

The UAr Production for **DARKSIDE-20K**: Urania, Aria, and **DArT** Projects

Federico Gabriele - INFN Cagliari Division
on behalf of the **DarkSide** Collaboration



Nagoya Workshop on Technology and Instrumentation
in Future Liquid Noble Gas Detectors - Feb, 14-16 2024

darkside
two-phase argon TPC for Dark Matter Direct Detection



OVERVIEW

- **Introduction of the context:**
 - The DarkSide Collaboration
 - A bit of history
- **The Underground Argon (UAr) Project:**
 - Urania
 - Aria
 - DArT in ArDM
- **Future interests**

INTRODUCTION: DarkSide

The DarkSide Program: A multi-stage approach

2011 - 2013

2013 - 2018

2026 - 2035

2030s - ...

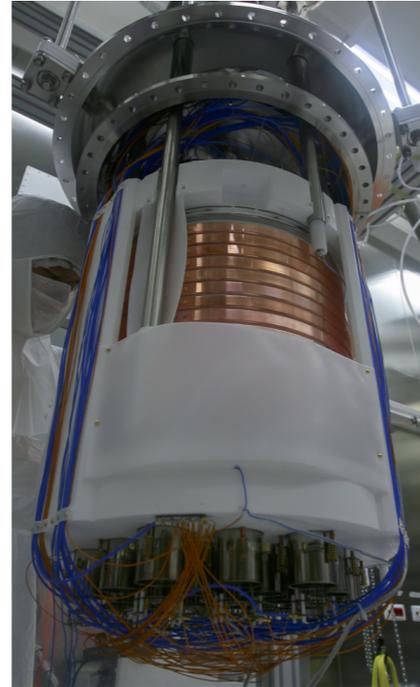


DarkSide-10

First prototype

Helped to refine the TPC design

No Dark Matter goal



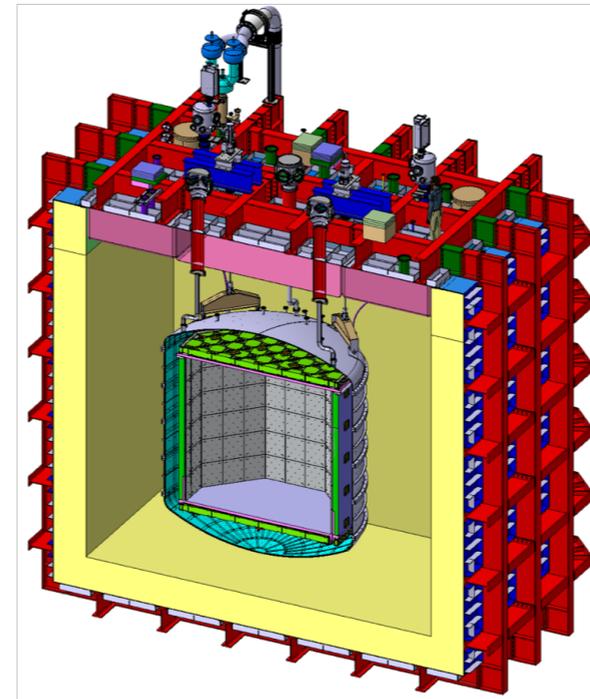
DarkSide-50

Science detector

Demonstrated the use of UAr

First background-free results

Best limits for low mass WIMP searches

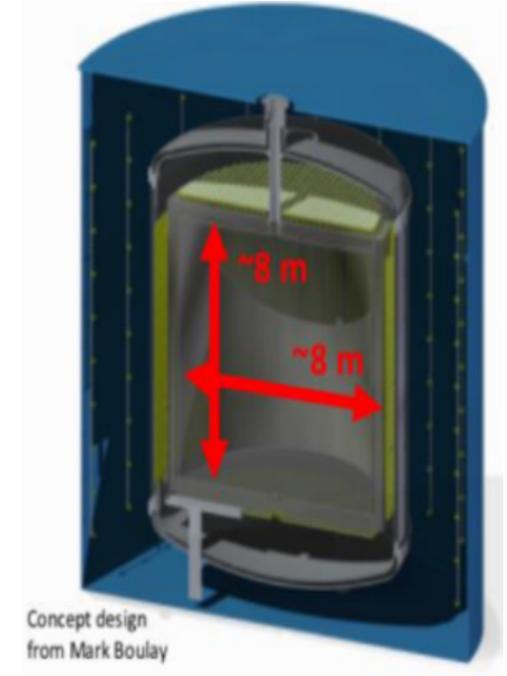


DarkSide-20k

Novel Technologies

First peek into the neutrino fog

Nominal exposure: 200 t y



Argo @ SNOLAB

Ultimate LAr DM detector

Push well into the neutrino fog

Nominal exposure: 3000 t y

Concept design
from Mark Boulay

- *Where we go with Liquid Ar-based Dark Matter Searches* - [M.Wada](#)
- *Spurious Electron and S2-only backgrounds at Darkside-50* - [M.Kimura](#)
- *Quality Assurance and Quality Control of the 26 m² SiPM production for the DS-20k dark matter experiment* - [G.Gallina](#)
- *The R&D of the dual phase argon TPC, from DarkSide-50 to DarkSide-20k* - [Y.Wang](#)

INTRODUCTION: History

Started about 2008...



...first extraction plant...



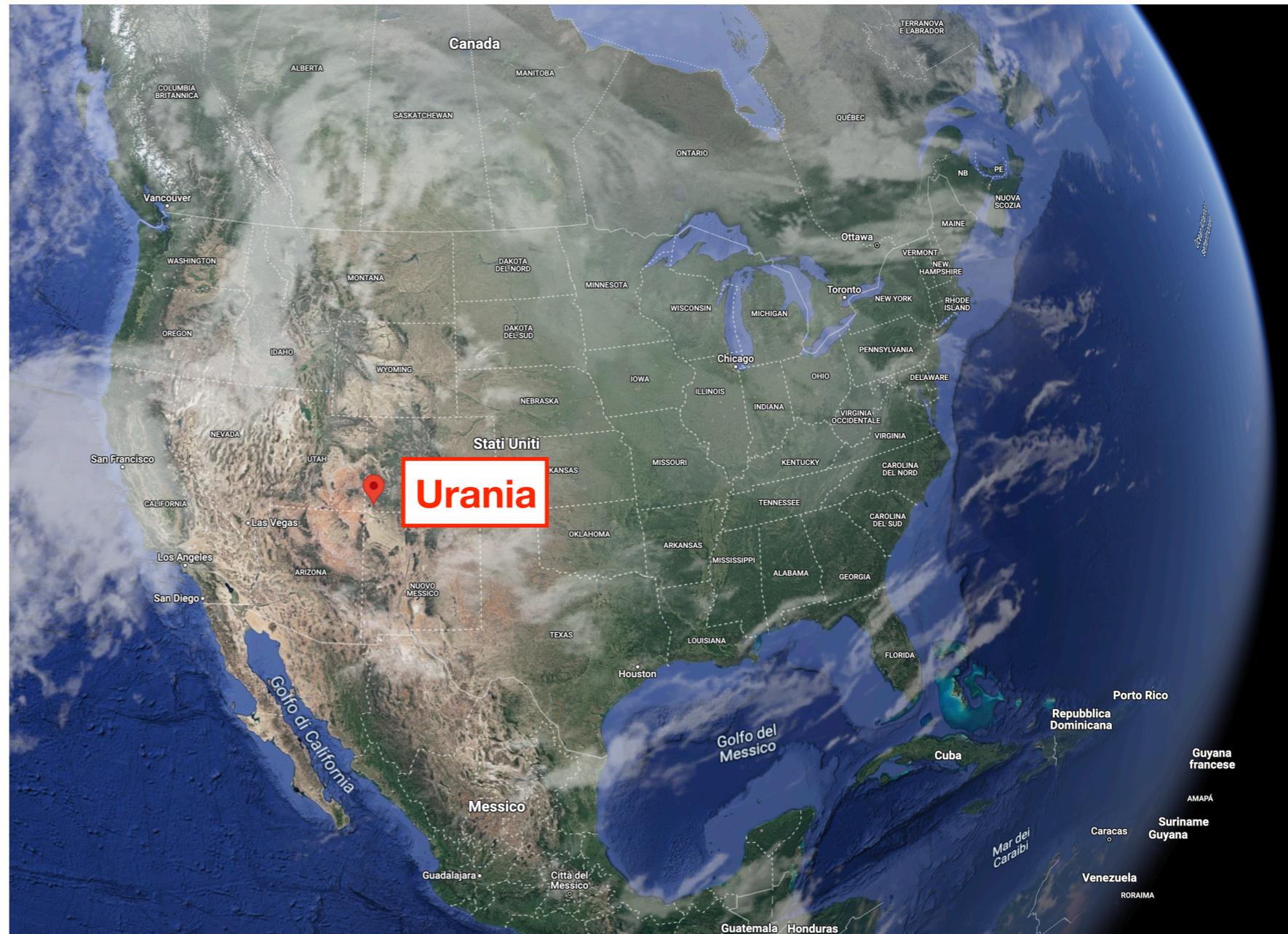
...and then purified at FERMILAB.



