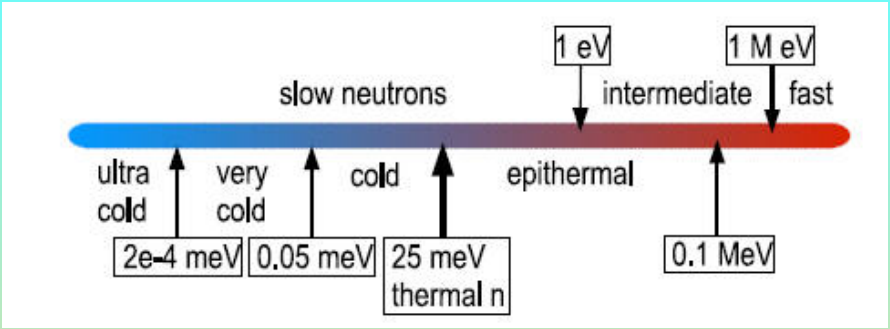
Neutrons and Innovation for practical applications at the Budapest Neutron Centre

László ROSTA
Wigner Research Centre for Physics
Hungarian Academy of Sciences
(Budapest Neutron Centre)
Email: rosta.laszlo@wigner.mta.hu

ERF Innovation, Trieste, 6.6.2013

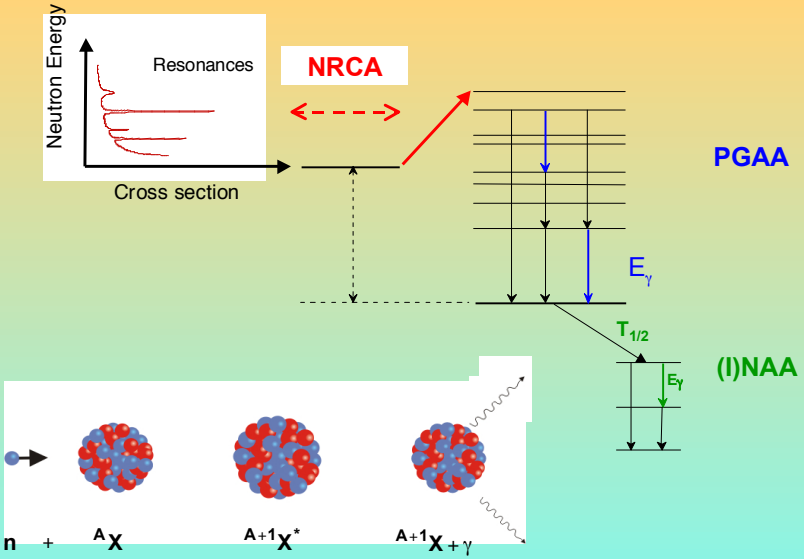
Neutron

- Mass: m=939 MeV/c^2
- Electric charge: Q=0
- Magnetic momentum: μ=–1,9 μ_N; Spin: 1/2

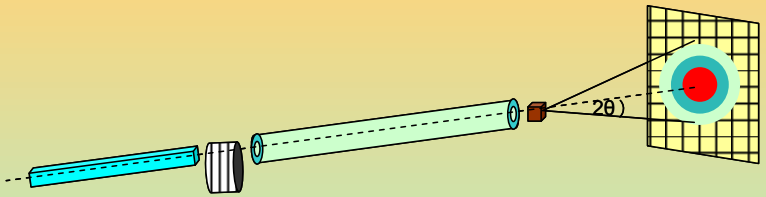


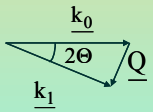
INTERACTIONS WITH MATTER

Radiative capture – (n,γ) reaction



Scattering (elastic or inelastic)





