Update on the simulation for ALERT

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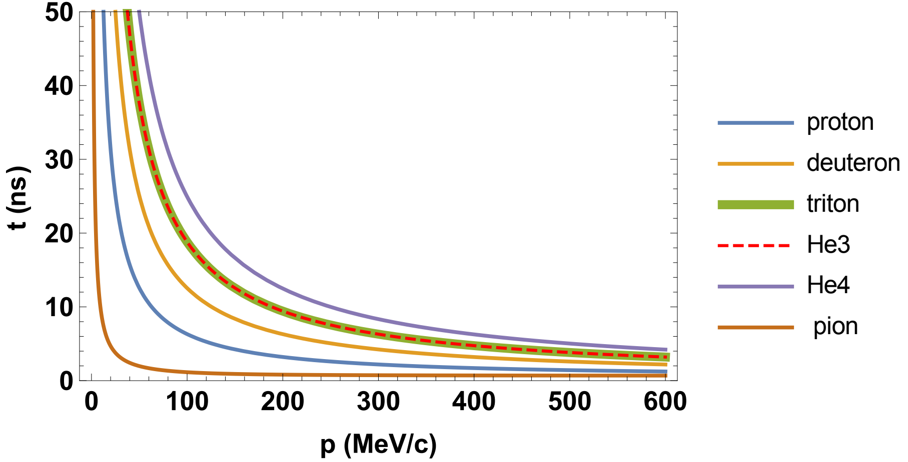
Time-of-Flight Calculation

$$TOF = \frac{L}{c}\frac{1}{\beta}$$

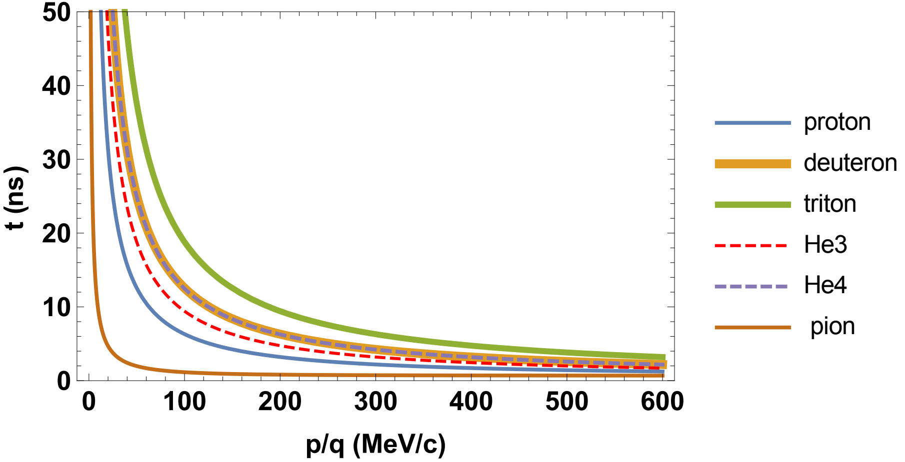
L is the distance traversed by the particle, $\beta = p/E$, and c is the speed of light.



Time-of-Flight Calculation

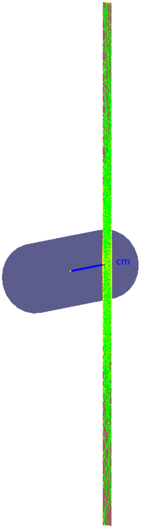
$$TOF = \frac{L}{c}\frac{1}{\beta}$$

Plotting as a function of the relevant quantity p/q, where q is the particle charge.



Geant4 Simulation - scint_test

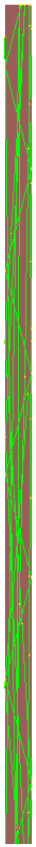
1. Simulate only the scintillator (no other detectors)
2. Understand material scintillation and light propagation
3. Optimize for efficient trigger and high time resolution

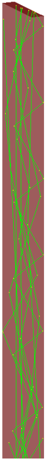


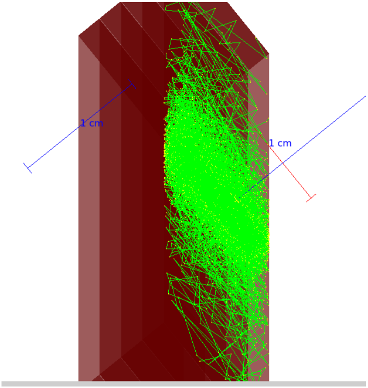
Simple setup to examine scintillator response

