JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

SOLARIS - current status and development

Marek Stankiewicz

Seminarium @ IFJ PAN

15.10.2020

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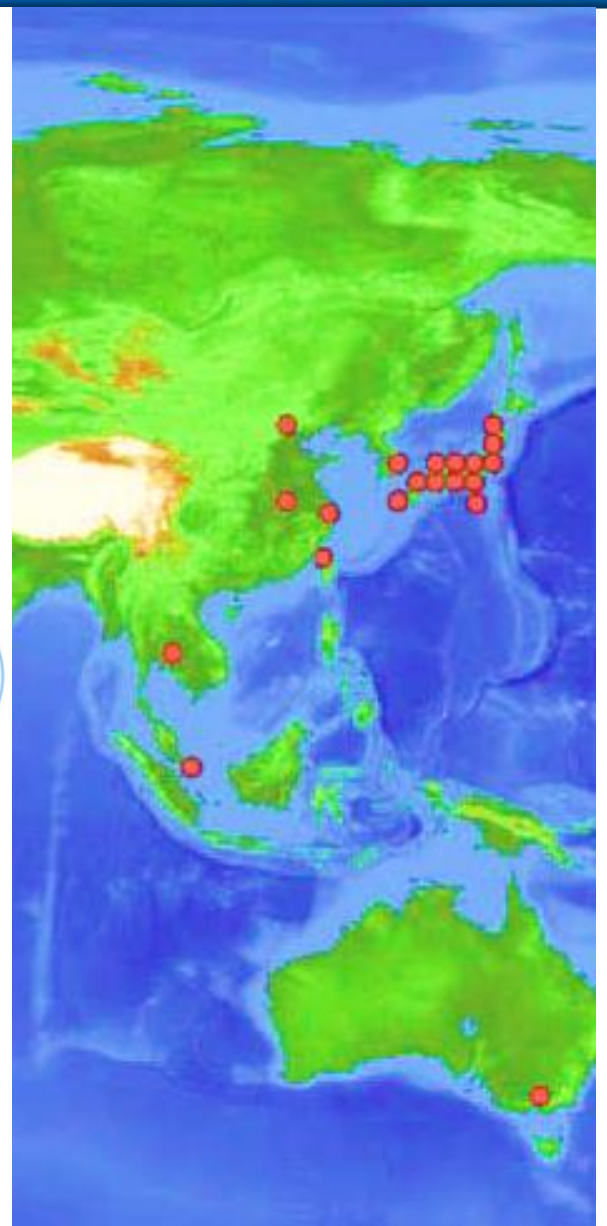
Synchrotrons of the world



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Research @ synchrotrons

XAFS 2018

17 International Conference
on X-Ray Absorption Fine Structure
22–27.07.2018 · Kraków · Poland

Organized by PTPS Polish Synchrotron Radiation Society

in cooperation with SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE; JAGIELLONIAN UNIVERSITY IN KRAKÓW; THE HENRYK NIEWODNICZAŃSKI INSTITUTE OF NUCLEAR PHYSICS POLISH ACADEMY OF SCIENCES

- Materials science and energy-related materials
- Magnetism
- hoto-out
- rafast
- Surfaces and interfaces
- X-ray microscopy and tomography
- Instrumentation, new sources and new beamlines

But there is much more methods than XAFS:

- **X-ray crystallography**
- **Spectroscopy**
- **Microscopy**
- **Fluorescence**
- **X-ray imaging**
- **……**

Research @ synchrotrons

Motivation: applications of synchrotron radiation - New research opportunities

Areas of research:

- **Physics**
- **Chemistry**
- **Biology**
- **Geology**
- **Mineralogy**
- **Environment**
- **New materials**
- **Medicine**
- **Drug research**
- **Archeology**
- **Arts**
- **Heritage**

- **Industry**
  - ✓ Semiconductors/chips
  - ✓ Pharmaceutical industry
  - ✓ Food industry
  - ✓ Batteries
  - ✓ Fuel cells……

Methods:

Imaging:
- Fluorescence
- Transmission or absorption

Photon diffraction or scattering
Scattered image, difractogram
=> processing
=> structure

Microscopy:
High resolution imaging
Spectral microscopy

Spektroscopy:
Absorption spectra
Emission spectra
- Electrons
- Ions
- Photons

unprecedented success story of Synchrotron Radiation (since the 80s)

- Synchrotron based photon sources: purpose-built synchrotrons – to generate electromagnetic radiation (EM) of extraordinary properties)
- many sources of radiation (light) from a single synchrotron
- synchrotrons are of unique designs – of different configurations and sizes – from very small (of few meter circumference) to very large (km)
- they operate 24/7 mode
- they are true multi user / multidisciplinary facilities
- provide exceptional opportunities in many areas of research for many groups at the same time
- continuous technological development : from the Ist to the IVth generation of synchrotrons + FELs
- ongoing upgrades , new centers emerging

SHORT HISTORY OF SOLARIS

- Community of SR users in PL - since the advent of synchrotron sources
- Polish Synchrotron Radiation Users Society (PTPS) **since 1991** (now 180 members)
- Polish Synchrotron Consortium – 36 members

  ==➔ Long lasting initiative to built a SR source in PL – user driven initiative
- Jagiellonian University management support
- 2009 money allocated (40 MEUR) **==➔**

INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

EUROPEAN UNION
EUROPEAN REGIONAL DEVELOPMENT FUND

- <u>Feasibilty</u>
  - ✓ brain storms
  - ✓ correlation with MAX-IV project and decision by Max-II lab management
- Decision taken by JU => SOLARIS as JU unit – but available for all researchers at no cost

==➔ 2010 contract signed – green field project started

==➔ 2015 project completed

SOLARIS - MAX IV synergy - challenges

- Replica of MAX-IV 1.5 GeV ring – but:
  - Different building
    - Different storage ring tunnel
    - Different building infrastructure
  - Different injection – linac but not full energy
  - Ramping

- Uniqueness (first such facility in PL)
  - There are no commercially available synchrotrons
  - Tailored made design
  - Tailored made equipment

- Challenges - *terra incognita*:
  - For the SOLARIS team
    - no team, no expertise (employment of Carlo Bocchetta)
  - For the Polish contractors
    - e.g. building, technological infrastructure……..
  - For the Administration
    - *Difficult money – public procurments – EU restrictions*

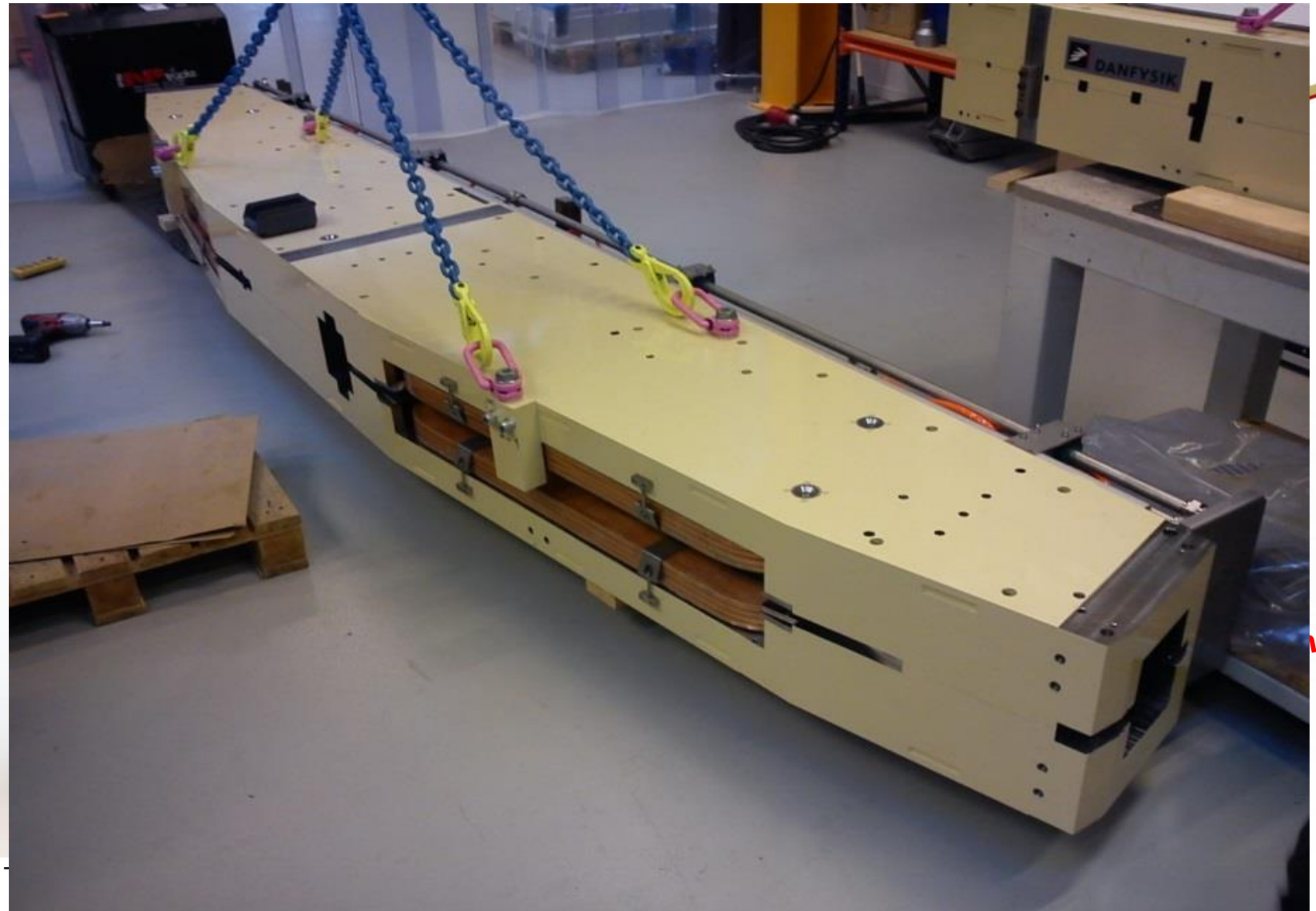
- Tight collaboration with MAX-lab and other SR facilities critical for success of the project

