An overview of photosensors testing and DU integration at CAPACITY lab in Caserta

15.11.2022

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UNIONE EUROPEA
Fondo Europeo di Sviluppo Regionale

Part one:
New measurements on an improved 3" Hamamatsu photomultiplier for the KM3NeT Neutrino Telescope

Part two:
DU integration at CAPACITY LAB

New measurements on an improved 3" Hamamatsu photomultiplier for the KM3NeT Neutrino Telescope

Andreino Simonelli
INFN-Napoli
on behalf of KM3NeT collaboration

Summary of part one

- Describe the new setup for Quantum Efficiency at INFN-Capacity lab in Caserta

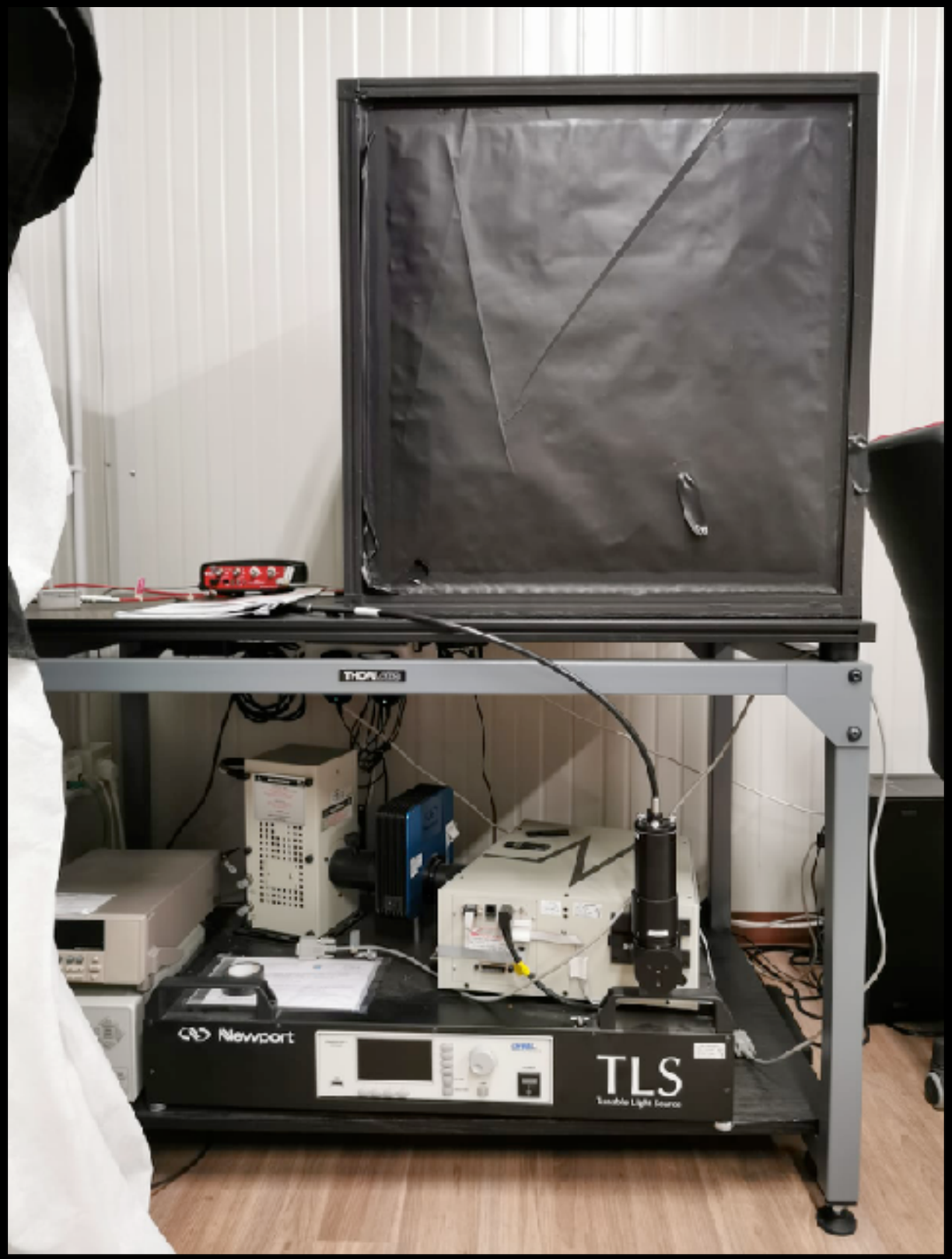
- Show the QE measurements and compare the OLD R12199 (cfr. 2018 *JINST* **13** P05035) to the NEW R14374 PMTs

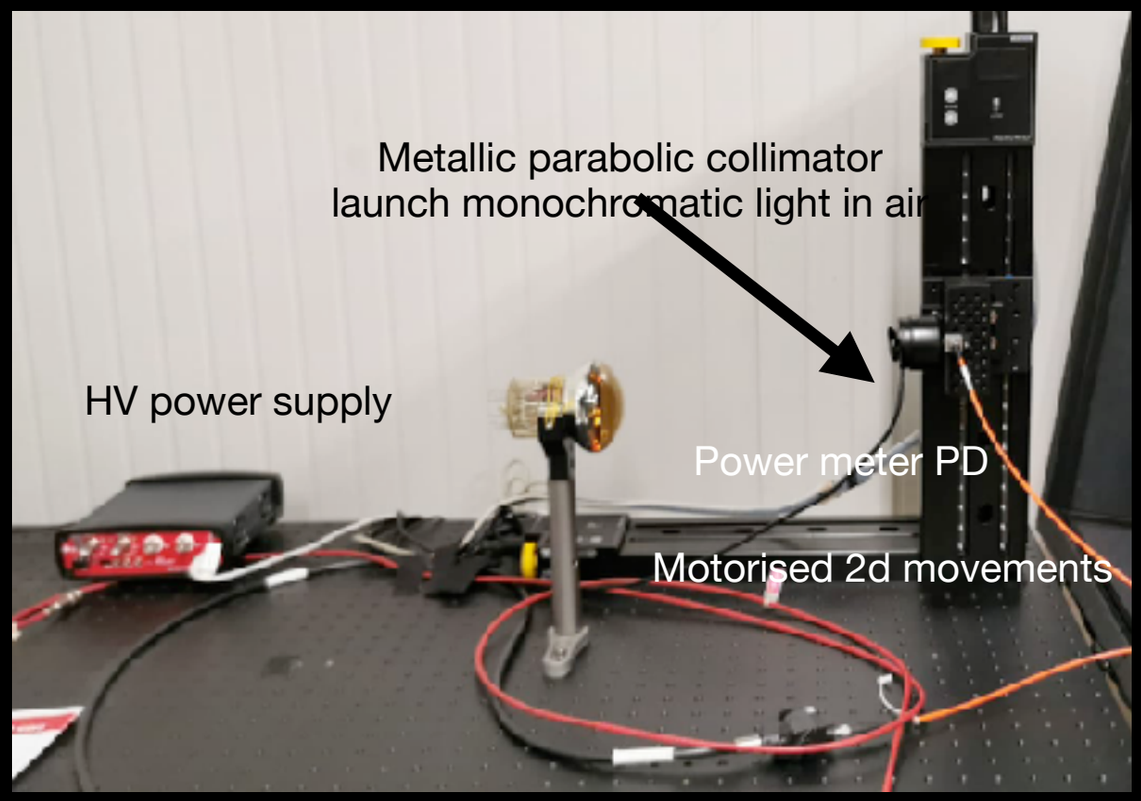
- Describe the special R14374 UBA increased QE PMT under test for possible future improvements

- Compare the time characteristics of a 500 set of new R14374 PMT using the Dark box apparatus to the old 3” PMT

- Conclusions

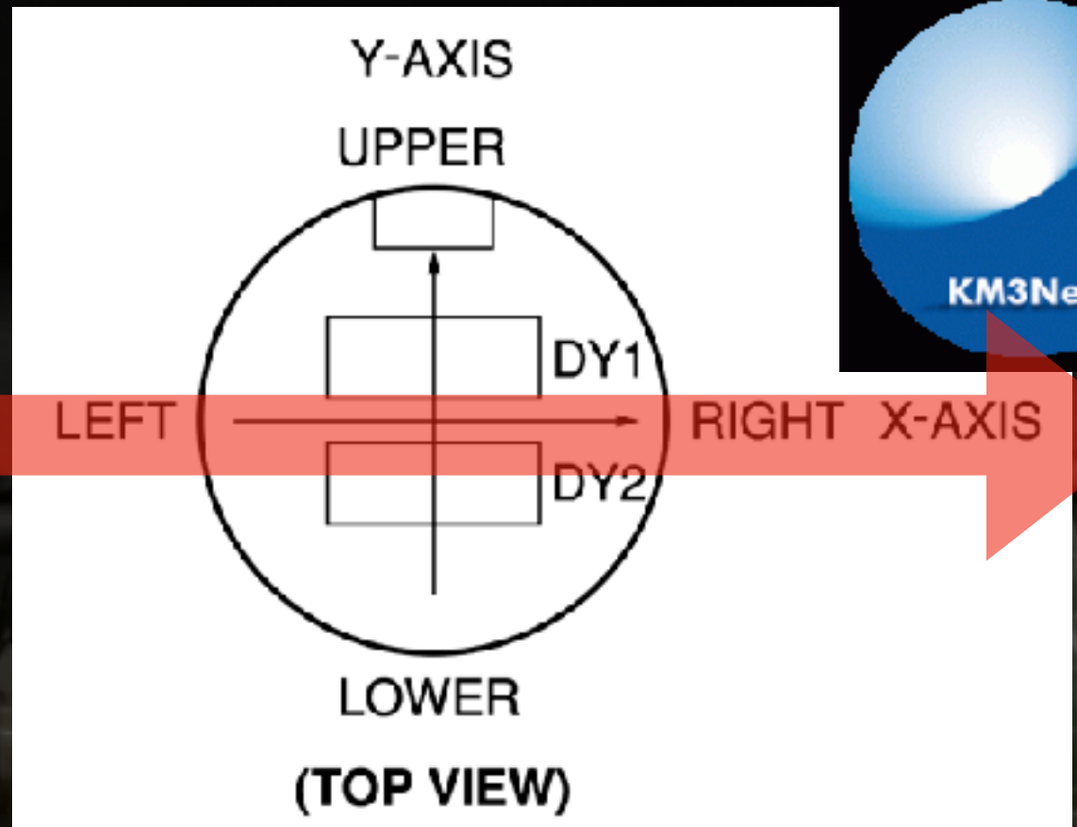
Experimental apparatus at CAPACITY lab of Caserta - INFN

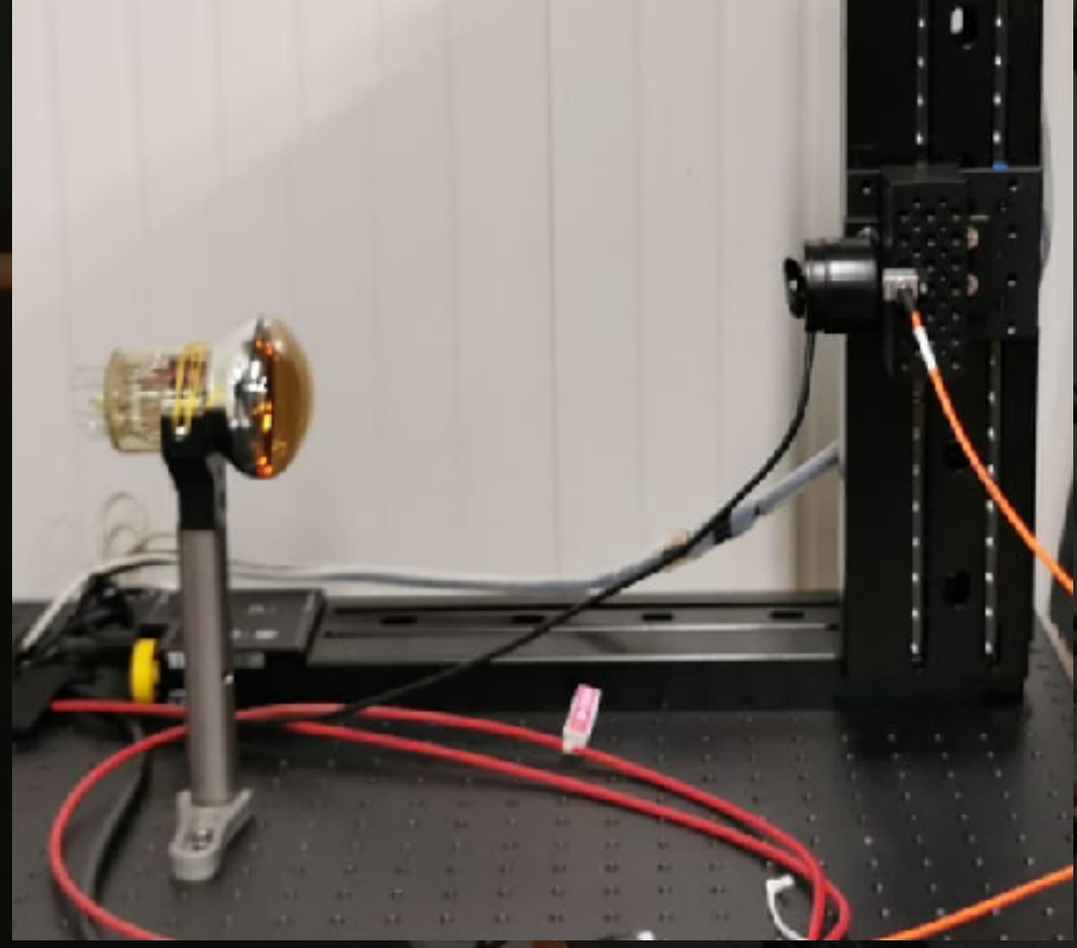




Experimental solutions

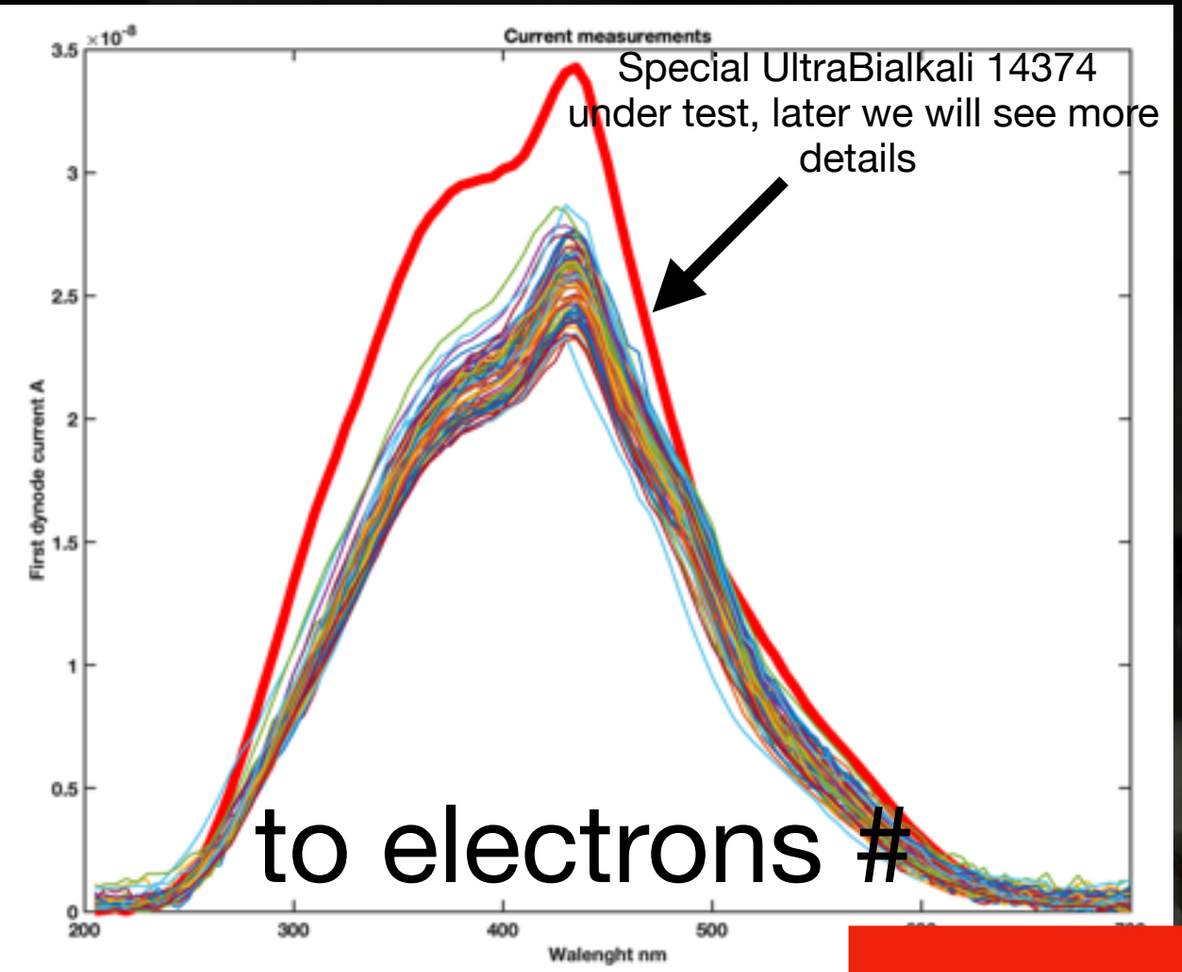
- 2D cathode scan is performed by programming the head motion in a comb movement shape.
- Custom code to read the Keythley pico ammeter via RS232 with instrument control toolbox.
- Cathode at -100 V respect to the first dynode grounded together with all the 9 remaining dynodes and anode in order to collect all possible electrons escaping from the first dynode

