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# Searching for Dark Sector Phenomena at LArTPC Fixed Target Experiments

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Yale University

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# Searching for the Dark Sector

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- ❖ What is it?
- ❖ Where to search
- ❖ How to search
- ❖ Prospects on the Short Baseline Neutrino (SBN) program at FNAL

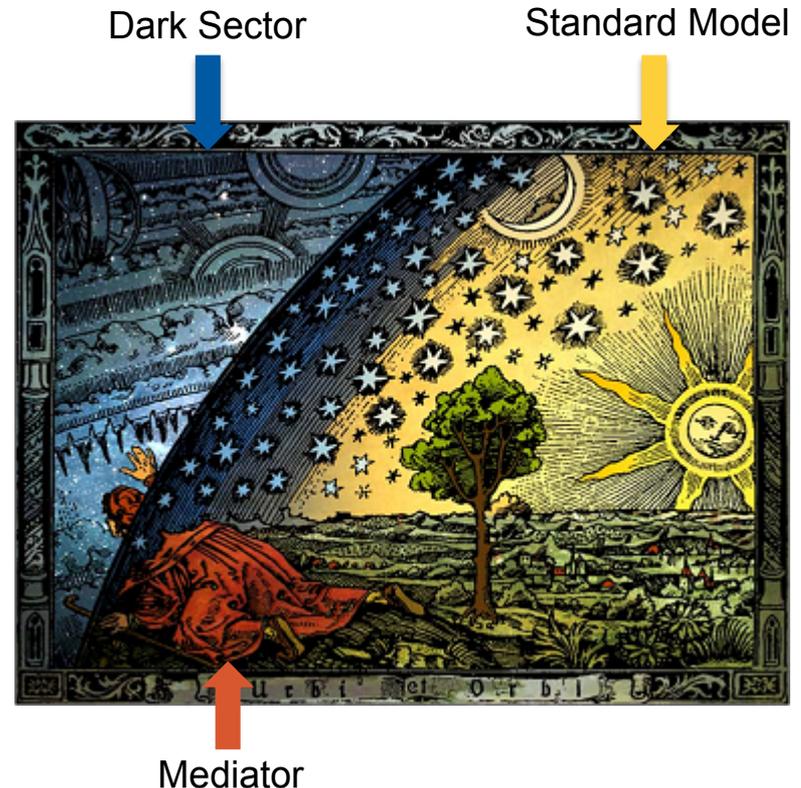
# Searching for the Dark Sector

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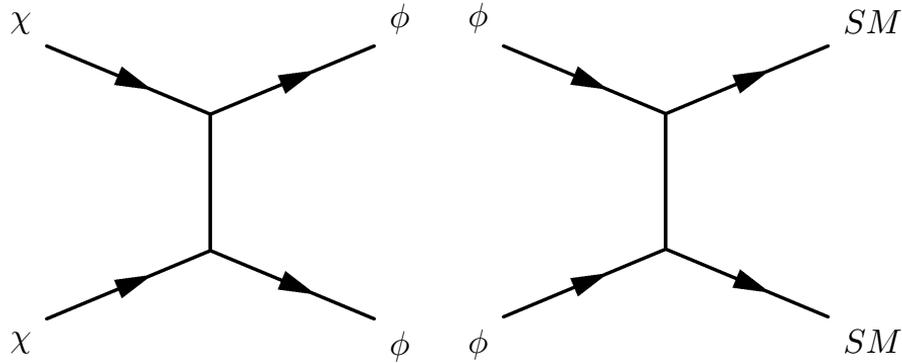
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# Searching for Dark Sectors

- ❖ A dark sector consists of particles that do not interact with known forces
- ❖ The dark sector has its own interactions apart from SM
- ❖ There may exist some mediator that couples the SM to the dark sector



