Accurate Reactivity Feedback Calculations for TRIGA Cores

M.Badea, C.H.M.Broeders, R.Dagan, A.Travleev

Forschungszentrum Karlsruhe
Institut für Reaktorsicherheit

P.O.Box 3640, D-76201 Karlsruhe, Germany

Topics

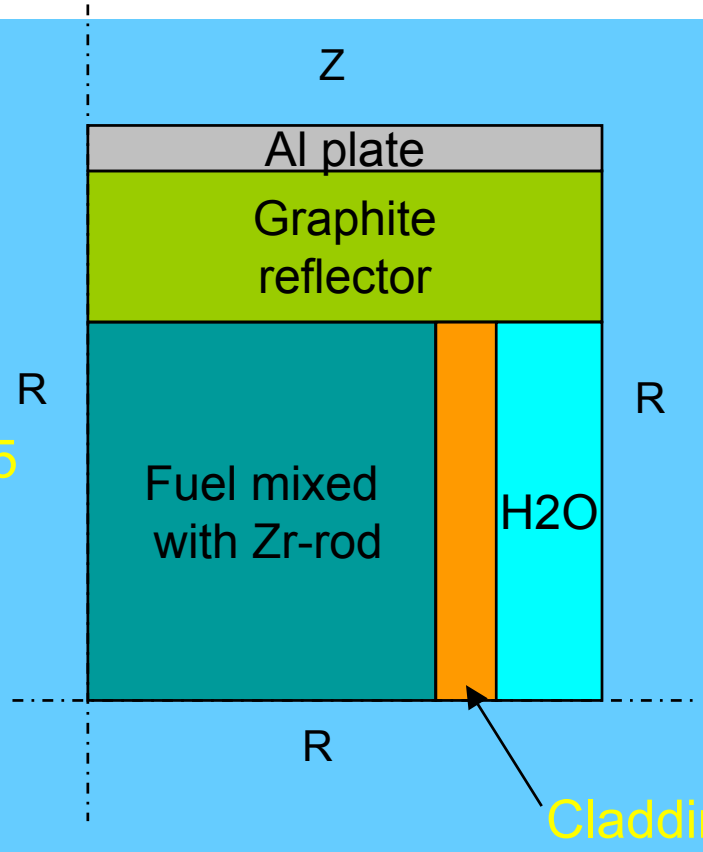
- **Introduction**
- **Accurate generating new thermal data for hydrogen bound in zirconium hydride**
- **Calculation methods and results**

Introduction

- The TRADE project utilises existing TRIGA reactor RC - 1 Cassacia in Italy;
- The experimental program of TRADE needs detailed information about the temperature feedback effects (also at higher temperature range between 80 – 120° C);
- The prompt fuel temperature dependent reactivity feedbacks contain 2 components :
  * the resonance broadening in the fuel (Doppler effect);
  * the upwards flux spectral shift due to enhanced temperature of the bound hydrogen in the fuel (scattering effect).

