The Eastern European Cooperation in Fast Neutron and ADSS Related Research

Why we see the light in the end of tunnel?

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Introduction

MSc Nuclear Engineering (CTU Prague), 2001

PhD in Nuclear data (JINR Dubna), 2008

2005-2008 lecturer (CTU)

2008-2012 reactor physicist at Nuclear Power Plant Dukovany

from 2012 assistant professor at Brno University of Technology

Research interests: ADSS, nuclear data, nuclear fuel cycle, neutron spectra issues

Motivation

Accelerator Driven Subcritical Systems

1. Design and simulation of ADS and its properties

2. Experimental determination of ADS properties

   from neutron point-of-view.

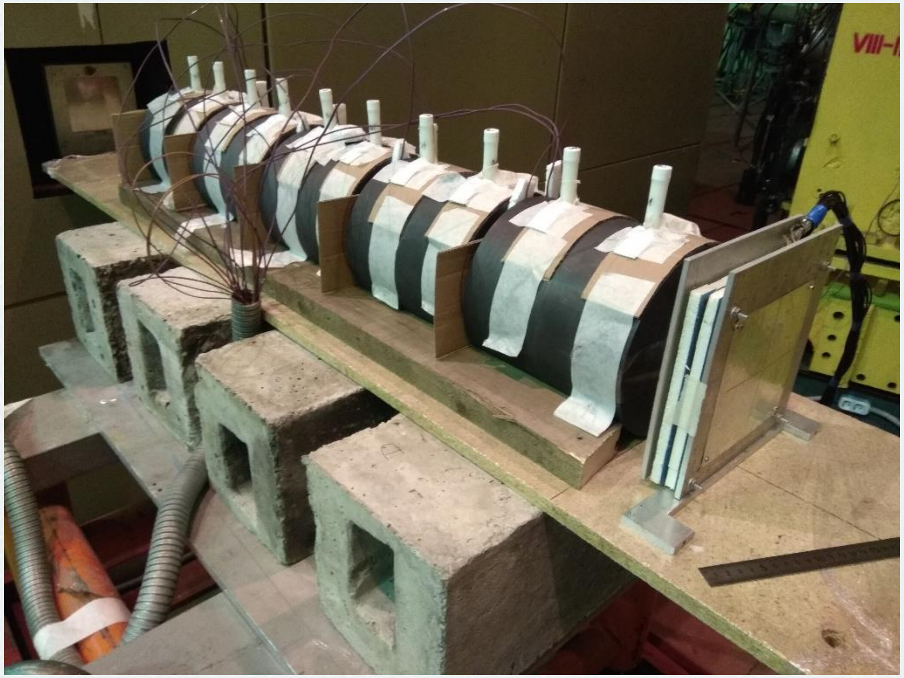
Tools – simulation

1. MCNP(X) – with evaluated nuclear data libraries with standard E_{max}=20 MeV
2. TALYS – could give data up to 200 MeV (based on modern nuclear models) or EMPIRE too
3. OR physics parameters in MCNP (different high-energy models)
4. Similar situation for FISPACT inventory code

5. Similar for GEANT, FLUKA, MARS, SHIELD,…

Tools – experiment

Graphite thick target on 660 MeV proton beam



Lead thick target on 660 MeV proton beam

Tools – experiment

1. Activation and threshold detectors (ideal monoisotopic with different (n,n'), (n,p), (n,a), (n,xn) channels)
2. Saturated activities determined (reaction rates)
3. Neutron spectra reconstruction method
4. Unfolding using maximal entropy approach, swarm optimization, least squares, neural etc.

5. However, for spectra reconstruction we need XS

F4ADS – Foils for ADS project

1. Research project with NUVIA Czech
2. Development of **alloy(s)** for high-energy neutron field properties (spectra) determination
3. Potential application ESS, JSNS, CSNS
4. Goal – to have as minimum as possible thin foils=alloys with well known composition (Al, Co, Nb, Au, Y, Sc, Mo, Ta, Cd, Ti, In, Cu,...)
5. Then data processing procedure could be automated – we know lines we are looking for
6. For low energy neutrons we are using filters (it might be used for background determination)