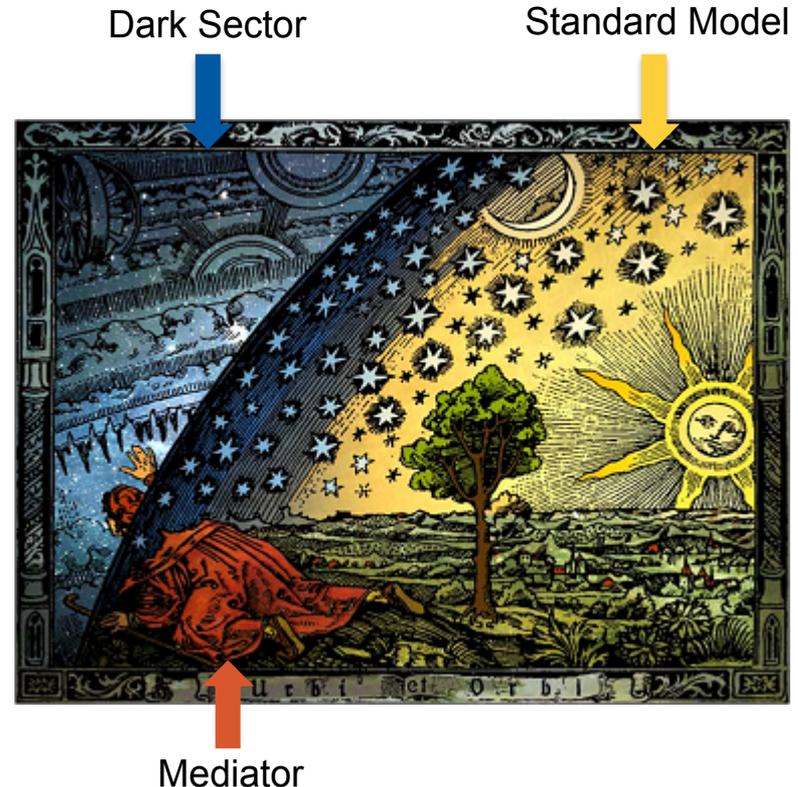
# Searching for Dark Sectors



$\chi$  Dark matter

$\phi$  Mediator

$SM$  Standard Model



# Searching for the Dark Sector

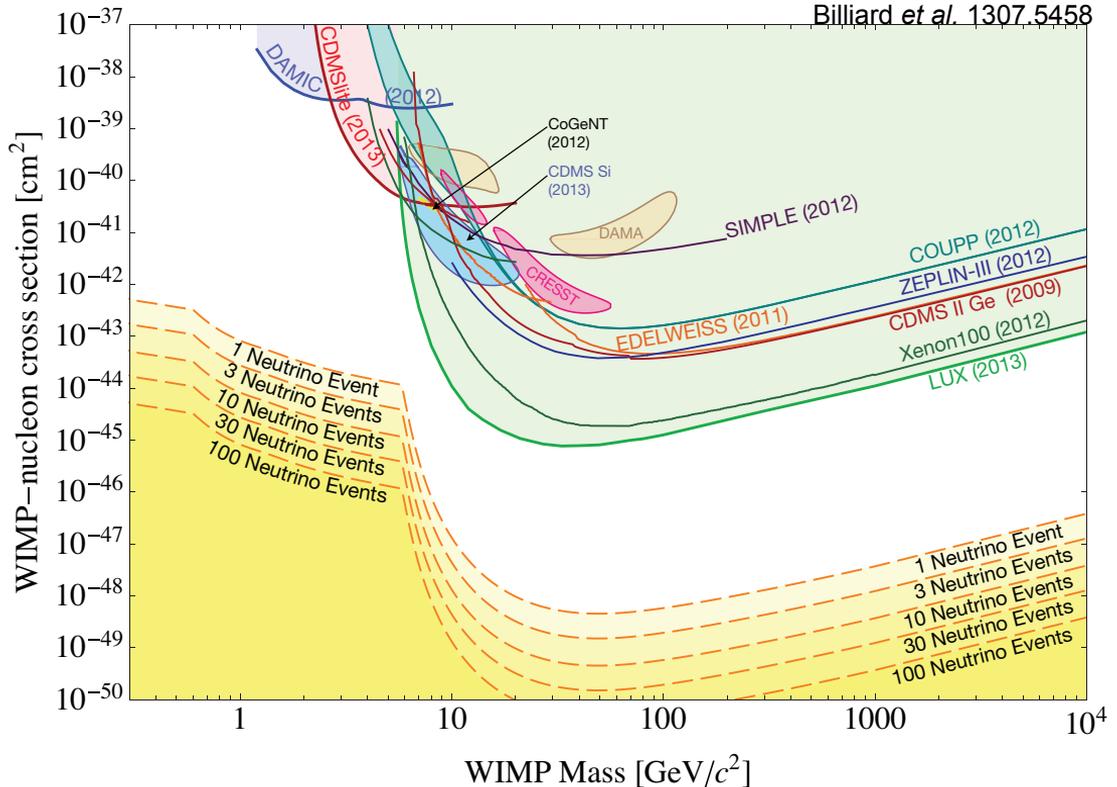
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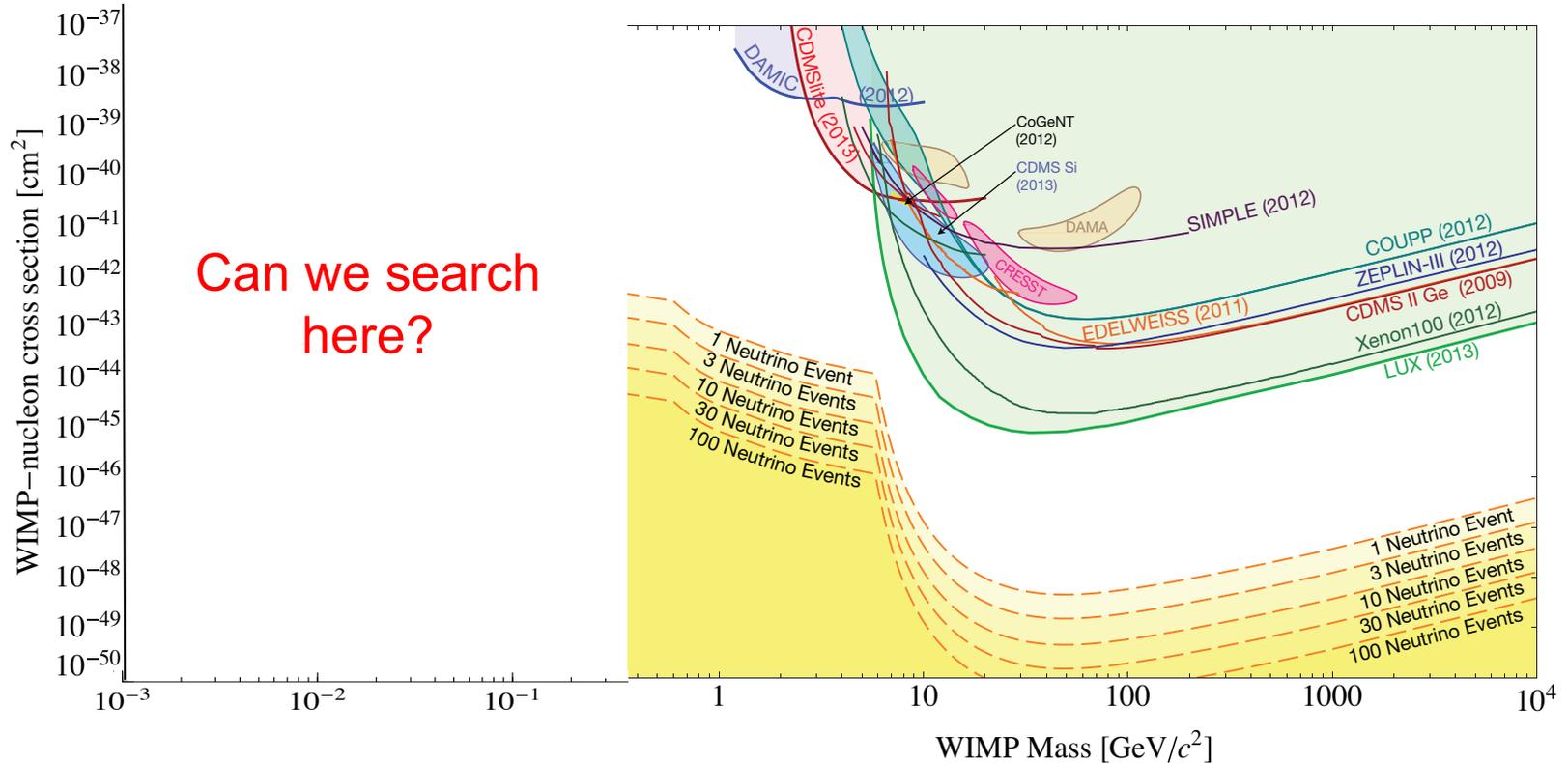
# Conventional DM Direct Detection WIMP Parameter Space

DM direct detection experiments have excluded a significant region of parameter space.

Where else can we search?



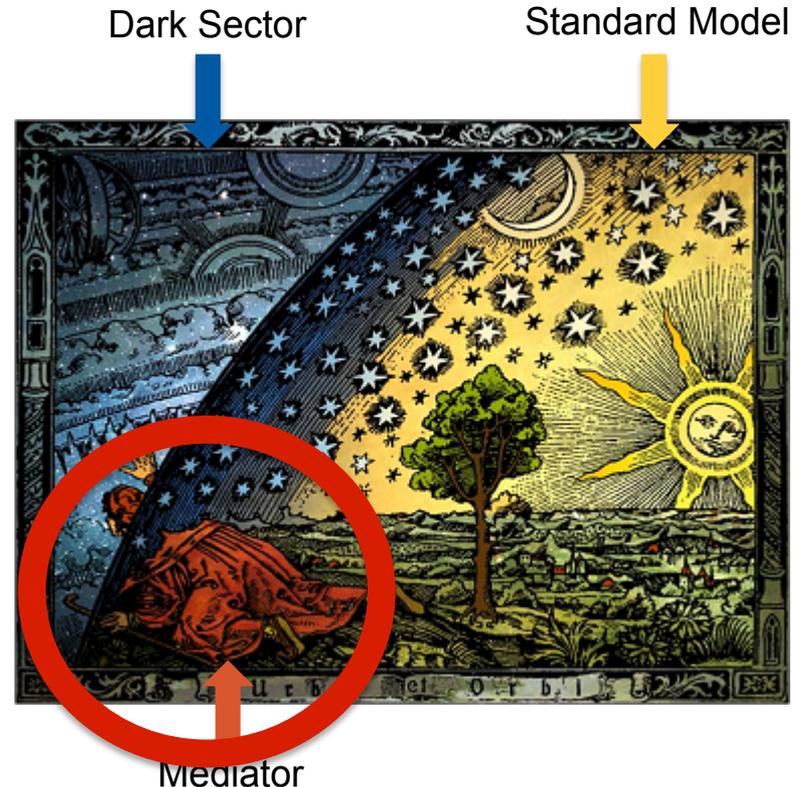
# Opening up new parameter space



# Searching for Dark Sectors

Role of the mediator:

- ❖ Mediate interactions with the SM
- ❖ Open new DM annihilation channels



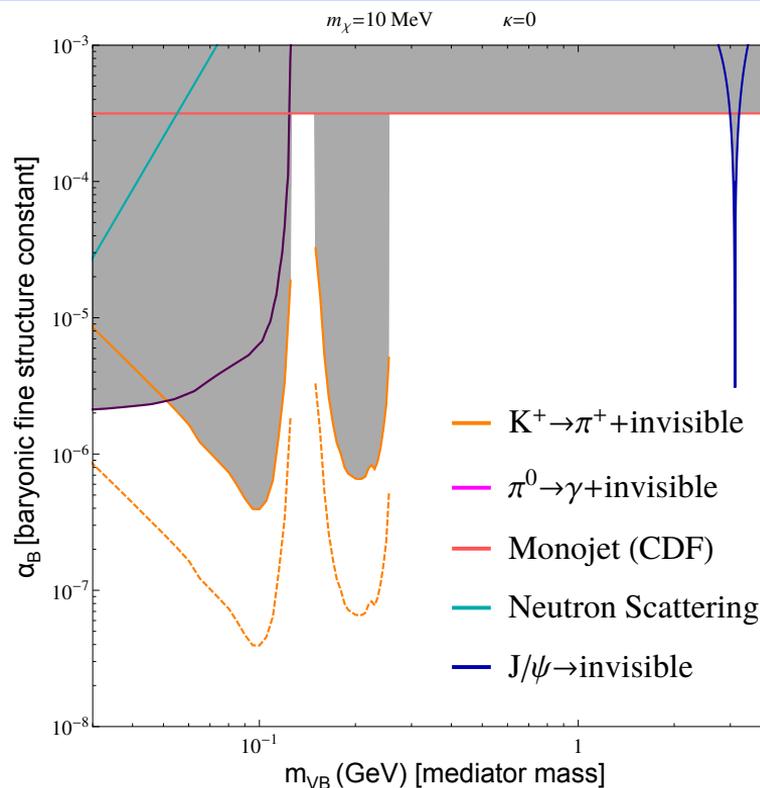
# Baryonic coupling: dark sector to SM

Many models based on a local U(1) symmetry

- ❖ Conserves CP, P and flavor

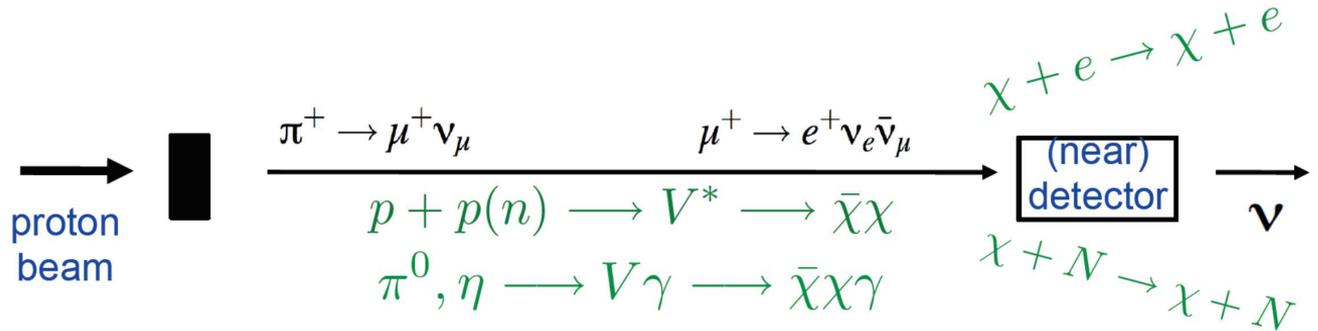
Leptophobic DM model:

- ❖ Local  $U(1)_B$  baryon number symmetry
- ❖ Baryonic gauge boson  $V_B$  serves as mediator
- ❖  $V_B$  is coupled to the baryon current

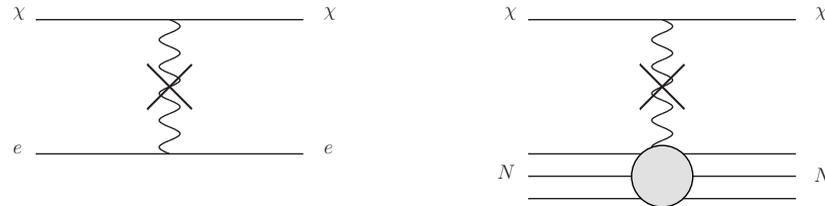


# MiniBooNE DM Search

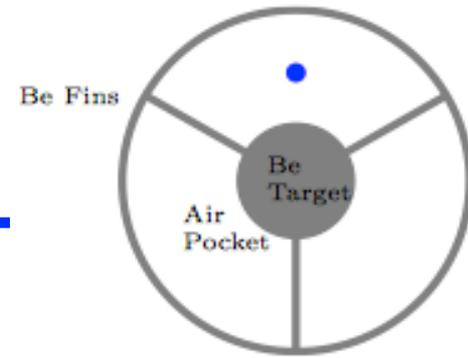
- ❖ First dedicated search for light DM at a proton fixed target experiment



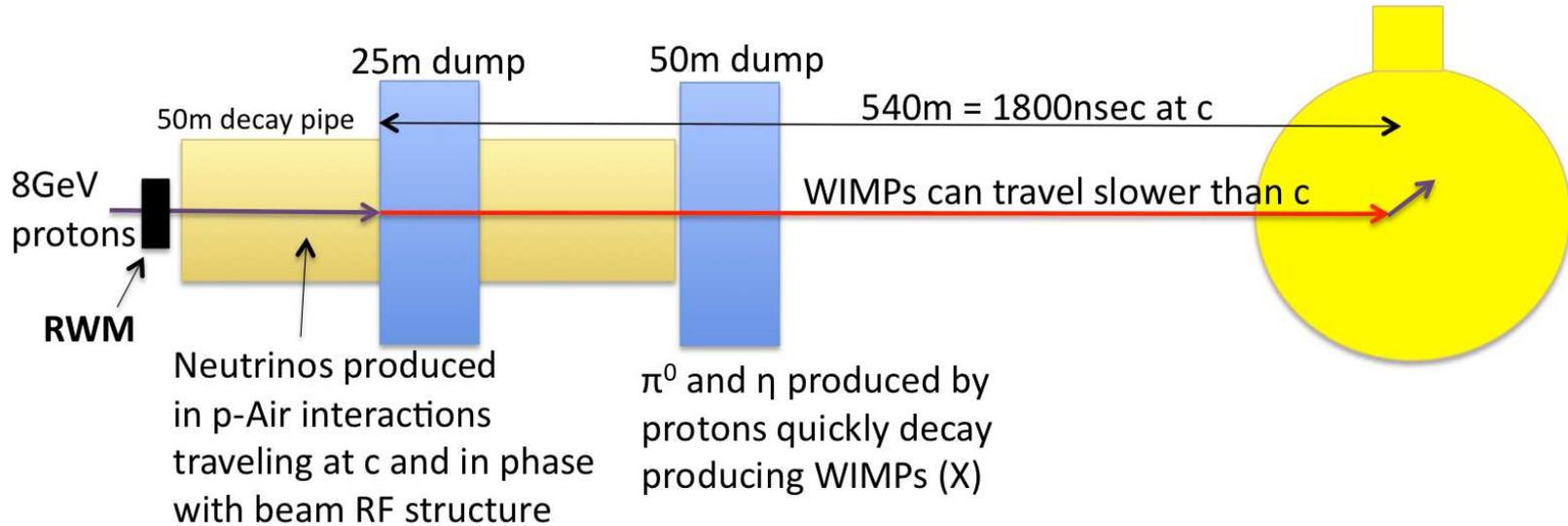
- ❖ Search for elastic scattering of DM downstream of target as additional contribution to NC-type signal