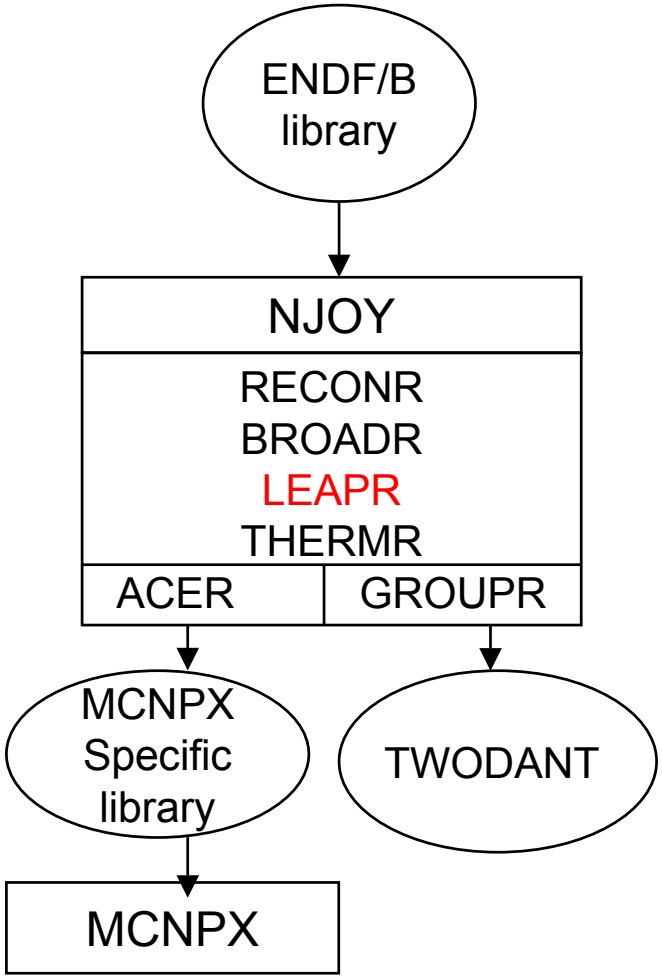
TRIGA fuel assembly model

* Fuel elements are cylinders of ternary alloy uranium-zirconium hydride with H-Zr ratio 1.7 and 20% enriched U -235
* Fuel cladding – stainless steel AISI 304
* Two graphite cylinders at the top and the bottom of the fuel rod



R – reflective boundary condition
Z – zero flux boundary condition

Cross section and scattering kernels generating



LEAPR module:

-a central force lattice dynamics model

-generate thermal neutron scattering data (conservation of momentum and energy transfer-"sum rule")

-standard temperature input deck →

dense temperature grid with 10 K intervals

THERMR module:

-additional refinements for hydrogen scattering (instead of standard 59 energy points to use more (83 energy points)

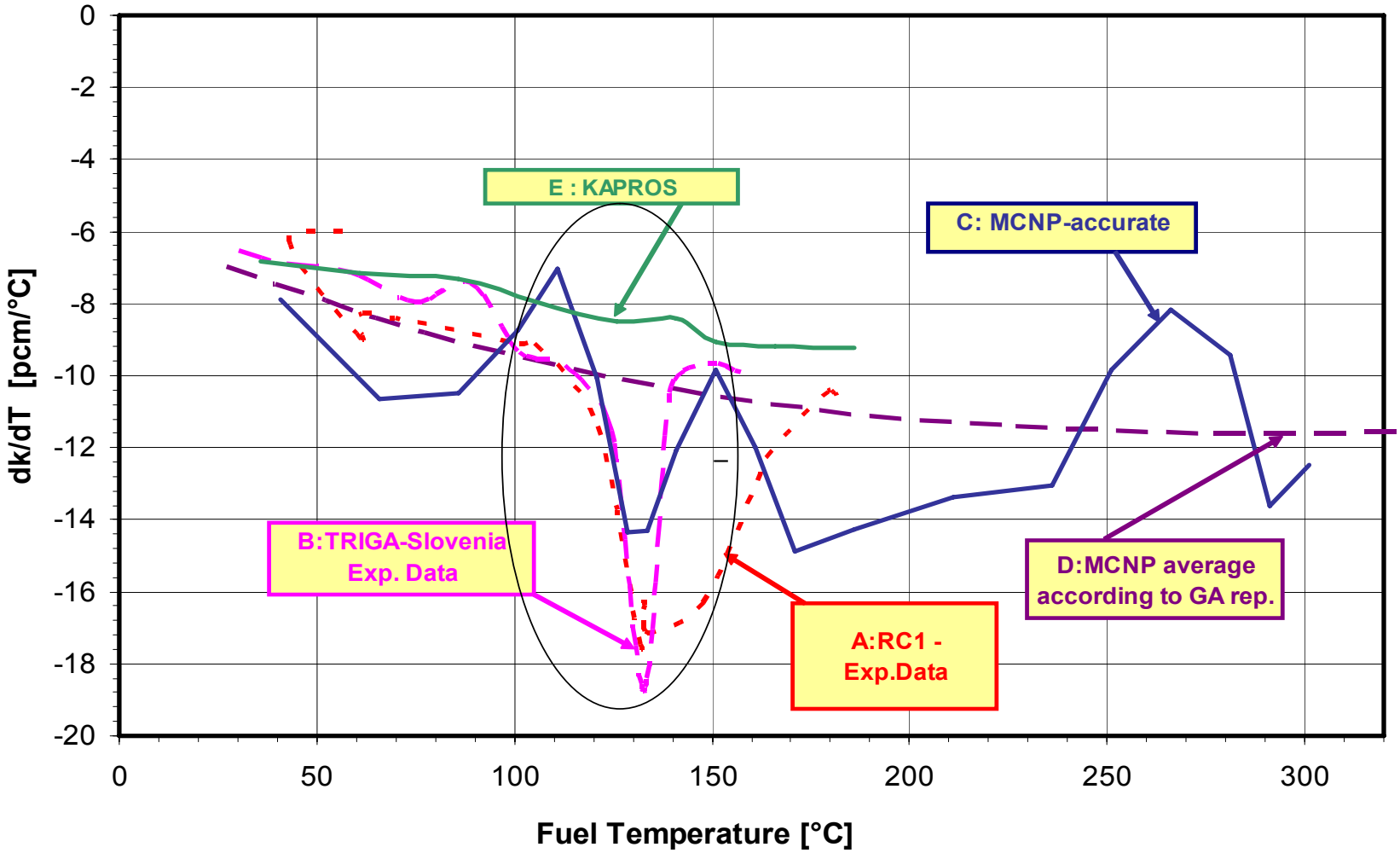
-increase the number of equi-probable energy points (20 → 30)

