

*Search for low mass dark
matter at ICARUS detector
using NuMI beam*

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for the ICARUS NuMI-Off axis WG
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NF Topical Groups:

- (NF3) Beyond the Standard Model

RF Topical Groups:

- (RF6): Dark Sector Studies at High Intensities

CF Topical Groups:

- (CF1) Dark matter: particle-like

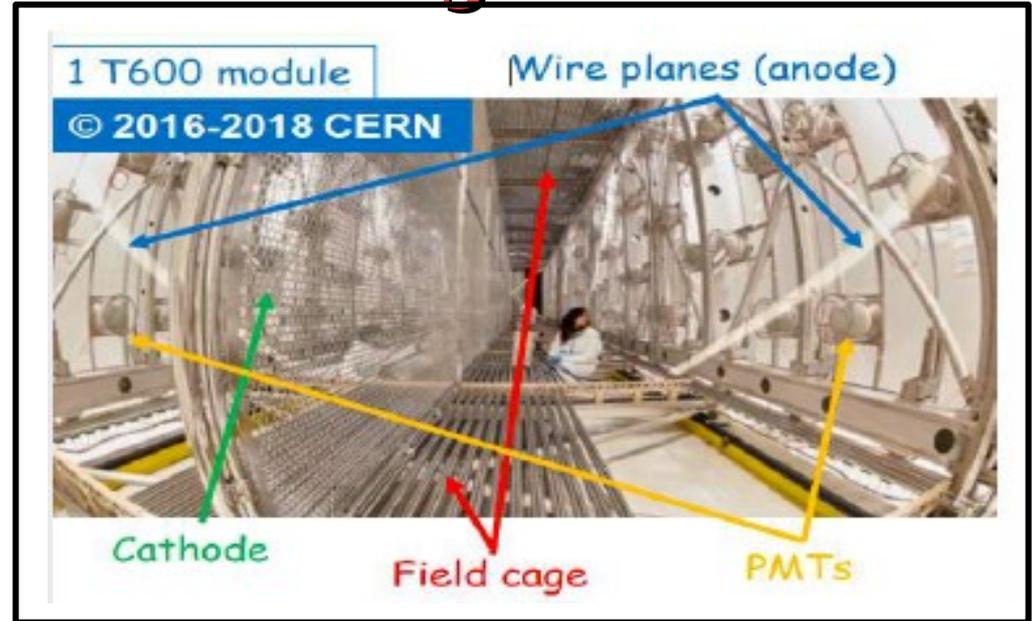
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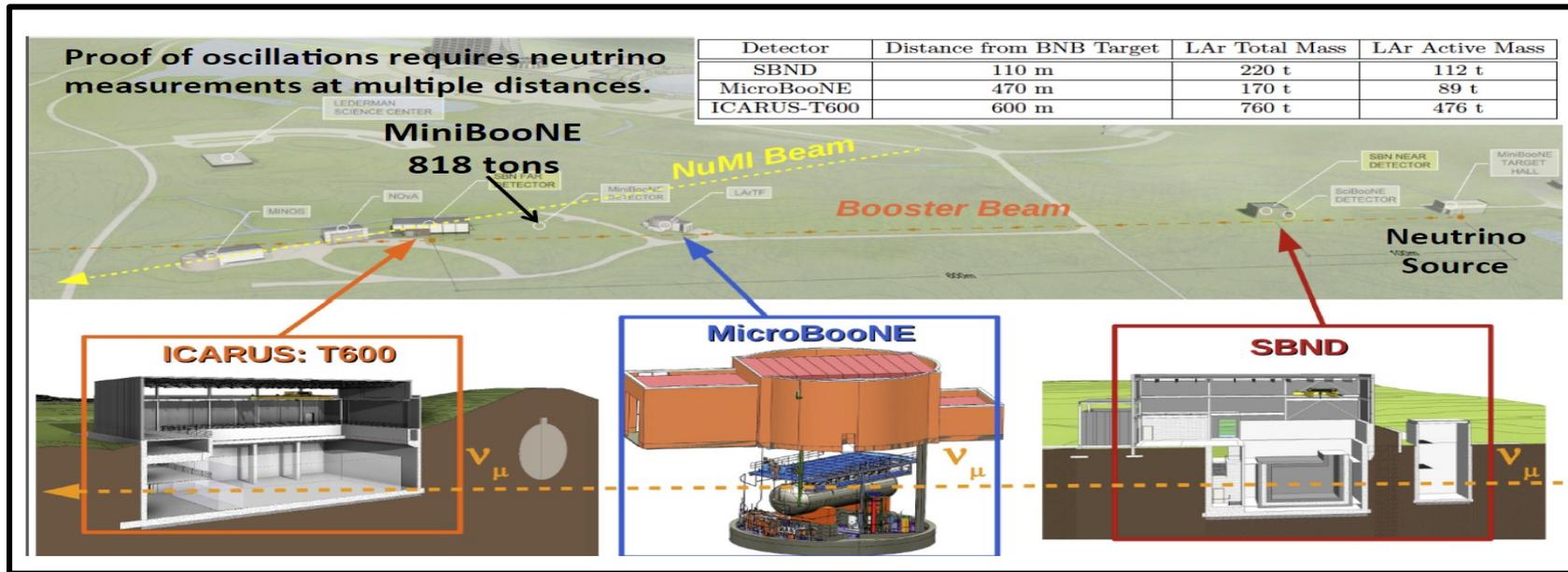
Abstract: This Letter of Interest discusses the opportunity to search for the low mass dark matter (LDM) at the ICARUS LArTPC detector at Fermilab Short-Baseline Neutrino (SBN) program, using the beam off-axis of the NuMI neutrino beam. Since ICARUS is situated about 5.7° off of the NuMI neutrino beam, at which LDM flux expects to peak in a wide range of mass with the neutrino flux greatly reduced, from which LDM searches would greatly benefit.

