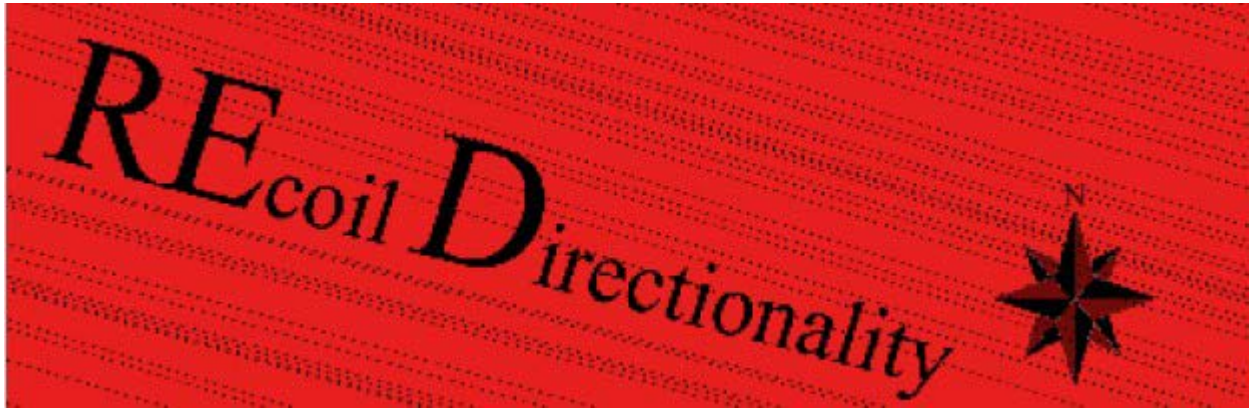


L. Pandola (LNS)

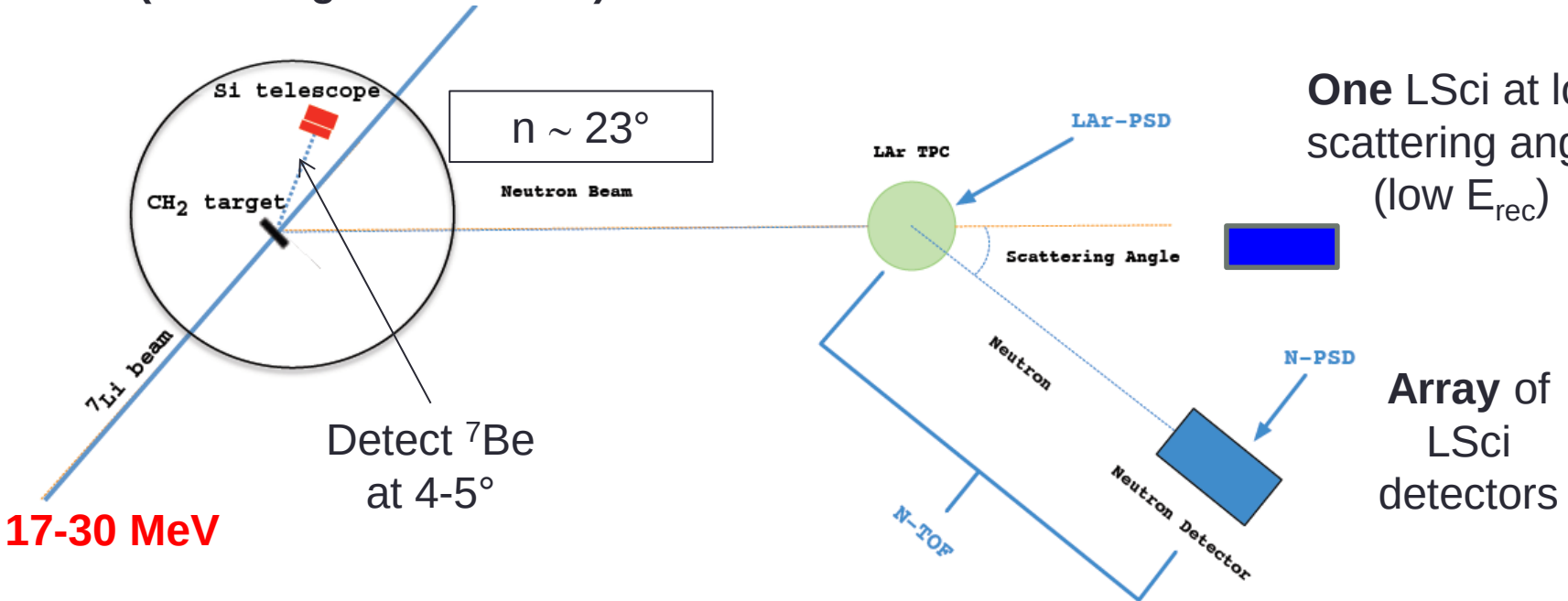
on behalf of the ReD Working Group

(DarkSide Collaboration)

darkside

ReD measurement at LNS – recap

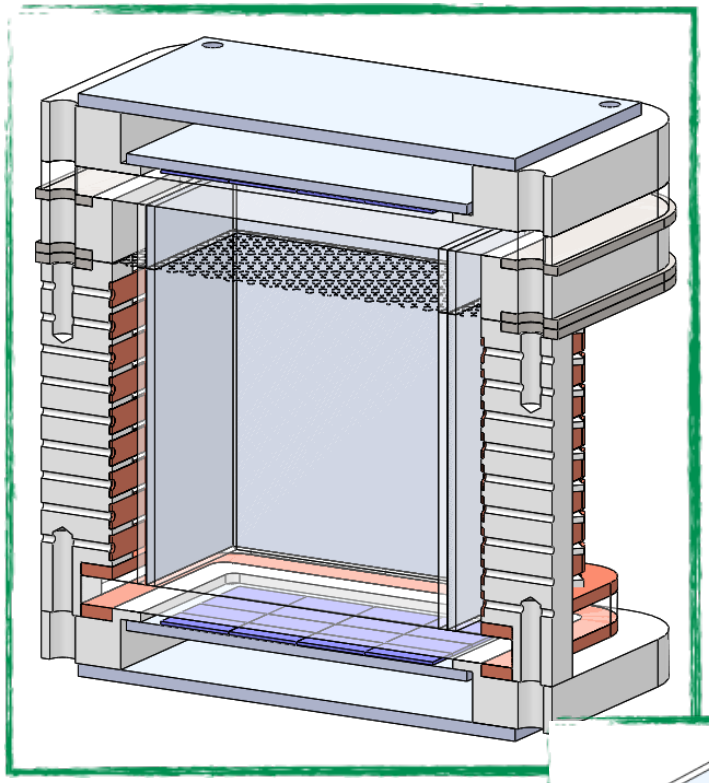
- Use a neutron beam produced via **p(^{7}Li,n)**
  - TANDEM accelerator at LNS, Catania
- Detect the associate particle (^{7}Be) and ToF to **tag neutron energy** event by event (fixed by kinematics)
- Pay attention to arrange the setup such to tag nuclear recoils ~parallel and ~perpendicular to the E
  - Displace the TPC **vertically**, such that the (n,n') interaction plane is not "horizontal"
  - Deploy LSci to tag recoils of the **same energy**, but different angle with respect to the E **(including 90° and 180°)**

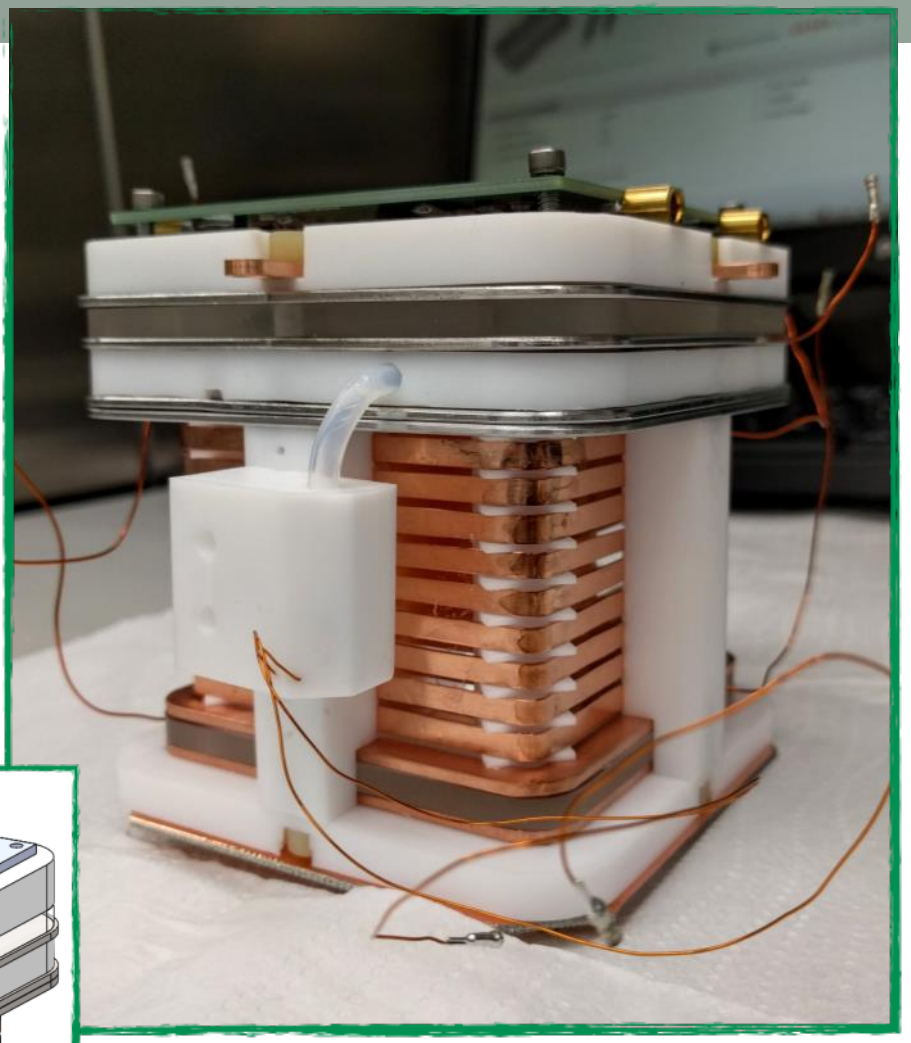


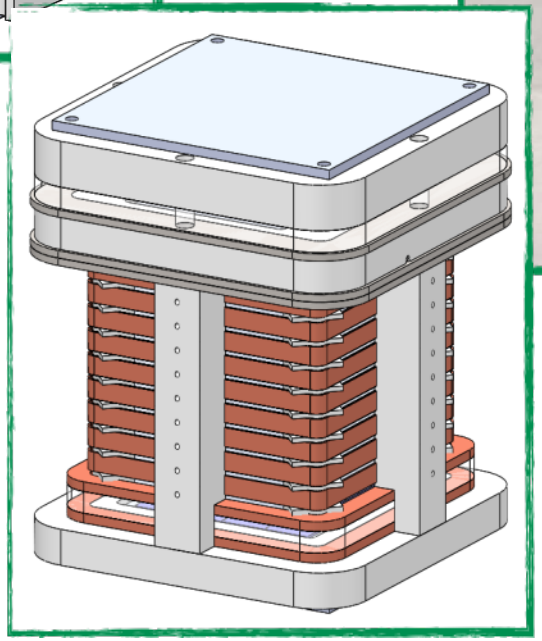
ACTIVITIES IN NAPLES

Commissioning in Naples

- Extensive campaign of measurements and tests carried out at the CryoLab in Naples (Feb, Apr-May)
  - Many participants, learning curve
- Main goals:
  - Test of the new TPC (by UCLA) and the new cryogenic system
  - Operate fields and gas pocket
  - Get familiar with the operational procedures, DAQ and slow control
  - Test TPC in its final configuration
    - Light readout: 5x5 cm^2 tiles ("a-la-DS-20k")
      - 24x1cm^2 FBK SiPM, 24 channel readout (top)
      - 24x1cm^2 FBK SiPM, 4 channel readout (bottom)
    - Light yield up to 10 phe/keV
  - Test one liquid scintillator (TPC + LSci integration)
  - Irradiate with γ source and DD neutron gun
  - Provide feedback to tune MC simulations