$$\underline{Q} = \underline{k_1} - \underline{k_0}$$

$$|\underline{k_1}| = |\underline{k_0}|$$

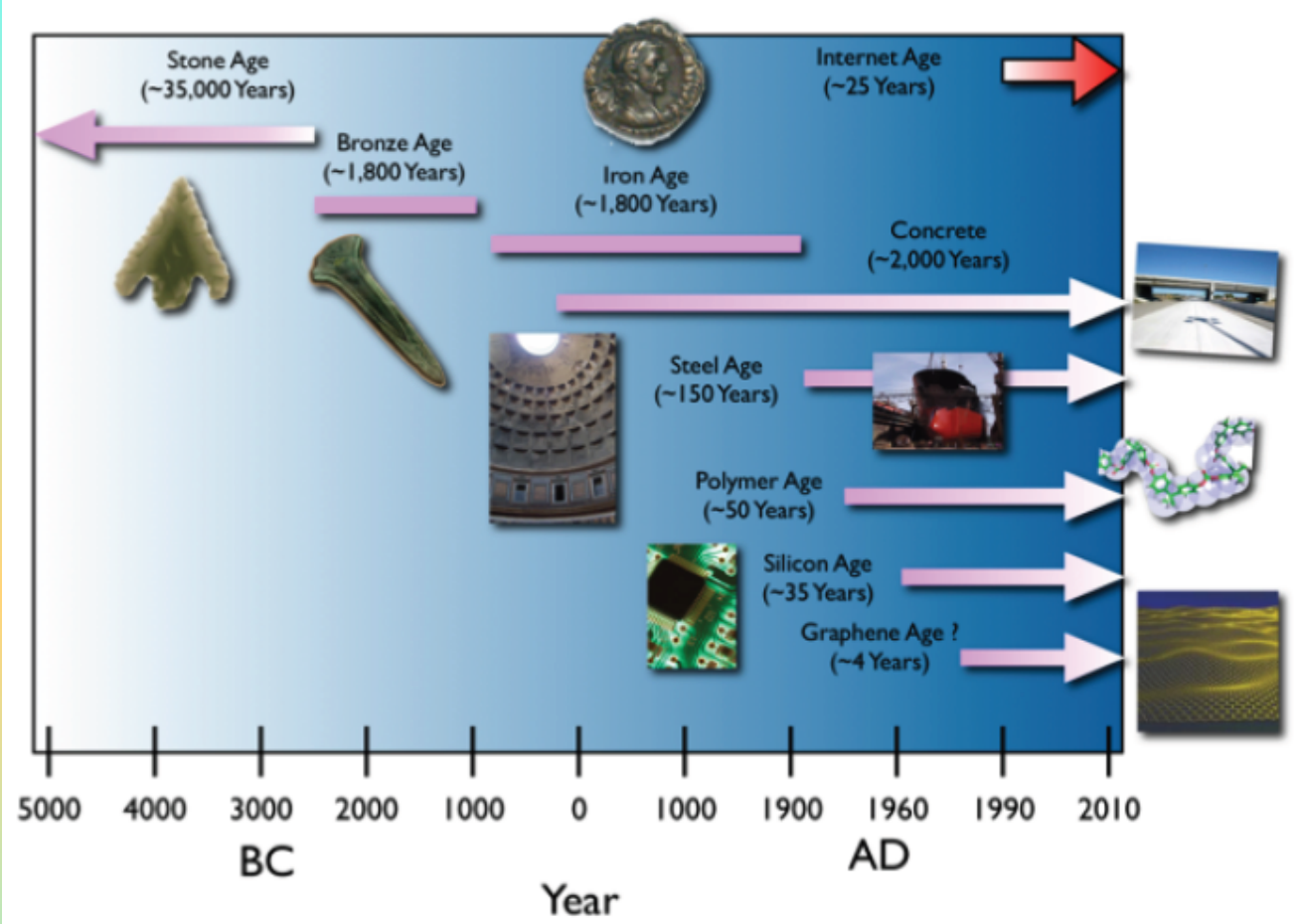
$$Q = \frac{4\pi}{\lambda}\sin\Theta$$

$$k = \frac{2\pi}{\lambda}$$

Composition: NRCA, PGAA, INAA

Structure: SANS, TOF-ND

Materials used by mankind – and neutrons



Three major advantages of neutrons for materials testing:

- ***Large penetration and non-destructivity***
- ***Sensitivity to H/D – approach to soft matter and biology***
- ***Magnetic scattering***

Neutron sources in the World: 60, User facilities: 25 (W) / 10 (EU) – BNC

Research Infrastructure

Budapest Research Reactor

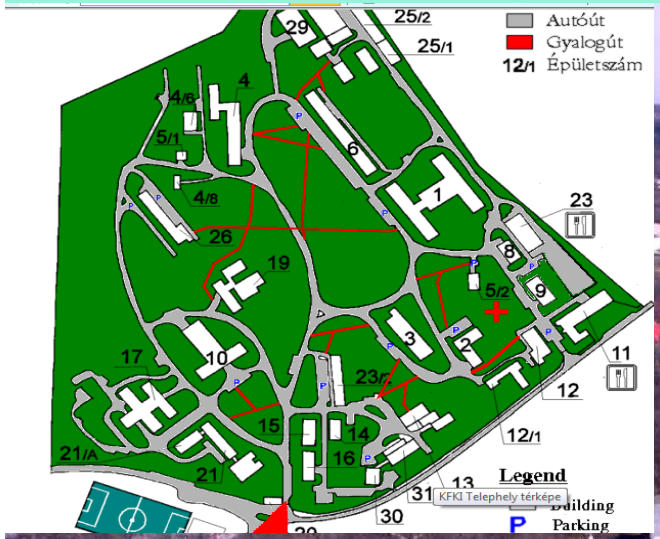
Tank-type reactor, moderated and cooled by light water

