BelleII excess, Muon g-2 & Thermal WIMP DM in $U(1)_{L_\mu - L_\tau}$ Model

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Based on arXiv: 2401.10112

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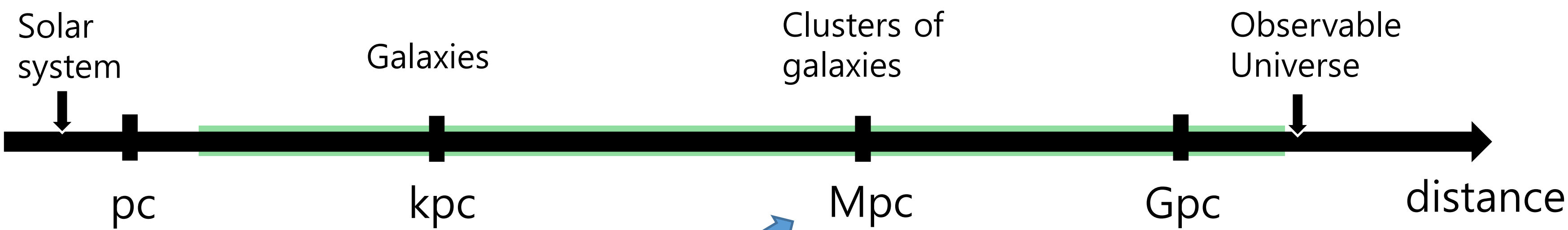
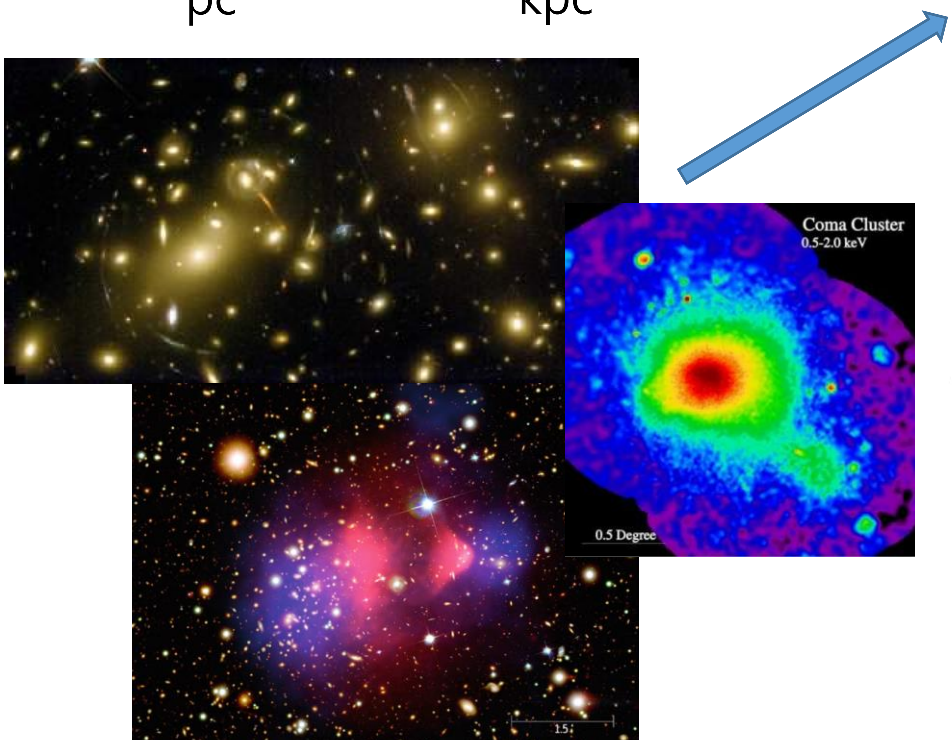
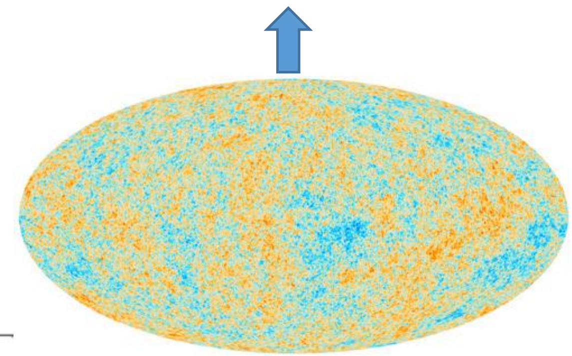
High1Workshop
2024. 1. 23

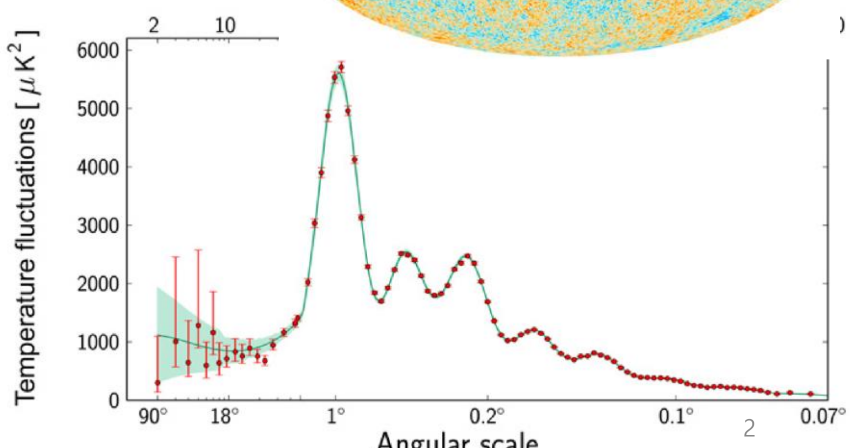
Evidences – Dark Matter

- There are undeniable evidences for dark matter in a wide range of distance scales





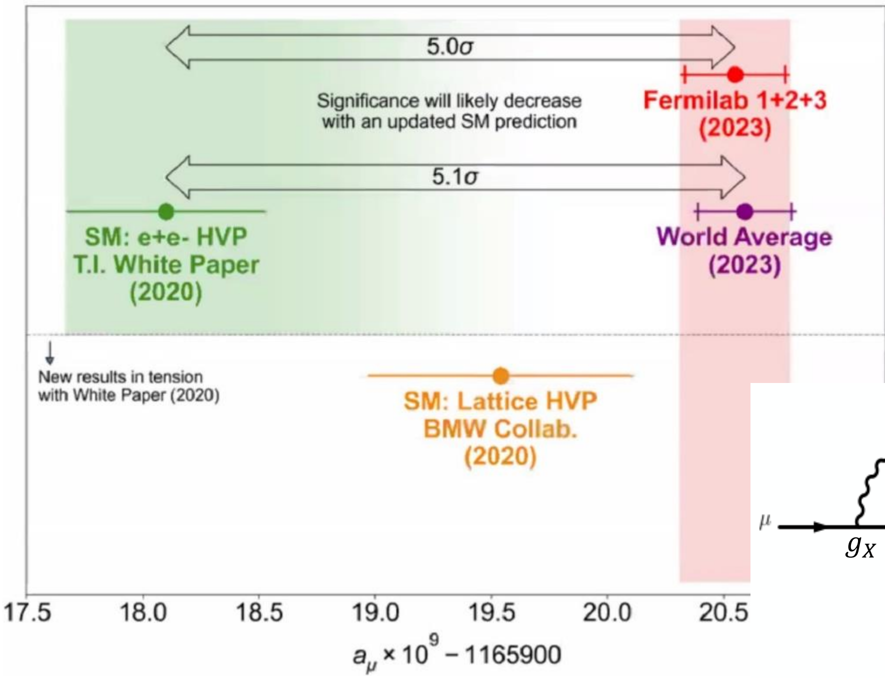


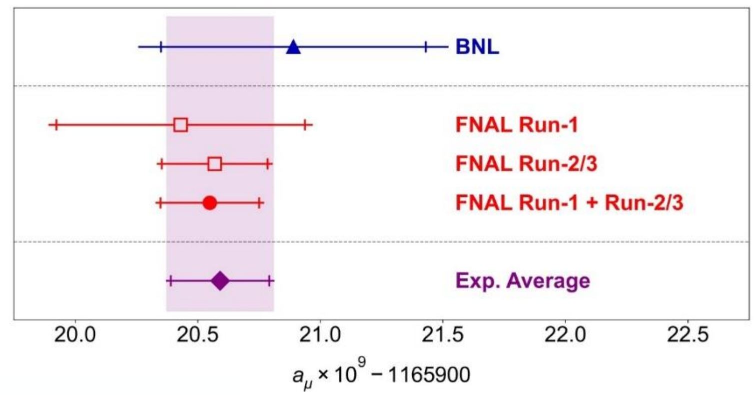


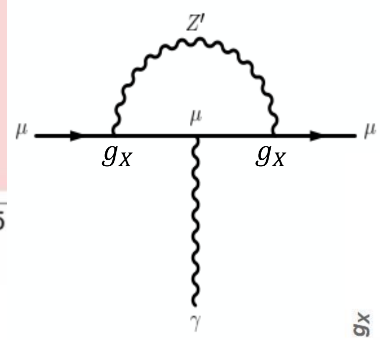
Evidences – muon g-2

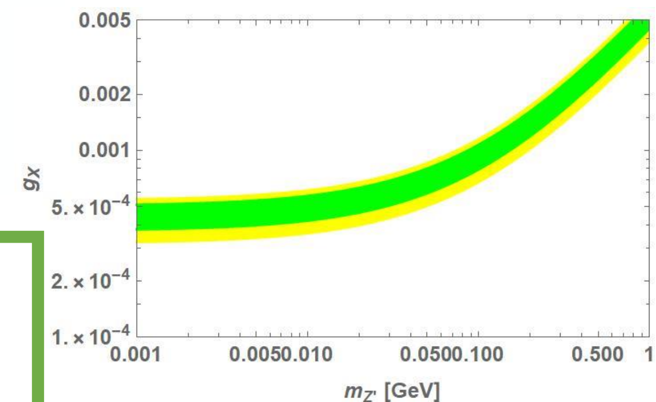
Muon g-2 collaboration, PRL 2023

- Muon g-2 experiment improves the precision of their previous result by a factor of 2









S. Baek, Deshpande, He, P. Ko, 2001
S. Beak, P. Ko, 2008
…

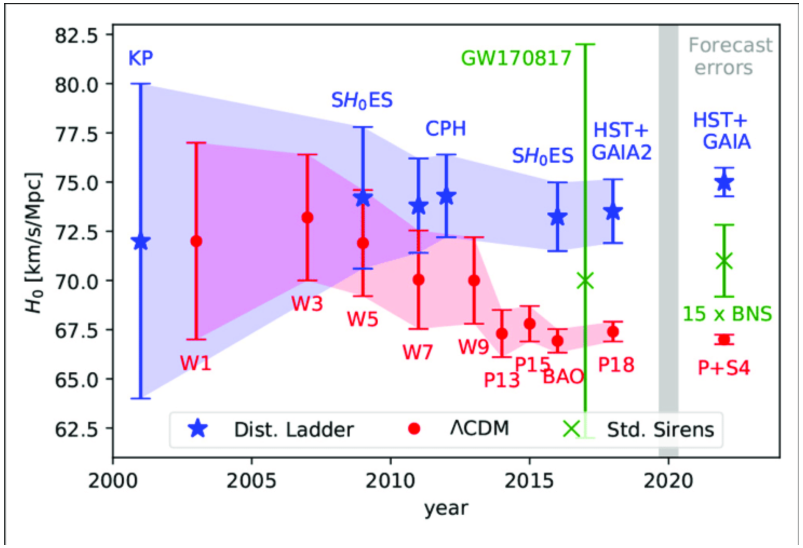
$$\Delta a_\mu = \frac{g_X^2}{4\pi^2}\int_0^1 dx \frac{2m_\mu^2 x^2(1-x)}{x^2 m_\mu^2 + (1-x)m_{Z'}^2}$$

Evidences – Hubble tension

- Large difference between early and late H_0 measurement
  - $H_0 = 73.2 \pm 1.3\ \mathrm{kms^{-1}Mpc^{-1}}$
  - $H_0 = 67.4 \pm 0.5\ \mathrm{kms^{-1}Mpc^{-1}}$

- The discrepancy either arises because
  - Our distance measurements are incorrect
  - Cosmological model we use to fit all those distances is incorrect

