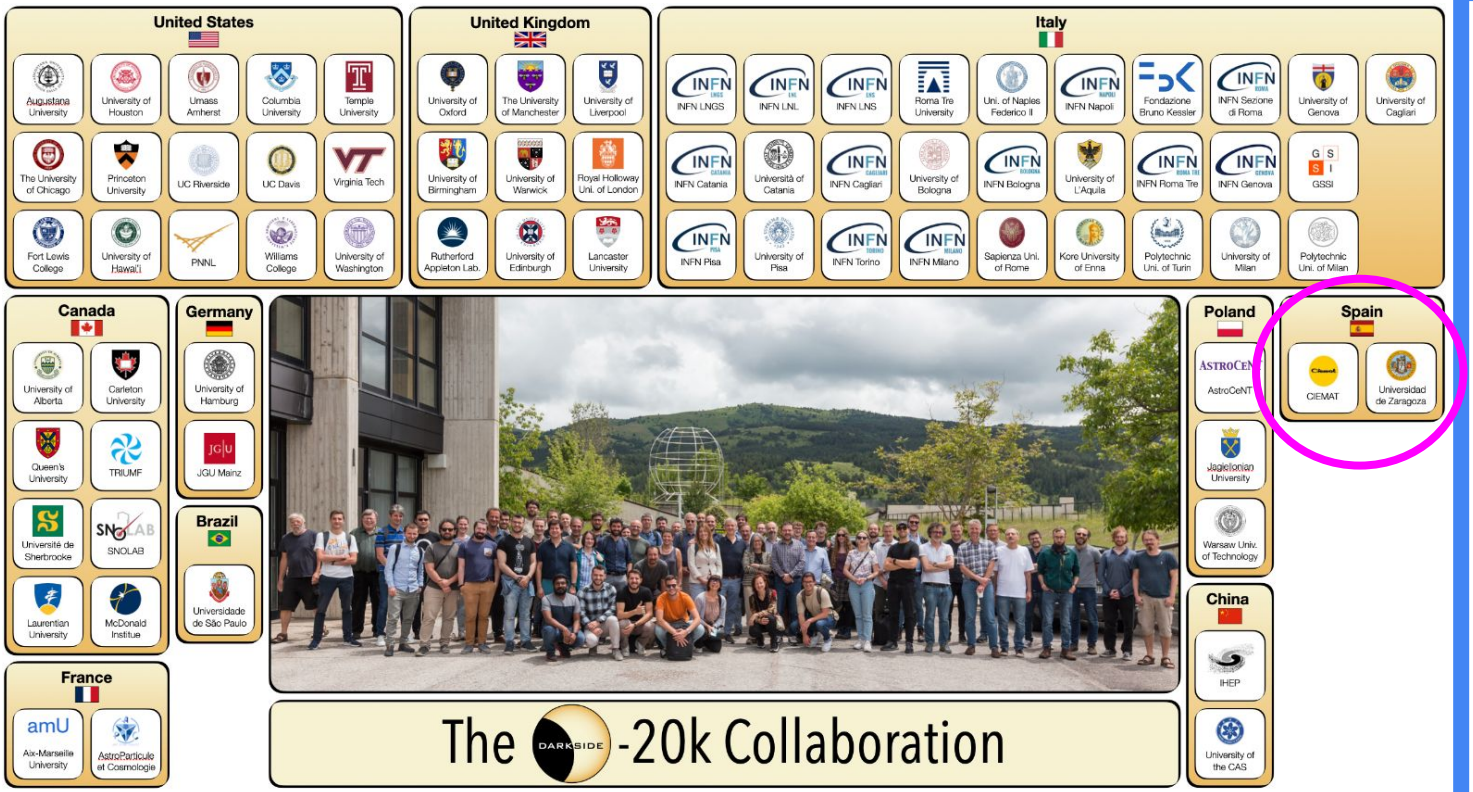
Status of DarkSide-20k and the underground Ar program

Vicente Pesudo
(CIEMAT / LSC)
for the GADMC

XVII CPAN Days

Valencia,
17th November 2025

DarkSide-20k and the GADMC: who?



