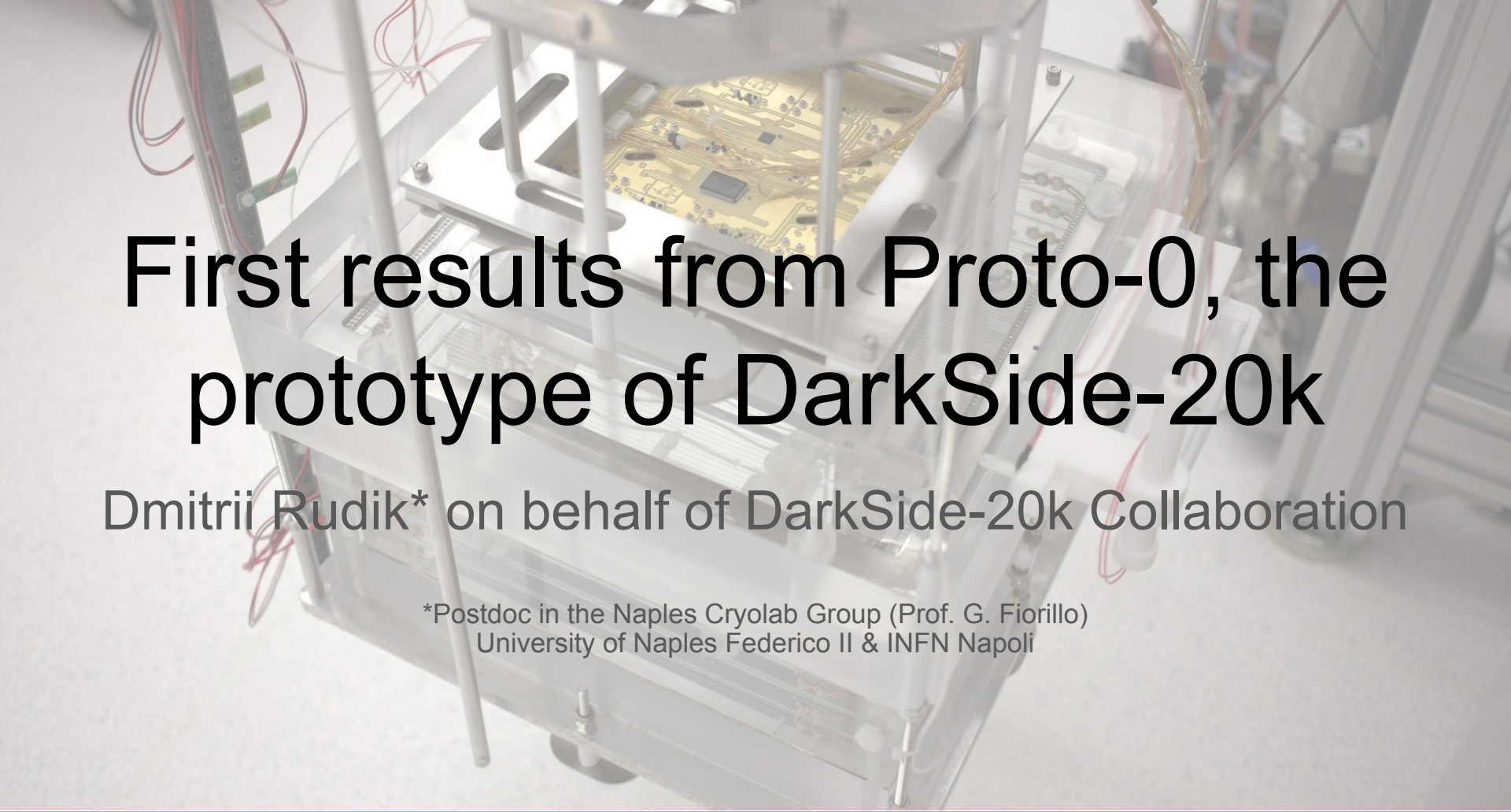


First results from Proto-0, the prototype of DarkSide-20k

Dmitrii Rudik* on behalf of DarkSide-20k Collaboration

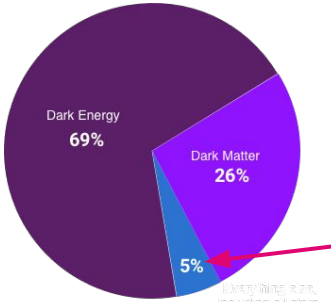
*Postdoc in the Naples Cryolab Group (Prof. G. Fiorillo)
University of Naples Federico II & INFN Napoli

Outline

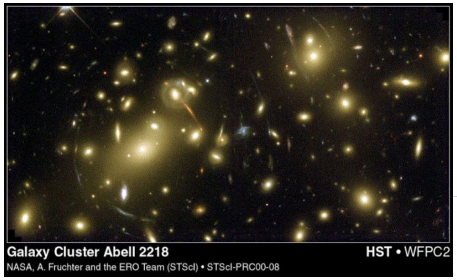
- Introduction
- Proto-0: prototype of the DarkSide-20k
  - Overview
  - First campaign
  - Second campaign
  - Current activity and future plans
- Conclusion

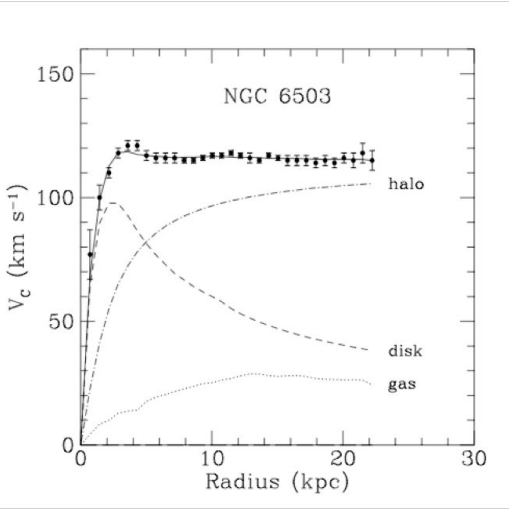
Dark Matter

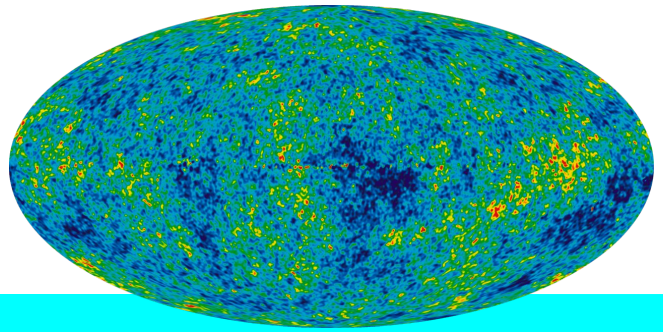
- There is more mass in the Universe than we can see…
- Many observational evidences
  - Galaxy rotation curves
  - Stars velocity dispersion
  - Galaxy clusters behaviour
  - Gravitational lensing
  - Cosmic microwave background anisotropy
- Probably it is some as-yet-undiscovered particle
  - E.g. Weakly interacting massive particle (WIMP)
- How to detect?
  - We need sensitive detector
  - With a lot of detecting material
  - Well shielded from the background



