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FRM-II

First Operational Experience with the Research Reactor FRM-II

H. Gerstenberg, J. Meier, C. Morkel,
I. Neuhaus, K. Schreckenbach,
TU München, FRM-II

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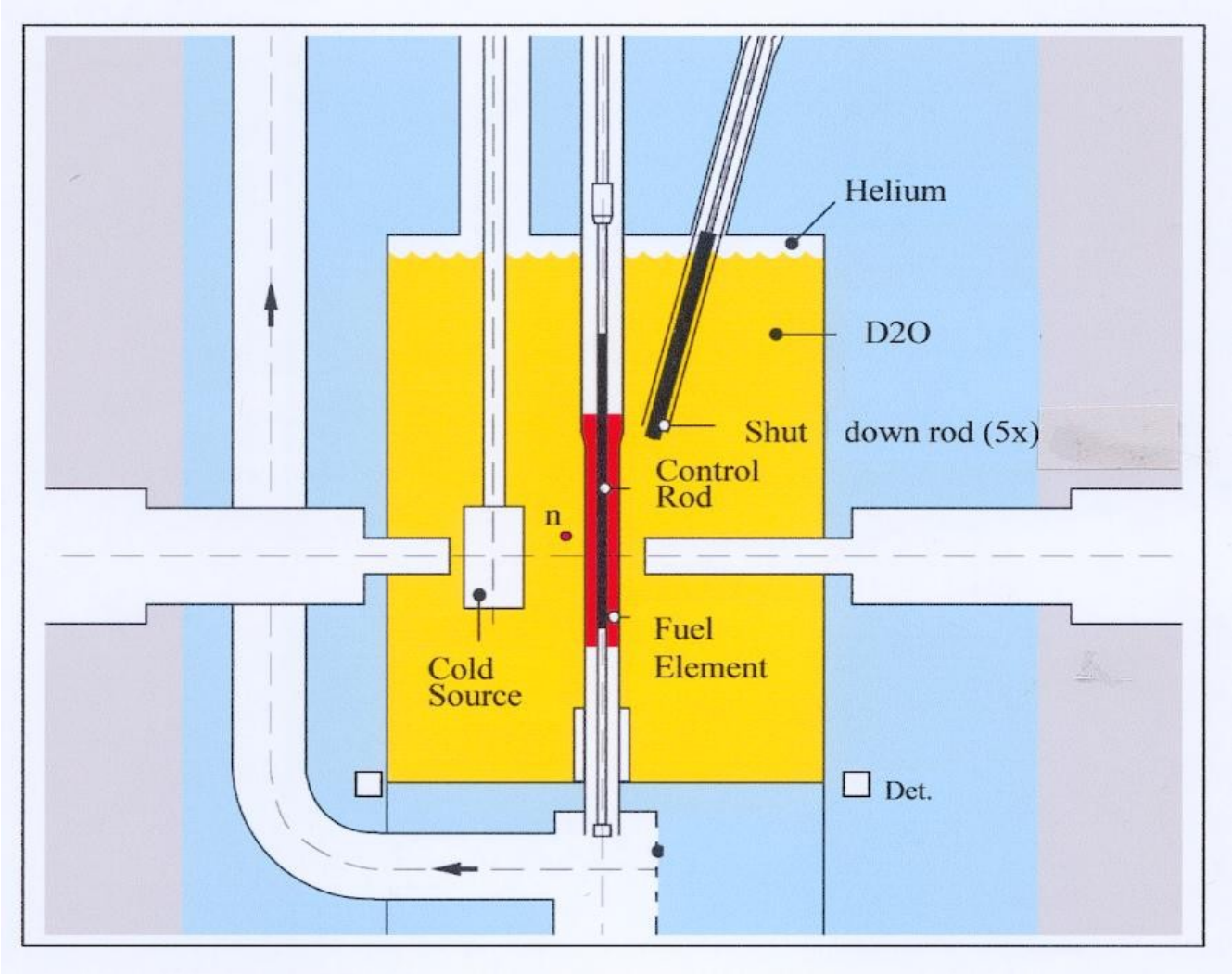
Neutron source FRM-II:

- **Research reactor optimized for production of neutrons for basic research and applications**
- **Concept/construction: Siemens/Framatome FANP und TUM**
- **Site: Campus of the Technical University Munich, Garching**
- **Basic characteristics :**
  - **20 MW thermal power**
  - **cylindrical compact core, 8 kg uranium (93% enriched), U_3Si_2-Al**
  - **52 d cycle per fuel element**
  - **H_20 coolant of fuel element, D_20 moderator/reflector**
  - **maximum thermal neutron flux in the moderator tank (from measurement): $6.5x10^{14}$ n/cm²s**