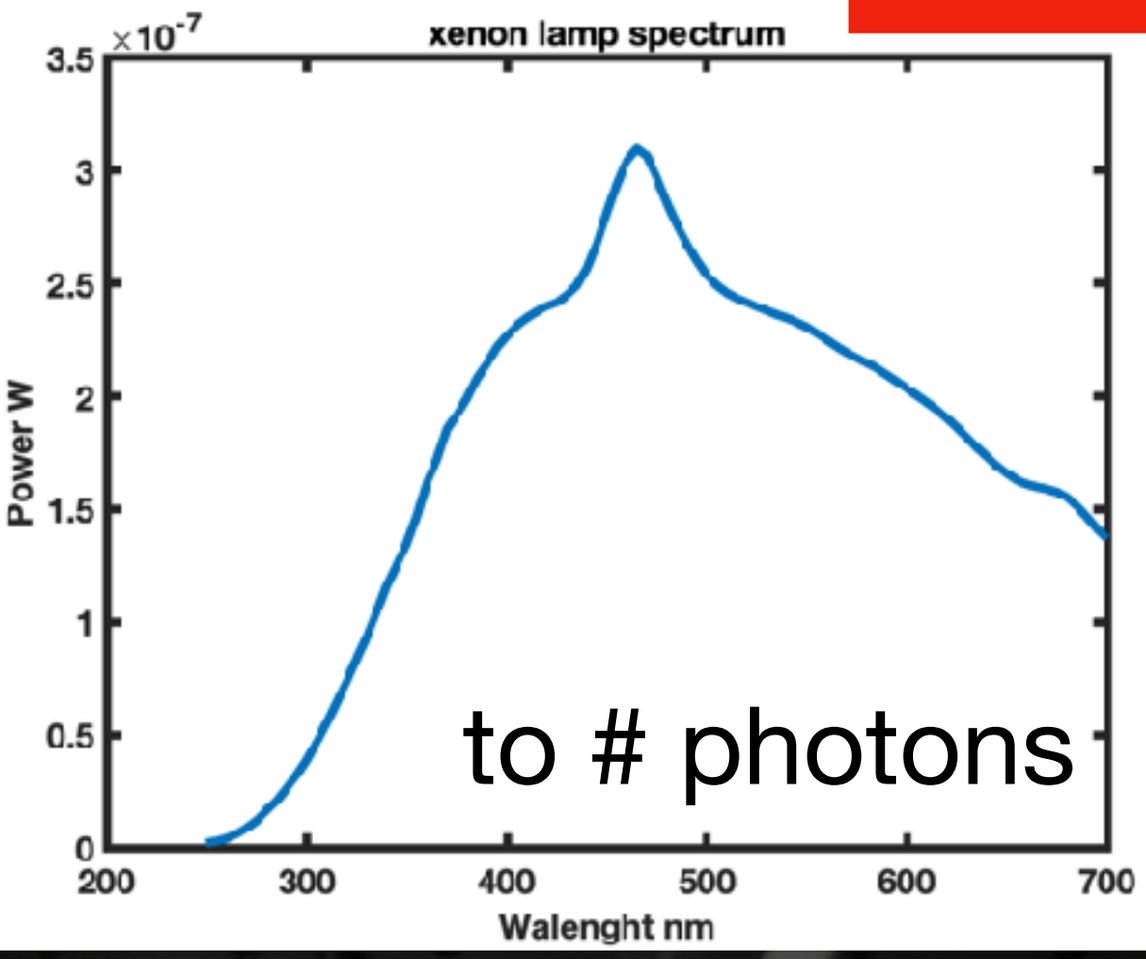


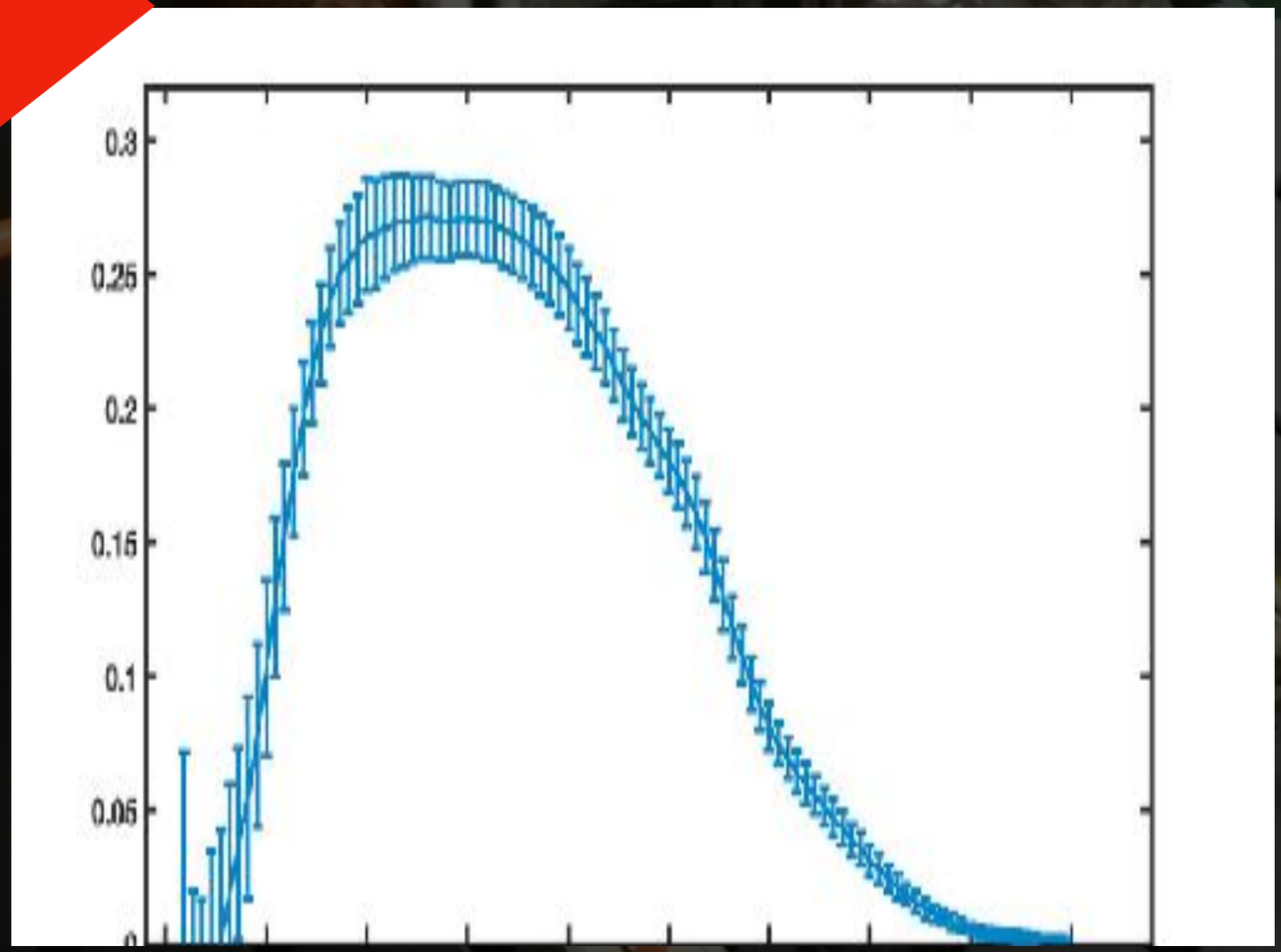


Method

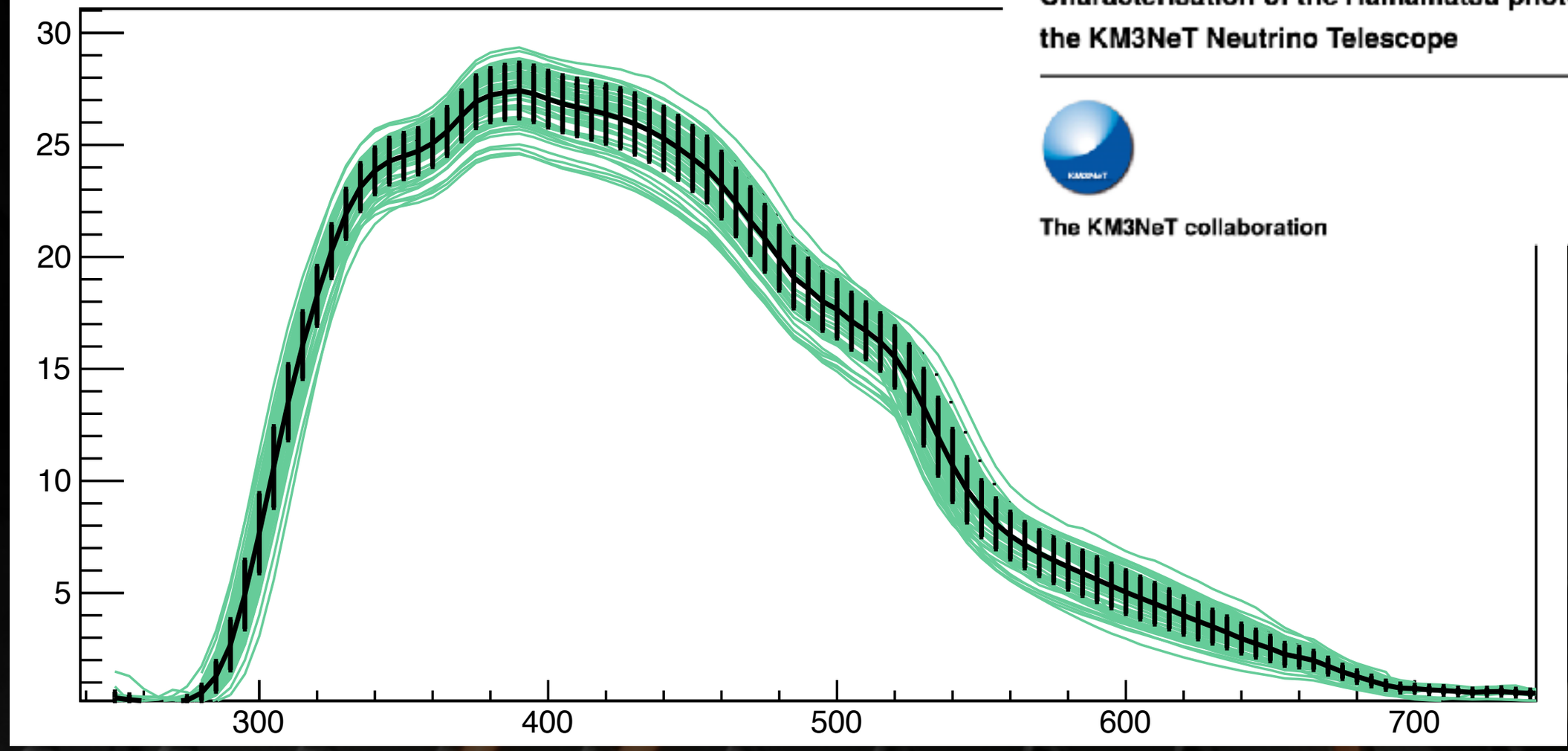
- We acquire a reference power spectrum every ten current spectra and measure PMT current vs Wavelength (use the monochromator scan function) and store it for post processing.







