EUROPEAN UNION
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MINISTRY OF EDUCATION, YOUTH AND SPORTS

Czech Republic contribution to SPIRAL2

Laboratory Of Fast Neutron Generators At NPI Řež

GROUP MEMBERS:

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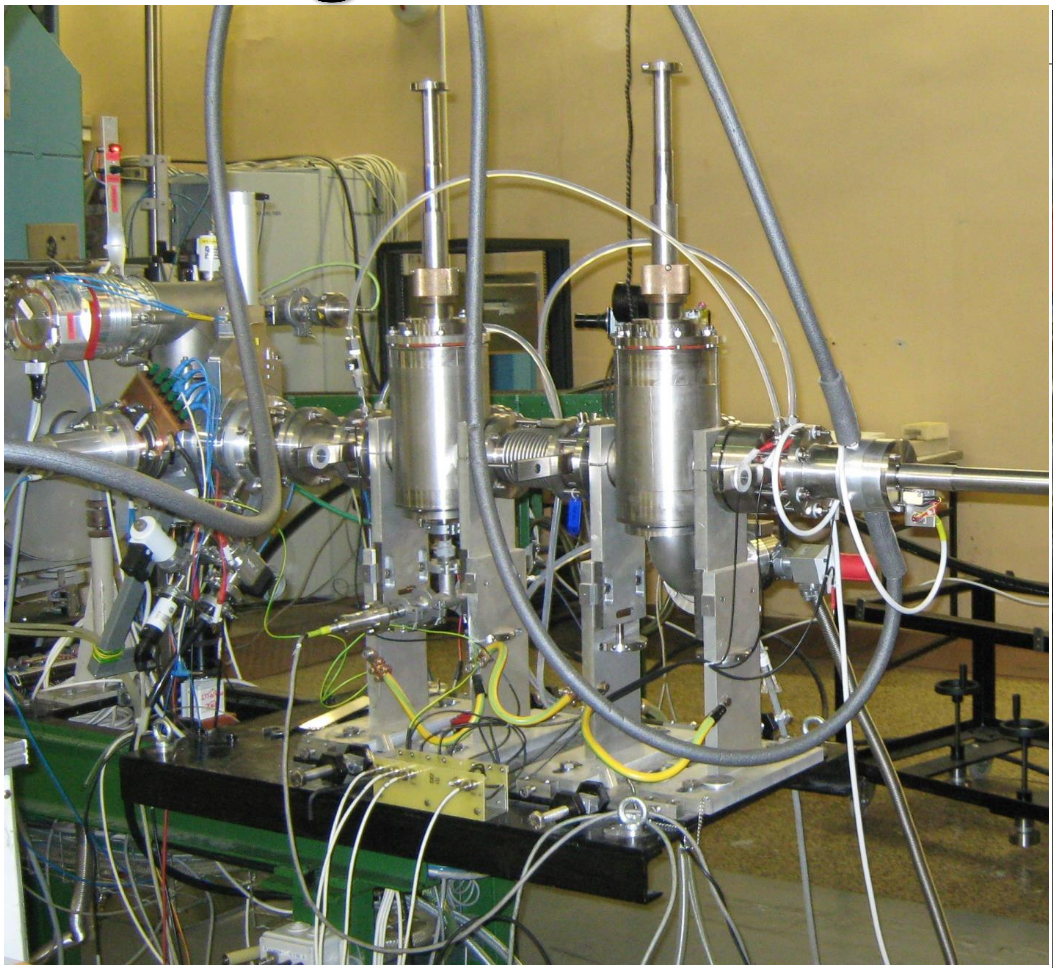
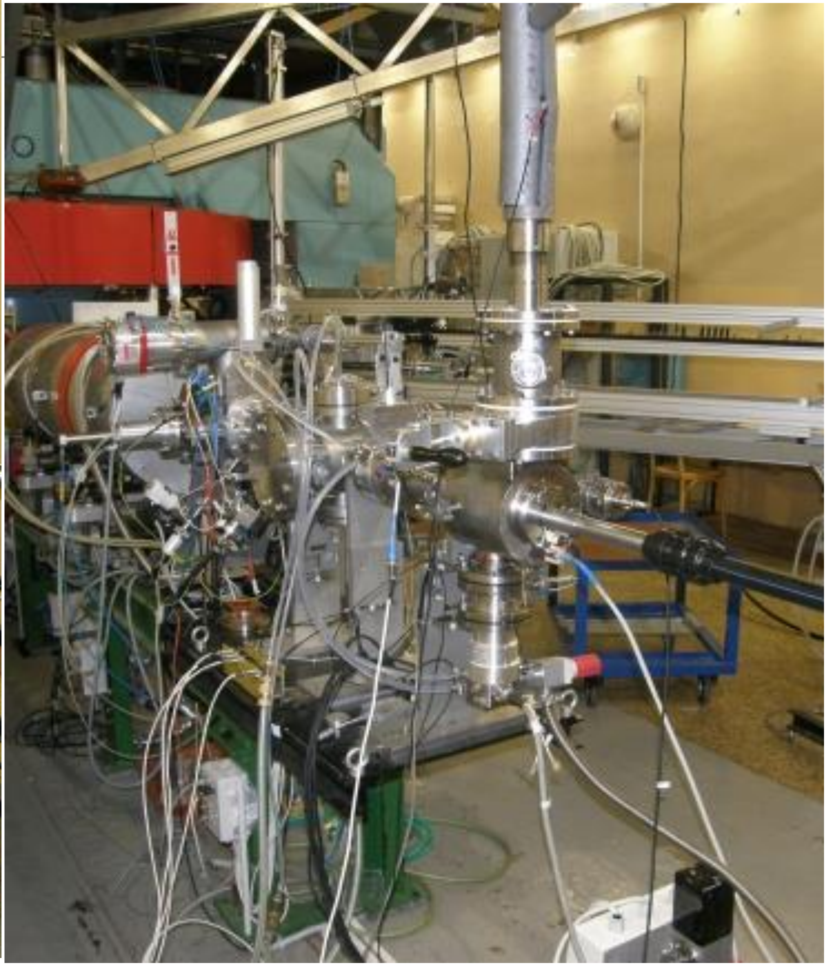
Introduction

