LHCb photon detector testing

Silvia Gambetta

University of Edinburgh

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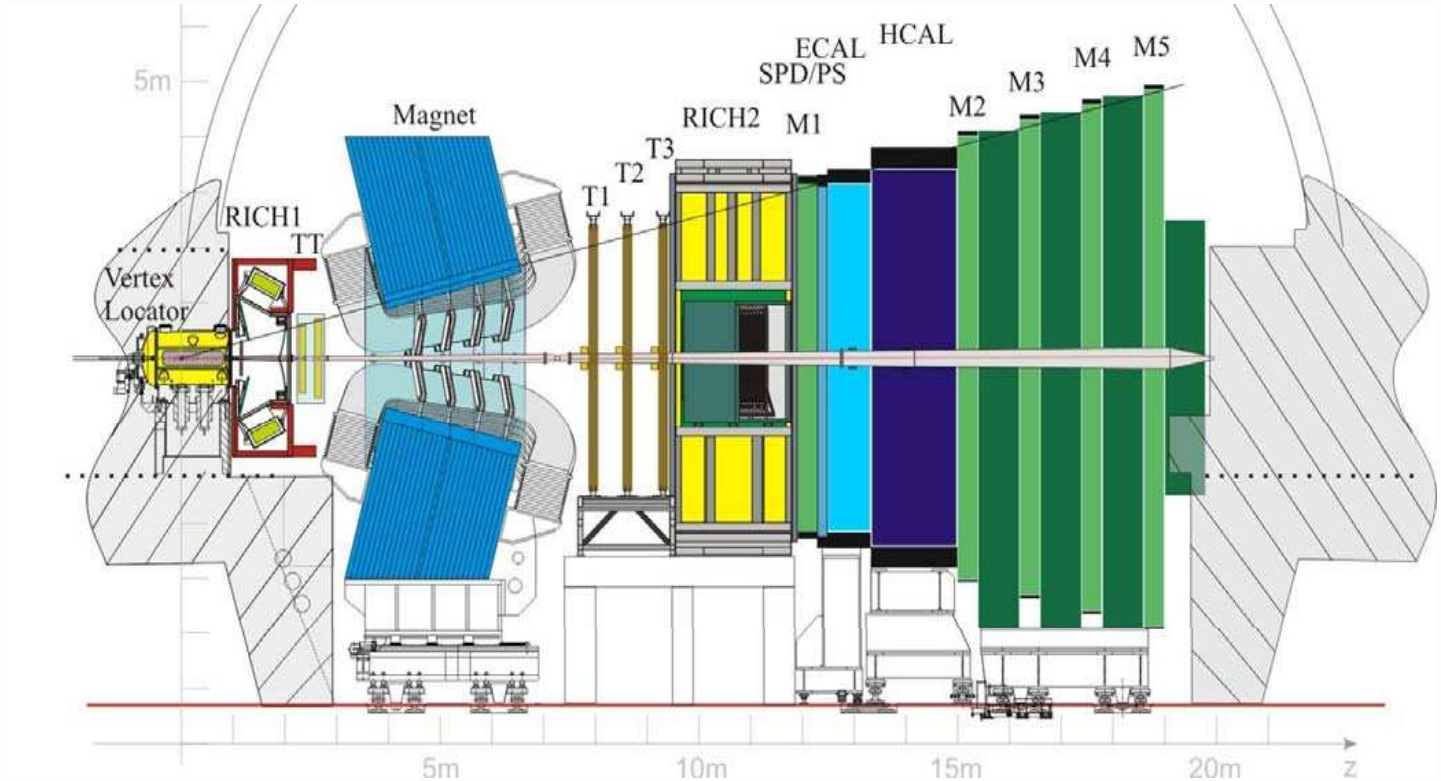
Outline

- LHCb upgrade
- RICH upgrade challenges
- the Photon Detector Quality Assurance
- status and tests done in Edinburgh

The LHCb experiment

LHCb is a flavour factory: search for new physics in the decays of heavy hadrons containing quarks b and c



	LHCera			HL-LHCera	
Run # (year)	Run 1 (2010-12)	Run 2 (2015-18)	Run 3 (2021-23)	Run 4 (2025-28)	Run 5+ (2030+)
Integrated luminosity	3 fb^{-1}	8 fb^{-1}	23 fb^{-1}	46 fb^{-1}	100 fb^{-1}
LHCb up to LS2			**after LHCb upgrade**		

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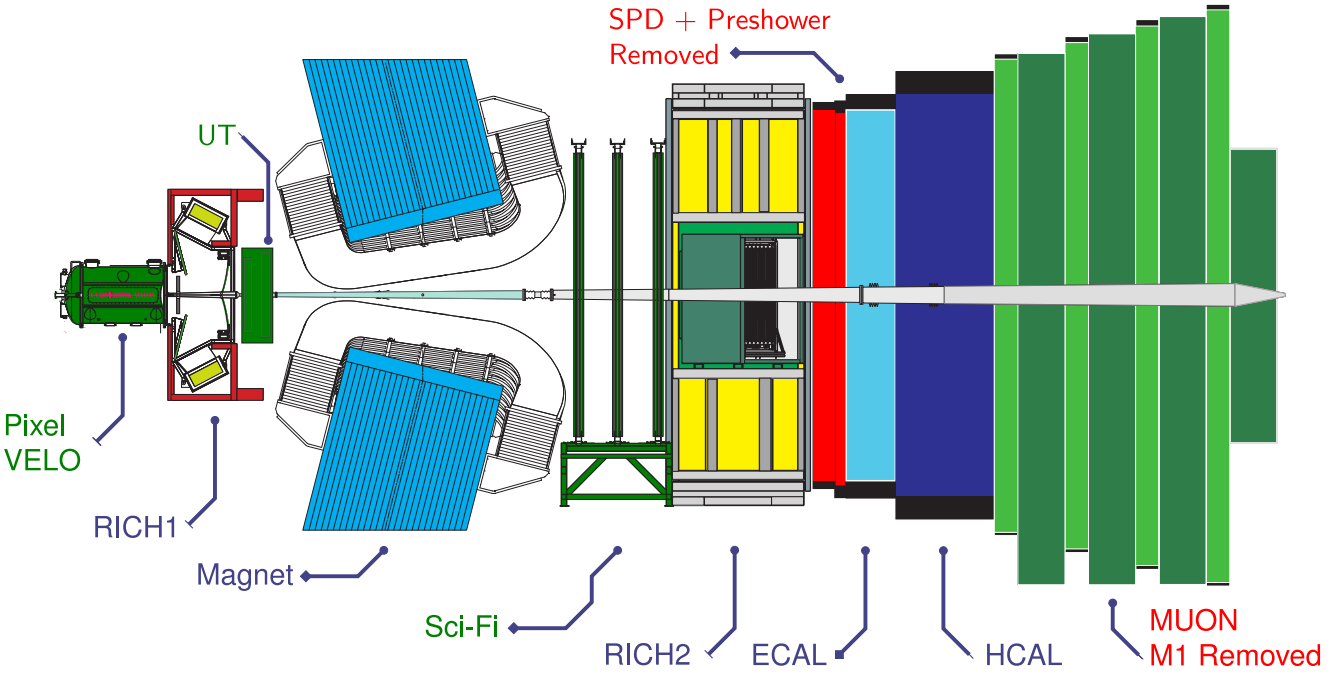

