

Dark **Sector** Searches in LArTPC Experiments

APS April Meeting

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On Behalf of the MicroBooNE Collaboration

Dark **Sector**, *not* Dark Matter

- Current Dark Matter searches
- Future Dark Sector searches (non-WIMP)
 - MeV-scale dark sector phenomena
 - Not accessible by direct detection experiments
- Leptophobic Dark Sector

Dark Sector



Standard Model

New Portal?

A New Window into the Dark Sector

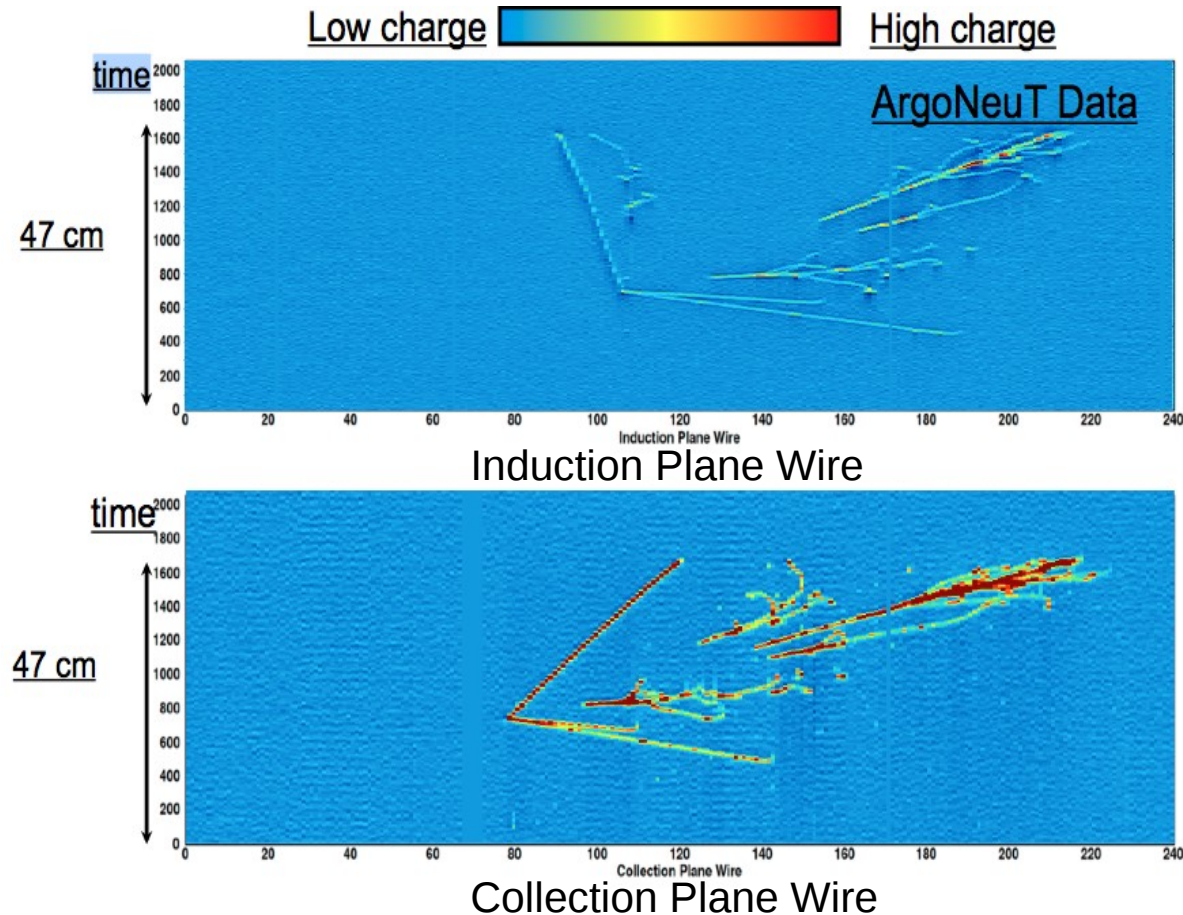
- High energy dark sector production signals
- Where? High-intensity fixed-target experiments
- Neutrino beams
 - 8 GeV Booster Neutrino Beam (BNB) at Fermilab
- LArTPCs
 - MicroBooNE, LAr1-ND

