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# Modelling of Multilayer Shielding Scenario for High Energy Neutron Accelerator Based using PHITS

**Fitrotun Aliyah[a,b], Azhar Abdul Rahman[a], Yasmin Md Radzi[a], Imam Kambali[c]**

[a]*School of Physics, Universiti Sains Malaysia, Minden, Penang, Malaysia*
[b]*Department of Nuclear Engineering and Engineering Physics, Universitas Gadjah Mada, Sleman, Yogyakarta, Indonesia*
[c]*Center for Research and Technology of Accelerator, National Research and Innovation Agency, Sleman, Yogyakarta, Indonesia*

**Coresponding author:arazhar@usm.my**

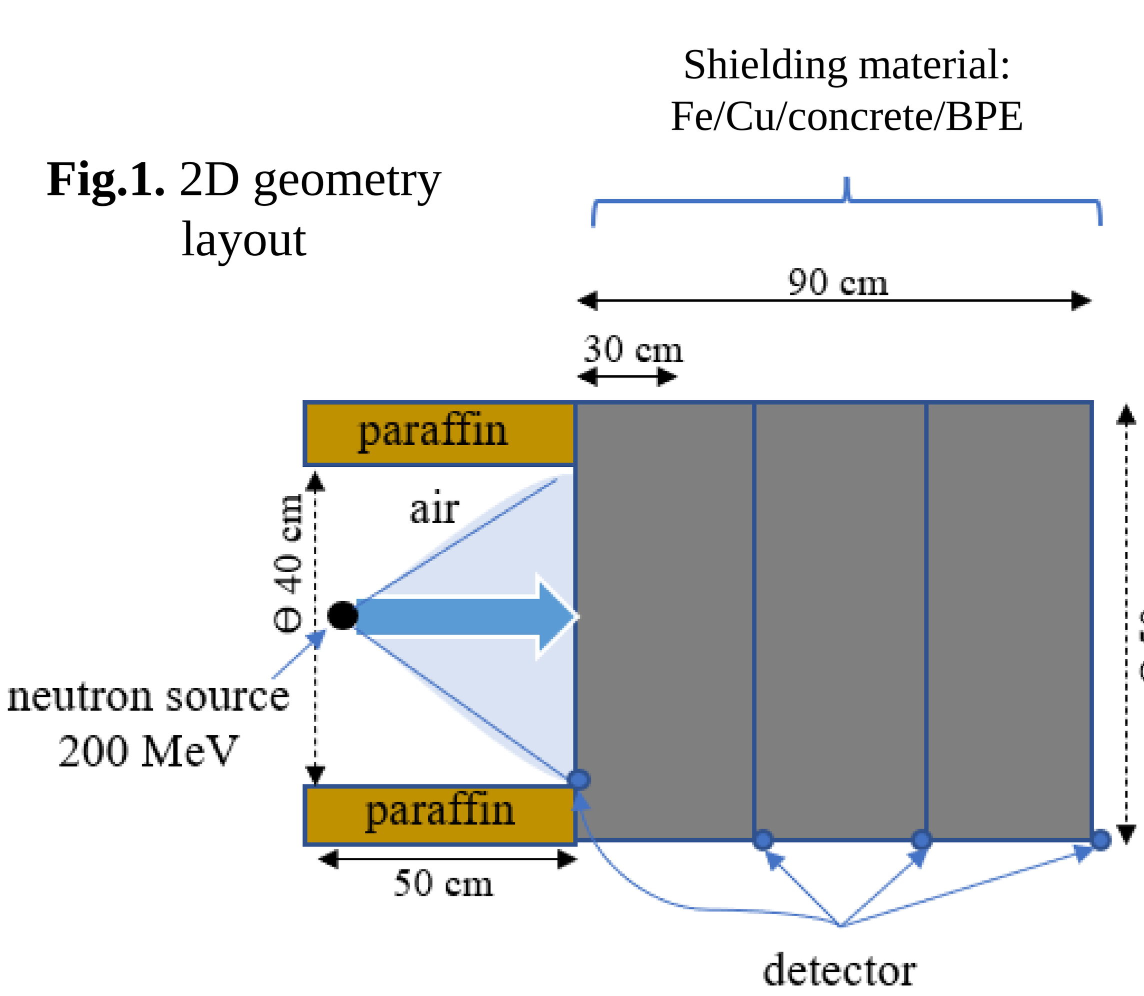
UNIVERSITI SAINS MALAYSIA

**Abstract.** Neutron shielding calculations have complex challenges that require conservative planning in designing shielding to meet radiation protection standards. So far, hydrogenous materials such as concrete, water, and polyethylene have been chosen to against neutron radiation. However, in high energy neutron sources, the use of these materials will require a very thick shielding design so that it has an impact on increasing the footprint and cost requirements. Therefore, in this paper, a multi-layer shielding scenario will be modelled for high energy neutron sources using metal and hydrogenous materials such as Fe, Cu, concrete, and borated polyethylene. Parameter data from simulation results are distribution of neutron flux, spectrum energy, neutron depth dose, and ambient dose H*(10) equivalent. The simulation results show that Cu has the best effectiveness in attenuating high energy neutrons even though it has the highest build-up factor value. Meanwhile, the multilayer combination of Fe-Fe-BPE and Fe-concrete-BPE provides the best choice compared to other material combination scenarios with the lowest flux values and ambient dose H*(10) equivalent.

**Keywords:** *neutron shielding, multi-layer shielding, PHITS, Monte Carlo*

**Methodology.** This research was conducted through a Monte Carlo simulation using the Particle Heavy Ion Transport Code System (PHITS). The 2D design of geometry is shown in Fig.1, and the programming flow is illustrated in Fig.2. The materials used are Fe (7.7 g/cm$^3$), Cu (8.96 g/cm$^3$), concrete (2.2 g/cm$^3$), and Borated Polyethylene (0.94 g/cm$^3$). A neutron source with an energy of 200 MeV is placed at 50 cm from the shielding material. Paraffin is used as a neutron beam collimator medium. The number of particles in this simulation is $10^6$, with maxcas $10^5$ and maxbch $10^1$. The simulation error is below 2%.