	LHC era			HL-LHC era	
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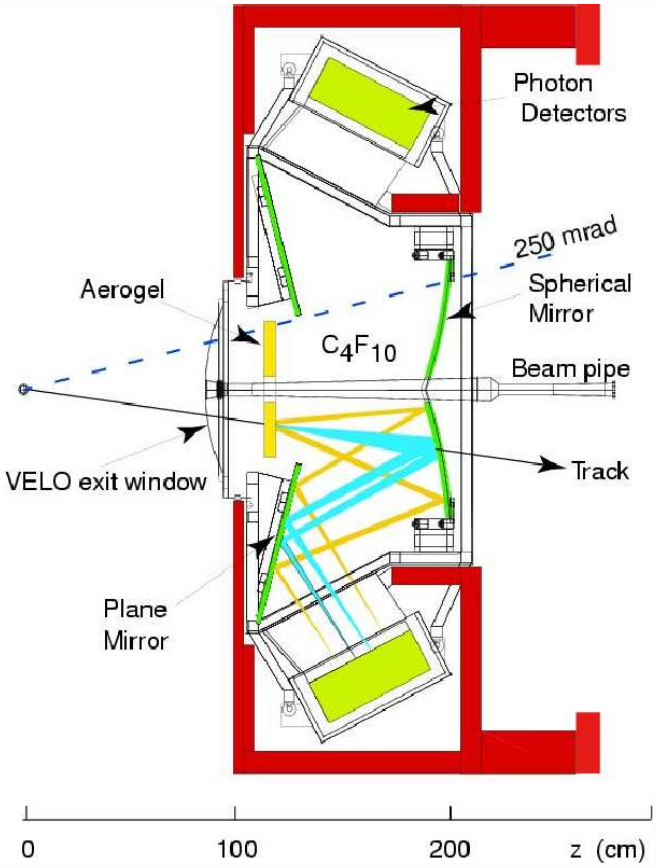
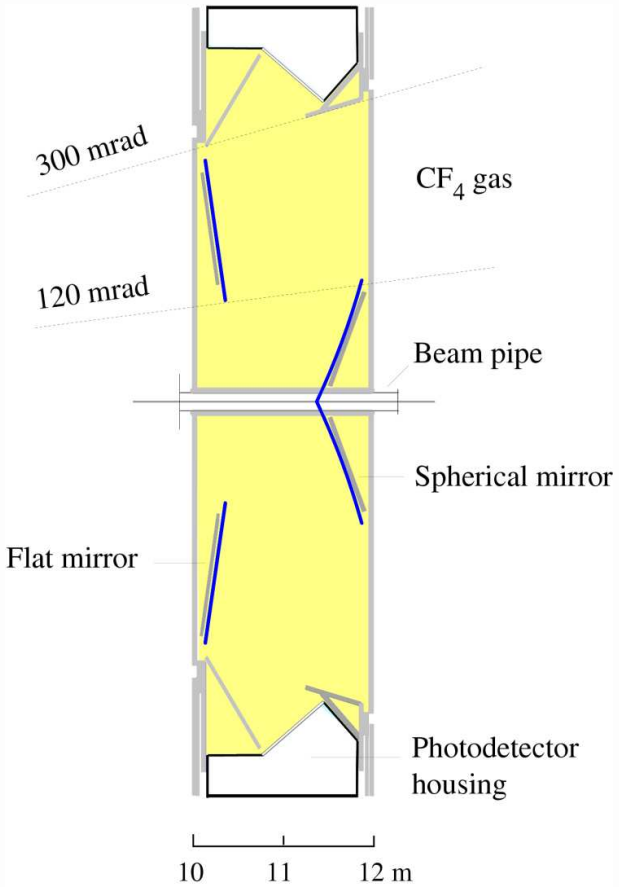
The RICH detector

Particle Identification: pion/kaon/proton separation needed to differentiate between kinematically nearly identical decays

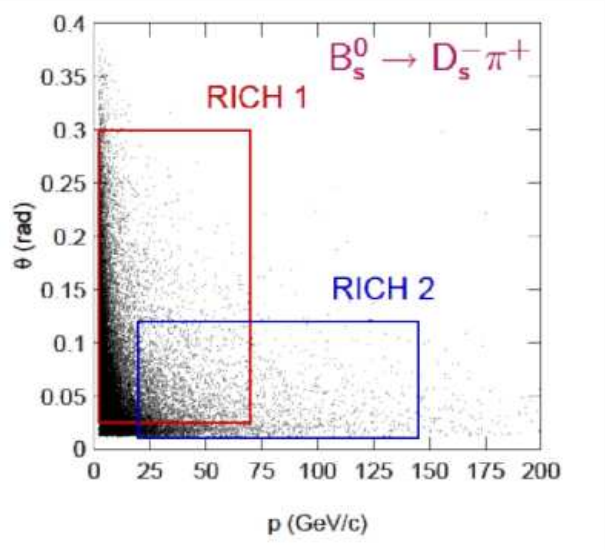
RICH 1



RICH2



- 2 detectors
- 2 radiators
- different energy range for PID



- same Photon Detector: Hybrid Photon Detector (with embedded front-end electronics)

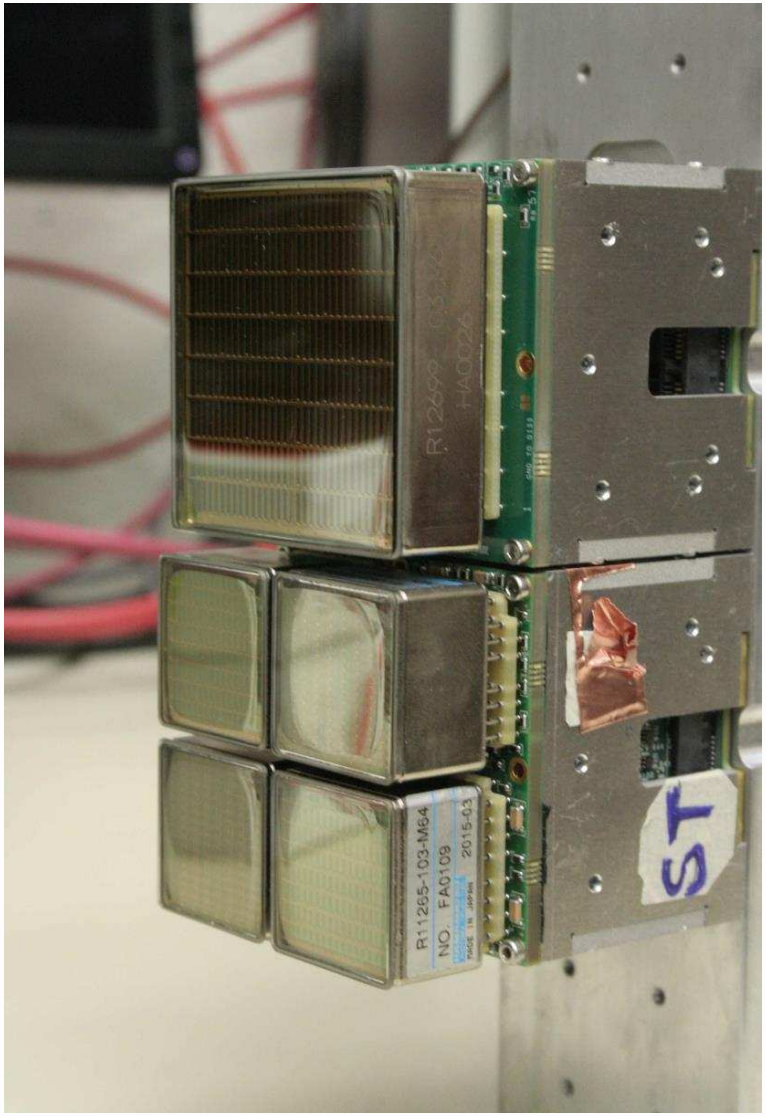
RICH upgrade challenges

LHCb upgrade will take place in 2018 during the second long shutdown $\Rightarrow$ higher luminosity: $2 \times 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$
Remove trigger limitations and readout detector$\Rightarrow$from 1 MHz to 40 MHz

- New readout electronics:
  - fast electronics (dead time $< 25\,\mathrm{ns}$)
  - low power consumption
  - radiation tolerance
- New photon detectors:
  - sensitive to single photons in the wavelength range between 200 and 600 nm
  - good spatial resolution
  - negligible cross talk between neighbouring pixels
  - negligible dark current rate
  - not affected by magnetic field
- significant modifications to RICH1 to reduce peak occupancy:
  - optics to be optimised
  - mechanics to be redesigned

The Photon Detectors for the RICH upgrade

Multi-anode Photomultiplier Tubes: fast, sensitive to single photons, large active area, excellent granularity, radiation hard



