



LSC

Laboratorio Subterráneo de Canfranc

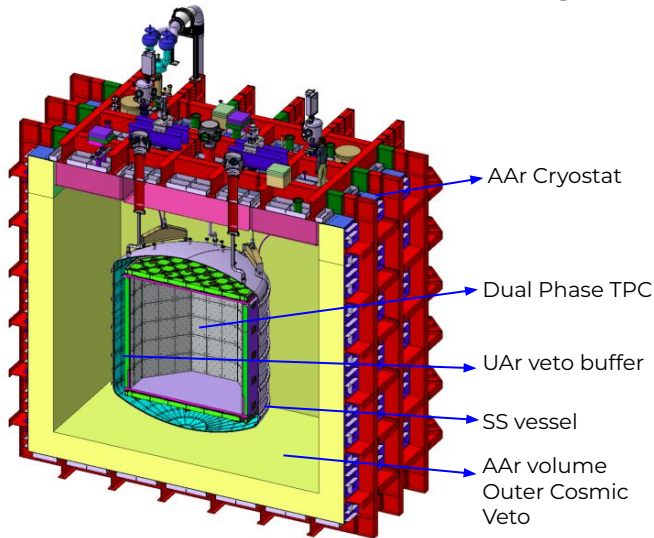
Measuring ^{39}Ar Background for DarkSide-20k with DArTinArDM

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On behalf of the DarkSide-20k
Collaboration.

DarkSide-20k : Overview

After DarkSide-50, the next project of GADMC is DarkSide-20k to be commissioned @LNGS Hall C.



- Octagonal shape dual phase argon TPC:
 - ◆ Active UAr mass: 49.7 tonnes;
 - ◆ Fiducial UAr mass: 20.2 tonnes;
- Neutron veto:
 - ◆ Active UAr mass: 32 tonnes.
- The inner detector is immersed in the AAr bath (~700 tonnes)

Projections for DarkSide-20k:

Sensitivity to SI WIMPs;

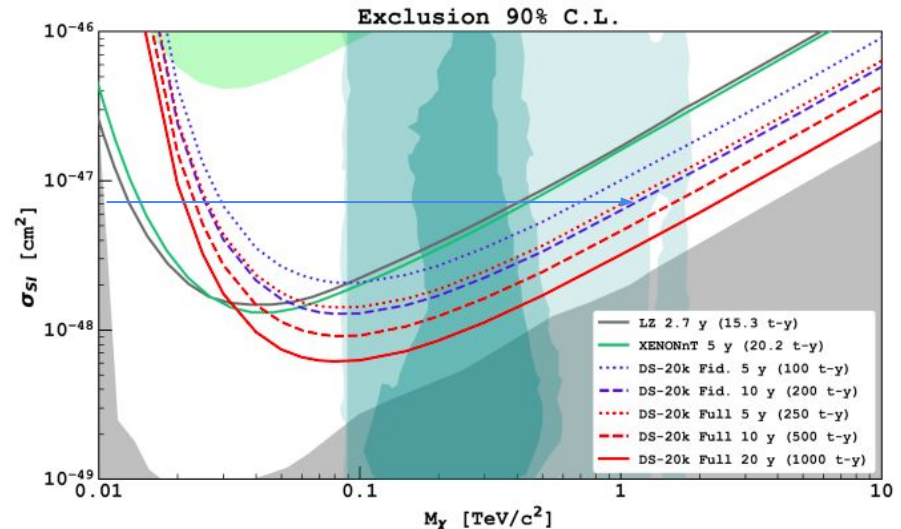
With nominal exposure 200 t-y (20 t x 10 years):

- 90% C.L. exclusion:
 $6.3 \times 10^{-48} \text{ cm}^2$ @1 TeV/c² ;
- 5 σ discovery:
 $2.1 \times 10^{-47} \text{ cm}^2$ @1 TeV/c² ;
- 3.2 CEvNS events expected.

Expected background:

< 0.1 neutron in RoI (30 ~ 200 keV_n) with 200 t-y exposure.

Turquoise filled contours from pMSSM11 model Eur. Phys. J. C 78, 87 (2018)



Liquid Argon : An ideal target...

Liquid Argon (LAr) is a very powerful tool for Dark Matter search and many rare event searches.

