ALLEGRO Project

EUROSAFE 2015

Branislav HATALA
Petr DAŘÍLEK
Radoslav ZAJAC

2nd - 3rd November 2015
Brussels

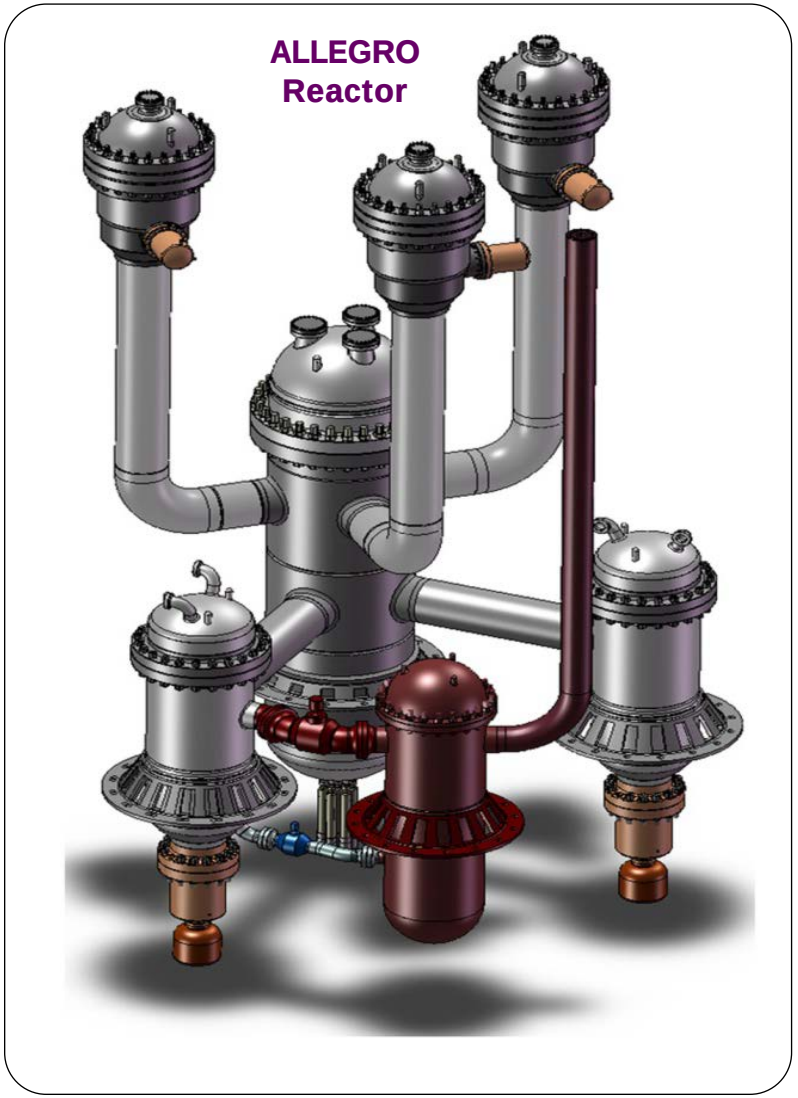
ALLEGRO Project

Content

- Introduction / ALLEGRO Demonstrator
- ALLEGRO Consortium
- V4G4 Centre of Excellence
- ALLEGRO Roadmap
- Description of EU Projects (ALIANCE, VINCO, ESNII+)
- Project „ALLEGRO Research Centre“ in Slovakia
- Results of the „ALLEGRO Research Centre“ – Neutronic analyses
- Summary

ALLEGRO Project

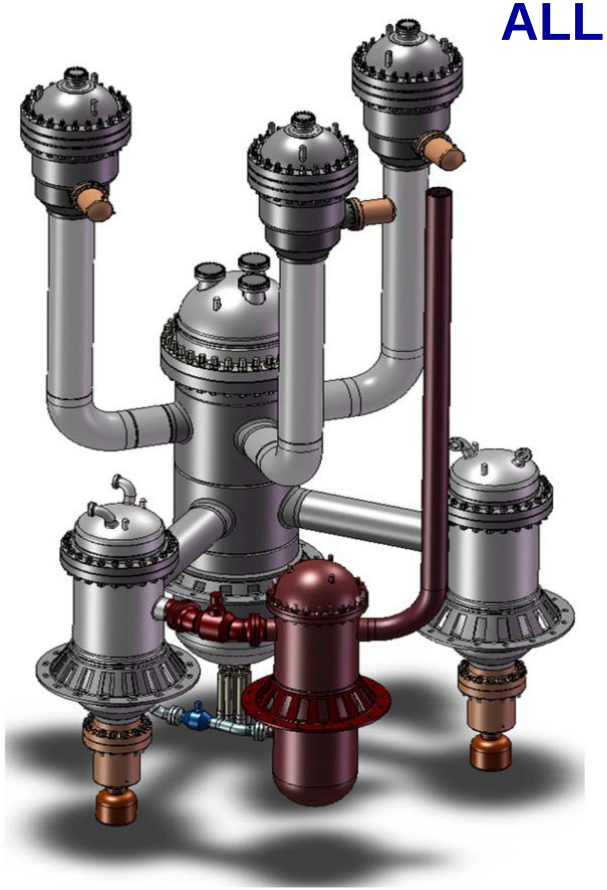
- ALLEGRO is low power GFR (Gas Cooled Fast Reactor) reactor without electricity generation, dedicated to demonstration of helium cooled high temperature fast reactor technology.
- Development and verification of refractory fuel and verification of reliable removal of decay heat after shut down with loss of pressure are of special interests.

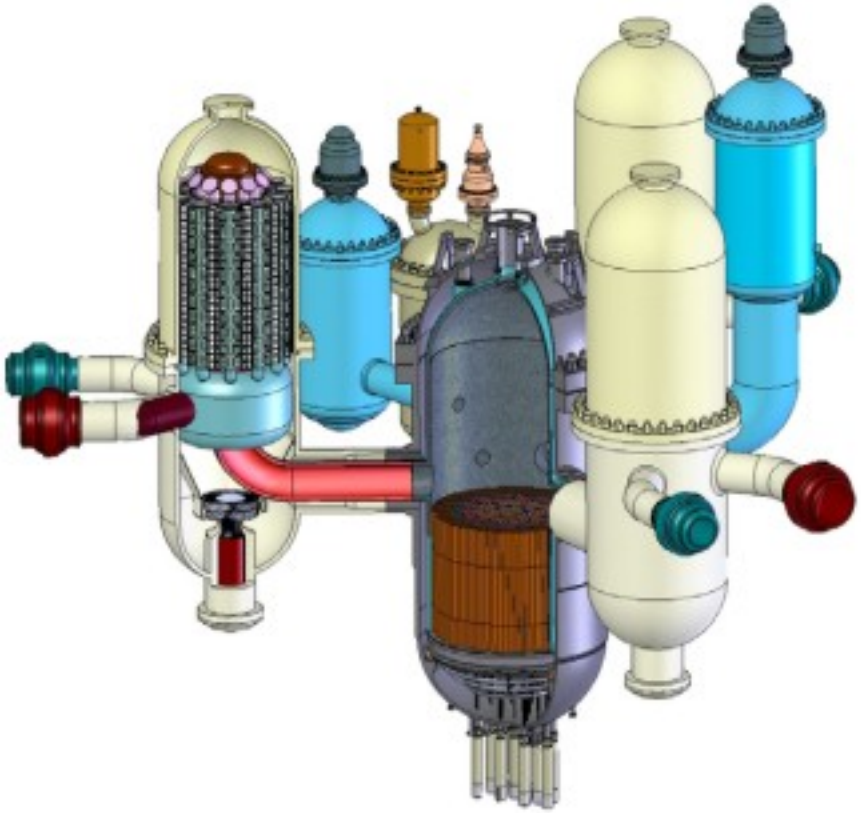


ALLEGRO Project

A technology demonstration as a first gas-cooled fast reactor

ALLEGRO → **GFR 2400**





The ALLEGRO Consortium

Joint preparatory work started in 2010 with support of CEA

In May 2010 signature of Memorandum of Understanding by:

Slovak republic VUJE, a.s.

