Inelastic Dark Matter and Millicharged Particles at DUNE

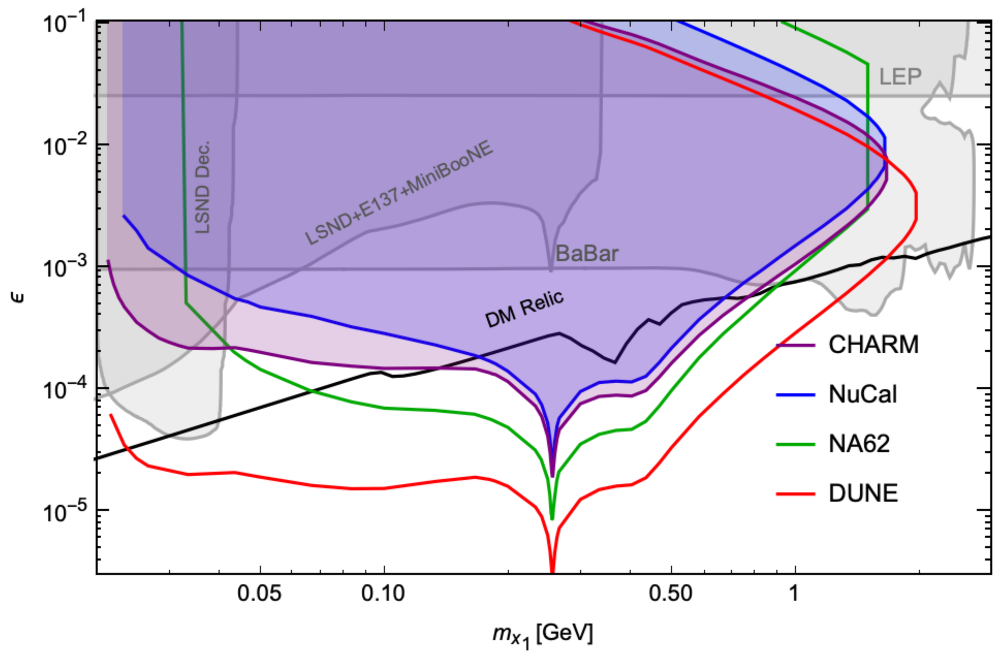
Yu-Dai Tsai (Fermilab) for the DUNE Collaboration

Inelastic Dark Matter

- Use Gas Argon Detectir (near detector complex)
- to study inelastic dark matter
- Because it is good for study of decaying particles (inelastic dark matter, dark photons) give lower density thus background

- One of the few viable **MeV – GeV thermal dark matter candidates**
- A "**thermal target**" for DM searches
- Can **explain g-2** and **freeze-out to the right relic DM abundance**
- Smith, Weiner, arXiv:0101138

Inelastic Dark Matter: $\mathcal{L} \supset \sum_{i=1,2} \bar{\chi}_i (i\partial\!\!\!/ - m_{\chi_i})\chi_i - (g_D A'_\mu \bar{\chi}_1 \gamma^\mu \chi_2 + \text{h.c.}).$

