Progress and prospects of research on the management of high -level radioactive waste: the example of the `transmutation` option

Prof. Dr. Bruno Thomauske

Institue of Nuclear Fuel Cycle

Content

1. Nuclear research and teaching in Aachen
2. Transmutation
   - Motivation – Reduction of High Level Waste (HLW)
   - Political background in Germany – Final disposal
   - The AGATE concept
   - The feasibility study
   - AGATE in comparison with MYRRHA
   - Next steps
   - Conclusion

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Institute of Nuclear Fuel Cycle (INBK)

- Interdisciplinary research institution
- Since 2008 at the RWTH Aachen University
- Development of innovative, technical solutions for the entire nuclear fuel cycle
- 25 employees in 4 work groups

Institute of reactor safety and reactor technology (Prof. Allelein)

Research focus

Nuclear Supply & Disposal

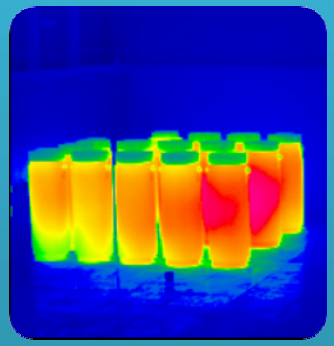
Dr.-Ing. Frank Charlier

6 employees

Transmutation & Characterization of Radioactive Waste

Dipl.-Phys. John Kettler

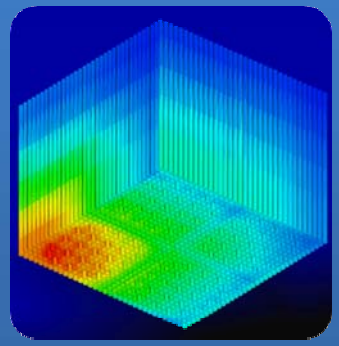
5 employees



Nuclear Simulation

Prof. Dr. rer. nat. Rahim Nabbi

7 employees



Communication & Public Relations

Sabine Backus, M. A.

5 employees

Teaching: New master programme

Nuclear Safety Engineering

- Degree: Master of Science
- Type: consecutive master‘s degree programme
- Study period: 4 semesters (2 years), full time studies
- First enrolment: winter term 2010/2011

Course contents

Focus:

- Nuclear fuel cycle
- Operation and safety of nuclear facilities
- Nuclear physics, nuclear chemistry
- Technologies for waste processing and disposal
- Simulation (High-Performance-Computing)
- Safety analyses
- Radioactive waste management and disposal

Objective: education of highly qualified specialists for the entire nuclear fuel cycle

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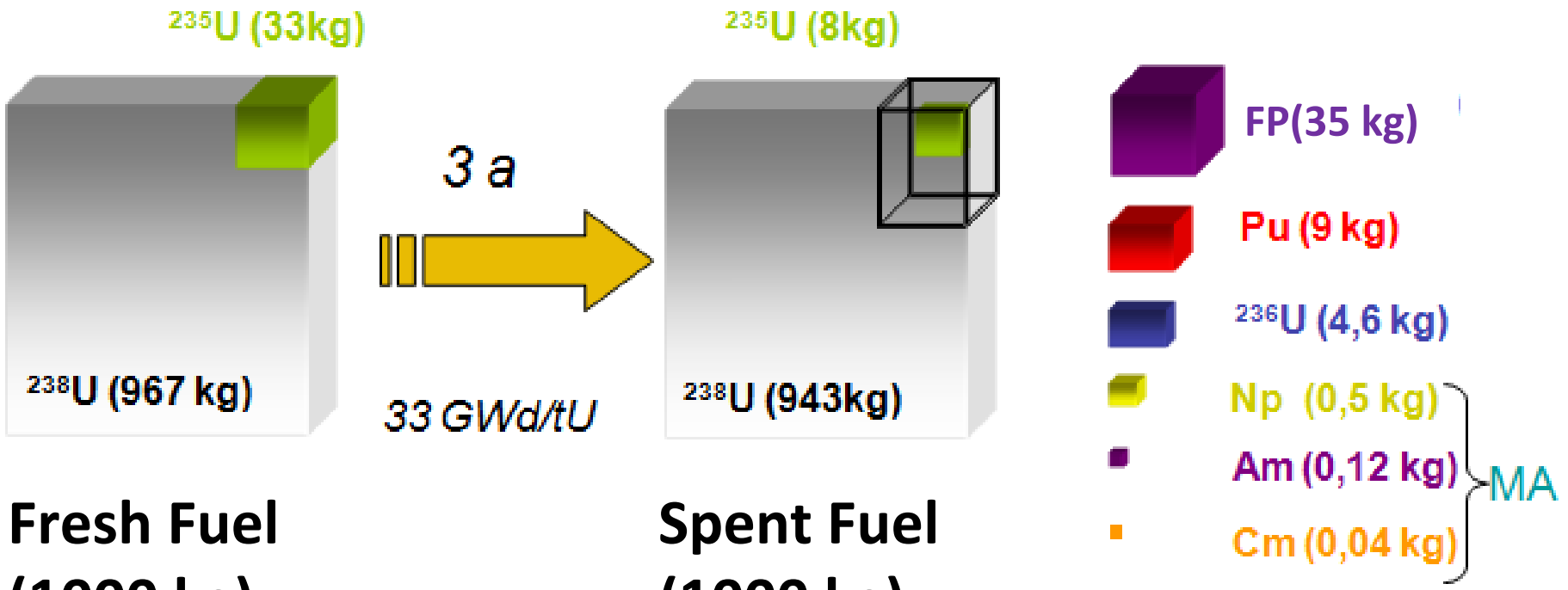
Burn-up process of 1000 kg nuclear fuel

