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DarkSide-20k

A 50-ton Liquid Argon Time Projection Chamber for Dark Matter searches

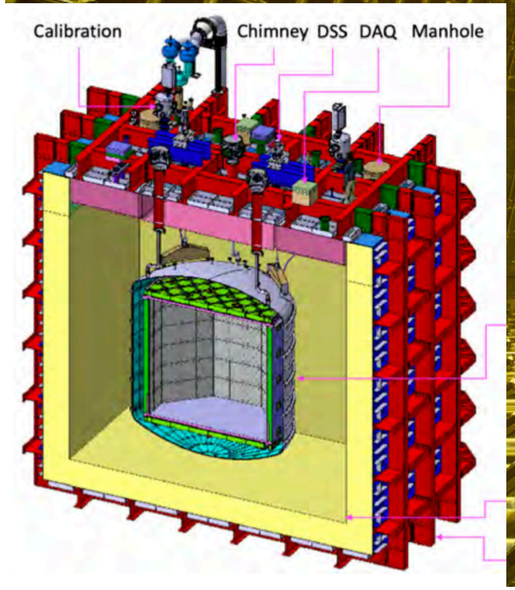
DarkSide-20k: A 50-ton LAr TPC for direct DM searches

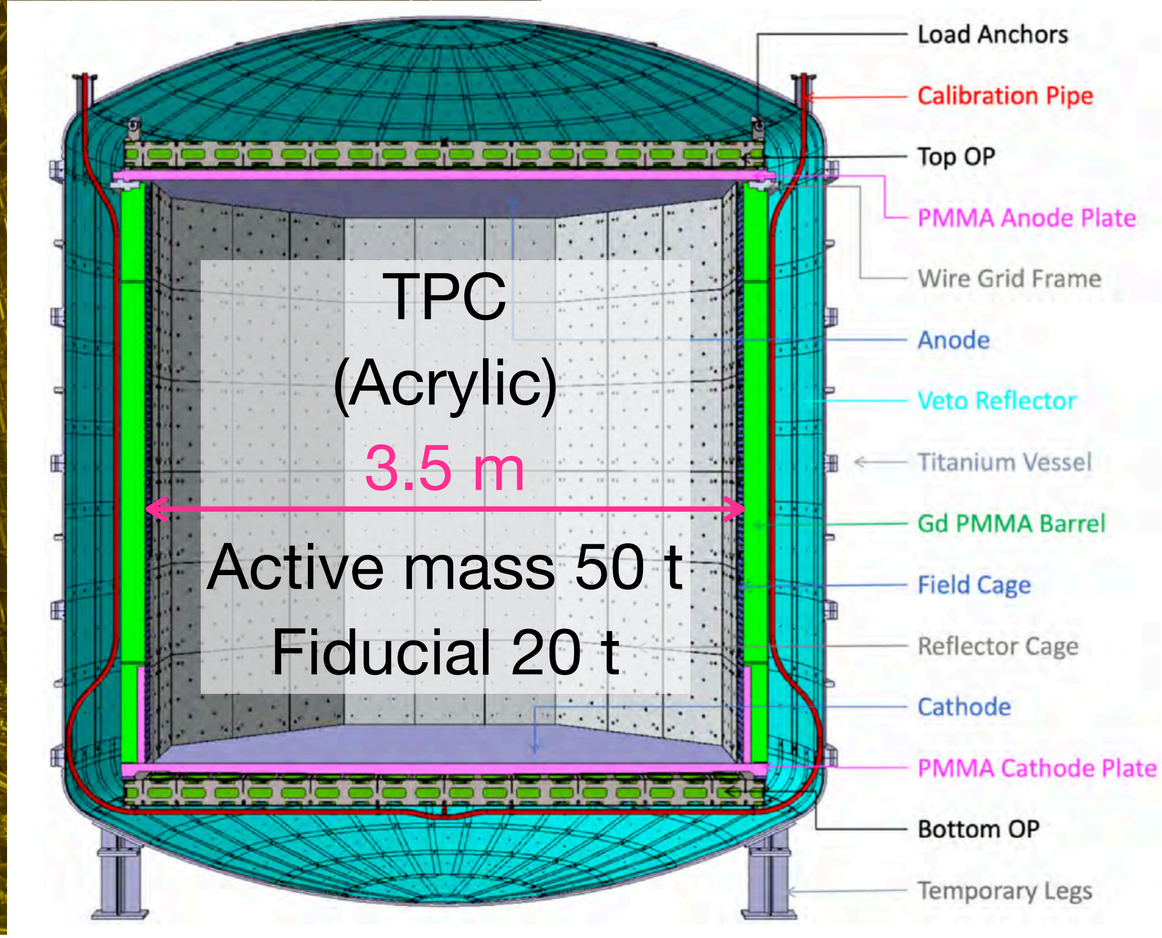
Will be the largest DM detector

Outer cryostat (“Proto-DUNE”)
Atmospheric argon (AAr), 700 t

Titanium vessel
Underground argon (UAr), 100 t
instrumented with neutron veto

Proto-DUNE, CERN

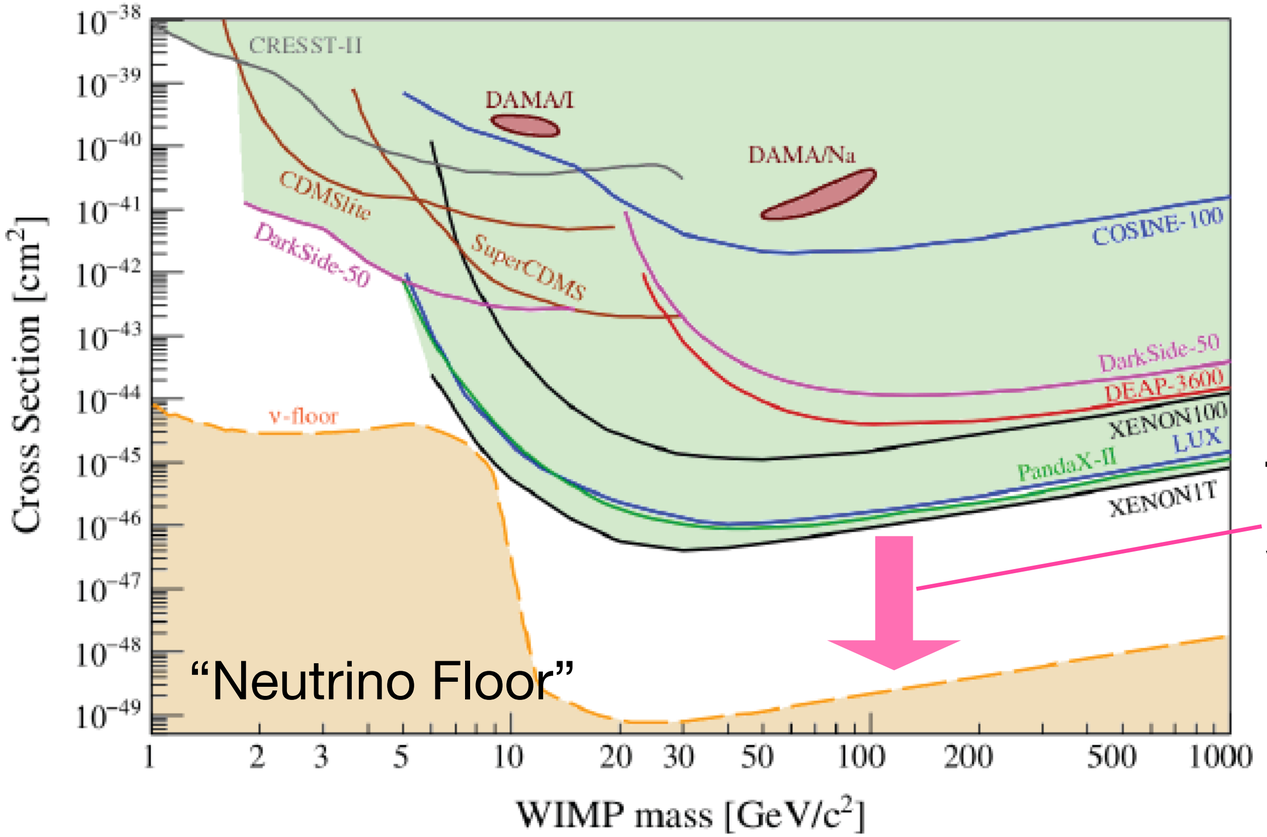




DarkSide-20k: Why do we need the large detector ?

