Ineastic Boosted Dark Matter Searches at ICARUS – Gran Sasso

Doojin Kim

Model-independent Reach

- **Non-trivial** to find appropriate parameterizations for providing **model-independent reaches** due to many parameters involved in the model
- Number of signal events $N_{\rm sig}$ is

$$N_{\rm sig} = \sigma_\epsilon \mathcal{F} A\, t_{\rm exp} N_e\,, \qquad (3)$$

  - σ_ϵ: scattering cross section between χ_1 and (target) electron
  - $\mathcal{F}$: flux of incoming (boosted) χ_1
  - A: acceptance
  - $t_{\rm exp}$: exposure time
  - N_e: total # of target electrons

$t_{\rm exp}$, N_e: **Controllable!** (once a detector is determined)

Here determined by distance between the primary (ER) and the secondary vertices, other factors such as cuts, energy threshold, etc are absorbed into σ_ϵ. Depending on analyses, some factors can be reabsorbed into A.

Model-independent Reach: Comprehensive

Two completely separated modules are assumed.

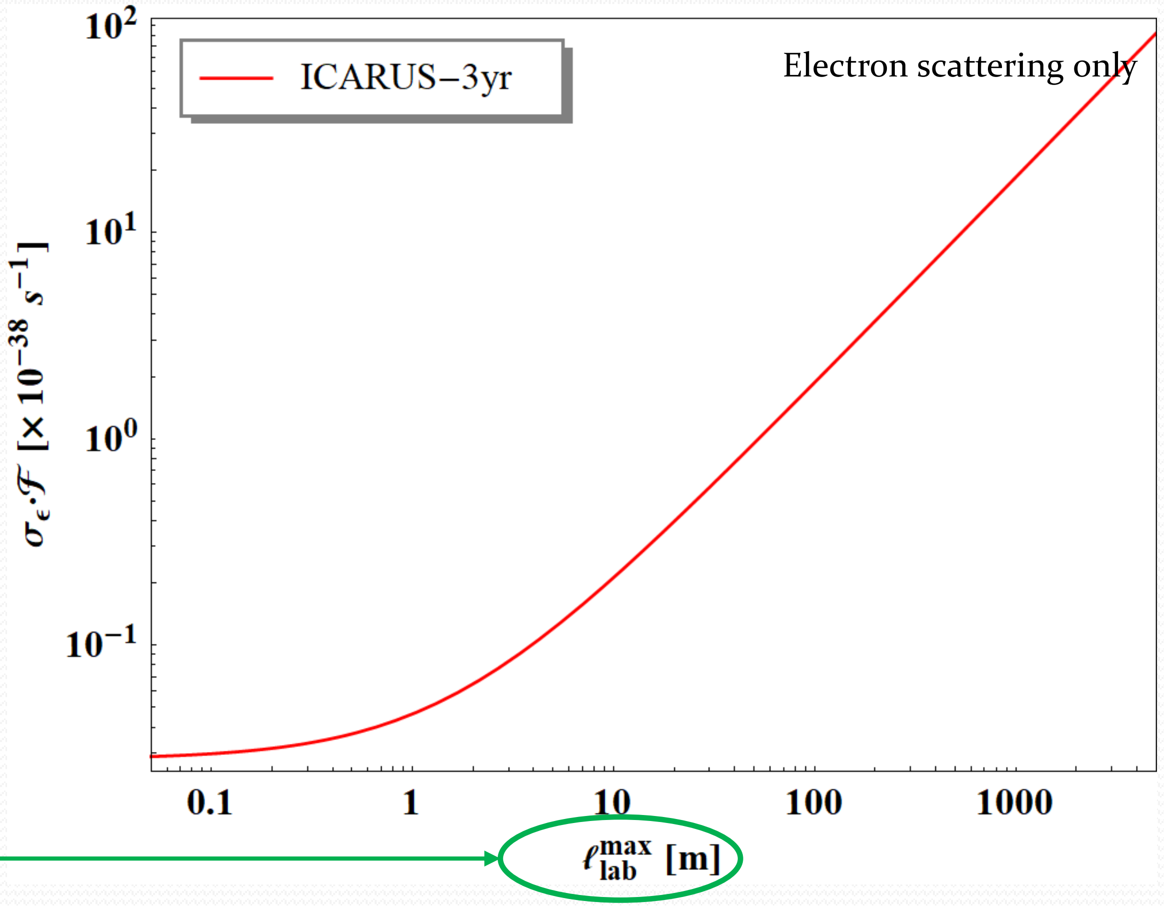
