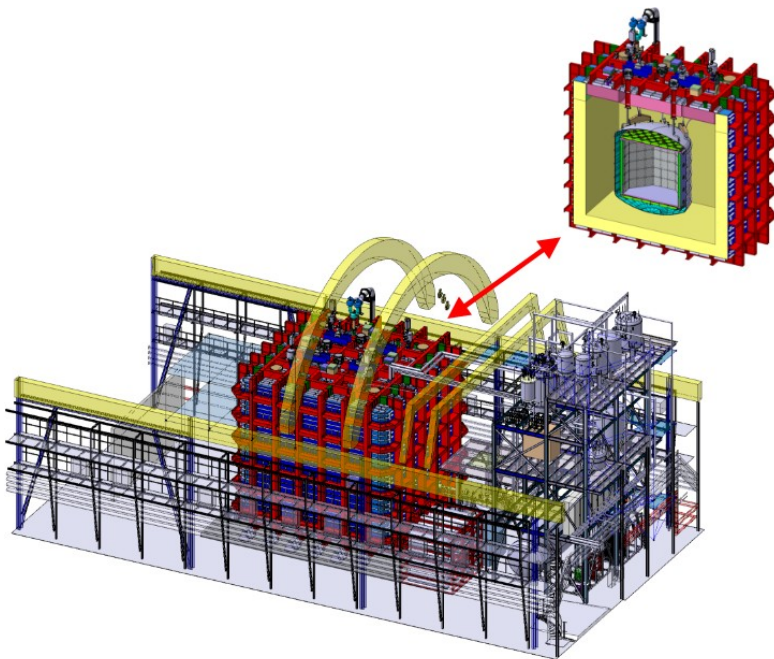




The DarkSide Program

(on behalf of the Global Argon Dark Matter Collaboration - GADMC)

Science Fair @ GSSI – 06 of February 2024



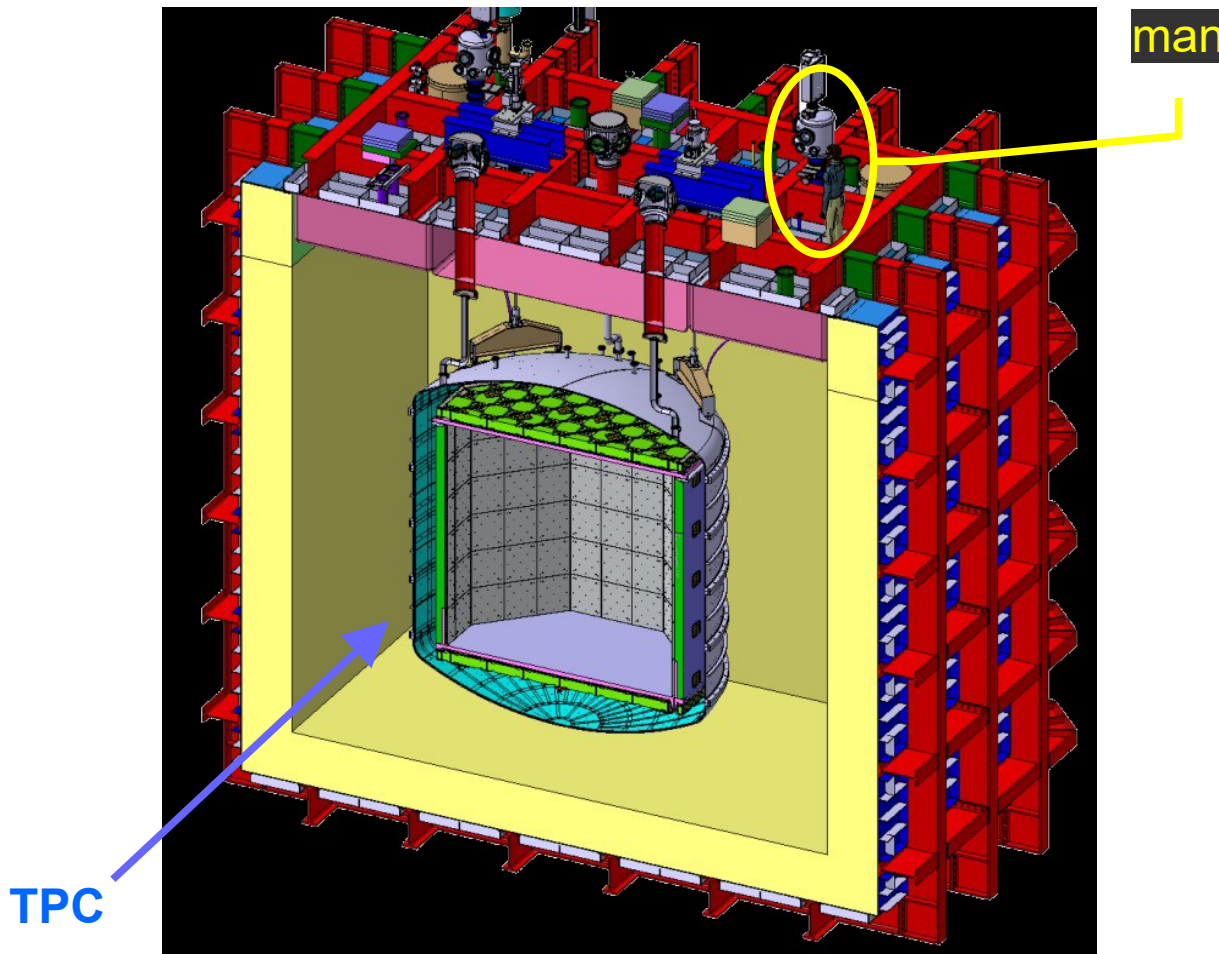
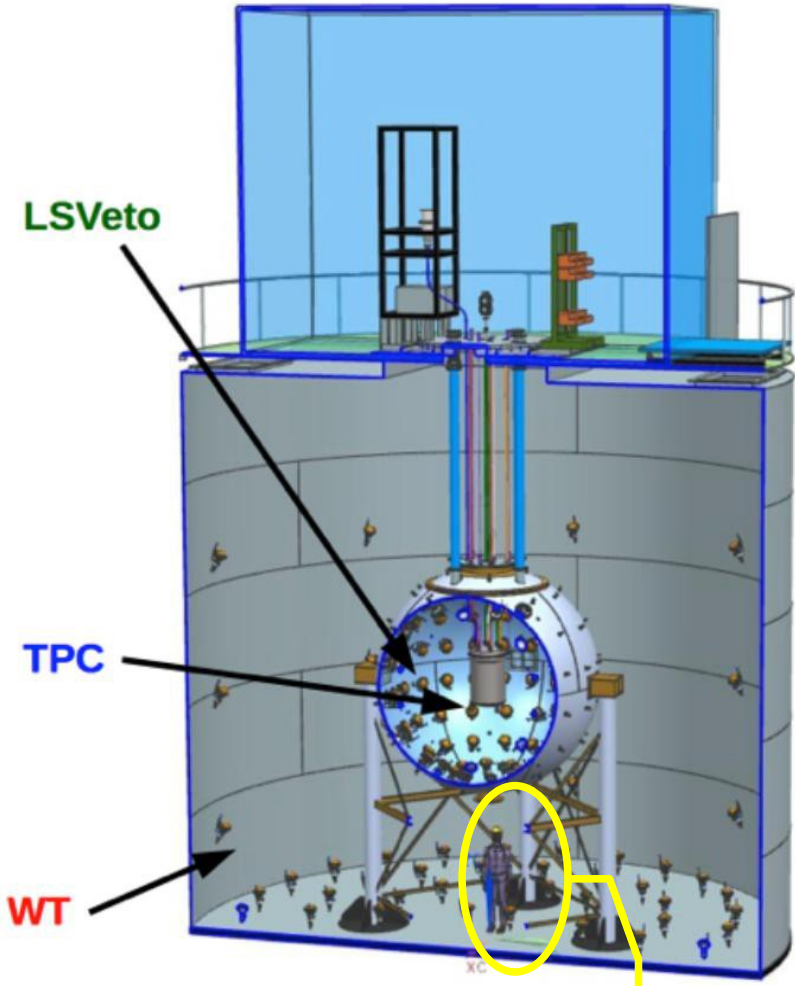