- High scintillation and ionization yield
- Ar has a light nucleus
- very high pulse shape discrimination (PSD) to identify nuclear recoils (NRs) separately from electron recoils (ERs).
(From DEAP 3600)
- Quite abundant in atmosphere (~ 1%)

These are good news when we think of designing a detector as big as DS-20k

DEAP-3600 PSD:
Eur. Phys. J. C 81.823 (2021)

Intrinsic background of atmospheric Ar,
Responsible isotope \Rightarrow ^{39}Ar , a beta emitter.

$Q_{\text{value}} = 565 \text{ keV}$

Activity = 1 Bq/kg

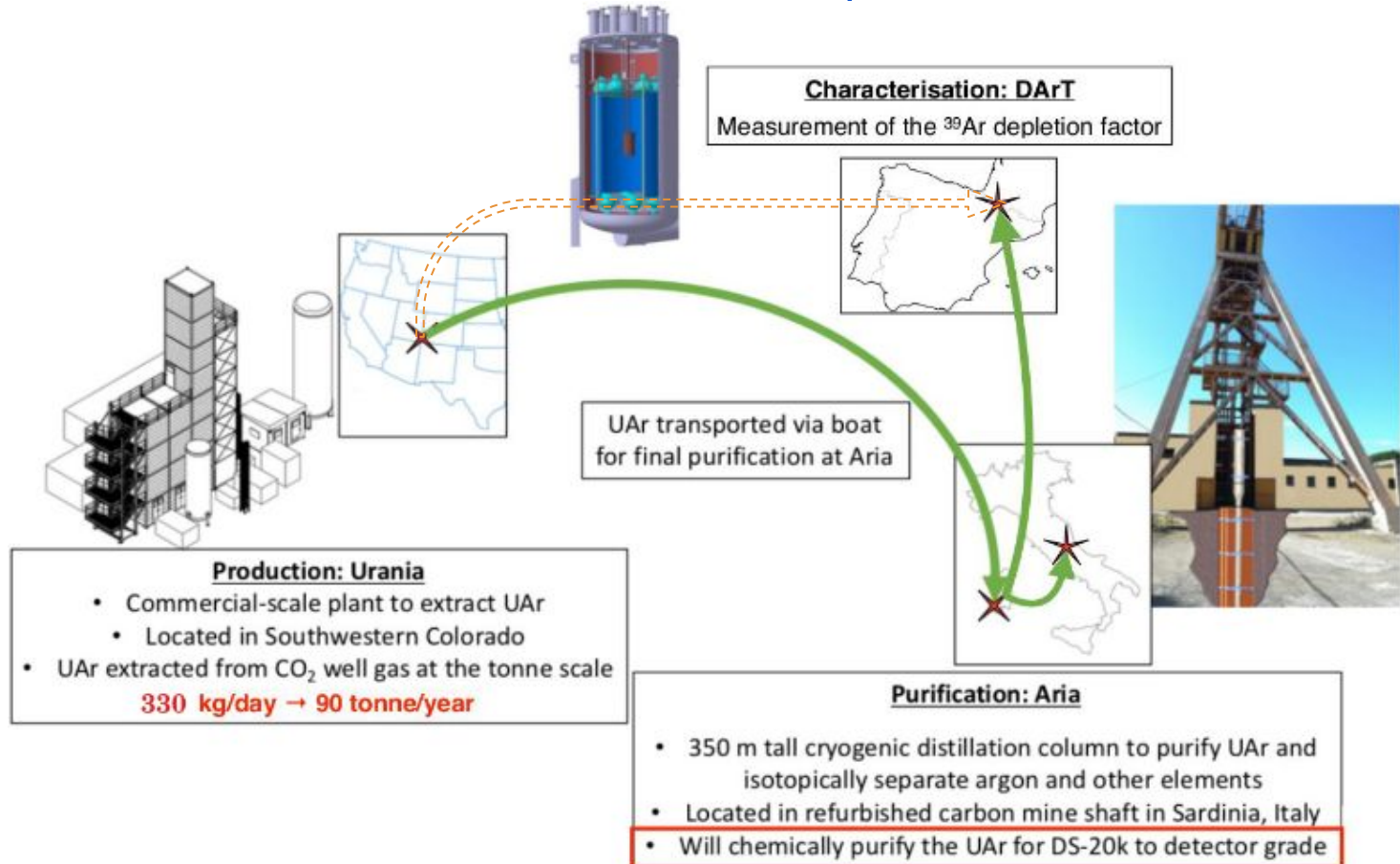
Half-life = 269 years

Primary Production \Rightarrow By spallation of cosmic rays on ^{40}Ar

- High trigger rate leading to pile up problem of ERs
- Poses a major problem for S2 only analysis
- Low performance of the PSD variable at lower energies

Argon stored underground is less depleted with ^{39}Ar . This is a choice we opt for.

