

# keV sterile neutrino dark matter enabled by a light dark photon

Gonzalo Alonso-Álvarez

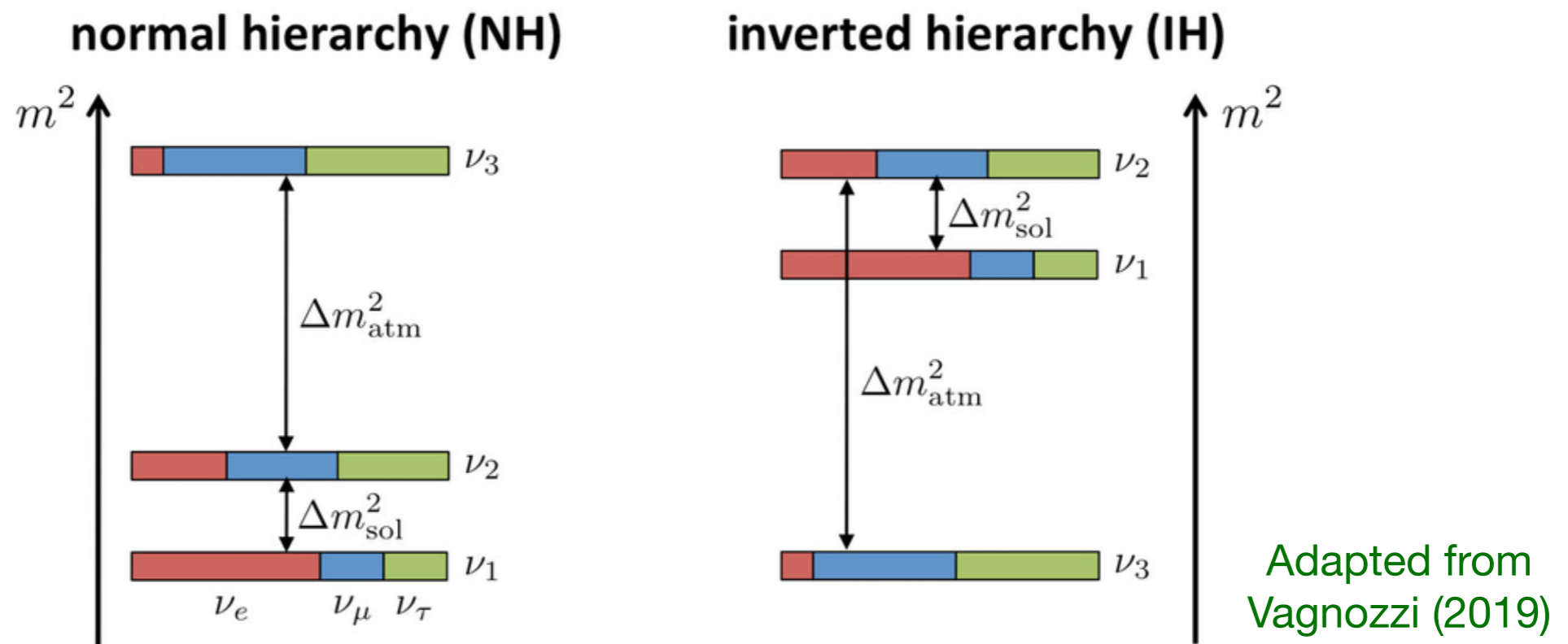
based on [2106.XXXX] with Jim Cline



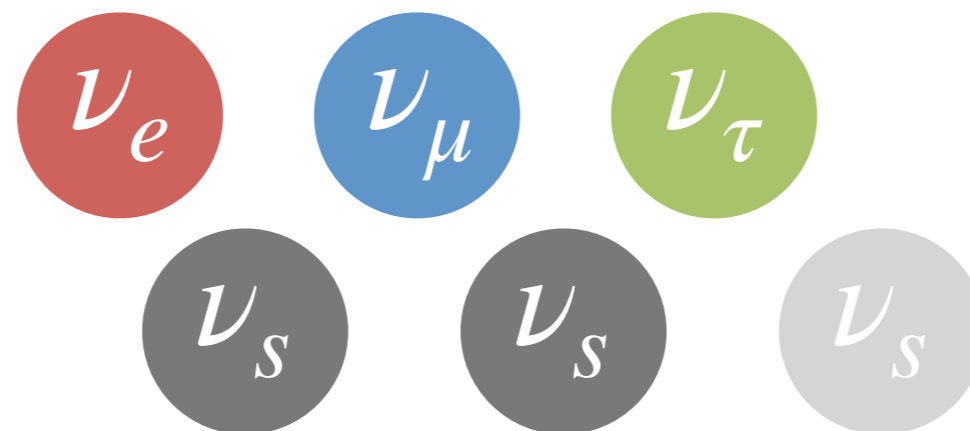
Pheno 2021 symposium  
University of Pittsburg, 26 May 2021

