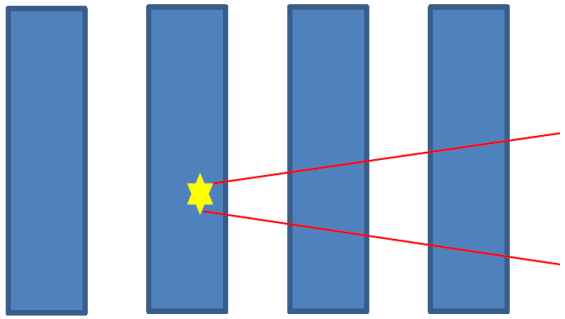
Neutron Detector Simulation
2015 / 03 / 20



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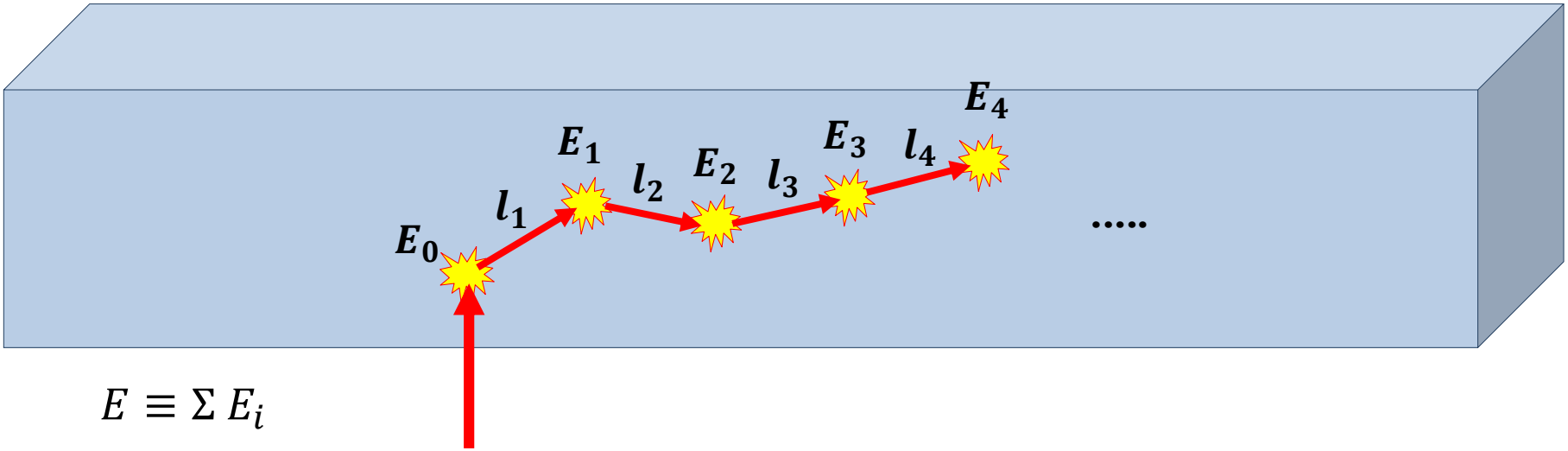
Signal Generation

- Scintillation response of organic scintillators
  - Birks formula
- Light propagation time for each PMT
- Light attenuation for each PMT
- Signal generation using the light energy arrived at each PMT
- Threshold & signal hitTime
- Time resolution related with energy deposit

Birks Formula



$E \equiv \Sigma E_i$

- Scintillator(BC-408) density $\rho = 1.032\ \mathrm{g\,cm^{-3}}$
- (density)*(distance between (i – 1)-th & i-th hit) $\equiv z_i = \rho l_i\ (\mathrm{g\,cm^{-2}})$
- (i-th GEANT4 deposited energy)/$z_i \equiv E_i/z_i = E_i/\rho l_i\ (\mathrm{MeV\,g^{-1}\,cm^2})$
- (i-th corrected deposited energy)/z_i)/((i-th GEANT4 deposited energy)/z_i)

