

Neutron Detection

Thermal and fast neutron sensitivity in a single detector.
ScintIQ scintillators based on CLYC, CLLBC, and 6Li-glass
enable neutron counting and gamma spectroscopy
simultaneously, without the supply constraint of helium-3.

APPLICATION BRIEF · SCINTIQ™ CUSTOM SCINTILLATION
DETECTORS · dc-62022201



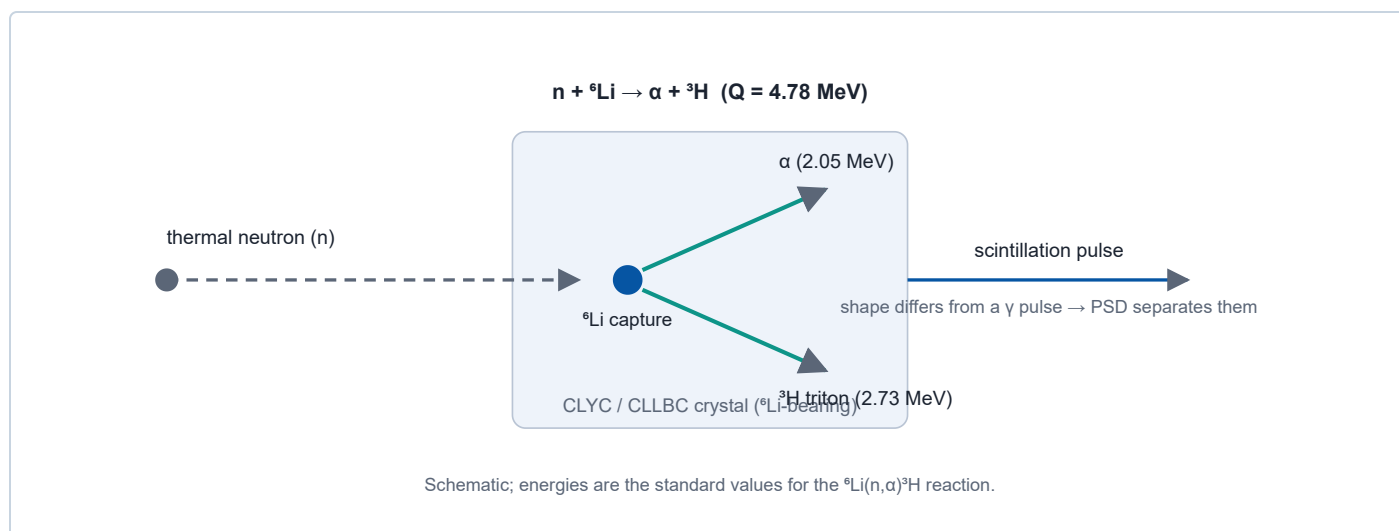
ScintIQ scintillation detector assemblies
with integrated photomultiplier tubes.

The Challenge of Neutron Detection

Neutrons carry no charge. They pass through most materials unimpeded and interact only via nuclear reactions, which makes their detection fundamentally different from gamma or charged-particle measurement. The detector cannot collect ionization directly in the conventional sense. Instead, the neutron must first be converted to a secondary particle, charged ion, or gamma photon that a scintillator can respond to.

For decades, helium-3 (He-3) proportional counters were the default solution for thermal neutron detection. They are sensitive, reliable, and selective. The problem is supply: He-3 is a scarce byproduct of tritium decay, and its cost and availability have constrained detector programs across homeland security, nuclear safeguards, and research. Solid scintillator alternatives now carry the neutron channel in fielded identifiers and portal monitors, and they are manufacturable at scale.

A second challenge is the field environment. Most neutron sources of practical interest (special nuclear material, reactor-adjacent positions, cosmic-ray spallation products) are accompanied by intense gamma backgrounds. A neutron detector that cannot reject gamma events reliably will saturate in those environments. Pulse-shape discrimination (PSD) is the principal tool for separating neutron and gamma signals in a single detector, and the crystal's intrinsic scintillation physics determines how cleanly PSD works.



■ SCHEMATIC Figure 1. The ${}^6\text{Li}(n,\alpha){}^3\text{H}$ capture reaction that gives CLYC and CLLBC their neutron response. The charged products deposit 4.78 MeV locally, and the resulting pulse shape is what PSD separates from gamma events.

ScintIQ Materials for Neutron Detection

Berkeley Nucleonics offers three ScintIQ crystal families suited to neutron work. Each brings a distinct tradeoff among sensitivity, energy resolution, PSD figure of merit, and environmental robustness.

CLYC ($\text{Cs}_2\text{LiYCl}_6\text{:Ce}$)

Dual-mode neutron and gamma detection. Excellent PSD separation. Fast components at 1 ns and 50 ns; slow component near 1 microsecond. Density 3.31 g/cm³. Hygroscopic, requires hermetic housing. Emission peak at 370 nm, PMT or SiPM compatible.

