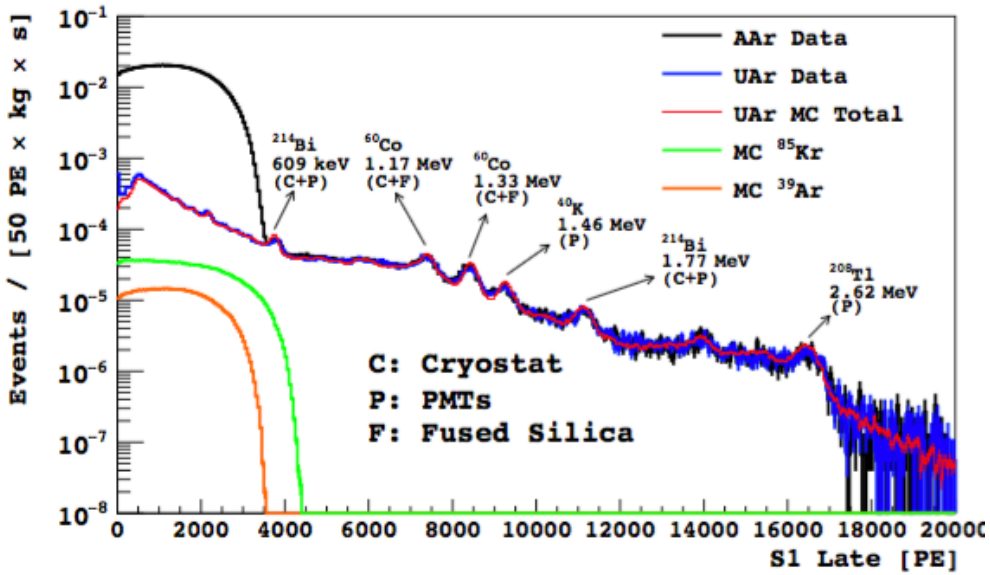
DArT in ArDM

W.Bonivento - INFN Cagliari for the DarkSide and Global Argon Dark Matter Collaboration


Fly
Emirat
25

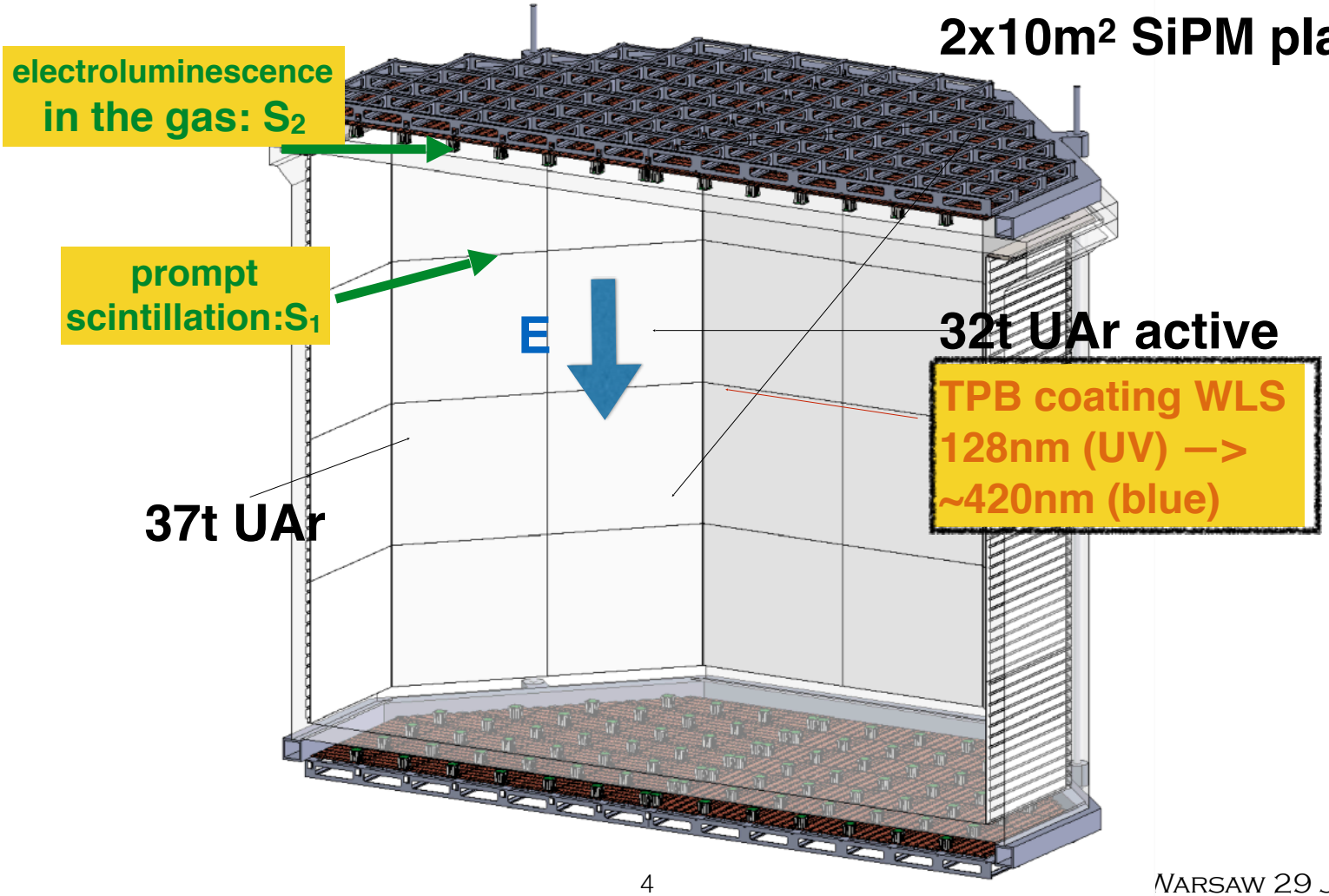
Essential ingredient for the DarkSide program: the low radioactivity argon



For DarkSide-50, about 70Kg of underground argon (UAr) were extracted with a pilot plant

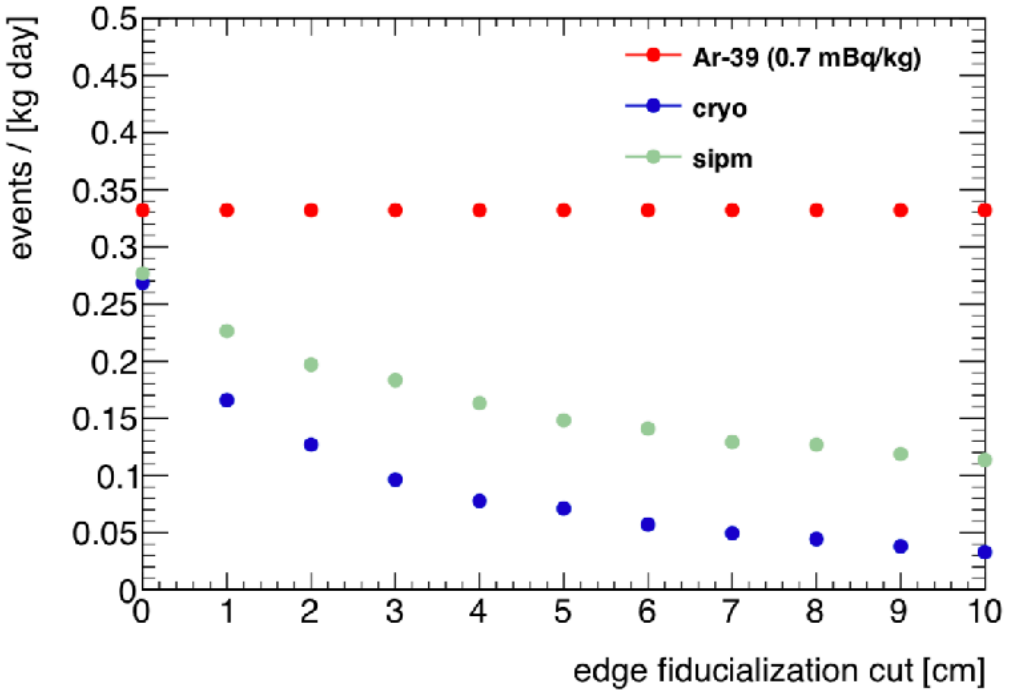
UAr vs AAr in DS-50: (0.73±0.11)x10^{-3}Bq/Kg vs 1Bq/Kg