GREEN FIELD PROJECT

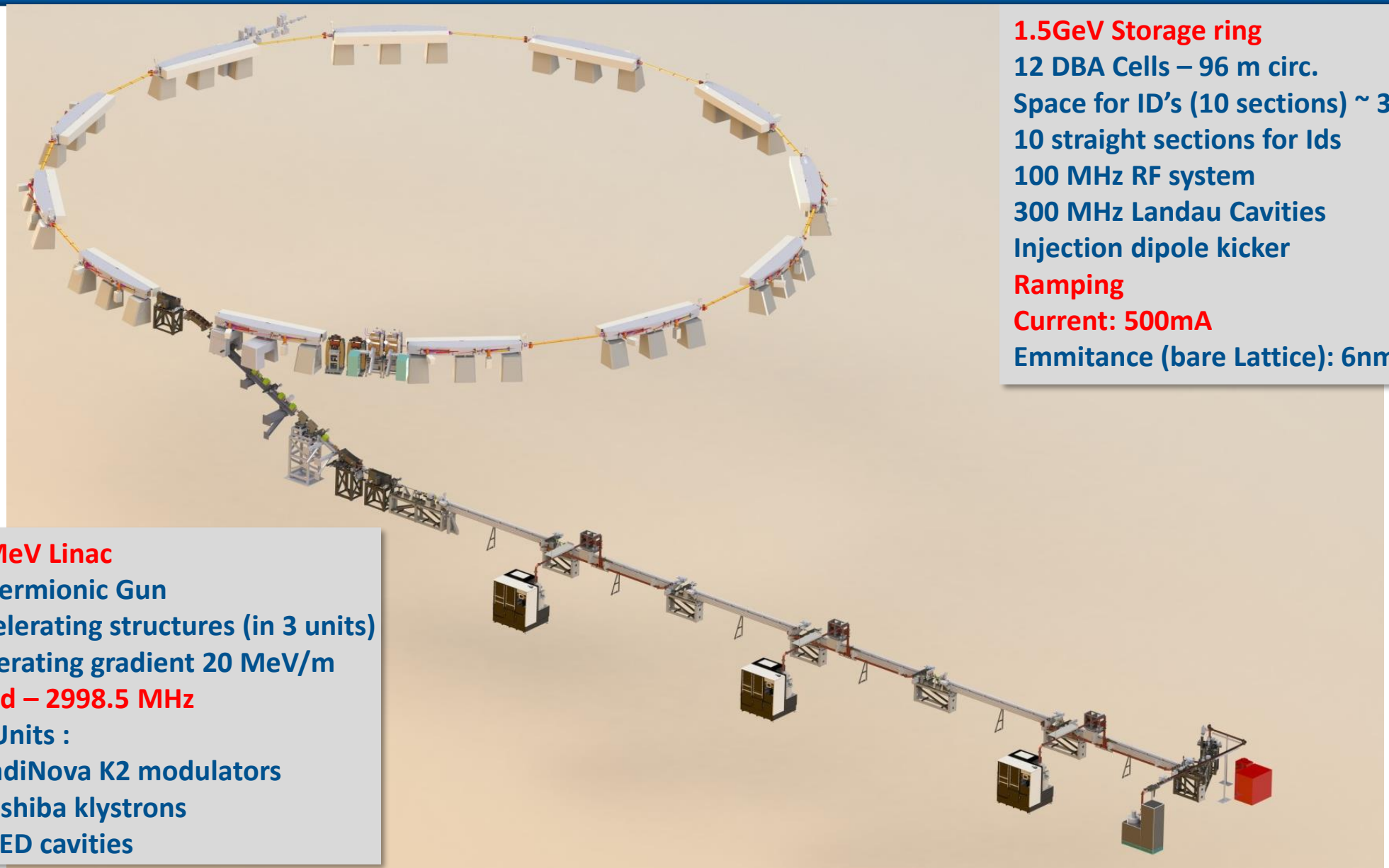
DELIVERABLES:

- Building
- Linac
- Storage ring
- Two beamlines
- **TEAM**

SOLARIS 1.5 GeV ring design - MAX-lab accelerator team - Mikael Eriksson



SOLARIS accelerators



1.5GeV Storage ring
12 DBA Cells – 96 m circ.
Space for ID's (10 sections) ~ 3.5 m
10 straight sections for Ids
100 MHz RF system
300 MHz Landau Cavities
Injection dipole kicker
Ramping
Current: 500mA
Emmitance (bare Lattice): 6nmrad

600 MeV Linac
RF Thermionic Gun
6 accelerating structures (in 3 units)
Accelerating gradient 20 MeV/m
S-band – 2998.5 MHz
3 RF Units :
- ScandiNova K2 modulators
- Toshiba klystrons
- SLED cavities

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SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

SOLARIS machine status

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

SOLARIS Machine Status Portal

Wednesday, October 14th 2020, 4:41 pm

Current	Energy
253.22 mA	1.50 GeV

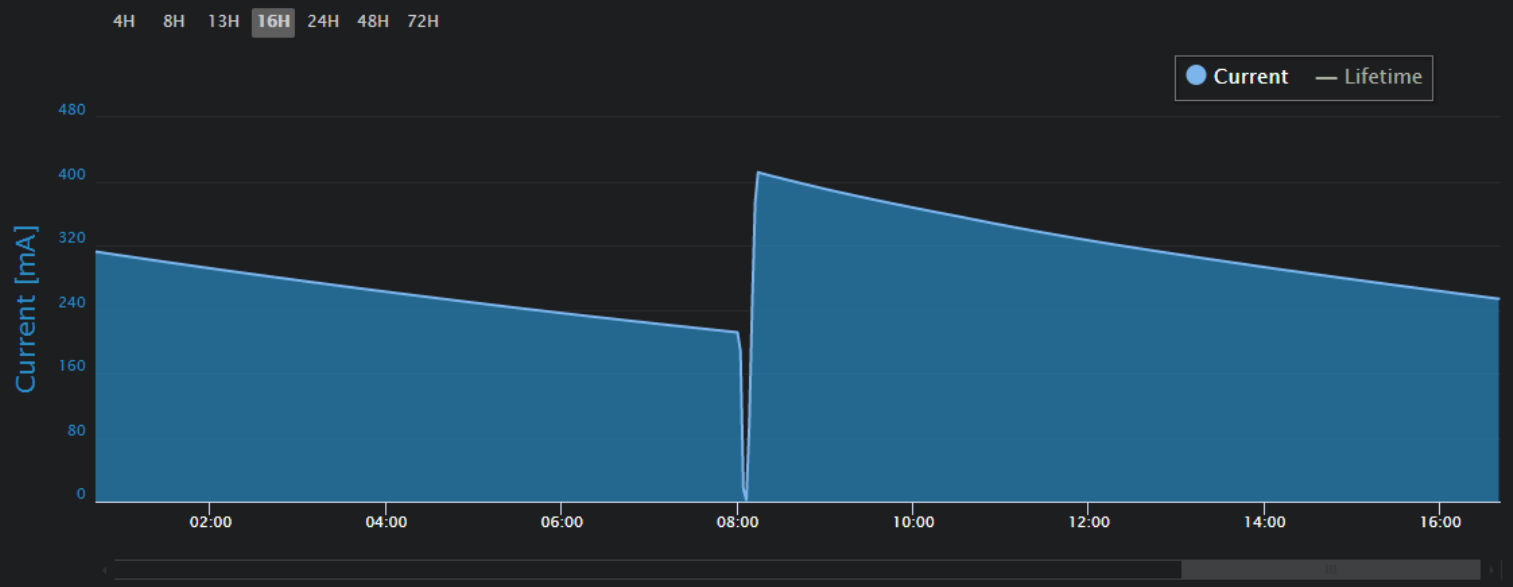
Lifetime	I·τ product
17.95 h	4.54 Ah

ID Beamlines

Name	Gap	State
PHELIX	32.20 mm	CLOSED
UARPES	37.15 mm	OPEN
XMCD	50.00 mm	CLOSED
SOLCRYS	0.00 mm	under construction

BM Beamlines

Name	State
PEEM/XAS	OPEN
SOLABS	under construction
SOLAIR	under construction
POLYX	under construction



Storage Ring Status: Beam Delivered

Operation Mode: User Operation

Next injections: 8am and 8pm during User Operation mode

OPERATOR MESSAGE

20-10-10 08:06

http://status.synchrotron.pl/

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Since 2018 SOLARIS is open to external users

XAS/PEEM Beamline

COLLABORATION WITH

AKADEMICKIE CENTRUM MATERIAŁÓW i NANOTECHNOLOGII AGH

AGH

WYDZIAŁ FIZYKI I INFORMATYKI STOSOWANEJ

PAN

Instytut Katalizy i Fizykochemii Powierzchni PAN

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SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

Since 2018 SOLARIS is open to external users

UARPES Beamline

COLLABORATION WITH

INSTYTUT FIZYKI UJ

UNIWERSYTET JAGIELLOŃSKI W KRAKOWIE

JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

Since 2018 SOLARIS is open to external users

PHELIX Beamline

COLLABORATION WITH

Wydział Nauk Ścisłych i Technicznych

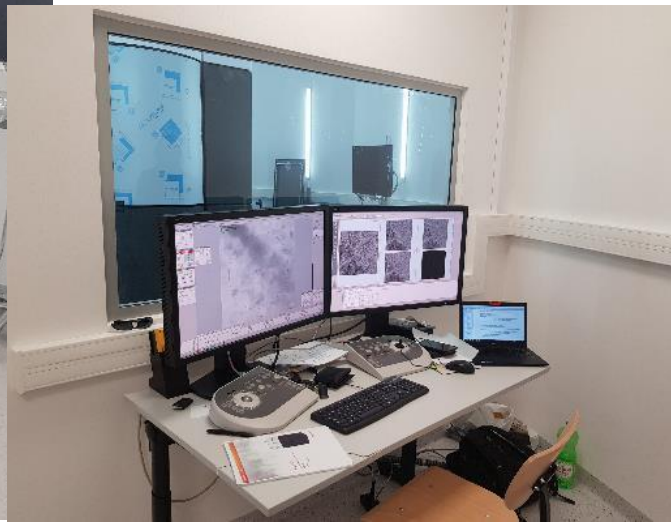
UNIWERSYTET ŚLĄSKI W KATOWICACH

Cryo-TEM 300 kV – Titan Krios G3i

1 March 2019

NATIONAL CRYO-EM FACILITY

at SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE



Detectors:

- Thermo Scientific™ Falcon™ 3EC Direct Electron Detector
- Gatan K3 Bioqantum
- Ceta 16M camera 300kV

COLLABORATION WITH

MAŁOPOLSKIE CENTRUM BIOTECHNOLOGII

STRUCTURAL BIOLOGY CORE FACILITY

SOLARIS continuous development

Due to the very limted budget serious compromizes had to be made

To utilize the full potential of the infrastructure further investment is needed

- **New beamlines (portfolio of initiatives)**
- **New sources (wigglers + undulators)**
- **Linac extension - full energy injection (1.5 GeV)=> 24 hrs operation**

DEVELOPMENT AND OPERATION PILLARS:

1. **Synergy** between SOLARIS & research centers
   a. Addressing expectations of research groups
   b. Addressing new research ideas and challanges

2. **Integration** of research groups

3. **User driven** development:
   1. users + SAC => ROAD to new research infrastructure
   2. "beamline consortia" – development of new beamlines - result of initiatives of external groups

4. **User driven** operation: operation of each beamline is backed up by "beamline consortia"

5. **Excellence**

6. **International collaboration**

Scientific Advisory Committee

1. Nils Mårtensson – Uppsala University – SAC Chair
2. Paul Dumas - Synchrotron SOLEIL
3. Paweł Grochulski - Canadian Light Source
4. Maya Kiskinova – Sincrotrone Elettra
5. Petra Rudolf – Groningen University

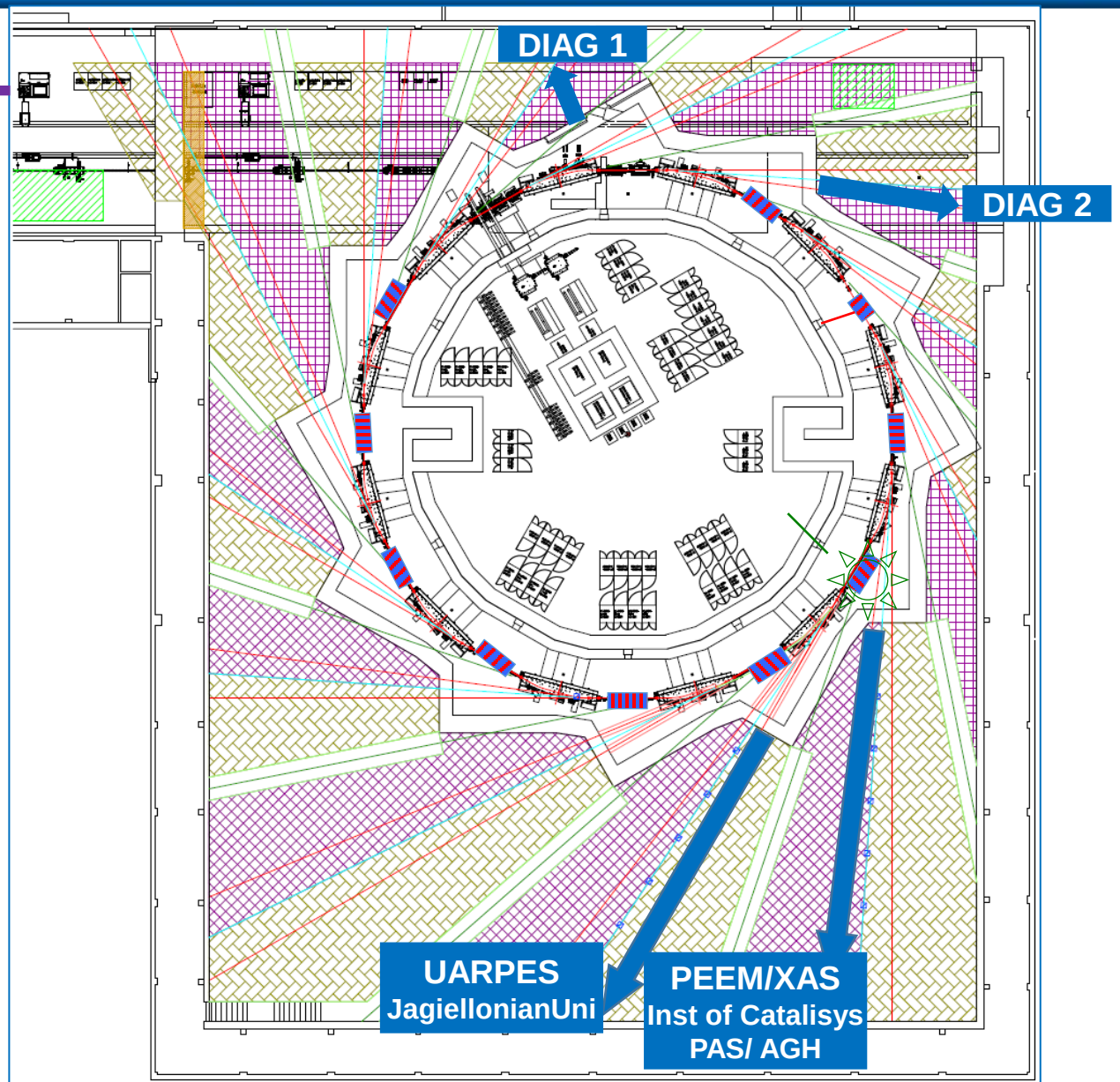
SOLARIS – today

Krios

Structural Biology Core Facility

NATIONAL CRYO-EM FACILITY

at SOLARIS



User driven beamlines initiatives

SOLARIS – today & tomorrow

Structural Biology Core Facility

Krios

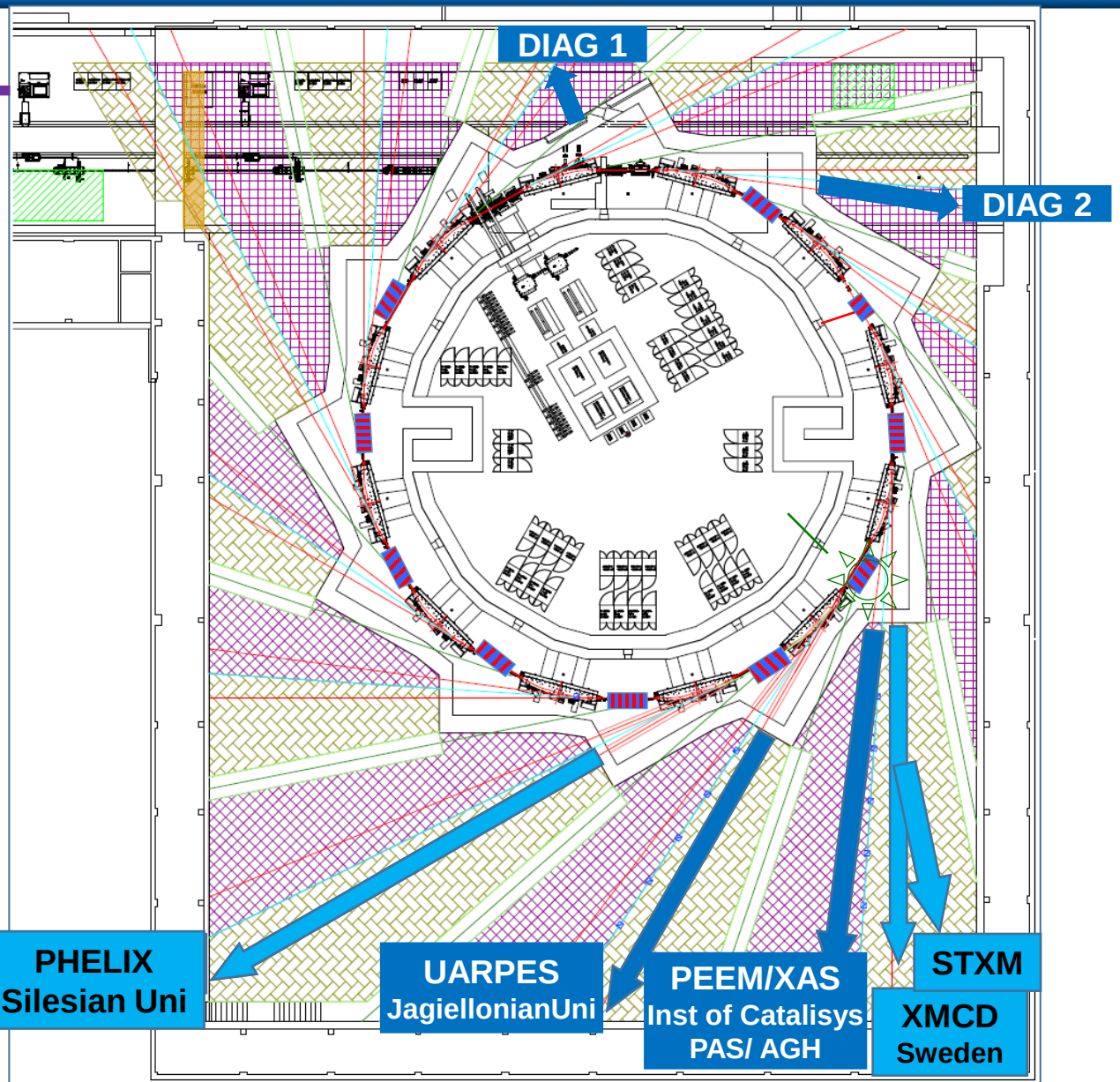
Glacios

NATIONAL CRYO-EM FACILITY at SOLARIS

Operating

Under construction – available 2020/2021

User driven beamlines initiatives



SOLARIS – today & tomorrow

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SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