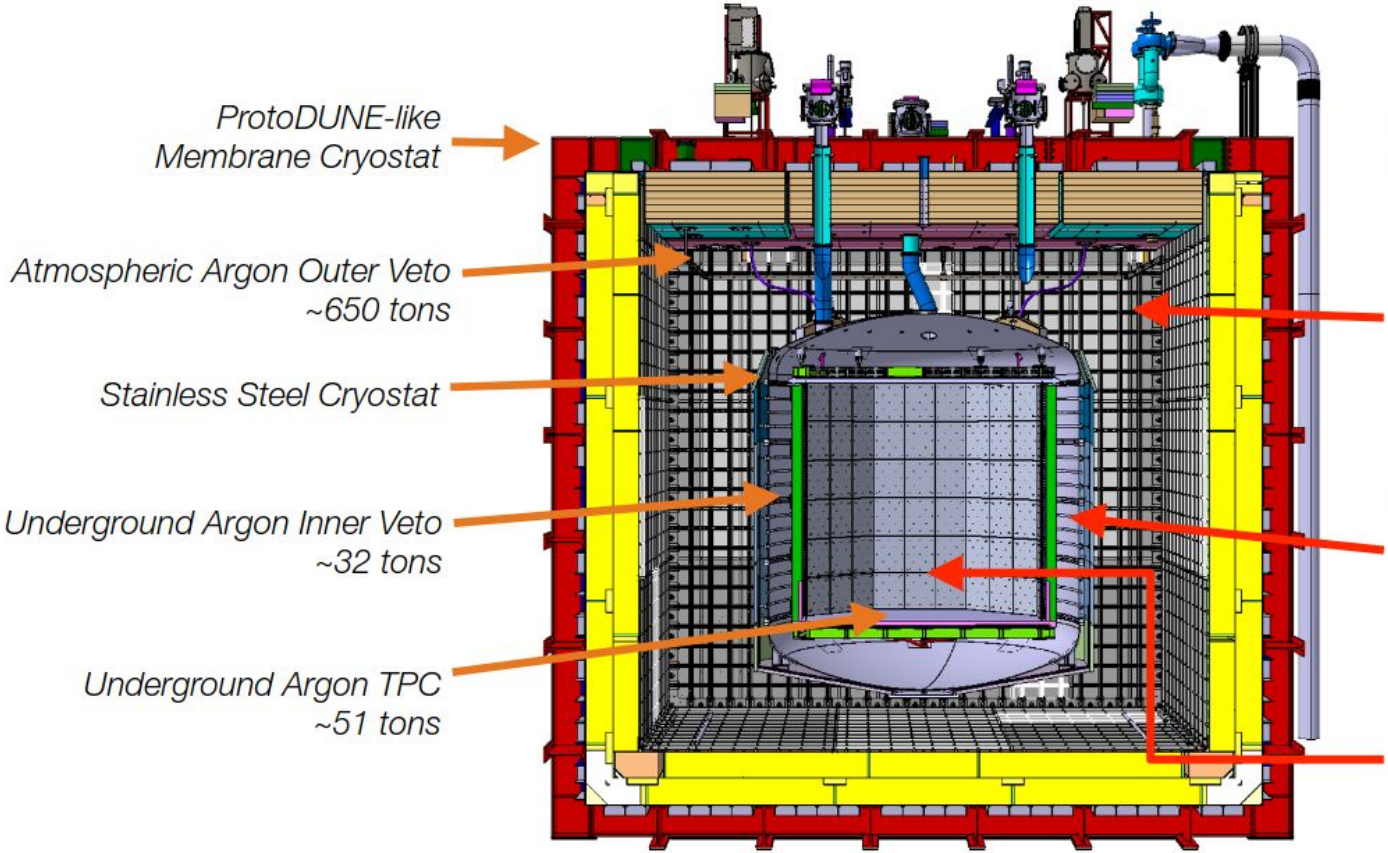
400 scientists

14 countries

Mostly INFN & NSF funded

Spanish contributions account for 2% of the ~100 M€ budget so far

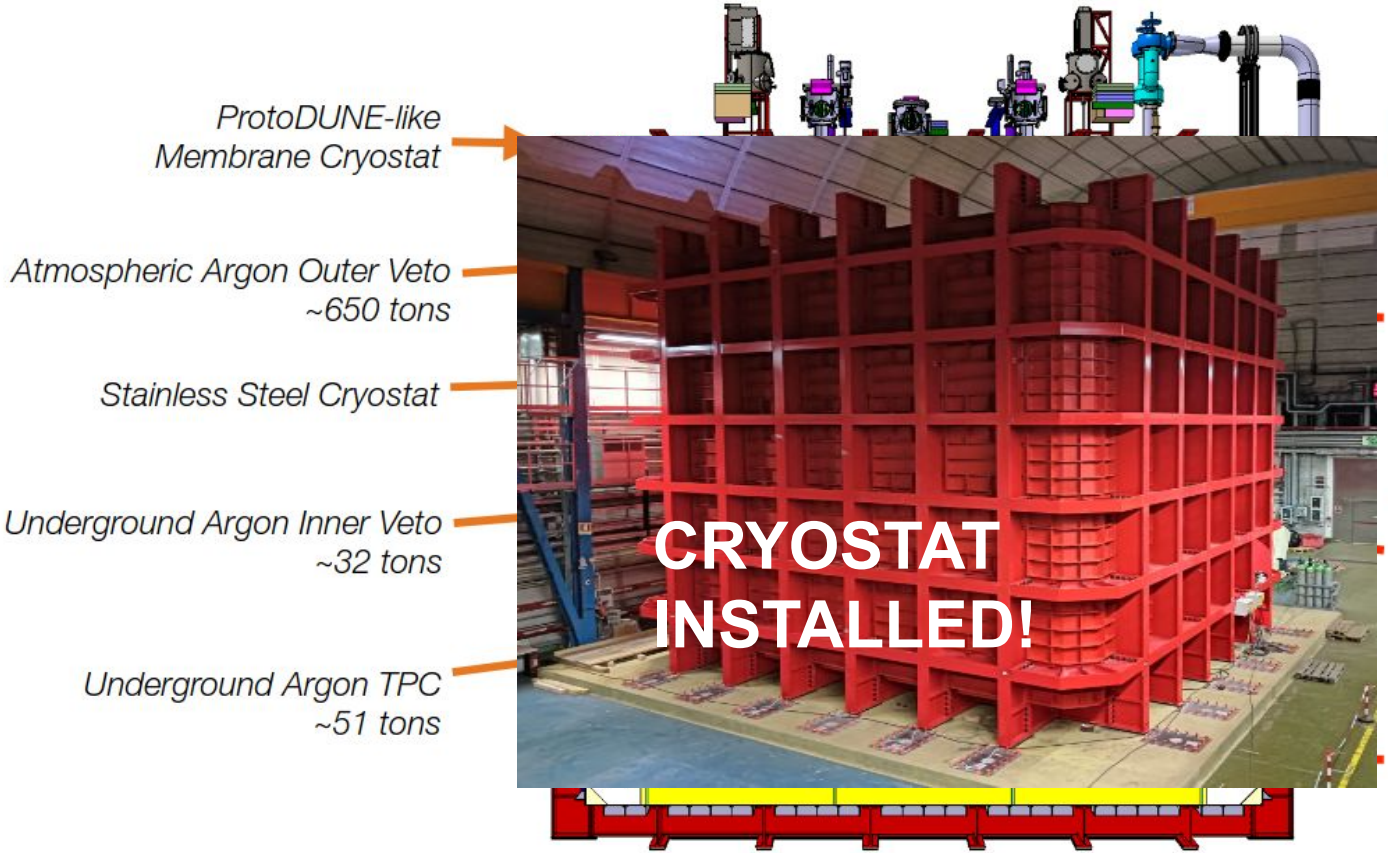
DarkSide-20k and the GADMC: what?



DarkSide-20k consists of three nested detectors:

- The **Outer Veto (OV)**, which is filled with AAr and designed to catch cosmogenic neutrons by detecting the primary muon
- The **Inner Veto (IV)**, which uses UAr to tag radiogenic neutrons by detecting gammas from their capture
- The **Dual-Phase UAr TPC**

DarkSide-20k and the GADMC: what?



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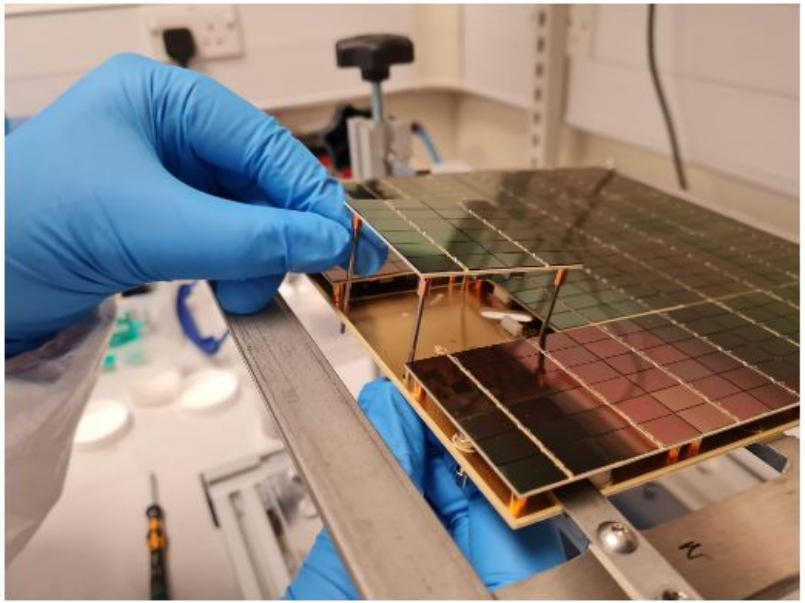
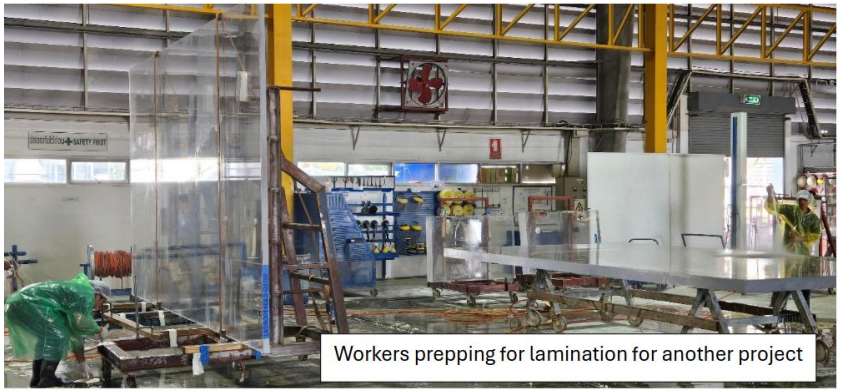
DarkSide-20k and the GADMC: what?

21 m^2 of radiopure cryogenic SiPMs being produced and tested within the collaboration

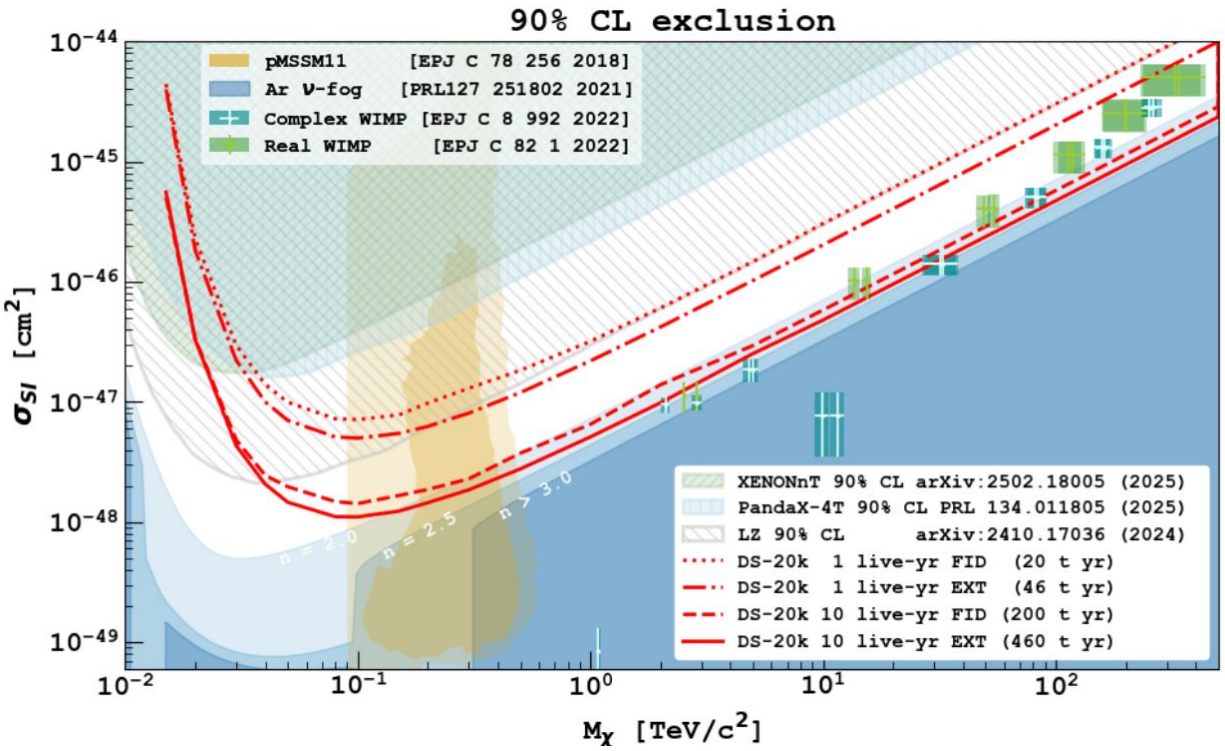


Acrylic panels casted and being machined



Workers prepping for lamination for another project

DarkSide-20k and the GADMC: why?



