# Energy Loss Model

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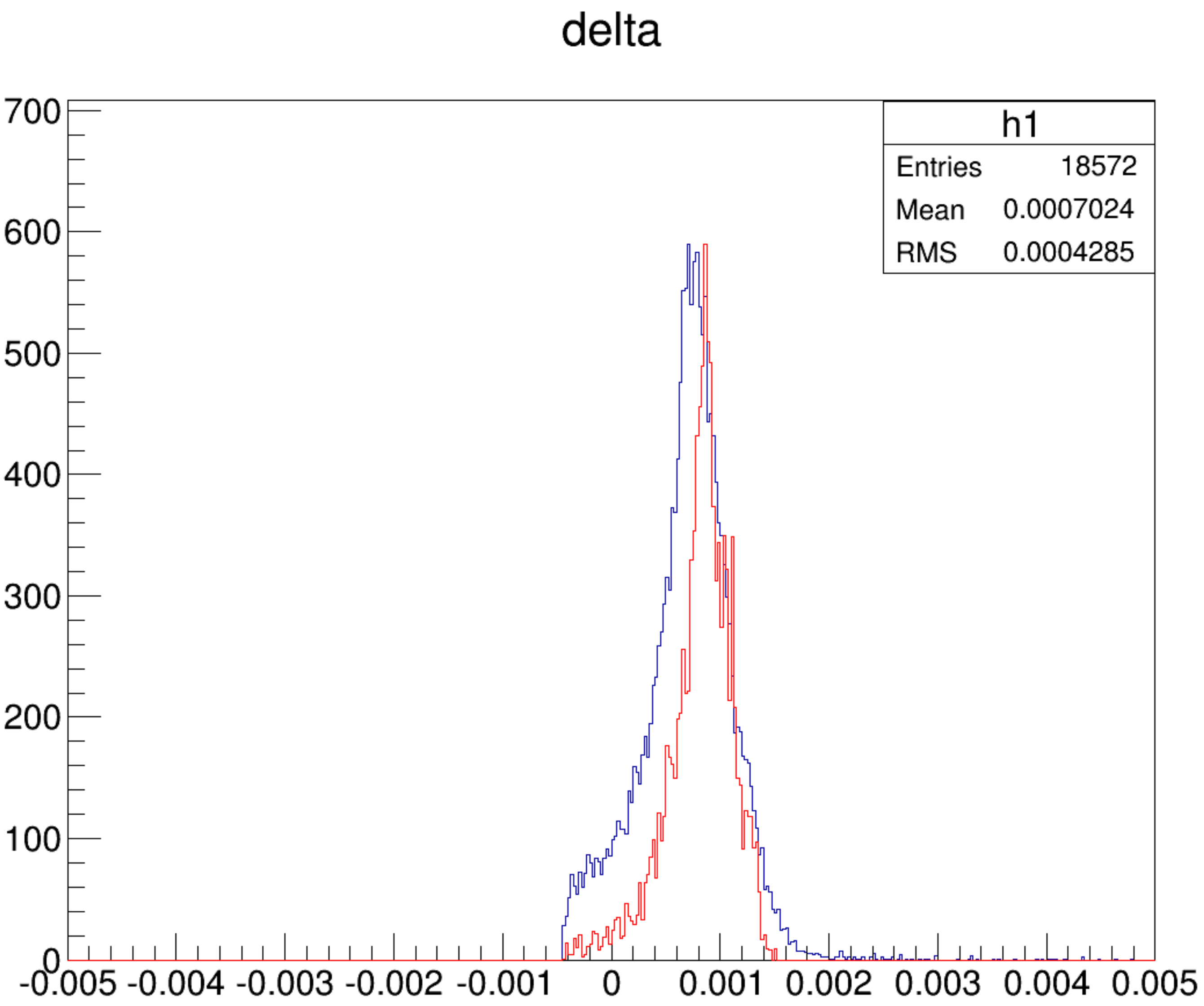
# Problem Review

