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DARK MATTER DETECTION

status and perspective of direct detection activities in Rome



Status of the Direct Dark Matter Search

- Dark Matter Hypothesis

(~25%):

- dark
- nonbaryonic
- cold

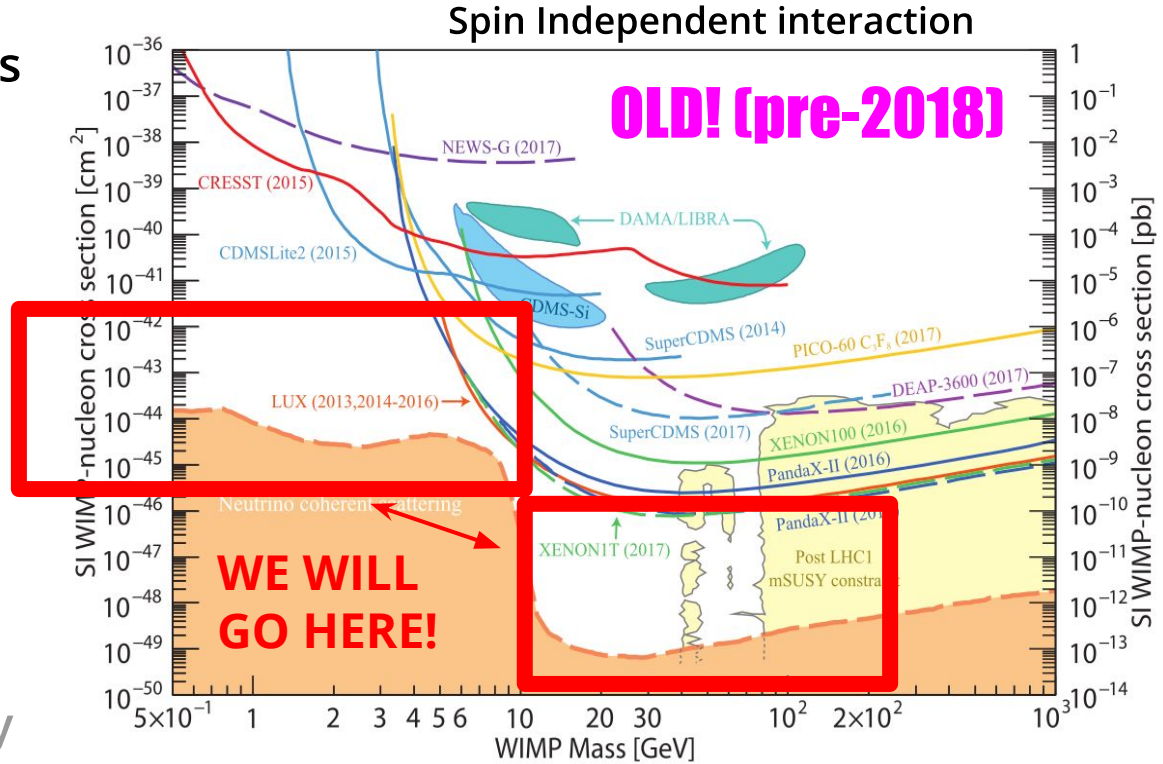
- The WIMP models

~ 100 GeV mass

It's worth to do down to the ν floor

- Other models

Direct search is anyway interesting



From PDG 2018
(not yet updated)

Noble gas challenge: Argon vs Xenon



- Noble gas revolution

- Easy purification
- PSD (Single phase/double phase)
- High LY (~40 PE/kev)
- Transparent to his own scintillation
- Acceptable quenching factor
- High electron mobility
- Scalability
- Self shielding

- Argon:

DarkSide, DEAP,...

- Xenon:

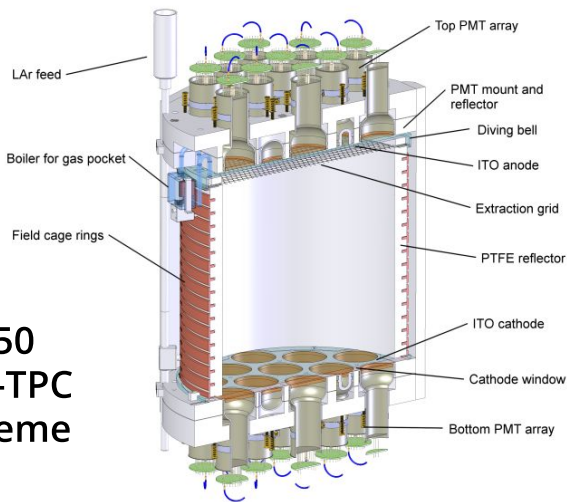
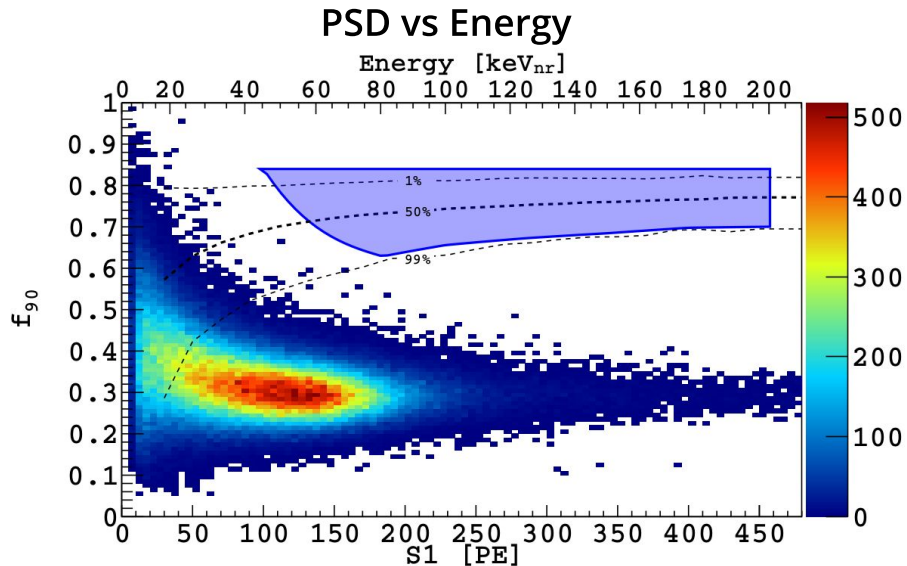
Xenon-1T, LUX,
PandaX,...

	Argon	Xenon
Atomic number	18	54
Liquid density	1.4 kg/l	3.0 kg/l
Scintillation wavelength	128 nm	178 nm
Boiling temperature	87 K	165 K
Ionizing energy	23.6 eV	25 eV
Scintillation Time components	6 ns 1600 ns	17 ns 24 ns
Rejection	~1/10 ⁹ (S1) ~1/300 (S2/S1)	~1/300 (S2/S1)

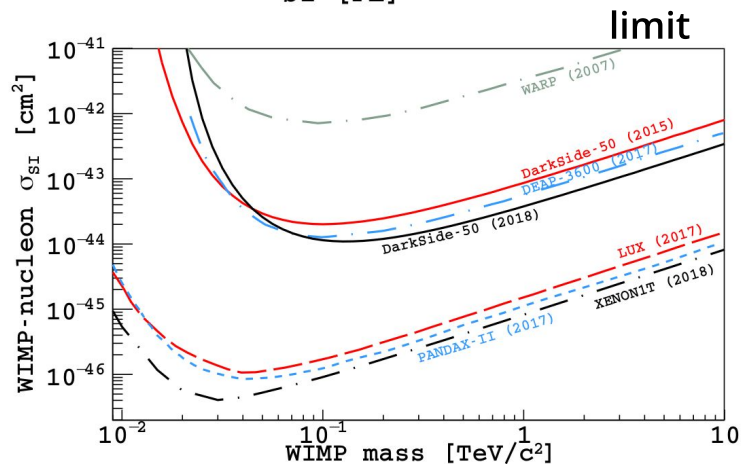
DarkSide-50 results: High-Mass

Results

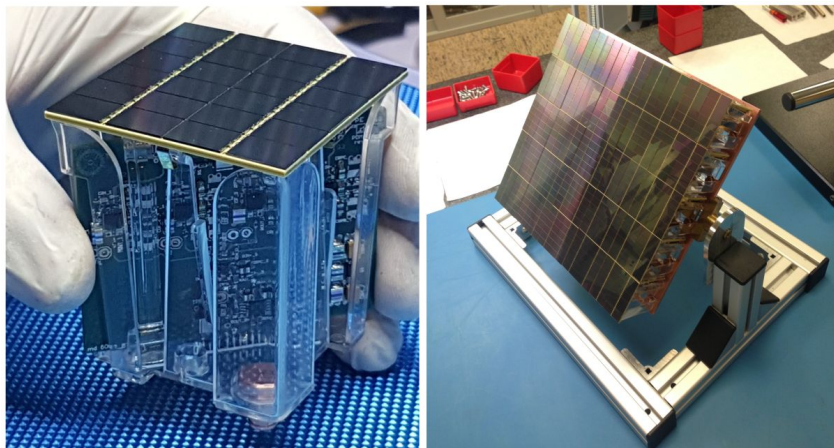
- 530 live days x 46 kg
- $1.14 \times 10^{-44} \text{ cm}^2 @ 100 \text{ GeV}$
- UAr $\sim 0.7 \text{ mBq/kg}$
- LY $\sim 8 \text{ PE/keV}$
- Blinding scheme