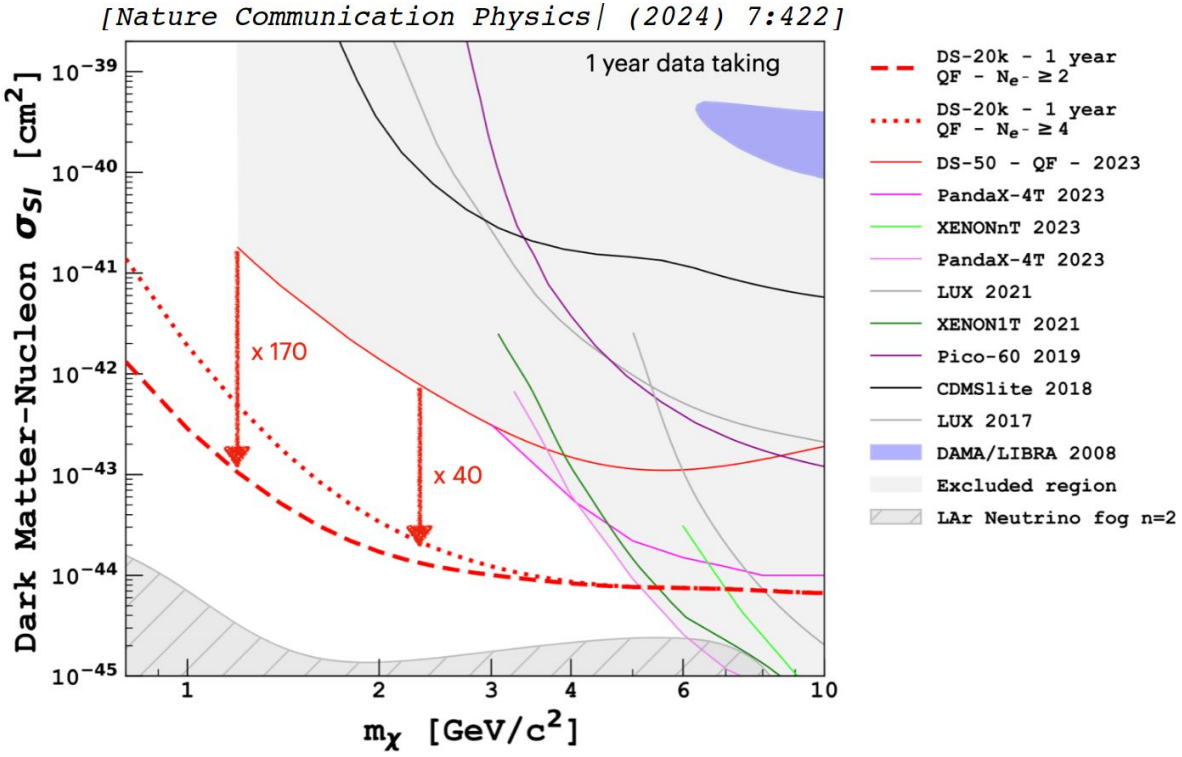
Prospects to lead the search for WIMPs in most of the "canonical" parameter space.

Prospects to lead the search for light (~ GeV) WIMPs

Best sensitivity to neutrinoless double electron capture in ^{36}Ar

Sensitivity to SN and ^{8}B solar neutrinos

DarkSide-20k and the GADMC: why?



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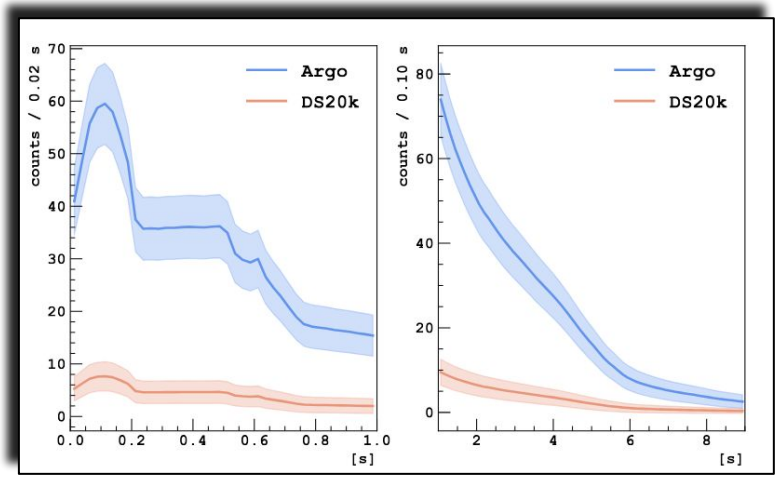

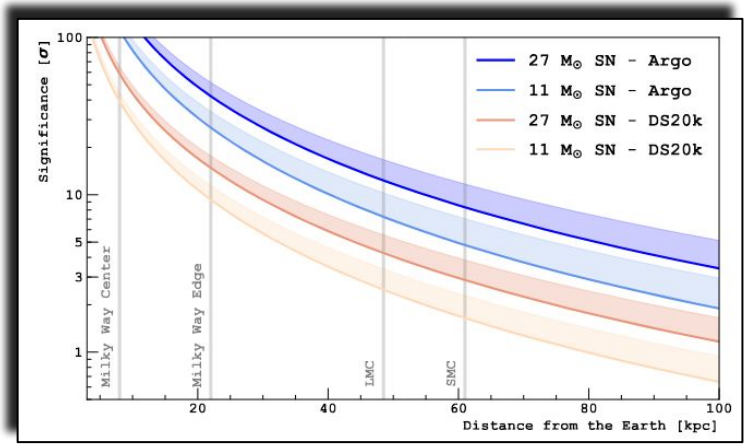

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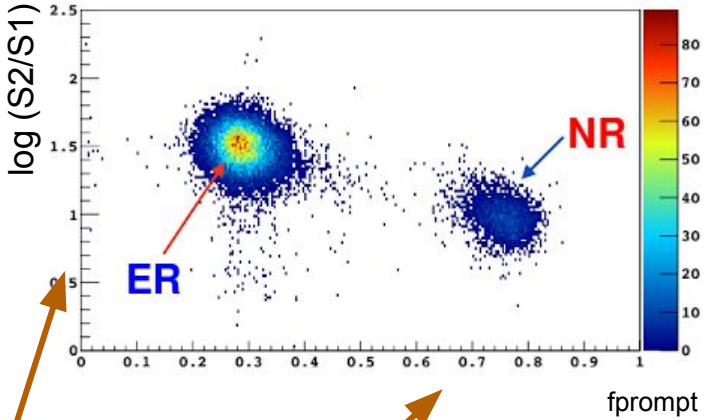
Ar, what's the point?

Additional discrimination variable.
Pulse shape of scintillation: singlet vs triplet components

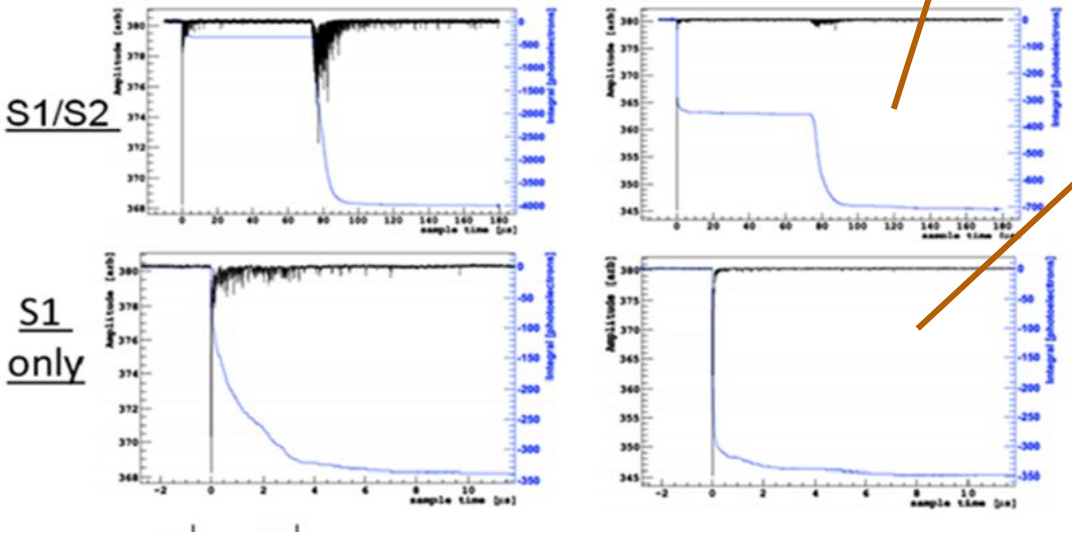


ER-like event

NR-like event

S1/S2

S1 only



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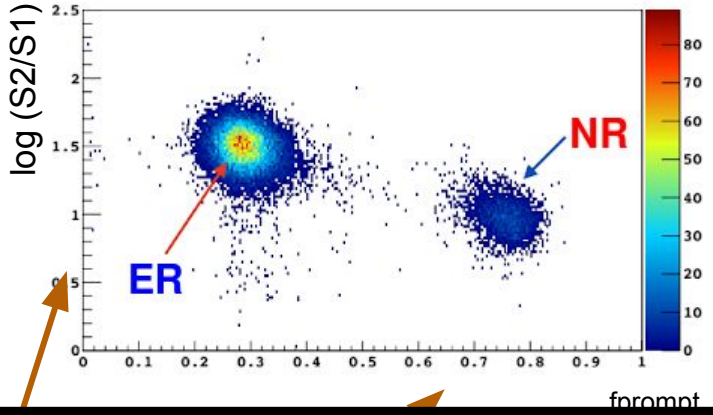
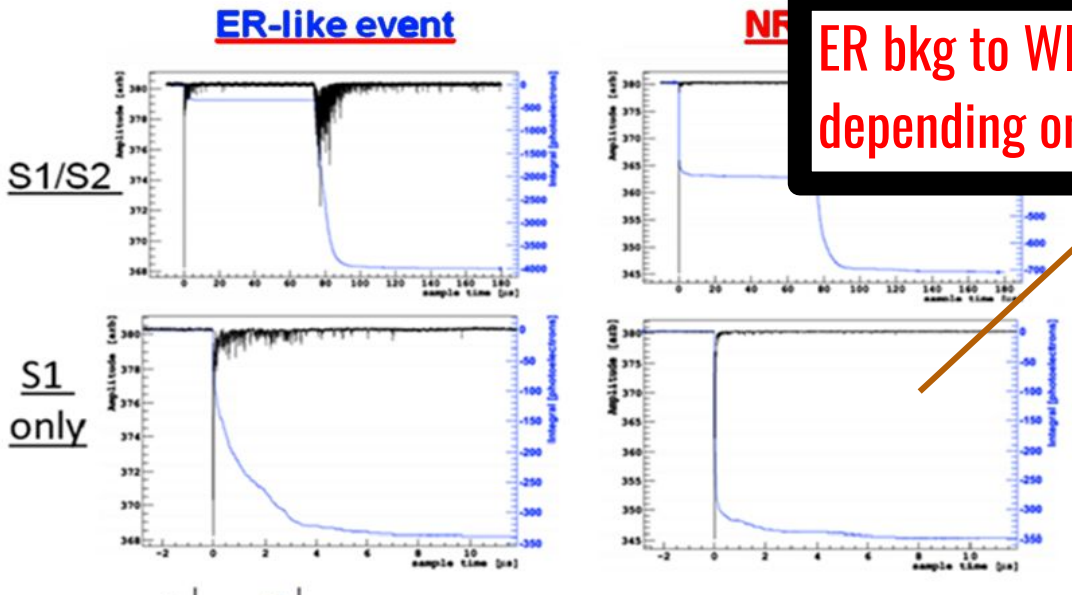
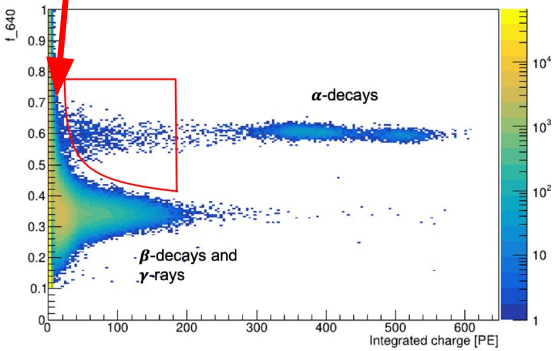


