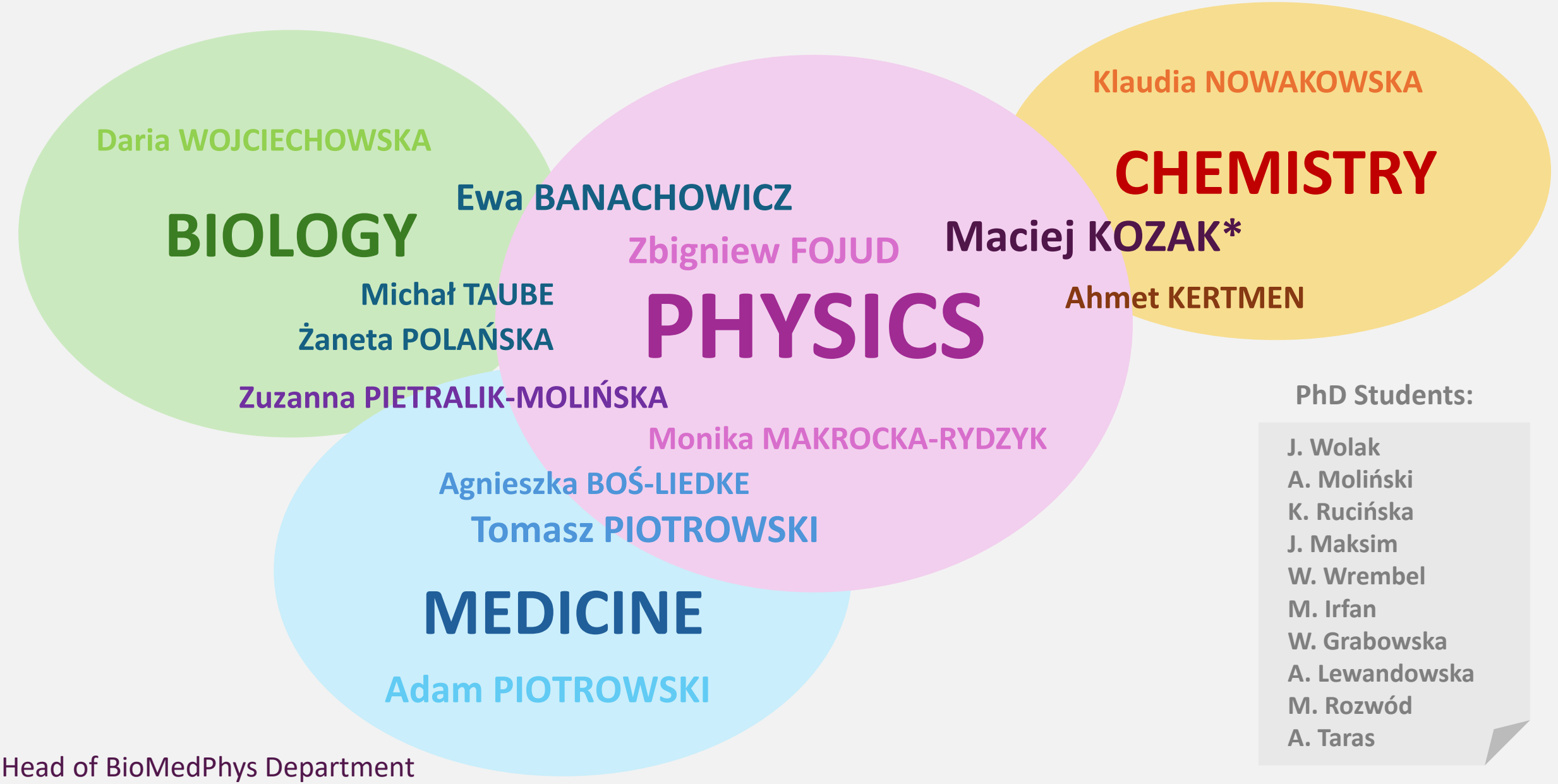
Instytut Fizyki
Zakład Fizyki Biomedycznej

Department of Biomedical Physics

Department of BioMedical Physics – Staff and Research areas



PhD Students:

- J. Wolak
- A. Moliński
- K. Rucińska
- J. Maksim
- W. Wrembel
- M. Irfan
- W. Grabowska
- A. Lewandowska
- M. Rozwód
- A. Taras

*Head of BioMedPhys Department

Main topics:

- Molecular basis of neurodegenerative diseases
- Non-viral vectors for gene therpy

BIOLOGY

MEDICINE

- Technical aspects of MRI imaging and X-ray diagnostics
- Structure and molecular dynamics of soft matter systems (oligomeric surfactants, drug carriers, lipids)

- Molecular dynamics of ligands, molecular dynamics of liquids in confined volumes, properties of porous materials
- properties of ionic liquids

PHYSICS

Main topics:

CHEMISTRY

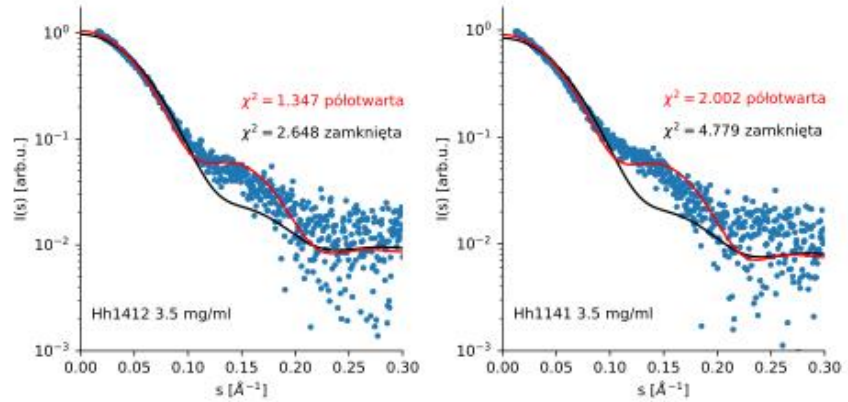
- Nanoparticles – synthesis, physical properties, cytotoxicity

- Prognostic parameters in PET imaging
- Chemical compounds that increase cell sensitivity to radiotherapy
- Physical and IT aspects of cancer diagnosis and radiotherapy planning

MEDICINE

PHYSICS

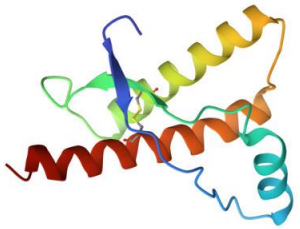
some examples



Molecular basis of neurodegenerative diseases

- Alzheimer's disease:
  - mutation of Cystatin C mutations and amyloid deposits
  - Amyloid β and interactions with HSA

- Creutzfeldt–Jakob disease:
  - Insoluble prion protein aggregates



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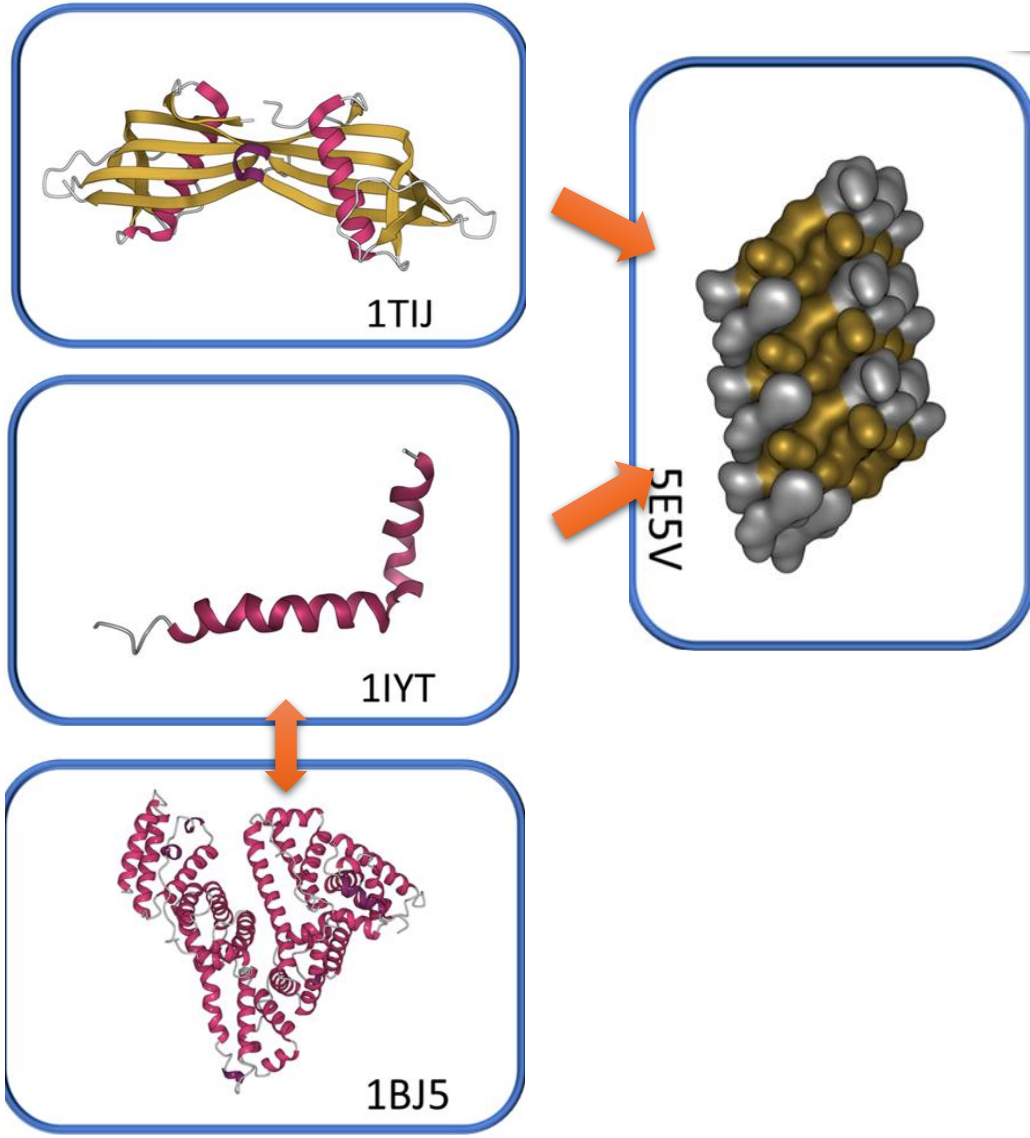
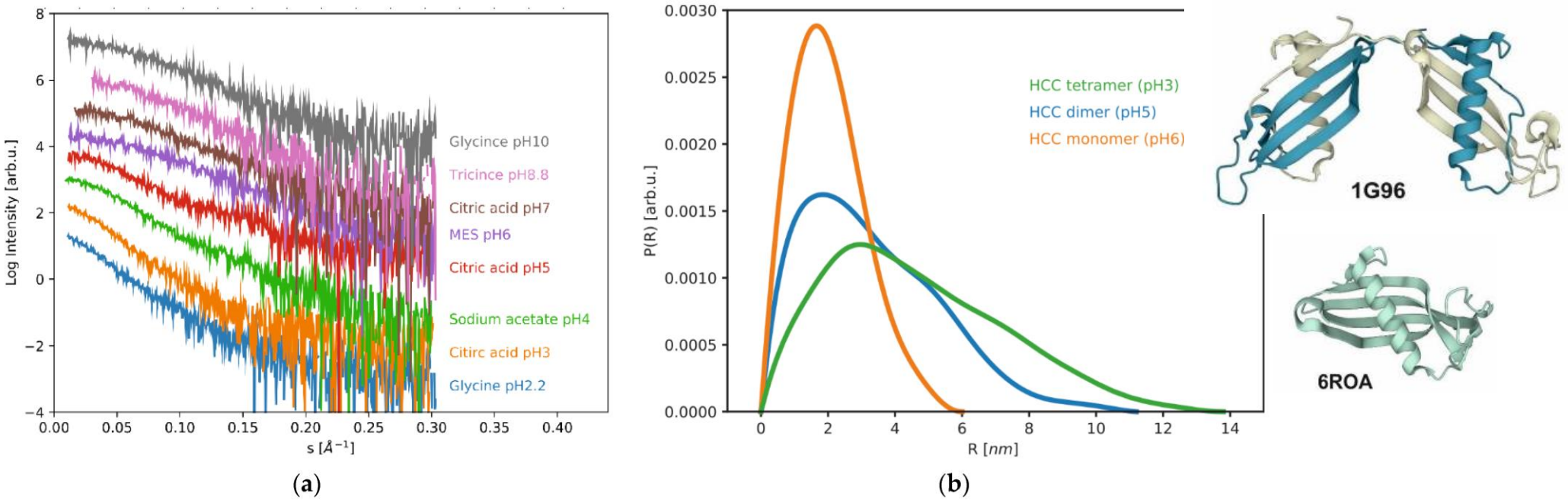


