CANAM
Center of Accelerators and Nuclear Analytical Methods

@ Nuclear Physics Institute of the CAS

Jan Dobeš
major Czech institution in nuclear physics field

~ 290 employees (220 FTE)  ~ 100 scientists (80 FTE)  ~ 30 PhD student

annual budget 8.5 MEUR
(50% institutional support CAS, 50% targeted support)
mission

➢ 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, SPIRAL-2)
➢ employment of home facilities and equipment
- a multipurpose research platform
- tools based on ion-beams and neutrons
- internal synergies
- multidisciplinary character

- open access
- cooperation in ESFRI facilities
- in Large-scale integrating projects

**Laboratory of Cyclotron and Fast Neutron Generators (LC & FNG)**
Operating cyclotrons
Isochronous cycl. U-120M
Recently purchased TR-24

**Laboratory of Tandetron (LT)**
Operating an accelerator
Tandetron 4130 MC

**Neutron Physics Laboratory (NPL)**
Providing facilities at the reactor LVR-15

~90 persons (48 FTE)
~ 30 scientists (10 FTE)
~ 7 PhD students

Annual budget 2.1 MEUR
(31% institutional, 69% targeted support)
only operation and investments of infrastructure
- 58 research infrastructures approved by MEYS
- operational costs funded by the MEYS
- investment costs - European Structural and Investment Funds
CANAM – open access

open access procedure
proposals via Users Portal
reviewed by 2 experts from SSF
technical feasibility by IR
start in the middle of 2012

~85 experts
8 members
user community

- **user community (2012 – 2016):**
  - Users (proposers and co-proposers of experiments) – 776
  - From abroad – 259
  - Accesses (experiments performed) – 278 (CZ – 167, ERA – 86, others – 25)
in 2012 - 2015 164 publications in impacted journals concerned with 22 scientific disciplines

Archaeology, anthropology, ethnology
Elementary particle theory and high energy physics
Nuclear, atomic and molecular physics, accelerators
Optics, masers and lasers
Plasma physics and discharge through gases
Solid-state physics and magnetism
Astronomy and celestial mechanics, astrophysics
Biophysics
Inorganic chemistry
Analytical chemistry, separation
Organic chemistry
Macromolecular chemistry
Biochemistry
Physical chemistry and theoretical chemistry
Electrochemistry
Nuclear and quantum chemistry, photochemistry
Geochemistry
Pollution and air control
Genetics and molecular biology
Microbiology, virology
Botany
Biotechnology and bionics
Food industry
Electronics and optoelectronics
Sensors, detecting elements, measurement and regulation
Composite materials
Other materials
Corrosion and material surfaces
Fatigue and fracture mechanics
isochronous machine with K=40

<table>
<thead>
<tr>
<th>Ions</th>
<th>Energy [MeV]</th>
<th>Max. current [μA]</th>
</tr>
</thead>
<tbody>
<tr>
<td>H⁺</td>
<td>6–25</td>
<td>5</td>
</tr>
<tr>
<td>H⁻/H⁺</td>
<td>6–37</td>
<td>50–30</td>
</tr>
<tr>
<td>D⁺</td>
<td>12–20</td>
<td>5</td>
</tr>
<tr>
<td>D⁻/D⁺</td>
<td>11–20</td>
<td>35–20</td>
</tr>
<tr>
<td>³He⁺²</td>
<td>18–52</td>
<td>2</td>
</tr>
<tr>
<td>⁴He⁺² (α)</td>
<td>24–38</td>
<td>5</td>
</tr>
</tbody>
</table>

+ ions  ΔE/E ~ 5.10⁻⁴
indirect methods

**Trojan Horse Method**

\[ d + d \rightarrow p + t \quad \rightarrow \quad ^2H\left(\ ^3\text{He},p^3\text{H}\right)^1\text{H} \]

\[ d + d \rightarrow n + ^3\text{He} \quad \rightarrow \quad ^2H\left(\ ^3\text{He},n^3\text{He}\right)^1\text{H} \]

**Asymptotic Normalization Coefficients method**

\[ ^{15}\text{N}(p,\gamma)^{16}\text{O} \quad \rightarrow \quad ^{15}\text{N}(^3\text{He},d)^{16}\text{O} \]
activation cross sections
d + construction materials
$E_d = 4 - 20$ MeV
requested by IFMIF
(International Fusion Irradiation Facility)

excitation functions for radioisotope production activities of NPI Radiopharmacy Dpt.

production routes to $^{230}$U
novel therapeutic nuclide for targeted $\alpha$ therapy

(i) $p + ^{232}$Th $\rightarrow ^{230}$Pa +3n $\rightarrow ^{230}$U + $\beta^-$ (8.4 %)

(ii) $p + ^{231}$Pa $\rightarrow ^{230}$U +2n

thick – target yields (i) and (ii) similar
Nanodiamond: biocompatible carbon nanomaterial (Ib HPHT) powder or aqueous solution, variable size ranging from ~ 5 nm after irradiation and annealing fluorescence nitrogen-vacancy (NV) centers formed.

