BNC Budapest Neutron Centre
Budapest XII, Konkoly Thege út 29-33, KFKI H-1525 Budapest, Pf. 49. Hungary

Multipurpose Utilisation of a Medium Flux Research Reactor – Benefit for the Society

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IAEA International Conference on Research Reactors: Safe Management and Effective Utilization
14-18 November 2011, Rabat, Morocco

Nuclear sciences and neutron research have long traditions in Hungary

Great fathers:

- WIGNER Jenő
- SZILÁRD Leó
- HEVESY György
- TELLER Ede

Nuclear Rector Facilities in Hungary

- Paks Nuclear Power Plant (4x500 MW-e)
- Budapest Research Reactor (KFKI, 10 MW)
- Training Reactor at the Budapest TU (0.8 MW)

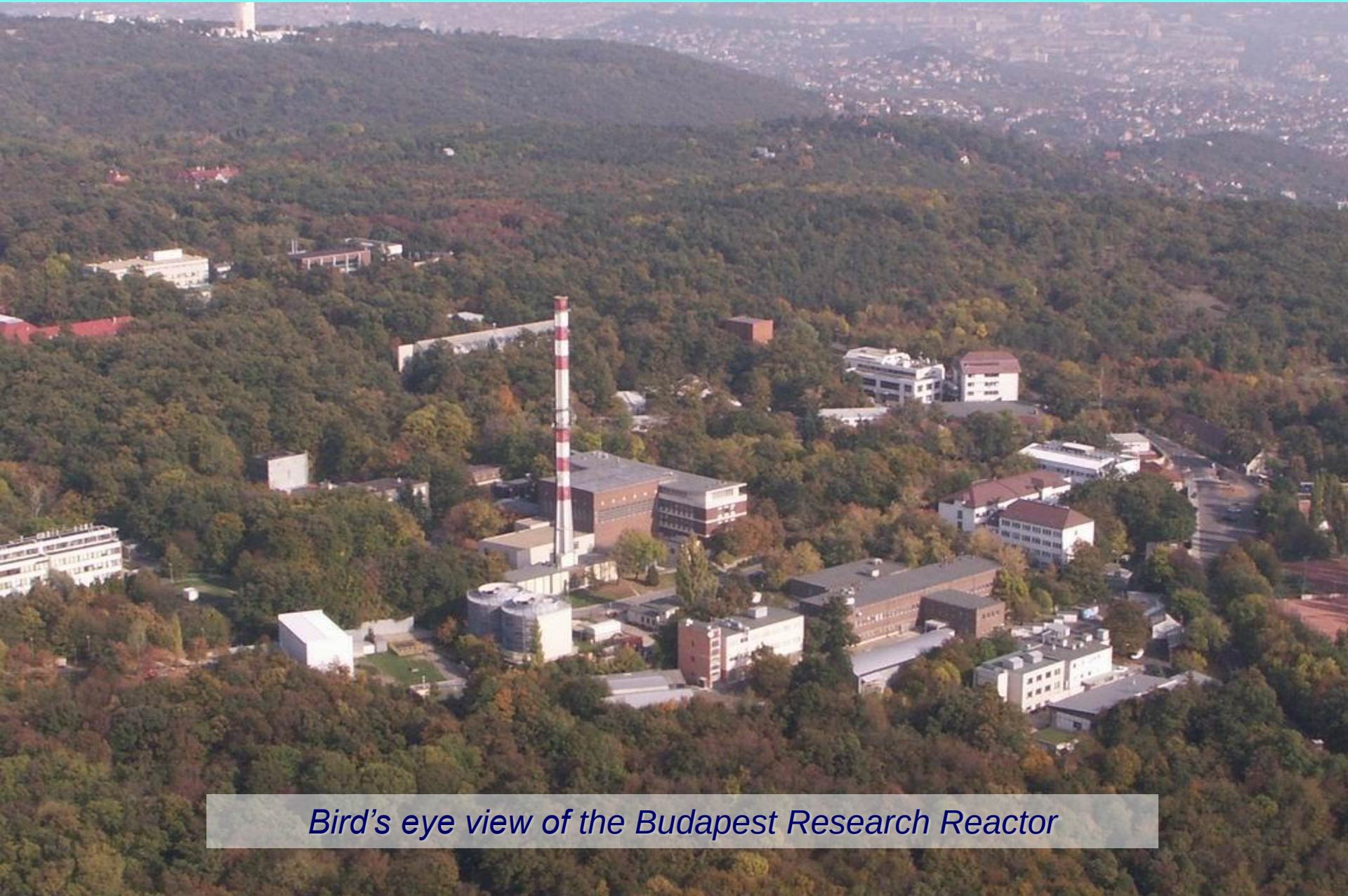
Research Reactor – Benefit for the society

- Support for the energy sector
- Research and radioisotope supply for healthcare
- Materials research for industry, life-sciences, nanotechnology....
- Basic science, methodical research, technology transfer, products...

