



Status and short-term prospects of DArT, the underground Ar measurement at Canfranc

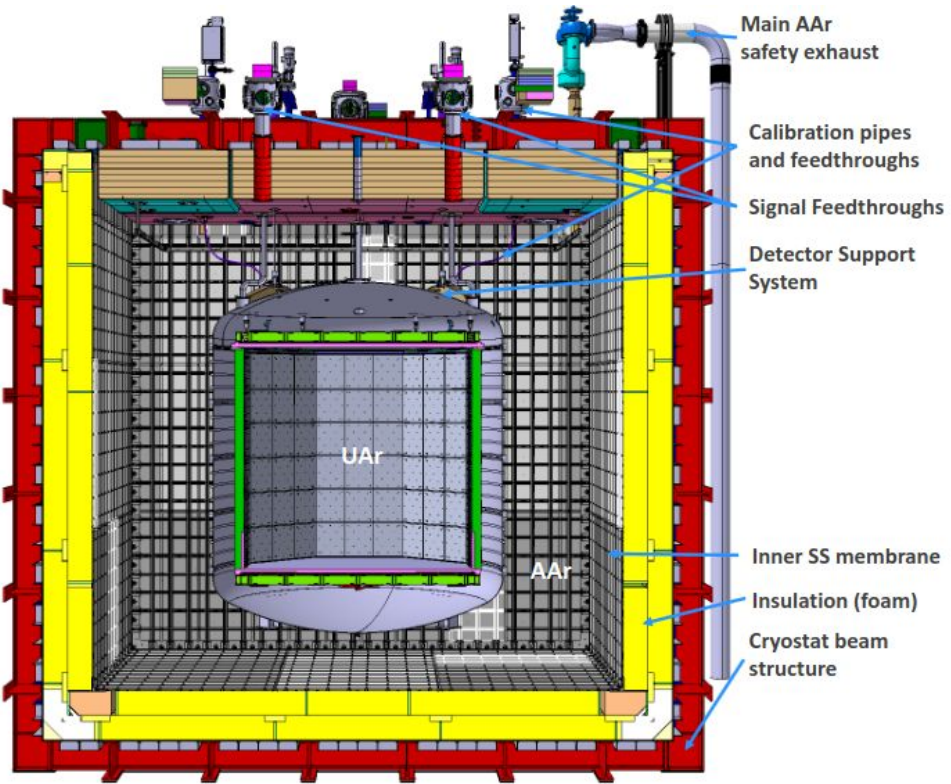
Vicente Pesudo
(CIEMAT / LSC)
for the GADMC

XV International
Workshop on the
Identification of
Dark Matter

L'Aquila,
8th July 2024

Overall context: DarkSide-20k and the GADMC

~ 100 institutions worldwide
~ 500 collaborators



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GADMC talks:

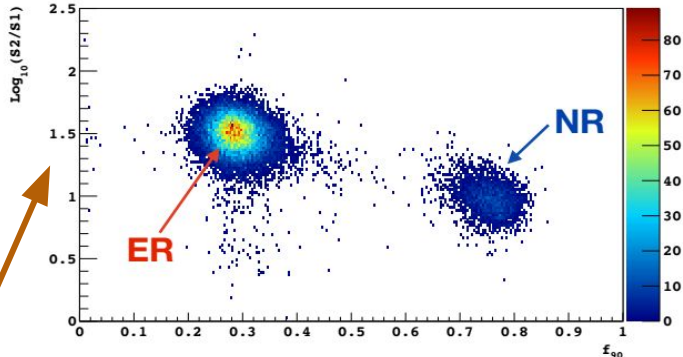
- Status of the DEAP-3600 experiment - P. Adhikari
- The DarkSide-20k experiment - I. Ahmad
- Low radioactivity Ar for DM searches and beyond - R. Stefanizzi
- Prospects for DS-20k sensitivity to light DM particles - M. van Uffelen
- Material assay campaign of the DS-20k experiment - R. Santorelli
- Characterization of low energy argon recoils with ReD and ReD+ - L. Pandola
- Boosted sub-GeV DM from Primordial Black Holes in DS-50 - R. Calabrese

GADMC posters:

- The cryogenics system for the underground Ar in DS-20k - K. Thieme
- Data-driven identification of EL signals from low-E NRs in a LAr TPC using self-supervised machine learning - N. Pino
- Characterization of DS-20k large-area SiPM Tiles - A. Marasciuli
- Photodetectors packaging process flow for the DS-20k experiment - P. Salomone

Ar, what's the point?

Additional discrimination variable: Pulse shape discrimination

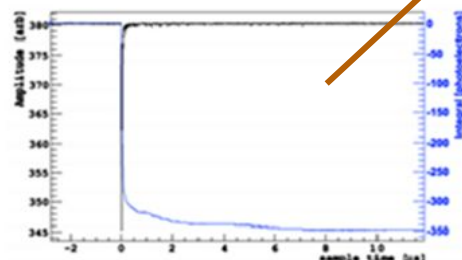
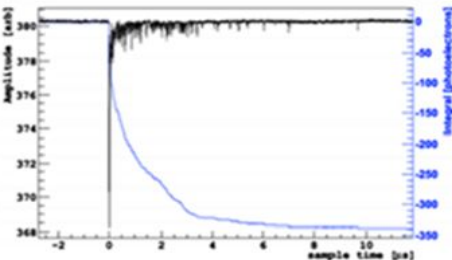
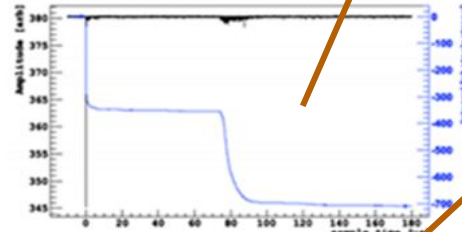
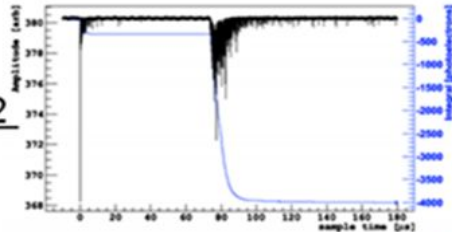


ER-like event

NR-like event

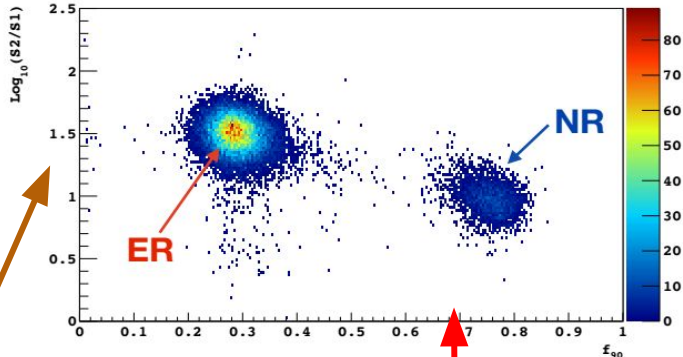
S1/S2

S1
only



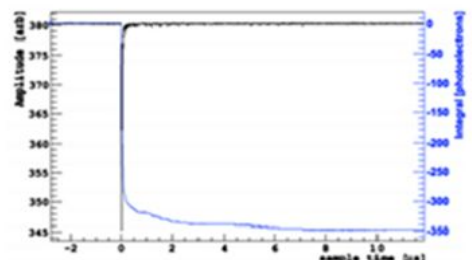
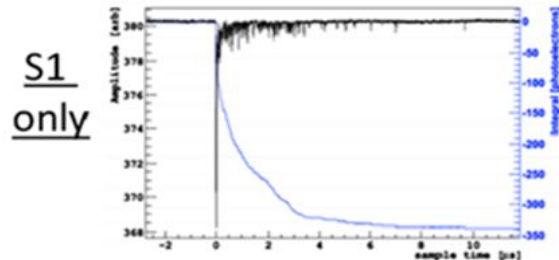
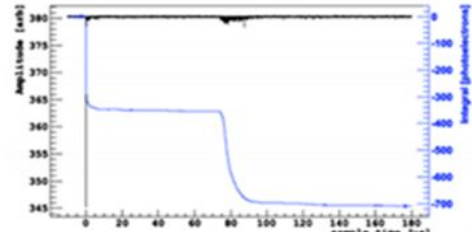
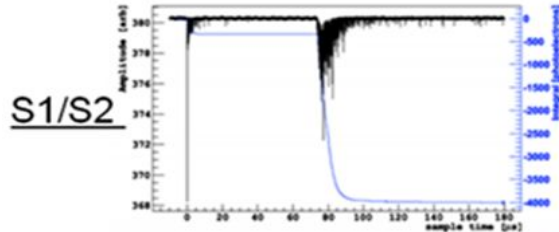
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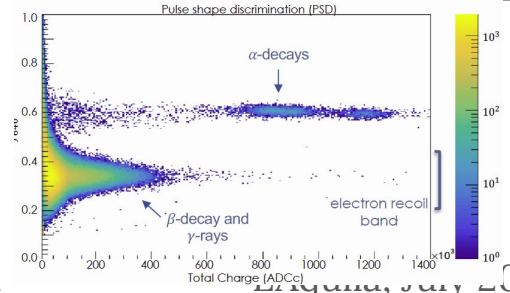


