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Light Leptophilic Boson Portal to DM in light of AMS-02

Work in progress in collaboration with S. Ghosh, A.D. Banik, D. Majumdar

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OUTLINE

- We revisit the dark matter annihilation as a source of the positron excess updated by AMS-02 (2019).
- The portal to DM is assumed to be a light leptophilic (pseudo)scalar ϕ decaying to muons and leading to Sommerfeld enhancement.
- The scenario is worked out in the framework of ϕ + 2HDMX with large tan(beta) which may explain the muon g-2 anomaly for $m_A \ll m_H \approx m_{H^\pm}$.
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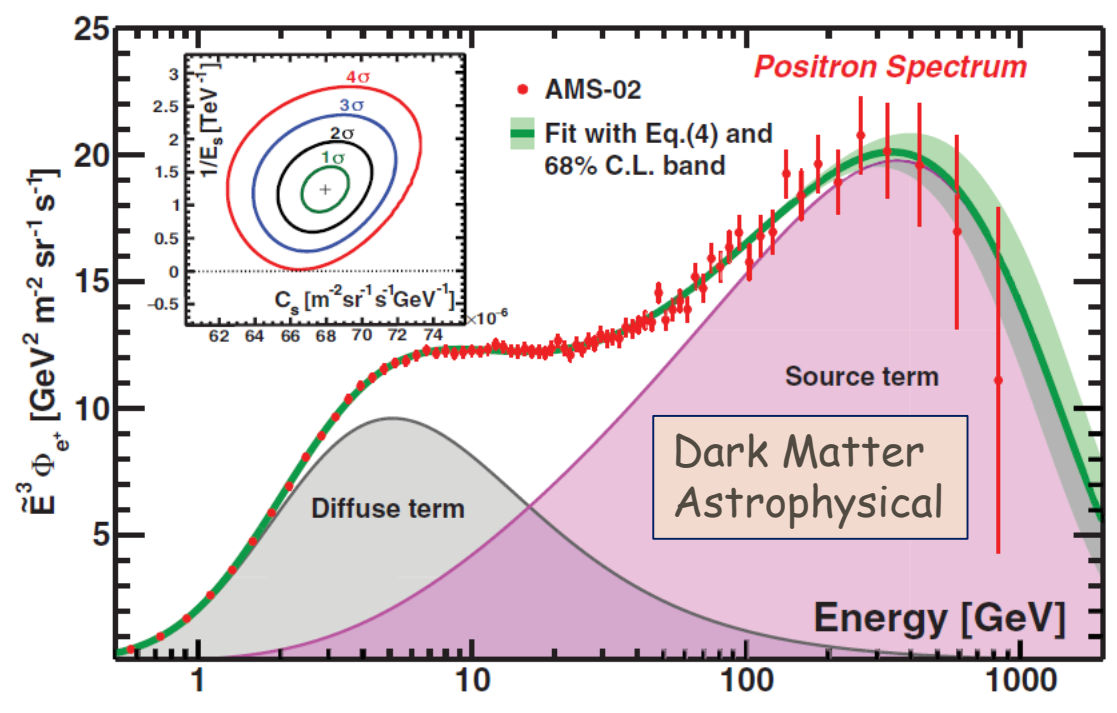
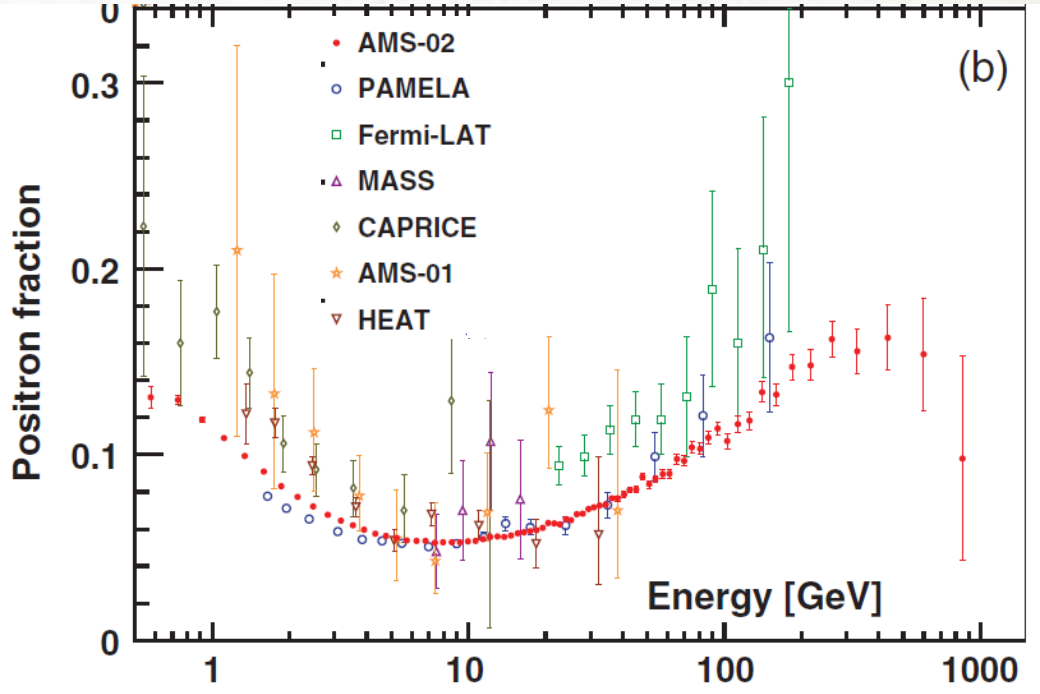
(*) ILC study: Talk by Tanmoy Modal

