

Progress report

Marcin Kuźniak
mkuzniak@camk.edu.pl

Group Leader

“Silicon Photomultiplier Systems for Astroparticle Physics and Medical Physics”

ASTROCENT



NICOLAUS COPERNICUS
ASTRONOMICAL CENTER
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NATIONAL SCIENCE CENTRE
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European
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Smart Growth



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Foundation for
Polish Science

European Union
European Regional
Development Fund



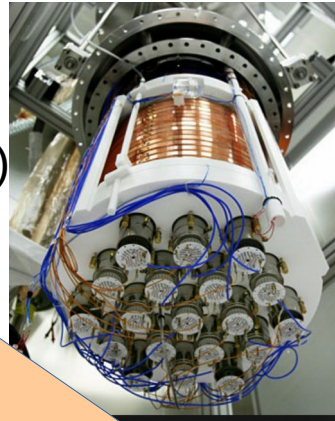
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 952480

LAr-based dark matter detectors

2010

10 kg

DarkSide-50
(50 kg, LNGS)



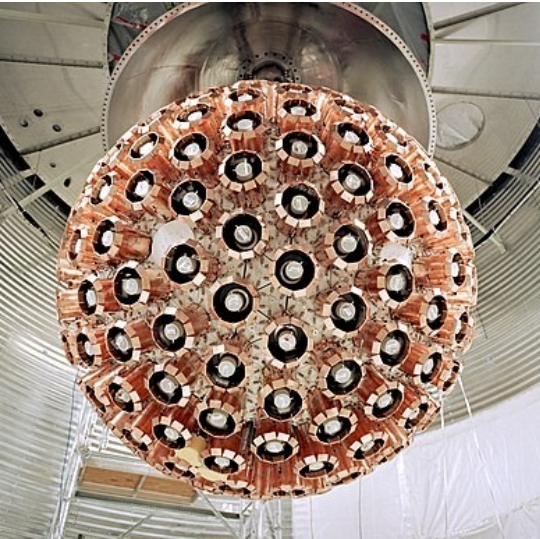
100 kg

ArDM (1t, LSC)

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

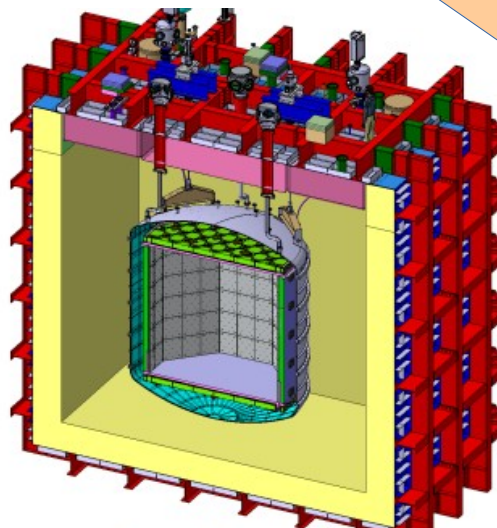
1000 kg

DEAP-3600 (3.3t, SNOLAB)



2015

Global Argon Dark Matter Collaboration formed



2020

100000 kg

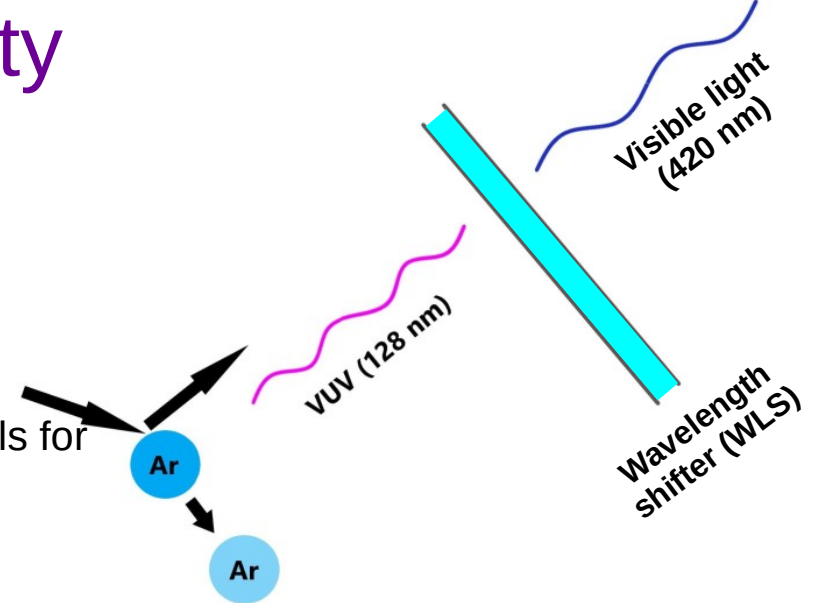
Argo: 400 t

DarkSide-20k
(50t, LNGS)

