

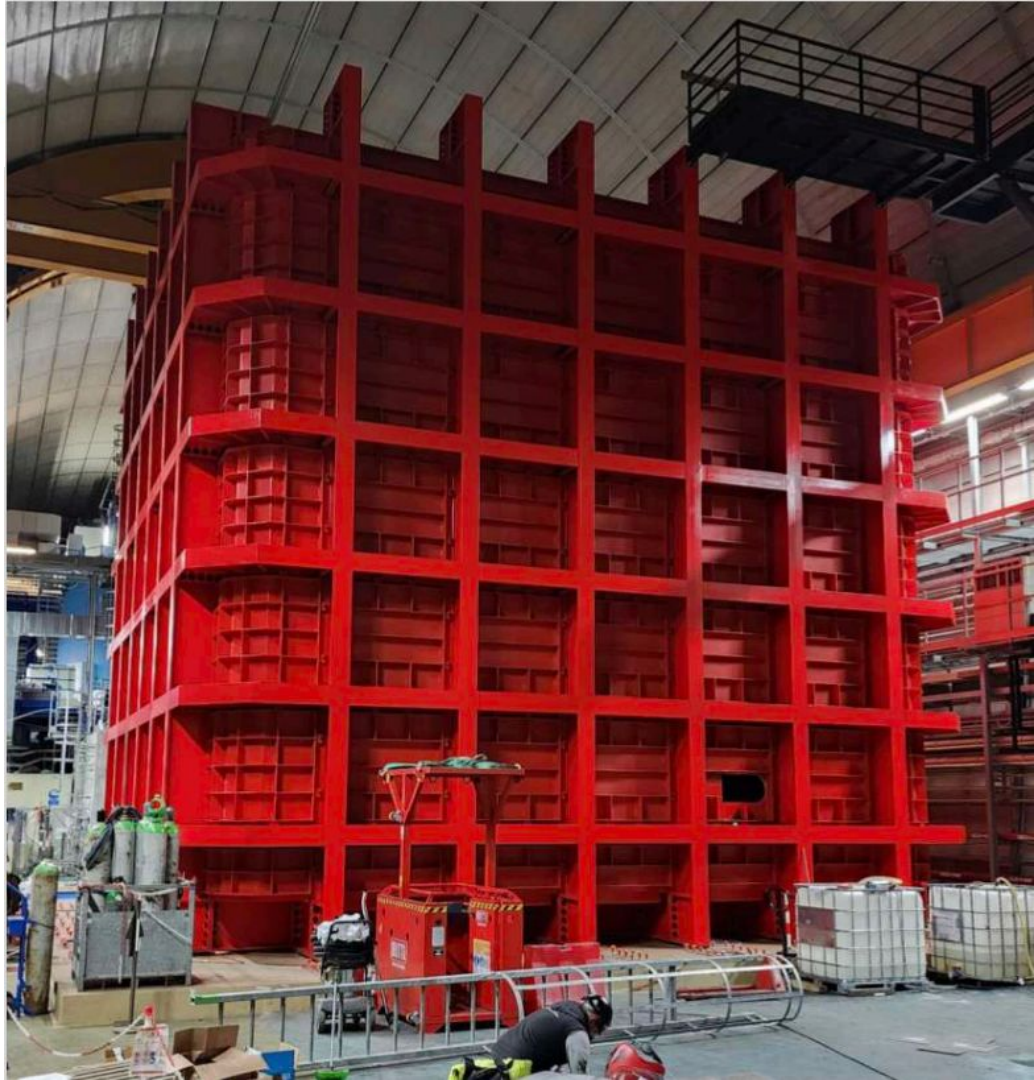


# The future of the dark matter search with DarkSide-20k

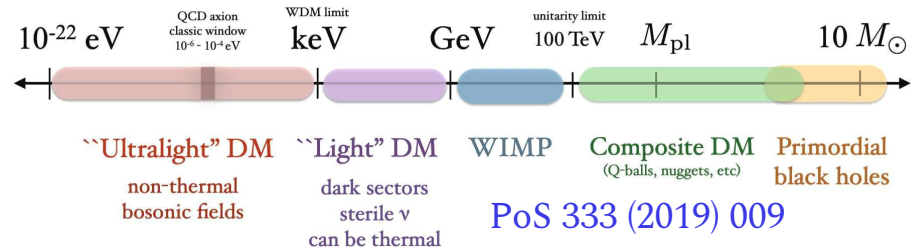
Dr. Michela Lai  
on behalf of  
DarkSide-20k Collaboration



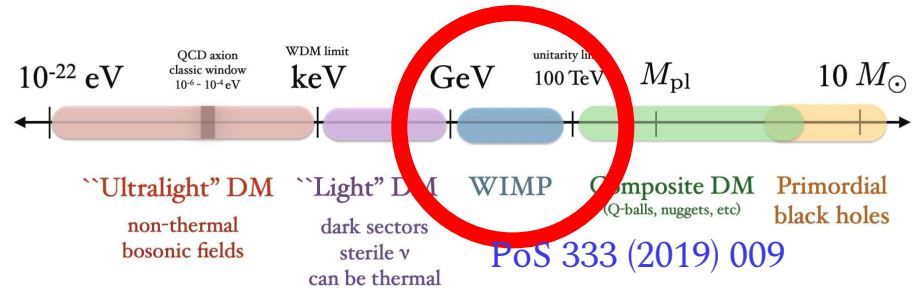
South Dakota Mines campus, May 14-16, 2024



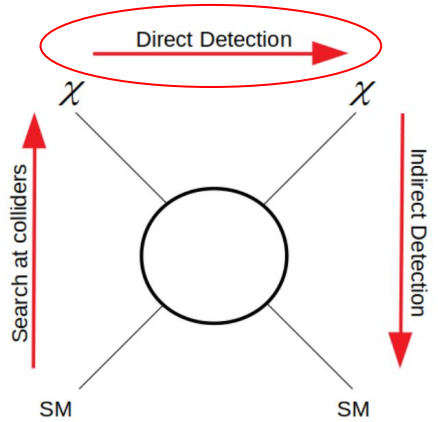
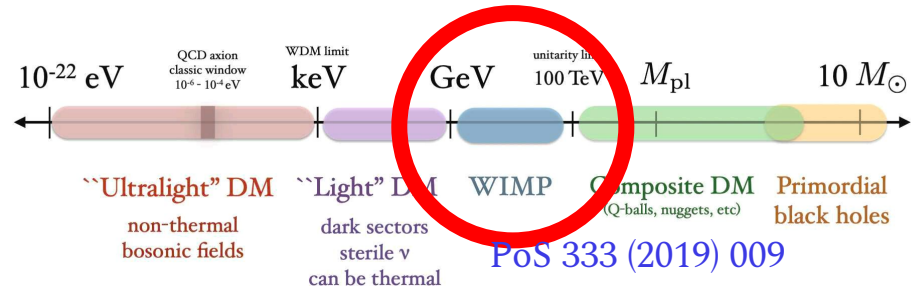
# Global Argon Dark Matter Collaboration



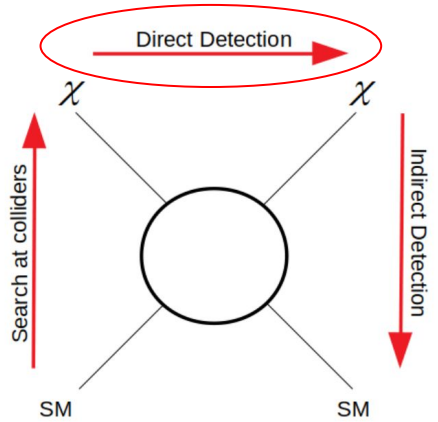
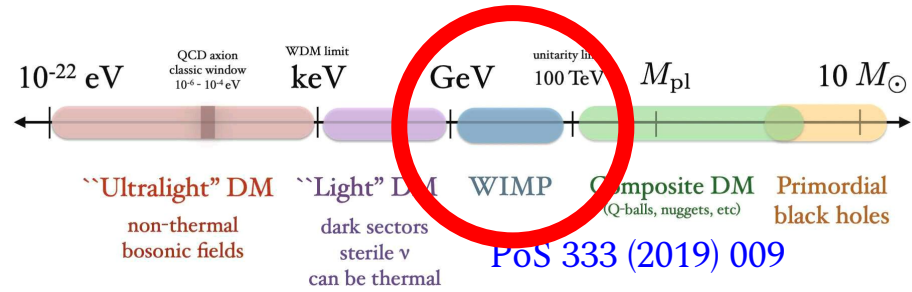
# Global Argon Dark Matter Collaboration



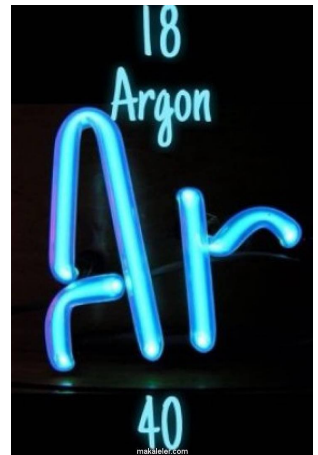
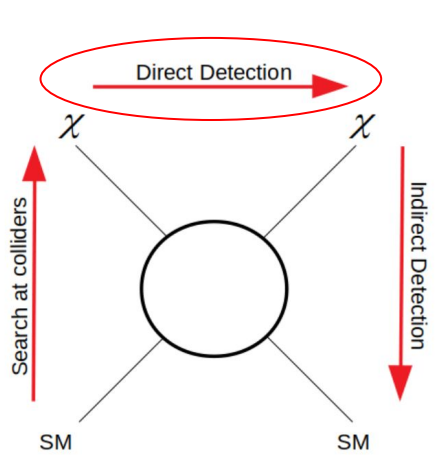
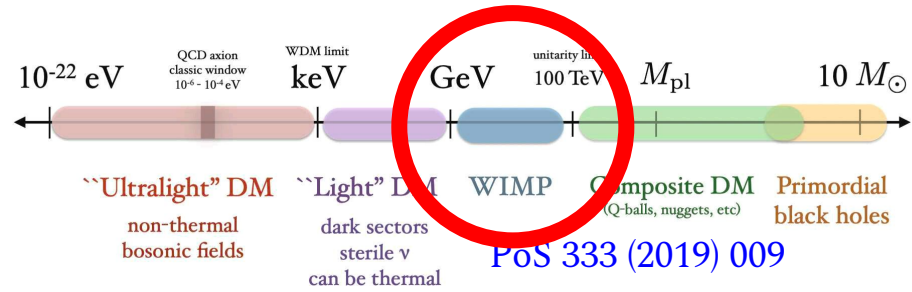
# Global Argon Dark Matter Collaboration



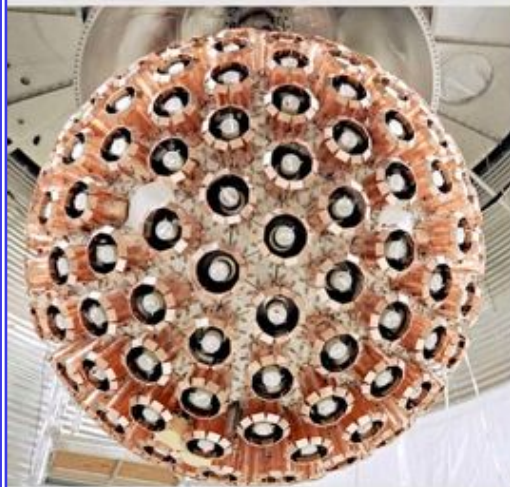
# Global Argon Dark Matter Collaboration



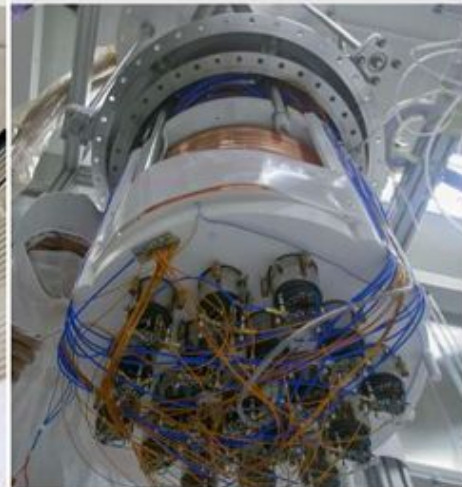
# Global Argon Dark Matter Collaboration



DEAP-3600 @SNOLAB



DarkSide-50 @LNGS



ArDM @LSC



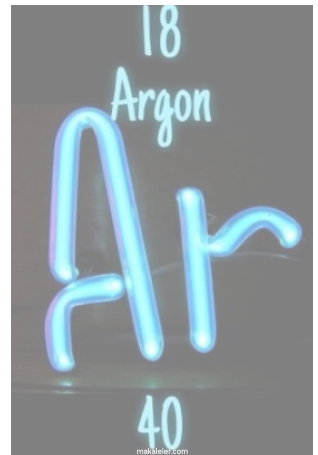
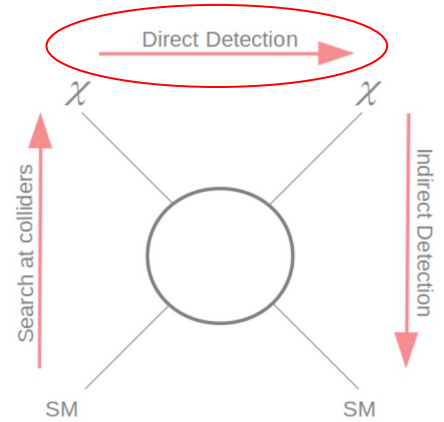
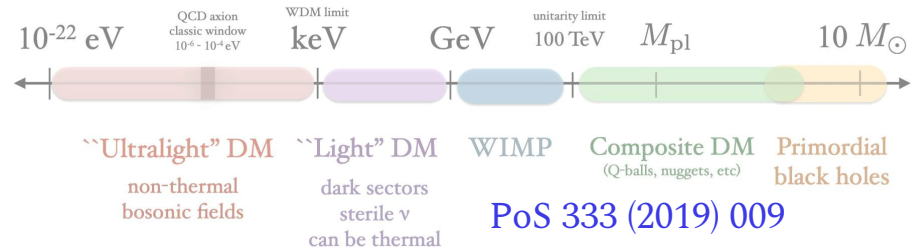
miniCLEAN @SNOLAB



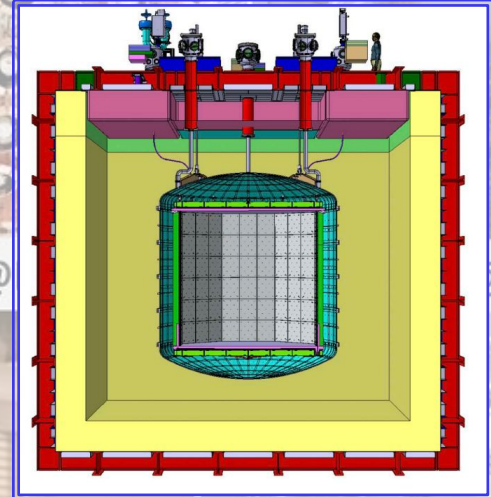
# Global Argon Dark Matter Collaboration

