Search for sub-GeV Dark Matter@DUNE

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Outline

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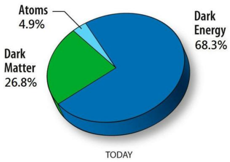
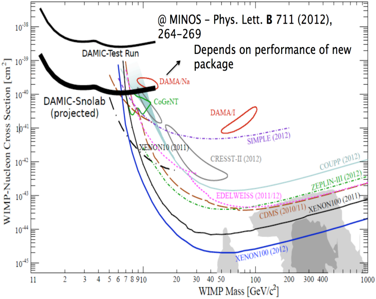
⇒After the discovery of Higgs we know ≈ 5% of the universe, 95% is unknown.
⇒ Dark matter has manifested its presence so far only via gravitational interactions with surrounding baryonic matter.



⇒ Weakly Interacting Massive Particles(WIMPs) are the leading particle physics candidate for the dark matter.
⇒Several Direct and Indirect Dark matter detection experiment put limits on Dark matter mass and cross-section.
⇒ Accelerator-Produced sub-GeV Dark Matter Search will also be a good probe.



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Benchmark Model

Dark Sector | κ | Standard Model

- Models of sub-GeV dark matter typically involve scalar or fermion DM and vector or scalar mediators.
- The simplest model may be the Dark Photon model. The mediator mixes with SM with the kinetic mixing κ.
- 4 free parameters, Dark mediator(V), dark matter particle(χ), kinetic mixing(κ), coupling constant α.

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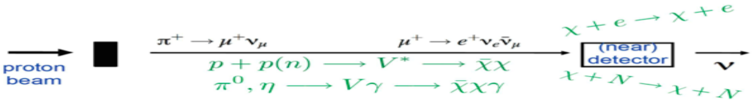
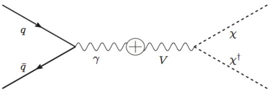
sub-GeV DM Production at neutrino experiment

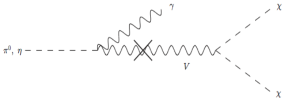
- Dark Matter production at fixed target experiment :



- DM Production :

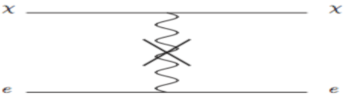


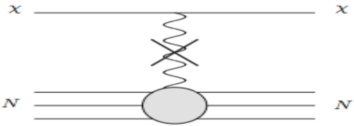
Higher E_p LBNF



Lower E_p MiniBooNE

- DM Detection :





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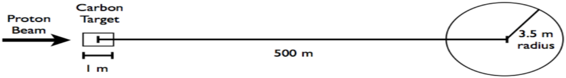
DM Simulation@DUNE : Setup

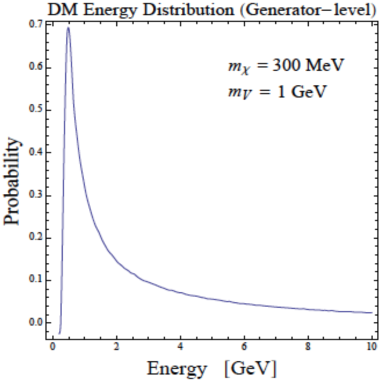
- We have started to study sub-GeV DM production at DUNE. We are in the early stages ..
- First attempt: We generate 1 million DM events using Madgraph5(in FT mode) for the following setup :

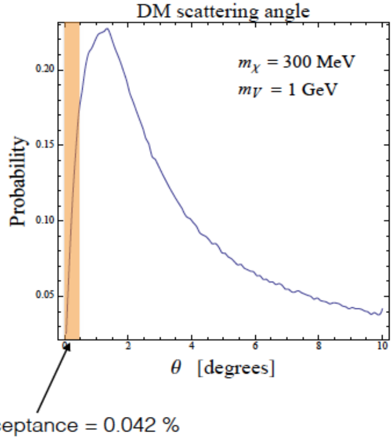


- $N_{POT} = 3 \times 10^{21}$ (number of protons on target)
- $n_T = 10^{23}$(number density of carbon atoms in the target)
- $L_T = 100cm$ (Length of the target), $R_D = 3.5m$(radius of the detector)
- $\theta_{det} = 3.5m/500m = 0.4degrees$ (angular acceptance)
- $n_D = 5 \times 10^{23}$ (number density of electrons in the detector)

