15th International Workshop on the Identification of Dark Matter 2024

Low-radiactivity argon for dark matter searches and beyond

Riccardo Stefanizzi

Walter M. Bonivento

on behalf of the DarkSide-50 collaboration

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Introduction: Pure argon procurement for DarkSide-20k and other experiments

Step 1. Extraction of underground argon from **URANIA** in Colorado

Step 2. Argon purification in **URANIA**

Step 3. Further argon purification in **ARIA** with Seruci-1 distillation column

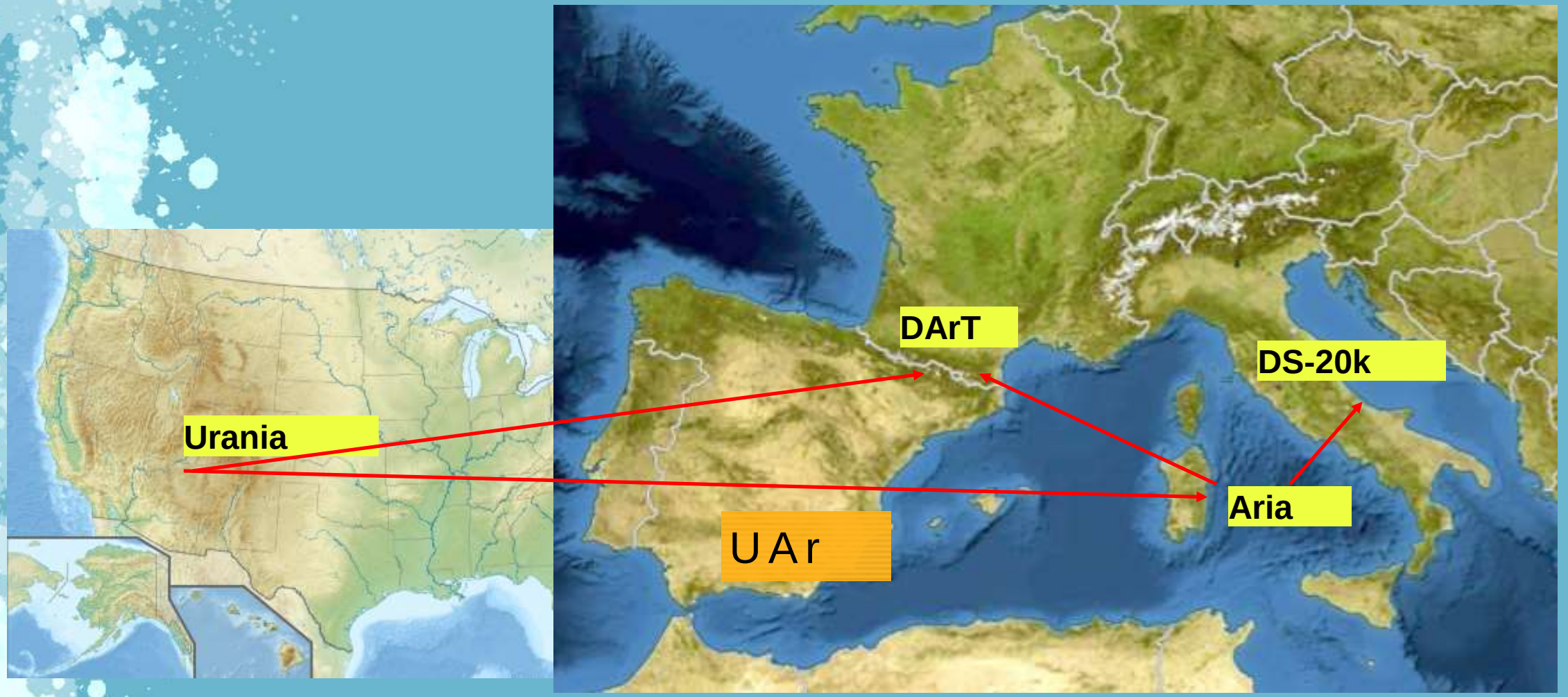
Step 5. Argon to GranSasso for **DarkSide-20k**

Other future uses of purified argon for experiments or purposes.