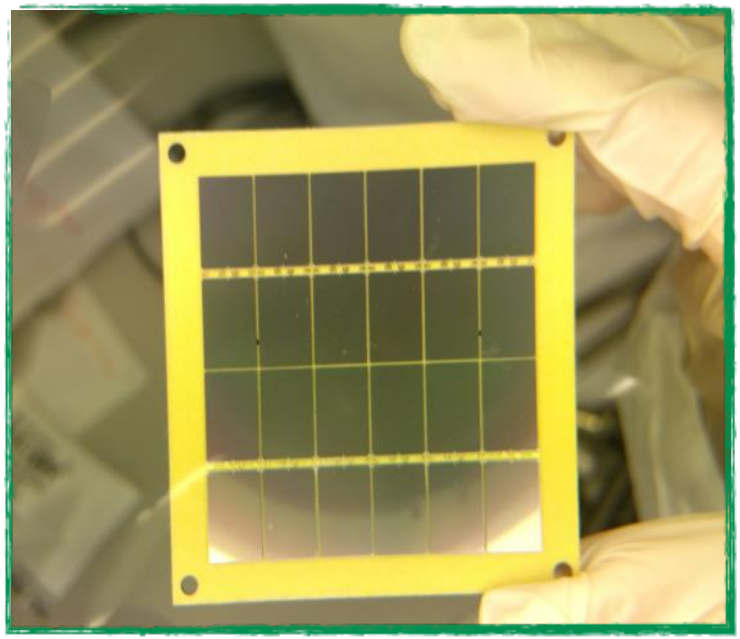


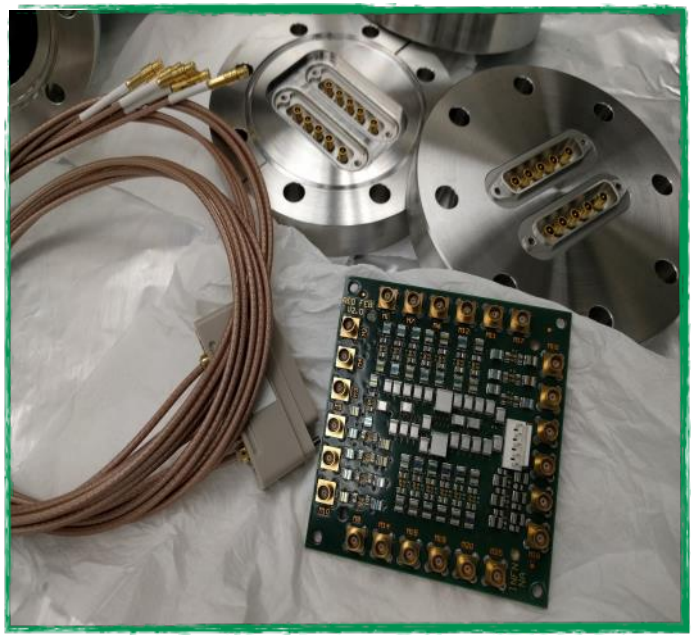


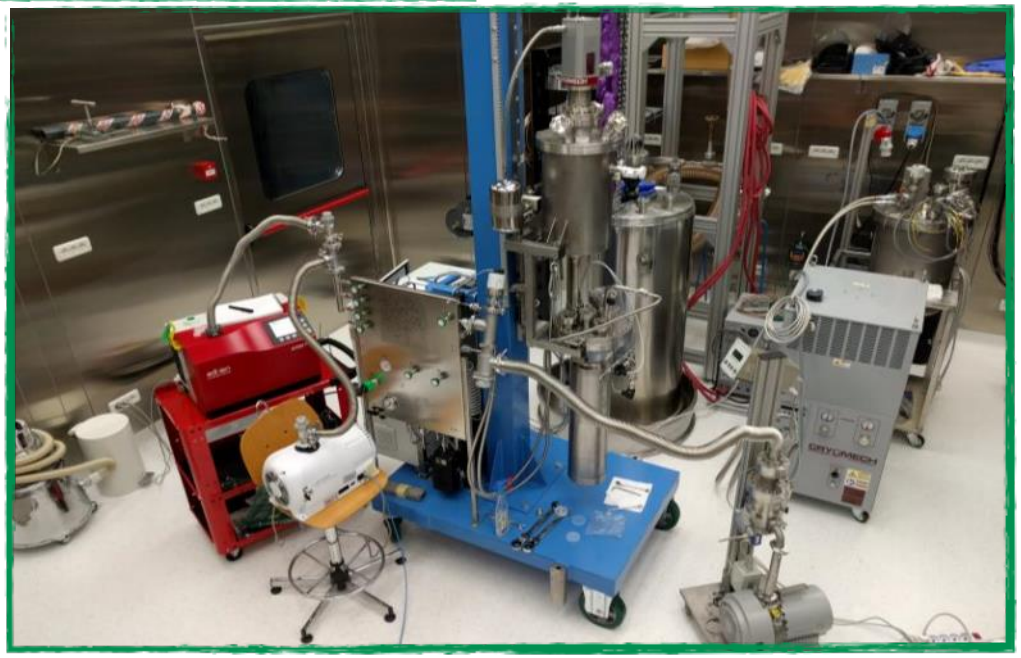


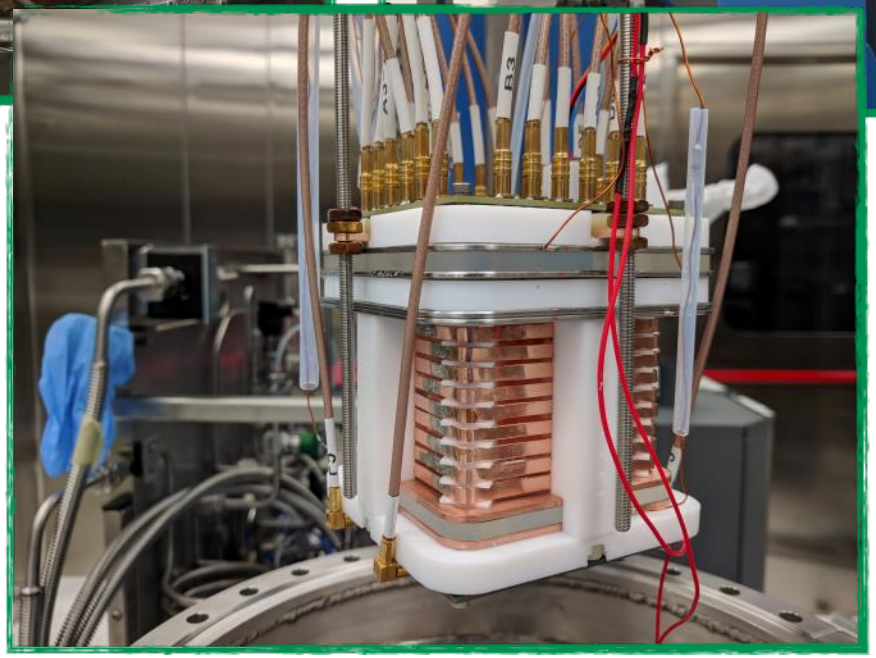
Photosensors

- TOP
  - new tile n° 1 (3x, rectangular SiPM, 10 MΩ quenching resistance, 25 μm cell, Arlon substrate)
  - new 24 channels FEB (made by INFN-NA, with the collaboration of INFN-BO and LNGS)
- BOTTOM
  - new tile n° 2 (3x, rectangular SiPM, 10 MΩ quenching resistance, 25 μm cell, Arlon substrate)
  - 4 channel FEB (LNGS)



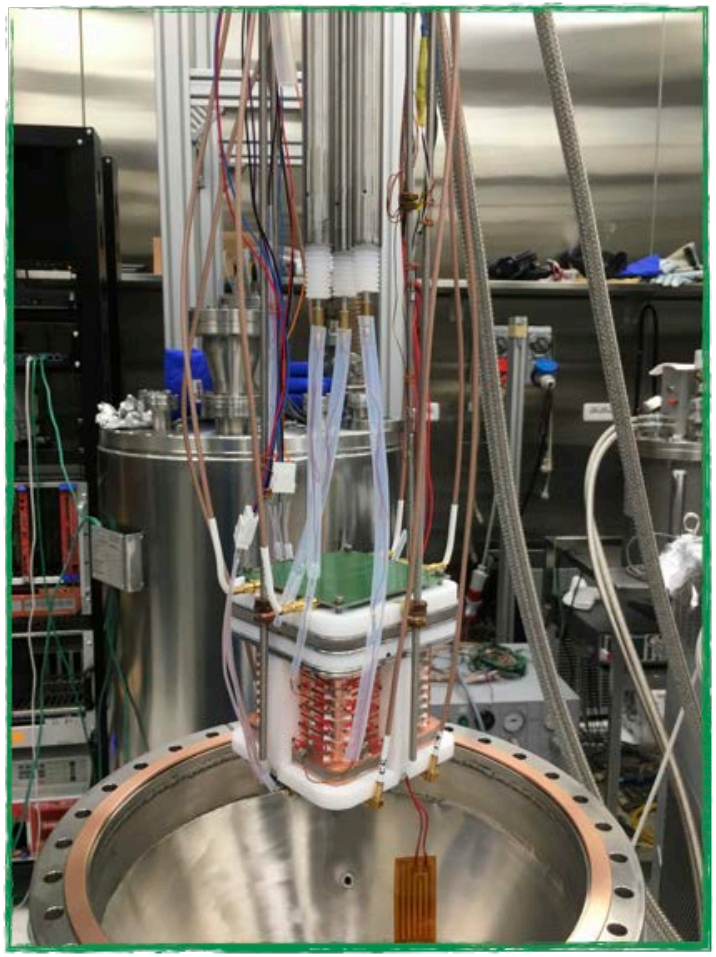


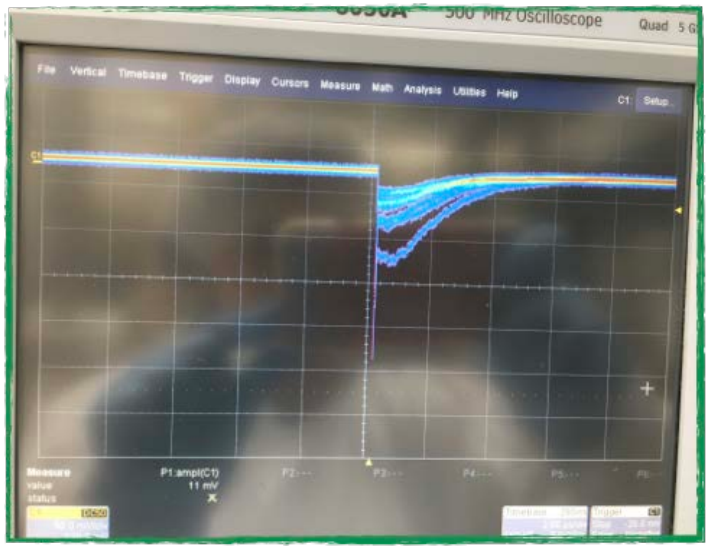




First test with the TPC inside!

- TPC installed in the dewar
- Closure of the cryostat and evacuation
- Leak test
- Cool down
- Filling
- **Switch ON ☺**



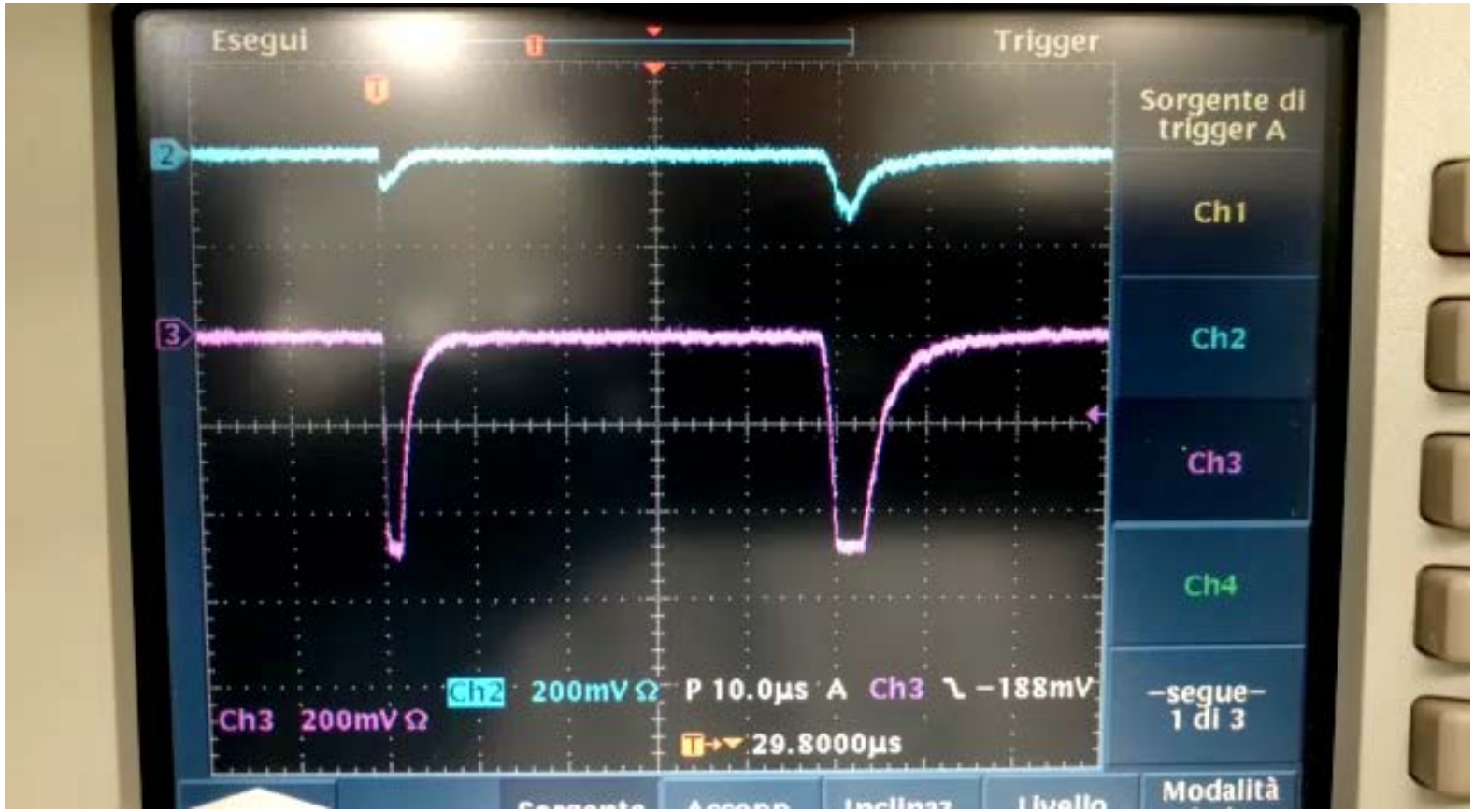


Top tile
V_{bias}= 28 V
Ch A1

← First signals

… and double phase

- Raise HV and create gas pockets
- First **S2** signals (almost plug-and-play)