The DarkSide-20k TPC



DarkSide-Proto

DarkSide-Proto

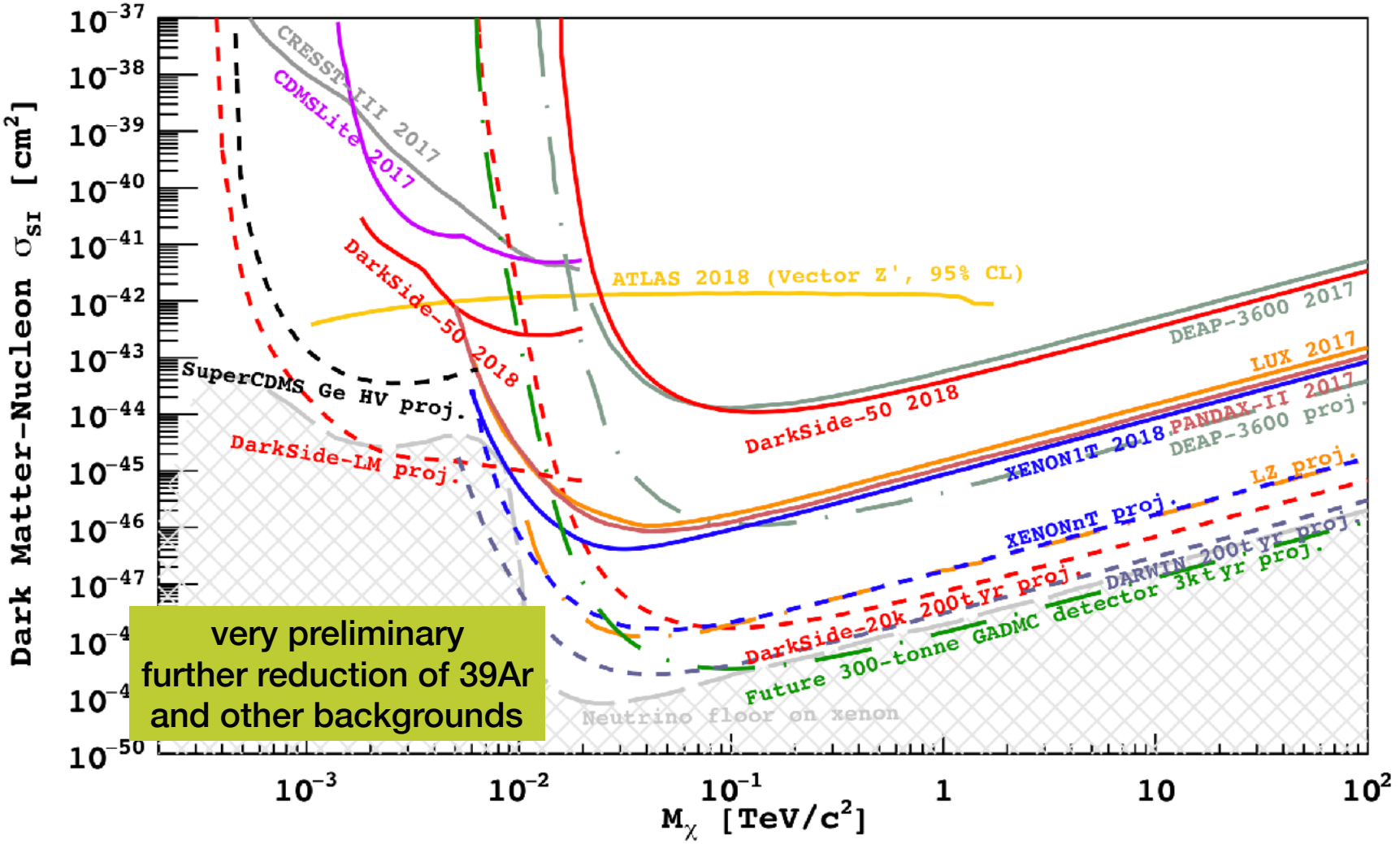


To be compared to DS50

^{39}Ar+^{85}Kr: 1.75 ev/kg/day

cryo: 0.27 ev/kg/day

PMT: 1.57 ev/kg/day


Dark Matter-Nucleon σ_{SI} [cm^2]
10^{-37}
10^{-38}
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-3}
10^{-2}
10^{-1}
1
10
10^{2}
M_χ [TeV/c^2]
CRESST-III 2017
CDMSLite 2017
DarkSide-50 2018
ATLAS 2018 (Vector Z', 95% CL)
SuperCDMS Ge HV proj.
DarkSide-LM proj.
DarkSide-50 2018
DEAP-3600 2017
LUX 2017
PANDAX-II 2017
XENON1T 2018
DEAP-3600 proj.
LZ proj.
XENONnT proj.
DarkSide-20k 200t yr proj.
DARWIN 200t yr proj.
Future 300-tonne GADMC detector 3kt yr proj.
Neutrino floor on xenon
very preliminary
further reduction of 39Ar
and other backgrounds

The argon path

The Urania project@Kinder Morgan Doe Canyon Facility, CORTEZ,CO (USA)

extraction of 50t of UAr from CO_2 deep wells where cosmic rays hardly make any ^{39}Ar

Starting from 95% CO2 and 440ppm of UAr!

New plant, funded, under tendering; planned to be operational by 2021

The Aria project: includes regional funds from Sardinia, Italy

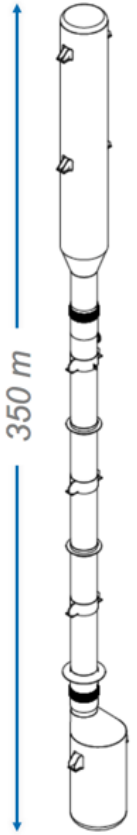
^{39}Ar isotopic separation with cryogenic distillation —> factor 10 suppression per pass (from UAr to DAr)

CarboSulcis mine in

Nuraxi-Figus

The Seruci-I column:

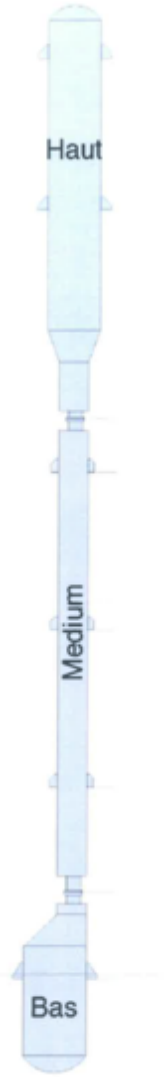
350m height, 30cm diameter



first step : installation and test of a 28m tall test column Seruci-0 in a surface building at the mine

installed and under testing and commissioning

Plan for installation of Seruci-1 for commissioning in second half of 2019



Aria

For DarkSide-20k and ARGO:

removal of chemical impurities to make the UAr detector grade with 2 passes at 1t/day with 85% recovery—> inlet purity required by DS20k getters of order 0.25-1ppm

For DarkSide Low-Mass:

10Kg/day isotopic distillation

—> to further improve the 1400 factor 39Ar depletion of the UAr from Urania (2021) and chemical purification

—> to use it with AAr with several passes to achieve similar depletion starting from 2019