Everything else: including stars, planets and us

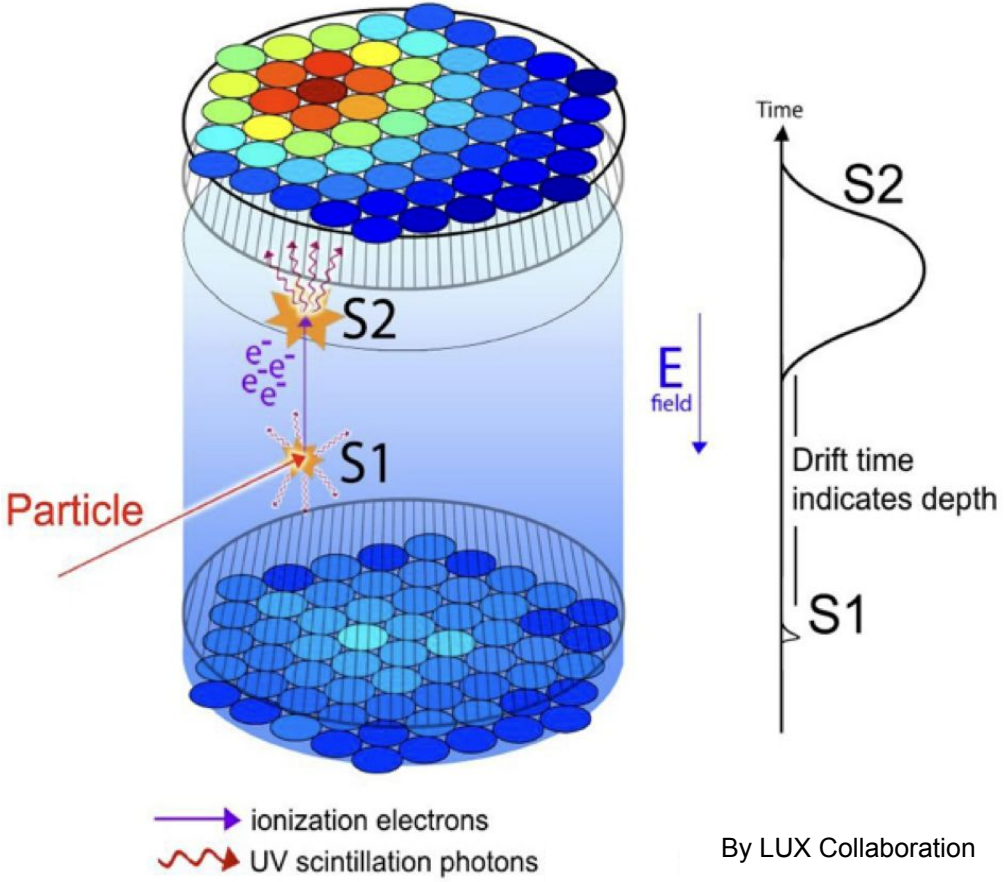






Double-phase TPC

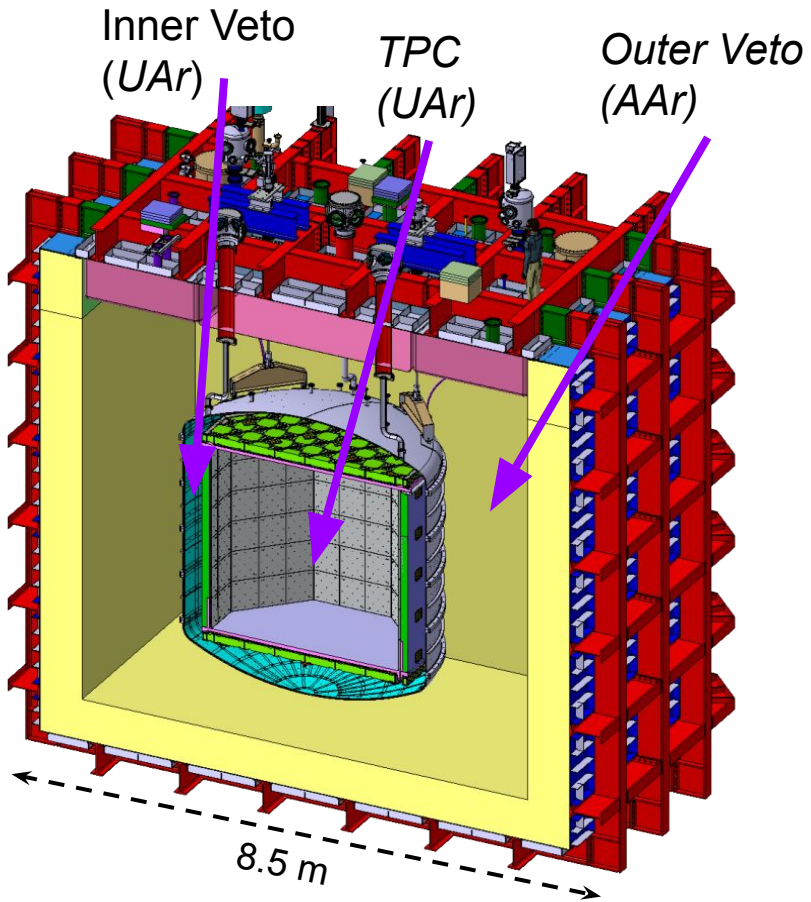
- Liquid noble gases (Ar, Xe)
- Two signals
  - Scintillation (S1)
  - Electroluminescence (S2)
  - λ = 128 nm for Ar $\rightarrow$ wavelength shifter is needed
- Electric field to extract ionization electrons
  - Sensitive to the single ionization electron (SE)
- Arrays of photodetectors from top and bottom
- 3D position reconstruction
- Self-shielding or “wall-less” detector
- Scalable



By LUX Collaboration

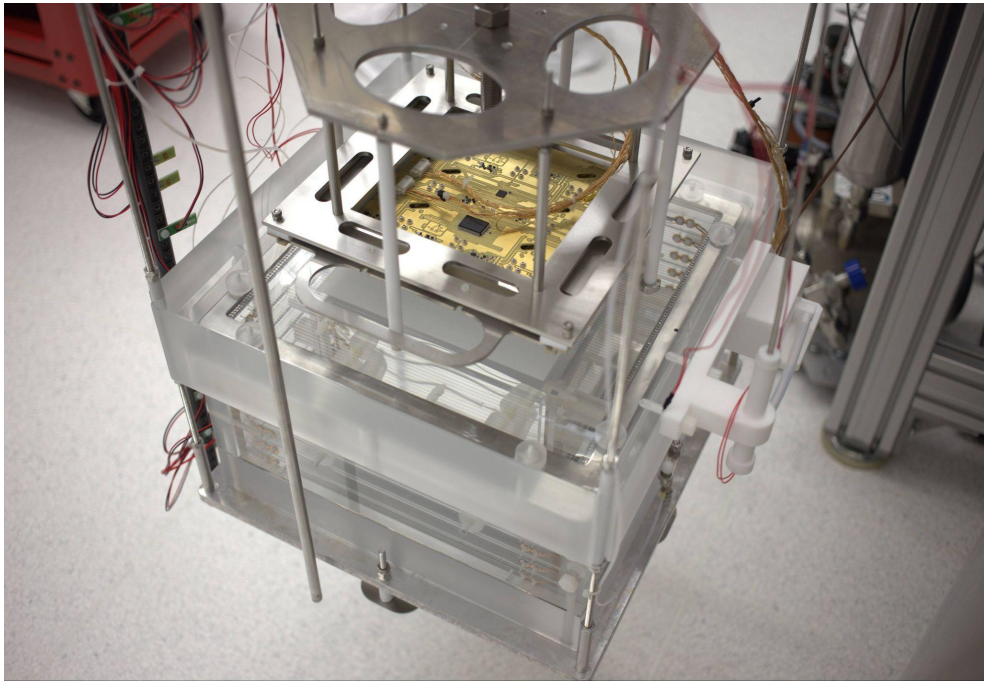
DarkSide-20k

- Double-phase LAr detector
- Under construction @ LNGS hall C (3800 m w.e.)
- Outer veto: DUNE-like membrane cryostat (8×8×8 m^3)
  - ~650 t of liquid atmospheric argon (AAr)
- Stainless steel inner detector
  - ~100 t of ultra pure underground liquid argon (UAr)
  - ~50 t of UAr in the active volume (~ 20 t in fiducial volume)
- Gas pocket: “diving bell” technology
- Fields:
  - clevios coated acrylic (PMMA) walls, cathode and anode
  - wire grid
- Readout:
  - TPB as a wavelength shifter
  - >500 SiPM-based Photo Detection Units (PDU) from top and bottom (see backup)
  - Enhanced Specular Reflector film (ESR)



