BRNO UNIVERSITY OF TECHNOLOGY
FACULTY OF ELECTRICAL ENGINEERING AND COMMUNICATION

Study of very fast neutron induced reaction cross-sections relevant to nuclear data needs for relativistic accelerator driven nuclear technologies

ADS-Accelerator Driven Systems: a Challenging mixture of Nuclear Physics and Nuclear Power Engineering for power production and spent fuel transmutation

Karel Katovsky

Nuclear Power Group
Department of Electrical Power Engineering
Brno University of Technology, Czech Republic
http://www.vutbr.cz

WHAT DOES SUCH TERRIBLE TITLE MEAN?

- Lawrence, Lewis (1946-1955)
- Semenov, Kurchatov
- Takahashi
- Tolstov, Vasylkov, Goldanski
- Barashenkov

- Bowman (Charles)

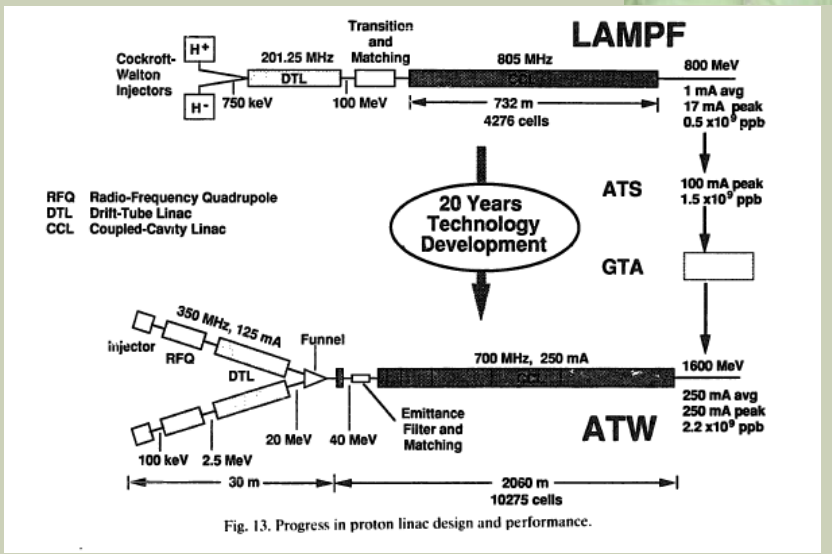
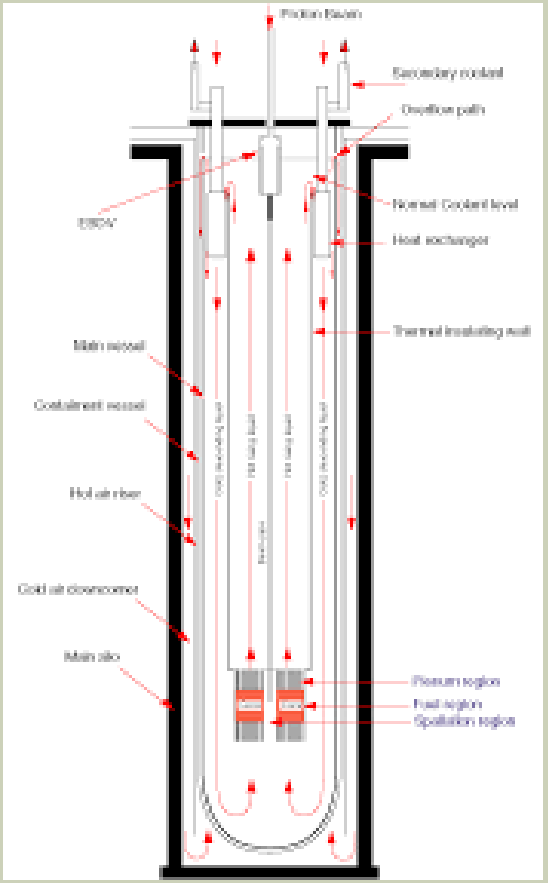


Fig. 13. Progress in proton linac design and performance.