DS-50
LAr-TPC
scheme



Technological challenges: SiPM-PDMs, ARIA & URANIA



TOWARDS HI-PURITY LIGHT DETECTION

24 SiPM 4x6 are arranged in a single **PDM**
5 cm x 5 cm

25 PDM are arranged in Mother Boards

Massive production in NOA

UNDERGROUND Ar:

URANIA

from CO₂ wells in Colorado

250 kg/d

Chemical distillation in Seruci-I

60t extracted in total (mid 2022)

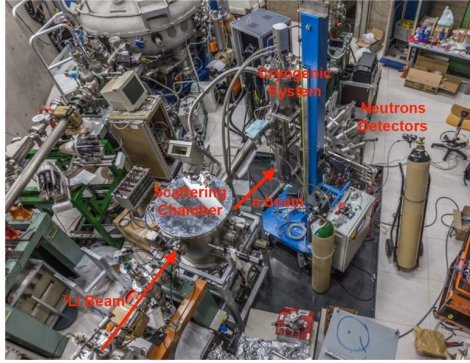


PURIFICATION: **ARIA**

350 m tall distillation column

Seruci-I 1t/d of UAr

Proving our technology: the Prototypes

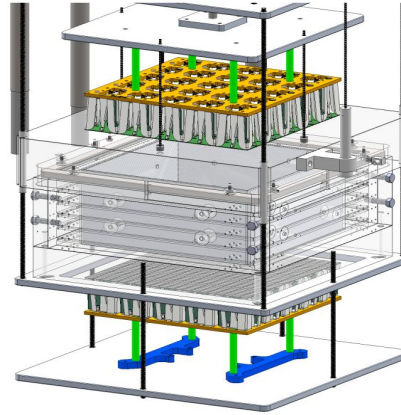


ReD (directionality)

5x5x5 cm³ acrylic
LAr-TPC with 2 PDMs

Light & charge response

@LNS TANDEM
p(Li7,Be7)n
Neutron-induced nuclear
recoil - directionality

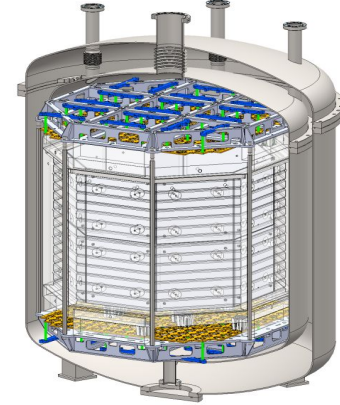


Proto-0

50 PDMs
commissioning

Read-out & DAQ

Xy resolution and gas
pocket



Proto-1 (low-mass)

