Laboratory Of Fast Neutron Generators At NPI Řež

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Introduction

• Nuclear Physics Institute, The Czech Academy of Sciences

• Fast neutrons 1 – 35 MeV

• Focused on the experimental validation of the neutron cross-section libraries for the materials used in the future thermonuclear technologies (IFMIF-DONES, ITER)

• FNG in operation, Commissioning of the new FNG units

• Fast neutron detector systems
Thick Be target station

Thin Li target station
FNG – neutron field characteristics

**Continuous neutron spectrum**
- Protons + 8 mm Be
- Continuous spectrum up to 35 MeV
- Max. flux: $\sim 10^{11}$ n/cm²/s

**Quasi-monoenergetic neutrons**
- Protons + 2 mm Li backed with Graphite beam stopper
- Monoenergetic peak width 2 MeV
- Energy range: 17-35 MeV
- Max. flux in peak: $\sim 10^9$ n/cm²/s

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![Graph showing neutron spectra](image-url)
New thin-Be FNG driven by U-120M cyclotron, collimated beams

- Quasi-monoenergetic source of fast neutrons: 0.5 – 2.5 mm of target thickness
- Placed very close to collimator to gain higher fluxes
- Low target thickness -> narrow monoenergetic peak -> better cross section evaluations for specific neutron energies, but lower statistics
- First test was successfully conducted last week

Graphite Beam Stopper

Be Thin Convertor

Proton beam
New thin-Be FNG driven by U-120M cyclotron, collimated beams

2.5 mm Be foil backed with Graphite beam stoper, cooled with demi-water.

Neutron Energy Spectrum at 2.5m distance on collimated beam
\( p + 2.5 \text{ mm } ^9\text{Be} \)
\( E_{\text{proton}} = 33 \text{ MeV} \)
High-flux fast neutron generator at TR-24

- Max. beam currents up to 0.3 mA
- Protons 24 MeV
- Up to 7.2 kW on the fixed target
- Water-based cooling systems under development
- Neutron production: p+Be(Thick)
- Integral flux expected: $5 \times 10^{12}$ n/sr/s
- Not operational yet
Time-of-Flight measurements

- Scintillator NE-213
- Scintillator data acq with CAEN V1751 digitizer: 1GHz sampling rate, 10 bits resolution
- Simultaneous sampling of the anode signal from the scintillation probe and the cyclotron accelerating frequency (RF)
- No need for initial knowledge of detector response function (its measured directly) or initial gues of final spectrum

Neutron Energy Spectrum at 4m distance

\( p + 2 \text{ mm } 7\text{Li} \)

\( E_{\text{proton}} = 27.5 \text{MeV} \)
Neutron Spectra measurements – Activation analysis

- Suitable for compact geometries
- No dead time in presence of intense neutron fields
- Unfolding with SAND-II code based on neutron CS data from EAF-2010, initial spectra guess with MCNPX simulation (with ENDF/B –VII and LA -150h data)
- Large set of activation materials (Al, Nb, Ni, Y, Co, Ti, Fe, In, Lu, Au, and Bi)) allows to measure spectrum across wide range of neutron energies
Delayed neutrons measurements

- Accurate knowledge of delayed neutrons at ADS needed - $^{232}$Th, $^{238}$U

- Array of BF$_3$ detectors in polyethylene matrix, proof of concept setup

- Cyclotron beam modulation controlled by arduino module.

- In April 2017 experiment with 50g natU was performed, QM neutrons 21 MeV.

- Delayed neutron curve is measured and fitted to 6 energy groups.
Total neutron CS measurements with liquid oxygen

- Data important for ADS setups of future nuclear reactors
- Direct transport measurements of total neutron cross-section with Quasi-monoenergetic colimated beams
- TOF neutron spectrum with/without box filled with liquid O2
- Decrease of peak in QM neutron spectrum is measured
- \((n,tot)\) cross-section is calculated based on the transmission
- Final results to be presented at ND2019 - Beijing

Neutron beam collimator!
NPI Chamber for Light Ion Detection – „CLID device“

• Inspired by MEDLEY setup, now at Ganil/Spiral2- NFS

• Measurements of double-differential cross sections for reactions (n, cp)

• Reactions induced by collimated fast neutron beams (18-35 MeV) from new FNG (0.5 mm thin Be) driven by U-120M

• Chamber still under construction, but almost ready for operation, first test expected later this year (2019)

• Equiped with dE-E Si telescopes

• Central ladder with 3 sample positions

• Fully remote controled
HPGe prompt γ-spectrometer on collimated neutron beams

- Neutron induced reactions \((n,\gamma)\) and collimated beams

- Consists of 4-piece array of HPGe with 25% of relative efficiency

- Placed around collimated beam of fast neutrons from U-120M

- Cyclotron duty cycle already useful for ms isotopes – eg. \(^{209}\text{Bi}(n,2n)^{208}\text{Bi}\), important in PbBi

- System in final stage of construction, should be operational lately in 2019
Neutron radiation damage measurements

- Fundamental data needed for materials exposed to high neutron fluxes at future fusion related facilities.

- Integral neutron flux of $10^{16}$ n/cm$^2$ is sufficient for the reliable PALS measurements: tens of hours at the current FNG p+Be source.

- Direct DPA measurements with Positron Anihilation Spectrometry (PALS).

- Cryostatic system to reduce thermal recombination during irradiation/transport/PALS is in construction.

- Could be done at NFS: 50 hours on d+Be (position on the target station), 10x more time in p+Li: in parallel with other experiments.

- IAEA launched coordinated research project on this topic: https://www.nds.iaea.org/CRPdpa/
Three FNG controlled by U-120M are in operation, two of them were used very often in the last decade.

Thick Be driven by TR-24 is still in the process of commissioning.

Fundamental Nuclear research oriented to fusion.

Evacuated chamber for (n,cp) reaction measurement (first experiments hopefully later this year 2019).

HPGe array for prompt (n,gx) and delayed gamma (milliseconds isotopes) measurements (2019/2020).

Continue research in the fusion framework.

New TR-24 cyclotron, 300 mA proton beam, construction of neutron converter (2018), Material damage with PALS (EUROFUSION from 2019), subcritical systems.

We are looking for new employees, postdocs, students...

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