Hochschule Niederrhein
University of Applied Sciences

XAS

Structural Biology Core Facility

Krios

Glacios

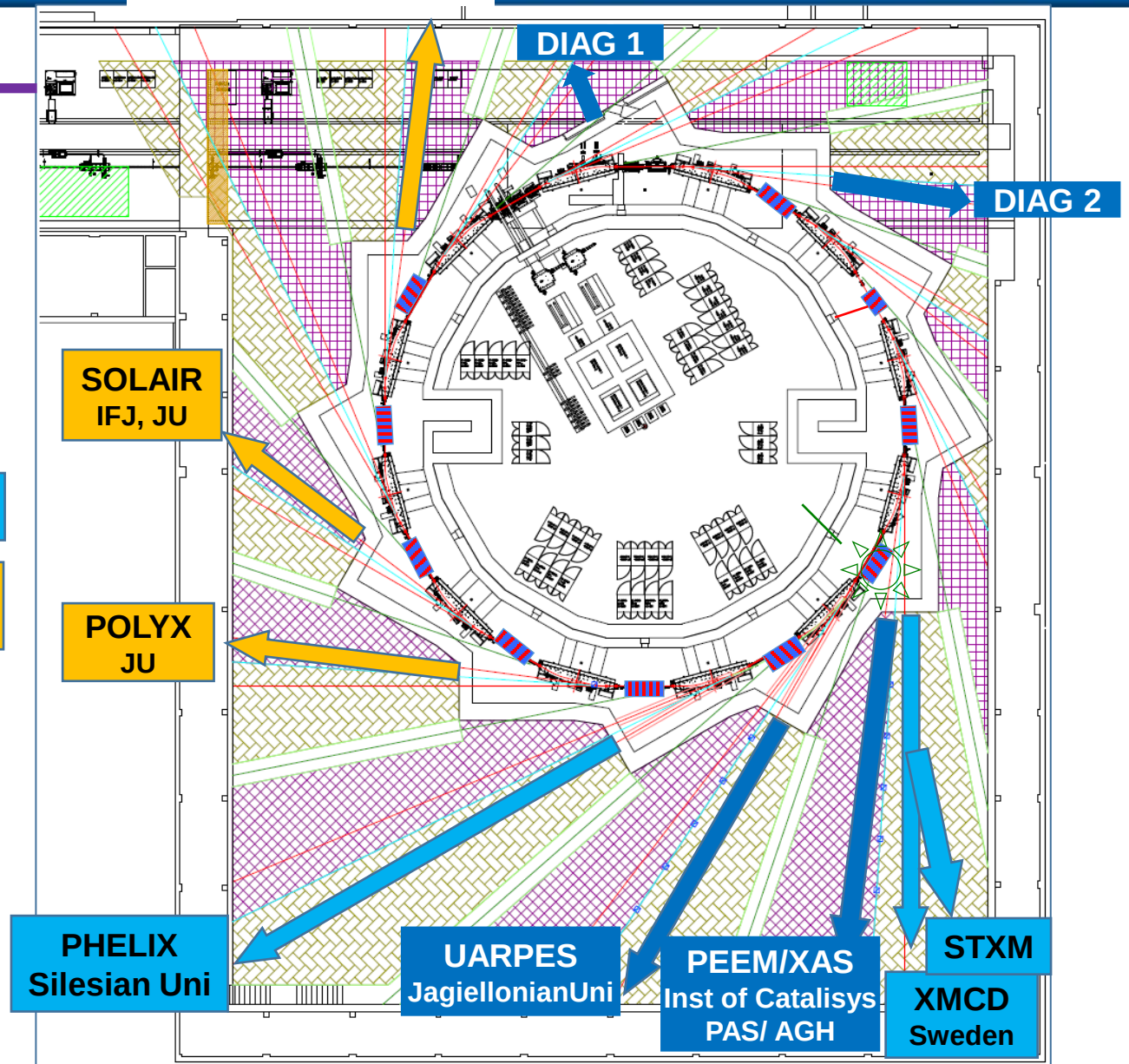
NATIONAL CRYO-EM FACILITY at SOLARIS

Operating

Under construction – available 2020/2021

Under construction - available 2021/2022

User driven beamlines initiatives



SOLARIS – today & tomorrow

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SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

Hochschule Niederrhein
University of Applied Sciences

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Structural Biology Core Facility

Krios

Glacios

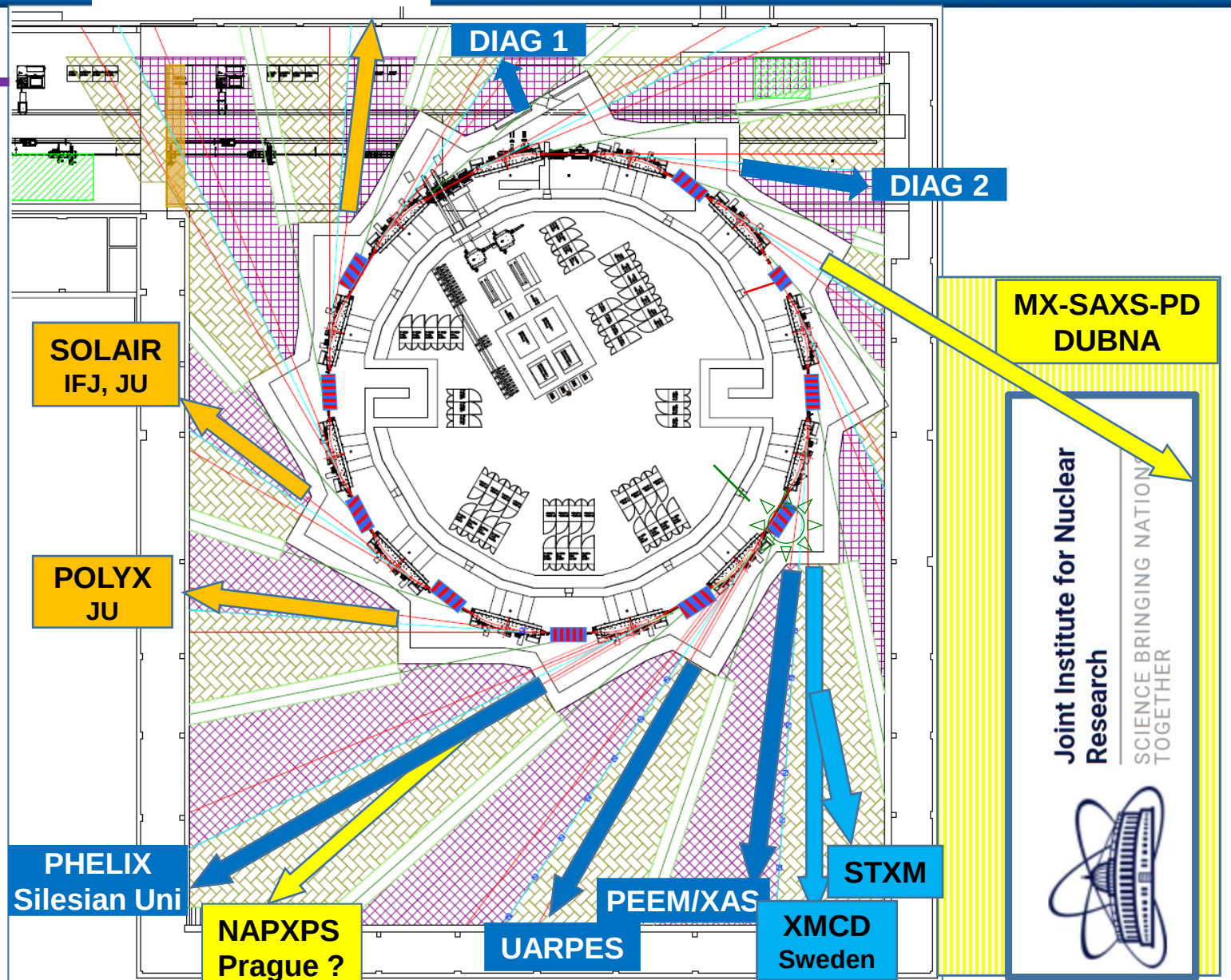
NATIONAL CRYO-EM FACILITY at SOLARIS

Operating

Under construction – available 2020/2021

Under construction - available 2021/2022

Under construction - available 2022/2023



Beamlines @ SOLARIS - summary

2018/19

2 working beamlines and 4 endstations

- XAS + PEEM endstation
- UARPES
- Krios

2020/21

2 new working Beamlines and 4 new endstations

- PHELIX
- XMCD with branch for STXM station
- Glacios stations

2021/22

3 new working beamlines

- SOLABS (XAS) (Krefeld)
- SOLAIR
- POLYX

2022/23

1 New working high enery beamline (3 techniques) and new endstation @ PHELIX (branch)

- SOLCRYS
- NAPXPS - branch endstation ?

	beamlines	endstations
2018/19	2	4
2020/21	4	8
2021/22	7	11
2022/23	8	15

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

June 2018

AGREEMENT

on Cooperation in the Field of Construction and Operation of the Laboratory for Structural Research of Macromolecules and New Materials at the SOLARIS National Synchrotron Radiation Centre

Joint Institute for Nuclear Research
SCIENCE BRINGING NATIONS TOGETHER

Project Leader: Maciej Kozak (UAM & SOLARIS)

UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU

The community of **protein crystallographers** in Poland comprises over **100 scientists**

