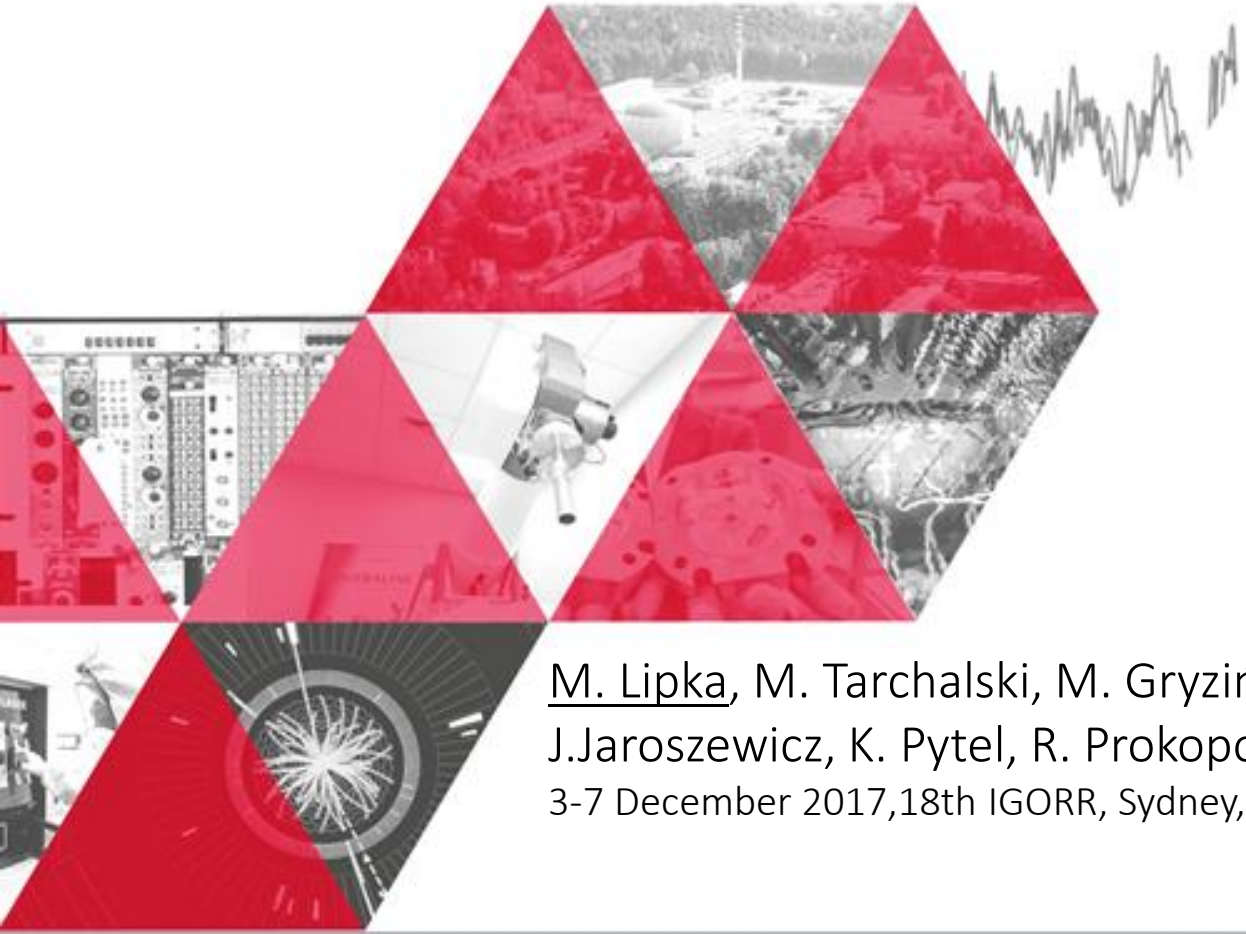
MARIA reactor safety improvements and research capacity improvements



NATIONAL CENTRE FOR NUCLEAR RESEARCH
ŚWIERK
POLAND

M. Lipka, M. Tarchalski, M. Gryziński, G. Krzysztoszek, J.Jaroszewicz, K. Pytel, R. Prokopowicz,

3-7 December 2017,18th IGORR, Sydney, Australia

Outline

- National Centre for Nuclear Research
- MARIA Research Reactor overwiew
- MARIA regular operation
- Modernization of fuel channels' power measurement system
- New research capabilities:
  - Neutron beams research
  - Biomedical research
  - 14 MeV irradiation
  - Irradiation inside fuel elements in fast spectrum
- Research on beryllium blocks poisoning
- New measurements in the reactor core
- Ageing management

National Centre for Nuclear Research

History of NCBJ

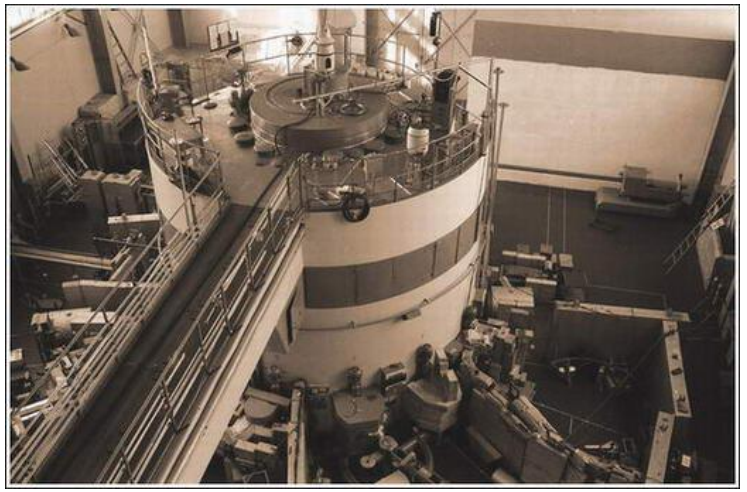
Institute of Nuclear Research (IBJ) was called in existence on June 4, 1955.

