



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

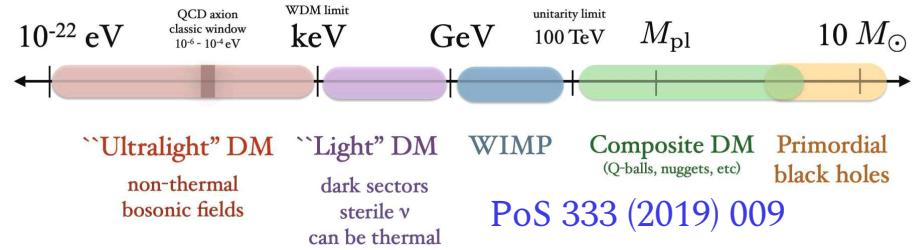
Dr. Michela Lai
on behalf of
DarkSide-20k Collaboration



South Dakota Mines campus, May 14-16, 2024

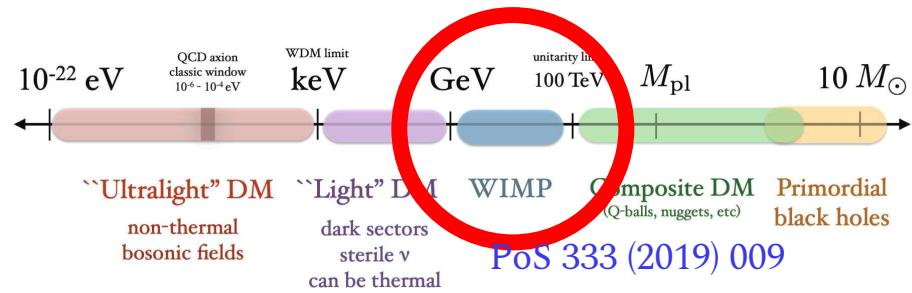


Global Argon Dark Matter Collaboration

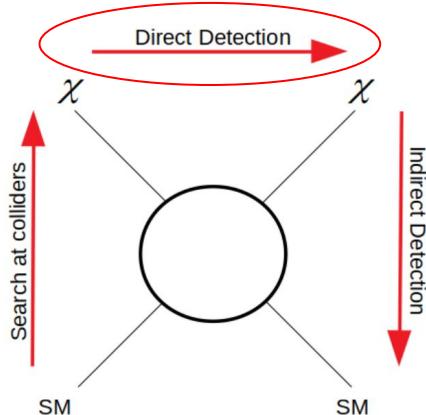
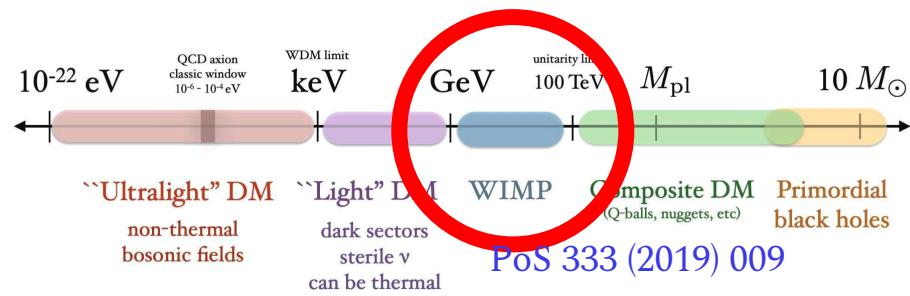


PoS 333 (2019) 009

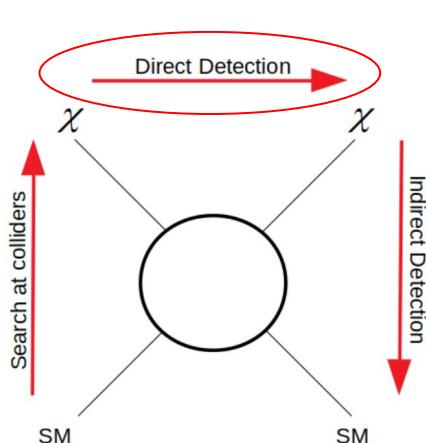
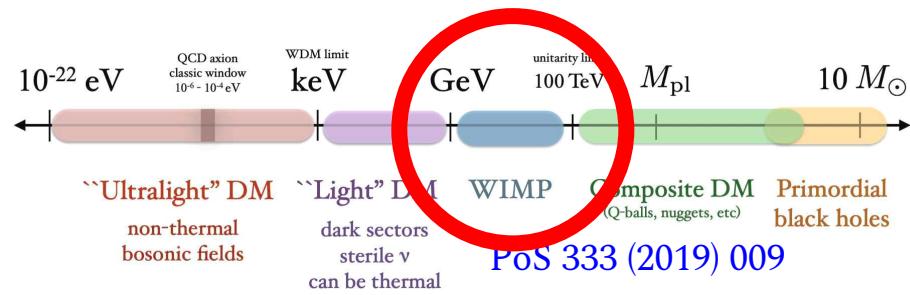
Global Argon Dark Matter Collaboration



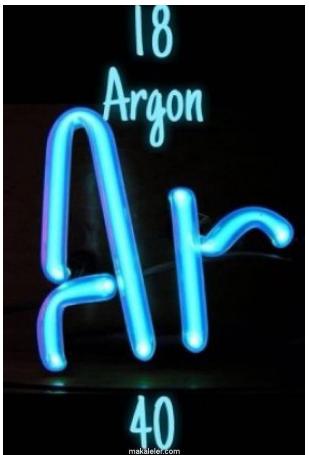
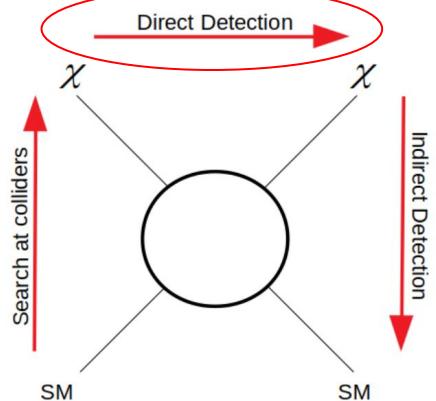
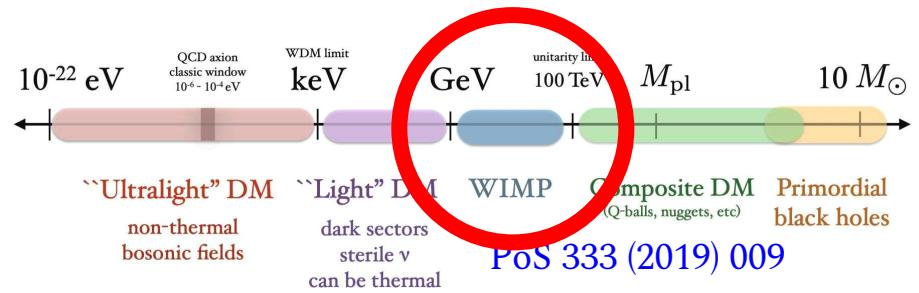
Global Argon Dark Matter Collaboration



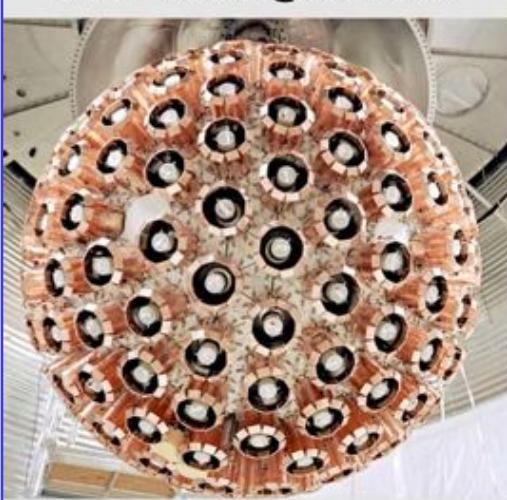
Global Argon Dark Matter Collaboration



Global Argon Dark Matter Collaboration



DEAP-3600 @SNOLAB



DarkSide-50 @LNGS



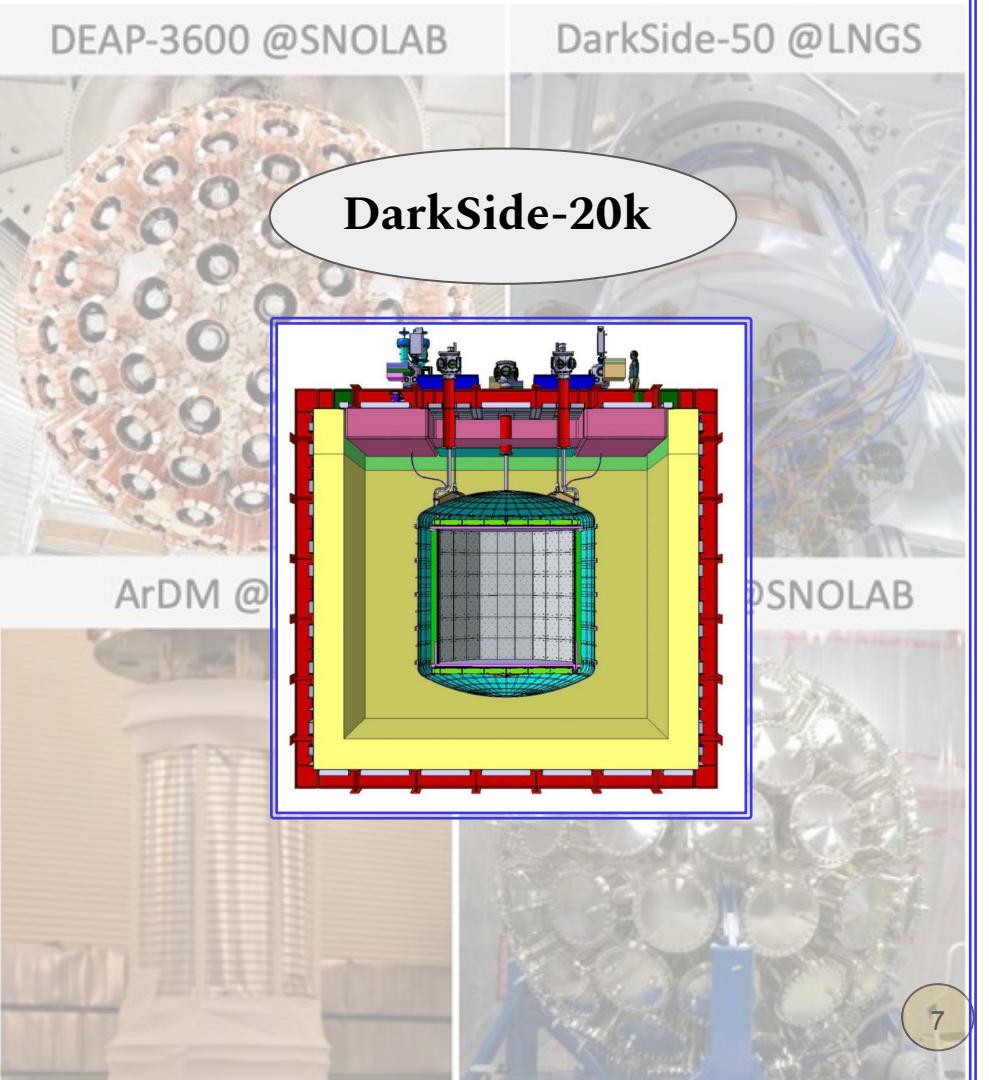
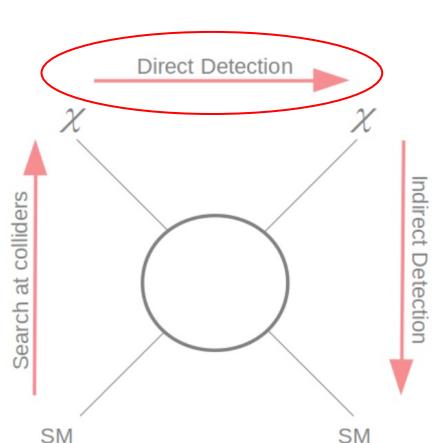
ArDM @LSC



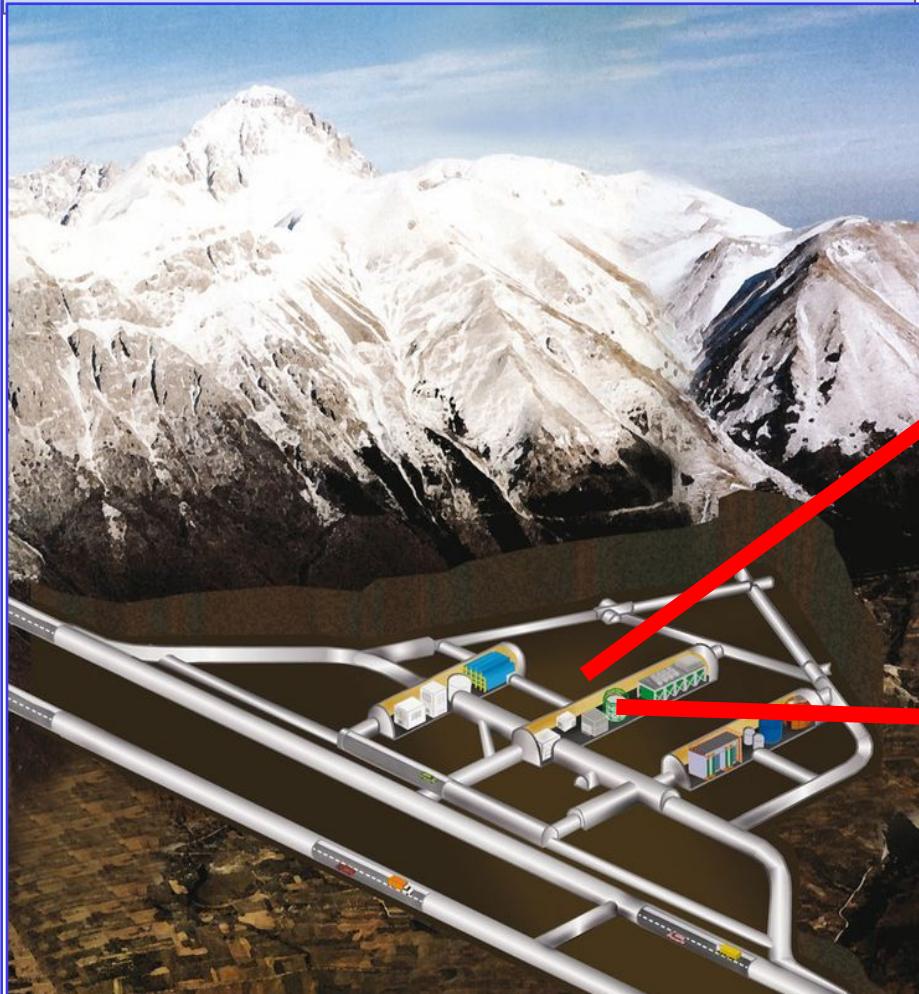
miniCLEAN @SNOLAB



Global Argon Dark Matter Collaboration



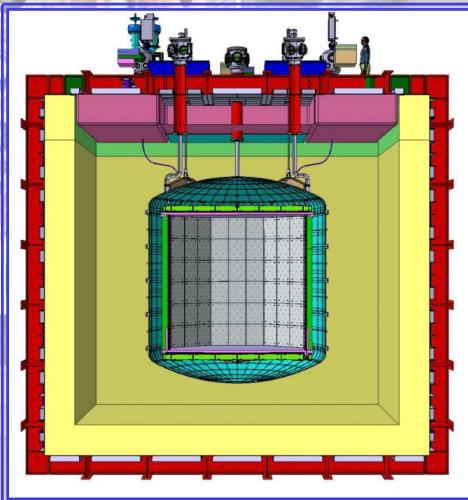
Global Argon Dark Matter Collaboration



DEAP-3600 @SNOLAB

DarkSide-50 @LNGS

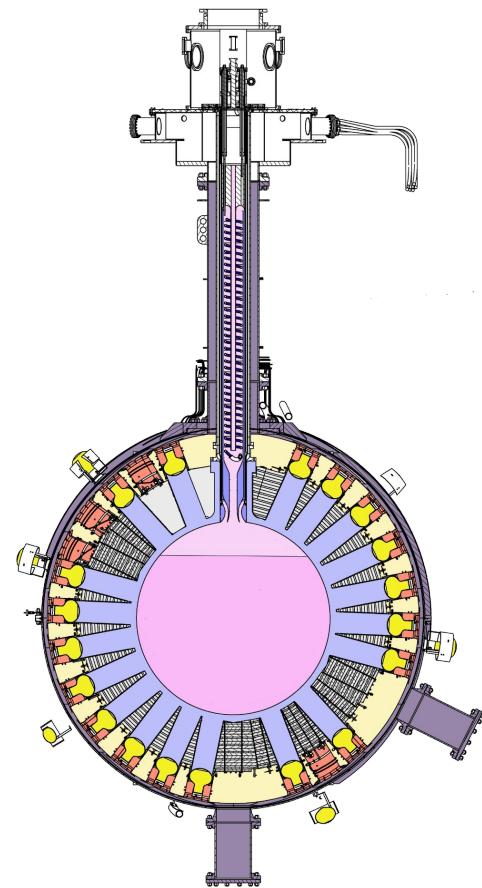
DarkSide-20k



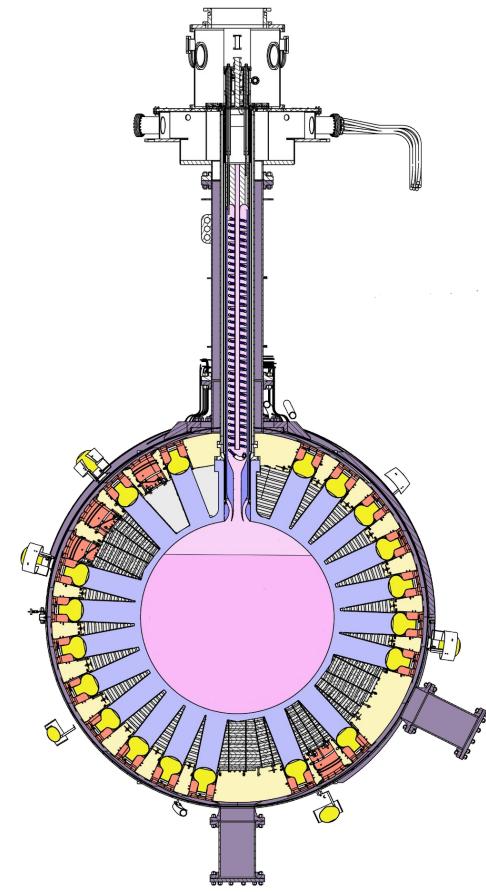
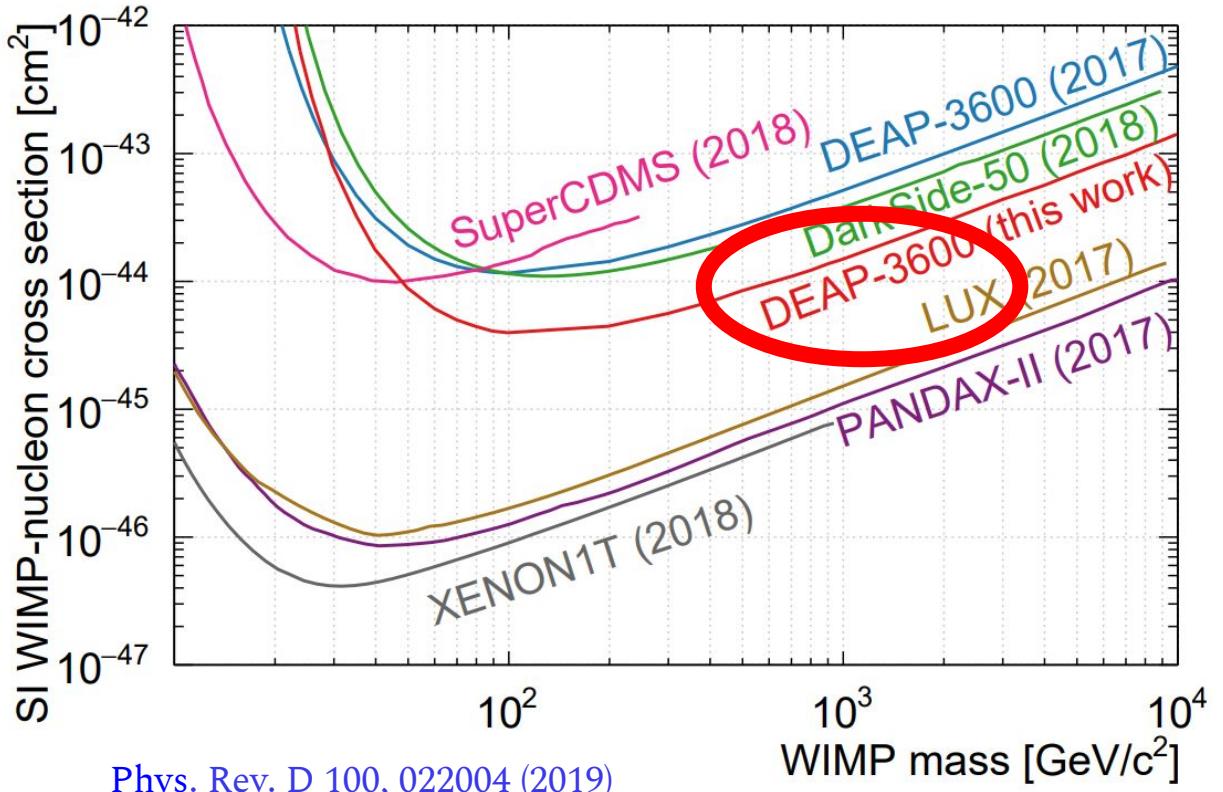
ArDM @

