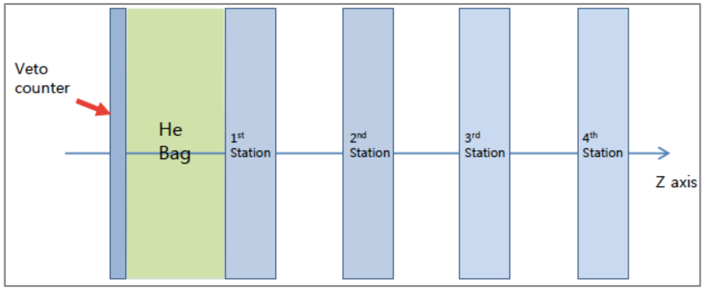
Neutron Detector Simulation For $LAMPS_H$

- Factors Limiting Timing
- Optimum Timing-CFD
- CFD Simulation
- Results



Factors Limiting Timing

⌘ Drift [..Aging, temperature]
⌘ Jitter [..Electronic noise]
⌘ Walk [..Input pulse amplitude]

$$Jitter = \frac{V_N}{(dV/dt)}$$

With:

- V_N: Noise voltage amplitude
- dV/dt: Signal slope when leading edge crosses threshold

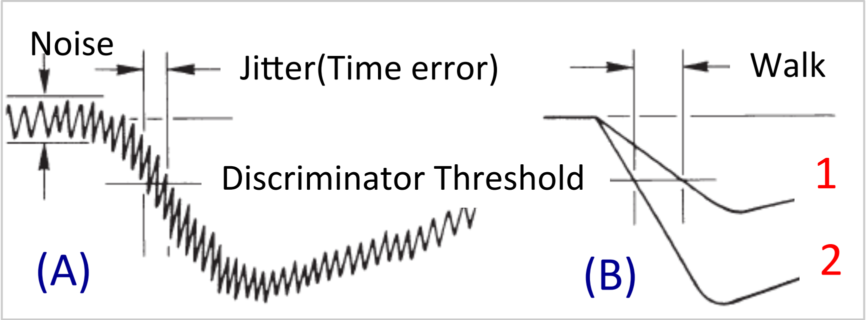


Fig.1: Jitter and Walk in Leading-Edge Timing Discriminator

★ Walk can degrade timing when a wide range of pulse amplitudes are processed

★ CFD & zero-crossing techniques → highly recommended for minimizing "walk"

Optimum Timing-CFD

Pulse Shaping by CFD:

- Splits input signal into two parts

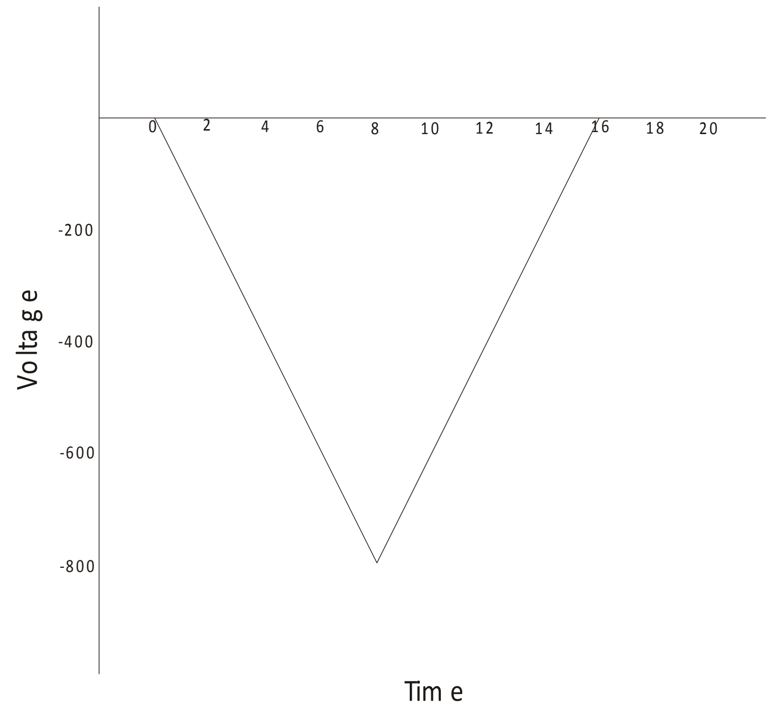


Fig.2: CFD input pulse

- Attenuates one part to certain fraction, *f*

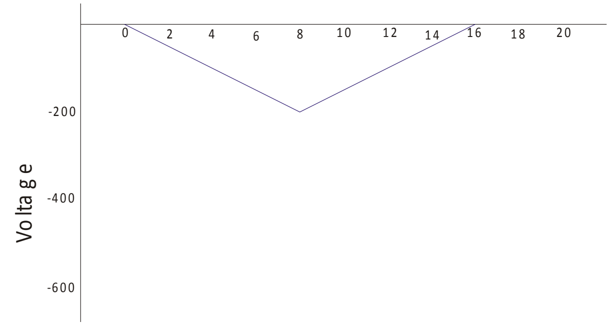


Fig.3: Attenuated pulse

- Delays and inverts the other part

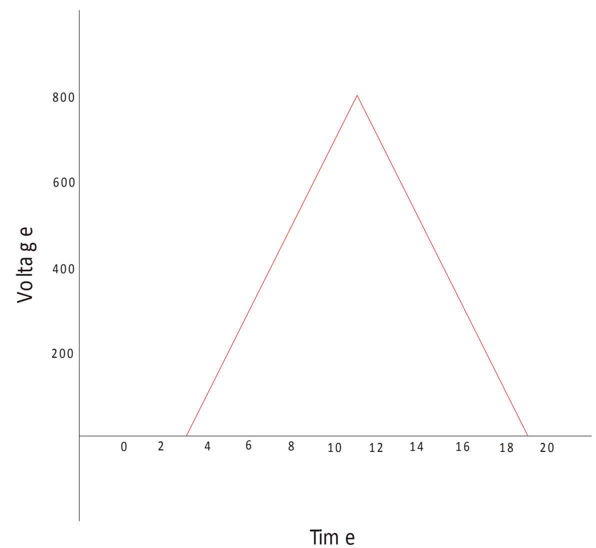


Fig.4: Delayed and inverted pulse

Optimum Timing-CFD...

- Attenuated, delayed and inverted pulses are added and zero crossing computed

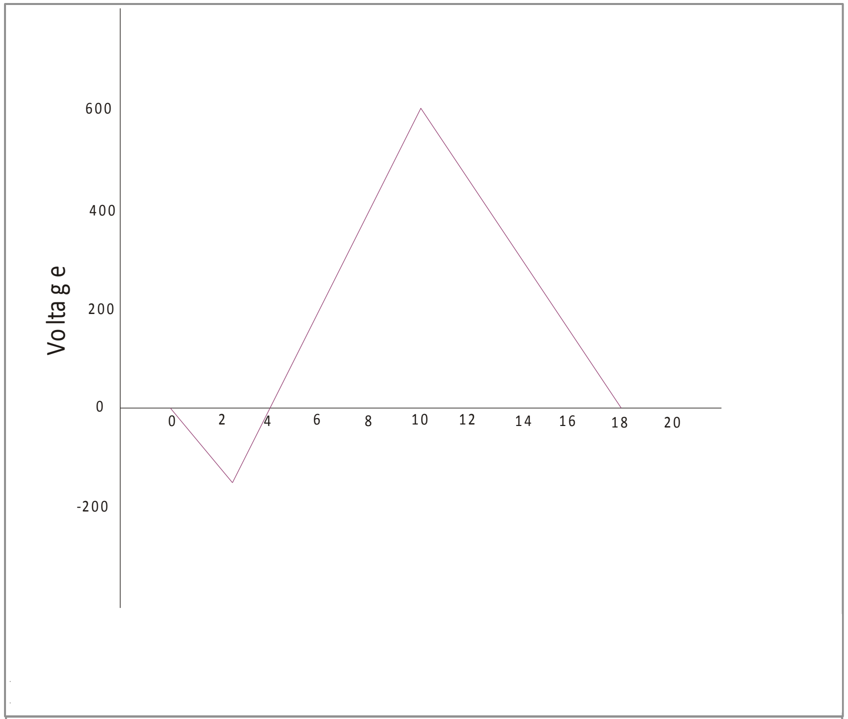


Fig.5: Sum of Attenuated, delayed and inverted pulses

Equations for CFD

- Input pulse, $V_i = -At$
- Attenuated pulse, $V_a = -fAt$
- Delayed & inverted pulse, $V_d = A(t-t_d)$