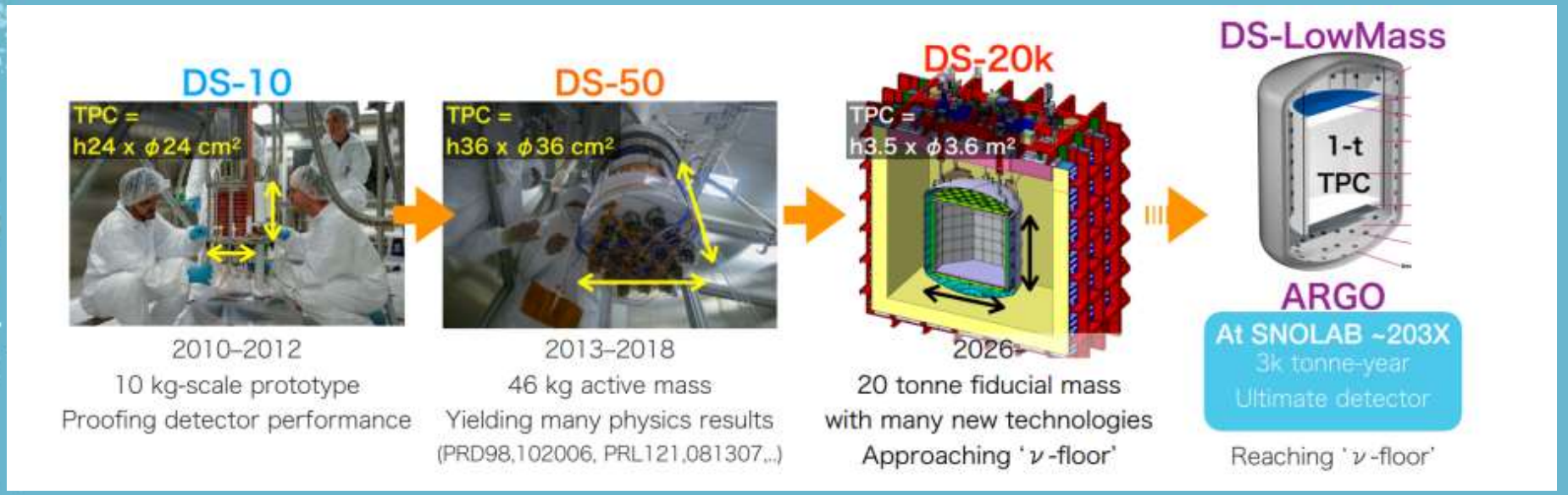
^{39}Ar measurement with **DArT** in Canfranc (Spain).

(More details about DArT in next presentation by Vicente Pesudo)

Coherent
Legend
Etc.


Urania
DArT
DS-20k
Aria
UAr

DarkSide and Darkside-20k



S1->Scintillation of argon

S2-> Electron(s) drift

PMTs detection -> xy-position

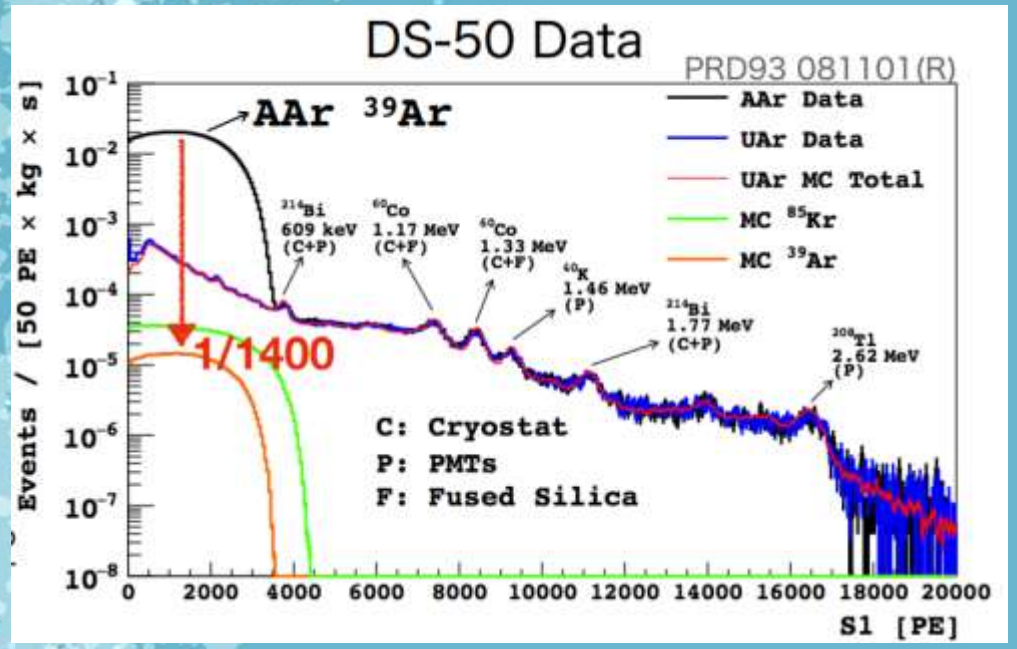
Δt-> z-position of interaction

→ **Powerful signal-background discrimination**

UAr should be chemically and isotopically pure

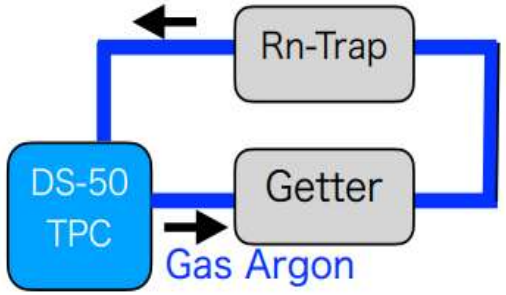
The underground argon extracted in Uraina must already be isotopically pure

