X-Arapuca long term test

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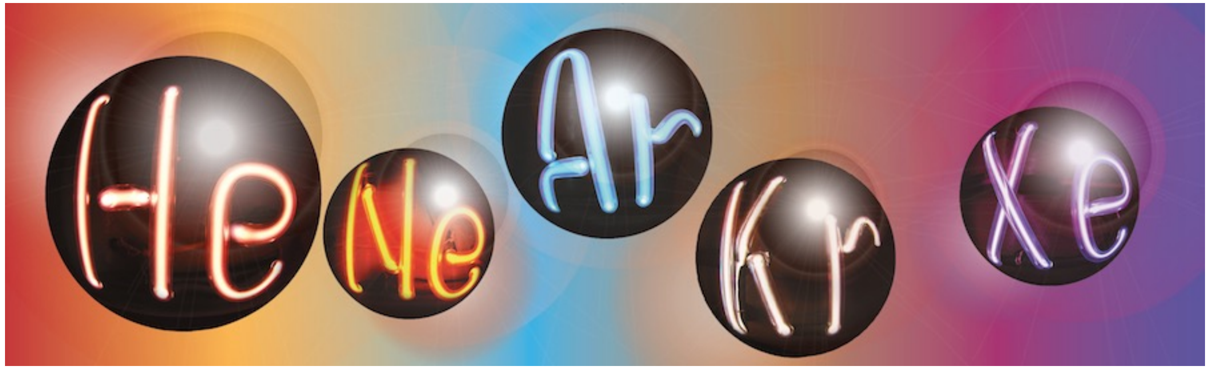
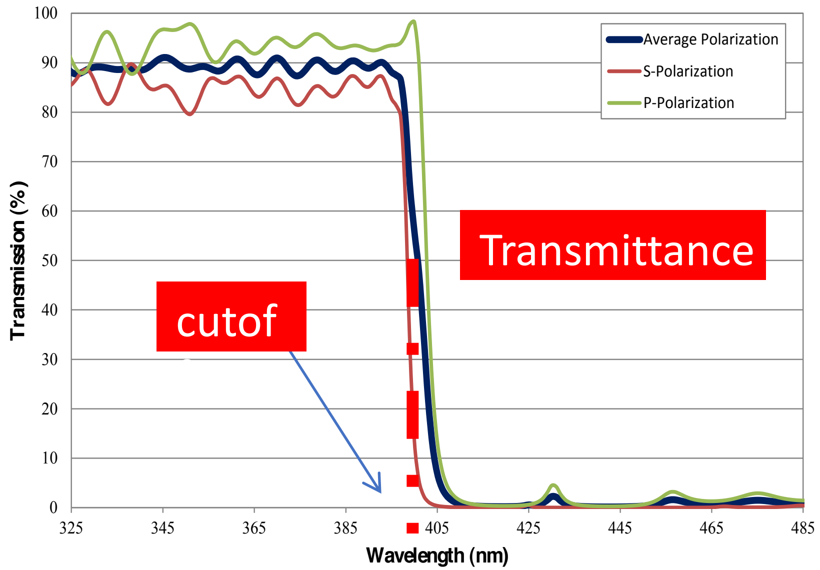


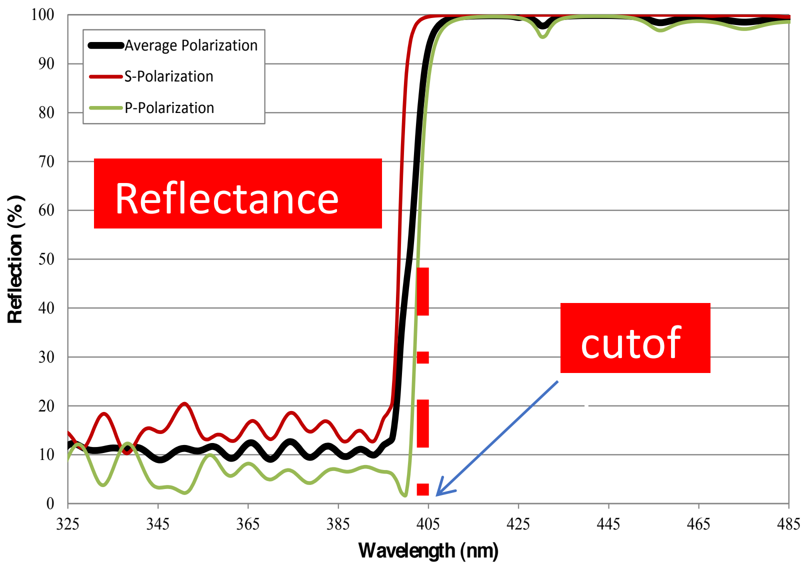
Outlines

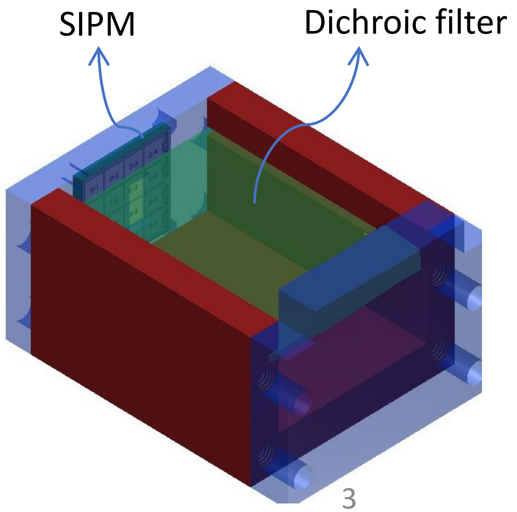
- x-Arapuca conceptual idea
- x-Arapuca application in DUNE experiment
- x-Arapuca test in Napoli cryogenic lab
- Results
- Conclusions and outlook

Arapuca conceptual idea

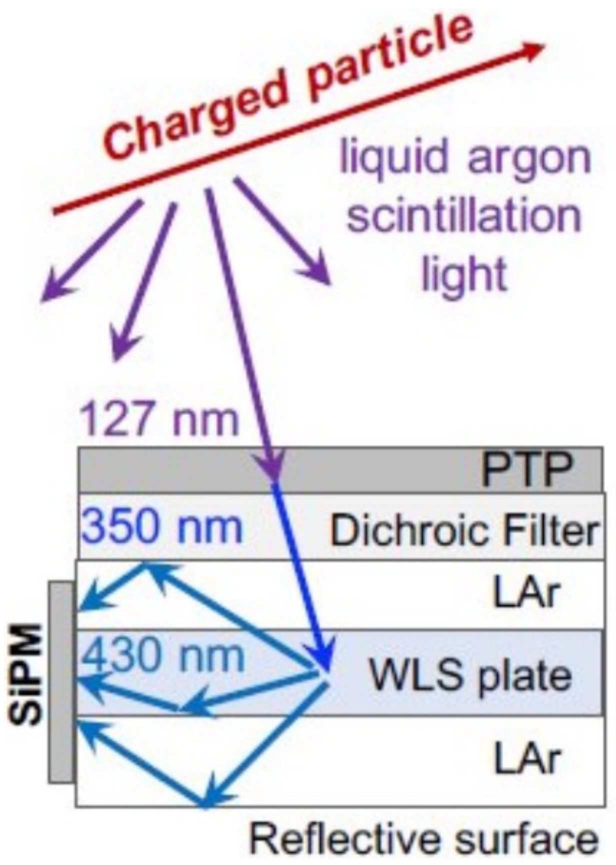
- Basic idea is to trap photons in a box with **highly reflective internal surfaces**
- Develop an **efficient photon collector** system which allows to increase the effective area of the active SiPM devices
- The core of the device is the **dichroic filter**: a multilayer acrylic film which is **highly transparent** for wavelength **below a cutoff** and **highly reflective above it**



