

How to Choose a Scintillator

A practical guide to navigating the tradeoffs between resolution, density, decay speed, hygroscopicity, and cost across the full range of scintillation materials.

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1 Why Material Selection Drives System Performance

No single scintillator is optimal for every application. The choice of crystal determines not only how efficiently radiation is detected, but also what energy resolution is achievable, how fast the detector can process successive events, and how difficult the assembly and long-term maintenance will be. Getting this decision right at the design stage avoids costly rebuild cycles later.

The field now spans roughly twenty practical materials, from well-established inorganic crystals such as NaI(Tl) and BGO to advanced halides like LaBr₃(Ce) and CLLBC. Each sits at a different point in a multidimensional tradeoff space. This note maps that space, explains the physics behind each dimension, and then walks through a structured decision process.

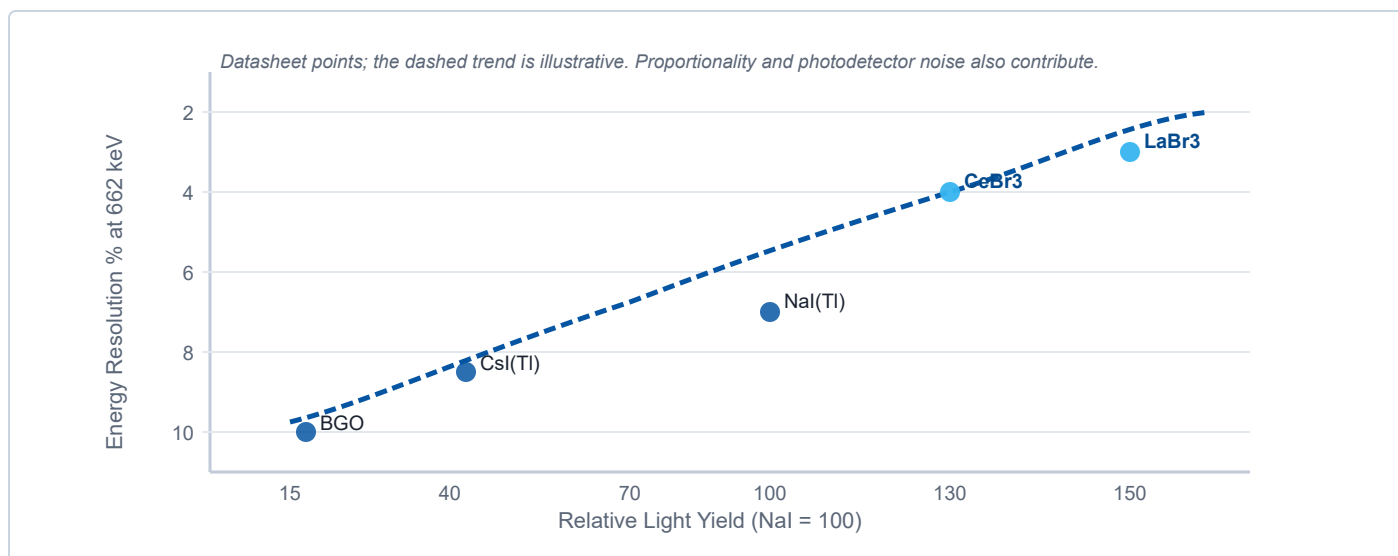
2 The Five Key Selection Axes

1. Energy Resolution

Energy resolution is the most visible figure of merit for gamma-ray spectroscopy. It is expressed as the full-width at half-maximum (FWHM) of a photopeak, divided by the peak energy, stated as a percentage. A lower number means the detector can distinguish gamma lines that are closer together in energy.

Resolution is governed by three factors working in combination: the total light yield of the crystal (more photons per keV means better counting statistics), the statistical spread in photon production (proportionality), and the noise of the photodetector. Materials with both high light yield and good proportionality achieve the best resolution. LaBr₃(Ce) reaches 3.0% at 662 keV. CeBr₃ delivers 4% at the same energy without the La-138 background that LaBr₃ carries. SrI₂(Eu), though slow, reaches about 3.5%. NaI(Tl) is at approximately 7% at 662 keV, which is adequate for a wide range of counting and identification tasks but insufficient for fine spectroscopy.

