Research centre Řež

SUSEN – CLOSING GAP TO TOMORROW´S ENERGY TECHNOLOGY

Karin Stehlik, Jiří Richter

18.3.2015

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Research Centre Rez

- **Since 2002, R&D organization developing ideas, technologies and solutions in power generation industry particularly focused at nuclear technologies**
- **Member of the UJV Group**
- **250 employees**
- **Our Vision**
  - To become a strong, economically independent research and development organization in power generation (especially nuclear)

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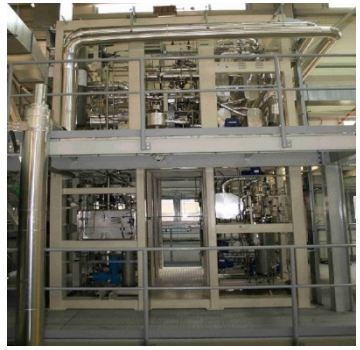
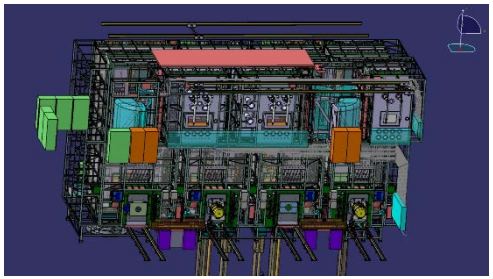
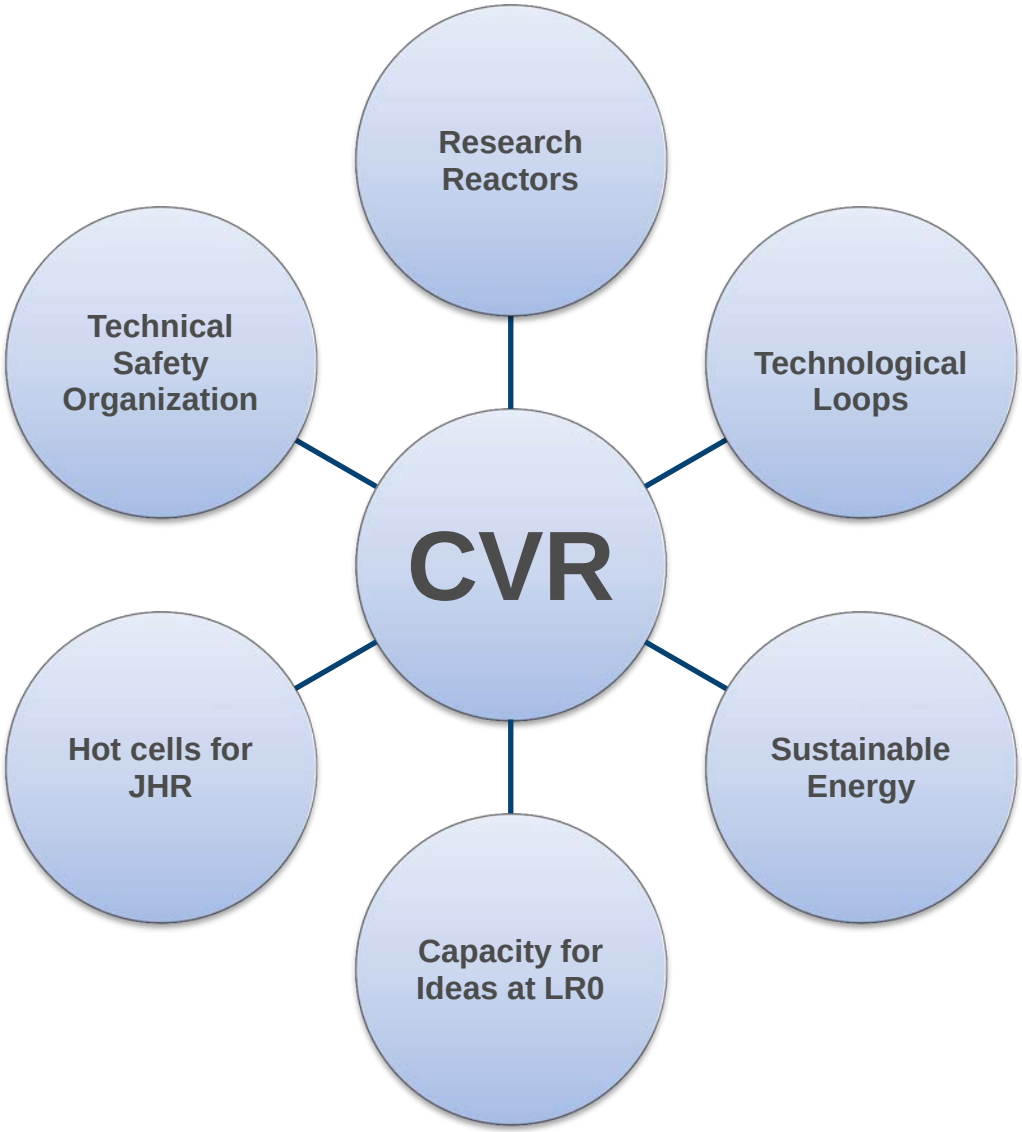
R&D Activities







Project SUSEN

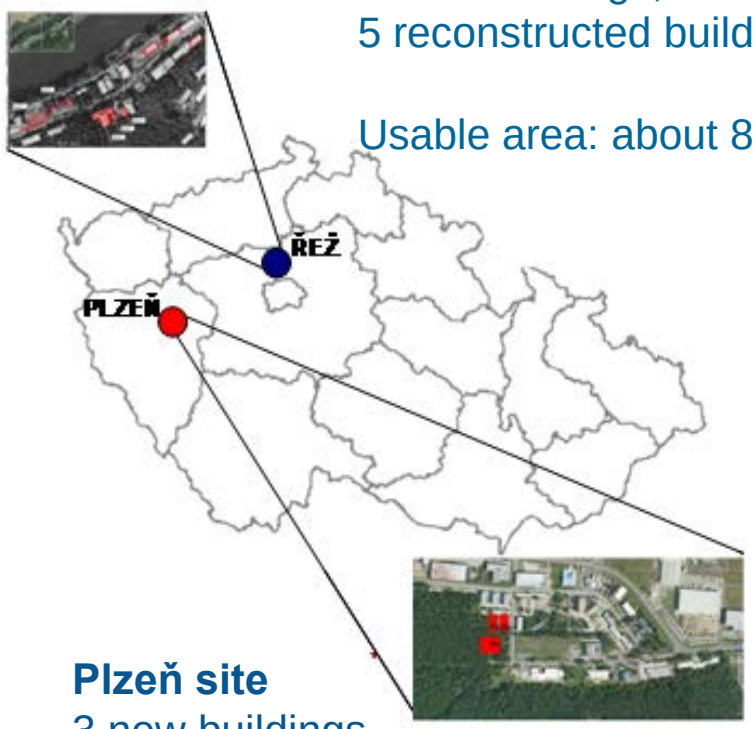
Objectives of project:
Construction of a research infrastructure focused to energy research with emphasis on nuclear technologies

SUBSIDY BENEFICIARY:
Centrum výzkumu Řež s.r.o.
(Research Centre Rez)
A member of the NRI Group
PARTNER:
West Bohemia University
MAXIMUM SUBSIDY AMOUNT:
CZK 2.451 milliard

01/2012:
Start of project

12/2013 -12/2020:
R&D outputs and proving sustainability

12/2015:
End of construction



Rez site
1 new buildings,
5 reconstructed buildings,

Usable area: about 8,450 m^2

Plzeň site
3 new buildings
Usable area: about 3,860 m^2

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Project objectives:

- **In addition to the general objectives of the project, 21 particular research outputs and 52 research outcomes have to be achieved within the period 2013 to 2020**

- **To achieve these objectives, it was necessary to extend the infrastructure of Research Centre Rez:**
  - Build new diagnostic centre and reconstruct or extend 5 buildings in Rez – all buildings but one are completed
  - Build new experimental hall and rent two more buildings in Plzen - completed
  - Procure necessary experimental equipment and instruments – in progress

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Technological Experimental Circuits

TEC

Structural and System Diagnostics

SSD

Project SUSEN

Nuclear Fuel Cycle

NFC

Material Research

MAT

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Structural and System Diagnostics

- **Main goals**
  - Lifetime prolonging of current generation of nuclear power plants, beyond 60 years
  - Supporting actions in development of materials and diagnostic systems for future operation of new generations reactors (Gen IV, Fusion)
- **Main aims**
  - Material studies of highly irradiated materials
  - R&D of diagnostic systems

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Structural and System Diagnostic

SSD

Highly sensitive analytical instruments centre

NDE laboratory

Severe accident laboratory

Hot cell laboratory

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Centre of Highly Sensitive Analytical Instruments

- **Main laboratories:**
  - **Transmission Electron Microscopy** (HR-STEM) with atomic resolution and very low detection limits of chemical elements
  - **Scanning Electron Microscopy** with **Focused Ion Beam** (SEM-FIB) and analytical detectors **EDS, WDS a EBSD**
  - **Secondary Ion Mass Spectroscopy** (SIMS) for isotopic analysis
  - **Sample preparation lab** for advanced electron microscopy and SIMS
  - **Light Optical Microscopy** (LOM) with **microhardness attachment** (MHV) for fundamental microstructure analysis
  - **Nanoindentor** for micro-mechanical material properties analysis