Where:

- A = *initial amplitude*
- f = *fraction*
- t_d = *delay*

Finding zero-crossing

Set

$0 = V_a + V_d$ [and solve for t]

$$0 = -fAt + A\left(t - t_d\right)$$

$$\therefore t_{cross} = \frac{t_d}{\left(1 - f\right)}$$

⌘ CFDs give optimum σ_t in fraction range $0.2 \le f \le 0.4$

Optimum Timing-CFD…

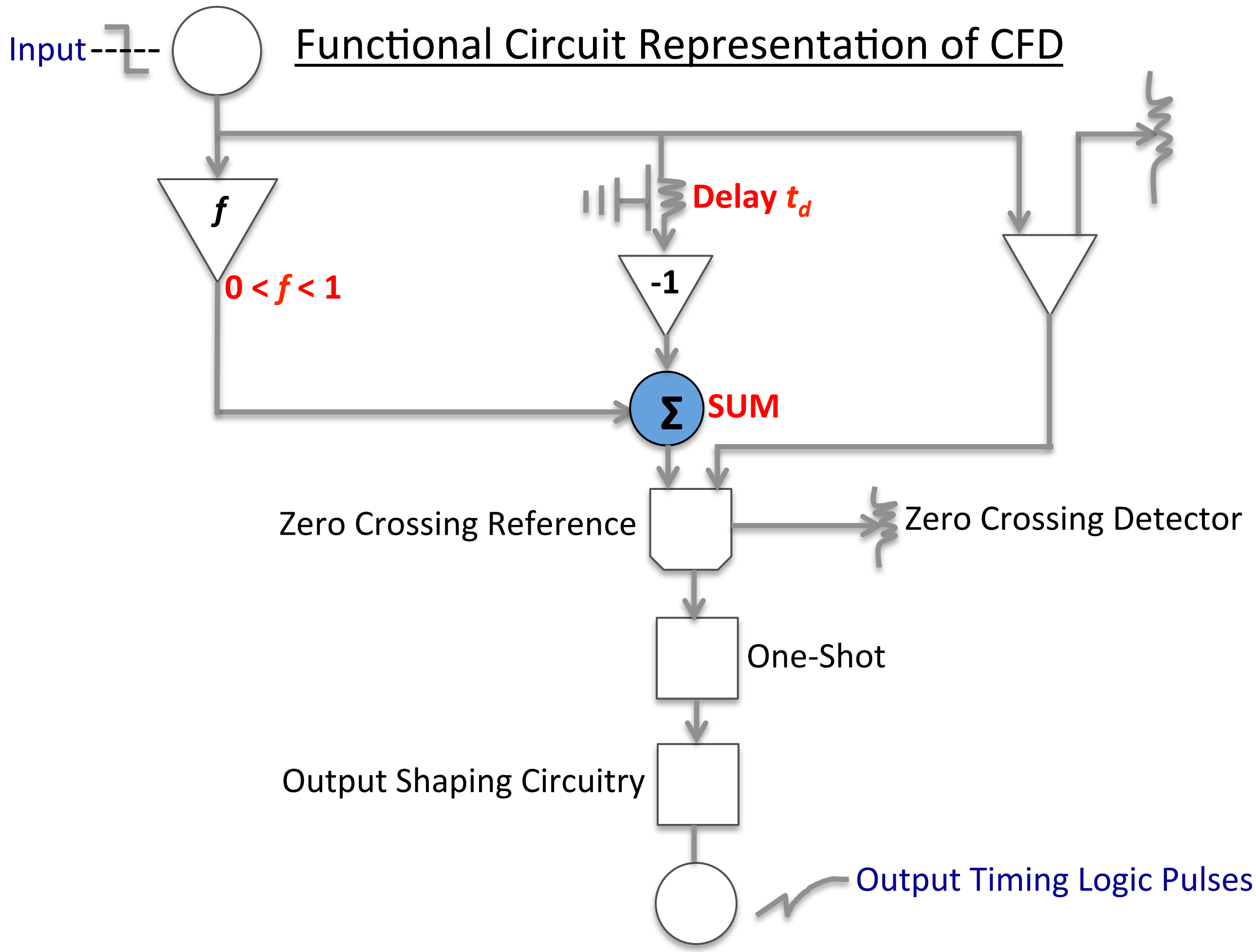


Fig.6: Functional Representation of Constant-Fraction Discriminator

CFD Simulation

Simulation Algorithm

Involved:

- ⦿ Photon generation
- ⦿ Signal generation
- ⦿ Signal propagation
- ⦿ Signal attenuation
- ⦿ Hit grouping

300 MeV Neutron Energy

Examined:

- ✸ Time Resolution
- ✸ Position Resolution.

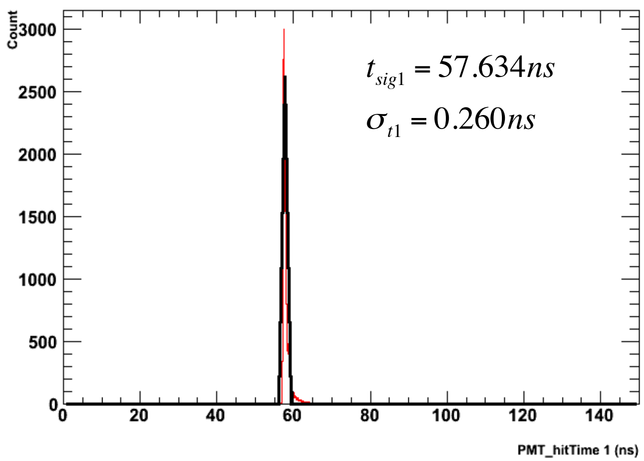
Simulation parameters:

- ⦿ L_1 = 1000 mm
- ⦿ L_2 = 1000 mm
- ⦿ T_d = 2 ns
- ⦿ f_{CFD} = 0.4

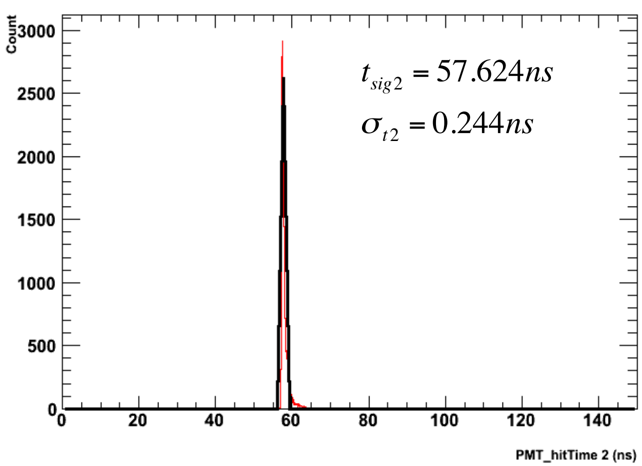
Time Resolution Result

300 MeV Neutron Energy

PMT1 Hit Time



PMT2 Hit Time

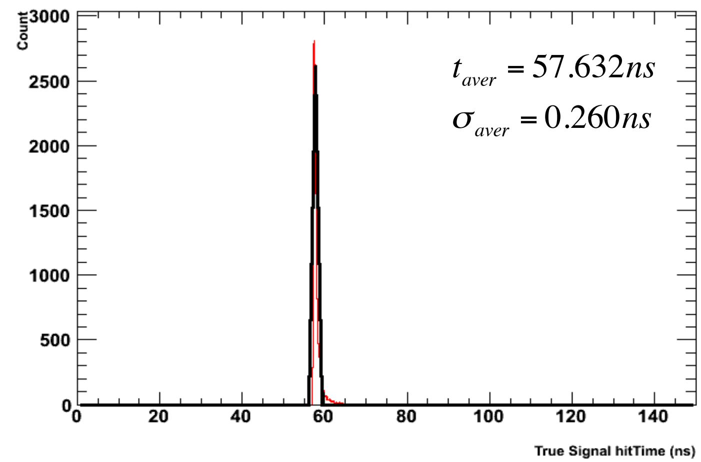


L_1 = 1000 mm

L_2 = 1000 mm

300 MeV Neutron Energy

Average Hit Time



- **Average Hit Time**

$$t_{aver} = \frac{t_{sig1} + t_{sig2}}{2}$$

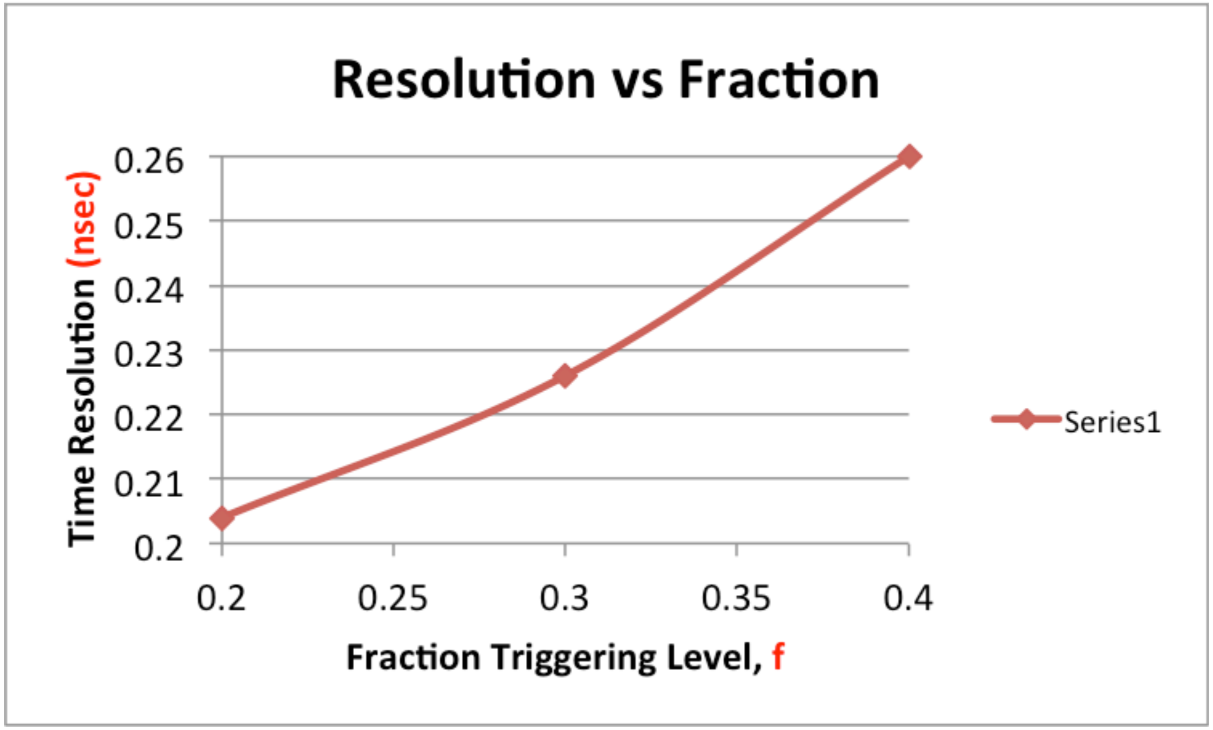
$$t_{aver} = 57.632ns$$