MicroBooNE
Cryostat



LArTPCs: Signature-Based Searches

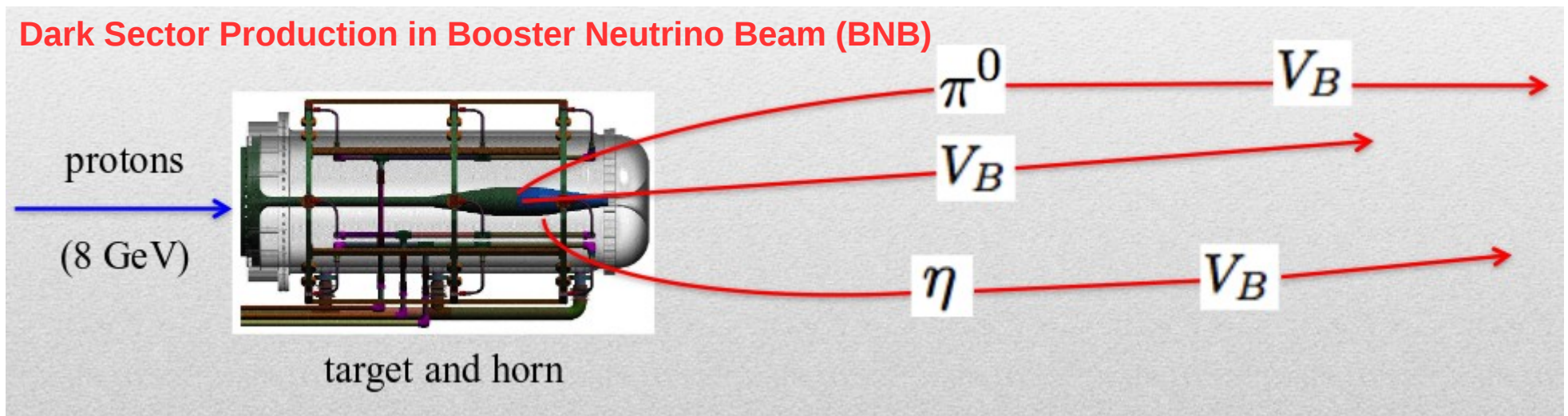
- LArTPC technology:
 - Ionization charge
 - Scintillation light
- High resolution:
 - Millimeter distances
 - GeV energies
- Spatial information: characterization of events by topology



C. Anderson *et al.* (ArgoNeuT Collaboration), “The ArgoNeuT detector in the NuMI low-energy beam line at Fermilab,” [Journal of Instrumentation](#) **7**, P10019 (2012).