370 PDM
commissioning

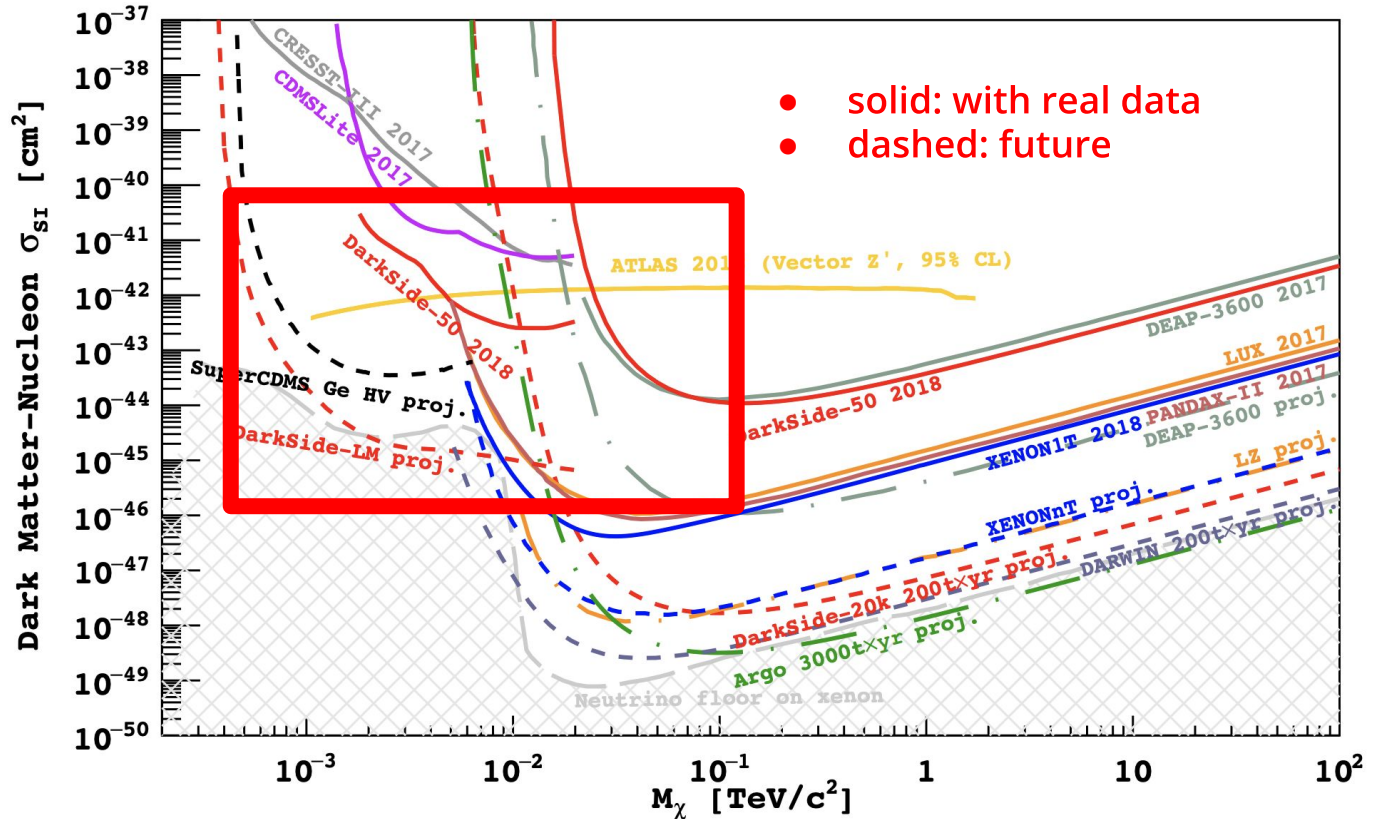
Study of the final
configuration

THE MOST SENSITIVE LOW-MASS EXPERIMENT



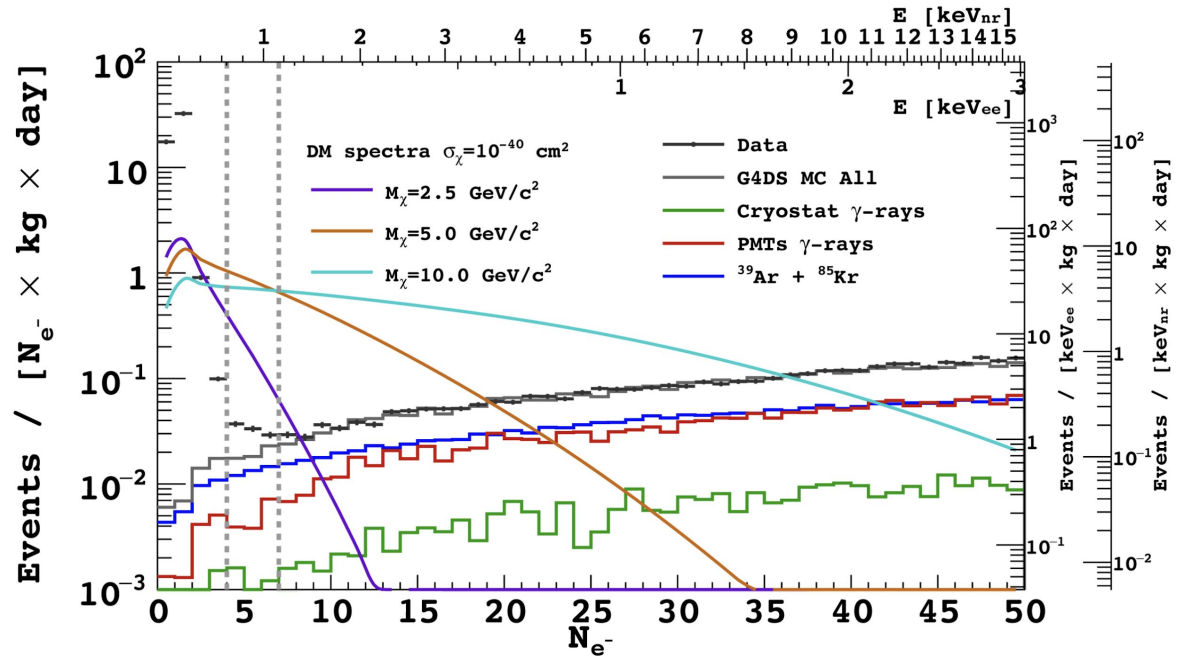
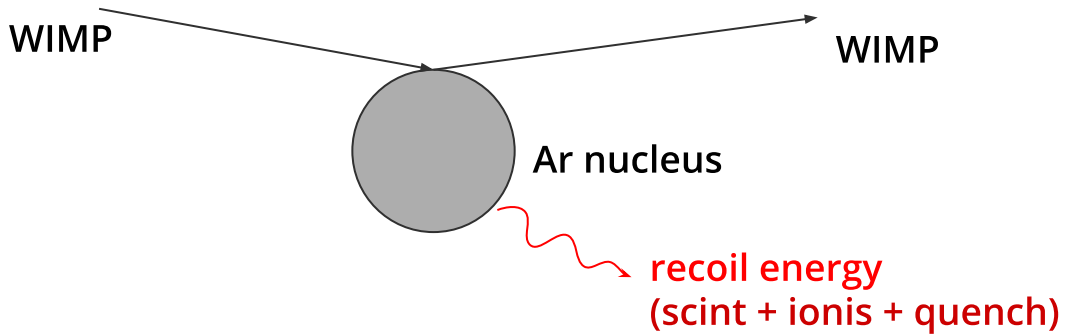
- with only 50 kg of Argon, world-best sensitivity between 1.8 and 6 GeV