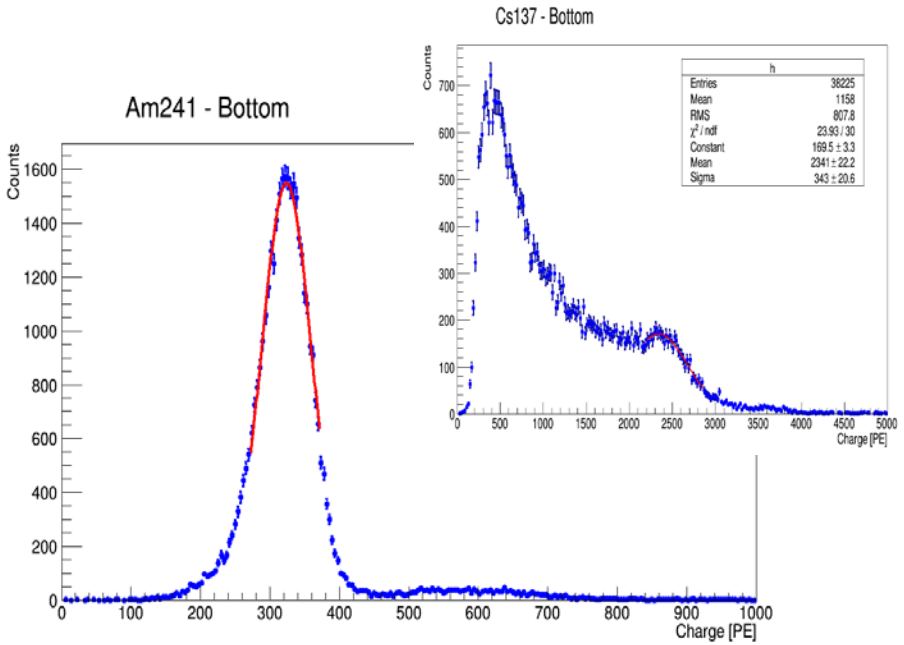


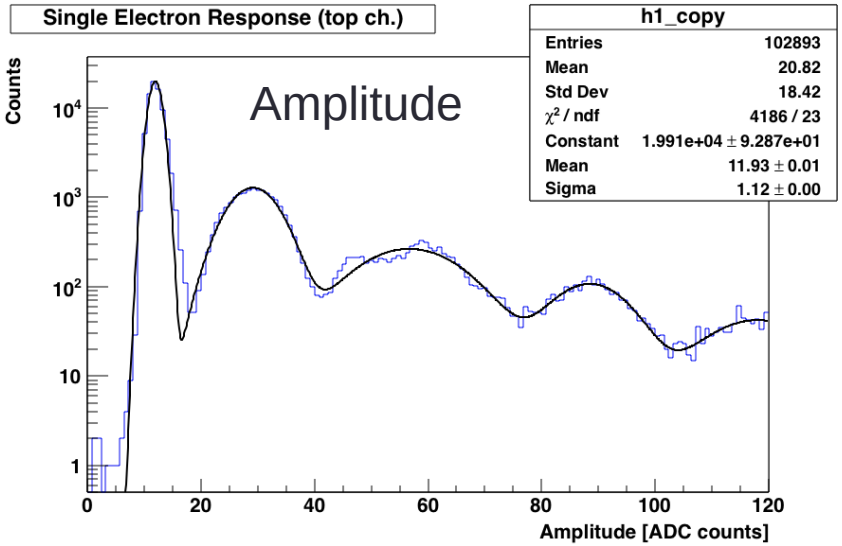
Data taking campaign (May-June)

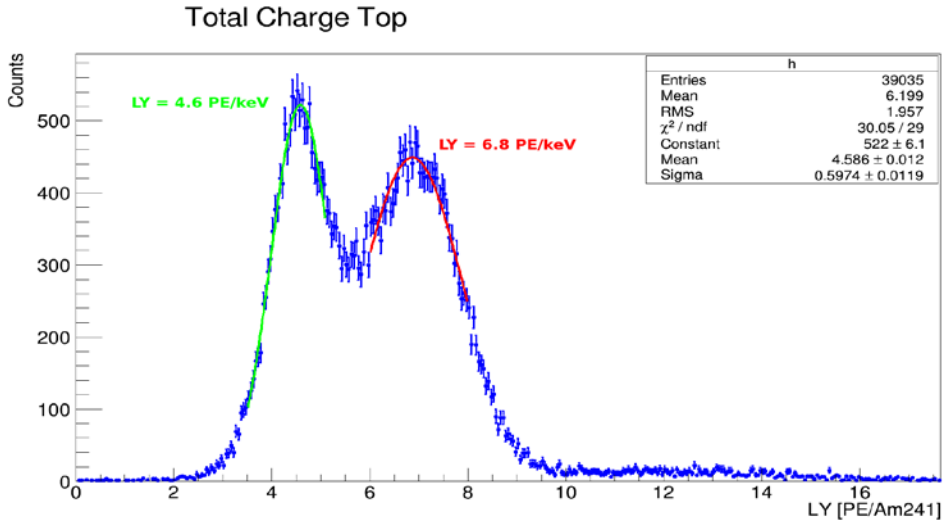
- Characterize the system in different operational configurations, such to define the **protocols to be used in Catania**
- Tested several configurations
  - Different bias voltage of SiPM
  - Single and double phase
  - Different trigger logics (majority, thresholds)
- Different types of measurement
  - Laser runs
  - Environmental background
  - Gamma sources: ^{133}Ba, ^{241}Am, ^{137}Cs
  - Neutrons: DD gun

Light yield

- Bottom tile working **nicely**
  - **5.5 phe/keV** @ NULL field
- Top tile giving
  - very bad S/N ratio in the SERs
  - a two-peak structure from the ^{241}Am source
  - Quite some headaches

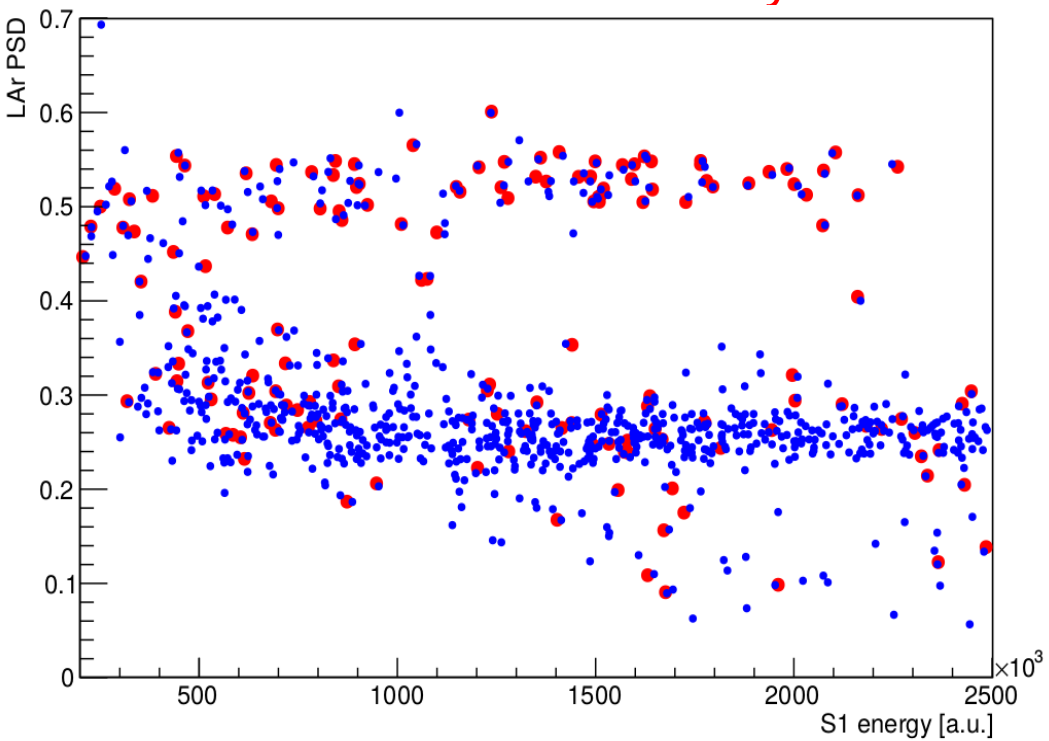






Neutron gun @ Naples

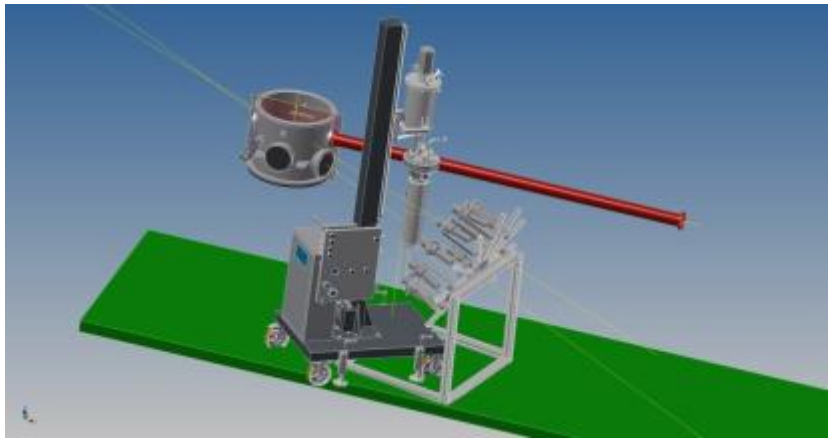
- TPC irradiated with neutrons from a DD gun
  - Test PSD performance
- Integration of one LSci
  - First test with two-detector systems



ACTIVITIES IN CATANIA

Refurbishment of the 80 deg beamline

- Scattering chamber procured and mounted
  - With ancillary systems: target-holder, etc.
- **Beamline modified** such to guarantee the required clearance for the cryo system and the LSci array
  - Support bars/legs removed, some beam elements relocated, floating floor dismounted
- Installed 32A plugs
- Vacuum-tested



Completed June 5th

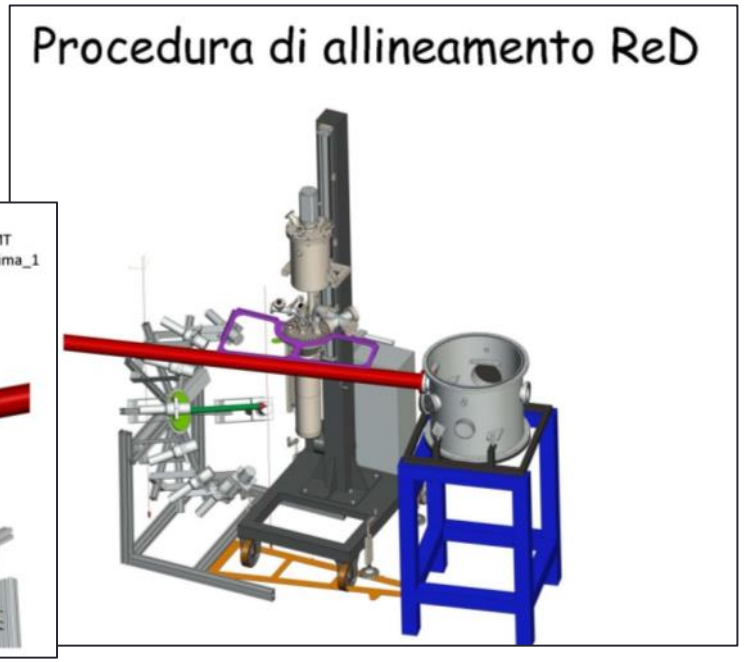
Beamtime schedule and plan - 1

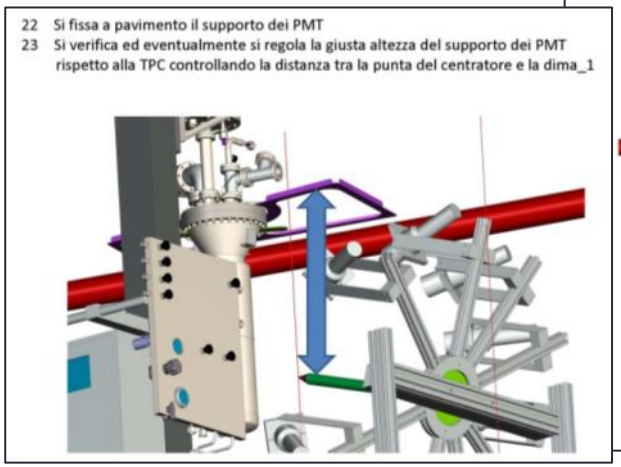
- Beamtime schedule for ReD negotiated with LNS and fixed: **two TANDEM beamtime slots** in **Q2**

