

# Khlopin Radium Institute ISTC projects for transmutation

#3486 “Experimental investigations of radioactive waste transmutation technology with electron-accelerator-driven neutron source (E-ADTT)”

#3567 “Synthesis and Investigation of Fullerene-Containing Carbon Matrices for Transmutation of Iodine-129”

## ISTC Project #3486

“Experimental investigations of radioactive waste transmutation technology with electron-accelerator-driven neutron source (E-ADTT)”

- Status – Approved without funding (3)
- Came to ISTC in March 2006
- Collaborators:
  - K.L.Peddicord, Texas A&M University, USA
  - W.Trzaska, University of Jyväskylä, Finland
- Duration: 30 months
- Estimated total cost of the project (US \$) 324000

## It is proposed in the given project:

- Construction of **neutron source** based on **photonuclear reactions** in different targets with compact electron driver of V.G.Khlopin Radium Institute (microtron MT-25, beam energy and current up to 25 MeV and 50 microampere, correspondingly)
- It supplies beam power up to 1,25 kWt which is sufficient for R&D works. Our estimations: intensity of secondary neutron beam may reach  $10^{11}$ - $10^{12}$  neutrons/sec.

Development and optimization (in experiments and calculations) of **neutron-generating targets** using

**deuteron breakup** reaction – heavy water targets with beryllium, carbon or lead reflectors;

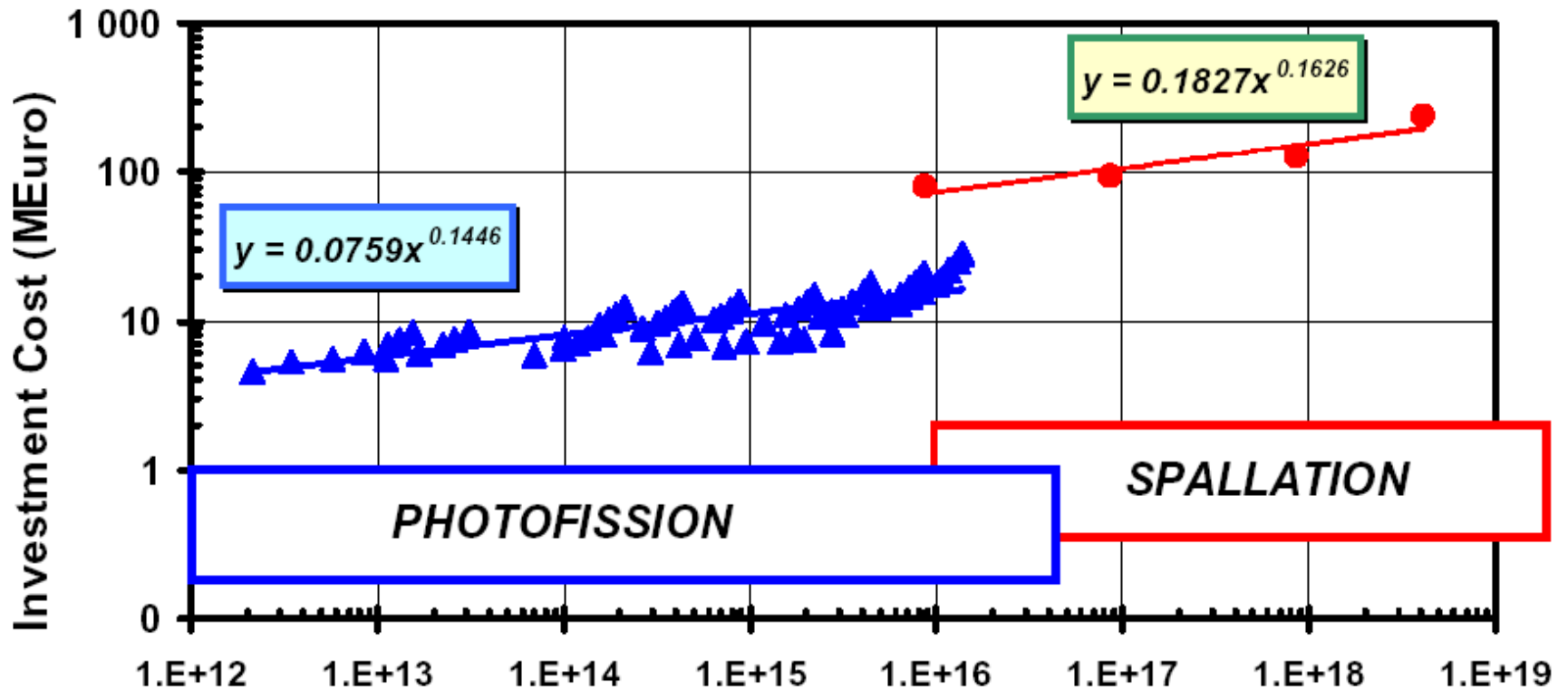
**( $\gamma,n$ )** reactions with metal targets (Ta, W, Ti) with beryllium, carbon, lead or heavy water reflectors.