Conceptual design of the reactor

Fuel Element

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Fuel plates

Step in fuel density (1.5/3.0 g/cm³)

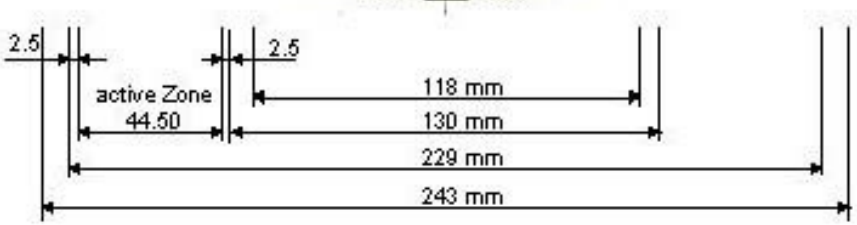
Control rod Beryllium zone

Slits between the plates for cooling

central channel

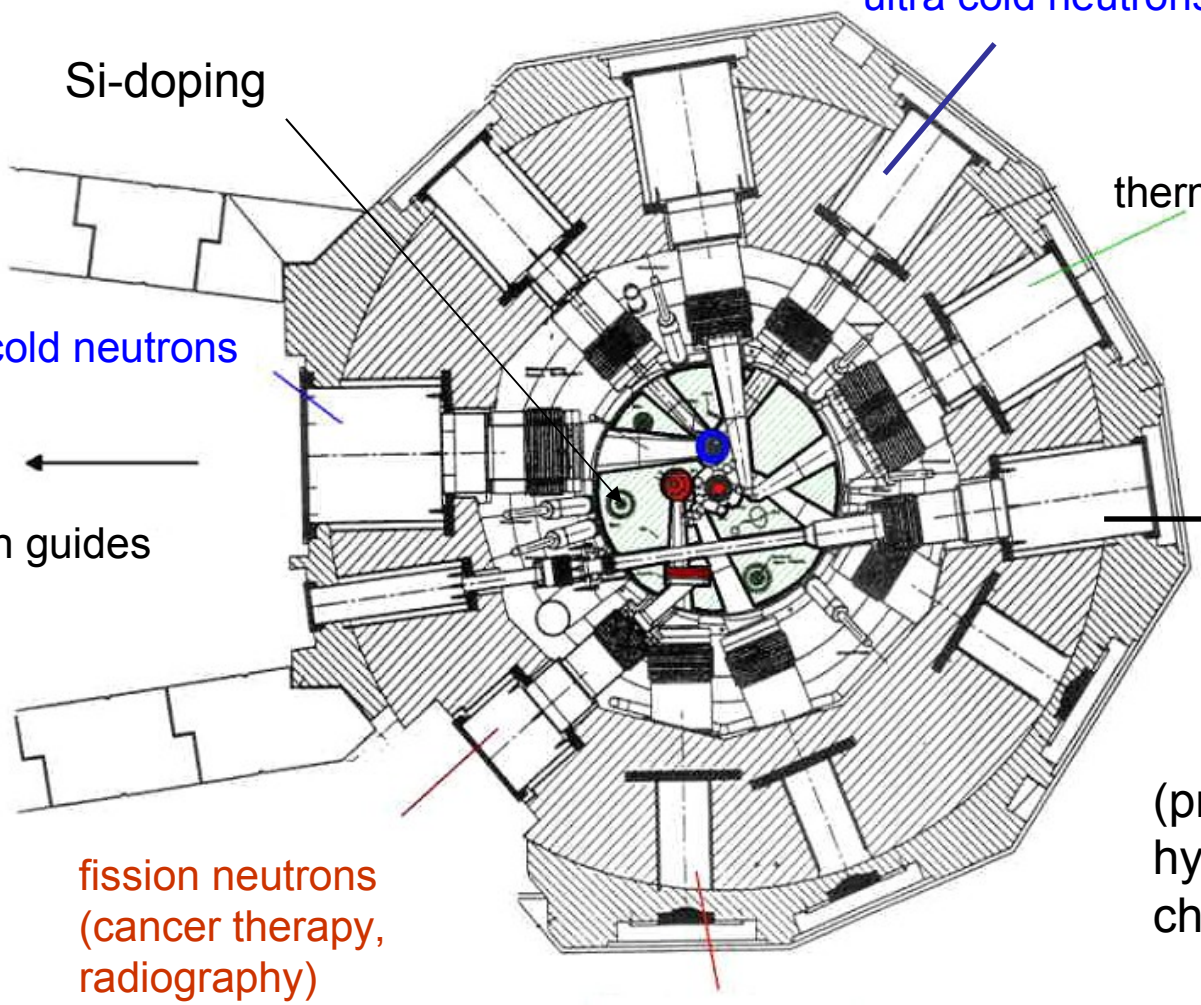
outer tube of the fuel element

inner tube of the fuel element



7.5 kg ^{235}U

Cross section of the reactor pool



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Experimental Area and Neutron Guide Hall