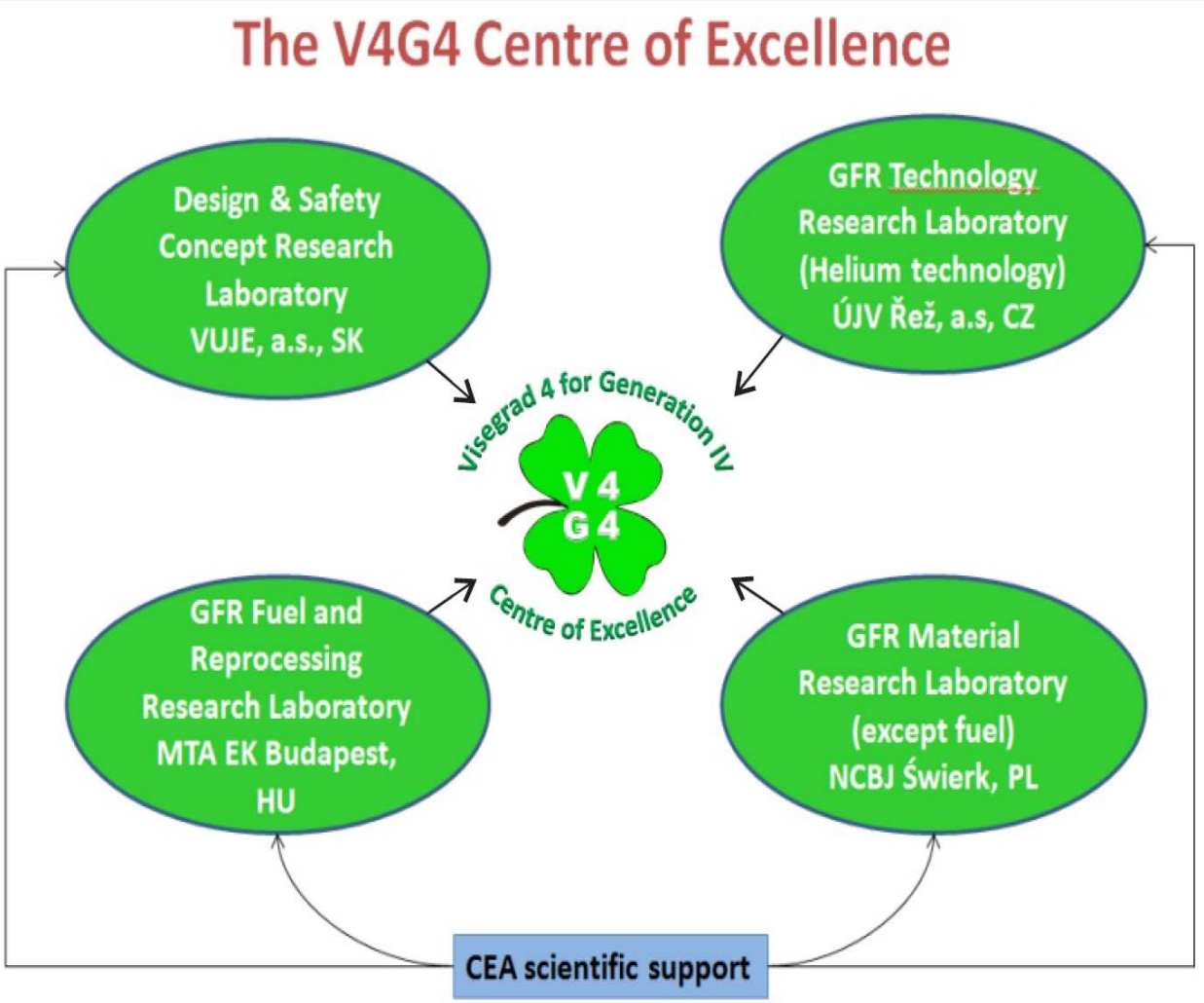
Czech Republic UJV Řež, a.s.

Hungary MTA-EK
(Magyar Tudományos Akadémia
Energiatudományi Kutatóközpont)

Poland NCBJ
(Narodowe Centrum Badań Jądrowych)
officially join the consortium in June 2012.

Establishment of V4G4 Centre of Excellence - July 18, 2013

Considering the various difficulties to overcome to succeed in building ALLEGRO, the four organizations decided to create a legal entity, the "**V4G4 Centre of Excellence**", which is in charge of the international representation of the project and of its technical coordination.



Four legs of the Centre:

- **Design & Safety Concept Research Laboratory – VUJE, a.s.**
- **GFR Technology Research Laboratory (Helium technology) – ÚJV Řež, a.s.**
- **GFR Fuel and Reprocessing Research Laboratory – MTA-EK**
- **GFR Material Research Laboratory (except fuel) – NCBJ**

V4G4 Centre of Excellence
Interest Association of Legal Entities

Aim of „V4G4 Centre of Excellence“

- investigating crucial aspects, in particular regarding safety, and generating experimental results for the development of Generation 4 nuclear reactors, especially for the innovative concept GFR (Gas Cooled Fast Reactors) for which a demonstrator, ALLEGRO, will be built and operate in the V4 region,

- promoting and popularizing the potential, perspectives, technical, political and environmental issues related to Generation IV nuclear reactors,

- contributing to the preservation of nuclear qualifications by involving young scientists and engineers into its challenging research and development activities,

- facilitating the integration of nuclear research in Central Europe.

