

Nuclear Physics Institute of the CAS

activities, possibilities for collaborations



Jan Dobeš

www.ujf.cas.cz

major Czech institution in nuclear physics field

~ 250 employees
(195 FTE)

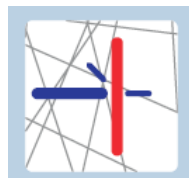
~ 80 scientists
(66 FTE)

~ 30 PhD student

- basis research in nuclear physics and related disciplines
- use of nuclear physics methods in interdisciplinary scientific and research areas
- participation in large-scale international projects (ALICE, STAR, HADES, CBM, KATRIN, ESS)
- employment of home facilities and equipment

Center of Accelerators and Nuclear Analytical Methods

canam.ujf.cas.cz



Laboratory of Cyclotron and Fast Neutron Generators (LC & FNG)

Operating the isochronous
cyclotron U-120M



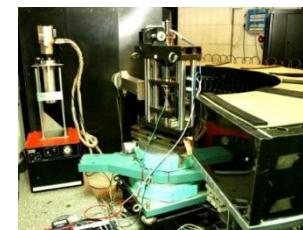
Laboratory of Tandetron (LT)

Operating an accelerator
Tandetron 4130 MC



Neutron Physics Laboratory (NPL)

Providing facilities at the
reactor LVR-15



operational costs supported from the MEYS program – enables open access
investment costs - project for European Structural and Investment Funds



10.1 | Physical Sciences

Center of Accelerators and Nuclear Analytical Methods

Acronym:
CANAM

Hosting institution:
Nuclear Physics Institute,
Academy of Sciences of the Czech Republic

Responsible person:
DOBES Jan
dobes@ujf.cas.cz

Website:
canam.ujf.cas.cz

Background description


The CANAM operates several different types of accelerators and neutron facilities, which are used in a wide range of scientific and technological disciplines. The ions are prepared at the isochronous cyclotron accelerator U-120M and at the electrostatic linear tandemron 4130M accelerator. The facilities for studies with thermal neutrons are installed at the irradiation channels of the LVR-15 research reactor operated by the Řež Research Center. Fast neutrons are obtained from production targets at the cyclotron U-120M. The possibilities and scope in combination with different techniques using the ion and neutron beams (which can be implemented in synergic combination in the CANAM laboratories) are unique, even at the international level. The production, modification and complex characterization methods of CANAM are offered with employment for basic and applied studies in various R&D fields such as physics, materials sciences, chemistry, biology, biomedicine, energetics, microelectronics, environmental sciences, archaeology, cultural heritage, etc.

Future development

Permanent effort is devoted to developing, upgrading and modernizing the CANAM laboratories. At present, the most important enlargement is the purchase of the new TR-24 cyclotron, which substantially increases the possibilities in the research of radionuclide production, with applications mainly in medicine and life sciences, and in fast neutron studies, with an impact on the development of future fission and fusion technologies. Other significant developmental step is considered, namely the purchase of an Accelerator Mass Spectrometry (AMS) system, presently not available in the Czech Republic.

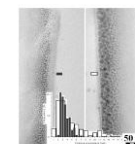
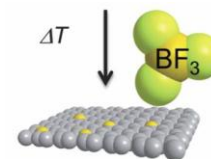
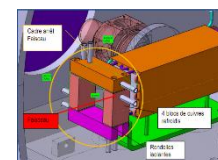
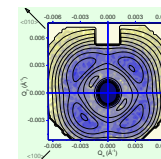
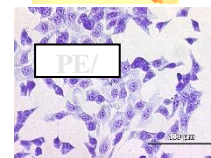
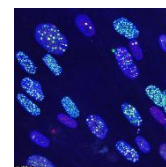
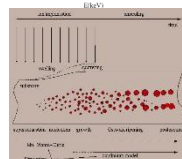
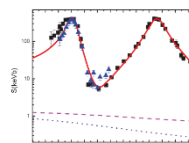
Socio-economic impact

Both ion and neutron beams are important for their performance in various targeted applications, which are important not only for the scientific community, but also for the commercial sector, as the development of new materials and technologies, nanostructure synthesis, ion beam micromachining, radiation hardness of electronic elements, and nuclear data for fusion and advanced fission systems. Cooperation between CANAM and the commercial sector concentrates not only on solving common R&D projects and tasks, but also on providing services at the CANAM facilities and expertise.