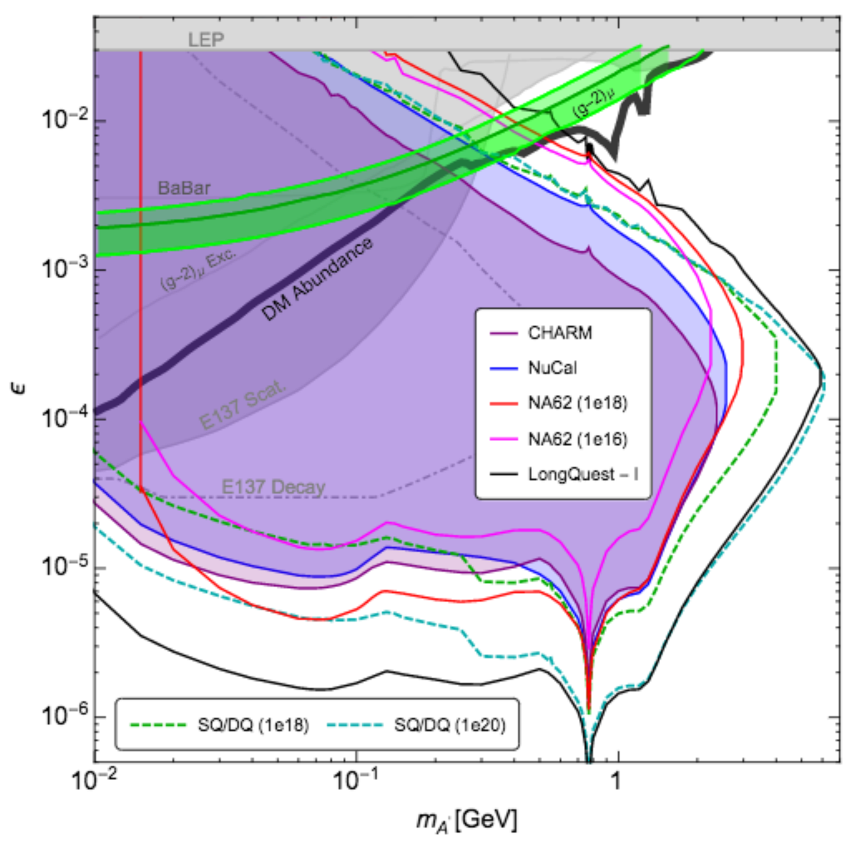


1703.06881 (Izaguirre, Kahn, Krnjaic, Moschella),
1804.00661 (SeaQuest: Berlin, Gori, Schuster, Toro)
1908.07525 (Tsai, de Niverville, Liu)

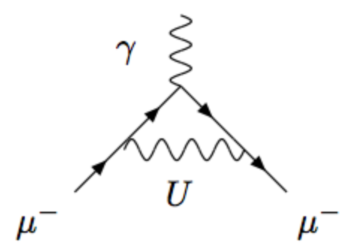
- x_1: dark matter with mass m_1
- x_2: heavier dark sector state with mass m_1
- $m_{A'}/m_1 = 3$,
- $\Delta = 0.05$: mass splitting between x_1 & x_2
- $\alpha_D = 0.5$: coupling between dark photon and dark matter

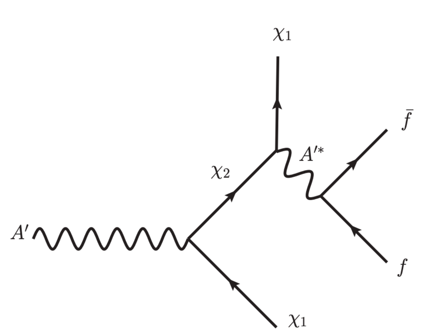
$$\Delta \equiv \frac{m_2 - m_1}{m_1}.$$
$$g_D \equiv \sqrt{4\pi\alpha_D}.$$

DUNE advantages: allows one to explore low-mass, low coupling regime, that can probe part of the relic abundance prediction of the dark matter



(a) iDM: $\Delta = 0.4$, α_D=0.1. With muon $g-2$ and DM regimes.



