

Characterization of JUNO Large-PMT electronics in a complete small scale test setup

V. Cerrone^{1,a}, on behalf of the JUNO collaboration

¹ University of Padova

^avanessa.cerrone@studenti.unipd.it

The JUNO experiment

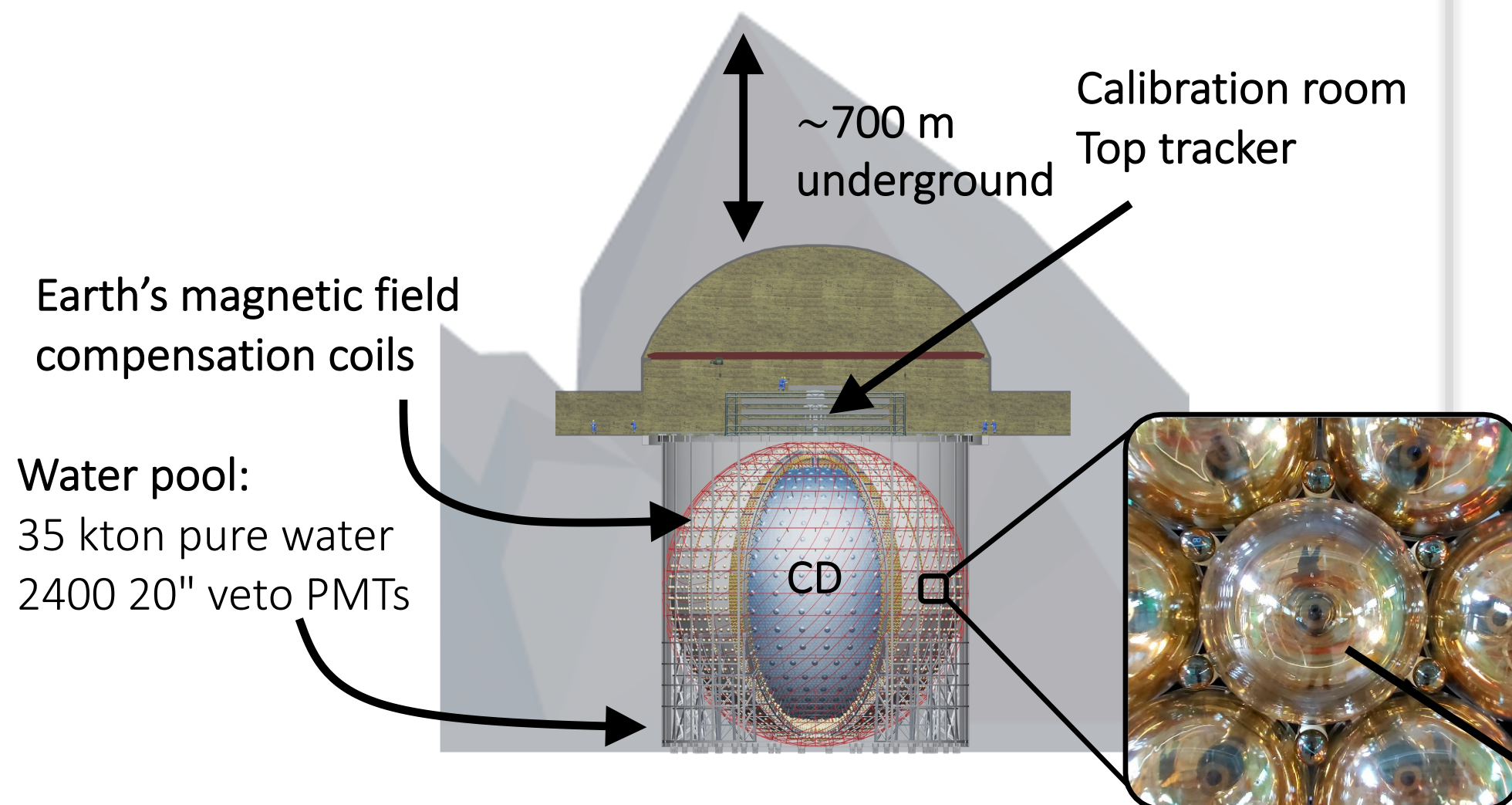
The Jiangmen Underground Neutrino Observatory (JUNO) is a **neutrino medium baseline** experiment with an expected unprecedented energy resolution of 3% at 1 MeV, under construction in southern China [1,2].