Former measurements on the R12199 performed at ECAP on a 46 pcs. set



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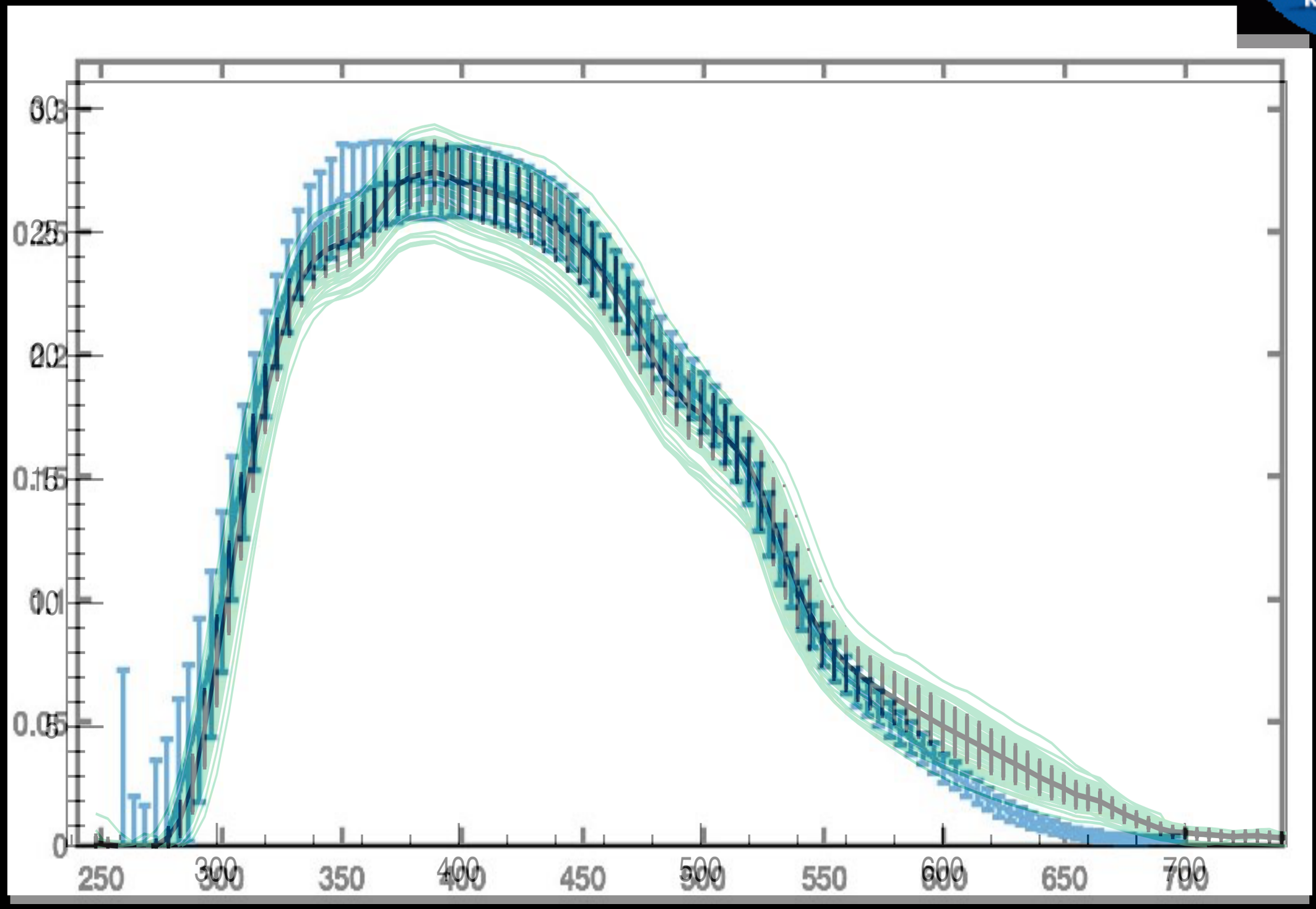
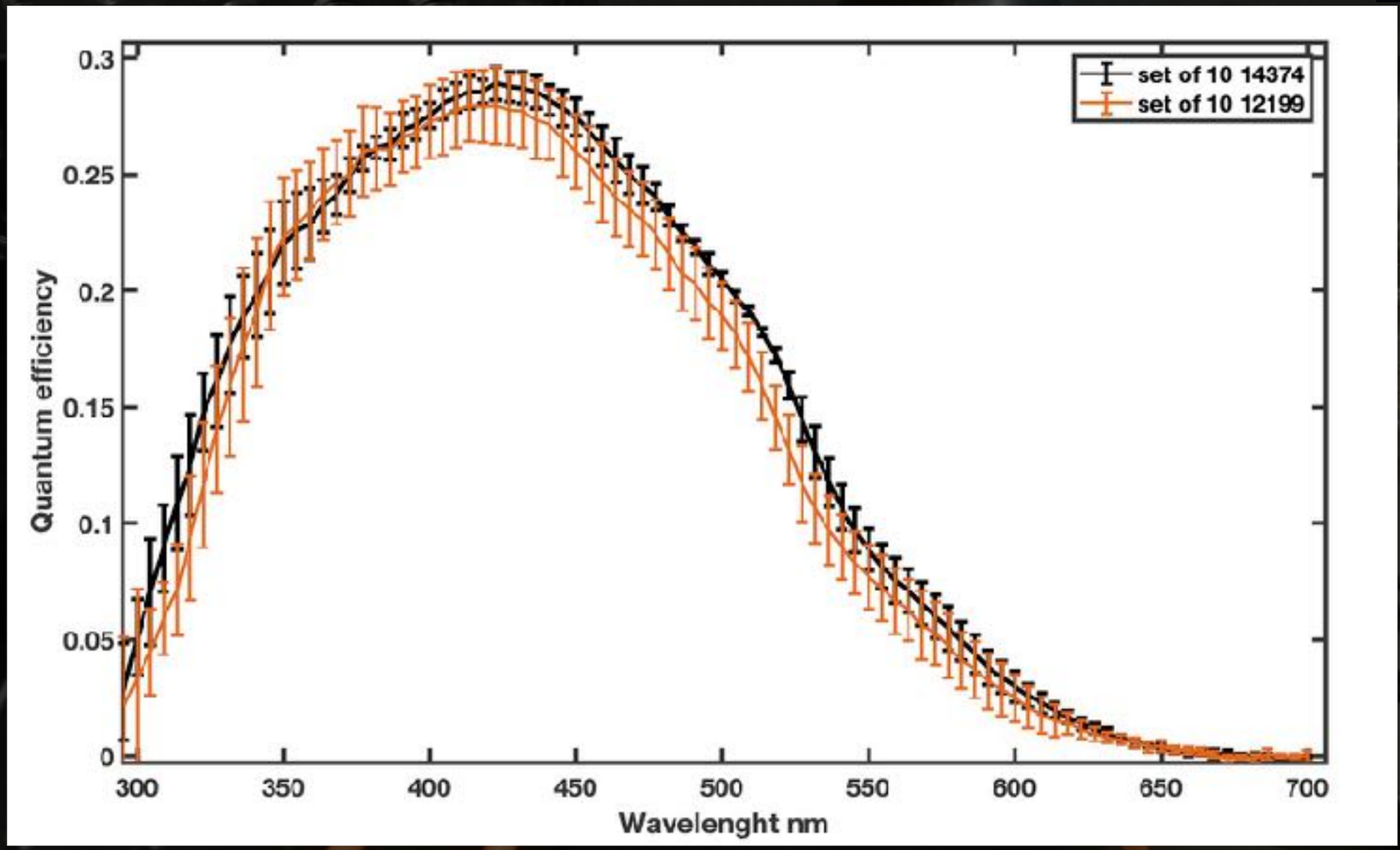
Characterisation of the Hamamatsu photomultipliers for the KM3NeT Neutrino Telescope

The KM3NeT collaboration

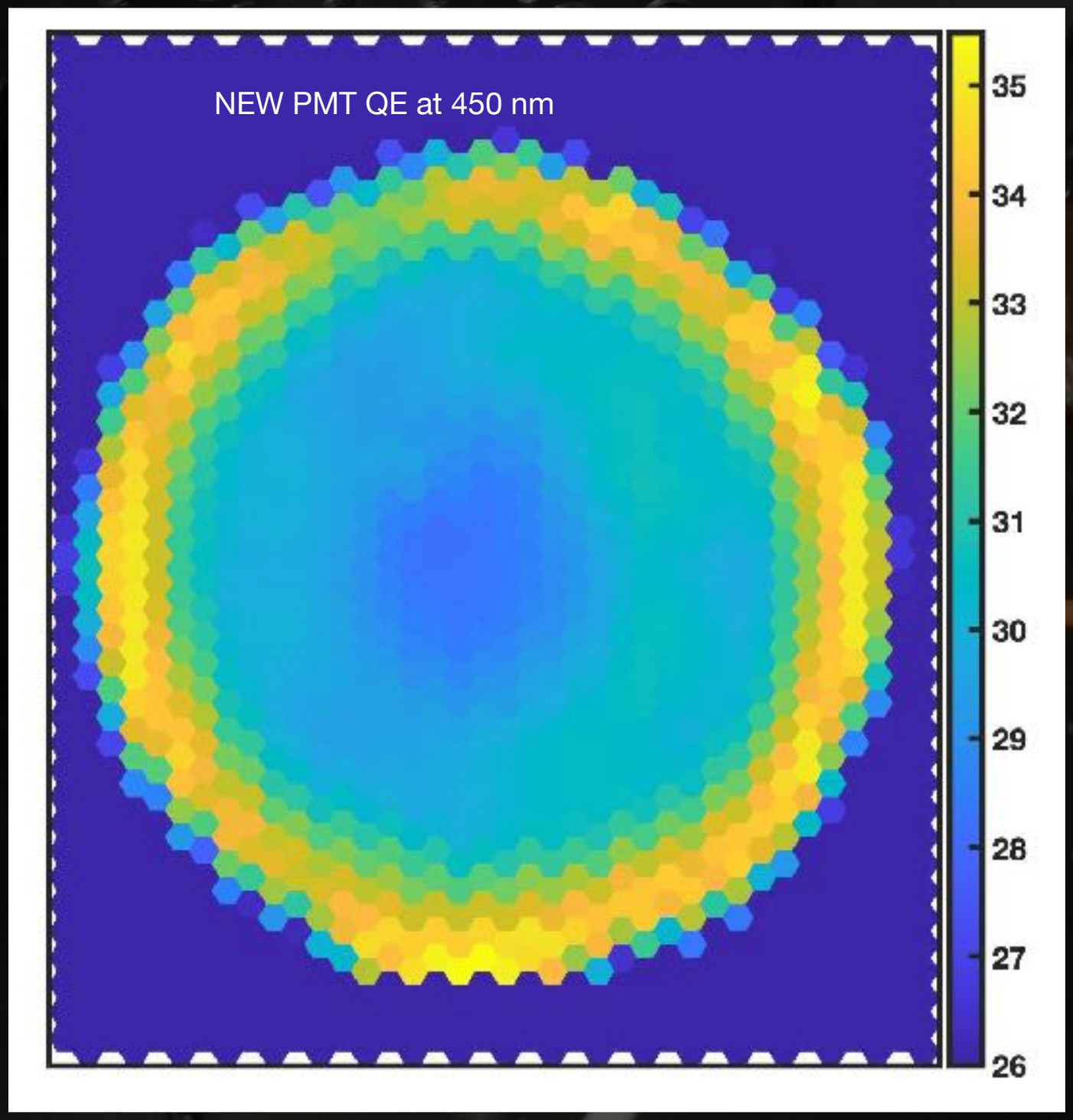
Comparing former measurements of ECAP with the new ones performed over a set of 200 PMTs



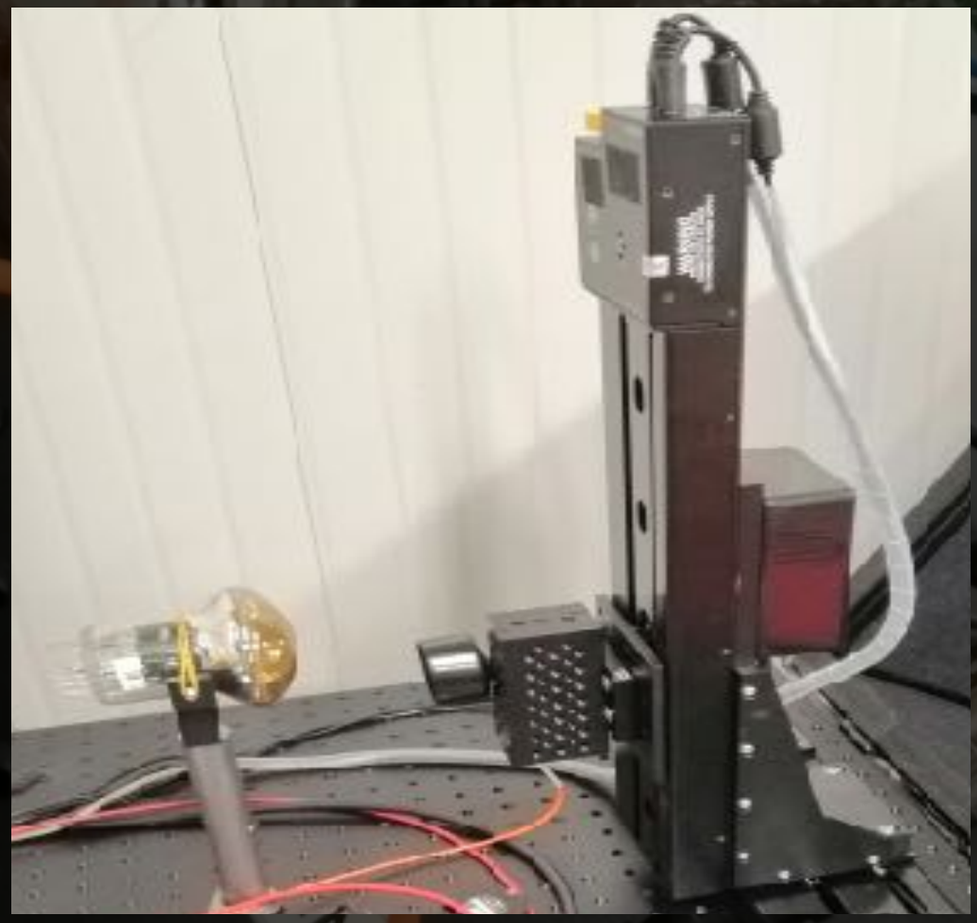
Small subset comparison :
average values of QE for OLD and NEW pmt by using
THE SAME EXPERIMENTAL SETUP in CASERTA



Spatial uniformity



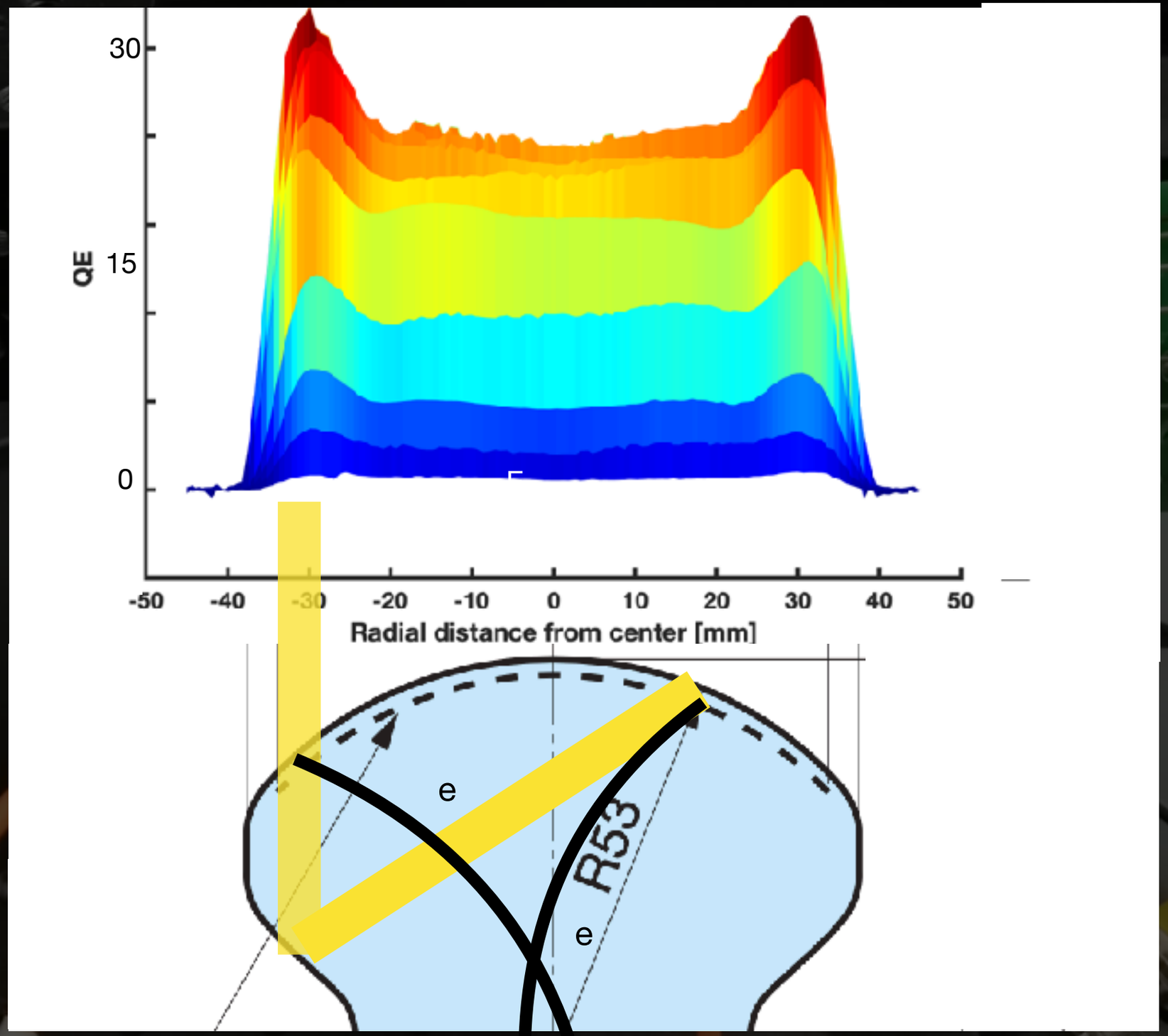
By using the 2D stage it was possible to program and execute the scan of the photocathode.
The central part is less sensitive than the borders where
there is a clear increase, mainly due to reflected light that stimulates the photoelectric emission twice.