- One "engineering" run
  - Preparation: June 18-21
  - Beamtime: June 22-24
- Main goals:
  - Mounting and mechanical set-up of the experiment,
  - Cabling, electronics, etc.
  - **Alignment** of the system (to be precise within a few mm)
  - Test of the scattering chamber, set-up and commissioning of the Si detectors
  - Check of TPC performance after dismounting and shipment
  - **Integration of the full system**
  - Test beam of the full system, with "real" neutrons

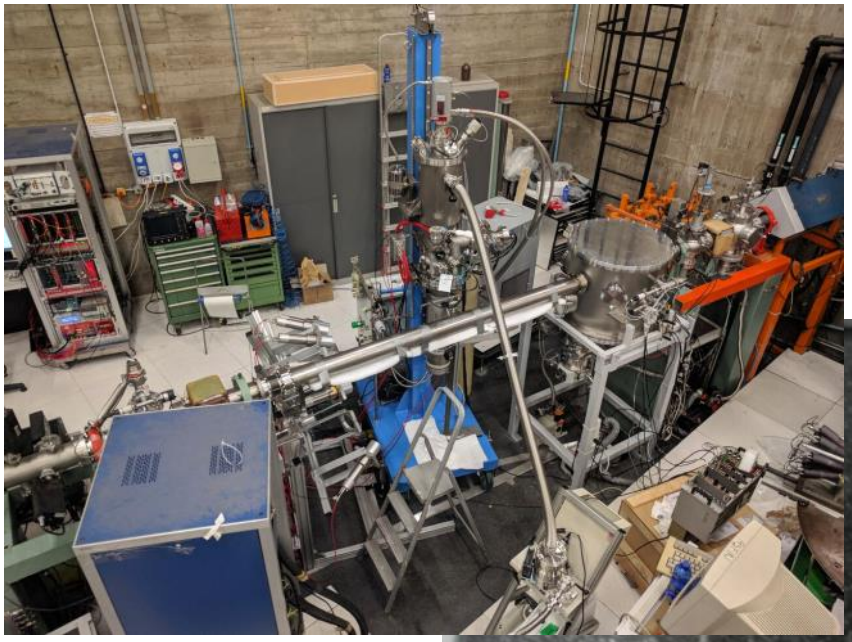
Alignment…

- Procedure for the alignment of TPC and LSci's wrt to the target **is very delicate** → non-horizontal interaction plane
  - Precise knowledge of the angles is critical for the analysis of physics data (especially critical for the low-energy measurement)
  - Aim to be at the **O(mm)** precision
- Procedure worked out by R. Cereseto (Genova) (with some feedback from LNS technicians)
  - Requires *ad-hoc* pieces to be machined (done in Genova workshop)
  - **23 steps** (!)

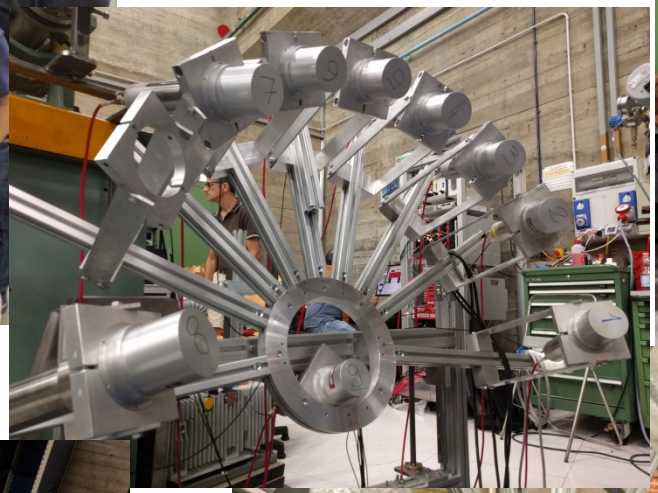


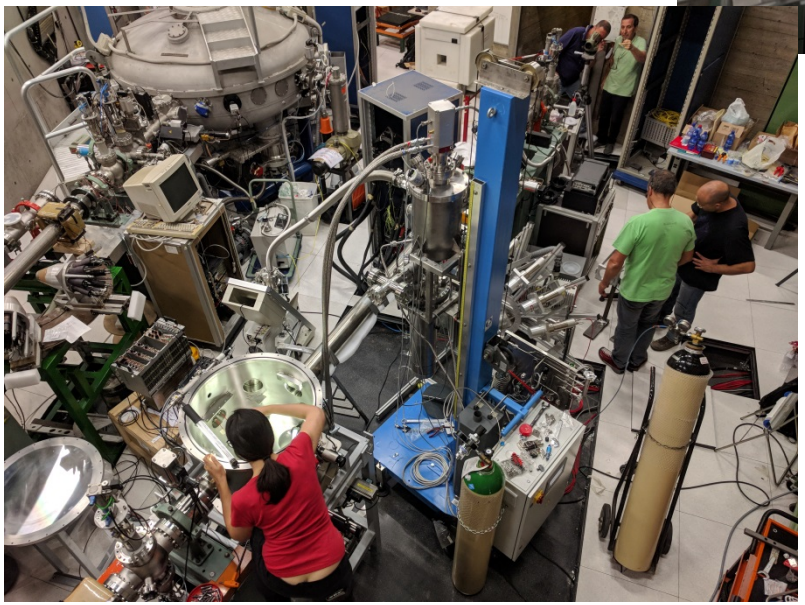


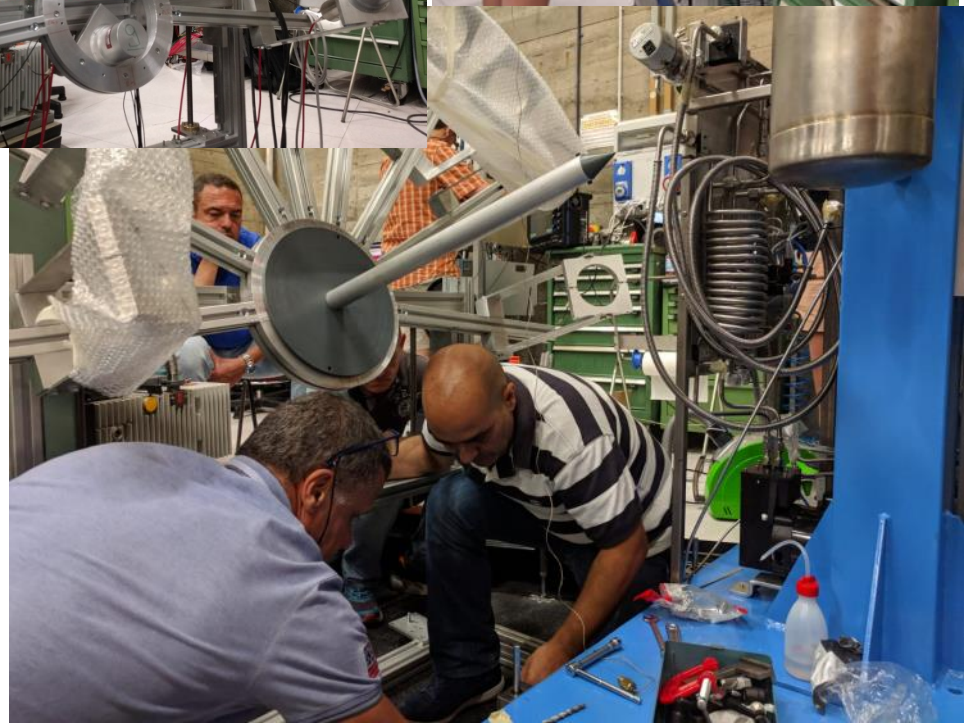
… worked



Setting the experiment up

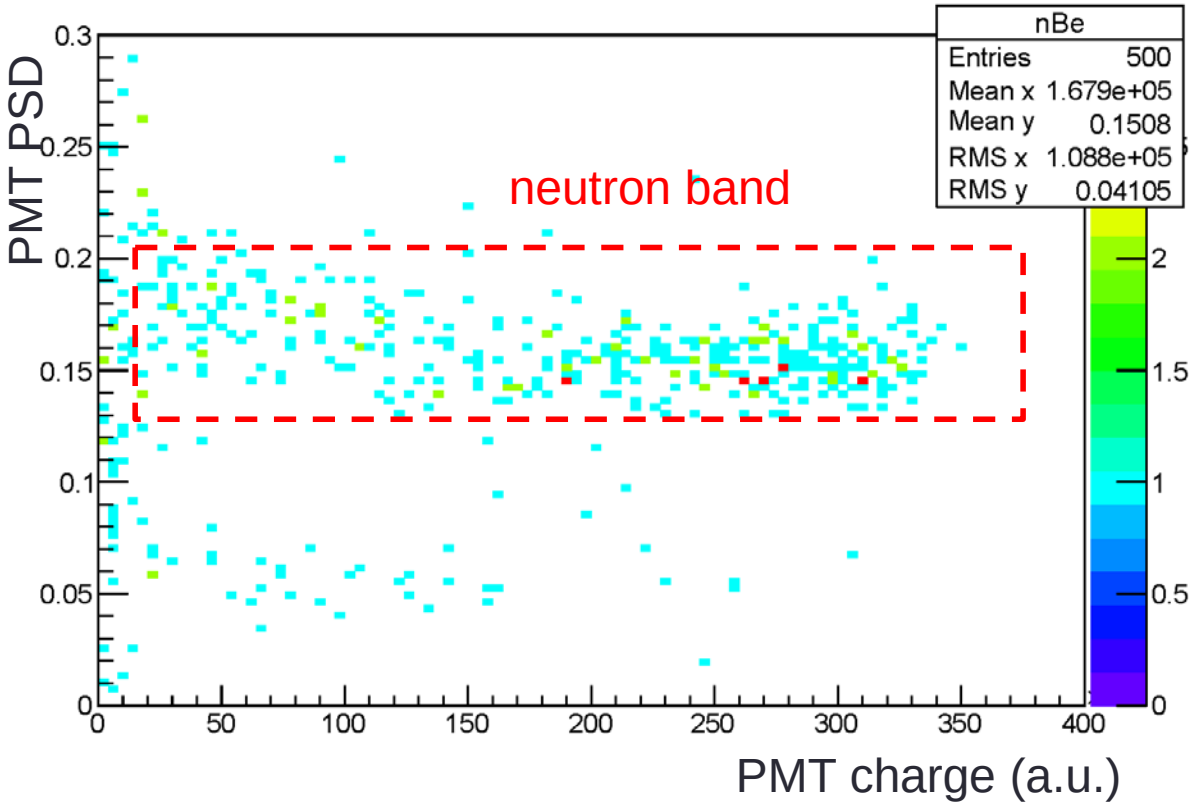




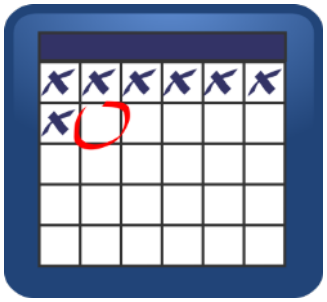


"Beam on": a few results

- One PMT placed right outside the scattering chamber, before the TPC
  - check for neutrons tagged by Si going in the right direction
  - End point compatible with 7.5 MeV neutrons
- Night run with (Si ∧ PMT0)
  - Trigger logic did not allow for (Si ∧ any PMT)
  - Physical coincidences **seen**
    - Only accidentals in ^{7}Li band

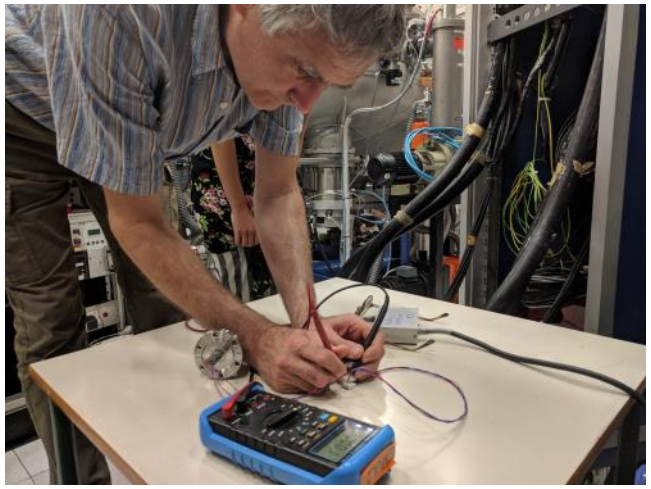


Beamtime schedule and plan - 2



- The "physics" run
  - Preparation: July 2-4
  - Beamtime: July 5-11
  - E_{beam} = 28 MeV (^{7}Li) →tagging of 66 keV Ar recoils
    - Plus one Lsci at small angle to tag few-keV neutrons
- Goals:
  - Fix the critical items met during the technical run
  - Take data with the beam on in a realistic "final configuration"
    - Fields on/off
    - Meaningful trigger condition (Si and TPC), (Si and any-PMT)
- Group
  - Presence on-site: ranging from 14 (first days) to 7 (towards the end)
  - Need to cover 24h shifts during the beamtime
    - Physically **demanding**, especially when we were in 7
    - Only a **few people** having **experience** with "beam" experiments

