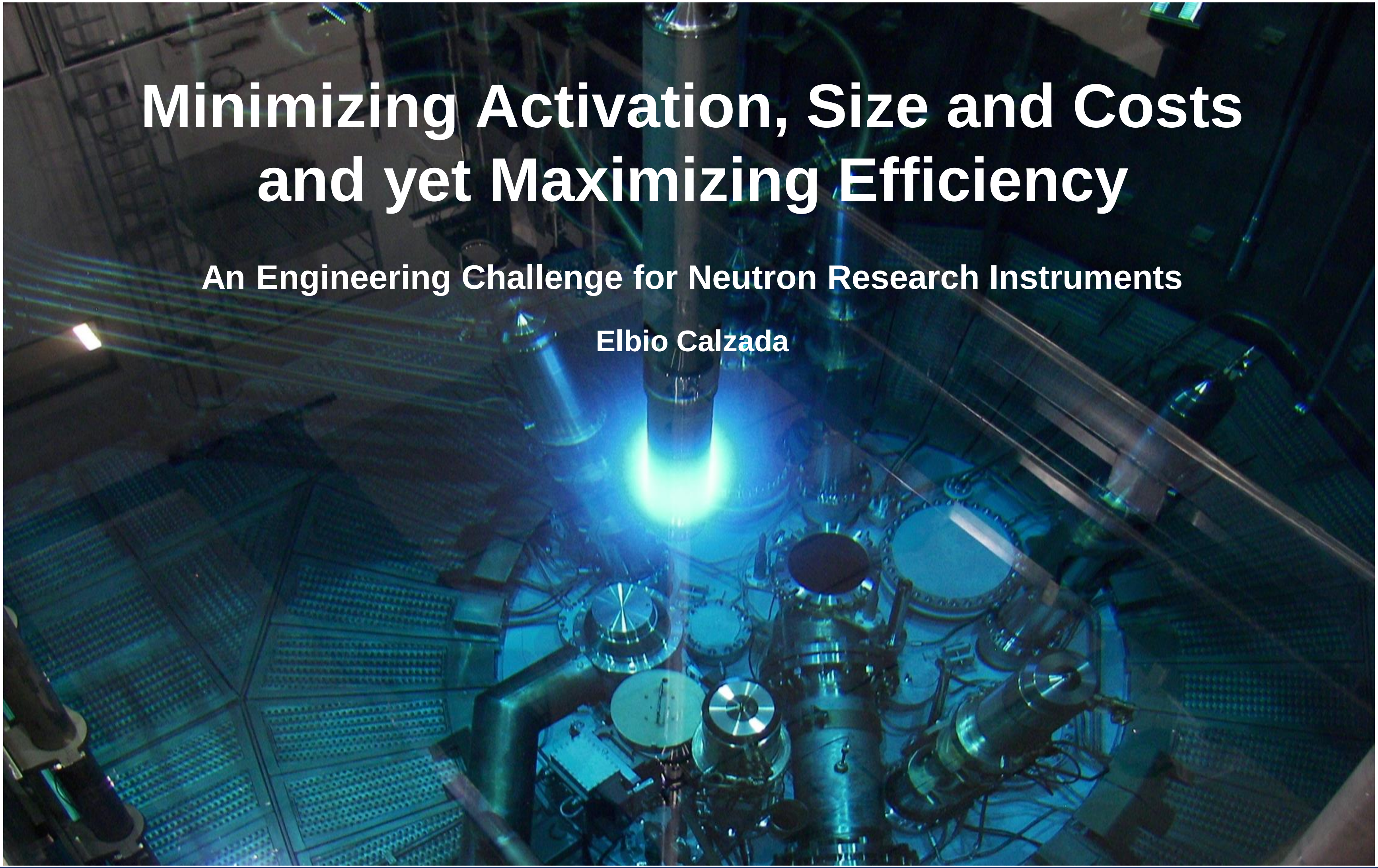
FRM II
Forschungs-Neutronenquelle
Heinz Maier-Leibnitz

MLZ
Heinz Maier-Leibnitz Zentrum

Minimizing Activation, Size and Costs and yet Maximizing Efficiency

An Engineering Challenge for Neutron Research Instruments

Elbio Calzada



MLZ is a cooperation between:

JÜLICH FORSCHUNGSZENTRUM

Helmholtz-Zentrum Geesthacht
Zentrum für Material- und Küstenforschung

TUM
Technische Universität München

Outline

- Introduction:
  - Neutron Source FRM II
  - Experimental Halls

- Experiences with Materials: the Good and the Ugly.
- Experiences with Shielding Elements
- Developement of a Reusable Shielding Material for Neutron and Gamma Radiation

- Conclusions

Research Center Garching

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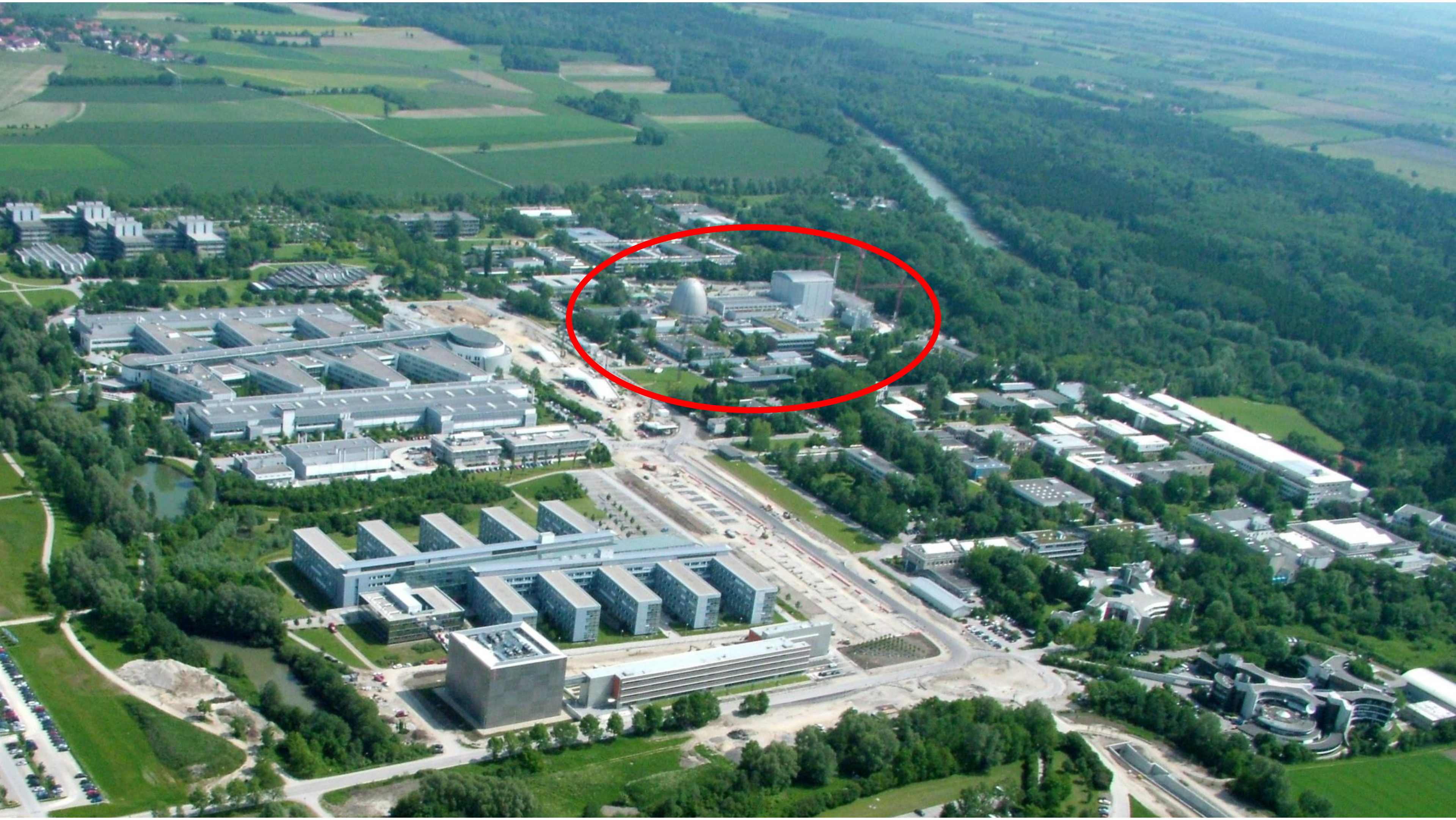

