

Boosted Dark Matter Resonant Scattering Theory

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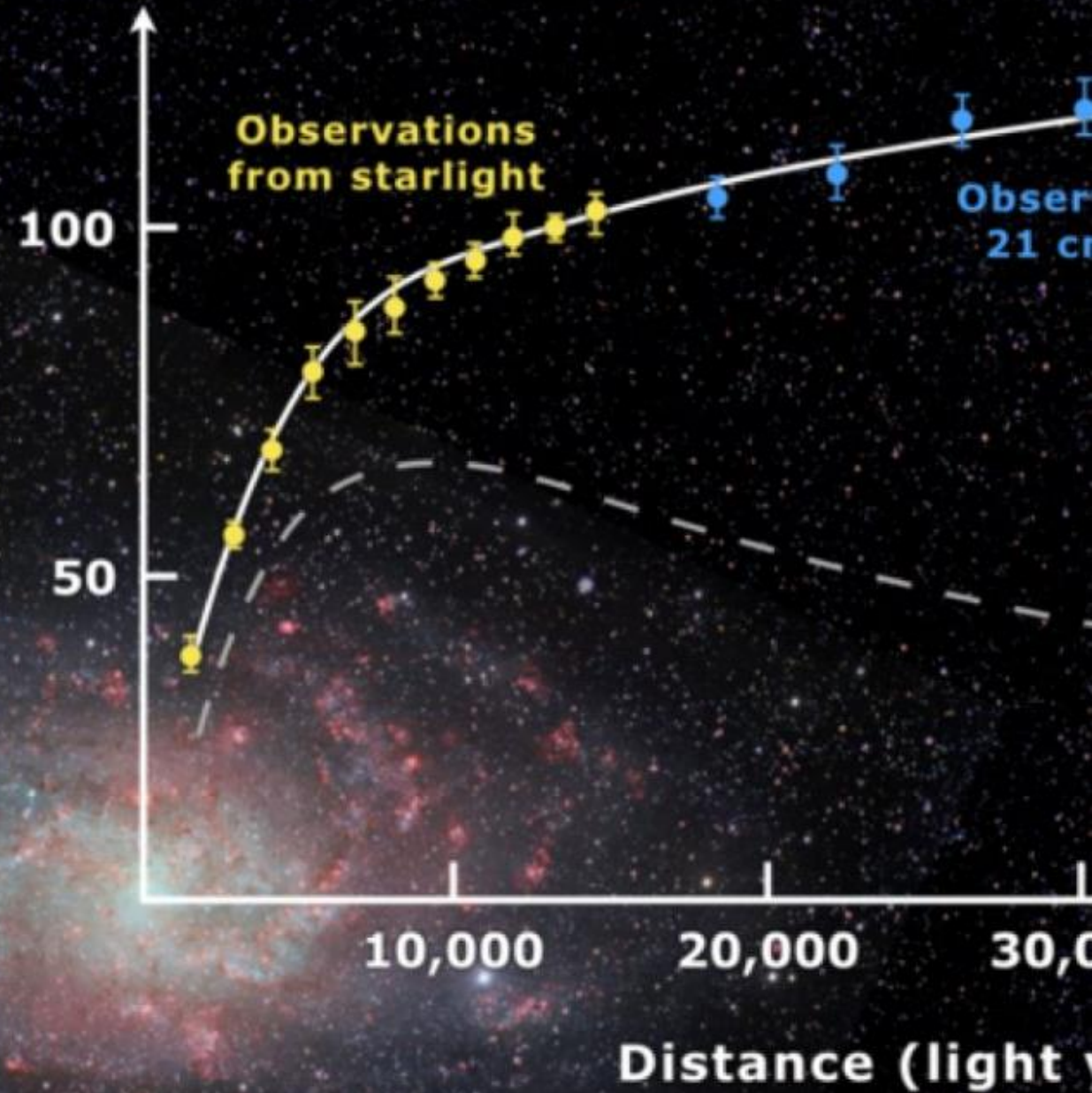
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Model: Boosted Dark Matter (BDM)