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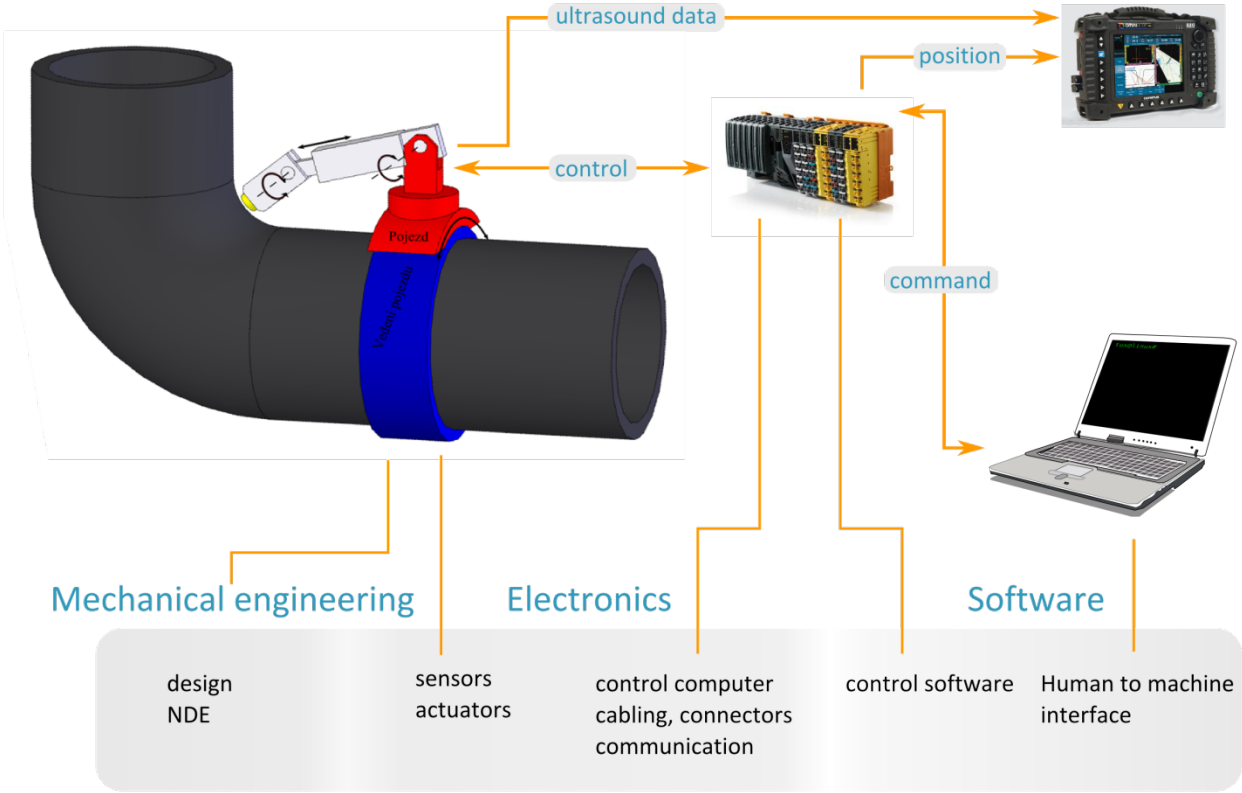
NDE Laboratory

- **Main laboratories**
  - Electro-mechanical laboratory of robotics
  - Laboratory of non-destructive testing
  - Laboratory of cracks and discontinuities studies
    - The laboratories cover whole automated NDE tool chain



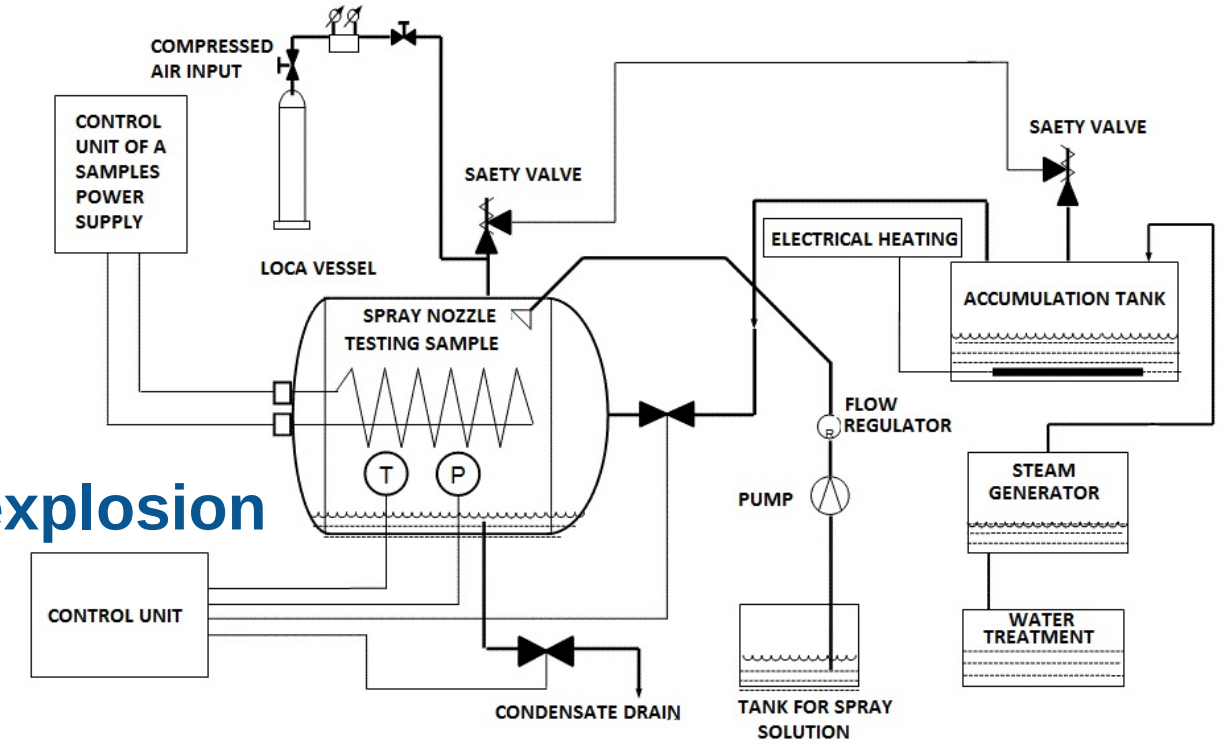
Severe Accidents Laboratory

- **Main objective:**
  - Developing new procedures of thermal and radiation resistance verification and behaviour of structural materials and systems under the extreme conditions of severe accidents.

- **Main technologies:**
  - LOCA device
  - High voltage testing room
  - Gamma irradiation device

LOCA Device

- **Main LOCA**
  - V = 1-10 m3
  - Tmax= 270-320 °C
  - pmax,(abs) = 20 - 112 bar
- **Vessel for simulation H2 explosion**
  - Tmax=320 – 550 °C
  - pmax,(abs) = 20 - 112 bar
- **Post-LOCA**
  - V = 1-10 m3
  - Tmax=150-250 °C
  - pmax,(abs) =10-20 bar



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Hot Cell Laboratory

- **Main objectives:**
  - Study of the microstructure degradation and mechanical properties of nuclear reactor structural components materials after long operational exposure;
    - Very high temperature testing (up to 1200°C) of mechanical properties,
    - CGR at cyclic loading, a development and implementation of low-cycle fatigue testing with creep interaction (fatigue-creep), and creep testing
  - Development of new fuel cycle technologies for fluorite technology-based nuclear reactors of new generations

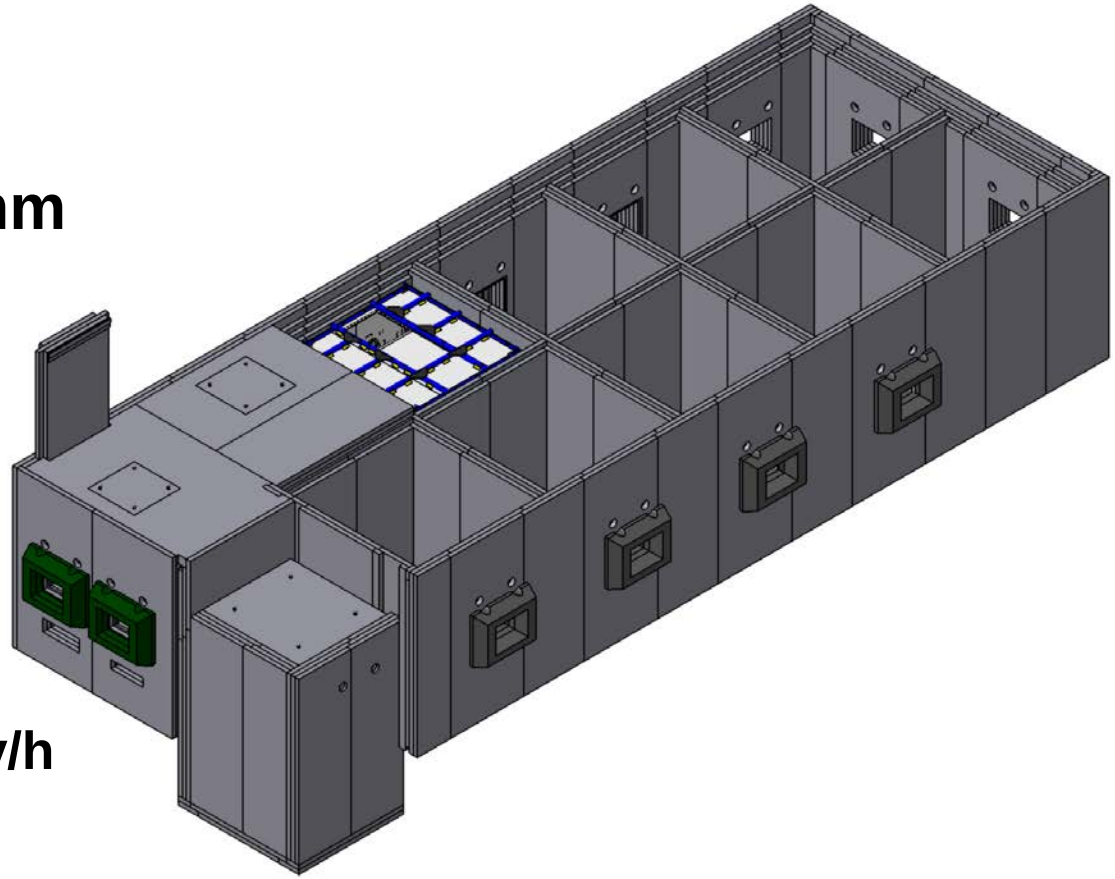
- **Main technologies**
  - 8 γ-hot cells, 2 α-hot cells, 1 semi hot cell and 1 dry pool

Layout of the Hot Cells

- **8 gamma hot cells, 2 alpha hot cells and 1 semi-hot cell** will be constructed.

