Research Neutron Sources Help Develop S/AMR And Train New Experts

(Europe Nuclear Energy & SMR Conference (ENES2025), Prague, Czech Republic, October 14 - 15 2025)

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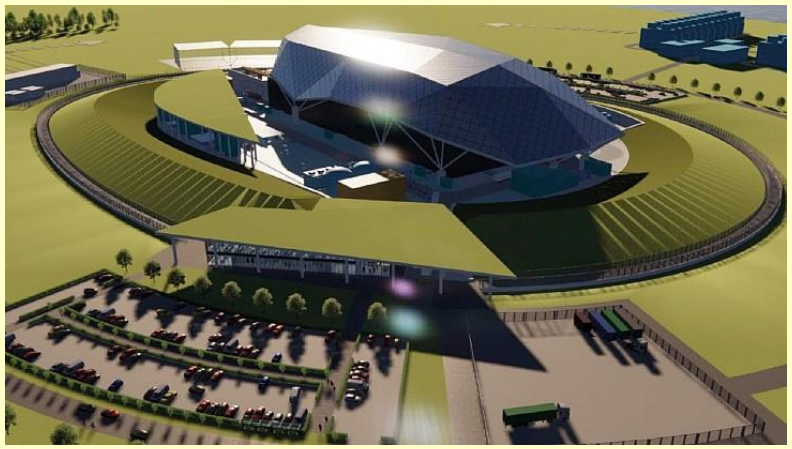
High school excursions in Řež

Nuclear renaissance in the Czech Republic

1) Czech Republic´s decision to use a low-emission mix based on nuclear and renewable sources
2) The two existing nuclear power plants (Dukovany and Temelín) will be operated for the longest time
3) The construction of two large APR1000 reactors (Korean KHNP) in Dukovany has been decided, the construction of two identical reactors in Temelin is very likely
4) Work is underway to use heat from Temelín and Dukvany in district heating
5) ČEZ company chose Rolls-Royce reactors as the preferred type of SMR, it wants to replace coal-fired cogeneration power plants and heating plants
6) ČEZ company wants to develop, produce and use SMR, the Czech Republic is industrial country, and the development of industries related to nuclear energy is very promising for it
7) A large number of young professionals will be needed for future development

Dukovany currently has fur VVER units

Two new APR1000 units are being prepared here

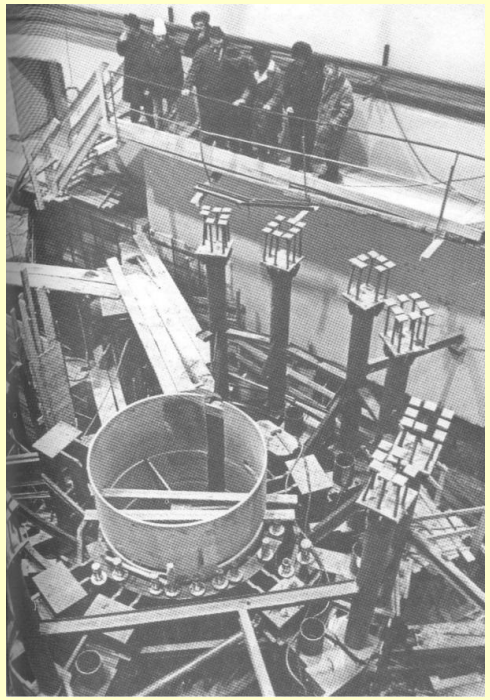


Czech MMR reacttors will be Rolls-Royce

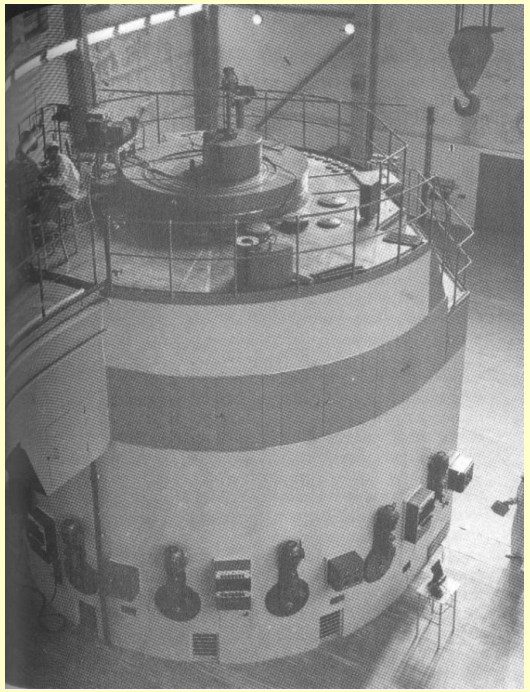
Continuity in the nuclear education of professionals

1) This year we celebrate the seventieth anniversary of nuclear science in the Czech Republic: Foundation of the Nuclear Physics Institute in Řež and Faculty of Nuclear and Physical Engineering of CTU
2) The first research reactor VVR-S was launched in Řež institute in 1957 (cooperation with Soviet union)
3) There are now two main institutions on the Řež campus: UJV with its subsidiary CVŘ (CEZ company) with two research reactors and Nuclear Physics Institute of CAS with accelerator based neutron sources
4) Currently, nuclear education is focused not only on FNSPE CTU, but also on other faculties of CTU, TU Brno and West Bohemian University Plzeň

The nuclear complex in Řež began to be bulit in 1955



Research reactor VVR-S under construction



Just after reaching criticality

Czechoslovakia was the country that developed its own power reactor (in cooperation with the Soviet Union).