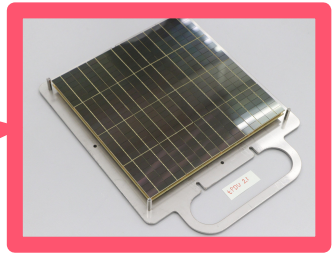
Proto-0: DarkSide-20k prototype in Naples

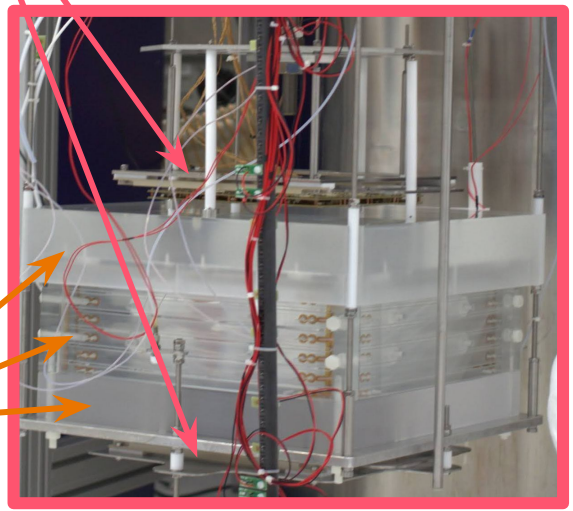
- The same technologies:
  - TPC made of PMMA
  - Fields by Clevios coating
  - Parallel wires extraction grid
  - Top and Bottom PDUs readout (4+4 channels)
  - TPB coated ESR reflectors
- It has movable TPC's parts to study:
  - S2 vs. Anode to Grid distance
  - S2 vs. gas-pocket height
  - S2 and Gas Pocket formation vs. pressure
- ISO-6 clean room environment
- Automated cryogenic system



Proto-0: some photos

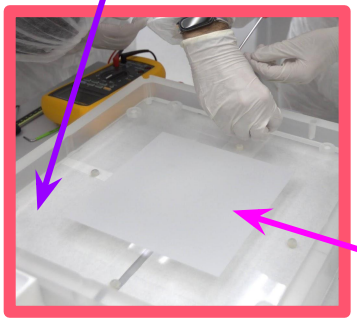
Top and Bottom PDUs



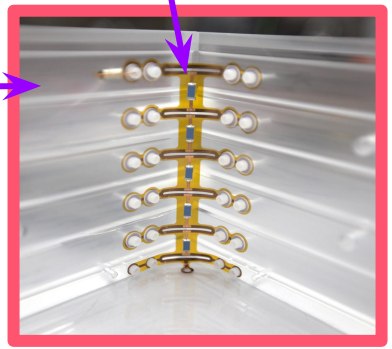


PMMA Anode, field cage and Cathode

Clevios coated Anode, Cathode, and Field cage



Resistor-chain

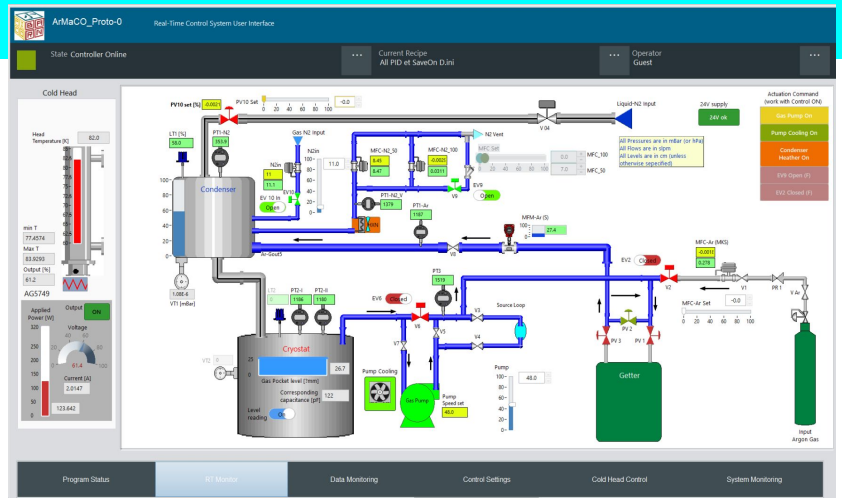


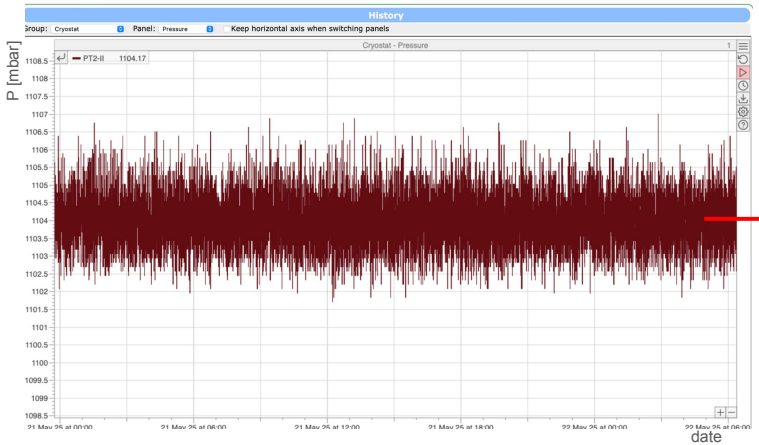
TPB coated Anode and Cathode 20x20 cm^2

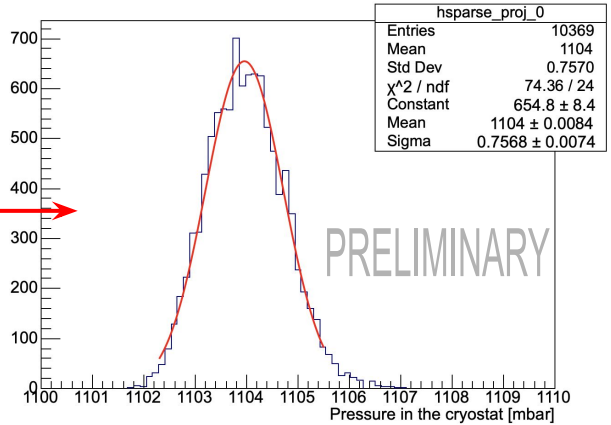
Reflector cage 20x20x12 cm^3

Cryogenic system and stability

- Dedicated cryogenic system:
  - 300L cryostat, ~ 200 kg of LAr in total
  - custom Ar condenser (similar to DS20k one) coupled with Cryomech GM cryocooler
  - gas panel with custom gas recirculation pump
  - Hot Getter inline Purifier
  - ^{83m}Kr source loop
  - All controlled by the dedicated NI HW and Labview based slow control
- PID-control of the cryostat pressure
  - Stability at the level of ~0.8 mbar (std. dev.)



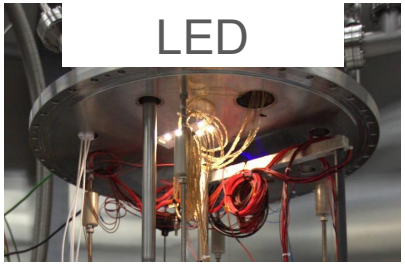


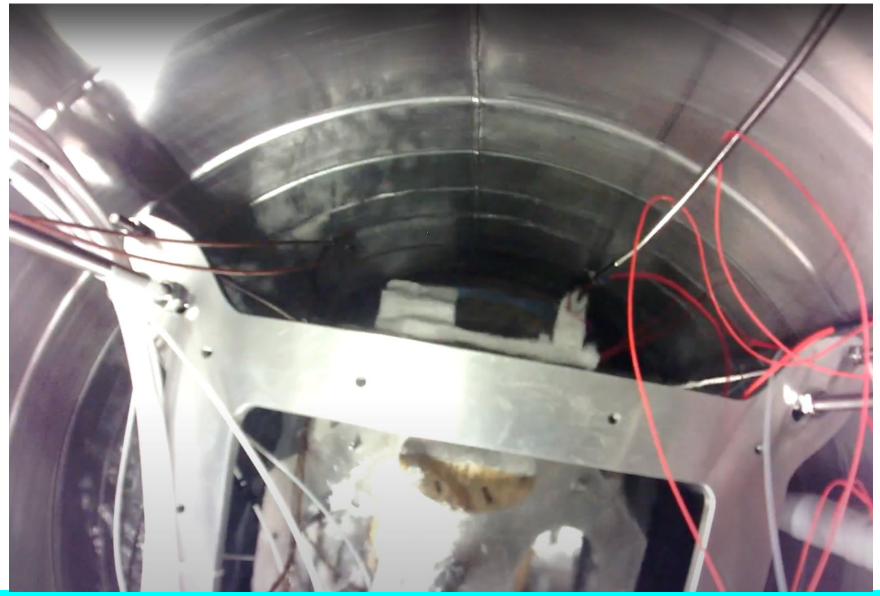


First campaign

- Assembled in 2024
- Three months in Fall/Winter 2024
- Tests in a single phase mode
- Gas pocket formation
- Tests in a double phase mode
- Tests of movable parts