CLYC Data Sheet

CLLBC ($\text{Cs}_2\text{LiLaBr}_{4.8}\text{Cl}_{1.2}\text{:Ce}$)

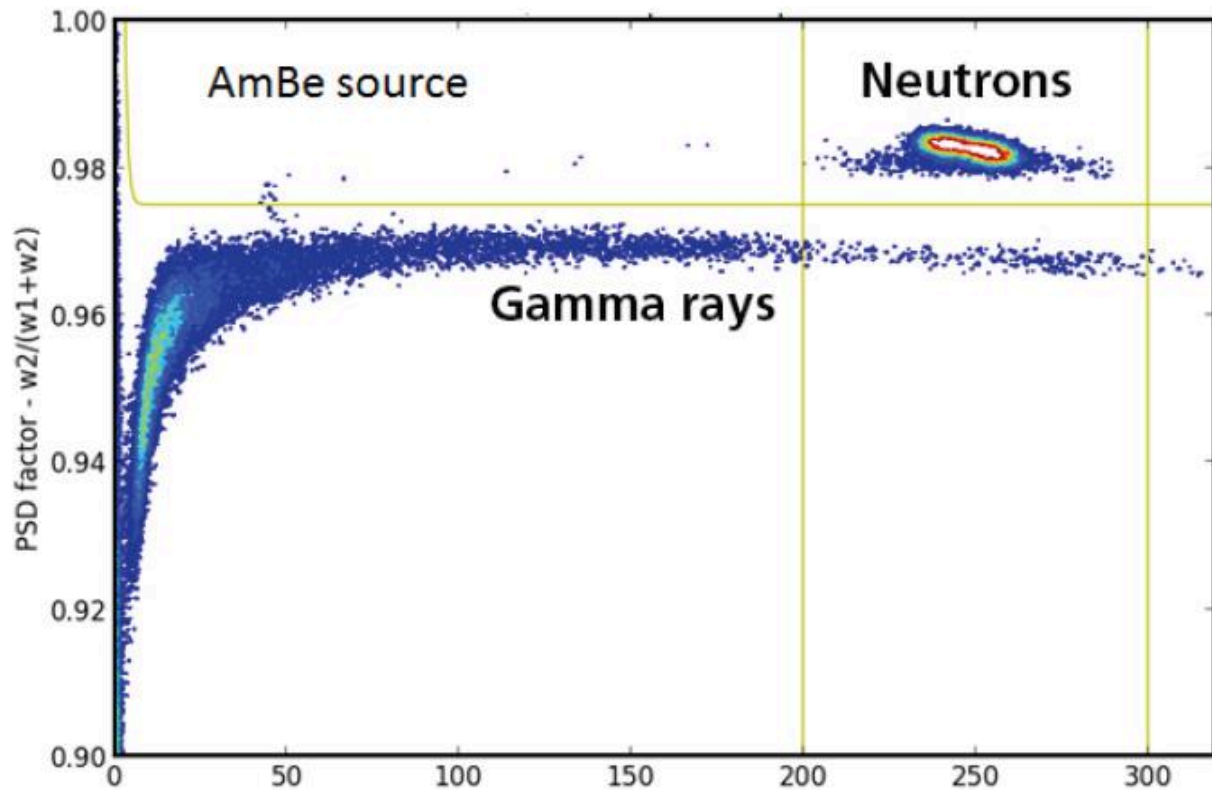
High-resolution dual-mode neutron and gamma detection. Higher photoelectron yield (70 percent of NaI(Tl)) than CLYC and energy resolution under 3.5 percent at 662 keV. Density 4.08 g/cm³. Decay components at 120 ns and 500 ns, about 150 ns average. Hygroscopic. Emission peak at 420 nm, well matched to bialkali PMTs and SiPMs.

CLLBC Data Sheet

6Li-glass

Thermal neutron detection via the ${}^6\text{Li}(\text{n},\alpha){}^3\text{H}$ reaction. Non-hygroscopic, mechanically rugged, decay 60 to 75 ns. Density 2.5 to 2.6 g/cm³. Low relative light yield (4 to 6, NaI(Tl) = 100) but a high thermal neutron cross section. No hermetic housing required.

6Li-glass Data Sheet



■ **MEASURED** **Figure 2.** CLYC pulse-shape discrimination with an AmBe source, from the CLYC datasheet. The PSD factor $w2/(w1+w2)$ is plotted against pulse height; gamma events form the lower band and neutron events the separated upper cluster, because gamma interactions excite the crystal's ultrafast core-valence luminescence and the alpha and triton from neutron capture do not.

Thermal vs. Fast Neutrons: What Each Material Provides

Thermal Neutron Detection

Thermal neutrons (energies below ~ 0.5 eV) react efficiently with ^6Li via the reaction $^6\text{Li} + n$ produces alpha + triton, releasing 4.78 MeV of kinetic energy. Both CLYC and CLLBC contain lithium enriched in ^6Li , giving them high thermal neutron detection efficiency. ^6Li -glass shares the same nuclear reaction and adds the option of position-sensitive detector arrays: thin glass tiles can be stacked or arranged to cover large areas with no hermetic packaging requirement.

In practice, a thermalized moderator (polyethylene shielding around the detector) increases thermal neutron flux at the crystal face and improves detection efficiency for fast-neutron sources such as Cf-252 or plutonium. The moderator design is application-specific and is discussed in the neutron-gamma discrimination technical note referenced below.