DEAP-3600 @SNOLAB

DarkSide-50 @LNGS

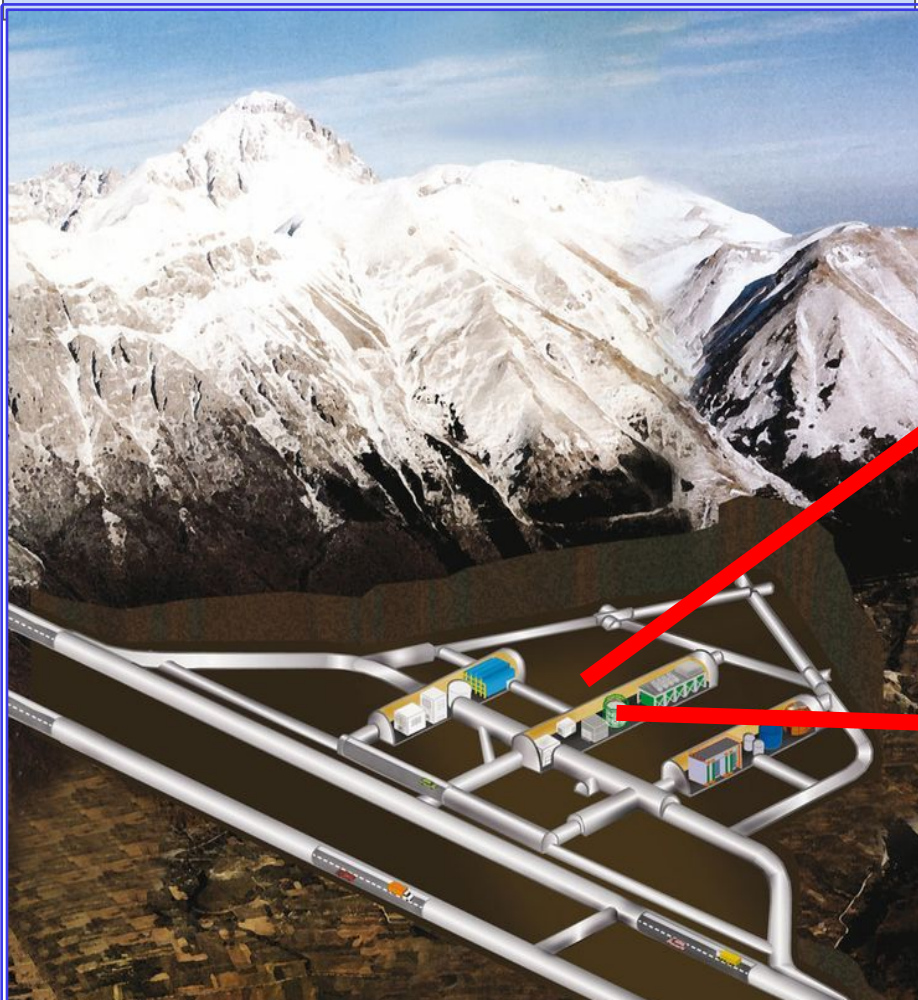


## DarkSide-20k

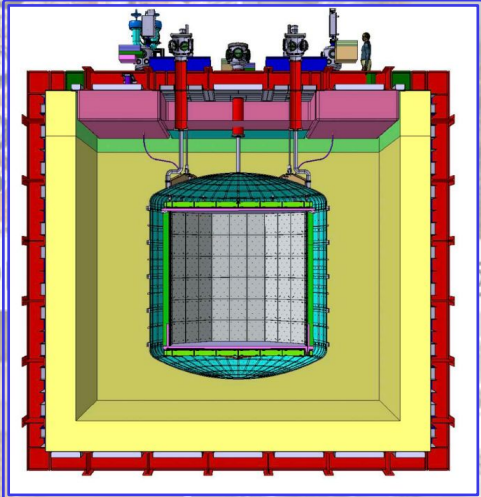


ArDM @

@SNOLAB



**DarkSide-20k**

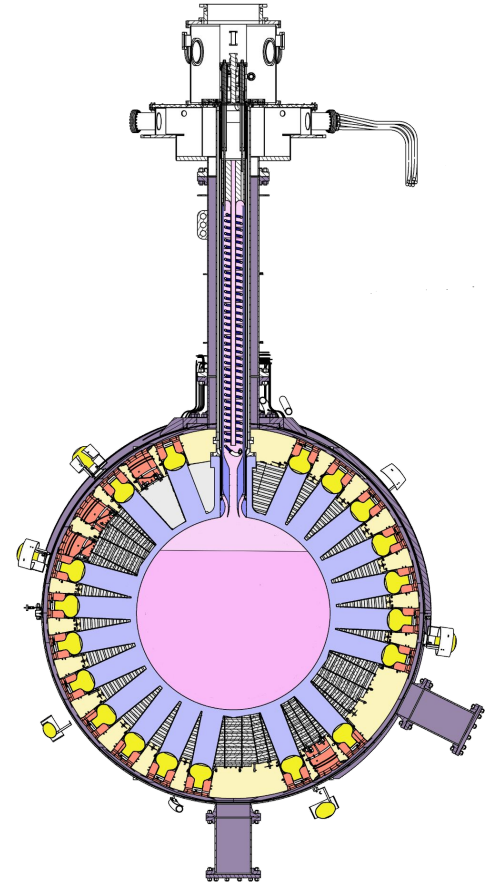


**LNGS - 2026**

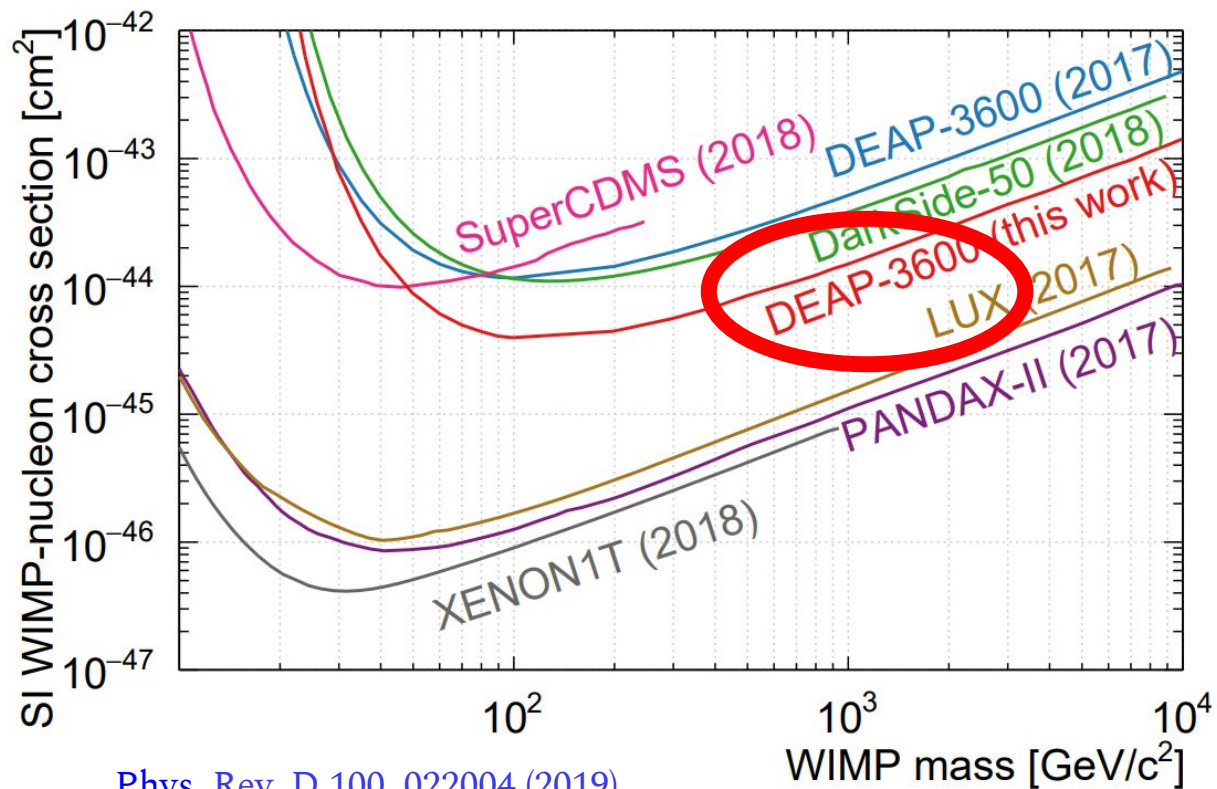




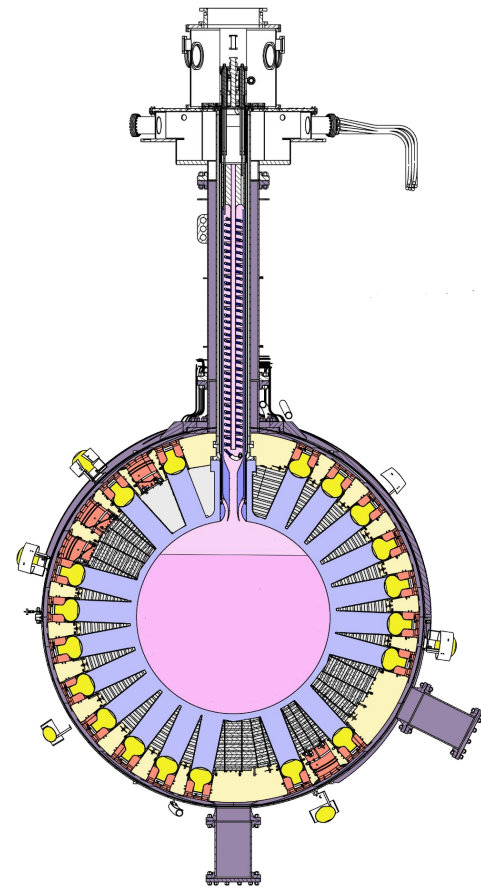
# What we learn from DEAP-3600



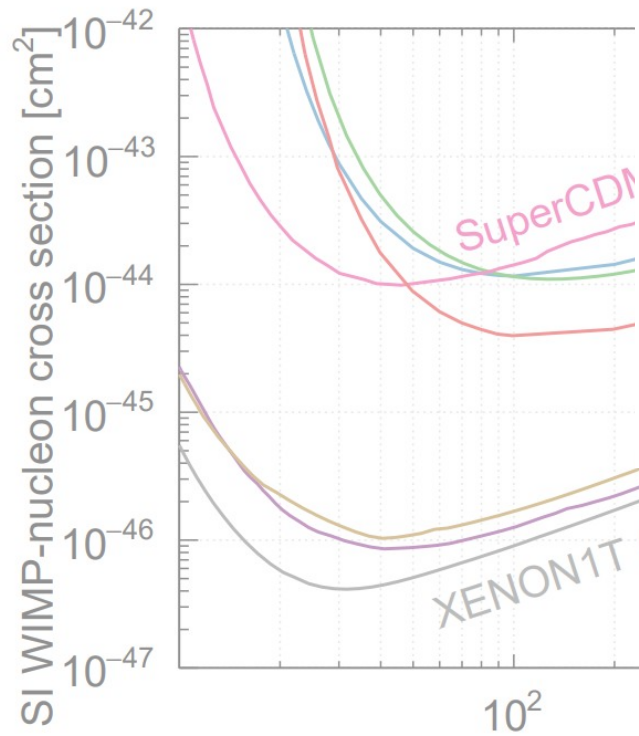
# What we learn from DEAP-3600



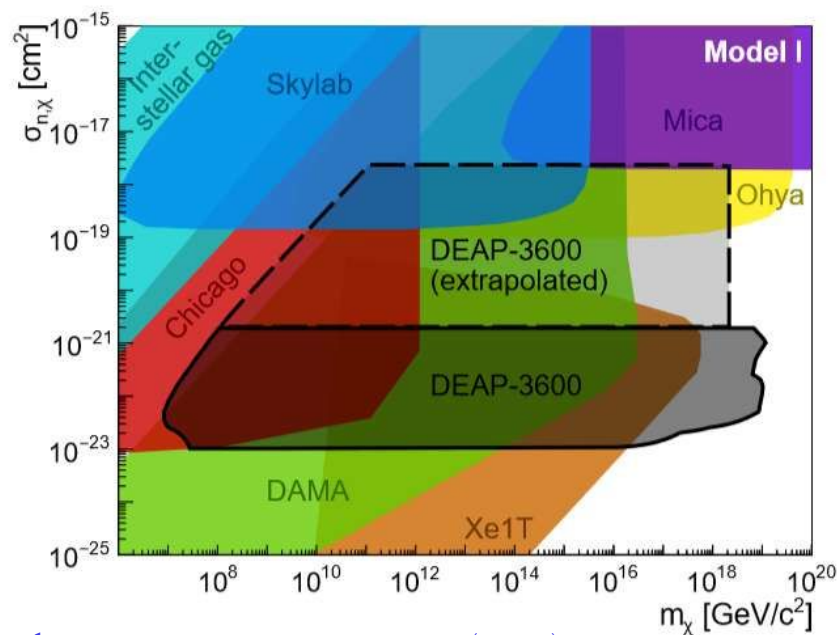
Phys. Rev. D 100, 022004 (2019)



# What we learn from DEAP-36

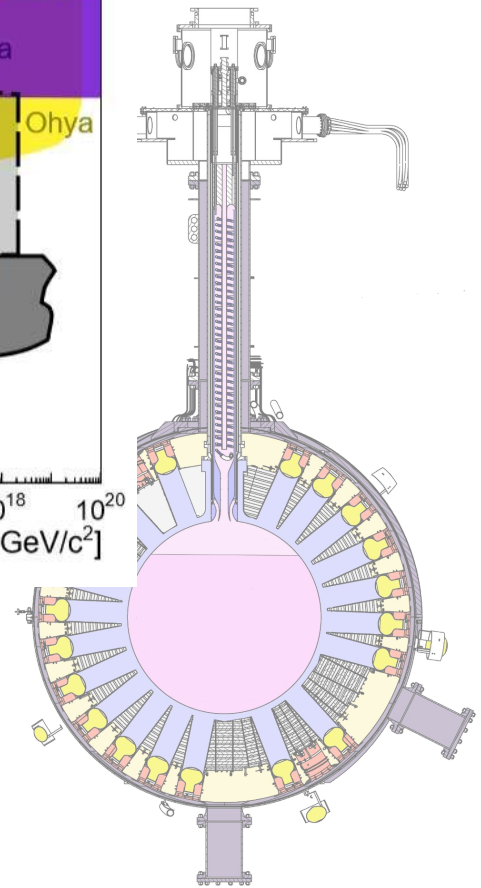


Phys. Rev. D 100, 022004 (2019)

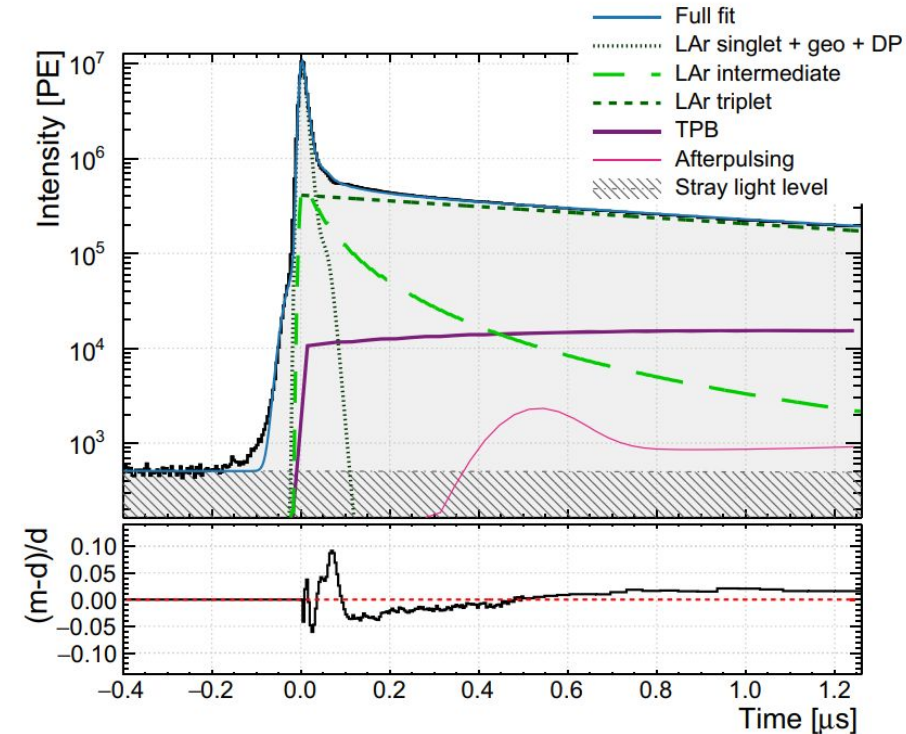


Phys. Rev. Lett. 128, 011801 (2022)

WIMP mass [GeV/c<sup>2</sup>]



# What we learn from DEAP-3600



**Pulse-Shape  
characterization**

$$I_{LAr}(t) = \frac{R_s}{\tau_s} e^{-t/\tau_s} + \frac{1 - R_s - R_t}{\tau_{rec}(1 + t/\tau_{rec})^2} + \frac{R_t}{\tau_t} e^{-t/\tau_t}$$

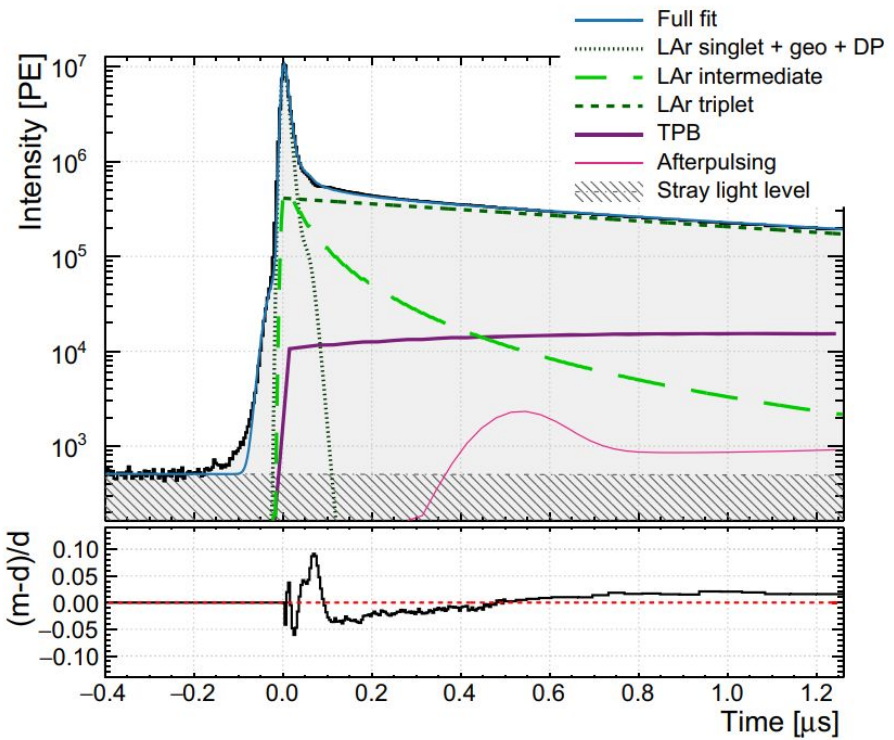
$\tau_s = 8.2ns$

$\tau_t = 1445ns$

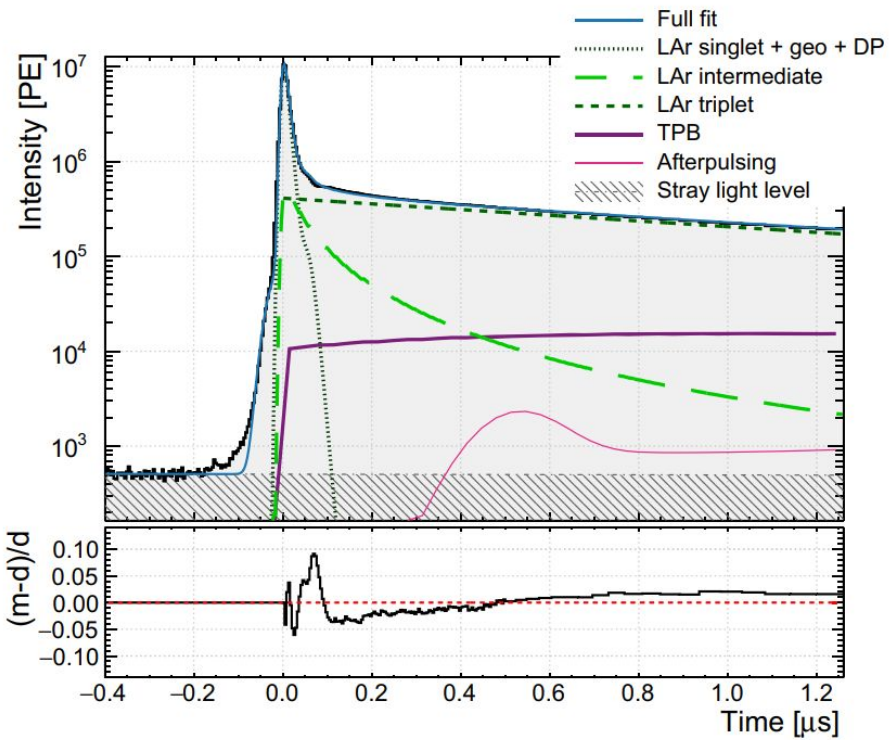
$\tau_{rec} = 175.5ns$

$R_s = 0.23$

$R_t = 0.71$



**Pulse-Shape characterization**



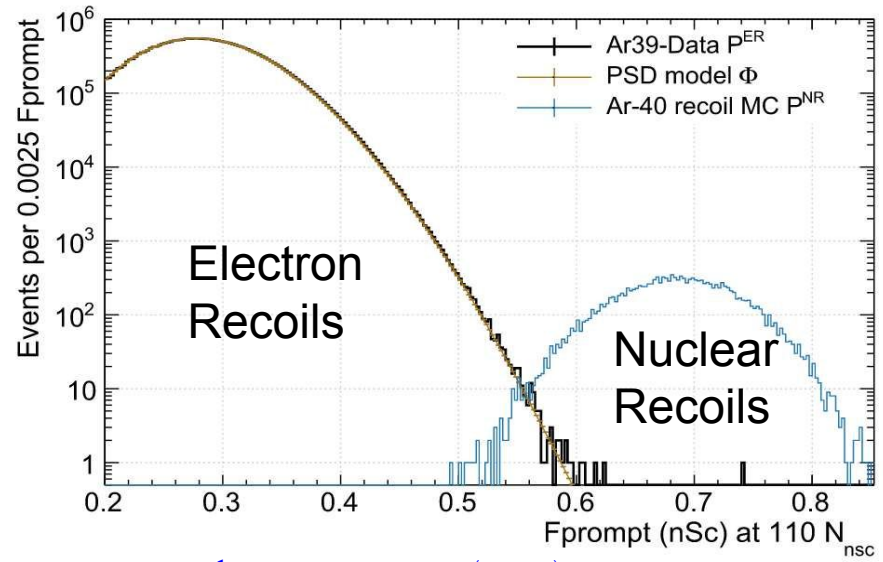
Eur. Phys. J. C 80,303 (2020)

$$I_{LAr}(t) = \frac{R_s}{\tau_s} e^{-t/\tau_s} + \frac{1 - R_s - R_t}{\tau_{rec}(1 + t/\tau_{rec})^2} + \frac{R_t}{\tau_t} e^{-t/\tau_t}$$

$$\tau_s = 8.2ns$$

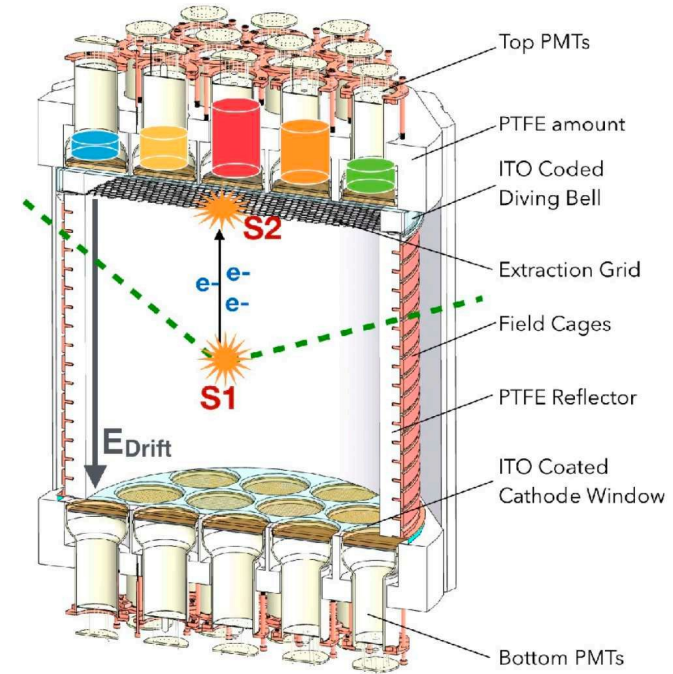
$$\tau_t = 1445ns$$

**Pulse-Shape Discrimination!**



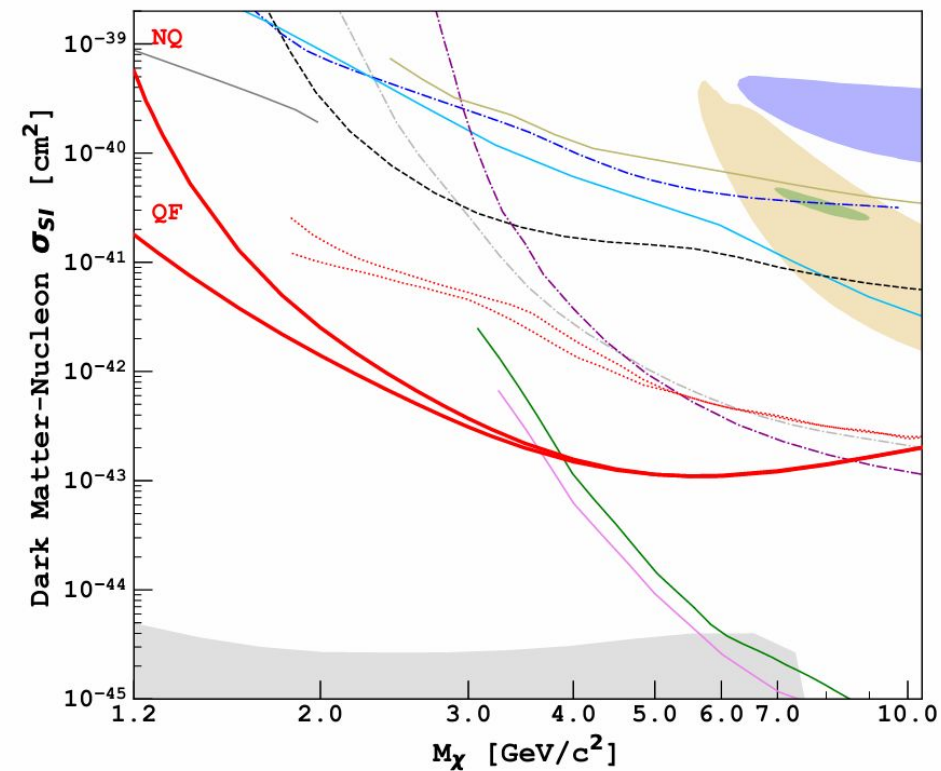
Eur. Phys. J. C 81,823 (2021)

# What we learn from DarkSide-50

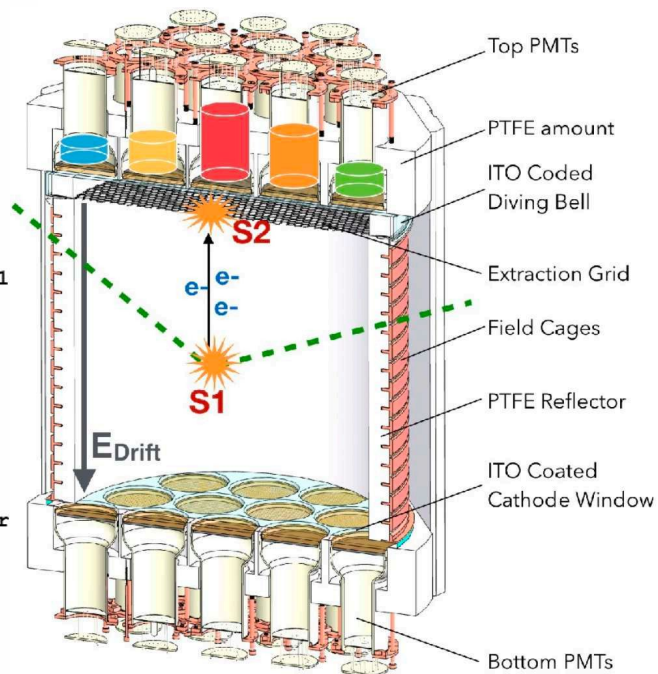


Drawing of DarkSide-50

# What we learn from DarkSide-50



- DS50 2022
- PandaX-4T 2022
- LUX 2021
- DAMIC 2020
- Xenon1T 2020
- Cresst-III 2019
- Pico-60 2019
- Xenon1T Migdal 201
- DS50 2018
- CDMSlite 2017
- PICASSO 2017
- CDMS 2013
- Cogent 2013
- DAMA/LIBRA 2008
- LAr Neutrino Floor