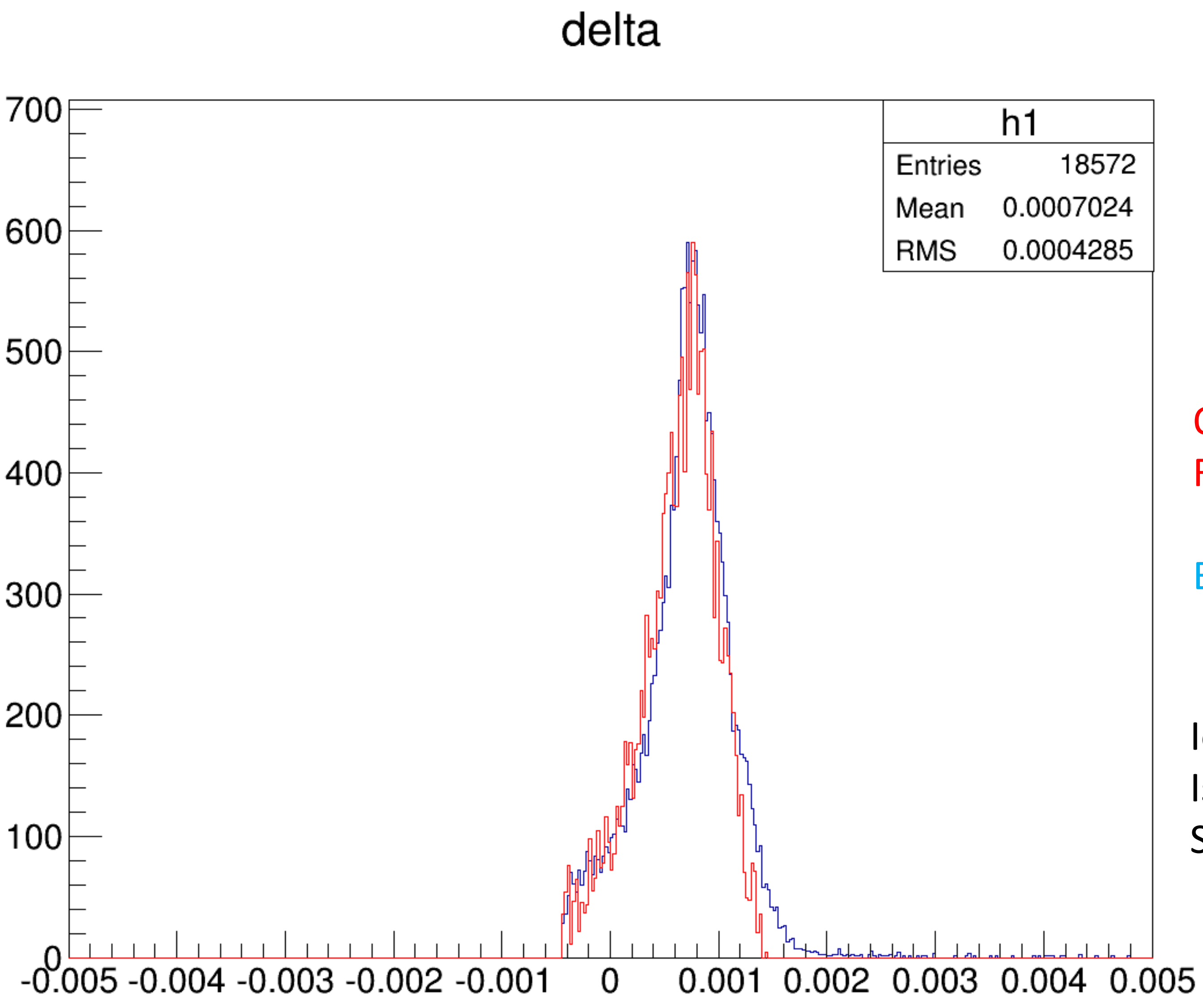



Optics run C
w/o He

Red:
g2psim
Blue:
Data

Ionization model
Is Berger-Seltzer
Formula, from
geant4

# Problem Review




Optics run C w/o He

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g2psim

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Data

Ionization model Is Landau Distribution, SAMC used

# Ionization- SAMC

The probability distribution of energy loss Δ by ionization is a Landau distribution, peaked at