Fast Neutron Sensitivity

Fast neutrons (MeV range) interact differently. There is no hydrogen in the crystal, so there are no recoil protons; in CLYC the fast-neutron response comes from the $^{35}\text{Cl}(n,p)^{35}\text{S}$ reaction, which deposits the proton energy in the crystal and gives an energy-dependent response that the CLYC datasheet lists as fast neutron detection via Cl-35. CLLBC, with bromine in place of most of the chlorine, has a smaller fast-neutron response and relies on moderation. Fast-neutron events appear at intermediate PSD values and are separated by gating or by moderating them to thermal energies first.

For instruments that need some intrinsic fast-neutron sensitivity without a moderator, CLYC is the ScintIQ option. CLLBC and 6Li-glass are thermal-neutron materials that need moderation for a fast-neutron source.

Gamma Spectroscopy Alongside Neutron Counting

One of the most important attributes of CLYC and CLLBC is that they deliver usable gamma energy resolution in addition to neutron detection. CLLBC achieves gamma energy resolution under 3.5 percent at 662 keV, about half the NaI(Tl) figure, with the added capability of neutron discrimination. This makes a single detector head sufficient for both isotope identification and neutron threat detection, which matters for handheld RIID instruments and portal monitors where size, weight, and cost all constrain the system.

The practical result: a CLLBC detector can identify Cs-137 and Co-60 peaks in a gamma spectrum while simultaneously flagging neutron counts above a threshold, without separate detector modules. The same readout electronics handle both channels.

Typical Applications

- **Radiological Identification Devices (RIIDs):** CLYC and CLLBC are established materials for handheld and backpack-carried instruments requiring combined neutron and gamma identification. Replacing He-3 tubes with a scintillator crystal reduces volume and eliminates pressurized-gas handling.
- **Portal and Vehicle Monitors:** Large-area neutron detection for border crossings and checkpoint portals. 6Li-glass tile arrays provide scalable active area; CLLBC provides higher resolution for confirmatory identification within the same footprint.
- **Nuclear Safeguards and Materials Accounting:** Neutron counting from fissile material (plutonium, uranium) at nuclear facilities. PSD capability allows operation in mixed gamma-neutron fields without external gamma shielding.
- **Reactor Instrumentation:** Ex-core neutron flux monitoring in mixed fields, where PSD separates the neutron count from the gamma background.
- **Cosmic-Ray Neutron Sensing:** Ground-level soil moisture sensing and atmospheric neutron spectroscopy. CLYC and CLLBC handle the mixed thermal/fast cosmic-ray neutron spectrum without moderation in some configurations.
- **Research and University Labs:** Neutron activation analysis, beam-line experiments, and cross-section measurements where simultaneous neutron and gamma data improve experiment efficiency.

Technical note

For a detailed treatment of pulse-shape discrimination methods, figure of merit calculations, and the physics of neutron capture in CLYC and CLLBC, see the ScintIQ technical note Neutron-Gamma Discrimination with Scintillators. That paper covers PSD algorithms, moderator geometry, and comparison data across material types.

Selecting the Right ScintIQ Material

Table 1.

Requirement	Recommended Material	Notes
Thermal neutron detection, no hermetic housing	6Li-glass	Rugged, non-hygroscopic, fast, scalable to large areas. Limited fast-neutron and gamma capabilities.
Dual-mode neutron + gamma with PSD	CLYC	Established PSD figure of merit. Hygroscopic, requires hermetic can or sealed housing.
Dual-mode neutron + gamma, higher gamma resolution	CLLBC	Better light yield and gamma energy resolution than CLYC. Hygroscopic. Slightly higher density.
Neutron detection + high-resolution gamma spectroscopy in one head	CLLBC	Best combined performance. Suitable for advanced RIID and safeguards instruments.
Large active-area portal, lowest cost per cm ²	6Li-glass	Tiles are manufacturable in large panels. Confirm panel dimensions with engineering.

All three materials are available as bare crystals or as assembled ScintIQ detector modules with PMT or SiPM readout, preamplifier, and housing. Detector assembly options, maximum crystal dimensions, and readout configurations are documented on the individual data sheets. For applications requiring a complete counting system, Berkeley Nucleonics offers the TOPAZ-HR and bMCA digital MCA platforms as companion electronics.

Talk to an Engineer

Neutron detector selection depends on source geometry, moderator design, gamma background level, and the PSD algorithm implemented in your readout chain. The Berkeley Nucleonics engineering team works through these tradeoffs with customers before recommending a crystal size and readout configuration.

Contact us to discuss your measurement geometry, throughput requirements, and budget. We can quote bare crystals, hermetically sealed detector heads, and complete counting systems depending on your integration stage.

Email: info@berkeleynucleonics.com

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[CLYC Data Sheet](#) | [CLLBC Data Sheet](#) | [6Li-glass Data Sheet](#)

[Technical Note: Neutron-Gamma Discrimination with Scintillators](#)

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Application Brief

ScintIQ™ Custom Scintillation Detectors | dc-62022201