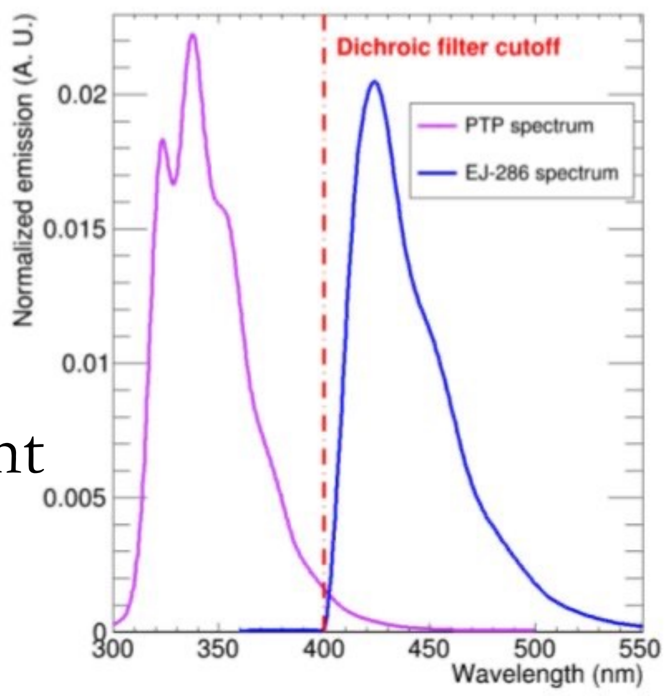




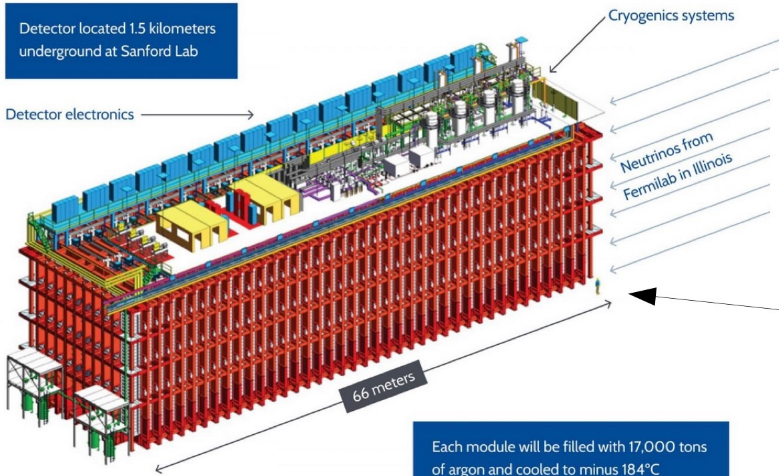
Arapuca operation principle

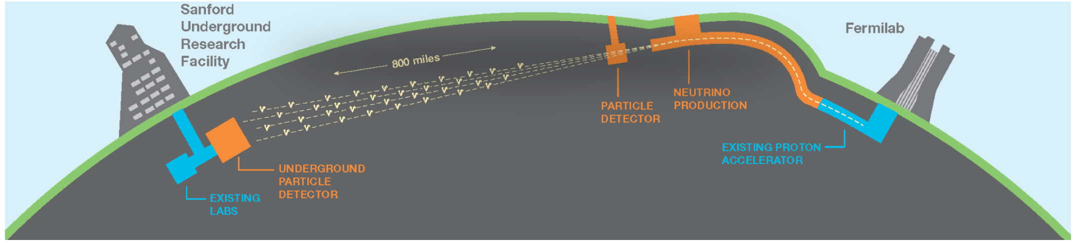


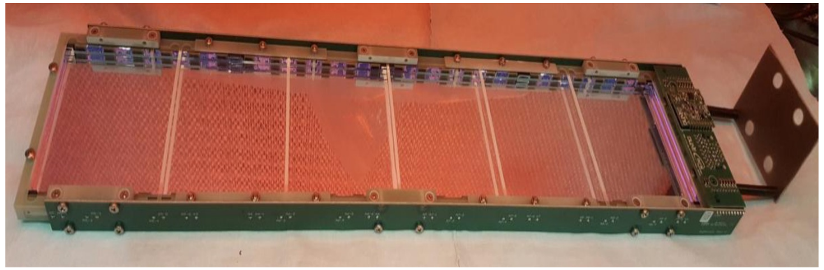
- VUV scintillation light produced in LAr
- PTP shifter deposited on the dichroic external side convert VUV light to a wavelenght < dichroic cutoff **(light transmitted)**
- The internal WLS bar convert the primary shifted photons to a wavelenght > dichroic catoff **(light is trapped)**
- After reflections the photons can be detected by SiPM positioned laterally with respect to the WLS plane