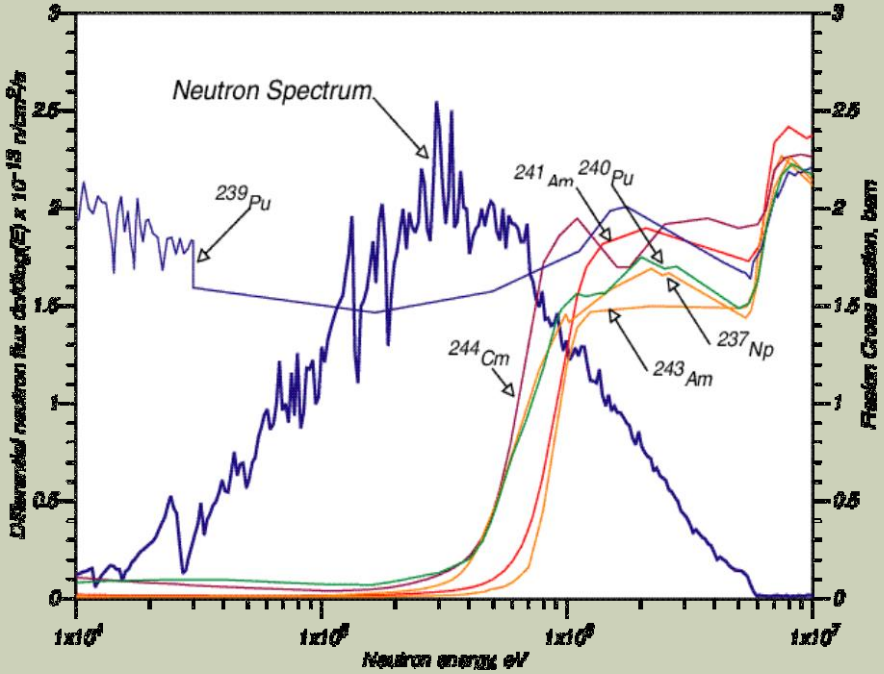
1992-1993 (Carlo) Rubbia

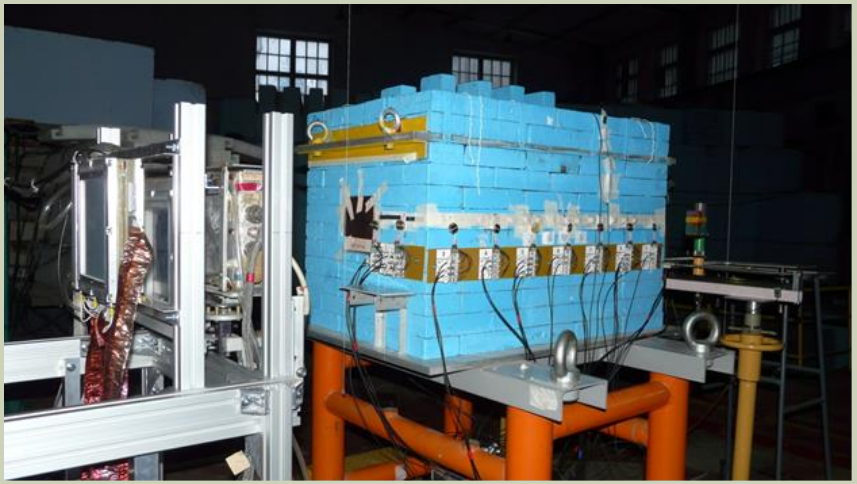
LASER DRIVEN SYSTEMS

- Gérard Mourou
- Nobel prize winner 2018
- The transmutation of radioactive waste by high-power lasers
- ELI centers
- Extreme light infrastructure

OUR RESEARCH

- Spallation neutron sources and Accelerator Driven Subcritical Systems



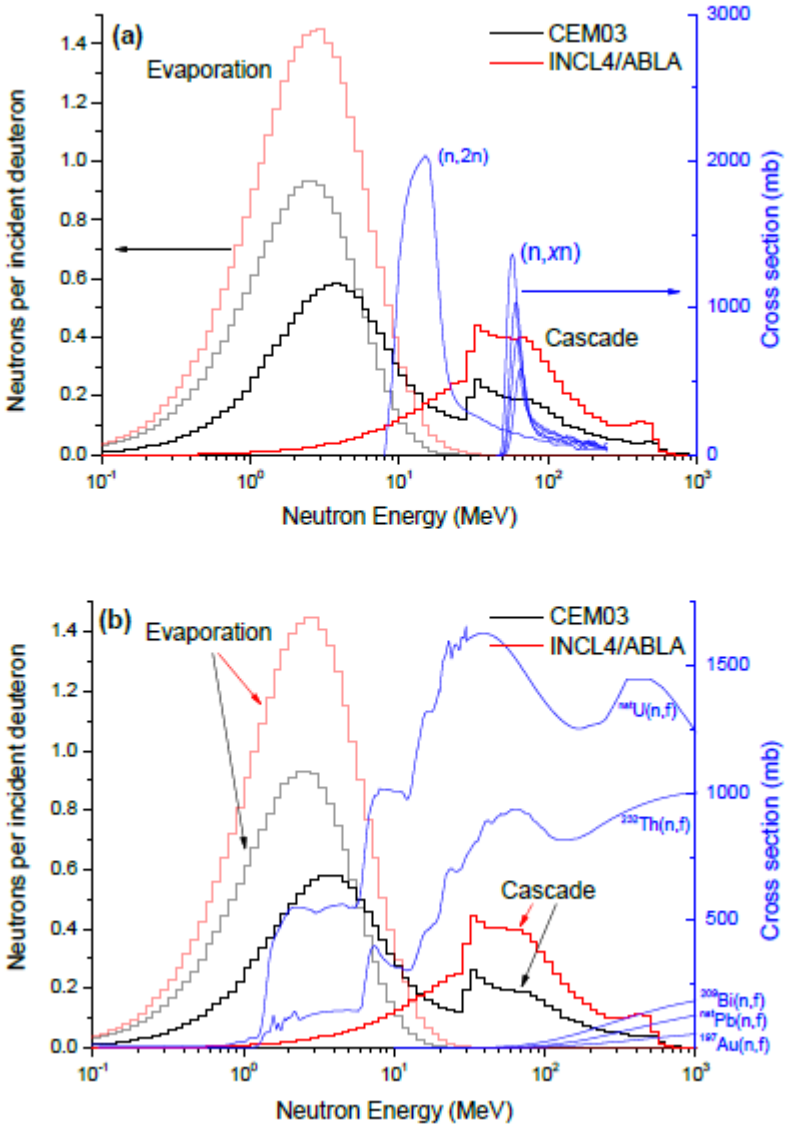


OUR RESEARCH

- $$n(E) = A_1 \cdot E^{1/2} \cdot e^{-\frac{E}{E_{T_1}}} + A_2 \cdot E \cdot e^{-\frac{E}{E_{T_2}}} + A_3 \cdot E \cdot e^{-\frac{E}{E_{T_3}}}$$

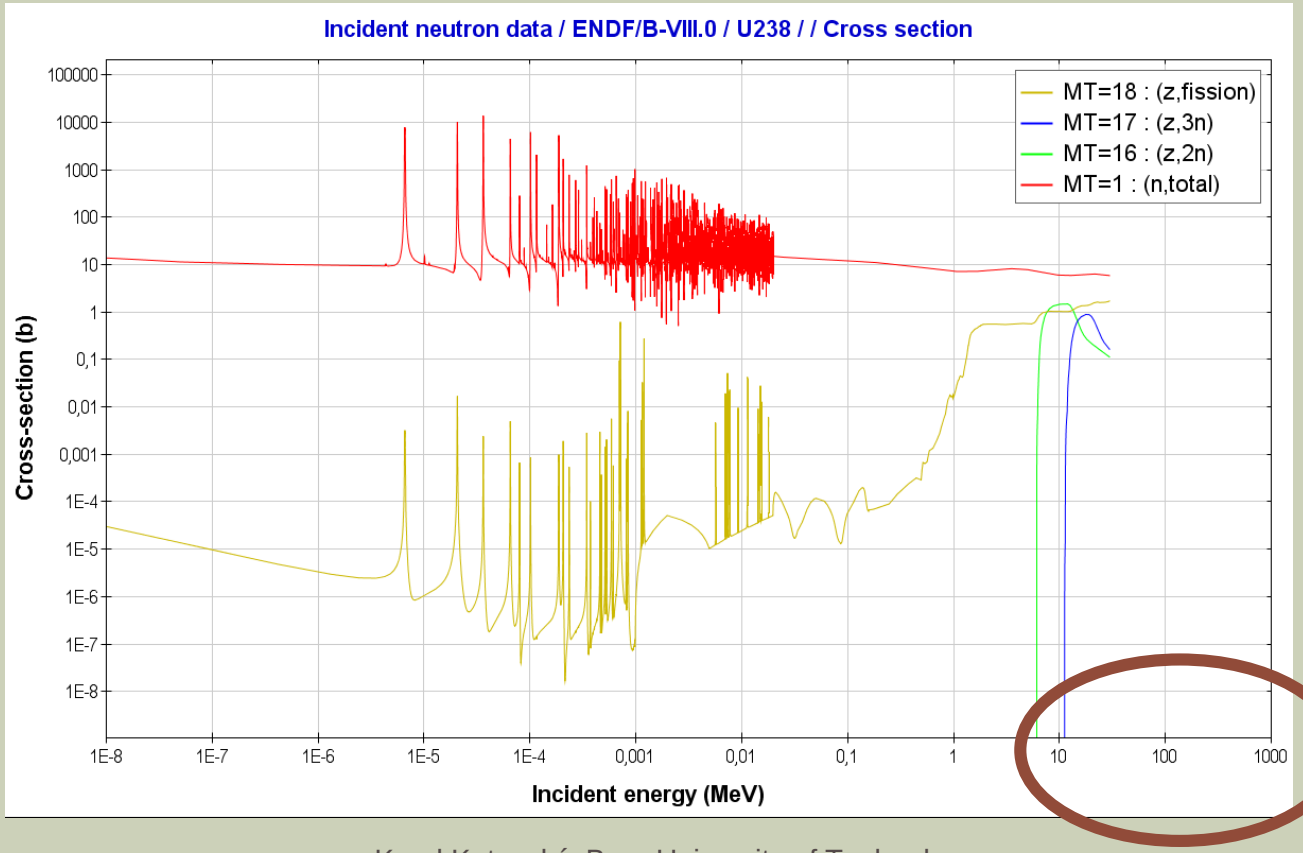
Miltifragmentation Evaporation, Fission Transient, Cascade (Simplified)