90% C.L. with zero BG

$$\sigma_\epsilon \mathcal{F} > \frac{2.3}{A(\ell_{\rm lab}) t_{\rm exp} N_e}\,, \qquad (4)$$

Calculable

Evaluated under the assumption of cumulatively isotropic χ_1 flux

$\ell_{\rm lab}$ different event-by-event, so taking $\ell_{\rm lab}^{\rm max}$ for more conservative limit



Model-independent Reach: More Familiar Form

- More familiar parameterization possible with the below modification!

$$\sigma_\epsilon \geq \frac{2.3}{\mathcal{F} \cdot A \cdot t_{\rm exp} \cdot N_e}$$

set to be $5 \times 10^{-26}\ \mathrm{cm^3 s^{-1}}$

$$\mathcal{F} = 1.6 \times 10^{-4}\ \mathrm{cm^{-2}s^{-1}} \times \left(\frac{\langle \sigma v \rangle_{0\to 1}}{5 \times 10^{-26}\ \mathrm{cm^3 s^{-1}}}\right) \times \left(\frac{\mathrm{GeV}}{m_0}\right)^2, \quad (1)$$

- Then having

$$\sigma_\epsilon \text{ vs. } m_0 (= E_1 = \gamma_1 m_1)$$

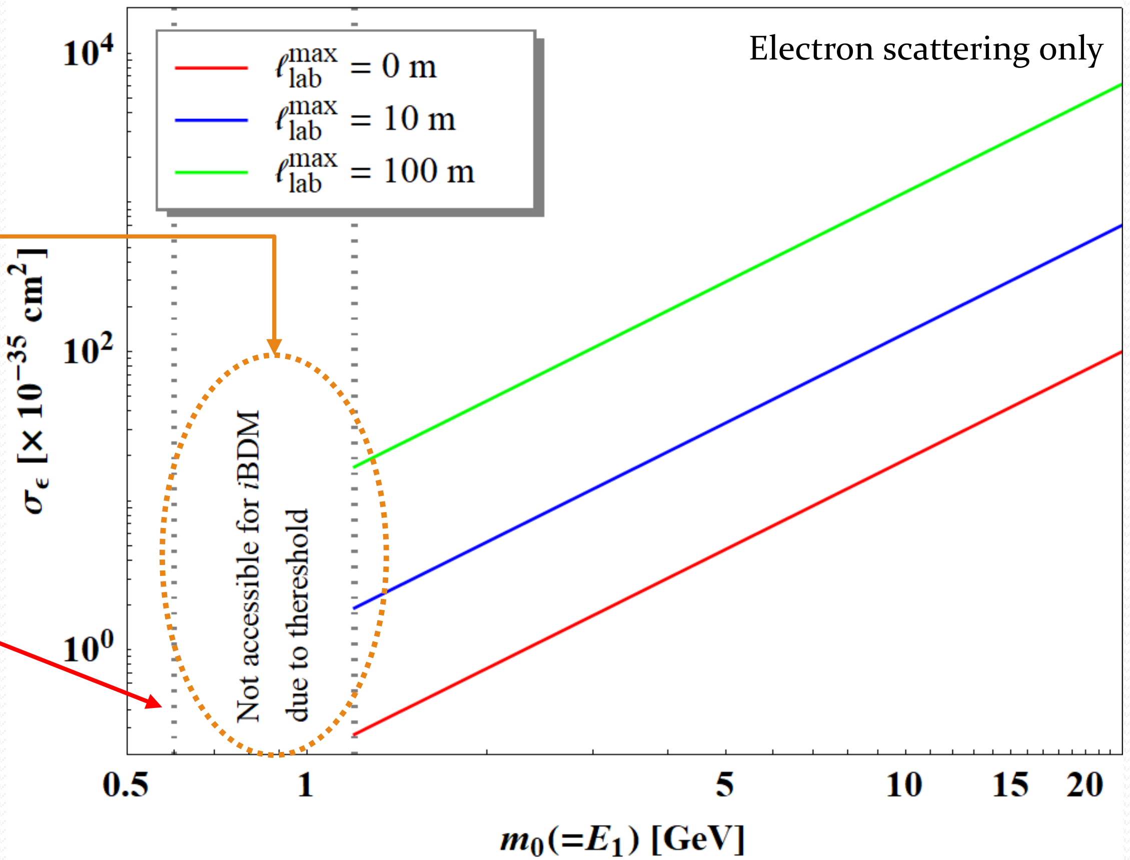
just like σ vs. $m_{\rm DM}$ in conventional WIMP searches

