Phenomenology of Inelastic Dark Matter at the SBN Experiments

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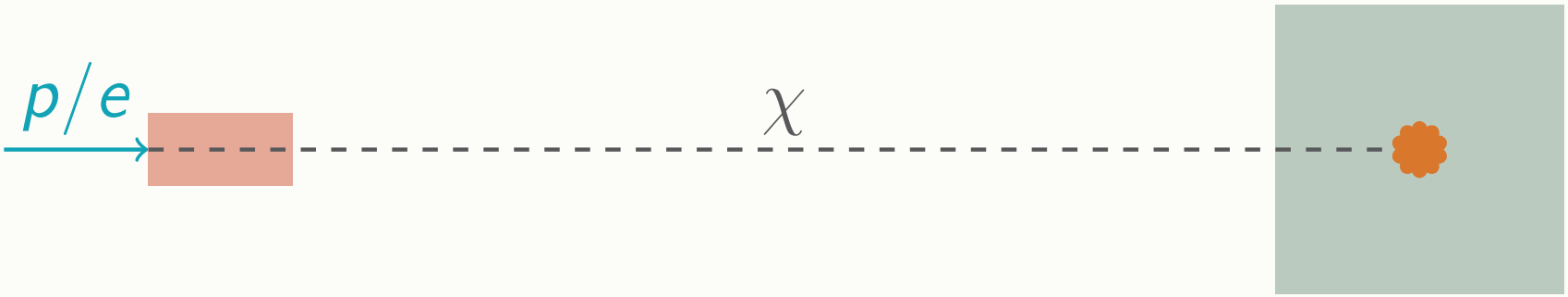
Dark Sectors at Fixed-Target Exp'ts



Direct: $p/e + N \to \chi + X$

Decay: $p + N \to H + X$

$H \to \chi + X$

Dark matter

Dark photon

Higgs portal scalar

Heavy neutral lepton

Axion

Dark sector decay

Scattering

Inelastic scattering

Missing energy

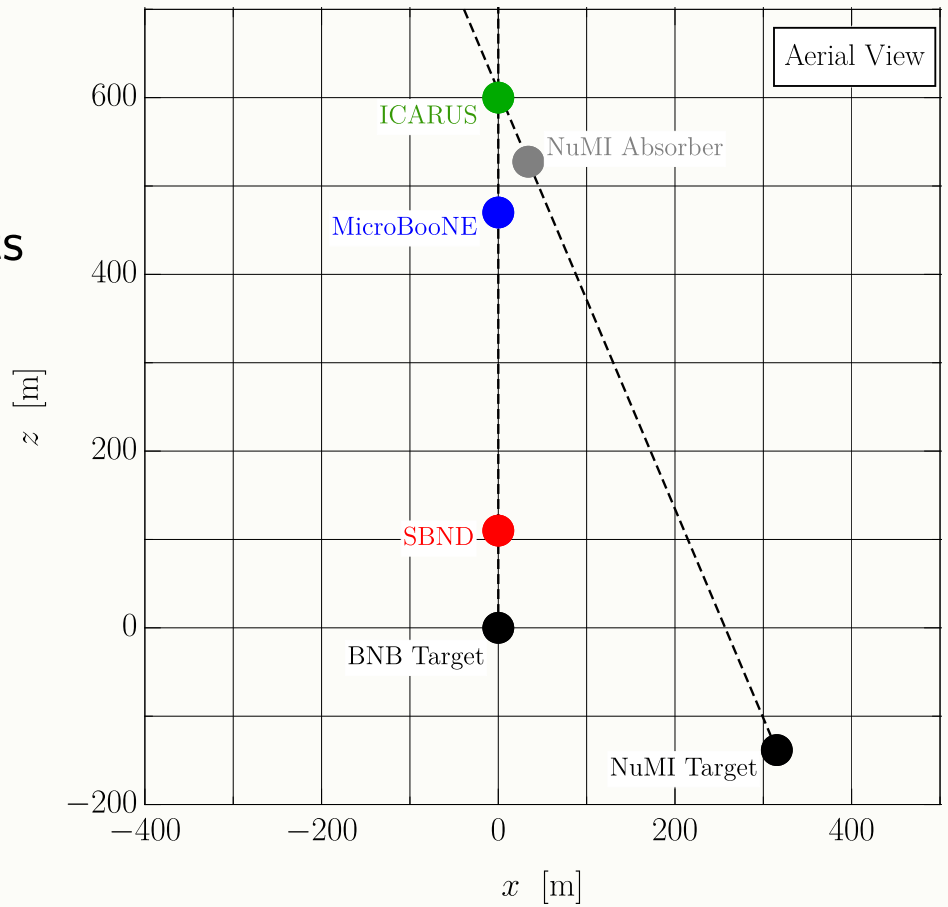
The SBN Experiments

3 Liquid Argon TPC detectors:

- Can reconstruct full 3D events

Two beamlines:

- BNB: 8 GeV, on-axis
- NuMI: 120 GeV, off-axis
- Possible run using BNB absorber (not illustrated)?