IBJ was split in 1982 into three smaller research institutions. Almost 30 years later two of them (IEA and IPJ) were merged to form National Centre for Nuclear Research (NCBJ).

NCBJ is the largest research Institute in Poland operating a nuclear reactor (MARIA reactor). Currently NCBJ is hiring over 1000 employees. The fundamental research includes experimental and theoretical efforts to discover the most fundamental laws of nature – not only nuclear.

EWA research reactor

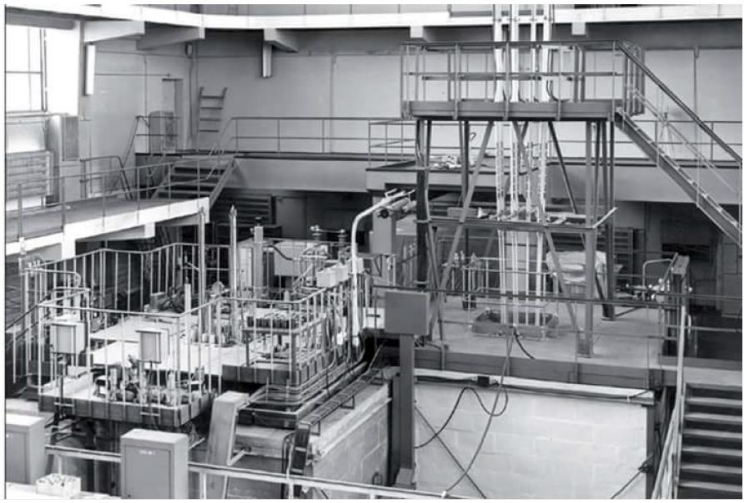
Apart from the MARIA research reactor, in years 1958-1995 the EWA research reactor was also operated at the Institute of Nuclear Research (later – the Institute of Atomic Energy). Initially, the reactor's thermal power was 2 MWth, however it was increased to 10 MWth.



The process of reactor decommissioning was started in 1997 and in 2002 the so called "end of phase two" was achieved. That means that all nuclear fuel and all irradiated structures and components, which have activity levels hazardous from the radiological protection viewpoint, were removed from the reactor. Further works were suspended and as for now it is not planned to continue the decommissioning process up to the state of "green grass" (denoted as phase three) due to the potential use of the reactor biological shield as a dry storage for spent fuel from the MARIA reactor.

ANNA, AGATA, MARYLA…

ANNA and MARYLA where first Polish zero power nuclear reactors individually developed by Polish engineers in 1963.



In 1973 AGATA reactor was built as MARIA reactor prototype and for analysis purposes before starting MARIA reactor.

All above facilities were already decommissioned up to "end of phase two".

POLATOM Radioisotope Centre

Polish manufacturer and distributor of the isotope used in medicine, science, industry and environmental protection.

They concern the nature of the application and radio-pharmation, chemical and nuclear technology and scientific disciplines such as radiochemistry, biochemistry, immunology.
The result of research is developing their own technology, implemented by NCBJ OR POLATOM

POLATOM

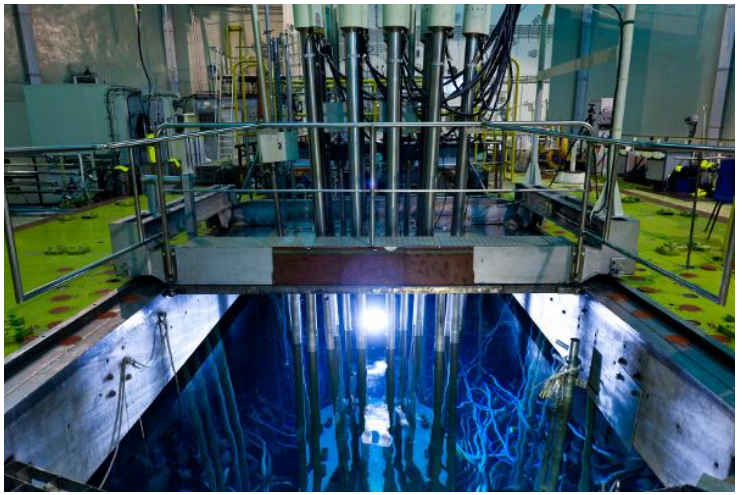
MARIA research reactor

- The high flux research reactor MARIA is a water and beryllium moderated reactor of 30 MWth nominal power level.
- Pool type reactor with pressurized fuel channels containing concentric tube assemblies of fuel elements.
- Fuel channels are situated in matrix containing beryllium blocks surrounded by graphite reflector.

nominal power	30 MWth
U-235 enrichment	< 20 %
thermal neutron flux density	$3 \cdot 10^{14}$ n/cm^{2}s
fast neutron flux density	$3 \cdot 10^{14}$ n/cm^{2}s
moderator	H_2O, beryllium
reflector	graphite in Al
cooling system	channels in pool

MARIA research reactor

The MARIA reactor has been in operation since December 1974 at the Institute for Nuclear Research in Świerk. In years 1985-1993 the reactor operation was stopped for its essential modernization. Since 2011 the reactor has been operated by the National Centre for Nuclear Research.

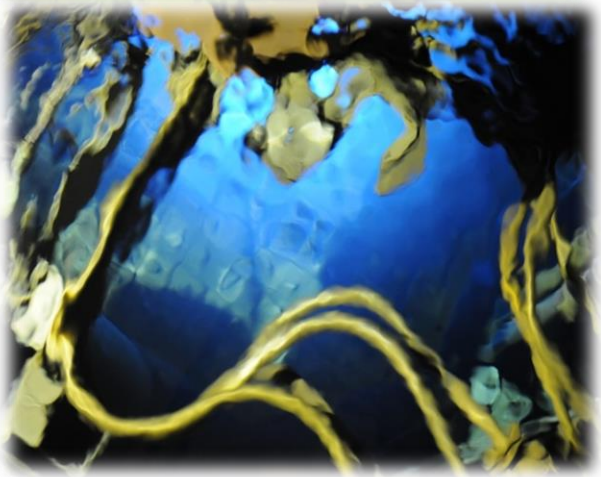


From April 1999 to June 2002 the reactor core was converted from highly enriched uranium (80%) to highly enriched uranium fuel (36%). In the years 2012-2014 the reactor core was further converted to low-enriched fuel LEU (concentration of U235 is below 20%). At present the fuel is 19.75% enriched Uranium 235 enclosed in Aluminium cladding.