# Sterile neutrinos

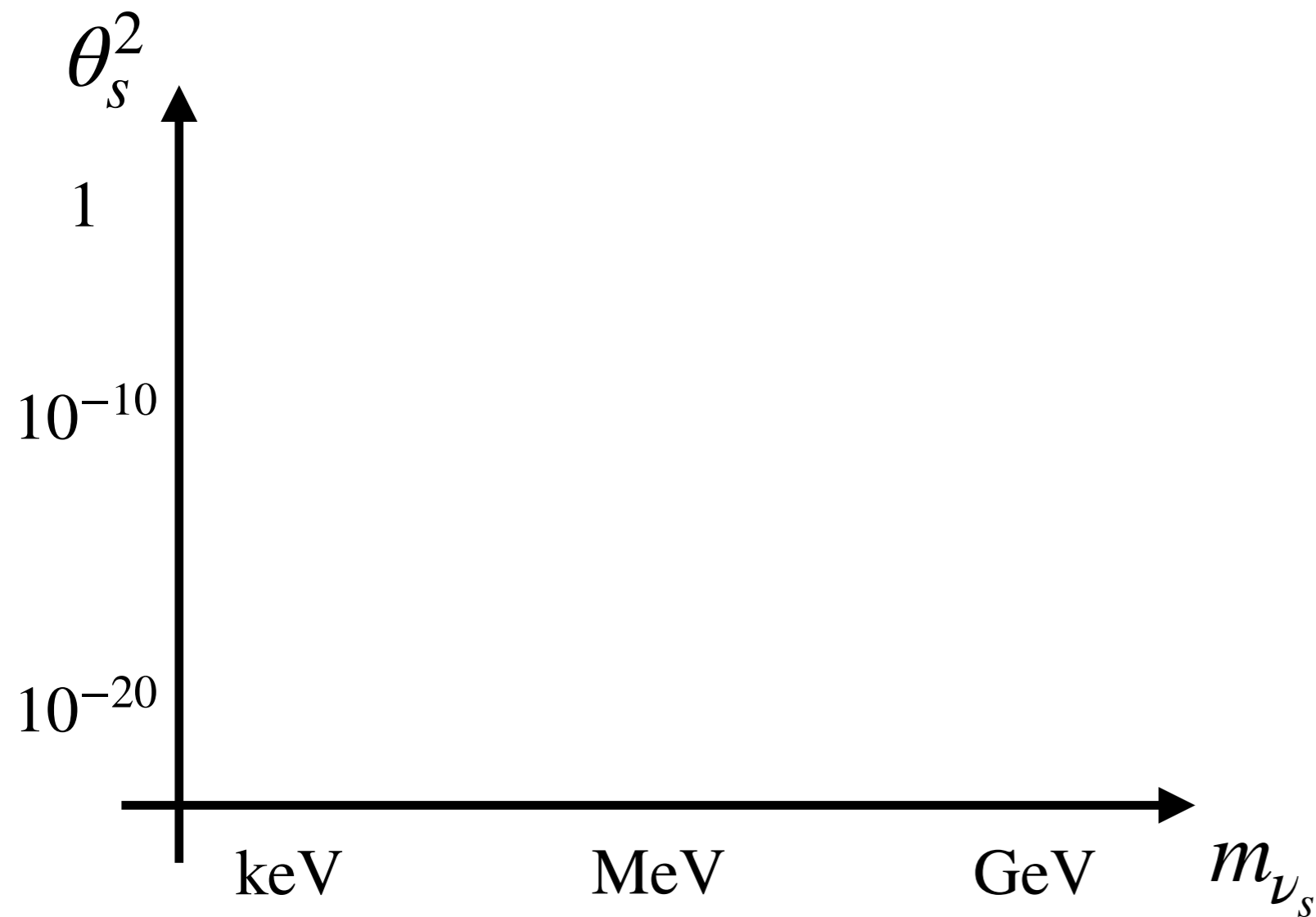
Neutrinos oscillate, and therefore have a mass



