NF03 WP: Cosmogenic Dark Matter and Exotic Particle Searches

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Letter of Interest

Physics opportunities with inelastic boosted dark matter in the next-generation large-mass neutrino and dark matter experiments

Search for boosted dark matter in DUNE-like experiments

Searches for boosted dark matter at surface experiments

Multi-scattering dark matter at neutrino experiments

Searches for exotic particles with the IceCube neutrino observatory

The exotics and cosmic ray physics program of NOvA

Physics beyond the Standard Model in DUNE

…… etc.

Physics Scope

- Cosmogenic particles
  - Not produced by artificial sources, e.g. accelerators
- Not detecting neutrinos
  - This can be found in NF04, neutrinos from natural sources
- Neutrino detectors have advantage compared to dark matter detectors
  - Conventional dark matter detection can be found in Cosmic Frontier, eps. CF01, dark matter: particle-like
- Communicating with other sub-groups, esp. NF04 and CF01

Contributors

Experimentalists and theorists…

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… and *your names*!

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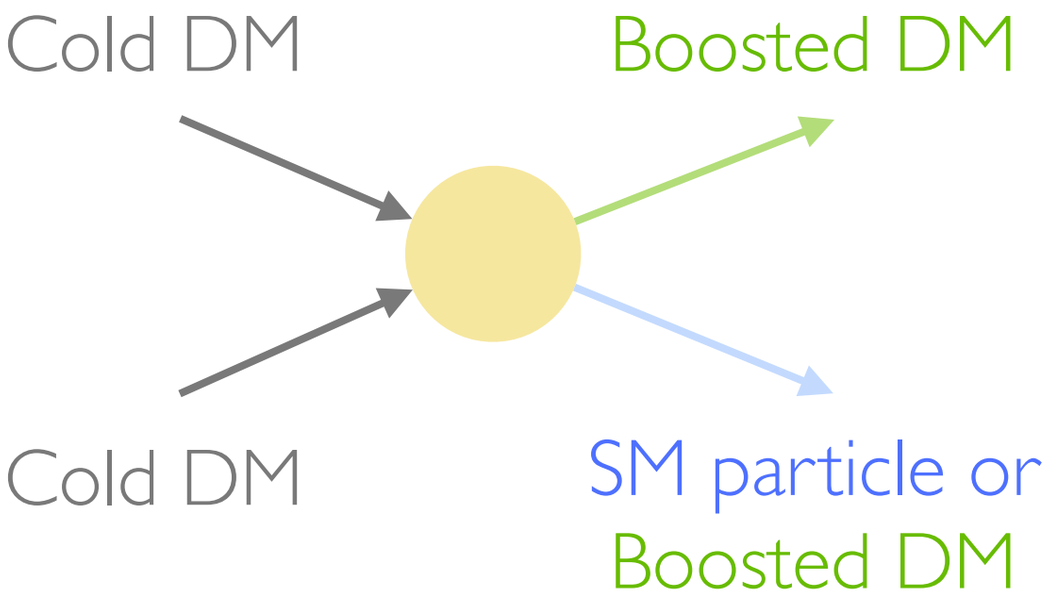
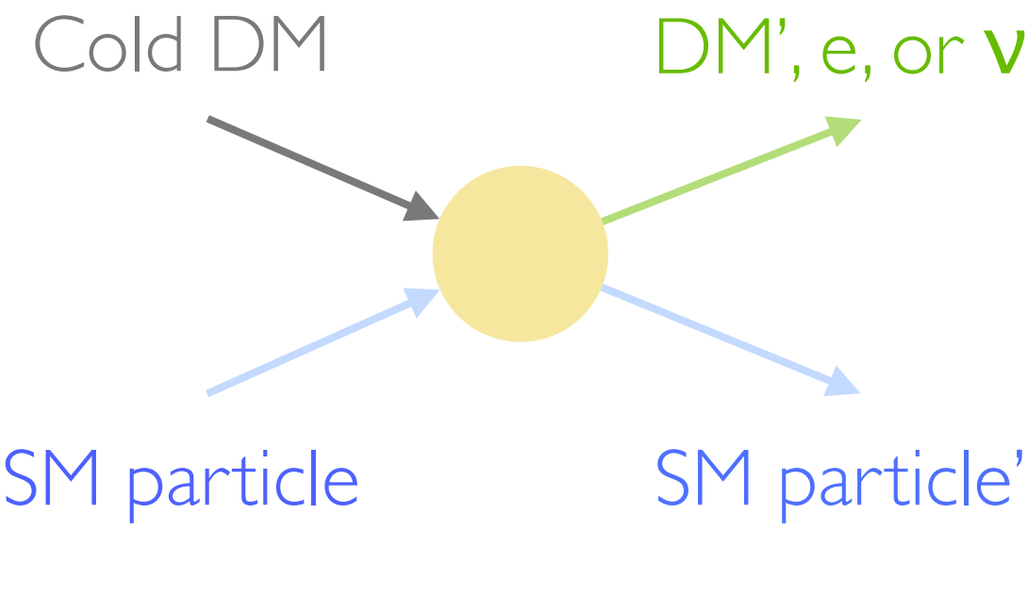
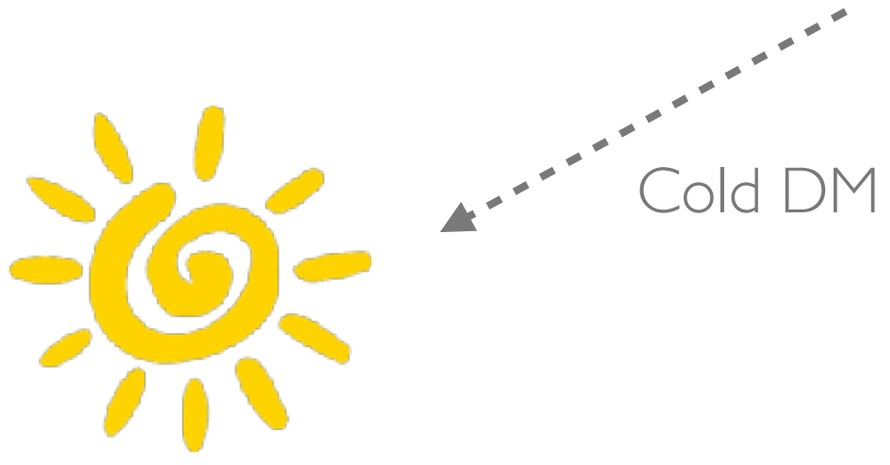
Cosmogenic Signals