The figure below illustrates how FWHM resolution improves as photon yield rises, though the relationship is not perfectly proportional because proportionality effects and photodetector noise also contribute.



■ **DERIVED** **Figure 1.** From the ScintIQ datasheets: relative photoelectron yield (bialkali PMT, NaI(Tl) = 100) against energy resolution at 662 keV for BGO (15 to 20, 8 to 12 percent), CsI(Tl) (45, 8 to 9 percent), NaI(Tl) (100, 7 percent), CeBr3 (130, 4 percent) and LaBr3(Ce) (150, 3.0 percent). Higher yield generally improves resolution, but proportionality and detector noise also contribute.

2. Density and Effective Atomic Number

Density and effective atomic number (Z) together determine stopping power: the ability of the crystal to absorb incident radiation within a given volume. This matters in two distinct ways. For gamma-ray applications, high density and high Z increase the photoelectric cross-section, making photopeak detection more efficient. For compact or portable instruments, high stopping power means a smaller crystal can achieve the same detection efficiency as a larger, cheaper alternative.

BGO (7.13 g/cm³), PbWO₄ (8.28 g/cm³) and LYSO(Ce) (7.2 g/cm³), with CdWO₄, are at the top of the density range. They are the materials of choice for PET scanners, high-energy physics calorimeters, and any application where detector volume is constrained. At the lower end, 6Li-glass (2.5 to 2.6 g/cm³) and CaF₂(Eu) trade density for sensitivity to specific particle types, thermal neutrons and beta particles respectively.

3. Decay Time

Scintillation decay time sets the maximum rate at which a detector can process separate events. Fast materials allow high count rates without pulse pile-up. They also enable coincidence timing applications, where two detectors must record simultaneous events within a narrow time window.

BaF₂ holds the record for conventional inorganic materials, with a fast component near 0.8 ns. YAP(Ce) and LYSO(Ce) both deliver decay times in the 20 to 50 ns range, fast enough for PET time-of-flight and physics coincidence work. CsI(undoped) is faster still. NaI(Tl) at 230 ns is adequate for most counting applications but limits throughput at high source activities. CsI(Tl) has a 600 ns principal component and a 3.4 μ s slow component, so its pulses need a long integration gate, and SrI₂(Eu) at 1 to 5 μ s is the slowest of the common choices; neither suits count rates above a few tens of thousands per second.

4. Hygroscopicity

Hygroscopic crystals absorb moisture from ambient air, causing surface clouding and degraded optical coupling. This has two practical consequences. First, the crystal must be hermetically sealed, adding cost and mechanical complexity. Second, the seal must remain intact throughout the service life, which is a maintenance and reliability consideration for field-deployed instruments.

NaI(Tl), LaBr₃(Ce), LBC, CeBr₃, CLYC, CLLBC and SrI₂(Eu) are hygroscopic and require sealed housings; CsI(Tl) is slightly hygroscopic and tolerates a lightly protected housing. BGO, GAGG(Ce), LYSO(Ce), PbWO₄, BaF₂, YAP(Ce), YAG(Ce) and 6Li-glass are not hygroscopic. For handheld instruments, outdoor monitoring stations, or any system that may experience

condensation, non-hygroscopic materials simplify packaging significantly. When resolution demands the best hygroscopic materials, the cost of a well-designed hermetic housing is usually justified.

5. Cost and Availability

Crystal cost scales with raw material rarity, growth difficulty, and yield. NaI(Tl) and BGO are the most established and economical choices at scale. CsI(Tl) and CsI(Na) fall in a mid-cost band. LaBr3(Ce) and SrI2(Eu) carry a significant premium due to the difficulty of growing large, uniform crystals. CLYC and CLLBC are specialist materials with limited commercial production capacity; lead times and pricing reflect that. For high-volume applications such as medical imaging arrays or portal monitor panels, cost and availability often override resolution as the deciding factor.

