LDM without the Target at DUNE

TEXAS A&M UNIVERSITY
Physics & Astronomy

Doojin Kim

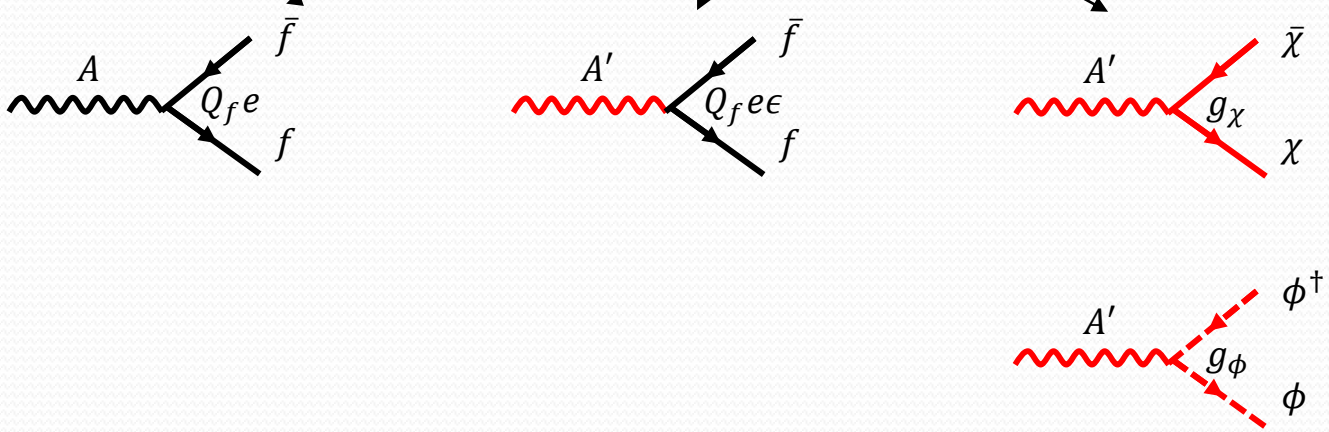
DUNE BSM Group Meeting

March 2nd, 2021

In collaboration with V. Brdar, B. Dutta, W. Jang, I. Shoemaker, Z. Tabrizi, A. Thompson, and J. Yu

Benchmark Model

$$\mathcal{L} \supset -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} - \frac{1}{4}F'_{\mu\nu}F'^{\mu\nu} + \frac{1}{2}m_{A'}^2 A'_\mu A'^\mu + eA_\mu J^\mu_{\rm EM} + \epsilon e A'_\mu J^\mu_{\rm EM} + g_\chi A'_\mu J^\mu_D + \mathcal{O}(\epsilon^2)$$