F4ADS project

Filters: Gd, Cd, Hf, W, In, B_4C, Er, Dy, Eu

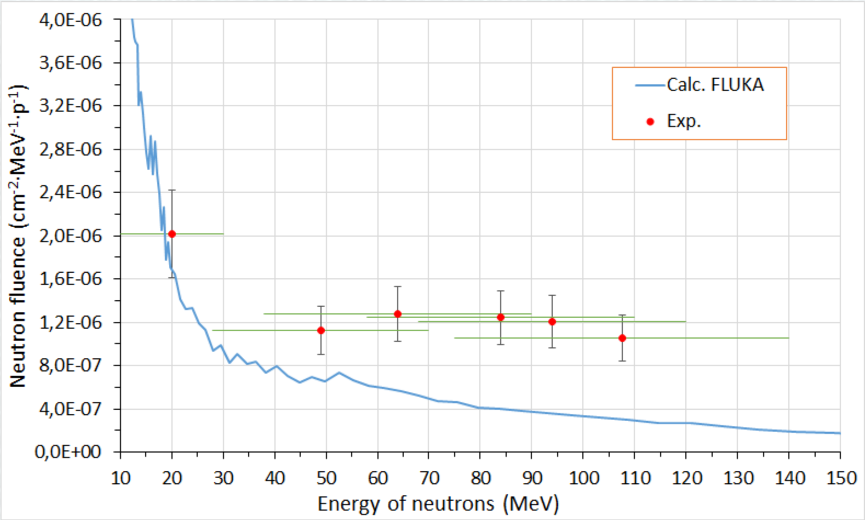
Tools – experiment

1. We could use EXFOR – benefit agains MCNP

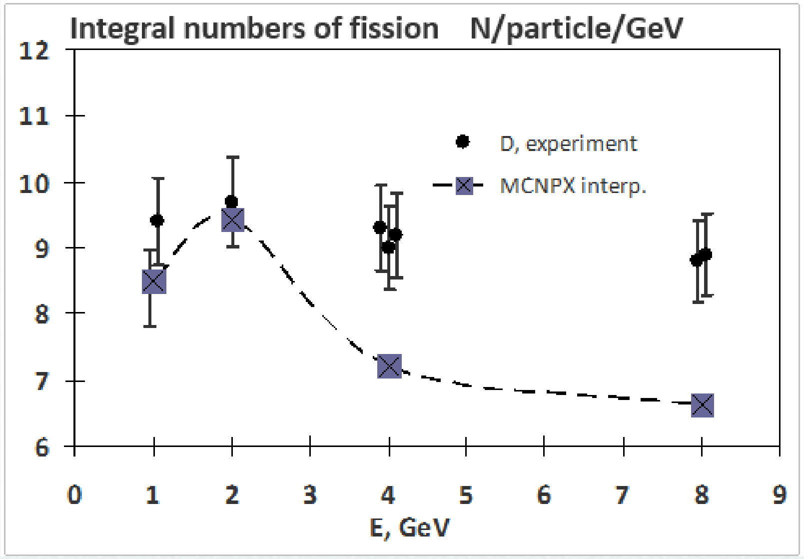
2. We need fission yields and HE fission/ evaporation/ multifragmentation yields