LNGS - 2026

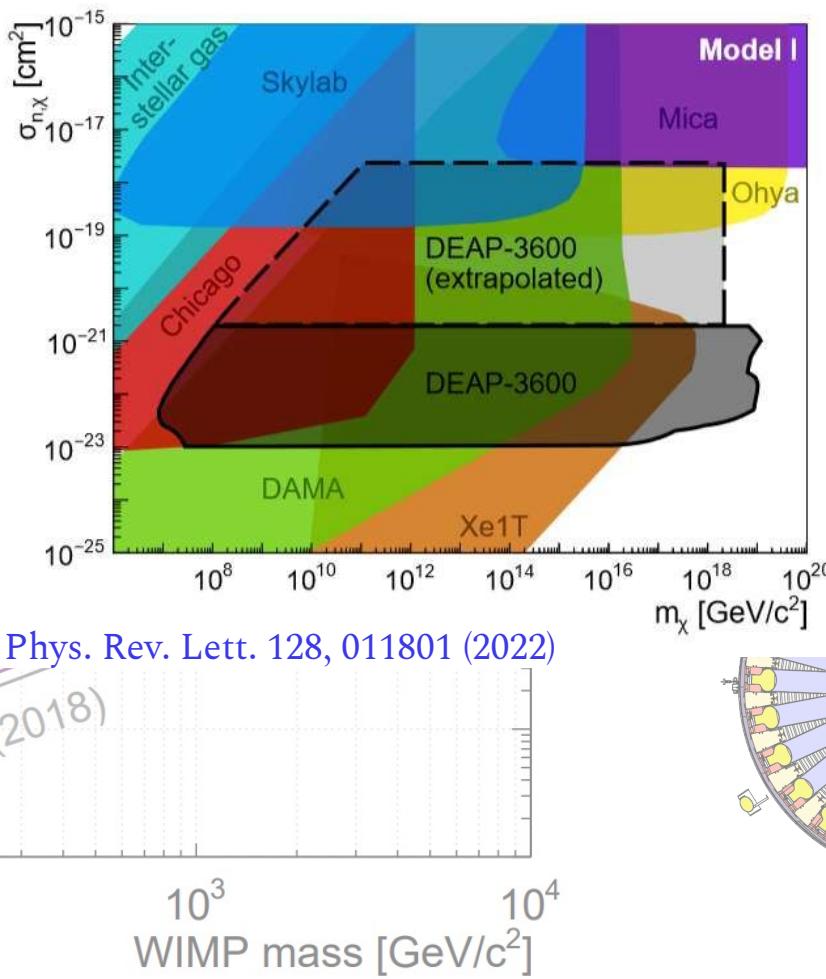
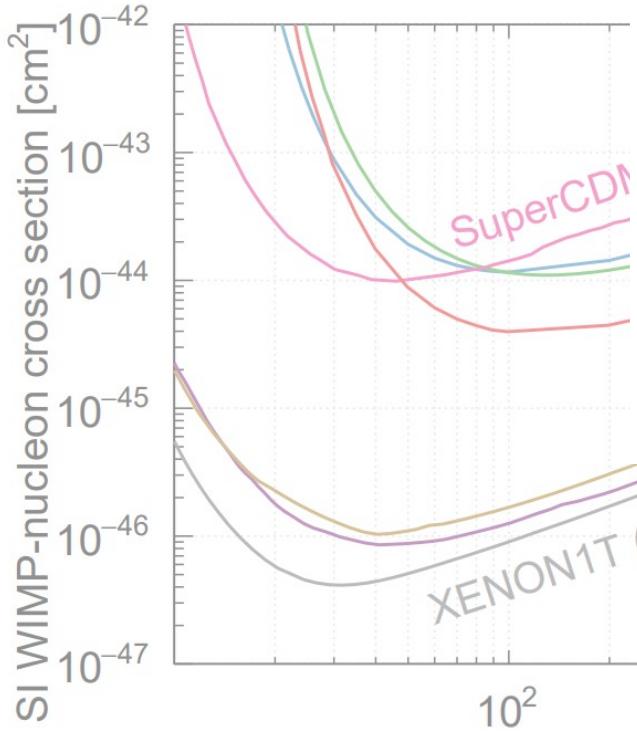
What we learn from DEAP-3600



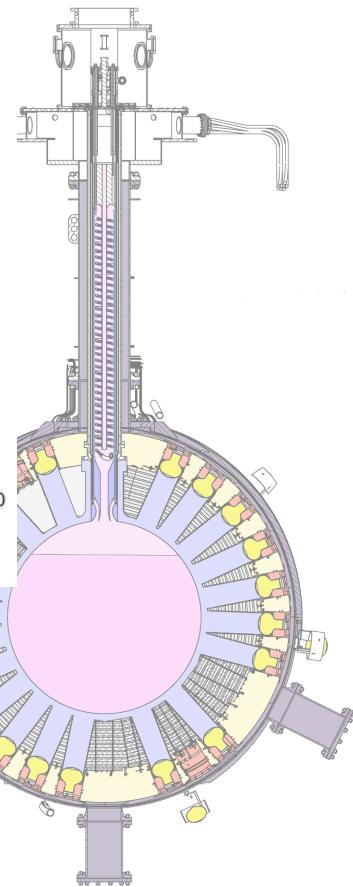
What we learn from DEAP-3600



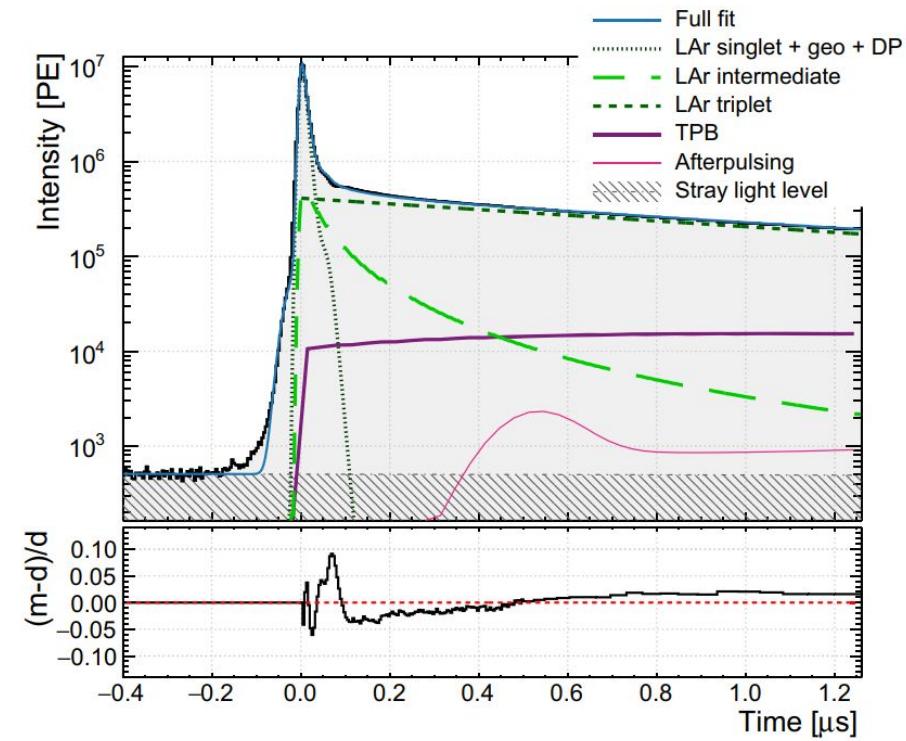
What we learn from DEAP-36



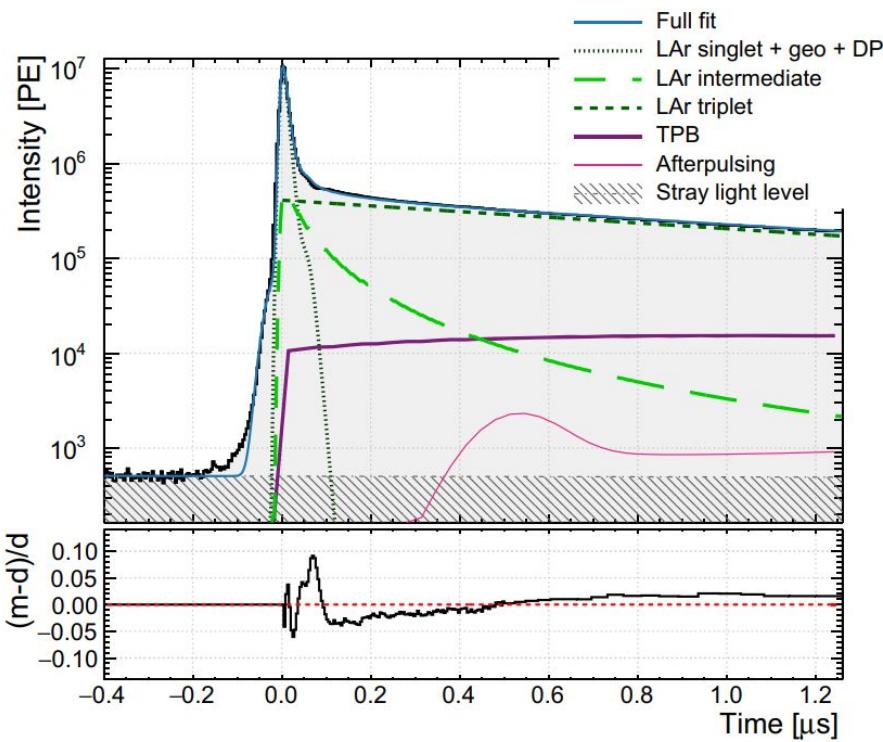
Phys. Rev. D 100, 022004 (2019)



What we learn from DEAP-3600



Pulse-Shape characterization



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

$$\tau_s = 8.2\text{ns}$$

$$\tau_t = 1445\text{ns}$$

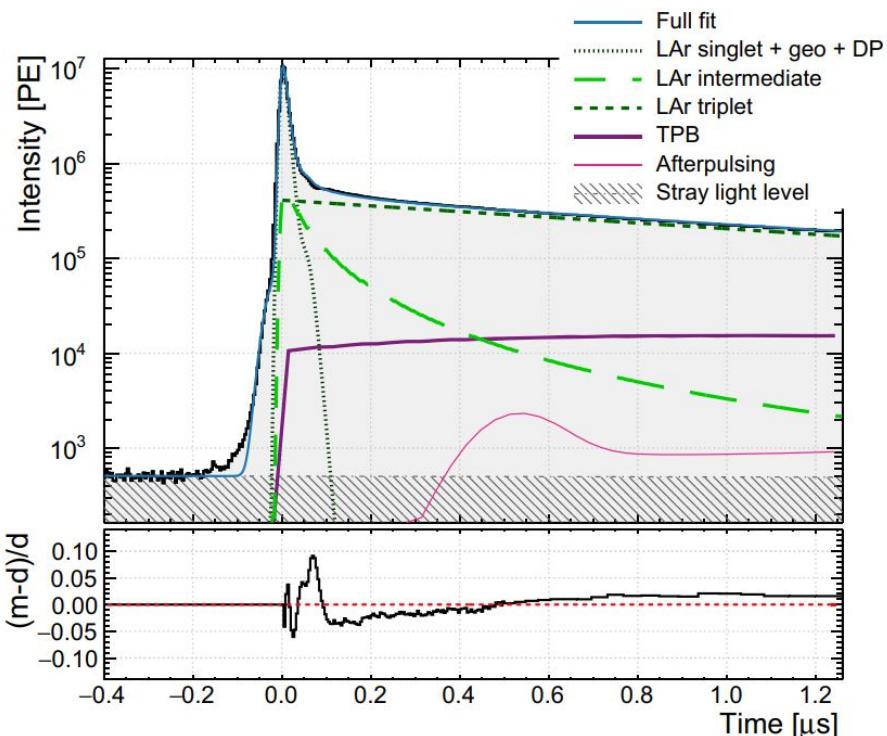
$$R_s = 0.23$$

$$\tau_{rec} = 175.5\text{ns}$$

$$R_t = 0.71$$

What we learn from DEAP-2600

Pulse-Shape characterization



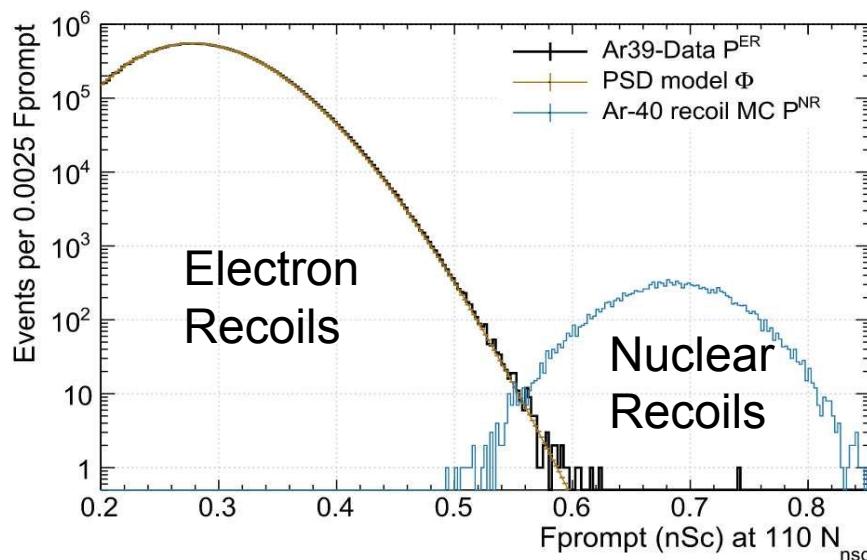
Eur. Phys. J. C 80,303 (2020)

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

$$\tau_s = 8.2\text{ ns}$$

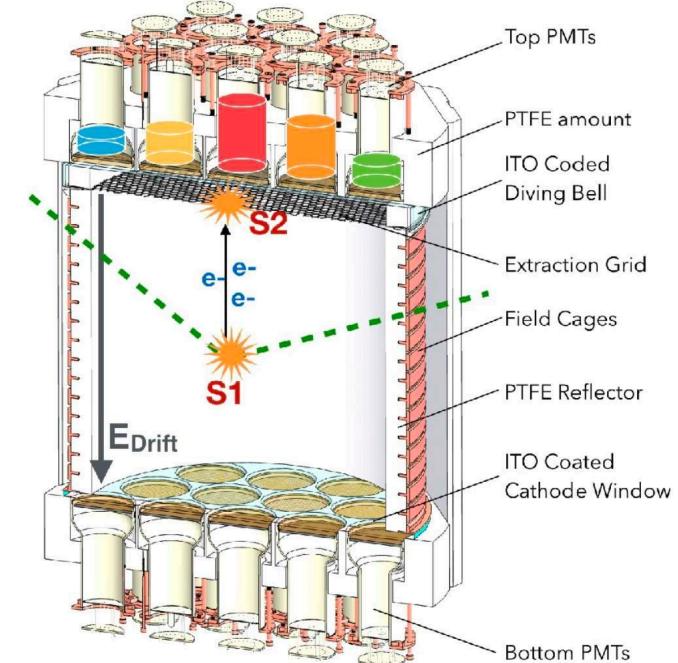
$$\tau_t = 1445\text{ ns}$$

Pulse-Shape Discrimination!



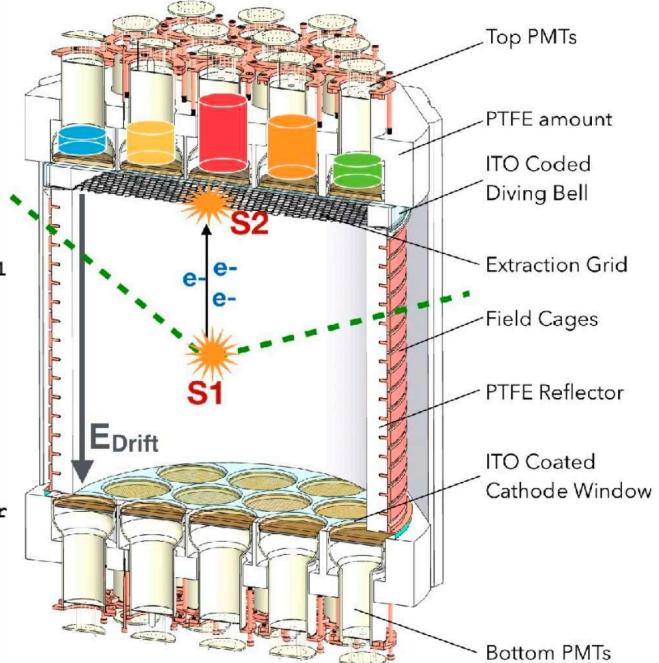
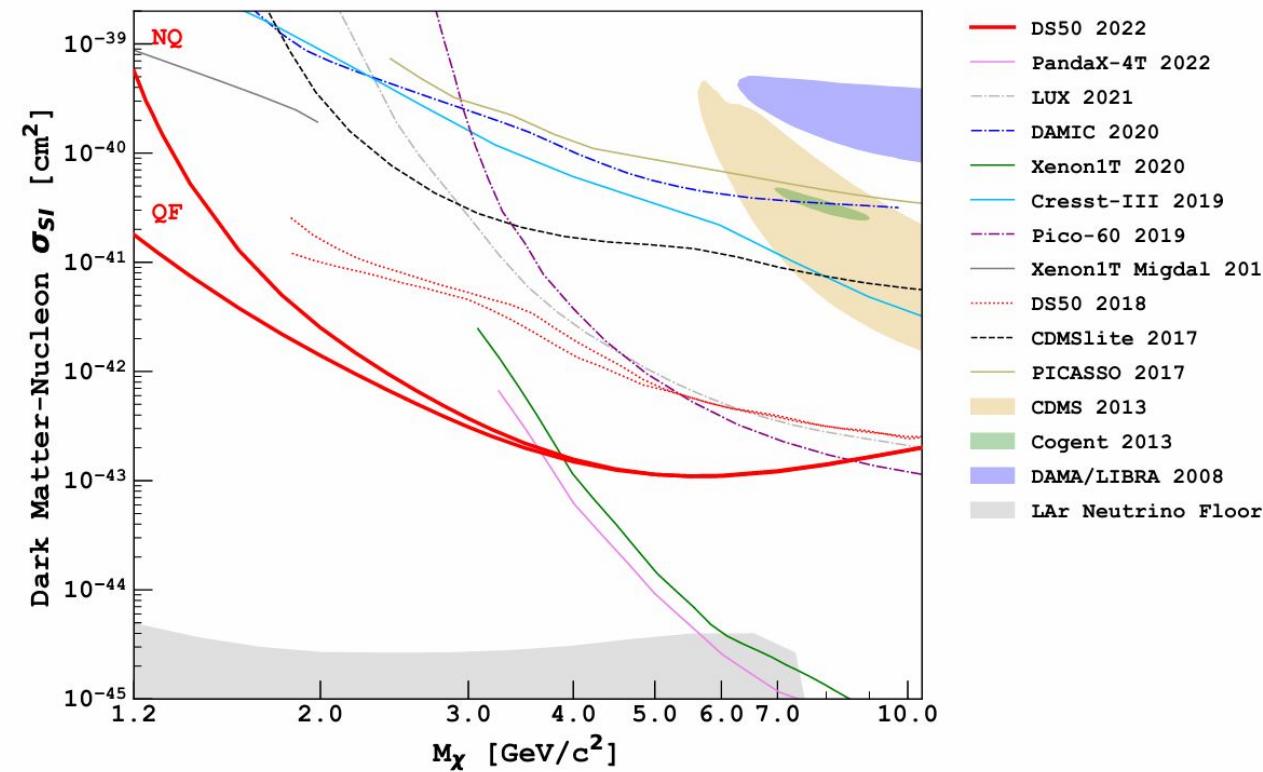
Eur. Phys. J. C 81,823 (2021)