ER bkg to WIMP search only at very low E and depending on ROI definition



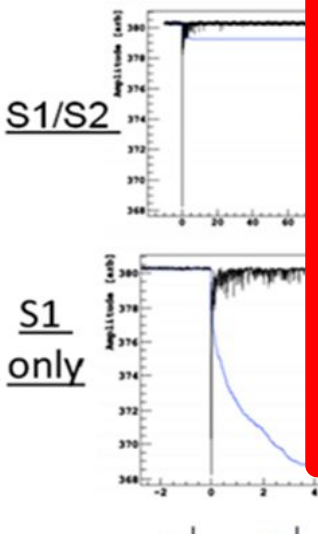


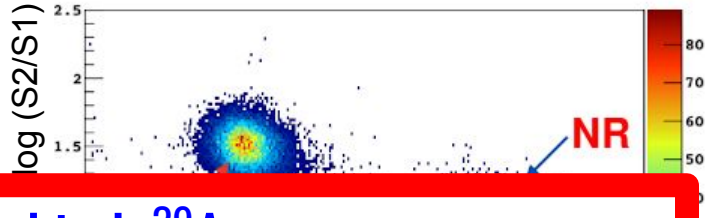
Ar, what's the point?

Additional
Pulse shap
triplet com

ER-li

E and





Nature is kind... but not so kind: ^{39}Ar

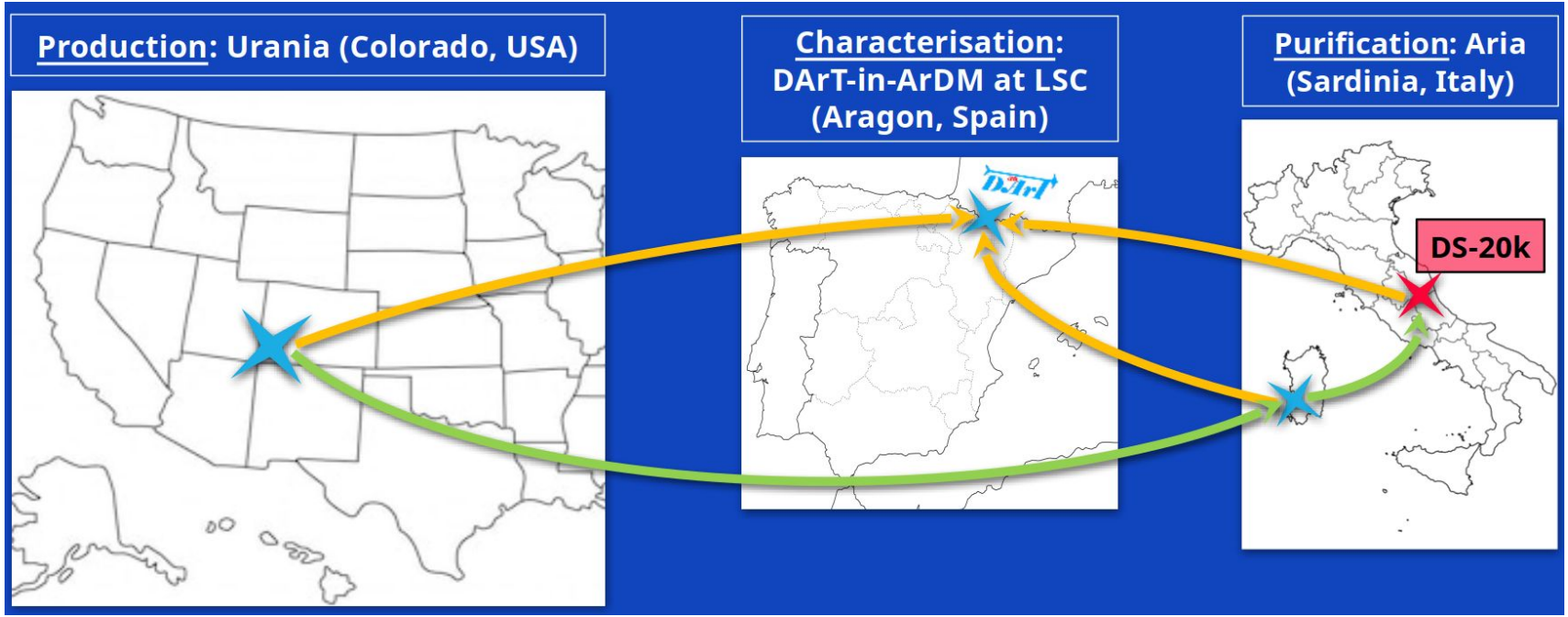
1Bq/kg in atmospheric Ar.

Makes the operation of a several-meter scale TPC too challenging.

At 50 kHz low-E S1-S2 coincidence unfeasible (and certainly not a low background experiment).

Mostly from cosmogenic activation

UAr program of DarkSide: Urania, Aria and DArT

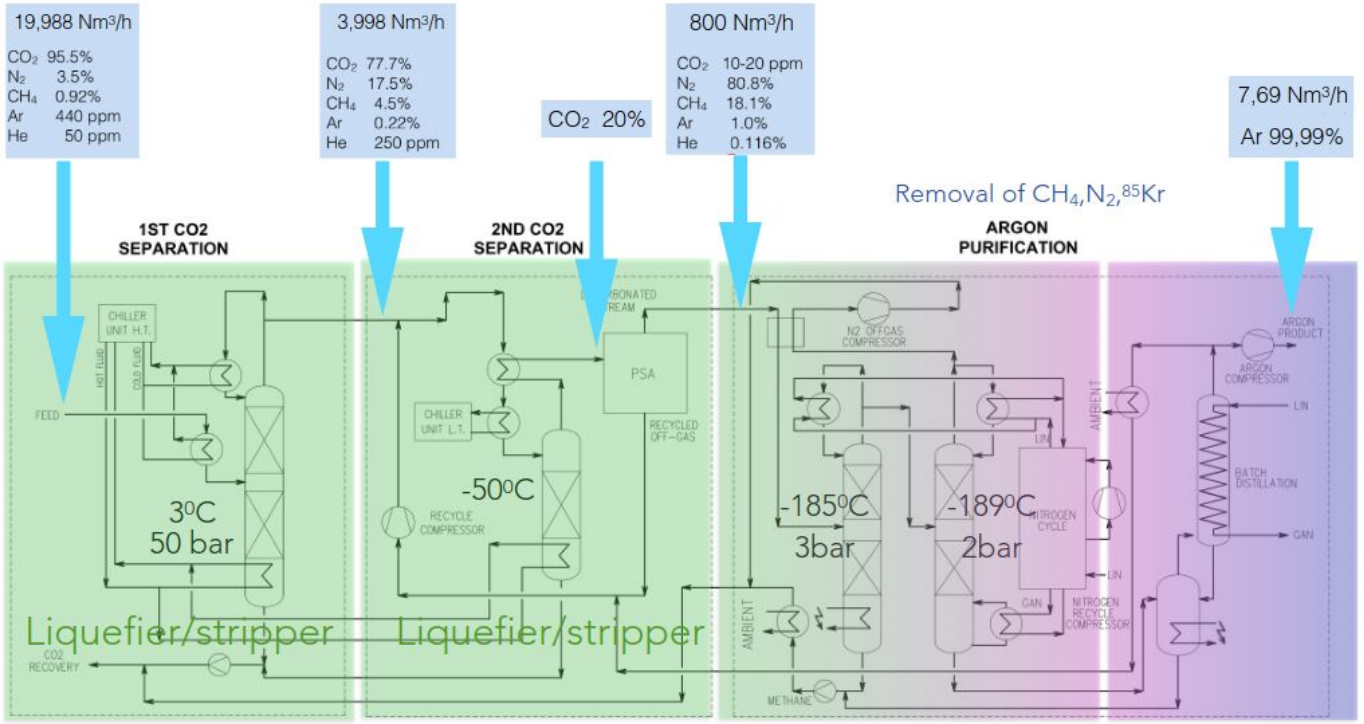


Cosmogenic activation above ground, during storage and shipping, quantified and subdominant for sea freight (few % of DS-50 reference): **Astroparticle Physics 152, 102878 (2023)**