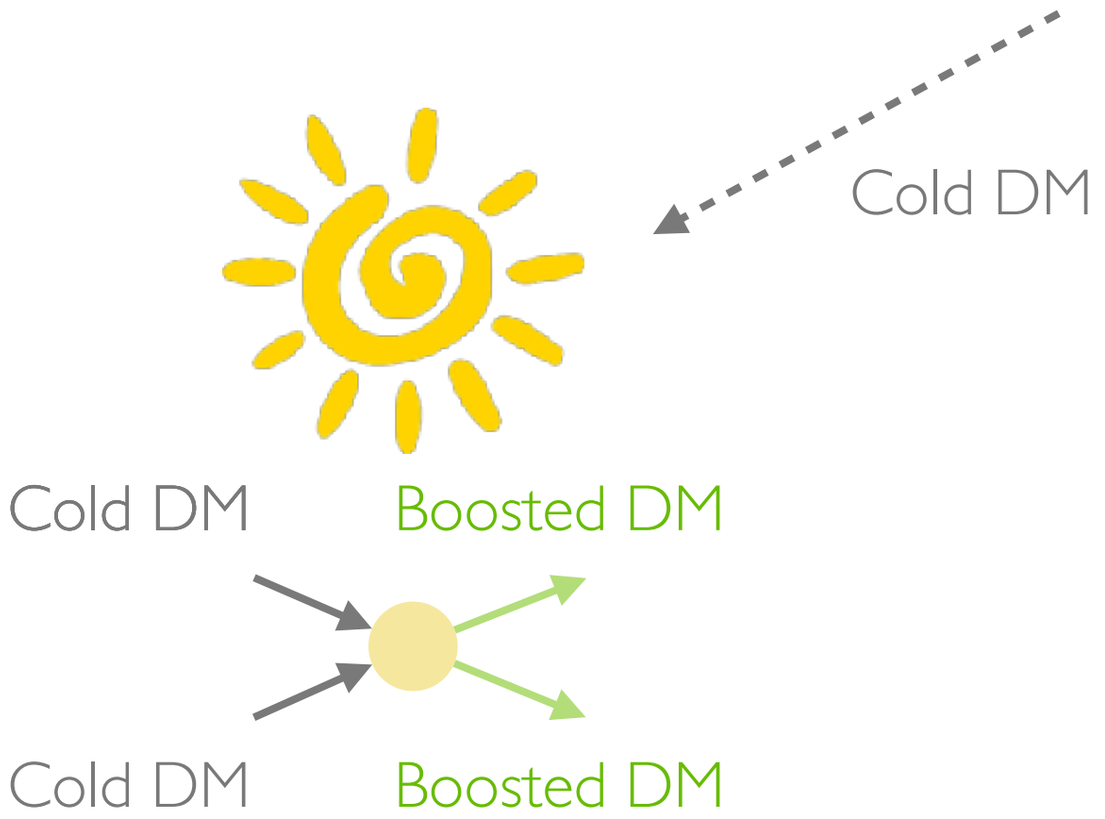
- Dark-matter-induced neutrinos
- Boosted dark matter
- Explosive slow-moving dark matter
- *Your models*

Boosted Dark Matter



1. Cold dark matter captured by dark matter concentrated region, such as the Sun or Galaxy Center

Boosted Dark Matter



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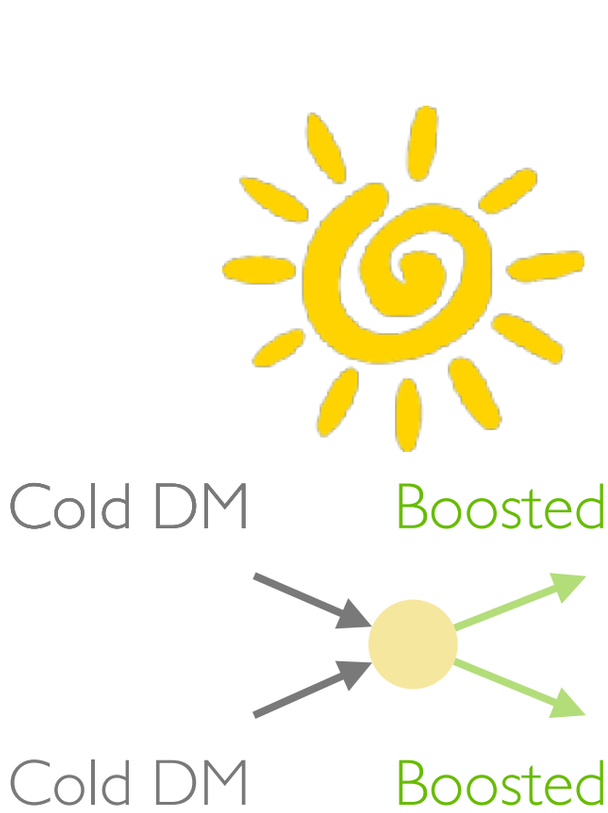
2. Produce lighter, boosted dark matter via annihilation or decay