$$\Delta_0 = \xi \left[ \ln \left( \frac{\xi}{\epsilon'} \right) + 0.20 \right]$$

$$\xi = \frac{2\pi\alpha^2 N_A}{m_e \beta^2} \frac{Z}{A} d$$

$$\ln \epsilon' = \ln \left[ \frac{\left(1-\beta^2\right) I_0^2 Z^2}{2 m_e \beta^2} \right] + \beta^2$$

$N_A$ Aagadro number, $\beta = v/c$ , d is the averaged density multiplied by length, A is the averaged mass number, $I_0$ is the ionization energy of material

# Ionization-geant4

How:

❑ Below an energy threshold: the energy loss is continuous

$$\left.\frac{dE}{dx}\right]_{T<T_{cut}} = 2\pi r_e^2 mc^2 n_{el} \frac{1}{\beta^2}\left[\ln\frac{2(\gamma+1)}{(I/mc^2)^2} + F^{\pm}(\tau,\tau_{up}) - \delta\right]$$

○ $T_{cut}$ : mininum cut for $\delta$-ray production

○ $\delta$ : density effect function

$$F^{+}(\tau,\tau_{up}) = \ln(\tau\tau_{up}) - \frac{\tau_{up}^2}{\tau}\left[\tau + 2\tau_{up} - \frac{3\tau_{up}^2 y}{2} - \left(\tau_{up} - \frac{\tau_{up}^3}{3}\right)y^2 - \left(\frac{\tau_{up}^2}{2} - \tau\frac{\tau_{up}^3}{3} + \frac{\tau_{up}^4}{4}\right)y^3\right]$$

✓ continuous energy loss has fluctuations, to take partially draggling effect

❑ above a energy threshold: simulated by the explicit secondary particles

Moller Scattering
$$\frac{d\sigma}{d\epsilon} = \frac{2\pi r_e^2 Z}{\beta^2(\gamma-1)} \times \left[\frac{(\gamma-1)^2}{\gamma^2} + \frac{1}{\epsilon}\left(\frac{1}{\epsilon} - \frac{2\gamma-1}{\gamma^2}\right) + \frac{1}{1-\epsilon}\left(\frac{1}{1-\epsilon} - \frac{2\gamma-1}{\gamma^2}\right)\right]$$

# Ionization fluctuation model

- Large fluctuations are due to small number of collisions of large energy transfers
- Characterised by $\kappa$ ~ ratio of mean energy loss to the maximum allowed energy transfer in a single collision with an atomic electron

$$\kappa = \frac{\xi}{E_{\max}}$$

$$\xi = \frac{2\pi z^2 e^4 N_{Av} Z \rho \delta x}{m_e \beta^2 c^2 A} = 153.4 \frac{z^2}{\beta^2} \frac{Z}{A} \rho \delta x \quad \text{keV},$$

