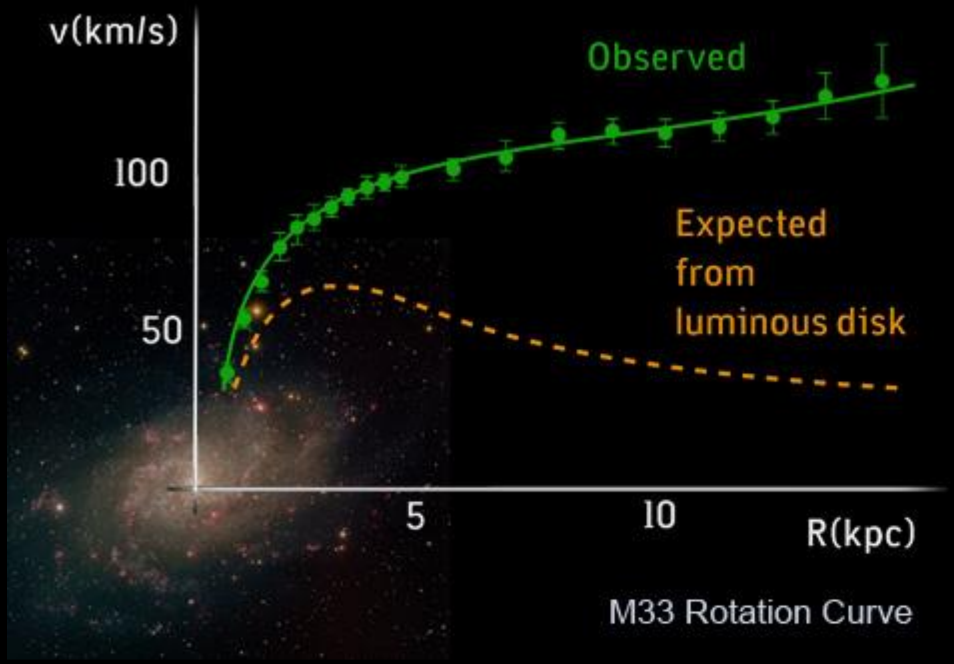
A FEEBLE WINDOW ON LEPTOPHILIC DARK MATTER

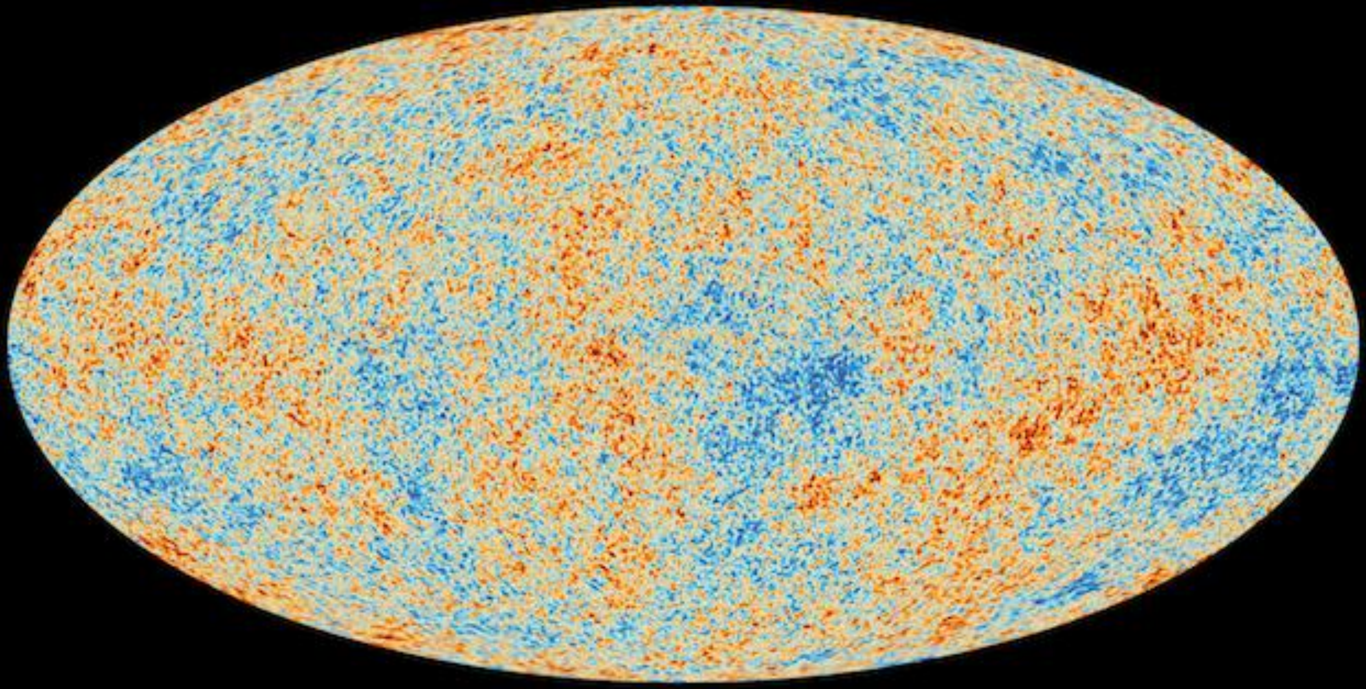
Based on arXiv:1904.07513 in collaboration
with Laura Lopez Honorez and Alberto Mariotti

SAM JUNIUS

EPS-HEP CONFERENCE – 12/07/2019

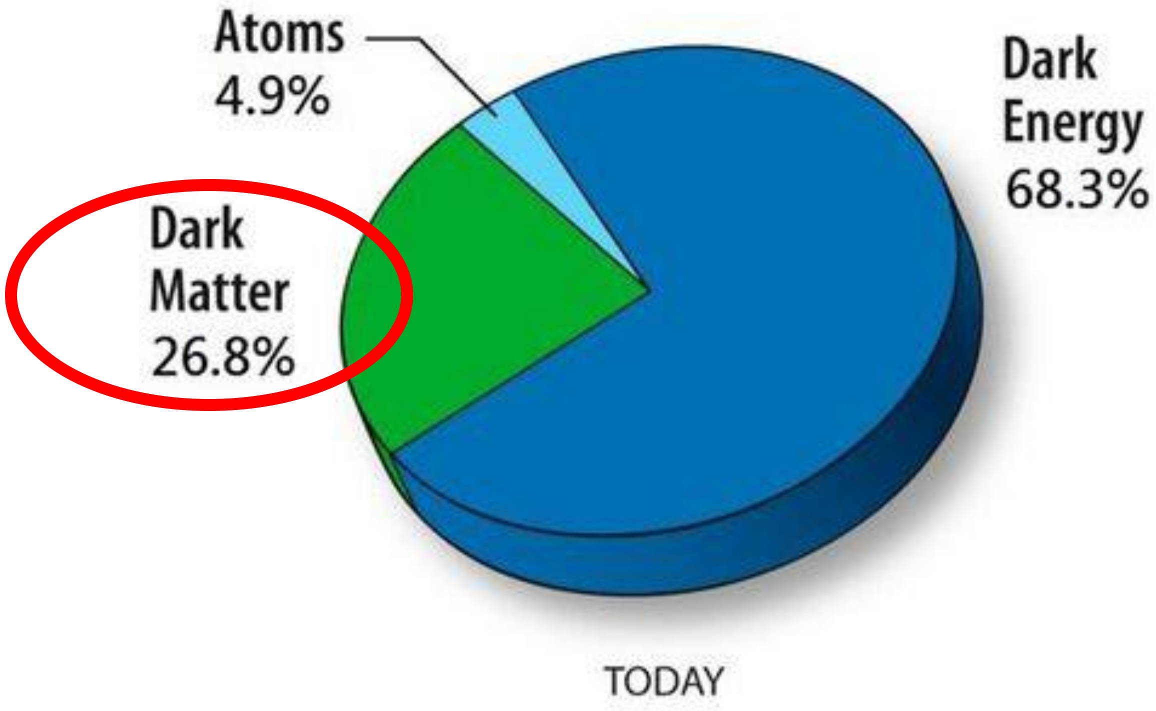
COMPELLING EVIDENCE FOR THE EXISTENCE OF DARK MATTER





Only gravitational evidence

AMOUNT OF DARK MATTER IN THE UNIVERSE TODAY



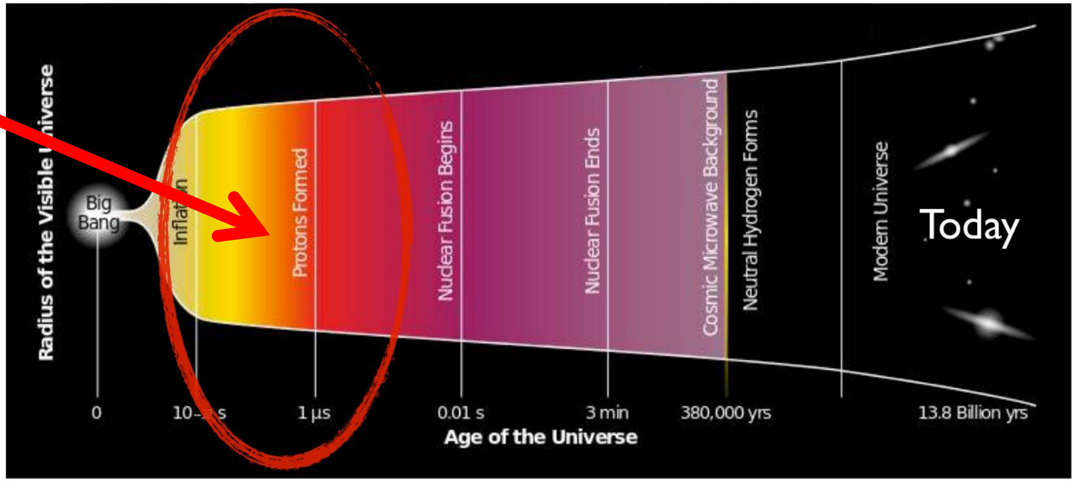
Dark matter relic abundance

$$\Omega_{DM} h^2 = 0.12$$

PRODUCTION OF DARK MATTER IN EARLY UNIVERSE

Thermal Bath

Expansion with Hubble rate *H*



Boltzmann equation for a b -> c d:

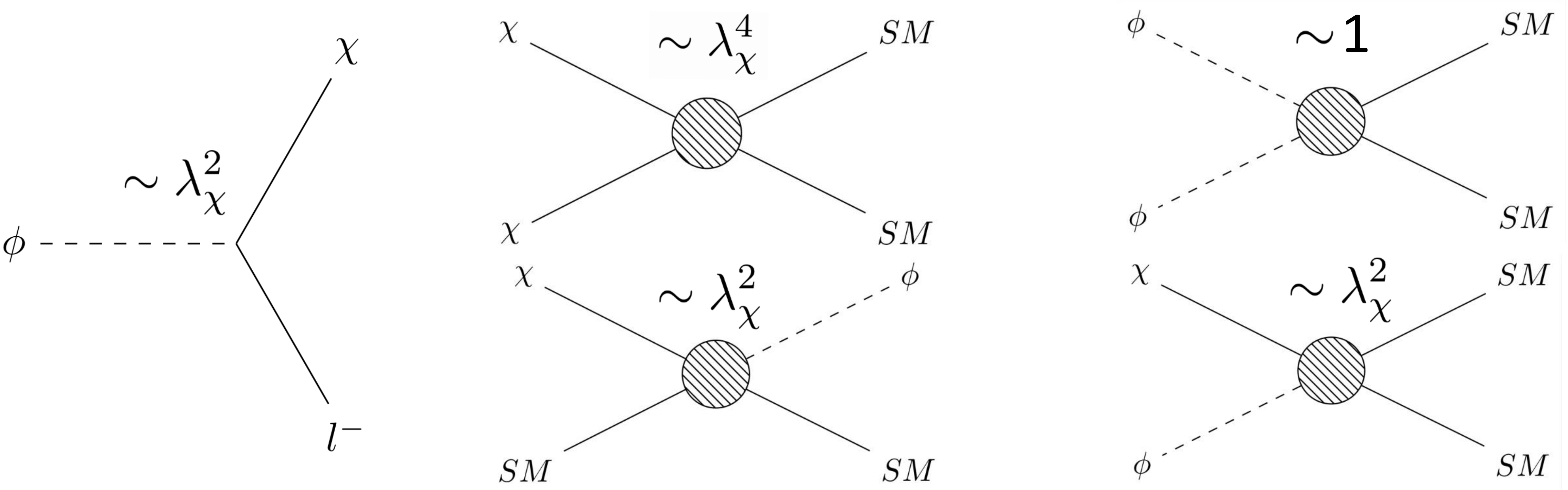
$$\frac{dn_a}{dt} + 3Hn_a = \Gamma_{ab\to cd}\left\{\frac{n_c n_d}{n_c^{eq} n_d^{eq}} - \frac{n_a n_b}{n_a^{eq} n_b^{eq}}\right\}$$

SIMPLIFIED LEPTOPHILIC DM MODEL

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{2}\bar{\chi}\gamma^{\mu}\partial_{\mu}\chi - \frac{m_{\chi}}{2}\bar{\chi}\chi + (D_{\mu}\phi)^{\dagger}\, D^{\mu}\phi - m_{\phi}^{2}|\phi|^{2} - \lambda_{\chi}\phi\bar{\chi}l_{R} - \lambda_{H}H^{\dagger}H\phi^{\dagger}\phi + h.c.$$

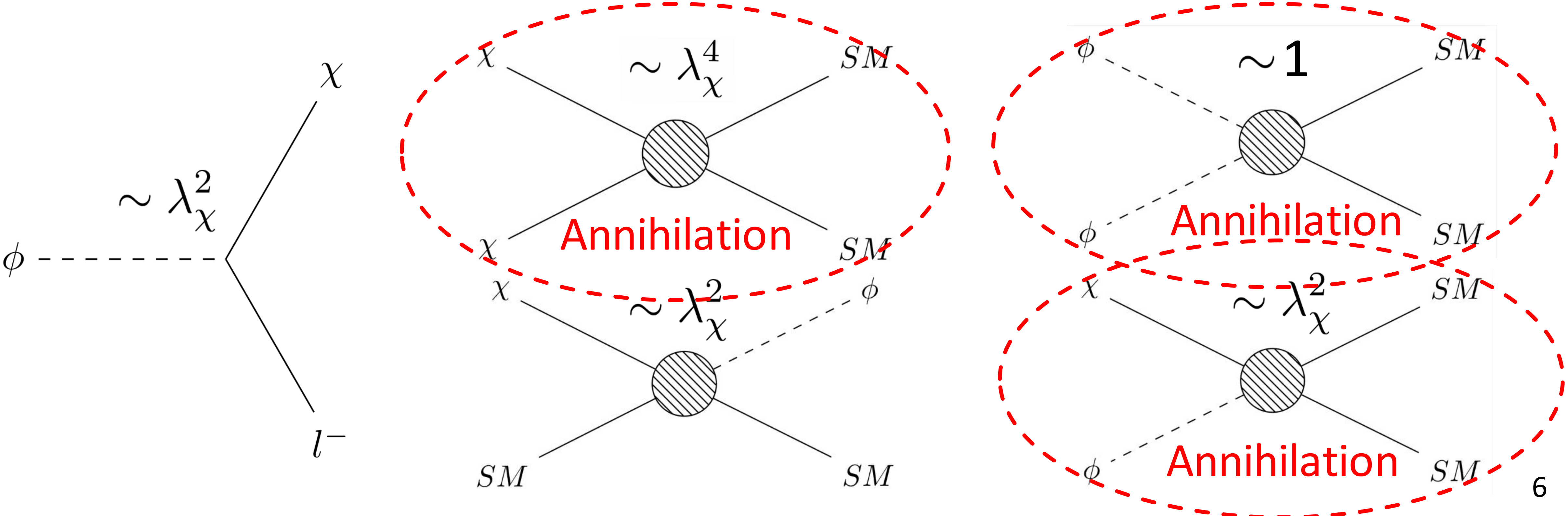
SIMPLIFIED LEPTOPHILIC DM MODEL

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{2}\bar{\chi}\gamma^{\mu}\partial_{\mu}\chi - \frac{m_{\chi}}{2}\bar{\chi}\chi + (D_{\mu}\phi)^{\dagger}\, D^{\mu}\phi - m_{\phi}^{2}|\phi|^{2} - \lambda_{\chi}\phi\bar{\chi}l_{R} - \lambda_{H}H^{\dagger}H\phi^{\dagger}\phi + h.c.$$



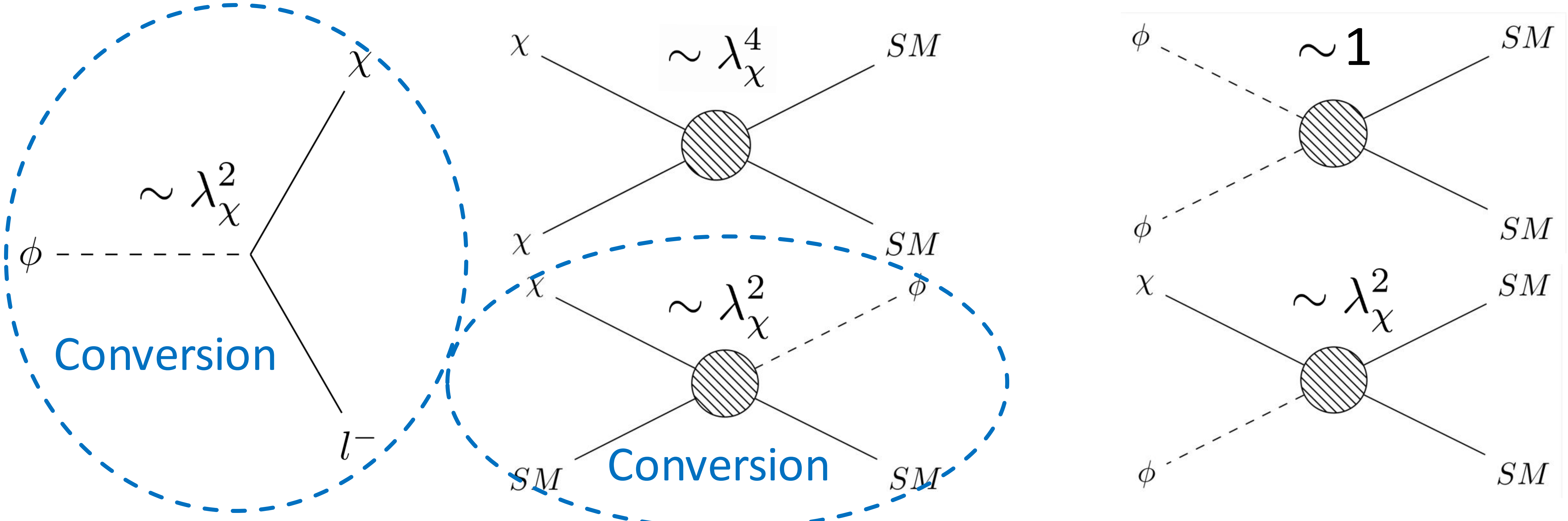
SIMPLIFIED LEPTOPHILIC DM MODEL

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{2}\bar{\chi}\gamma^{\mu}\partial_{\mu}\chi - \frac{m_{\chi}}{2}\bar{\chi}\chi + (D_{\mu}\phi)^{\dagger} D^{\mu}\phi - m_{\phi}^{2}|\phi|^{2} - \lambda_{\chi}\phi\bar{\chi}l_{R} - \lambda_{H}H^{\dagger}H\phi^{\dagger}\phi + h.c.$$



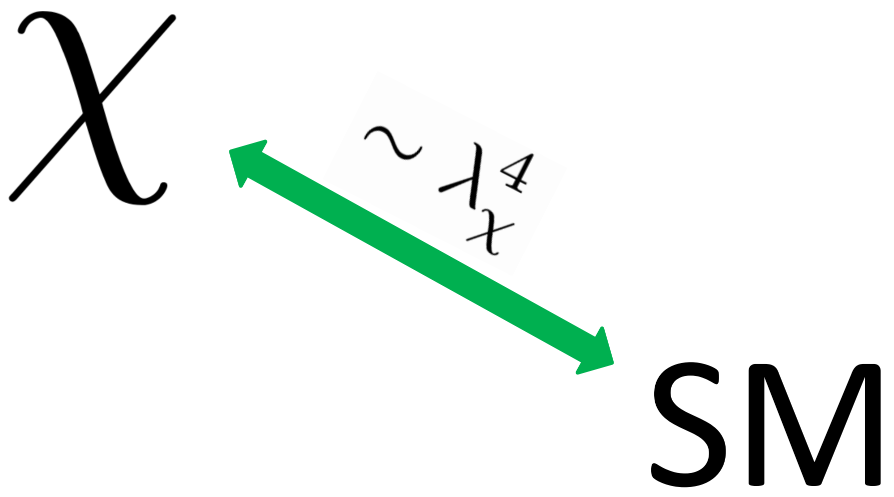
SIMPLIFIED LEPTOPHILIC DM MODEL

$$\mathcal{L} = \mathcal{L}_{SM} + \frac{1}{2}\bar{\chi}\gamma^{\mu}\partial_{\mu}\chi - \frac{m_{\chi}}{2}\bar{\chi}\chi + (D_{\mu}\phi)^{\dagger}\, D^{\mu}\phi - m_{\phi}^{2}|\phi|^{2} - \lambda_{\chi}\phi\bar{\chi}l_{R} - \lambda_{H}H^{\dagger}H\phi^{\dagger}\phi + h.c.$$