BNC

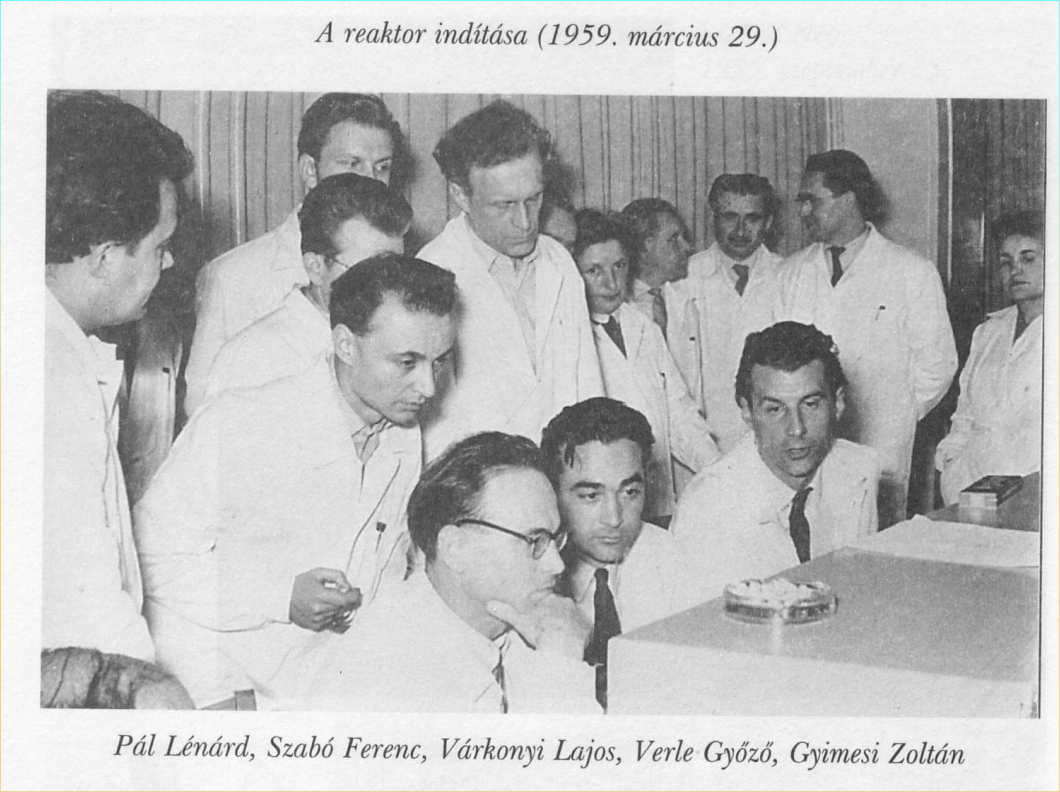
The 10 MW Budapest Research Reactor

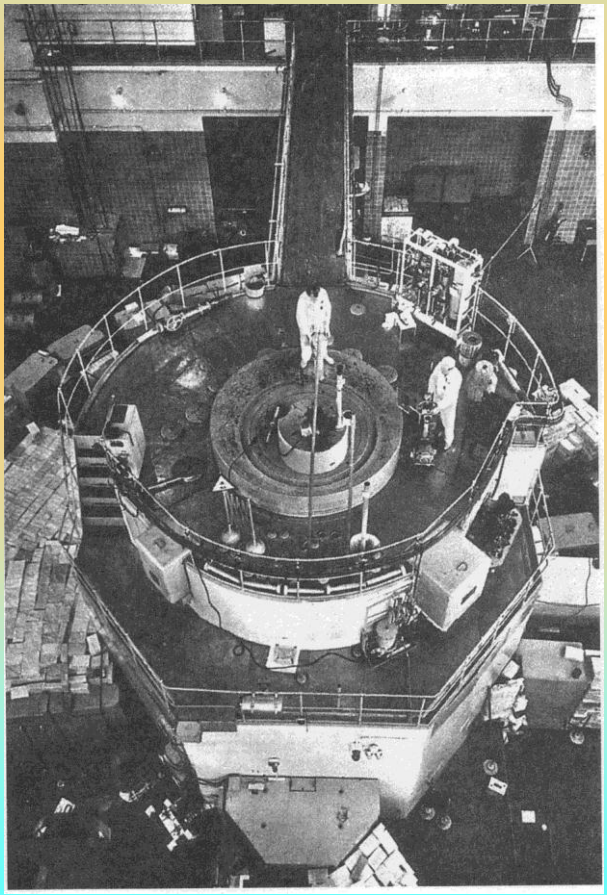
KFKI RESEARCH CENTRE



Bird's eye view of the Budapest Research Reactor

Neutron research was established in Hungary with starting the reactor in 1959

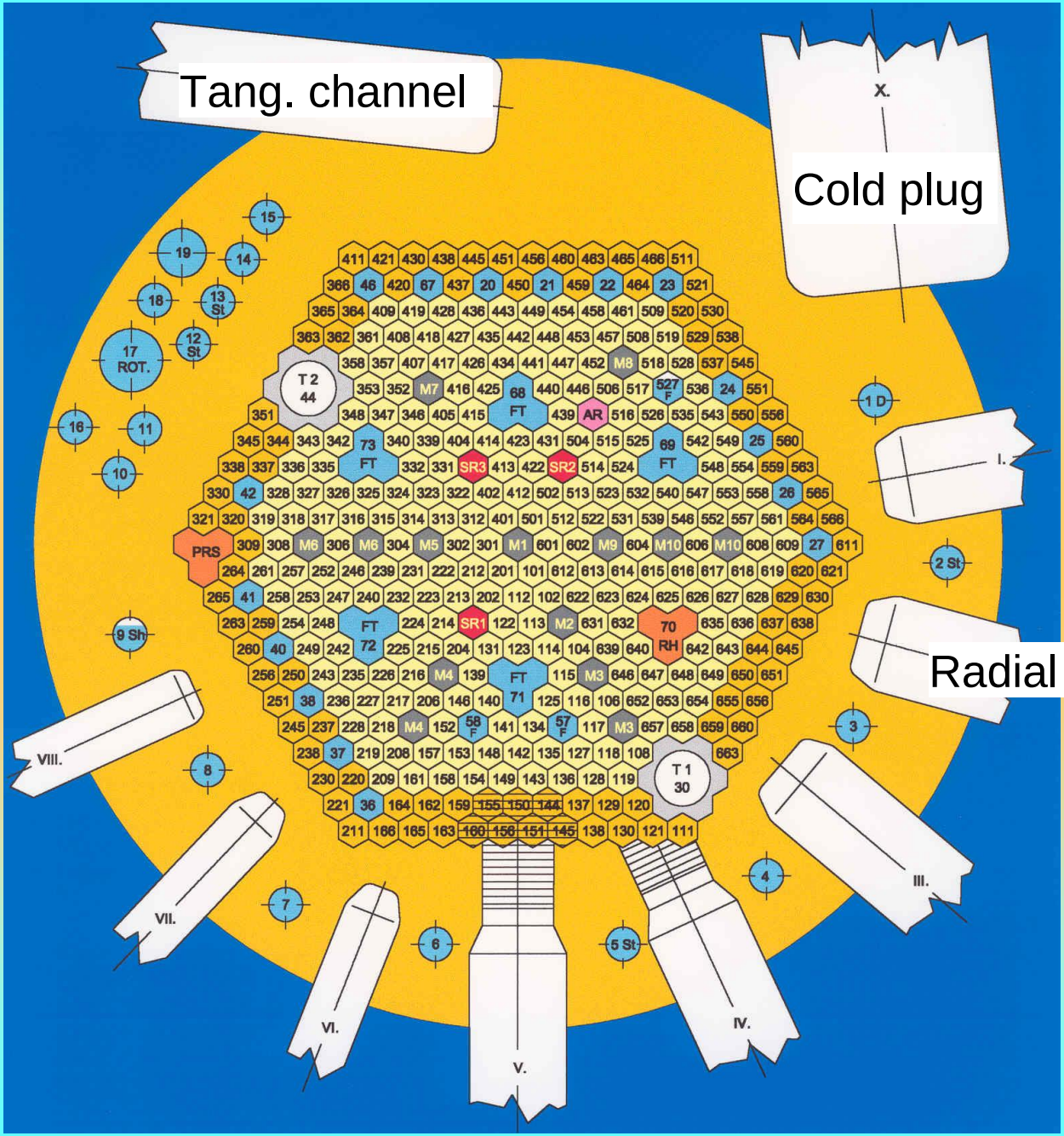




Major milestones:

- Upgrad: 1967, 5 MW
- Start: 1959, 2.5 MW
- Full scale refurbishment: 1986-90
- **Recommissioning: 1992, 10 MW –** international opening
- **Cold neutron source: 2000-01** – participation in EU projects
- **Fuel cycle management 2008-09** – invitation to projects
- **Operation foresight: 2023** – NEKIFUT: strategic infrastructur

Reactor core



225 fuel elements, 36% of ^{235}U

T ~ 20 K

$\lambda_{\text{maximum flux}} = 4\text{Å}$

NEW: Bagira loop

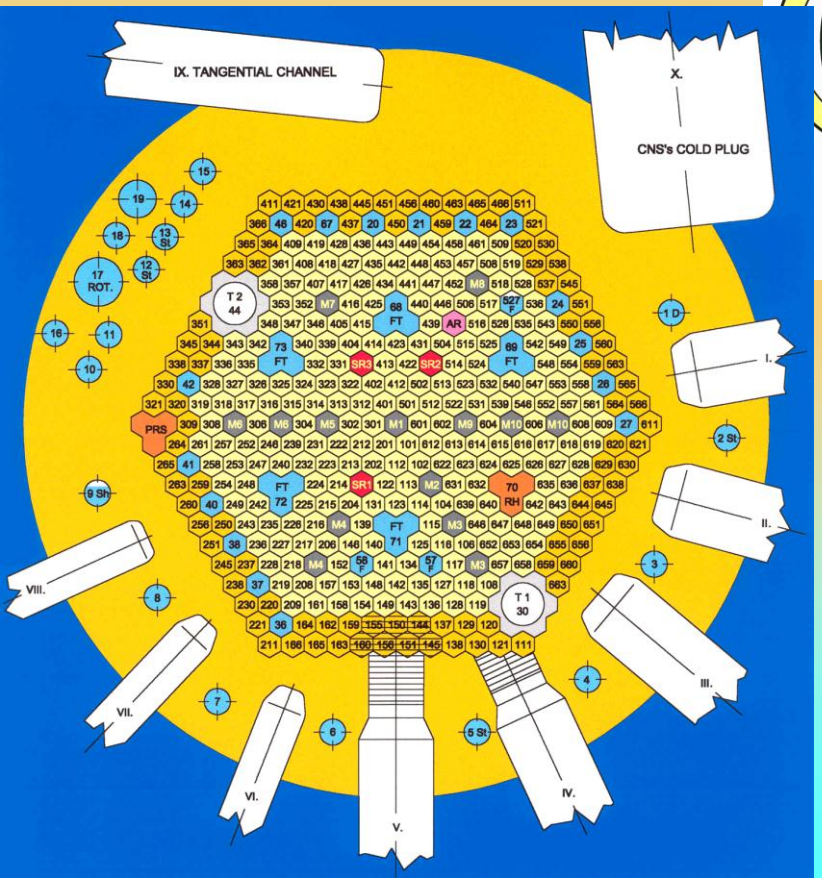
Radial channels

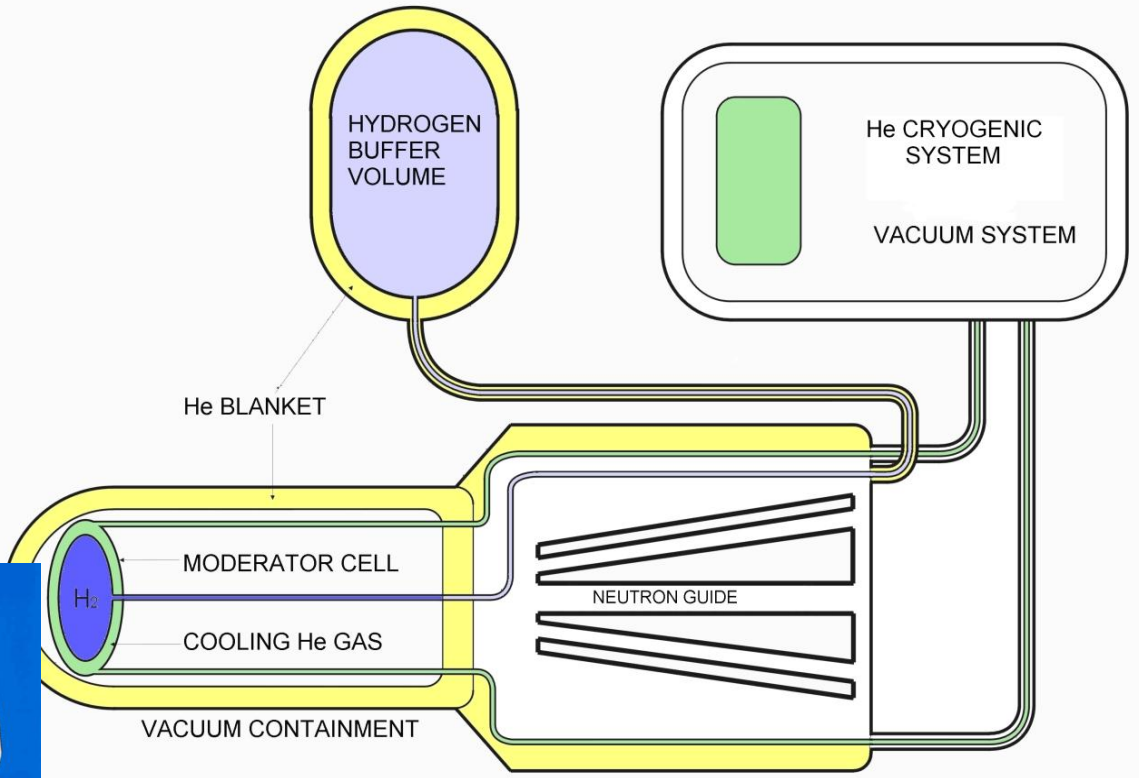
T ~ 320 K

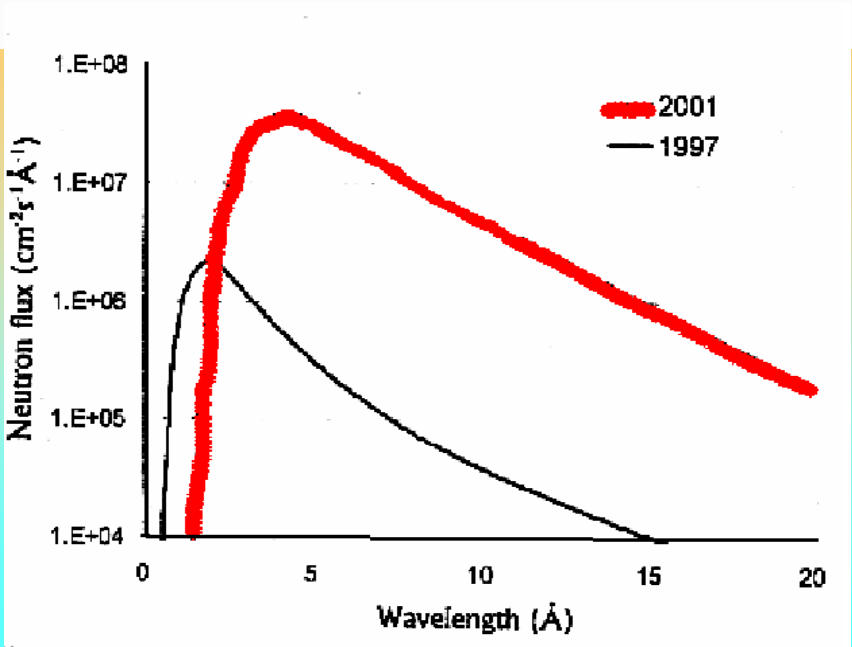
$\lambda_{\text{max flux}} = 1.2\text{Å}$

