

Institute of Experimental  
and Applied Physics, CTU in Prague  
- scientific activities

Karel Smolek

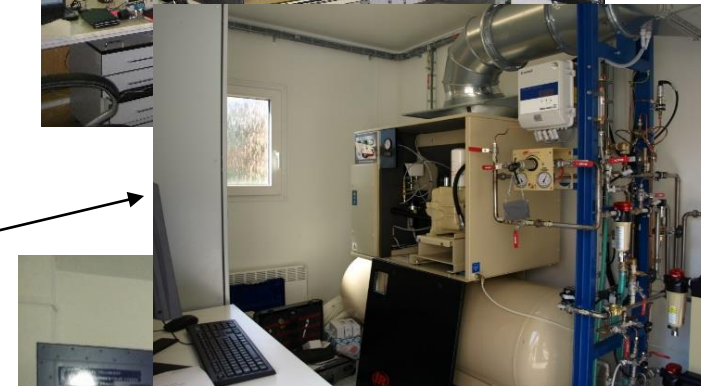
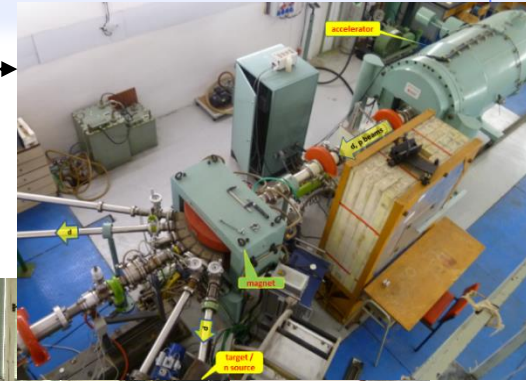
# IEAP – general information

- **Institute of Experimental and Applied Physics (IEAP)** of the Czech Technical University in Prague (CTU)
- Founded in 2002 as a scientific and educational institute of the CTU, focusing on **a research in the field of particle and subatomic physics** (R&D in instrumentation & participation in fundamental experiments).
- 89 employees (~60 FTE) including, ~30 foreigners, ~10 Ph.D. students.



# Research infrastructure of IEAP

- **Van de Graaff accelerator**
- **Underground laboratory LSM** in Modane, France
- **Small underground laboratory in Prague** in a nuclear shelter
- **Laboratory for high-resolution X-ray radiography and 3D X-ray tomography in IEAP, Specialized laboratory for experimental imaging** – common laboratory of IEAP and 3<sup>rd</sup> faculty of medicine of CU
- **Radon laboratory** (ultrasensitive measurement, radon-free chambers) – common laboratory of IEAP and the National radiation protection institute;
- **Tunable electron source and equipment for scintillators measurements** – common laboratory of IEAP and the Nuvia company.

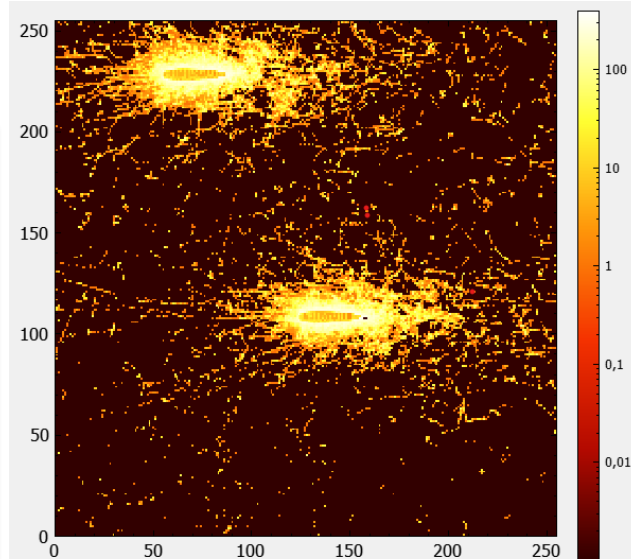
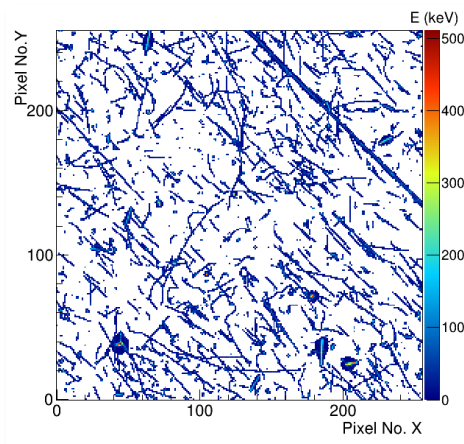
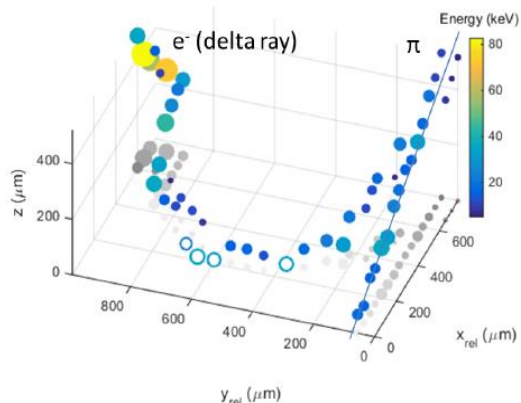
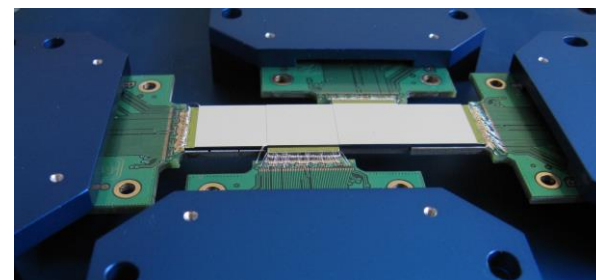


# Technology of semiconductor pixel detectors

- R&D of new types of detectors
- Activities within the **Timepix, Timepix 3, and Timepix 4 pixel detectors** developed within the Medipix collaboration

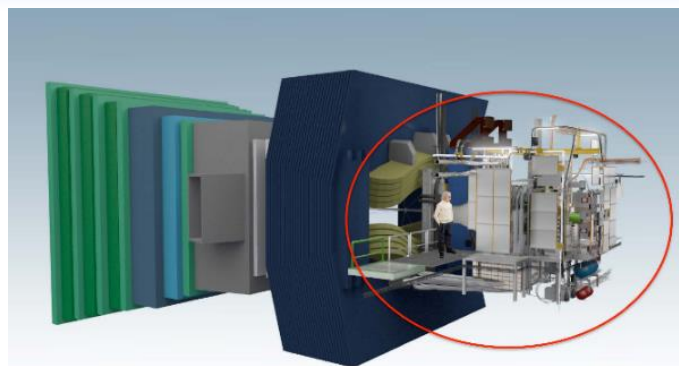


- Characterization of different sensor materials (GaAs, CdTe)
- Improving methodology for particle detection, tracking, and discrimination, 3D track reconstruction
- Dosimetry applications - in cooperation with NRPI (SURO)
- Development of readout systems in collaboration with the West Bohemian University in Pilsen
- Applications in the ATLAS experiment, in Space,...





