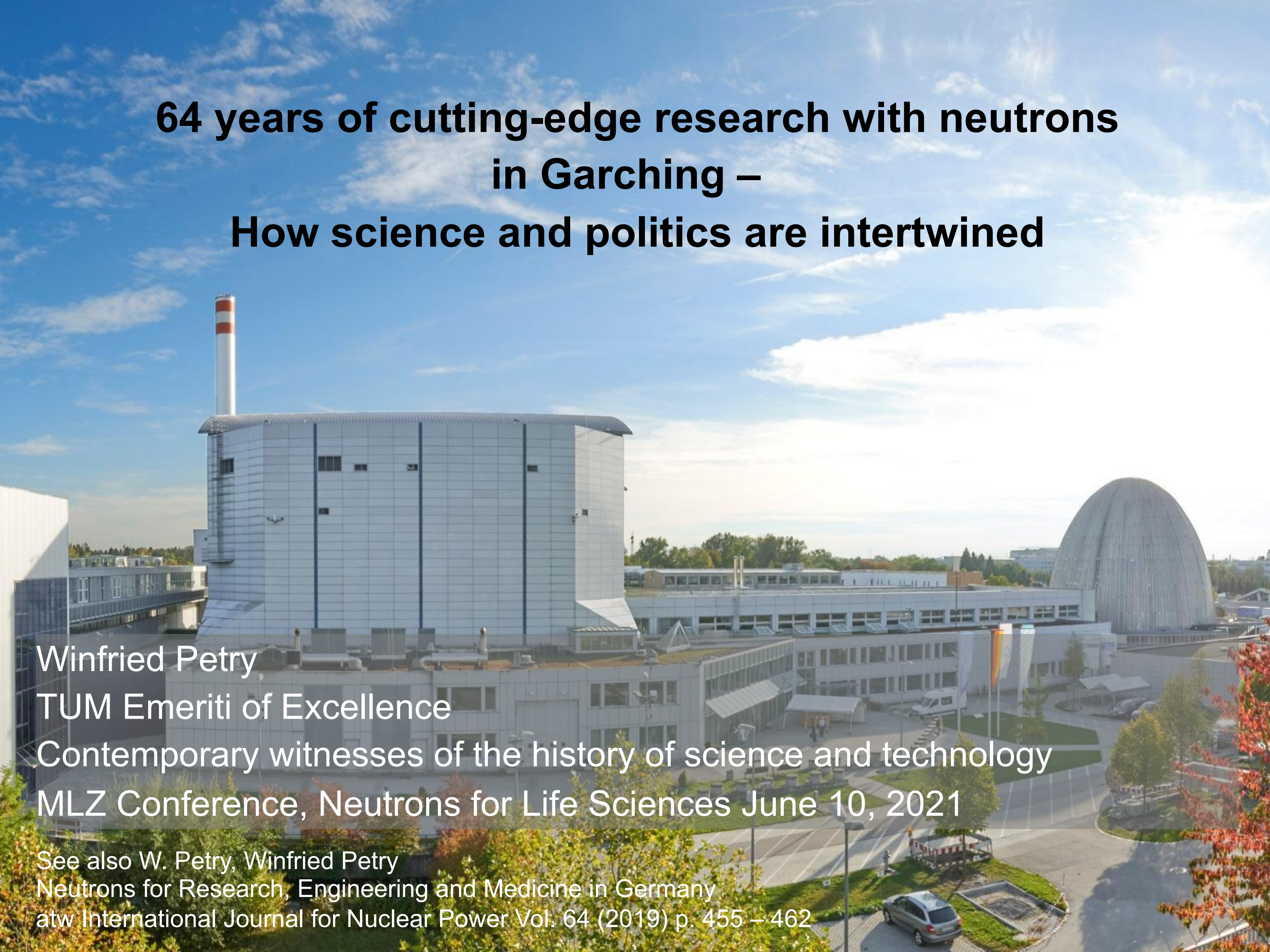


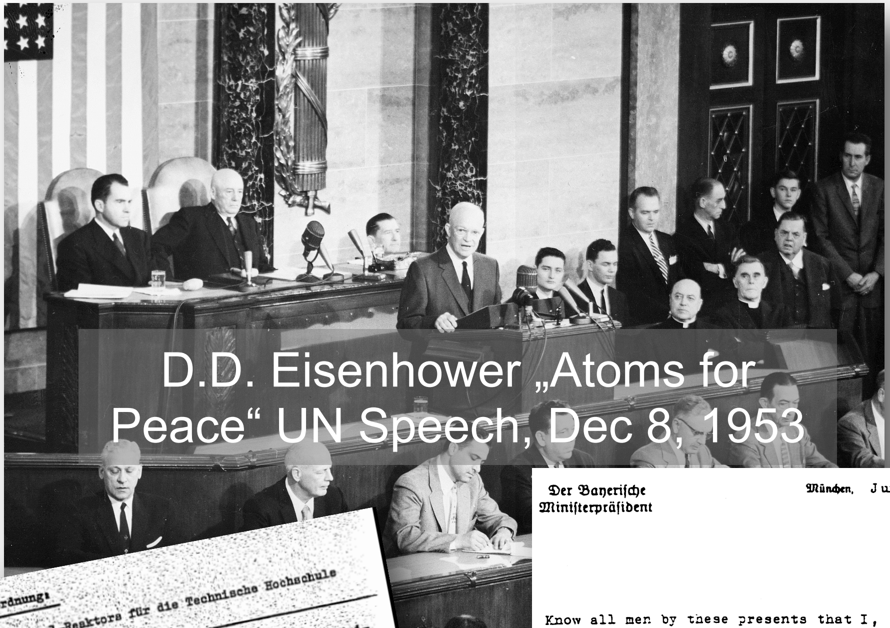
64 years of cutting-edge research with neutrons in Garching – How science and politics are intertwined

Winfried Petry
TUM Emeriti of Excellence

Contemporary witnesses of the history of science and technology
MLZ Conference, Neutrons for Life Sciences June 10, 2021

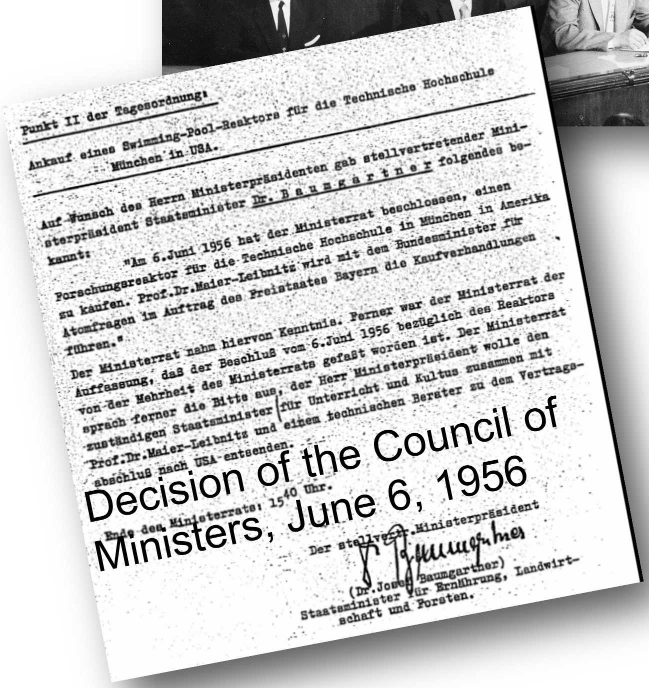
See also W. Petry, Winfried Petry
Neutrons for Research, Engineering and Medicine in Germany
atw International Journal for Nuclear Power Vol. 64 (2019) p. 455 – 462

„Atoms for peace“ – A research reactor for the Technische Hochschule München



D.D. Eisenhower „Atoms for Peace“ UN Speech, Dec 8, 1953

Tasso Springer at the place of the future „Atomic Egg“ in the heathland in Garching



Punkt II der Tagesordnung:

Ankauf eines Swimming-Pool-Reaktors für die Technische Hochschule München in USA.

Auf Wunsch des Herrn Ministerpräsidenten gab stellvertretender Ministerpräsident Staatsminister Dr. B a u m g a r t n e r folgendes bekannt:

„Am 6.Juni 1956 hat der Ministerrat beschlossen, einen Forschungsreaktor für die Technische Hochschule in München in Amerika zu kaufen. Prof.Dr.Maier-Leibnitz wird mit dem Bundesminister für Atomfragen im Auftrag des Freistaates Bayern die Kaufverhandlungen führen.“

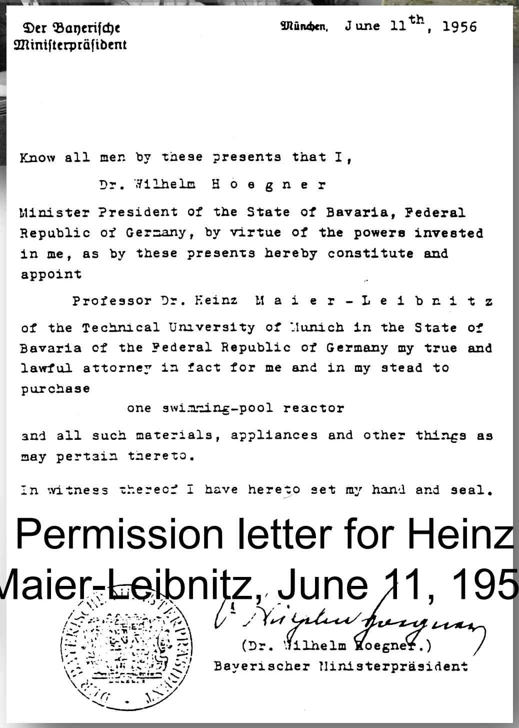
Der Ministerrat nahm hiervon Kenntnis. Ferner war der Ministerrat der Auffassung, daß der Beschluß vom 6.Juni 1956 bezüglich des Reaktors von der Mehrheit des Ministerrats gefaßt worden ist. Der Ministerrat sprach ferner die Bitte aus, der Herr Ministerpräsident wolle den zuständigen Staatsminister für Unterricht und Kultus zusammen mit Prof.Dr.Maier-Leibnitz und einem technischen Berater zu dem Vertragsabschluß nach USA entsenden.

Ende des Ministerrats: 15[40] Uhr.

Der stellvertr. Ministerpräsident

(Dr. Josef Baumgartner)
Staatsminister für Ernährung, Landwirtschaft und Forsten.