Direct DM (WIMP) search experiment

- WIMP exclusion curves
  - Current best limit: ~$4 \cdot 10^{-47}$ cm^2 at ~30 GeV/c^2 WIMP mass (XENON1T)



To push down the sensitivity curve you need to increase the exposure:

target mass × time

DarkSide-20k

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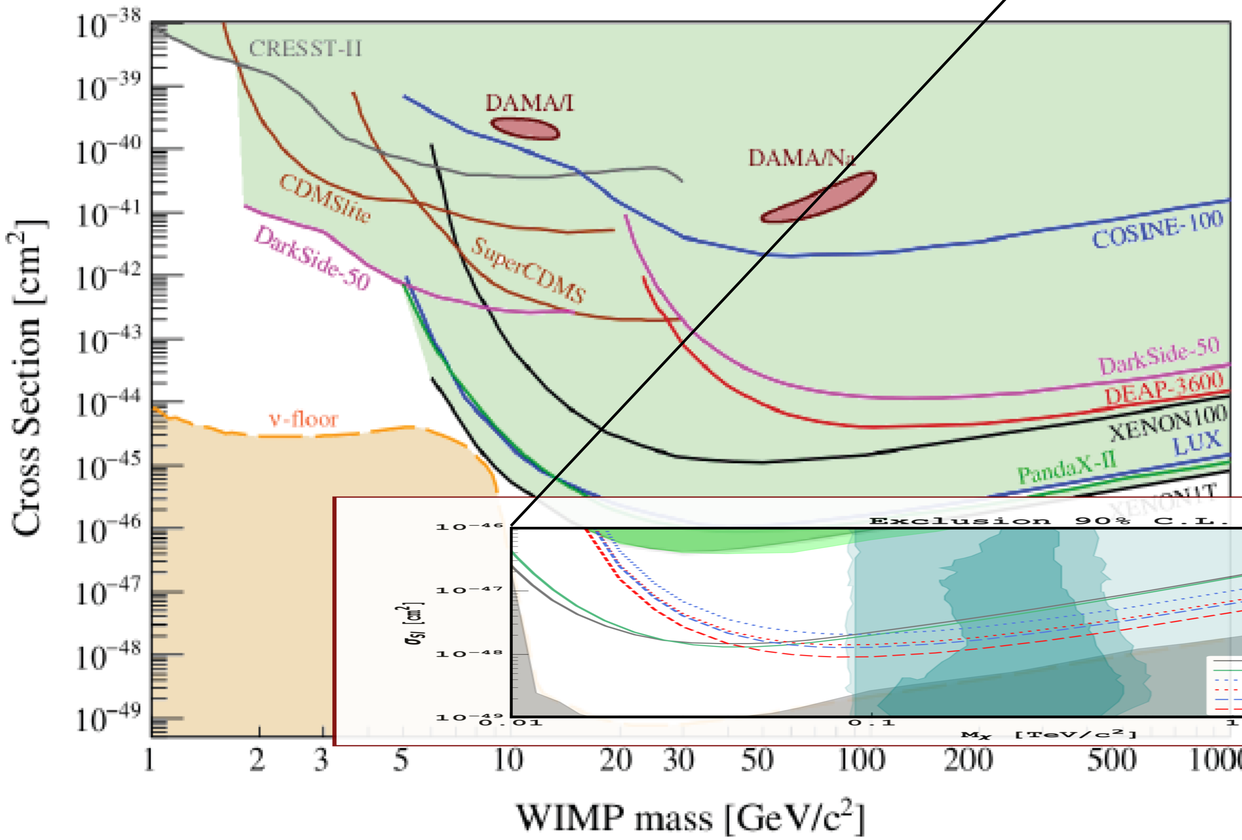
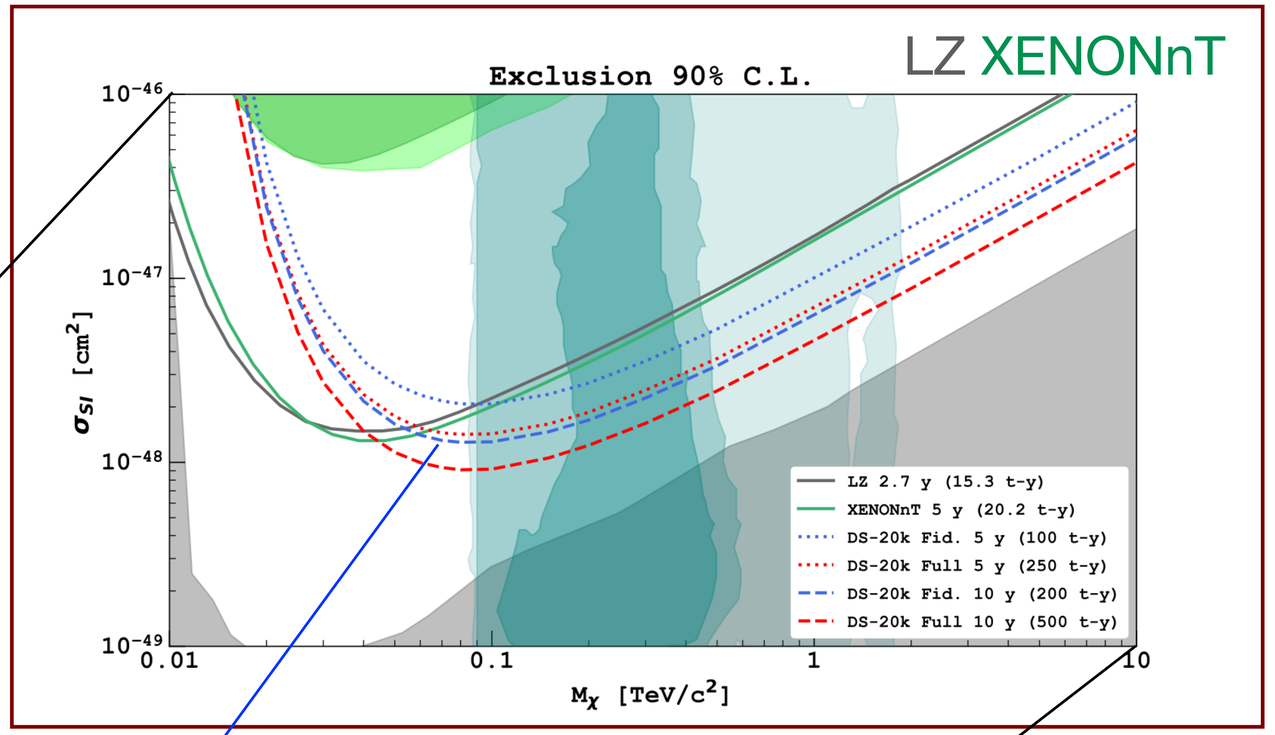




