Dark matter search with liquid argon and the new MAB Astrocent project

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Group Leader
“Photonics for astroparticle physics and sustainable energy”

ASTROCENT

NICOLAUS COPERNICUS ASTRONOMICAL CENTER OF THE POLISH ACADEMY OF SCIENCES

NATIONAL SCIENCE CENTRE POLAND

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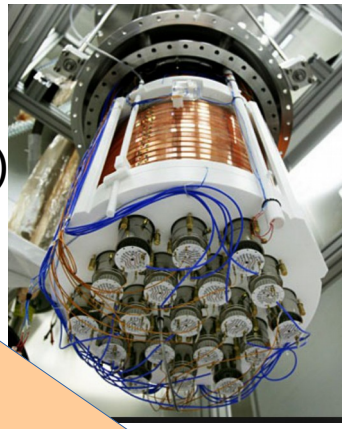
LAr-based dark matter detectors

2010

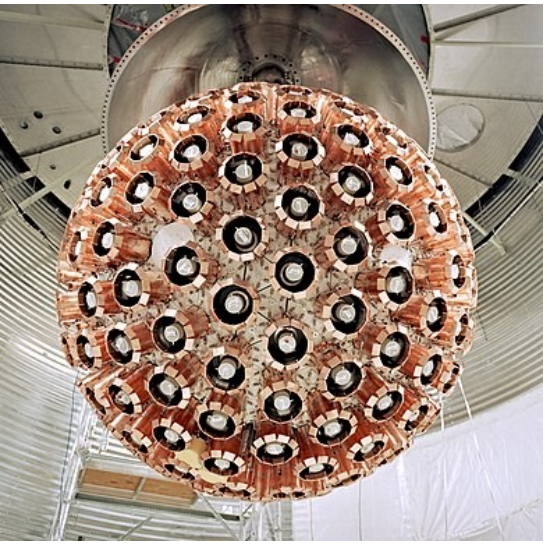
10 kg

DarkSide-50 (50 kg, LNGS)



100 kg

ArDM (1t, LSC)



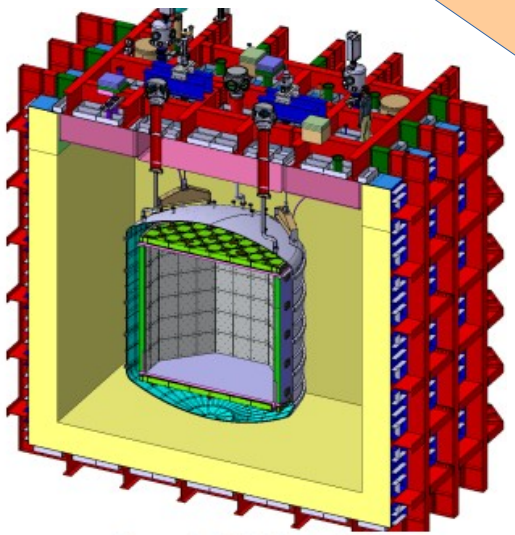
1000 kg

2015

DEAP-3600 (3.3t, SNOLAB)

- More than 300 scientists from 15 countries and 60 institutions
- Officially supported by underground labs: LNGS, LSC, and SNOLAB

Global Argon Dark Matter Collaboration formed



2028

DarkSide-20k (50t, LNGS)