Reactor KS-150 as unit Jaslovské Bohunice A1 was heavy water reactor cooled by carbon dioxide

Reactor did not reach commercial use, but it raised generations of Czech and Slovak experts

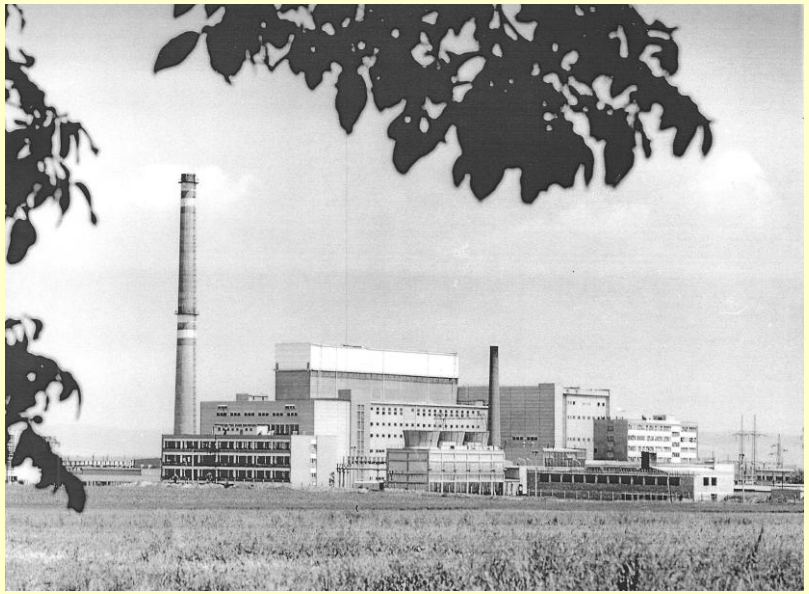
At that time, a heavy water research reactor was operating in Řež, which was converted to lightwater LR-0

Czechoslovakia began to use and produce Soviet VVER light water reactors

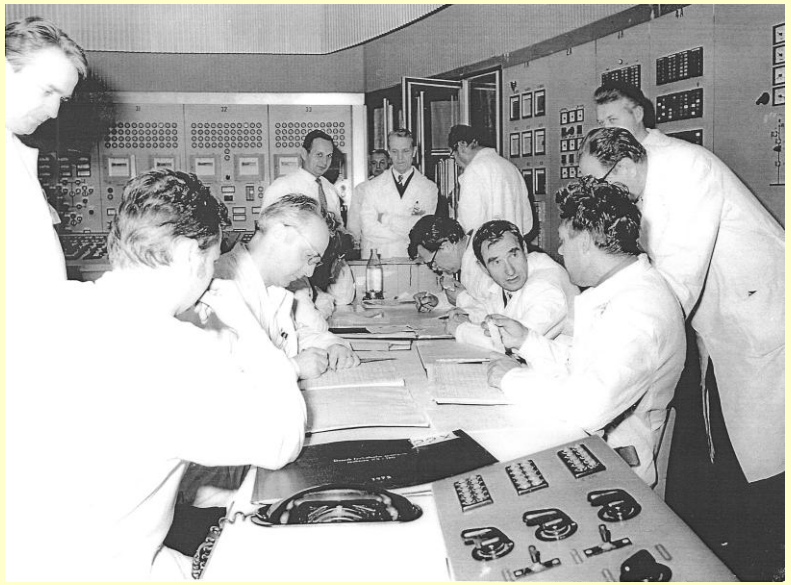
UJV and later its subsidiary CVŘ have always worked on the development of advanced nuclear technologies

For example, they are now working on liquid salt-cooled SMR Energy Well,

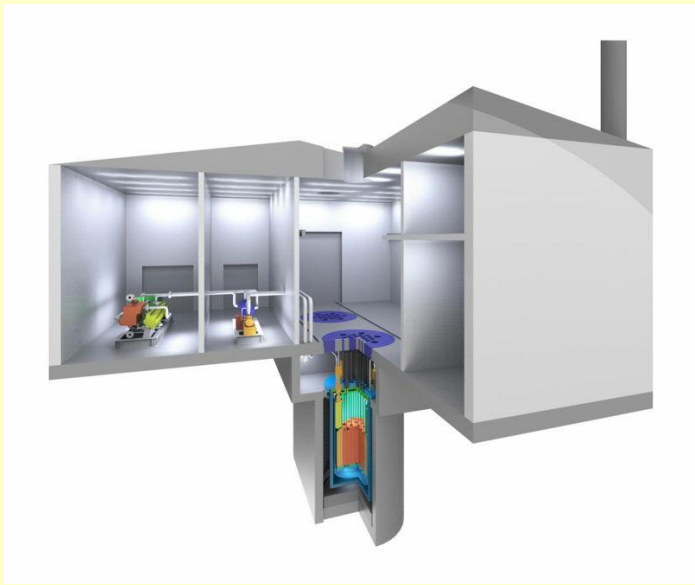
Czech universities and industry are working on several SMR concepts, these projects contribute to the education



Jaslovské Bohunice A1 unit



Block A1 control room



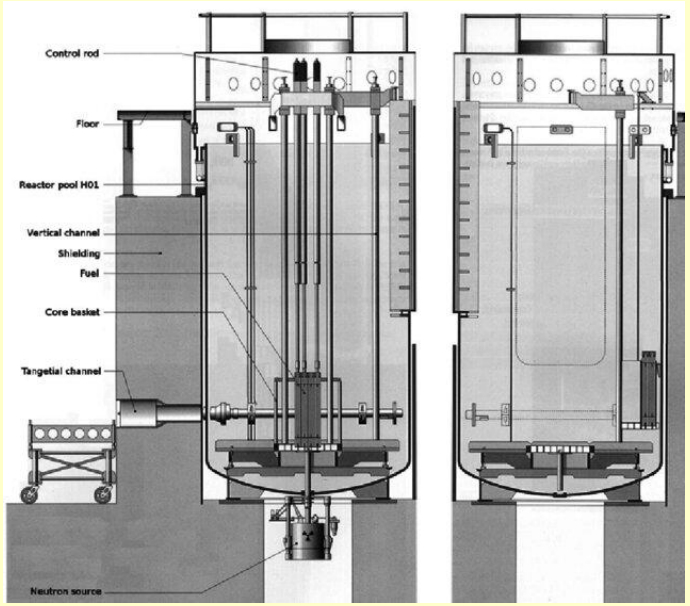
Energy Well advanced SMR (CVŘ)