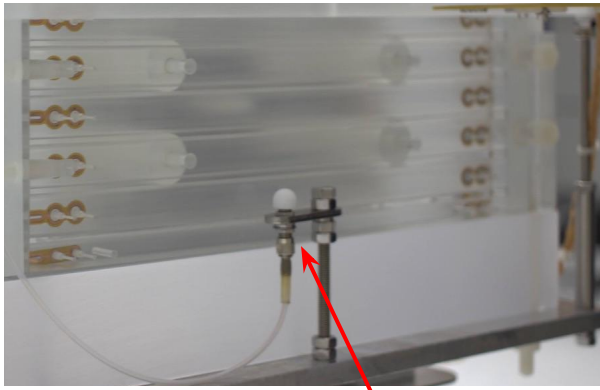
- **First time DS20k technologies are merged together in a single working LAr detector**

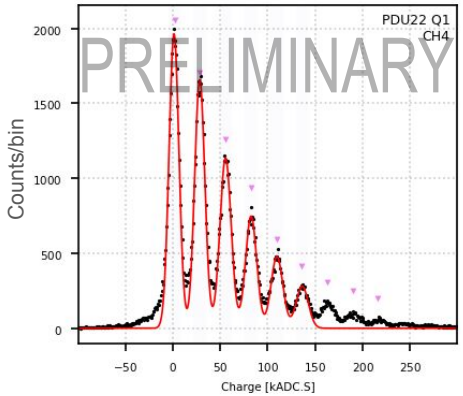


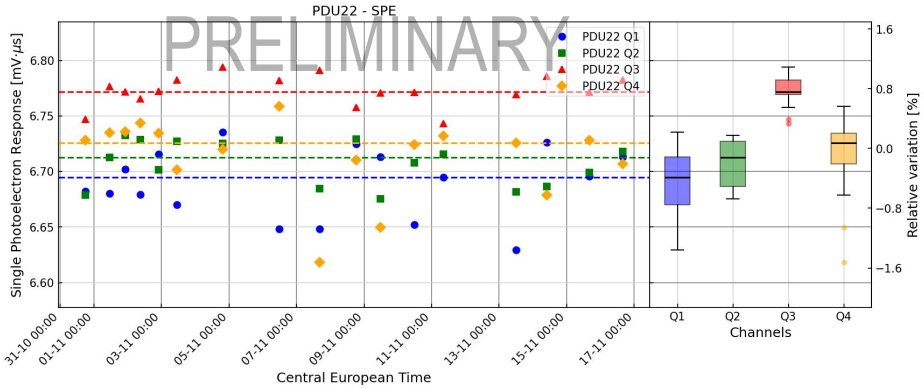


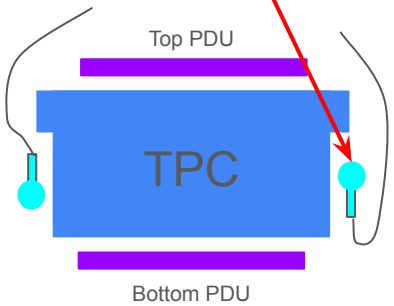
PDU calibration and stability

- PDUs calibration with laser pulses (λ = 403 nm)
- PDUs were working fine and stable (it is the first time DS20k PDUs are working in LAr)
  - 0.3% rms per channel (averaged over all channels)



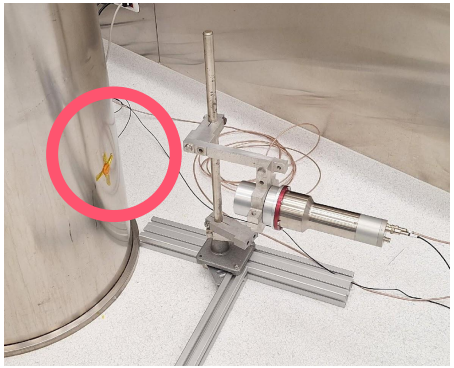


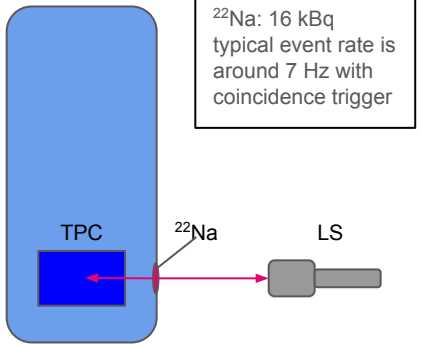


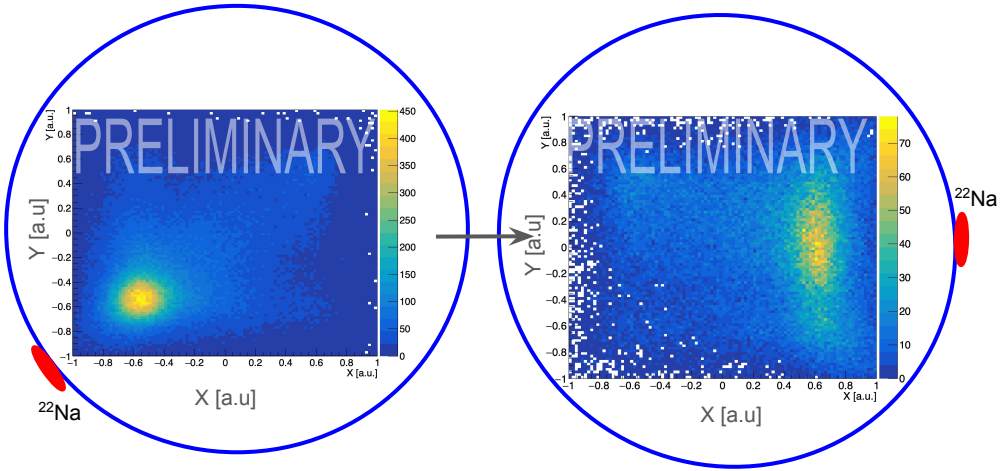


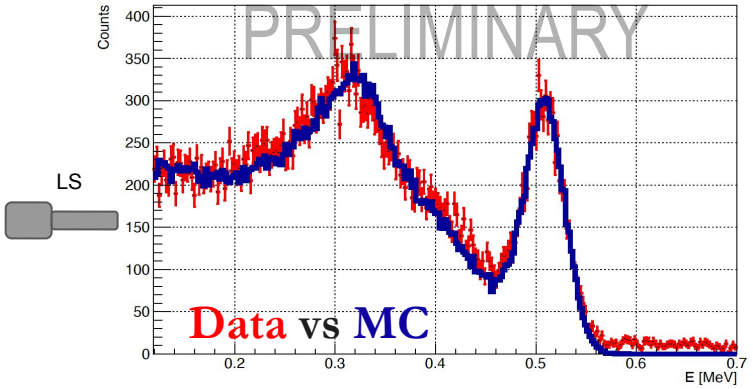
Calibration and first data

- Calibration with ^{22}Na source
- Back-to-back tagging with liquid scintillator detector (LS)
- We see 511 keV full absorption peak
- Good agreement with MC
- Disadvantage: high energy



