Characterization of the SAFARI-1 Material Testing Reactor

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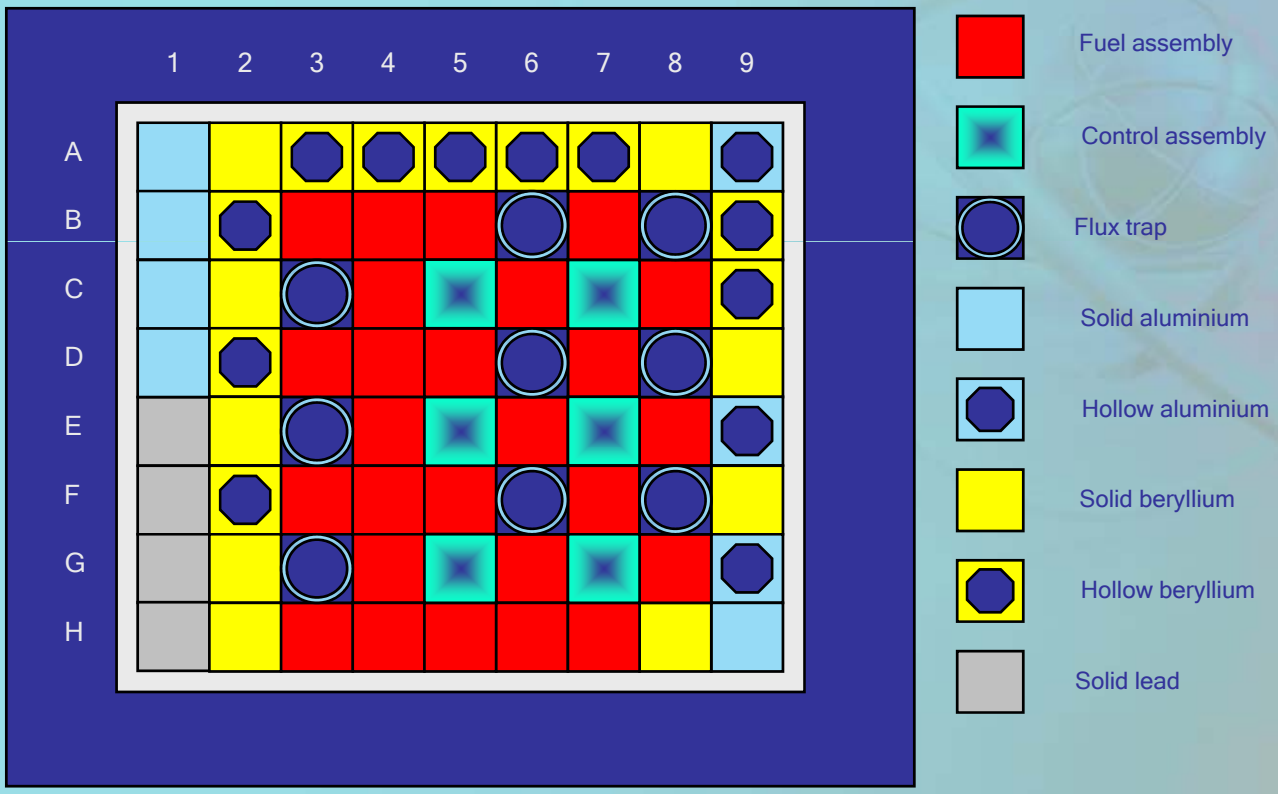
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Outline

1. Purpose of the study
   - ✓ SAFARI-1 Reactor Core layout
   - ✓ Support for PBMR Fuel Research and Development
2. Tools and Software
   - ✓ OSCAR-4
   - ✓ MCNP
   - ✓ OSMINT
3. Results and Discussions
   - ✓ Core Flux and Power Distributions
   - ✓ Flux and Power Distributions in B6, D6, F6
4. Conclusions and Future Work