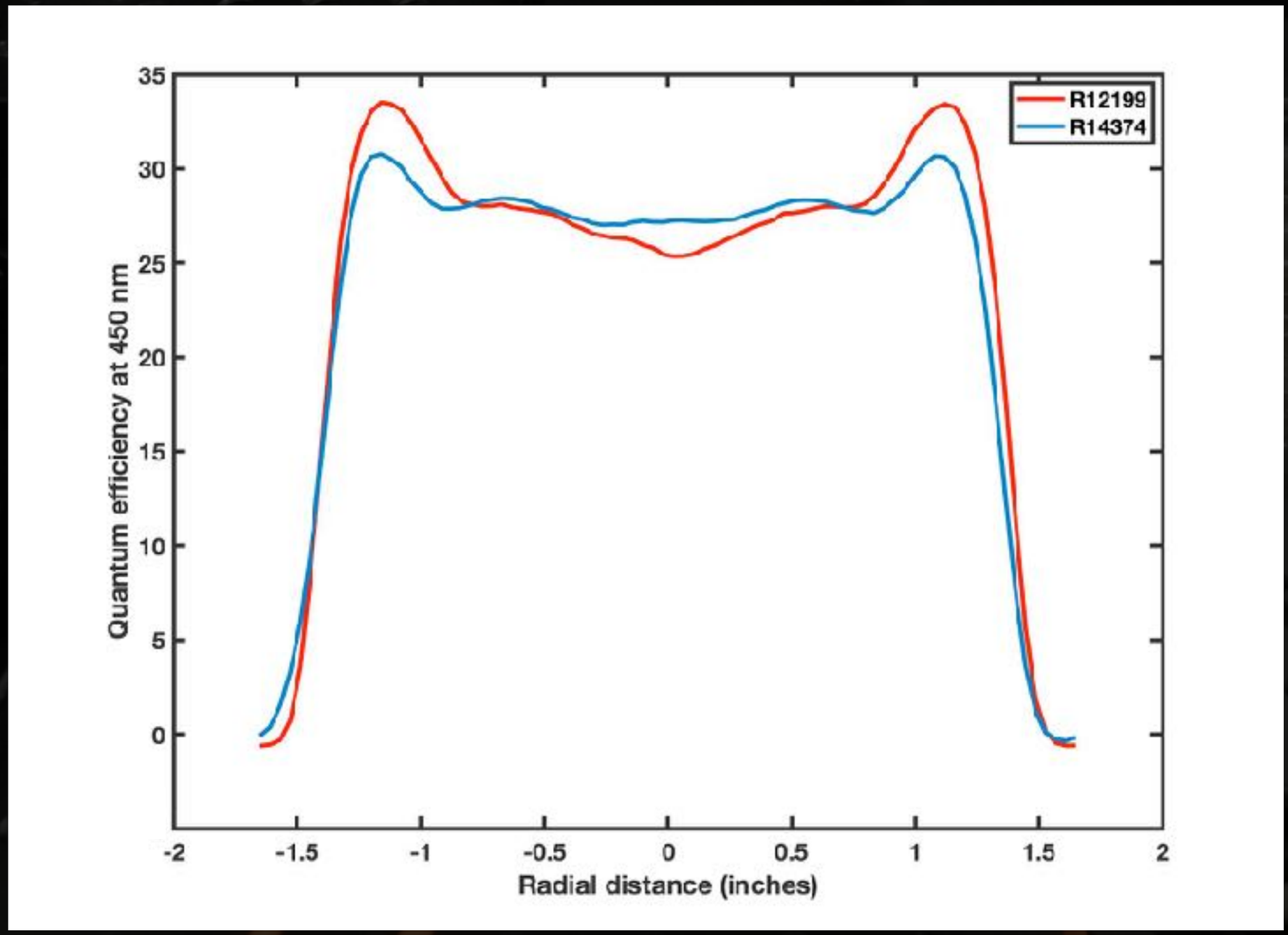
Radial uniformity vs wavelength

Evidences:

- The QE is minimal at the center at normal incidence
- The inner borders of the PMT “mushroom” is internally coated with a metal sheet (i.e a perfect mirror for all the wavelengths)
- This effect is documented by producers but not fully explained



Radial homogeneity comparison between old (red) and new (blue) PMTs



A special version of 14374 with increased QE is under test

Nuclear Instruments and Methods in Physics Research A 623 (2010) 276–278

Contents lists available at ScienceDirect

Nuclear Instruments and Methods in Physics Research A

journal homepage: www.elsevier.com/locate/nima

Latest bialkali photocathode with ultra high sensitivity

Kimitsugu Nakamura*, Yasumasa Hamana, Yoshihiro Ishigami, Toshikazu Matsui

Hamamatsu Photonics K.K. Electron Tube Division, Shimokanzo 314-5, Iwata, Shizuoka 438-0193, Japan

ARTICLE INFO

ABSTRACT

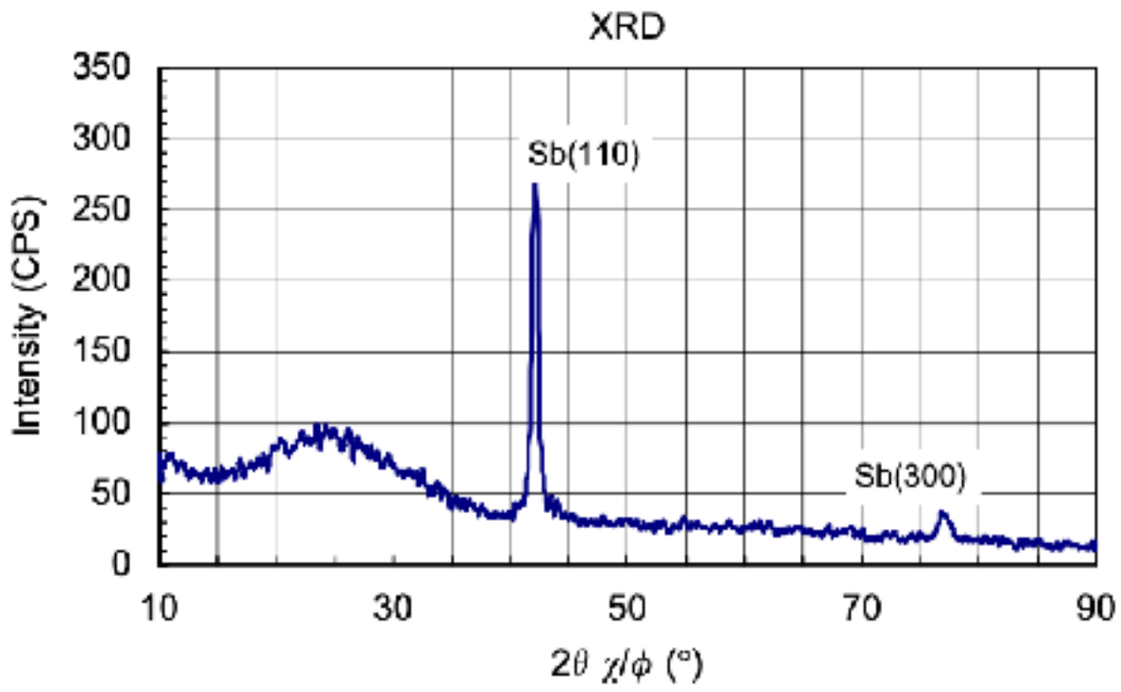


Fig. 1. The X-ray diffraction analysis result of Sb thin film.

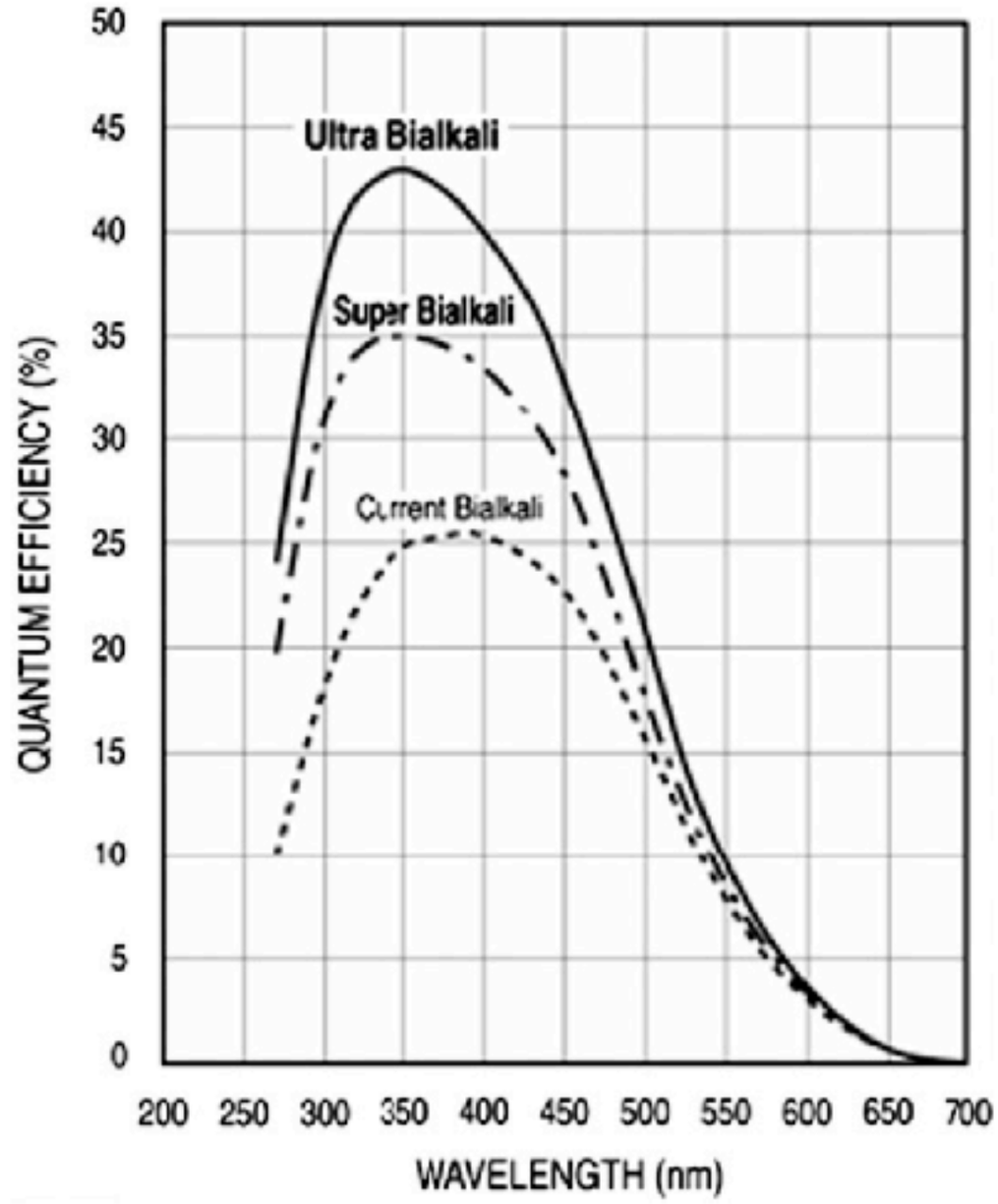
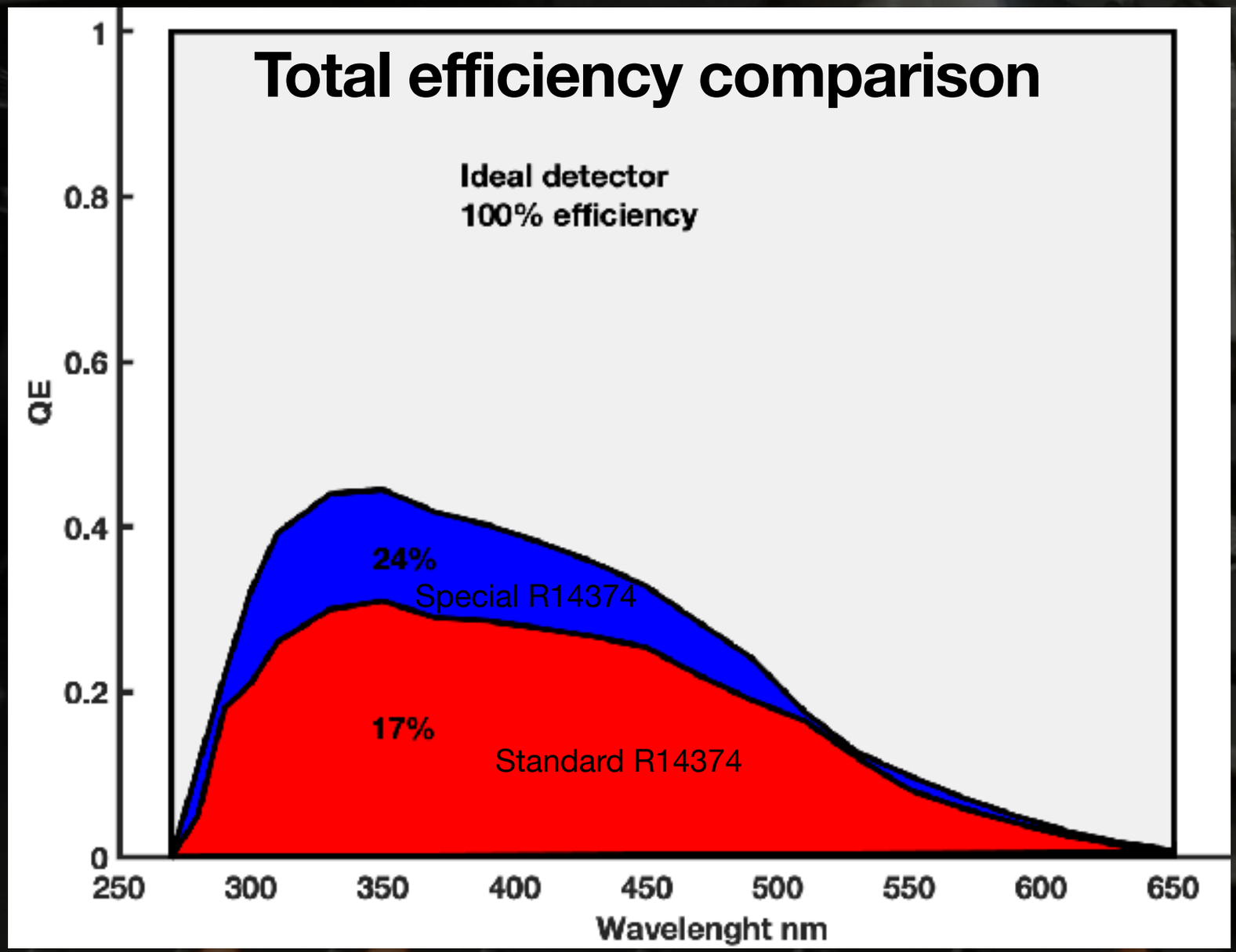


Fig. 2. Typical QE curves for UBA, SBA and standard bialkali photocathodes.