Models differ a lot



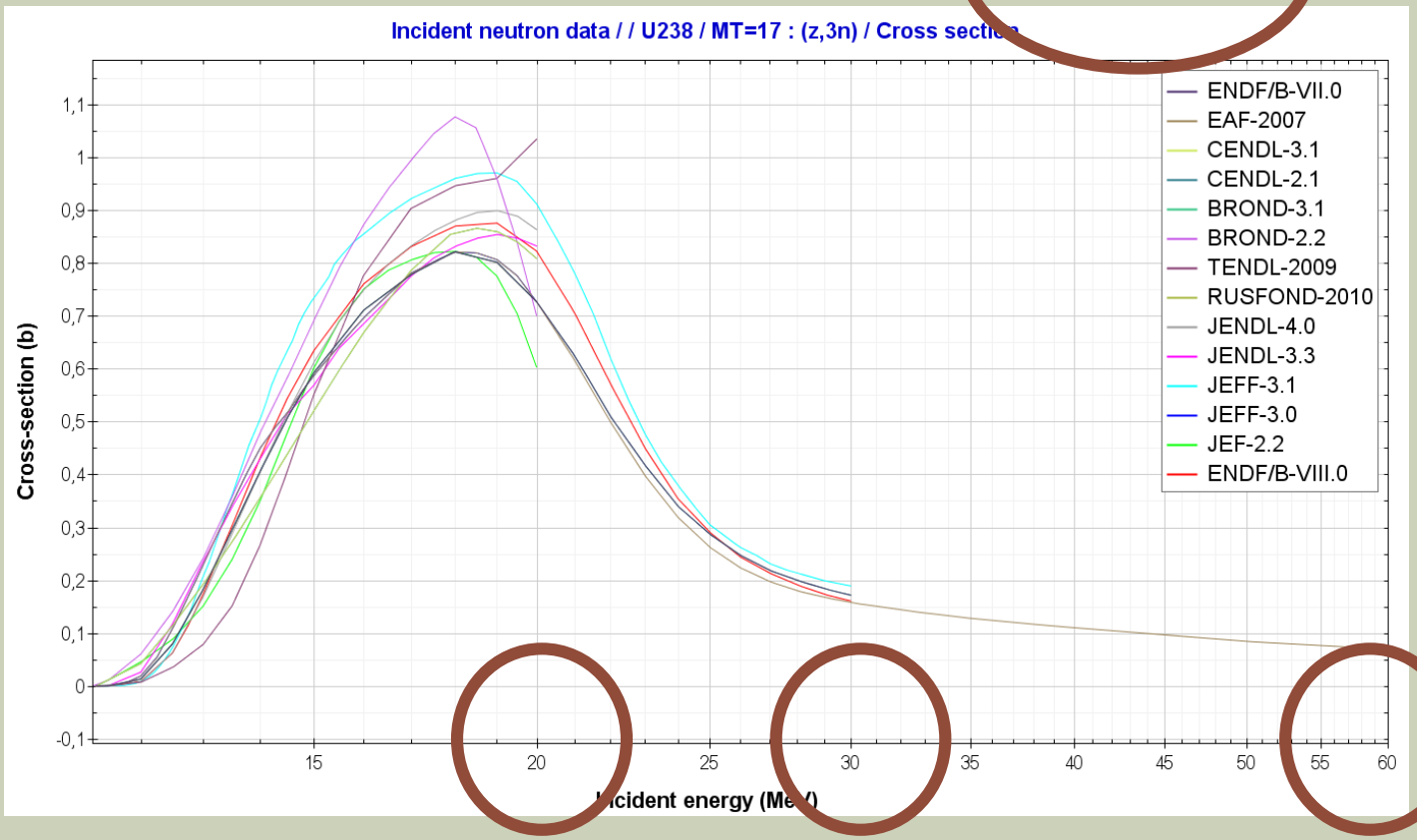
FISSION REACTOR

- Energy spectra up to about 10 MeV



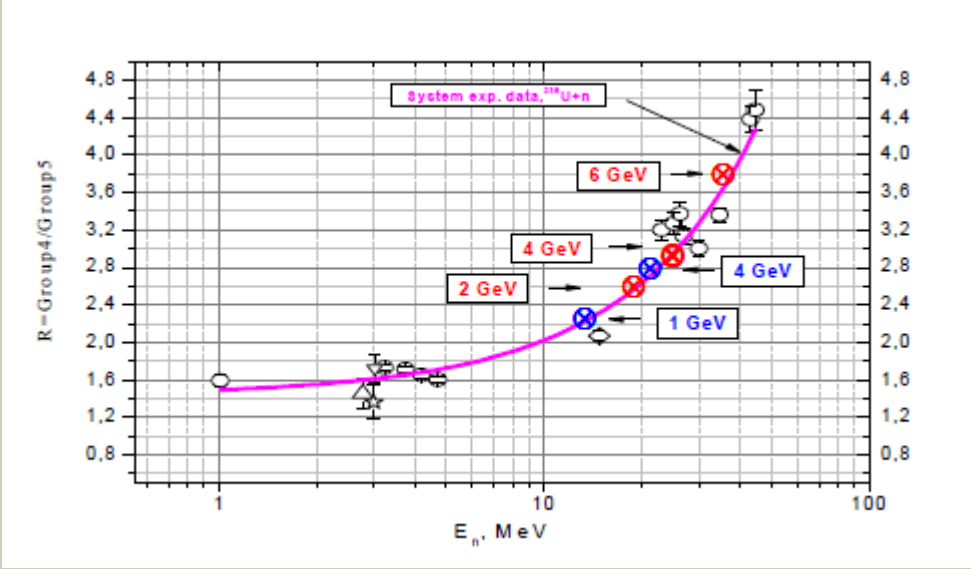
ACCELERATOR DRIVEN REACTOR

Accelerator driven reactor: spektrum
up to energy of primary beam (> 100 MeV)