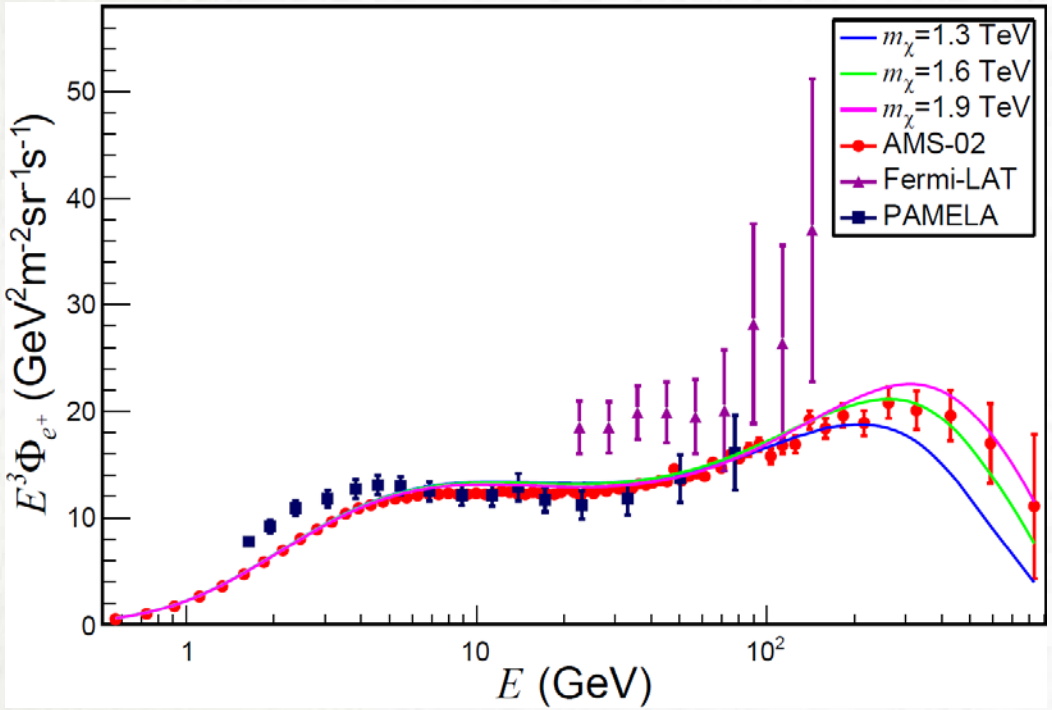
AMS-02 positron data 2019

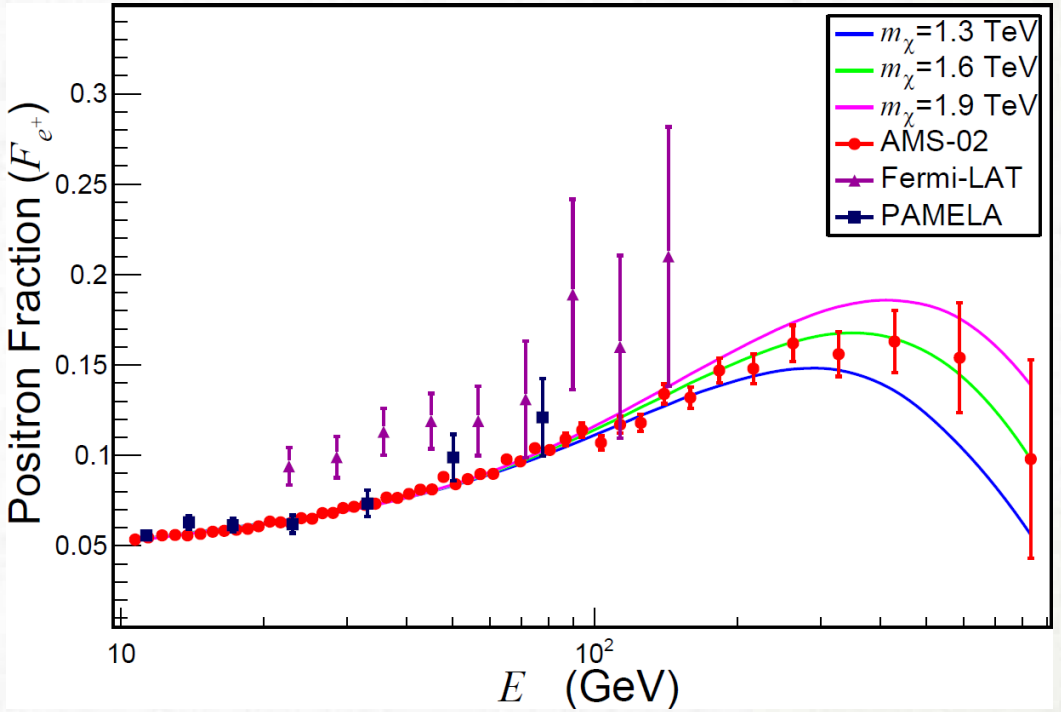




PRL 122, 041102; 101101