UAr supply:
URANIA

Cortez, Colorado, USA

Urania: From 440 ppm to 99.99% Ar



+ Extraction rate 250-330 kg/day.
+ Full amount for DarkSide-20k (120 tonne) produced in 1.3 y

The Plant

Production

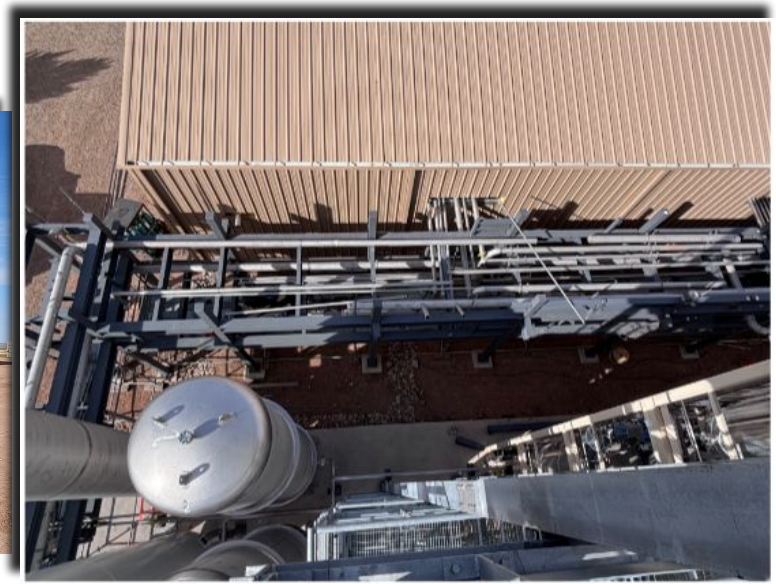
Leak test

+ Plant going through precommissioning.

+ Input gas already available for chemical test.

+ Commissioning run starting beginning of next year and taking 3 months.

The site



UAr purification: ARIA

Carbosulcis, Sardinia, Italy

ARIA

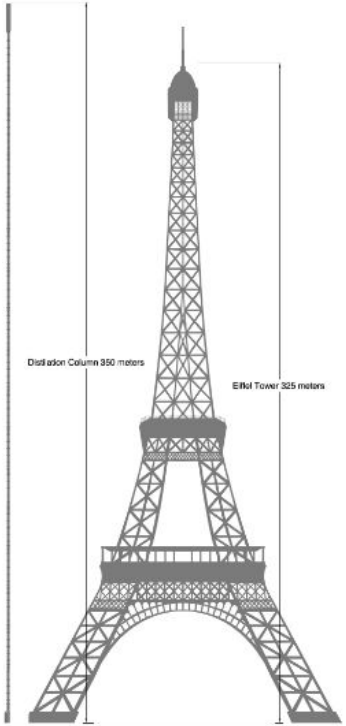
Cryogenic distillation column (total height ~350 m) in the shaft of a coal mine

- 28 Central modules: 12 m each
- 1 Condenser (top) module: 7 m
- 1 Reboiler (bottom) module: 5m
- Outer Diameter of the column: 32.3 cm
- Outer Diameter of cold box: 71.2 cm

Process is based on the difference in volatility

Number of theoretical stages: ~2870

Chemical Purification rate: 1 t/d (or more)



ARIA: Seruci-0

- Reduced scale cryogenic distillation column (total ~26 m)
    - 1 Central module: 12 m each
    - 1 Condenser top module: 7 m
    - 1 Reboiler bottom module: 5 m
    - ~80 theoretical stages
- First operation with nitrogen in 2019

Eur. Phys. J. C (2021) 81:359

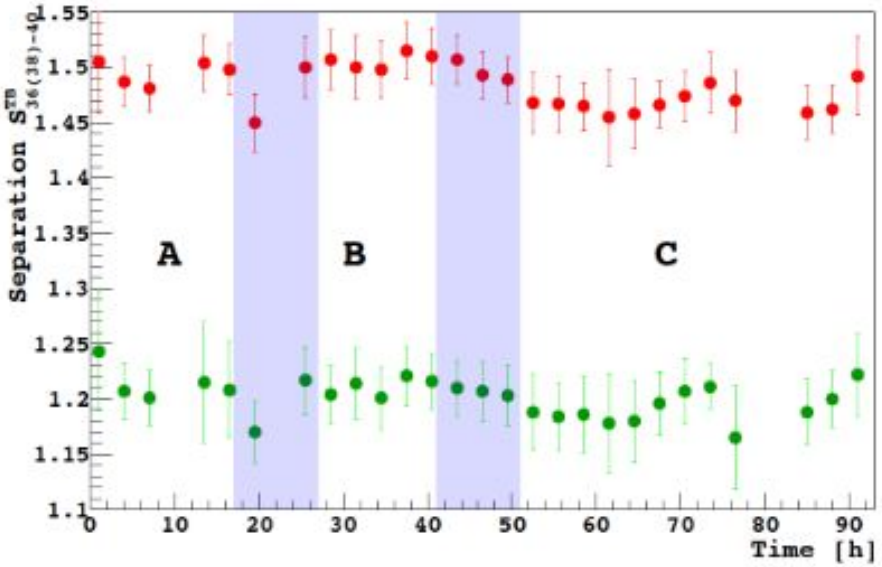
- Second operation with argon in 2021

Eur. Phys. J. C (2023) 83:453

ARIA: Seruci-0

Measurement of **isotopic separation of nitrogen and argon** with the prototype of the cryogenic distillation plant Aria for dark matter searches

Eur. Phys. J. C (2023) 83:453

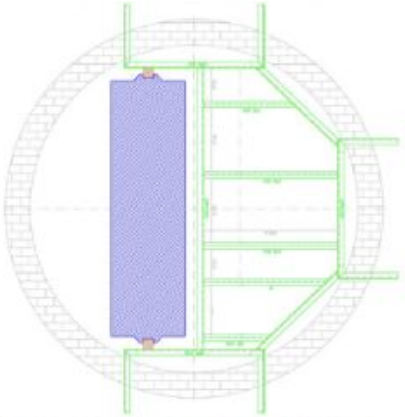


Separation $S^{TB}_{36\text{-}40}$ (red) and $S^{TB}_{38\text{-}40}$ as a function of time

$$S_{36-40} = S_{T-B} = \frac{\left(\frac{x_{36}}{x_{40}}\right)_T}{\left(\frac{x_{36}}{x_{40}}\right)_B}$$

ARIA

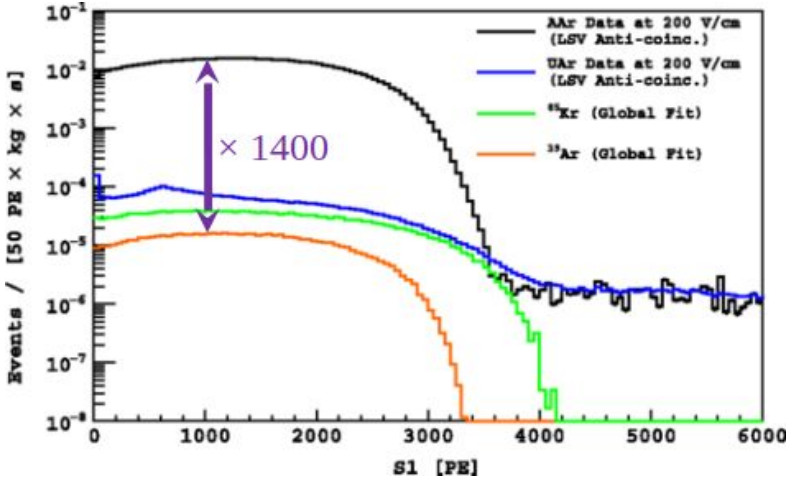
ARIA



UAr measurement: DArT

Canfranc, Aragon, Spain

UAr in DarkSide-50 (history)



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

Extraction and purification of UAr is a proven technology… industrial extraction and purification are projects themselves

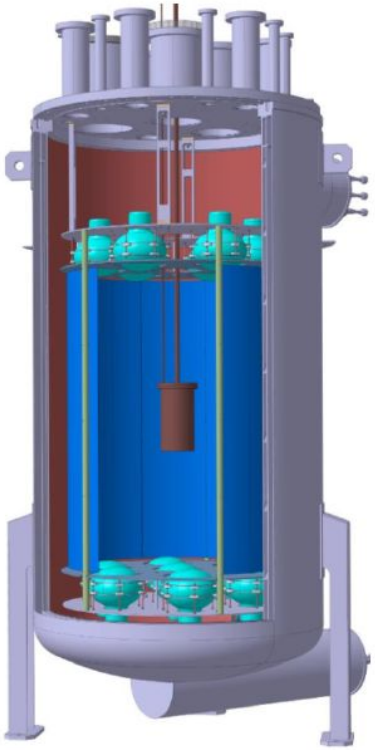
Presence of ^{85}Kr evidences **exposure to air** at some point…

Increasing ^{39}Ar activity.

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

Verification of UAr compliance is needed for each batch.