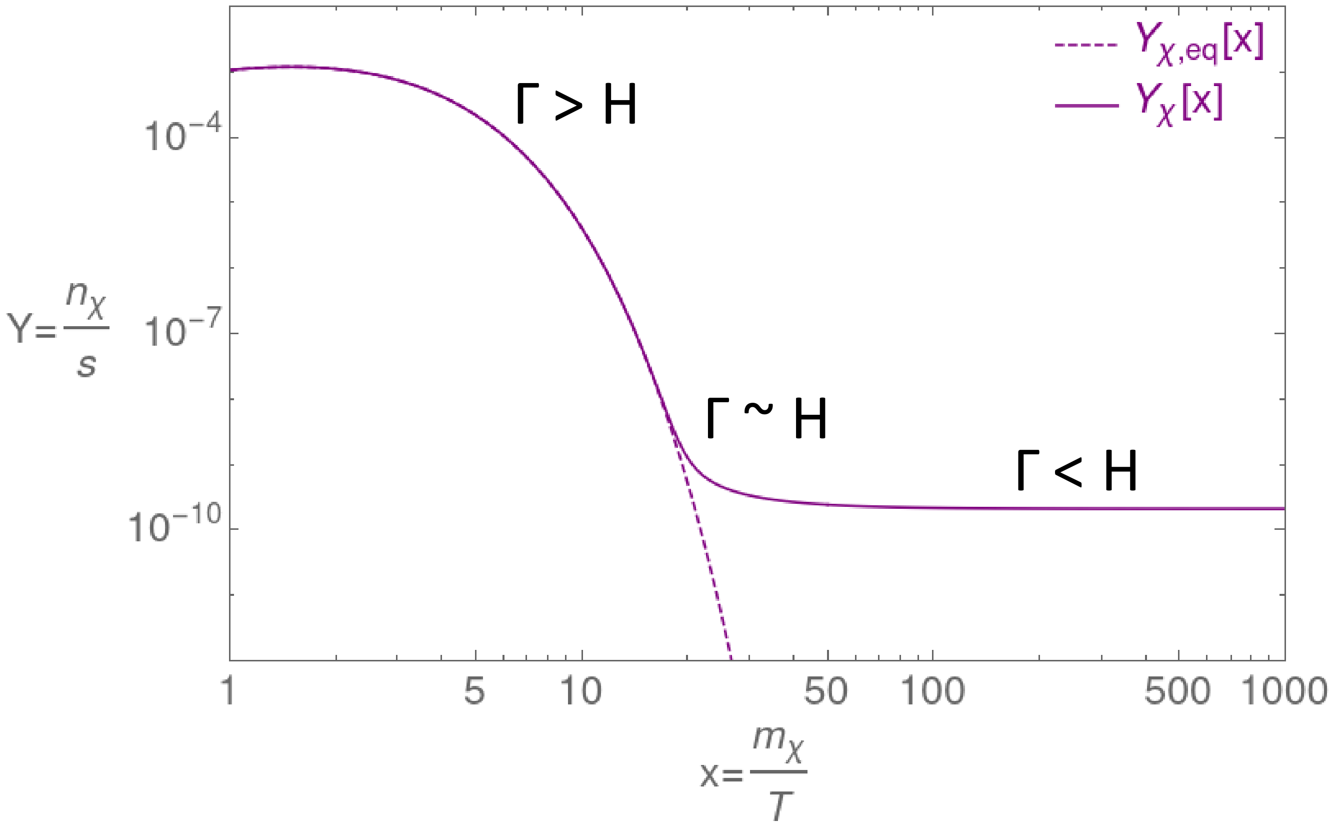


DARK MATTER PRODUCTION MECHANISMS

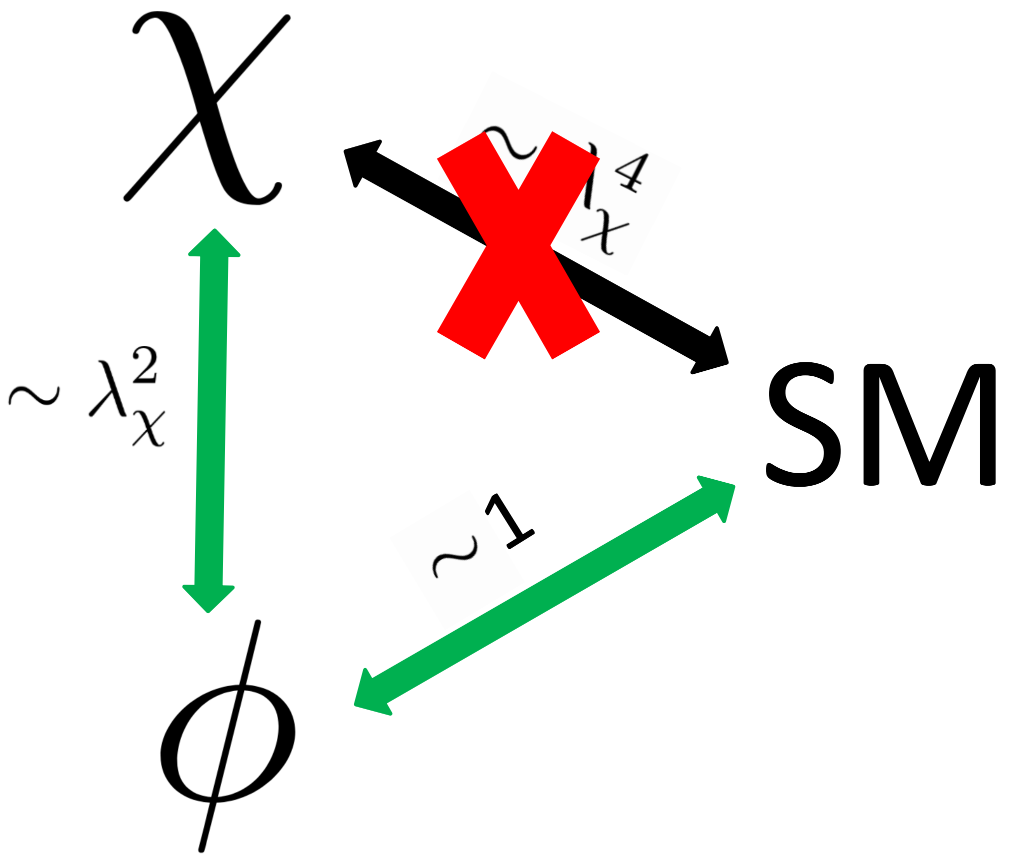
DARK MATTER FREEZE-OUT



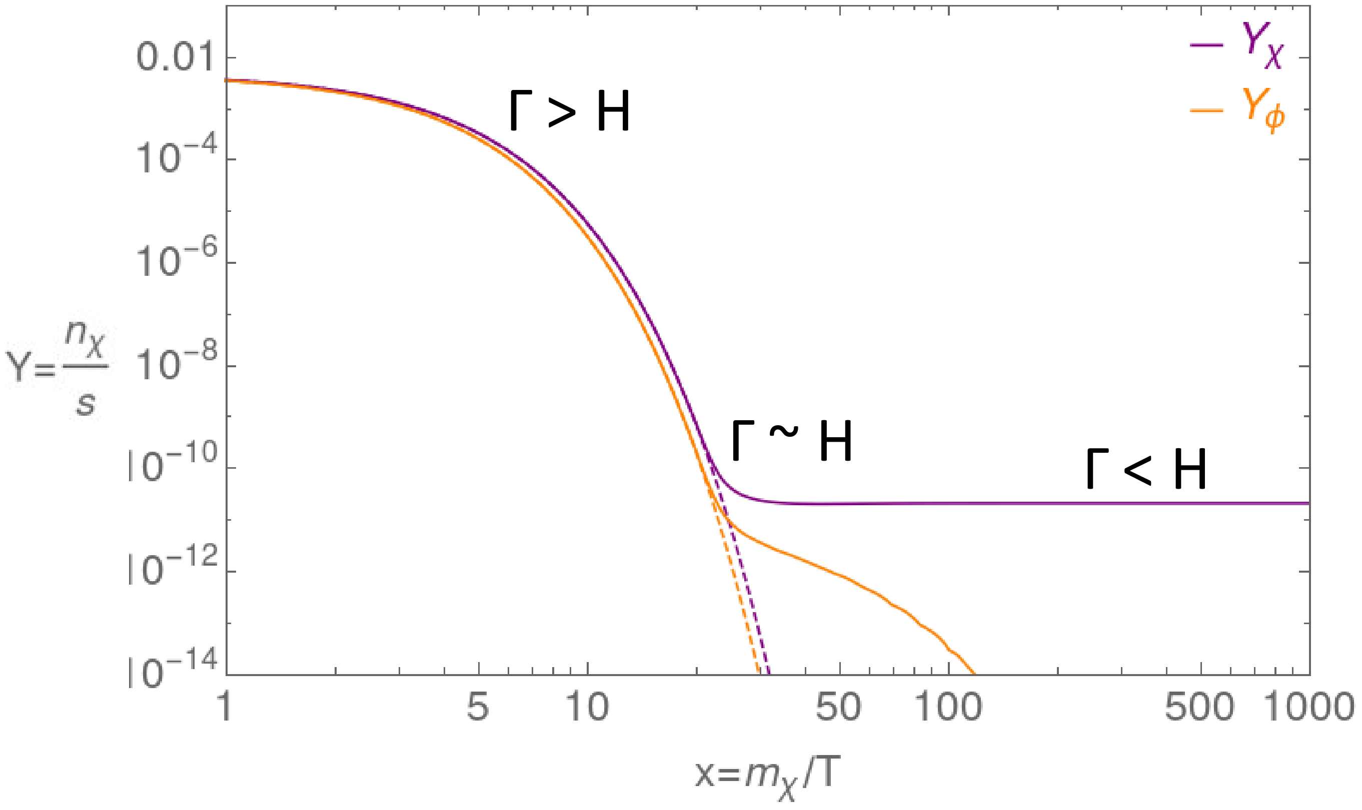
$\lambda_\chi = 5 \cdot 10^{-1}$



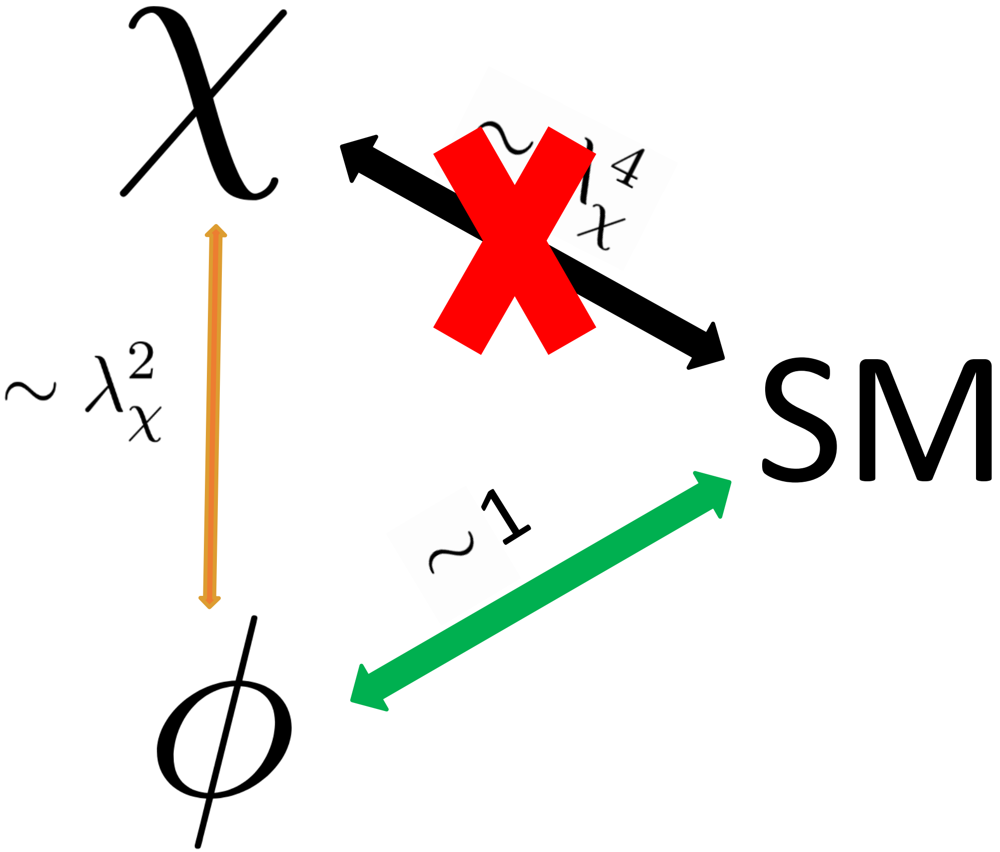
MEDIATOR DRIVEN FREEZE-OUT



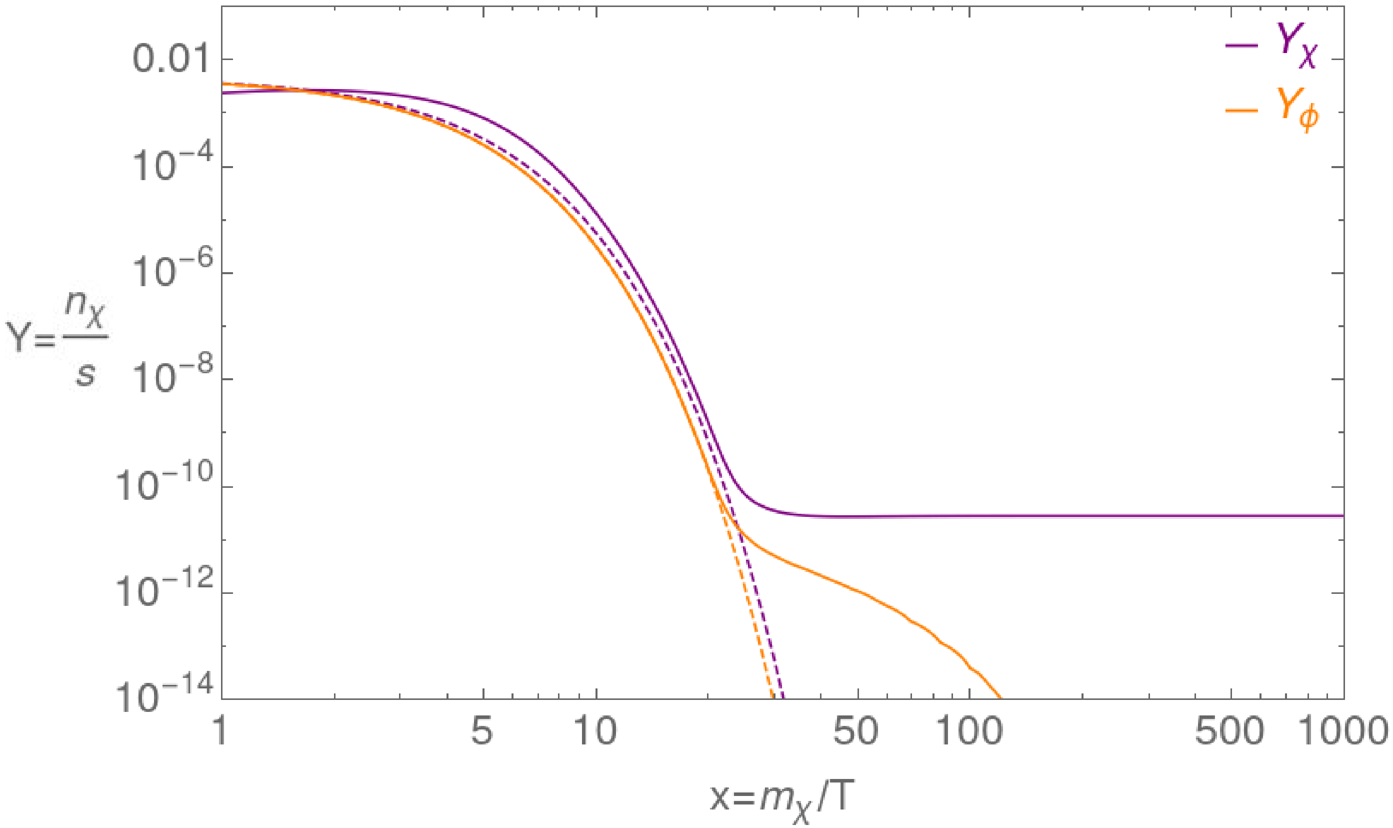
$\lambda_\chi = 10^{-4}$



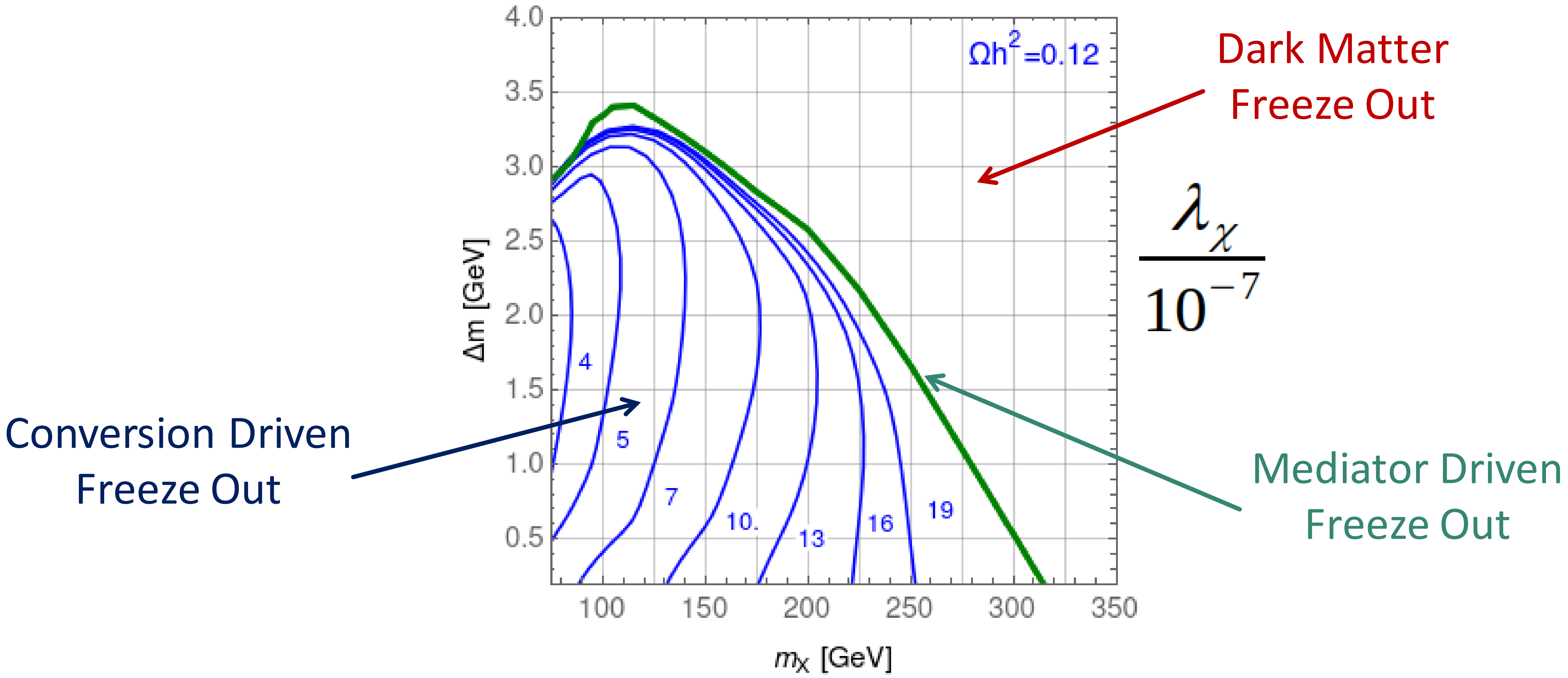