Crystallinity of the Antimony coating plays the fundamental role of improving QE in bialkali photocathodes

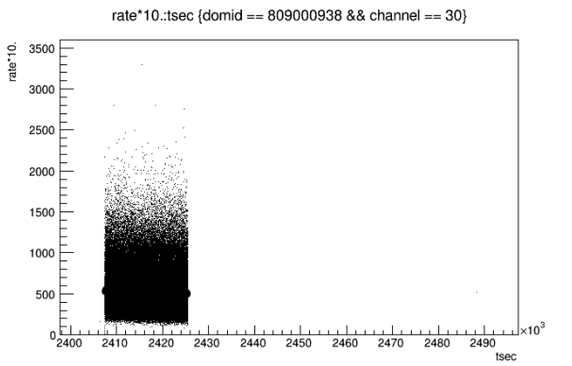
A special version with increased QE is under test

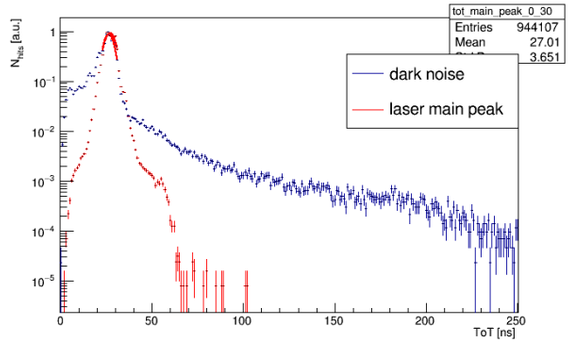


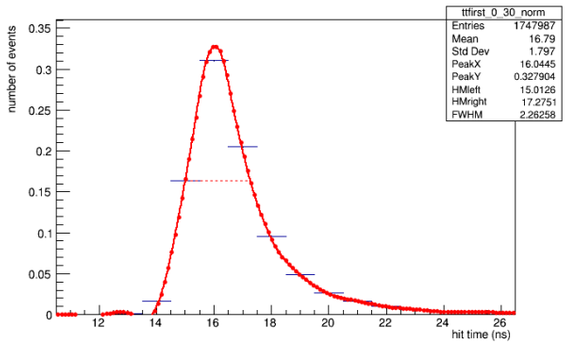
+41%

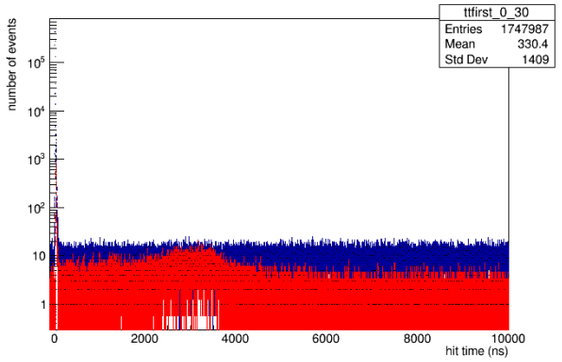
A special version with increased QE is under test

DarkBox test summary (Test #QEE)
PROMIS ID: 0060E6
Quality : RED
UPI : UNKNOWN
Tuned HV : -1073.91 V
DarkRate : 496.68 Hz
ToT peak : 27.1501 ns
Prepulses : -0.00490972%
Delayed : 2.51926%
Afterpulses : 0.933275%
TT peak (fit): 16.0445 ns
TT FWHM (fit): 2.26258 ns
TT peak : 16 ns
TT FWHM : 2 ns

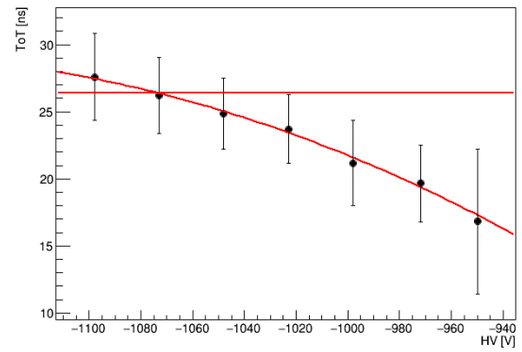




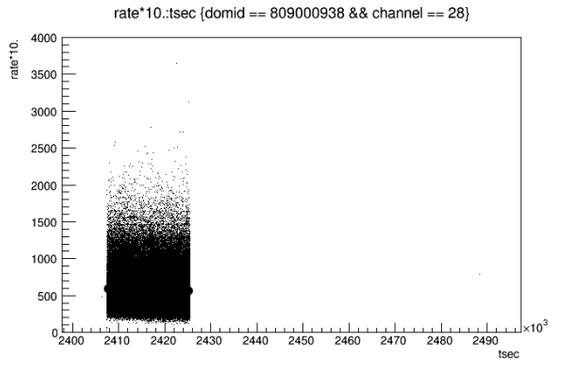


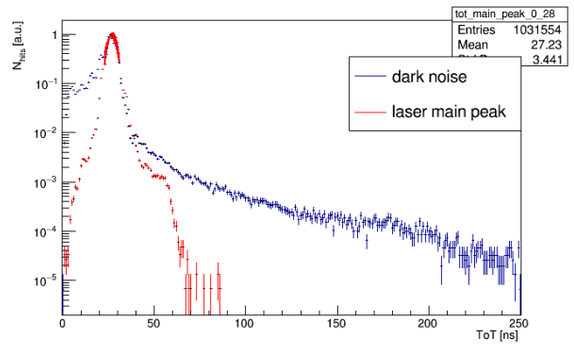


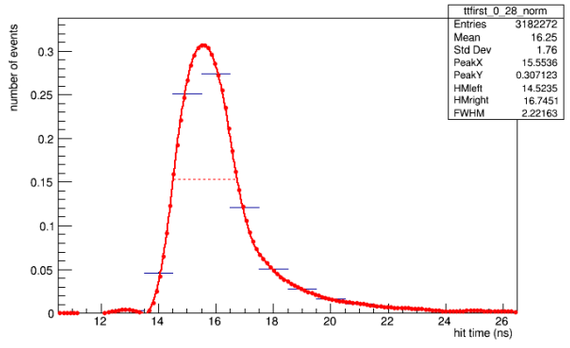
HV tuning

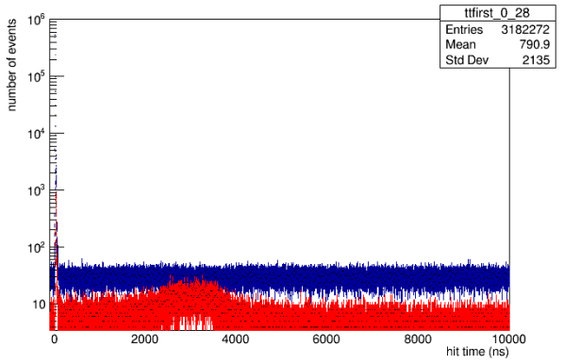


DarkBox test summary (Test #QEE)
PROMIS ID: 007440
Quality : GREEN
UPI : UNKNOWN
Tuned HV : -1135.21 V
DarkRate : 569.42 Hz
ToT peak : 27.2669 ns
Prepulses : -0.0076867%
Delayed : 2.52154%
Afterpulses : 1.26181%
TT peak (fit): 15.5536 ns
TT FWHM (fit): 2.22163 ns
TT peak : 16 ns
TT FWHM : 1 ns

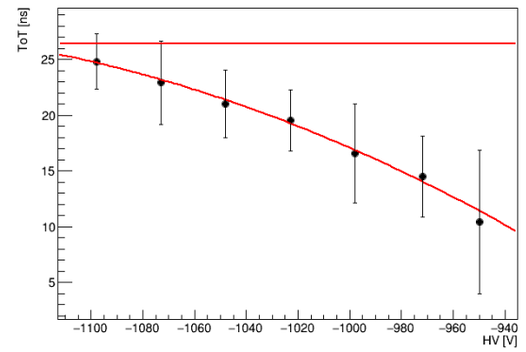




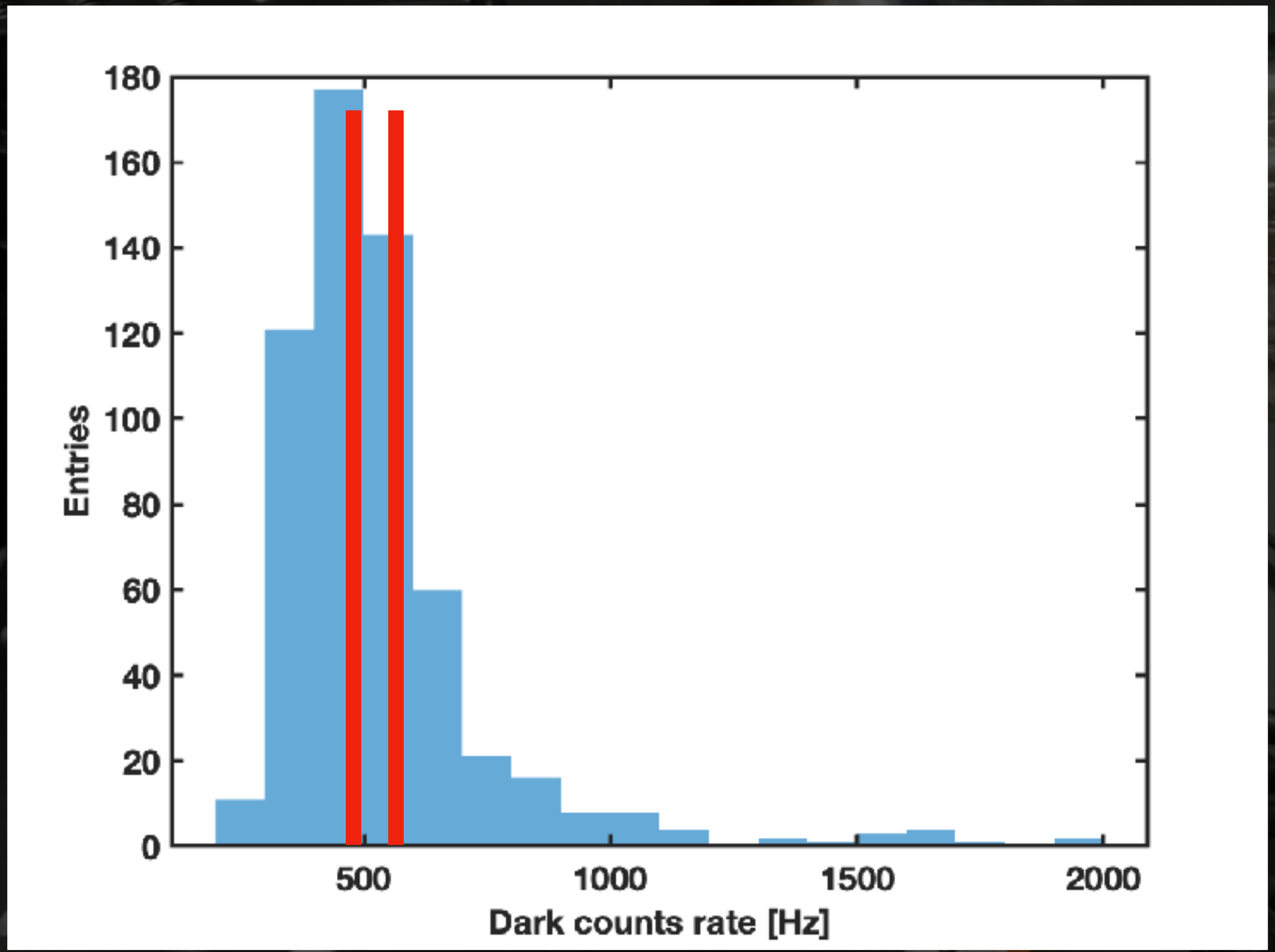




HV tuning



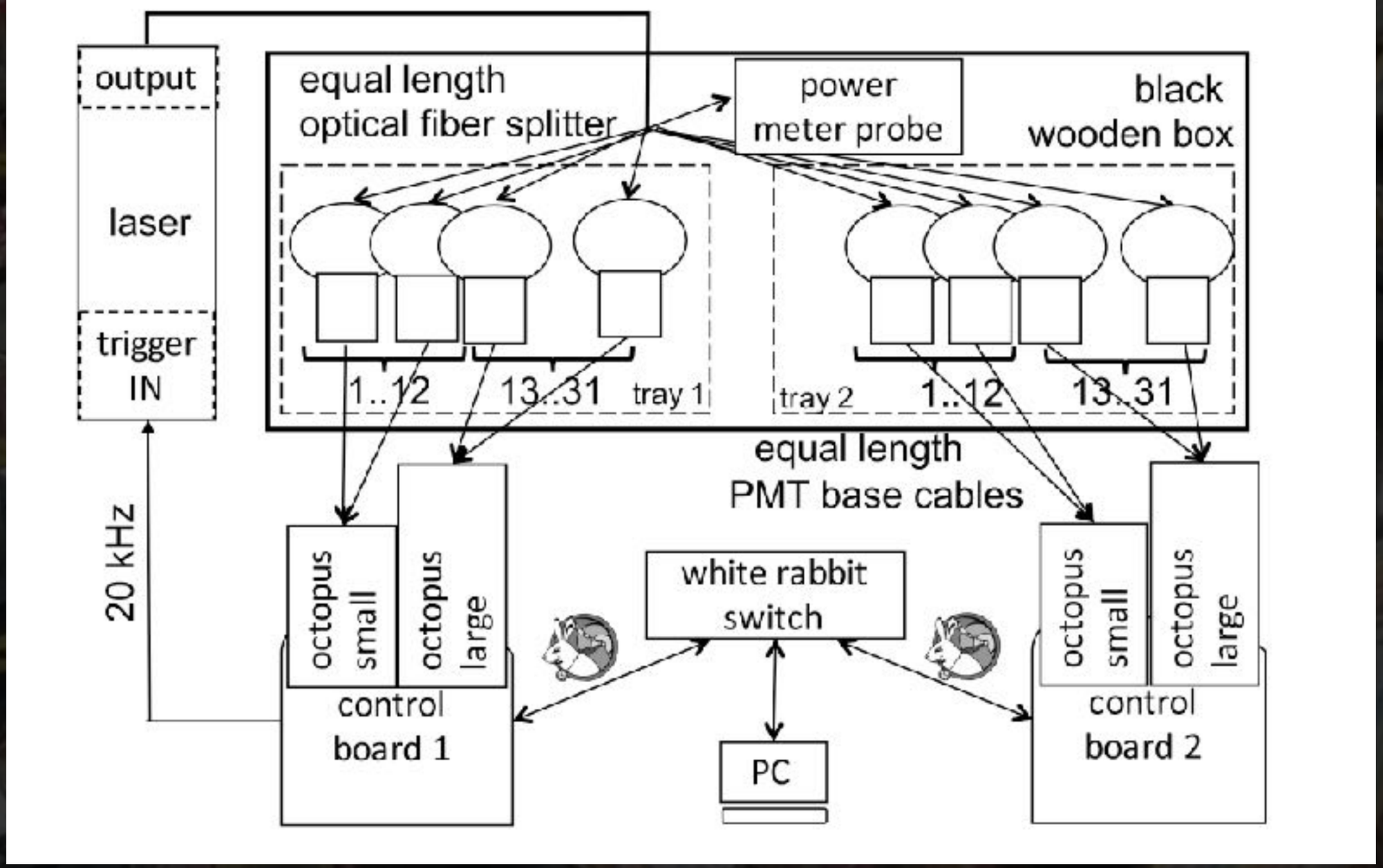
Dark counts comparison with standard R14374



The DARK box apparatus for timing properties measurements

M.C. Mollo et al.
The Dark Box instrument for fast automatic testing of the photomultipliers for KM3NeT
Volume 236 - The 34th International Cosmic Ray Conference (ICRC2015)

The DARK box apparatus for timing properties measurements



M.C. Mollo et al.
The Dark Box instrument for fast automatic testing of the photomultipliers for KM3NeT
Volume 236 - The 34th International Cosmic Ray Conference (ICRC2015)

Some Time characteristics of concern

- **After-pulses:** *are spurious pulses that appear in the wake of true pulses.*
they can limit the number of true pulses that can be registered.
After-pulses have two main causes:
    (a) light emitted by electrodes due to electron bombardment.
    (b) ionisation of residual gas traces.