DS-20k: 10 y (200 t-y) to reach ~10^{-48} cm^2

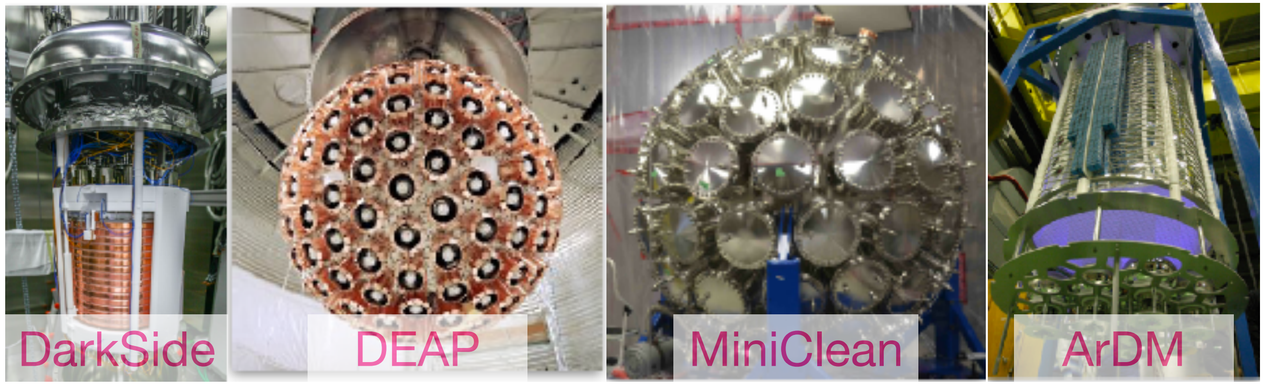
Main goal: High WIMP mass (≳0.1 TeV/c^2) complementary to LHC

Keys:
Low background
High detector efficiency

Global Argon Dark Matter Collaboration (GADMC)

Present goal: DarkSide-20k

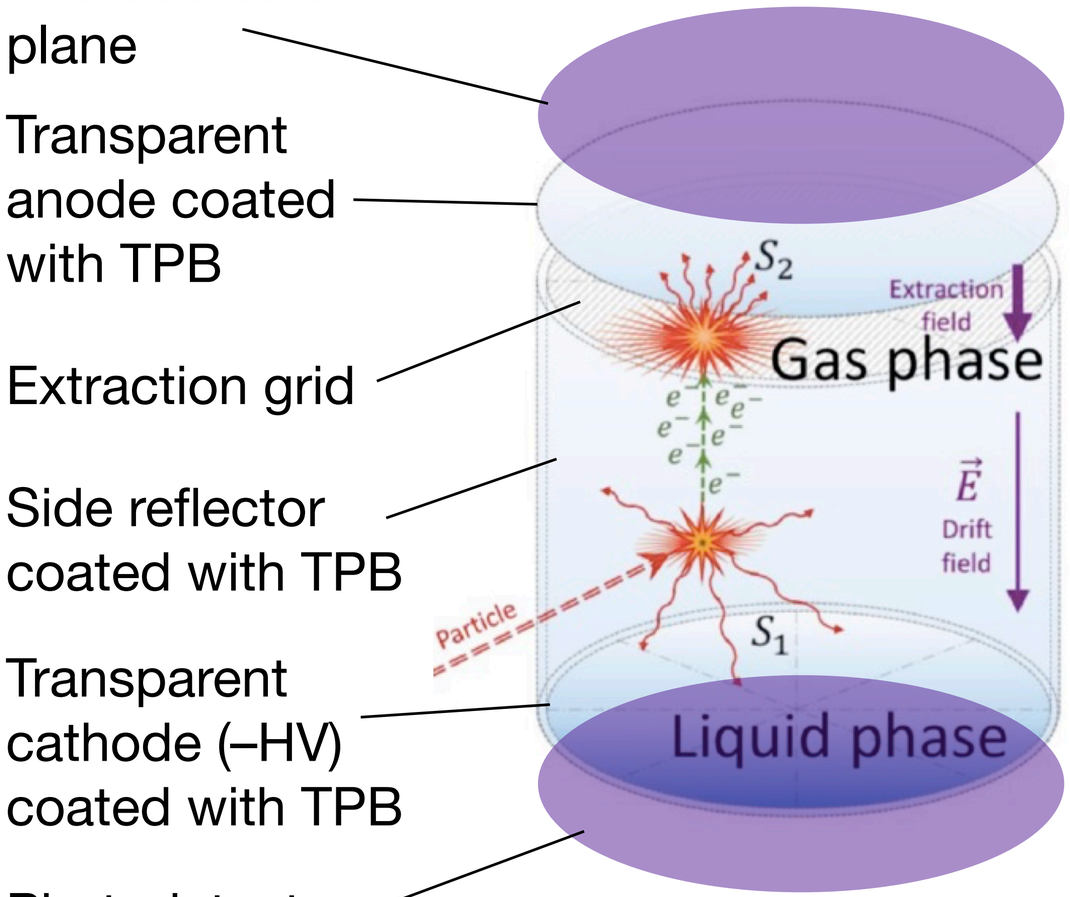
- >500 collaborators from ~100 institutions from all over the world
- Join the expertise from LAr-based DM experiments



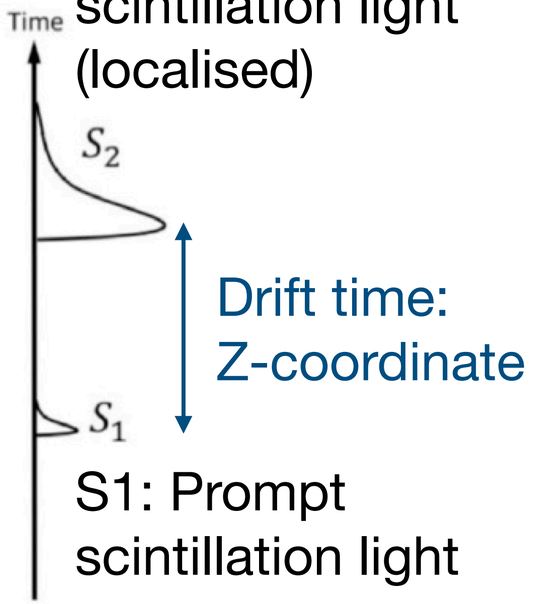
- **Future goal: ARGO at SNOLAB**
  - O(1000) t·y, several 100 tonnes of UAr
  - To reach the neutrino floor
  - Conceptual studies in progress