Molecular basis of neurodegenerative diseases

- Wojciechowska, D.; Taube, M.; Rucińska, K.; Maksim, J.; Kozak, M. **Oligomerization of Human Cystatin C—An Amyloidogenic Protein: An Analysis of Small Oligomeric Subspecies**. *Int. J. Mol. Sci.* 2022, 23, 13441

SAXS

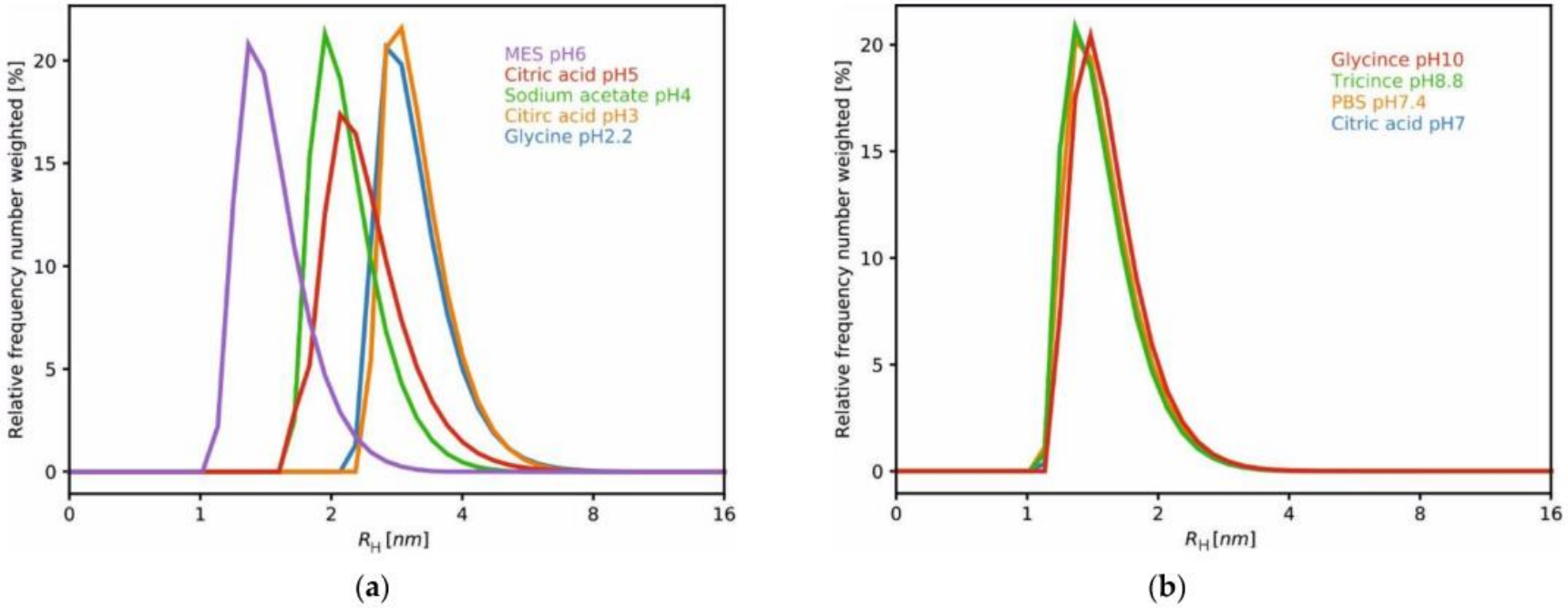


Solution scattering data collected for human cystatin C at different pH levels: (a) SAXS curves recorded for HCC in pH from 2.2 to 10; (b) pair distance distribution functions for HCC monomers (pH 6), dimers (pH 5) and tetramers (pH 3).

Molecular basis of neurodegenerative diseases

- Wojciechowska, D.; Taube, M.; Rucińska, K.; Maksim, J.; Kozak, M. **Oligomerization of Human Cystatin C—An Amyloidogenic Protein: An Analysis of Small Oligomeric Subspecies**. *Int. J. Mol. Sci.* 2022, 23, 13441

DLS

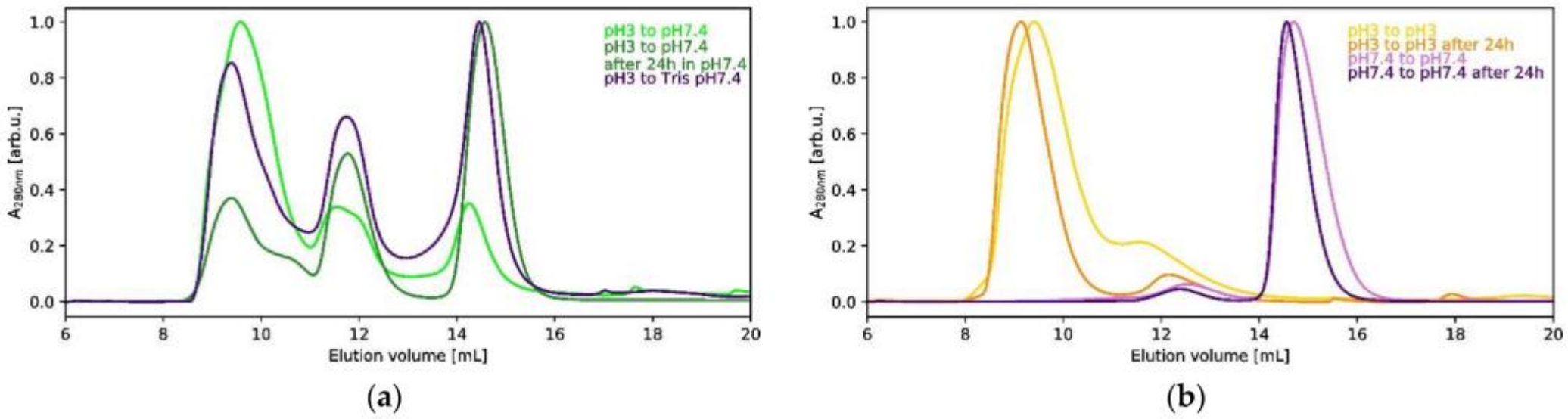


DLS data collected for human cystatin C at different pH levels: (a) DLS results—particle size distribution of human cystatin C (HCC) in various buffers; (b) pH dependence (range 2.2–6); (b) pH dependence (range 7–10).

Molecular basis of neurodegenerative diseases

- Wojciechowska, D.; Taube, M.; Rucińska, K.; Maksim, J.; Kozak, M. **Oligomerization of Human Cystatin C—An Amyloidogenic Protein: An Analysis of Small Oligomeric Subspecies**. *Int. J. Mol. Sci.* 2022, 23, 13441

SEC



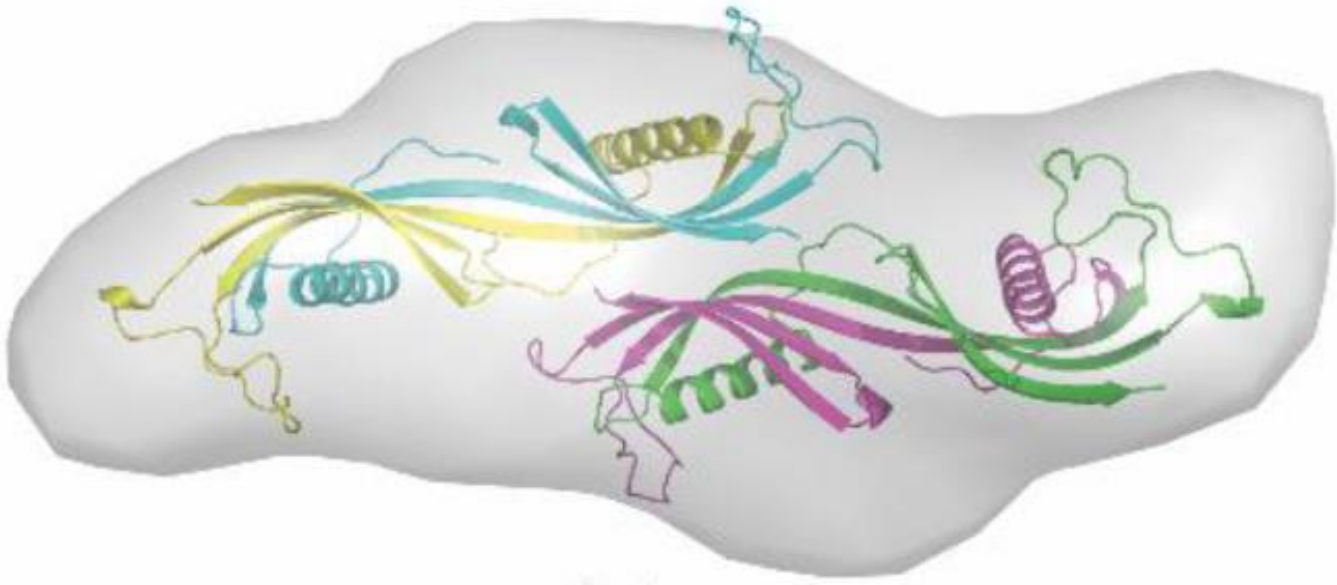
The results of the SEC analysis of the formation and stability of the tetrameric HCC form: (a) SEC elution profiles for HCC at pH 3 and transferred to pH 7.4 (PBS and Tris buffers); (b) SEC elution profiles for HCC at pH 3 transferred to pH 3 and pH 7.4 (PBS buffer). The chromatogram traces were normalized to value 1.