ER-like event

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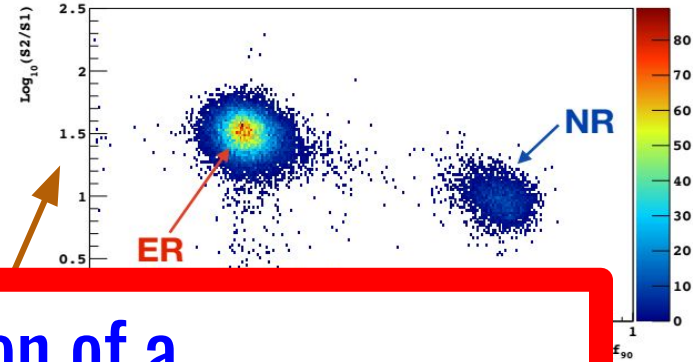


ER contributes as bkg to WIMP searches only at very low E



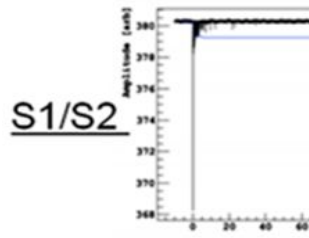
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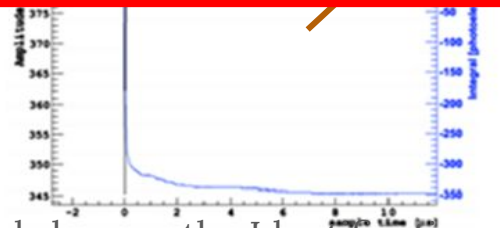
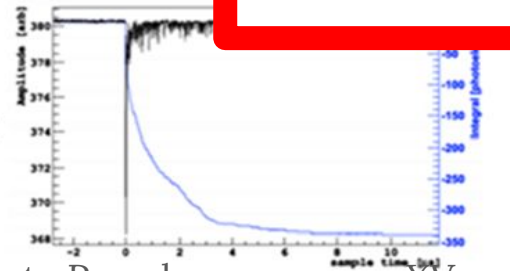


^{39}Ar makes the operation of a several-meter scale TPC too challenging. S1-S2 coincidence at 50 kHz unfeasible.

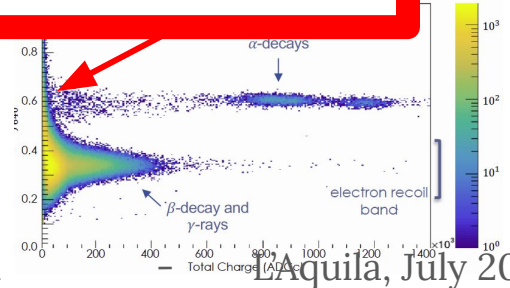
ER-I



S1 only

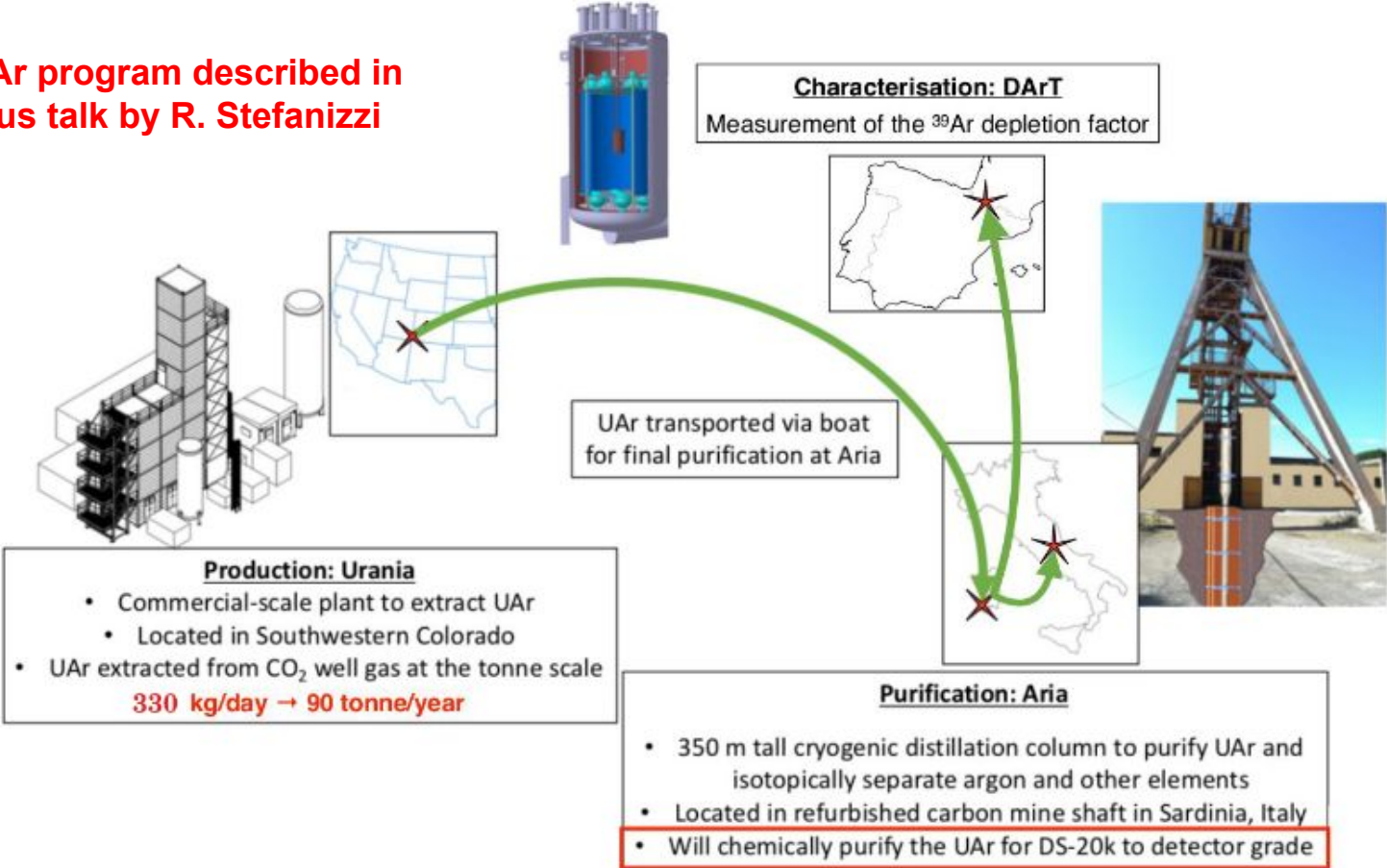


as bkg
nes
/ E

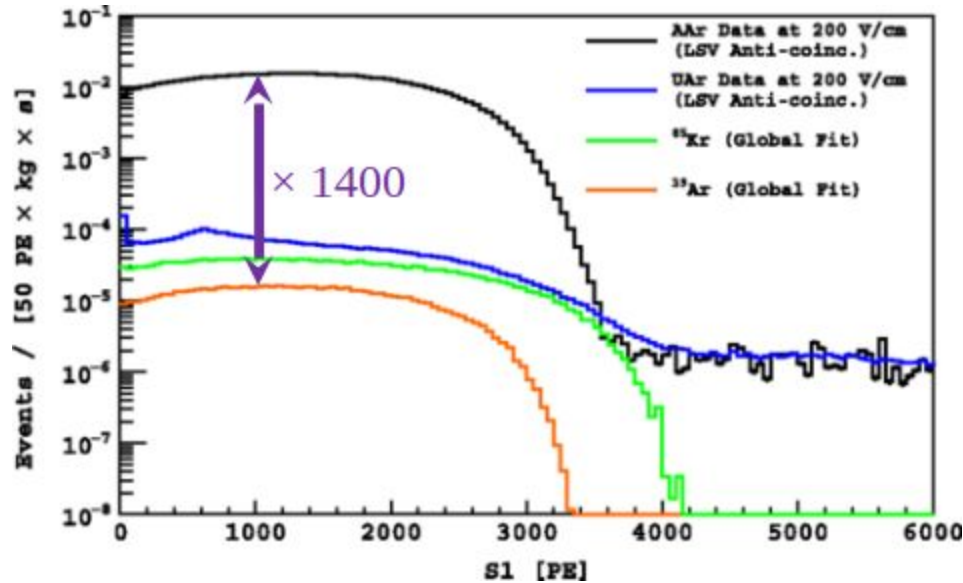


UAr program of DarkSide: Urania, Aria and DArT

The UAr program described in previous talk by R. Stefanizzi



Underground Ar in DarkSide-50



DarkSide-50 showed a depletion factor of 1400 in UAr with respect to atmospheric Ar activity:
 $A(\text{UAr}) = 0.73 \pm 0.11 \text{ mBq/kg}$.