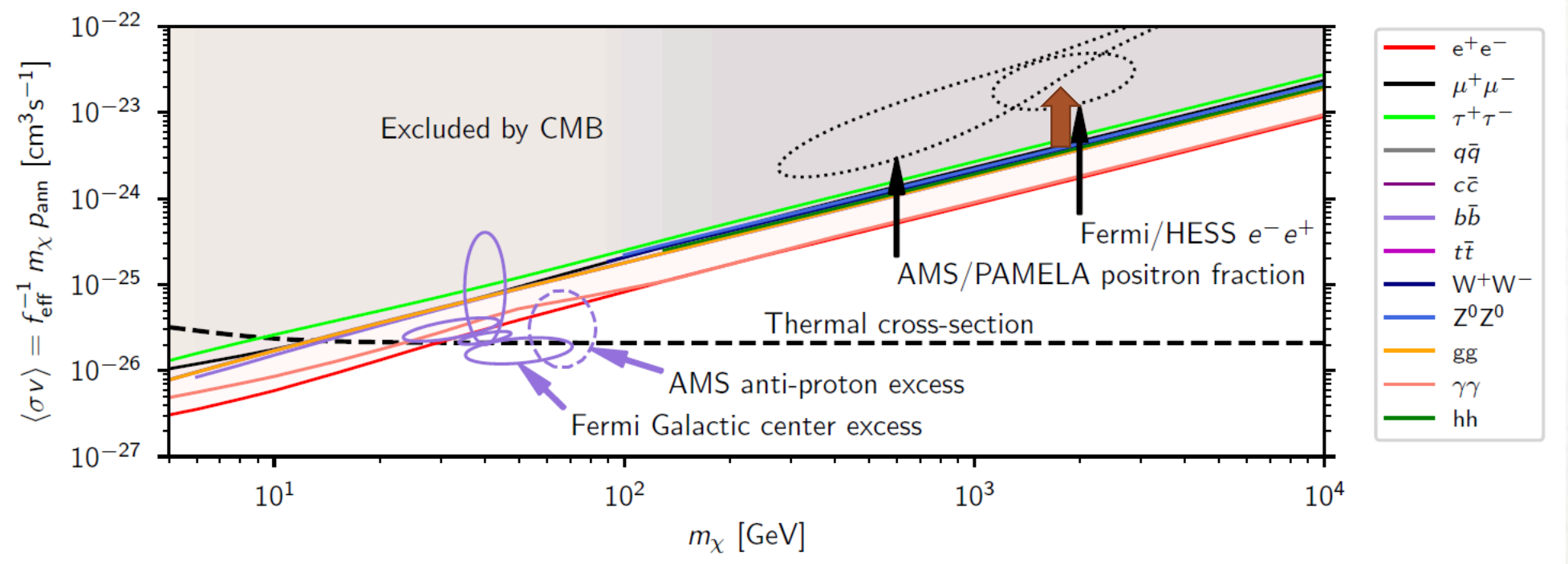
Our fit: $\chi\chi \to \phi\phi \to (\mu^+\mu^-)(\mu^+\mu^-)$





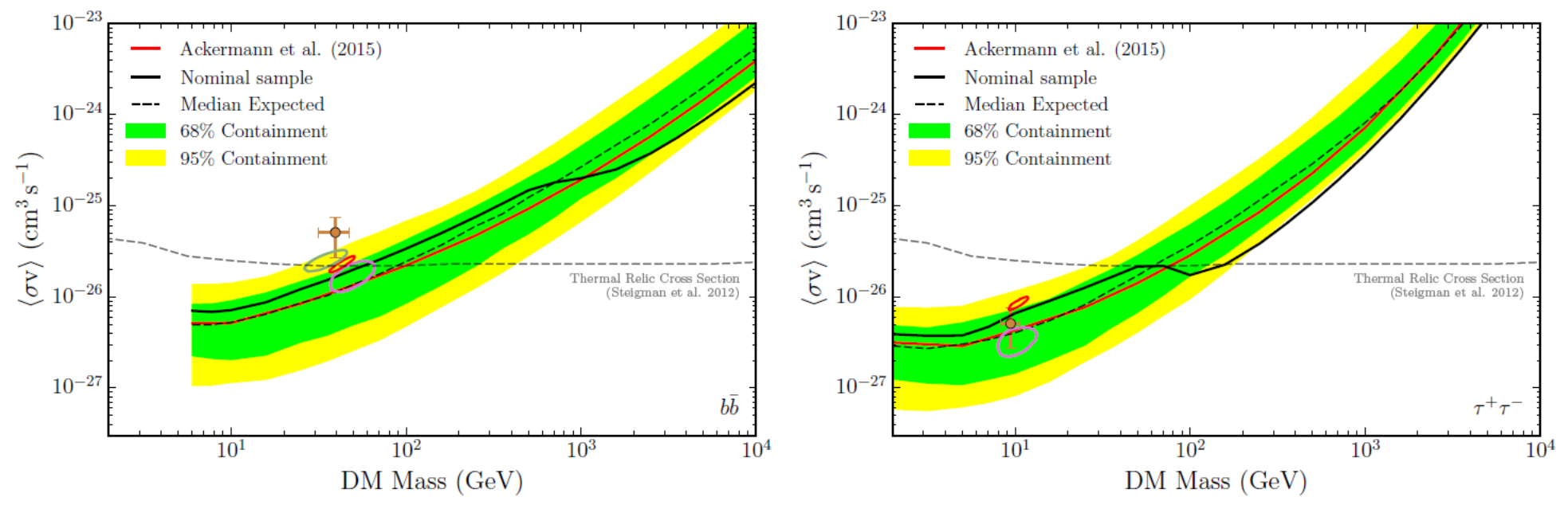
$\langle\sigma v\rangle_{AMS} \sim 2 \times 10^{-23}\ cm^3/s\ \sim 10^3\ \langle\sigma v\rangle_{f.o.}$ - **Still viable?**

