DarkSide
the quest for dark matter with liquid argon

D. Franco
on behalf of DarkSide-France

Conseil Scientifique IN2P3 – October 2018

DarkSide in France

The team:

- ☑ **APC**: D. Franco, A. Tonazzo + 1 PhD (M. Lai)
- ☑ **LPNHE**: C. Giganti, S. De Cecco (on leave) + 1 PhD (A. Navrer-Agasson)
- ☑ Technical support for beam tests by **IPNO** (M. Lebois, J. Wilson)

Several responsibilities:

- ☑ Executive Board, Technical Board, DS-50 Steering Committee, Speaker Bureau
- ☑ L1 WBS Manager "Science, Simulation, and Computing"
- ☑ L2 WBS Manager: "Monte Carlo Simulations"

French main contributions to (among 17 publications since 2013):

- ☑ Pulse shape discrimination for a **background-free** experiment PLB 743 (2015) 456 — 2015
- ☑ **Solar neutrino** physics in a large LAr detector JCAP 1608 (2016) 8, 017 — 2016
- ☑ ^{39}Ar depletion faction in **underground argon** PRD 93 (2017) 081101 — 2017
- ☑ **Simulation** and LAr response model JINST 12 (2017) P10015
- ☑ Most accurate constraint of **LAr response** with ARIS, PRD 97 (2018) 11 112005 — 2018
- ☑ World **best exclusion limit for 1.8-6 GeV WIMPs** PRL 121 (2018) 081307
- ☑ Extension of existing **exclusion limit to WIMP-electrons** PRL 121 (2018) 111303

DarkSide-50

Detector

- a **50 kg** dual-phase Liquid Argon TPC
- Using **Underground Argon**: depleted in ^{39}Ar
- In a **30 ton** borated liquid scintillator **neutron veto**
- In a **1000 ton Water** Cherenkov Veto
- Underground at Gran Sasso National Lab, Italy

Performance

S1 and S2 Yields:

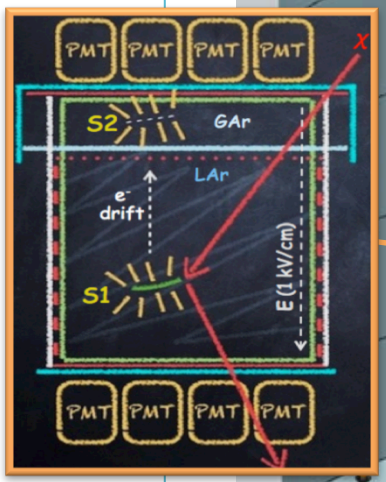
- S1 Yield ~7.9 pe/keV at null field
- S1 Yield **~7.0 pe/keV** at 200 V/cm
- S2 yield **~23 pe / e$^-$**

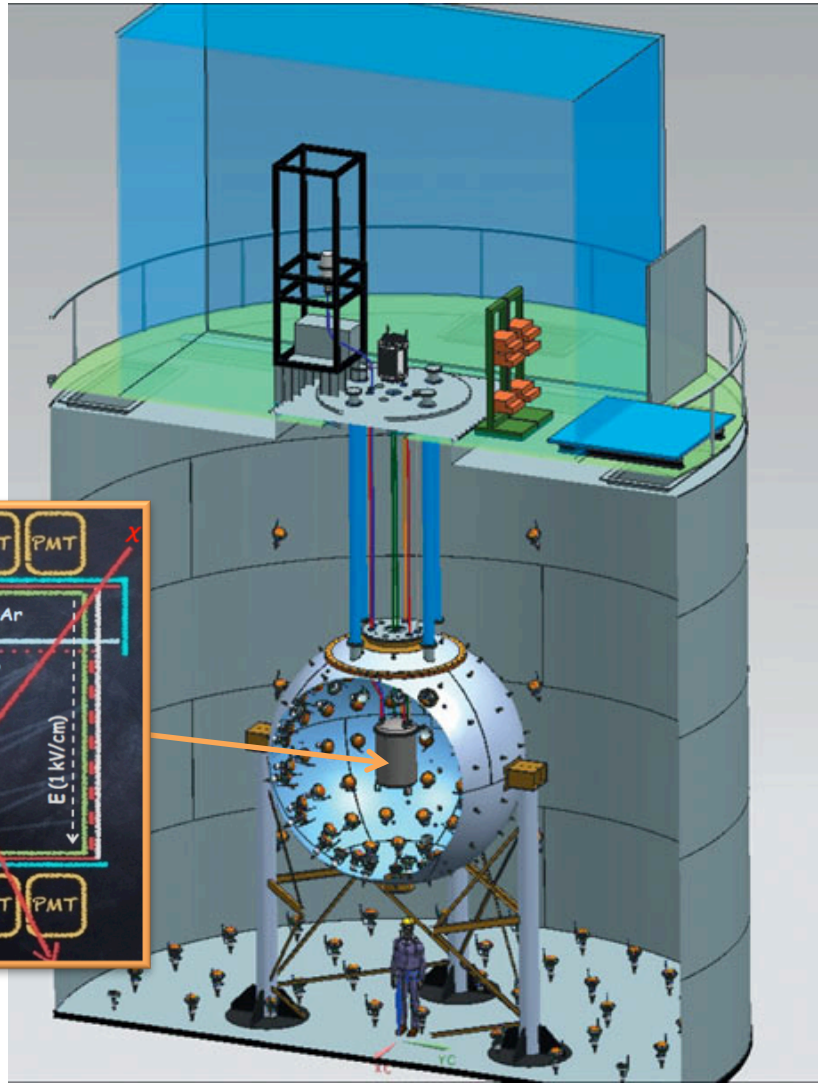
Electron lifetime > 10 ms
Maximum drift time: 376 μs

Position reconstruction:

- Resolution in Z **~1 mm**
- Resolution in XY **<1 cm**

Neutron Veto Rejection Efficiency: 99.6%





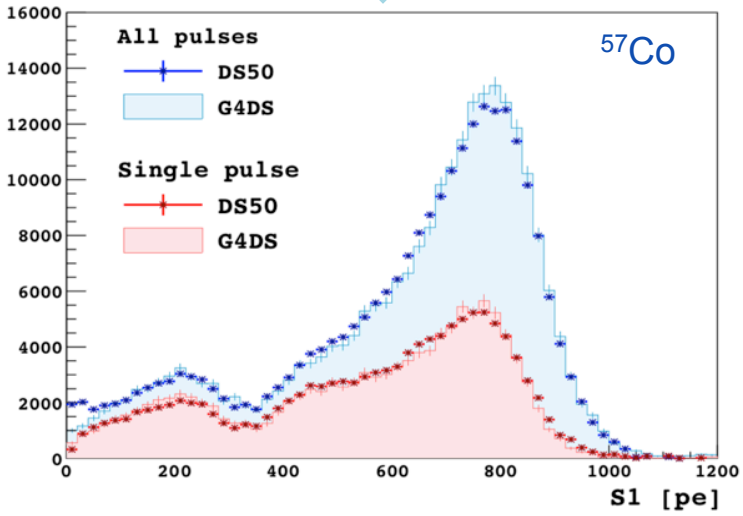
^{39}Ar issue: fixed!