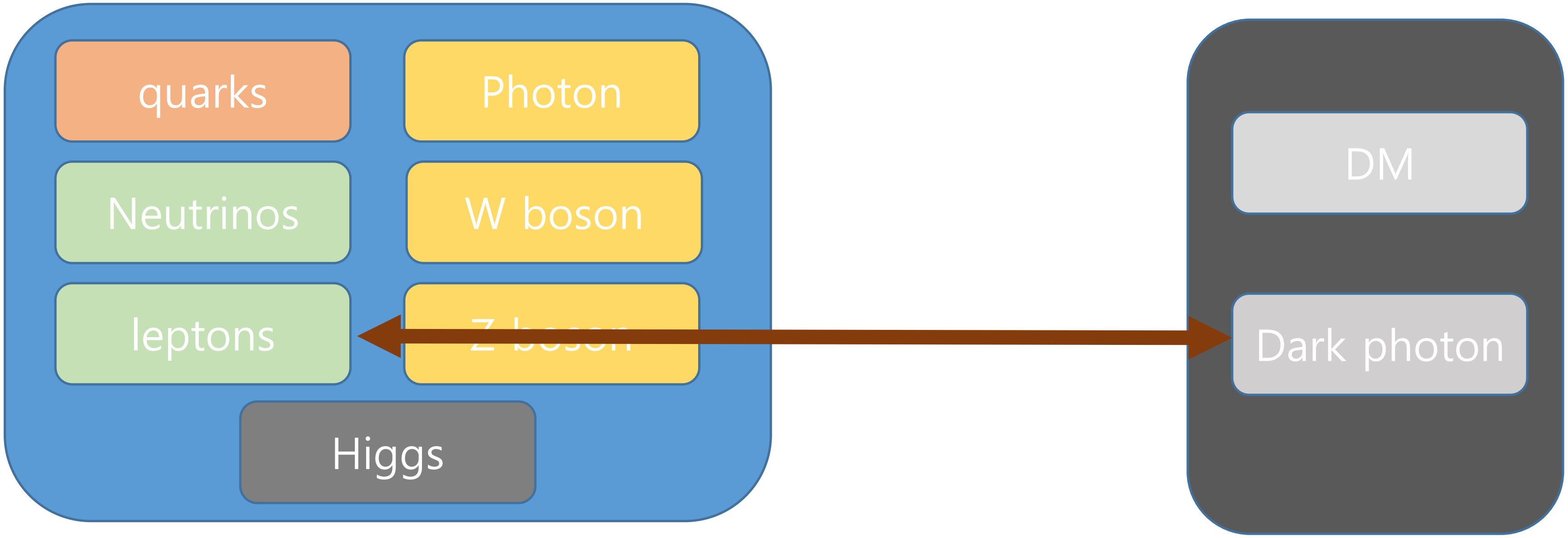
  - ΔG_N vs ΔN_{eff}



P. Shah et al, AAR 2021

$U(1)_{L_\mu - L_\tau}$-charged DM

- $U(1)_{dark} \equiv U(1)_{L_\mu - L_\tau}$



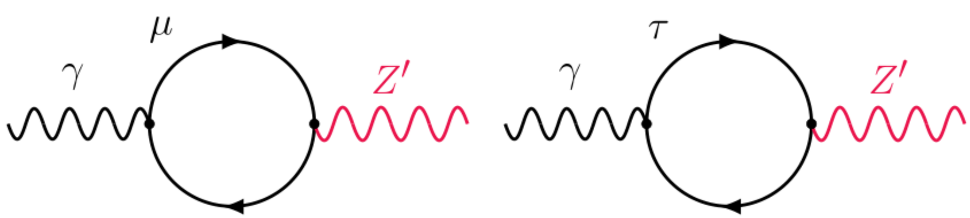
- Let's call Z', $U(1)_{L_\mu - L_\tau}$ gauge boson, dark photon since it couple to DM

Leptophilic Z' model

- Possible to gauge one of the differences of two lepton-flavor numbers

X. G. He et al, PRD 1991

  - $L_e - L_\mu, L_\mu - L_\tau$: anomaly free without extension of fermion contents
  - Symmetry including L_e is strongly constrained
  - The simplest anomaly free U(1) extension that couple to the SM fermions directly

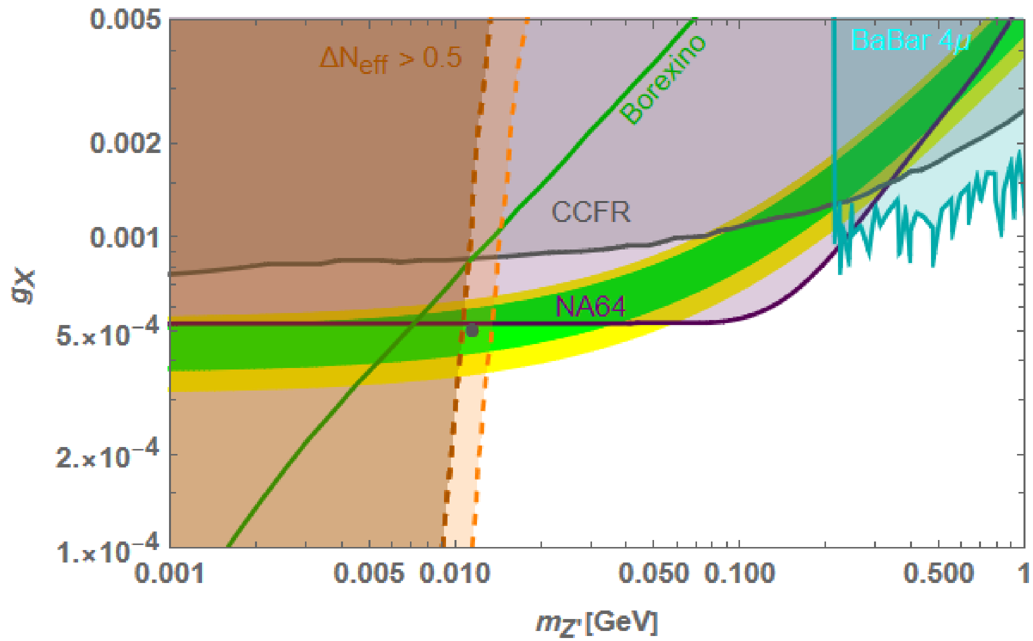
- No kinetic mixing between Z' and B @ high-energy
  - Kinetic mixing is generated through
  - 

  - $\epsilon = -\frac{e g_{\mu-\tau}}{2\pi^2} \int_0^1 dx\, x(1-x) \log\left[\frac{m_\tau^2 - x(1-x)q^2}{m_\mu^2 - x(1-x)q^2}\right] \xrightarrow[m_\mu \gg q]{} -\frac{e g_{\mu-\tau}}{12\pi^2} \log\frac{m_\tau^2}{m_\mu^2} \simeq -\frac{g_{\mu-\tau}}{70}.$

Leptophilic Z' model

M. Escudero et al, JHEP 2019

- ***Hubble tension***
  - Tension between early and late-time determinations of Hubble constant
  - $10 - 20\text{MeV}\ Z'$ reached thermal equilibrium in the early Universe and decays, heating the neutrino population
  - Delay the process of neutrino decoupling
  - $0.2 < \Delta N_{\text{eff}} < 0.5$: substantially relaxes the tension



In this talk

- BP : $m_{Z'} = 11.5\text{MeV},\ g_X = 5 \times 10^{-4}$

$U(1)_{L_\mu - L_\tau}$-charged DM model

- Simplest $U(1)_{L_\mu - L_\tau}$-charged fermion DM model

$$\mathcal{L} \supset \mathcal{L}_{\rm SM} - \frac{1}{4} Z'_{\alpha\beta} Z'^{\alpha\beta} + \frac{1}{2} m_{Z'}^2 Z'_\alpha Z'^\alpha + i\bar{\chi}\gamma^\alpha \partial_\alpha \chi - m_\chi \bar{\chi}\chi$$
$$+ g_X Q_\chi Z'_\alpha \bar{\chi}\gamma^\alpha \chi + g_X Z'_\alpha \sum Q_\ell \bar{\ell}\gamma^\alpha \ell$$

  - New gauge boson Z' plays a role of messenger particle between DM and the SM leptons

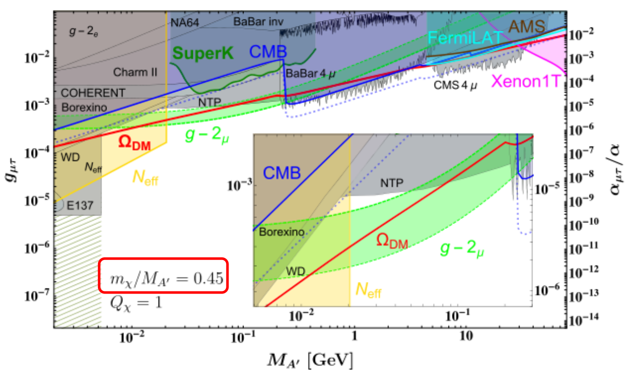
- New parameters: $\{g_X, m_{Z'}, m_\chi, Q_X\}$

- Consider Z' boson only & **$g_X \sim (3-5) \times 10^{-4}$ for the muon g-2**
  - $\chi\bar{\chi}(X\bar{X}) \to f_{SM}\bar{f}_{SM}$: dominant annihilation channels
  - $g_X \sim 10^{-4}$ is too small to get $\Omega_\chi h^2 = 0.12$

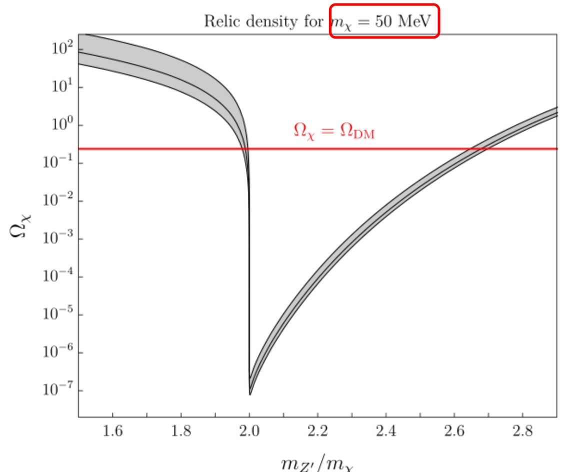
$U(1)_{L_\mu - L_\tau}$-charged DM model

- $\chi\bar{\chi}(X\bar{X}) \to Z'^* \to \nu\bar{\nu}$: dominant annihilation channels
  - $m_{Z'} \sim 2m_\chi$ with the **s-channel Z' resonance** only gives the correct relic density

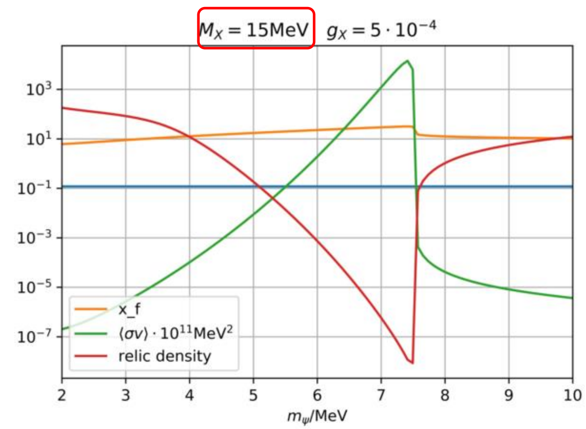
P. Foldenauer, PRD 2019



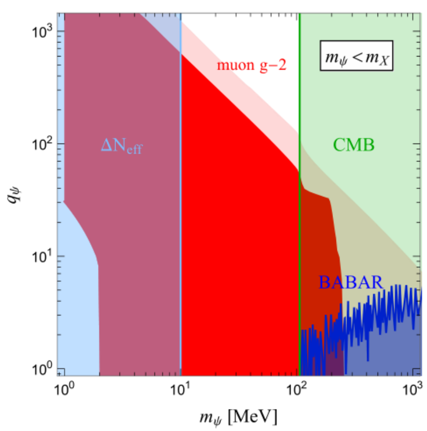
I. Holst, D. Hooper, G. Krnjaic, PRL 2022

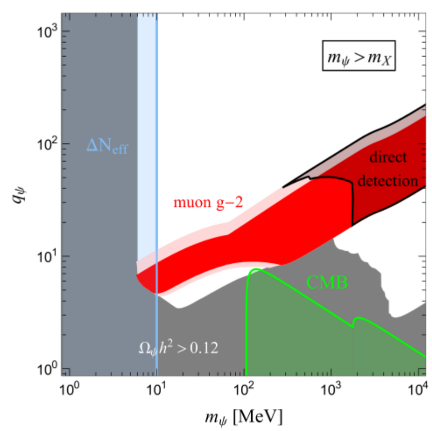


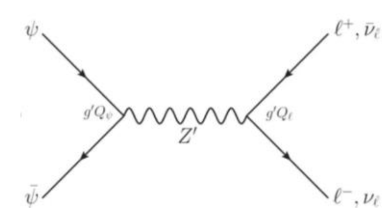
M. Drees, W. Zhao, PLB 2022



- Large DM charges **Asai, Okawa, Tsumura, JHEP 2021**







$U(1)_{L_\mu - L_\tau}$-charged DM model

• Complex scalar DM (Here X: complex scalar DM)

- $g_X \sim 10^{-4}$ is too small to get $\Omega h^2 = 0.12$
- $m_{Z'} \sim 2m_\chi$ with the s-channel Z' resonance
- sub-GeV **DM**
- No direct detection bound