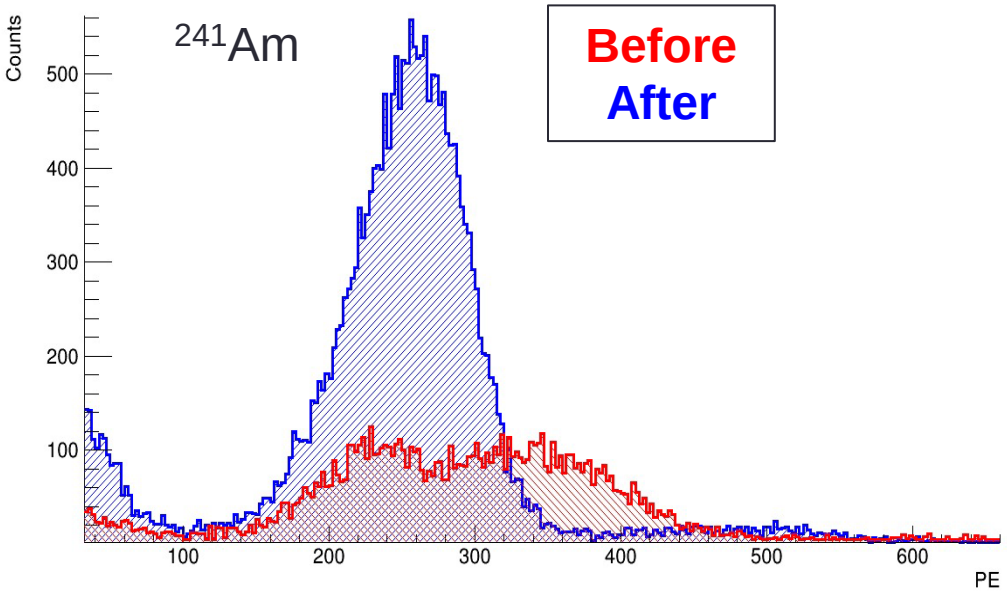
Noise-hunting campaign

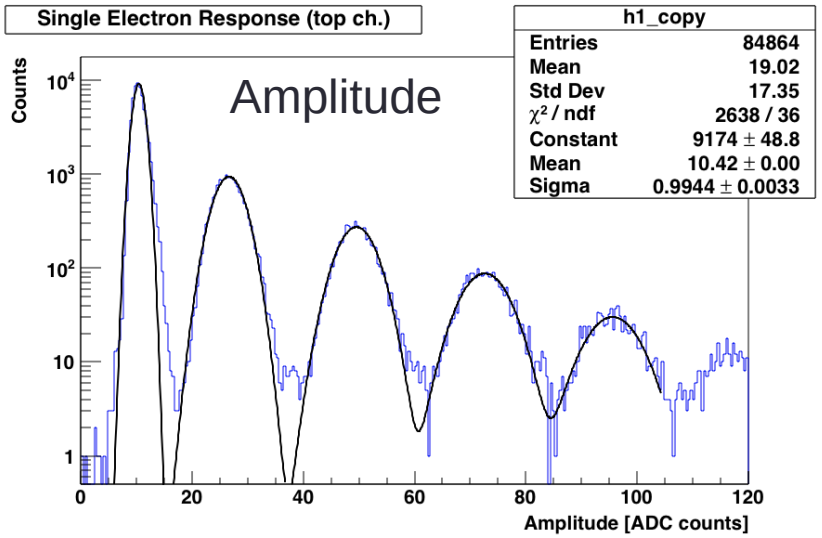


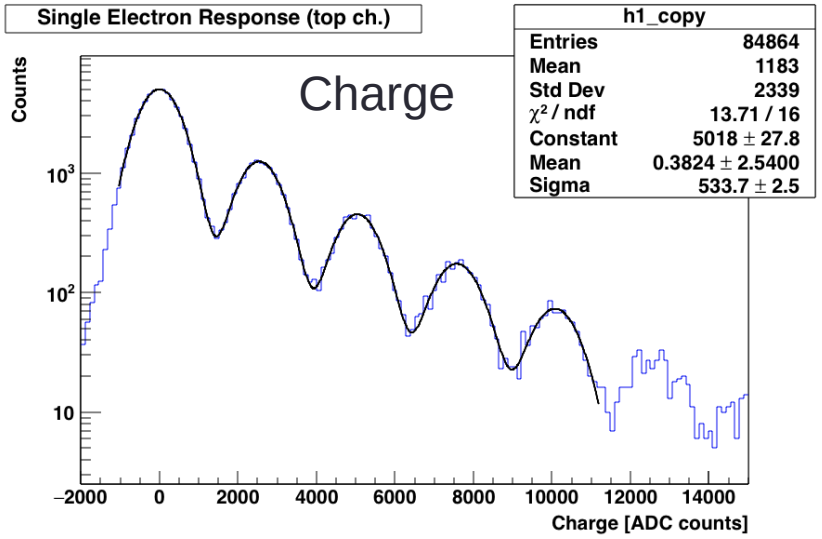
- Done with the help of George Korga
- 24ch FEB replaced
  - Instability and double-peak structure **gone**
- TPC signal cables shielded and re-routed
  - Improved noise situation, allowing for a lower threshold

…and the results

- Single-electron spectra very much **improved**
- Double-peak structure in the top tile for the ^{241}Am source **gone**

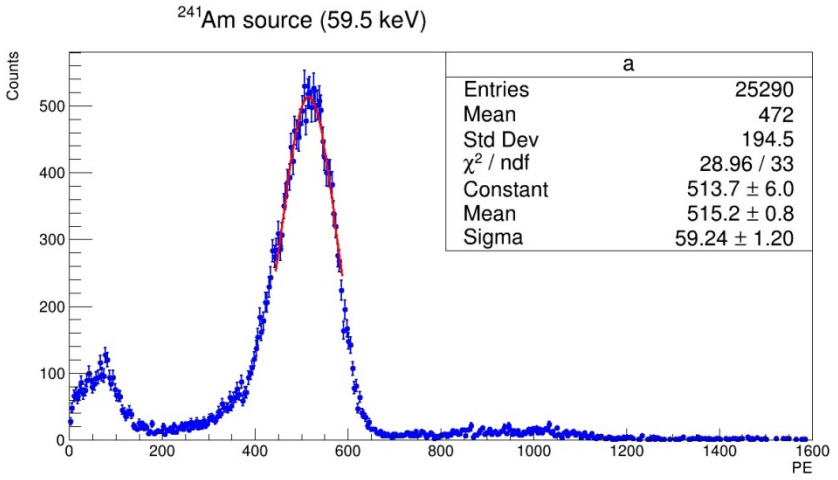


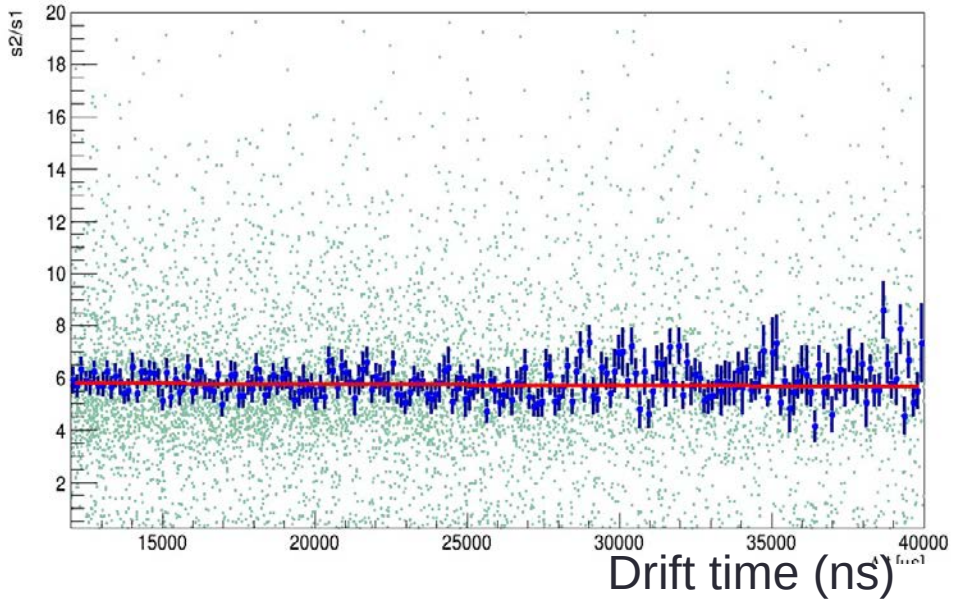


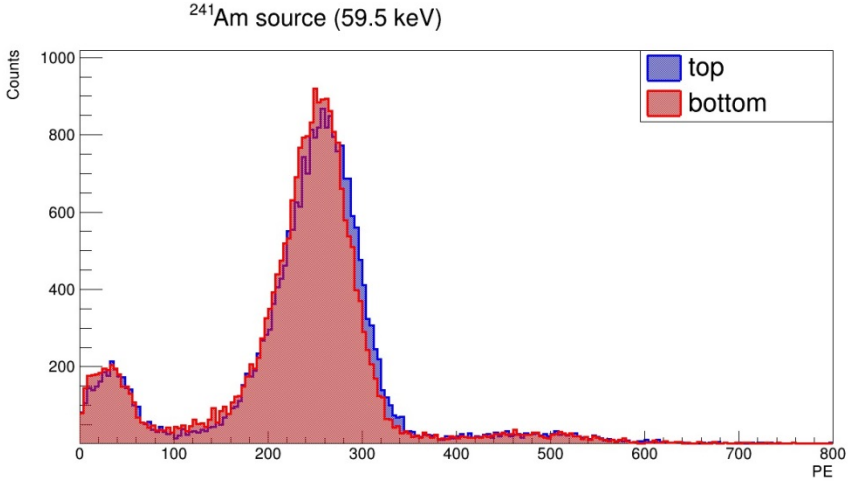


Results from individual systems: TPC

- Total light yield @ null field **8.6 phe/keV**
  - Top/bottom spectra are OK
- LAr purity OK
  - Electron life time: **255 µs**