Thickness of steel shielding:

- **perimeter shielding 500 mm**
- **ceiling shielding 400 mm**
- **floor shielding 300 mm**



- **Max. source activity up to 300 TBq ^{60}Co**

Dose Equivalent Rates γ = 1.38 μSv/h

In each hot cell will be hermetic, easily removable box from stainless steel

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Equipment inside Hot Cells

- The hot cells will be equipped for manufacturing of the specimens (cutting, welding, drilling, machining) with:
  - Electrical discharge machine (EDM)
  - CNC machining center
  - Electron beam welding machine (EBW)
- The hot cells will be equipped for mechanical testing with:
  - Universal tensile test machine loading up to 250kN
  - Tensile test machine for combined axial-torsional
  - High frequency resonance pulsator up to 50kN
  - Electromechanical creep machine up to 50kN
  - Fatigue machine
  - Autoclave with water loop
- The microscopes (SEM, LOM) will be placed in the semi-hot cell also with nanoindentation device.

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Nuclear Fuel Cycle

- **Main goals**
  - To expand and construct a research infrastructure to support:
    - nuclear fuel cycle of IVth GEN reactors,
    - radioactive waste management (RWM), including its final disposal,
    - severe accidents experimental studies,
    - non-spreading of nuclear weapons and the environmental impact,
    - SUSEN project analytically

Project SUSEN

Nuclear Fuel Cycle NFC

Laboratory of Induction Heating

Laboratory of Geological Disposal

Laboratory of Radioactive Waste Management Technologies

Laboratory of Nuclear Fuel Reprocessing and Fluoride Chemistry

Analytical Laboratory

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Laboratory of Geological Disposal

Anaerobic glove boxes:

GP(concept)-II-S,
GP(concept)-II-P

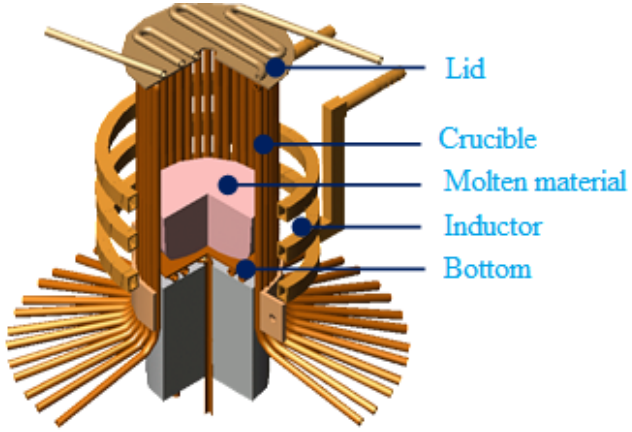
Jacomex, France

- allow to handle the product sensitive to atmospheric components (O2, H2O,…) in environment under neutral gases (dry air, nitrogen, argon, helium…)
- create a barrier which separate the inner work volume from the surrounding space where the operators are located

Laboratory of Induction Heating

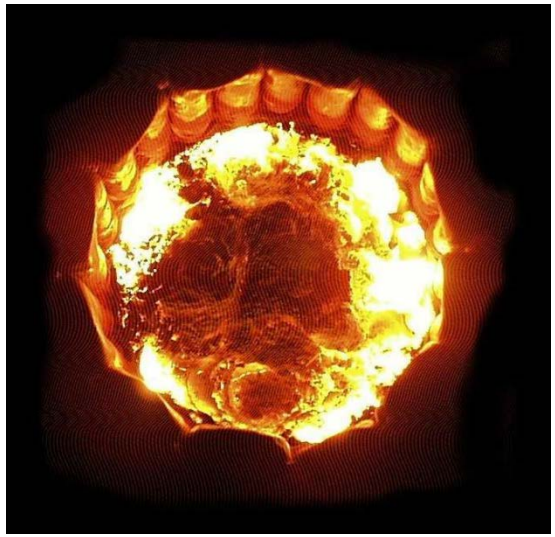
What is planned?

- Induction heater with cold crucibles:
  - Generator A – 160 kW (1-2 MHz) – **also in ZCU**
  - Generator B – 300 kW (0,1 – 0,5 MHz)
- Equipped with vacuum chamber
- Located within a controlled area (Cat. 3 workplace with IRS) - **Rez**



What can it do?

- Heating up conductive/semiconductive and/or non-conductive materials up to 3000°C
- Different conditions:
  - Gases
  - Radioactivity
  - Volumes of cold crucible (up to 50 kgs of material ~ 25 Ltrs



For what research?

- Investigation of phase diagrams and melts properties
- Modeling and investigation of nonstandard situations at nuclear power reactors (in- and ex-vessel severe accidents)
- Vitrification of radioactive wastes
- Powder remelting to ingot
- High temperature synthesis of materials
- Crystal growth (mono-, multicrystals)
- Glass synthesis
- Production of fused refractors

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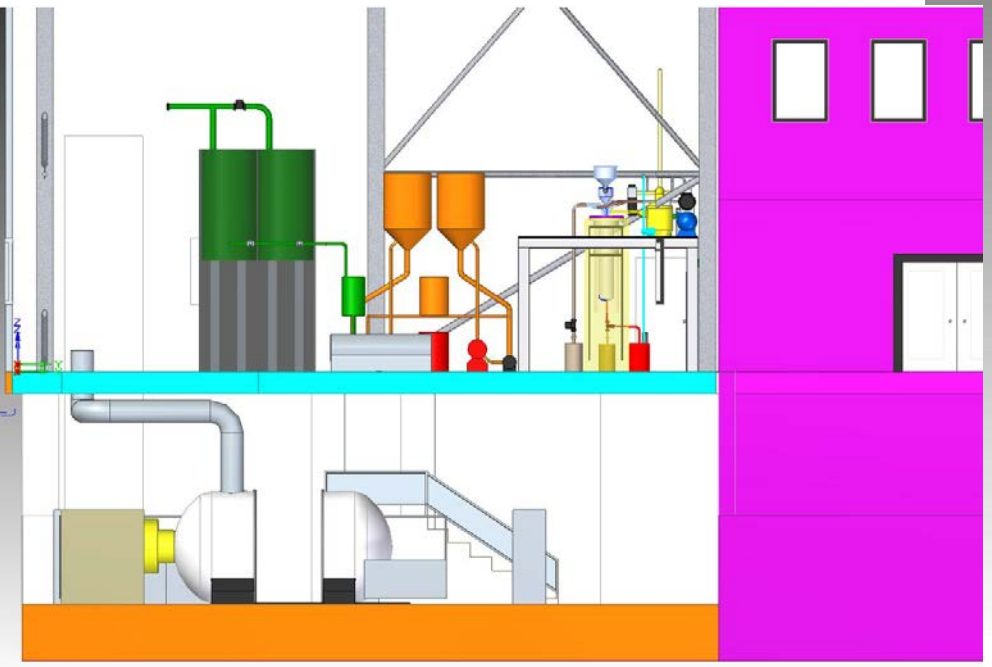
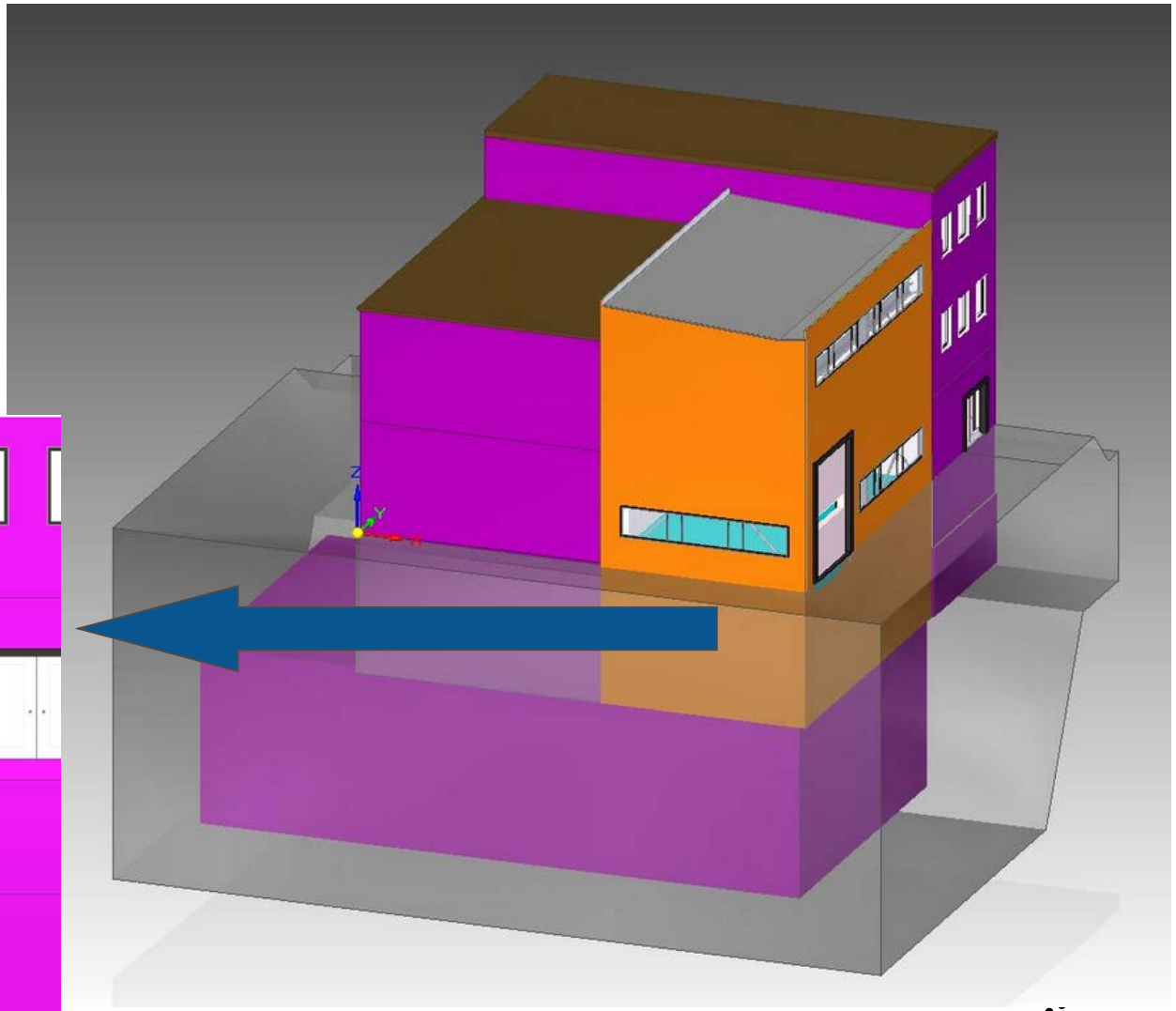
Laboratory of RAW management