# MiniBooNE DM Search



## WIMP Time of Flight





# Suppose dark matter is heavier than the SM-dark sector mediator.

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$$2m_x < m_{VB}$$

Rate of visible decays is negligible  
→ preferentially decays to DM

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Preferentially decays to SM  
(i.e. visible decay)

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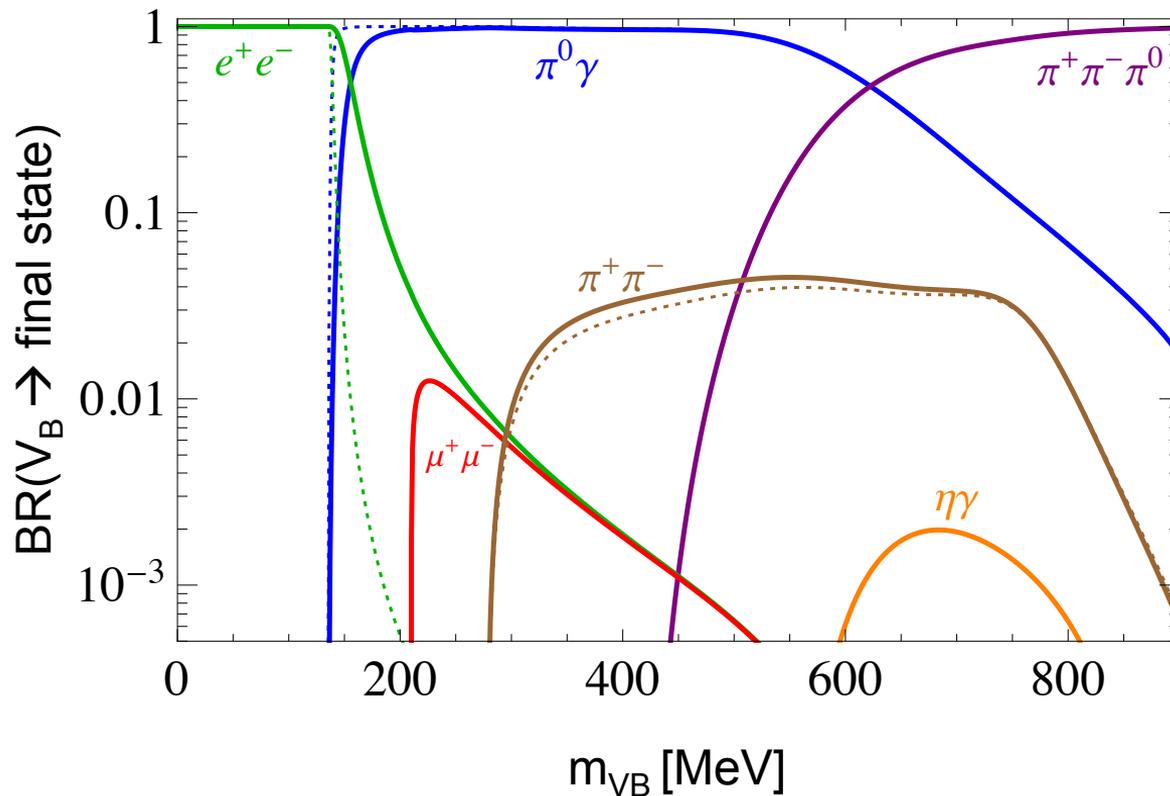
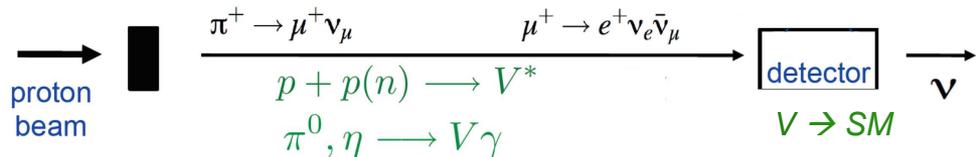
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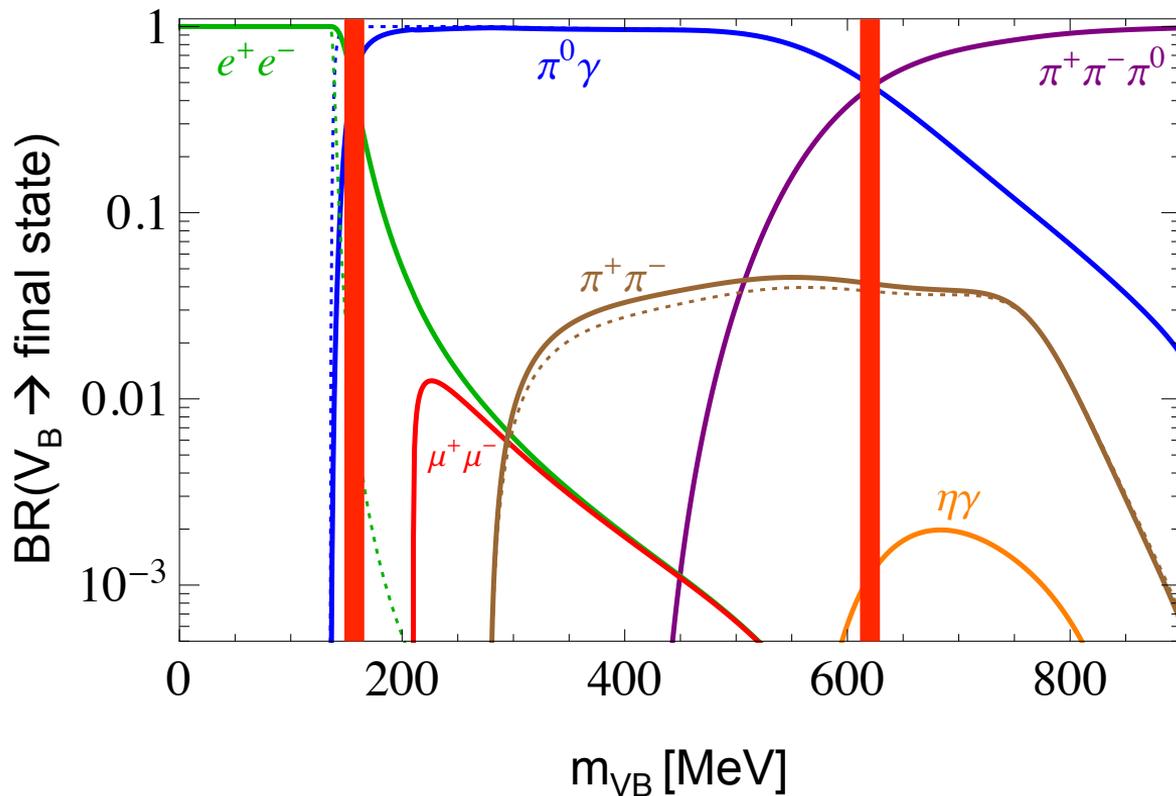
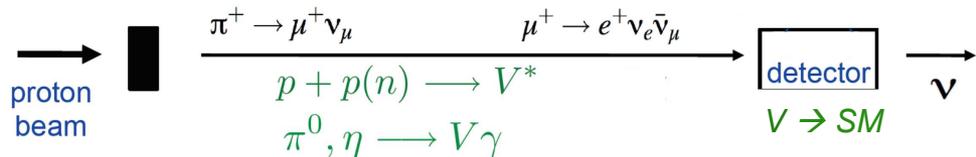
Preferentially decays to SM  
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Can we detect the decay  
of this mediator to the SM?

