

Light DM @ ν Experiments & Heavy DM @ DAMPE

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SFG, Ian Shoemaker [arXiv:1710.10889 [hep-ph]]

SFG, Hong-Jian He [arXiv:1712.02744 [astro-ph.HE]]

Thermal Relic DM

- Symmetric
- Relic density fully determined by annihilation cross section

$$\rho_\chi \propto \frac{1}{\langle \sigma v \rangle}$$

$\Rightarrow \langle \sigma v \rangle \sim 1$ pb, the typical size of cross sections at LHC

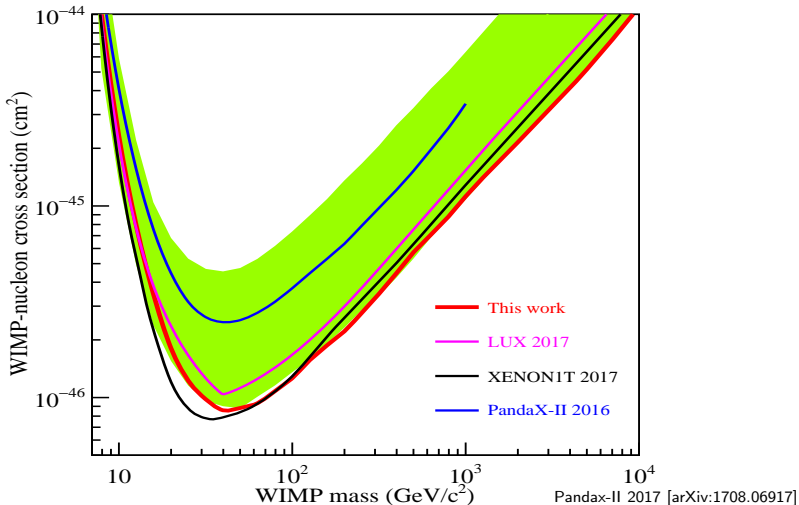
- Characteristic scale of EW

$$\langle \sigma v \rangle \propto \frac{g_\chi^4}{m_\chi^2}$$

corresponding to $m \sim 100$ GeV for EW coupling.

Current Status of DM Search

- DM can be light if its coupling is small: $\langle\sigma v\rangle \propto g_{\chi}^4/m_{\chi}^2$



Light DM

- Relic Density - $m_\chi \propto g_\chi^2$
- DM has no SM gauge coupling
- Renormalizable portals – limited

$$\mathcal{L}_{\text{portal}} = \begin{cases} \epsilon F_{\mu\nu} F_h^{\prime\mu\nu} & (\text{photon portal}) \\ h |H^2| |H_h^2| & (\text{Higgs portal}) \\ y(LH)N & (\text{neutrino portal}) \end{cases}$$

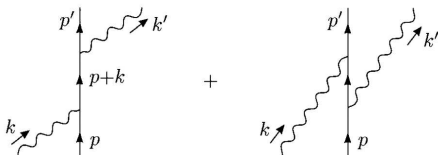
where $F'_{\mu\nu}$, H_h , and N are hidden sector fields.

- Full Lagrangian

$$i\bar{\chi}\not{D}\chi - m_\chi\bar{\chi}\chi - \frac{1}{4}F'_{\mu\nu}F^{\prime\mu\nu} + \frac{1}{2}m_{V'}^2 V'^\mu V'_\mu - \epsilon F_{\mu\nu}F^{\prime\mu\nu}$$