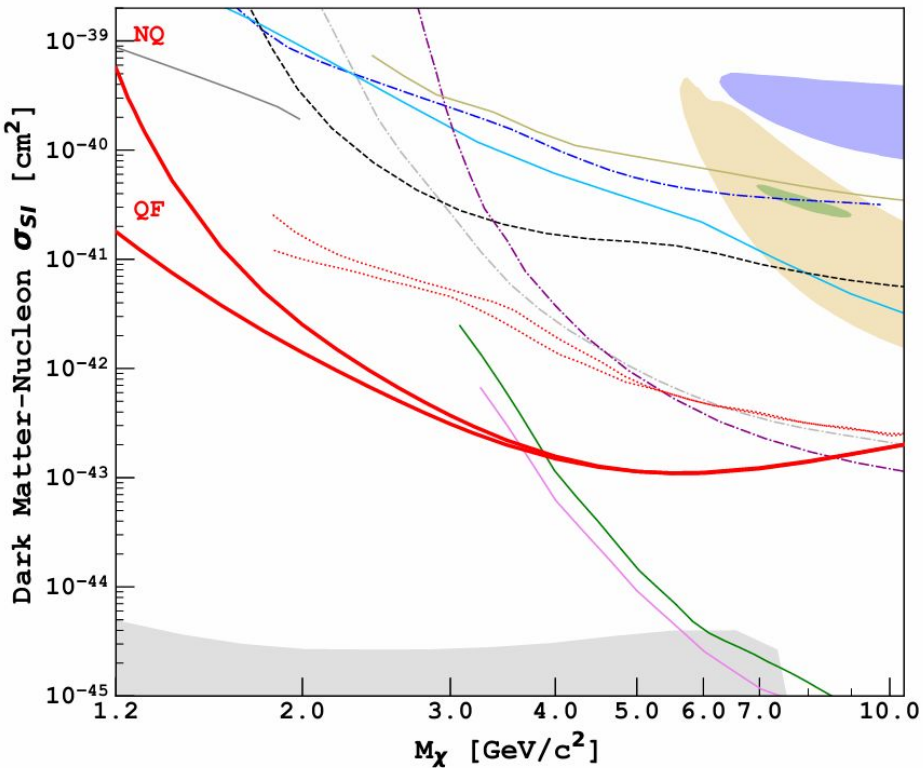


Drawing of DarkSide-50

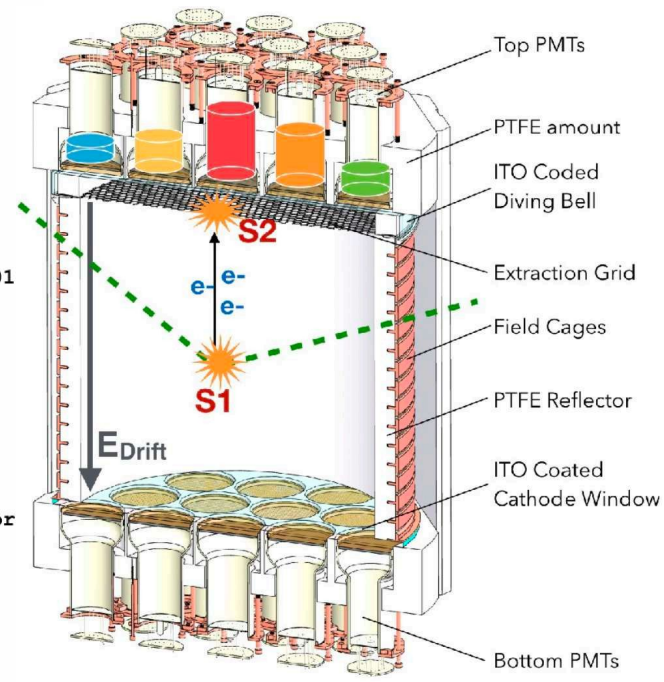


# What we learn from DarkSide-50

Unique sensitivity to GeV DM!



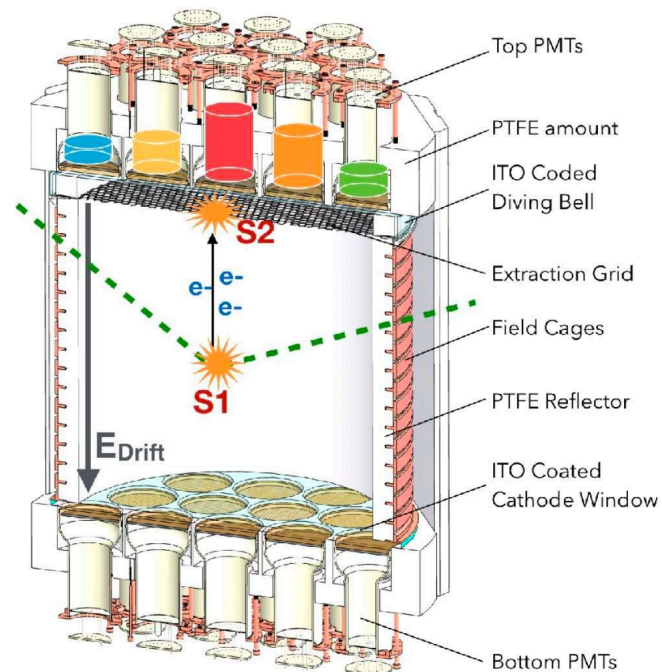
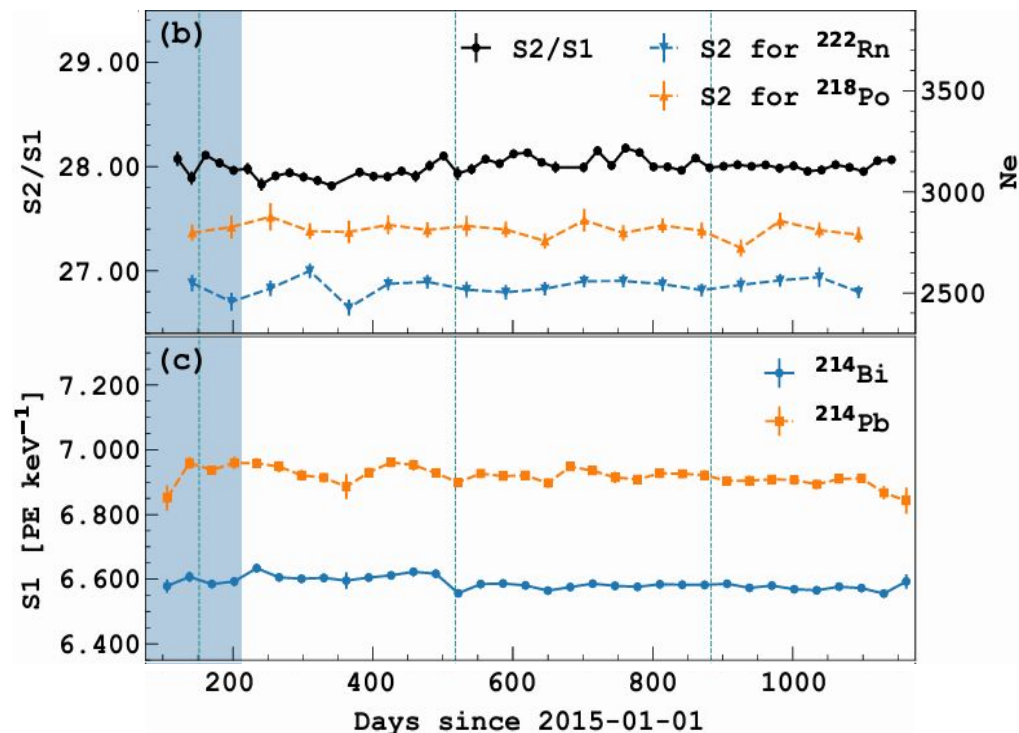
- DS50 2022
- PandaX-4T 2022
- LUX 2021
- DAMIC 2020
- Xenon1T 2020
- Cresst-III 2019
- Pico-60 2019
- Xenon1T Migdal 201
- DS50 2018
- CDMSlite 2017
- PICASSO 2017
- CDMS 2013
- Cogent 2013
- DAMA/LIBRA 2008
- LAr Neutrino Floor



Drawing of DarkSide-50

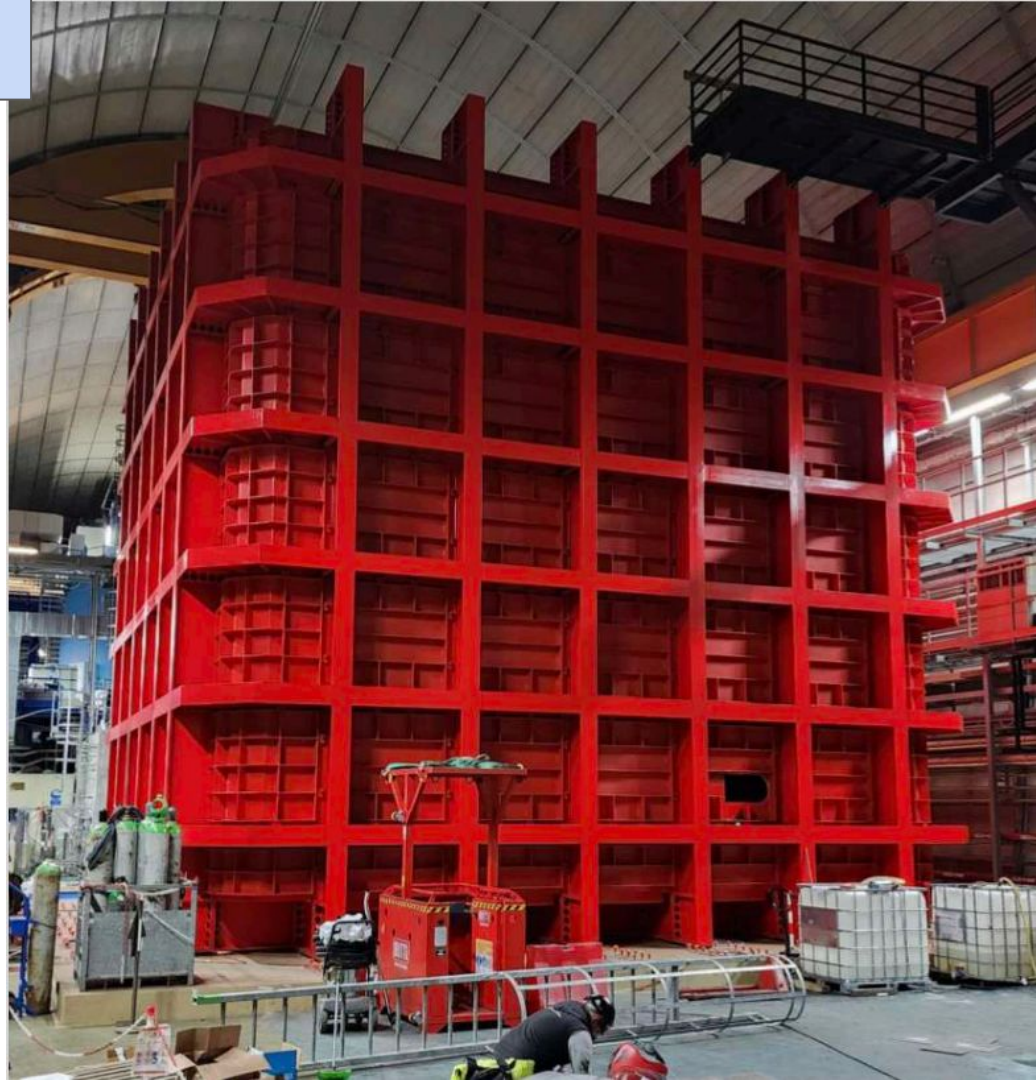
# What we learn from DarkSide-50

Demonstrated long-term stability

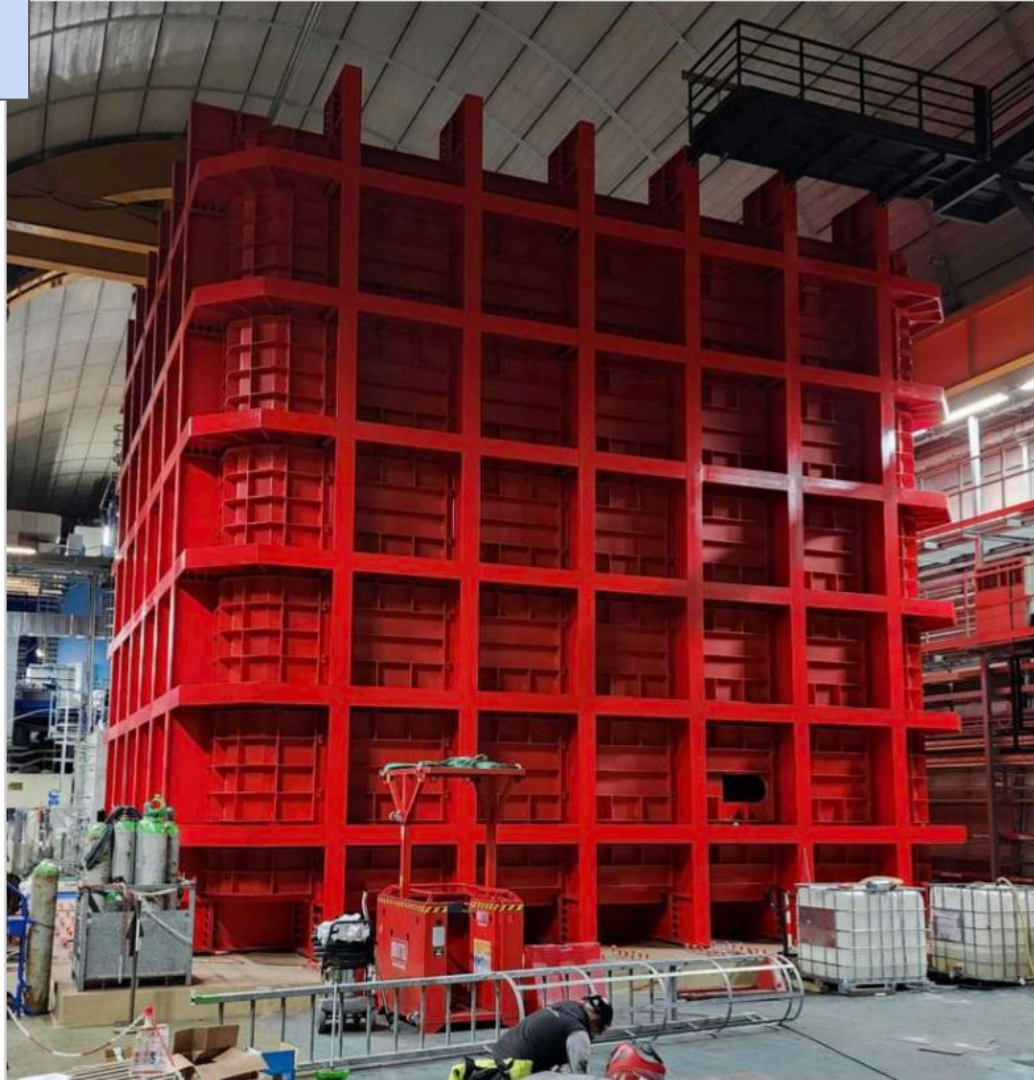
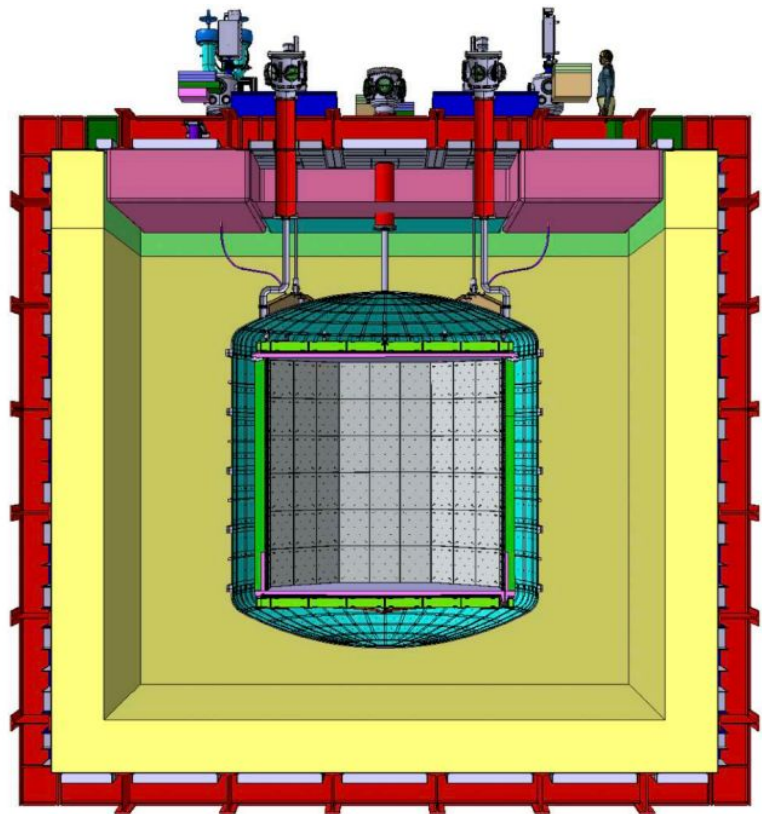


Drawing of DarkSide-50

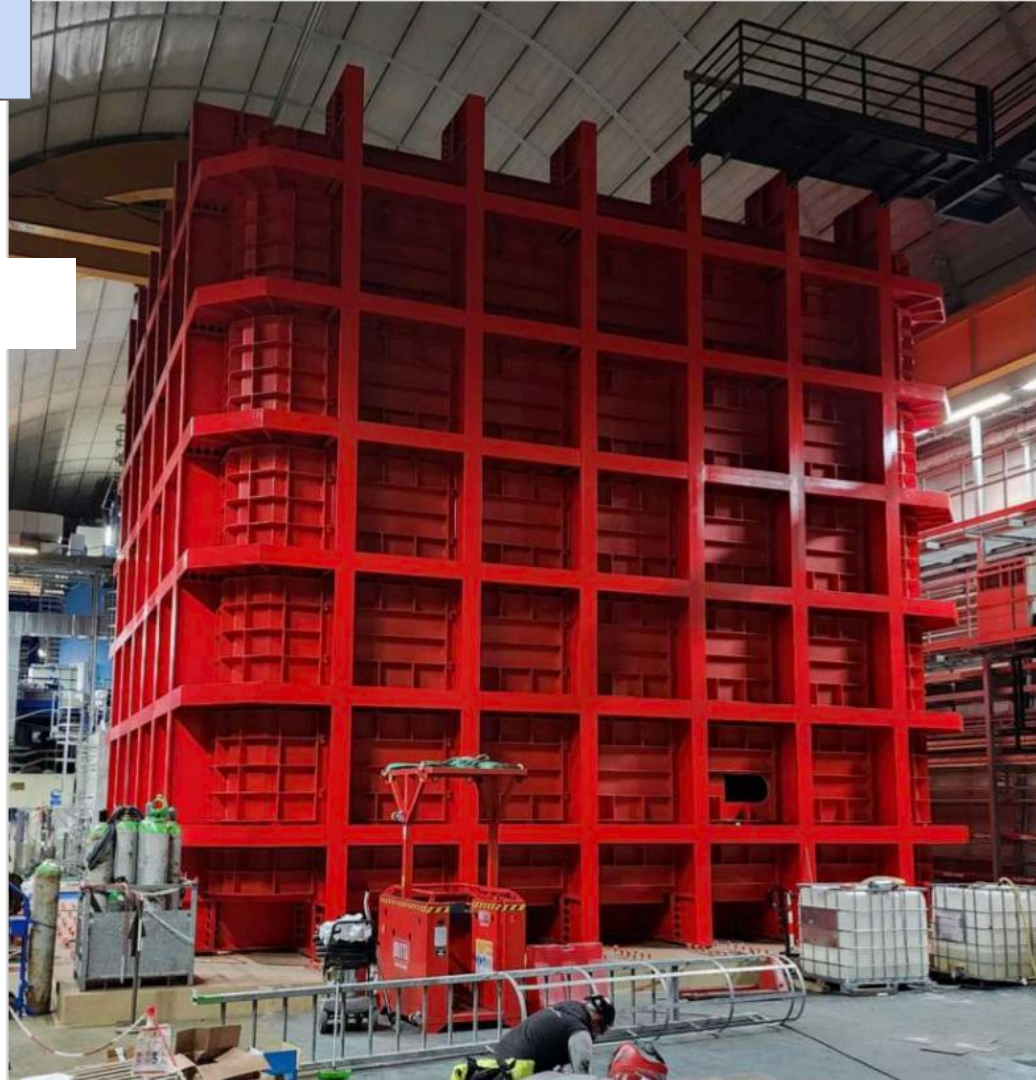
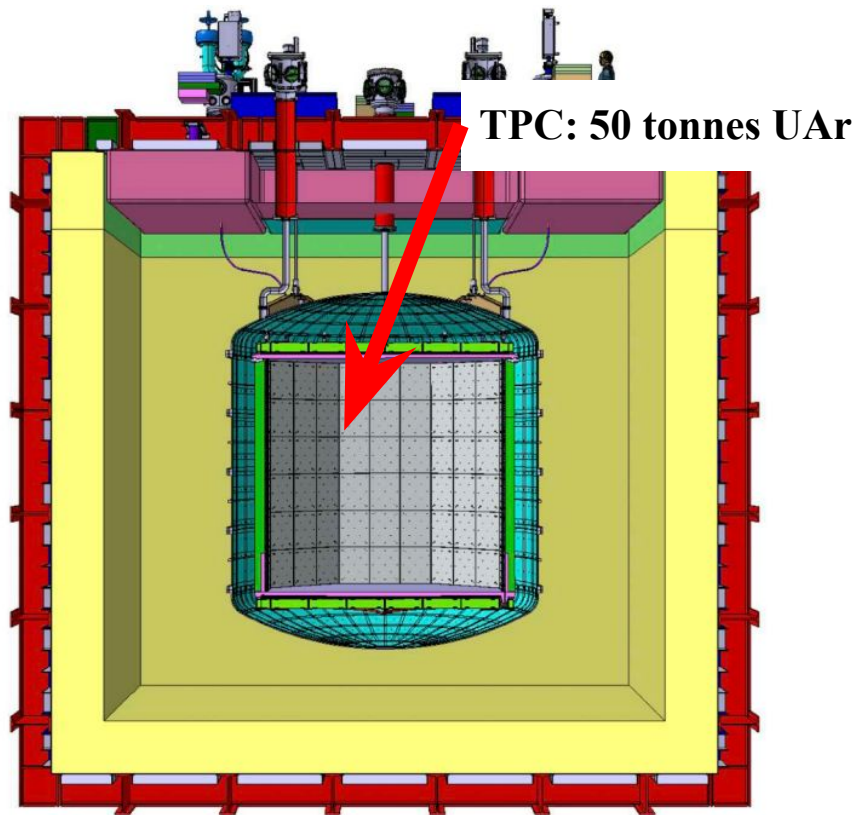
# The next phase: DarkSide-20k detector