Neutron Source FRM II

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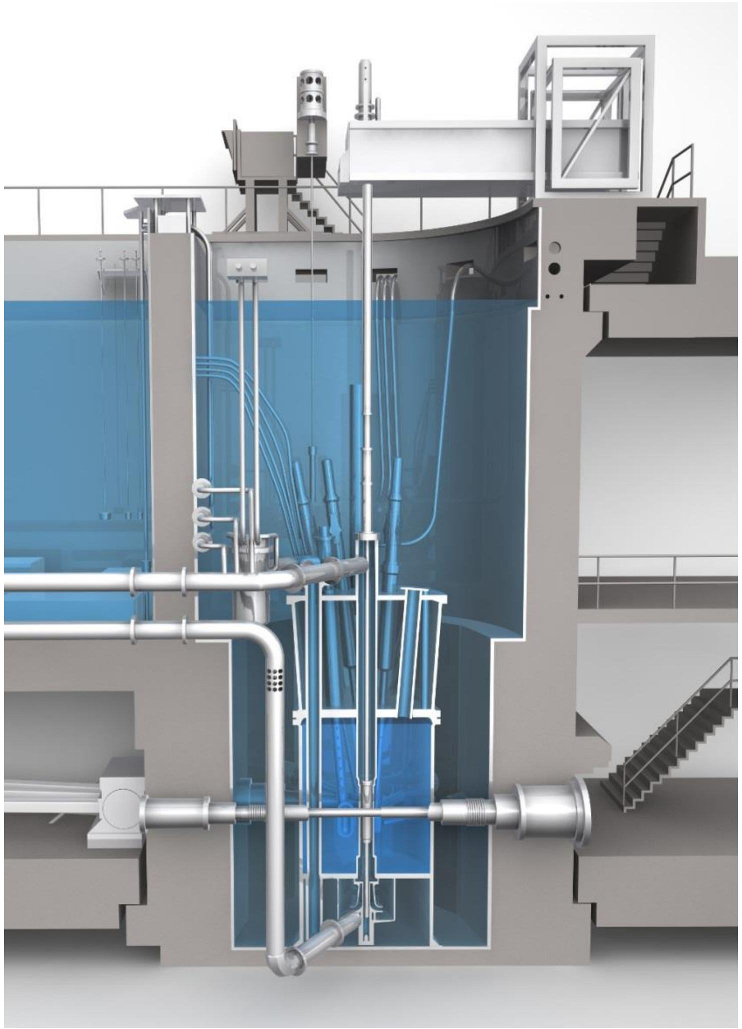
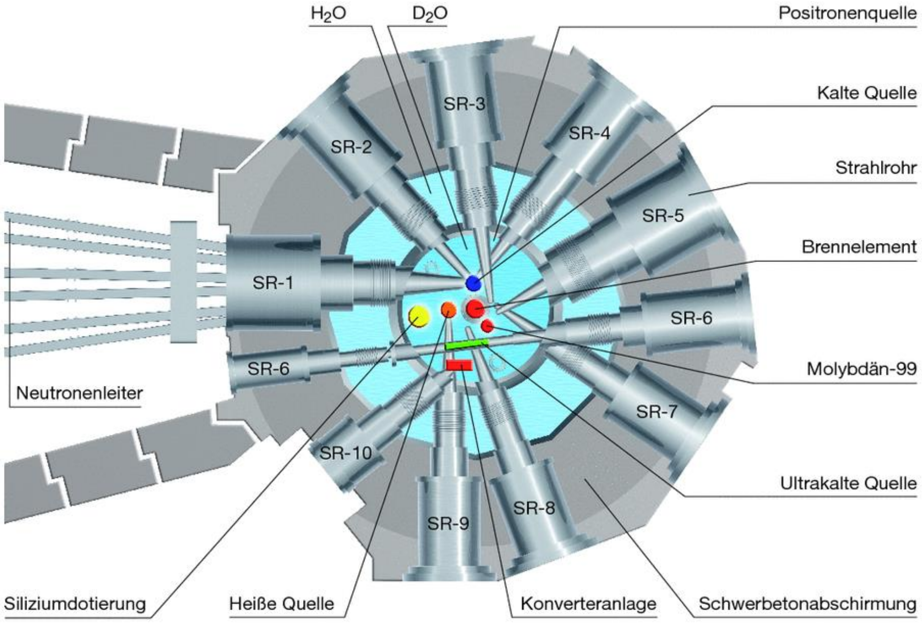
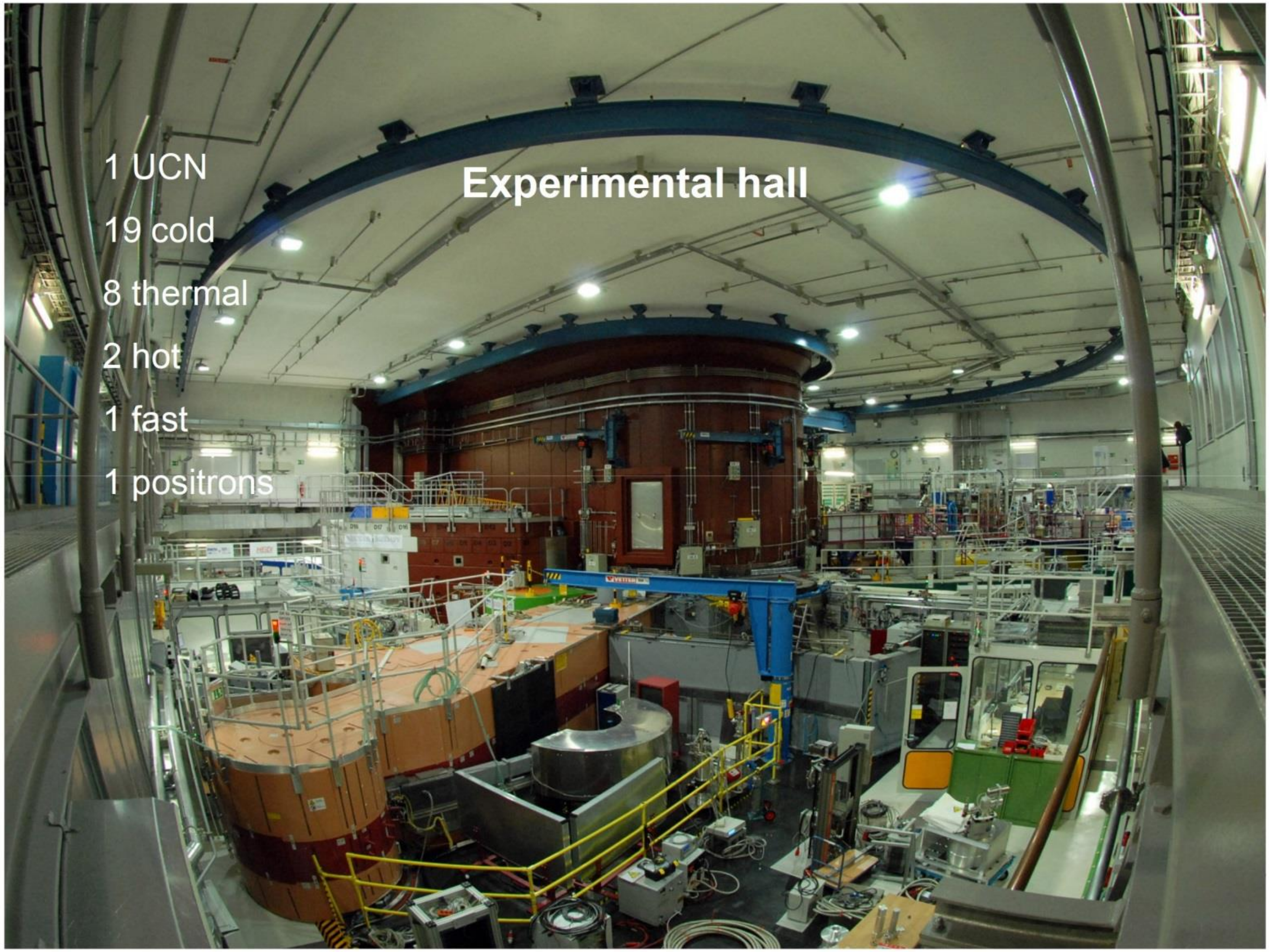
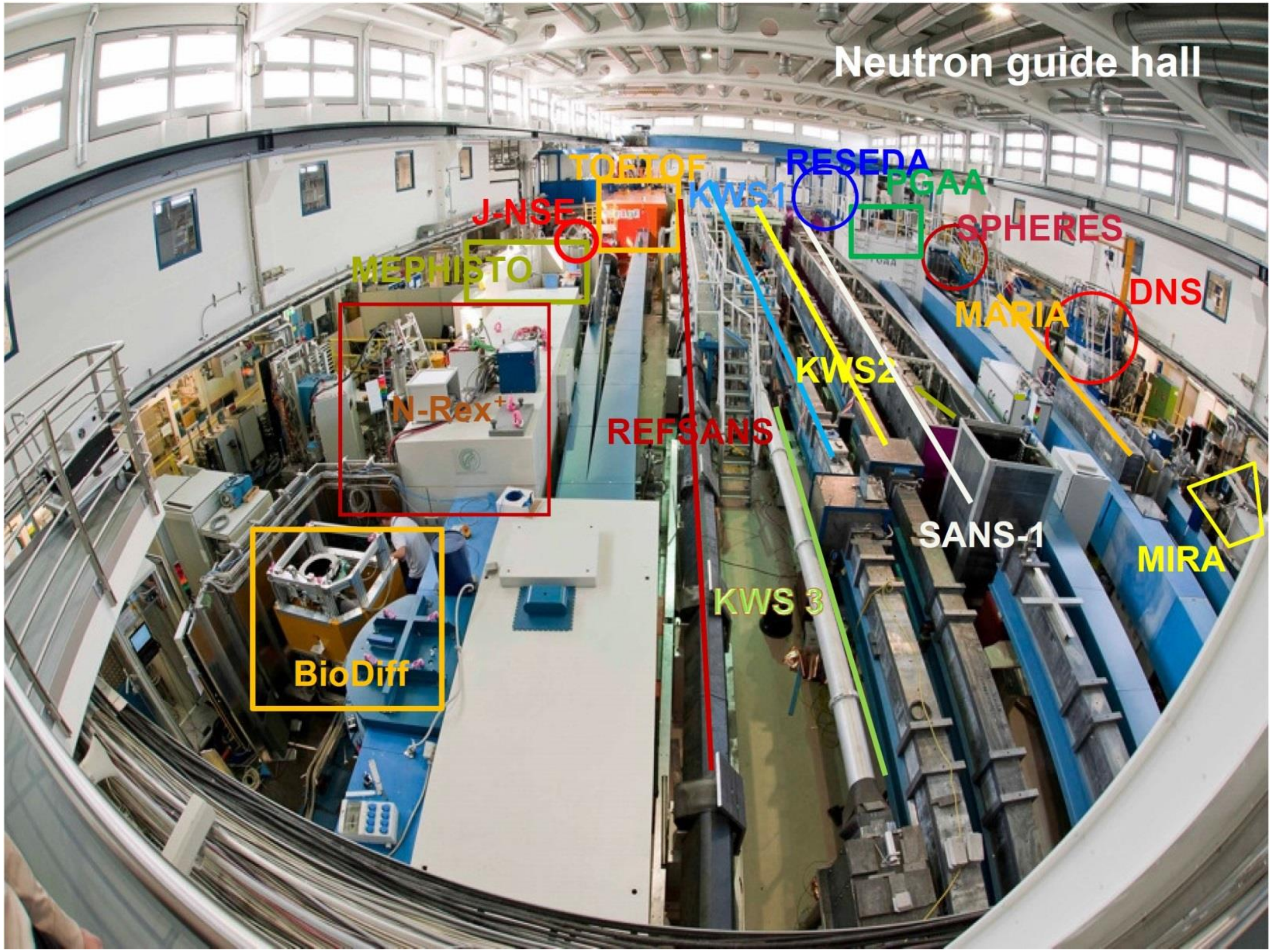