What we learn from DarkSide-50



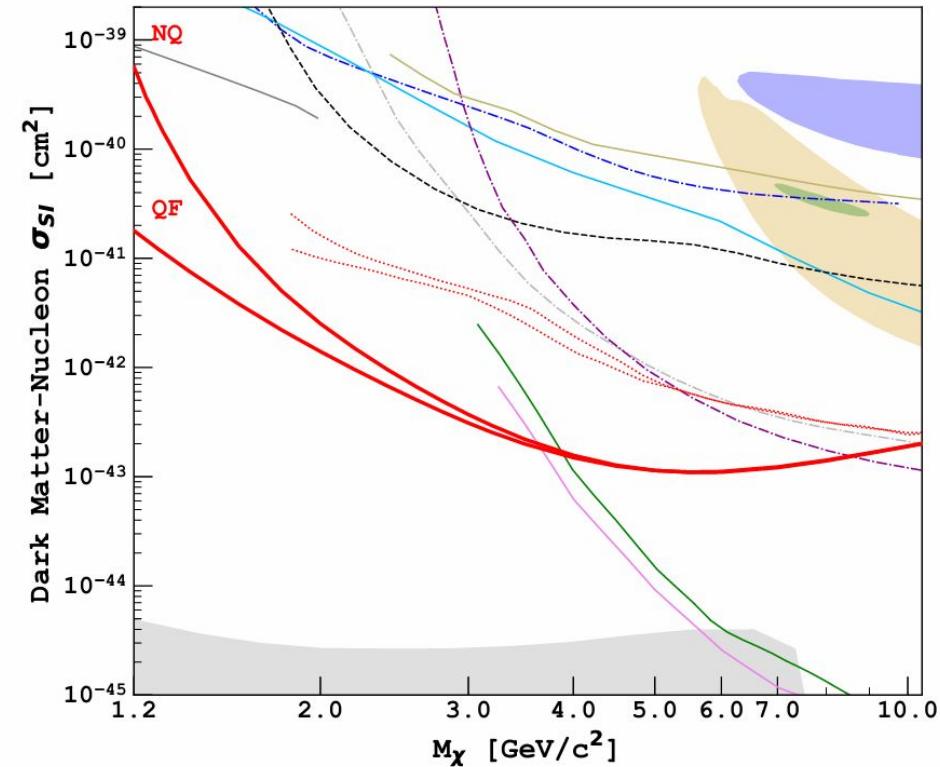
Drawing of DarkSide-50

What we learn from DarkSide-50

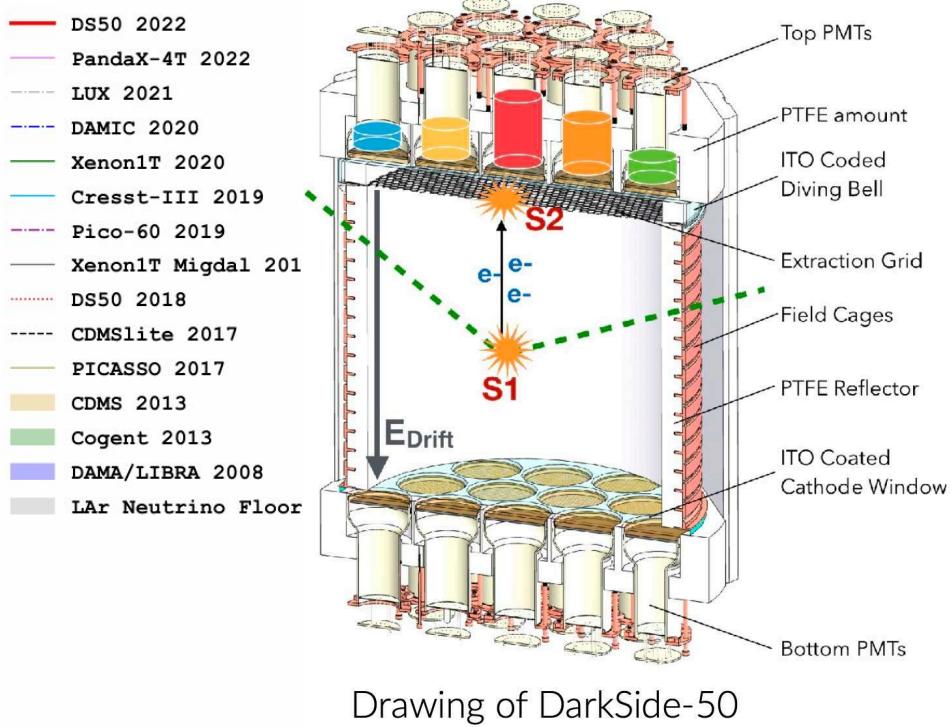


Drawing of DarkSide-50

What we learn from DarkSide-50

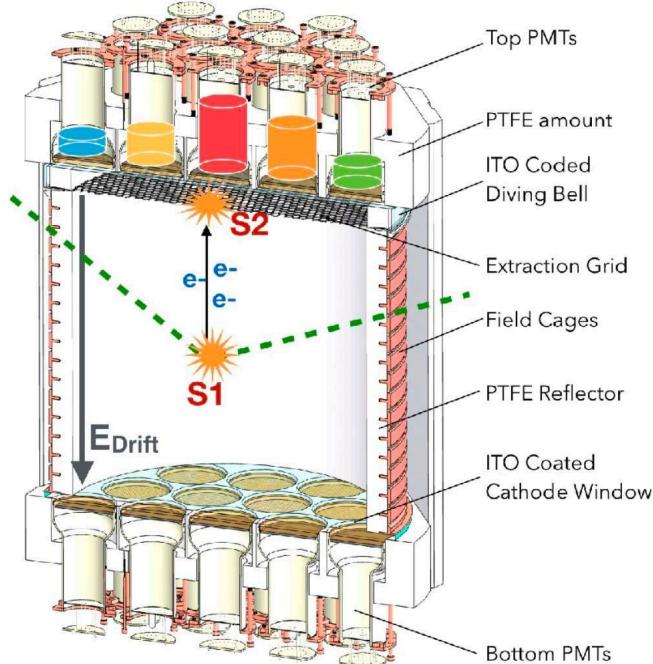
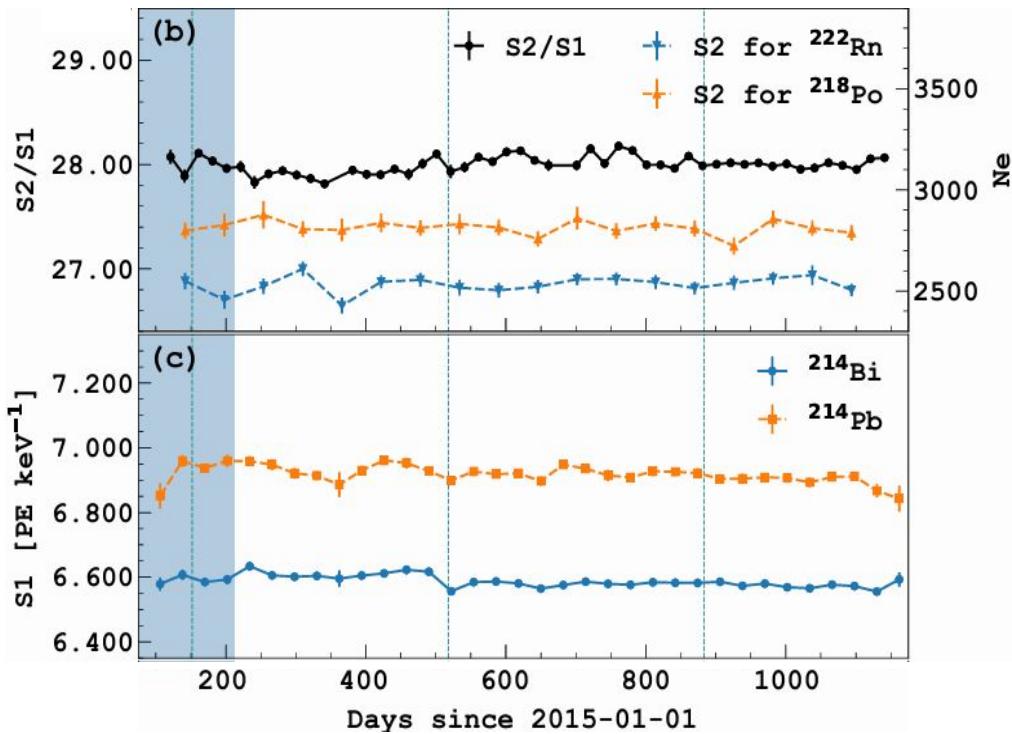


Unique sensitivity to GeV DM!



