Monte Carlo method for the design of nuclear power reactors and research facilities

P. Console Camprini[1], R. Pergreffi[1], M. Sarotto[2], F. Lodi[1], G. Grasso[1]

1 NUC-ENER-PRO, ENEA, Via dei Mille 21, 40121 Bologna (Italy)
2 NUC-ENER-PRO, ENEA, Strada per Crescentino 41, 13040 Saluggia (Italy)

2nd ENEA Nuclear Energy System Division Workshop

Monte Carlo method models the inherent stochastic nature of particles through a probabilistic approach. Such codes are fundamental tools for nuclear systems analysis and experiments preparation. Results of interest are response functions of particle flux in the system. Simulations regard either fixed source or eigenvalue problems. The first ones present a given source of particles: the transport equation has a source term. The eigenvalue problems concern multiplicative systems (i.e. including fissile materials: source depends on the system itself). Examples of eigenvalue problems are about power reactors (Gen-III EPR, Gen-IV LFRs) and research reactors (TAPIRO). Flux distributions are obtained; sensitivity and uncertainty analysis regard the multiplication coefficient with respect to parameters of interest. Fixed source problems are about irradiation tests at n_TOF facility (CERN) and studies of subcritical systems (ADS). Used codes are MCNP6.3, OpenMC and Geant4.

Eigenvalue Problems

Particle flux by (static) Boltzmann equation (no source):

$$k\, L\phi = M\phi$$

$\phi(\vec{r}, E, \hat{\Omega})$: flux at given position, energy, direction

M, L : multiplication and leakage operators

k : <u>multiplication coefficient (eigenvalue)</u>

Core Flux shape: first eigenfunction

Fixed Source Problems

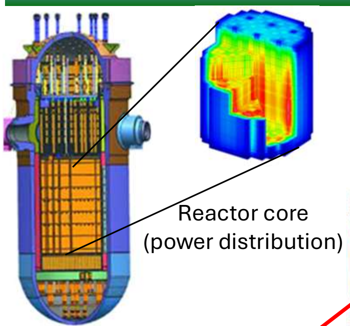
Particle flux field solved by (static) Boltzmann equation:

$$L\phi = M\phi + S$$

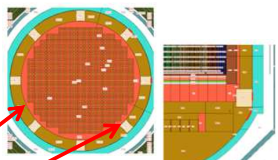
$S(\vec{r}, E, \hat{\Omega})$: Particle source (position, energy, direction)

Flux and responses: solution by source

Nuclear Power Reactors

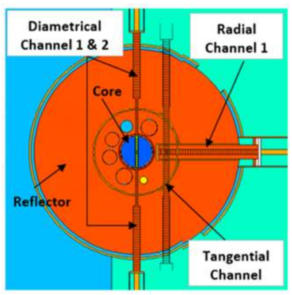


- supporting core design
- fuel cycle, burnup, depletion
- safety analysis
- material damage
- radiation protection



Flux at positions for vessel dose – detector dose

Nuclear Research Reactors



TAPIRO reactor cross-section

Minor Actinides irradiation (Gen-IV)

235U	239Pu	241Am	243Cm
238U	240Pu	243Am	244Cm
237Np	242Pu	-	245Cm

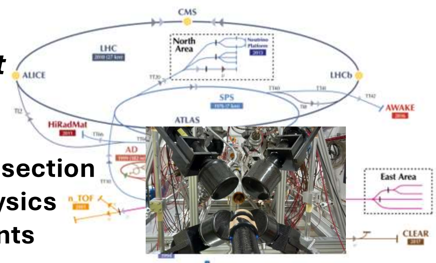
TAPIRO reactor at ENEA Rome

Sensitivity for integral parameters

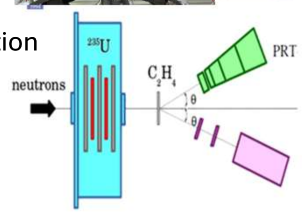
n_TOF Experimental facility

Neutron time-of-flight facility

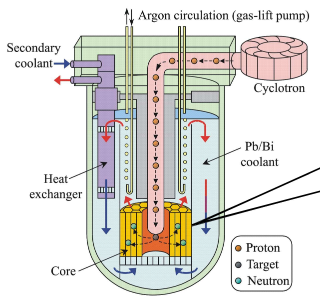
neutron cross-section neutron physics experiments

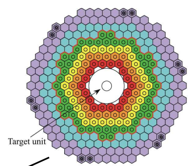


- experiment preparation
- detector design
- data analysis and comparison



Accelerator Driven Systems





- core design
- breeding
- fuel/waste burning
- system coupling

AKNOWLEDGMENT

- Dr Luca Falconi, responsible for the TAPIRO Reactor and Dr Valentina Fabrizio from ENEA NUC-IRAD-RNR laboratory
- Dr Guido Guarnieri and all the CRESCO HPC team supporting infrastructure (TERIN-ICT-HPC laboratory)
- Prof. Cristian Massimi (Dept. of Physics, University of Bologna) and the INFN (Italian National Institute for Nuclear Physics), Bologna section
- n_TOF Collaboration at CERN (European Organization for Nuclear Research)

Contact | Patrizio Console Camprini
Researcher ENEA NUC-ENER-PRO

Mail | patrizio.consolecamprini@enea.it