Extensive neutrino physics and astrophysics program [1]

- **Reactor $\bar{\nu}_e$** : 60 IBD/day
- Supernovae burst: 5000 IBD + 2300 ES in 10 s (@ 10 kpc)
- DSNB: 2-4 IBD/year
- Solar ν : O(100)/year
- Atmospheric ν : O(100)/year
- Geo- ν : ~400/year

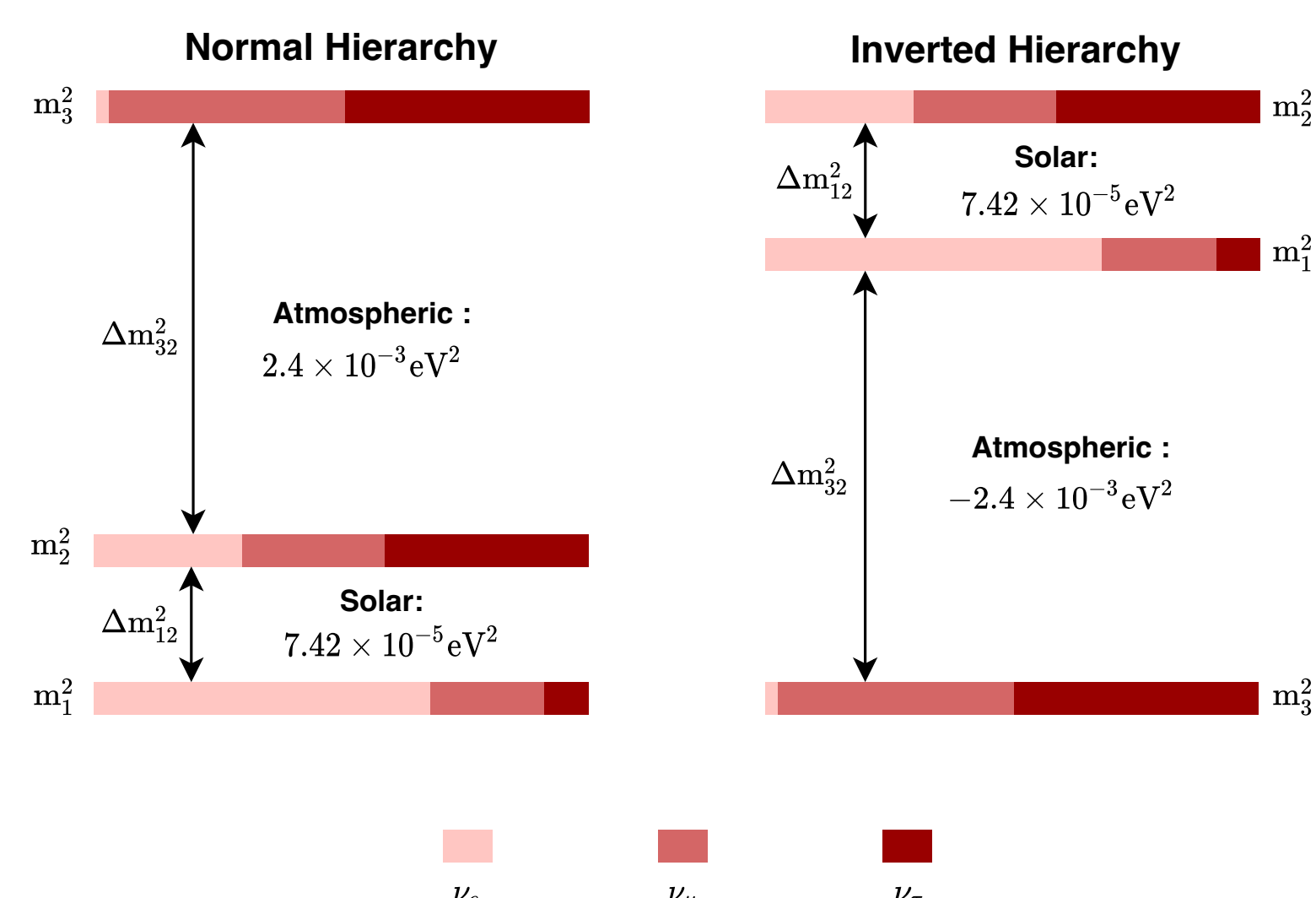
Main physics goals:

- **neutrino mass ordering** determination @ 3σ in 6 years
- measurement of three **oscillation parameters** with sub-percent precision



Central detector (CD):
20 kton liquid scintillator (LS) inside an acrylic vessel (AV) (ϕ 35.4 m), supported by a stainless-steel latticed shell

CD PMT system:
~18000 20" (Large-)PMTs
~25600 3" (Small-)PMTs
photocoverage > 75%
~1300 pe/MeV expected



Large-PMT readout electronics

Main tasks: digital conversion of the analog signals from the PMTs, local trigger generation, charge reconstruction, timestamp tagging, temporary storage in local FPGA memory, data transfer to DAQ.