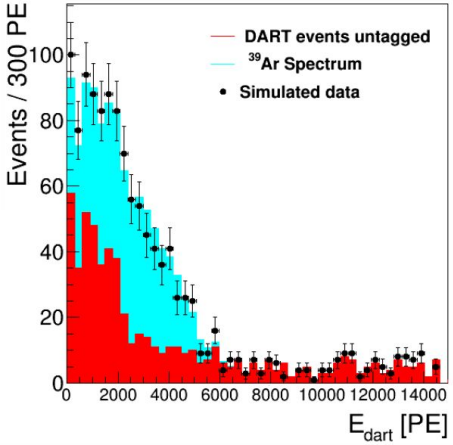
DArT-in-ArDM: the concept



JINST 15 (2020) 02, P02024

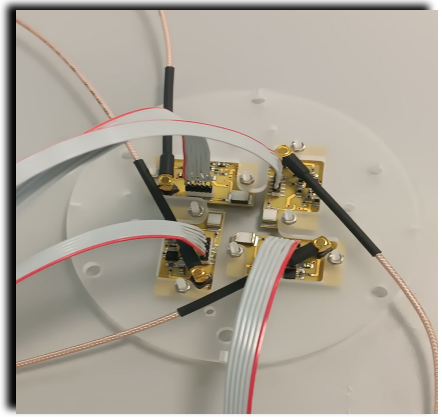
Depletion factor with respect to AAr	Statistical uncertainty [%]
10	0.4
100	1.3
1400	**6.7**
14000	41.1

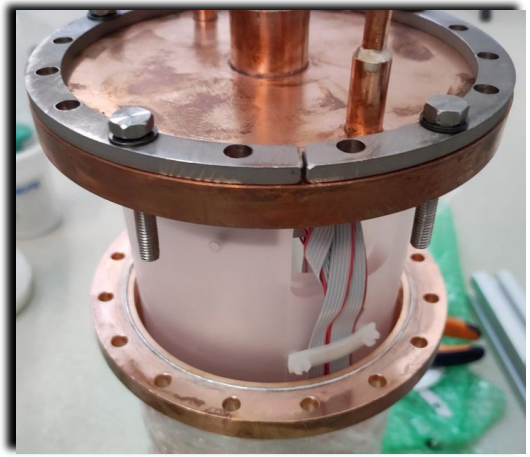
DS-50

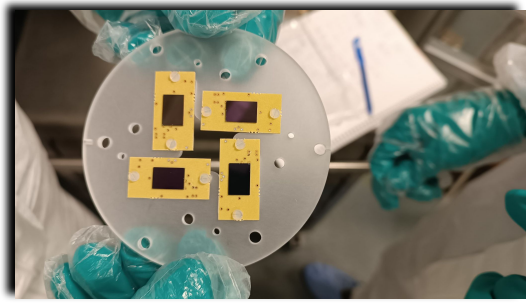


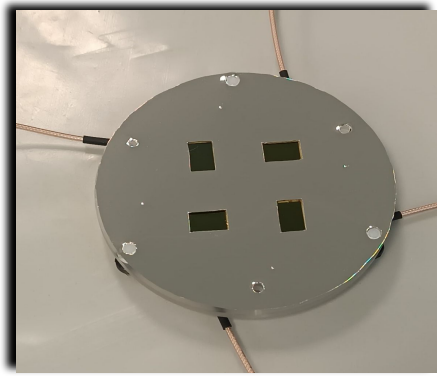
- 1 L active volume of UAr (DArT) seen by 8 SiPMs.
- ArDM full of atmospheric Ar as veto.
- Located at Laboratorio Subterráneo de Canfranc

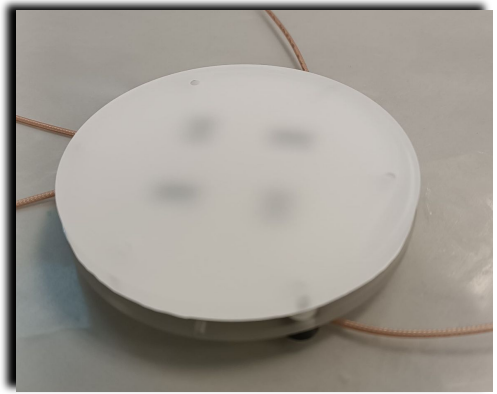
DArT-2



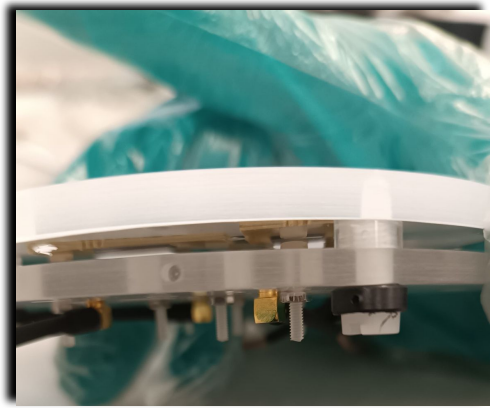








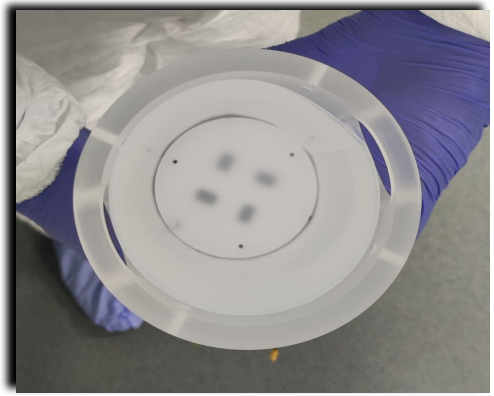
DArT-2

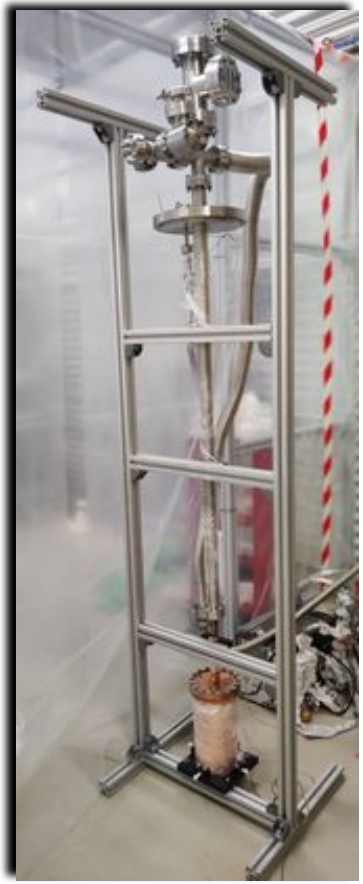


Assembled in September 2024

Tested in cold in May.

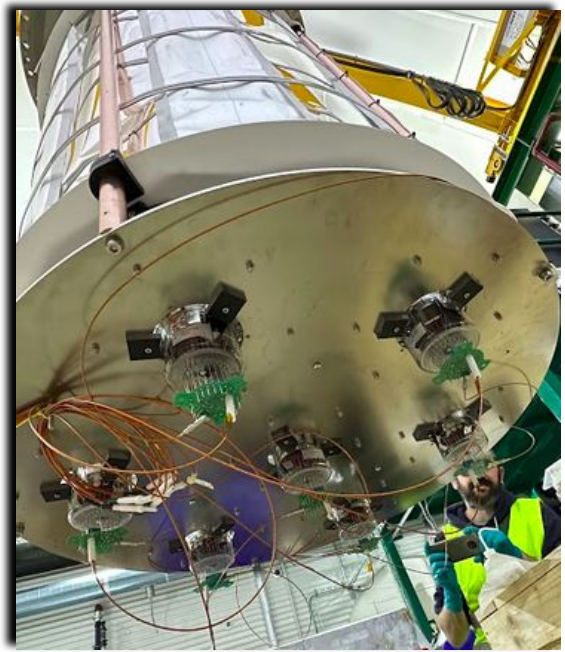
Integrated in ArDM in May.





ArDM

ArDM fully refurbished and closed since Jan 2024.



