

ASTROCENT

Explore the hidden Universe

Particle Astrophysics Science and Technology Centre

<https://astrocent.camk.edu.pl/>

Leszek Roszkowski



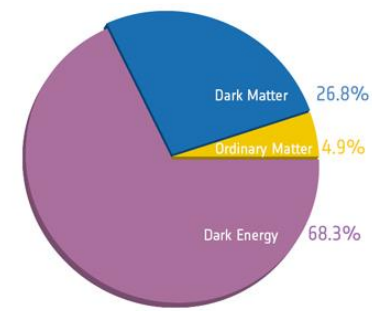
Vision



Particle astrophysics

9 Nobel prizes so far

Study of elementary particles in the invisible Universe



Fruitful cooperation of:

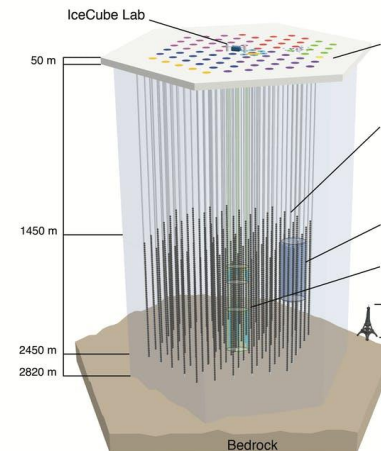
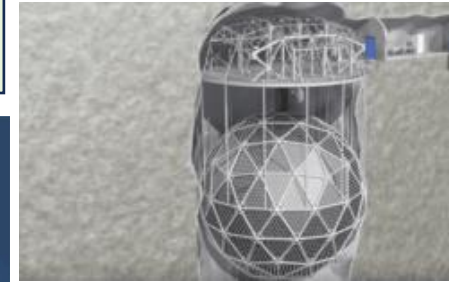
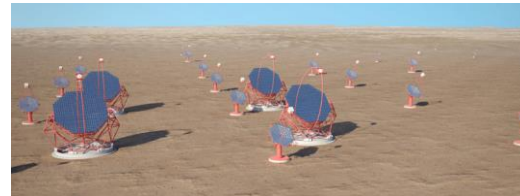
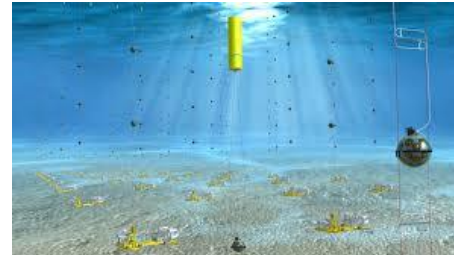
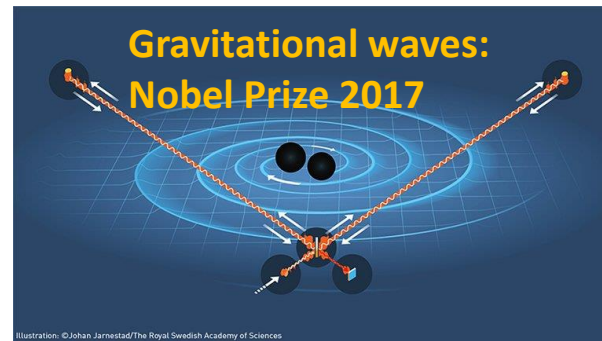
- Fascinating, frontline, highly promising science (with bright future), and
- Innovative, cutting-edge technologies

- ❑ Dark matter
- ❑ Gravitational waves
- ❑ Neutrinos
- ❑ ...

Technological requirements:

- Extremely sensitive
- Prepared for long-term use
- Work in extreme conditions
- Own/limited power supply
- Sturdy, no/little option for repair
- Process huge amount of data, online
- Requires inventing new solutions
- Affordable
- ...