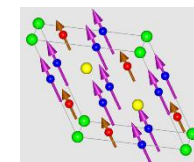


▶ 28

Archeology, Anthhropology, Ethnology
Elementary Particles and High Energy Physics
Nuclear, Atomic and Molecular Physics, Accelerators
Solid Matter Physics and Magnetism
Astronomy and Astrophysics
Biophysics
Inorganic Chemistry
Analytical Chemistry
Organic Chemistry
Biochemistry
Electrochemistry
Geochemistry
Botany
Biotechnology
Nuclear and Quantum Chemistry
Electronics and Optoelectronics
Composite Materials
Other Materials

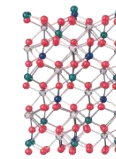


TEM image of PEKK implanted with WdBr⁺ ions with fluence $5 \times 10^{17} \text{ cm}^{-2}$ (left) and $1 \times 10^{18} \text{ cm}^{-2}$ (right).



Detection limits INAA, g

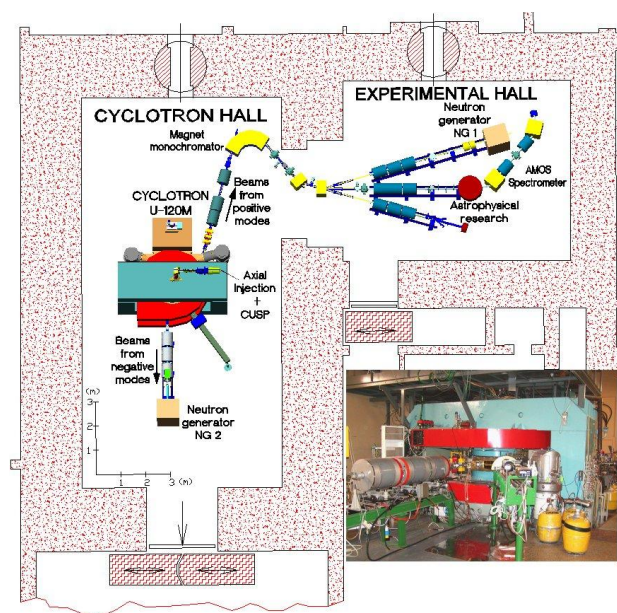
Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	Rb	Sr	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
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JRC, Institute for Transuranium Elements - NPI CAS

Morgenstern, Phys. Rev. C 80, 054612; Anal. Chemistry 80, 8763

LC&FNG U120-M cyclotron



isochronous machine with $K=40$

accelerated ions	energy [MeV]	extracted currents [μA]
H^-	6 - 38	15 - 35
H^+	6 - 38	3
d^+	11 - 20	3
$^3\text{He}^{2+}$	16 - 55	3
$^4\text{He}^{2+}$	22 - 40	3

