UNIVERSITY OF TARTU
Institute of Physics

# "INCREASING EXCELLENCE IN UTILIZING X-RAY RESEARCH AND NEUTRON SCATTERING TECHNIQUES AT THE UNIVERSITY OF TARTU" (EXANST) - THE RESULTS OF PILOT RESERACH PROGRAM DURING THE FIRST YEAR OF EC TWINNING PROJECT EXANST

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On behalf of the EXANST consortium

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20.09.2025


Funded by the European Union

# Outline

- Estonian Research Infrastructures Roadmap
- EXANST and advanced partners

- Pilot research projects
- Activities
- Output

# Estonian Research Infrastructures Roadmap in 2010

Launched by the *Ministry of Education and Research* together with the *Estonian Academy of Sciences*

- A roadmap is a long term (10-20 years) **planning instrument** that lists research infrastructures of national importance, either new or in need of upgrading.
- Including a research infrastructure into the roadmap **does not mean that it will be funded nor ranked** but the roadmap will be used as an input for the investment decisions under preparation.
- Research infrastructures are „facilities", "resources" and related "services" that are needed by the scientific community for the development of leading-edge research in the most efficient manner.

- *Consortia of collaborating Estonian Universities and Research Institutes*

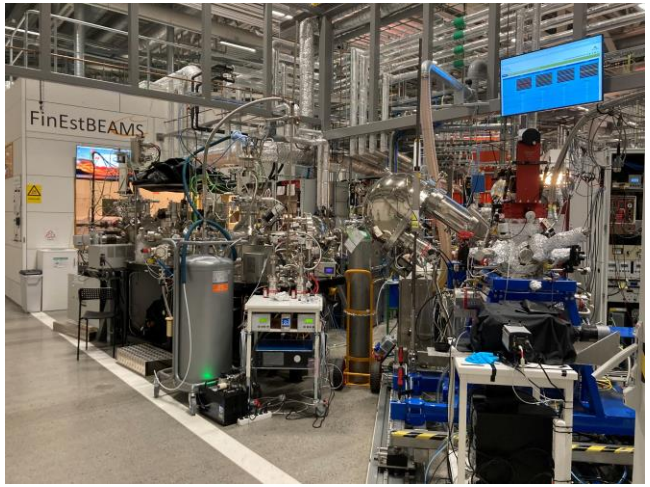
Outcome - 20 research infrastructures selected

# Estonian Research Infrastructures Roadmap in 2024

- Center of Nanomaterials Technologies and Research NAMUR+ UTARTU, TalTech, NICBP
- **Estonian-Finnish beamline at MAX-IV Synchrotron Radiation Source** FinEstBeAMS UTARTU, TalTech, NICBP
- **European Spallation Source** ERIC UTARTU, TalTech, NICBP
- European Organization for Nuclear Research CERN NICBP, UTARTU, TalTech

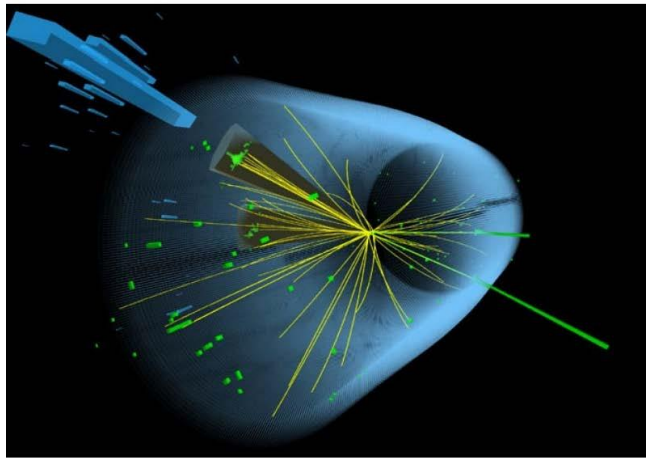
TEM in Tartu

FinEstBeAMS in Lund

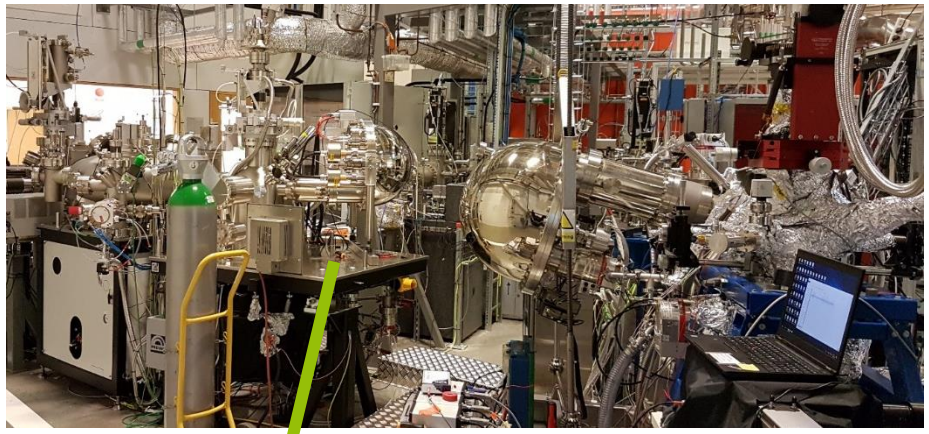



ESS in Lund

Higgs boson? H°

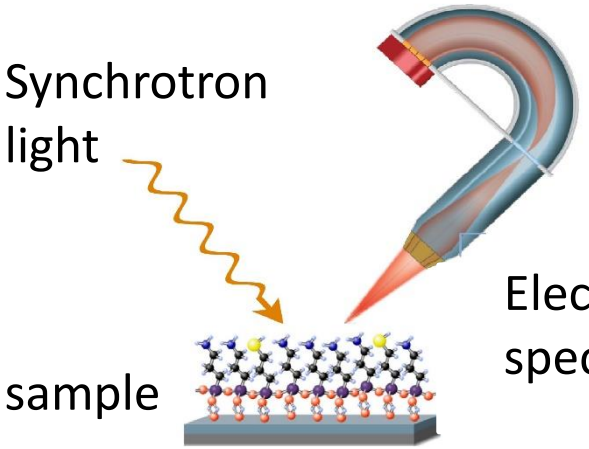


# FinEstBeAMS : Finnish – Estonian beamline for atmospheric and material sciences, in operation since 2018

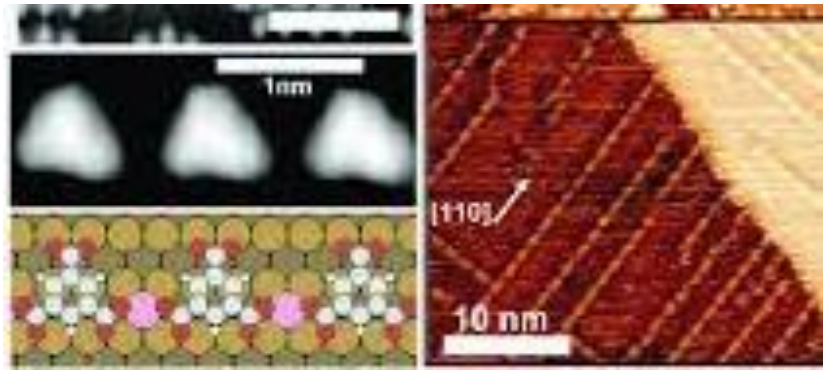


**Surface science endstation**

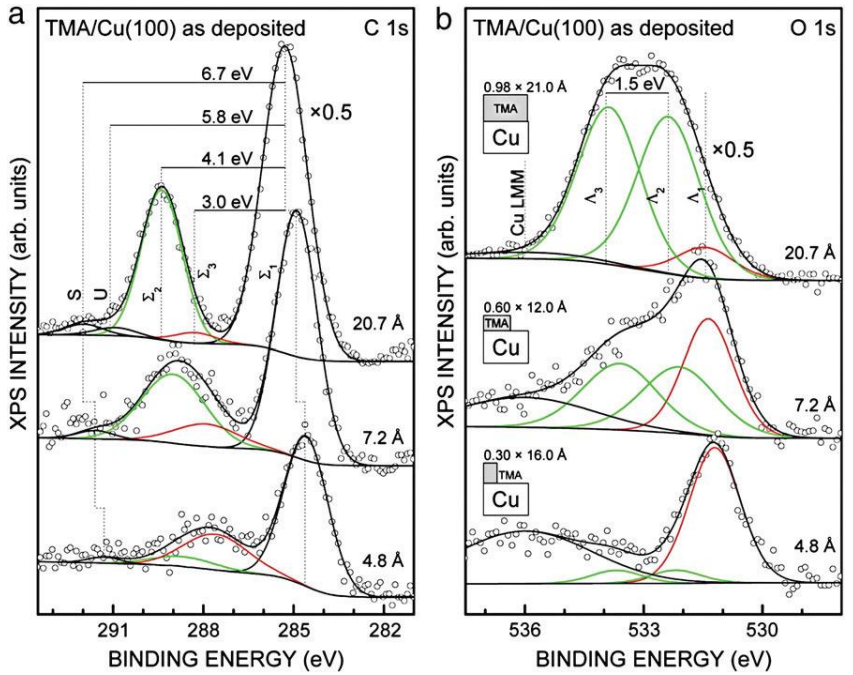
- XPS, UPS and ARPES
- X-ray absorption spectroscopy (L-edge)