3 Material Comparison at a Glance

The table below summarizes the key figures for the materials available from Berkeley Nucleonics ScintIQ. Resolution ratings are approximate at 662 keV. Cost tiers are relative (low / mid / high / premium) and are indicative only; contact BNC for current pricing.

Table 1.

Material	Density (g/cm³)	Emission (nm)	Decay	Rel. Yield (NaI=100)	Hygroscopic	Res. at 662 keV	Cost Tier	Best For
NaI(Tl)	3.67	415	0.23 µs	100	YES	~7%	Low	General counting, health physics
CsI(Tl)	4.51	550	0.6 / 3.4 µs	45	SLIGHT	~8–9% (PMT)	Low	Rugged crystal, lightly protected housing, SiPM / photodiode readout
CsI(Na)	on request	on request	on request	on request	YES	on request	Low	Geophysical, general detection
CsI (undoped)	on request	on request	on request	on request	NO	on request	Low	Fast physics (calorimetry)
CaF2(Eu)	on request	on request	on request	on request	NO	on request	Low/Mid	Beta, alpha/beta phoswich
BaF2	4.88	220 / 310	0.8 ns / ~630 ns	5 / 16	NO	~12%	Mid	Ultra-fast timing, positron lifetime
YAP(Ce)	5.55	350	27 ns	35–40	NO	Not listed at 662 keV	Mid	Fast timing, e-microscopy
BGO	7.13	480	0.3 µs	15–20	NO	8–12%	Low/Mid	PET, anti-Compton, geophysical
LYSO(Ce)	7.2	420	50 ns	76	NO	~8%	Mid/High	PET, HEP, fast timing
GAGG(Ce)	6.6	520	<90 ns	~50,000 ph/MeV	NO	~6% (high-QE PMT)	Mid/High	PET, HEP, SiPM-friendly, rad-hard
CdWO4	on request	on request	on request	on request	NO	on request	Mid	CT arrays, high-intensity X-ray

Material	Density (g/cm³)	Emission (nm)	Decay	Rel. Yield (NaI=100)	Hygroscopic	Res. at 662 keV	Cost Tier	Best For
PbWO4	8.28	~420	7–10 ns	0.3–0.4	NO	poor	Mid	HEP calorimetry (density priority)
6Li-glass	2.5–2.6	~395	60–75 ns	4–6	NO	N/A (neutron)	Low/Mid	Thermal neutron detection
CLYC (Cs2LiYCl6:Ce)	3.31	370	1 / 50 / 1000 ns	~50	YES	4.5–5.5%	Premium	Dual n/γ PSD, RIID
CLLBC	4.08	420	120 / 500 ns	70	YES	<3.5%	Premium	High-res dual n/γ, RIID
CeBr3	5.23	370	18–25 ns	130	YES	~4%	High	High-res spectroscopy, low background
LaBr3(Ce)	5.07	370	16–20 ns	150	YES	3.0%	High	Best gamma resolution (La-138 bg)
LBC	4.90	380	35 ns	140	YES	3%	High	High-res, more rugged halide
SrI2(Eu)	4.6	400–480	1–5 μs	120–140	YES	~3.5%	Premium	Highest resolution, slow
YAG(Ce)	4.57	550	70 ns	~30,000 ph/MeV	NO	Not listed	Mid	Electron microscopy, beam imaging

4 A Structured Decision Flow

Rather than optimizing all five axes simultaneously, most application decisions reduce to a short sequence of primary filters. The flow below reflects the most common ordering. Each gate narrows the candidate set; the final comparison within the surviving candidates then focuses on secondary tradeoffs.