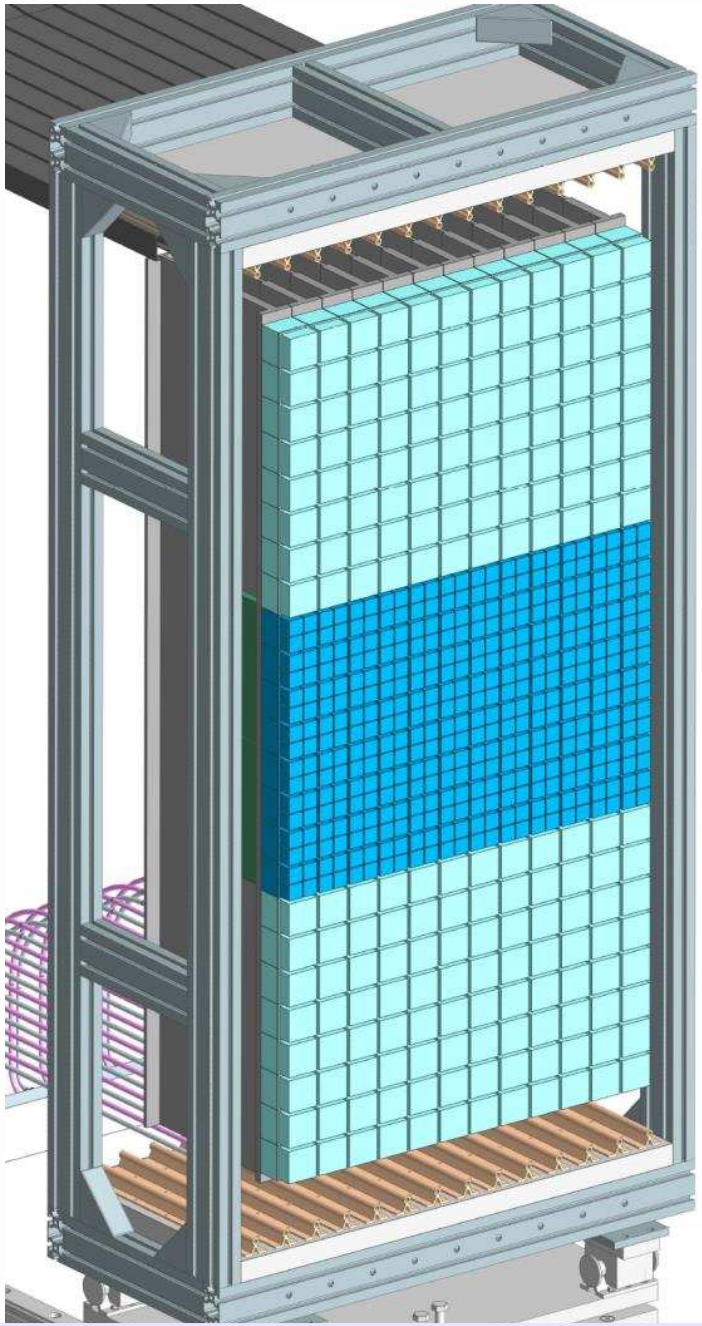
intense test campaign to select:

- Hamamatsu R11265: 1", 64 (8×8) pixels for RICH1 and RICH2
- Hamamatsu H12699: 2", 64 (8×8) pixels for RICH2 peripheral areas only (PID performance only slightly degraded, costs significantly reduced)

devices characteristics tested:

- single photon detection, gain and uniformity
- dark count rate
- cross-talk
- behaviour vs temperature
- tolerance to magnetic field
- ageing

The Photon Detector Quality Assurance



High number of units to be tested over two years:

- 3100 R11265: 1”
- 450 H12699: 2”

Aim of the PDQA:

- verify minimum contractual specifications
- determine parameters for the selection of photon detectors
- gather initial calibration variables

Requirements for testing:

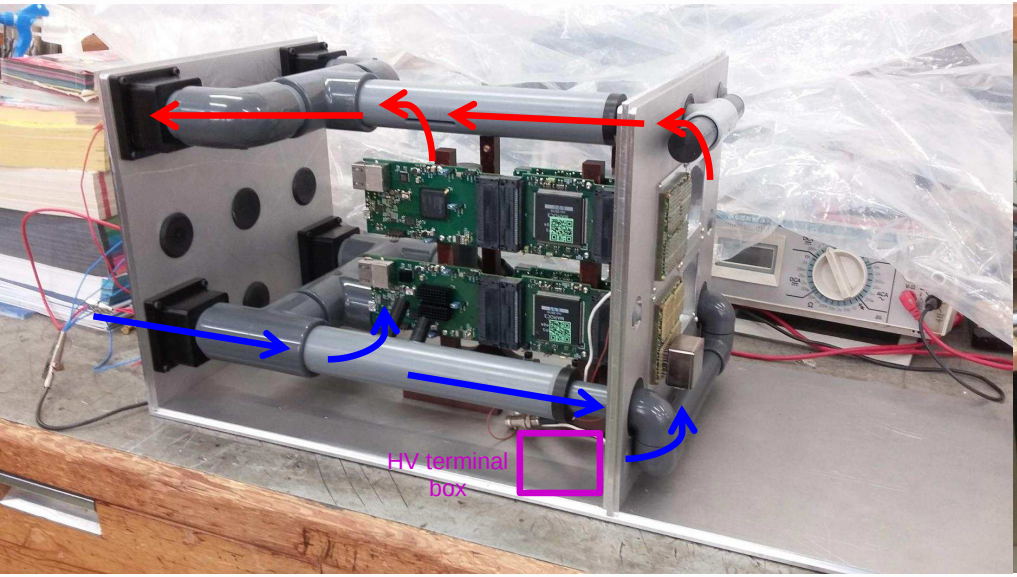
- reliability
- redundancy
- elevated automation

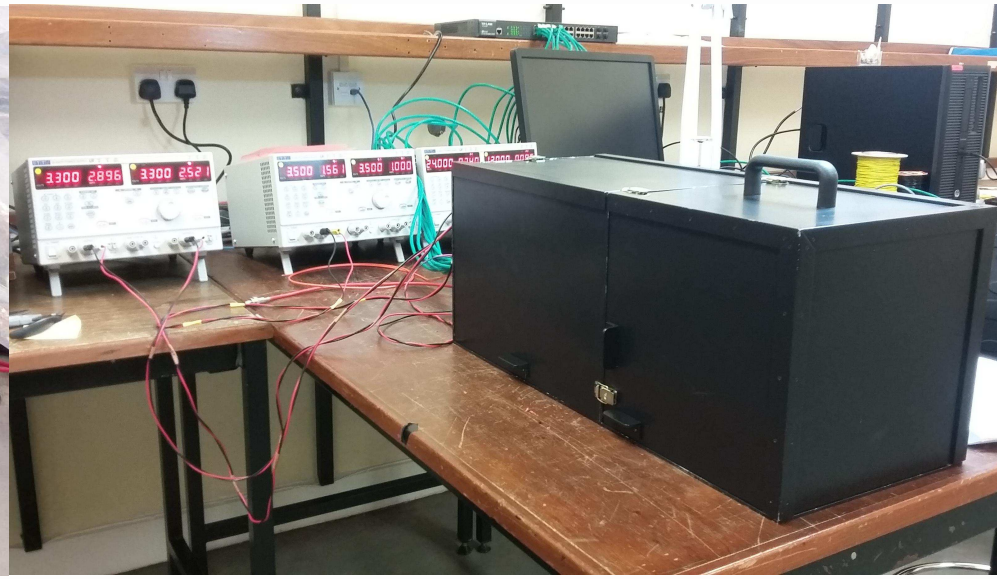
Two tests facilities:

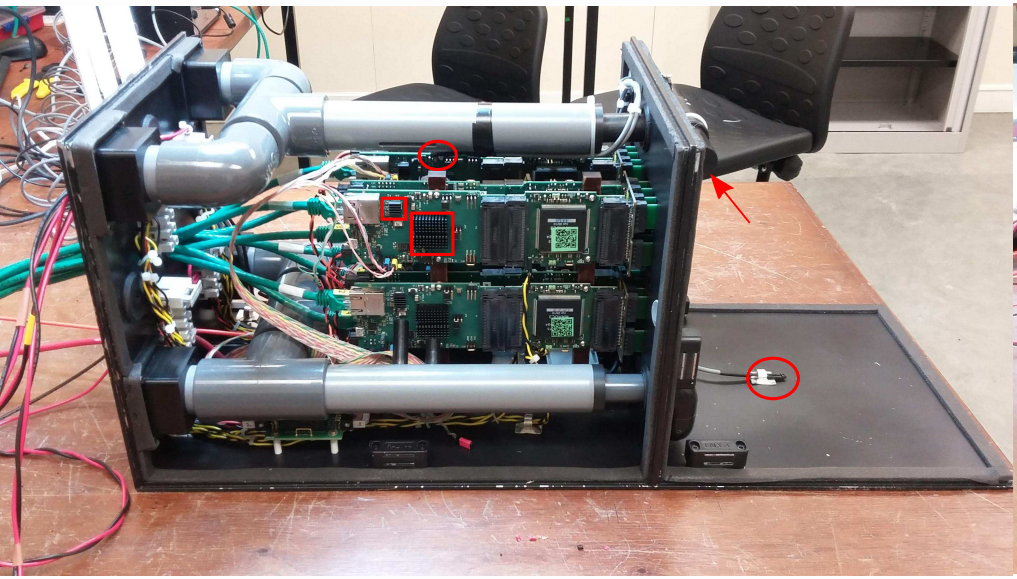
- Edinburgh
- Padova

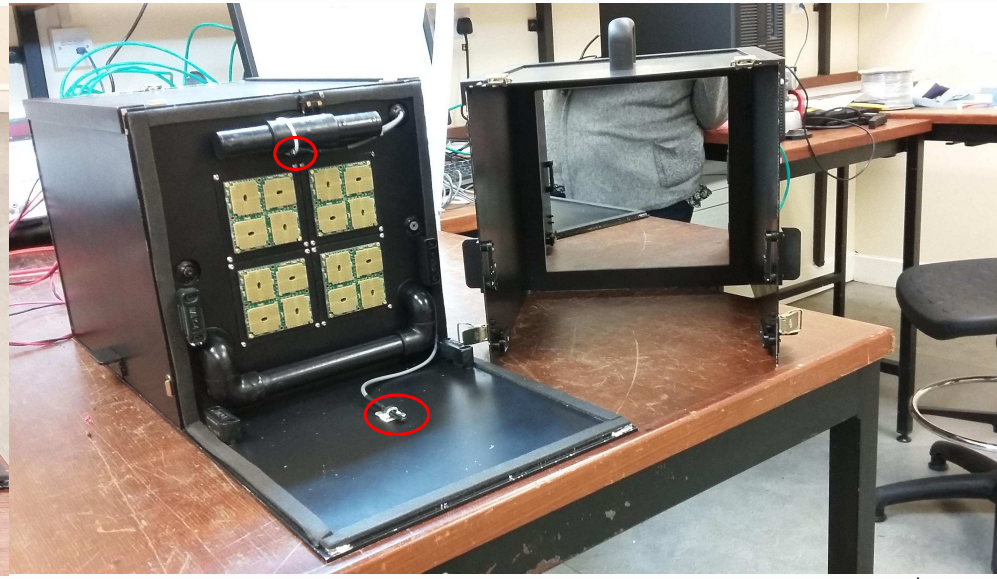
Test setup

Setup conceived, designed and produced in Edinburgh



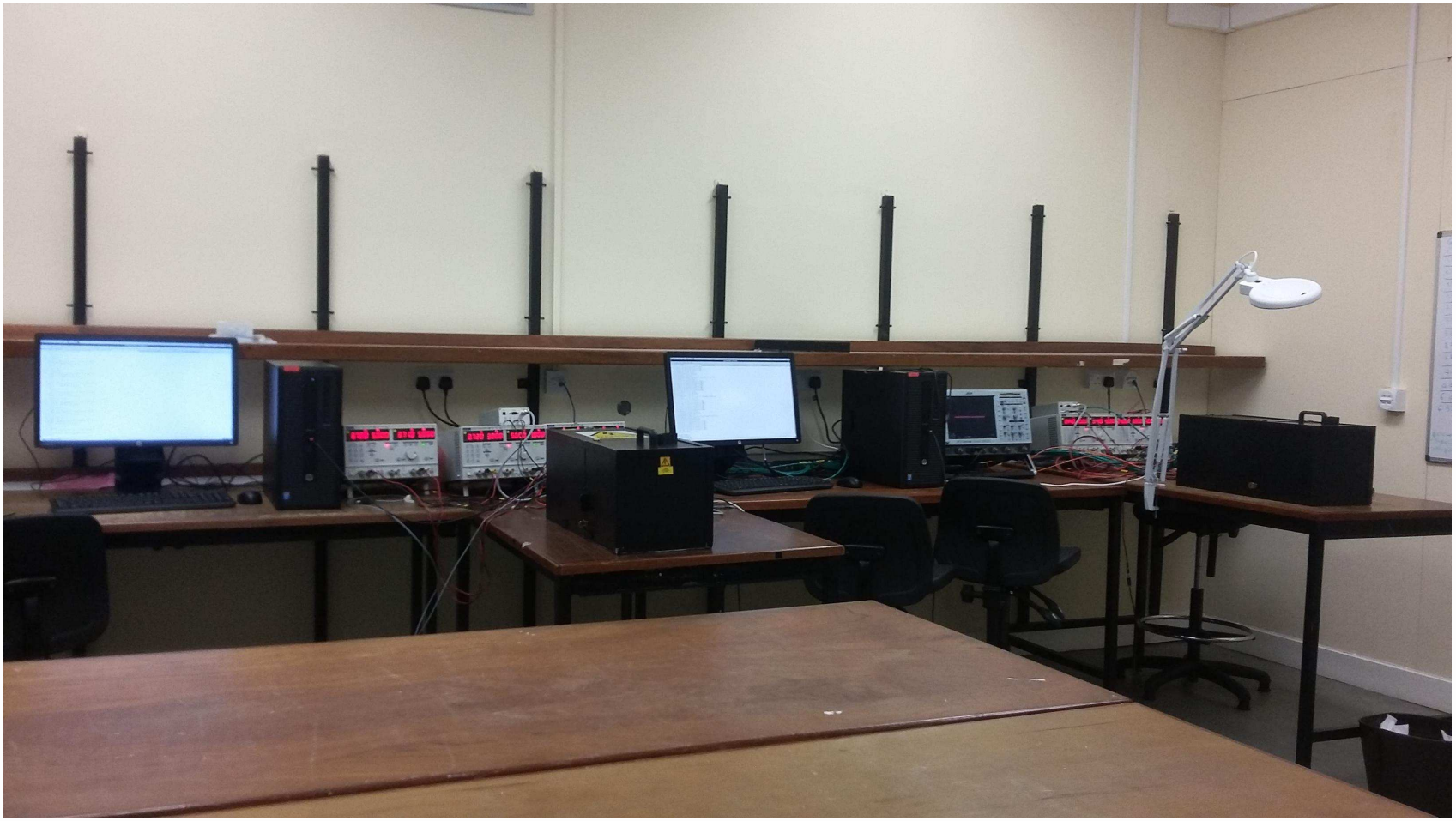






