Understanding e/gamma Separation

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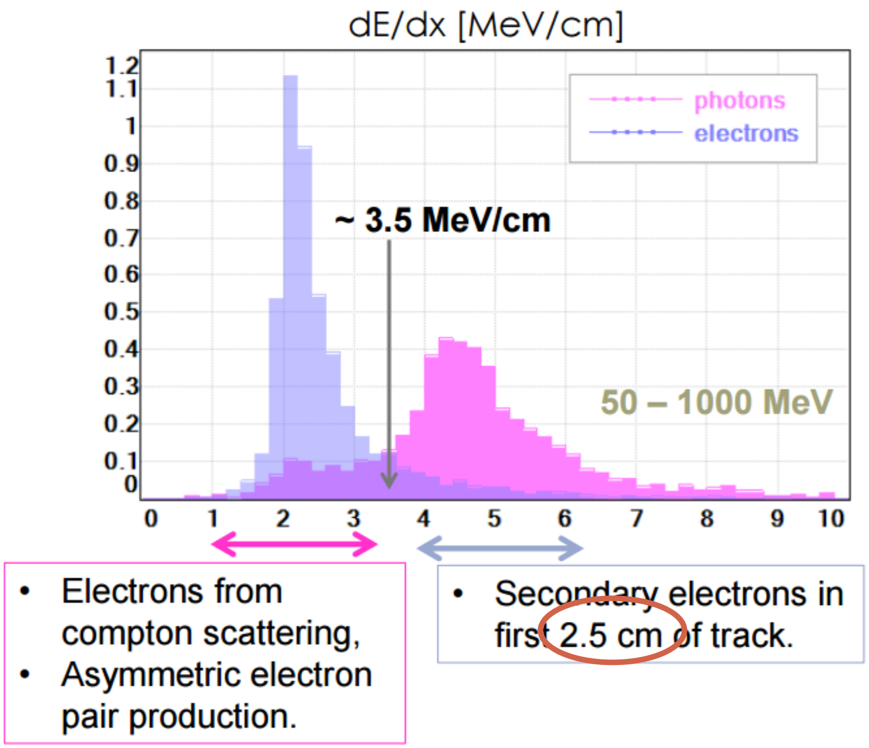
e/gamma Separation

- Three ways to handle e/gamma separation
  - Topology:
    - pi0 decay: 2 shower vs. 1 shower
  - Gap from primary vertex:
    - Gamma: ~ 18 cm
  - dE/dx at the beginning of the shower
    - 2 MIP (gamma) vs 1 MIP (e-)
    - *Focus of this talk*

dE/dx for Electron and Gamma

https://indico.fnal.gov/getFile.py/access?contribId=32&sessionId=1&resId=0&materialId=slides&confId=9740

from Robert & Dorota



- Why 2.5cm?
  - Where does a single electron become two or more?

Secondary Electrons from Delta Ray

From Xin

$$\frac{d^2N}{dTdx} = \frac{1}{2}\cdot\frac{K}{A}\cdot z^2\cdot Z\cdot\frac{1}{\beta^2}\cdot\frac{(1-\beta^2\cdot\frac{T}{T_{\max}}+\frac{1}{2}\left(\frac{T}{E+Mc^2}\right)^2)}{T^2}$$

- For incident e- particle, we have (Moller scatter)

$$\frac{dN^2}{dTdx} = \frac{K}{A}\cdot\frac{Z}{2}\cdot\frac{1-T/E+\left(T/E\right)^2}{\left(E-T\right)^2T^2}\cdot E^2$$

$$T_{\max} = E/2$$

- => Mean free path ~ 5 cm (for T_cut = 0.5 MeV)

Secondary Electrons from Radiation

- Primary electron -> Brem photons -> pair production / Compton / photoelectric electrons
- Radiation length in LAr ~ 14 cm
  - What does it mean?