Decision of the Council of Ministers, June 6, 1956



Der Bayerische Ministerpräsident

München, June 11th, 1956

Know all men by these presents that I,

Dr. Wilhelm H o e g n e r

Minister President of the State of Bavaria, Federal Republic of Germany, by virtue of the powers invested in me, as by these presents hereby constitute and appoint

Professor Dr. Heinz M a i e r - L e i b n i t z

of the Technical University of Munich in the State of Bavaria of the Federal Republic of Germany my true and lawful attorney in fact for me and in my stead to purchase

one swimming-pool reactor

and all such materials, appliances and other things as may pertain thereto.

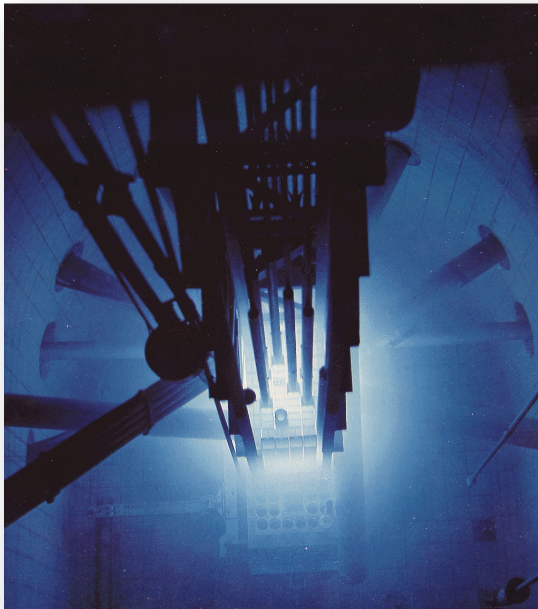
In witness thereof I have hereto set my hand and seal.

(Dr. Wilhelm Hoegner.)
Bayerischer Ministerpräsident

Permission letter for Heinz Maier-Leibnitz, June 11, 1956

Prime Minister Högner unpacks the first fuel element, Sep 9, 1957

The dawn of a new era



First criticality of the „Atomic Egg“: October 31, 1957

First German nuclear facility in Garching

Coat of arms of Garching, 1957

Wissen und Können

Mitteilungen der Deutschen Landwirtschafts-Gesellschaft

Ausgabe B

72. Jahrgang — Frankfurt/Main, den 13. Juni 1957 — Heft 24

AUS DEM INHALT

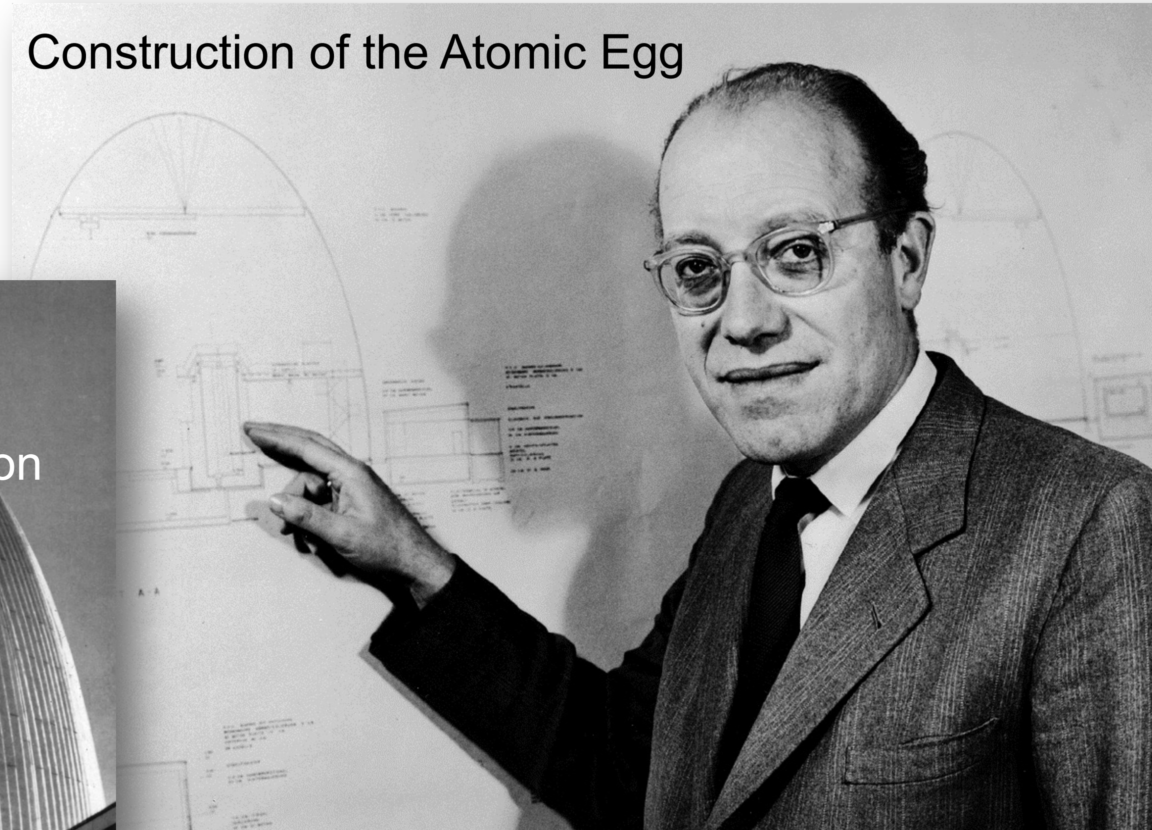
Zeichen der neuen und der alten Zeit: Vor einem im Bau befindlichen deutschen Atomreaktor bereitet ein Bauer mit seiner Egge den Acker vor.

Aufnahme: Wirth

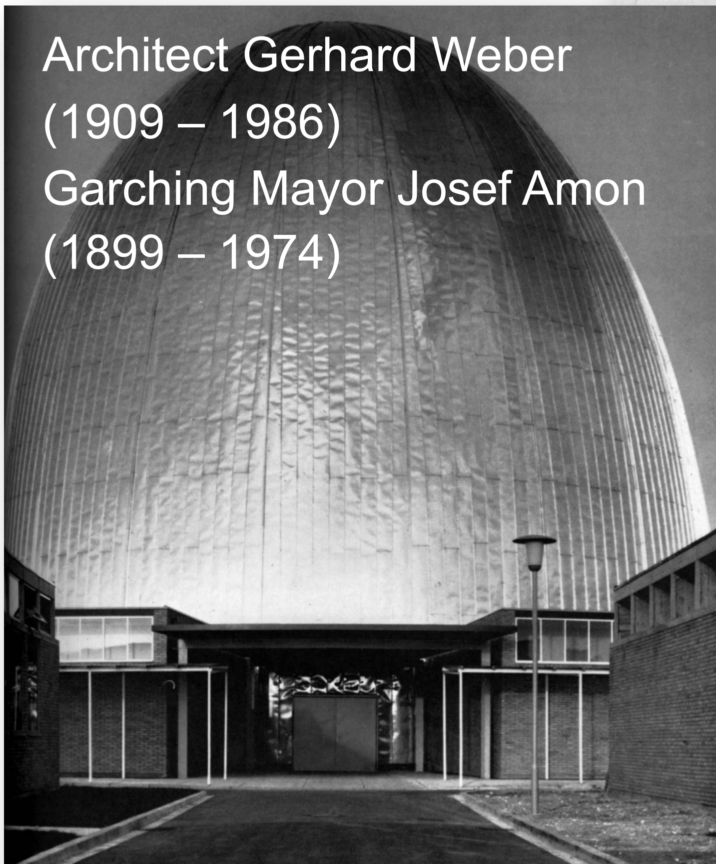
Rossendorf research reactor in „the zone under Soviet occupation“

- First criticality, **Dec 16, 1957**
- **Heavy water moderator**, **10 MW**
- Decommissioning, **June, 1991**

Prof. Heinz Maier-Leibnitz (1911 – 2000)



Construction of the Atomic Egg

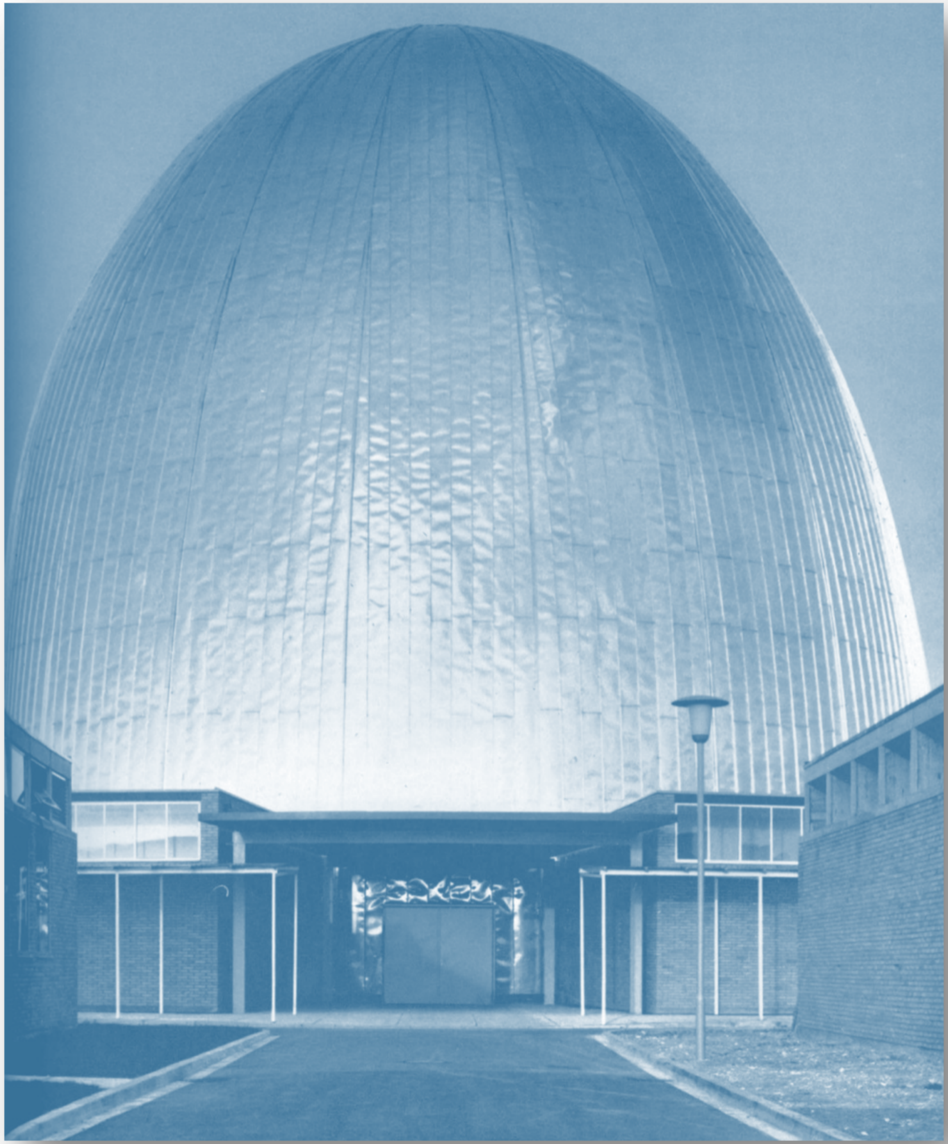


Architect Gerhard Weber
(1909 – 1986)
Garching Mayor Josef Amon
(1899 – 1974)

