Quantitative Evaluation of using VeriShield® shielding modules to address the problem of the decommissioning of Proton Therapy facilities

PTCOG 61
MADRID 2023

El Hassane Bentefour, PhD. - Director of Physics
Hassane.bentefour@veritasmedicalsolutions.com
Robert J. Farrell , CEO

Department of Physics of Radiation Shielding and Radioprotection
Veritas Medical Solutions, Harleysville, PA USA
www.veritas-medicalsolutions.com

veritas Medical Solutions

INTRODUCTION

The decommissioning of a proton therapy facility is challenging due to neutron-induced activation of the facility shielding, structure, and equipment. Activation is caused by a series of nuclear reactions that produce radioactive isotopes with half-lives ranging from hours to many years. Long-lived isotopes, such as ^{152}Eu, ^{133}Ba, ^{134}Cs, ^{60}Co, and ^{22}Na, commonly present in concrete, are particularly problematic because, in addition to their long half-life, they require very low Clearance Index (CI) to qualify as non-nuclear waste.

AIM

To review the neutron shielding attenuation characteristics of VeriShield, a high-density, engineered shielding material. Then, to explore the extent of neutron activation for these modules when made with different proportions of cement, reduced to just 2%.

METHODS

Review of VeriShield® Neutron Attenuation:

We have studied more than a half dozen different Veritas shielding materials utilizing a thin, copper target as a source of neutrons as it was bombarded by 230 MeV protons. A WENDI neutron detector, operated in integration mode, was shielded from 5 sides by a specially constructed, shielded cave with one side open to detect neutrons from the source at a set angle as they passed through the shielding stack. Some of the materials in the study featured both high-density elements in combination with special additives designed to increase their attenuation efficiency.

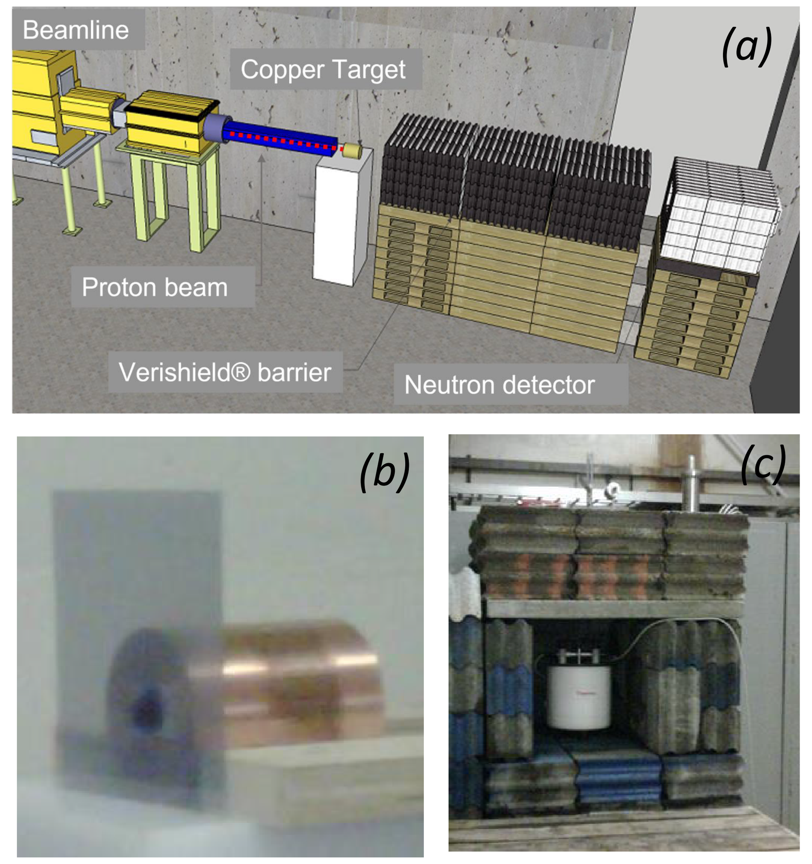

***Figure 1**: (a) Sketch of test set-up, (b) signature of clinical proton beam on a copper target, (c) Neutron detector shielded from bouncing neutrons on vault's walls, (d) Typical structure of VeriShield® barrier.*

Addressing Proton Therapy's Neutron Activation Issue:

In order to minimize the proton therapy's neutron activation issue, we experimented with two approaches:

(i) Creating a new generation of VeriShield that uses low cement content and alternative binding agents.

(ii) Exploring the practicality of the company's sacrificial layer concept to increase the longevity of proton therapy facilities.

