Towards Rare-Event Searches: My work with the DarkSide Collaboration

The International Doctorate Network in Particle Physics, Astrophysics and Cosmology (IDPASC)

Celín Hidalgo
Gran Sasso Science Institute

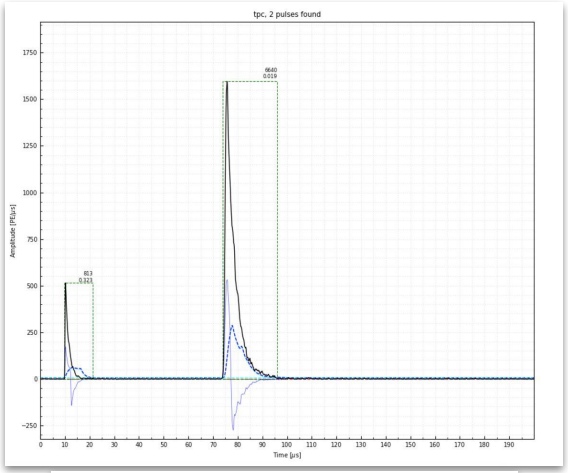
Background and Research Path

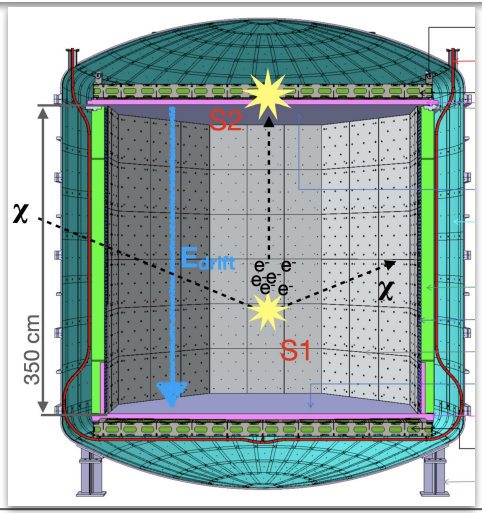
1. Bachelor Degrees in Astrophysics and Art History from Rutgers University, NJ, USA
   a. Specialization in Observational Astrophysics
2. Research Assistant at Wright Lab, Yale University
   a. As part of the Project 8 and CUORE Collaborations
3. Research Assistant at Princeton University
   a. As part of the DarkSide-20k Collaboration
4. **PhD Student at the Gran Sasso Science Institute**
   a. Innovative Technologies for Space Missions and Radiation Detection Program with the DarkSide-20k Collaboration.

Working Principle of Dual-Phase TPCs

Dual-phase time projection chambers (TPCs), are used in rare-event searches for dark matter and neutrino physics.

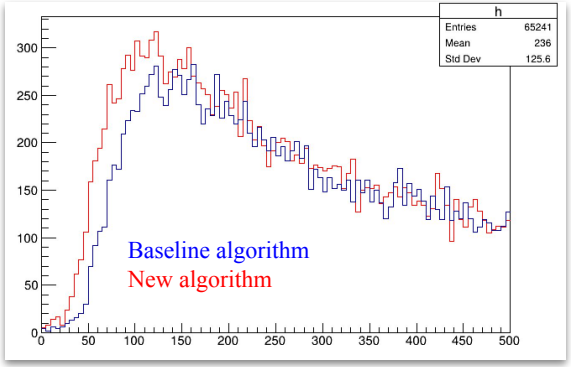
- These detectors operate with a noble gas (e.g. argon, xenon) in both liquid and gas phases.
- A particle interaction in the liquid generates:
  - S1: prompt scintillation light from excited atoms
  - Ionization electrons, which drift upward under an applied electric field.
- At the liquid-gas interface, electrons are extracted into the gas phase and accelerated
  - S2: a delayed signal from electroluminescence (light generated by accelerated electrons).
- The electroluminescence gain depends on the electric field and is key to signal reconstruction and detector calibration.



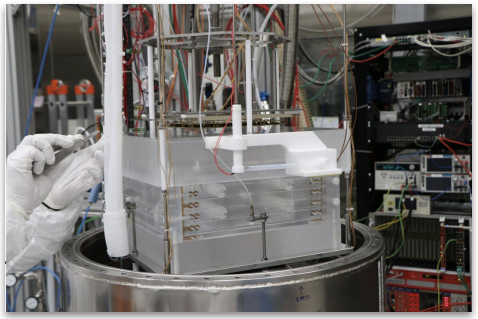


Current PhD Activity: Optimizing Pulse Reconstruction in Proto-0

- Proto-0 is a Darkside-20k TPC prototype (20x20x12 cm^3 volume, filled with 7 kg of liquid argon).
- Joined the experimental effort at INFN Naples and focussed on tuning the pulse reconstruction algorithms
- The optimization effort improves detection and characterization of low-energy pulses, with particular attention to single-electron signals (SEs) from photoionization at the cathode.
- These SEs serve as a well-defined calibration source for measuring the electroluminescent gain, a detector's light response to drifting electrons as a function of electric field configurations.
- Incidentally, SE signals are a limiting background for low-energy searches with extremely low-thresholds (20 eV) – *arXiv:1802.06994 DS50*