- Need teams of scientists, engineers, software programmers
- Need innovative R+D



AstroCeNT

Particle Astrophysics Science and Technology Centre

- ❖ International Research Agenda: new centre of excellence
- ❖ Funding: 38 MPLN (8.3 MEuro) for 5 years (1 July '18 – 30 June '23)
- ❖ Autonomous department of CAMK PAN

source: FNP
(EU structural
funds)

31 December '23

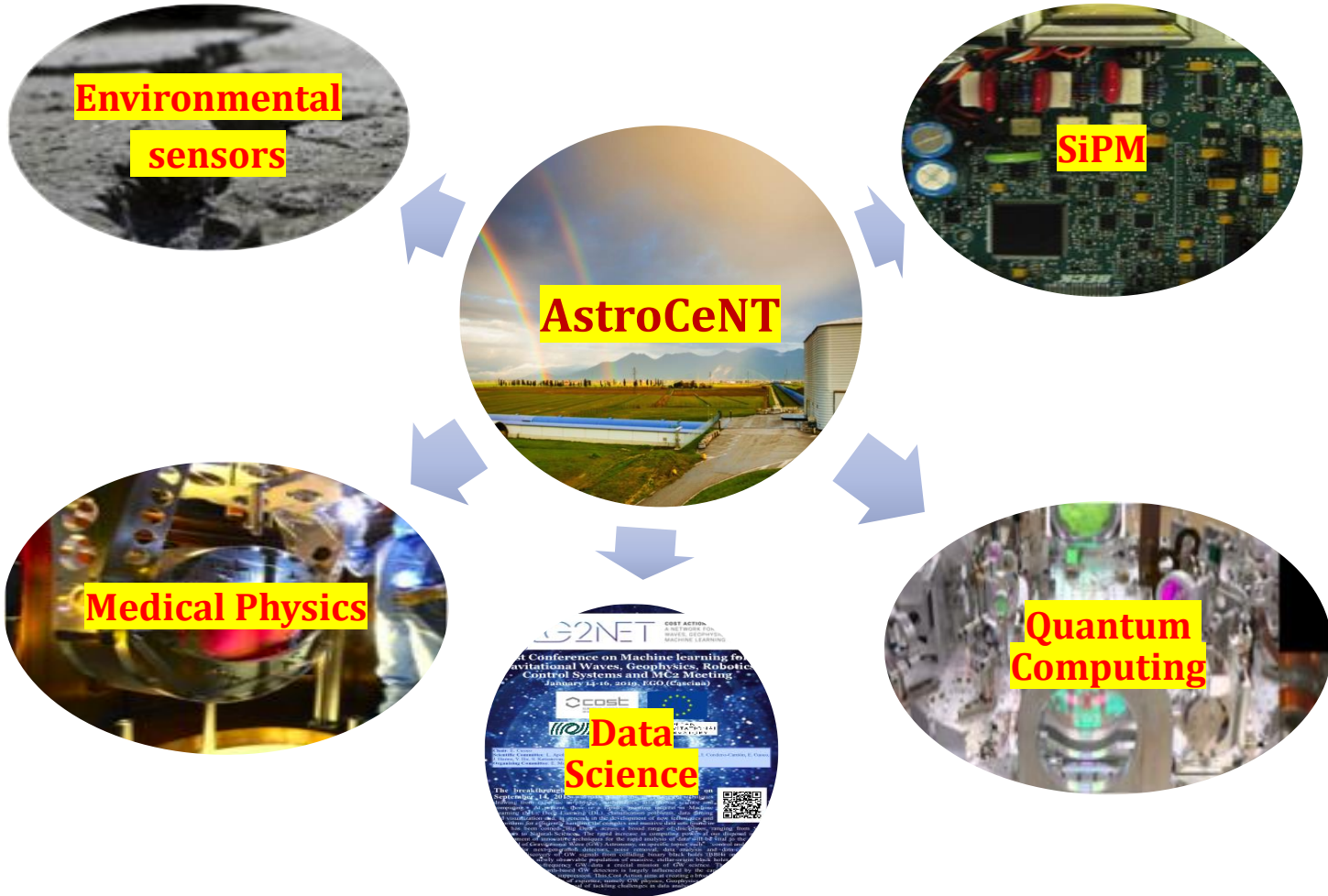
Main objectives:

- Studies of the invisible Universe (gravitational waves, dark matter, neutrinos...)
- Ultra-sensitive instruments to detect extremely faint signals
 - Seismic sensors, modules of silicon photomultipliers (SiPMs), ...
- Big data collection and processing
- Applications to hi-tech industry and medicine (e.g., PET)
- ...