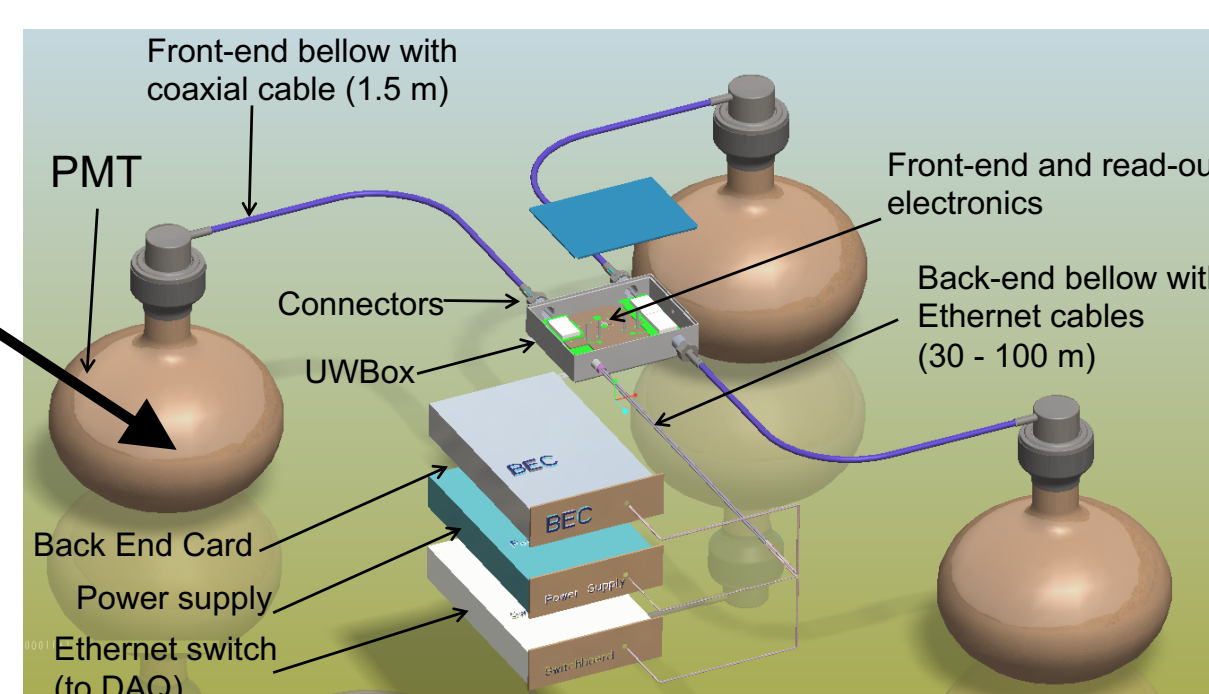
Electronics specifications [3,4]:

- Waveform **sampling**: 1 GS/s
- Wide **dynamic range**: 1-1000 pe
- Acquisition **rate** up to 10 kHz
- High **reliability**: 0.5 % failure rate over 6 years
- System **synchronization**, 8 ns clock alignment

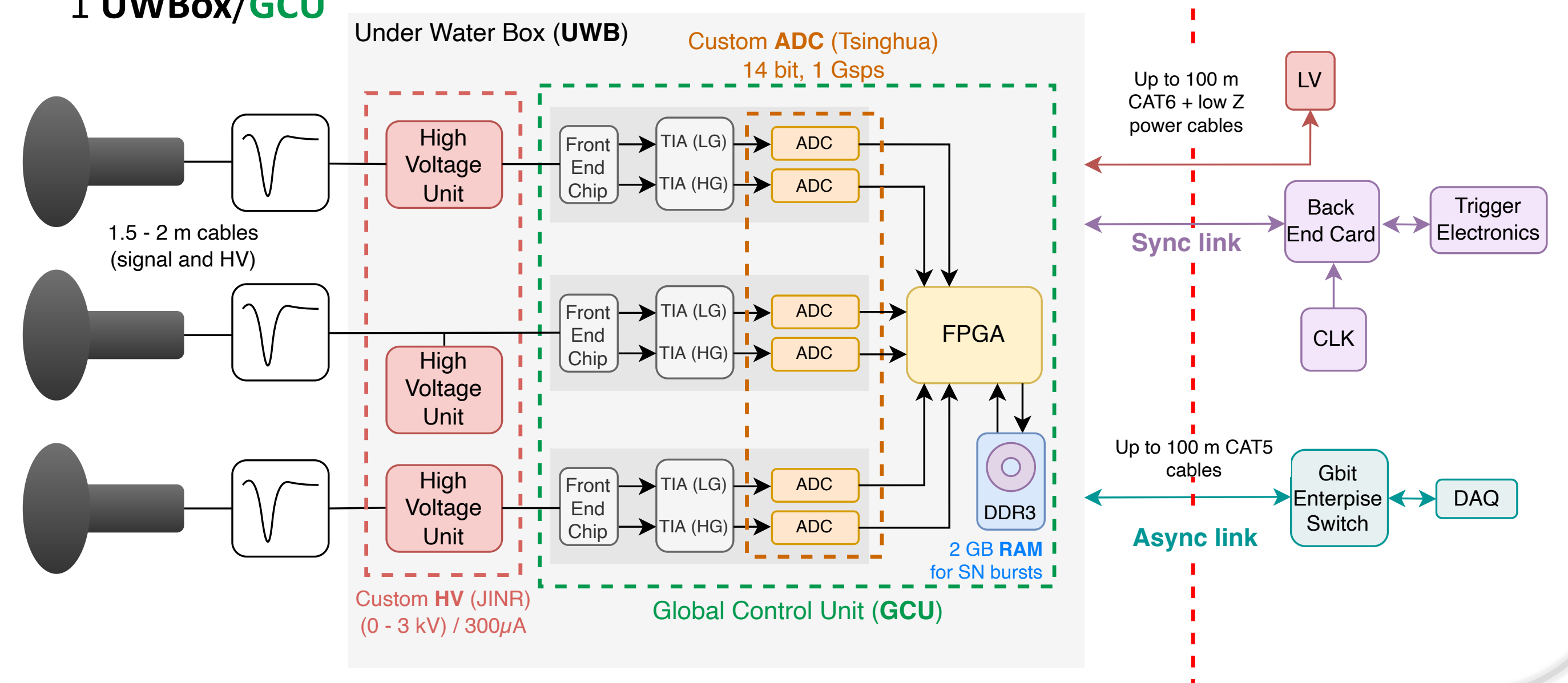
Total components:

- 20012 LPMTs
- 6670 GCUs
- 152 BECs
- 7 RMUs
- 1 Global Trigger Unit

GCUs are the **key component** in the processing of **Large-PMT signals**: a thorough characterization is required.



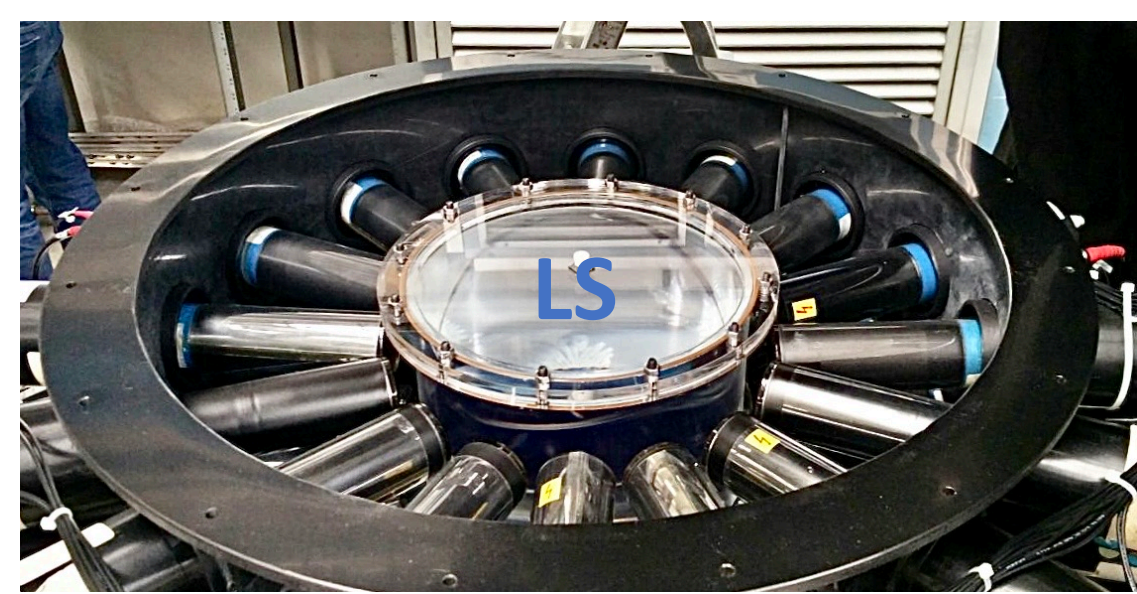
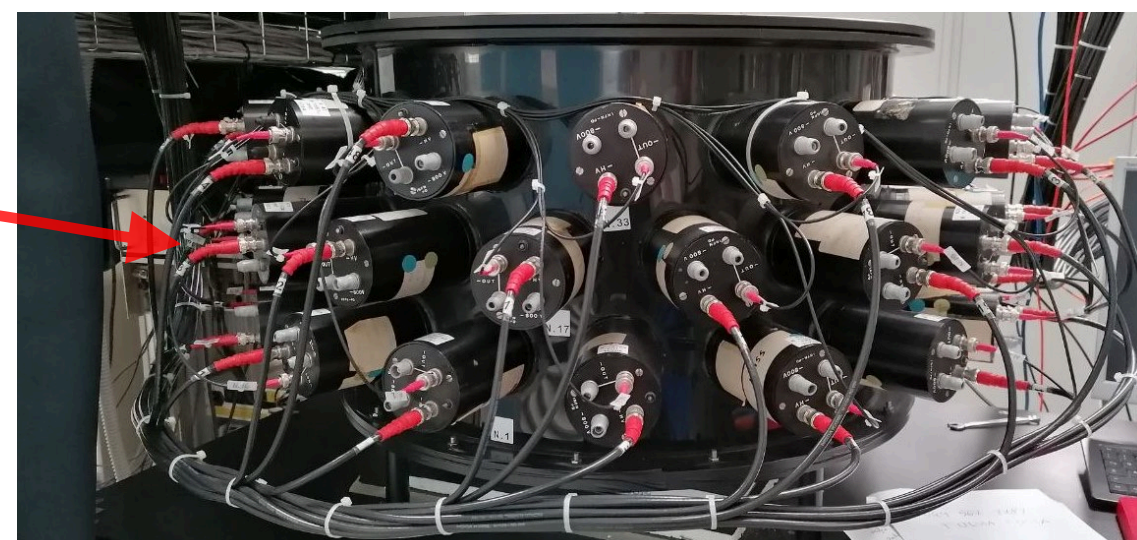
3 PMTs are connected to 1 UWBBox/GCU