CONVERSION DRIVEN FREEZE-OUT



$\lambda_\chi = 5 \cdot 10^{-7}$



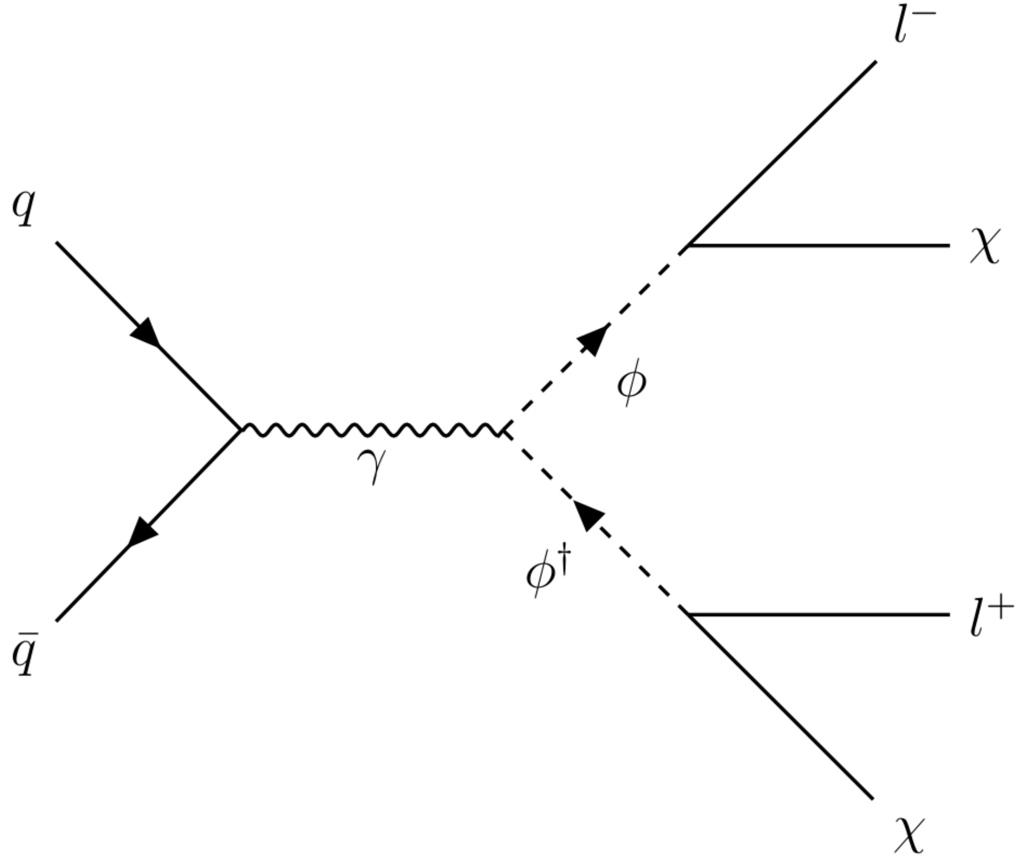
VIABLE PARAMETER SPACE FOR CONVERSION DRIVEN FREEZE OUT



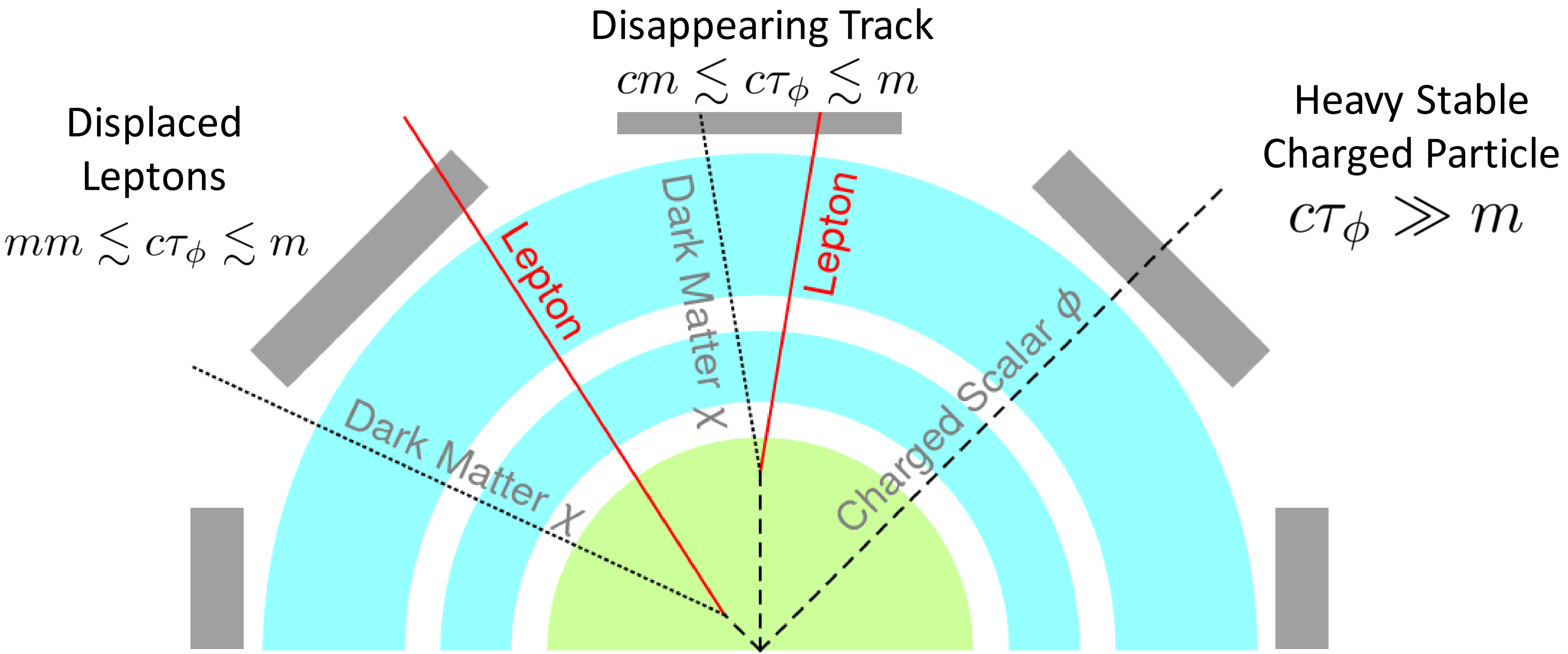
$$\frac{\lambda_\chi}{10^{-7}}$$

LONG LIVED COLLIDER SIGNATURES

LONG LIVED COLLIDER SIGNATURES



LONG LIVED COLLIDER SIGNATURES



COLLIDER CONSTRAINTS

Heavy Stable Charged Particle