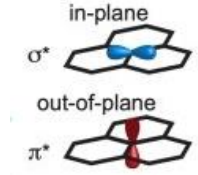

STM

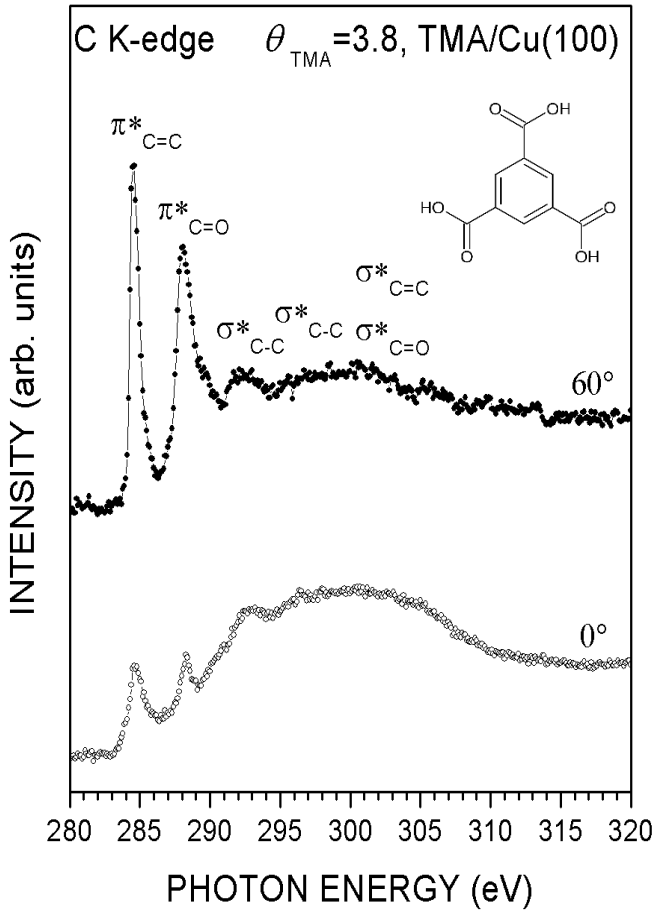



XPS




NEXAFS

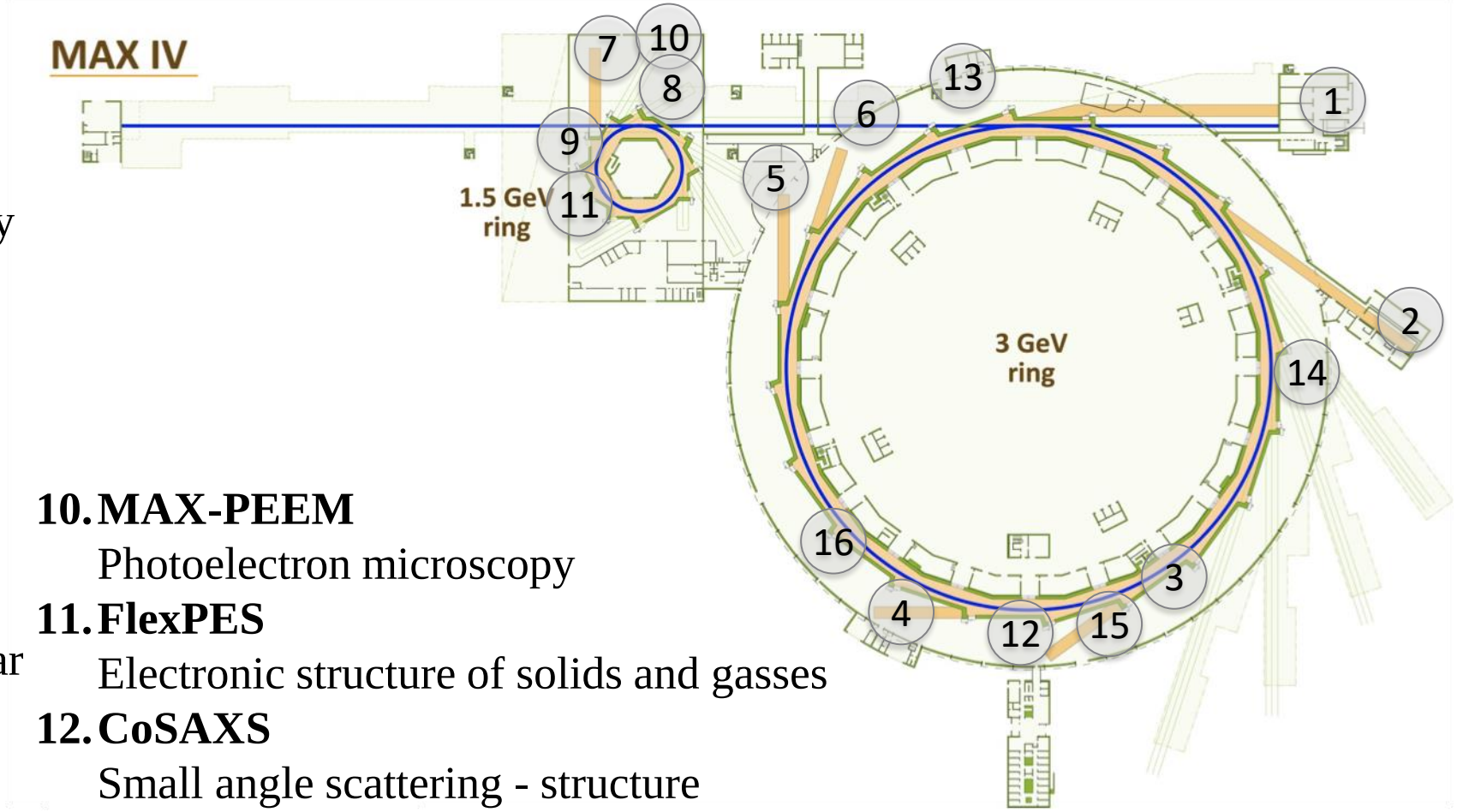



Benzene ring
rel. to surface 30 deg

# 16 beamlines at MAX IV laboratory for world-class research

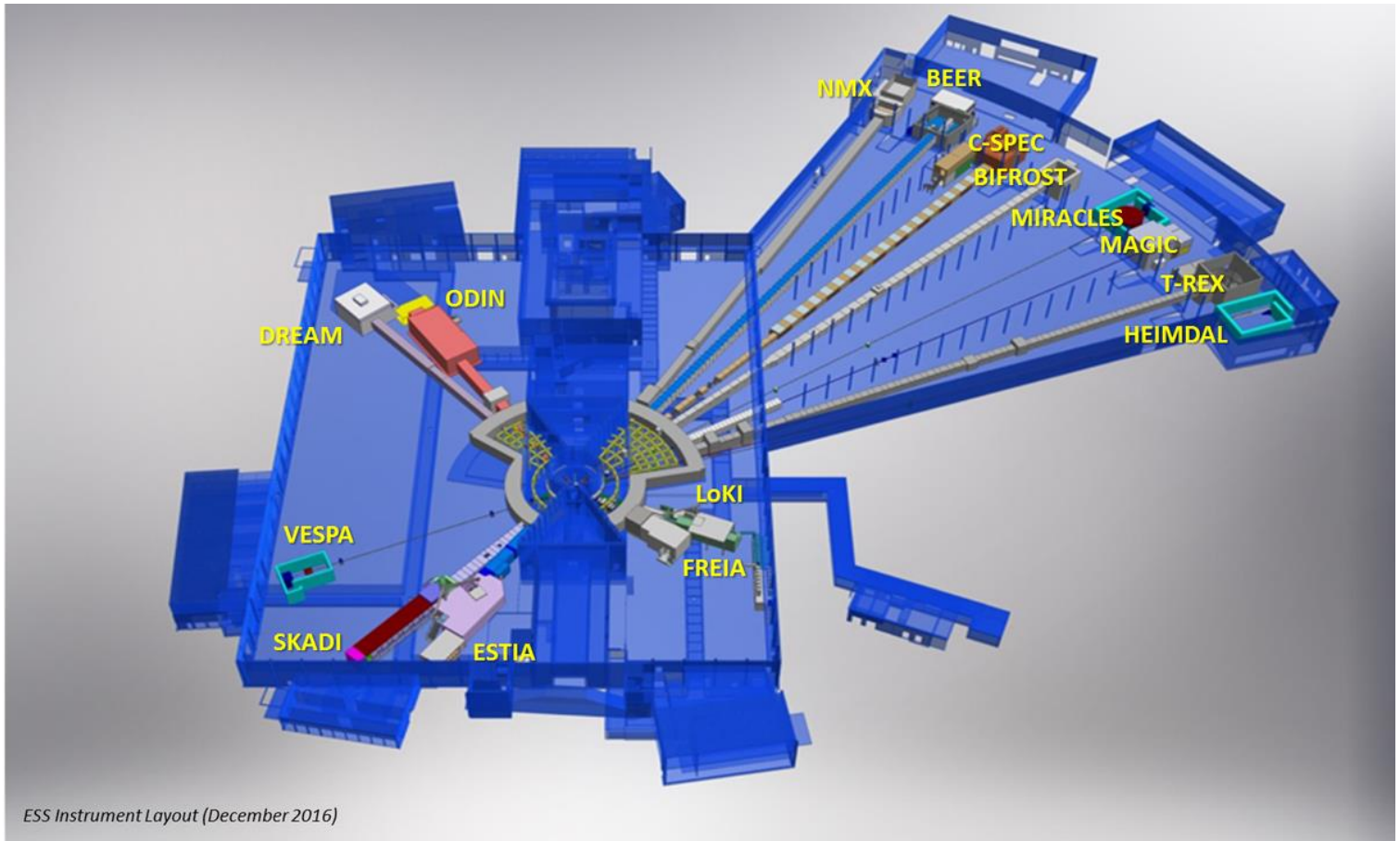
1. **FemtoMAX**
   fs dynamics (solids)
2. **NanoMAX**
   Nano microscopy and spectroscopy
3. **BALDER**
   EXAFS, spectroscopy in real time
4. **BioMAX**
   Protein crystallography
5. **Veritas**
   X-ray emission
6. **Hippie**
   Photoelectron spectroscopy at mBar
7. **BLOCH**
   Electronic structure - ARPES
8. **FinEstBeAMS**
   Low density matter/solids
9. **SPECIES**
   Electronic and magnetic structure




