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NUCLEAR TECHNOLOGY

P B M R

Shielding calculations in the CUD area of the PBMR Design

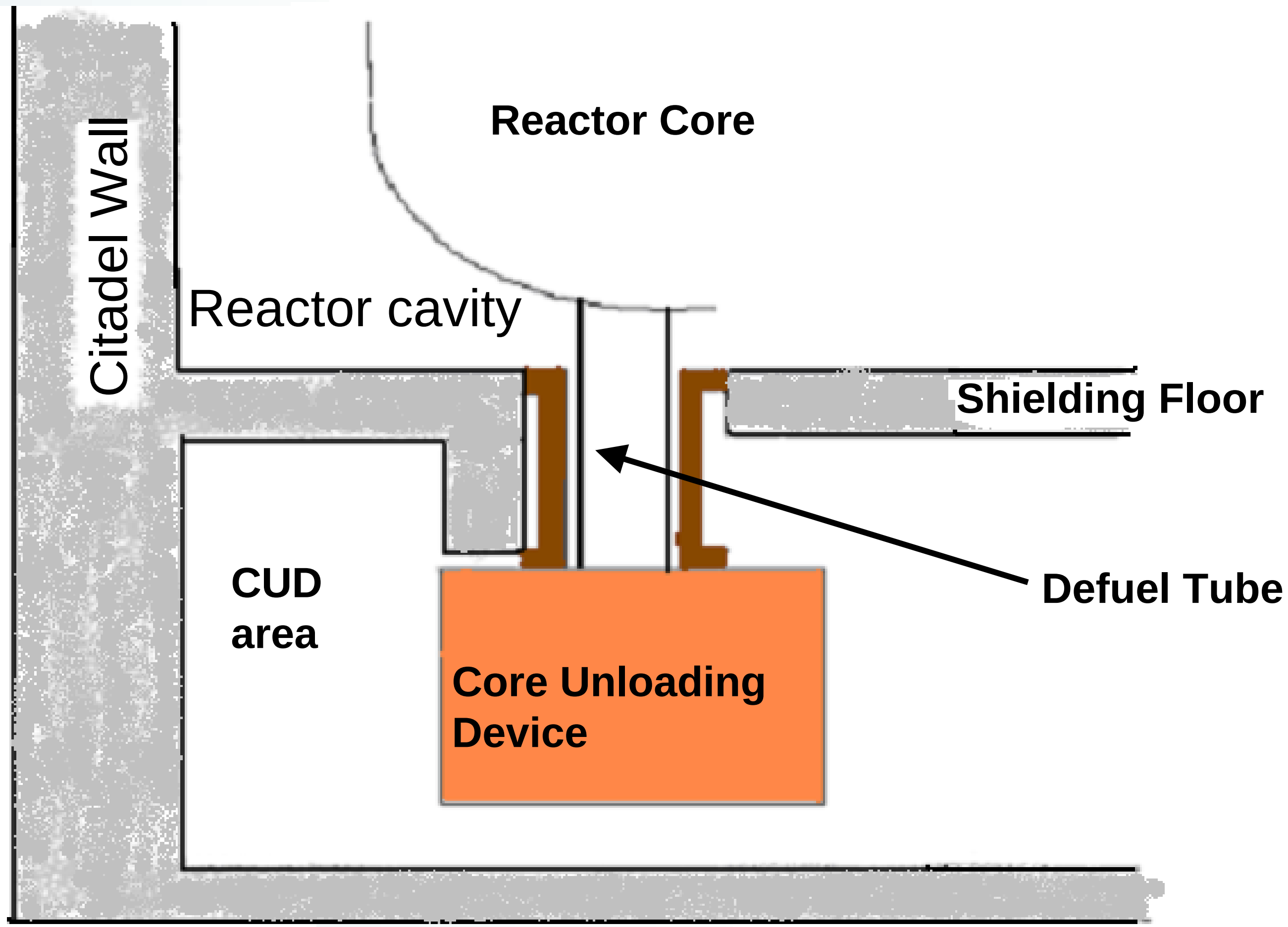
Vuyani Xulubana

South African Nuclear Energy Corporation / Pebble Bed Modular Reactor (South Africa)

Introduction:

- The PBMR Project in South Africa is currently in its design phase.
- The core analysis design work is performed by the Radiation and Reactor group from NECSA.
- MCNP is mostly used in the criticality and shielding calculations.
- The Reactor analysis group works in conjunction with the design engineers in determining shielding requirements of the plant.