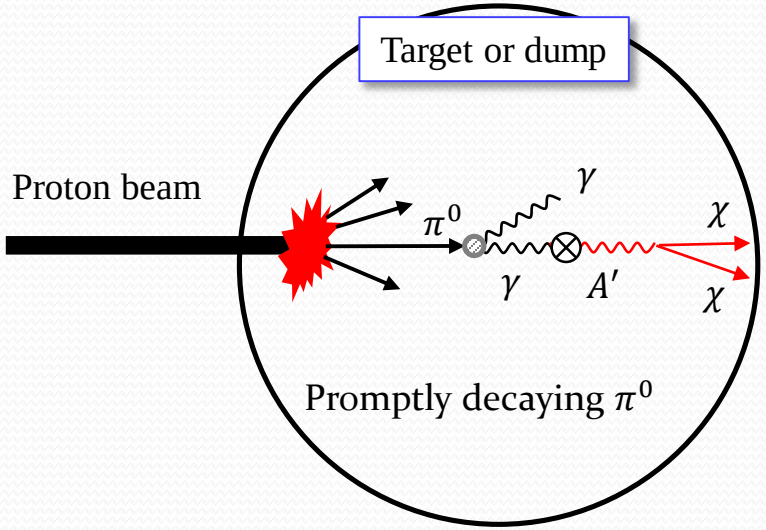


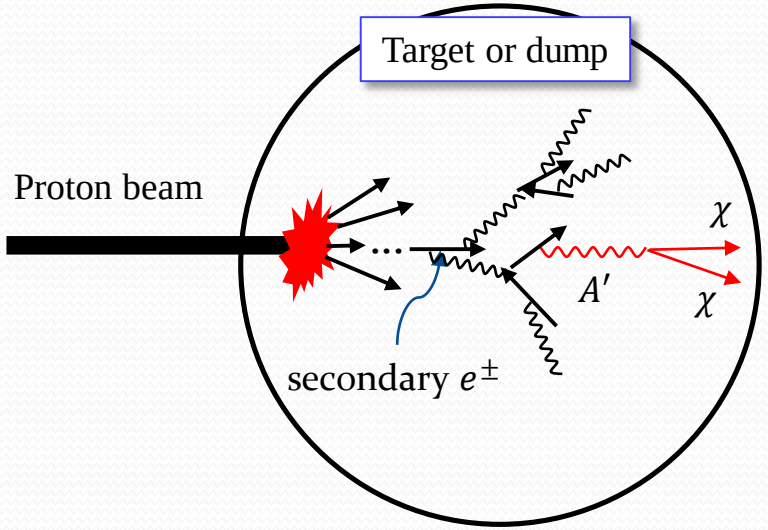
Fermionic DM

Scalar DM

- Production of dark matter can begin with photon, and photon → dark photon → dark matter:

Dark Matter Production



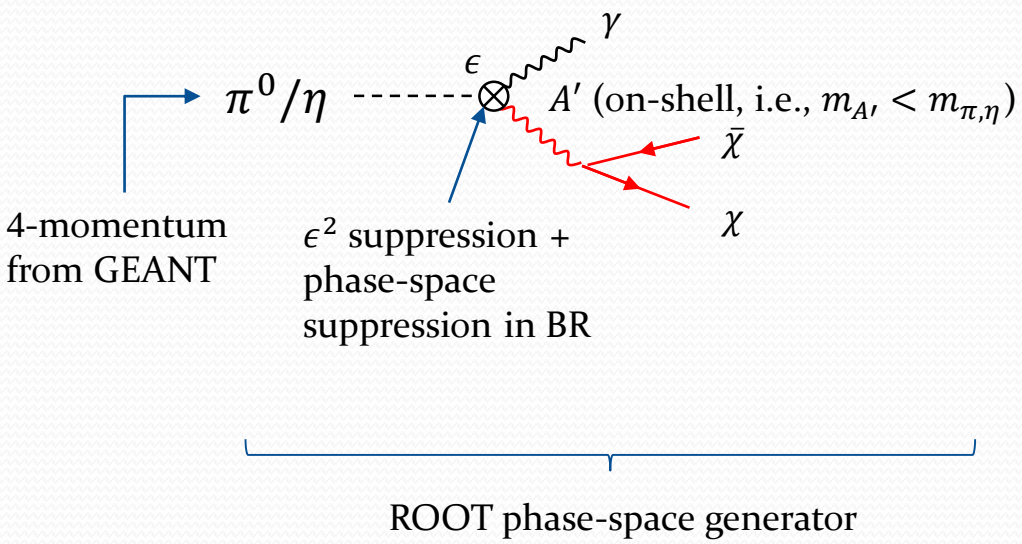


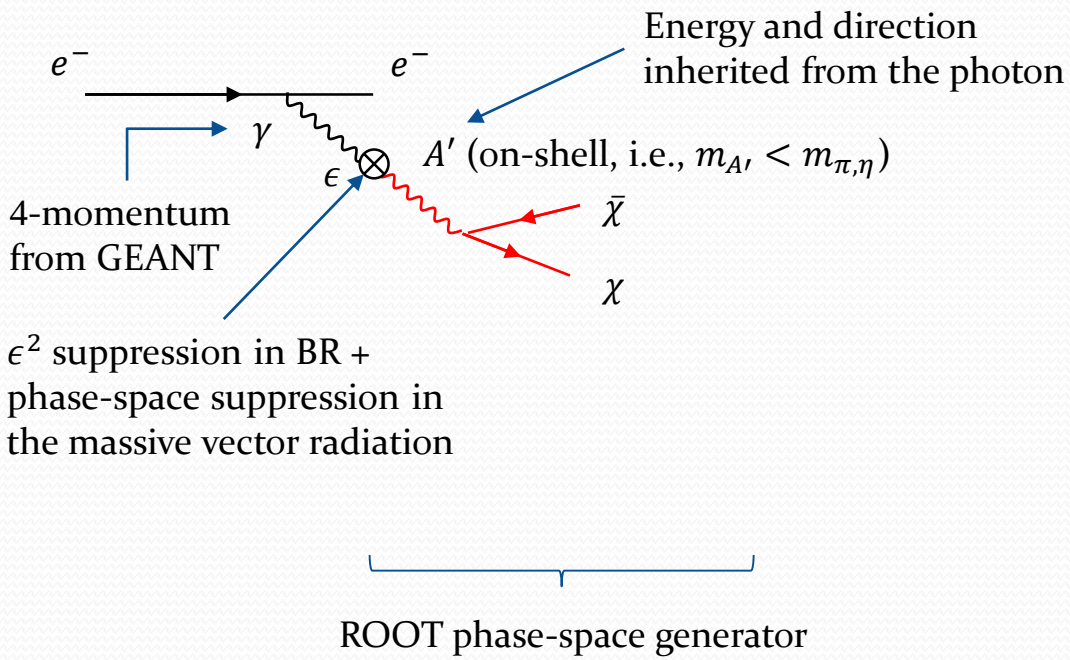
$\pi^0 \to \gamma + A'$ $\quad$ $A' \to \chi + \chi$