- Thin scintillator strips with photon detectors at ends
- 10 mm $\times$ 2 mm $\times$ 40 cm
- Scintillator material only has one component (fast)
- Photons are detected and absorbed at both ends
- For each event the individual photon information recorded
- Event averages for each surface are also recorded (and mostly used for this analysis)

Geant4 Simulation





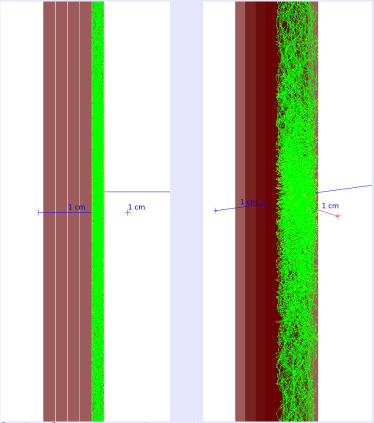


Geant4 Simulation

A quick check of the range

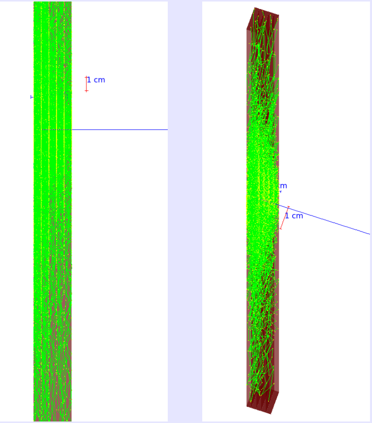
Vs.

300 MeV α particles



Only first layer has photons

300 MeV protons



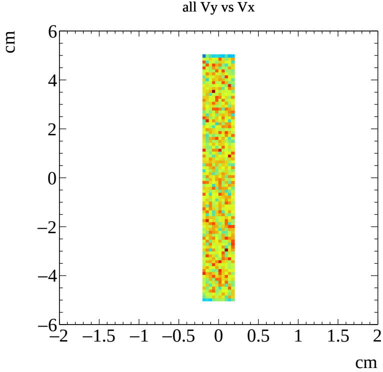
Proton penetrates all layers

Of course this is the expected behavior.

Thrown Events

Simple event generator for studying scintillator

- Events thrown from fixed z position: 10 cm upstream
- The x and y coordinates varied, uniformly covering a rectangle.
- Particles enter normal to scintillator surface



Will study in the future...

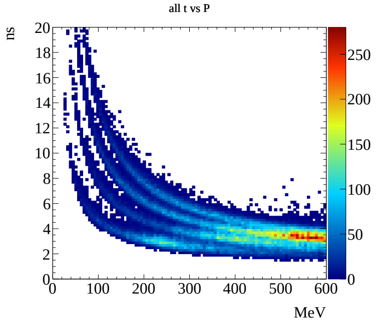
- Varying the angle of incidence
- The layer/particle topology

Time-of-Flight

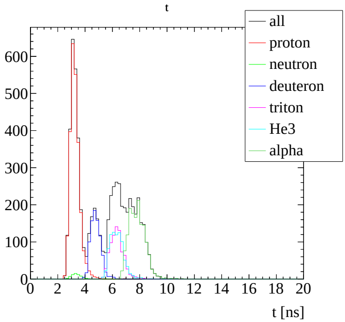
Five layers of duel ended readout scintillator bars

$$T_i = TOF + d_i/a \qquad TOF = \frac{L}{c}\frac{1}{\beta}$$

d_i is the distance from where the track entered the scintillator to photon detector i, a is the average light pulse propagation speed, L is the length traversed by the particle which was thrown at t=0, $\beta = p/E$, and c is the speed of light.



Bands lower to upper: p, d, ^{3}H & ^{3}He, ^{4}He



$p = 200 \pm 25$ MeV

Note these times are relative to the thrown time

Time-of-Flight : TDC Sums

Five layers of duel ended readout scintillator bars

Problem

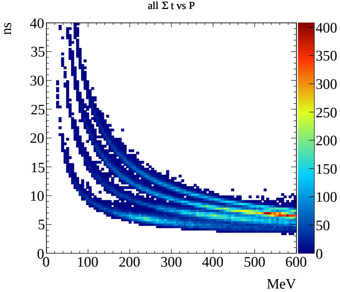
Single detector TOF information is smeared by the position along scintillator