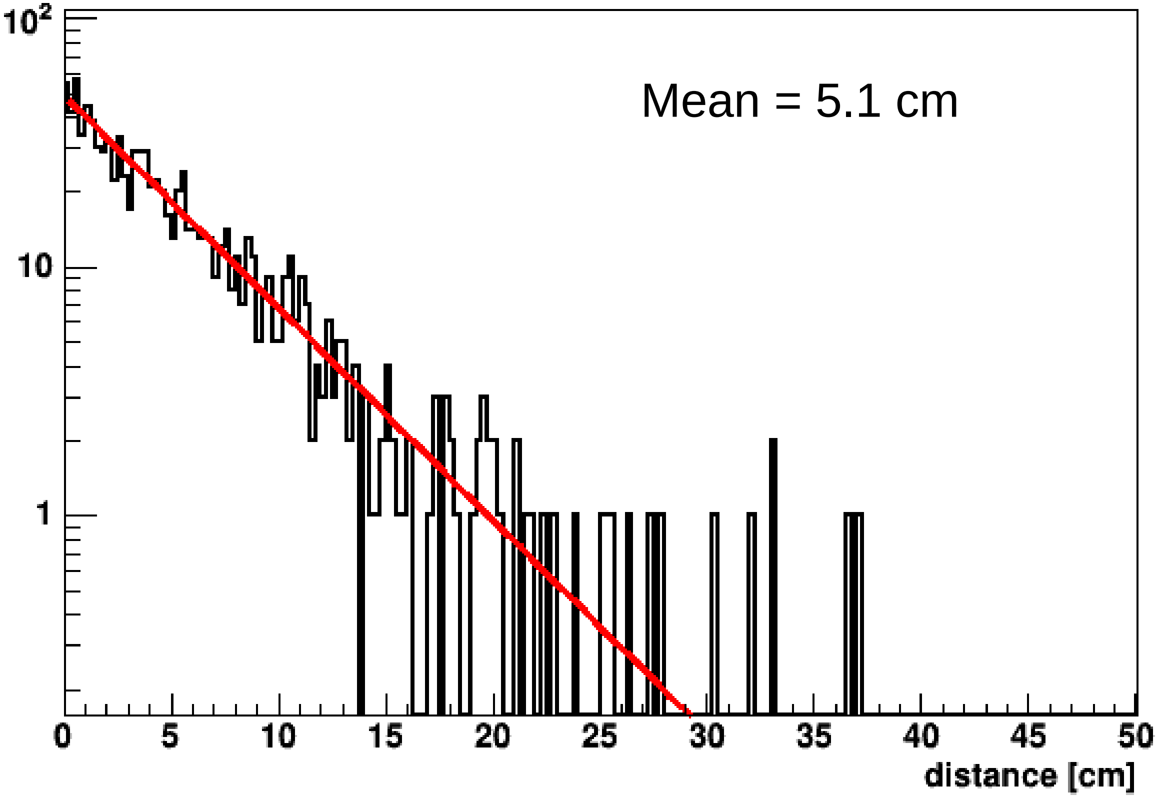
27.4.1. ***Radiation length*** : High-energy electrons predominantly lose energy in matter by bremsstrahlung, and high-energy photons by e^+e^- pair production. The characteristic amount of matter traversed for these related interactions is called the radiation length X_0, usually measured in g cm^{-2}. It is both (a) the mean distance over which a high-energy electron loses all but $1/e$ of its energy by bremsstrahlung, and (b) $\frac{7}{9}$ of the mean free path for pair production by a high-energy photon [39].

- Does NOT mean the average distance of the second photon/electron from Brem is 14 cm
- (for photon, it does mean the average distance of the second e-/e+ from pair production is 14/7*9 = 18 cm)