G4DS

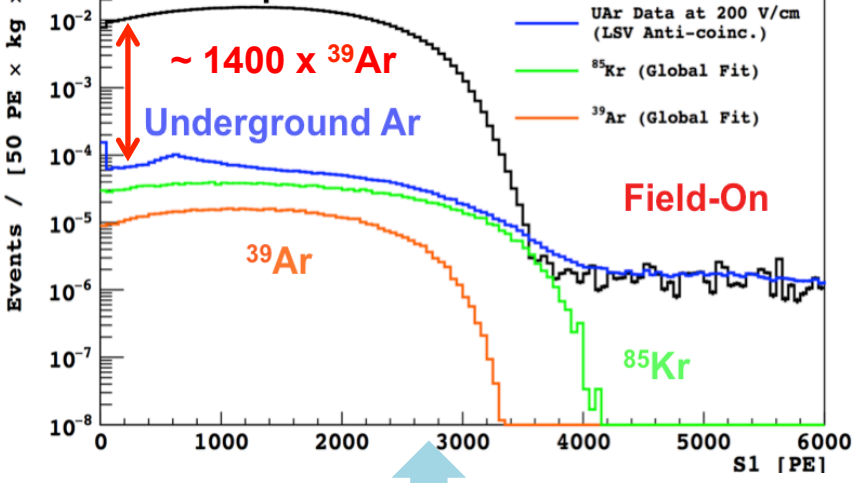
the DarkSide Monte Carlo package

- ☑ PARIS: custom made LAr scintillation-ionization response model
- ☑ Percent level accuracy in energy scale and resolution