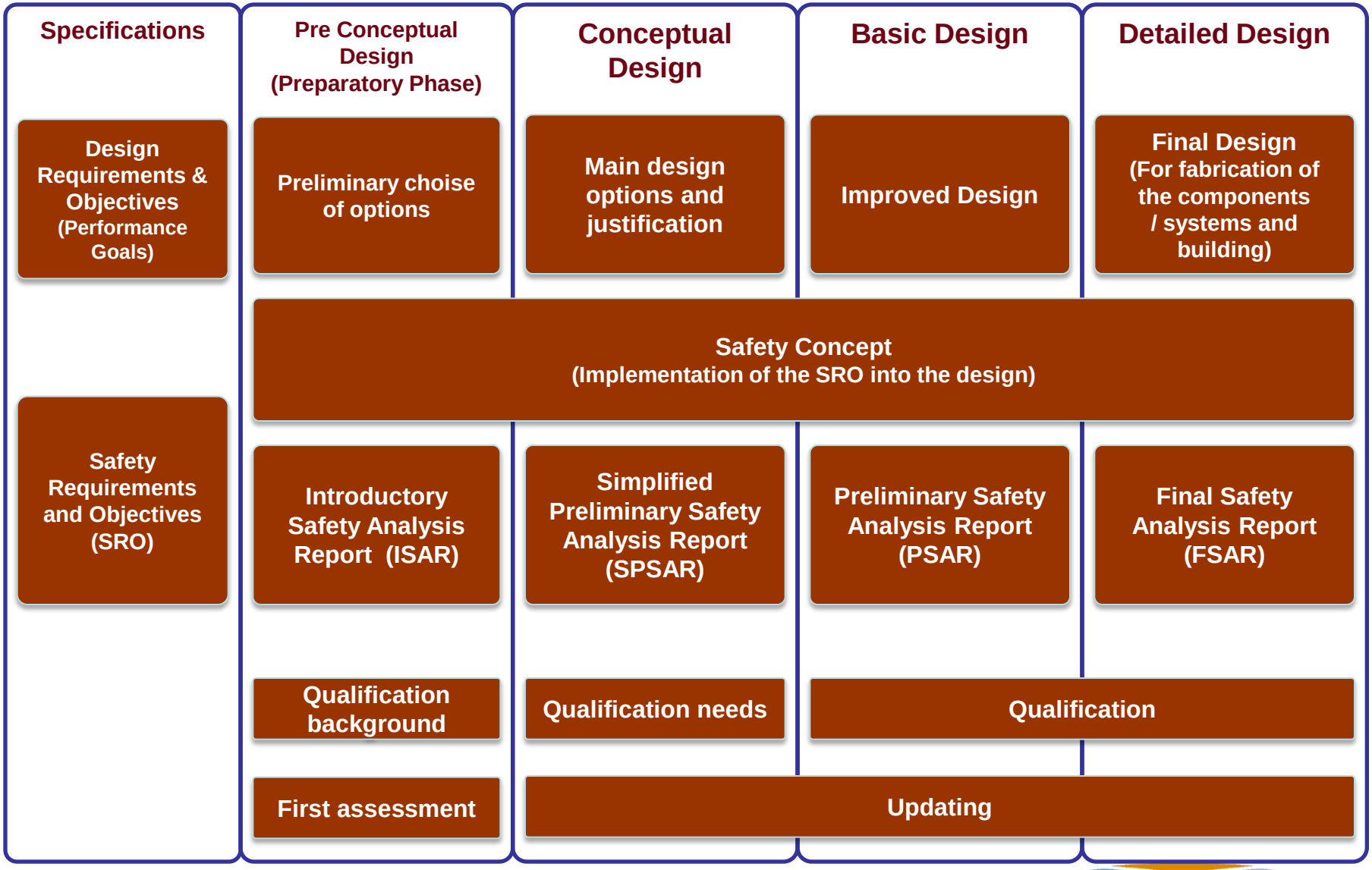
ALLEGRO Design and Safety Roadmap

Define a common work plan among the V4G4 partners described by tasks, with two technical orientations.

For each task define what?, who?, when?, how much?

- **Technical content and phasing**
- **Input data needed and tools (codes, experimental facilities,…)**
- **Links with other tasks**
- **Leadership and partners**
- **Time schedule**
- **Cost in manpower and investments.**

The ALLEGRO Consortium
ALLEGRO project PHASES and Outputs



EU Projects

ALLIANCE - ALLegro Implementing Advanced Nuclear Fuel Cycle in Central Europe

coordination and support action

Beginning of the project October 2012, Duration of the project 36 month

VINCO - Visegrad Initiative for Nuclear COoperation

coordination and support action

Beginning of the project September 2015, Duration of the project 36 month

ESNII +

European Sustainable Nuclear Industrial Initiative (ESNII) addresses the need for demonstration of Gen-IV Fast Neutron Reactor technologies, together with the support to research infrastructures, fuel facilities and R&D work.

VUJE Participation: WP 6 - Core Safety (ASTRID, ALFRED, ALLEGRO), Core Specification, No Burnup Calculation

Project
„ALLEGRO Research Centre“ in Slovakia

Contract between

Ministry of Education, Science, Research and Sport of the Slovak Republic

Slovak Academy of Sciences

Beginning of the project - 9. September 2014

End of the project - 31. December 2015

Project is financed from EC Structural Funds (program period 2007 – 2013➔2015)

Operational programme - Research and development

The executive authority of the OP Research and Development is the Ministry of Education, Science, Research and Sport of the Slovak Republic.

VUJE – subcontractor of Slovak Academy of Sciences (SAS)

Project
„ALLEGRO Research Centre“in Slovakia

Work packages

1. Establishment and initiation of the ALLEGRO Research Centre

Goal: Development of specialised places of work and laboratories, rooms for employees and technology transfer.

2. Applied research and development in the area of new materials and technologies

Goal: Realisation of cutting-edge research and development in the area of new materials and technologies, preparation, testing and diagnostics of prototypes

3. Establishment of technology transfer platform

Goal: Establishment of a contact point for communication with entrepreneurial sector in frame of the Office for technology transfer (KTT), establishment of incubator, identification of spin-offs and programme for support of technology transfer and mobilisation of innovations.

Research of the safety concept and systems design of the 4th generation ALLEGRO reactor

A.1 Research on the concept of ALLEGRO nuclear facility
A.2 Analysis of the primary circuit behaviour
A.3 Analysis of the systems behaviour to ensure fundamental safety functions
A.4 Research of decay heat removal systems
A.5 Analysis of accidents with fuel damage
A.6 Analysis of containment system
A.7 Sub-criticality analysis of ALLEGRO core configuration
A.8 Analysis of power and fission products distribution in the Allegro fuel
A.9 Research of reactivity control systems
A.10 Research on fuel handling concept of the Allegro system
A.11 The development of computational complex for 3D reactor kinetic analysis for ALLEGRO reactor
A.12 Development of the methodology for assessment of passive safety systems reliability
A.13 Theoretical analysis of the mechanisms of structural materials degradation
A.14 Proposal for experimental verification of the impact of operational loads
A.15 Research of the reactor vessel and piping systems structural response during normal and accident conditions

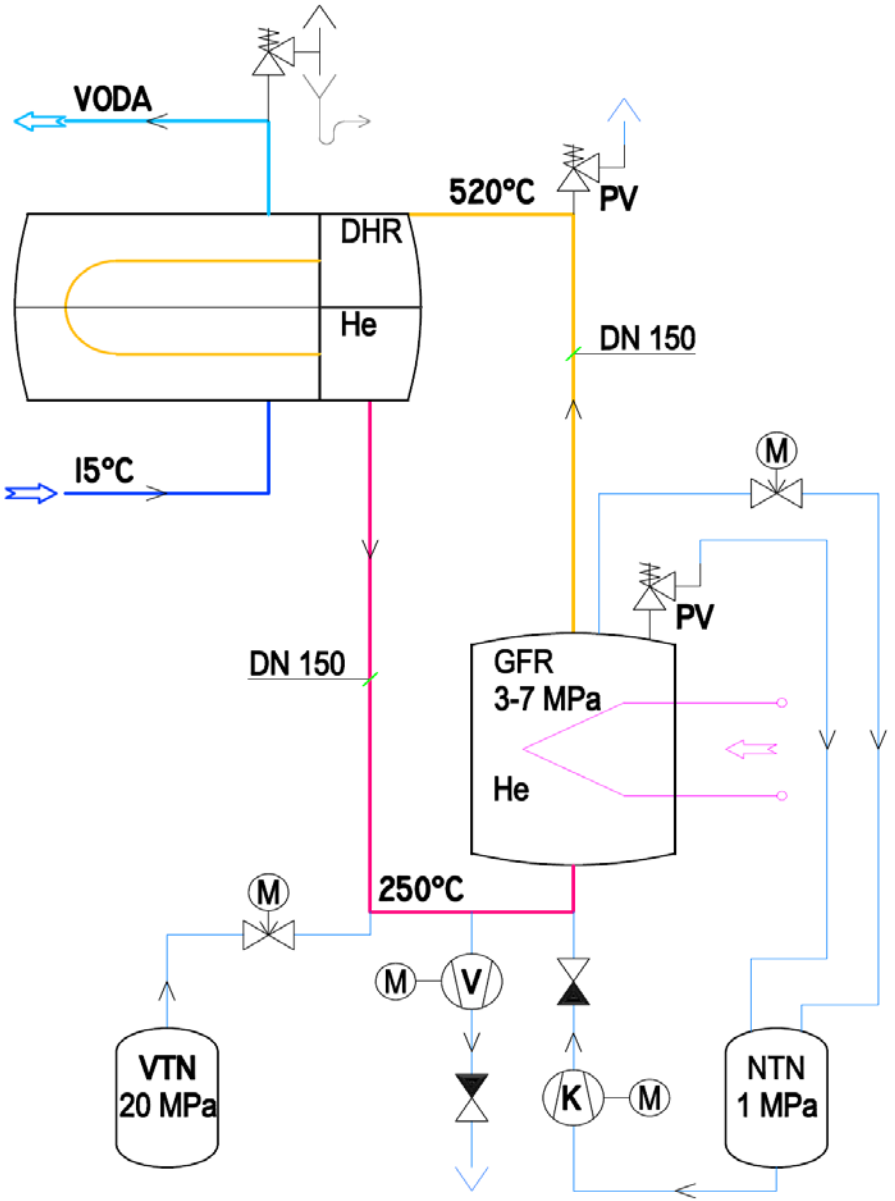
Project
„ALLEGRO Research Centre“in Slovakia