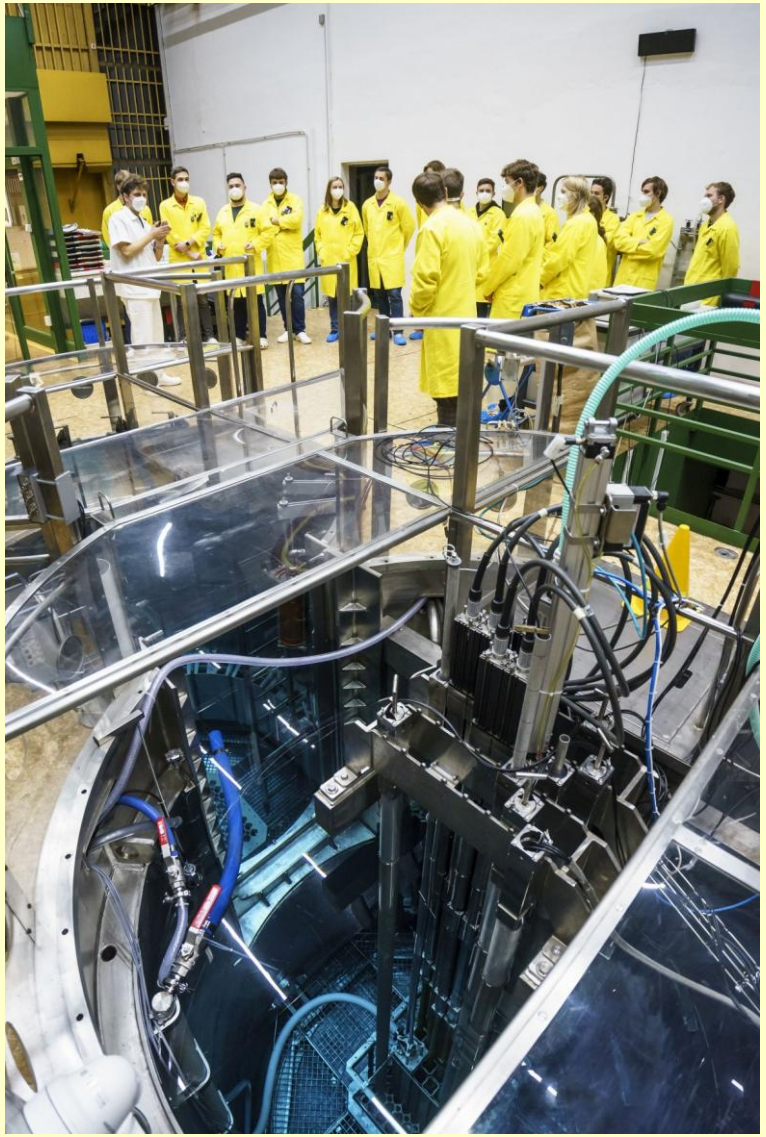
University reactors (VR-1 and VR-2 FNSPE)

The training reactor VR-1 (Sparrow) – lightwater, zero power research reactor with enriched uranium - the pol type arrangement assures quick and simple access to reactor core, easy insertion and extraction of various experimental samples and detectors

The idea of university reactor originated in 1960s, but it was only realized in the 1980s. The reactor went critical for the first time on 3rd December 1990.

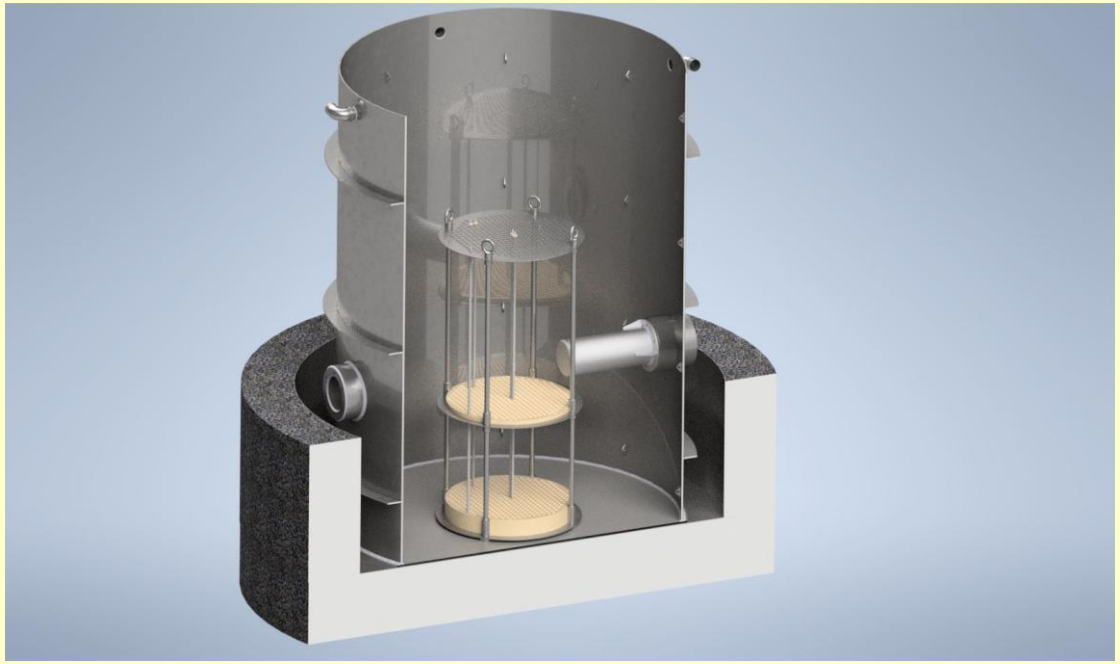
The project was joined by the companies Chemoprojekt Praha and ŠKODA JS. The Faculty participated in work coordination, core calculations, safety analysis and the design of reactor control equipment. It use fuel IRT-4M now