$$\sigma_{aver} = 0.260ns$$

CFD-Fraction Triggering Level Scan

300 MeV Neutron Energy

Fraction, *f*: 02 ≤ 0.4



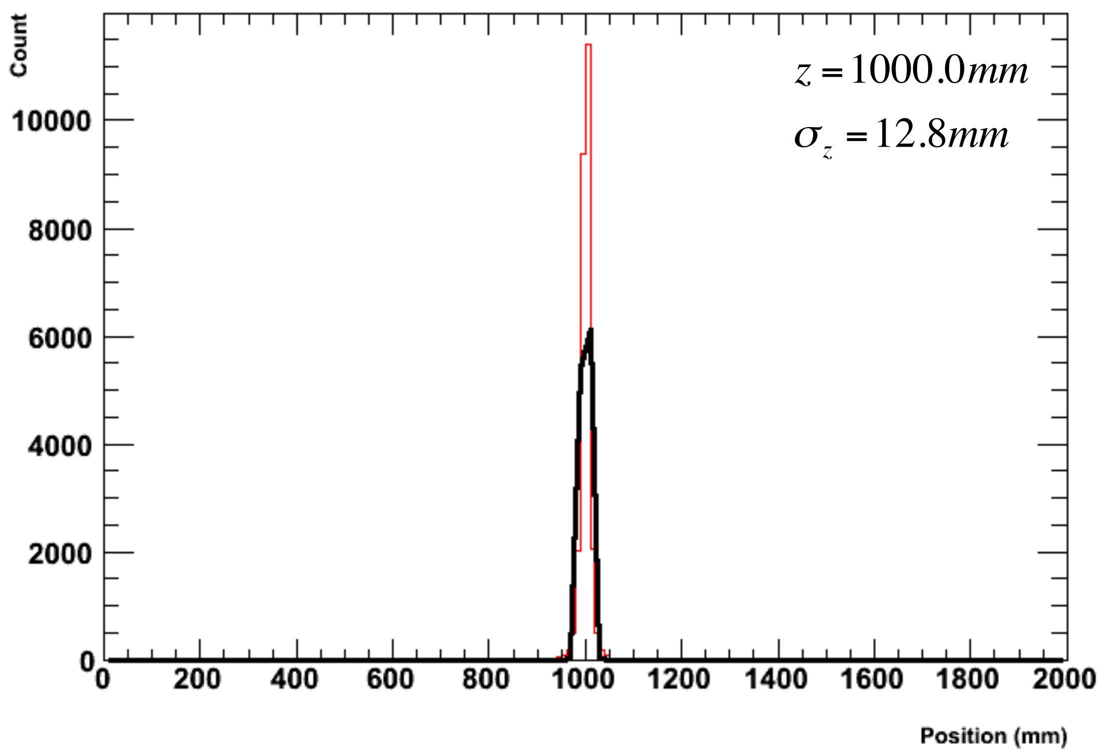
Fraction, *f*	Resolution
0.2	204 ps
0.3	226 ps
0.4	260 ps

Simulation parameters

- 300 MeV Neutrons
- L_1 = 1000 mm
- L_2 = 1000 mm
- f_{CFD} = 0.2 ≤ 0.4
- T_d = 2 ns

Position Resolution Result

Hit Position (Center = 1000 mm)



Simulation parameters

- 300 MeV Neutrons