Leptophobic Dark Sector

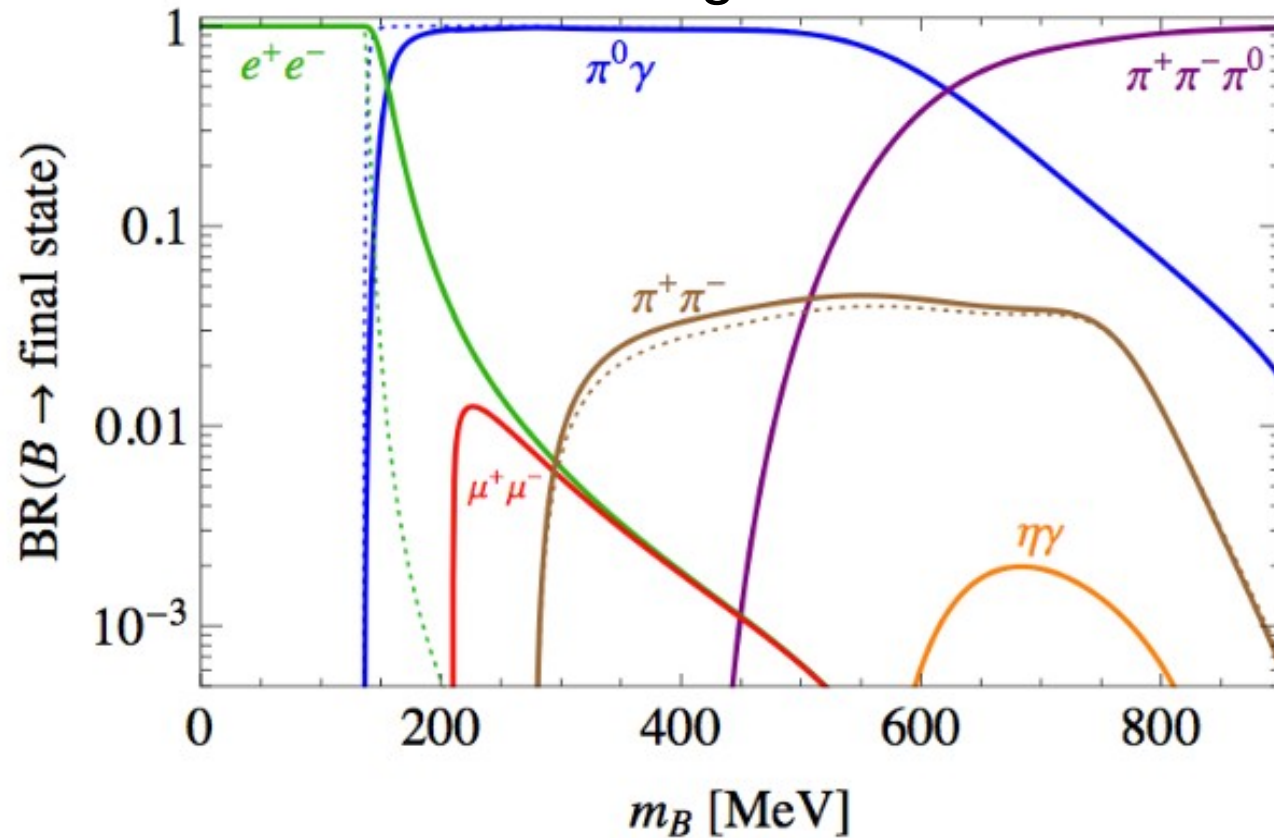
- Vector boson is a mediator between the dark sector and the Standard Model that couples dominantly to quarks
- V_B produced via meson decay and direct QCD production



- Meson production in BNB is well-understood, so we can incorporate V_B in production simulations