ℓ^-, ν_ℓ

$\ell^+, \bar{\nu}_\ell$

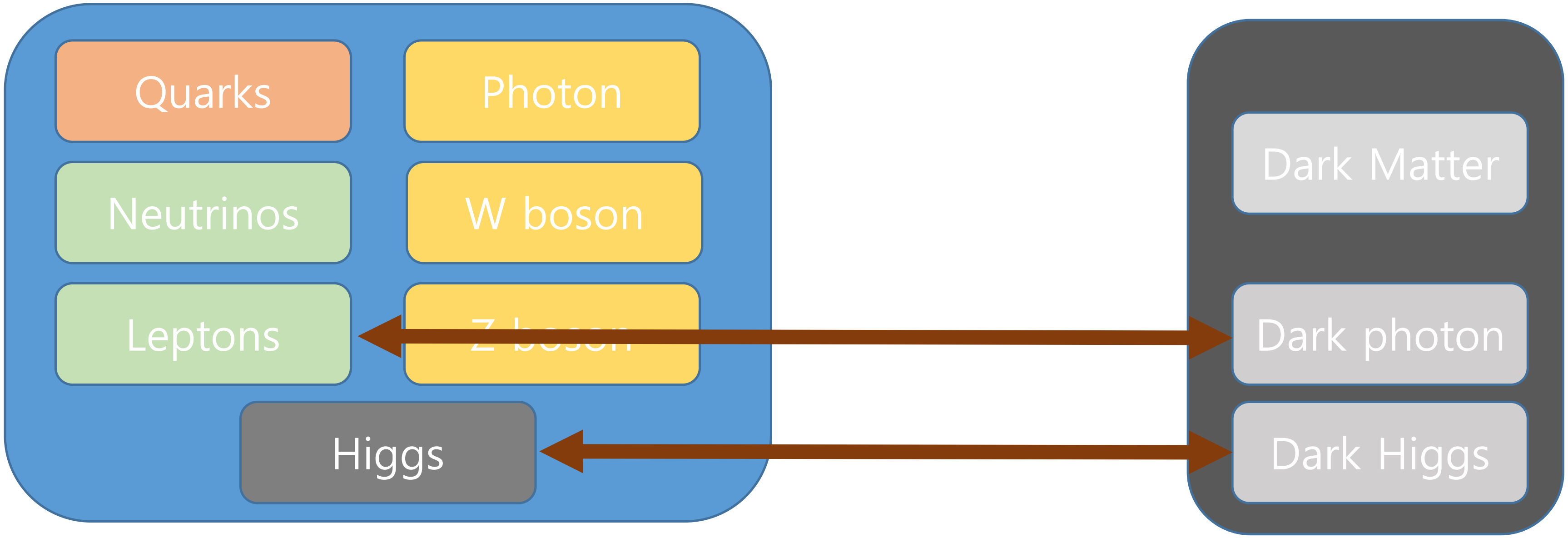
Tight correlation between DM mass and Z' mass

$$m_{Z'} \sim 2m_\chi$$

$m_{Z'}$[GeV]

$U(1)_{L_\mu - L_\tau}$-charged DM + Dark Higgs

- $U(1)_{dark} \equiv U(1)_{L_\mu - L_\tau}$
  - Let's call Z', $U(1)_{L_\mu - L_\tau}$ gauge boson, dark photon since it couple to DM



- **UV complete** $U(1)_{L_\mu - L_\tau}$-charged **scalar** DM model
- Dark photon Z' gets massive through $U(1)_{L_\mu - L_\tau}$ breaking
- A new singlet scalar (**Dark Higgs**), which mixes with the SM Higgs

$U(1)_{L_\mu - L_\tau}$-charged DM + Dark Higgs

- Scalar potential

$$V = \lambda_H \left(H^\dagger H - \frac{v_H^2}{2} \right)^2 + \lambda_\Phi \left(\Phi^\dagger \Phi - \frac{v_\Phi^2}{2} \right)^2 + \lambda_{\Phi H} \left(\Phi^\dagger \Phi - \frac{v_\Phi}{2} \right) \left(H^\dagger H - \frac{v_\Phi}{2} \right)$$

- If dark symmetry is spontaneously broken, $\Phi(x) = \frac{1}{\sqrt{2}} (v_\Phi + \phi(x))$
- Dark photon Z' gets massive: $m_{Z'} = g_X |Q_\Phi| v_\Phi$

- Two CP-even neutral scalar bosons

$$\tan 2\theta = \frac{\lambda_{\Phi H} v_\Phi v_H}{\lambda_H v_H^2 - \lambda_\Phi v_\Phi^2}$$

- $$\begin{pmatrix} \phi \\ h \end{pmatrix} = \mathcal{O} \begin{pmatrix} H_1 \\ H_2 \end{pmatrix} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} H_1 \\ H_2 \end{pmatrix}$$
- $$\begin{pmatrix} 2\lambda_\Phi v_\Phi^2 & \lambda_{\Phi H} v_\Phi v_H \\ \lambda_{\Phi H} v_\Phi v_H & 2\lambda_H v_H^2 \end{pmatrix} = \begin{pmatrix} m_{H_1}^2 \cos^2\theta + m_{H_2}^2 \sin^2\theta & (m_{H_2}^2 - m_{H_1}^2) \cos\theta \sin\theta \\ (m_{H_2}^2 - m_{H_1}^2) \cos\theta \sin\theta & m_{H_1}^2 \sin^2\theta + m_{H_2}^2 \cos^2\theta \end{pmatrix}$$
- 3 independent parameters: $m_{H_1},\ m_{H_2},\ sin\theta$

SM Higgs

$U(1)_{L_\mu - L_\tau}$-charged DM + Dark Higgs

- After spontaneous symmetry breakings
  - Additional interactions with the dark Higgs

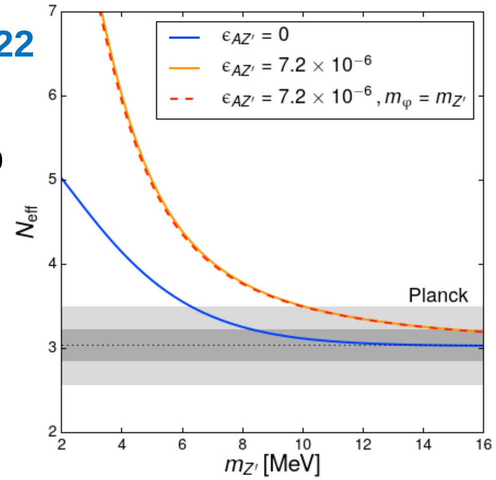
$$\mathcal{L}_\phi \supset \frac{1}{2} g_X^2 Q_\Phi^2 Z'^\mu Z'_\mu \phi^2 + g_X^2 Q_\Phi^2 v_\Phi Z'^\mu Z'_\mu \phi - \lambda_\Phi v_\Phi \phi^3 - \lambda_H v_H h^3 - \frac{\lambda_{\Phi H}}{2} v_\Phi \phi h^2 - \frac{\lambda_{\Phi H}}{2} v_H \phi^2 h$$

- Constraint from N_{eff} @ T_{CMB}
  - If light dark Higgs masses are lighter than $T_{dec}^{\nu} \sim$1MeV, the light dark Higgs mainly decays into $e^{\pm} \rightarrow \Delta N_{eff} \neq 0$
  - The dark Higgs decay before 1sec

- **Higgs invisible decay**

PDG 2022

  - $\mathrm{Br}(H_2 \rightarrow \mathrm{inv.}) = \frac{\Gamma_{H_2}^{ZZ^* \rightarrow 4\nu} + \Gamma_{H_2}^{H_1 H_1} + \Gamma_{H_2}^{Z' Z'} + \Gamma_{H_2}^{XX^*}}{\Gamma_{H_2}^{SM} + \Gamma_{H_2}^{H_1 H_1} + \Gamma_{H_2}^{Z' Z'} + \Gamma_{H_2}^{XX^*}} < 13\%$
  - $sin\theta$ should be small → $\phi \cong H_1, h \cong H_2$

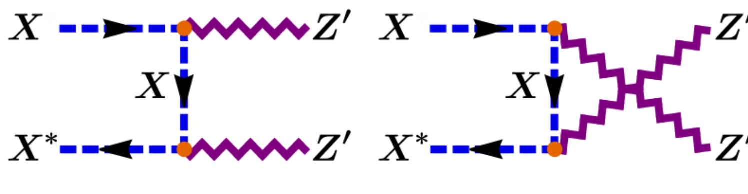


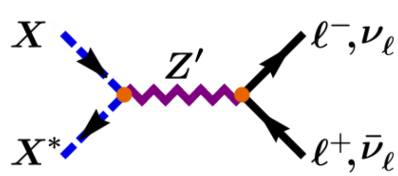
$U(1)_{L_\mu - L_\tau}$-charged DM + Dark Higgs

- Simplest $U(1)_{L_\mu - L_\tau}$-charged scalar DM model

$$\mathcal{L}_{\text{int}} = i g_X Z'_\mu (X^* \partial^\mu X - X \partial^\mu X^*) + g_X Z'_\alpha \sum Q_\ell \bar{\ell} \gamma^\alpha \ell$$

  - Free parameters: $\{m_{Z'}, g_X, m_X, Q_X = 1\}$





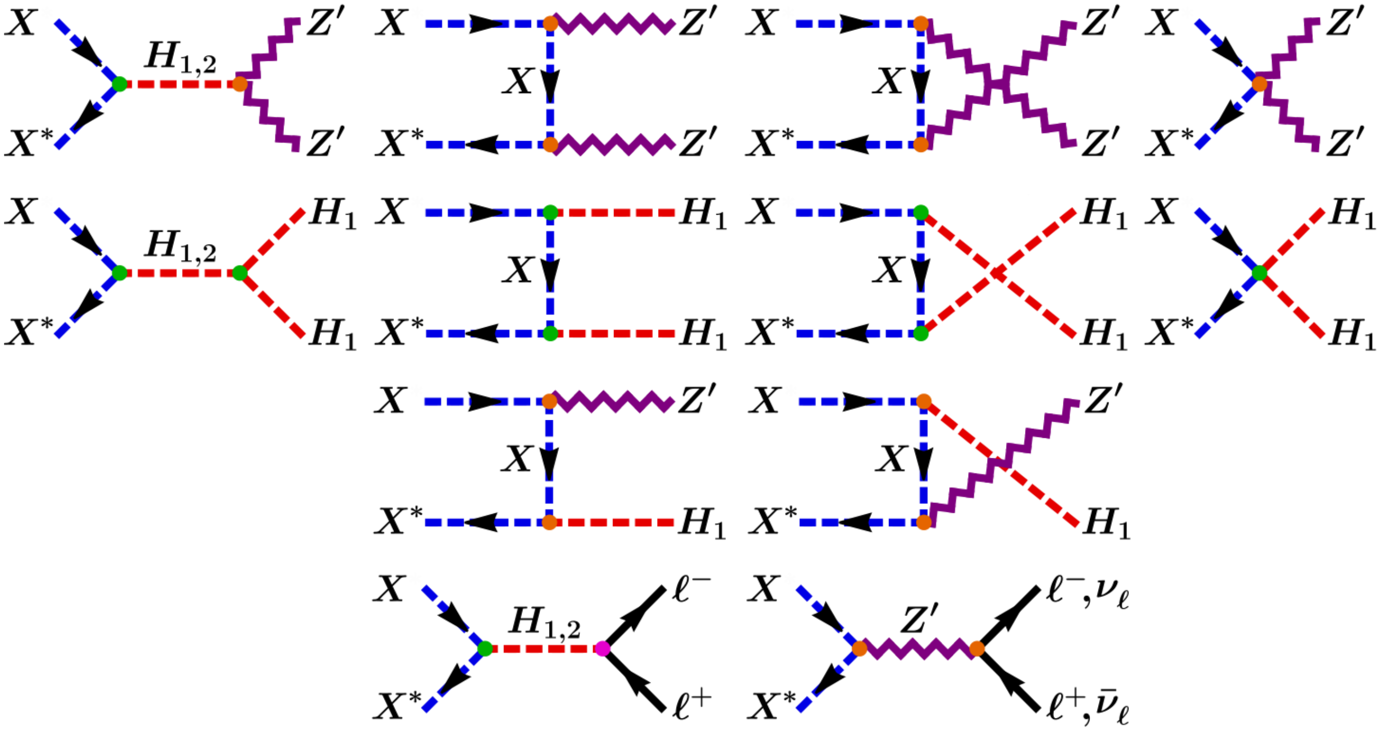
$U(1)_{L_\mu - L_\tau}$-charged DM + Dark Higgs

Baek, **JK**, Ko, 2204.04889

- UV-complete $U(1)_{L_\mu - L_\tau}$-charged scalar DM model

$$\mathcal{L}_{\rm DM} = |D_\mu X|^2 - m_X^2 |X|^2 - \lambda_{\Phi X} |X|^2 \left(|\Phi|^2 - \frac{v_\Phi^2}{2} \right) - \lambda_{HX} |X|^2 \left(H^2 - \frac{v_H^2}{2} \right)$$

- Free parameters: $\{m_{Z'}, g_X, \sin\theta, m_X, m_{H_1}, Q_\Phi, \lambda_{\Phi X}\}$