Right-handed (sterile) neutrinos necessary to generate masses



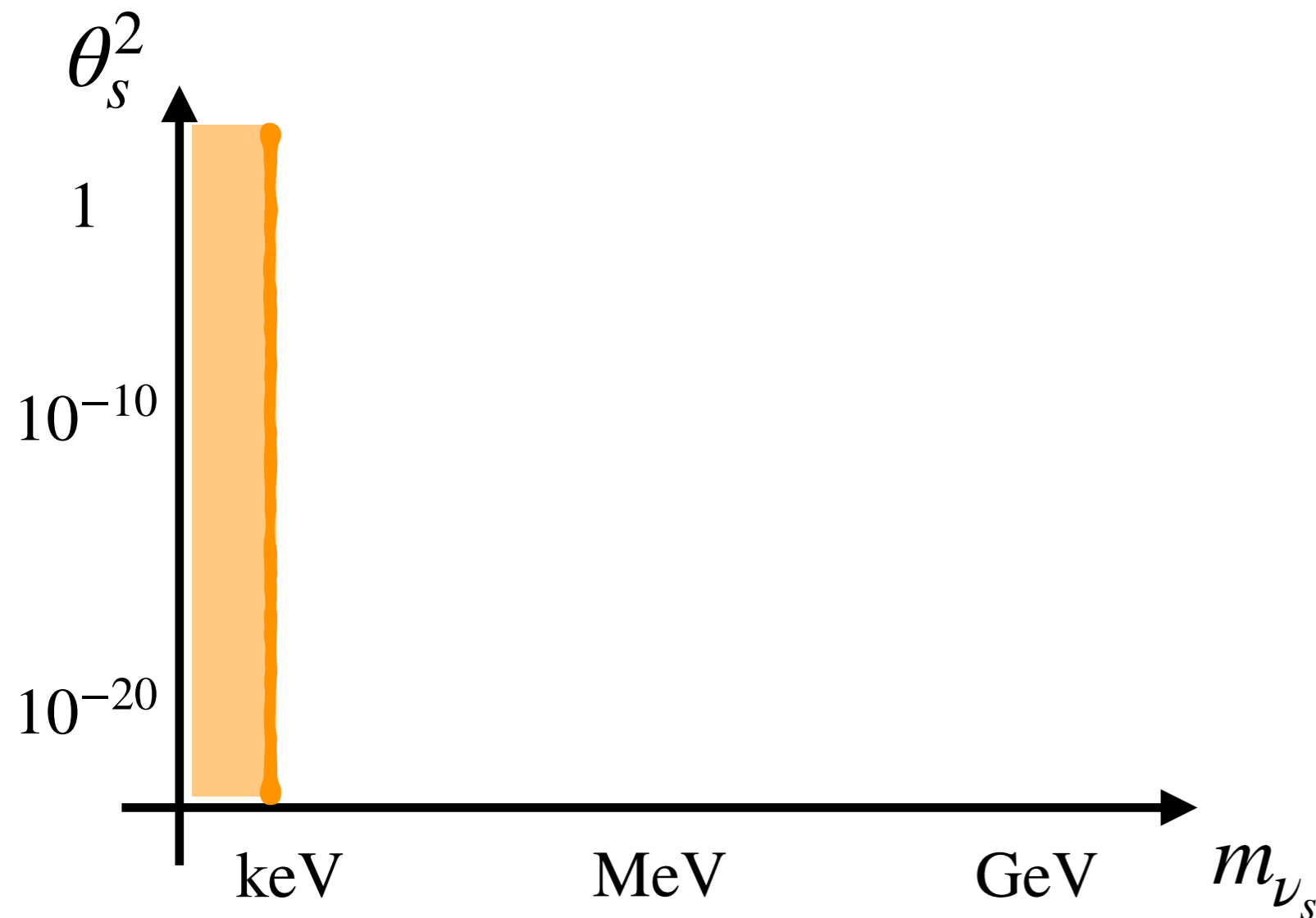
# Sterile neutrino dark matter



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- Warm