10. **MAX-PEEM**
    Photoelectron microscopy
11. **FlexPES**
    Electronic structure of solids and gasses
12. **CoSAXS**
    Small angle scattering - structure
13. **Softi*MAX***
    X-ray microscopy
14. **DanMAX**
    Powder diffraction - structure
15. **ForMAX**
    Forest raw material
16. **MicroMAX**
    powder crystallography

# European Spallation Source (ESS) is a ERIC of 13 European countries incl. Estonia

**A multi-disciplinary research facility based on the world's most powerful neutron source.**
**Initially 15 instruments will be launched in 2026.**

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# Situation in 2022

*Estonia* is well-integrated into activities of large-scale facilities: *FinEstBeAMS* is a collaboration platform with MAX IV for research; *Estonia* is a member of ESS Eric to be launched in 2026.

In order to get **a full benefit of investments into large-scale facilities** :

- to *increase competence* of Estonian researchers in Academia and Industry on advanced research methods (X-rays and neutrons);
- to *develop* the respective Estonian community (incl. young researchers) and *enlarge* it outside of Physics&Chemistry;
- *deepen knowledge* on *modern theoretical and materials modelling methods* needed *in the analysis* of high-quality data obtained at large-scale facilities.

# Twinning 2023 call of the WIDENING Programme in HORIZON EUROPE

- **Boost a defined field of research** in a university or research org. from a Widening country - by linking it with at least two internationally-leading research institutions in other MS or AC
- **Raise the research profile of the institution** from the Widening country **and of its staff**
- **Reinforce the research management and administrative skills** of the coordinating institution
- **Enhance networking activities, knowledge transfer, exchange of best practices** between the institution of the Widening country and top-class leading European counterparts

# Increasing Excellence in utilizing X-Ray research and Neutron Scattering Techniques at the University of Tartu (EXANST)

TARTU ÜLIKOOL

**Project 101159716 –EXANST 2024-2027**

**HORIZON-WIDERA-2023-ACCESS-02 – Twinning**

**94 projects funded of 848 submitted**

*University of Tartu (UTARTU) – Tartu, Estonia*

*MAX IV Laboratory (MAX IV) – Lund, Sweden*

*Forschungszentrum Jülich Gmbh (FZJ) – Jülich, Germany*

*Imperial College of Science Technology and Medicine (ICL) – London, UK*

**EU contribution 1 299 707.50 €**

**UK contribution 174 010 £**

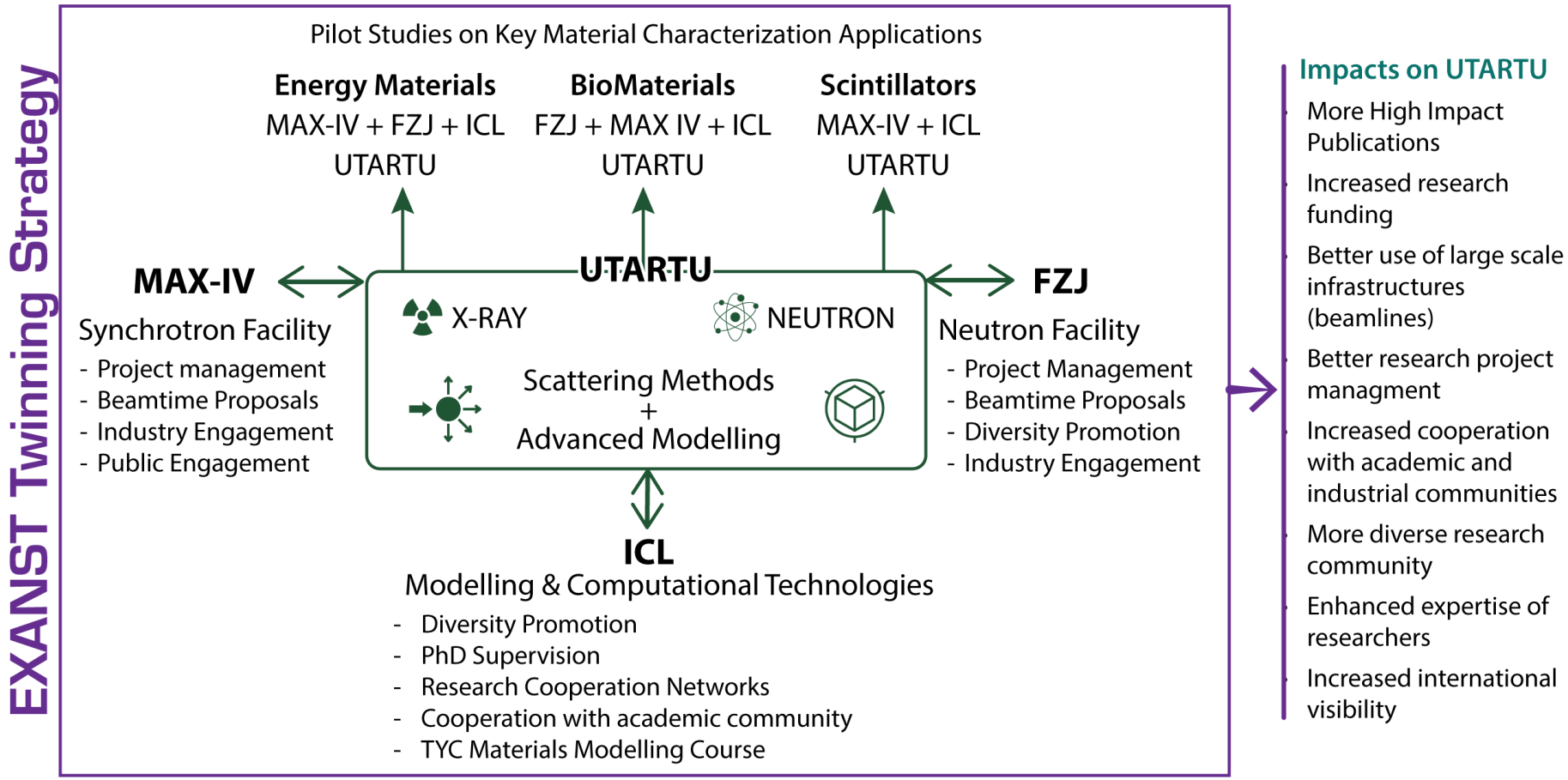
Funded by the European Union

# Goal of EXANST

**The main objective of the EXANST project is to increase scientific excellence of materials science research at UTARTU by leveraging existing strengths and developing new knowledge and skills to improve capacity in state-of-the-art use of large-scale synchrotron, neutron radiation facilities, modelling of results and advanced data analysis**

- **Advance UTARTU's scientific excellence by linking together X-ray and neutron scattering techniques with advanced computational (modelling) methods.**
- **Improve UTARTU's research management capacity and its ability to prepare competitive funding proposals.**
- **Enhance the international visibility and attractiveness of UTARTU and raise the research profile of staff.**
- **Establish the foundation for long-term cooperation between EXANST partners**
- **Improve gender balance and develop a diverse, inclusive environment at UTARTU.**