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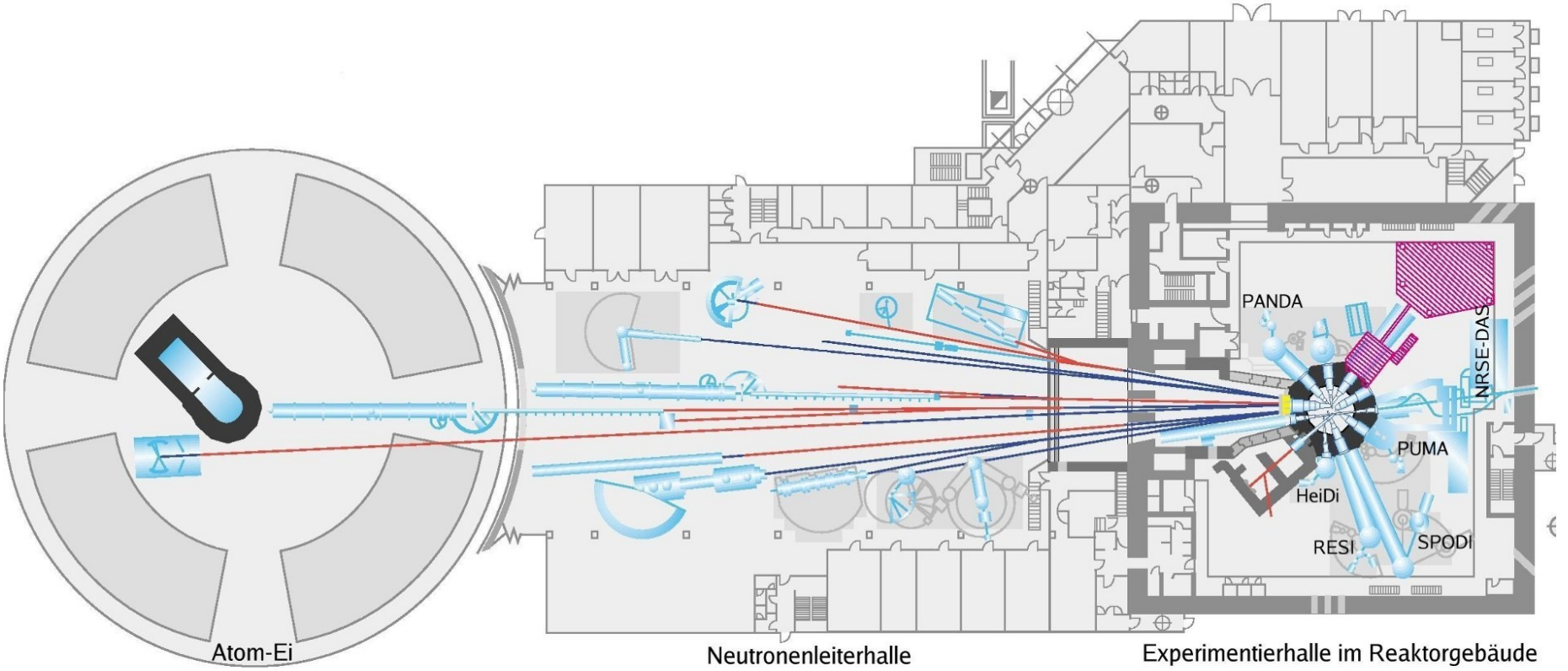

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Safety Characteristics of FRM-II (I)

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- Inherent safety against H_2O/D_2O leakage
- 2 independent shut down system
  - Hf control rod moving in the center of the fuel element
  - 5 Hf emergency shut down rods within the moderator tank
- Digital reactor control system
- Heat release via
  - primary coolant circuit (4 pumps, 300 l/s, 37°C → 52°C)
  - secondary cooling circuit (releases also the heat from the moderator tank and the reactor pool)
  - 4 cooling towers

Safety Characteristics of FRM-II (II)

- Emergency cooling system

  - 3 battery supplied pumps being operated for 3 hours subsequent to rector shut down