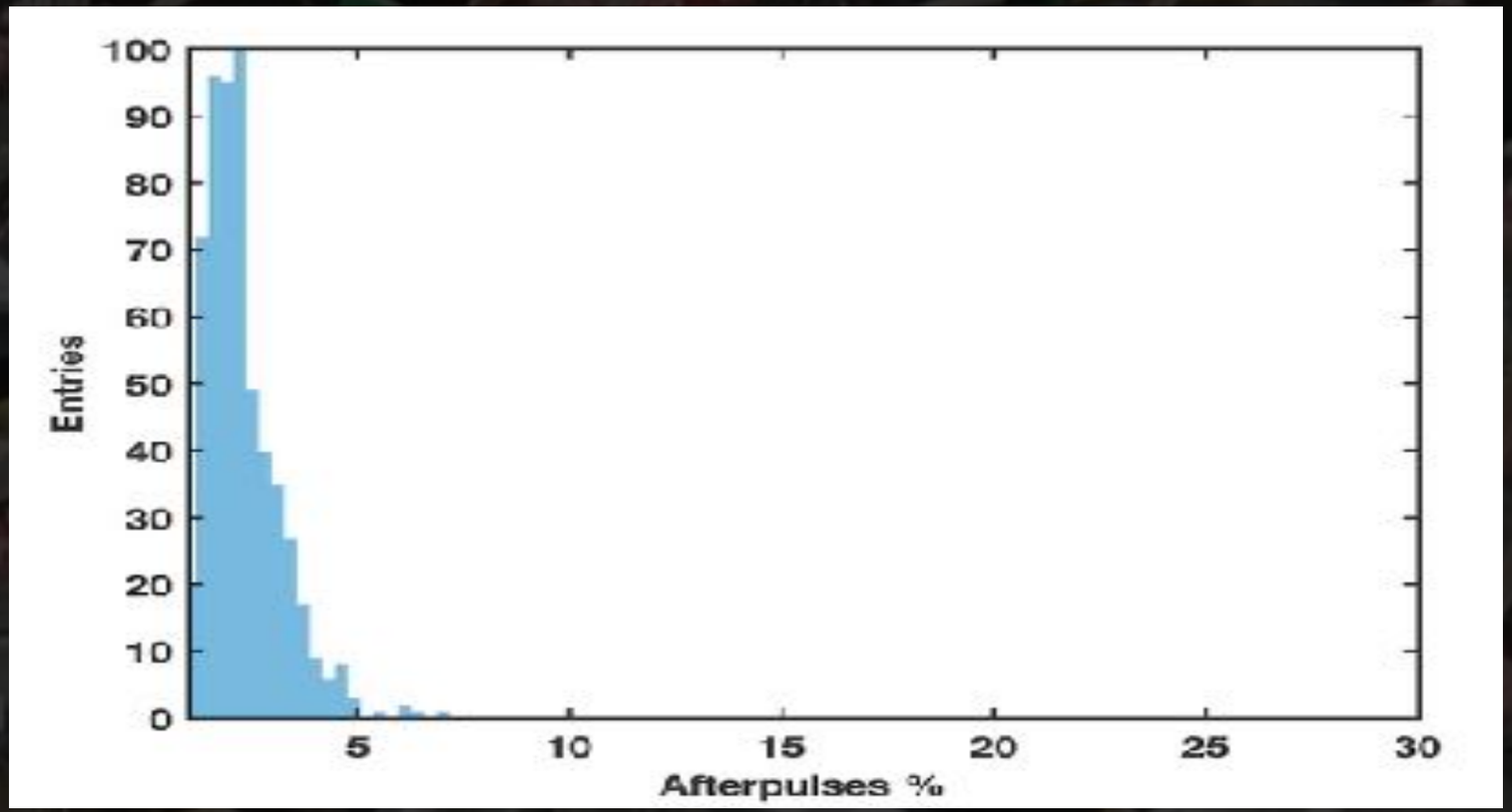
- **Dark counts:** *A small amount of current flows in a photomultiplier tube even when operated in a completely dark state.*
    (c) Thermionic emission
    (d) Leakage current
    (e) Photocurrent produced by scintillation from glass envelope or electrode supports
    (f) Ionisation current from residual gases (ion feedback)

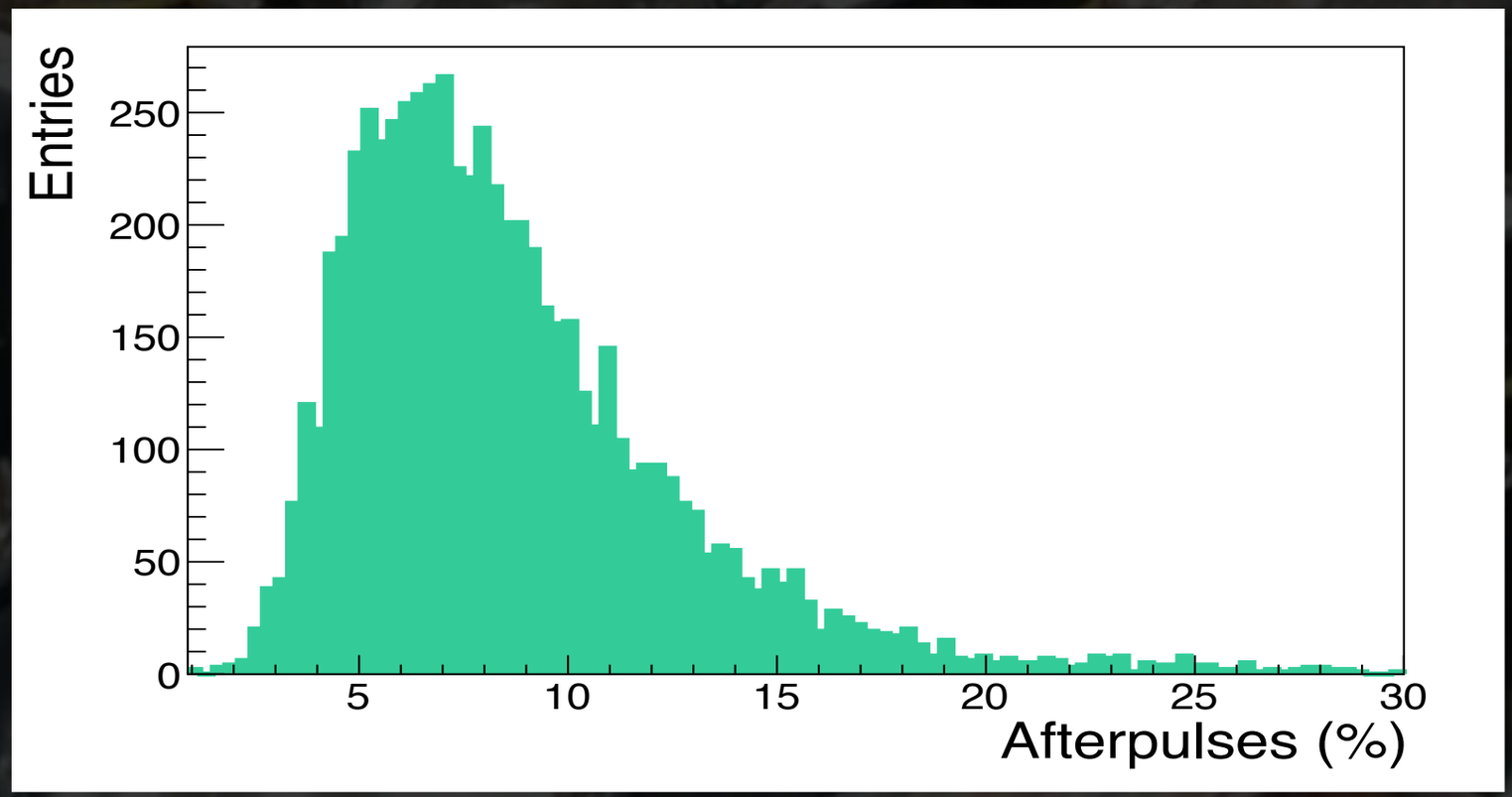
- **The *transit-time spread*: *variations in the single photoelectron transit time***