MARIA research reactor

Neutron sources in MARIA research reactor

- High neutron flux research reactor
- Individually cooled fuel elements
- >4800 hours operation per year
- Radioisotope production 600 TBq/year
- ^{99}Mo production 6000 TBq/year
- **34 years of operation (**1974-1985, 1993-2004, 2005-…)
- Current operation licence 2015-2025



MARIA reactor overview

Gate for vehicles

Researchers and offices building

Reactor service personnel building

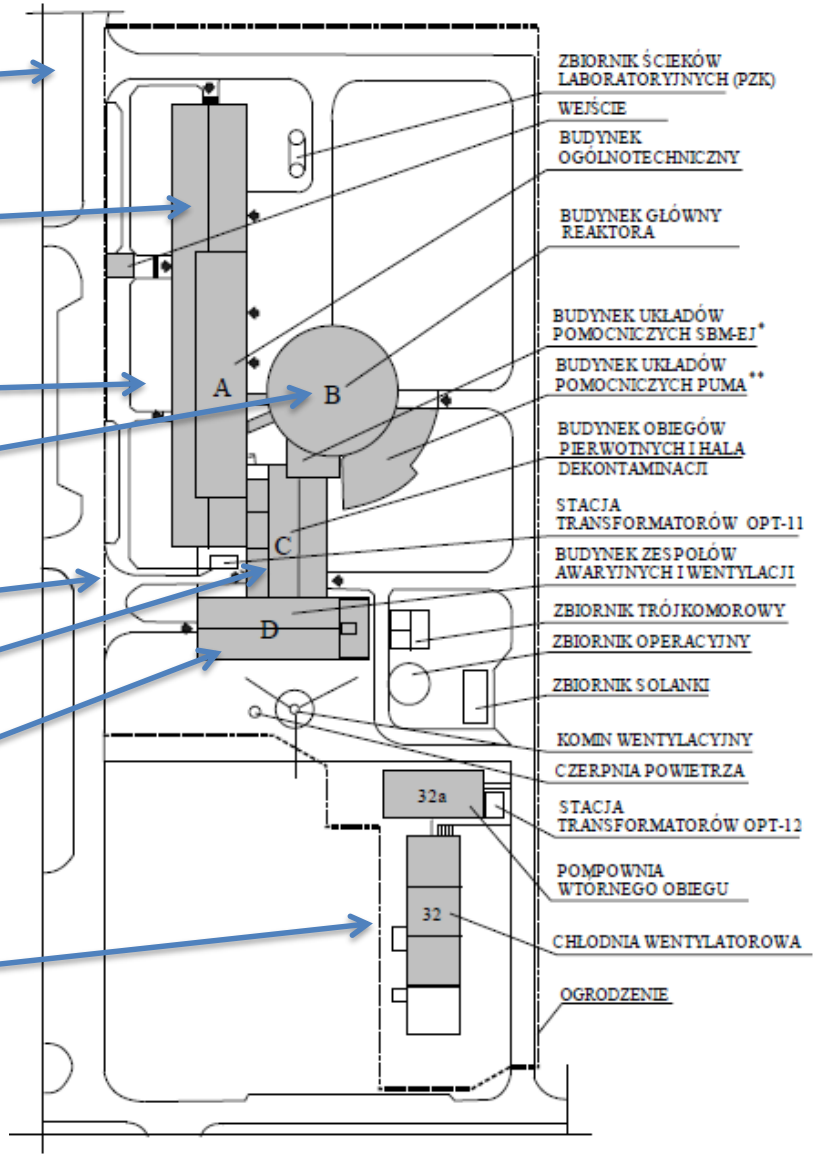
Reactor building

Gate for vehicles

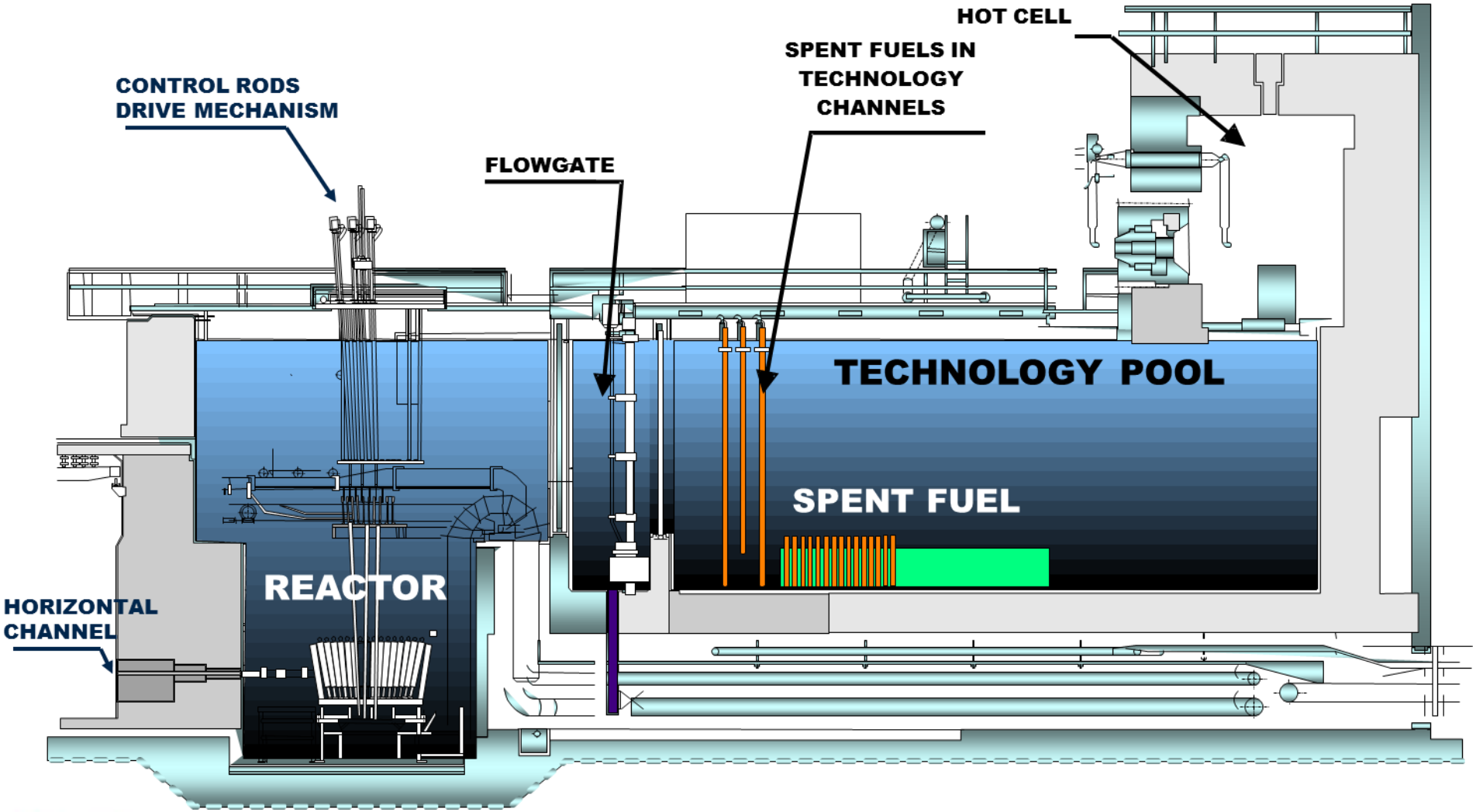
Decontamination hall
Cooling circuit pumps