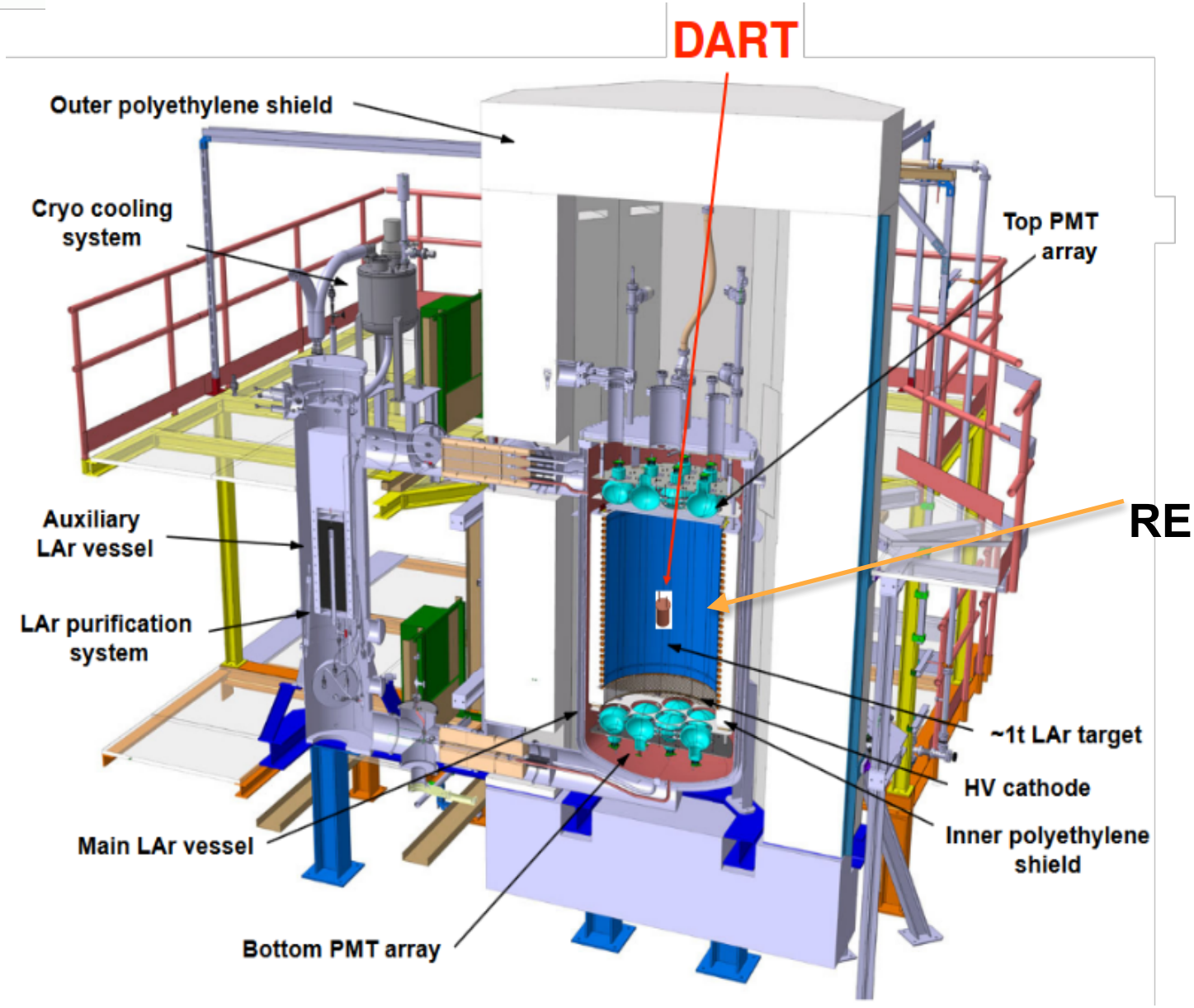
DArT in ArDM

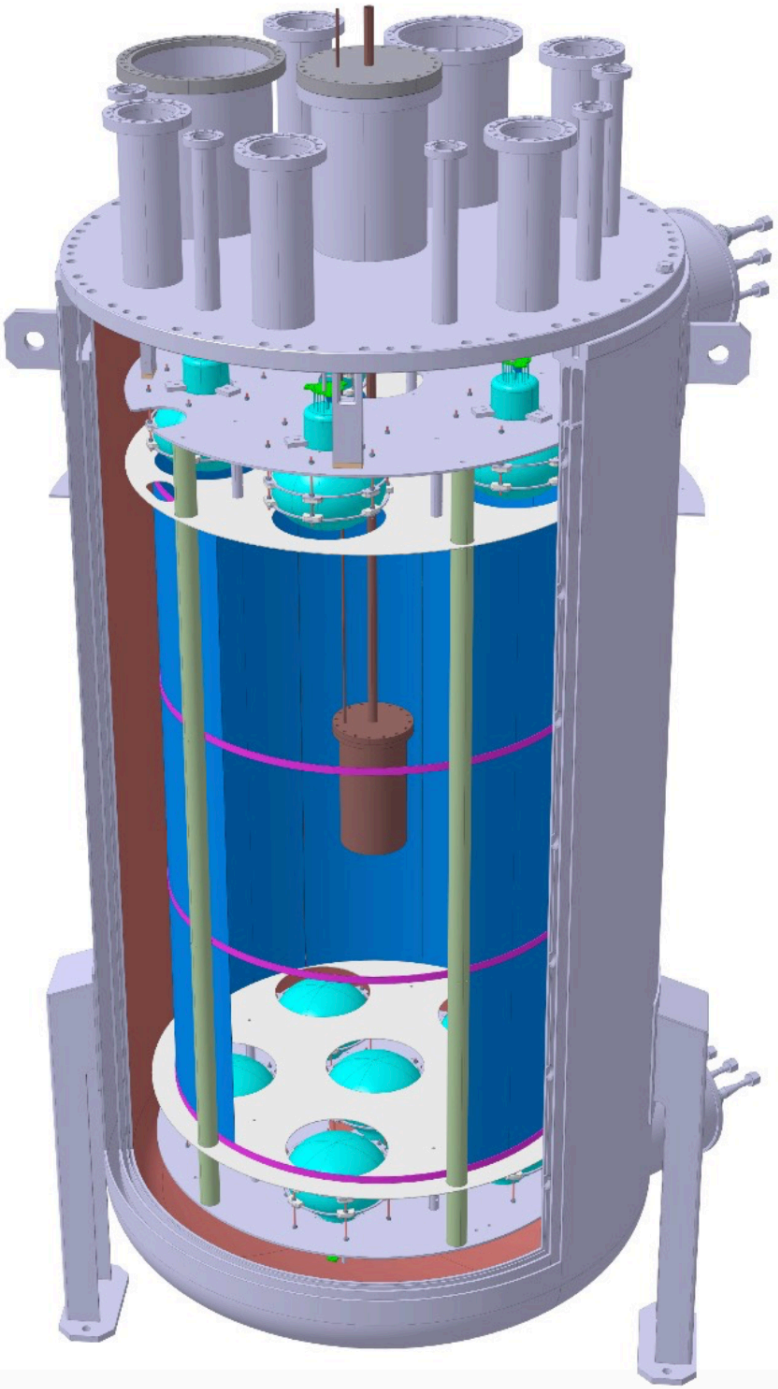
A measuring device:

The measurement of ^{39}Ar content in the argon coming from Urania and Aria is planned with a specific innovative device named DArT based on LAr active vetoing approach

Not only to perform testing of Aria and Urania

The precision to which the depletion factor is know impacts directly on the achievable DM sensitivity!

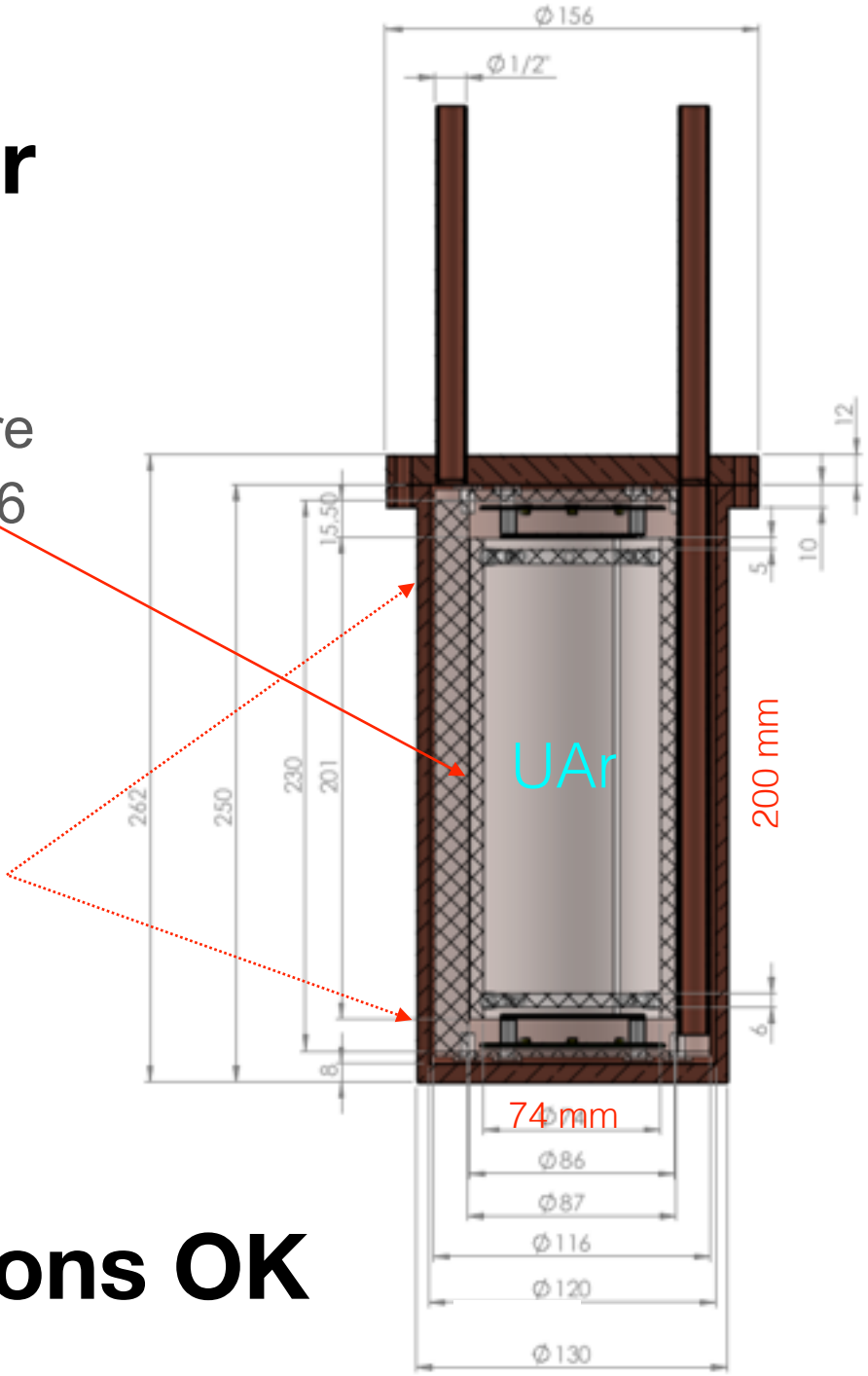

DART
Outer polyethylene shield
Cryo cooling system
Top PMT array
REMOVED
Auxiliary LAr vessel
LAr purification system
~1t LAr target
HV cathode
Inner polyethylene shield
Main LAr vessel
Bottom PMT array