Present day DM is moving slow by HEP standards $\sim O(-3)$

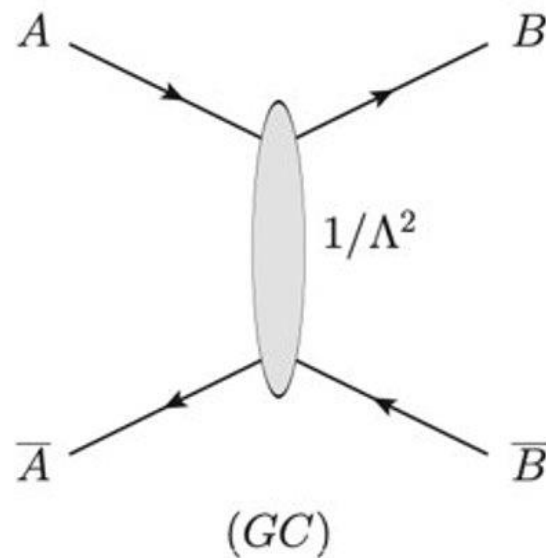
- Alternative Search Method:
 - Some of the DM receives a Lorentz boost.
 - BDM: relativistic particles with very weak interactions to SM stuff...
 - Can we use neutrino experiments to search for dark matter?



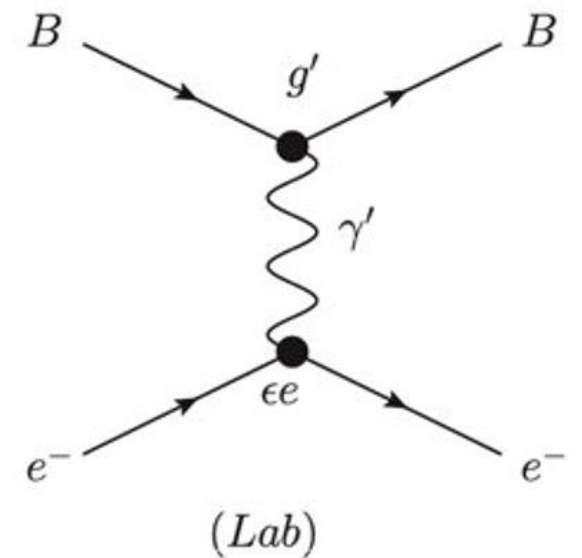
An Example of BDM: 2-Component

- Consider two fermion species DM:
 - Dominant species (No SM Coupling) makes up the bulk of DM
 - Lighter, sub-dominant, species (With SM Coupling) produced through an annihilation process where it receives a Lorentz boost

$$\mathcal{L} = \frac{1}{\Lambda^2} \bar{\psi}_A \psi_B \bar{\psi}_B \psi_A$$

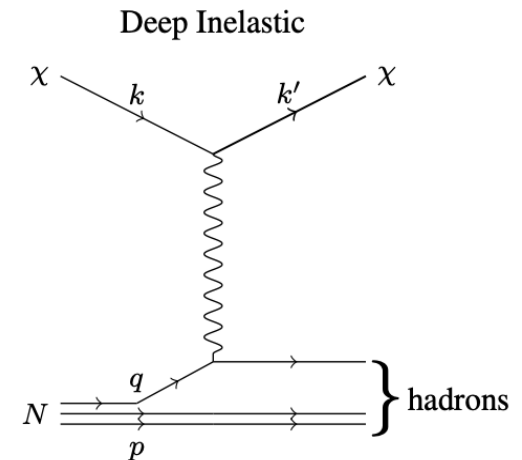
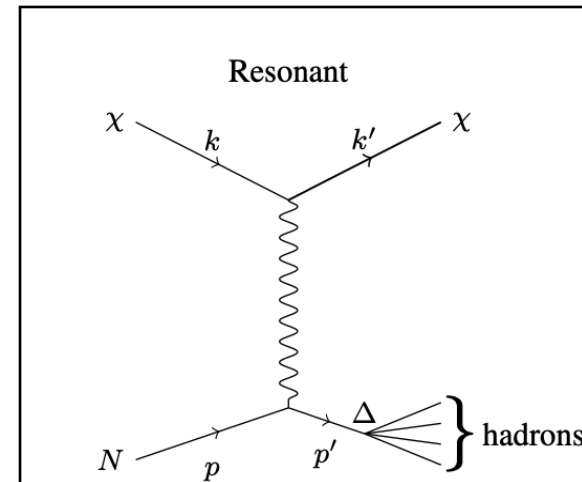
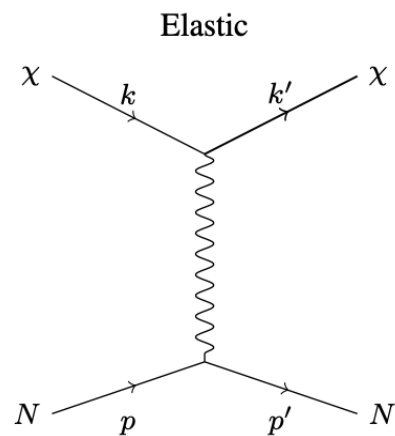
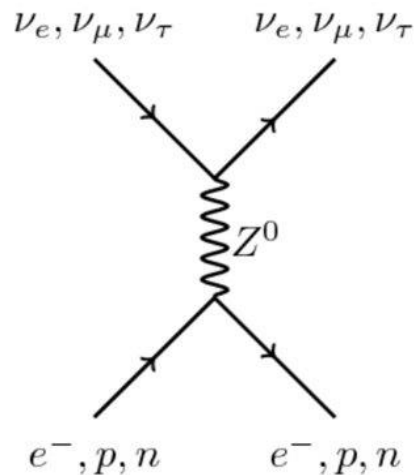