# EXANST Twinning strategy



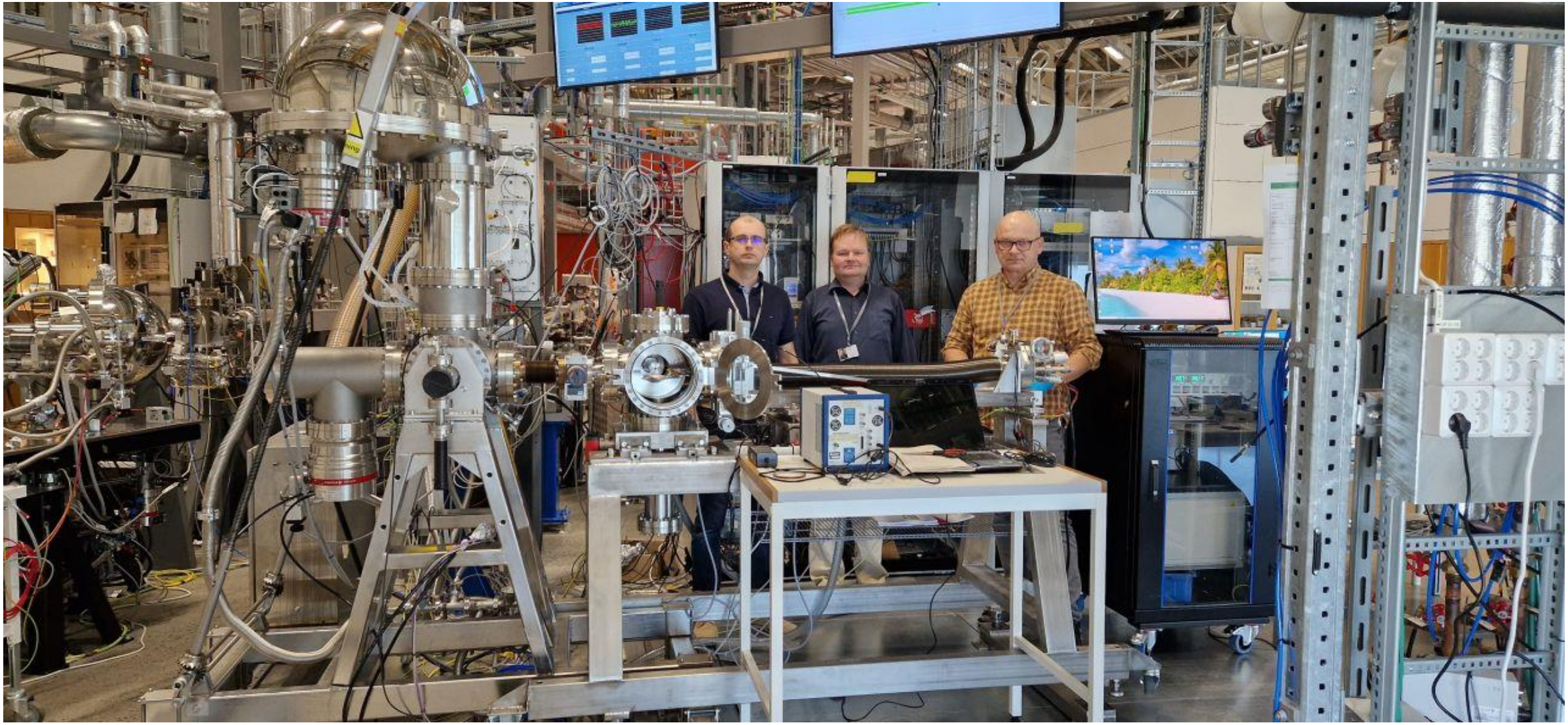

PILOT research:

***(i) Energy Materials:*** **Solid-electrolyte-interfaces formed in energy storage devices based on ionic liquids**

***(ii) BioMaterials:*** **Photoactive proteins that can serve as optical switches or tuneable fluorescence markers,**

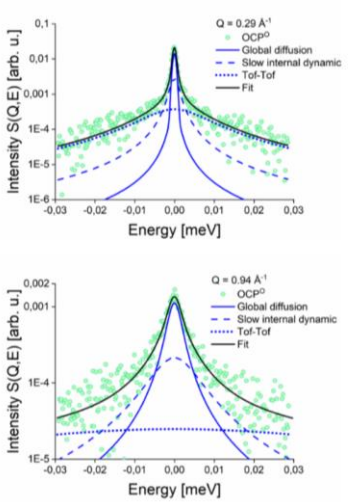
***(iii) Scintillator*** **materials for ultrafast radiation detection devices**

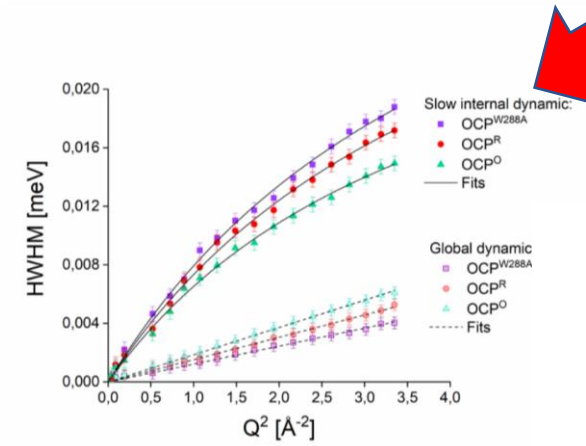
# A New Sustainable Energy Research setup in operation at FinEstBeAMS –August 2025, Rainer Pärna, Jaanus Kruusma, Arvo Tõnisoo