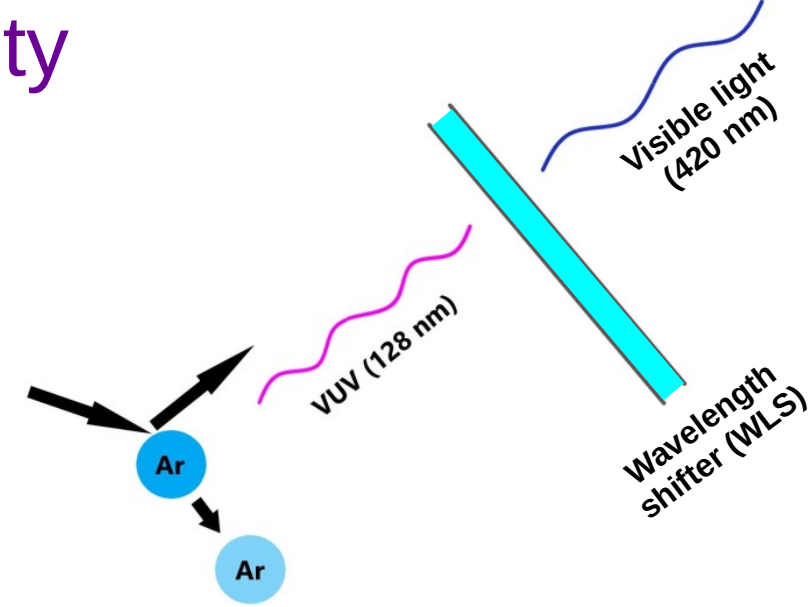
100000 kg

Argo: 400 t

Slide courtesy J. Monroe

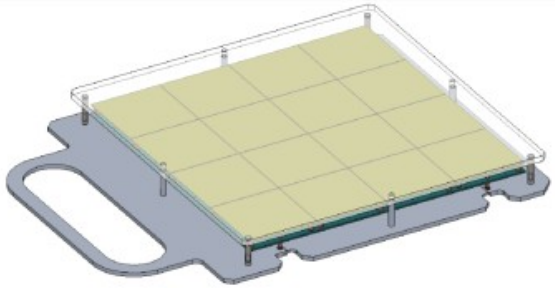
Our specialty

- **Light collection**
  - Wavelength shifter (WLS) materials
    - Liquid argon scintillates at 128 nm (VUV)
    - Proposed new scalable materials
    - Developed concept for new wavelength shifting materials for background mitigation
  - Reflector and optics configuration/optimization



- **... and light detection**
  - SiPM: new cutting edge devices, DarkSide-20k is the first experiment to use them on that scale
  - Collaboration with DarkSide-20k:

    Veto SiPM system: analysis, testing and development



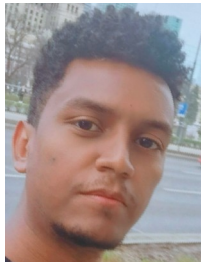
20cm x 20cm SiPM array

- **Main collaborations**:
  - Direct search for dark matter with liquid argon detectros:
    - **DEAP-3600** (running at SNOLAB, Canada)
    - **DarkSide-20k** (under construction in Italy)
    - **ARGO** (conceptual phase)
    - **DRD2/CERN** (liquid detector R&D)

    Global
    Argon
    Dark
    Matter
    Collaboration
  - Synergies: DUNE (via **CERN Neutrino Platform**), **KM3NeT** (with APC Paris)

Group profile






- Group members:
  - **Leader** Marcin Kuźniak
  - **PhD students:**
    - Sarthak Choudhary (graduated in June)
      - Pulse shape discrimination analysis + light collection optimization
    - Iftikhar Ahmad (graduated in February)
      - SiPM testing for DarkSide-20k
    - Samuel Belayneh
      - SiPM testing for DarkSide-20k, reflectors and WLS for DarkSide-20k
    - Aheesh Hegde
      - SiPM testing for DarkSide-20k, NEMESIS simulations
  - **Postdocs:**
    - Michał Olszewski
      - DS-20k database development
      - DEAP-3600 WIMP data analysis and database manager
  - **MSCA Fellow:** Andre Cortez (+ Pedro Silva, Diego Rodas)
  - **Support from technicians and an engineer**
- Past members: Theo Hugues, Cenk Turkoglu, Marek Walczak
- Access to electronics, chemistry and cryogenic (cleanroom) lab at CEZAMAT
- Cooperation agreement with the University of Warsaw, Chemistry Department

Grants and leadership roles

Ongoing

- M. Kuźniak, 2.1 MPLN/ 3 yr, *Search for dark matter with liquid argon detectors*, **OPUS, NCN**
- L. Roszkowski, Horizon Europe Teaming, 15 MEur/6 years (as a team member)
- A. Cortez, *"innovative STructures for improvEd Light colLection in ARgon-based TPCs"*, **MSCA Postdoctoral Fellowship, European Commission** (as supervisor)
- M. Kuźniak, 34 MPLN/4yr, Astrocent – Particle Astrophysics Technology Centre, **MAB FENG, FNP**

Submitted proposals:

- M-ERA.NET3 with Universite de Bordeaux, Univ. Jaume I de Castelon (Spain), Warsaw University of Technology (rejected)
- NCBR SMART FENG with Roltec Sp. z o.o., Łukasiewicz Research Network Industrial Chemistry Institute (as a consortium partner, rejected)
- FNP MAB FENG (as a group leader, rejected)
- **FNP MAB FENG (as the leader, awarded)**