○ based on ionisation-only analysis



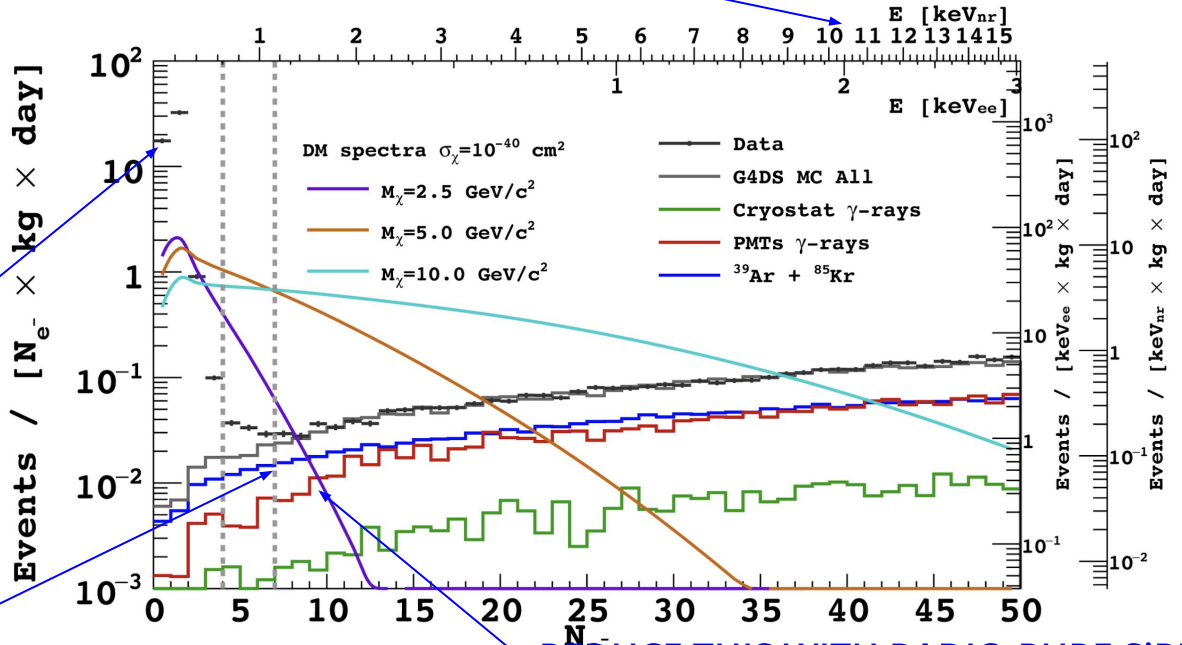
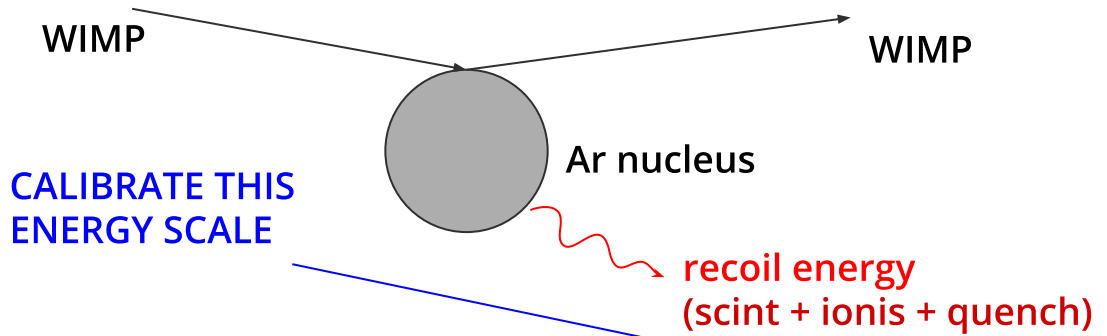
HOW DOES IT WORK