Vector Boson Visible Decay

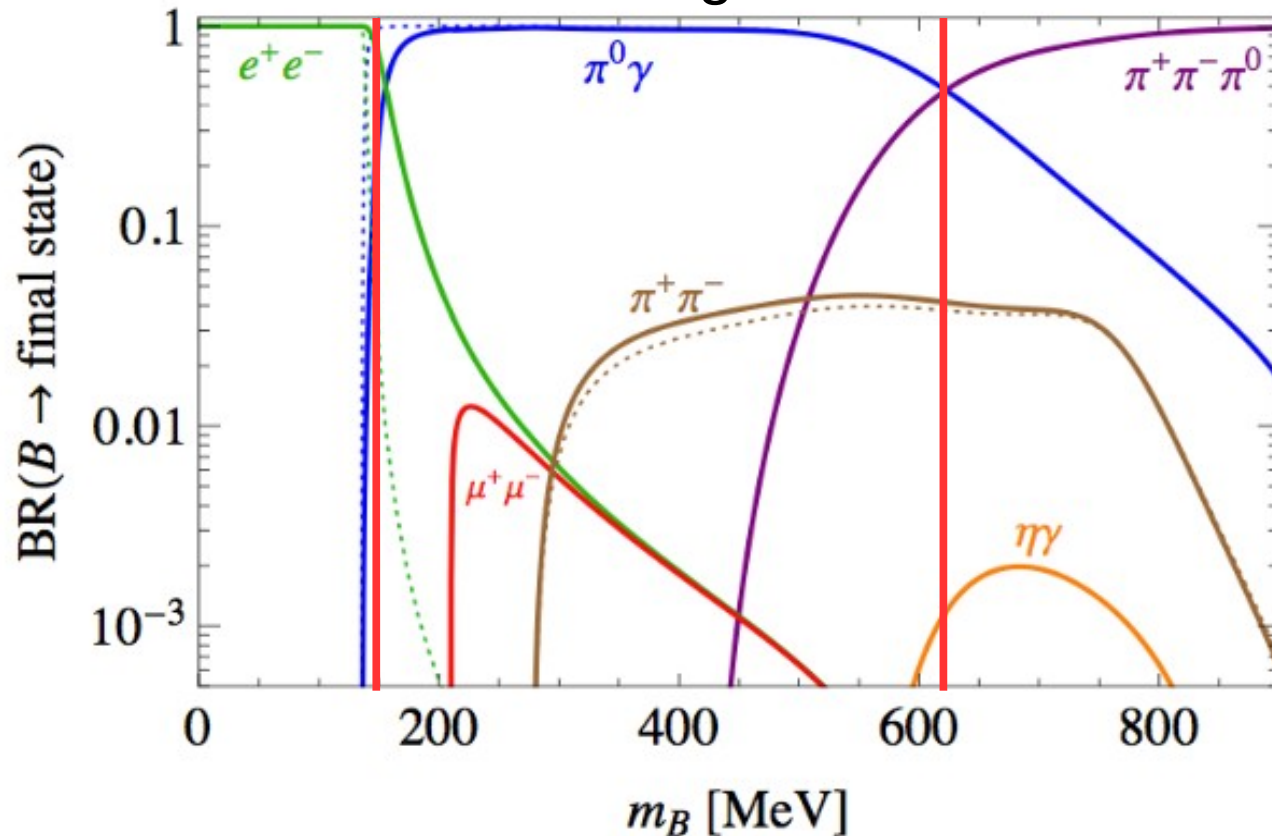
Branching Ratios



S. Tulin, *New weakly coupled forces hidden in low-energy QCD*, Phys.Rev. **D89**, 114008 (2014).

Vector Boson Visible Decay

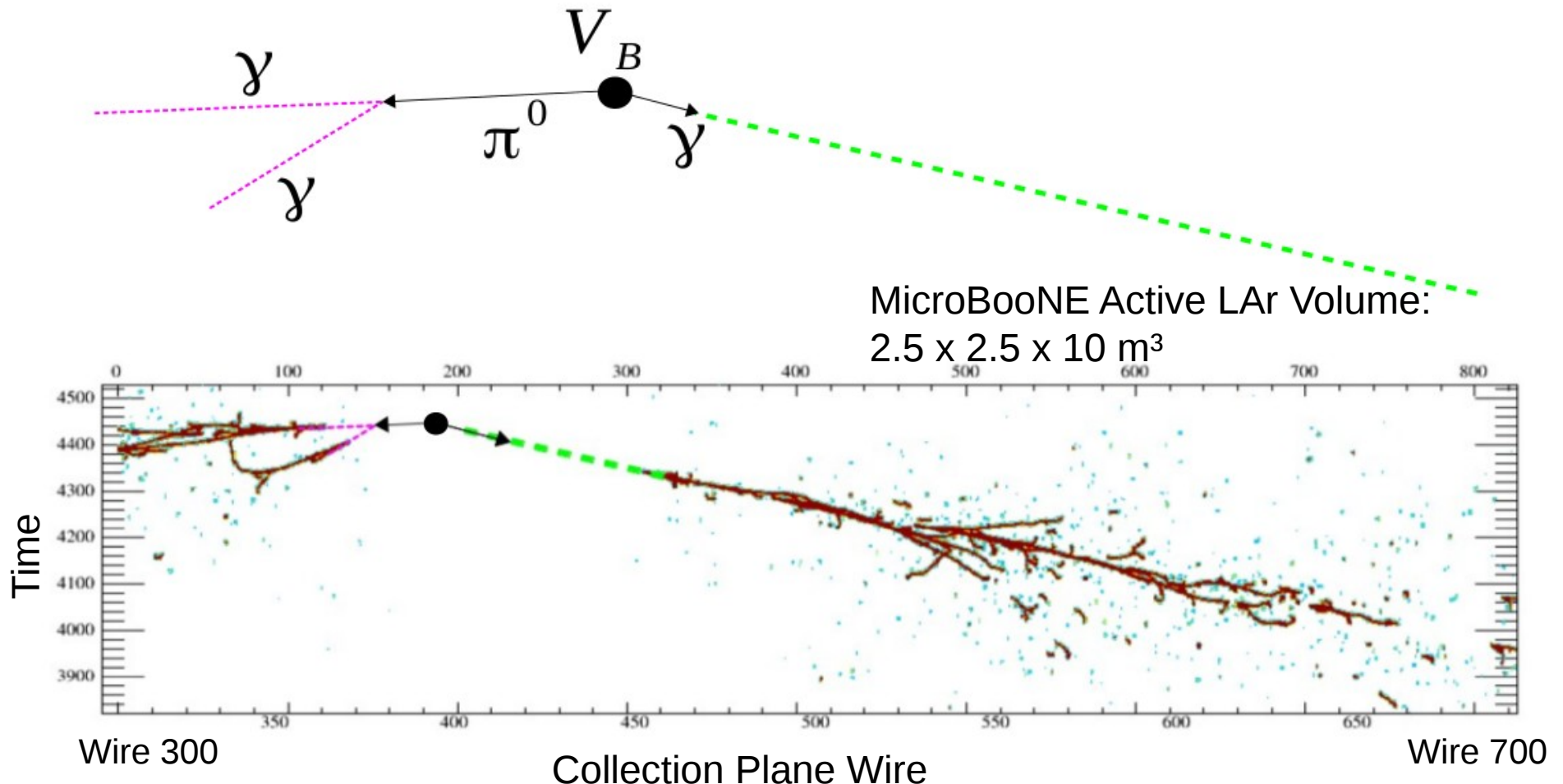
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- Focus on three-photon decay channel
 - Primary decay mode 140-620 MeV
 - Is faked by well-understood SM processes