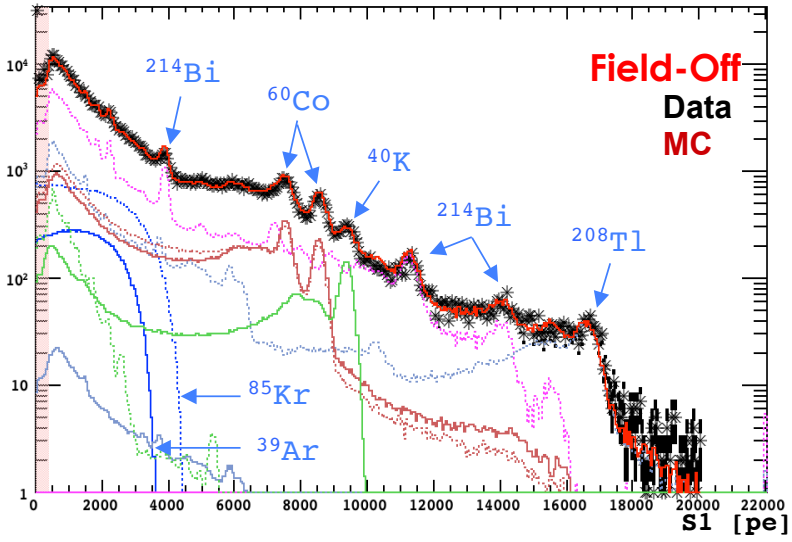
Calibration



Fit

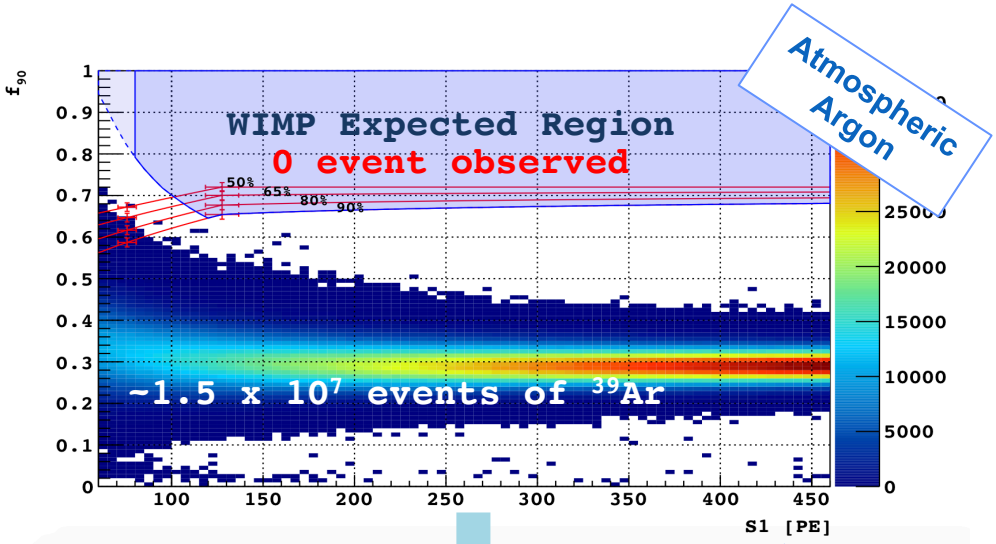


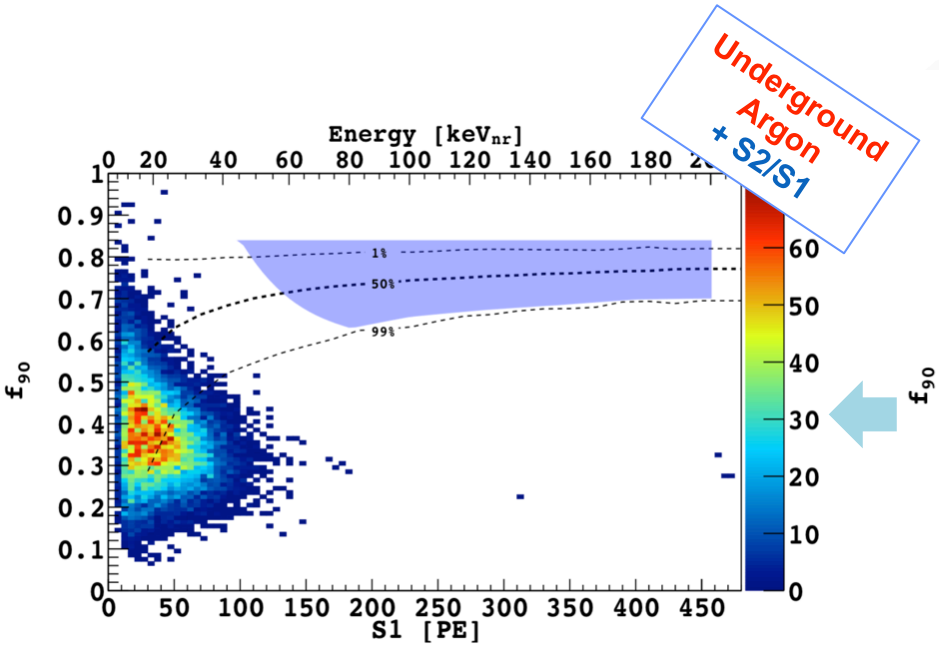
Result

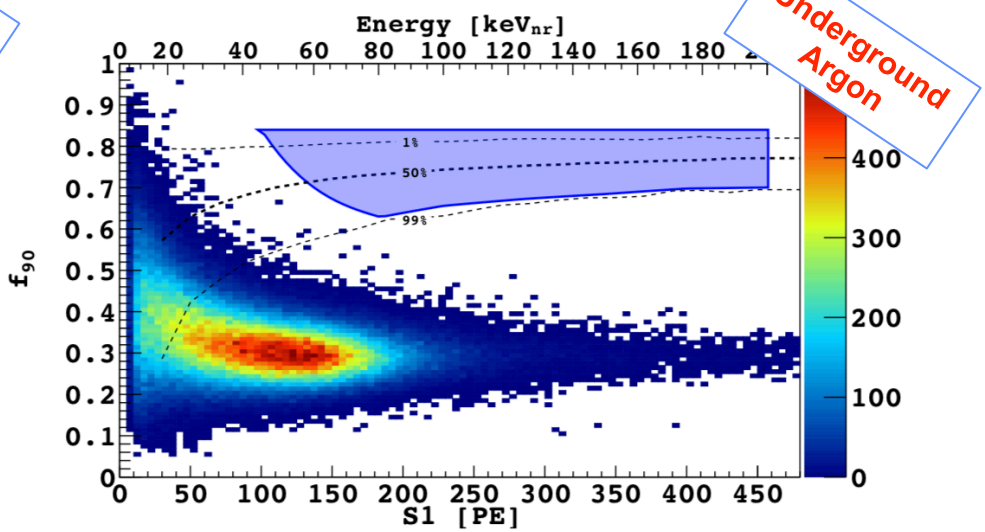


A background-free experiment

- ☑ **Pulse shape discrimination (f90)** power demonstrated with atmospheric argon
- ☑ **Blind analysis** in the ~532 days analysis
- ☑ **f90 analytical model by APC & LPNHE**





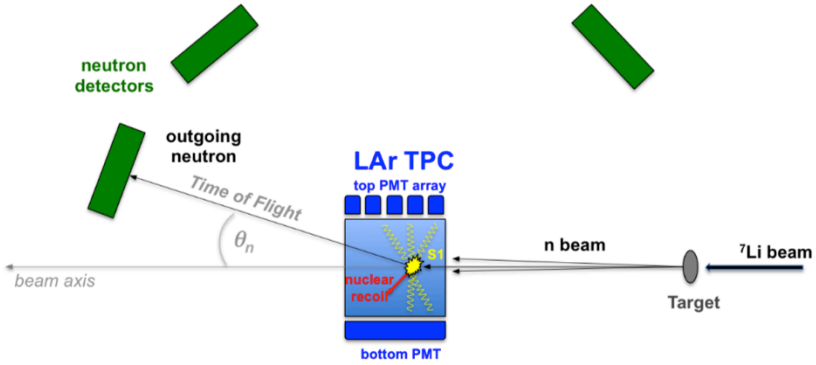


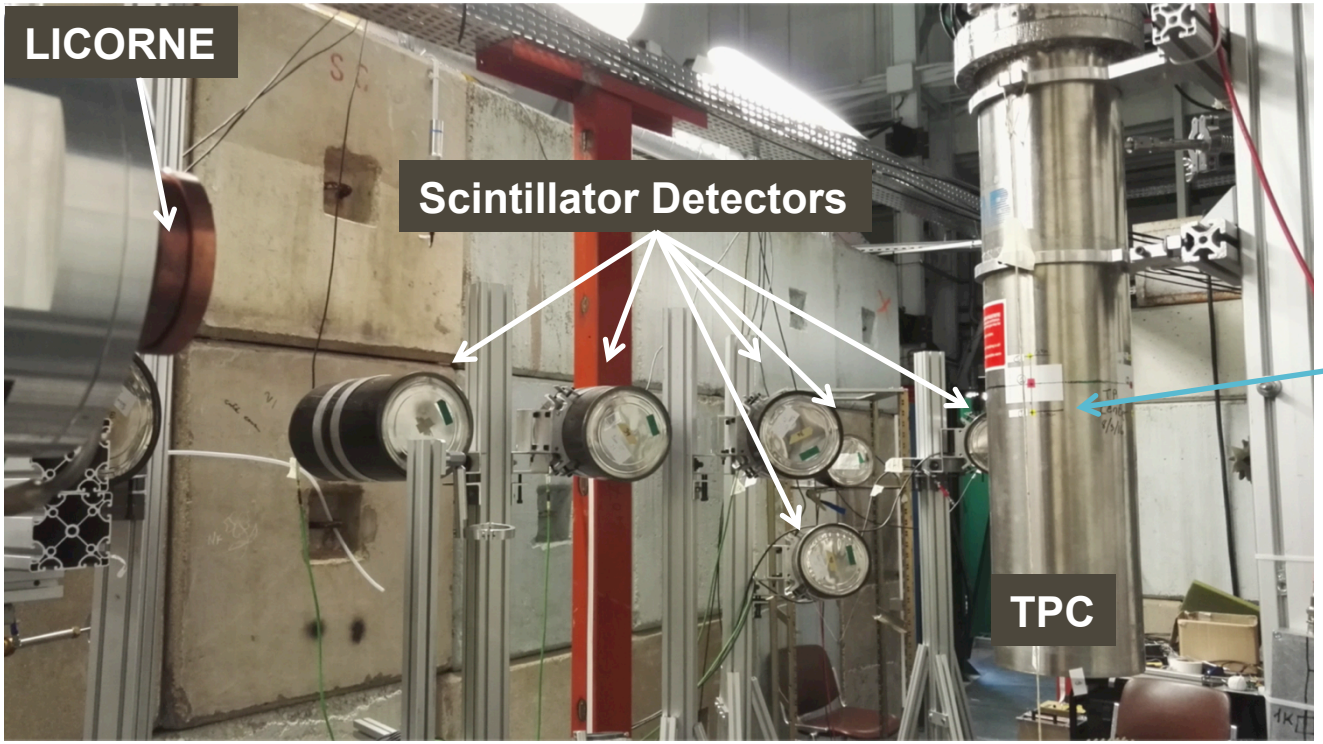
Background-free over more than 530 days!

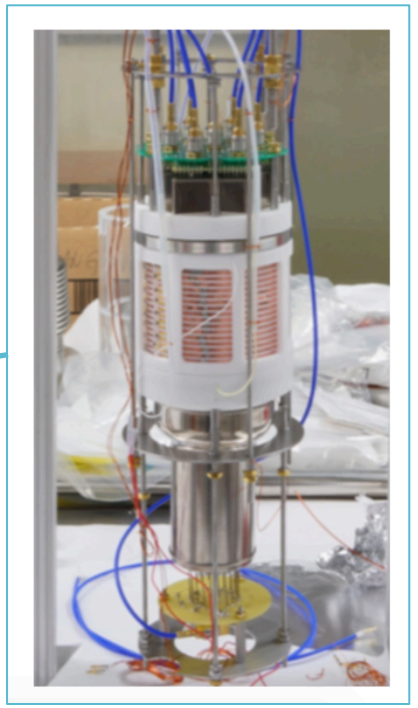
ARIS @ IPNO

LICORNE source: **inverted ^{7}Li(p,n)^{7}Be** reaction

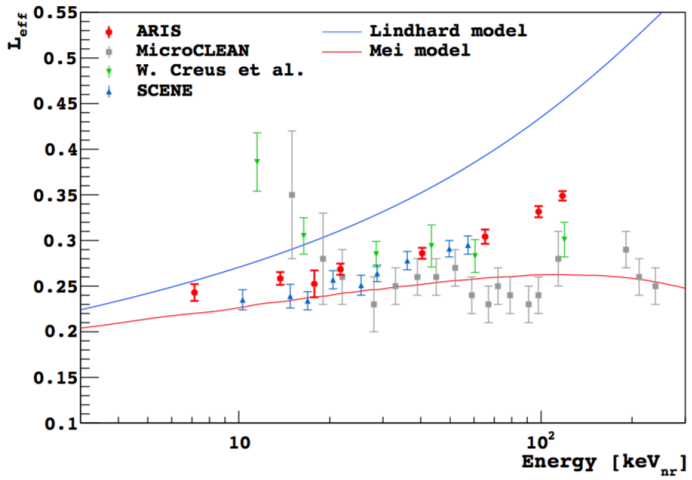
- ☑ Pulsed (1.5 ns width)
- ☑ Monochromatic: <6% (μ~1450 keV σ~85 keV)
- ☑ Collimated: < 2 degrees
- ☑ Correlated 478 keV gammas: ER calibration