- Investigation of radiation resistance of matrices doped with actinides of high concentrations, their activation and transmutation rates of minor actinides in different neutron spectra and bremsstrahlung radiation field
- Investigation of transient processes arising in matrices irradiated by neutrons of different spectra or bremsstrahlung photons;

# Advantages of electron driver in the comparison with the proton or deuteron machines at least at R&D stage

- compactness and reliability of main systems of electron accelerators,
- significantly higher level of radiation safety at operations with electrons in comparison with proton or deuteron beams,
- significantly lower cost of high intensity electron accelerators construction and operations,
- possibility of extended interaction of electron bremsstrahlung beam with nuclei in the target volume to increase the useful (for neutron generation) target volume and remit questions of heat load on the target.

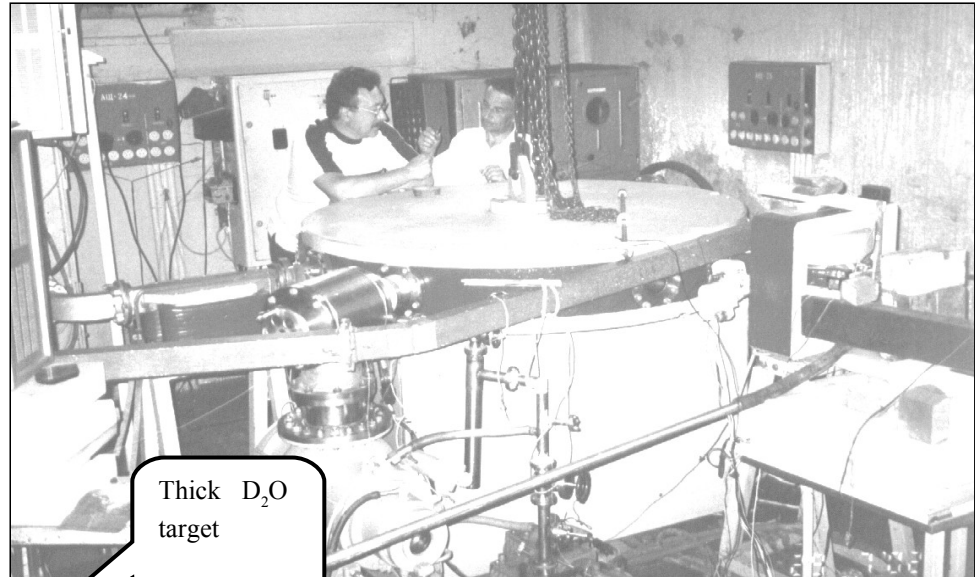
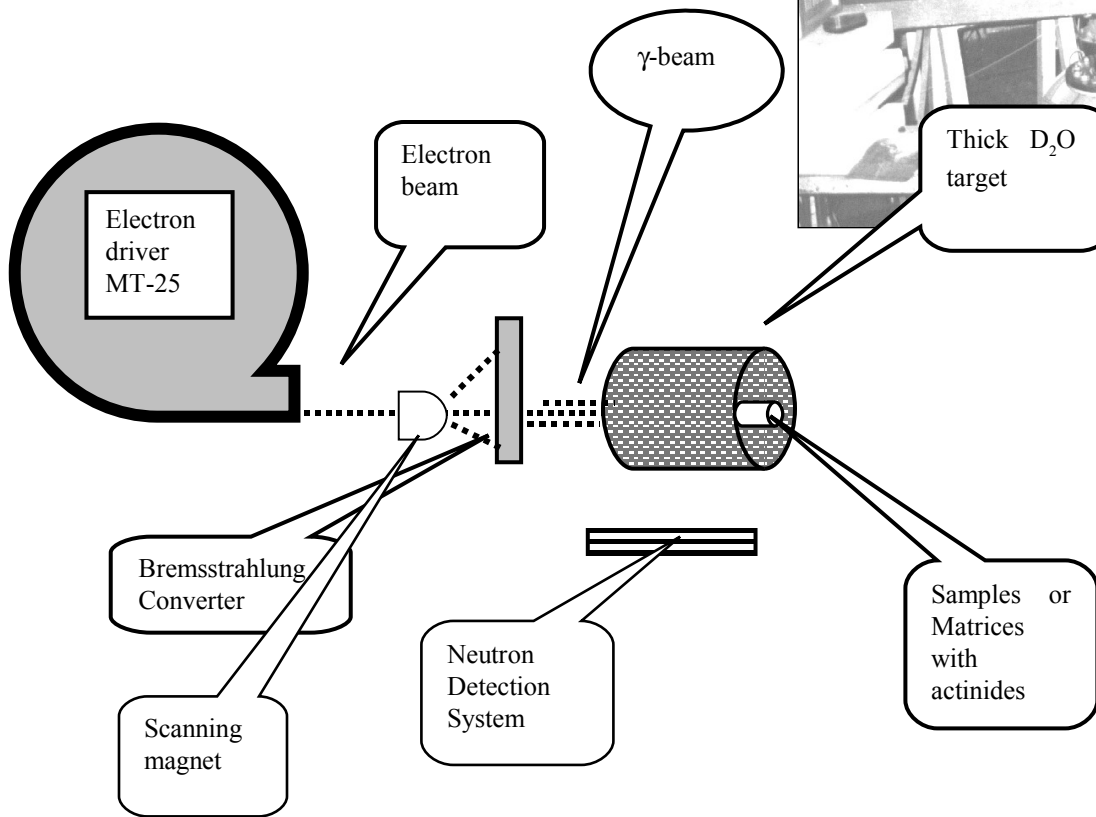
# Neutron cost



# Ceramics (matrices) for waste immobilization and transmutation

- Multi-purpose ceramics for waste immobilization which are stable in the neutron fields and based on solid solutions of actinides in the cubic zircon dioxide and garnet.
- It is at present necessary:
- to choose most optimal composition of zircon ceramics for transmutation and following storage of given types of radioactive waste,
- to study radiation effects on ceramics in neutron and  $\alpha$ -particle fields
- to simulate the transmutation processes of actinides for matrices of different chemical composition.

# Electron driver MT-25 (microtron) of V.G.Khlopin Radium Institute



**Scheme of neutron facility**

# We have

- All necessary licensing
- Microtron
- Experimental hall with shielding
- $\gamma$ - and neutron spectrometry
- Experience of work with accelerators and targets
- Components for manufacturing of neutron-generating targets and MA-doped matrixes
- Necessary theoretical support, transport and nuclear data codes

# We plan

- Tuning of microtron
- Design and manufacturing of targets
- Development of detector systems
  
- Manufacturing of ceramics-targets doped by minor actinides (MA-targets);
  