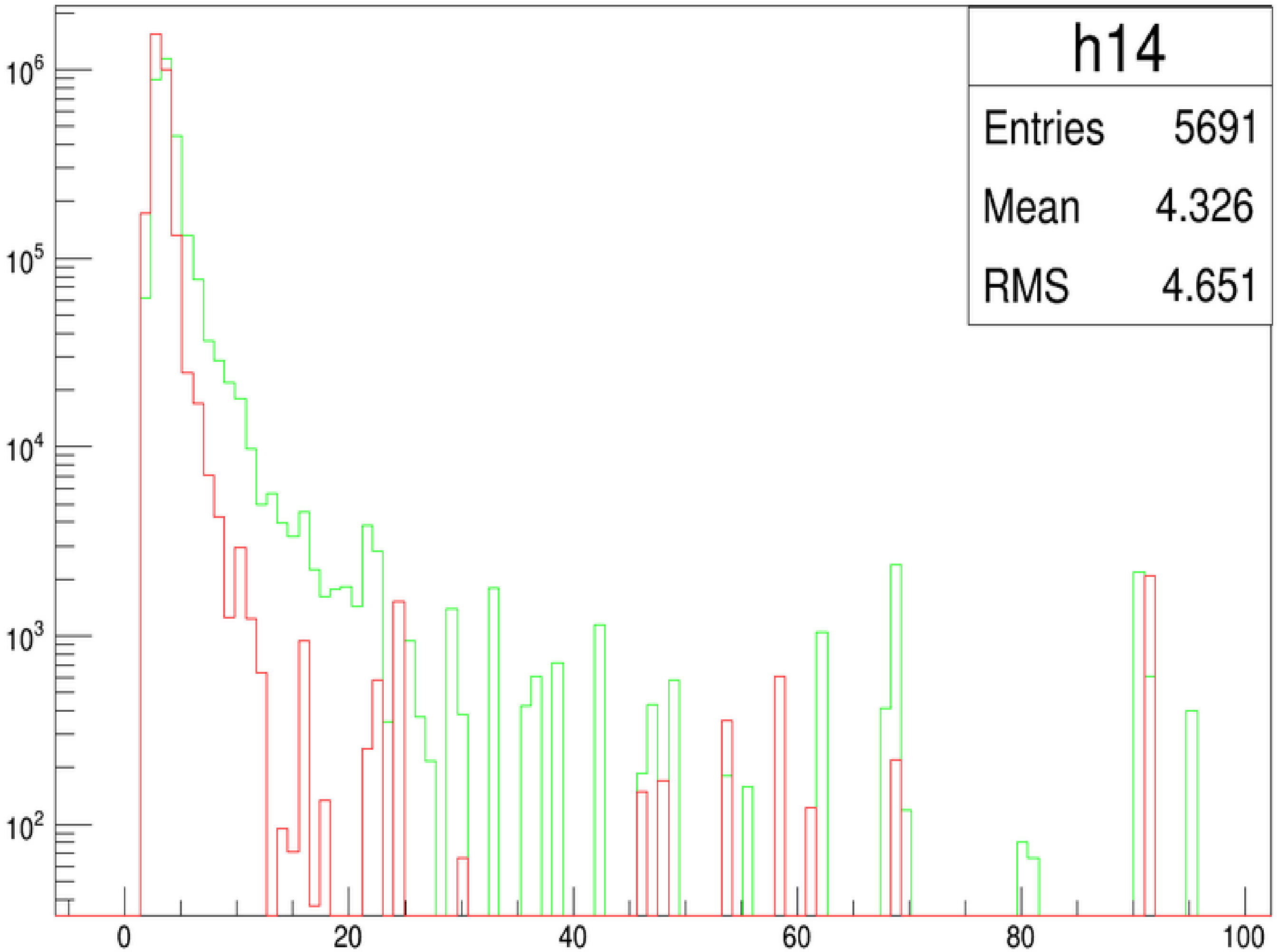
- Heavy absorbers : $\kappa$ >10 Gaussian distribution
- Moderate absorbers: $0.01 < \kappa < 10$ , Vavilov
- Thin absorbers: $\kappa < 0.01$, with collisions numbers $N_c > 50$, Landau
- Very thin absorbers : $N_c < 50$ ($\kappa \ll 0.01$) , approximation model

# Ionization fluctuation model

- Compute the mean energy loss first

- Geant 4 use **Urban model** to simulate the fluctuation of the mean energy loss.
- General idea:
  - Atoms have only two energy levels with binding energy E1 and E2.
  - particle–atom interaction will then be an excitation with energy loss E1 or E2.
  - Or an ionization with an energy loss distributed according to a function $g_E = 1/E^2$
- Can be used for any thickness of a medium.
- Approaching the limit of the validity of Landau's theory, the loss distribution approaches smoothly the Landau

