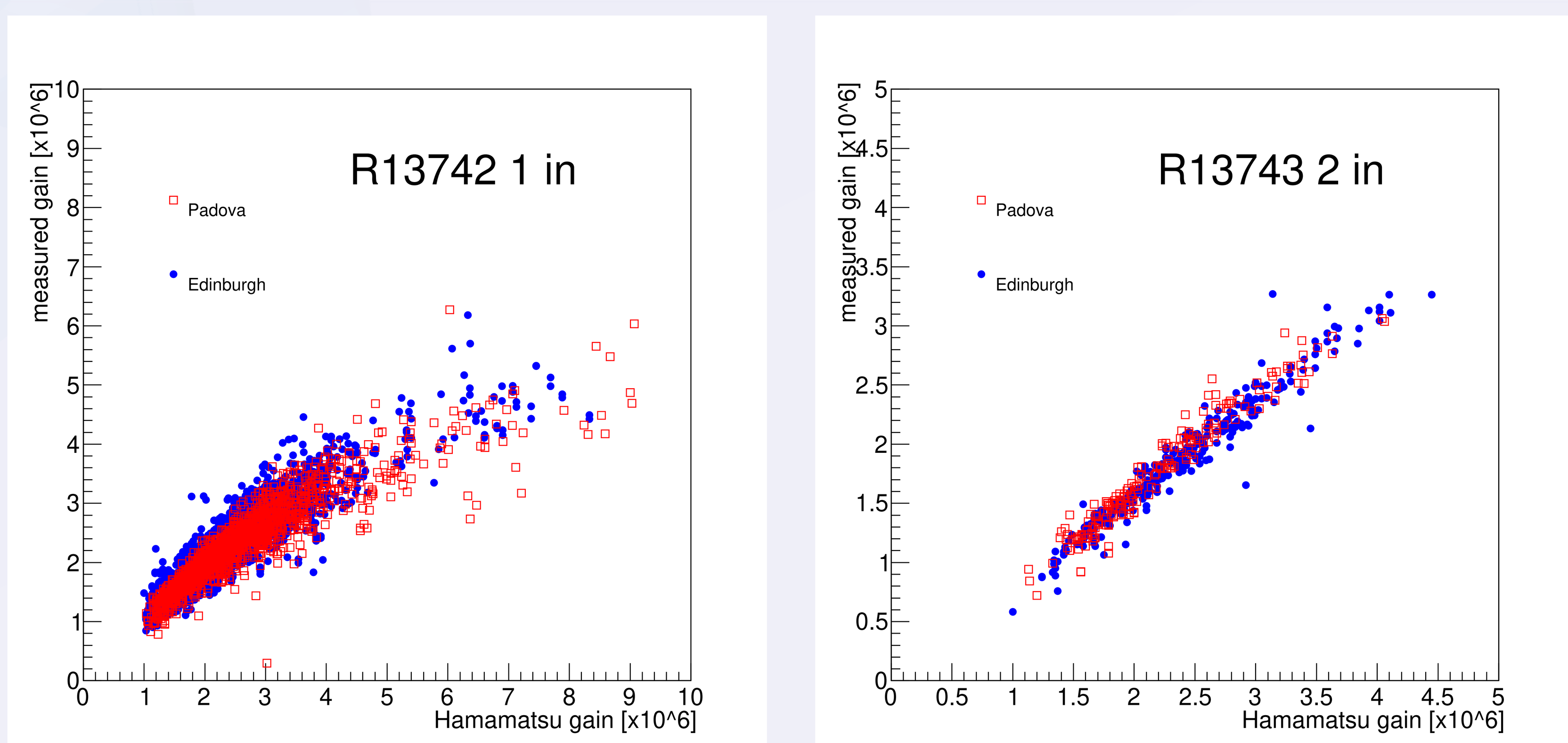
The Automated System

In the past two years, testing involved a strict schedule and highly standardised procedure. 4 test stations were successfully set up in 2 different test facilities - Edinburgh, UK and Padua, Italy. *[Nucl.Instrum.Meth. A876 (2017) 206-208]*

- General API
- Easily adapted to other projects
- LabView GUI
- Low-level in C++ for performance
- XML for conf. human readable
- CERN ROOT for data analysis



Results



Comparing Hamamatsu datasheet values for gain 1 in (left) and 2 in (right). The average gain is one of the most important parameters. We require a gain of at least a 1M electrons.

Conclusion

The QA operated by the automated system tested a total number of 3100 & 450 (1 in & 2 in) MaPMTs. The system was deployed on four stations in two labs and consistently characterised 16$\times$1 in (4$\times$2 in) PMTs per station per day. The results show excellent gain, uniformity and single photon resolution. Moreover, the automation allowed for thorough consistency between the two labs and overall efficiency increase.