+ ions $\Delta E/E \sim 5 \cdot 10^{-4}$

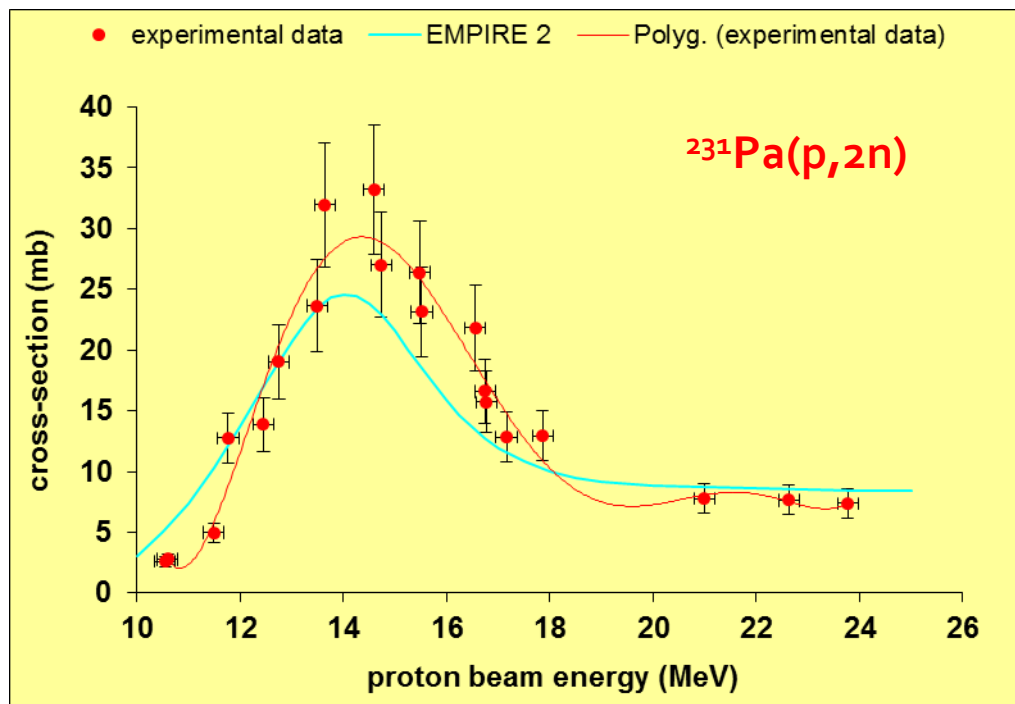
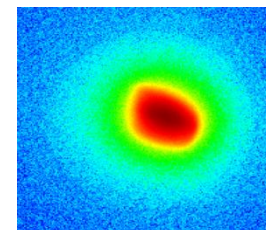
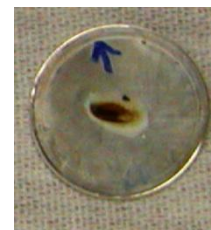
^{230}U ($T_{1/2}=20.8\text{ d}$) $\rightarrow \alpha + ^{226}\text{Y} \rightarrow$ cascade of α decays

novel therapeutic nuclide for targeted α therapy

production routes



targets, irradiations and measurements



data one order of magnitude
lower than prediction of TALYS or ALICE

data agree with EMPIRE prediction
(p induced fission channel contribution)

thick – target yields (^{230}U MBq / $\mu\text{A} \cdot \text{h}$)

- (i) 0,24
- (ii) 0,25
- (iii) 0,12

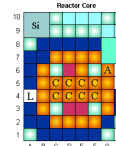
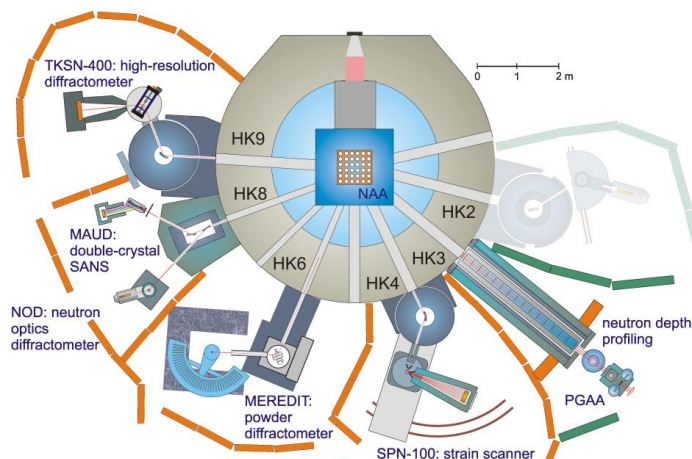
JRC, Institute for Reference Materials and Measurements
Roebben, Report EUR 22111 EN

NPL @ LVR 15

LVR-15 research reactor
operated by the Research Centrum Řež, Ltd.
thermal power 10 MW
max. flux 10^{14} n/s/cm²