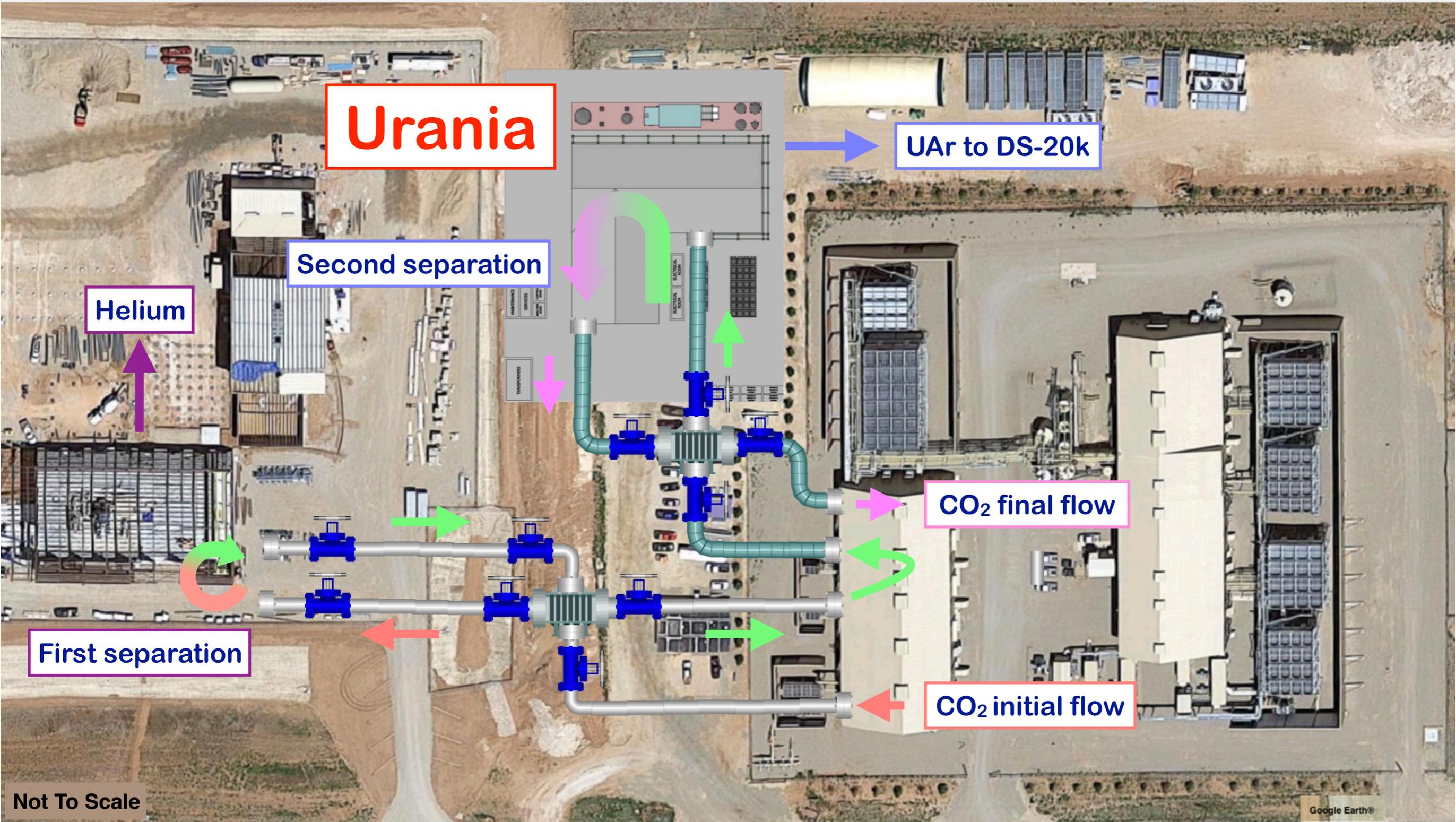
UNDERGROUND ARGON PROJECT: Urania

Main Partners and Institutes involved

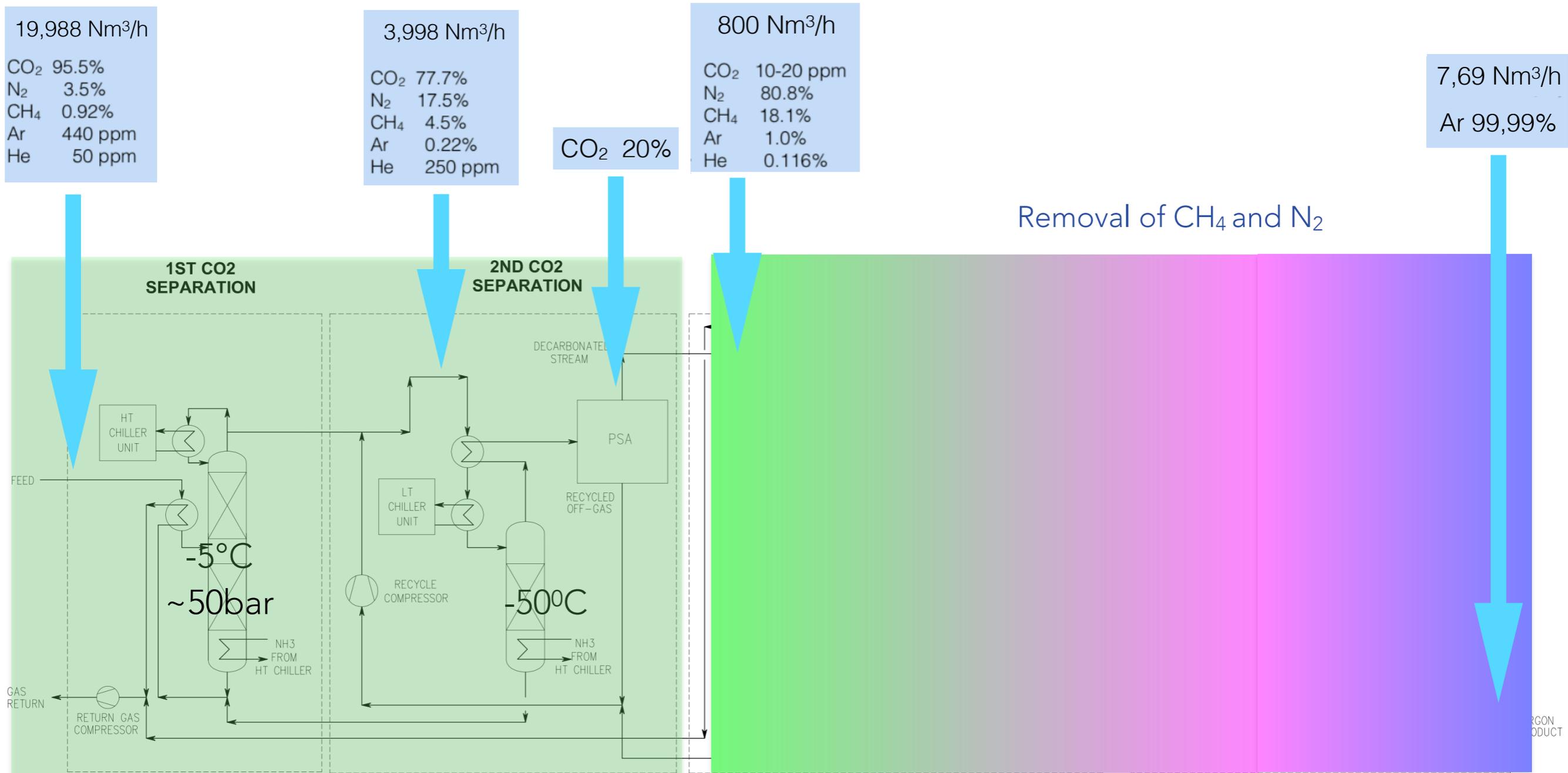
- INFN
- Università Federico II di Napoli
- Princeton University (NSF)
- Houston University (NSF)
- Carleton University (CFI)
- PNNL (DOE)
- Fermilab (DOE)
- Fort Lewis College (NSF)
- DarkSide Collaboration



UNDERGROUND ARGON PROJECT: Urania



UNDERGROUND ARGON PROJECT: Urania



- UAr Extract rate: 250-330 kg/d at 99.99% of purity

UNDERGROUND ARGON PROJECT: Urania

Urania Status: plant



Production



Leak test



Shipping & Storage



UNDERGROUND ARGON PROJECT: Urania

Urania Site: Executive Design



UNDERGROUND ARGON PROJECT: Urania

Urania Site Civil Construction



UNDERGROUND ARGON PROJECT: Urania

Urania Site Civil Construction

13182 Rd 15, Cahone, CO 81320, USA

☀ 10° N (T) • 37.708184, -108.773187 ±315ft



20 Dec 2023,
5:09:06 PM

13182 Rd 15, Cahone, CO 81320, USA

☀ 70° NE (T) • 37.709308, -108.773112 ±16ft



19 Dec 2023,
1:52:05 PM

UNDERGROUND ARGON PROJECT: Urania

Transportation Vessel

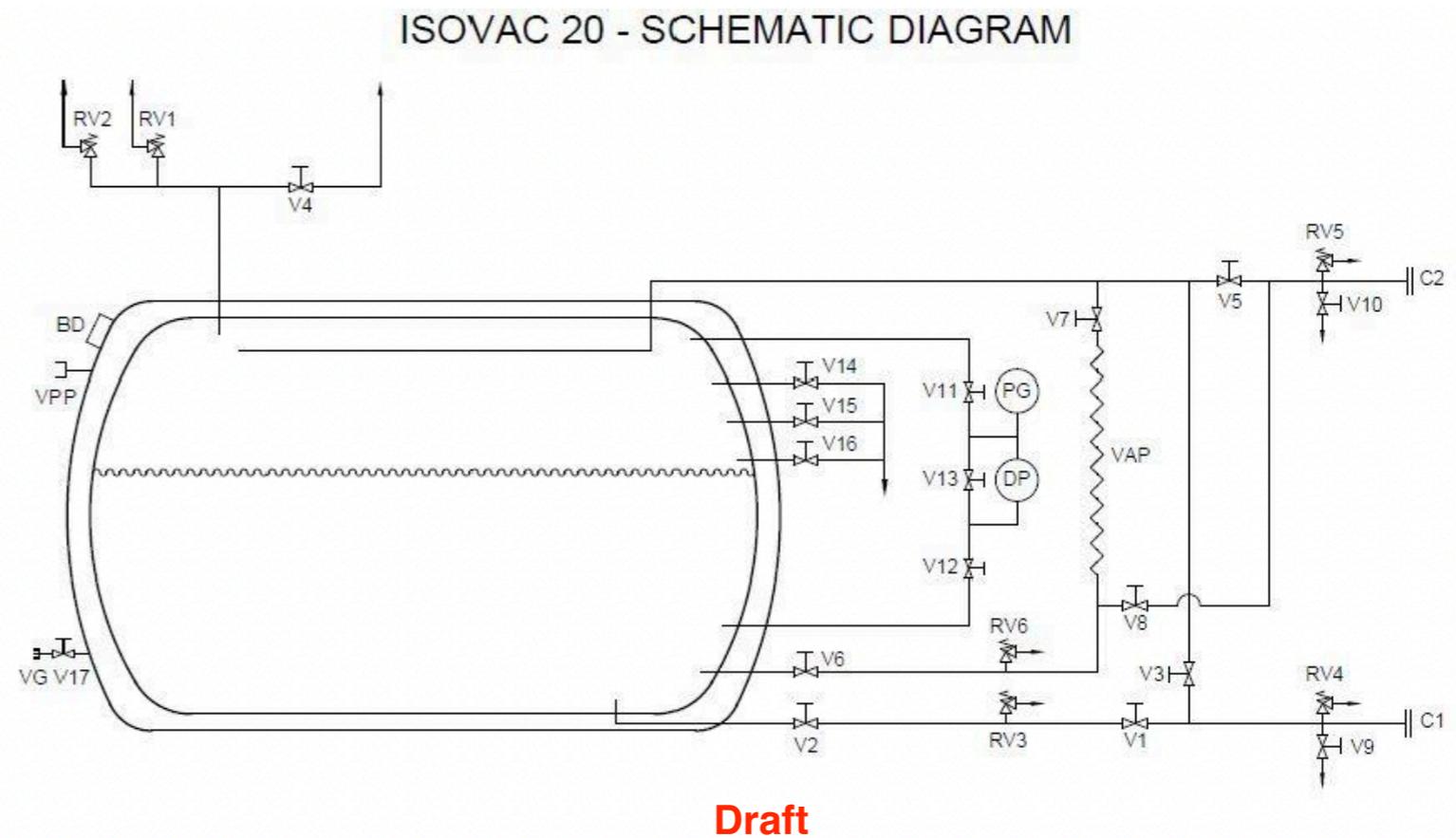


Urania LUAr Vessel - example of model

UNDERGROUND ARGON PROJECT: Urania

Transportation Vessel

- Tanks will include an integrated cooling coil for condensing the argon
- Cooling coil is estimated to a minimum of 18m in length and 1 inch diameter
- Approximately 3 days to reset container to 0 barg from peak pressure



UNDERGROUND ARGON PROJECT: Aria

Main Partners and Institutes involved

- INFN
- Carbosulcis S.p.A. & Regione Autonoma della Sardegna (RAS)
- Princeton University
 - Polaris Engineering
- DarkSide Collaboration
 - Università di Cagliari
 - LNGS
 - Fermilab
 - ITIM
 - Politecnico di Milano
 - UCLA
 - Università Federico II di Napoli
 - ENEA
 - Fondazione Aria
 - CERN (for leak test contribution)