Purpose of the Study

- ✓ SAFARI-1 Reactor Core Layout

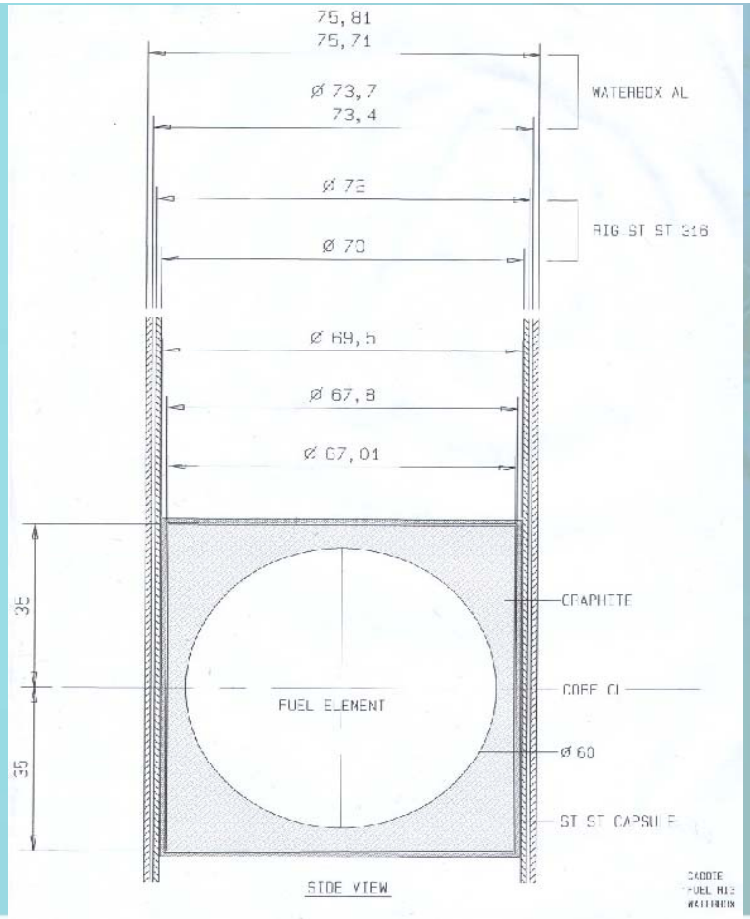


Tools and Software

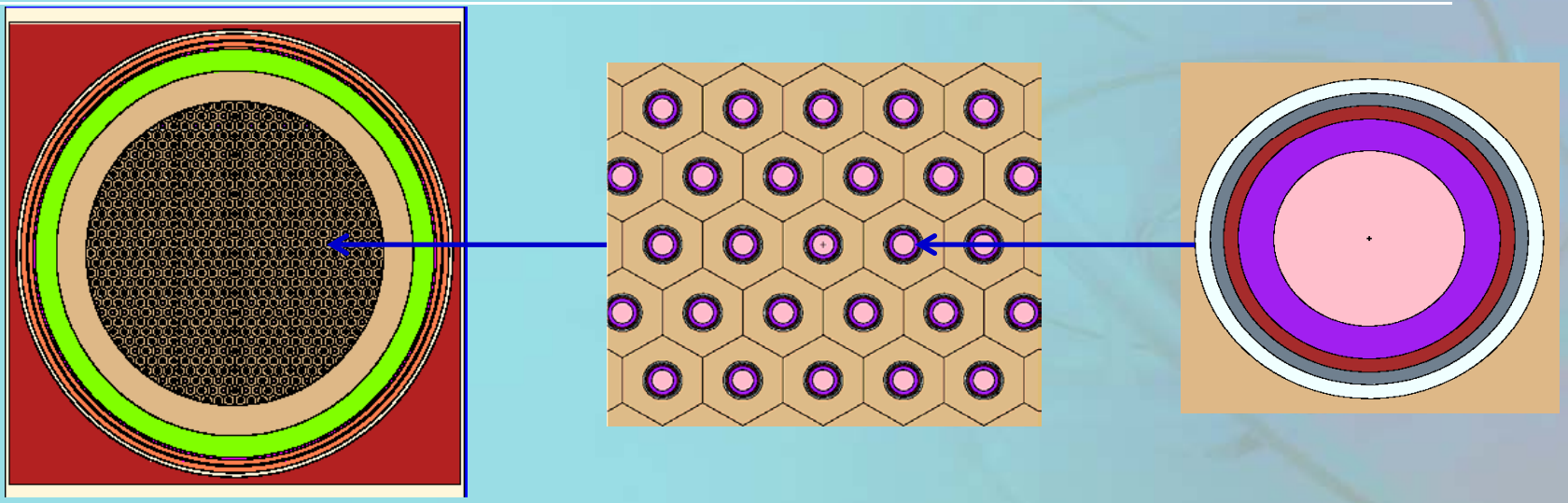
- OSCAR4 – Overall System for CAlculation of Reactors
  - » a core depletion code that is based on nodal diffusion methods
- MCNP – Monte Carlo N-Particle code
  - » for neutron, photon and electron transport
  - » capability to model very complex geometries
- OSMINT – Oscar4-MCNP INTerface
  - » links OSCAR and MCNP
  - » transfer material isotopics from OSCAR to MCNP
  - » generating a core that is correct in space and time