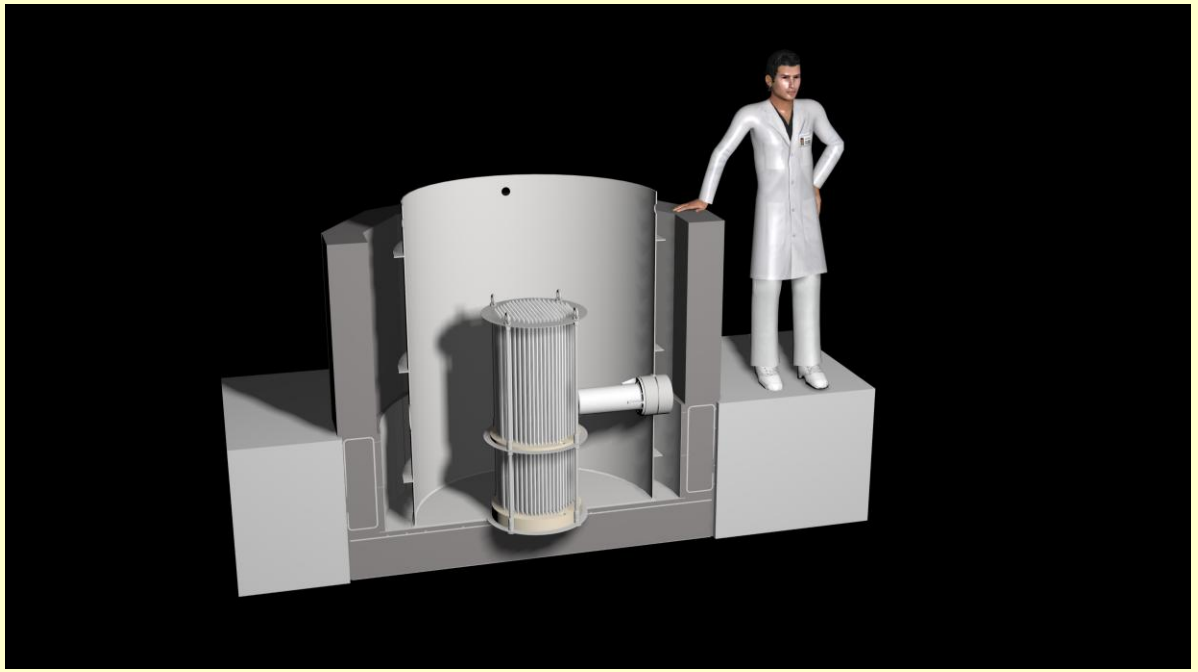




The training subcritical set-up VR-2 – new educational nuclear facility at the FNSPE, a subcritical assembly controlled by a neutro generator. Pool arrangement of reactor vessel with internal installation with fuel rods with 10 % enrichment forming the reactor core. The light watter is used for moderation. Commissioning was realized during 2023.

The d-d type of neutron generator is used to control reactor. The neutron generator makes possible to switch reactor on or off and also allows you to change the parameters of neutron generation, such as increasing or decreasing neutron emissions or operating in a continuous, resp. pulse mode.