Simulation

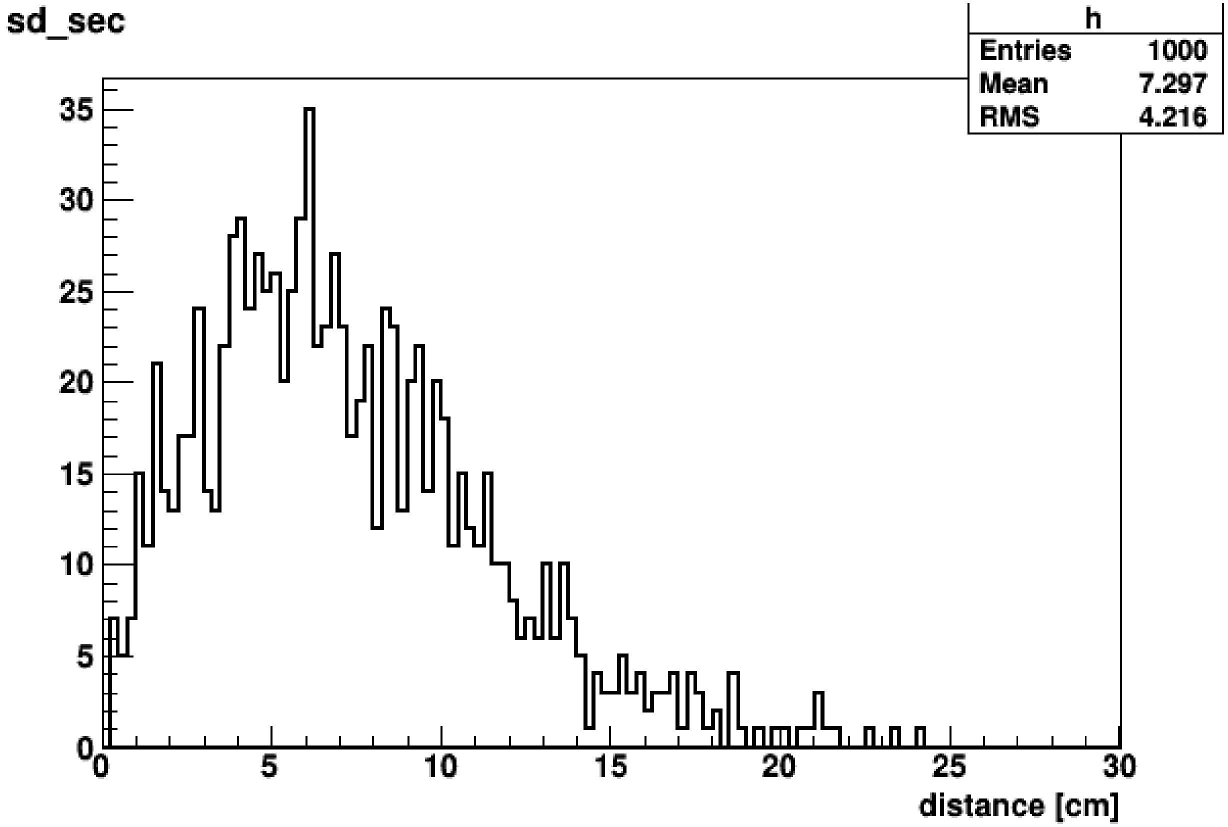
- Simulated 1000 3GeV electrons with LArSoft, using dune35t geometry
  - All horizontal electrons parallel to the APA
  - Only care about the beginning of the shower where secondary electrons are produced
- Record the closest secondary electron that
  - Either produced by ionization (delta electron) or produced by secondary brem photons
  - Minimum energy of the electron (Tcut) set to 0.5 MeV as default, but can be changed

Closest Second Electron from Delta Ray



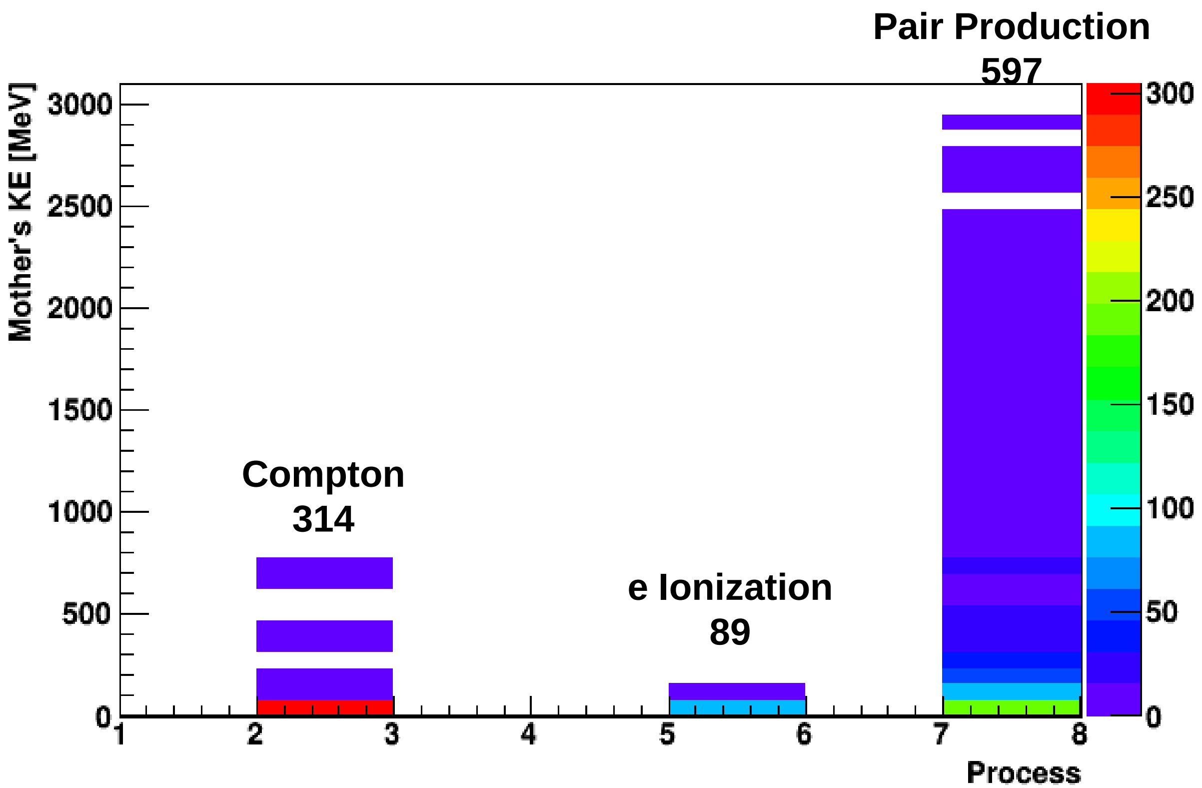
- This agrees with our previous analytical calculation from Moller scattering