  - after 3 h cooling by natural convection of pool water

- Layout against

  - earthquake up to power of 6.5

  - airplane crash

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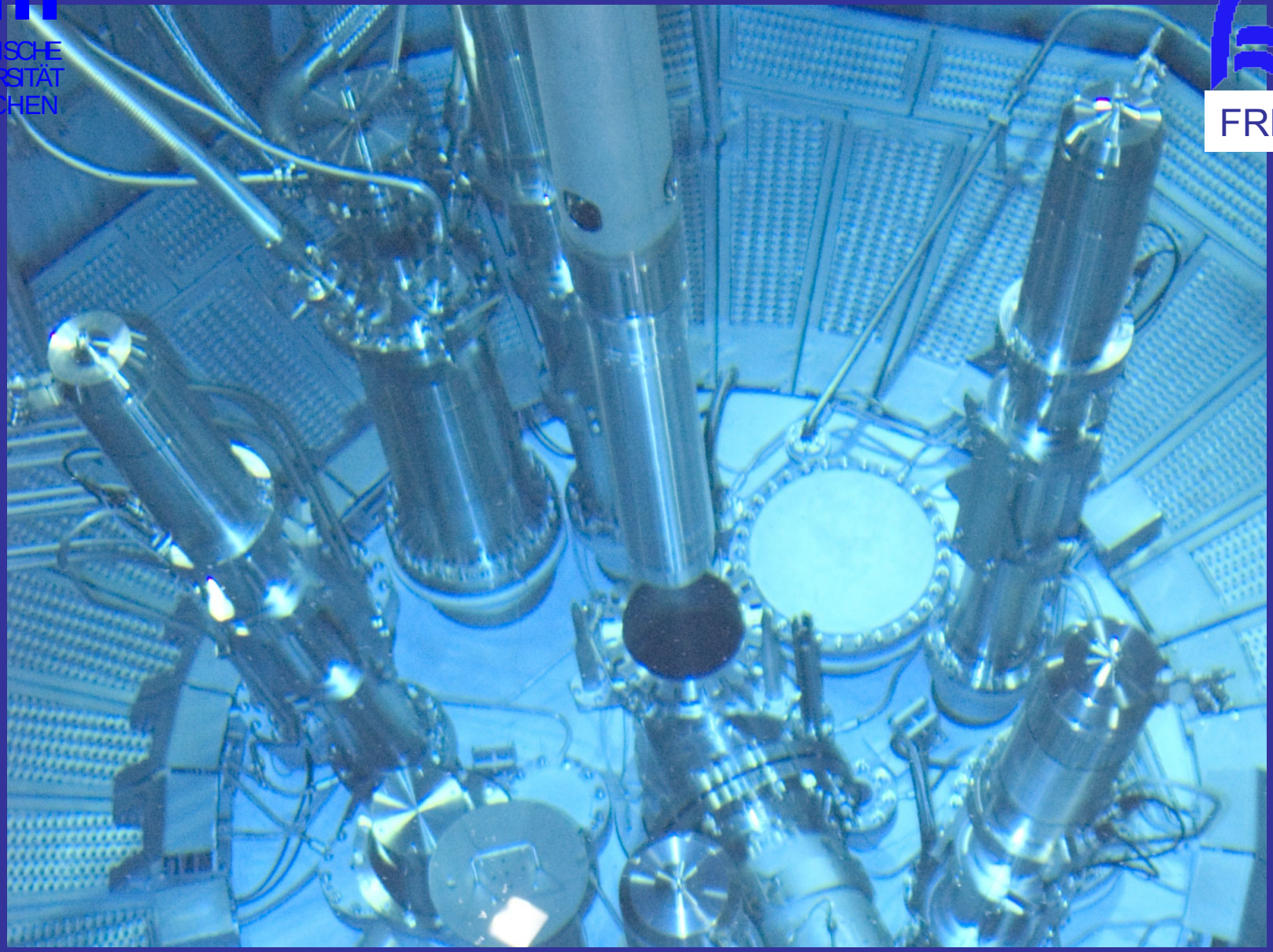

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Nuclear Start-up March-October 2004:

- Investigations at low power (<200 kW)
- Investigations in 7 steps

  - 200 kW,
  - 6MW,
  - 14 MW,
  - 20 MW
  - 2 MW
  - 10 MW
  - 18 MW

- Burndown of the fuel element to 1040 MWd

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Investigations at low Reactor Power (below 0,2 MW)

2. March 2004 to 25.March 2004

- **fuel element placed in the central channel with empty moderator tank**
- **check of undercriticality during D_2O filling of the moderator tank**
- **first criticality** *2. March 2004 14:01*
- **measurement of neutron flux density**
- **measurement of efficiency of the control rod and the shut-down rods**
- **partial gamma-emission tomography of the fuel element under water for determination of the power density distribution.**