- Irradiation of MA-targets by neutrons of different sources;
- Irradiation of MA-targets by bremsstrahlung photons;
  
- Measurement of radiation effects in MA-targets;
  
- Measurement of actinide transmutation rates in MA-targets
  
- Theoretical simulations

# Targets

- $(\gamma, n)$  targets (Ta, W)
  - Heavy water target
- } neutron-generating
- Ceramics doped by minor actinides

# D<sub>2</sub>O target

- Low activation
- More harden spectra of neutrons

# Neutron spectra

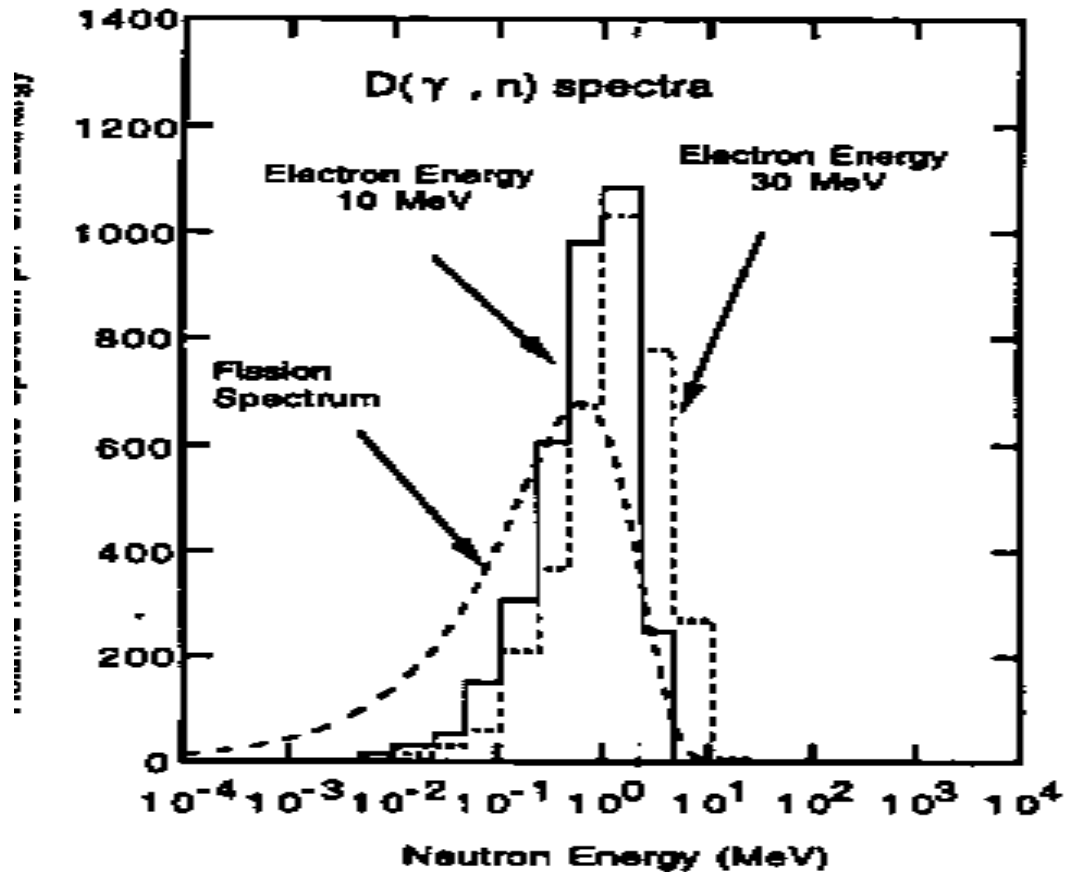
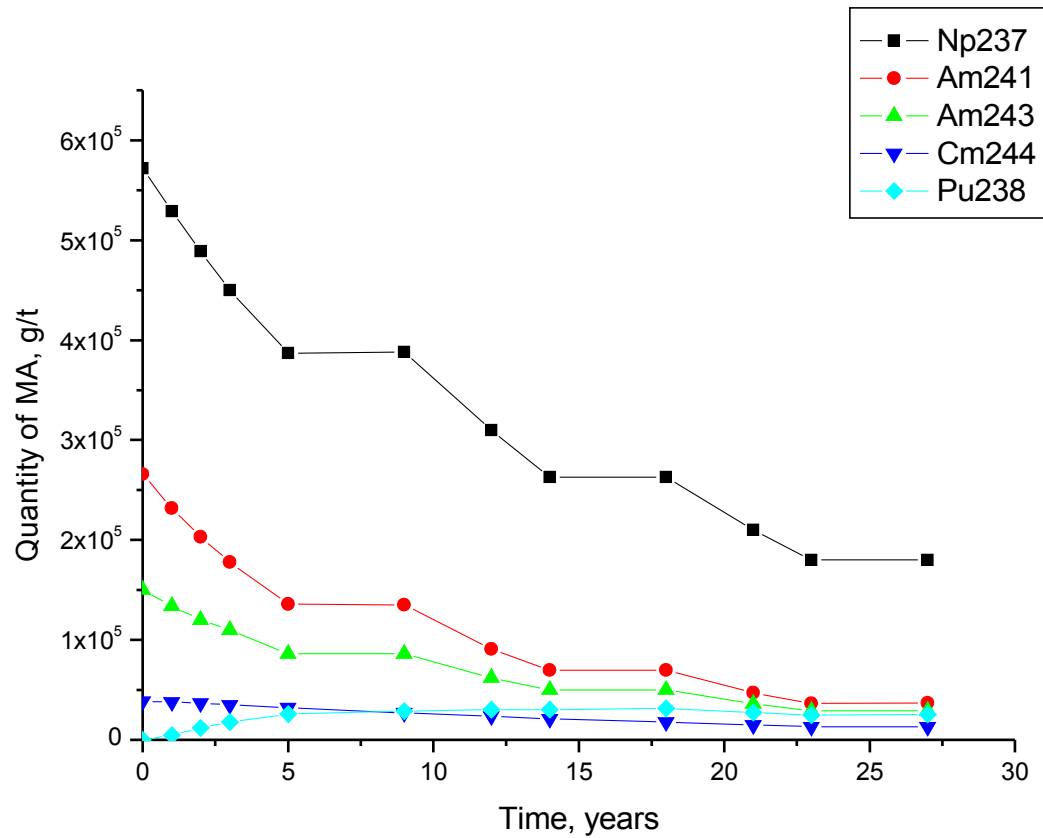
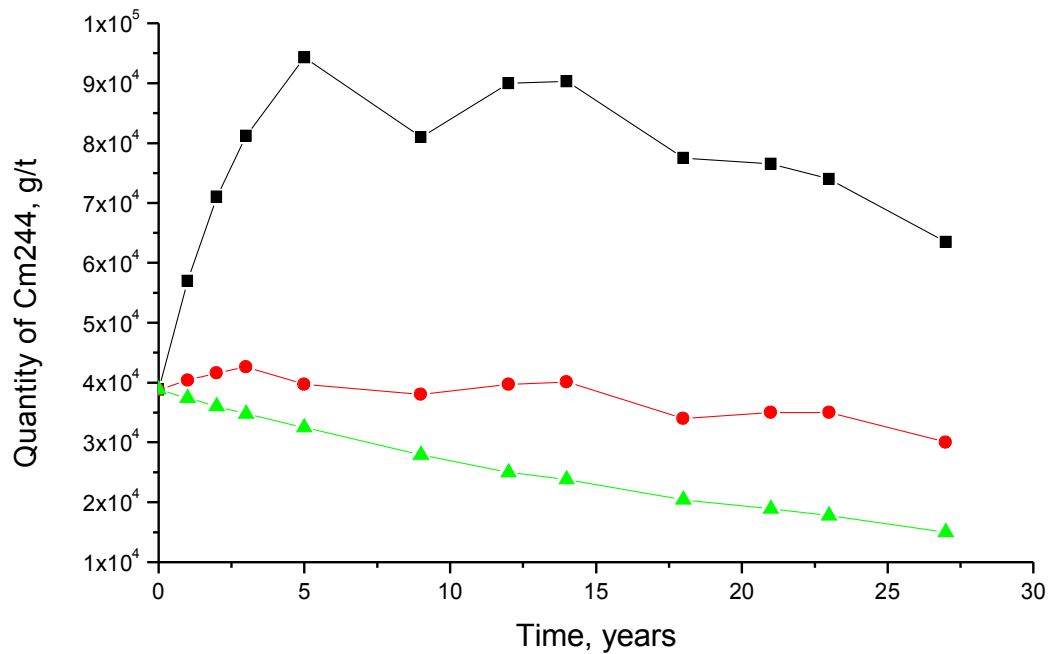