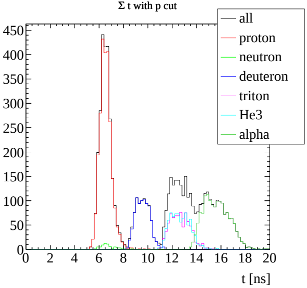
$$T_i = TOF + d_i/a \qquad \Sigma t = T_1 + T_2$$

$$L = d_1 + d_2 \qquad = 2TOF + d_1/a + d_2/a$$

$$= 2TOF + L/a$$

Summing the time at both ends ($i = 1$ and 2) produces a result proportional to the **TOF plus a constant,** $\frac{L}{a}$.





p = 200 ± 25 MeV

Having photon detectors at both ends of the scintillator improves the TOF separation

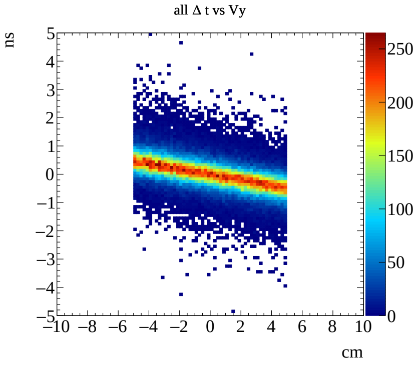
Time-of-Flight : TDC Differences

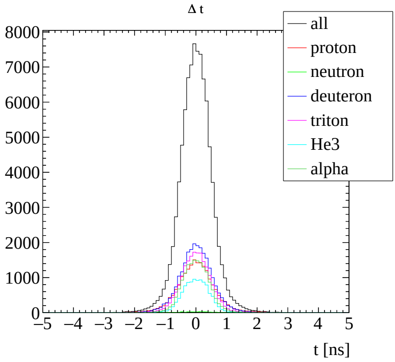
Five layers of duel ended readout scintillator bars

$$\begin{aligned}\Delta t &= T_1 - T_2 \\ &= d_1/a - d_2/a \\ &= (L - 2\ d_2)/a\end{aligned}$$

$$d_2 = L - \frac{a}{2}\Delta t$$

$$d_1 = \frac{a}{2}\Delta t$$



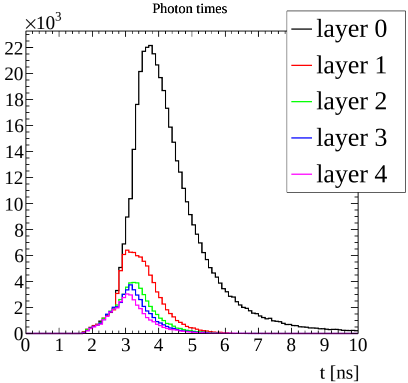


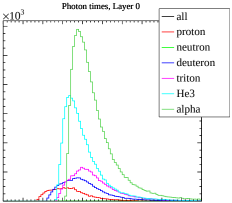
Useful for rough position correlation.

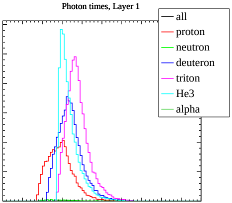
Photon arrival times

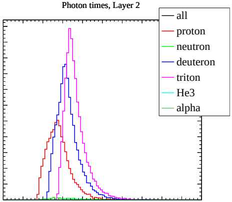
Five layers of duel ended readout scintillator bars

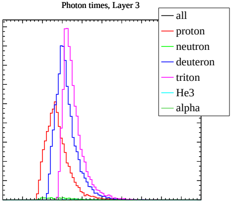
Particle beam's primary vertex position now fixed.

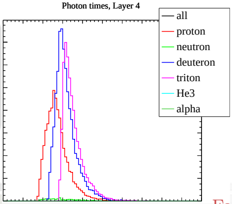












Forming pulse shapes

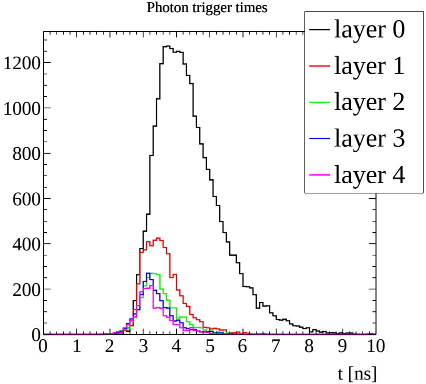
- Can accurate pulse shapes be constructed using photon arrival times?
- Could these be used for some PID?