- look only for ionisation signal (S2)
 - reach lower recoil energy (~ 2 keV)
- can study seasonal modulation
- must characterise backgrounds
- must calibrate response to nuclear recoils



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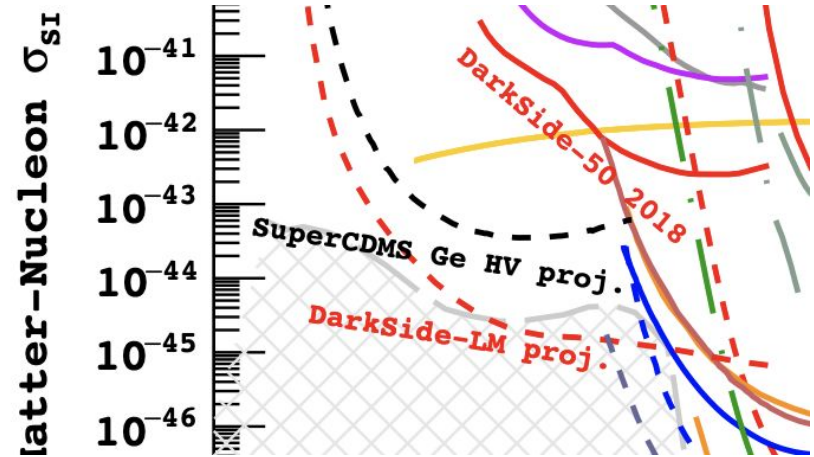
CHARACTERISE THIS BACKGROUND

REDUCE THIS WITH URANIA (^{85}Kr)+ARIA (^{39}Ar)

REDUCE THIS WITH RADIO-PURE SiPMs

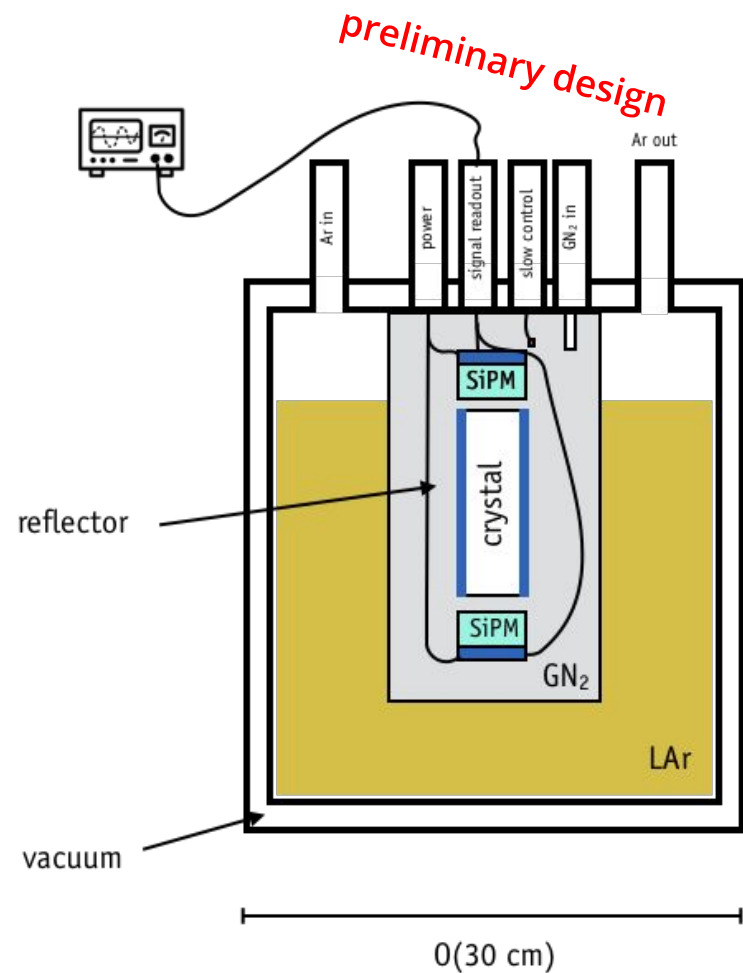
TARGETS

- how to do **10x better?** use DS-Proto (1 ton) in Gran Sasso for 1 year
 - we are preparing a proposal for LNGS
- how to **reach neutrino floor?** use DS-20k technologies
 - URANIA+ARIA to purify argon with cryogenic distillation
 - ultra-pure SiPMs
 - radio-pure stainless-steel cryostat
- crucial for both: **calibrate Ar**
response to ~1 keV nuclear recoils
 - ReD or dedicated experiments