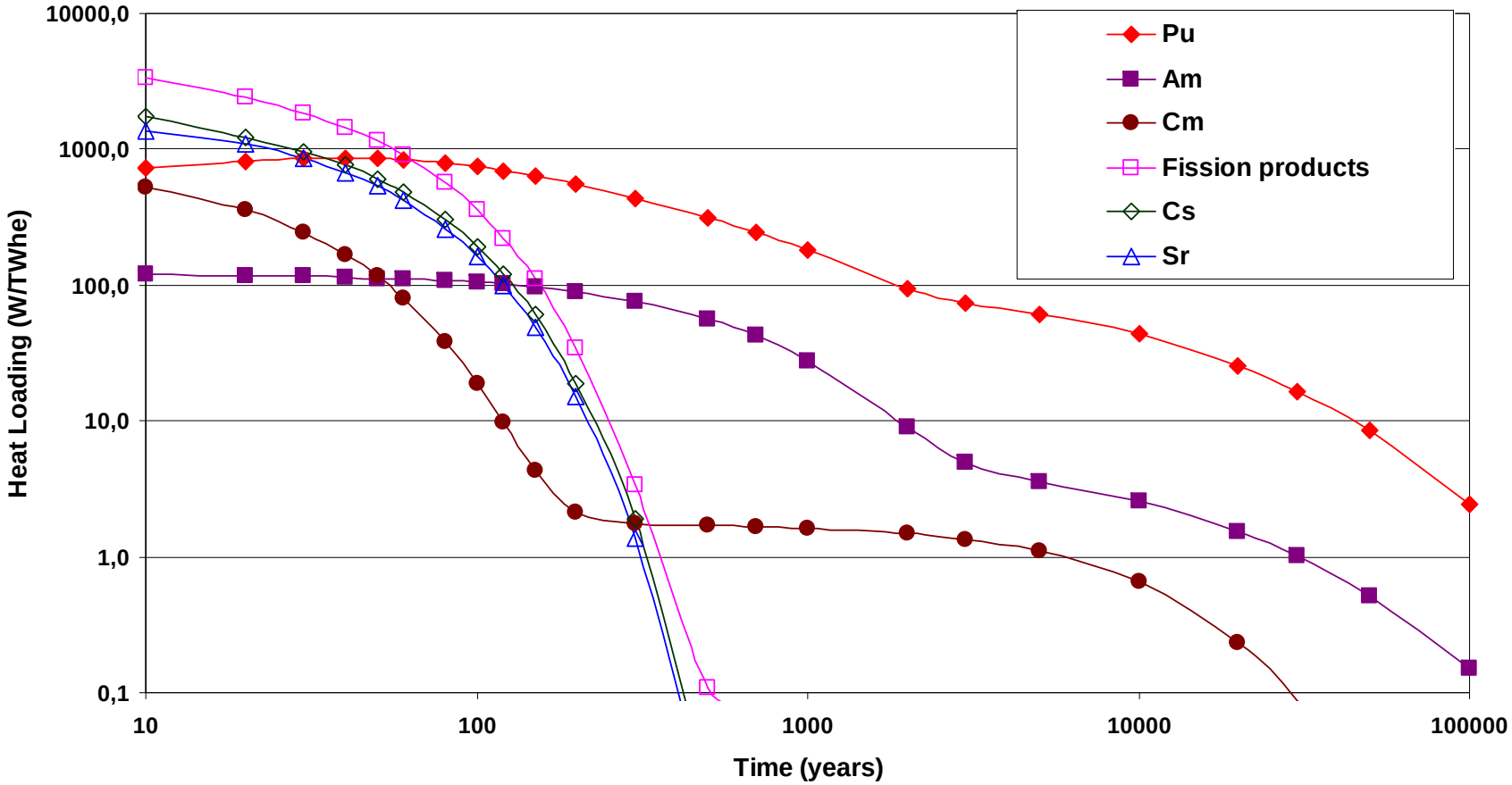


Fresh Fuel (1000 kg)

Spent Fuel (1000 kg)

- Final Disposal: Long term toxicity of Plutonium and Minor Actinides are a problem
- Different Solutions:
  - **Partitioning** (reprocessing) and **Transmutation** (destruction of long lived nuclei)
  - or **Direct Disposal** of fuel elements in casks