PLANCK 18



$$\langle\sigma v\rangle_{CMB} \lesssim 3\times 10^{-24} cm^3/s \sim 0.1\,\langle\sigma v\rangle_{AMS}$$

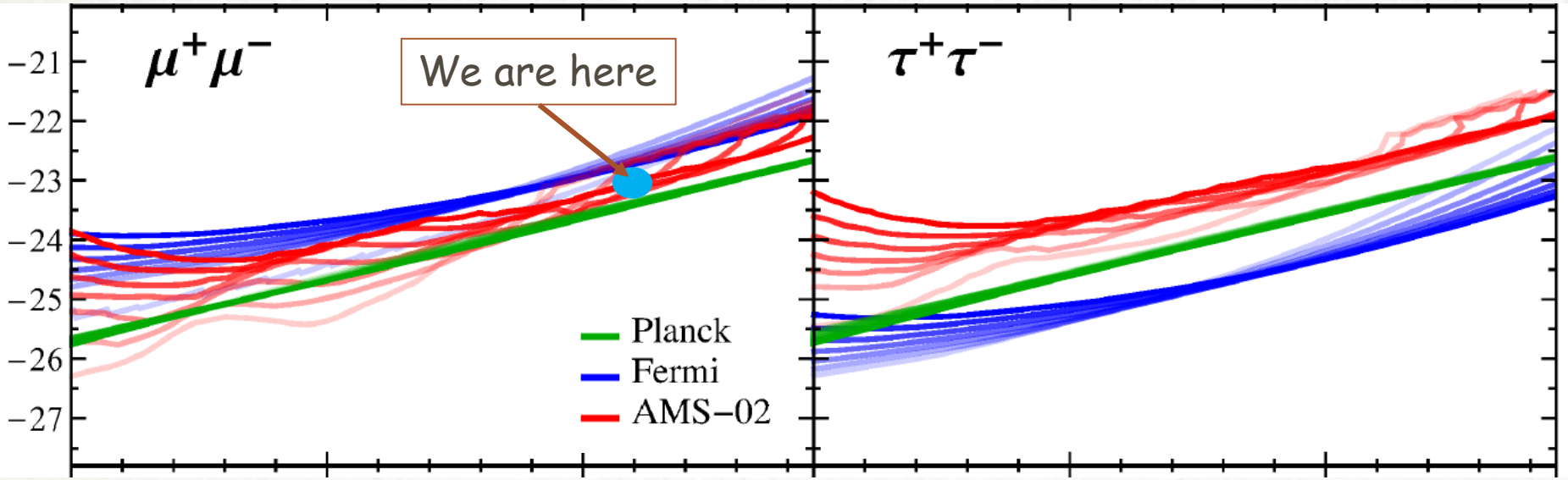
Fermi-LAT 16



$$\langle\sigma v\rangle_{\tau\tau} \lesssim 10^{-24} cm^3/s \sim 0.05\,\langle\sigma v\rangle_{AMS}$$