Extraction and purification of UAr is a proven technology.

Presence of ⁸⁵Kr evidences **exposure to air** at some point...
Increasing ³⁹Ar activity.

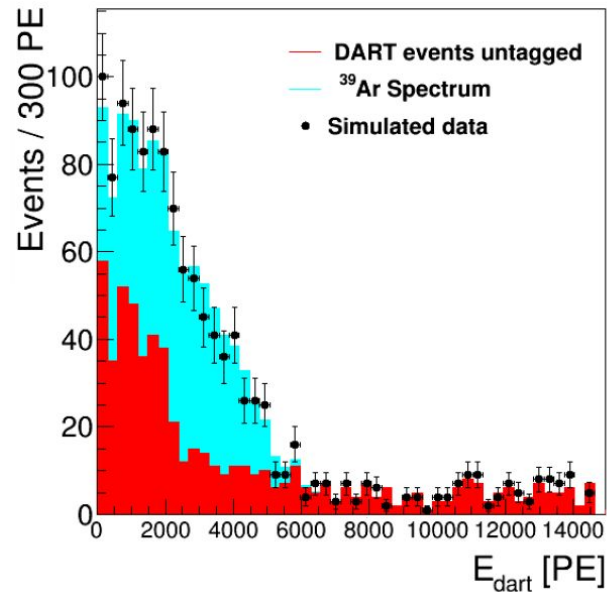
Verification of UAr compliance is needed for each batch.

UAr intrinsic activity should be lower than in DarkSide-50.

DArT-in-ArDM: the concept

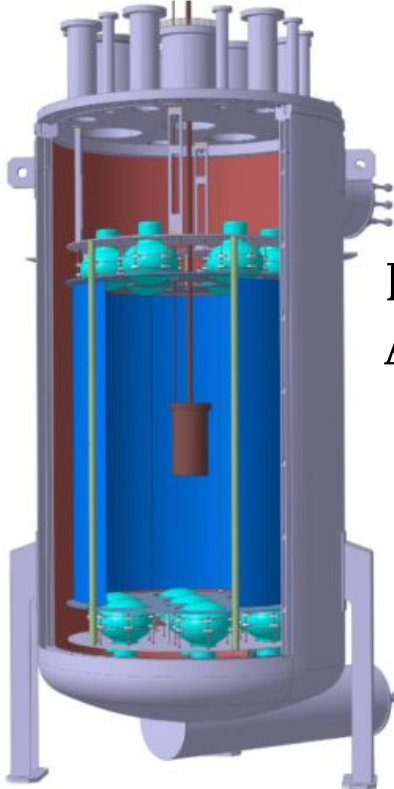
JINST 15 (2020) 02, P02024

Depletion factor with respect to AAr	Statistical uncertainty [%]
10	0.4
100	1.3
1400	6.7 DS-50
14000	41.1



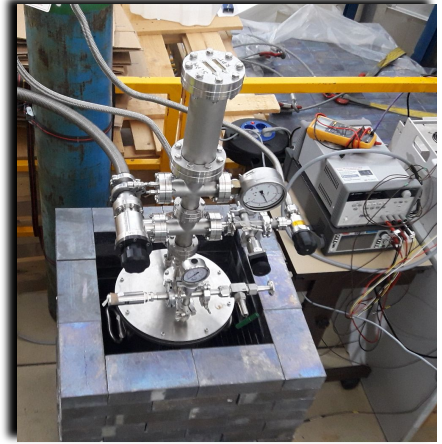
- 1 L chamber full of UAr (DArT) seen by 8 SiPMs.
- ArDM full of atmospheric Ar as veto

Overview

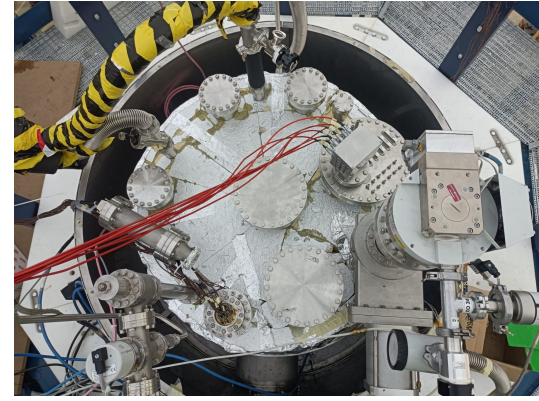


DArT in ArDM

DArT (in test cryostat)



ArDM



Milestones of DArT

Data taking on surface

Data taking @ LSC (atmospheric Ar)

Construction of Pb castle (DArT)

Gas system and slow control

Tests: gas system + integration

Components received for assembly 2.0

Data taking with UAr from DS-50

Characterization of radiopure SiPMs

Installation of 7 tonne Pb ring

Refurbishment of ArDM

PMT test and calibration



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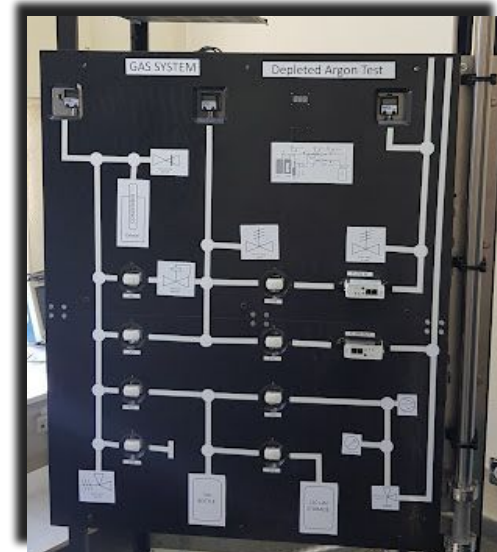
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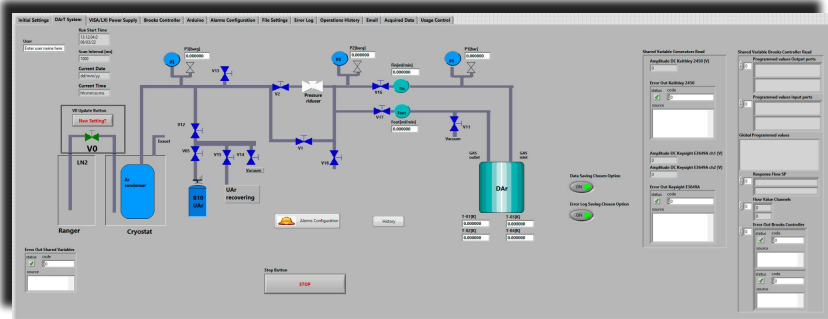
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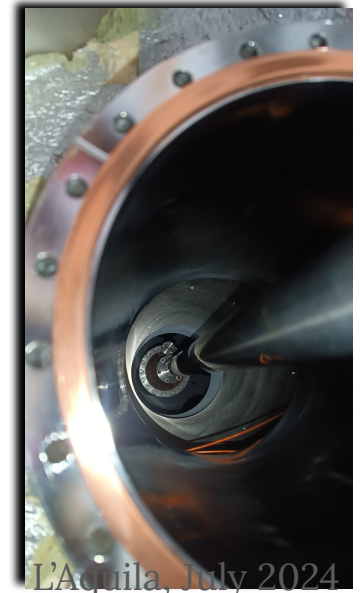
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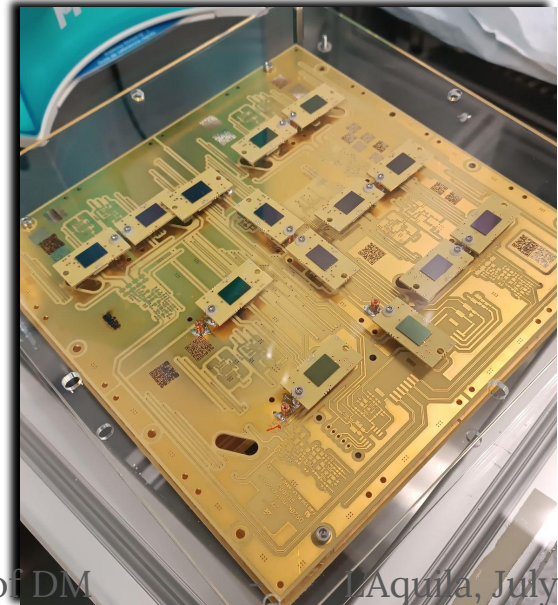
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UAr data!