Model-independent Reach: More Familiar Form

3-year data collection assumed.

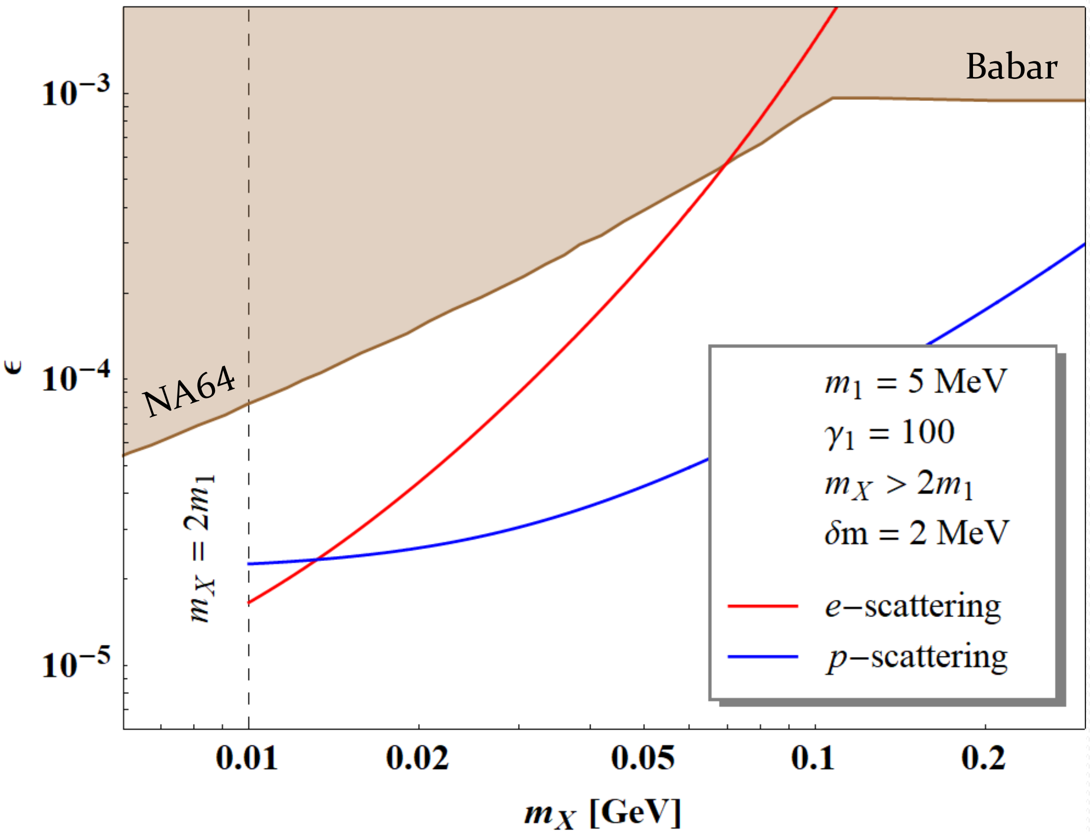
Absolute lower bound for visible tri-track events due to the threshold energy of 400 MeV. (The actual lower bound may involve minor model-dependence.)