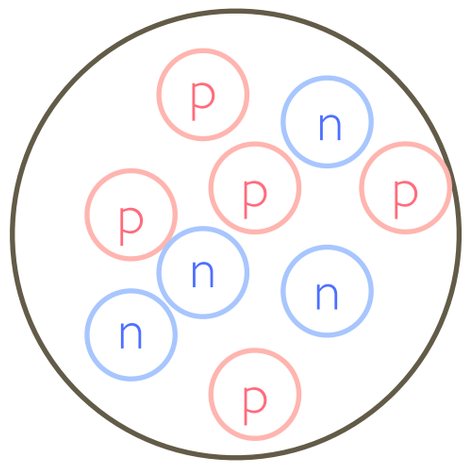
Boosted Dark Matter



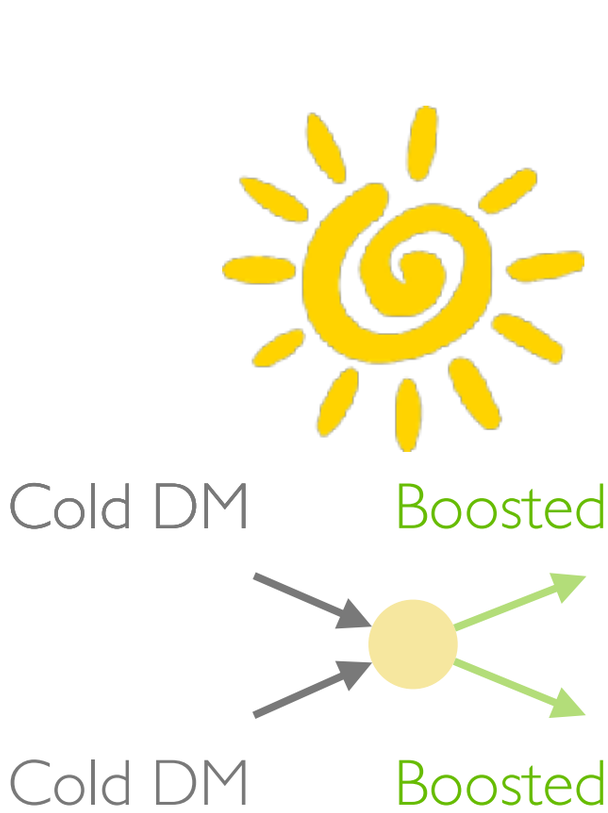
1. Cold dark matter captured by dark matter concentrated region, such as the Sun or Galaxy Center

2. Produce lighter, boosted dark matter via annihilation or decay

3. Boosted dark matter interact with electrons or nucleons in detectors



Boosted Dark Matter



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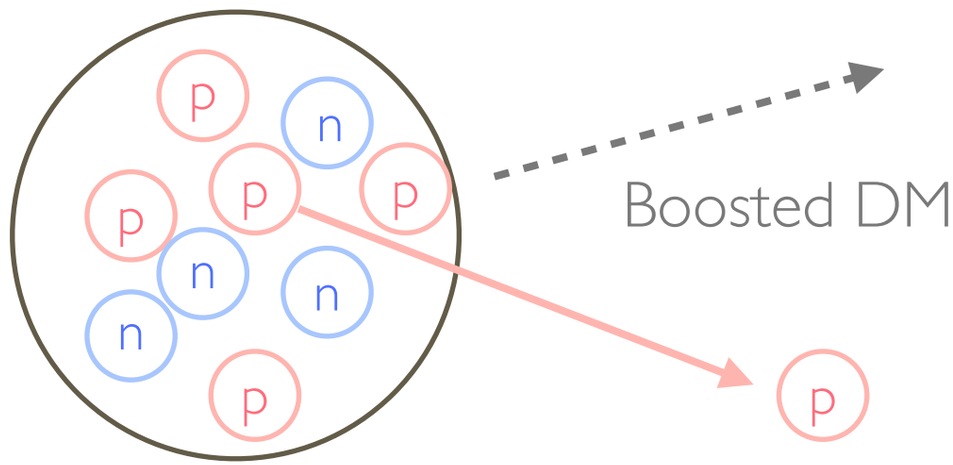
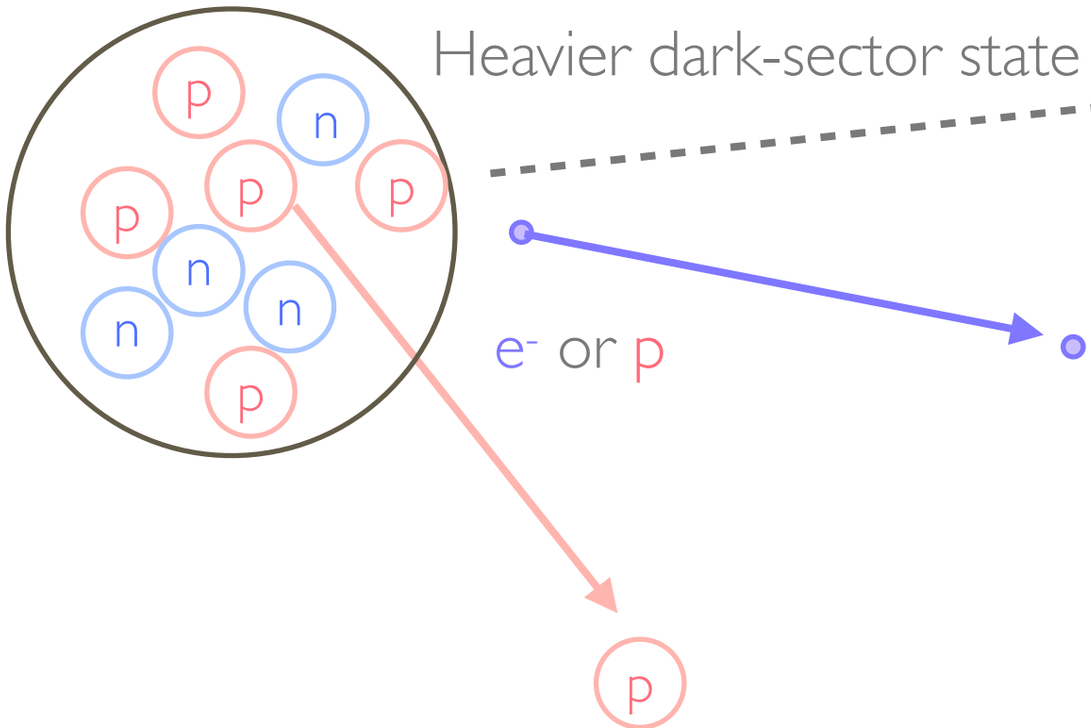