Argon Chain of DS-20k : Urania, Aria and DArT



ARIA : Cryogenic Isotopic Distillation Plant

Aria will be the facility devoted to the cryogenic distillation of Ar.

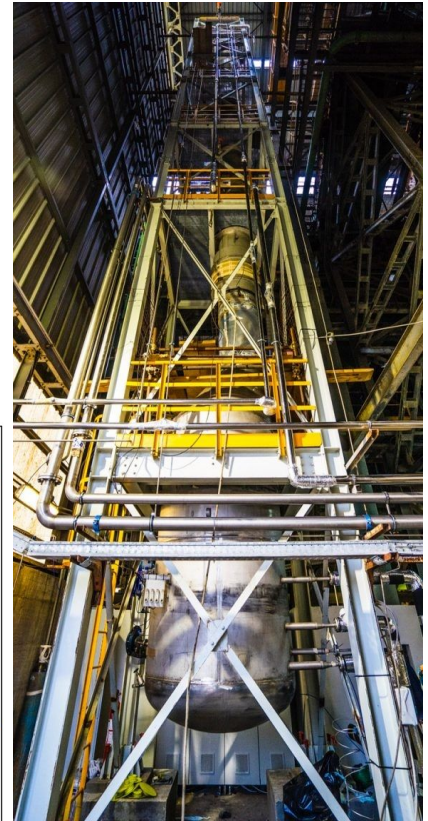
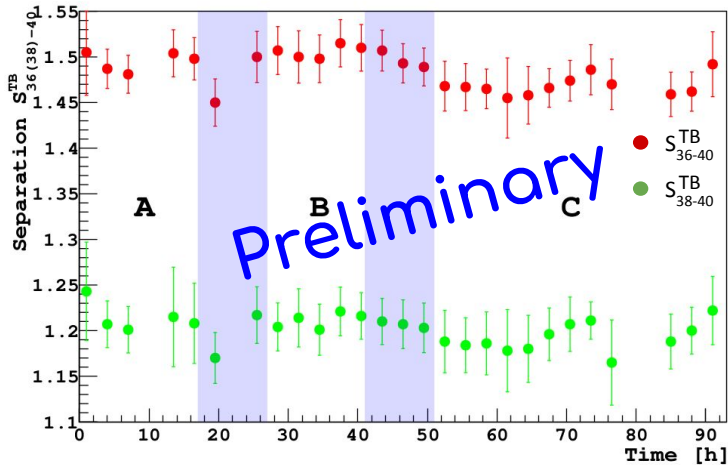
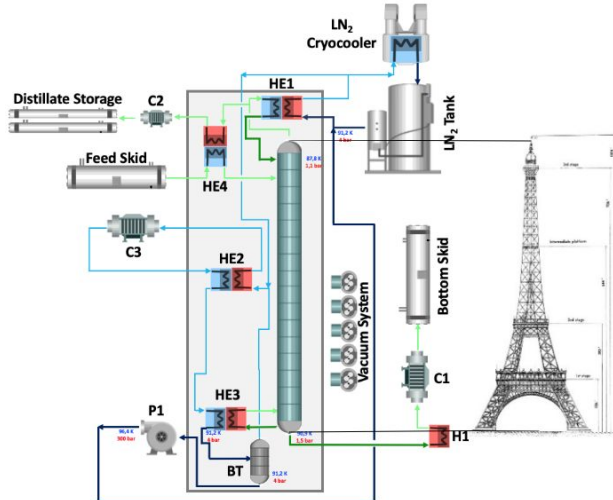
Seruci-0 (26 m instead of 350 m) already proved isotopic distillation of N_2 (in 2019 - 20).

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

In 2021, the same column processed Ar.

The first ever direct measurement of isotopic distillation of Ar in the world.

S_{i-j}^{TB} = main parameter for measuring the isotopic separation



Need for Characterization of UAr

As demonstrated by DarkSide-50, the UAr can have a depletion factor of ~ 1400 , w.r.t AAr activity (0.96 mBq ^{39}Ar equivalent activity).

