

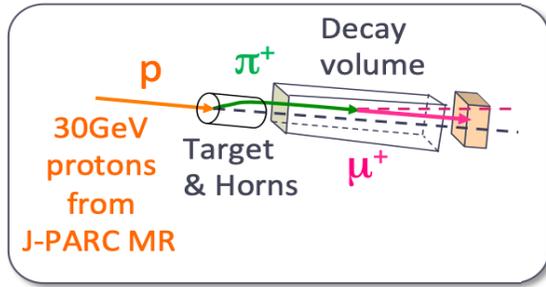
Hyper-Kamiokande

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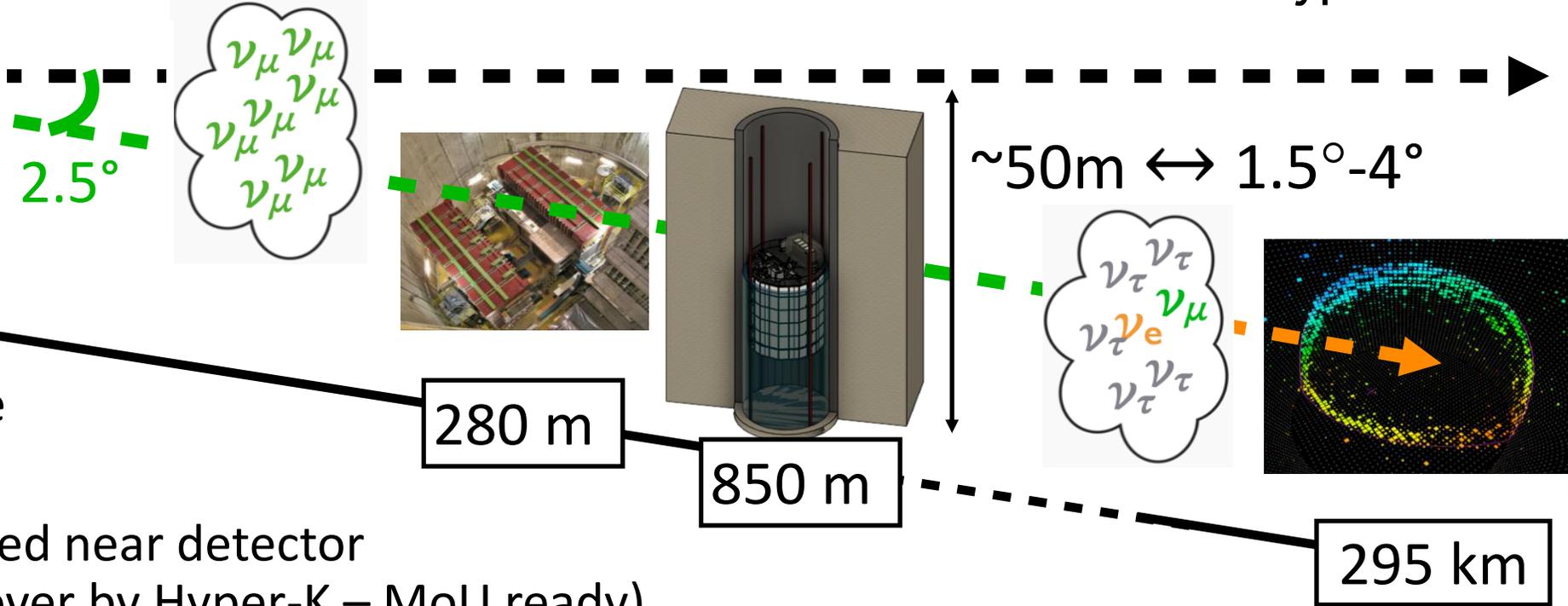
Hyper-Kamiokande Experiment