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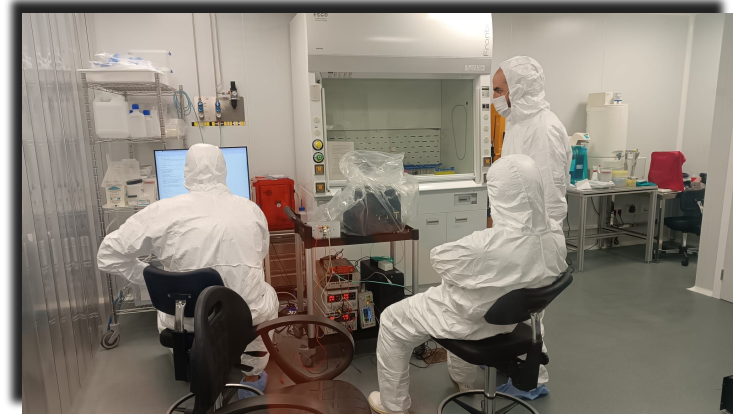
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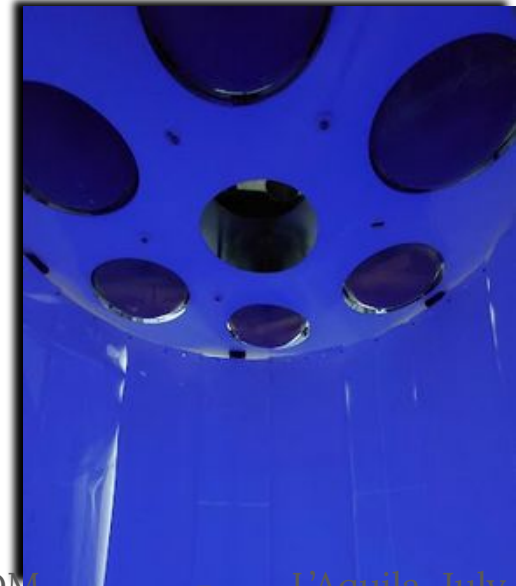
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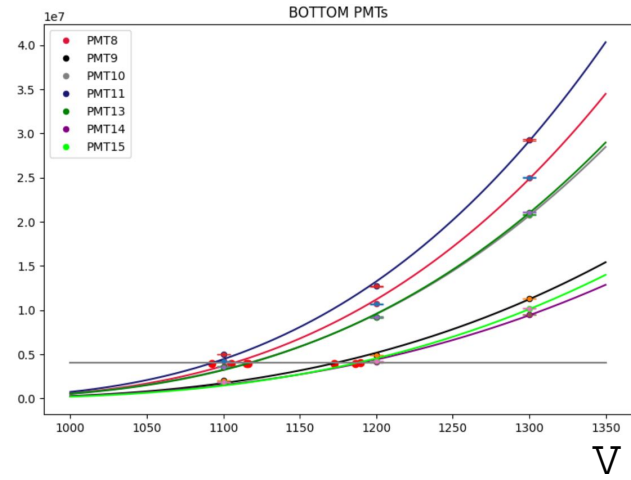
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gain



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Coming soon:

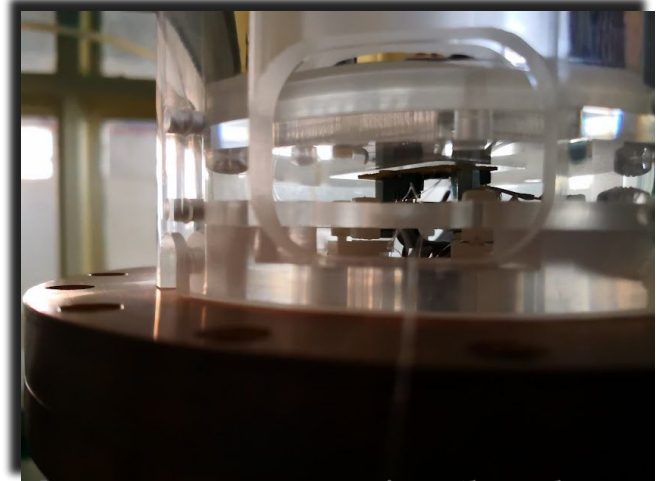
Assembly of DArT 2.0 (Sept)

Installation of 7 tonne Pb ring

Refurbishment of ArDM

PMT test and calibration

Maintenance of cryocoolers (Sept)



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Maintenance of cryocoolers

**No showstopper for
having the detector
cold before the end of
this year.**

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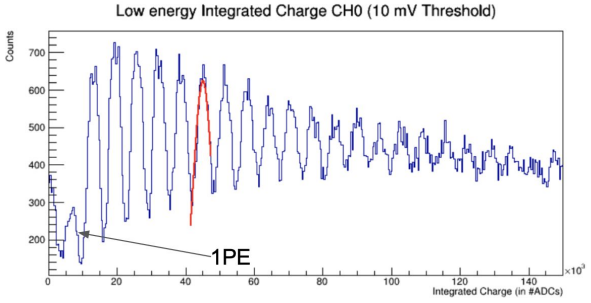
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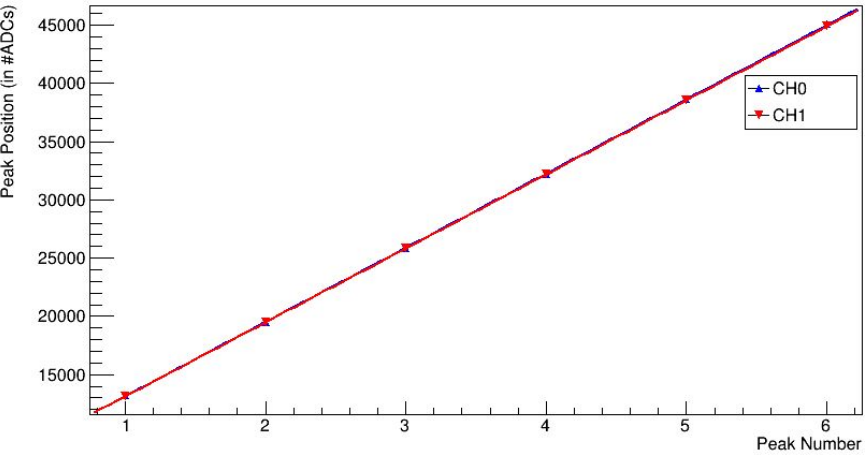
**Commissioning with
UAr batches from
URANIA expected in Q1
2025**