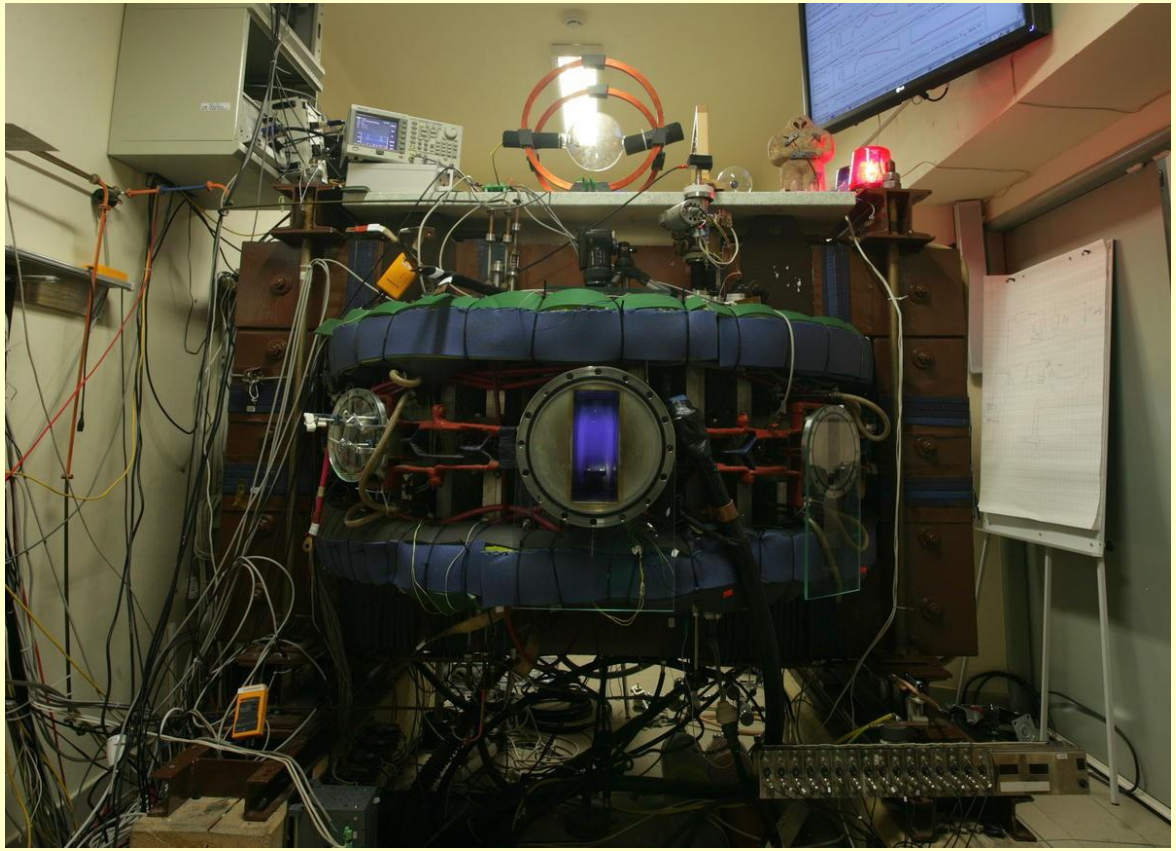


FNSPE CTU has also training small tokamak Golem

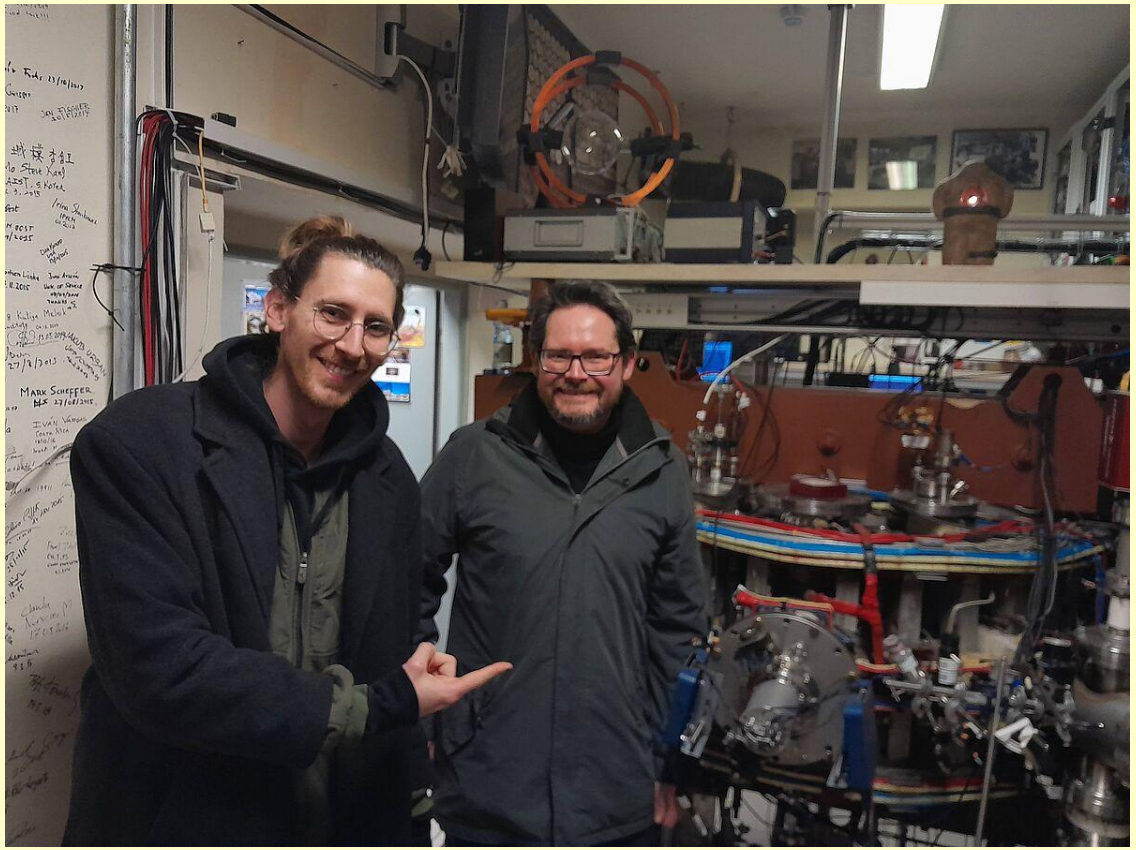
The faculty also has a very strong field focused on nuclear fusion. Here too, students can use the training facility

Tokamak Golem allows remote access even for students from abroad

The is great synergy between advanced fission and fusion technologies, for example both has intense neutron fluxes



Tokamak Golem



Visit from Greifswald University

Research reactors (CVŘ Řež)

Research reactor LVR-15 – is pool type reactor with heat power 10 MWt, created by rebuilding the VVR-S reactor, it currently uses fuel IRT-4M with an enrichment 19.75 %. It was put into standard service in the mid-1990s

It has horizontal and vertical channels for providing neutrons and loops

The LVR-15 reactor is used primarily for irradiation of materials, production of radiopharmaceuticals and experiments applications of neutron beams mainly for material studies.

Nuclear Physics Institute uses four horizontal thermal neutron channels for material science