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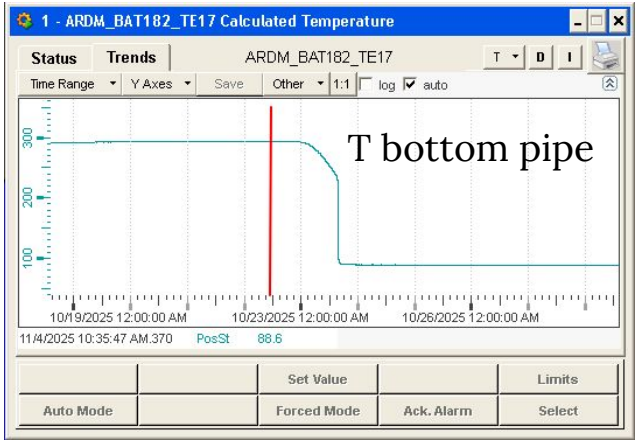
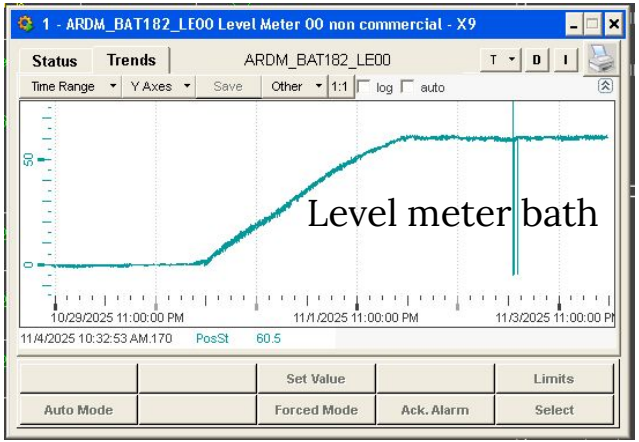
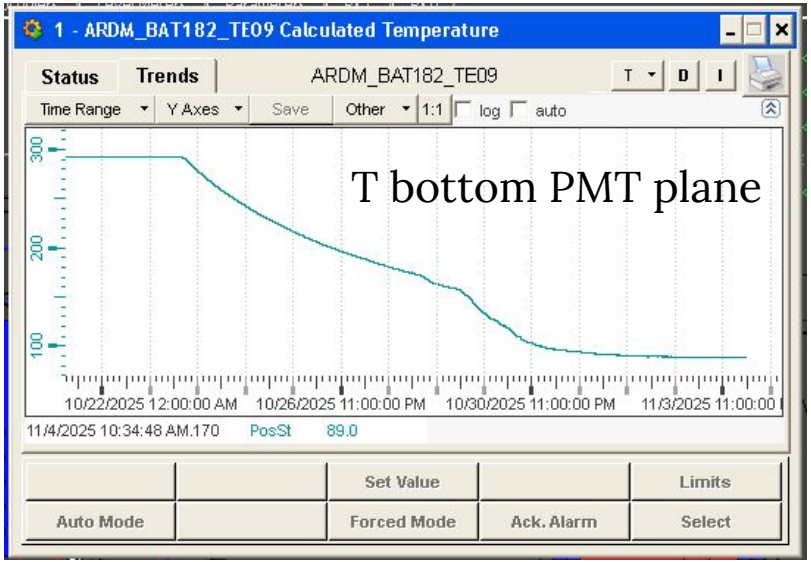
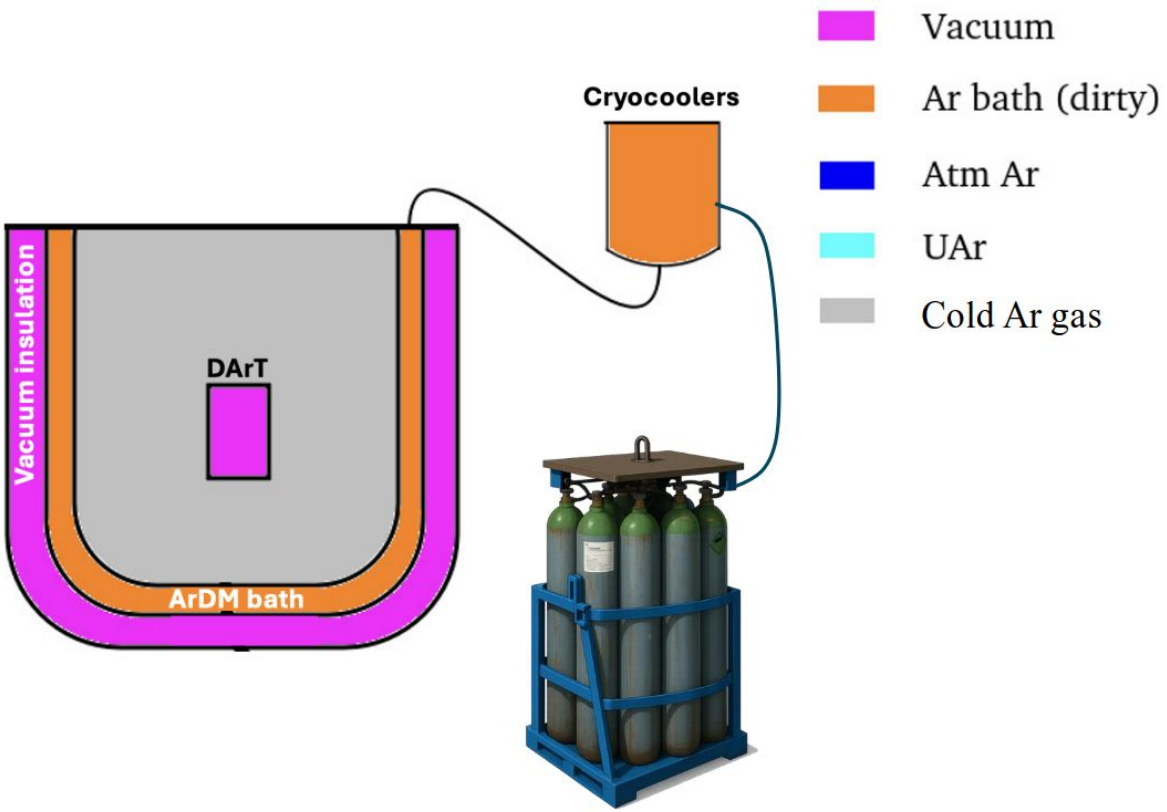




ArDM cool down started on October 22nd.
Filling with 2 tonnes of LAr starting next week.



ArDM

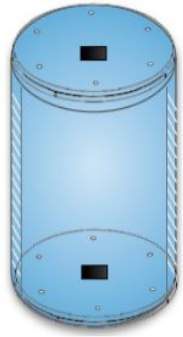


DArT taking data with atmospheric Ar during Christmas break

DArT taking data with UAr (DS-50) from January

UAr from Urania expected by Feb-March

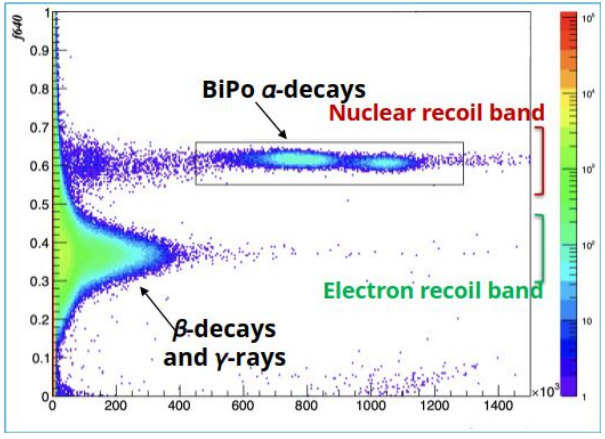
DArT-1 (2 SiPMs, external cryostat, Pb shield)

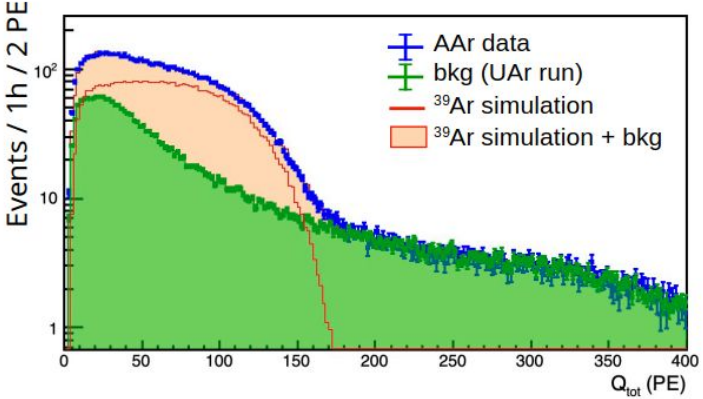


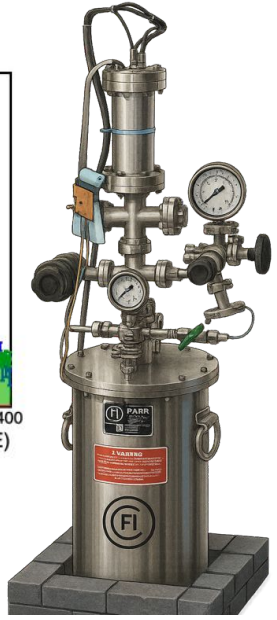
- Test of hardware operations, computing infrastructure, analysis.
- Test of slow control, gas system and UAr recovery procedure.
- Training

Data taken with AAr and UAr (DS-50):

+ **Competitive measurement of ^{39}Ar activity in AAr (analysis ongoing)**







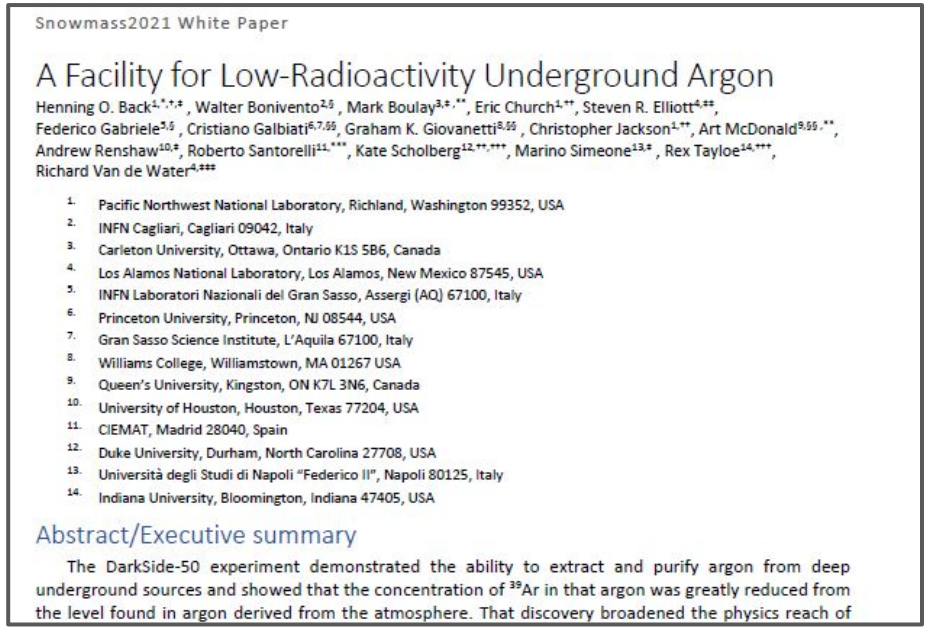
UAr beyond DarkSide

White paper (+EOI) from

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

The infrastructures built for DarkSide-20k (URANIA, ARIA, DArT) can meet the UAr demand for most of the foreseen future experimental needs.