# Activities at CERN

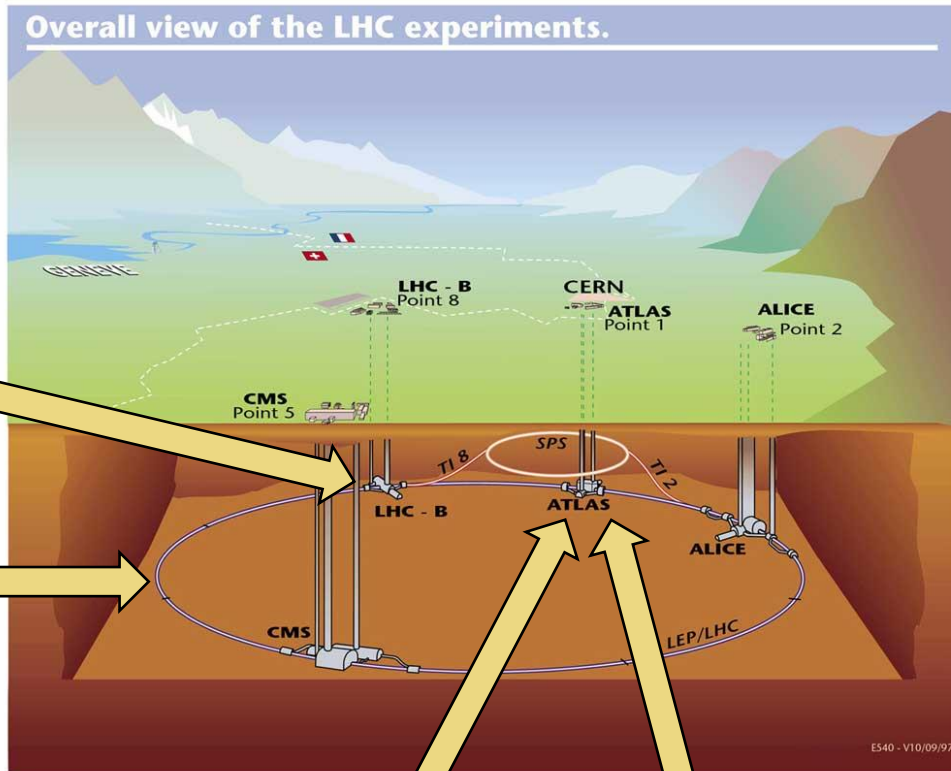


LHCb

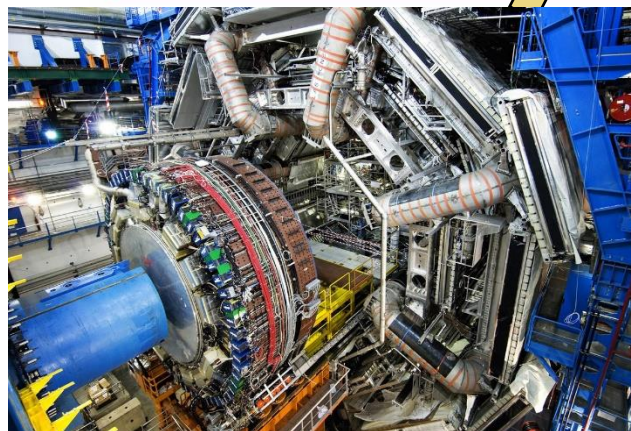
MoEDAL



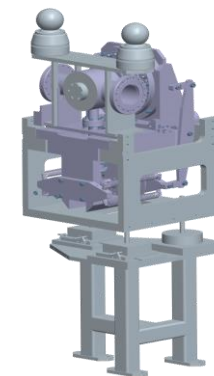
LHC collider



E540 - V10/09/97



ATLAS detector



AFP detector

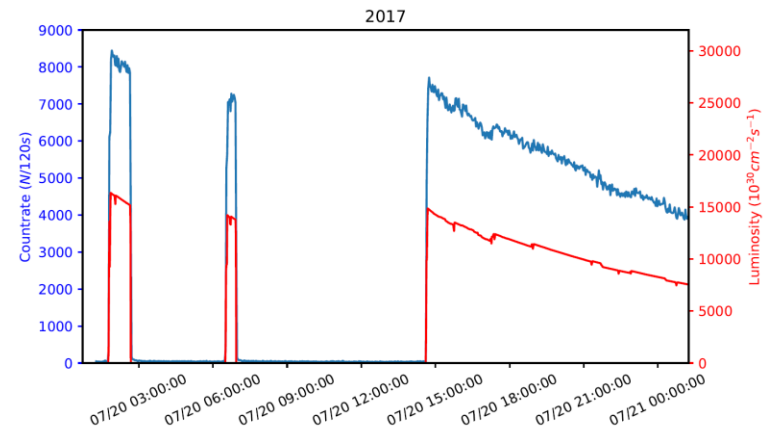
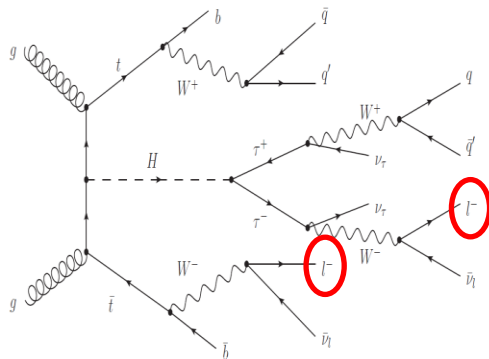
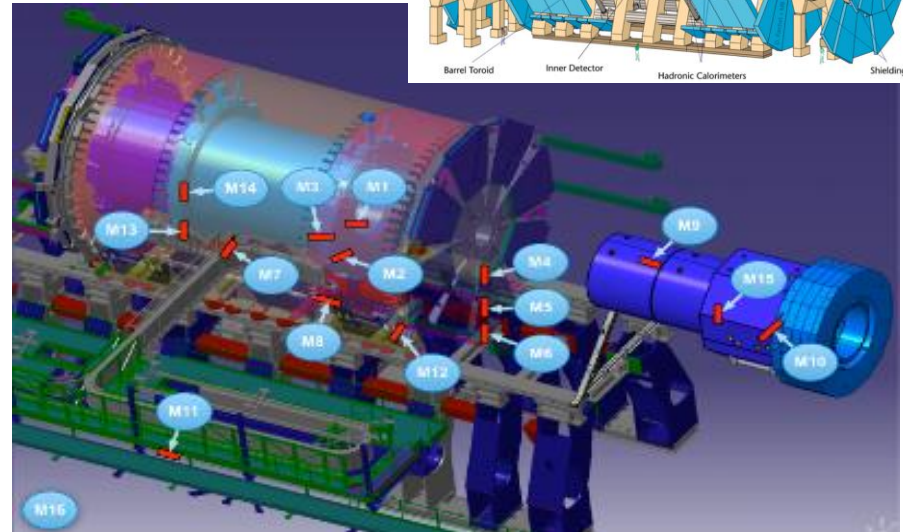
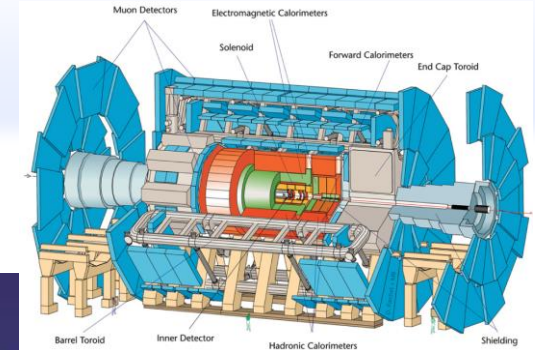
- RD50
- RD51
- MEDIPIX
- Neutrino platform
- ISOLDE
- AEgis

# Experiment ATLAS

- ATLAS-TPX network - radiation fields measurement and luminosity monitoring
- Tau-trigger contribution
- AFP

## Physics Analysis:

- $t\bar{t}H$  ( $H \rightarrow \tau\tau$ ) data analysis
- $HH$  analysis in multilepton final states
- top-quark pair production in proton-lead collisions
- AFP data analysis



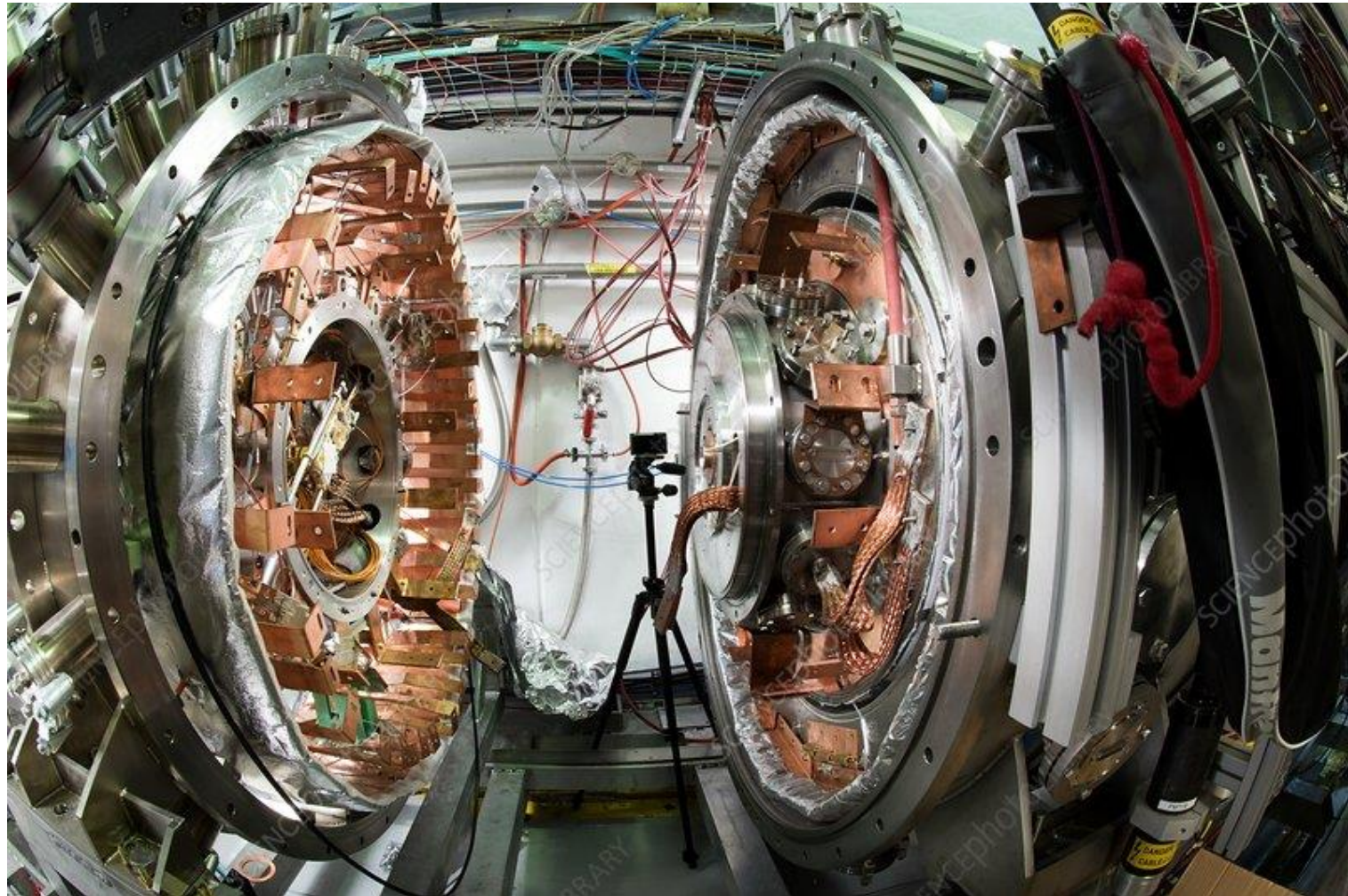
Comparison of cluster rate versus ATLAS luminosity. One bin corresponds to 120 s.





# AEGIS

- The direct measurement of the Earth's gravitational acceleration on antihydrogen.
- IEAP provided Timepix 3/4 for the detection of antiatoms and positronium.





# Neutrino and underground experiments

- **Experiments for the measurement of (not only) double beta decay** in the LSM underground laboratory in Modane, France

- NEMO 3, SuperNEMO, SPT, TGV, OBELIX

- LEGEND – double beta decay in 1 t  $^{76}\text{Ge}$

- ICARUS

- **Technologies for underground experiments**

- Ultra-low background technologies (radon...)

- Development of plastic scintillating detectors

- **Theory** for double beta decay.

- S3 - detector of reactor neutrinos

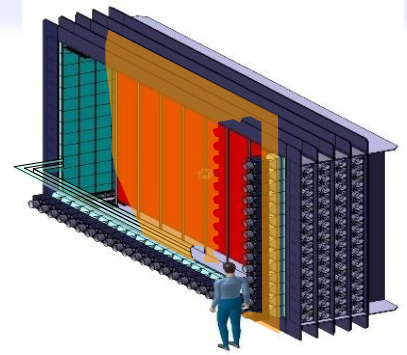
- Detection of sterile neutrinos in low-distance oscillations.