3. It influence also total number of neutron produced in ADSS system per proton /deuteron

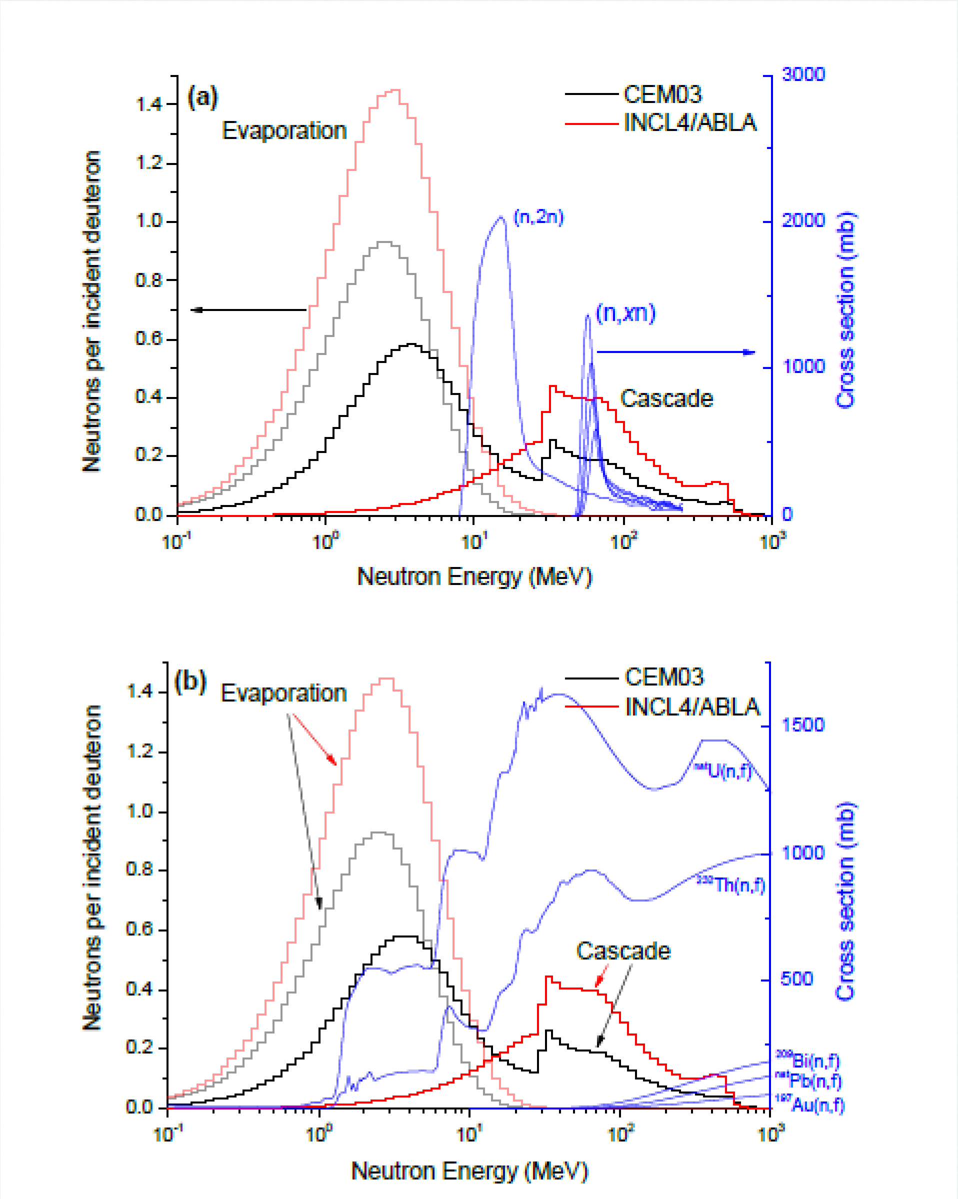
Examples



Kushvatov et al., JINR Dubna, 2018



Voronko et al., KIPT Kharkov, 2016



Ascquit et al., The University of Sydney, 2015

Tools – experiment

1. Neutron spectra unfolding – well known method, however, with large sensitivity to nuclear data
2. To combine it with spallation spectra coefficient fitting method, supreme threshold method, etc.
3. We „manufactured“ „portable“ rabbit system for short-lived isotopes (students’ improvisation)
4. To have universal and fast detection technique for spectra determination at acc.driven neutron sources, small enough to be placed to various places inside or outside of the source

„Supreme“ threshold method

$$R_{exp} = \int_{E_{th}}^{\infty} \sigma(E) \cdot \phi(E) \cdot dE$$

$$R_5 = \phi(5) \int_{E_{theff}(n,4n)}^{E_{max}} \sigma_5(E) \cdot dE$$

$$\Rightarrow \phi(5) = \frac{R_5}{\int_{E_{theff}(n,4n)}^{E_{max}} \sigma_5(E) \cdot dE}$$

Reaction	E_{theff} (MeV)	$T_{1/2}$
$^{59}Co(n,\gamma)^{60}Co$	0.1	5.27 y
$^{59}Co(n,p)^{59}Fe$	3.9	44.5 d
$^{59}Co(n,2n)^{58}Co$	10.4	271.8 d
$^{59}Co(n,3n)^{57}Co$	16.5	312.3 d
$^{59}Co(n,4n)^{56}Co$	31.9	77.3 d

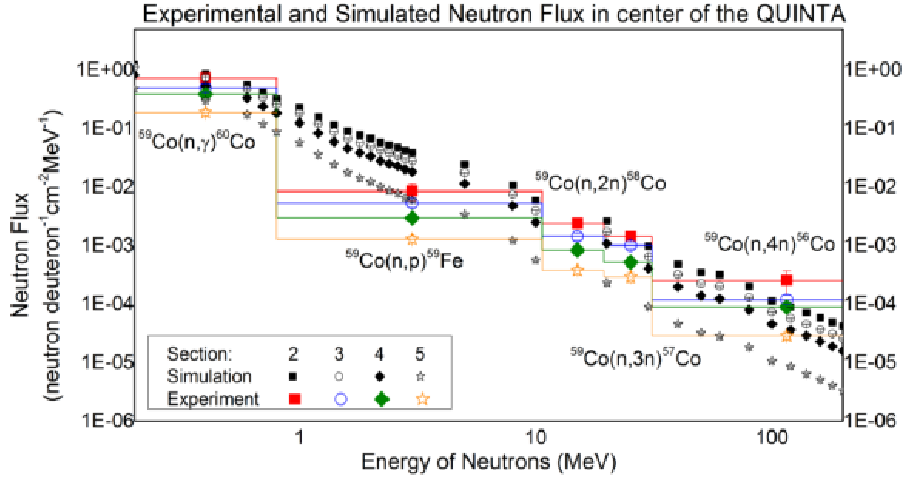
$$R_4 = \phi(4) \int_{E_{theff}(n,3n)}^{E_{theff}(n,4n)} \sigma_4(E) \cdot dE + \phi(5) \int_{E_{theff}(n,4n)}^{E_{max}} \sigma_4(E) \cdot dE$$