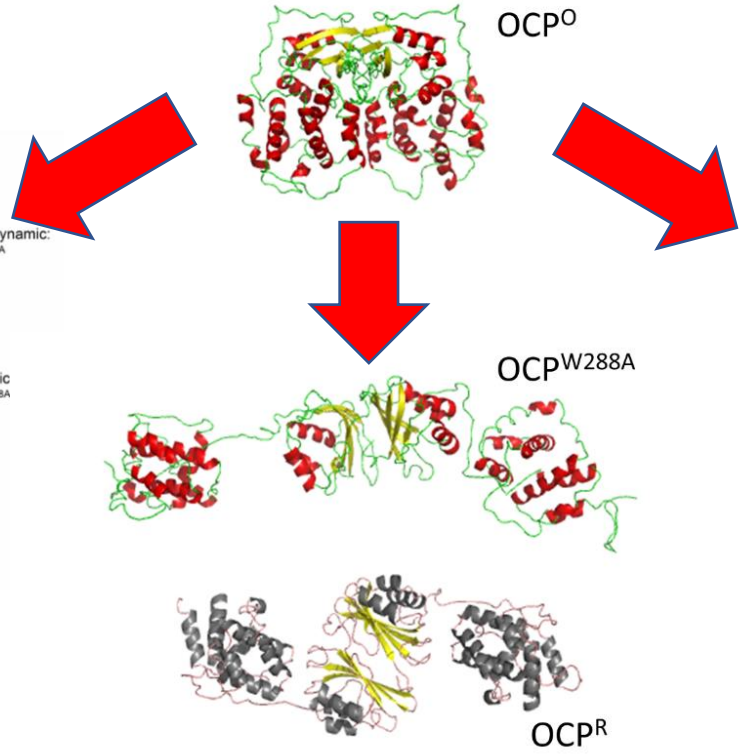
# Neutron Scattering - pilot research

## Photoactive Biomolecules: Orange Carotenoid Protein

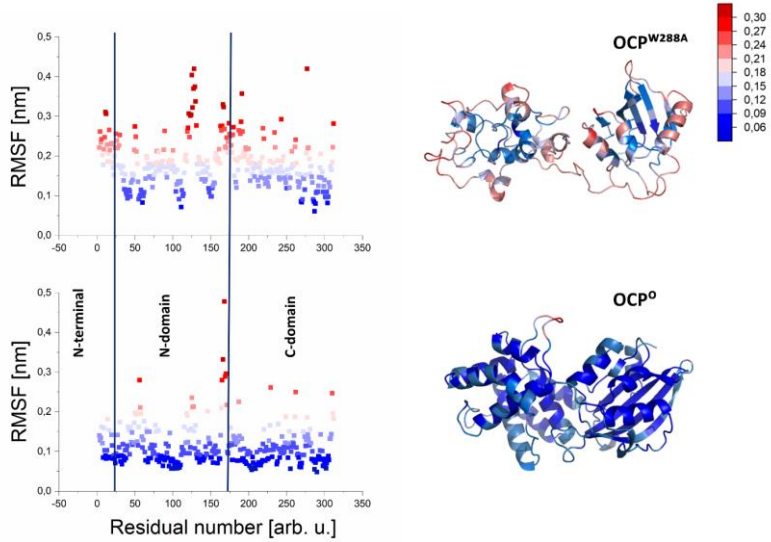



**Neutron Spectroscopy**
OCP global diffusion and internal dynamics
Collaboration with FZJ / ILL



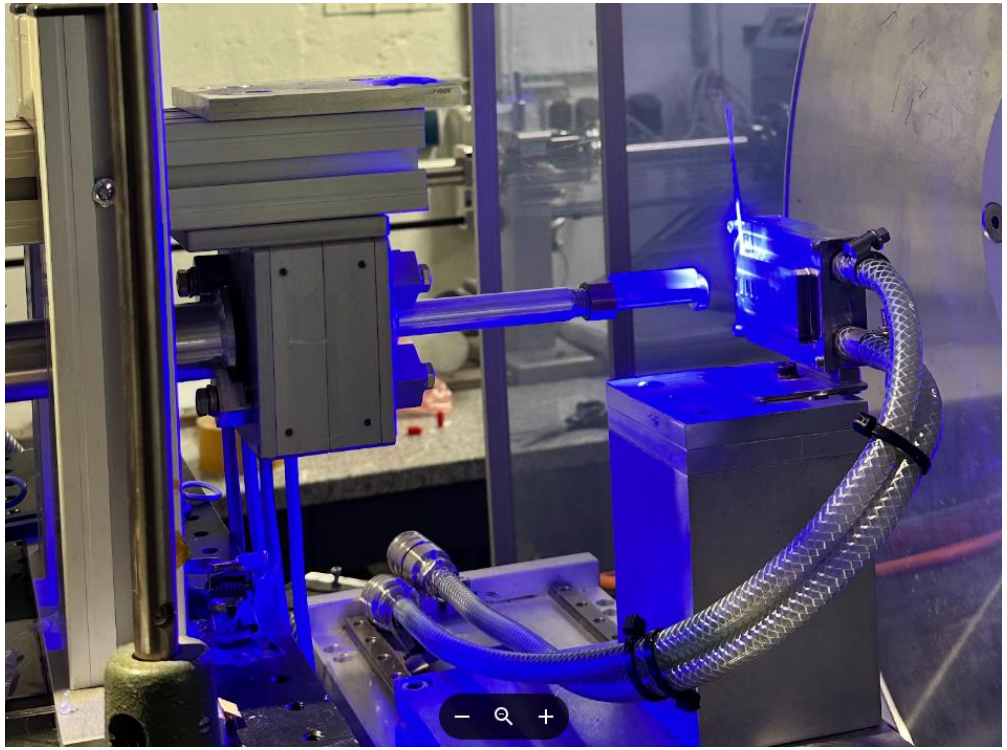

**Solution Structure by SANS/SAXS**
Combination of neutrons/X-rays




**MD simulation**
**OCP internal dynamics**
Collaboration with Theory

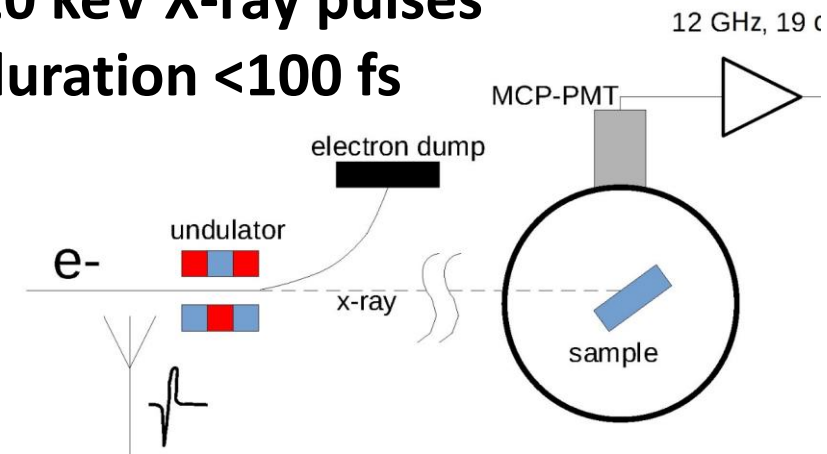
# KNOWLEDGE TRANSFER ON NEUTRON SCATTERING TECHNIQUES AT FZ JÜLICH

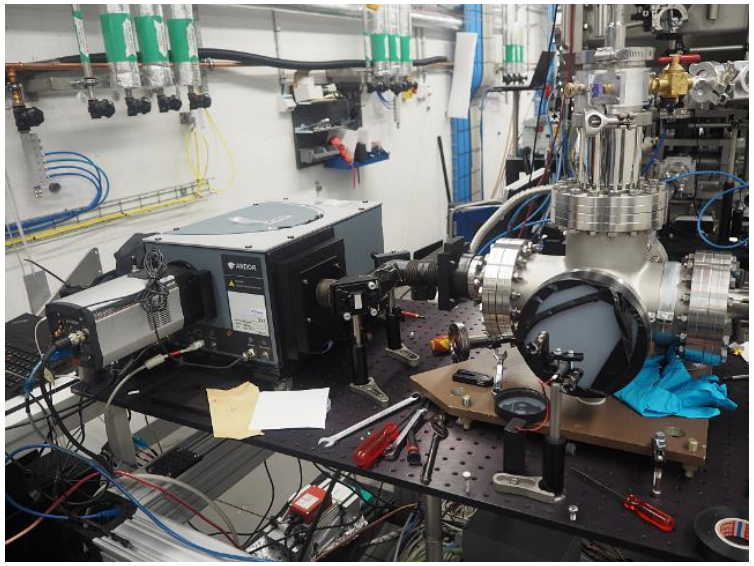
- Development of the TR-SAXS setup: UT team contributed a custom-built illumination setup for the TR-SAXS experiments on the Ganesha SAXS device at FZJ.
- Experimental sessions at ILL neutron source