Anisotropic power density in FRM-II fuel element

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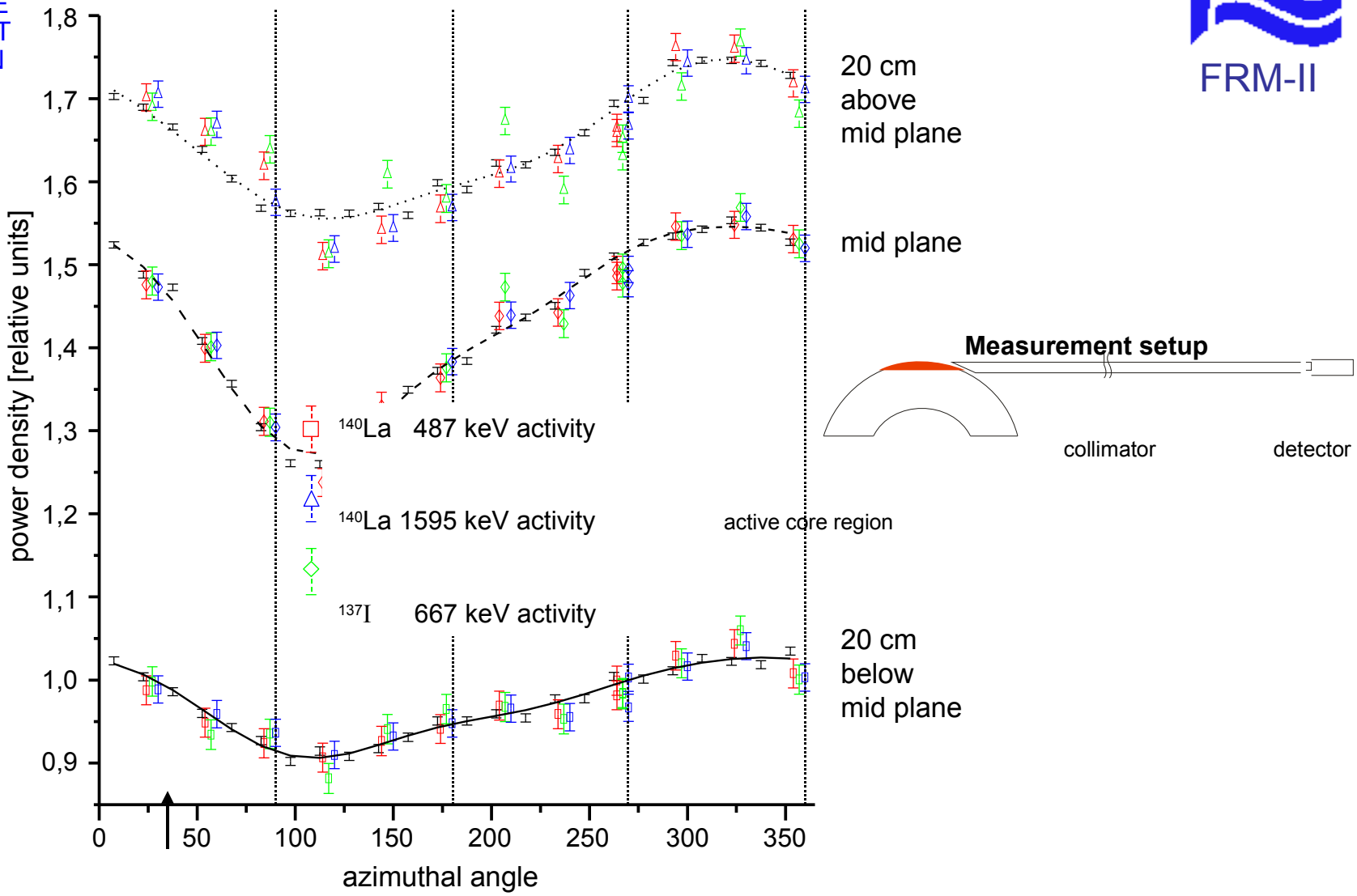

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Investigations at reactor power 0.2 MW …20 MW