**Fig.1.** 2D geometry layout



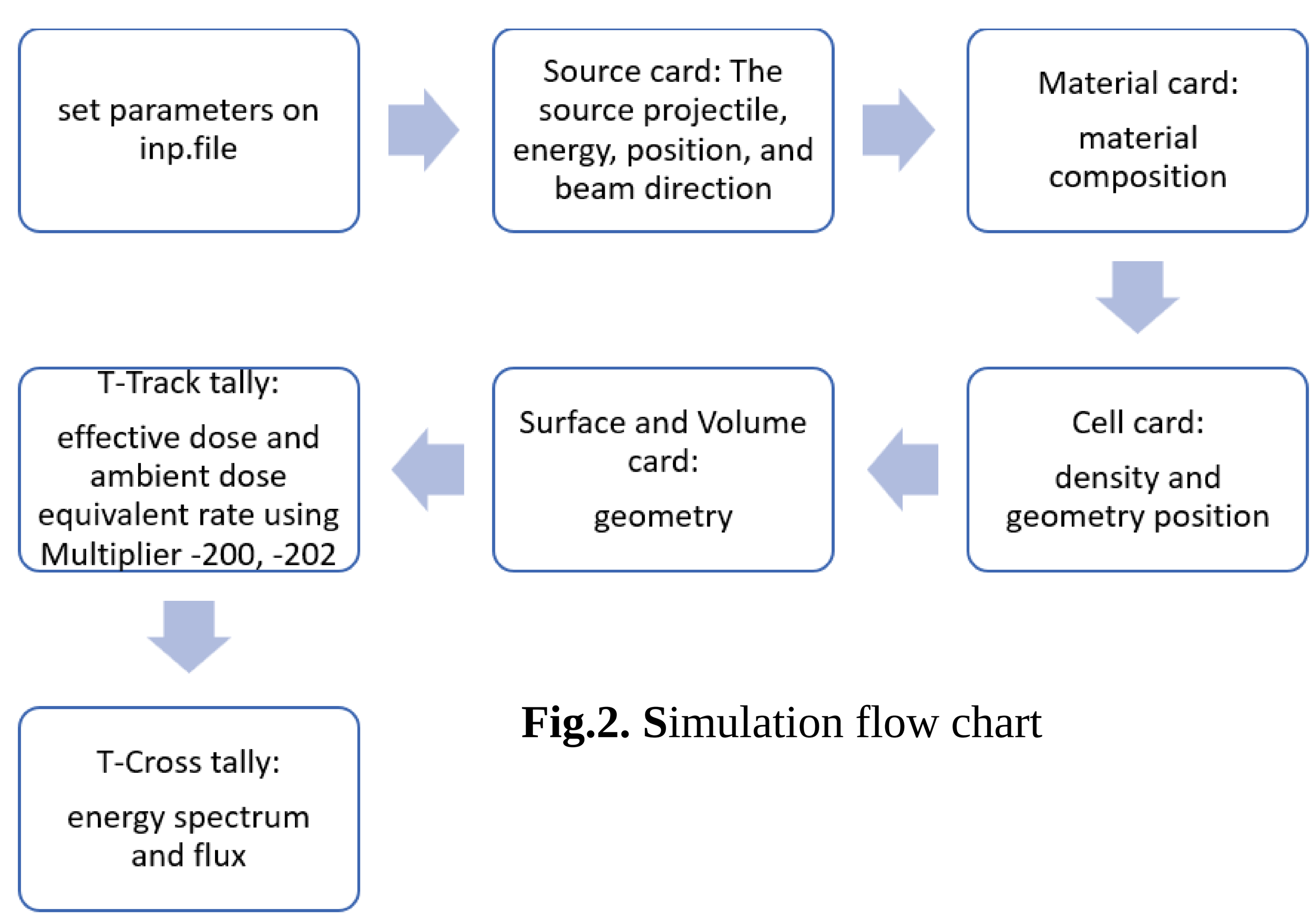
