



Search for Boosted Dark Matter in DUNE- like Experiments



Yun-Tse Tsai (SLAC)
on behalf of the authors
Snowmass NF03, Oct. 1st 2020

Snowmass2021 - Letter of Interest

Search for Boosted Dark Matter in DUNE-like experiments

NF Topical Groups:

- (NF3) Beyond the Standard Model

CF Topical Groups:

- (CF1) Dark matter: particle-like

TF Topical Groups:

- (TF08) BSM model building
- (TF09) Astro-particle physics & cosmology

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Additional Authors: (Listed after the references)

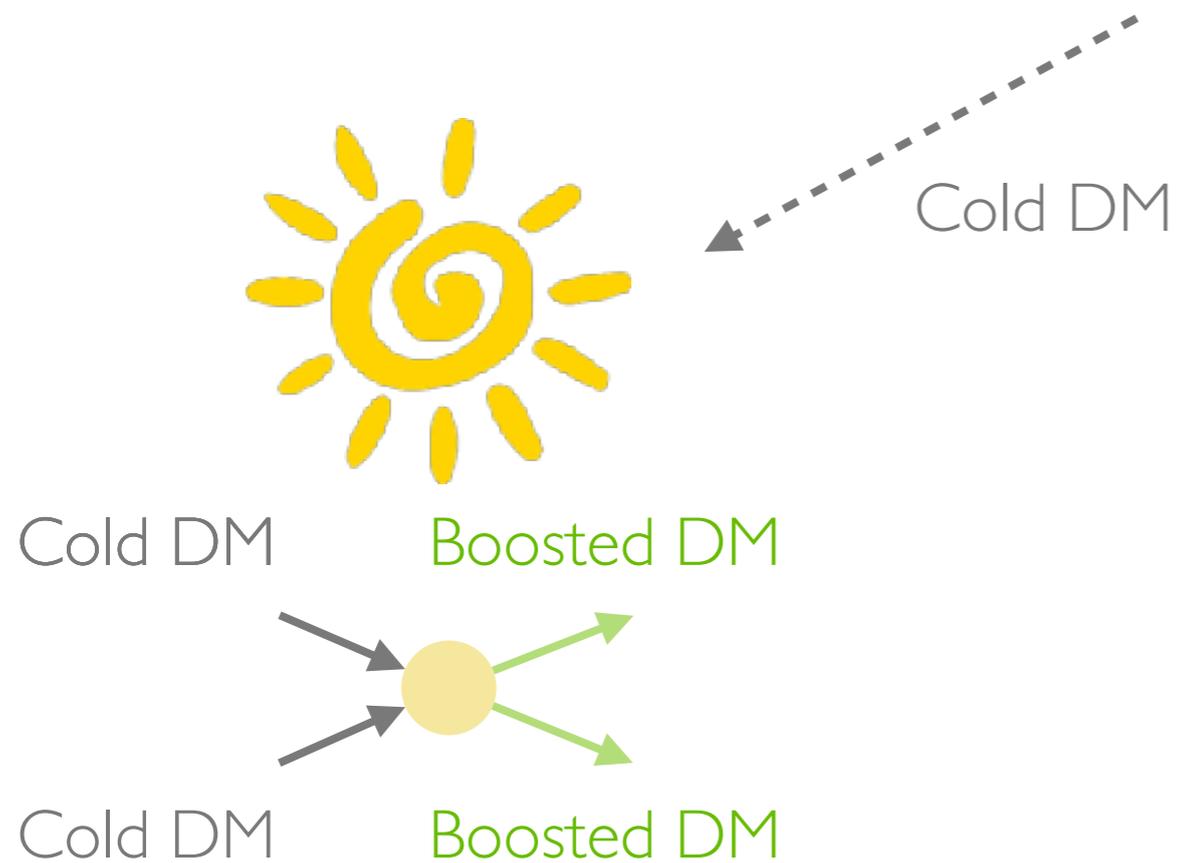
Boosted Dark Matter



Cold DM

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

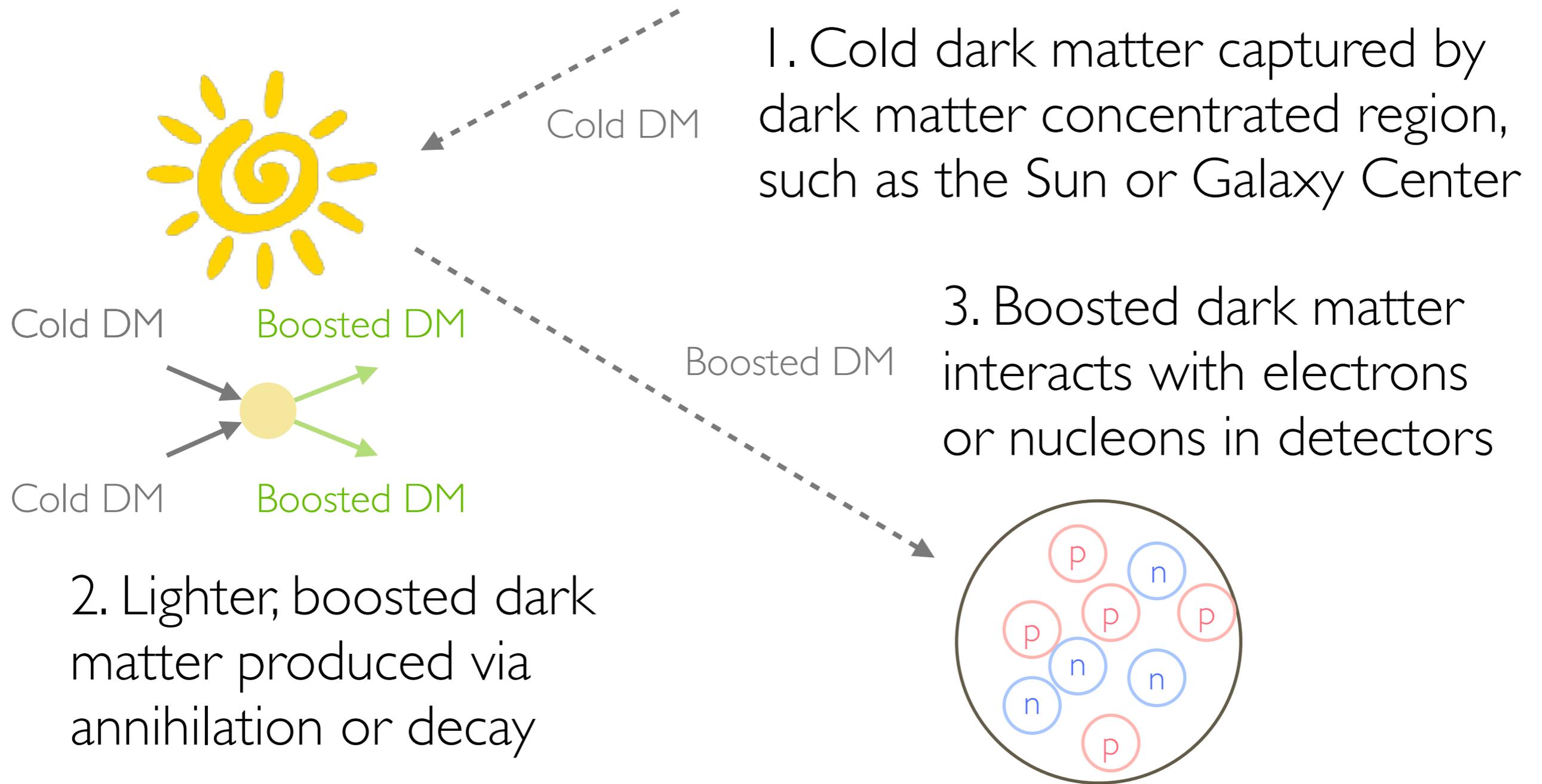
Boosted Dark Matter



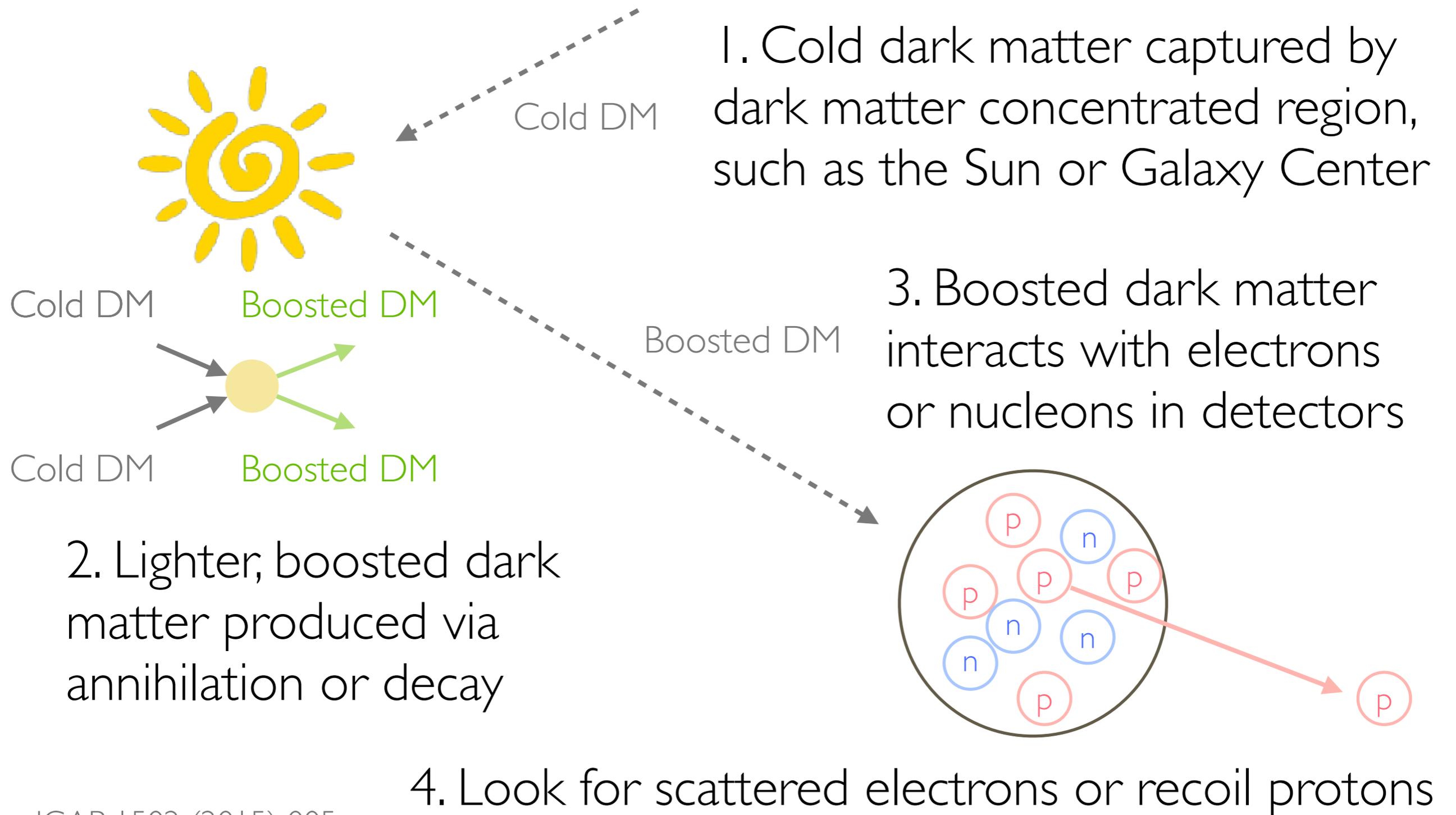
1. Cold dark matter captured by dark matter concentrated region, such as the Sun or Galaxy Center