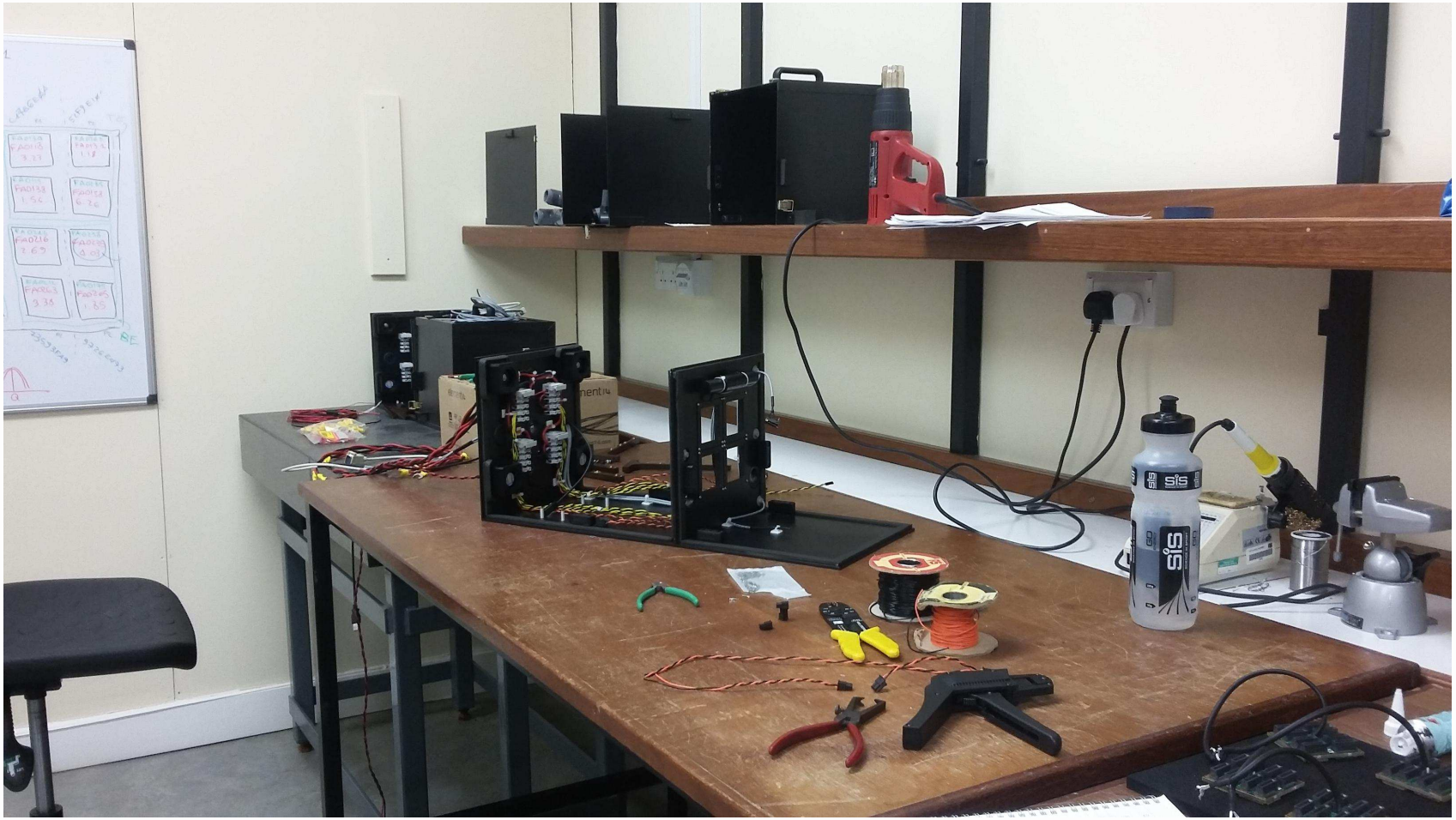
The PDQA lab

Edinburgh test stations produced, installed and commissioned in 5207



The twin facility

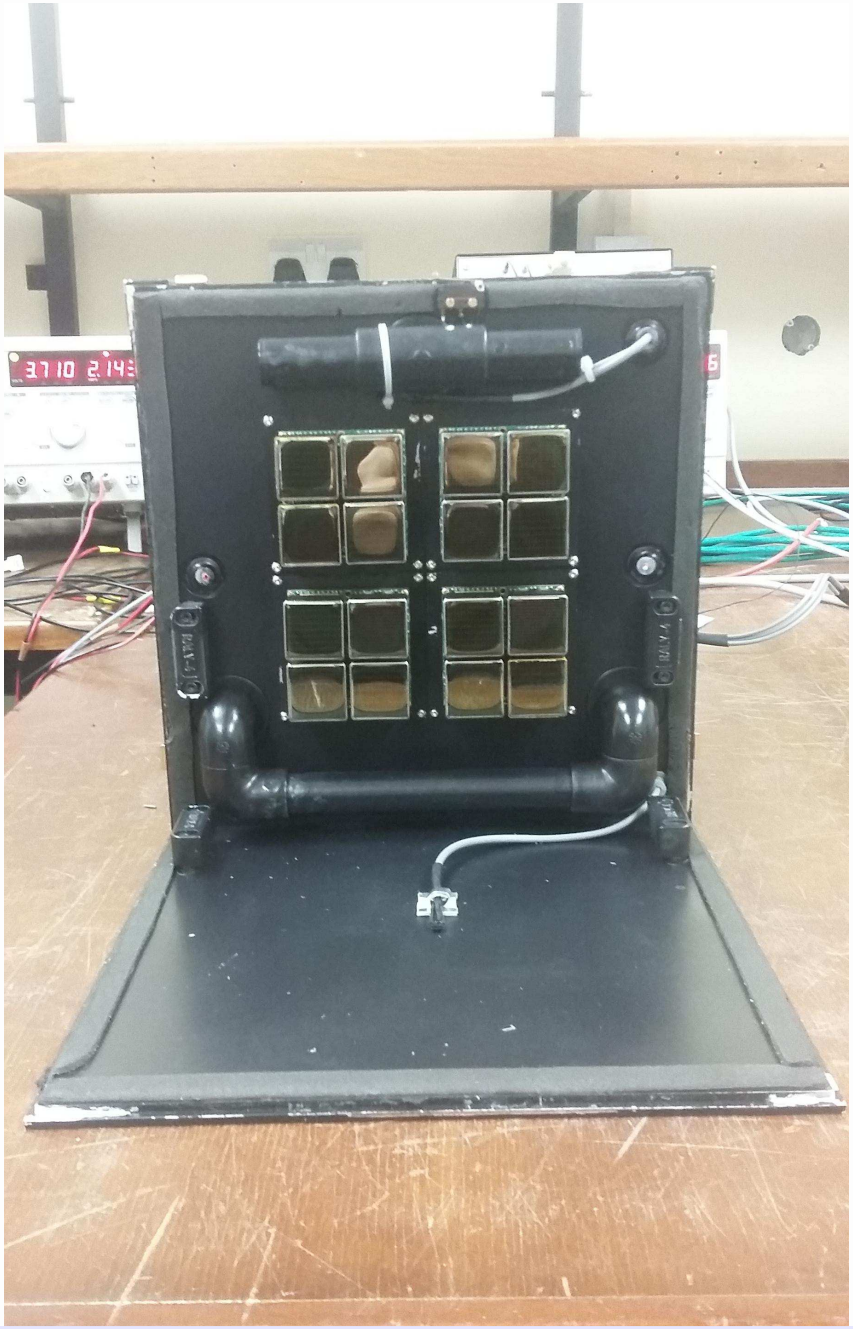
Two more test stations produced, ready to be shipped to Padova