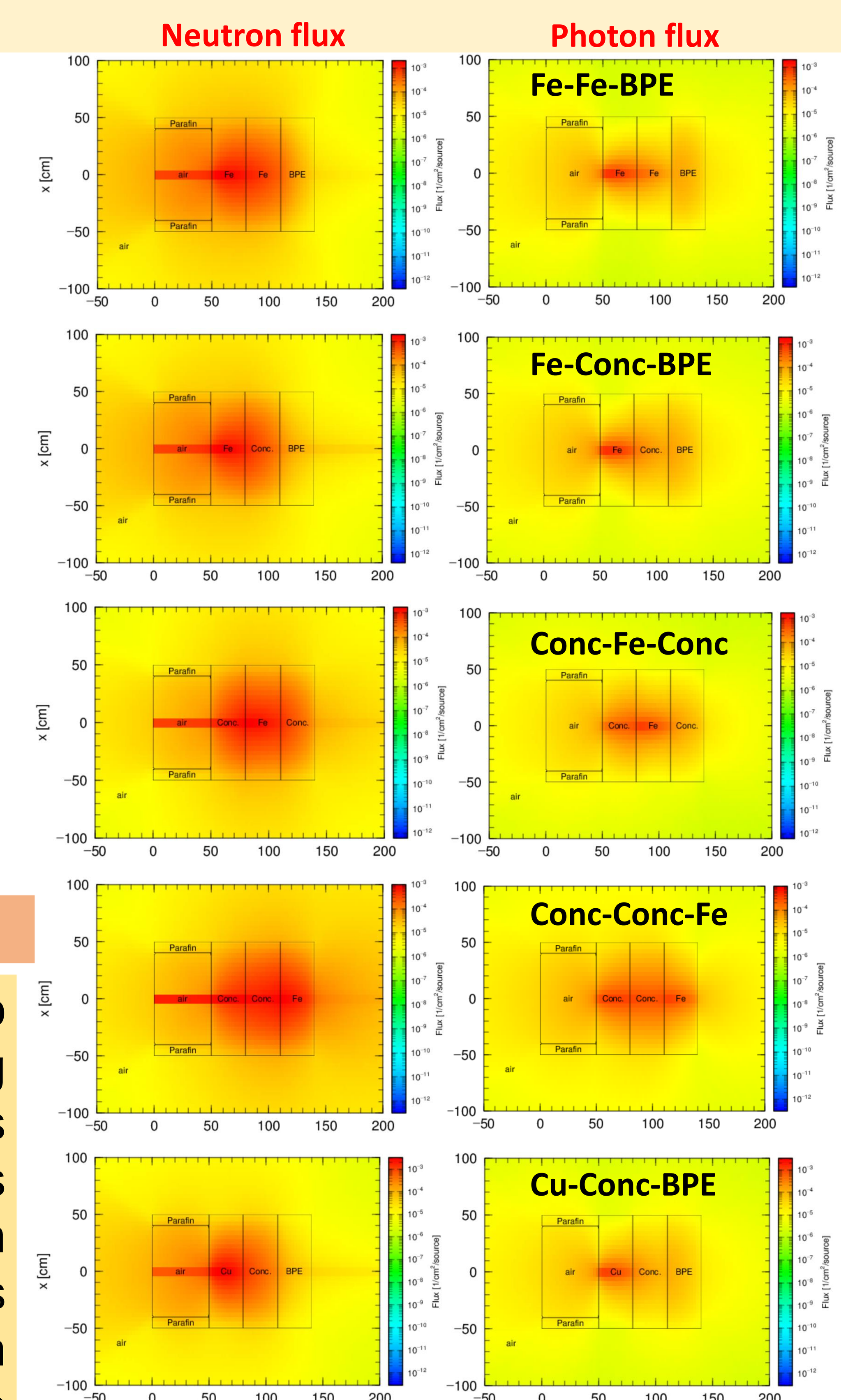