Three-Photon Signature in MicroBooNE



Three-photon topological signature: photons can be traced back to a common point with no vertex activity (i.e. no hadronic interaction)

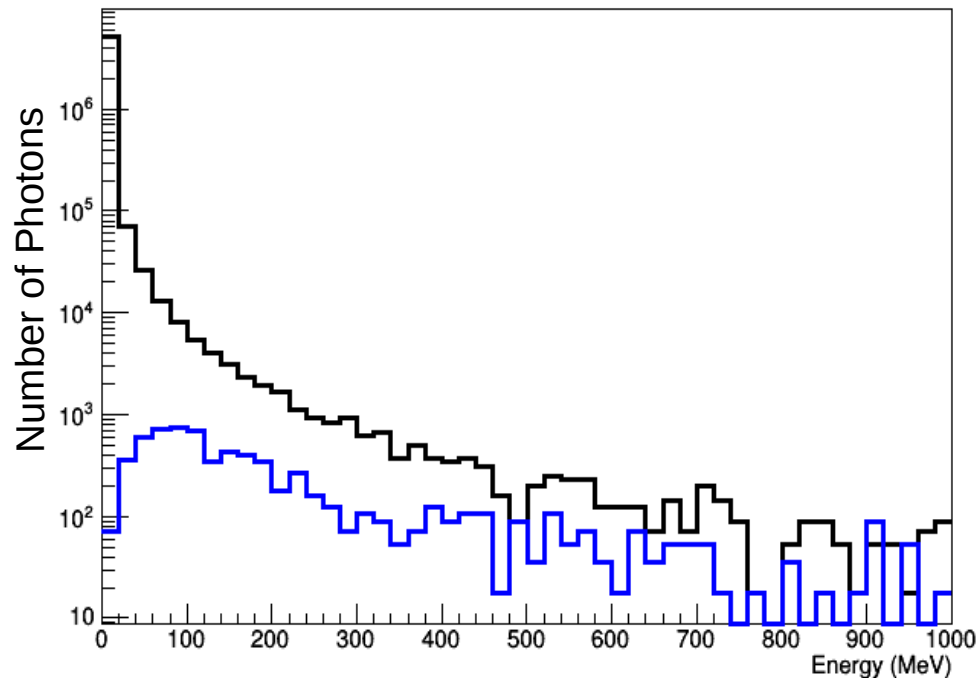
Background Analysis

- Study three-photon channel in MC events
- Goals:
 - Identify types of processes that fake the signal
 - Quantify their rate
 - Characterize their kinematics
 - Identify effective cuts to remove backgrounds
- Approach:
 - Topology-based event search and characterization
 - Fiducial volume spatial cut
 - Cut based on photon energy and physical distribution
 - Optimize cuts