NPL

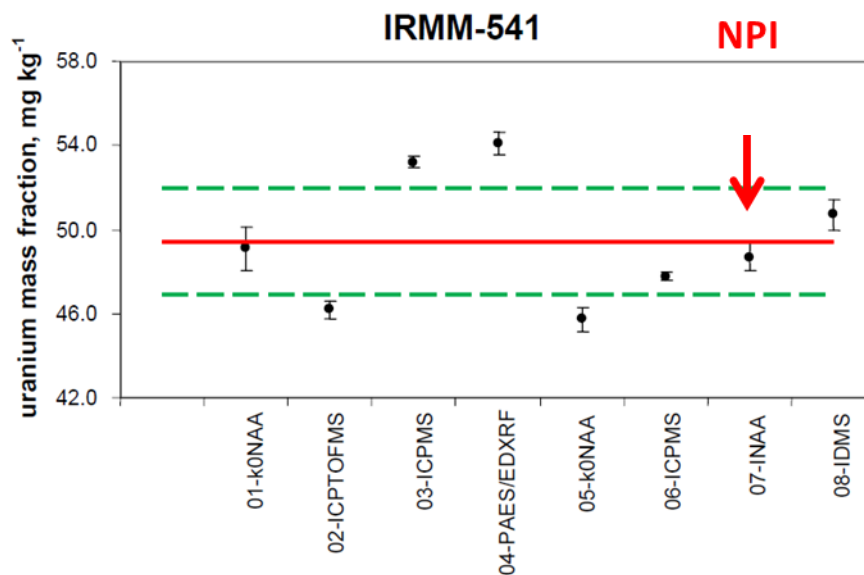
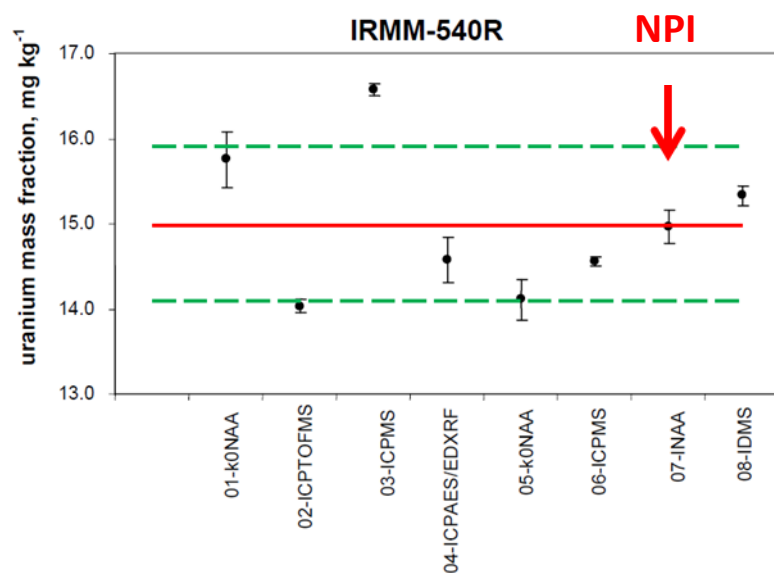


Neutron Activation Analysis:
low-level elemental characterization -
biology, biomedicine, environment,
geology, archaeometry

JRC, Institute for Reference Materials and Measurements
Roebben, Report EUR 22111 EN

uranium mass fractions in uranium-doped glasses
important, e.g. for fission track measurement

NPI - Instrumental Neutron Activation Analysis



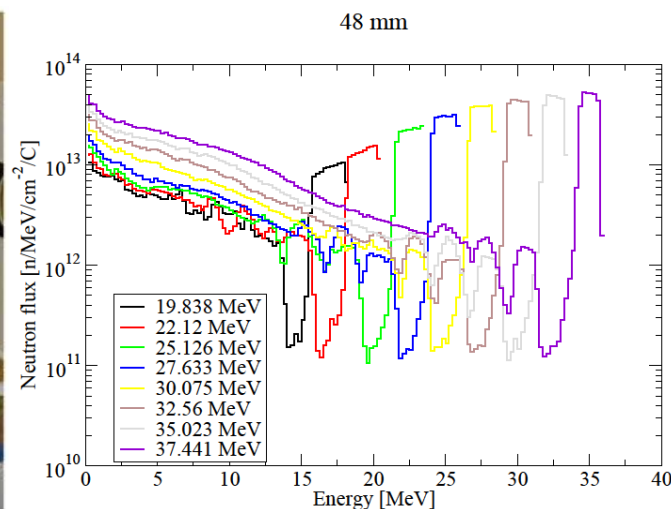
— certified value

- - - expanded uncertainty (k=2)

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LC&FNG Fast Neutron Generators