Transition to 20% enriched fuel (2007-08)

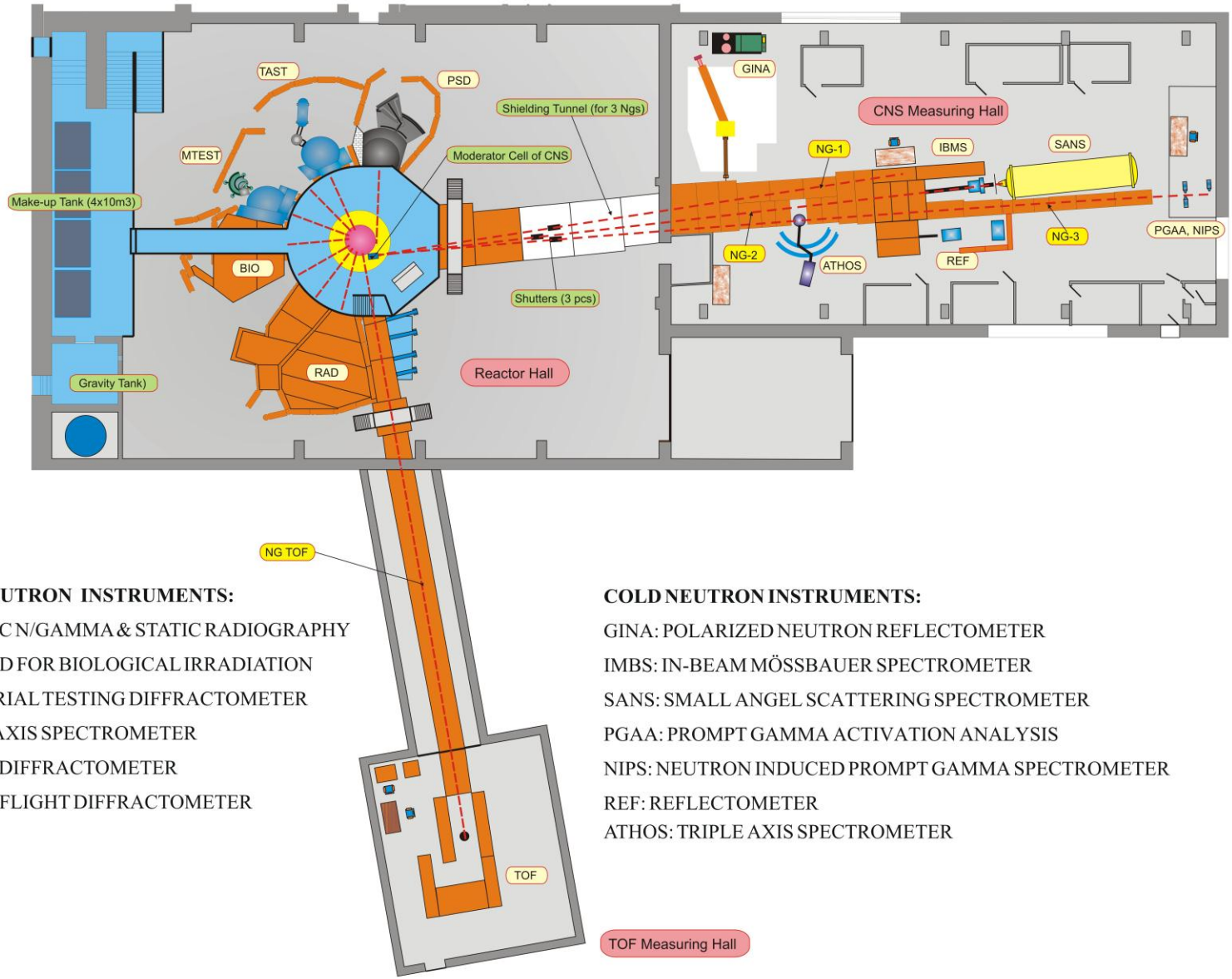
Liquid Hydrogen Cold Moderator







Lay out of the Horizontal Neutron Beam Facilities



THERMAL NEUTRON INSTRUMENTS:

RAD: DYNAMIC N/GAMMA & STATIC RADIOGRAPHY

BIO: PORT USED FOR BIOLOGICAL IRRADIATION

MTEST: MATERIAL TESTING DIFFRACTOMETER

TAST: TRIPLE AXIS SPECTROMETER

PSD: POWDER DIFFRACTOMETER

TOF: TIME-OF-FLIGHT DIFFRACTOMETER

COLD NEUTRON INSTRUMENTS:

GINA: POLARIZED NEUTRON REFLECTOMETER

IMBS: IN-BEAM MÖSSBAUER SPECTROMETER

SANS: SMALL ANGEL SCATTERING SPECTROMETER

PGAA: PROMPT GAMMA ACTIVATION ANALYSIS

NIPS: NEUTRON INDUCED PROMPT GAMMA SPECTROMETER

REF: REFLECTOMETER

ATHOS: TRIPLE AXIS SPECTROMETER

Three major fields of activity:

i) **Research and development base for the energy sector – to support the national Paks Nuclear Power Plant operation and developments; serve as scientific and development tool in various fields of energy research, production, storage etc.**

ii) **This medium flux reactor serves as a complex source of irradiations for materials testing and modification, diagnostics in nanotechnologies, engineering, healthcare etc.**

iii) **The most extended utilization of BRR is neutron beams from the horizontal channels of the reactor to serve for exploratory as well as for applied research in a very wide range of disciplines.**

- Research of structure and dynamics of condensed matter
- Development of neutron scattering methods and instrumentation
- Contribution to the development of national and international R&D infrastructures

Neutron beam research activity:

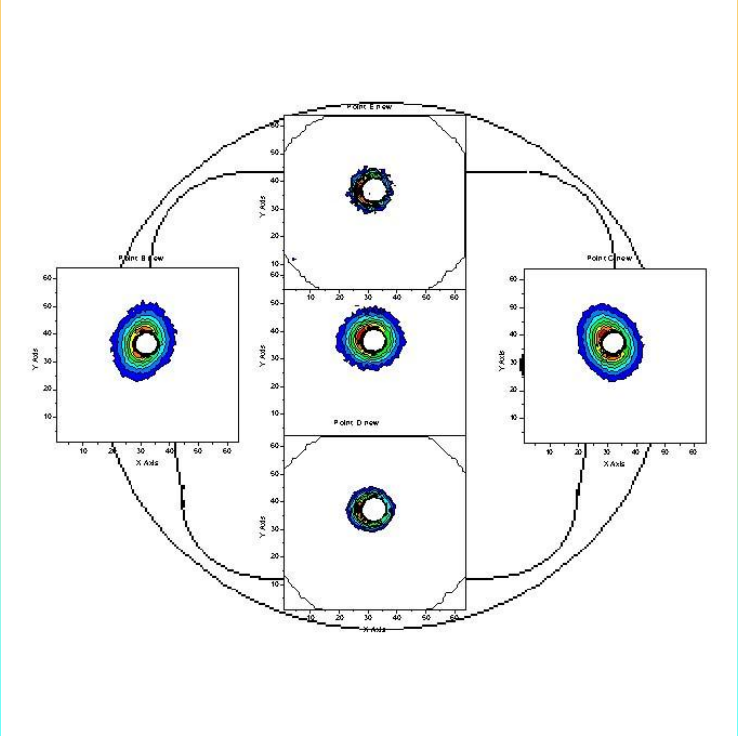
- **Research of structure and dynamics of condensed matter**

Highlights

Life-time investigation of Ferrari engine pistons

Small angle neutron scattering study of the nanoscale defect structure in Al-alloy pistons at different stages of usage. Anisotropic distribution and highly geometry dependent growth of precipitates was revealed.

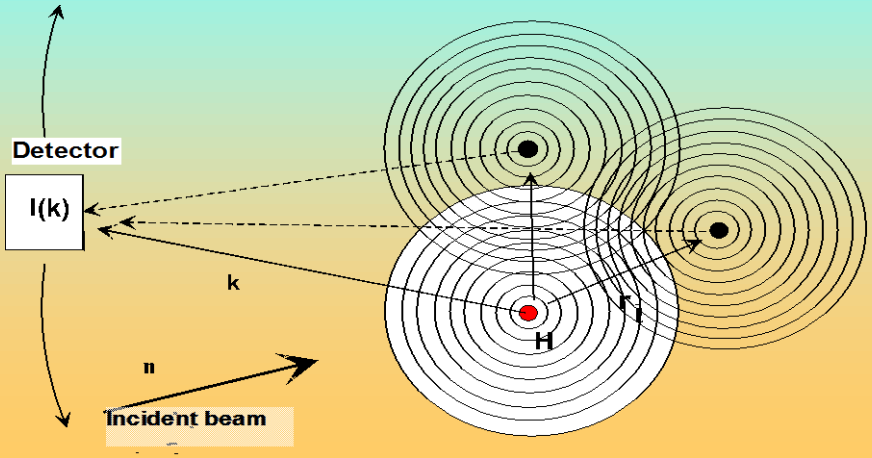
M. Rogante, V.T. Lebedev, F. Nicolae, E. Rétfalvi, L.Rosta, Physica. B 358, 224 (2005)



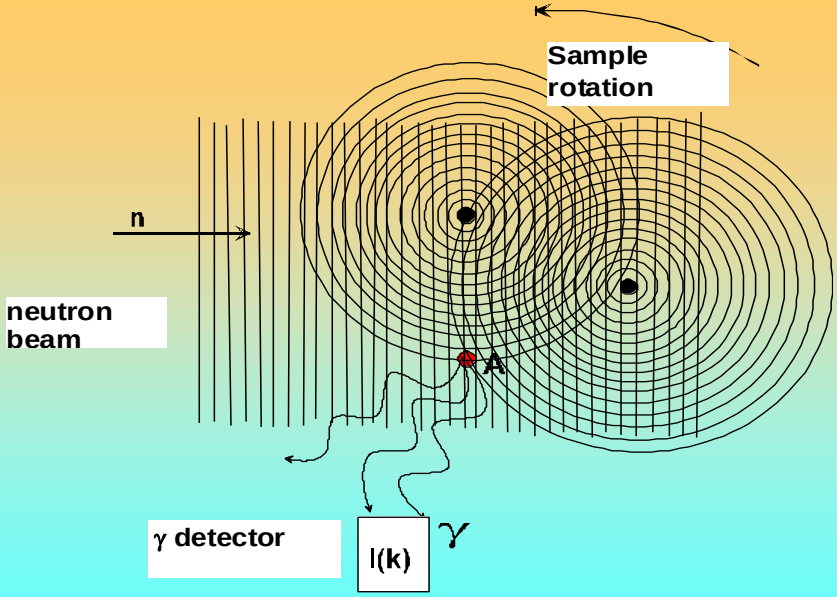
Atomic resolution neutron holography

In 2001 László Cser proposed two ways of realisation of holography with neutrons:

Inside source concept

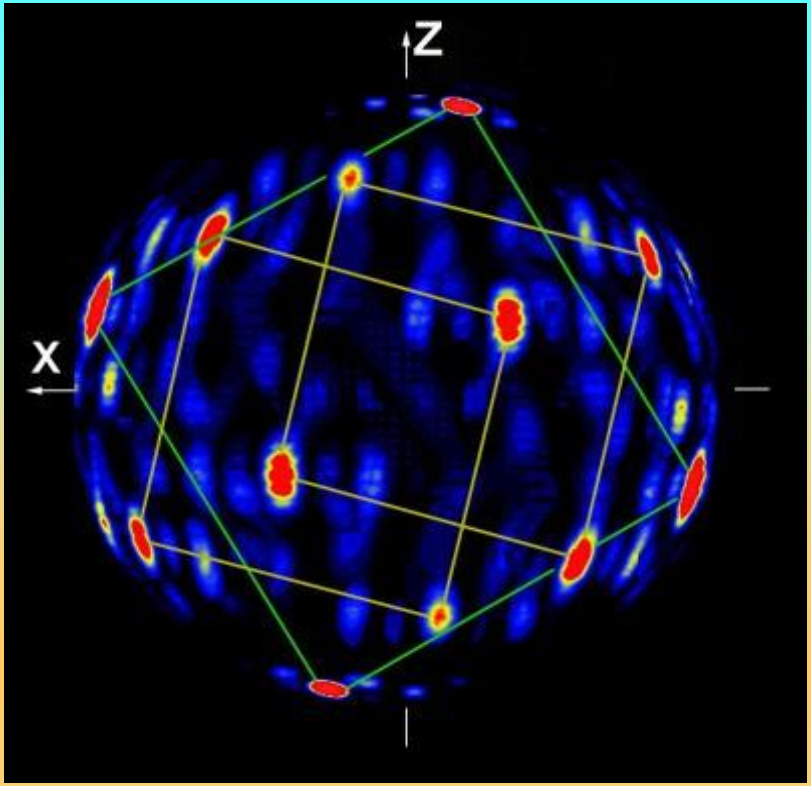


Inside detector concept

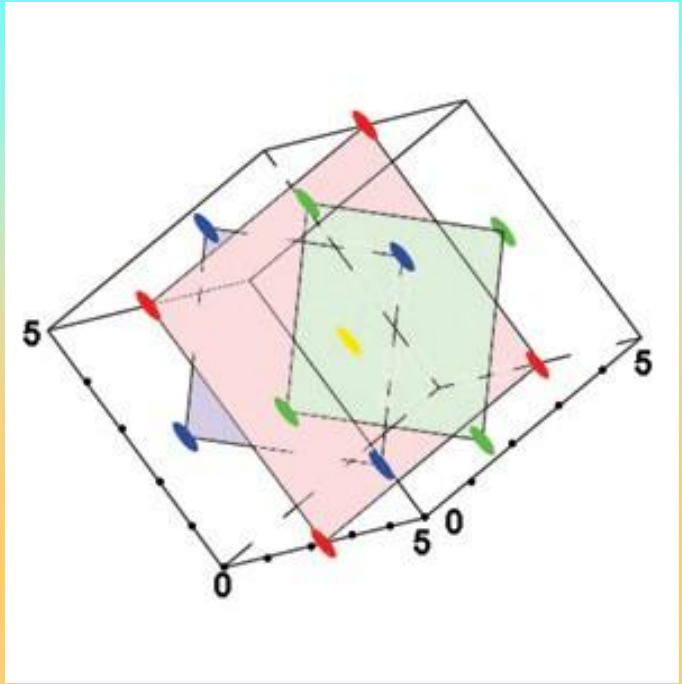


Various experiments have been realised using both methods

Experiment on PbCd alloy



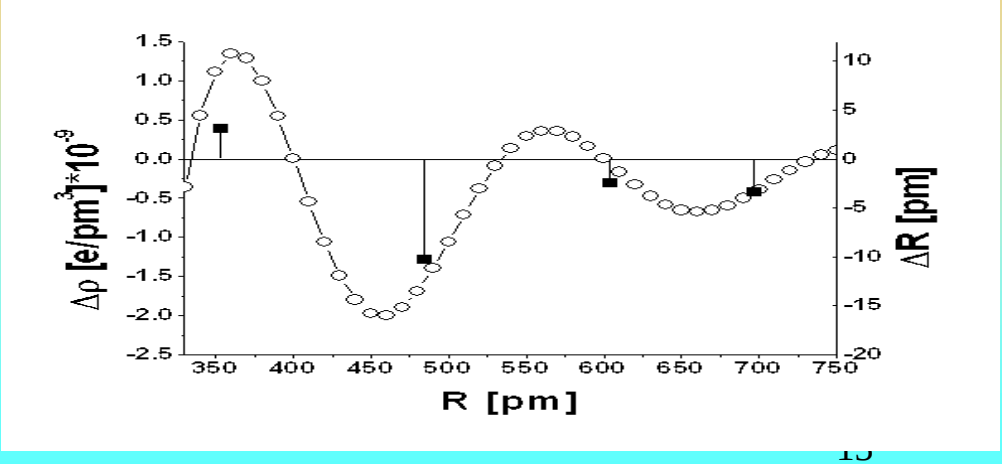
Stereoscopic view of the first Pb neighbours of the Cd nucleus



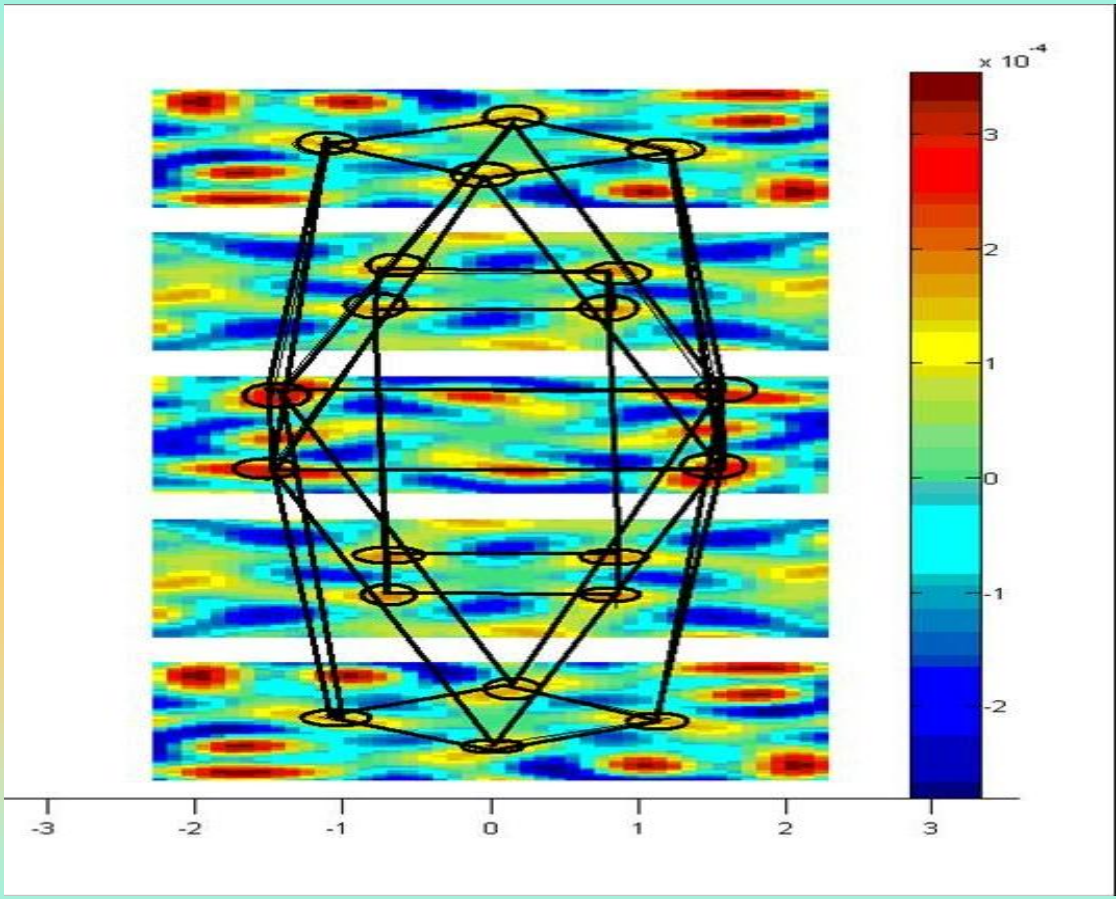
Schematic view of the left side picture

Local distortion of the lead lattice due to Cd impurity derived from the restored holographic intensity can be determined with picometric accuracy