dark matter

$$m_{\nu_s} \gtrsim 1 \text{ keV}$$



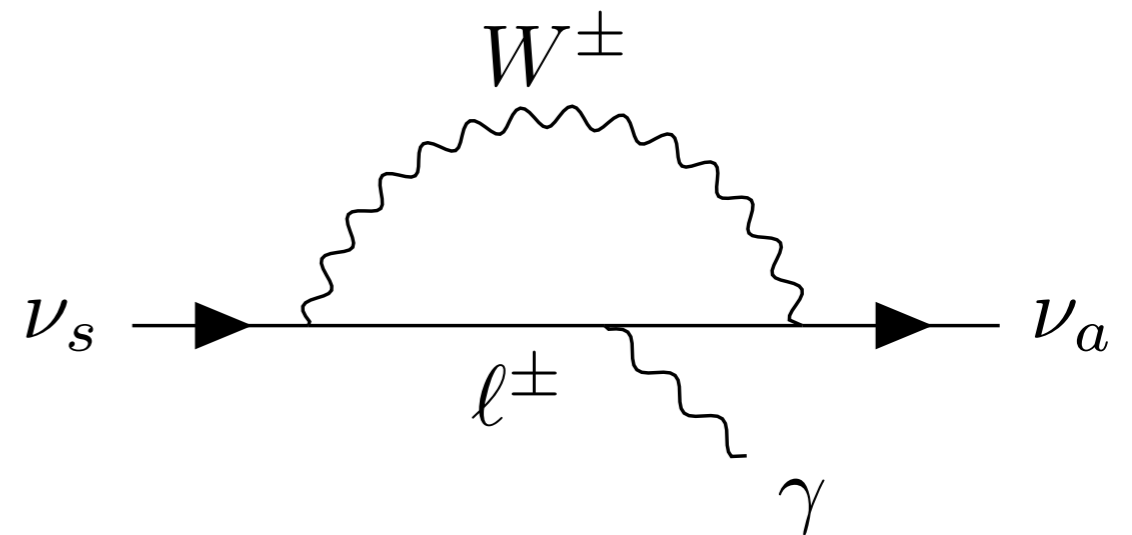
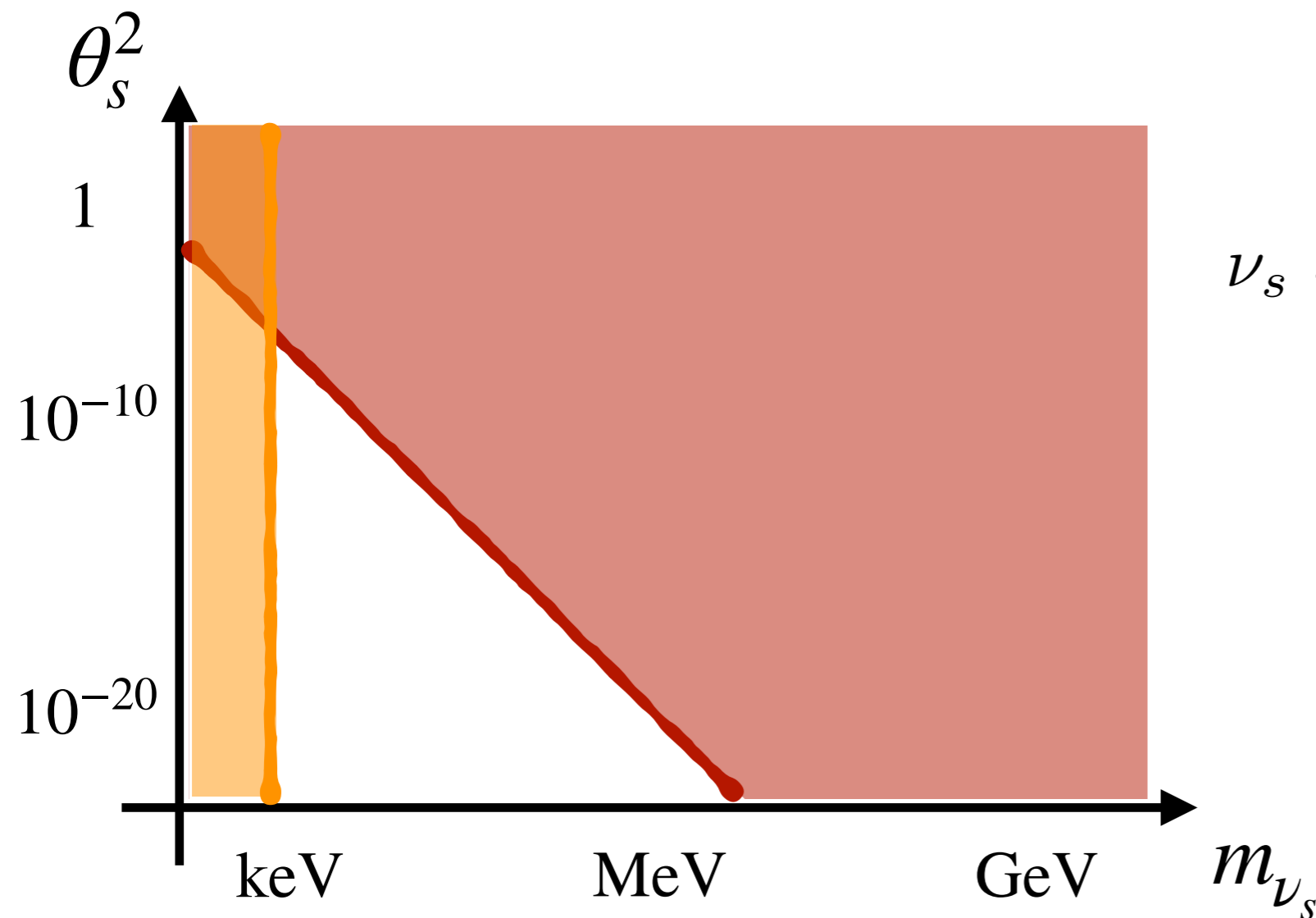
# Sterile neutrino dark matter