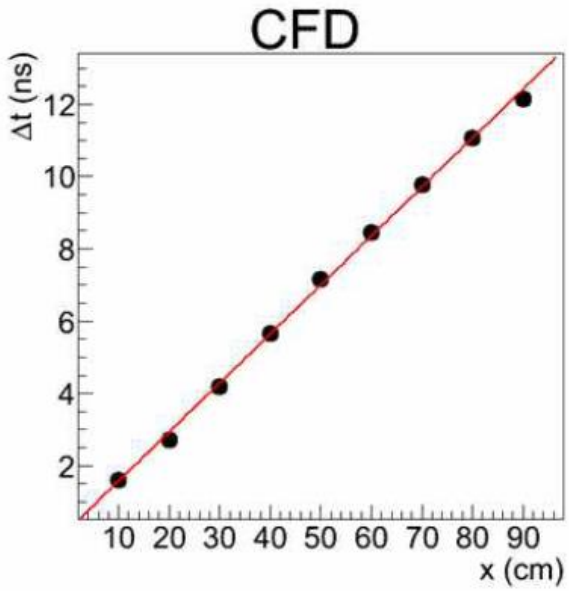
$$= \frac{E_{corr-i}/z_i}{E_i/z_i} = \frac{1}{1+kB(E_i/z_i)}$$ (Birks parameter $kB \approx 0.977 \times 10^{-2}\ \mathrm{g\,cm^{-2}\,MeV^{-1}}$)

- $E_{corr} \equiv \Sigma E_{corr-i}$: Scintillator-response-corrected total deposited energy

Light Propagation Time

❖ It takes some time until the light reach to the PMT at each side of scintillator.

l_1 l_2



$$x = |l_1 - l_2|$$

$$\Delta t = \frac{x}{v} = \frac{|l_1 - l_2|}{v}$$

1/(slope) $= v \approx 75$ mm/ns

Light Attenuation

- As the light moves through scintillator, it loses its energy.

l_1 l_2

$$E_{PMT1} = E_{corr}\exp[-\frac{l_1}{3800}]$$

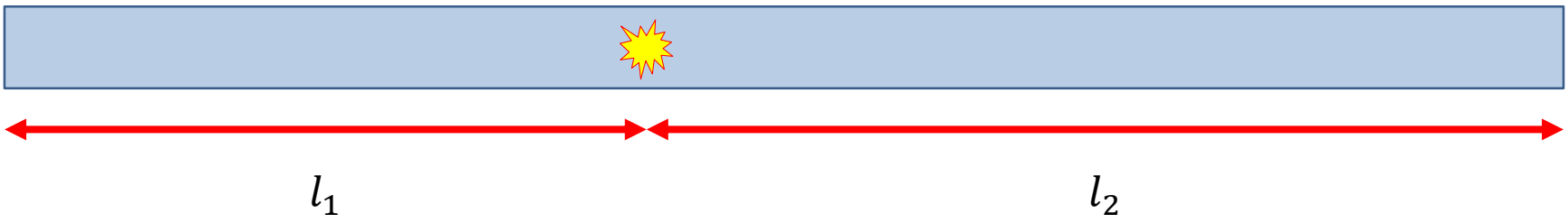
$$E_{PMT2} = E_{corr}\exp[-\frac{l_2}{3800}]$$