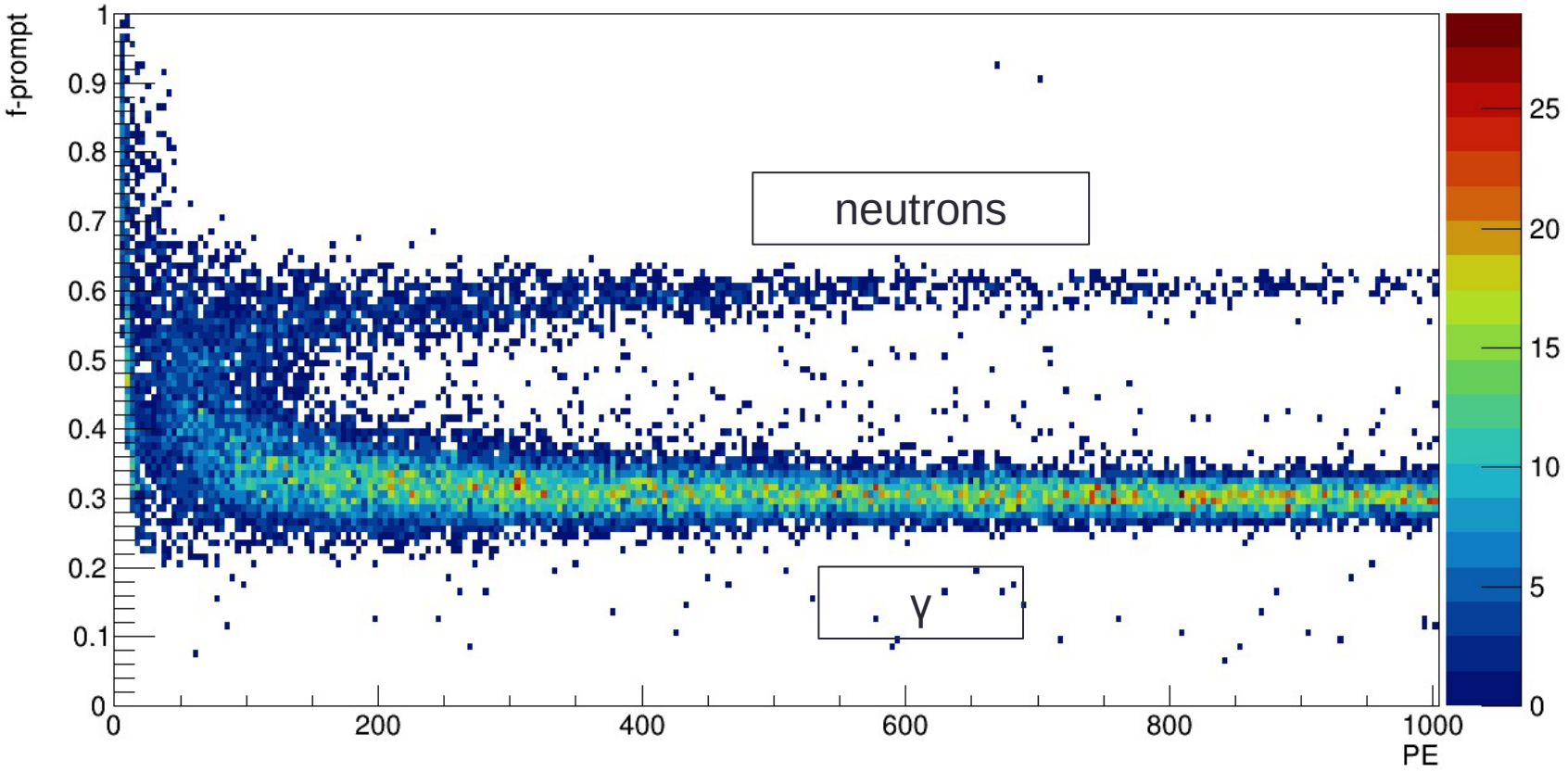






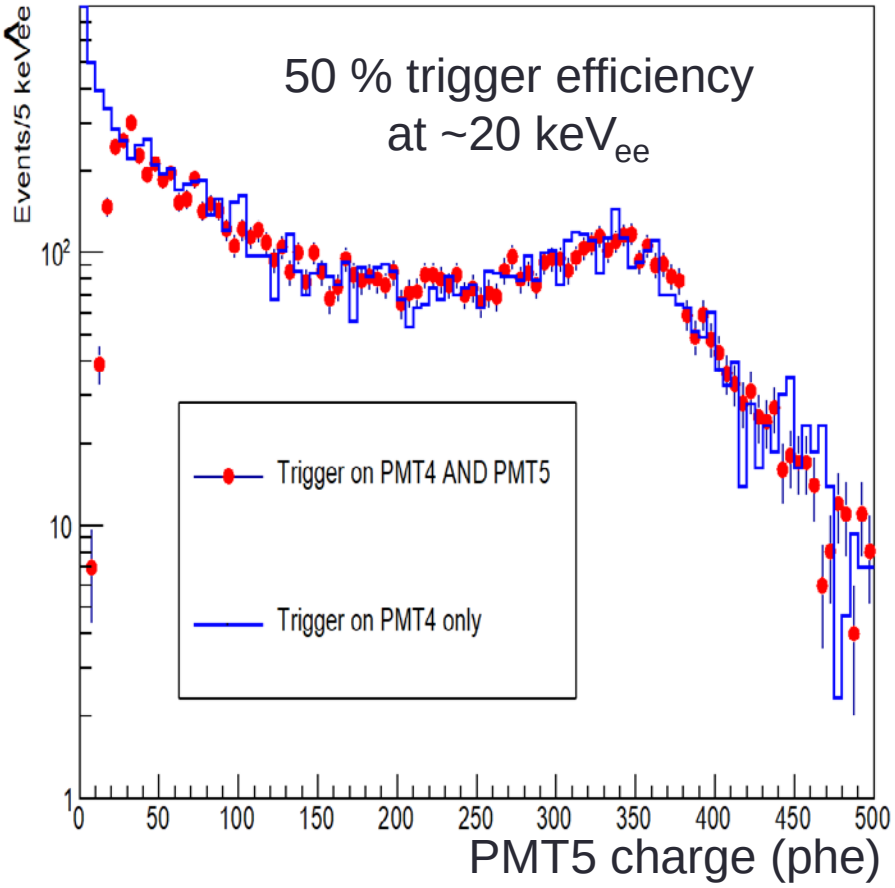
Results from individual systems: TPC

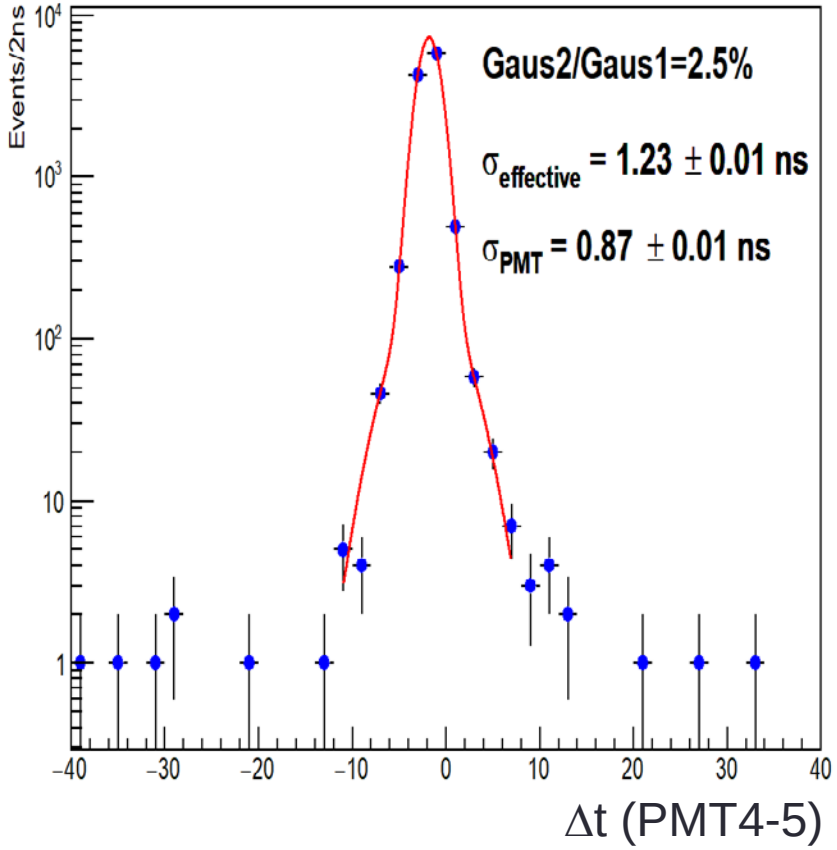
- Calibration with a ^{252}Cf neutron source
  - Check of LAr PSD



Results from individual systems: LSci

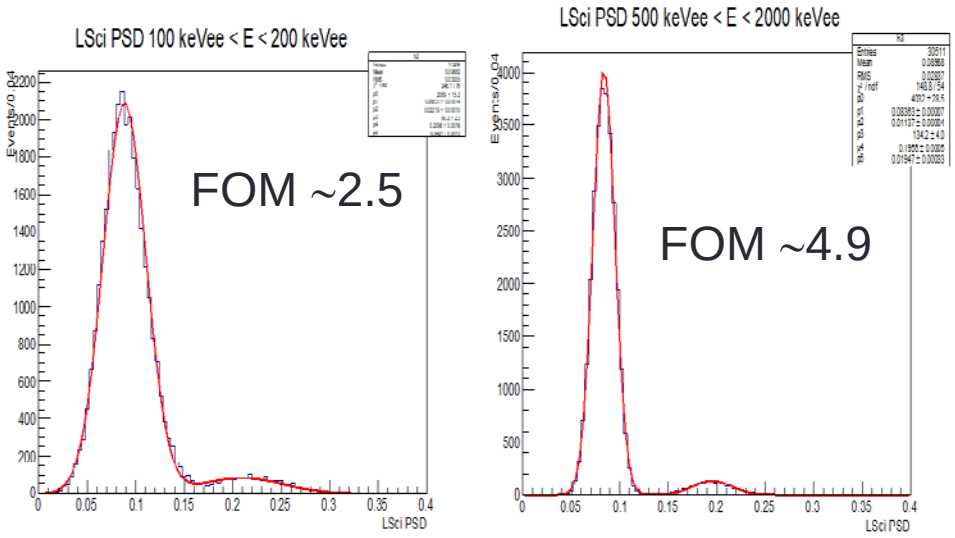
- Scintillators performing **very well** as timing and PSD
- Timing and trigger tests performed with ^{22}Na
  - Source placed between PMT4 and PMT5

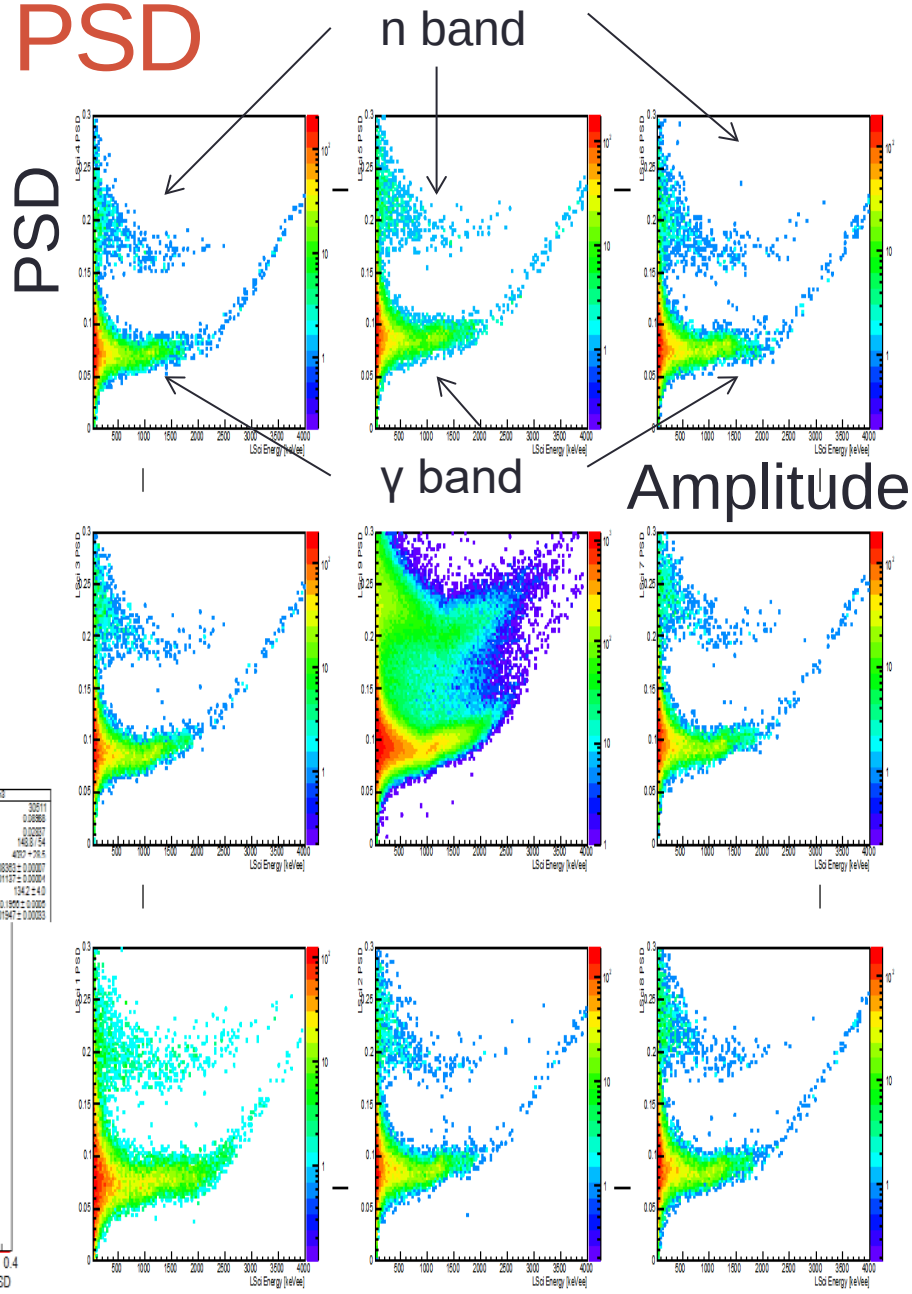




LSci n/γ discrimination PSD

- PSD checked with a ^{252}Cf source illuminating all LSci cells
- PSD = short/long gate integral (60 ns)
  - FOM = $\Delta/(\sigma_\gamma^2+\sigma_n^2)$
  - Better than expected