Dashed: CMS @ 8 TeV

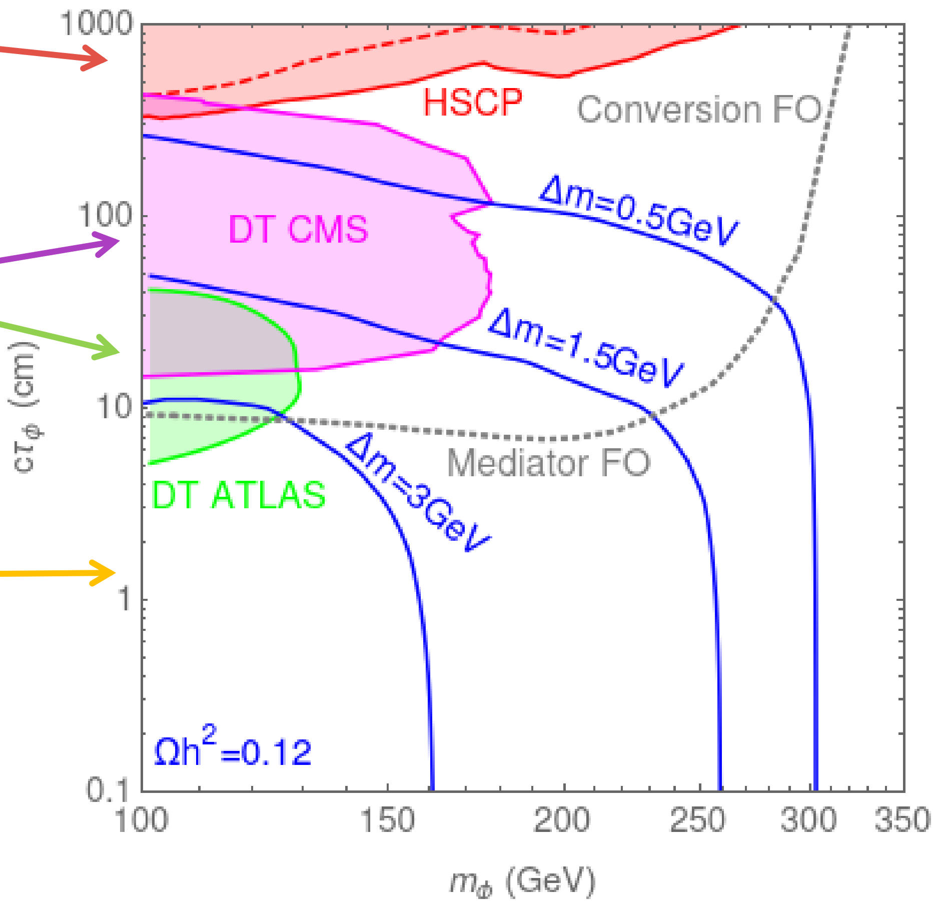
Solid: CMS @ 13 TeV

Disappearing Track

CMS and ATLAS @ 13 TeV

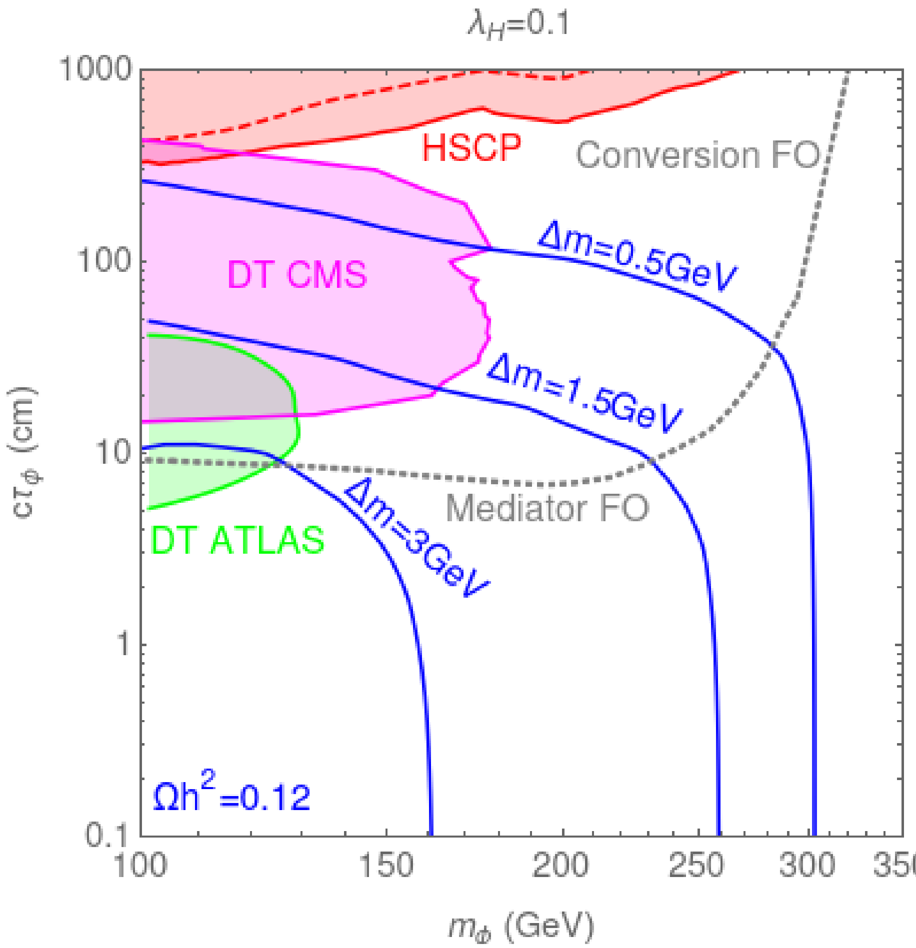
Displaced Leptons

CMS and ATLAS @ 8 TeV and 13 TeV



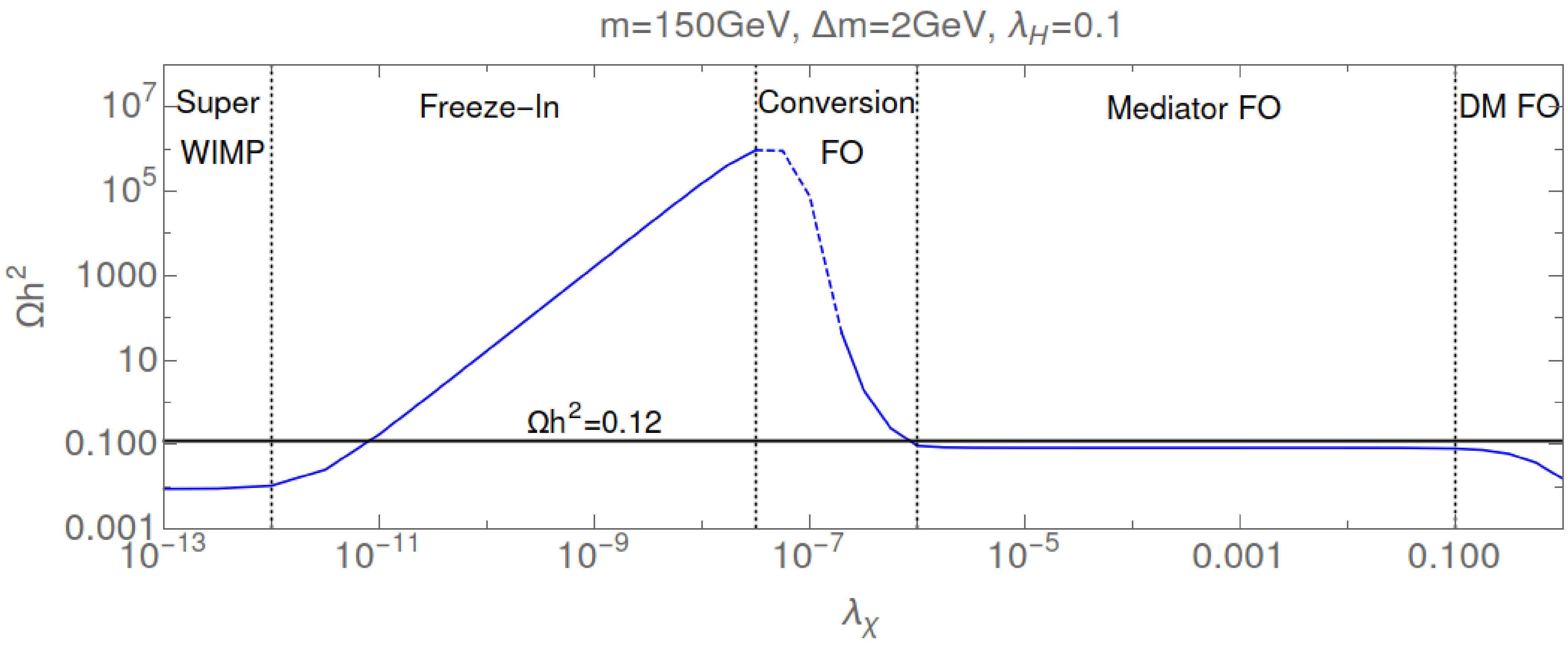
SUMMARY

- Leptophilic dark matter model
- Feebly interacting dark matter
- Novel production mechanism
- Long lived particle signatures at colliders