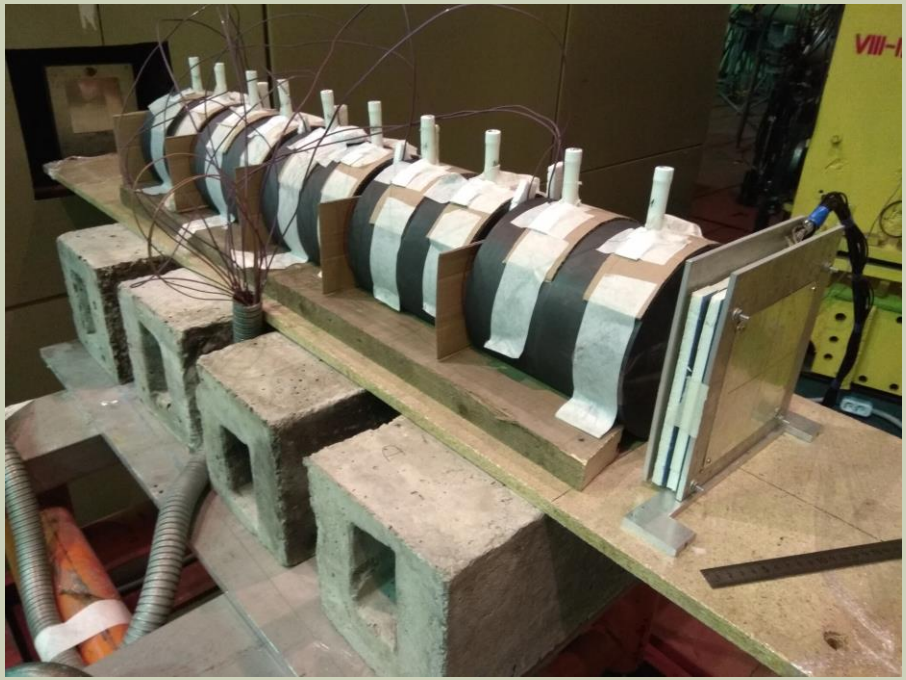
CHALLENGES AND WHITE SPOTS

- Also experiments differ a lot!
- Threshold detectors
- Missing cross-section data lead to high uncertainties and deconvolution is hard to be done
- Other techniques do not confirm results



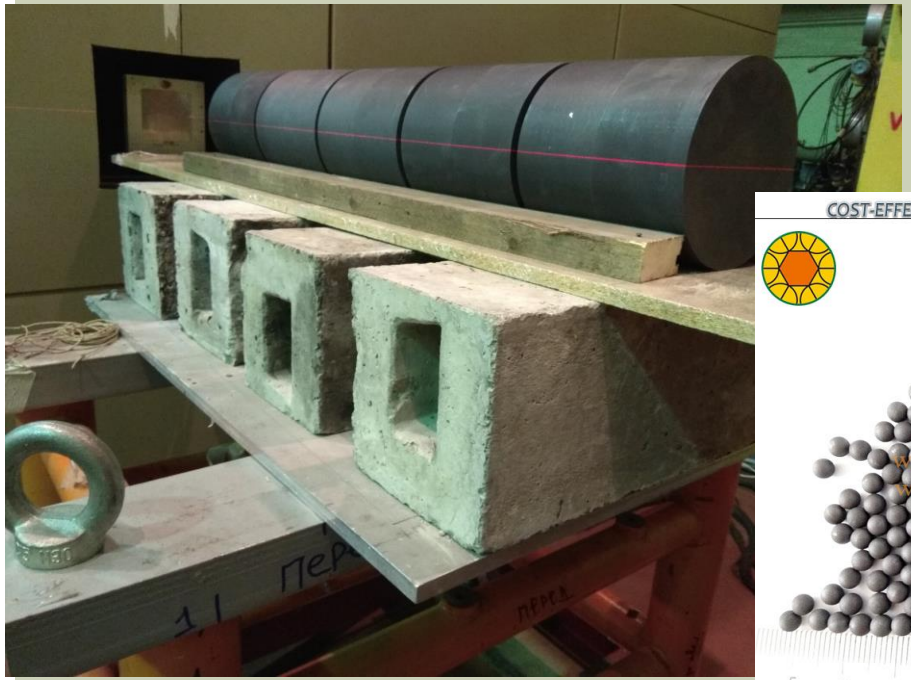
Furman et al., Proc.of Science, 2012

MASSIVE THICK TARGETS – LIGHT OR HEAVY…?