Molecular basis of neurodegenerative diseases

- Wojciechowska, D.; Taube, M.; Rucińska, K.; Maksim, J.; Kozak, M. **Oligomerization of Human Cystatin C—An Amyloidogenic Protein: An Analysis of Small Oligomeric Subspecies**. *Int. J. Mol. Sci.* 2022, 23, 13441

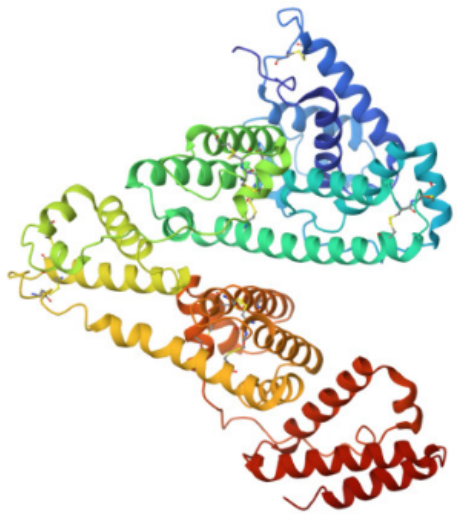
Model

Figure 7. Low-resolution model of tetrameric HCC obtained using DAMMIF modeling and SAXS data collected at pH 3.0.



Structural studies of human serum albumin using cryo-EM up to 0.38 nm resolution

Biological Assembly 1



Explore in 3D: Structure | Sequence Annotations | Electron Density | Validation Report

Global Symmetry: Asymmetric - C1
Global Stoichiometry: Monomer - A1

Display Files | Download Files | Data API

8Q3F

Structural studies of human serum albumin using cryo-EM up to 0.38 nm resolution

PDB DOI: https://doi.org/10.2210/pdb8Q3F/pdb **EM Map EMD-18126:** EMDB EMDataResource

Classification: TRANSPORT PROTEIN
Organism(s): Homo sapiens
Mutation(s): No

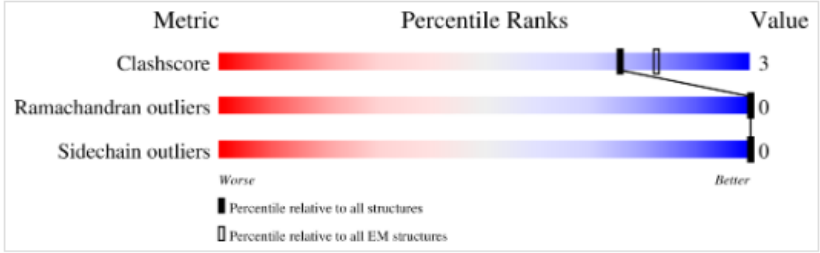
Deposited: 2023-08-04 **Released:** 2023-08-16
Deposition Author(s): Slawek, J., Taube, M., Rawski, M., Wojciechowska, D., Kozak, M.
Funding Organization(s): Polish National Science Centre

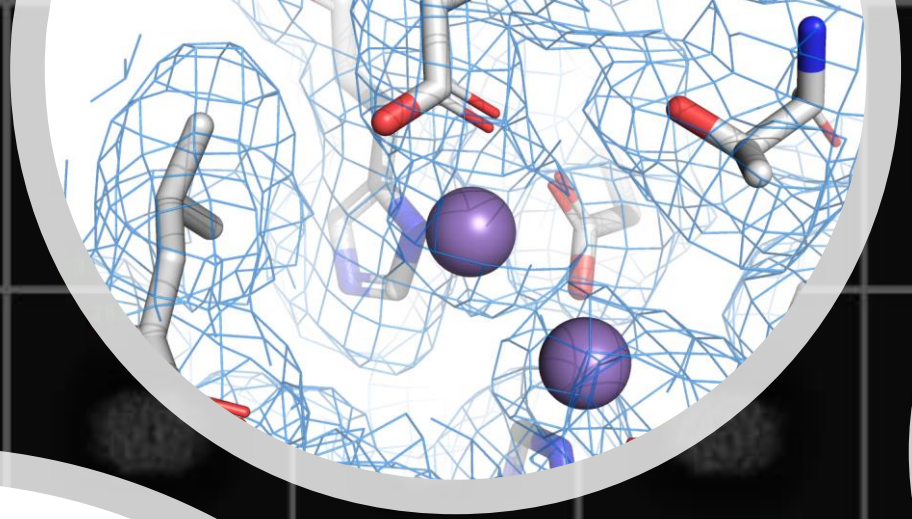
Experimental Data Snapshot

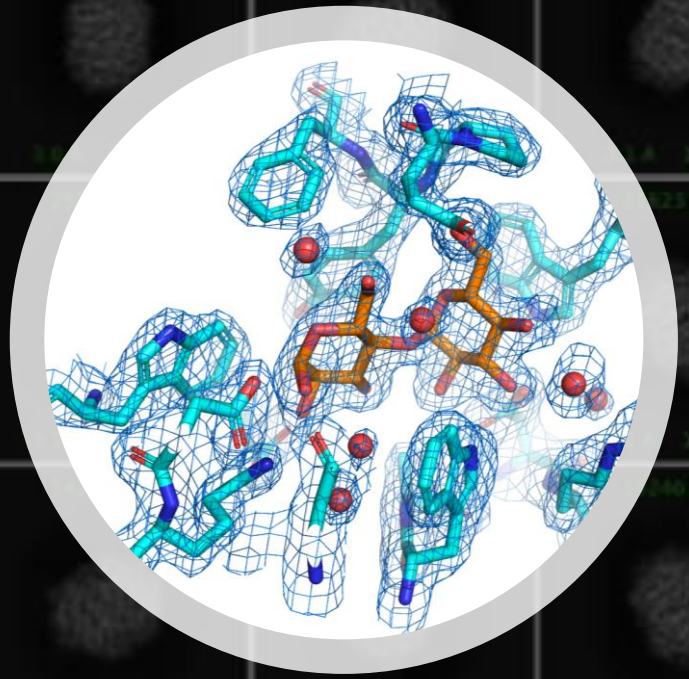
Method: ELECTRON MICROSCOPY
Resolution: 3.77 Å
Aggregation State: PARTICLE
Reconstruction Method: SINGLE PARTICLE

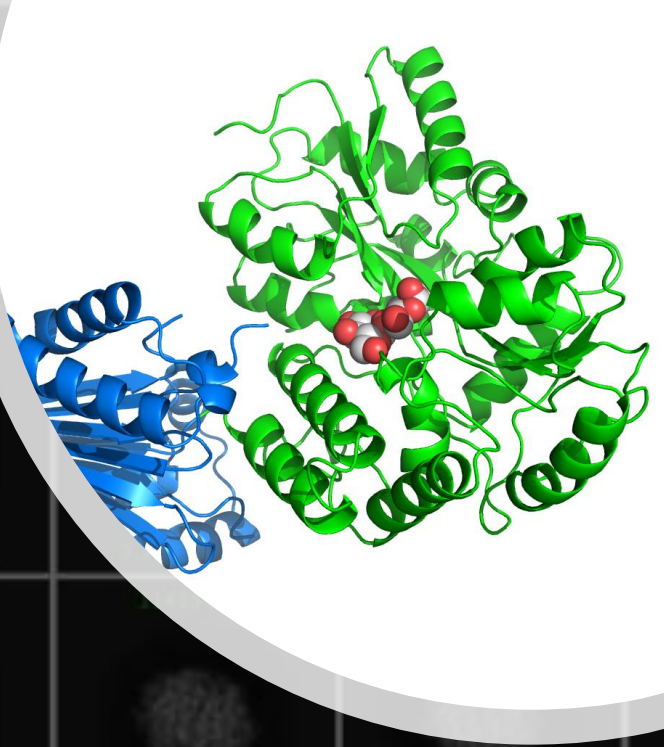
Starting Model: experimental
View more details

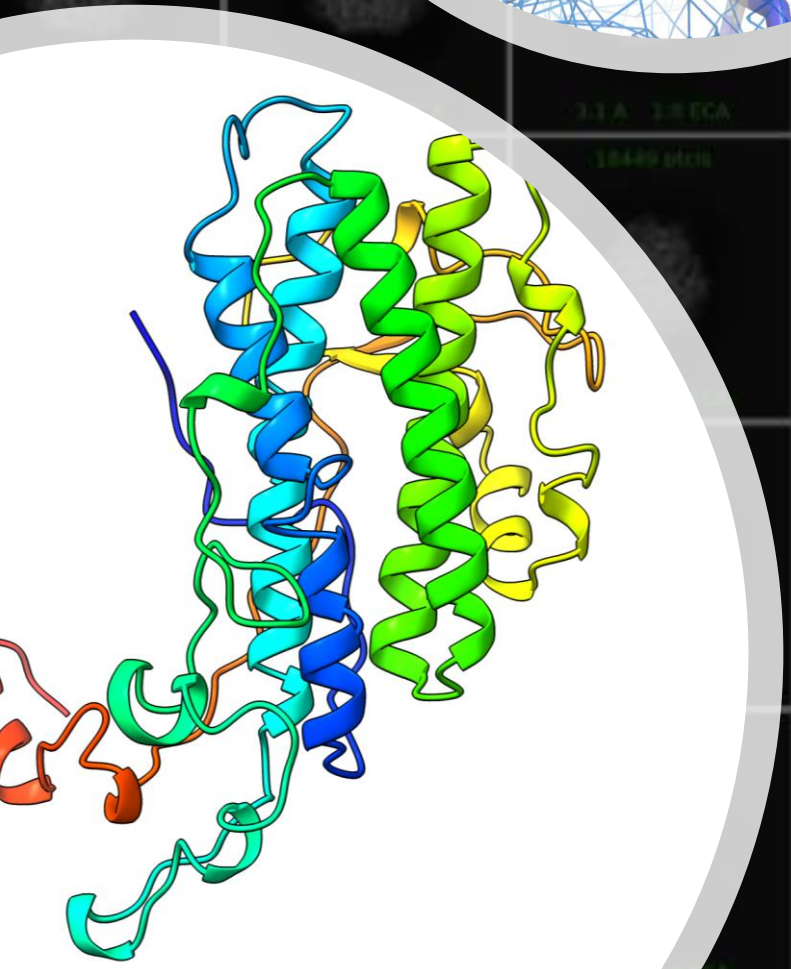
wwPDB Validation 3D Report | Full Report