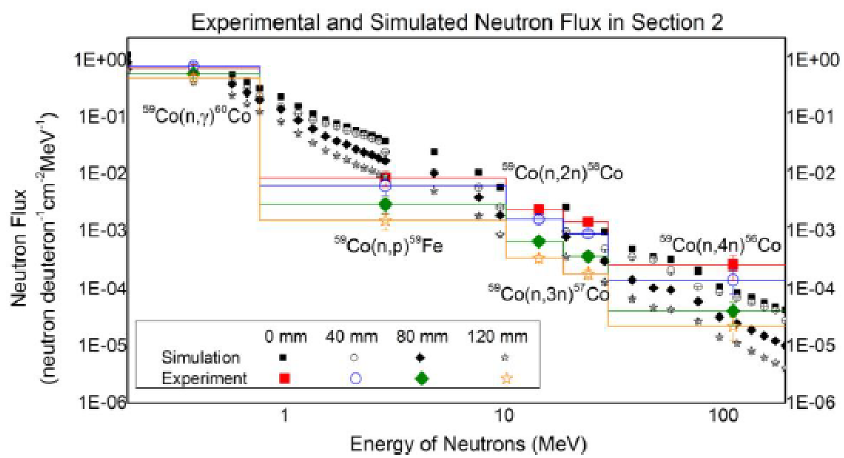
$$\Rightarrow \phi(4) = \frac{R_4}{\int_{E_{theff}(n,3n)}^{E_{theff}(n,4n)} \sigma_4(E) \cdot dE + \int_{E_{theff}(n,4n)}^{E_{max}} \sigma_4(E) \cdot dE}$$

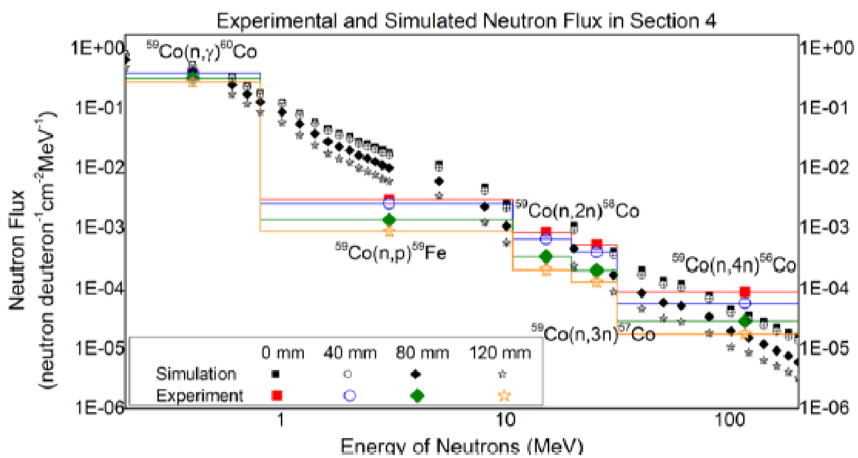
- Cross section calculated in TALYS 1.6
- Simulation performed in MCNPX 2.7 (INCL4/ABLA)

x 7,50 "