- BAIKAL-GVD experiment (Baikal Gigaton Volume Detector)

- Water in the Baikal lake as a neutrino detector.
- Suspended.

- **KM3NeT**

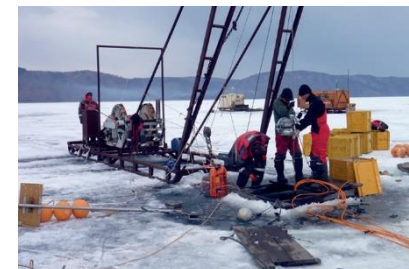
- Water in the Mediterranean sea as a neutrino detector.



- **PICO** experiment

- SNOLAB underground laboratory.

- Detection of neutralinos as dark matter candidates using a bubble detector.



# Applications at space

- Miniaturization of detectors of ionizing particles (dosimeters) is important.

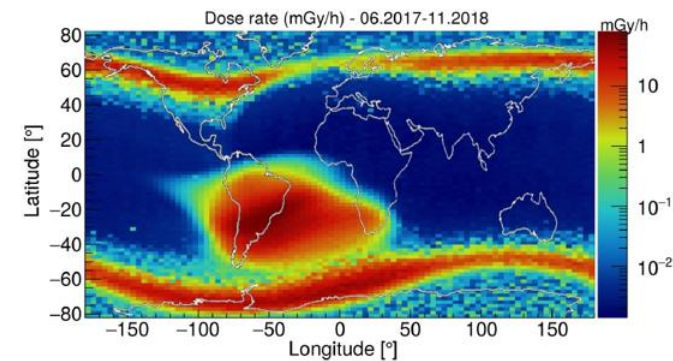
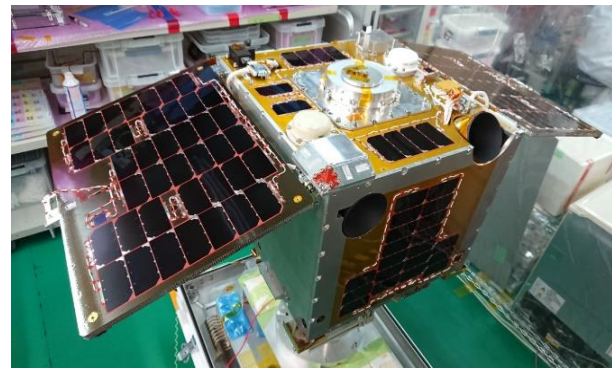
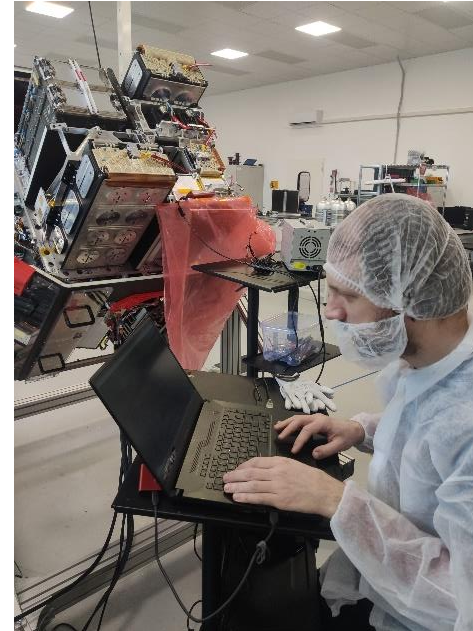
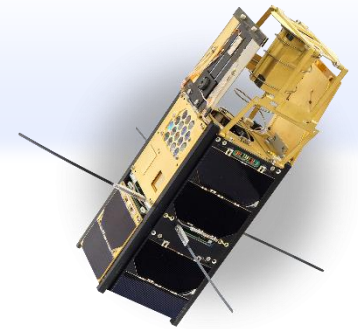


Courtesy of NASA



# Applications at space

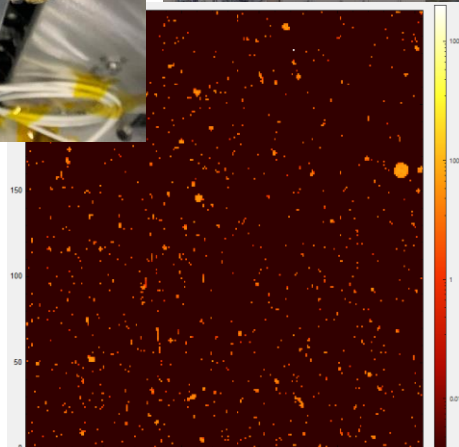
- Our equipment based on Medipix/Timepix detectors are at space.
- International Space Station (NASA)
- PROBA-V (ESA)
- ...





# HardPix Radiation Spectrometer

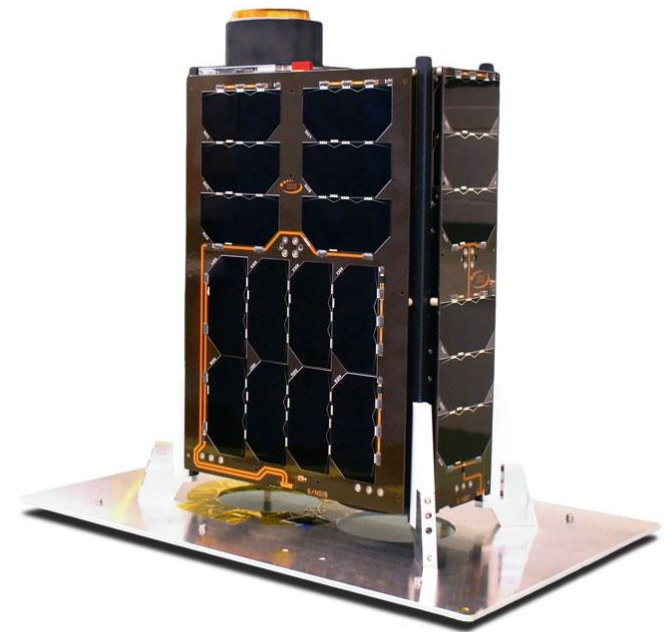
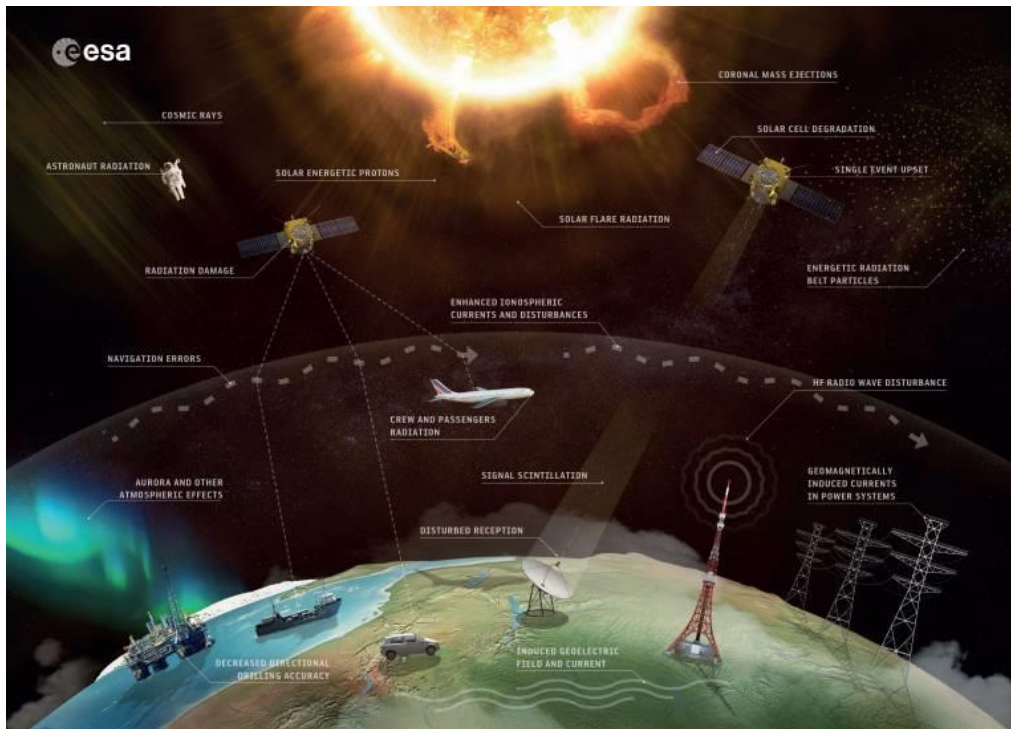
HardPix prototype (single layer, no onboard processing) launched to space in June 2023 onboard D-Orbit ION satellite as part of UKRI STFC SWIMMR (Space Weather Instrumentation, Measurement, Modelling and Risk) programme.