But, this is just an upper limit, as re-evaluation of the UAr were indicative of air contamination. ($^{39}\text{Ar}/^{85}\text{Kr}$ source)

To avoid this in future, systems in place for air monitoring during future UAr production (at Urania)

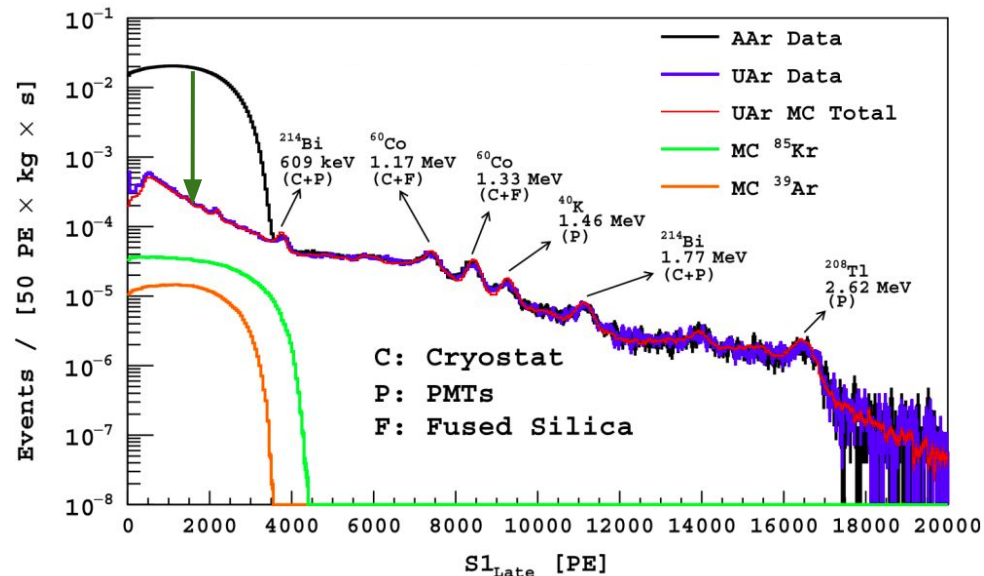


Final verification of ^{39}Ar levels are still required



This requires continuous operation.

Phys. Rev. D 93, 081101 (2016)



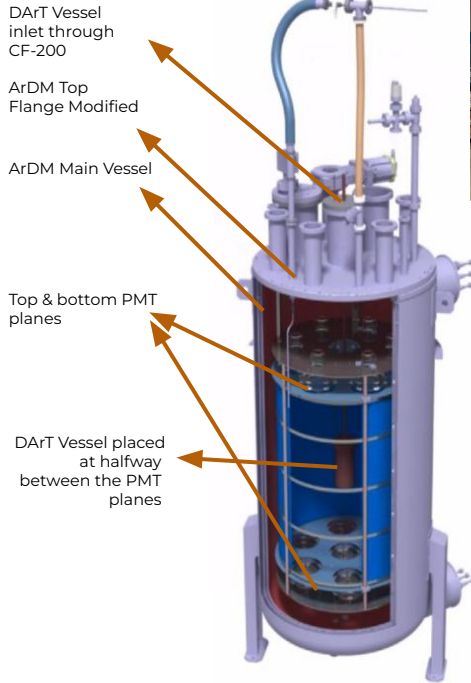
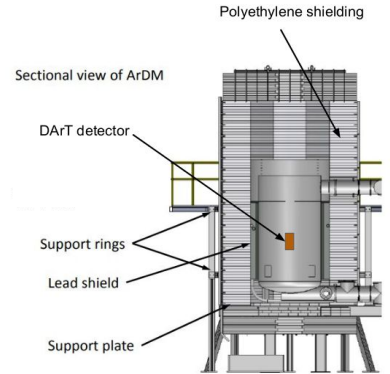
DArTinArDM Project at LSC



Full description: JINST 15 P02024 (2020)

DArT (Depleted Argon Target) refers to the small amount of Ar filled in a Cu vessel with an active mass of 1.35 kg.

- seen with two 1 cm^2 SiPMs
- Mylar reflectors
- inner acrylic structure coated with TPB.



The previous ArDM main vessel will be used as a active veto and shield.