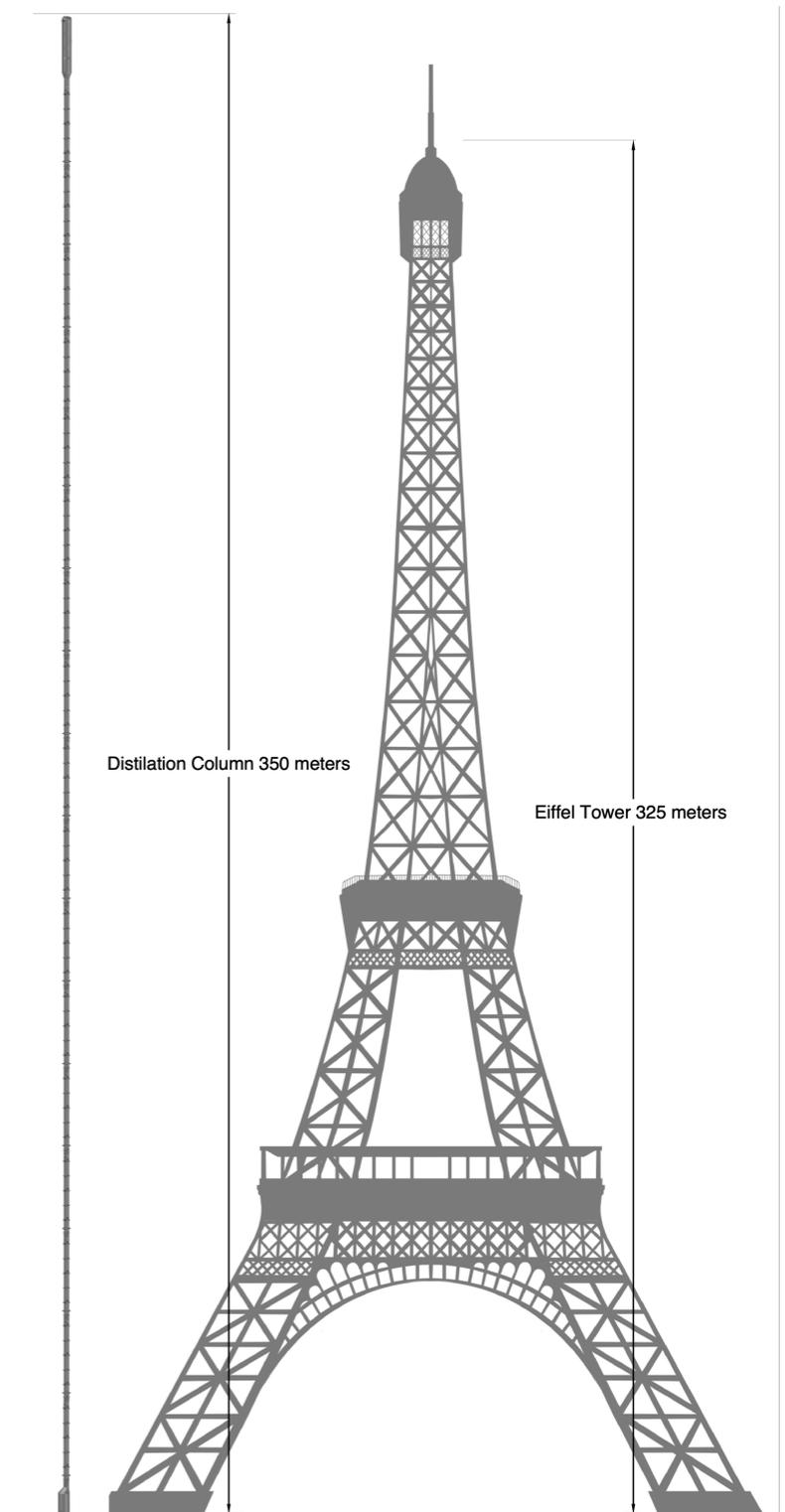


UNDERGROUND ARGON PROJECT: Aria

Main Featuring

- Cryogenic distillation column (total height ~350 m)
 - 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
 - Inner Diameter of the column: 31.8 cm
 - Outer Diameter of cold box: 71.2 cm
- Process is based on the difference in volatility
- Packing: CY from Sulzer
- Number of theoretical stages: ~2870
- Chemical Purification rate: 1 t/d (or more)