DArT in test cryostat

Data analysis

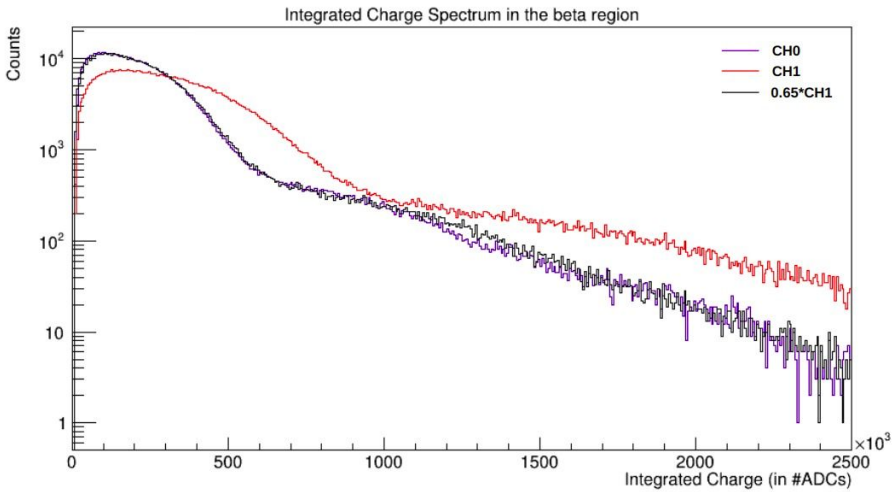


Peak position vs no. of peak

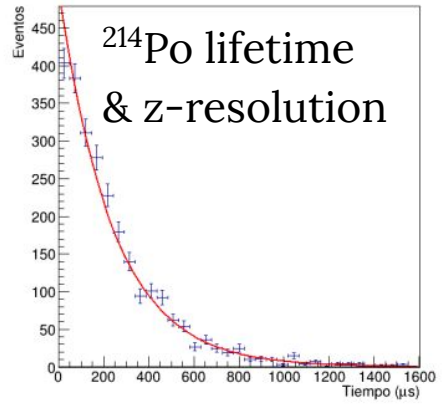
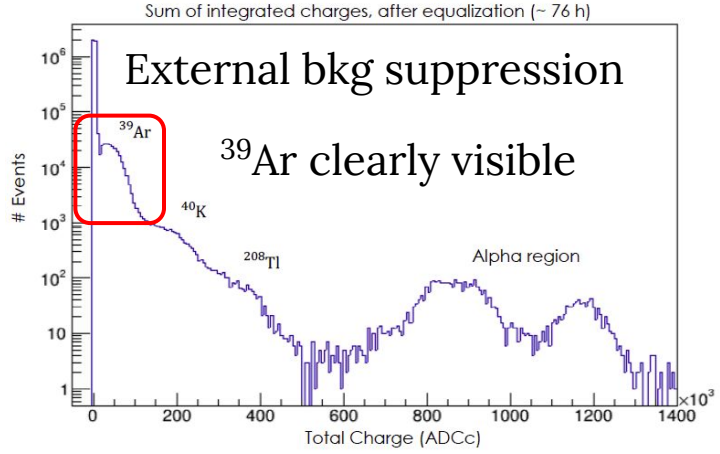
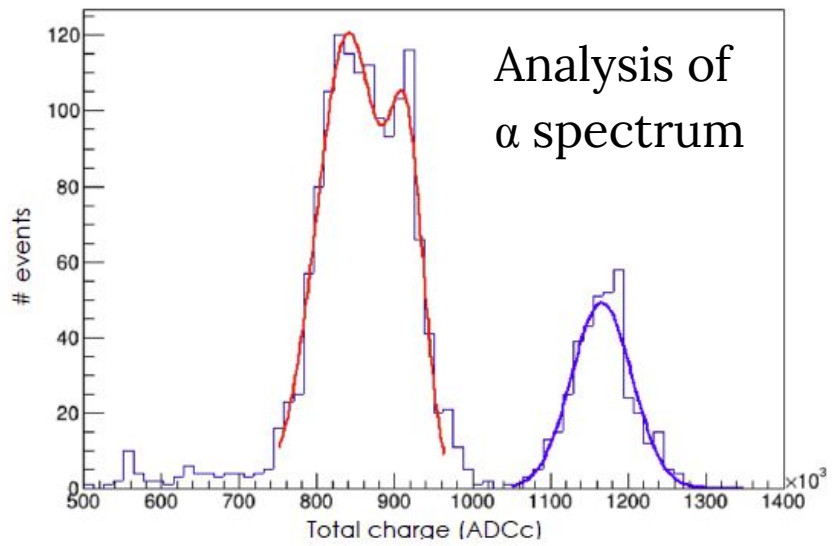
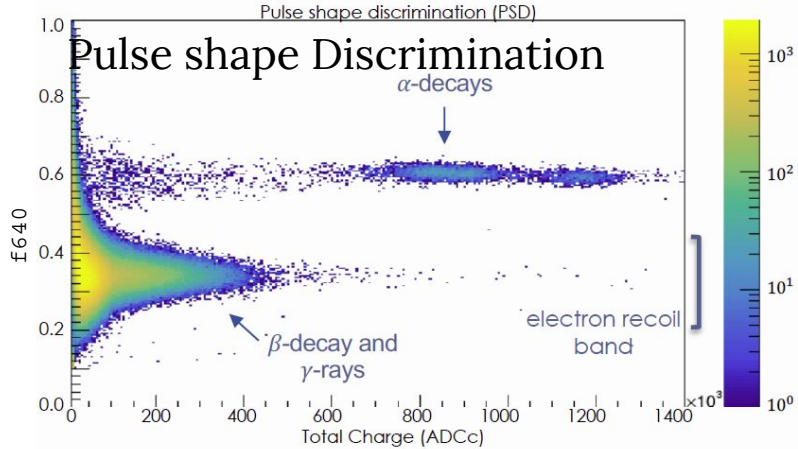


Single Photoelectron (SPE) calibration:

- + Same gain in both SiPMs but light yield different.
- + Lots of progress in optical simulation:
 - + Compatible with 2 mm shift of the top SiPM position.
- + Corrected offline.



Data analysis

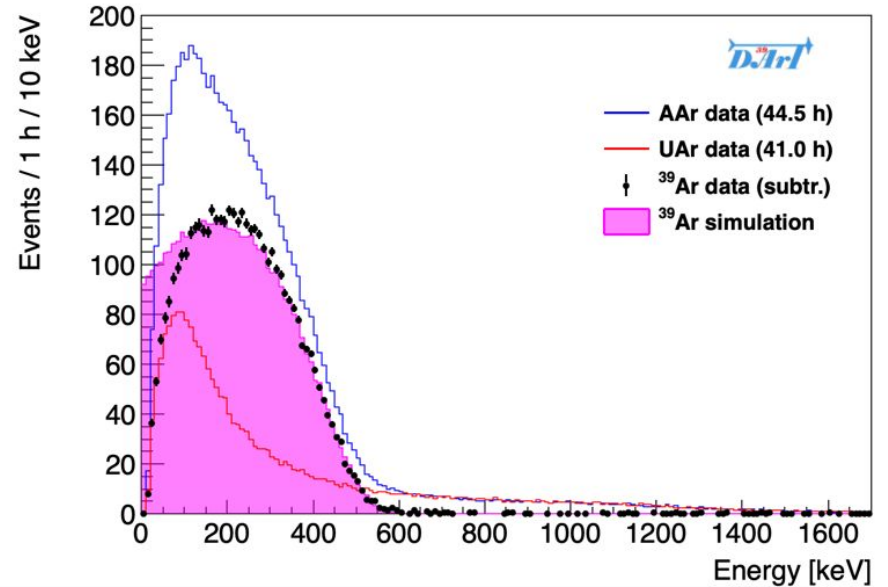
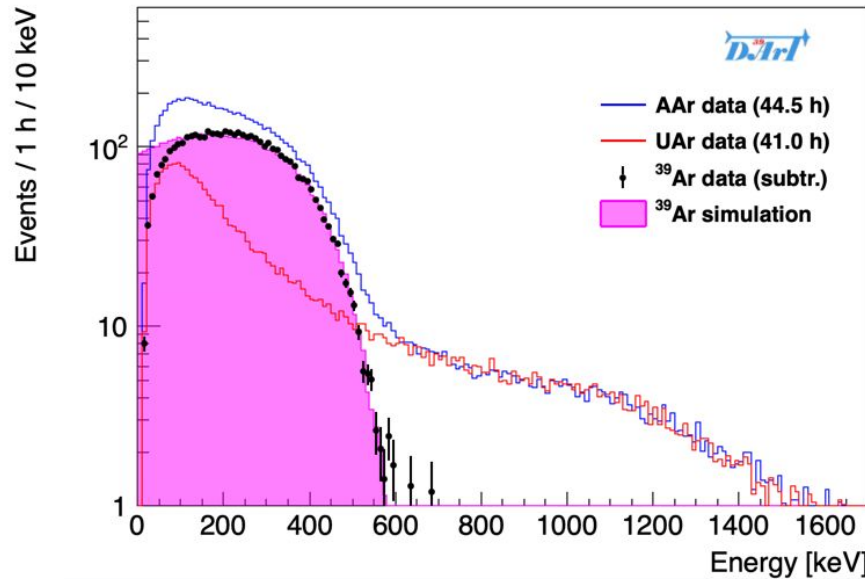