Proposed Fuel Pebble Irradiation Rig

- ✓**Fuel pebble**
  - **» 6 cm in diameter**
- ✓**Graphite cup**
- ✓**Helium gas flow**
- ✓**Stainless steel capsule**
- ✓**Helium gas flow**
- ✓**Stainless steel rig**
- ✓**Aluminium water box**



The Proposed Rig and the Fuel Pebble

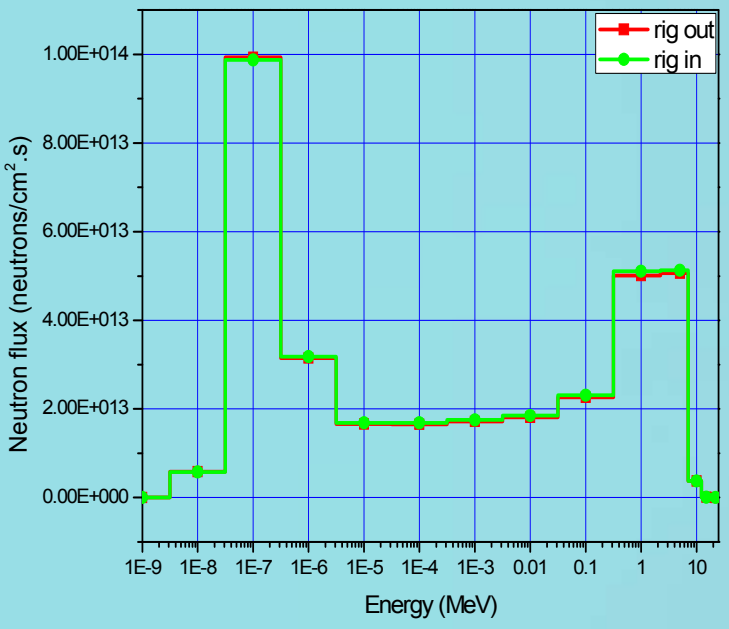


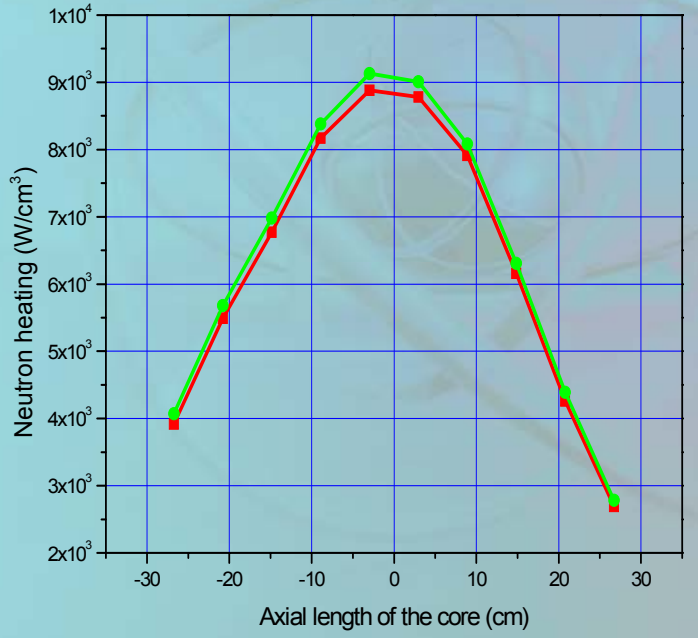
- ✓**Fuel pebble**
  - » **2.5 cm radius – fuel region**
  - » **~ 15 000 coated fuel particles on a 3-D triangular lattice**
  - » **3 cm radius non-fuel shell (graphite)**