Tests of the Large-PMT readout electronics at LNL(*)

Setup

- 20 l liquid scintillator (LS)
- 13 boards (GCUs)
- 39 channels (37 active) with **PMTs**
- 1 back-end card (BEC)
- 3 plastic scintillator bars to trigger cosmic muons

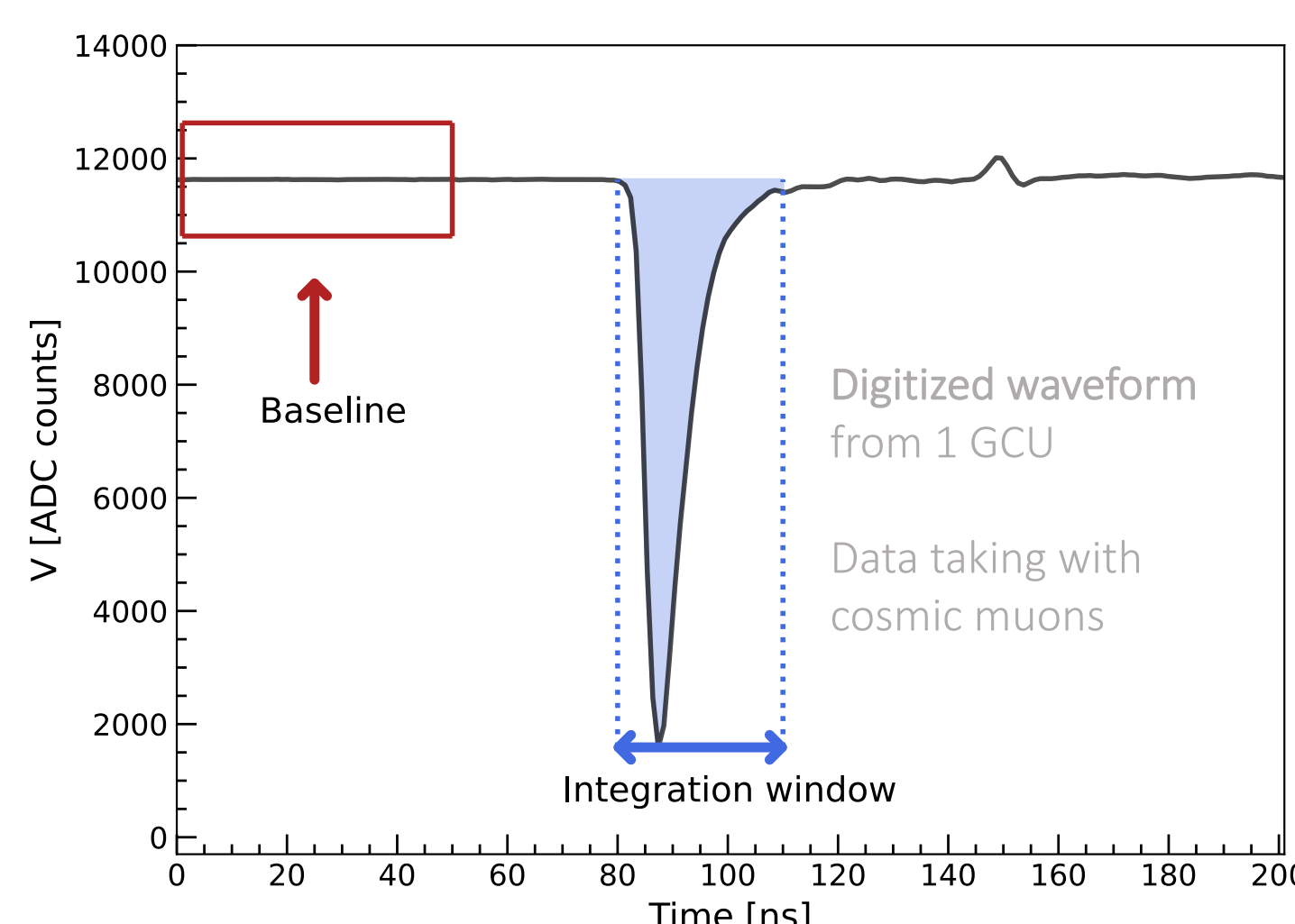


Next step: complete the synchronous link chain with the Global Trigger Unit and test the whole electronic chain.

Note: the PMTs used in this setup are not JUNO's PMTs.