Big
science

Innovative
technologies

AstroCeNT and new technologies



Main research directions, collaborations and partners

main roadmap directions (APPEC)

Large experimental collaborations:

Dark matter:

- DarkSide, DEAP-3600
- Global Argon Dark Matter Collaboration (ARGO) - future

Gravitational waves/seismic noise:

- Advanced VIRGO/LIGO,
- Einstein Telescope - future

Neutrinos:

- KM3Net (observer)
- Hyper-Kamiokande (joined 2021)

Technology for science and industry:

- Silicon Photo Multiplier (SiPM) systems
- systems of seismic sensors
- data acquisition and large data set processing
- quantum computing and artificial intelligence
- Liquid Argon PET

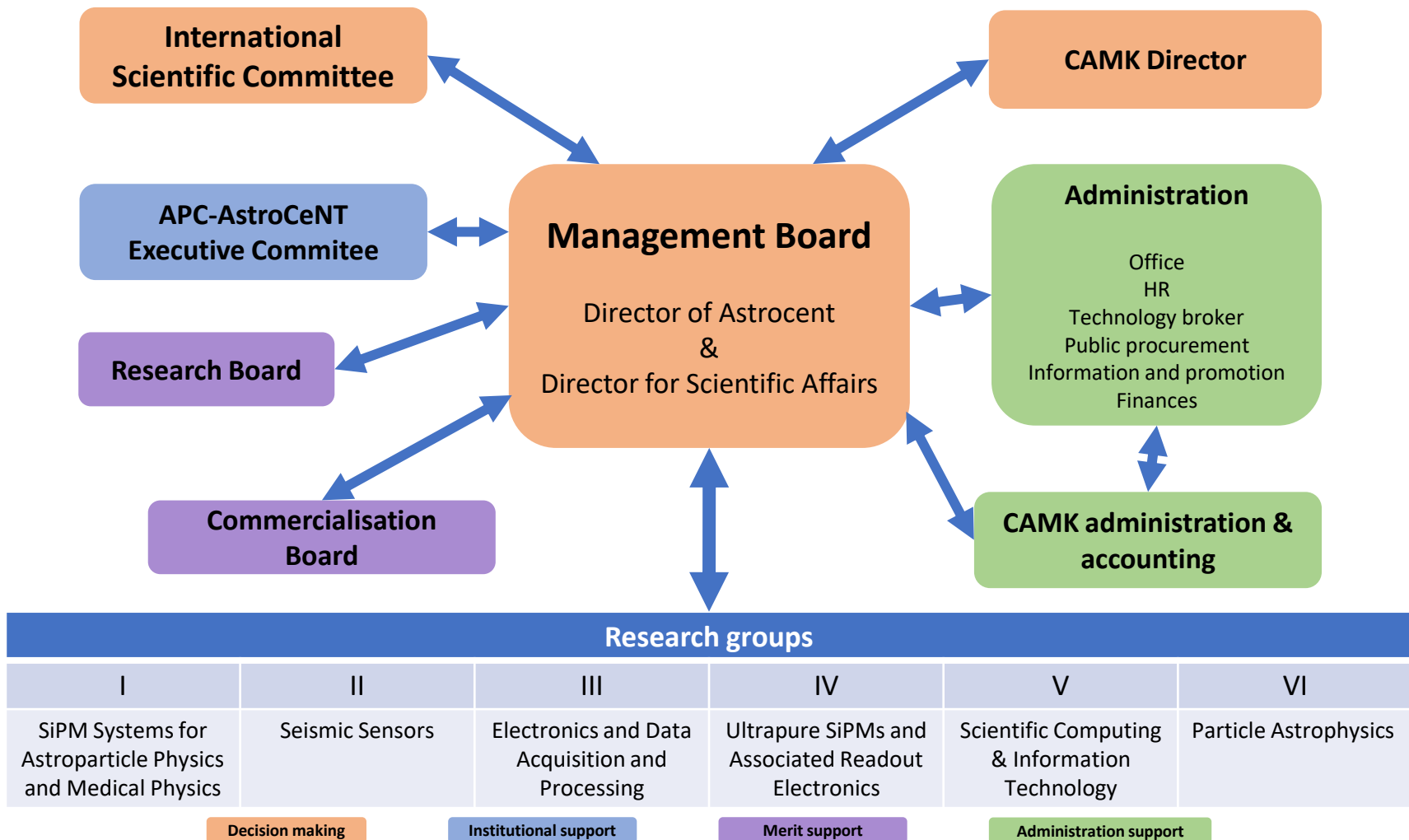
Main scientific partners:

- APC
- European Gravitational Observatory
- Princeton University
- Gran Sasso Science Institute
- + TUM, (via DarkWave)

- National Centre for Nuclear Research
- Warsaw University of Technology
- University of Warsaw

Strategic partner APC

- growing collaboration in large international experiments: Virgo (GW), DarkSide (DM), KM3Net (neutrino), ...
- Joint (cotutelle) student
- plan to expand KM3Net and other collaboration involvement

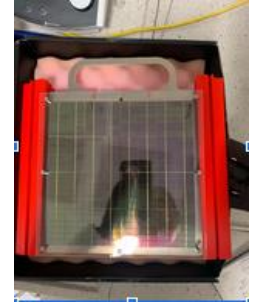


Astrocent Research Groups and main activities

Group 1: SiPM Systems for Astroparticle Physics and Medical Physics

Leader: Dr Marcin Kuźniak, prof. CAMK

- Dark matter experiments: DEAP-3600 (running), DarkSide-20k (under construction)
- Light detection and collection (wavelength shifters and photosensors) in cryogenic dark matter and neutrino detectors)* in LAr, synergy with DUNE



Group 2: Seismic Sensors

Leader: Prof. Tomasz Bulik

- seismic and environmental sensors for gravitational wave detectors (Virgo, ET) and for industry



Group 3: Electronics and Data Acquisition and Processing

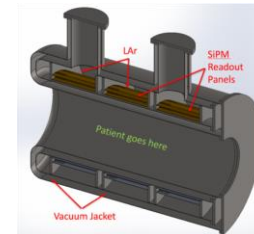
Leader: Dr Mariusz Suchenek

- autonomous seismic sensors for GW detectors and for industry
- Seismic data acquisition and processing

Group 4: Ultrapure SiPMs and Associated Readout Electronics

Leader: Dr Masayuki Wada

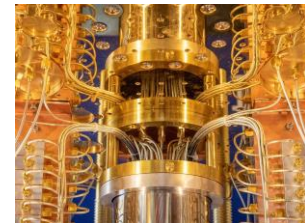
- Ultrapure photodetectors (DM search DarkSide, neutrinoless double beta decay)
- Liquid Argon PET scanner (Princeton U, ...)



Group 5: Scientific Computing and Information Technology

Leader: Prof. Piotr Gawron

- Application of deep neural networks for GW data analysis
- Bayesian modelling of events from dark matter detectors (DEAP-3600)



Group 6: Particle Astrophysics

Leader: Prof. Leszek Roszkowski

- Dark matter theory of relevance to experiments
- New physics beyond the Standard Model
- Non-standard models of the Big Bang

Dark matter:
1/4 of the
Universe

Next generation of sensors

(Autonomous, without communication and synchronization cables)

Developed from research on gravitational wave detection

- Characterized by their low cost (~8x relative to commercial products), low power consumption and high sensitivity

Two technologies fully worked out by Gp 3 (led by M. Suchenek):

- **Autonomous Seismic Sensor** patent applications pending approval
 - 48 units produced (NCN MINIATURA grant) for research
 - commercialisation pending signing contract with Ergo Plus Polska
- **Acoustic Infrasound Sensor**
 - 190 units produced (NCN MINIATURA grant) for The European Gravitational Observatory

Potential applications beyond science with commercialisation prospects:

- perimeter defence, surveillance
- wind farm monitoring
- Large constructions (e.g., skyscrapers) and health diagnostics
- exploration of geothermal deposits, soil testing in mining industry
- earthquake monitoring
- ...