Aria column



UNDERGROUND ARGON PROJECT: Aria



UNDERGROUND ARGON PROJECT: Aria





UNDERGROUND ARGON PROJECT: Aria

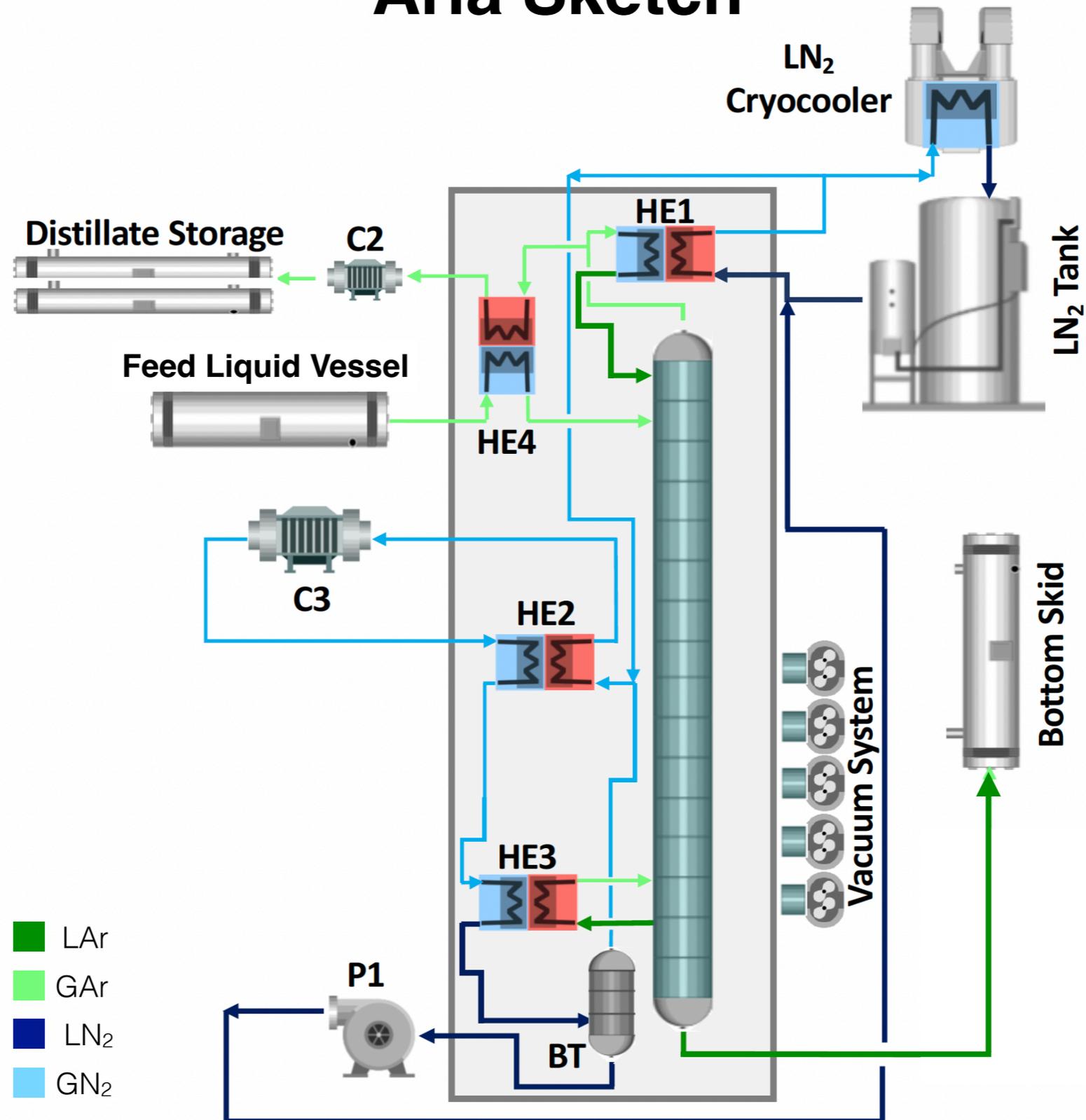
CarboSulcis Mine

Seruci Mine Shaft



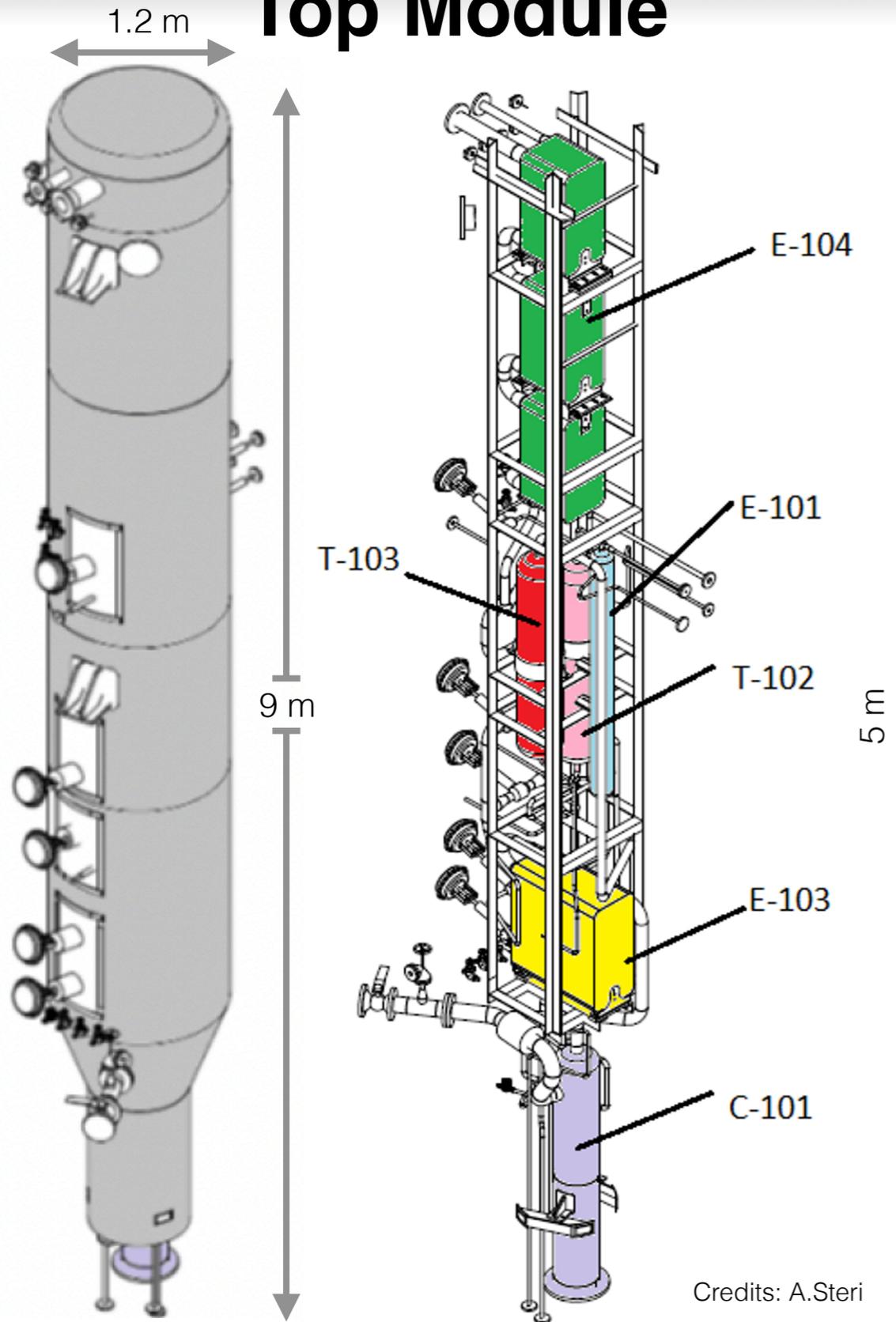
UNDERGROUND ARGON PROJECT: Aria

Aria Sketch

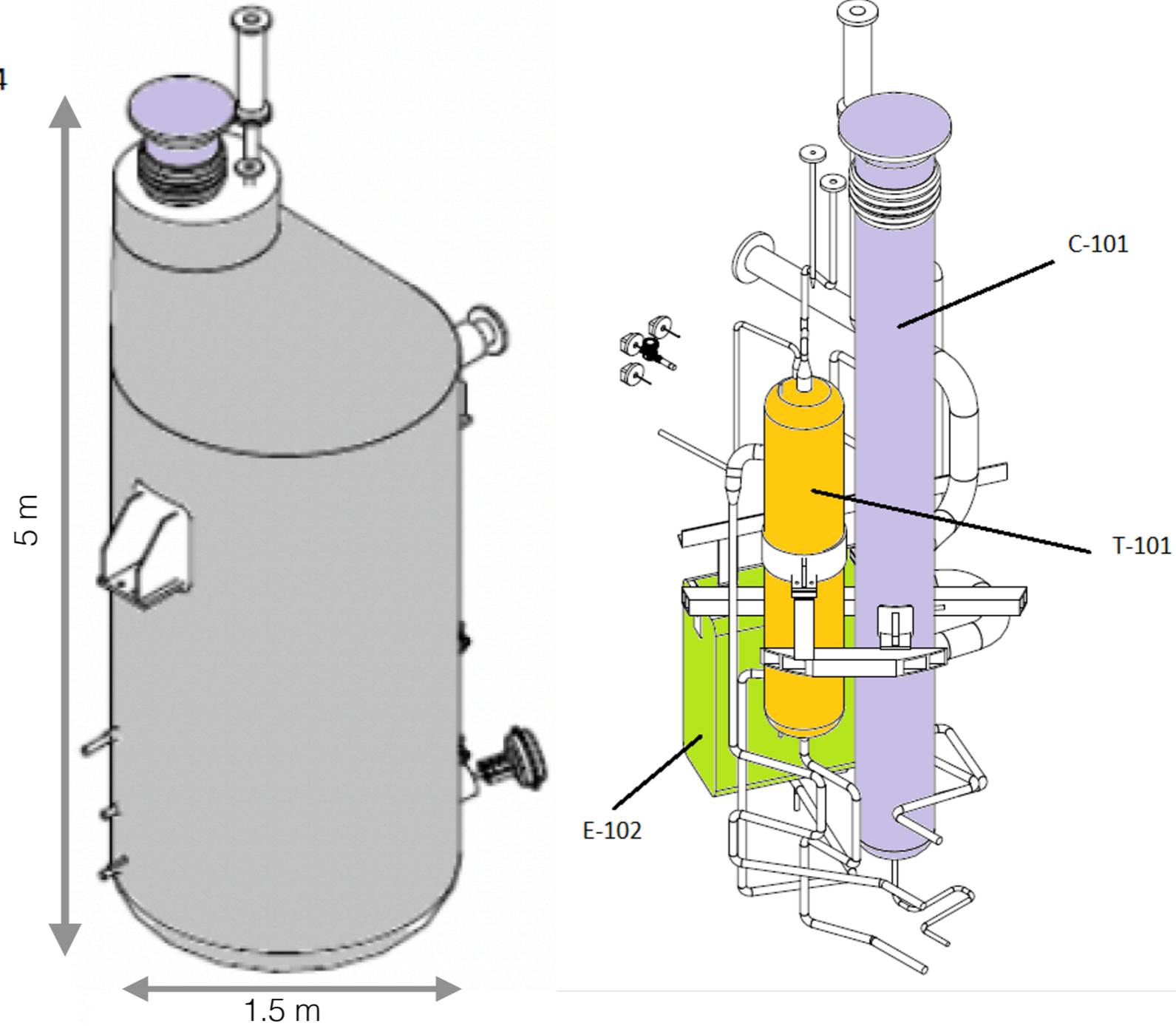


UNDERGROUND ARGON PROJECT: Aria

Top Module



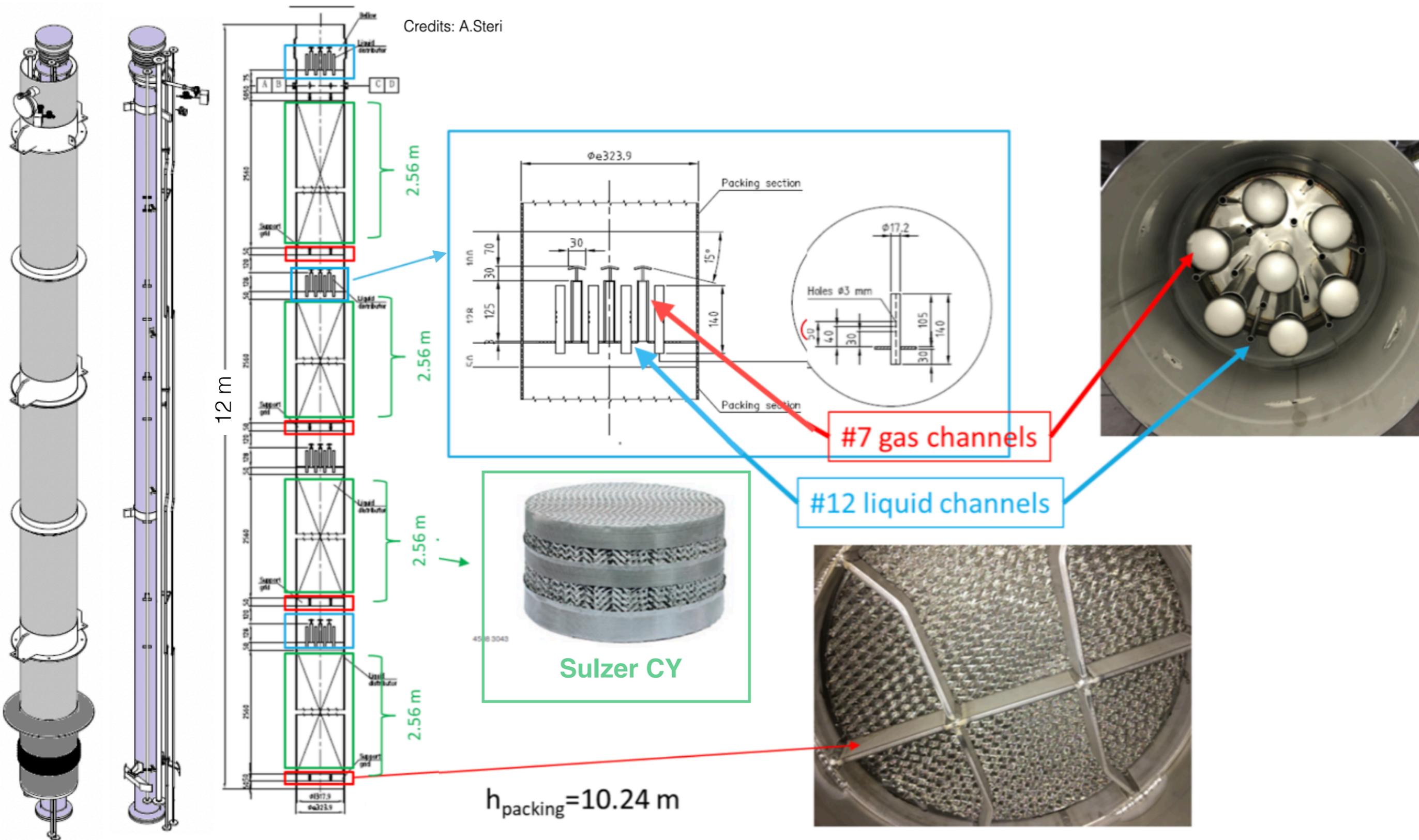
Bottom Module



Credits: A.Steri

UNDERGROUND ARGON PROJECT: Aria

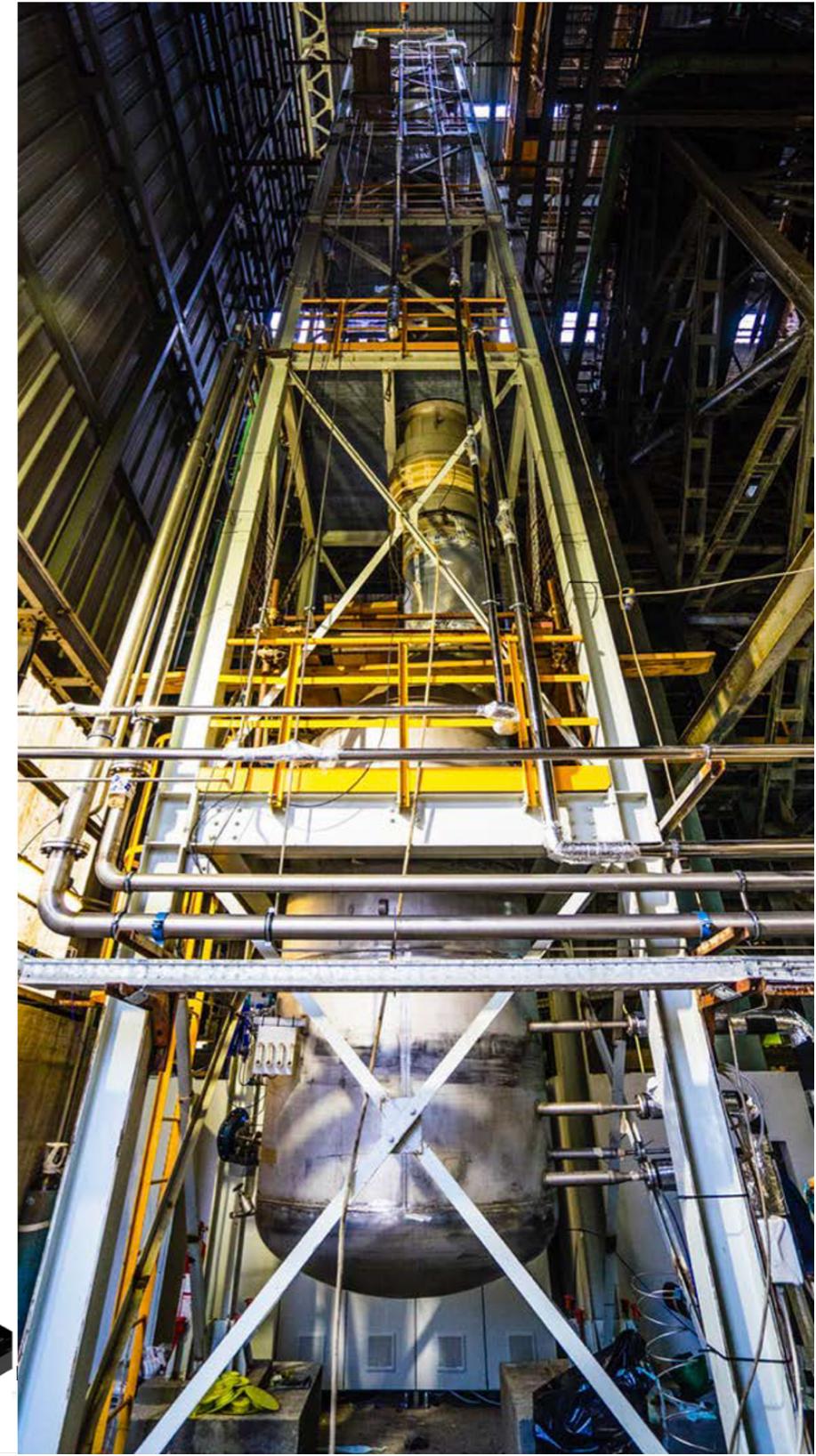
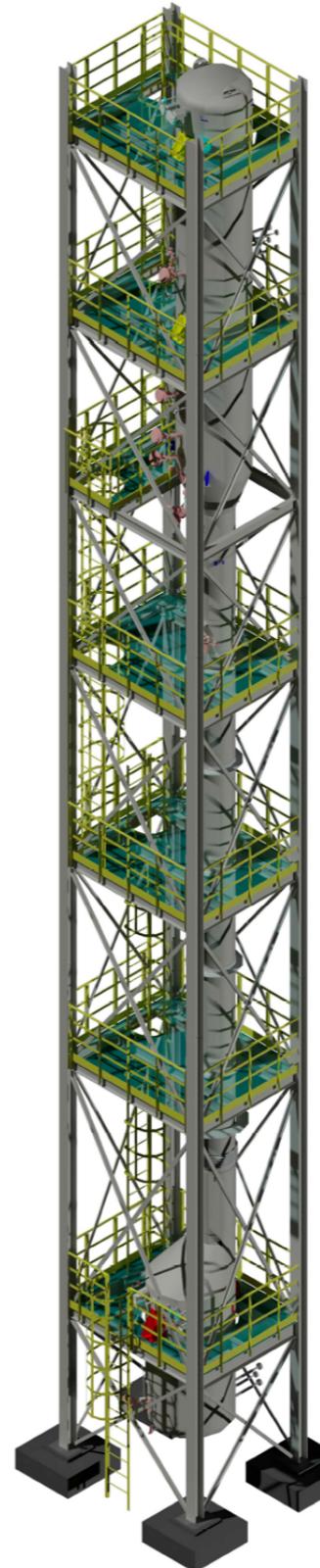
Central Module