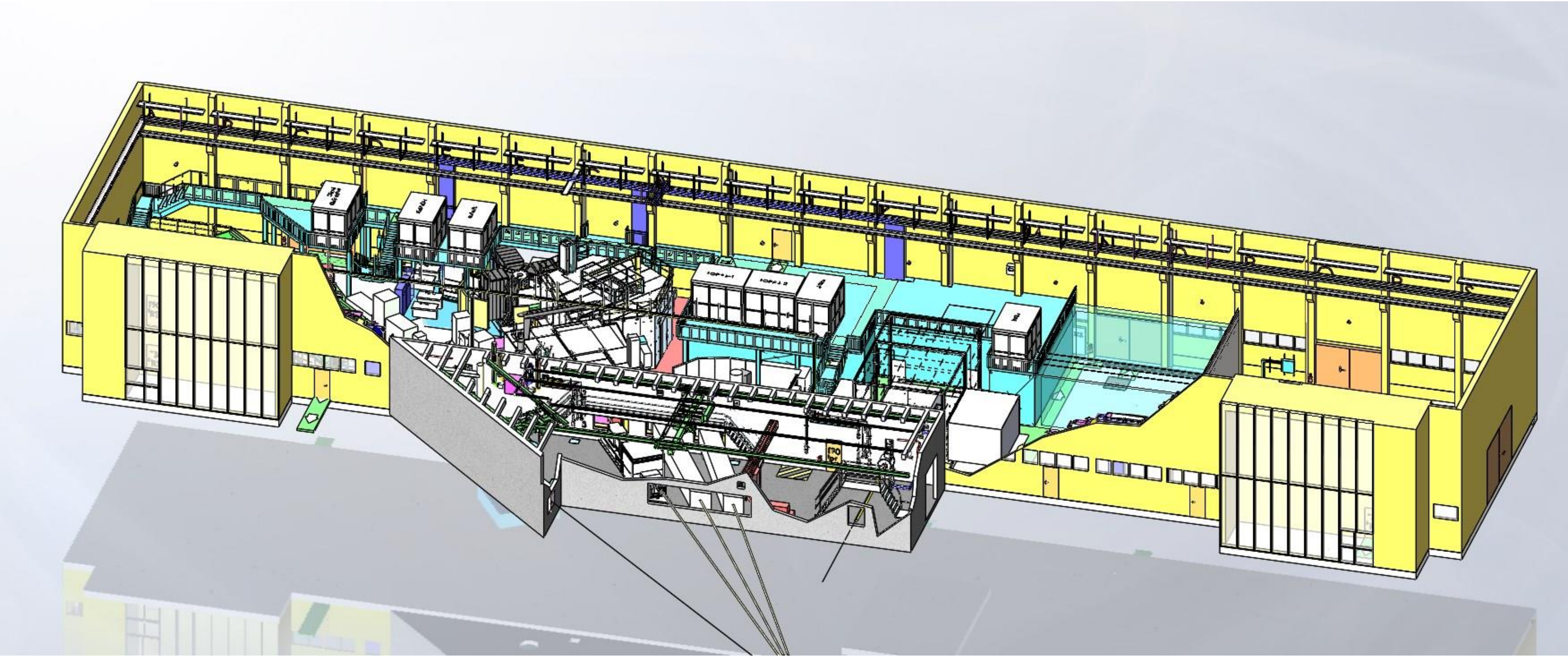
Experimental Hall at FRM II



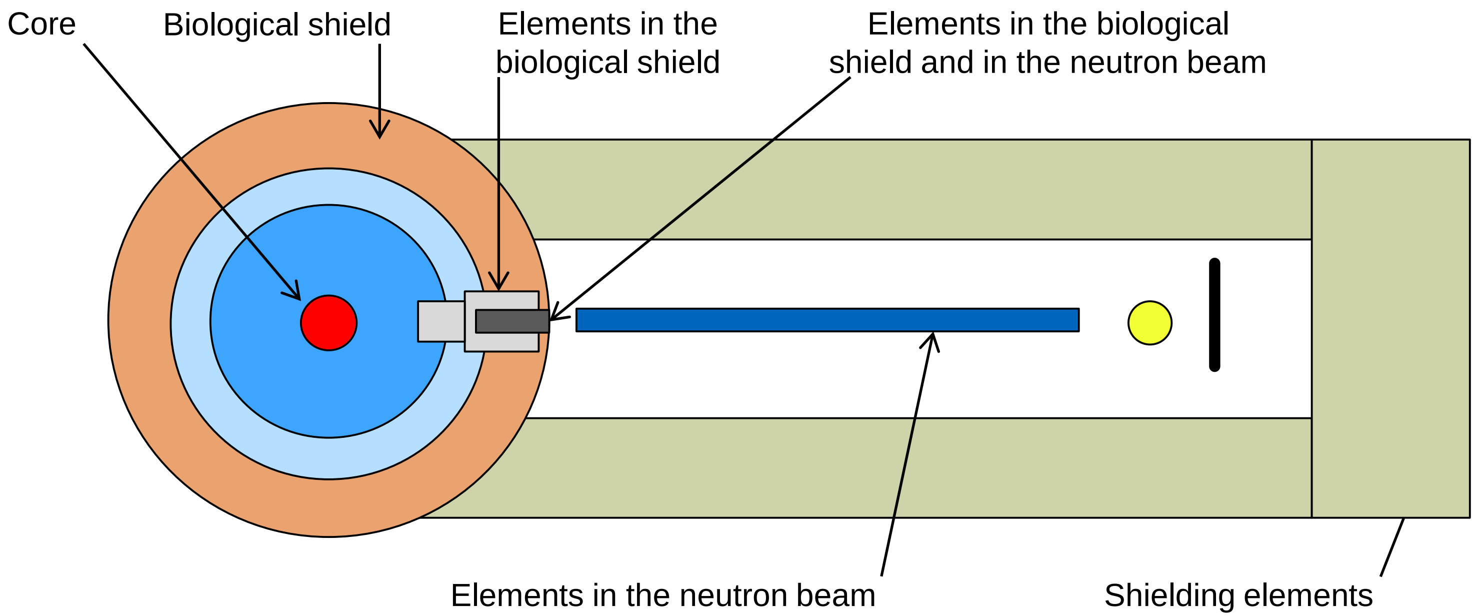
Neutron Guide Hall West at FRM II



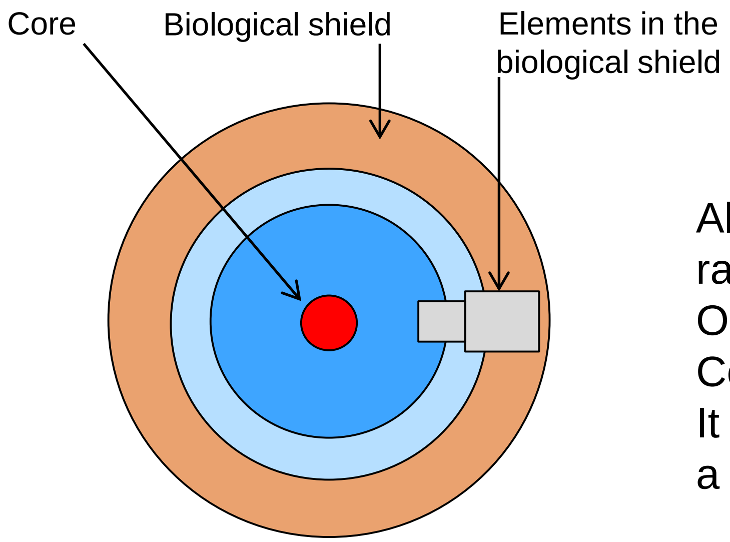
Neutron Guide Hall East at FRM II



Activation in Materials



Activation:
Elements in the Biological Shield



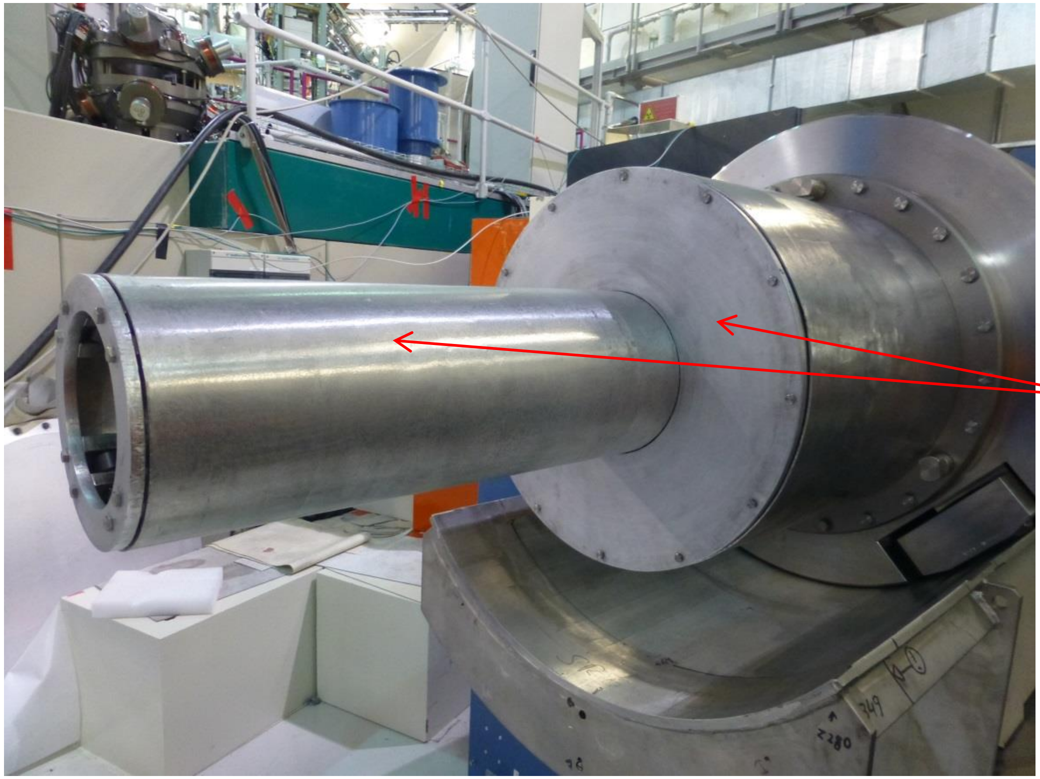
All materials in contact with neutrons become radioactive.
One of the most uncomfortable material is Cobalt.
It is present mostly in stainless steels and has a half life of 5 years.