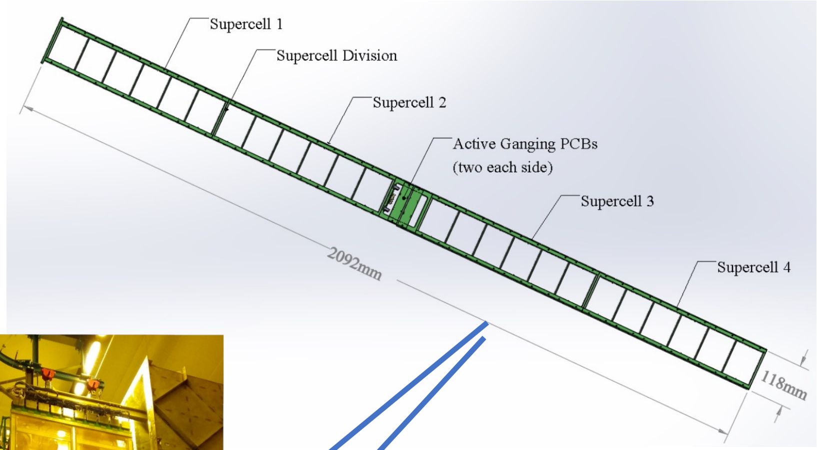


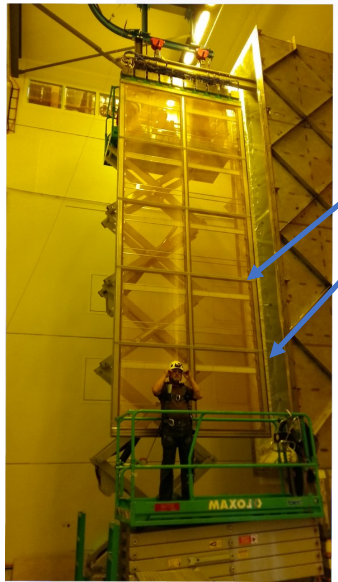
x-Arapuca in DUNE – Horizontal Drift





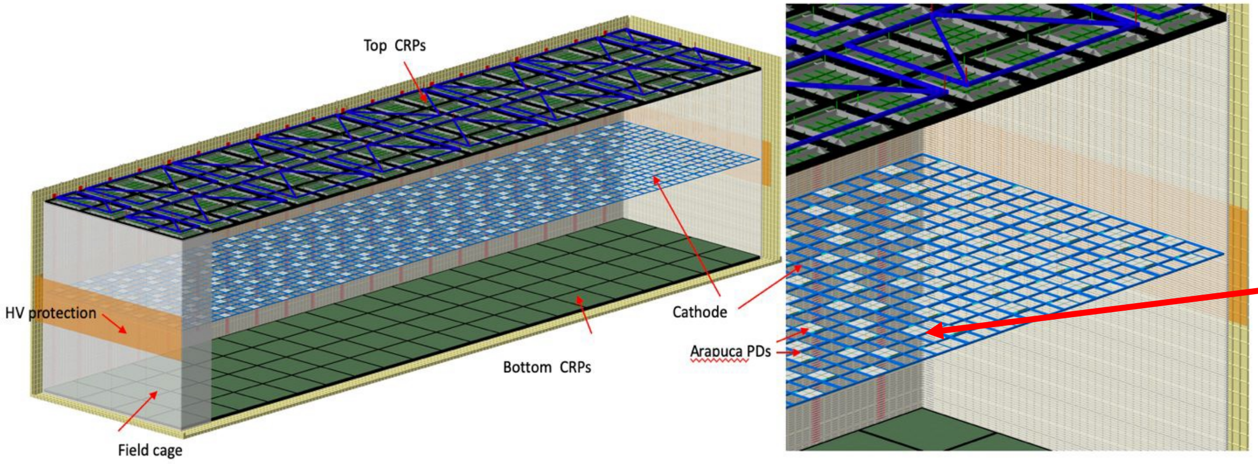


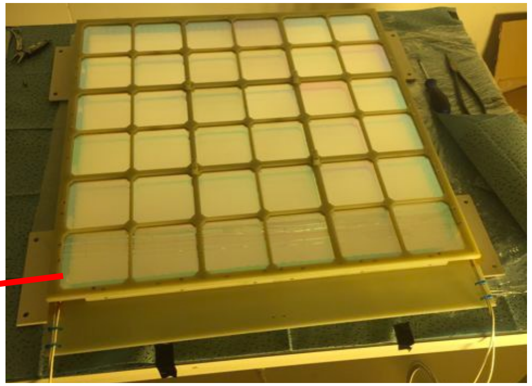




- Photon detection system in 1st module of DUNE far detector
- X-Arapuca basic light collector (supercell) made of 6 dichroic filters and 1 single WLS plate
- 48 ganged SiPMs and 1 readout channel
- Detection pinciple succesfully tested in Protodune-HD Run1
- Several Arapuca types (different combination of WLS and SiPMs) will be tested in Protodune-HD Run2 (end of year)

x-Arapuca in DUNE – Vertical Drift

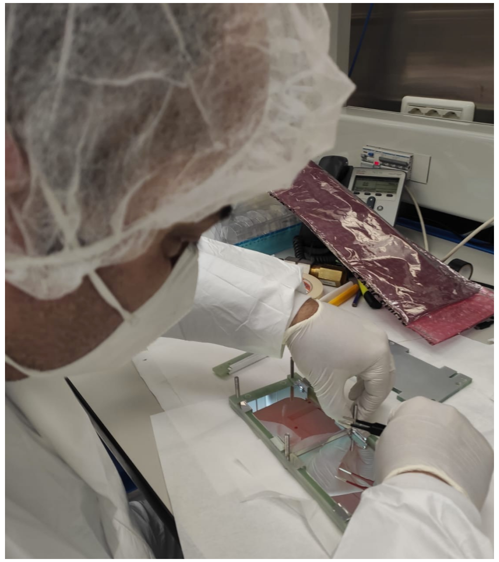


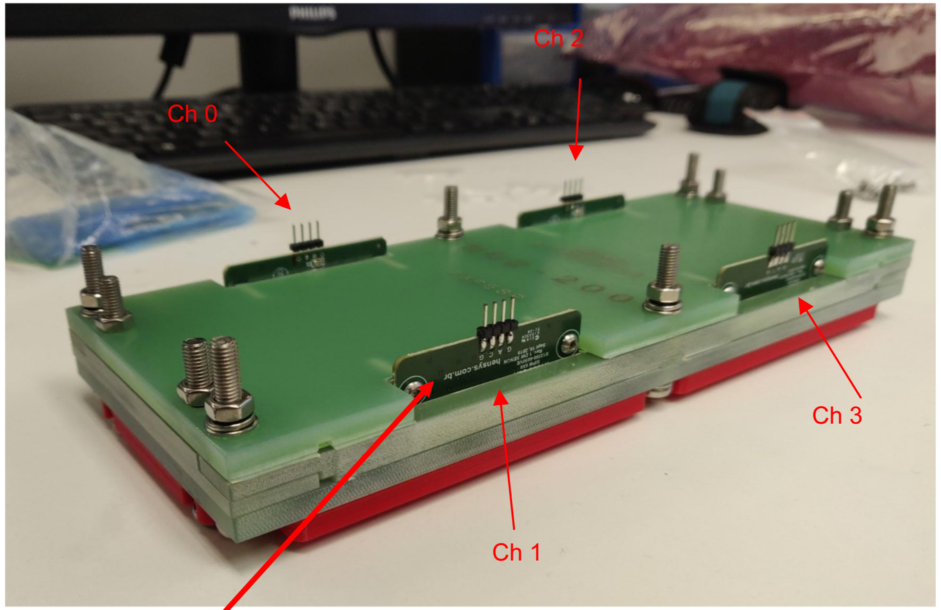


Megacell: new version of the photon detection system

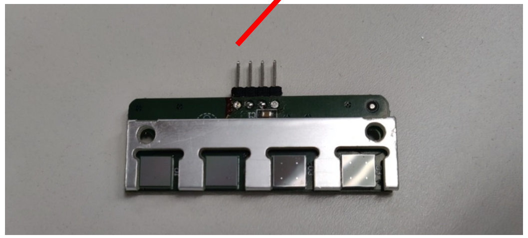
- The DUNE Vertical Drift concept proposed for the second module
- Cathode hanging at mid-height bias voltage: -300 kV; Electron drift vertically over 6.5 m
- Photon sensors on cathode and on the lateral walls
- Megacell Arapuca (60x60): 36 dichroic filters, SiPMs on the lateral sides with flex circuit
- The new version is going to be tested in cold box test at Cern and other laboratories
- A future ProtoDUNE-VD run is foreseen