DarkSide Program: dark matter direct-detection experiments with double phase (U)Ar TPCs

The DS Program is staged with detectors of increasing mass.

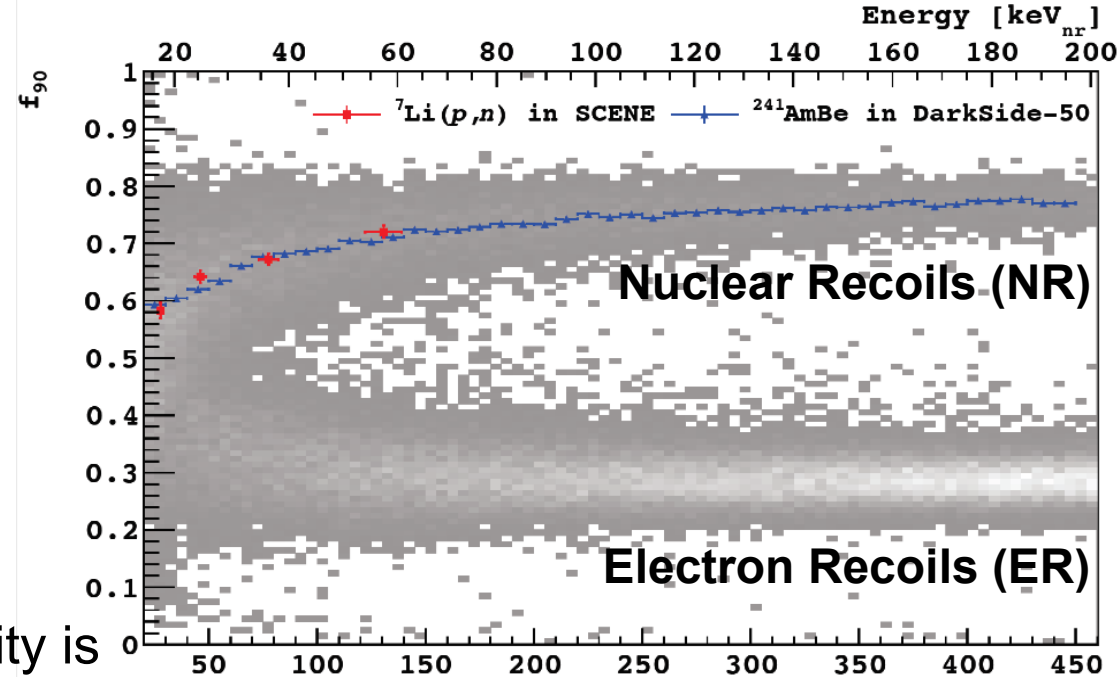
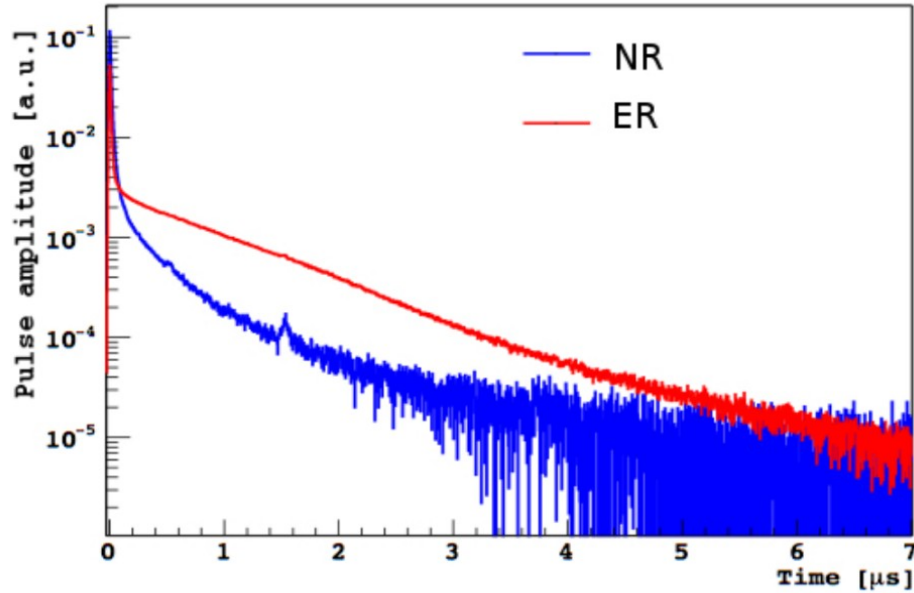
Last running experiment
DarkSide-50 ~ 50 kg UAr