- ✓**Coated fuel particle**
  - » **low enrichment (<10% ^{235}U) – UO_2 fuel kernel**
  - » **Carbon buffer layer**
  - » **IPyC/SiC/OPyC – TRISO-type fuel**

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Results and Discussions I

Global Effects (Core)

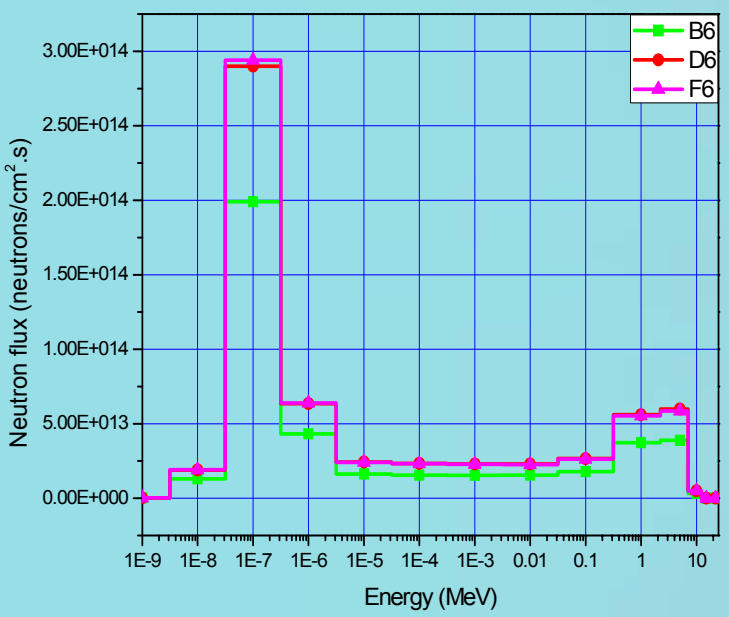


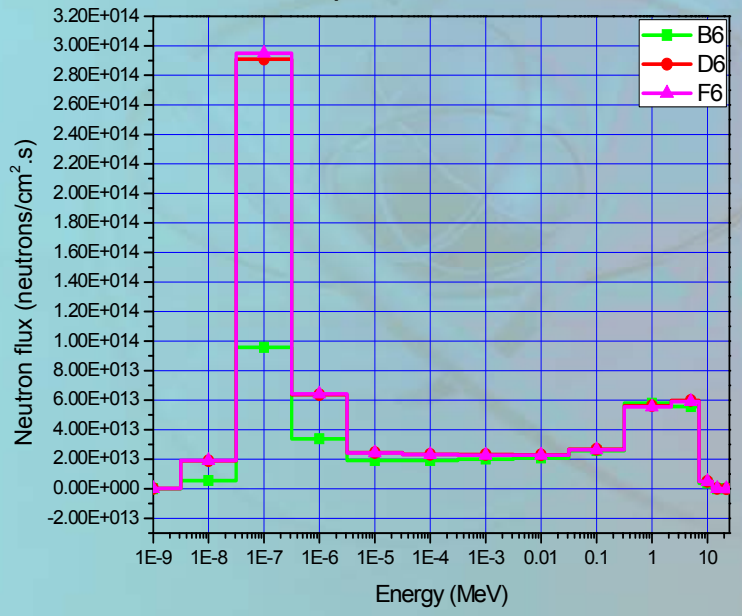


- ✓ Flux decrease in the thermal energy range <1%
- ✓ Flux increase in the epithermal and fast energy range <2%
- ✓ Axial neutron heating increase (~4%) – pronounced in the region of the core centerline