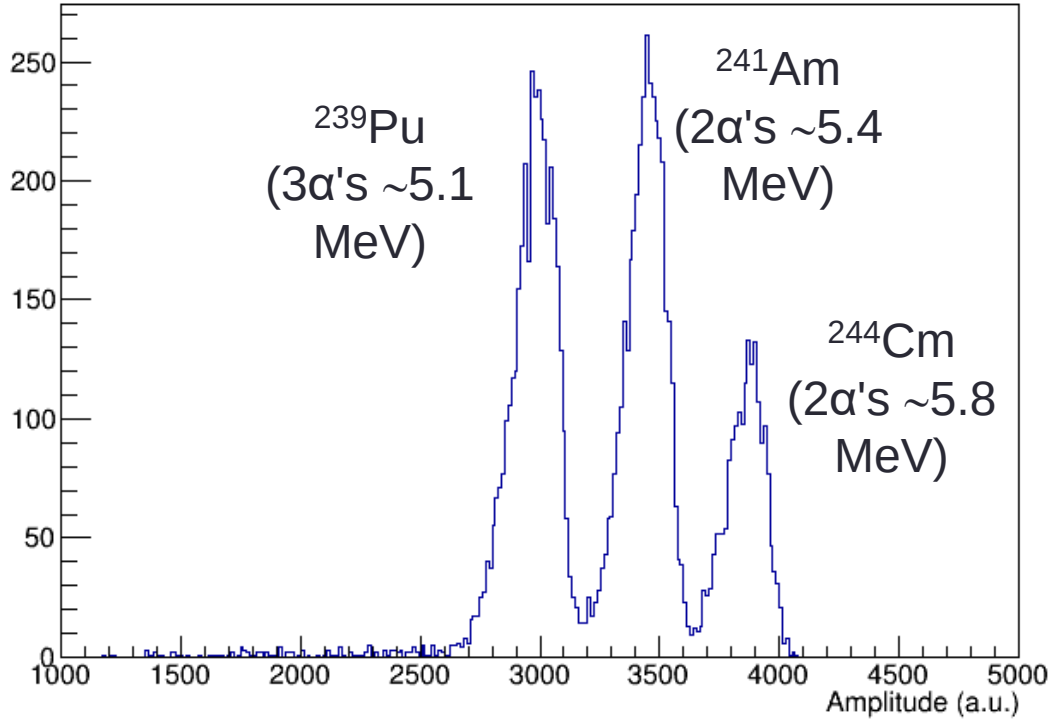


Results from individual systems: Si detectors

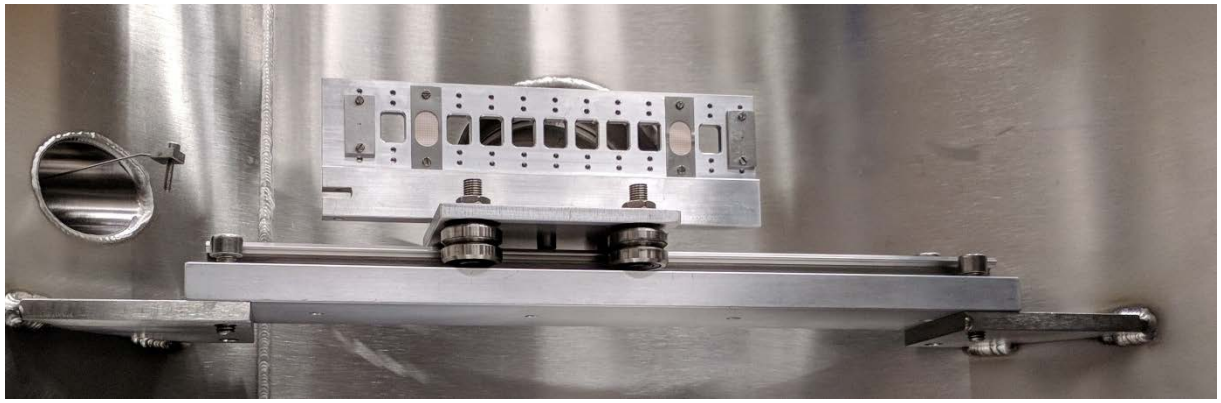
- **ΔE Si** detector (20 μm), **E Si** detector (200 μm)
  - Borrowed from an other group, as our detectors were not delivered in time by ORTEC (ordered Dec 2017 by Roma1)
- Frame, holders and collimator inside the scattering chamber
  - Angles fixed

Si detector

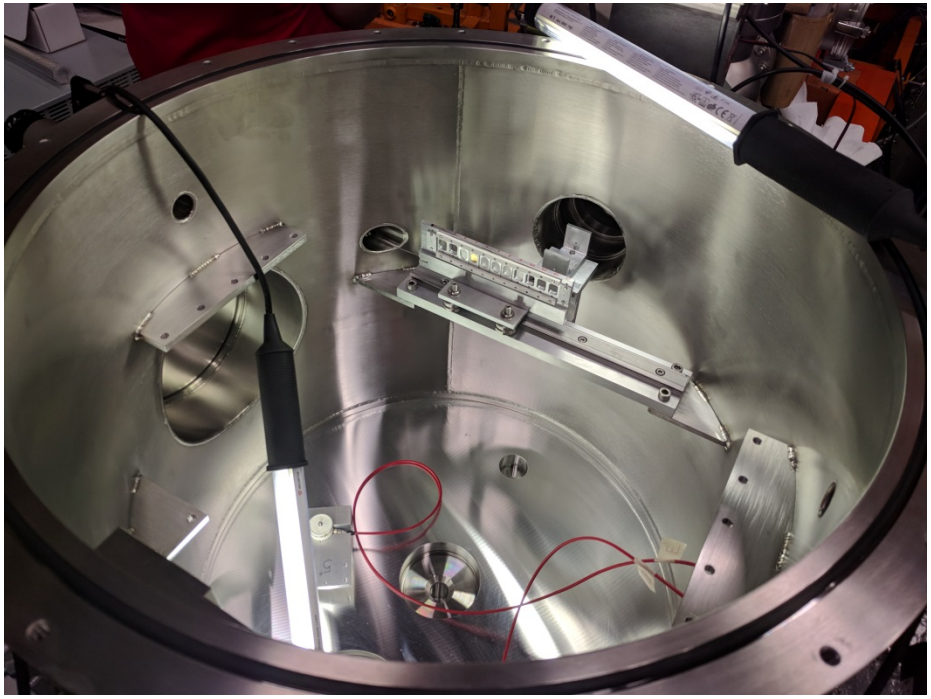
Thick Si detector

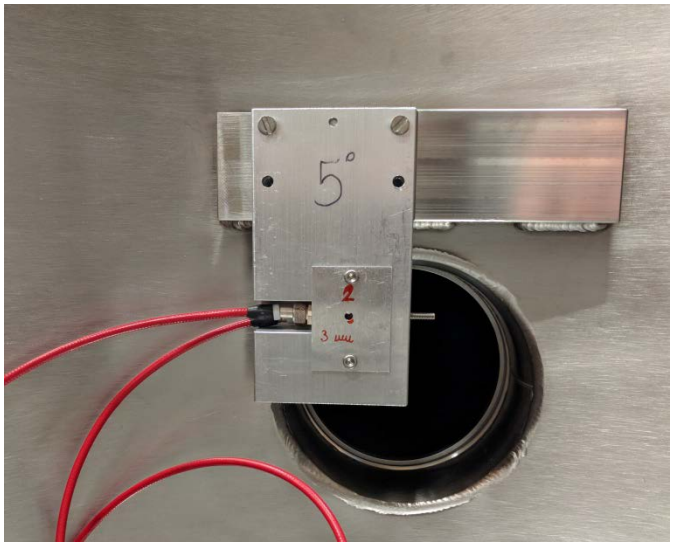


Inside the scattering chamber



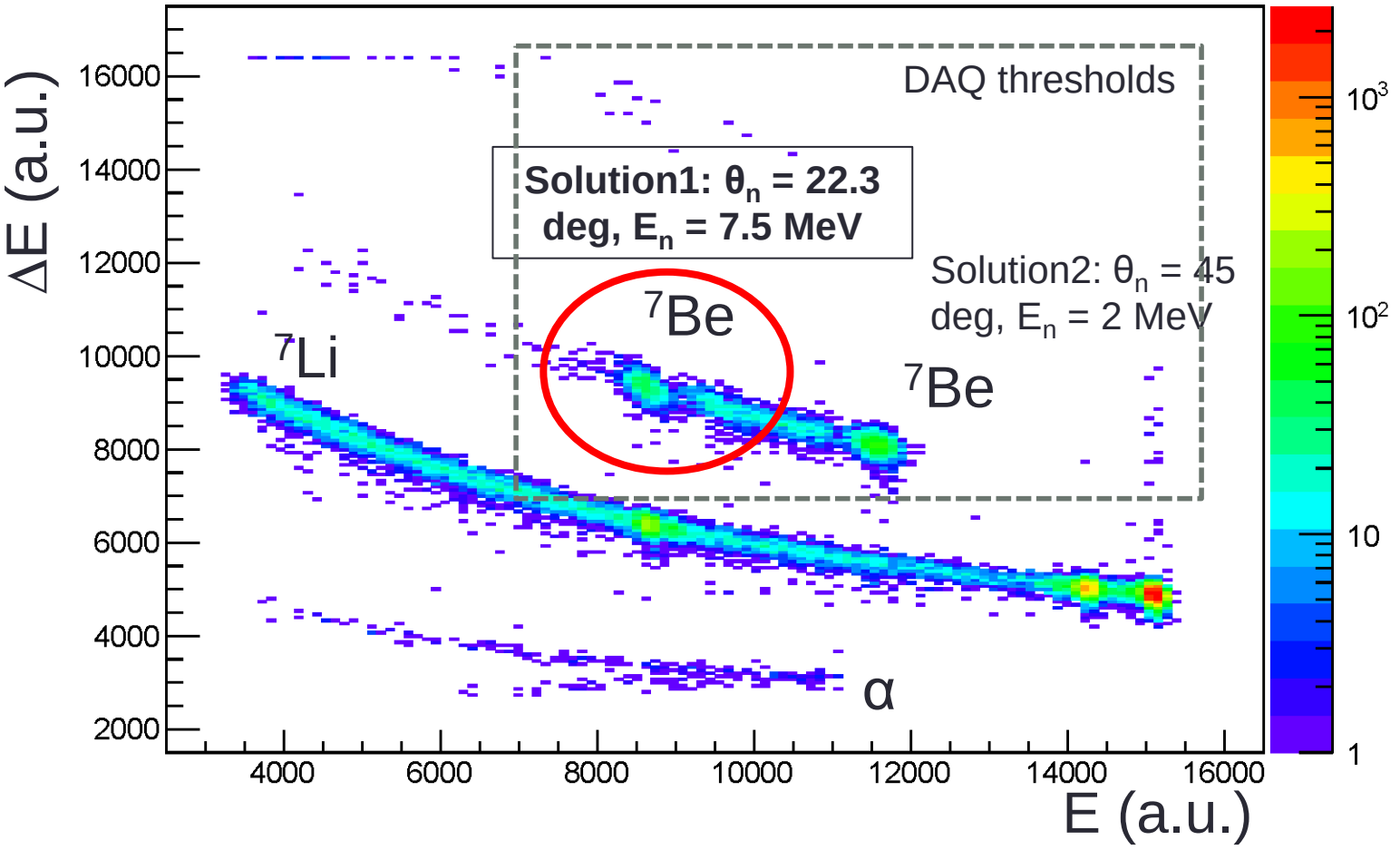
- Si telescope at **5 deg**
- Two-solution kinematics: two ^{7}Be's at 5°, associated with
  - **θ_n = 22.3°, E_n = 7.5 MeV (→TPC)**
  - θ_n = 45°, E_n = 2 MeV





Beamtime! Si detectors

- ^{7}Li beam delivered by LNS-TANDEM: 28 MeV, CH_2 target
  - Current between 0.5 and 7 nA
  - Must be limited, to avoid burning of Si detectors

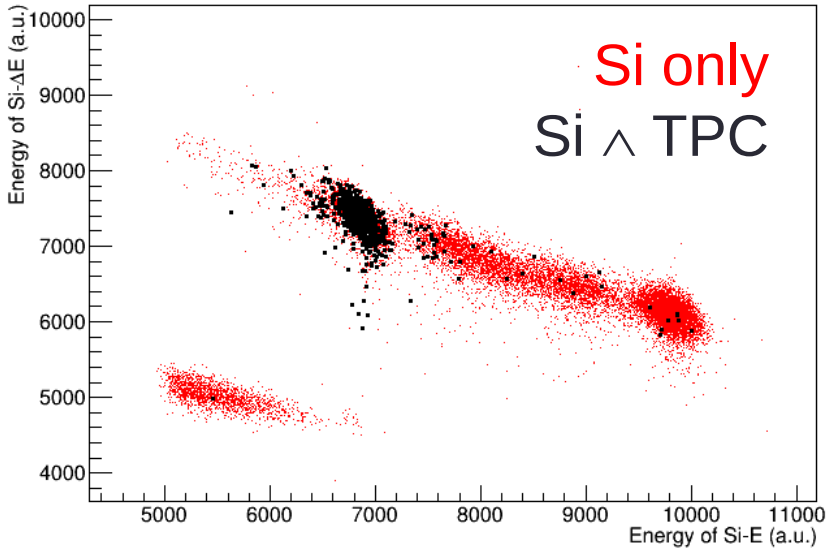


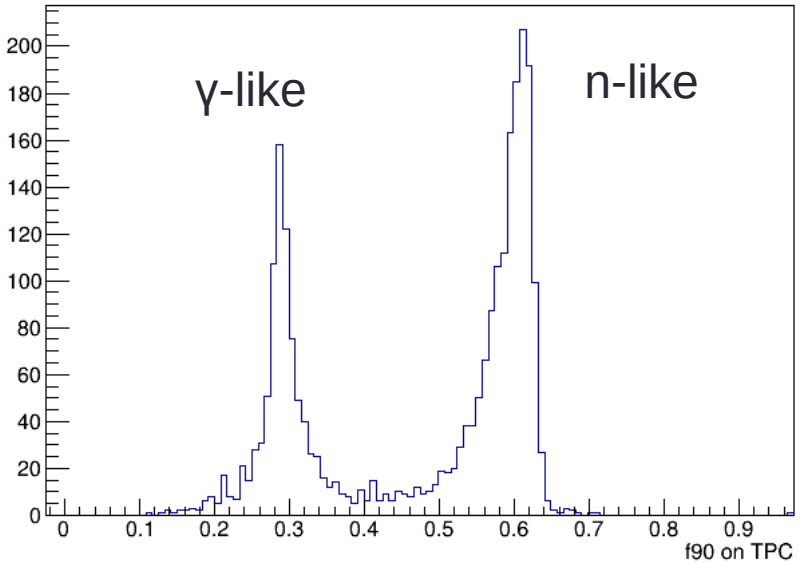
After the beam-on

- Start of beam: July 5th, afternoon. No physical coincidences seen between Si and TPC (only accidentals!)
  - Initially thought about a trigger/gate problem and ran some tests accordingly
  - Troubleshooting complicated by a voltage spike in the lab, which drove the preAmps of the Si detectors crazy
  - Eventually, **small mis-alignment of the collimator** of the Si detectors
- Data taking situation restored July 10th, evening
  - Runs taken with fields ON and OFF
  - Two trigger schemes tested
    - **Si $\wedge$ TPC**
      - Maximizes physical coincidences, but fails to trigger for low-energy recoils (small S1 or S2 only)
    - **Si $\wedge$ (any PMT)**
      - A lot of accidentals, but potentially able to detect (offline) low-energy recoil in the TPC
  - Trigger rate between 0.1 and 0.7 Hz
    - Hard cuts on Si "bananas", to avoid the ^{7}Li band