Diesel generators

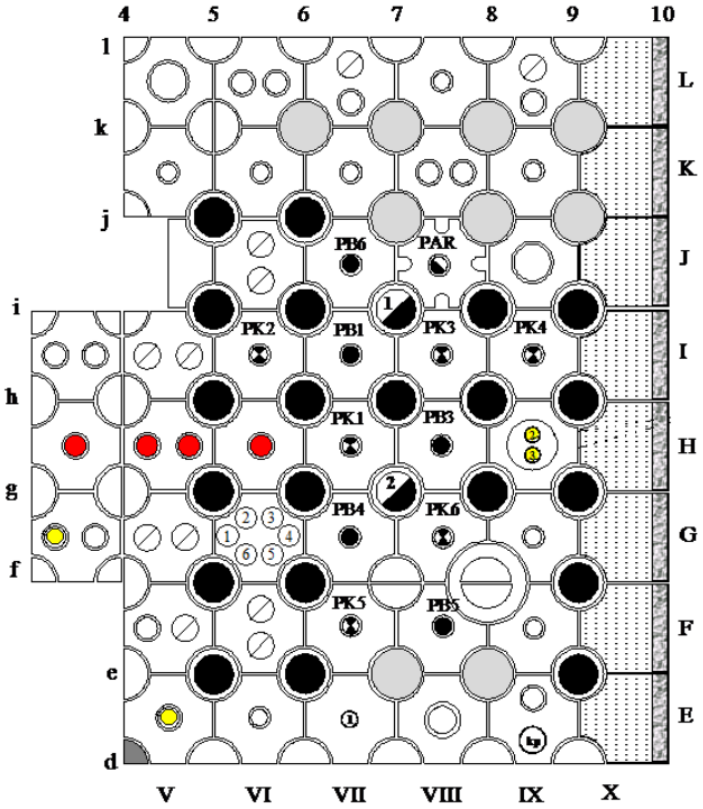
Cooling towers

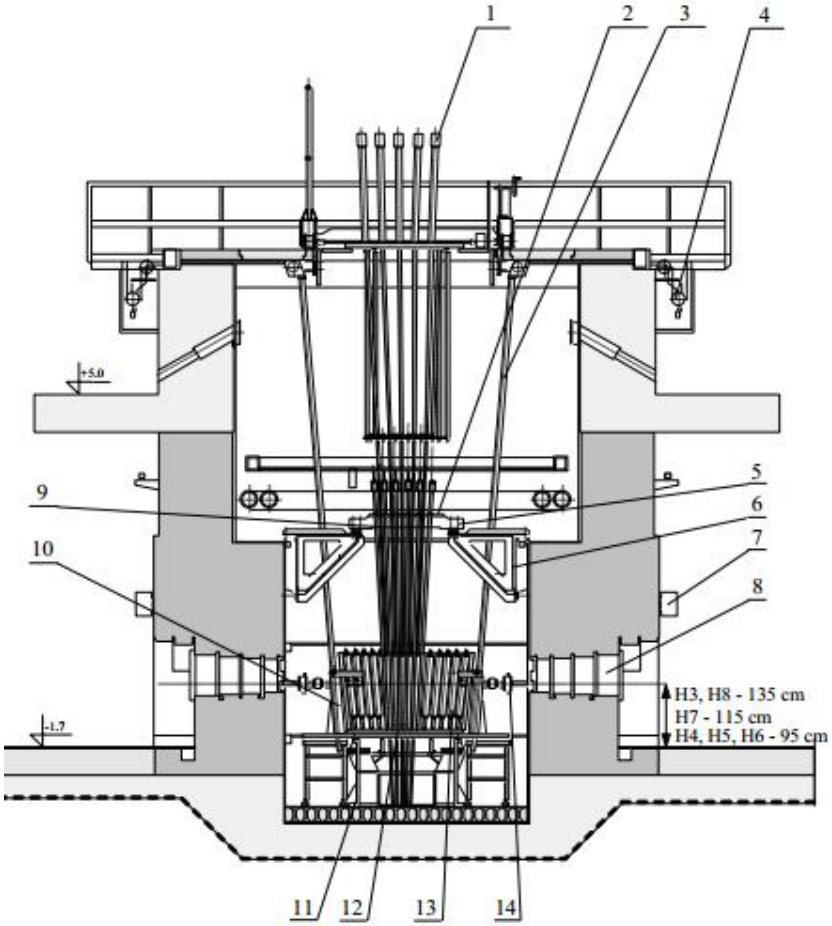


MARIA reactor vertical cross section

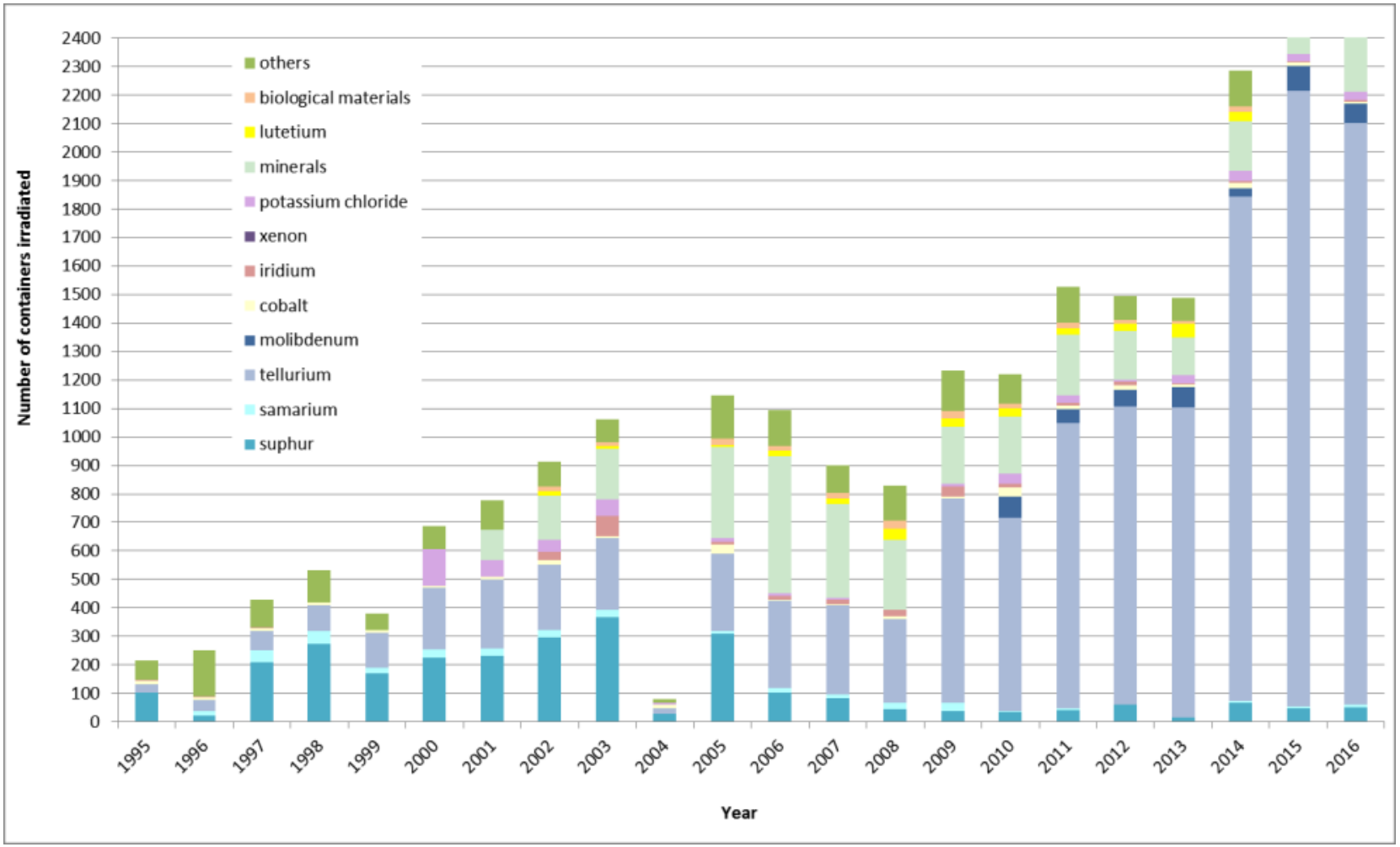


MARIA reactor core





Target irradiations in MARIA reactor



MARIA reactor upgrades

- 1985-1991 modernization of reactor equipment and technology
- 1996-2003 1st conversion from 80% to 36% U-235
- 2010-2014 2nd conversion from 36% to <20% U-235
- Replacement of fuel channels cooling circuits's pumps
- Replacement of emergency power inverters

MARIA reactor upgrades

- Renovation of the reactor hall building
- Renovation of the buildings and rooms accompanying MARIA reactor
- Fuel elements power measurement system replacement
- Horizontal channels instrumentation replacement (in progress)
- Replacement of diesel generators
- Cooling towers modernisation (planned)
- Replacement of second cooling circuit (planned)