RESULTS

Verishield Shielding Compared to Concrete

The experimental results, supported by Monte Carlo calculations; as illustrated in Fig. 2a, 2b, 2c, and 2d, show that the VeriShield barrier has a higher cumulative shielding efficiency compared to concrete. This cumulative efficiency, along with the shielding depth increases as the proton beam energy (i.e., neutron energy) increases. Per Figure 2d, One can see that for a 230 MeV clinical proton beam, one would need 6.4 feet of VeriShield V300 to reduce the neutron dose down to 0.01% compared to 10.7 feet of concrete. Thus, a savings of about 40% of space would otherwise be covered by mass concrete if used for the shielding.

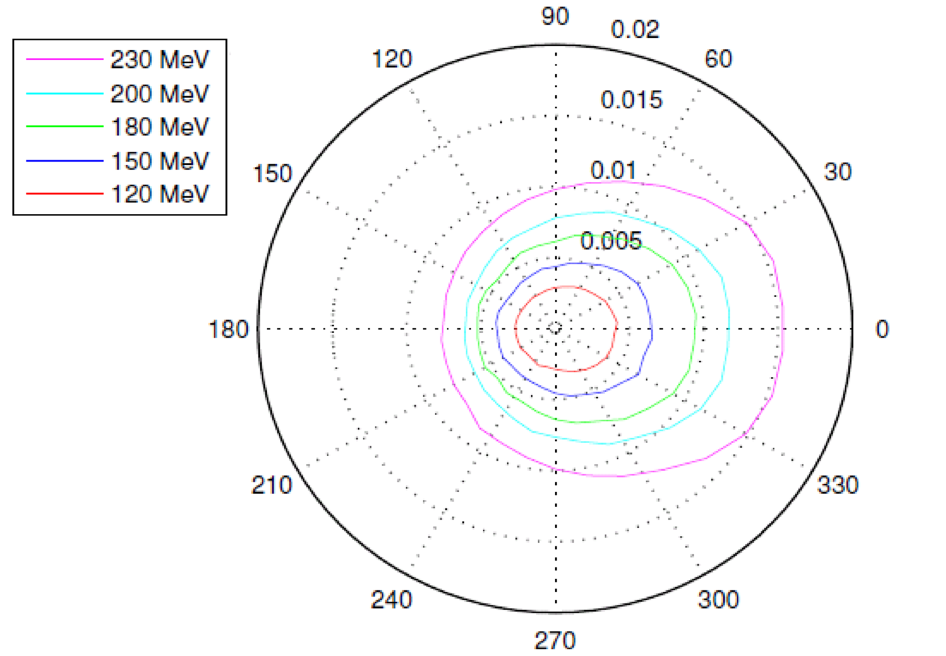

Fig. 2a: *Angular distribution of emitted neutron from copper target under proton beam irradiation*

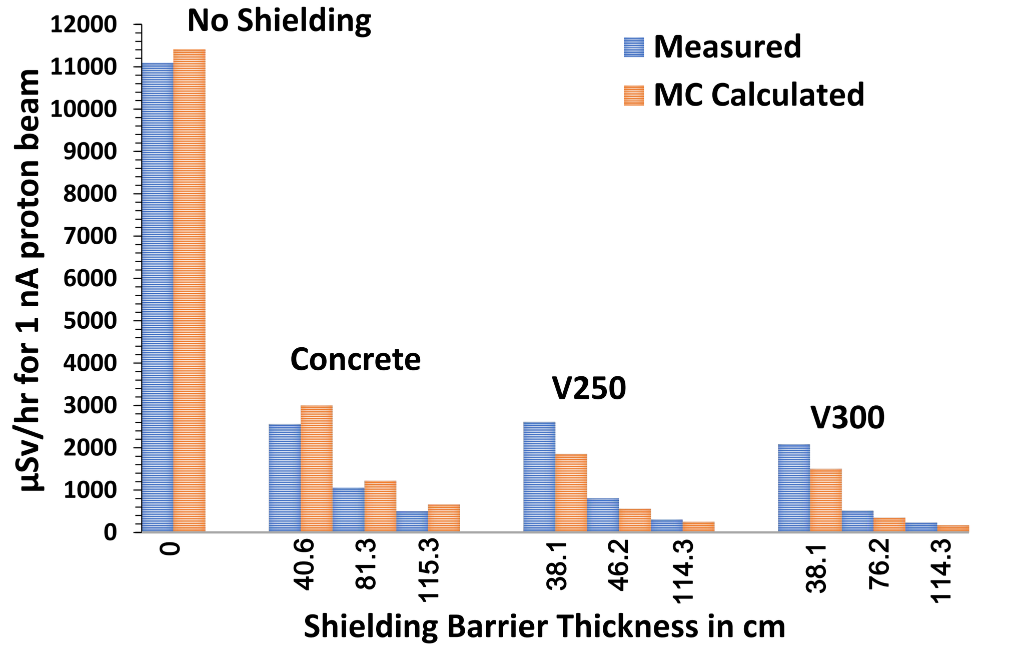

Fig. 2b: *Neutron attenuation by various thicknesses of concrete and VeriShield barriers at 200 MeV beam*