Dual-Phase LAr Time Projection Chamber

Working principle of DarkSide-20k



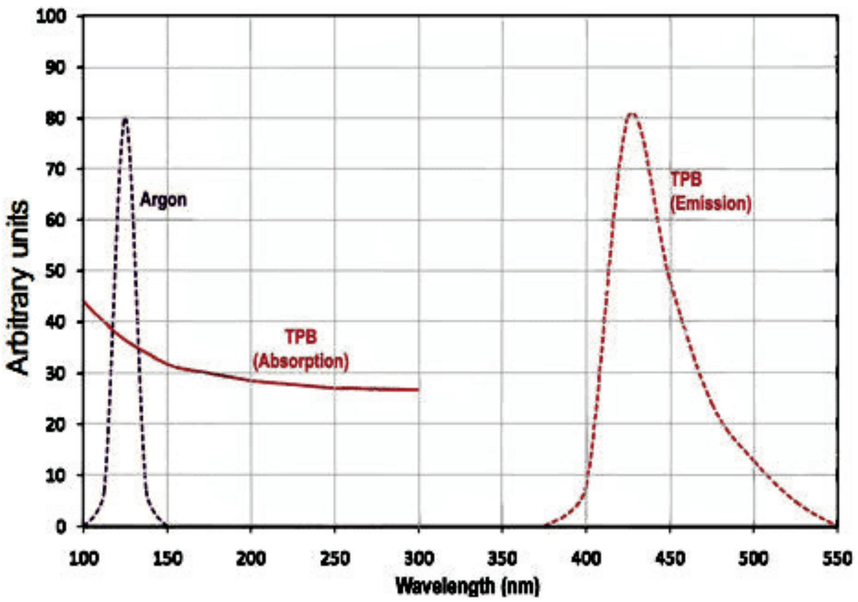
S2: Charge extracted in the gas phase producing delayed scintillation light (localised)



S1: Prompt scintillation light

3D imaging of event: Z (time) and XY (CM of the S2 signal)

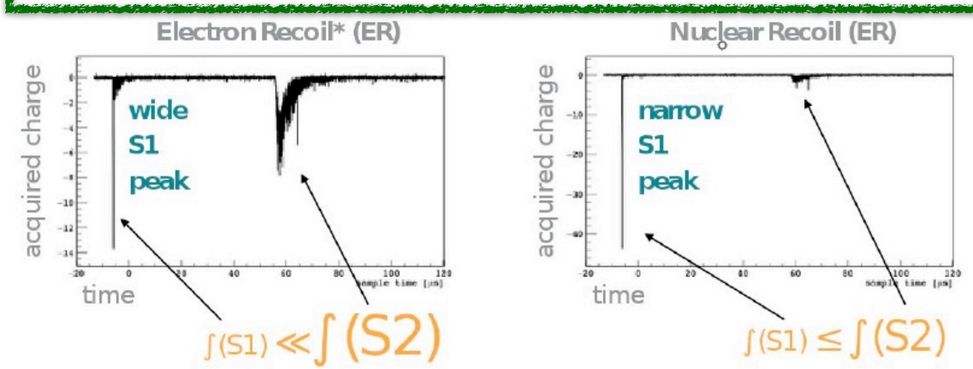
- Detection of charge/light signals by the top and bottom photodetectors
- VUV scintillation photons (128 nm) converted to visible blue photons by WLS (TPB) on the TPC inner surfaces



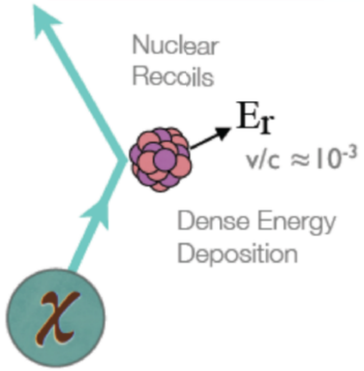
Liquid Argon

As the WIMP target

- High density cryogenic liquid: BP = 87 K
- High scintillation and ionisation yield
- Available in large quantity
- Outstanding ER (electronic-recoil) BG discrimination
  - **Pulse Shape Discrimination (PSD)**
    - Fast (6 ns) and slow (1.5 μs) scintillation, Fast/Slow
    - >10^8 discrimination power demonstrated (DEAP-3600)
  - Additionally, by Light/Charge in dual phase TPC

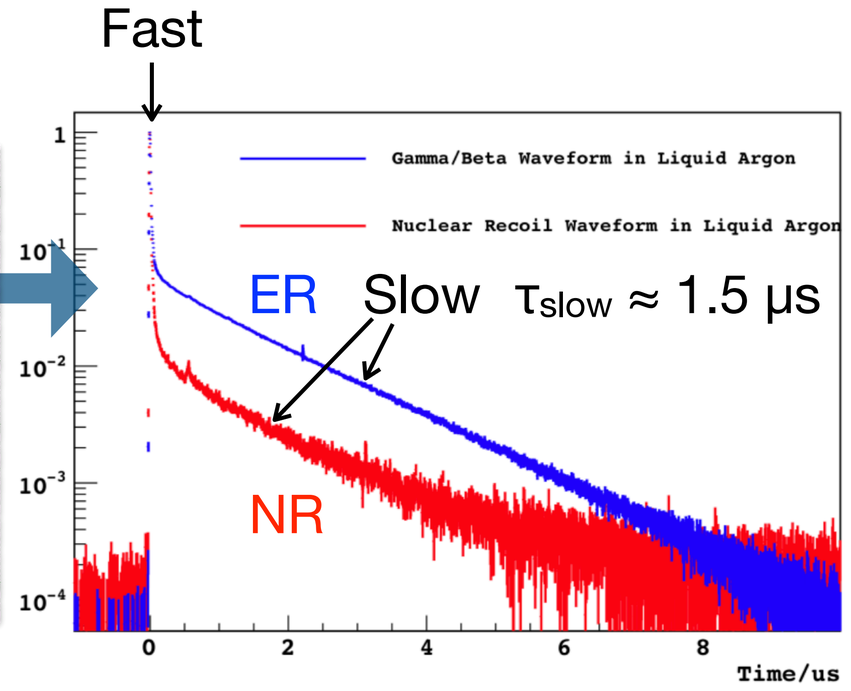


Signal: NR



Background:

- ER BG (β, γ)
- Neutron BG
  → Produce NR, partially irreducible

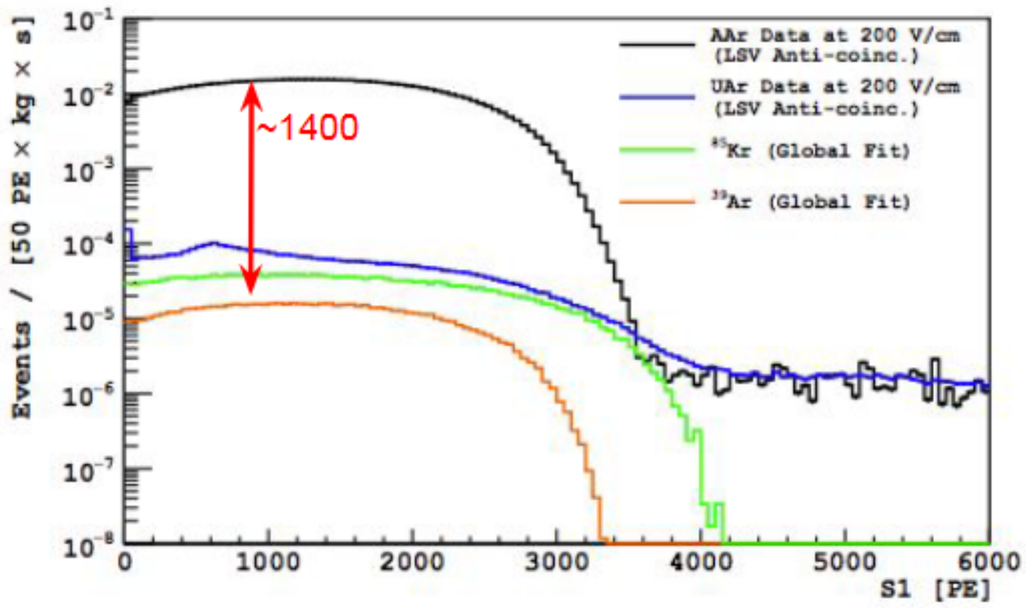


Drawback: β-emitting isotope ^{39}Ar
1 Bq/kg in atmospheric argon

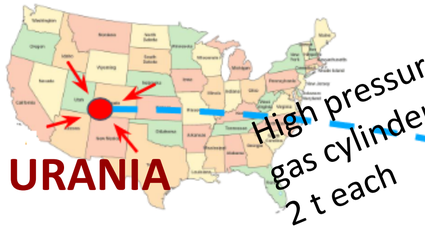
Underground Argon

Key to large-scale LAr DM detectors

- Discovery of argon with low ^{39}Ar ($\tau_{1/2}$ = 269 y) content in an underground well in Colorado, by DarkSide-50

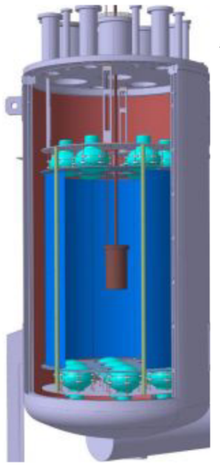


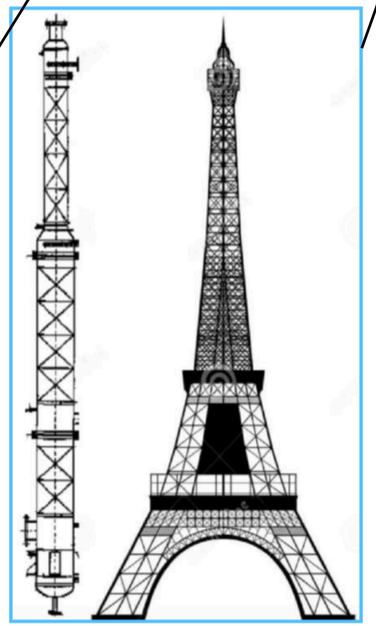
- This opened the door to large-scale LAr DM detectors: <0.1 ER leakage over 200 t-y exposure at DS-20k

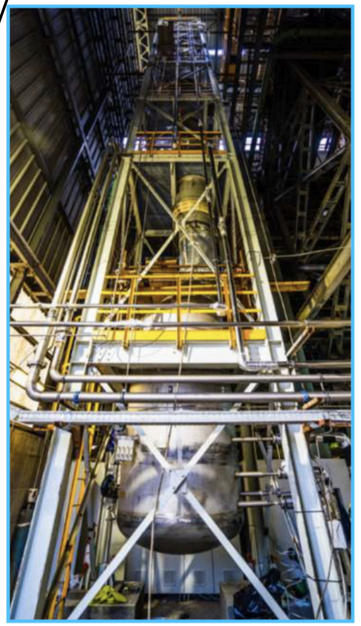


UAr extraction from a CO_2 well

^{39}Ar activity to be measured in DArT



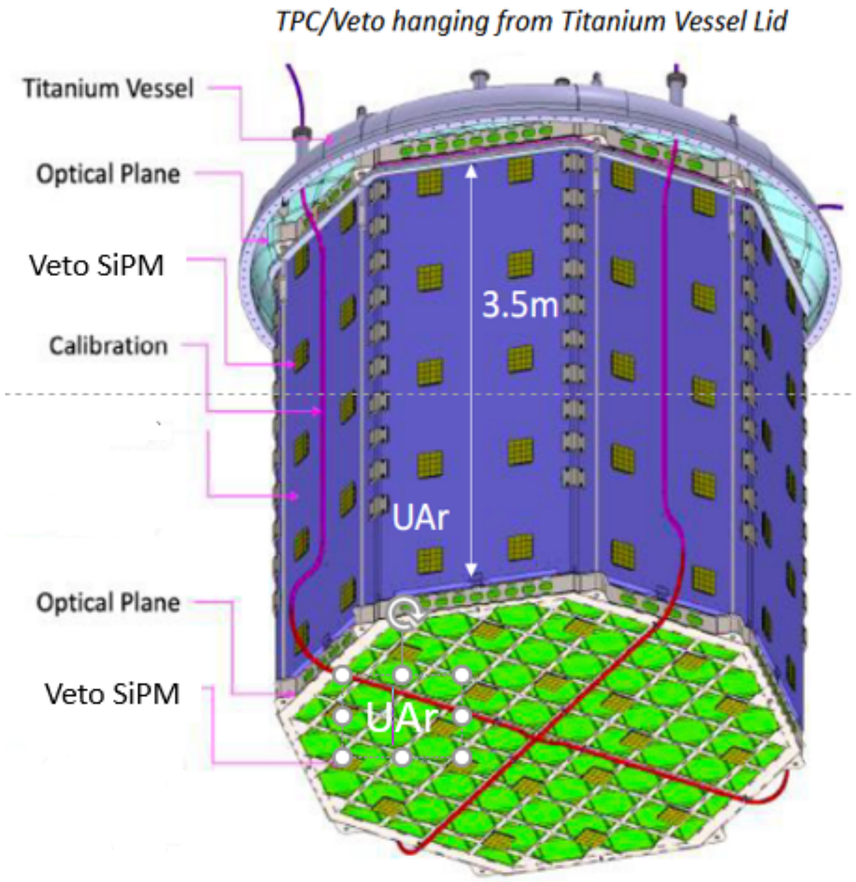




Chemically purified in ARIA, 350-m distillation column in Sardinia: Isotopic separation demonstrated using the first module

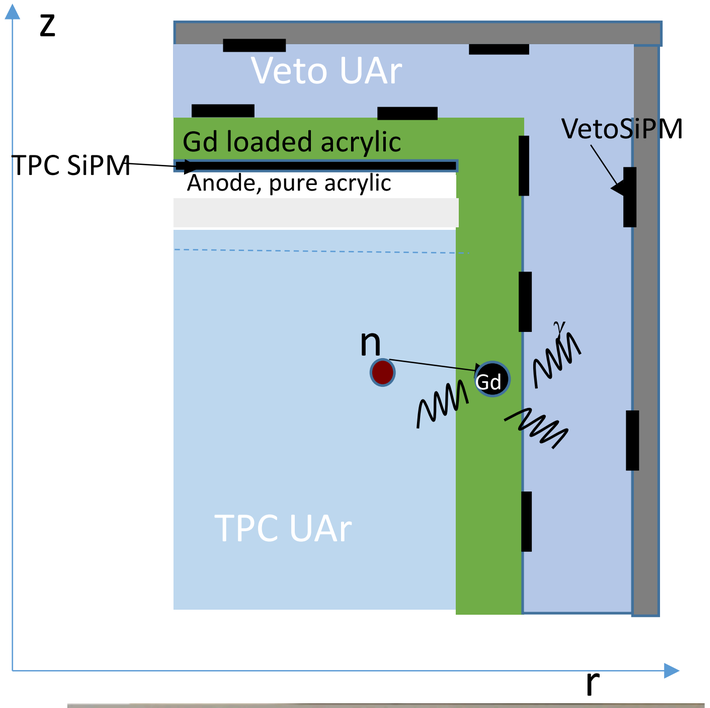
TPC / Neutron Veto

Integrated design



- Entire TPC “cage” structure made of Gadolinium loaded acrylic for neutron veto
- Radio-pure detector material and components carefully selected following extensive “screening” campaigns
- “Clevios” transparent conductive polymer for transparent cathode, anode, field shaping electrodes