… COMPLEX MIXTURE OF BOTH! ANNULAR OR GRANULAR APPROACH

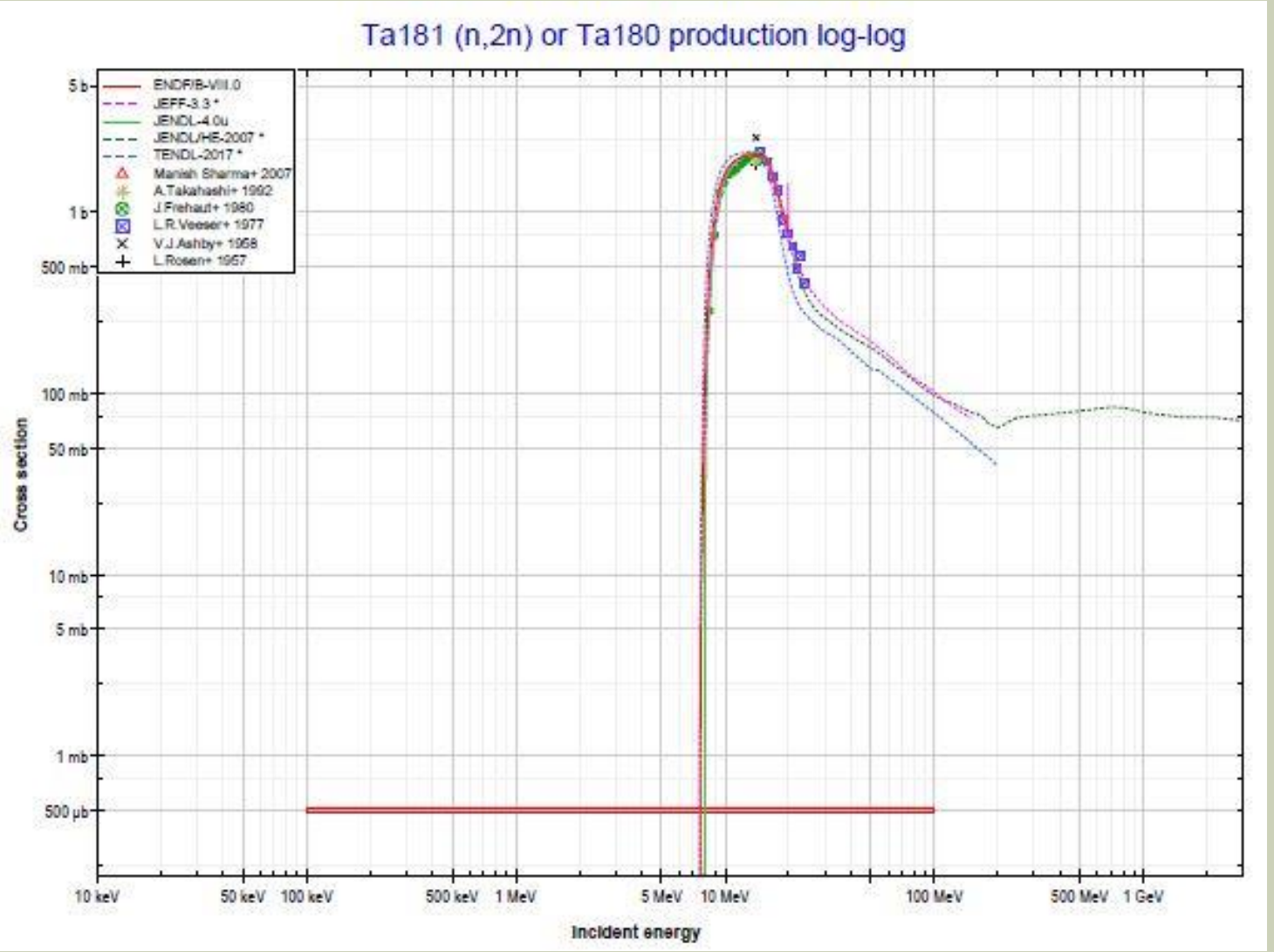
- Mixed cylinders of carbide and lead/tantalum
- Or compound like WC



- Mixed small balls of carbon, tungsten, or sintered WC, carbides of tantalum, lead, Bi, U

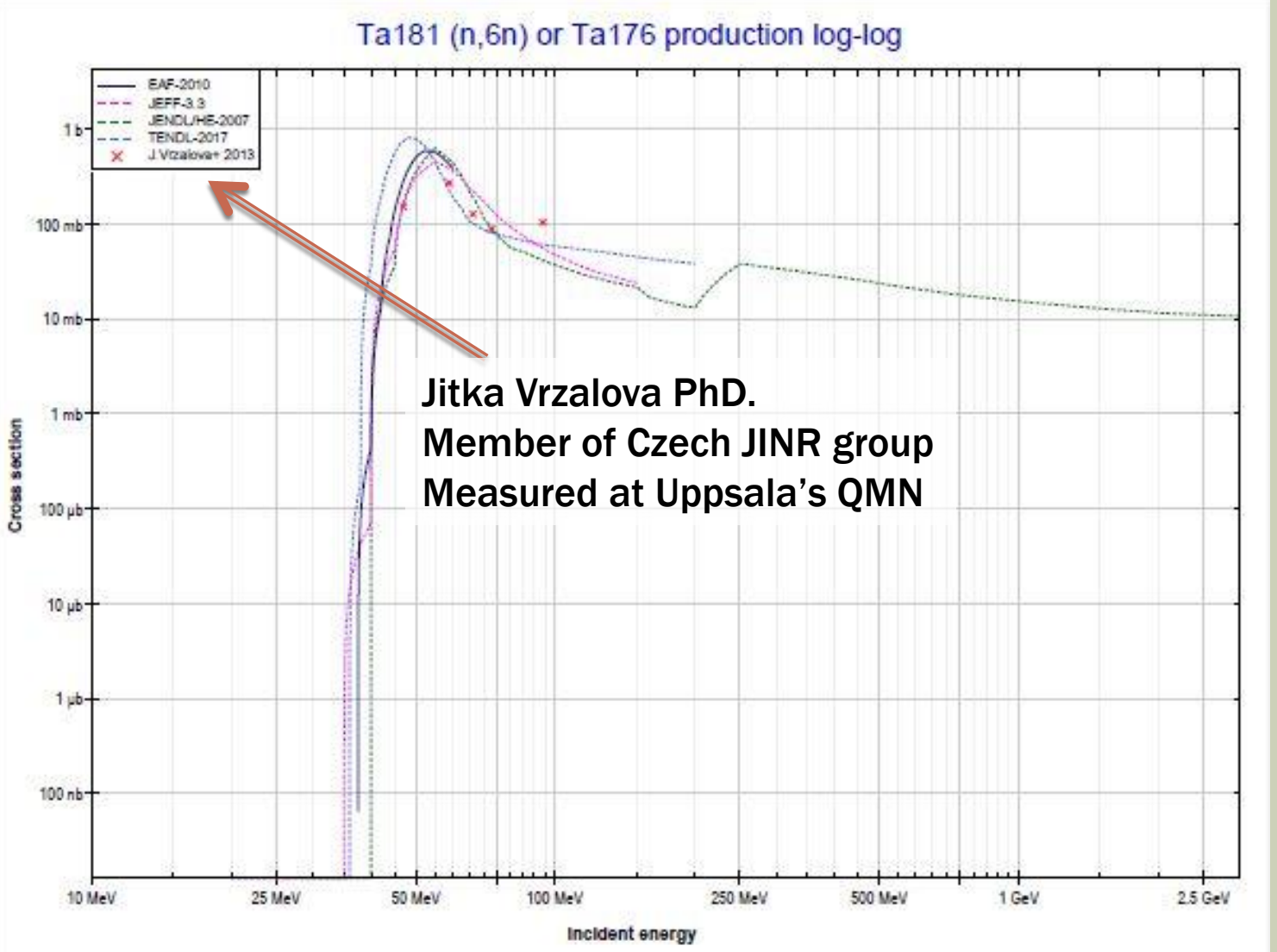
WHY PROPOSING EXPERIMENTS?