2. Lighter, boosted dark matter produced via annihilation or decay

Boosted Dark Matter

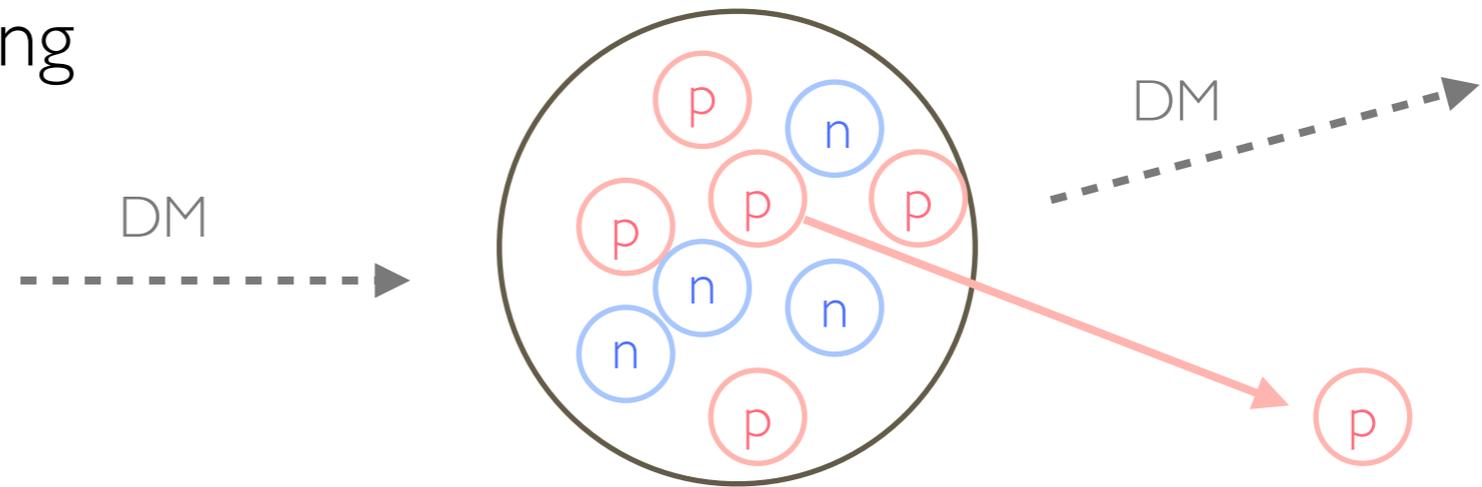


Boosted Dark Matter



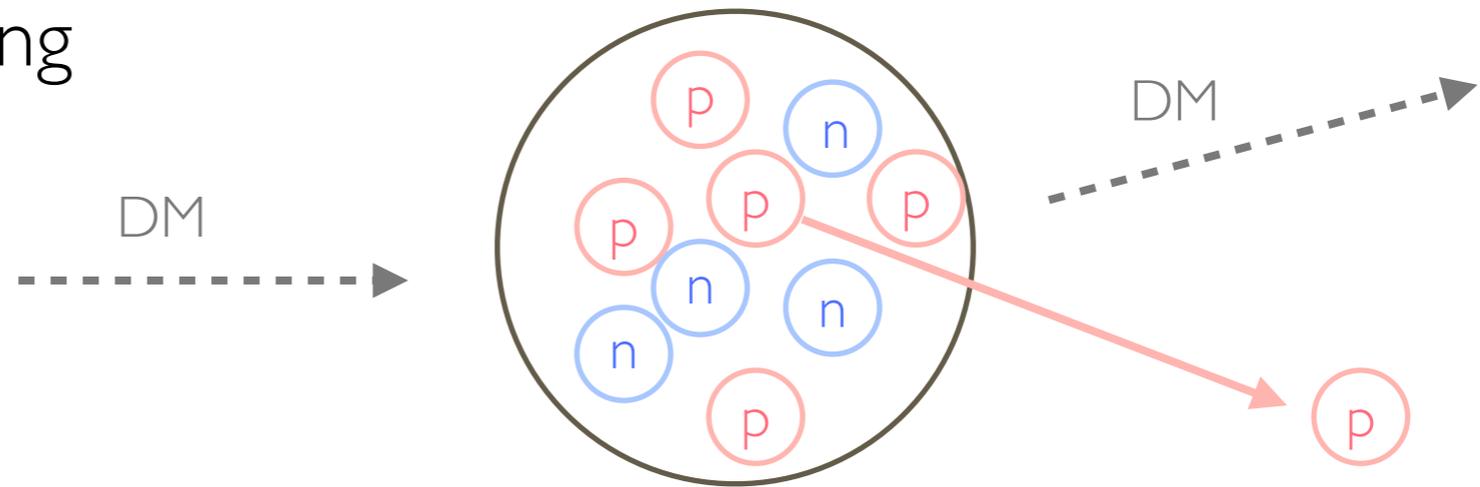