Quasi-monoenergetic neutron generator



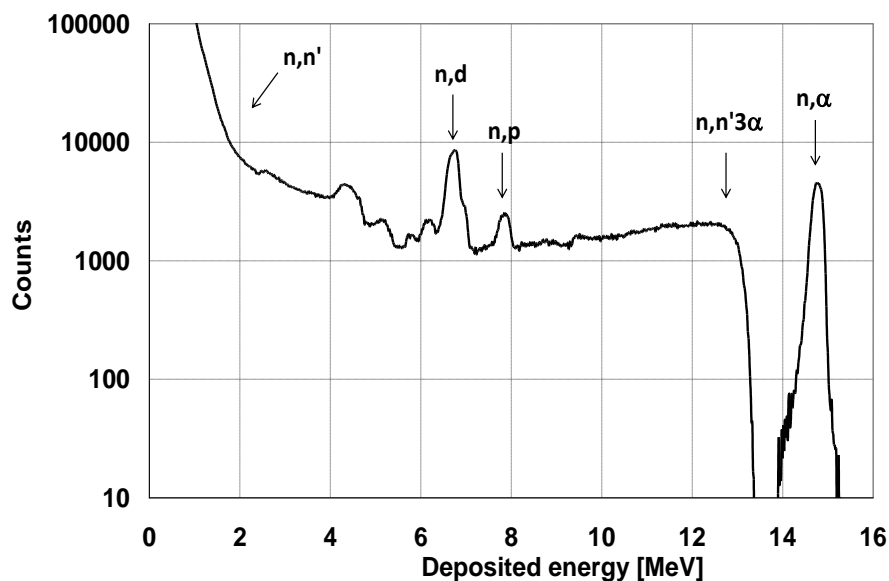
$p+{}^7\text{Li}$ $E_p = 20 - 37$ MeV
peak energy: up to 36 MeV
neutron flux density in the QMN peak
up to 10^9 n/cm²/s

suitability of a single crystal diamond (SCD) for fast neutron spectroscopy

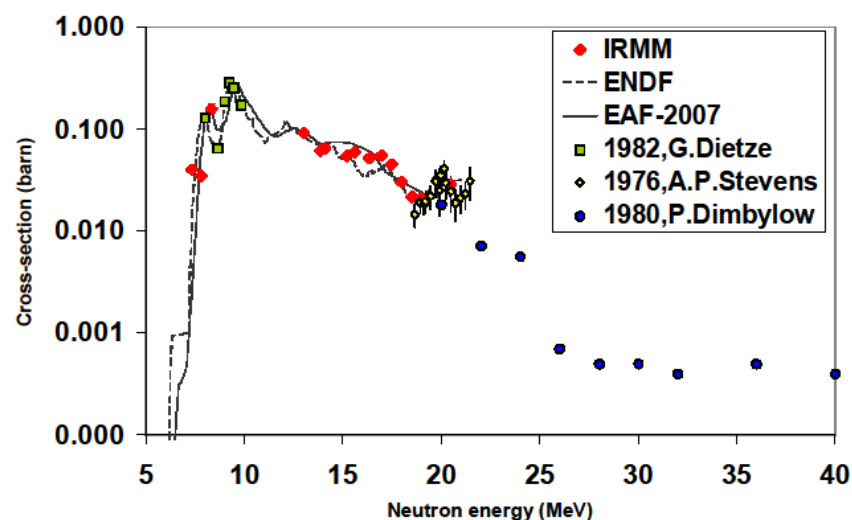
neutrons from ${}^7\text{Li}(p,n){}^7\text{Be}$

at IRRM $E_p = 4 \text{ MeV}$, E_n up to 21 MeV

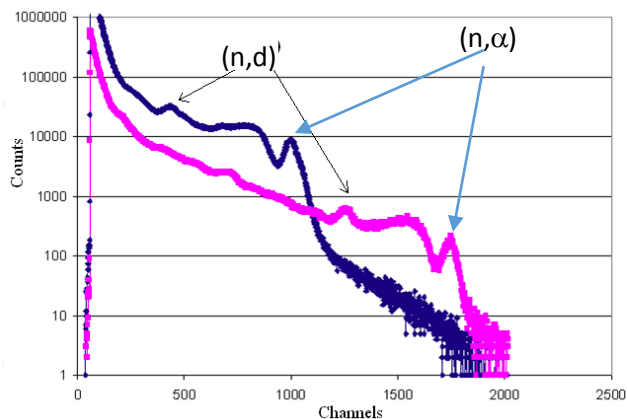
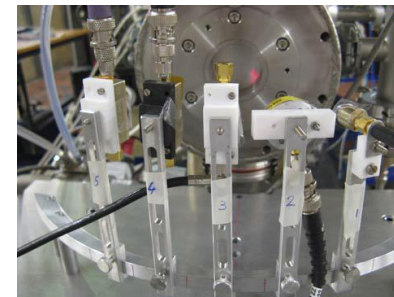
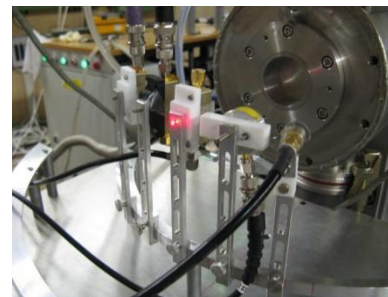
response function