- Warm dark matter

$$m_{\nu_s} \gtrsim 1 \text{ keV}$$

- Decay into X/Gamma-rays

$$\Gamma_{\nu_s \rightarrow \nu_a \gamma} \propto \theta_s^2 m_{\nu_s}^5$$



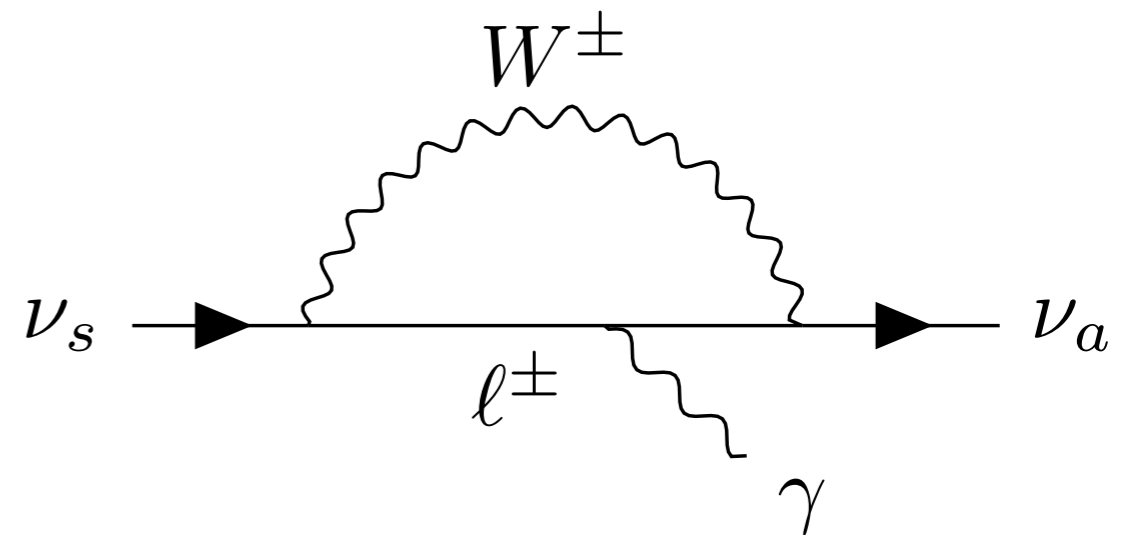
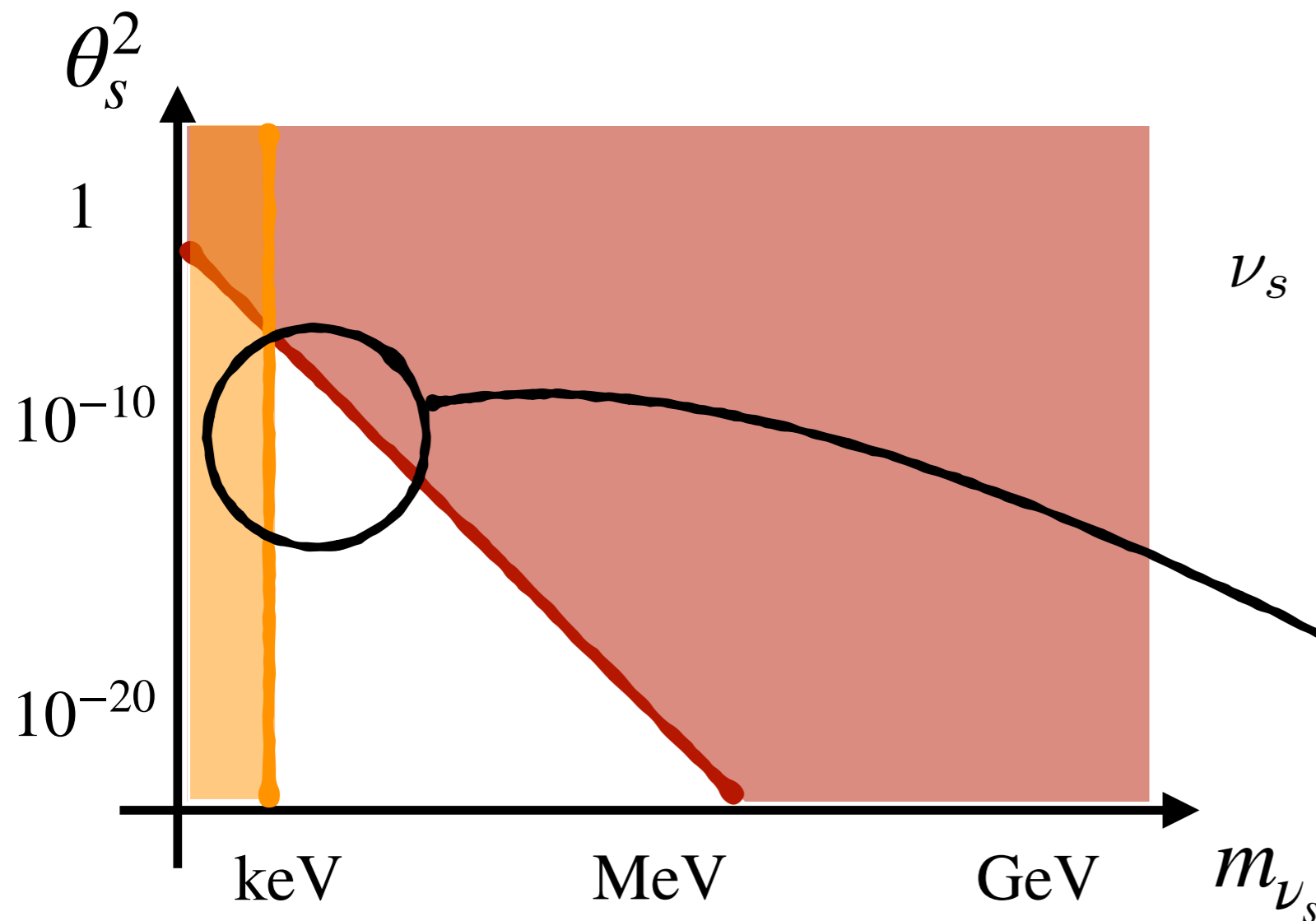
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