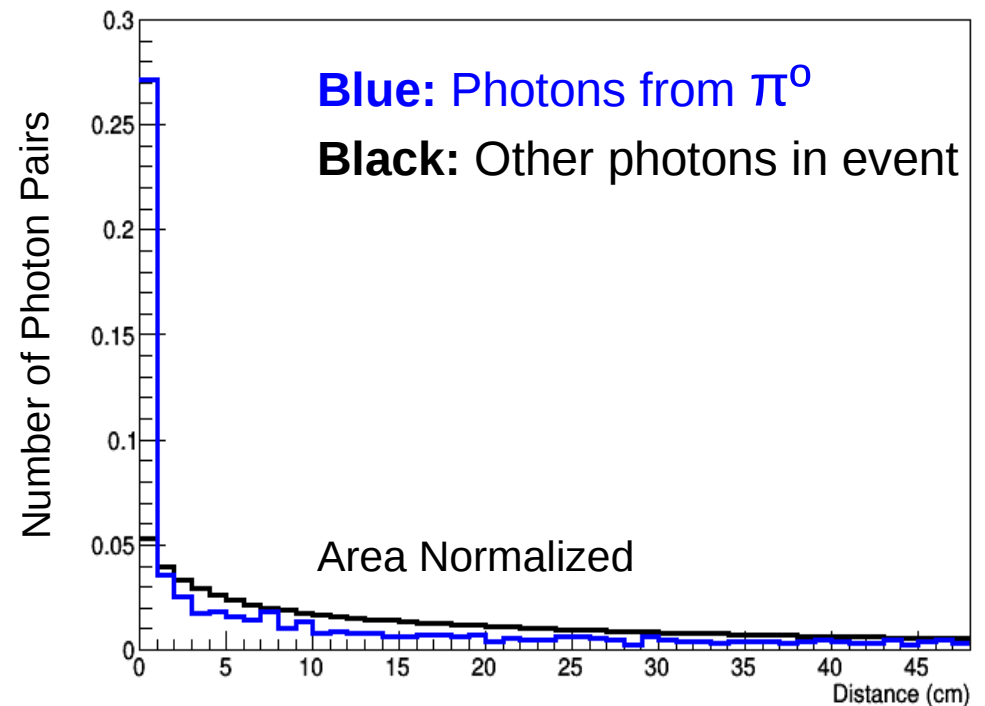
Background Event Characterization

- In simulation of MicroBooNE's full exposure, 2% of events have ≥ 3 γ , including ≥ 2 γ from a π^0

Photon Energy Distribution in π^0 Decay



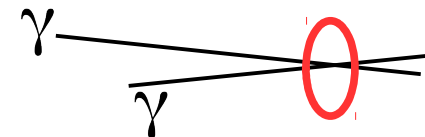
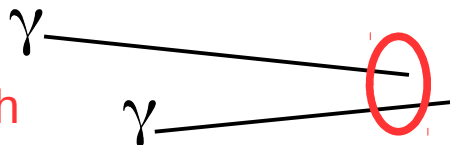
Normalized Photon Distance Distribution in π^0 Decay