Next future → construction on going
DS20k ~ 20 t UAr (50 t active)



Why LAr? - Pulse Shape Discrimination (PSD) in LAr

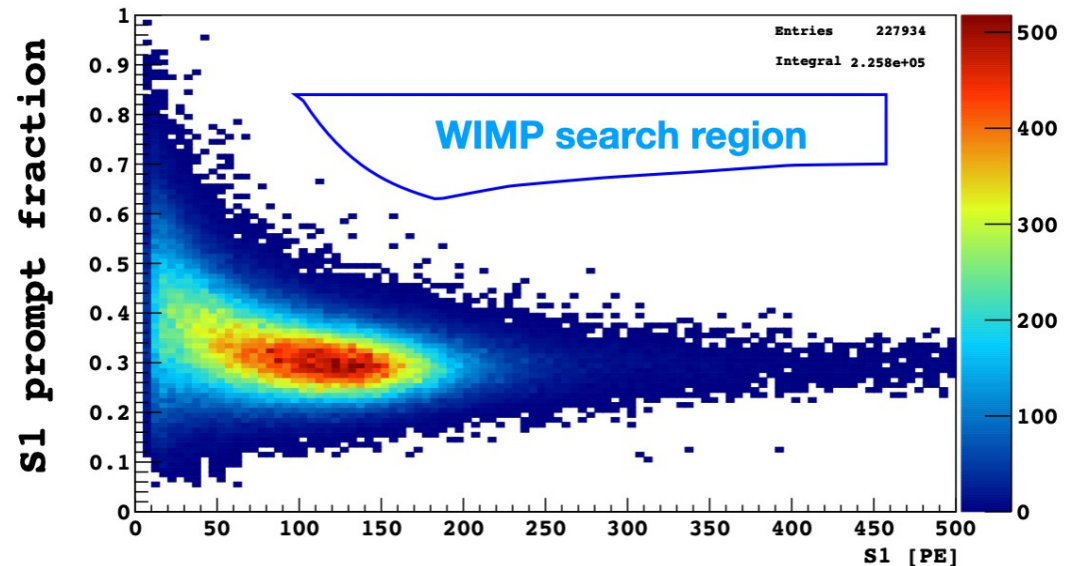
→ BG free WIMPs search



- The ratio of singlet/triplet excimer density is function on recoil type
- De-excitation: singlet 6 ns, triplet 1.5 us

$$f_{prompt} = \frac{\int_{t_0}^{t_{prompt}} S1(t) dt}{\int_{t_0}^{t_{tot}} S1(t) dt}$$

β/γ bg rejection up to factor 10⁹
 demonstrated by DEAP-3600
EPJC 81,823(2021)

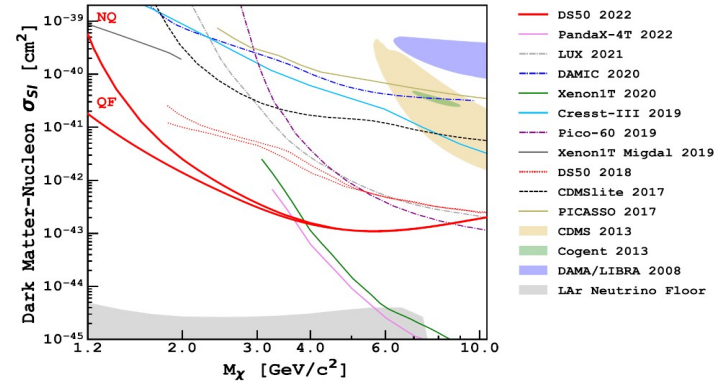


Still ongoing DarkSide50's data analysis - 2023 results

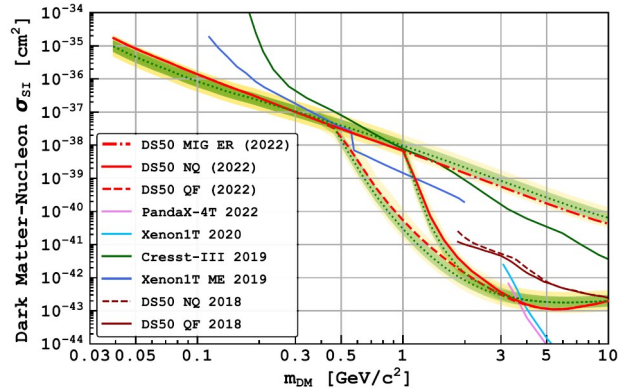
"Search for low-mass dark matter WIMPs with 12 ton-day exposure of DarkSide-50"
 PhysRevD.107.063001

- World's best limits for WIMPs with masses in the range $(1.2 - 3.6) \text{ GeV}/c^2$