Argon purity requirements



Reduced up to ppt or ppb

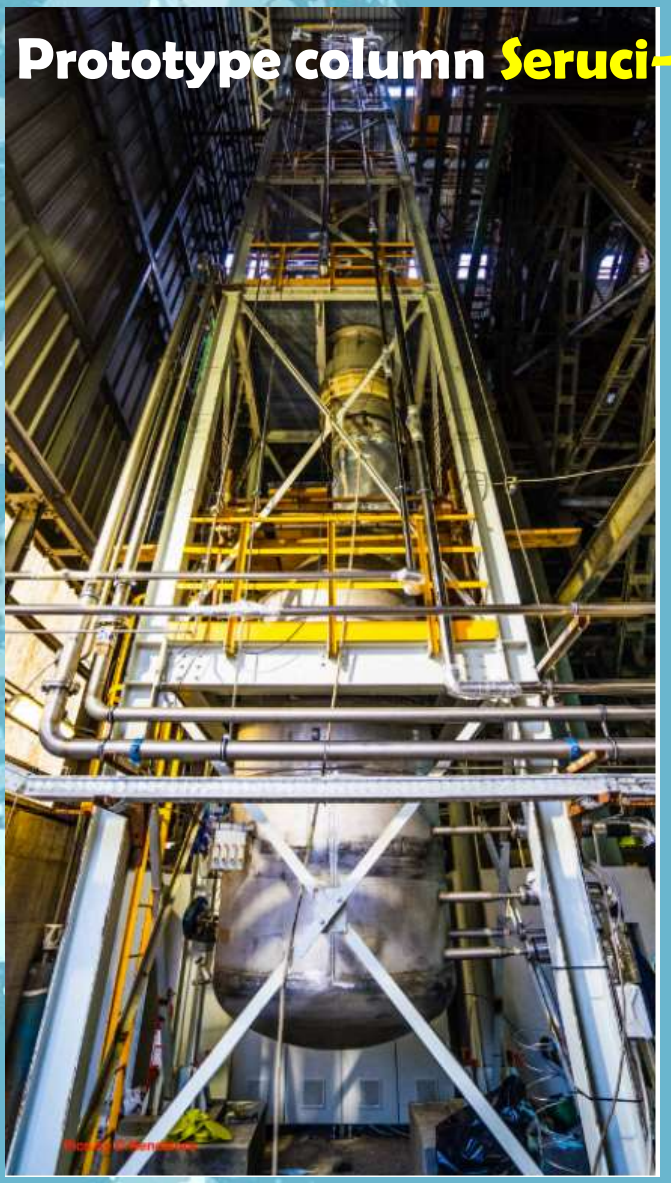
Argon inside the cryostat was continuously circulated and purified through hot getter and charcoal trap



The two main requirements are that the argon be isotopically and chemically, thus we need to

1) **Remove ^{39}Ar as in atmosphere it consists of 1 Bq/kg of β-decays (endpoint 565 keV, $\tau_{1/2}$= 268 years). This isotope needs to be reduced as it creates significant background and pile-ups. It can be reduced by taking UAr or purifying via isotopic distillation (Aria isotopic distillation). ^{39}Ar is already reduced by using UAr**
2) **Use a purification system (e.g. getter) in DarkSide we can constantly remove chemical impurities such as nitrogen, oxygen, methane, etc. However, to function effectively, the argon must already be extremely pure from the start; therefore, chemical distillation with Aria is performed. (Aria chemical distillation). Contaminants in the argon would quench the scintillation light and worsen the pulse shape discrimination.**