Determination of neutron flux – deuteron beam

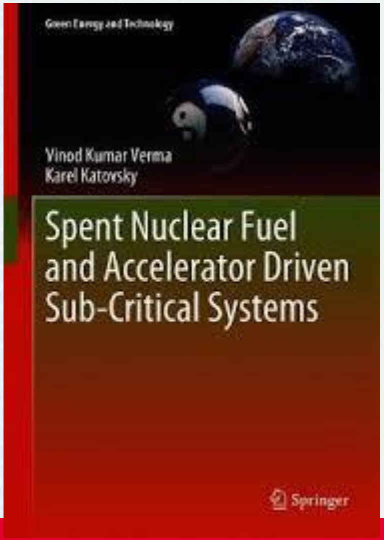






Experiments

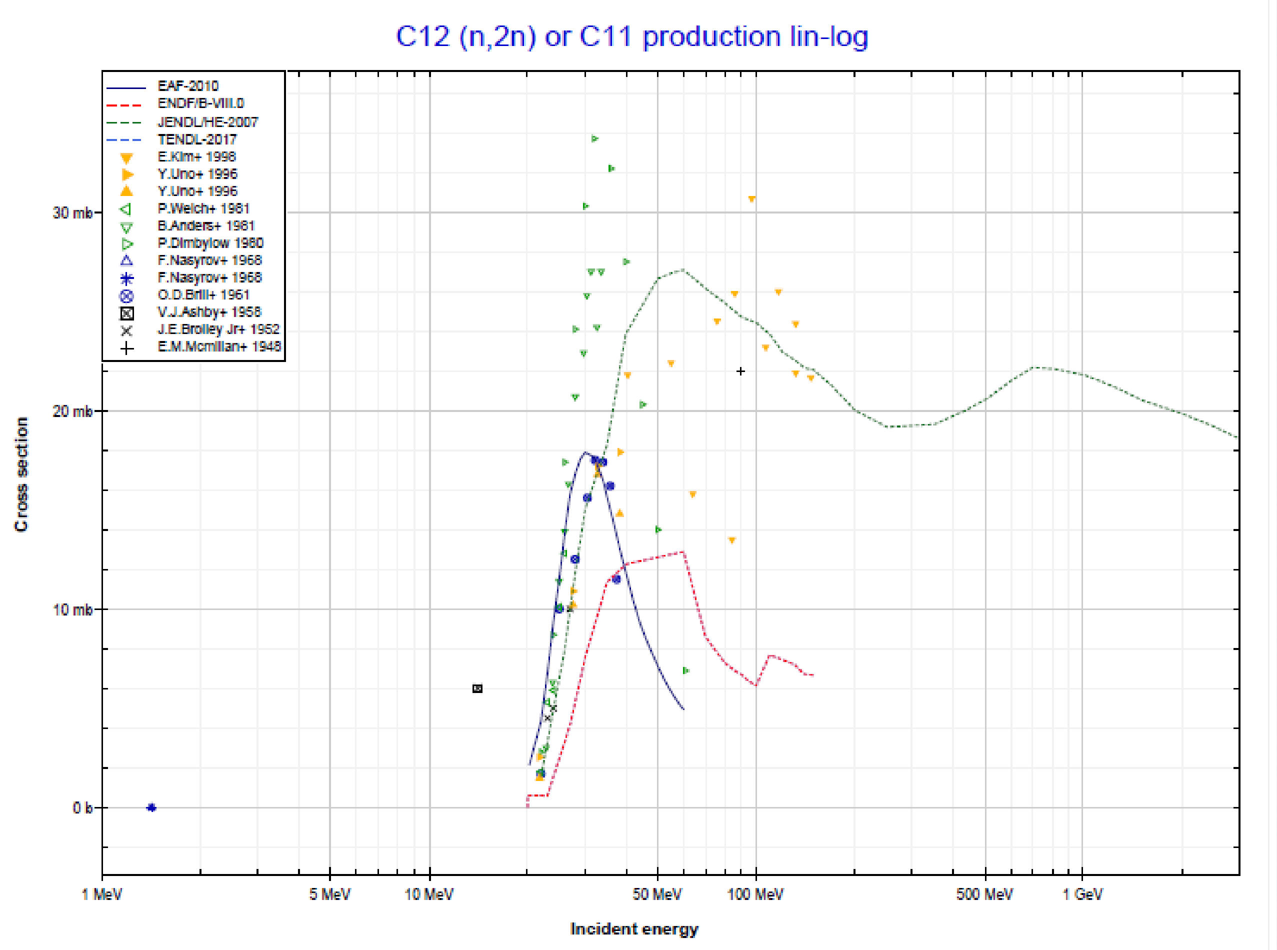
1. We perform experiments from 1996 in Joint Institute for Nuclear Research at Dubna (different spallation neutron sources)
2. We see discrepancies in C/E for some reactions
3. Missing data for ADSS were defined (there were EU, Japanese or Russian projects in the past, but data is still missing)
4. There is an overlap with fusion and even with GFR and LFR !!!