- Great! This cross-section looks very good!



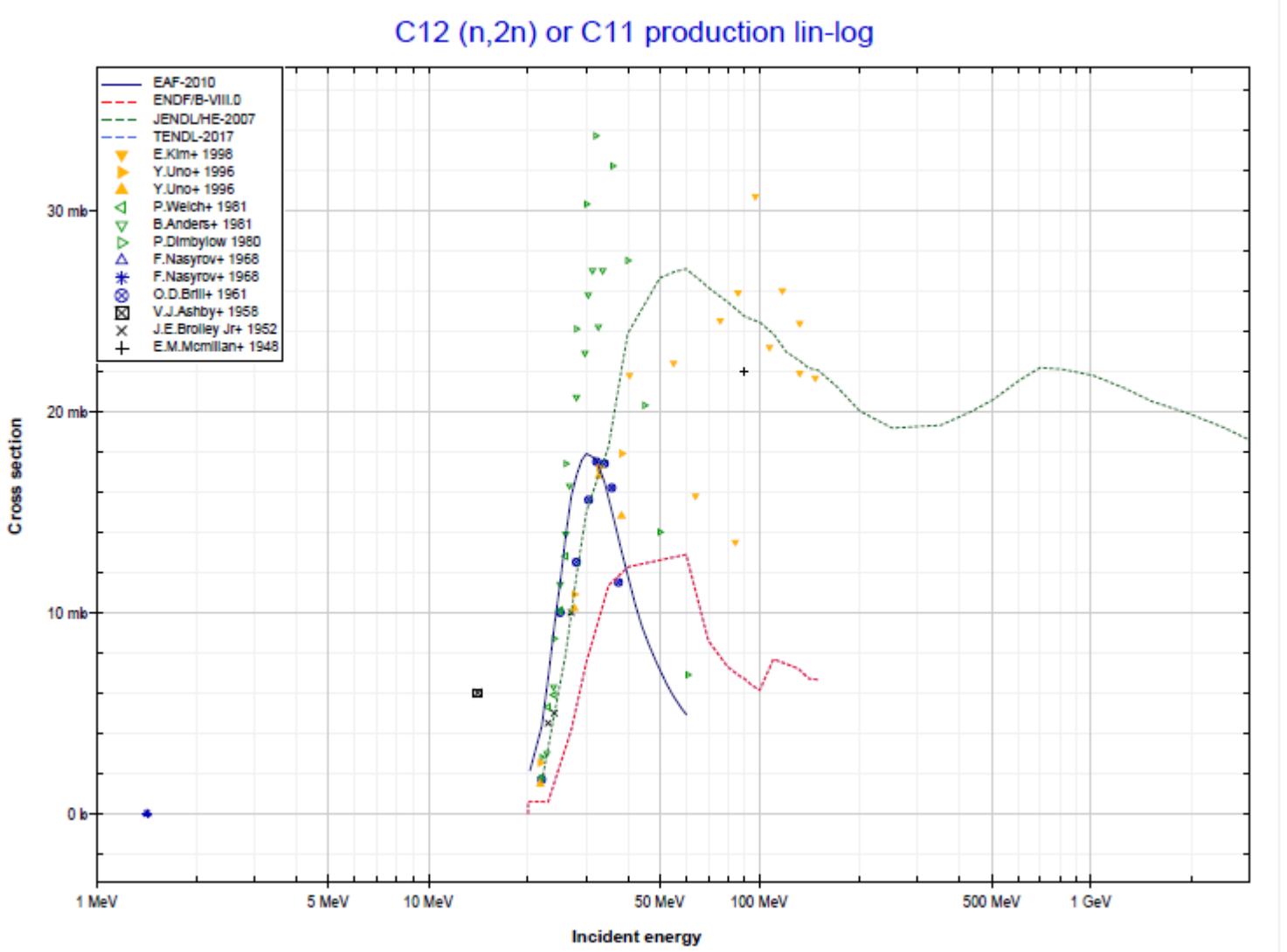
(N,6N); FISSION; MULTIFRAGMENTATION YIELDS

- This cross-section needs a little bit more efford…



CARBON (N,2N)

- Oooh! This cross-section data is awfull!



SECONDARY GOALS

- Dosimetry foil detector testing
- Widely known and used technique, for HE neutrons tricky but usable
- We are developing alloy – one foil rules them all
- Microdosimetry needed by medical accelerators and SNS

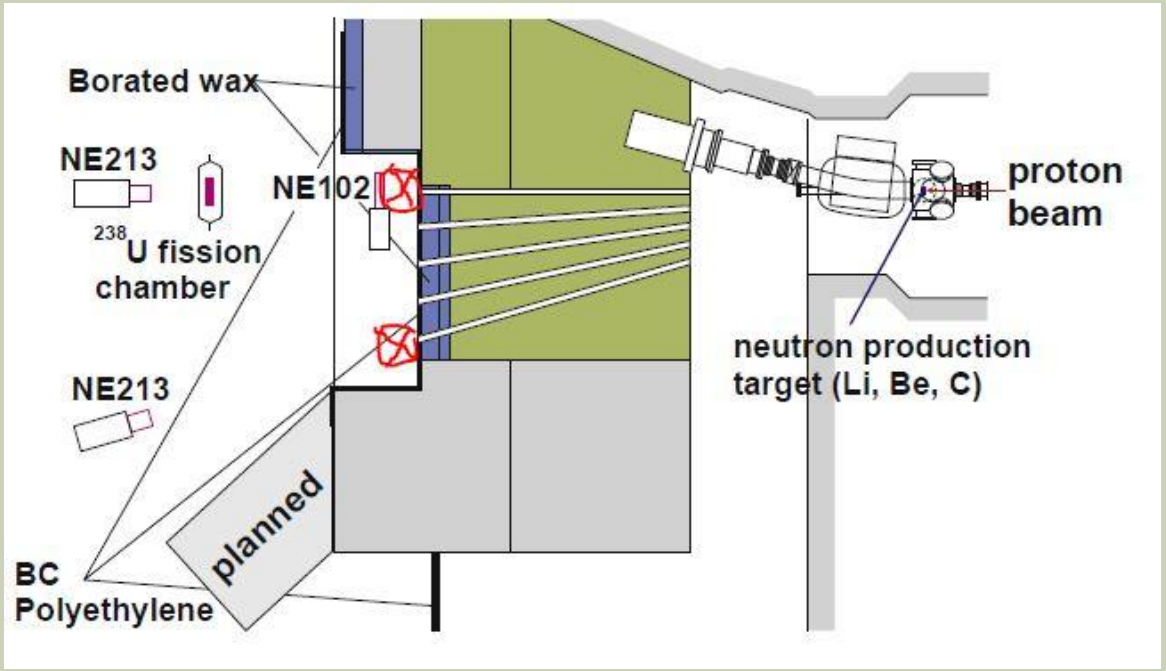
- We have portable rabbit system (60m long, time of sample movement is 3 s), which can be installed and used for short lived isotopes (including carbon)