Main Goals and applications of isotopic distillation with Aria



Isotopic distillation

↓

It could potentially further reduce ^{39}Ar by a factor of 10

Chemical distillation

↓

Complete suppression of impurities such as $N_2/CH_4/O_2/Kr/CO_2$ and more

Seruci-1 under construction

350 m

Chemical purification of Argon

Presence of contaminants
$N_2/CH_4/O_2/Kr/CO_2$

10^{-4}

Distillation in Seruci-1
Liquid extracted from the bottom: suppression of N_2

$<<10^{-10}$

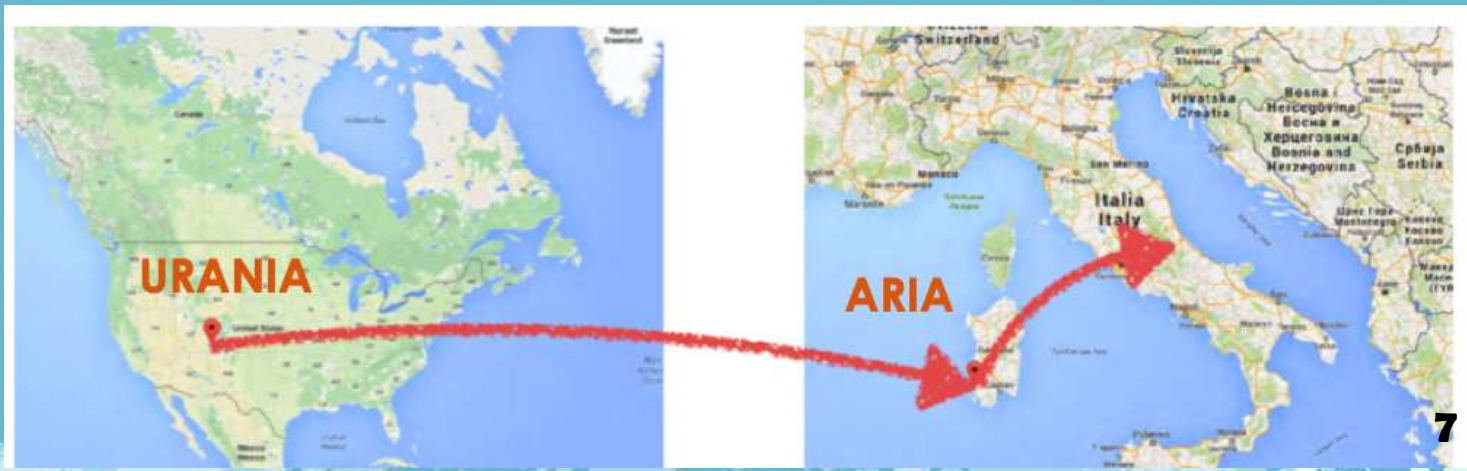
Much below requirements of the getter

$<<10^{-10}$

Optional second distillation in Seruci-1
Gas extracted from the top:
Suppression of every other element

DARKSIDE

High purity Argon used for DarkSide20k experiments
Up to 1 tonne/day



Isotopic distillation

All the data are from simulations. These are based on the experimental measurements taken during the runs of the prototype

Natural abundance of ^{39}Ar in atmosferic argon

10^{-15}

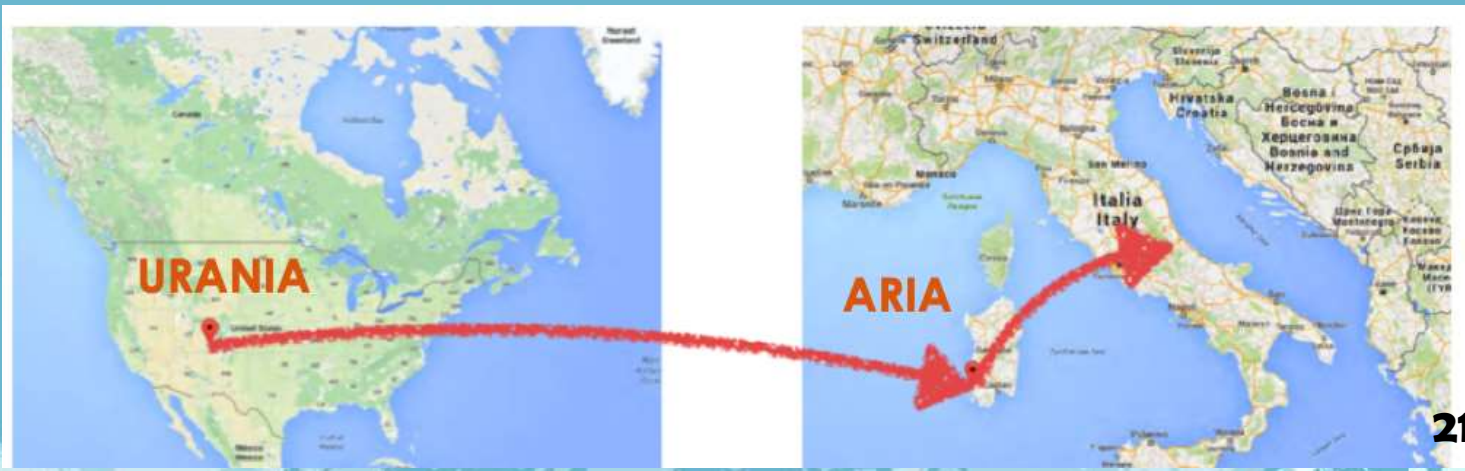
10^{-18}

Underground Argon extracted in Urania

10^{-19}

Argon distilled in Aria (Sercui-1)