$$\gamma = \frac{m_A}{m_B}$$



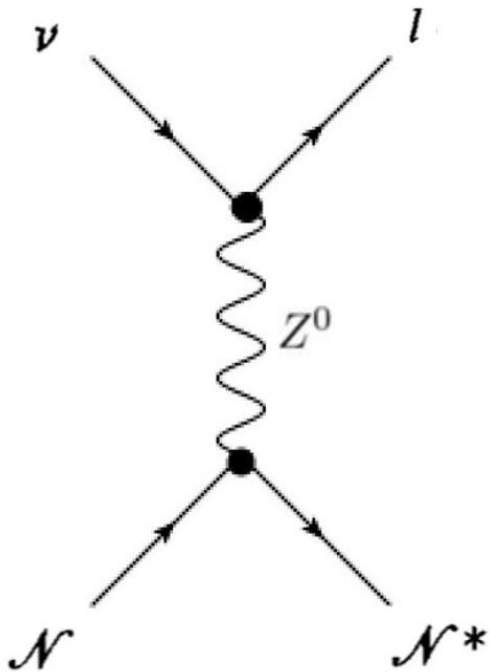
DM Scattering

- LArTPC at DUNE, and others, use GENIE: a Monte Carlo event generator code implemented to search for neutrino scattering events.
- The goal of this research is to modify their GENIE code for Dark Matter scattering events.



Neutrino-Nucleon Resonant Scattering

$$\nu + \mathcal{N} \rightarrow l + \mathcal{N}^*$$



$$T(\mathcal{N}\nu \rightarrow \mathcal{N}^*l) \propto G_c [\bar{u}_l \gamma^\mu (1 - \gamma^5) u_\nu] \langle \mathcal{N}^* | J_\mu | \mathcal{N} \rangle$$

Cross-section:

- Kinematics
 - Massless lepton approximation
- Helicity Amplitudes (Left, Right, Scalar)
 - Interaction type (Charge, Neutral, EM)

$$\sigma \propto G_c^2 [u^2 \sigma_L + v^2 \sigma_R + 2uv \sigma_S]$$

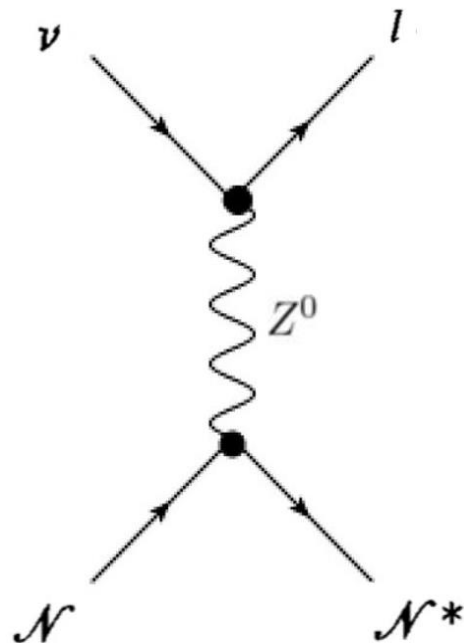
$$u = \frac{(E + E') + Q}{2E}$$

$$v = \frac{(E + E') - Q}{2E}$$

Boosted Dark Matter Scattering

- Similar to neutrino event generator.