BDM Signatures

- Hadronic scattering
(this talk)

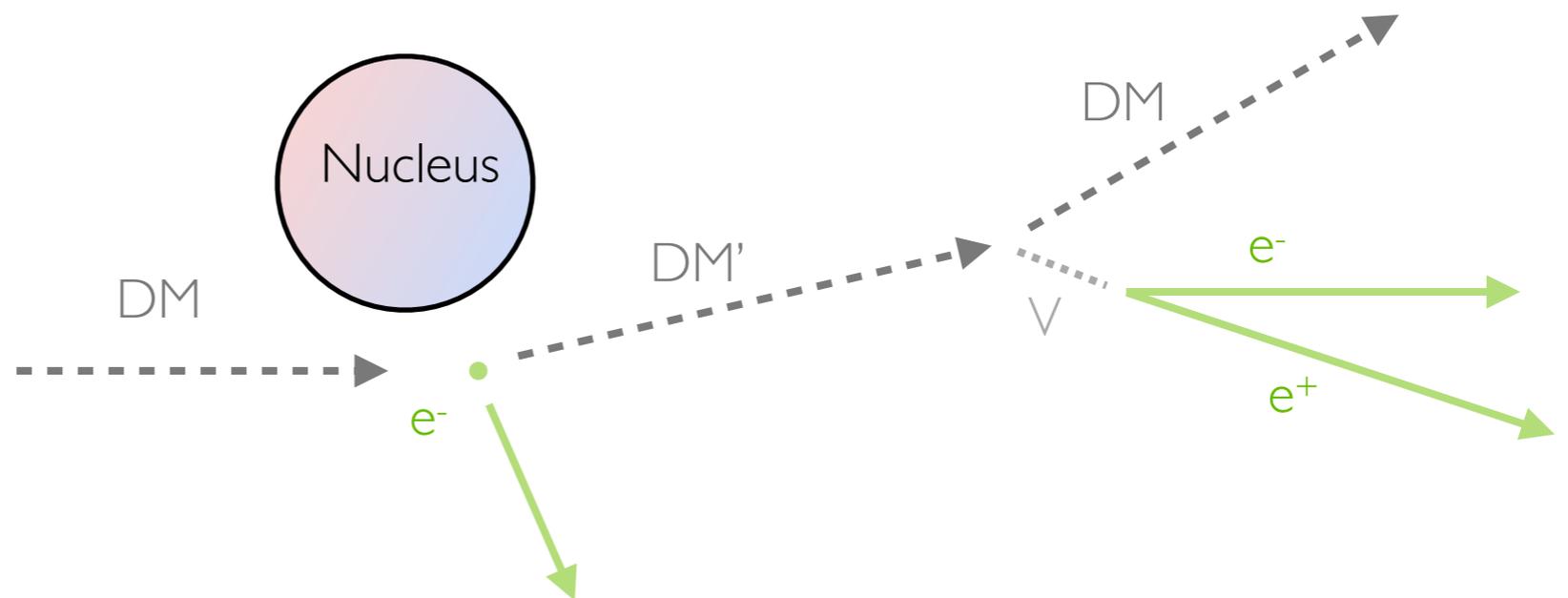


BDM Signatures

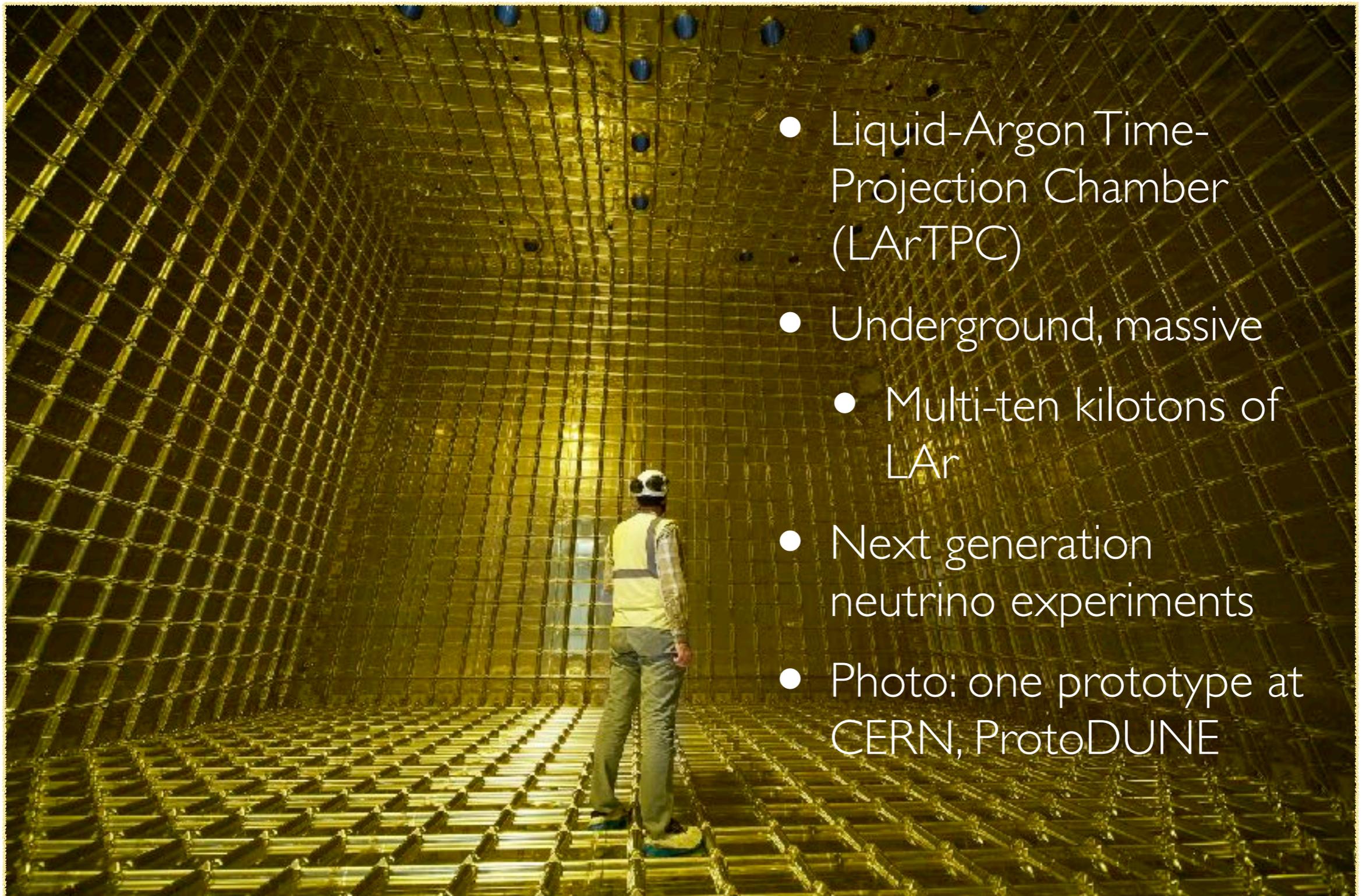
- Hadronic scattering (this talk)