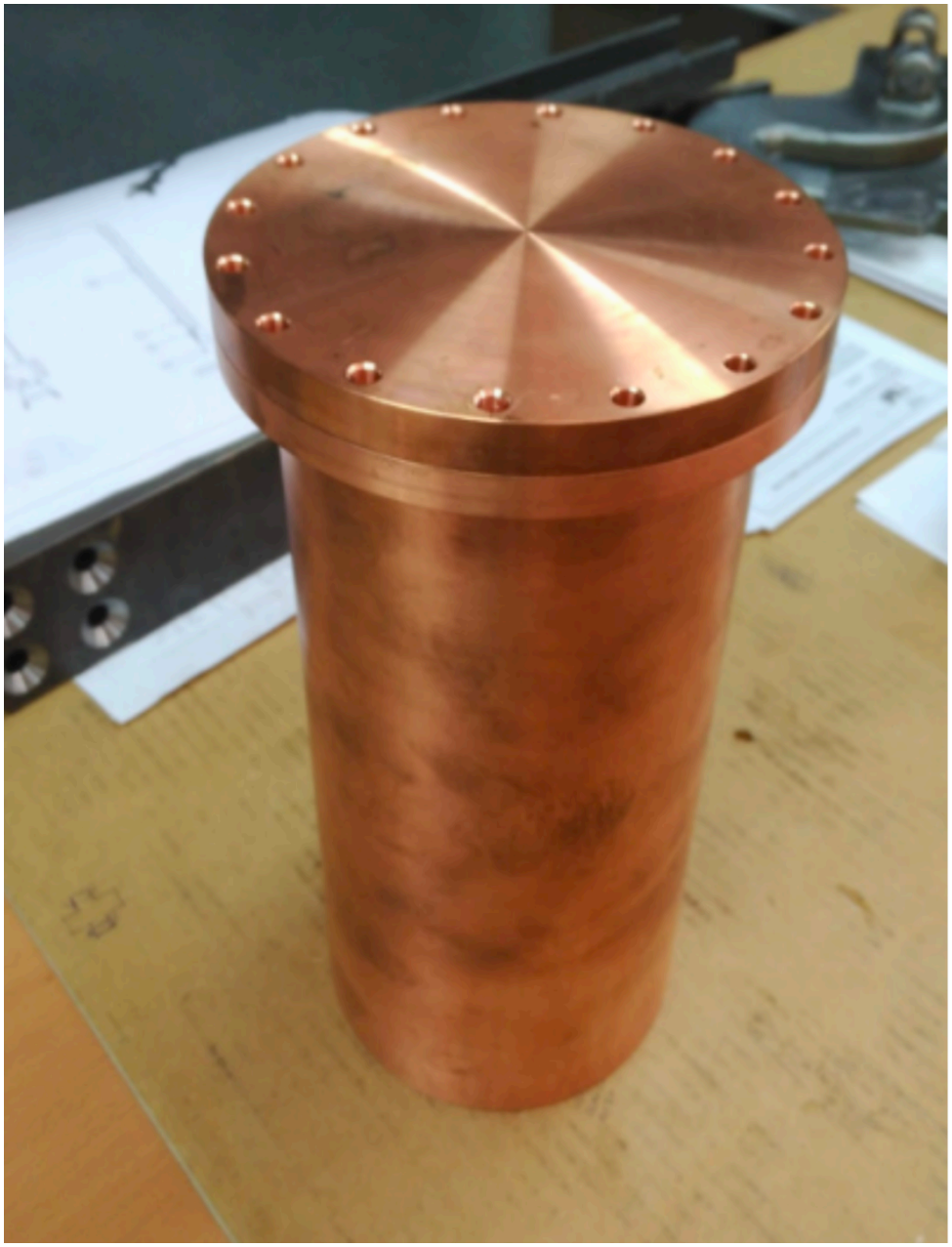
new structure to be assembled and tested at CERN in the spare ArDM cryo

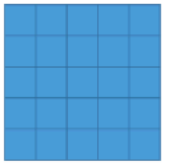
Inner chamber

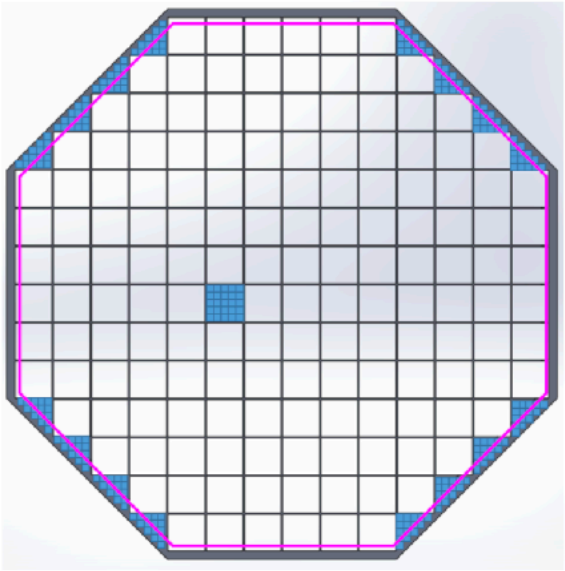
- OFHC copper vessel ~6.9 kg.
- PMMA cylindrical support structure (two halves cylinder + two plates 6 mm thickness) ~200 g.
- Lateral (outer) 3M foil.
- 2 SiPM tiles (top+bottom).
- Maximum internal volume ~2.6 L.
- LAr volume ~0.8 L.