- ~ 1 tonne of AAr.
- seen with 13 PMTs
- Pb + Polyethylene shield



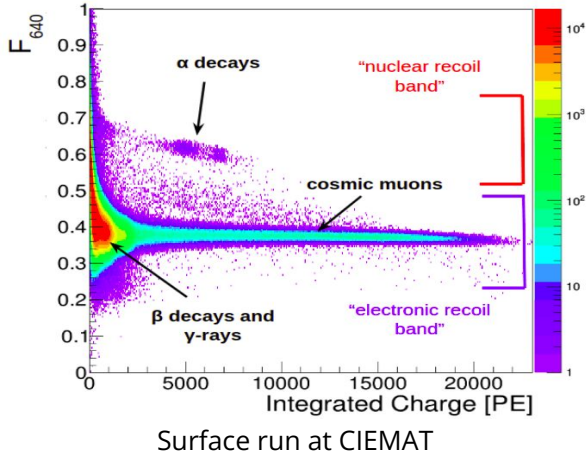
Based at Hall A of Canfranc Underground Lab (Spain) under 2400 m.w.e



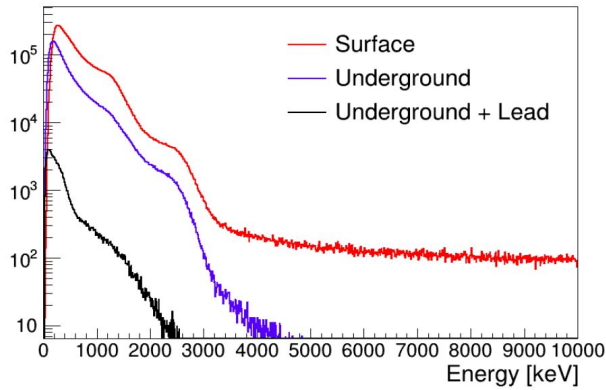
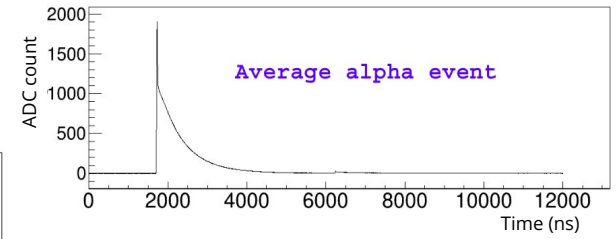
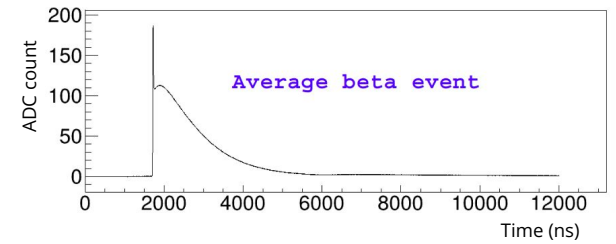
DArT From Surface (CIEMAT) to Underground at LSC

One of the first tests were done at CIEMAT, Madrid.

For the performance of SiPMs in LAr.



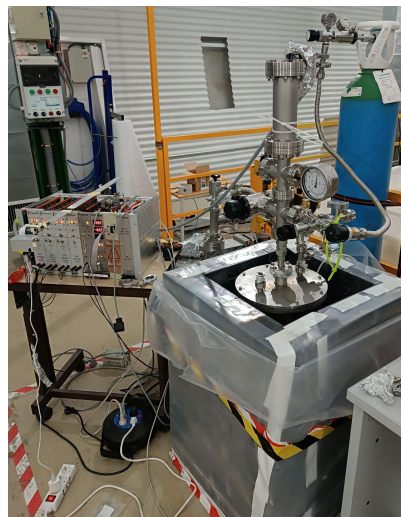
The typical events look like



Reduction in event rate and background with different state of the detector

Clear PSD even with slower SiPM response.

DArT is Live : The Test Setup and Operation.



