Neutron coincidence Counter Based on Boron-Coated Straws

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Computer models of a neutron coincidence counter based on a distributed array of boron-coated straw (BCS) detectors have previously shown that the BCS can successfully replace ^{3}He tubes in existing commercial counter designs, while maintaining overall dimensions[11]. A full-scale, fully operational prototype to replace the High Level Neutron Coincidence Counter (HLNCC-II) has been fabricated and tested at the 3He Alternatives for International Safeguards Workshop that took place at the JRC in Ispra, Italy, in October 2014. The prototype, pictured in Fig. 1, has overall and cavity dimensions identical to those of the HLNCC-II, and weighs135 lbs, only 14 lbs heavier than its 3He-based counterpart. It is populated with 804 BCS detectors, each 4.4 mm in diameter, and lined with 2-μm of vapor-deposited 10B4C. The straws, pictured in Fig. 2 prior to assembly, are uniformly distributed in the moderator, as illustrated in Fig. 3. They are connected together in 6 groups of 134, each read out with a custom-designed amplifier, fully compatible with a standard shift register.

Despite the large number of detector elements, fabrication is facilitated by a series of BCS production enhancements and automations, including a high-yield, continuous operation, reel-to-reel boron coating process. At the same time, new sealing methods guarantee reliable operation over many decades, comparable to other sealed proportional counters.

Measurements of performance parameters collected at the workshop, including detection efficiency, ε, and neutron dieaway time, τ, are summarized in Table 1. Results demonstrate that the BCS-based counter achieves better performance than the standard 3He-based HLNCC-II, also tested at the workshop. The Figure-of-Merit (FOM) defined as $\varepsilon/\sqrt{\tau}$, that reflects thermal neutron coincidence precision, equals 2.66 %/√μs, an improvement over the 3He-based counter, due to the significantly lower die-away time. The latter is attributed to the more uniform dispersion of neutron absorber throughout the moderator. Other counters based on different replacement technologies, including 6LiF-doped scintillators, and conventional boron-lined tubes, did not reach the same level of performance (see Table 1), partly because of incomplete geometries.

In conclusion, a full-scale neutron coincidence counter, based on reliable, low-cost boron-coated straw detectors, was shown capable of successfully replacing the standard 3He-based system, in a compact geometry, fully compatible with existing electronics and procedures.

Table 1. Performance parameters measured at the Workshop for different replacement technologies.

	^{3}He HLNCC	*Straw HLNCC*	^{6}LiF-based HLNCC ("1/4 populated")	Boron-lined HLNCC ("not optimized")
Efficiency (ε)	16.5%	*13.6%*	8.9%	10.2%
Die away time (τ)	43.3 μs	*26 μs*	56 μs	65 μs
FOM (ε/√τ)	2.51	*2.66*	1.19	1.26

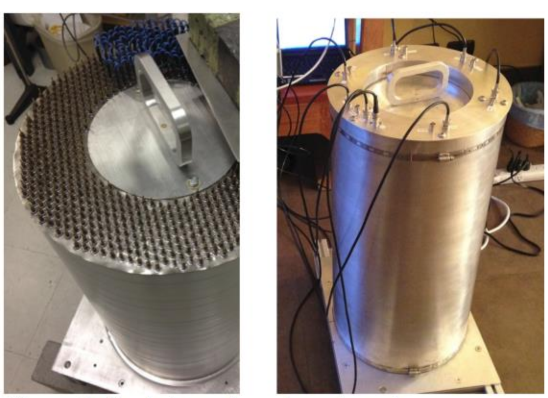

Figure 1. Prototype straw-based neutron coincidence counter.

Figure 2. Sealed boron-coated straw detectors.

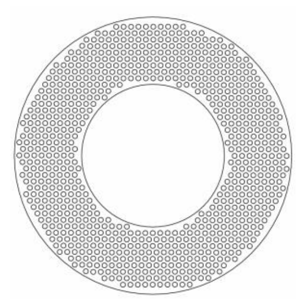

Figure 3. Cross sectional drawing of moderator showing 804 holes, to accommodate an equal number of BCS detectors.

[1] J. L. Lacy, A. Athanasiades, C. S. Martin, L. Sun, and G. J. Vazquez-Flores, "Design and Performance of High-Efficiency Counters Based on Boron-Lined Straw Detectors", INMM Annual Meeting, July 15-19, 2012, Orlando, FL.