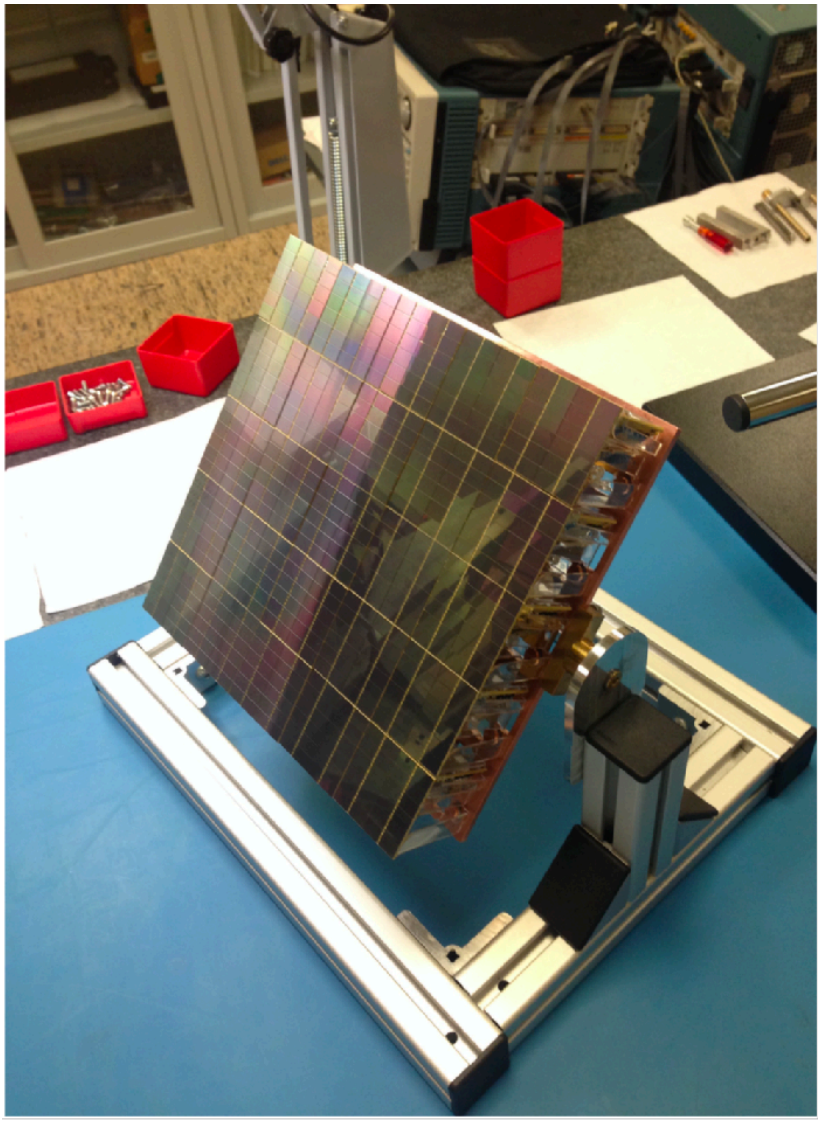
mechanical simulations OK



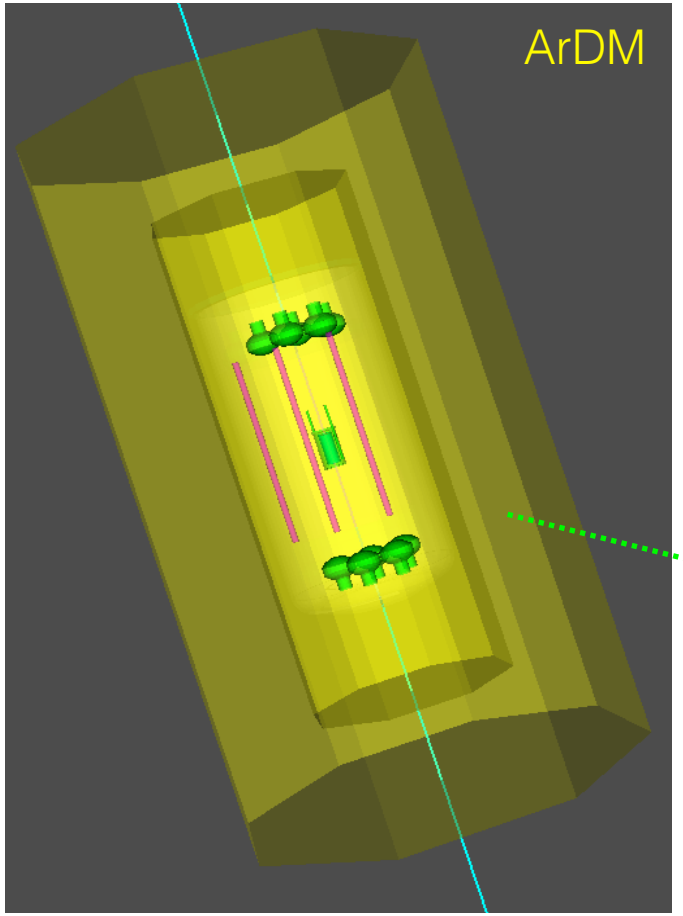




we will use one SiPM on the top and one on the bottom

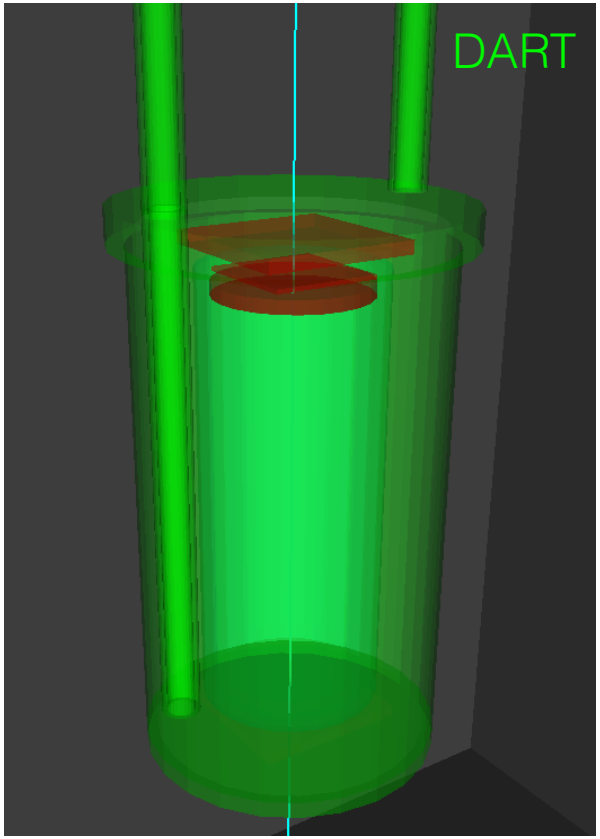


Simulation with Geant4



Full ArDM and DART simulation, geometries and materials:

Optical simulation also implemented



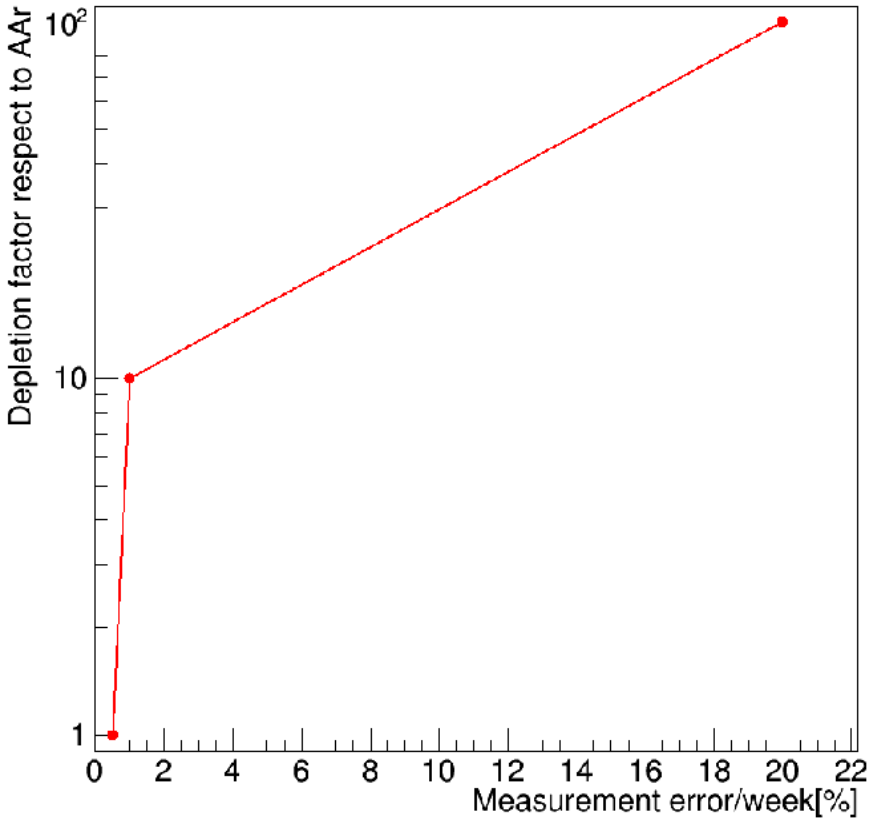
Source		^{238}U[mBq/kg]	^{232}Th[mBq/kg]	^{40}K[mBq/kg]	^{60}Co[mBq/kg]	^{210}Pb[Bq/kg]	Mass[kg]
ArDMCryo		3.42	6.37	1.3	11.21(*)		1630
ArDM PMTs	Base	9277	11036	16588			
	Metal	183	75	3110			26.4
	Glass	643	115	441	1.8		
Lead Belt		0.37	0.073	0.31		10	6000
DArTCu		0.19	0.04	0.06	0.04		6.95
SiPM Arlon	Up	3.8					
	Mid	53	70	1300			0.004
	Low	137					
External		0.72	0.13	0.05			