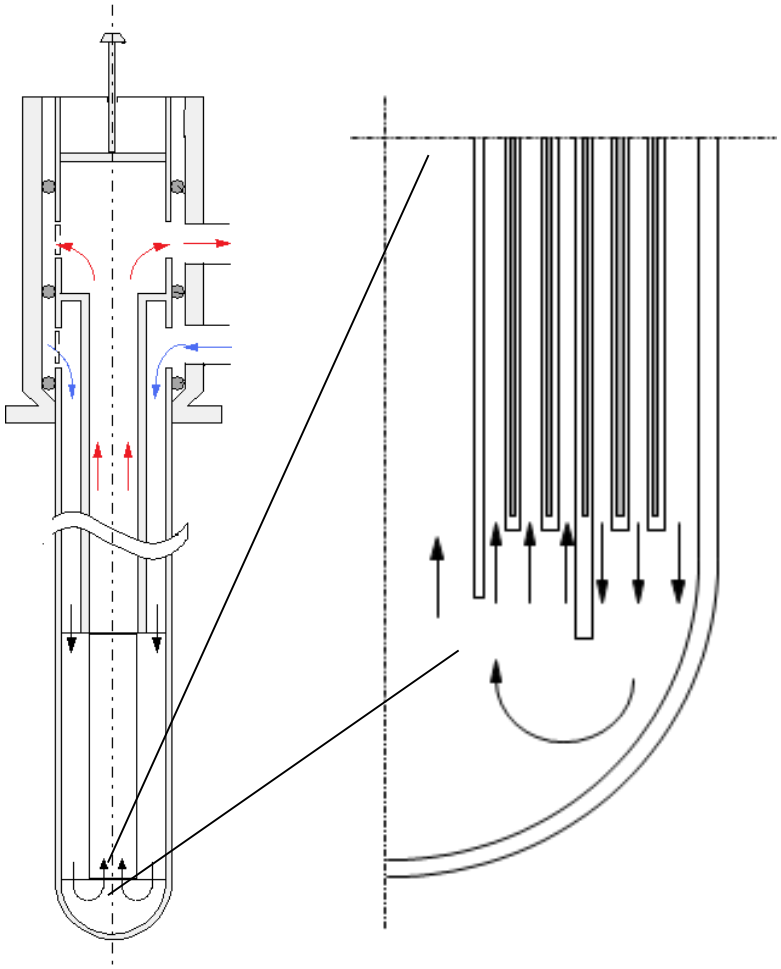
MARIA reactor upgrades

- New instruments dedicated to neutron studies delivered by Helmholtz-Zentrum
- Reactor laboratory for nuclear and biomedical research
- Fast neutrons irradiation channel with 14 MeV neutron flux > $1 \cdot 10^{9}$ $n \cdot cm^{-2} s^{-1}$
- Design of new irradiation probe for material modification in sophisticated conditions
- Performing irradiations inside fuel elements with fast neutrons flux ~1×10^{14} $n \cdot cm^{-2} s^{-1}$,

MARIA reactor upgrades

- New methods for radioisotopes production
- High gamma flux irradiation
- Testing New types of fuel elements
- Regular Programme of beryllium blocks' replacing
- Research on beryllium blocks poisoning
- Nuclear instrumentation and measurement methods development
- Development of nuclear calculation tools

Modernization of fuel element's power measurement system



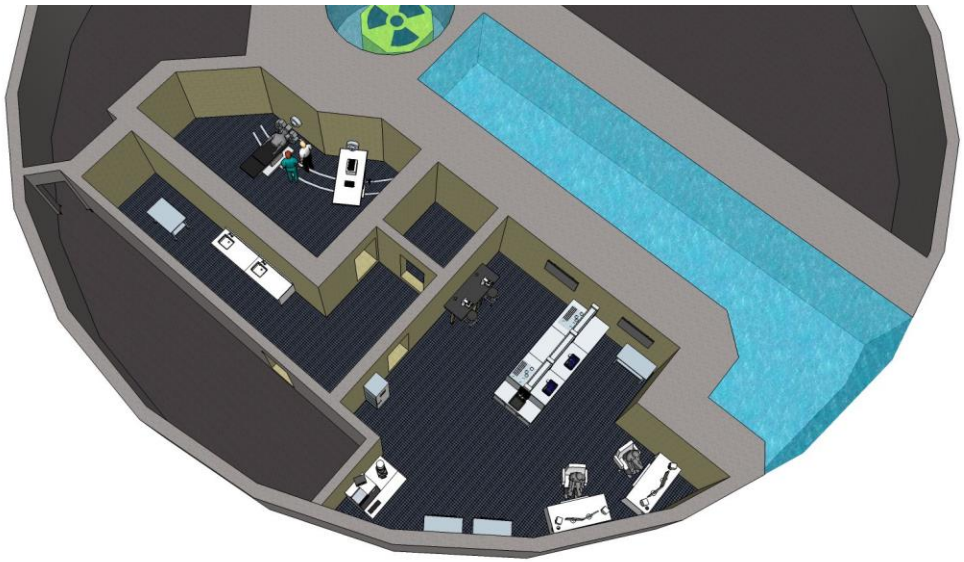
- Individual power measurement in each fuel channel
- Four new thermometers in each fuel channel
- Connected to the reactor safety system
- SIL2 and NEUR23 certified

Modern instruments for neutron research

- Collaboration between NCBJ and Helmholtz-Zentrum Berlin
- Wide-angle diffractometer
- Diffractrometer for monocrystals
- Difrfractrometer for 3D maps of crystals
- Cryogenic setup ?

Biomedical research

- Epithermal neutron beam ~10^9 n·cm^{-2}s^{-1}
- Neobor
- Boron neutron capture therapy (BNCT)
- 2018