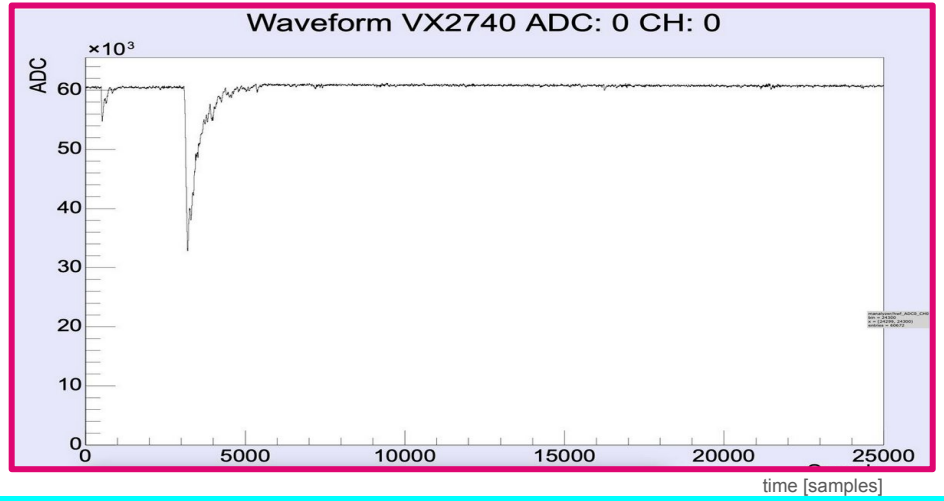


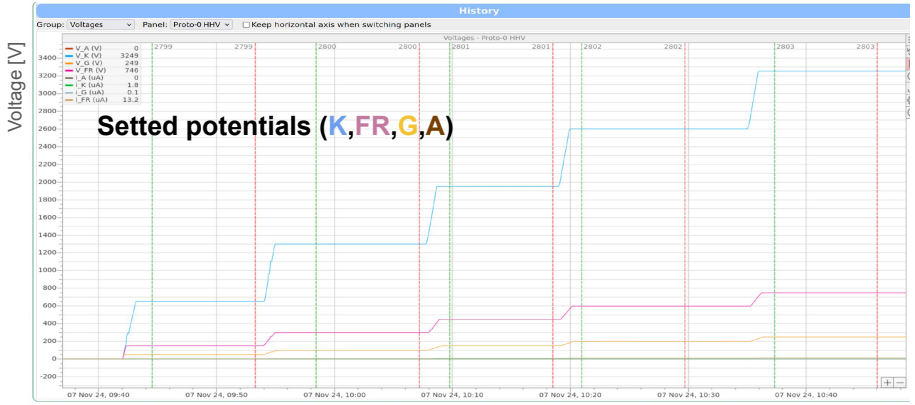


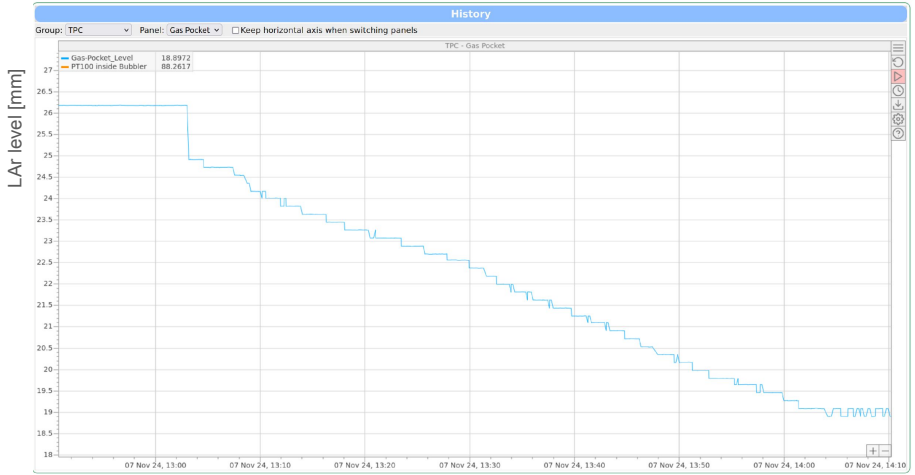


First electroluminescence

- Electric fields were applied and were stable during all the campaign
- Gas pocket was smoothly formed within one hour and stable during the measurement period of several weeks
- First S2 signal in Proto-0

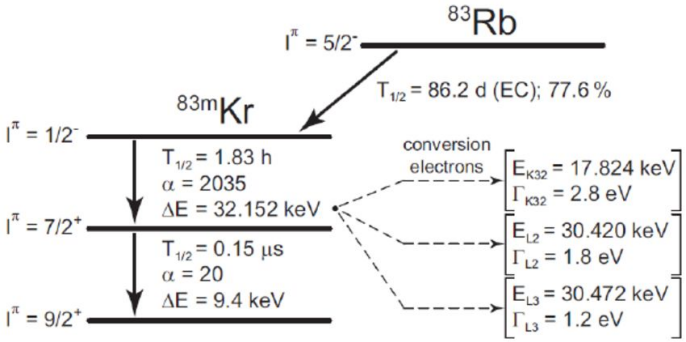




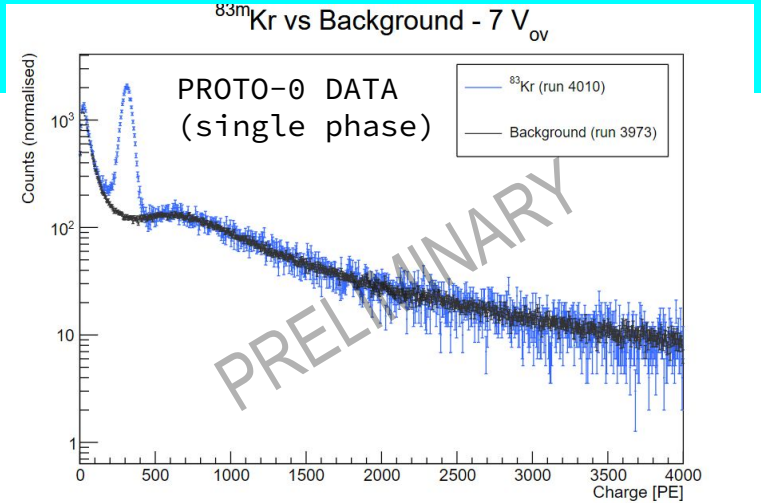


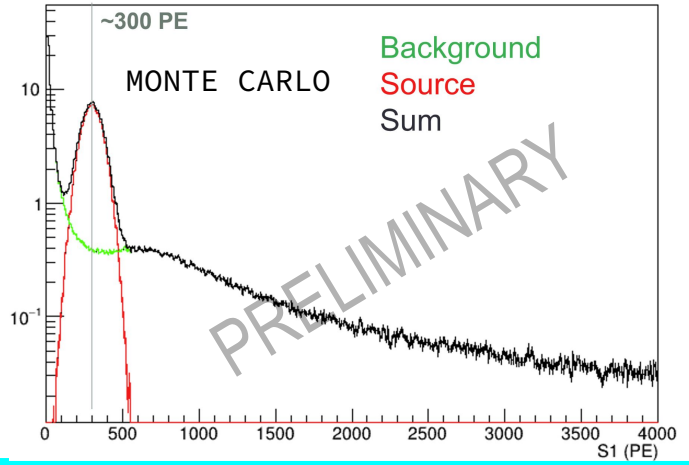
Second campaign

- Several improvements of TPC and cryogenic system
- Lead shielding installed to reduce background for better visibility and study of low energy source
- **^{83}Rb/^{83m}Kr source installed into the source loop**
  - Volume distributed gaseous source
  - Decays in two stages with total energy deposition of 41.5 keV
- Three months Spring/Summer 2025
- Data analysis is ongoing