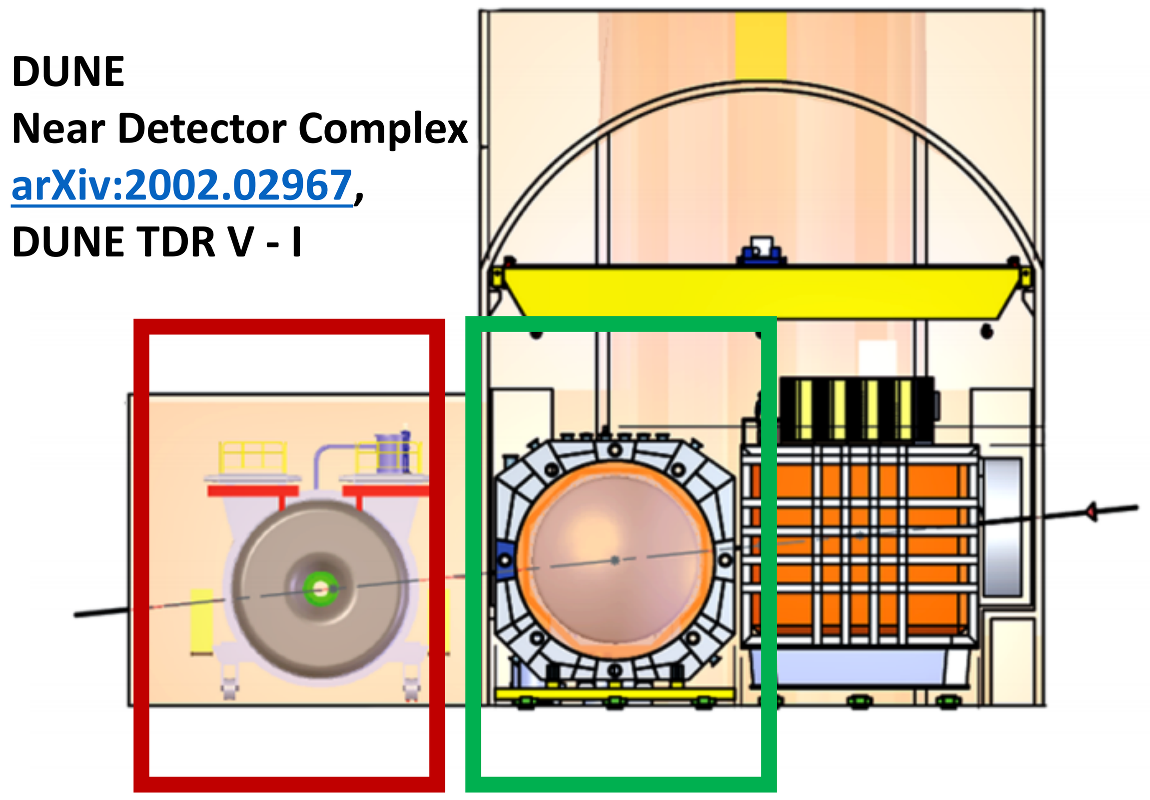


$$\Delta a_\mu \equiv a_\mu^{exp} - a_\mu^{th} = (274 \pm 73) \times 10^{-11},$$

- See, e.g., Fayet, 2007 (hep-ph/0702176)

- arXiv:1902.05075 by Mohlabeng
  arXiv:1908.07525 (Tsai, de Niverville, Liu)