High purity Argon ≈ 1-2 tonne/year



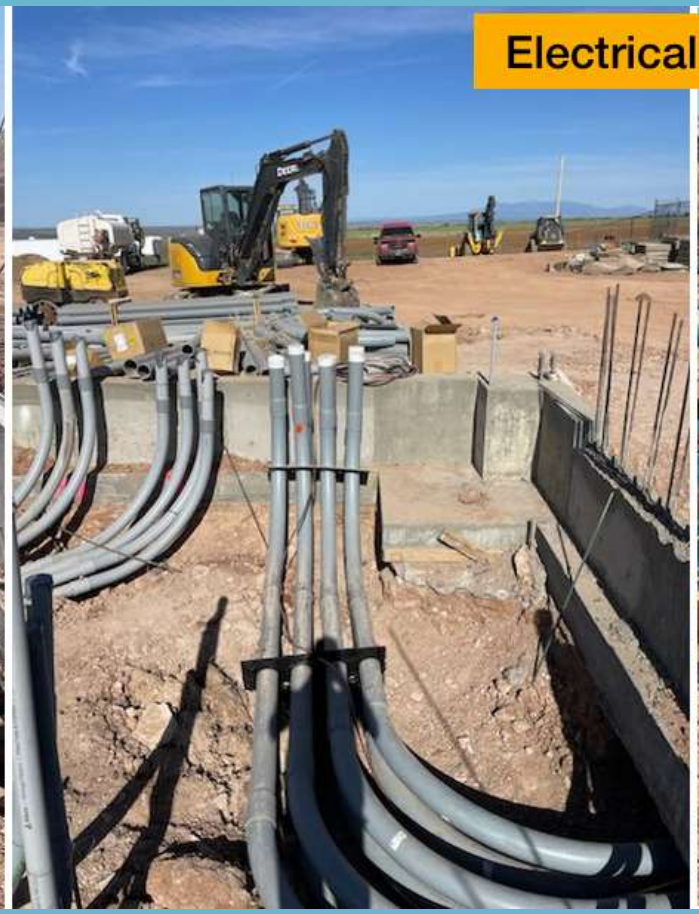
Urania

Urania plant productivity **250-300 kg/day** of UAr from CO_2

Estimated **99.99%** purity. **Nitrogen** contaminations can be at most around 10^{-4}, while we expect other contaminants to be less than at least 10^{-6}

Urania Status:

Currently under construction



Urania Status:

Footing excavation in progress

Concrete footings cast along gridline A

Transport of argon from Urania to Aria

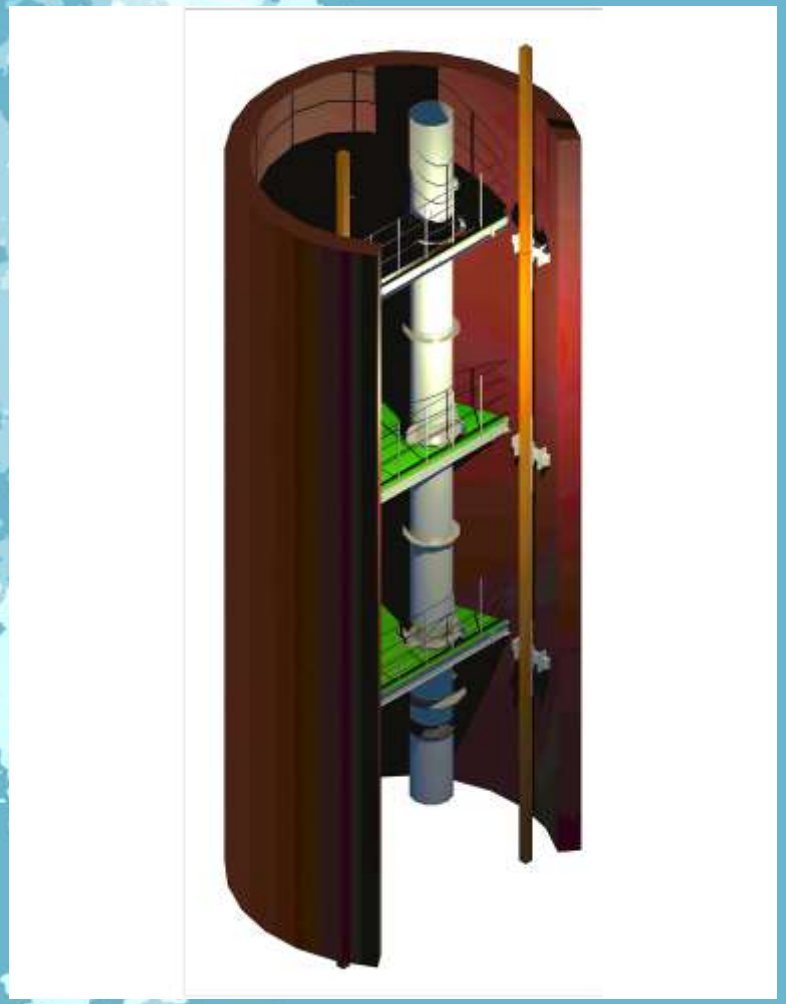
ISOVAC 20 - SCHEMATIC DIAGRAM

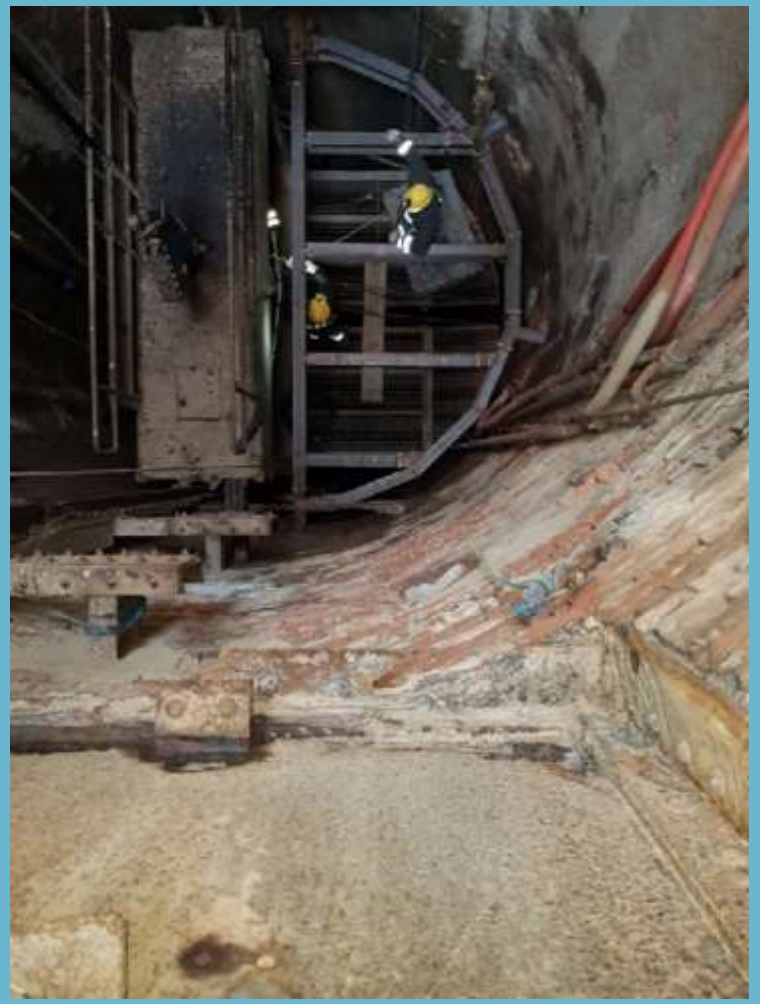
15 ton shipping and storage vessels will be used to transport liquid argon from Urania to Aria (after liquefaction).
The contract has been signed, but the delivery is scheduled and has not yet arrived

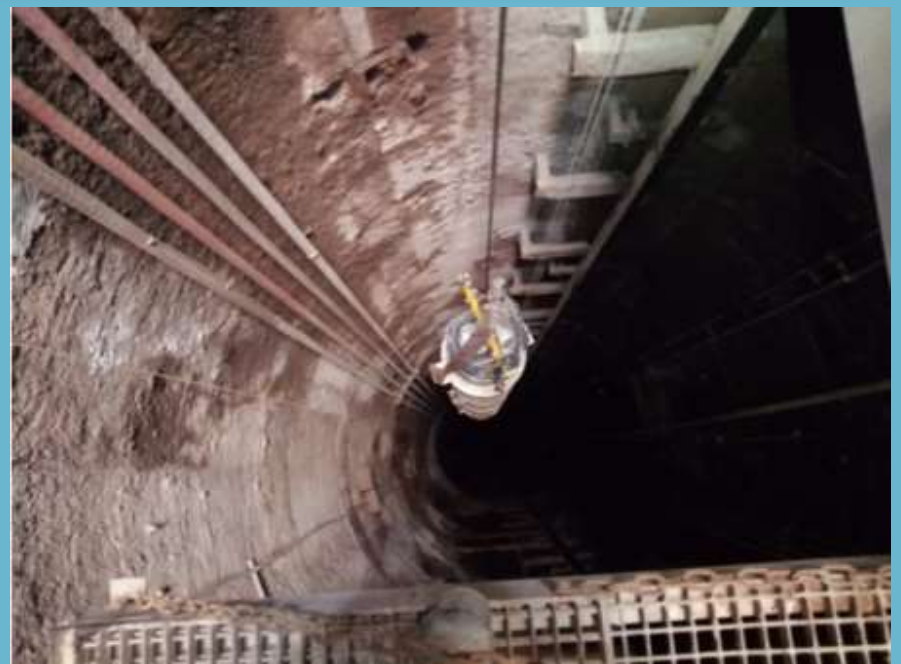
The activity of ^{39}Ar induced during extraction, purification and **transport on surface**, in baseline conditions, is evaluated to be **<5%** of the UAr activity measured in DarkSide-50 (Astropart.Phys. 152 (2023) 102878), and thus considered acceptable.

Castello support structure completed!