- Background (in exp. hall) measurement using foils and filters (spectral indices)

FUTURE STEPS

- 3 to 20 MeV (quasi mono) neutrons given by TIFR&FOTIA Tandem&Pelletron facilities in Mumbai – **irradiation time already approved and done by our Indian friends without our in person participation due to covid (from 2019)**
- 20 to 37 MeV neutrons (quasi mono) facility CANAM in Řež – **irradiation time already approved and several experiments done**
- 37 to 200 MeV – applied and irradiation time approved in iThemba Labs. Experiments should be later this year (? – funding question).
- 200 to 400 MeV (quasi mono) RCNP Osaka (applied in 2018, but not successful)
- Proton cross-section to be measured ~~at Dubna~~ (90-660 MeV) [after February 24 not possible for our group]

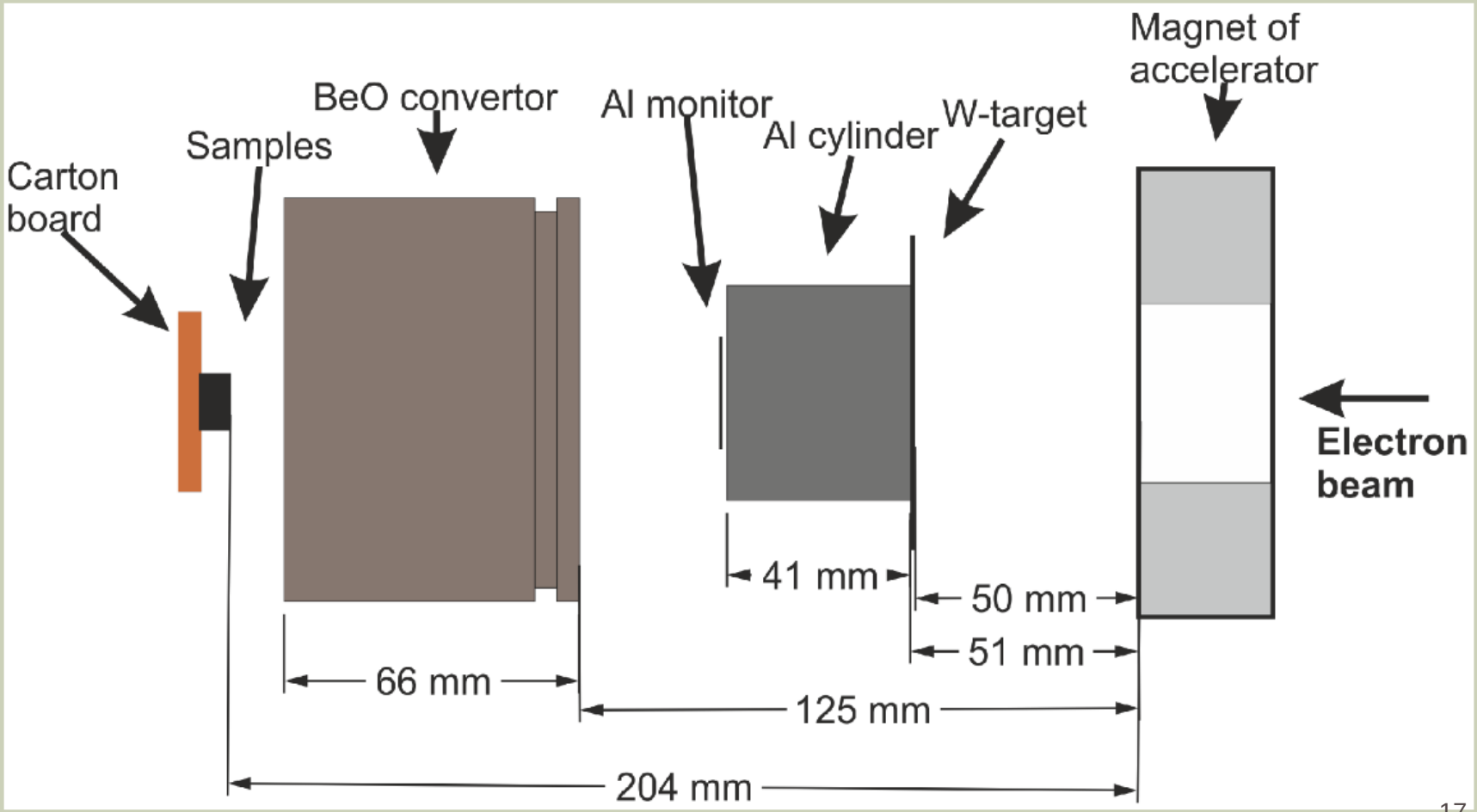
ARRANGEMENT IN ITHEMBA



- Four En proposed
  - 70 MeV
  - 90 MeV
  - 130 MeV
  - 180 MeV
- (^{nat}C, ^{nat}Ta, ^{182}W, ^{183}W, ^{186}W, ^{nat}W, ^{207}Pb, ^{nat}Pb, ^{209}Bi)
- Al, Cu, In, Th monitors
- Irradiation – 2x 14 hours /En
  (with close geometry 2x 6 h/En would be enough)
- Calculation using TALYS, EMPIRE, MCNP, PHITS, GEANT4, FLUKA