(For more info, see poster)

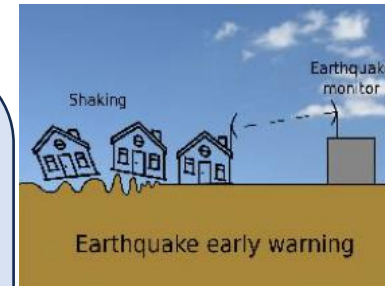
seismic sensors can tell the origin of vibrations (vehicles, people, animals,...) and their location



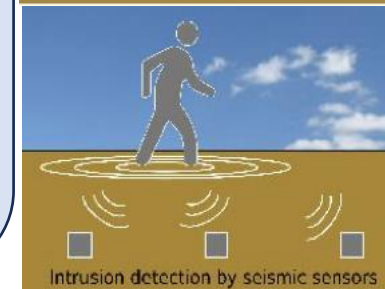
Autonomous Seismic Sensor



Acoustic Infrasound Sensor



Earthquake early warning



Intrusion detection by seismic sensors

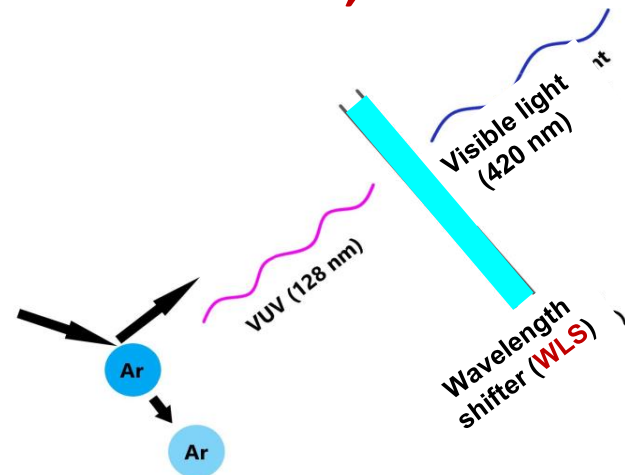
Spinoff from dark matter searches for photovoltaics, etc

➤ In liquid argon based detectors of dark matter and neutrinos it is necessary to convert ultraviolet scintillation light (at 128 nm) to visible light, which can be efficiently registered

➤ M. Kuźniak et al (Gp1) at AstroCeNT developed scalable large format polymeric reflector and WLS films, as well as tailored WLS

Potential applications:

- photovoltaics: increased cell efficiency
- environmentally-friendly alternative to current fluors
- radiation counters and dosimetry
- ...



(For more info, see poster)

Cooperation with Roltec Sp. z o.o., Polish producer of thin-film CIGS photovoltaic cells