Power: 10 MW

Thermal neutron flux: $2.5*10^{14}$ n/cm^{2}s

KFKI RESEARCH CAMPUS
of the Hungarian Academy of Sciences

BNC
Budapest Neutron Center



User offices at Bldg. 10 and 16

3 research centres

30 compa-nies

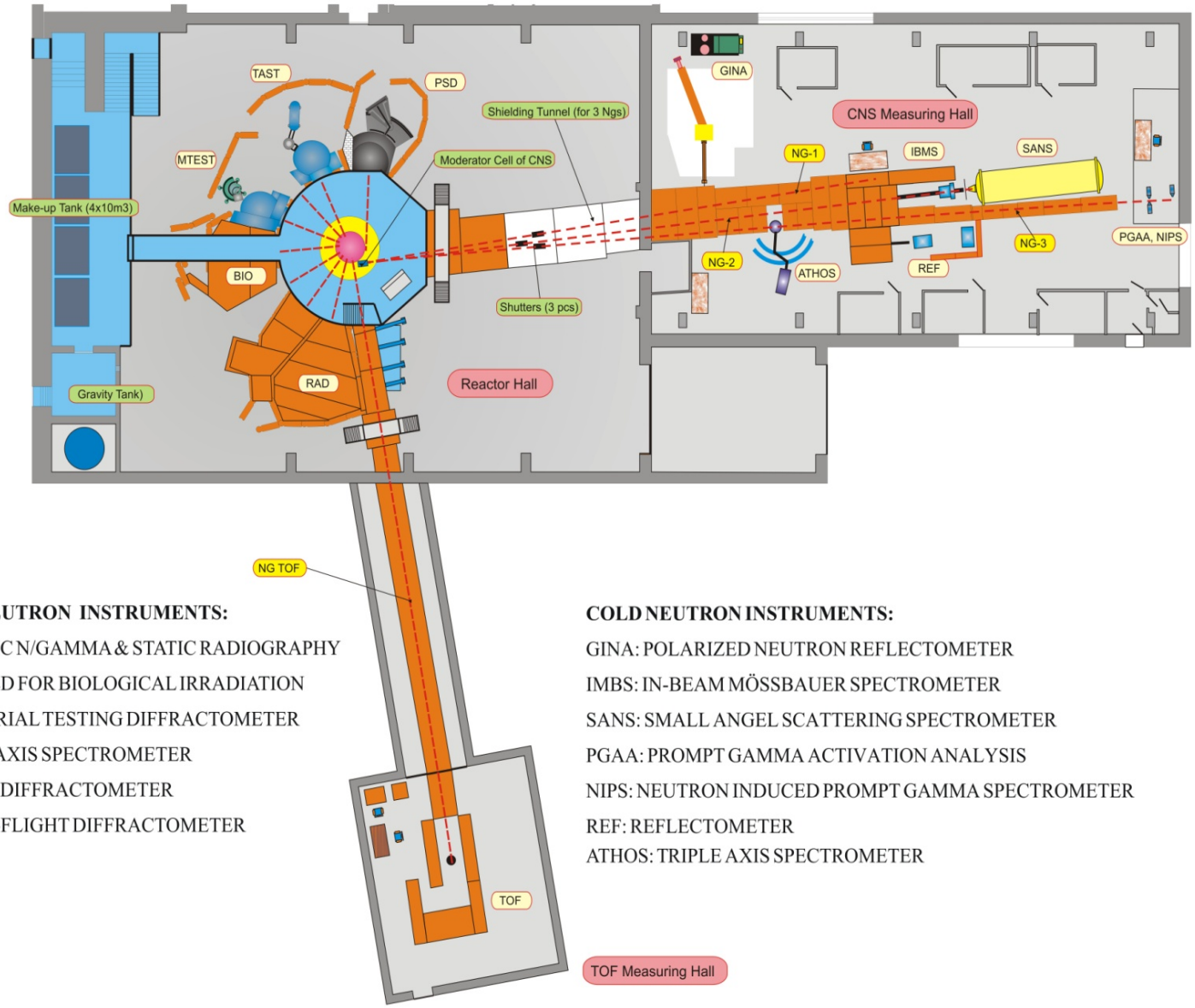
2000 people

2 canteens

Library

Guest house

12 neutron beam instruments in the user program



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

PSD – Neutron diffractometer

Uranium loaded borosilicate glasses as storage material for radioactive vaste

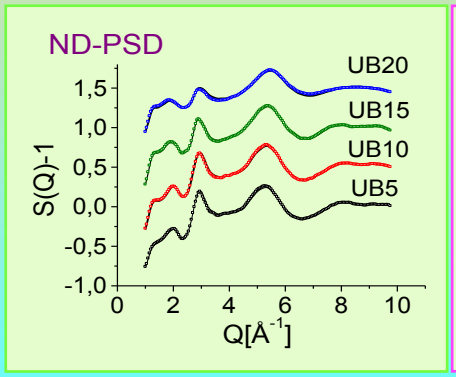
http://www.bnc.hu
contact: Margit FÁBIÁN
fabian@szfki.hu

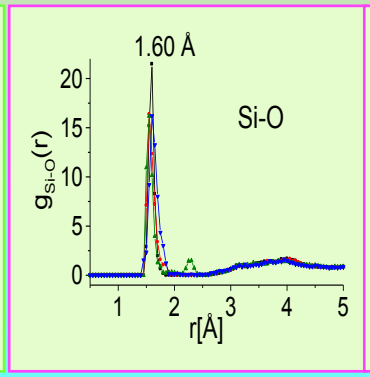
Atomic structure of amorphous and crystalline materials:

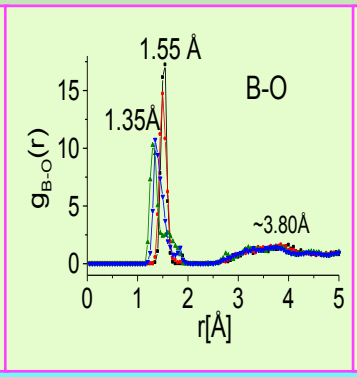
✓ Borosilicate-, chalcogenide and rare-earth oxide glasses

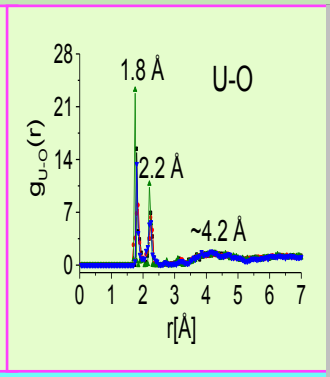
✓ $YAl_3(BO_3)_4$ (YAB) substituted with Er^{3+}, Yb^{3+}, Y^{3+}, manganites, perovskites and hexaferrites

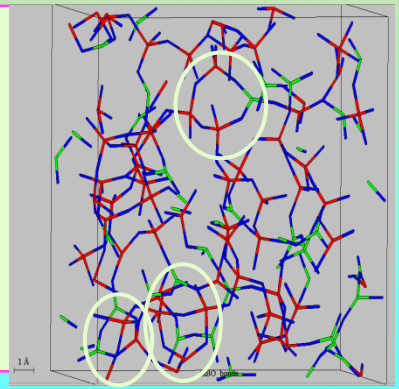
Uranium loaded borosilicate glasses:
70wt%[SiO_2(60-x)B_2O_3(x)Na_2O(25%)BaO(5%)ZrO_2(5%)]+30wt%UO_3, x=5-20mol,: UB5 UB10 UB15 B20