Figure1: Illustration of the system geometry



Core Unloading Devices

- The CUDs are situated just below the Reactor and are used for unloading the reactor core
- CUDs are separated from the Reactor core cavity and from each other by High Density concrete (3.5 g/cc, ~55.0 wt % Fe)
- There are three CUDs connected to the Reactor Core by three individual defuel tubes.
- They are also used to remove damaged fuel spheres from the fuel cycle.

Radiation Sources

- Neutrons and Gammas from the Reactor Core and neutron induced gammas throughout the concrete shielding floor

- Gammas from Fuel Spheres in the Defuel Tubes and CUDs.

- Neutron activation of the CUDS

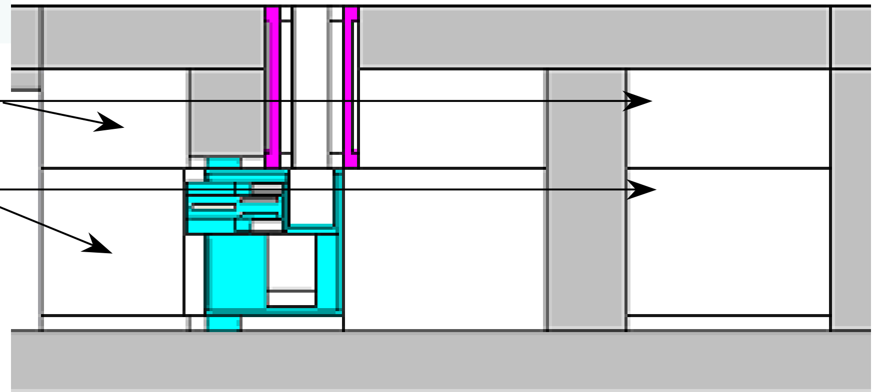
Neutron source below the Rector

- Criticality calculation of the PBMR
  - neutron / fission γ source written on the core inner surfaces
  - transported from the core inner surfaces through the reflectors, Core Barrel and Reactor Pressure Vessel (RPV)
  - Source written on the outer surface of the RPV.
  - Tallying at the top surface of the shielding floor gave a spatial dependent source composed of neutron streaming through defuel tubes and those from the Reactor.