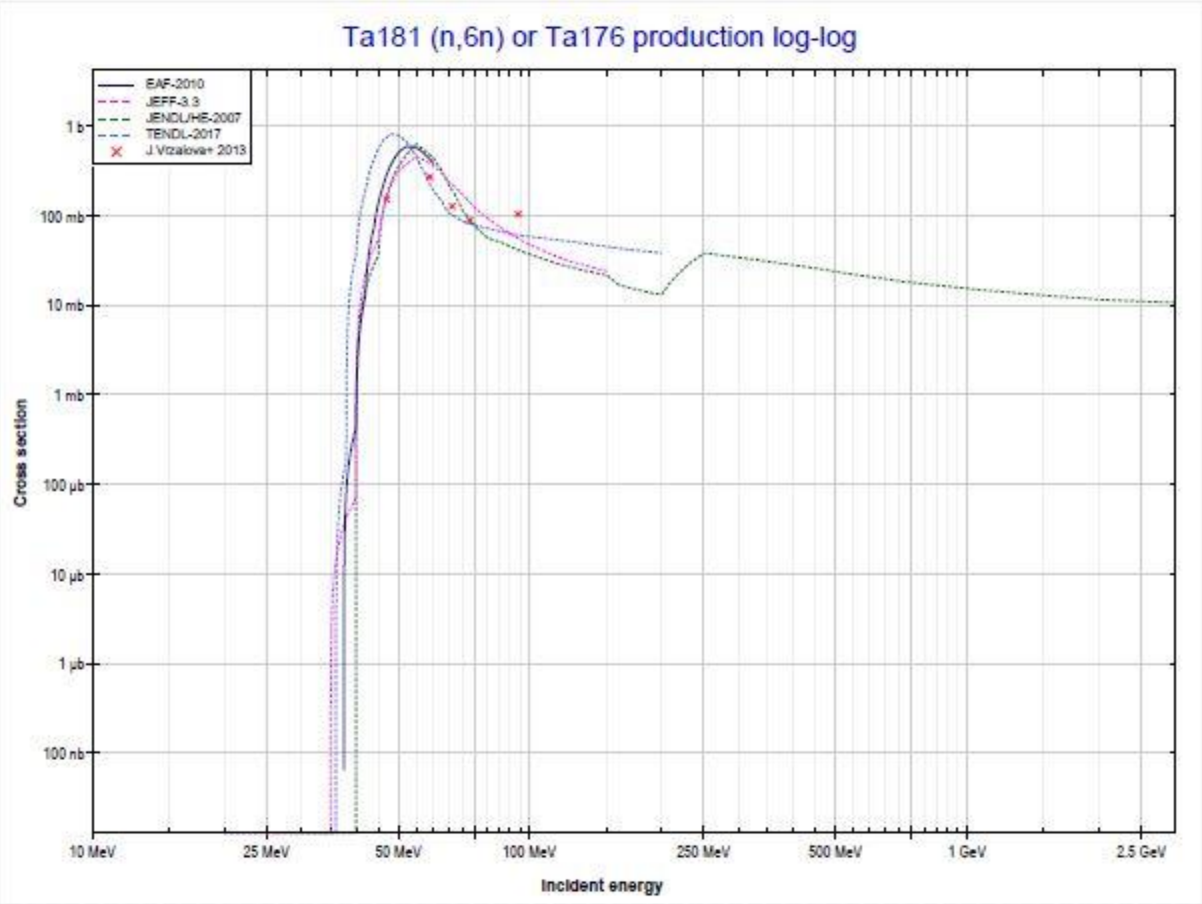
Data for ADSS

1. Target: Pb, Bi, Hg, Ta, W, U, Th
2. Coolant/target: LBE (everytime contains traces of Ag, Fe, Ni, Sn, Cd, Al, Cu, Zn) – crucial data: Po production yields
3. Structural materials: Al, Sn, Fe, Cr, Ni, Mo, Zr, V, Ta, W, O; beam window: Mo steels
4. Fuel U, Pu, Th, N, O, F, Cl
5. MA, FP
6. radiation damage and gas production !!