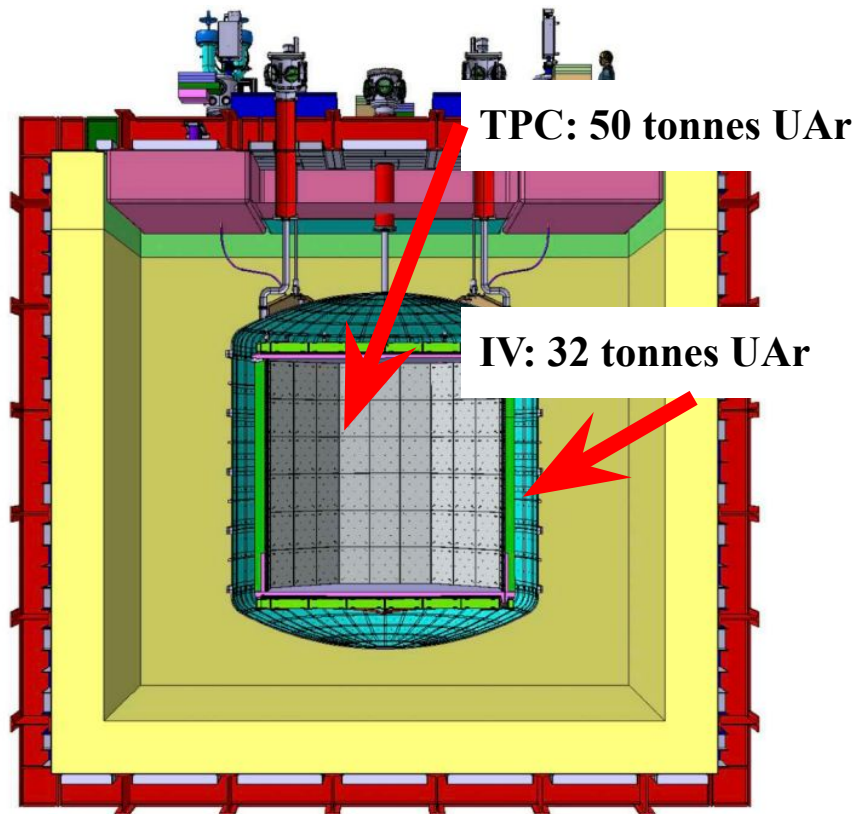
# The next phase: DarkSide-20k detector



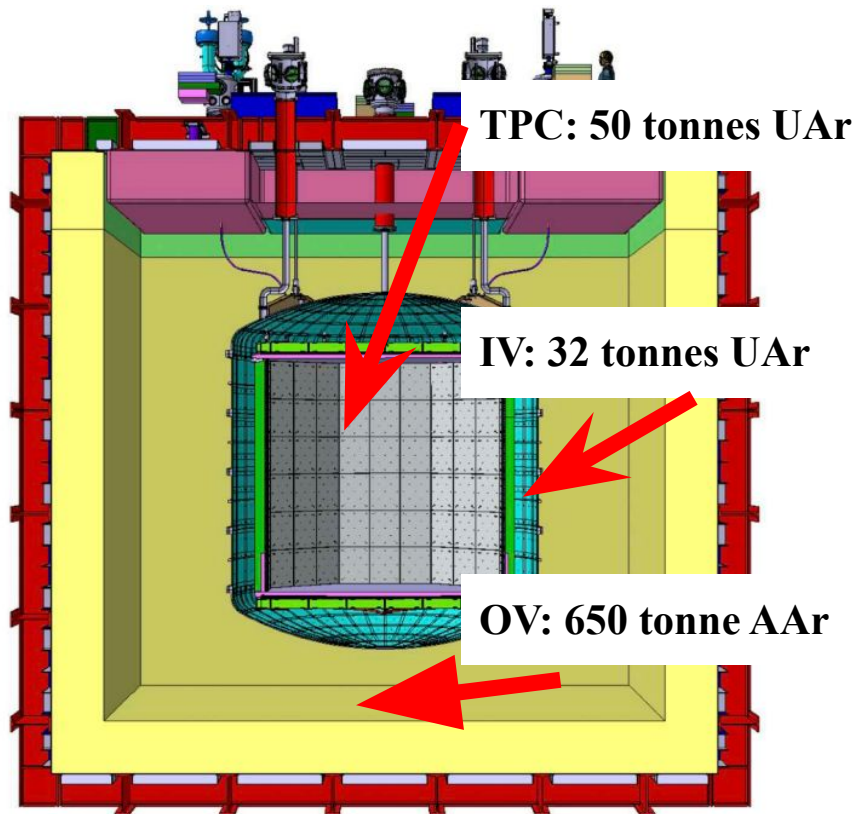
# The next phase: DarkSide-20k detector



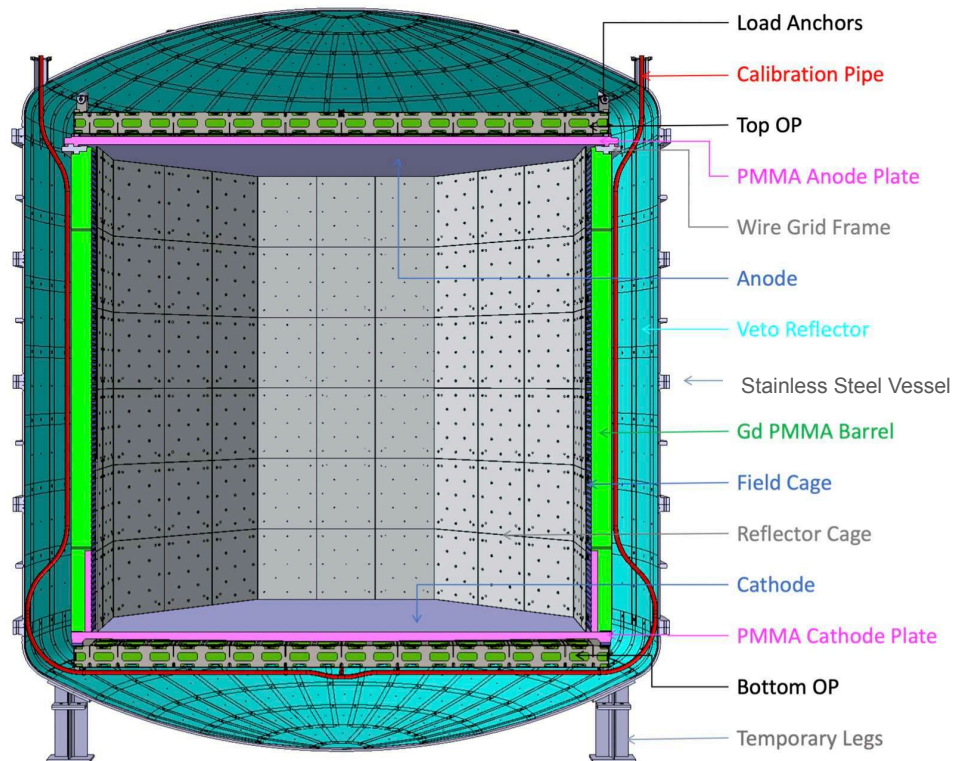
# The next phase: DarkSide-20k detector



# The next phase: DarkSide-20k detector



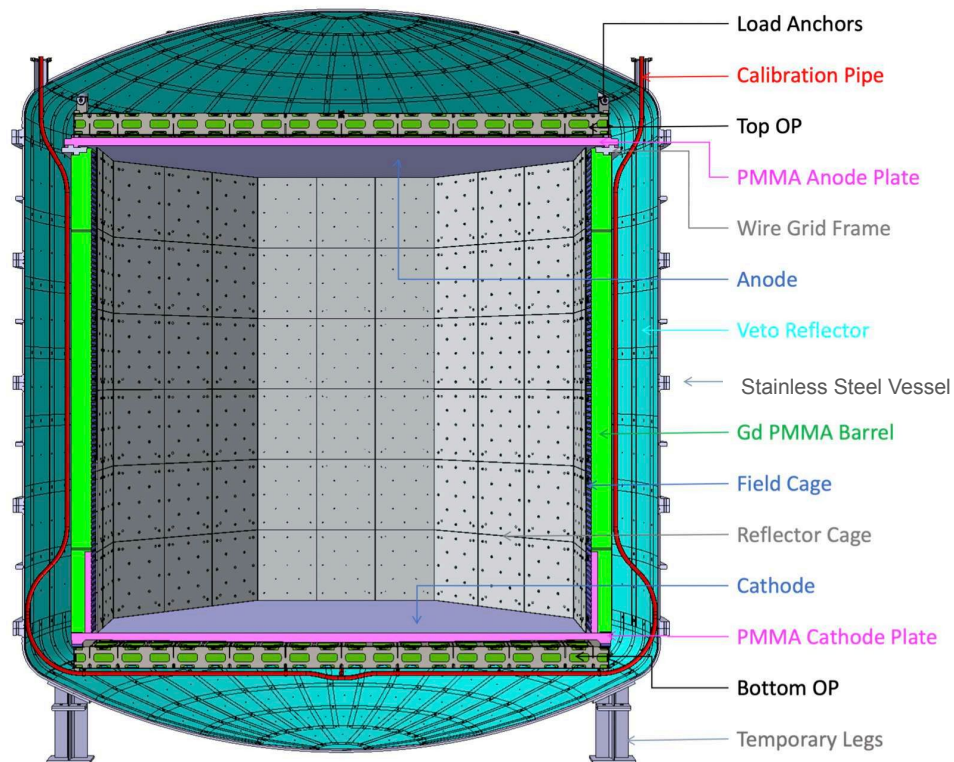
# A closer look at the Inner Detector





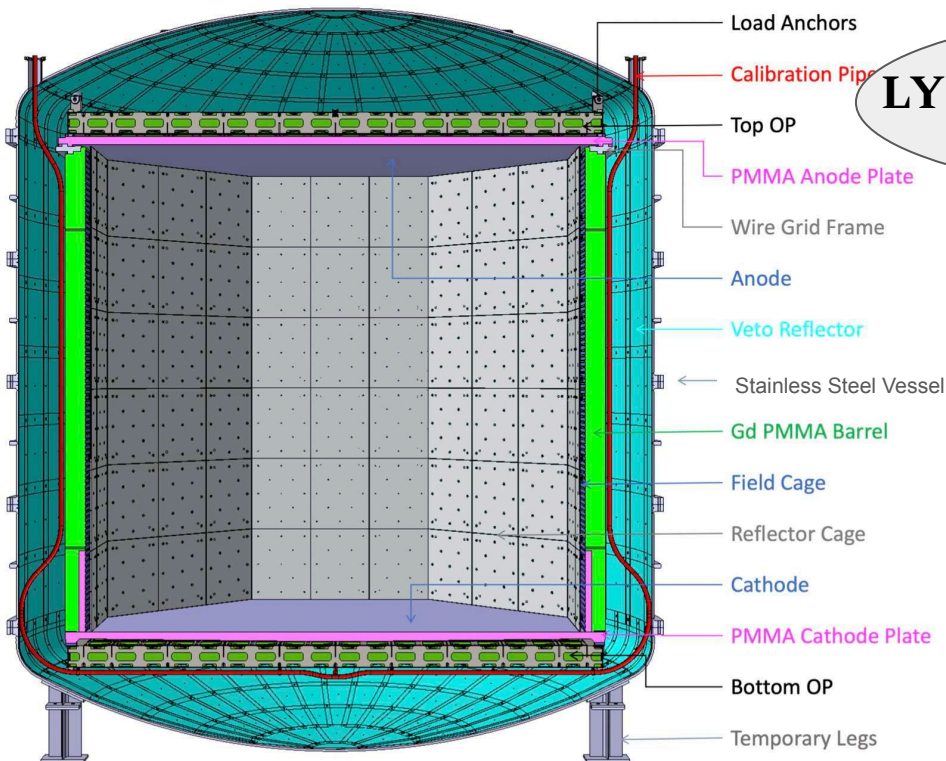
# A closer look at the Inner Detector

TPC: Active (fiducial) UAr mass: 49.7(20.2) tonnes



# A closer look at the Inner Detector

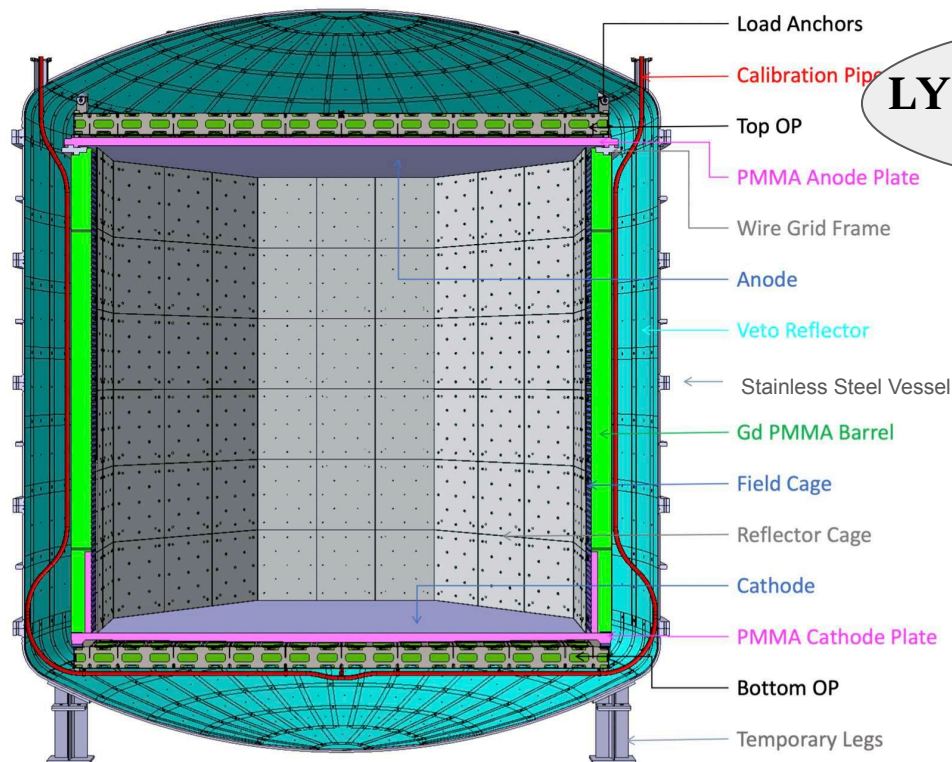
TPC: Active (fiducial) UAr mass: 49.7(20.2) tonnes



LY (null drift field): 10 PE/keV<sub>ee</sub>

# A closer look at the Inner Detector

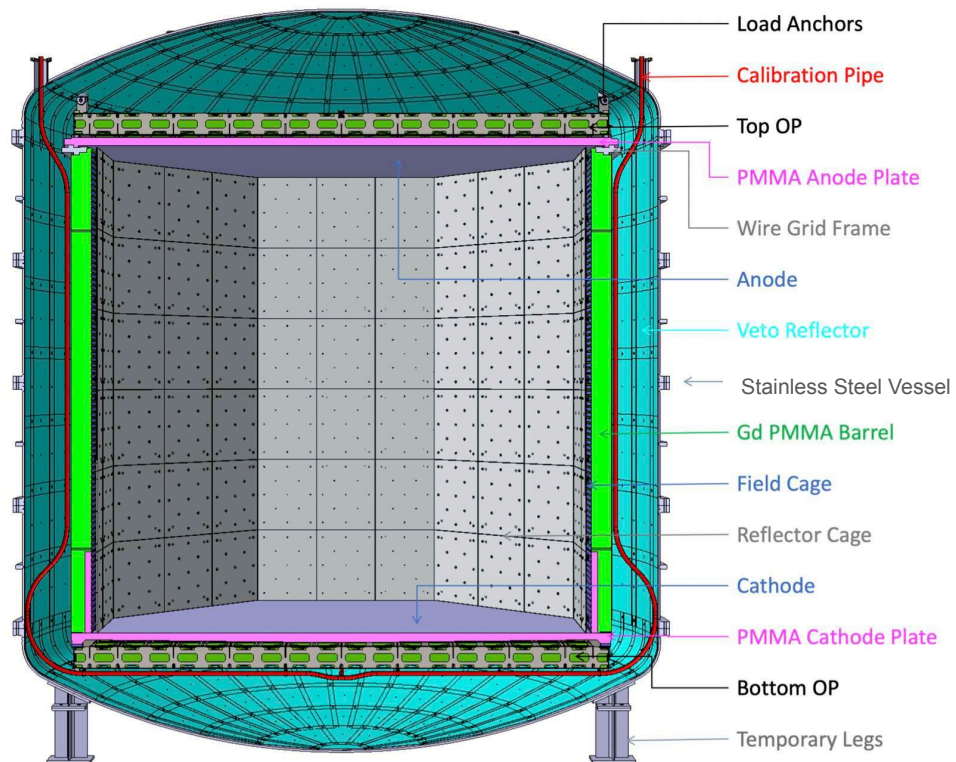
TPC: Active (fiducial) UAr mass: 49.7(20.2) tonnes



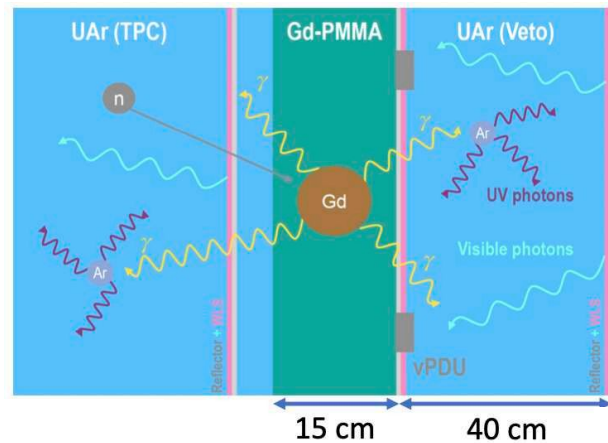
LY (null drift field): 10 PE/keV<sub>ee</sub>