Location

- Building 211/3 - reconstruction
- Active zones (controlled areas)
- Workplace 3rd category with IRS





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Laboratory of Nuclear Fuel Reprocessing

- Thermal hydraulic experiments
- Corrosion behaviour study (static and dynamic corrosion experiments)
- Basic components (valve, flanges, pumps, sensors, seals, etc.) testing
- Basic operational procedures verification
- Loops are necessary for development of crucial components of MSR/FHR
- Further development of structural materials and their evaluations

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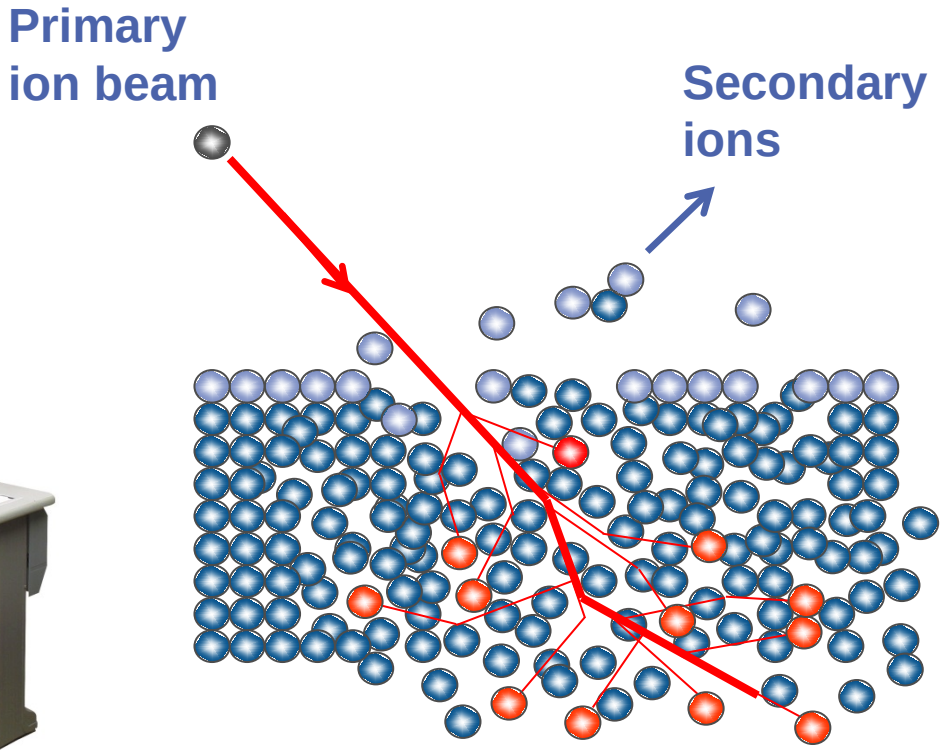
Analytical Laboratory

Magnetic sector SIMS: CAMECA ims 7f

SIMS principle



SIMS reveals elemental and isotopic surface composition

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Material Research

- **Main goals**
  - supporting actions in development of ferritic/martensitic steels for application in an environment with temperatures up to 650°C (steam turbines and supercritical fossil power plants and inactive circuits of Generation IV nuclear reactors), austenitic steels and high-level austenitic alloys for components stable in aggressive environments at high temperatures and pressures, and new welding technologies for advanced materials

- **Main aims**
  - create a regionally unique workplace, equipped with cutting-edge research instruments and highly qualified service staff

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Material Research

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Mechanical Testing Laboratories

Laboratories of Analytical Chemistry and Electrochemistry

Laboratory of Metallography and Surface analysis

Laboratory of Fusion Welding

(partner UWB)

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Mechanical Testing Laboratories

- **Key activity:**

  - Tests under static, dynamic and impact loading
  - Brittle fracture resistance tests
  - Fatigue tests of structural materials at temperatures up to 1000 °C
  - Crack growth rate measurement at cyclic (fatigue) loading
  - Heat resistance, relaxation and structural stability tests
  - Hardness tests on metals and plastic materials
  - Stress corrosion tests, corrosion fatigue test
  - Corrosion test in HLM

Mechanical Testing Laboratories

- **Key equipment:**
  - static servo-electric materials testing machine
  - servo-hydraulic high-force axial/torsional dynamic test system
  - servo-hydraulic medium-force axial dynamic test system
  - clamping plate with dimensions 2 x 3 m with two free hydraulic servo-cylinders of loading power 10 kN and 50 kN
  - resonant testing machine for HCF
  - high frequency low-force axial-torsion test system
  - motorized impact testing system
  - universal hardness testing machine
  - creep test stands
  - experimental corrosion loops for liquid Pb

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Mechanical Testing Laboratories

Laboratories of Analytical Chemistry and Electrochemistry

- **Key activity:**
  - chemical analysis of metals, alloys and other inorganic materials
  - wide-range measurement of carbon and sulfur in inorganic materials
  - wide-range measurement of oxygen, nitrogen, and hydrogen content of inorganic materials, ferrous and nonferrous alloys
  - electrochemical measurement (polarization curves, EIS, electrochemical noise

- **Key equipment:**
  - glow discharge atomic emission spectrometer
  - elemental analyzer for Carbon and Sulfur
  - Oxygen/Nitrogen/Hydrogen analyzer

Laboratories of Metallography and Surface analysis

- **Key activity:**
  - sample surface imaging
  - fracture features analyses
  - chemical microanalysis
  - cutting and sectioning materials
  - mounting, grinding and polishing of metallographic specimen
- **Key equipment:**
  - light optical microscope - LOM
  - field emission scanning electron microscope – SEM
  - optical profilometer
  - metallographic specimens preparation : precise metallographic abrasive saw, hydraulic press, grinder/polisher
  - image analysis software

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Laboratory of Fusion Welding /partner UWB/

- **Key activity:**
  - Developing new fusion welding technologies for advanced materials of fossil and nuclear power plants
- **Key equipment:**
  - Robotic welding system incl. accessories
  - Welding equipment for TIG AC, Advanced CMT MIG/MAG
  - Orbital Welding Equipment
  - Plasma cutter (air)
  - Laser welding system
  - Software for num. simulation of welding

Faculty of Mechanical Engineering

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Technological Experimental Circuits TEC

SCWR Loop for Fuel Qualifiacation Tests

Ultracritical Water Loop

High Heat Flux Test Facility for ITER Programme

TBM Platform

S-ALLEGRO Helium Loop

HTHL Loop

CO2 Loop

Neutron Generators

Hydrogen Technologies

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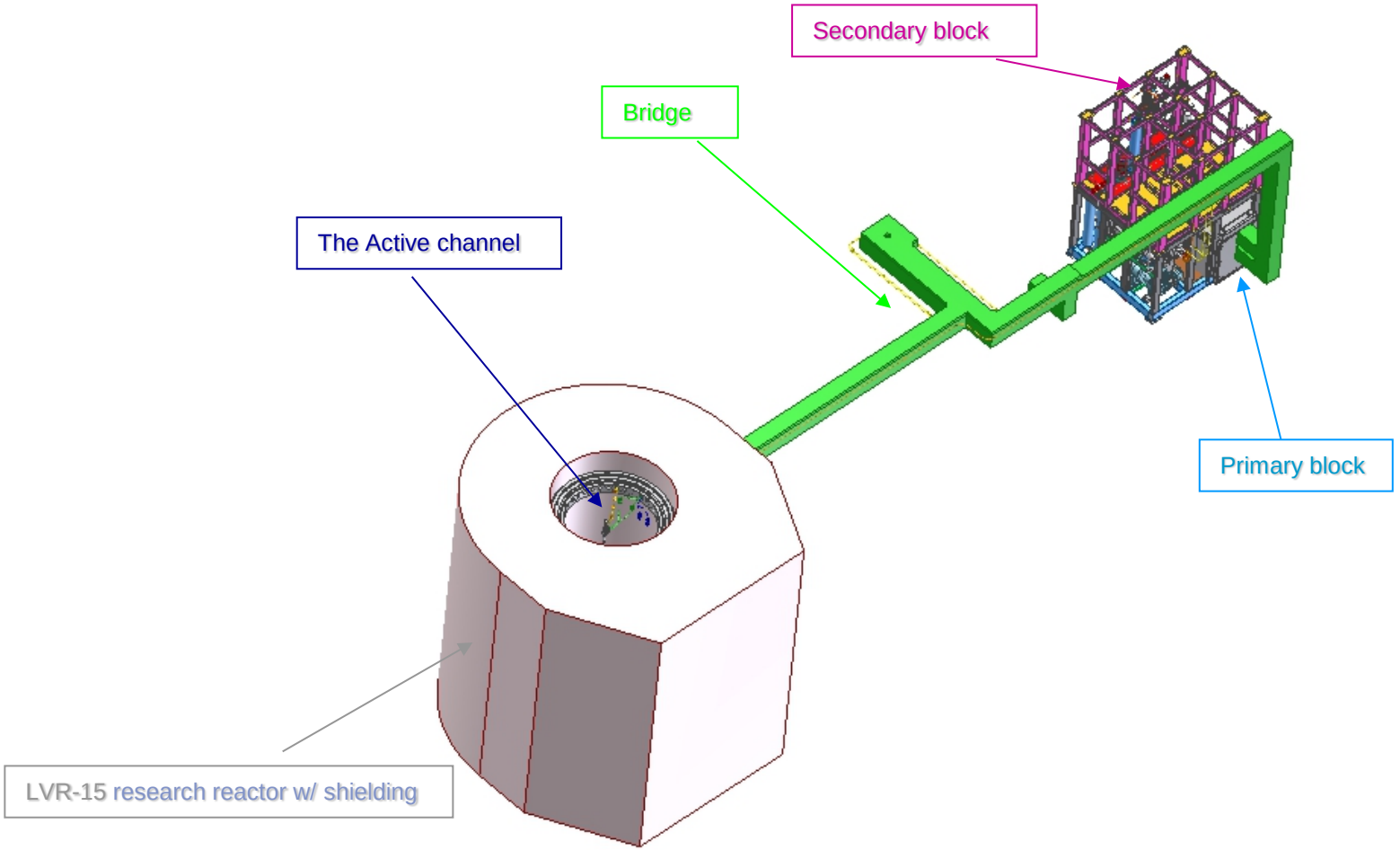
FQT SCWR Loop

- **Main goal:**
  - Testing of a small-scale fuel assembly under typical prototype conditions of the SCWR.