Example 1: Elements in the Biological Shield of the Reactor

Plate made of
stainless steel (Co)

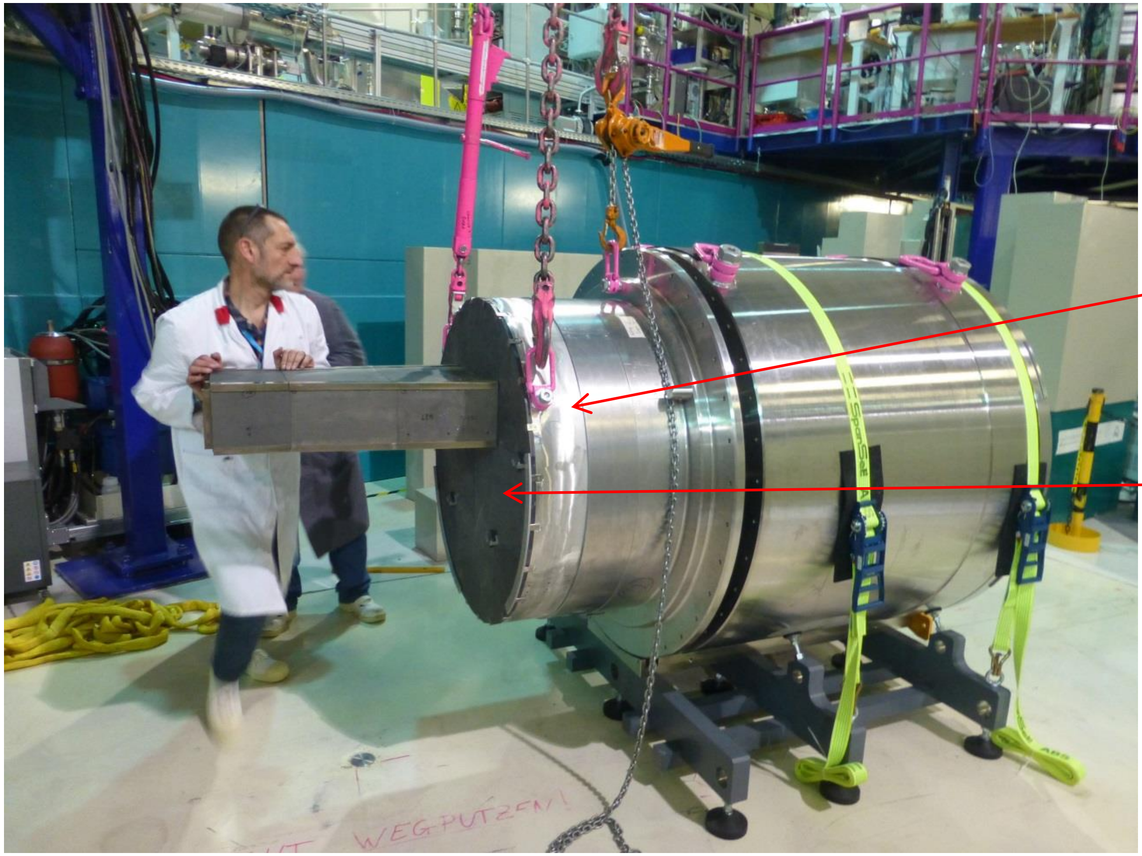
after 10 years in operation the front part gets a dose rate of 5 Sv/h

Example 1: Elements in the Biological Shield of the Reactor



Coating made of borated aluminum

Example 2: Elements in the Biological Shield of the Reactor

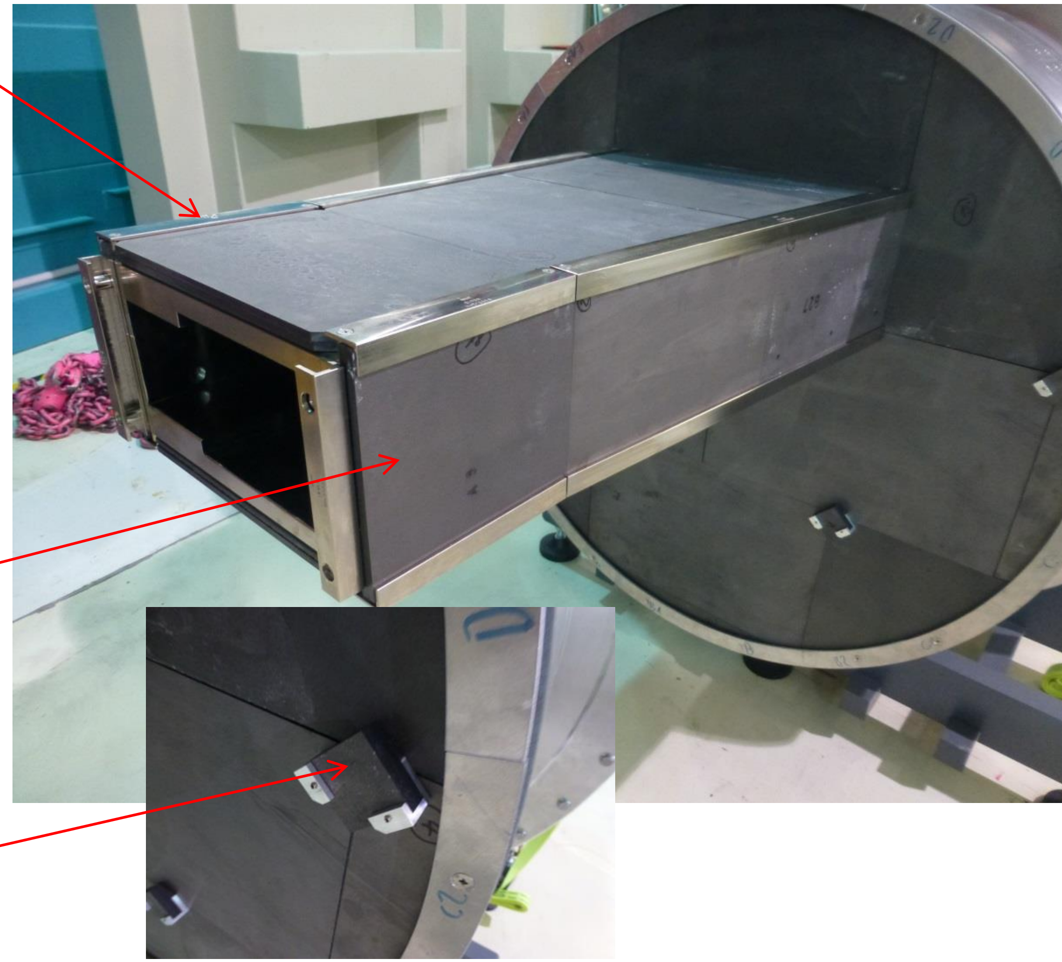


Coating made of borated aluminum

Coating made of boron carbide plates

Example 2: Elements in the Biological Shield of the Reactor

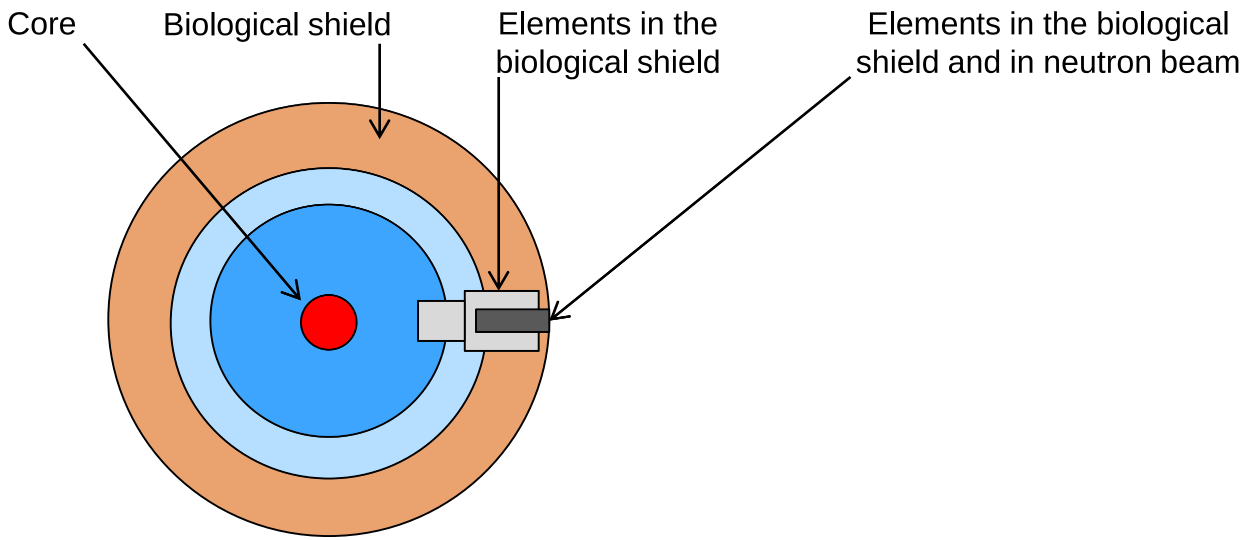
Fasteners made of titanium



Coating made of
boron carbide plates

Screws shielded with
boron carbide plates

Activation in Materials



Example 3: Elements Placed in Neutron Beam

Collimator made of low cobalt steel

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Collimator made of low cobalt steel