Results and Discussions II

Local Effects (Specific to B6, D6 and F6)

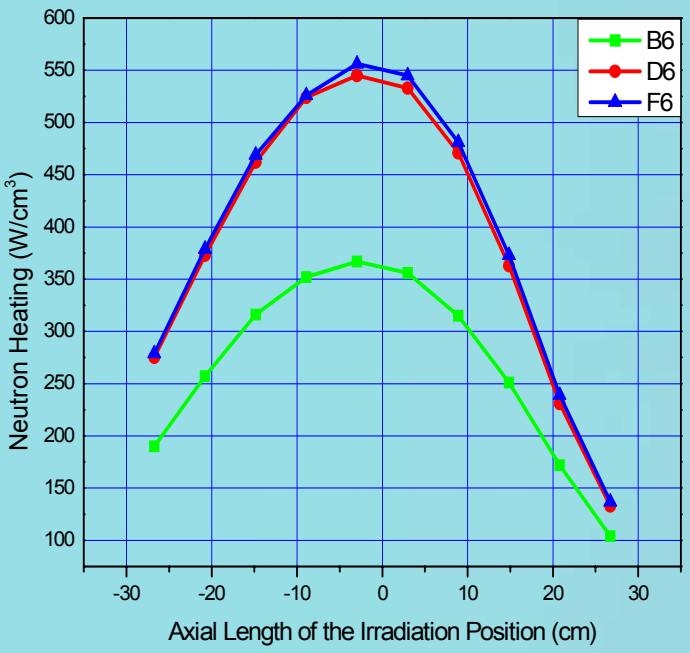


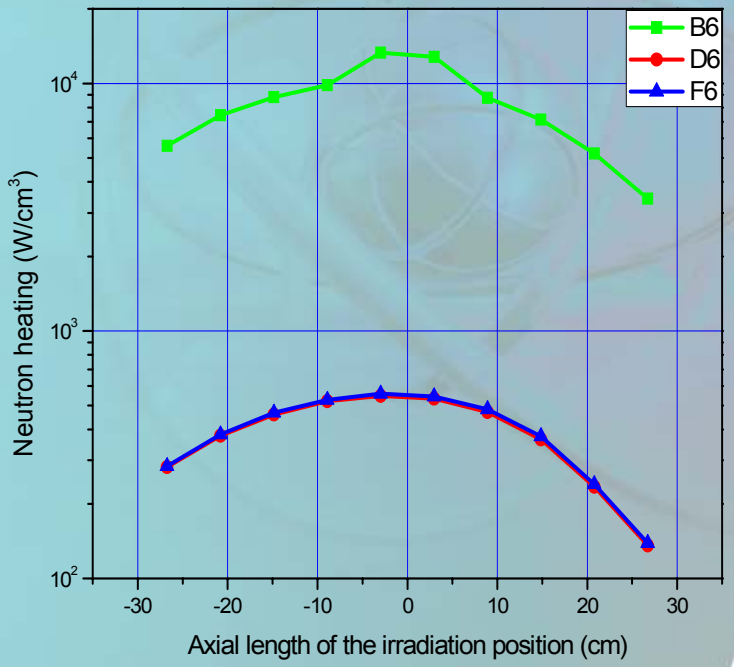


- ✓ rig out (left hand side figure) and rig in (right hand side figure)
- ✓In B6, flux decrease ~50% at 1e-7 and ~20% at 1e-6 (thermal region)
- ✓ Also in B6, ~50% increase in the fast neutron flux
- ✓ neutron flux in D6 is insignificantly perturbed by insertion of the rig in B6, similarly in F6, the perturbation in the neutron flux due to rig insertion was found to be very little