- **The main objective:**
  - Testing of the fuel cladding under more realistic conditions;
  - Testing of the integrity of the assembly (welds, wire wraps, etc.);
  - Obtaining data for heat transfer predictions for supercritical water conditions.

FQT SCWR Loop

- **Main facility / laboratories:**
  - Fuel Qualification Test (FQT) loop for the LVR-15 research reactor



Ultracritical Water Loop (UCWL)

- Conception of UCWL is based on our experiences with supercritical water loop (SCWL).
- The parameters of UCWL are the same as the parameters, which are expected of future conventional Rankine-Clausius cycles.

Experimental Complex HELCZA

- **Parameters**
  - Electron source power: 800 kW
  - Accelerating voltage: 60 kV
  - Rasterizing frequency: 20 kHz
  - Heat flux density: 40 MW/m^2 (maximum 40 GW/m^2)
  - Modules dimension: 2m x 1m or 1,5m x 1,5m
  - Angle of incidence of beam: 90^o

- **Use**
  - High heat flux cyclic loading of various materials
  - Extreme heat flux testing of various materials
  - Testing of fusion first wall and divertor targets modules

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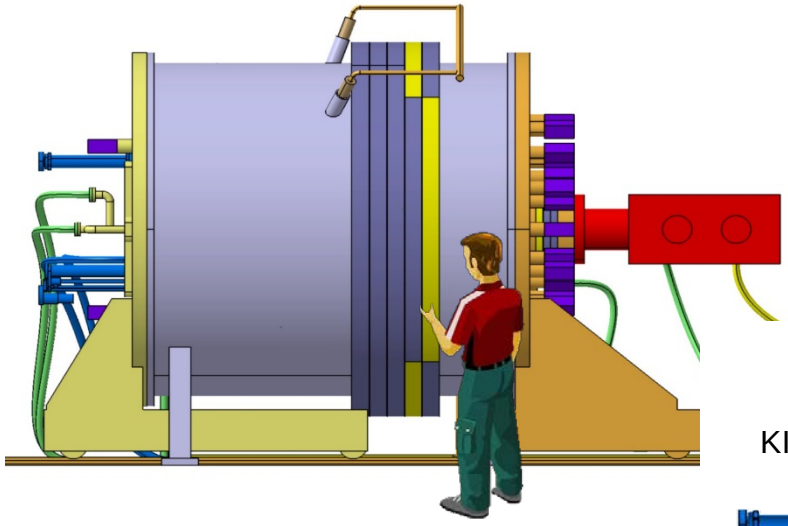
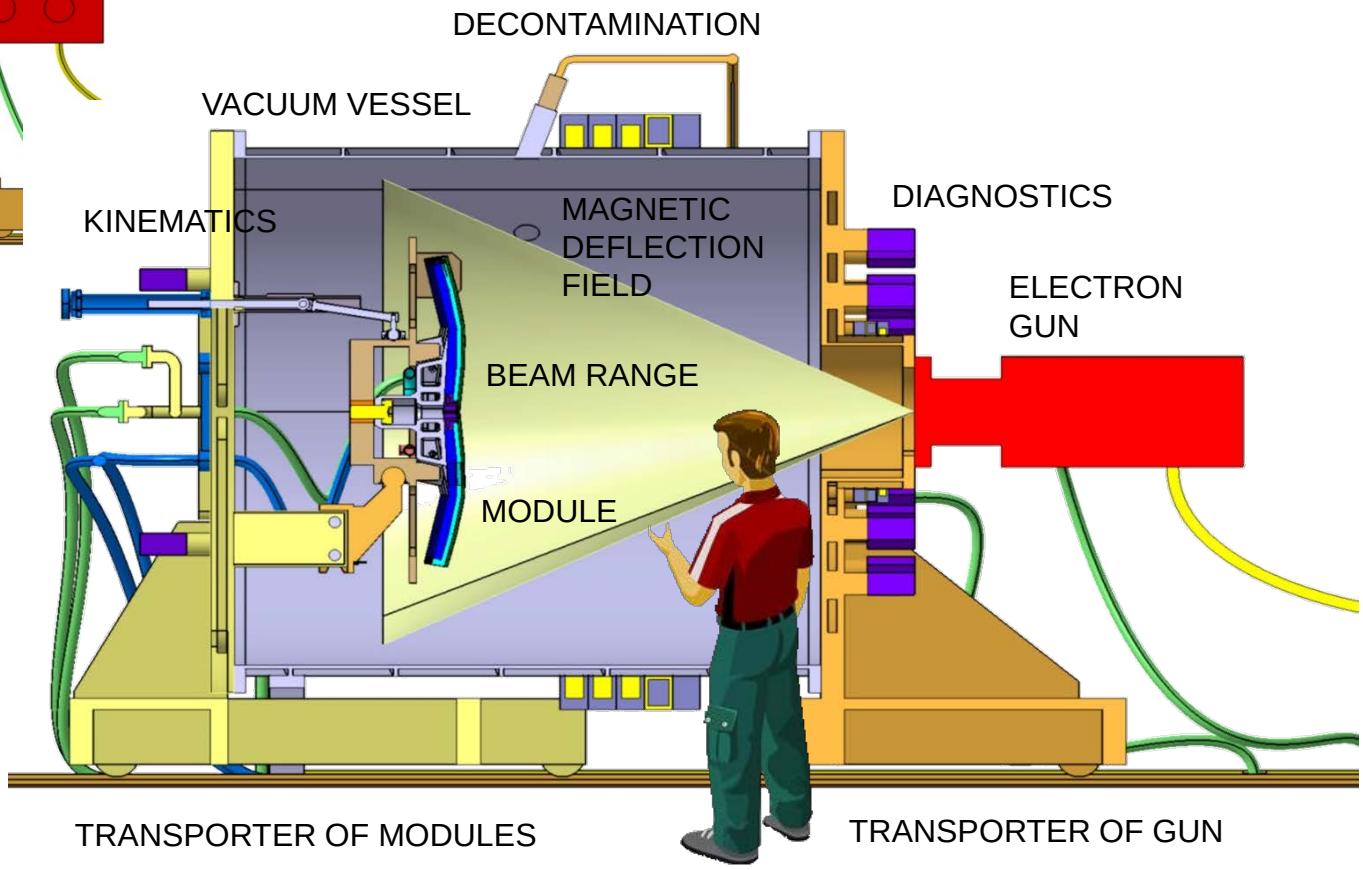
Experimental Complex HELCZA





Exposition distance	2 m
Vessel inner diameter	2.5 m
Vessel inner length	2.8 m
Vessel volume	11 m^3
Vessel weight	22 t

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TBM Platform for Maintenance Testing

Experimental facility in support of the EU Test Blanket Module (TBM) systems development and operation

Main goals:

Experimental facility intended for:

- tests of accessibility conditions in Port Cell and Port InterSpace of ITER
- tests, development and training of maintenance operations to be done during Long Term Maintenance shutdowns of ITER
- tests of remote handling tools dedicated to TBM systems
- development, testing and training of maintenance and remote handling procedures

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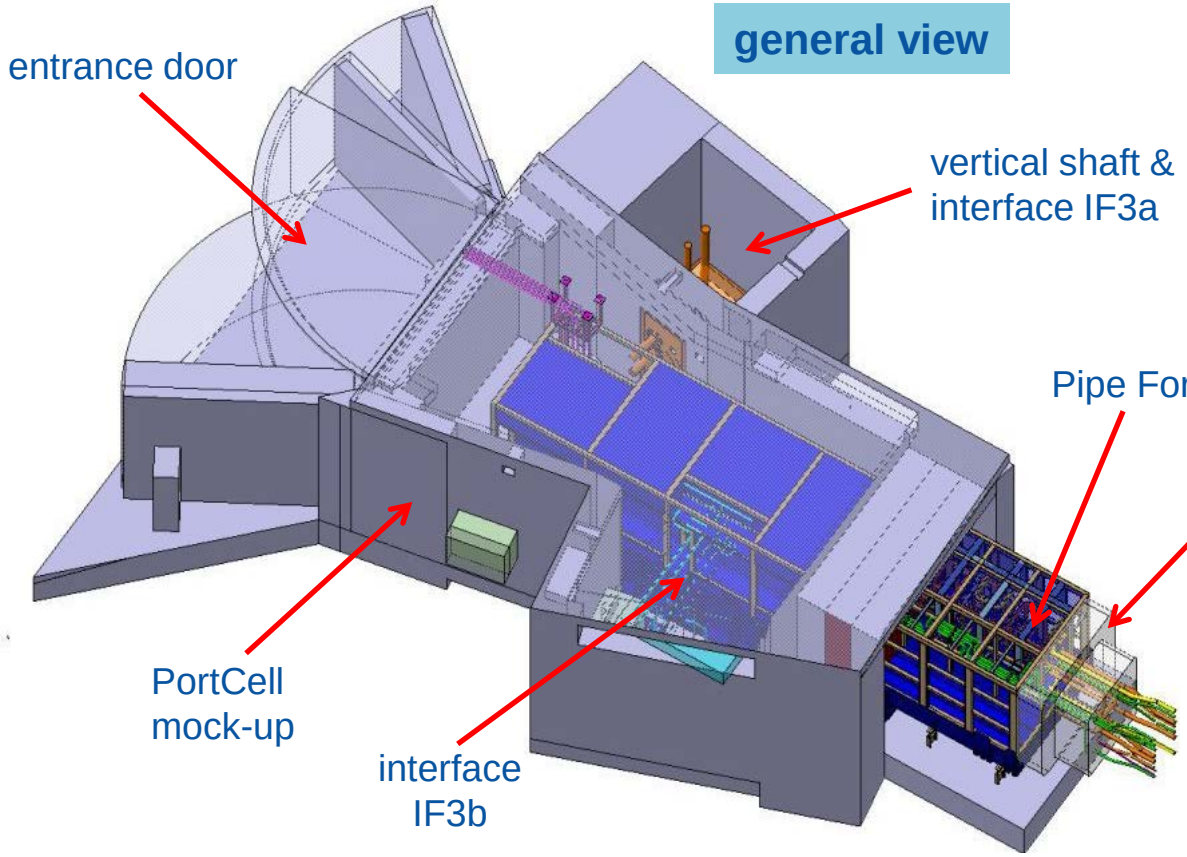
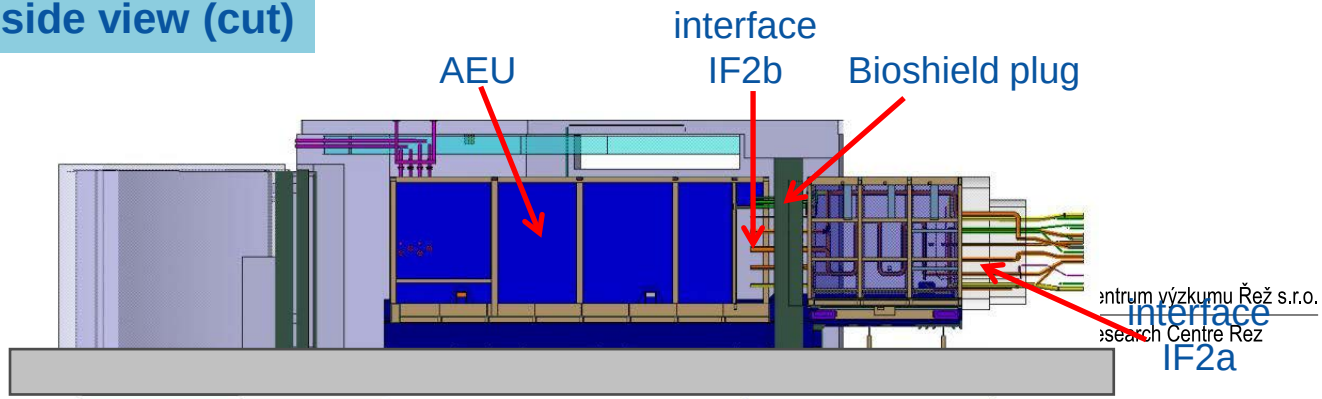
TBM Platform – 3D Previews (Basic Design)