ScintIQ Material Decision Flow

- 1 What radiation type must you detect?** If the primary requirement is thermal neutron detection, move directly to **CLYC, CLLBC, or 6Li-glass**. For dual neutron-gamma discrimination with spectroscopy quality, CLYC and CLLBC are the ScintIQ choices. For a neutron-only counter, 6Li-glass is rugged, non-hygroscopic and economical. All other paths below address gamma and X-ray.
- 2 Is density the dominant requirement?** Applications such as PET scanners, HEP calorimeters, and downhole logging in compact geometries require maximum stopping power. Candidates: **PbWO4, LYSO(Ce), BGO, GAGG(Ce), CdWO4**. Among these, LYSO and GAGG provide far better light yield than PbWO4 or CdWO4; BGO is the established low-cost choice for PET arrays where individual crystal cost matters.

- 3 **Is timing the dominant requirement?** Coincidence systems, positron lifetime measurements, and TOF-PET require sub-100 ns decay. Candidates by speed: **BaF2** (sub-ns, UV output), **YAP(Ce)** (27 ns, good light yield), **LYSO(Ce)** (50 ns, high density), **GAGG(Ce)** (under 90 ns). BaF2 demands UV-sensitive photomultipliers. YAP is well matched to standard bialkali PMTs.



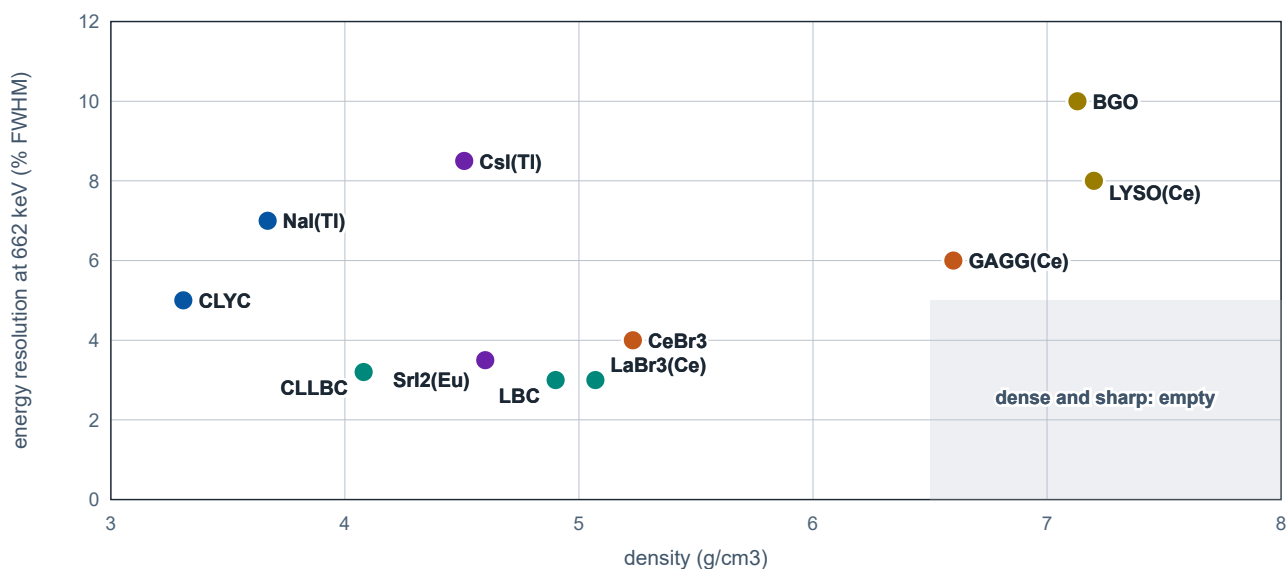
- 4 **What energy resolution is required?** For isotope identification, security screening, or environmental monitoring with closely spaced gamma lines: target <5% at 662 keV. Leading candidates: **LaBr3(Ce)** (3.0%), **LBC** (3%), **CLLBC** (under 3.5%), **SrI2(Eu)** (about 3.5%), **CeBr3** (4%). Note that LaBr3 and LBC carry a La-138 internal background line near 1.46 MeV. CeBr3 avoids this and is often preferred for low-background counting even at slight resolution cost.