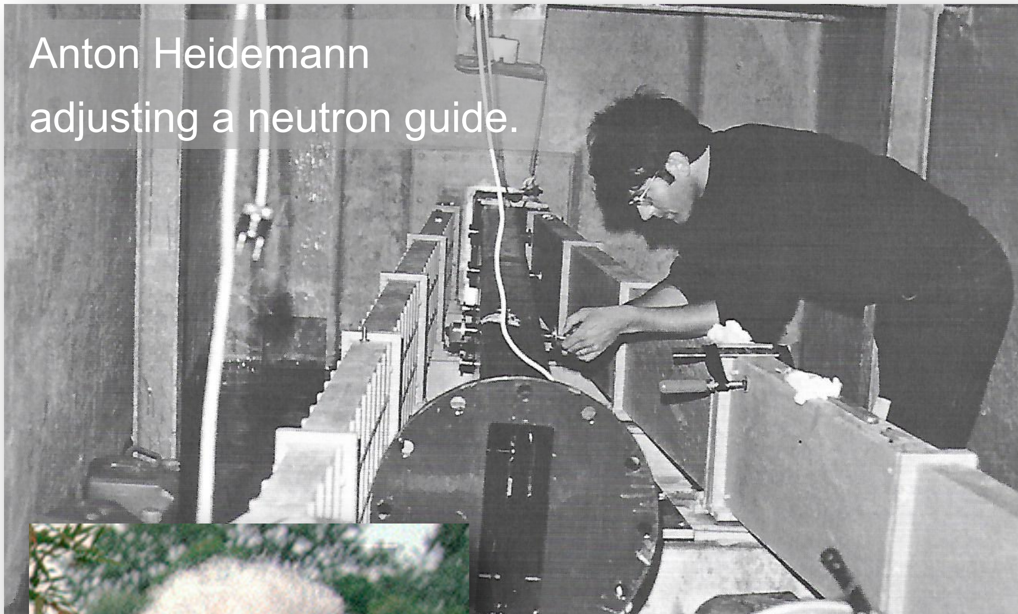
→ „Do something new !“

→ Father of research with neutrons in Europe.

„News“ from the Atomic Egg



Neutron Guide



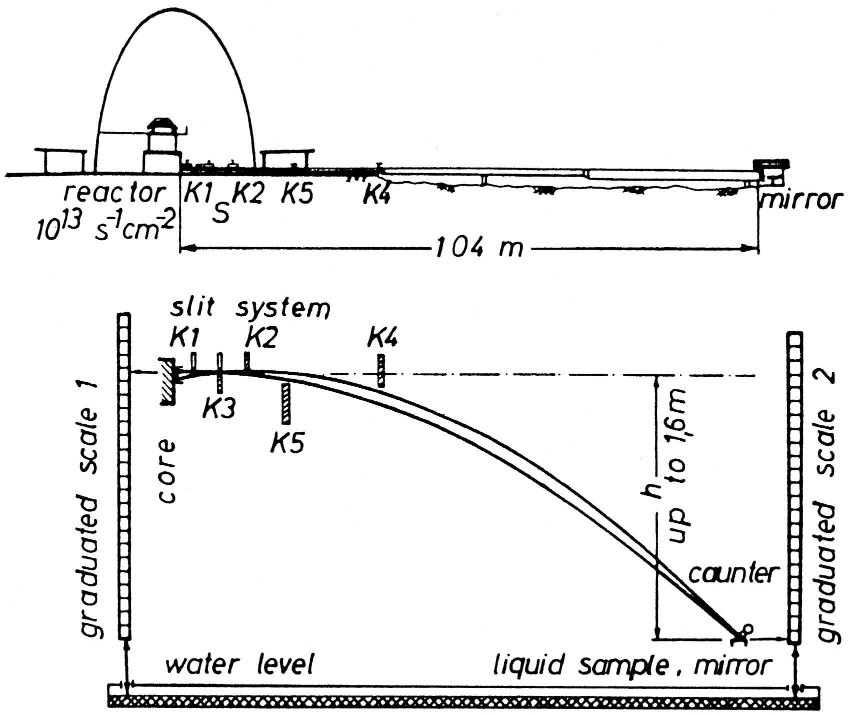
Anton Heidemann adjusting a neutron guide.

Tasso Springer (1930 – 2017): Discoverer of the neutron guide.

Erich Steichele (1938 – 2019): Technology transfer from neutron guides to living room tables.

J. Christ, T. Springer Über die Entwicklung eines Neutronenleiters am FRM Reaktor, Nukleonik 4 (1962) 23

Precise measurements of effective cross sections

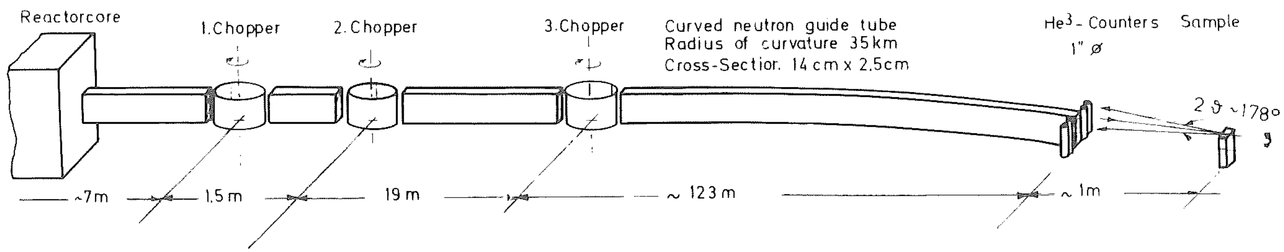


Gravity diffractometer,
measurement of the drop height of thermal neutrons
Köster & Rauch's effective cross-sections

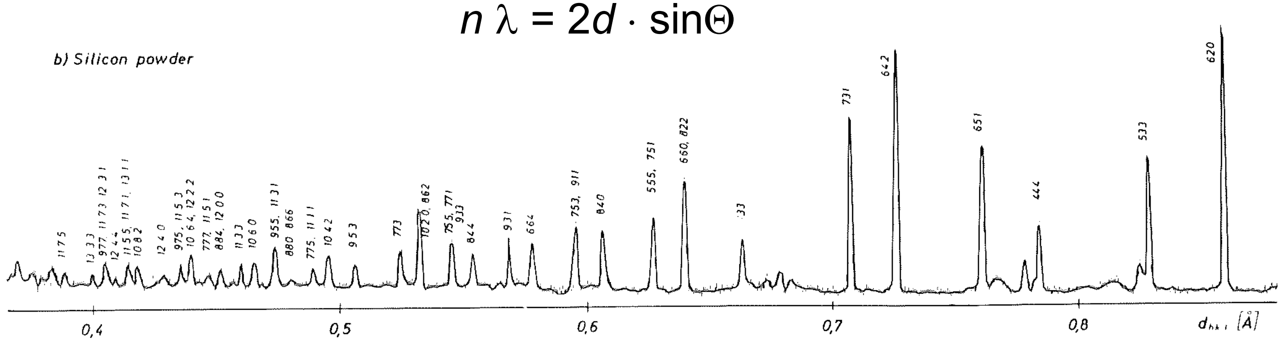
$$(\sin\alpha_c)^2 = (Nb/\pi)^2 \cdot \lambda$$

L. Koester, Neutron Scattering Lengths and Fundamental Neutron Interactions, Springer Tracts Mod. Phys. 80, 1 (1977).
L. Koester, H. Rauch, E. Seymann, Neutron Scattering Lengths: a Survey of Experimental Data and Methods, Atomic Data and Nuclear Data Tables, 49,65 (1991)

Time-of-flight diffractometer



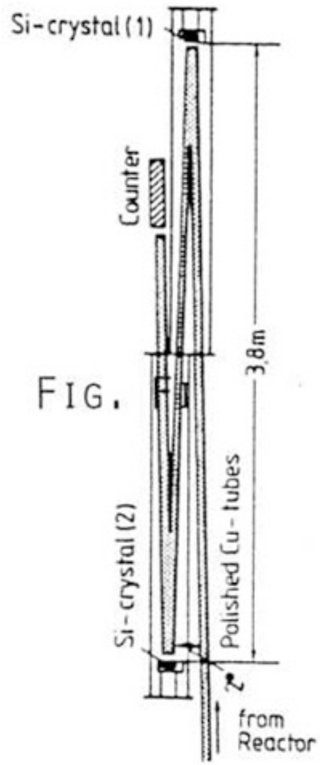
$n\,\lambda = 2d \cdot \sin\Theta$

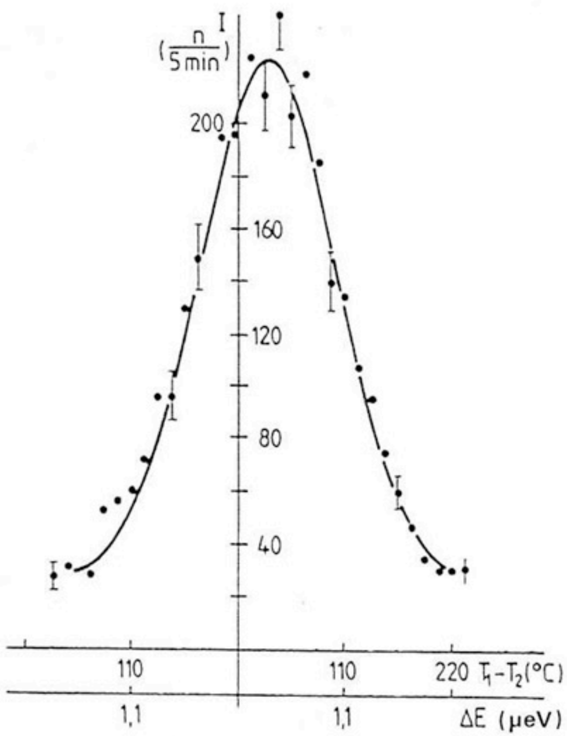


Erich Steichele, Nagel: First time-of-flight diffractometer, highest resolution, 141 m long n-guide, basic technique for spallation neutron sources