Underground Argon

UAr from DS-50

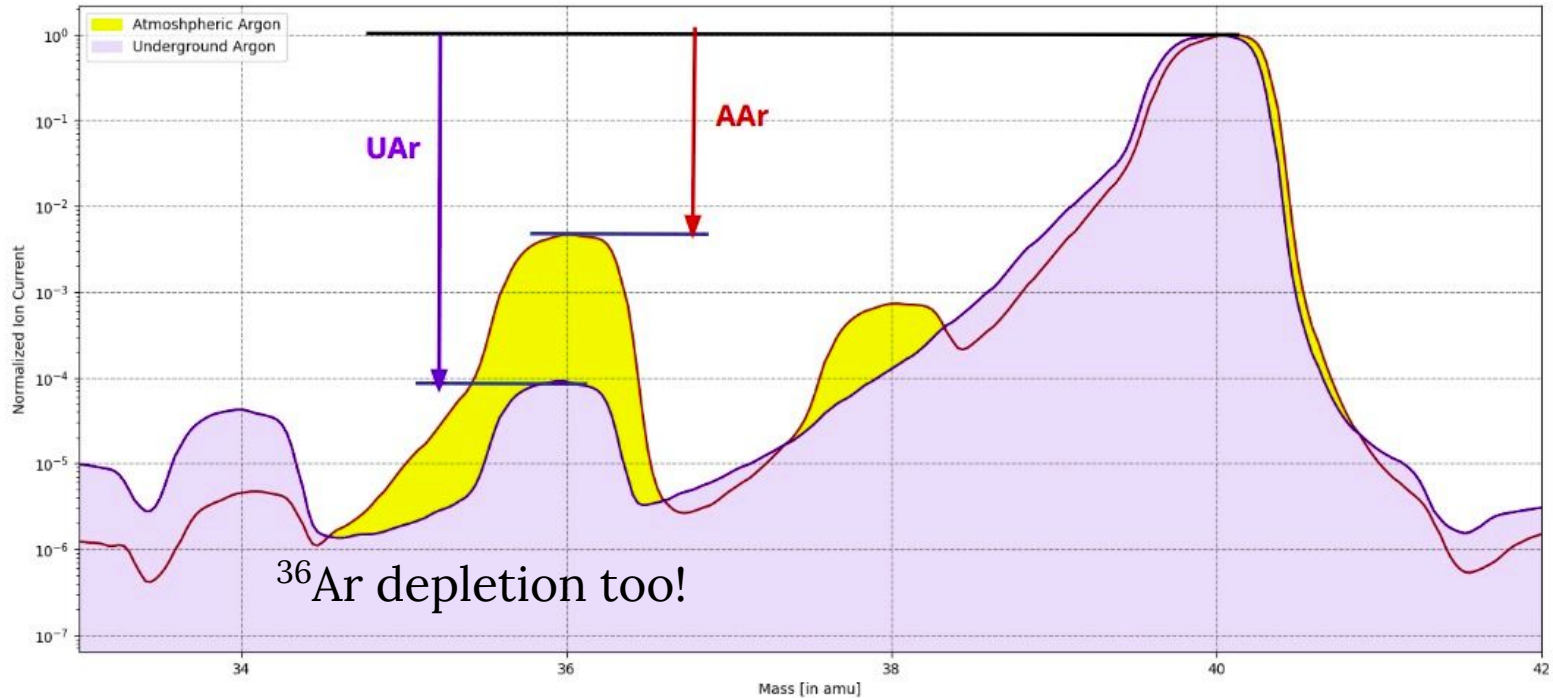
- 3 bottles of **UAr from DS-50 received** and stored underground:
 - 3 x 50 L @ 20 bar ~ 3 m³ of gas or **5.3 kg**. We can get more if needed.
- **Detailed spectroscopy** at CIEMAT.
- First: tested and gained experience with the UAr **recovery system** using atmospheric Ar.
- **Measurement in DArT (test cryostat)** with UAr:
 - + background subtraction for ³⁹Ar measurement in atm. Ar.
 - + AAr run followed by UAr run. **Successful recovery of UAr in a B50 bottle.**

Data analysis: AAr vs UAr



- + UAr data is essentially a bkg measurement of the instrument.
- + Beautiful shape of the ^{39}Ar after subtraction. Working on competitive quantification of ^{39}Ar activity in atmospheric Ar.
- + Characterizing threshold effects and systematics.

UAr spectroscopy measurement

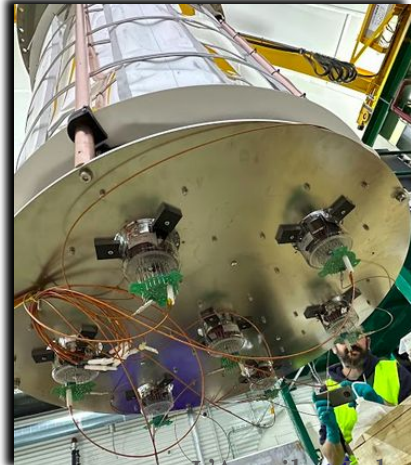
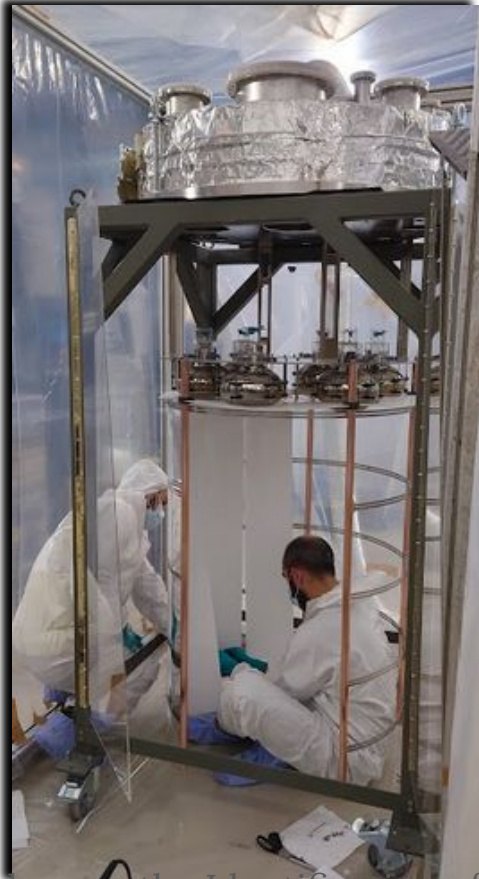
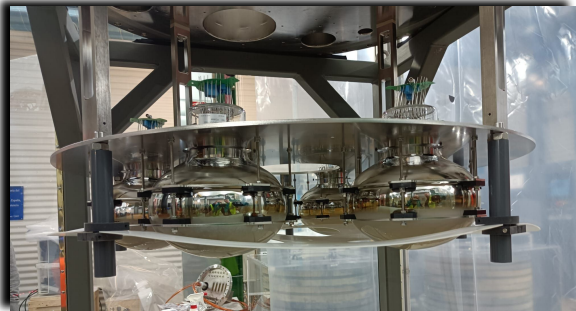


Study of isotopic abundances as evidence of cosmogenic exposure?
Promising. Better resolution needed to disentangle mass 38.