$$\nu + \mathcal{N} \rightarrow l + \mathcal{N}^*$$

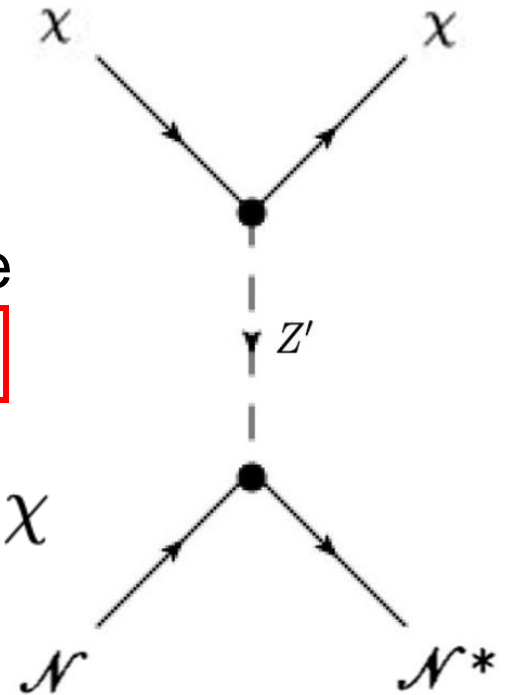


- Adjustments:

- Massive DM / Mediator
- Free Params: Couplings / Charge
- No leptonic current conservation

$$\mathcal{L}_{\chi, \text{int}} = g_{Z'} Z'_\mu \bar{\chi} \gamma^\mu (Q_L^\chi P_L + Q_R^\chi P_R) \chi$$

$$\chi + \mathcal{N} \rightarrow \chi + \mathcal{N}^*$$



BDM Resonant Scattering Cross-Section

BDM Cross-Section:

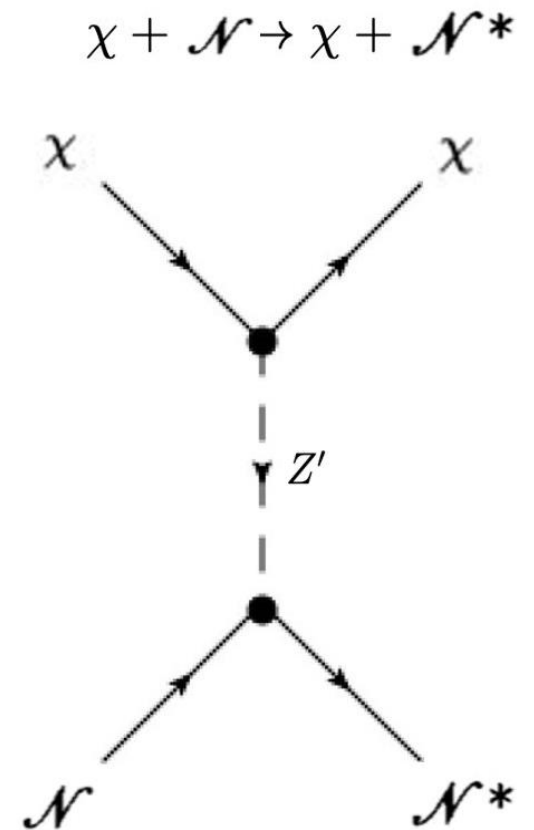
$$\sigma \propto \left(\frac{g_{Z'}}{m_{Z'}}\right)^4 [A_L \sigma_L + A_R \sigma_R + A_S \sigma_S + A_Z \sigma_Z]$$