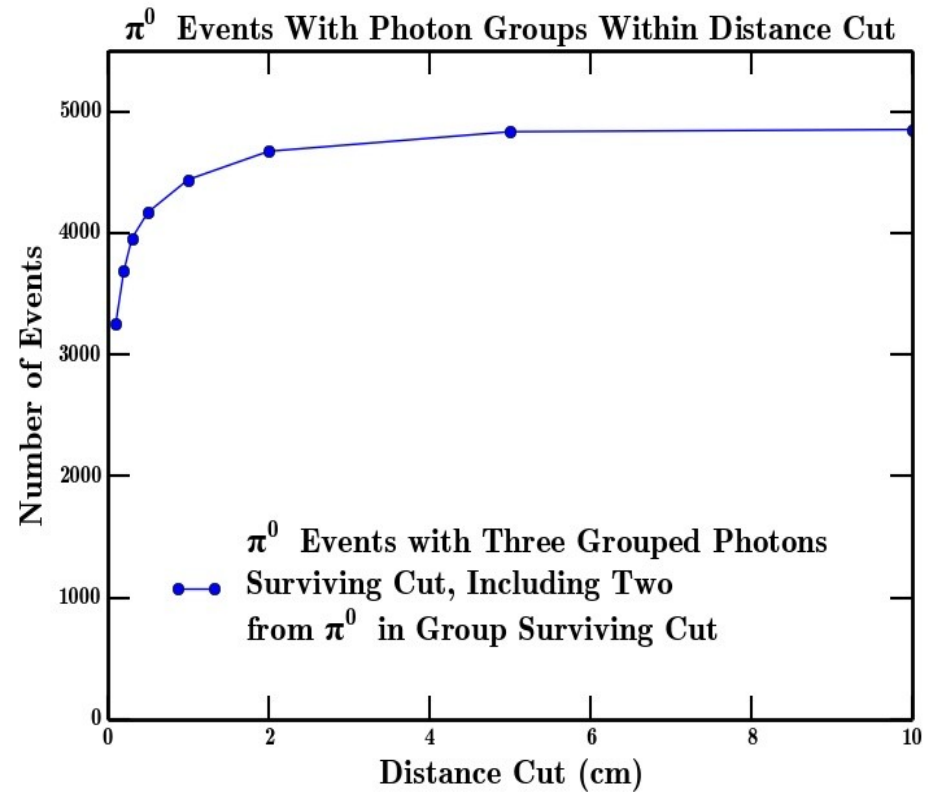
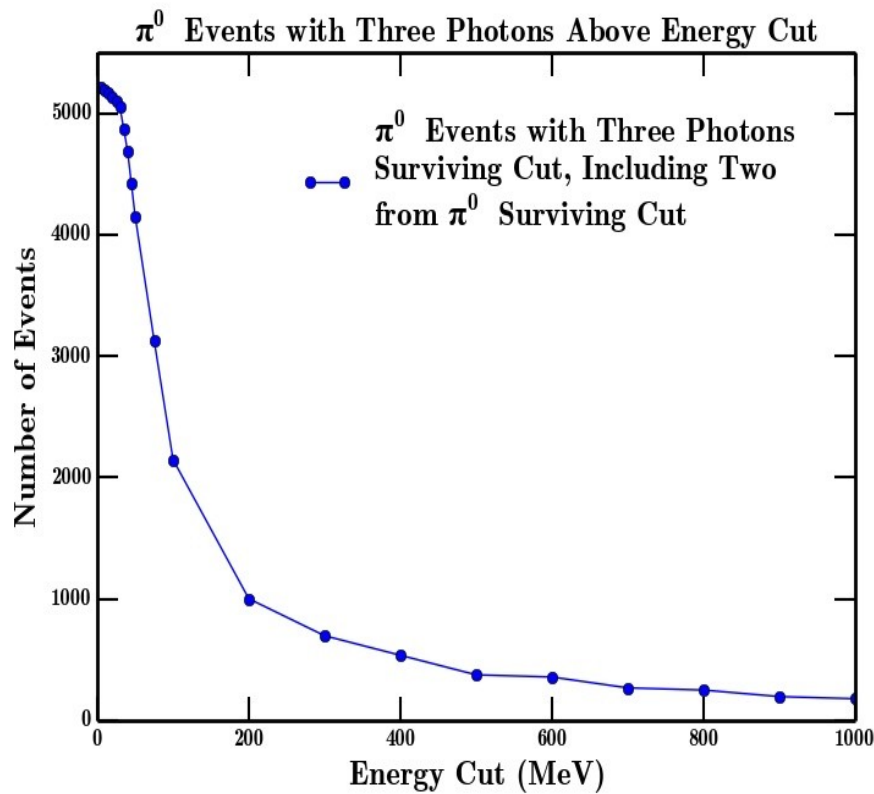
Distance Calculation:

Distance of Closest Approach

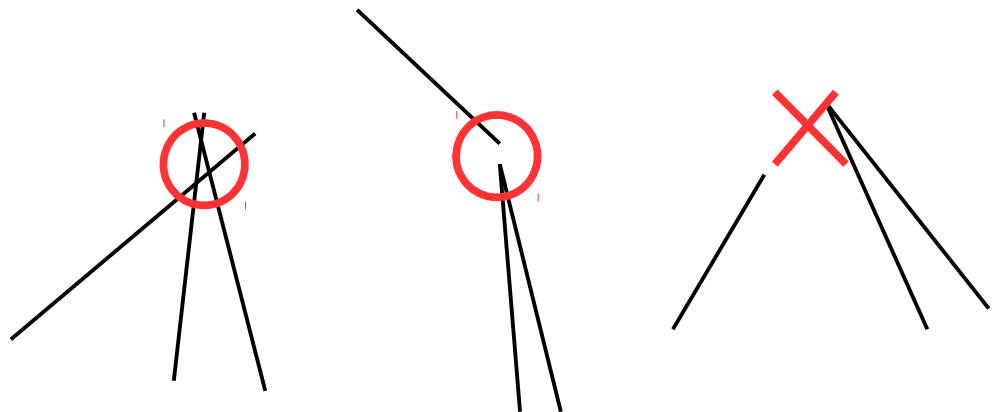
Lines do not necessarily intersect in 3D!



Cuts to Minimize Background



Distance Cut Visualization



Plans for the Future

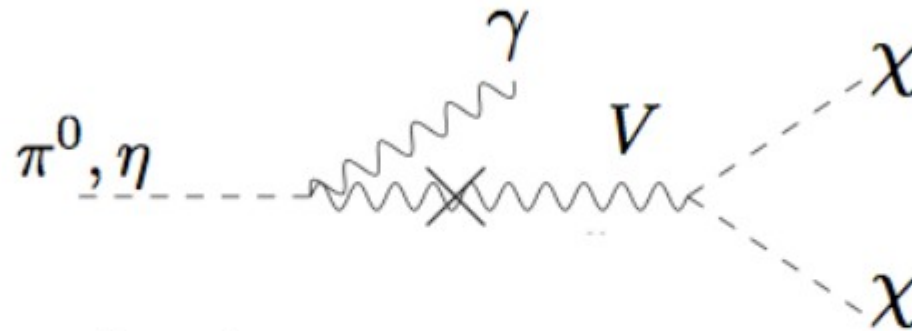
- Use vector boson production statistics to optimize signal/background ratio
- Apply energy and distance cuts simultaneously
- Continue refining signal reconstruction
- Extend analysis to other channels / models
- Quantify signal detection efficiency



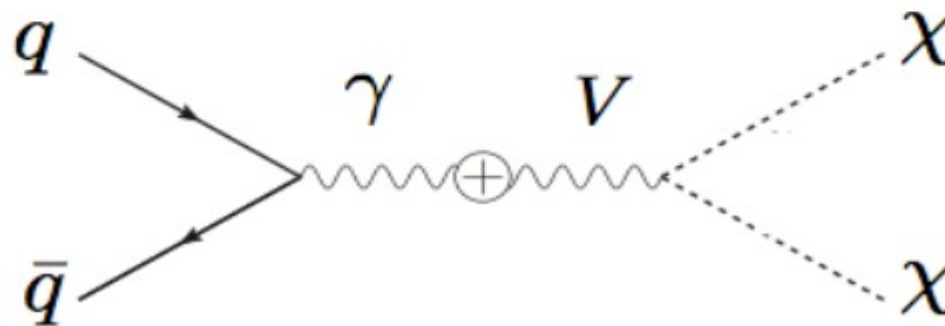
Backup Slides

Production of Vector Bosons

- Production of secondary hadrons followed by decay
(e.g. pseudoscalar meson decay, scalar meson-vector boson mixing)



- Direct QCD production



Normalized Photon Distance Distribution in π^0 Decay