10600 events/week after vetoing

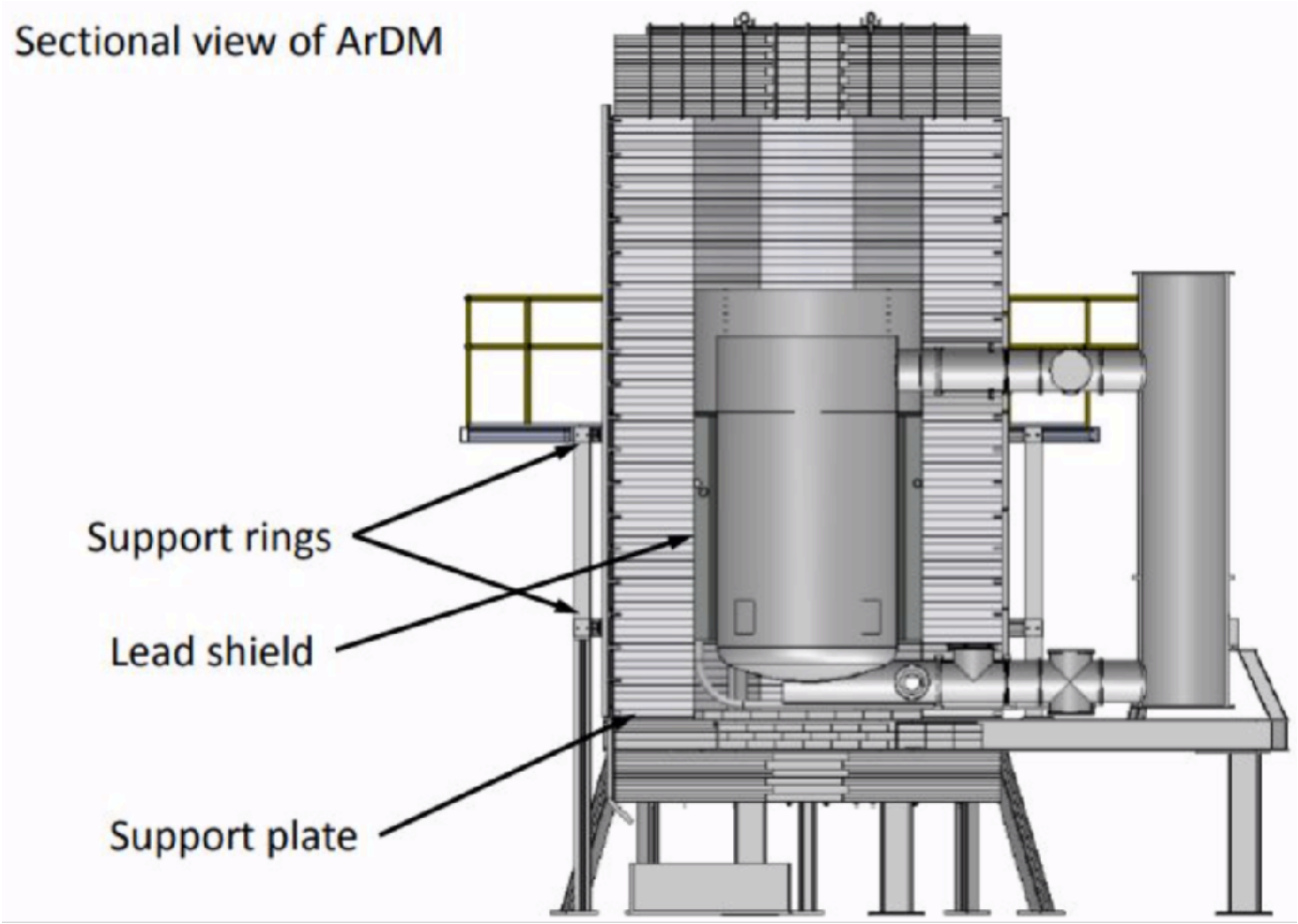
VETO rejection factor: factor 15 on external background, PMT and CRYO

12PE/KeV

test of small depletion factors: e.g. Seruci-1 with AAr



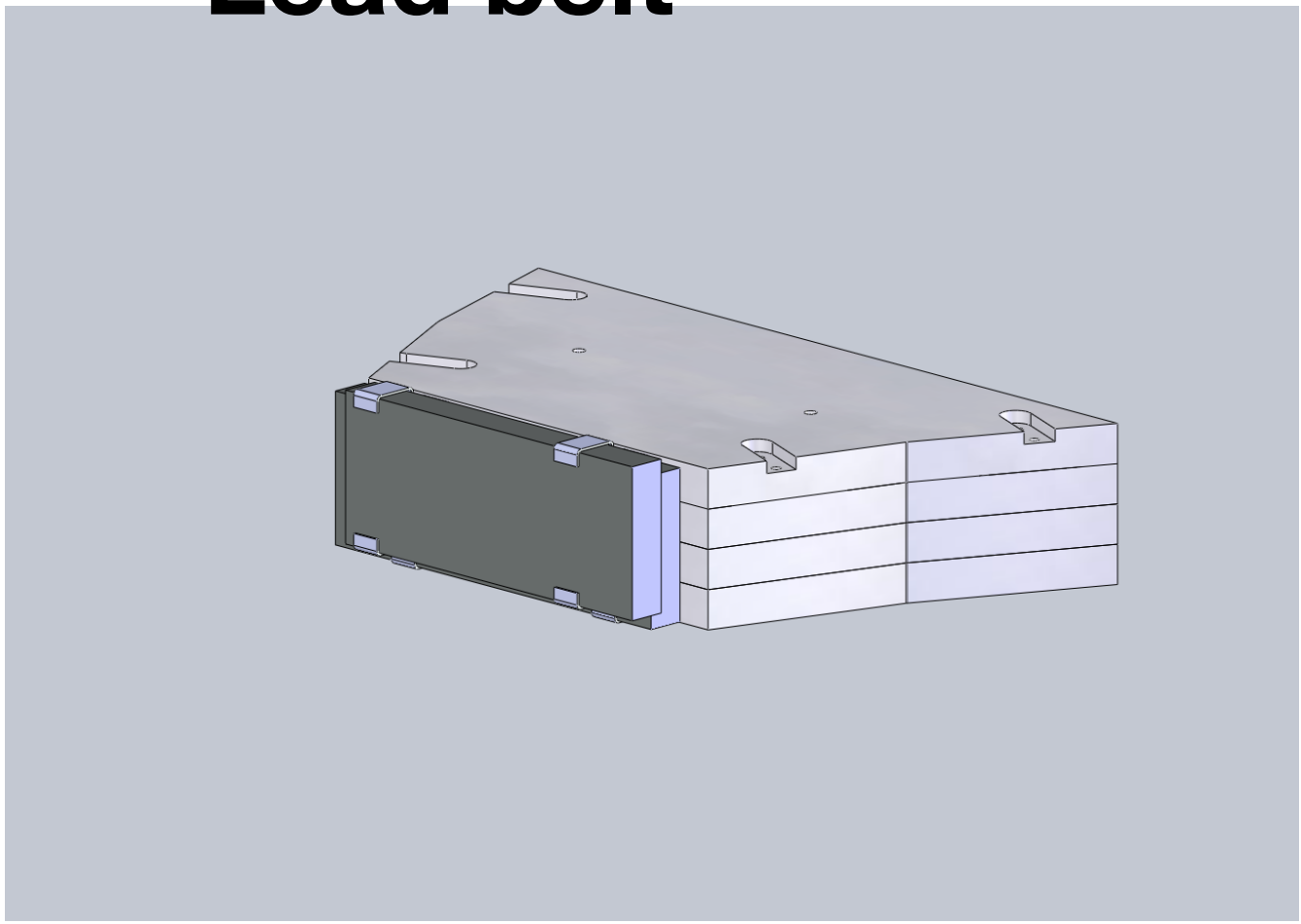
Pb belt against external background



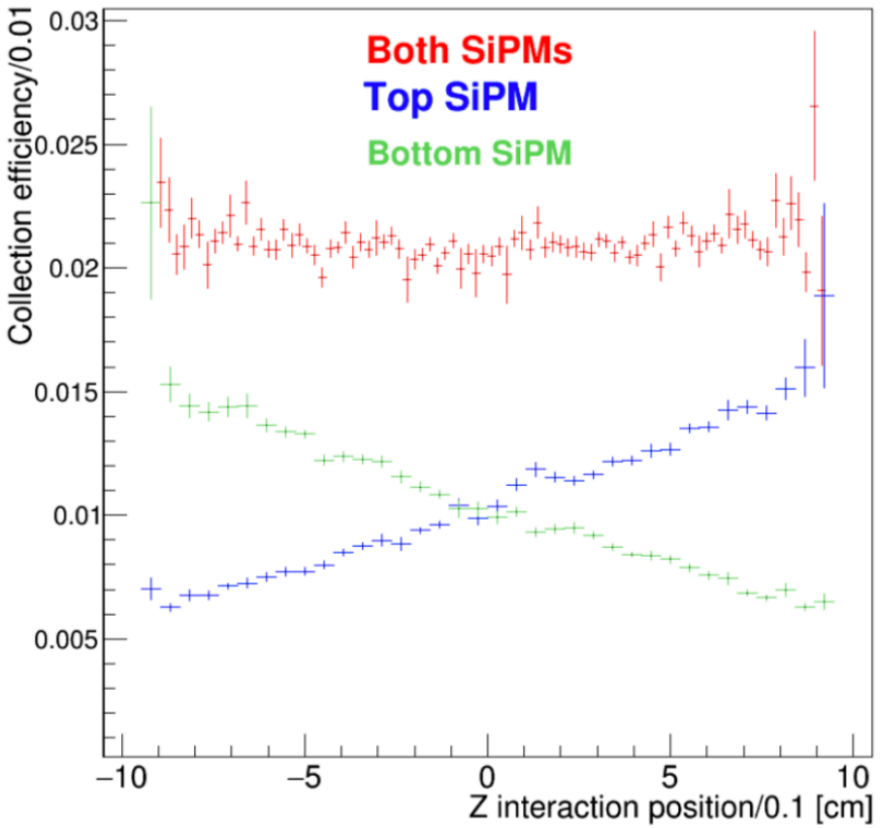
Reduction factor ≈25 with a 140x10x460 cm^3 Pb belt.