- BC-408 bulk attenuation length : 380 cm = 3800 mm

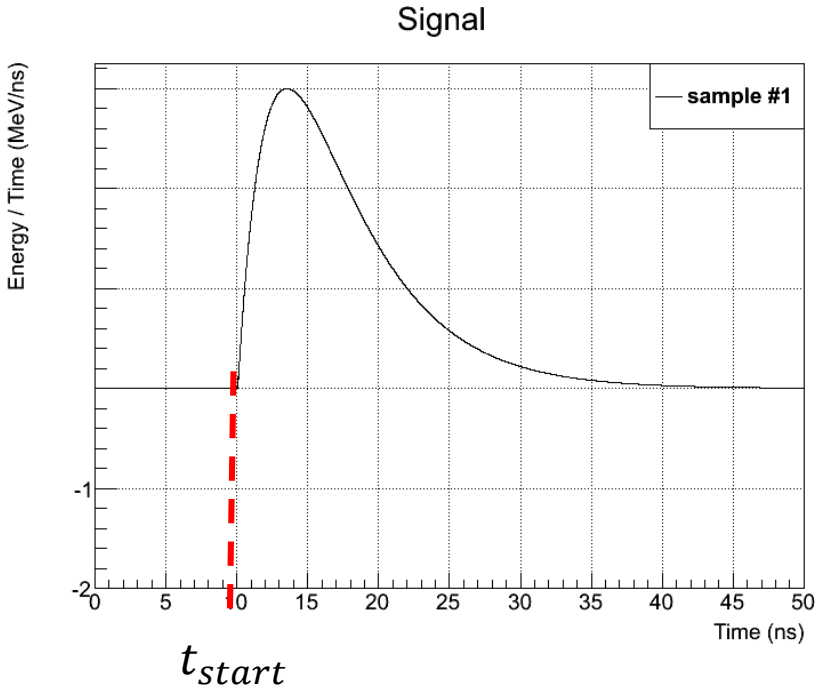
Signal generation

$t_{start1} = t_0 + t_{p1} = t_0 + \frac{l_1}{v}$

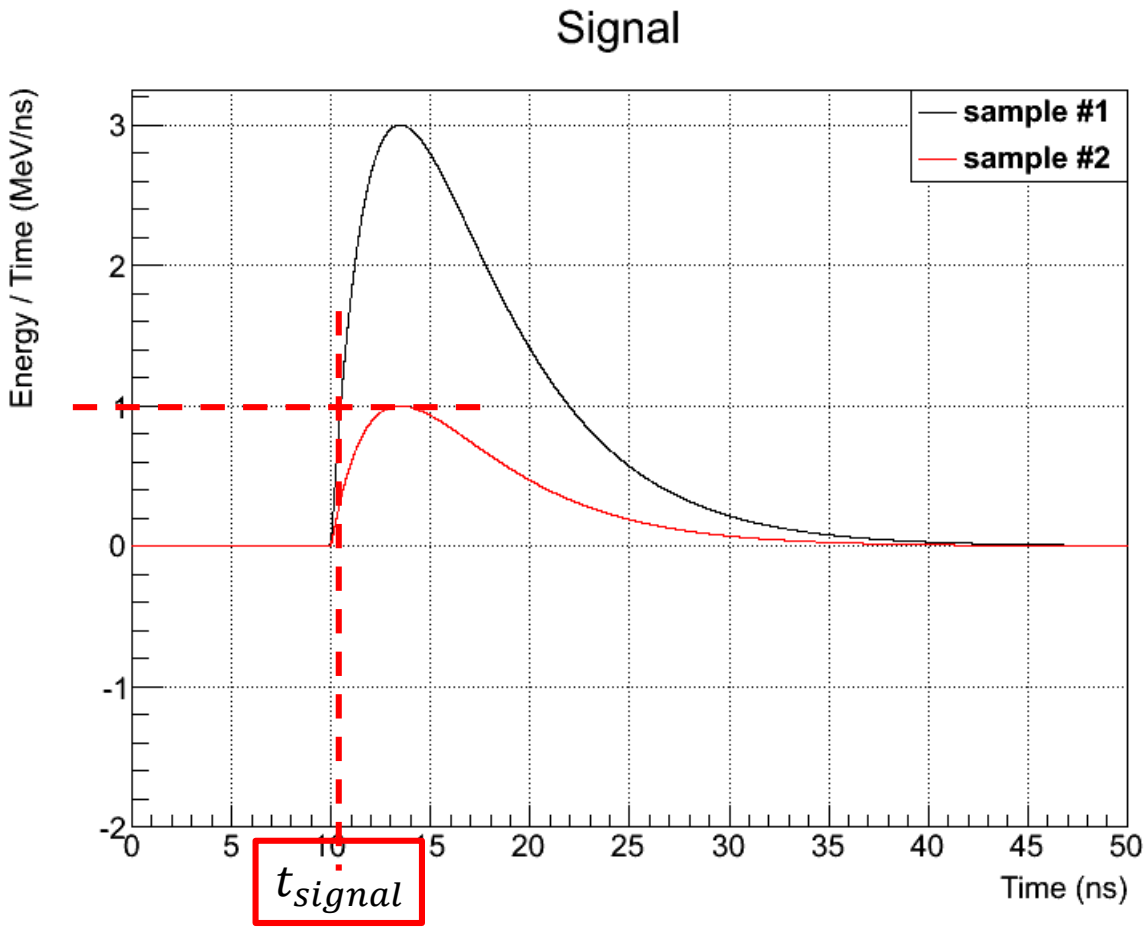
$t_{start2} = t_0 + t_{p2} = t_0 + \frac{l_2}{v}$