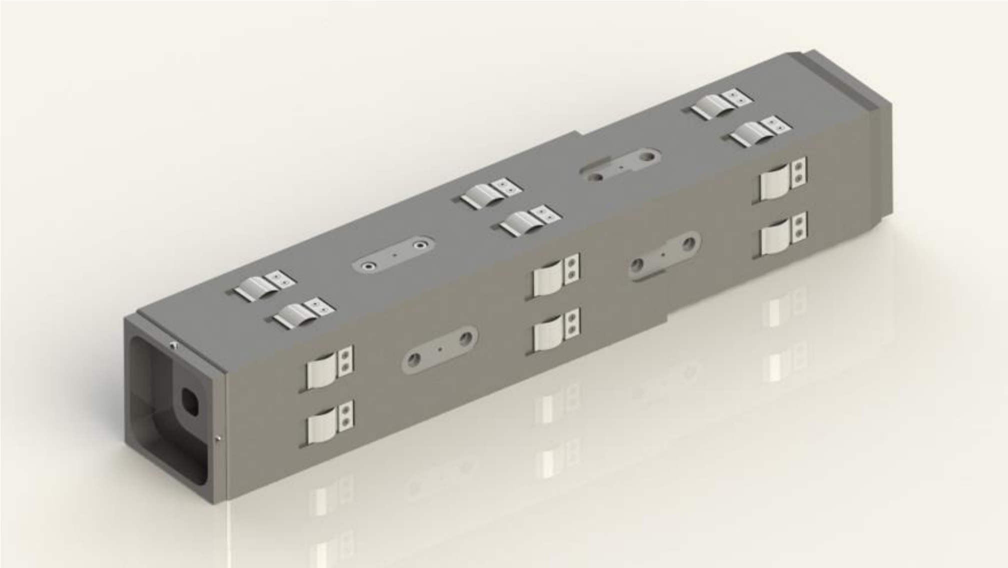
Example 3: Elements Placed in Neutron Beam

A hot cell was necessary to handle the activated collimators

Example 3: Elements Placed in Neutron Beam

Even small amounts of Cobalt contained in every steel become activated so much during operation that a later handling and removal becomes a major problem.

The new collimators are therefore manufactured from borated steel plates as they are used for nuclear power plant shielding. The cross section of the contained boron overshadows the iron cross section in order to decrease the activation.

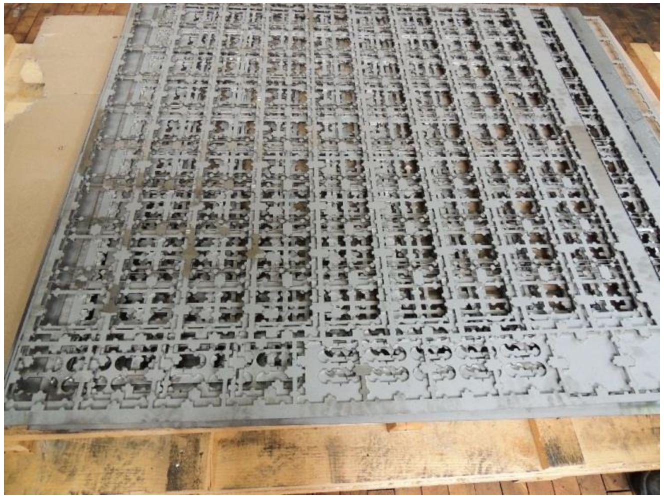


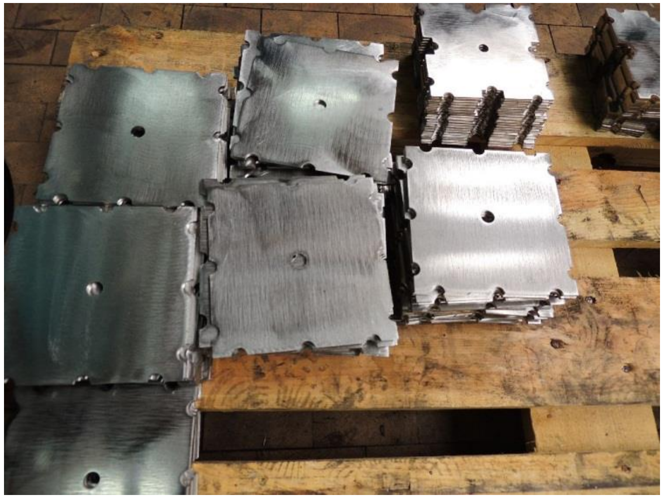
Example 3: Elements Placed in Neutron Beam

For the manufacture of the new collimators a steel alloy was used.

An Austrian company produces borated steel plates that contain up to 1.88 wt% boron in granular form, encased in the rolling process of steel plates.

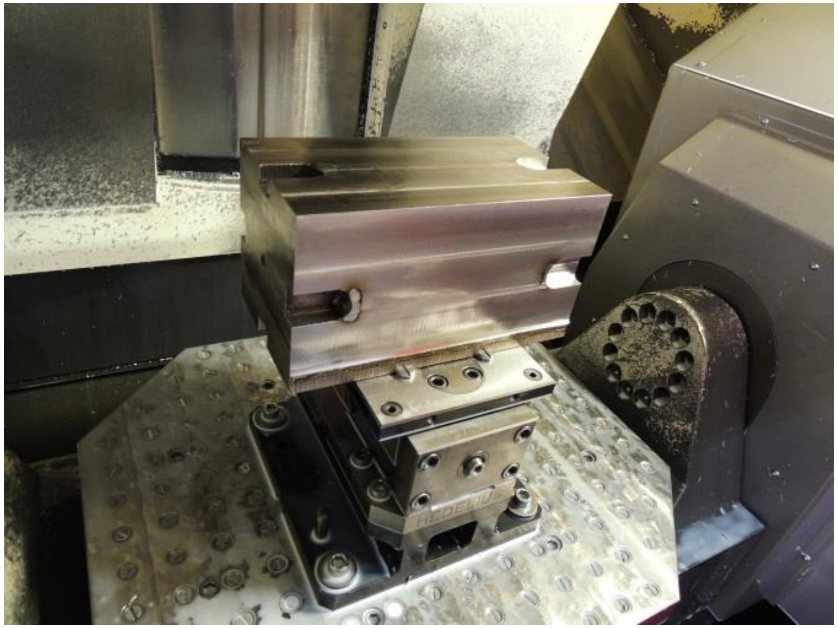
Since the boron is encased during the rolling process, this material is not available as semi-finished blocks, but only as sheet metal with a maximum thickness of 3.4 mm or less.





Example 3: Elements Placed in Neutron Beam

The cut-out pieces were stacked and aligned in a press, then welded together in the pre-fabricated grooves, forming a solid block in the process



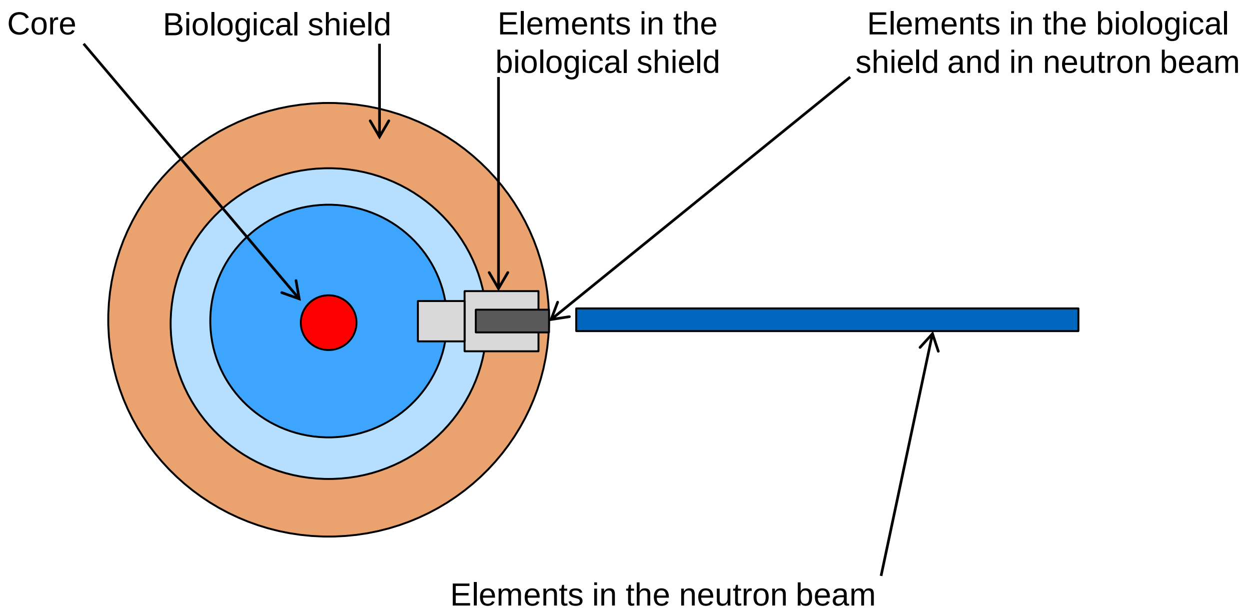
These blocks were placed in a milling machine and reduced to the required cross section

Example 3: Elements Placed in Neutron Beam

To produce the conical channels in the collimators, stepped layering by laser cutting of varying diameter holes had been considered.

Wire-cut electric discharge machining (wire EDM) with a threaded wire was the best way to cut the complicated contours of the pinhole camera projection.