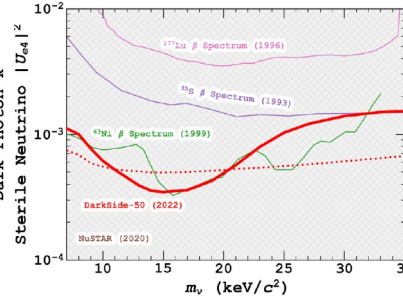
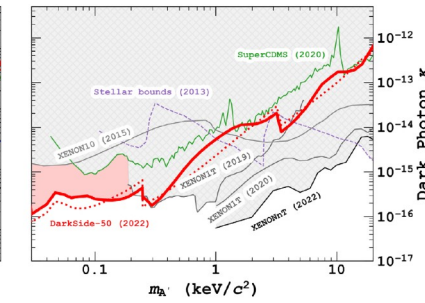
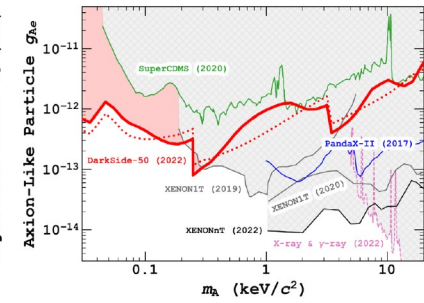
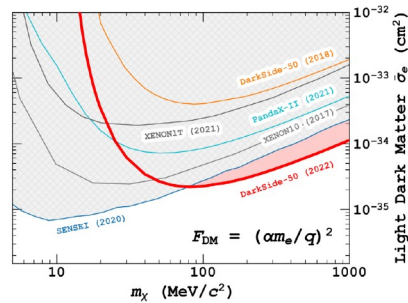
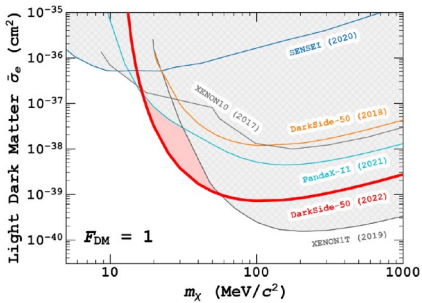
- One of the most downloaded Physical Review D papers of 2023



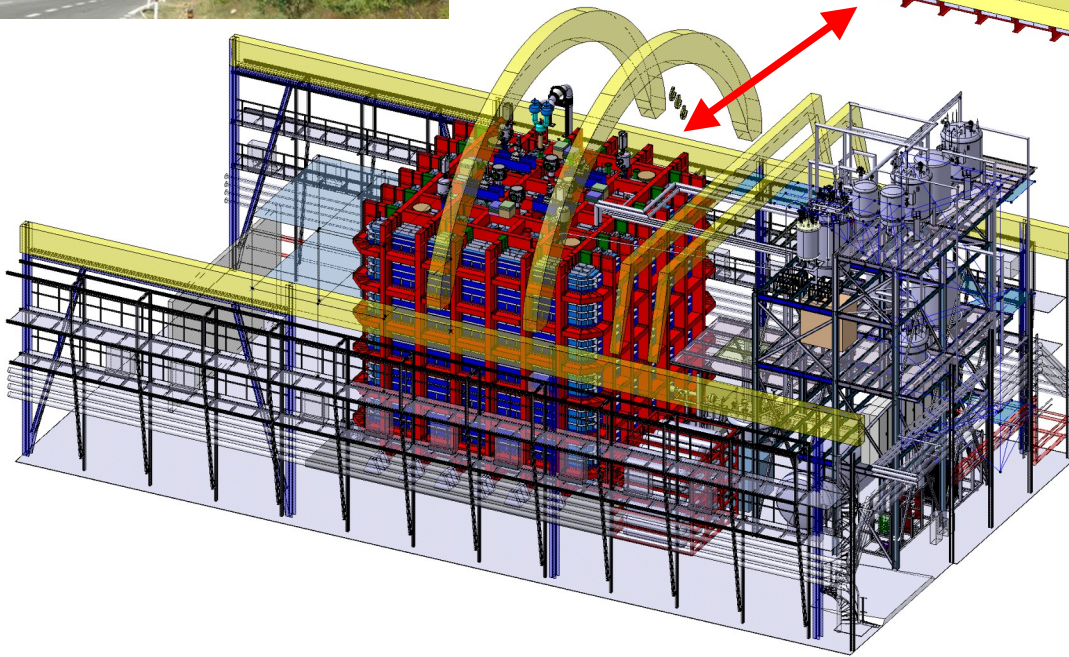
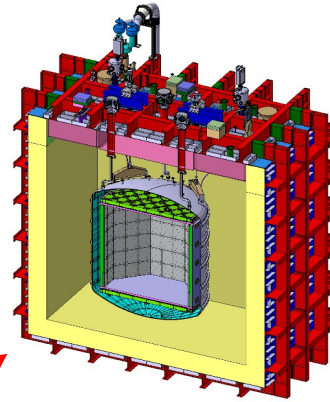
"Search for dark-matter--nucleon interactions via Migdal effect with DarkSide-50"
 PhysRevLett.130.101001



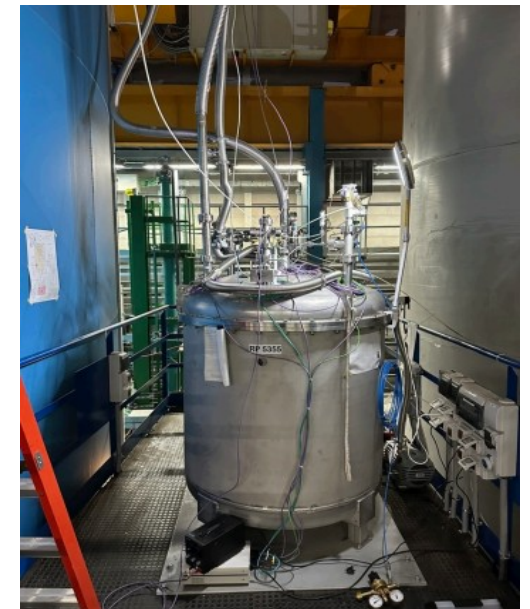
"Search for dark matter particle interactions with electron final states with DarkSide-50"
 PhysRevLett.130.101002