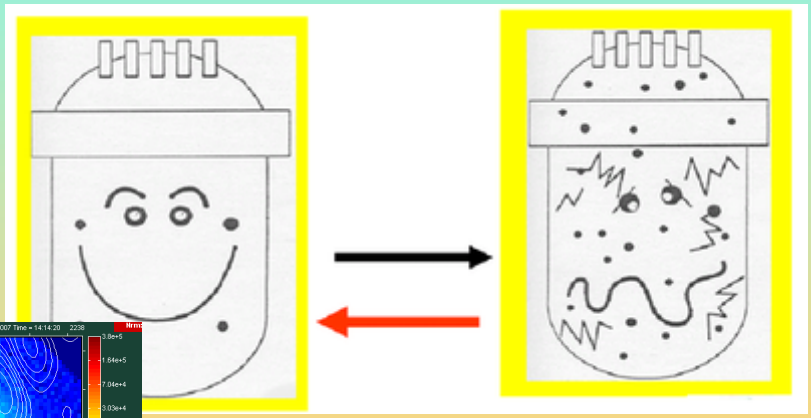


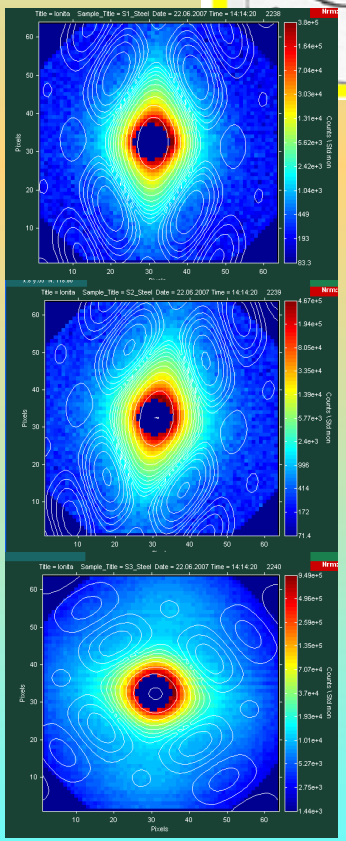






Research for new materials and investigation of thermal and irradiation ageing of reactor pressure vessel steels





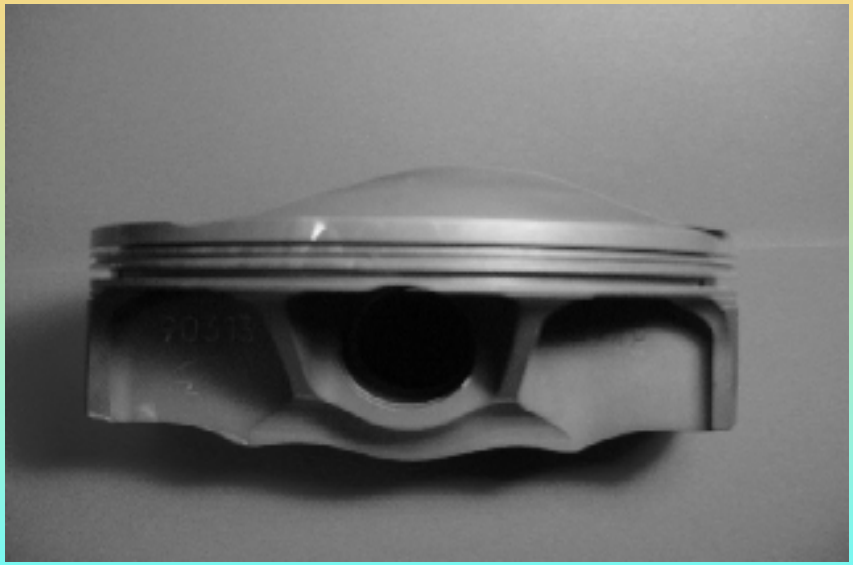
Technical challenges & Leading physical phenomena

Fast neutron damage (fuel and core materials)
→ *Effect of irradiation on microstructure, phase instability, precipitation*
→ *Swelling growth, hardening, embrittlement*
→ *Effect on tensile properties (yield strength, UTS*
→ *Irradiation creep and creep rupture properties*
→ *Hydrogen and helium embrittlement*
High temp. resistance (future reactors > 500 °C)
→ *Effect on tensile properties (yield strength,*
→ *High temperature embrittlement*
→ *Effect on creep rupture properties*
→ *Creep fatigue interaction*
→ *Fracture toughness*
Corrosion resistance (primary coolant,hydrogen)
→ *Corrosion and stress-corrosion cracking*

A SANS study of nanostructured „duplex steels" (two-phase) revealed a cuboid growth of precipitates fom ~17 nm to ~20 nm due to thermal treatment and irradiation

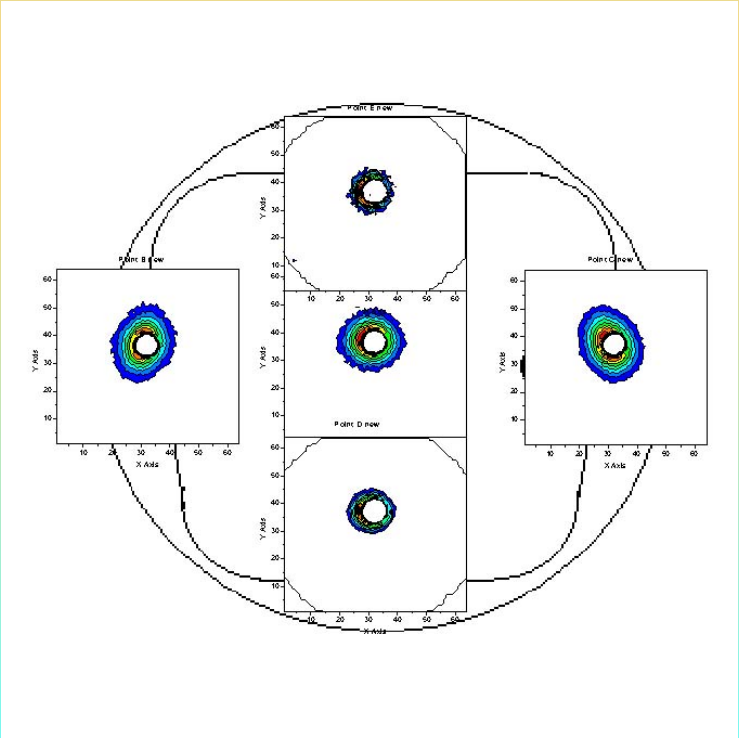
Giredmet, Prometei....