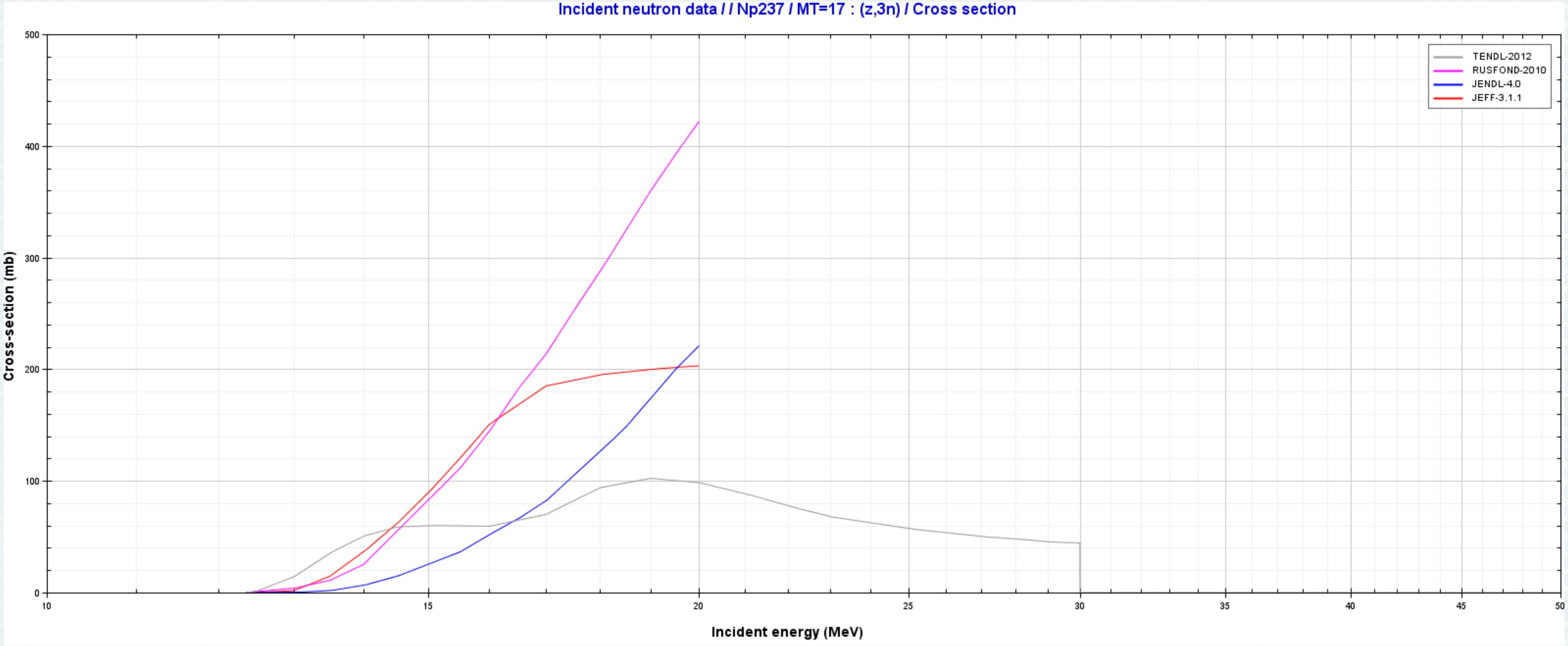
Carbon target ?



Tantalum target ?



Neptunium fuel ?



Indo-Czech cooperation

1. Based on programme on cooperation between Indian and Czech universities, we started to cooperate with MSU Baroda and UNIRAJ Jaipur
2. prof. Kumar, prof. Mukherjee, prof. Singh, dr.Tyagy

3. Utilization of AN-400 van de Graaf BHU Varanasi – deuteron+tritium 14.2 MeV (EPE2018)
4. TIFR Pelletron at BARC ^{7}Li+p, E_n<20 MeV (PhysRevC96-2017); FOTIA 6MV Tandem

Indo-Czech cooperation

1. AN-400 irradiation of structural materials (Zn-66, Zn-64, Mn-55, As-75, V-51, Ni-58)
2. TIFR irradiation:
   1. Heavy metal target materials (W-186, W-182)
   2. Special materials – lanhanoides (Gd-154, 160)
   3. Energies: E_n = 5.08; 8.96; 12.47; 16.63 MeV

3. However, TALYS/EMPIRE calculations were used to subtract low energy tail !!

US-Czech cooperation

1. Joint project of 4 Czech universities managed by BUT with Texas A&M University (called ADAR – Accelerator Driven Advanced Reactor)

2. Molten salt vs. LBE: Integral tests with standard sources (AmBe, PuBe, Cf)
3. „Radiation damage“ measurement (gas production)
4. „New“ detector techniques deployment (SiC, diamond, special scintillators...)