$U(1)_{L_\mu - L_\tau}$-charged DM + Dark Higgs

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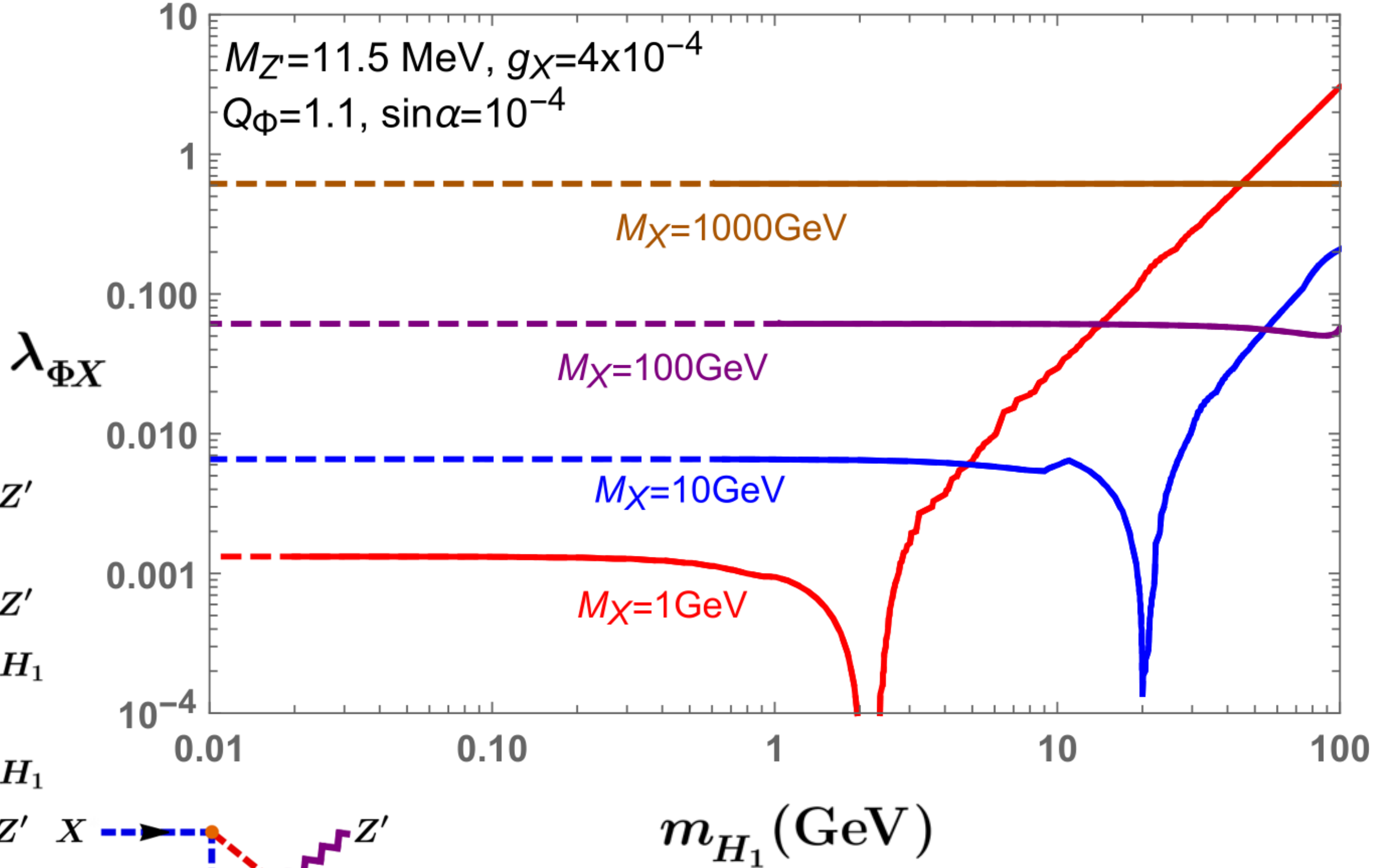
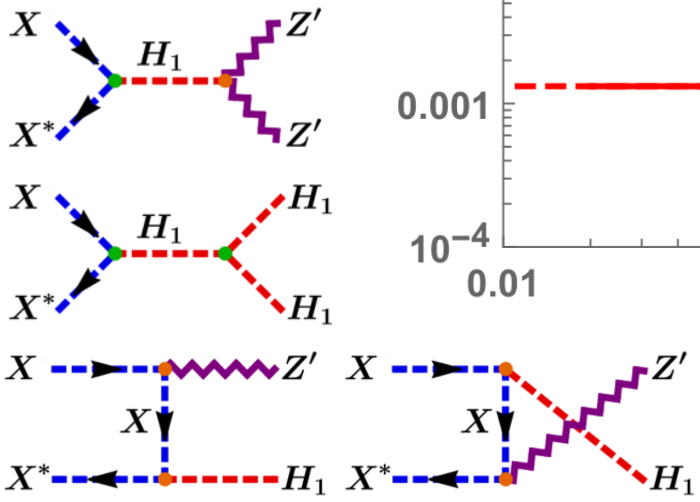
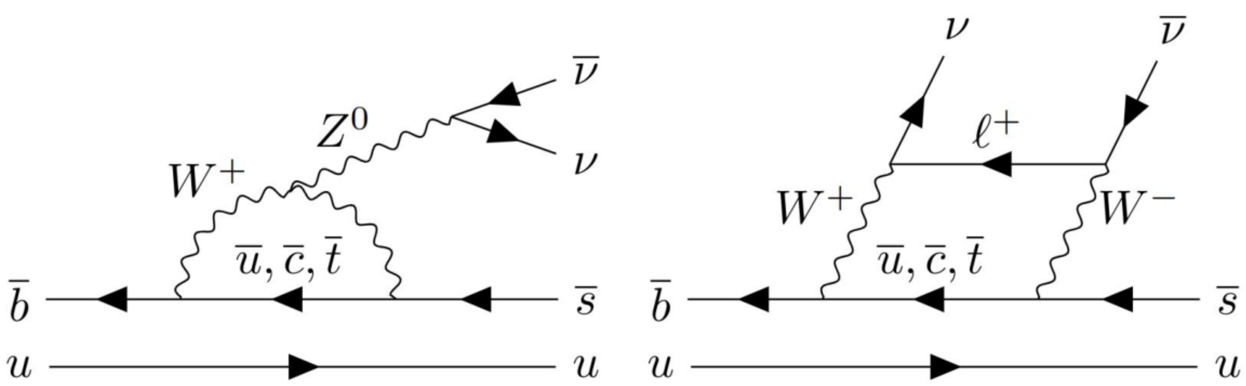




Measurement of $B^+ \to K^+ \nu\bar{\nu}$

- The $B^+ \to K^+ \nu\bar{\nu}$ process is known with high accuracy in the SM:
  - $Br(B^+ \to K^+ \nu\bar{\nu}) = (4.97 \pm 0.37) \times 10^{-6}$ **HPQCD, PRD 2023**



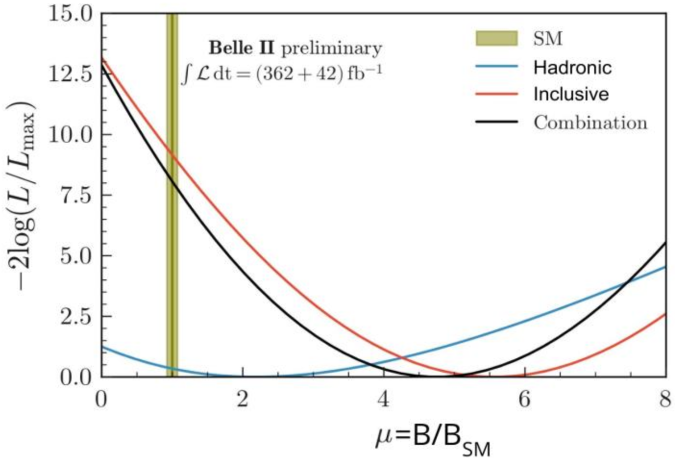
- $\mathcal{L}_{b\to s\nu\bar{\nu}} = -C_\nu \bar{s}_L \gamma^\mu b_L \bar{\nu}\gamma^\mu \nu$

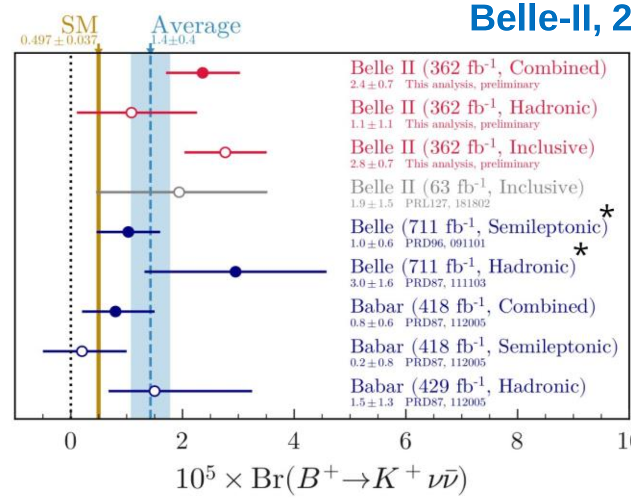
$$C_\nu = \frac{g_W^2}{M_W^2} \frac{g_W^2 V_{ts}^* V_{tb}}{16\pi^2} \left[\frac{x_t^2 + 2x_t}{8(x_t - 1)} + \frac{3x_t^2 - 6x_t}{8(x_t - 1)^2} \ln x_t \right],$$

where $x_t = m_t^2 / M_W^2$.

Measurement of $B^+ \to K^+ \nu\bar{\nu}$

Belle-II, 2311.14647





- $Br(B^+ \to K^+ \nu\bar{\nu}) = (2.4 \pm 0.7) \times 10^{-5}$
  - Significance of observation is 3.6σ
  - 2.8σ tension with the SM prediction
- $Br(B^+ \to K^+ E_{\text{mis}})_{NP} = (1.9 \pm 0.7) \times 10^{-5}$
- Indicate not only the presence of NP in the $b \to s\nu\bar{\nu}$ transitions but even the presence of new light states (particles in dark sector?)

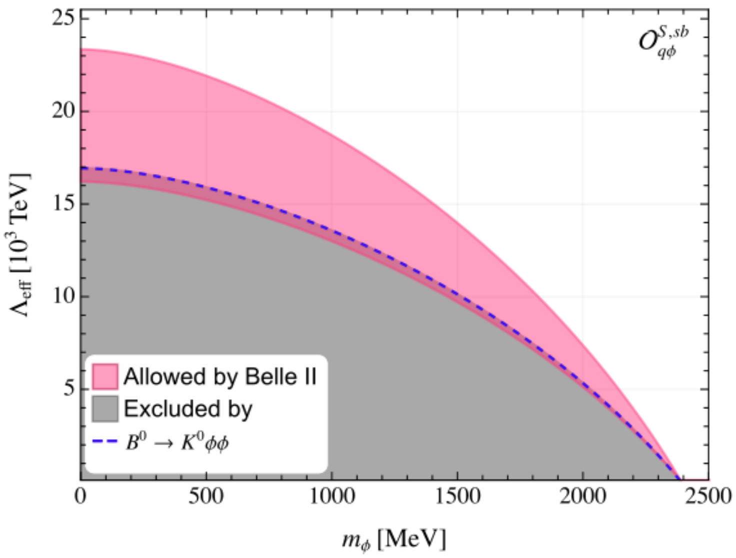
Solutions: EFT-approach

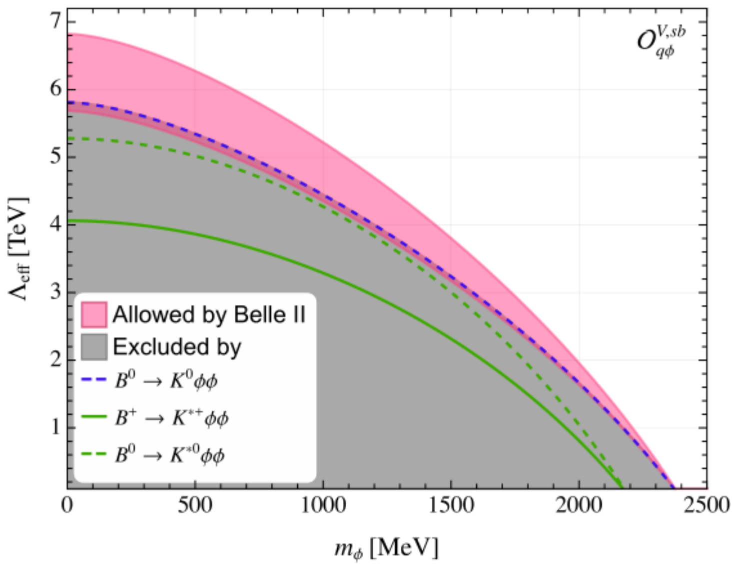
- Scalar DM

X. He et al, 2309.12741

$$\mathcal{O}_{q\phi}^{S,sb} = (\overline{s}b)(\phi^\dagger\phi),$$

$$\mathcal{O}_{q\phi}^{V,sb} = (\overline{s}\gamma^\mu b)(\phi^\dagger i\overleftrightarrow{\partial_\mu}\phi),\ (\times)$$