Activation in Materials

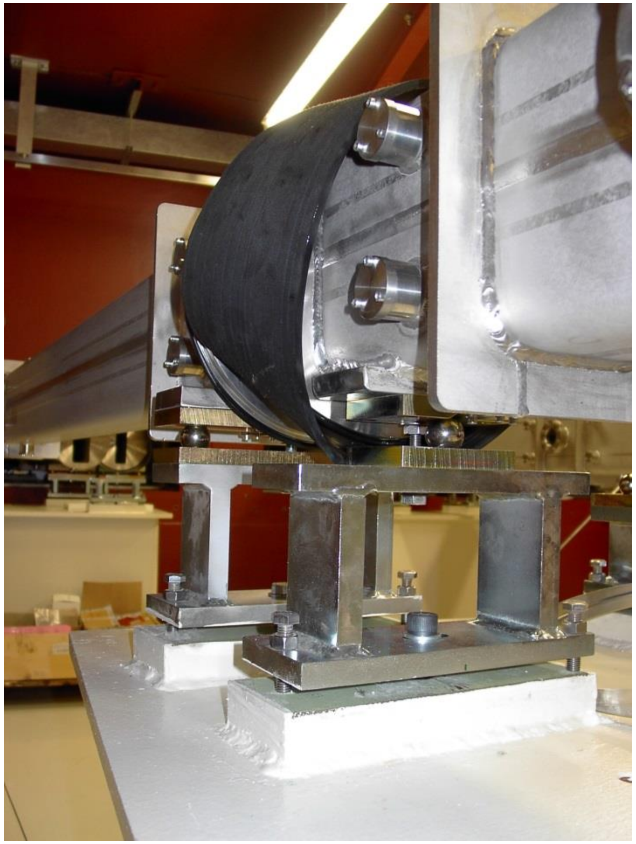


Example 4: Elements Placed in Neutron Beam

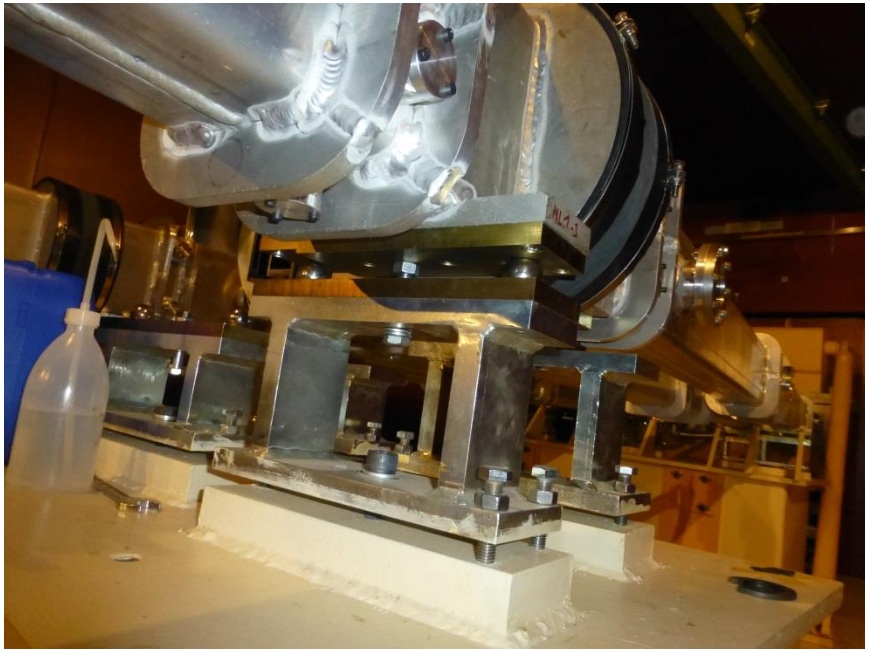
Neutron guides with vacuum tubes made of stainless steel (Co)

Example 4: Elements Placed in Neutron Beam

Vacuum tubes made of stainless steel (Co)

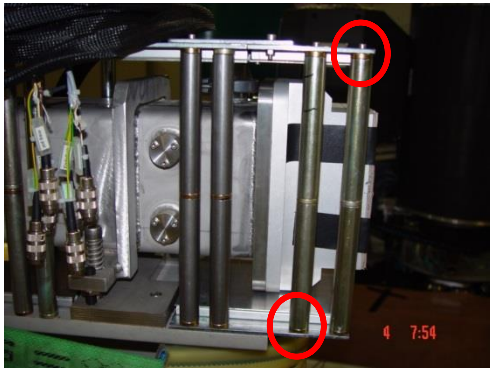


Vacuum tubes made of aluminum

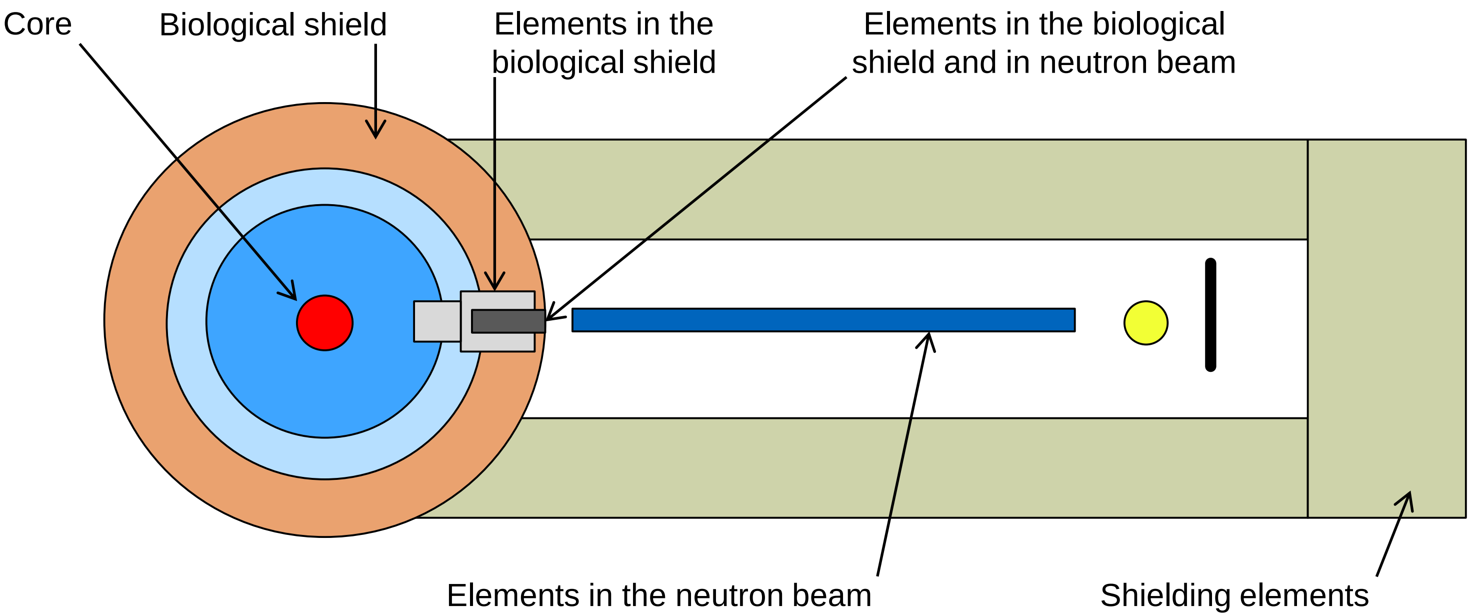


Example 5: Elements Placed in Neutron Beam

Neutron guides with cobalt coating



Activation in Materials

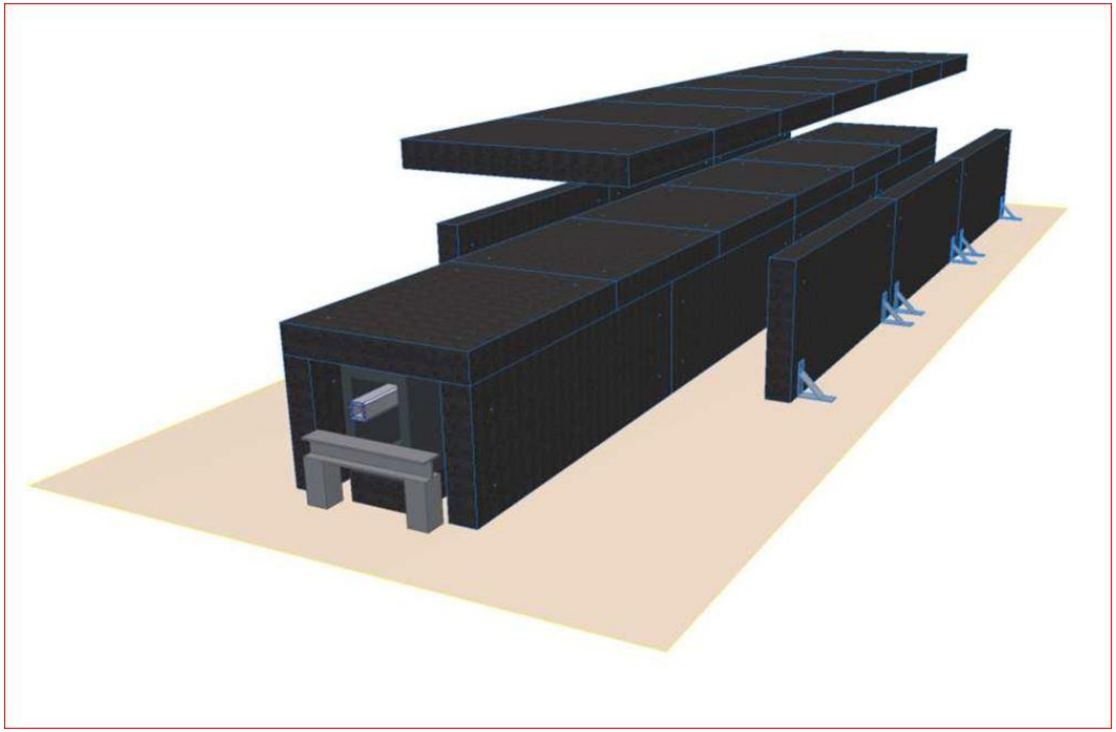


Shielding Elements for Neutron and Gamma Radiation

Some properties to be considered in the design of shielding elements:

- Whenever the areas of the reactor need to be accessed, the shielding elements must be able to be disassembled.
- The elements mu
- The joint betweer ... the interior of the inst
- The dose rate on ... ver than the dose rate stip ... led area.
- Shielding elemen
- Shielding elemen
- The surface must be ab ... ted.
- The activation in shieldi ... e be as low as possible.