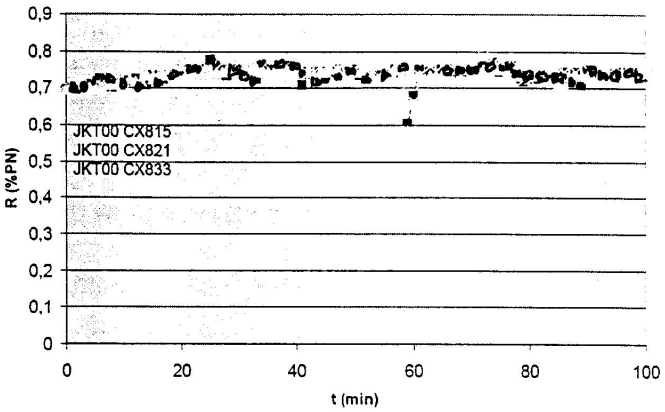
- **Investigations in 7 power steps up to the nominal power of 20 MW:**

➢**Power calibrations**
➢**Check of the systems at higher reactor power**
➢**Functioning of the in-pile sources**
(in particular cold source when changing reactor power)
➢**radiological measurements**
➢**Scram tests**

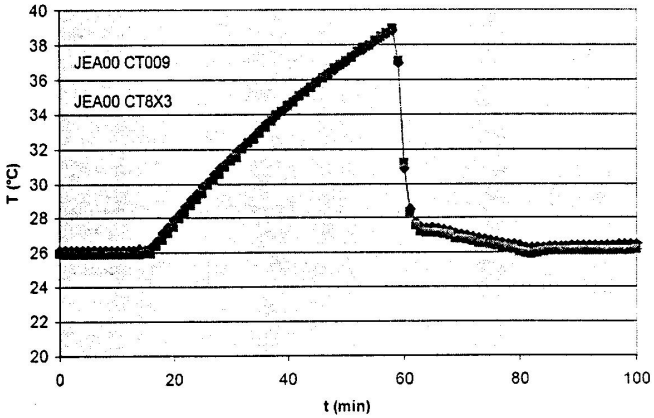
5 MW ***May 10, 2004***
10 MW ***July 7, 2004***
Nominal power 20 MW ***Aug 24, 2004***

- **24 h test run at 20 MW** ***Aug. 25, 2004***

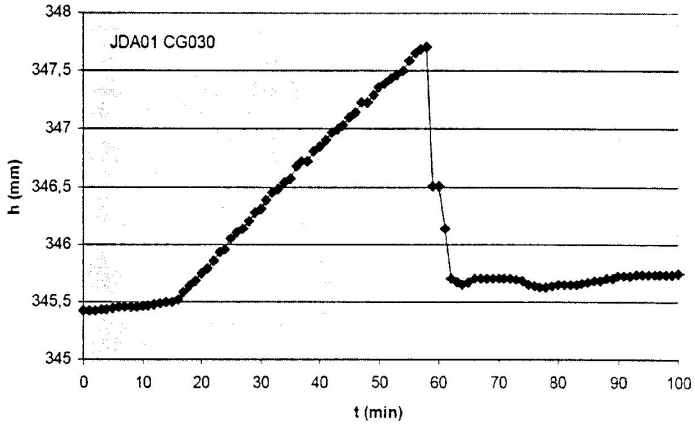
- **continous runs at 20 MW till end of cycle** **Sept.11 – Oct. 20, 2004**
  -> still further 8 days at nominal power possible
- **visual inspection of the fuel element under water**



Reactor power



Temperature of primary coolent



Position of control rod

Adiabatic heating of the coolant. The primary and secondary water pumps are running, the tenary cooling is stopped in the time period 20 to 60 min. .The reactor power (upper plot) is stabilized at 150 kW by moving the control rod (lower plot). At the time 60 min the teneray cooling is started again. The movement of the control rod shows the negative reactivity coefficient of the primary coolent of about -9pcm/°C.

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Initial Instrumentation of the FRM-II

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Secondary Sources:	Hot source	T > 2300 K
	Liquid D_2-cold source	T ≈ 25 K
	Converter facility	cancer therapy
	High intensity positron source	
Irradiation devices:	pneumatic rabbit system	6 channels
	hydraulic rabbit system	2 channels
	irradiation device inside control rod	
	Si doping	Ø ≤ 200 mm
Radio- and Tomography	thermal neutrons fast neutrons	

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Initial Instrumentation of the FRM-II

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Spectrometers:	Cold neutron 3-axis spectrometer	PANDA
	Thermal neutron 3-axis spectrometer	PUMA
	3-axis neutron resonance spin echo	NRSE-DAS
	Diffractometer for materials research	STRESS-SPEC
	Structure Powder Diffractometer	SPODI
	Hot neutron, single crystal diffractometer	HEIDI
	High resolution time of flight spectrometer	TOF-TOF
	Backscattering spectrometer	BSSM
	Resonace spin-echo spectrometer	RESEDA
	Reflectometer	REFSANS
Visions:	Fission fragment accelerator	MAFF
	Ultra-cold neutron source	
	Fast rabbit system	