Veto working principle



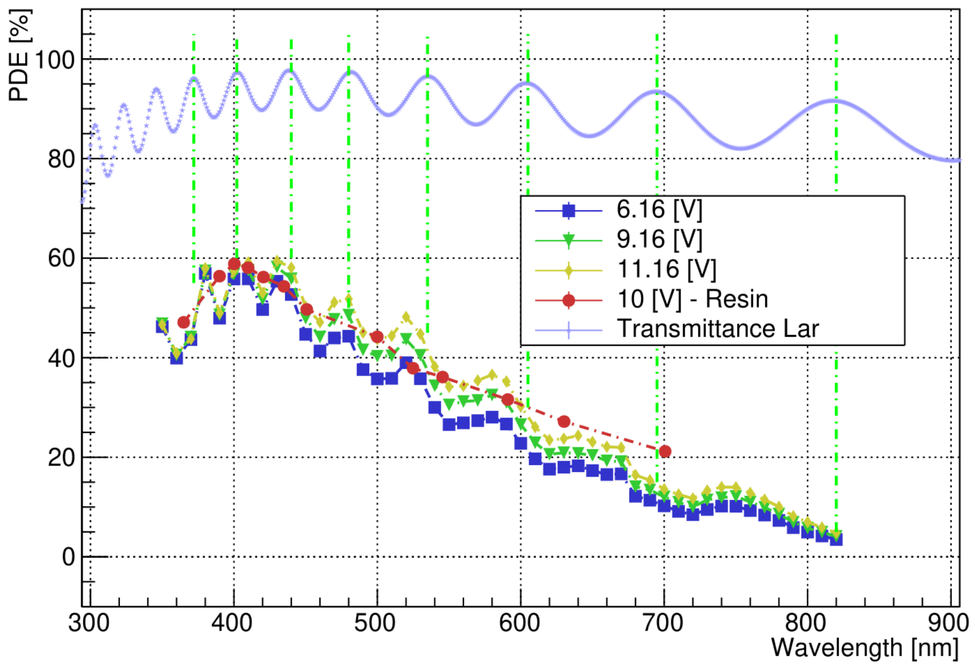
Acrylic coated with Clevios

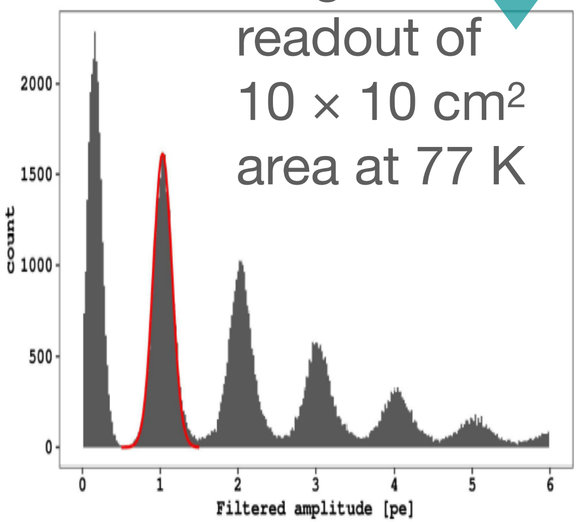
Instrumental background-free experiment:
<0.1 neutron BG expected over 200 t-y exposure

Silicon Photomultiplier Array

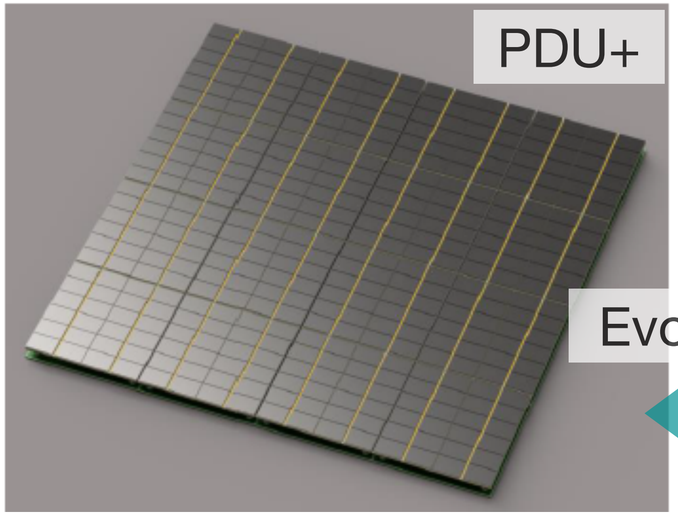
State-of-the-art photodetector

- Developed by FBK & DarkSide Group
- **Low radioactivity**
- Excellent single-photoelectron resolution
- High PDE (>50% at RT, 420 nm)

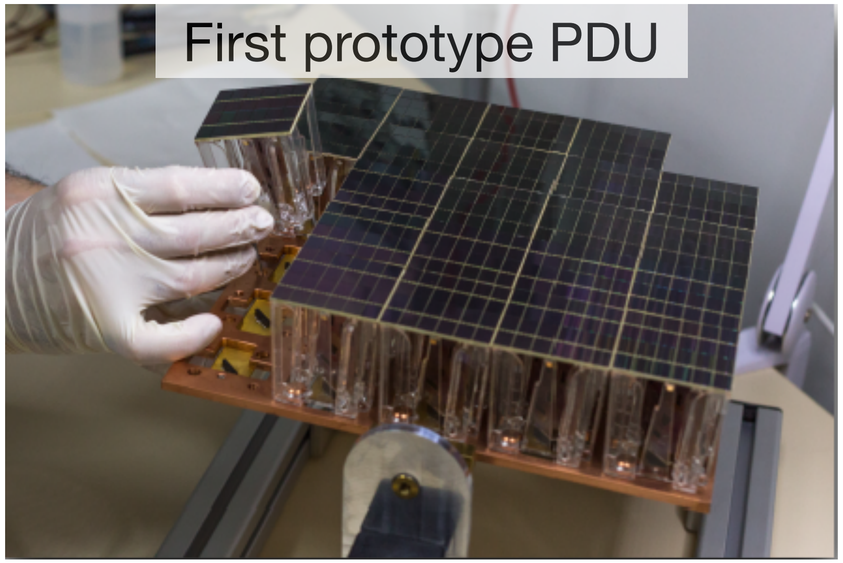




Single channel readout of 10×10 cm^2 area at 77 K



Evolution



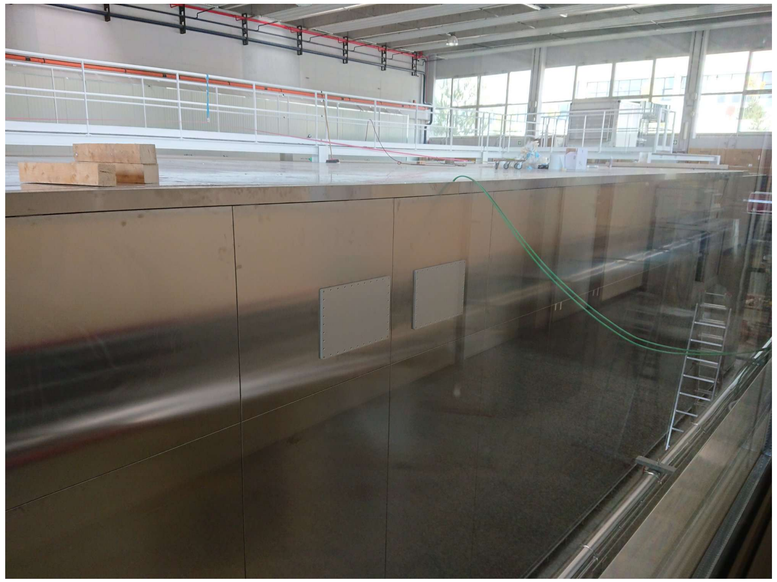
Continuous active area over 2× ~12 m^2 to be covered entirely with SiPM arrays