X-Arapuca sample used in this work





- 2 cell x-Arapuca assembled in Naples
- dichroic filters from OPTO Brazilian company, PTP deposition performed at Campinas University
- WLS plan was an ELJEN plastic plane
- **SIPMs** from Hamamatsu (S13360-6050VE)
- Ganging of the four SiPMs on the same output: 16 SiPMs and 4 channels)

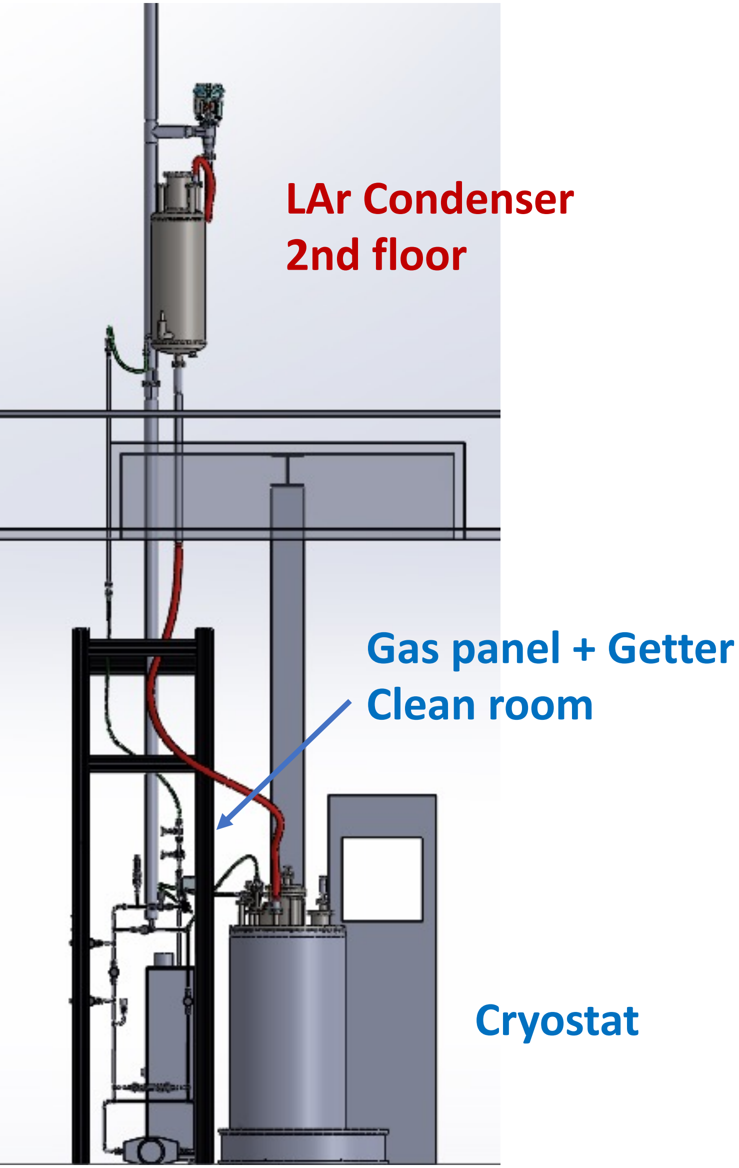


SiPM board

X-Arapuca test setup

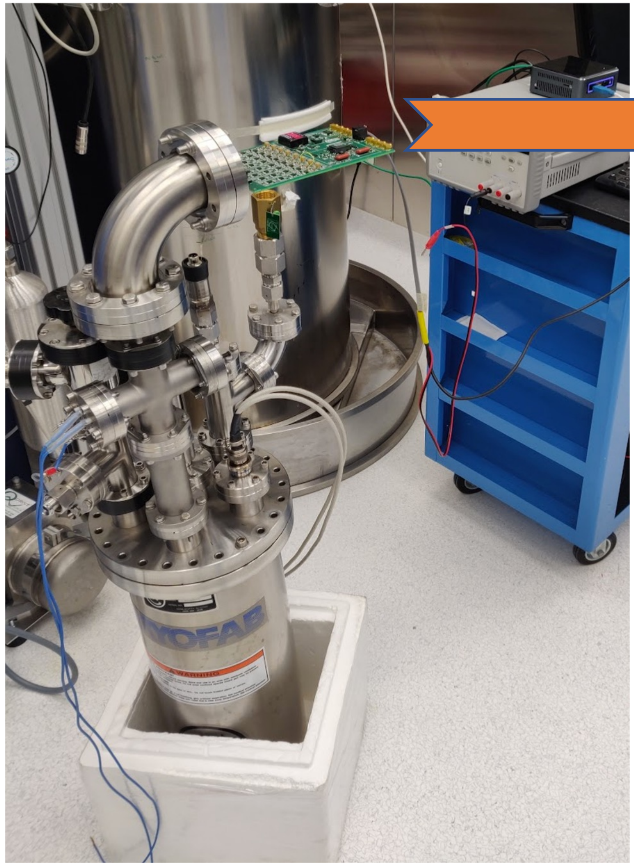
- x-Arapuca mounted in small **13 liters** double walls cryostat
- Low activity (100 Bq) **^{241}Am alpha source** mounted inside the cryostat on a manipulator system (10 cm excursion range)
- Top flange equipped with optical feedthrough for laser (407 nm) illumination (SPE determination)
- Six temperature sensors to carefully monitor LAr level during filling and recirculation operations