Our specialty

• Light collection

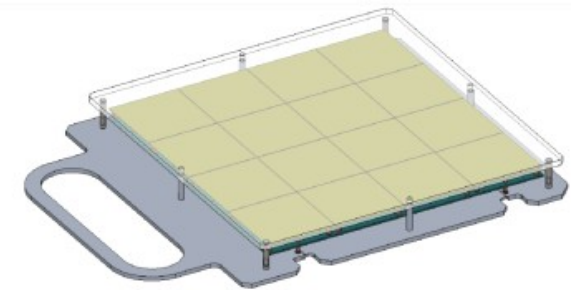
- Wavelength shifter (WLS) materials
 - Liquid argon scintillates at 128 nm (VUV)
 - Proposed new scalable materials
 - Developed concept for new wavelength shifting materials for background mitigation
- Reflector and optics configuration/optimization



• ... 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

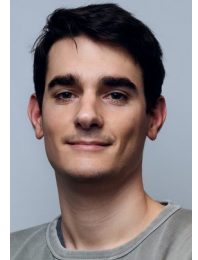
• Main collaborations:

- Direct search for dark matter with liquid argon detectors:
 - **DEAP-3600** (running at SNOLAB, Canada)
 - **DarkSide-20k** (under construction in Italy)
 - **ARGO** (conceptual phase)
- Synergies: DUNE (via **CERN Neutrino Platform**), **KM3NeT** (with APC Paris)

**Global
Argon
Dark
Matter
Collaboration**

Group 1 profile

- Group members:
 - **Leader** Marcin Kuźniak
 - **2 PhD students:**
 - Sarthak Choudhary
 - Pulse shape discrimination analysis + light collection optimization
 - Theo Hugues (cotutelle with APC Paris, [graduating](#))
 - DEAP-3600 physics data analysis
 - Annual modulation analysis for DarkSide-50
 - **2 Postdocs:**
 - Michał Olszewski
 - Monte Carlo simulations
 - Marek Walczak ([moving on to GSSI](#))
 - SiPM analysis software development, analysis and testing
 - **Visiting scientist:** Andre Cortez
 - **Support from technicians and an engineer**
- Access to electronics, chemistry and cryogenic (cleanroom) lab at CEZAMAT
- Cooperation agreement with the University of Warsaw, Chemistry Department





Completed

- European Commission Horizon 2020 Twinning, "**DarkWave: Novel technologies for dark matter search and frontier astroparticle physics experiments**"
 - **900 kEUR budget, ~80 people involved**
 - Consortium of CAMK (coordinating institution), APC/CNRS, GSSI, INFN and TUM
 - Training, travel, short and long-term exchange support **for all AstroCeNT groups**
 - Enabled key contributions to DarkSide-20k, Virgo, Einstein Telescope:
 - Admin. coordination / communication by Y. Hoika
 - **Excellent feedback from EC following the final review meeting, awaiting acceptance of the final report any day now**

Ongoing

- M. Kuźniak, 2.1 MPLN/ 3 yr, Search for dark matter with liquid argon detectors, **OPUS, NCN**

Submitted

- Kuźniak (with Gawron, Suchenek, Wada), 30 MPLN/5 yr, AstroCeNT – Particle Astrophysics Science and Technology Centre, **MAB FENG, FNP**

Papers and conferences

- 1) *SiPM cross-talk in liquid argon detectors*, Boulay, M. G.; Camillo, V.; Canci, N. ..., 2023, *FrP*, 11, 1181400
- 2) *Study of cosmogenic activation above ground for the DarkSide-20k experiment*, Elersich, A.; Agnes, P.; Ahmad, I. ..., 2023, *APh*, 152, 102878
- 3) *Measurement of isotopic separation of argon with the prototype of the cryogenic distillation plant Aria for dark matter searches*, Aaron, E.; Agnes, P.; Ahmad, I. ..., 2023, *EPJC*, 83, 453
- 4) *Precision measurement of the specific activity of ^{39}Ar in atmospheric argon with the DEAP-3600 detector*, Adhikari, P.; Ajaj, R.; Alpízar-Venegas, M. ..., 2023, *EPJC*, 83, 642
- 5) *Sensitivity projections for a dual-phase argon TPC optimized for light dark matter searches through the ionization channel*, Agnes, P.; Ahmad, I.; Albergo, S. ..., 2023, *PhRvD*, 107, 112006
- 6) [M. Kuźniak, Direct detection of heavy dark matter particles \(\$> \sim 1\$ GeV\), Proceedings of Science \(TAUP2023\) 018 \(2023\)](#)