EXPERIMENTS WITH ELECTRON BEAMS

YerPhI, 70 MeV, 3 experiments, 2019



Courtesy of Elmira Melyan

YERPHI, 70 MEV, 3 EXPERIMENTS, 2019

- 6.6.2019 D2O convertor
- Begining of irradiation: 12:47
- End of irradiation: 15:50
- Average electron flux 1.91E12 e/s

time	I(μA)
12:47	0,33
13:30	0,23
14:00	0,34
14:30	0,30
15:00	0,31
15:50	0,32

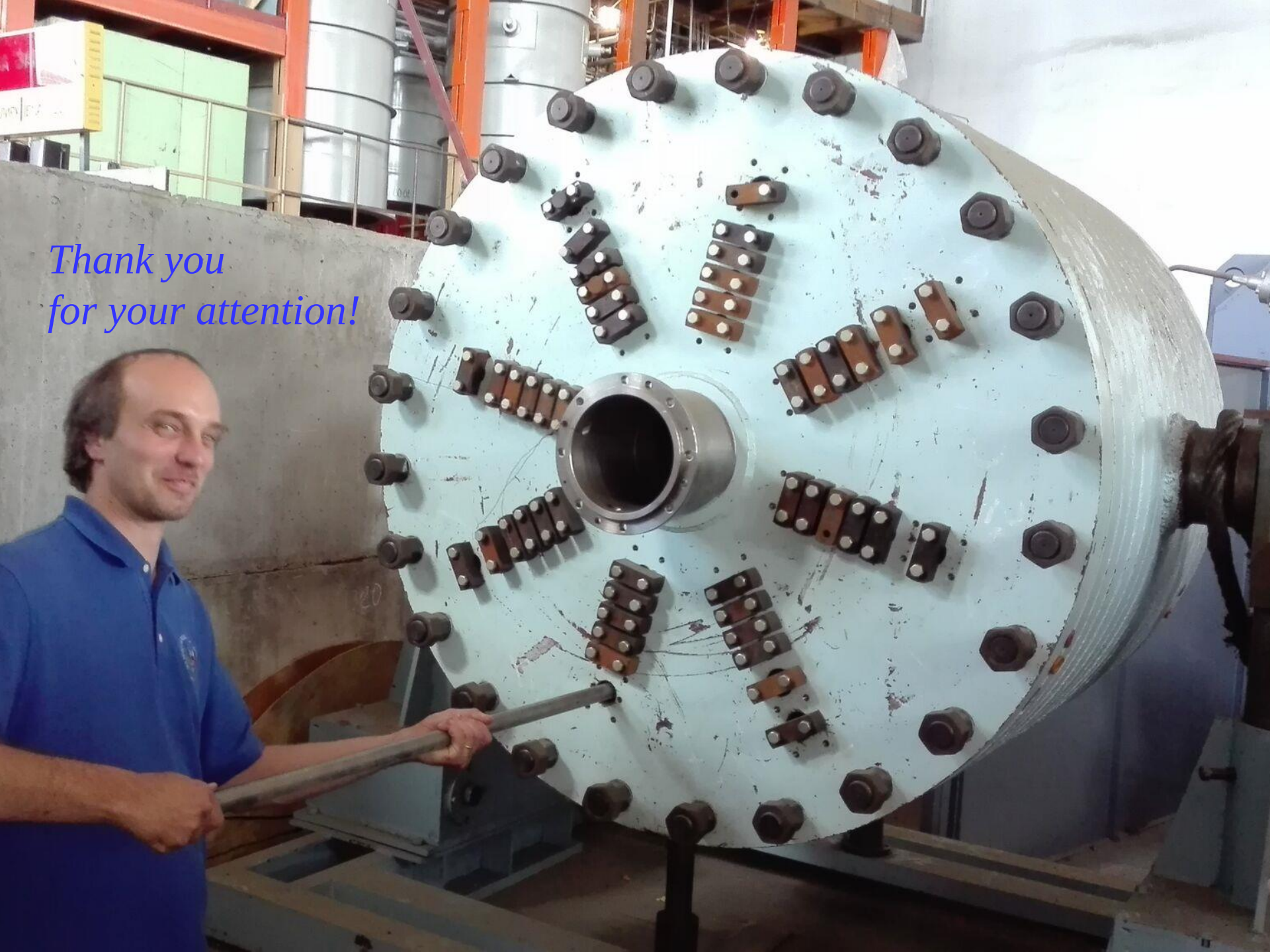
- Preliminary results: Experiment does not fit with simulation!

EXPERIMENTS WITH ELECTRON BEAMS

- Similar experiments have been done in
  - Prague (microtron up to 24 MeV)
  - Uzhhorod (2 microtrons up to 12/24 MeV, betatron up to 25 MeV)
  - And there was a plan to do it in Dubna on LEU200 and in Kharkiv on 100 MeV [impossible after February 24]
- We would like to continue in Yerevan – if possible

COOPERATION

- Yerevan State University a Yerevan Physics Institute, Jerevan, Armenia
- Texas A&M University, College Station, TX, USA
- University of Massachusetts, Lowell, MA, USA
- Uzhorod National University, Uzhhorod, Ukraine
- Majaraja Sayajiaro University of Baroda, Vadodara, Gudjarat, India
- Banaras Hindu University, Varanasi, Uttarpradesh, India
- Rajiv Gandhi University Itanagar, Arunačalpradéš, India
- Netaji Subhas University of Technology, Dwarka, Delhi, India
- Institute of Modern Physics, Chinese Academy of Sciences, Lanzhou, Gānsù, China
- KINGS - KEPCO International Nuclear Graduate School, Ulsan, Korea


Thank you
for your attention!

OUR SELECTED ACHIEVEMENTS

- Makwana, Singh, Katovsky, et al.: Measurements of the cross sections of the W-186(n,g), W-182(n,p), Gd-154(n,2n), and Gd-160(n,2n) reactions at neutron energies of 5 to 17 MeV, PhysRev C 96, 2017
- Stefanik, Katovsky, et al.: Experimental determination of neutron room background at the NPI cyclotron U-120M, Proc. of EPE 2012, Vol. 2, pp. 1275-1278, Brno, 2012
- Stefanik, Katovsky et al.: Neutron spectrum determination of d(20)+Be source reaction by the dosimetry foil method, Radiation Physics and Chemistry, Vol. 140, pp. 466-470, 2017.
- Singh et al.: Measurement of Mo-100(n,2n) reaction cross-sections using 10-20 MeV quasi-monoenergetic neutrons, EPE 2018, Brno 2018
- Balabekyan , Adam, Katovsky, et al., Symmetric and asymmetric fission modes in proton-induced fission at 660 MeV of 238U, Physics of Atomic Nuclei 73, (2010), pp. 1814-1819
- HOLOMB, HAYSAK, ZEMAN, KATOVSKÝ, et al.: Cross-Sections of Nuclear Isomers in the Interaction of Protons on Thin Thorium Target. IEP-2017 International Conference of young scientists and postgraduates, pp. 63-64. ISBN: 978-617-7344-37-6.