Overview of the existing equipment

After-pulses measurements

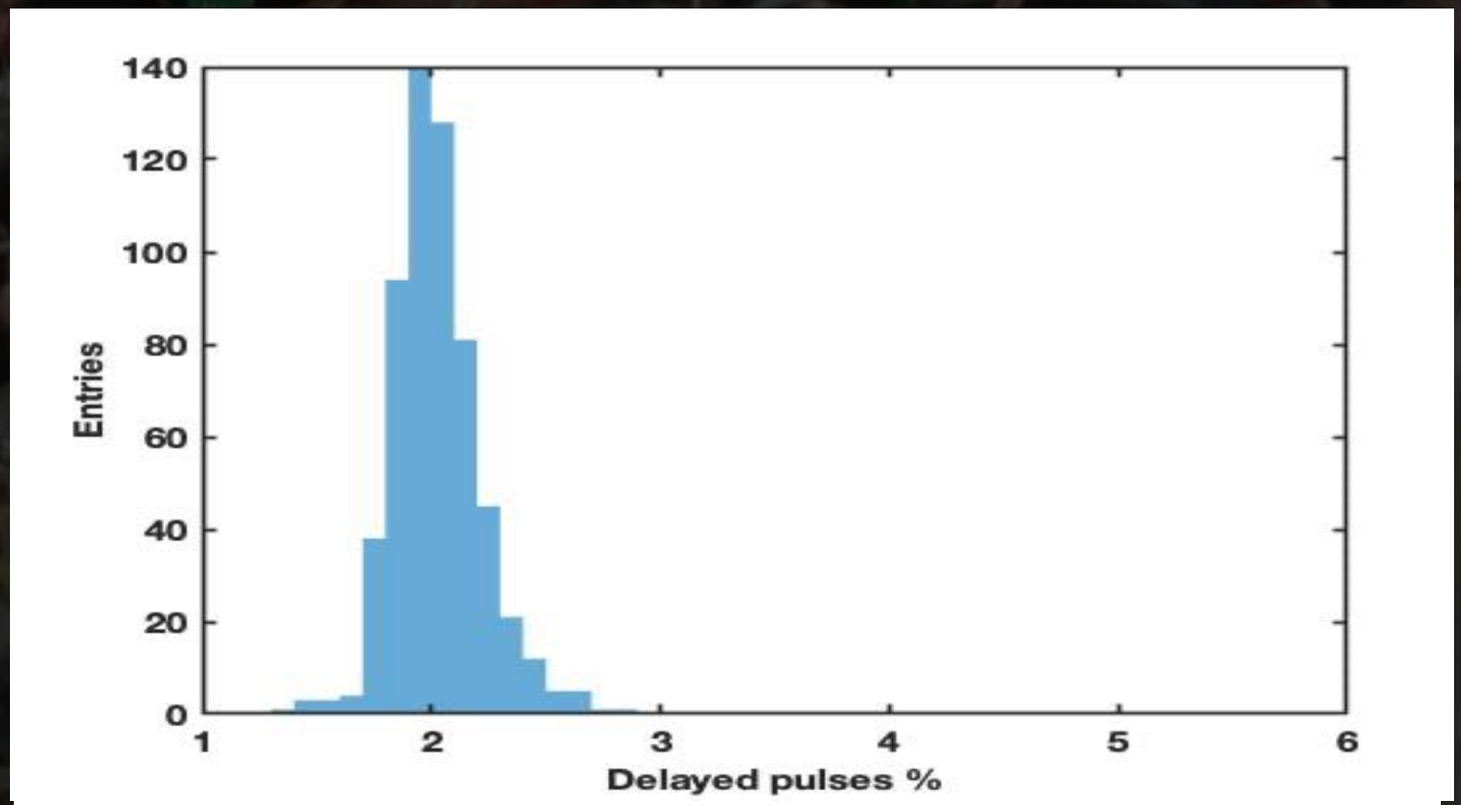
between 100 ns and 10 μs

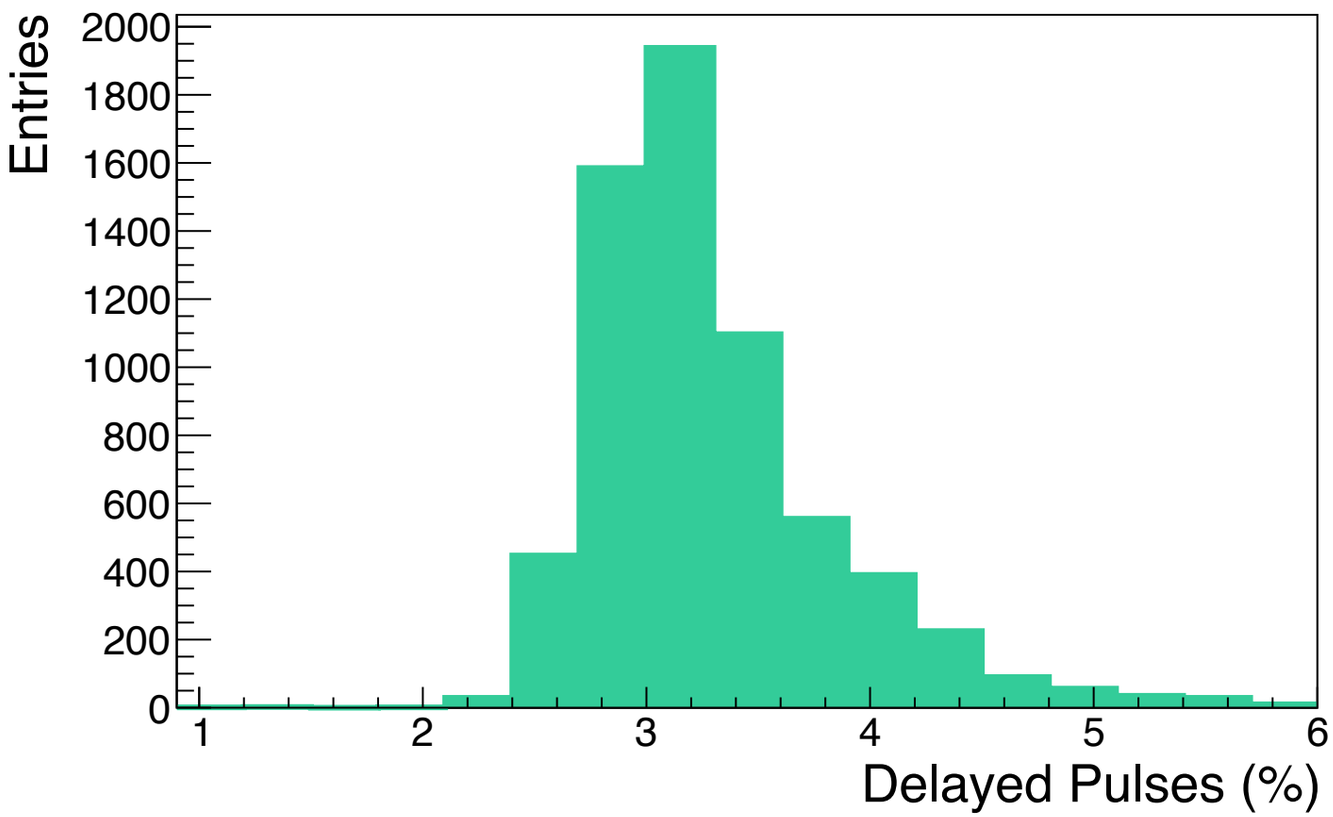




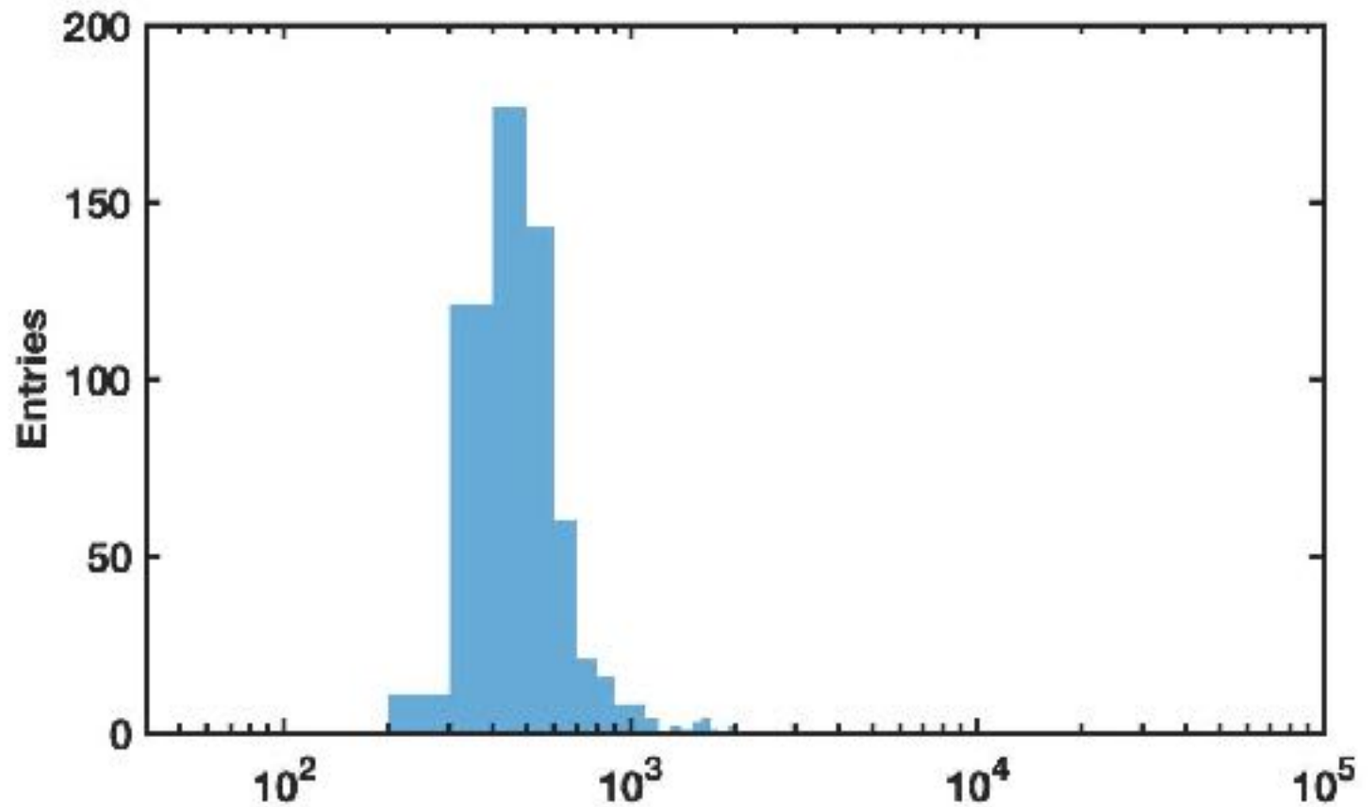
Delayed pulses

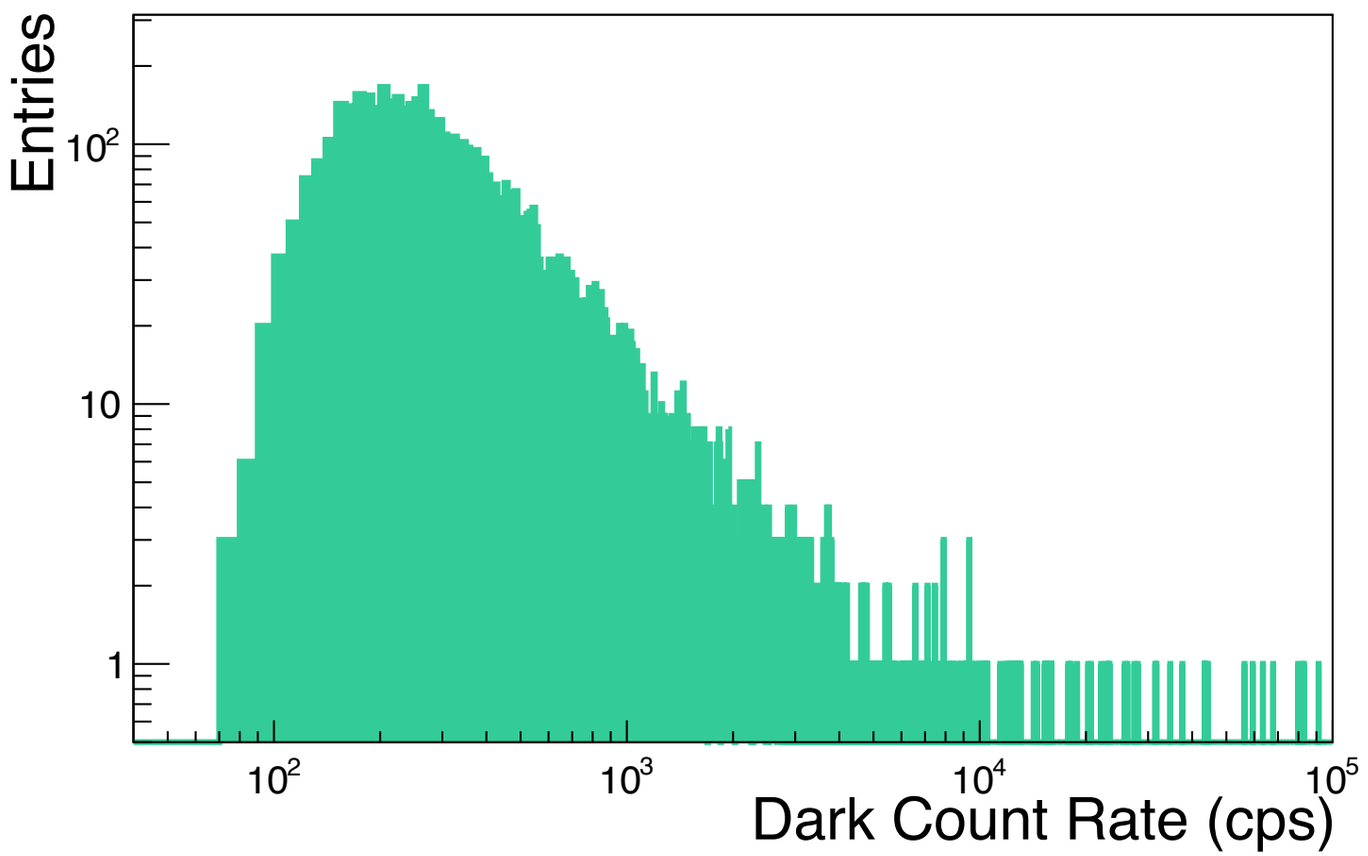
between 15 ns and 60 ns



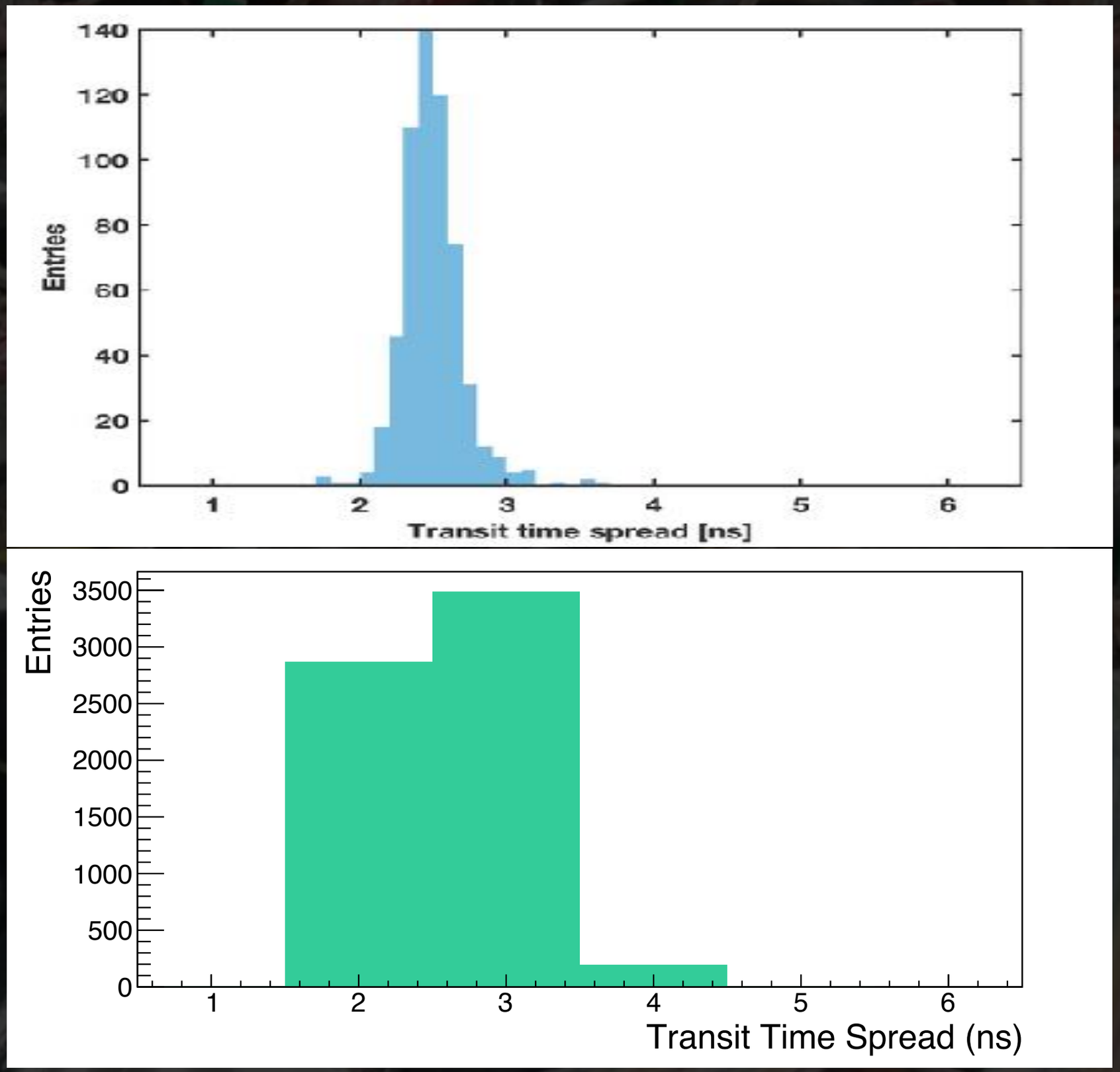


Dark counts rate





Transit time spread comparison



Conclusions of part one

- The new QE setup in Caserta is now fully operative
- New R14374 shows a better spatial QE uniformity and same QE over wavelength
- A comparison between old and new PMT with the same setup is done
- The DarkBox is again operative in Capacity lab for PMTs timing characterisation
- 500 pcs of R14374 PMTs have been measured showing far better timing properties
- A dedicated variation to the QE setup is near to completion for QE measurements of the Assembled DOMs

UNIONE EUROPEA
Fondo Europeo di Sviluppo Regionale

DU integration at CAPACITY LAB in Caserta

The team

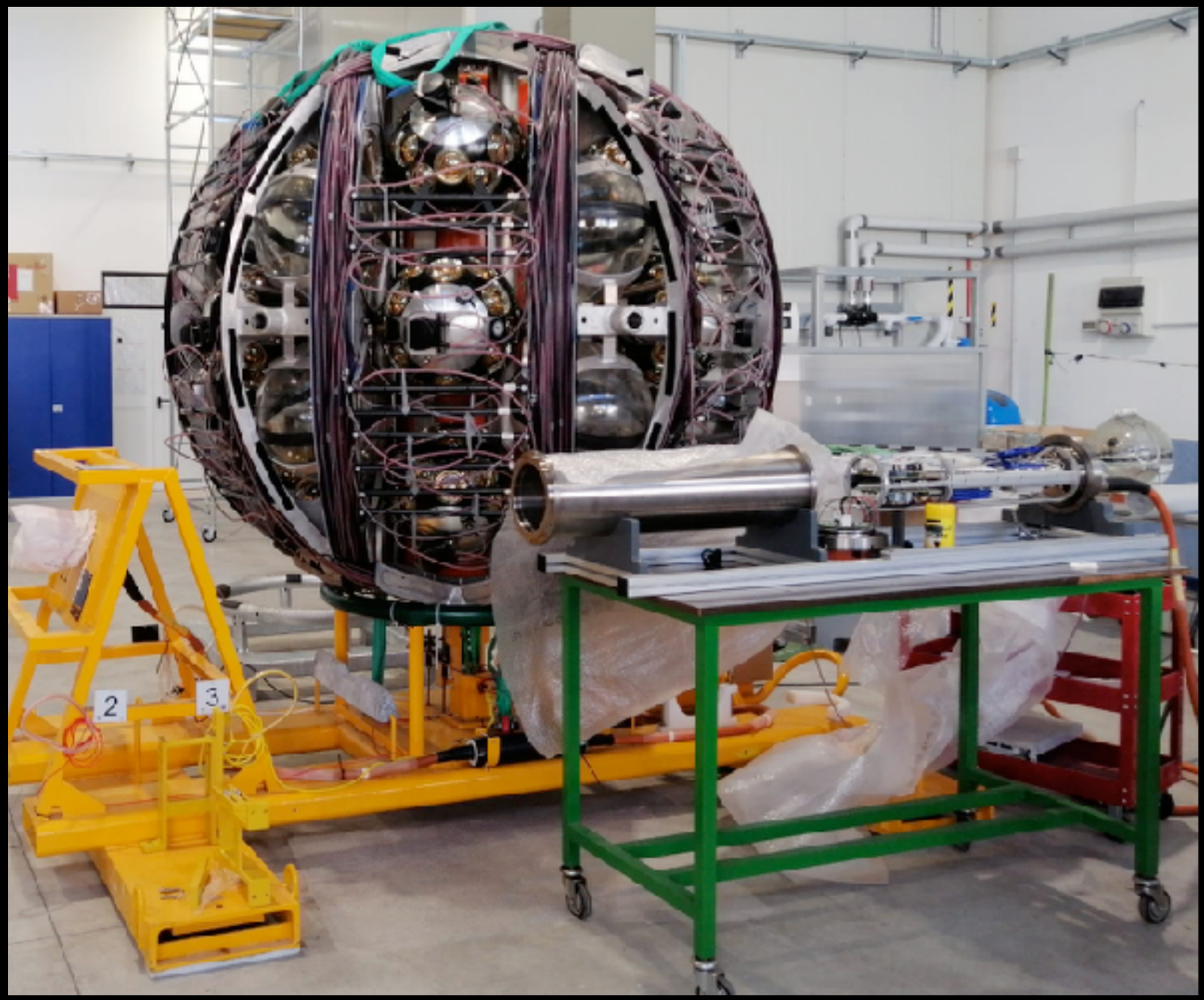
Overview

DU UPI	DU serial	DU nickname	Seafloor	Currently	Process 1	Process 2 in	Process 3 in	Process 4 in	Process 5 in
3/DU-A:IT/1.8	8	ARCA.0009 (was ARCA-DU1)	9	Y	Amsterdam	Naples	Naples	Naples	Naples
3/DU-C:IT/1.43	43	ARCA.0024	24	Y	Caserta	Caserta	Caserta	Caserta	Caserta
3/DU-B-BEACON:IT/1.46	46	ARCA.0032	32	Y	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-D:IT/1.48	48	ARCA.0023	23	Y	Caserta	Caserta	Caserta	Caserta	Caserta
3/DU-C:IT/1.49	49	ARCA.0011	11	Y	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-C:IT/1.54	54	ARCA.0028	28	Y	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-D:IT/1.55	55	ARCA.0022	22	Y	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-C-BEACON:IT/1.58	58	ARCA.0016	16	Y	Genova (in	Caserta	Caserta	Caserta	Caserta
3/DU-B_MOD:IT/1.9	9	ARCA-DU2	14	N	Amsterdam	Naples	Naples	Naples	Naples
3/DU-D:IT/1.10	10	ARCA-DU3	13	N	Naples	Naples	Naples	Naples	Naples
3/DU-C-BEACON:IT/1.40	40	ARCA.0018 (was ARCA-DU5)	18	N	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-A:IT/1.45	45	ARCA.0031	31	N	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-A:IT/1.52	52	ARCA.0017	17	N	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-A:IT/1.60	60	ARCA.0006	6	N	Caserta	Caserta	Caserta	Caserta	Caserta
3/DU-B:IT/1.61	61	ARCA.0003	3	N	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-D-BEACON:IT/1.63	63	ARCA.0008	8	N	Genova	Caserta	Caserta	Caserta	Caserta
3/DU-B:IT/1.65	65	ARCA.0002	2	N	Caserta	Caserta	Caserta	Caserta	Caserta