Solutions: EFT-approach

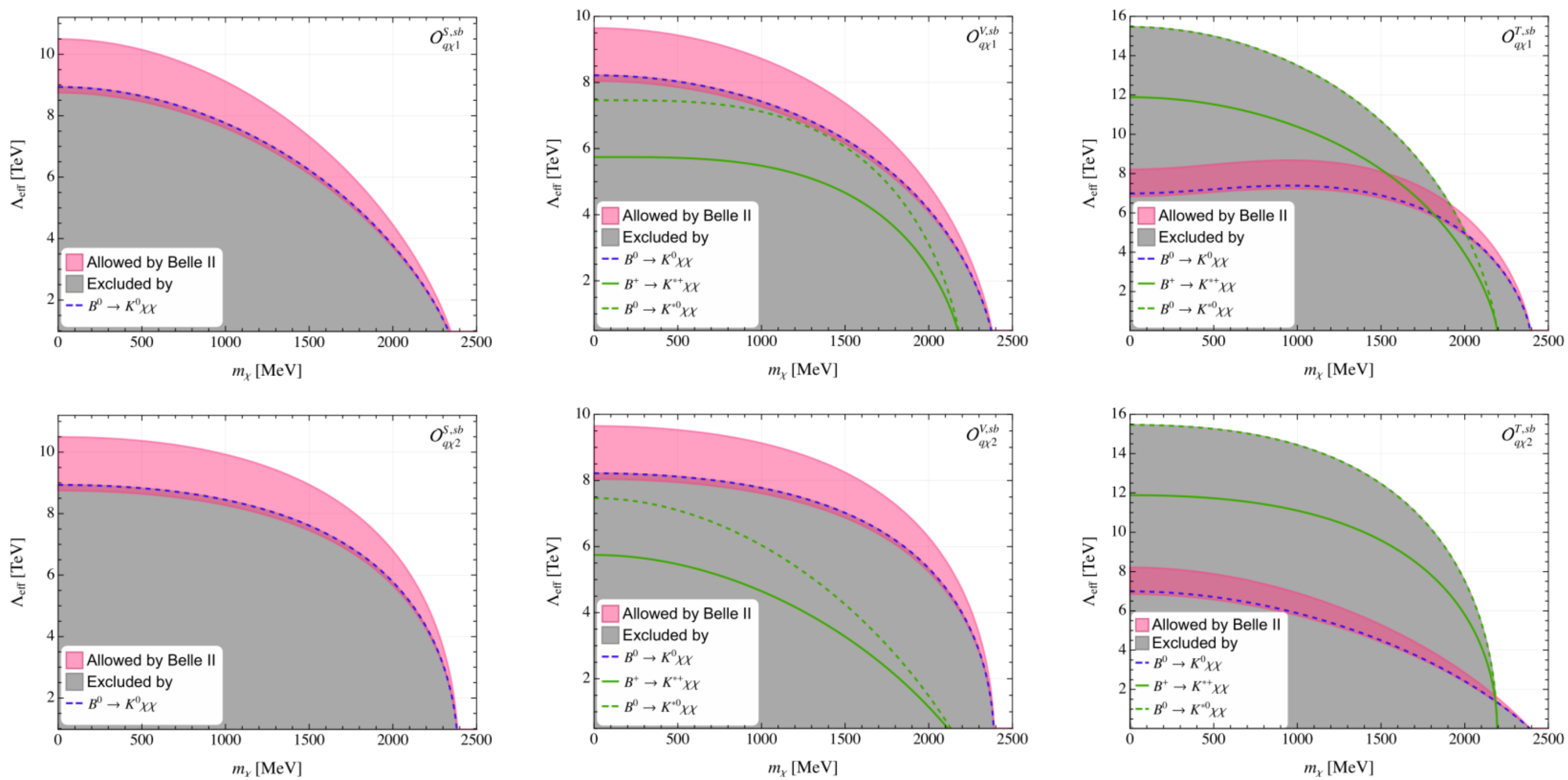
- Fermion DM

X. He et al, 2309.12741

$$\mathcal{O}_{q\chi 1}^{S,sb} = (\bar{s}b)(\bar{\chi}\chi), \qquad \mathcal{O}_{q\chi 2}^{S,sb} = (\bar{s}b)(\bar{\chi}i\gamma_5\chi),$$

$$\mathcal{O}_{q\chi 1}^{V,sb} = (\bar{s}\gamma^{\mu}b)(\bar{\chi}\gamma_{\mu}\chi), \ (\times) \qquad \mathcal{O}_{q\chi 2}^{V,sb} = (\bar{s}\gamma^{\mu}b)(\bar{\chi}\gamma_{\mu}\gamma_5\chi),$$

$$\mathcal{O}_{q\chi 1}^{T,sb} = (\bar{s}\sigma^{\mu\nu}b)(\bar{\chi}\sigma_{\mu\nu}\chi), \ (\times) \qquad \mathcal{O}_{q\chi 2}^{T,sb} = (\bar{s}\sigma^{\mu\nu}b)(\bar{\chi}\sigma_{\mu\nu}\gamma_5\chi), \ (\times)$$



Solutions: EFT-approach

- Vector DM

X. He et al, 2309.12741

$$\mathcal{O}^{S,sb}_{qX} = (\bar{s}b)(X^\dagger_\mu X^\mu),$$

$$\mathcal{O}^{T,sb}_{qX1} = \frac{i}{2}(\bar{s}\sigma^{\mu\nu}b)(X^\dagger_\mu X_\nu - X^\dagger_\nu X_\mu),\ (\times)$$

$$\mathcal{O}^{T,sb}_{qX2} = \frac{1}{2}(\bar{s}\sigma^{\mu\nu}\gamma_5 b)(X^\dagger_\mu X_\nu - X^\dagger_\nu X_\mu),\ (\times)$$

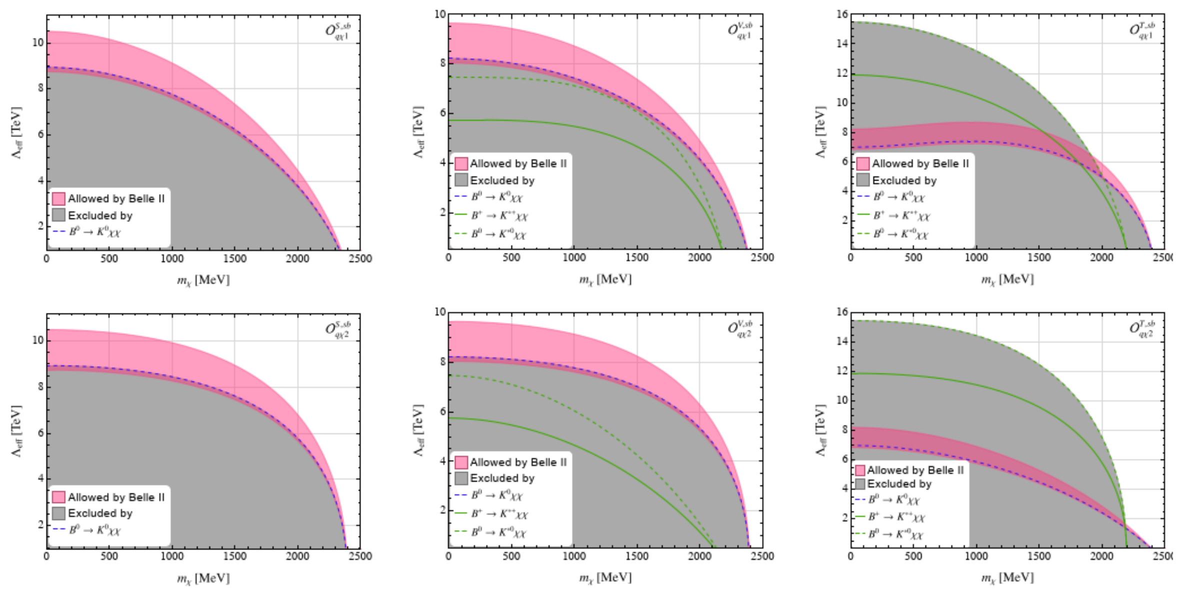
$$\mathcal{O}^{V,sb}_{qX2} = (\bar{s}\gamma_\mu b)\partial_\nu(X^{\mu\dagger}X^\nu + X^{\nu\dagger}X^\mu),$$

$$\mathcal{O}^{V,sb}_{qX3} = (\bar{s}\gamma_\mu b)(X^\dagger_\rho \overleftrightarrow{\partial_\nu} X_\sigma)\epsilon^{\mu\nu\rho\sigma},$$

$$\mathcal{O}^{V,sb}_{qX4} = (\bar{s}\gamma^\mu b)(X^\dagger_\nu i\overleftrightarrow{\partial_\mu} X^\nu),\ (\times)$$

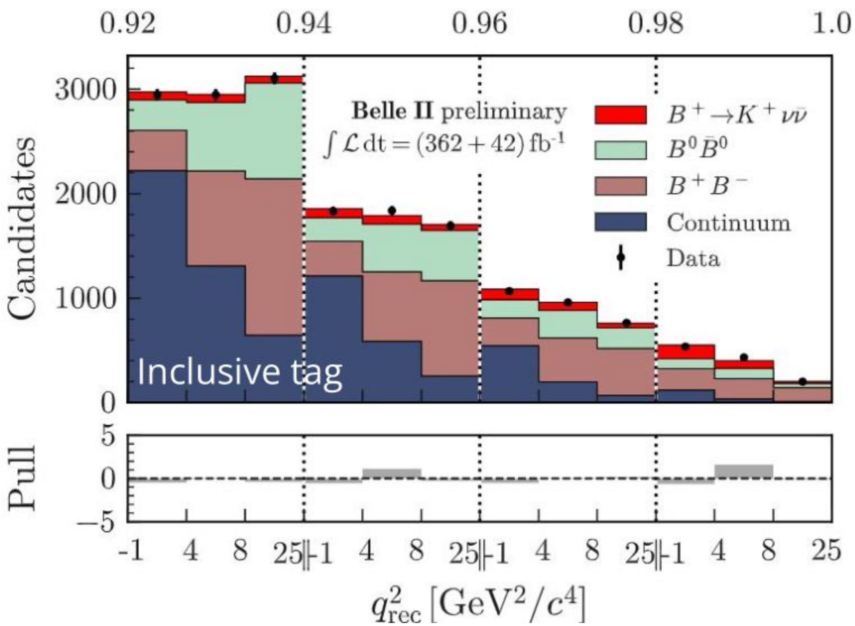
$$\mathcal{O}^{V,sb}_{qX5} = (\bar{s}\gamma_\mu b)i\partial_\nu(X^{\mu\dagger}X^\nu - X^{\nu\dagger}X^\mu),\ (\times)$$

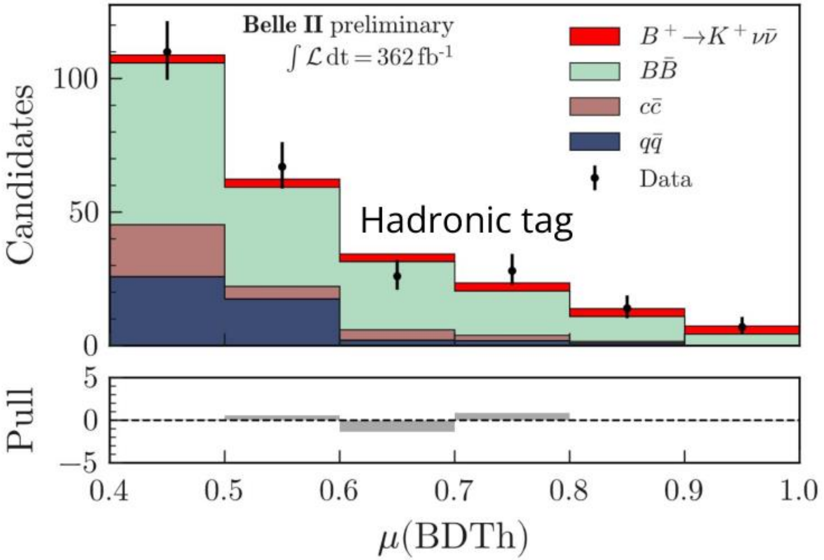
$$\mathcal{O}^{V,sb}_{qX6} = (\bar{s}\gamma_\mu b)i\partial_\nu(X^\dagger_\rho X_\sigma)\epsilon^{\mu\nu\rho\sigma}.\ (\times)$$



Solutions: 2-body decay

W. Altmannshofer et al, 2311.14629





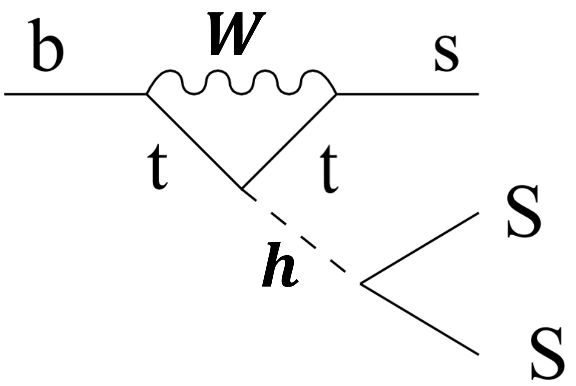
- Belle II provides information on the q^2 spectrum
  - A peak localized around $q^2 = 4\text{GeV}^2$
  - ➔ Two-body decay $(B \to KX), m_X = 2\ \text{GeV}$

Solutions: 3-body decay

Bird et al, PRL 2004

- Singlet scalar DM model ($m_s \leq 2.3\text{GeV}$)

$$-\mathcal{L}_S = \frac{\lambda_S}{4}S^4 + \frac{m_0^2}{2}S^2 + \lambda S^2 H^\dagger H$$
$$= \frac{\lambda_S}{4}S^4 + \frac{1}{2}(m_0^2 + \lambda v_{EW}^2)S^2 + \boxed{\lambda v_{EW} S^2 h} + \frac{\lambda}{2}S^2 h^2,$$