UNDERGROUND ARGON PROJECT: Aria

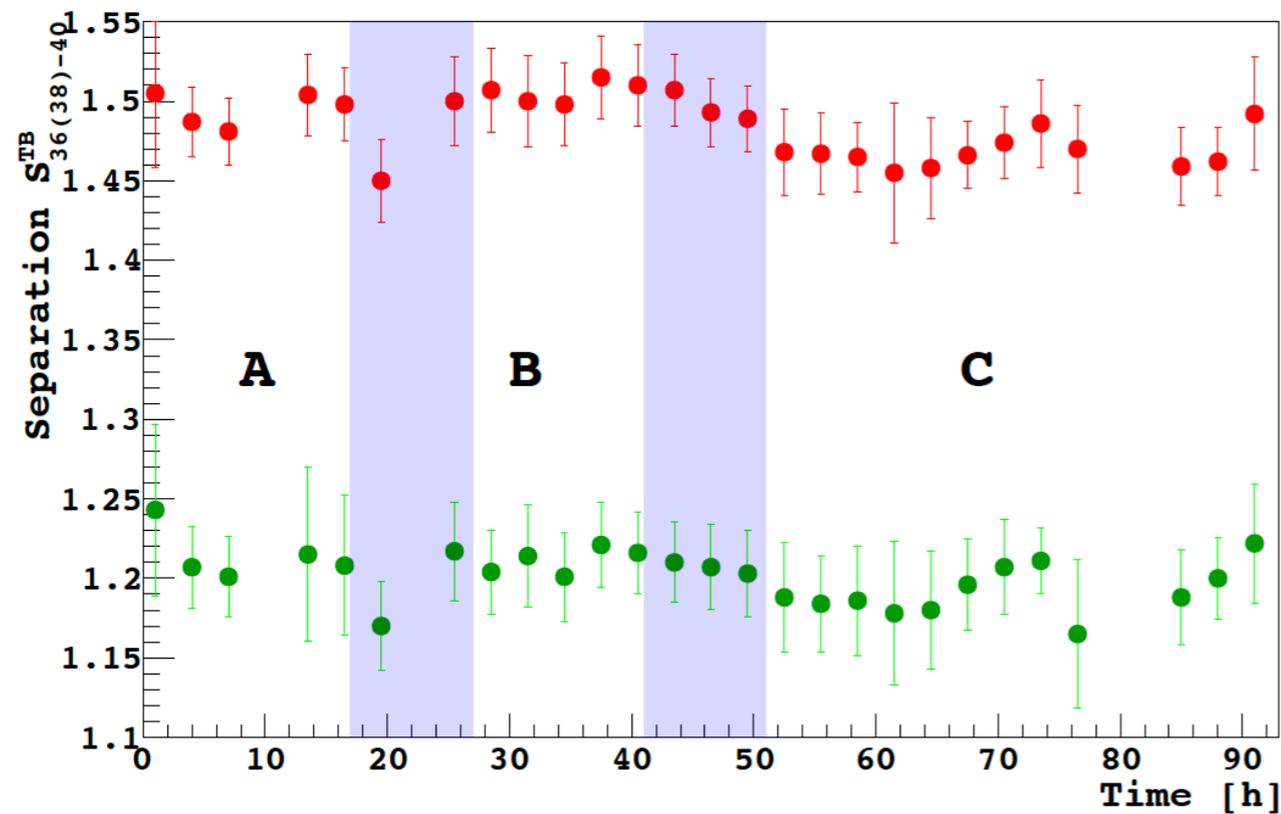
Aria Status: Seruci-0

- Reduced scale cryogenic distillation column (total height ~26 m)
 - 1 Central modules: 12 m each
 - 1 Condenser (top) module: 7 m
 - 1 Reboiler (bottom) module: 5m
- 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)



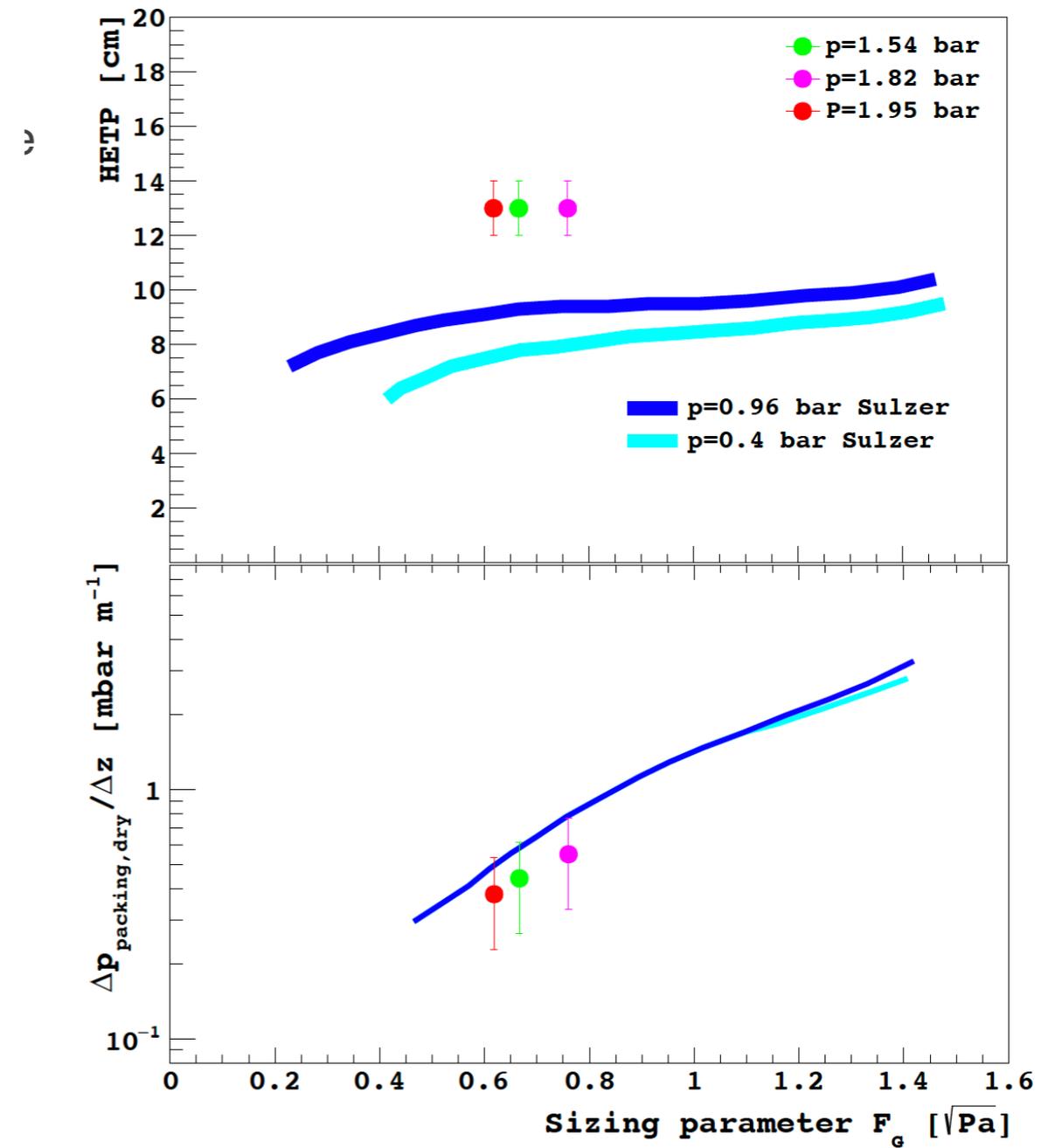
UNDERGROUND ARGON PROJECT: Aria

Aria Status: Result from Ar run



Separation S_{36-40}^{TB} (red) and S_{38-40}^{TB} as a function of time

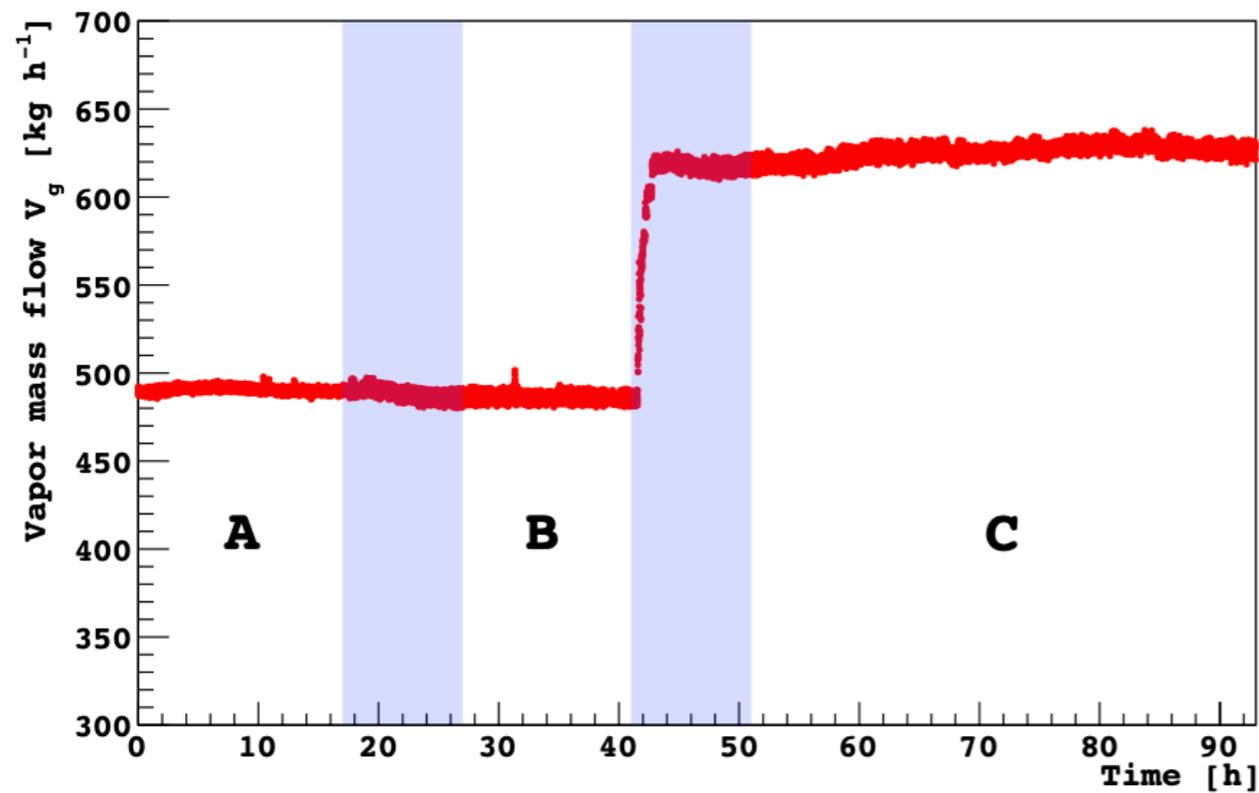
$$S_{36-40} = S_{T-B} = \frac{\left(\frac{x_{36}}{x_{40}}\right)_T}{\left(\frac{x_{36}}{x_{40}}\right)_B}$$