V Hannen *et al* 2011 *JINST* 6 P10013





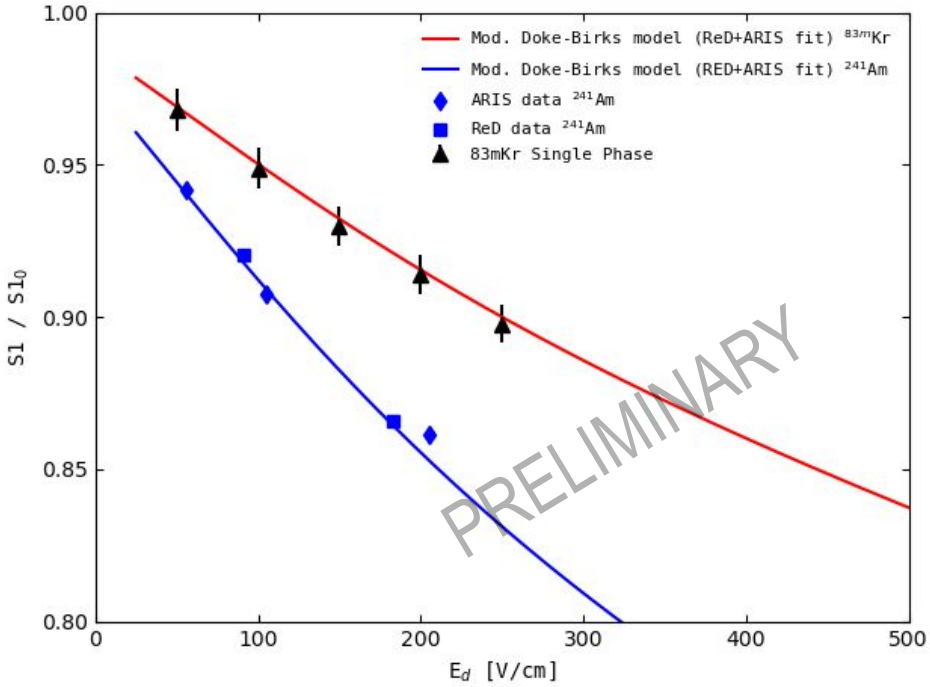
Single phase quenching study

Modified Doke-Birks model fit with ReD+ARIS data
(*Eur. Phys. J. C (2021) 81:1014*)

Assumption: Energy-average for the two electron emission as an entry to the formulae

dE/dx data from ESTAR Stopping Power and Range Tables for Electrons (NIST)

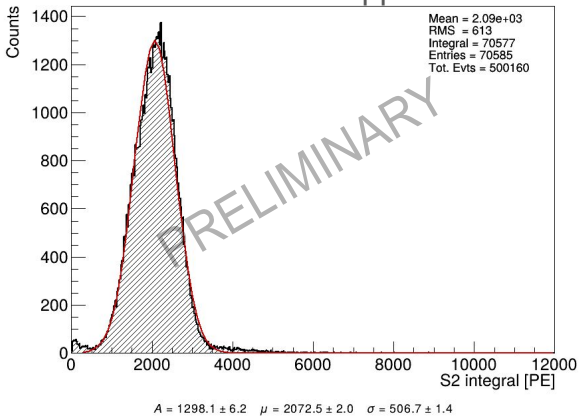
→ Expected field and detector response

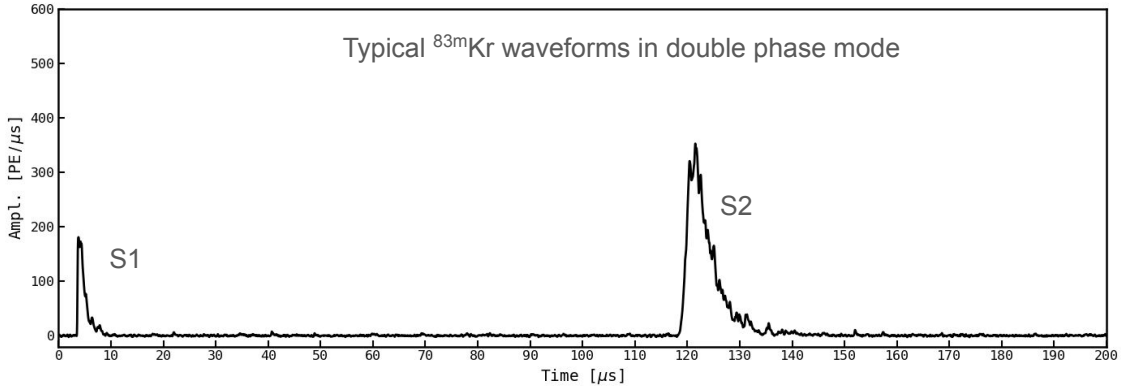


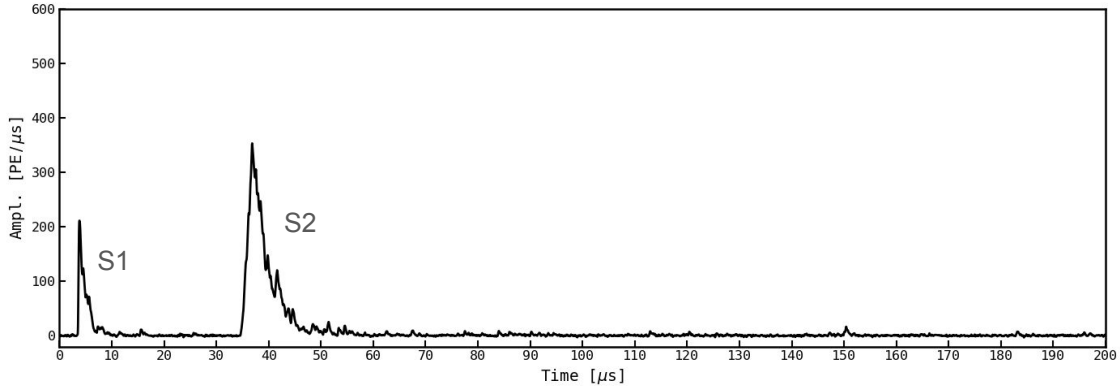
^{83m}Kr: double phase mode

- Good discrimination between S1 and S2 signals
- S2/S1 ~7.5, lower than in DS-50, expected due to geometrical factor

S2 integral example, no corrections applied



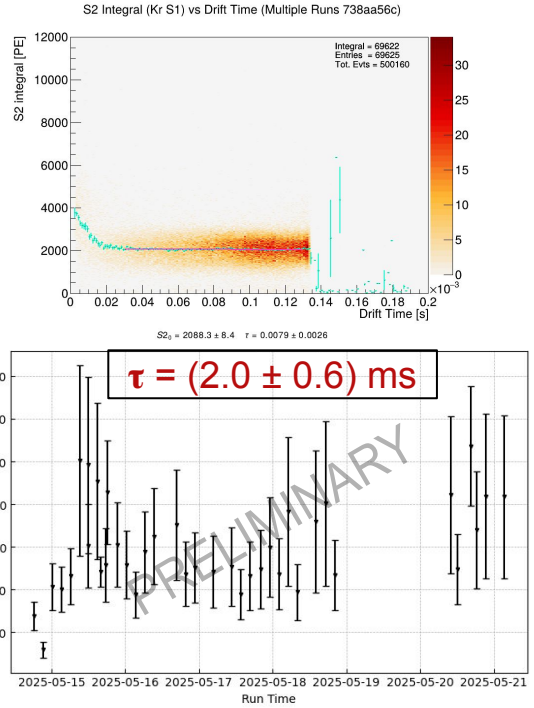




LAr purity

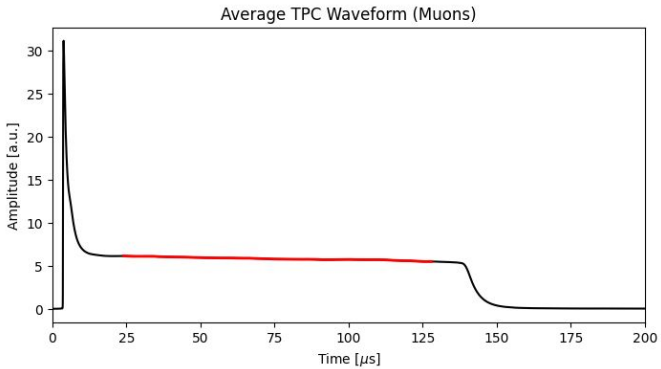
Ionization electrons can be captured by the electronegative impurities