Final Disposal: Thermal power of spent fuel



- The heat load is dominated in the first hundred years by Sr an Cs-Isotopes (Fission products)

Political background in Germany – Final disposal

Waste with negligible heat generation

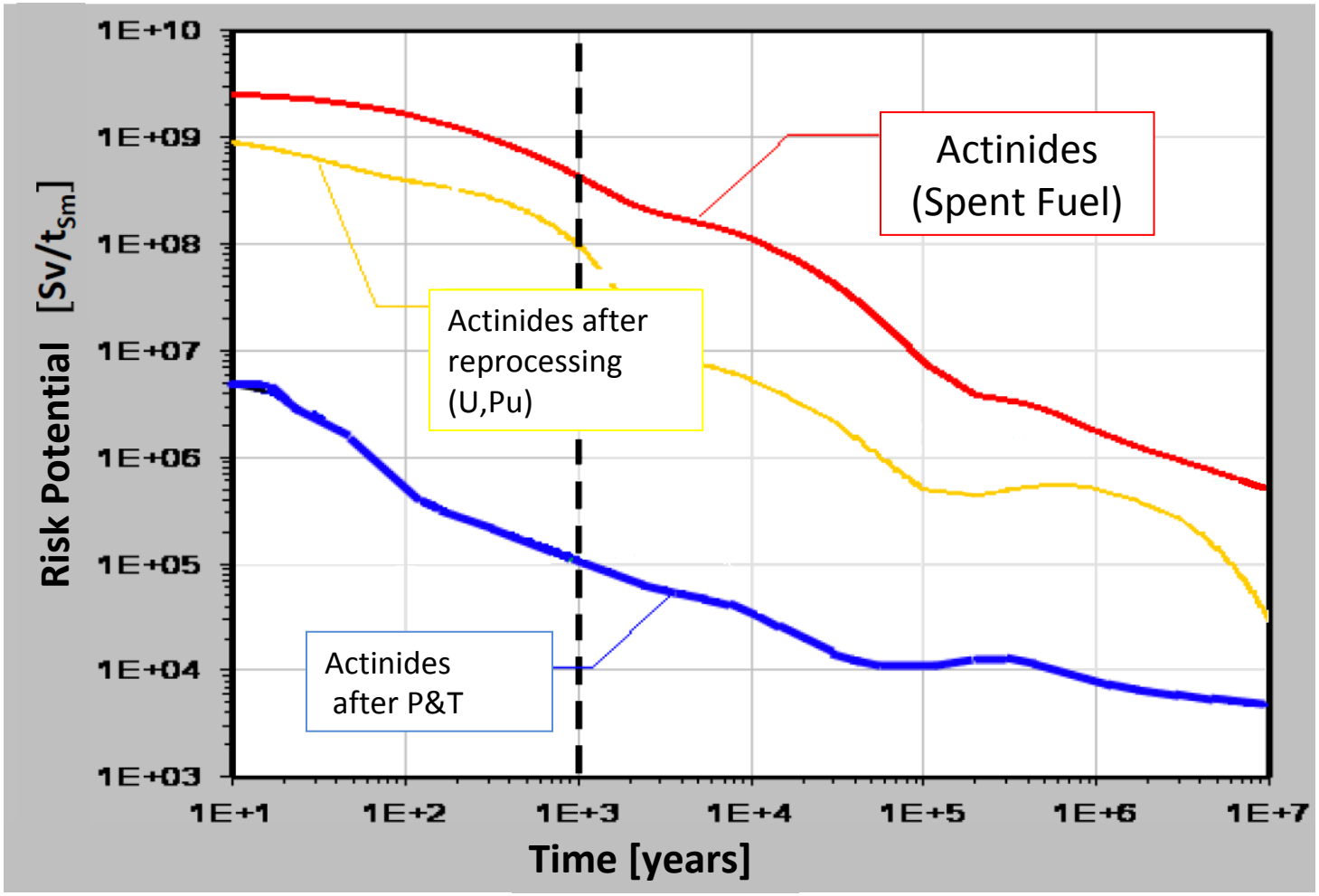
Konrad	2014/2015 40 - 80 years of operation
Morsleben	1978 - 1998
Asse	1967 - 1978