- 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 detecor systems

Thick Be target station



Thin Li target station



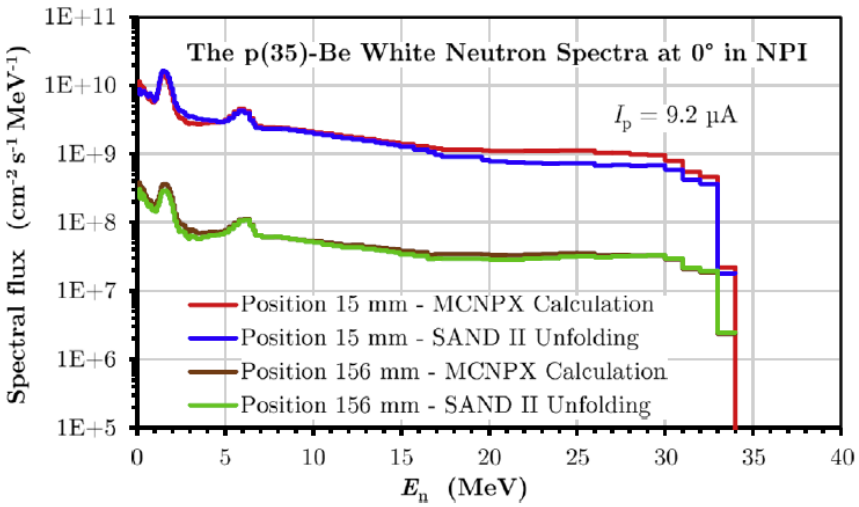
FNG – neutron field characteristics

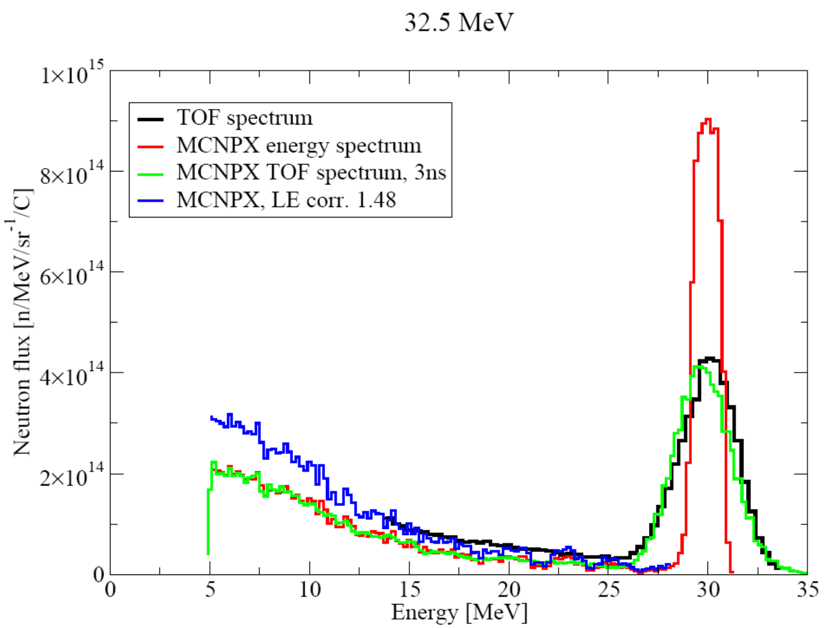
Continuous neutron spectrum

- Protons+8mm Be
- Continuous spectrum up to 35 MeV
- Max. flux: ~10^{11} n/cm^2/s