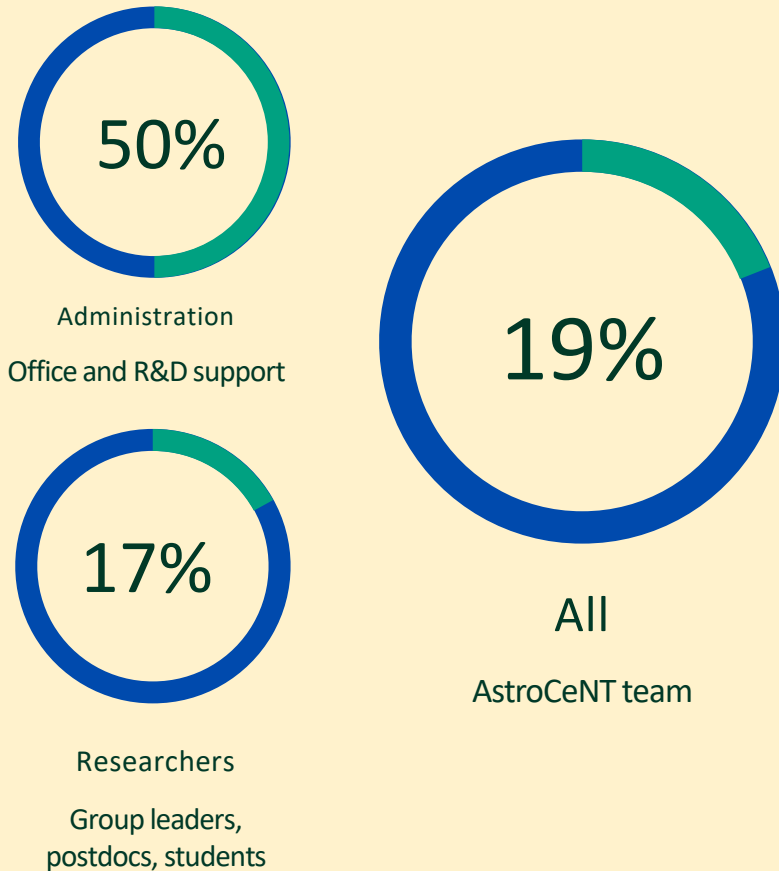
AstroCeNT -- some highlights

... up and flying...

including 20 postdocs, 8 technicians,
6 PhD students + several internships (ug students)
+ 5 long-term visitors

- **Set up from scratch into an internationally recognised research centre**
 - **Research groups created following basically assumed schedule**
 - **Interdisciplinary (physics, engineering, programming,...)**
- **Currently 41 researchers from 10 countries, 5 continents**
- **Member of 7 large international experimental collaborations**
- **MoUs with SNOLab and McDonald Institute (Canada)**
- **Several grants, notably 3yr EU Twinning grant (900kEuro) and Hyper Kamiokande (~8M PLN, our contribution to the world biggest and most advanced neutrino detector)**
- **Three technological innovations: one utility model granted, two patents pending**
- **Collaboration with research and industrial partners established and growing**
 - **Two formal agreements signed, one in preparation**
- **Co-operation with our strategic partner APC flourishing**
- **Strong support from International Scientific Committee**
- **PR, visits and public talks by Nobel Prize Laureates and other VIPs, promotional film**
- **...**

Gender composition of AstroCeNT



Women in decision-making positions

ISC OF ASTROCENT

Prof. Roxanne Guenette – the University of Manchester, UK
Dr Federica Petricca – Max Planck Institute, Germany
Prof. Silvia Pascoli – University of Bologna, Italy

ASTROCENT TEAM

Dr Marta Borowiec – Director for Scientific Affairs

NCAC PAS: GENDER EQUALITY PLAN (2023-2026): [LINK](#)

A strategic document aimed at increasing awareness of existing biases and differences in the treatment of men and women, and enabling all employees and doctoral students to have equal opportunities for scientific and personal development.

AstroCeNT in numbers

GROUP
LEADERS

6

POSTDOCS

24

PHD STUDENTS

6

TECHNICIANS

11

STUDENTS

12

LONG-TERM
VISITING SCIENTISTS

5

PATENTS

1#

PUBLICATIONS

~150

TRAVELS

~300

CONFERENCES
AND SYMPOSIA

~150

HONORARY
MEMBERSHIPS

3*

- plus two pending

* T. Bulik elected to Polish Academy of Sciences
(corresponding member)

L. Roszkowski elected to:

- European Academy of Sciences and Arts
- Copernican Academy

Public talks by Nobel laureates Art McDonald and Barry Barish (22 Feb. 2023)



L. Roszkowski, FNP conference, 12.10.2023

Some events and PR activities

- **20-21 May '19:** 4th biennial conference "Particle Astrophysics in Poland"
Special session devoted to Astrocent:
 - keynote talk by **Dr Art McDonald, a 2015 Nobel Prize in Physics** winner,
 - several VIPs, attended incl. ambassadors of France and Italy & president of INFN
 - Astrocent announced to join DEAP-3600, DarkSide and GADMC/ARGO