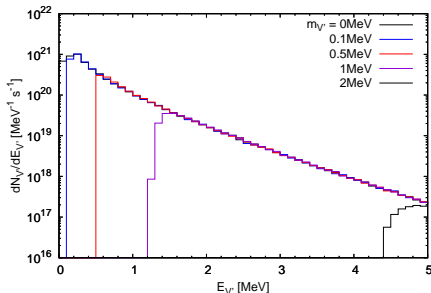
Reactor Compton-like Production of DM

- $\gamma e^- \rightarrow V' e^-$ with prompt γ -rays from nuclear fissions



$$\frac{dN_\gamma}{dE_\gamma} = 0.58 \times 10^{21} \left(\frac{P}{\text{GW}} \right) \exp \left(-\frac{E_\gamma}{0.91 \text{ MeV}} \right)$$

$$\frac{dN_{V'}}{dE_{V'}} = \int \frac{1}{\sigma_{\text{tot}}} \frac{d\sigma_{\gamma \rightarrow V'}}{dE_{V'}} \frac{dN_\gamma}{dE_\gamma} dE_\gamma$$

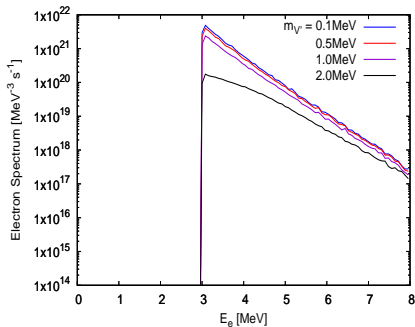
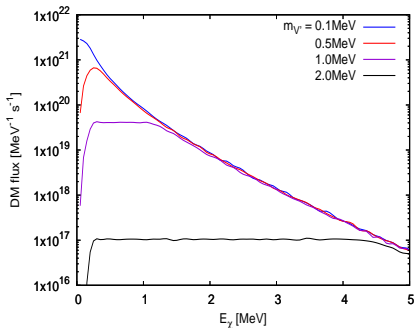


$$\frac{d\sigma_{\gamma \rightarrow V'}}{dE_{V'}} = \frac{\epsilon^2 \alpha m_e}{(s - m_e^2)^2} \left[\frac{3m_e^4 - m_e^2(t - 3m_{V'}^2) + s(2m_e^2 - u)}{(s - m_e^2)^2} + \frac{3m_e^4 - m_e^2(t - 3m_{V'}^2) + u(2m_e^2 - s)}{(u - m_e^2)^2} + 2 \frac{m_e^2(4m_e^2 + m_{V'}^2) - (m_e^2 + m_{V'}^2)t}{(s - m_e^2)(u - m_e^2)} \right]$$

typical power reactor is $P \sim \mathcal{O}(\text{GW})$

Constraint on Unstable V'

- $m_{V'} > 2m_\chi \Rightarrow$ Prompt decay $V' \rightarrow \chi\bar{\chi}$ with $\text{Br} \approx 1$
- Elastic Scattering: $\sigma(\chi e^- \rightarrow V'^* \rightarrow \chi e^-) \propto \epsilon^2 g_\chi^2$

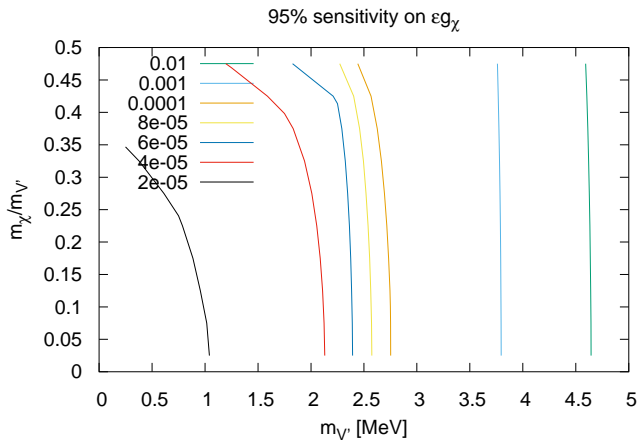


- Energy threshold $E_e > 3 \text{ MeV}$ @ TEXONO
- Mainly sensitive to $m_{V'} \lesssim 1 \text{ MeV}$

SFG & Ian Shoemaker [arXiv:1710.10889 [hep-ph]]