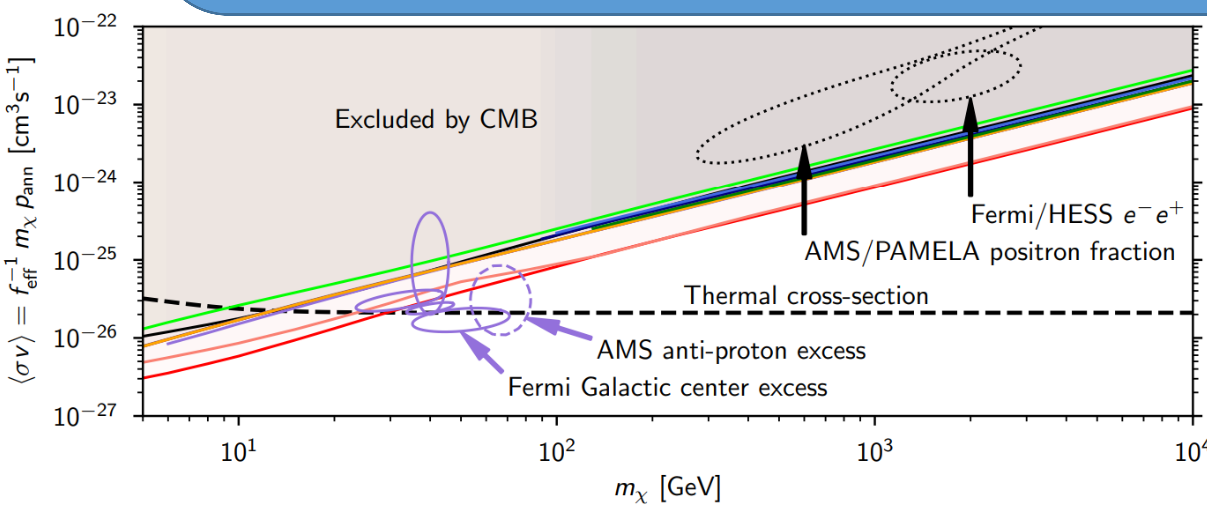
- Belle ➡ $\frac{C_{DM}}{C_\nu} \simeq \frac{4.4\lambda M_W^2}{g_W^2 m_h^2}$
- Relic density $\sigma_{\text{ann}} v_{\text{rel}} = \frac{8 v_{EW}^2 \lambda^2}{m_h^4}\left(\lim_{m_{\tilde{h}} \to 2m_S} m_{\tilde{h}}^{-1}\Gamma_{\tilde{h}X}\right).$
  - λ should be large to fit the relic as well as Belle II

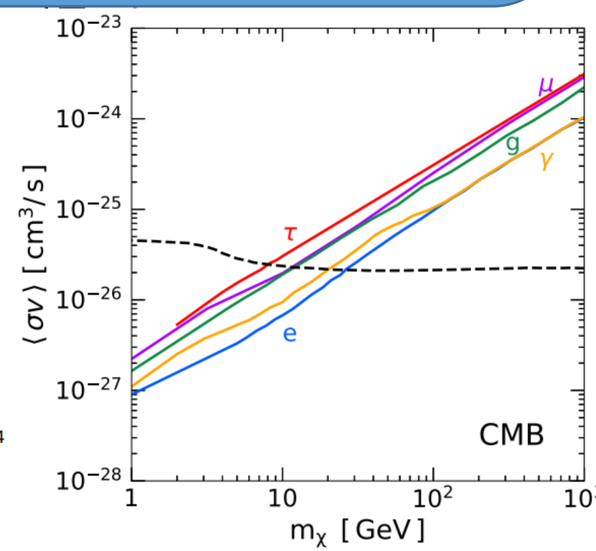
- $m_s \leq 1\text{GeV}$ is already excluded by BABAR limits (2004 data).

Solutions: 3-body decay

- For $m_\chi \lesssim 10\mathrm{GeV}$, CMB bound (DM annihilation @ $T \sim \mathrm{eV}$) excludes the thermal DM freeze-out determined by ***s-wave*** annihilation
  - DM annihilation should be mainly in **p-wave**
  - **Forbidden** DM channel
  - Asymmetric DM

$$\langle \sigma v \rangle \sim a + b\, v^2$$





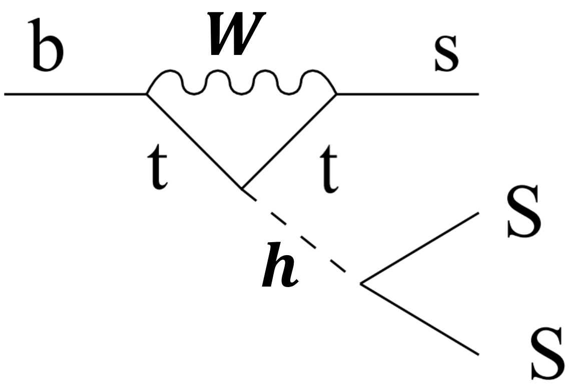
Planck 2018,
R. K. Leane et al, PRD 2018

Solutions: 3-body decay

Bird et al, PRL 2004

- Singlet scalar DM model ($m_s \leq 2.3\mathrm{GeV}$)

$$-\mathcal{L}_S = \frac{\lambda_S}{4} S^4 + \frac{m_0^2}{2} S^2 + \lambda S^2 H^\dagger H$$
$$= \frac{\lambda_S}{4} S^4 + \frac{1}{2}(m_0^2 + \lambda v_{EW}^2) S^2 + \boxed{\lambda v_{EW} S^2 h} + \frac{\lambda}{2} S^2 h^2,$$



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  - λ should be large to fit the relic as well as BelleII

- $m_s \leq 1\mathrm{GeV}$ is already excluded by BABAR limits (2004 data).
- At that time, the authors did not consider the CMB bounds.
  - **This model does not work anymore.**

Can we find the integrated solution of Δa_μ, DM relic density, Hubble tension and $B^+ \to K^+ \nu\bar{\nu}$ at Belle II?

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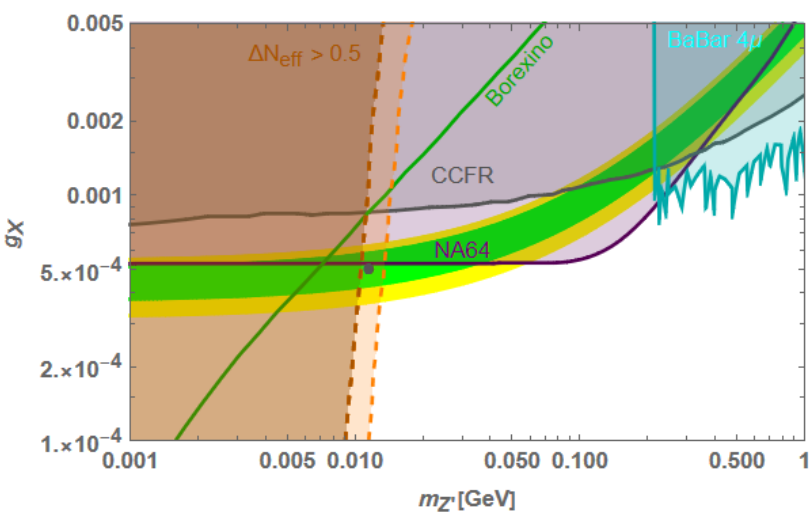
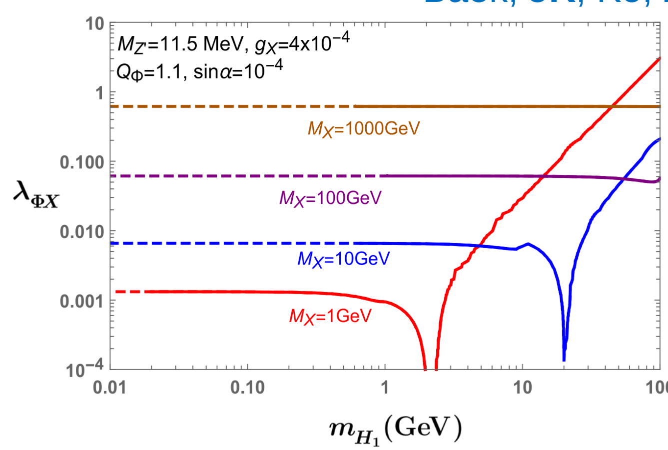
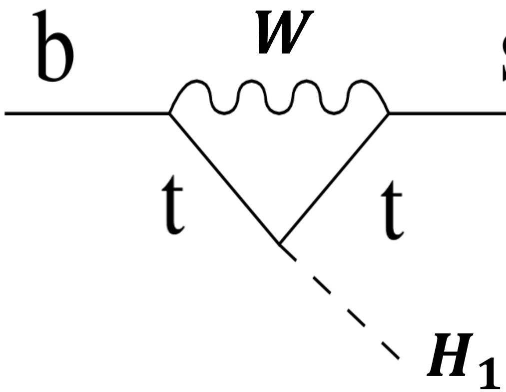
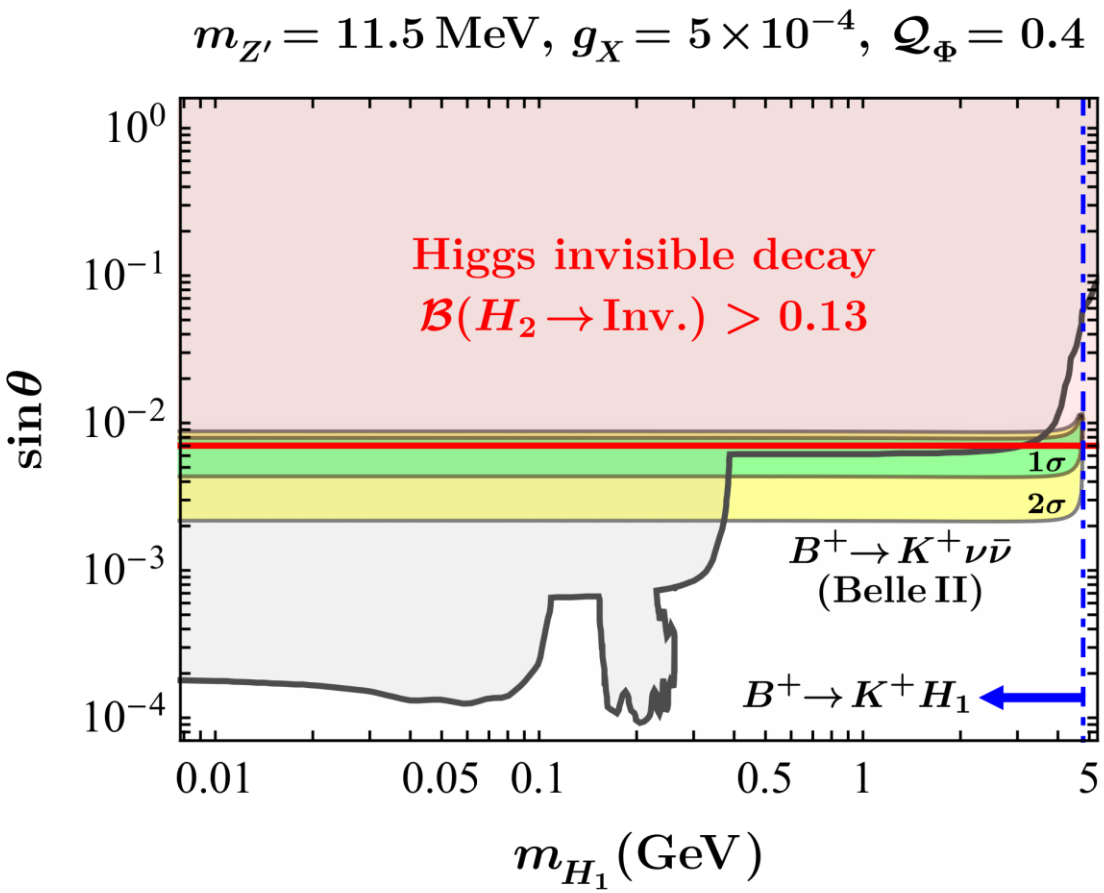