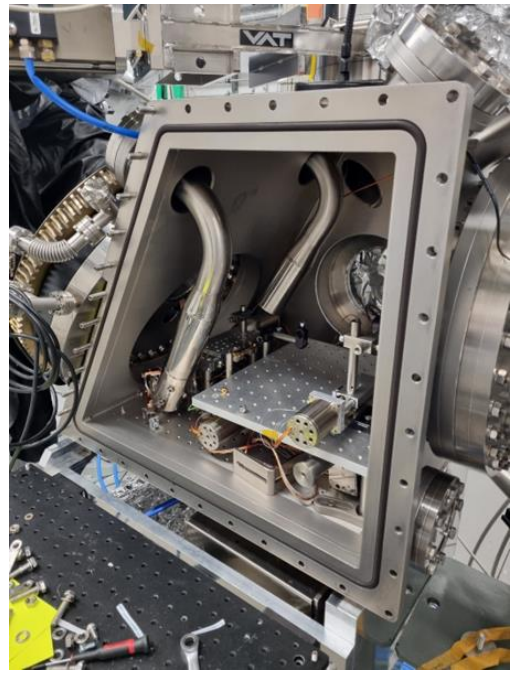


# Pilot research on novel UF scintillators at FemtoMAX beamline

**10 keV X-ray pulses**
**duration <100 fs**

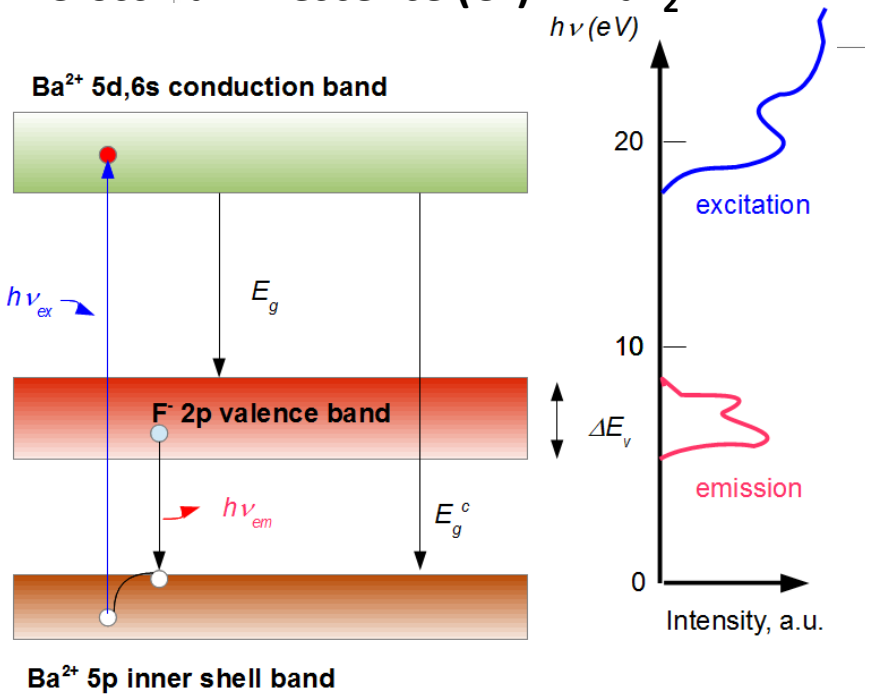


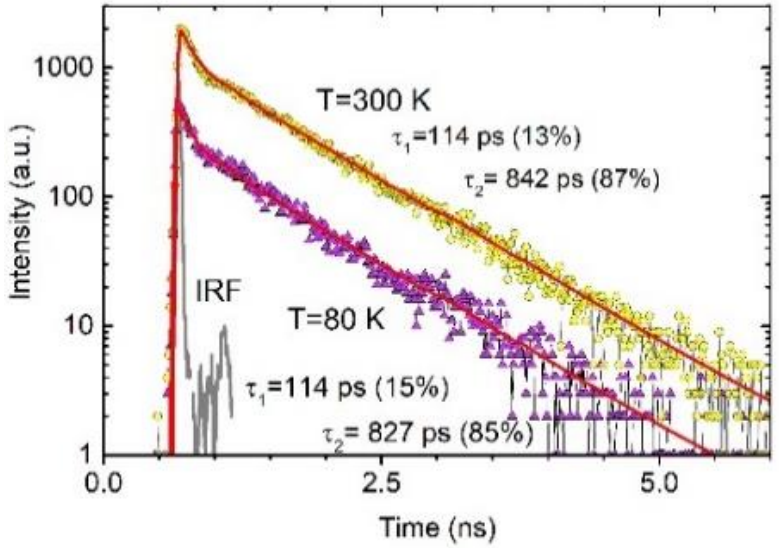


**Ultrafast (UF) Luminescence: IRF 30 ps**

**Cross-Luminescence (CL) in $BaF_2$**




**CL decay recorded at 225 nm in $BaF_2$**



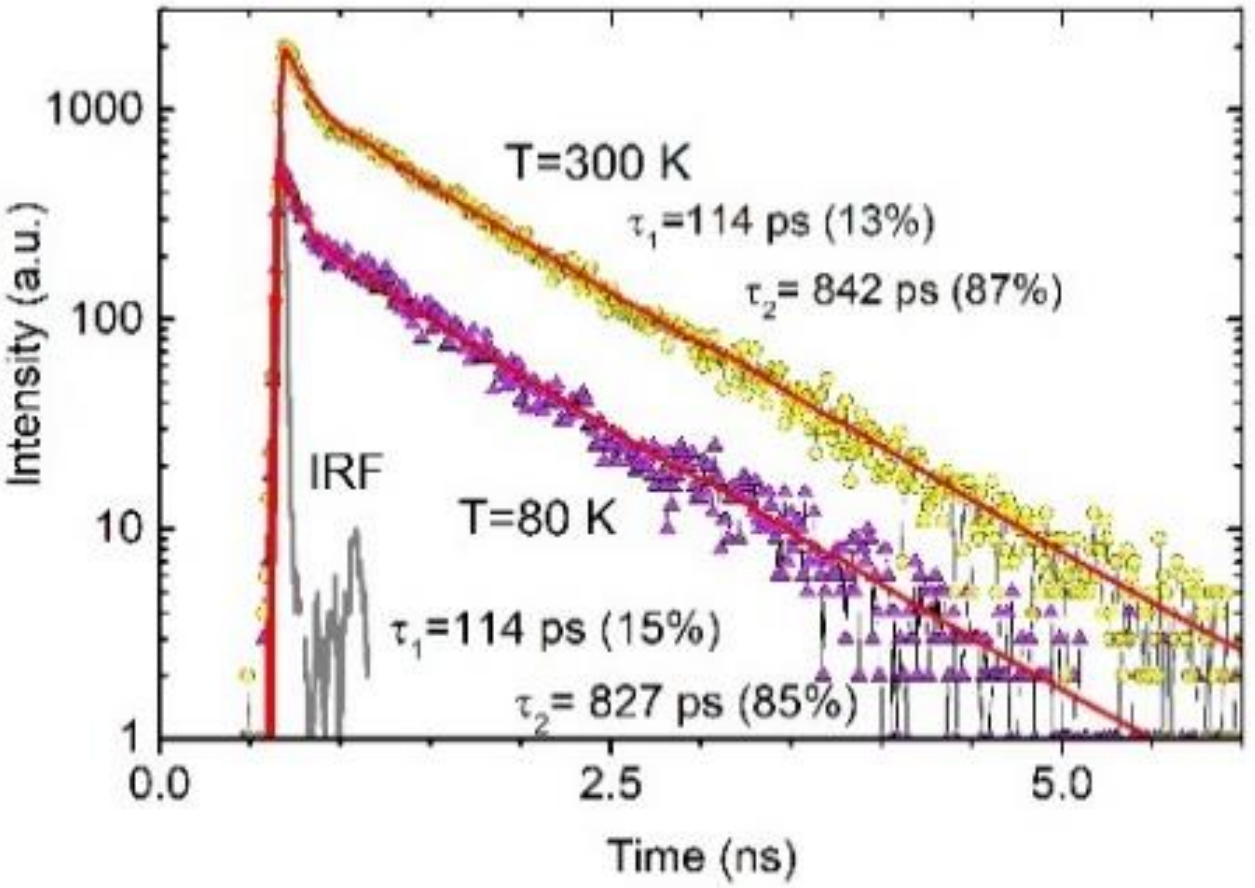

S.I. Omelkov *et al.*, J. Physics: Conf. Ser. **2380** (2022) 012135

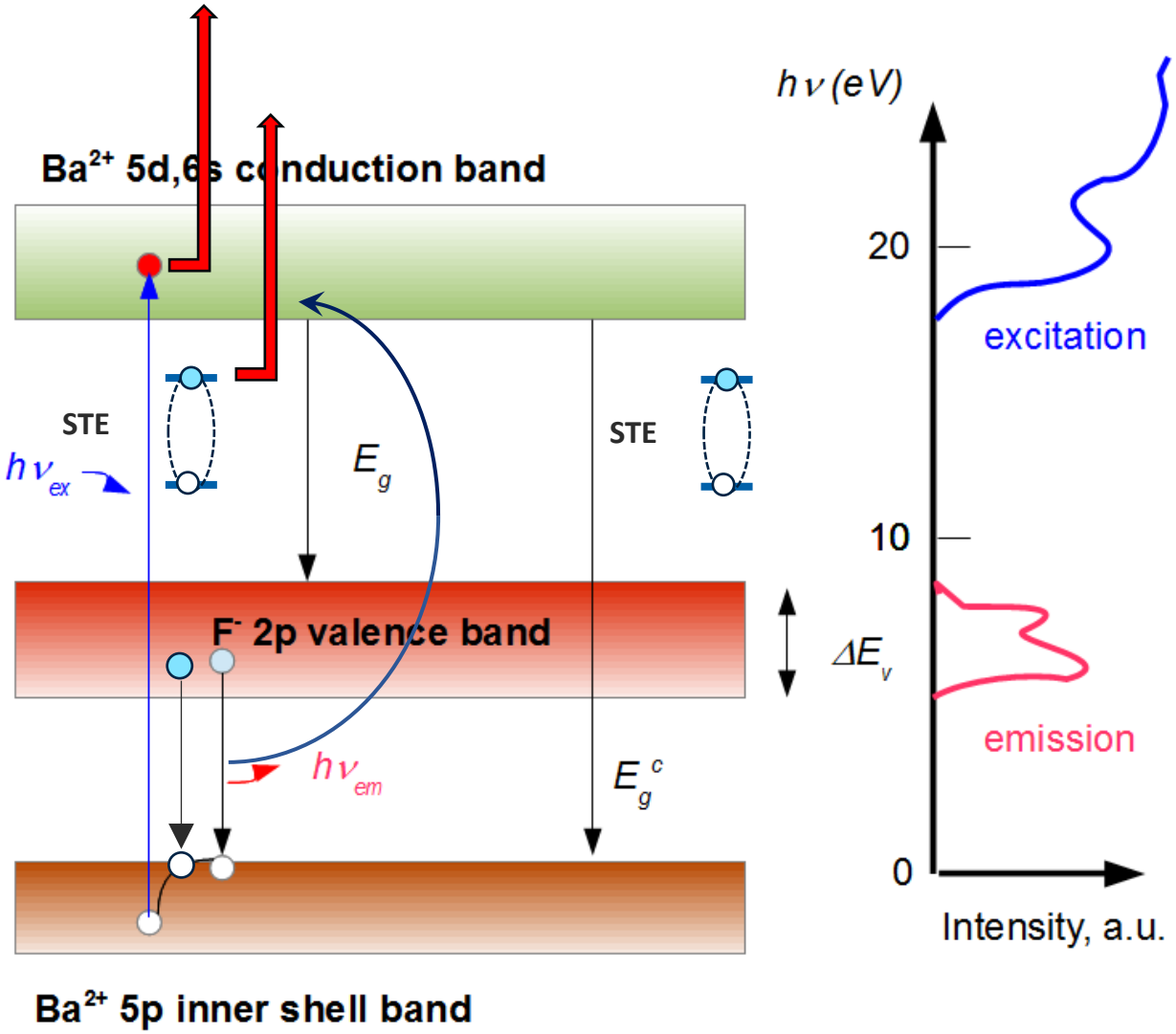
J. Saaring, *et al.*, J. Alloys Compd. **883** (2021) 160916. $K_2GeF_6$