Next step → DarkSide-20k @ LNGS



Construction on going

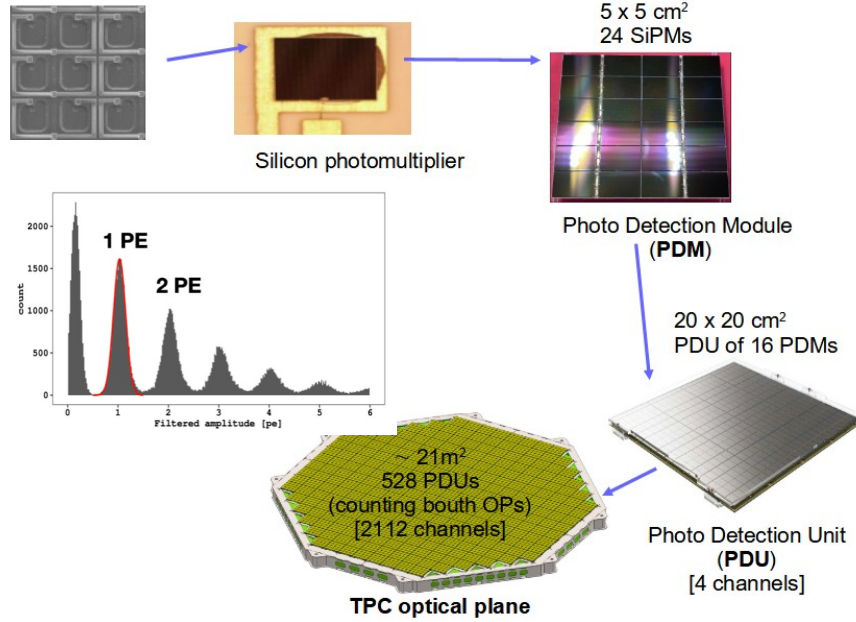


- about 50 t of Underground Ar inside the TPC (20t fiducial)
- 10 years of foreseen activity
- Expected **0.1 background events in 200 t*yr exposure [FV]**
→ **still background free [instrumental background]**

DarkSide @ GSSI - 1

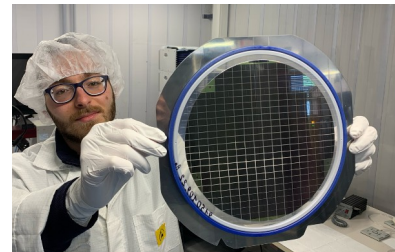
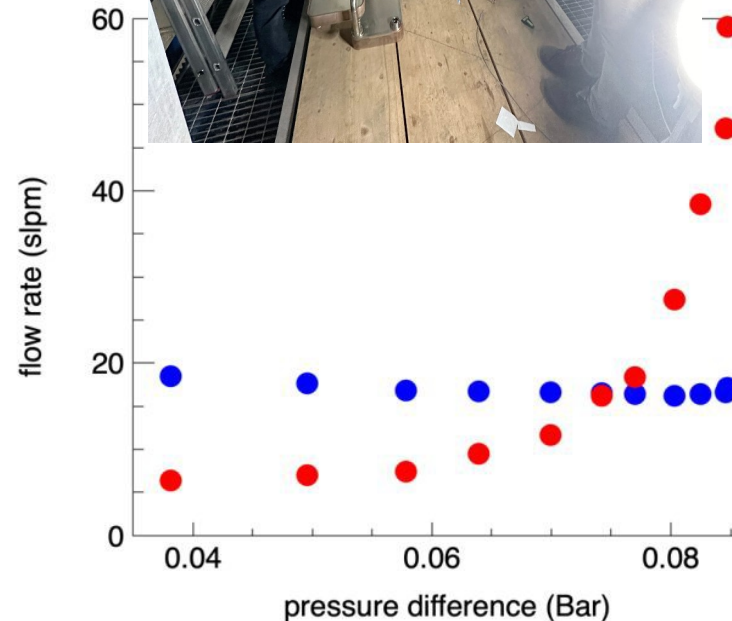
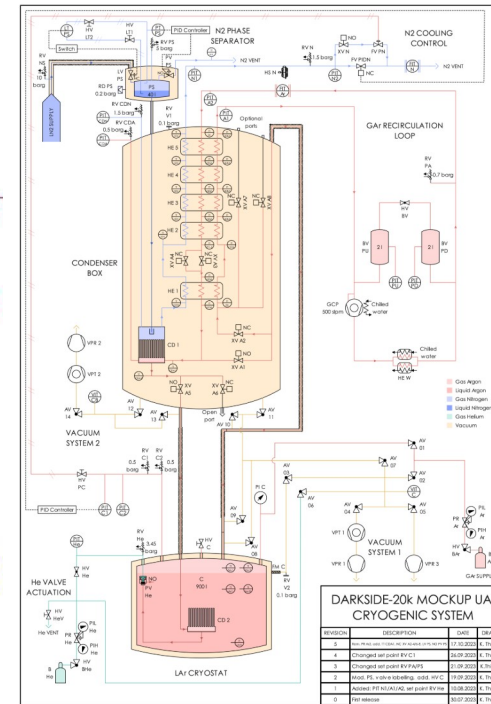
From PMTs to Silicon PhotoMultipliers

Photodetector production and characterisation @ Nuova Officina Assergi (NOA)



UAr Cryogenics

Responsibilities in testing the DarkSide-20k UAr cryogenic system. Activities in Hall C - on going.