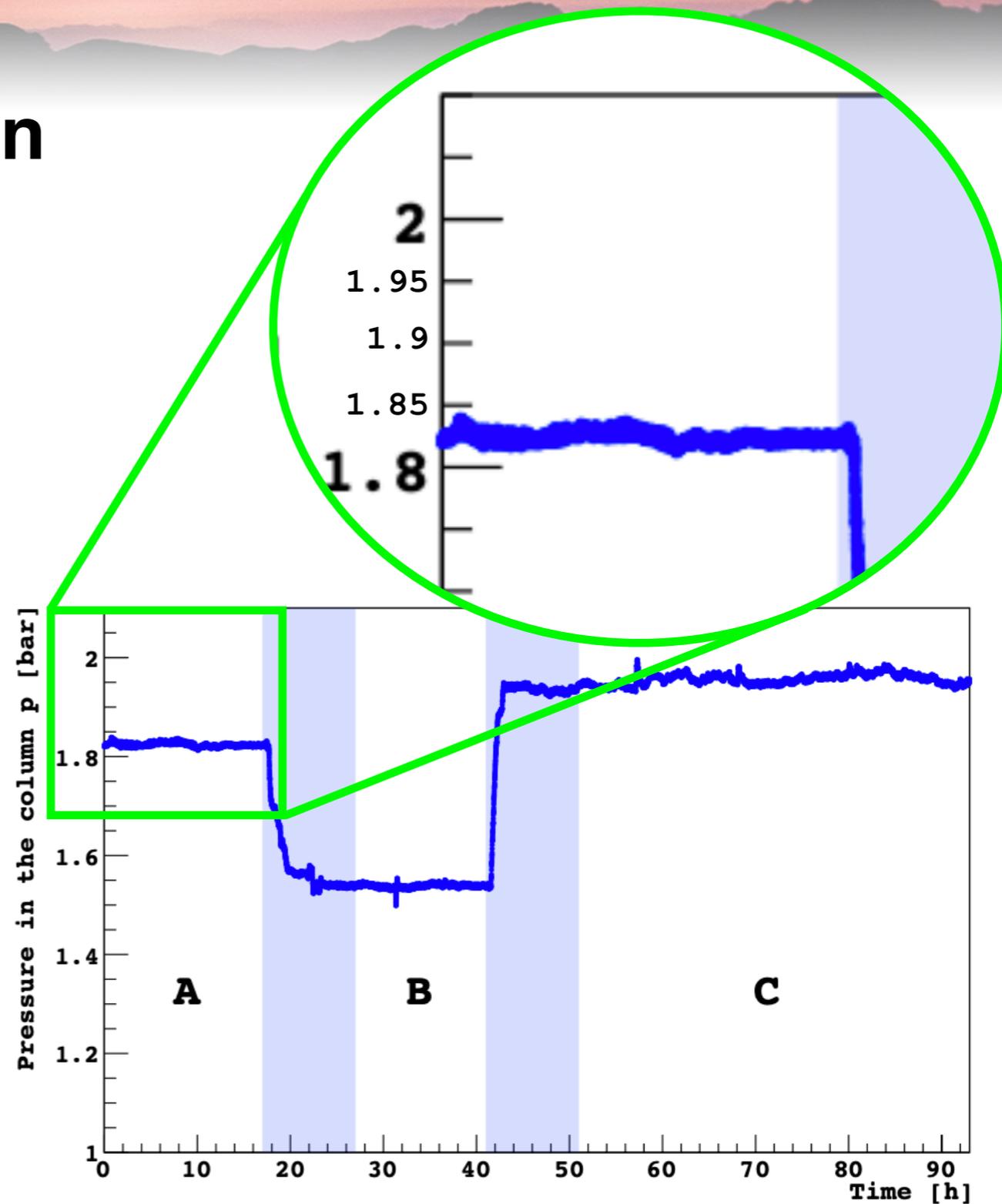
Measured HETP and comparison with Sulzer

UNDERGROUND ARGON PROJECT: Aria

Aria Status: Result from Ar run



Vapour mass flow rate in the auxiliary system.



Pressure inside the column.

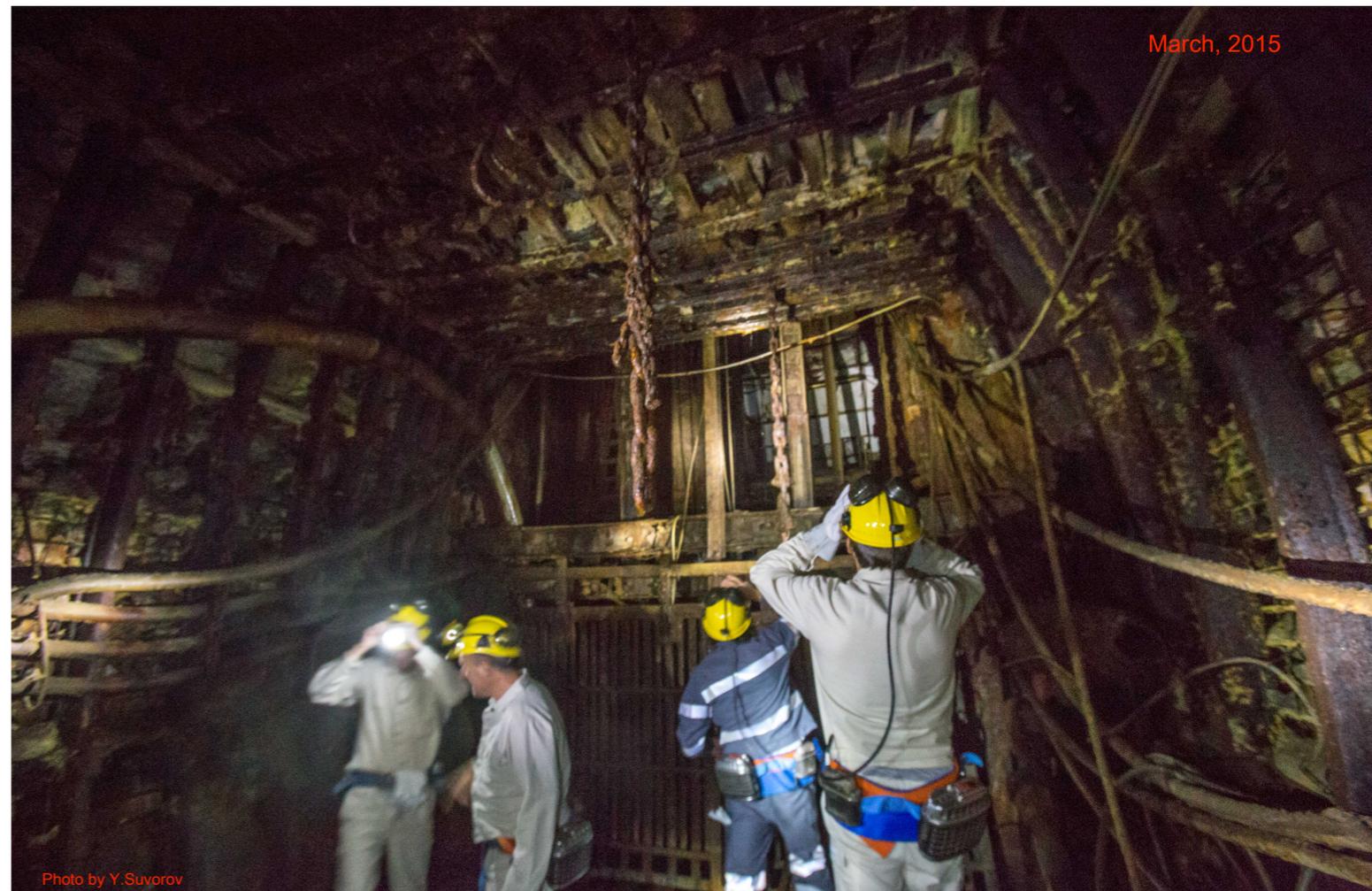
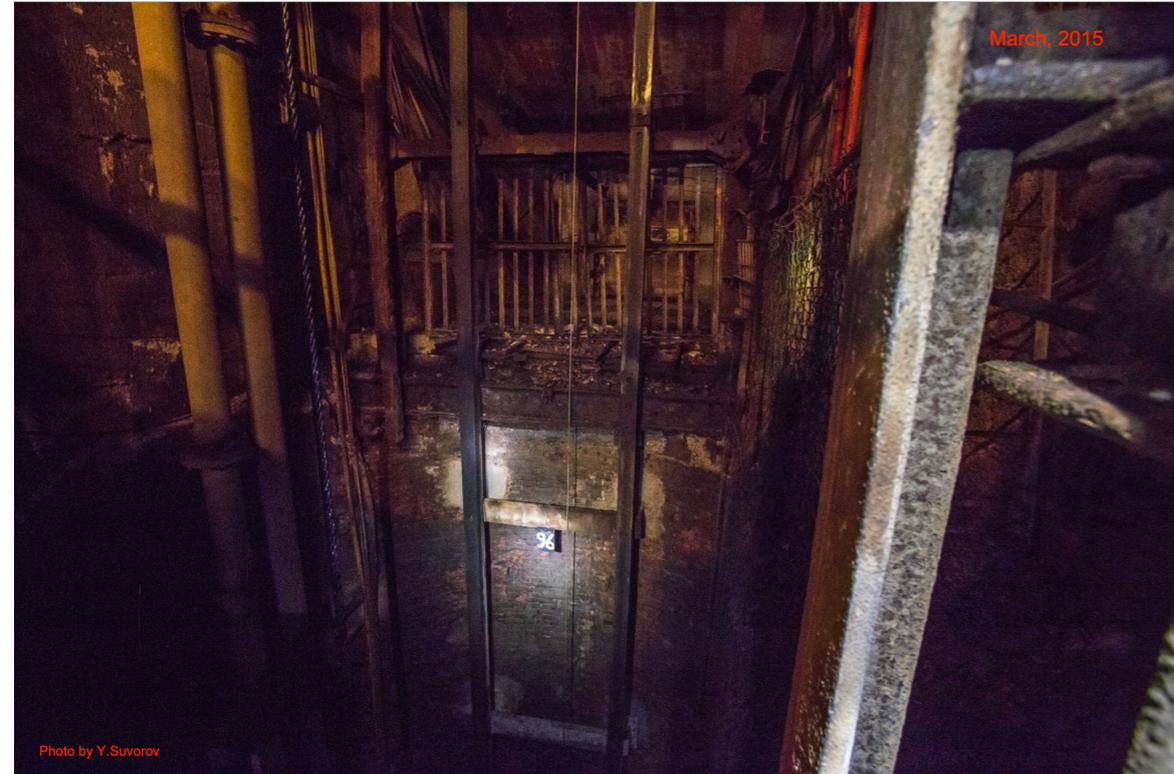
UNDERGROUND ARGON PROJECT: Aria