# HardPix Radiation Spectrometer – planned missions

Second UK SWIMMR mission in Oct 2024  
onboard D-Orbit ION

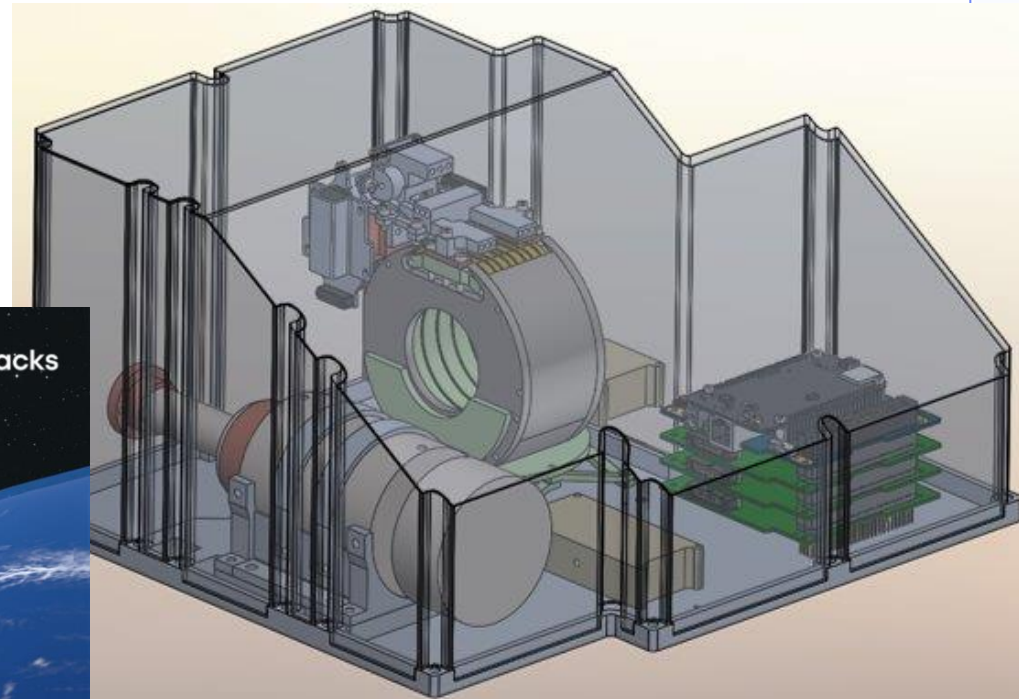
European Commission In-orbit  
demonstration/validation Cassini mission to  
provide space heritage for new payloads.  
Provided by ISISPACE 6U Cubesat. Launch  
2025



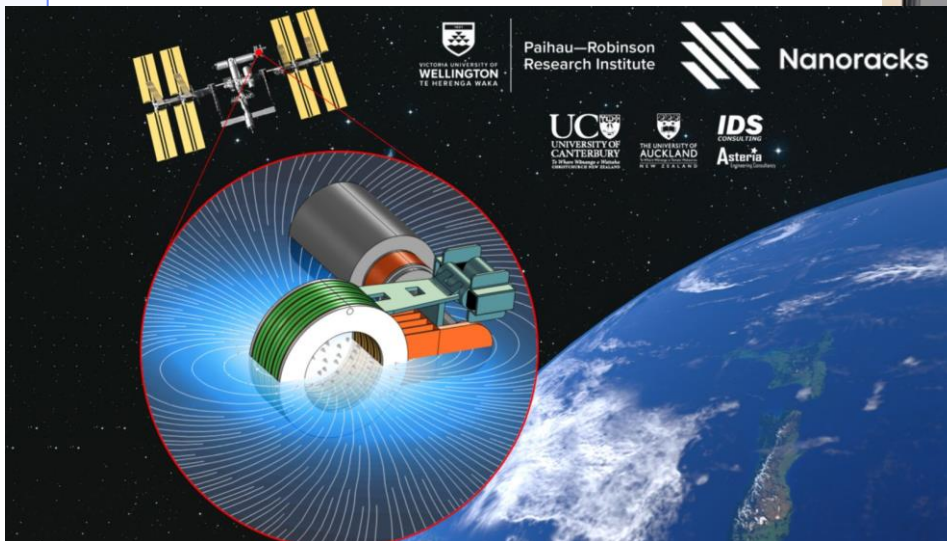
Credit: ISISpace

# HardPix Radiation Spectrometer – planned missions

Heki - Mission to study radiation field influence of the superconducting magnet by Robinson-Paihau research institute in New Zealand using 2 HardPix detectors. Launch to ISS/Nanoracks in 2025



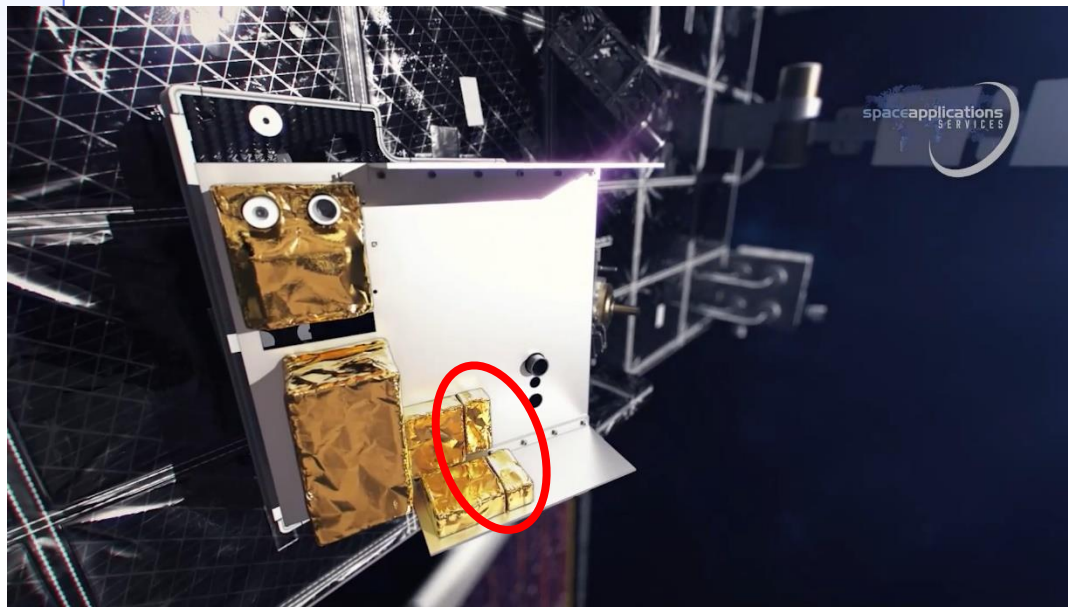
Credit: Robinson Paihau institute



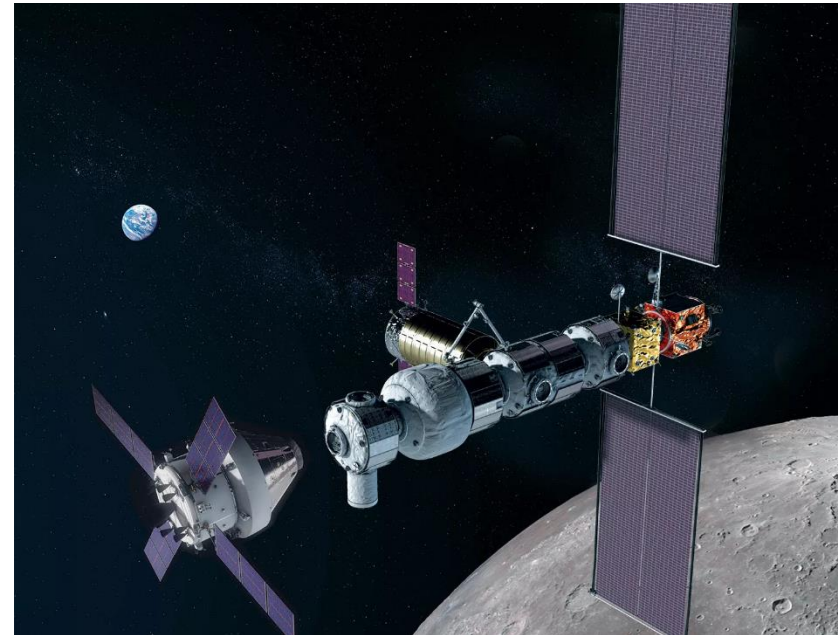


# HardPix Radiation Spectrometer – planned missions

Lunar Gateway will host an external scientific instrument suite from ESA called European Radiation Sensors Array (ERSA) including 2 HardPix detectors. ERSA measurements can tell us about the physics of radiation in the solar system, and understand the risks posed by radiation to human spacefarers and their hardware.

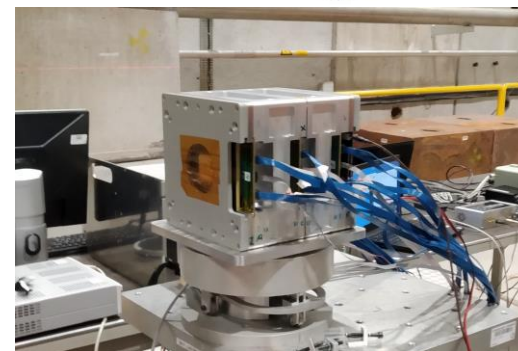
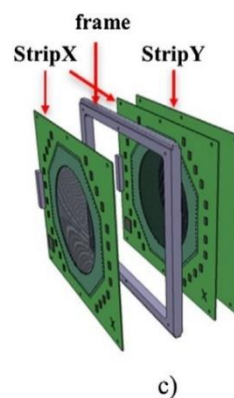
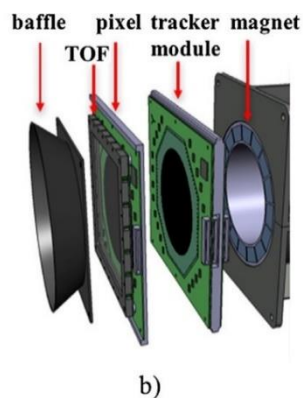
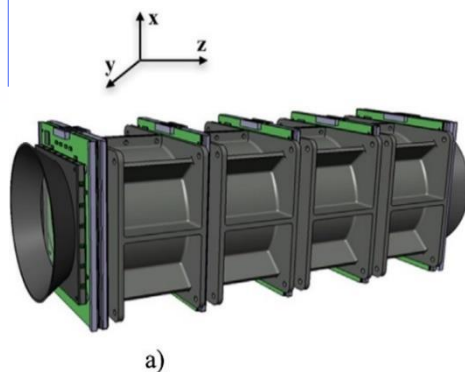
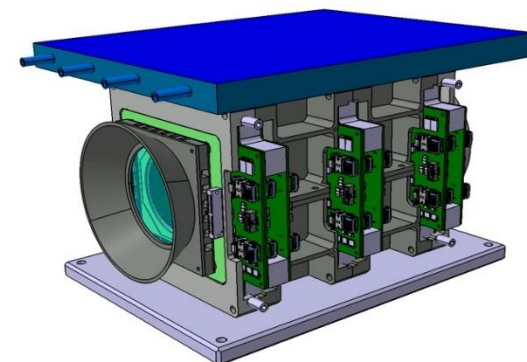
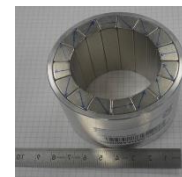
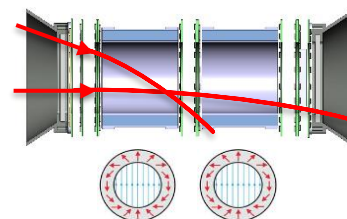