DarkSide @ GSSI - 2

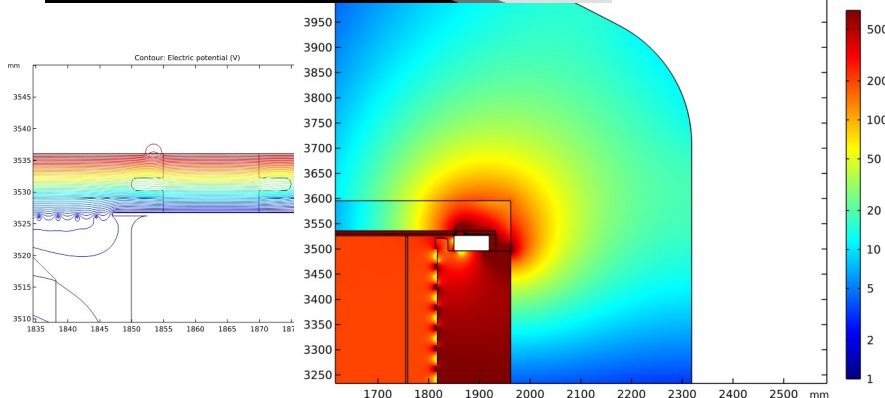
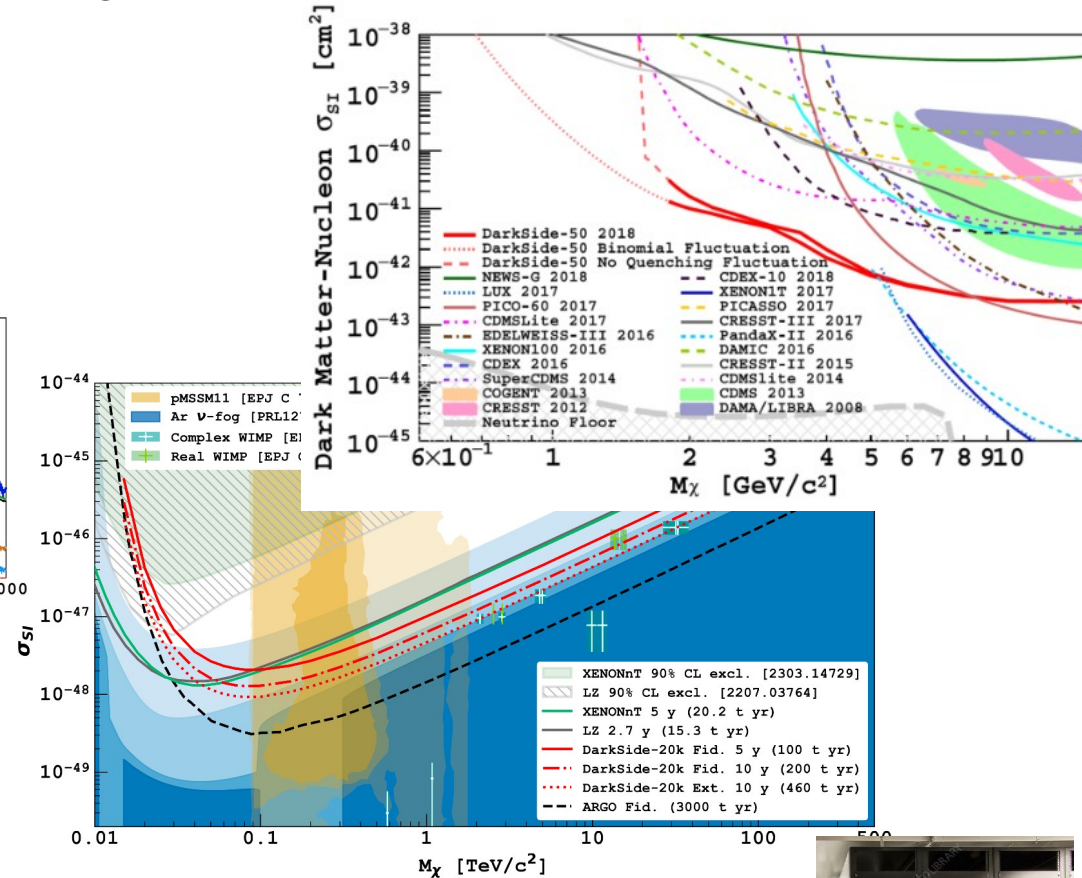
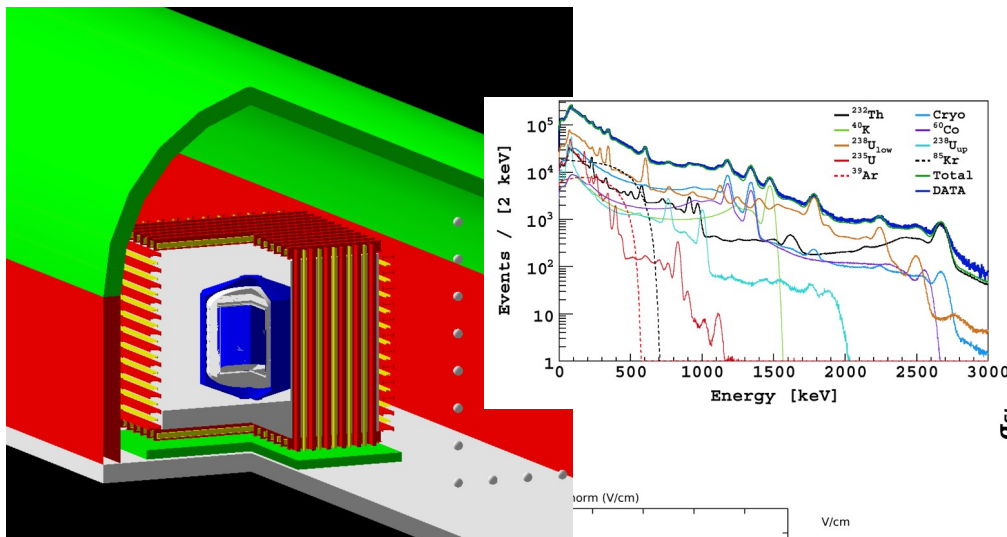
Analysis and sensitivity studies

Detector simulations

- Leadership in simulation for:
- Background levels (NR and ER) from the detector materials, the Hall C, cosmic rays
 - Optimization of detector configuration
 - Requirements on the DAQ
 - Electric fields in the TPC

Leadership in analysis work for:

- DarkSide-50 data analysis
- Sensitivity studies
- Performance of analysis and reconstruction algorithms



DAQ systems

Responsibilities in:

- determine the optimal format for the data
- minimize data stream
- install and run DAQ prototype



DarkSide @ GSSI - People



Paolo Agnes



Mauro Caravati



Pablo Kunzé



Oscar Taborda



Marek Walckzak

...and others
are arriving...