L. Cser,1, G. Krexner, M. Markó, I. Sharkov, and Gy. Török, **Phys. Rev. Lett. 97, 255501 (2006)**



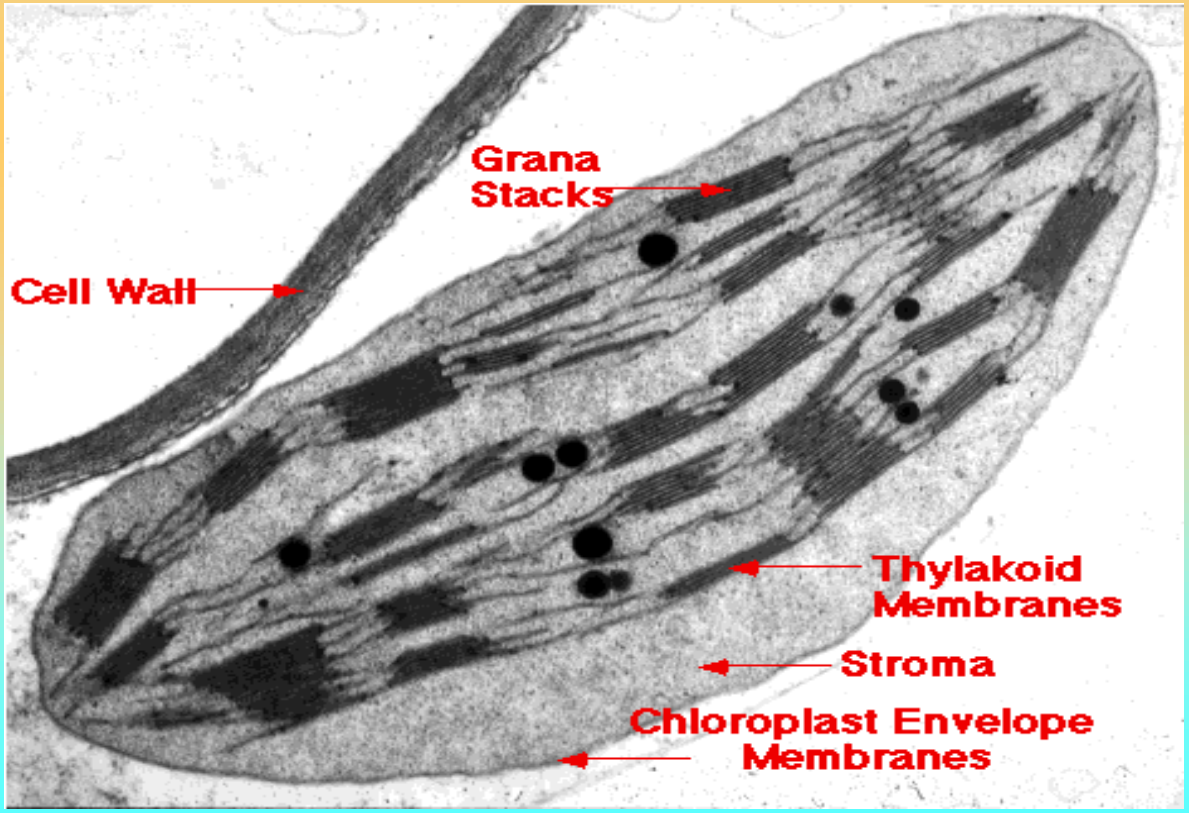
View of the holographic instrument installed at the beam line #8 of the Budapest Research Reactor



Inside source expriment: lattice structure of NH4Cl

Artificial photosynthesis – membrane structure studies

Life on earth depends on photosynthesis, the conversion of light energy to chemical energy. In chloroplasts, the thylakoid membranes, flat membrane vesicles, – a unique assembly of protein, pigment and lipid molecules (about 200 different proteins, two dozens of different lipid species and several types of pigment molecules) – accommodate all light-harvesting and energy- transducing functions. In most higher **plants performing photosynthesis, thylakoid membranes are differentiated into grana and stroma regions**, also known as stacked and unstacked regions, respectively.

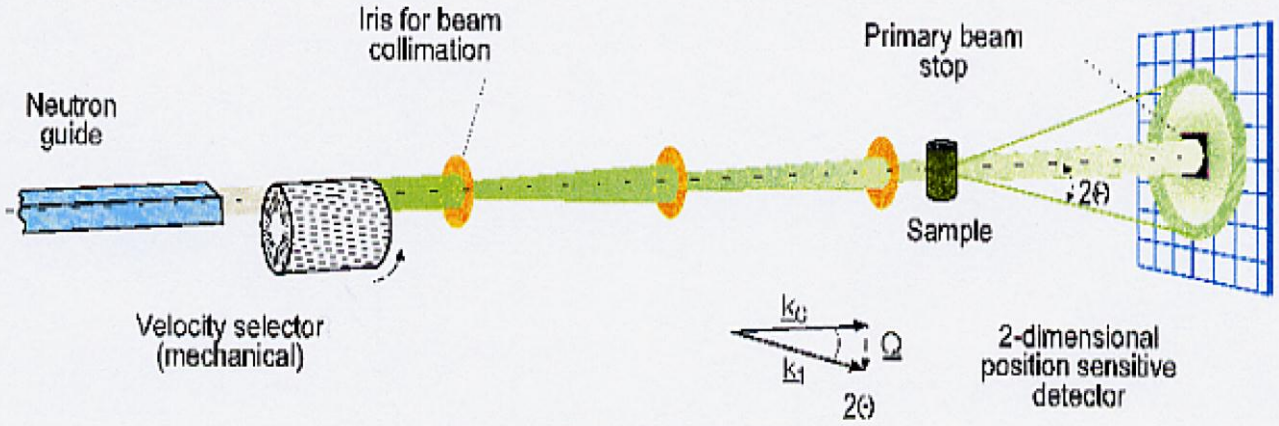


Work started in 2006, Collaboration of SZFKI, SZBK and ILL

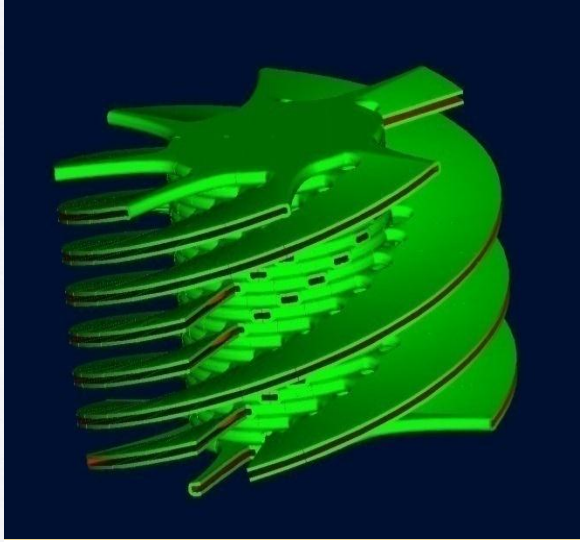
OTKA grant (2010)

SZFKI, SZBK, KK; 150 MHUF (F. Mezei)

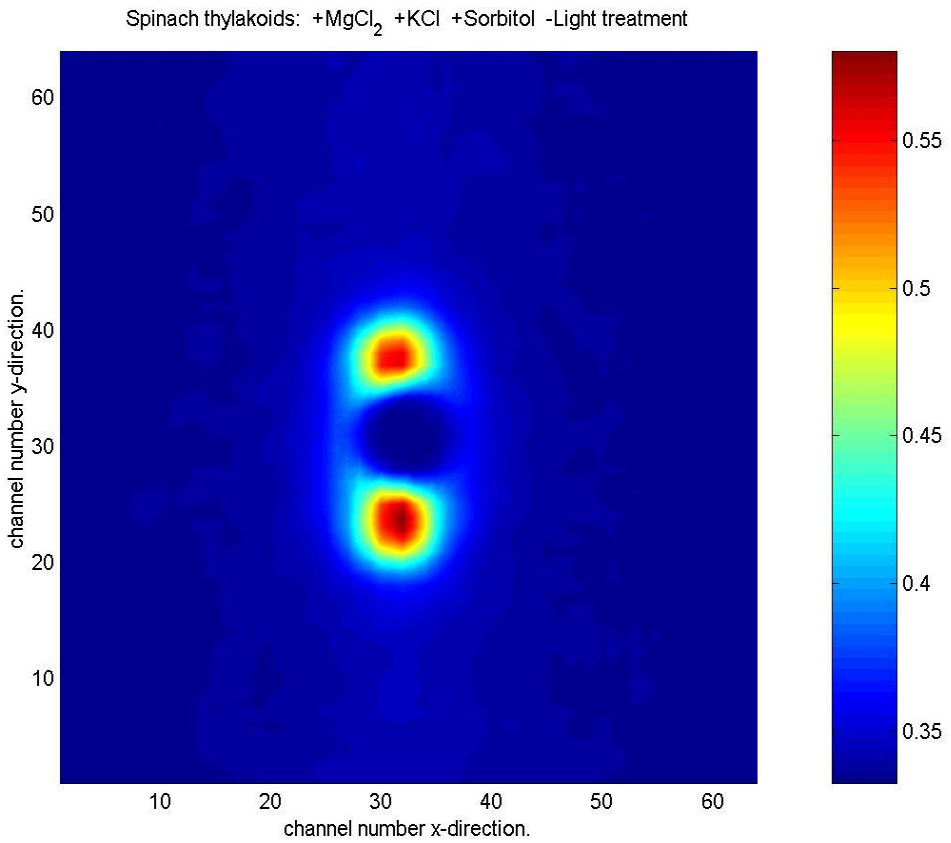
PhD thesis Nagy G.(2010)



Scheme of the SANS diffractometer

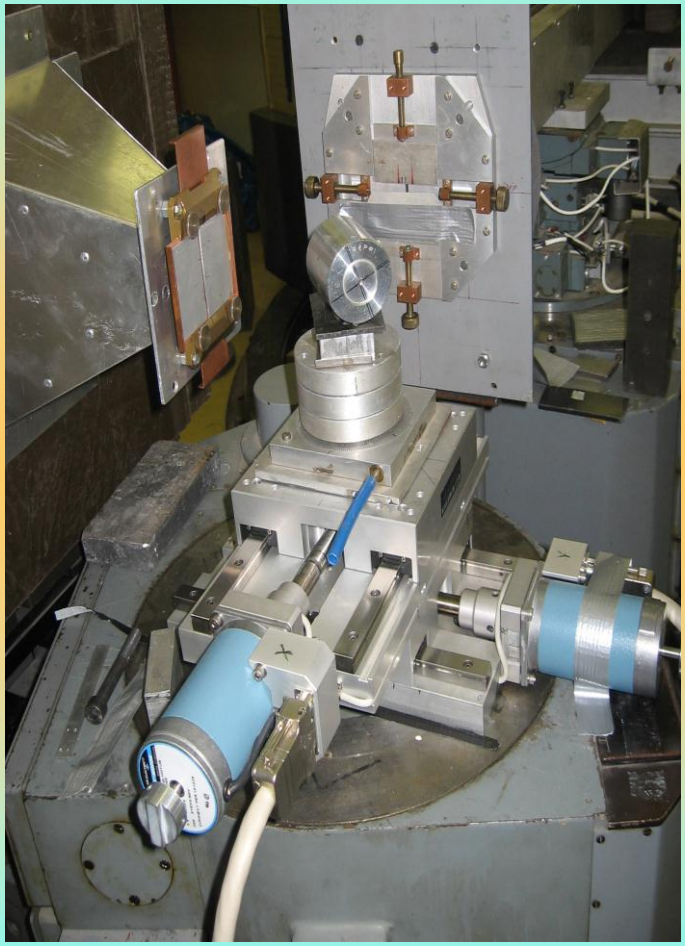


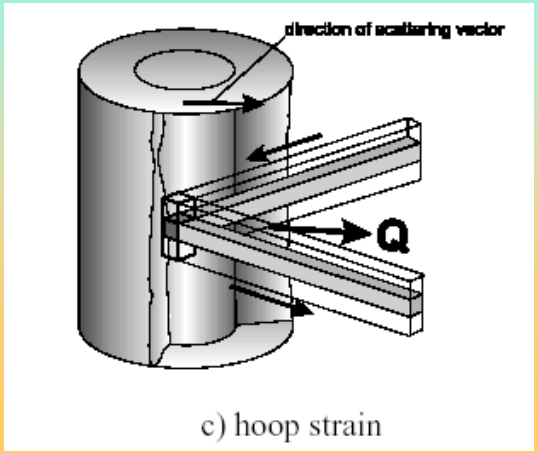
SANS
on magnetically aligned thylakoids membranes