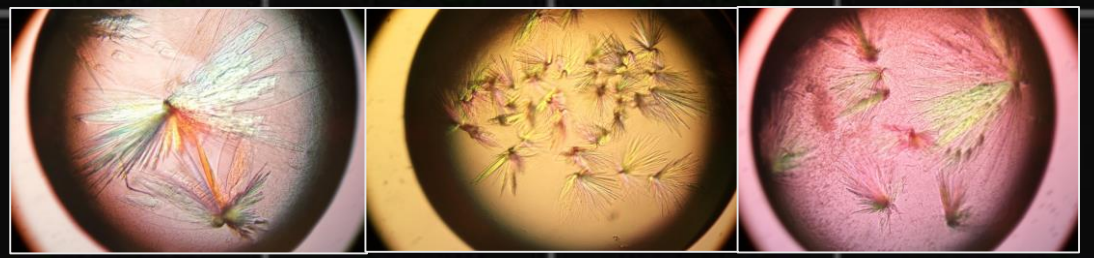


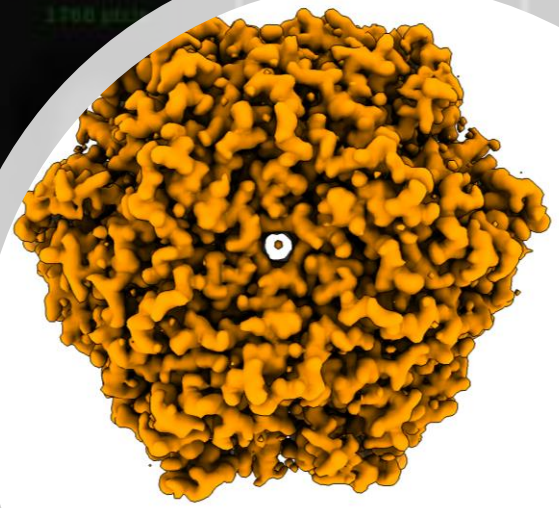




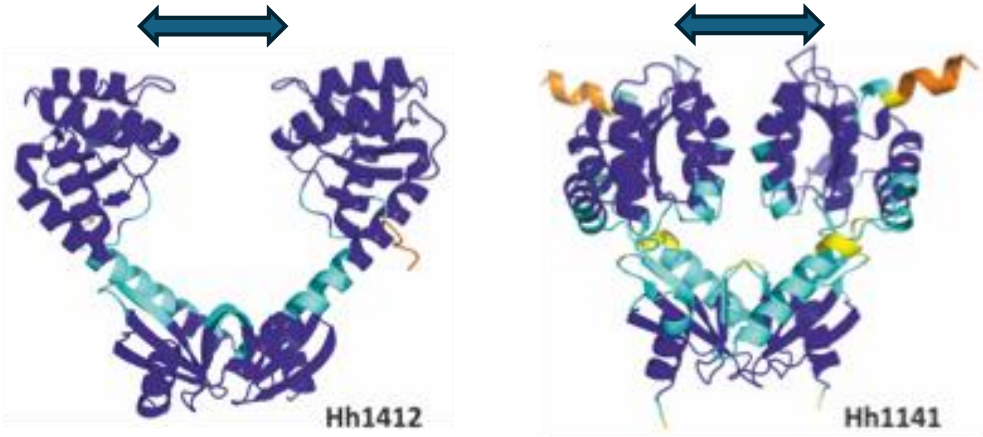
by Michał Taube

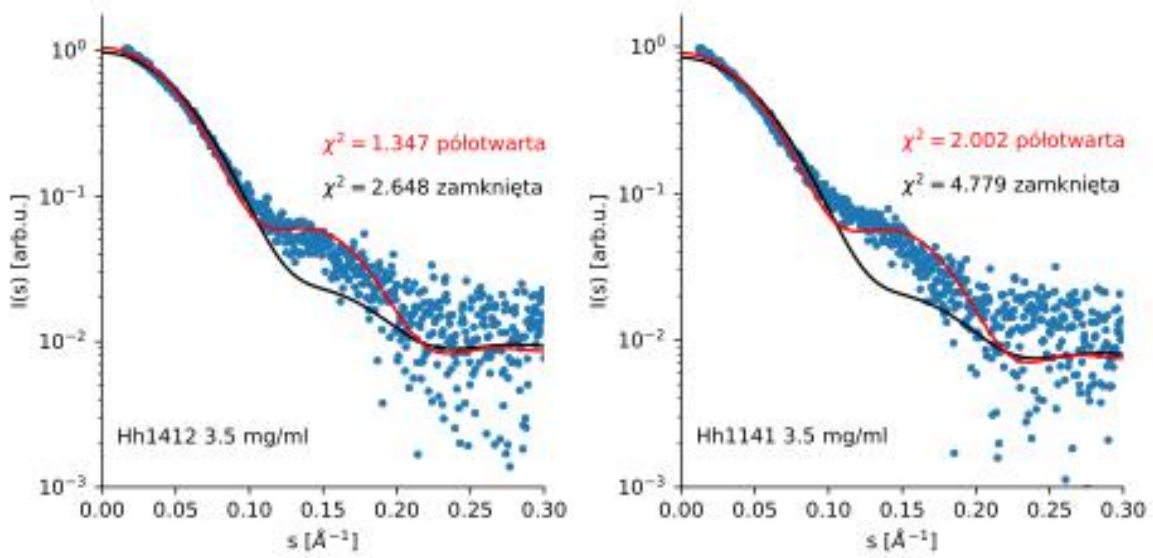
structure analysis:
X-ray diffraction, SAXS, cryoEM





SAXS and Molecular Dynamics



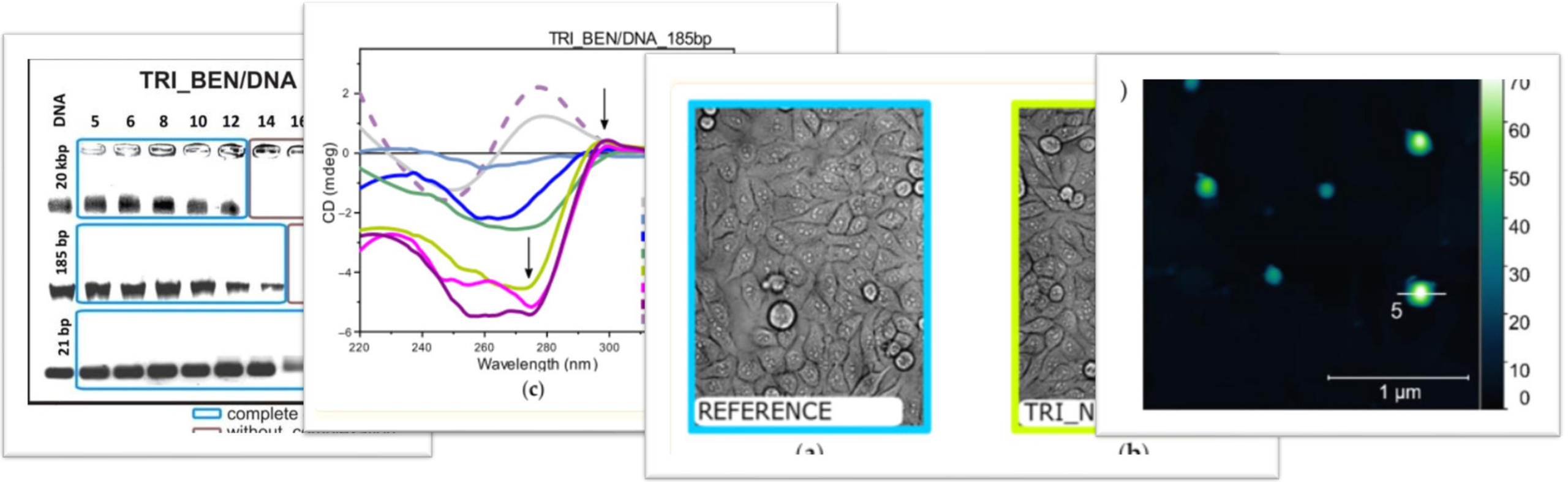


Disulfide oxidoreductase/isomerase from Helicobacter hepaticus

by Michał Taube

Nonviral vectors for gene therapy

Polańska Ż, Pietralik-Molińska Z, Wojciechowska D, Moliński A, Weiss M, Skrzypczak A, Kozak M. **The Process of Binding and Releasing of Genetic Material from Lipoplexes Based on Trimeric Surfactants and Phospholipids**. *Int J Mol Sci*. 2021 Jul 20;22(14):7744.



Carrent projects and cooperation

(Molekularne podstawy powstawania chorób neurodegeneracyjnych - wpływ wybranych nanocząstek metalicznych)

Molecular basis of neurodegenerative diseases - the influence of selected metallic nanoparticles

- 2021-12-23 - 2025-12-22, NCN OPUS 21 - 2021/41/B/ST4/03807

(Czy występuje synergistyczne działanie surfaktantów roślinnych i antybiotyków wobec komórek bakteryjnych?)

Is there a synergistic effect of plant surfactants and antibiotics on bacterial cells?