$e^{\pm *} \to e^{\pm} + A'$ $\quad$ $A' \to \chi + \chi$

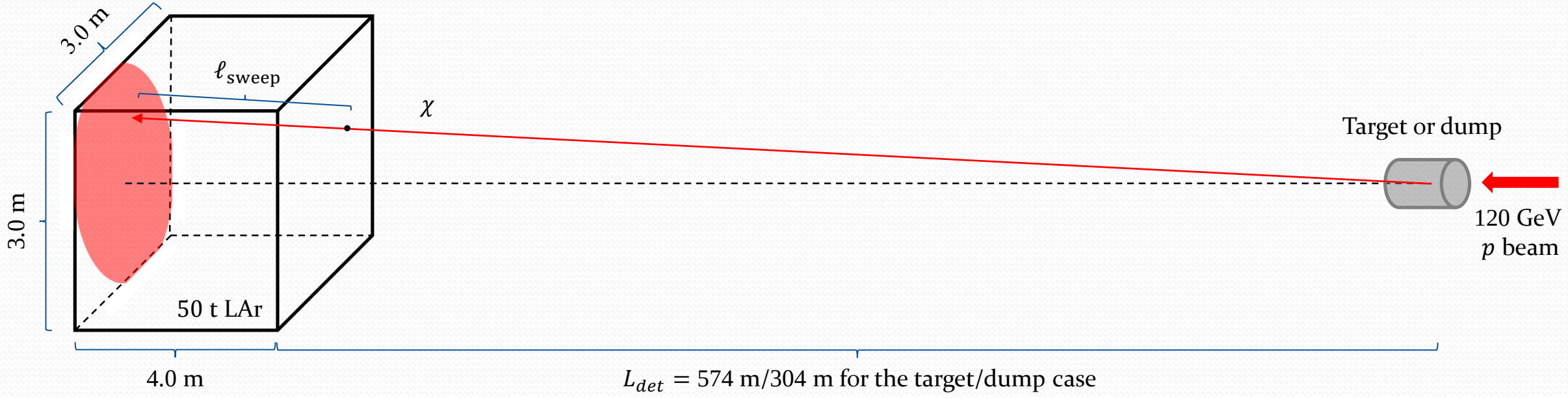
Full photon spectra at the target and the dump simulated with GEANT!

Simulation of LDM Production





Event Rate Calculation



- For a given set of dark matter particles getting through the detector

~400 cm

# of electrons per atom

$$R = \sum_{\text{all accepted } \chi} n_T \, \sigma_\chi \, \ell_{\text{sweep}}$$

$$\sigma_\chi = \int_{E_{r,e}^{th}}^{E_{r,N}^{\max}} dE_{r,e} \, \frac{(\epsilon e)^2 \alpha_D Z \, m_e^2}{\pi \lambda(s, m_e^2, m_\chi^2) \left\{2m_e(m_e - E_{r,e}) - m_V^2\right\}^2} \times \left[m_e \left\{E_\chi^2 + (m_e + E_\chi - E_{r,e})^2\right\} + (m_e^2 + m_\chi^2)(m_e - E_{r,e})\right]$$

$E_{r,e}^{th}$ = 30 MeV

Background Estimates (for the Target Mode)

Neutrino-electron elastic scattering for flux determination at the DUNE oscillation experiment [arXiv:1910.10996]