MCNP modeling of the CUDs

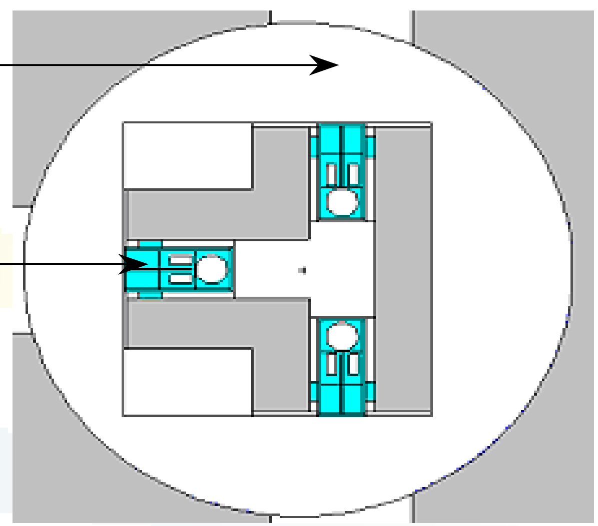
Upper Cavity

Lower Cavity

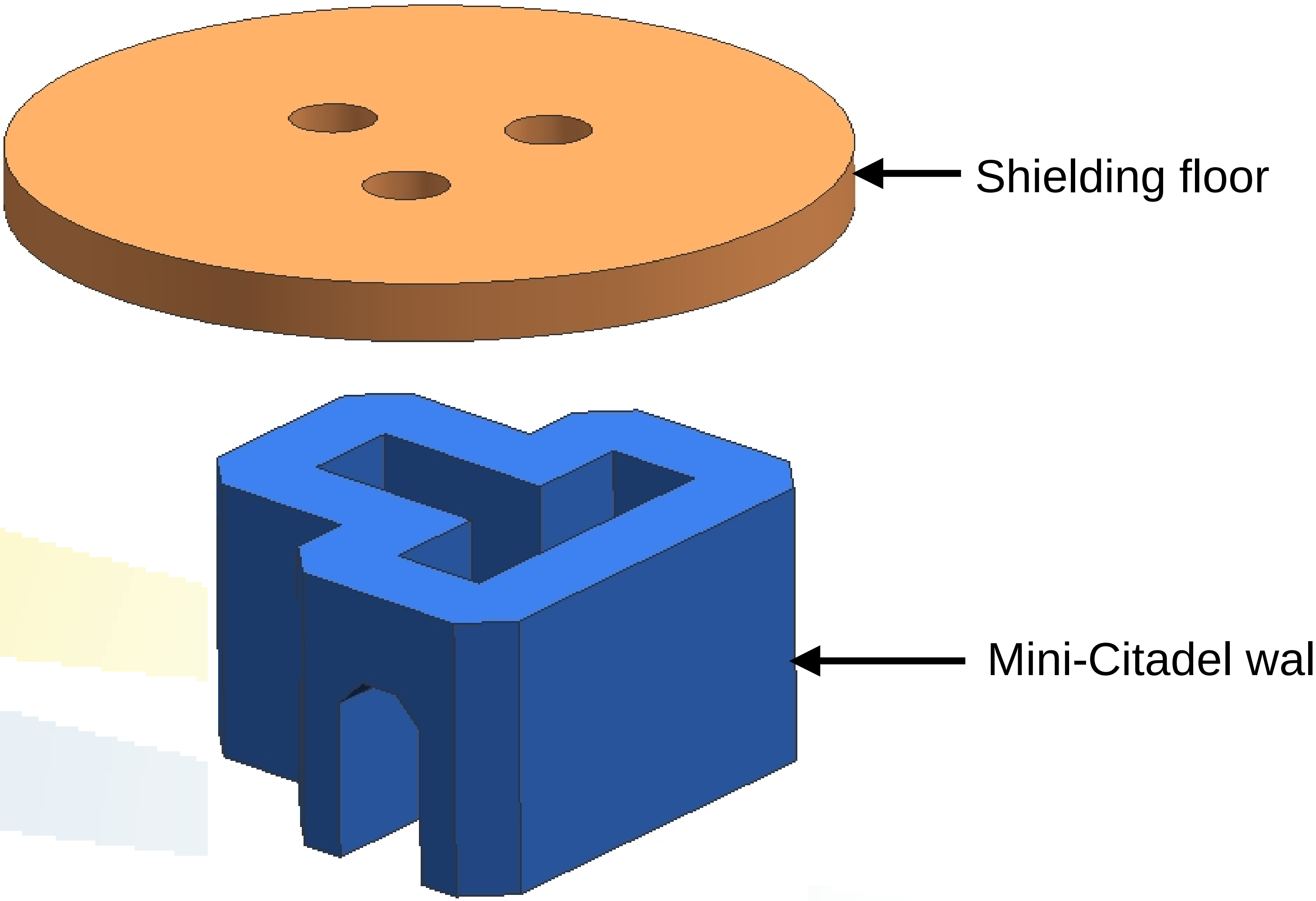


Upper / Lower Cavity