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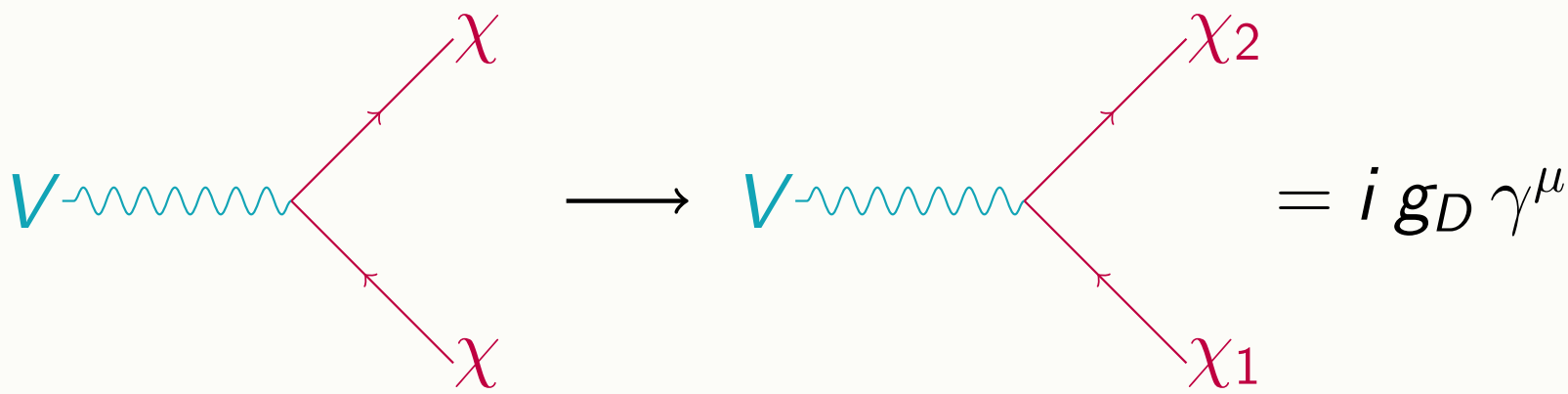
Inelastic Dark Matter Model

$\propto \epsilon$

- Broken $U(1) \rightarrow$ massive V with gauge portal



- Also splits charged fermions into separate Majorana states

Overview of Signals

- Both direct and decay production mechanisms

- Three possible signals in detector:
  - Up-scattering $\chi_1\, e^- \to \chi_2\, e^-$ at short lifetimes
  - Decay $\chi_2 \to e^+\, e^-\, \chi_1$ at long lifetimes
  - Up- and down-scattering at very long lifetimes

$$\gamma\, v\, \tau \approx 10^3 \text{ m} \left(\frac{\Delta_\chi}{0.1}\right)^{-5} \qquad \Delta_\chi = \frac{M_{\chi_2} - M_{\chi_1}}{M_{\chi_1}}$$