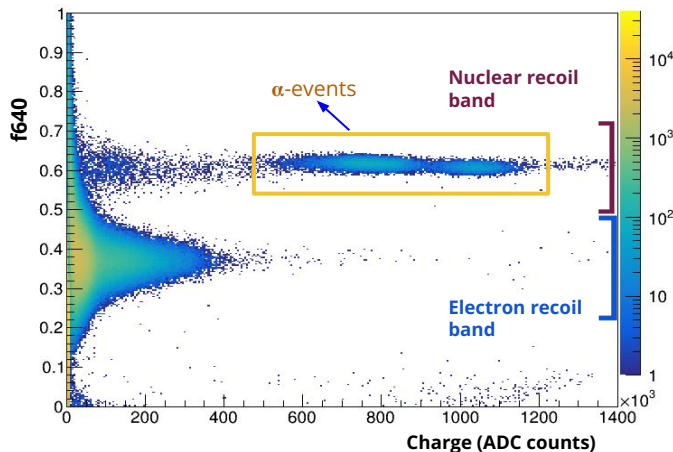
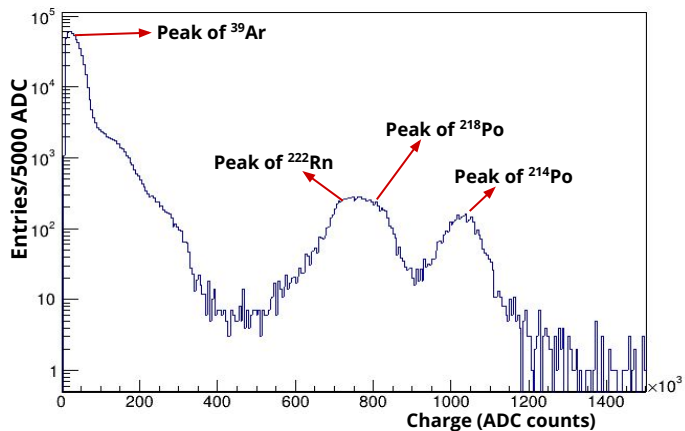
- Need to ensure the robustness and tightness of the design
- Testing the SiPMs in conditions very similar to the full operational conditions
- Understanding the potential of the detector
- The setup consists of:
 - ◆ External Lead Shield
 - ◆ SS-Cryostat acting as temperature bath with pressurized LN₂. (**No veto**)
 - ◆ The DArT Vessel (filled with AAr)
- Pb shield is flushed with Rn-free air

Observation from the test setup :

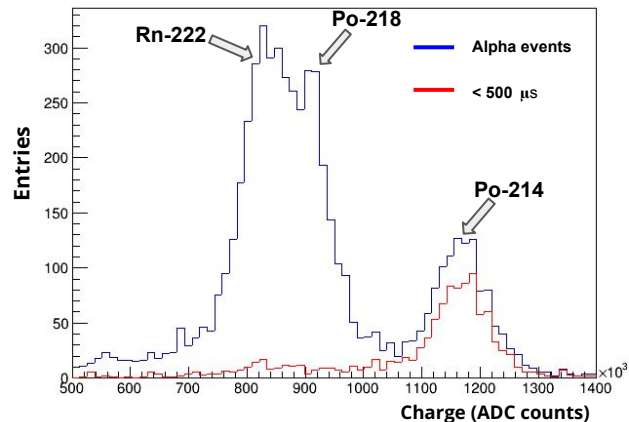
- The detector can **run stably over weeks**,
- Characterization of **photoelectronics and light collection efficiency**,
- **Setting protocols** for operating the inner detector
- Preliminary measurement of ³⁹Ar activity with AAr



DArT is Live : Data taking in Test Setup.



- Data taken with AAr filled in DArT, demonstrate very good sensitivity of the detector.
- This is also tested by the observation of BiPo coincidences.
- The linear behaviour of the detector, even at higher energies has also been tested.



The half life of the events marked in red is calculated to be = $158.25 \pm 6.1 \mu\text{s}$
Compatible with $t_{1/2}({}^{214}\text{Po}) = 164.3 \mu\text{s}$