Credit: SAS Belgium



# PAN – Penetrating particle ANalyzer

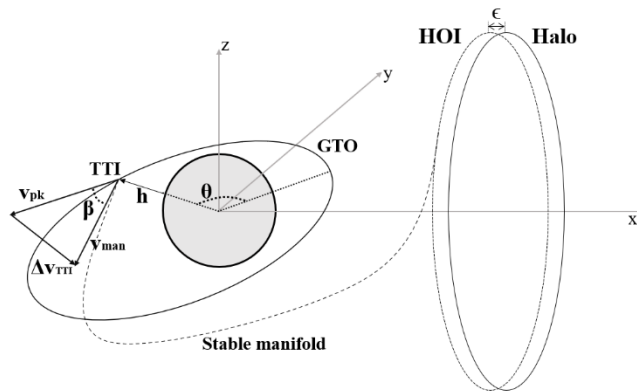
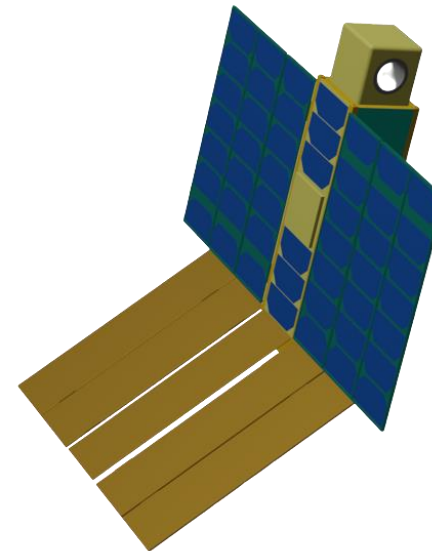
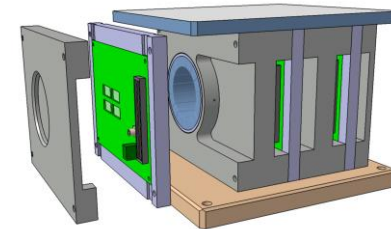
- ◆ Magnetic spectrometer for detection of highly energetic particles (tens of GeV).
- ◆ IEAP CTU part of EU H2020 FETOPEN project to develop a smaller demonstrator MiniPAN in collaboration with University of Geneva and INFN Perugia.



# REMEC Mission study

The investigation of the properties of galactic cosmic rays and solar energetic particles in deep space in the 10 MeV/n – 10 GeV/n range.

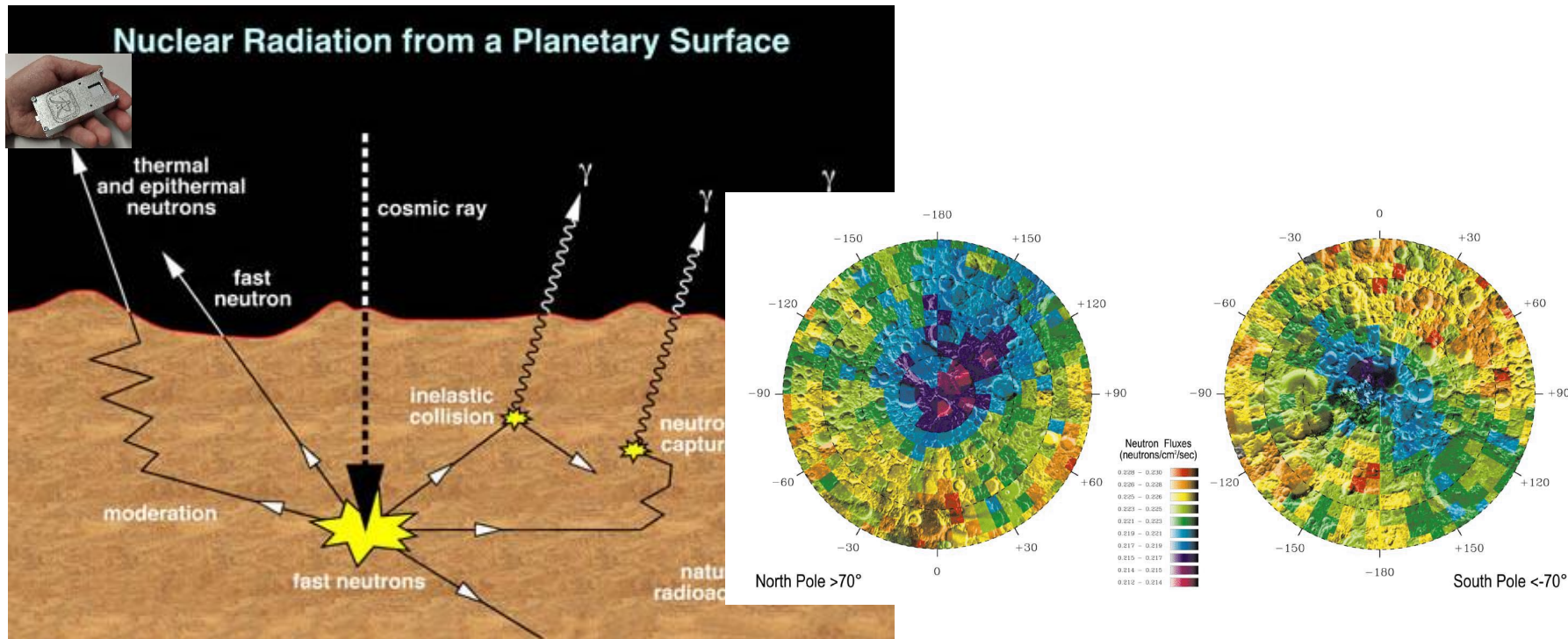
Pix.PAN + HardPix in Sun – Earth L2 orbit





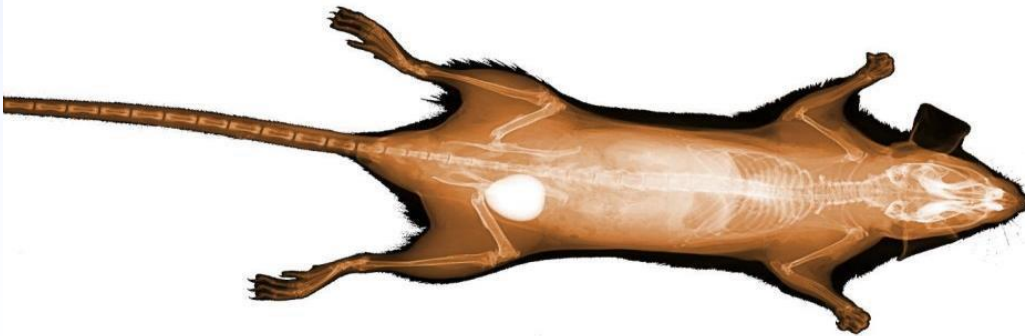
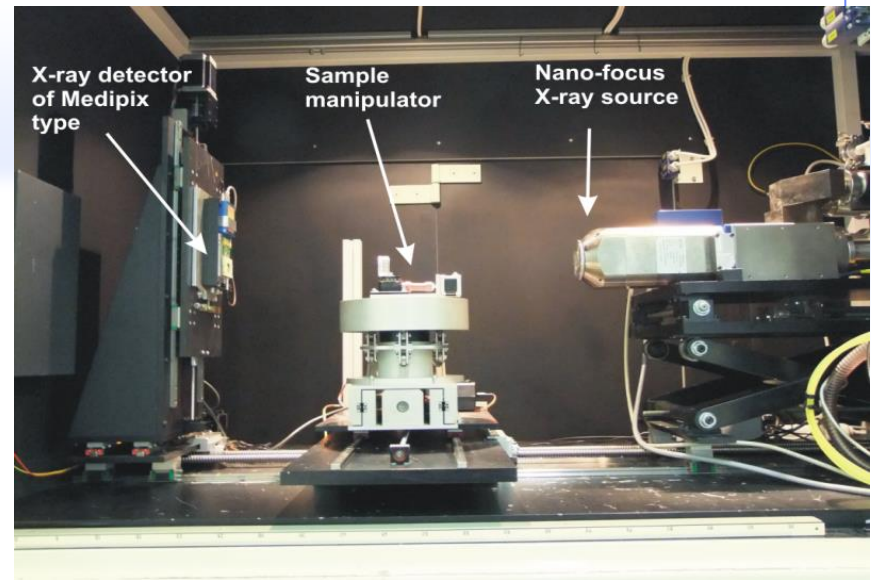
# Lunar prospecting – neutron spectrometer

- ◆ Equipped with neutron conversion layer, HardPix can perform as a neutron spectrometer, measuring flux variations of thermal and epithermal neutrons scattered by hydrogen, a clear signature of enhanced hydrogen (water-ice) abundance.