Results and Discussions III

Local Effects (Specific to B6, D6 and F6)

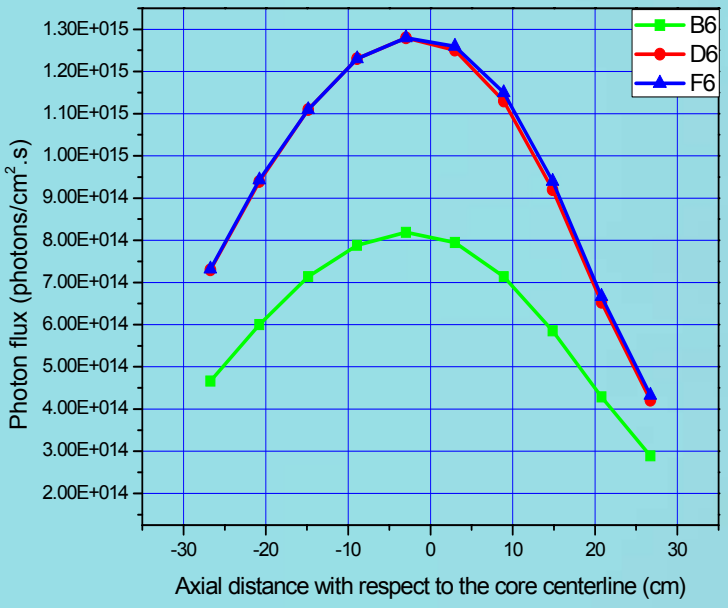


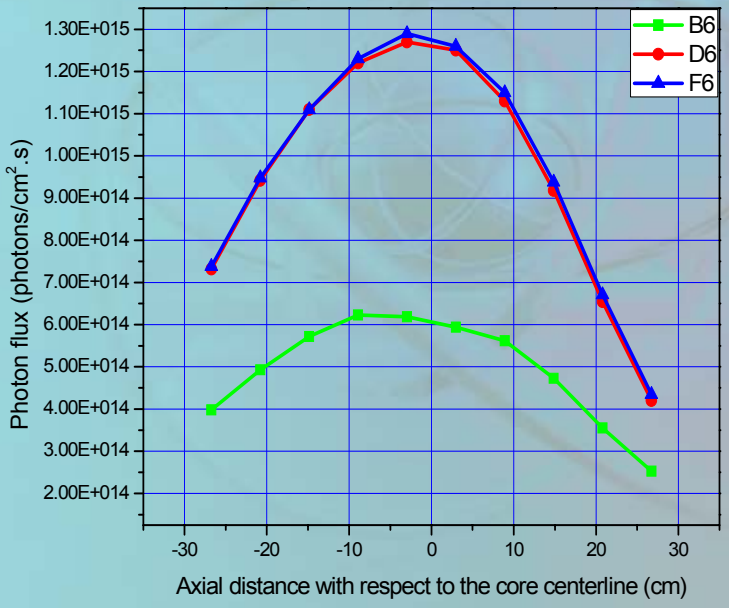


- ✓ rig out (left hand side figure) and rig in (right hand side figure)
- ✓Neutron heating in D6 and F6 remains unchanged
- ✓ In B6, the amount of neutron heating increases by two orders of magnitude

Results and Discussions IV

Local Effects (Specific to B6, D6 and F6)