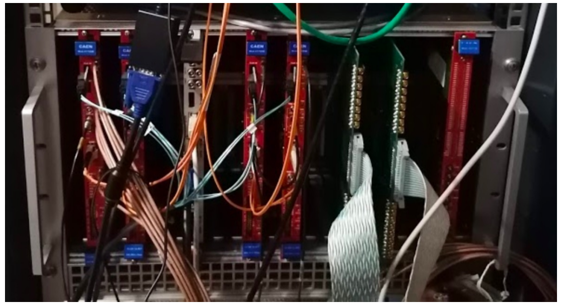
Napoli LAr cryogenic system



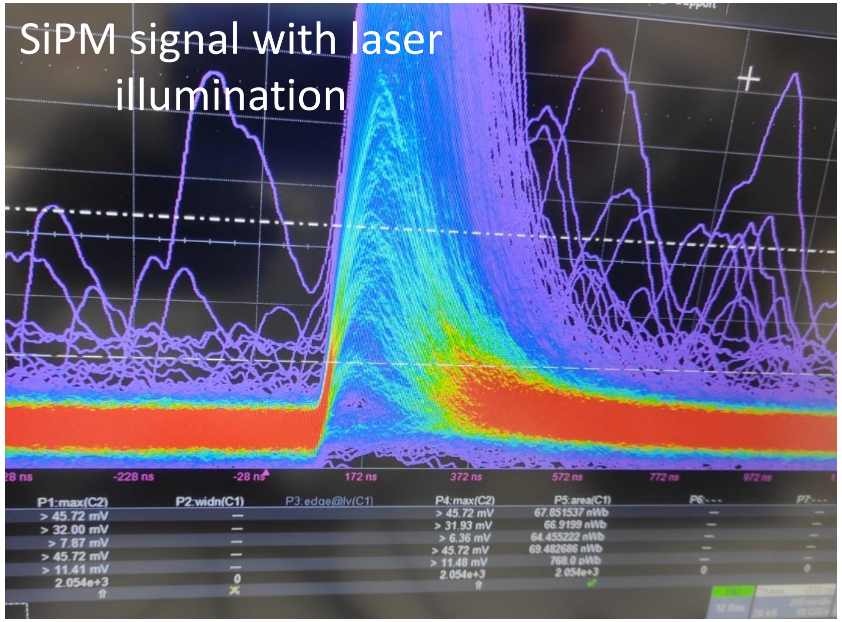
- Cryostat filling performed liquefying 6.0 argon gas (< 1ppm) in pressurized bottle
- Gas sent to condenser which currently works with constant supply of liquid nitrogen
- Recirculation line connected with SAES purification getter model **PS4-MT50-R**
- System tested for stable continuous operations over several days
- Constant pressure in the cryostat
- X-Arapuca completely immersed in LAr
- Many more details on the LAr system will be provided in **G. Grauso** talk ***A versatile Cryogenic System for Liquid Argon detectors*** on Friday 23/09

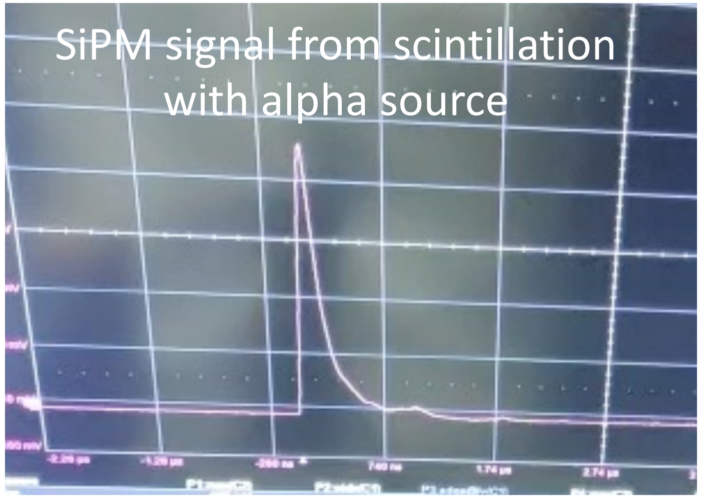
X-Arapuca readout electronics and DAQ





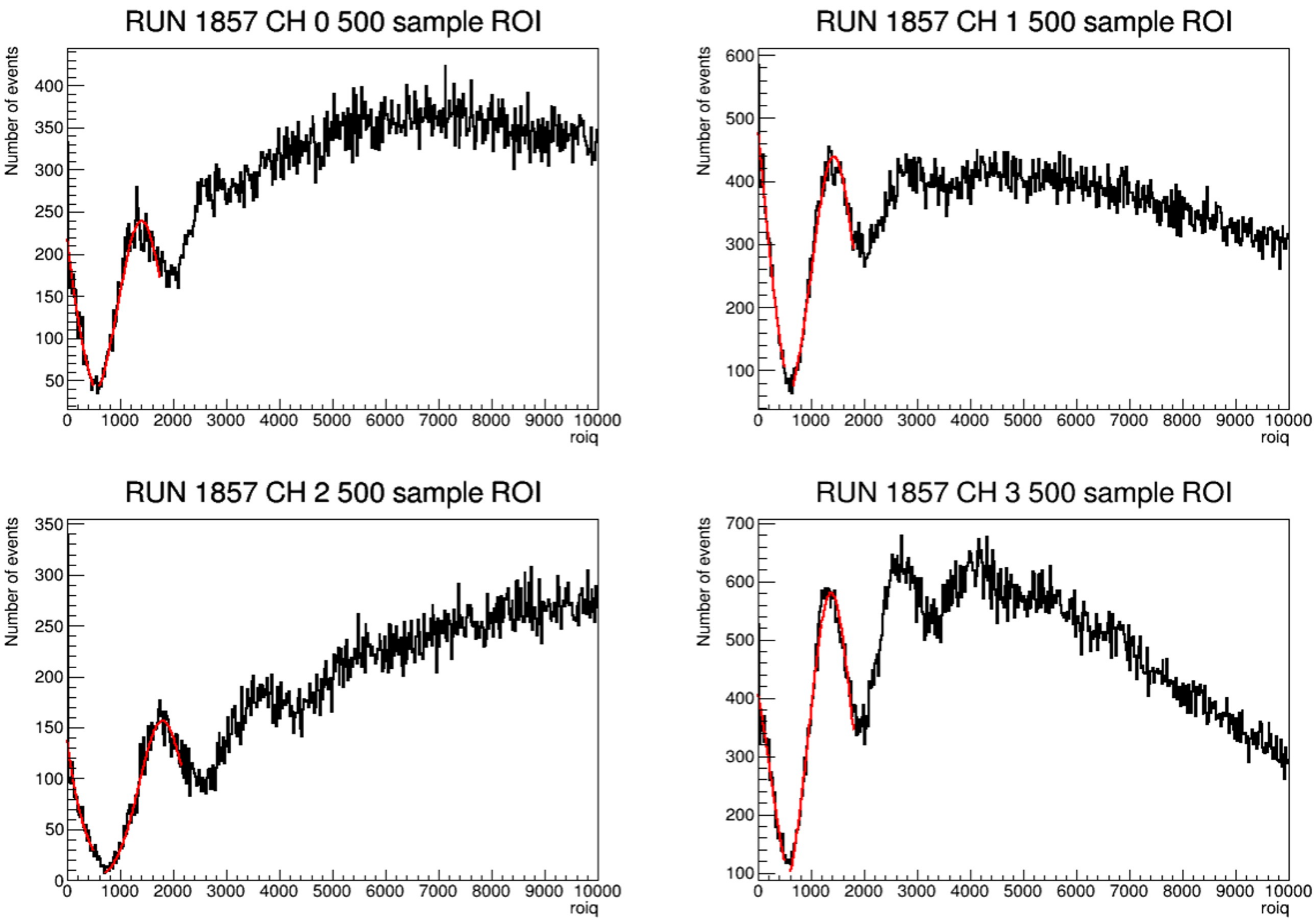
- Used front-end electronics developed in SBND experiment (APSAIA)
- APSAIA provides bias to SiPMs which can be set through easy RS232 interface
- APSAIA provides two adjustable gain options
- APSAIA front-end board operated at warm directly mounted on CF63 flange with DB37 connector
- SiPMs operated at 4 Volt overvoltage
- Very good signal shape without undershoots
- four x-Arapuca outputs sent to CAEN V1725B digitizers: 250 MS/s, 14-bit, 16 channels)