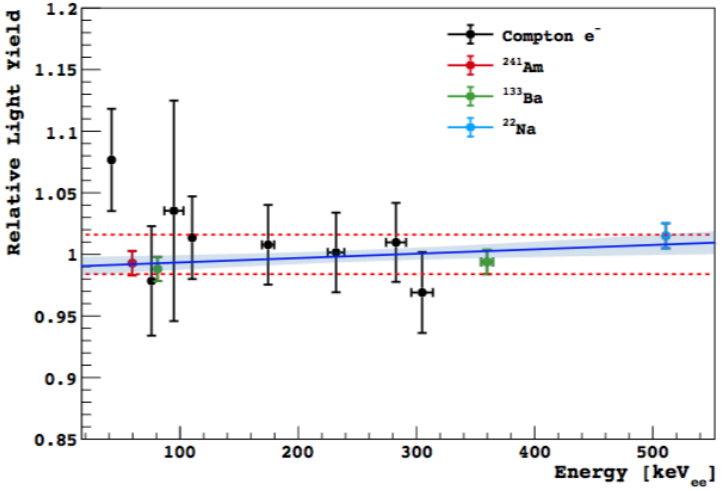


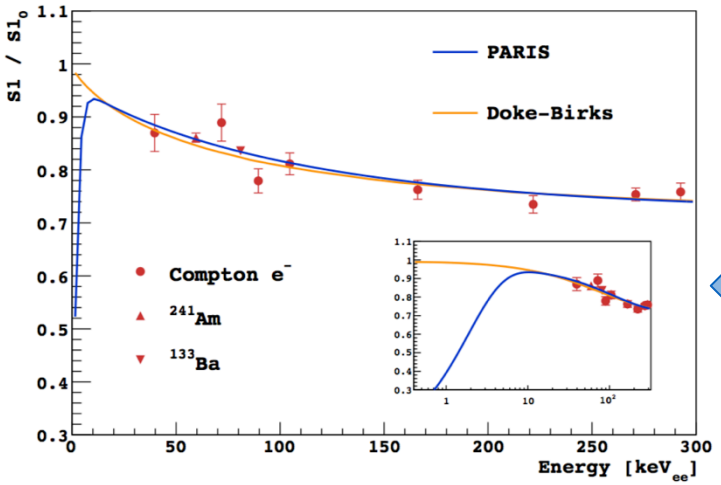
ARIS Results



Most accurate measurement of the **quenching** effect: **crucial for the low-mass analysis**

Best constraint on **linearity** of LAr response to ER at field-off

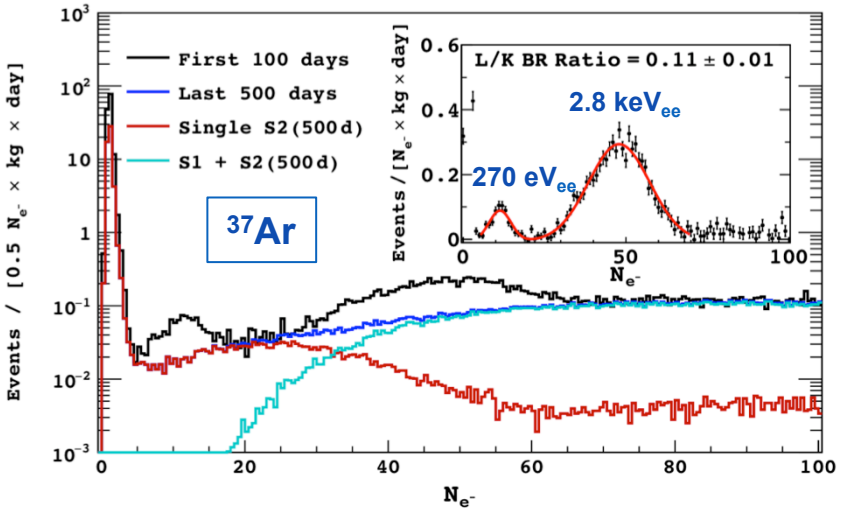


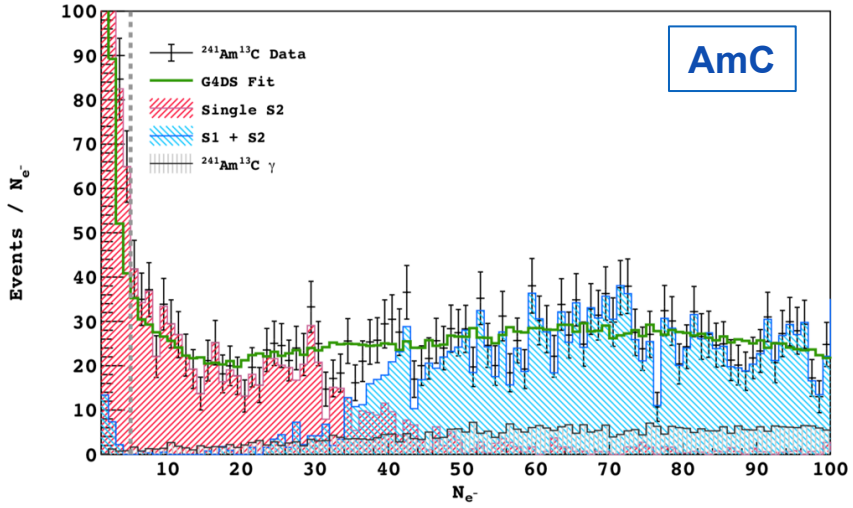


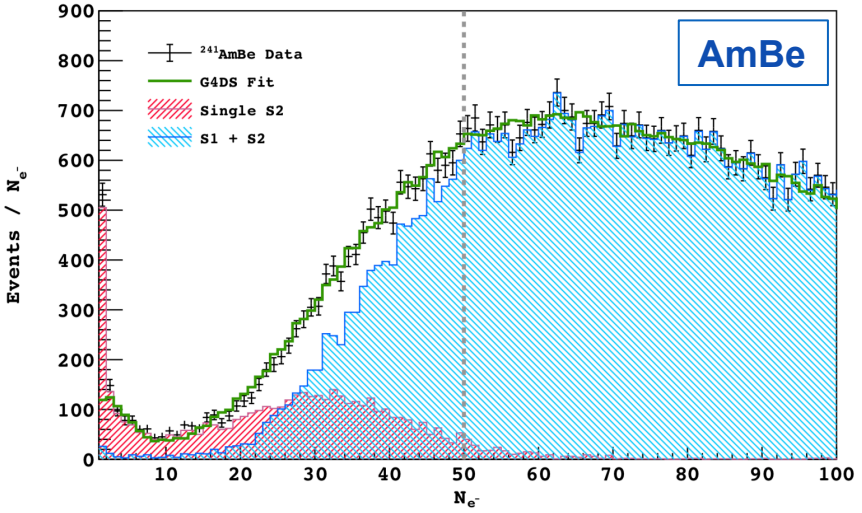
Excellent agreement with the **PARIS** model