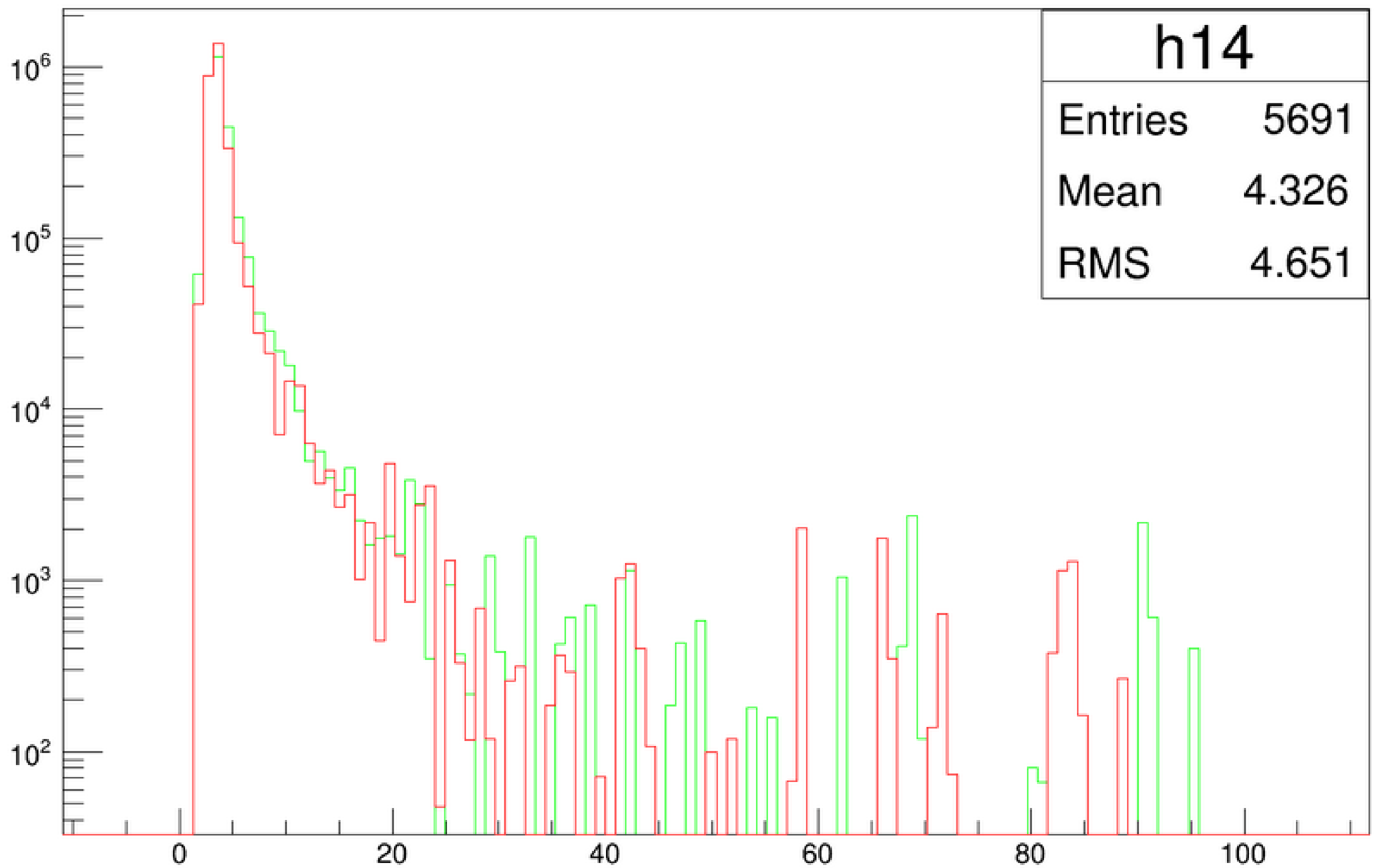
# Model Comparison




Only Ionization
Red: g2psim
Green: SAMC

Red: not include
$\delta$-ray production
But include
Continuous energy
loss

Model Comparison

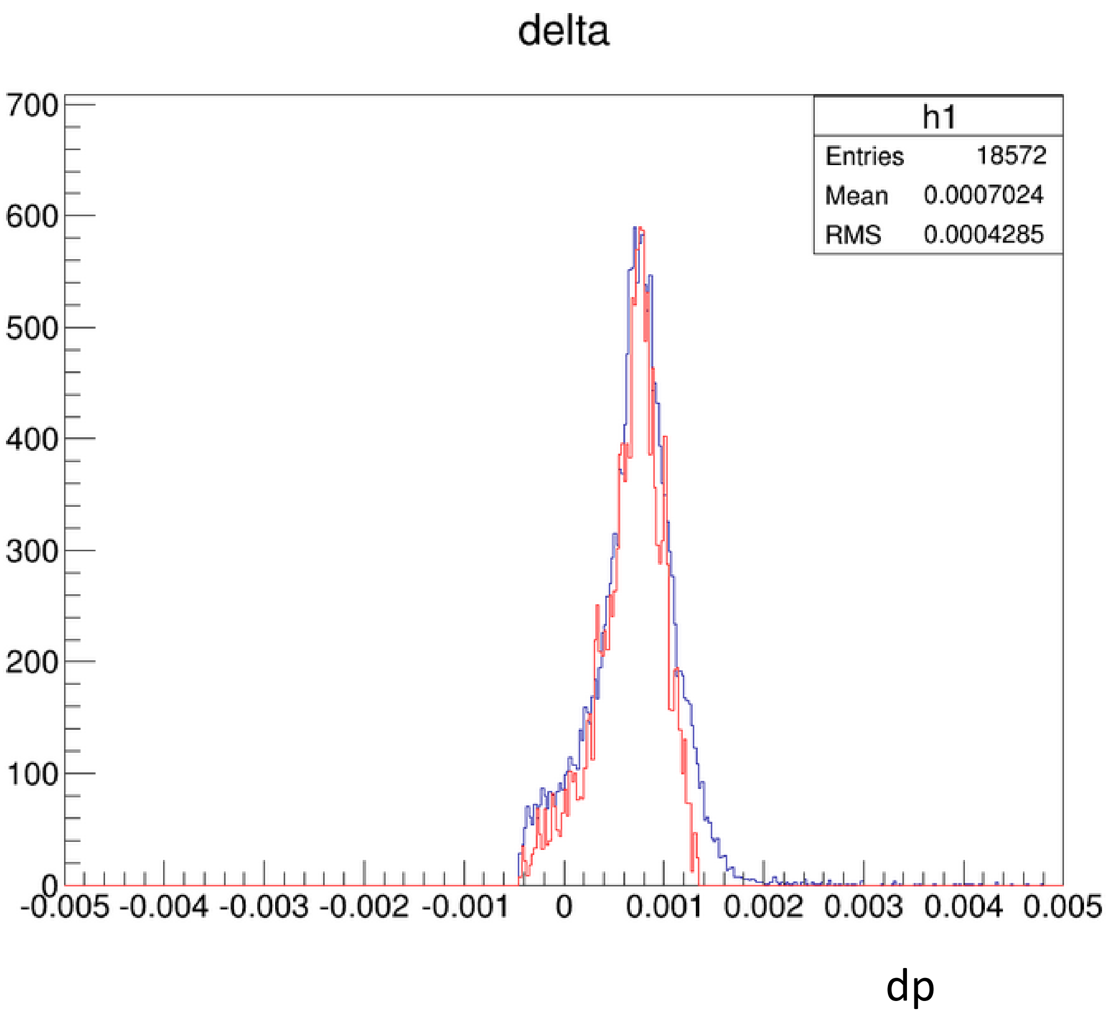



Nu/MeV

Only Ionization
Red: g2psim
Green: SAMC

Red: include 1 $\delta$-ray production And continuous Energy loss

# Model Comparison




Red: g2psim
Green: SAMC

Red: include 1
$\delta$-ray production
And continuous
Energy loss
+ Bremesstrahlung

# Todo

- Need to verify the free path for $\delta$-ray production
- Check it on other target settings
- Packing simulation