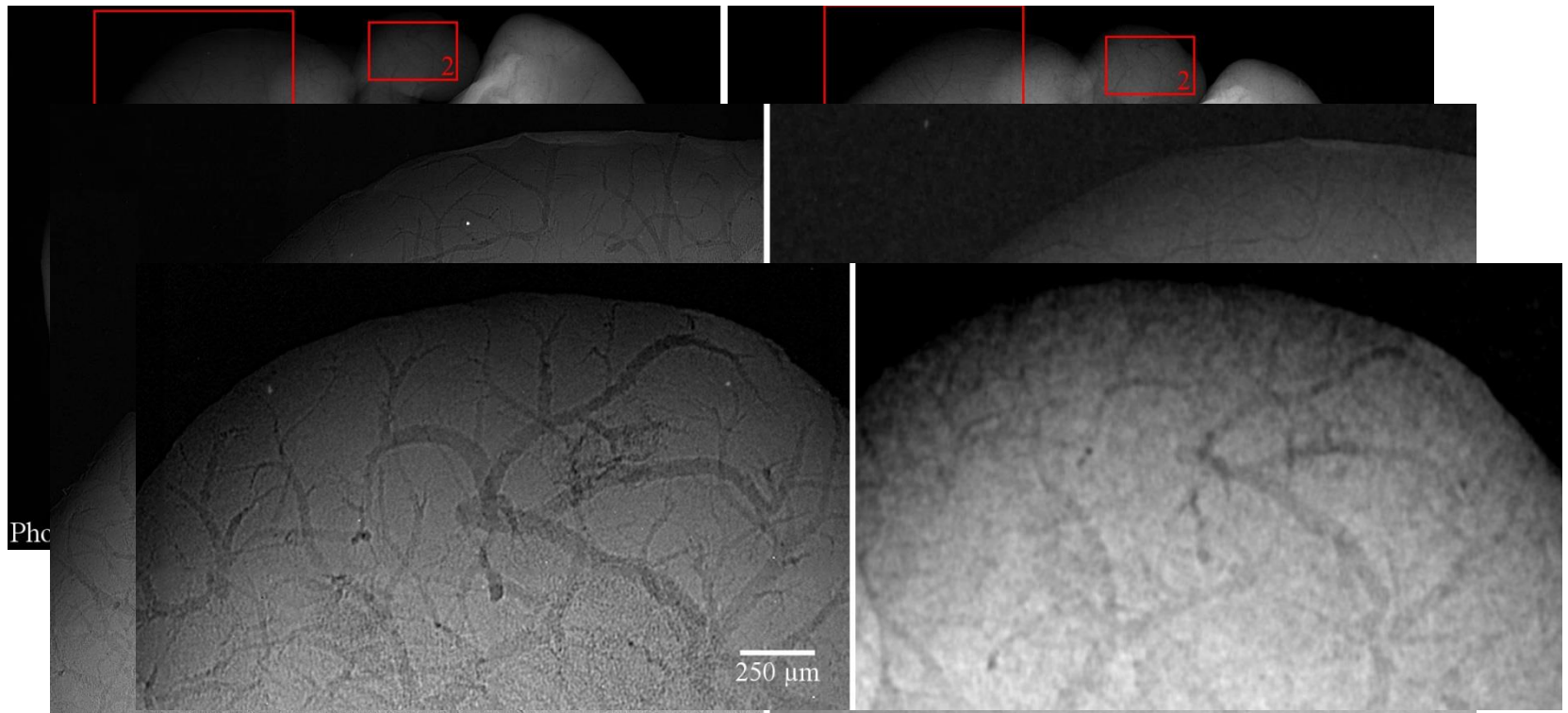
# Pixel detectors in imaging

- X-ray radiography and tomography with very high resolution
  - Imaging of biological objects
  - Imaging in material sciences
  - Applications in art
- Neutron radiography



# Imaging of biological samples

- ◆ High contrast, high resolution
- ◆ Energetically-sensitive detector response

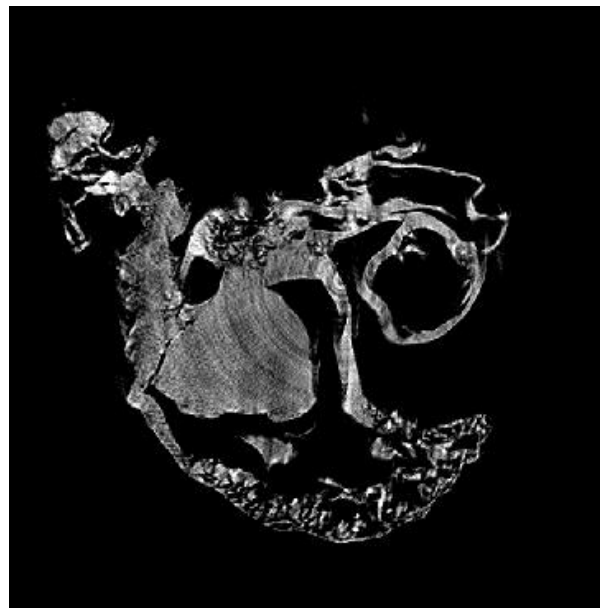
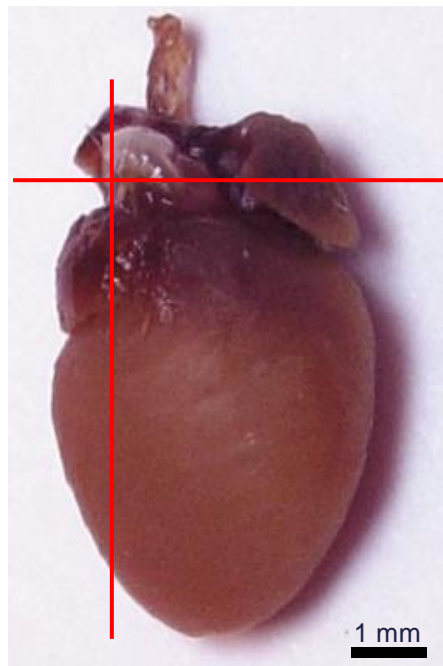
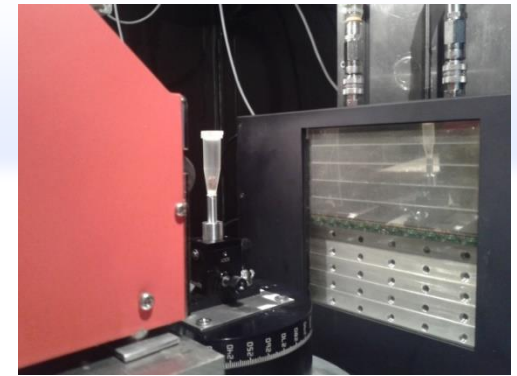


- Timepix detector - 55 μm pixel, 300 μm Si sensor
- CCD camera – 9 μm pixel, 22 μm Gadox scintillator



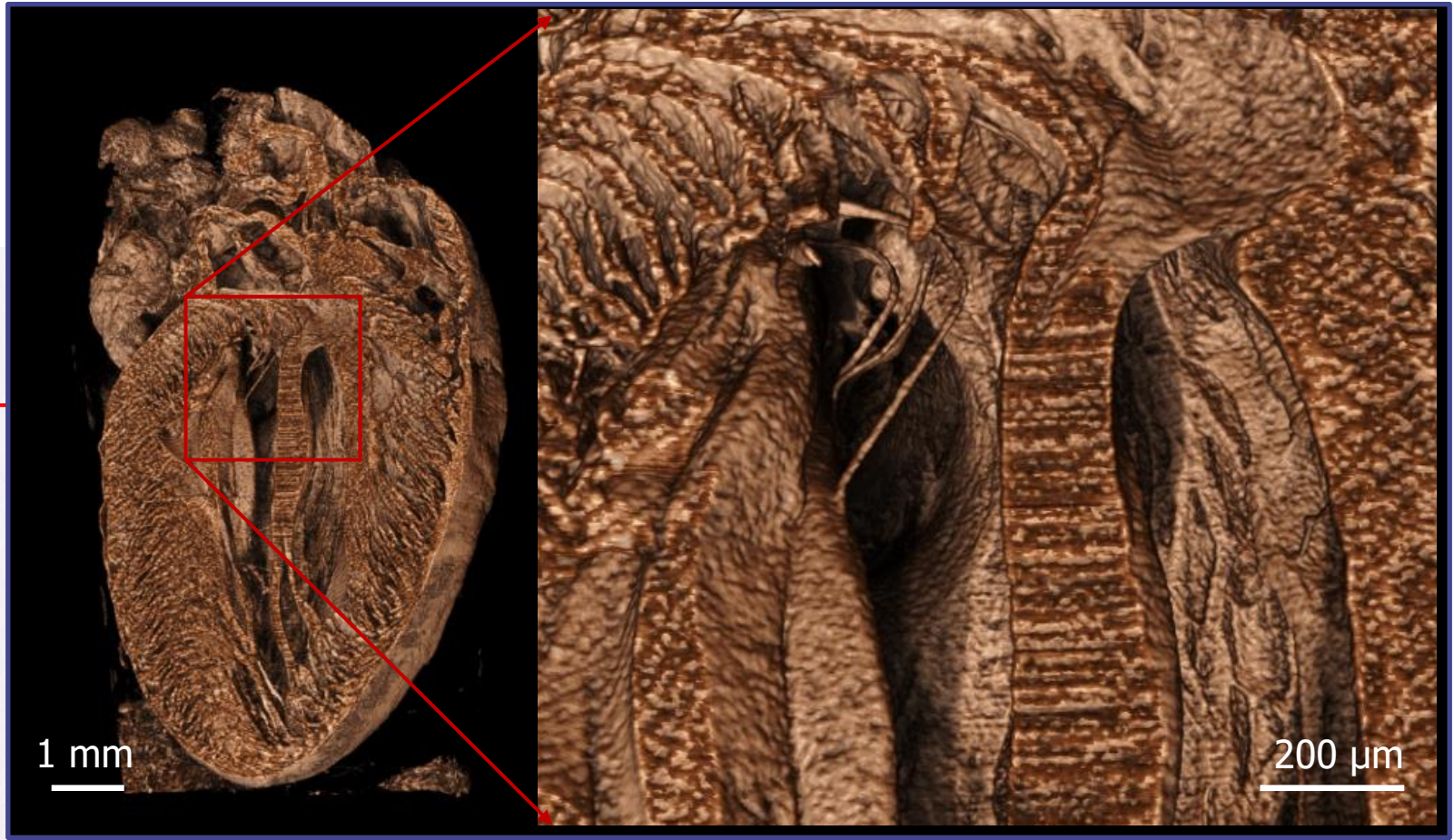
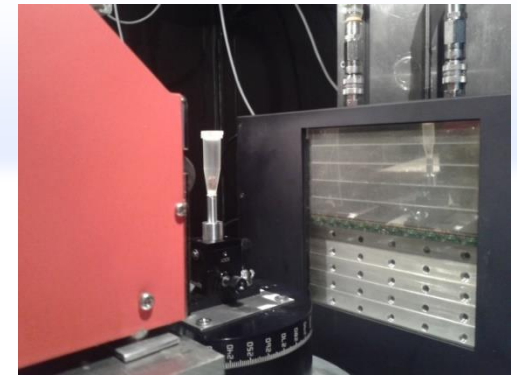
# Microtomography of a mouse heart