# $V_B$ Mediator Decay



# $V_B$ Mediator Decay



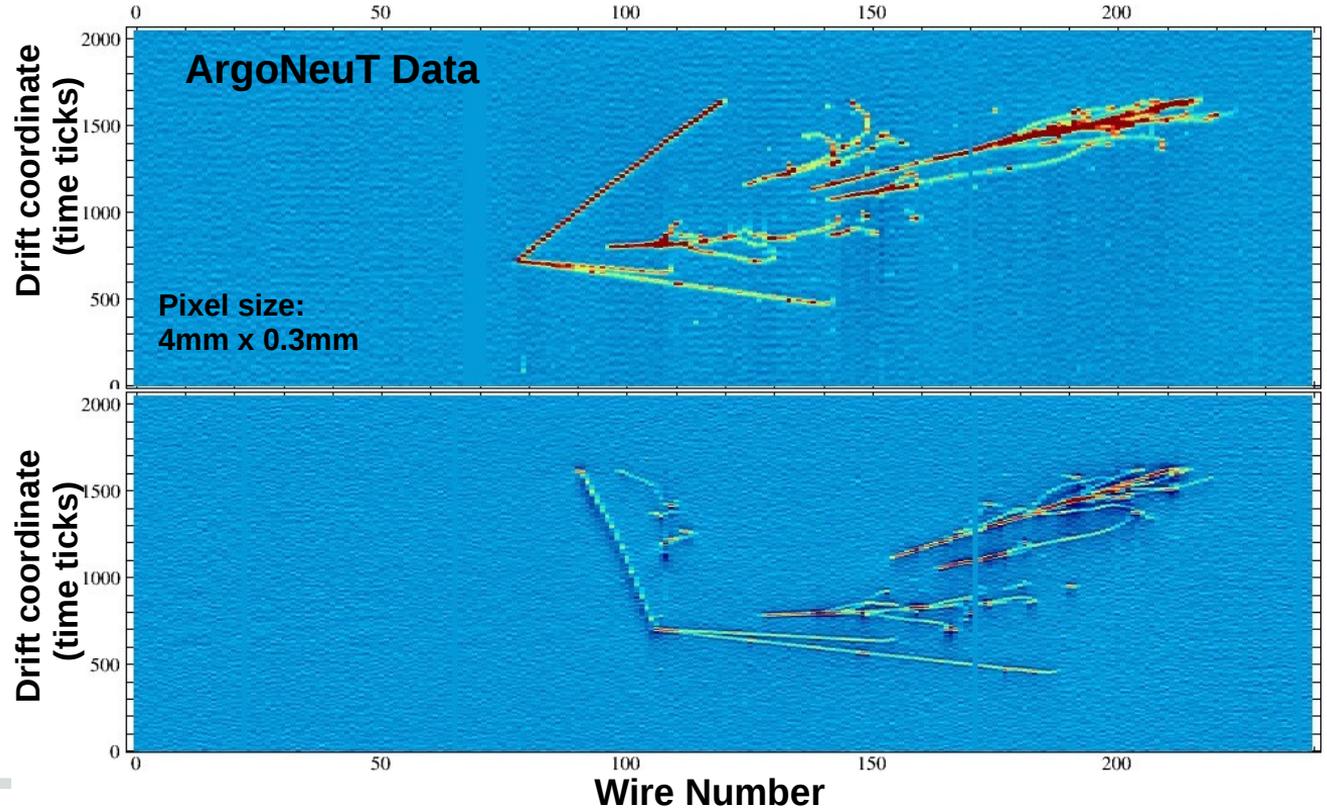
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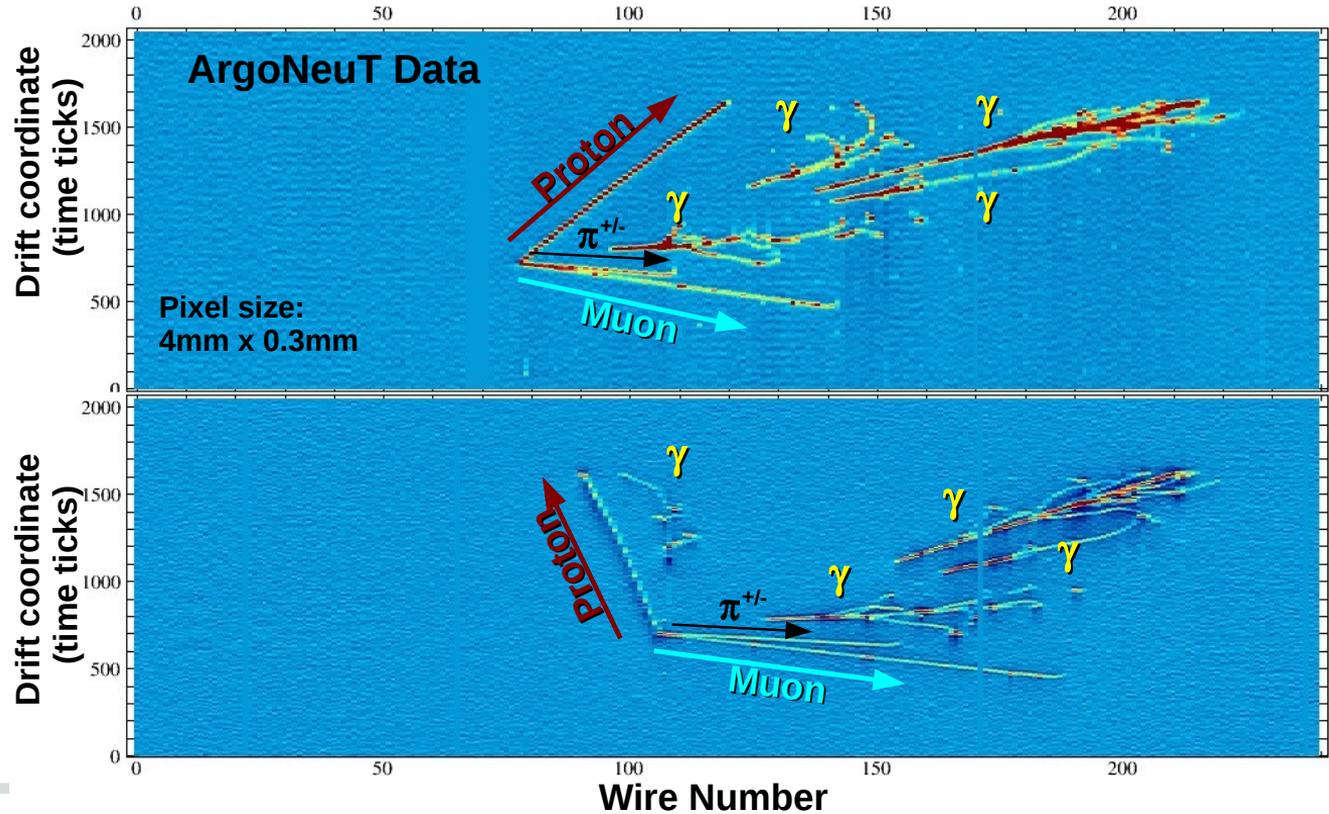
# Signal Detection Capabilities