Smaller thresholds allow to probe smaller cosmological dark matter mass.



Dark Photon Parameter Space: Invisible X Decay

❑ Case study 1: mass spectra for which dark photon decays into DM pairs, i.e., $m_X > 2m_1$



❑ 3-year data collection is assumed.

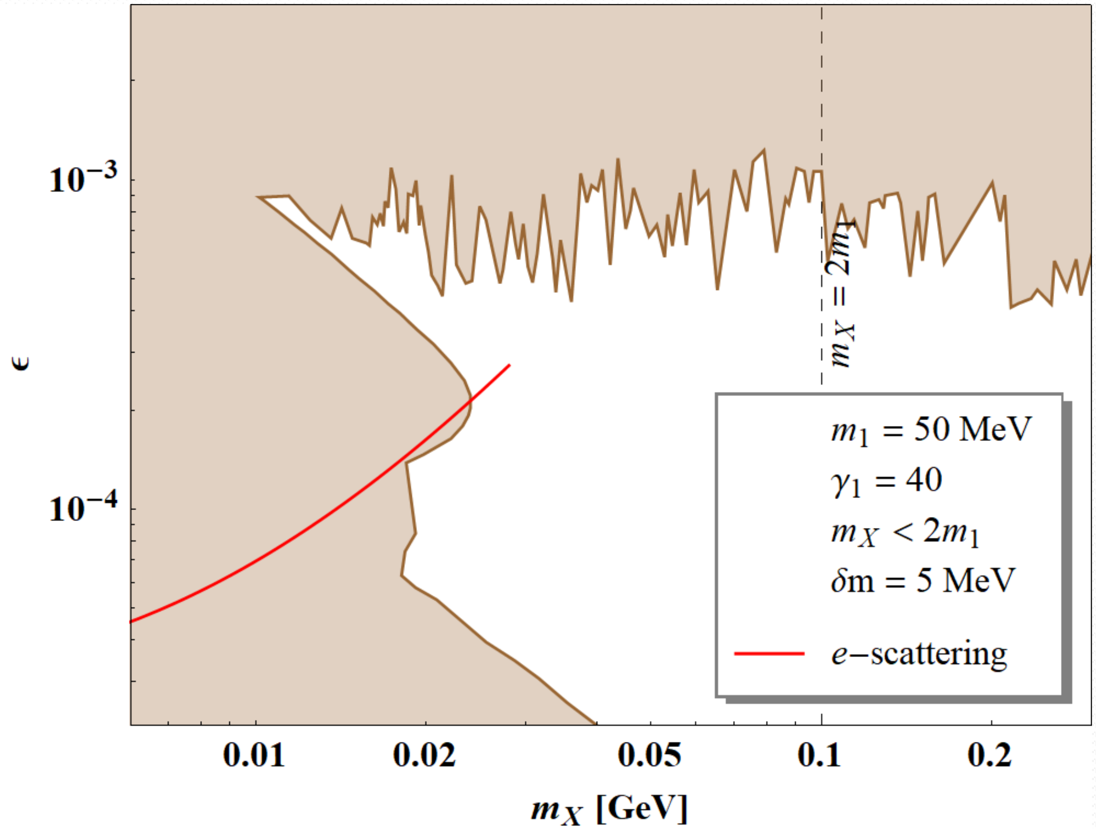
❑ 400 MeV threshold is assumed.

❑ ICARUS can probe the uncovered parameter region by an order of magnitude in the ϵ axis.

❑ p-scattering is preferred for heavier dark photon masses [**DK**, Machado, Park, Shin, in progress]

Dark Photon Parameter Space: Visible X decay

- Case study 2: mass spectra for which dark photon decays into lepton pairs, i.e., $m_X < 2m_1$



- 3-year data collection is assumed.
- 400 MeV threshold is assumed.
- ICARUS can probe the uncovered parameter region by half order of magnitude in the ϵ axis.