CUD



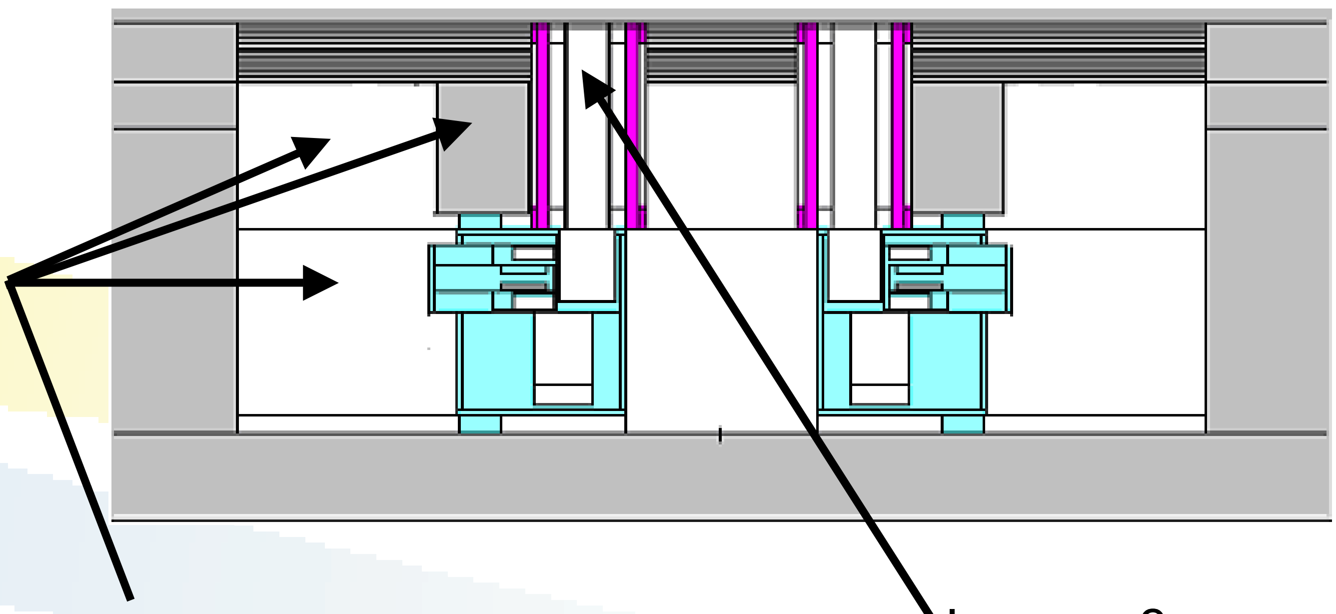
Problem



Calculational Method

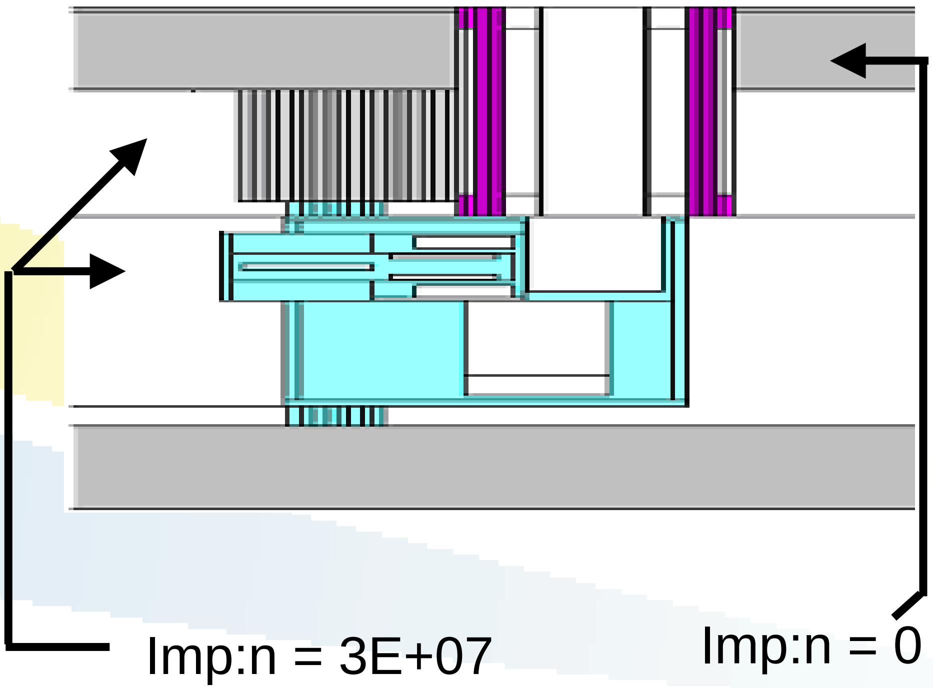
Method 1