- 5 **Is the deployment environment sealed or open-air?** For field instruments, harsh-environment monitors, or assemblies that cannot be hermetically sealed: prefer non-hygroscopic materials. From the high-resolution candidates above, none are non-hygroscopic; this forces either a sealed housing or a step down to **GAGG(Ce)**, **LYSO(Ce)**, or **BGO**. For general counting with relaxed resolution: **CsI(Tl)** is the rugged mid-tier crystal that tolerates a wider range of environments without a hermetic seal.



- 6 **What are the cost and lead-time constraints?** If cost must be minimized at moderate resolution: **Nal(Tl)** remains the default. If cost is secondary and the best resolution is required: LaBr3 or SrI2. If volume production with SiPM readout and non-hygroscopic handling is required: GAGG(Ce) has emerged as the engineering-preferred choice for modern detector arrays.



Derived from the ScintIQ datasheets; BGO, CsI(Tl) and CLYC plotted at the middle of their published ranges.

- **DERIVED** **Figure 2.** From the ScintIQ datasheets: energy resolution at 662 keV against density for the materials with both values published. No material is both denser than 6.5 g/cm³ and sharper than 5 percent, which is the tradeoff the decision flow walks through.

5 Common Application Scenarios and Recommended Starting Points

Isotope Identification and Radiological Security (RIID)

These instruments require the best possible gamma resolution in a field-portable package. The detector must identify isotopes by their gamma-line signatures, which means resolving peaks separated by as little as 30 to 60 keV in the 200 to 1400 keV range. **LaBr3(Ce)** is the established premium choice. **CeBr3** is preferred when the La-138 background at 1.46 MeV would interfere with environmental monitoring. **CLLBC** adds simultaneous neutron sensitivity. All three require hermetic sealed housings. If cost must be contained, **Nal(Tl)** remains adequate for coarse isotope discrimination.

Environmental and Low-Background Monitoring

Long-duration monitoring at low count rates places the emphasis on intrinsic background purity, resolution, and stability. **CeBr3** leads here because it combines high light yield, good resolution, and the absence of the La-138 self-activity that burdens LaBr3 crystals. Large-volume **Nal(Tl)** detectors remain the workhorse for regulatory monitoring stations where the crystal geometry matters more than ultimate resolution.

Medical Imaging (PET and SPECT)

PET requires fast, dense crystals with good light yield. **LYSO(Ce)** dominates modern commercial PET because of its combination of high density (7.20 g/cm³), 50 ns decay, and non-hygroscopic nature. **GAGG(Ce)** is gaining adoption in SiPM-based small-animal and compact PET systems. **BGO** remains relevant for cost-sensitive large-panel designs. SPECT and CT applications often favor **CsI(Tl)** for its emission wavelength compatibility with silicon photodiodes and its structural robustness.

High-Energy Physics and Fast Timing

Calorimeter applications at particle accelerators prioritize stopping power above all else. **PbWO4** is the established choice for electromagnetic calorimeters at the highest energies. Where some light yield can be traded for reduced hermeticity concerns, **LYSO** or **GAGG** are preferred. Timing applications, such as positron lifetime spectroscopy, demand BaF₂ or YAP(Ce).

Geophysical and Harsh-Environment Logging

Downhole instruments operate at elevated temperatures and cannot be easily serviced. **Nal(Tl)** remains the most used logging crystal, with its hermetic housing engineered for the tool. **BGO** is used where density matters at moderate temperature, since its datasheet range ends at 100 C, and it is free of afterglow that would corrupt count-rate measurements in high-flux boreholes. **CsI(Tl)** (rated to 125 C) and **GAGG(Ce)** are strong alternatives; for geophysical applications requiring moderate resolution without hygroscopic complexity, GAGG is a current design choice.

General Laboratory Counting and Health Physics

When the application does not impose extreme constraints on resolution, density, or timing, **Nal(Tl)** is the clear starting point. It delivers the highest light yield of the established materials, an emission spectrum well matched to standard bialkali PMTs, and a decades-long supply chain. The hygroscopicity penalty is managed by standard aluminum-can housings, which are mature, inexpensive, and widely available.