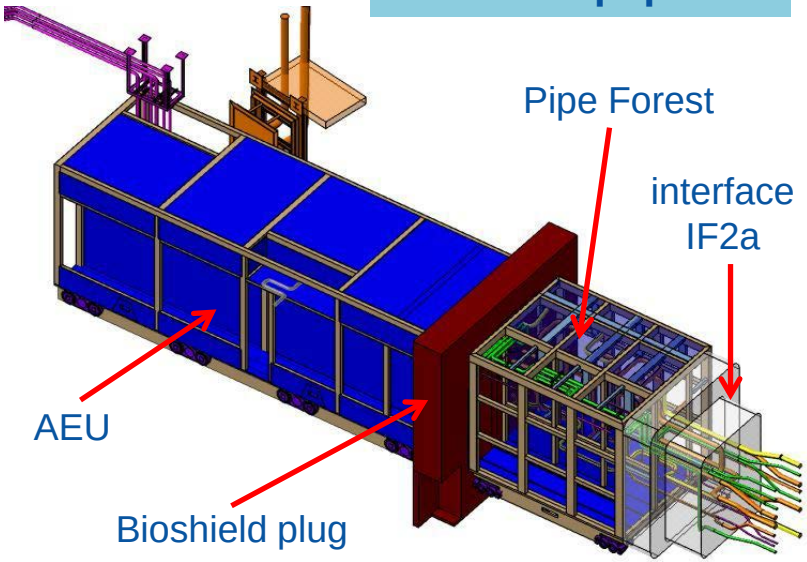
general view



side view (cut)



internal equipment



S-ALLEGRO - Helium Experimental Loop

- **Main goals:**
  - Verify the basic safety characteristics of helium cooled reactors
  - Ensure data for TH codes validation
  - Non-active functional tests, reliability tests, long-term component testing
  - In model scale check these ALLEGRO characteristics
    - Emergency heat removal system, decay heat removal system
    - Transients
    - Piping system
    - Construction materials
    - Manufacturing technology (welding)
    - Purification system
    - Component testing

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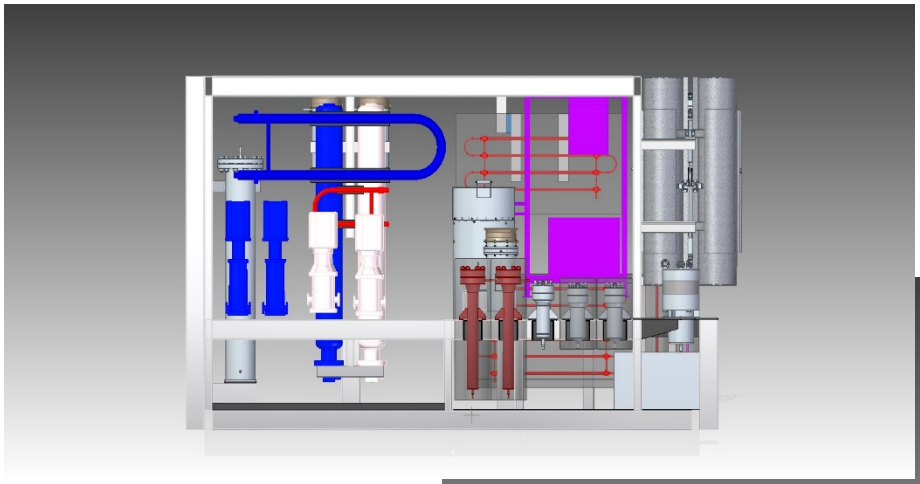
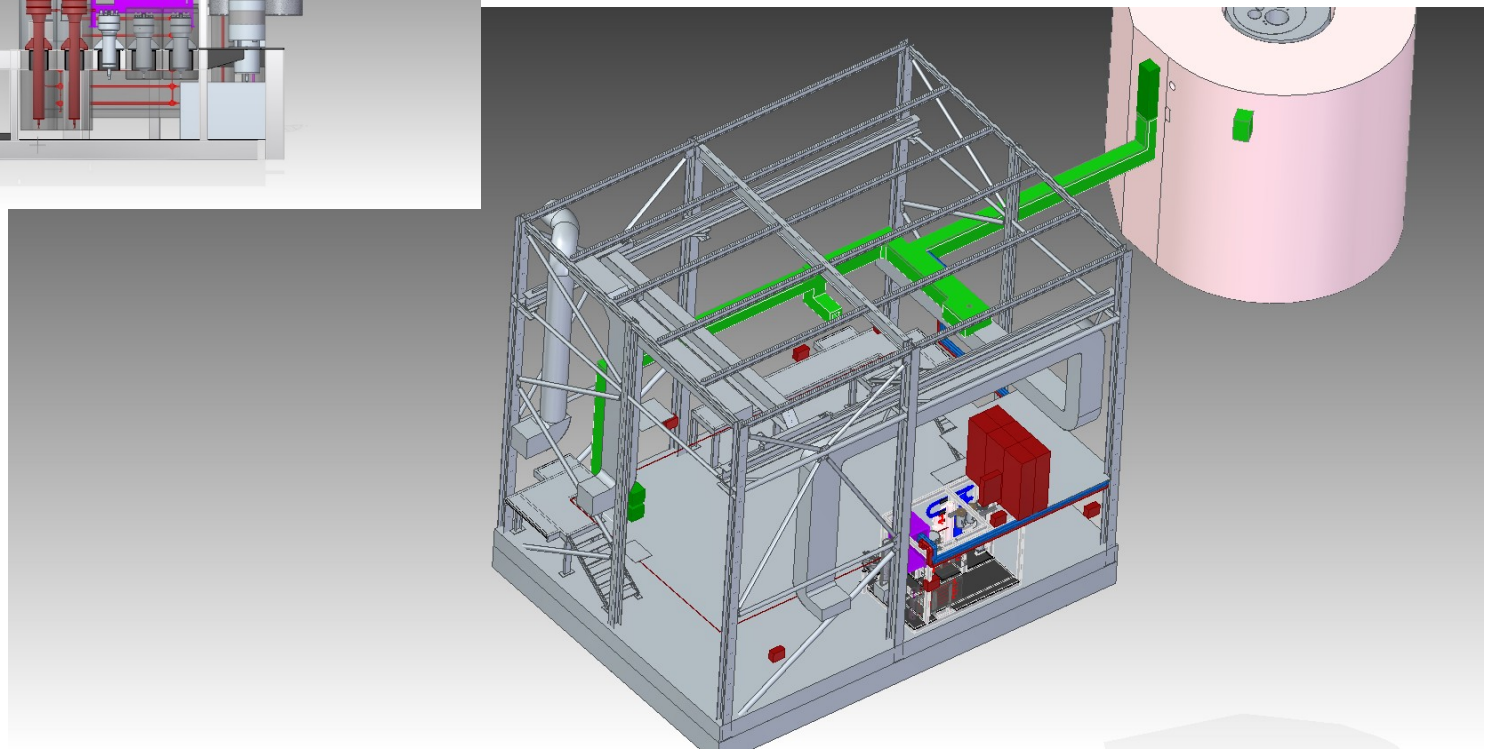
High Temperature Helium Loop



Operating parameters
Temperature: 900 °C
Pressure: 7 MPa
Flux rate: 38 kg He/h
In-pile operation



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CO2 Loop

- Research and development of heat transfer
- Material tests
- Corrosion and errosion experiments

Maximum temperature	550 ˚C
Low pressurepart:	7 - 12,5 MPa
High pressure part:	up to 25 MPa
Flow rate:	0,35 kg/s
Power:	120 kW

Laboratory of Neutron Sources / Fission

Laboratory of neutron and gama spectrometry

Focus: Mixed neutron and gama fields :
Spectrometry: En = 0,06-20MeV, Eg = 0,1 -10 MeV.
Sources: **CF-252**, AmBe