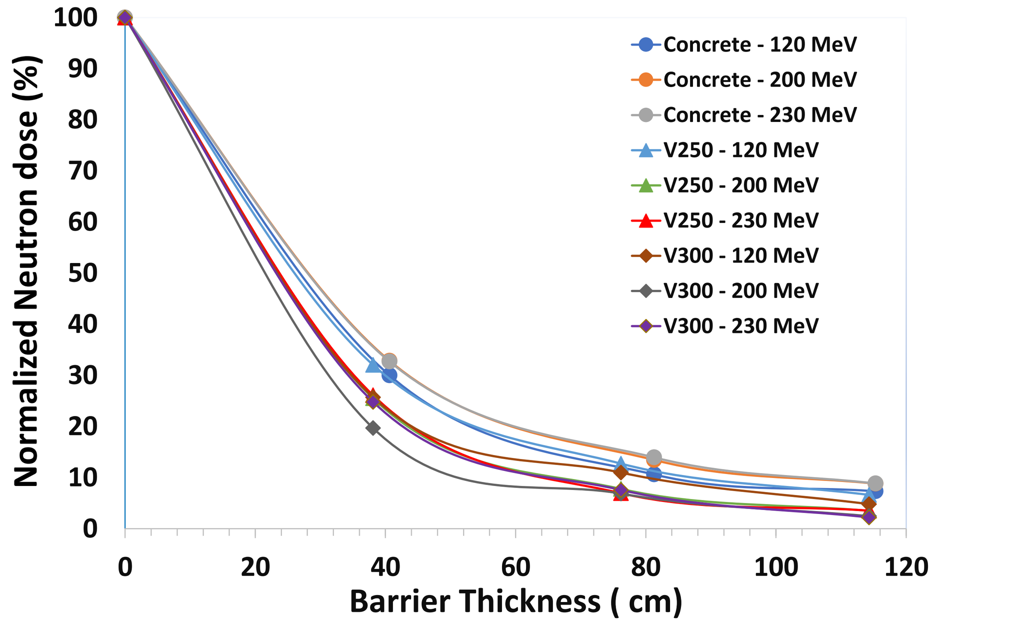

Fig. 2c: *Experimental results for various beam energies*

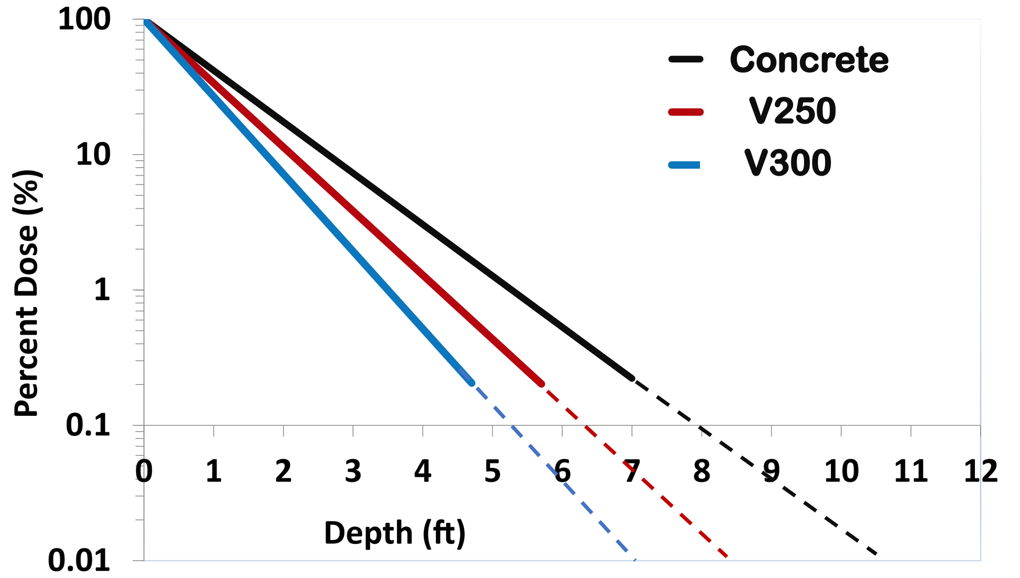

Fig. 2d: *Average Neutron shielding power of VeriShield at 230 MeV clinical proton beam*

VeriShield and Neutron activation

A new generation of VeriShield using an alternative binding agent with minimal content of cement, only 3% (77% less than in the current VeriShield has been developed. Fig. 3a shows a few samples with cement content varying from 5% down to 0%. With these new modules, the long-term activation problem is significantly reduced as the presence of long half-life elements such as ^{152}Eu, ^{133}Ba, ^{134}Cs, ^{60}Co and ^{22}Na is practically nonexistent.