Many students use this reactor for different type of studies

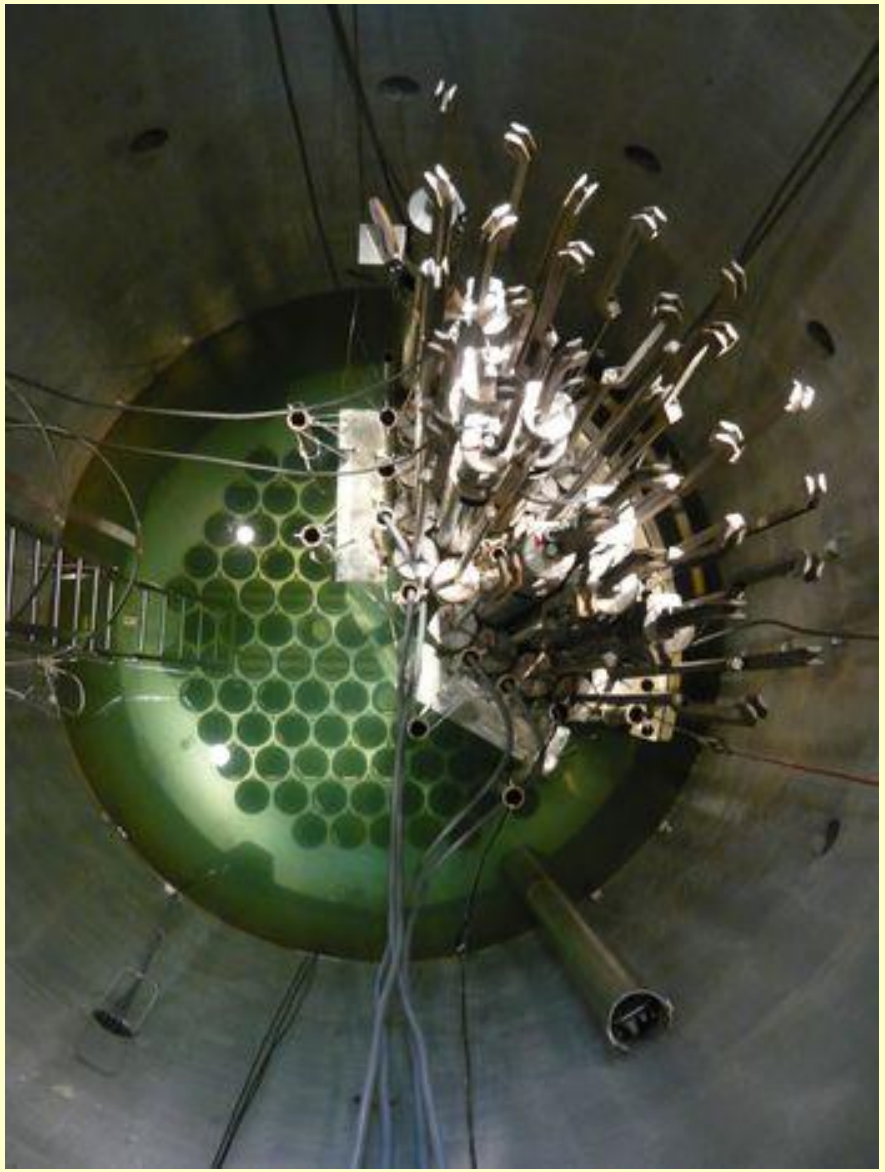
Research reactor LR-0 – is zero power pool type reactor, very flexible, in which it is possible to model virtually any configuration of power reactors to verify their neutron-physical characteristics.

It is mainly intended for testing operating conditions and their influence on light water reactors.

It is mainly focused on VVER reactors used in the Czech Republic

Students of Czech universities very often participate in research using it.

Excursion of high school students during open days for schools



Reactor LR-0

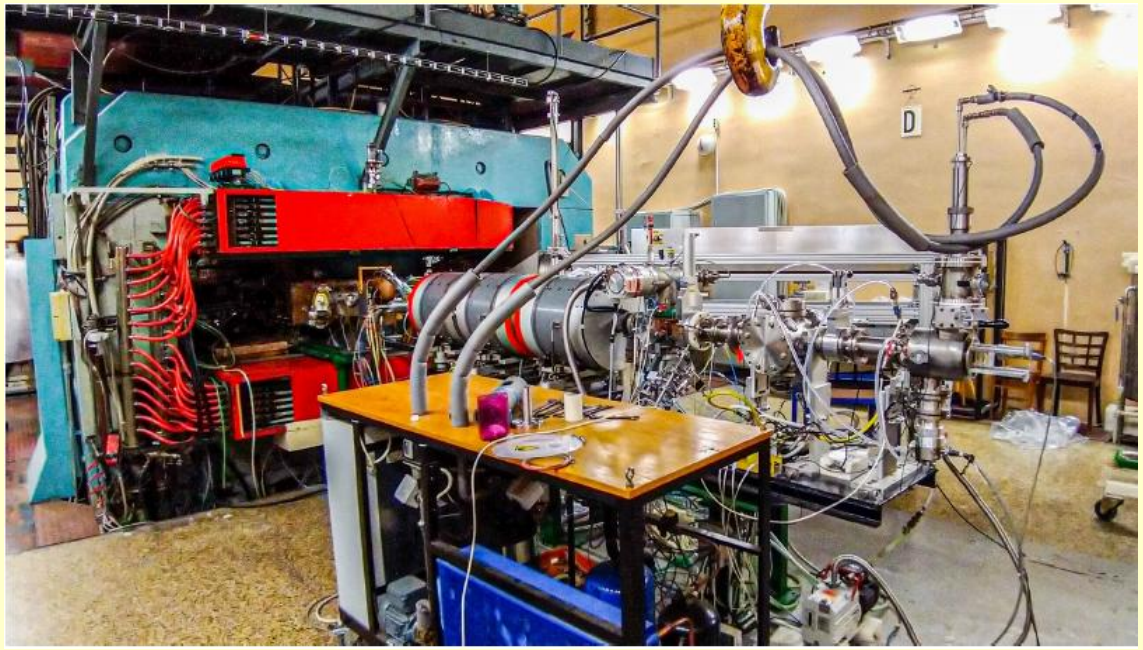
Accelerator based neutron sources at NPI CAS