Closest Second Electron from Radiation



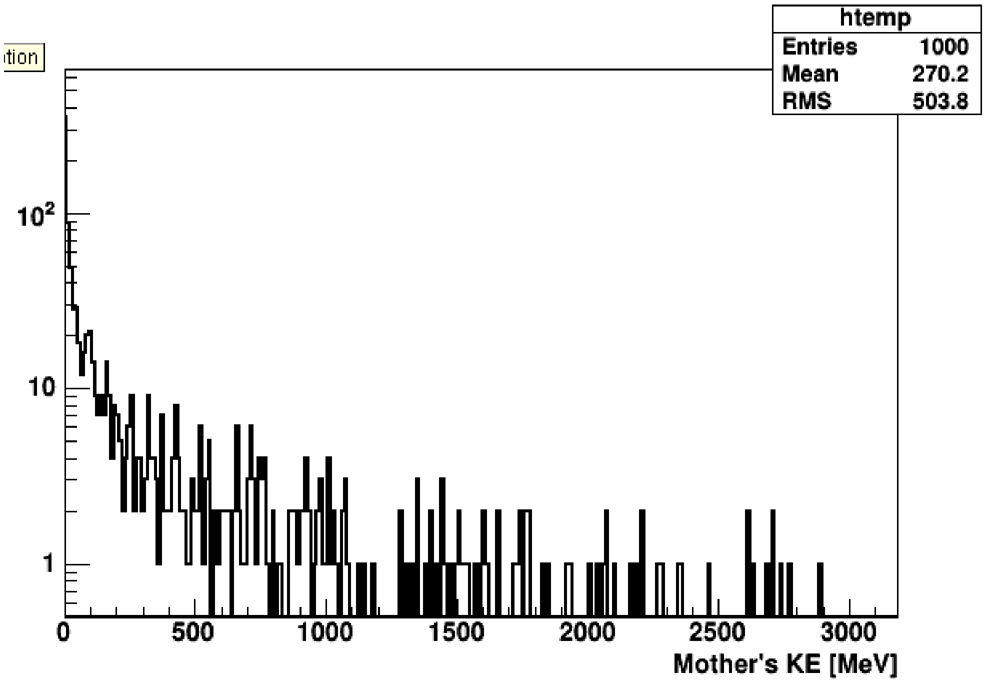
- Not an exponential distribution
- Mean distance = 7.3 cm