ArDM

Refurbishment and integration

ArDM fully refurbished spring 2023

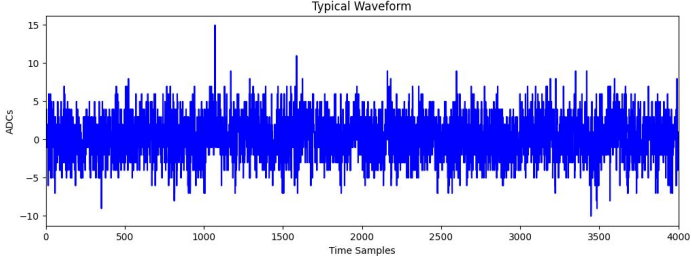
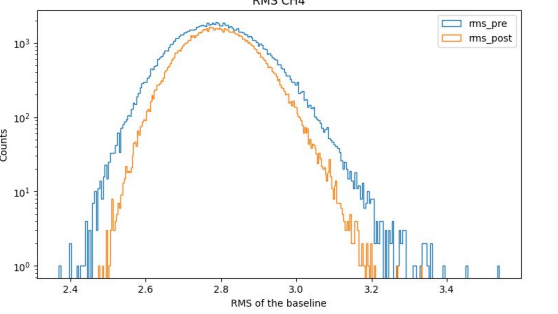
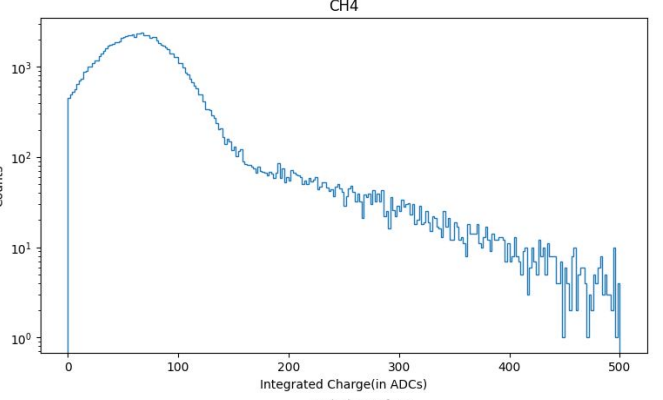
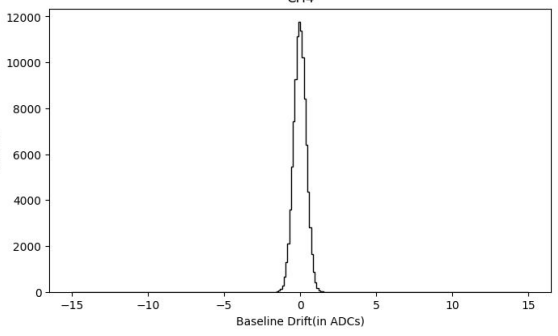
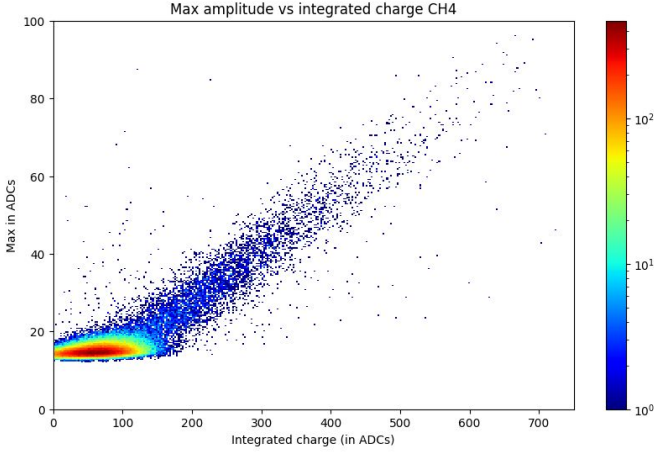
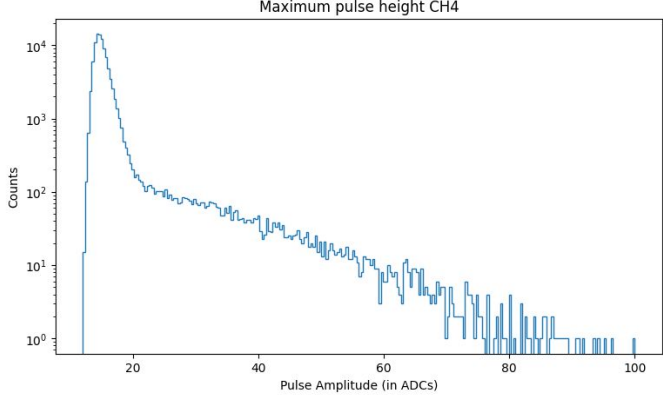
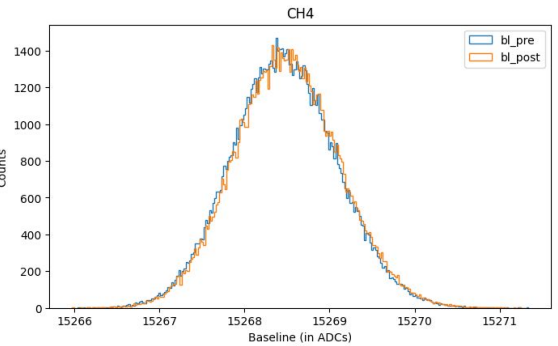


Vicente Pesudo

XV workshop on the Identification of DM

L'Aquila, July 2024

Plots for Ch4 @950 V:



All PMTs operative and calibrated.

Grounding problem fixed January 2024.

Only cryocooler maintenance missing

Integration test

November 2023



Schedule

Item	Description	Responsible	2024							2025
			JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Cryocooler refurbishing and repair			Red							
DARTEYE2	tests in the lab	LSC/CIEMAT	Orange							
DART2	leak tests at cold and warm of the vessel	LSC/CIEMAT	Orange							
DARTinArDM DAQ upgrade	digitizer software integration	Zaragoza		Orange						
DART2	Installation of radio-pure acrylic@ LSC	CIEMAT	Orange	Orange						
DART2	installation and tests of the DARTEYE2	INFN/CIEMAT/LSC	Orange	Orange						
DART2	assembly and tests of DART2 in test cryostat	LSC/CIEMAT/INFN			Orange	Orange				
DART 2/ArDMintegration	integration DArT2/ArDM	CIEMAT/ETHZ				Orange				
Operations @LSC	ArDM+DArT safety approval	ALL				Pink				
	ArDM filling and commissioning	ALL				Purple				
	DART filling and commissioning	ALL				Purple				
UAr arrival	Batches from LUAS/Urania to LSC									Green

With UAr of DS-50



DArT beyond DarkSide

White paper (+EOI) from

- ❑ COHERENT
- ❑ DUNE
- ❑ GADMC (DS-LowMass, ARGO)
- ❑ LEGEND

→ **UAr fundamental for several low-background experiments beyond DM**

The infrastructure built for DarkSide-20k could meet the UAr demand for most of the foreseen future experimental needs

→ **DArT recognized as the facility to validate the UAr for these experiments**

Snowmass2021 White Paper

A Facility for Low-Radioactivity Underground Argon

Henning O. Back^{1,*,†,‡}, Walter Bonivento^{2,§}, Mark Boulay^{3,*,**}, Eric Church^{4,††}, Steven R. Elliott^{4,**,†}, Federico Gabriele^{5,§}, Cristiano Galbiati^{6,7,§§}, Graham K. Giovanetti^{8,§§}, Christopher Jackson^{11,††}, Art McDonald^{9,§§,**}, Andrew Renshaw^{10,§}, Roberto Santorelli^{11,††}, Kate Scholberg^{12,††,***}, Marino Simeone^{13,†}, Rex Tayloe^{14,†††}, Richard Van de Water^{4,***}

- ¹ Pacific Northwest National Laboratory, Richland, Washington 99352, USA
- ² INFN Cagliari, Cagliari 09042, Italy
- ³ Carleton University, Ottawa, Ontario K1S 5B6, Canada
- ⁴ Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA
- ⁵ INFN Laboratori Nazionali del Gran Sasso, Assergi (AQ) 67100, Italy
- ⁶ Princeton University, Princeton, NJ 08544, USA
- ⁷ Gran Sasso Science Institute, L'Aquila 67100, Italy
- ⁸ Williams College, Williamstown, MA 01267 USA
- ⁹ Queen's University, Kingston, ON K7L 3N6, Canada
- ¹⁰ University of Houston, Houston, Texas 77204, USA
- ¹¹ CIEMAT, Madrid 28040, Spain
- ¹² Duke University, Durham, North Carolina 27708, USA
- ¹³ Università degli Studi di Napoli "Federico II", Napoli 80125, Italy
- ¹⁴ Indiana University, Bloomington, Indiana 47405, USA

Abstract/Executive summary

The DarkSide-50 experiment demonstrated the ability to extract and purify argon from deep underground sources and showed that the concentration of ³⁹Ar in that argon was greatly reduced from the level found in argon derived from the atmosphere. That discovery broadened the physics reach of

Formal request by the LEGEND coll. for 25 tonnes of UAr

("...extraction, purification, and testing of the 25 tonnes of UAr required for the LEGEND-1000 experiment")

Conclusions

- DArT is the **facility for UAr characterization.**
- DArT in ArDM will **start operations before the end of the year.**
- We will receive **samples from each batch from Urania and ARIA** to measure ^{39}Ar and identify potential problems before insertion in DS-20k.
- We are working towards a competitive measurement of ^{39}Ar activity in atmospheric Ar.
- We are studying other characterization techniques and sensitivity beyond ^{39}Ar

Thanks
for your
attention
!