bioimaging, biolabeling, substitution of quantum dots, single particle tracking etc.
High-power broad-spectrum neutron generator

\[ p + D_2O \quad E_p = 37 \text{ MeV} \]
integral flux up to \(10^{11}\) \(\text{cm}^{-2} \text{s}^{-1}\)
IFMIF like white spectrum with a mean energy of 14 MeV and extension up to 32 MeV

Variable-energy broad-spectrum neutron generator

\[ d+Be \quad E_p = 10 – 37 \text{ MeV} \quad E_d = 8 – 20 \text{ MeV} \]
integral flux: up to \(10^{11}\) \(\text{sr/s}\)
mean energy: 4 - 12 MeV

Quasi-monoenergetic neutron generator

\[ p+^7\text{Li} \quad E_p = 20 – 37 \text{ MeV} \]
peak energy: up to 36 MeV
neutron flux density in the QMN peak:
up to \(10^9\) n/cm\(^2\)/s
neutronics data
neutron data above 15-20 MeV needed for fusion and ADTT programs

FNG involved in projects

detector and electronics tests
ATLAS & LHC  ALICE & LHC  CBM @ FAIR
Cyclotron TR-24

2013 – 2015 investment (CAS, MEYS, NPI)

<table>
<thead>
<tr>
<th>TR 24 – Advanced Cyclotron System Inc. (Canada)</th>
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</thead>
<tbody>
<tr>
<td>Proton energy range</td>
</tr>
<tr>
<td>Max. proton beam current</td>
</tr>
<tr>
<td>Acceleration frequency</td>
</tr>
<tr>
<td>Acceleration voltage</td>
</tr>
<tr>
<td>H⁻ ion source</td>
</tr>
<tr>
<td>Simultaneous beams</td>
</tr>
<tr>
<td>Weight</td>
</tr>
<tr>
<td>Dimensions</td>
</tr>
<tr>
<td>Power</td>
</tr>
<tr>
<td>Middle magnetic field</td>
</tr>
</tbody>
</table>
Research program associated with
- generation of high fluxes of fast neutrons:
  - nuclear data for new fusion-fission and advanced fission systems
  - neutron radiation tests of electronic or diagnostic components
- production of novel medical radionuclides
  - theranostics $^{64}$Cu, $^{68}$Ga,...
  - $^{99m}$Tc via ($p$,2$n$) reaction as an alternative to reactor-produced generator $^{99}$Mo/$^{99m}$Tc
LT Tandetron 4130 MC

terminal voltage  200 kV - 3 MV

duoplasmatron ion source

sputter ion source

ions  H – Au

ion energies  400 keV – 24 MeV

ion currents  nA - uA
nano- and micro-structured systems
- preparation
- modification
- complex characterization

RBS-C optical waveguides
Er implanted in sapphire ($\text{Al}_2\text{O}_3$)

polymer bio-materials
PE irradiated by O ions

PIXE multi-elemental analyses
atmospheric aerosols

high-energy ion implantation

multi-analytical chamber
LT instrumentation

- 10° line

Ion Micro-beam

PIXE  RBS  PESA

3D elemental mapping
oxidation study of Zr alloys

heavy ion micromachining
optical microcomponents
LVR-15 research reactor
operated by the Research Centrum Řež, Ltd.
thermal power 10 MW
max. flux $10^{14}$ n/s/cm$^2$
<table>
<thead>
<tr>
<th>Facility</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TKS N-400</td>
<td><strong>High-resolution diffractometer</strong>: microstrains in polycrystals, in-situ thermo-mechanical processing, phase transformations in alloys (steels, SMA etc.)</td>
</tr>
<tr>
<td>SPN-100</td>
<td><strong>Diffractometer for macrostrain scanning</strong> of polycrystalline materials (welds, materials after processing)</td>
</tr>
<tr>
<td>MAUD</td>
<td><strong>Double crystal small-angle neutron scattering</strong>: microstructural studies (precipitation in alloys, porosity in ceramics)</td>
</tr>
<tr>
<td>NOD</td>
<td><strong>Neutron optics diffractometer</strong> for tests of neutron optics and imaging</td>
</tr>
<tr>
<td>MEREDIT</td>
<td><strong>Medium resolution powder diffractometer</strong>: standard diffraction experiments; experiments with sophisticated sample environment (T, deformation)</td>
</tr>
</tbody>
</table>
Neutron Activation Analysis: low-level elemental characterization - biology, biomedicine, environment, geology, archaeometry

**synthesis of graphene**

different oxidation and reduction steps introduce varying types and amounts of elements into the graphene materials

Was Tycho Brahe poisoned by Hg?
NAA and μ-PIXE analyses of hair samples
Installations and methodological development:
2017 – 2019
- high-intensity neutron source at TR-24
- n-TOF method, modernization of the detection system at FNG
- upgrade LT - ion microprobe and external analytical end-stage
- upgrade NPL - supermirror neutron guide

2020 and beyond:
- TR-24 - dual beam regime, neutron lines with TOF
- Accelerator Mass Spectrometry (AMS)

Research:
- nuclear data for basic and applied tasks
- nano-structured materials for optoelectronics
- lithium ion batteries
- materials research
canam.ujf.cas.cz

is looking forward to continuing collaboration with and proposals from TALYS/TENDL community

Thank you for attention