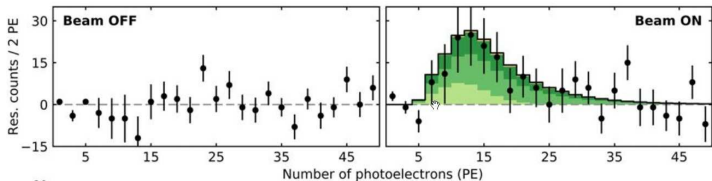
TEXONO Constraint

- 187kg CsI(Tl) @ 28m from the core of a 2.9GW reactor



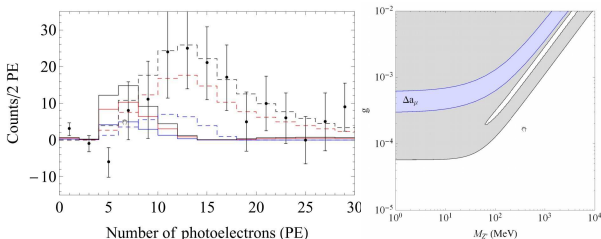
COHERENT data

- 308.1 live-days (Beam ON) with 7.48 GWhr ($\sim 1.76 \times 10^{23}$ POT)



COHERENT [arXiv:1708.01294]

- Constraint on NSI



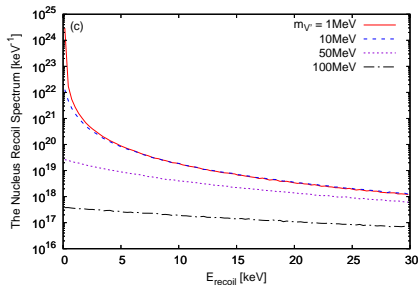
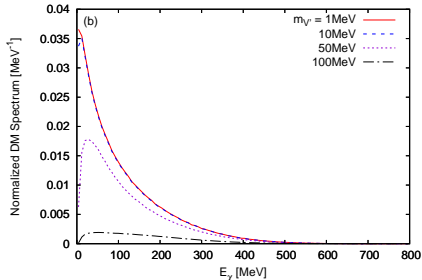
Liao & Marfatia [arXiv:1708.04255]

COHERENT Constraint on Light DM

- $\pi^0 \rightarrow \gamma V'$ with $f_{\pi^0} \approx f_{\pi^\pm}$

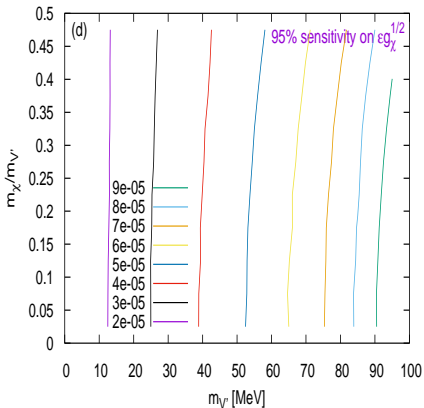
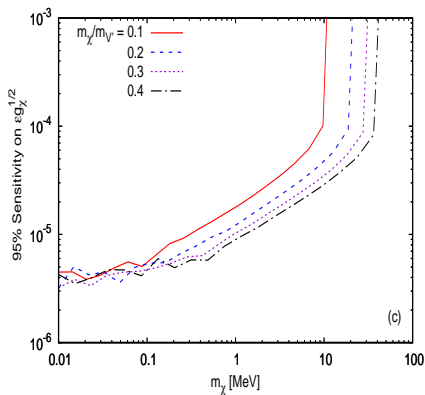
$$\text{Br}_{\pi^0 \rightarrow \gamma V'} \approx 2\epsilon^2 \left(1 - \frac{m_{V'}^2}{m_{\pi^0}^2}\right)^3$$