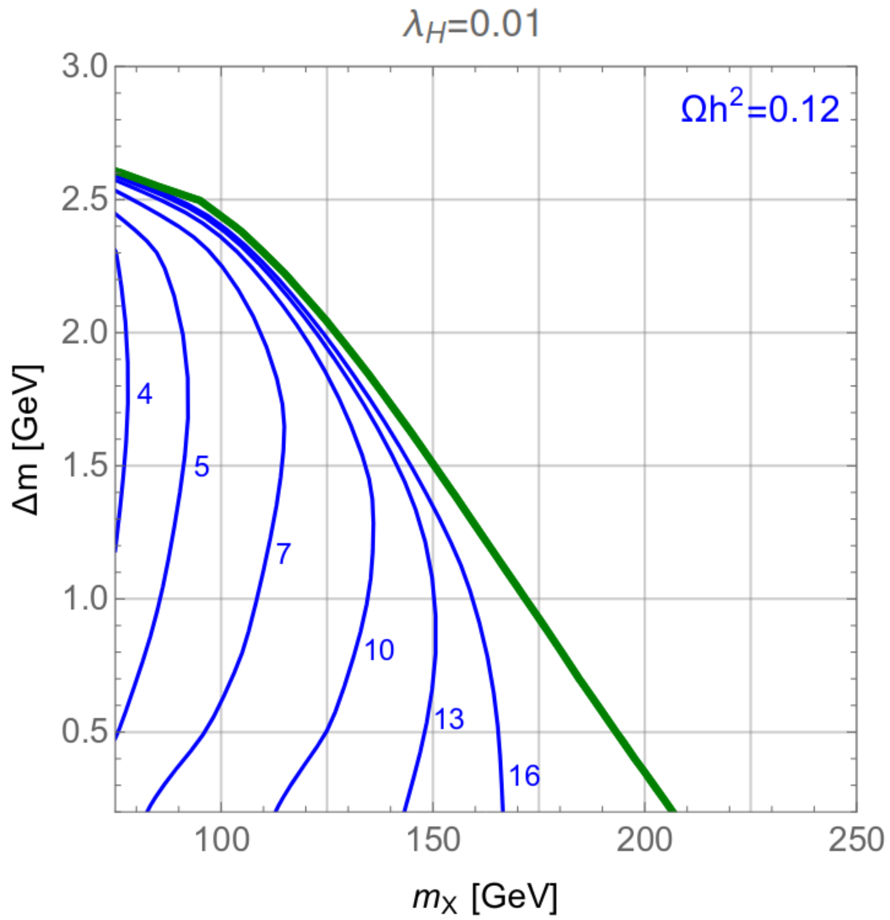


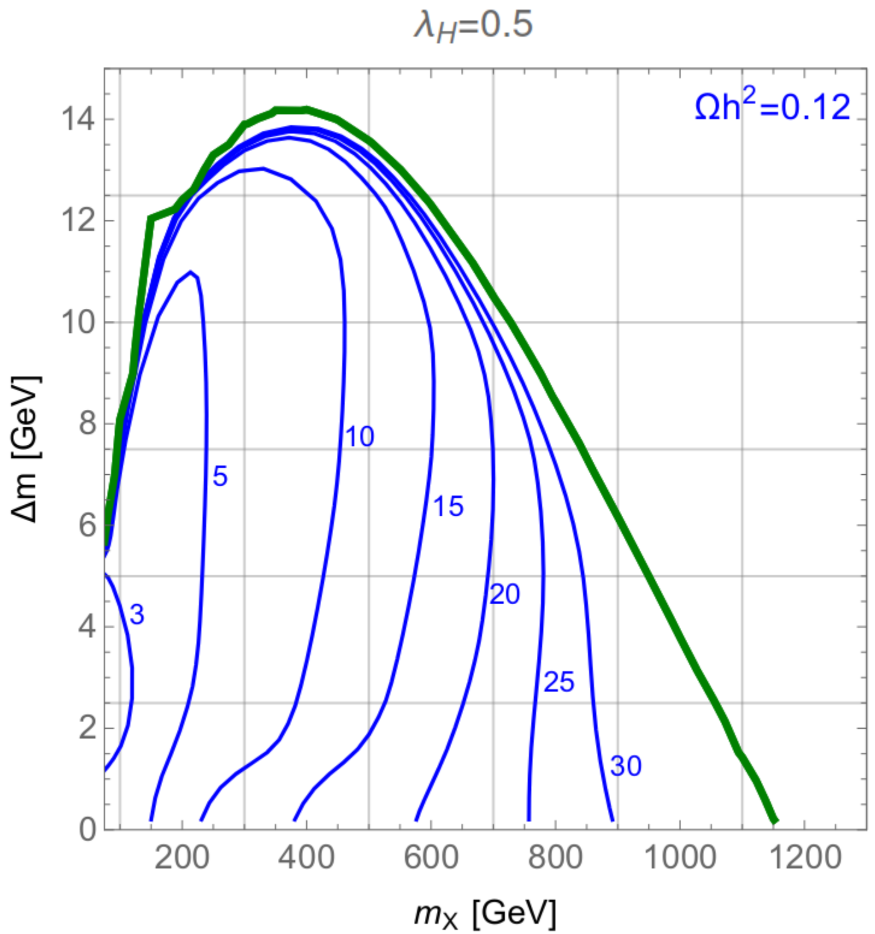
BACK-UP SLIDES

DARK MATTER PRODUCTION

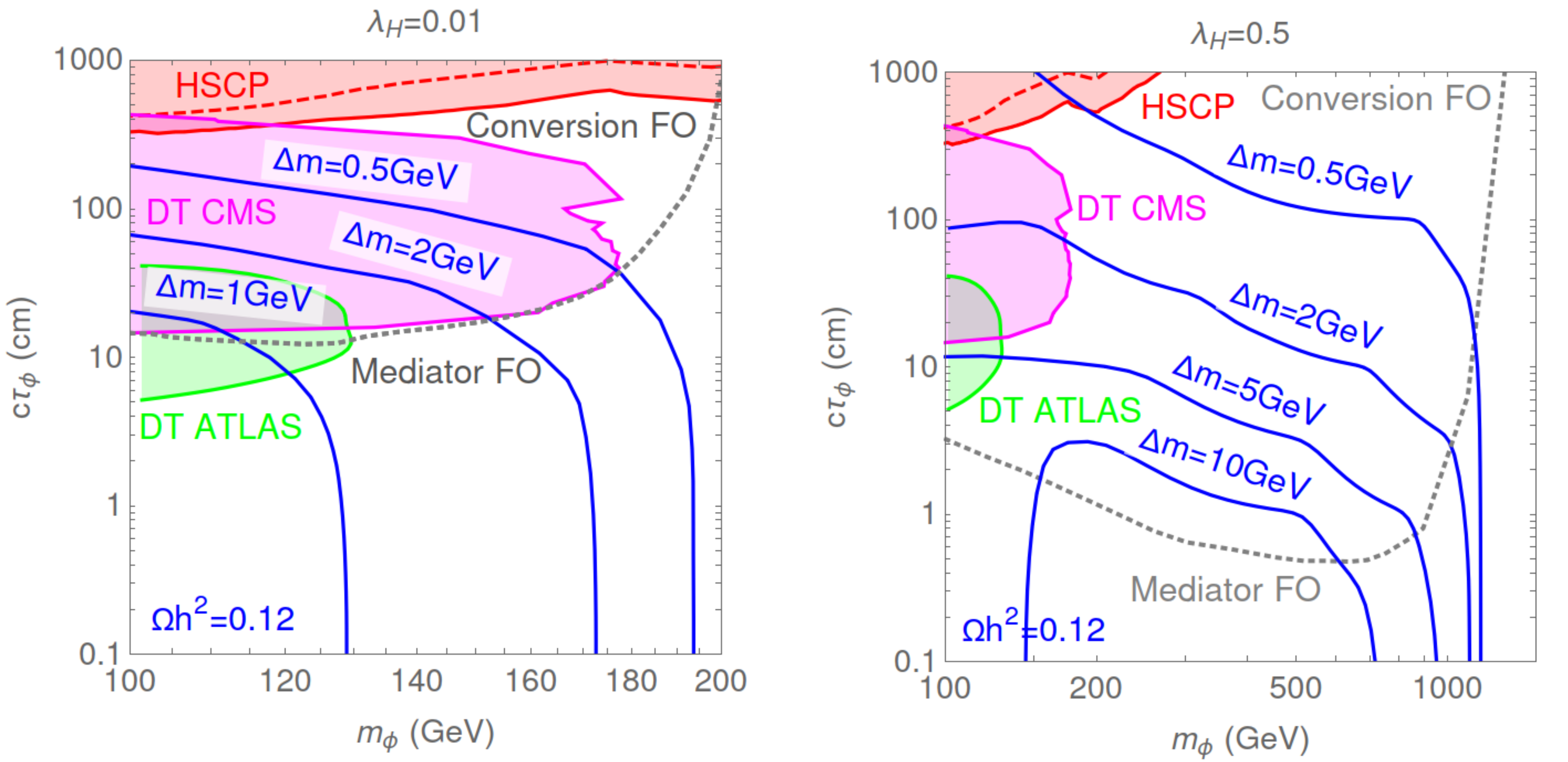


VIABLE PARAMETER SPACE FOR CONVERSION DRIVEN FREEZE OUT

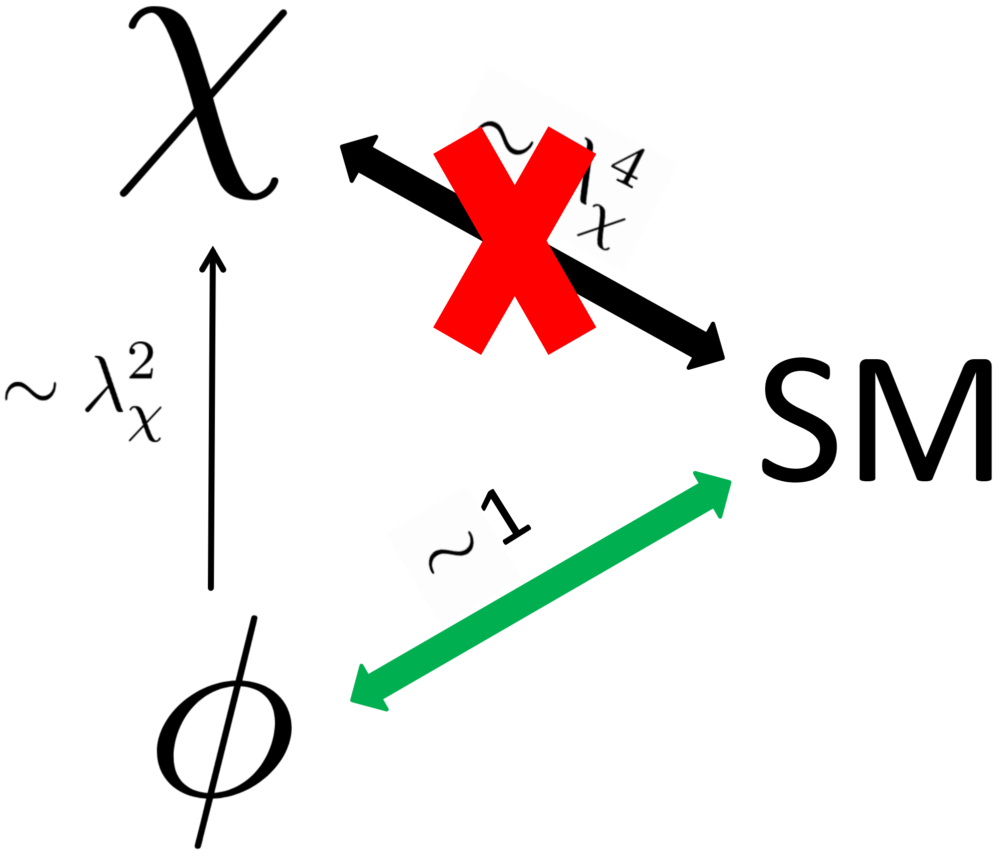




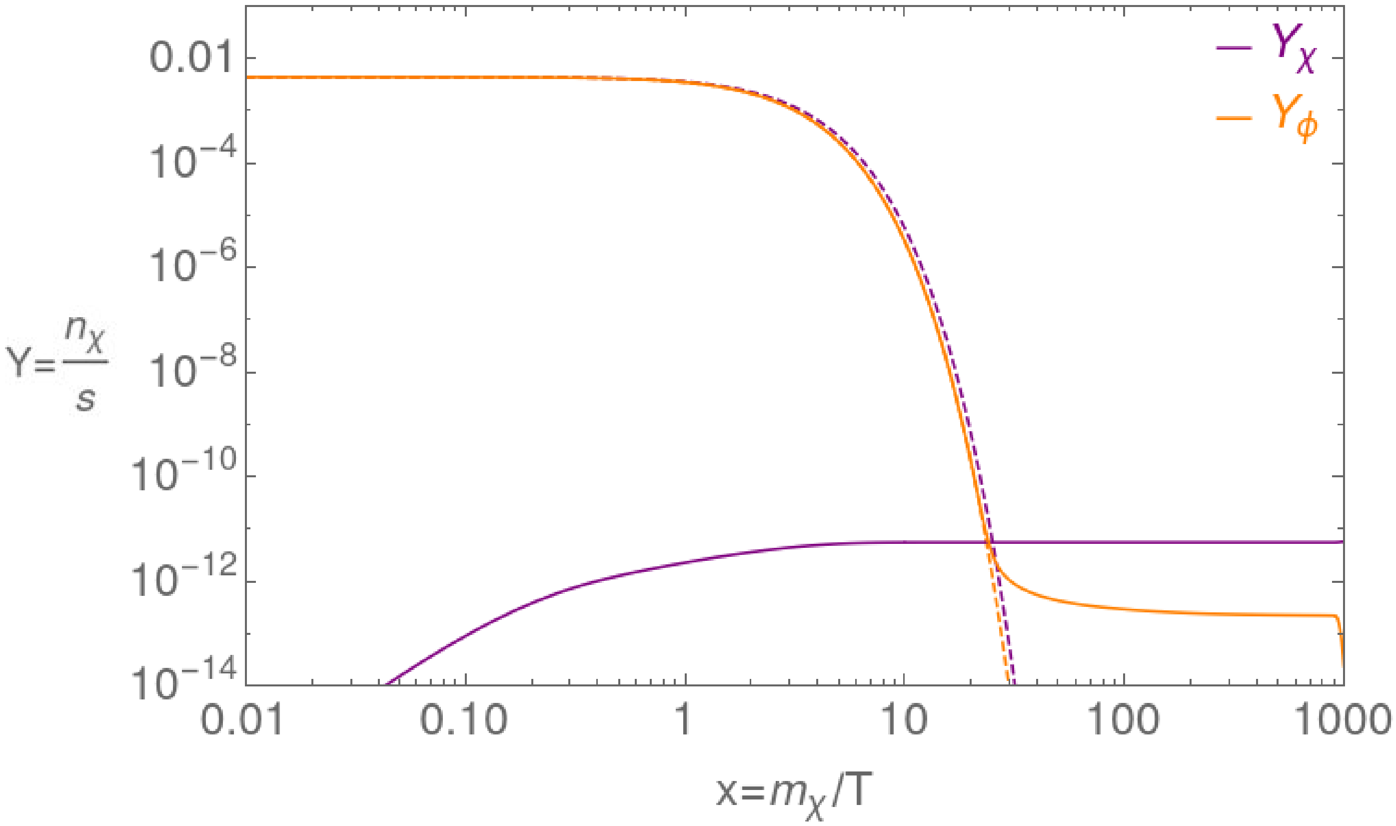
COLLIDER CONSTRAINTS



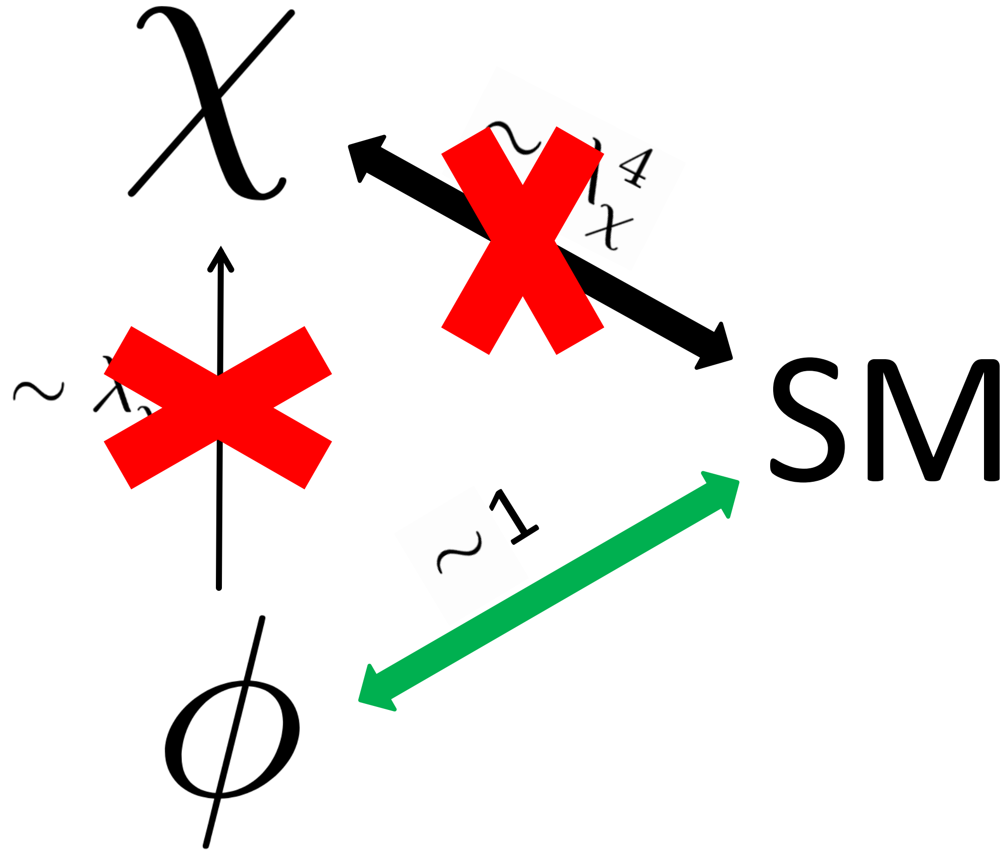
FREEZE-IN



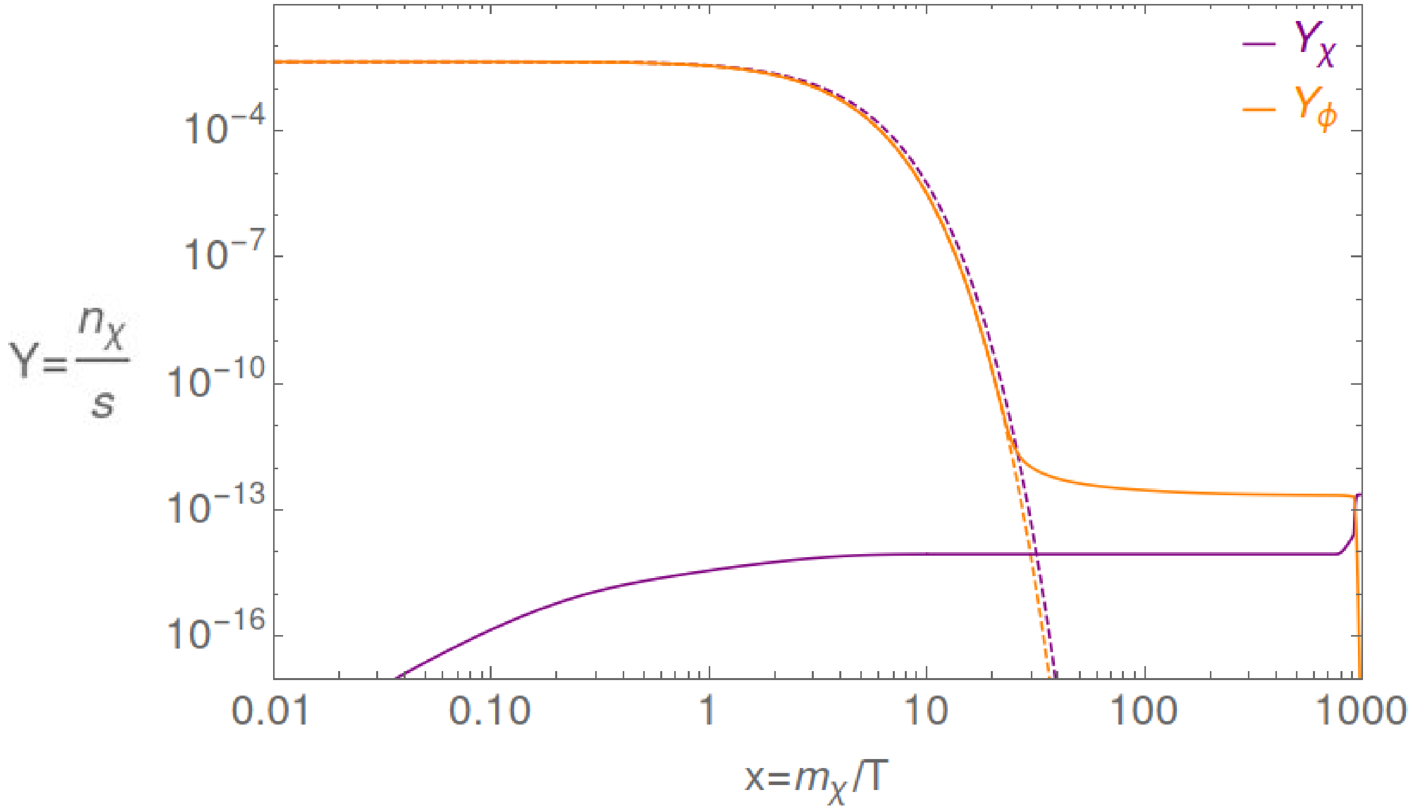
$\lambda_\chi = 10^{-11}$



SUPERWIMP



$\lambda_\chi = 10^{-13}$



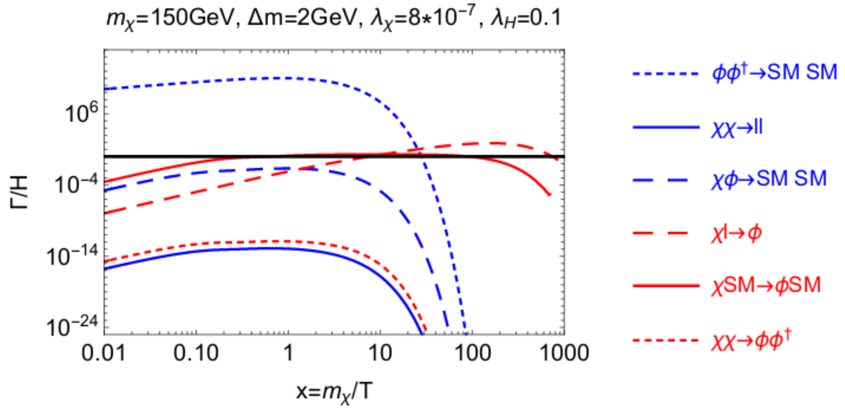
COANNIHILATION DRIVEN FREEZE-OUT

$$\frac{dY_{DM}}{dx} = \frac{s\langle \sigma v_{\text{eff}} \rangle}{Hx} \left(Y_{DM}^2 - Y_{DM,eq}^2 \right)$$

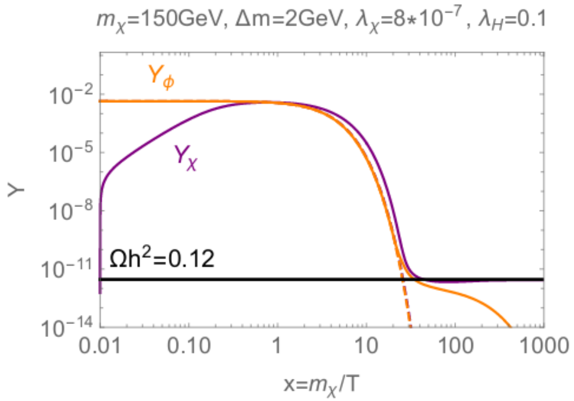