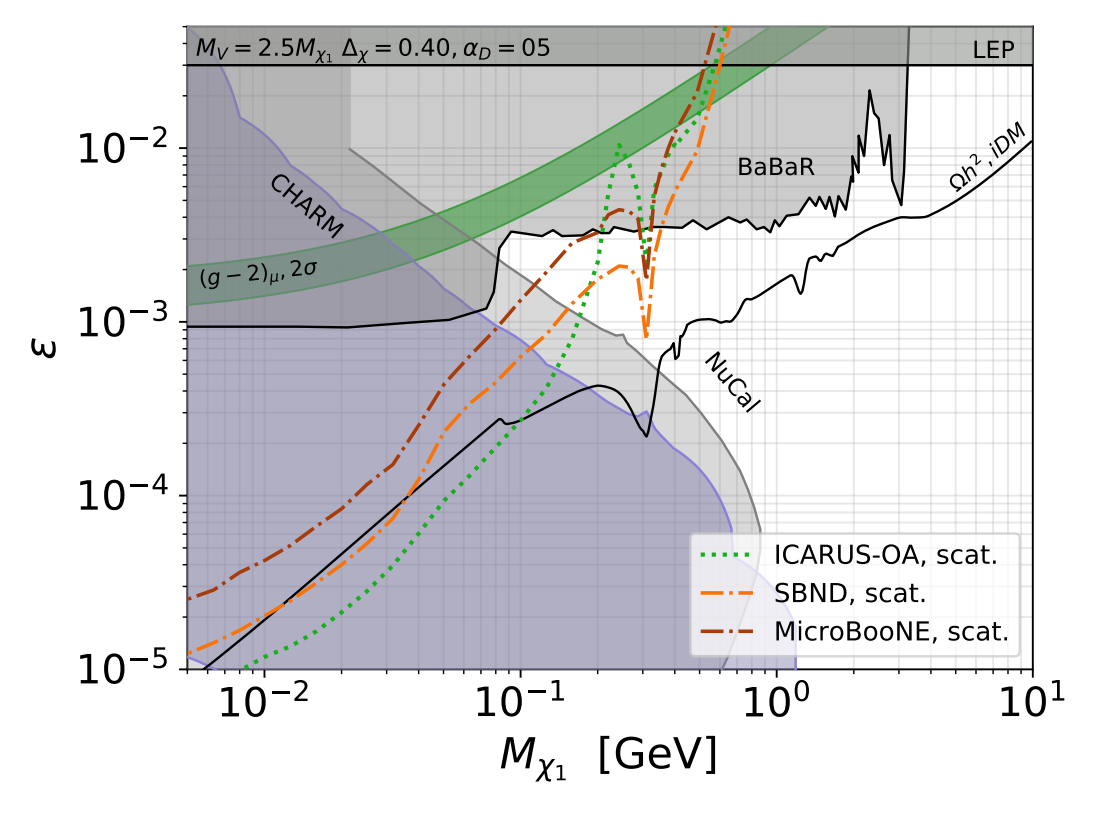
Simulation of Signal

Signal production using modified version of `BdNMC`

- Meson distributions from empirical Sanford-Wang or `Geant4` as available
- Proton bremsstrahlung from `BdNMC` including interference with vector meson resonances
- DIS using `MadDump`

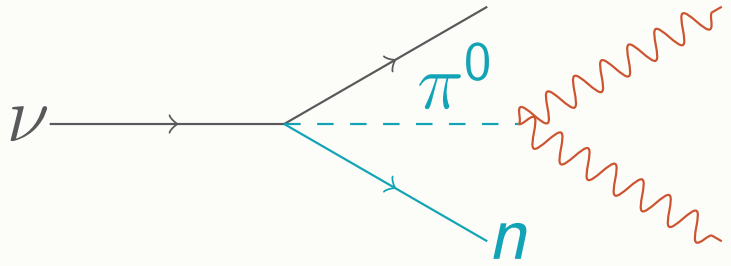
Large Splitting Region

Some space accessible at large splitting via up-scatter



Small Splitting Background

Dominant bkg from π^0 production in ν scattering



- Photons convert into $e^+ + e^-$ after $X_0 \sim 14$ cm
- Resulting electrons can fake signal

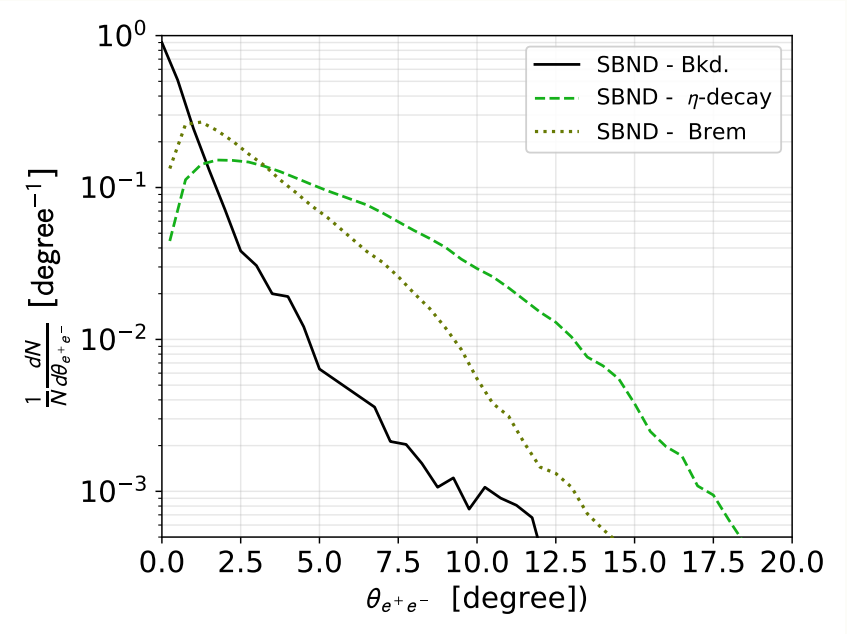
  To study, need to convert photons
- Run photons (only) through `Geant4` to do this: extract conversion (or scattered electrons)