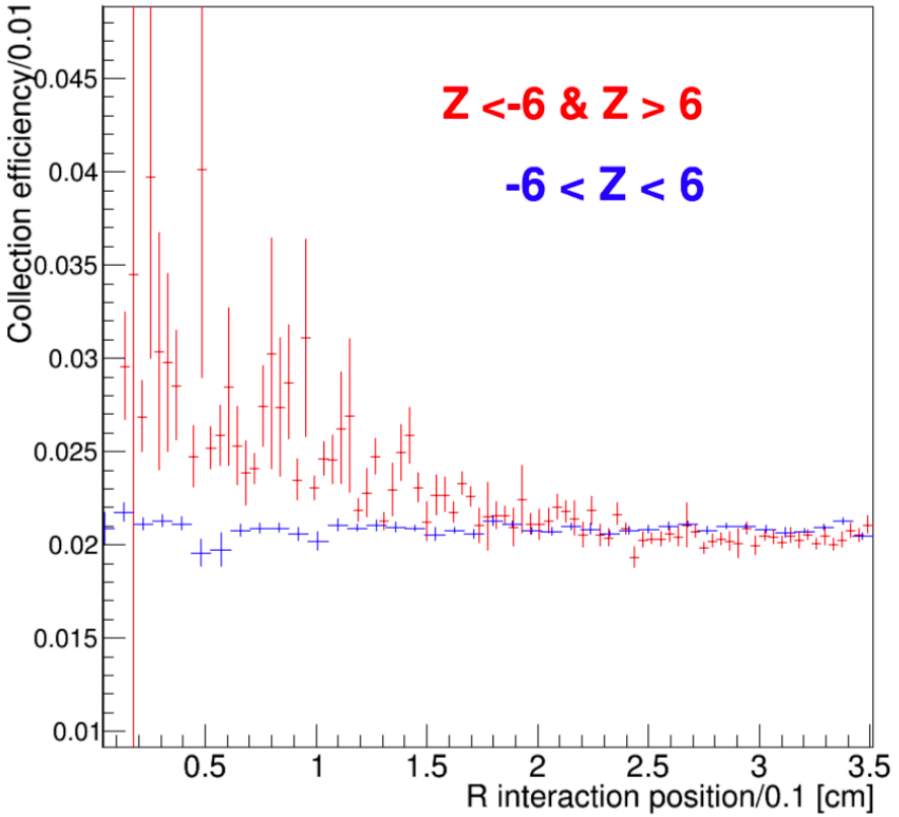
Weight increase ≈6 Tons.

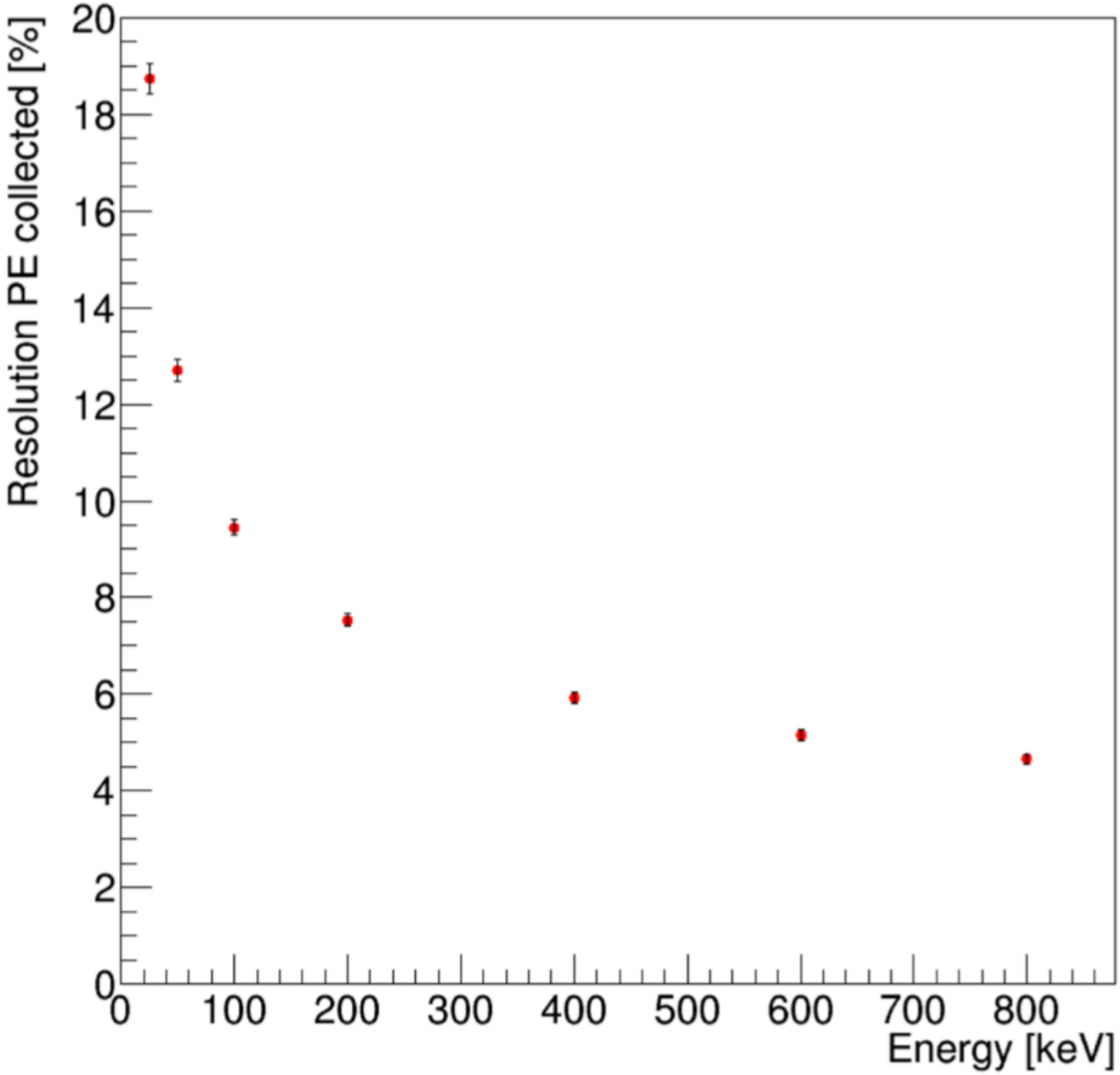
Lead belt

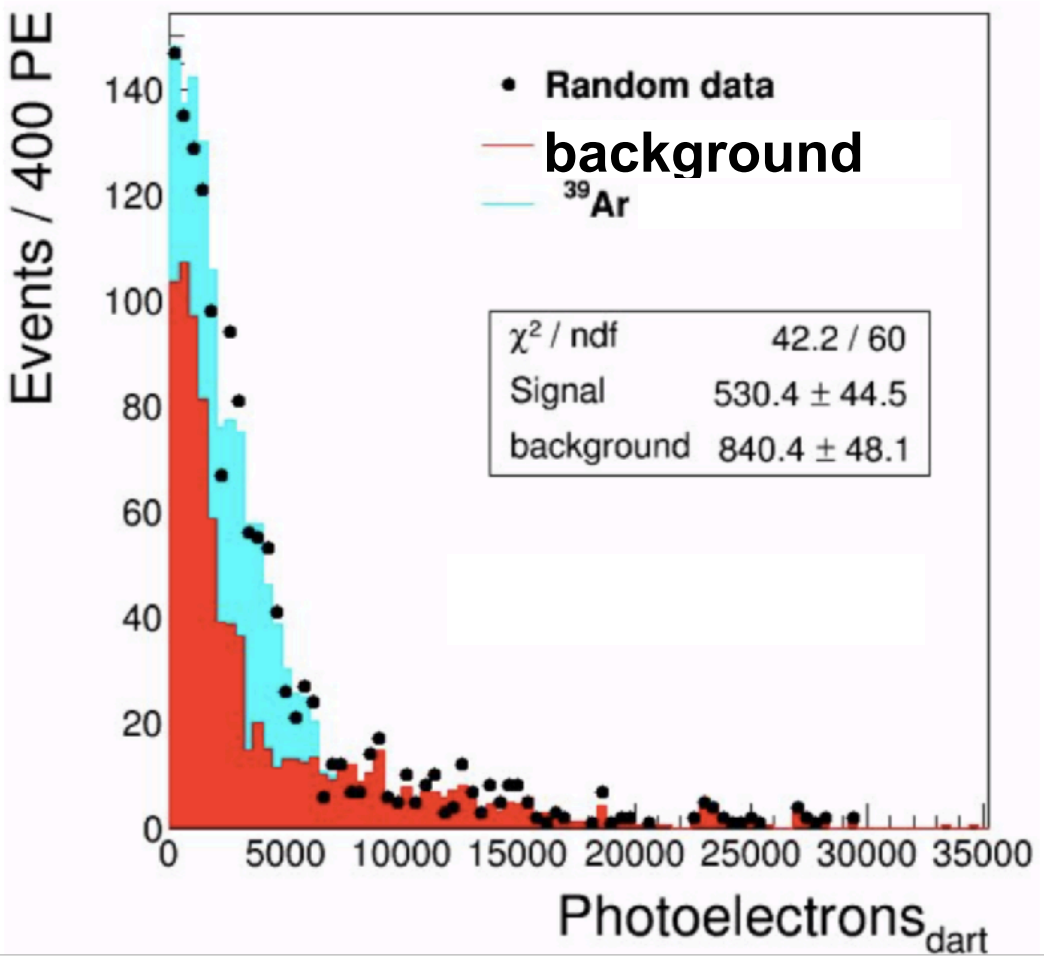


Source	Evt/week in ROI	Evt untagged/week in ROI
ArDM Cryo	3,161	187.3
ArDM PMTs	973.9	46.5
Lead Belt	150.5	16.2
DArT vessel	36.2	8.1
Arlon SiPM	25	15
External without the lead belt	160,000	10,600
Total without the lead belt	**xx**	**zz**
External with the lead belt	6,866.1	350.7
Total with the lead belt	**aa**	**623.8**