- ◆ Imaging with the detector WidePIX<sub>10x5</sub>
- ◆ 3D resolution 7  $\mu\text{m}$



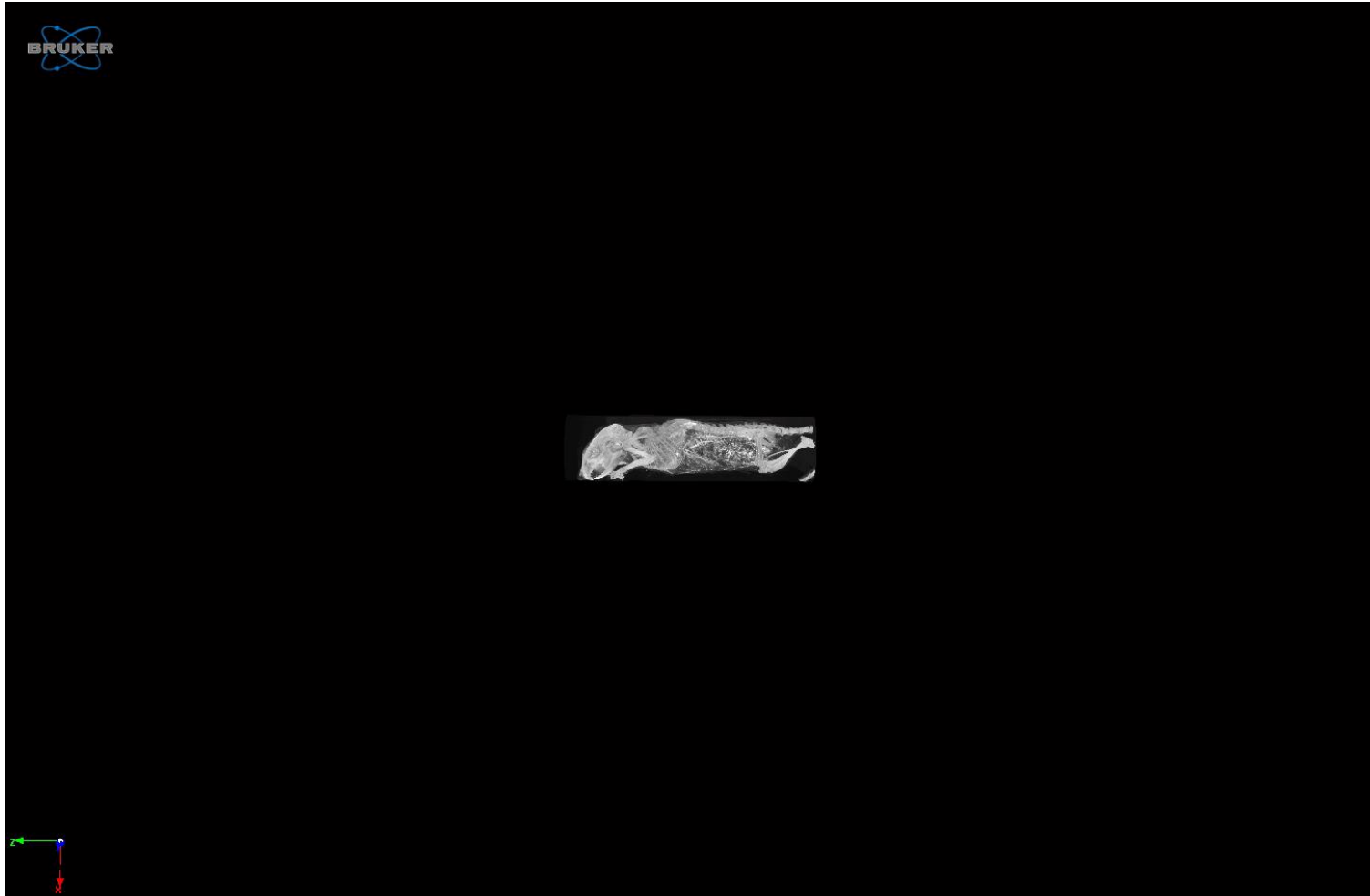
# Microtomography of a mouse heart

- ◆ Imaging with the detector WidePIX<sub>10x5</sub>
- ◆ 3D resolution 7  $\mu\text{m}$