Data taking

- laser
- cosmic muons
- calibration sources
- internal test pulser

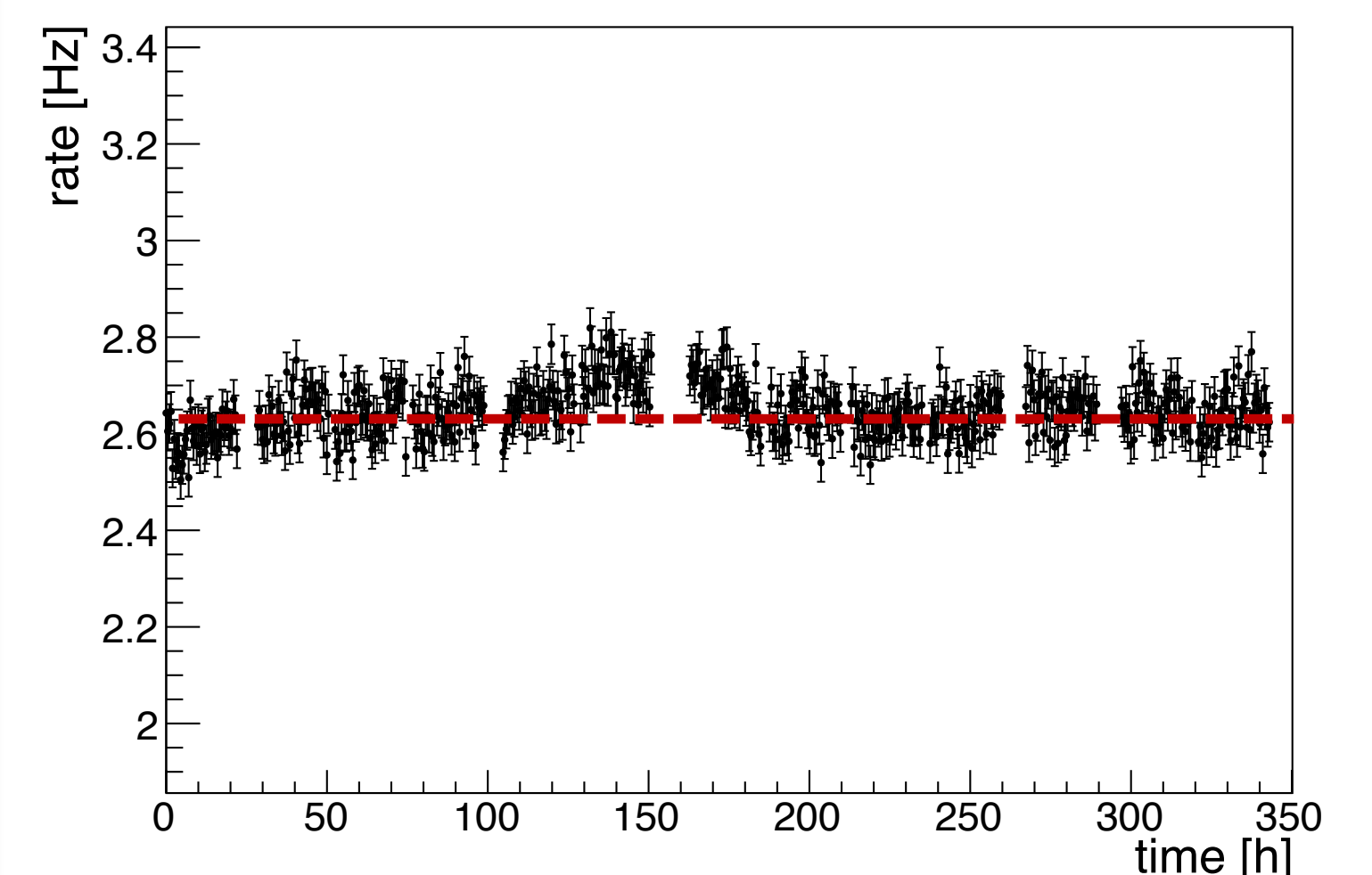


Waveform properties to check:

- baseline
- noise
- trigger stability
- integrated charge
- packet size validity
- timestamp validity