Fig. 5. Calculated photoneutron spectra (before slow-down) and the fission spectrum (Maxwell distribution).



Irradiation of MA mixture with neutrons from the D<sub>2</sub>O target. Flux 10E+15, energy spectrum calculated by S.Yavshits et. al.



Comparison of Cm244 yields in irradiations of Np, Am and Cm mixture in PWRU, LMFBR and D<sub>2</sub>O neutron fields. Neutron flux is 10E+14 n/cm<sup>2</sup>sec for PWR and D<sub>2</sub>O and 10E+15 in LMFBR.

# In D<sub>2</sub>O target

- Low production of <sup>238</sup>Pu
- Possibility of Cm isotopes transmutation

- In short
- Development of flexible neutron and  $\gamma$ -sources
- Measurements of different aspects of MA transmutation in the real immobilization matrices for different neutron and  $\gamma$ -fields

# #3567 “Synthesis and Investigation of Fullerene-Containing Carbon Matrices for Transmutation of Iodine-129

- Status: Submitted to Parties for Board Decision
- Manager: Dr.Burakov
- Collaborators:
  - Battelle Energy Alliance LLC (BEA) / Idaho National Laboratory
  - University of Sheffield / Department of Engineering Materials / Immobilisation Science Laboratory
- Duration: 36 months
- Estimated total cost of the project (US \$) 300 000

# Project goals

Main goal:

- investigation of iodine-129 transmutation process using fullerene-containing carbon material (FCC) simultaneously as iodine host-matrix and transmutation target.
- Samples of FCC doped with different amount of iodine: initial and irradiated by neutrons in research nuclear reactor WWR-M will be studied.

- An additional goal of the Project is calculation of optimal conditions of  $^{129}\text{I}$  transmutation and evaluation of its economical sensibility for existing types of nuclear reactors.

# Motivation

- There are no so far ecologically acceptable methods of  $^{129}\text{I}$  immobilization
- prospective carbon material FCC has been recently developed at Laboratory of Applied Mineralogy and Radiogeochemistry of the V. G. Khlopin Radium Institute. It can be used not only for iodine absorption but also as a host matrix of transmutation target, which then becomes a final waste form after  $^{129}\text{I}$  transmutation.

- main advantage of FCC in comparison with other absorbents is its ability to keep absorbed iodine during physical-chemical conversion of FCC into other forms, for instance, during hot pressing.
- additional advantage of FCC, which, however, requires further investigation, is its “transparency” for xenon forming as a decay product during  $^{129}\text{I}$  transmutation. This feature of FCC allows avoiding essential absorption of neutrons in FCC matrix and matrix swelling under irradiation (as a result, destruction of nuclear fuel rods). In general, initial

- In the framework of ISTC Project the principal features of FCC under various conditions of neutron fluxes will be studied in details. The results obtained will be used for calculation of optimal conditions of  $^{129}\text{I}$  transmutation and evaluation of economical sensibility of iodine transmutation at modern nuclear reactors.