Quasi-monoenergetic neutrons

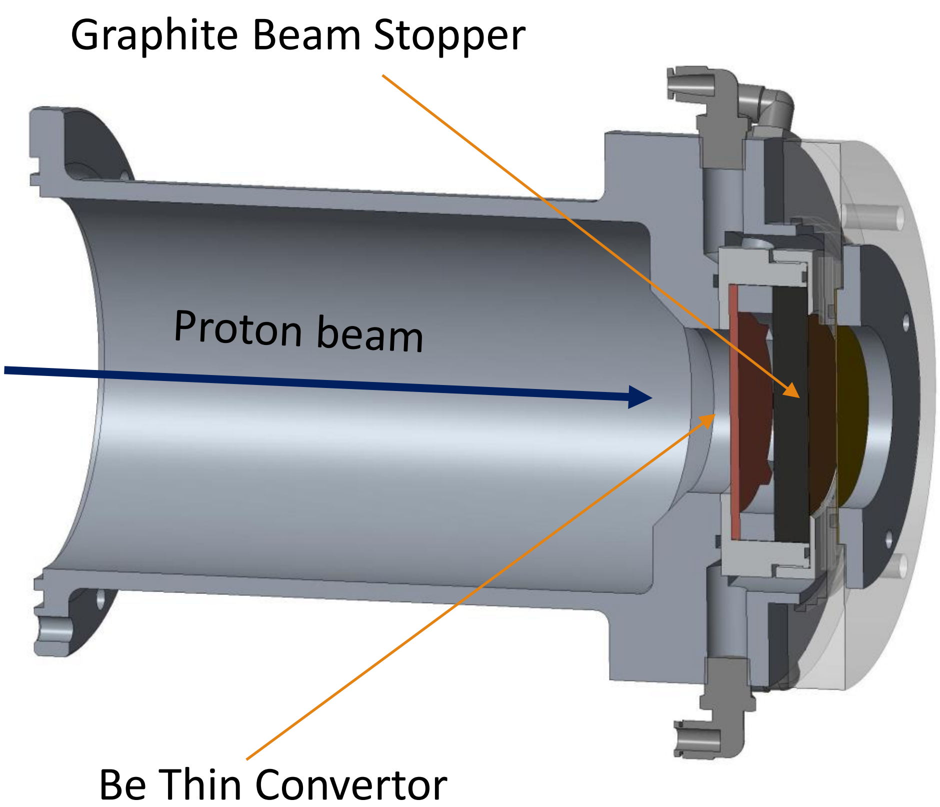
- Protons+2 mm Li backed with Graphite beam stopper
- Monoenergetic peak width 2 MeV
- Energy range: 17-35 MeV
- Max. flux in peak: ~10^9 n/cm^2/s