E. Steichele, P. Arnold, Phys. Lett. 44A (1973) 165 ff

Backscattering spectrometer



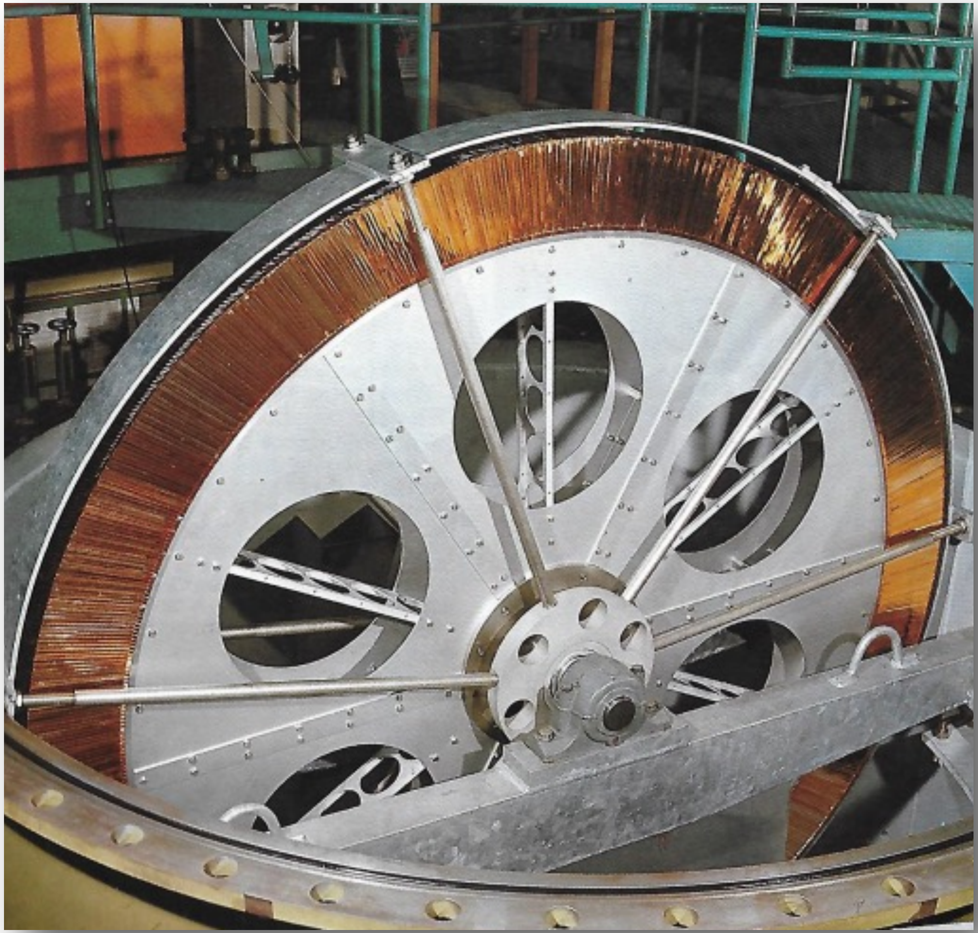


Experimental setup in vertical position above the reactor pool $\Delta\lambda/\lambda = \Delta d/d + \cot\Theta \cdot \Delta\Theta$

Berthold Alefeld (1937 – 2012)
Anton Heidemann

A. Alefeld, M. Birr, A. Heidemann Proc. Neutron Inelastic Scattering, vol. II, IAEA, Vienna (1968), p. 381
M. Birr, A. Heidemann, R. Alefeld Nucl. Instr. and Meth., 95 (1971), p. 435

Ultracold Neutrons



UCN Turbine blade

*A. Steyerl, NIM **125**, 461 (1975)*

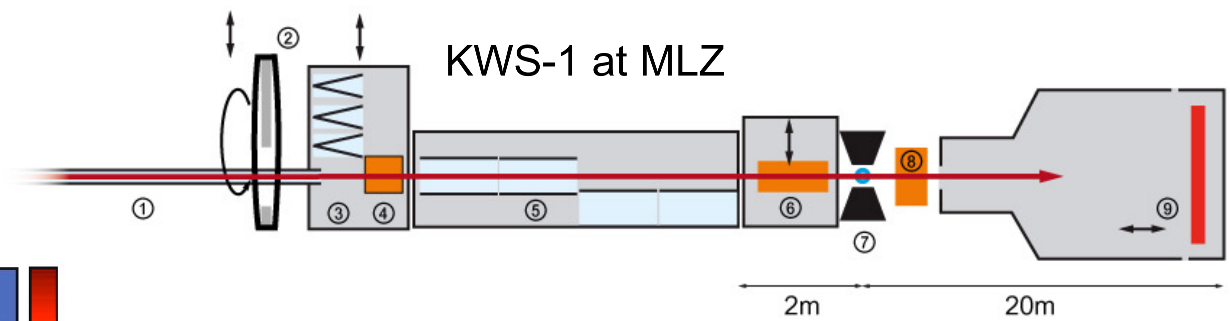
Albert Steyerl

1938 -2020

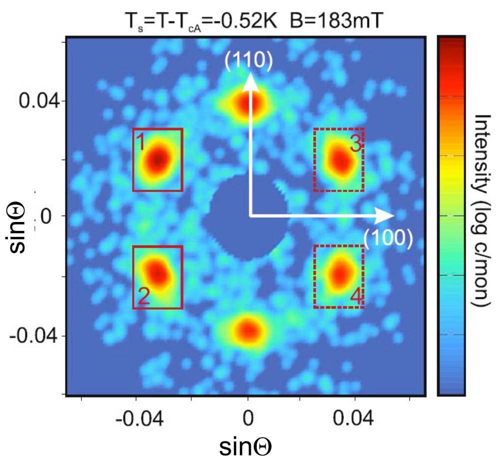
Small-angle scattering

→ First ideas M.-L. Doctoral student Werner Schmatz (1933 – 1986)

$1/d = 2/\lambda \cdot \sin\Theta$



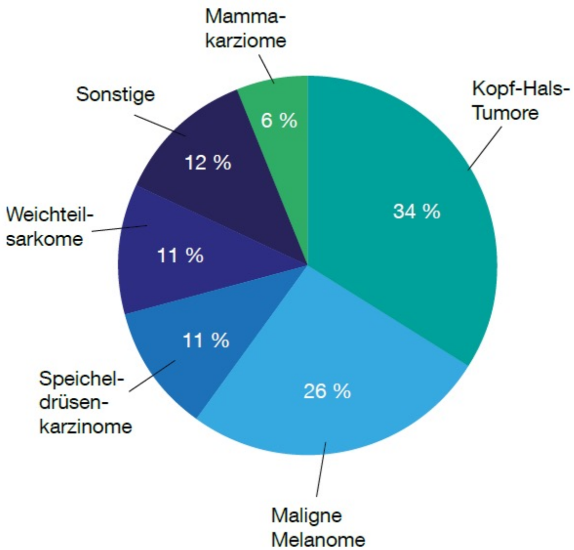
① Neutron guide NL3
② High-speed chopper $\Delta\lambda/\lambda = 1\%$
③ Changeable polarisers
④ Spin flipper
⑤ Neutron guide sections 18 x 1m
⑥ MgF_2 focussing lenses
⑦ Sample position with magnet
⑧ ^3He spin filter with reversable polarisation (to be implemented)
⑨ Anger-type scintillation detector



Magnetic vortex scattering pattern

W. Schmatz, T. Springer, J. Schelten, K. Ibel; Neutron Small-Angle Scattering: Experimental Techniques and Applications Neutron Small-Angle Scattering: Experimental Techniques and Applications, 3". Appl Cryst. (1974). 7, 96

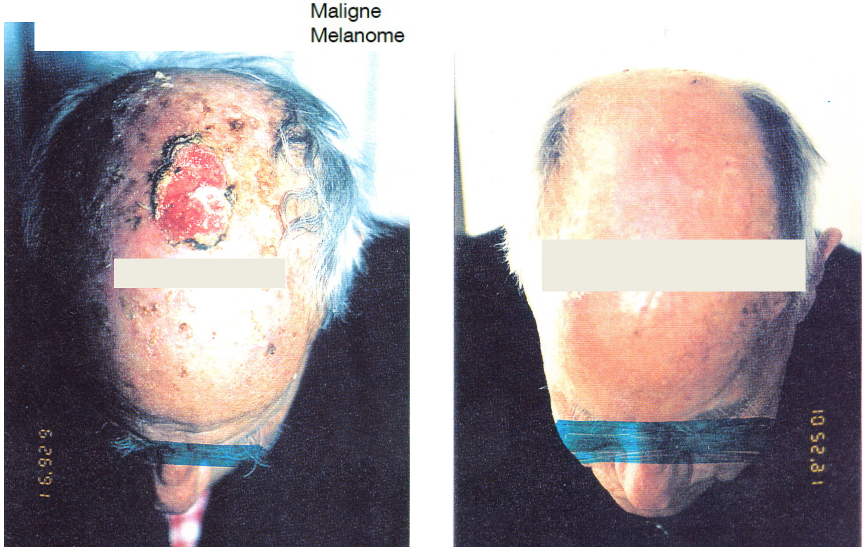
Tumor therapy with fast neutrons



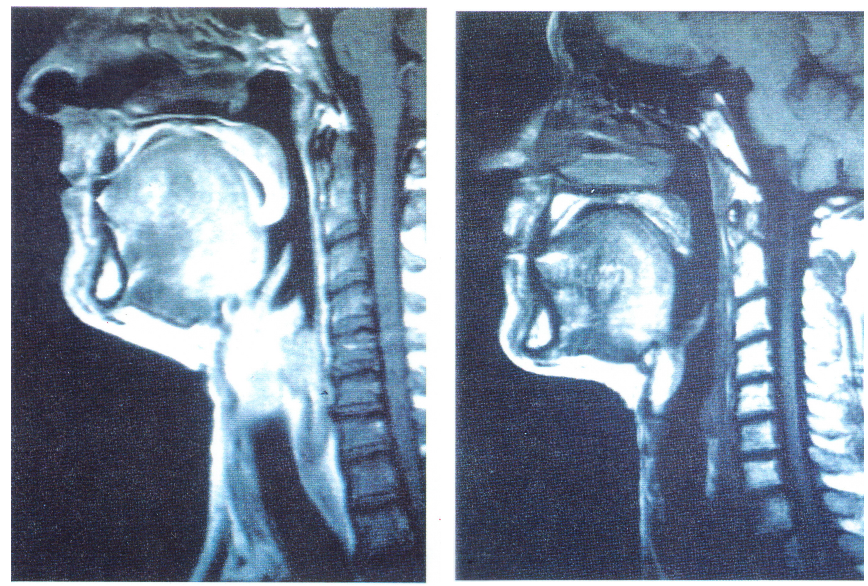
L. Köster
(1922 – 2015)