- $V' \rightarrow \chi\bar{\chi}$ & $\chi N \rightarrow \chi N$ via V' mediation



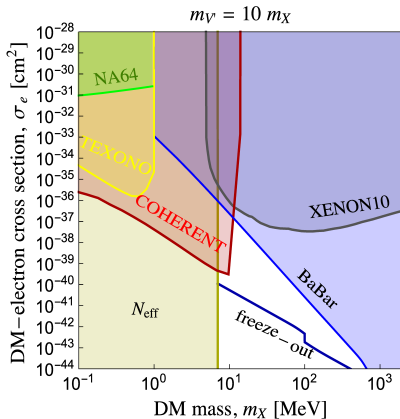
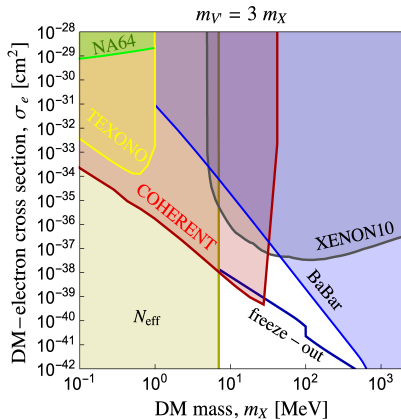
SFG & Ian Shoemaker [arXiv:1710.10889 [hep-ph]]

COHERENT Sensitivity on Light DM



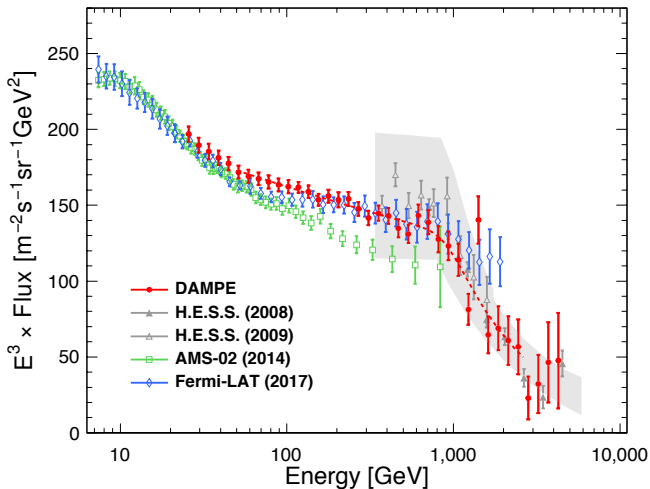
SFG & Ian Shoemaker [arXiv:1710.10889 [hep-ph]]

Constraints on Light DM

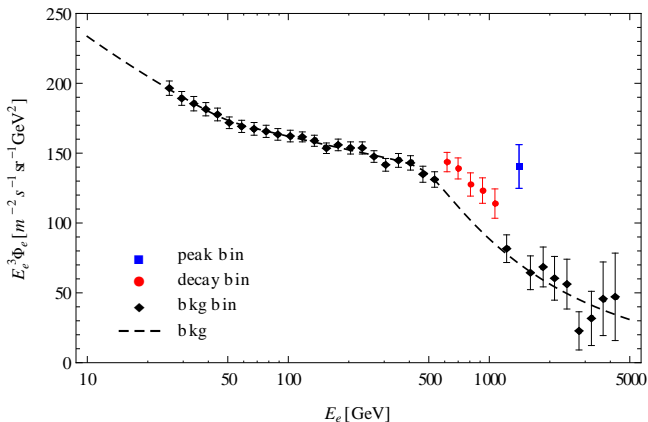


$$\bar{\sigma}_e = \begin{cases} 16\pi\alpha\alpha_X\epsilon^2\mu_{eX}^2/m_{\nu'}^4 & (m_{\nu'} \gg m_X v) \\ 16\pi\alpha\alpha_X\epsilon^2\mu_{eX}^2/(m_e\alpha)^4 & (m_{\nu'} \ll m_X v), \end{cases}$$

Heavy DM @ DAMPE?