- Inelastic BDM (iBDM, Doojin's talk)



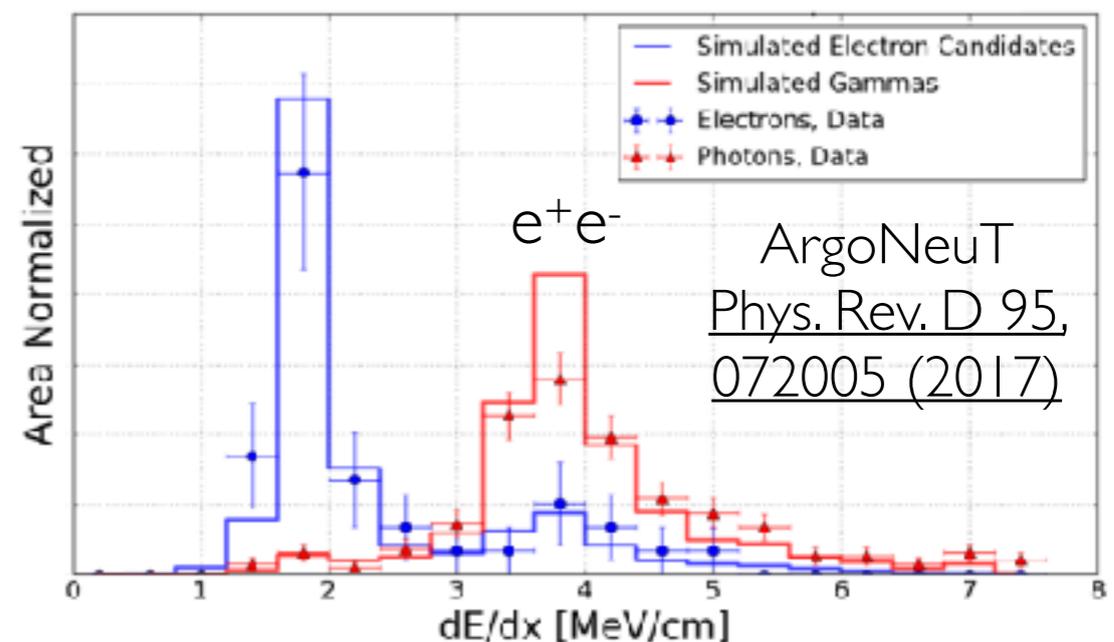
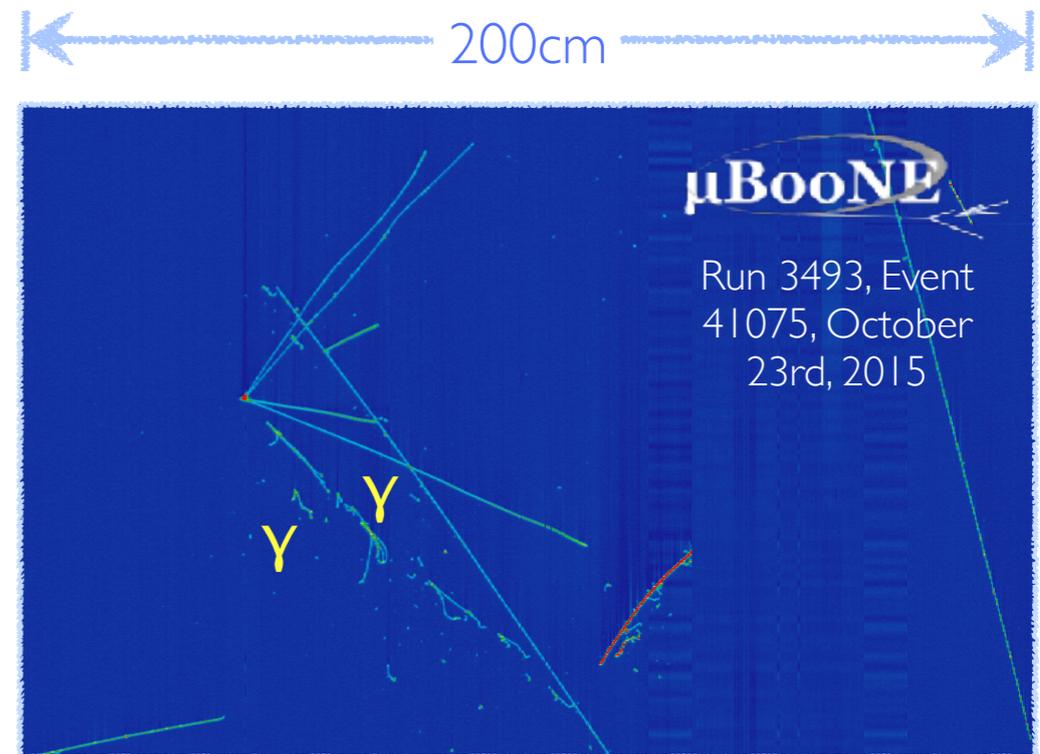
DUNE-like Detector



- Liquid-Argon Time-Projection Chamber (LArTPC)
- Underground, massive
 - Multi-ten kilotons of LAr
- Next generation neutrino experiments
- Photo: one prototype at CERN, ProtoDUNE

Why LArTPC?