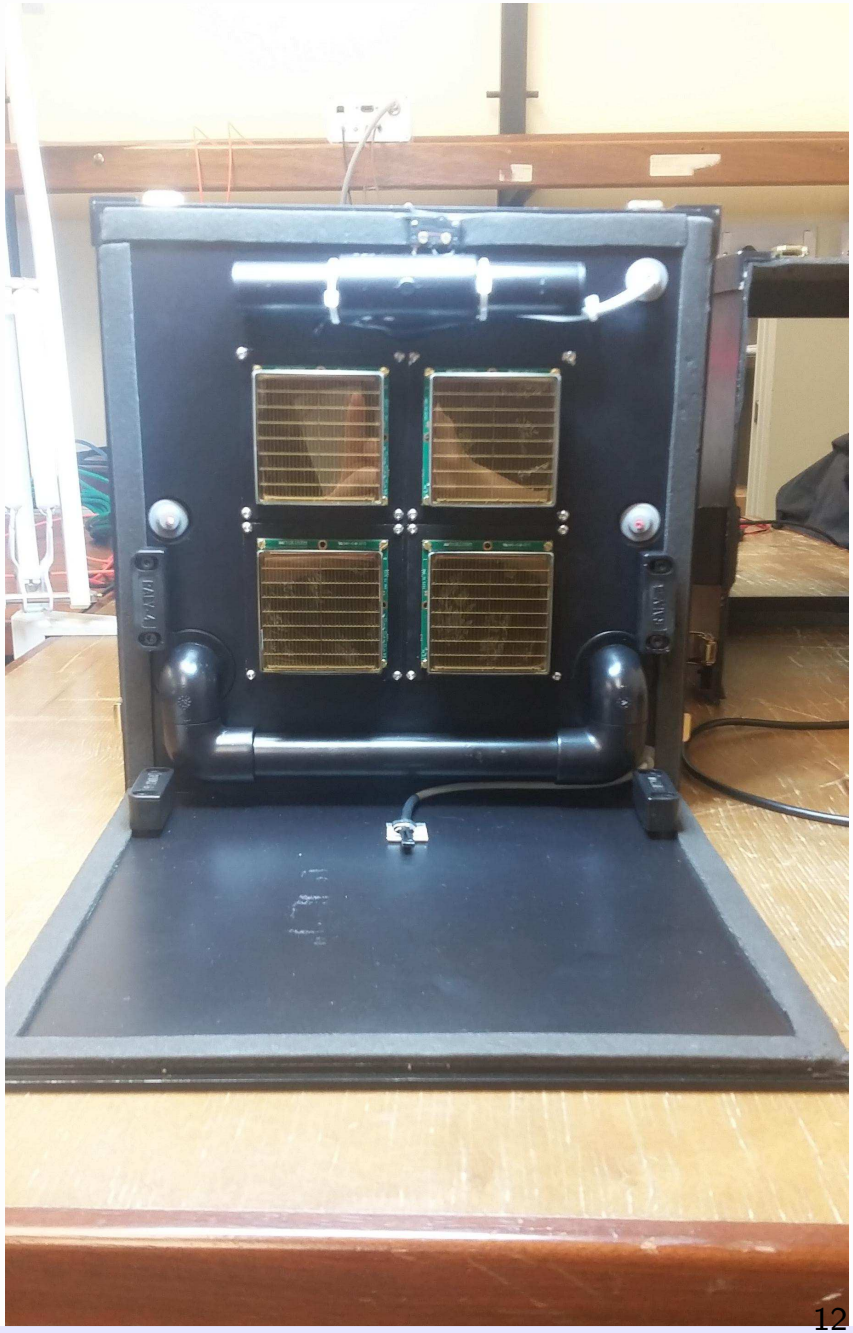


The pre-production

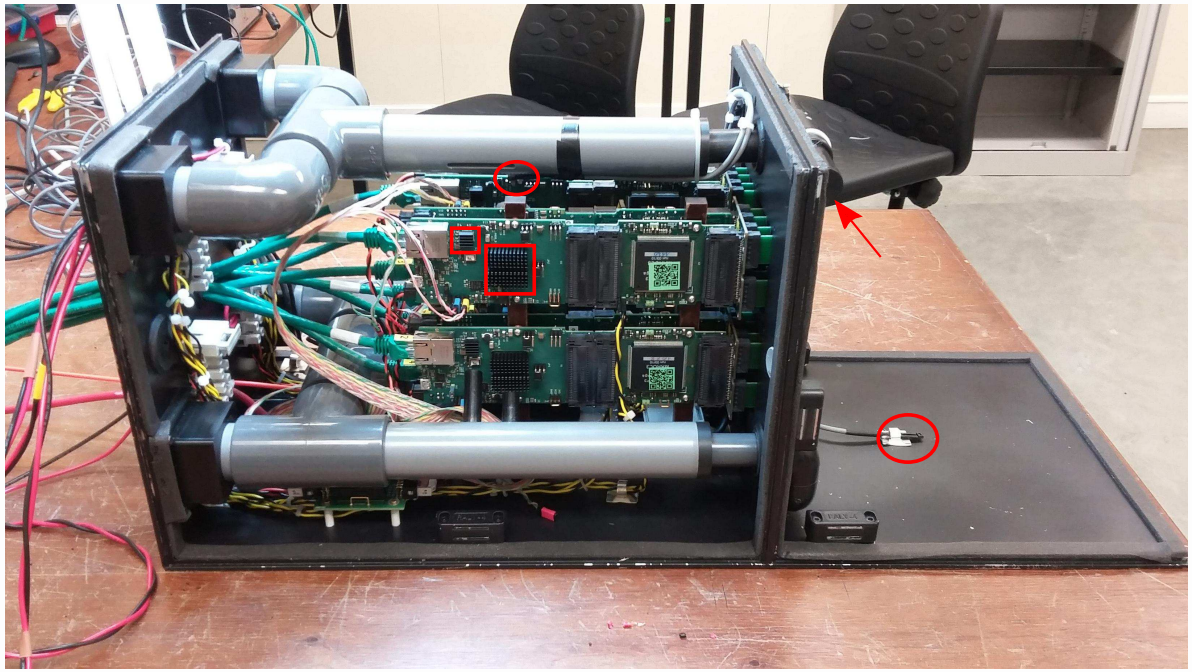
54 units of 1" MaPMTs and 20 units 2" MaPMTs received by Hamamatsu

The first tests



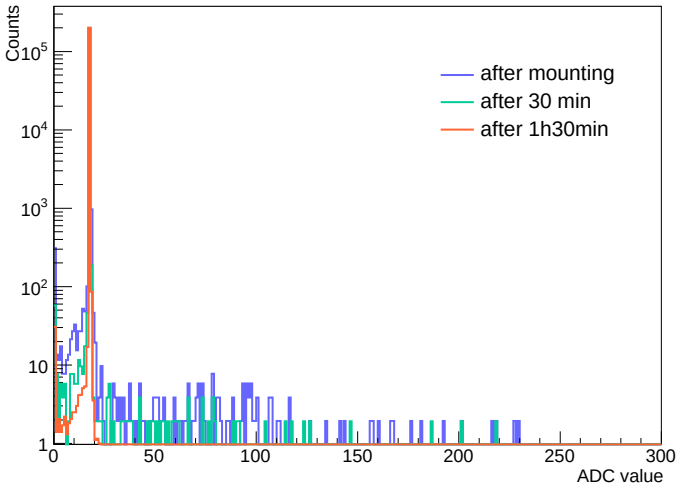


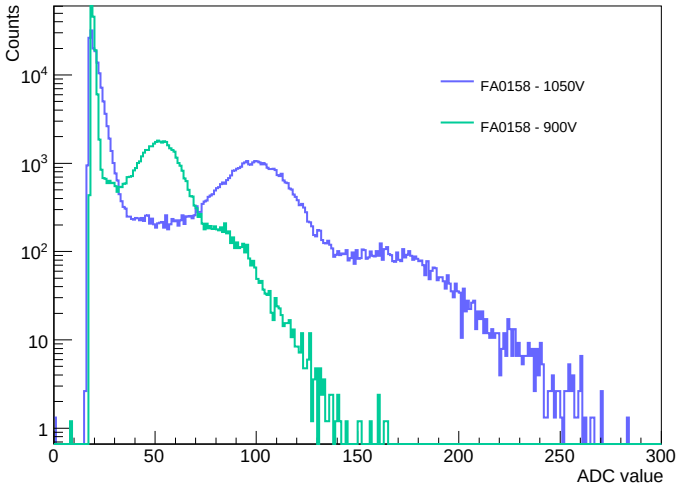
DAQ chain



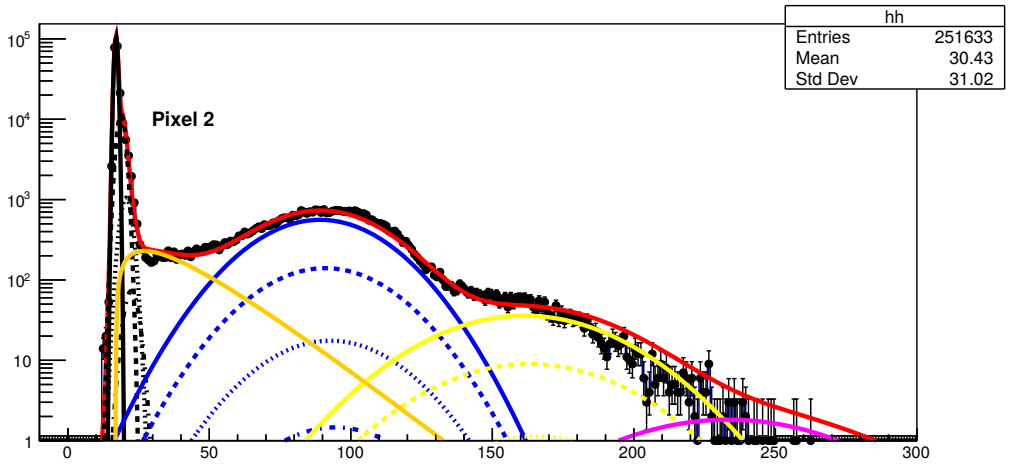
- baseboard to power MaPMTs (Genova)
- adapter board to interface baseboard to front-end (Edinburgh)
- MAROC3 chip by Omega
- 64 channels chip designed to readout signal from MaPMTs
- 2 fast digital channels + 1 slow analog channel available
- preamplification stage to adjust gain per pixel
- MAROC chip mounted on dedicated board (Cambridge)
- Chimaera board to readout MAROC output (Cambridge)