ICARUS-T600 at SBN Program

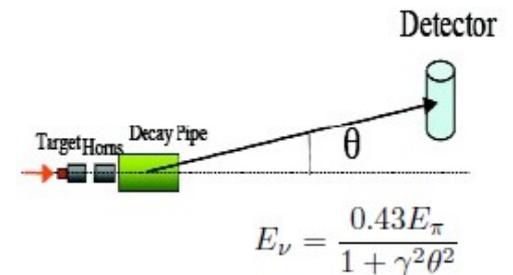


- *First large-scale LAr-TPC in a neutrino beam.*
- *Two identical module: each module size : 19.6 (L) x 3.6(W) x 3.9(H) m³ ; total LAr mass ~760 tons, active LAr mass 476 tons.*
- *Drift distance 1.5m, drift field 500V/cm → drift time ~ 1ms.*
- *Installation of all the detector components completed in December 2019*
- *Detector commissioning ongoing, will start taking with neutrino beam in mid November of this year.*

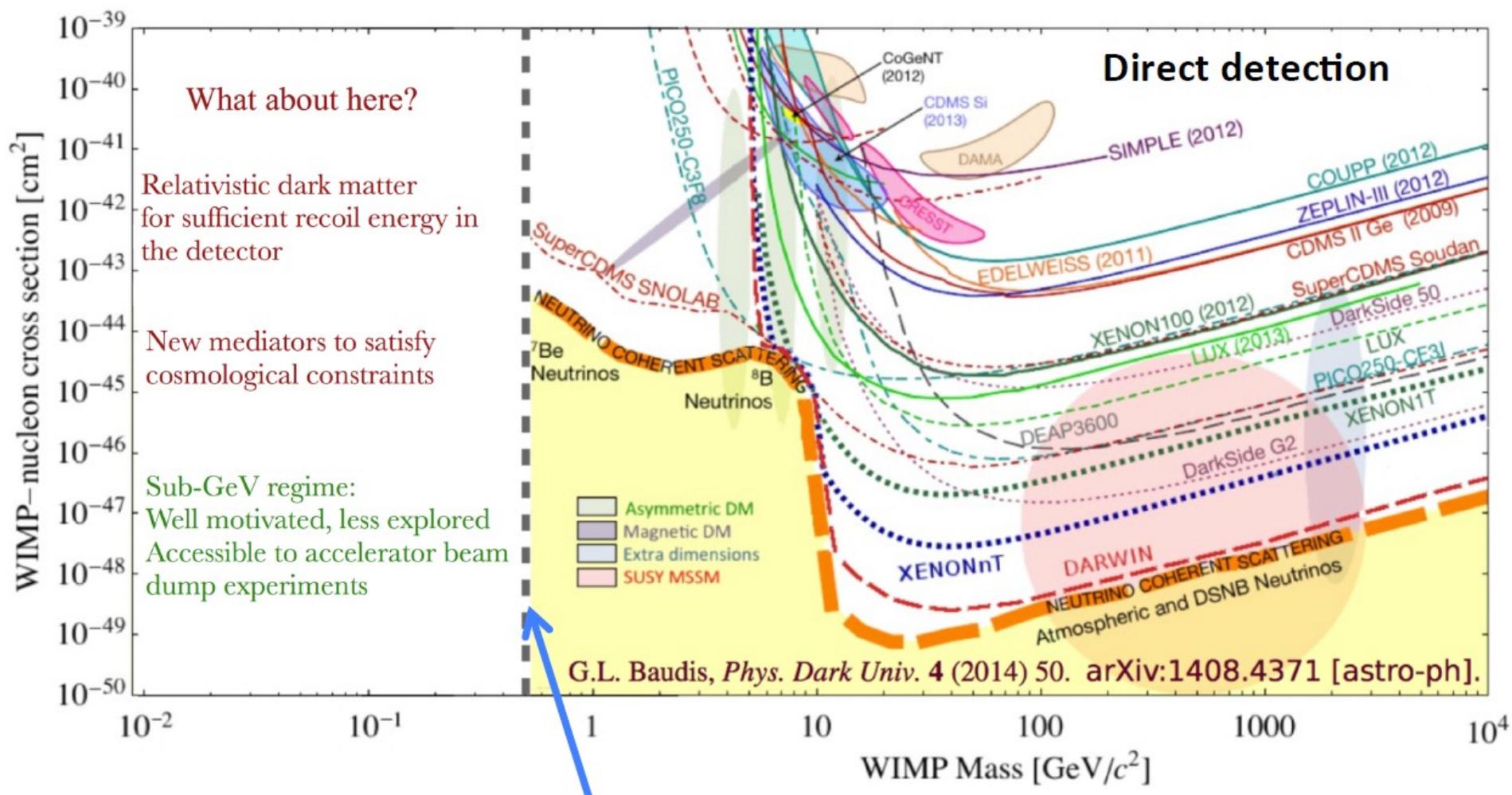
Physics motivation of ICARUS



- Primary physics motivation of ICARUS experiment is search for the existence (or not) sterile neutrino.
- ICARUS is located 103 mrad off axis from NuMI beam.
- ICARUS Detector with NuMI Off axis beam will play a key role in BSM search, like Dark matter search