BACKUP

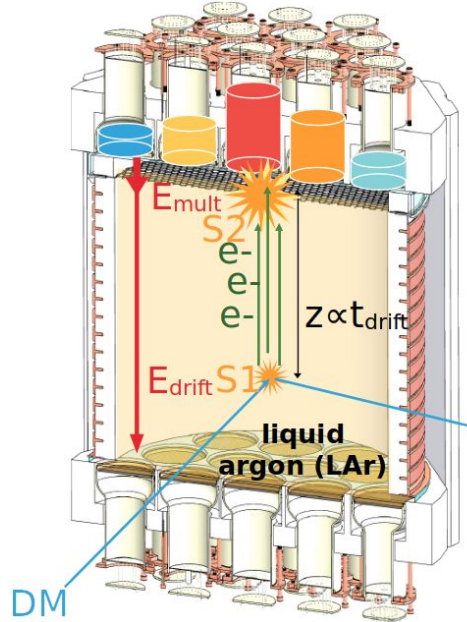
Dual-phase TPCs

Massive targets

Scintillation detected promptly (S1)

Uniform E field to measure ionization: prevents recombination + drifts e^- to anode

**At low Energies, S1 and S2 almost featureless:
Unambiguous identification of S1-S2 necessary**



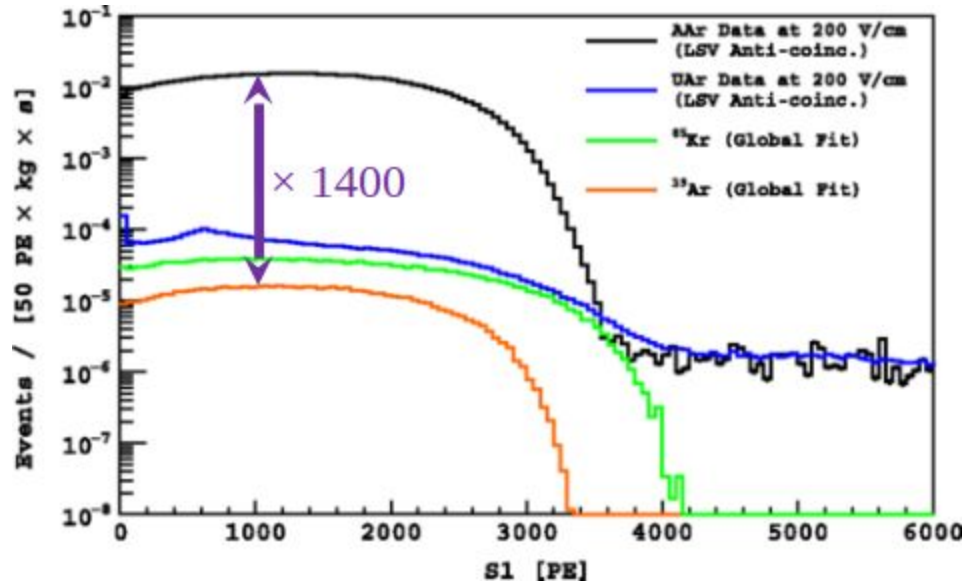
e^- extracted to gas phase in stronger field to induce electroluminescence (S2)

light pattern in detection plane provides XY information

Time difference between S1 and S2 provides Z info
(mm resolution)

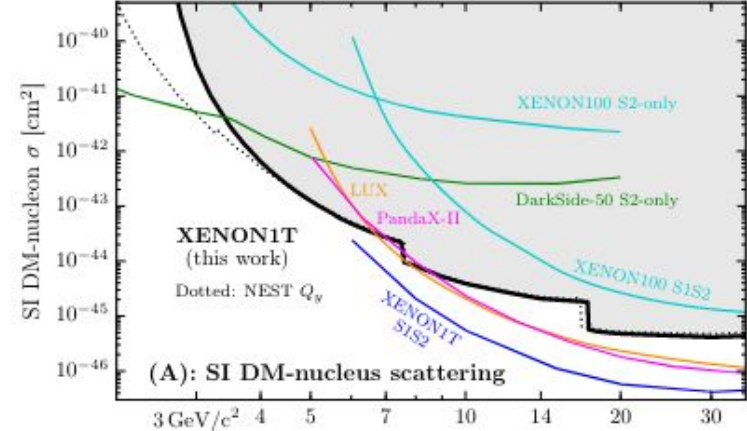
S2/S1 provides particle discrimination

Underground Ar in DarkSide-50



DarkSide-50 showed a depletion factor of 1400 in UAr with respect to atmospheric Ar activity:
 $A(\text{UAr}) = 0.73 \pm 0.11 \text{ mBq/kg}$.

Phys. Rev. Lett. 123, 251801
arXiv:1907.11485



Still world-leading for some region of the **low mass WIMPs** parameter space with S2-only analysis.

Solid alternative to bolometers in view of the recurrent excess found so far

DarkSide-20k

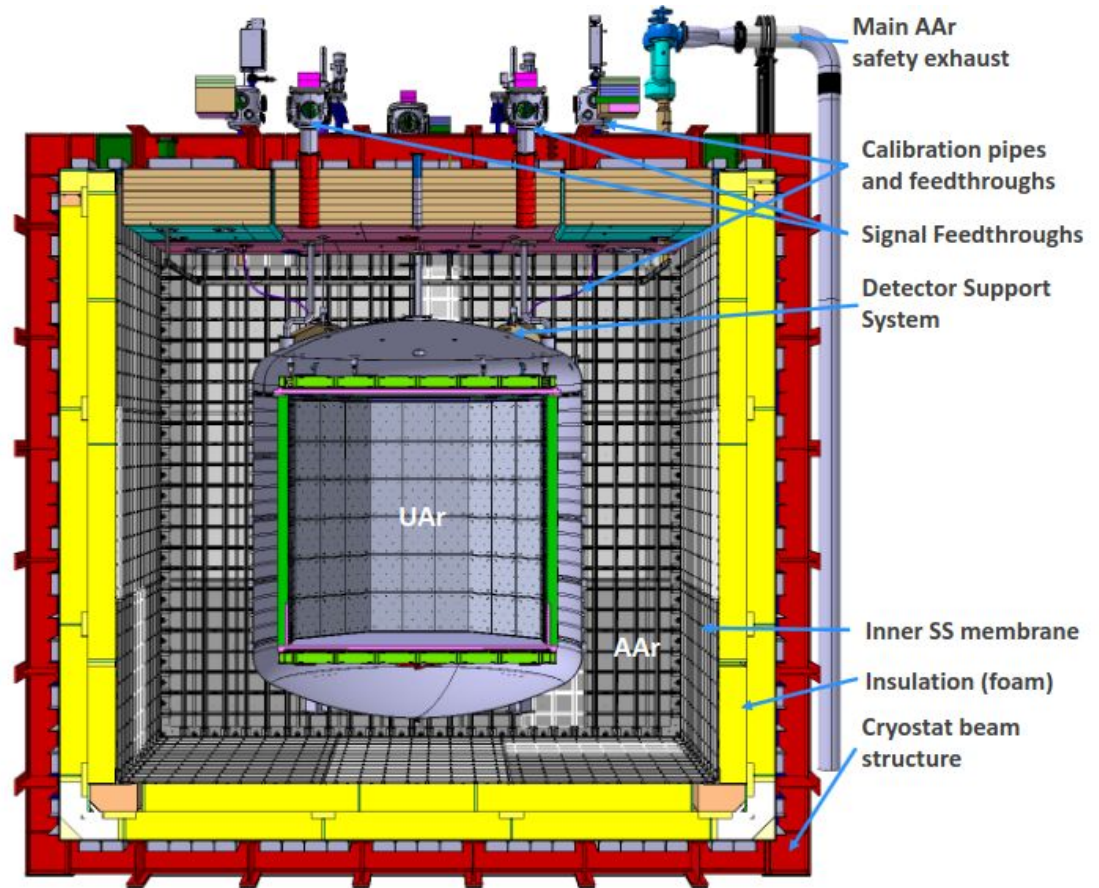
90 tonnes of UAr

50 TPC (20 fiducial) + 40 Veto

650 tonnes of AAr as buffer and muon veto

ProtoDune-like cryostat

21 m² of cryogenic & high QE & radiopure SiPM + electronics



First detector of the Global Argon Dark Matter Collaboration