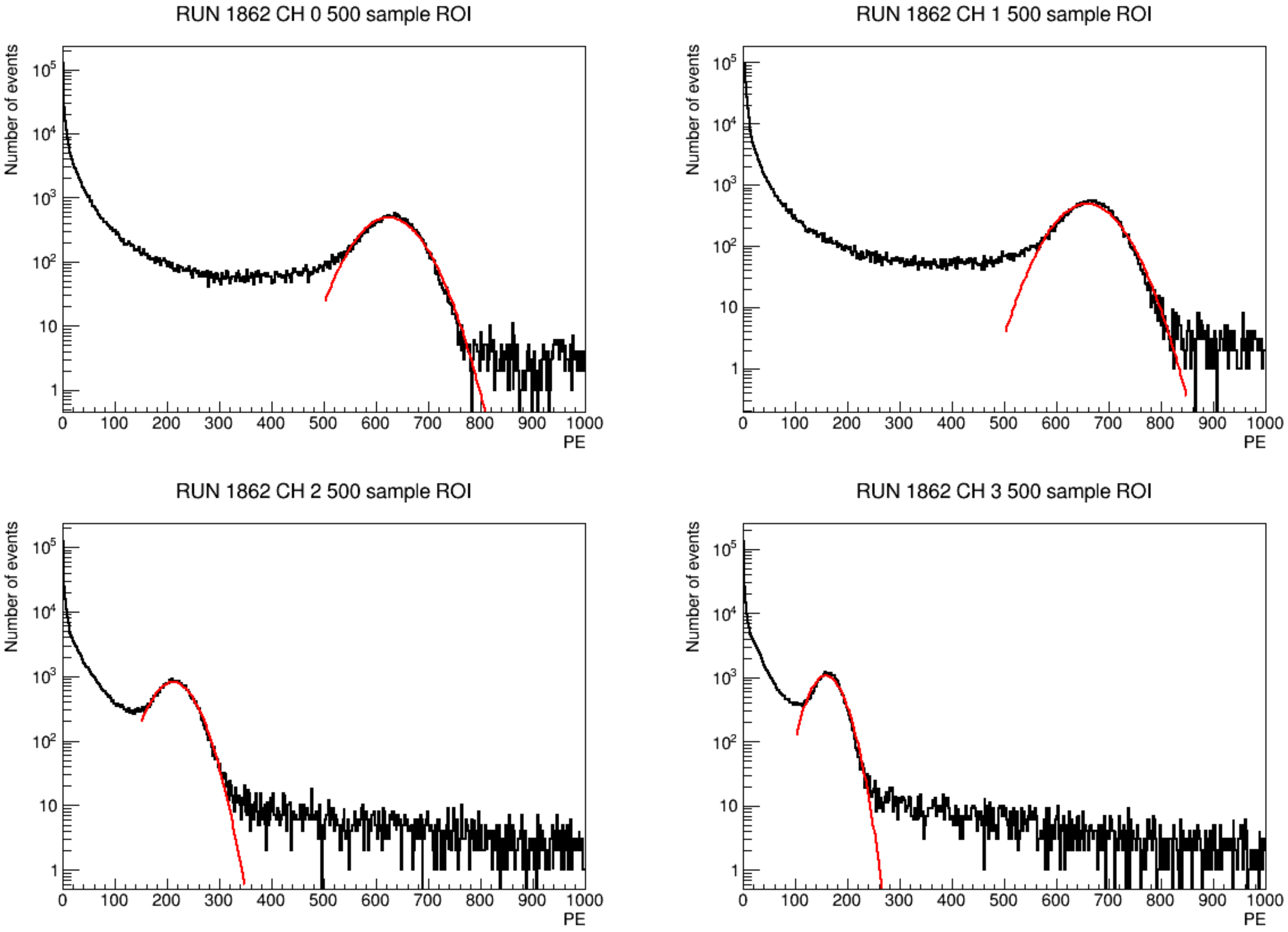
Laser run: SPE analysis

- Laser triggered runs
- Baseline evaluated with 150 samples in pre-trigger region
- 1 PE pulse integral (charge)
- 1 PE charge peak fitted in the region of interest