Background Reduction

Background γ give $e^+ + e^-$ with small opening angle

Arbitrarily small angle not reconstructable anyway

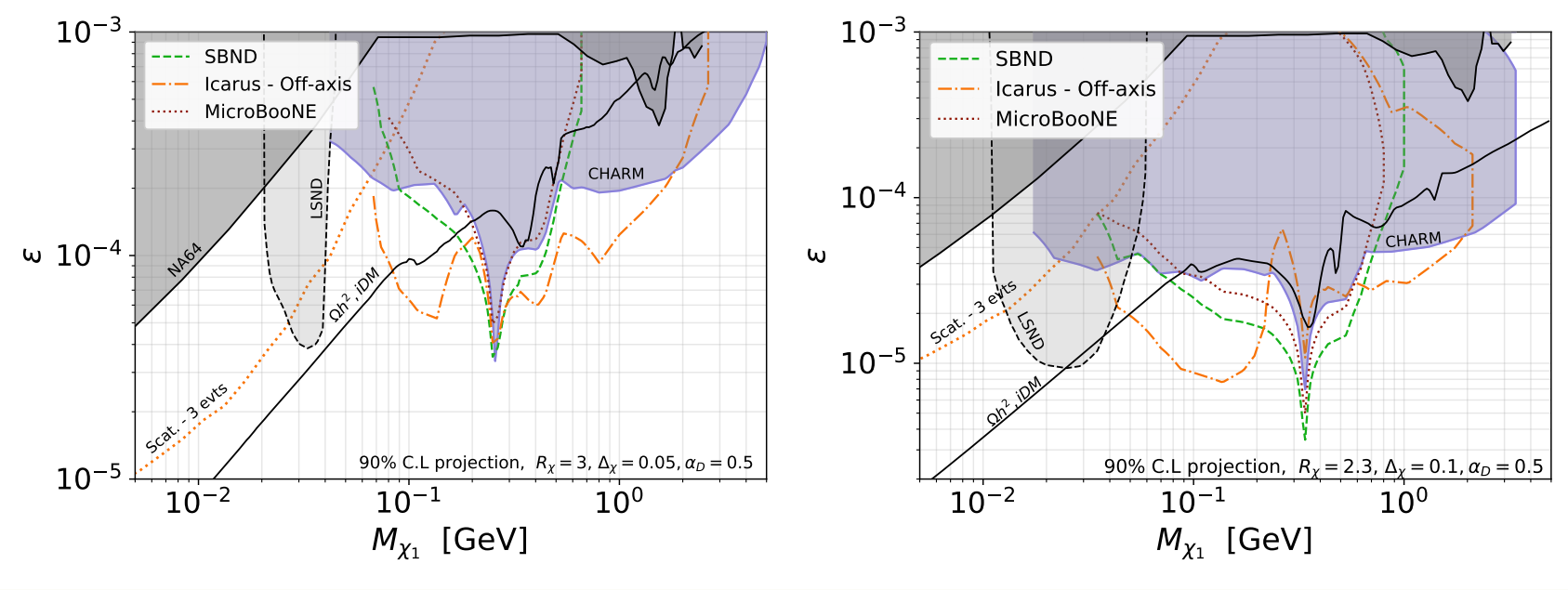
- Place angular cut of 5°



Small Splitting Region

Significant improvements from ICARUS and SBND!

Includes some parts of thermal relic parameter space



Possible "Iron Dump" Run

MiniBooNE steered BNB off target and into absorber

Can reduce distance DM needs to travel *and* bkg