Low Mass: ER/NR Response

- ☑ **100%** trigger efficiency at ~1.5 e^-
- ☑ Analysis threshold at 4 e^-: **~100 eV** or ~600 eVnr
- ☑ ER calibration with ^{37}**Ar**: 270 eV and 2.8 keV
- ☑ NR calibration with ***in situ*** AmC and AmBe neutron sources
- ☑ Beam experiment results (**ARIS** + SCENE)

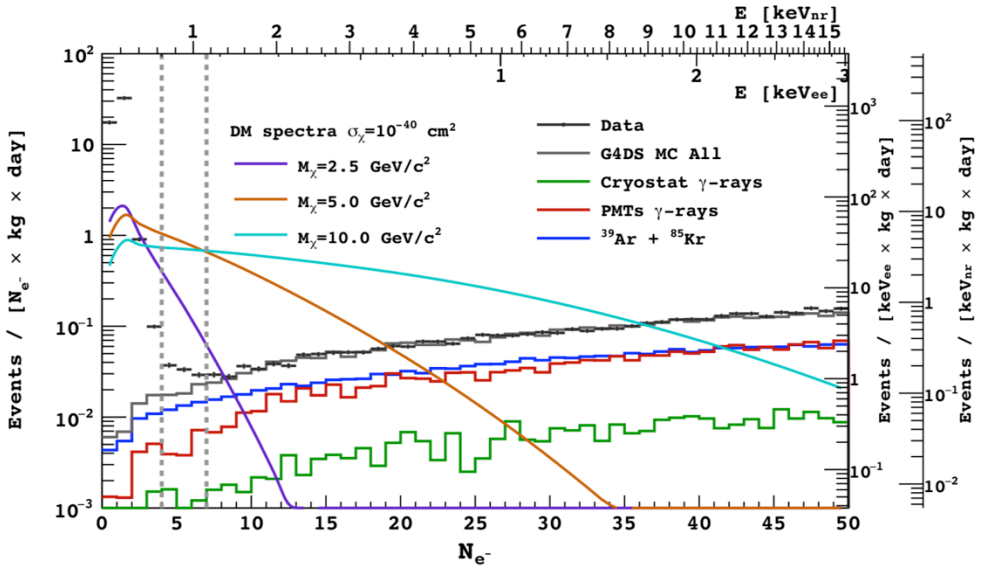


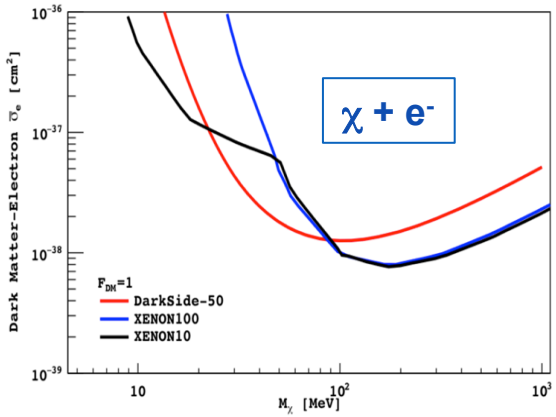


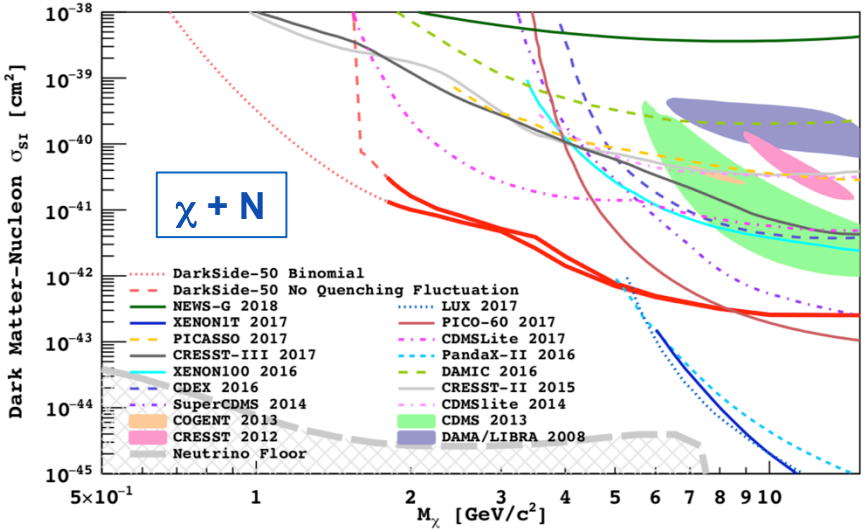


Low-Mass: Best Limit

- ☑ **Background model** simulated with G4DS, extrapolated from the high energy range
- ☑ **Excellent agreement** down to 7 electrons and excess between 4 and 7 electrons conservatively attributed to DM
- ☑ **Best limits to WIMPs-nucleus <6 GeV/c²** limited at 1.8 GeV/c² because of the unknown quenching fluctuation model
- ☑ Improved limits in the **WIMP-electron scattering** assuming heavy mediator