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



Snowmass2021 White Paper

A Facility for Low-Radioactivity Underground Argon

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

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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 ^{39}Ar 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 for LEGEND-1000

Conclusions

- Ar has PSD capabilities, which make it a top choice for the next generation of low background experiments.
- UAr solves the problem of the intrinsic ^{39}Ar activity,
- There is an ambitious program to extract, purify and characterize ~150 tonnes of UAr.
- Beginning of next year fresh new UAr will be extracted with URANIA
- ARIA will chemically purify it at a rate of 1 tonne/day.
- DArTinArDM is cold and will be filled in the coming weeks. Commissioning will follow with atm. and DS-50 Ar.
- This program will have an strong impact in DM searches, 0vbb, CEvNS and more, so stay tuned.

Gràcies!


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39
DArT


DARKSIDE


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Gràcies!

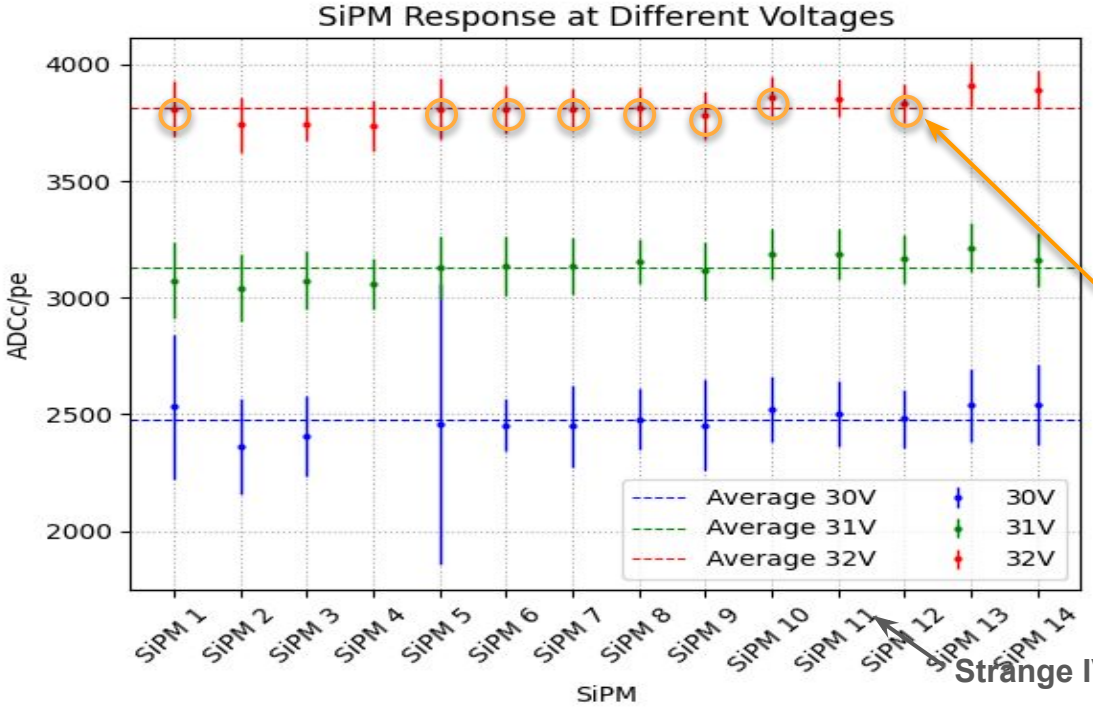
(ChatGPT crea'm una imatge amb gent vestida amb indumentaria de sala blanca, i posant una paella dins d'un detector de partícules molt gran)

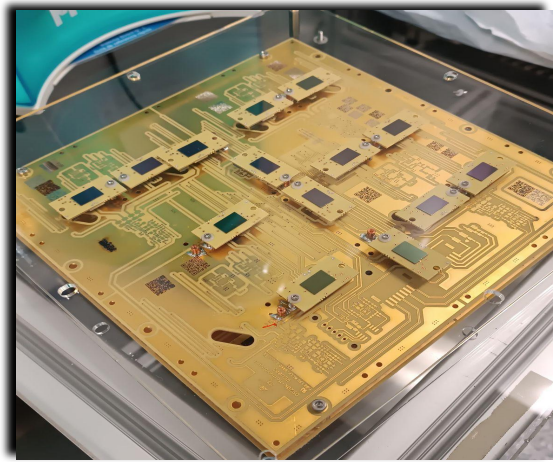
BACKUP

SiPM characterization and choice

DArTeyes assembled at LNGS.

Choice based on performance in cold:

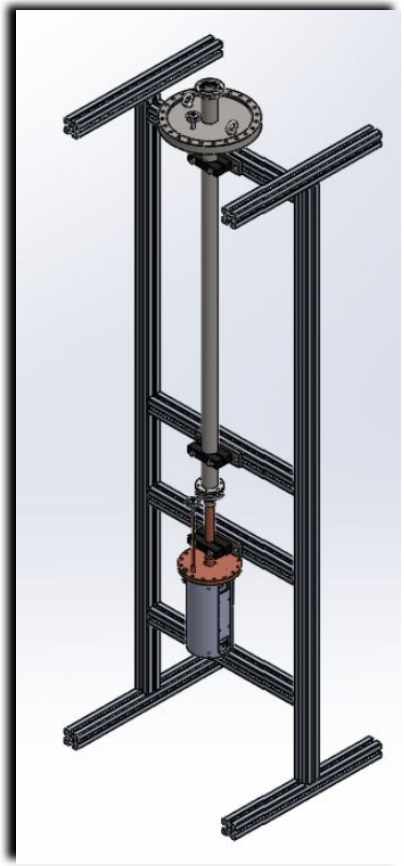




chosen SiPMs for DArT 2.0

Strange IV curve

Wrapping it up

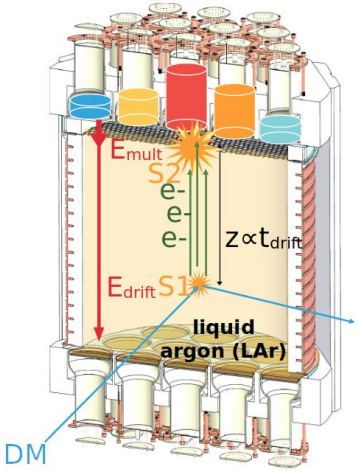


Dual-phase TPCs

Massive targets

Scintillation detected promptly (S1)

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



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)

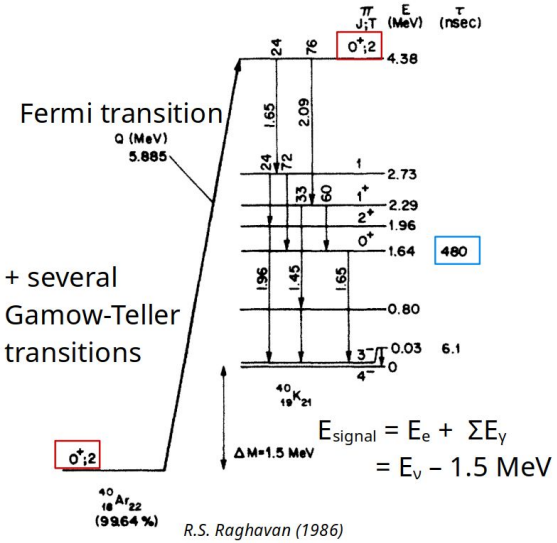
S2/S1 provides particle discrimination

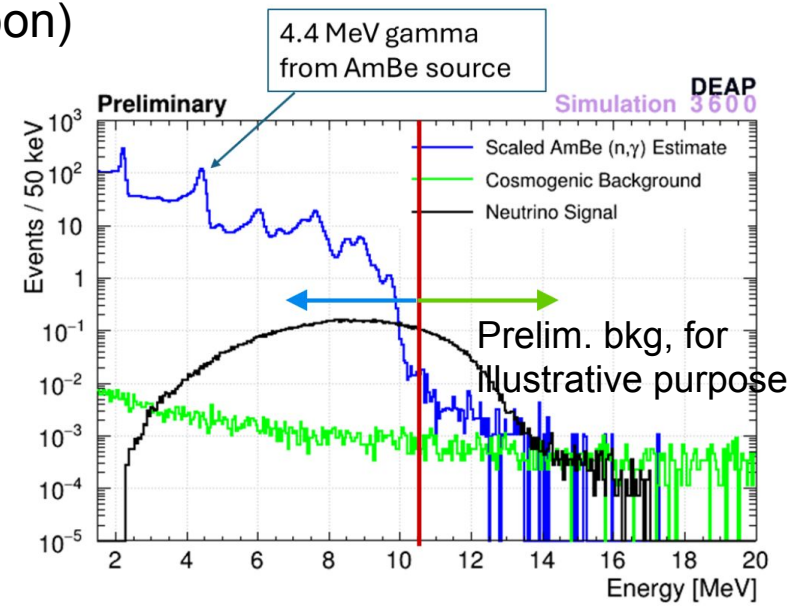
At low Energies, S1 and S2 almost featureless: Unambiguous identification of S1-S2 necessary

Detecting ^{8}B solar neutrinos (coming soon)

$$^{40}Ar + \nu_e \rightarrow {}^{40}K^* + e^-$$

Enhanced cross section for populating the isobaric analog state (although not directly measured!)





Two approaches towards radiogenic bkg estimation

Cosmogenic background from muon activation thoroughly studied