Extraction of ^{39}Ar Spectrum and Activity

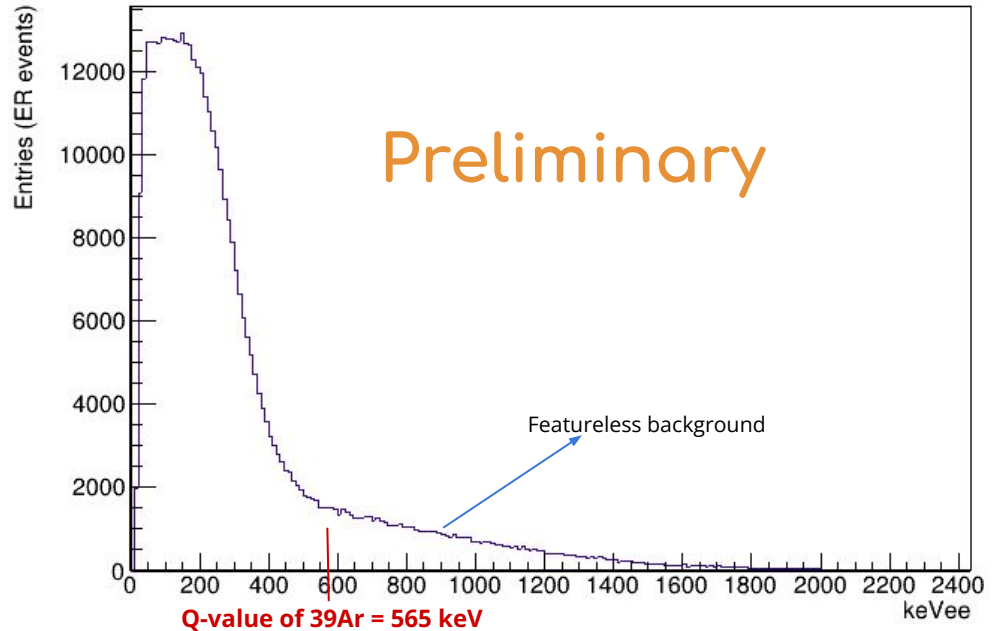
The simulation of the backgrounds is done using the 'G4DS' package.

JINST 12 P10015 (2017)

After subtraction of backgrounds, a **clear pattern of ^{39}Ar is visible** in the underground data set with Pb-shield.

Subtracting a featureless background below the ^{39}Ar spectrum, and with a threshold at 33 keV, **we measure 1.0 cps.**

The uncertainty is lead by systematics, and this is **under evaluation.**

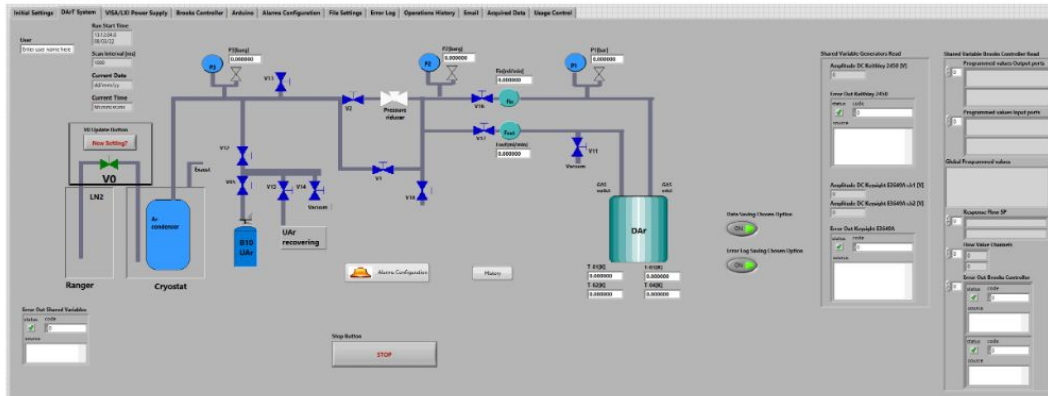
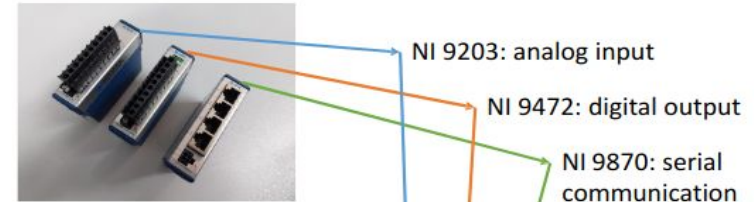


Design of the Gas System and Slow Controls for DArTinArDM

DArT slow control independent from ArDM's.

Developed at U. Cagliari based on NI compactRIO-9068 hardware.

Gas system done by INFN-Cagliari and CIEMAT. Ready to be installed when DArT goes into ArDM.