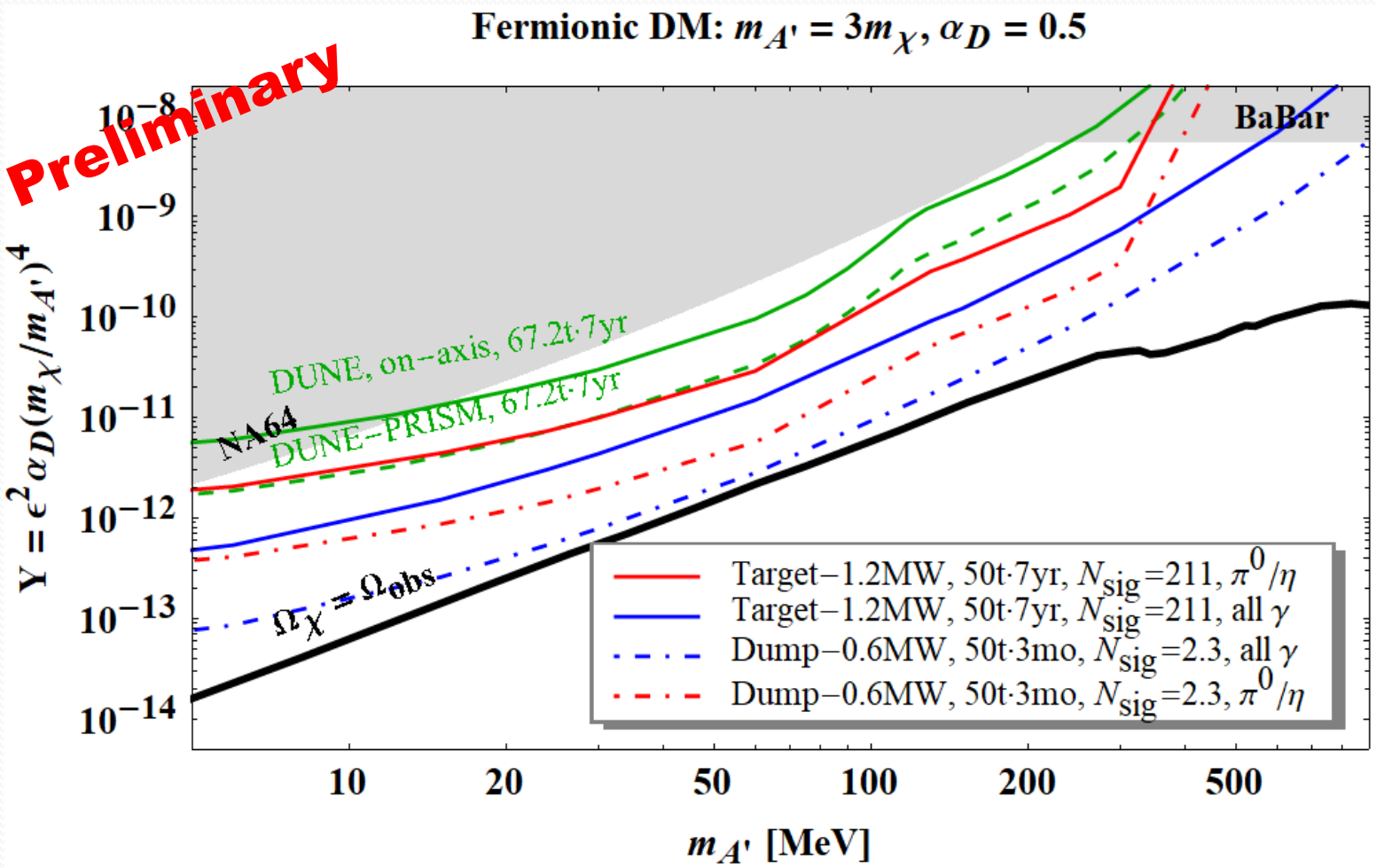
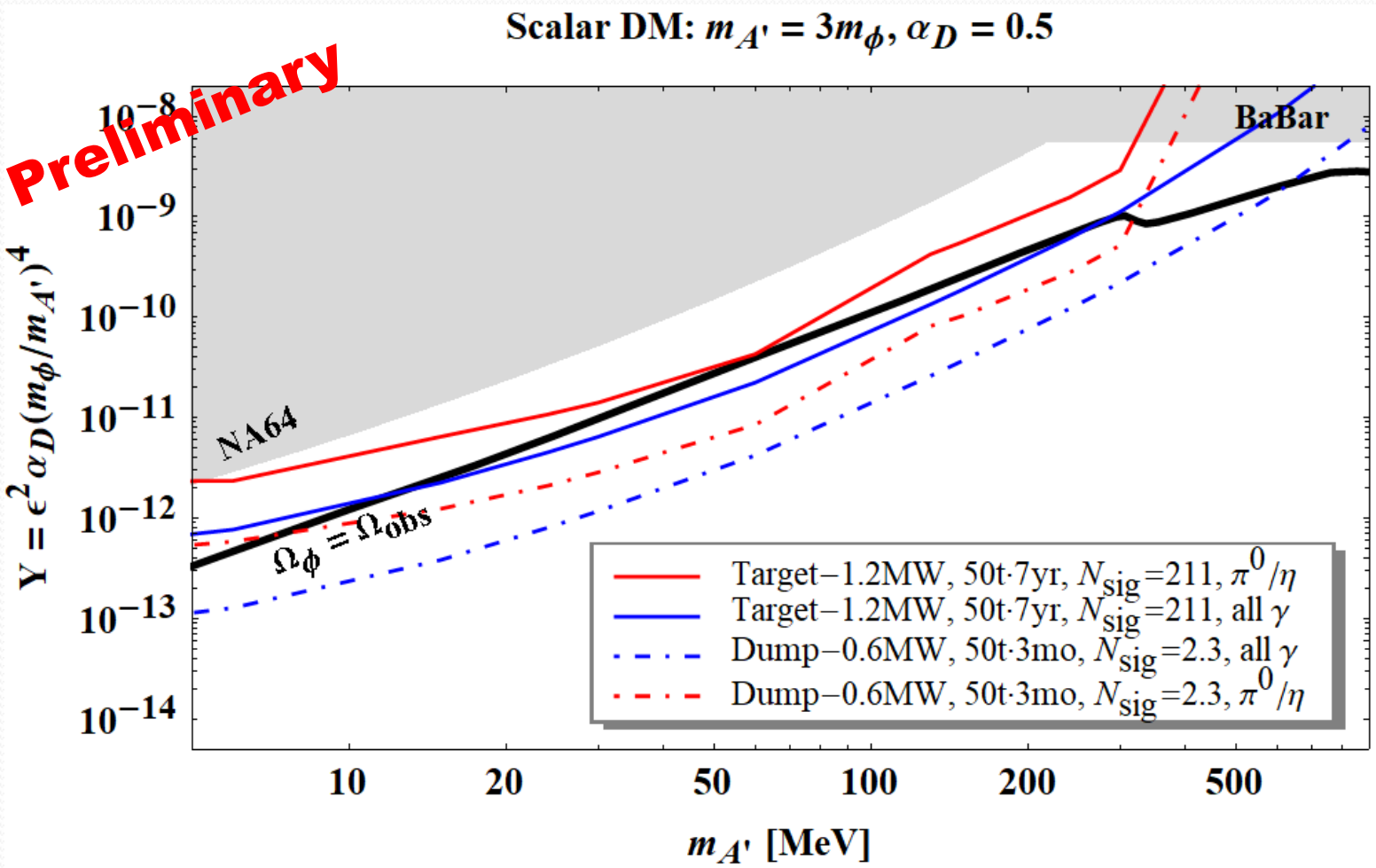
Chris M. Marshall,[1] Kevin S. McFarland,[2] and Callum Wilkinson[3]