Life-time investigation of Ferrari engine pistons

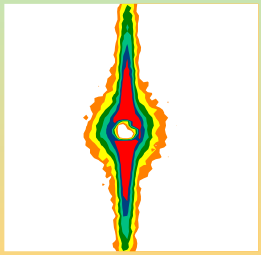


Small angle neutron scattering study of the nanoscale defect structure in Al-alloy pistons at different stages of usage. Anisotropic distribution and highly geometry dependent growth of precipitates was revealed.

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



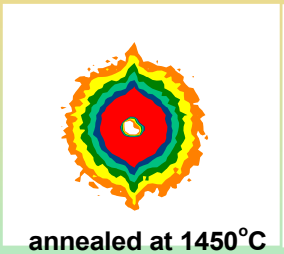
Tungsten filaments



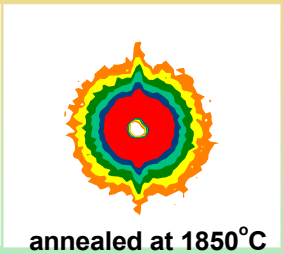
unannealed

annealed at 700°C

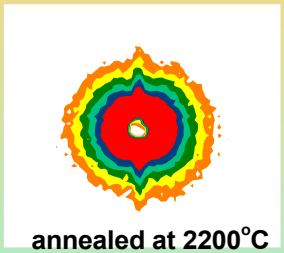
annealed at 1150°C



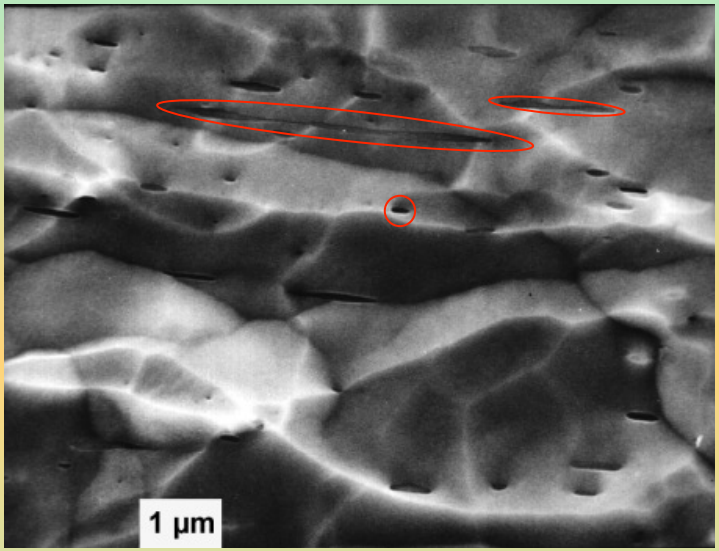
annealed at 1450°C



annealed at 1850°C



annealed at 2200°C

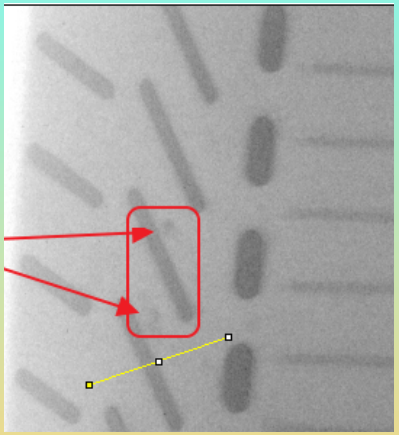


L. Bartha, P. Harmat, O. Horacsek, T. Grósz, L. Rosta: Characterisation of second phase dispersoids of doped tungsten wire by means of small angle neutron scattering Orlando, Florida, USA (1998) p. 203-210

ellipsoids: 95 %, $2r_a$ = 24 nm, Aspect ratio: A = 15
spheres: 5 %, $2r_s$ = 58 nm

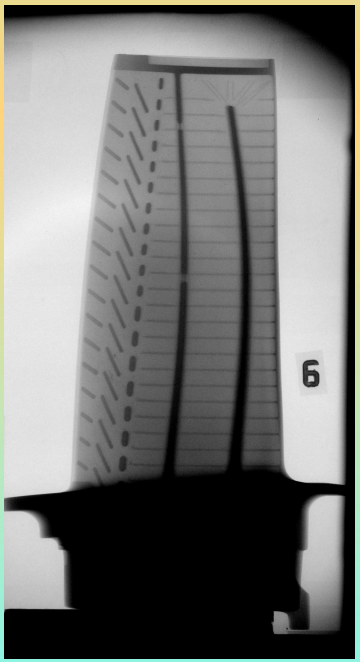
PGAA facilities at the Energy Research Centre, Tamás BELGYA et al.