High Level Waste with heat generation

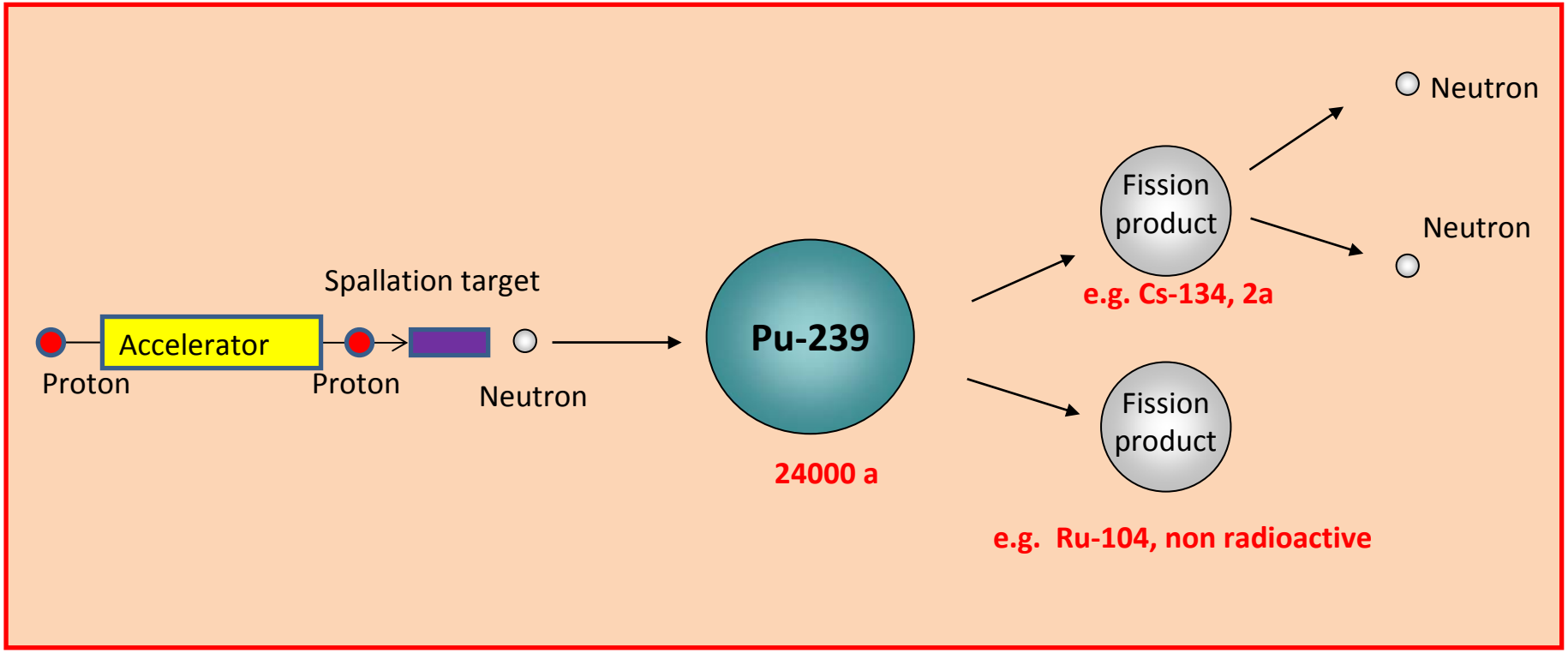
Gorleben	operation will start in 2035 at the earliest, if the suitability can be demonstrated