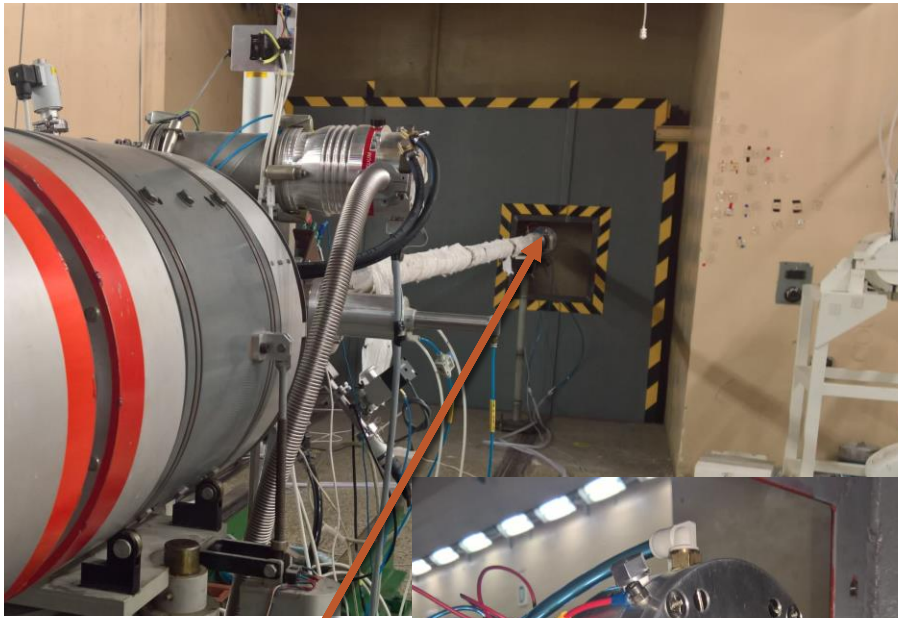


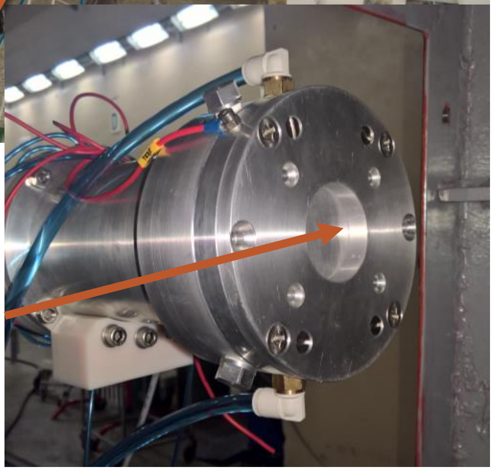
New thin-Be FNG driven by U-120M cyclotron, collimated beams

- 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

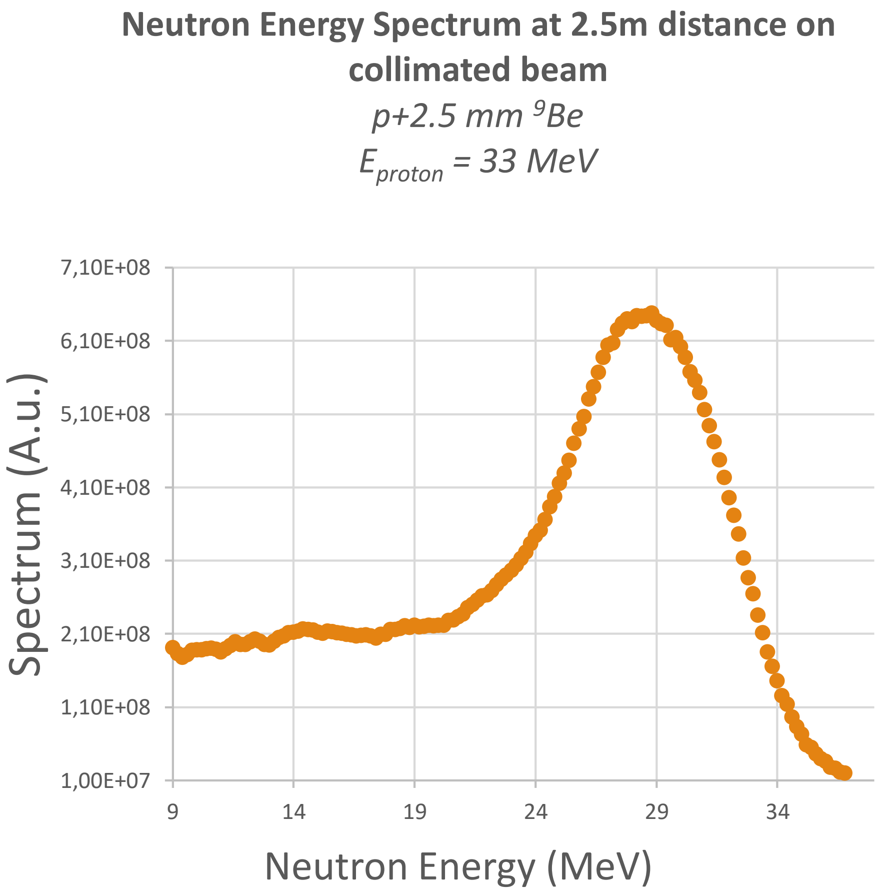


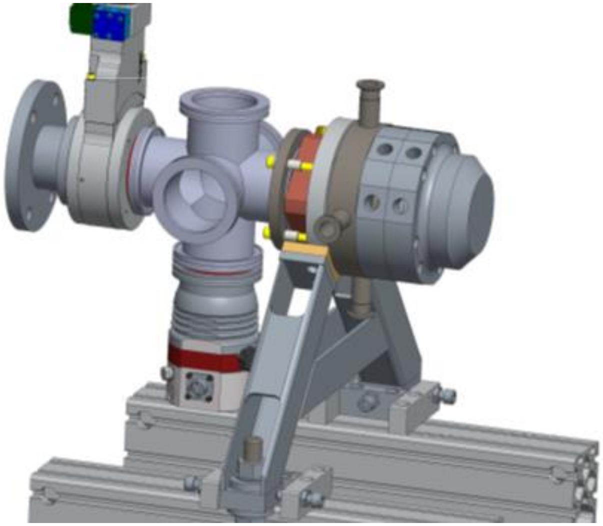
New thin-Be FNG driven by U-120M cyclotron, collimated beams





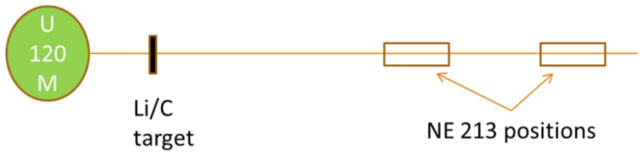
2.5 mm Be foil backed with Graphite beam stoper, cooled with demi-water.