Chosen leadership roles:

- APPEC Scientific Advisory Committee member
- DarkSide-20k review office member
- DRD2 collaboration work package leader
- LIDINE conference International Scientific Committee

Papers and conferences

1) *Benchmarking the design of the cryogenics system for the underground argon in DarkSide-20k, DarkSide-20k Collaboration, 2025, JInst, 20, P02016*
2) ***New candidate polymeric wavelength shifters for noble liquid detectors Kuźniak, M. et al., 2025, JInst, 20, C05006***
3) ***Quality assurance and quality control of the 26m2 SiPM production for the DarkSide-20k dark matter experiment, DarkSide-20k Collaboration, 2025, EPJC., 85, 534***
4) ***Demonstration of the light collection stability of a PEN-based wavelength shifting reflector in a tonne scale liquid argon detector, Gupta, V. Et al, 2025, JInst, 20, C05033***
5) *Flow and thermal modelling of the argon volume in the DarkSide-20k TPC, DarkSide-20k Collaboration, 2025, JInst, 20, P06046*
6) *Characterization of low energy argon recoils with ReD and ReD+, Ave, M. et al., 2025, JInst, 20, C06062*
7) *Position reconstruction in the DEAP-3600 dark matter search experiment, DEAP-3600 Collaboration, 2025, JInst, 20, P07012*
8) *Direct measurement of the 39Ar half-life from 3.4 years of data with the DEAP-3600 detector, DEAP-3600 Collaboration, 2025, EPJC, 85, 728*
9) ***Production, quality assurance and quality control of the SiPM Tiles for the DarkSide-20k Time Projection Chamber, 2025, EPJC, 85, 1334***

- **Conference presentations**
  - Polish Physical Society Meeting (Katowice), talk
- **Other presentations**
  - University of Warsaw, Physics Department, Institute of Expermintal Physics Seminar
  - Queen's University, Astroparticle Physics Seminar
- **Conference organisation**
  - PAiP-2025 — Particle Astrophysics in Poland| Astrocent/CAMK PAN: LOC chair
  - LIDINE 2025: LIght Detection in Noble Elements, Hong Kong: SOC member
  - DRD1 Collaboration Meeting| Astrocent/CAMK PAN: LOC member

DS-20k veto SiPM module testing

- One of our main obligations in DarkSide-20k: final cryogenic testing of SiPM modules for the veto before their installation in the detector
- Majority of them are tested at Astrocent
- Test stand completed in 2023-2024 and fully commissioned
- Intensive testing campaign Oct 2025 – Feb 2026: nearly 200 person-days of lab shifts

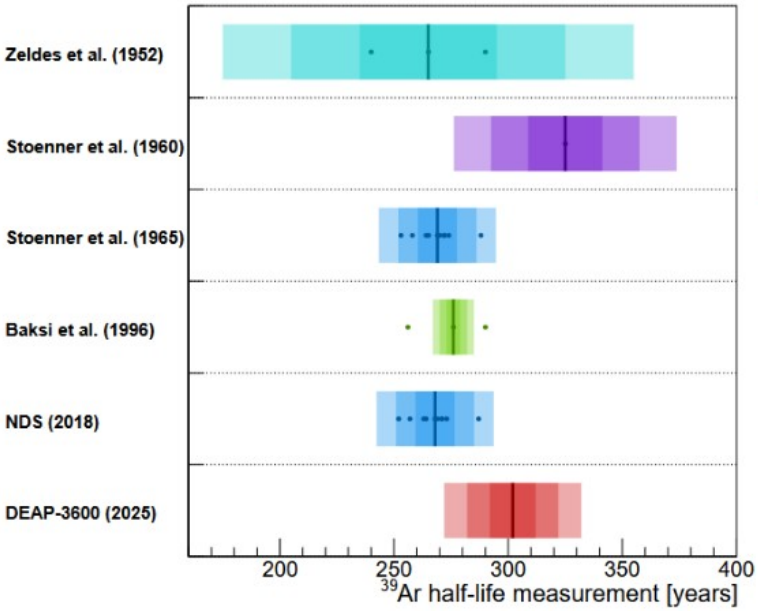
  => More in Samuel Belayneh's talk later today

Interesting by-product result

Ar-39: half-life measurement

Eur.Phys.J.C 85 (2025) 7, 728

In addition to impacting measurements sensitive to this isotope's half-life, such as studies of meteorites, this result is relevant for future experiments using atmospheric argon.