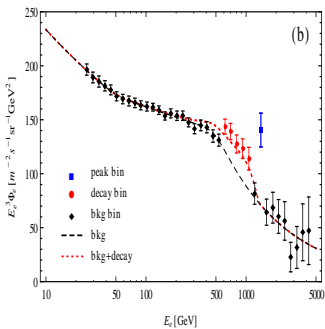
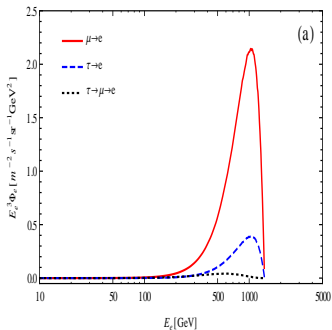


$$\Phi_{\text{bkg}} = \frac{\Phi_0}{E_e^\gamma} \left[1 + \left(\frac{E_{\text{br},1}}{E_e} \right)^\delta \right]^{\frac{\Delta\gamma_1}{\delta}} \left[1 + \left(\frac{E_e}{E_{\text{br},1}} \right)^\delta \right]^{\frac{\Delta\gamma_2}{\delta}}.$$



with $\Phi_0 = 244 \text{ GeV}^{-1}$, $\gamma = 3.1$, $E_{\text{br},2} = 493 \text{ GeV}$, $(\Delta\gamma_1, \Delta\gamma_2) = (0.1, -0.57)$.

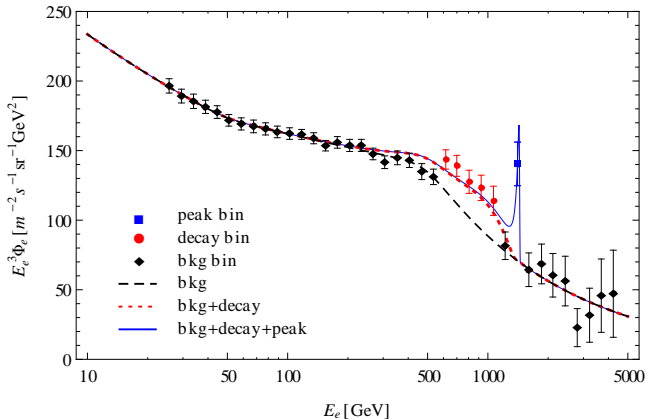
Hidden Excess from μ/τ Decay



$$\frac{1}{\Gamma} \frac{d\Gamma}{dE_e} \simeq \frac{4}{E_\mu} \left(\frac{5}{12} - \frac{3E_e^2}{4E_\mu^2} + \frac{E_e^3}{3E_\mu^3} \right)$$

- $\mu \rightarrow e$ (100%)
- $\tau \rightarrow e$ (17.83%)
- $\tau \rightarrow \mu \rightarrow e$ (17.4%)

Flavor Structure of DAMPE Excesses



$$N_e : \left(N_\mu + \frac{1}{6} N_\tau \right) \approx 1 : 12.7$$

SFG, Hong-Jian He [arXiv:1712.02744 [astro-ph.HE]]

Summary

- Light DM @ Neutrino Experiments
 - Reactor prompt gamma ray @ **TEXONO**
 - Compton-like ($\gamma e \rightarrow V' e$)
 - Inverse Compton-like processes ($\chi e \rightarrow \chi e$)
 - Coherent scattering @ **COHERENT**
 - Neutral pion decay ($\pi^0 \rightarrow V' \gamma$)
 - Coherent scattering ($\chi N \rightarrow \chi N$)
- Heavy DM @ **DAMPE**
 - Hidden excess in (0.6-1.1)TeV region
 - Muon/Tau decay of 1.4TeV DM
 - SAME 1.4TeV DM annihilation \rightarrow 2 different excesses

Thank You!