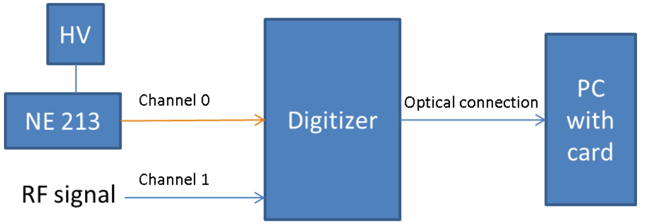




High-flux fast neutron generator at TR-24

- 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: $5x10^{12}$ n/sr/s
- Not operational yet

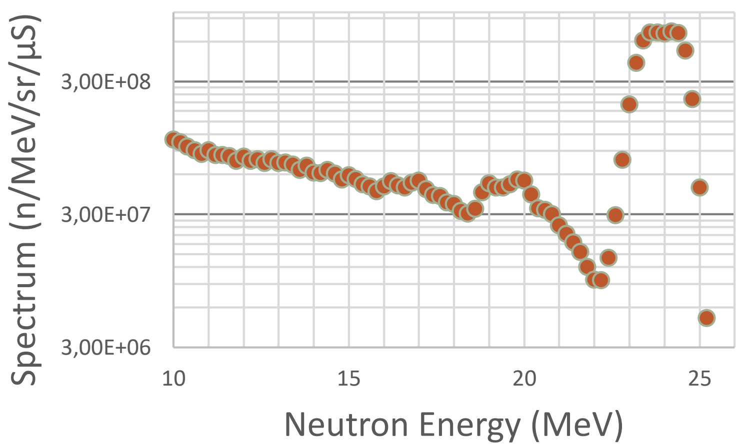




Neutron Energy Spectrum at 4m distance

p+2 mm 7Li

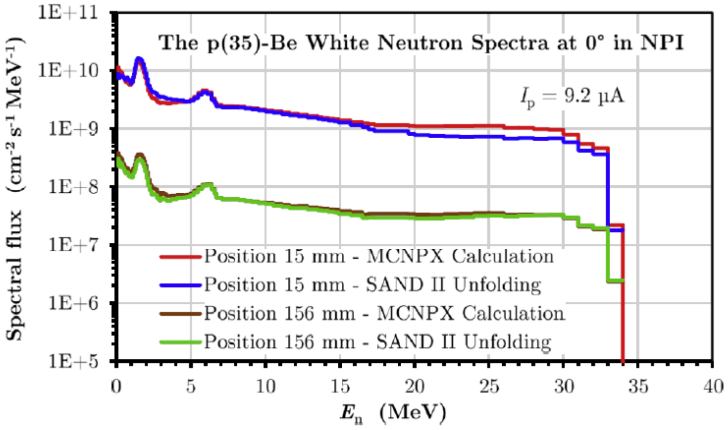
$E_{proton} = 27.5MeV$

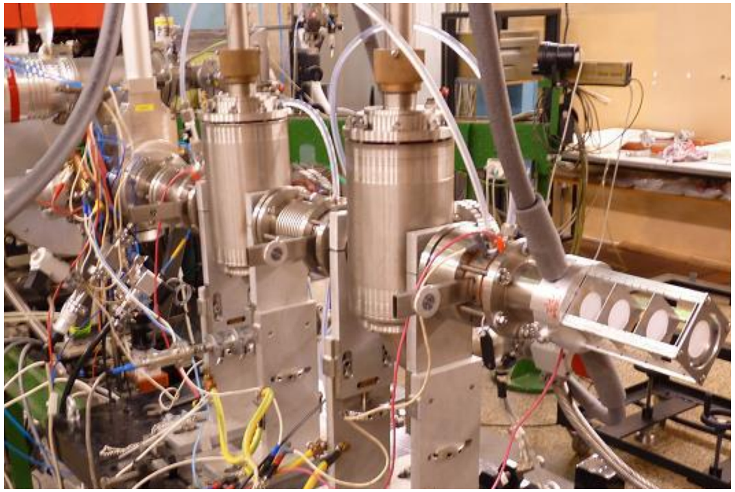


Time-of-Flight measurements

- Scintilator 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

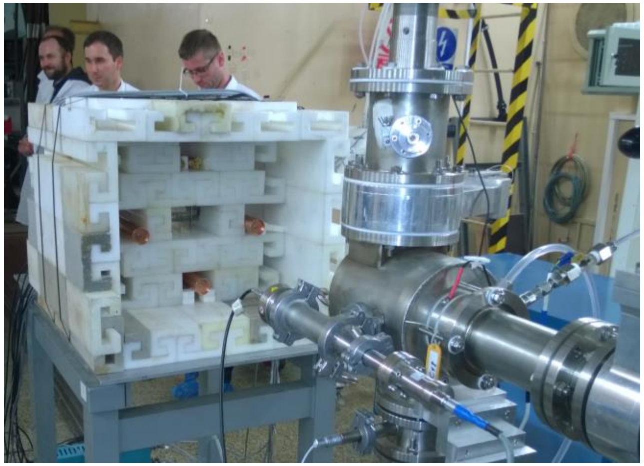
Neutron Spectra measurements – Activation analysis

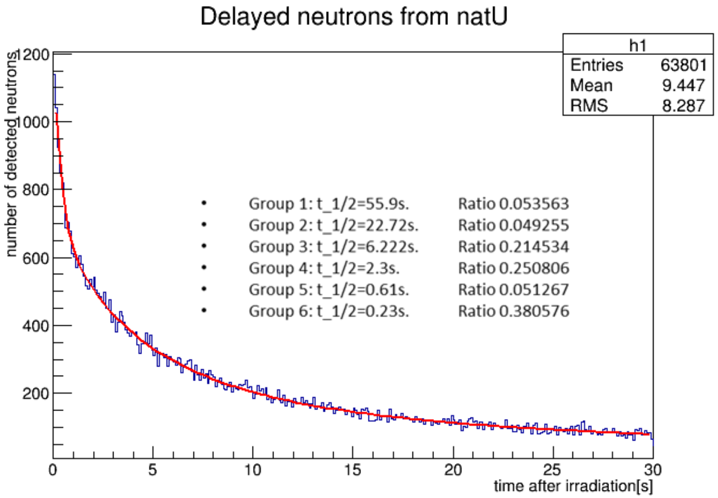




- Suitable for compact geometries
- No dead time in presence of intense neutron fields
- Unfolding with SAND-II code based on neutron CS data from EAF-2010, initial spectra guess with MCNPX simulation (with ENDF/B –VII and LA -150h data)