What we learn from DarkSide-50

Demonstrated long-term stability

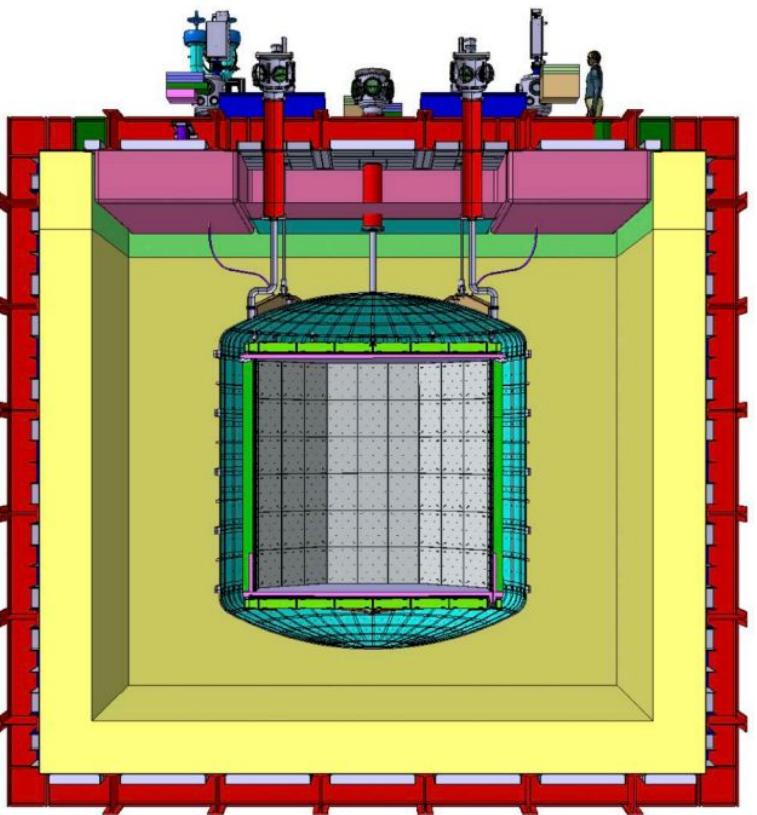


Drawing of DarkSide-50

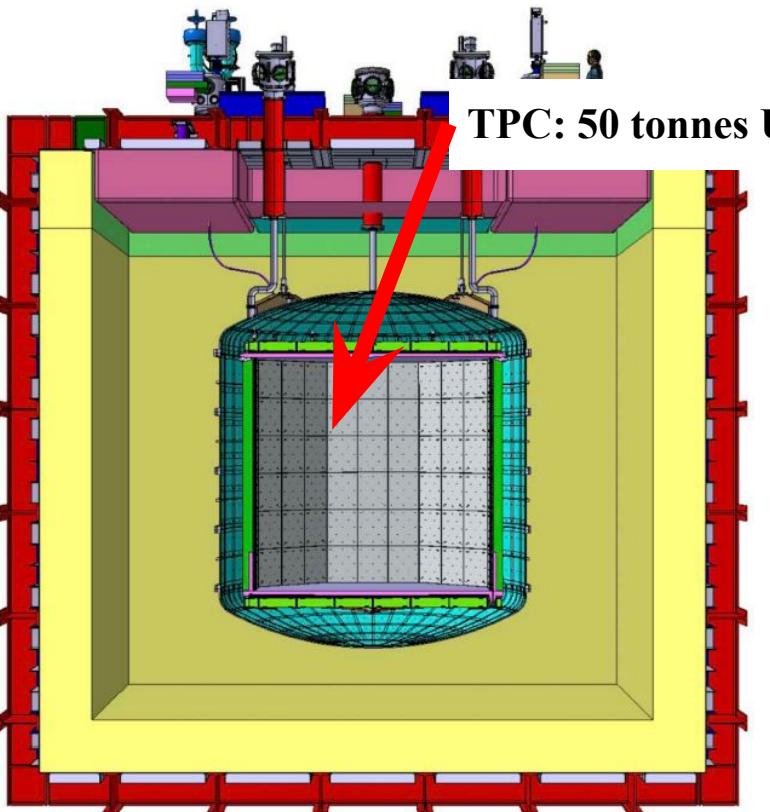
The next phase: DarkSide-20k detector



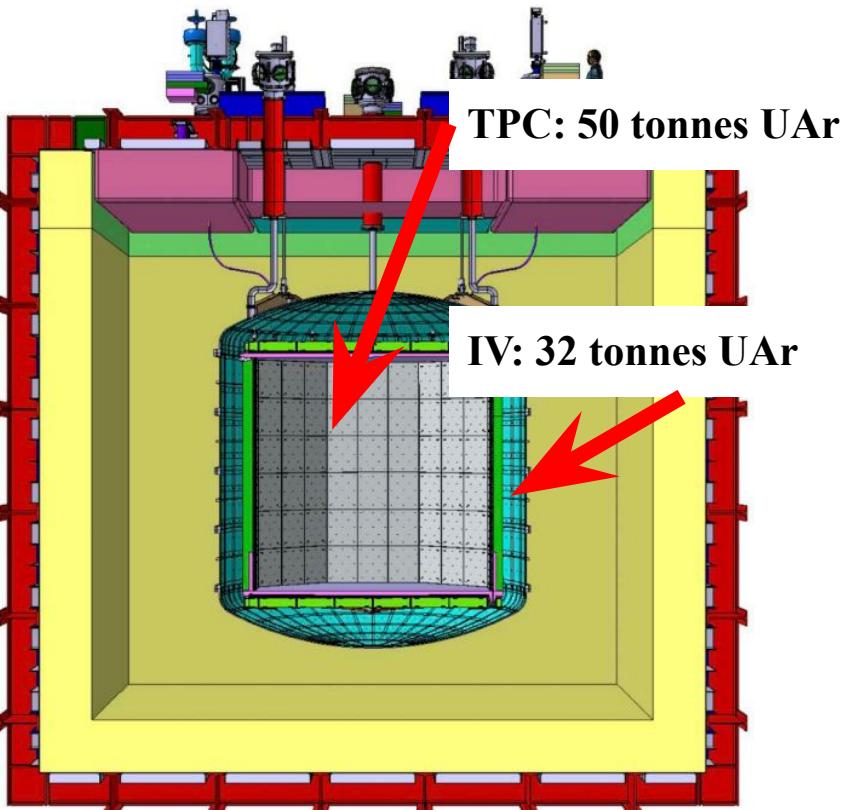
The next phase: DarkSide-20k detector



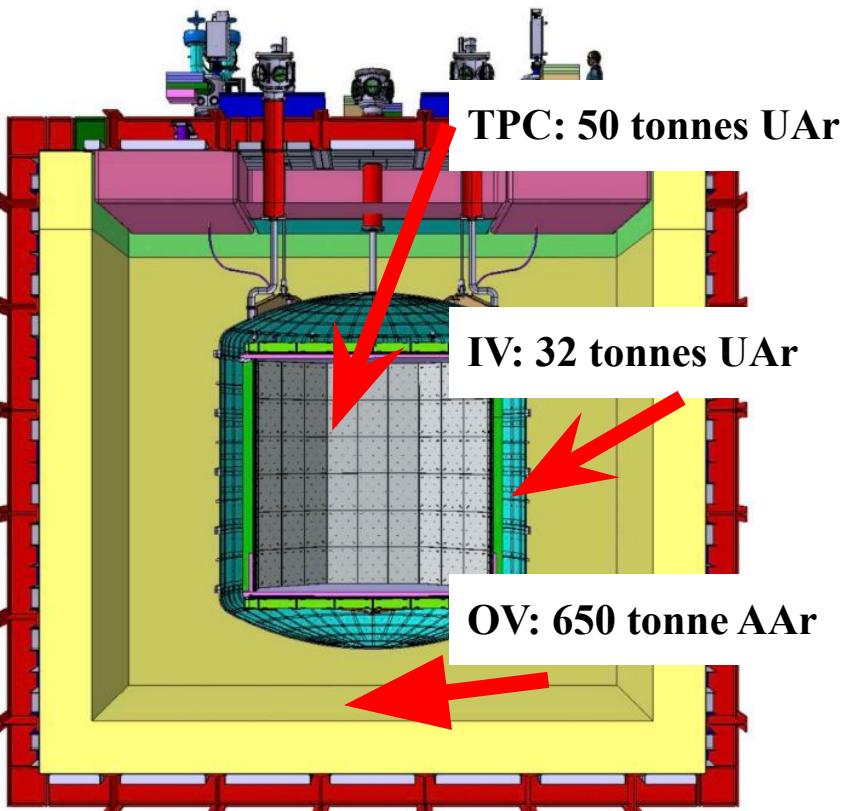
The next phase: DarkSide-20k detector



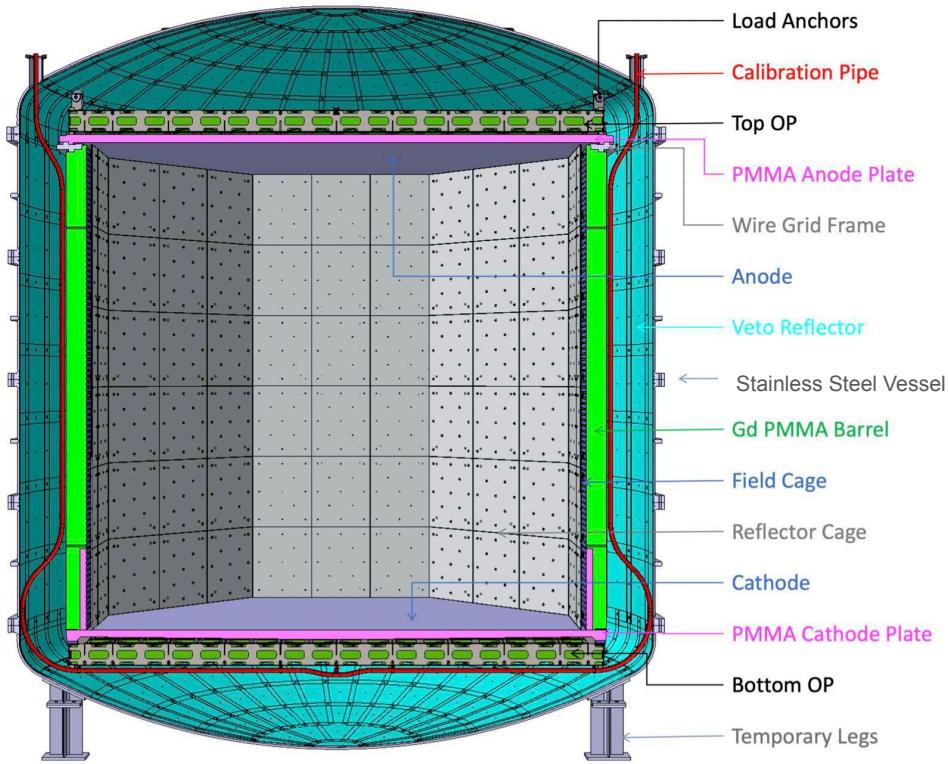
The next phase: DarkSide-20k detector



The next phase: DarkSide-20k detector

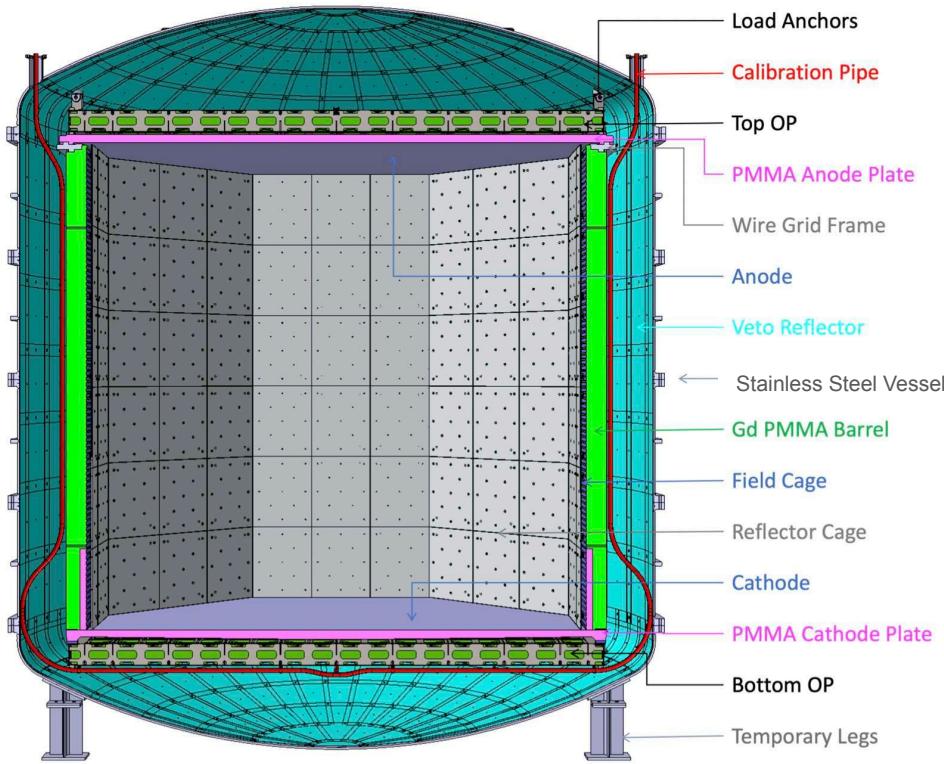


A closer look at the Inner Detector



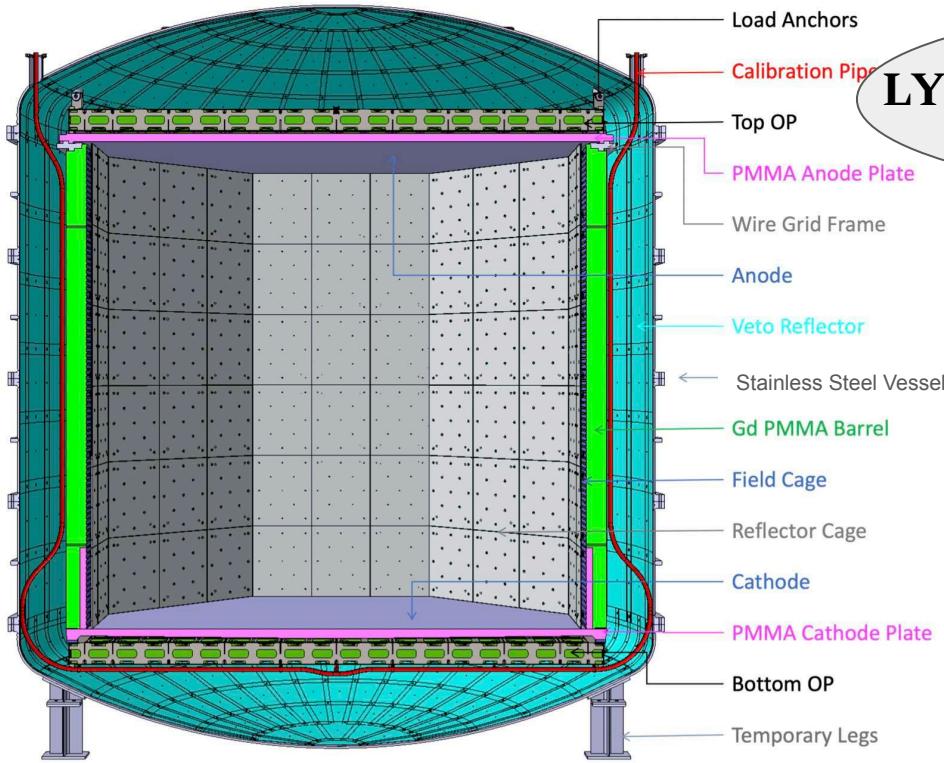
A closer look at the Inner Detector

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



A closer look at the Inner Detector

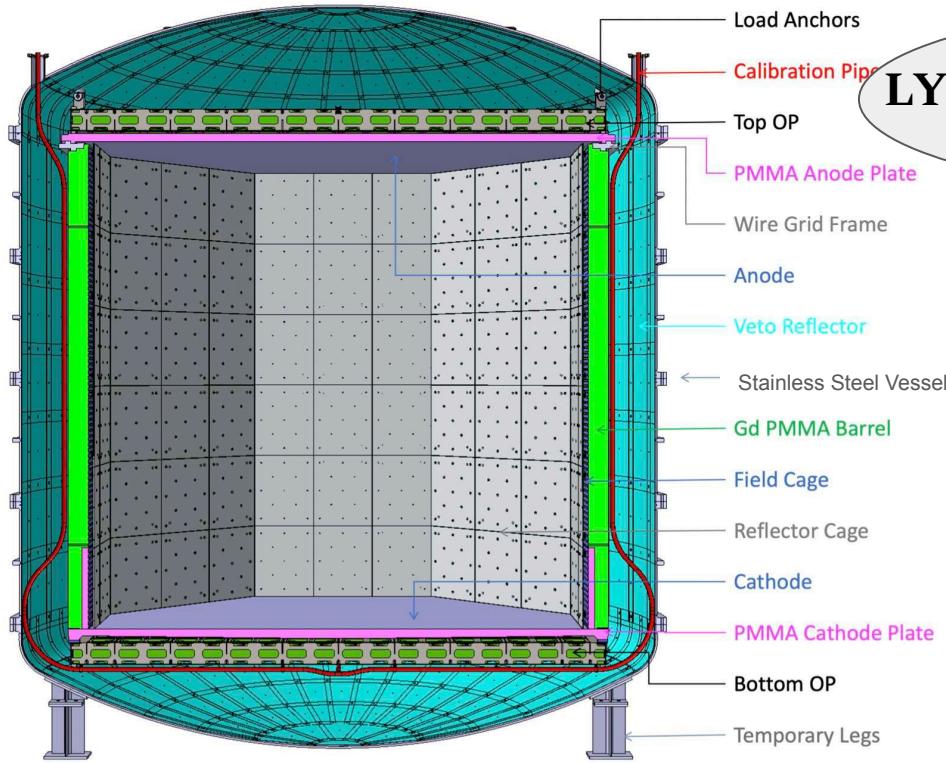
TPC: Active (fiducial) UAr mass: 49.7(20.2) tonnes



LY (null drift field): $10 \text{ PE/keV}_{\text{ee}}$

A closer look at the Inner Detector

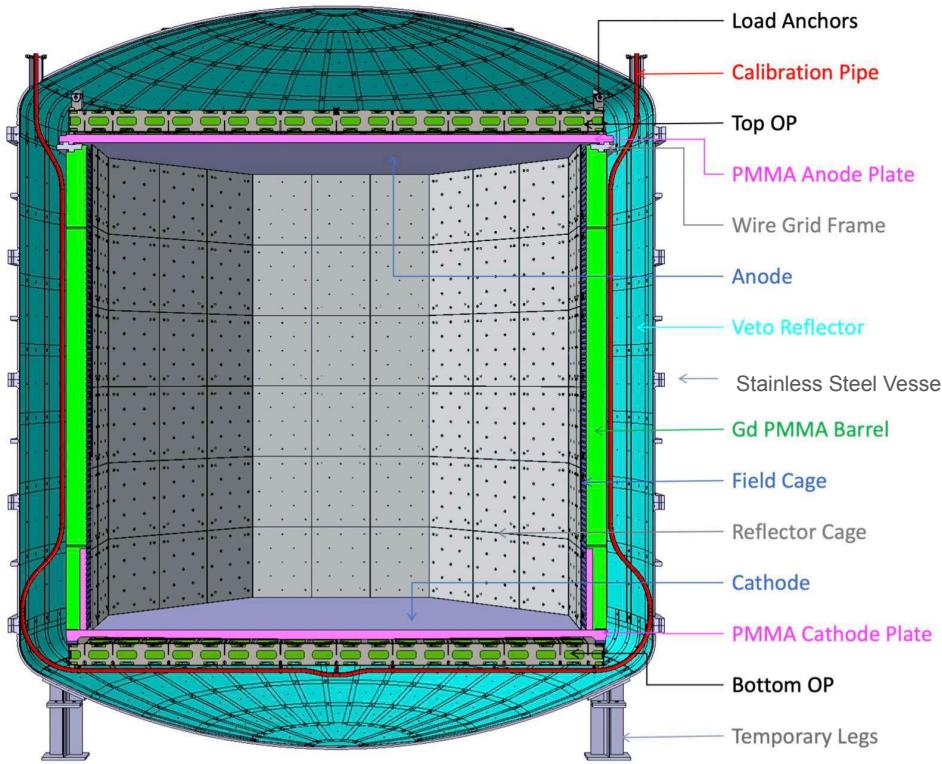
TPC: Active (fiducial) UAr mass: 49.7(20.2) tonnes



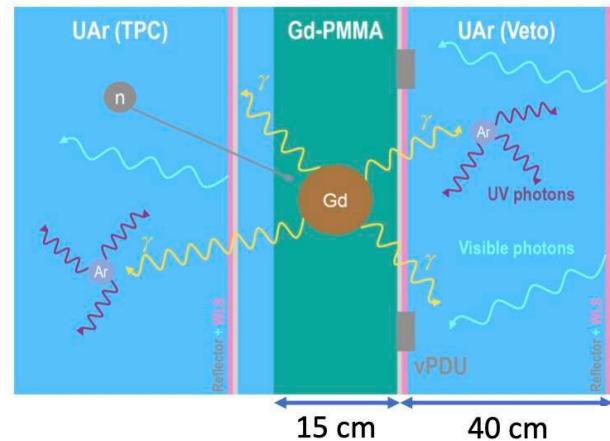
LY (null drift field): $10 \text{ PE/keV}_{\text{ee}}$

S2 yield $> 20 \text{ PE/e-}$

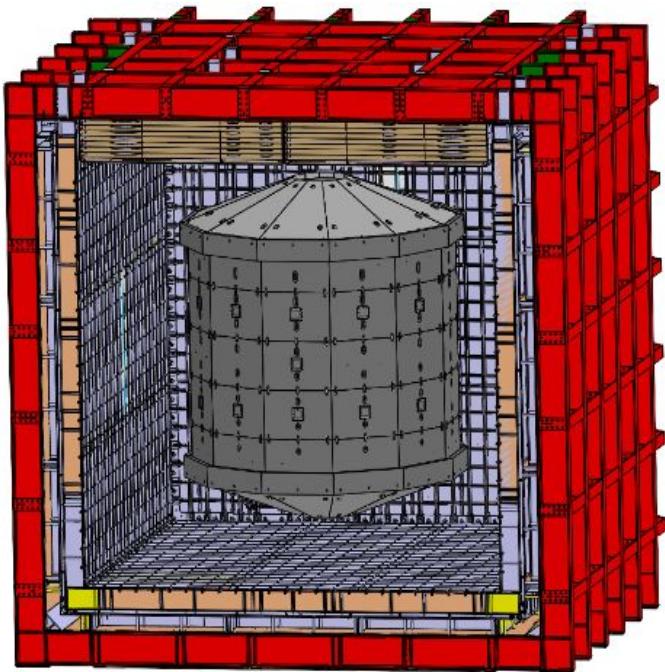
A closer look at the Inner Detector

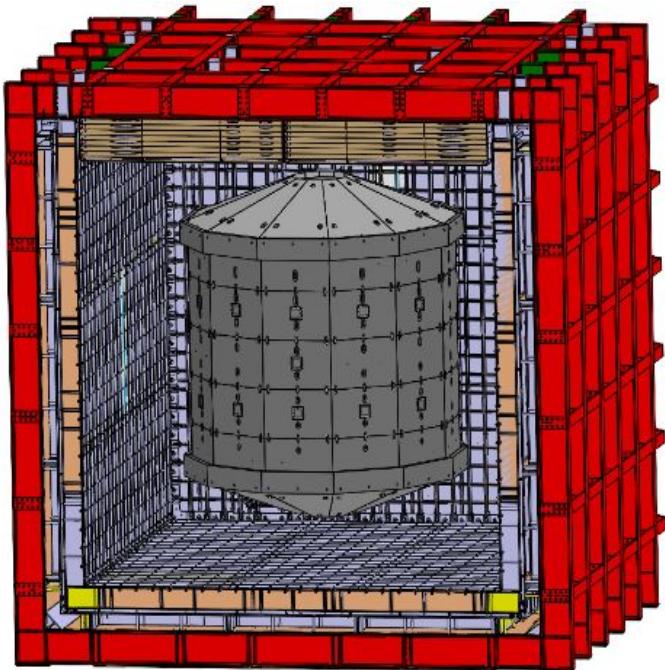


**Neutron rejection
thanks to (n,γ)**

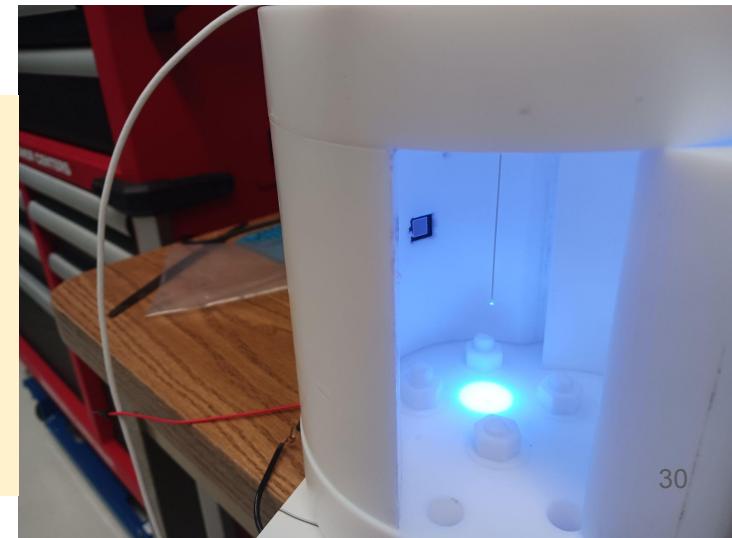


R&D for the Outer Veto

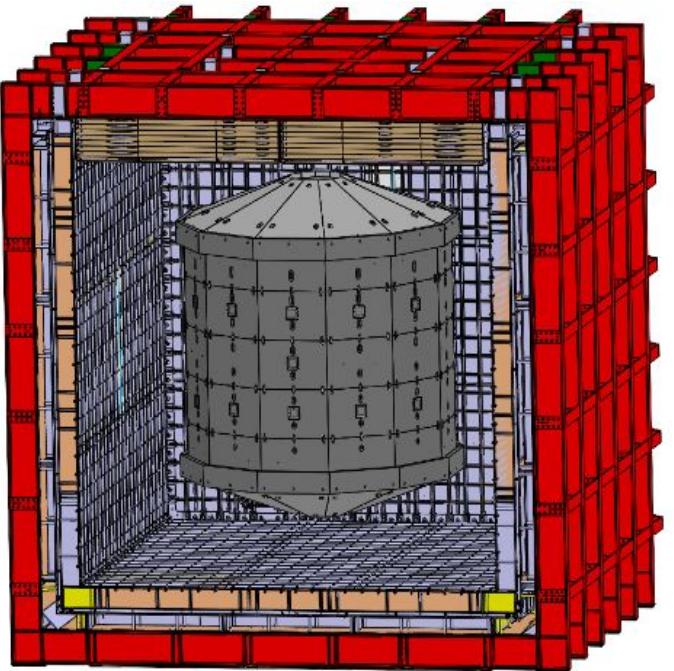




Reflectance
Effects
From
LAr
Exposure
Characterization
Tool



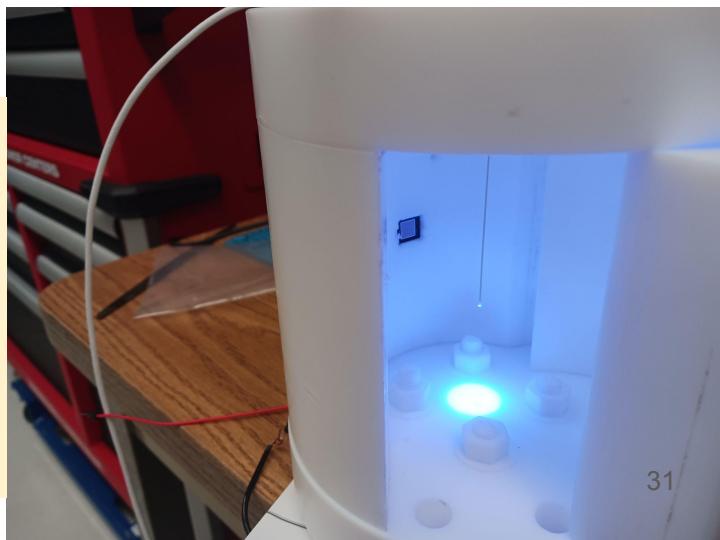
R&D for the Outer Veto



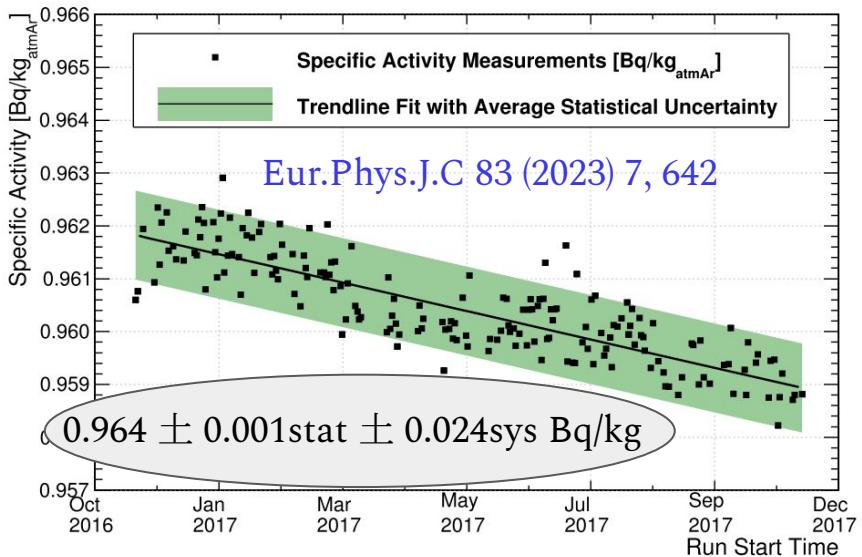
Apparatus for
Researching
Argon for
New
Detector
Designs for
Exciting
Experiments