S2 yield > 20 PE/e-

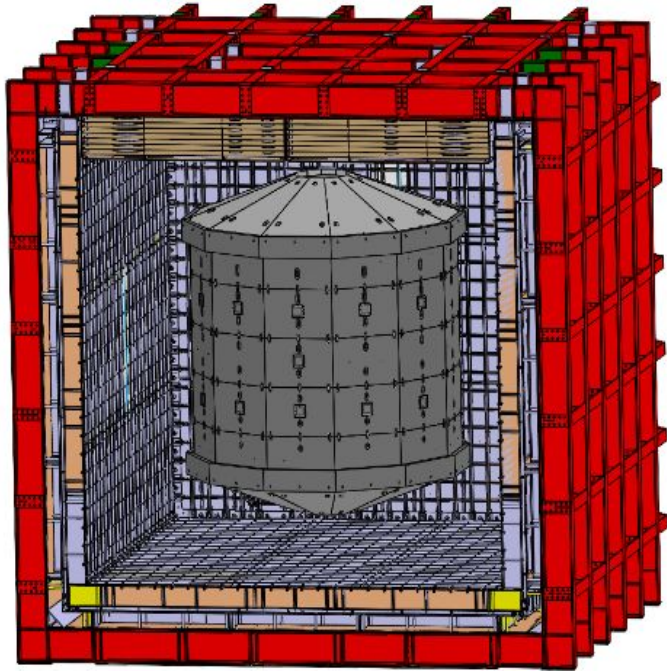
# A closer look at the Inner Detector

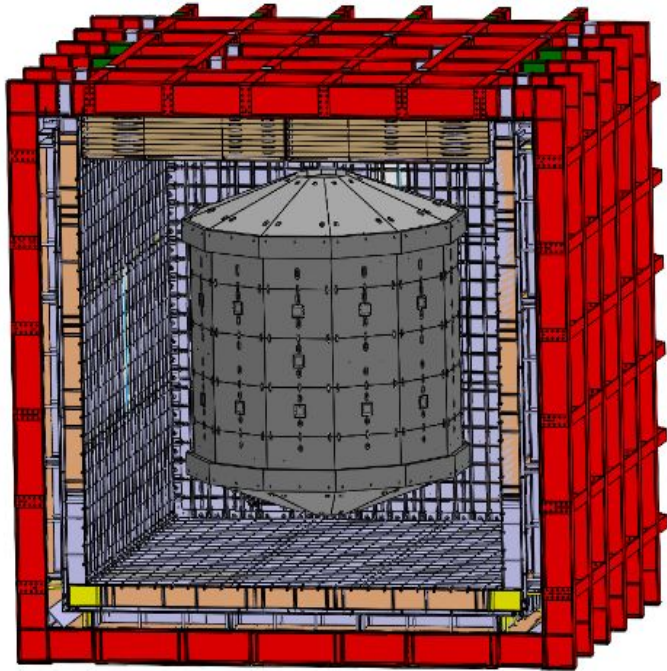


**Neutron rejection thanks to  $(n, \gamma)$**

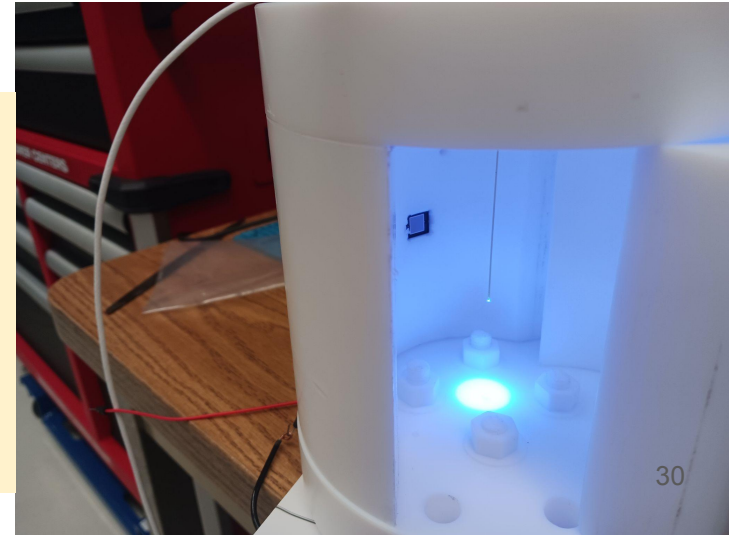


# R&D for the Outer Veto

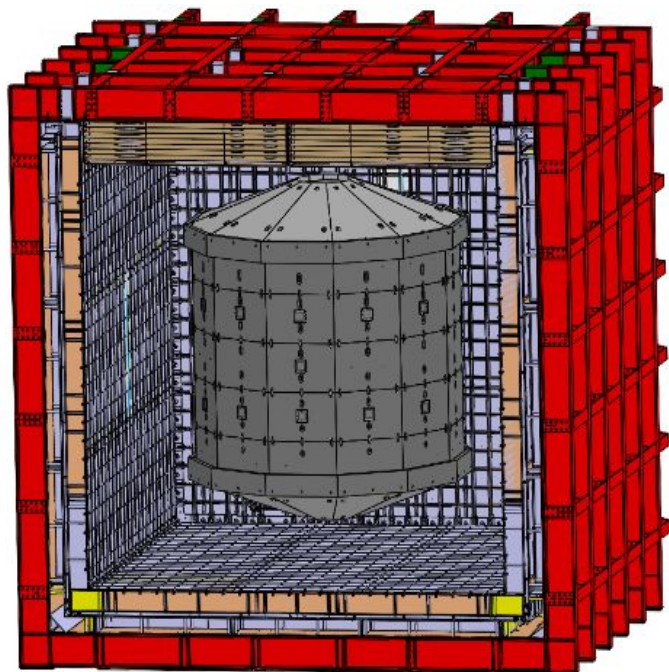




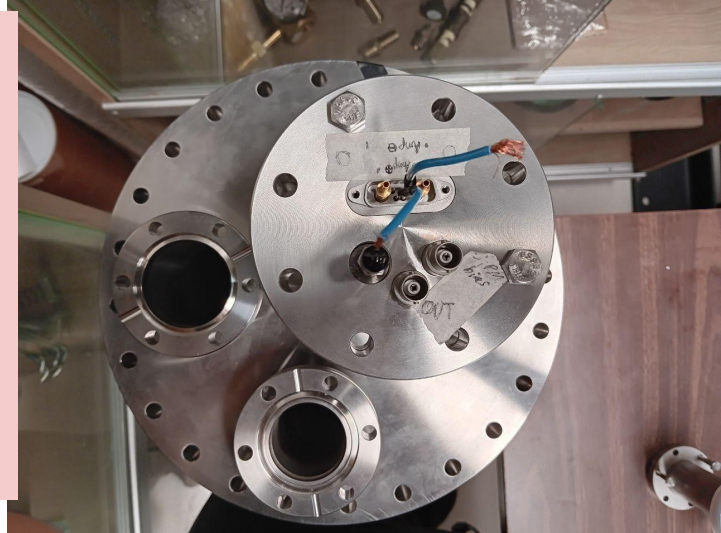
Reflectance  
Effects  
From  
LAr  
Exposure  
Characterization  
Tool



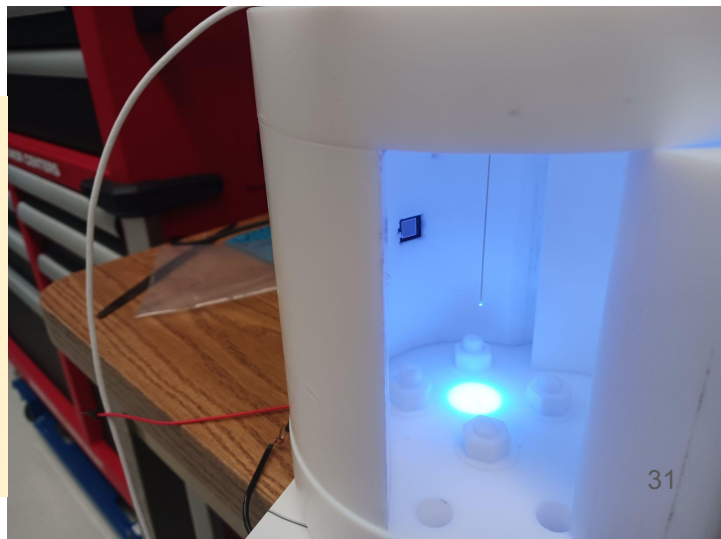
# R&D for the Outer Veto



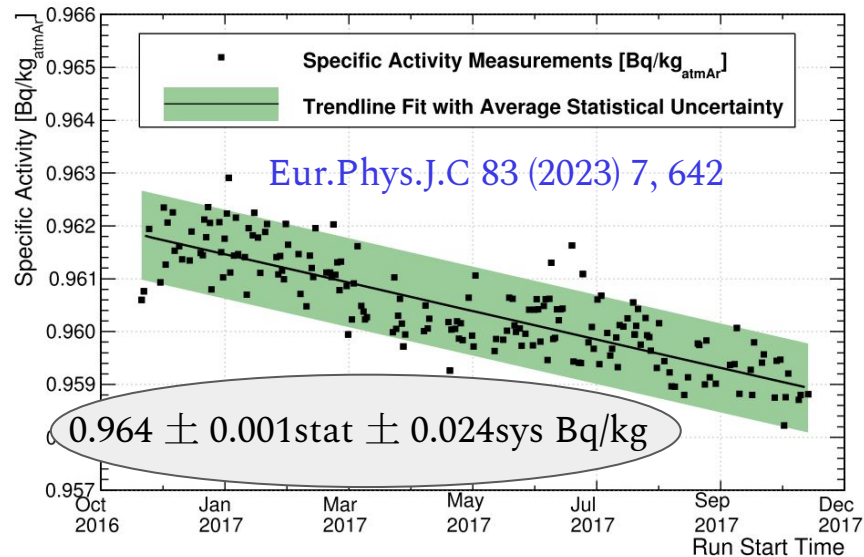
Apparatus for  
Researching  
Argon for  
New  
Detector  
Designs for  
Exciting  
Experiments



Reflectance  
Effects  
From  
LAr  
Exposure  
Characterization  
Tool

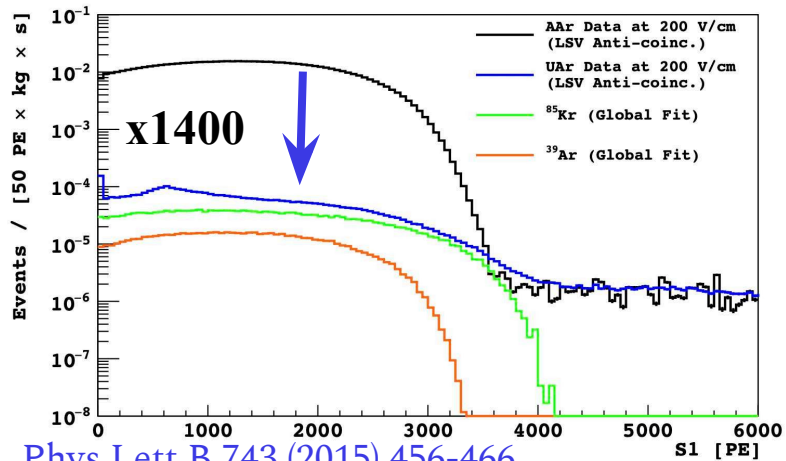


# DarkSide-20k UAr recipe

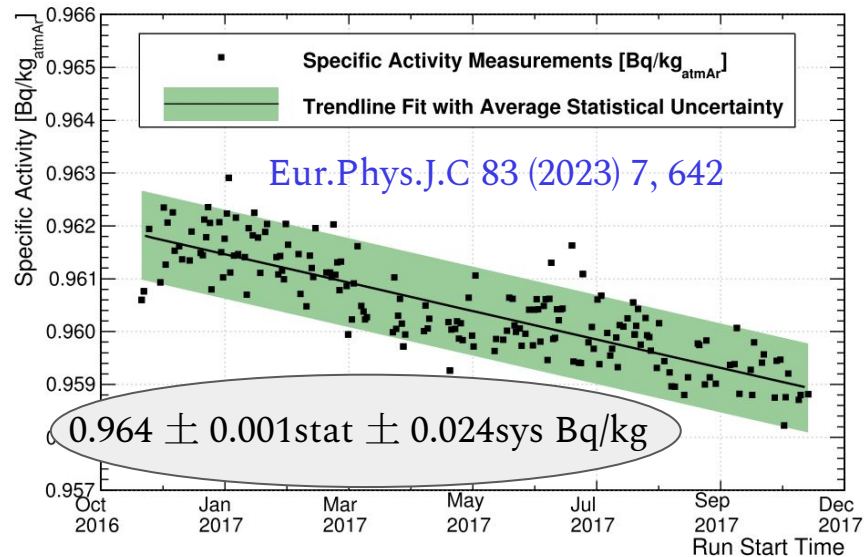




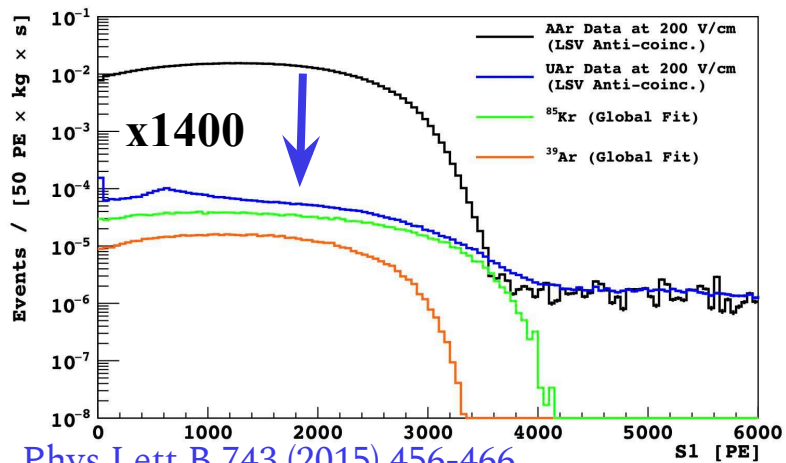
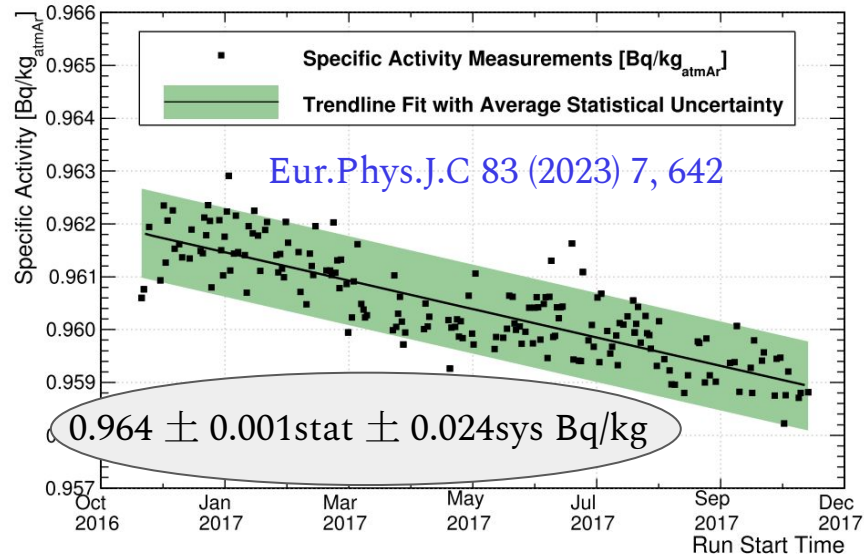
# DarkSide-20k UAr recipe



Phys.Lett.B 743 (2015) 456-466

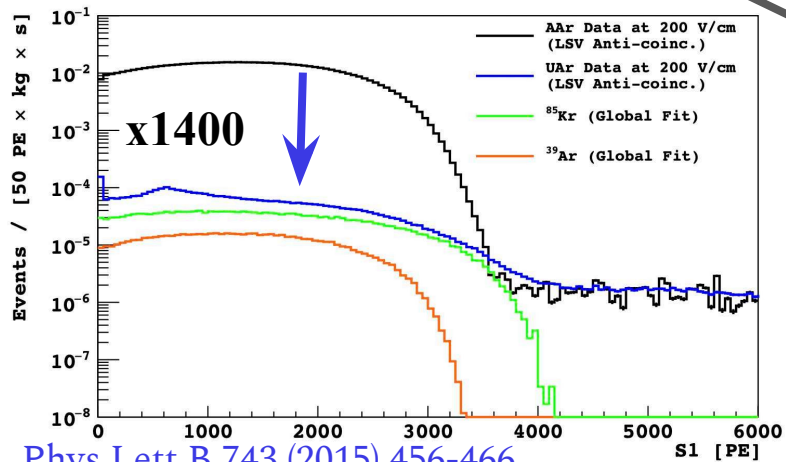
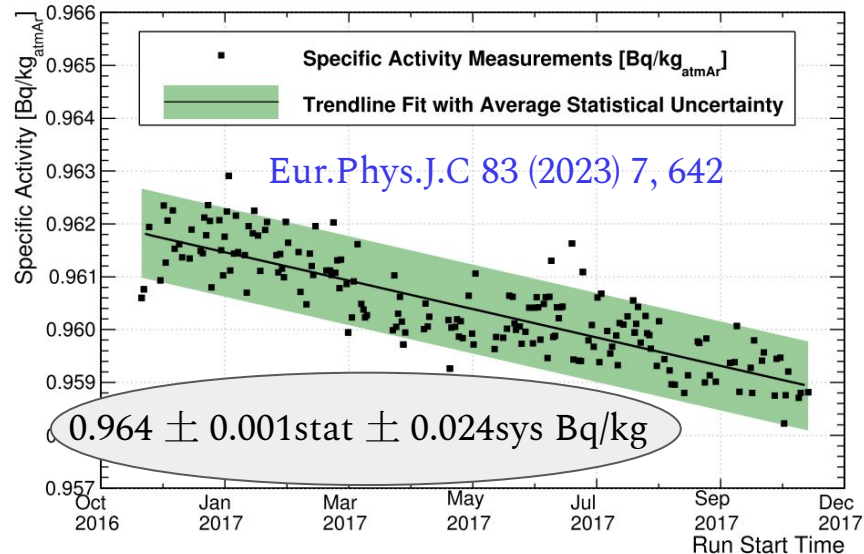


# DarkSide-20k UAr recipe



Phys.Lett.B 743 (2015) 456-466

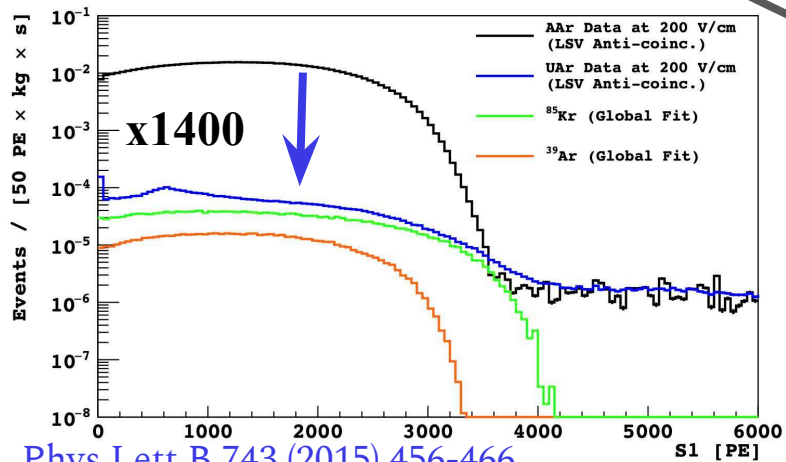
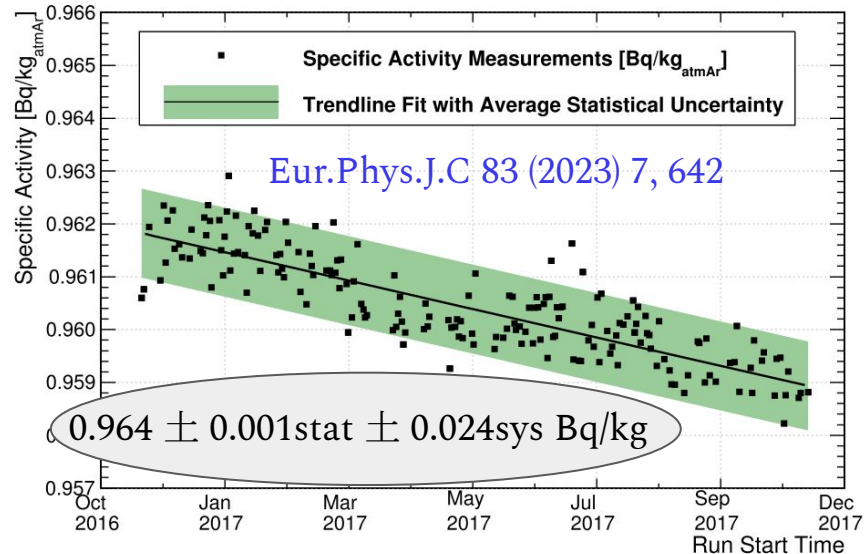
# DarkSide-20k UAr recipe



Phys.Lett.B 743 (2015) 456-466



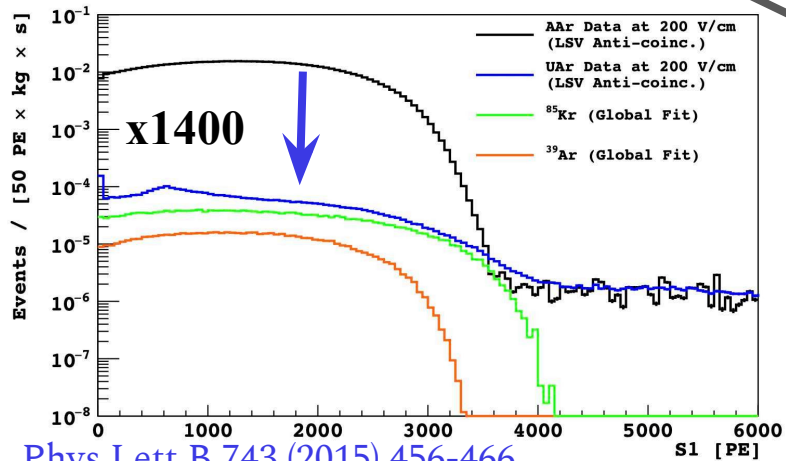
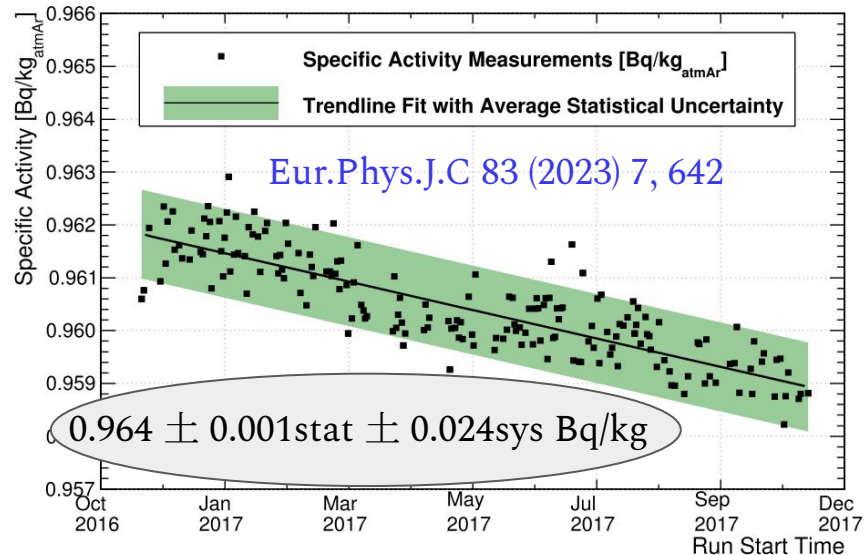
# DarkSide-20k UAr recipe