J-PARC beamline



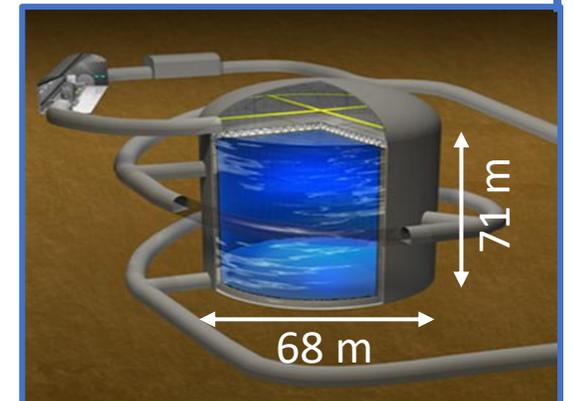
Near Detectors

Hyper-K FD



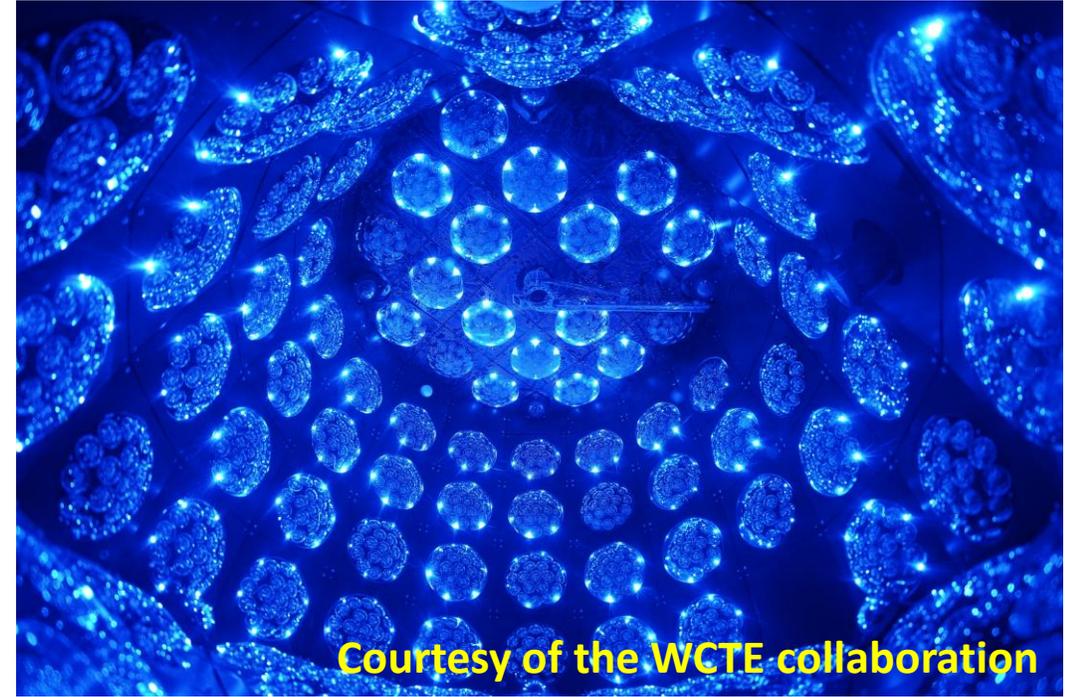
- Upgraded beamline 0.5 MW \rightarrow 1.3 MW
- ND280 as magnetised near detector (plans to be taken over by Hyper-K – MoU ready)
- A new Intermediate Water Cherenkov Detector (IWCD) (movable along off-axis angle, approx. kt-scale)
- Water Cherenkov far detector: 188.4 kton fiducial volume ($\approx 8.4 \times$ Super-K)

ON-GOING CONSTRUCTION (completion in 2027)



Water Cherenkov Test Experiment

- Water Cherenkov Test Experiment @ CERN
 - 50-ton scale detector ($\sim 4\text{m} \times 4\text{m}$ cylinder)
 - To study detector calibration and response with known p , e , π , μ fluxes of 0.2-1.1 GeV/c and develop percent level calibration of water Cherenkov detector.
 - Major test bed for Hyper-Kamiokande multi-PMT systems and several calibration strategies
- Experiment complete
 - Detector completed (Oct. 2024)
 - Two data taking runs – Q4 2025, Q1+Q2 2026
 - Decommissioning in Q3 2026 (completed)
- Problems with light leaks, electronics, DAQ and mPMT efficiency
 - Electronics problems resolved for running in 2026
 - Significant feedback for IWCD construction
 - Unexpected UV detection efficiency degradation due to interaction of gel with dopant in filament used to 3D-print PMT support structures
 - Two mPMTs drowned (mechanical failures)