J. Saaring, *et al.*, J. Lumin. **244** (2022) 118729 $BaGeF_6$

# The origin of ultrafast components in CL of $BaF_2$

**$BaF_2$: La 1% crystal, 225 nm emission**
**FemtoMAX: 10 keV X-ray pulses < 100 fs**



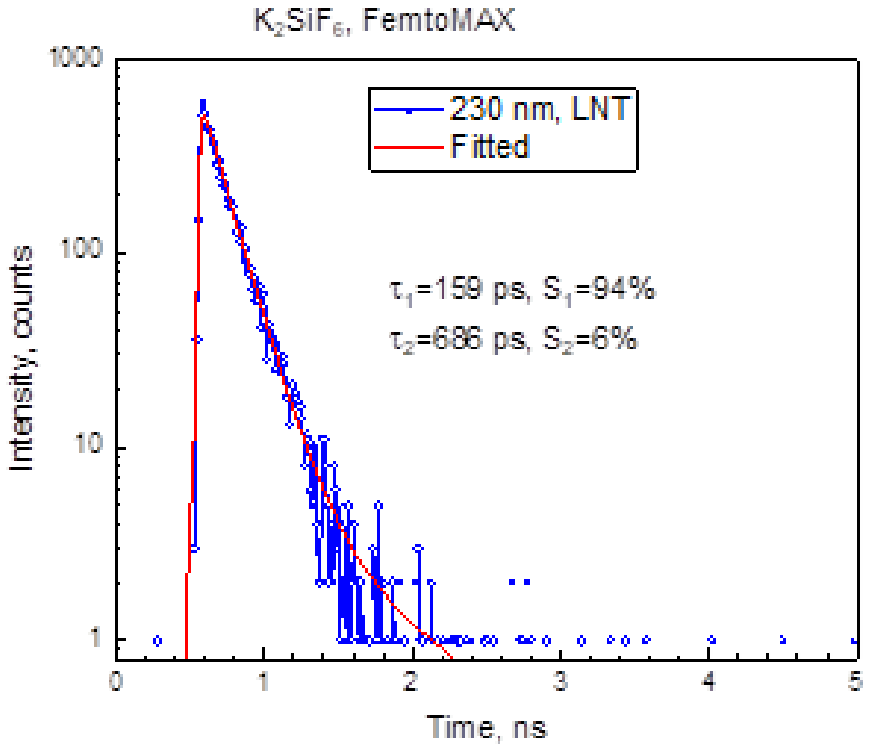




**Core holes do interact with excitons**

S.I. Omelkov *et al.,* J. Physics: Conf. Ser. **2380** (2022) 012135

# PILOT RESEARCH COMBINING X-RAY and NEUTRON TECHNIQUES TO ANALYSE SMART MATERIALS UTARTU

- The development of time-resolved luminescence setup together with the FemtoMAX staff has been successfully completed and it was used for research during the beamtime in May 2025.
- The graph shows an ultrashort decay of intraband and cross-luminescence excited by pulsed 7 keV X-ray radiation in a novel $K_2SiF_6$ scintillator material.
- Many more decay times of various emissions in wide gap hosts were determined in the temperature range of 20 – 500 K.
- The „ordinary“ time-resolved luminescence spectroscopy is carried out at the FinEstBeAMS beamline to reveal relaxation processes leading to scintillation under selective VUV excitation.



# EXANST Expected outcome

EXANST will objectively demonstrate UTARTU has achieved these objectives in multiple ways:

- ✓ Complete sub-research on novel scintillators, energy materials and smart biomaterials - **ongoing**
- ✓ At least 10 co-authored articles with advanced partners submitted to high impact journals – **several published**
- ✓ At least 24 presentations at leading conferences - **ongoing**
- ✓ Lead the submission of at least 2 international research proposals **– 1 submitted**
- ✓ **Host an international summer school with at least 40 participants /DONE**
- ✓ At least 3 Joint PhDs supervised with advanced partners – **2 PhD**
- ✓ At least 10 project managers trained in international project management

Acknowledgements: J.M. Kahk, V. Kisand, J. Pieper, R. Pärna and to our advanced partners MAX IV, FZJ and ICL

Funded by the European Union

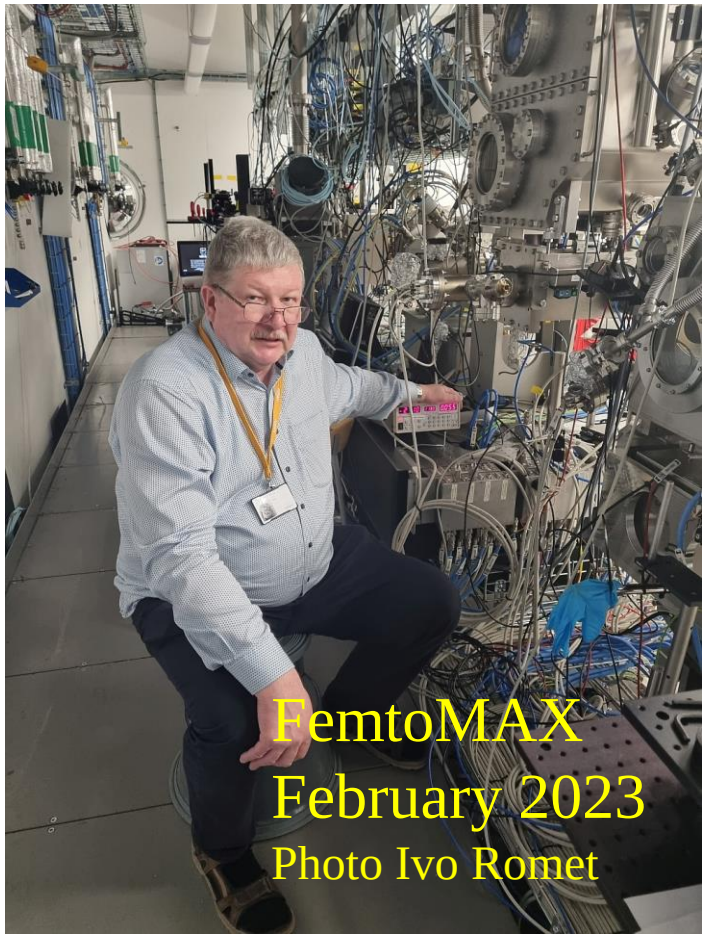
The EXANST research activities are progressing well

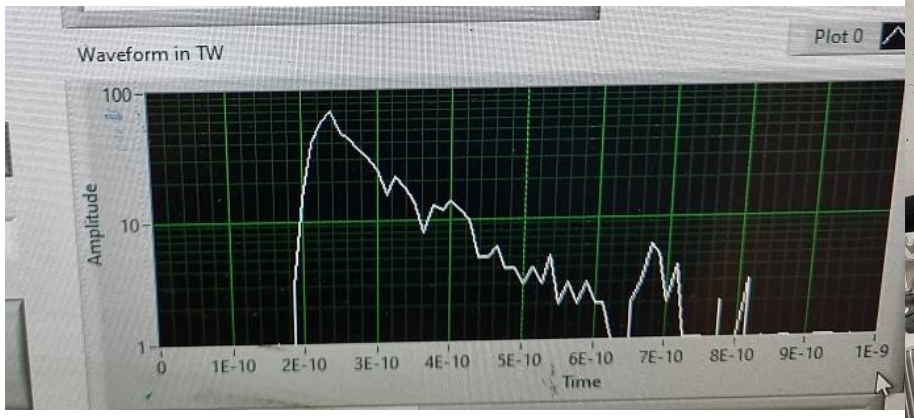
We will report our final EXANST results in 2027!

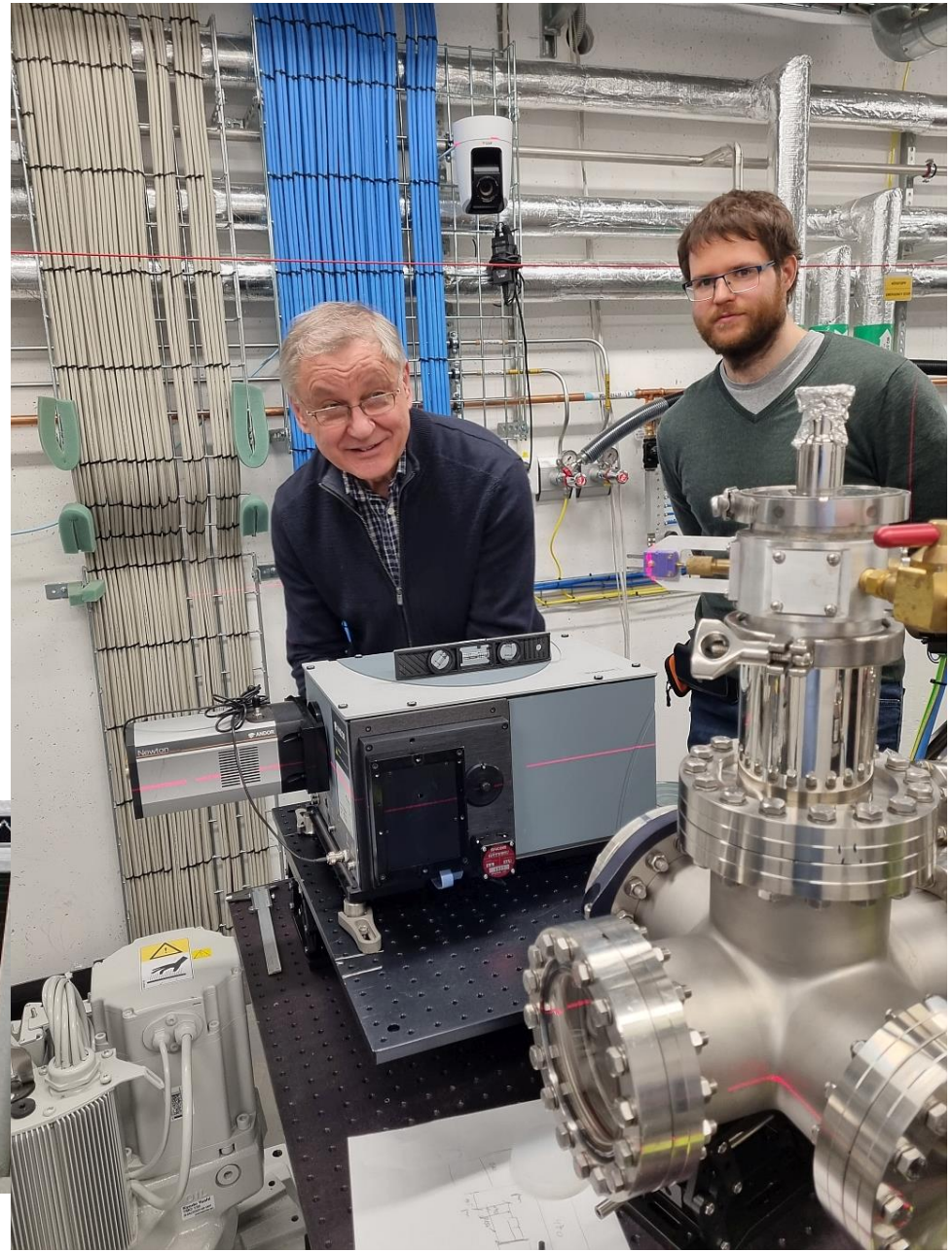
The conference FM&NT 2027 will take place in Tartu in June 2027 !