- L_1 = 1000 mm
- L_2 = 1000 mm
- f_{CFD} = 0.4
- T_d = 2 ns

Hit position results

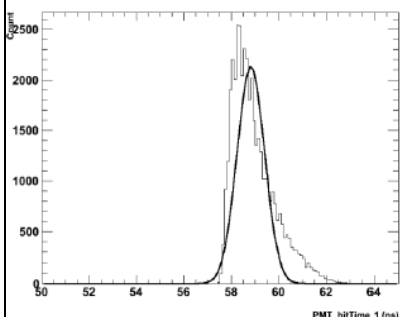
- Position = 1000 mm
- Resolution = 12.8 mm

Backup1

VTD RESULT

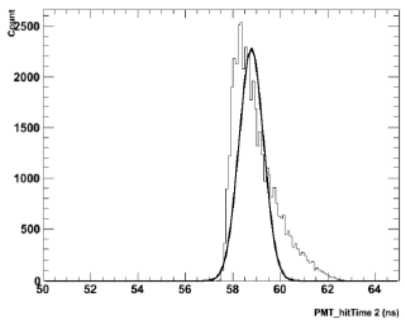
- 300 MeV neutrons were fired to the center of 10 m away from $0.1 \times 0.1 \times 2\ \mathrm{m}^3$ bar-type scintillator module
  - Electro equivalent threshold = 2 MeV
  - 40000 events

Beomgon K.