$$A_L \propto (Q_L^\chi)^2 u^2 + (Q_R^\chi)^2 v^2 + m_\chi^2 Q_L^\chi Q_R^\chi$$

$$A_R \propto (Q_L^\chi)^2 v^2 + (Q_R^\chi)^2 u^2 + m_\chi^2 Q_L^\chi Q_R^\chi$$

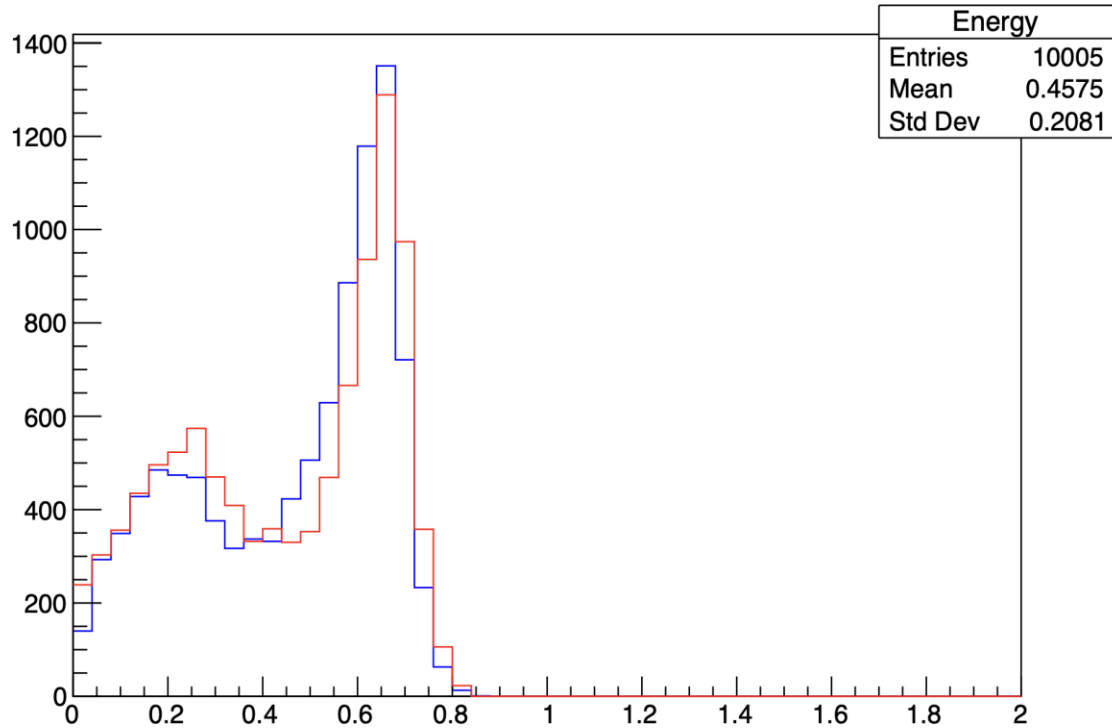
$$A_S \propto 2uv[(Q_L^\chi)^2 + (Q_R^\chi)^2] + m_\chi^2 (Q_L^\chi - Q_R^\chi)^2$$