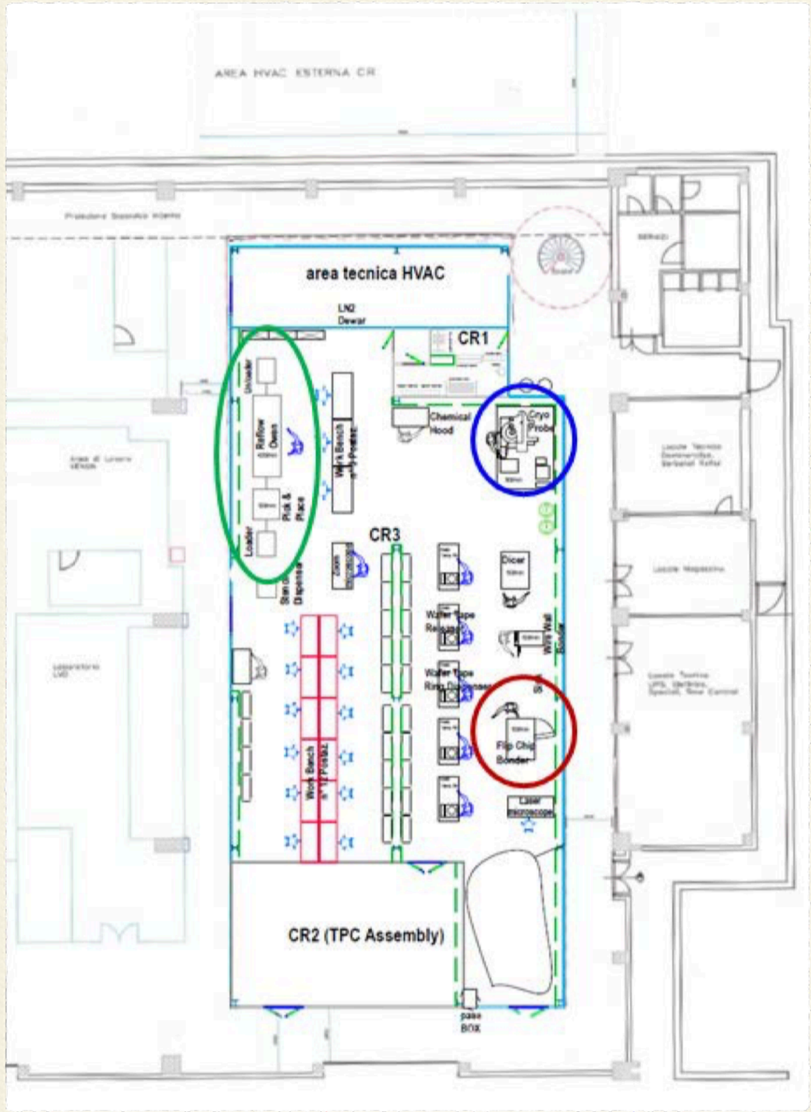
SiPM mass production at LFoundry in Avezzano

Transitioning to the construction phase

Nuova Officina Assergi (NOA)

- A “factory” is under construction at LNGS
  - Clean rooms with industrial machineries for:
    - Mass production of the photodetector units:
      - Wafer tests → Tile & FEB → PDU
    - TPC assembly