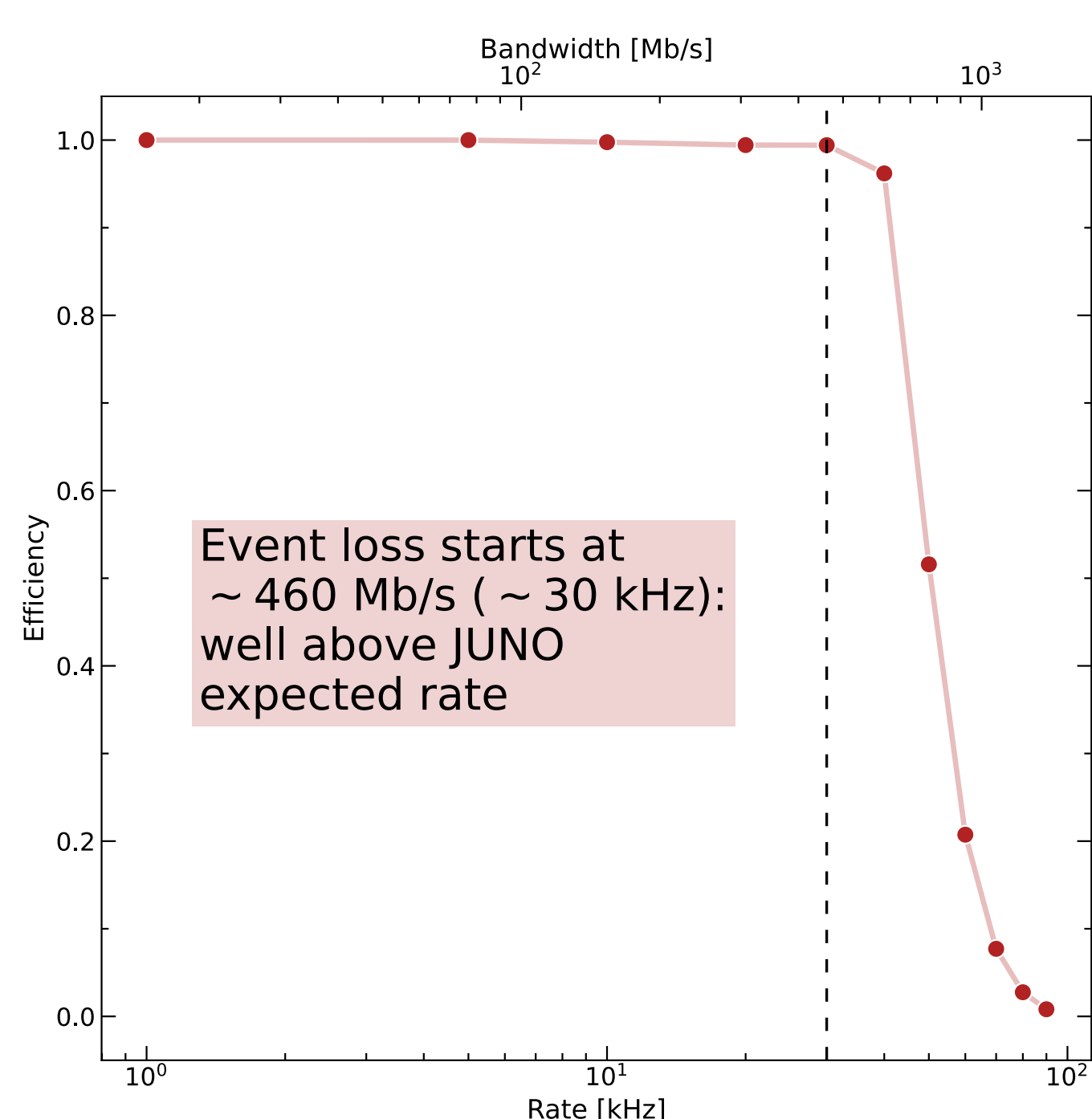
Trigger rate stability

- with cosmic muons (external trigger)
- 13 1-day-long runs over 14 days
- almost 350 consecutive hours of runtime



Measured cosmic muon rate ~ 2.65 Hz. During the test, we verified that all 13 GCUs stayed **synchronized** over the whole data taking period.

Bandwidth measurement



- external pulser at fixed rates: 1-100 kHz
- data acquisition from 3 channels of 1 GCU
- fixed packet size: 1 event = 5.12 kb

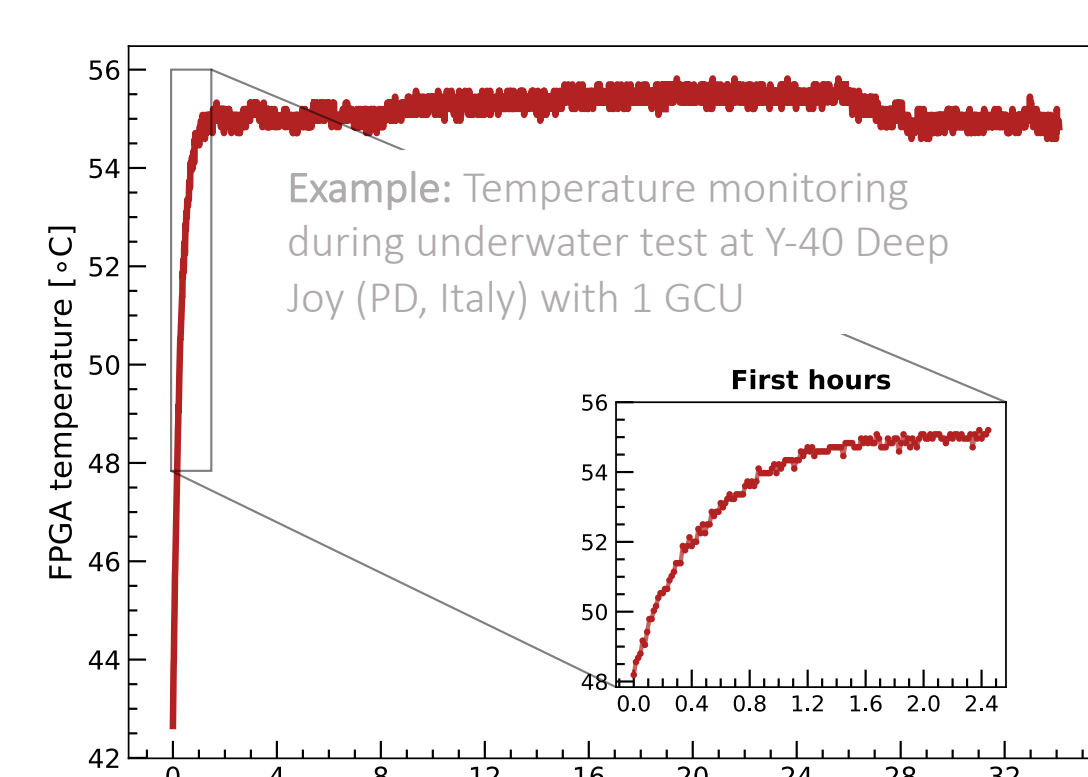
$$\text{bandwidth [Mb/s]} = \text{rate [evt/s]} \times \text{packet size [kb/evt]} \times (\# \text{ channels})$$