Aria Status: plant



UNDERGROUND ARGON PROJECT: Aria

Aria Status: Refurbishing



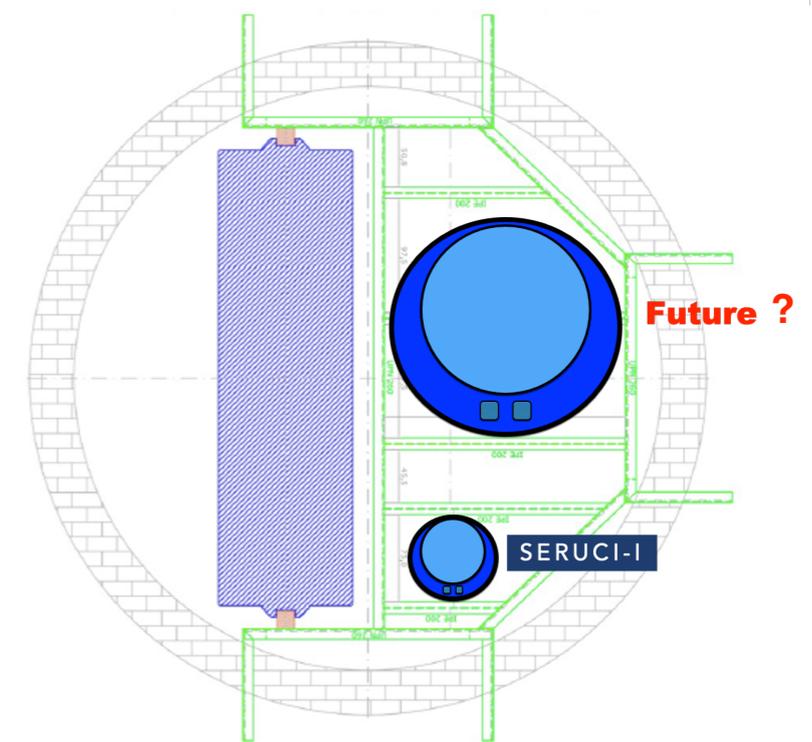
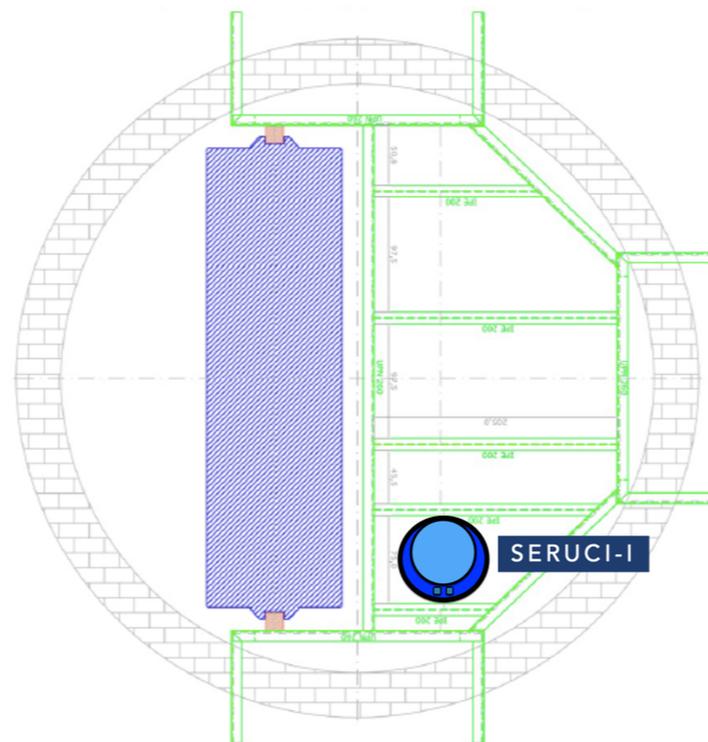
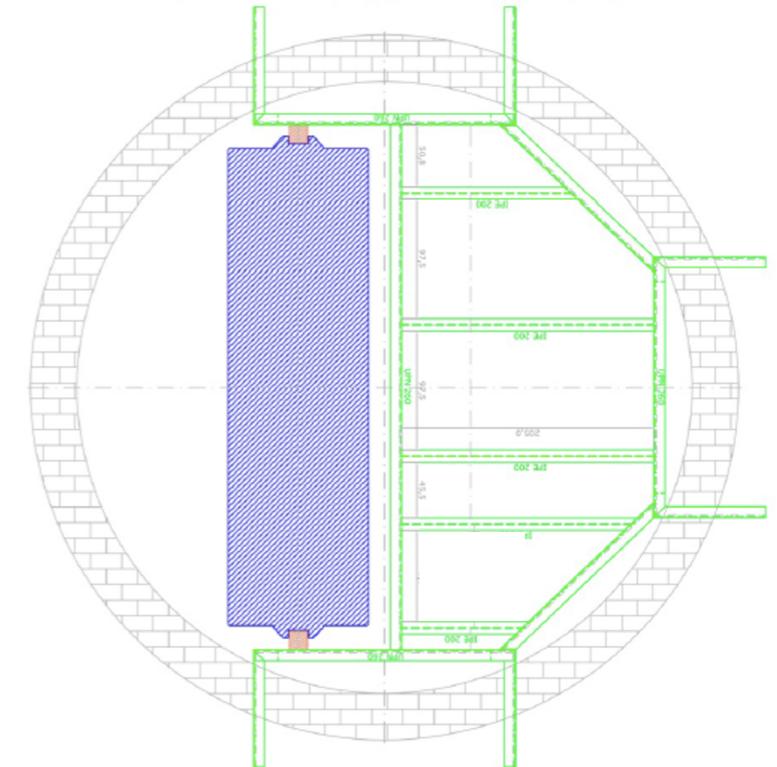
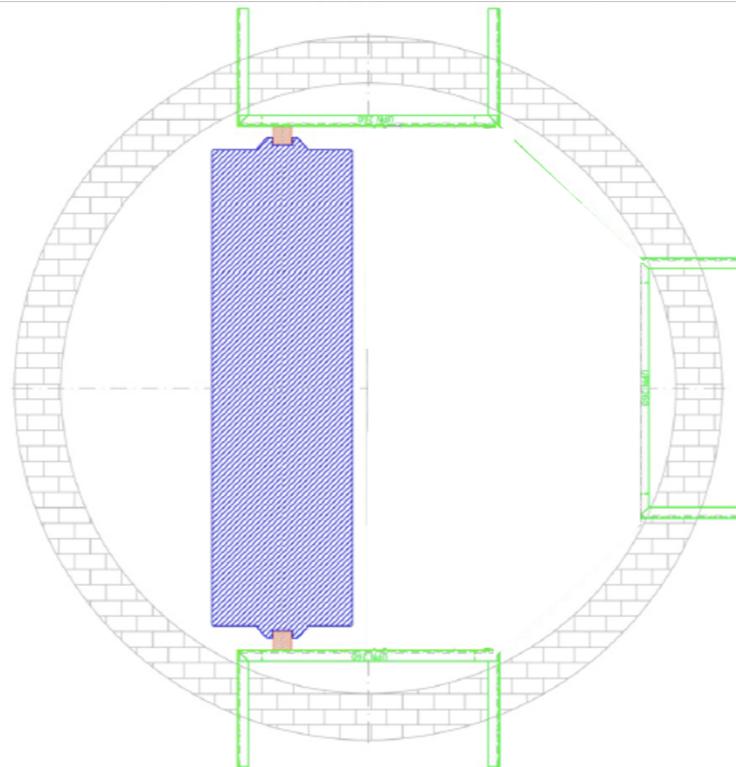
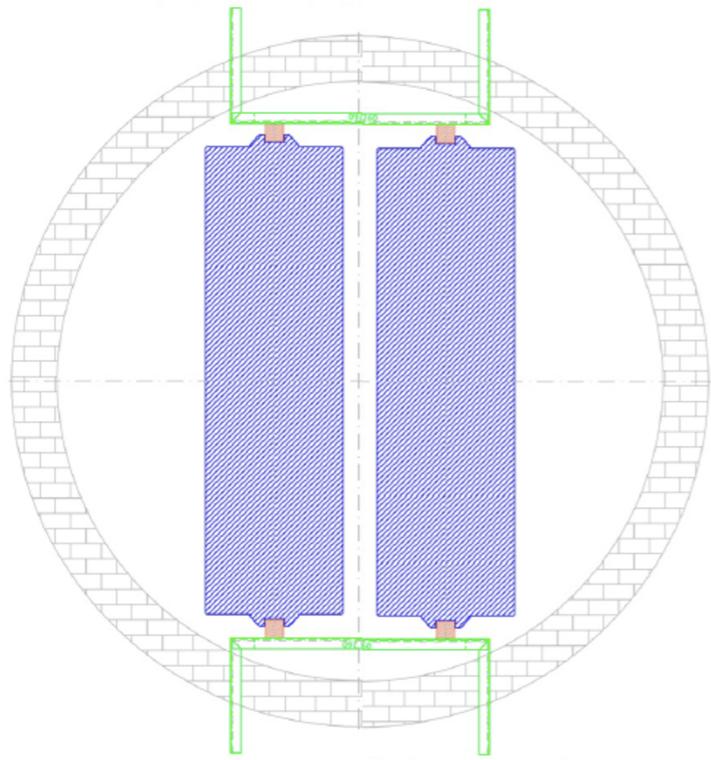
UNDERGROUND ARGON PROJECT: Aria

Aria Status: Refurbishing



UNDERGROUND ARGON PROJECT: Aria

Aria Status: Shaft



Ph. by Carbosulcis S.p.A

UNDERGROUND ARGON PROJECT: Aria

Aria Status: Refurbishing





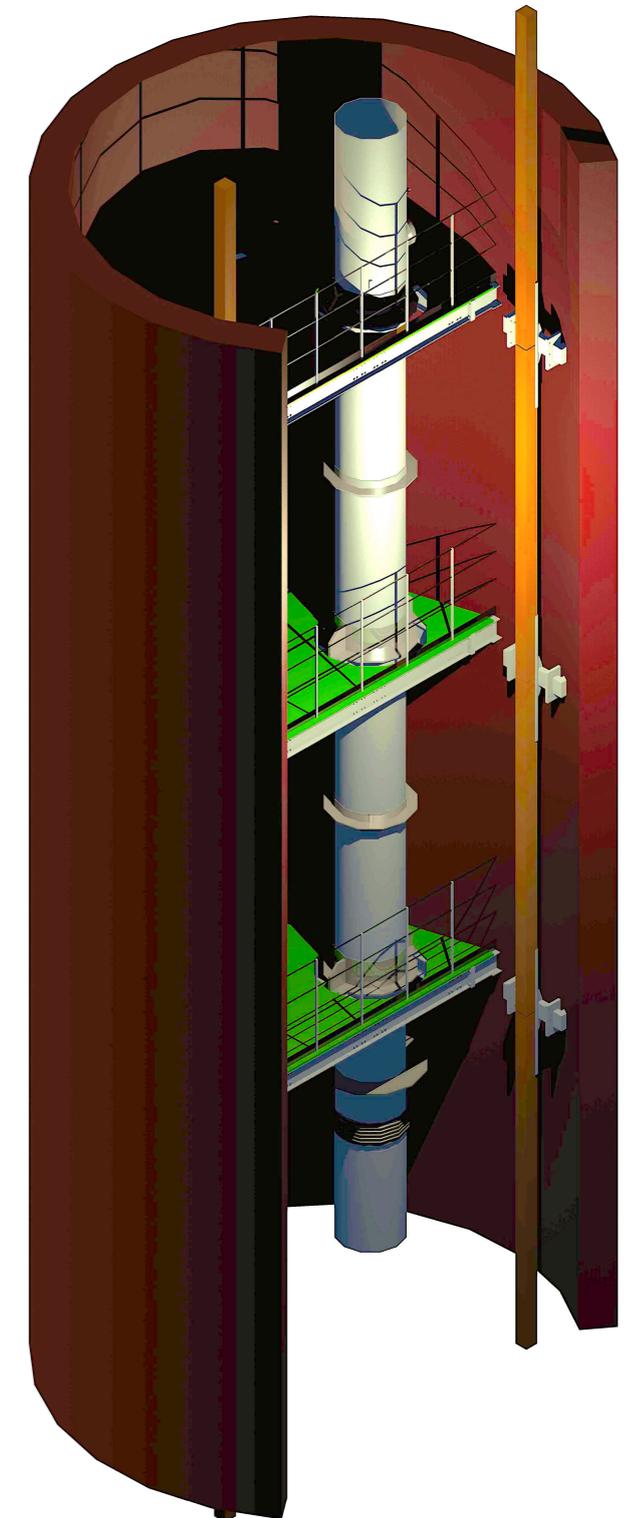
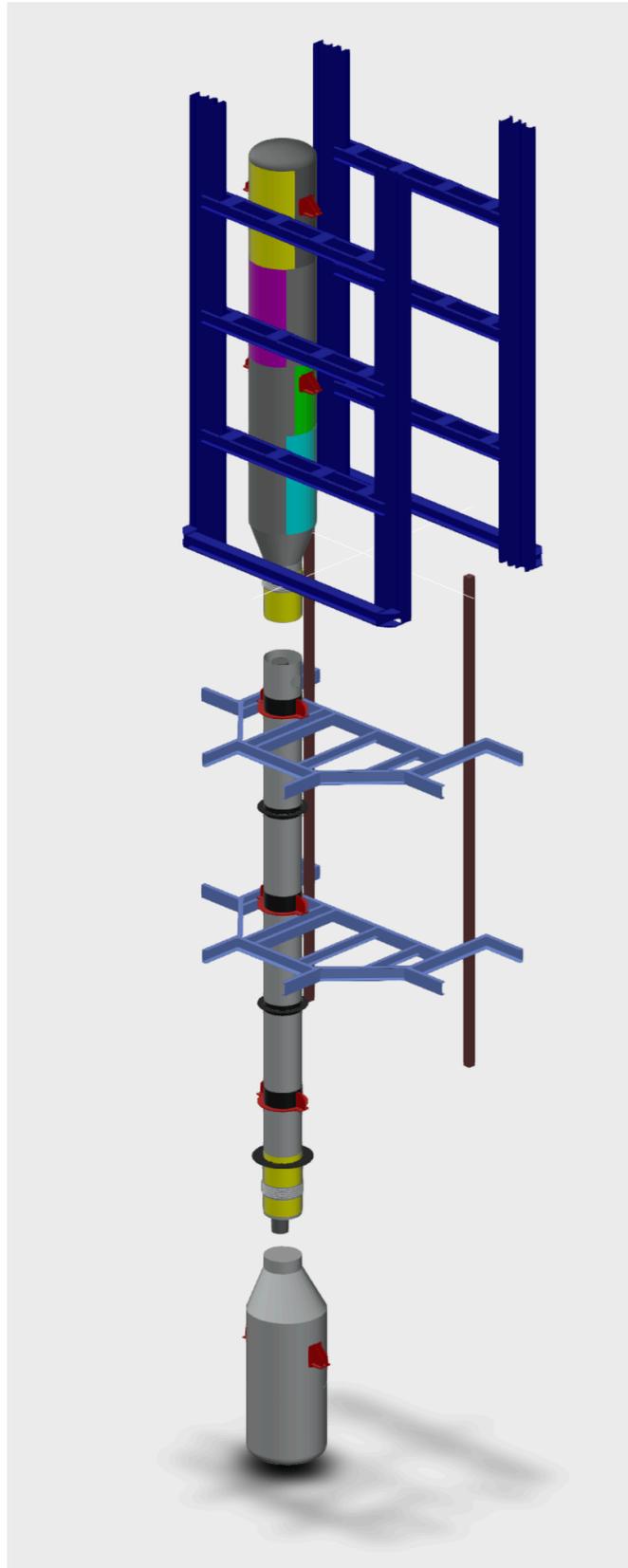
UNDERGROUND ARGON PROJECT: Aria