- **Preprints**

- [DarkSide-50 collaboration, P. Agnes et al. \(T. Hugues, M. Kimura, M. Kuzniak, M. Wada\) Search for dark matter annual modulation with DarkSide-50, arXiv:2307.07249 \(2023\)](#)
- [DarkSide-50 collaboration, P. Agnes et al. \(T.Hugues, M.Kimura, M.Kuzniak, M.Wada\), Long-term temporal stability of the DarkSide-50 dark matter detector, arXiv:2311.18647 \(2023\)](#)
- [S. Choudhary et al., Cryogenic setup for the characterization of wavelength-shifting materials for noble element radiation detectors, LIDINE 2023 peer-reviewed proceedings, submitted to Journal of Instrumentation \(2024\)](#)

- **Conference presentations**

- LIDINE 2023 (Madrid)
- TAUP 2023 (Vienna), invited plenary review talk
- IRAP Conference (Warsaw)

- **Other presentations**

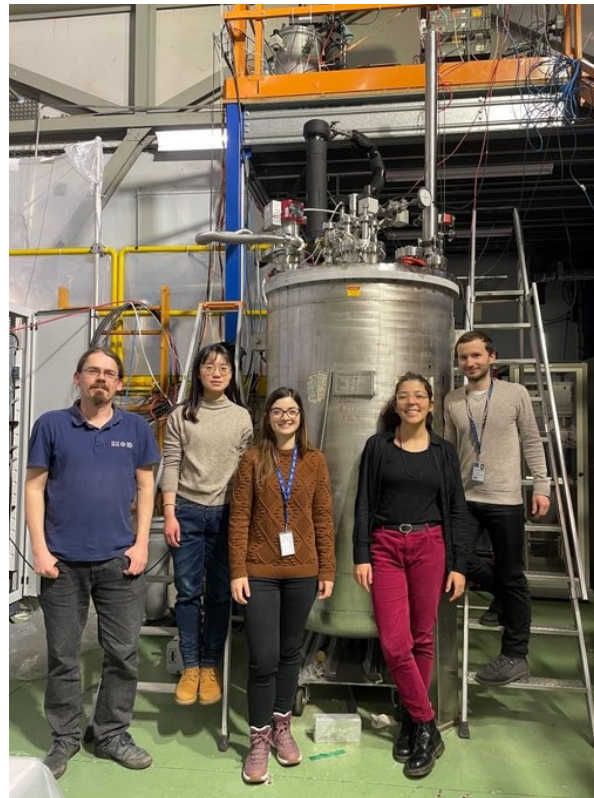
- SNOLAB Seminar, CAMK Seminar

- **Other**

- Elected to APPEC (AstroParticle Physics European Consortium) Scientific Advisory Committee

General purpose WLS reflector campaign

- Jointly with TUM, Uni Zurich, NIKHEF, Uni Edinburgh and CERN
 - Groups from LEGEND, DUNE and DarkSide-20k
- Most promising combination of reflector (ESR) and PEN identified with table-top measurements (Zurich, TUM, Astrocent)
- Large scale LAr test completed at CERN in February to demonstrate light yield and light yield **stability over 2 weeks** long run with an alpha source inside:
 - 1 m tall aluminum cage lined with ESR/PEN (LAr gap inbetween)
 - Viewed by 2 PMTs from the top (Vis and VUV)
 - Analysis currently ongoing

