Successful time coincidence measurements are based on the properties of the various radiation detectors providing the signal inputs and the selection alignment and calibration of the electronic signal processing system. The detectors must provide signals of the correct amplitude, shape, time duration, stability, etc. Current electronics allow the generation of time gates based on two signals that are only a few tens of picoseconds apart. Certain nuclear measurements use the time coincidence of the signals from two or more detectors. Examples of these measurements include:

- Identification of a radioactive material
- Calibration of the decay rate of an excited nuclear state
- Measurement of the lifetime of an excited nuclear state
- Compton suppression
- Gain-stabilization
- Improvement in the signal-to-noise ratio as a result of the suppression of uncorrelated background noise
- Positron emission detection
- Emission of multiple gamma rays from a single excited nucleus

Two or more detectors, not necessarily of the same type, are used in each of these examples. A Compton suppression system frequently will include a germanium (Ge) detector surrounded by either a NaI(Tl) or BGO annulus. Gamma rays are partially or completely absorbed in the central germanium detector. Compton-scattered gamma rays then interact in the surrounding NaI(Tl) or BGO annulus. These two signals [Ge and NaI(Tl) or BGO] are time coincident and may be used to reject or gate off the Ge electronics channel to eliminate these partially absorbed events from the Ge spectrum.

Other Time Coincidence Applications

Time coincidence noise rejection is frequently used in a liquid scintillation counter. In this case, two phototubes view the liquid sample. Spontaneous noise from each phototube is rarely time coincident while valid events from the liquid are coincident. In this case, only the coincident signals are analyzed. (In the Compton suppression system, coincident signals are rejected.)

Phoswich detector systems are unique in that several electronic logic decisions may be made. The two scintillators coupled to a single PMT have very different decay times. (1) Scintillator signals can be distinguished based on decay times. (2) With the proper gating, the data for each scintillator can be separated and stored. With the new SGC BrilLanCe®*350 (LaCl₃:Ce) and BrilLanCe®380 (LaBr₃:Ce) materials, fast and better performing phoswiches can be built.
Time Coincidence

When measuring time performance capabilities, a plastic scintillator (such as BC-408) or a fast inorganic scintillator (such as BaF$_2$ or BrilLanCe 380) is used to provide a start pulse to the TAC. The start signal is usually the highest rate detector. This minimizes dead time in the TAC. The fast decay time scintillator provides the smallest amount of time-spread in the reference signal. Thus, slower scintillators [such as NaI(Tl), BGO, CsI(Tl) and CsI(Na)] can easily be measured for their Coincidence Resolving Time (CRT).

Whether the scintillator is slow (BGO) or fast (CsI pure or BrilLanCe™ 380), good time performance is based on a scintillator plus PMT providing pulses having a constant rise and fall time, independent of energy.

Fast Scintillator

The BrilLanCe™ 380 crystal emits light with a relatively short decay time of 16ns. This is about 15 times faster than NaI(Tl); and, if taken together with the high light output, excellent timing is possible. Defining the ratio of the decay time to the light output as a figure of merit**, it is clear from the table that the timing properties of a BrilLanCe crystal are expected to be very close to BaF$_2$. Indeed, sub-nanosecond coincidence resolving times of 250ps and lower have been measured.

The linearity of light generation of the BrilLanCe 380 scintillator with energy is excellent. It is well known that the amount of light produced per unit of energy by NaI(Tl) increases below 400keV and peaks at ~1.23 around 12keV. The light output of the BrilLanCe 380 crystal stays constant with energy, the maximum deviation at low energies being less than 5%.


*These original patents were granted to Stichting Voor de Technische Wetenschappen. Inventors are P. Dorenbos, C.W.E. van Eijk, H.U. Gudel, K.W. Kraemer, E.V.D. van Loef. Technology is licensed to Saint-Gobain Cristaux & Detecteurs.

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