Shielding Elements for Neutron and Gamma Radiation



- Manufacturing Cost
- Installation Cost / Time
- Decommissioning Cost

Shielding Elements for Neutron and Gamma Radiation

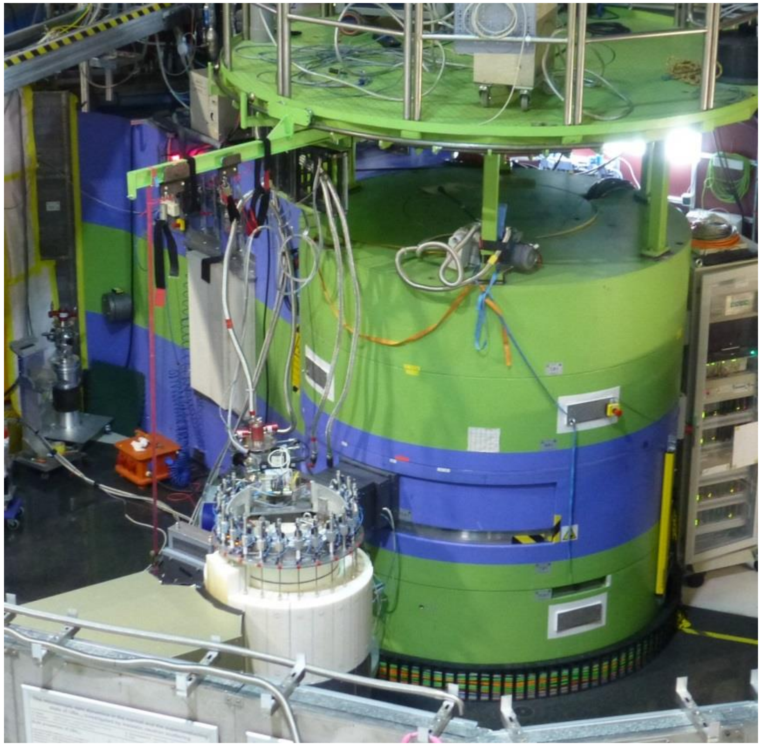
Typical challenges in places with limited space:

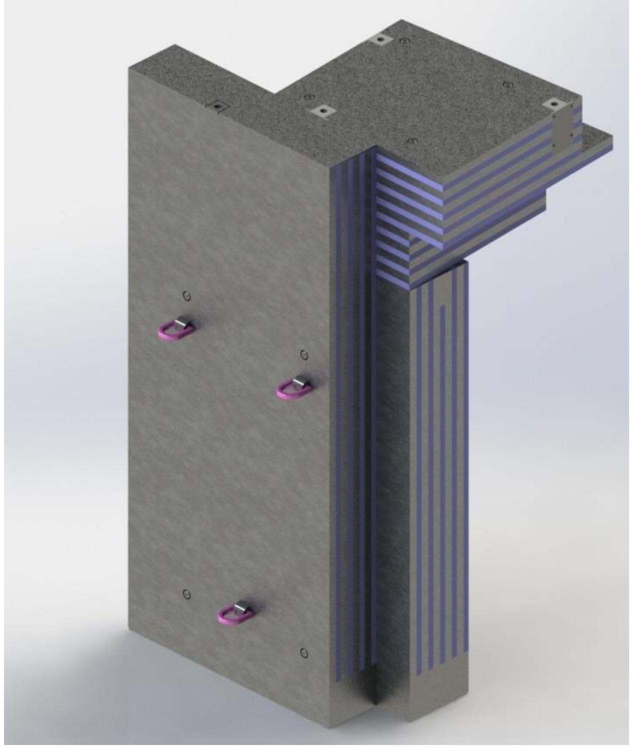
- With a limited wall thickness, the possible shielding properties may fall below the required value.
- For the required thickness, the load on the floor may be greater than allowed.

Shielding Elements for Neutron and Gamma Radiation

Material for typical shielding elements for neutron and gamma radiation

- Heavy concrete with or without formwork.
- Combination of steel and polyethylene plates





Shielding Elements for Neutron and Gamma Radiation

Disadvantages of heavy concrete shieldings:

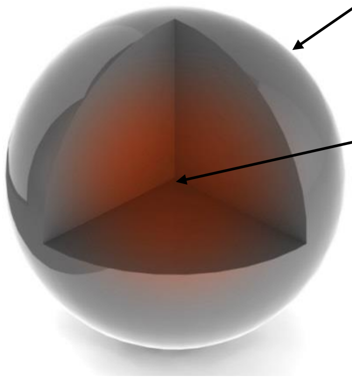
- Not all contained elements attenuate neutron- and gamma-radiation
- Available space at facility may be an issue
- Weight of shielding element may be an issue
- Processing difficult in winter time
- Decommissioning of concrete in steel containers is complex, costly and time consuming.

Reusable shielding material will have to consist of

- a neutron moderator based on hydrocarbon
- a neutron absorber based on B
- a gamma absorber based on Fe

Shielding Elements for Neutron and Gamma Radiation

First approach



Calculations

- Monte Carlo Model

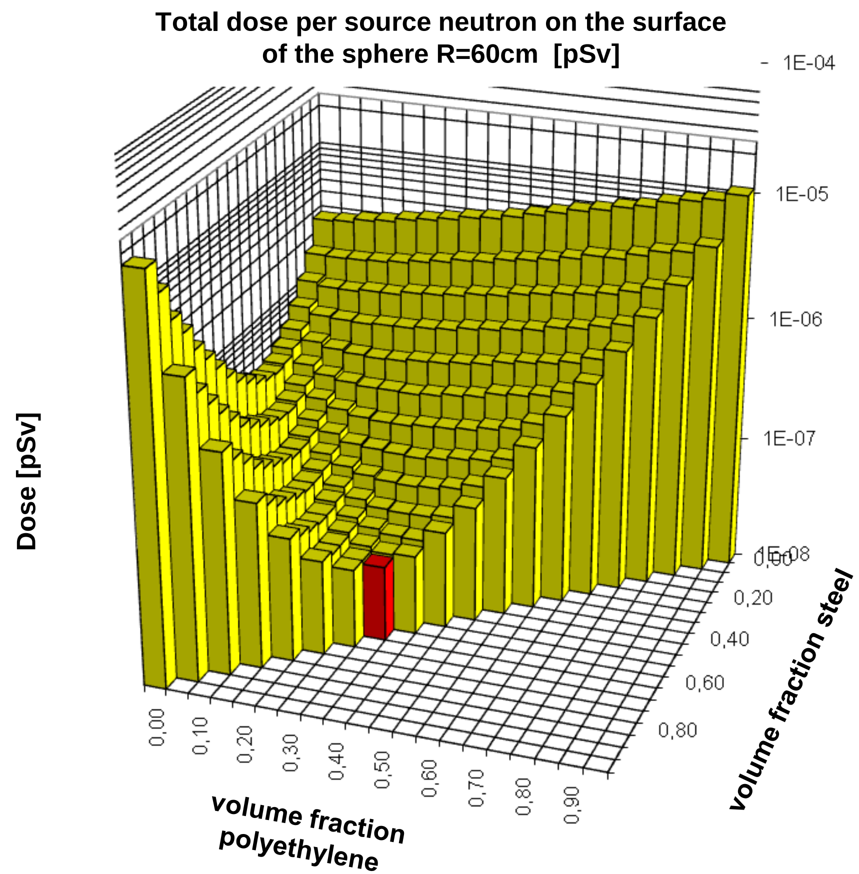
Objectives

- Explore the **optimal proportion** of polyethylene, iron and boron carbide to reach the lowest dose rate
- Explore the **ideal powder density** to reach the same shielding quality as concrete

Parameters

- Use of a sphere with a 60 cm radius and a theoretical powder density of 100%
- Use of two radiation sources for neutron- and gamma-radiation

First Approach



Result of Montecxarlo Simulations:

The lowest total dose rate at the surface of the simulation model assuming 100% powder density is reached with a mixture of