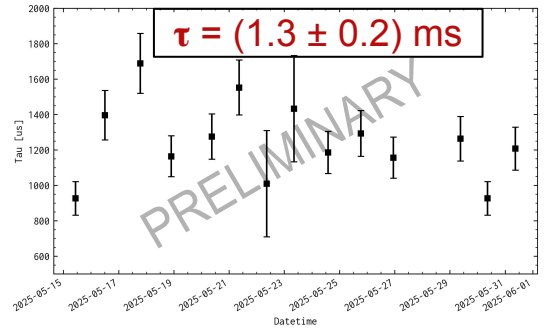
Purity from S2 vs t_{Drift}



- Two methods give consistent results
- Electrons lifetime > 1 ms

Purity from muons





D.Yu. Akimov *et al* 2024 *JINST* 19 T11004

Current activity and future plans

- Proto-0 is a test bench for the DS20k technologies
- A lot of data with different gaspocket characteristics were acquired (height, pressure, distance between electrodes)
- Currently under analysis
- Next campaign is planned for this Fall

Conclusion

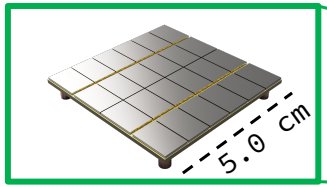
- Proto-0 was assembled and two runs were carried out
- It is the first time that all technologies of DarkSide-20k are assembled together in a single working prototype
- First real experimental data obtained by PDUs in LAr
- Lots of data acquired, first results are promising
- Still a lot of things to do
- Data analysis is ongoing, stay tuned!

Thank you for your attention!

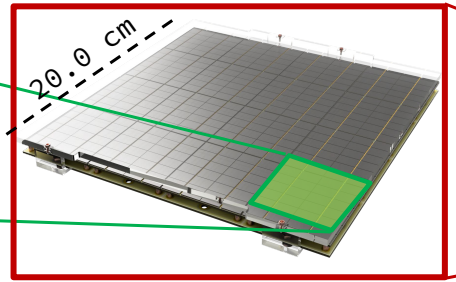
Special thanks to Giuseppe Matteucci for several slides and materials

BACKUP

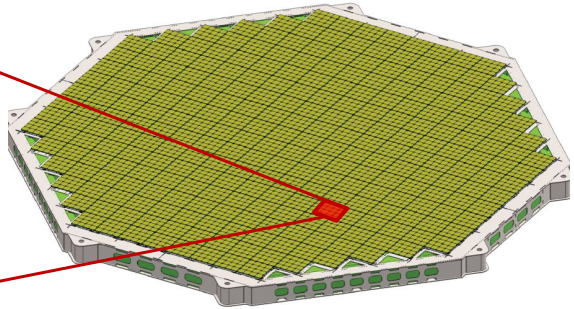
The PDU



Tile: 5x5 cm^2
24 SiPMs directly mounted on a FEB

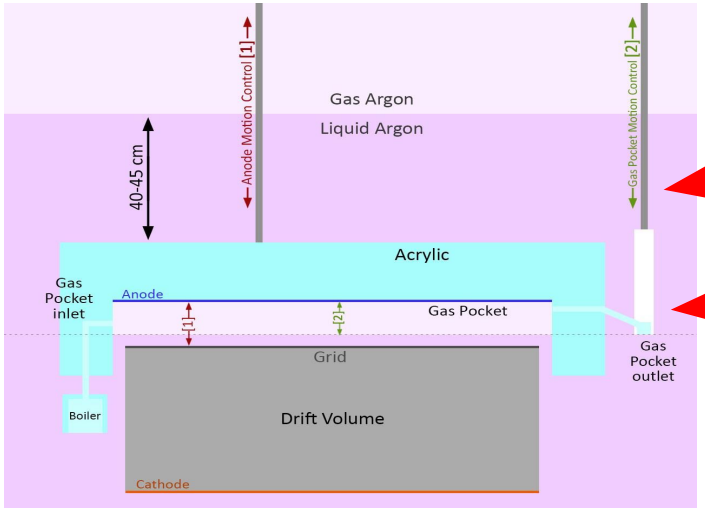


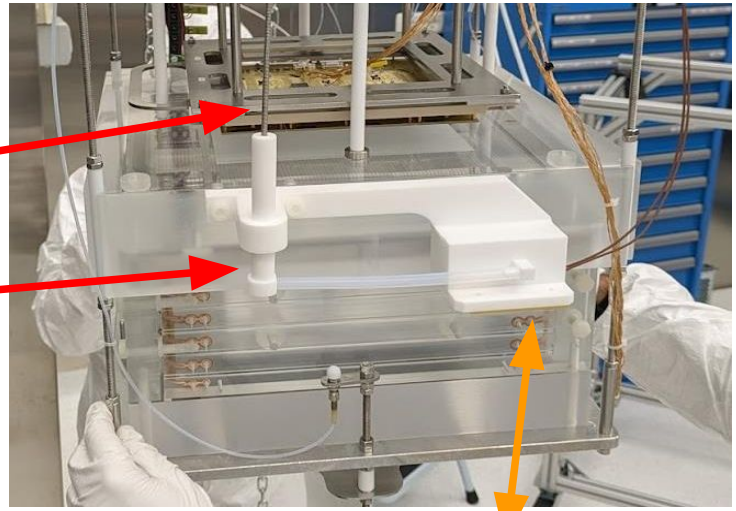
PDU: 20x20 cm^2
Radiopure modular cryogenic silicon-based photon counter device



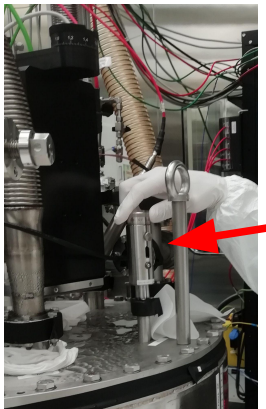
Optical planes: ~2x10 m^2
Total PDUs used (TPC): 528
Readout Channels: 2112

Peculiar features of TPC - Moving bubbler by dedicate motion feedthrough → settable Gas-Pocket thickness (also a Gas-Pocket Level meter)