R&D(ILETTANTEs): THE LArNaI FACILITY

- we are designing a portable, multi-purpose cryogenic test-stand
 - INFN grant neoassunti + support from DS-RM
 - NR, VI, Biagio Rossi (Napoli)
- small cryostat to be operated with LAr (or LN)
 - light collection with **SiPMs**
- flexible design to allow R&D for low-mass WIMPs
 - small TPC to study background to S2-only search
 - crystals for light-yield vs temperature (figure)
- logistic support from INFN Roma is essential (lab space, services)



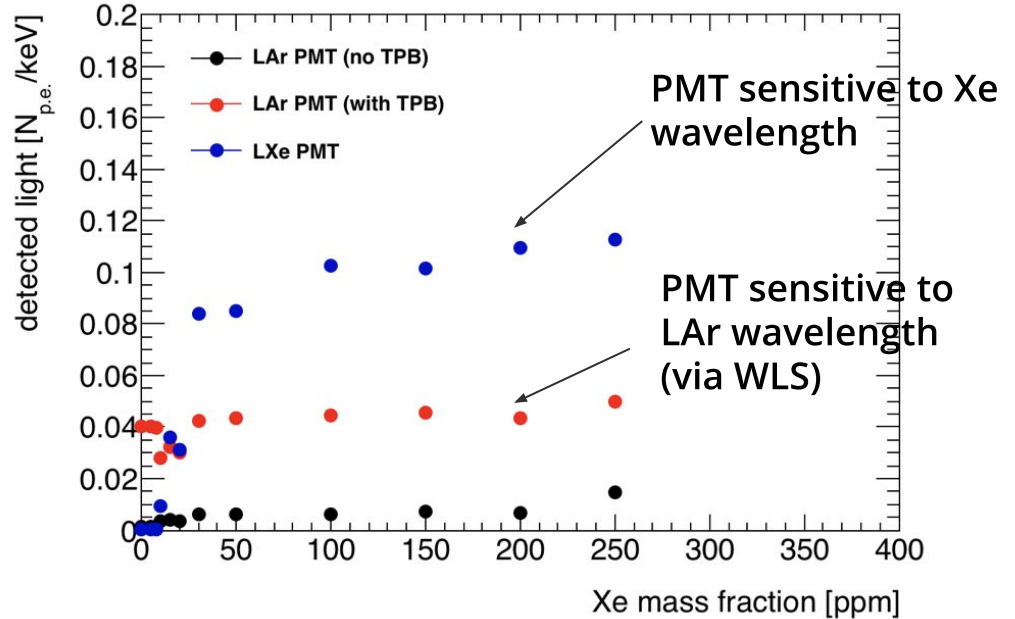
R&D: LAr AND LXe

- you can add O(1000 ppm) xenon to LAr and fasten light response

○ test performed at CERN (Aug 2018) in the context of CH₄ doping studies

- potential applications in LAr-PET or with larger-scale doping

○ mixture of argon + isotopically-enriched xenon could be used for ultimate **double-beta decay experiment**



HOW TO FIND WIMPs WITH $\sim 10'000$ SiPM channels?