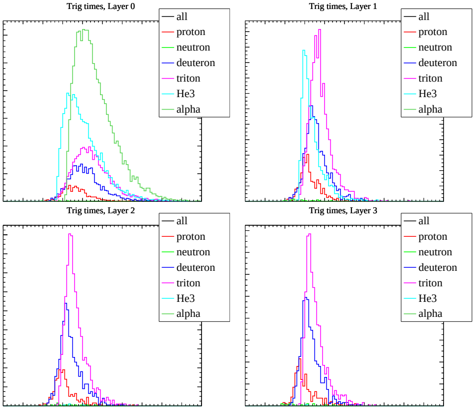
A thoughtfully designed first layer may provide useful information.

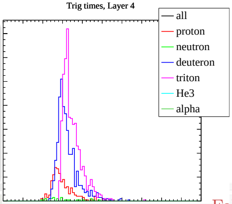
Photons times → discriminator trigger

Five layers of duel ended readout scintillator bars

Particle beam's primary vertex position now fixed.







Discriminator Emulation

- Define threshold number of photons: N_0
- Define time window: δ
- For each photon hit if N_0 photons arrive within the next δ ns, then select that time to fire the discriminator

A thoughtfully designed first layer may provide useful information.

Tile Scintillator

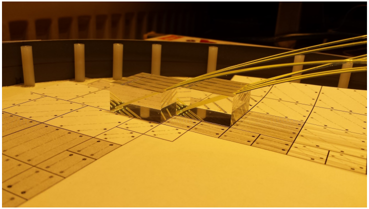
CLAS12 FT-hodo scintillator

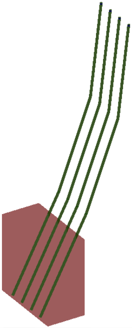
4 sizes

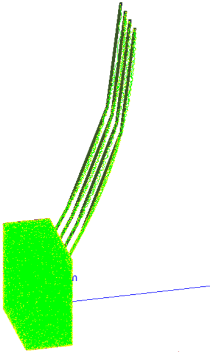
- (15×15) mm^2
- (30×30) mm^2
- Thicknesses: 7 mm or 15 mm

Scint. embedded with multiple WLSFs

- WLSF glued into drilled holes
- $\approx$ 10 cm of WLSF fused to clear fiber
- $\approx$ 5 m clear optical fibers coupled to SiPM

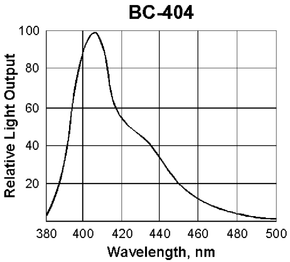


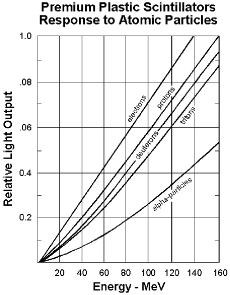




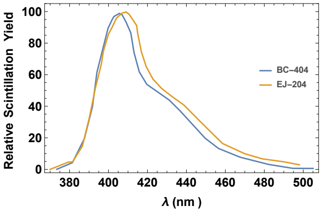
Scintillator Properties in Geant4

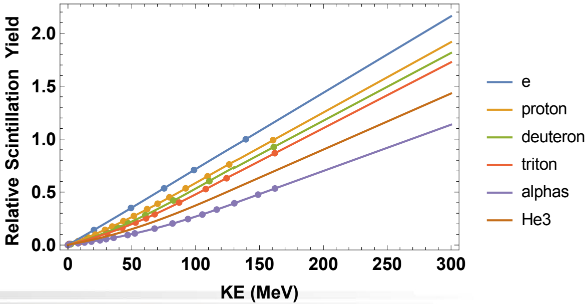
Scintillation yield by particle type





- Data digitized from graph then fit
- Relative yields extrapolated using last few points fit to a straigh line
- New tables created from fits
- He3 approximated as average between triton and alpha.
- Geant4 modified to include He3 on the list of particles with non-linear scintillation yields