For M01- 2023 6 DUs are expected: 40, 45, 52, 61, 63, 65

The DU integration LAB

DU 45



- Opened BM
- OT shows 2 DOM missing
- OTDR test will occur on 31/10-1/11 with J.W. visiting CAPACITY
- We plan to purchase an OTDR tester

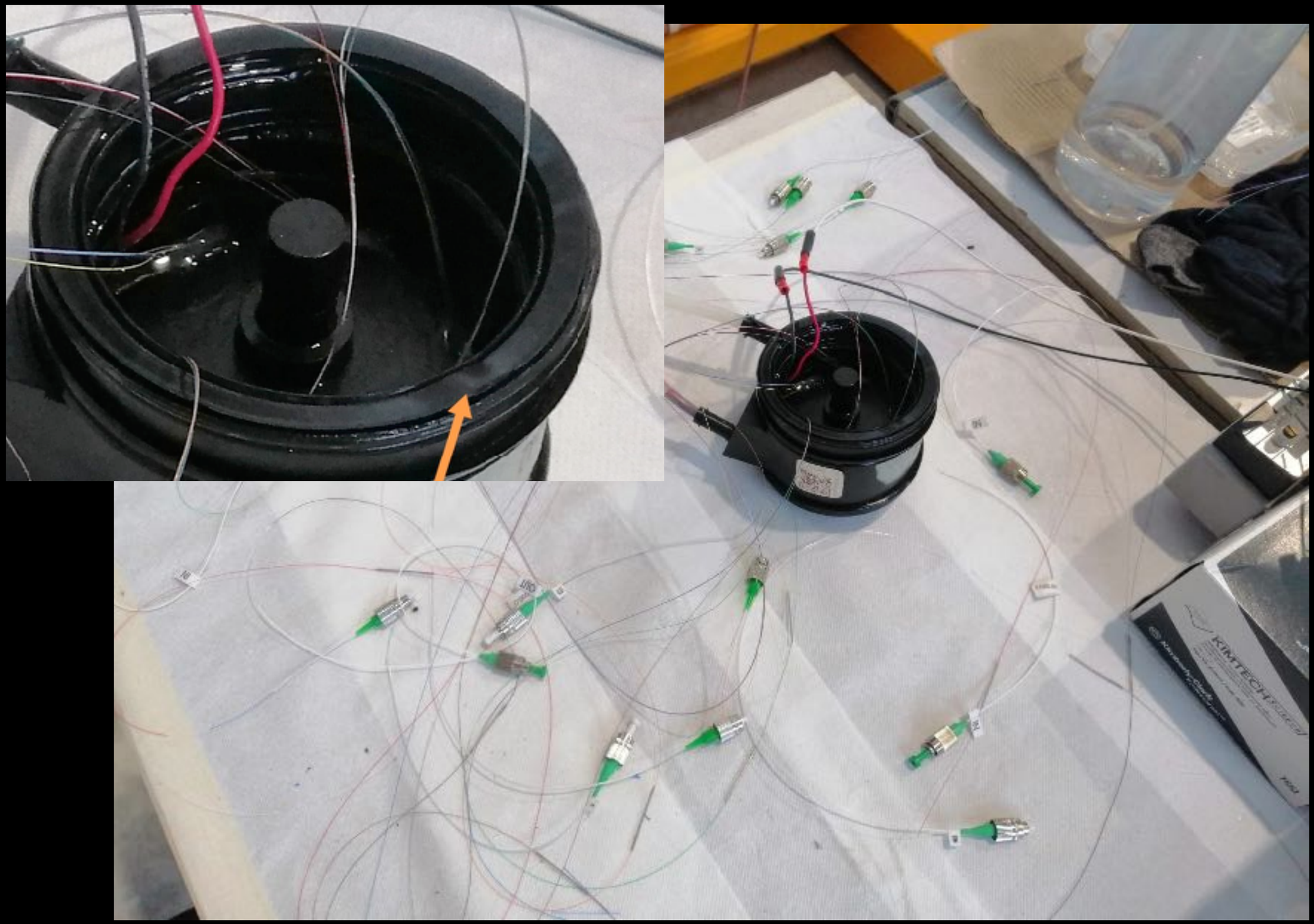
OTDR test and fault locator revealed a problem at 70 meters from the light injection point

DU 45

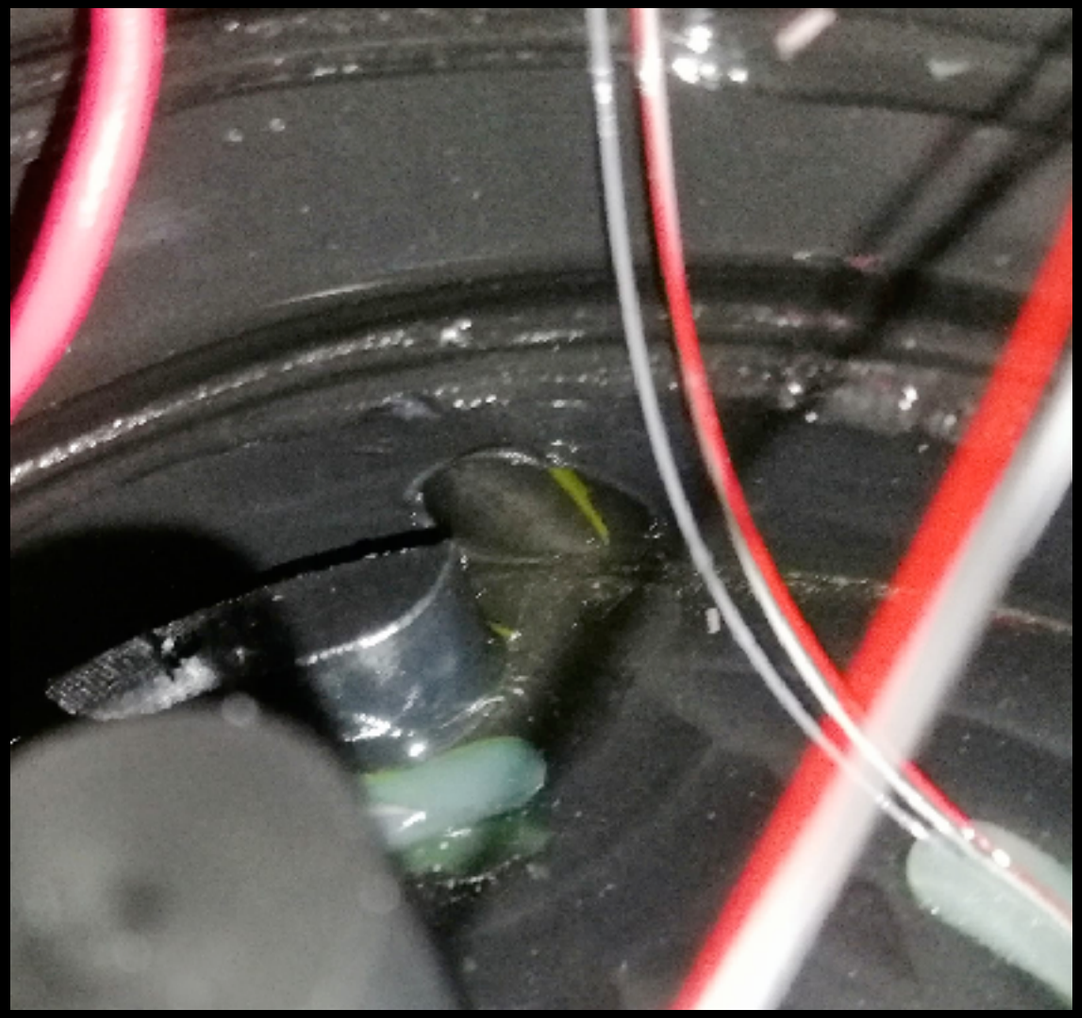
DU 52

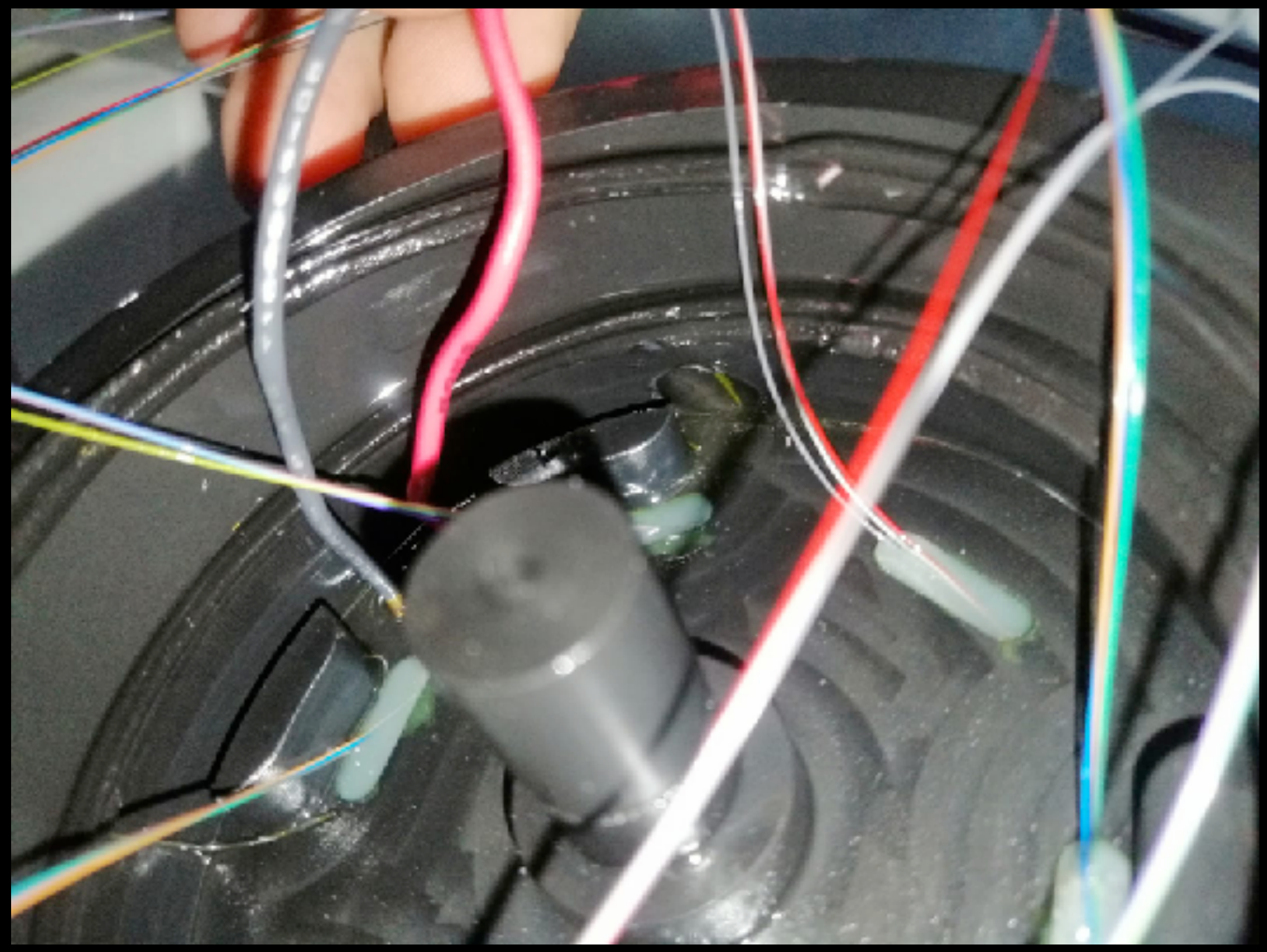
- Opened BM
- OT shows 8 DOM missing
- OTDR test will occur on 31/10-1/11 with J.W. visiting CAPACITY
- We plan to purchase an OTDR tester

DU 52



DU 52





DU 40

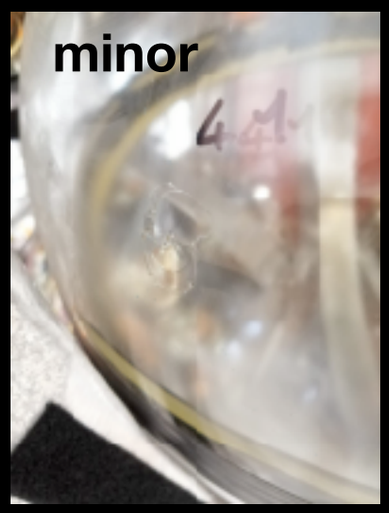
DU 61

DU 63

Other current activities

Damaged spheres NRB on LOMs : investigations and removal

Caserta LOMS					
LOM UPI	single hemisphere	full hemisphere	total hemispheres	picture number	needs rubber ?
6.6.2.3/ R2/2.8	1/18 9/6		2	1.1 1.2	y
6.6.2.3/ R3/1.22	15/10 15/4	3/16	4	2.1 2.2 2.3 2.4	y
6.6.2.3/ R3/1.17	3/16 18/7		3	3.1 3.2	y
6.6.2.3/ R1/1.45	n.a.	n.a.	5	4.1 4.2 4.3 4.4 4.5	n
6.6.2.3/ R2/1.18					y
6.6.2.3/ R2/1.15					y
6.6.2.3/ R2/1.23					y
TOTAL			14	minor=5 medium=2 large=7	



Modifications on new LOMs

Conclusions for part two

- 8 DUs deployed
- 3 DUs in refurbishment
- 2 DUs in integration
- new LOMs modifications ongoing
- Broken bentospheres on LOMs classified and documented
- For M01- 2023 6 DUs are expected

General conclusions

- The equipment for QE measurements and time properties of the PMTs are fully operative
- The measurements obtained are and will be of great importance for the KM3NeT telescope and for the experiments using this kind of photosensors
- The DU production process is well established and will expand the production capacity in the next future, for M1 2023 we plan to ship six DUs