China-Czech cooperation

1. Project ChiCheTT2018 (ChinaCzech ThickTargets) – proposal to put together light and heavy material (C+Pb, B+Ta, Be+W,...)
    1. annular
    2. granular
2. Institute of Modern Physics Lanzhou – proposal of granular target for ADS

EU eastern partnership

1. Follow our previous cooperation started in JINR Dubna and with a support of EU use neutron sources available in participants' institutes

2. Ukraine – Uzhhorod National University (microtron, betatron – (γ,n) neutron sources up to 25 MeV)
3. Ukraine – Kharkov Institute of Physics and Technology („real“ ADSS – support of ANL, finished but not in operation, 100 MeV e^- + U, W)

EU eastern partnership

1. Armenia – Yerevan State University and Yerevan Physics Institute (75 MeV e^- LINAC with U, W, Be, D_2O)

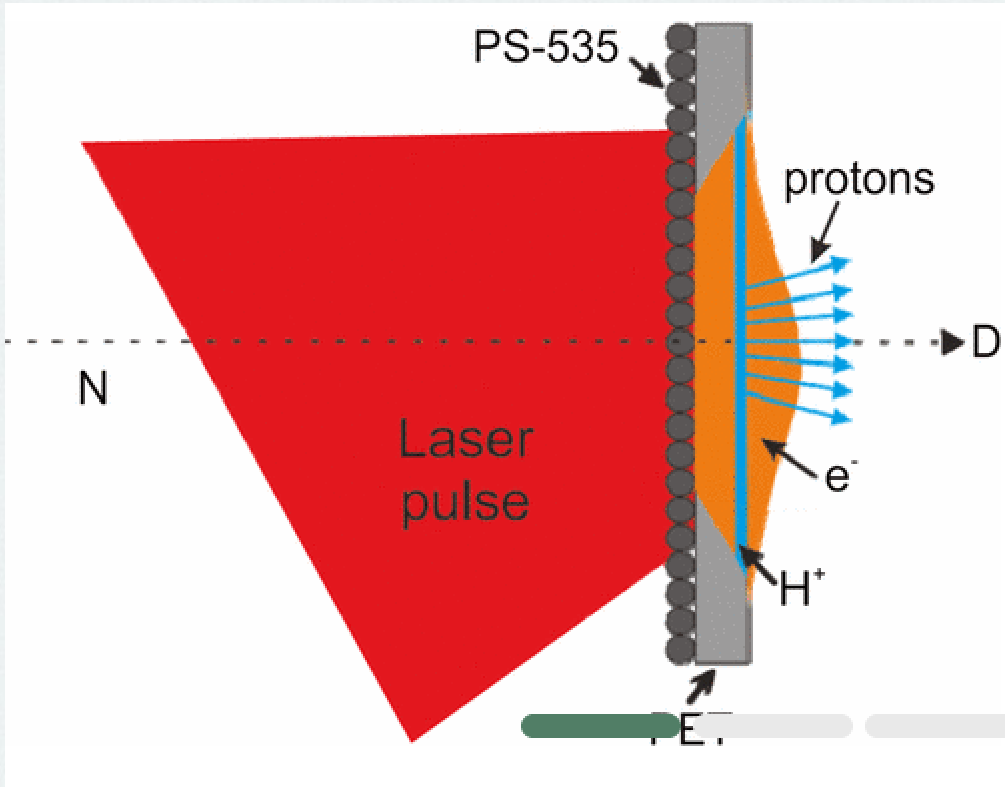
2. Vinca Institute of Nuclear Sciences, Serbia
3. Aristotele University Thessaloniki, Greece
4. Poland, Hungary, Slovakia, Belarus, Moldova, Bulgaria express their interest

F4HEL – Focuse on new light (Foils for High Energy Lasers)

The ELI project

1. ELI beamlines in Czech Republic
2. ELI NP in Romania
3. Acceleration of electrons, protons, ions using high power lasers
4. Conversion of protons to neutrons (Li, Be, C)
5. Laser driven neutron sources might be feasible, low cost, stable, and high intensity sources

Laser Driven Proton Acceleration



Laser-Driven Proton Acceleration Enhancement by Nanostructured Foils

D. Margarone, O. Klimo, I. J. Kim, J. Prokůpek, J. Limpouch, T. M. Jeong, T. Mocek, J. Pšikal, H. T. Kim, J. Proška, K. H Nam, L. Štolcová, I. W. Choi, S. K. Lee, J. H. Sung, T. J. Yu, and G. Korn

Phys. Rev. Lett. **109**, 234801 – Published 3 December 2012

Conclusion

1. Even though it looks, that ADSS are not in the focus of prominent research institutes, still there are small groups interested in the investigation
2. It have sense to acquire beam time on different QM neutron sources to get XS and yields data
3. It is important to further enhance alloy foil project (F4ADS) to have small detectors capable to determine fast neutron spectra anywhere
4. It is highly important to take interest in LDNS

thank you
for your attention

www.vut.cz