WP2. Applied research and development in the area of new materials and technologies

Task 3
Equipment research for ALLEGRO reactor

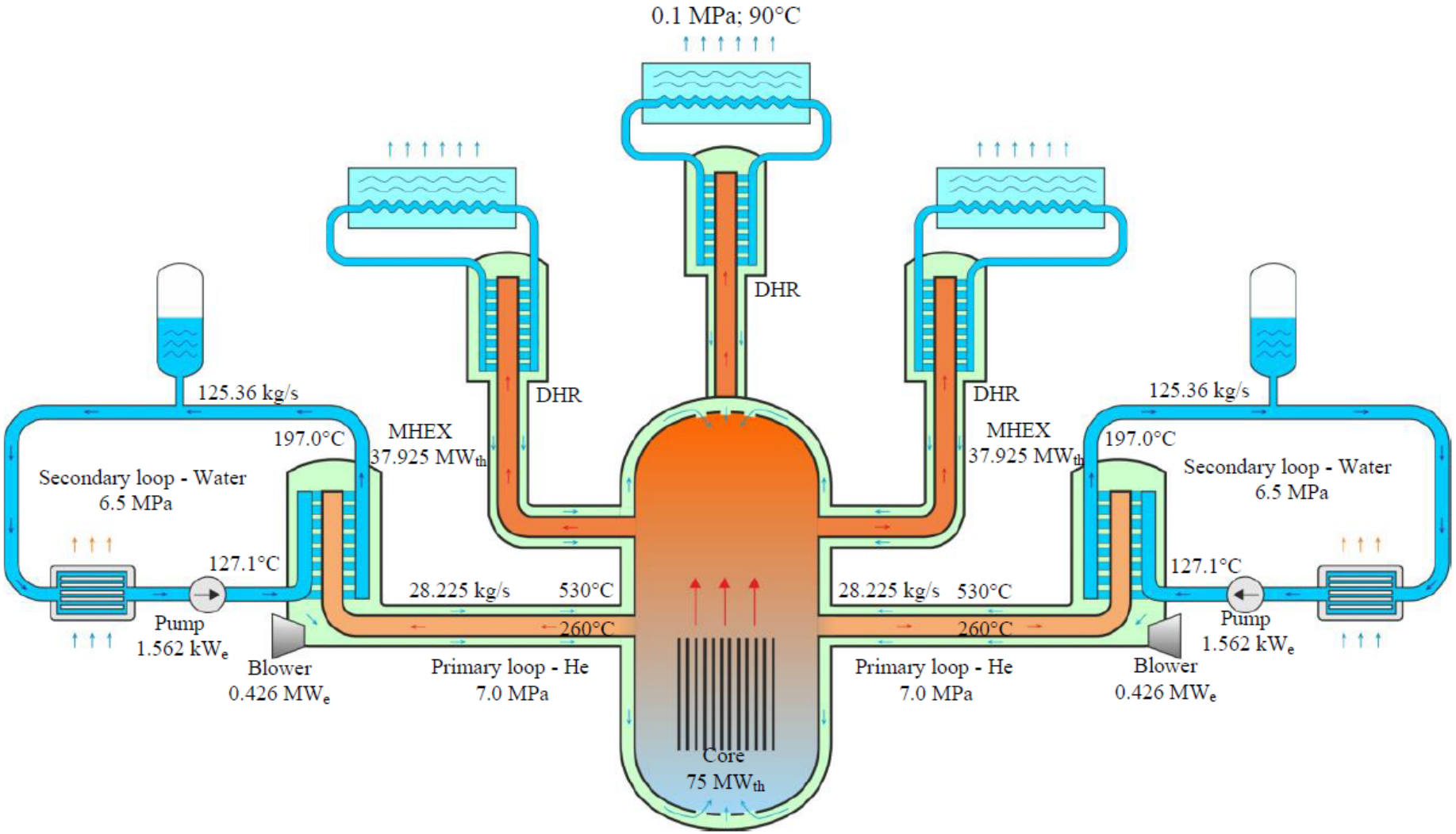
Experimental helium loop

Faculty of Mechanical Engineering,
Slovak University of Technology

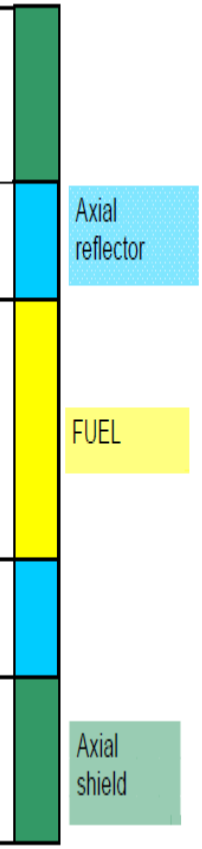


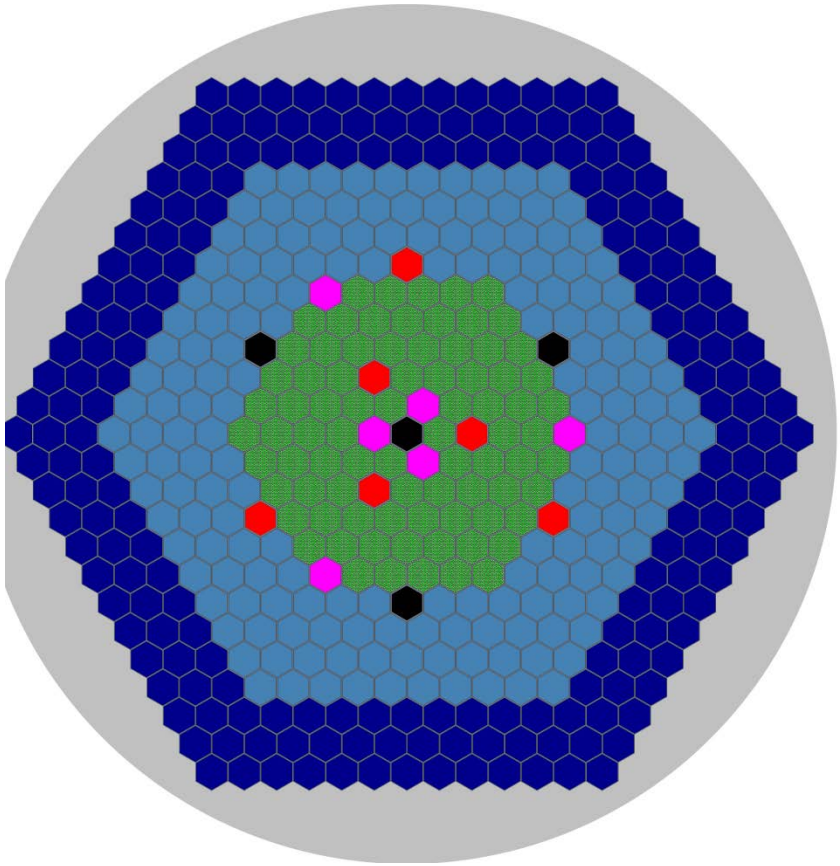
ALLEGRO Project

Review of the Design by CEA



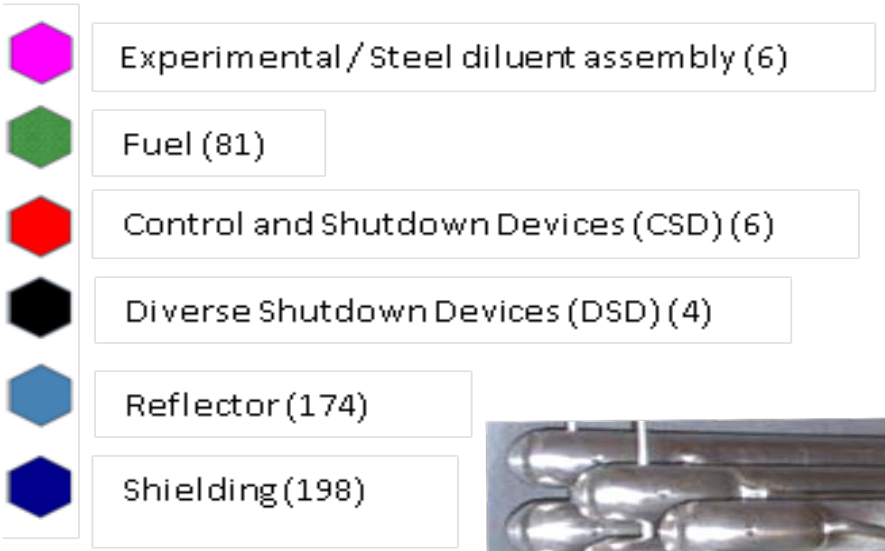
Main characteristic of the ALLEGRO core



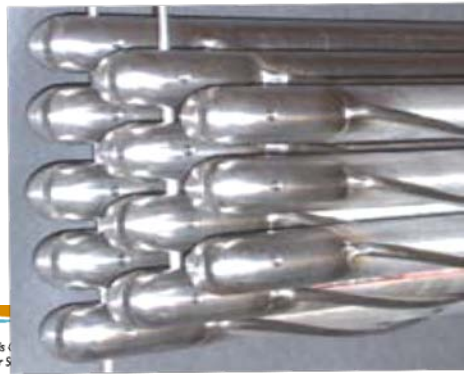


The reactor shall be operated with two different cores: The starting MOX core will serve to test the operation of the gas cooled fast reactor with well established fuel.

The second core using the ceramic fuel will serve for testing the new fuel design.



	MOX Core	Ceramic Core
Core power	75 MWth	
Coolant pressure	7 MPa	
Primary mass flow rate	53 kg/s	36 kg/s
Core inlet temperature	260 °C	400 °C