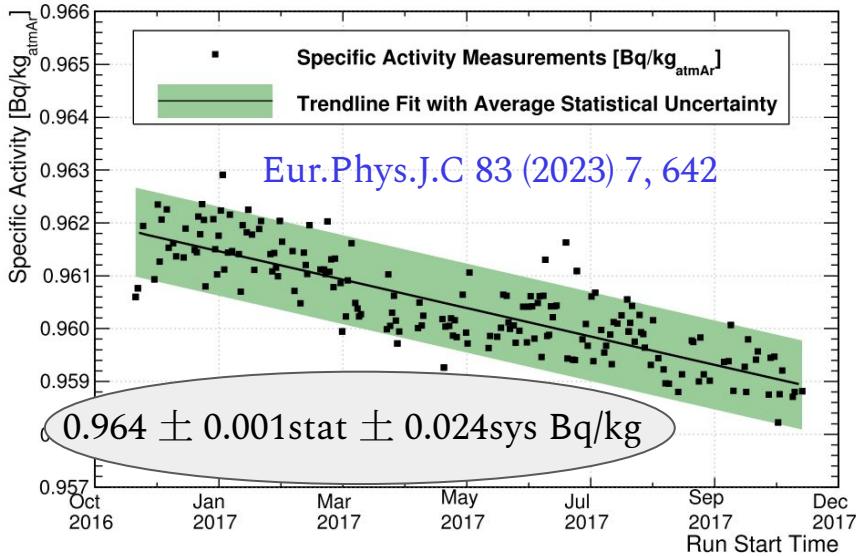
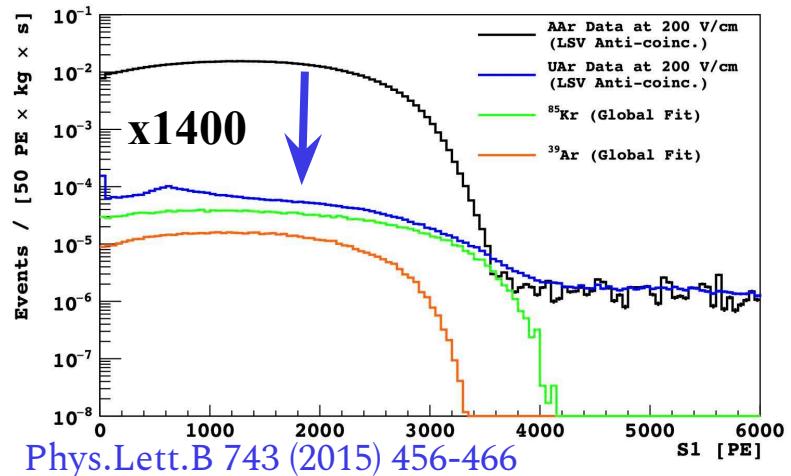
Reflectance
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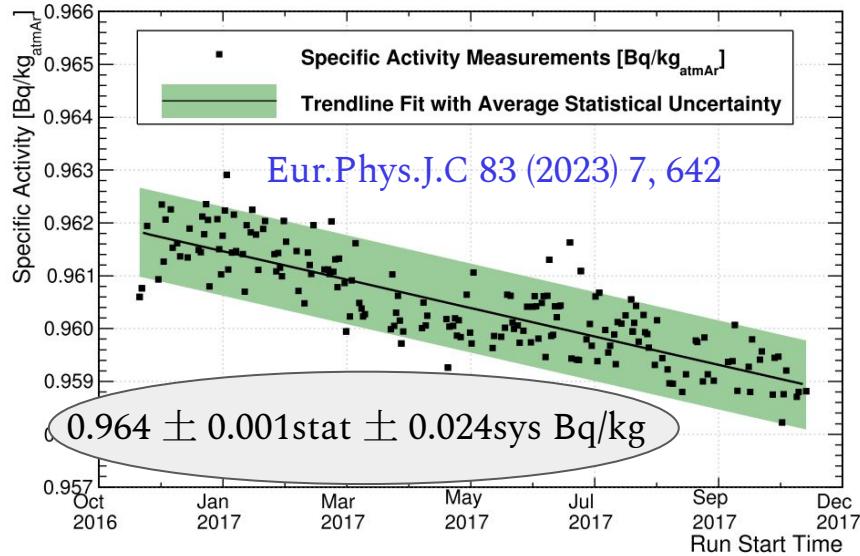
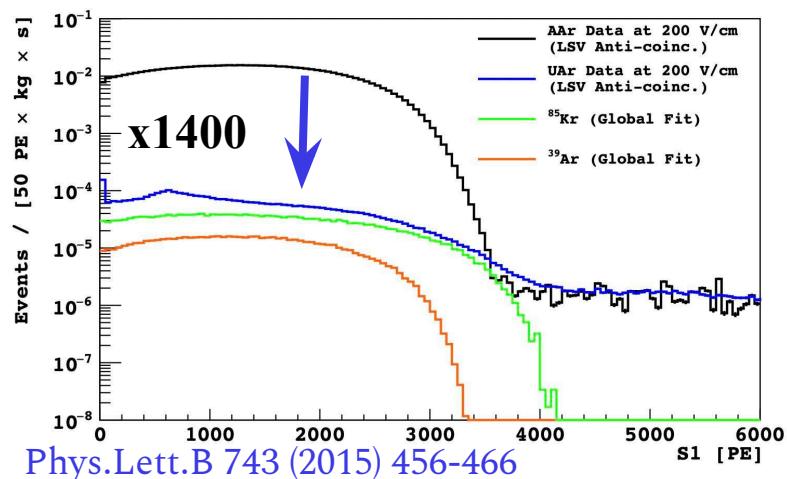
DarkSide-20k UAr recipe



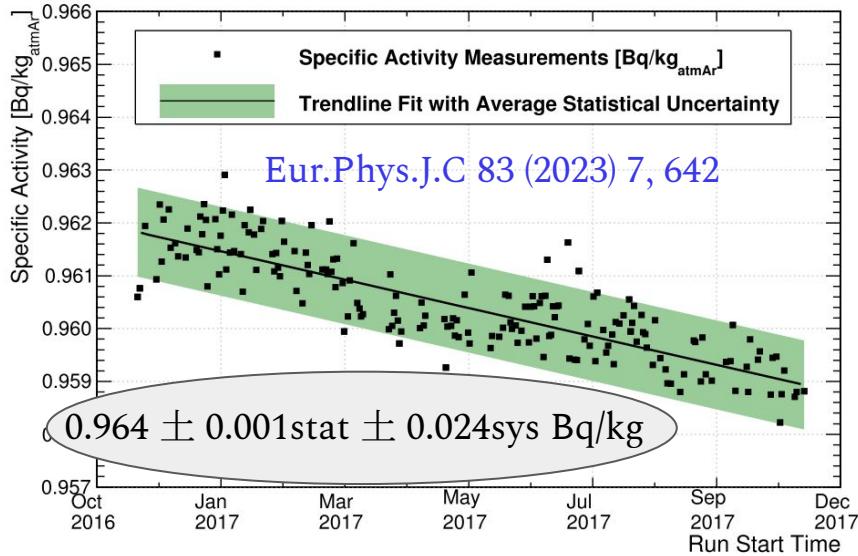
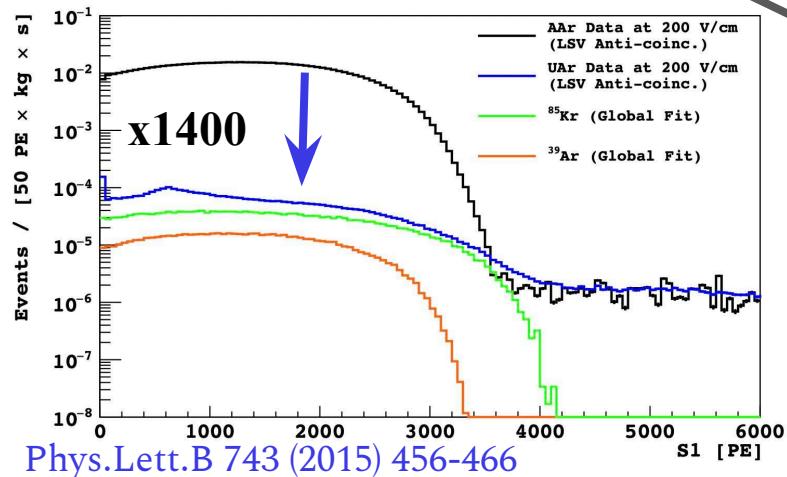
DarkSide-20k UAr recipe



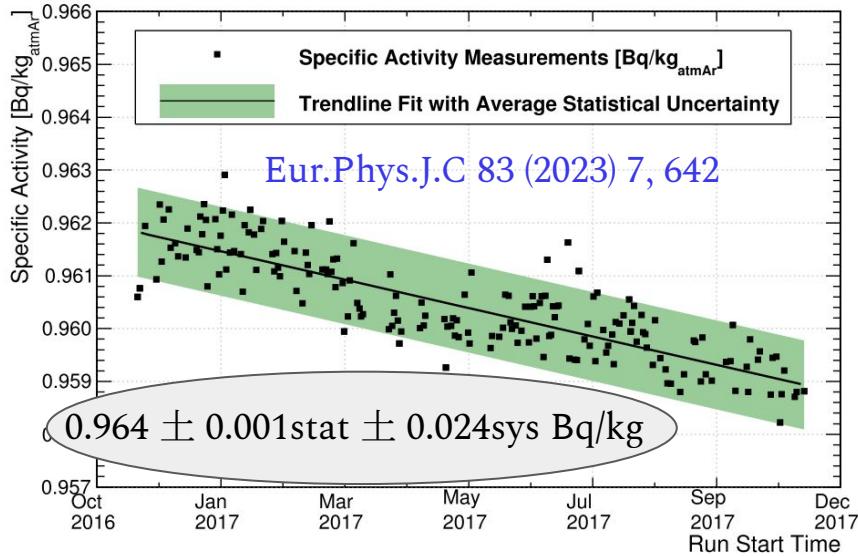
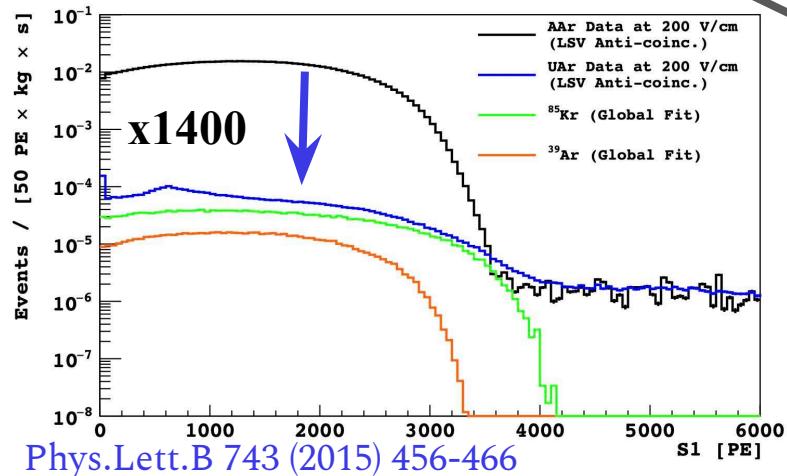
DarkSide-20k UAr recipe



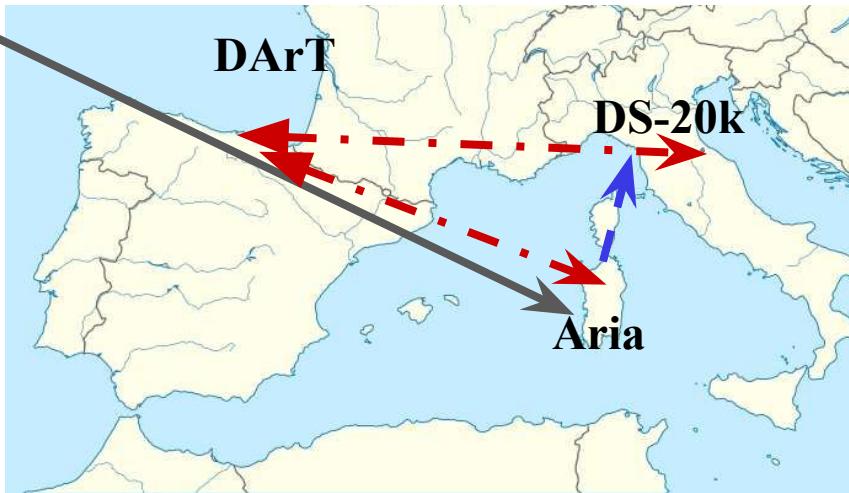
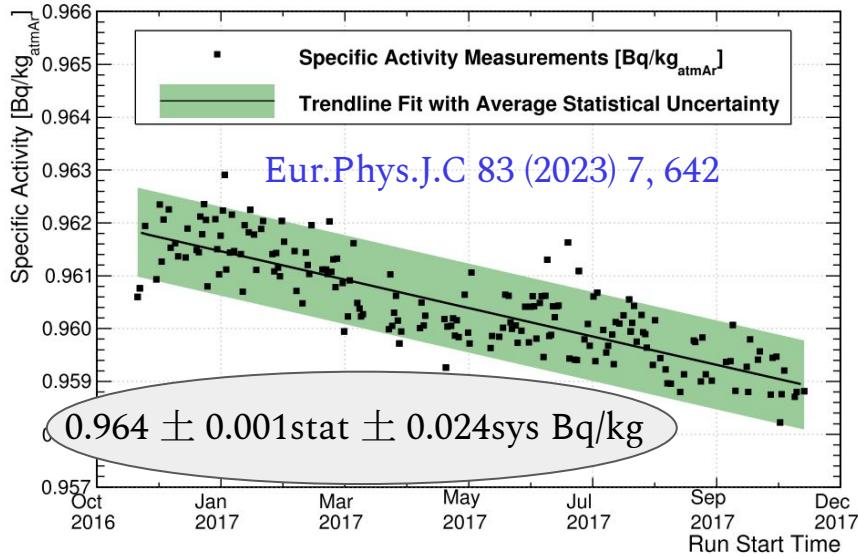
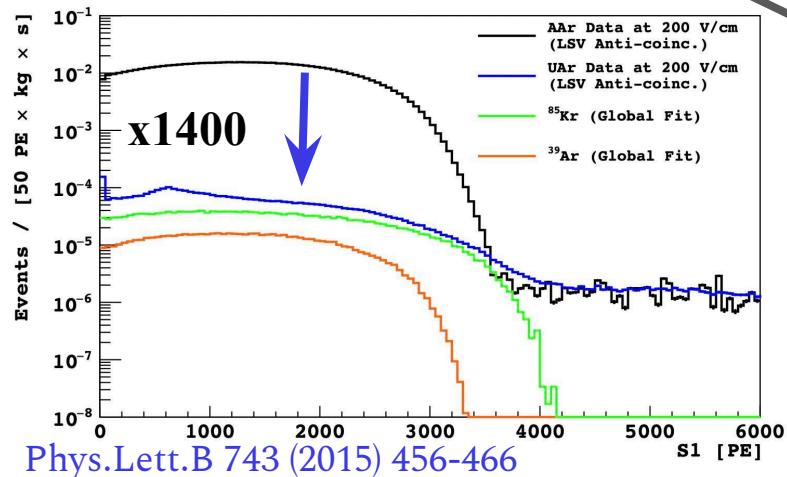
DarkSide-20k UAr recipe



DarkSide-20k UAr recipe



DarkSide-20k UAr recipe



DarkSide-20k UAr recipe

**2009: found low activity UAr at
Southwest Colorado CO₂ wells**



DarkSide-20k UAr recipe

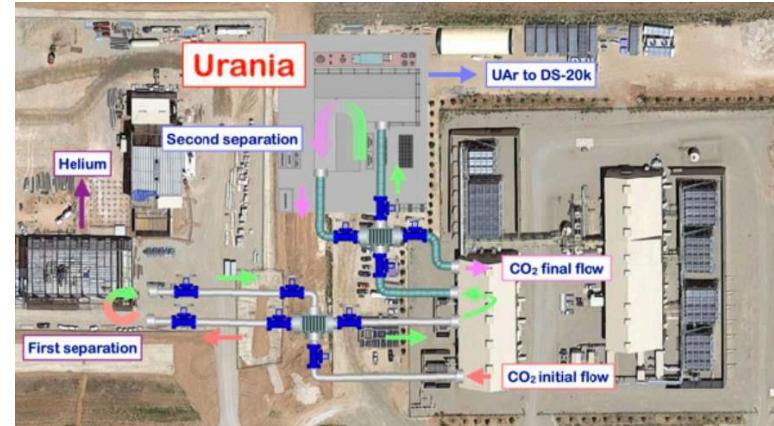
2009: found low activity UAr at Southwest Colorado CO₂ wells



DarkSide-20k UAr recipe

2009: found low activity UAr at Southwest Colorado CO₂ wells

Estimated extraction rate: 250 kg/day



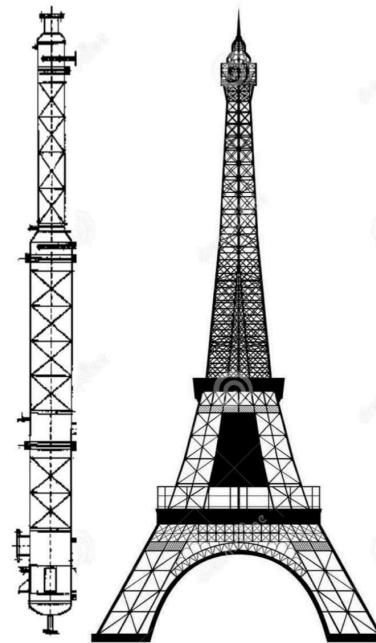
Expected purity from Urania:
99.99%

Need a factor 10^3 more!

Expected purity from Urania:
99.99%

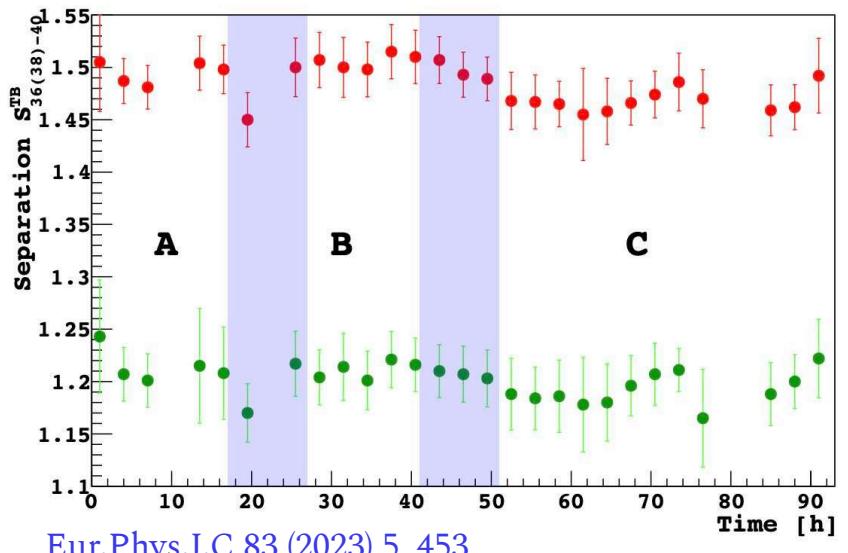
Need a factor 10^3 more!