The GADMC Collaboration (meeting @ LNGS - June 2023)

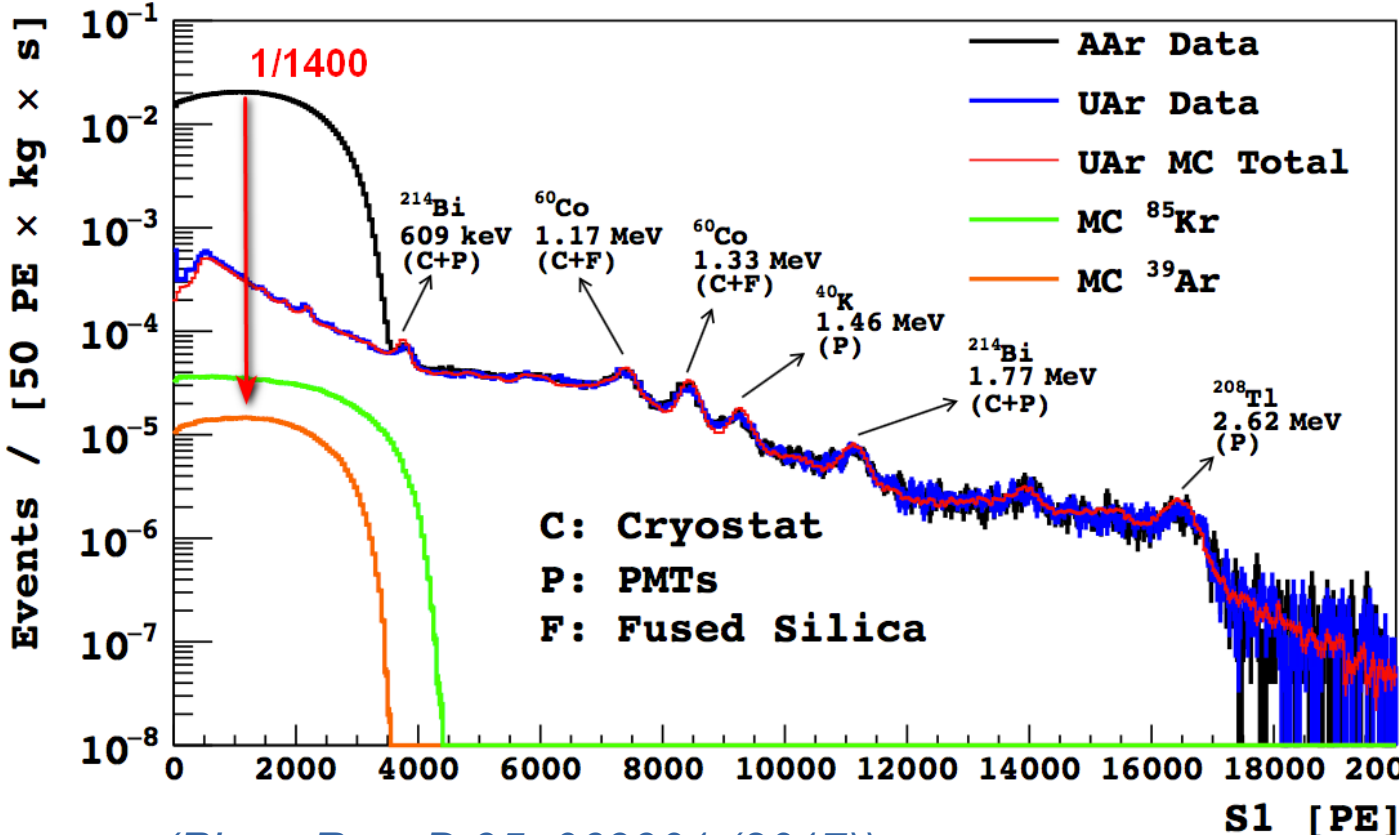
Backup

A key player: low radioactive Underground Argon (UAr)

- ^{39}Ar activity in atmospheric argon (AAR) is $\sim 1 \text{ Bq/kg}$ \rightarrow pileup problem w/ increasing mass target (β -decay; $Q = 565 \text{ keV}$; $t_{1/2} = 269 \text{ yr}$)
- ^{39}Ar activity sets the detection threshold at low energies (PSD is less effective or not usable)
- ^{39}Ar is produced by cosmic rays in the atmosphere
[as ^{37}Ar : E.C. - (0.27 - 2.82) keV (L- K) -shell - $t_{1/2} \sim 35 \text{ d}$]

\rightarrow Argon from Underground (CO_2 well in Colorado)

DS50's UAr ^{39}Ar activity at $0.73 \pm 0.10 \text{ mBq/kg}$ \Rightarrow ~ 1400 reduction factor wrt AAR



DarkSide-50 had runned:

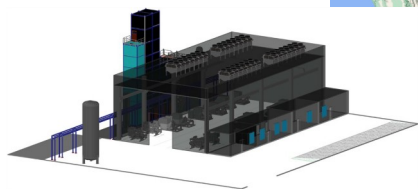
- first with AAr run
- hence
- with UAr (First 70.9 live-days)
- Presence of ^{85}Kr
 \rightarrow air contamination?
(\rightarrow less UAr ^{39}Ar 's specific activity)
- (Data fitted with the background model)

(Phys. Rev. D 95, 069901 (2017))

The Underground Argon journey in a nutshell

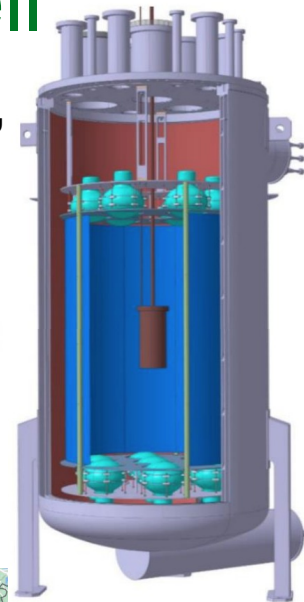
1) UAr extraction at the URANIA plant Industrial CO₂ extraction plant in Cortez (CO)

- Expected argon purity at outlet: 99.99%
- **UAr extraction rate: 250-330 kg/day**