- Liquid-Argon Time-Projection Chamber
- LAr: large interaction rate
- Modular and scalable
- Millimeter resolution
- Calorimetric measurement
 - e/γ separation
- Supernova ν_e ($E \sim 10$ MeV)
- Low hadron threshold
- Potential for new physics

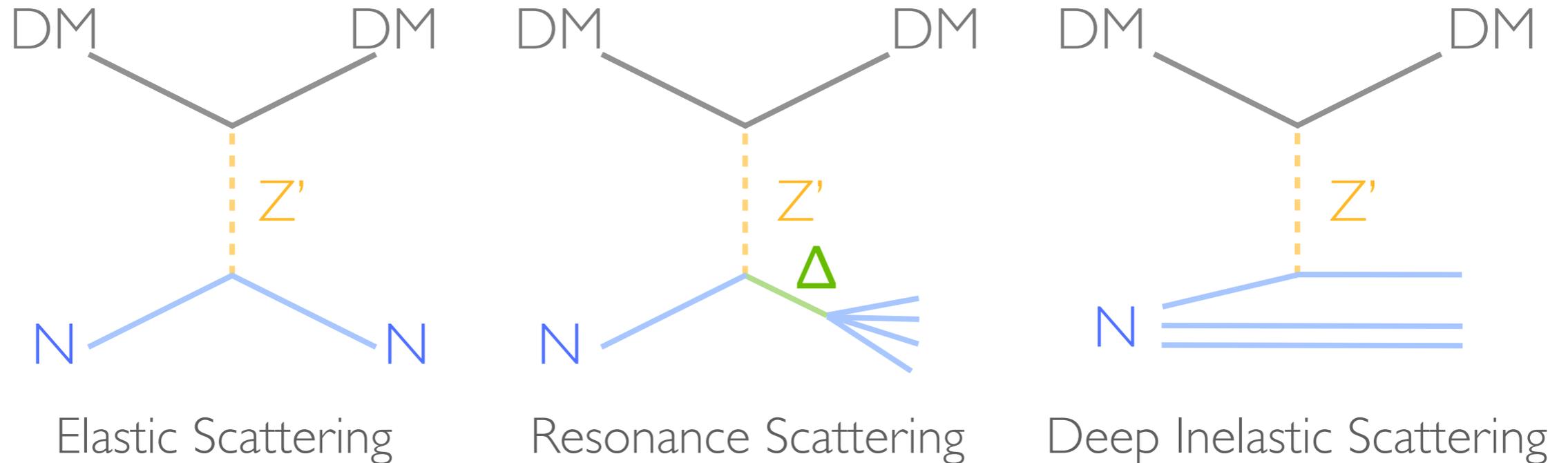


Production



- Focus on boosted DM produced via annihilation in the **Sun**
- Benchmark classification: mono-energetic boosted DM flux ([JCAP 1502 \(2015\) 005](#))
- Energy depends on masses of dark matter

Detection



- DM-SM particle interactions mediated by Z' vector boson (neutral current-like)
- **Hadronic** interactions: better sensitivity in DUNE; complementary to other searches
- MC simulation including nuclear effects from **GENIE**
- Probe $g_{Z'}$, the **(DM- Z' , Z' -SM) coupling constants**

Main Background

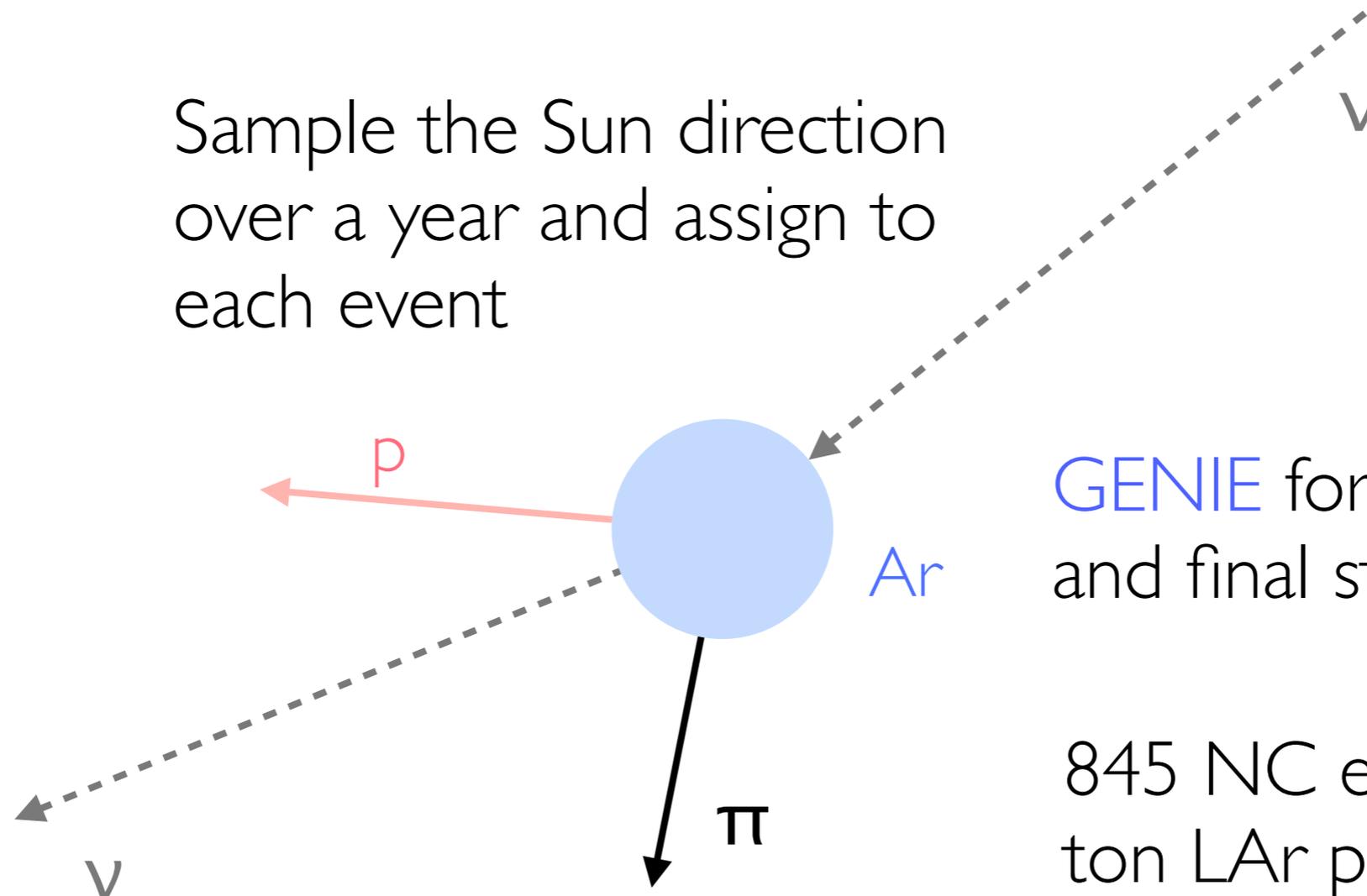
Main background events:
neutral-current (NC)
atmospheric neutrinos