- 2021-09-01 - 2025-08-31, NCN OPUS 20 - 2020/39/B/NZ9/03196

(Mechanizmy wiązania i transportu w osoczu oligomerów amyloidu beta przez albuminę ludzką (HSA) w obecności wybranych ligandów)

Mechanisms of binding and transport of amyloid beta oligomers in plasma by human albumin (HSA) in the presence of selected ligands

- 2018-06-29 - 2023-06-28Topic 3, NCN OPUS 14 - 2017/27/B/ST4/00485

Some example
Research by Zbigniew Fojud

mgr Katarzyna Pawlak-Barszczewska

Impact of some acquisition parameters and a type of RF-coil on the image in MRI imaging diagnostics

mgr Weronika Wrembel

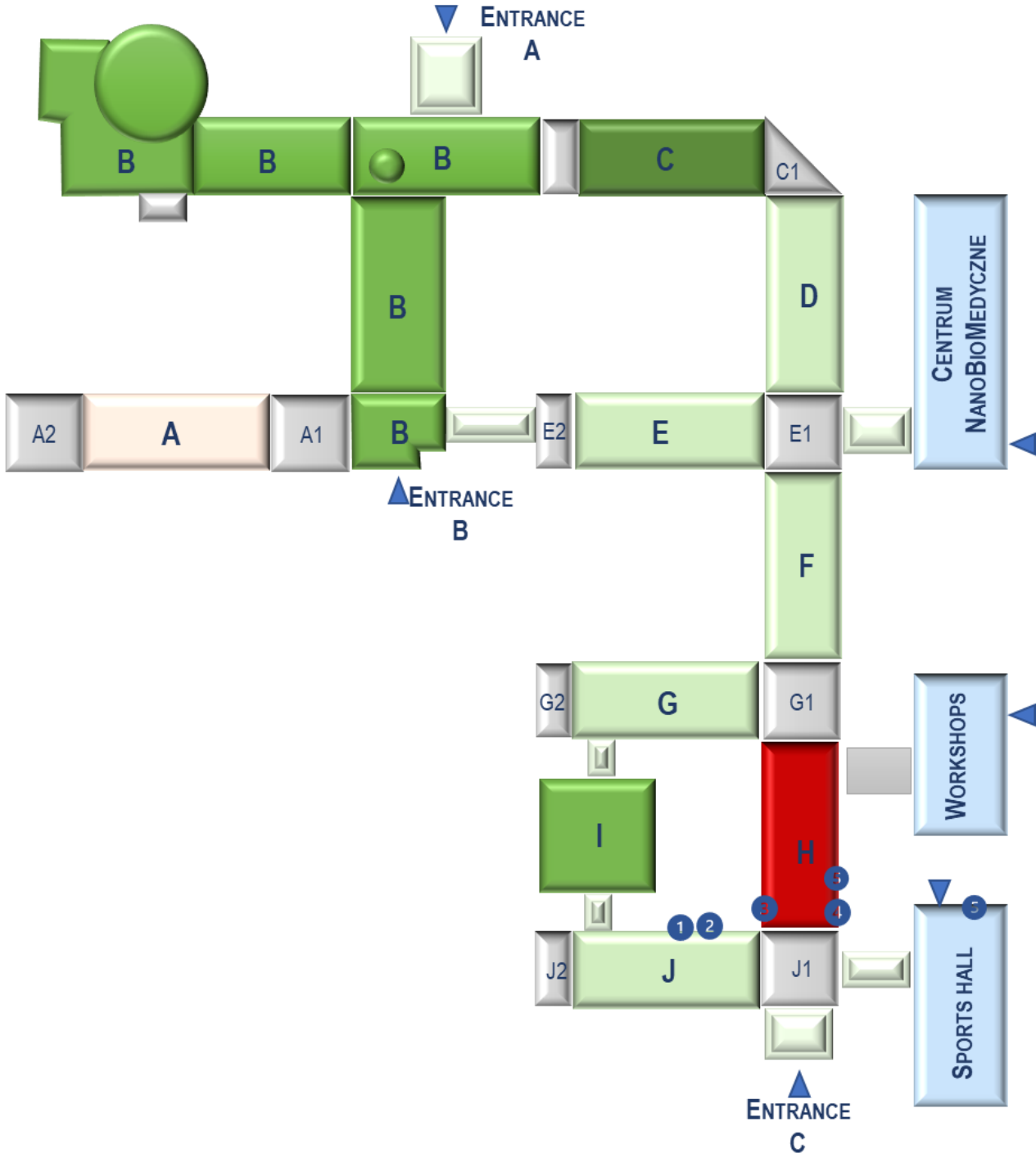
Quantum Detection Efficiency (DQE) and power distribution in the edge stripe detector with direct conversion of the digital signal of the DR breast imaging system, using the Image Analysis tools in the extended weekly "image homogeneity" test procedure

mgr Gerard Pietruszczak

Nuclear magnetic spin-lattice relaxation in C7–CQAB (N,N-dioctylazepanium bromide) – the fourth generation antiseptic – examined with Nuclear Magnetic Resonance (NMR) and Differential Scanning Calorimetry (DSC) techniques

Infrastructure

- NMR laboratories
- DSC stand
- Broadband Dielectric Spectrometer stand
- Rheological laboratory
- Cell laboratory & Biochemical laboratory
- Chemical laboratory
- SAXS laboratory
- Spectroscopic laboratory
- Chromatography laboratory
- AFM laboratory
- **SMAUG** (Solaris, JU Kraków, launch in December 2024)



NMR laboratories

- NMR Fast Field Cycling Relaxometer - spectrometer Stelar - Spinmaster 2000

Marek Kempka, Zbigniew Fojud

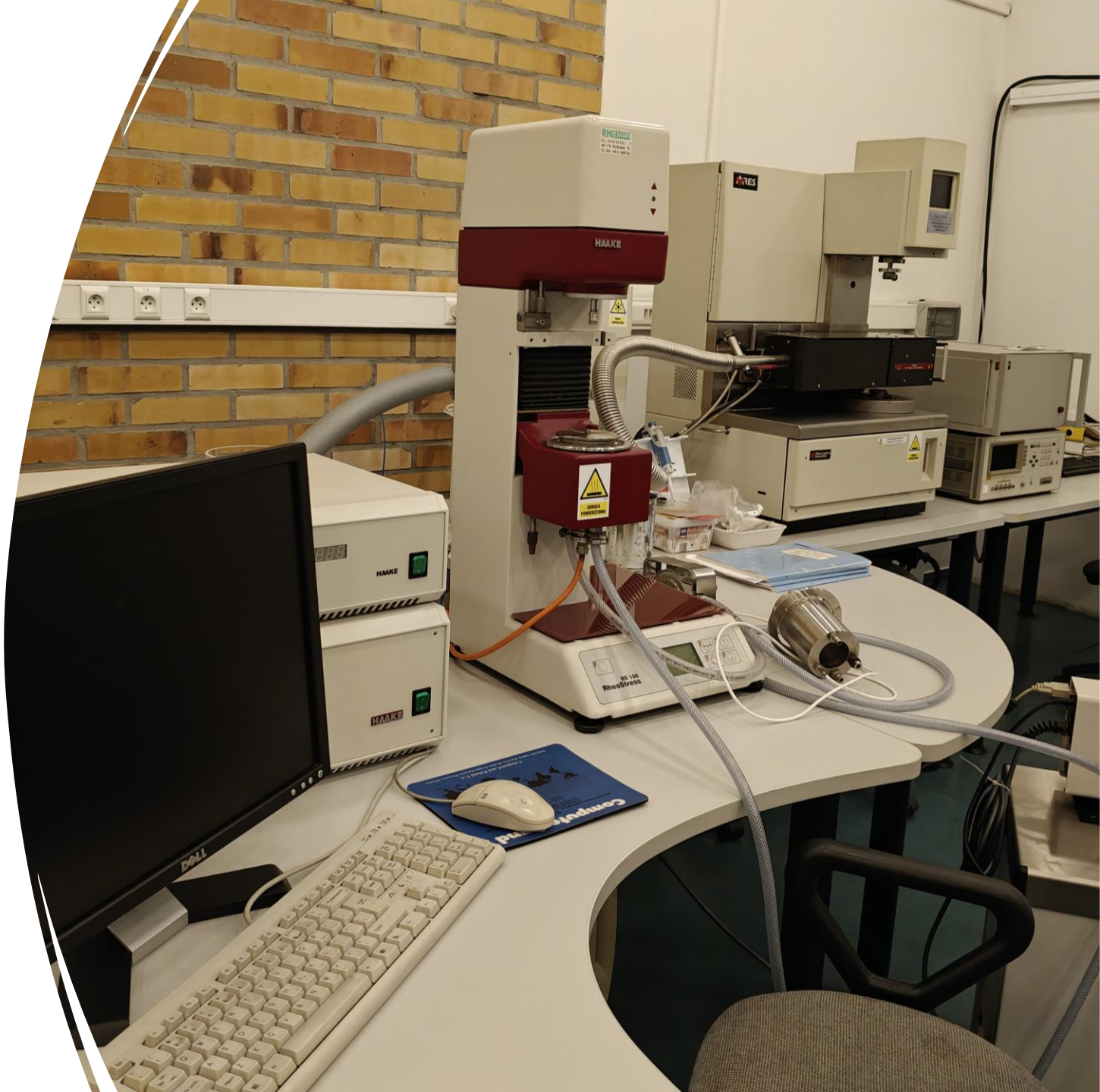
NMR laboratories

- Bruker CXP 200 MHz Spectrometer
- Bruker Avance DMX 400 MHz Spectrometer

Marek Kempka, Zbigniew Fojud

Rheological laboratory

- RheoStress RS150 HAAKE with Temperature controler TC 501
  and Cooling system DC-50 with K-75 circulator.



Maria Dobies

DSC stand

- Differential Scanning Calorimeter - Netzch DSC 204 Phoenix
- Temperature range: -180 to 700 °C
- High heating and cooling rates
- Gold-plated measuring cell
- Different interchangeable sensors

Zbigniew Fojud, Zuzanna Pietralik-Molińska, Żaneta Kołodziejska

Cell laboratory

- Cell Toxicity/Survival Tests - testing the toxicity of various biological and physical factors, e.g. nanoparticles
    - MTT tests (based on the conversion of tetrazolium salt to formazan)
    - Clonogenic tests (also known as colony count tests)
    - Trypan blue staining – stains dead cells
- Available cell lines: HeLa

Daria Wojciechowska, Michał Taube

Cell laboratory

Equipment

- PHCBI incubator with CO2 atmosphere MCO-170AC
- water bath,
- inverted phase contrast microscope with a set of lenses and IB-100 LED digital camera by Delta optical;
- laminar flow cabinet class A2 II safety class BIO 100 by Alpina;
- aspirator FTA-1 with glass bottle;
- Hettich Universal 32 centrifuge with swing-out rotor;

Biochemical laboratory

- Sample preparation: filtration, dialysis, centrifugation, temp. Incubation with shaking
- Concentration measurement of proteins and nucleic acids
- Protein aggregation kinetic assays
- Protein and nucleic acid electrophoresis

Equipment

- FLUOstar Omega plate reader with optical grating and a solid-state array detector for ultrafast whole spectrum recording: UV-VIS spectroscopy, Fluorescence measurement (with filters), FL polarization, Luminescence measurements
- Biorad Mini-Protean protein electrophoresis system with power supply
- Horizontal nucleic acid electrophoresis equipment
- Denovix DS11 ultra low-volume UV-VIS spectrometer (1-2 μl)
- Hydrolab ultra pure water system
- -20^{o}C freezer for sample storage