3) Qualification at Canfranc (ES), DArT in ArDM

- Single-phase LAr detector
- Active volume ~1L
- Capable of measuring ³⁹Ar depletion factors of the order of 1000 with 10% precision in weeks



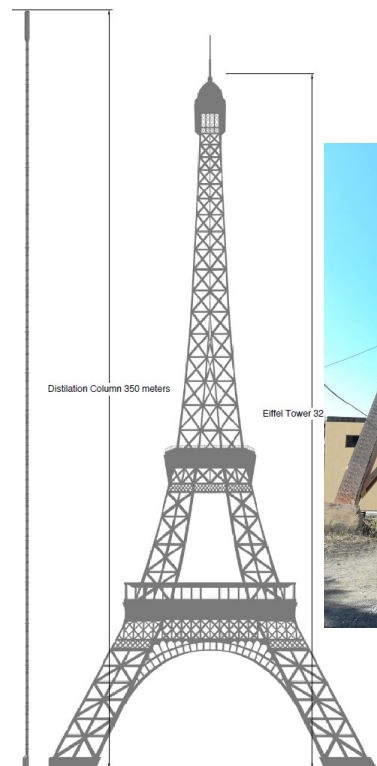
2) Cryogenic distillation at the ARIA facility

350 m tall cryogenic distillation column installed in the shaft of a dismissed coal mine in Sardinia (It)

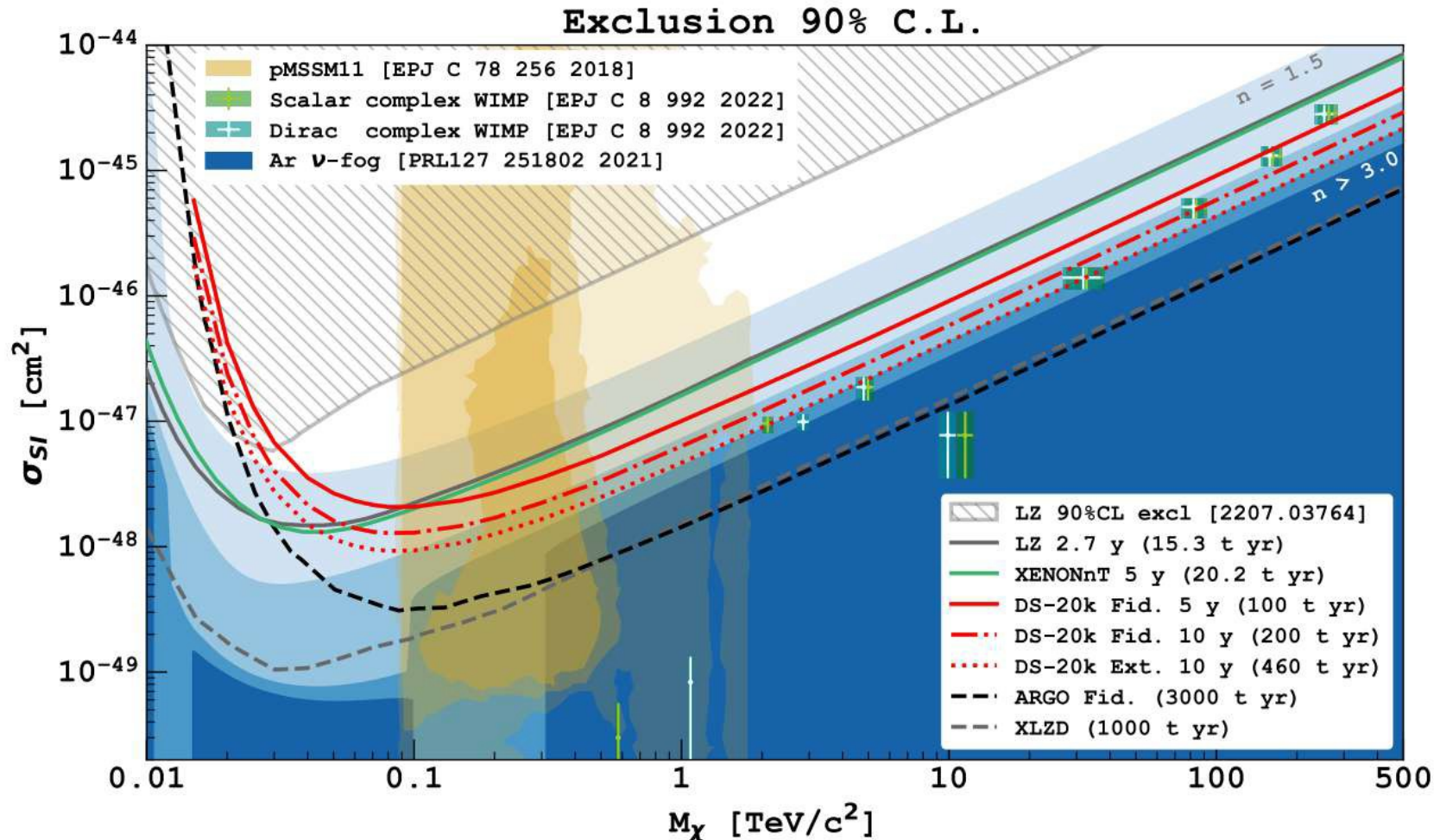
- **Chemical purification rate 1 t/day**

Prototype module actioned with nitrogen and argon showed the expected isotopic separation capability:

Expected a factor 10 of ³⁹Ar reduction per pass in the isotopic separation running configuration (~ some kg/day)



DarkSide-20k WIMP sensitivity



Sensitivity of DarkSide-20k to spin-independent WIMPs for different exposures, w/ or w/o fiducial cuts applied

With 20 tonnes fiducialization and 10 years running:

- Probing at 90% CL: $M_\chi = 1 \text{ TeV}/c^2$ $\sigma_{SI} \simeq 6.3 \times 10^{-48} \text{ cm}^2$

- Instrumental background < 0.1 neutrons in RoI (30~200 keV_{NR})
 - in the neutrino fog