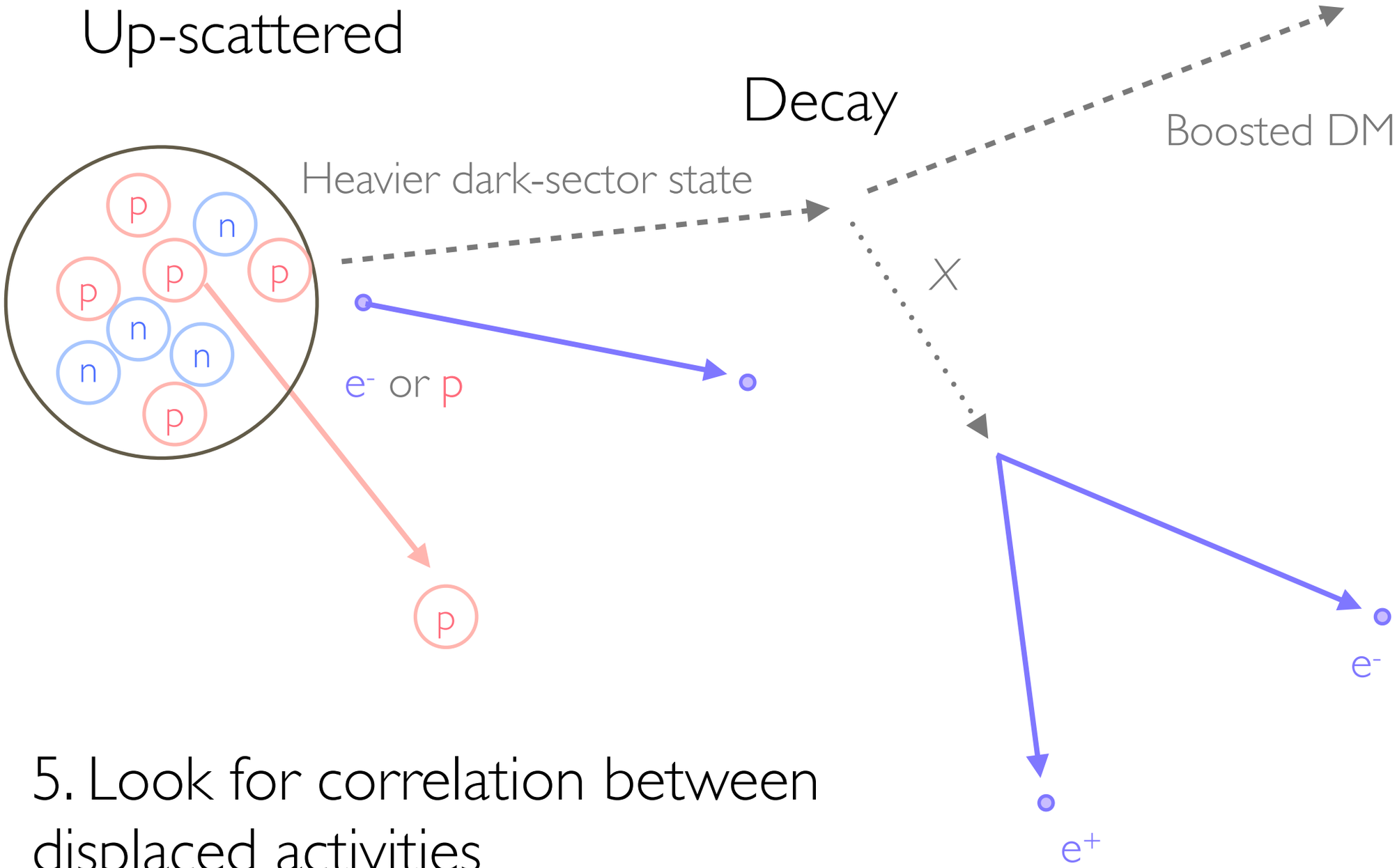
4. Look for scattered electrons or recoil protons