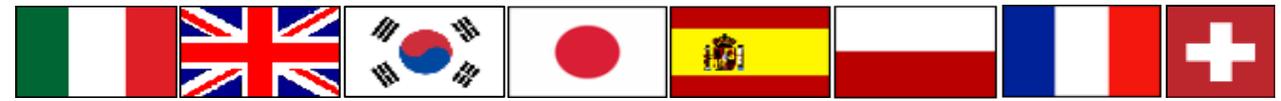
Far Detector Update



- 256 kton total mass (H = 73 m, \varnothing = 69 m), 188.4 kton fiducial volume (~8.4 x Super-K)
- Largest ever human-made cavern
- Tank lining construction in progress



Far Detector Electronics



- Far detector electronics will be submerged in water
 - Reduction in cable lengths (better signal integrity, less weight)
 - Stringent requirements on reliability (20 years of operation, no serviceability)
 - **System to feed nitrogen into vessels (prevent vacuum due to operation in degassed water)**
- Modular system
 - High voltage supply (redundant control)
 - Fully redundant low voltage supply
 - Digitizers (T/Q + Time over Threshold)
 $\sigma_{\text{time}} \approx 0.25 \text{ ns}$, $\sigma_q \approx 0.16 \text{ pC}$ (at 1 PE = 19 pC)
 - **Data processing card (clock recovery, buffering, slow control)**
- Timing system and DAQ on tank top
- Prototypes complete, performance confirmed, testing pre-production versions
- Starting final production, tendering almost complete

Timing distribution system

- *Two-stage system*
- *GPS/GNSS + atomic clock (redundant)*
- *Achieved clock jitter $\approx 0.5 \text{ ps}$*
- *Far & near site beam spill timing via GPS/GNSS time stamping*

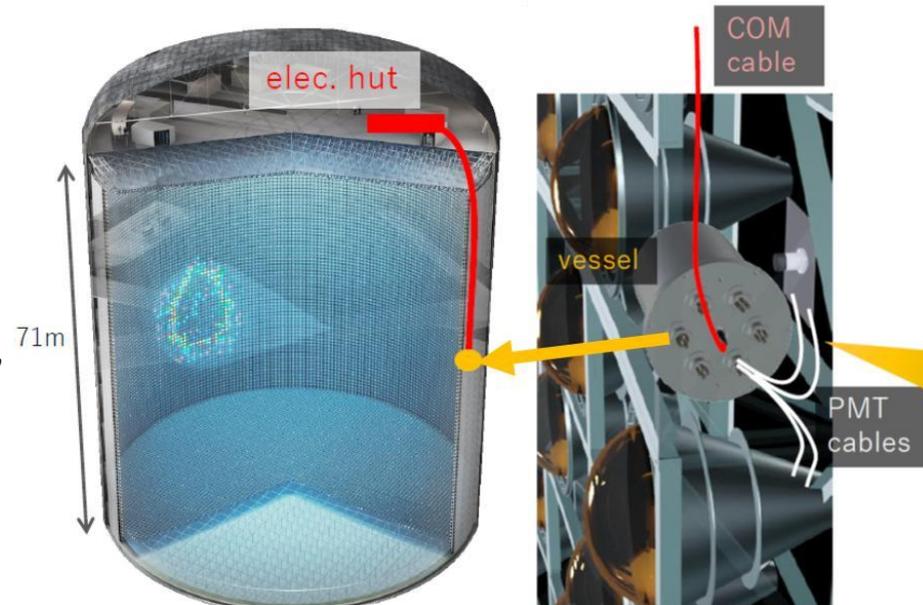
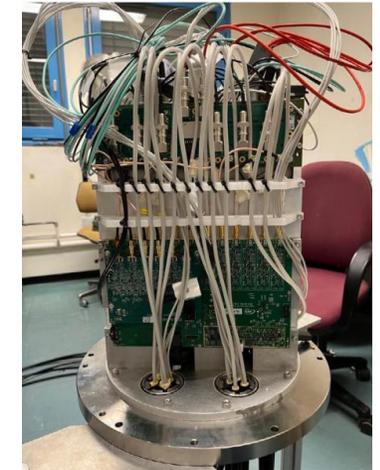
1-st stage distributor