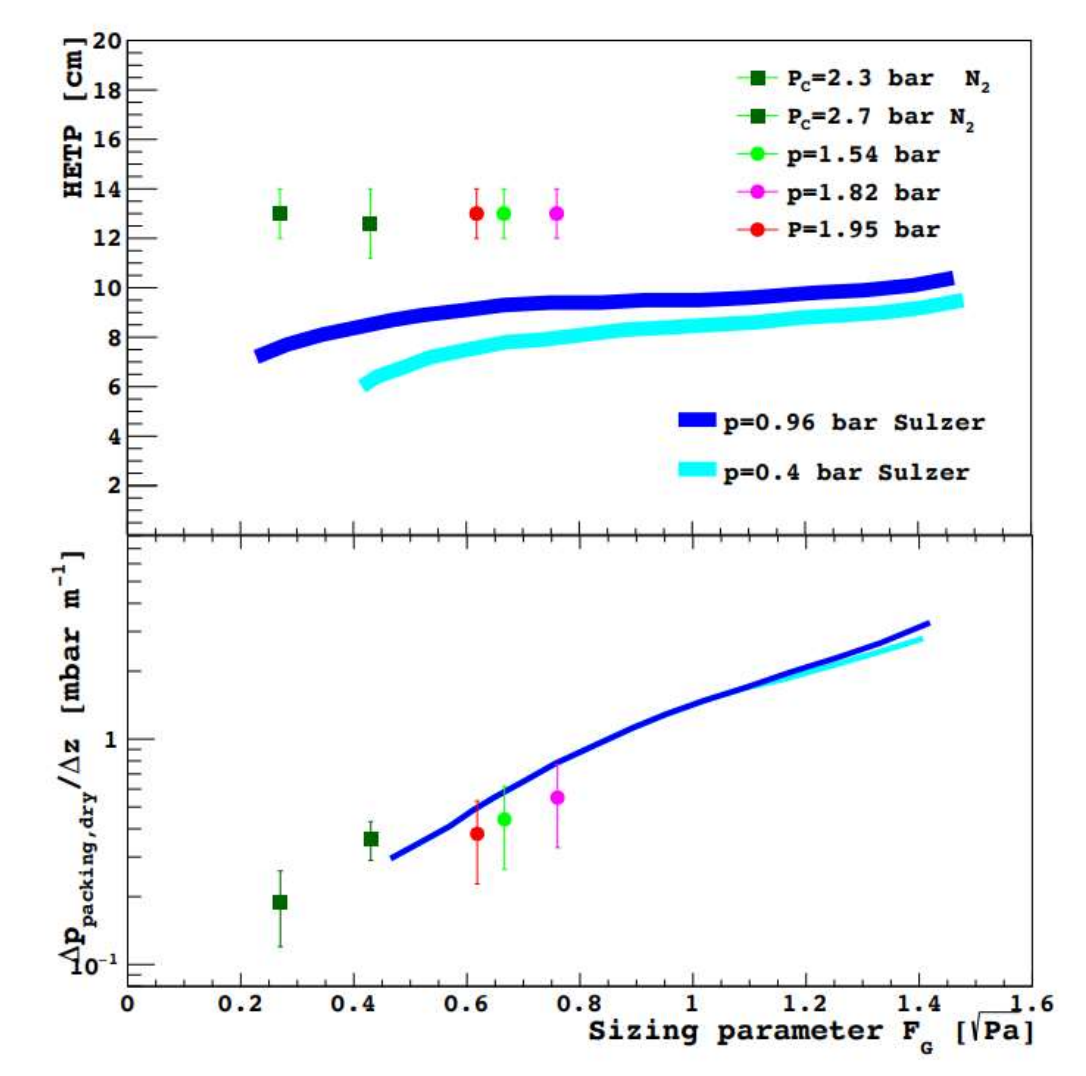
Installation of supports and module drop test.







Previous successful runs with the Seruci-0 prototype



Argon run (2021)

$^{36}Ar/\ ^{40}Ar$ 0.336% ⇒ 0.45%

$^{38}Ar/\ ^{40}Ar$ 0.063% ⇒ 0.076%

In total reflux conditions: extracting a small flux from the column

Nitrogen run (2019)

$^{15}N^{14}N/\ ^{14}N^{14}N$ 0.84% ⇒ 0.91%

Next runs with Seruci-0

- Perform chemical separation
- Not in total reflux condition (extracting a significant quantity of argon)

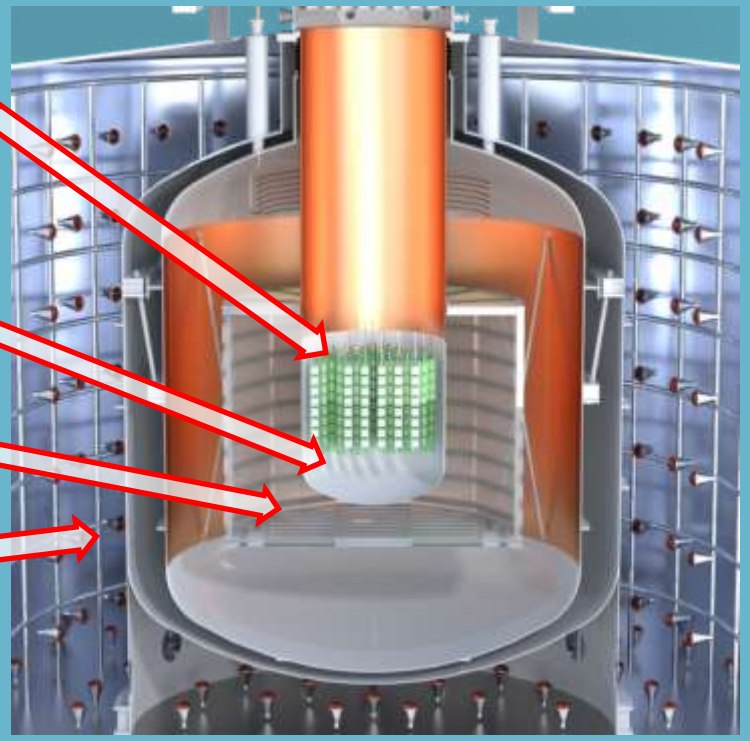
Other purposes of the argon procurement chain and of purification with Aria