Inelastic Boosted DM

Up-scattered



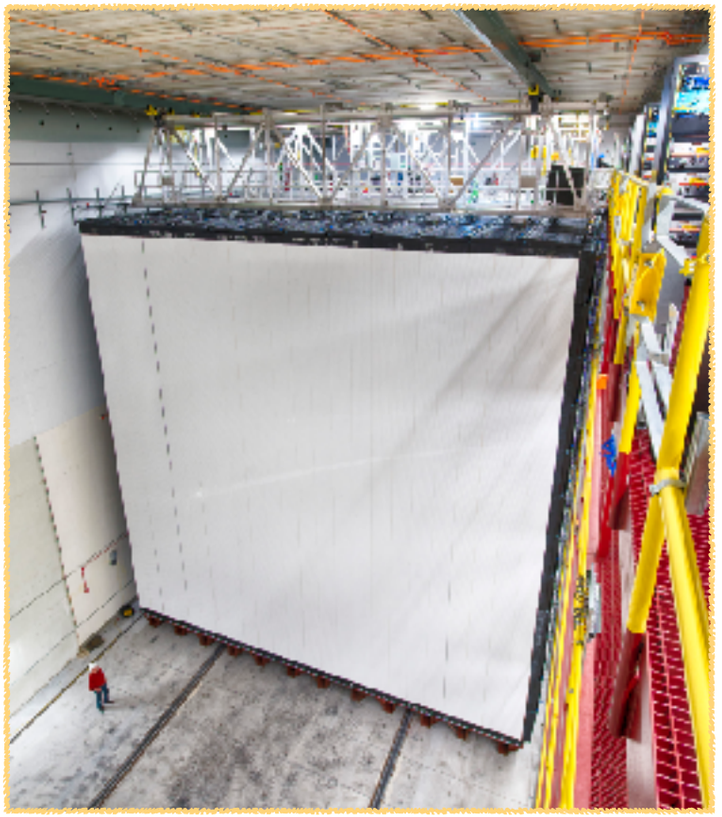
Inelastic Boosted DM



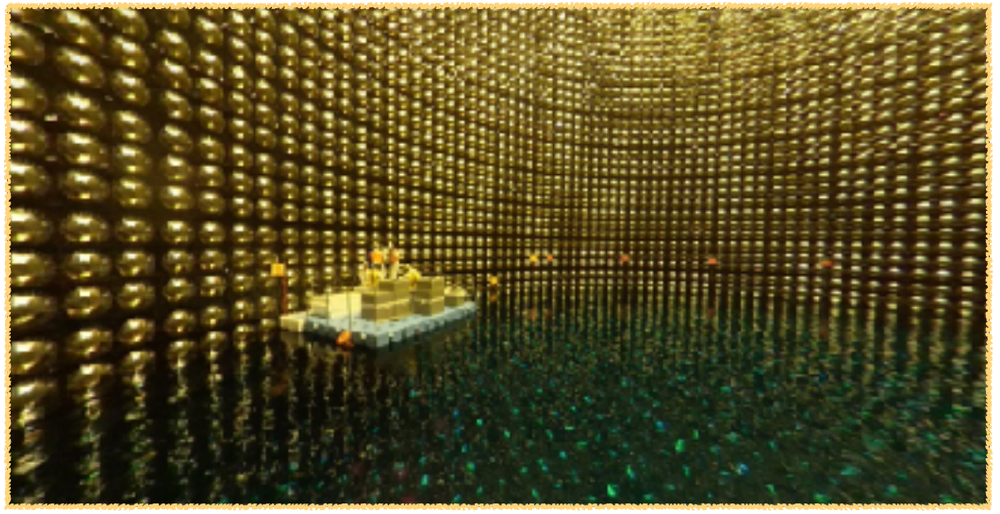
5. Look for correlation between displaced activities

Neutrino Detectors

- Scintillation detectors
  - Large homogeneous: KamLAND, Borexino, SNO+, etc.
  - Segmented: NOvA
  - With Gd: JUNO, Double Chooz, RENO, Day Bay, etc.

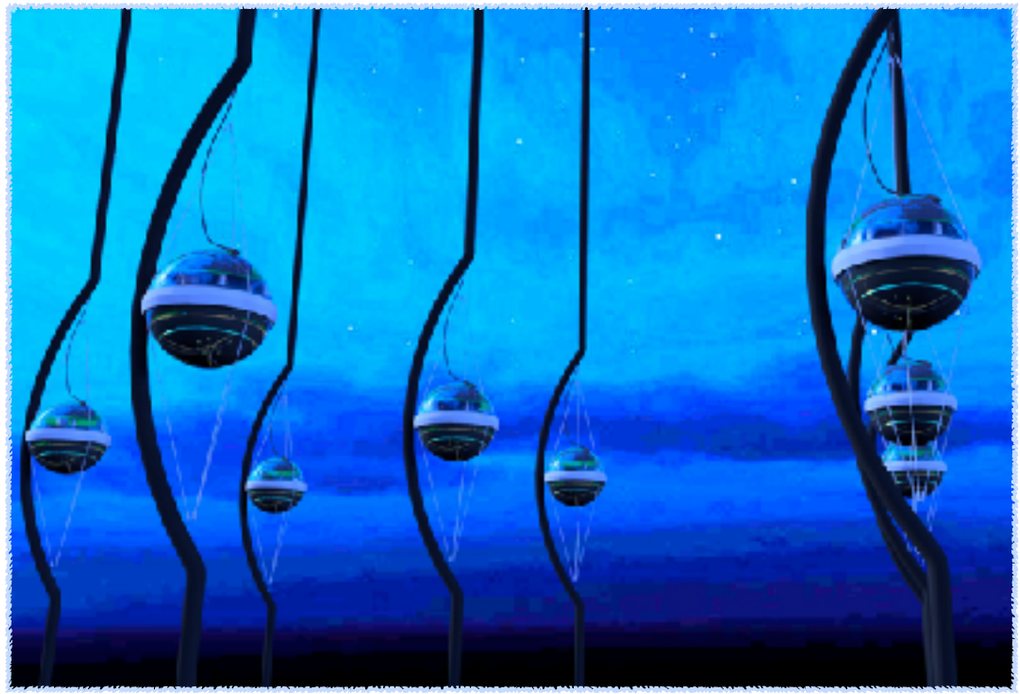


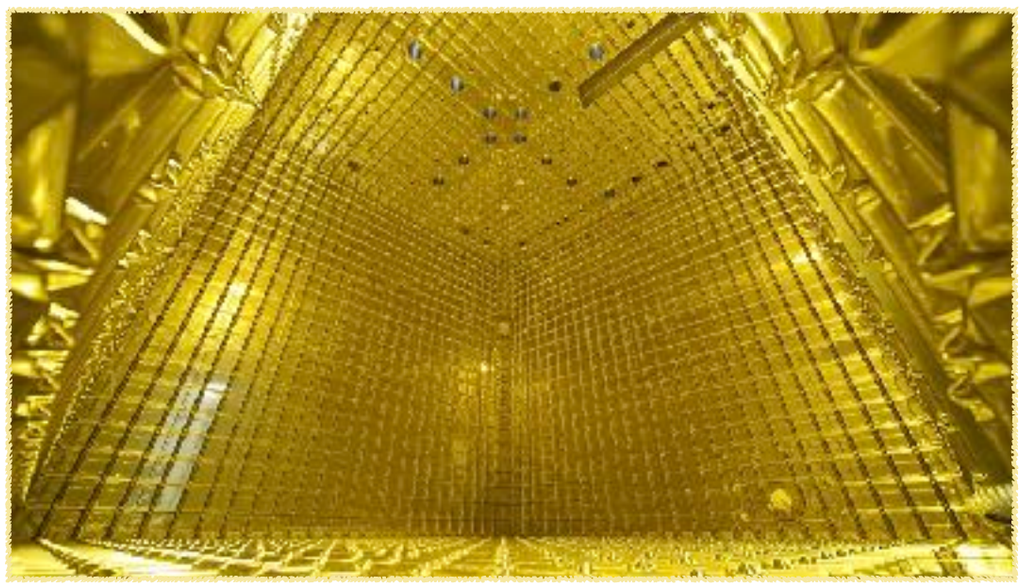
- Water Cherenkov detectors
  - IMB, Super/Hyper-Kamiokande, SNO, etc.
  - With Gd: Super-Kamiokande