FRM:

- 715 patients, over 2300 irradiations
- Together with Clinic for Radiotherapy, TUM
- L. Köster, A. Breit, M. Molls, P. Kneschaurek



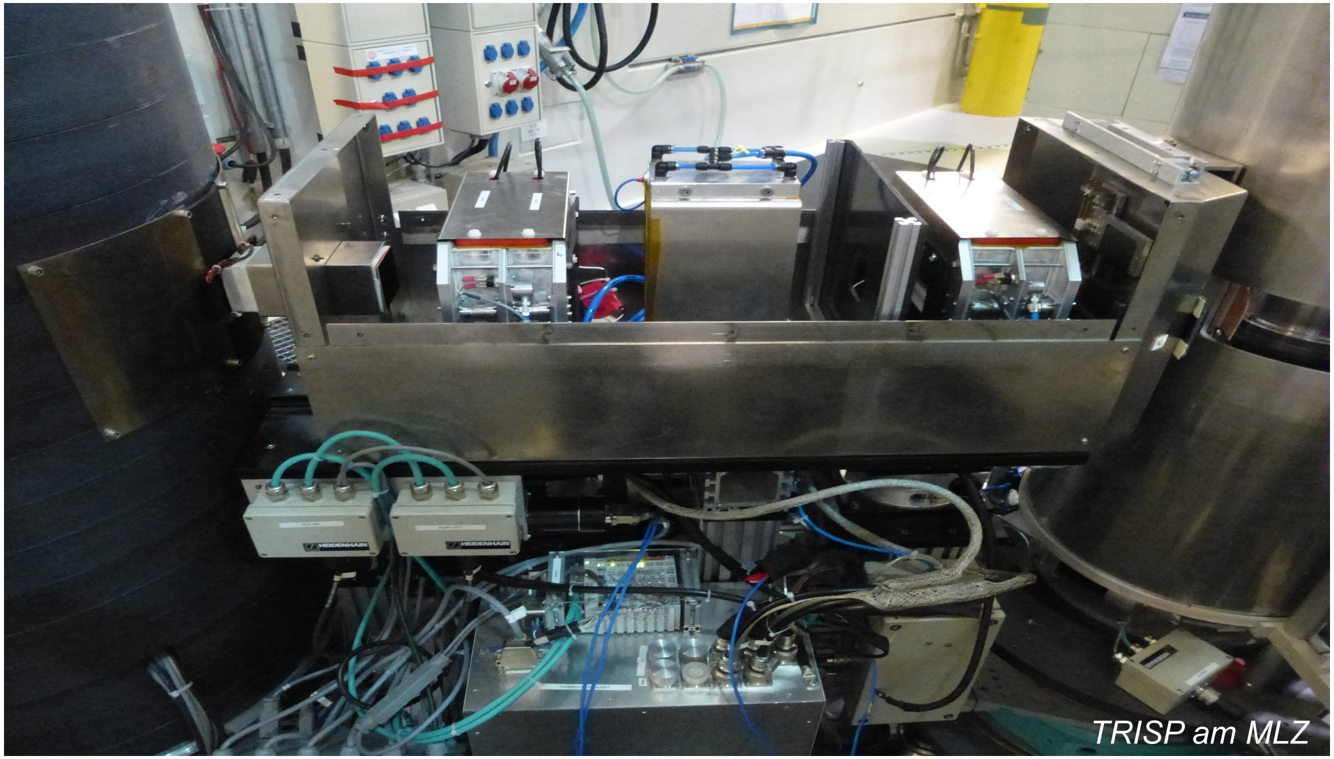
Malignant melanoma, elderly Patient



Laryngeal tumor, 39-year-old patient

*Specht et al., Frontiers in oncology **5**, 262 (2015)*
Köster L. , Breit A. et al. The Munich Therapy Project (1981)

Neutron resonance spin echo



Development of neutron resonance spin echo for high-resolution spectroscopy and diffractrometry

$\Delta E/E$, $\Delta d/d < 10^{-6}$

Developers: Bob Golub, Roland Gähler, Thomas Keller, Klaus Habicht

*R. Golup, R. Gähler Phys. Lett. A **123** (1987) 43; M. Köppke et al. J. Neutron Research **7** (1998) 65; T. Keller et al. Physica B 241-243 (1998) 101*

„News“ from the Atomic Egg

1. **Neutron guides**
2. **Precise measurements of effective cross sections**
3. **High precision nuclear spectroscopy**
4. **Time-of-flight diffraction**
5. **Backscattering spectrometer**
6. **Ultracold neutrons**
7. **Small-angle scattering**
8. **Low temperature irradiation system (4.6 K)**
9. **Tumor therapy with fast neutrons**
10. **Neutron resonance spin echo**

…

→ The development of methods at the Atomic Egg laid the foundation for the leadership of Europe in research with neutrons.

The Atomic Egg in figures

Oktober 31, 1957 – first criticality

1957 1 MW 20 % enrichment ϕ_{th} = 6.6 x 10^{12} $ncm^{-2}s^{-1}$
1960 1 MW 90 % enrichment
1962 Installation of low-temperature 4.6 K irradiation device
1966 2.5 MW 90% enrichment
1968 4 MW 90% enrichment
1982 Be-Reflector ϕ_{th} = 8 x 10^{13} $ncm^{-2}s^{-1}$
1997 Installation of cold source

July 31, 2000 Decommissioning of FRM

Coat of arms of Garching, 1957

From Garching to Europe

- **Jan 22, 1963 Élysée-Vertrag**, Charles de Gaulles, Konrad Adenauer, entente franco-allemande, science in the service of diplomacy, creation of a Franco-German cultural identity.
- Establishment of the **"Max von Laue-Paul Langevin Institute"** (ILL) in Grenoble by **Heinz Maier-Leibnitz** and **Jules Horowitz** (1967 – 1972).
- **Maier-Leibnitz** could implement at the ILL (a tailor-made neutron source with the highest neutron flux) everything he had learned at the Garching „Atomic Egg", together with his students.

→ **With the ILL, Europe has taken the lead in research with neutrons to this day.**

The ILL in figures

1963	Creation of a Franco-German cultural identity through a joint large-scale research institution, namely the Laue Langevin Institute (ILL) Heinz Maier-Leibnitz, Louis Néel, Jules Horowitz, Robert Dautray, Félix Bertaut take the initiative for the high-flux neutron source in competition with the dominance of the USA in the field of neutron research, colloquia in Grenoble und Munich, idea of a cold source à la Harwell.
Jan 19, 1967	Signing of the ILL contract, Gerhard Stoltenberg – Alain Peyrefitte.
1967 – 1972	**Heinz Maier-Leibnitz founding director**, Bernard Jacrot French deputy director.
Nov 6, 1970	UK joins the ILL contract thanks to its science secretary Margret Thatcher. In the absence of buildings in Grenoble, the ILL theory group initially settles at the Walther-Meißner-Institut in Garching.
1972	First criticality, 93 % enrichment, 58 MW, ϕ_{th} = 1,3 x 10^{15} $ncm^{-2}s^{-1}$ hot source, cold source, D_2O moderator and cooling.

Mutual fertilization of Science and Diplomacy still applies today

Renewal of the Élysée Contract on Jan 23, 2019.

Knowledge Transfer from Garching and FZ-Jülich to Grenoble

- ILL Directors from the Garching area:

  Heinz Maier-Leibnitz, Rudolph Mößbauer, Tasso Springer, Wolfgang Armbruster,

  Wolfgang Gläser, Reinhard Scherm, Dirk Dubbers, Helmut Schober
- User system, service facility (Rudolph Mößbauer)
- Neutron guide (Erich Steichele), experimental hall outside the reactor building
- Small angle scattering (Schmatz, Ibel, Schelten)
- Backscattering (Berthold Alefeld, Anton Heidemann)
- Nuclear spectroscopy (GAMS + BILL, von Egidy)
- UCN (Albert Steyerl)
- Theory group


Mike Lomer und Rudolph Mößbauer, ILL directors, 1972 – 1977

Development of the Research Neutron Source Heinz Maier-Leibnitz (FRM II)

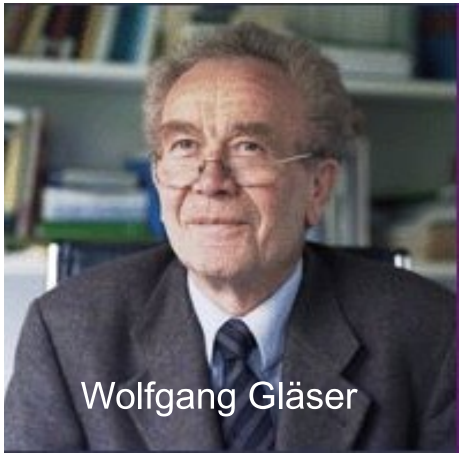
1981	Presentation of the compact core concept at the Argonne National Laboratory by Klaus Böning → Example of knowledge transfer from ILL back to TUM!
1985	Cancellation of the German Spallation Source project.
1993	Government declaration of Minister President Stoiber at the TUM, construction of the FRM II from funds of the „Offensive Zukunft Bayern“ (Bavarian Future Offensive).
1993	Completion of the regional planning procedure.
1995	Approval by Garching Municipal Council for the construction.
1994	General contractor agreement with Siemens, turnkey costs DM 720 million.
Apr 04, 1996	First partial construction permit.
Aug 01, 1996	Groundbreaking ceremony + start of construction.
1997	Second partial construction approval.
1998	Red-Green Federal Government.
2001	approx. **2 years construction** stop due to concerns of Federal Environmental Minister Trittin. → **Steinmeier** coordinates the Federal Government‘s statement of FRM II → Catenhusen Commission prepares compromise (conversion option) → Zehetmair coordinates federal states

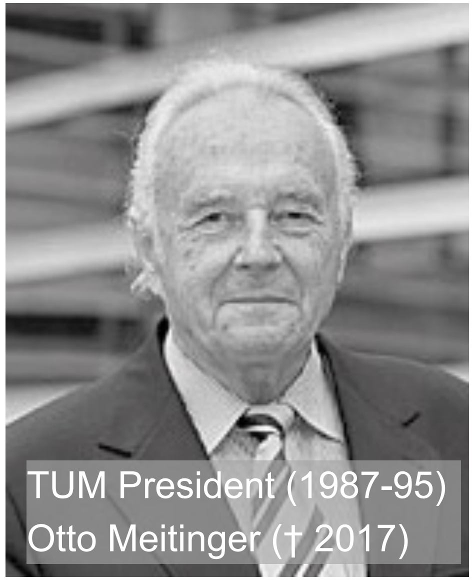
Development of the Research Neutron Source Heinz Maier-Leibnitz (FRM II)

May 2, 2003	Third partial construction and permit to start operation.
Mar 2, 2004	**First criticality**, total construction cost of the FRM II € 435 million.
Apr 29, 2005	Start of user operation with > 10 instruments.
2006	Closure of research reactor DIDO, FZ-Jülich, initially 5 DIDO instruments. move to FRM II
Jan 01, 2011	Cooperation agreement between Federal / Bavarian Government and Helmholtz / TUM for the scientific use of FRM II. bundling of German research with neutrons in the Heinz Maier-Leibnitz Center (MLZ).