- There is no final disposal for HLW so far!

Comparison of waste management strategies



Principle of Transmutation

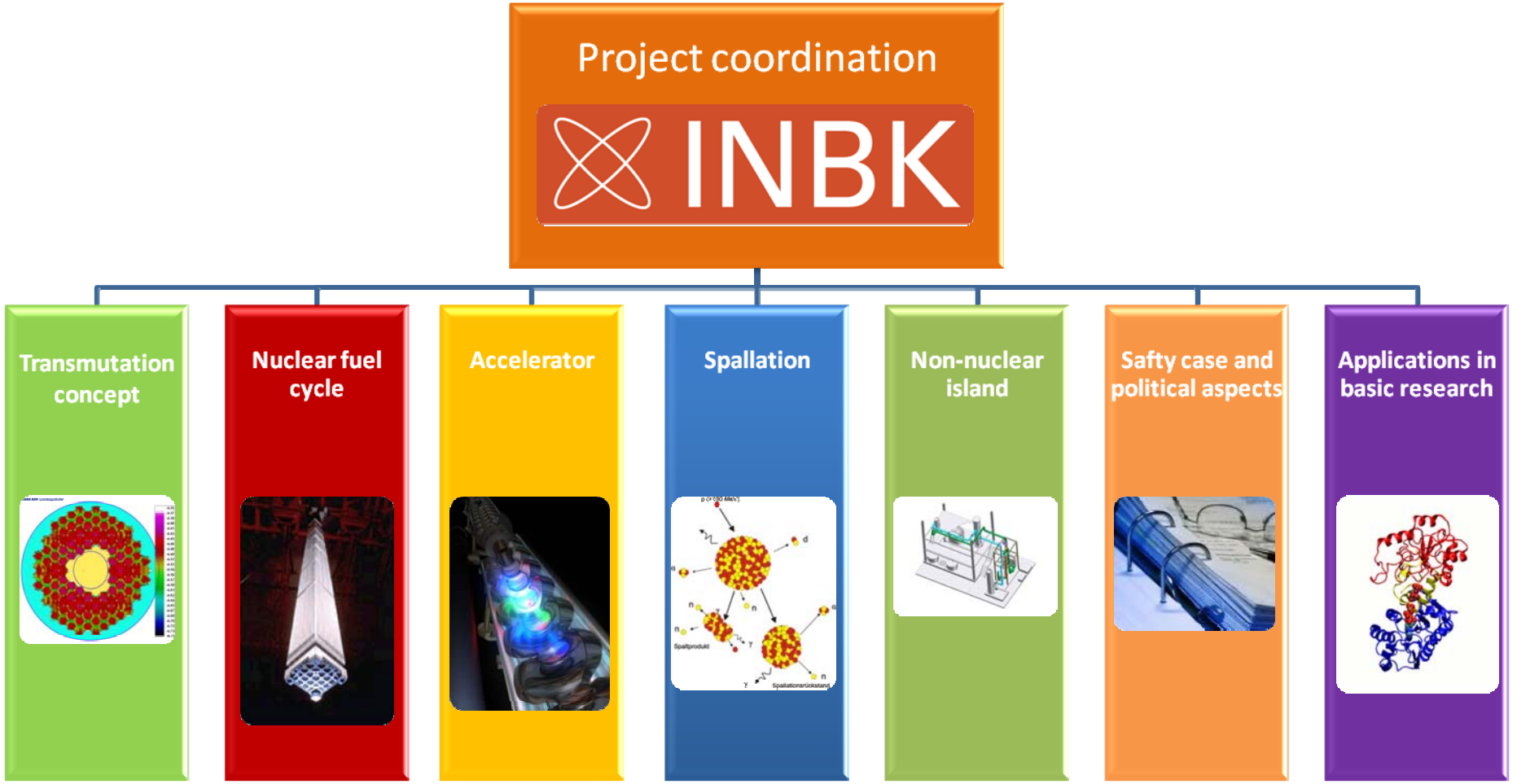


Accelerator-Driven System (**ADS**) = Subcritical reactor system with fast neutron spectrum (Spallation neutron induced fission reaction)

Investigation in P&T

- Project Partners:
  - INBK/RWTH - Institute for Nuclear Fuel Cycle Aachen
  - FZJ - Research Center Jülich
  - Siemens
  - Fias - Frankfurt Institute of Advanced Sciences
- Development of an **a**ccelorator driven subcritical **ga**s cooled **t**ransmutation **e**xperiment (AGATE)
- Targets:
  - compatible with phase-out policy
  - subcriticle system
  - Development of a feasibility study
    - Start: October 2009
    - Termination: February 2011