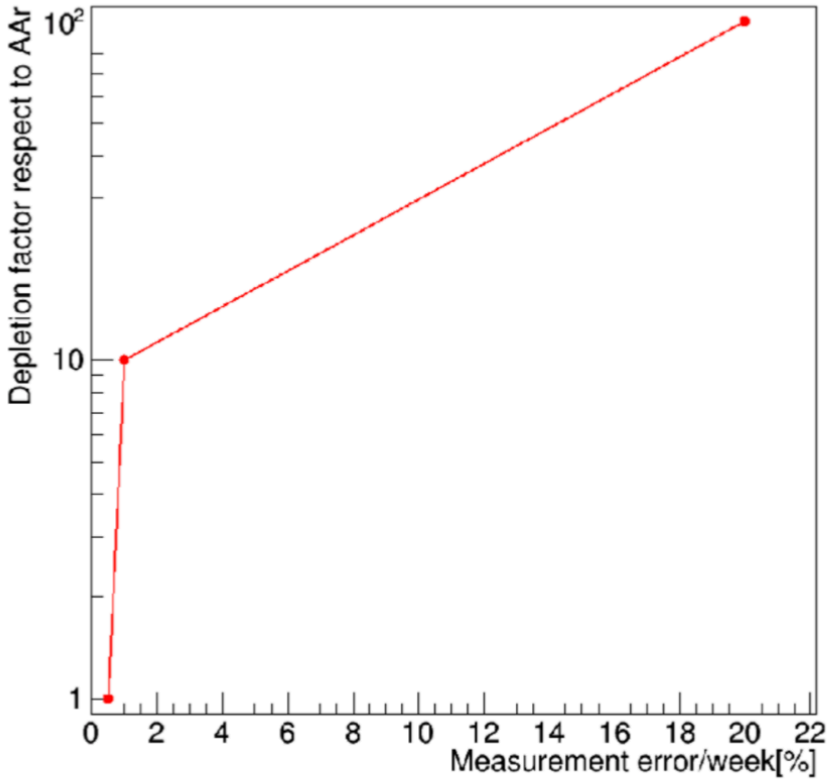

Both SiPMs
Top SiPM
Bottom SiPM
Collection efficiency/0.01
0.03
0.025
0.02
0.015
0.01
0.005
−10
−5
0
5
10
Z interaction position/0.1 [cm]

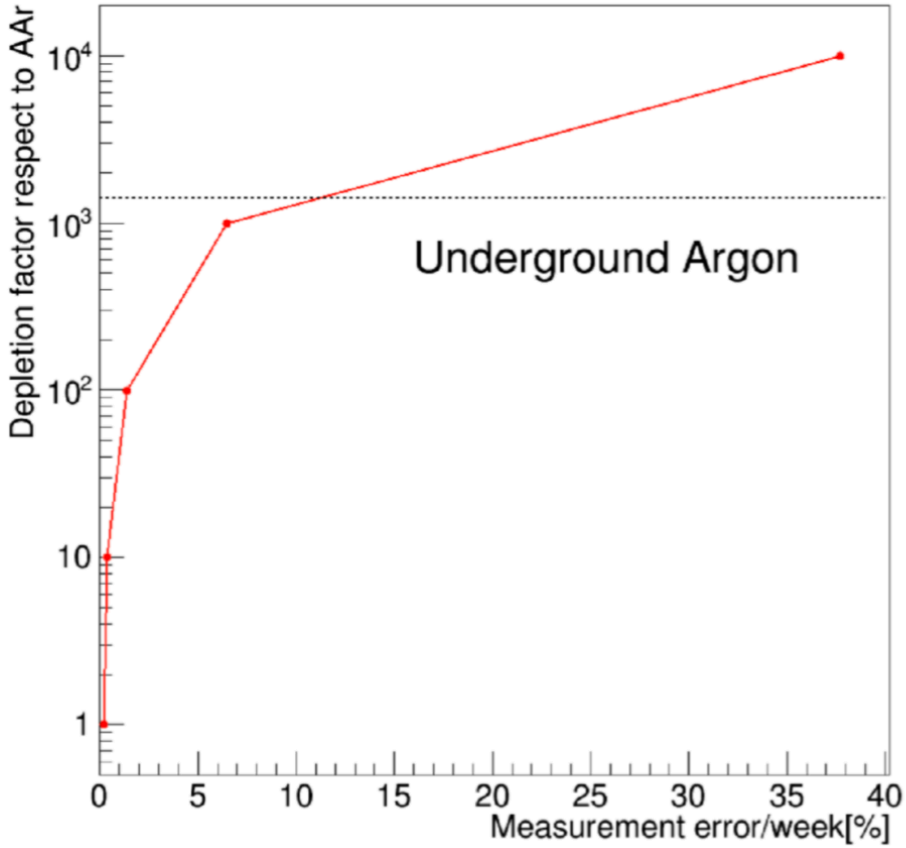

Z <-6 & Z > 6
-6 < Z < 6
Collection efficiency/0.01
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.5
1
1.5
2
2.5
3
3.5
R interaction position/0.1 [cm]


Resolution PE collected [%]
20
18
16
14
12
10
8
6
4
2
0
0
100
200
300
400
500
600
700
800
Energy [keV]



External, PMT and cryo background can be normalised with all events before applying the VETO tag


Depletion factor respect to AAr
10^2
10
1
0
2
4
6
8
10
12
14
16
18
20
22
Measurement error/week[%]


Depletion factor respect to AAr
10^4
10^3
10^2
10
1
Underground Argon
0
5
10
15
20
25
30
35
40
Measurement error/week[%]

PNNL March 2018

Low-Radioactivity Underground Argon Workshop

A workshop synopsis

Thomas Alexander[1], Henning O. Back[1,*], Walter Bonivento[2], Mark Boulay[3], Philippe Collon[4], Zhongyi Feng[5], Michael Foxe[1], Pablo Garcia[6], Pietro Giampa[7], Christopher Jackson[1], Christine Johnson[1], Emily Mace[1], Peter Mueller[8], László Palcsu[9], Walter Pettus[10], Roland Purtschert[11], Andrew Renshaw[12], Richard Saldanha[1], Kate Scholberg[13], Marino Simeone[14], Ondřej Šrámek[15], Rex Tayloe[16], Ward TeGrotenhuis[1], Signe White[1], Richard Williams[1]

2 The global needs for low-radioactivity underground argon

The largest needs for low-radioactivity underground argon are in the fundamental nuclear and particle physics fields. The DarkSide experiments have been driving the demand and production for low-radioactivity underground argon [1], but with that success the demands have risen. Beyond WIMP dark matter detection, the physics that is more easily reached by the availability of low-radioactivity underground argon includes: neutrinoless double beta decay by eliminating ^{42}Ar and ^{39}Ar in the argon that surrounds the germanium crystals of the LEGEND experiment [2], measuring low-energy neutrinos in the DUNE detector by reducing the ^{39}Ar beta rate and also the higher energy beta from ^{42}K (the daughter of ^{42}Ar) [3], and coherent elastic neutrino nucleus scattering within the series of COHERENET experiments through increasing live-time by reducing ^{39}Ar decays [4].

IV. TIMELINE AND READINESS

- Assembly and test of the DArT chamber: starting Dec. 2018 ; all the material for the chamber in hand. The readout electronics is in hand in the non radio-pure version. Radio-pure version will be ready by June 2019.
- New single phase assembly design and test at CERN: starting from Feb. 2019; new low-radioactivity PMTs ordered
- Installation at LSC and run of phase 1: starting from August 2019.
- Installation at LSC of the lead belt: starting from January 2020.