Calculation Methods

- Monte Carlo calculations with the continuos energy option for MCNPX code, ***beta version 2.5d;***
- Deterministic multi-group calculation with KAPROS-E LINUX *version 2.02* using the TWODANT code.

Measurements

- TRIGA cores in Cassacia and Slovenia;
- were performed by increasing the power ⟶ the temperature of the fuel;
- the averaged temperatures for the whole core were derived based on the measuring positions and the power shape of the core.

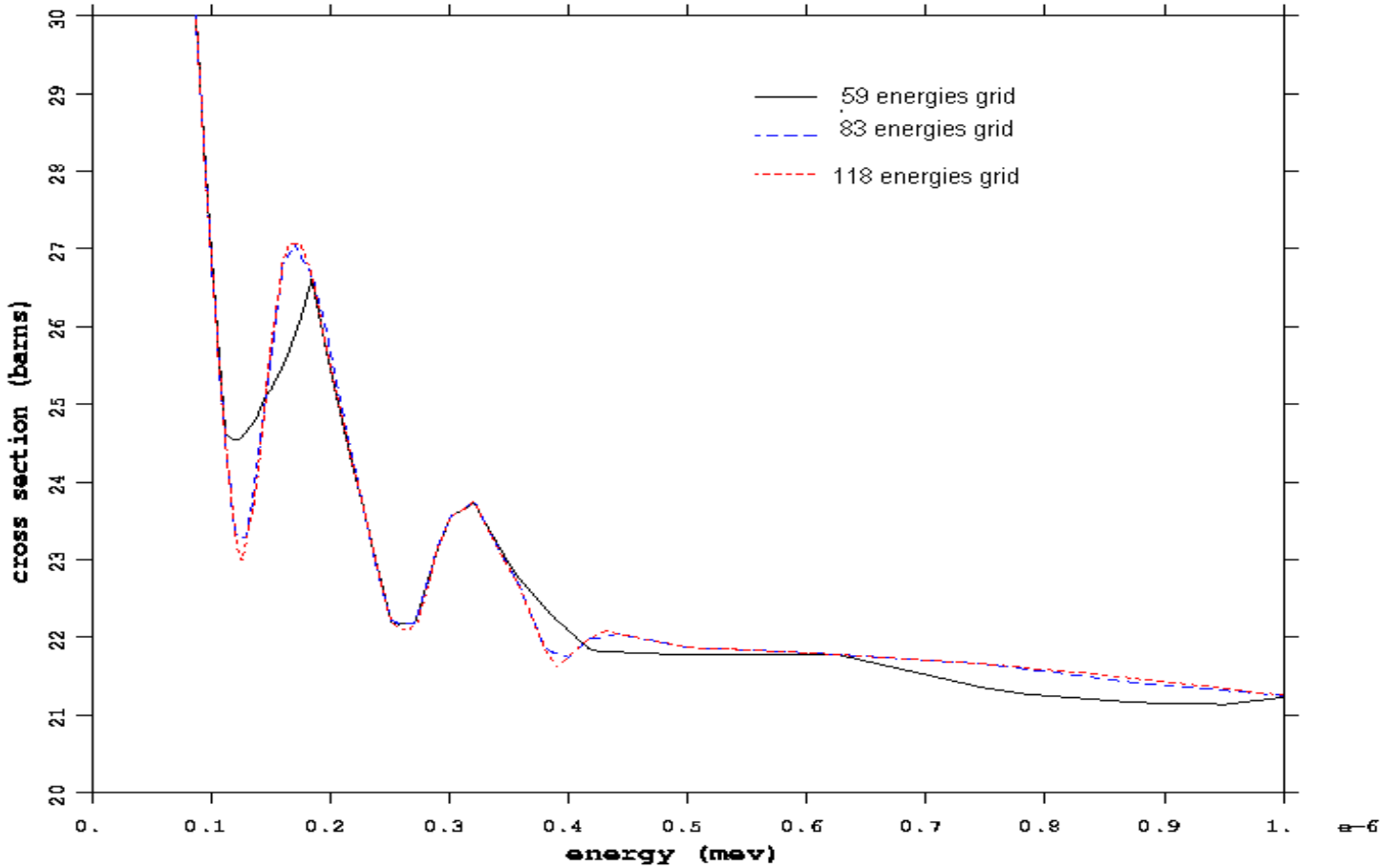


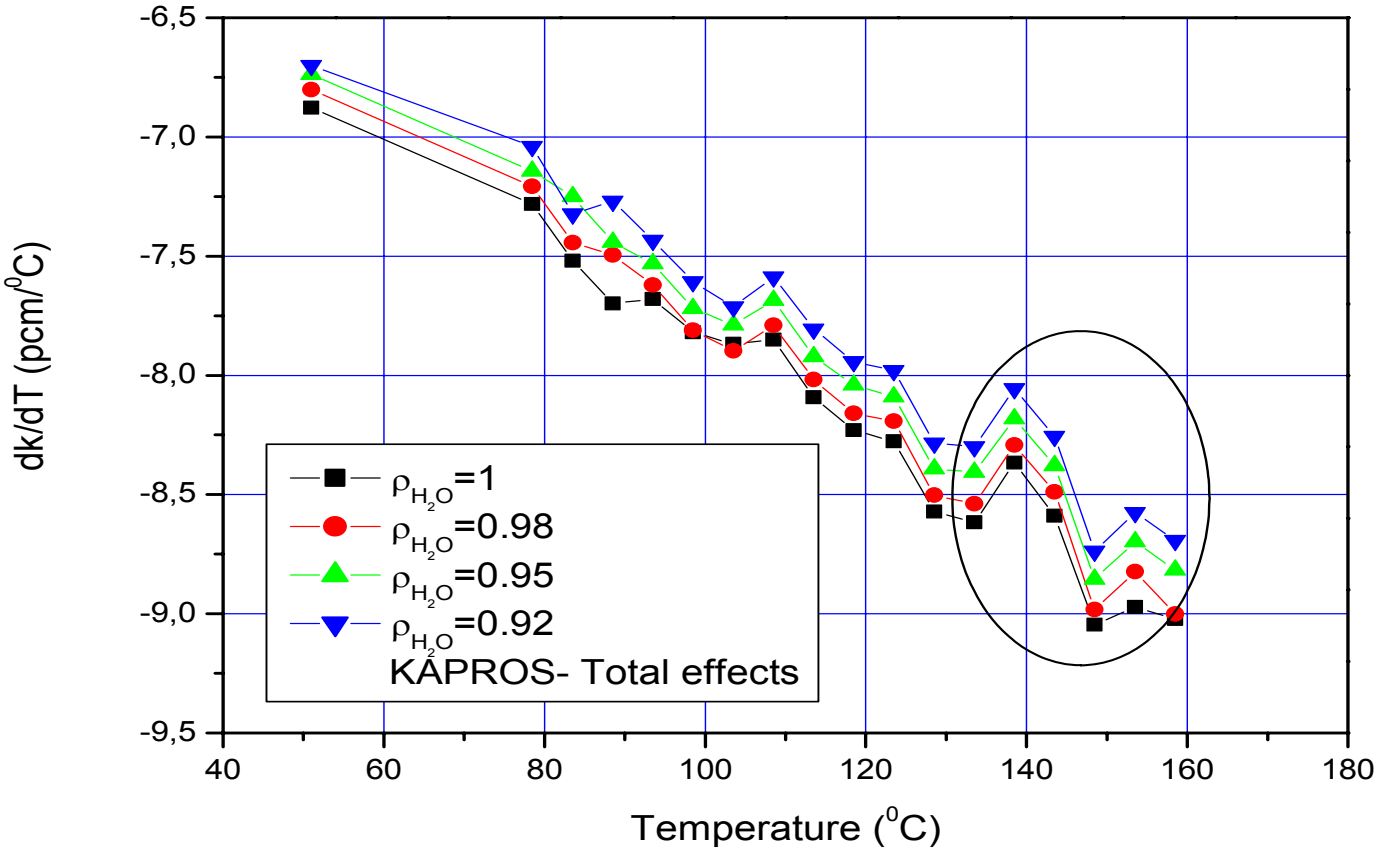
The comparison of experimental and computational results for the reactivity feedback of the TRIGA core and the TRIGA fuel pin respectively