DM energy and θ spectrum(Preliminary)

- $\alpha = 1,\ \kappa = 0.01$



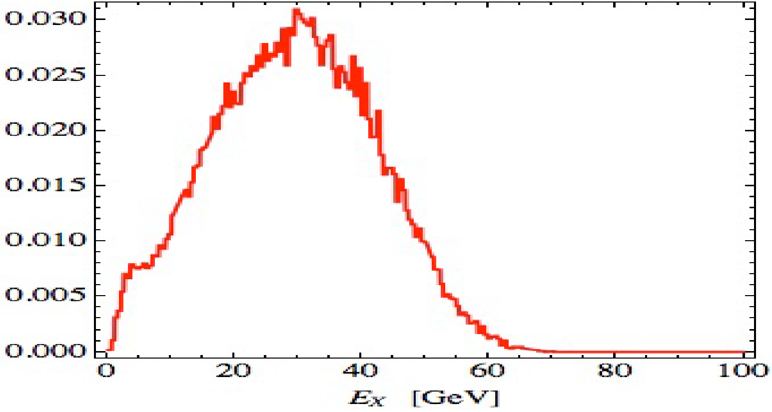


Signal rate(Preliminary)

- How many DM particles could we possibly detect
  $N_{event} = 12 N_{POT} n_T L_T \sigma(pp \to \chi\chi) n_D R_D \sigma_{\chi e} \eta_{det}$
- The cross sections are approximately:
  $\sigma(pp \to \chi\chi) = 10^{-29} cm^2$(madgraph)
  $\sigma_{\chi e} = 10^{-32} cm^2$(analytic)
- Plugging the numbers from previous slide:
  $N_{event} = 10^{10} \kappa^4 (\frac{\alpha}{0.1})^2$
- Plenty of signal events to constrain the model parameter space(provided we can deal with the pesky neutrino background).

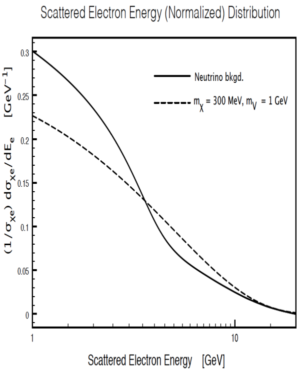
Dark Matter Flux at the Detector(Preliminary)

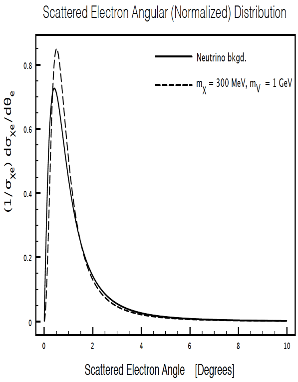
- After putting angular cuts, DM flux at the detector ..



Scattered electron

Energy and θ distribution(Preliminary)





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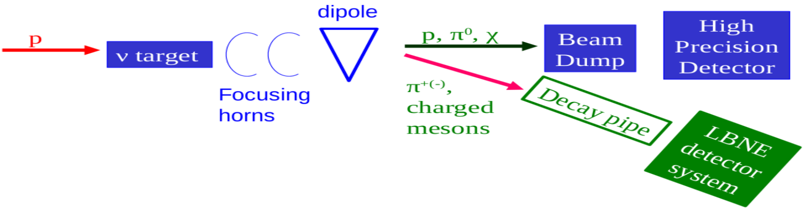
- High flux proton beam is ideal for DM statistics.
- Although we are in very early stage, the signal rates look promising!
- Main background for DM signal is neutrino neutral current event.
- The energies of scattered electrons from DM and neutrinos are very similar, will not help much to reduce the background.
- Higher energy WIMP-electron scattering will put the electron in a very forward direction(w.r.t beam direction), will help to distinguish from neutrino background.

Reduction of neutrino background

- Beam dump experiment would be the best, since beam dump can be made to absorb all the mesons which are the source of neutrinos.
- Tilt the beam ...



- DM and neutrinos will take different time to travel from the production point to the detection point, hence another possible reduction of the background can be gained by timing the events.

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Conclusion

- DUNE offers potentially exciting option for detecting and studying sub-GeV dark matter.
- We are in a very early stage of the study, detail study is ongoing.
- Another study could be an optimal location and size of detector for DM studies, closer and larger detector will result in larger signals.