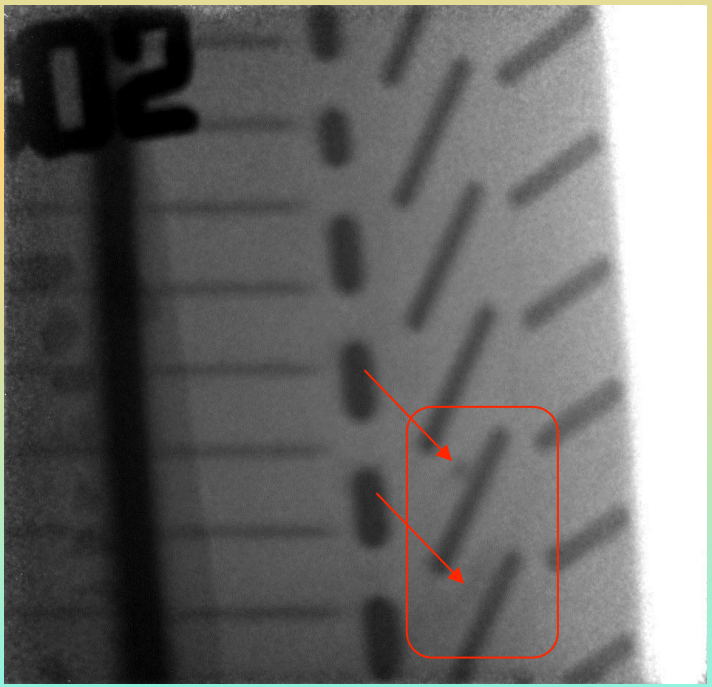
Neutron Tomography



Turbine blade –
visualization of template remains

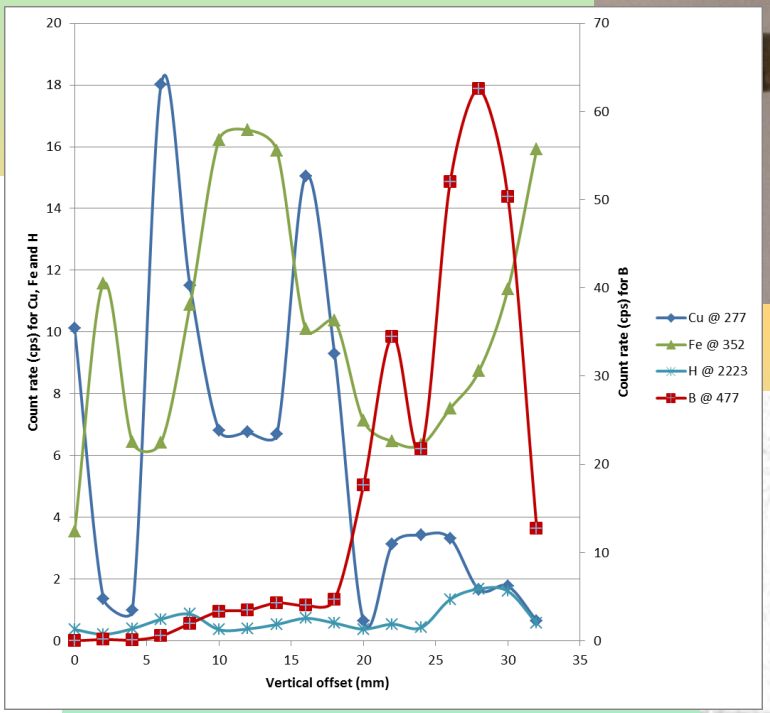
Images from DNR vs. NORMA

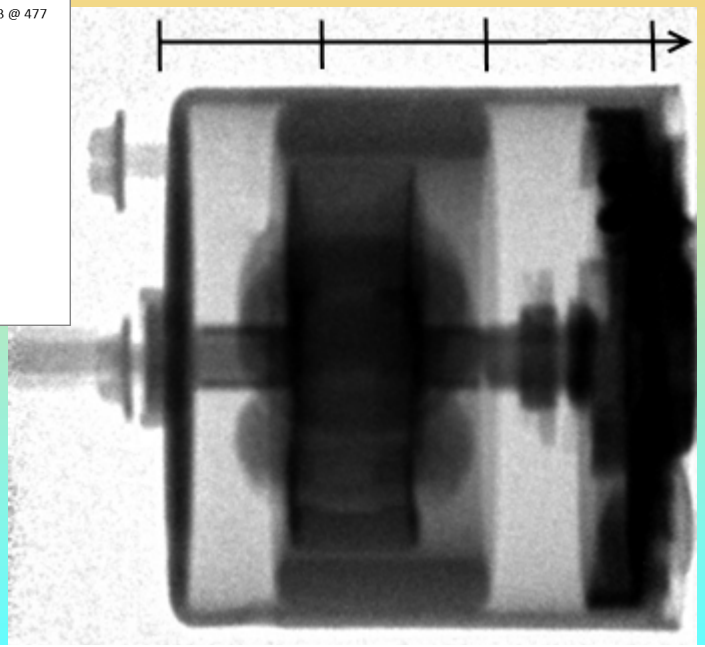




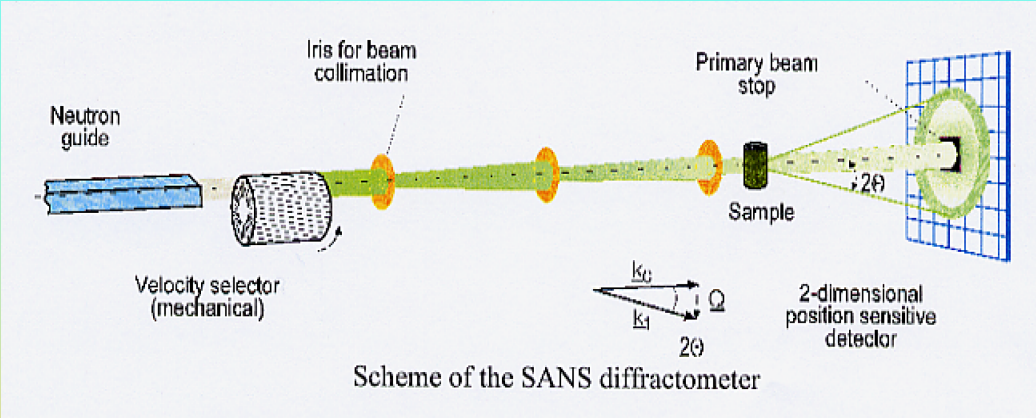
Contrast enhancement with a Cd-solution

Linear scan of a stepper motor

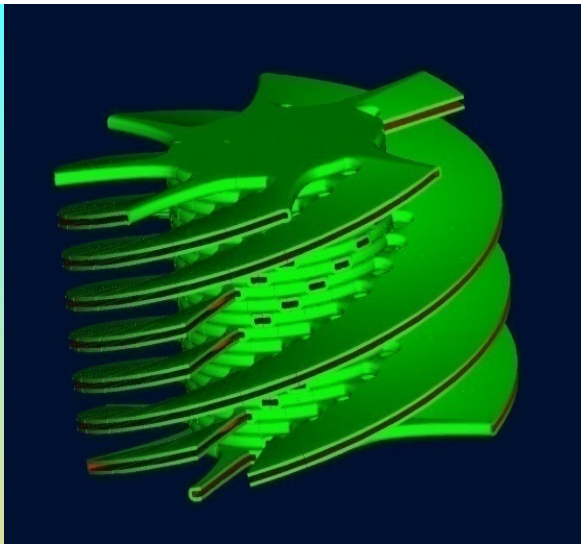




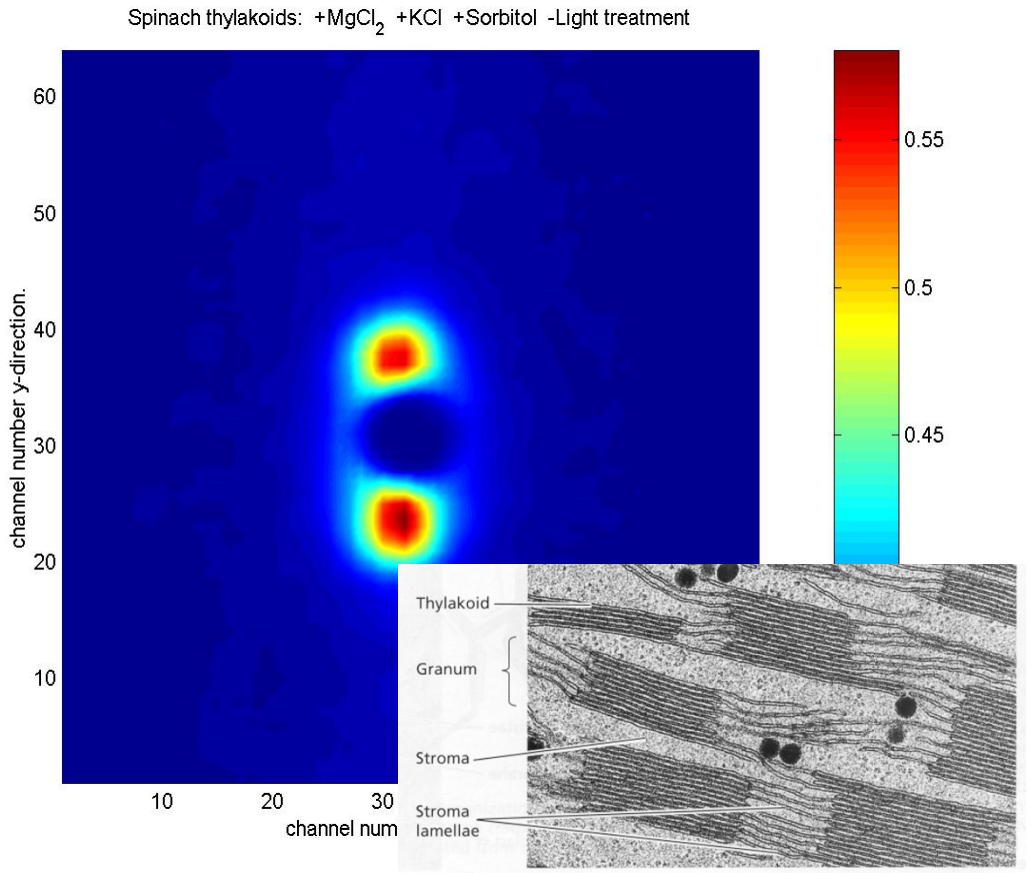
Photosynthetic mechanism in algaes – transfer to agiculture



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

- **Proof of meteoritic origin of mankind's earliest iron artefacts, 3200 BC, by neutron and X-ray techniques**
  Principal Proposer: Thilo Rehren – UCL London
- 3 iron beads were investigated by non-destructive techniques (**NR, TOF-ND, PGAA, PIXE**)
- Meteoritic iron has several characteristics that distinguish it from smelted iron. Most prominent are the large crystal grain size, elevated bulk concentrations of **Ni** (1-10 wt%), **Co** (1000-10000 ppm) and **Ge** (200-400 ppm)