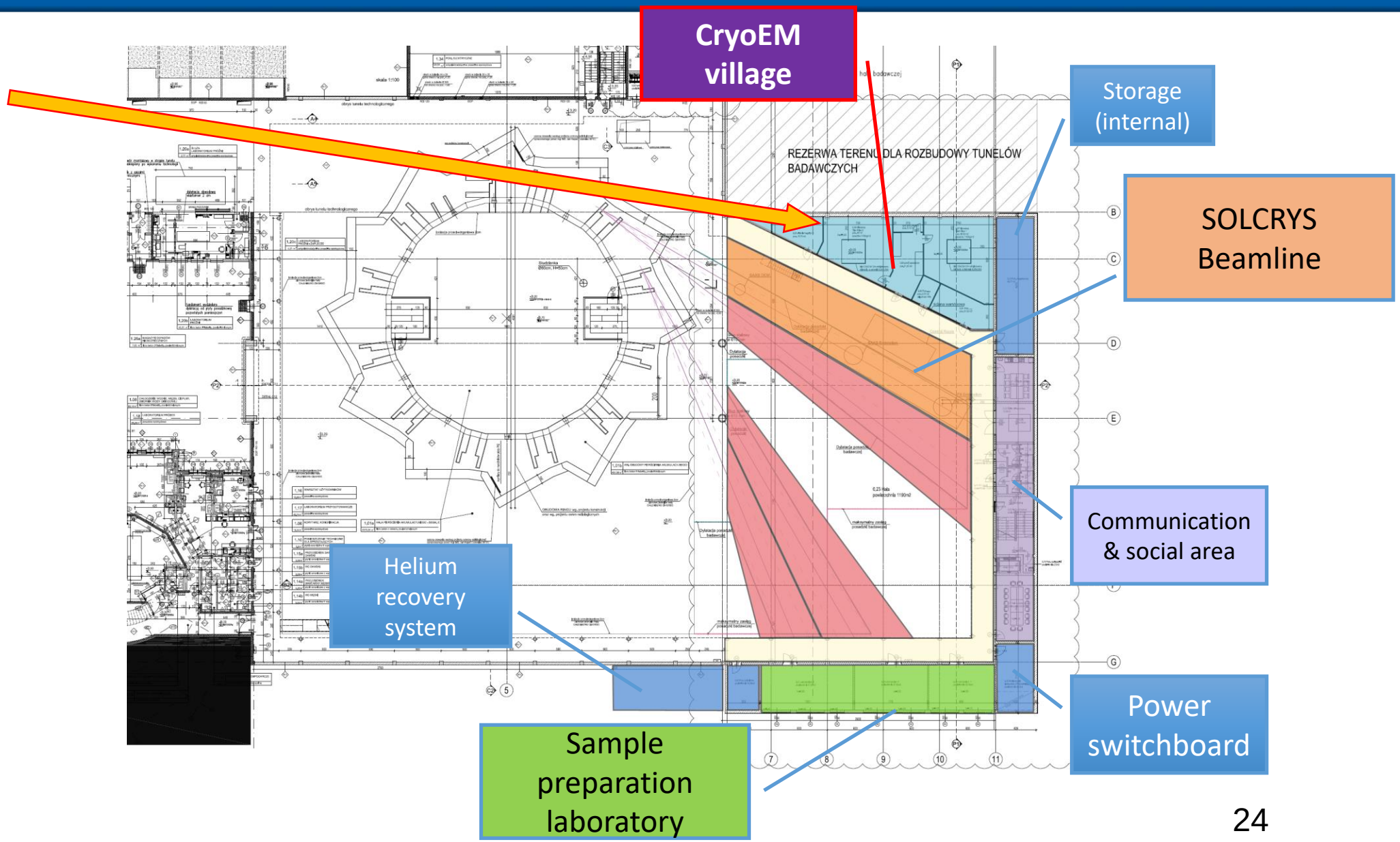
PX Groups in Poland:

CBB IChB PAS Poznań, AMU Poznań, Warsaw University, TU Lodz, IIMCB Warsaw, IBB PAS Warsaw, Gdansk University, Mikołaj Kopernik University of Torun, University of Wrocław, MCB & Facuty of Chemistry Jagiellonian University, Kraków, ICSC Polish Academy of Sciences, Kraków …

Pharma industry, high pressure XRD users etc

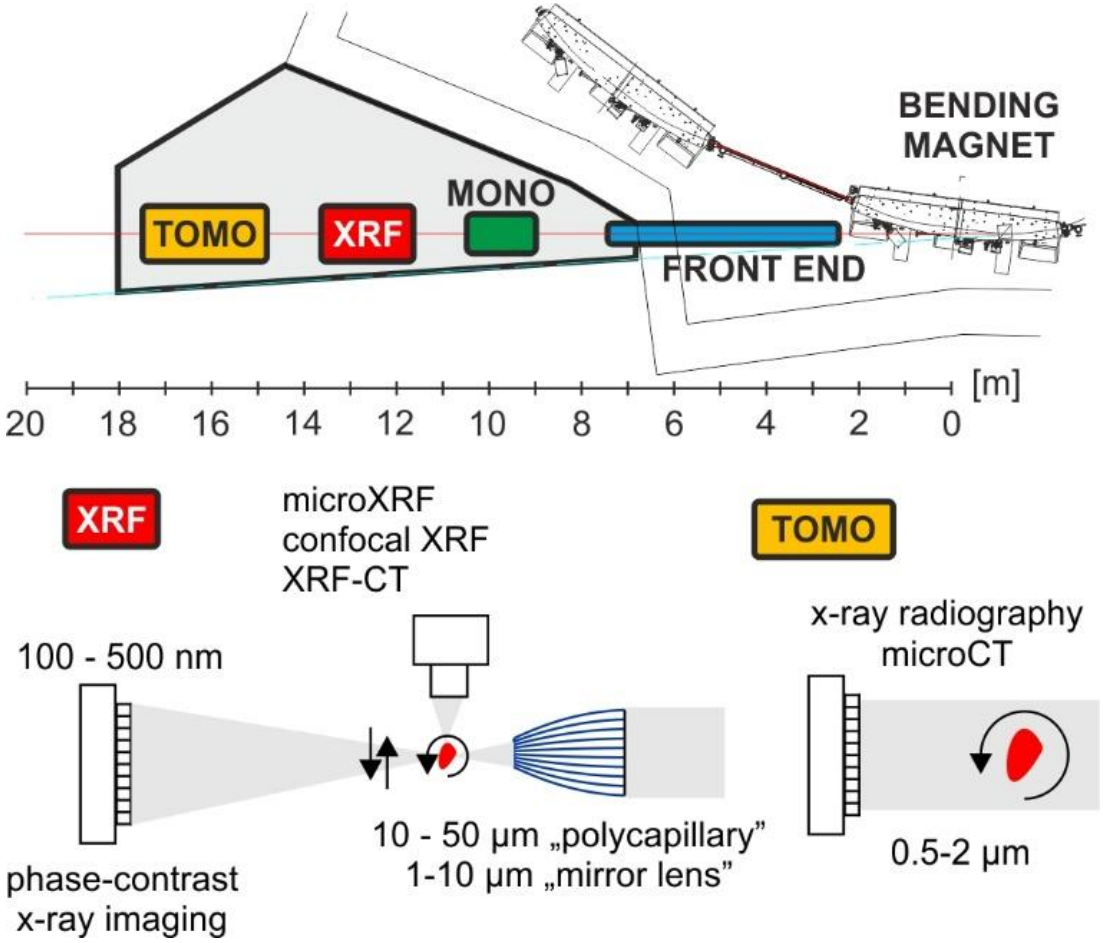
NCPS Solaris –hall extension Conceptual design

STRUCTURAL BIOLOGY CORE FACILITY
Krios
Glacios
NATIONAL CRYO-EM FACILITY
at SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE



NCPS Solaris –hall extension Conceptual design

POLYX - beamline for multimodal „hard" x-ray imaging (4 -18 keV)



POLYchromatic **X**-rays - white beam or double multilayer monochromator (2-3% bandwidth)

&

POLYcapillary **X**-ray optics - achromatic focusing optics

will partially compensate for low-energy energy spectrum at SOLARIS bending magnet

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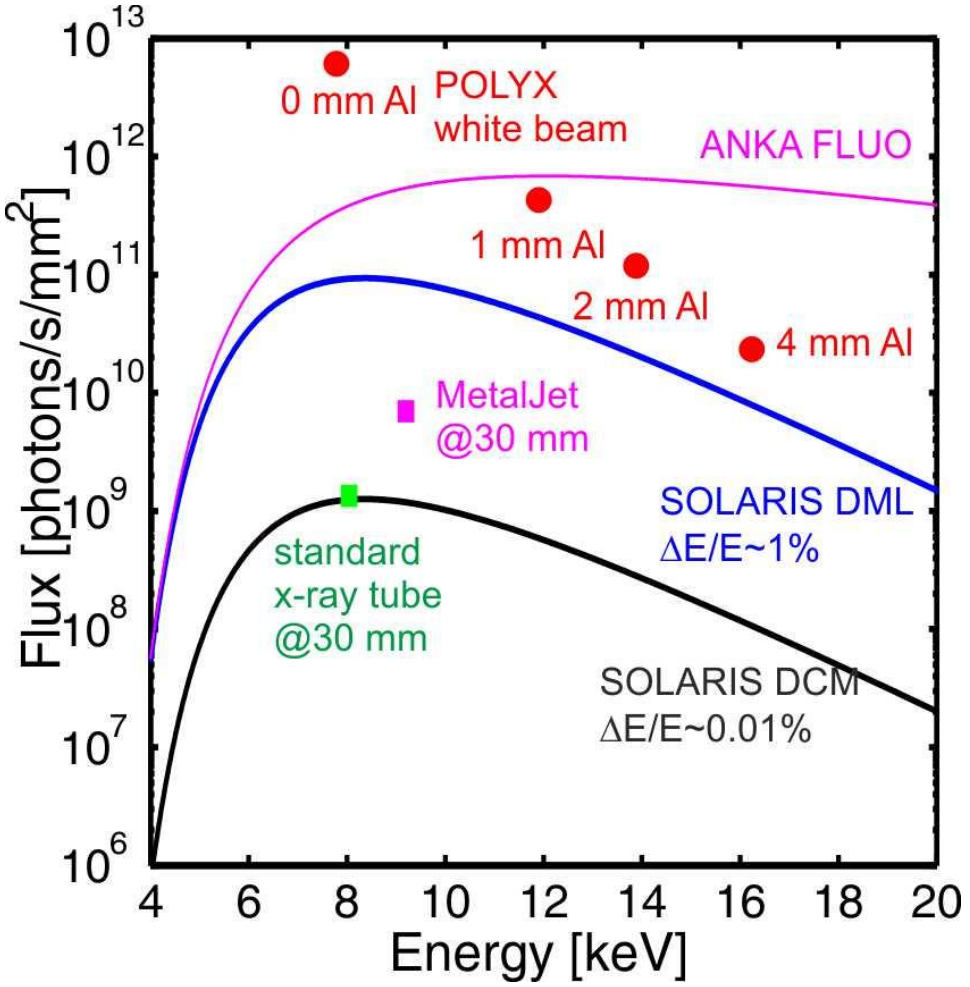
POLYX@SOLARIS