Test procedure



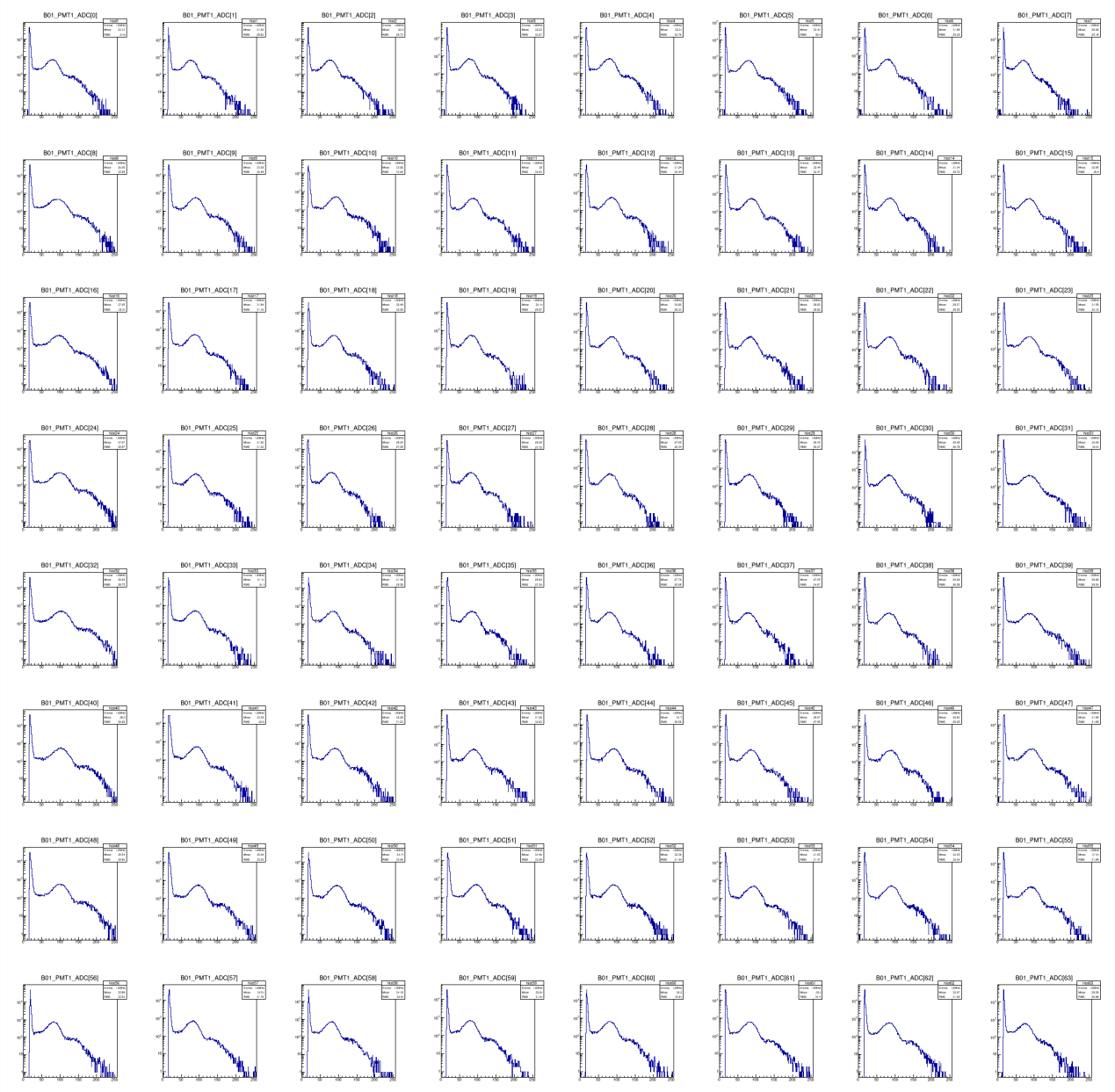


- MaPMTs loaded
- runs with no illumination to monitor dark counts
- runs at different values of HV
- fit all the data!



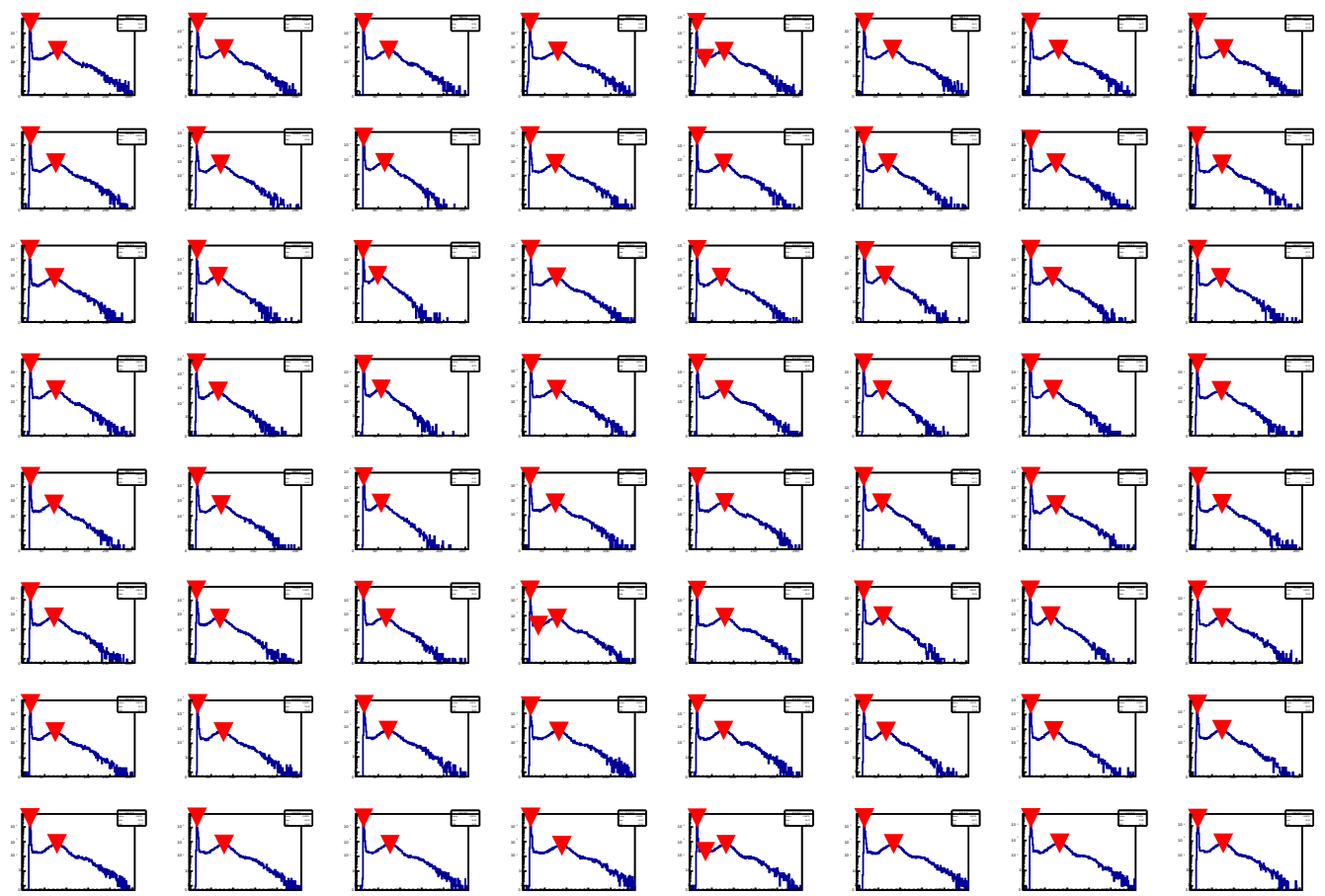
- pixel gain (at different HV)
- MaPMT gain uniformity
- signal loss
- peak/valley
- uniformity

Typical run



$64 \times 16 = 1024$ fits per run $\Rightarrow \sim 10000$ fits per testload of 1" !!!

Preliminary analysis on pre-series

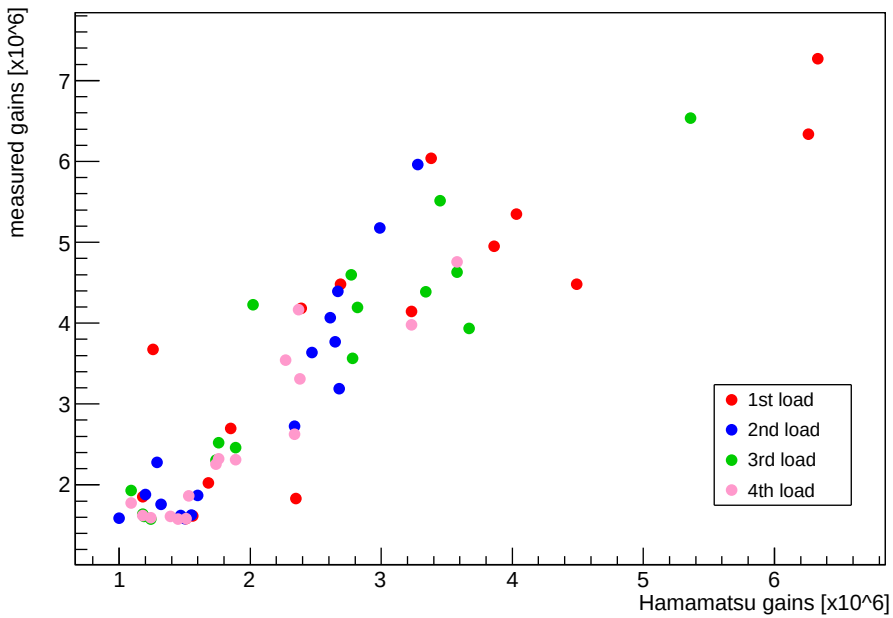


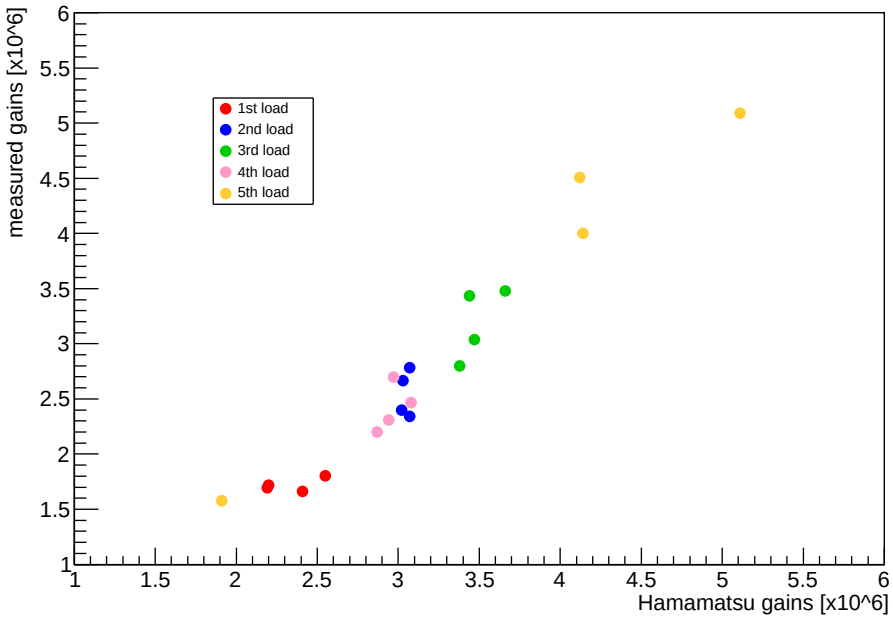
- quick analysis to have a global view ⇒ average gain
- first look at single peaks position ⇒ correlation with datasheet
- check minimum requirements on uniformity
- check minimum requirements on peak/valley

