MiniBooNE
Dark Matter Search

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Dark Matter particles could belong to a Hidden Sector with coupling to the Standard Model

New gauge boson increases DM annihilation cross section to give correct relic density

- New vector mediator could be solution to g-2 anomaly

M. Pospelov, Phys. Rev. D 80 095002 (2009)
Explore an interesting region of phase space

What about here?

Relativistic dark matter for sufficient recoil energy in the detector

New mediators to satisfy cosmological constraints

Sub-GeV regime:
Well motivated, less explored
Accessible to accelerator beam dump experiments

An intense beam, a large and sensitive detector, and a mechanism to suppress the Standard Model backgrounds.
• 8 GeV protons from FNAL Booster
• Be target for neutrino production
  540 m from the detector
• 50 ‘decay pipe’ with steel dump at the end


Well understood beam and detector
CCQE and NCE interactions

- Charged Current Quasi-Elastic
- W boson mediated
- Single muon and decay electron

- Neutral Current Elastic
- Z boson mediated
- Scintillation with no muon or pion

Double differential cross section measurement

NCE cross section measurement and ratio to CCQE


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Dark matter will mimic this interaction


Beam dump mode: Reducing neutrino background

- Protons steered off-target towards 50 Fe dump
- Charged mesons absorbed before decay to neutrinos
- Neutral mesons unaffected
Beam dump mode: Reducing neutrino background

- Flux reduced by factor \(~30\)
- Event rate reduced by factor of \(~50\)
- Stable run for 9 months in this mode
Event selection

- Protons detected by scintillation light
- Neutrons via secondary scatter off protons
- Selection cuts to isolate single track proton-like events and reject beam related and cosmic backgrounds
  - Event coincident with beam time
  - No veto activity
Dark Matter simulation

- BdNMC: Proton beam fixed target simulation tool
- Includes $\Pi^0$, $\eta$ and Bremsstrahlung processes

deNiverville, Chen, Pospelov, Ritz

https://github.com/pgdeniverville/BdNMC/releases
Analysis Strategy

- Simultaneous fit to 4 distributions
  - $\text{CCQE}_\nu$ neutrino mode
  - $\text{CCQE}_{\text{off}}$ beam-dump mode
  - $\text{NCE}_\nu$ neutrino mode
  - $\text{NCE}_{\text{off}}$ beam-dump mode

- CCQE ratios help reduce flux uncertainty while NCE ratio reduce cross section uncertainty
Results

90% Confidence Limits

- CL on value of $\varepsilon^4 \alpha_D$ for given $m_V$ and $m_\chi$
- Slice to compare to other experiments
- Considered on-shell decays ($m_V > m_\chi$)

- Data consistent with background

<table>
<thead>
<tr>
<th>#events</th>
<th>Uncertainty</th>
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<tr>
<td>Beam unrelated bkg</td>
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<td>Beam rel: $\nu_{\text{det}}$ bkg</td>
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<td>Fit Results</td>
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$\varepsilon^4 \alpha_D$ at 90% CL
Results

solid lines: DM coupling to quarks/nucleons
solid-dashed lines: DM coupling to electrons

Future results from MiniBooNE-DM

Dark matter $\Delta$ resonance scattering with $\pi^0$
- Neutrino NC $\pi^0$ main background
- Clean signal, low beam unrelated background

Dark elastic scattering off electrons
- Neutrino-electron main background
- Very forward peaked signal

Using time-of-flight
- Dark matter delayed as compared to neutrinos
Future Prospects

- Number of high-resolution detectors in pipeline on BNB (SBN program)
- A dedicated beam-dump idea
- LOI submitted to Fermilab PAC

For details, see talk by R. Van de Water @ U.S. Cosmic Visions 2017
Summary:

• First dedicated proton beam dump search for dark matter by MiniBooNE-DM

• Published results for dark matter -nucleon scattering. Analysis on other dark matter scattering channels ongoing

• Exploring future opportunities at Fermilab SBN program