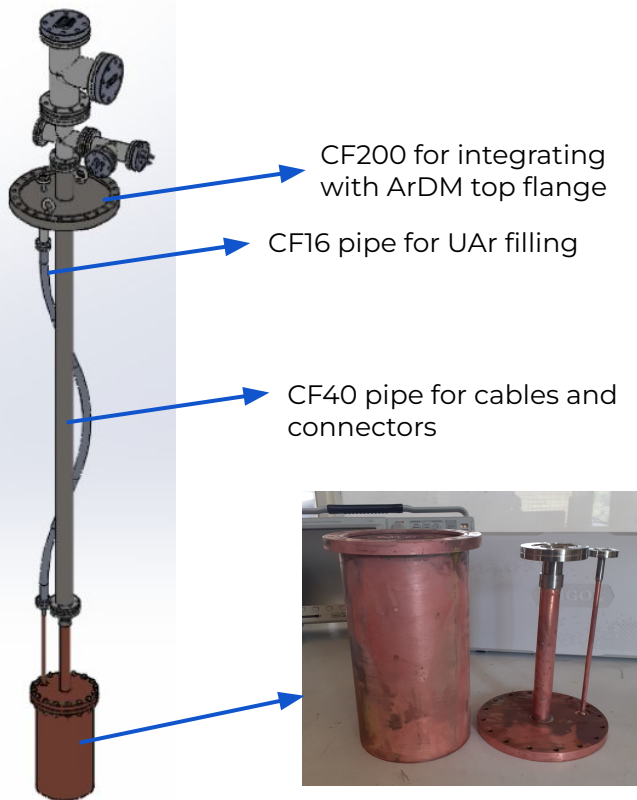


Software developed and at the fine tuning stage. First tests onsite to be undertaken soon.

DArT 2.0 : Towards the Commissioning of Full Phase

New cables and gas connectors have been procured for the ArDM integration.

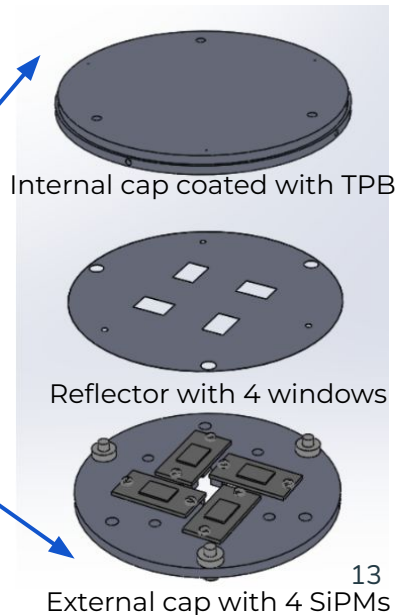
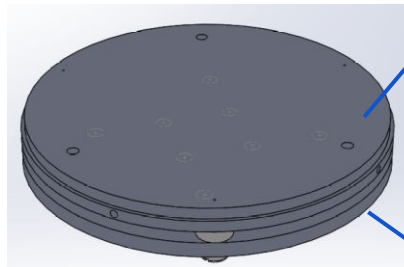
The final setup is being put in place for ArDM



New DArT vessel ready

A few changes in design have been brought.

The top & bottom acrylic structures are modified to a unified structure.



No. of SiPMs increased from 2 to 8.

Conclusion and Future

- We are getting ready for the direct measurement of radiopurity of UAr in coming months.
This is a must for DS-20k and future experiments.
- The assessment of each batch that goes into DS-20k and any future experiments :
Requires us to do continuous operation for several years.
- The DArT in test setup has proved very fruitful for evaluating the long term stable performance of the detector.
- The test setup data has shown a clear ability to measure ^{39}Ar activity over the backgrounds (**AAr and no veto**).
- We are on way to restart ArDM. Protocols for DArT integration has been set by the group.
- Commissioning is foreseen by the end of 2022 or beginning of 2023.
- No showstopper for the characterization of underground Argon with a depletion factor of ~ 14000 (10 times cleaner than that of DS-50).

*Thank you
For your Attention*

Backup Slides

DArT: Detector Design



Copper Pipe for Cables

Pipe to Fill LAr

Copper Vessel

Acrylic Support
Structure External

Mylar Reflectors

SiPMs (mounted on the
Acrylic Support)

Acrylic Support
Structure Internal

TPB coating is done on
the inner side of Acrylic

RPTs
(4 at bottom 2 at top)