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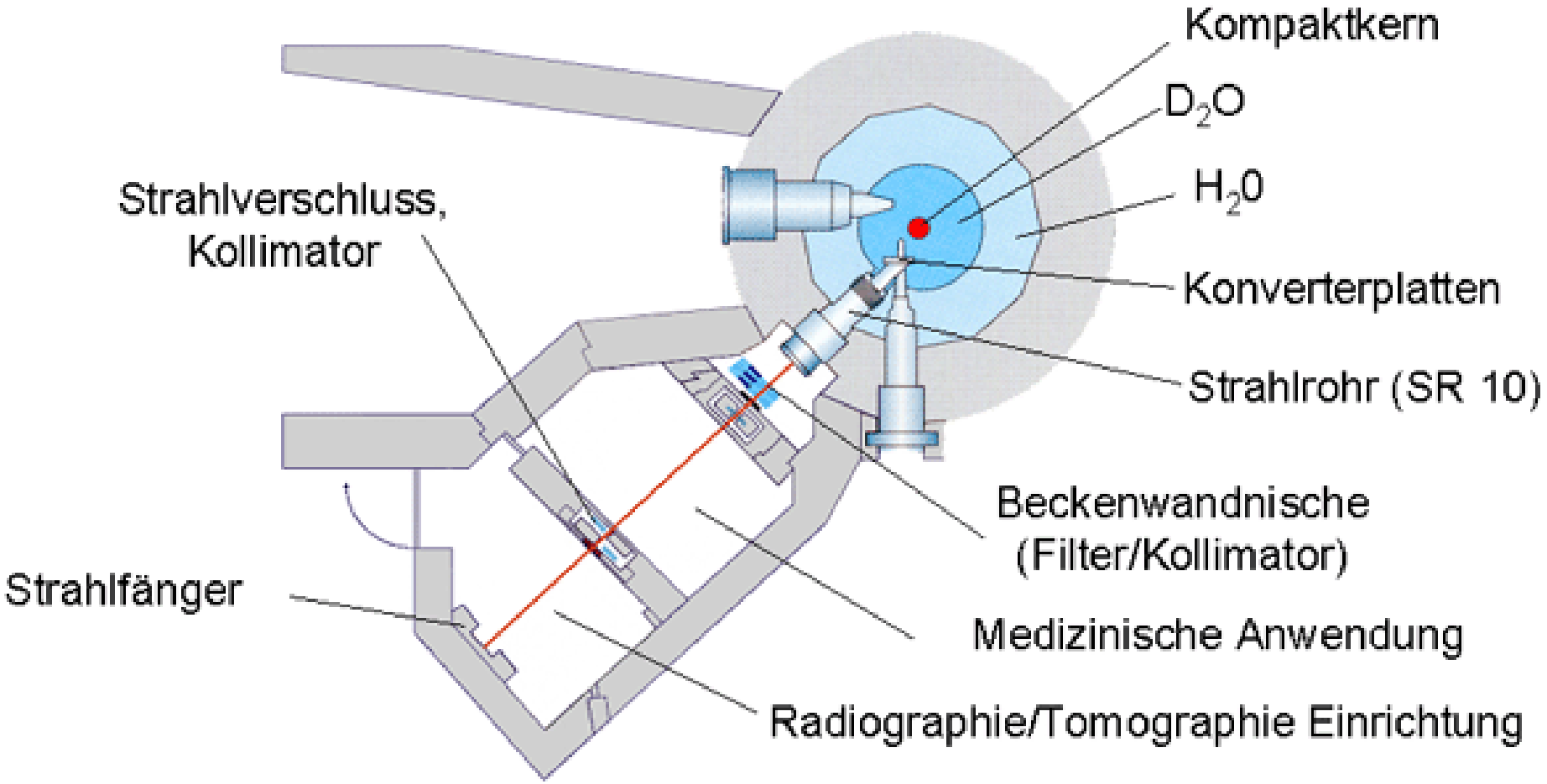
Example 1: Cancer Therapy by fast neutrons



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Example 2: Si-doping facility at FRM-II