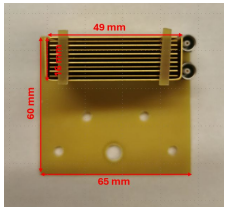


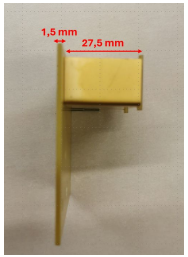


Fixed Grid - Cathode distance: 120 mm



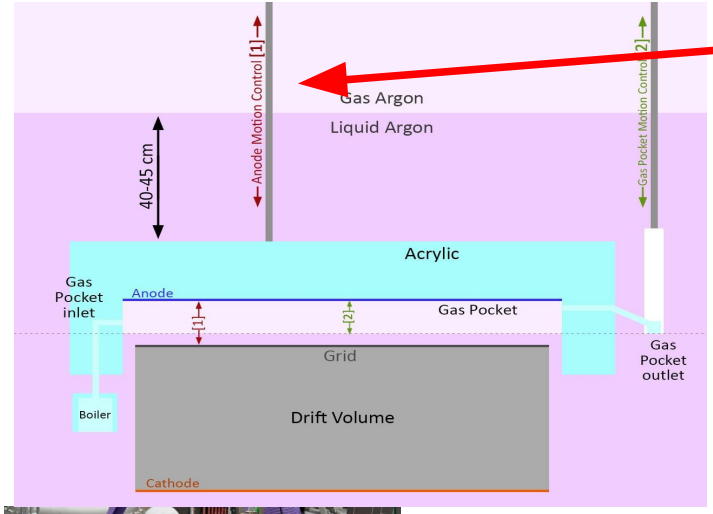
Total stroke: 25mm
Resolution: 0.1mm



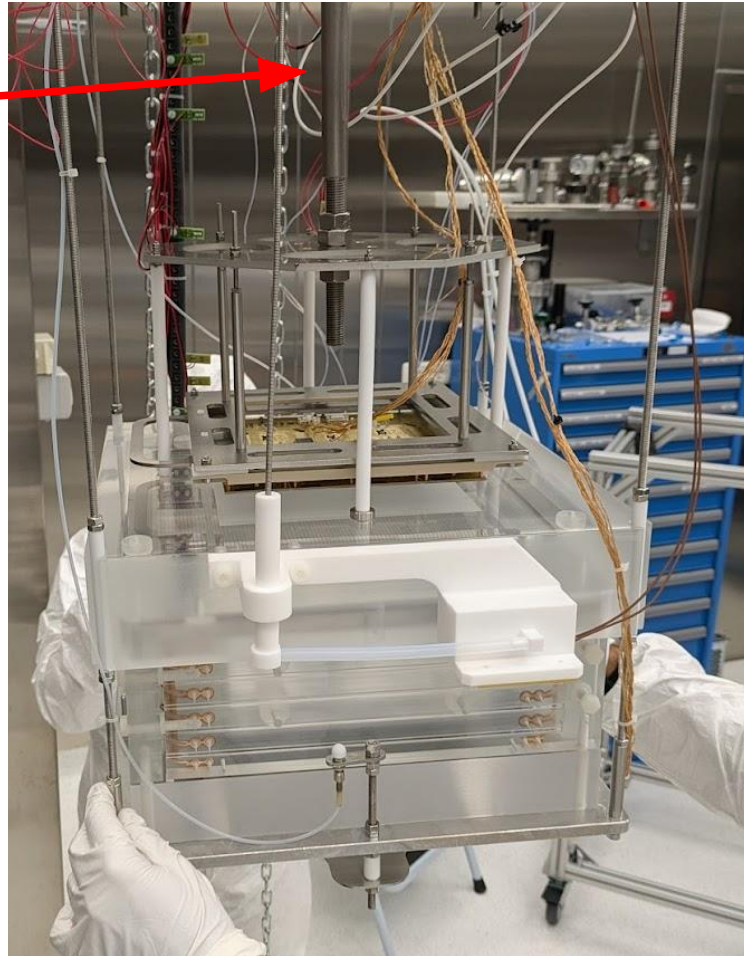


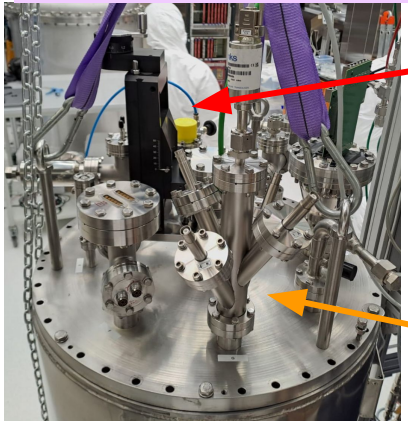
Capacimeter as GasPocket level meter a-la-ArDM (UnivAQ)

Peculiar features of TPC - Moving Anode by dedicate motion feedthrough → settable Anode-Grid distance



Anode moving rod

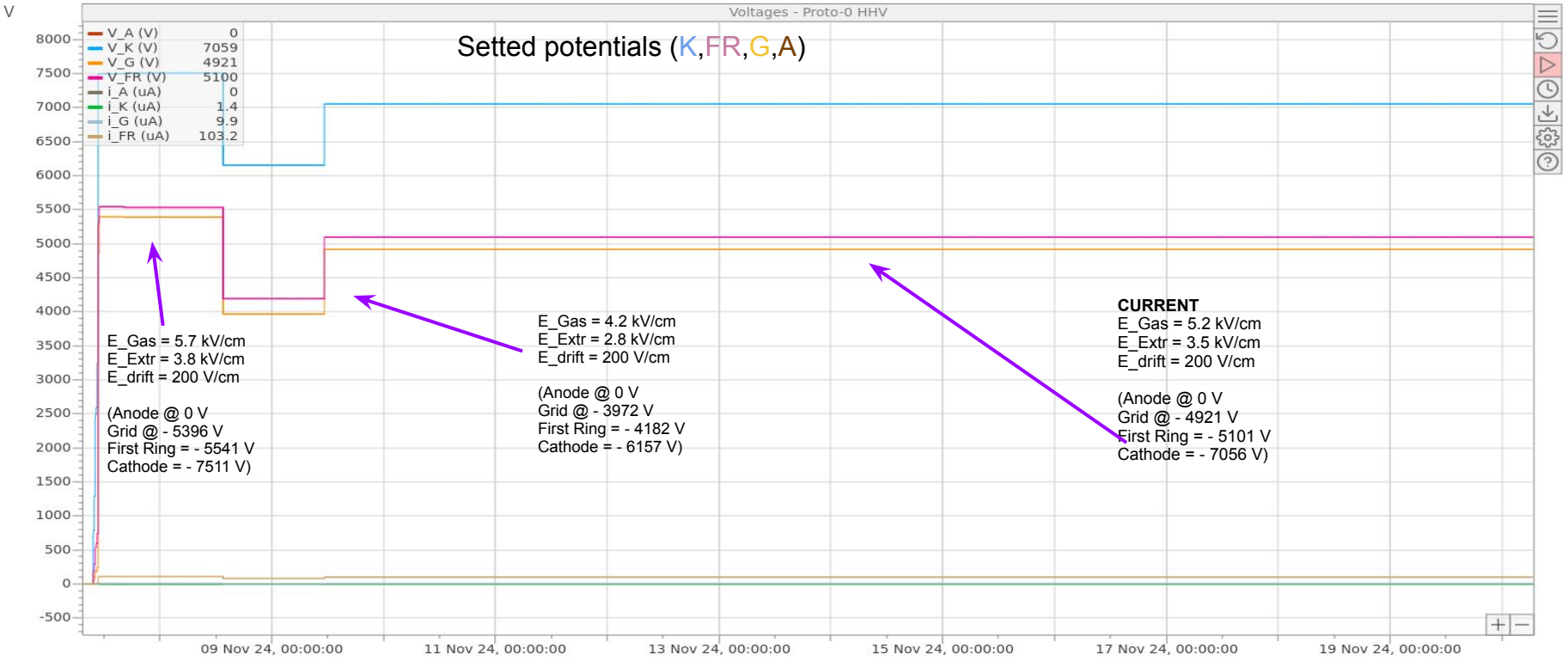




Motion feedthrough on the flange

Current setting (DS20k like):
Anode - Grid distance: 10 mm
Anode - "Boiler output": 7 mm (GP)

HHV 4 ports "flower" flange


V
Voltages - Proto-0 HHV
V_A (V) 0
V_K (V) 7059
V_G (V) 4921
V_FR (V) 5100
i_A (uA) 0
i_K (uA) 1.4
i_G (uA) 9.9
i_FR (uA) 103.2
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
-500
09 Nov 24, 00:00:00
11 Nov 24, 00:00:00
13 Nov 24, 00:00:00
15 Nov 24, 00:00:00
17 Nov 24, 00:00:00
19 Nov 24, 00:00:00
Setted potentials (K,FR,G,A)
E_Gas = 5.7 kV/cm
E_Extr = 3.8 kV/cm
E_drift = 200 V/cm
(Anode @ 0 V
Grid @ - 5396 V
First Ring = - 5541 V
Cathode = - 7511 V)
E_Gas = 4.2 kV/cm
E_Extr = 2.8 kV/cm
E_drift = 200 V/cm
(Anode @ 0 V
Grid @ - 3972 V
First Ring = - 4182 V
Cathode = - 6157 V)
CURRENT
E_Gas = 5.2 kV/cm
E_Extr = 3.5 kV/cm
E_drift = 200 V/cm
(Anode @ 0 V
Grid @ - 4921 V
First Ring = - 5101 V
Cathode = - 7056 V)