

Fast Neutron Beam Dosimetry Characterization for Biomedical Sample Irradiations

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BACKGROUND



❑ FRINGE

Investigation on **neutron generated electronic excitation** as a foundation for a radically **new cancer therapy**

❑ Irradiations are performed in order to **experimentally verify the FRINGE principles** at:

- Swiss Spallation Neutron Source (SINQ) facility, at Paul Scherrer Institut (PSI, Switzerland) for **thermal neutrons**
- Tandem Accelerator at National Centre for Scientific Research “Demokritos” (NCSR) for **fast neutrons**

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SCOPE



- ❑ **Characterization** of the **neutron beams** at the NCSRD Tandem Accelerator Laboratory
- ❑ **Evaluation** of **dosimetric characteristics** in vials containing photo-sensitizer solutions
- ❑ **Provision** of **theoretical data** for understanding the FRINGE experiments



Monte Carlo simulations

❑ NeuSDesc code (Neutron Source Description) **input:**

- Neutron producing reactions: ${}^7\text{Li}(p,n)$, ${}^2\text{H}(d,n)$, ${}^3\text{H}(d,n)$
- Target description (solid LiF, deuterium gas cell, solid TiT)
- Entrance foil description (Mo)

Output: Neutron spectrum according to the reaction kinematics

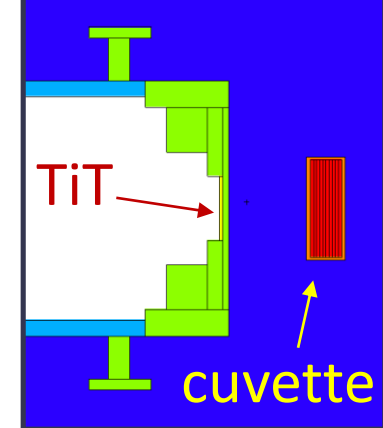
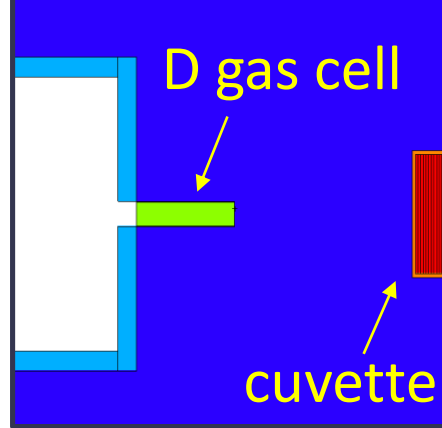
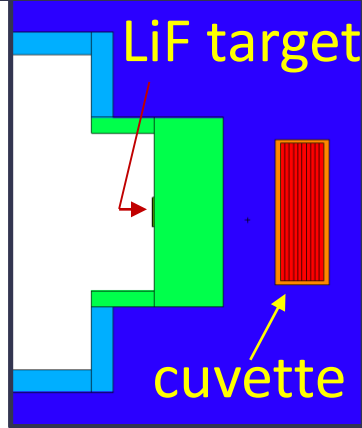
❑ MCNP 6.1 code (Neutron Transport) **input:**

- Neutron spectrum from NeuSDesc
- Geometry of the irradiation setup

Output: Neutron energy distribution and energy deposition in the irradiated samples



SIMULATIONS



- ❑ Cuvettes with photo-sensitizer solutions (10 slices of 1 mm)
- ❑ Scoring quantities:
 - Neutron fluence and energy distribution over the cuvette
 - Energy deposition (+f6) with respect to depth taking into account all particles in the problem



Different compounds in DMSO (C_2H_6OS , $\rho=1.1004 \text{ g/cm}^3$) solvent:

- 10 mM TPP-Gd-Klauri ($C_{55}H_{51}CoGdN_4O_9P_3$)
- 10 mM TPP-Gd-Tp ($C_{53}H_{38}BGdN_{10}$)
- 10 mM TFPF-Gd-Klauri ($C_{55}H_{31}CoF_{20}GdN_4O_9P_3$)
- 10 mM 4OMe-TPP-Gd-Klauri ($C_{59}H_{59}CoGdN_4O_{13}P_3$)