- ❖ 3D imaging
- ❖ Precise calorimetric energy reconstruction
- ❖ Efficient particle identification



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- ❖ 3D imaging
- ❖ Precise calorimetric energy reconstruction
- ❖ Efficient particle identification
- ❖ **Detailed reconstruction of final state event topologies**

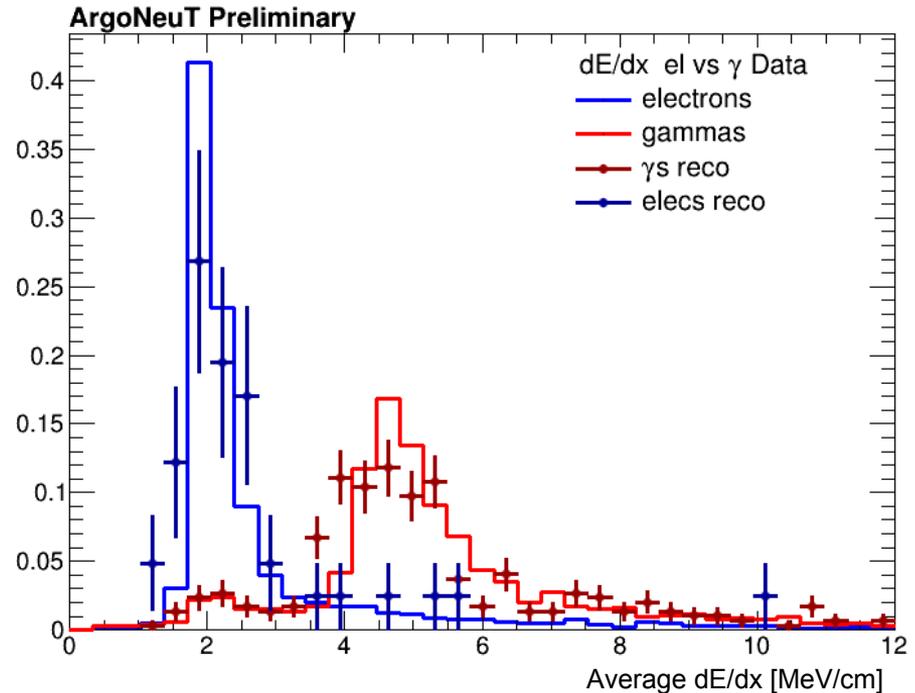


# Signal Detection Capabilities

Discriminate electromagnetic showers by analyzing the  $dE/dx$  for the start of the shower