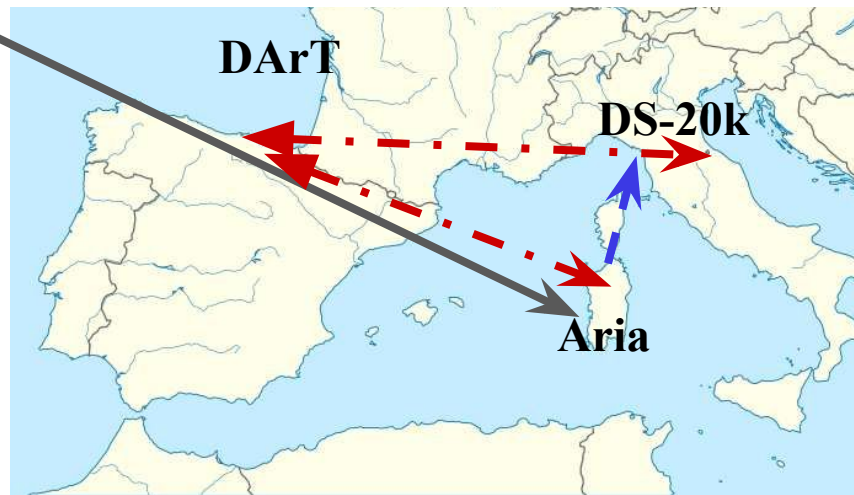
Phys.Lett.B 743 (2015) 456-466



# DarkSide-20k UAr recipe



Phys.Lett.B 743 (2015) 456-466



## DarkSide-20k UAr recipe

**2009: found low activity UAr at Southwest Colorado CO<sub>2</sub> wells**



# DarkSide-20k UAr recipe

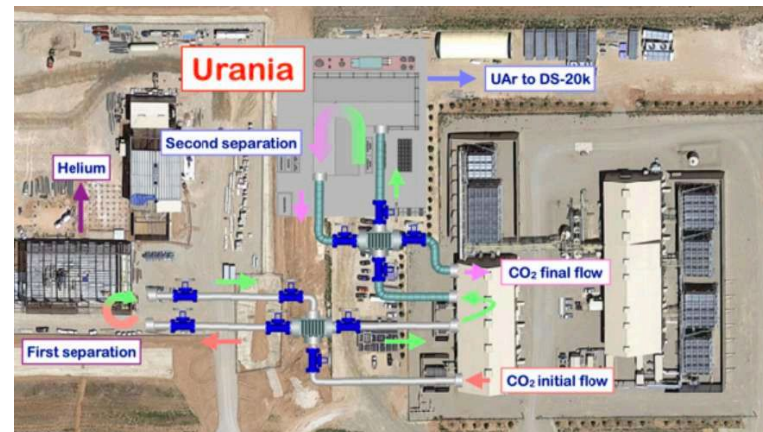
2009: found low activity UAr at Southwest Colorado CO<sub>2</sub> wells



# DarkSide-20k UAr recipe

2009: found low activity UAr at Southwest Colorado CO<sub>2</sub> wells

Estimated extraction rate: 250 kg/day





## DarkSide-20k UAr recipe

**Expected purity from Urania:  
99.99%**

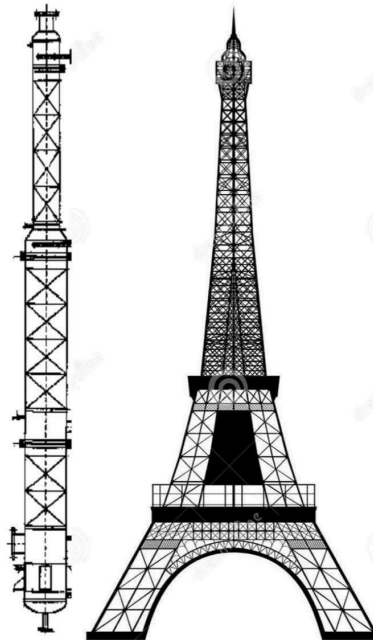
**Need a factor  $10^3$  more!**

# DarkSide-20k UAr recipe

Expected purity from Urania:  
99.99%

Need a factor  $10^3$  more!

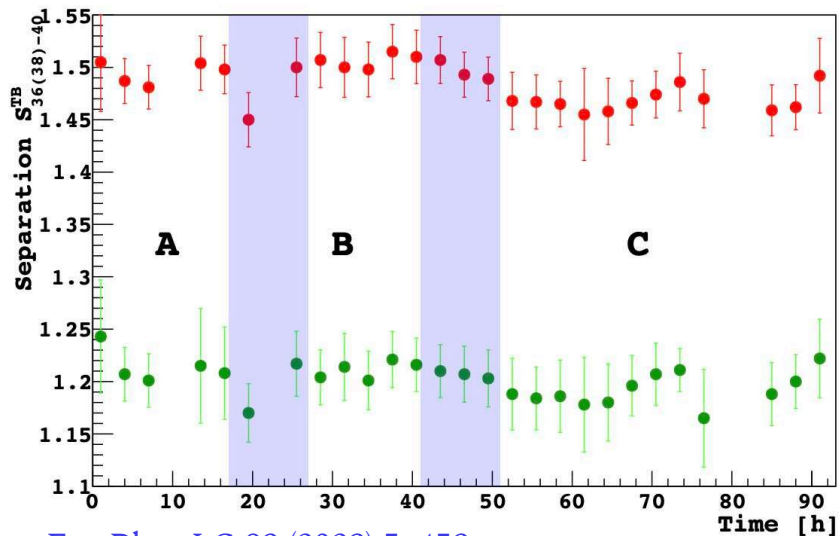
Seruci-1: 350 m tall



# DarkSide-20k UAr recipe

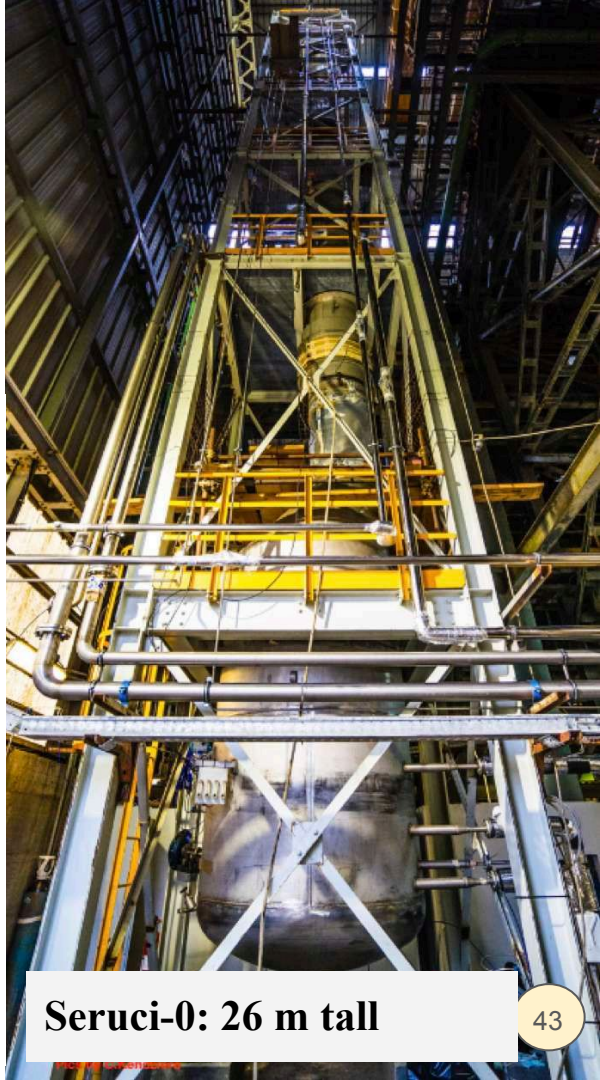
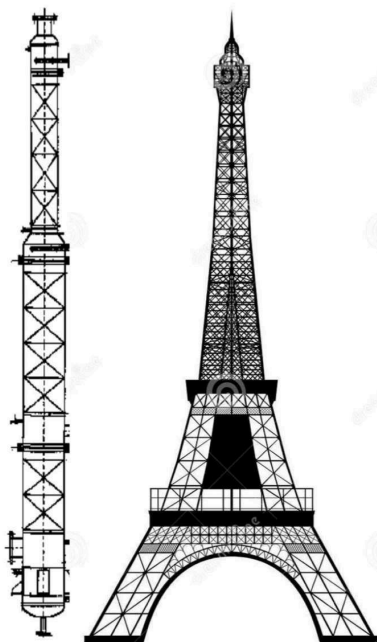
Expected purity from Urania:  
99.99%

Need a factor  $10^3$  more!



Eur.Phys.J.C 83 (2023) 5, 453

Seruci-1: 350 m tall



Seruci-0: 26 m tall

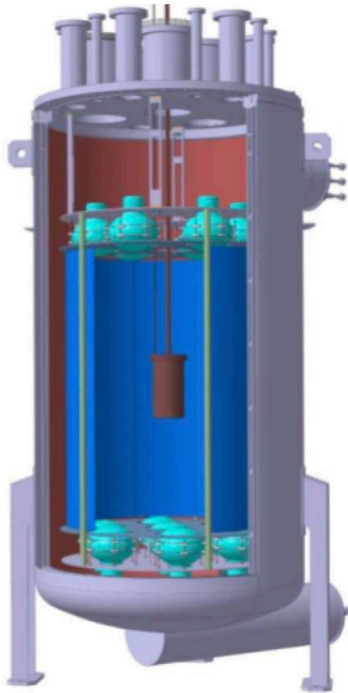
## DarkSide-20k UAr recipe

**DArT in ArDM, at Laboratorio Subterráneo De Canfranc (LSC, Spain, 1400 m.w.e.)**



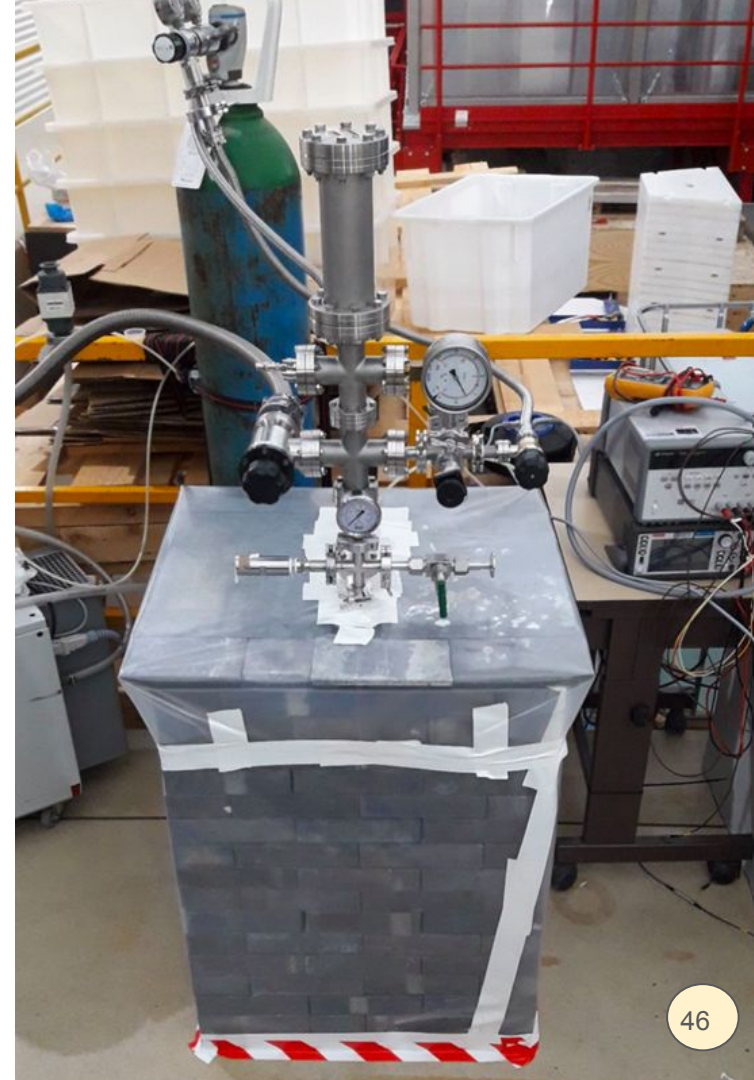
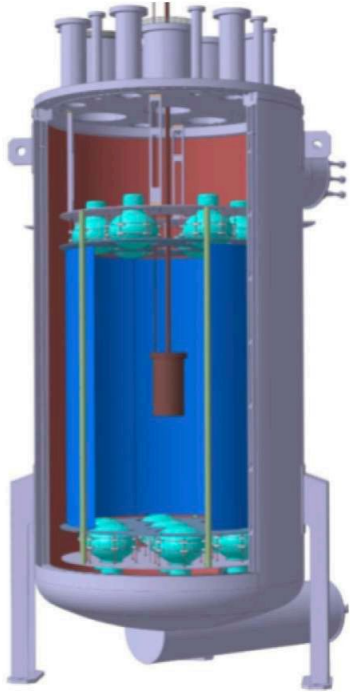
# DarkSide-20k UAr recipe

**DArT in ArDM, at Laboratorio Subterráneo De Canfranc (LSC, Spain, 1400 m.w.e.)**

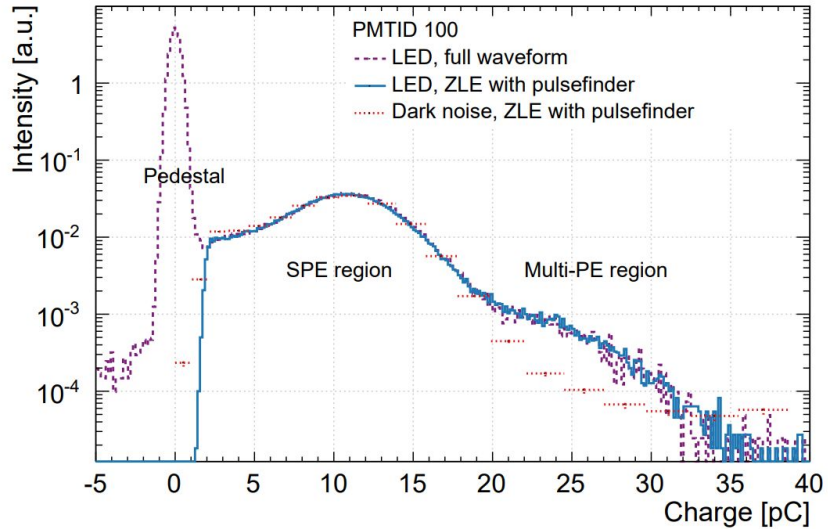
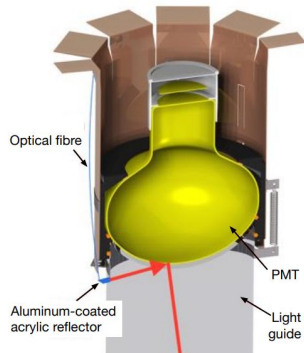


# DarkSide-20k UAr recipe

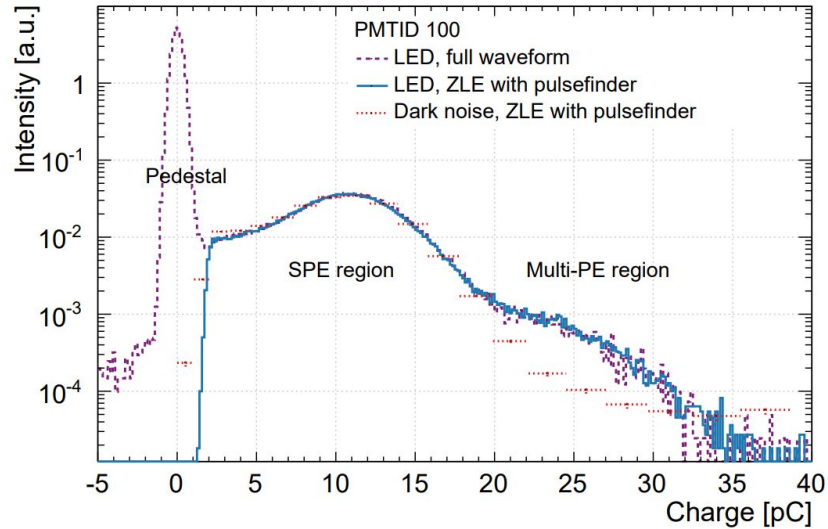
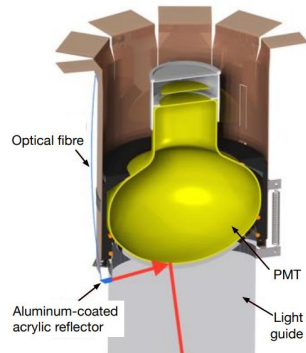
**DArT in ArDM, at Laboratorio Subterráneo De Canfranc (LSC, Spain, 1400 m.w.e.)**



# DarkSide-20k photosensors

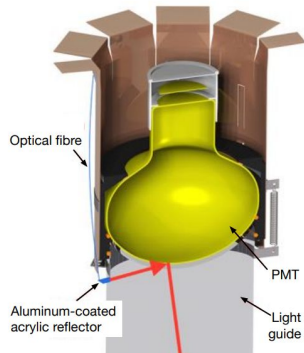


# DarkSide-20k photosensors

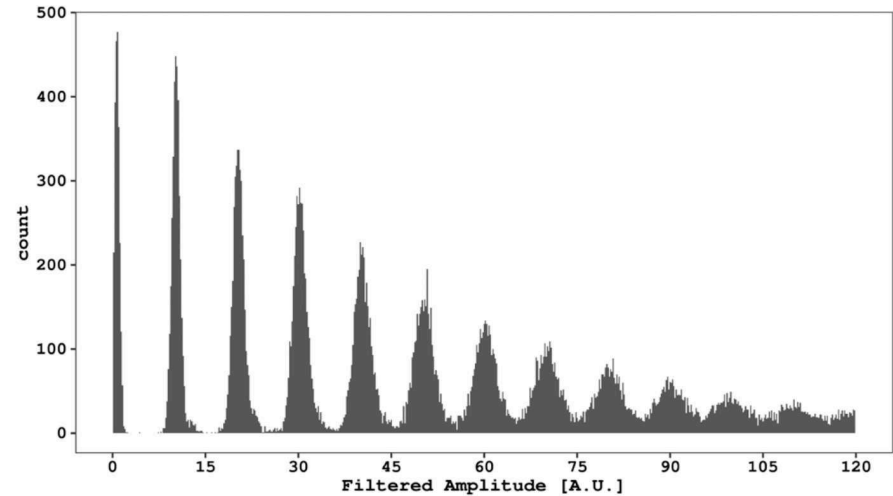
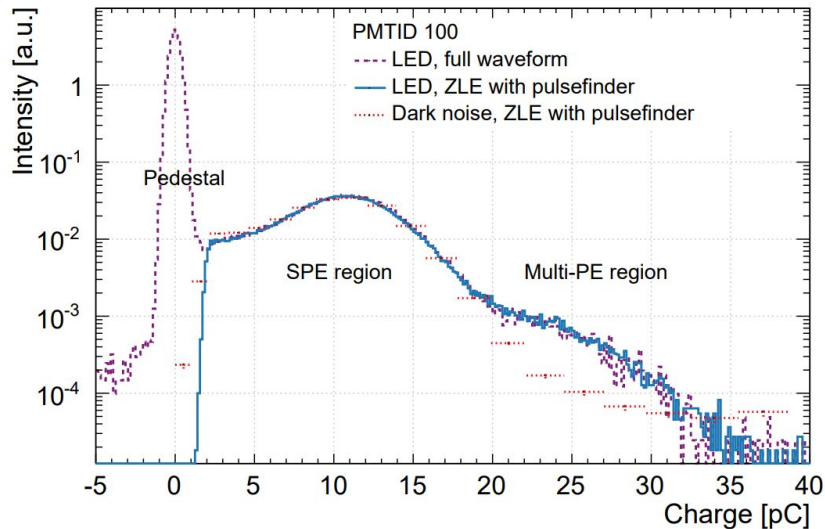
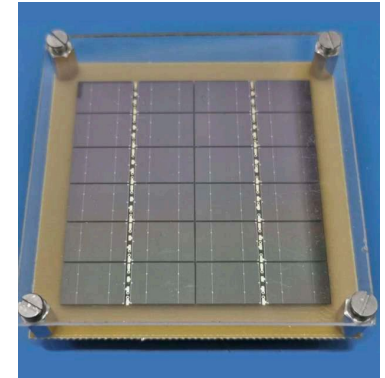




# DarkSide-20k photosensors

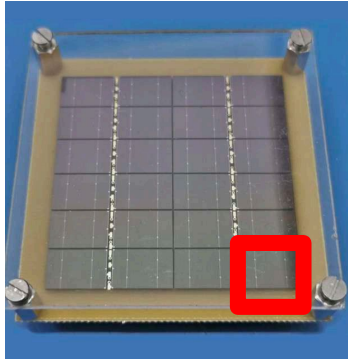


Silicon Photomultipliers (SiPMs)  
customly developed with  
Fondazione Bruno Kessler (FBK)