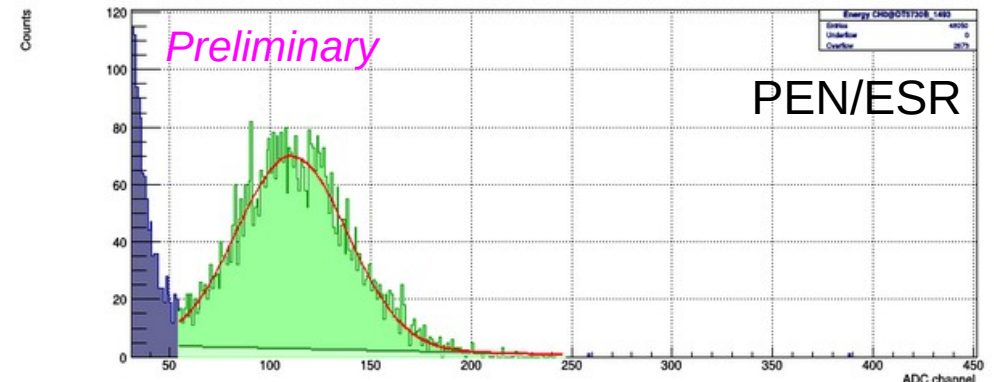
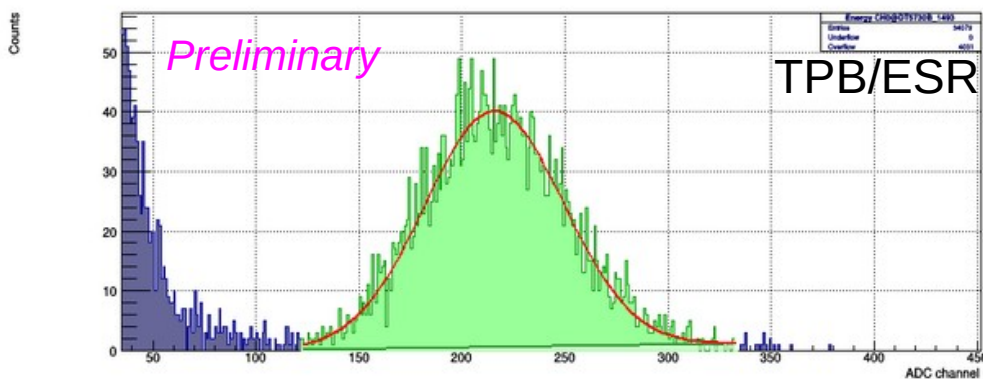
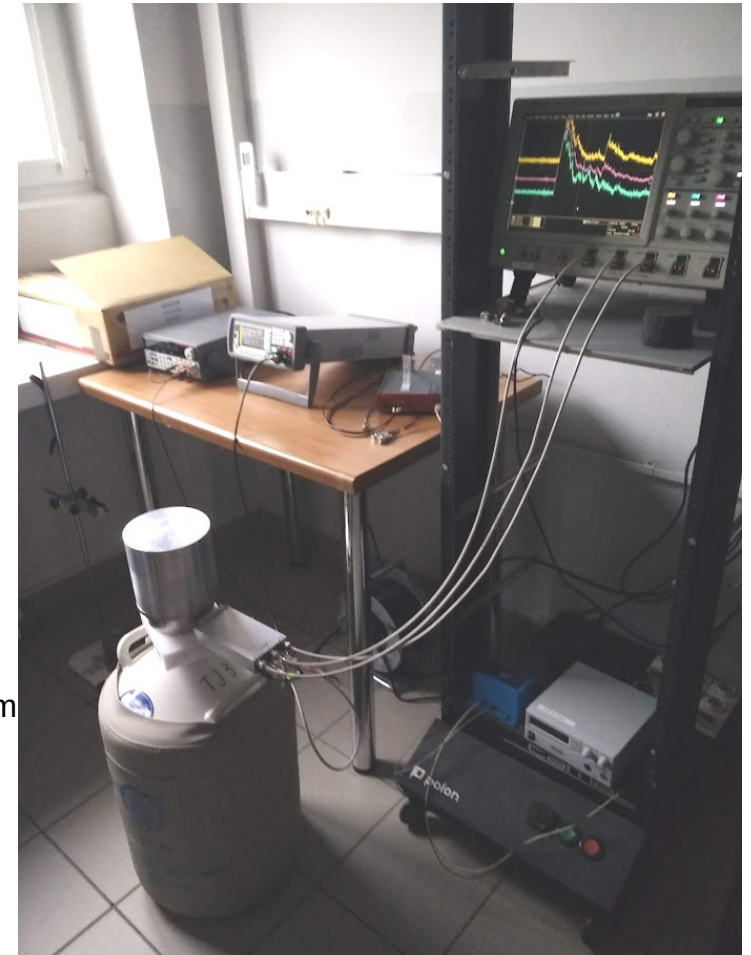
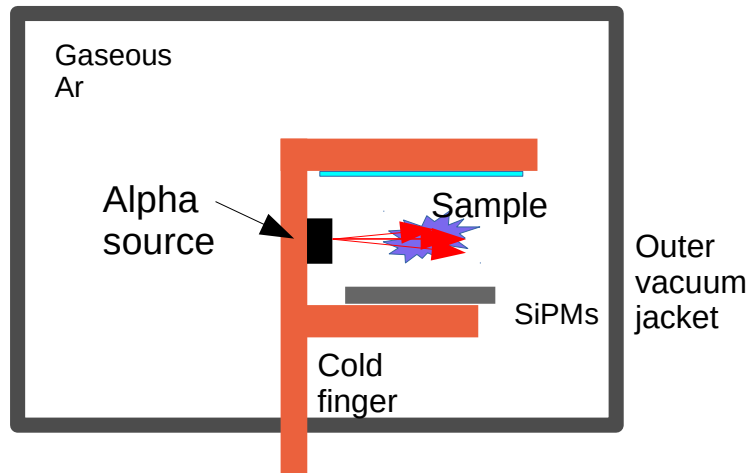