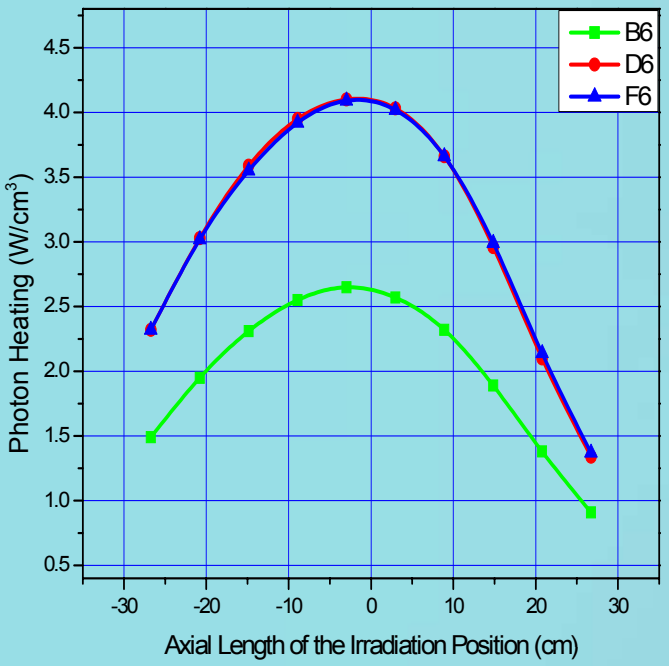


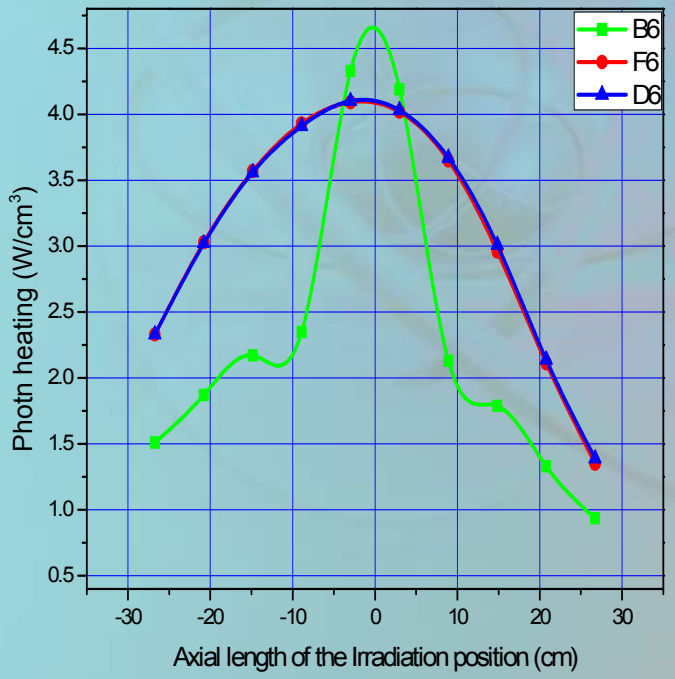


- ✓ rig out (left hand side figure) and rig in (right hand side figure)
- ✓In B6, axial photon flux is decreased by ~ 50% due to absorption of photons in the rig materials)
- ✓ The magnitude of the photon flux in D6 and F6 is only slightly perturbed in the region of the core centerline

Results and Discussions V

Local Effects (Specific to B6, D6 and F6)





✓ rig out (left hand side figure) and rig in (right hand side figure)

✓In B6, axial photon heating is increased by over 50% due to absorption of photons in the rig materials)

✓ The magnitude of the photon heating remains almost unchanged in D6 and F6.

6. CONCLUSIONS

- It is required to irradiate fuel pebbles at very high temperature environment in the SAFARI-1 core – to simulate the high temperature in the PBMR core
- For such high temperatures to be confirmed as can achieved in the SAFARI-1 core, we require neutronic as well as thermal hydraulic calculations
- So far, the increase in the amount of neutron heating and photon heating in position B6 of the core when this rig is inserted gives hope that the envisaged high temperature environment can be achieved – pending thermal hydraulic calculations

FUTURE WORK

- Extend the rig to contain up to four pebbles and study its impact on the core parameters
- Investigate heat deposition variations in water and helium to better explain some of the striking phenomena
- Use high temperature cross sections for the fuel pebble materials – to account for doppler effects