- **2 September '19:** visit of Governor General of Canada and meeting with FNP & government officials and ISC representatives

- **1 June 2022:** visit of Vice Minister of Education and Science, Dr T. Rzymkowski



- **22 February 2023:** Visit of B. Barish and A. McDonald



- **21 February 2020:** visit of the President of CNRS, Prof. Alain Schuhl



- Conference LIDINE—2022 hosted by Astrocent on 20-23 September (local chair: M. Kuźniak)

L. Roszkowski, FNP conference, 12.10.2023

- **23 June 2023:** Visit of B. Barish



Grants and other income – partial list

Title	PI	Source and scheme	Amount	Period	Remarks
AstroCeNT: Particle Astrophysics Science and Technology Centre	LR	FNP, Int. Research Agenda	38 MPLN	07/18-06/23	Main IRA grant
Dark matter search with liquid argon	LR	IN2P3-COPIN	24 person-days	01/20-12/20	Scientific exchange with APC, LPNHE Paris and CPPM Marseille
Novel technologies for dark matter search and frontier astroparticle physics experiments (DarkWave)	MK	Horizon 2020-WIDESPREAD-2018-2020	880 kEUR	07/20-06/23	Consortium DarkWave: AstroCeNT (coordinator), APC, GSSI, TUM, INFN. Support for scientific exchange and equipment
Development of the Most Sensitive Dark Matter Detector with Liquid Argon	MW	NCN, Sonata BIS	2852 kPLN	Nov 22 – Oct 25	2 postdocs, 2 PhD students, equipment
PROBES of new physics and technological advancements from particle and gravitational wave physics experiments. (Europe - USA- Asia)	LR	Horizon 2020, MCSA-RISE 2020	2 189 600 Euro (total), 32 200 Euro (CAMK)	March 2022 - Feb 2024 (CAMK)	EU consortium grant CAMK: Scientific exchange and trainings for 7 person/months
LUMI-QPI	PG	EuroHPCJU	225 kEUR	Q2 2023-Q2 2028	To provide a European-wide quantum computing environment integrated with the EuroHPC infrastructure
EuroQHPC-Integration	PG	EU	449,828 Eur (total), ~0.5 Meuro (CAMK)	2024, 4 yrs, submitted	Linked to LUMI-QPI
Hyper-Kamiokande	MZ	MEiN	67 596 799,26 PLN (total), 8 985 964,47 PLN (CAMK)	Dec 2022 - Nov 2027	1 technician, international neutrino detector construction project
Methods for the reconstruction of signals from seismic detector networks	MC	NCN, Miniatura-6	48 048,00 PLN	Aug 2022 – July 2023	Materials, small equipment and services
Environmental Noise Studies with Infrasound Microphone Array	MS	NCN, Miniatura-6	49 742,00 PLN	Aug 2022 – July 2023	Materials, small equipment and services
Development of the Most Sensitive Dark Matter Detector with Liquid Argon	MW	NCN, Sonata-Bis 11	2 852 105,00 PLN (614 kEUR)	Dec 2022 – Dec 2025	Funds for laboratory equipment, consumables, travels and remuneration (2 postdocs, 2 PhDs and technician)
The feasibility study of constructing a tonne-scale dual-phase argon detector for light dark matter searches	MW	NCN, Sheng-3	687 066,00 PLN (148 kEUR)	36 months SUBMITTED	Project in cooperation with Institute of High Energy Physics, Chinese Academy of Science laboratory equipment, consumables, travels and remuneration
Search for dark matter with liquid argon detectors	MK	NCN, OPUS-24	2 151 300,00 PLN (463 kEUR)	36 months granted	Funds for laboratory equipment, cleanroom rental costs, consumables, travels and remuneration (PI + co-investigator, postdoc, 1 PhD)
Astrocent Plus: Particle Astrophysics Science and Technology Centre	LR	EU	15 MEuro	Q3 2024 (?) – 6 years	Teaming for Excellence , Passed to 2 nd stage, in preparation
Astrocent: Particle Astrophysics Science and Technology Centre	MK	FNP	30 MPLN	Q1 2024 (?) – 5yrs, submitted	IRA competition grant, pending decision

End of Project in sight

➤ **Budget spending on track**

expected underspent at ~110-150 kPLN (0,3% - 0,4%)

➤ **All grant indicators already exceeded initially declared values**

2 formal co-operation agreements signed, one being prepared

➤ **Two patents pending approval and one granted (utility model)**

➤ **Co-operation with industry developed (groups 1, 3, 5)**

➤ ...