$$A_Z \propto -\frac{m_\chi^2 (Q_L^\chi - Q_R^\chi)^2}{m_{Z'}^2}$$

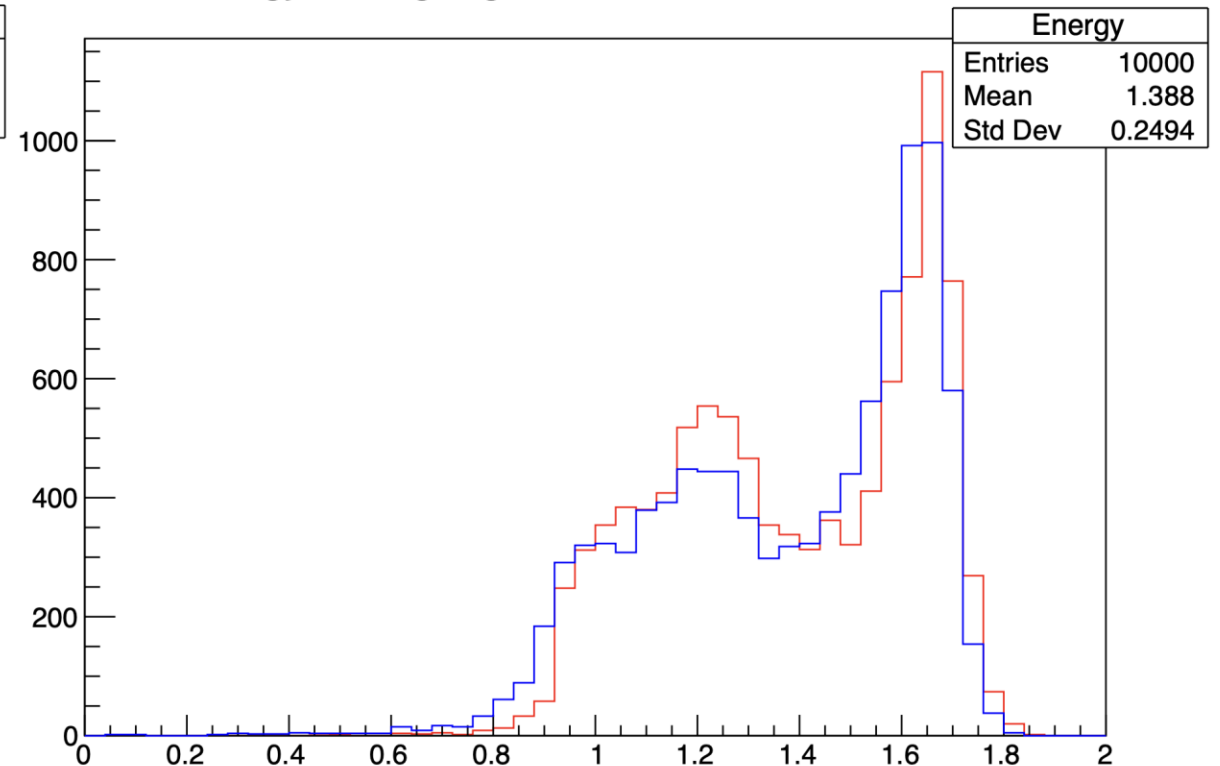


Cross Checks EM: Preliminary

Energy of Outgoing electron/DM from 1GeV Event



Energy of Outgoing electron/DM from 2GeV Event



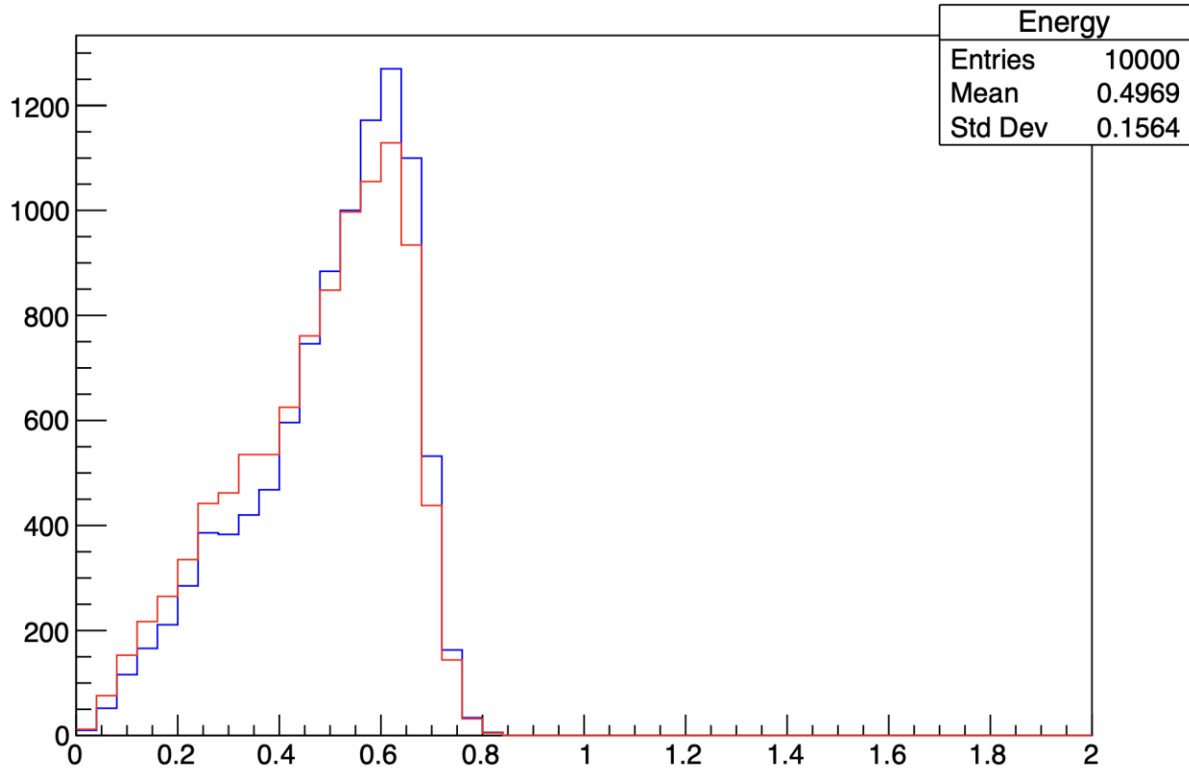
Spectrum of final state energies after resonant scattering with proton at 1 and 2GeV