# Imaging of whole laboratory animals

- ◆ Collaboration with the 3<sup>rd</sup> Faculty of Medicine of the ChU

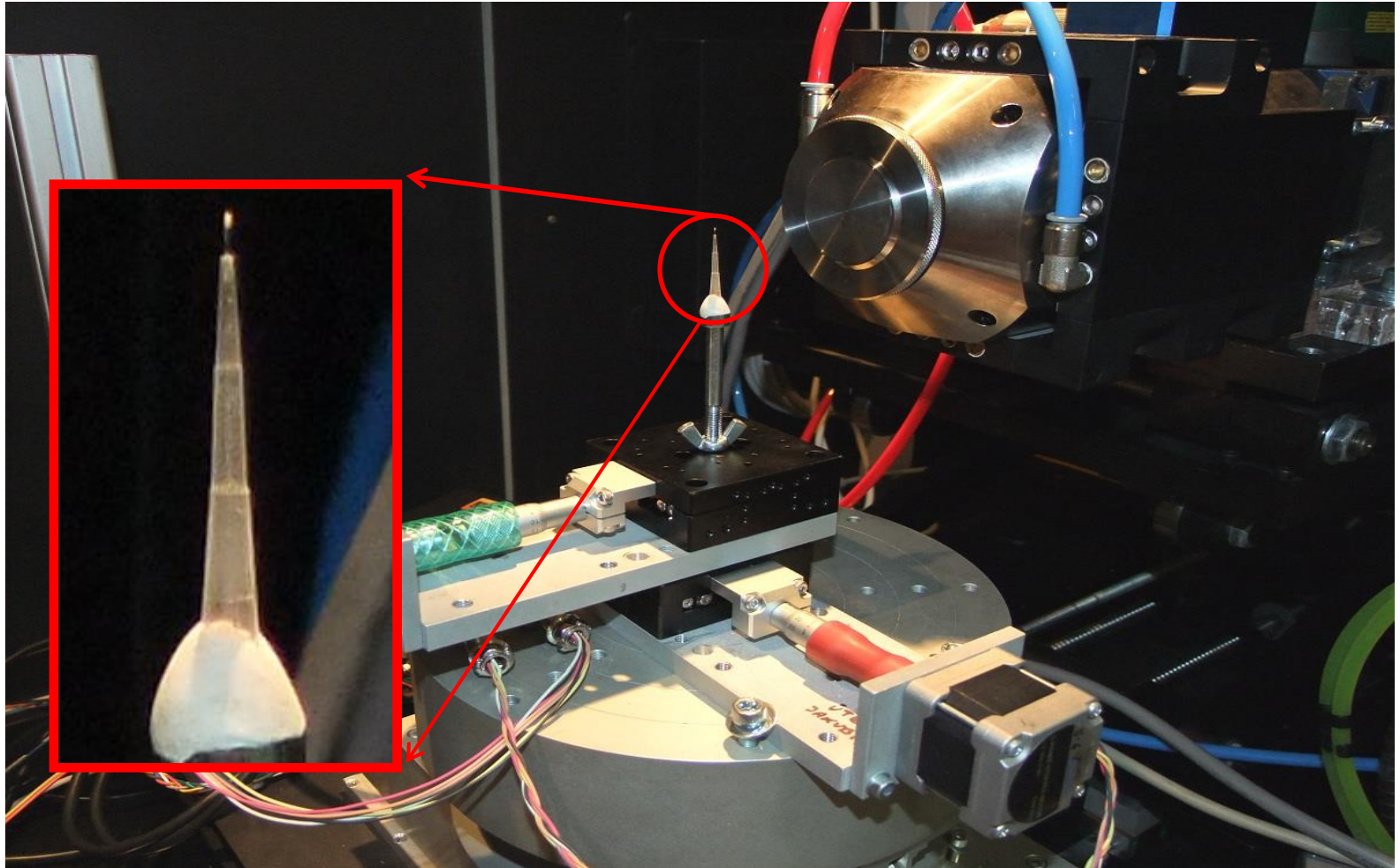


- Micro-CT of mouse
- Space resolution cca. 45  $\mu\text{m}$



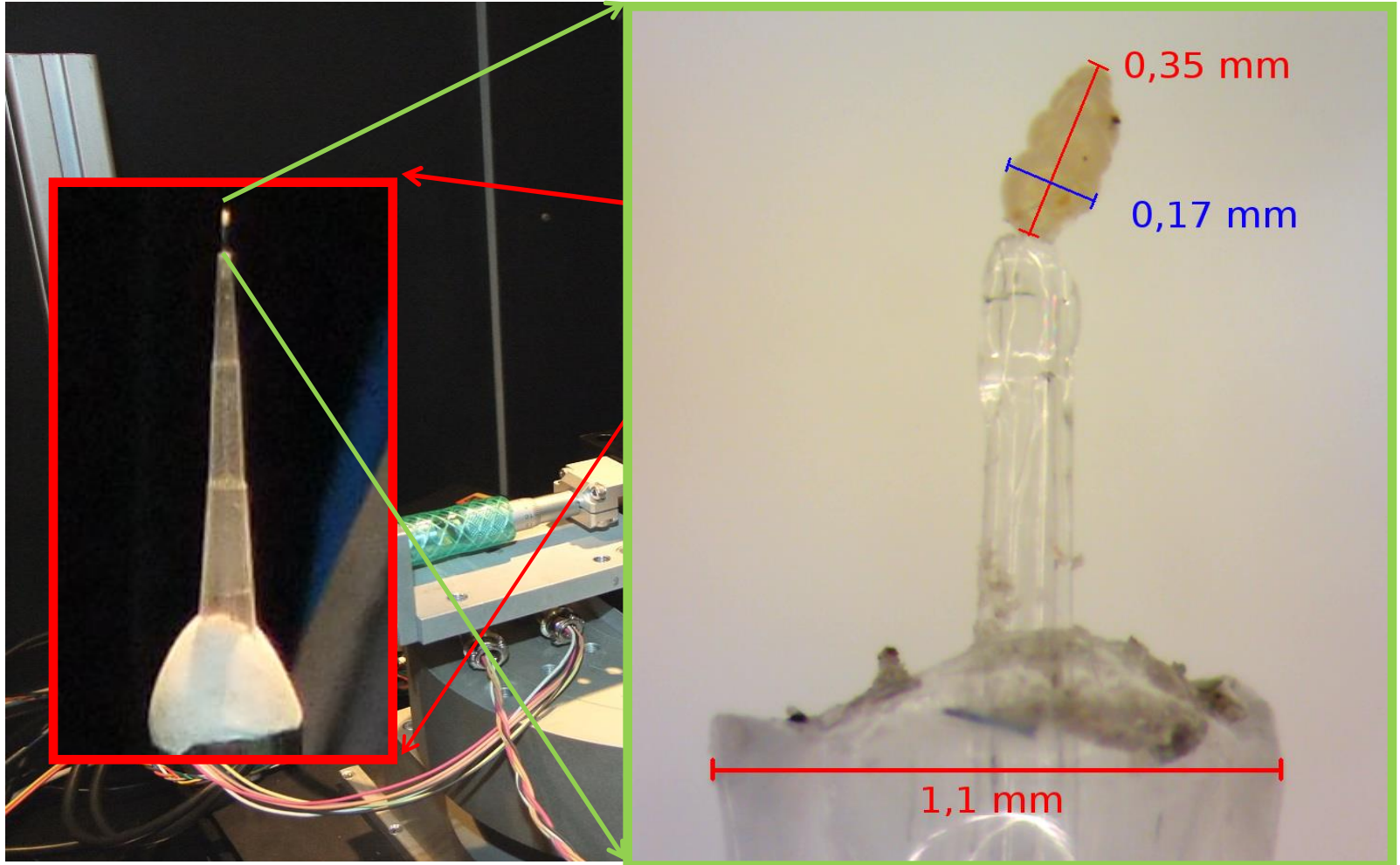
# RTG imaging with sub-micron resolution

- ◆ Foraminifera – one-cell sea organism



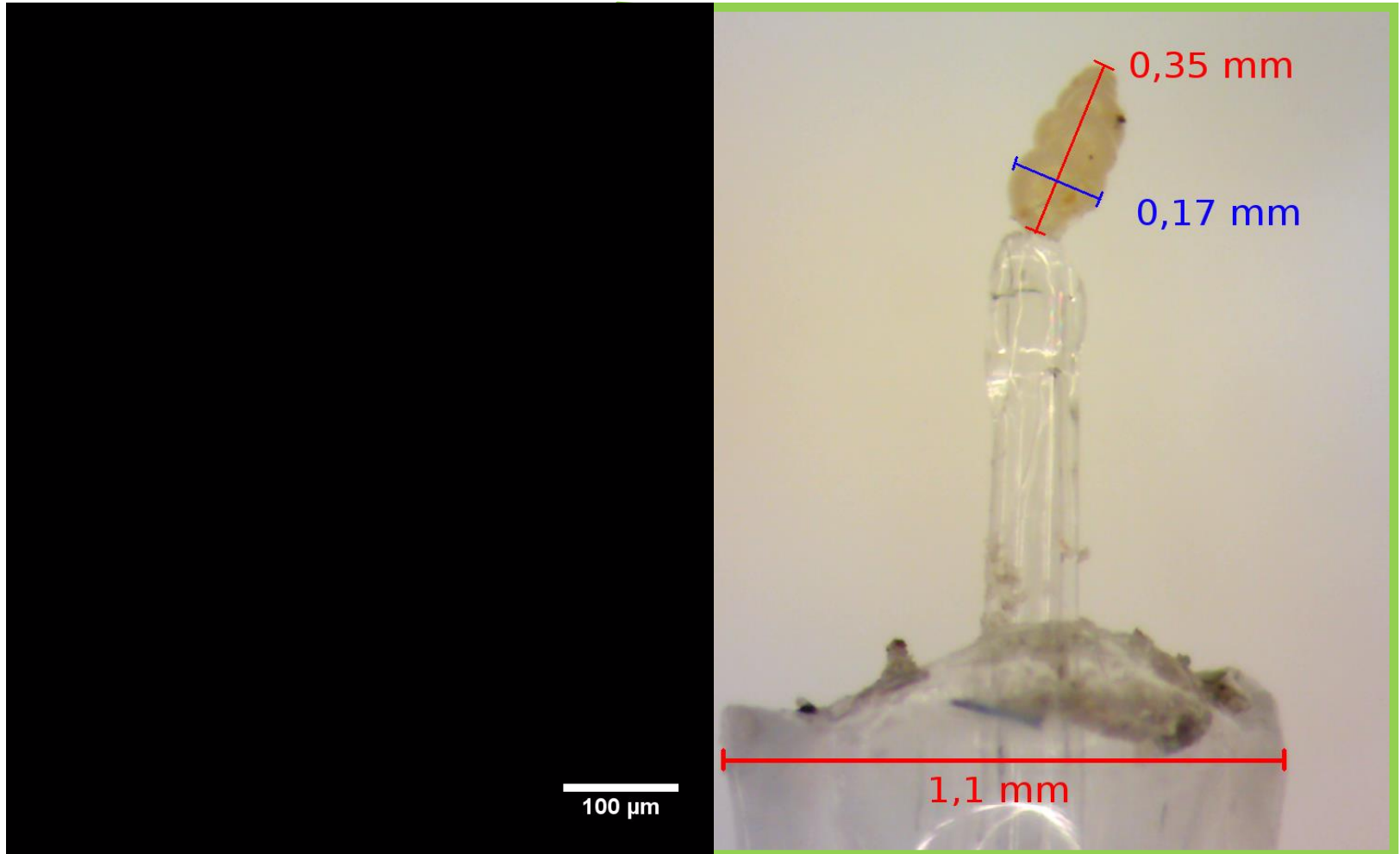
# RTG imaging with sub-micron resolution

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# RTG imaging with sub-micron resolution

- ◆ Foraminifera – one-cell sea organism



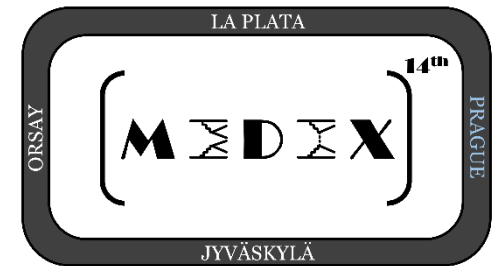


# Theory, organization of conferences

- Theory related to particle & nuclear physics
- The institute is a **member of EuCAPT** (European Center for AstroParticle Theory) – the activity of APPEC (Astroparticle Physics European Consortium)



- Organization of the **MEDEX conferences** (Matrix Elements for the Double beta decay Experiments) once, every 2 years).
- Organization of the **ANIMMA conference** in Prague in 2021.



September 4 – 8, 2023




# Education and outreach activities

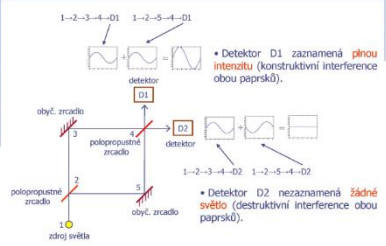
- **Supervising university students** within their Bc., MSc. or Ph.D. thesis.
- We organize two **courses of the University of the 3<sup>rd</sup> age** (educational activity for seniors)
  - Courses *Secret of microworld, Laws of microworld* - aimed at nuclear and particle physics and corresponding history.
- **Courses** of working with Medipix/Timepix educational toolkit for **secondary school teachers**.
- **IEEE international schools** of working with Medipix/Timepix detectors for university students.
- **Long-term internships** for university students (IAESTE)
- **Seminars and summer practices** for secondary school students, winners of physics olympiads.
- **Citizen measurement of ionizing radiation** using special equipment and mobile phones – collaboration with National radiation protection institute

### Anizotropie reliktního záření

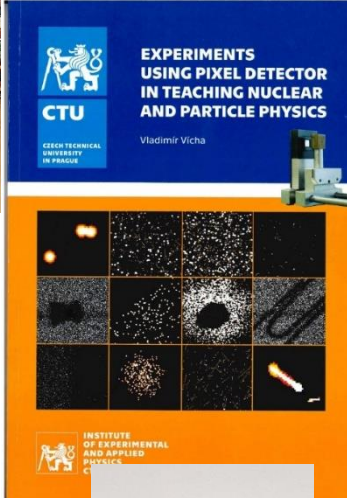
- První měření ukazovala, že reliktní záření k nám přichází ze všech směrů stejně.
- Velmi přesná družicová měření pozorovala **drobné anizotropie** – oblasti **nepatrně teplejší a chladnější**.
- Teplejší oblasti odpovídají oblastem s trochu vyšší hustotou, z tohoto prvotního materiálu se vlivem gravitačního smršťování později vyvinuly galaxie a hvězdy.
- Z velikosti anizotropie reliktního záření bylo možno vypočítat mnoho vlastností Vesmíru.
- Nejpřesnější měření – (Wilkinson Microwave Anisotropy Probe):
  - ✓ Stáří Vesmíru: 13.7 mld let
  - ✓ Plochá Eukleidovská geometrie
  - ✓ Většinu Vesmíru tvoří tmavá hmota.
- Tmavná energie odpovídá vlastnostem
- Vesmír expanduje, od doby vzniku zvětšuje.



### Machův-Zehnderův interferometr



- Detektor D1 zaznamená **plnou intenzitu** (konstruktivní interference obou paprsků).
- Detektor D2 nezaznamená **žádné světlo** (destruktivní interference obou paprsků).



EXPERIMENTS USING PIXEL DETECTOR IN TEACHING NUCLEAR AND PARTICLE PHYSICS  
Vladimír Vicha  
CTU  
CZECH TECHNICAL UNIVERSITY IN PRAGUE