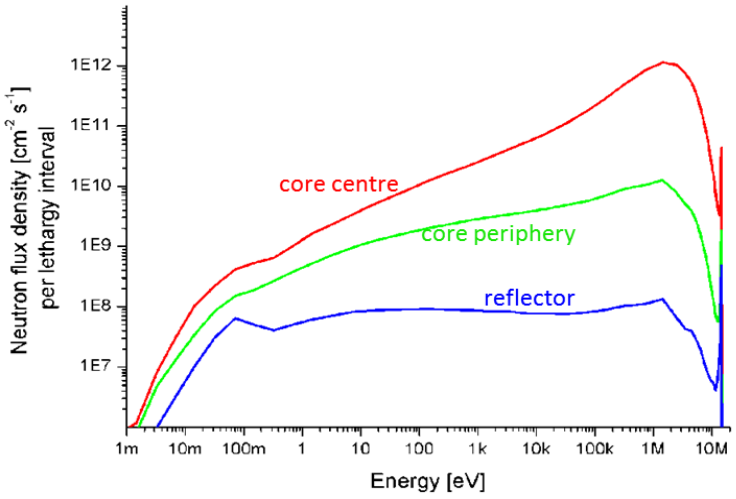
14 MeV neutron converter

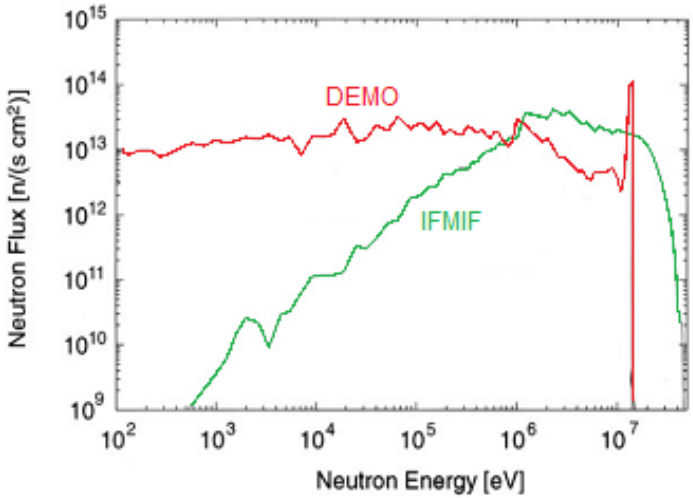
- Neutron flux~10^9 n·cm^{-2}s^{-1}
- One of the most intense 14 MeV neutron source in the world
- Material testing for IV gen reactors

$$^6Li + n_{th} \rightarrow t + {}^4He$$

$$t + D \rightarrow {}^4He + n_{14MeV}$$

$$t + {}^6Li \rightarrow {}^8Be + n_{14MeV}$$





Irradiation inside MR-2 fuel element

- Normal irradiation conditions:
  - thermal neutron flux densitym up to $3 \cdot 10^{14}$ n·cm^{-2} s^{-1}
  - fast neutron flux density up to $2 \cdot 10^{13}$ n·cm^{-2} s^{-1}
- Some positions in the core:
  - thermal neutron flux is reduced to $3.4 \cdot 10^{10}$ n·cm^{-2} s^{-1}
  - fast neutron flux density is up to $1.7 \cdot 10^{12}$ n·cm^{-2} s^{-1}
- Inside MR-2 fuel (Ø34 mm)
  - Expcected fast neutron flux density $1 \cdot 10^{14}$ n·cm^{-2}s^{-1}

Research on beryllium blocks poisoning

- Model of poison generation
- Experimental verification
- APOLLO2, CRONOS2, TRIPOLI 4
- Development of a computational system

$$^{9}\mathrm{Be}(n,\alpha) \rightarrow {}^{6}\mathrm{He}$$

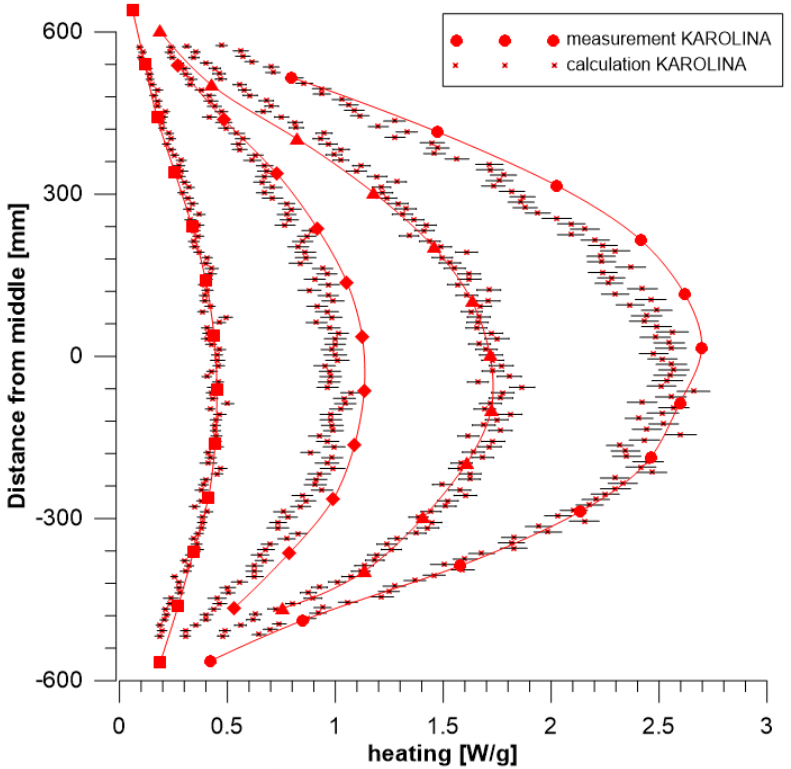
$$^{6}\mathrm{He} \xrightarrow{\beta^-} {}^{6}\mathrm{Li}, \quad T_{1/2} = 0.8\,\mathrm{sec}$$

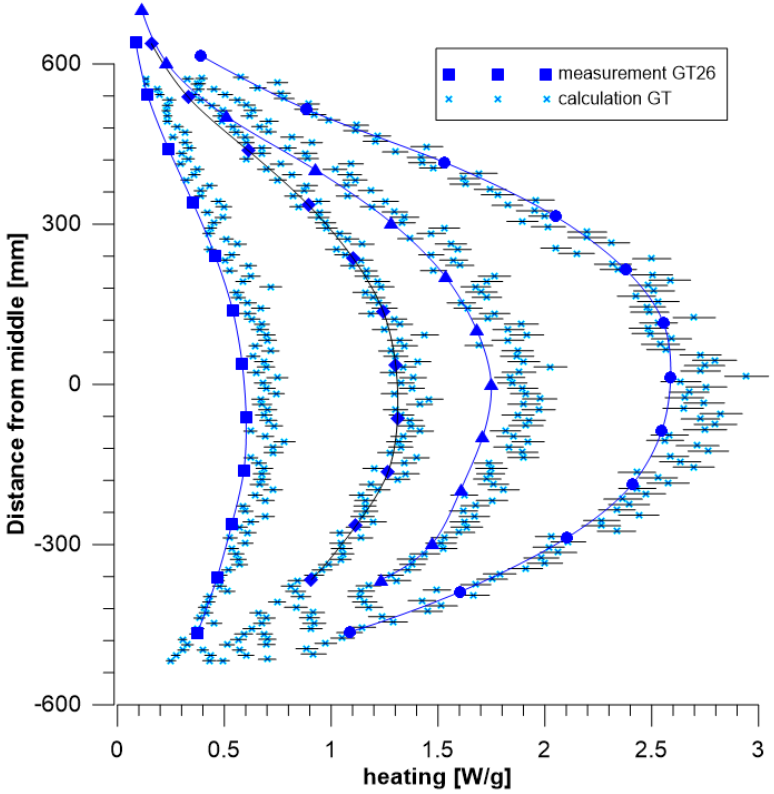
$$^{6}\mathrm{Li}(n,\alpha) \rightarrow {}^{3}\mathrm{H}$$