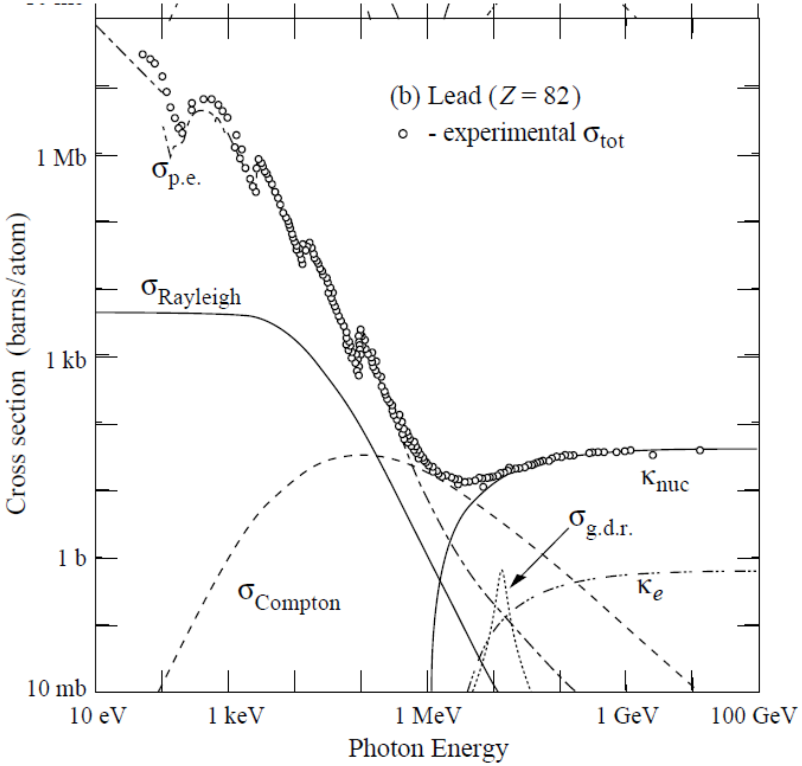
Closest Second Electron from Radiation



- This shows the process that generate the closest second electron from radiation, and the energy of its mother particle (gamma or electron)
- Some are from "e Ionization", meaning that they are from brem photon -> electron -> delta electron. This electron likely went backwards so it's closer to the primary electron