Baek, **JK**, Ko, 2204.04889



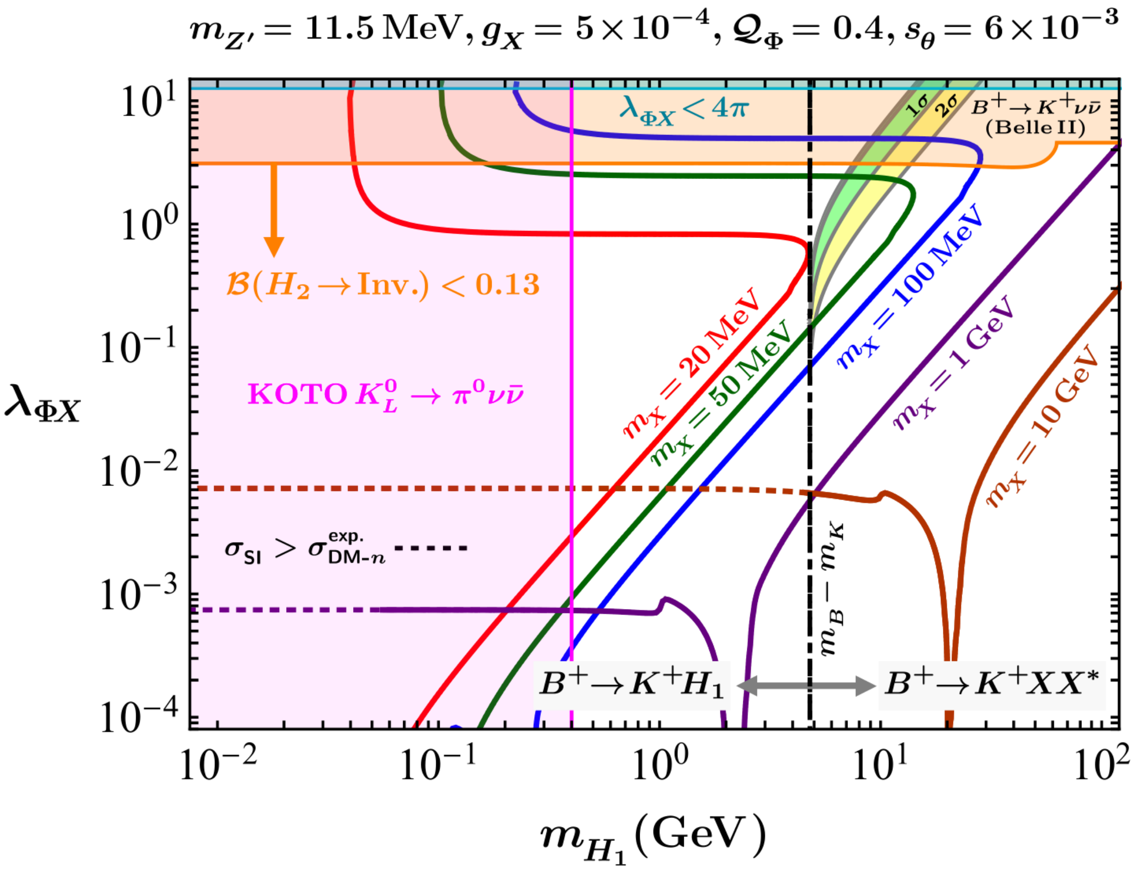
BelleII anomaly: 2-body decay

- When $m_{H_1} < m_B - m_K$, two-body decay
- 



BelleII anomaly: 2- or 3-body decay

- When $m_{H_1} > m_B - m_K$, H_2 is off-shell → three-body decay
  - Two-body decay: $m_X \lesssim 10\text{GeV}$ ($m_{H_1} \lesssim m_B - m_K$)
  - Three-body decay: $20\text{MeV} < m_X \lesssim 60\text{MeV}$ ($m_{H_1} > m_B - m_K$)



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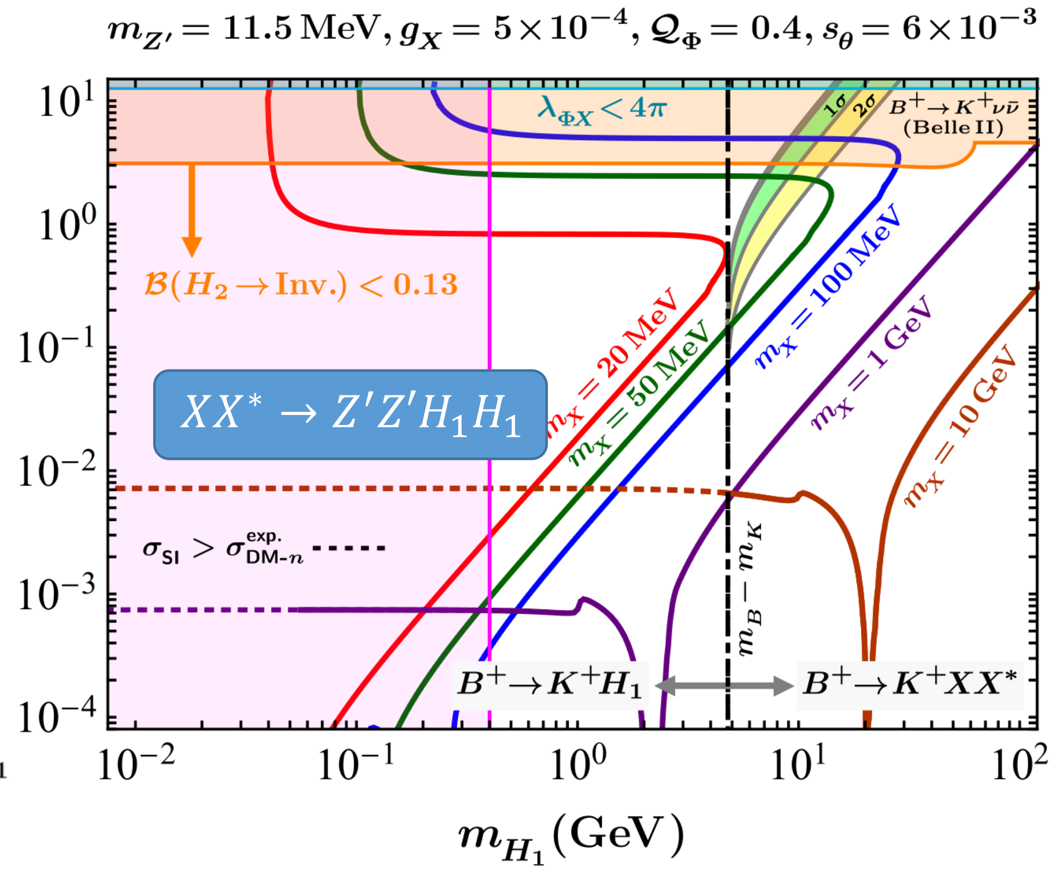

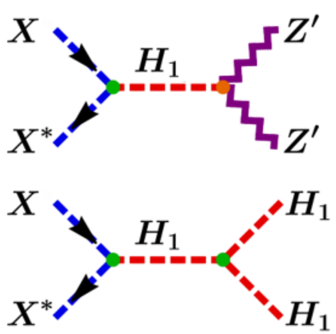

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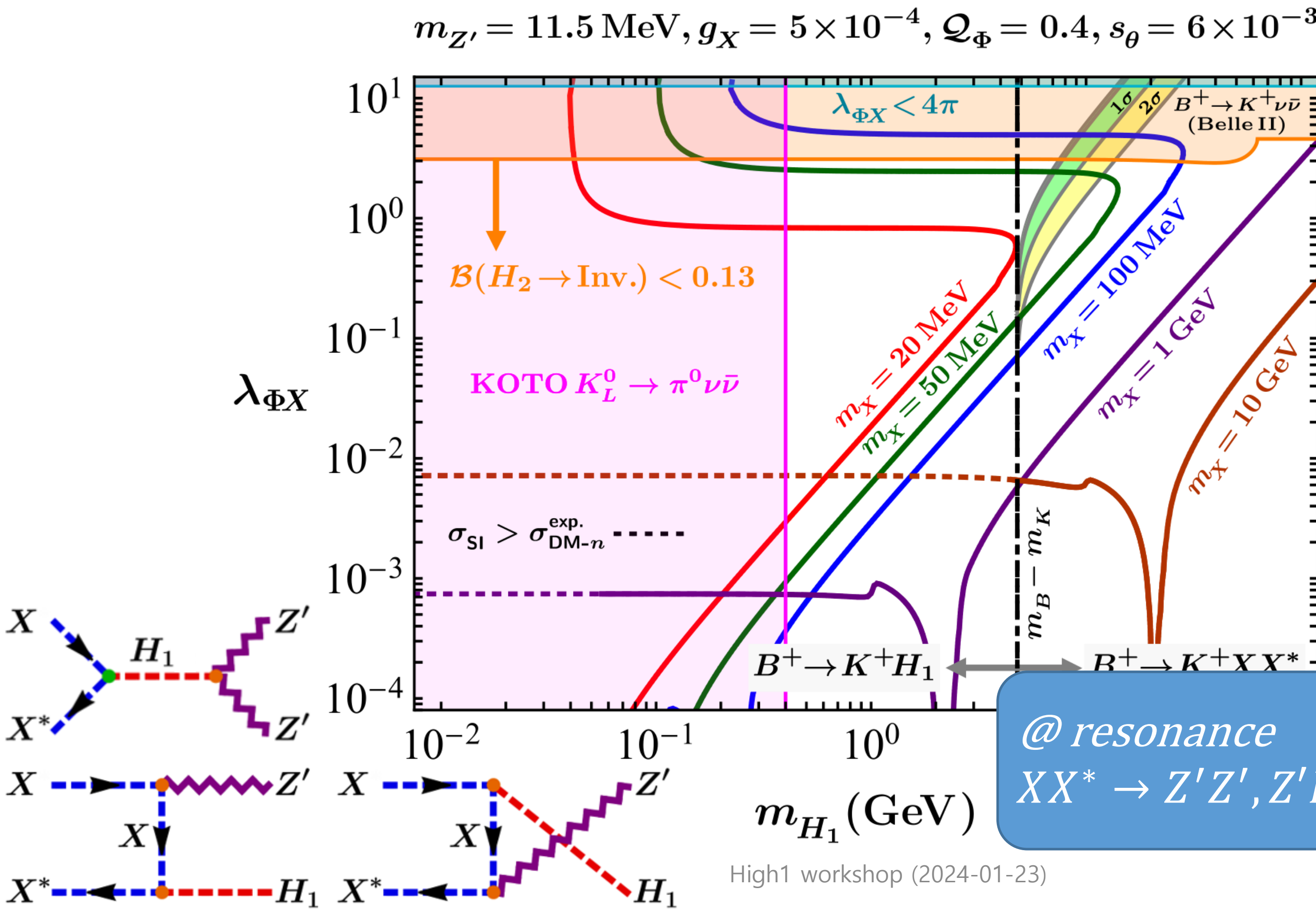

@ resonance
$XX^* \to Z'Z', Z'H_1$

BelleII anomaly: 2- or 3-body decay

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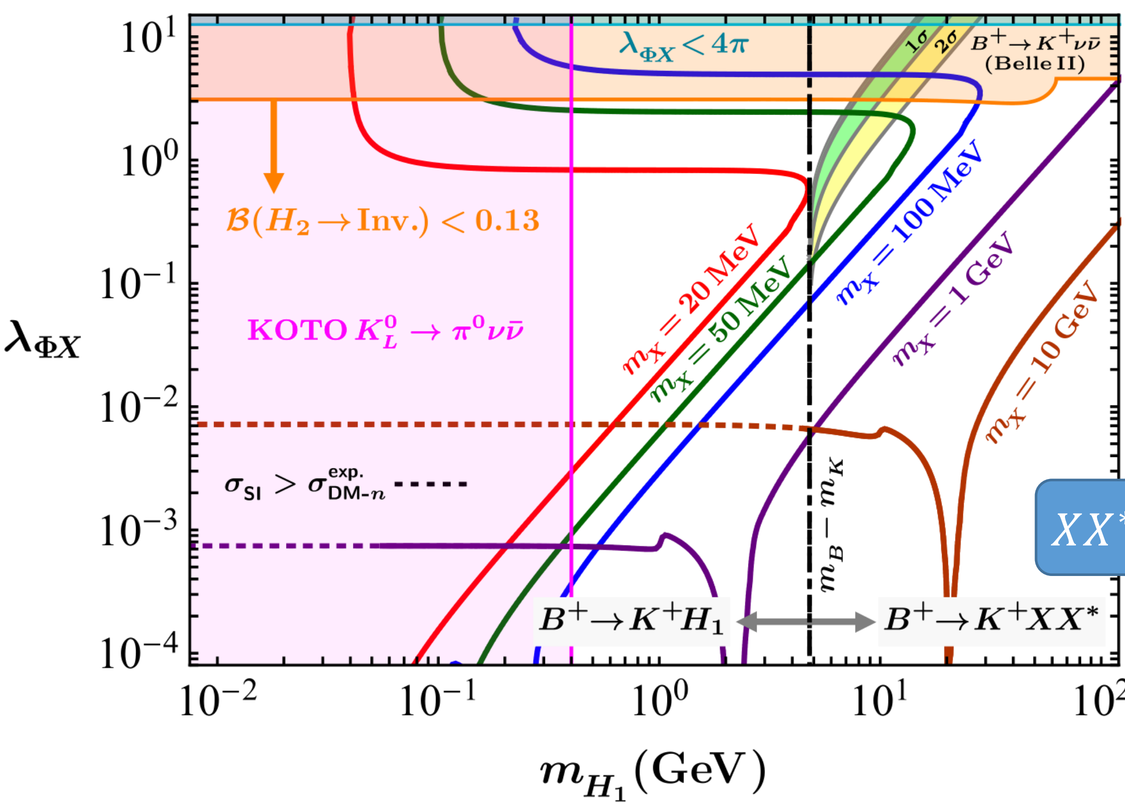
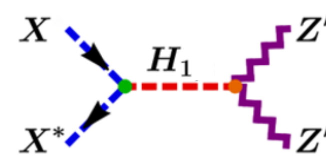
$m_{Z'} = 11.5\,\text{MeV}, g_X = 5\times10^{-4}, \mathcal{Q}_\Phi = 0.4, s_\theta = 6\times10^{-3}$