Core outlet temperature	**560 °C**	**850 °C**



Project
„ALLEGRO Research Centre“in Slovakia

A.7 Sub-criticality analysis of ALLEGRO core configuration

Assurance criteria of sub-criticality

- Regulation 57/2006 Coll. of Slovak Republic from 12. January, 2006. This regulation modifies the requirements details regarding to radioactive materials transport
- Regulation of the Slovak regulatory body 30/2012 Coll. from 30 January 2012 specifies the requirements shipment of nuclear materials, nuclear waste and spent fuel

  Multiplication coefficient k_{eff} is equivalent to this requirement:

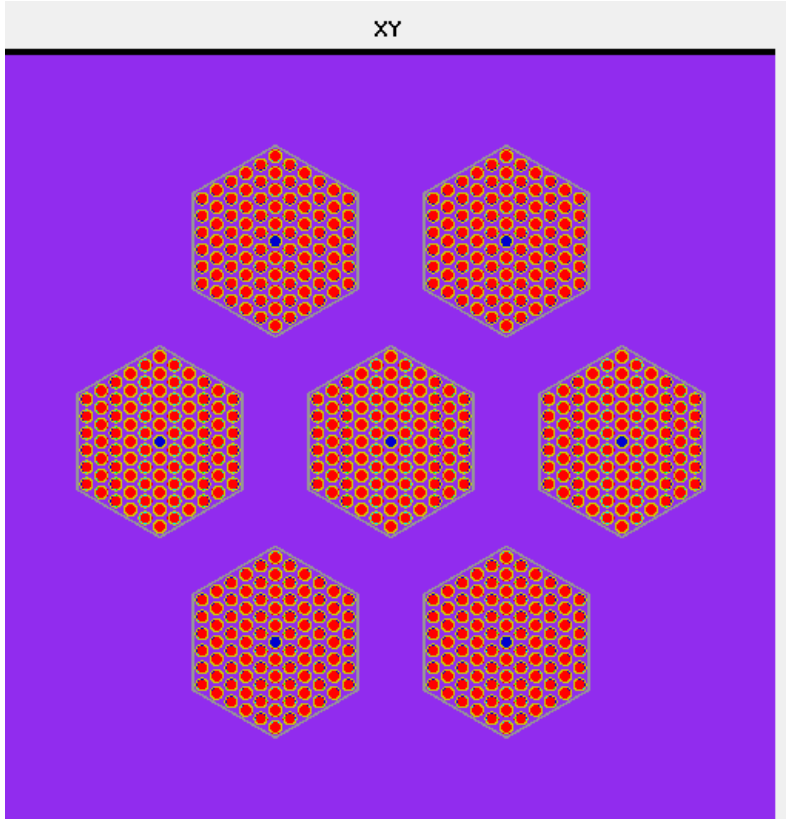
  k_{eff} < 0.95 routine states

  k_{eff} < 0.98 accident events

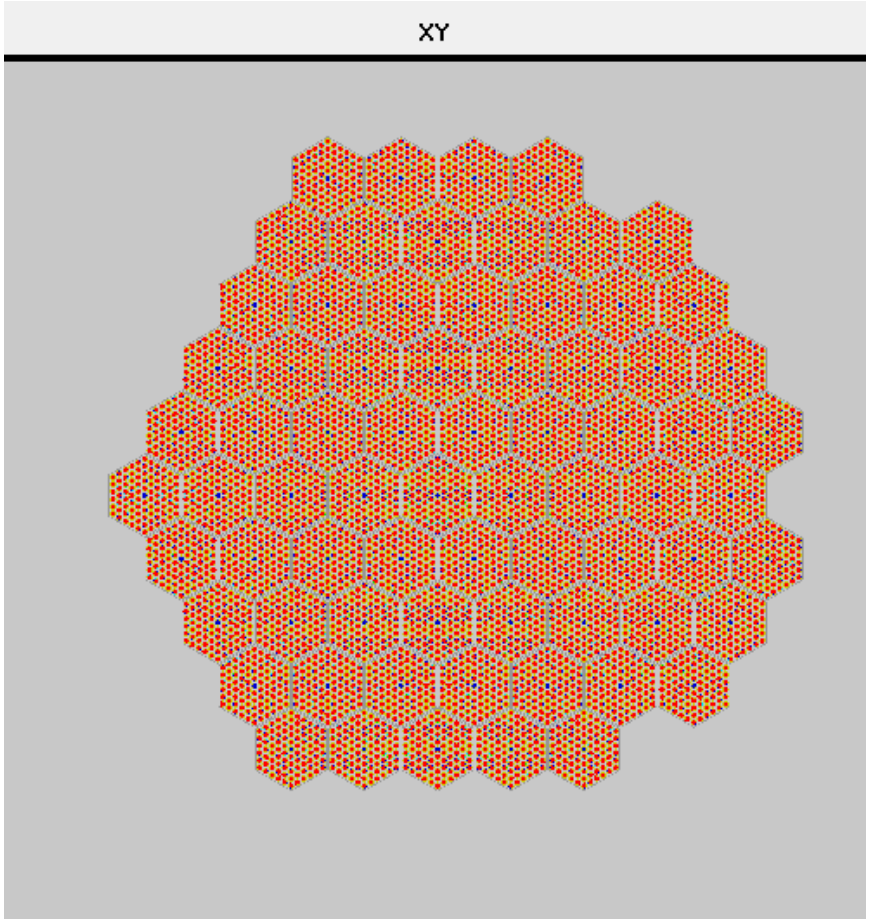
The international requirements are listed in IAEA documents: SSG-15, SSG-27 a SSR-6. These documents recommends sub-criticality 5 % with note that national rules are binding.