${}^{12}\text{C}(n,\alpha)$ reaction



at NPI ${}^7\text{Li}(p,n){}^7\text{Be}$ $E_p = 22, 31, 36 \text{ MeV}$, E_n up to 40 MeV



response function

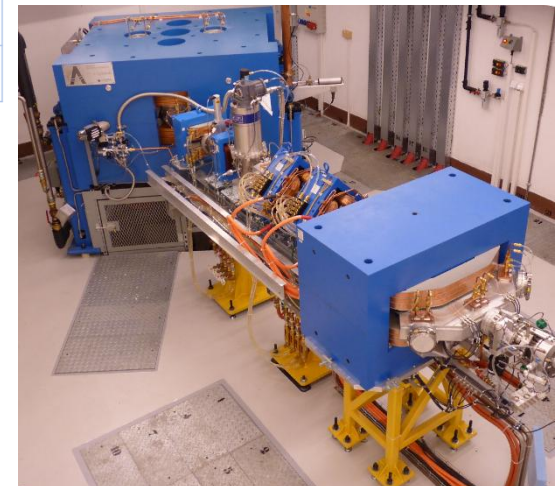
the suitability of a single crystal diamond
for fast neutron spectroscopy

${}^{12}\text{C}(n,\alpha)$ reaction for $E_n > 20 \text{ MeV}$

observation in contrast with the only
data available in the EXFOR database

2013 – 2015 investment (CAS, MEYS, NPI)

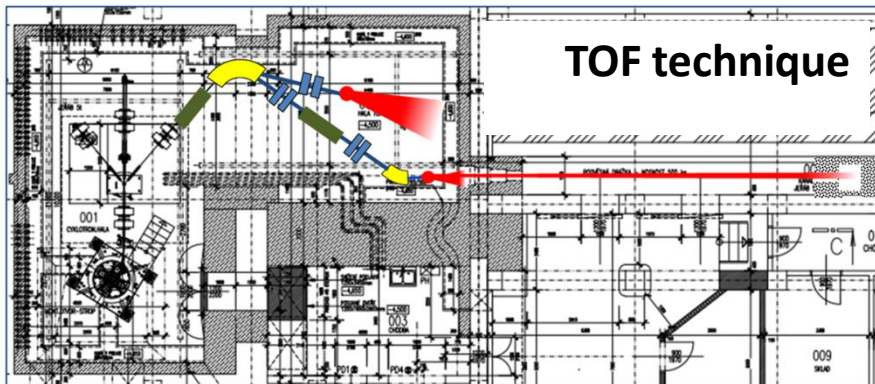
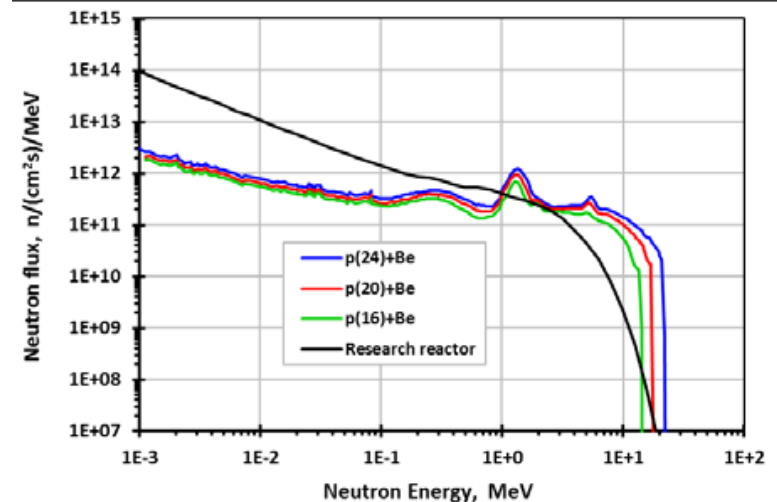
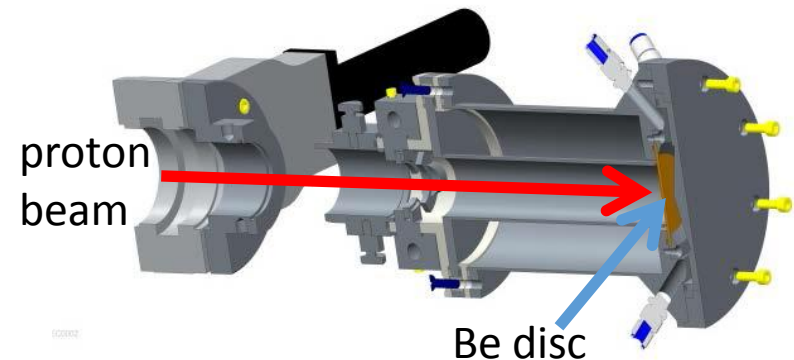
TR 24 – Advanced Cyclotron System Inc. (Canada)	
Proton energy range	18–24 MeV
Max. proton beam current	300 μ A
Acceleration frequency	85 MHz
Acceleration voltage	50 kV
H ⁻ Ion source	Multi-CUSP
Simultaneous beams	2
Weight	25 t
Dimensions	1.8×1.8×2.5 m
Power	180 kW
Middle magnetic field	1.4 T