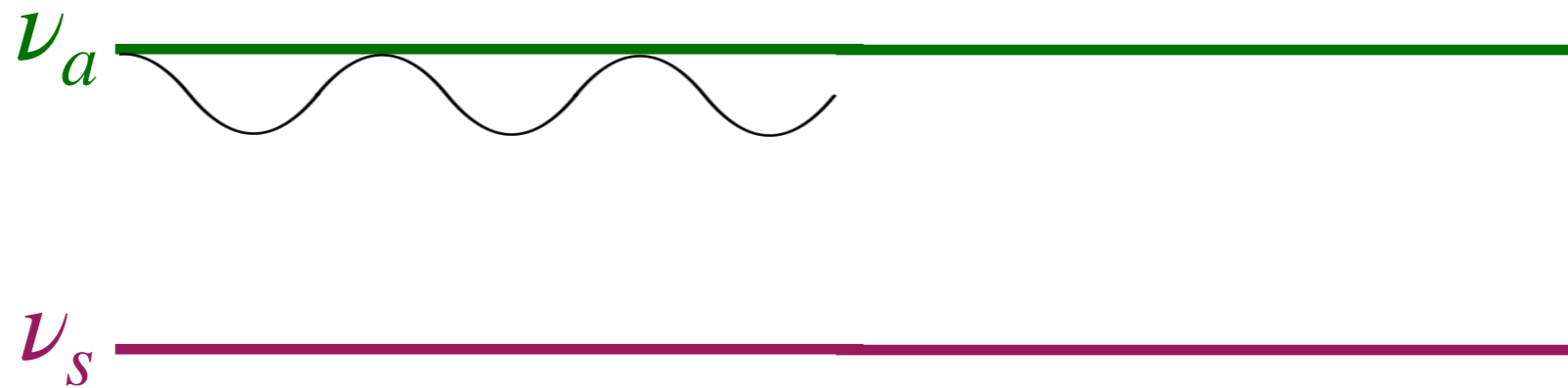
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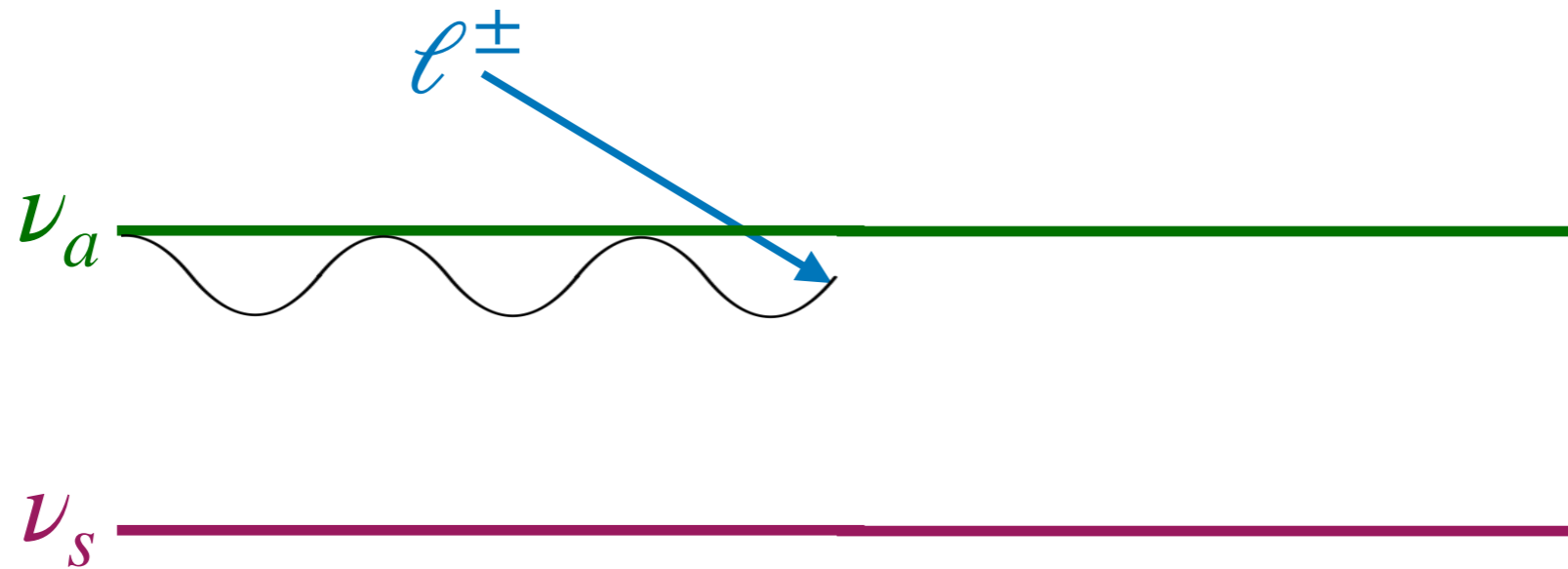