Different solvents with TPP-Gd-Klauri compound:

- DMSO (C_2H_6OS , $\rho=1.1004 \text{ g/cm}^3$)
- DMSO-d6 ($(CD_3)_2SO$, $\rho=1.19 \text{ g/cm}^3$)
- Acetone (C_3H_6O , $\rho=0.7845 \text{ g/cm}^3$)
- Acetone-d6 ($(CD_3)_2CO$, $\rho=0.872 \text{ g/cm}^3$)



RESULTS

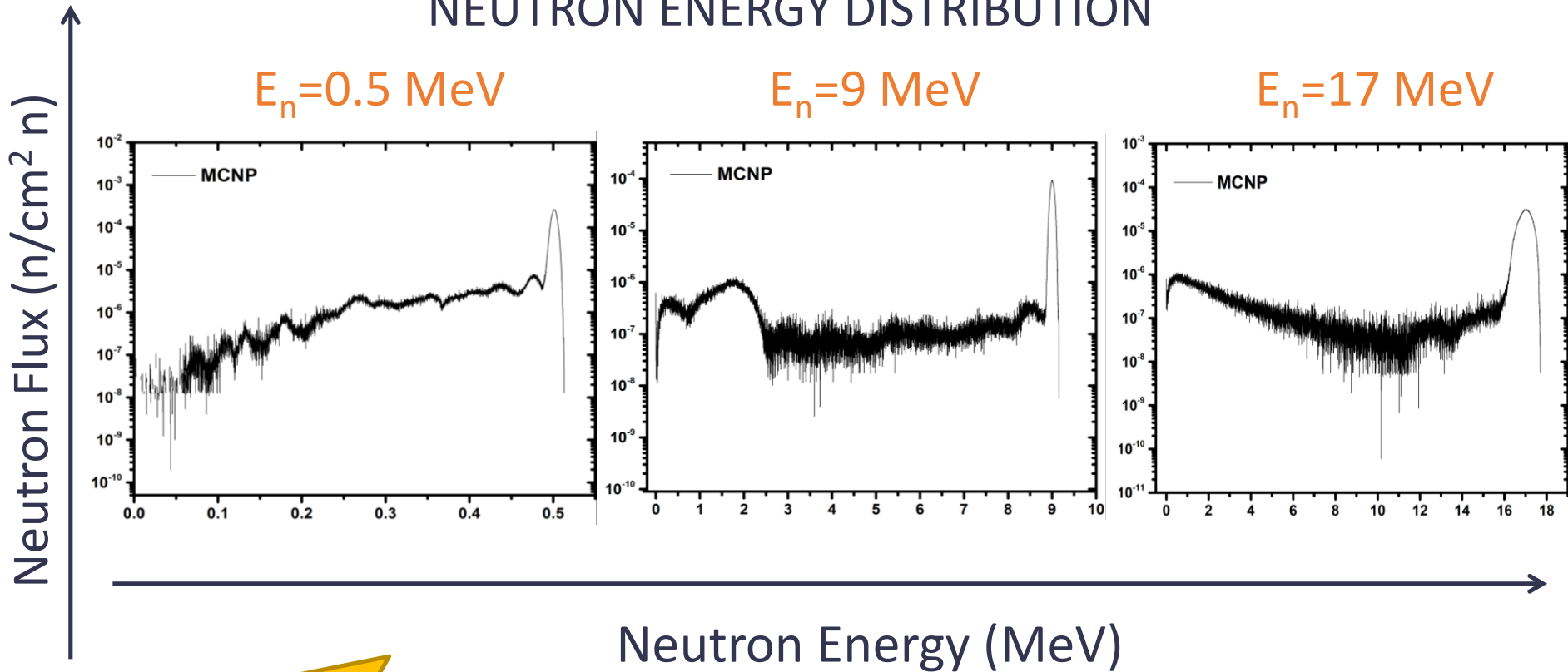


NEUTRON ENERGY DISTRIBUTION

$E_n = 0.5 \text{ MeV}$

$E_n = 9 \text{ MeV}$

$E_n = 17 \text{ MeV}$



Statistical error of simulations < 1%