$$\langle \sigma v_{\text{eff}} \rangle \quad \simeq \quad \frac{1}{g_{\text{eff}}^2} \sum_{ij} r_i r_j \langle \sigma v \rangle_{ij} \quad \text{with} \quad g_{\text{eff}} = \sum_i r_i$$

$$\text{and} \quad r_i = g_i (1 + \Delta_i)^{3/2} \exp(-x_f \Delta_i) \,.$$

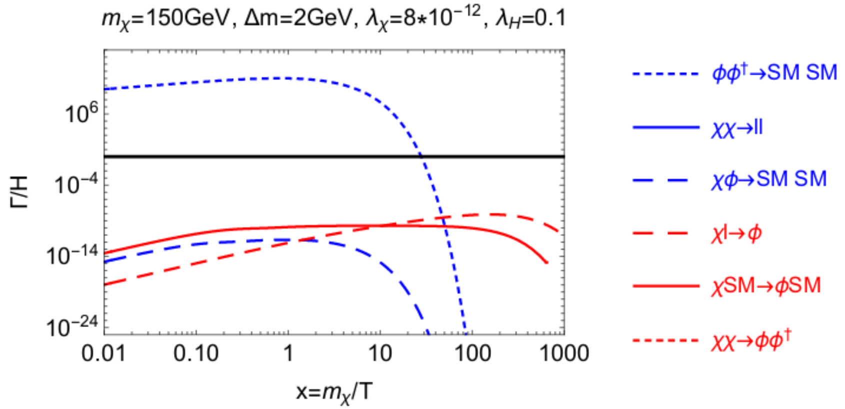
RATE COMPARISON

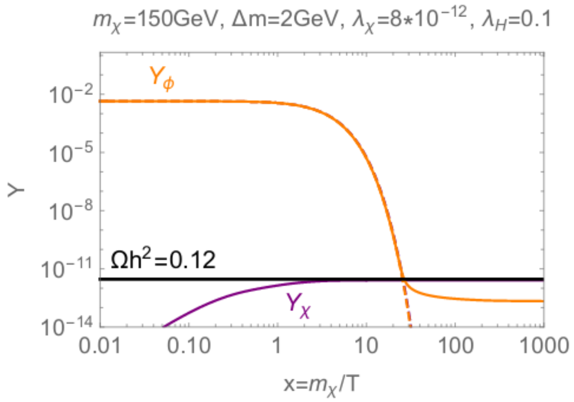


(a)

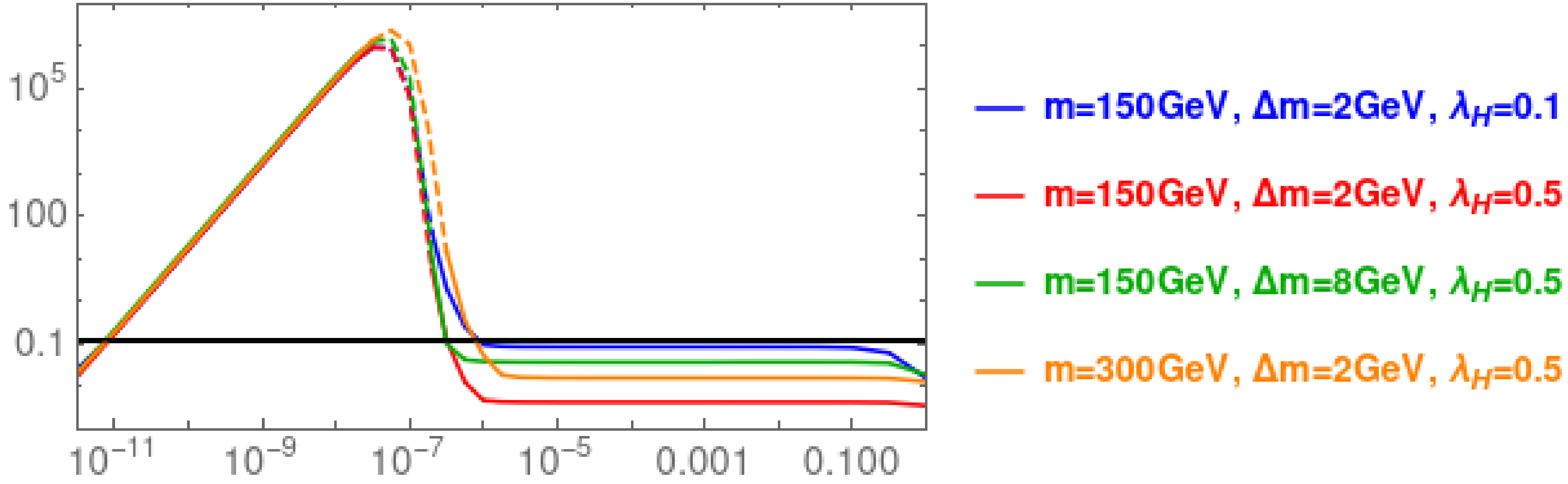


(b)





DEPENDENCE ON PARAMETERS



BOLTZMANN EQUATIONS

$$\frac{dY_\chi}{dx} = \frac{-2}{Hxs}\left[\gamma_{\chi\chi}\left(\frac{Y_\chi^2}{Y_{\chi,eq}^2} - 1\right) + \gamma_{\chi\phi}\left(\frac{Y_\chi Y_\phi}{Y_{\chi,eq}Y_{\phi,eq}} - 1\right) + \gamma_{\chi\to\phi}\left(\frac{Y_\chi}{Y_{\chi,eq}} - \frac{Y_\phi}{Y_{\phi,eq}}\right) + \gamma_{\chi\chi\to\phi\phi^\dagger}\left(\frac{Y_\chi^2}{Y_{\chi,eq}^2} - \frac{Y_\phi^2}{Y_{\phi,eq}^2}\right)\right]$$