Feasibility study

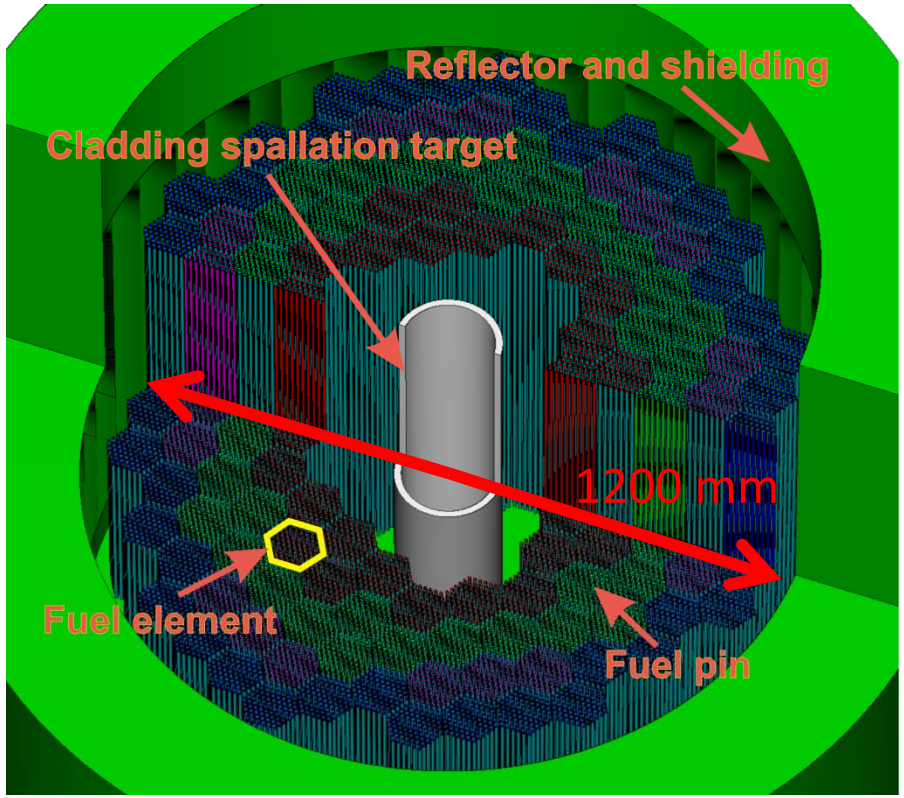


Main questions of the study

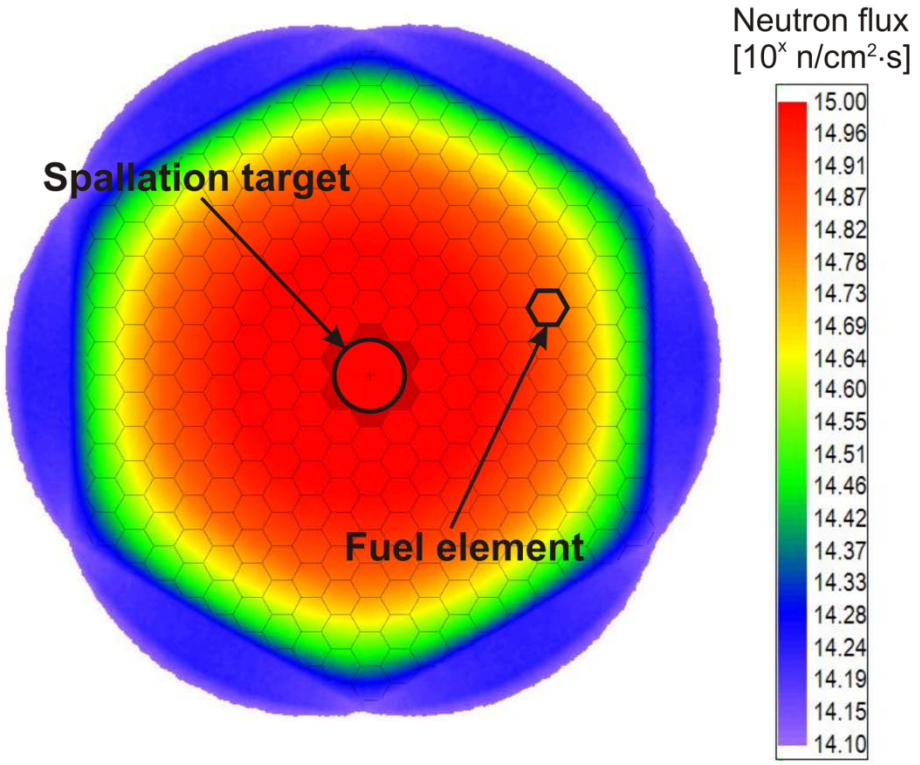
- Nuclear Fuel
- Accelerator
- Neutron Source (Spallation Target)
- Neutronics and Thermal Hydraulics of an subcritical gas-cooled reactor
- Benefits of the AGATE concept for the final disposal of High Level Waste

Layout of the undercritical reactor

Design of the reactor core



Neutron flux distribution



Cross section of the reactor core

Advanced Nuclear Systems, International Concepts

- **ASTRID:** Sodium-cooled **fast breeding** reactor (CEA, EDF - France)

- **ALLEGRO:** European Gas-cooled **fast breeding** reactor (AEKI Budapest, UJV Rez and VUJE Trnava – Czech Republic, Hungary and Slovakia)

- **MYRRHA:** Lead-Bismuth-cooled undercritical/**fast breeding** reactor, which will also run in an ADS mode (critical / subcritical system) (SCK●CEN - Belgium)

- **AGATE:** Subcritical gas-cooled accelerator-driven system, with the main focus on transmutation (RWTH, FZJ, FIAS, Siemens - Germany)

AGATE in comparison with MYRRHA

AGATE (He / CO_2)

Advantages

- Simplified fuel element handling
- Simplified decontamination in case of a fuel element defect
- Advantages in licensing process because of the experiences with HTR
- Higher flexibility of the spallation target layout
- Exchangeable beam window and spallation target
- Linear neutron source

Disadvantages

- Lower heat capacity of the coolant
- Higher operational pressure

MYRRHA (Lead / Lead-Bismuth)

Advantages

- Higher heat capacity of the coolant
- Lower operational pressure

Disadvantages

- Corrosion of the structural material
- Contamination of the whole coolant in case of a fuel element defect
- Complex handling of the fuel elements
- Activation of the coolant $^{209}Bi \rightarrow {}^{210}Po$