RESULTS

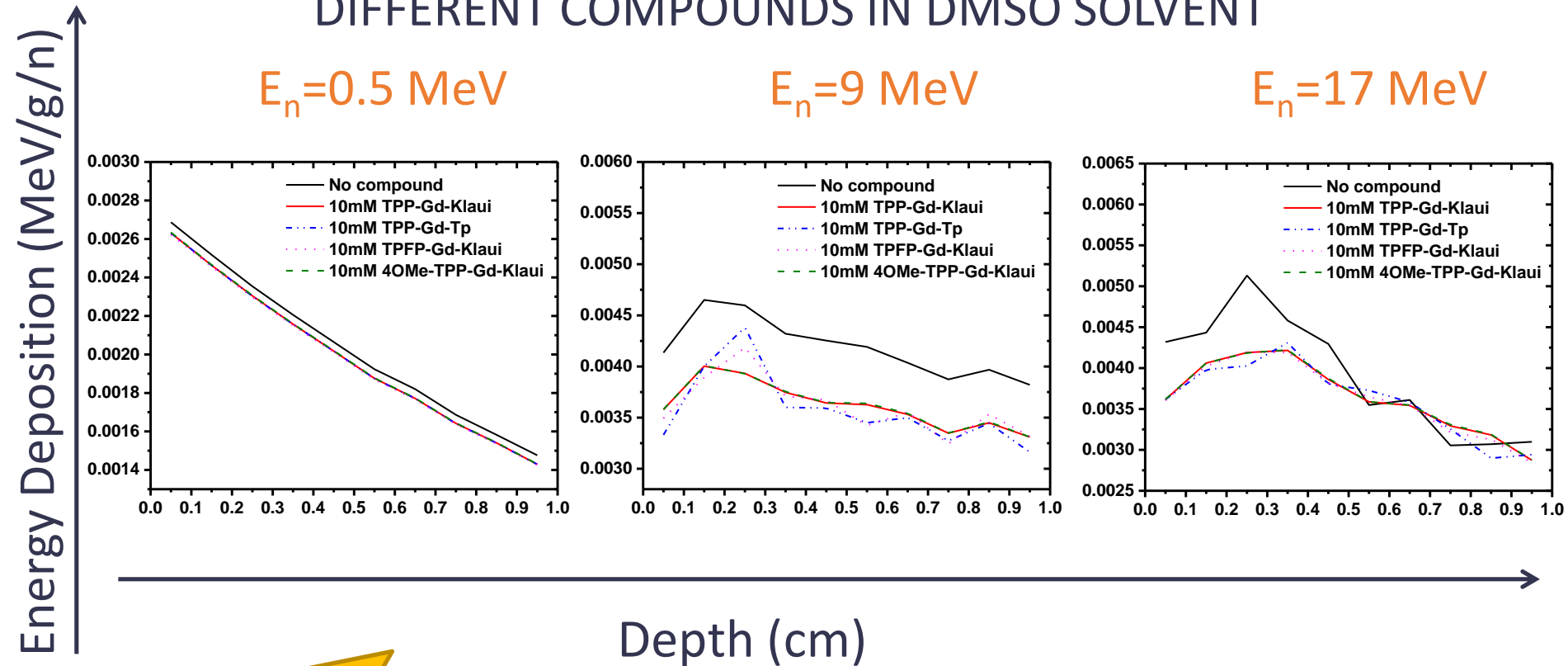


DIFFERENT COMPOUNDS IN DMSO SOLVENT

$E_n = 0.5 \text{ MeV}$

$E_n = 9 \text{ MeV}$

$E_n = 17 \text{ MeV}$



Statistical error of simulations < 5%



RESULTS

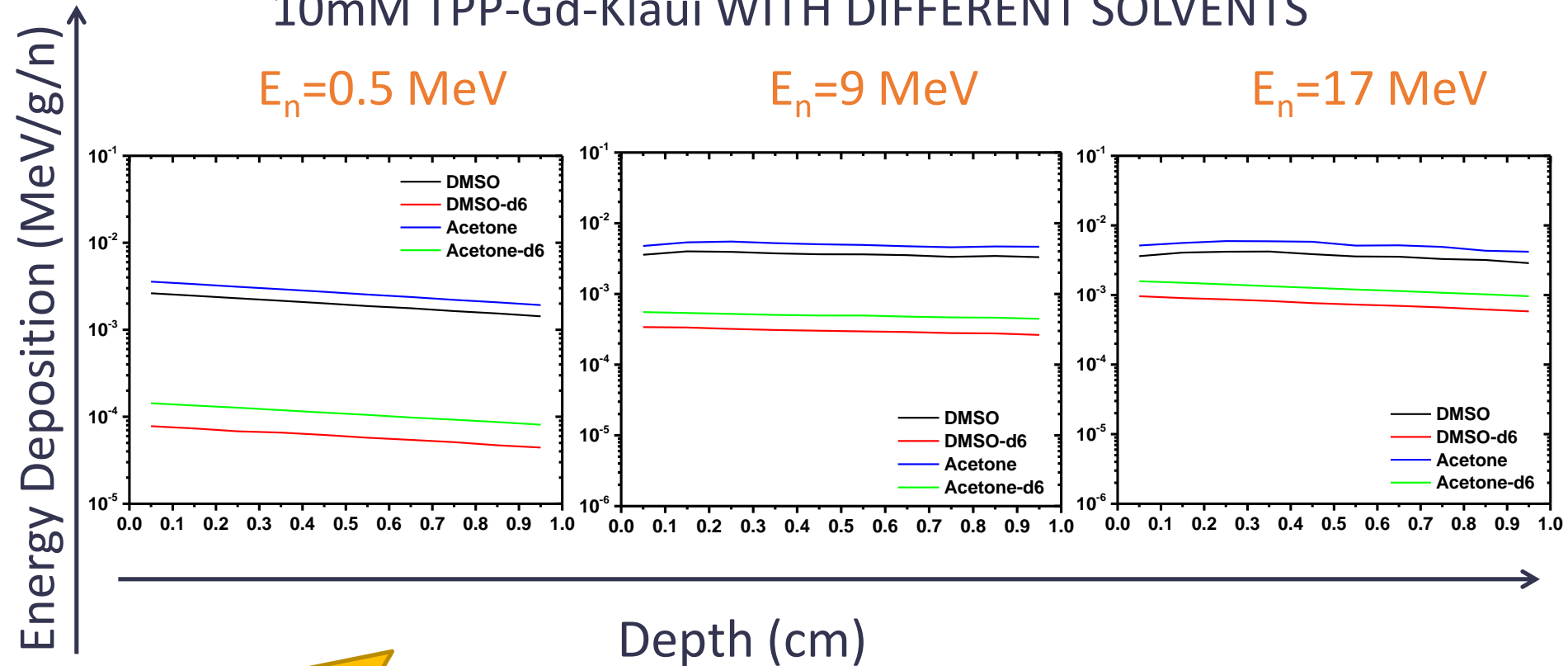


10mM TPP-Gd-Klauri WITH DIFFERENT SOLVENTS

$E_n = 0.5 \text{ MeV}$

$E_n = 9 \text{ MeV}$

$E_n = 17 \text{ MeV}$



Statistical error of simulations < 5%



CONCLUDING REMARKS



- ❑ The **neutron spectra** from the reactions ${}^7\text{Li}(p,n)$, ${}^2\text{H}(d,n)$ and ${}^3\text{H}(d,n)$ at the NCSRD Tandem Accelerator were determined by coupling the NeuSDesc and MCNP 6.1 codes.
- ❑ **Neutron energy deposition** in the cuvette for **different combinations** of **compounds** and **solvents** tested in FRINGE experiments was calculated.
- ❑ The **strong dependence** of **energy deposition** on the selection of the **solvent** was demonstrated.