Seruci-1: 350 m tall



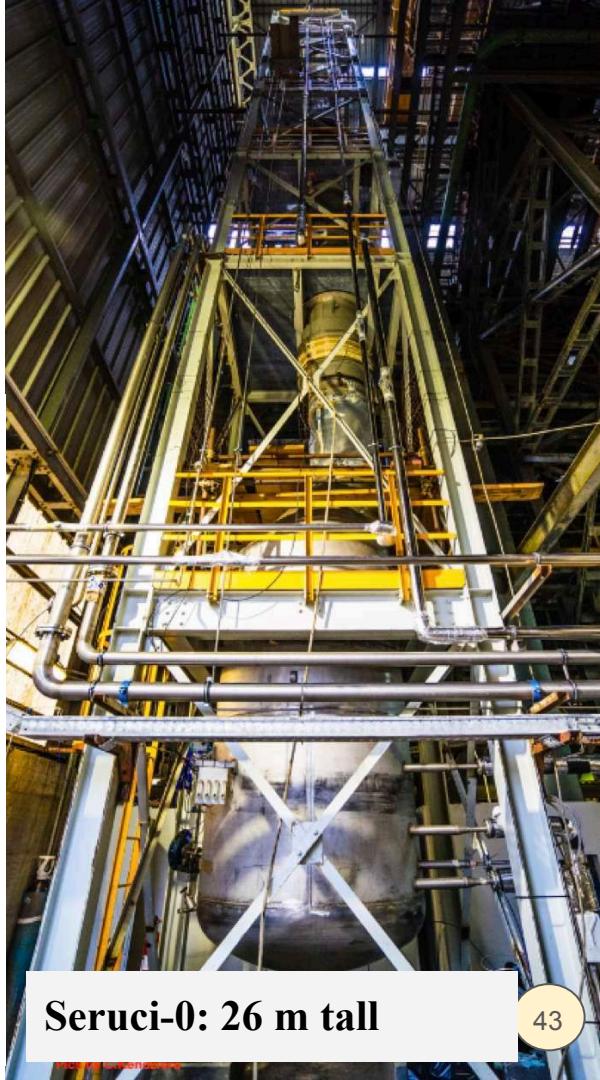
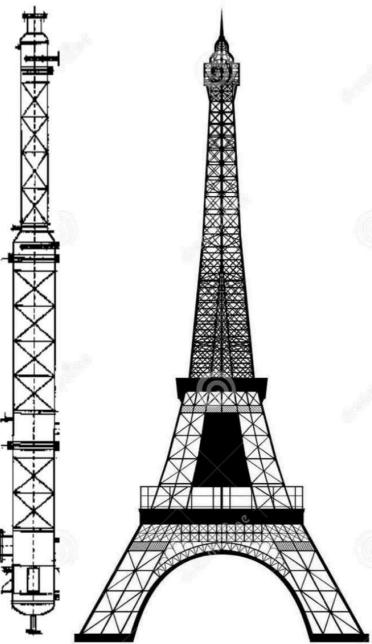
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Eur.Phys.J.C 83 (2023) 5, 453

Seruci-1: 350 m tall

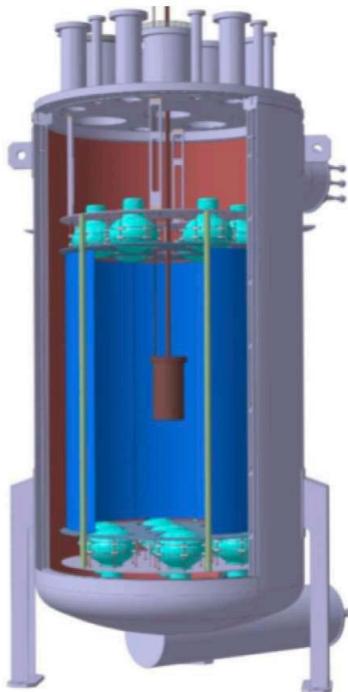


Seruci-0: 26 m tall

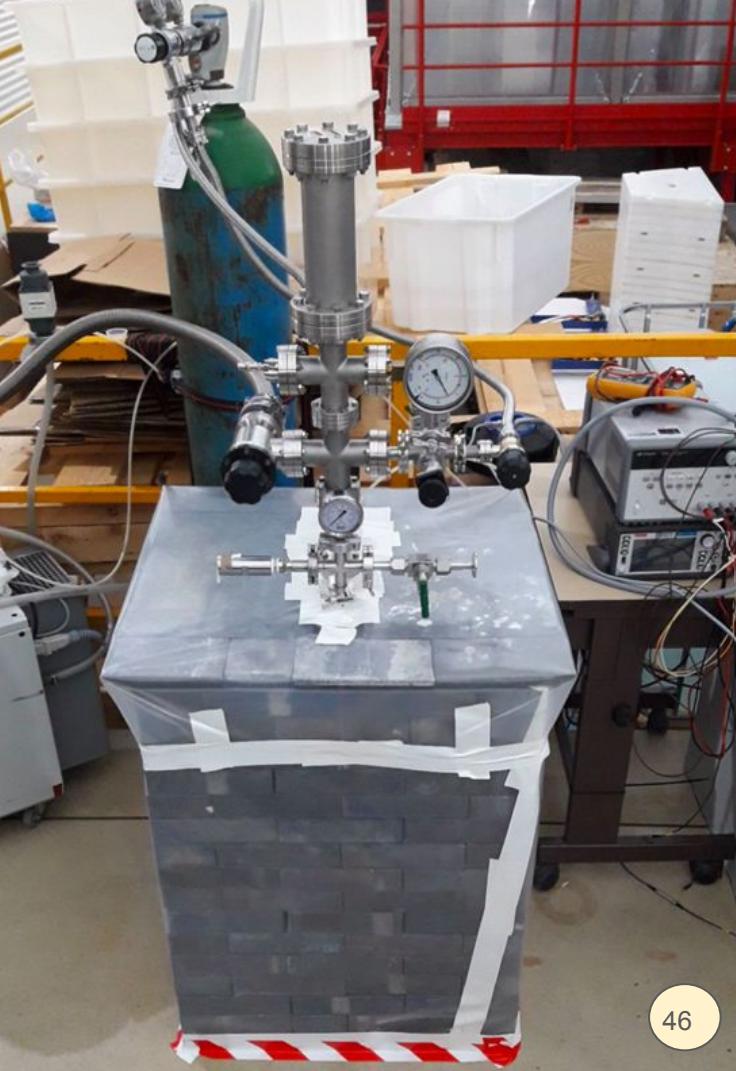
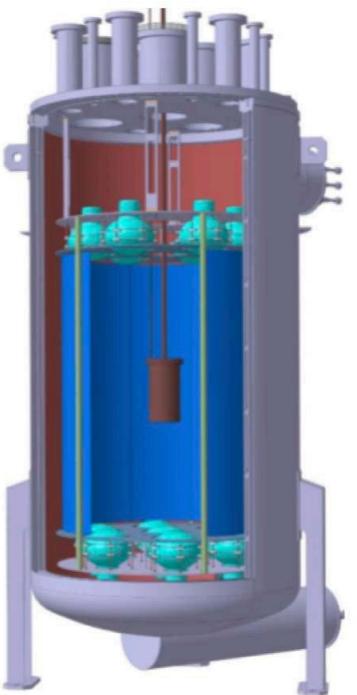
**DArT in ArDM, at Laboratorio Subterraneo De
Canfranc (LSC, Spain, 1400 m.w.e.)**



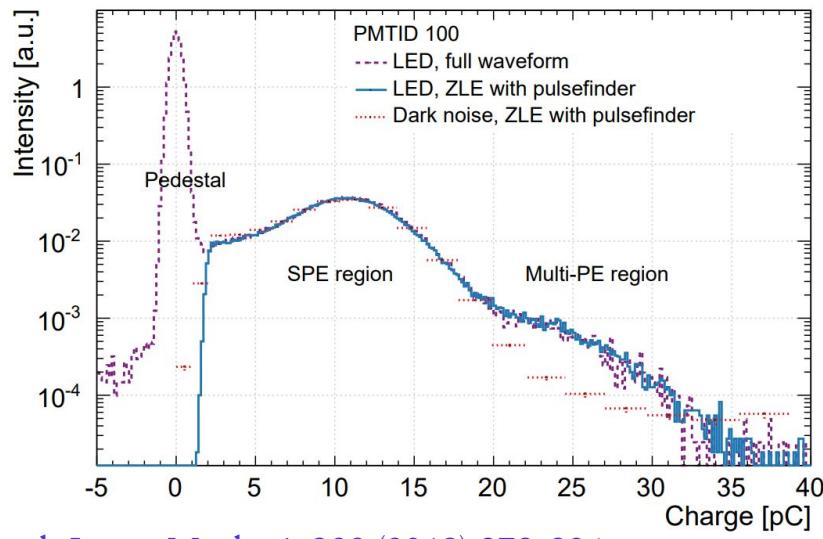
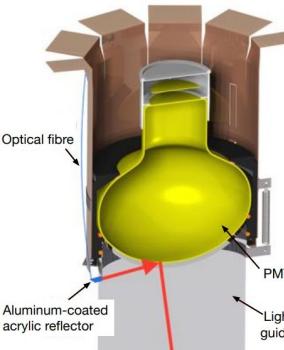
**DArT in ArDM, at Laboratorio Subterraneo De
Canfranc (LSC, Spain, 1400 m.w.e.)**



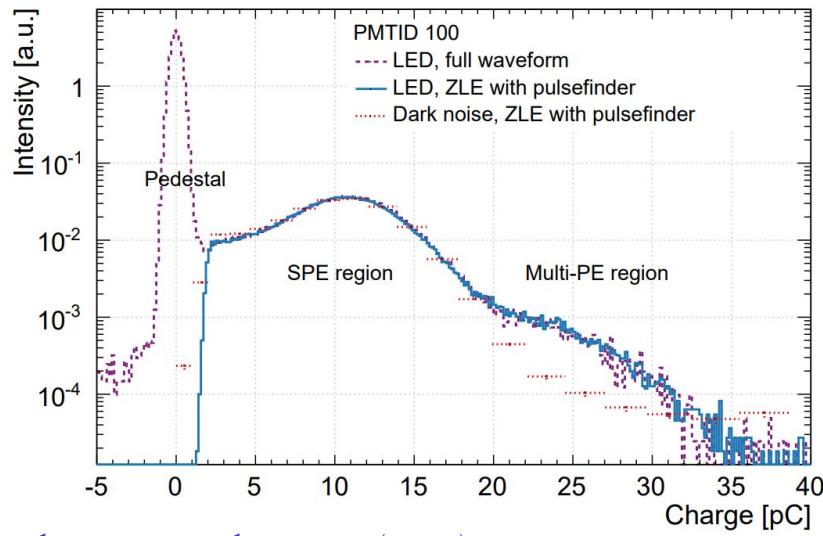
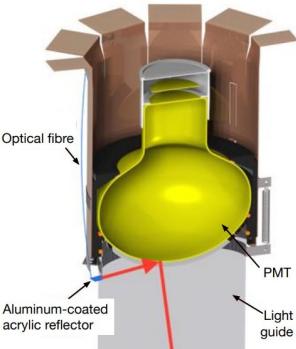
DArT in ArDM, at Laboratorio Subterraneo De Canfranc (LSC, Spain, 1400 m.w.e.)



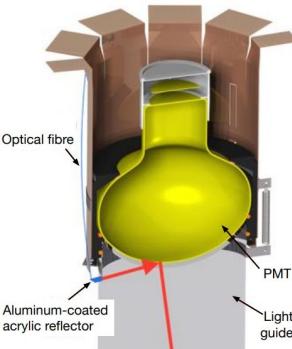
DarkSide-20k photosensors



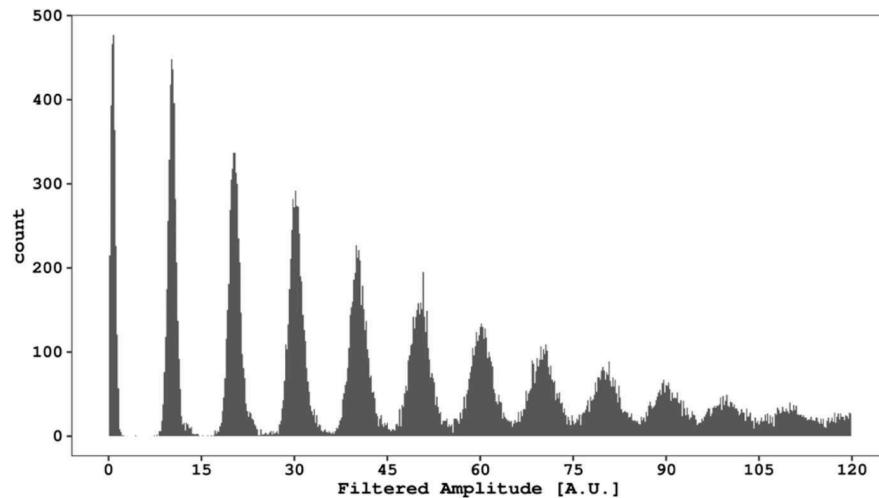
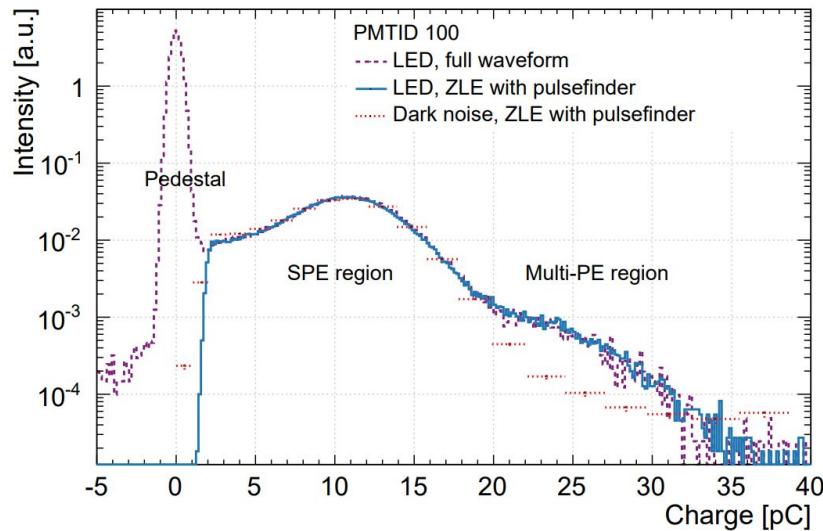
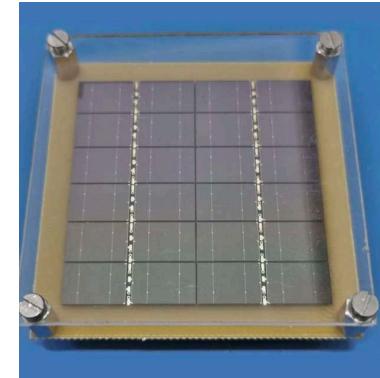
DarkSide-20k photosensors



DarkSide-20k photosensors

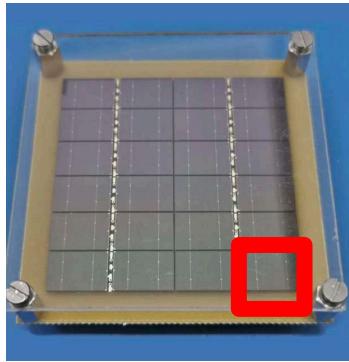


Silicon Photomultipliers (SiPMs)
customly developed with
Fondazione Bruno Kessler (FBK)



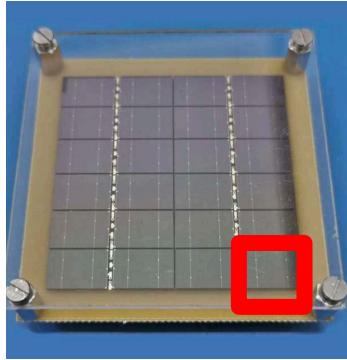
DarkSide-20k photosensors

Tile: 25 cm²

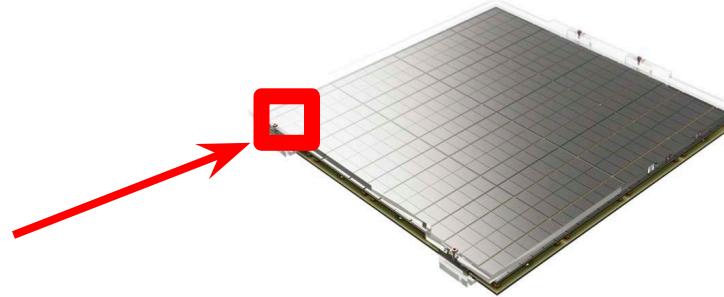


DarkSide-20k photosensors

Tile: 25 cm²



PDU: 400 cm²



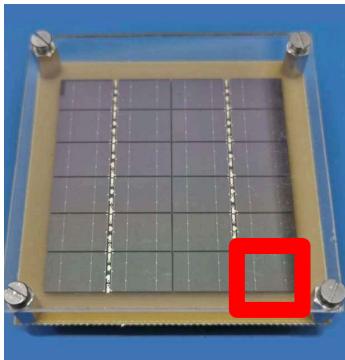
TPC: 525 PDU

IV: 20 vPDU

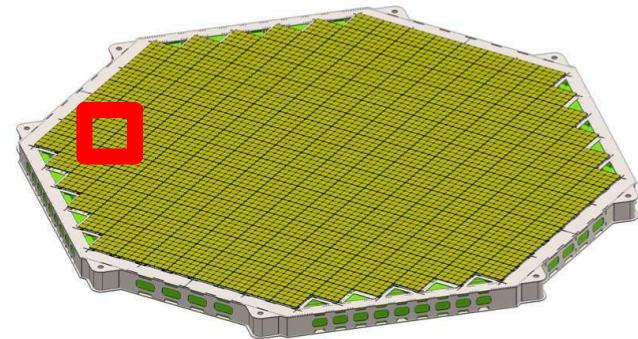
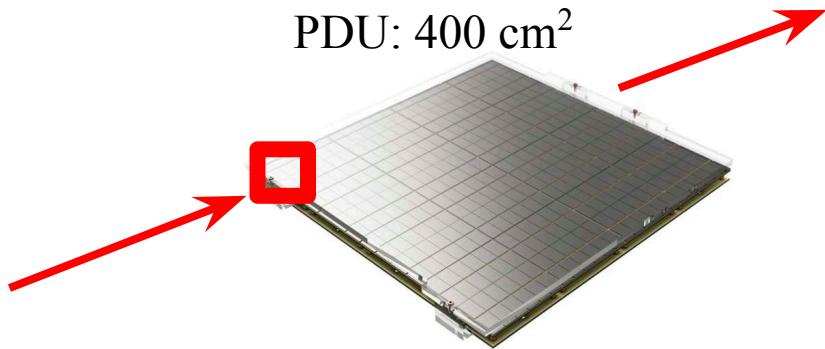
OV: 32 vPDU

DarkSide-20k photosensors

Tile: 25 cm^2



PDU: 400 cm^2



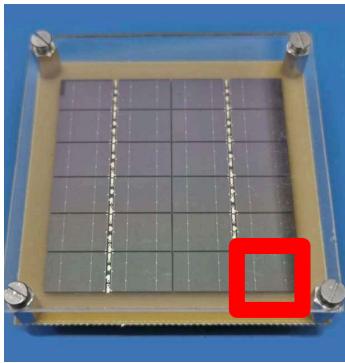
TPC: 525 PDU

IV: 20 vPDU

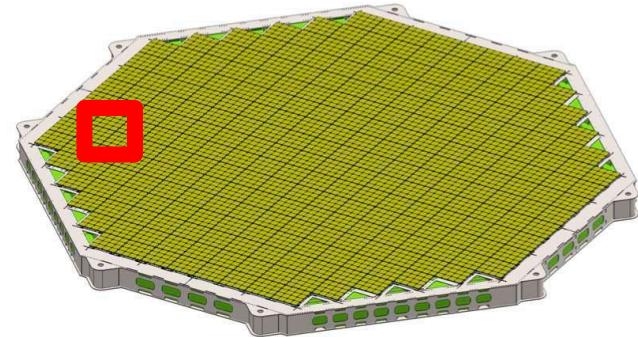
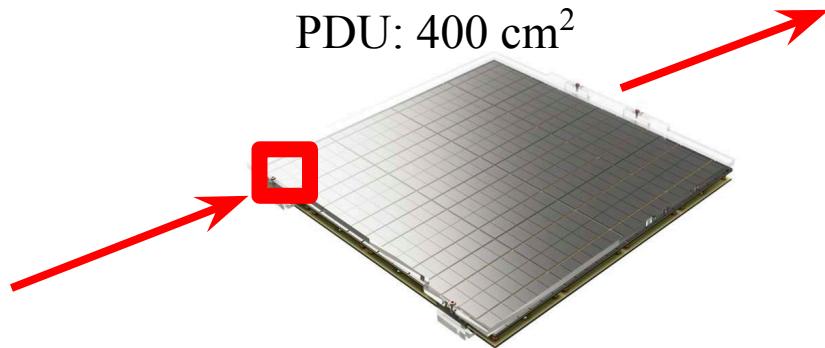
OV: 32 vPDU