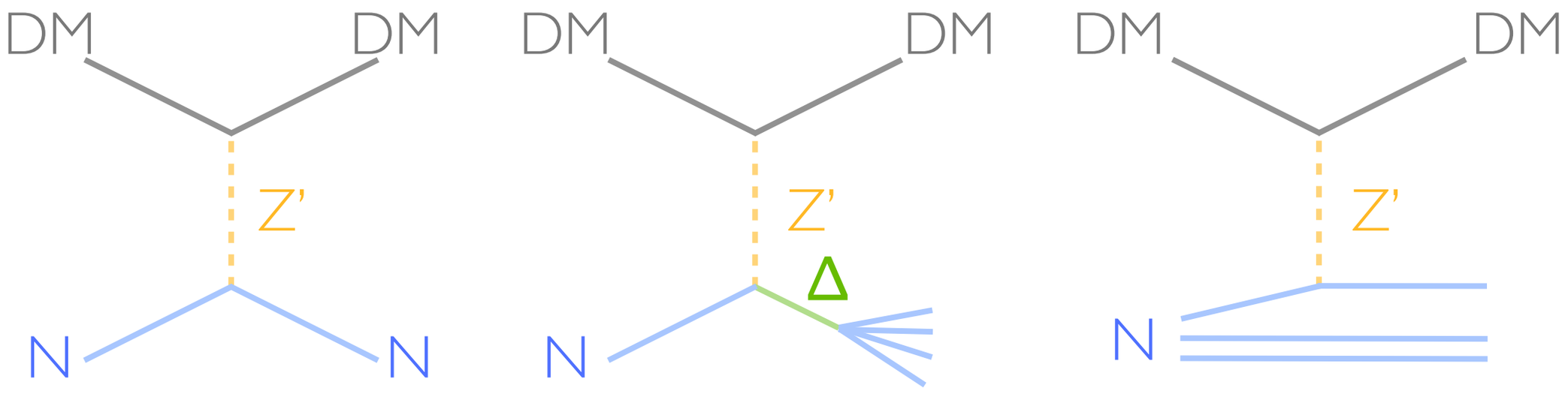
Neutrino Detectors

- Long-string water Cherenkov detectors
  - IceCube, DeepCore, ANTARES, KM3NET, etc.
- Liquid-argon time-projection chambers (LArTPCs)
  - Underground: DUNE
  - Surface: MicroBooNE, ICARUS, SBND, ProtoDUNE





Signal Simulation

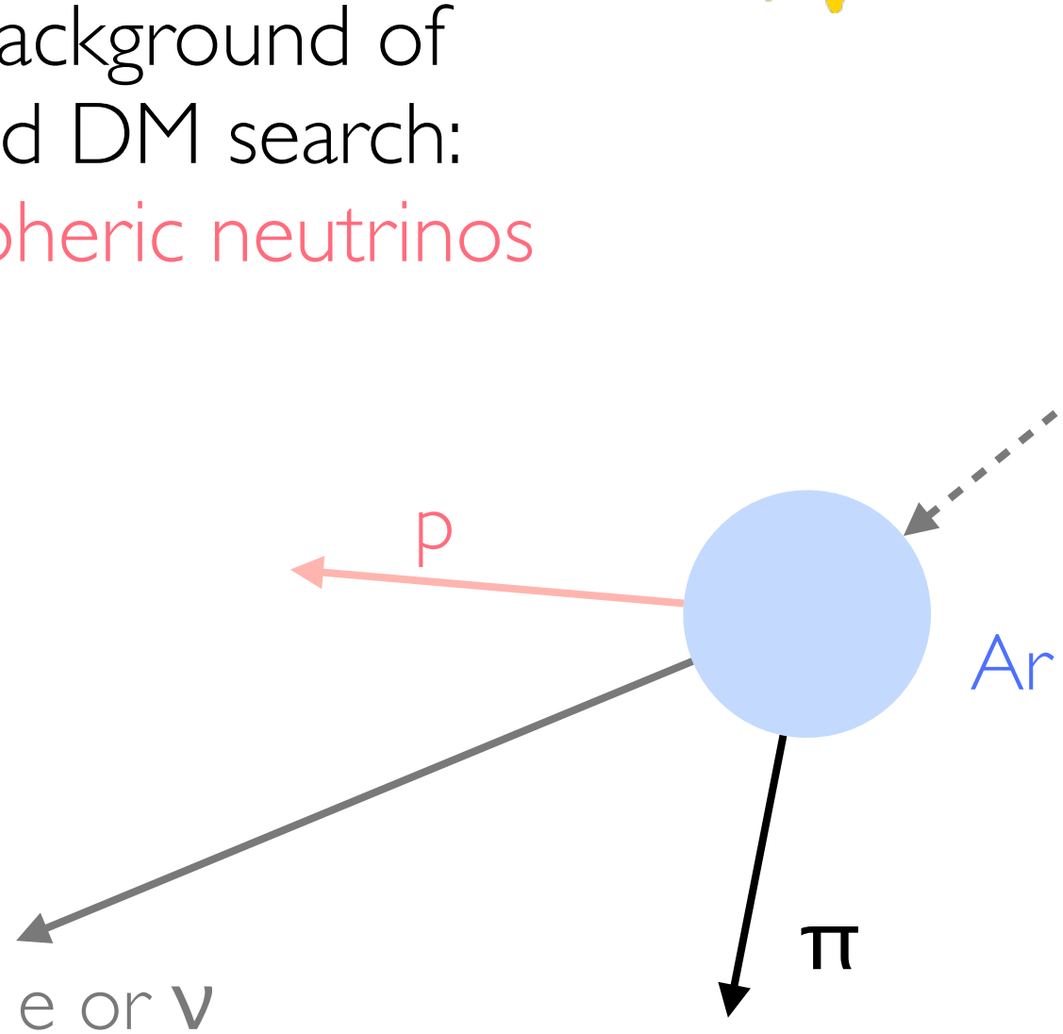


- Electron scattering is easier to model
- Interactions between BSM particles and nucleus are not straightforward
  - Nuclear effects matter (eps. In large nucleus, Ar)
  - Tools exist; a lot of room for improvement

Background

Main background of boosted DM search: atmospheric neutrinos

How do we constrain uncertainties from neutrino fluxes?