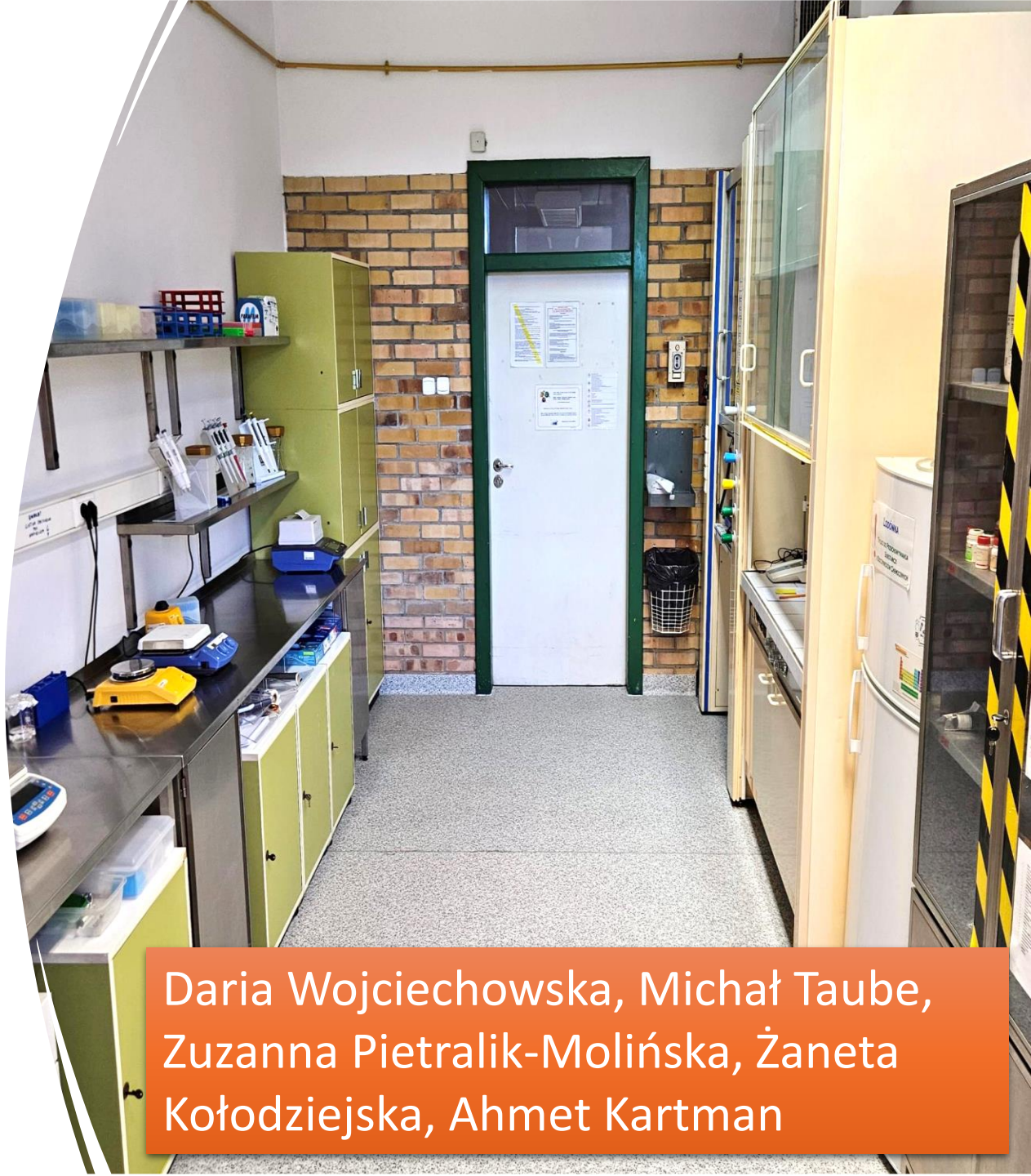
Daria Wojciechowska, Michał Taube, Zuzanna Pietralik-Molińska, Żaneta Kołodziejska

Chemical laboratory

- Preparatory work: weighing, dissolving, evaporating, adjusting pH, degassing, calcination, etc.
- Nanoparticle synthesis

Equipment:

- Hydrolab system (ultra pure water)
- magnetic stirrers, laboratory scales, fume hoods, refrigerator, etc.



Daria Wojciechowska, Michał Taube, Zuzanna Pietralik-Molińska, Żaneta Kołodziejska, Ahmet Kartman

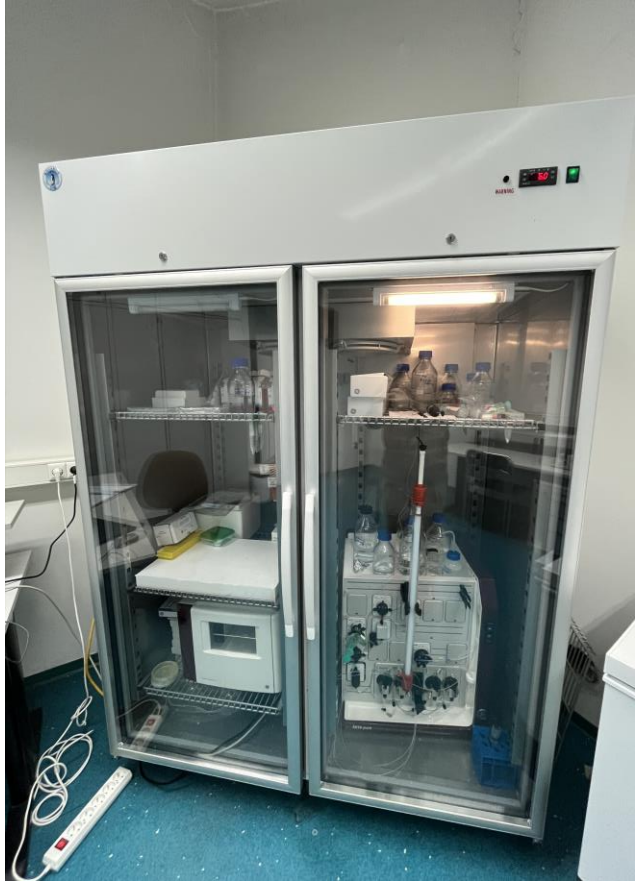
Chromatography laboratory

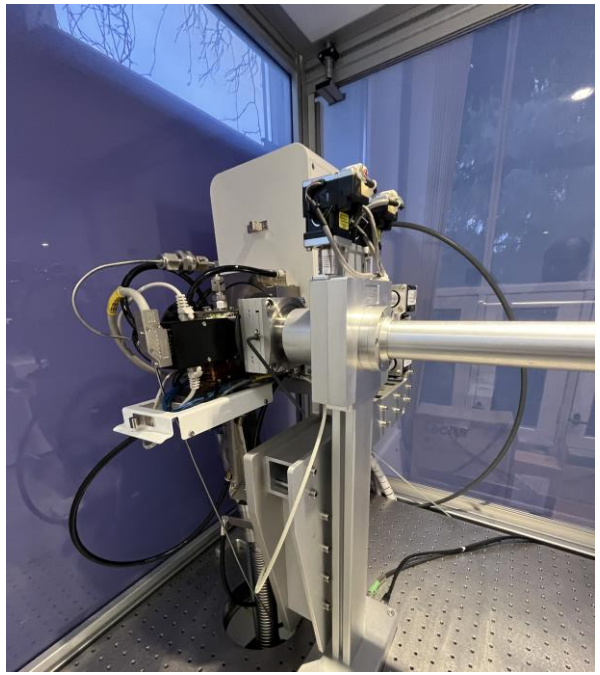
- Protein and nucleic acid purification by chromatographic techniques
  - Size Exclusion Chromatography (SEC)
  - Ion exchange (IEX)
  - Affinity chromatography (HisTag proteins etc.)
- Sample preservation at low temperature and pressure
- -80°C sample storage

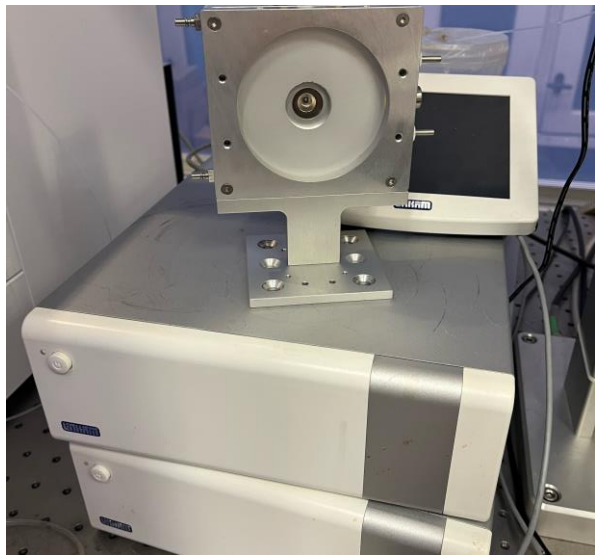
Equipment

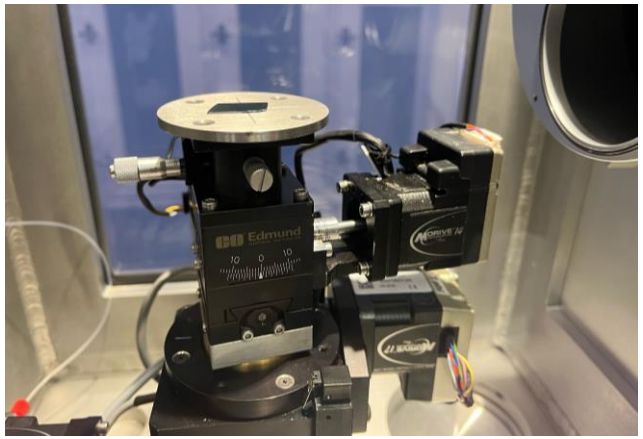
- Liquid chromatography system – Äkta Pure L (GE healthcare)
- Lyophilize Christ Alpha 1-2 LD Plus (lowest temp. -55°C)
- -80°C freezer
- 4°C cabinet for sample storage and Äkta Pure L

Daria Wojciechowska, Michał Taube, Zuzanna Pietralik-Molińska









SAXS laboratory

Sample characterization by small angle-x-ray scattering (with optional WAXS setup)

Xeuss 2.0 SAXS system (Xenocs) with MetalJet liquid metal (gallium alloy) anode and 2D semiconductor CMOS detector Pilatus R 1M

- Biopolymers in solution: proteins, nucleic acid etc.
- Lipids and surfactant systems
- Polymers
- Solids, gels and other soft matter systems
- Ionic liquids
- Nanoparticles
- Thin layer systems(GISAXS in tests)