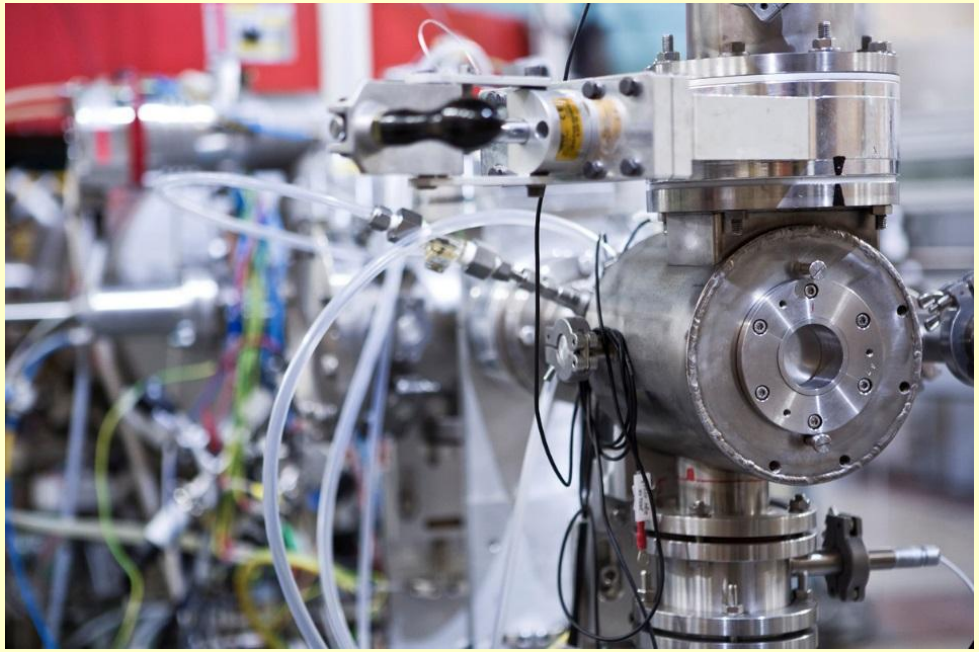
Neutron sources based on cyclotron U120M – proton (6 – 37 MeV) and deuteron (11 – 20 MeV) beams on beryllium a lithium targets are used to produce fast neutrons

Continuous neutron source: A proton or deuteron beam is directed at a thick beryllium target → continuous spectrum with energy up to 33 MeV with neutron flux up to 10^{11} n/cm^2/s is produced

Quasi-monoenergetic (QM) neutron sources: A proton beam is directed on thin lithium target → quasi-monoenergetic spectrum is produced with a peak fluxes of up to 10^9 n/cm^2/s

It is used for validation of reaction cross-sections, validation of cross-section libraries for fusion and advanced fission technologies, material damage and radiation hardness studies, activation analysis with fast neutrons





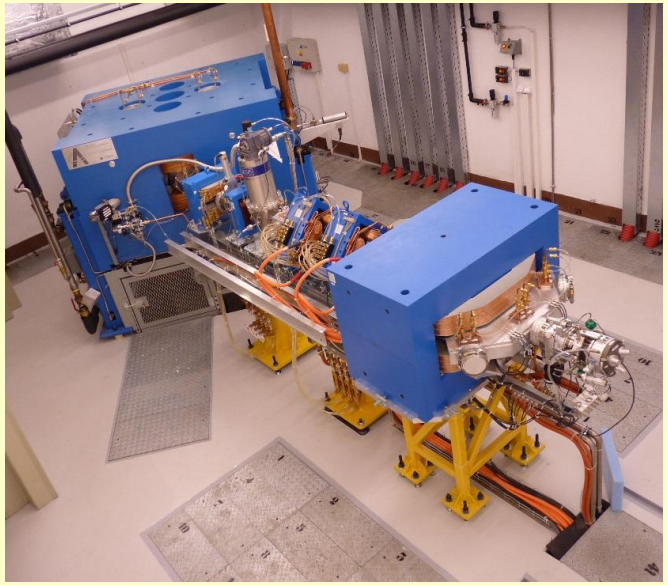
High intensive neutron source based on cyclotron TR24 – cyclotron produces proton beams with energy 18 – 24 MeV with maximal beam current 300 μA

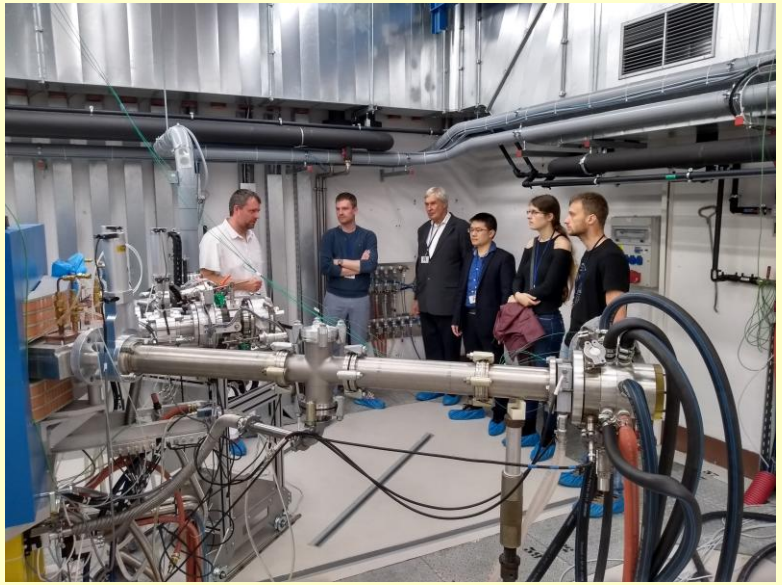
The high power neutron source using reaction of 24 MeV protons on beryllium target is being developed. This generator will provide a neutron field density of 10^{12} n/cm^2/s

Time-of-flight measurements will be available to determine neutron energy

There are also hot chambers built for processing radionuclides for research and production of radiopharmaceuticals

It will allow studying radiation resistance in very intense neutron fluxes and validating libraries of neutron reaction cross sections