Combination

Elor et.al. 1511.08787



$1\ TeV$

$\langle\sigma v\rangle_{AMS} \sim 10\ \langle\sigma v\rangle_{CMB}$

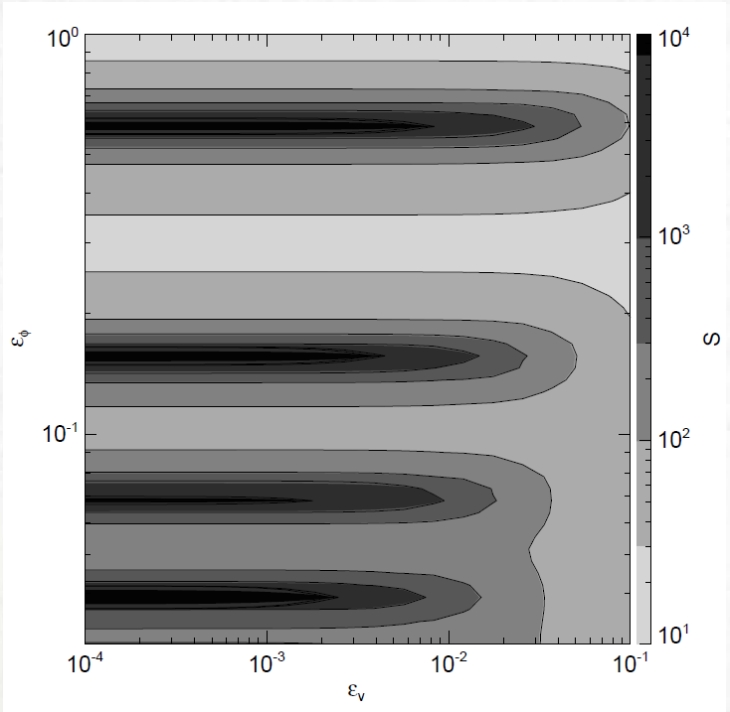
Require $m_\phi < 2\, m_\tau$

Freeze-out, Sommerfeld, Local clump

$$\langle\sigma v\rangle_{AMS} \sim \langle\sigma v\rangle_{F.O.} \times 100 \times 10 \sim \langle\sigma v\rangle_{CMB} \times 10$$

$$\epsilon_\phi = \frac{m_\phi}{\alpha_\chi m_\chi}$$

$$\epsilon_v = \frac{v}{\alpha_\chi}$$



Arkani-Hamed et.al. 0810.0713

$$\langle\sigma v\rangle_{\chi\chi\to\phi\phi} \sim 2\pi \frac{\alpha_\chi \alpha'_\chi}{m_\chi^2} \sim \frac{2\times10^{-9}}{GeV^2}$$

$$SE \sim \frac{1}{\epsilon_\phi} = \frac{\alpha_\chi m_\chi}{m_\phi} \text{ saturated for } \frac{1}{m_\chi v} \gtrsim \frac{1}{m_\phi}$$

$m_\chi \sim 1\,TeV$ $v_{local} \sim 10^{-3}$ $SE \sim 100$

$m_\phi \gtrsim 1\,GeV$ $\alpha_\chi \sim 0.1$ $\alpha'_\chi \sim 0.01$

Our framework: 2HDMX+ϕ

- 2HDM Higgs bosons: $h, H, H^{\pm}, A$
- Type-X in the alignment limit:

$$\mathcal{L}_Y = \frac{m_q}{v}\frac{1}{t_\beta}\,\bar{q}(H + i\gamma_5\, A)q + \frac{m_l}{v}\,t_\beta\,\bar{l}(H + i\gamma_5\, A)l$$

- Muon g-2 favored:

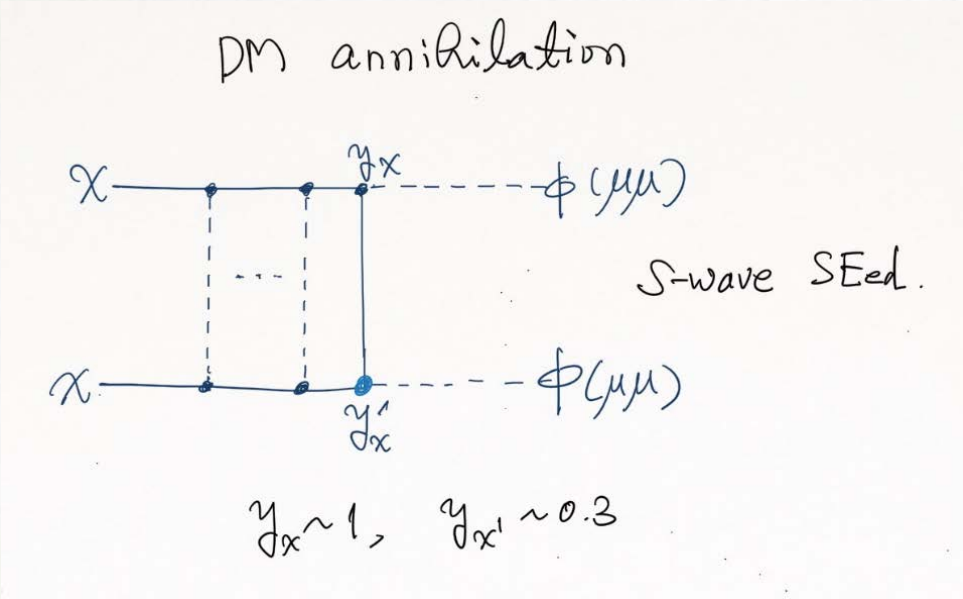
$$m_H \approx m_{H^\pm} \gg m_A \gtrsim 20\ GeV,\ \ t_\beta \gtrsim 30$$

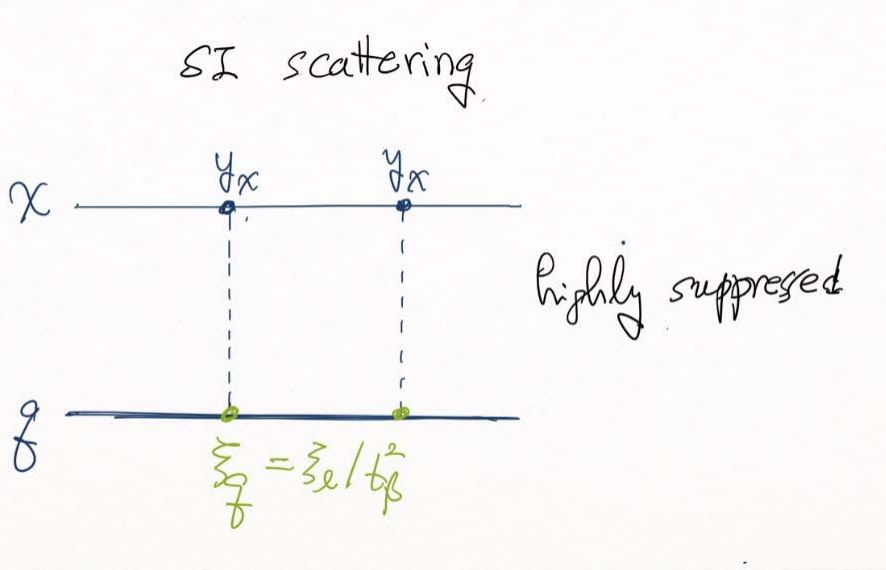
- Singlet portal couplings: 2HDM$-\phi-$DM
- $\mathcal{L}_{\phi\chi} = \phi\,\bar{\chi}\left(y_\chi + i\gamma_5\, y'_\chi\right)\chi$
- $\mathcal{L}_{\phi H} = i\mu\,\phi\,(H_1\,H_2^+ - h.c.)$

$$+\,\phi^2\left(\kappa_1|H_1|^2 + \kappa_2|H_2|^2 + \kappa_3(H_1H_2^+ + h.c.)\right)$$