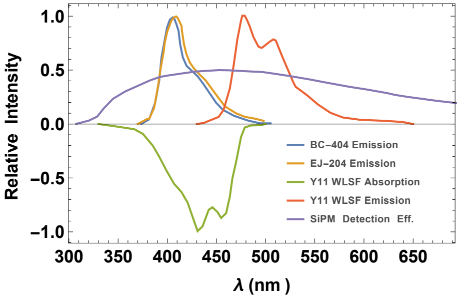
WLS Fiber Properties in Geant4

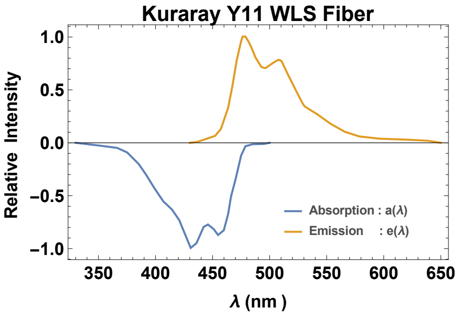
- Emission spectrum
- Absorption length spectrum

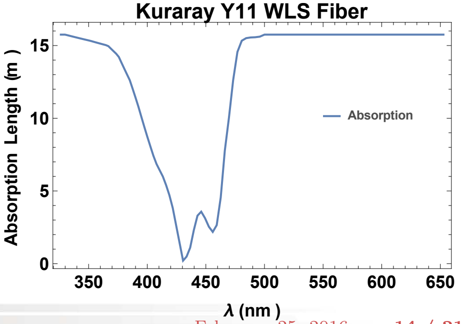
$$l_A(\lambda) = \frac{l_A(\lambda_0)}{1 - a(\lambda_0)}\left[1 - a(\lambda)\right]$$

where

$$l_A(\lambda_0 = 445nm) \simeq 3.5m$$



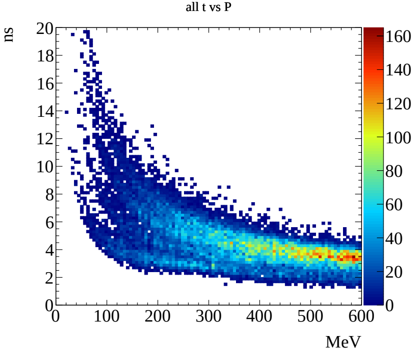




Scintillator Tile Simulation

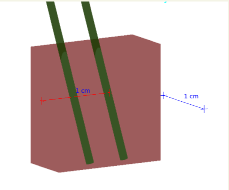
$30 \times 30 \times 15\ mm^3$

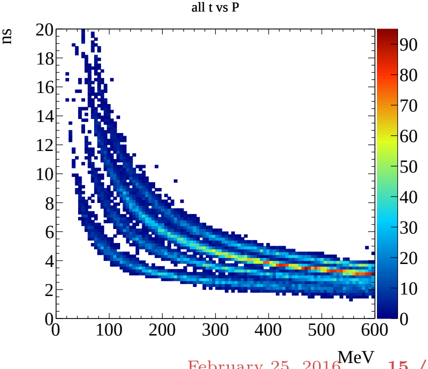
- Poor time resolution...
- Many bounces inside scintillator until photon hits embeded WLSF
- Photons that are not shifted have very small acceptance