IN COLLABORATION WITH INSTYTUT FIZYKI UJ

Source	bending magnet
Energy	4 keV – 18 keV
Flux (without optics)	Si(111) 10^9 ph/s/mm^2 @ 8keV DML: 10^{11} ph/s/mm^2 @ 8keV White 10^{13} ph/s/mm^2
Energy resolution	Multilayer (DML) – 2% Channel-cut Si(111) – 0.02%
Beam size	~1 μm (paraboloidal x-ray mirror lens) 10 μm – 100 μm (polycapillaries) 100 μm (slits) max. 10 mm x 25 mm (VxH)
Detectors	Quad 50 mm2 FAST SDD, 1M hybrid pixel detector Scintillator/sCMOS (pixel 0.65-3.2 μm)
Sample	Air, He, room temperature, cryo-stream
Techniques	μXRF, macro-XRF, confocal XRF, XRF tomography, μXAFS (channel cut, von Hammos) μXRD, μCT, phase contrast radiography



USER COMMUNITY AROUND POLYX

- beamline concept: Paweł Korecki (JU) + Paweł Wróbel (AGH)
- key user: Chair of Medical Physics and Biophysics (AGH), head: Joanna Chwiej
- approx. **30 users** from Poland and CE Europe filled a „potential user questionnaire" for the beamline construction proposal

- Potential applications (from the questionnaire):

BIO	x-ray elemental mapping and 2D/3D imaging of bio-tissues,
ART	cultural heritage (National Museum)
GEO	mineral inclusions in fossil resins, petrography
CAT	catalysis (von Hammos geometry)
DET	test of new detectors (hybrid pixel & microstrip), monochromatic beam required (channel-cut Si)
NEW	developments of new experimental and analytical techniques

The talk about 3D Multpoint-projection X-ray microscopy will be presented on Thursday at 18^{30} by K.M. Sowa et al.

Micro- and nano-FTIR microscopy

Key collaborators: Wojciech Kwiatek @ Kamilla Małek

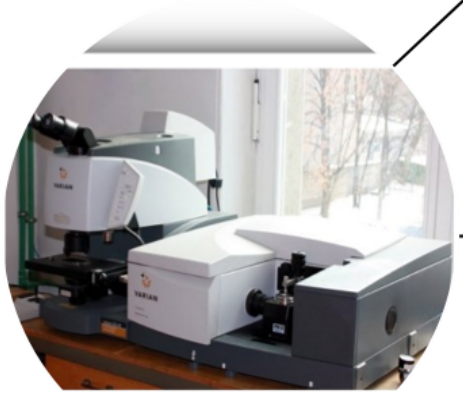
The IR end-station dedicated to infrared microscopy and nanospectroscopy:

- Two sets of instrumentation:
  - classical FTIR microscopy (spatial resolution up to **2 µm**):
    - in the range of far- and mid-IR,
    - transmission, reflection, ATR – Attenuated Total Reflectance techniques,
    - imaging option (MCT and FPA detectors).
  - sSNOM-AFM-FTIR nanospectroscopy (spatial resolution up to **30 nm**):
    - in the range of mid-IR,
    - simultaneous measurements of near-field optical images, topography and chemical properties (IR spectra).

The combination of micro- and nanometric chemical characterisation will open new opportunities for potential users and will be complementary with other Solaris beamlines.

Micro- and nano-FTIR microscopy

Applications of synchrotron FTIR microscopy

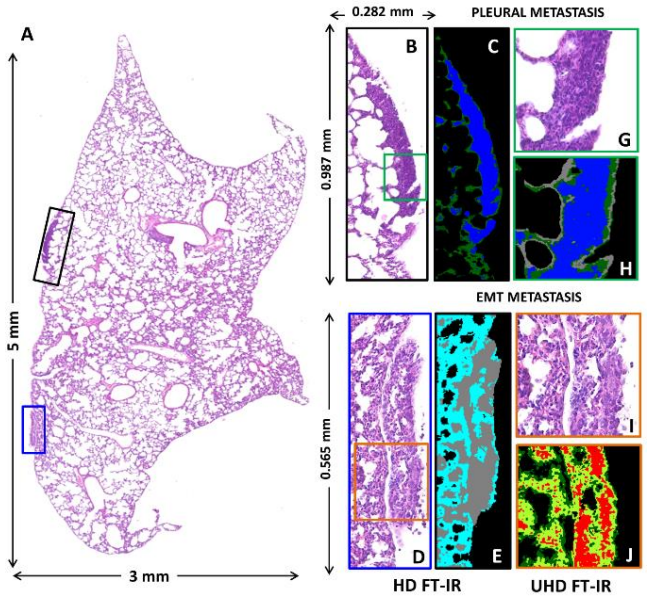


Biomedicine
- Label-free *in vitro* and *ex vivo* studies
- Diagnostic biomarkers
- Drug development
- Pharmaceuticals

Materials
- Catalysis
- Polymers
- Energy conversion
- Biosensors
- Surface chemistry

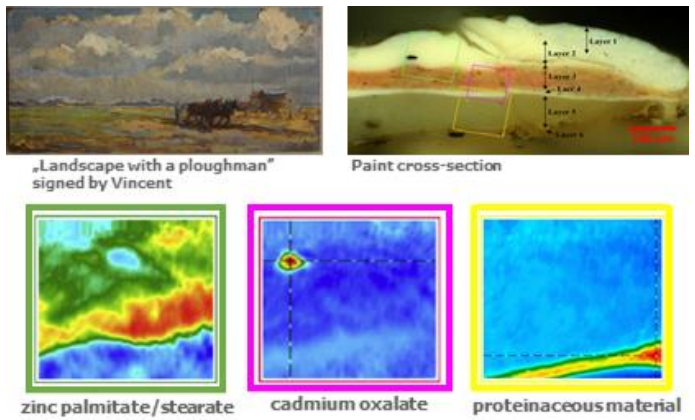
Others
- Geology
- Cultural heritage
- Forensic chemistry
- Solid state physics
- Industrial applications

FTIR-based detection of micrometastasis in High and Ultra-High definition



K. Augustyniak et al., J. Biophotonics, 2019

FTIR-based identification of degradation products in paint layers



Z. Kaszowska et al., Vib. Spectrosc., 2013

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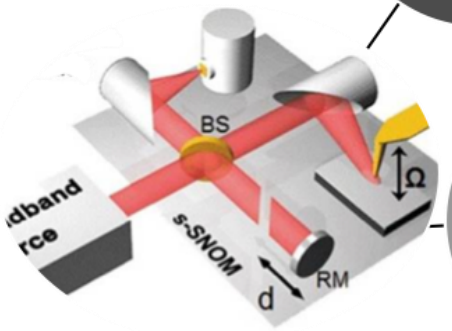
Micro- and nano-FTIR microscopy

IN COLLABORATION WITH IFJ PAN & WYDZIAŁ CHEMII UJ

Applications of synchrotron FTIR nanospectroscopy

Biomedicine

- *In situ* cellular membrane studies
- Aggregation motif of proteins and nucleic acids
- Identification of pathogens
- Drug-receptor interactions



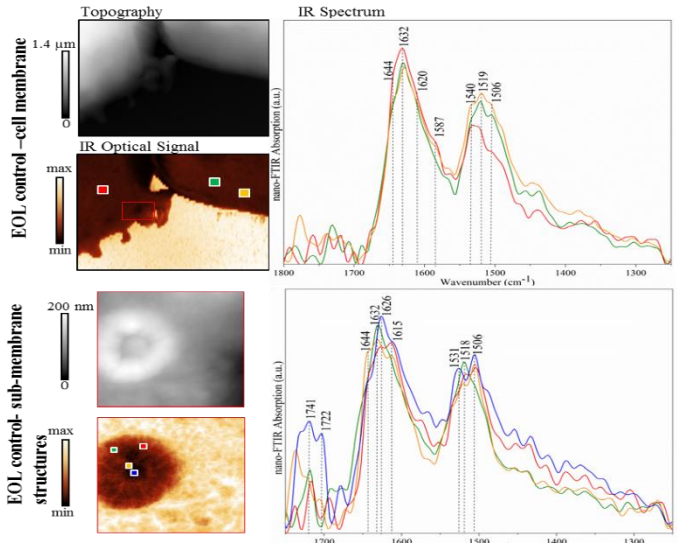
Materials

- Nanomaterials and their functionalisation
- Artificial biofilms and biomembranes
- Catalytic reactions
- Plasmonic nanostructures
- Nanocrystals, etc.