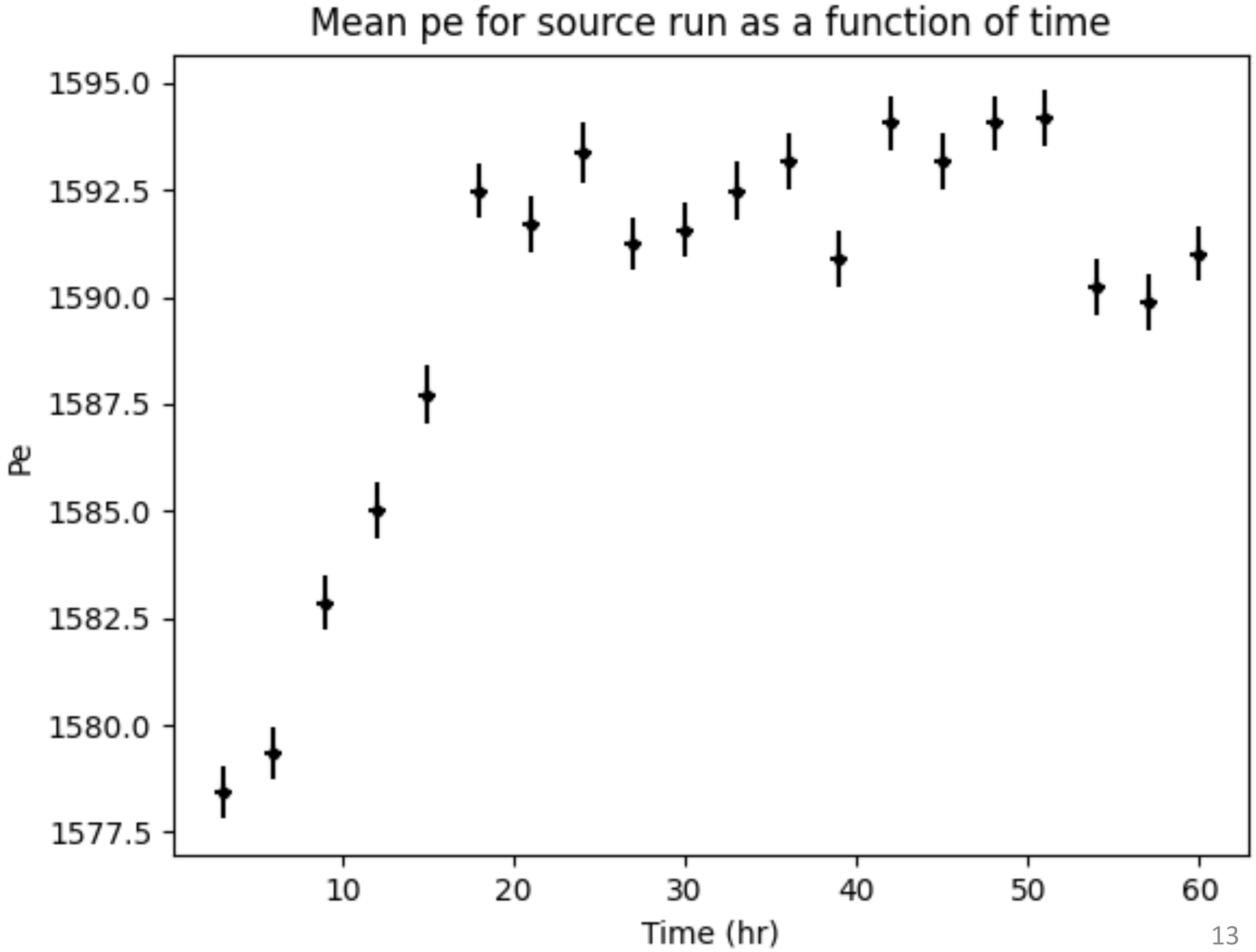
Alfa source runs

- Self trigger runs
- Using the 1 PE peak positions in laser run the charge spectra has been converted in PE spectra
- Alpha source peak fitted for each channel and for each run
- Higher PEs on the channels 0 and 1 corresponding to fired cell from alpha source
- Similar behaviour is observed inverting the source position on the top dichroic filter



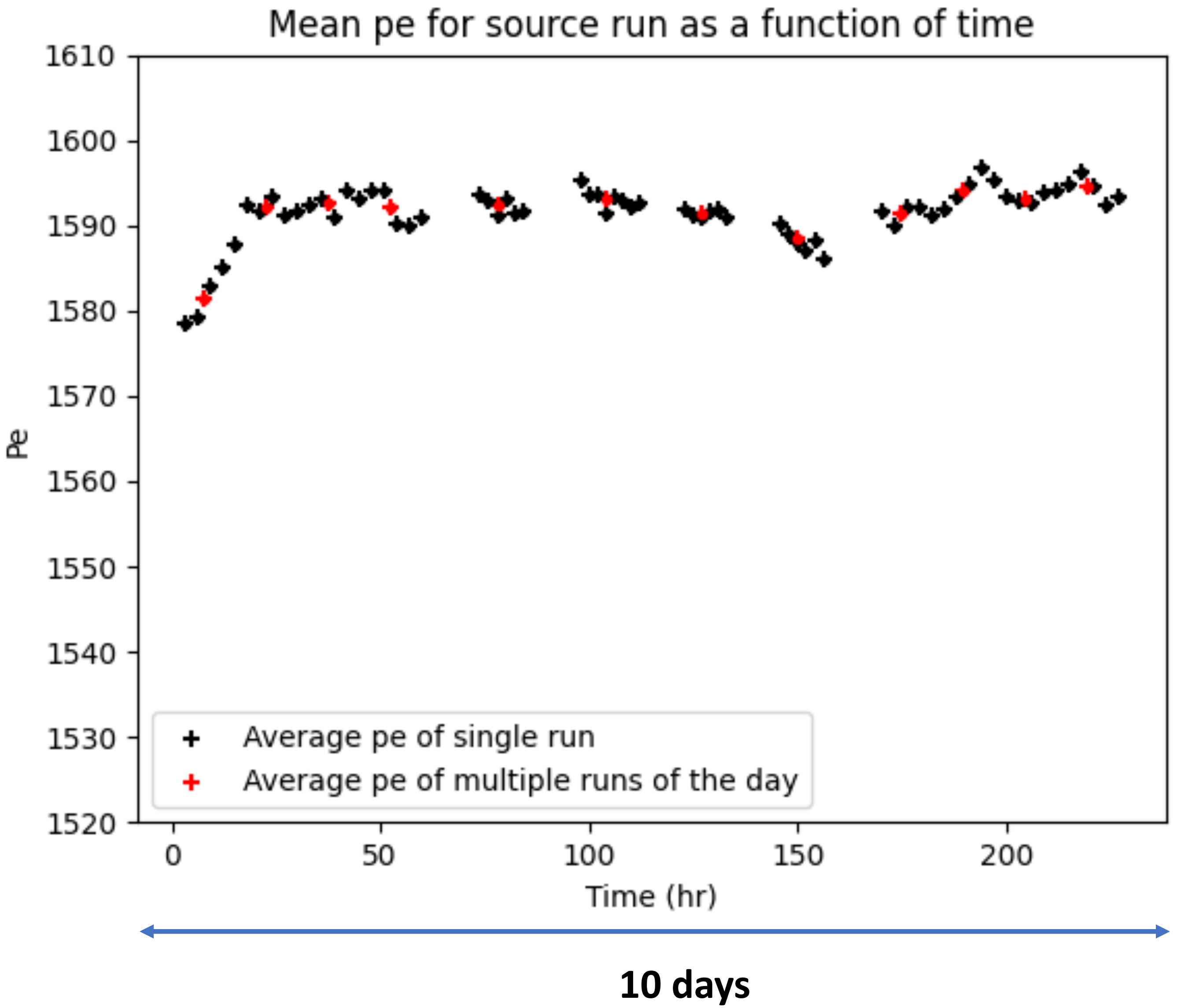
First days results on mean observed PEs

- All channel summed
- Found about stable 1590 PE after 20 hours of recirculation time
- Started operations from Argon with <=1ppm impurity
- Removal of impurities from cables, outgassing and other materials in the cryostat