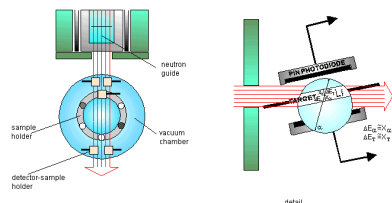
Cyclotron TR-24

Research program associated with

- generation of high fluxes of fast neutrons:
 - neutron radiation tests of electronic or diagnostic components
 - nuclear data for new fusion-fission and advanced fission systems
- production of novel medical radionuclides.
 - feasibility study of implementing direct production of ^{99m}Tc via (p,2n) reaction as an viable alternative to reactor-produced generator $^{99}\text{Mo}/^{99m}\text{Tc}$.



T-NDP @ NPL



Neutron Depth Profiling:
non-destructive analysis of concentration
profiles of light elements

Modernization of T-NDP

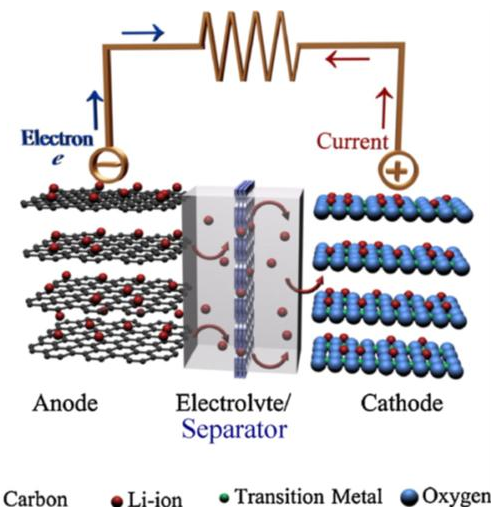
energy storage to exploit fully renewable energy

Lithium ion batteries

new generation / solid type electrolyte

fabrication - ion beam sputtering and thermal processing

characterization and dynamical studies - Neutron Depth Profiling



project submitted for European Structural and Investment Funds

NPI partners Czech Technical University in Prague

Institute of Archaeology CAS

accelerator mass spectrometry (AMS)

ultra-trace isotope research in social and environmental studies

- radiocarbon ^{14}C dating
- ^{14}C in environment - CO_2 transport, impact of fossil fuel combustion
- portion of bio- and fossil- components in biofuels and food, pharmaceuticals and cosmetic materials
- actinides and fission products in environmental studies
- long-lived cosmogenic radionuclides in paleoecological studies

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