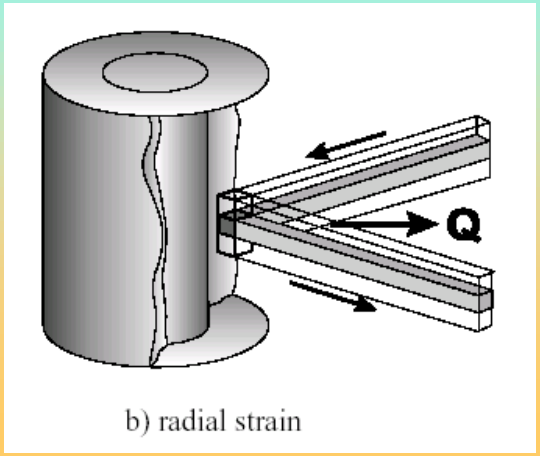
Várkonyi Zs; **Nagy G**; Lambrev P; Kiss Anett Z; Székely N; Rosta L; GarabGy:. Photosynthesis research 2009; **99**(3);161

Residual stress measurements in metal standards. A worldwide Round Robin test was performed on samples VAMAS Aluminium Ring & Plug Aluminium Ring & Plug Set. (IAEA supported project)

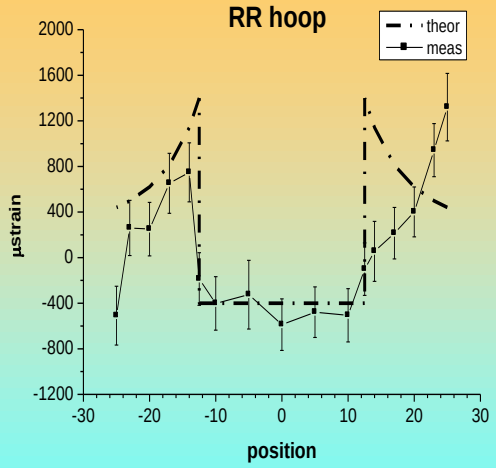


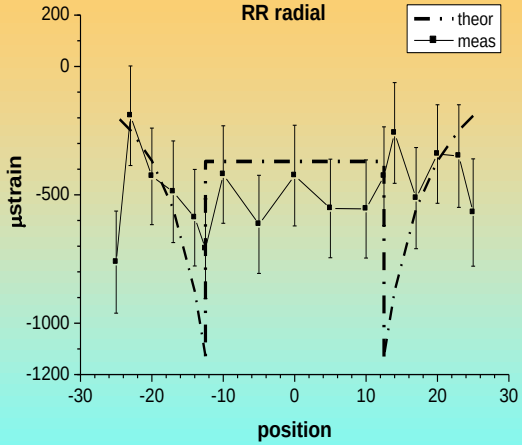


c) hoop strain



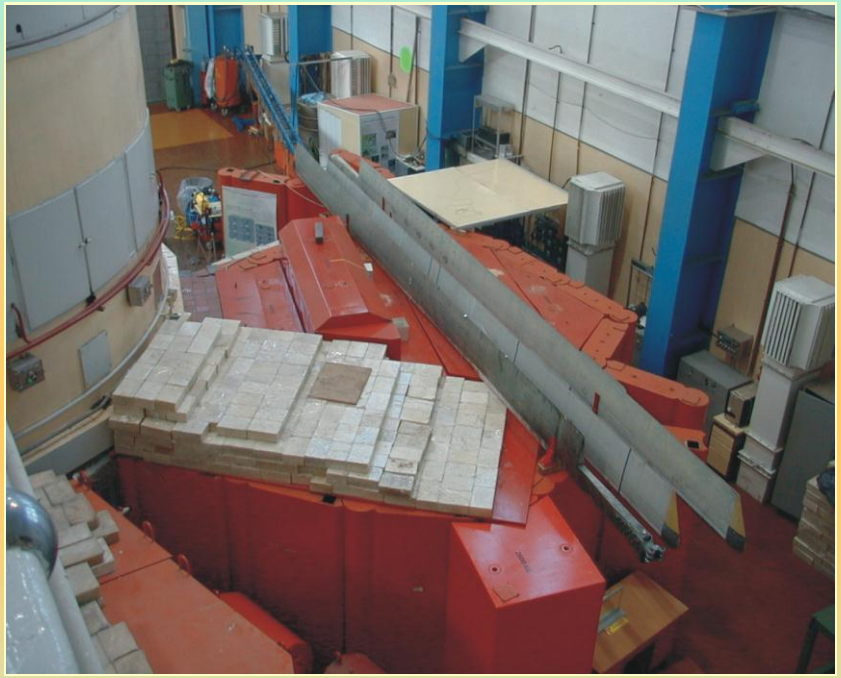
b) radial strain

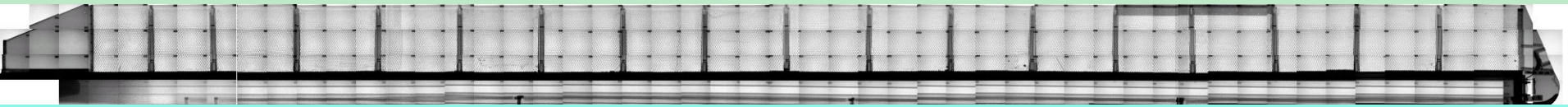




Direct industrial application of the reactor radiation facilities

2001-04, Haditechnikai Intézet: ***Neutron-, gamma- and X-ray radiography***





Balaskó, Veres, Molnár, Sváb .
Physica B, **350,** 107 (2004)

Investigation of objects of cultural heriage

BNC **Budapest Neutron Centre**

Budapest XII, Konkoly Thege út 29-33, KFKI H-1525 Budapest, Pf. 49. Hungary

nmi3 ... Access to 10 neutron and 2 muon facilities ... travel and subsistence support

Integrated Infrastructure Initiative for Neutron Scattering and Muon Spectroscopy

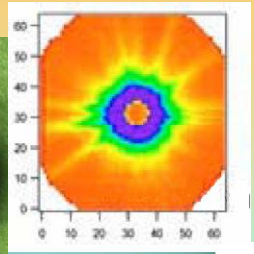
2000-2003

2004-2008

CAPACITIES

2009-2013

PGAA



TOF-ND

SANS

RADIOGRAPHY

Highlight 2008

Neutron beam research activity:

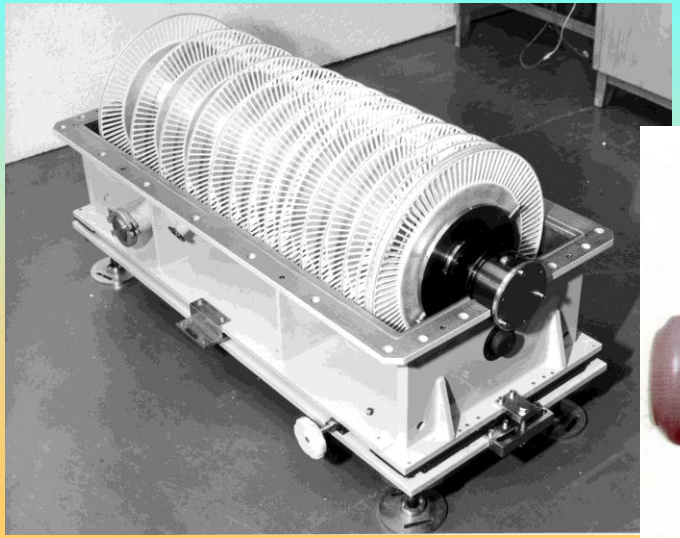
- **Development of neutron scattering methods and instrumentation**

Three aspects / funding schemes of an extended instrument development programme

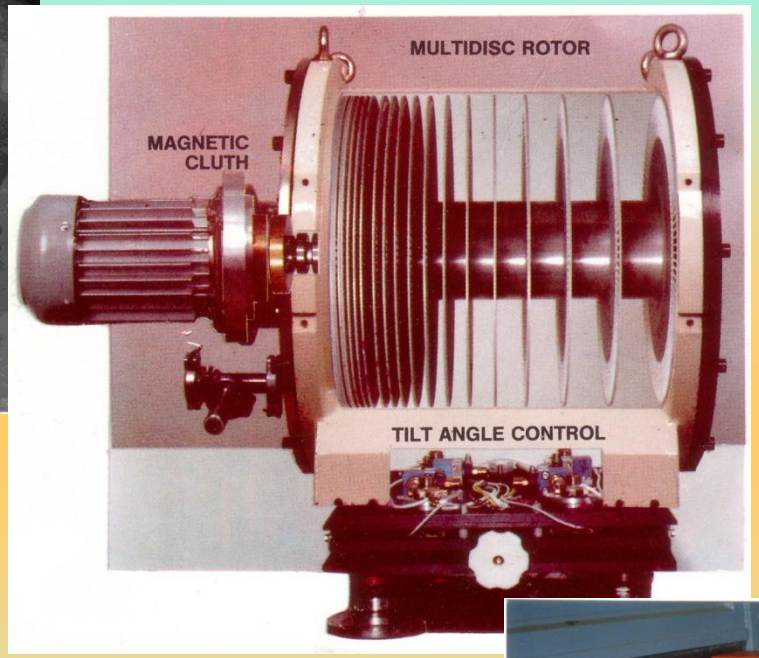
- Construction of large scale experimental stations: via strategic in-house developments
- Grants for development and technology transfer:
  → resources for our own research
  → economic development (high tech industry, export)
- Collaborative participation in cutting edge international developments (e.g. prototype diffractometry for European Spallation Source at BNC, 70 % international funding)