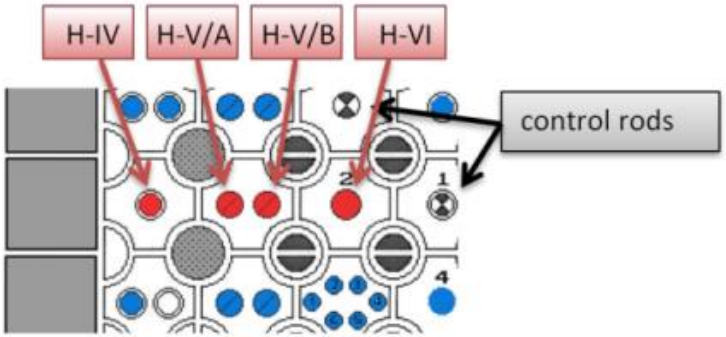
$$^{3}\mathrm{H} \xrightarrow{\beta^-} {}^{3}\mathrm{He}, \quad T_{1/2} = 12.33\,\mathrm{yr}$$

$$^{3}\mathrm{He}(n,p) \rightarrow {}^{3}\mathrm{H}.$$

Gamma heat measurement







	C/E
AVERAGE KAROLINA	0.95 +/-0.03
AVERAGE GT	1.09 +/-0.04

Ageing management

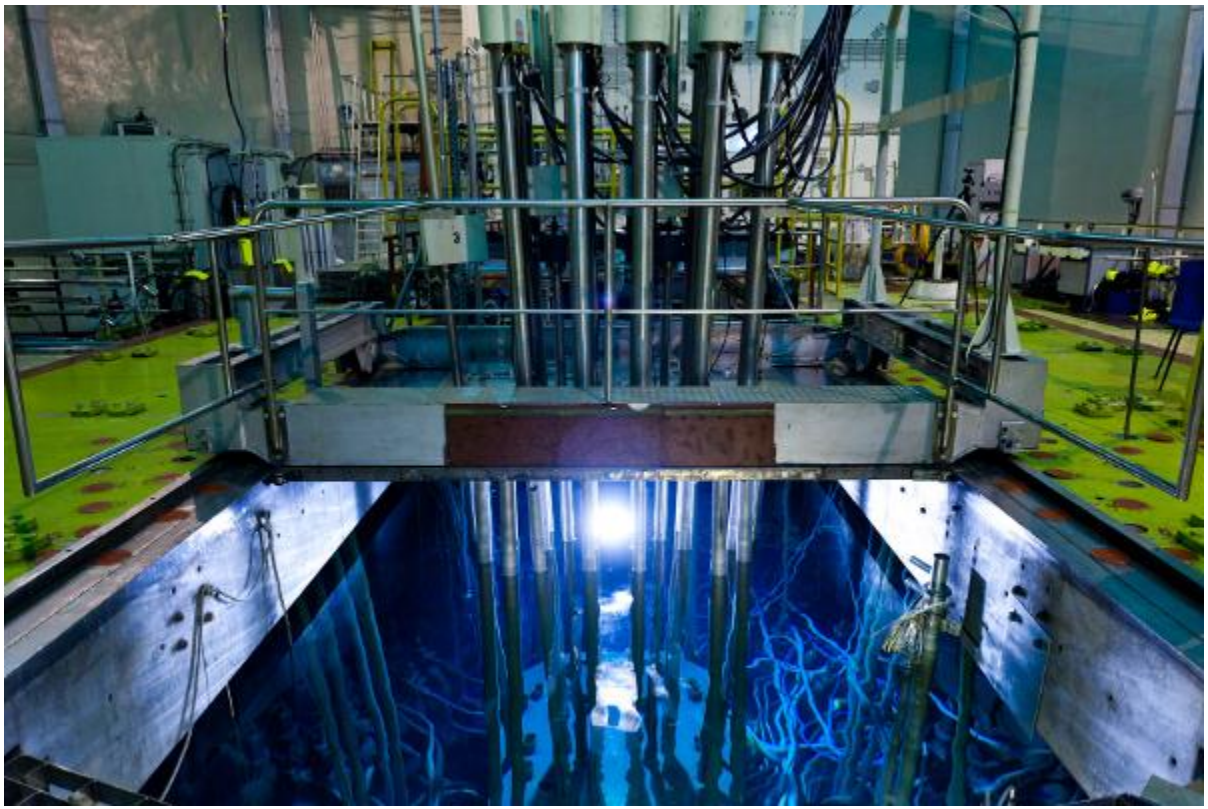
Every two years MARIA reactor ageing comission is performing analysis of the operation and safety compotents this is:

- Reactor core
- Reactor and technology pool
- Control systems
- Reactor hall
- Cooling circuits
- Electrical circuits
- Ventilation system
- Dosimetry control system
- Infrastructure

Management of Research Reactor Ageing – IAEA, ***TECDOC-792***
Ageing Management for Research Reactors – IAEA, Specific Safety Guide No. ***SSG-10***
Maintenance, Periodic Testing and Inspection of Research Reactors – Safety Guide No. ***NS-G-4.2***

Young personnel in MARIA reactor

Well trained and experienced young personnel of MARIA reactor is already implementing new rules of security and safety.



Thank you for attention

m.tarchalski@ncbj.gov.pl