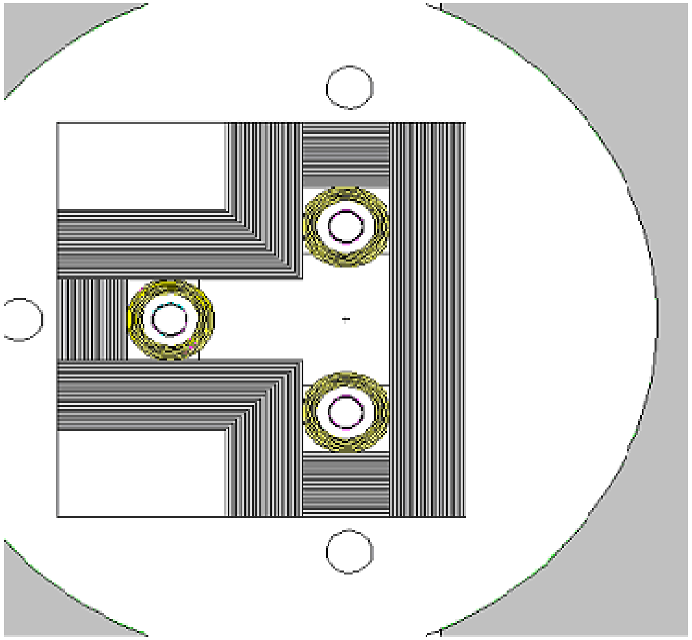
Part 1: The Reactor Cavity bottom shielding floor splitting into cells of increasing importance (Variance Reduction)