Others

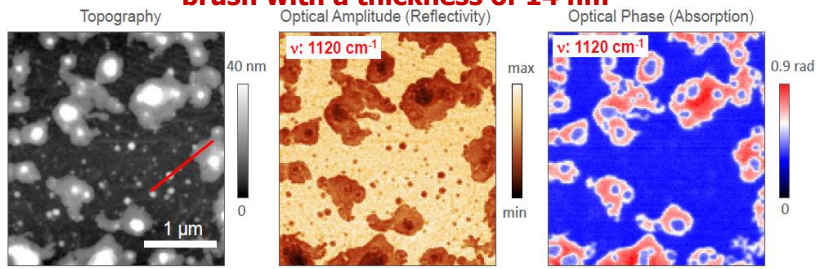
- Plasmonic optics
- Solid state physics
- Forensic chemistry

Variation in secondary structure of proteins in membrane of a eosinophilic model



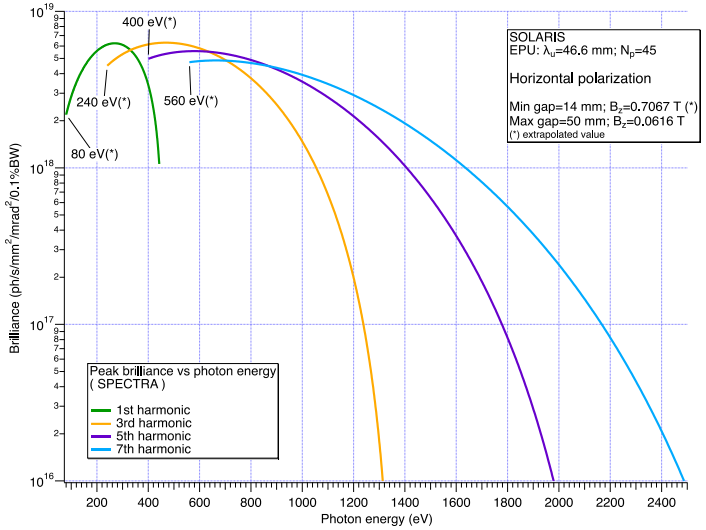
A. Rygula et al., Brit. J. Haematol., 2019

FTIR nanospectroscopic imaging of a polimer brush with a thickness of 14 nm

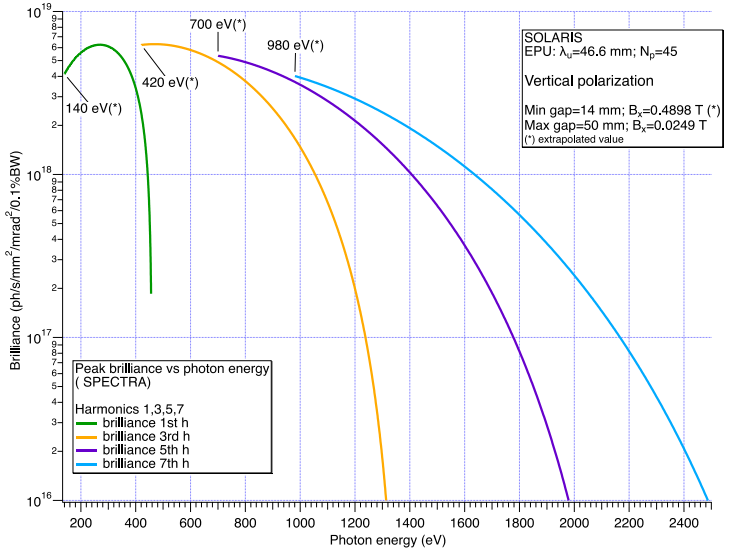


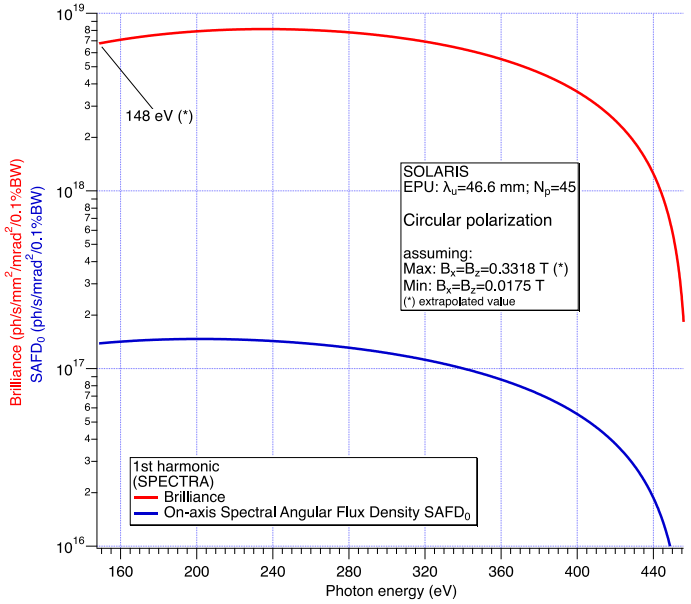
Data of Neaspec

STXM – endstation @ XMCD beamline



EPU

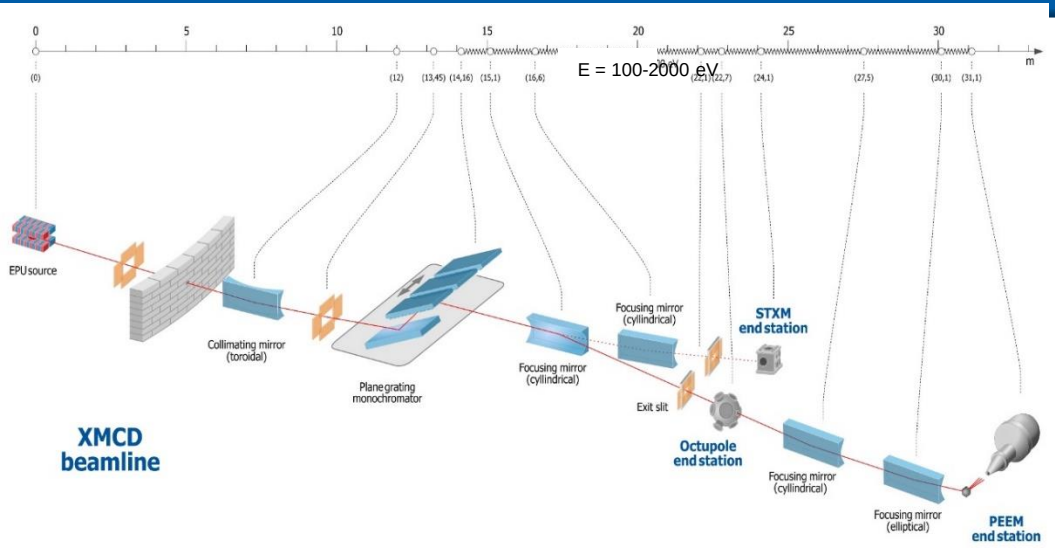




calculations carried out by Anna Bianco

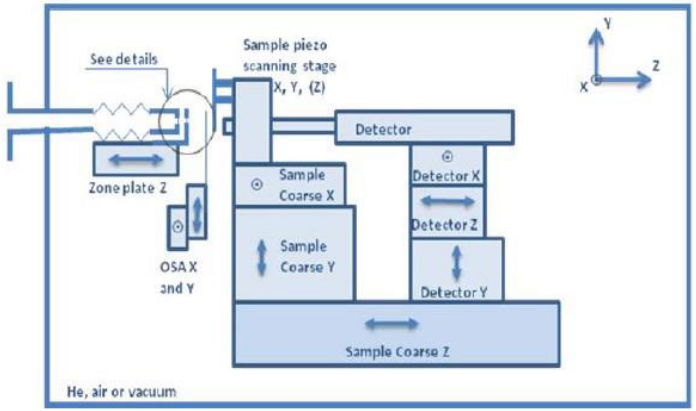
Source	Elliptically polarizing undulator
Polarization state	Circular left- and right-handed, linear horizontal or vertical
Pre-focusing optics	Vertically collimating and horizontally focussing toroidal mirror
Monochromator	Plane grating monochromator (336 l/mm, 1221 l/mm, 1400 l/mm) with plane mirror.
Focusing optics	Two vertically focussing cylindrical mirror (for PEEM and for STXM)
Energy range	100-2000 eV
Energy resolution	E/dE = $3x10^3$ – $1.5x10^4$
Photon flux on sample	~ 10^{12} ph/s/0.1%bw

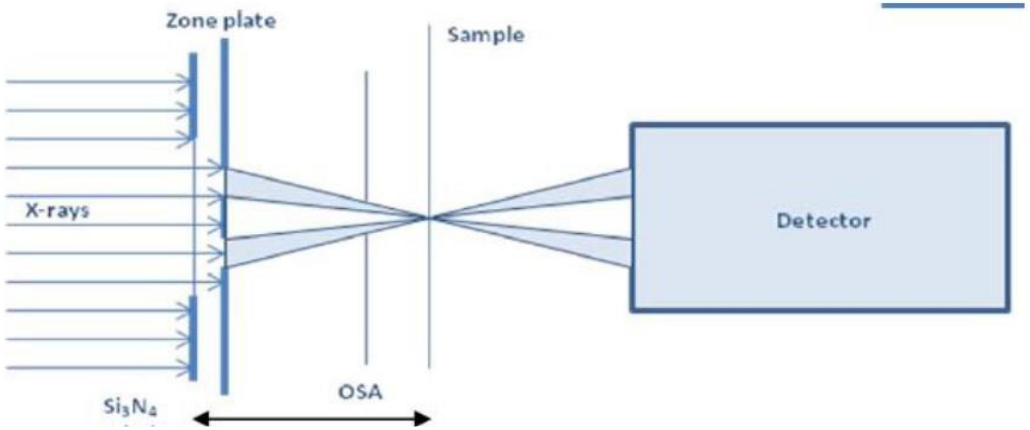
STXM



STXM - endstation

Concept of the endstation – Tolek Tyliszczak (formerly at ALS)





Several groups from Poland and from abroad prepared the draft research projects for the application to MNiSW