- Large set of activation materials (Al, Nb ,Ni, Y,Co, Ti, Fe,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

Delayed neutrons measurements





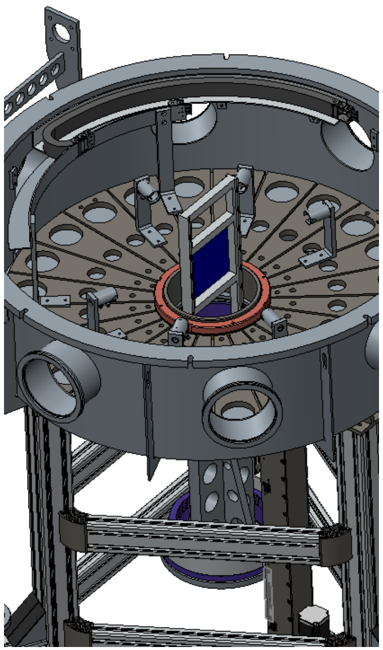
- Acurate knowledge of delayed netrons at ADS needed - ^{232}Th, ^{238}U
- Array of BF_3 detectors in polyethylen matrix, proof of concept setup
- Cyclotron beam modulation controlled by arduino module.
- In April 2017 experiment with 50g ^{nat}U was performed, QM neutrons 21 MeV.
- Delayed neutron curve is measured and fitted to 6 energy groups.

Neutron beam collimator!

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 - Bejiing

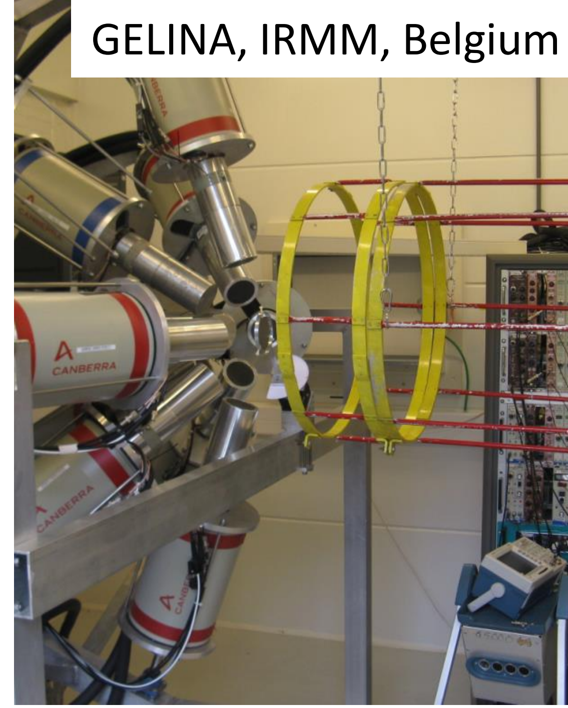
NPI Chamber for Light Ion Detection – „CLID device“