DUNE
Near Detector Complex
arXiv:2002.02967, **DUNE TDR V - I**



Gas Argon Detector **Liquid Argon TPC**

~ 500 meters down the 120 GeV beam-on-target

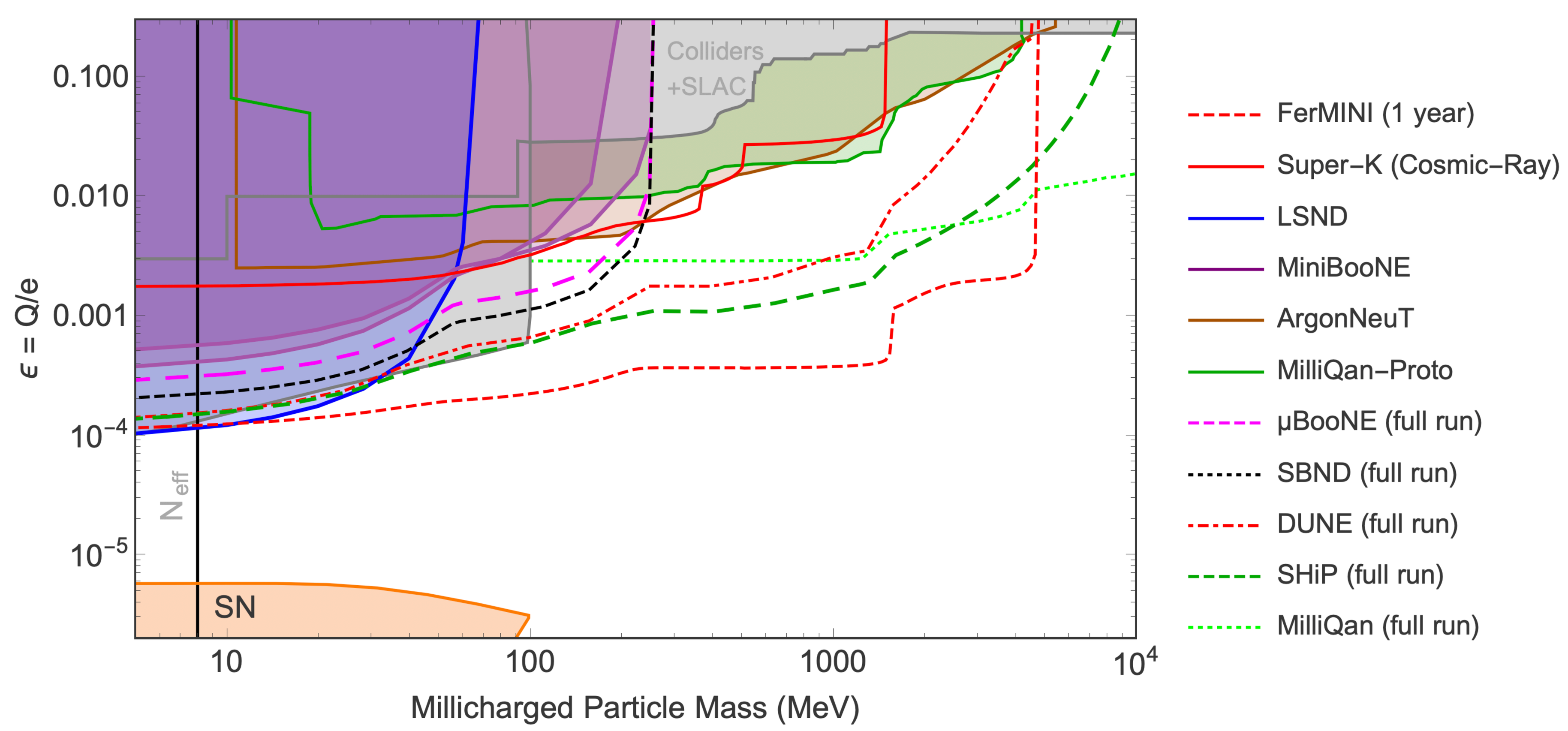
Millicharged Particles

- Use Liquid Argon TPC (LArTPC) at the near detector complex
- to study millicharged Particles (MCP)
- Because it is good for study of scattering particles (neutrino / MCP) given higher density (to scatter with)

- A particle fractionally charged under SM U(1) hypercharge

$$\mathcal{L}_{\text{MCP}} = i\bar{\chi}(\partial\!\!\!/ - i\epsilon' e B\!\!\!/ + M_{\text{MCP}})\chi$$

- Can just consider these Lagrangian terms by themselves (no extra mediator, i.e., dark photon). Naively violating the empirical charge quantization (cool!).
- We are only probing **MCP** here! **Minimal assumptions. Most robust constraints.**
- This could be from vector portal **Kinetic Mixing** (Holdom, '85)
  - give a nice origin to the above term
  - an example that gives rise to **dark sectors**
  - easily compatible with **Grand Unification Theory**
  - I will not spend too much time on the model
- ϵ is the fractional charge (with respect to the electron charge)



DUNE advantages: allows leading sensitivity for large mass millicharged particles without additional detection (using DUNE LArTPC near detector!)

- Magill, Plestid, Pospelov, **Tsai** (1806.03310, ***PRL '19***)
- Kelly, **Tsai**, 1812.03998
- Plestid, Takhistov, **Tsai**, Bringmann, Kusenko, Pospelov, 2002.11732
- Harnik, Liu, Palamara : multi-scattering, point back to target to reduce the background (ArgoNeuT & DUNE), arXiv:1902.03246 / ArgoNeuT collab: arXiv:1911.07996