Audyt NCBR / Audit of National Centre for Research and Development

15 October 2020

- Część formalna: bez żadnych korekt
- Część merytoryczna (15.10.20):

C. OCENA ZGODNOŚCI REALIZACJI PROJEKTU Z ZAŁOŻENIAMI ZAWARTYMI WE WNIOSKU I/LUB UMOWIE O DOFINANSOWANIE PROJEKTU

II. Czy zakres wykonanych w ramach etapów/zadań prac merytorycznych jest zgodny z zaplanowanymi we wniosku/umowie o dofinansowanie?

TAK NIE

Uzasadnienie i opis zrealizowanych zadań/etapów

What deserves special emphasis is the creation of administrative foundations in the first two years of the project (management of research groups, IP protection, creation of the position of a technology broker and HR expert), ... and, above all, the employment of very good scientists as group leaders.

the selection of leaders was carried out properly, which guarantees a high scientific level of fundamental and applied research conducted at the Center.

It is also worth pointing out the strong presence of AstroCeNT in various international networks and programs, which makes the initiative recognizable. Combined with the fact that the technologies developed at the Center are attractive to external partners, this is a very good forecast for further intensive development and further building of the position in the international arena.

Biggest achievements...



Thank you

Backup

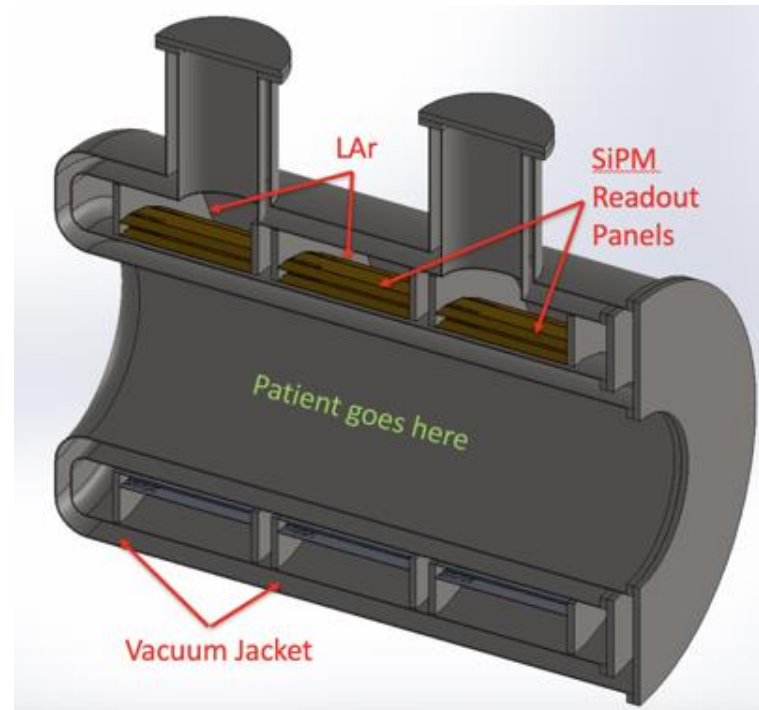
Group 4 (M. Wada):

MEDICAL APPLICATION

LIQUID ARGON PET SCANNER

X

- ▶ Positron emission tomography (PET) scanner measures physiological function of human body (effective against such as **Alzheimer** and **Parkinson** diseases)
- ▶ 3D position identification with **sub-cm spacial resolution** for each emission
- ▶ High detection efficiency to minimize radio active dose (especially **important for pediatric patients**)
- ▶ **SiPM readout is crucial**



Liquid Argon technology for Dark matter search is applicable in medical science!!