Monte Carlo activation studies have been conducted on VeriShield modules and concrete. The preliminary results, in Fig. 3b, show similar neutron activation to concrete, but with two advantages:

- The current VeriShield has the advantage to be used as a sacrificial layer as it is a dry build that enables barriers to be selectively removed and replaced.
- The new VeriShield module presents the promise of reduced long-term activation issues. Additional studies are warranted.

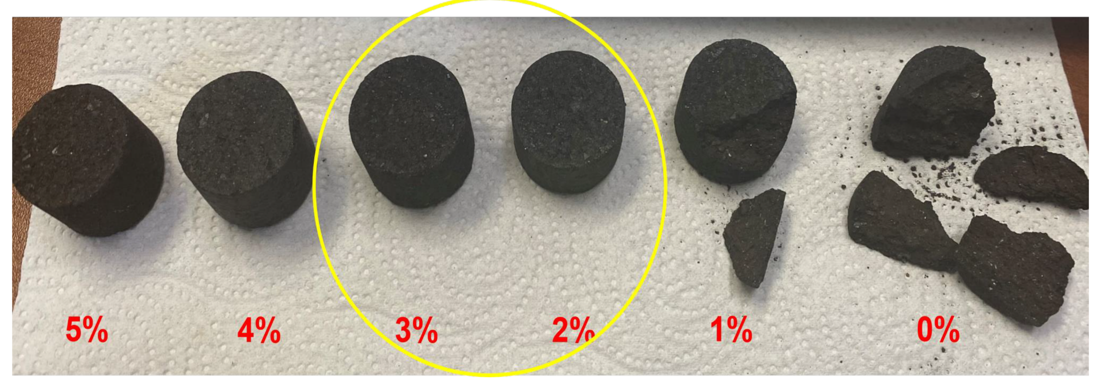

Fig. 3a: *consistency of VeriShield samples made with low concentration of cement and alternative binding agent*

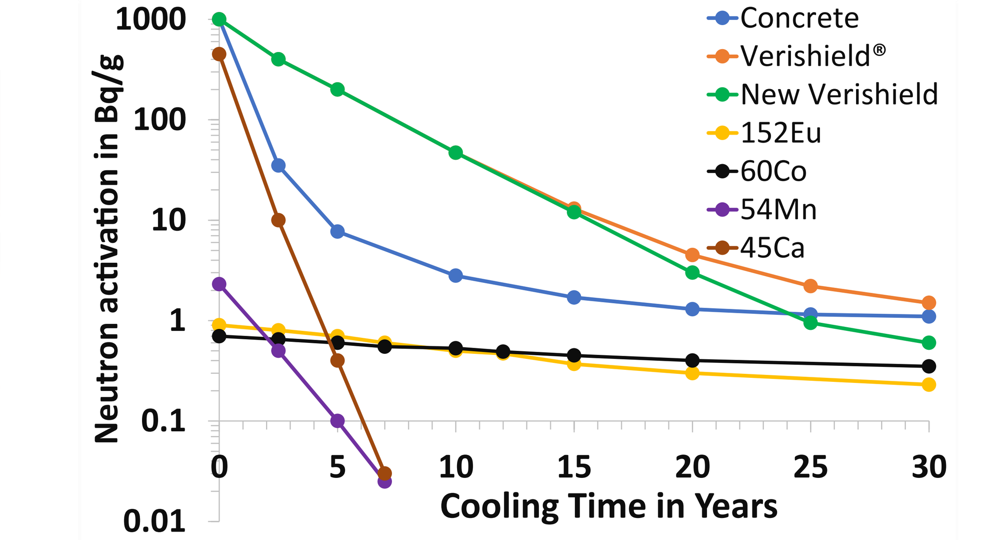

Fig. 3b: *Projected Cooling time from Neutron activation*

CONCLUSIONS

VeriShield is a means to save space and time when designing a proton therapy facility as it offers a higher degree of shielding efficiency against neutrons. In contrast to mass concrete, it allows for better management of neutron activation as it can be used as a shielding sacrificial layer. A new prospective generation of VeriShield which uses an alternative binding agent to cement is likely to improve its actual performance and suitability for proton therapy.

REFERENCES

1. Experimental data from Veritas-MIT VeriShield® testing report, V. Nazaryan et al. Unpublished.
2. Tomaž Žagar, Matjaž Ravnik, "MEASUREMENT OF NEUTRON ACTIVATION IN CONCRETE SAMPLES". Int. conference, Nuclear Energy in Central Europe 2000