Bartol

maximum+minimum
flux: ν_e , ν_μ , $\bar{\nu}_e$, $\bar{\nu}_\mu$

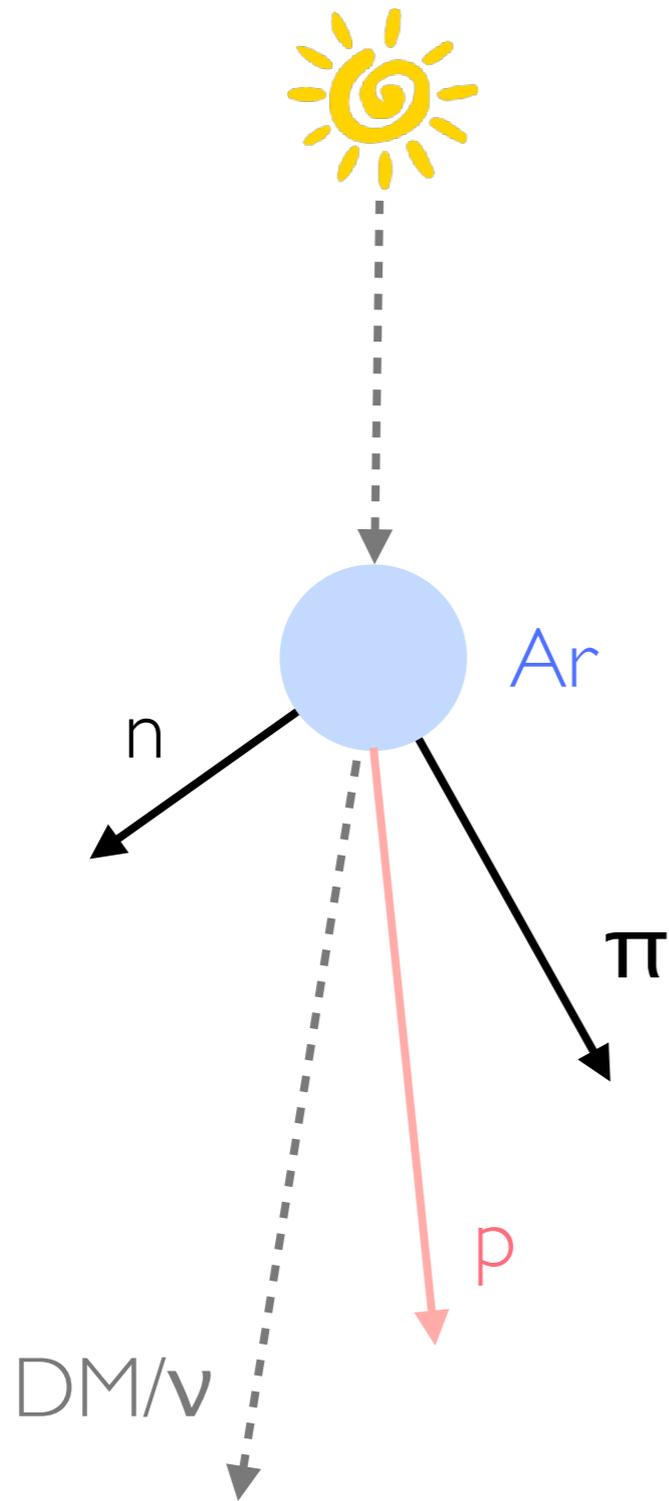
Sample the Sun direction
over a year and assign to
each event



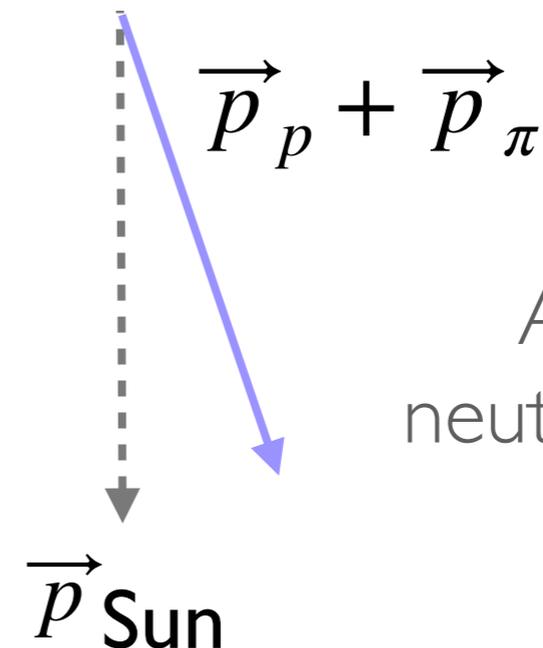
GENIE for neutrino-Ar
and final state interactions

845 NC events in 10k
ton LAr per year

Single Variate Analysis

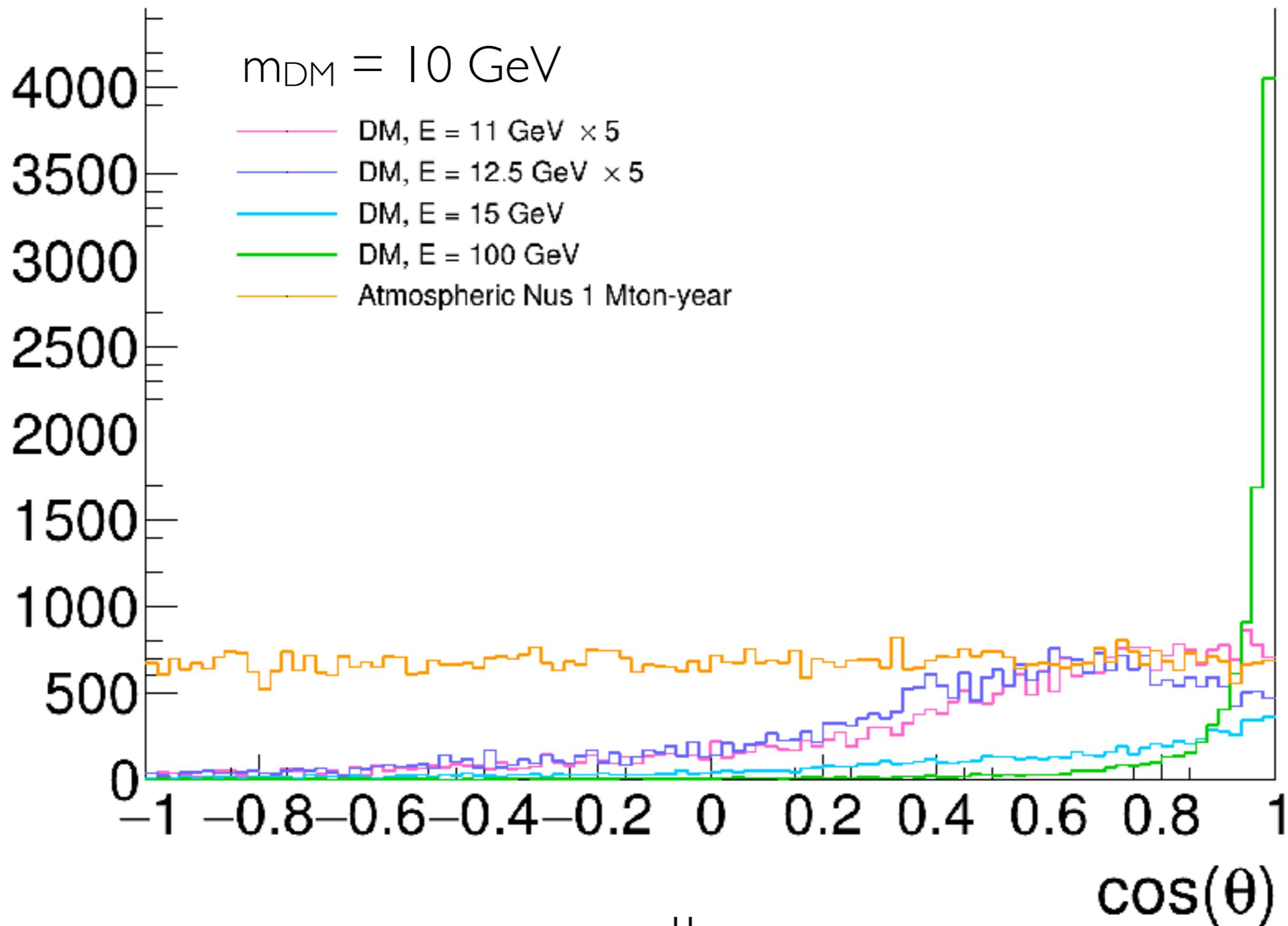


Angle (θ) between the Sun direction and the total momentum of all the visible particles in the detector, taking into account the detector resolution, threshold