→ Identify and separate photons from electrons

## Electron/Photon Discrimination



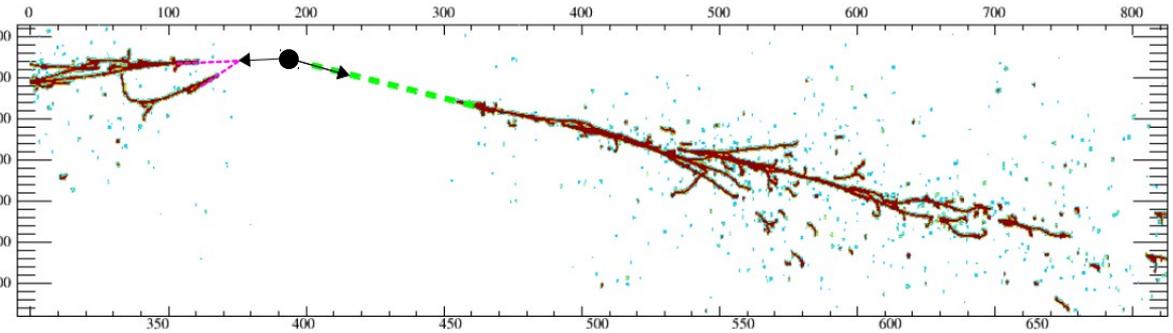
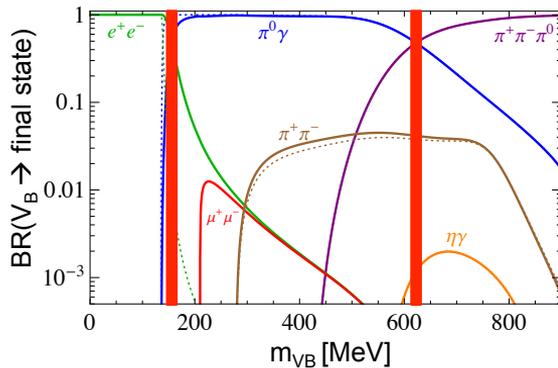
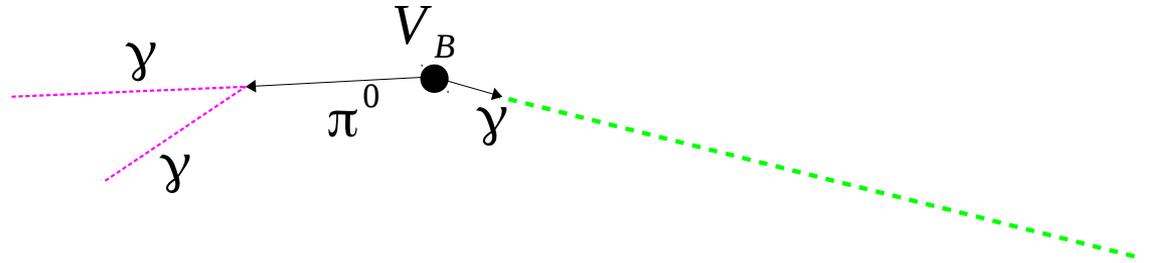
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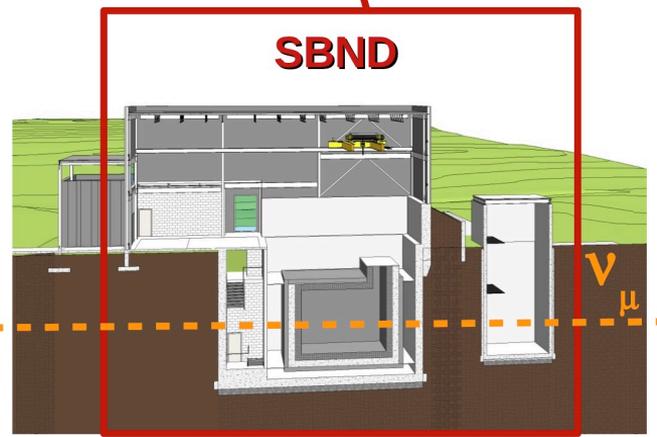
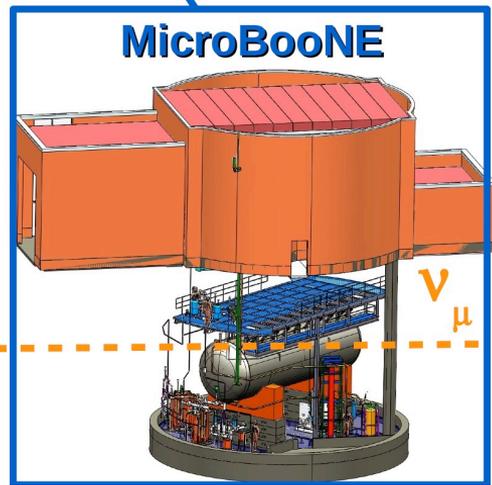
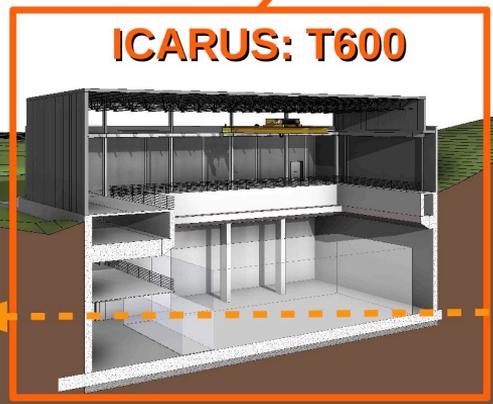
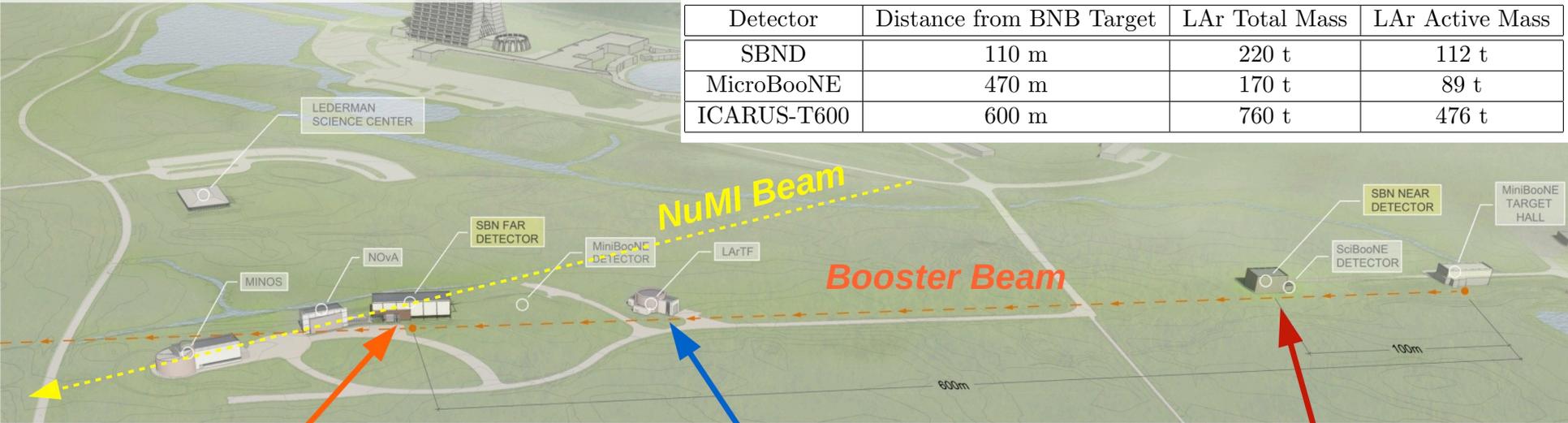
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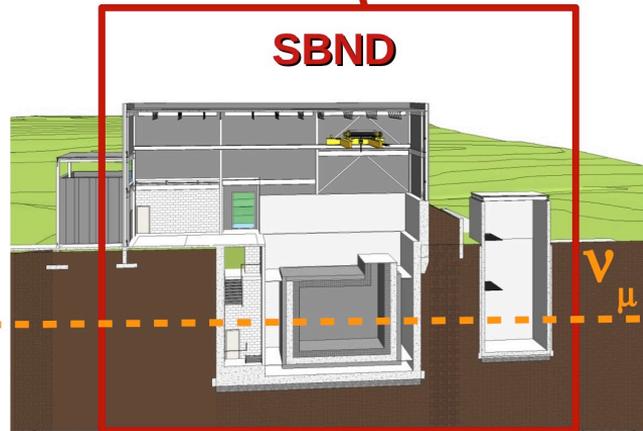
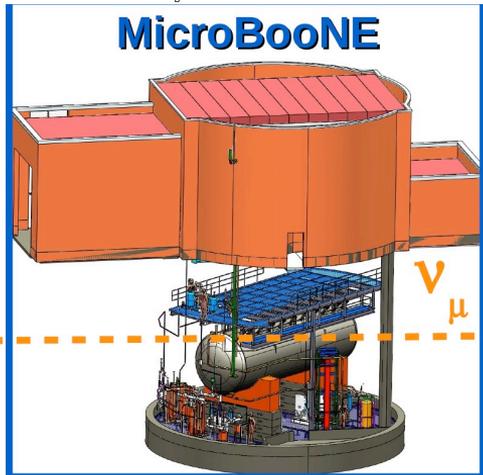
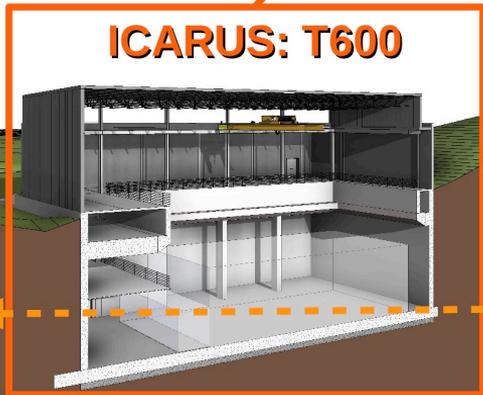
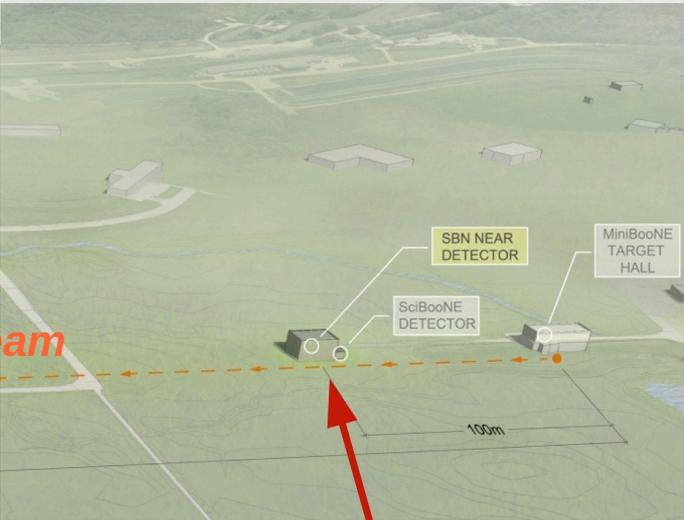
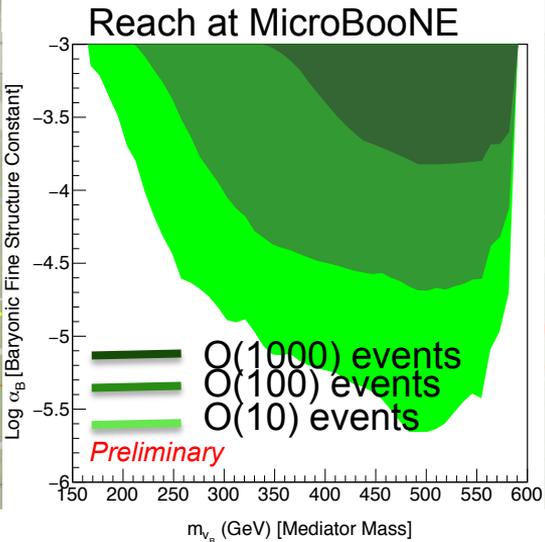
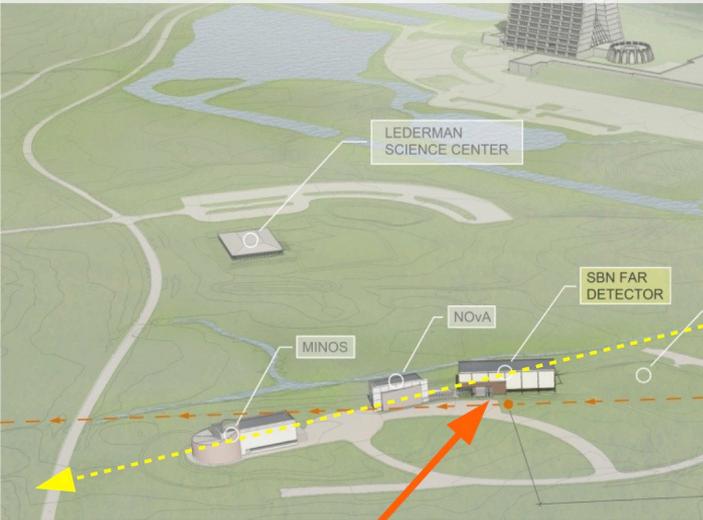
# Dark Sector Searches at SBN