Project
„ALLEGRO Research Centre“in Slovakia

A.7 Sub-criticality analysis of ALLEGRO core configuration



7 UPuC assemblies in water

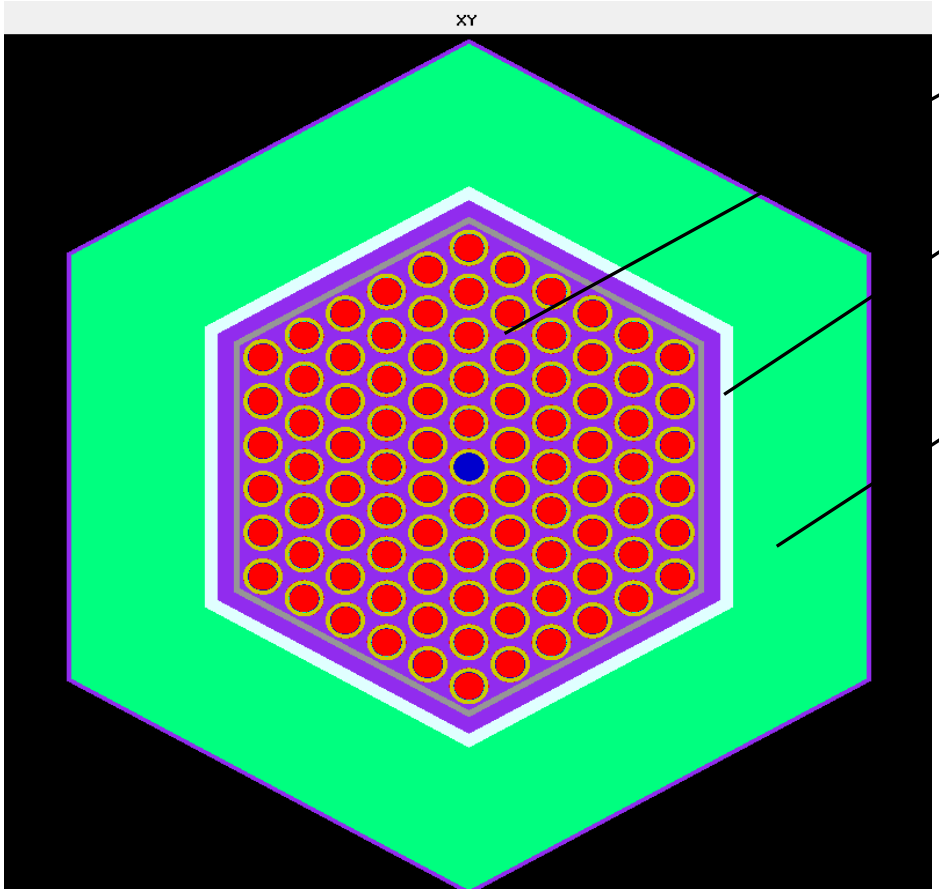


72 UPuC assemblies in air

Project
„ALLEGRO Research Centre“in Slovakia

A.7 Sub-criticality analysis of ALLEGRO core configuration

Design of storage can for fresh and spent fuel assembly



UPuC Fuel Assembly

ATABOR Steel (Boron 1%)