Dec 17, 2010 – Signing of the cooperation agreement between TUM, FZJ, HZG und HZB and federal-state agreement between BMBF and StMBW.

Personalities


Wolfgang Gläser


TUM President (1987-95)
Otto Meitinger († 2017)


Klaus Böning


Gert von Hassel
† 2009


Ministerial Director
StMBW (until 2004)
Jürgen Großkeutz


Ministerial ´Director
BMBF (until 2005)
Herrmann Schunk

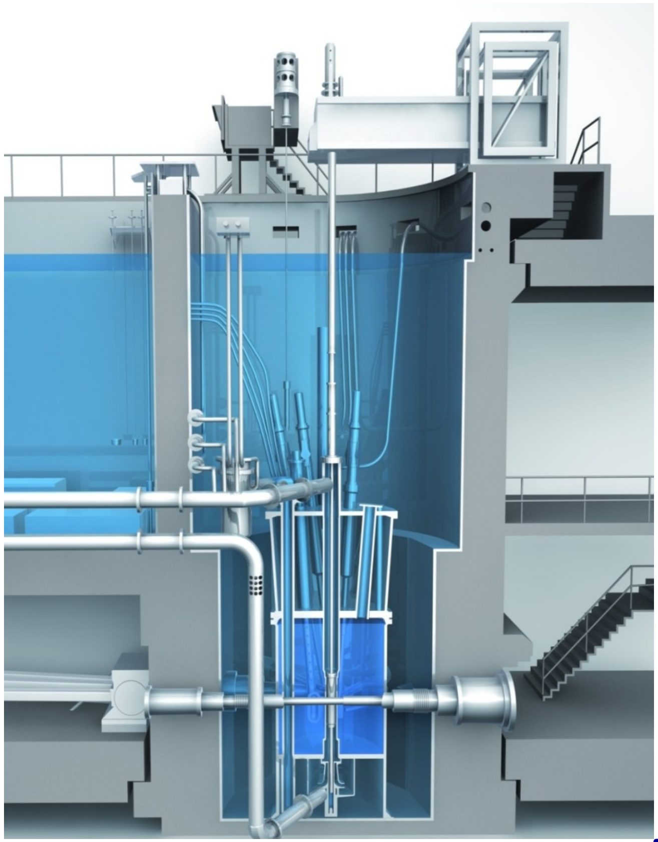

Guido Engelke
† 2008


Klaus Schreckenbach
† 2013

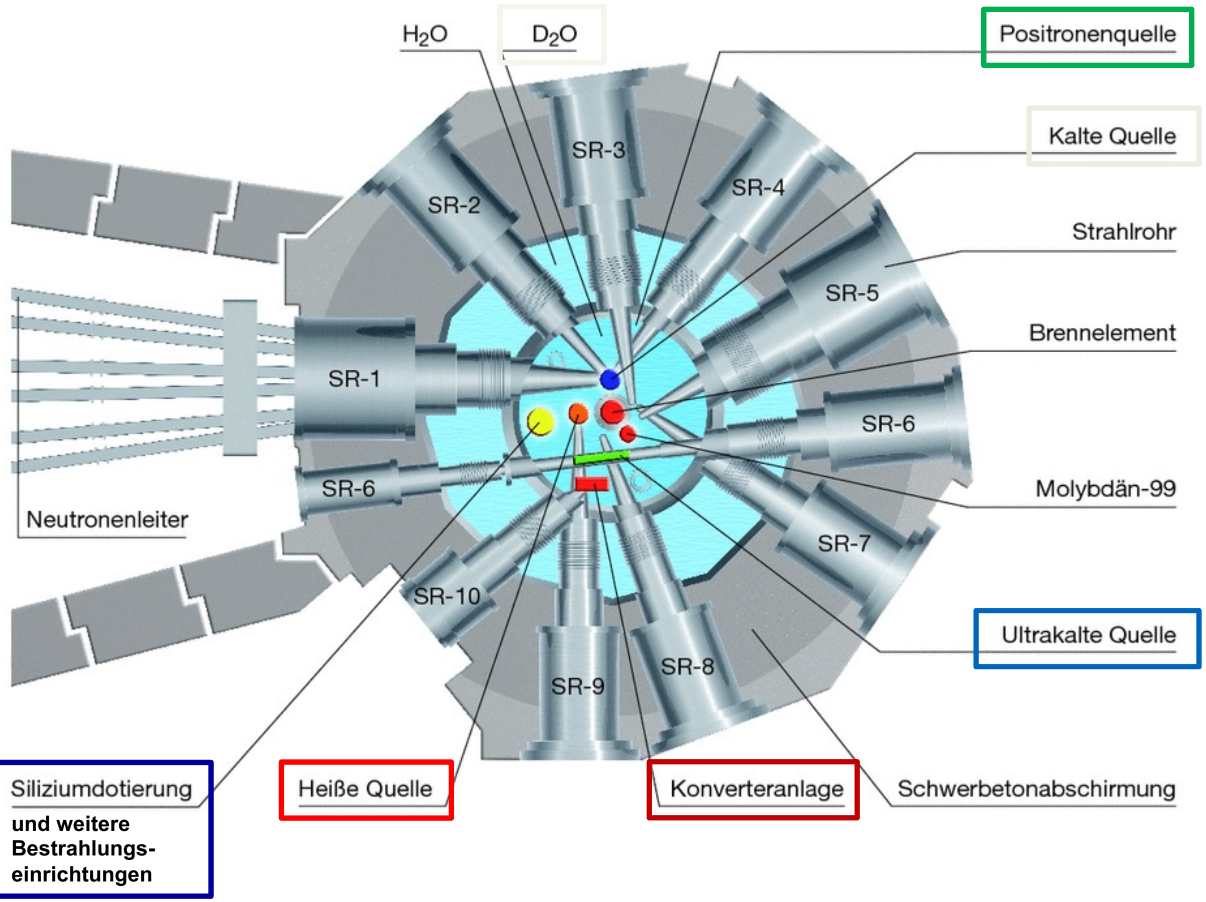
Personalities

Project Director Anton Axmann, TUM President Wolfgang Herrmann,
Bavarian Minister President Edmund Stoiber,
Minister Hans Zehetmair, Mayor Helmut Karl († 2012)

Tailor-made neutron wavelength



Thermal flux: $\phi_{th} = 8.0 \times 10^{14}\ ncm^{-2}s^{-1}$



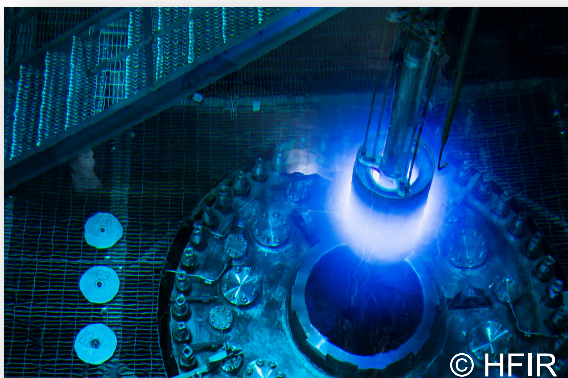
→ **Most modern neutron source with the broadest application spectrum**

W. Gläser, K. Böning, A. Axmann, E. Steichele, K. Schreckenbach: Design and Realisation of FRM II

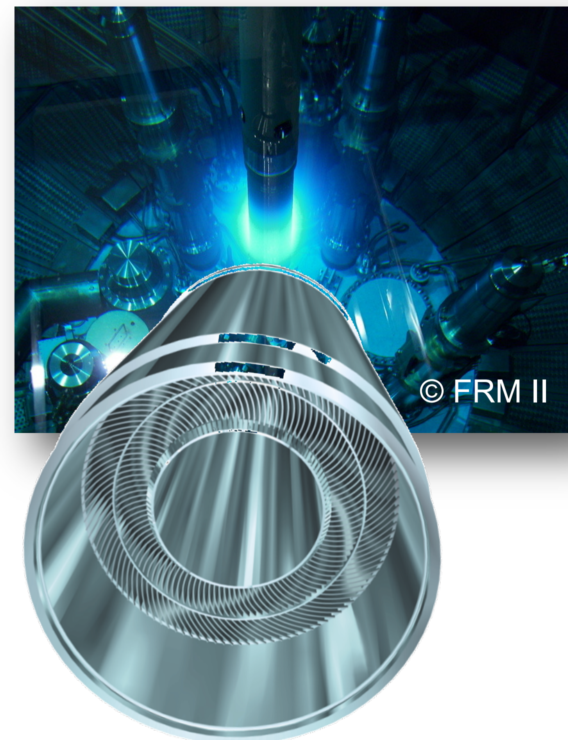
*Zeitelhack et al., NIM **A560**, 4442 (2006)*

Comparison of compact high flux neutron sources

		Operating since	Thermal Power	Cycle Length	HEU	Uranium Density	Thermal Flux
HFIR	Oakridge, USA	1965	100 MW	23 Days	8 - 10 kg	1 g U/cm³	~ 10^{15} Neutrons/cm^{2}s
ILL	Grenoble, France	1972	58 MW	44 Days		1 g U/cm³	
FRM II	**Munich**	**2004**	**20 MW**	**60 Days**		3 g U/cm³	



© ILL



→ FRM II: Best neutron flux to thermal power ratio.

Optimal use of a large-scale research facility

Why a large research institution at a university?

- The Federal Government can not guarantee long-term stability for nuclear facilities.
- TUM has unique competence in operation and use of neutron sources.
- The FRM II offers possibilities of use far beyond TUM.