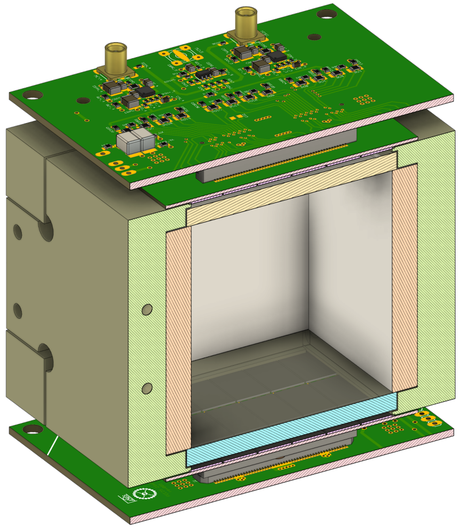


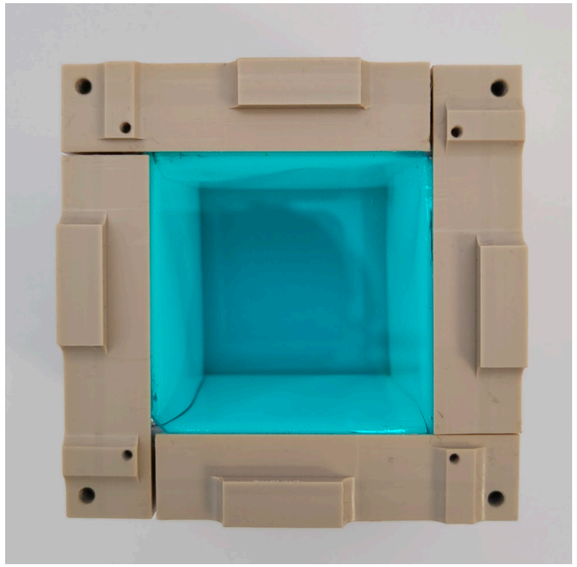


R&D at LNGS with GSSI students

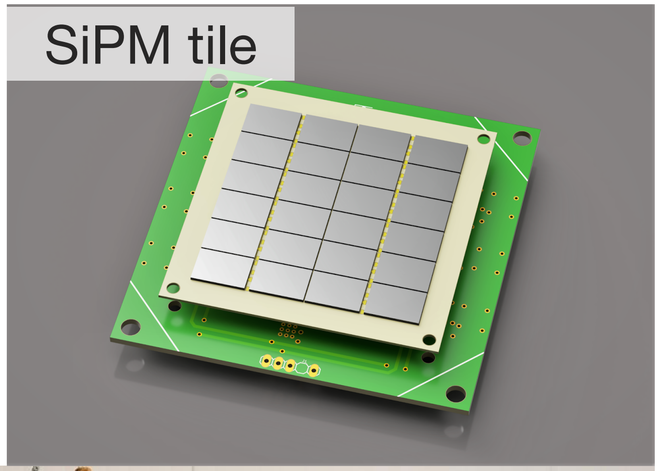
Detailed characterisations of SiPMs

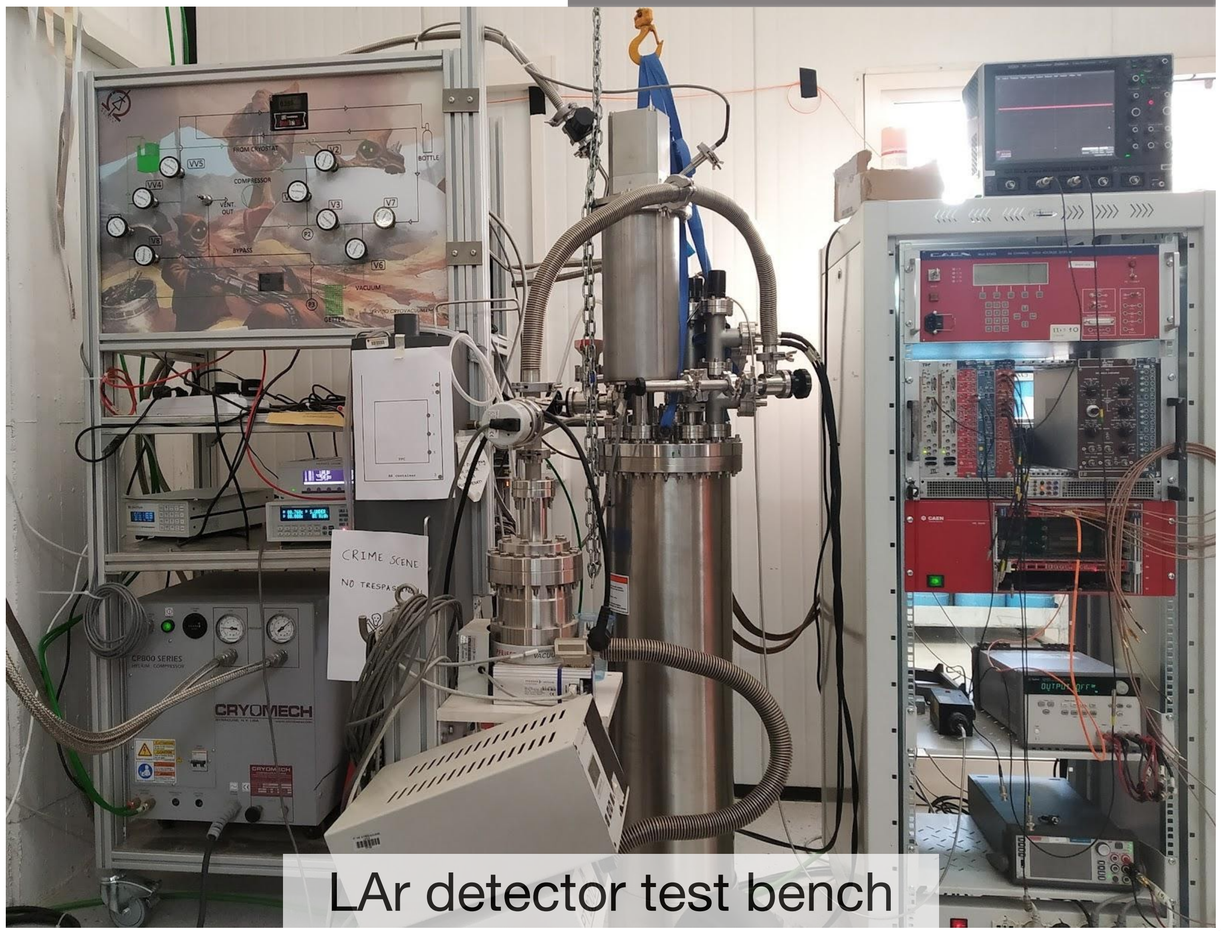
- Time resolution, PDE, optical crosstalk … at room and cryogenic temperatures
- SiPM response to LAr scintillation light
  - Using a (5-cm)^3 single-phase “micro-DS” prototype → Demonstrated LY of ~12 pe/keV$_{ee}$





Essential inputs to the simulation and the preparation for the physics analysis





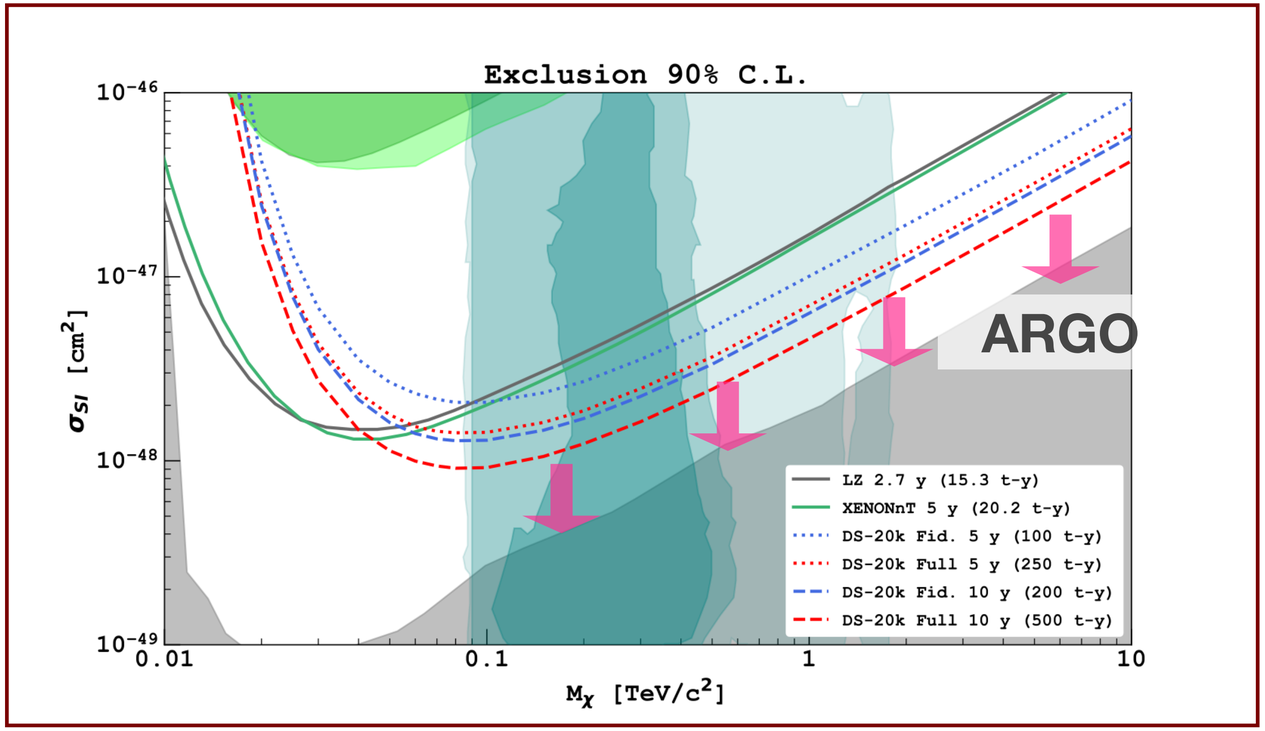
LAr detector test bench

Ready for building DarkSide-20k

And beyond …

- **Transitioning to the construction phase**
  - Construction starting in 2022
  - Data taking from 2025

- **R&D at LNGS**
  - SiPM R&D
    - Time resolution
    - SiPM development for a higher PDE
  - To increase the light yield
    - More efficient WLS
- MC simulation and analysis software
- DArT, ARIA, …



Interesting opportunities for the PhD program within DarkSide-20k, also R&D towards our future goal, **ARGO**, hitting the neutrino floor !

For more information, contact us