$15 \times 15 \times 7\ mm^3$

- Much better time...
- Need try elongated tile in the direction of the fibers





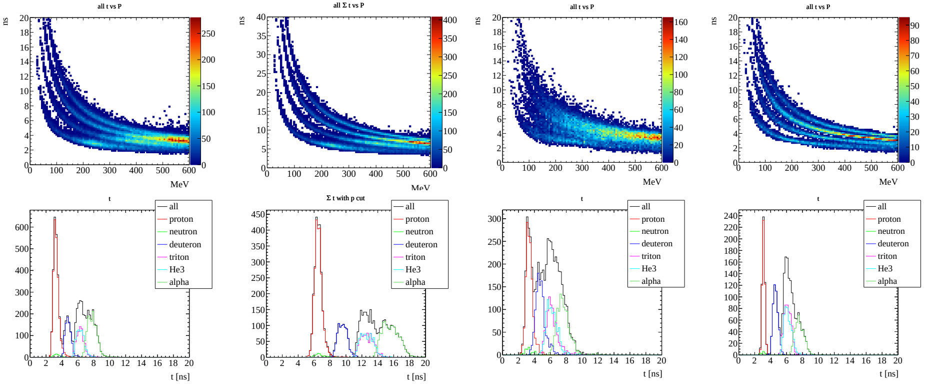
Scintillator Tile Simulation

Bar $2\times10\times400$ mm^3 single-end readout

Bar $2\times10\times400$ mm^3 dual-end readout

Tile: $30\times30\times15$ mm^3

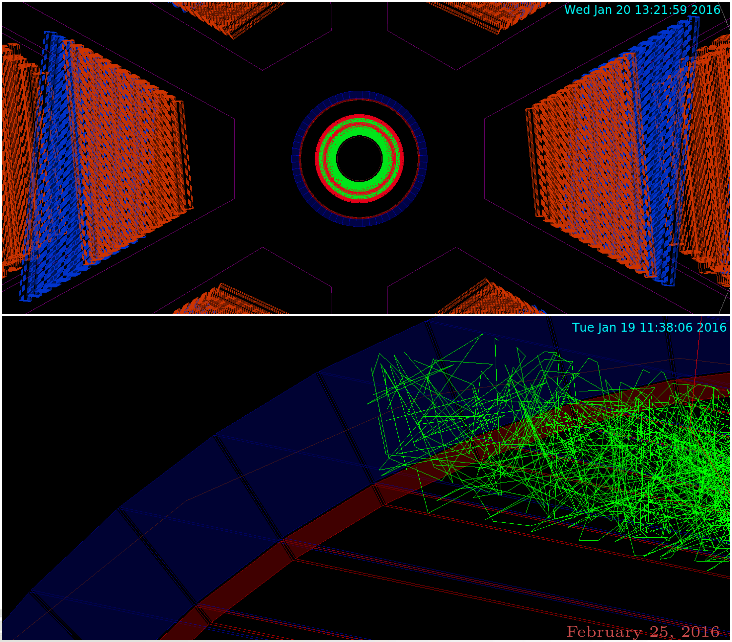
Tile: $15\times15\times7$ mm^3



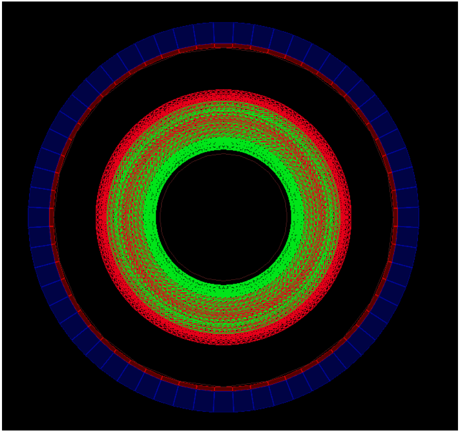
p $= 200 \pm 25$ MeV

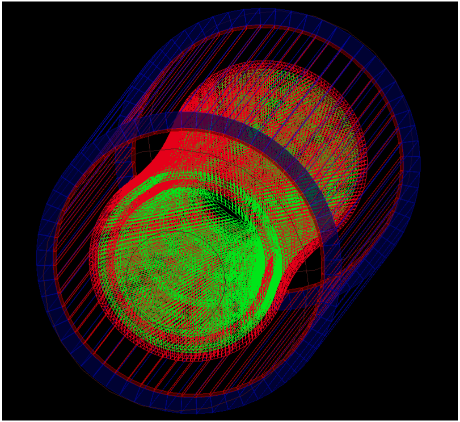
Keep in mind that the TOF here is using an ideal (perfect) reference time.
Also when plotted vs p/q, the ^4He will be degenerate with the deuteron here and the ^3He will be between the proton and deuteron.

Preliminary Design



Preliminary Design





Event Generator

Simulation Input

- Event generator for coherent and incoherent DVCS developed using approximate form from EG6 fit
- Can easily incorporate new process (just need the cross section)
- Default simulation is ep elastics this will be changed to e-^{4}He elastics.
- Useful for studying acceptance and signal/background

Open to requests of the event generator for implementing new cross sections

Current Status

- Installed on the farm: `/group/clas12-alert`
- Output is easy-to-use root files
- `https://clasweb.jlab.org/wiki/index.php/ALERT_Software`
- Everything is on gitlab
- Not integrated with clas12 fast-MC

Recoil Scintillator Simulation Summary

- Full Geant4 simulation for studying recoil detector completed
- Event generator available for producing realistic input

Future Work

- Design scintillator system around recoil drift chamber.
- Study different geometry/scintillator combinations
- Explore possible geometry scenarios (e.g. long fibers to detect light farther away).
- Determine how to measure photons: PMTs, SiPM, APDs, ...
- Add reconstruction using recoil chamber and scintillator for more realistic analysis