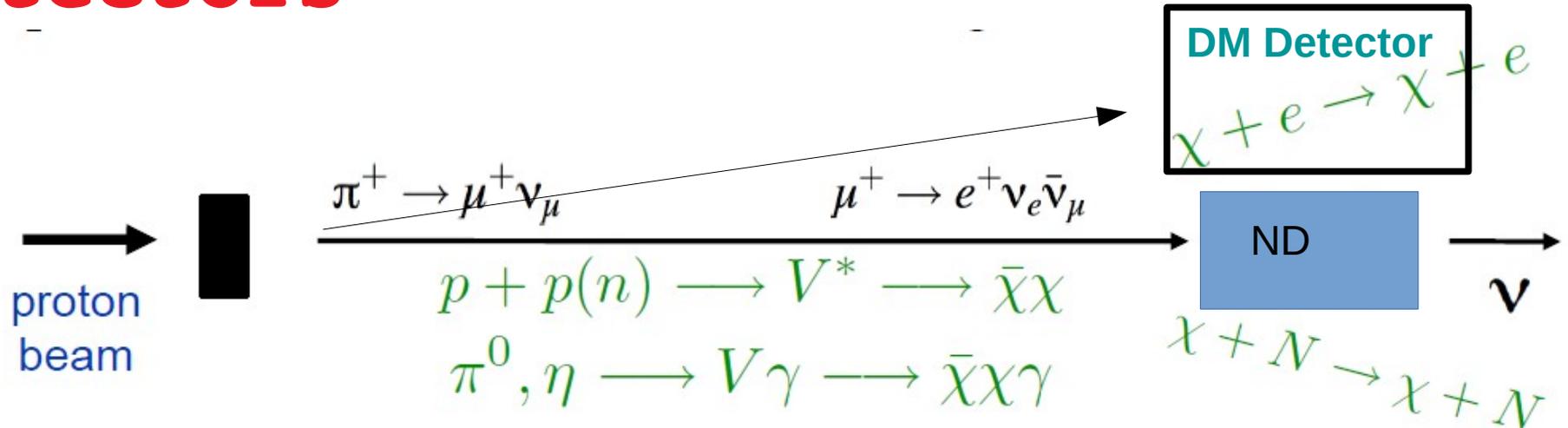


Experimental motivation for searching sub-GeV DM using Neutrino detectors



- Direct detection \sim GeV threshold limit
- Accelerator based fixed target experiment has experienced much recent theoretical and experimental activity below GeV range

DM Search with fixed target: Neutrino detectors



We can use the neutrino (near) detector as a dark matter detector, looking for recoil, but now with accelerator based proton beam

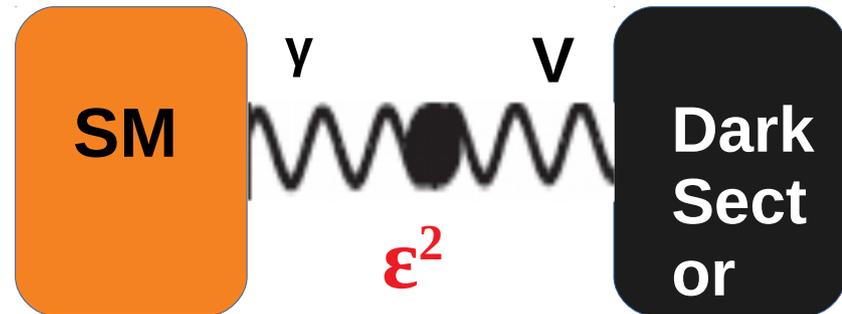
MiniBooNE
 8GeV BNB Beam
 540m to the mineral oil detector

SBN
 8.9 GeV BNB and
 120 GeV NuMI
 Beam, 3 LArTPC
 detector

Our main focus is to study LDM at ICARUS-T600 Detector using NuMI off-axis beam

The model: "Vector portal"

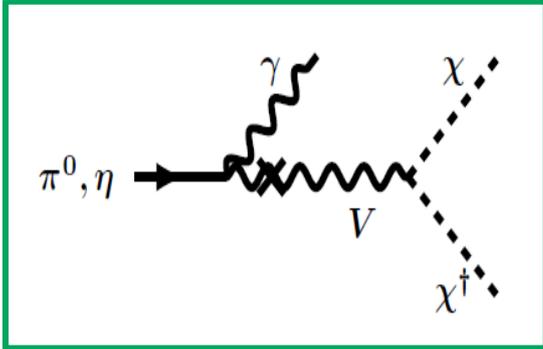
- Models of sub-GeV dark matter typically involve scalar or fermion DM and vector or scalar mediators
- Maybe the simplest model is known as the "dark photon" model. The mediator is a new gauge field which "mixes" with the SM photon through ϵ
- 4 free parameters
 - Mass of the dark photon m_A
 - Mass of the dark matter m_χ
 - Mixing between SM and dark sector ϵ
 - Coupling between dark photon and dark matter α