DarkSide-20k photosensors

Tile: 25 cm²



PDU: 400 cm²



TPC: 525 PDU

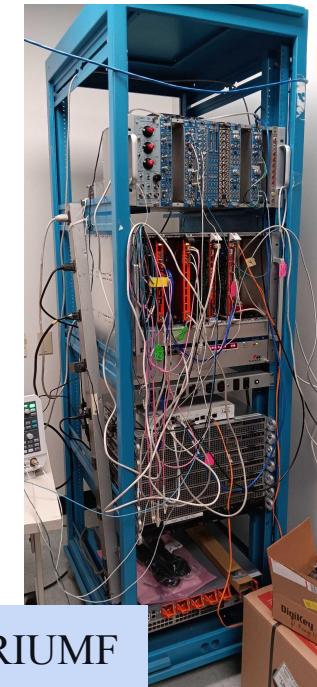
IV: 20 vPDU

OV: 32 vPDU

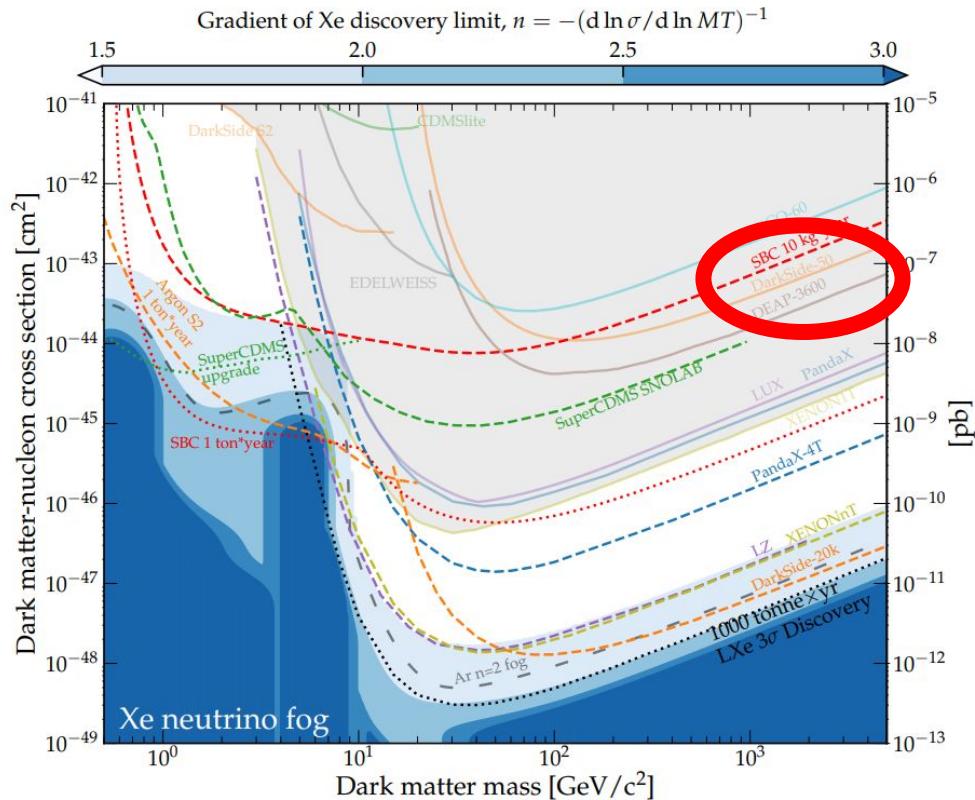


NOA facility

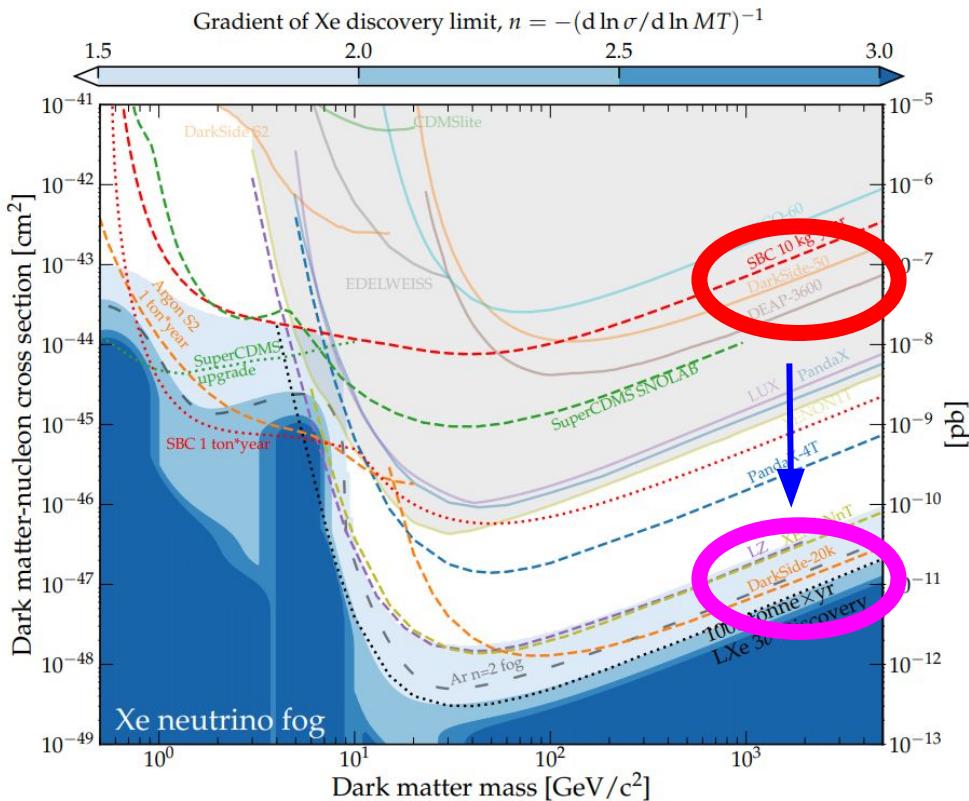
TRIUMF



Expected sensitivity to WIMPs



Expected sensitivity to WIMPs

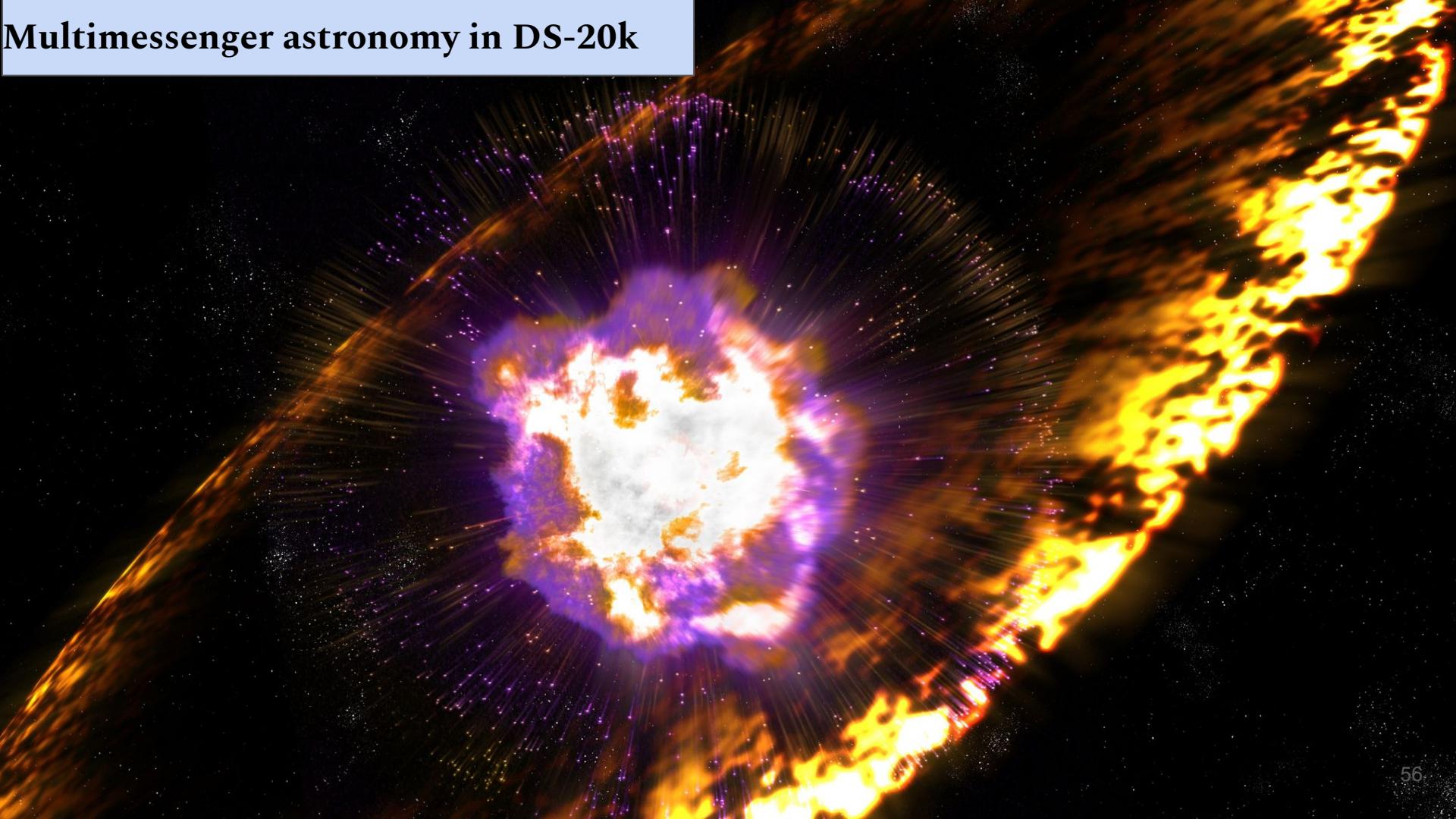


With 20 tonnes x 10 years:

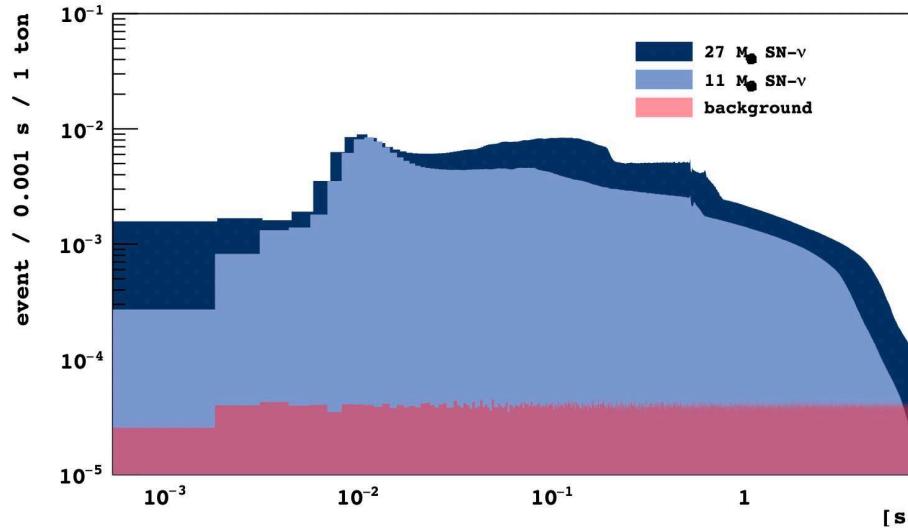
< 0.1 neutrons in ROI (30~200 keV_{NR})

90% C.L. exclusion:
 $6.3 \times 10^{-48} \text{ cm}^2$ at 1 TeV/c²

Multimessenger astronomy in DS-20k

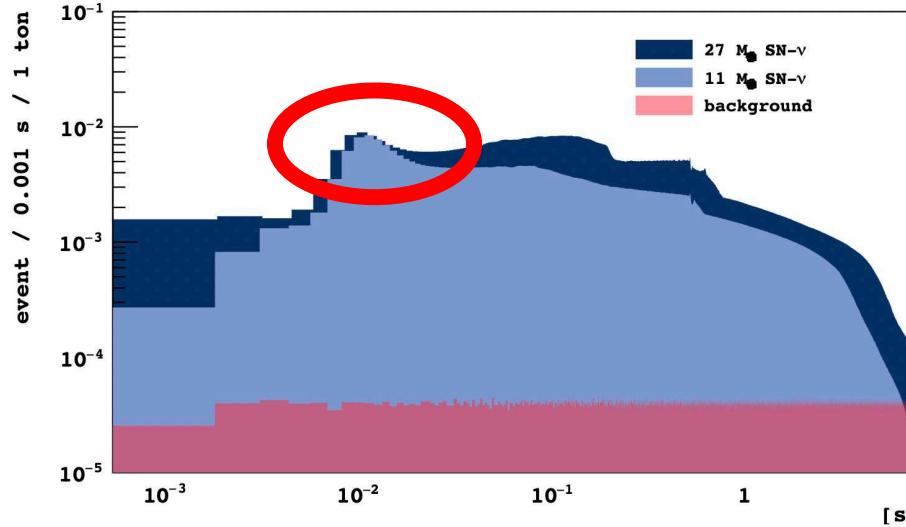


Multimessenger astronomy in DS-20k

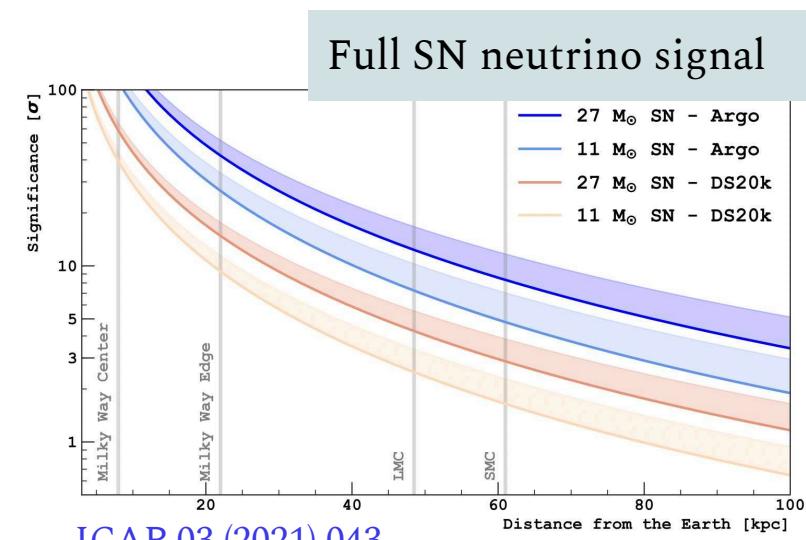


	DarkSide-20k	Argo
$11 M_{\odot}$ SN- ν s	181.4	1396.6
$27 M_{\odot}$ SN- ν s	336.5	2591.6
^{39}Ar	4.3	33.8
external background	1.8	8.8
single-electrons	0.7	5.1

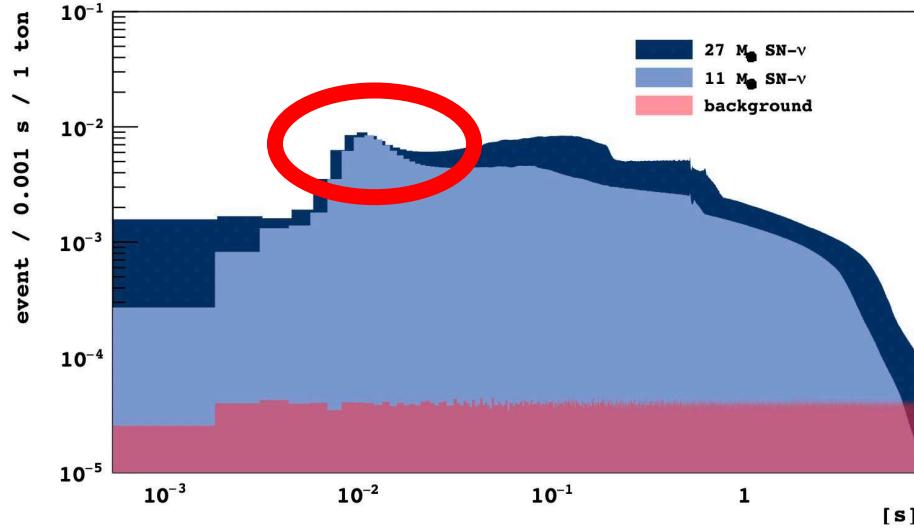
Multimessenger astronomy in DS-20k



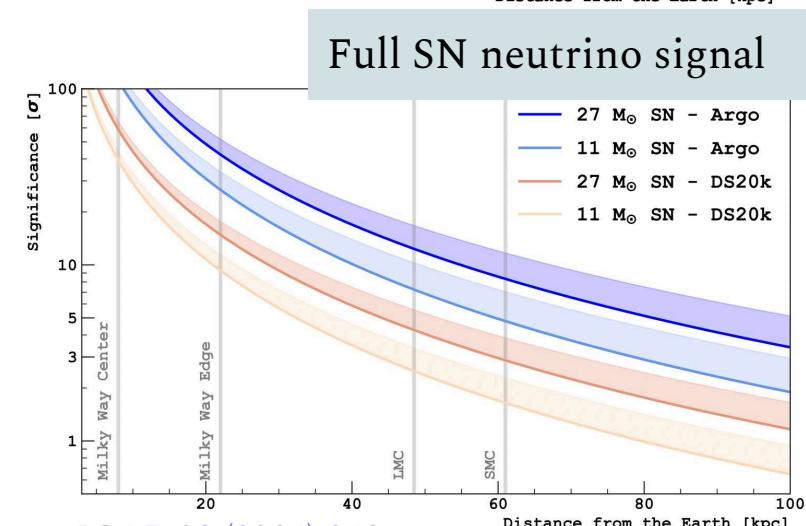
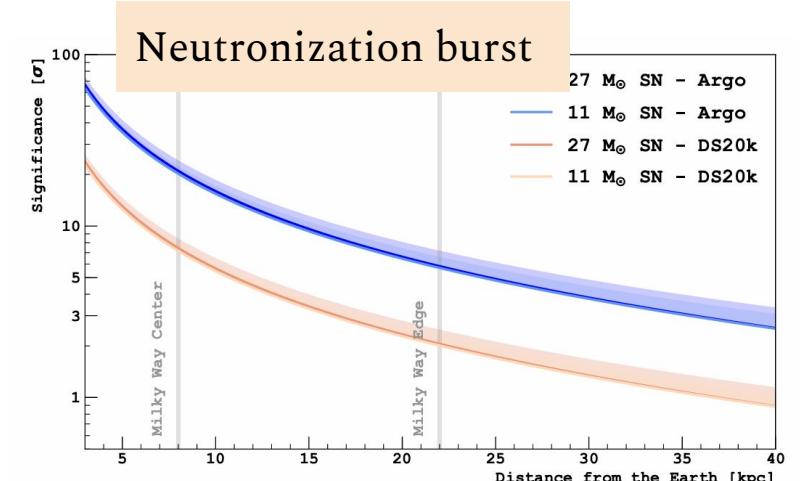
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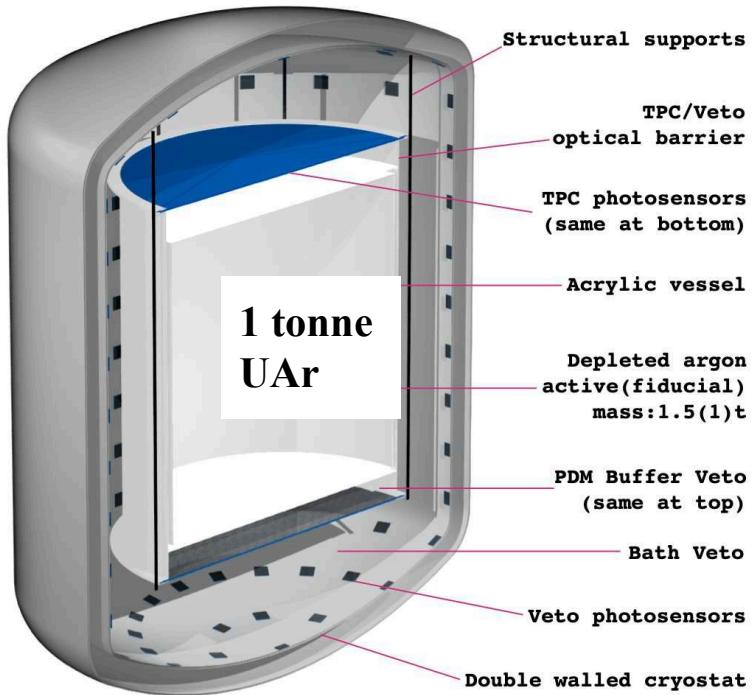
Multimessenger astronomy in DS-20k