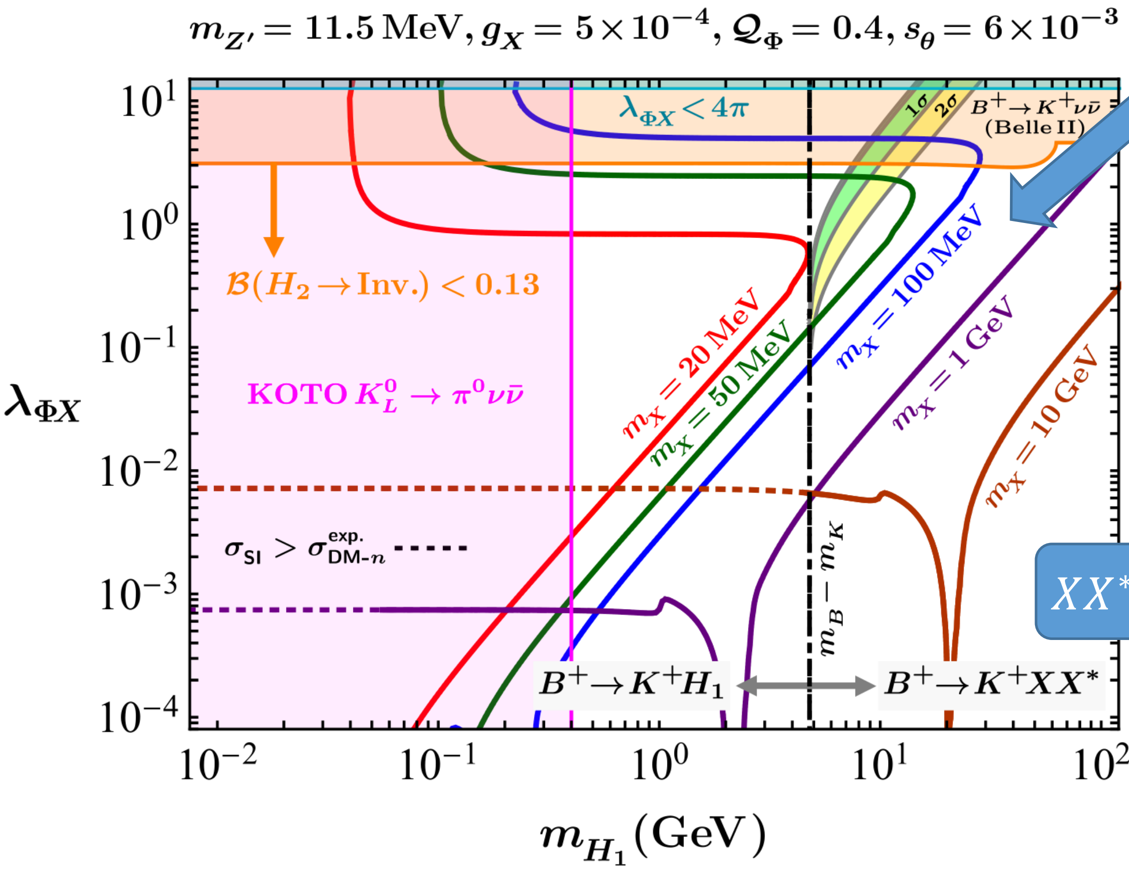


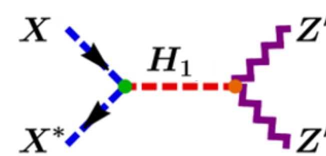
$XX^* \to Z'Z'$

BelleII anomaly: 2- or 3-body decay

- When $m_{H_1} > m_B - m_K$, F
  - Two-body decay: $m_X \lesssim 1$
  - Three-body decay: 20MeV

$$\sigma v \simeq \frac{\lambda_{\Phi X}^2}{16\pi m_X^2} \frac{4m_X^4 - 4m_X^2 m_{Z'}^2 + 3m_{Z'}^4}{(4m_X^2 - m_{H_1}^2)^2 + m_{H_1}^2 \Gamma_{H_1}^2} \sqrt{1 - \frac{m_{Z'}^2}{m_X^2}}$$





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BelleII anomaly: 2- or 3-body decay

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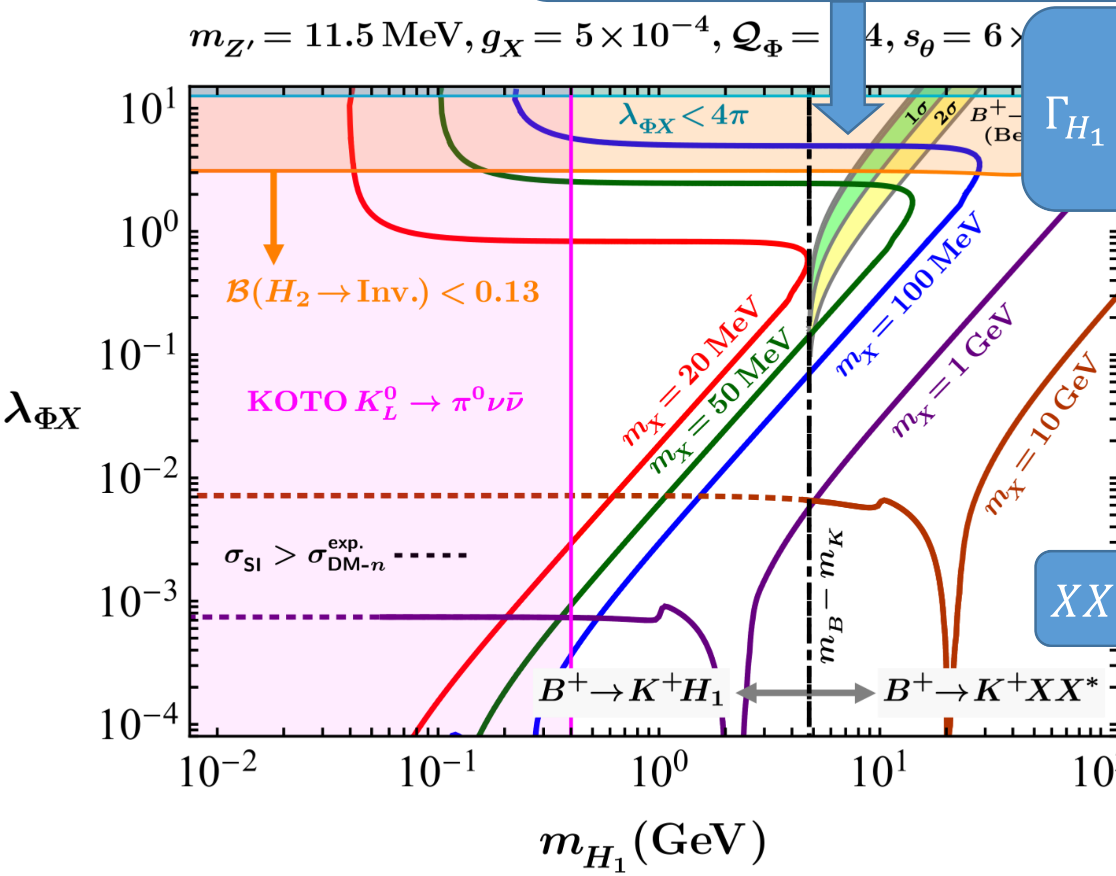
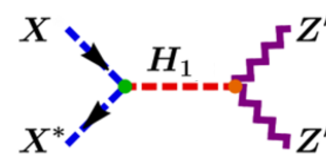
  - Two-body decay: $m_X \lesssim 1$
  - Three-body decay: $20\mathrm{Me}$

$$\sigma v \simeq \frac{\lambda_{\Phi X}^2}{16\pi m_X^2}\frac{4m_X^4 - 4m_X^2 m_{Z'}^2 + 3m_{Z'}^4}{(4m_X^2 - m_{H_1}^2)^2 + m_{H_1}^2\Gamma_{H_1}^2}\sqrt{1-\frac{m_{Z'}^2}{m_X^2}}$$

$$\Gamma_{H_1} \simeq \frac{\lambda_{\Phi X}^2 v_\Phi^2}{16\pi\, m_{H_1}}\sqrt{1-\frac{4m_X^2}{m_{H_1}^2}}$$





$XX^* \to Z'Z'$

BelleII anomaly: 2- or 3-body decay

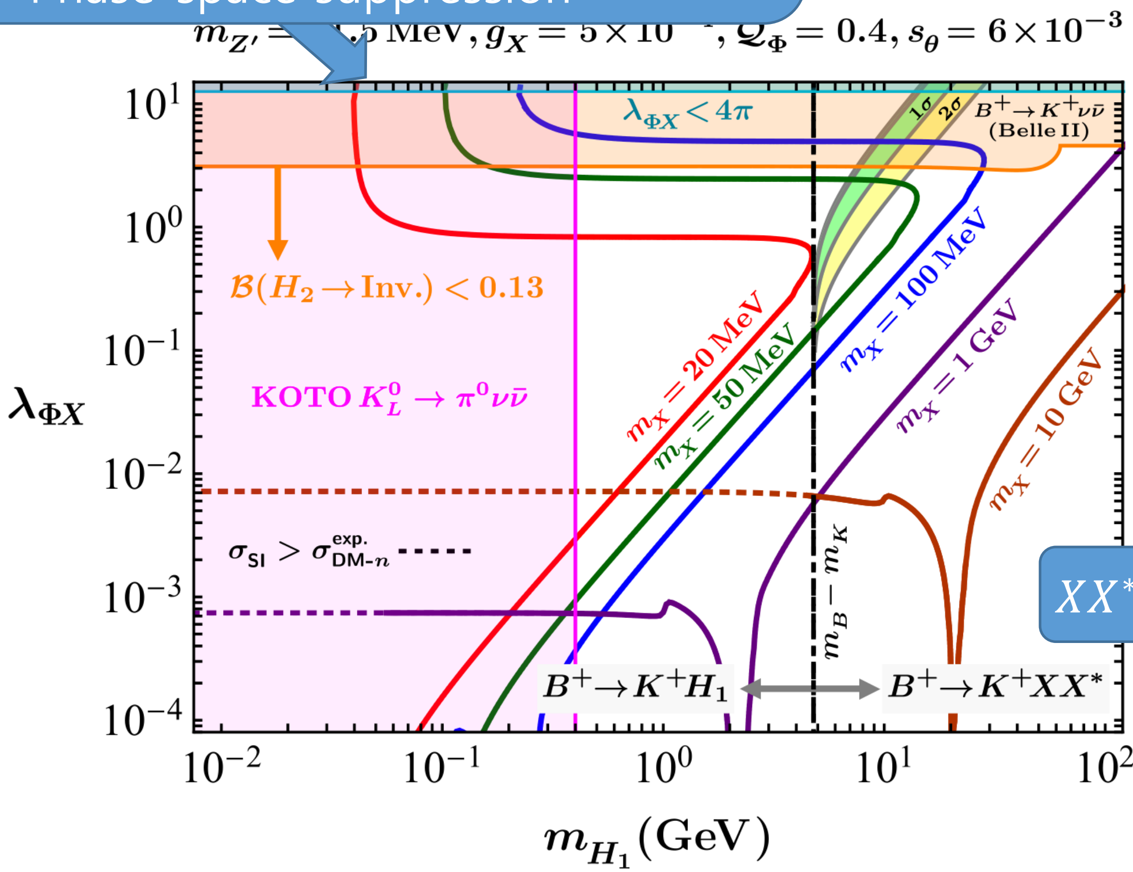
$$\Gamma_{H_1} = \frac{\lambda_{\Phi X}^2 v_\Phi^2}{16\pi\, m_{H_1}} \sqrt{1 - \frac{4m_X^2}{m_{H_1}^2}} \quad \& \ \sigma v \propto \frac{\lambda_{\Phi X}^2}{m_{H_1}^2 \Gamma_{H_1}^2}$$

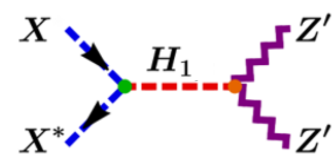
Phase-space suppression

ll → three-body decay

$m_B - m_K)$

eV ($m_{H_1} > m_B - m_K$)





$XX^* \to Z'Z'$

CMB constraints

- Dominant DM annihilation channel
  - $XX^* \to Z'Z', H_1H_1$: **s-wave** annihilation
  - $XX^* \to Z'H_1$: **p-wave** annihilation

- H_1 decays
  - A pair of DM (open when $m_{H_1} > 2m_X$)
  - A pair of Z'
  - SM particles

- Z' decay
  - A pair of ν ($m_{Z'} = 11.5$MeV, $g_X = 5 \times 10^{-4}$)

CMB constraints

- Dominant DM annihilation channel
  - $XX^* \to Z'Z', H_1H_1$: **s-wave** annihilation
  - $XX^* \to Z'H_1$: **p-wave** annihilation

- H_1 decays
  - A pair of DM (open when $m_{H_1} > 2m_X$)
  - A pair of Z' ($Z' \to \nu\nu$)
  - SM particles (suppressed due to small Yukawa coupling & $\sin\theta$)

- Z' decay
  - A pair of ν ($m_{Z'} = 11.5$MeV, $g_X = 5 \times 10^{-4}$)
  - Br($Z' \to e^+e^-$) $\simeq 10^{-5}$ due to smallness of kinetic mixing ($\epsilon \equiv -g_X/70$)

- We can naturally avoid the stringent CMB bound thanks to invisible decay of both H_1 and Z'

Conclusions

- New physics beyond the Standard Model shows up through 80% dark matter

- DM physics with massive dark photon cannot be complete without including dark gauge symmetry breaking mechanism which have been largely ignored by DM community

- We shows the importance of the dark Higgs in DM phenomenology via Muon g-2 anomaly, BelleII excess

Thank you very much