**Fig.2.** Simulation flow chart




## Main Findings

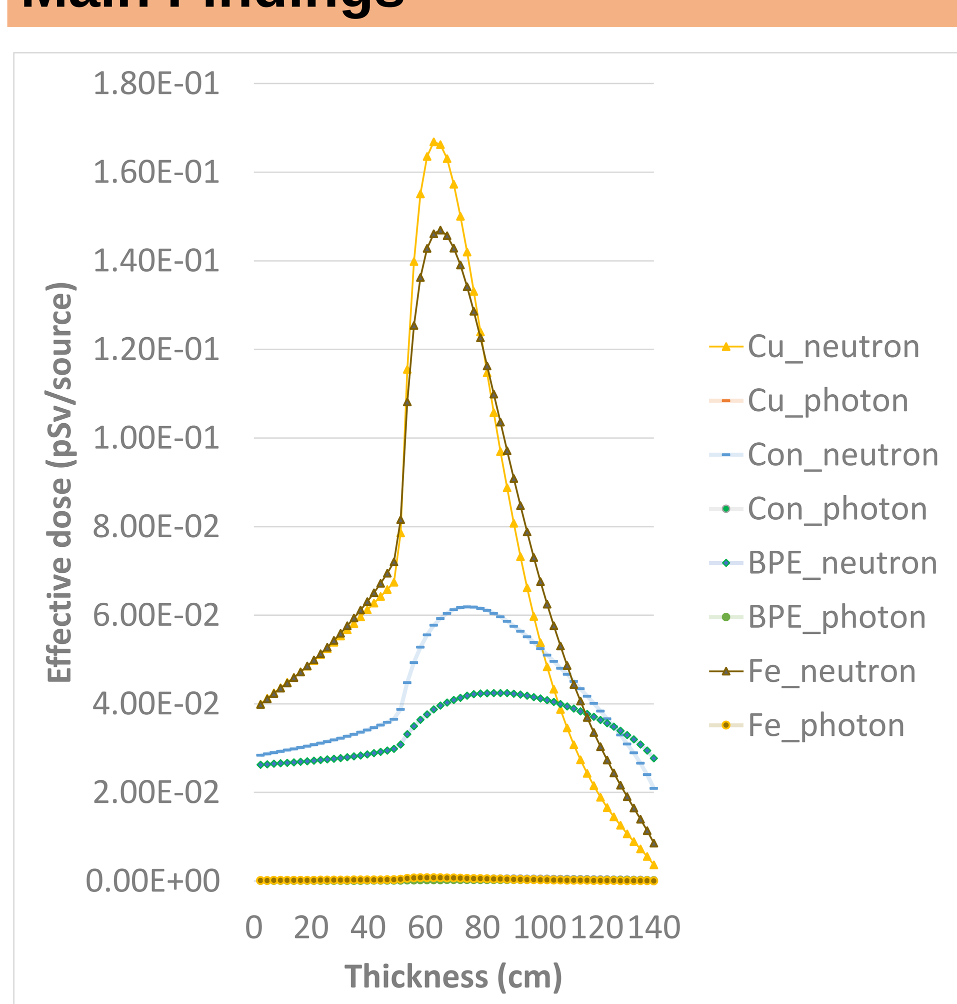



**Fig.3.** Effective dose in shielding depth

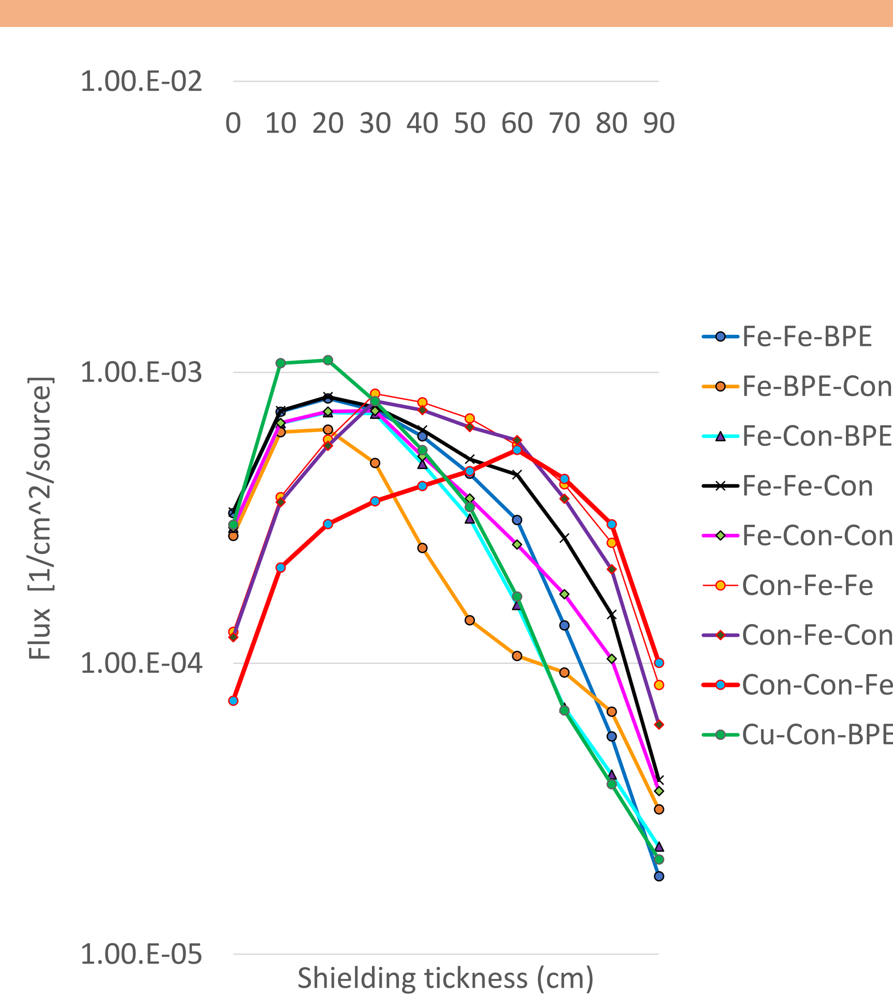



**Fig.4.** Flux distribution in depth

Multilayer shielding is a concept to optimize the radiation shielding function. This simulation shows that the multilayer combination's material structure composition dramatically affects the shielding's effectiveness. Cu material can attenuate high-energy neutrons better than Fe but has a higher buildup factor value. However, the multilayer simulation scenario shows that the composition of Fe-Concrete-BPE is better than Cu-Concrete-BPE with a smaller Flux value and ambient dose.

| Material | H*(10) (pSv.cm²) |
|---|---|
| Fe-Fe-BPE | 4.98E-03 |
| Fe-BPE-Concrete | 1.07E-02 |
| Fe-Concrete-BPE | 8.19E-03 |
| Fe-Fe-Concrete | 6.02E-03 |
| Fe-Concrete-Concrete | 9.30E-03 |
| Concrete-Fe-Fe | 2.48E-02 |
| Concrete-Fe-Concrete | 1.23E-02 |
| Concrete-Concrete-Fe | 3.58E-02 |
| Cu-Concrete-BPE | 1.62E-02 |
| Conc-Conc-Concrete | 1.96E-02 |

## Conclusion

Multilayer shielding design for high energy neutron accelerator has been successfully simulated using PHITS. Fe-concrete-BPE and Fe-Fe-BPE have the lowest flux and ambient dose values compared to other material combination scenarios. Multilayer shielding Fe-concrete-BPE (100-150-30) cm is equivalent to 455 cm of shielding concrete, or 38.5% lower than conventional shielding thickness.