Examples

Neutron velocity selectors



Multidisc selector – first prototype (1983)



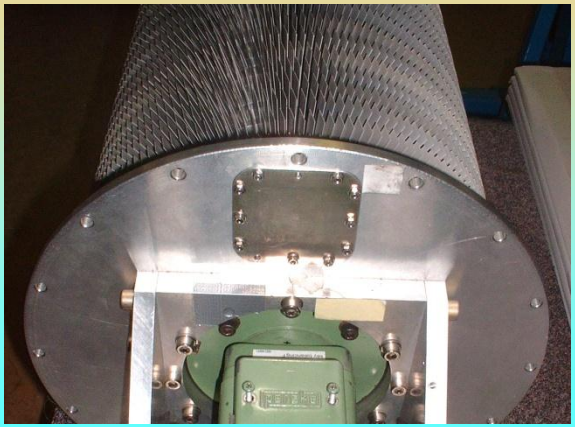
Fabrication:

KFKI - MSZI

Selectors as commercial products (in the middle and below) were sold to France, USA, Japan etc.

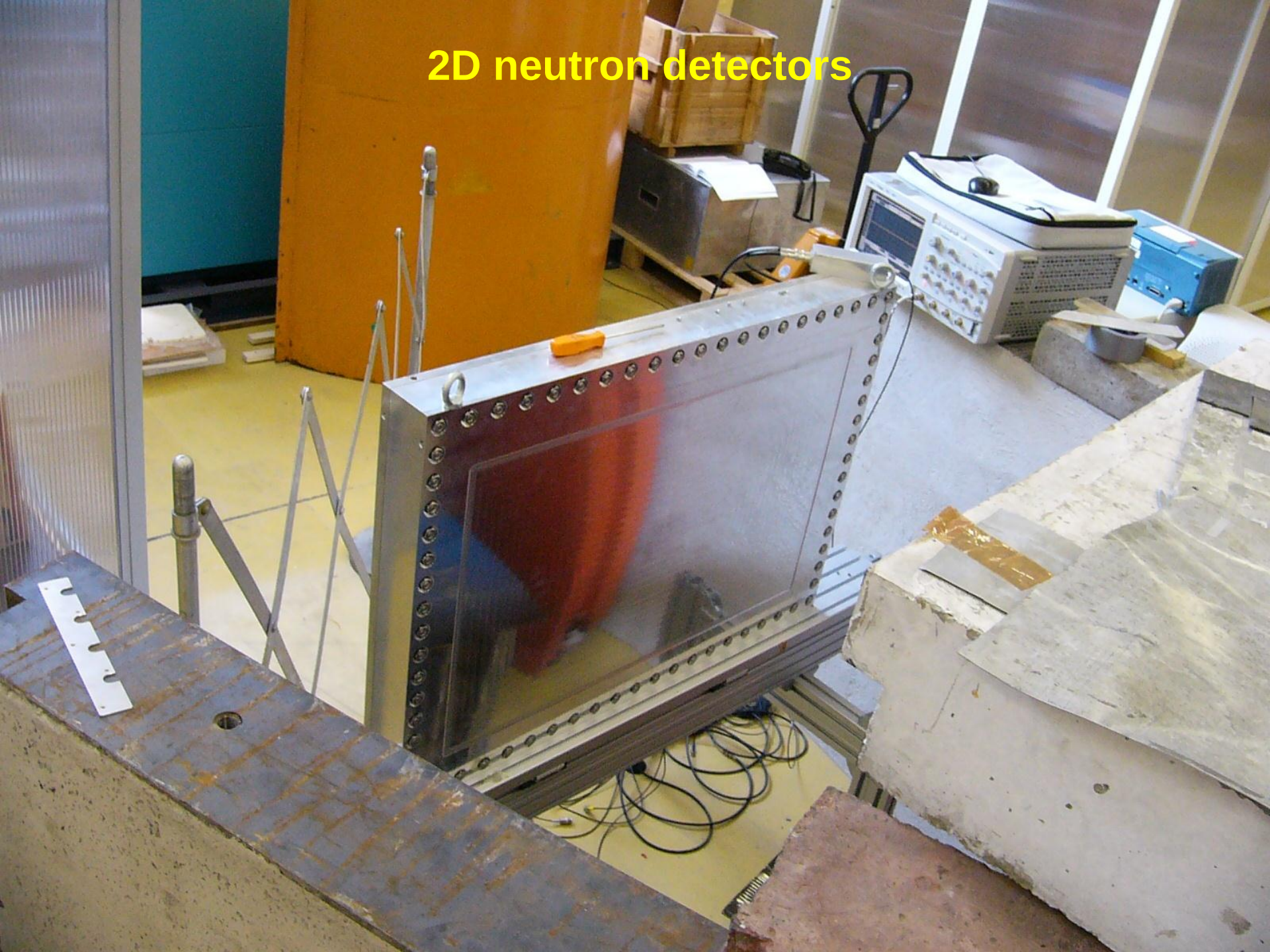
1996-2002: New development

Multiblade selector

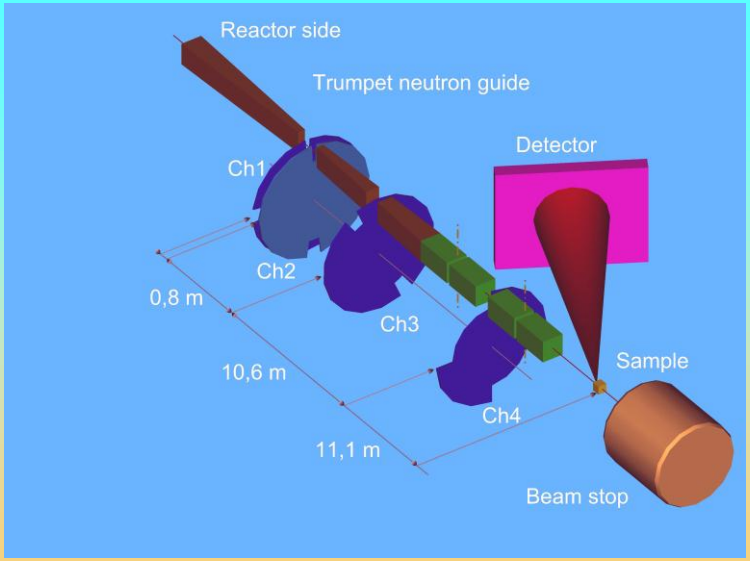


OMFB project SZFKI – RegTron -MIRROTRON Collaboration of MTA research institute with SMEs

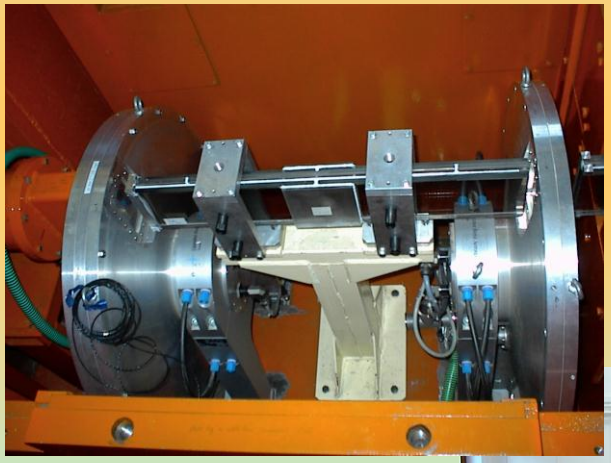
2D neutron detectors

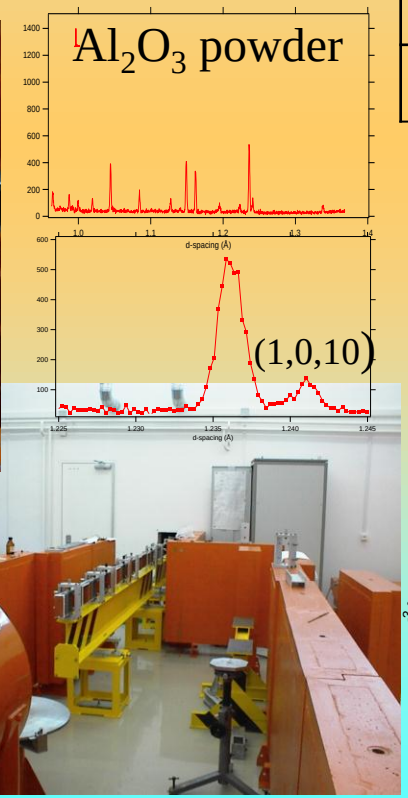


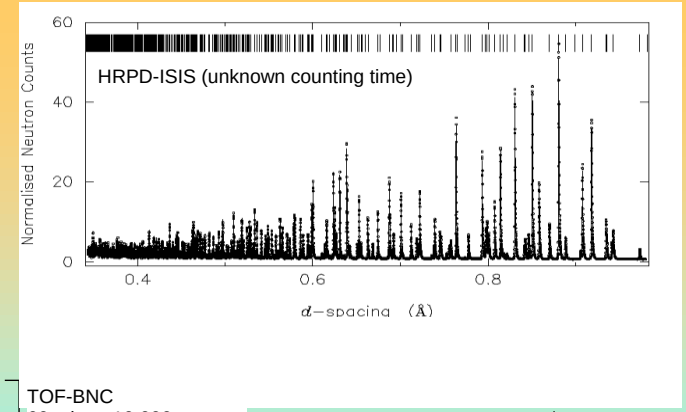
TOF powder diffractometer

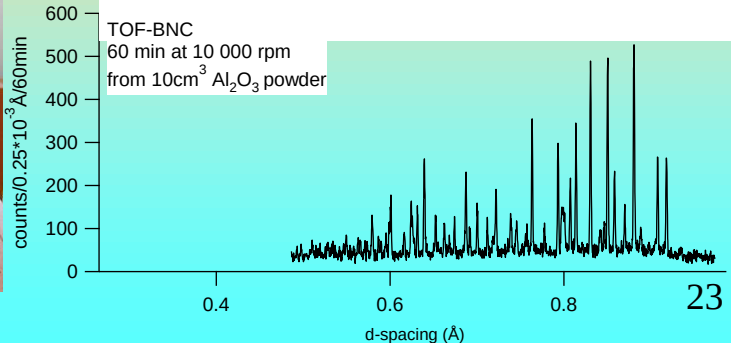


Flight path	L=25.5 m
Bandwidth	0.3 -0.1 nm
Resolution	$\Delta d/d < 1x10^{-3}$
Guide cross section	$25x100mm^2$
Coating	NiTi, m=2
Beam flux	$3x10^6$ neutron/s/cm^2
Disk material	Carbon fibre epoxy - Gd_2O_3
Max. speed	12000 rpm - 6000rpm
Detector size and angle	600x800 mm2 160°-170°









Instrument scientists:

György Káli

Zsombor Sánta

Development of neutron research and reactor utilisation during the past 20 years

A. Staff

	BRR related staff (FTE)	Neutron researchers at Csillebérc	Hungarian neutron researchers
1991	70	18	40
1996	100	55	69
2004	227	91	176
2009	244	99	180*

* Tartalmazza a BKR-nél dolgozó 75 professzionális neutronkutatót-mérnököt, 65 külső felhasználót, és 10 ipari felhasználót, továbbá mintegy 20 fő neutronfelhasználót, akik külföldi neutronforrásokat használnak valamint 10 külföldön dolgozó magyar professzionális neutronkutatót.

