# Effects on modern microprocessors and method of shielding from neutron irradiation in photon therapy vaults

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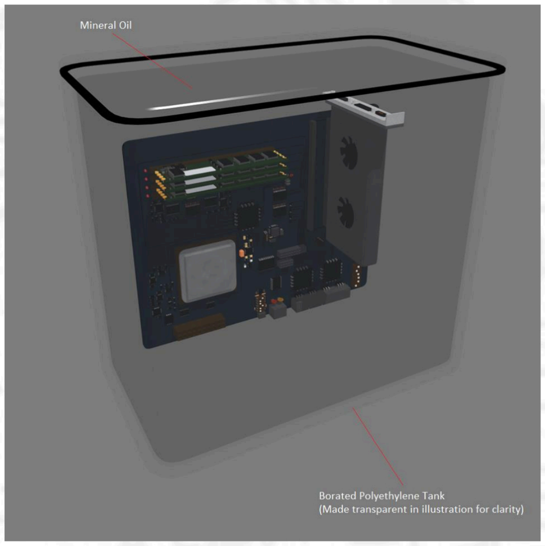
## Purpose

To quantify and reduce frequency of neutron induced single event CPU-errors in photon treatment vaults and develop affordable and effective neutron shielding for high-performance computing in radiation treatment rooms.

## Materials and Methods

- Computers used Intel Core2Duo 65nm CPUs and NVIDIA QuadroNVS 295 graphics cards.
- They were placed in the treatment room ~3.21m from LINAC, out of beamline, and left running for exposure to neutron irradiation for 24 months.
- Nominal photon beams of 18MV and 6MV delivered 621,984MU and 4,122,374MU, respectively. Neutron induced errors were recorded during exposure.
- Computer stability was tested for 6 hours per 90 days.
- Geant4 simulation approximated the reduction in thermal and epithermal neutron flux for a CPU shielded with 60x100x100cm3 borated polyethylene tank filled with mineral oil.
- Simulated 232 MeV proton induced neutrons were then introduced into the environment (approximately 10 cubic meter) and directed towards the shielded CPU.
- Testing of temperature and stability of computer with and without oil was done using AMD Ryzen7 3700X and NVIDIA 1070GTX under maximum load.




**Experiment Setup**

## Results

- CPU core errors were induced by neutron exposure resulting in unrecoverable OS crash.
- Average rate of errors/MU was $8.039 \times 10^{-5}$ at 18X
- Average rate of errors/MU was 0 at 6X.
- Shielding simulation resulted in a neutron flux of 4.66% of unshielded flux.
- No additional core errors were observed on any system when left running for 30 days after irradiation.
- Testing of computer temperature and stability resulted in rapid overheating of system without oil.
- Ambient temperature under load reached 77.4C with significant loss of stability and consistent crashes noted above 70C.
- When submerged in oil temperature increase reached a maximum of 51.4C after six hours.
- No system instability was observed at this temperature.

## Conclusion

Computer systems in treatment room environments experience stochastic errors due to neutron irradiation causing system instability. High performance and modern computer are more susceptible. Standard shielding using only borated polyethylene resulted in overheating. Combining borated polyethylene with mineral oil resulted in a stable system. Simulation of neutron flux reduction of this shielding configuration in Geant4 demonstrated a greater than 95% reduction in thermal and epithermal neutron flux.

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