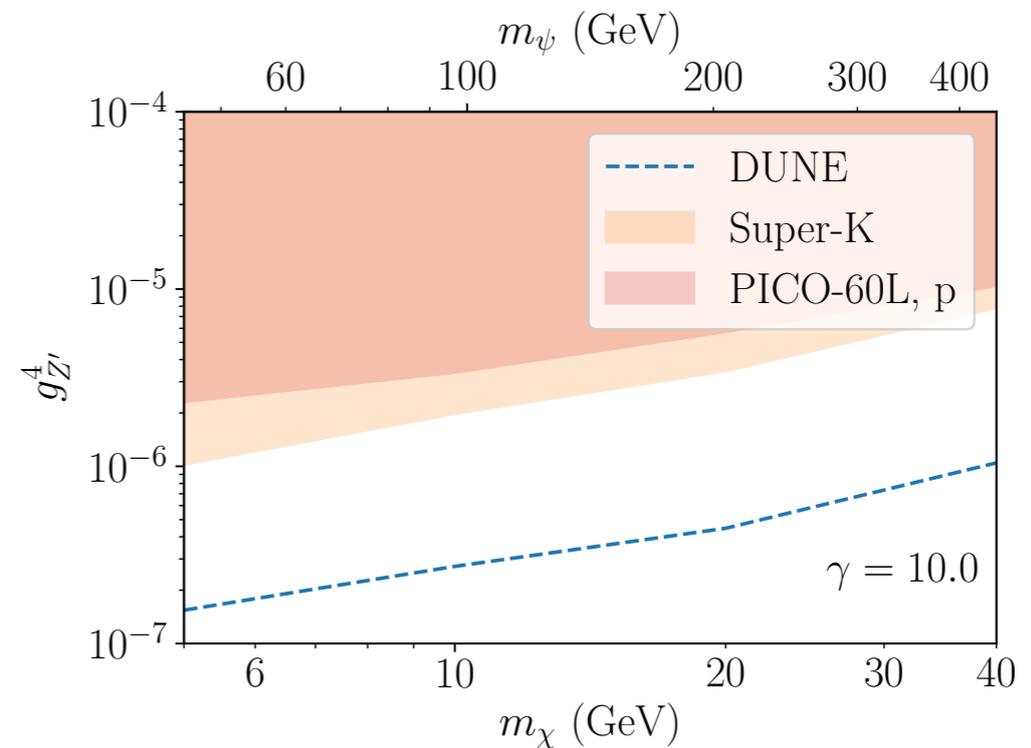
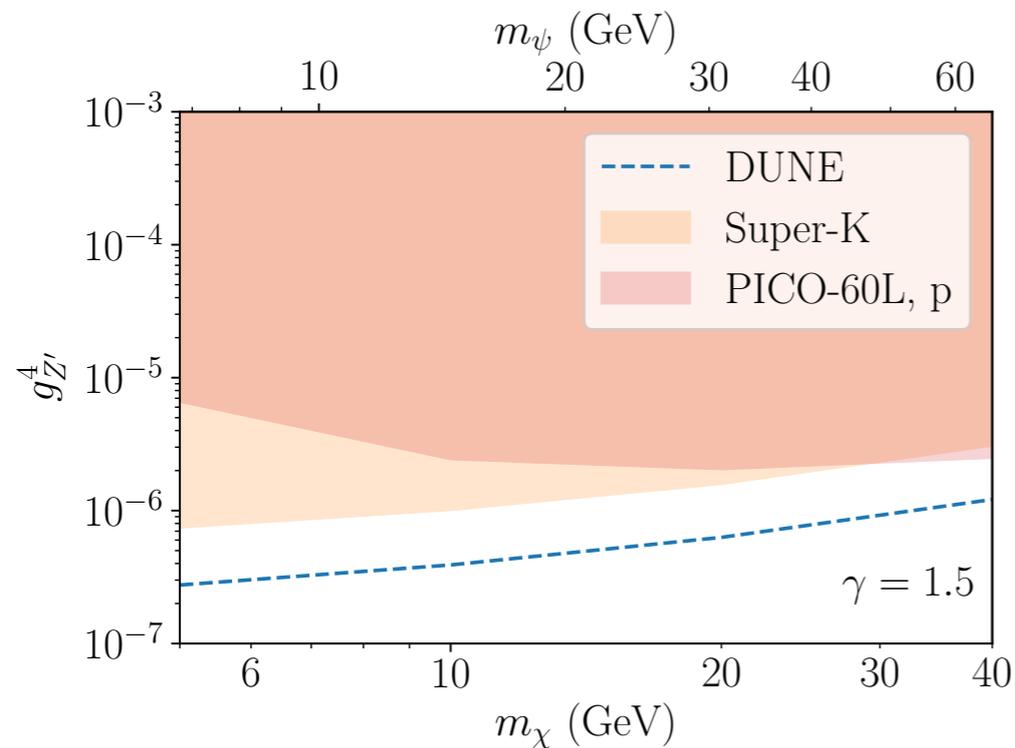
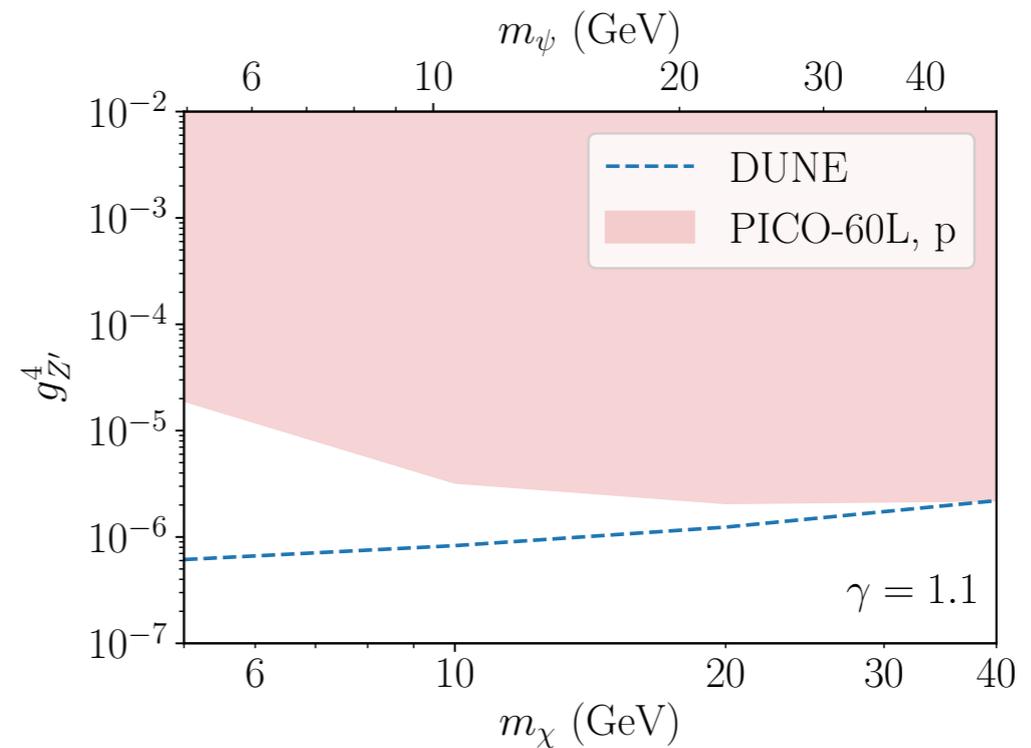
Assume no neutron detection