[1] *Lawrence Berkeley National Laboratory, Berkeley, California, USA*
[2] *University of Rochester, Rochester, New York, USA*
[3] *University of Bern, Bern, Switzerland*

TABLE I: Number of E_ν template, and template binning for all detectors and beam configurations considered. The binning was decided by requiring ≥500 events/template in the GENIE prediction. The predicted event rates given are the total number of neutrino-electron events in five years of running in the nominal 1.2 MW beam for each detector.

Beam	Detector	Rate	N. bins	E_ν binning (GeV)
FHC (ν-mode)	30t LAr	22458	28	0.0, 1.25, 1.5, 1.75, 2.0, 2.125, 2.25, 2.375, 2.5, 2.625, 2.75, 2.875, 3.0, 3.125, 3.25, 3.5, 3.75, 4.0, 4.25, 4.625, 5.125, 5.875, 6.875, 8.5, 10.0, 12.0, 14.5, 18.5, 100
RHC ($\bar{\nu}$-mode)	30t LAr	15885	18	0, 1.25, 1.625, 1.875, 2.125, 2.375, 2.625, 2.875, 3.125, 3.375, 3.625, 4.0, 4.375, 5.0, 6.0, 7.75, 10.5, 14.0, 100

Expected Sensitivity Reaches: Fermionic Dark Matter



Expected Sensitivity Reaches: Scalar Dark Matter