Hydrogen technologies

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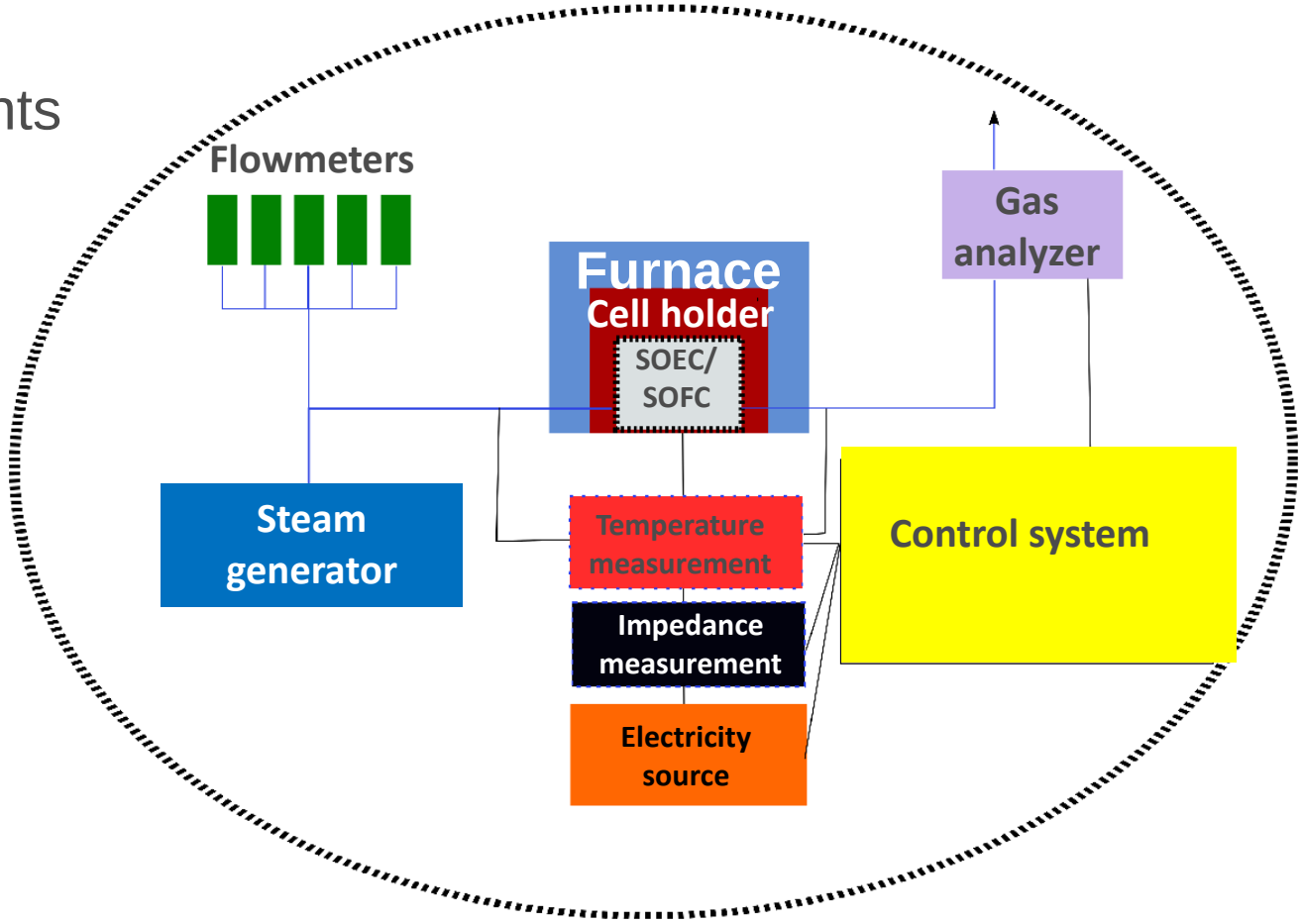
Facility for Testing of High Temperature Fuel Cells

- **Tests:**
  - Power measurements
  - Polarization curves
  - Gas composition
  - Impedance
- **Long-term tests:**
  - SOEC/SOFC
  - Various flowrates, power, temperature



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Motivation for high-temperature electrolysis

- Effective hydrogen production
- CO_2-free hydrogen production
- Balance of supply and demand

- Reduction of required electrical energy

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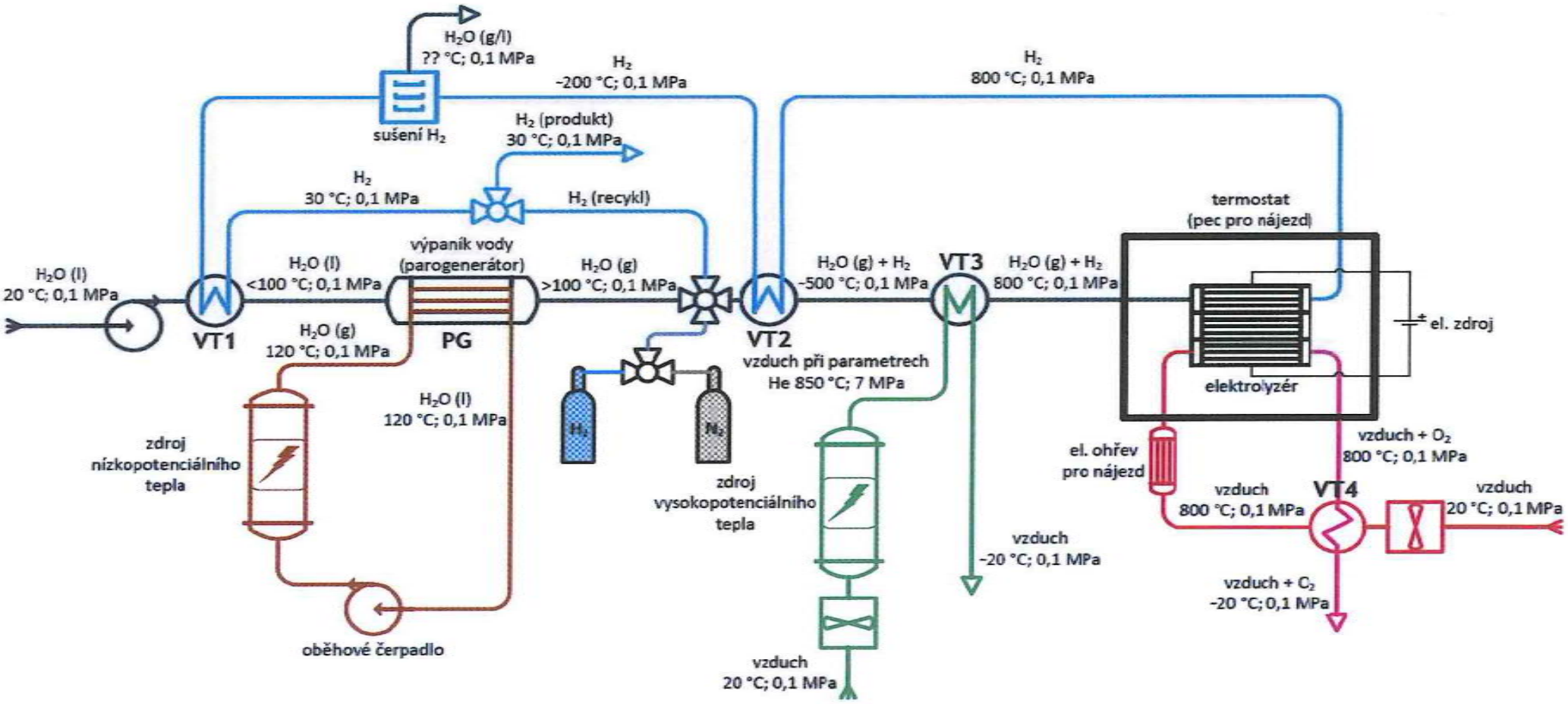
High Temperature Electrolysis Device