LArTPCs are well equipped to search for visible decays of a dark sector mediator

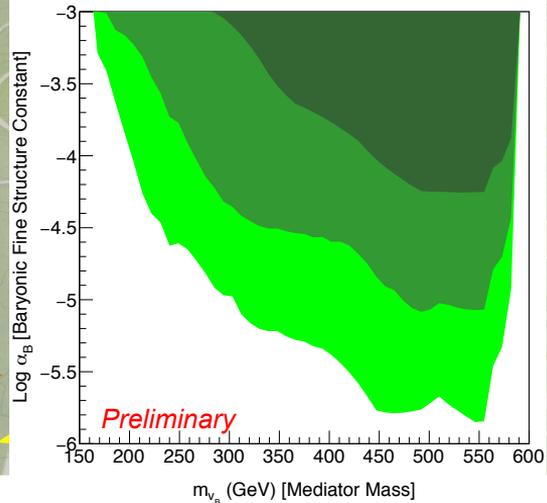


Detector	Distance from BNB Target	LAr Total Mass	LAr Active Mass
SBND	110 m	220 t	112 t
MicroBooNE	470 m	170 t	89 t
ICARUS-T600	600 m	760 t	476 t

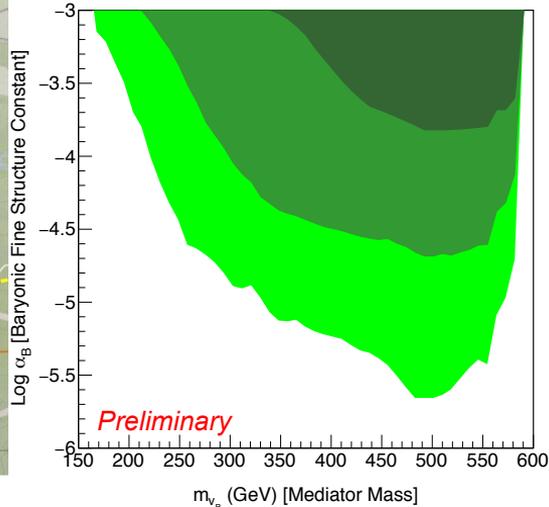




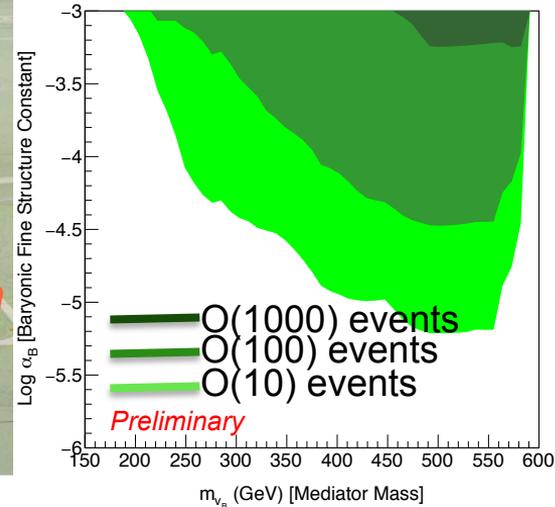
### Reach at ICARUS



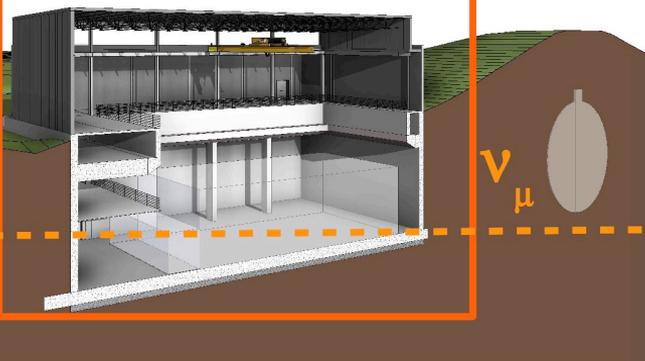
### Reach at MicroBooNE



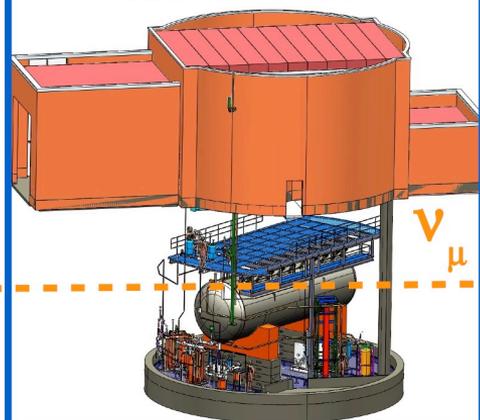
### Reach at SBND



### ICARUS: T600



### MicroBooNE



### SBND



# Summary

- ❖ The upcoming SBN program may be sensitive to dark sector mediators at a wide range of masses and coupling strengths
- ❖ This is our first look. LArTPCs are an attractive detector technology to probe a number of dark sector models