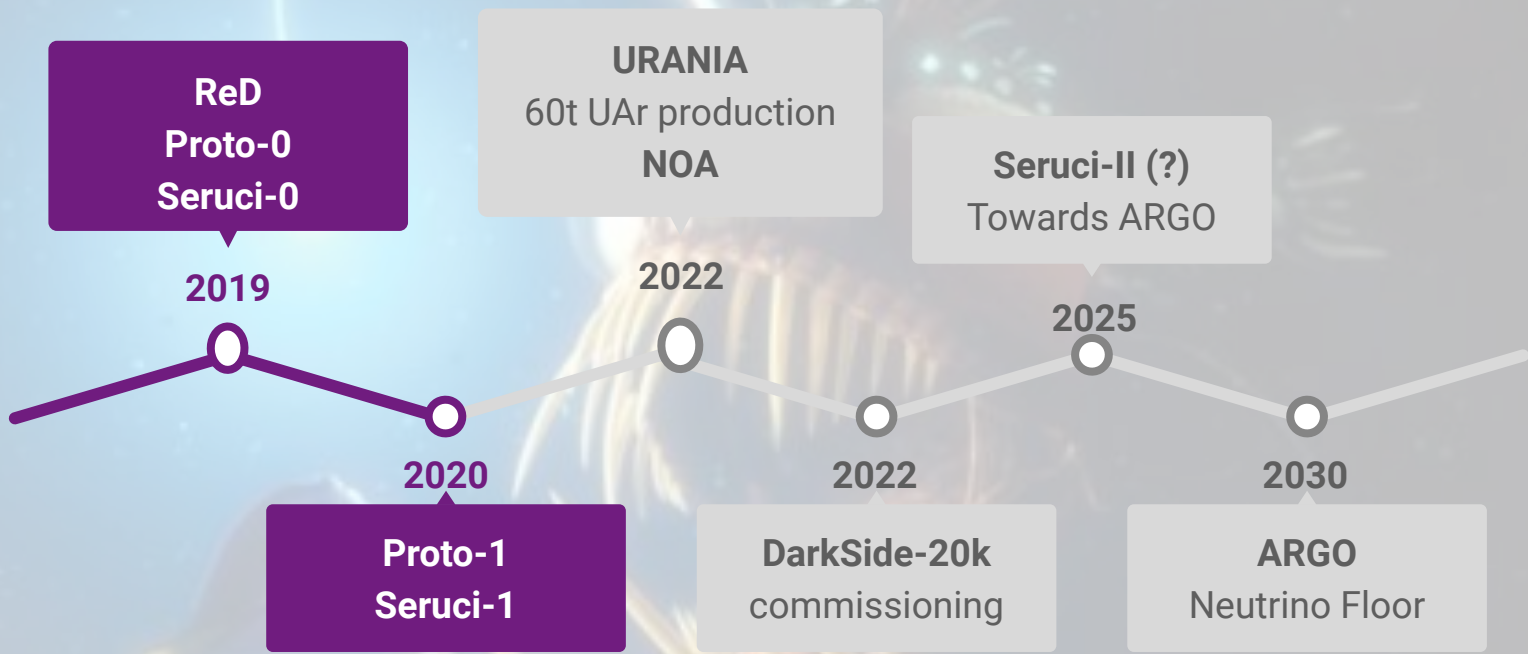
- **TDAQ: as difficult as LHC experiments**
 - software trigger (possibly at FPGA-level!)
- **reconstruction: need clever techniques**
 - fast signal processing
 - machine learning
- **low-mass: reach neutrino floor**
 - simulation & data analysis
 - radio-pure cryostat design for prototypes
- **calibration**
 - ReD, LArNal
- **directionality & R&D**
 - ReD, argon+xenon doping

HOW IT'S DONE



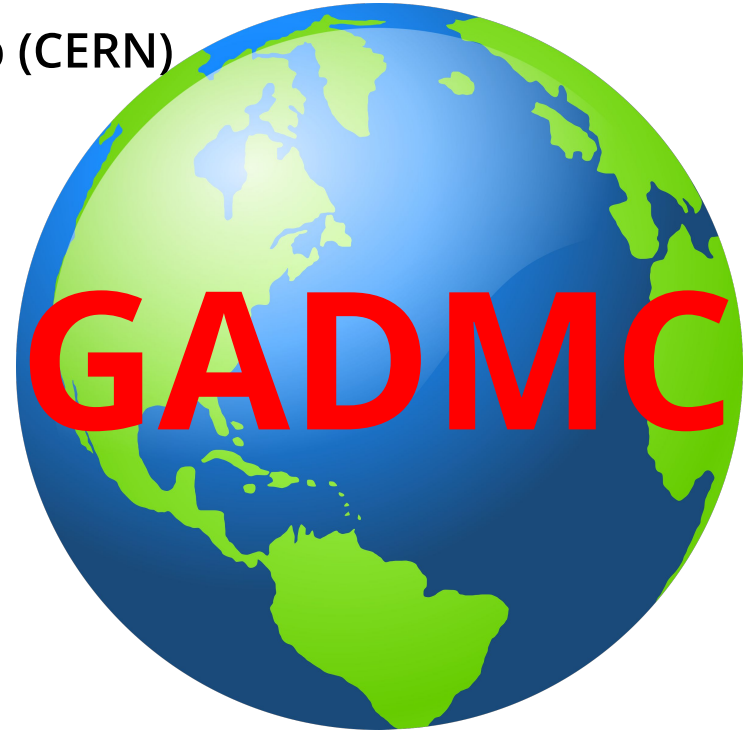
IN ROME

The DarkSide Project timeline



Global Argon Dark Matter Community

- **Neutrino Platform & Cryogenic group (CERN)**
 - ProtoDUNE veto
 - cryogenic systems
- **Canfranc Laboratory (ArDM)**
 - UAr measurement in DArT
- **SNOLab**
 - Acrylic
 - DAQ
- **DarkSide-50 & DarkSide-20k**
 - LAr-TPC
 - innovative PDM's
 - High and low mass



CONCLUSIONS

- **argon leads the WIMP search at low-mass**
 - shown by DS-50 with depleted Ar
- **could reach neutrino floor using DS-20k technologies**
 - needs radiopure SiPM and materials
 - needs depleted Ar with reduced ^{37}Kr and ^{39}Ar contamination (URANIA+ARIA)
- **ongoing R&D to broaden applications**
 - LAr+LXe: pet? double-beta?
 - LArNaI project - a facility for cryogenic R&D
 - intense synergy with CERN neutrino platform