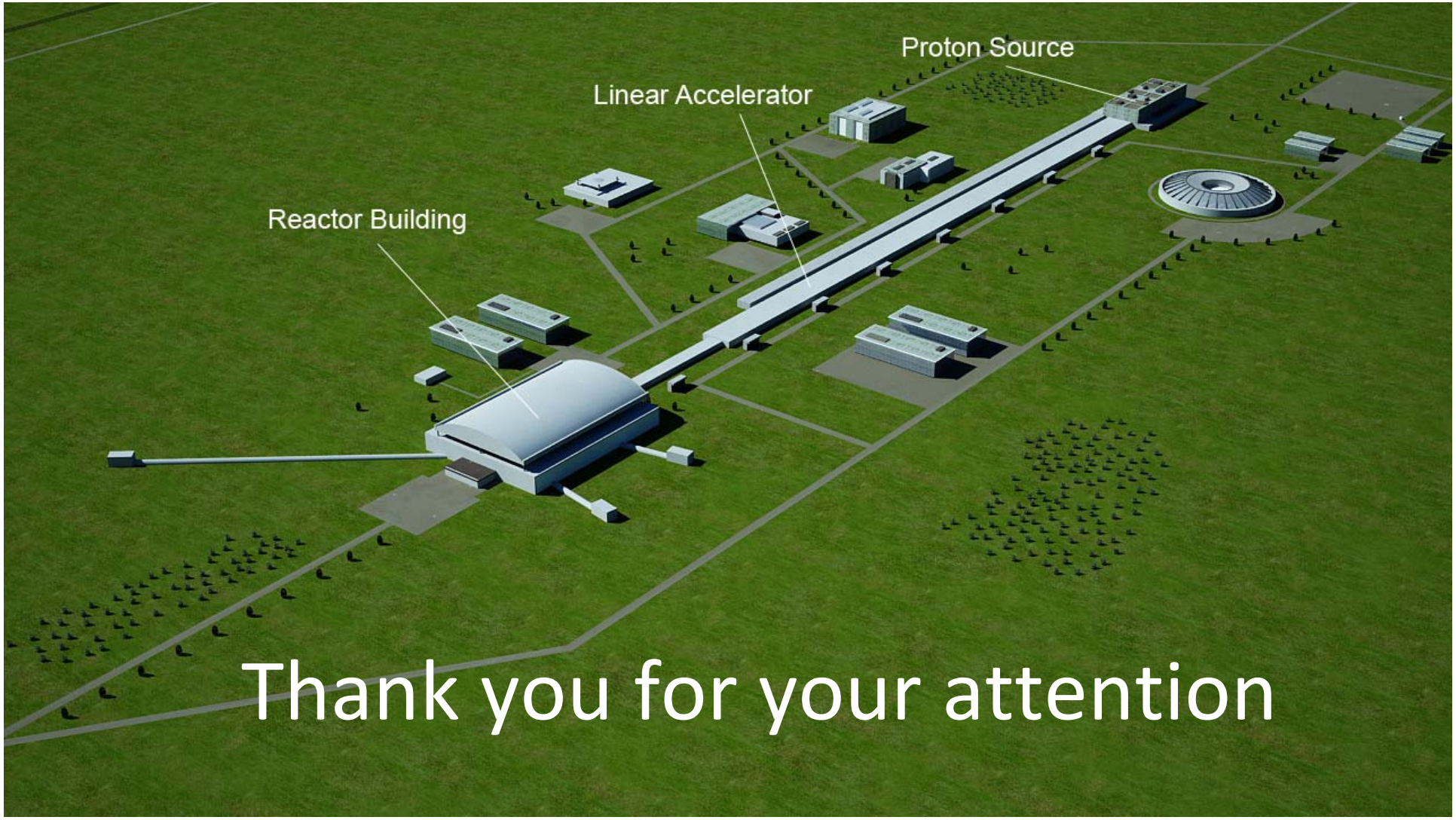
Next steps

- Decision making process for a German participation in the Myrrha project
- Further development of the gas cooled subritical device AGATE
- Initiation of the decision making process, if P&T should be integrated in the final disposal strategy

Conclusion

- Partitioning and Transmutation contribute **if feasible** to a reduction of radiotoxicity and thermal power of High Level Waste.
- The subcritical Accelerator-Driven System is appropriate to contribute to the High Level Waste reduction.
- The feasibility study of the AGATE concept will show the technical specifications of a Gas-cooled ADS and its components.
- Research and technical developments are necessary to finally show the technical feasibility of a transmutation device.
- Besides Myrrha AGATE could be a demonstrator facility for a Gas-cooled Fast Reactor.

AGATE – Concept of a demonstrator facility



AGATE – Concept of a demonstrator facility