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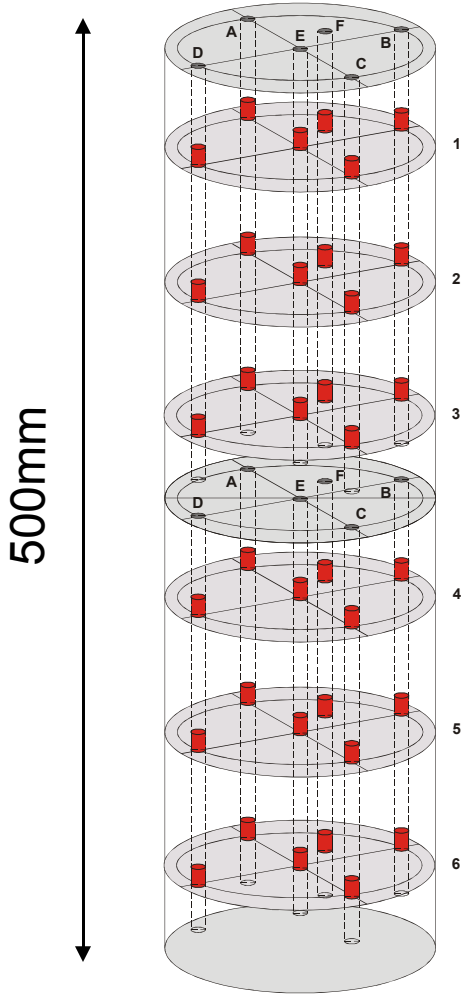
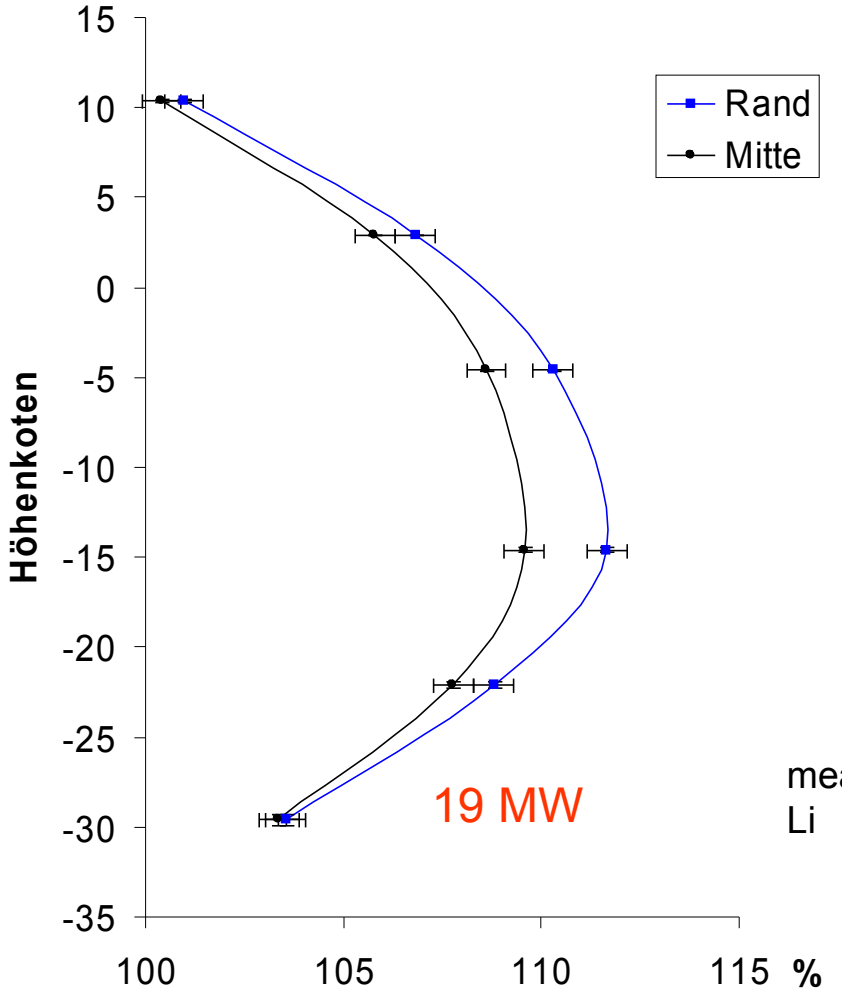
Neutron flux profil within a Si-ingot (Ø=15cm)





measurement by X. Li

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Summary - Milestones

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May 3, 2003	operational license of FRM-II has been granted by the State of Bavaria
July 10, 2003	delivery of the first 2 fuel elements
March 2 – 25, 2004	zero power tests
April 25 – Aug 25, 2004	tests at 7 power stages up to 20 MW, including the start-up of the main experimental installations
Sept. 11 – Oct. 20, 2004	long term continous runs at 20 MW
April 25, 2005	license for routine operation has been granted by the State of Bavaria
April 29 – June 24, 2005	first cycle of routine operation
July 12 – Sept. 8, 2005	second cycle of routine operation