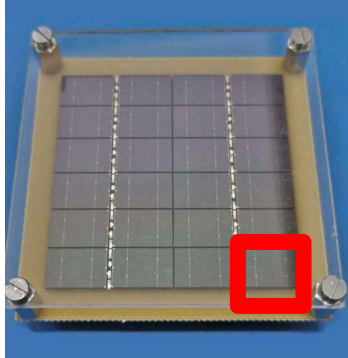
# DarkSide-20k photosensors

Tile: 25 cm<sup>2</sup>

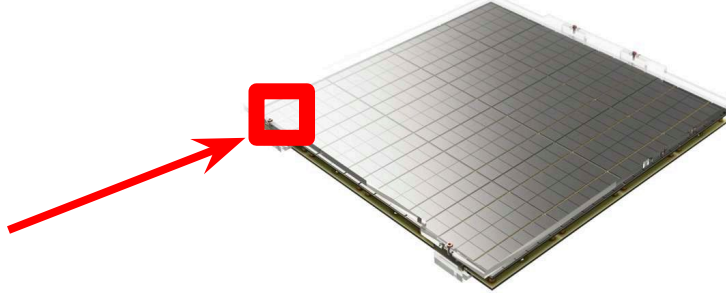


# DarkSide-20k photosensors

Tile: 25 cm<sup>2</sup>



PDU: 400 cm<sup>2</sup>



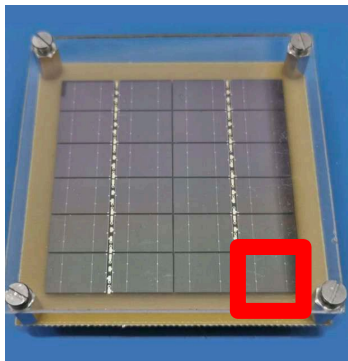
TPC: 525 PDU

IV: 20 vPDU

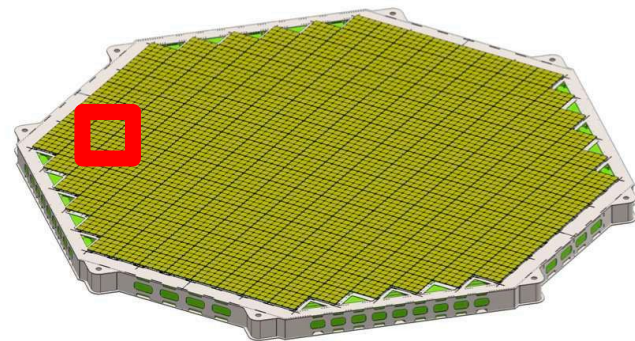
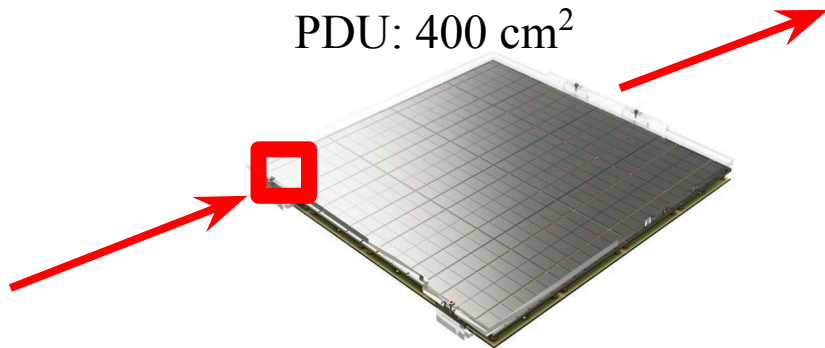
OV: 32 vPDU

# DarkSide-20k photosensors

Tile:  $25 \text{ cm}^2$



PDU:  $400 \text{ cm}^2$



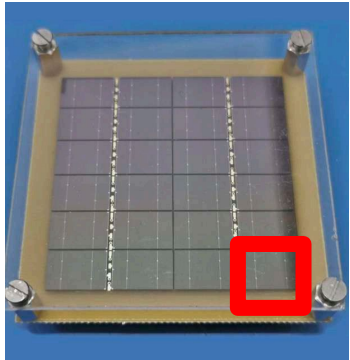
TPC: 525 PDU

IV: 20 vPDU

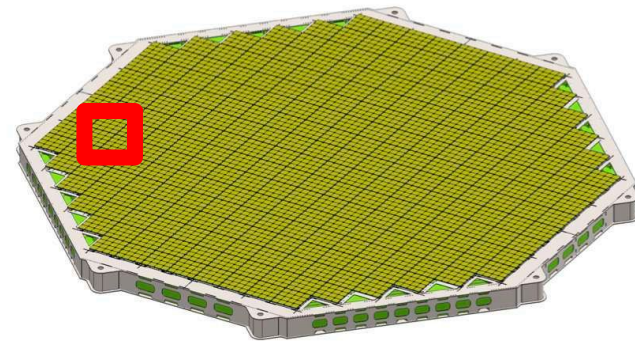
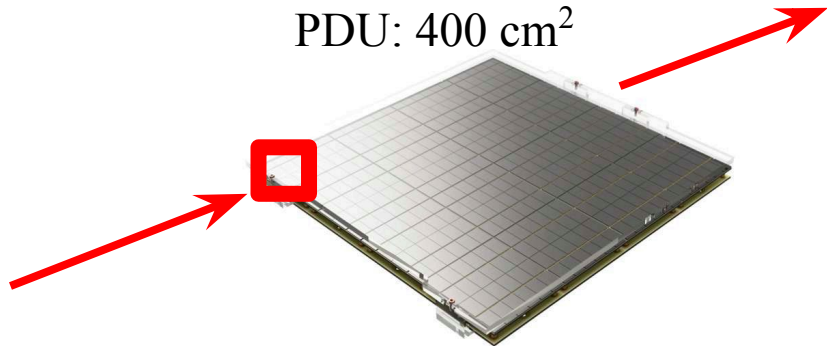
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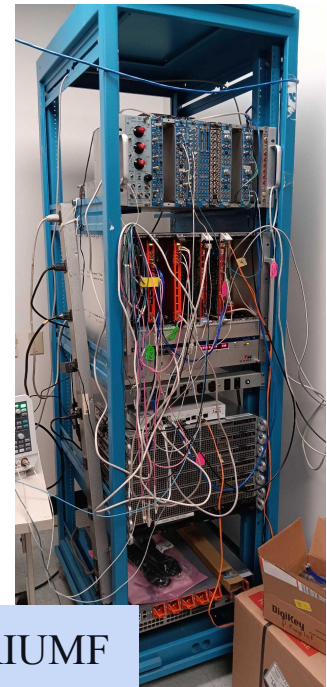
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OV: 32 vPDU

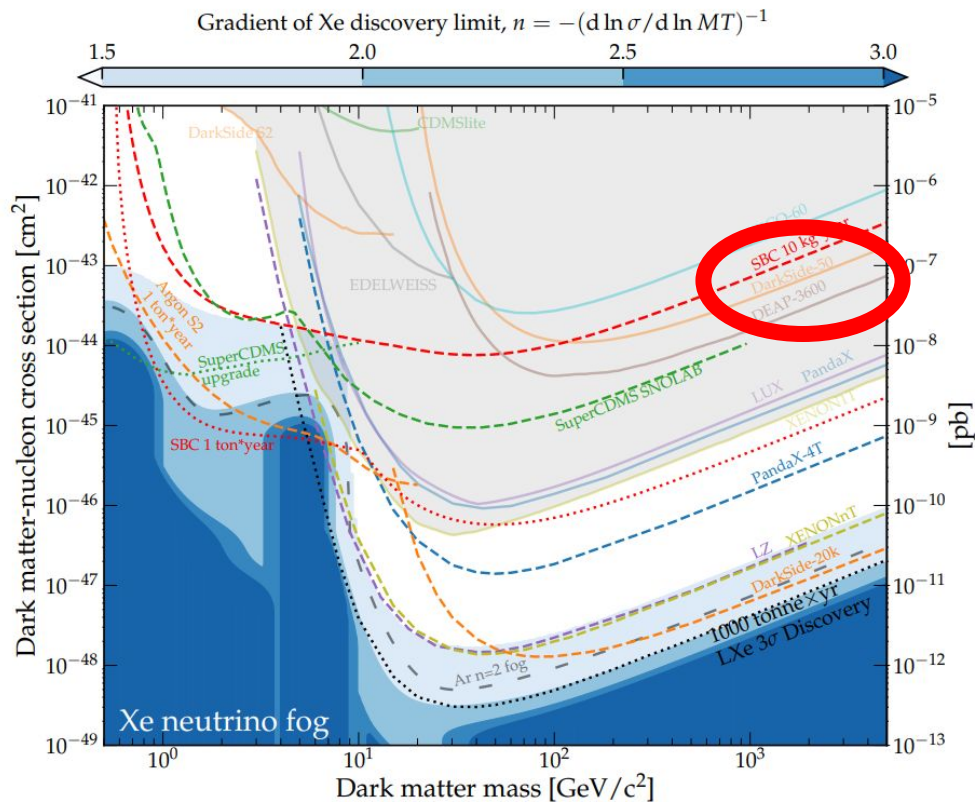


NOA facility

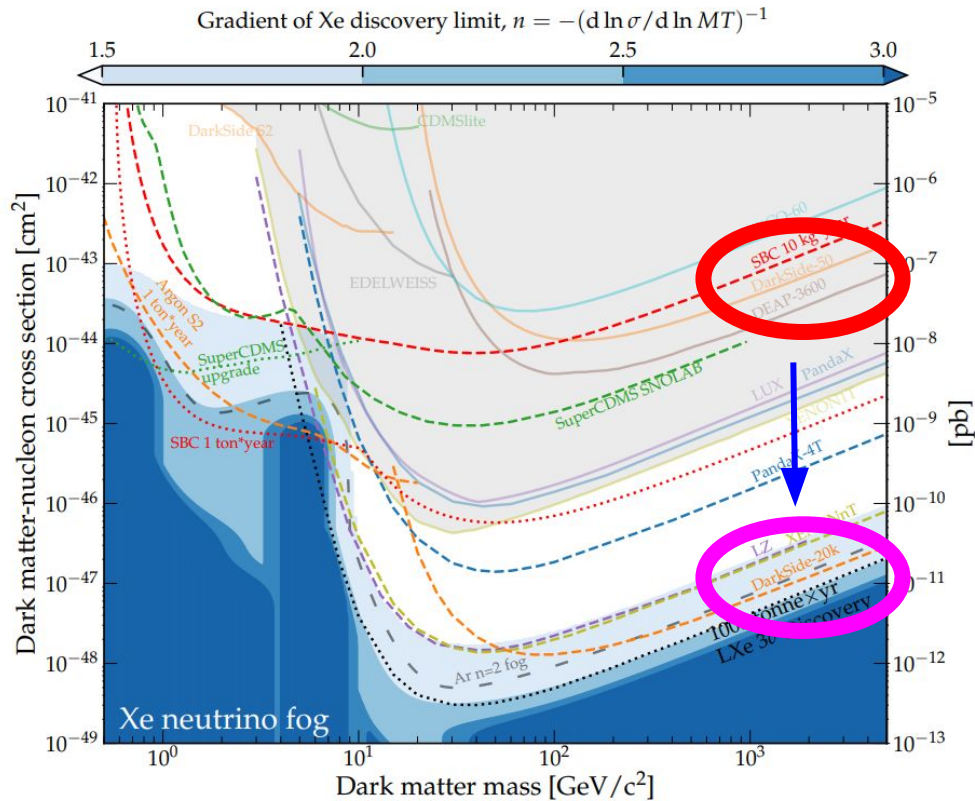


TRIUMF

# Expected sensitivity to WIMPs



# Expected sensitivity to WIMPs

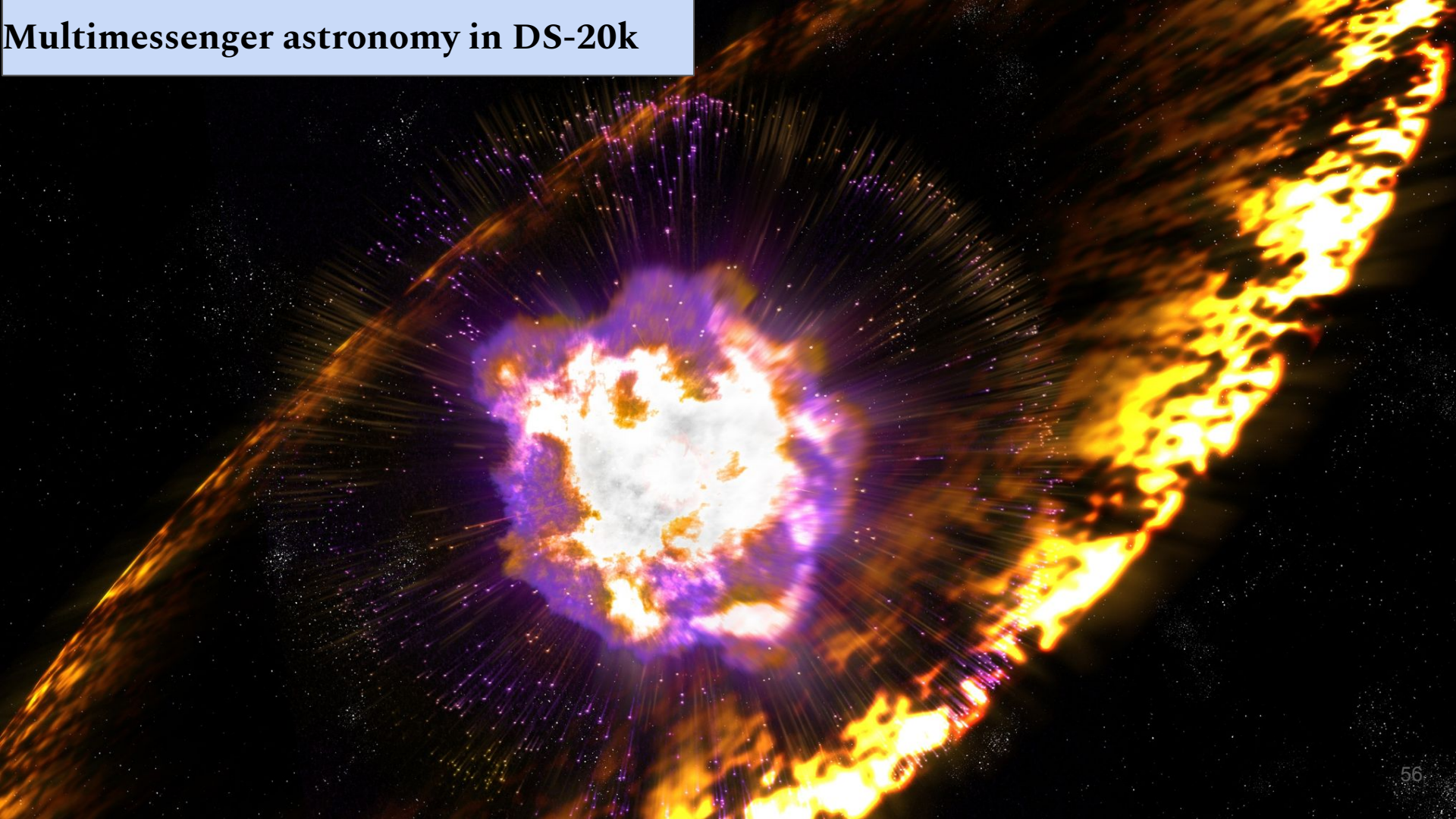


With 20 tonnes x 10 years:

< 0.1 neutrons in RoI (30~200 keV<sub>NR</sub>)

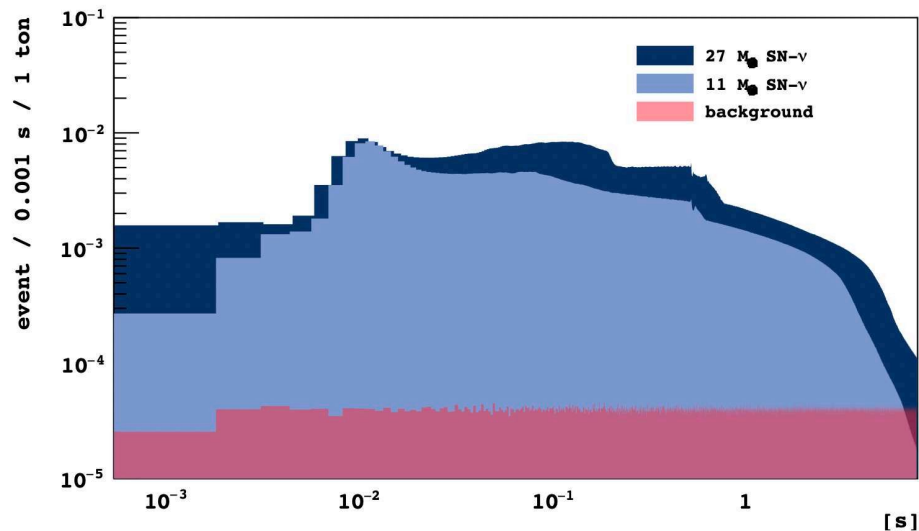
90% C.L. exclusion:  
 $6.3 \times 10^{-48} \text{ cm}^2$  at  $1 \text{ TeV}/c^2$

# Multimessenger astronomy in DS-20k



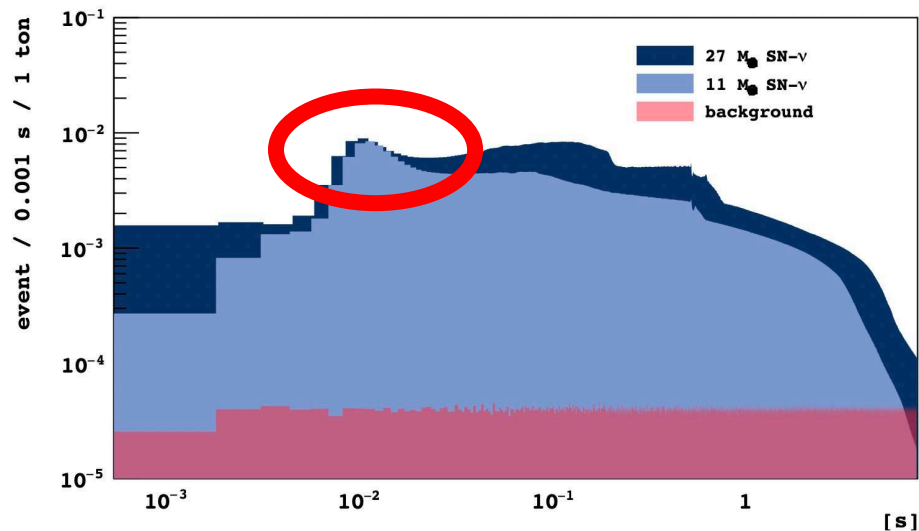


# Multimessenger astronomy in DS-20k



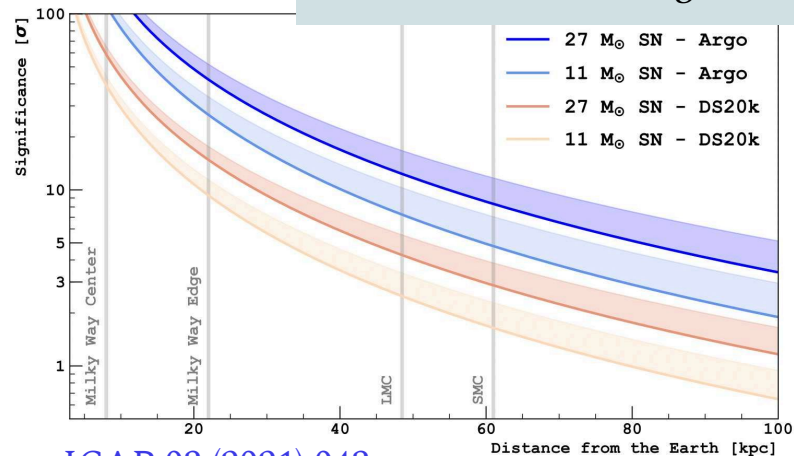
	DarkSide-20k	Argo
11- $M_{\odot}$ SN- $\nu$ s	181.4	1396.6
27- $M_{\odot}$ SN- $\nu$ s	336.5	2591.6
$^{39}\text{Ar}$	4.3	33.8
external background	1.8	8.8
single-electrons	0.7	5.1

# Multimessenger astronomy in DS-20k



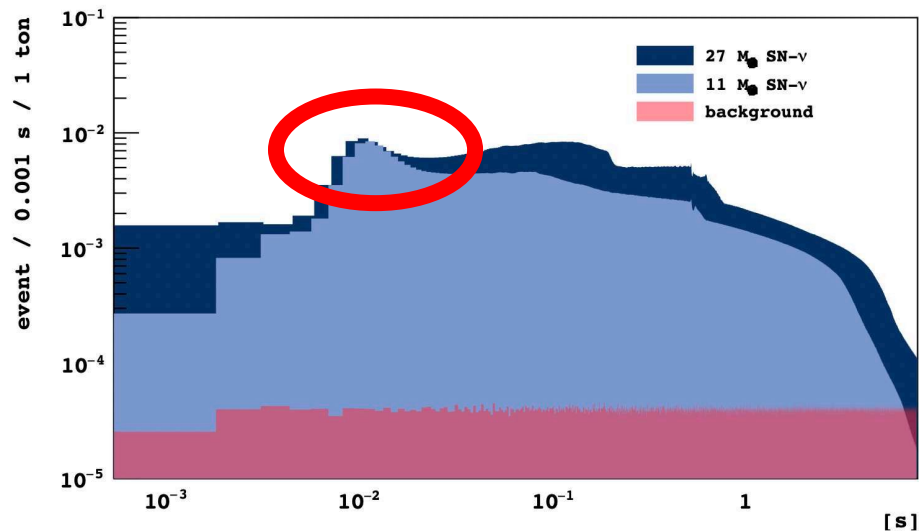
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## Full SN neutrino signal