Development of neutron research and reactor utilisation during the past 20 years

B. Research data

	BRR instruments	Beam-days	Publications
1992	4	120	30
1996	6	800	50
2004	11	1235	120
2009	13 (+2)	1420*	115

*2009-ben a reaktor fűtőelem konvezriója miatt az üzemelő napok száma lényegesen kevesebb volt, 2010-től a korábbi szintre való visszaállás után évi 156 nap üzemmel számolva.

Development of neutron research and reactor utilisation during the past 20 years

C. Finances

	Reactor operation costs (MFt/y)	Research grants total (nominal values in MHUF) (MFt)	Direct income of reactor utilisation (BNC institutes) (MFt/y)	Reactor utilisation (Total turnover of reactor related companies MFt/y)
1993	15	5	0	5
1996	80	90	5	15
2004	300	1200	45	600
2009	650	2500	80	1400

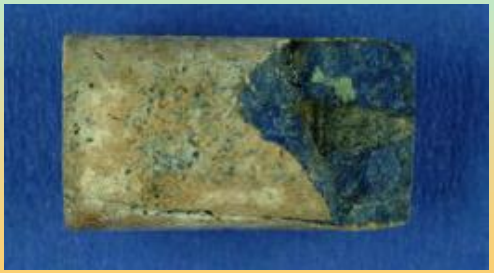
*Gazdasági társaságoknak a reaktor üzemeltetésével közvetlenül összefüggésben álló tevékenységéből származó árbevétele (izotópgyártás, műszergyártás, mérnöki szakértői tevékenység stb.)

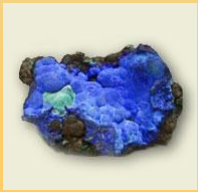
Future prospects for BNC

- Reactor upgrade (2014-15)
  - Increase of power (12-15 MW)
  - Cold source modernisation
  - Improvement of the infrastructure
- Instrumentation development
  - Instrument upgrade by replacement/improvement
  - Sample environment

Opreation until 2023

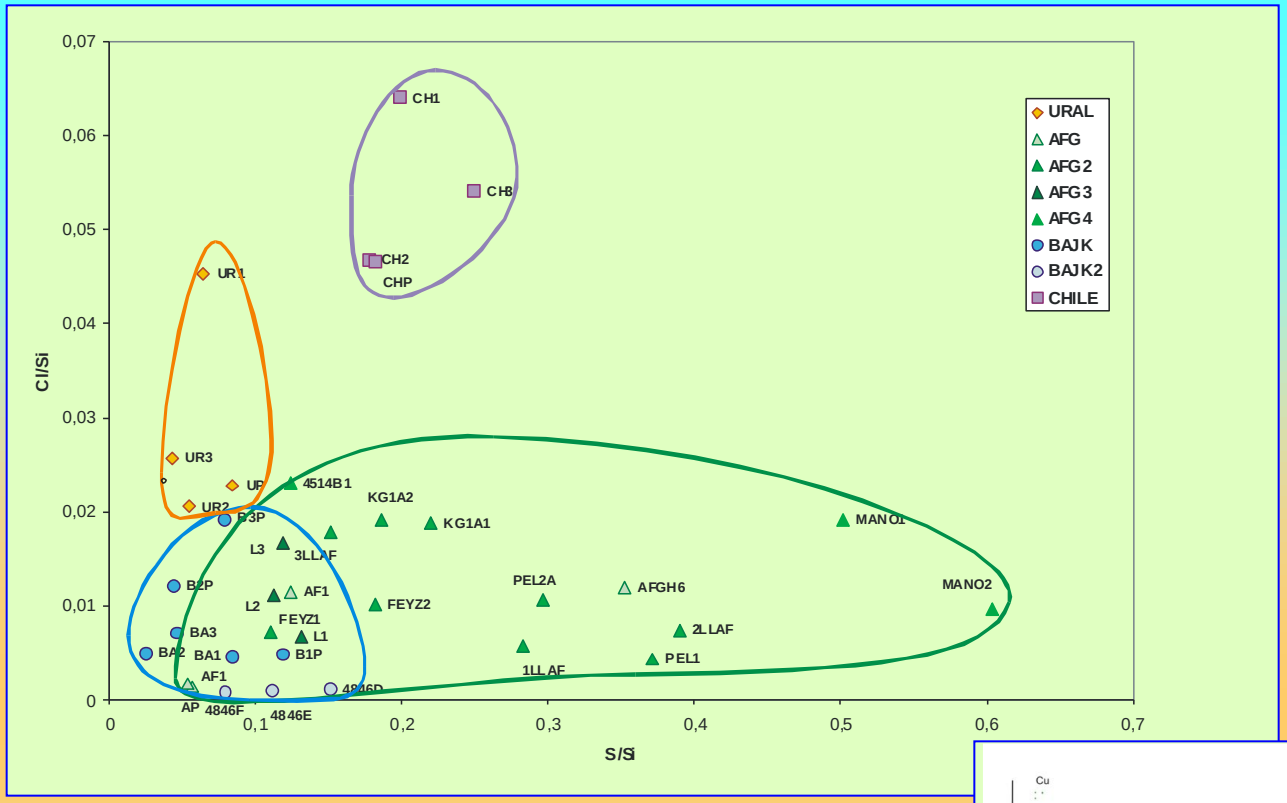
Investigation of objects of cultural heriage
PROVENANCE STUDY OF LAPIS LAZULI

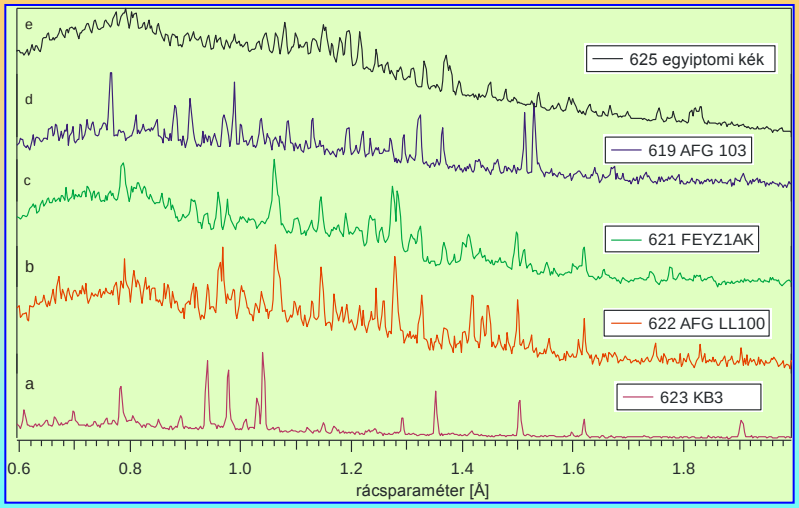


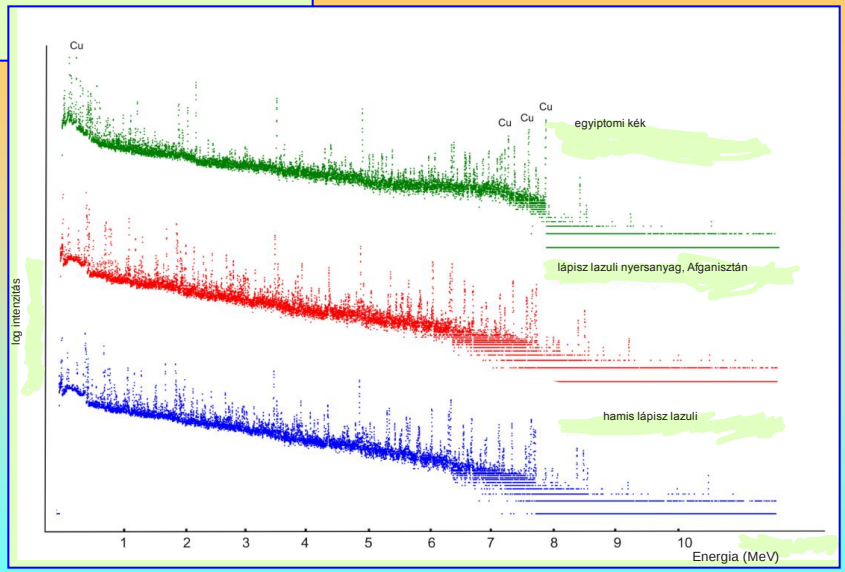


- A few geological occurances in the World (Ural, Chile, Afghanistan, Lake Bajkal)
- **Main mineral**: Lazurit / $(Na,Ca)_{7\text{-}8}(Al,Si)_{12}O_{24}[(SO_4)Cl_2(OH)_2]$
- **AIM**: Identification of raw materials, provenance of art objects
- **PGAA**: H, Na, Mg, Al, Si, K, Ca, Ti, Mn, Fe, S, Cl

Characterisation of raw materials with PGAA







Fake identification with TOF-ND

Fake identification with PGAA

Thank you for your attention!

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