2-nd stage (TDM)



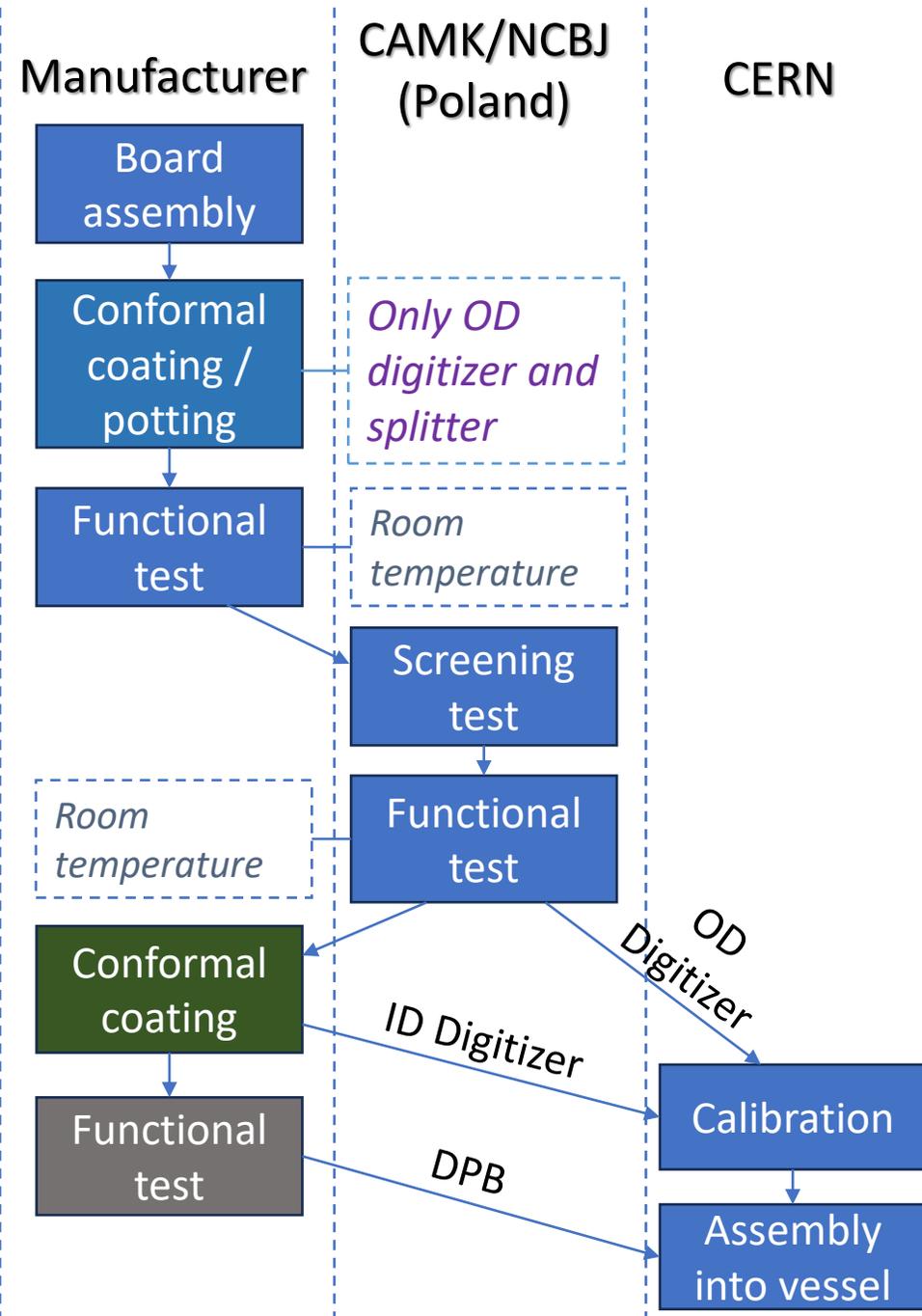
Underwater pressure vessel



ASSEMBLY STARTS AT CERN in SEPTEMBER 2026

Quality Assurance (Board screening)