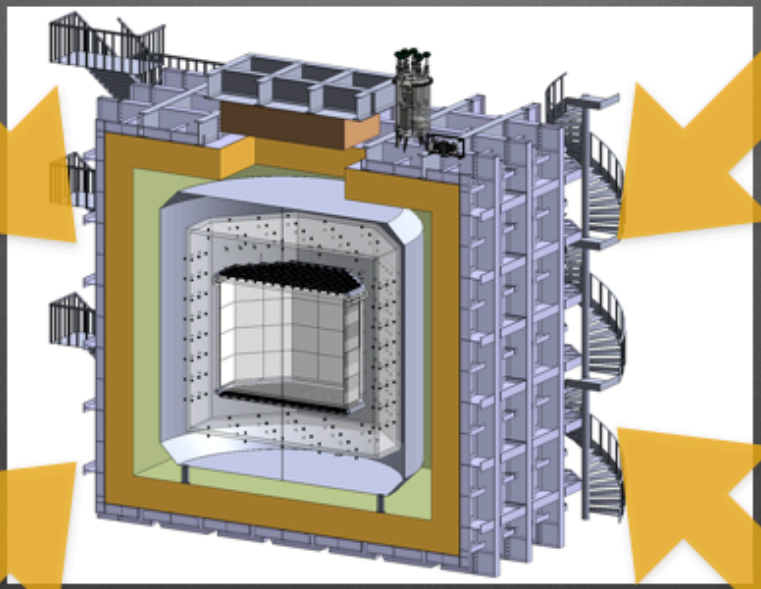




The Global Argon Dark Matter Collaboration

DarkSide-50

DarkSide-20k

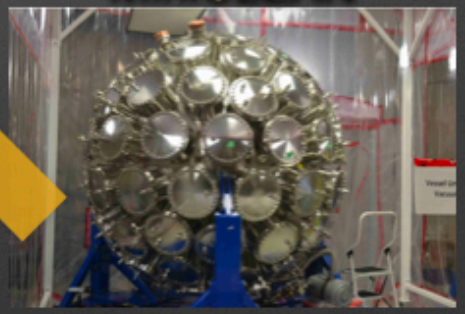


DEAP-3600

Access to DEAP-3600 data

ArDM

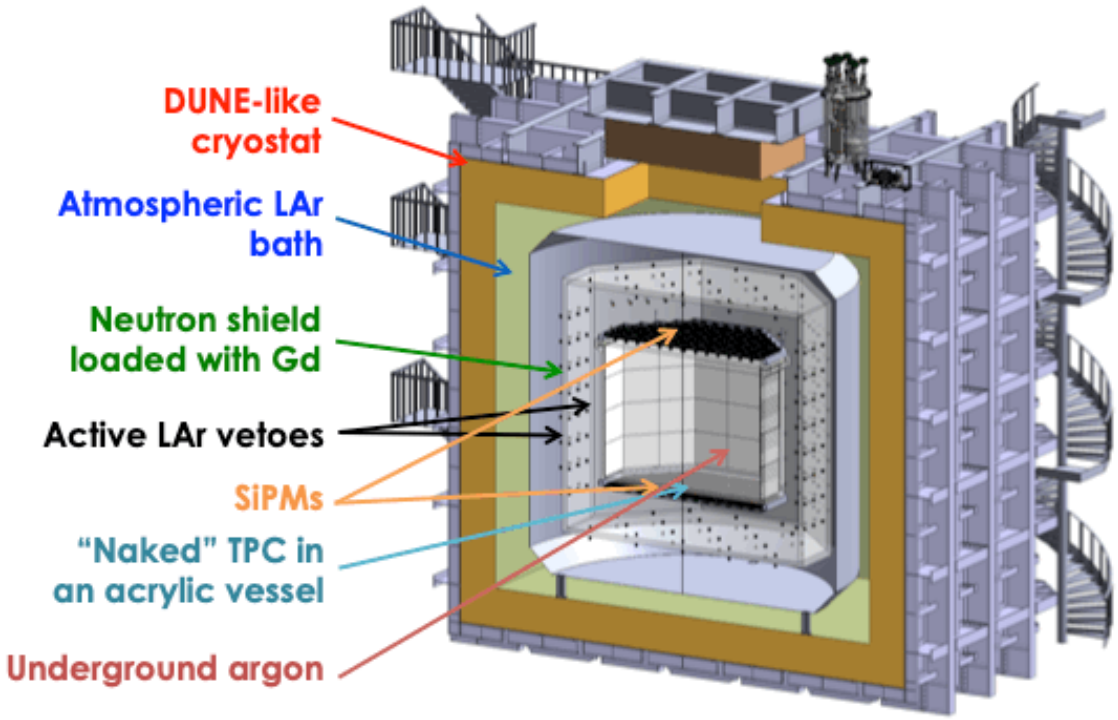
MiniCLEAN



CERN Neutrino Platform joined DarkSide-20k → many synergies with DUNE (DS-20k cryostat will be the same of protoDUNE)

DS-20k collaboration
350 scientists
13 countries

Design for a large mass bg-free LAr TPC



TPC: cryostat + teflon vessel => **only acrylic vessel**

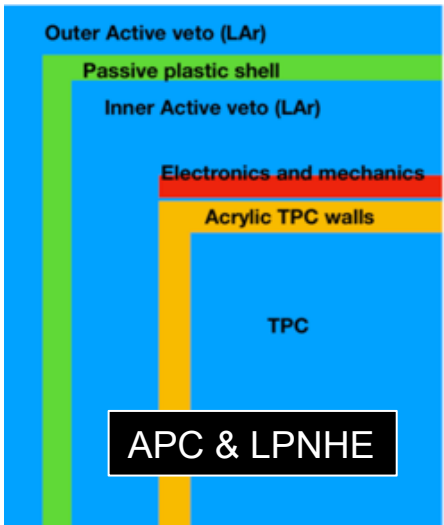
- ☑ Almost doubled the target mass (no UAr buffer): ~35 tonnes
- ☑ Removed cryostat, among the main sources of radiogenic neutrons

Photo-sensors: **~15 m^2 of SiPMs**

- ☑ **Radiopure** and limited amount of material
- ☑ High photodetection **efficiency**

Vetoes: **LAr bath + moderator in acrylic loaded with Gd**

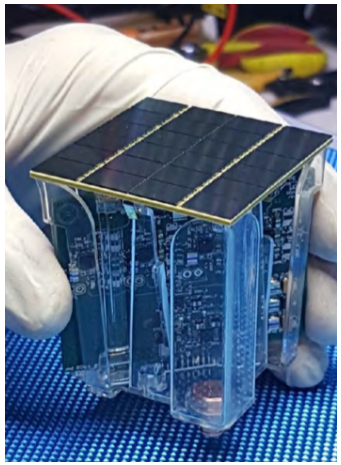
- ☑ **Neutron veto conceptual design by APC&LPNHE**
- ☑ **DUNE-like cryostat** (GTT patent)
- ☑ CERN Neutrino Platform technical support
- ☑ No organic scintillators

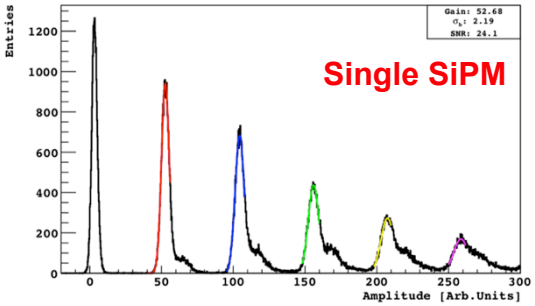


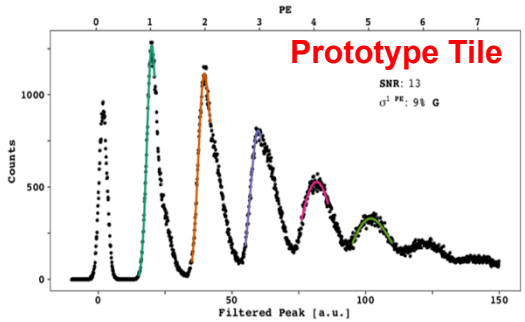
FBK NUV-HD SiPM

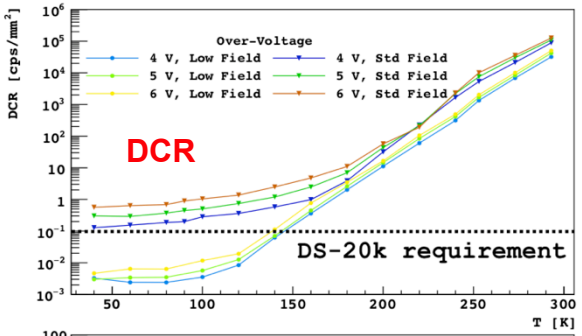
- ☑ Strict collaboration with Fondazione Bruno Kessler (**FBK**): development of specific SiPM for LAr (50 PDM under way)
- ☑ The FBK technology on transfer to **LFoundry** for mass production (starting April 2019)
- ☑ Packaging of 240,000 SiPMs at **NOA**, a facility funded at LNGS

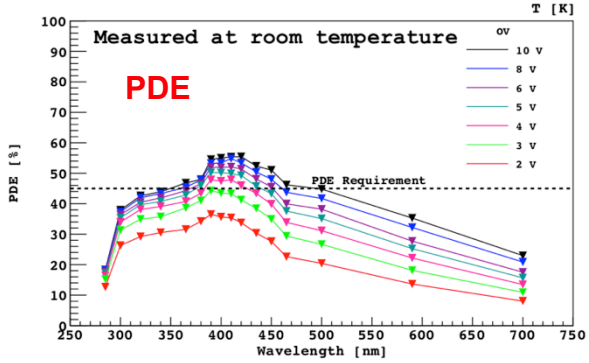
	DS-20k requirement	SiPM tile (PDM)	
Surface	5x5cm^2	24cm^2 prototype 25cm^2 final PDM	✓
Power dissipation	<250mW	~170mW	✓
PDE	>40%	50% · ε_{geom} = 45%	✓
Noise Rate	<0.1cps/mm^2	0.004cps/mm^2	✓
Time Resolution	O(10ns)	16ns	✓
Dynamic Range	>50	~100	✓