$$\frac{dY_\phi}{dx} = \frac{-2}{Hxs}\left[\gamma_{\phi\phi^\dagger}\left(\frac{Y_\phi^2}{Y_{\phi,eq}^2} - 1\right) + \gamma_{\chi\phi}\left(\frac{Y_\chi Y_\phi}{Y_{\chi,eq}Y_{\phi,eq}} - 1\right) - \gamma_{\chi\to\phi}\left(\frac{Y_\chi}{Y_{\chi,eq}} - \frac{Y_\phi}{Y_{\phi,eq}}\right) - \gamma_{\chi\chi\to\phi\phi^\dagger}\left(\frac{Y_\chi^2}{Y_{\chi,eq}^2} - \frac{Y_\phi^2}{Y_{\phi,eq}^2}\right)\right]$$

COLLIDER SEARCHES

- Heavy Stable Charged Particles: CMS @ 13 TeV and 12.9 fb^{-1}
- Disappearing Tracks: CMS @ 13 TeV and 38.4 fb^{-1}
- Disappearing Tracks: ATLAS @ 13 TeV and 36.1 fb^{-1}
- Displaced Leptons: CMS @ 8 TeV and 19.7 fb^{-1}
- Displaced Leptons: CMS @ 13 TeV and 2.6 fb^{-1}