- Light arrival time at the end of the scintillator = signal start time(t_{start1}, t_{start2})



Threshold & Signal hitTime



- Signal 과 시작점이 같고, 파형이 같은 threshold signal 을 만든다.
- Signal 의 높이가 threshold signal 의 최대값과 같아지는 지점의 시간
  = simulation 에서 사용하는 signal hitTime
  ≈ 실제 실험에서 얻어지는 signal hitTime

Time Resolution

- Signal hitTime t_{signal}

  = (중성자에 의해 scintillator 에 light 이 발생하는 시간 t_0)

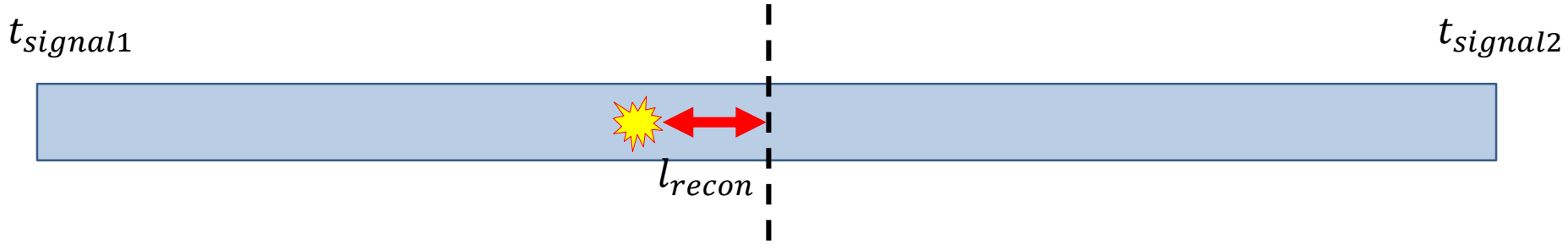
  + (light propagation time $t_p = \frac{l}{v}$)

  + (PMT 에서 발생한 signal 의 높이가 threshold signal 의 최대값과 같아질 때까지 걸리는 시간)

- Deposited energy 값에 따라, 중성자가 같은 위치를 지나가는 경우만을 비교하더라도 signal hitTime 이 달라질 수 있다.
  - Time resolution

- 양 쪽 PMT 에서 만들어지는 두 signal 모두 threshold height 를 넘길 때에만 true 로 간주하고, true signal hitTime 을 계산하여 저장한다.
  - True signal hitTime = 0.5*($t_{signal1} + t_{signal2}$)

Position Reconstruction



- 양쪽 PMT 의 signal hitTime 의 차이를 이용하여, light 이 발생한 위치(≈ 중성자가 지나간 위치)를 reconstruct.

- Reconstructed position = $0.5(t_{signal1} - t_{signal2})v$

Result

- ❖ 100 cm – 100 cm 위치(center)에서 300 MeV 의 중성자가 지나간 경우의 signal hitTime 분포(≈ 10000 events)
- Threshold signal integration energy = 1 MeV

Result

- Threshold signal integration energy = 5 MeV