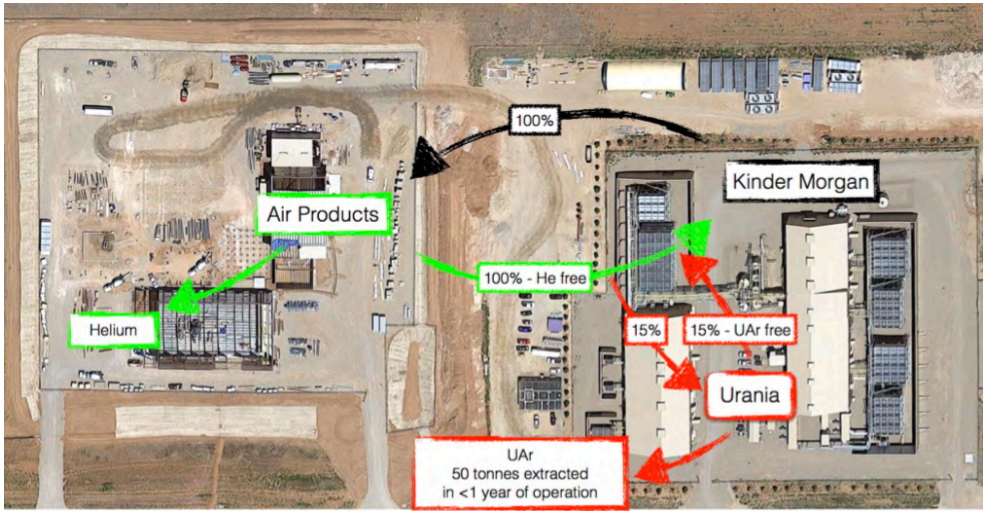


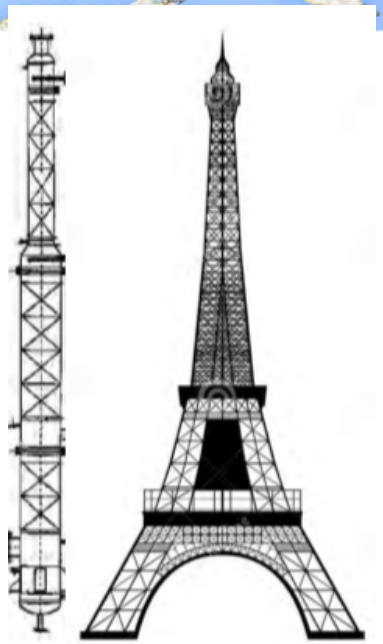


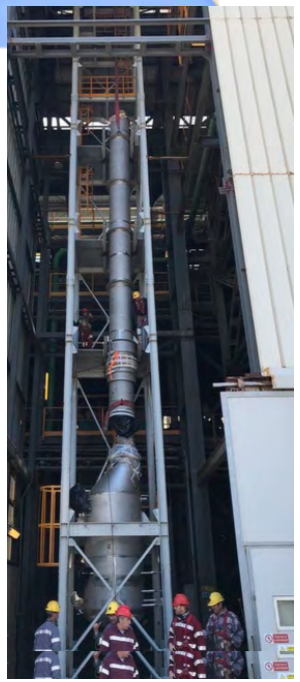




Underground/Depleted Argon





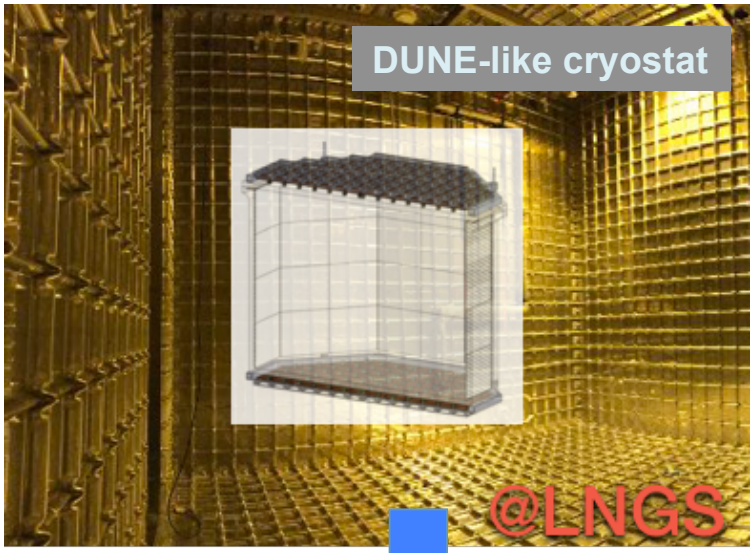


DS-Proto: 1-ton prototype

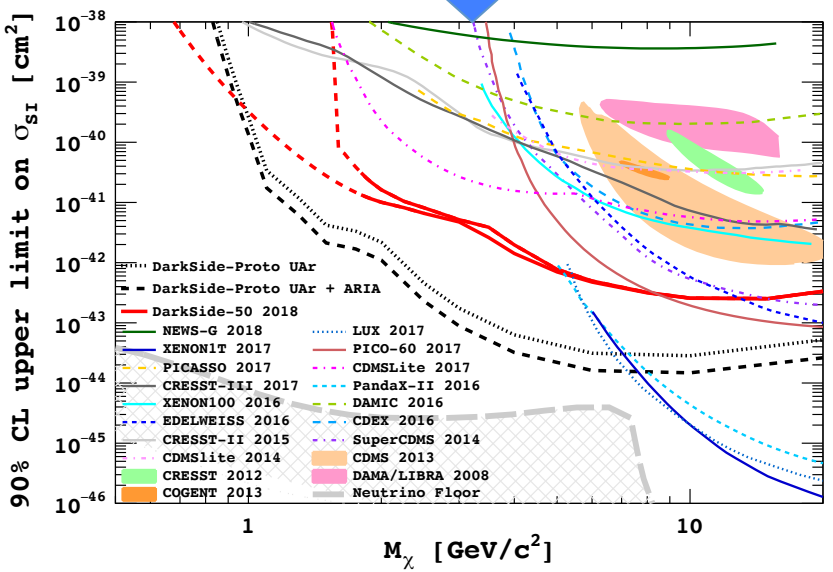
DS-Proto

(?)