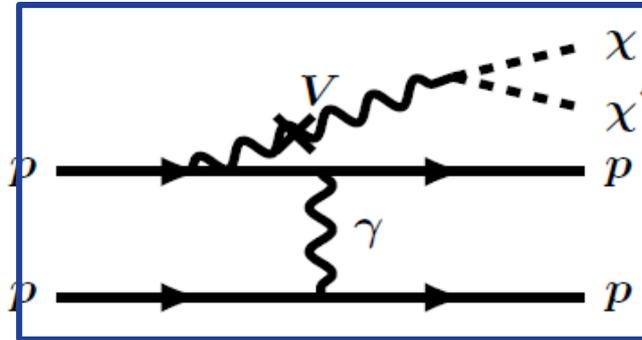
DM Production and Detection

- Production**

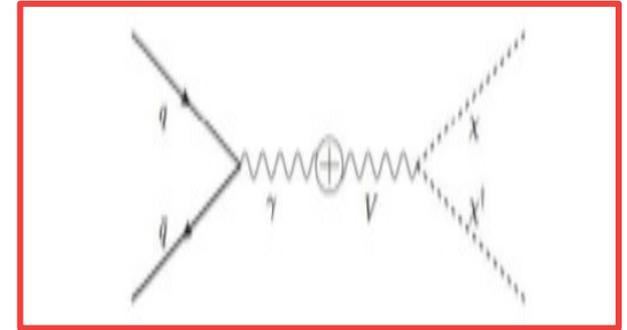
Meson decay



Proton bremsstrahlung

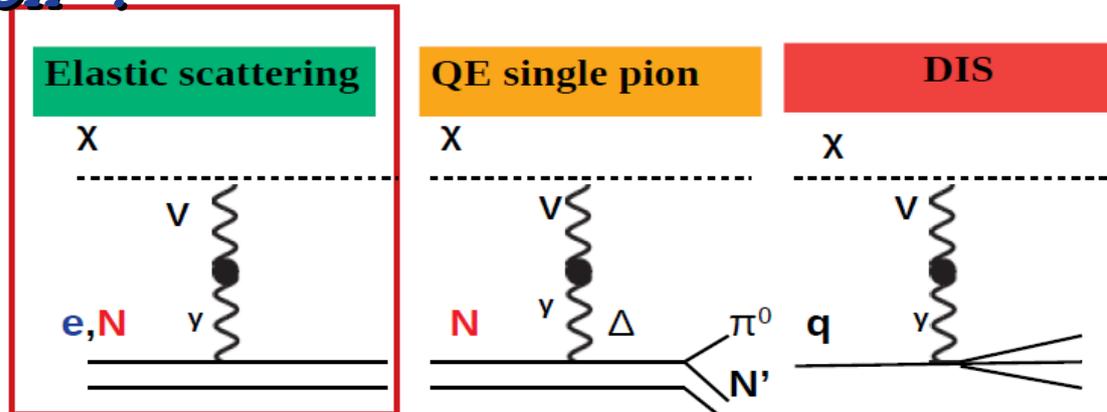


Direct production



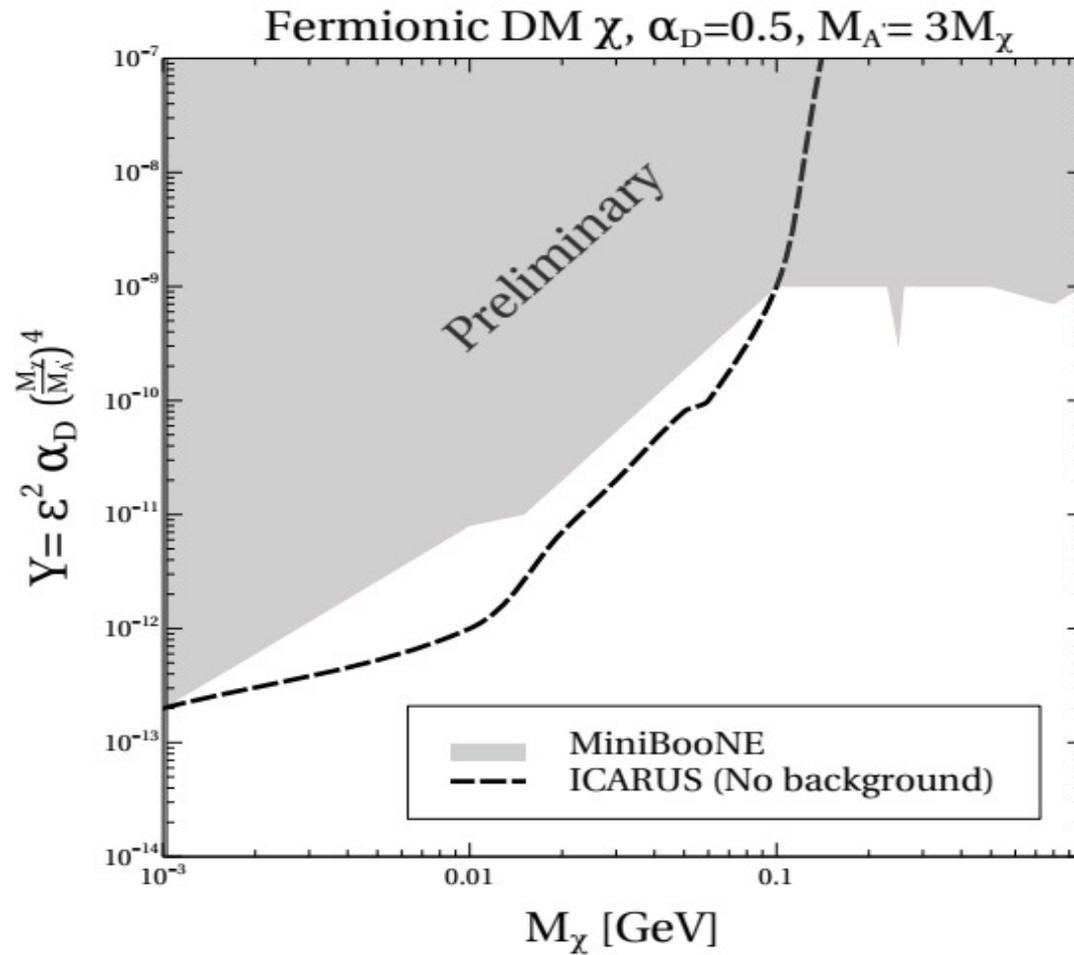
→ DM produced in the radiative decay of neutral hadrons or direct parton-level production

- Detection :**



Preliminary sensitivity result

$$\langle \sigma v \rangle \propto \frac{Y}{m_\chi^2}$$



- Preliminary sensitivity study looks promising.
- Complete detector simulation of the signal and background in progress.

Outlook and plan

- The idea of a light dark sector containing (sub-)GeV-scale DM coupled to the Standard Model through a light mediator particle has emerged as a compelling framework for DM physics.
- LDM could be copiously produced in high flux neutrino target for neutrino oscillation experiments
- ICARUS detector with NuMI Off-axis beam configuration will play a key role to search for the ldm.
- Detector simulation of the signal and background event is in progress.
- In a process of developing software tools for analyzing data.
- ICARUS detector will start taking beam data in November this year, stay tuned.