But the FRM II is too expensive for a university:

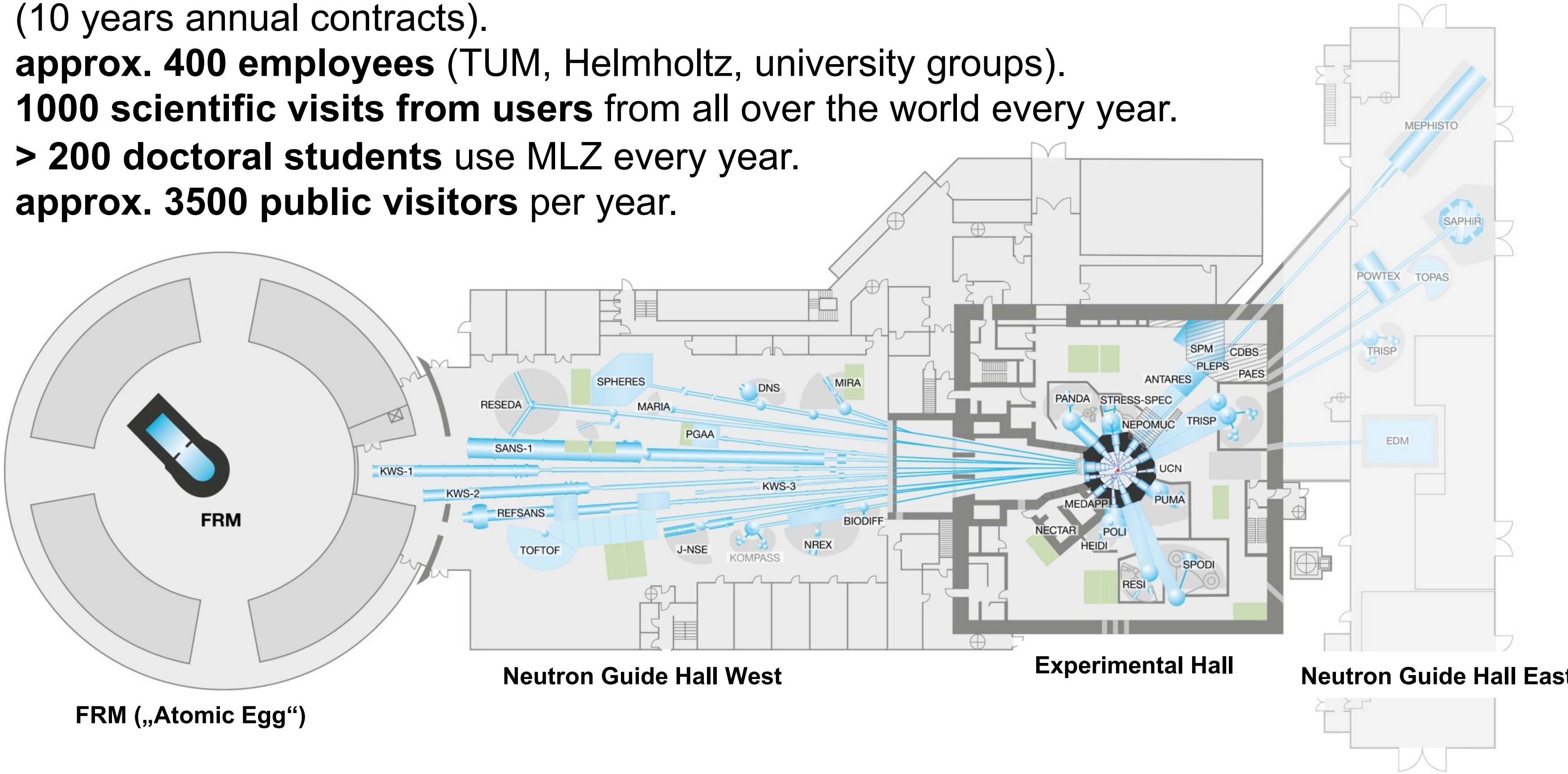
- Involvement of the Federal Government = Co-financing by the Federal Government
  - a) Participation of German university groups in the development and operation of instrumentation, financed by collaborative research funds from BMBF, between 1998 – 2020 > 70 Mio. €
  - b) Institutional funding via collaboration with the Helmholtz Association
- 2007 SMS from Science Minister Thomas Goppel to Petry: Federal Government (Annette Schavan) contributes annually with € 20 million to scientific operation
- It took 4 years until the organizational framework was found in the form of a scientific cooperation between FZ-Jülich, HZ-Berlin und HZ-Geesthacht, problem: direct Federal funding of the university was prohibited by German constitution.
- Contract signature Dec 17, 2010, coming into force Jan 01, 2011

→ **Heinz Maier-Leibnitz Zentrum (MLZ)**

Dieter Richter, W. Petry
Naming of the MLZ 2013

Heinz Maier-Leibnitz Zentrum (MLZ)

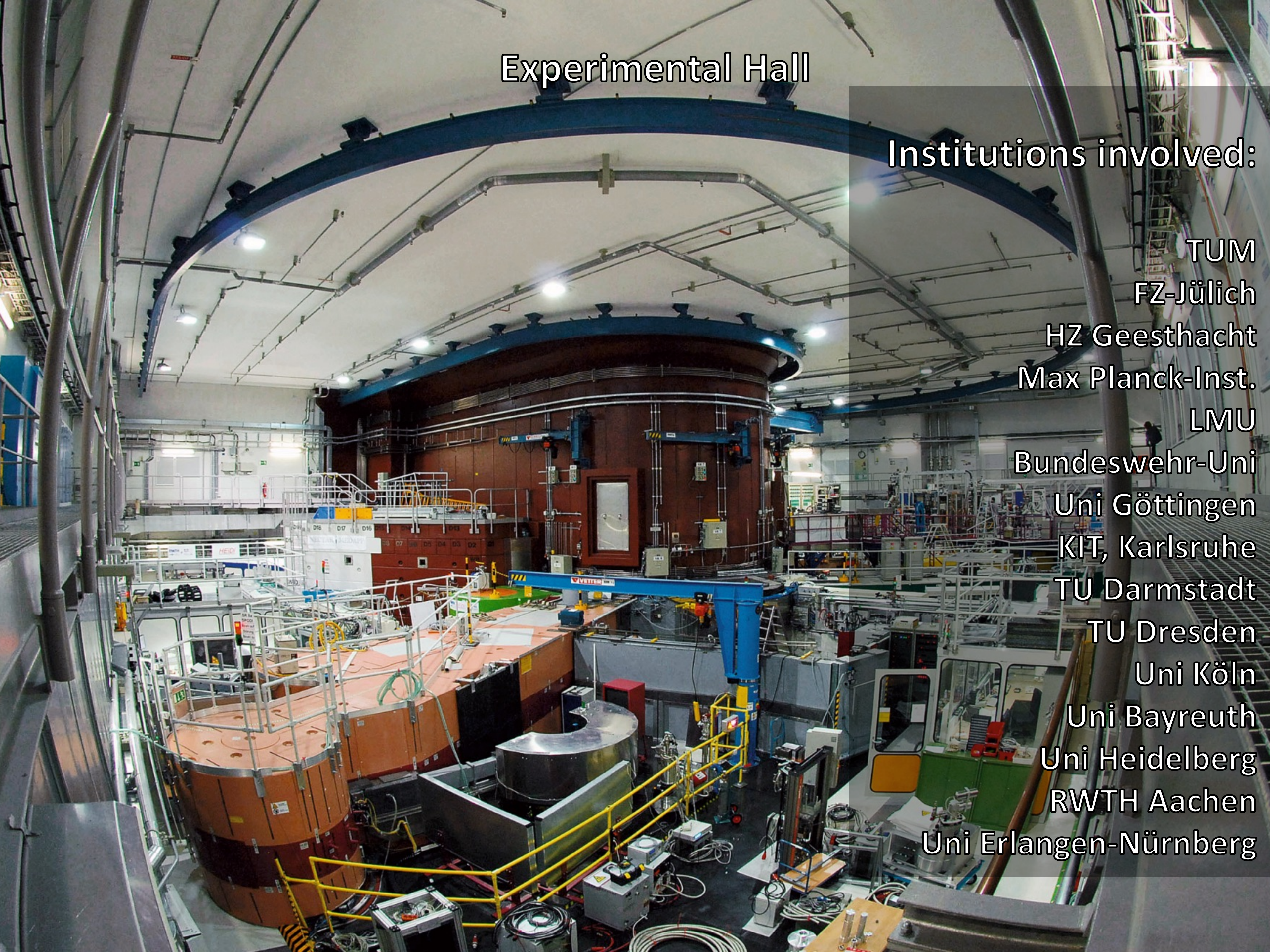
- **National service/user institution with international impact.**
- **Long-term cooperation beween Federal Government and Bavaria** (10 years annual contracts).
- **approx. 400 employees** (TUM, Helmholtz, university groups).
- **1000 scientific visits from users** from all over the world every year.
- **> 200 doctoral students** use MLZ every year.
- **approx. 3500 public visitors** per year.



→ **27 measuring instruments in operation, 5 more under construction.**

→ **MLZ – A model case of the policy inspired networking of university and large-scale research.**

Experimental Hall



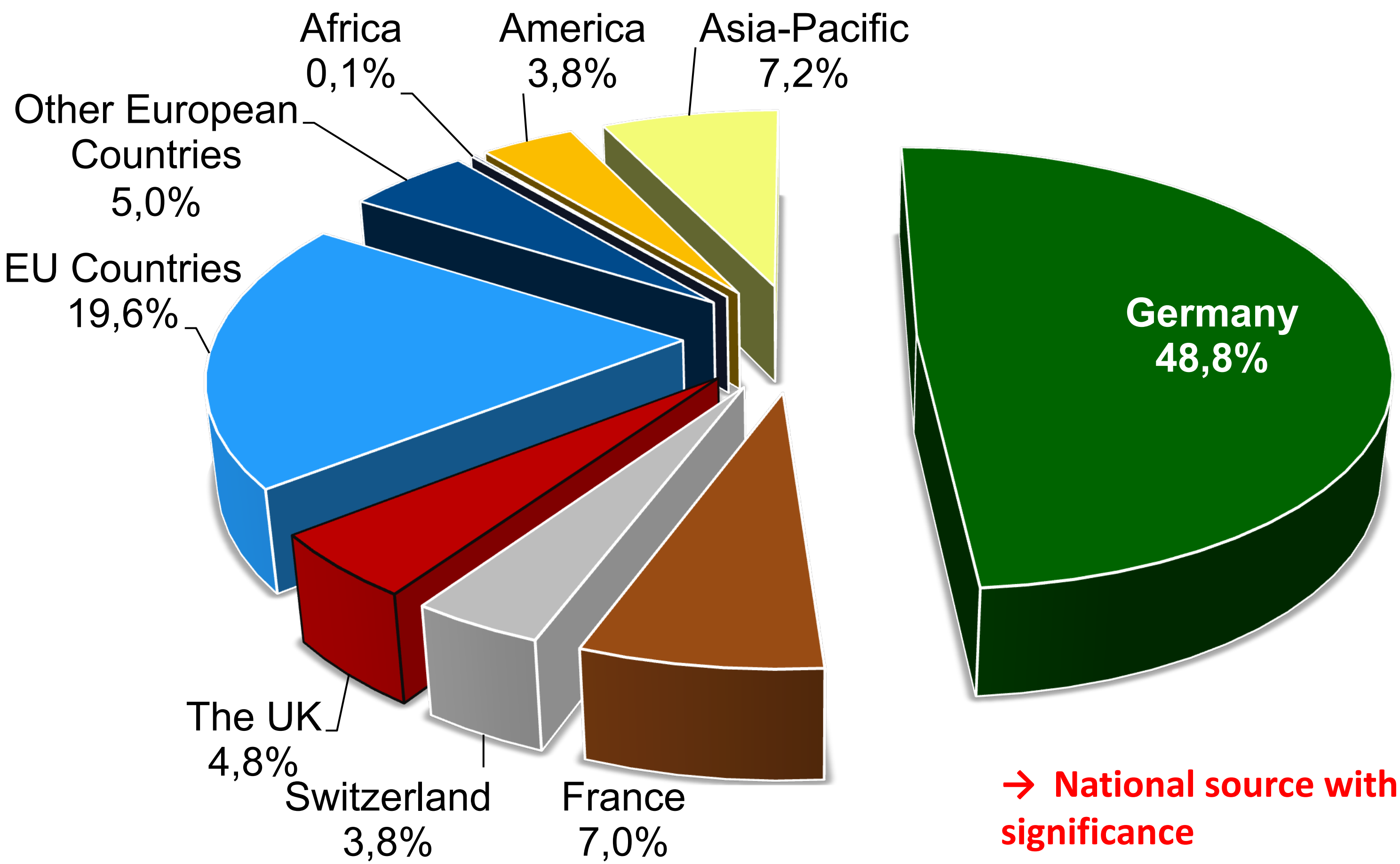
Institutions involved:

TUM
FZ-Jülich
HZ Geesthacht
Max Planck-Inst.
LMU
Bundeswehr-Uni
Uni Göttingen
KIT, Karlsruhe
TU Darmstadt
TU Dresden
Uni Köln
Uni Bayreuth
Uni Heidelberg
RWTH Aachen
Uni Erlangen-Nürnberg

Who uses neutrons at the MLZ?

- Use of neutrons for industry and medicine: 30 % - Research: 70 %
- 1000 scientific visits from users per year from all over the world!

Visitors for external beam time from all over the world (2011 – 2016)

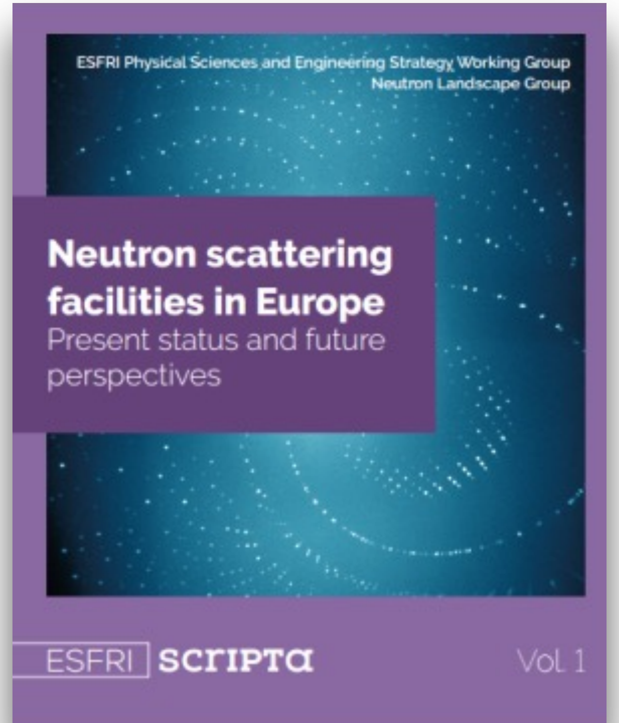


→ National source with great international significance

Neutrons provide answers to the great challenges of our society

- Energy
- Key Technologies
- Information & Communication
- Life Science & Health
- Earth, Environment & Cultural Heritage
- …
- Curiosity

Quo vadis ?



Report by ESFRI Physical Sciences
& Engineering Strategy Working Group

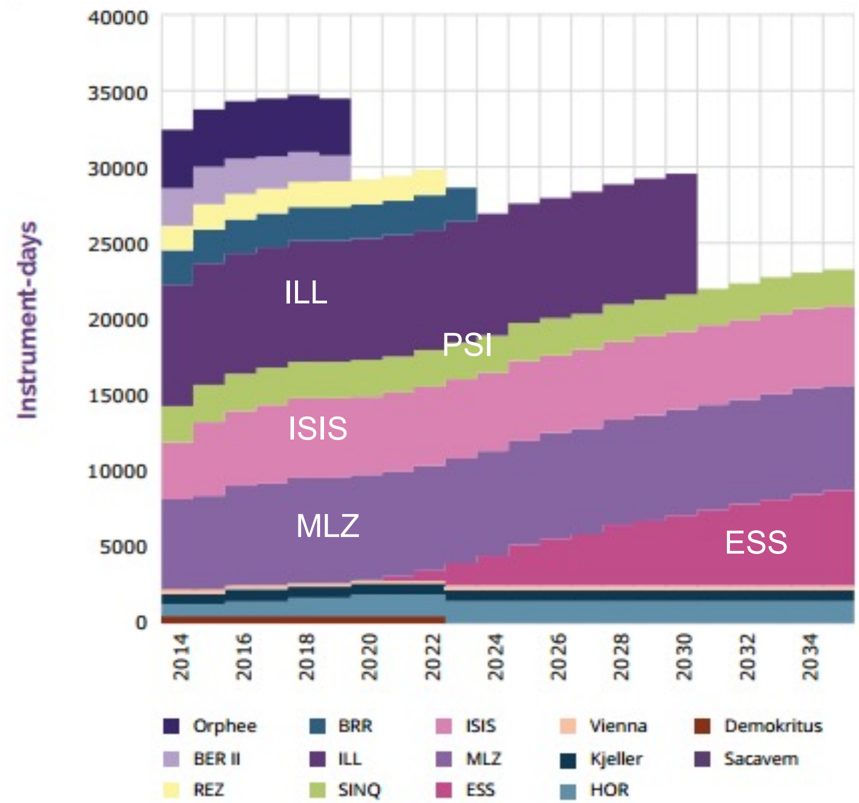


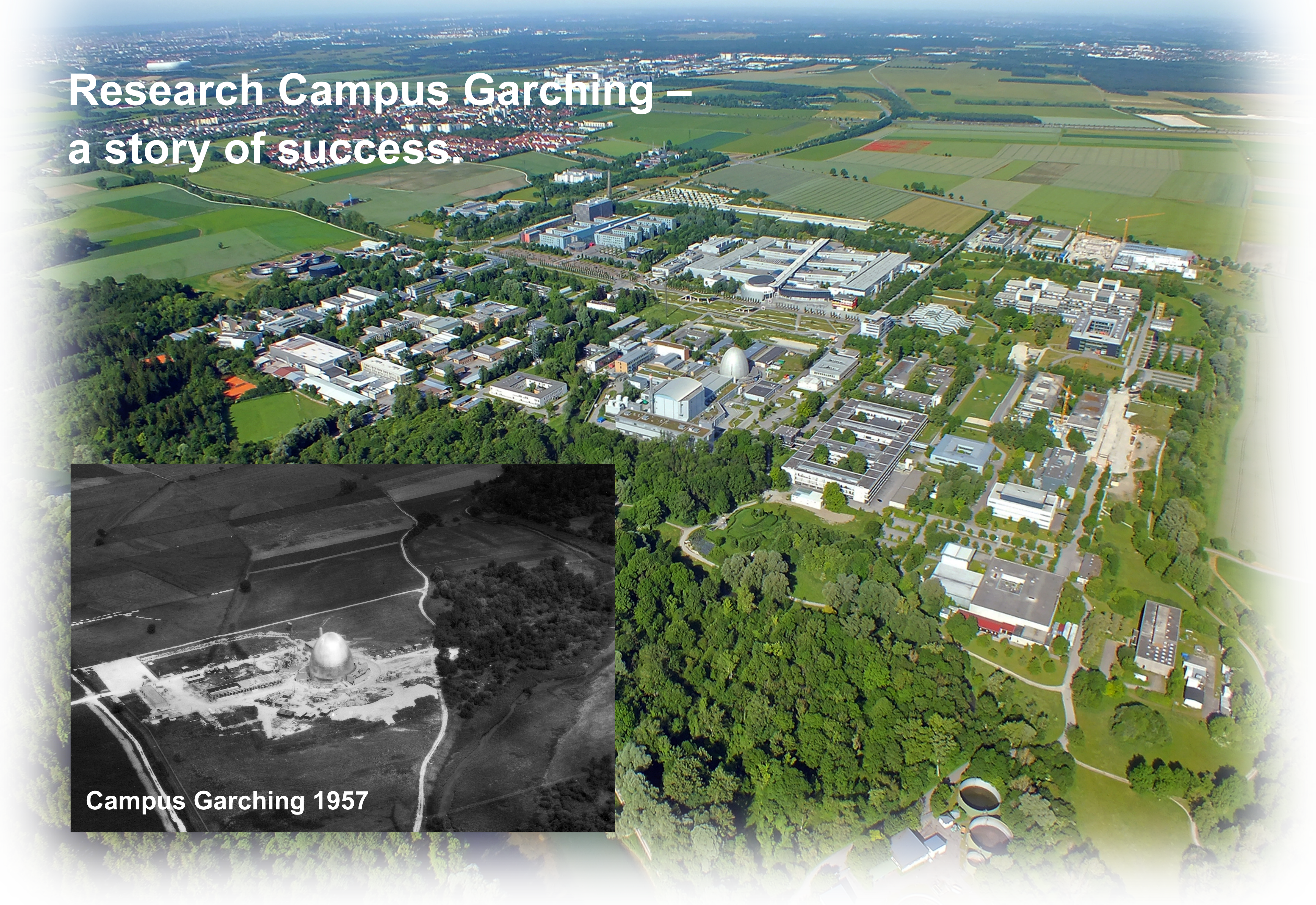
Figure 11. Enhanced Baseline Scenario

The predicted delivery of instrument beam-days in the Enhanced Baseline Scenario: ILL operates until 2030, ESS with 35 instruments beyond 2035.

→ **In the coming decade, the MLZ will provide a large neutron research capacity in Europe, have the world's most intense UCN source and delivers great amount of radionuclides for medicine!**

MLZ Heinz Maier-Leibnitz Zentrum TUM

Research Campus Garching – a story of success.



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