- Will do in-house screening tests of electronics boards
 - Stripped IPC9592B procedure – temperature & power cycling
 - Cost saving
 - Simplifies test fixtures – no need to test high speed links, since DPB is connected to digitizer
- Test fixture only needs to inject constant signals at fixed frequency
 - Simple microcontroller circuit can do that
- Stock power supplies with voltage/current monitoring + distribution system
- Test framework based on already developed framework



- 720-liter thermal chamber at NCBJ
- Up to six *DPB* + 2 *digitizers* sets per shelf (incl. test fixture)
- Testing speed: 36 *DPB* and 72 *digitizers* per day

Summary 1/2

- Many milestones reached in 2025
 - Completion of WCTE experiment, incl. de-commissioning
 - Analysis of WCTE data, significant feedback for IWCD and FD mPMT production
 - Solved de-gassing problems for electronics vessel and mPMTs for the far detector
 - Concluded agreements for NP08 Neutrino Assembly project at CERN (MoU signed)
 - On-going aging tests of electronics (still no failures)
 - Improved testers for mPMTs
 - Finalized assembly protocols for far detector electronics
 - Analyzed and optimized grounding of far detector electronics
- Papers:
 - WCTE mPMT construction paper, target: NIM A (accepted)
 - HK Supernova Sensitivity, target: PRL (accepted)
- Technical notes:
 - Protocol for Hyper-Kamiokande electronics acceptance test at the assembly site (complete)
 - Protocol for calibration of Hyper-Kamiokande digitizers (complete)

Summary 2/2

- Procurements:
 - 6000 PMTs for FD multi-PMT modules (done), 1400 PMTs for IWCD multi-PMT modules (done)
 - 1160 Underwater feed-throughs for FD electronics (1050 contracted, 110 on-going)
 - 24000 HV and front-end cards for mPMT modules (tenders complete, signing contracts)
 - 940 data concentrator cards for the FD (on-going procurement)
- To do:
 - **Paper:** WCTE mPMT electronics paper, target: NIM A (writing)
 - **Paper:** WCTE beam telescope paper, target: JINST (submitted)
 - **Technical note:** Protocol for HASS tests of Hyper-Kamiokande electronics
 - **Procurement:** LV cables for the far detector
 - **Hardware:** Setup for HV tests at the assembly site at CERN → CAMK + Warsaw University of Technology
 - **Hardware:** Setup for HASS (Highly Accelerated Stress Screening) at NCBJ → CAMK + Warsaw University of Technology
 - **Hardware:** Production of 300 mPMT for FD and 80 mPMTs for IWCD
 - **Hardware:** Fixing 50 mPMT from WCTE (gel degradation)
 - **Logistics:** Shipment of mPMTs to Japan (already booking containers and slots on ships)