Si ∧ TPC (work-in-progress)

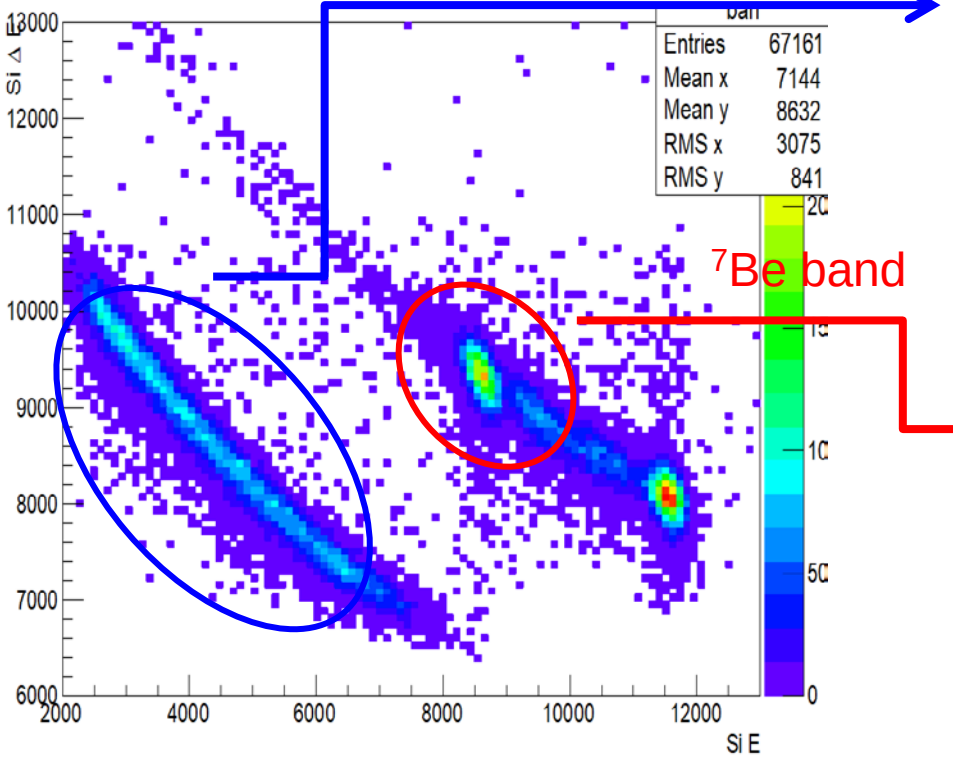
- Runs in single phase
- Events in coincidence between Si and TPC are mostly associated with the "right" ^{7}Be blob
  - A few accidentals (and γ's?) in the other ^{7}Be and in the ^{7}Li blobs
- Events in the TPC are largely (>50%) ascribed to neutron-induced recoils, based on LAr PSD
- The global picture looks consistent

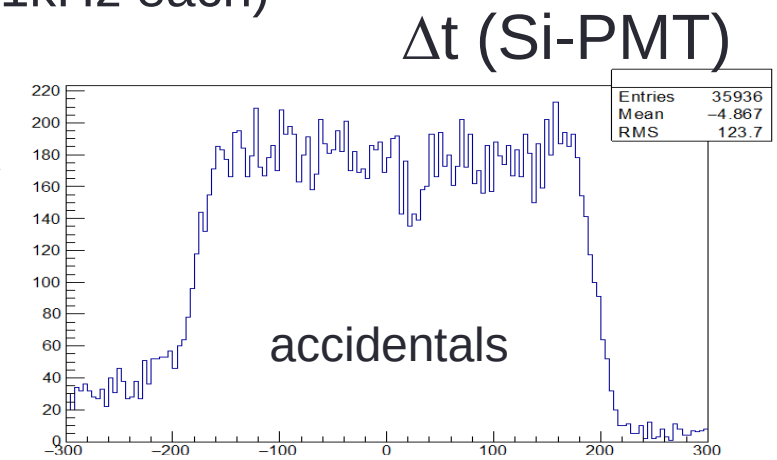


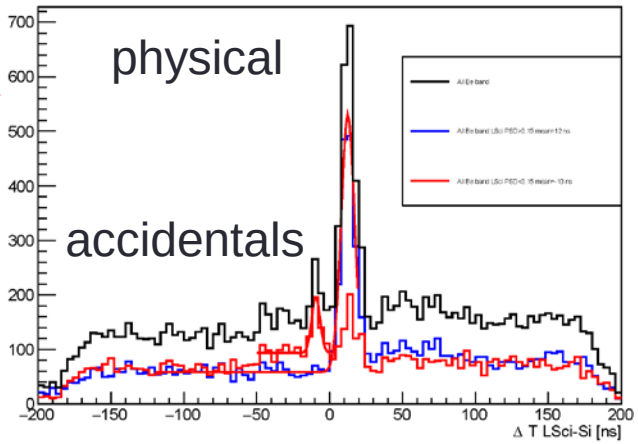


Si ∧ PMTs (work-in-progress)

- Trigger rate between 0.1 and 0.7 Hz, depending on the beam current (very variable, last night of measurement)
  - Driven by **accidentals** (PMTs rate: ~1kHz each)
  - Gate: ± 200 ns

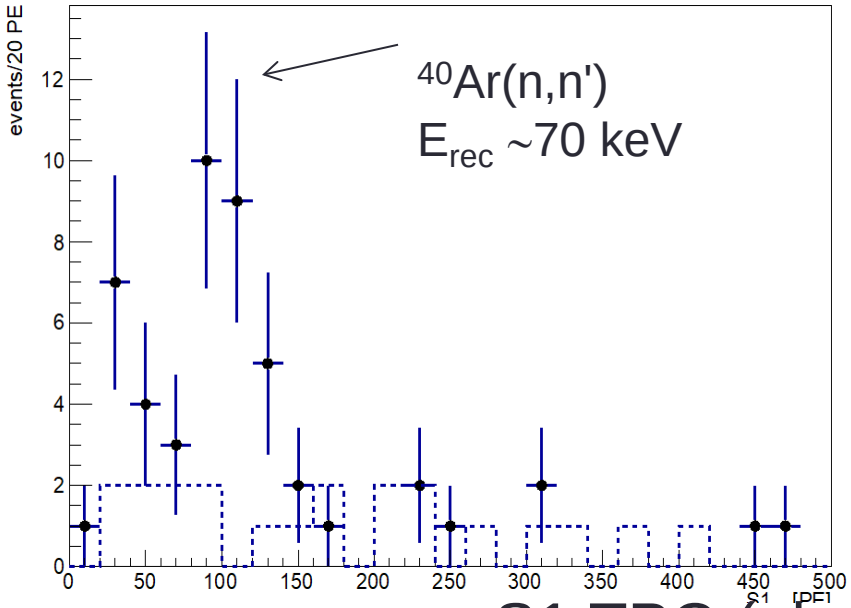




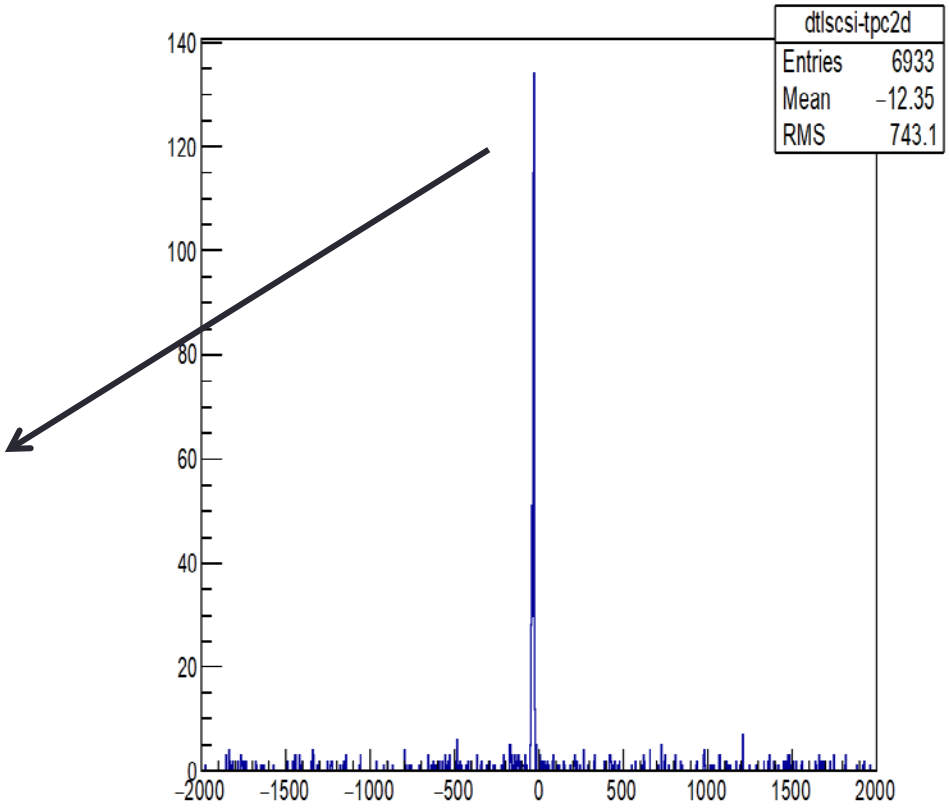


Si ∧ PMTs (work-in-progress)

- **Looking for** a TPC signal offline
  - *Work in progress*, may require tuning of the reconstruction software
  - Potential access to low-energy recoils
  - Accidentals with S2
- Clear correlation peak seen
- **SUPER-PRELIMINARY**



S1 TPC (phe)



Δt (Si-TPC)

Recap: lesson learnt and perspectives

- Next beamtime: **24-29 September 2018** (TBC)
  - Last slot for 2018
  - Going to ask for beamtime in 2019
- The system is deployed on the "80 deg" beamline
  - Aligned and fixed on the floor
  - Not interfering with the other projects on the same beamline
    - Usually devoted to irradiations "in air" at the far end
  - Plan: make it a **long-term facility** for tests of LAr with neutrons
    - Directionality, low-energy response, etc.
- A lot of hardware used for ReD was **borrowed**
  - From *other groups* at LNS (Si detectors, VME crate, …)
  - From the *Electronics Service* of LNS (modules, oscilloscopes, supplies)
  - From *other groups of DarkSide*, but hardware meant for other activities (e.g. laser system, meant for DS-20k MB testing in Naples)
- In the long-term perspective, some pieces of hardware should be purchased and taken as "stable part" of the setup

Recap: lesson learnt and perspectives

- A lot of experimental activities and tests
  - 5.8 TB of data on disk, will take a while to digest and intepret
- Critical items identified to be addressed before the next beamtime
  - **Manpower on-site**, especially when have to cover 24h shifts
    - (International) groups/people **interested to join**
  - Si detectors: we need more people with expertise in nuclear physics, such that the burden is not on 1-2 key persons only (which turn out to be permanently on call)
  - DAQ and trigger logic. Improved, but not fully satisfactory yet
    - Need to sort out the bottleneck of the DAQ rate (disk access)
    - Waveform access "in real time"
  - Better integration of the Si detectors in the slow control (remote monitoring and operation)
  - Shifter's procedures, including standard "immediate" analysis plots
  - More to come…
- **Support** from the **LNS was excellent**
  - Professional, effective and quick