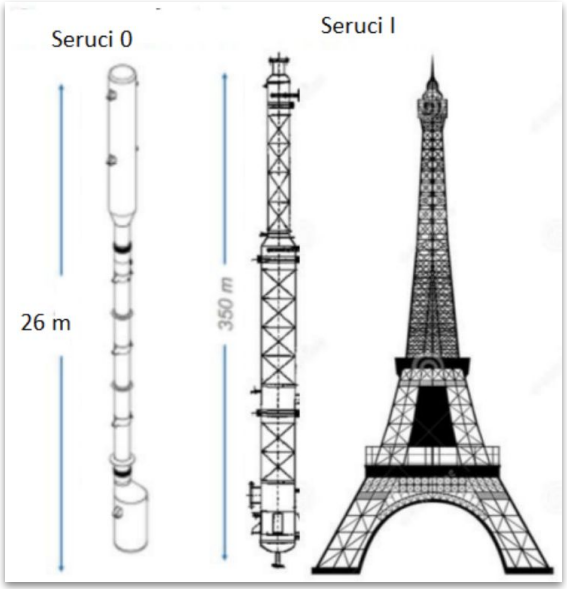


S2 integral [number of PEs]



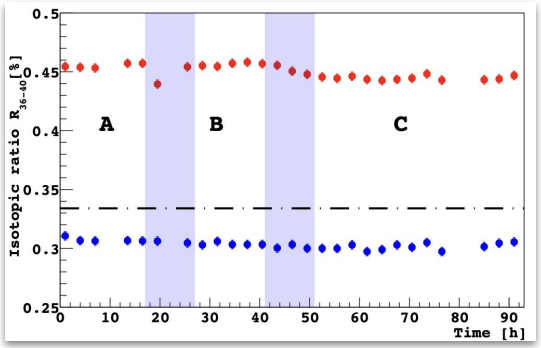
Future: production/applications of ultra-pure isotopes

- The future DarkSide-20k experiment will require ultrapure argon (UAr), extracted from underground wells (depleted in cosmogenically-activated 39Ar: *from 1 Bq/kg to 73 μBq/kg*).
- The argon will be further chemically purified (to minimize impurities which potentially lead to SE), at the rate of 1 tonne per day at ARIA, a <u>350 m</u> tall distillation column, to be installed in a mine shaft in Sardinia.



- Proof of principle demonstration on a 26 m section of the column:

https://arxiv.org/pdf/2301.09639



Top of the column

Nat. abundance

Bottom of the col.

Future: production/applications of ultra-pure isotopes

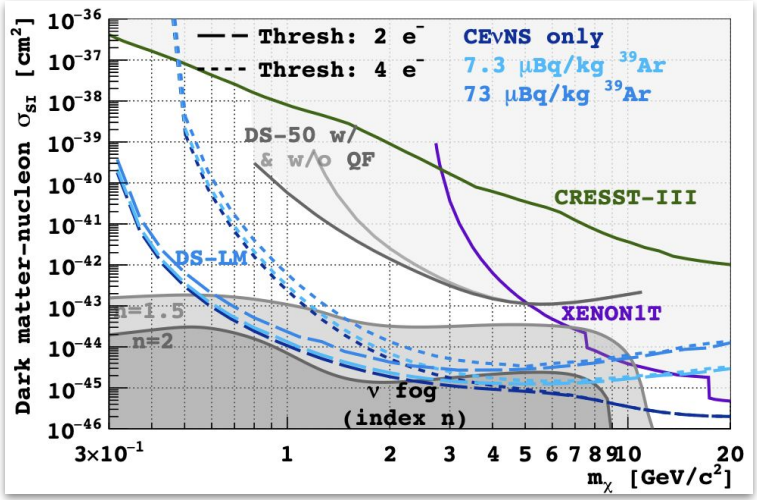
Cryogenic distillation offers the opportunity to **isotopic separation** at an unprecedented scale:

– further separate ^{39}Ar from ^{40}Ar by 10x per pass (7 kg per day) for applications such as DarkSide-LowMass (1 tonne detector optimized for GeV-scale dark matter searches)

– possibly more opportunities for target enrichment for rare-events searches such as dark matter and 0νββ (124Xe, 136Xe, 76Ge, 36Ar…) or medical applications (17O, 18O)

My future work will focus on exploring these opportunities:

- With the existing column, by optimizing the process
- With an optimized column geometry



An example https://arxiv.org/pdf/2209.01177