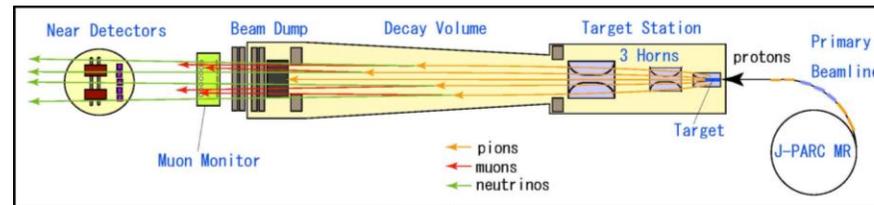
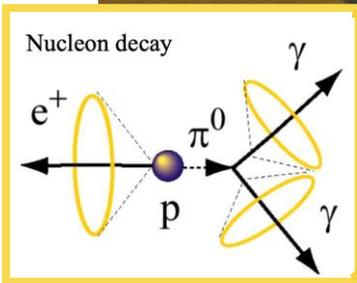
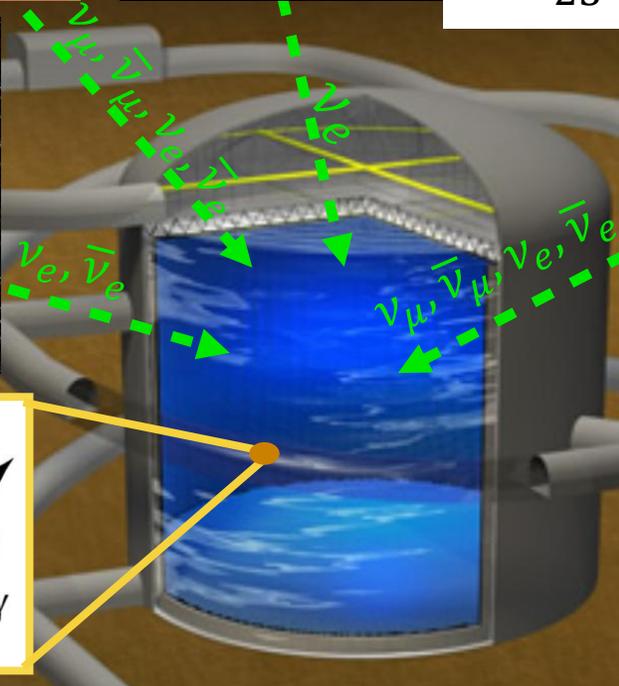
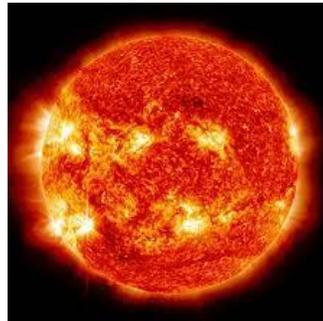
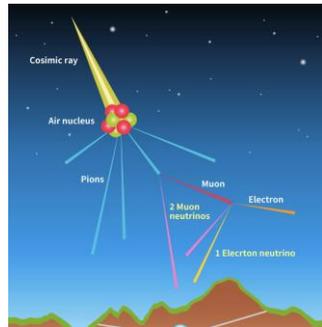
BACKUP

Hyper-Kamiokande Experiment – Physics Goals

The next generation water Cherenkov experiment in Japan

Oscillation of accelerator and atmospheric ν 's

- CP violation \rightarrow matter/antimatter asymmetry
- Neutrino mass ordering (MO) $\rightarrow \nu$ masses, input for $0\nu\beta\beta$ and direct mass experiments
- θ_{23} octant and δ_{CP} \rightarrow lepton symmetries



Other physics program:

- Solar ν 's
- Supernova burst and diffuse background ν 's
- Search for proton decay
- Indirect Dark Matter search



- 22 countries, 106 institutes, ~650 people (December 2024)

- Still growing (~24% Japanese and ~76% non-Japanese)



Activities in Poland (2025)

- Management:

- Executive Board membership (*prof. Ewa Rondio from NCBJ*)
- Speakers Board chair
- Three deputy conveners for far detector working groups (**electronics**, calibration, **mPMTs**)
- **Deputy convener** – IWCD and WCTE detectors (photodetectors & electronics)
- Technical coordinator, working group level (multi-PMTs)
- **Steering Committee membership** (IWCD, WCTE)

- R&D + production:

- Linear accelerator (NCBJ)
- Far detector electronics (CAMK, WUT, UJ)
 - **Data processing module (DPB)** ← **Collaboration with UPV (Valenzia)**
 - Data concentrator card for multi-PMTs (MCC)
 - **Reliability estimations**
 - **Ground system design**
 - **Design reviews**
- IWCD electronics (WUT, UJ, AGH, CAMK)
 - **Multi-PMT front-ends**
 - High voltage supplies
 - Data concentrator card for multi-PMTs (MCC)
 - **Quality assurance** (incl. dedicated test hardware)
 - **Design reviews**
- multi-PMTs (WUT, CAMK)
 - Photosensor characterization
 - Optimization of assembly strategy
 - **Mass production** (completed for WCTE, preparing for FD)
 - Quality assurance
- WCTE (CAMK, WUT)
 - Electronics for beam tests, detector construction & commissioning
- Analysis + simulations + computing

*Over 40 people in Poland from 9 institutions;
WUT/CAMK/AGH/UJ -> 17 people, ≈13 FTE*

**Close collaboration with
TRIUMF and INFN Naples**