Calculational Method … cont

Part 2: The mini-Citadel wall splitting into cells of increasing importance

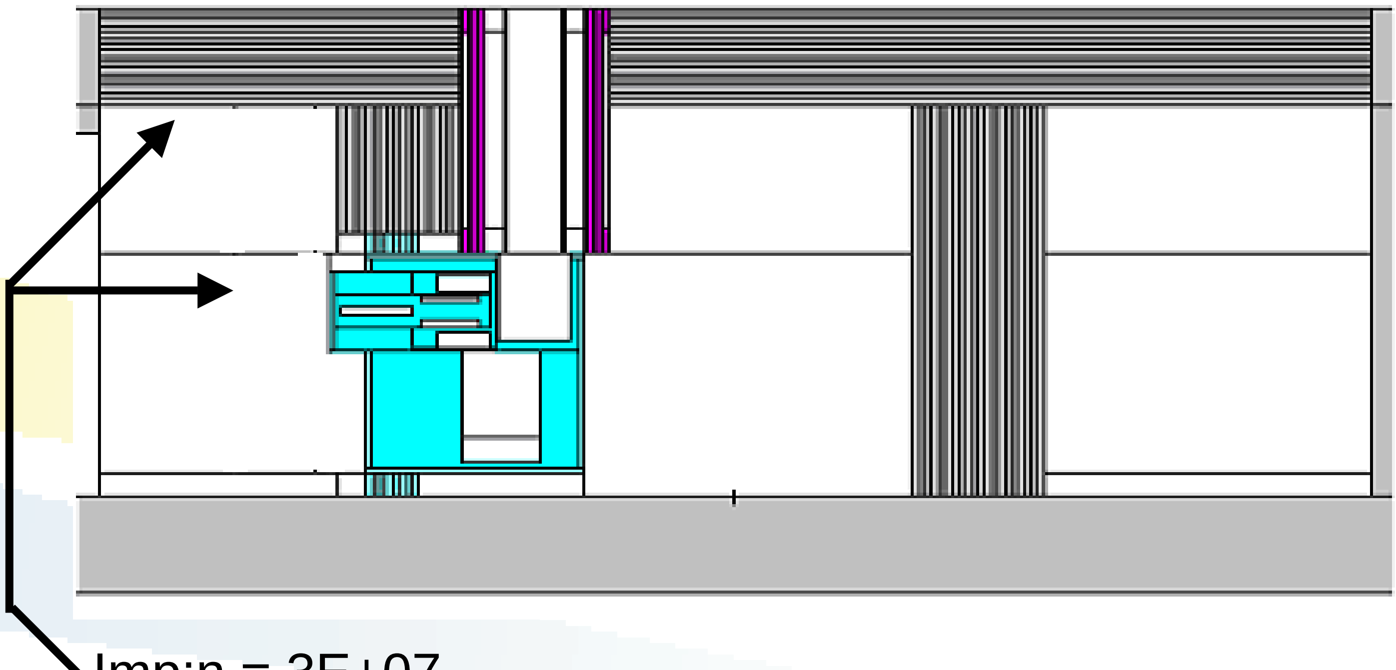




Calculational Method … cont

Method 2

Both the Reactor Cavity bottom shielding floor and the Mini-Citadel split into cells of increasing importance



Imp:n = 3E+07

MCNP results

Table 1: The combined results of Part 1 and 2 (Method 1) (~55 min & 40 min, respectively)

Floor Thickness cm	Dose Rate ($mSv.hr^{-1}$)					
	Upper Cavity			Lower Cavity		
	Neutrons	Gamma	Total	Neutrons	Gamma	Total
60	0.290	0.848	1.138	0.254	0.427	0.681
80	0.021	0.104	0.126	0.011	0.064	0.075
90	0.006	0.039	0.045	0.003	0.027	0.031
100	0.002	0.011	0.013	0.001	0.008	0.009

Table 2: The results obtained with Method 2 (from 7hrs to ~ 20hrs)

Floor Thickness cm	Dose Rate ($mSv.hr^{-1}$)					
	Upper Cavity (UC)			Lower Cavity (LC)		
	Neutrons	Gamma	Total	Neutrons	Gamma	Total
60	0.288	0.896	1.184	0.117	0.502	0.619
80	**0.022**	**0.104**	**0.126**	**0.021**	**0.064**	**0.085**
100	0.002	0.011	0.013	0.001	0.008	0.009