^{76}Ge High purity

20 t UAr

200 t AAr

Water Tank

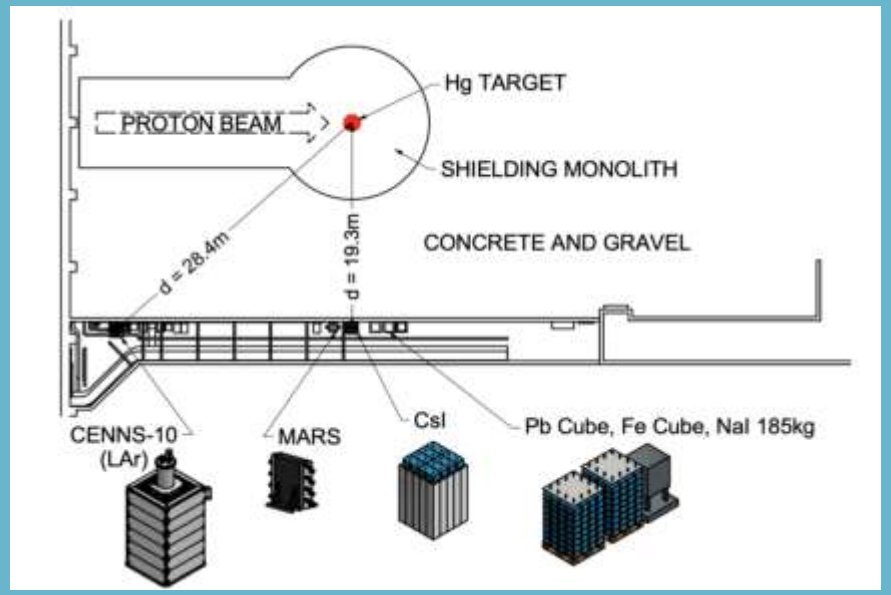


In **LEGEND** 1000 kg of 76Ge are required to look for neutrinoless double beta-decay.

Even LEGEND-1000 requires chemically purified argon. Therefore, with the same procedure as for DarkSide-20k, it will also be possible to produce for LEGEND.

COHERENT and others

The **COHERENT** experiment studies coherent elastic neutrino-nucleus scattering (CEvNS), a process predicted by the Standard Model of particle physics. It aims to measure this interaction to better understand neutrino properties and test for potential new physics beyond the Standard Model.



They will use **LAr TPC** with **purified argon** as well

We will provide **1 ton** of purified argon

We are considering possible new requests for purified argon or other isotopes distilled for other experiments...

References:

Aria:

Agnes, P., et al. "Separating 39 Ar from 40 Ar by cryogenic distillation with Aria for dark-matter searches." The European Physical Journal C 81.4 (2021): 359.

Aaron, E., et al. "Measurement of isotopic separation of argon with the prototype of the cryogenic distillation plant Aria for dark matter searches." The European Physical Journal C 83.5 (2023): 1-13.

DarkSide:

Fan, Alden. "Status and results from DarkSide-50." arXiv preprint arXiv:1511.00676 (2015).

Aalseth, Craig E., et al. "DarkSide-20k: A 20 tonne two-phase LAr TPC for direct dark matter detection at LNGS." The European Physical Journal Plus 133 (2018): 1-129

Legend:

Edzards, Frank. Characterization of Point Contact Germanium Detectors and De
velopment of Signal Readout Electronics for LEGEND. Diss. TU München Munich,
2021.

Pictures:

DarkSide Collaboration meeting presentations about Aria (Federico Gabriele) and Urania (Marino Simeone)

Forti Committee review meeting presentations from Federico Gabriele and Farrokh Rad

Walter Bonivento’s talks

Conclusions

- **DarkSide-20k Experiment**: Aims to detect dark matter by observing interactions of WIMPs within a 50-ton liquid argon target using double-phase time projection chamber technology.
- **Argon Source:** Low-radioactivity argon depleted in isotope 39 is sourced from the Urania plant in Colorado, extracting approximately 250 kg/day.
- **Initial Purification:** At Urania, the argon undergoes initial purification through distillation columns and a pressure swing absorption stage.
- **Secondary Purification:** The purified argon is transported to the Aria plant in Sardinia, Italy, where a 350 m cryogenic distillation column further reduces residual impurities to detector-grade levels.
- **Extended Applications**: The argon purification process can also be used to produce argon for other experiments such as LEGEND and COHERENT. The Aria distillation column can also be used to produce other isotopes of interest for other experiments

Backup