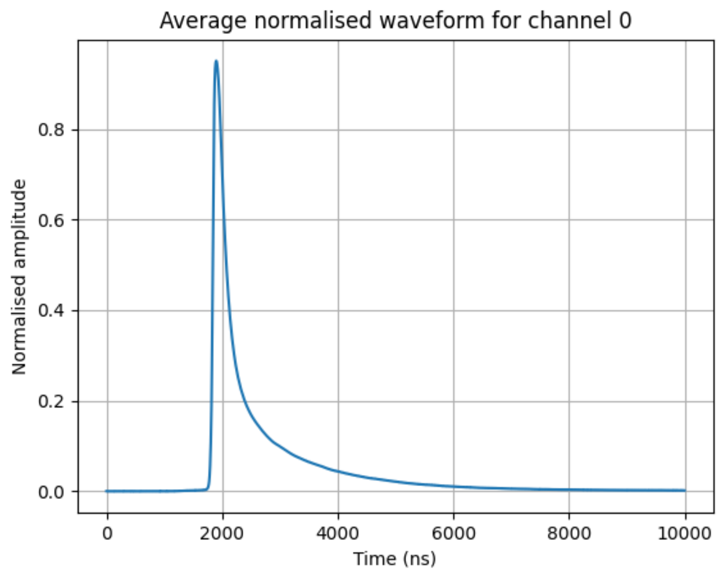
Stability over full 10 days of running period

- Average PE from alpha source: fluctuation within same day limited to ±2PE
- stability during full DAQ period ± 5PE (<1%)



Alfa source: waveform fit

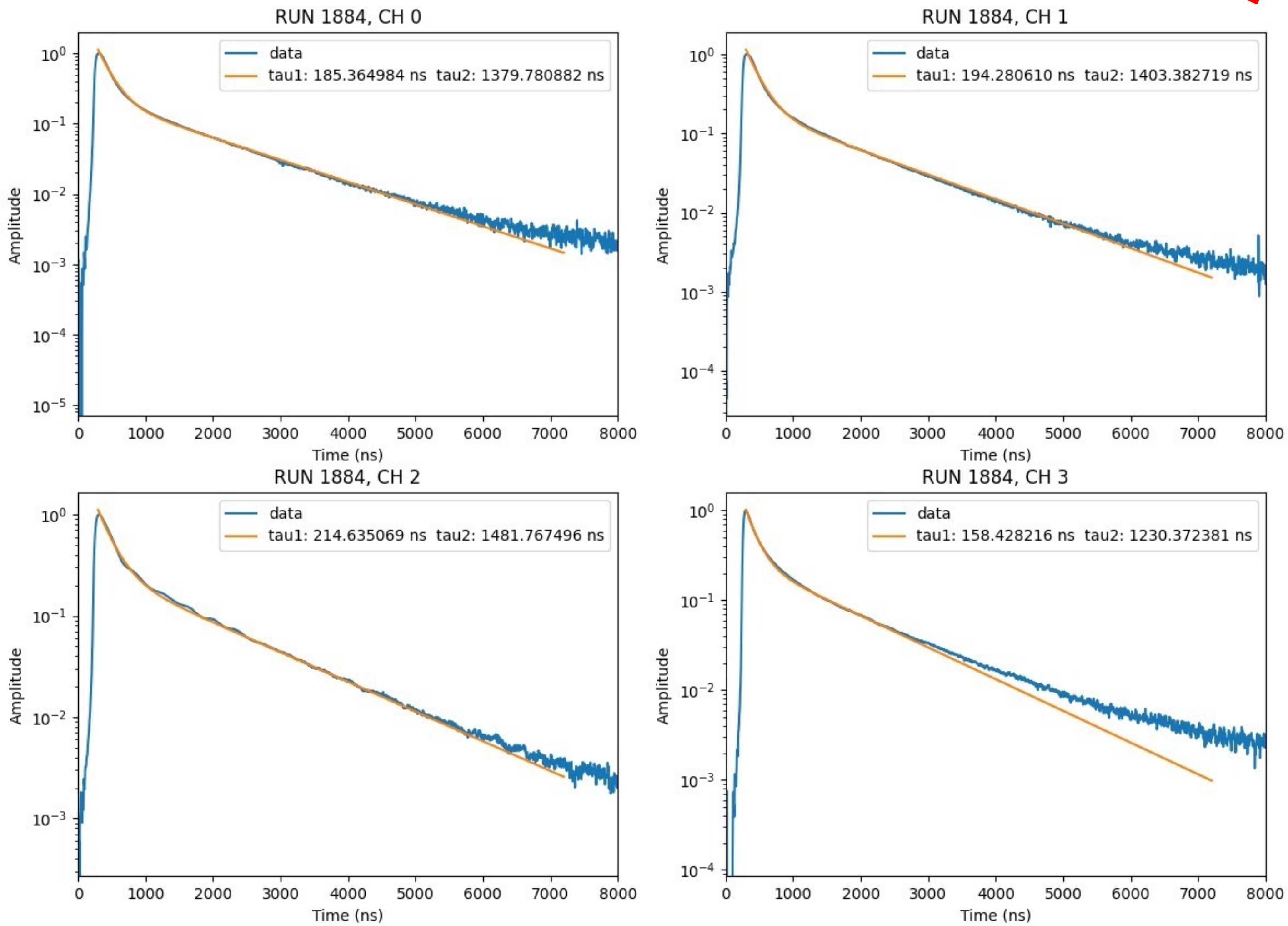
PRELIMINARY



- Fitted function

$$I(t) = A_S \exp\left(-\frac{t}{\tau_S}\right) + A_T \exp\left(-\frac{t}{\tau_T}\right),$$

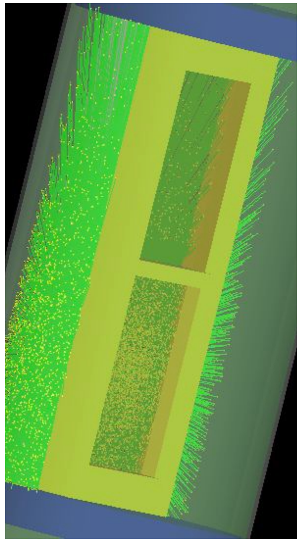
- Waveforms need to be deconvoluted with SPE signal
- Long taus about 1.4 us



Efficiency estimation

PRELIMINARY

- Setup has been simulated with Geant4 and alpha source scintillation simulated in LAr
- 21% out of overall produced VUV photons reach the x-Arapuca dichroic filters
- Pure geometrical solid angle calculation results is 17% (good agreement)
- Efficiency estimated to be 3.0%



Efficiency estimation	
LY (included quenching)	35000 ph/MeV
Alpha source energy	5.48 MeV
Total produced photons	191800
Geometrical factor	21.0%
Total detected photons	1590
Detected Photons after cross-talk correction*	1223
Efficiency	3.0±0.2%

- cross-talk correction assumed on the base of results found in «*First results on ProtoDUNE-SP liquid argon time projection chamber performance from a beam test at the CERN Neutrino Platform*», published on 2020 JINST 15 P12004

Conclusions and Outlook

- x-Arapuca two cell sample has been tested continuously for 10 day in Napoli cryogenic Lab
- LAr cryogenic system allows test in very stable condition and purity
- Alpha source inserted in Lar and signal found stable over full running period
- Preliminary efficiency determination is in agreement with what found in other laboratory
- Further test will be performed after thermal cycles
- Improve SPE determination
- Include a reference detector inside the cryostat: more solid efficiency determination

Stability tau long over running period