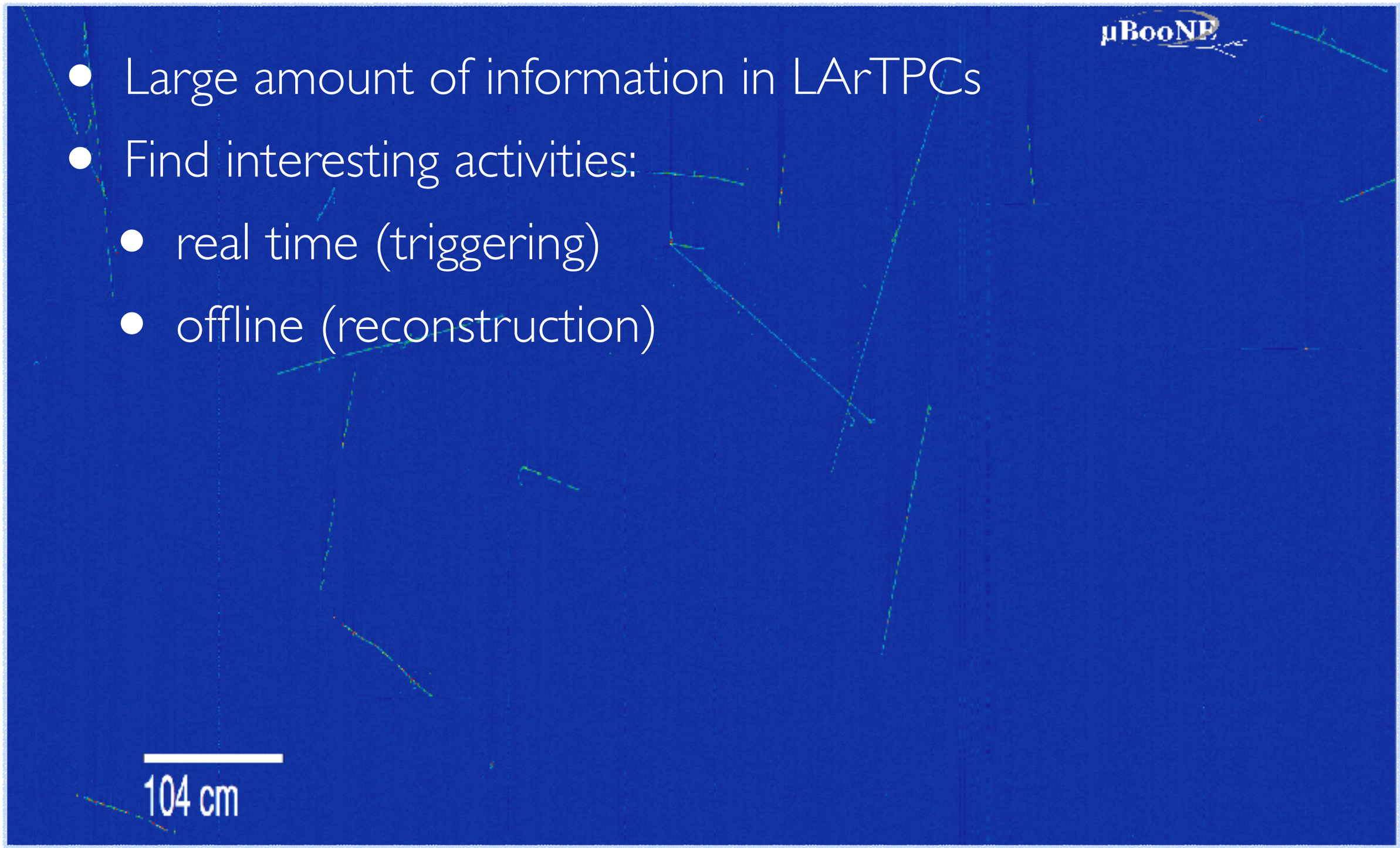
Use pointing features and activities correlation to distinguish signals

Other background sources?