Angular Distribution



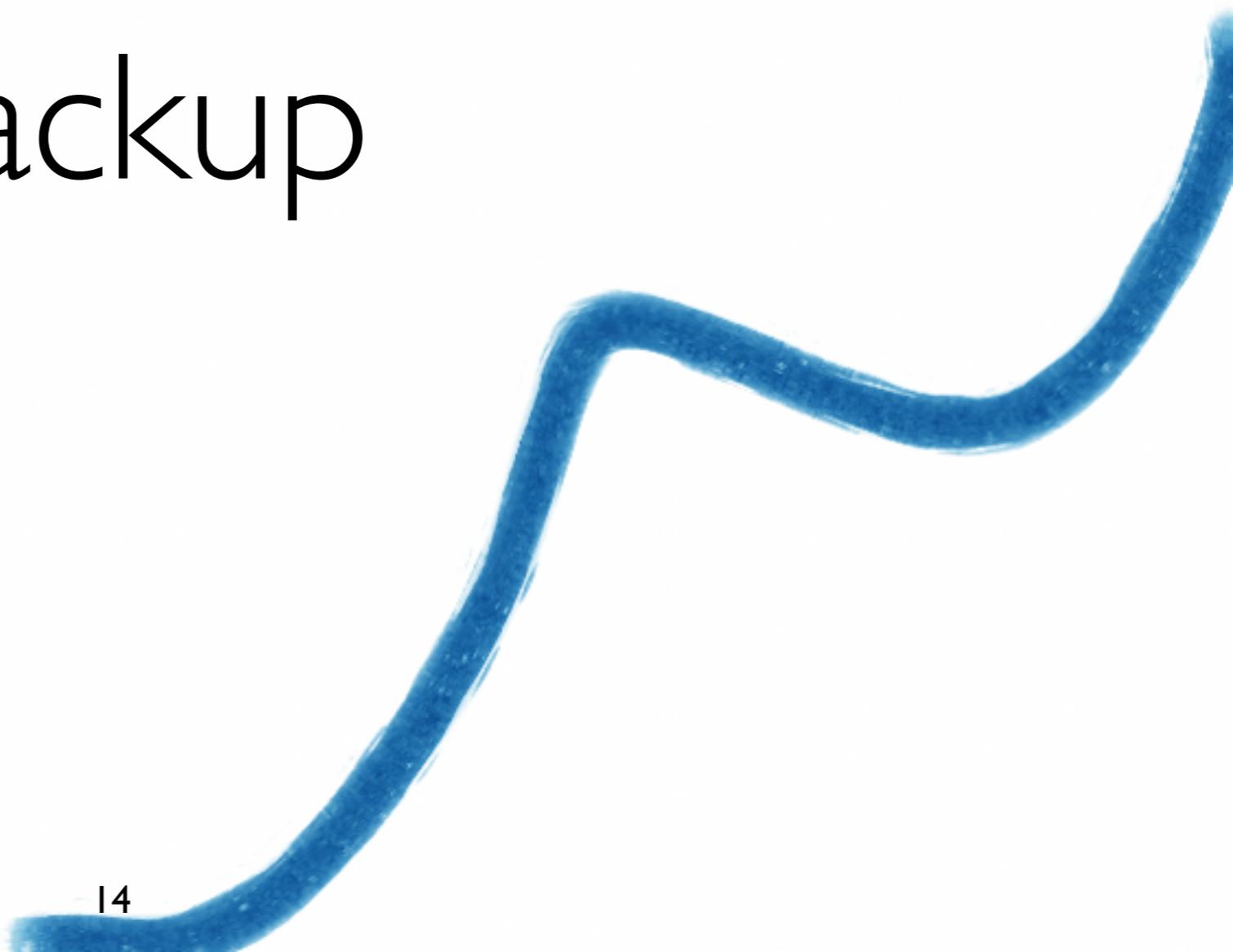
Sensitivity

- **DUNE** 10 years and 40k tons
- **Super-Kamiokande** 6 years and 22.5k ton fiducial volume, Phys. Rev. D 79, 112010 (2009)
- **PICO** Phys. Rev. Lett. 118, 251301 (2017)



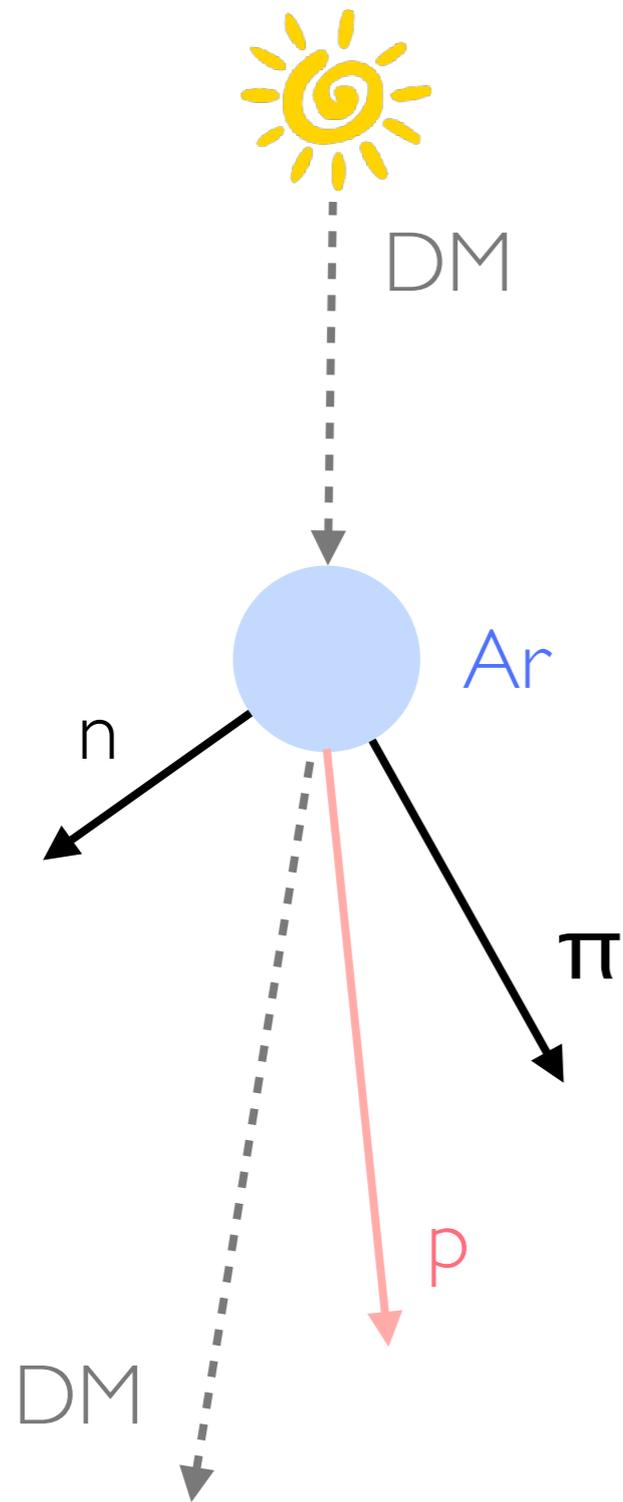
Summary

- Search for **boosted dark matter** in underground, massive **LArTPC** neutrino detectors
- **Complementary** to direct detection of dark matter and to other neutrino experiments
- Can **determine the properties** of a BDM model by combining all the results
- Broadens the physics program in neutrino experiments



Backup

Boosted DM Signal



- **Mono-energetic** boosted DM flux encodes the Sun direction with respect to DUNE over a year
- DM-nucleon interaction cross section calculated by J. Berger
- **GENIE** simulates the final state interactions
 - GENIE default FSI model: HAlntranuke model
- Probe the (DM- Z' , Z' -SM) coupling constants (gz')