- transmission, fluorescence and ptychography modes of operation

First experiments - fall 2020

JAGIELLONIAN UNIVERSITY IN KRAKOW

SOLARIS NATIONAL SYNCHROTRON RADIATION CENTRE

Hochschule Niederrhein
University of Applied Sciences

SOLARIS
today & tomorrow

STRUCTURAL BIOLOGY CORE FACILITY

NATIONAL CRYO-EM FACILITY at SOLARIS

Krios

Glacios

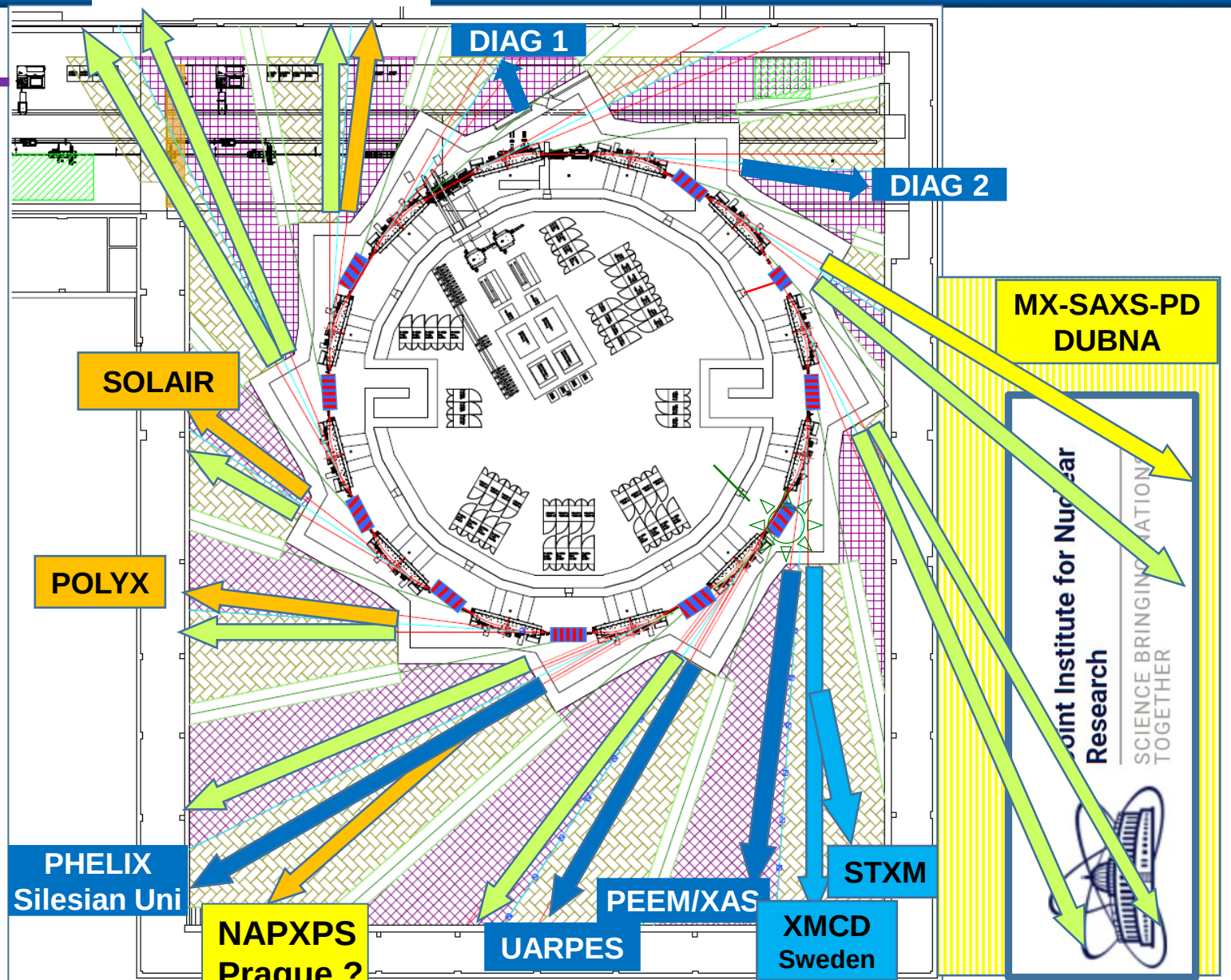
Operating

Under construction – available 2020/2021

Under construction - available 2021/2022

Under construction - available 2022/2023

10 slots unoccupied
- SOLARIS is open to domestic/international initiatives resulting in building new beamlines and end stations.



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ACCESS to SOLARIS

- ✓ SOLARIS accepts external domestic and international applications – keeping the balance between those groups
- ✓ Regular calls, every 6 months - International Evaluation Committee
- ✓ Applications via Digital User Office

- ✓ Since 1 September call open for PEEM, XAS, UARPES & PHELIX
- ✓ STXM – next call

https://duo.synchrotron.pl/#/login

- ✓ From March 2019 we are all facing COVID 19
- ✓ However, SOLARIS is operating and open for users.
- ✓ Of course we all need to monitor the situation and observe relevant rules and restrictions

SOLARIS – synergy with international research landscape

Talk

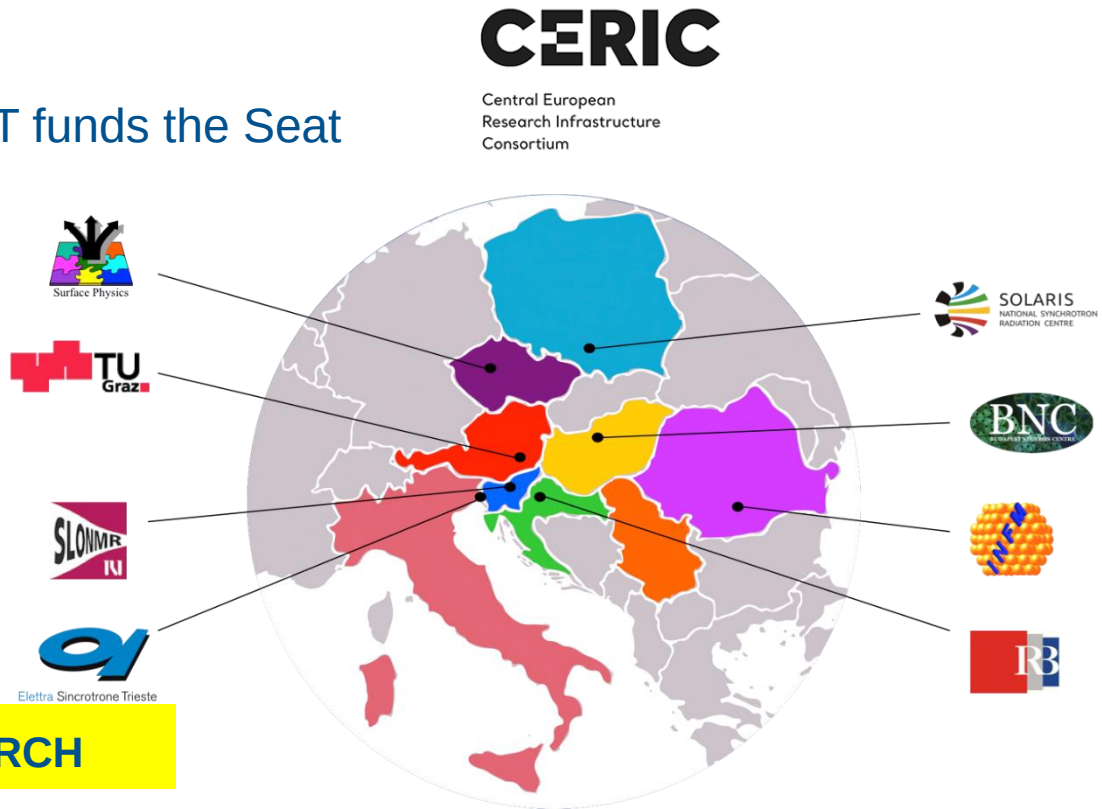
SOLARIS – part of Central European Research Infrastructure Concortium CERIC-ERIC

CERIC-ERIC: a unique distributed research facility in 8 countries

Number of infrastructures (Partner Facilities), one from each member countries made available to member countries for free

- ***no transfer of money***, but transfer and share of values, IT funds the Seat
- ***single entry point***, offering over 40 available techniques;
- ***peer evaluation system*** to select the best proposals;
- ***free and open access*** by quality selection only;

STRUCTURE:
Participating Country (member)
Representing Entity
Partner Facilities



PROVIDING ENVIRONMENT FOR MULTITECHNIQUE RESEARCH

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LEAPS - European synergy

League of Accelerator Based Photon Sources

est. November 2017 - www.leaps-initiative.eu

LEAPS - the League of European Accelerator-based Photon Sources - is a strategic consortium initiated by the Directors of the Synchrotron Radiation and Free Electron Laser (FEL) user facilities in Europe. Its primary goal is to actively and constructively ensure and promote the quality and impact of the fundamental, applied and industrial research carried out at their respective facility to the greater benefit of European science and society.

LEAPS members will produce a road map for the development of the next-generation light sources and instrument technologies, advocate for its funding and together address the big data challenge.

LEAPS will also:

- Play to the strengths of individual facilities through smart specialisation, recognising strengths in a more coordinated way to better serve the future needs of the user community
- Strengthen and expand services to industry to trigger innovation more widely and efffectively
- Standardise and improve access modes for users, capture and map socio-economic impact, enhance training and outreach programmes
- Strengthen scientific integration, both across Europe and globally

Acknowlegements

- **Project success relied on exceptional transnational collaborations**
- **FOREMOST - The freely given design of the MAX IV 1.5 GeV ring and its injector technology by MAX-lab**
- **MAX IV – Solaris Collaboration:**

  Training and exchange of personnel

  Exchange of ideas and requirements

  Collaboration in procurements and contract specifications: Procurements for Solaris were as options in MAX IV tenders

  Provision of state-of-the-art components: Gun System, Landau cavities, modifications to vacuum chambers and magnets

  Technical support with industrial follow-up and FATs

  Maximised return for cash by allowing industry to plan for double purchase orders

Acknowlegements

Elettra-Sincrotrone Trieste - Expert advice, contracts for PSS, design of transfer line, vacuum chamber components, beamline and front-end, EPU insertion device

Swiss Light Source - Expert advice, trainingBake-out oven and control

Diamond - Expert advice

Soleil - Expert advice, commissioning software

ALBA - Expert advice, commissioing software, training

ESRF - Expert Advice, IcePAP motion controllers

Machine Advisory Committee – Expert advice of 5 world class experts from Diamond, Soleil, PSI

National Centre for Nuclear Research, Świerk - Vacuum system installation inclusive of linac, storage ring and RF cavities.

Polish Synchrotron Consortium (36 universities and institutes)

Polish Synchrotron Radiation Society

Polish Physical Society

PL-Grid

Institute of Catalysis and Surface Chemistry PAS – PEEM End Station

Cracow University of Technology

Large infrastructure cost

1 km motorway = 10 MEUR

SOLARIS = 5 km motorway

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Thank you for your attention!!!

visit us: http://www.synchrotron.uj.edu.pl/