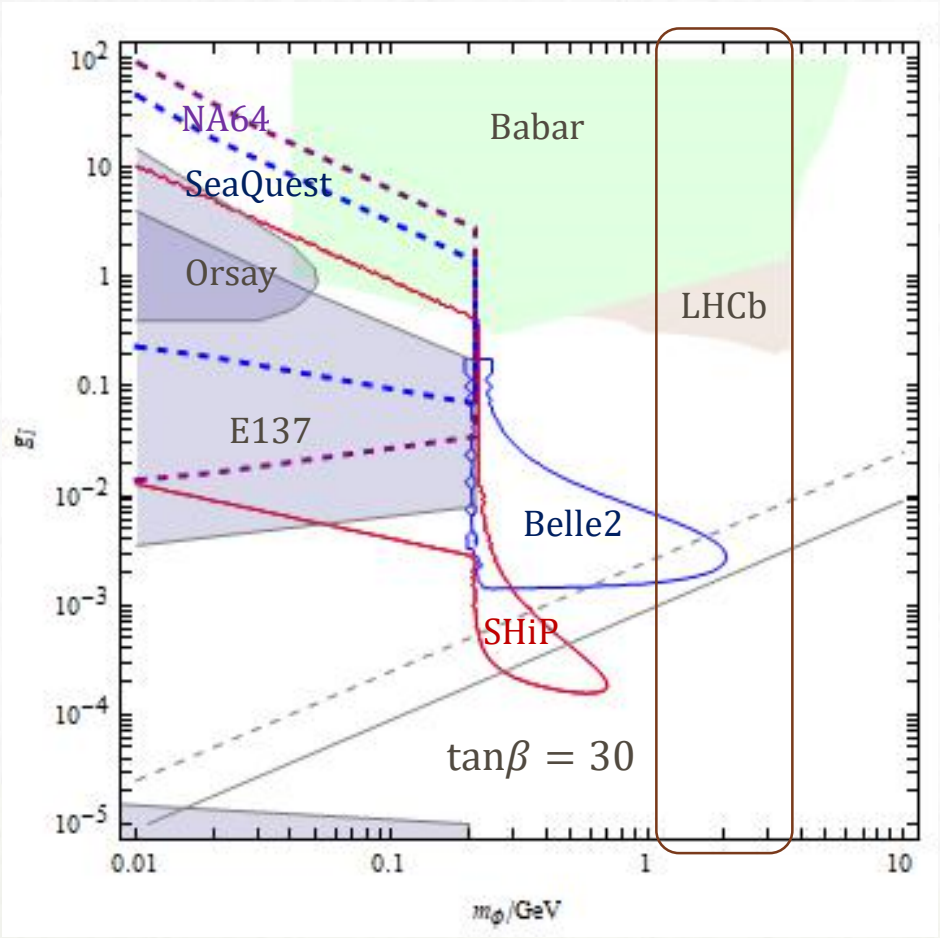
- $\phi - A$ mixing: $\theta_{\phi A} \approx \mu v c_{2\beta}/m_A^2$
- $\mathcal{L}_{\phi ff} = \frac{m_f}{v}\,\xi_f\,\phi\,\bar{f} i\gamma_5 f$ $\qquad \xi_l = t_\beta\,\theta_{\phi A};\ \ \xi_q = \frac{\theta_{\phi A}}{t_\beta} = \frac{\xi_l}{t_\beta^2}$
- Generically sizable $h \to AA, \phi A, \phi\phi$

Indirect/direct DM detections





Searching for a light leptophilic boson



LHCb, Belle2, SHiP

$B \to K\phi(\mu\mu)$

involving $\xi_q = \xi_l / t_\beta^2$

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