International cooperation and synergy

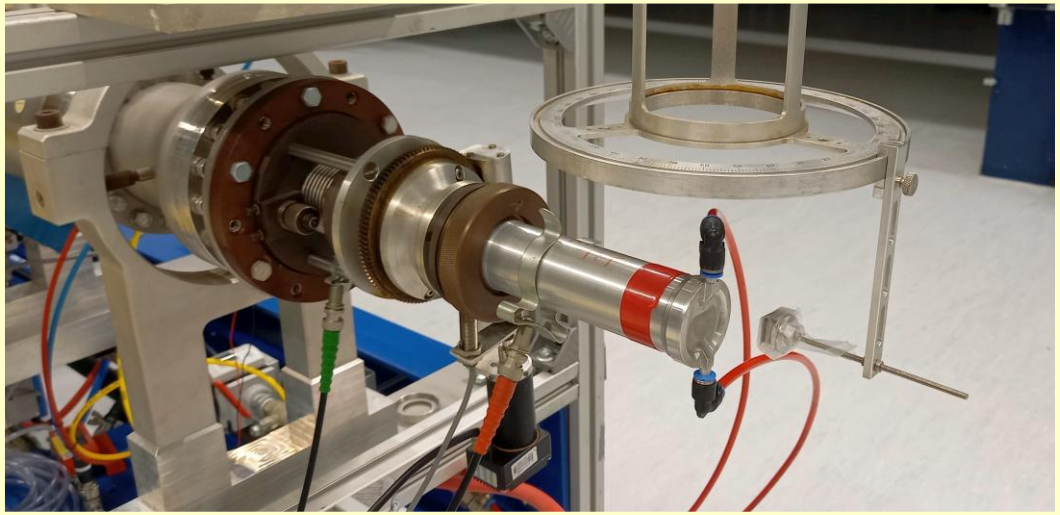
Our neutron sources are mostly open for users and students from abroad

There are a number of different neutron sources in Europe, very often they complement each other very well, they work in different ranges of energies and intensities

Joint measurements on different devices suppress systematic uncertainties

Our students have the opportunity (not only EU grants) to work also on foreign neutron sources and thus gain valuable international experience

Unfortunately, many neutron sources and especially research reactors have been closed



MONNET neutron source (JRC) was used by our student last year – target station

Neutron source nELBE at Rosendorf

Our students used neutron source at Uppsala (was later closed)

Example of realized student studies

Jiří Jarošík completed his bachelor´s and master´s theses on neutron source based on the U120M cyclotron at NPI CAS. For his PhD thesis, he also performed measurements on the MONNET neutron source at JRC (Belgium). His PhD defense will be next week.

He completed his PhD studies while working at ČEZ on fuel preparation for nuclear power plants and also participated in the work related to tender for Dukovany

Two PhD students from last years work at SUJB (State Office for Nuclear Safety) and on MYRRHA project at SCK CEN MOL (Belgium)

Many foreign students have completed their internships in our studies of neutron reaction cross-section.

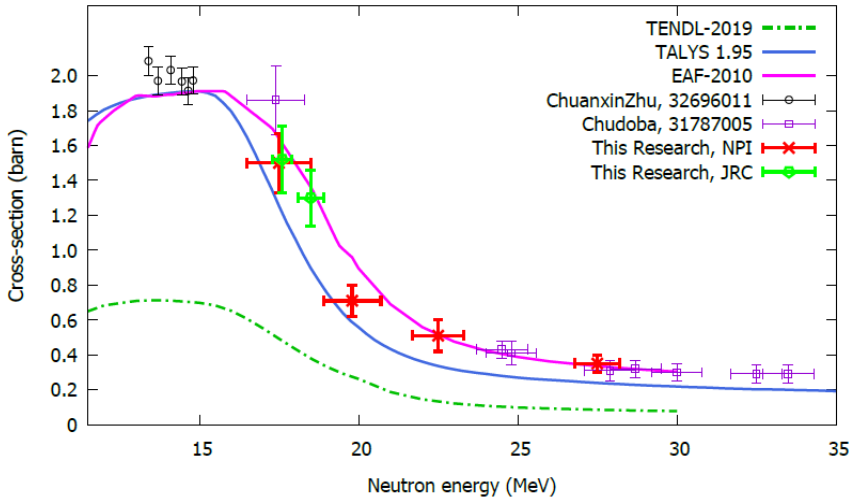


Figure A.4: Experimental data on the ^{197}Au(n, 2n)$^{196g+m1}$Au reaction cross-section compared with evaluated nuclear data [22, 41], TALYS 1.95 [15] calculations, and data available in EXFOR [8, 62] (author and EXFOR ID number are shown).

Czech Technical University in Prague
Faculty of Nuclear Science and Physical Engineering

Department of Nuclear Reactors
Field of Study: Nuclear Engineering

Study of Nuclear Reactions Important for Advanced Nuclear Systems

Studium reakcí neutronů důležitých pro pokročilé jaderné systémy

DOCTORAL THESIS

Author: Ing. Jiří Jarošík
Supervisor: RNDr. Vladimír Wagner, CSc.
Year: 2025

Summary

1) A nuclear energy renaissance is beginning in the Czech Republic and other European countries → a large number of new experts will be needed

2) The Czech Republic has a long-term continuous tradition in nuclear education ↔ in 1955 FNSPE CTU and NPI CAS (Řež nuclear campus) were founded

3) Research neutron sources are needed for the development of advanced nuclear technologies ↔ at the same time, these sources are very useful tool for educating young scientists and other nuclear experts

4) The Czech Republic has two university training reactors, two research reactors and two accelerator-based neutron sources

5) A wide range of bachelor´s, diploma and PhD theses are carried out at these facilities. Many Czech and foreign students use these facilities for their education

6) Similar facilities exist in other European countries. There is intensive cooperation between them, exploiting the potential of mutual synergies

7) Neutron sources are very important tool in the development of advanced nuclear technologies, such as SMR, and also fusion systems

8) There is chance that even with the help of neutron sources we will be able to train enough experts for future development of nuclear energy