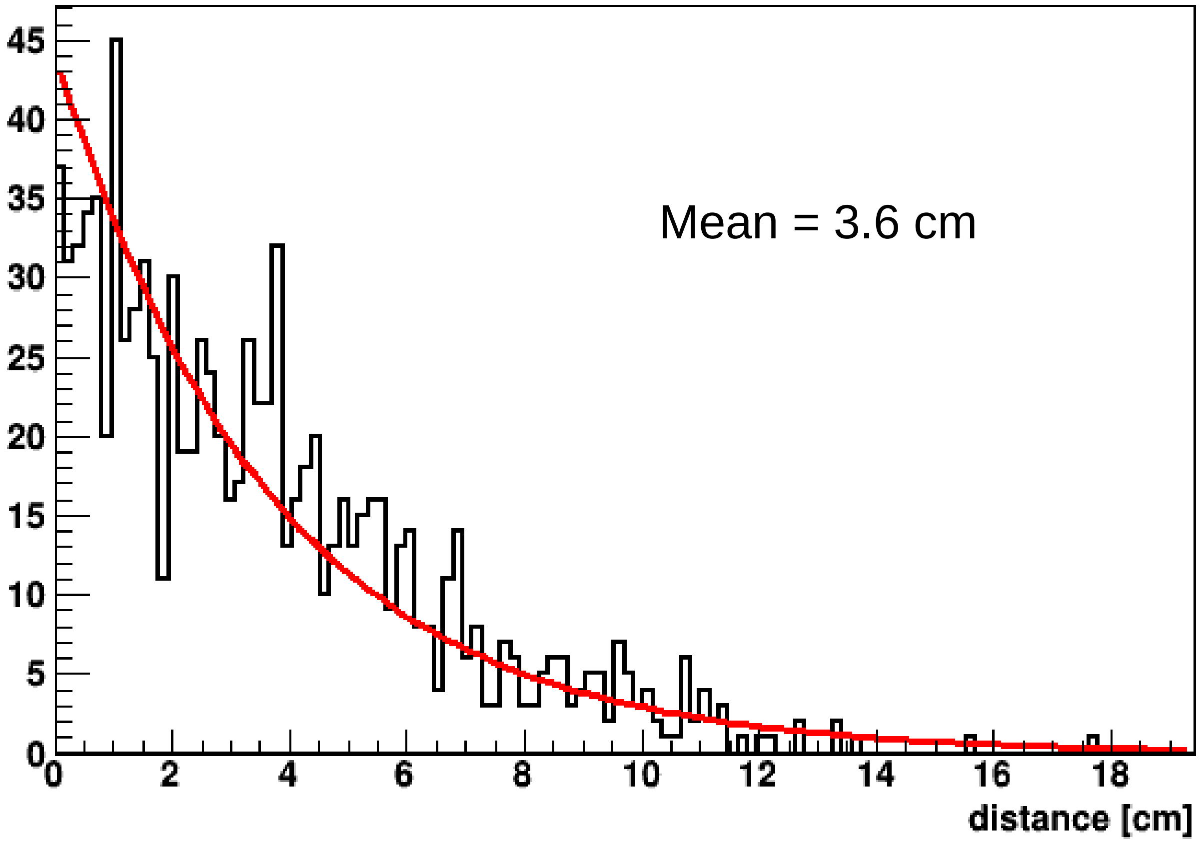
Closest Second Electron from Radiation





- Compton ~ Z, Pair production ~ Z^2 , ratio ~ Z
- In Ar, difference between Compton and pair production is ~ 82/18 = 4.5 times smaller than the above plot for Pb

Closest Second Electron



- Now we combine the delta electrons and radiation electrons to get whichever is the closest
  - Mean = 3.6 cm (delta e = 5.1 cm, radiation e = 7.3 cm)

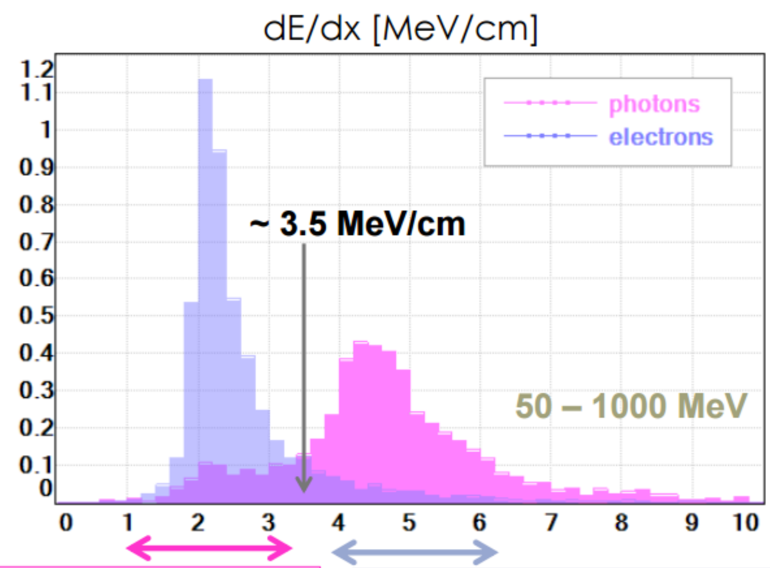
Mean Closest Second Electron vs. Tcut

	0.3 MeV	0.5 MeV	1 MeV
Delta e-	3.0 cm	5.1 cm	9.5
Radiation e-	6.7 cm	7.3 cm	8.0
Combined	2.5 cm	3.6 cm	5.3

- 2.5 cm is a reasonable distance to separate e/gamma
  - Might be further optimized by looking at dE/dx vs. distance
- Tcut is determined by the hardware such as wire pitch
  - low energy (E<Tcut) secondary electrons will contribute to the high end tail of the dE/dx distribution.

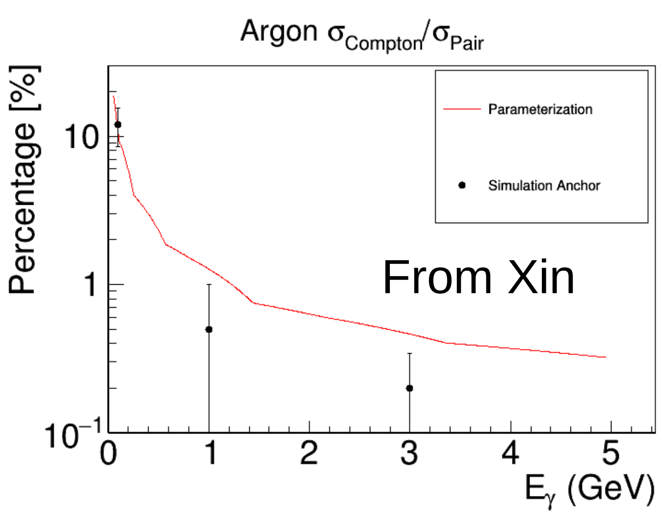
About the Gamma Side

- For DUNE energy (>500MeV) the low dE/dx tail for gamma should be much less
  - Compton scatter
  - Asymmetric pair



- Electrons from compton scattering,
- Asymmetric electron pair production.

- Secondary electrons in first 2.5 cm of track.



- Might be better to study the separation power in different energy range