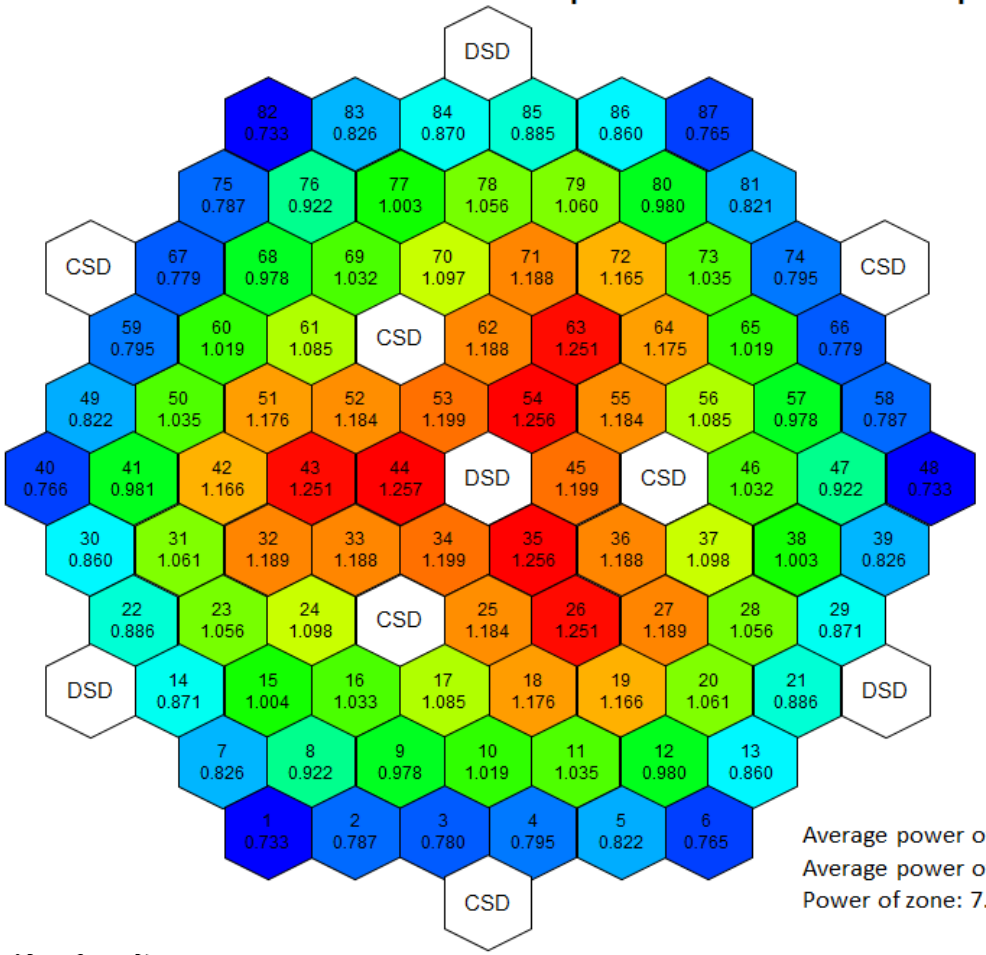
Aluminium

Project
„ALLEGRO Research Centre“in Slovakia

A.8 Analysis of power and fission products distribution in the Allegro fuel

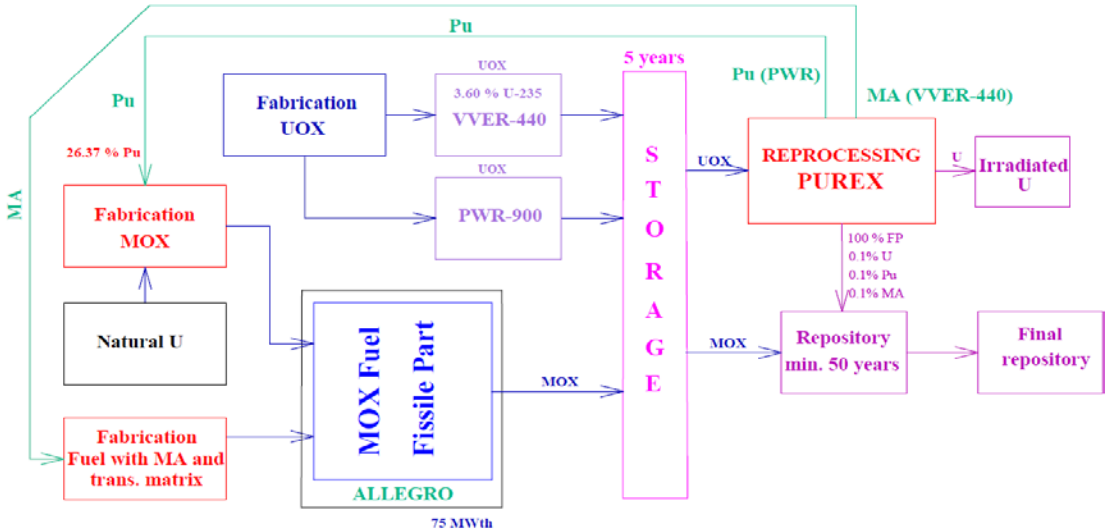
Distribution of assemblies relative power in the core at burnup of 18.8 MWd/kg$_{HM}$ and critical position of CSD rods

Distribution of assemblies relative power in the core at burnup of 18.8 MWd/kg$_{HM}$

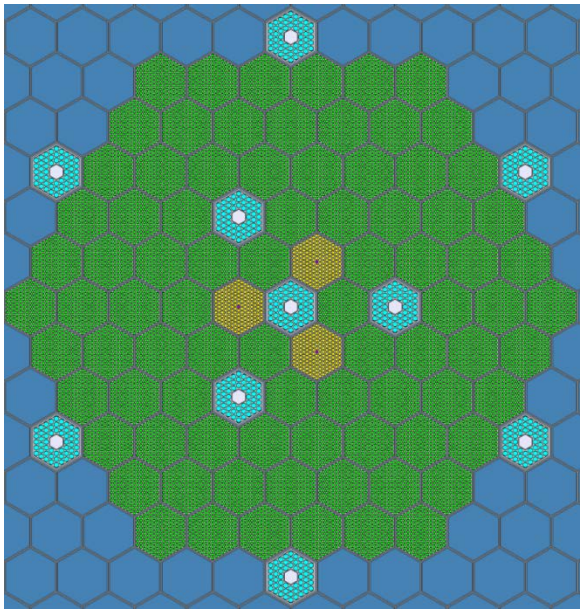


Average power of node: 1.72414E+05 W
Average power of assembly: 8.62069E+05 W
Power of zone: 7.50000E+07 W

Project
„ALLEGRO Research Centre“in Slovakia
A8 Breeding and transmutation capabilities



Cycle of Pu and MA recyclation from LWR spent nuclear fuel and fabrication of heterogeneous fuel and MA mixture for ALLEGRO reactor



Scenario of heterogeneous transmutation where mixture was placed in the central pins (pink pins) of the assemblies at first orbit in experimental position (assemblies with yellow pins).

- **second transmutation scenario:** Separation of the Am and its integration to the inert $MgAl_2O_4$ matrix. The mixture contained 11 % of AmO_2 by mass.
- **third transmutation scenario:** Separation of the Am and Np separation and their integration to the depleted UO_2 with 0.25 % content of U-235 isotope. The mixture of oxides (UO_2, AmO_2, NpO_2) contained 20 % by mass of MA.
- **fourth transmutation scenario:** Separation of the Am, Np and Cm separation and their integration to the depleted UO_2 with the U-235 isotope content of 0.25 %. The mixture of oxides (UO_2, AmO_2, NpO_2, CmO_2) contained 20 % by mass of MA.

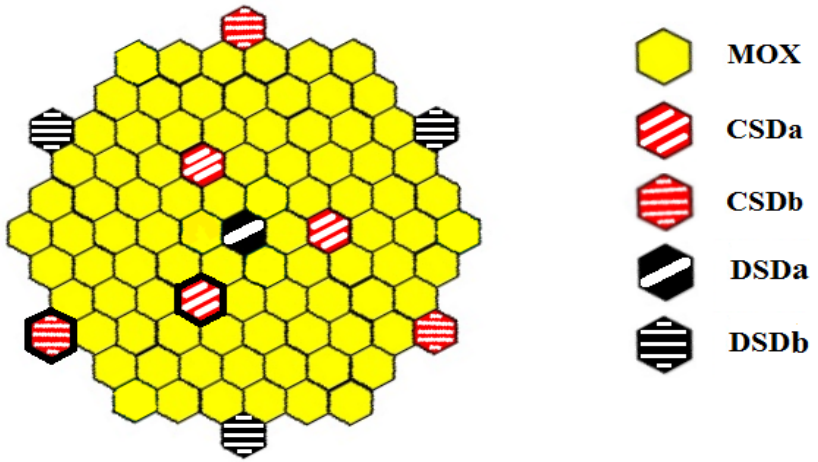
Project
„ALLEGRO Research Centre“in Slovakia

A.9 Reactivity control system optimisation

Analytical comparison of the original CEA concept design of the reactivity control system with new designs and proof that the selected design is the most suitable

The comparison of the worth of the groups of CSD and DSD has been performed within the entire reactor core and the groups have been divided into subgroups CSDa, CSDb (due to better control – high differential efficiency) and DSDa DSDb

CSDa	CSDb	DSDa	DSDb	ρ_k [pcm]
ULP		ULP		6 320
ULP		LLP		2 155
LLP		ULP		-2 453
LLP		LLP		-6 288
LLP	ULP	ULP		-1 045
ULP	LLP	ULP		5 116



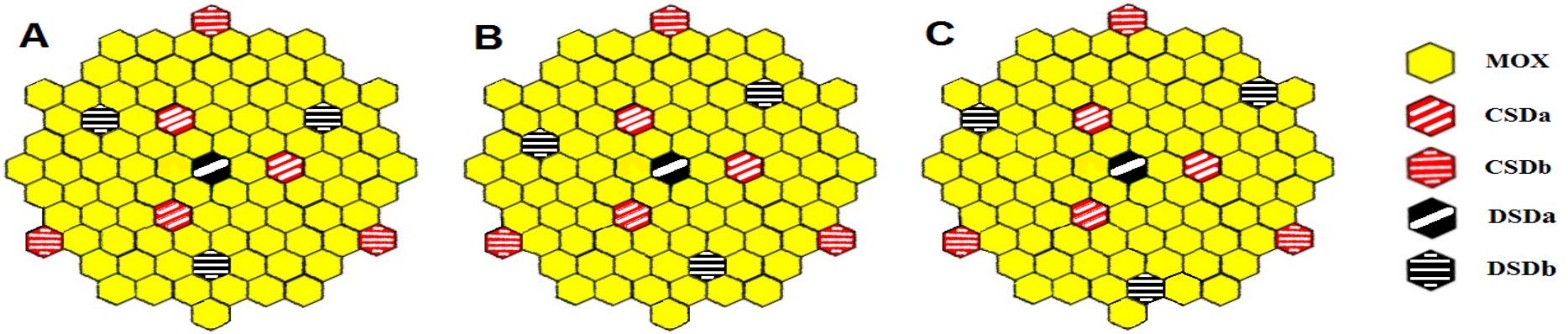
- the disadvantage of the referential model – DSD group is not able to shutdown reactor separately and independently if CSD group is in ULP (temperature effect is circa 1000pcm)

Project
„ALLEGRO Research Centre“in Slovakia

A.9 Reactivity control system optimisation

Analytical comparison of the original CEA concept design of the reactivity control system with new designs and proof that the selected design is the most suitable