Blue: Electron

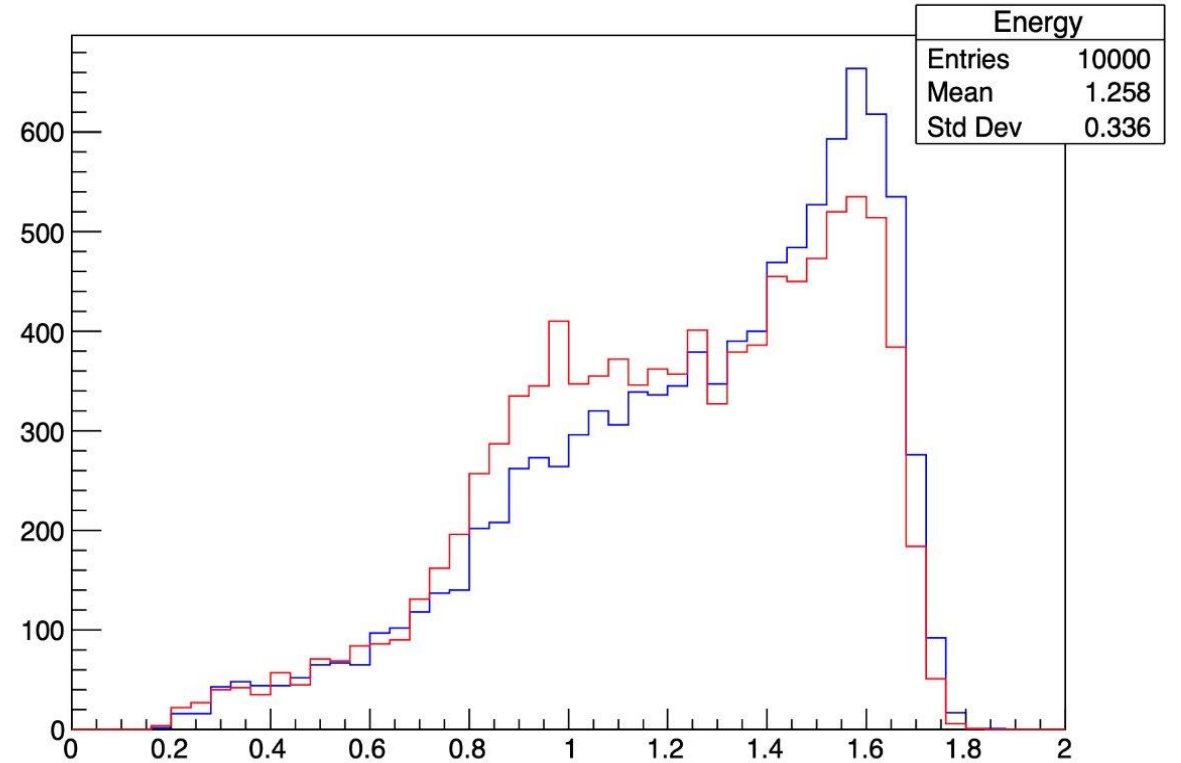
Red: BDM (behaving like an electron)

Cross Checks NC: Preliminary

Energy of Outgoing neutrino/DM from 1GeV Event



Energy of Outgoing neutrino/DM from 2GeV Event



Blue: Neutrino

Red: BDM (behaving like a neutrino)

Thank You

The background is a complex, abstract pattern of thin, overlapping lines in various colors including purple, blue, red, and yellow. These lines form intricate, swirling shapes that resemble a network or a series of interconnected paths. Scattered throughout the composition are numerous small, multi-colored dots, adding to the overall sense of depth and complexity. The overall effect is a vibrant, multi-colored digital or data-like aesthetic.