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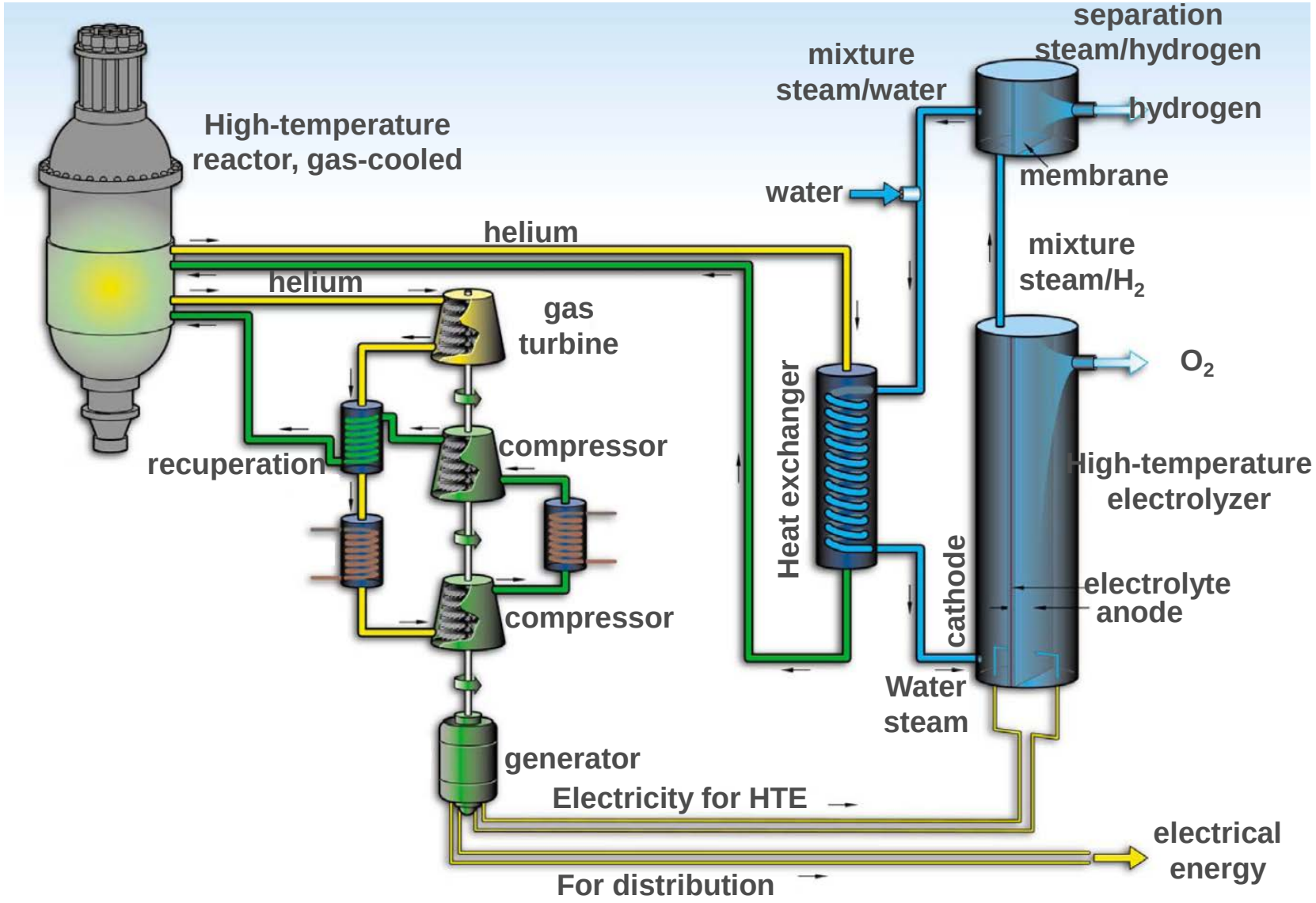
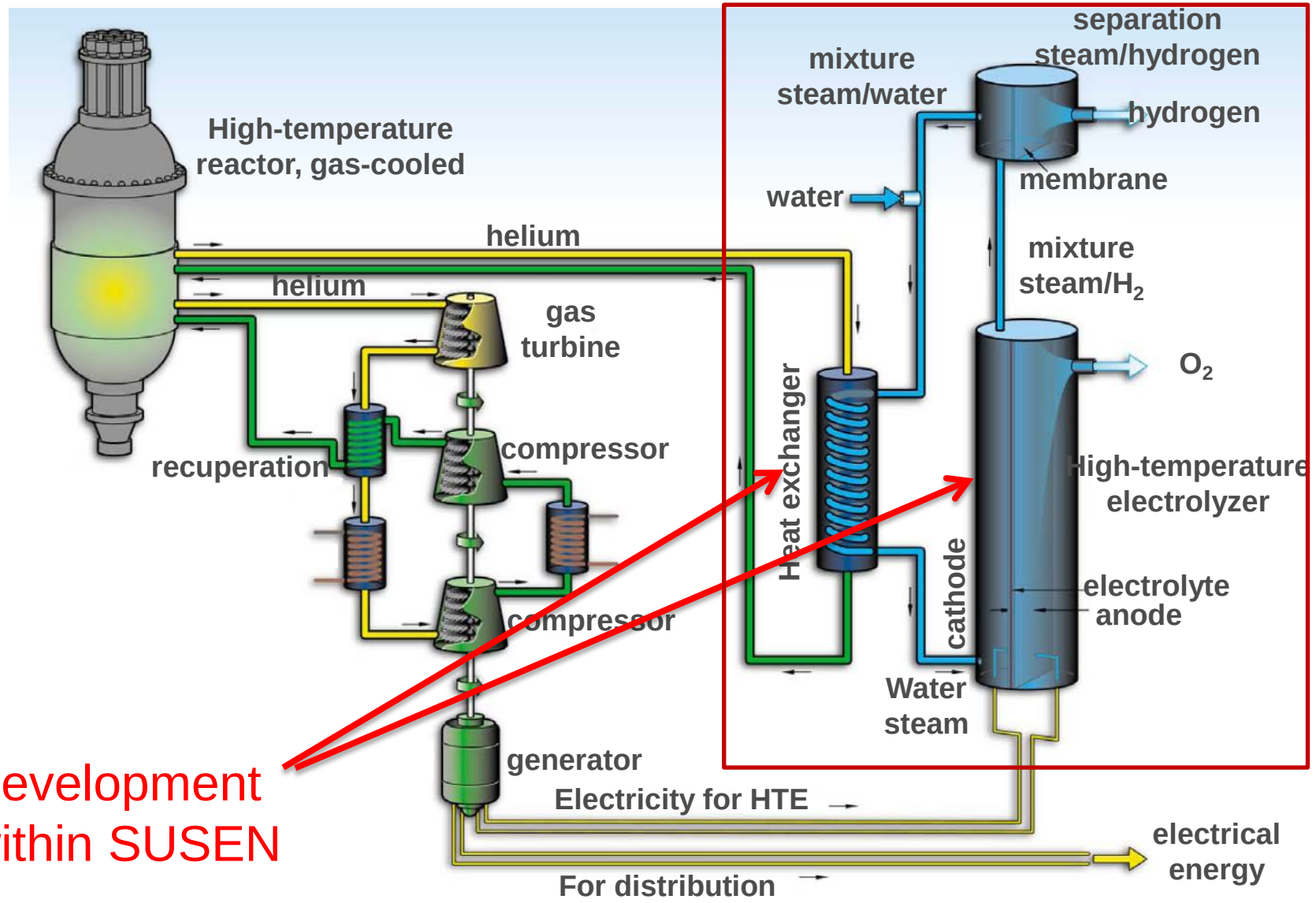
High-temperature electrolysis - motivation



Source: J.E. O'Brien et al., Int. J. of Hydrogen Energy (2010) p. 4808–4819

High-temperature electrolysis - motivation



Development
within SUSEN

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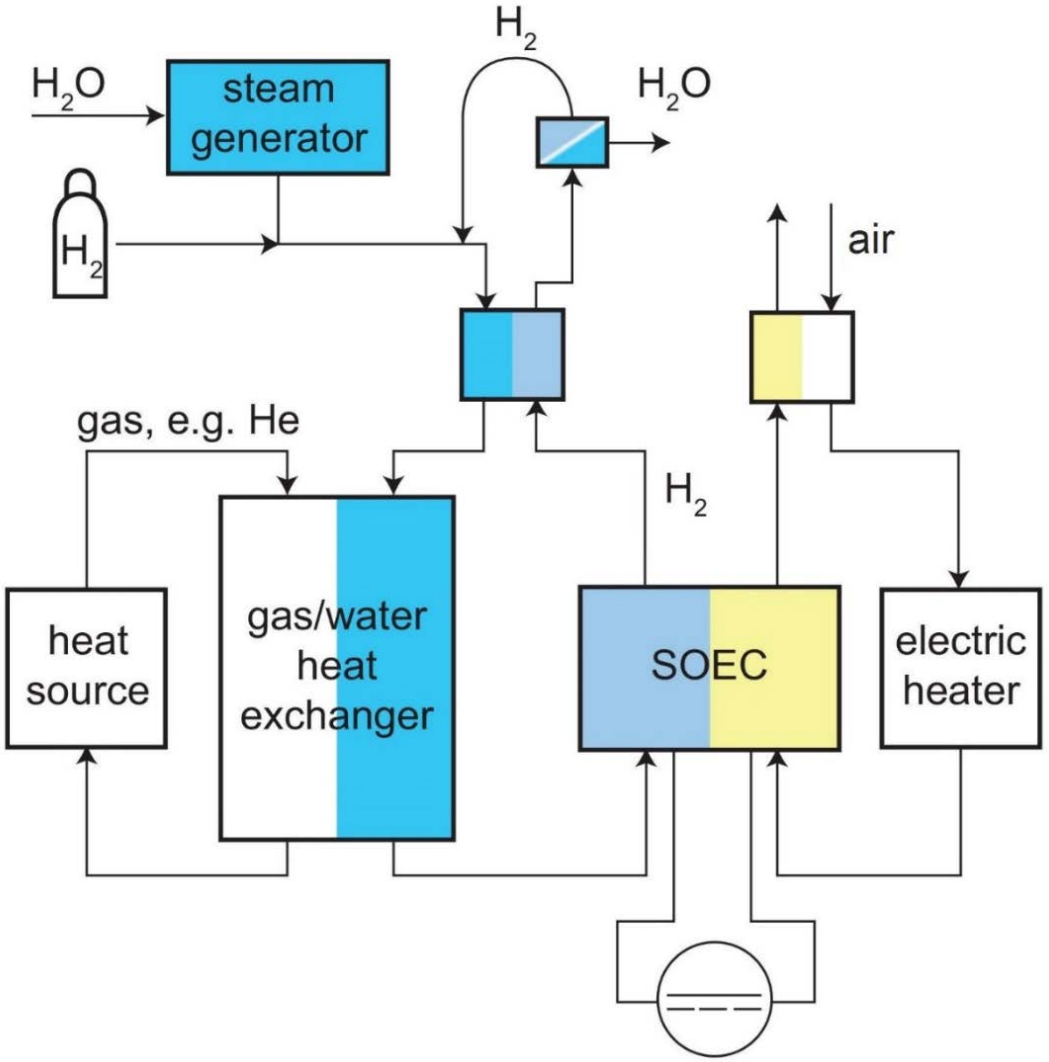
High-temperature electrolysis - realization

Experimental loop for hydrogen generation



High-temperature electrolysis - realization

- **High-temperature electrolysis with heat recuperation**
  - High-temperature source simulated by heating unit
  - Specialization: long-term degradation (approx. 1000 h)
- **Equipment for single cell testing**
  - Necessary for understanding behavior of cells
  - Necessary for better interpretation of the degradation results
- **Equipment for cell production**
  - Necessary for optimalisation of cells
  - Possibility of testing different types of cells

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Research outlook

- **Medium-term objectives**
  - results for hydrogen production via co-generation

- **Long-term objectives**
  - long-term focus on life-time degradation
  - especially accelerated testing methods
  - open access for research institutions to all facilities

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Conclusions

- **Building up infrastructure for high-temperature electrolysis**
- **Useable also for high-temperature fuel cells**
- **Key aspects**
  - hydrogen production via co-generation
  - investigations in cell degradation
- **Open for collaboration**

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Thank you for your attention!

Looking forward to collaboration in

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

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