Additional sensitivities of the reactivity feedback

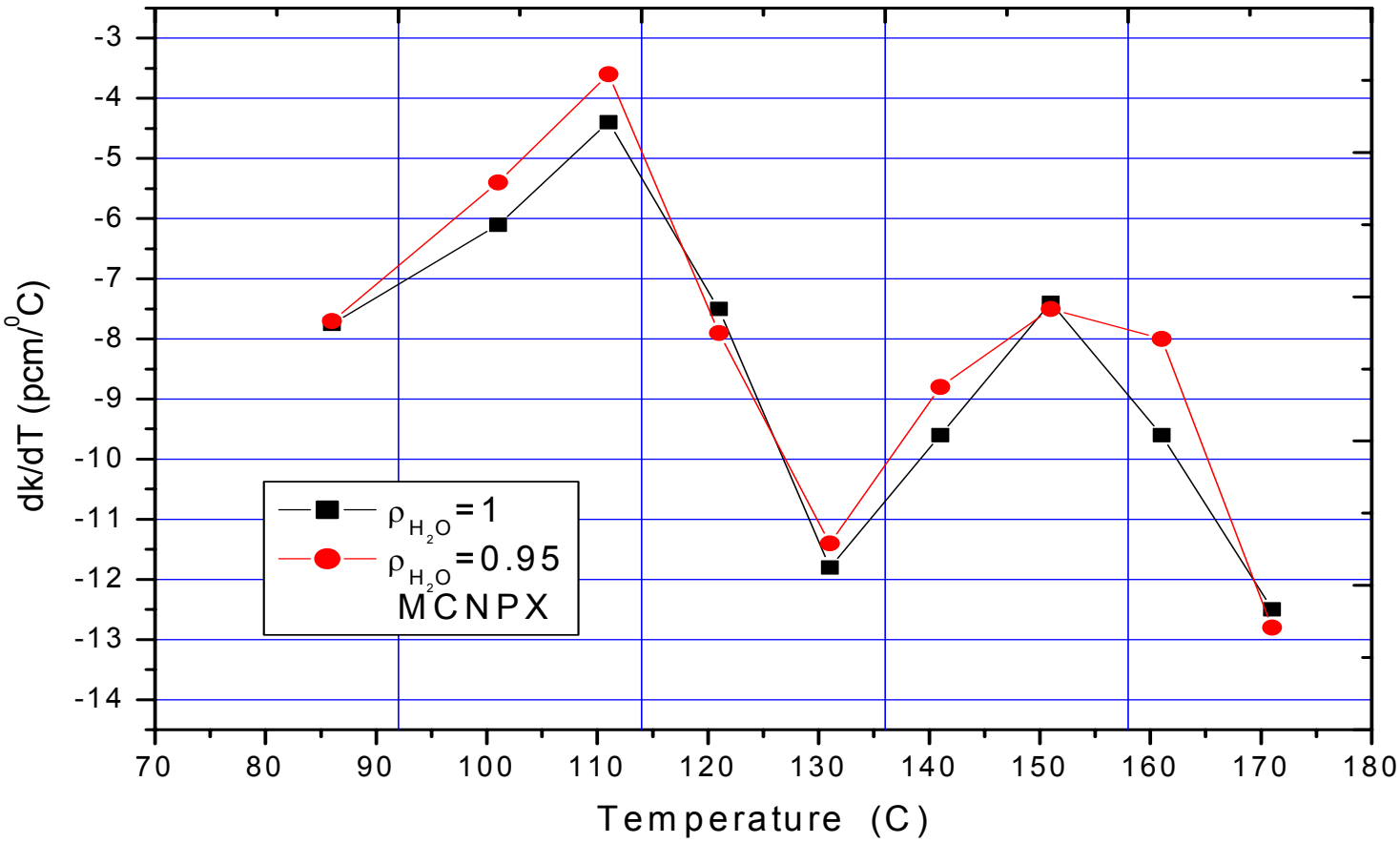
- Increasing the energy grid in NJOY from 59 to 83 points for the scattering law data reduced by about 1.5 pcm/degree keeping the shape of the reactivity curve.
  Additional study is mandatory for the optimized energy grid considering a new model in the LEAPR module;
- The increase of the number of equi-probable energy points (20 → 30) for the S(α,β) tables → no trend was observed;
- The modified Doppler effect by using resonant dependent S(α,β) tables for heavy isotopes showed negligible reactivity feedback growth due to the relative small U238 concentration

The total cross section for hydrogen bound in zirconium for different energy points





Total reactivity feedback effect of TRIGA fuel pin as function of void level in the water coolant using deterministic codes



Thermal reactivity feedback effect of TRIGA fuel pin as function of void level in the water coolant using MCNPX

Conclusion

- The unique phenomenon of the TRIGA reactivity feedback growth around 125° C was shown to be directly connected to the treatment of the bound hydrogen cross section based on specific S(α,β) probability tables ;
- Preliminary results show that also between 20 – 125° C the reactivity coefficient is sensitive to the improved S(α,β) probability tables;
- The overall core reactivity feedback is only slightly affected by the moderator density. Stochastic and deterministic calculations show the same trend .

OUTLOOK

- The differences between the 2-dimensional calculations and the experimental results need 3D calculations;
- A MCNPX new data set based upon an improved model for the bound hydrogen in zirconium hydride is currently under investigation;
- A TRIGA oriented energy group structure will be applied to study the scattering effects by deterministic codes in order to comply with the MCNPX and experimental results.


THANK YOU FOR ATTENTION!