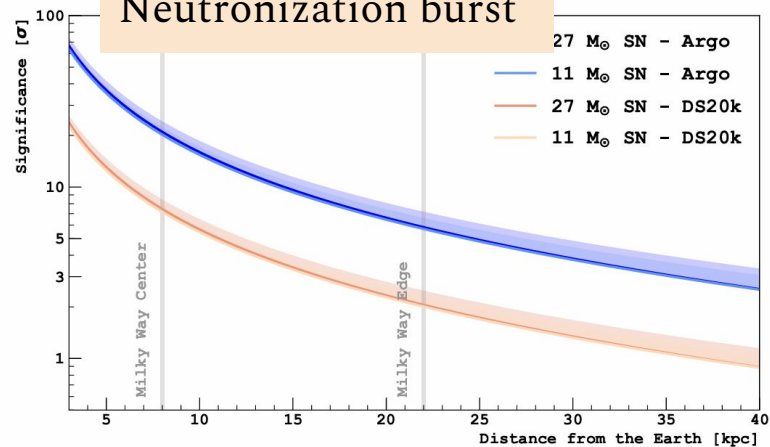
JCAP 03 (2021) 043

# Multimessenger astronomy in DS-20k

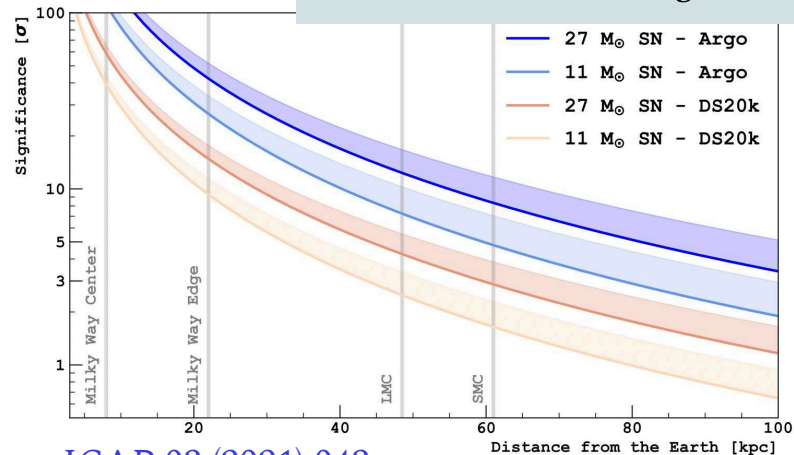


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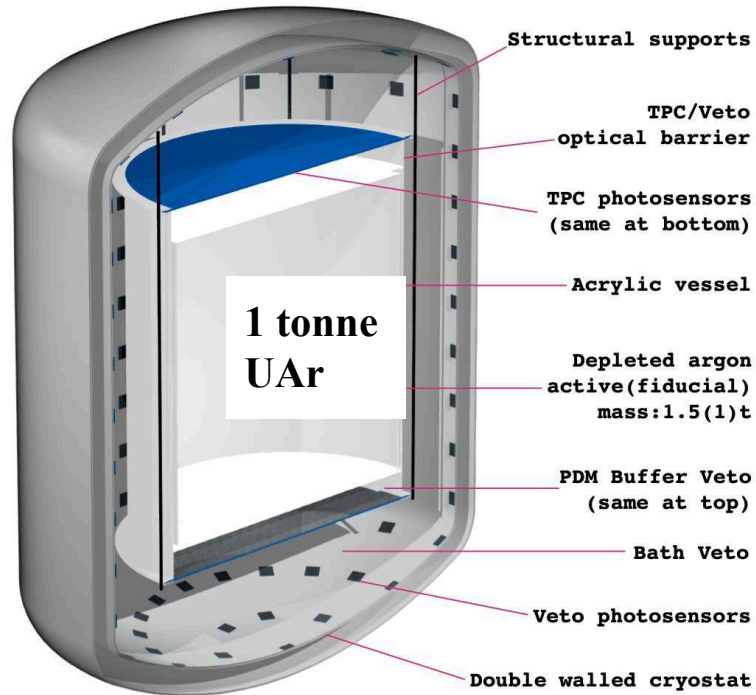
## Neutronization burst



## Full SN neutrino signal

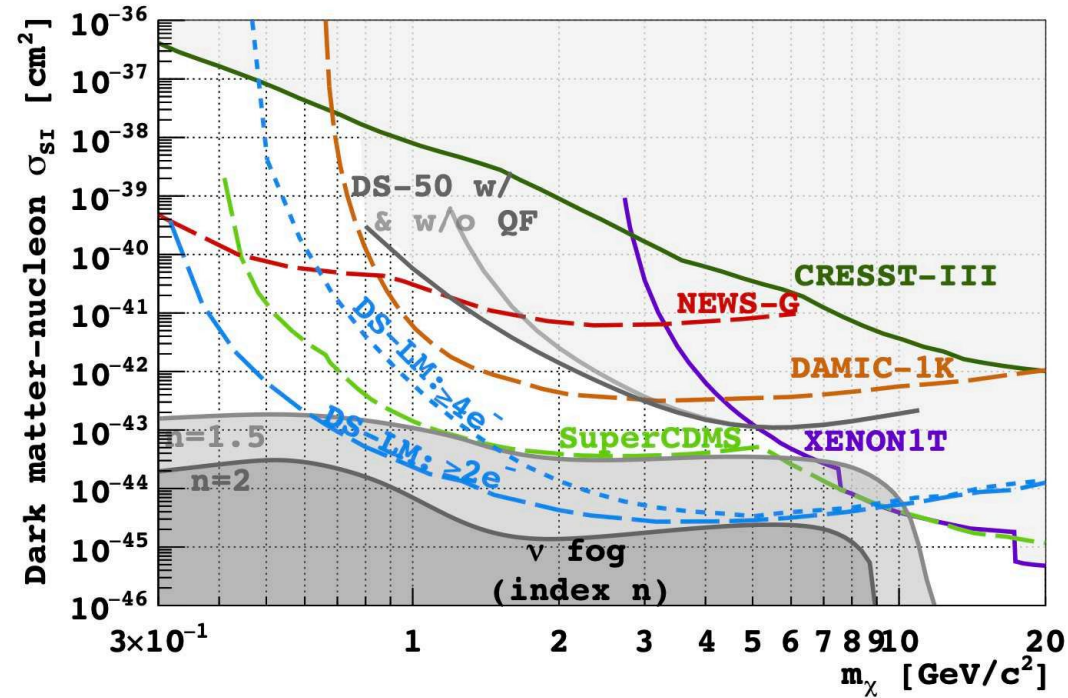
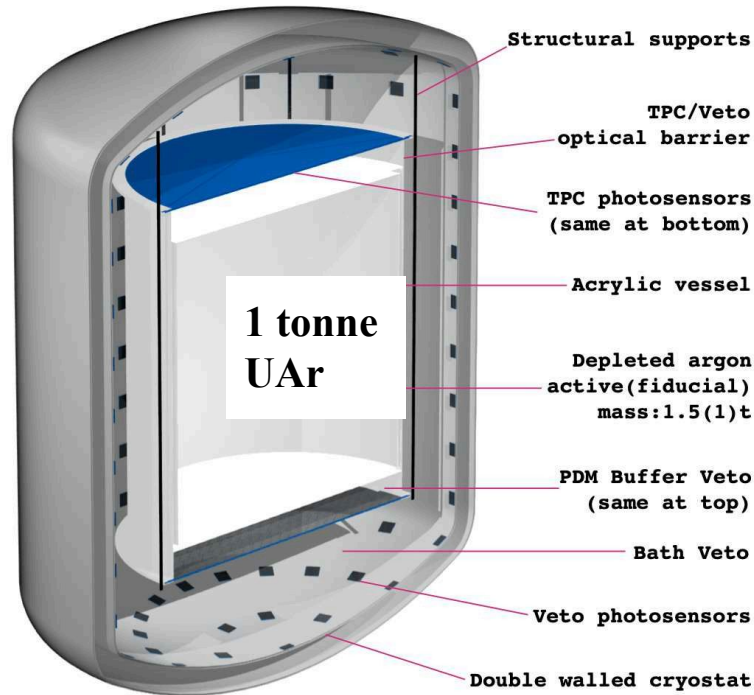


# Side project: DarkSide-LowMass



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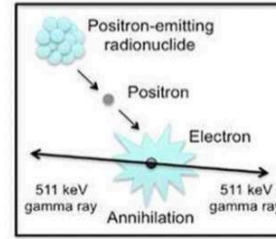
Designed to reach the neutrino floor with 1 tonne year exposure



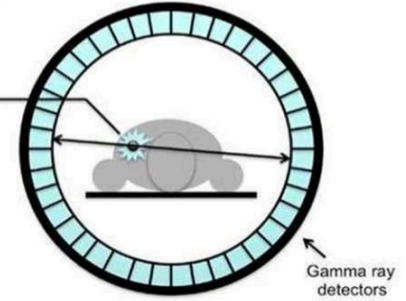
Phys. Rev. D 107, 112006 (2023)

# Side project: 3DII Scanner

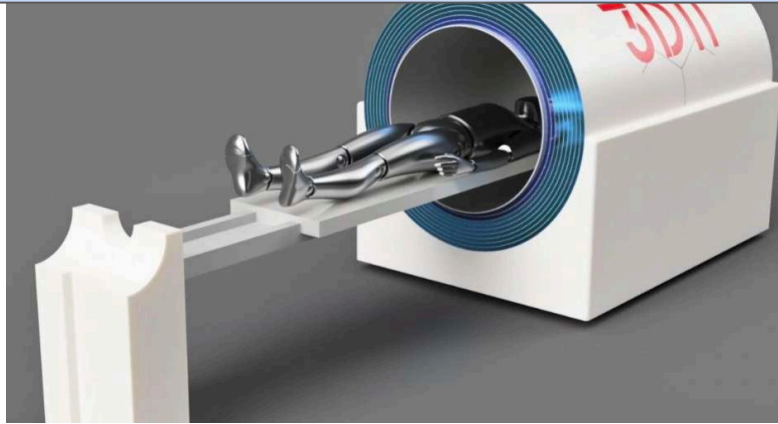
Positron emission and positron-electron annihilation



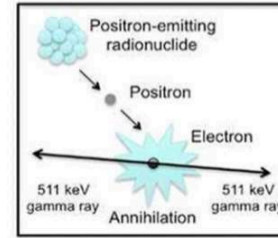
PET scanner



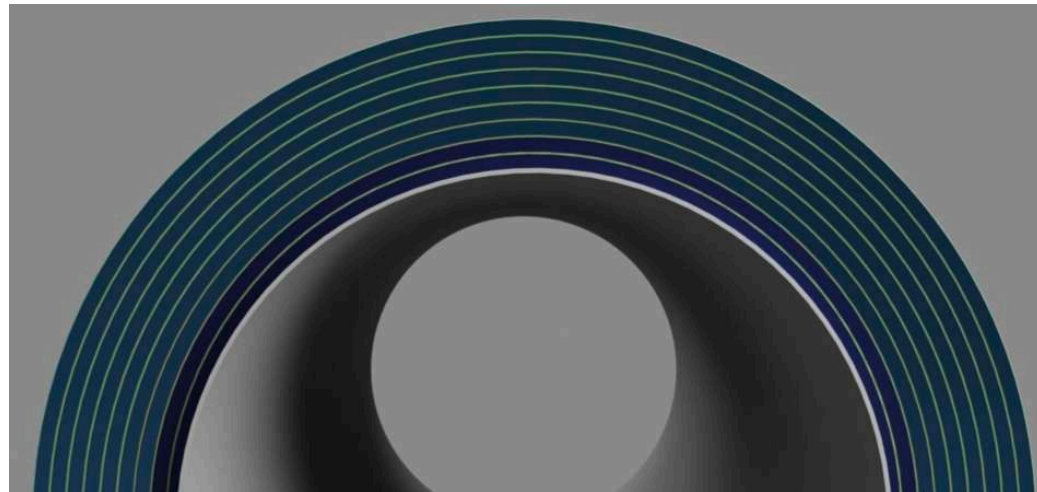
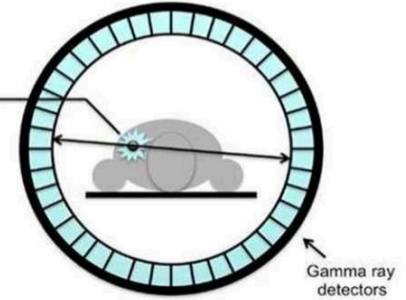
# Side project: 3DII Scanner



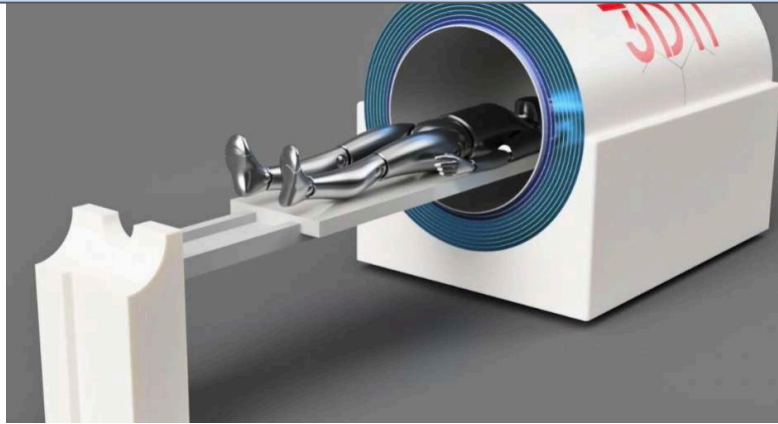
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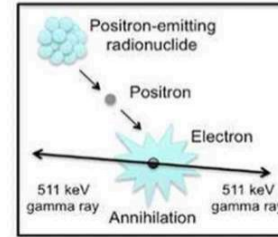
PET scanner



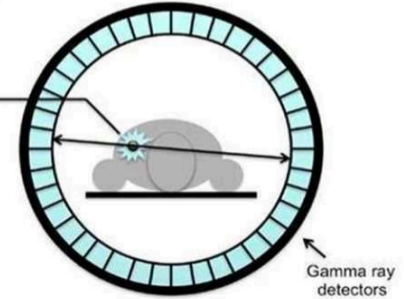
# Side project: 3DII Scanner



Positron emission and positron-electron annihilation



PET scanner



Time-of-Flight PET scanner Total body design

High sensitivity allow for low dose or ultra-fast scanning time!



## Take home from this talk

DarkSide-20k is the first experiment from GADMC

Designed to be instrumental background free

Unique sensitivity in argon to WIMPs and GeV-scale candidates

Contribution to the Supernova Early Warning System 2.0



Thank you!

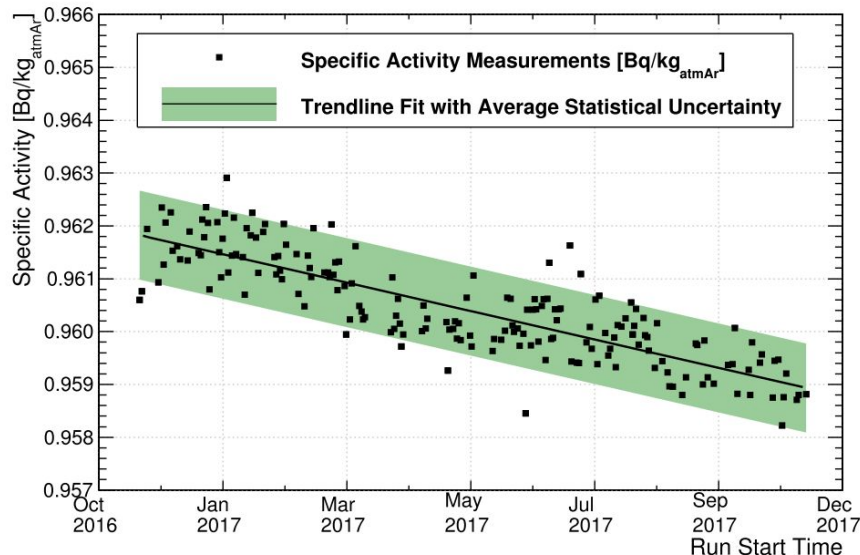


# Backgrounds

Main contaminant, rejected with PSD:  
 $^{39}\text{Ar}$  beta decays ( $Q = 565 \text{ keV}$ )

Produced in the atmosphere mainly by  
 neutron capture on  $^{40}\text{Ar}$ ,  
 $^{40}\text{Ar}(n,2n)^{39}\text{Ar}$

**Most precise measurement of its  
 activity in DEAP-3600!**

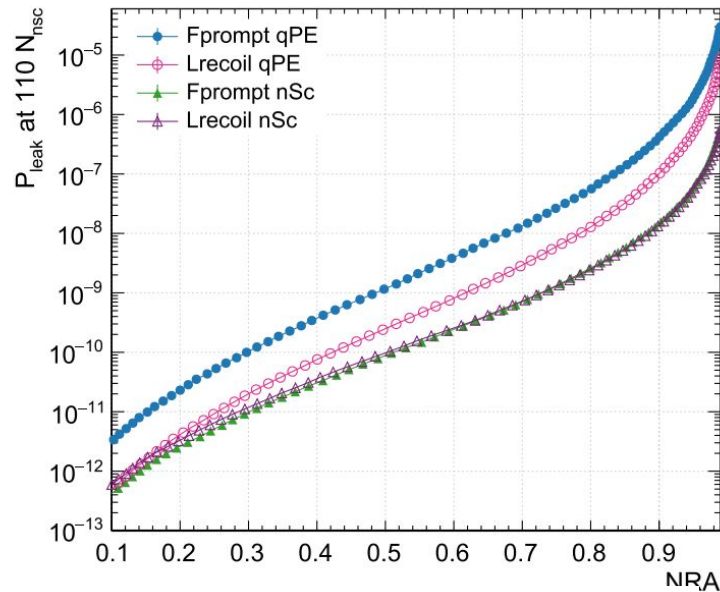
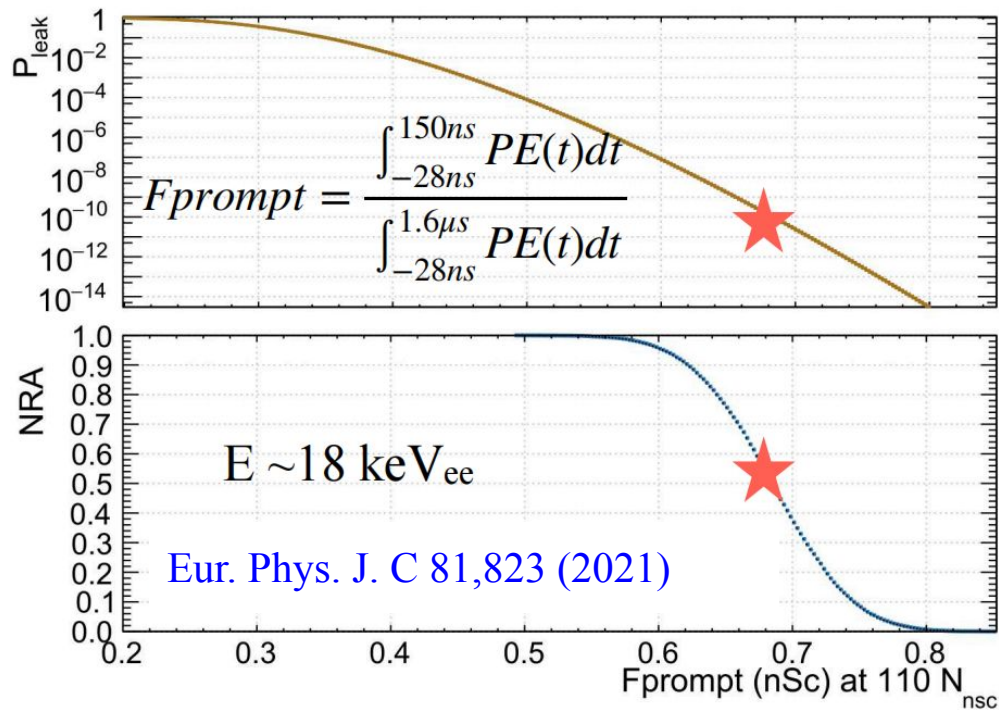


Measurement	Specific activity [Bq/kg <sub>atmAr</sub> ]
WARP [15]	$1.01 \pm 0.02_{\text{stat}} \pm 0.08_{\text{sys}}$
ArDM [16]	$0.95 \pm 0.05$
DEAP-3600 (this work)	$0.964 \pm 0.001_{\text{stat}} \pm 0.024_{\text{sys}}$

$$S_{\text{Ar}39} = \frac{N}{T_{\text{live}} \cdot m_{\text{LAr}}}$$

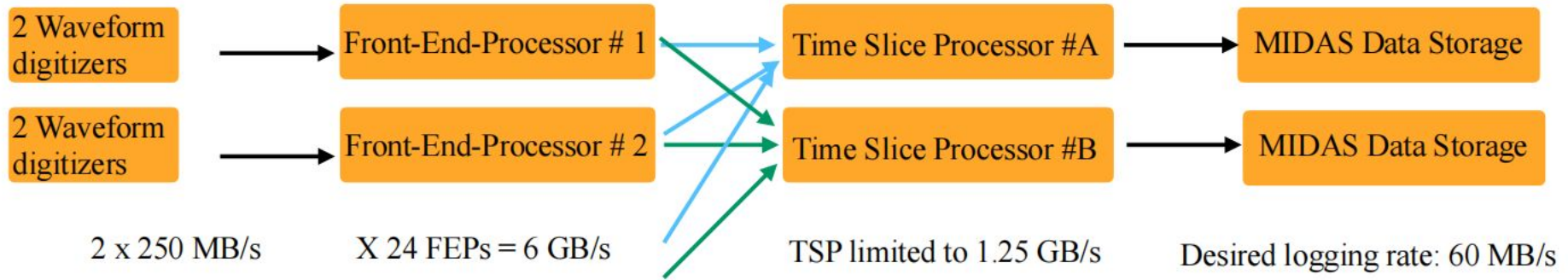
$$m_{\text{LAr}} = (3269 \pm 24)$$

# PSD



Eur. Phys. J. C 81,823 (2021)

# DS-20k read-out



Parameter	Value
Total number of readout channels in TPC detector	2112
Total number of readout channels for inner Veto detector	480
Total number of readout channels for outer Veto detector	128
Minimum number of digitizer boards for TPC readout	36
Minimum number of digitizer boards for inner and outer Veto readout	12