- proposal to change DSD group layout in the reactor core so that DSD group could be able independently and separately shutdown reactor if CSD group is in ULP because material modification is no sufficient for shutdown



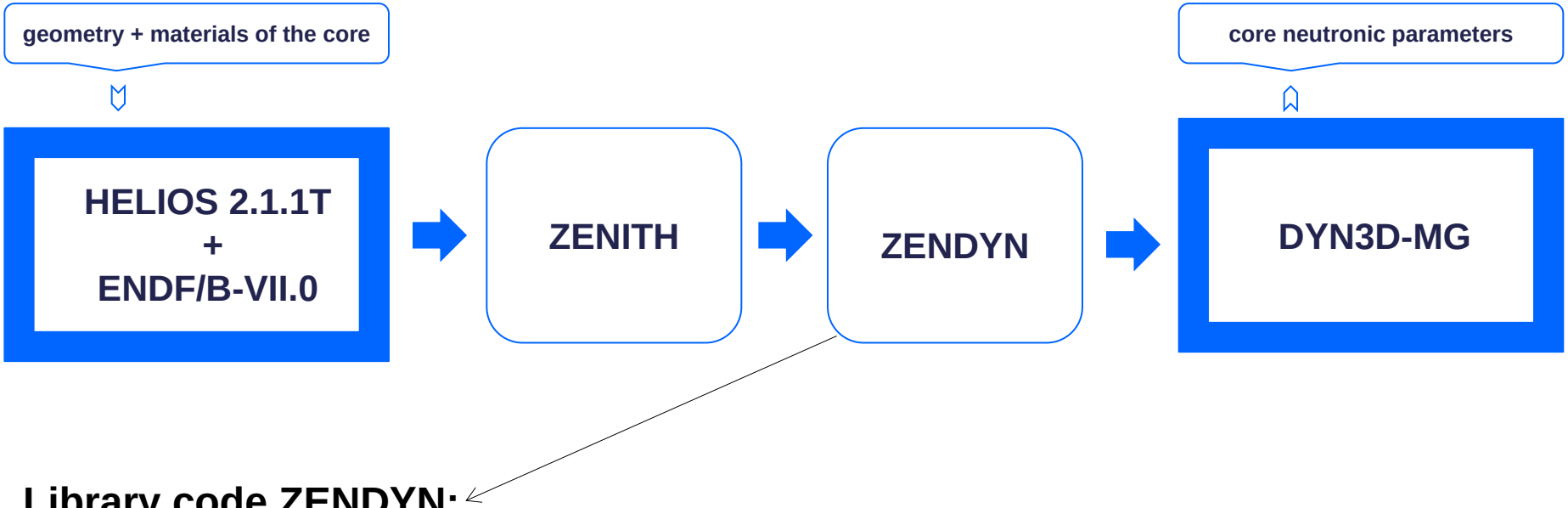
- variants A and B are able to shutdown reactor after taking into account temperature effect
- variant C is not able to shutdown reactor even without temperature effect

Model	CSD	DSD	ρ_k [pcm]	$\rho_{k\ 20°C}$ [pcm]
A	ULP	LLP	-2 488	-1 412
B	ULP	LLP	-2 136	-1 060
C	ULP	LLP	1 169	2 245

Project
„ALLEGRO Research Centre“in Slovakia

A.11 The development of computational complex for 3D reactor kinetic analysis for ALLEGRO reactor

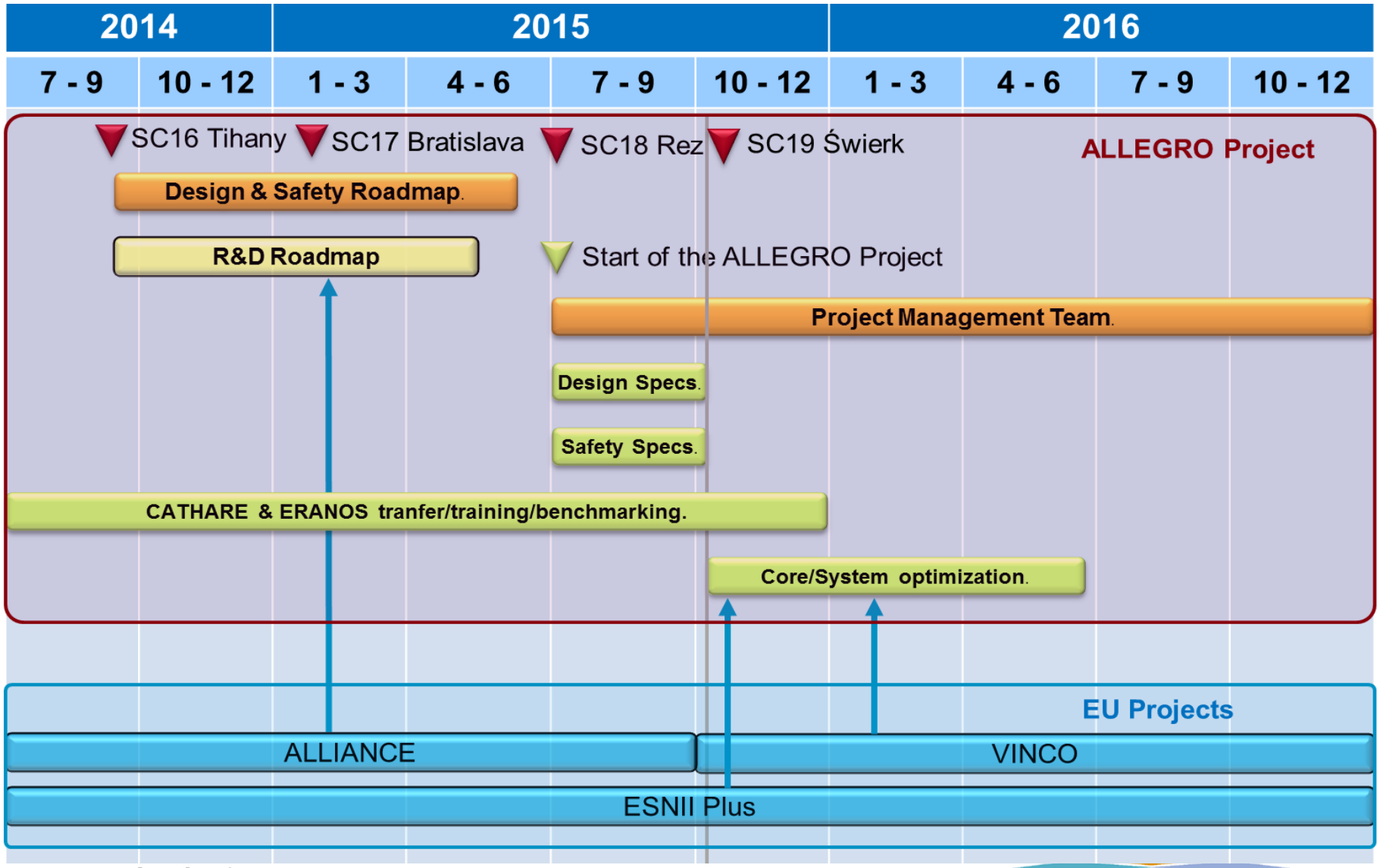
Codes for library file preparation



Library code ZENDYN:

- Input of operation parameters and burn-up dependent cross sections
- Inclusion of it into interpolation tables
- Input and inclusion of burn-up only dependent cross sections
- Library file creation

Summary / Conclusion



Summary / Conclusion

- **The initial period (2010-2013)**
  was devoted
  to the establishment of legal background
  for the ALLEGRO development in the V4 countries.

- **The subsequent period (2014-2015)**
  enabled a real restart of the ALLEGRO development.

Thank you
for your attention

VUJE, a.s.

Okružná 5
918 64 Trnava
Slovak Republic

www.vuje.sk