survival fraction: $\frac{\# \text{ of events acquired by all 3 channels}}{\# \text{ expected events}}$

On-going tests and large-scale integration test

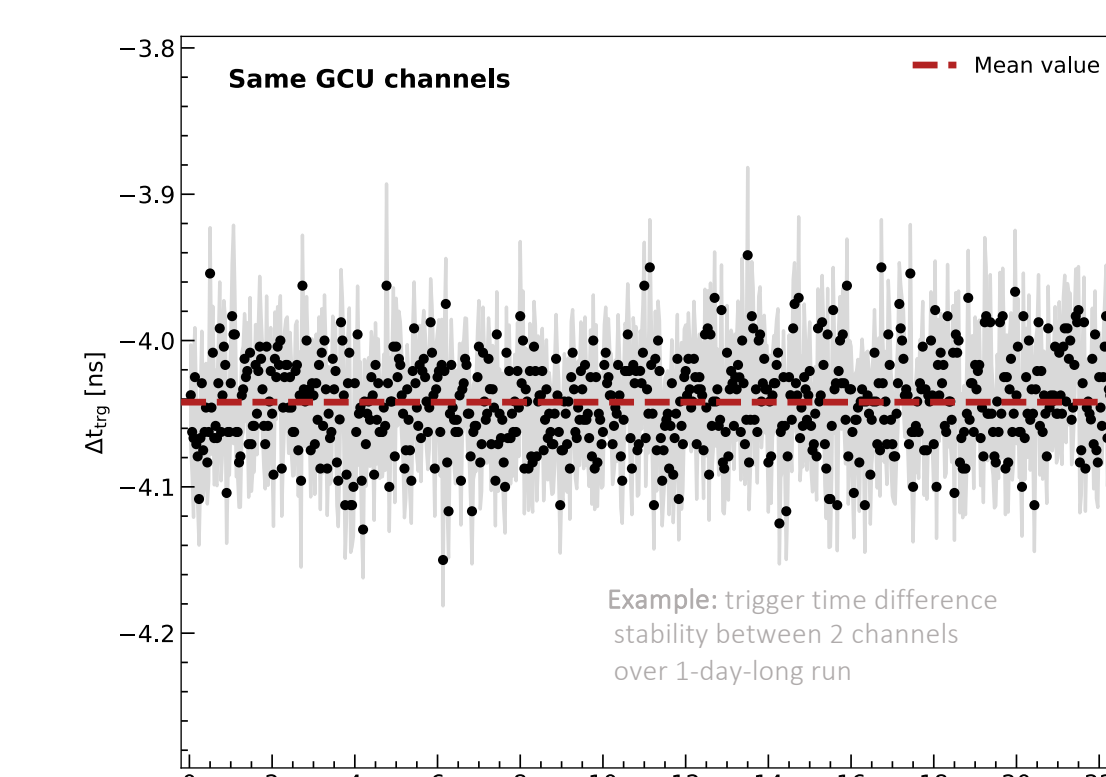
Slow control:

- check parameters:
 - temperatures
 - internal voltages
 - internal currents
- check connection with HVUs



Tests with a laser:

- check linearity of the ADCs
- check temporal synchronization of the GCUs:
 - Temporal mismatch is inside the expected interval



Integration tests in Kunshan, China:

mass testing of 344 GCUs at production site

See poster by R.Triozi, *Mass testing of Large-PMT electronics at Kunshan for the JUNO experiment*

References:

- [1] JUNO Collaboration, JUNO Physics and Detector, 2021, arXiv:2104.02565
- [2] JUNO Collaboration, Neutrino Physics with JUNO, J. Phys. G43, 3, 030401 (2016), arXiv:1507.05613
- [3] JUNO Collaboration, JUNO CDR, 2015, arXiv:1508.07166 (chapter 7)
- [4] JUNO Collaboration, Embedded Readout Electronics R&D for the Large PMTs in the JUNO Experiment (2020), arXiv:2003.08339

(*) Laboratori Nazionali di Legnaro, INFN, Italy