Test stand @ AstroCeNT for quality control

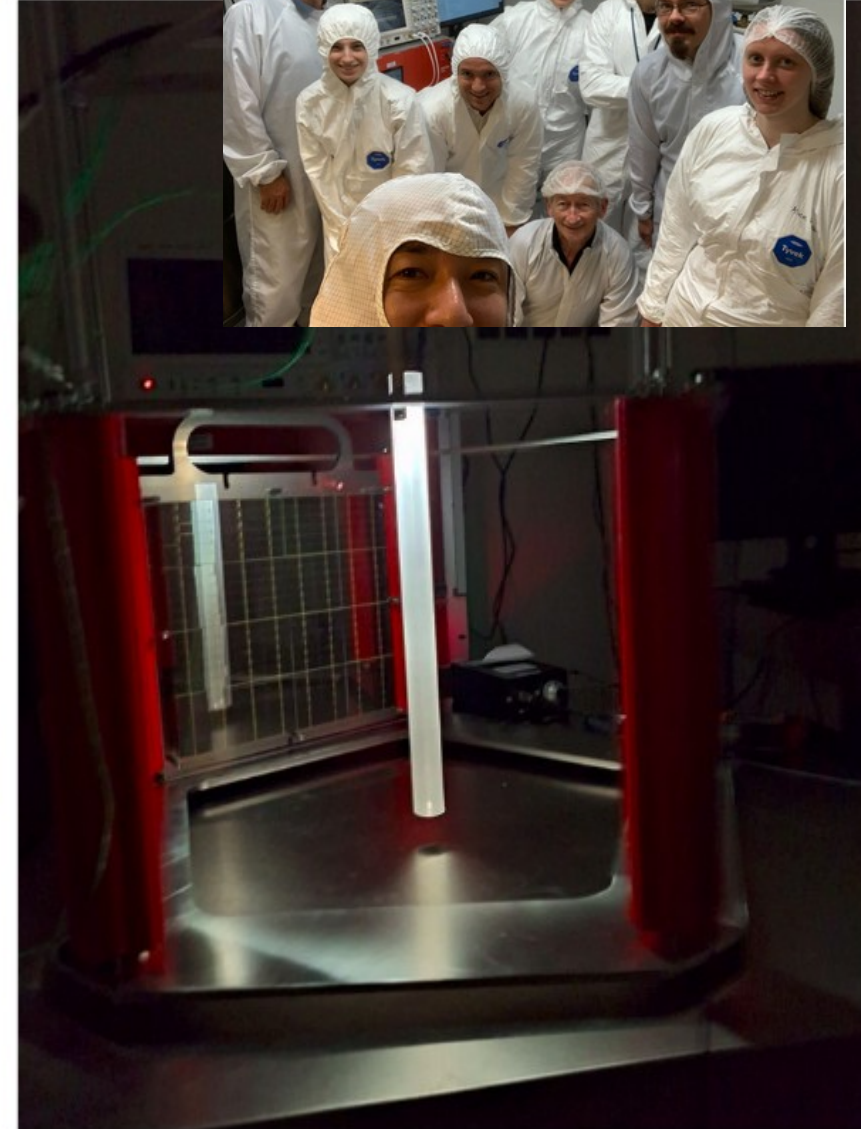
- DarkSide-20k to use ~300 m² of PEN as the WLS in the veto
- Recently successfully commissioned an alpha-excited gaseous Ar cell with a cryogenic stage for PEN WLS quality control

Next steps:

- QC for DarkSide-20k
- New materials
- Add a nanosecond-pulsed VUV source
- Gaseous TPC configuration



DS-20k veto SiPM module testing



- ISO-7 class cleanroom in CEZAMAT laboratory
- Allows tests of 5 (10) units per cooldown
- CAEN power supplies and VX2740 digitizer

Summary

- ★ Two fully functional cryogenic test facilities at the cleanroom lab
- ★ Successful wrap-up of the DarkWave project
- ★ Most of time and effort in 2023 devoted to funding proposals - for the group and entire Astrocent:
 - Near-term future secured with NCN OPUS
 - MAB FENG results coming up within weeks
 - (Horizon Europe Teaming for Excellence results this Fall)