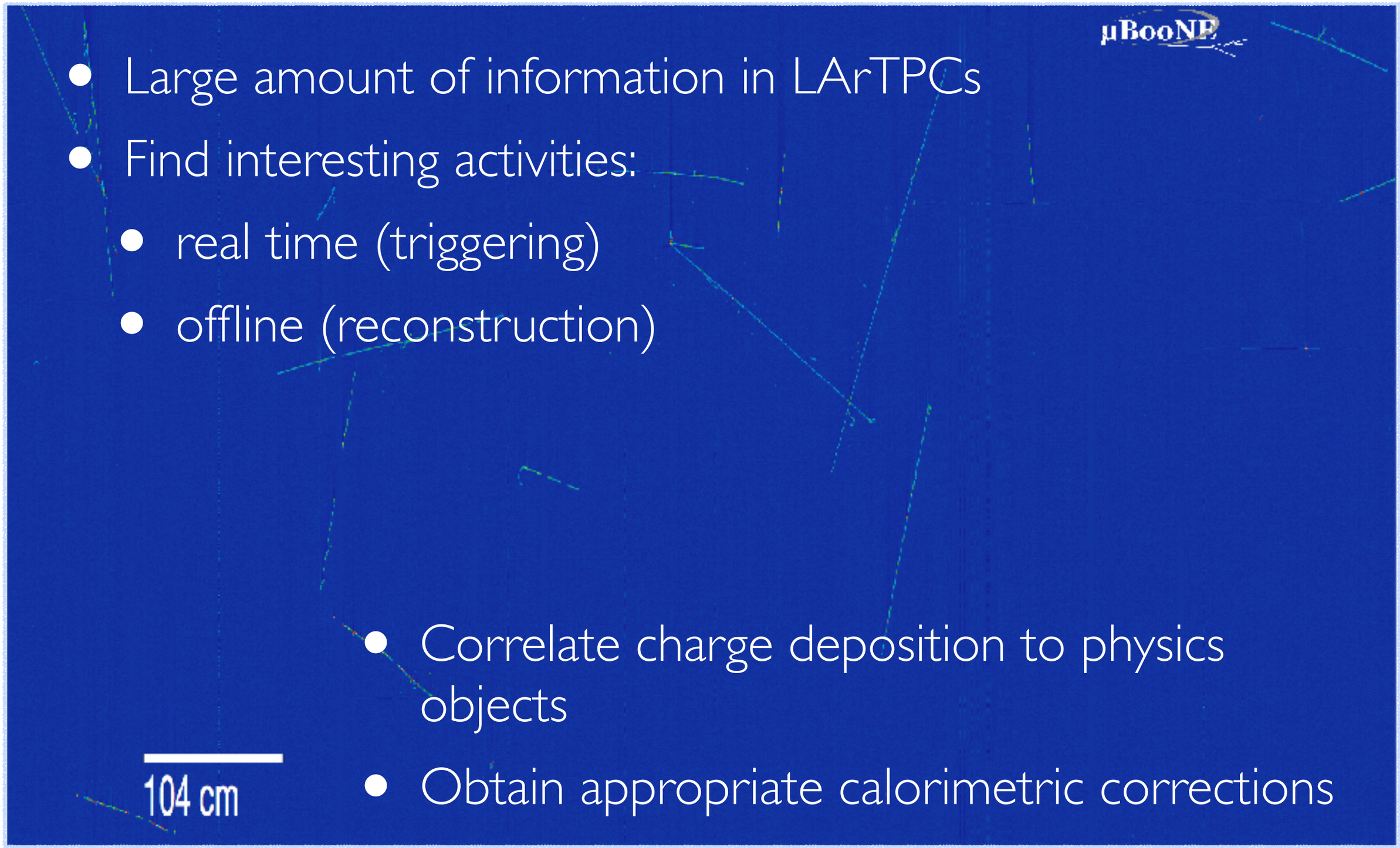
Triggering & Reconstruction

Triggering & Reconstruction

- Large amount of information in LArTPCs
- Find interesting activities:
  - real time (triggering)
  - offline (reconstruction)



Triggering & Reconstruction



- Large amount of information in LArTPCs
- Find interesting activities:
  - real time (triggering)
  - offline (reconstruction)
- Correlate charge deposition to physics objects
- Obtain appropriate calorimetric corrections

Analysis Strategy

- Overall strategy
- On-off methods
- Signal+background fitting
- Time modulation, angular correlation methods
- Background modeling and uncertainty
- Least model-dependent approach

Summary

- New opportunities on probing cosmogenic BSM particles with the operating and future neutrino experiments
- Discuss consistency and complementarity among different detection technologies
- Describe techniques developed for new detection technologies (e.g. LArTPCs)
- Summarize analysis strategies
- Your contributions are welcome!!

White paper

https://www.overleaf.com/read/ksstjhnjjkcx

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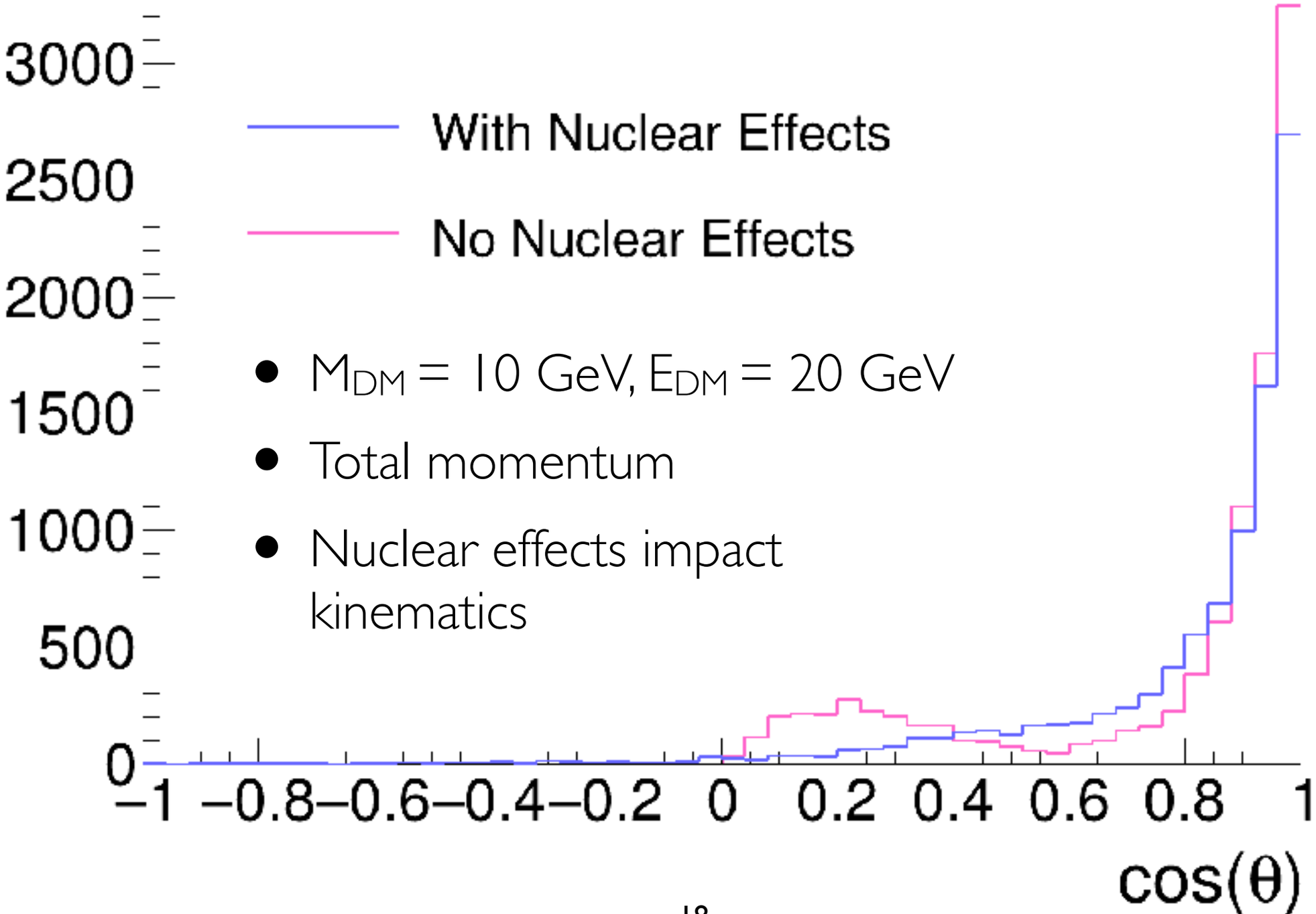
Backup

Nuclear Effects in Argon



- M_{DM} = 10 GeV, E_{DM} = 20 GeV
- Total momentum
- Nuclear effects impact kinematics