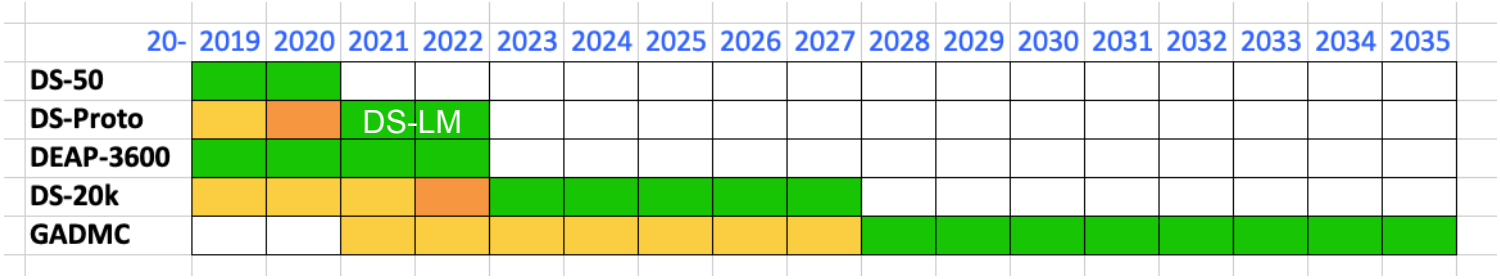
DS-LowMass



Test of the DS-20k technology
(SiPM, electronics, cryogenics) and calibration/tuning of S2 amplification factor



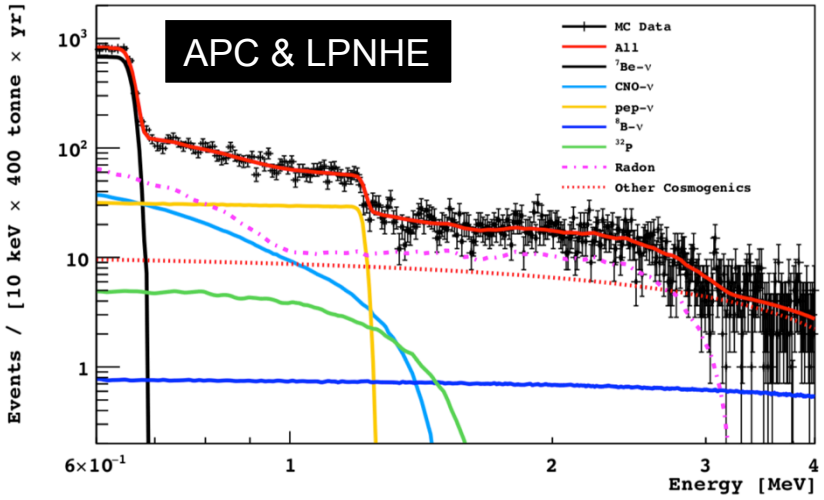
DarkSide Program



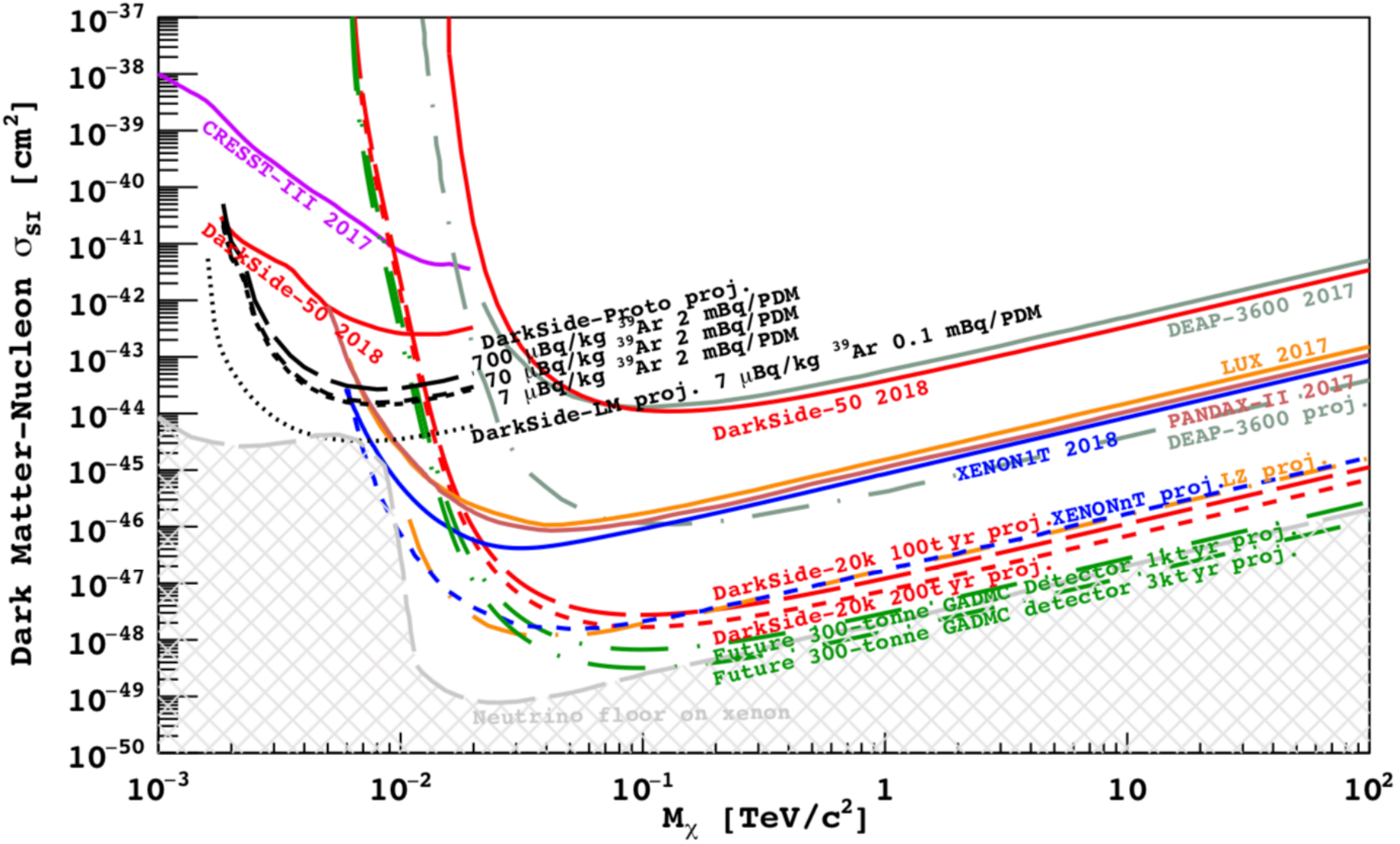
GADMC

- ☑ **300 tonnes** detector
- ☑ **Background-free** (<0.1 background events) in the high-mass WIMP range
- ☑ Possible location at **SNOLAB**: letter of intent for collecting and stocking UAr underground
- ☑ Additional strong physics case with **CNO solar neutrinos**

First observation of CNO Solar neutrinos and solution to the Solar Metallicity Problem



Toward the Neutrino Floor



Conclusions and Prospects

DarkSide

- ☑ **Background-free** experiment for high mass WIMP thanks to pulse shape discrimination in S1 (unique to LAr)
- ☑ **Best limit** in the low mass 1.8-6 GeV window
- ☑ Strong WIMP **discovery potential** in the next decade (from 1 GeV to 10 TeV)
- ☑ New opportunities also in looking for **WIMP directional signature** and **medical applications** (backup slides)
- ☑ **France** is having **large impact** in the DarkSide physics and technology: G4DS, the PARIS model, ARIS, background model, low-mass analysis, solar neutrino physics, new veto design, etc.
  - ☑ Direct/leading contributions to several papers
  - ☑ Interest for DarkSide by F. Hubaut and P. Pralavorio (**CPPM**): discussion on going
- ☑ Potential **synergies with DUNE**: astroparticle physics, cryostat and cryogenics, optical simulations, photo-collection efficiency, calibrations