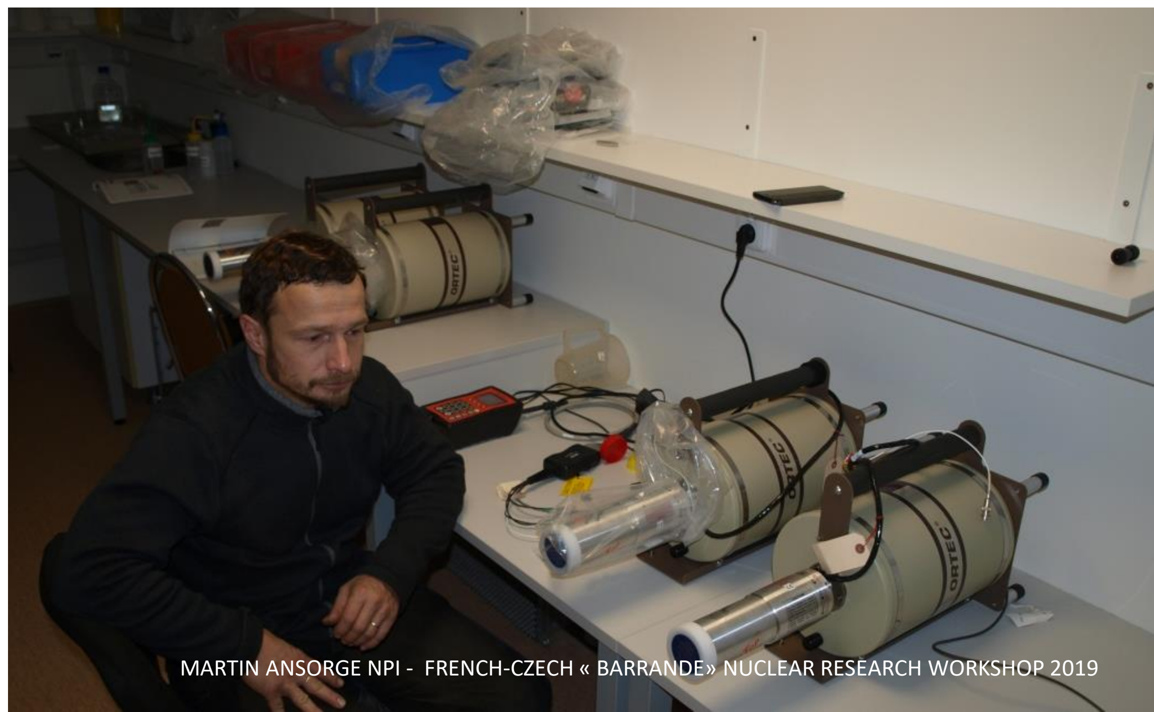


- Inspired by MEDLEY setup, now at Ganil/Spiral2- NFS
- Measurements of double-differential cross sections for reactions (n, cp)
- Reactions induced by collimated fast neutron beams (18-35 MeV) from new FNG (0.5 mm thin Be) driven by U-120M
- Chamber still under construction, but almost ready for operation, first test expected later this year (2019)
- Equiped with dE-E Si telescopes
- Central ladder with 3 sample positions
- Fully remote controled