MaPMTs gain

Comparison of average gain measured with the average gain provided by Hamamatsu for 54 1" and 20 2":

- peak position extracted for each pixel of MaPMT
- average of peak position converted to charge and than gain
- no quality cut of single pixels

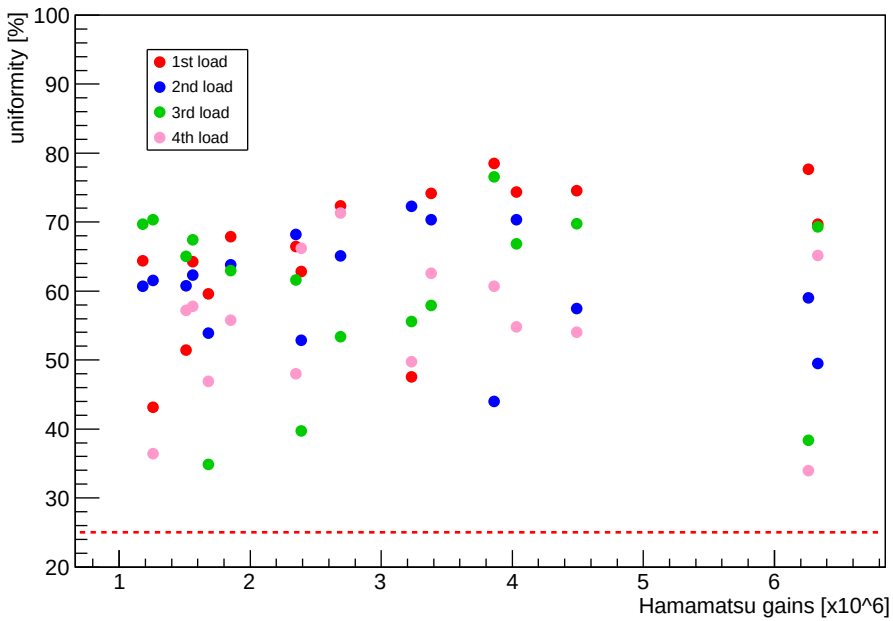


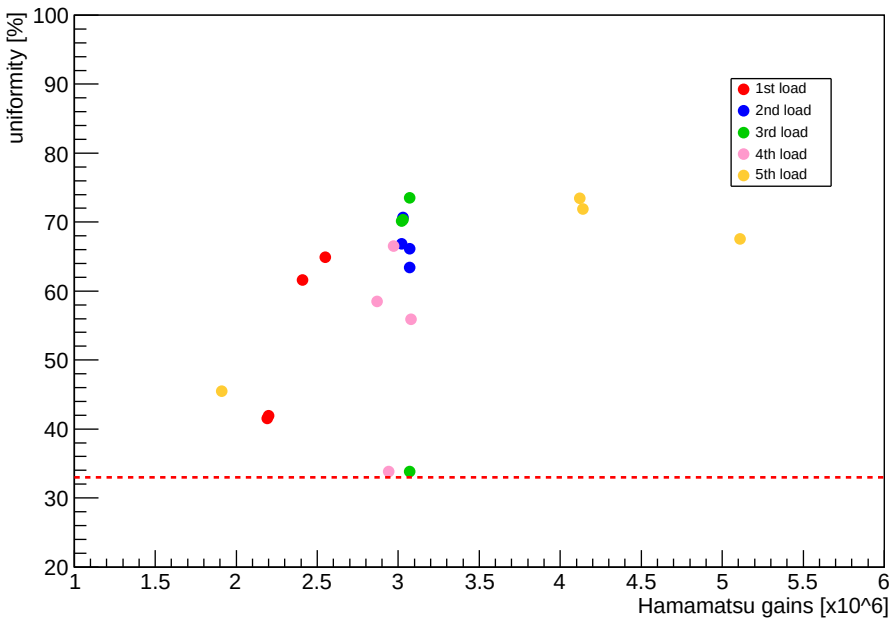


MaPMTs uniformity

Gain uniformity requirement: 1:4 for the R11265 and 1:3 for the H12699

- peak position extracted for each pixel of MaPMT
- peak positions normalised to the pixels with highest gain





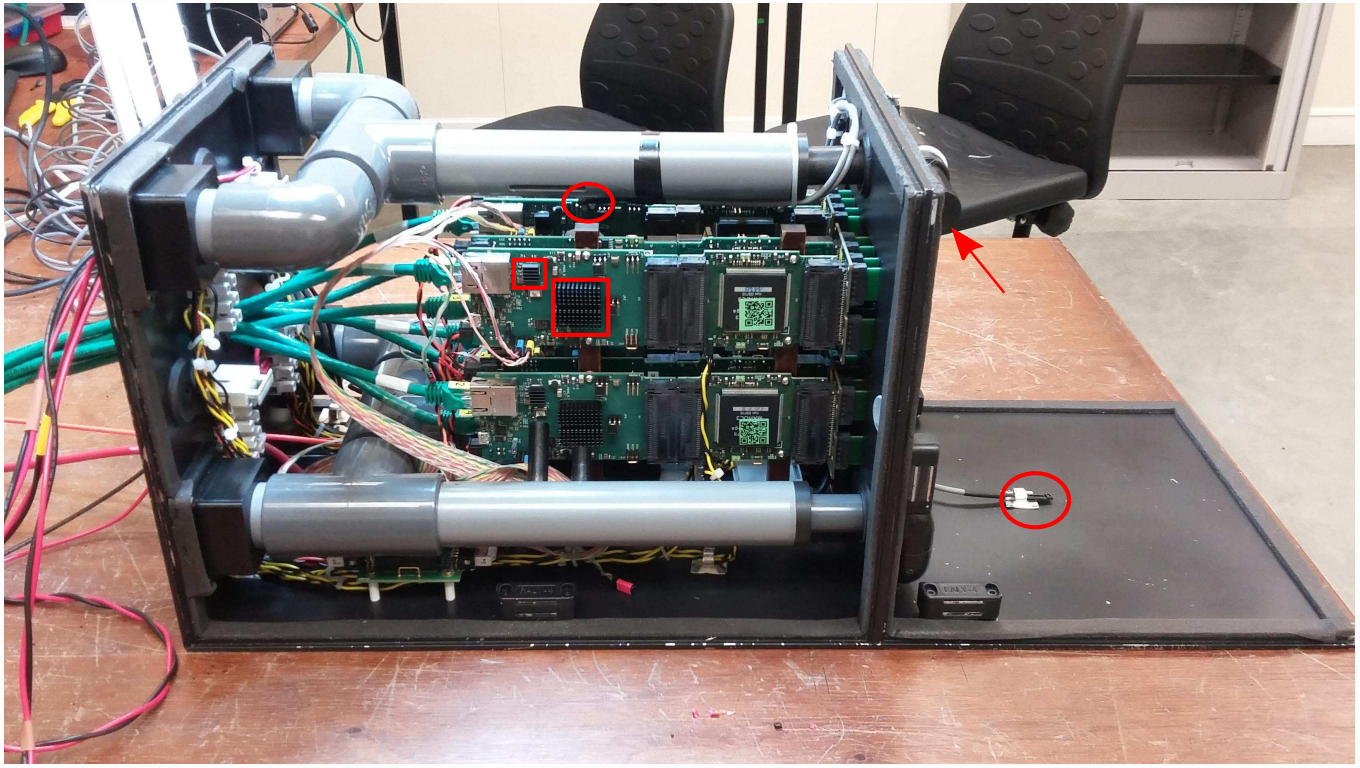
Conclusion

- new laboratory setup in 5207 for the RICH upgrade PDQA
- MaPMTs pre-production received and tested
- green light to Hamamatsu for full production
- new test boxes will be installed in Padova in few weeks

- MaPMTs production on its way: first delivery in July
- $\sim$ 150 MaPMTs to be tested every 2 months for the next 2 years!!!

Extra slides

DAQ chain



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