RÅC 2025 Summer school , Hestia Europe , Talllinn, 24-31.08.2025

# Thank You Aitäh !



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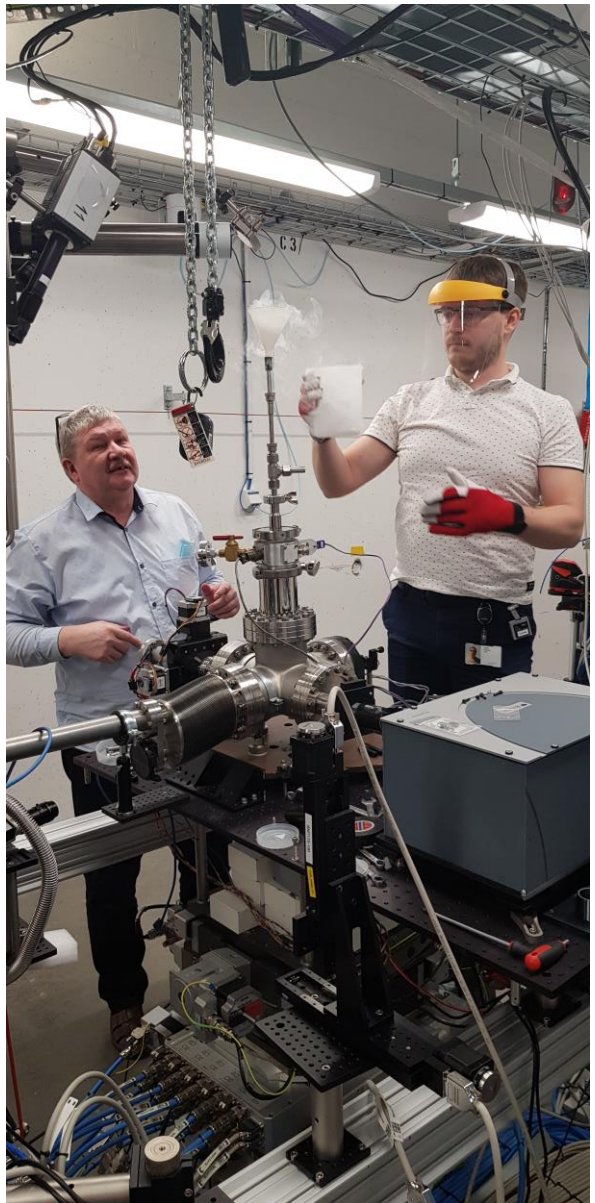

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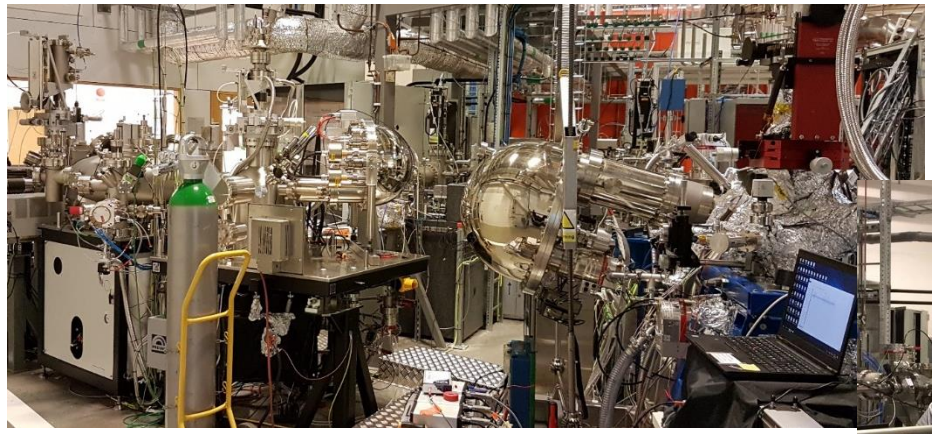
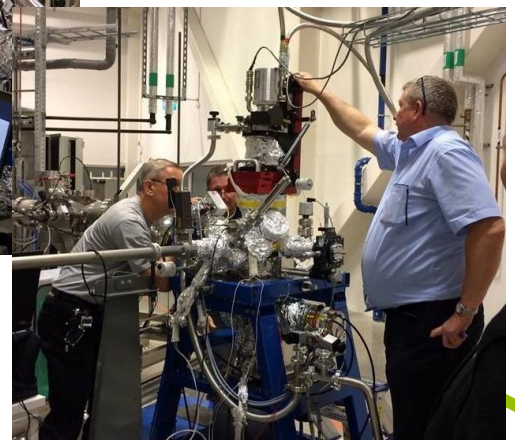
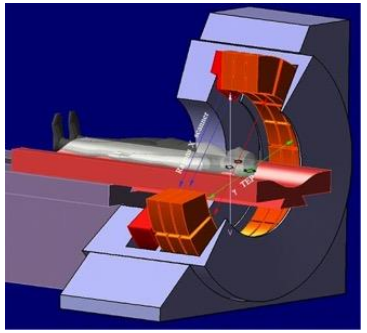
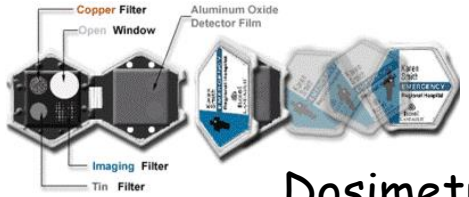




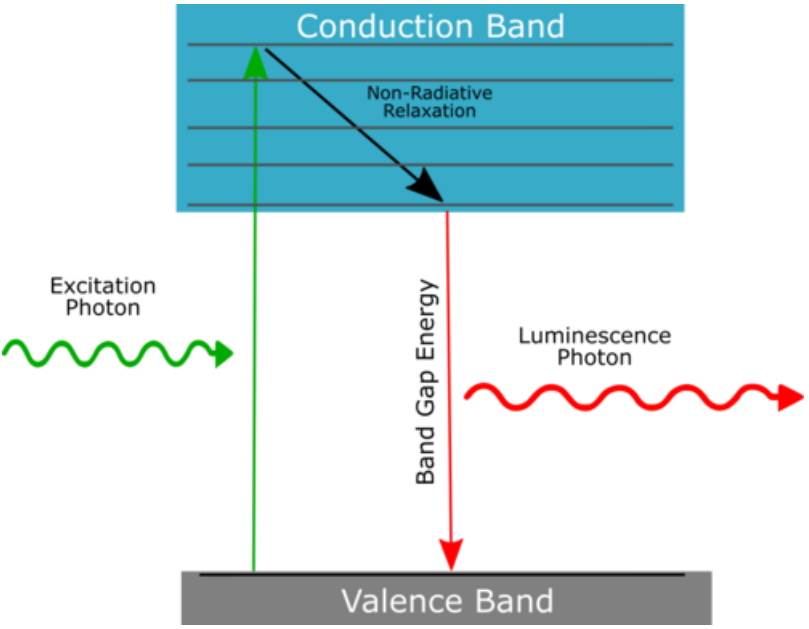
Lighting and displays

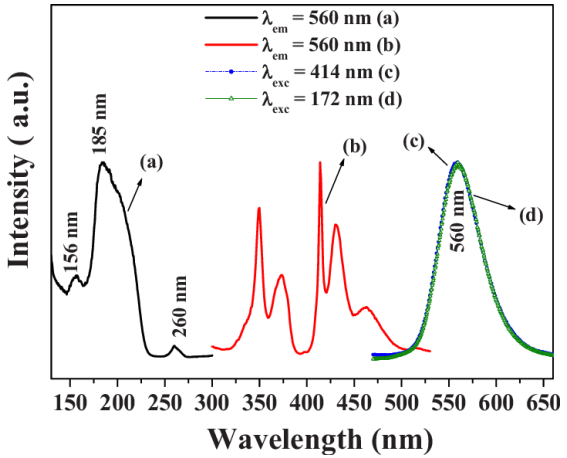


Medicine
PET, X-ray CT, bioimaging




Dosimetry




## Photoluminescence endstation

- Emission spectra from UV to NIR
- Excitation, absorption and reflection spectra
- Decay kinetics