Properties of The Petrie Museum of Egyptian Archaeology, London

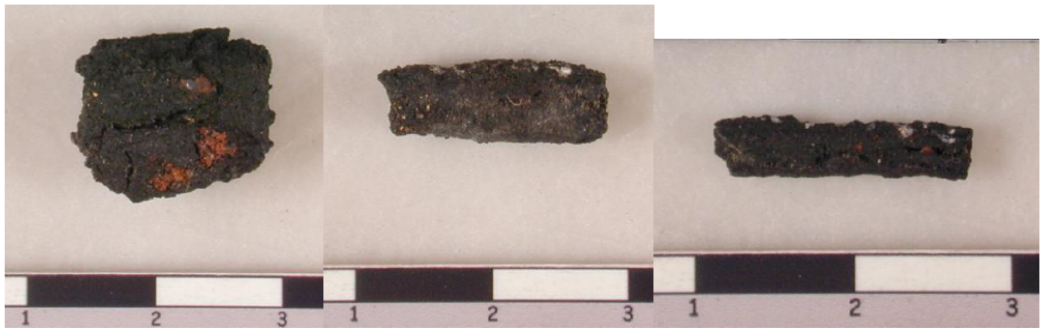
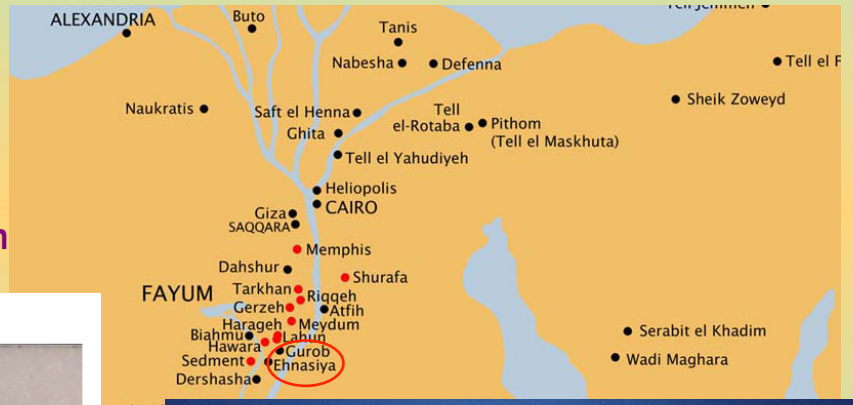
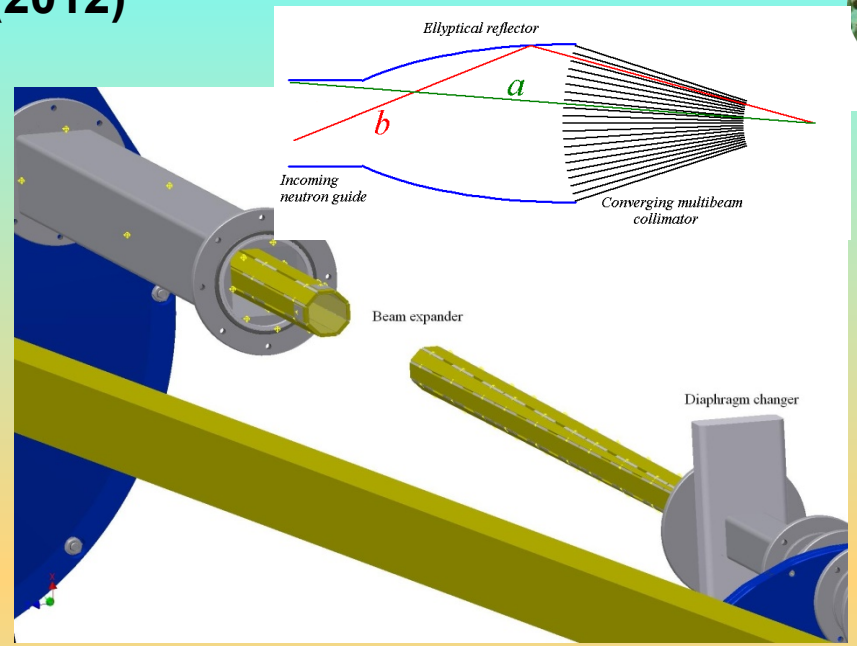


Fig. 1: Beads UC10738 (left), UC10739 (centre) and UC10740 (right). Scale in cm.

One of the beads had been analysed in the 1920s and found to contain about 7.5 wt% Ni



New focusing SANS spectrometer (2012)



KFKI REGTRON
Instrumentation & Measuring Co.,Ltd.

1121 Budapest, Hungary
Konkoly-Thege út 29-33.
Phone: +36 1 392-2286
Fax: +36 1 392-2641
E-mail:regtron@regtron.hu
Web: www.regtron.hu

Some references of KFKI-REGTRON

Item	Hu		Abroad
	Pcs	Pcs	
Multi-channel neutron monitor systems	20	20	Finnland
Neutron velocity selector	3	Cca 20	France Japan, Germany Portugália USA
Detector simulator	3	4	India France
FTL test generator	10	10	USA Canada UK Australia China Turkey

BNC
Budapest Neutron Center

MIRROTRON LTD
THE 20TH ANNIVERSARY

ANTE
Innovative technologies

Neutron instrumentation: 2 billon €/10y market
5 Companies (+120) > Turnover: 2x BNC op

Thank you for your attention!

László ROSTA
Wigner Research Centre for Physics
Hungarian Academy of Sciences
(Budapest Neutron Centre)
Email: rosta.laszlo@wigner.mta.hu

ERF Innovation Trieste, 6.6.13

MIRROTRON LTD

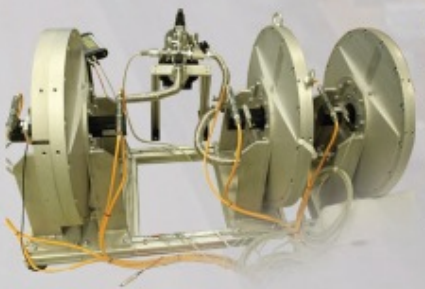
20 Years in Neutron Instrumentation

Velocity Selector

- Multi - disk / Multi - Blade types
- Driving system and controller
- Speed up to 15.000 rpm / 250Hz

Fermi Chopper

- Si / wafer coated with ^{10}B / Gd
- Coated Al sheets / Gd foils
- Vertical translation for dual slit package
- Magnetic bearing driving and control system
- Custom designed into beam / flexible design
- Speed up to 36,000rpm / 600Hz
- Complete safety analysis



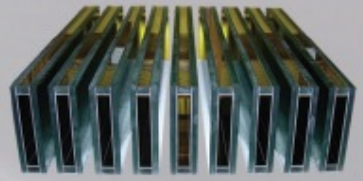
Disk Chopper

- Single or double disk system
- Integrated into complet system
- Speed up to 20.000 rpm / 333.33Hz
- Custom designed single / double / symmetric / asymmetric slots
- traditional / magnetic bearing

Transmission neutronically tested, ^{10}B / Gd absorbent layer

Guide sytems

- Costum Guide system design: in-pile, shutter, out of pile
- Converging / Focusing / Bender / guide sections
- Manufacture and assembly with 0.01 mm accuracy
- Vacuum housings
- Mechanical support and alignment frames
- Vacuum evacuation / He filling system



Metal - glass sandwitch guides

- Best reflectivity up to m = 5
- Minimalized outer dimensions
- Equivalent to vacuum housing
- Metal or elastomer vacuum sealing between steel plates
- Eliminates fast/streaming neutrons
- 0.3 mm gap between glass and steel frame
- Additional gamma shielding can be applied easy and safe
- Easy and fast installation and replacement