Aria Status: Castello Support Structure



UNDERGROUND ARGON PROJECT: Aria

<https://www.carbosulcis.eu>



UNDERGROUND ARGON PROJECT: DArT

Main Partners and Institutes involved

- LSC
- Ciemat
- DarkSide Collaboration
 - INFN di Cagliari
 - Università di Cagliari
 - Università Federico II di Napoli
 - APC Paris
 - ETH Zurich
 - LNGS
 - GSSI
 - University of Carleton



UNDERGROUND ARGON PROJECT: DArT



Not in scale

Polyethylene shielding

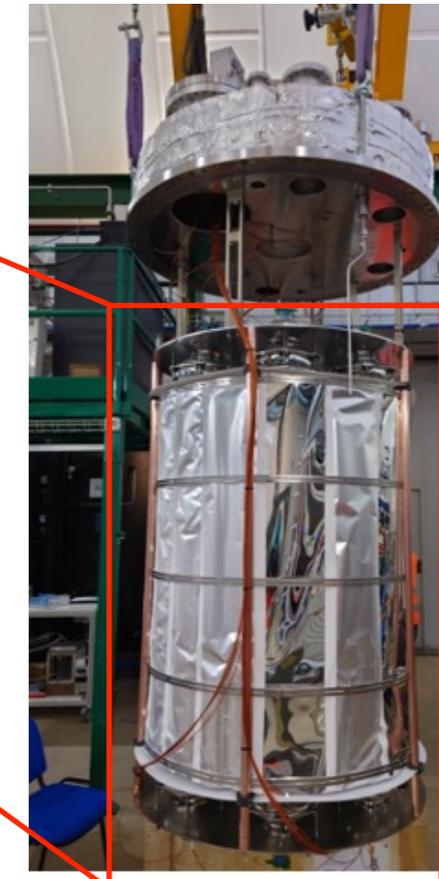
Sectional view of ArDM

DArT detector

Support rings

Lead shield

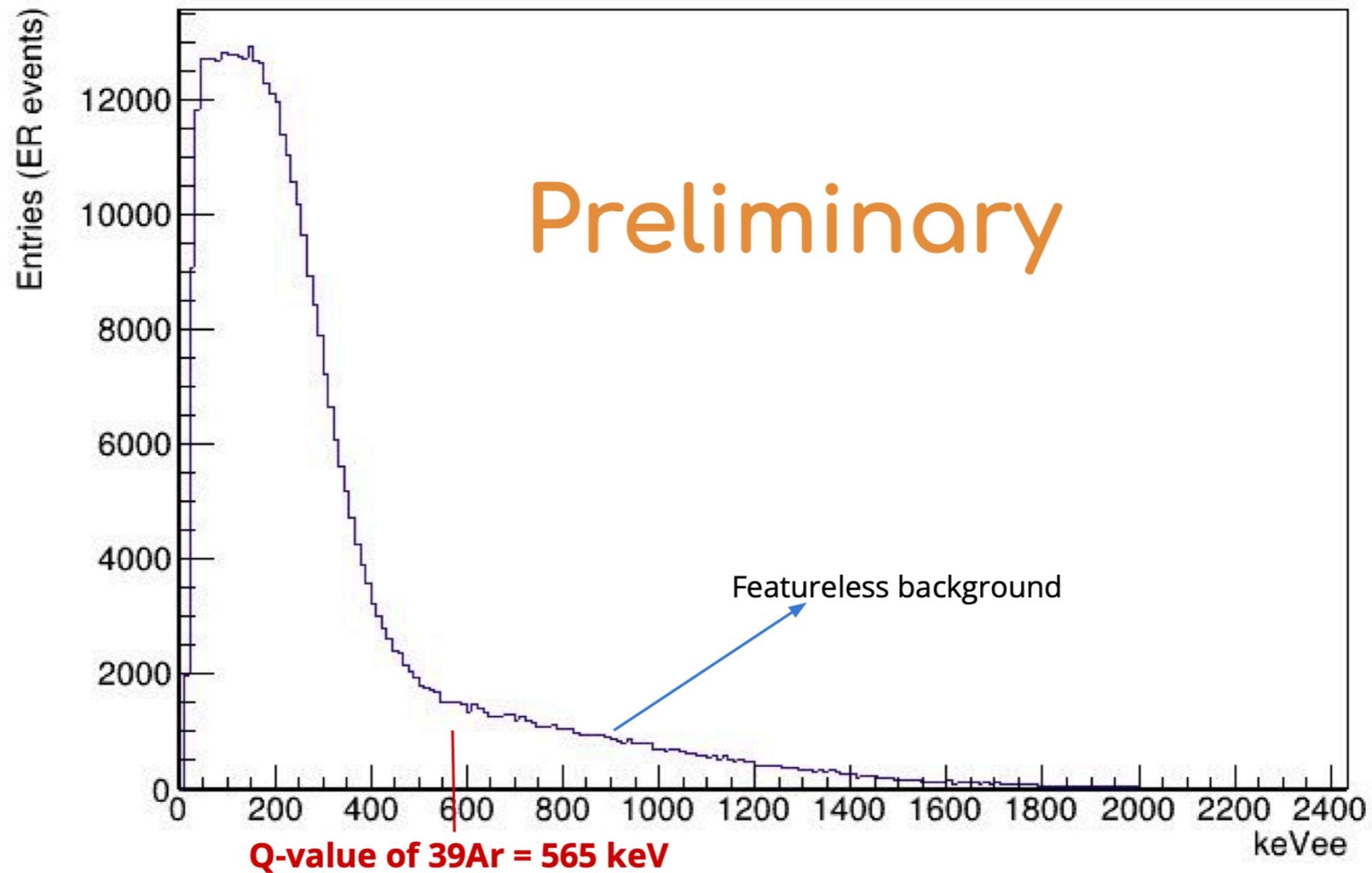
Support plate



- Single-phase inner detector for 1.42 kg of liquid UAr
- DArT will be installed inside ArDM:
 - 13 PMTs
 - ~1 tonne liquid AAr buffer
 - New Pb-Shield

UNDERGROUND ARGON PROJECT: DArT

DArT: Preliminary Result



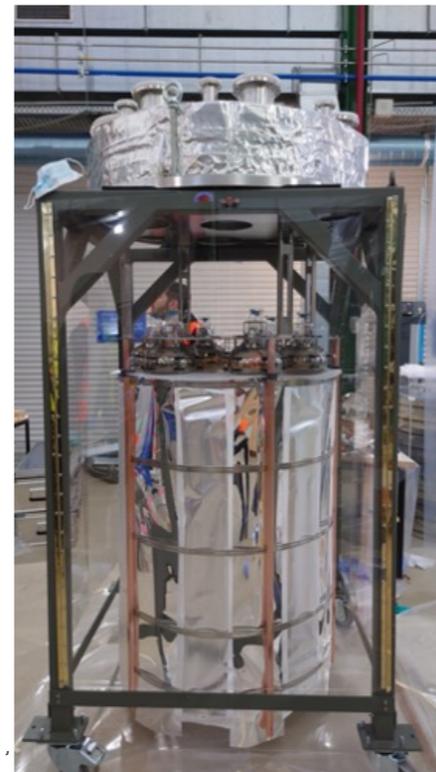
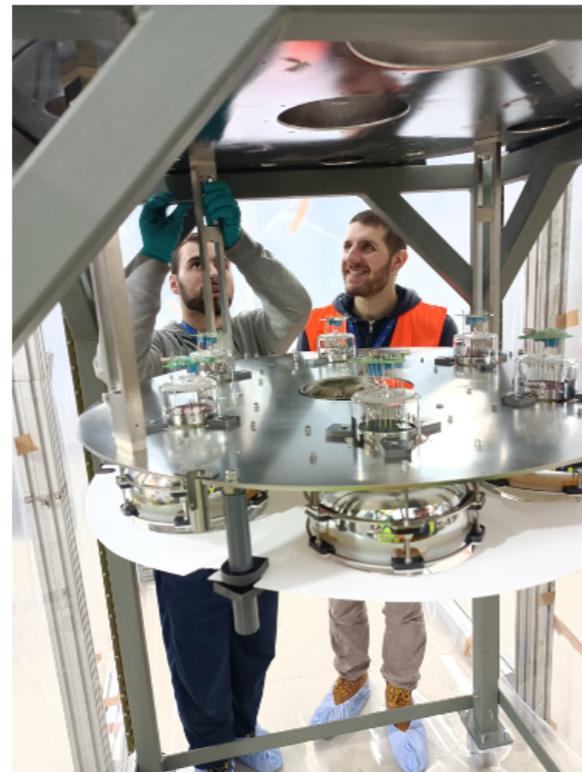
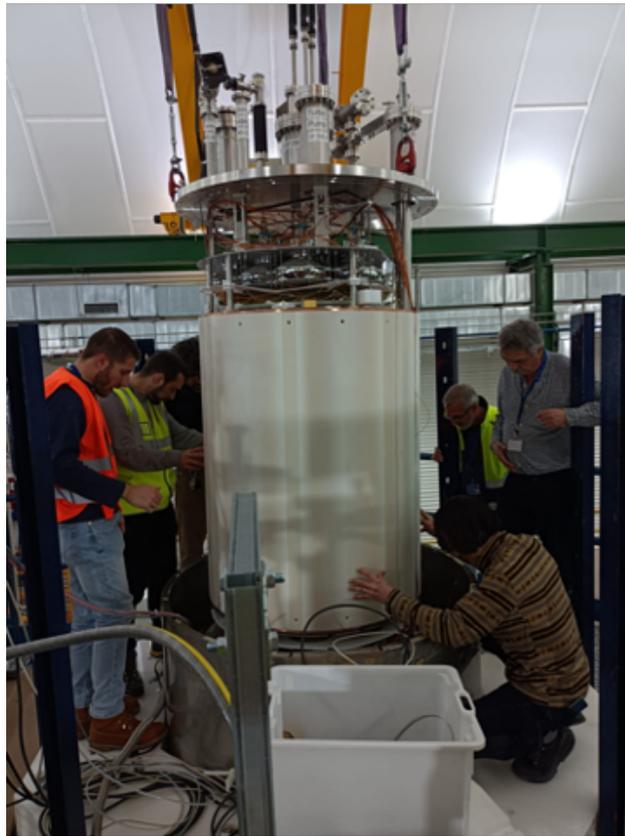
^{39}Ar depletion factor sensitivity: (2020 JINST 15 P02024)

UNDERGROUND ARGON PROJECT: DArT

DArT Status

...infrastructures for cleaning and assembly procedures...

Old ArDM extracted....



...insertion
in final configuration.



UNDERGROUND ARGON PROJECT: Future Interests

Future interests in particle physics:

- DarkSide-20k  120 t
- LEGEND 1000  30 t
- COHERENT LAr  1 t
- ARGO  400 t
- DarkSide-Lowmass 1t of depleted argon
- SN neutrinos in a DUNE-like detector



The end

Contact:

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