Sample environments

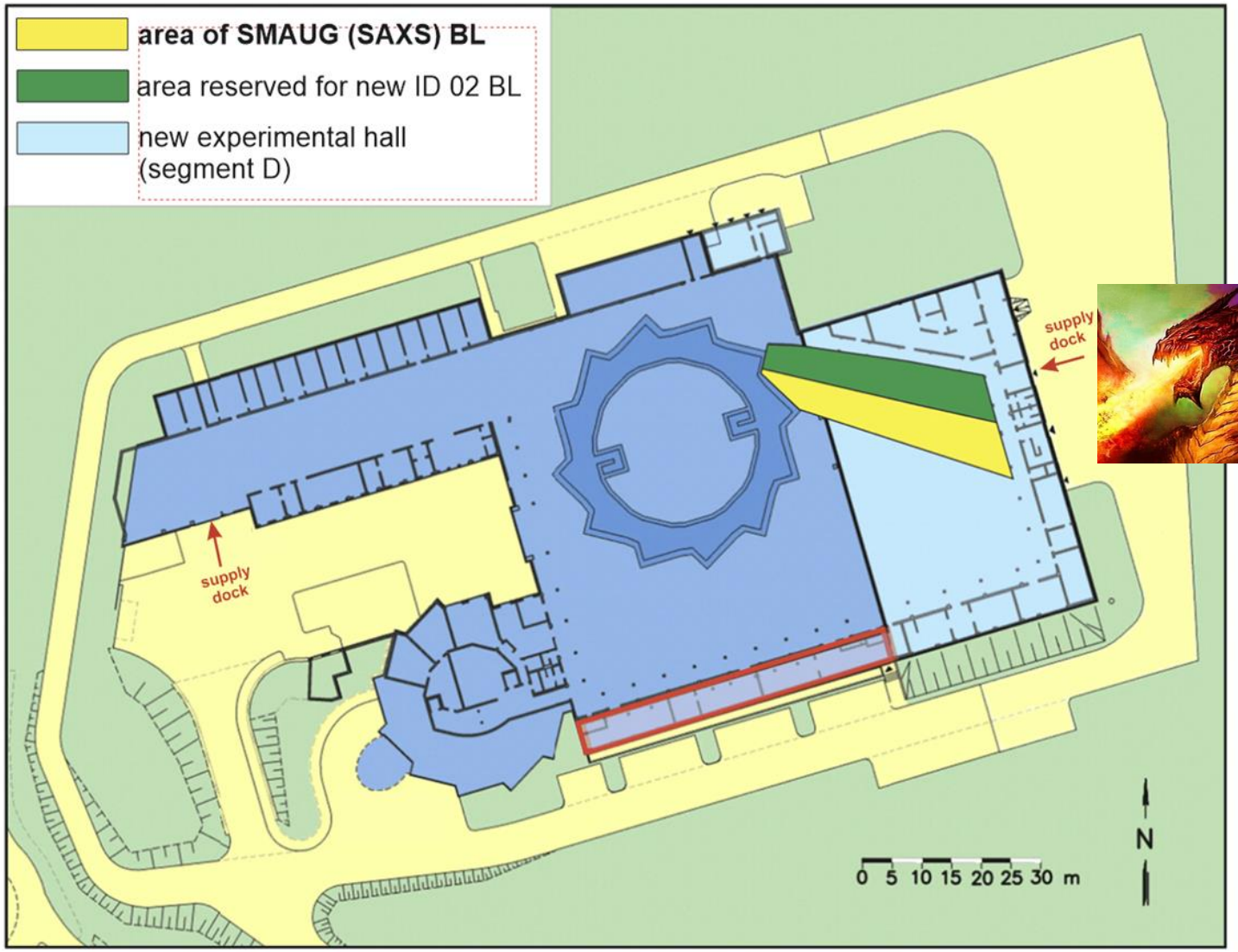
- Low noise, low volume (30μl) liquid sample cell
- Liquid sample changer (in tests)
- Linkam sample holder for temperature measurements in glass or quartz capillaries temp. range -195°C to 350°C (with possibilities to measure powders and gels in home made attachment)
- Grazing Incidens SAXS (GI-SAXS) stage
- Standard holders for solid samples and liquids (ambient conditions)

Michał Taube

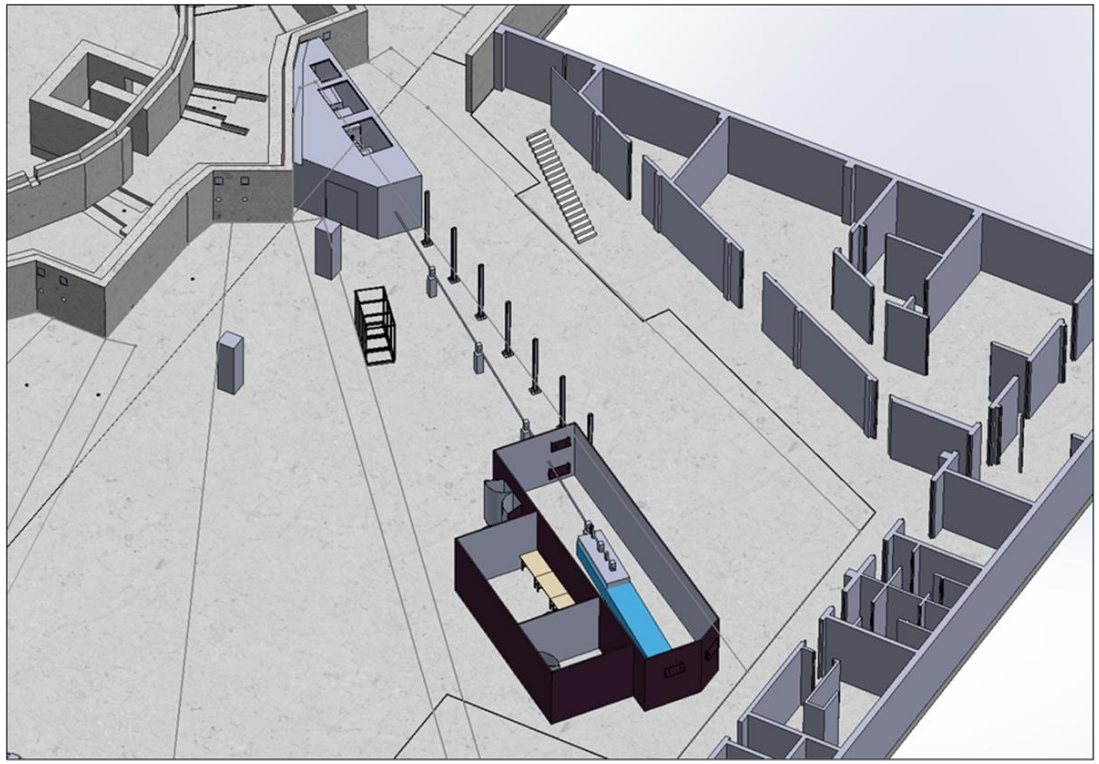
SOLARIS National Synchrotron Radiation Centre with new experimental hall – SMAUG beam line

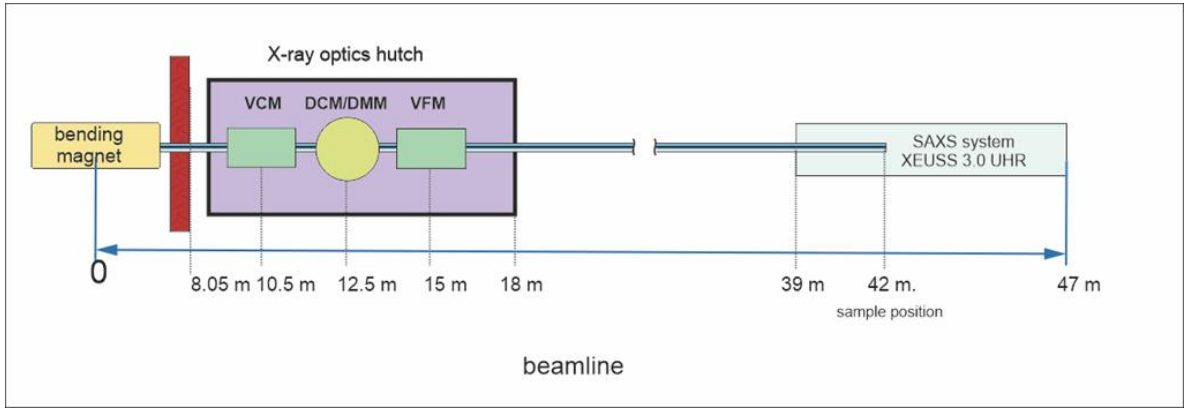
SMAUG beamline (Small Angle X-ray Scattering) - under constraction

- **bioSAXS** (studies of biological systems in solutions),
- **SEC-SAXS** (combined SAXS studies with simultaneous chromatographic separation),
- **SAXS static measurements** (including tests at low and high temperatures, magnetic or electric field)
- **SAXS liquid measurements** at high pressures.



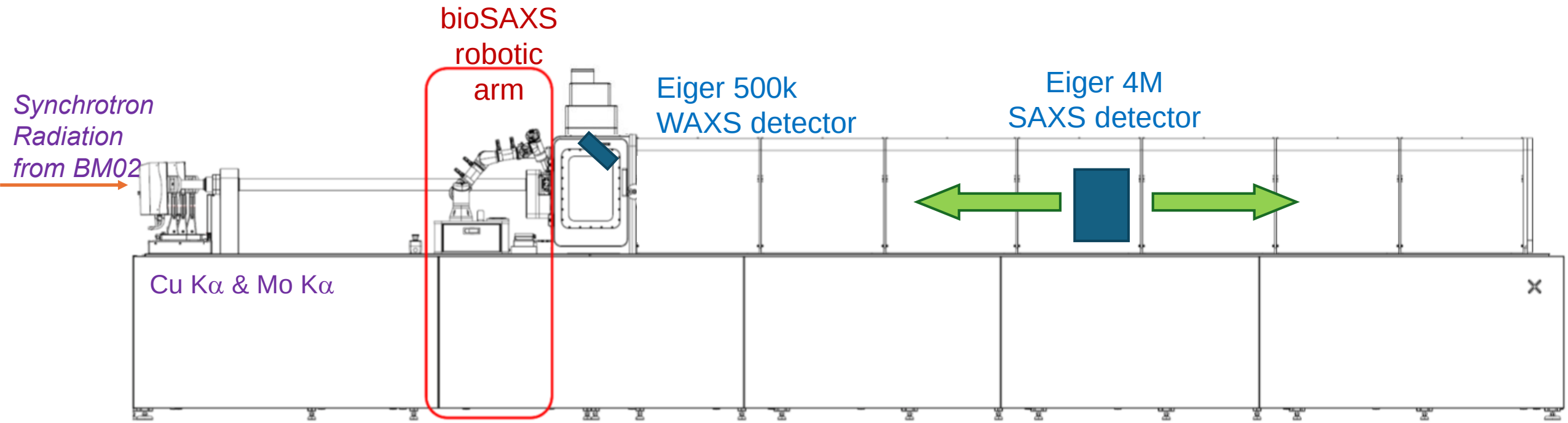
SMAUG – 3D layout





hard X-rays in the range of 6 to 14 keV

SAXS/WAXS end station for SMAUG



Schematic representation of XEUSS 3.0 UHR (adopted and modified from XENOCS technical documentation)

SAXS/WAXS end station for SMAUG

Synchrotron radiation

6-15 keV (0.2067 nm – 0.0827 nm)

Microfocus sources

CuKα 8.08 keV (0.154178 nm) & MoKα 17.4 keV (0.071073 nm)

Use of SMAUG infrastructure – areas of research

- Structure of **proteins and viruses in solution**.
- **Carriers** of drugs, vaccines and gene therapy systems.
- **Structural analysis of other new materials and biomaterials.**
- **Structure of functional nanomaterials** - metallic, magnetic or semiconductor nanoparticles.
- Research on the **microstructure of fuel cell components**
- **Hydrogen technologies** - structure of molecular sieves.
- **New materials for the automotive industry** - analysis of the structure of polymers, copolymers, composites and polymer nanocomposites.
- **Catalysts** for the chemical and petrochemical industries.