- 60 % Iron
- 35 % Polyethylene
- 5% Boron Carbide

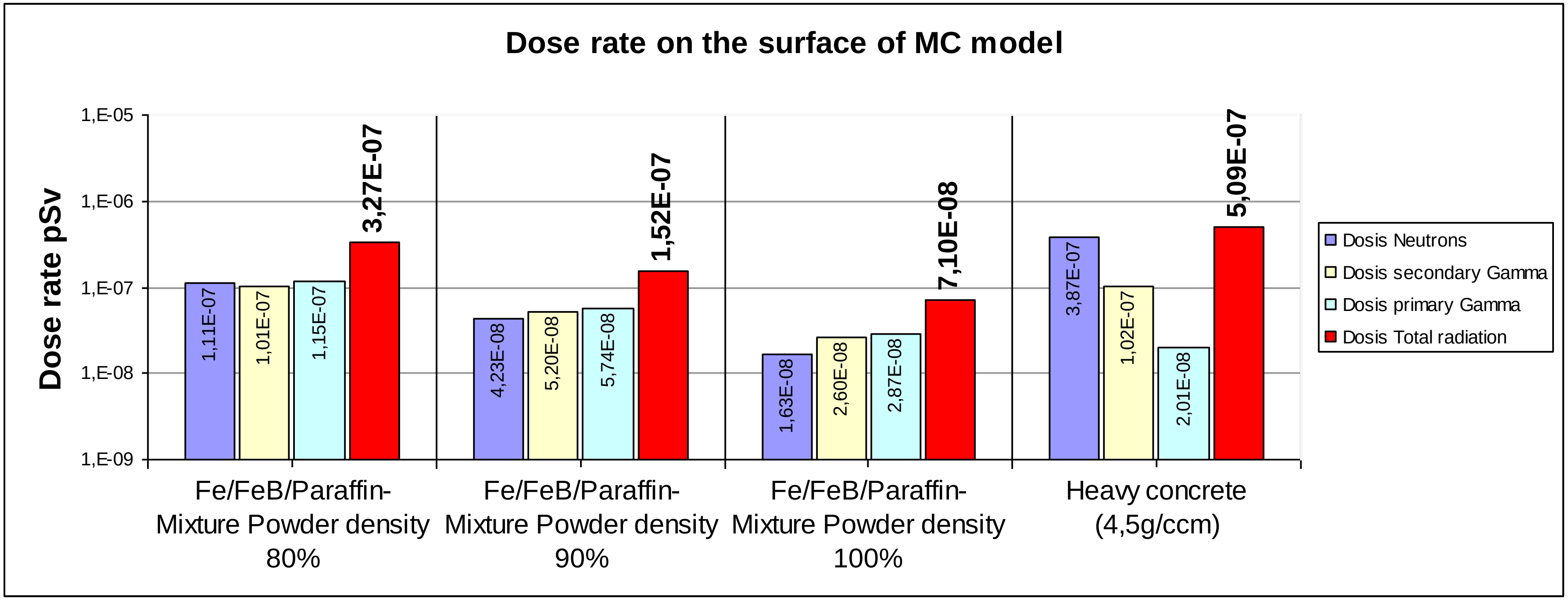
Three alternative models

Polyethylene pellets with boron and iron powder

Steel granulate with a layer of wax and boron powder

A mixture of iron powder, ferroboron powder and liquid paraffin

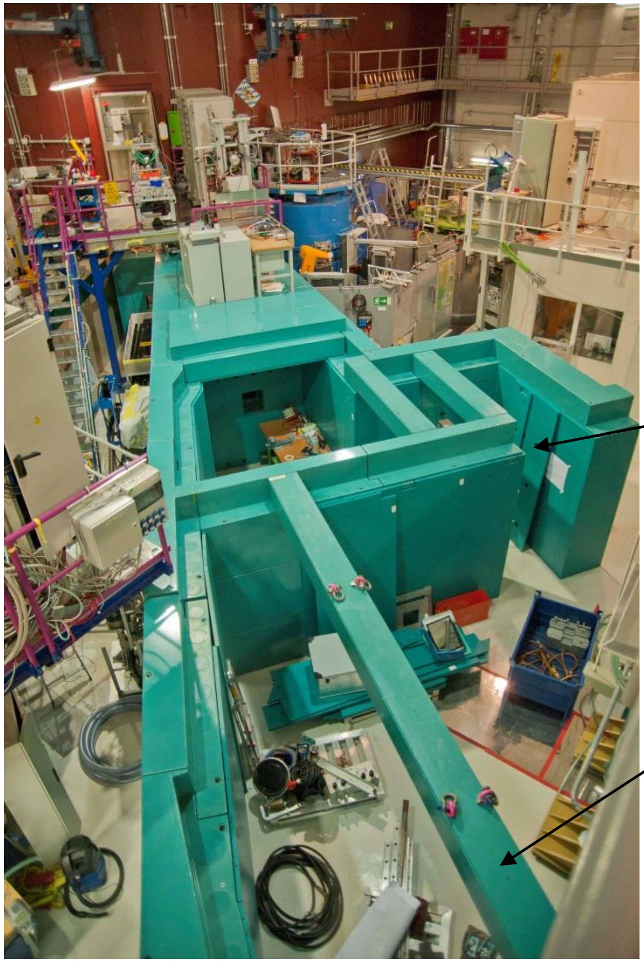
Ideal Powder Density



Result: A powder density of 80% is sufficient to reach the same shielding quality as heavy concrete.

Practical Implementation

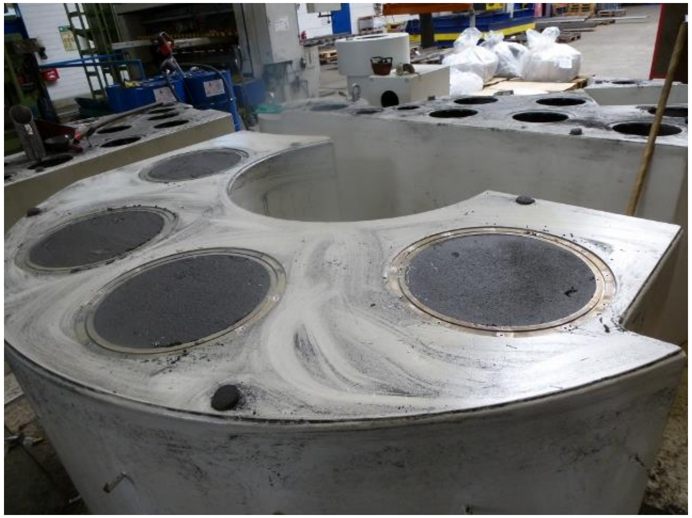
Filling holes

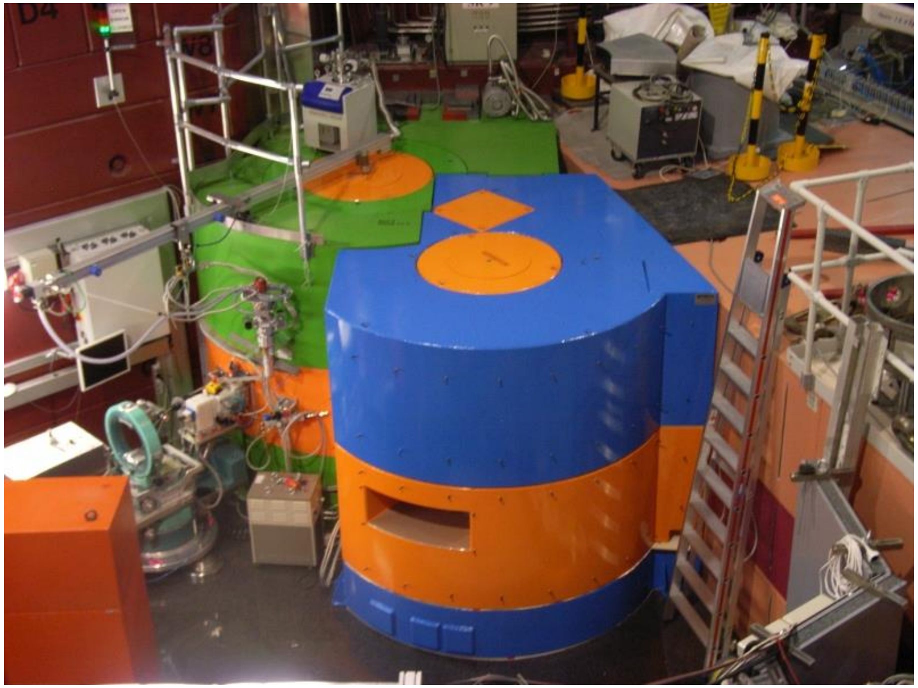


Borated polyethylene

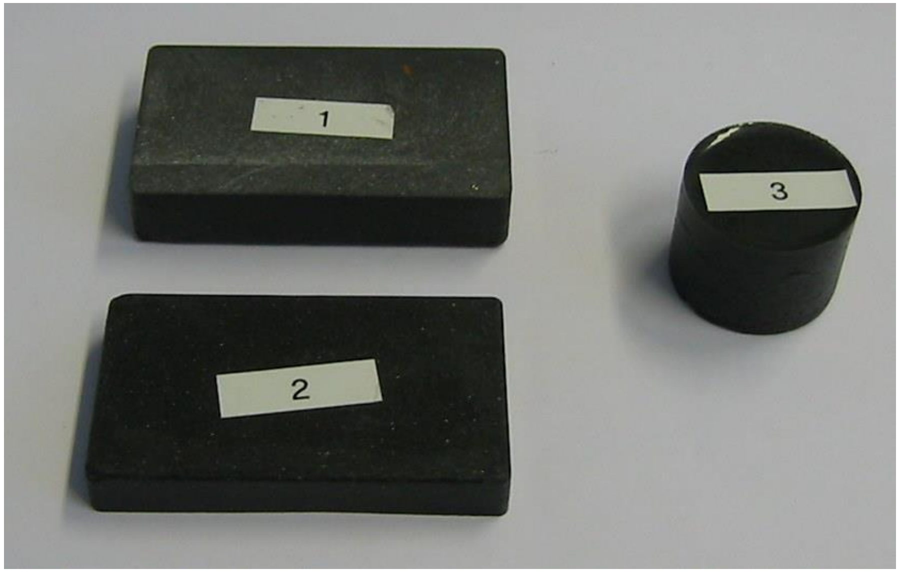
Iron beam filled with shielding material

Improvements:





Possible Applications:



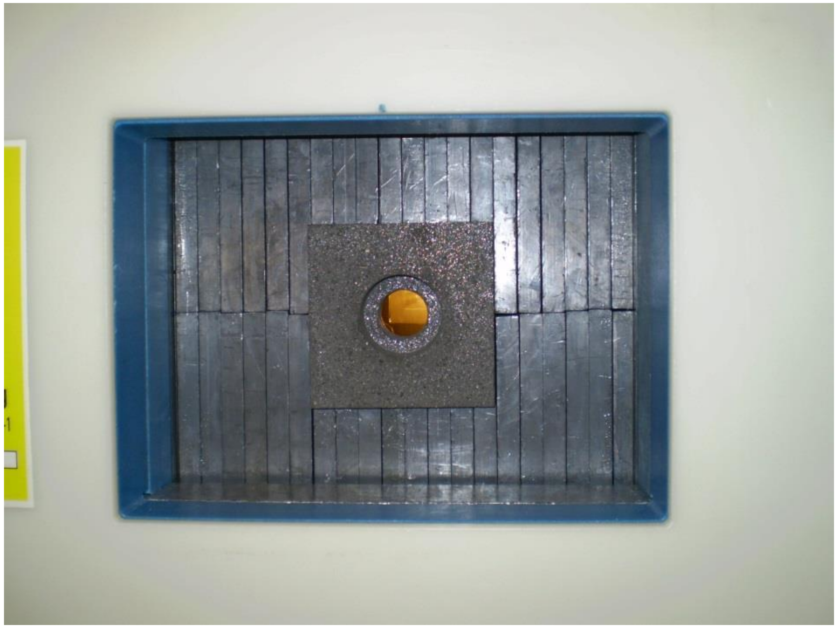
Mixture of Fe + FeB casted with epoxy resin

Density 4.7g/cm^3

This material can be finished with machine tools.

Inserts with screw thread can be mounted with precision.

Possible Applications:



Collimator components made of Fe + FeB + Epoxy resin

Conclusions:

- The selection of suitable materials is essential to guarantee the required functionality in each component of an instrument and to minimize its activation at the same time.
- The best choice of materials guarantees the efficient operation of the components of an instrument but also minimizes radioactive waste.
- In the long term, that choice can be the most cost-efficient.

About Shielding material:

- We have successfully developed a **truly innovative** shielding material for neutron- and gamma-radiation at FRM II.
- This new shielding material is **reusable**, has a **better shielding quality** than heavy concrete and is **cost-efficient**.
- Shielding elements with the same shielding effect that heavy concrete are **10 % to 20 % thinner.**
- This innovative shielding material is being **implemented** at the new facilities at FRM II.
- TU-München holds a **patent** for this innovative shielding material**.**

Thank you for your attention!

Questions are welcome...