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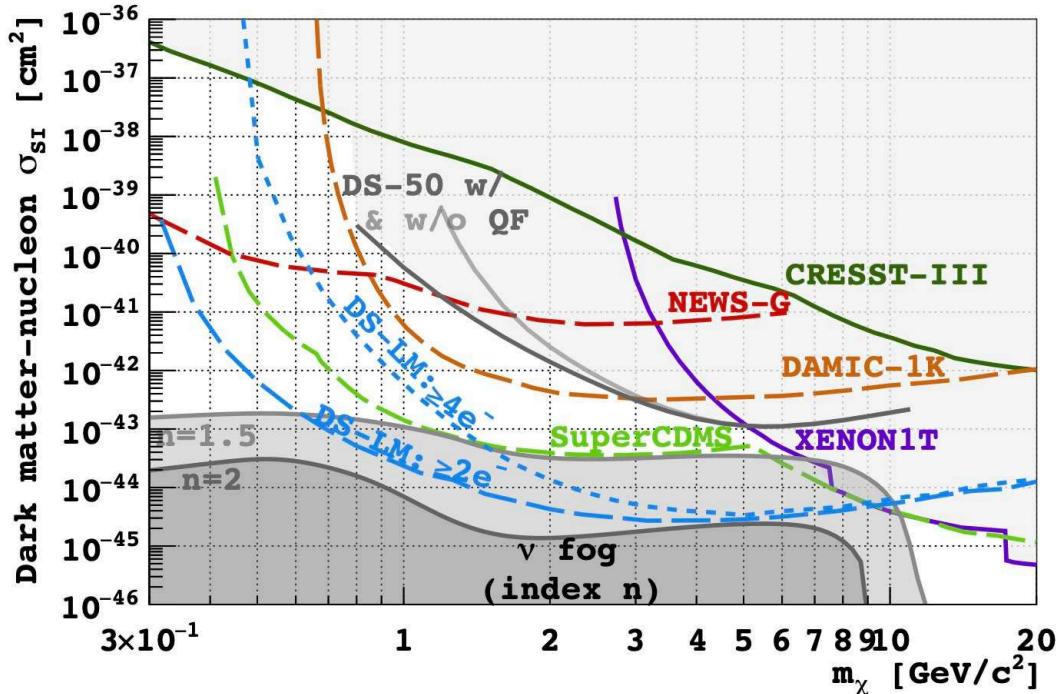
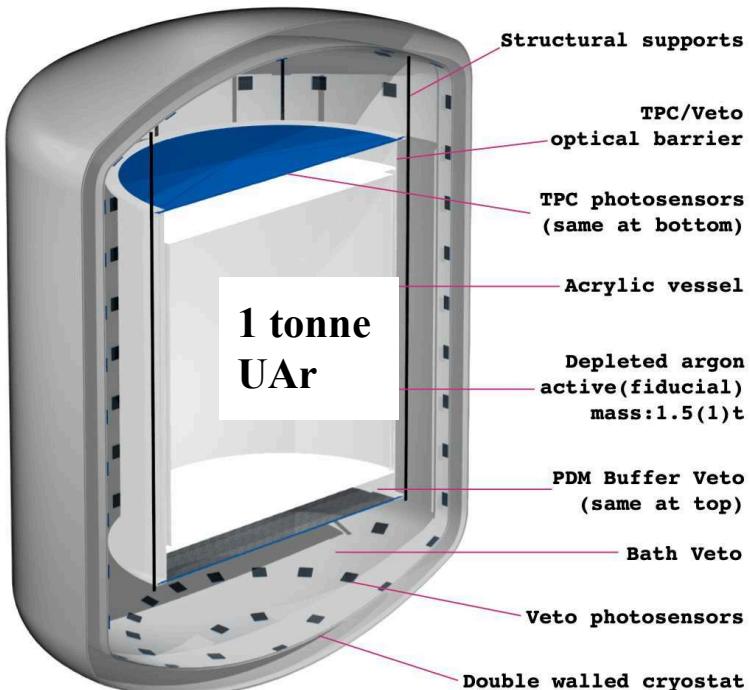


Side project: DarkSide-LowMass



Side project: DarkSide-LowMass

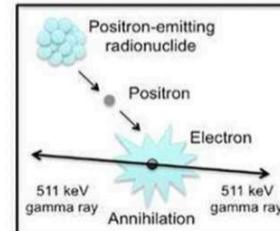
Designed to reach the neutrino floor with 1 tonne year exposure



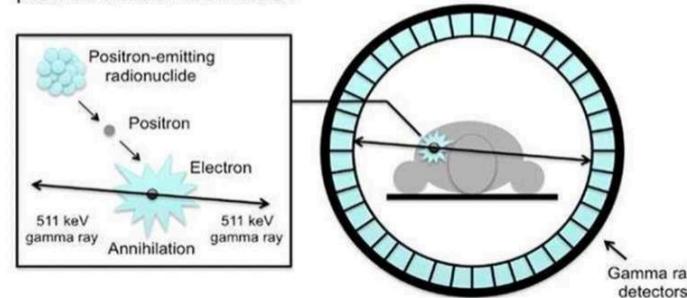
Phys. Rev. D 107, 112006 (2023)

Side project: 3DII Scanner

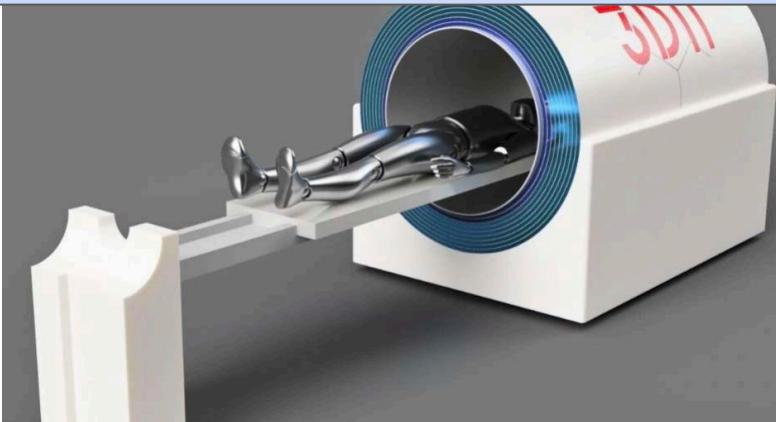
Positron emission and positron-electron annihilation



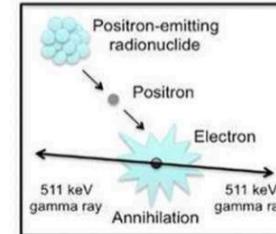
PET scanner



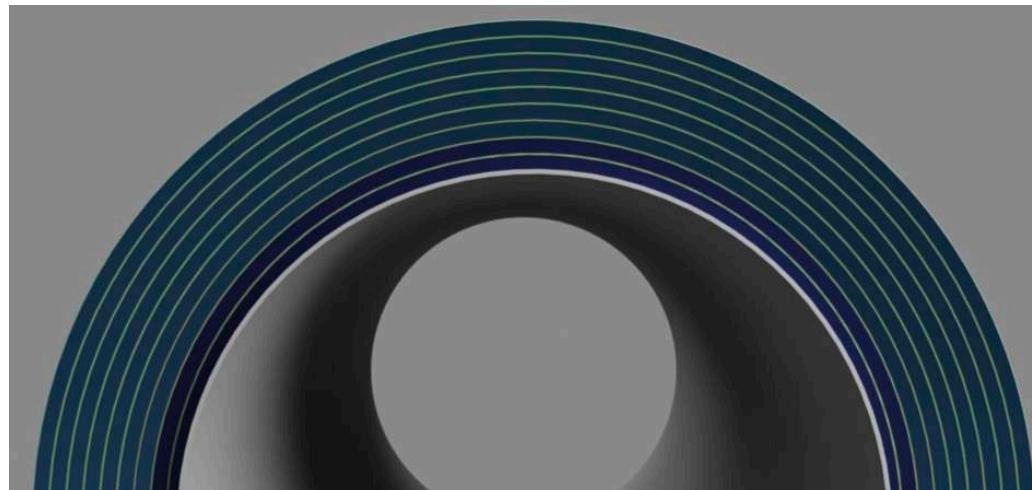
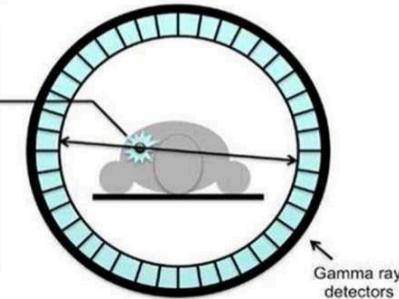
Side project: 3DII Scanner



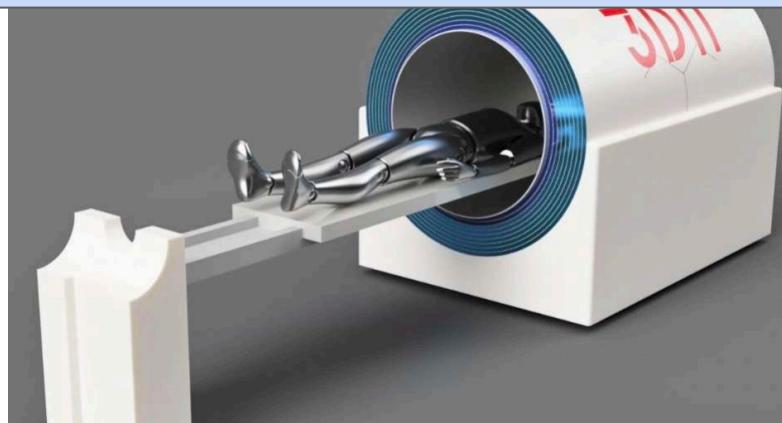
Positron emission and positron-electron annihilation



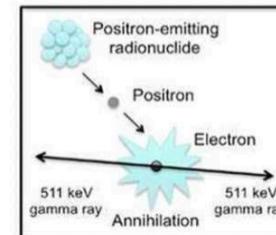
PET scanner



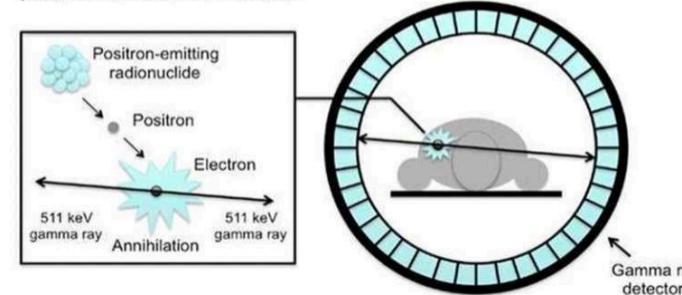
Side project: 3DII Scanner



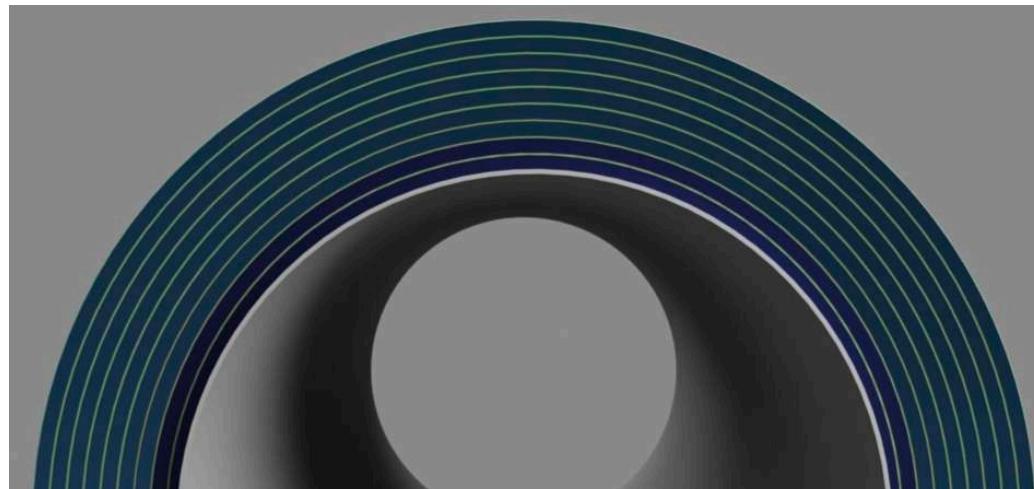
Positron emission and positron-electron annihilation



PET scanner



Gamma ray detectors



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!



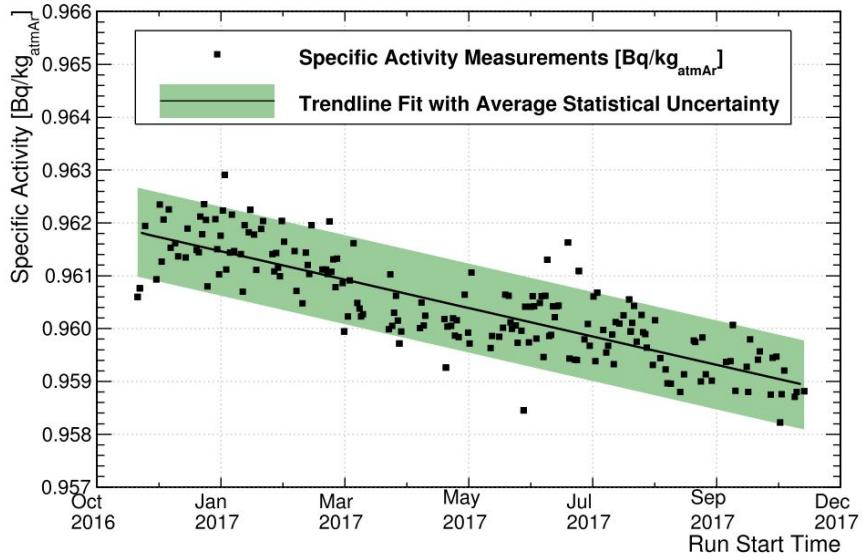
Backgrounds

Main contaminant, rejected with PSD:
39-Argon beta decays ($Q = 565$ keV)

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

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

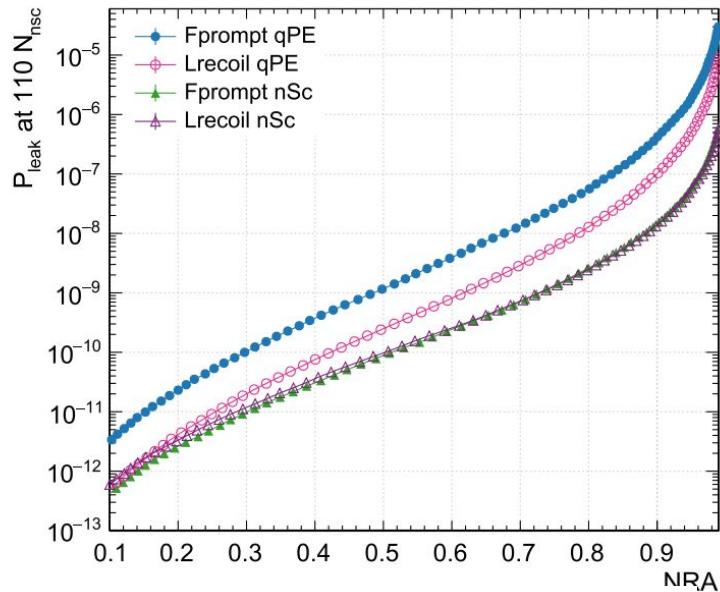
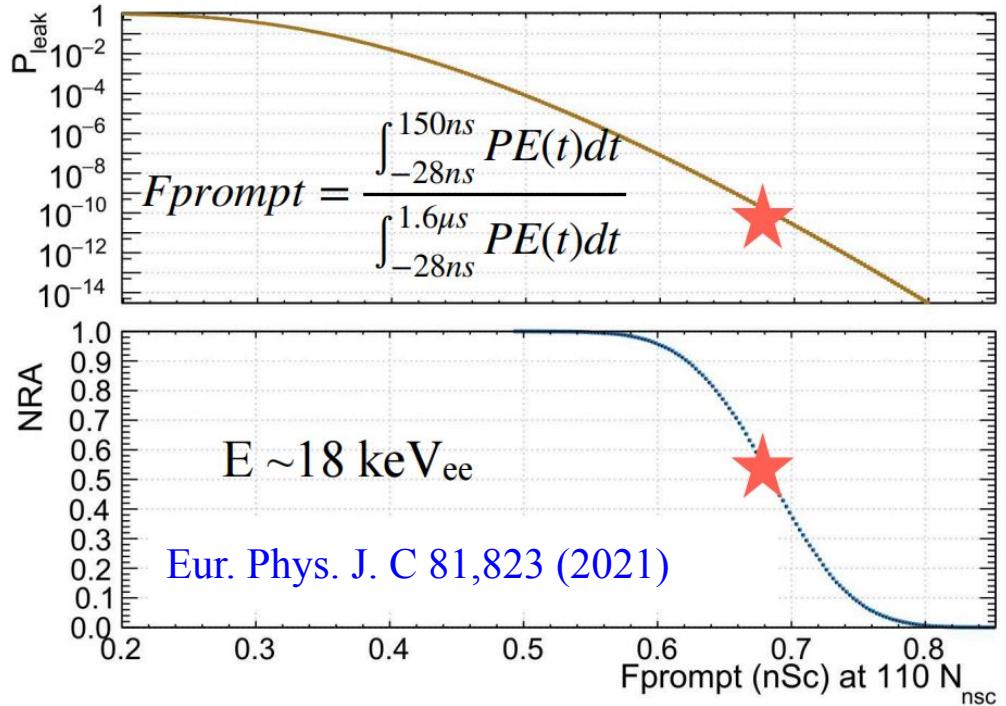
Measurement	Specific activity [Bq/kg _{atmAr}]
WARP [15]	$1.01 \pm 0.02_{\text{stat}} \pm 0.08_{\text{sys}}$
ArDM [16]	0.95 ± 0.05
DEAP-3600 (this work)	$0.964 \pm 0.001_{\text{stat}} \pm 0.024_{\text{sys}}$



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

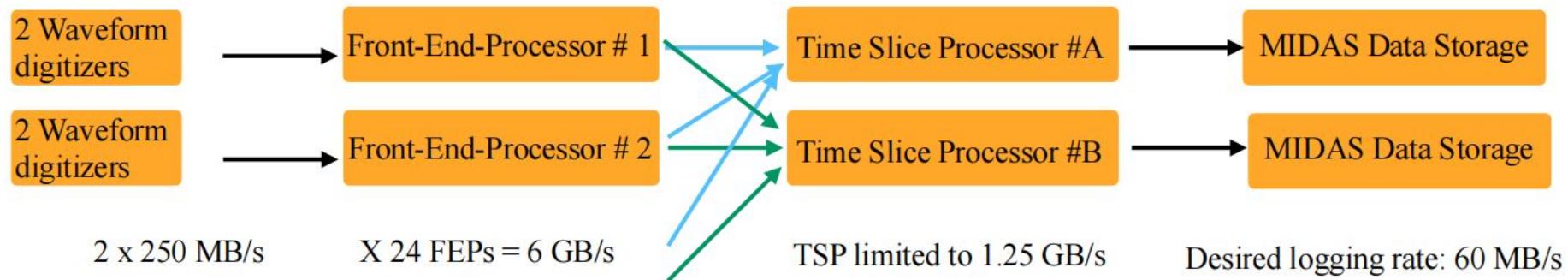
$$m_{LAr} = (3269 \pm 24)$$

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