***Relative errors of the neutron / photon dose rates are ~ 20 %.**

MCNP results … cont

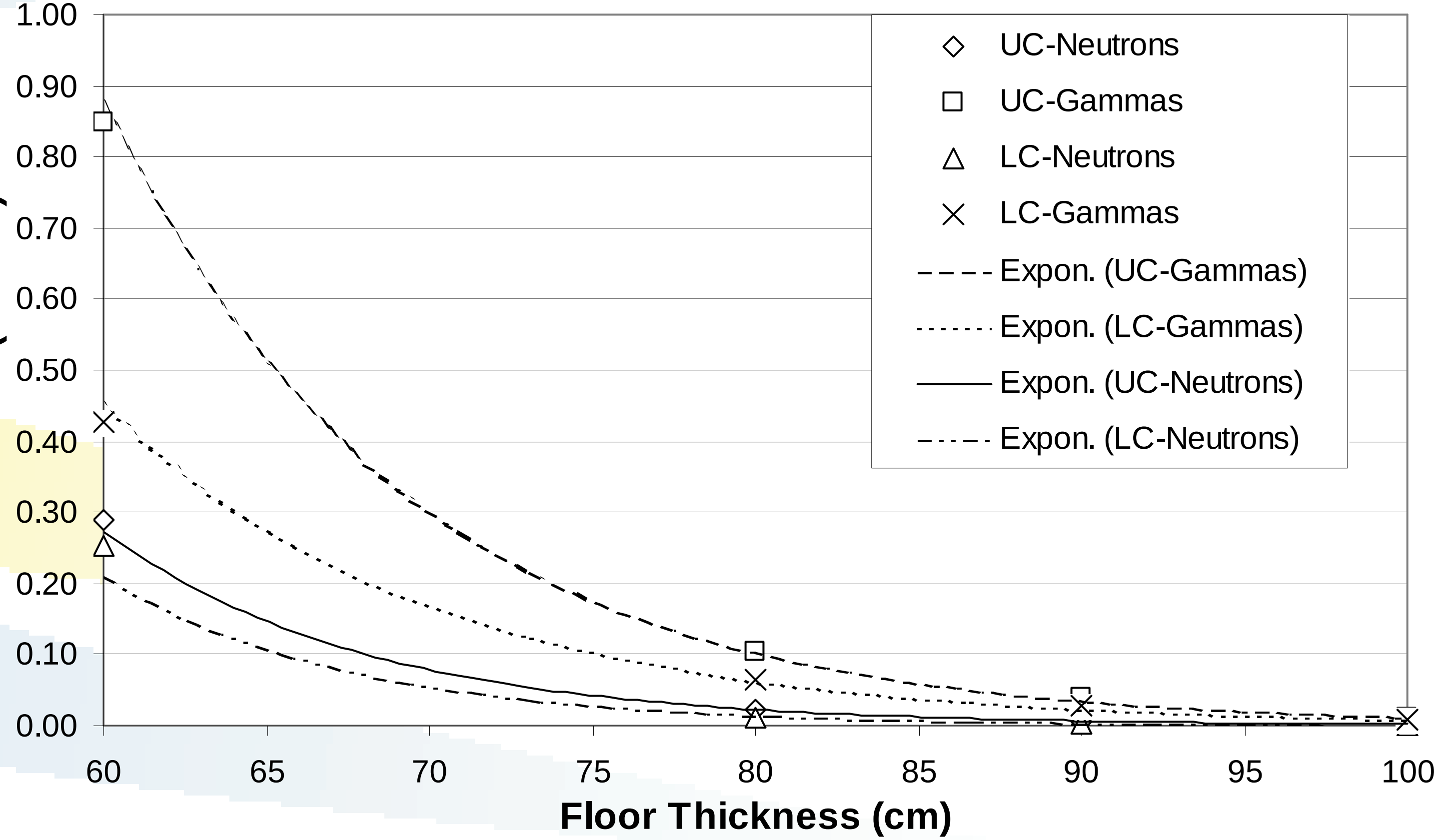
Table 3: The percentage contribution to total dose by neutron streaming in the defuel tubes (Part 2 of Method 1).

Floor Thickness cm	% contribution to the total dose from neutron streaming in defuel chutes.					
	Upper Cavity			Lower Cavity		
	Neutrons	Gamma	Total	Neutrons	Gamma	Total
60	**0.05**	**0.04**	**0.04**	**0.034**	**0.014**	**0.021**
80	**0.74**	**0.29**	**0.36**	**0.817**	**0.091**	**0.193**
90	**2.66**	**0.77**	**1.02**	**2.590**	**0.212**	**0.469**
100	**7.40**	**2.72**	**3.48**	**6.965**	**0.774**	**1.647**

The observed small contribution to the total dose by neutrons streaming from the defuel tubes is attributable to the high content of Fe in the Defuel chute tubes (~96 wt% Fe)

MCNP results … cont

Figure 1: Dose rates in the CUD region as a function of floor thickness (Table 1).



Conclusions and Discussions

- The natural Fe used for defuel tubes is an efficient shielding to most neutrons in the defuel tubes.
- Due to the above point, both methods used in this work yielded similar results.
- Either of the two methods can thus be used in determining fluxes for machine activation.