HPGe promt γ-spectrometer on collimated neutron beams

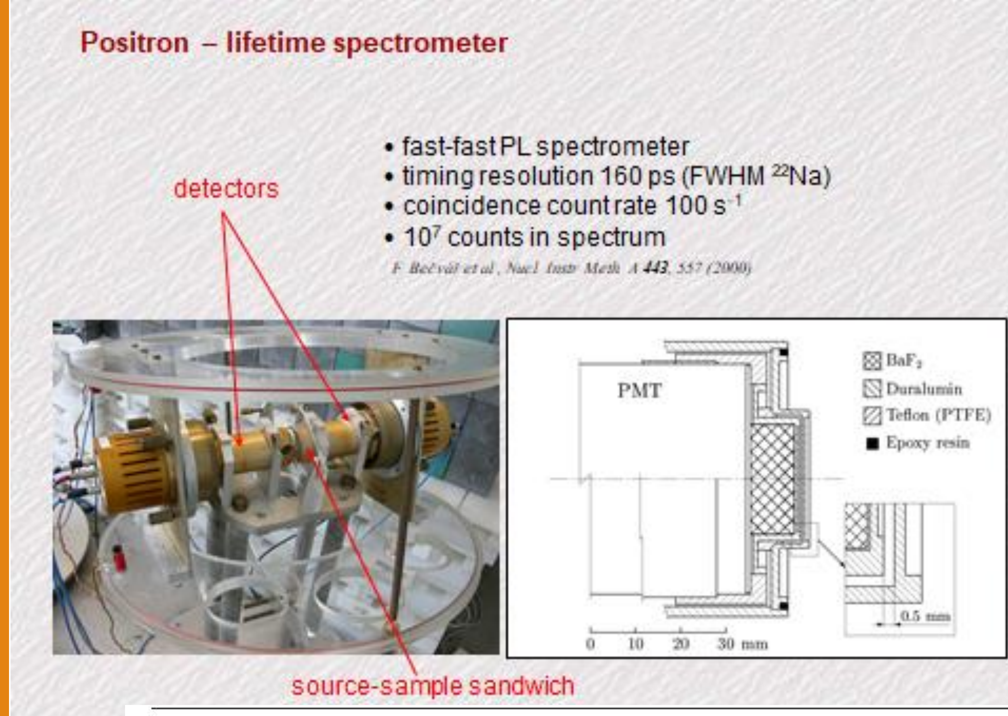
- Neutron induced reactions (n,xγ) an collimated beams
- Consists of 4-piece array of HPGe with 25% of relative efectivity
- Placed around colimated beam of fast neutrons from U-120M
- Cyclotron duty cycle already useful for ms isotopes – eg. ^{209}Bi(n,2n)^{208m}Bi, important in PbBi
- System in final stage of construction, should be operational lately in 2019

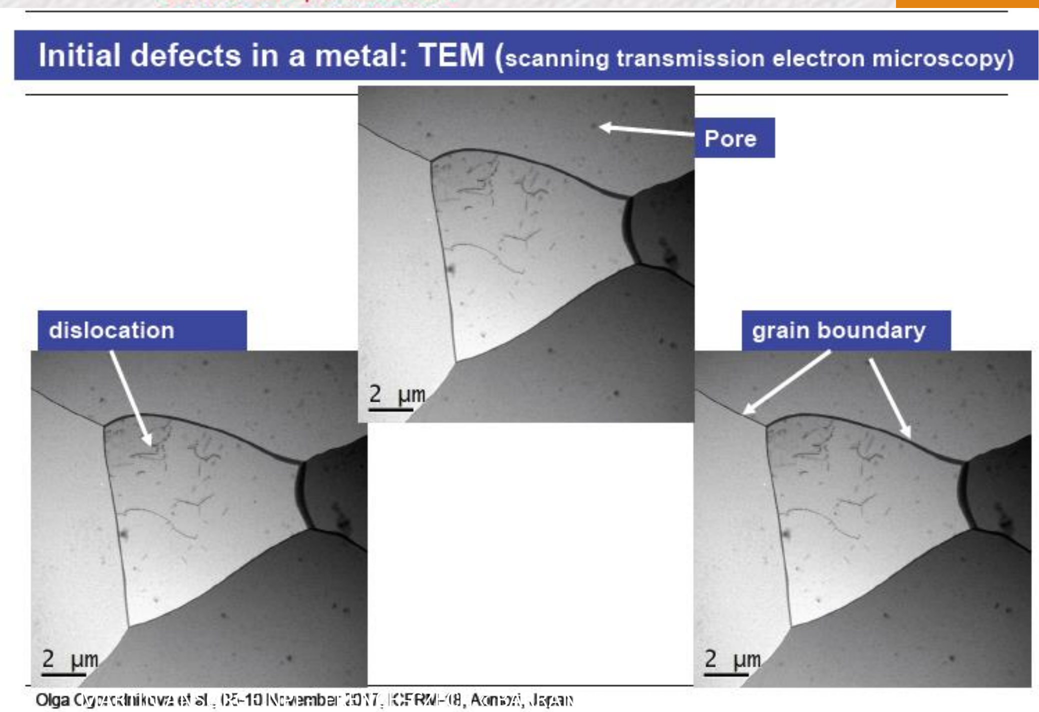




Neutron radiation damage measurements

- 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/





Summary

- Three FNG controled by U-120M are in operation, two of them where used very often i last decade
- Thick Be driven by TR-24 is still in proces 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 (milisecond 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…
- Visit http://www.ujf.cas.cz or email on ansorge@ujf.cas.cz

Thank You for Your Attention