Spectroscopic laboratory

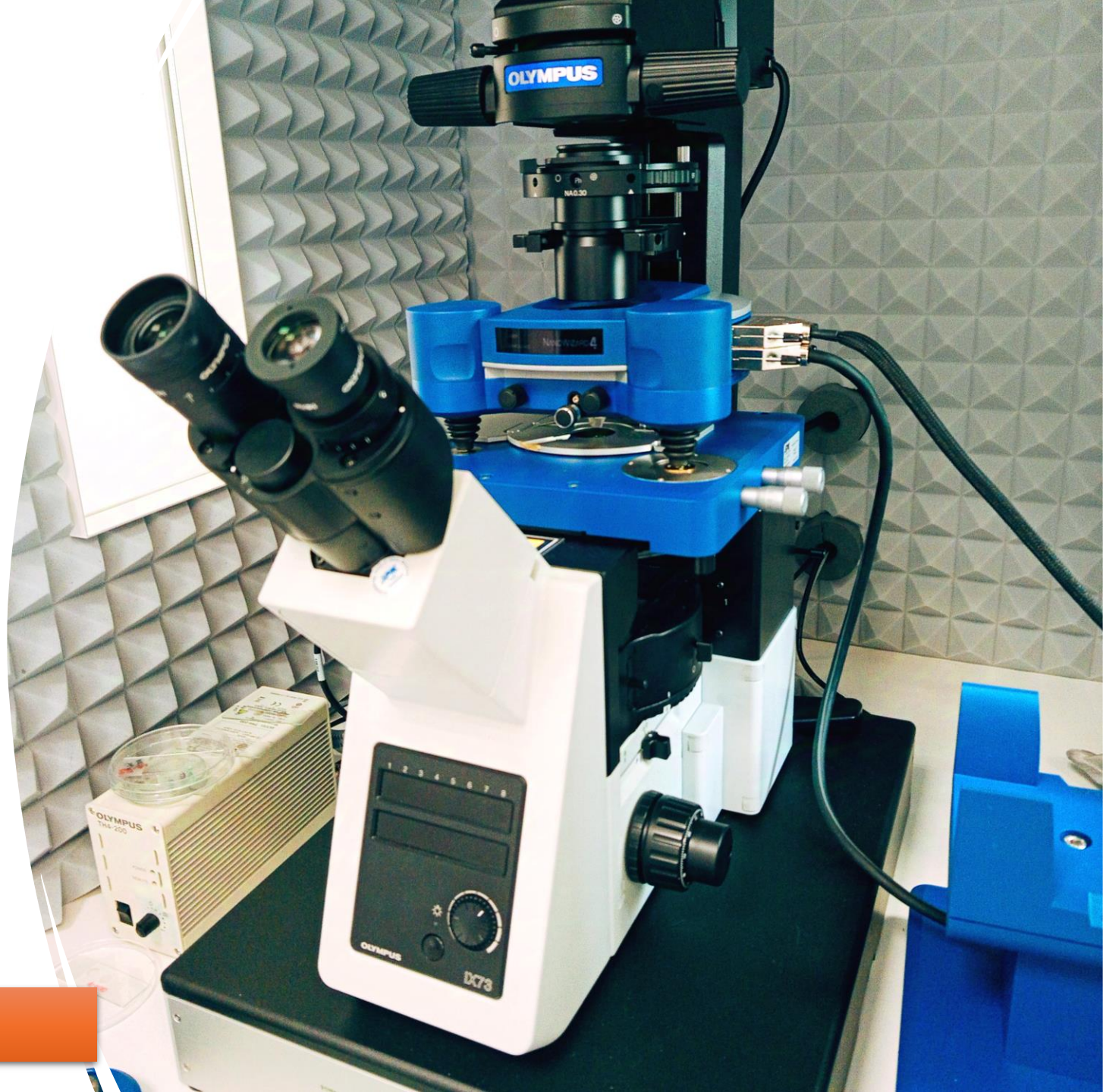
- Litesizer 500 (DLS, SLS, zeta potential)
- Bruker Tensor 27 FT-IR Spectrometer
- CD spectrometer JASCO J-815
- UV-vis spectrometer JASCO V-650
- Microfluidic device

Daria Wojciechowska, Michał Taube,
Zuzanna Pietralik-Molińska, Żaneta Kołodziejska

Atomic Force Microscope

- AFM Microscope Nanowizard IV, Bruker
  - Measuring modes:
    - Contact mode
    - Non-contact
    - AC mode (tapping)
    - QI imaging (quantitative imaging)
    - Force spectroscopy

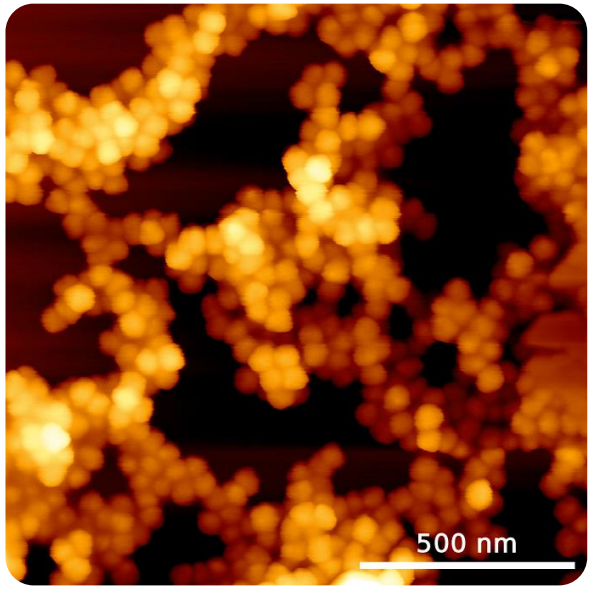
- Olympus, inverted optical microscope with fluorescent source and camera
  - Direct overlay software (combining optical or fluorescent image with AFM image)



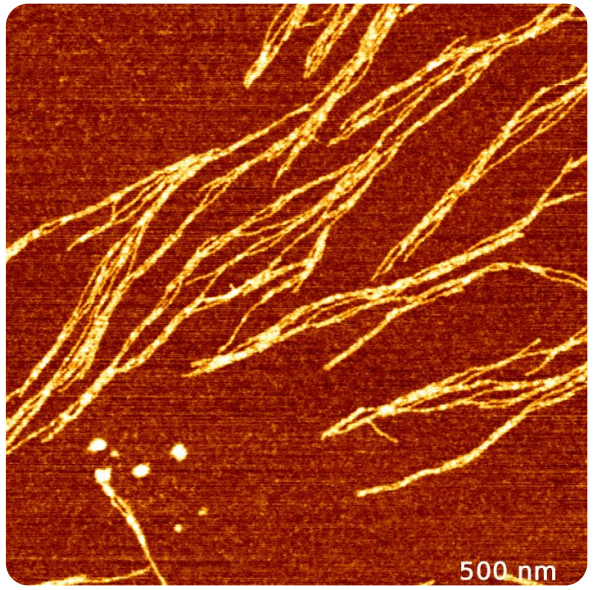
Zuzanna Pietralik-Molińska

Atomic Force Microscopy

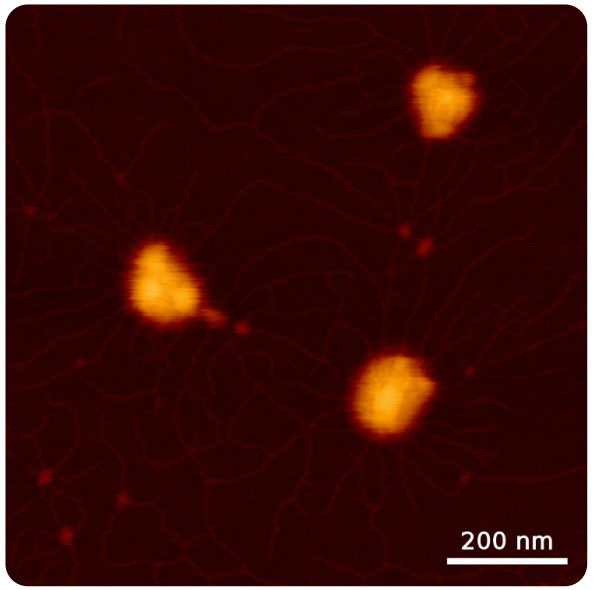
selected applications



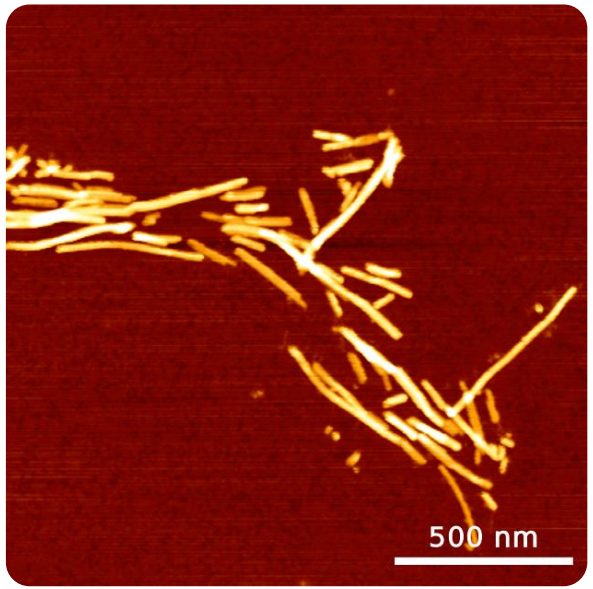
gold nanoparticles



amyloid beta fibrils



surfactant-based DNA-carriers



human cystatin C fibrils

- **Nanotechnology:** Nanoparticle characterization, nanolithography, manipulation of nanostructures.
- **Biology:** Biomolecule imaging, cell surface analysis, protein unfolding.
- **Materials Science:** Surface roughness, thin film analysis, phase imaging.
- **Chemistry:** Surface chemistry, single-molecule reactions.
- **Medicine:** Tissue mechanics, drug delivery, biofilm studies.
- **Polymers:** Morphology, elasticity, and viscoelasticity.