- Direct observation of the decay curve
- Analysis performed on $T_{livetime}$ = 3.4 years

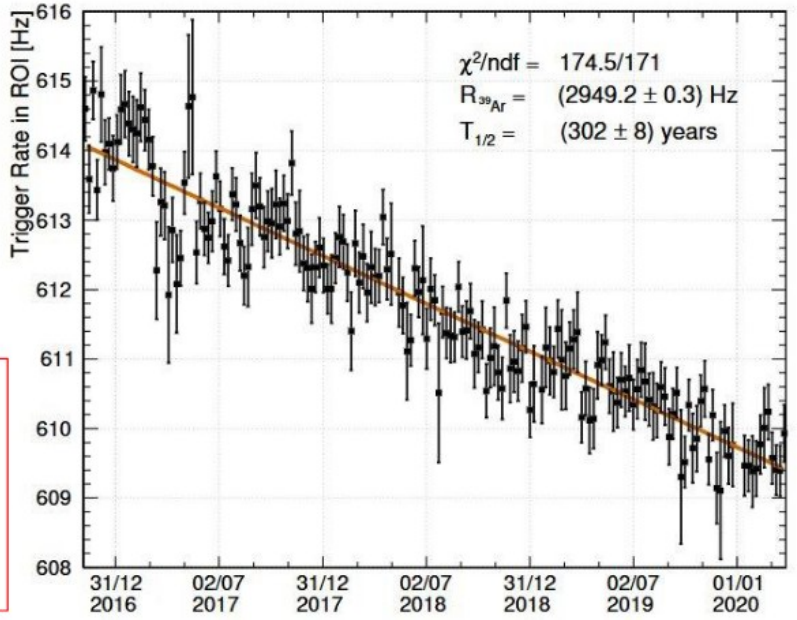


Fig. 7 The trigger rate fit for the full dataset. Each point here represents the rates averaged over a one week period. The best-fit values of R_{39Ar} and $T_{1/2}$ are shown with statistical uncertainties only.

Measurement	Half-life [years]	Method
Zeldes et al. (1952)	265 ± 30	Isotopic ratios of argon samples using mass spectrometry
Stoenner et al. (1960)	$325 \pm 16^{a}_{stat}$	Activity ratios of ^{39}Ar to ^{37}Ar
Stoenner et al. (1965)	$269 \pm 3_{stat} \pm 8_{sys}$	Activity ratios of ^{39}Ar to ^{37}Ar
Baksi et al. (1996)	$276 \pm 3_{sys}$	Isotopic ratios of ^{39}Ar to ^{38}Ar in a double-spike using mass spectrometry
NDS (2018)	$268 \pm 8_{sys}$	Re-evaluation of the Stoenner et al. (1965) result with an updated ^{37}Ar half-life
DEAP-3600 (2025)	$302 \pm 8_{stat} \pm 6_{sys}$	Direct observation of the decay curve

First direct measurement of the 39Ar half-life
2.5σ tension with Nuclear Data Sheets (NDS)

12

Consequence: past Ar radioisotope dating results require a significant correction (typically ~10% for 1000 year old samples). Relevant for ice cores, and tracking climate changes.

MAB Astrocent: Particle Astrophysics Technology Centre

- **Group 1 “Photonics for astroparticle physics and sustainable energy” (Marcin Kuźniak)**
  - WLS coatings / Luminescent downshifters for photovoltaics
  - Novel photosensors
    - Partcipation in testing / development of Si-based devices
    - New organic / hybrid photodetectors
- **Group 2 “Medical physics and radiation detectors” (Masayuki Wada)**
  - LAr-based PET (3dπ), Xe-doped LAr, digitally readout and UV-sensitive SiPMs
- **Group 3 “Electronics, seismic and environmental sensors” (Mariusz Suchenek)**
  - Networks of seismic or infrasound sensors (for ET, Virgo, KM3NeT and commercial applications)
  - Reliable, long-lifetime electronics for use in extreme environments

Summary

- Much time last year devoted to project development and proposal writing
- Massive campaign of vPDU testing for DarkSide-20k nearly complete
- Gearing up for the next major obligation: production of ~300 m2 od WLS and reflector liner for the detector, then installation at Gran Sasso
- New physics results from DEAP just around the corner (observation of a solar neutrino absorption on Ar-40, new WIMP limits)
- New MAB Astrocent recently launched; stable funding for the next 4-5 years is in place!

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