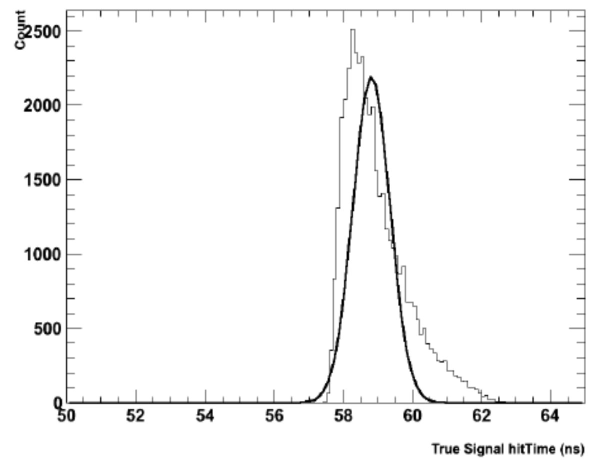
$m_{t1} = 58.817$ ns
$\sigma_{t1} = 0.566$ ns

$t_{signal1}$



$m_{t2} = 58.774$ ns
$\sigma_{t2} = 0.510$ ns

$t_{signal2}$



$m_{true} = 58.806$ ns
$\sigma_{true} = 0.524$ ns

$t_{true} = 0.5 \times (t_{signal1} + t_{signal2})$

Backup2

BC-400/BC-404/BC-408/BC-412/BC-416
Premium Plastic Scintillators

General Description

The premium plastic scintillators described in this data sheet include the most economical (BC-416) as well as those with the highest light output.

General Technical Data

Base .... Polyvinyltoluene
Density .... 1.032 g/cc
Refractive Index 1.58
Coefficient of Linear Expansion .... 7.8×10^{-5}, below 67°C
Atomic Ratio, H/C .... ~1.1
Light Output Temperature Dependence .... At +60°C = 95% of that at +20°C; independent of temperature from -60°C to +20°C
Vapor Pressure .... May be used in a vacuum
Solubility .... Soluble in aromatic solvents, chlorine, acetone, etc. Insoluble in water, dilute acids, lower alcohols, silicone fluid, grease and alkalis.

Radiation Detected	Scintillator
< 100 keV X-rays	BC-404
100 keV to 5 MeV gamma rays	BC-408
>5 MeV gamma rays	BC-400 BC-416
Fast neutrons	BC-408 BC-412
Alphas, betas	BC-400 BC-404
Charged particles, cosmic rays, muons, protons, etc.	BC-408 BC-412 BC-416

Properties

	BC-400	BC-404	BC-408	BC-412	BC-416
Light Output, % Anthracene	65	68	64	60	38
Rise Time, ns	0.9	0.7	0.9	1.0	—
Decay Time, ns	2.4	1.8	2.1	3.3	4.0
Pulse Width, FWHM, ns	2.7	2.2	~2.5	4.2	5.3
Light Attenuation Length, cm*	160	140	210	210	210
Wavelength of Max. Emission, nm	423	408	425	434	434
No. of H Atoms per cm^3, ($\times 10^{22}$)	5.23	5.21	5.23	5.23	5.25
No. of C Atoms per cm^3, ($\times 10^{22}$)	4.74	4.74	4.74	4.74	4.73
Ratio H:C Atoms	1.103	1.100	1.104	1.104	1.110
No. of Electrons per cm^3, ($\times 10^{23}$)	3.37	3.37	3.37	3.37	3.37
Principal uses/applications	general purpose	fast counting	TOF counters, large area	large area	large area economy