6 Readout Compatibility and Optical Coupling

Material selection and photodetector selection are not independent decisions. Several points are worth noting before the final material choice is locked.

PMT bialkali sensitivity peaks near 380 to 420 nm. Materials that emit in this window (Nal(Tl), LaBr₃, LBC, CeBr₃, CLYC, CLLBC, LYSO, 6Li-glass) couple efficiently to standard PMTs. BaF₂ fast-component emission at 220 nm requires quartz-window PMTs with UV-extended photocathodes, which are more expensive and less common.

SiPM photon detection efficiency peaks near 420 to 450 nm and stays usable through the green, while silicon photodiodes peak further toward the red. CsI(Tl) at 550 nm and GAGG at 520 nm are well matched to silicon sensors, and LYSO and CLLBC at 420 nm to SiPMs. CeBr₃ and LaBr₃ at 370 nm work with SiPMs at reduced efficiency. YAP(Ce) at 350 nm is marginal for silicon; PMT readout is preferred.

Refractive index mismatch at the crystal-window interface causes internal reflection losses. BGO at 2.15 and PbWO₄ at 2.16 have high refractive indices; coupling with optical grease helps, but not all index-matching fluids are compatible with all window materials.

For detailed guidance on PMT versus SiPM readout tradeoffs across the ScintIQ lineup, see the companion note *SiPM vs. PMT Readout for Scintillation Detectors*.

7 Quick-Reference: Material by Primary Priority

Table 2.

Primary Priority	First Choice	Strong Alternative	Budget / Volume
Best gamma resolution	LaBr3(Ce)	LBC, CLLBC, Srl2(Eu), CeBr3	NaI(Tl)
Highest density / stopping power	PbWO4, LYSO(Ce)	BGO, GAGG(Ce)	BGO
Fast timing	BaF2 (0.8 ns)	PbWO4 (7 to 10 ns), YAP(Ce) (27 ns), LYSO(Ce) (50 ns)	CsI (undoped)
Neutron-gamma discrimination	CLYC, CLLBC	6Li-glass (neutron only)	CLYC
Non-hygroscopic (field / harsh env.)	GAGG(Ce), LYSO(Ce)	BGO, CsI(Tl)	CsI(Tl) or BGO
SiPM / photodiode readout	GAGG(Ce), CsI(Tl)	LYSO(Ce), CdWO4	CsI(Tl)
General counting, lowest cost	NaI(Tl)	CsI(Tl), BGO	NaI(Tl)
Low internal background (La-138 free)	CeBr3	GAGG(Ce), BGO	NaI(Tl) at large volume
Beta / alpha detection (low Z)	CaF2(Eu)	YAP(Ce)	CaF2(Eu)
Electron microscopy / beam imaging	YAG(Ce)	YAP(Ce)	YAG(Ce)

8 Working With the Berkeley Nucleonics ScintIQ Team

Selecting a scintillation material is a system-level decision. The crystal interacts with the photodetector, the signal chain, the housing geometry, and the mechanical environment in ways that sometimes produce surprising results in practice. The Berkeley Nucleonics engineering team can review your application requirements and recommend a configuration from the ScintIQ line, which spans materials from NaI(Tl) through CLLBC, along with readout options from standard PMT assemblies to compact SiPM-based modules and integrated MCA electronics.

Contact the ScintIQ team directly:

- Email: info@berkeleynucleonics.com
- Phone: 800-234-7858

Going deeper on scintillation physics? Berkeley Nucleonics publishes the *Nuts and Bolts of Scintillation Detectors* web book, covering photon production, energy resolution, pulse-shape discrimination, and detector design in depth. [Open the book](#) for the full reference.

Interactive tools

The ScintIQ Material Comparison Table lets you sort and filter the ScintIQ materials by application, density, decay time, and hygroscopicity. The Guided Material Selector steps through the decision flow above and returns a ranked recommendation.

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