Most interesting region

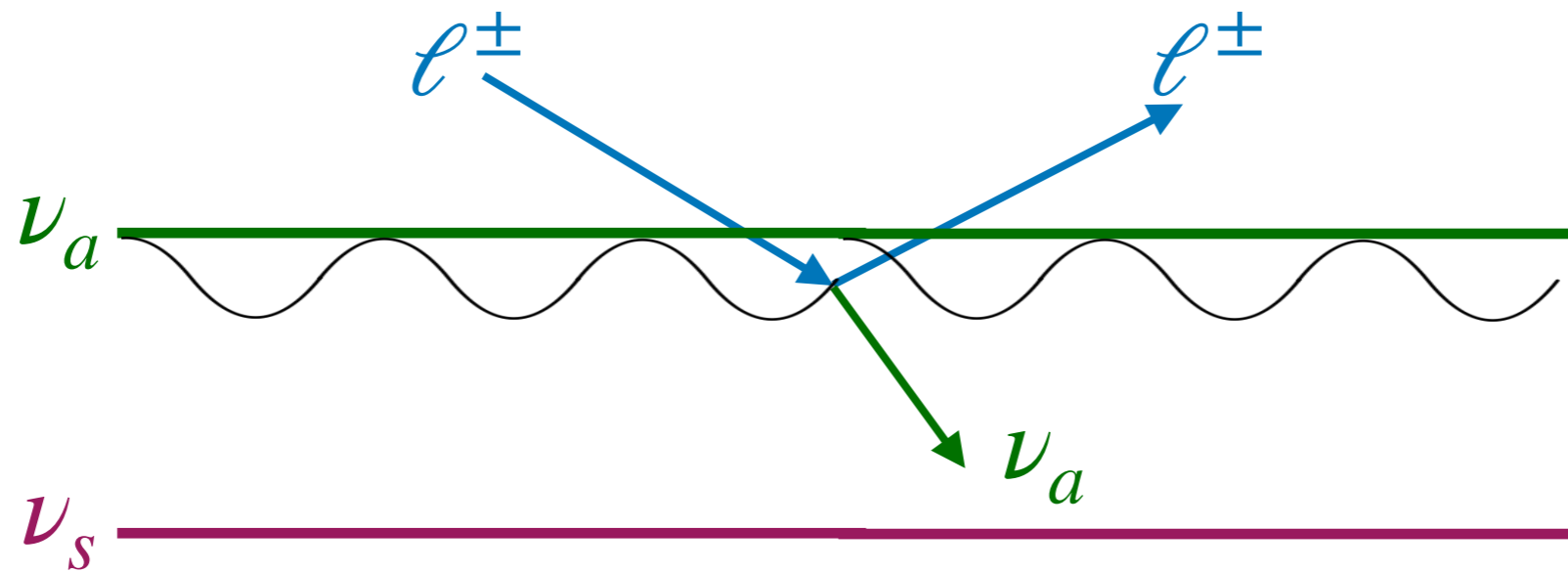
# Non-resonant production



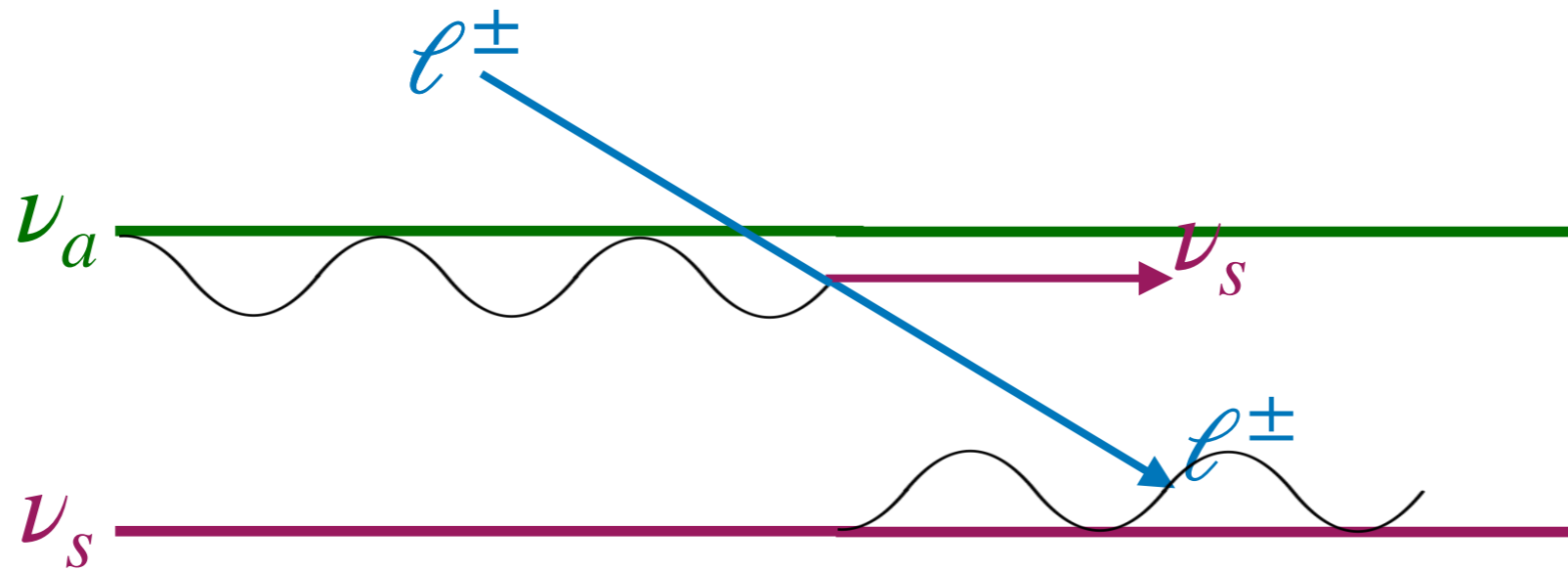
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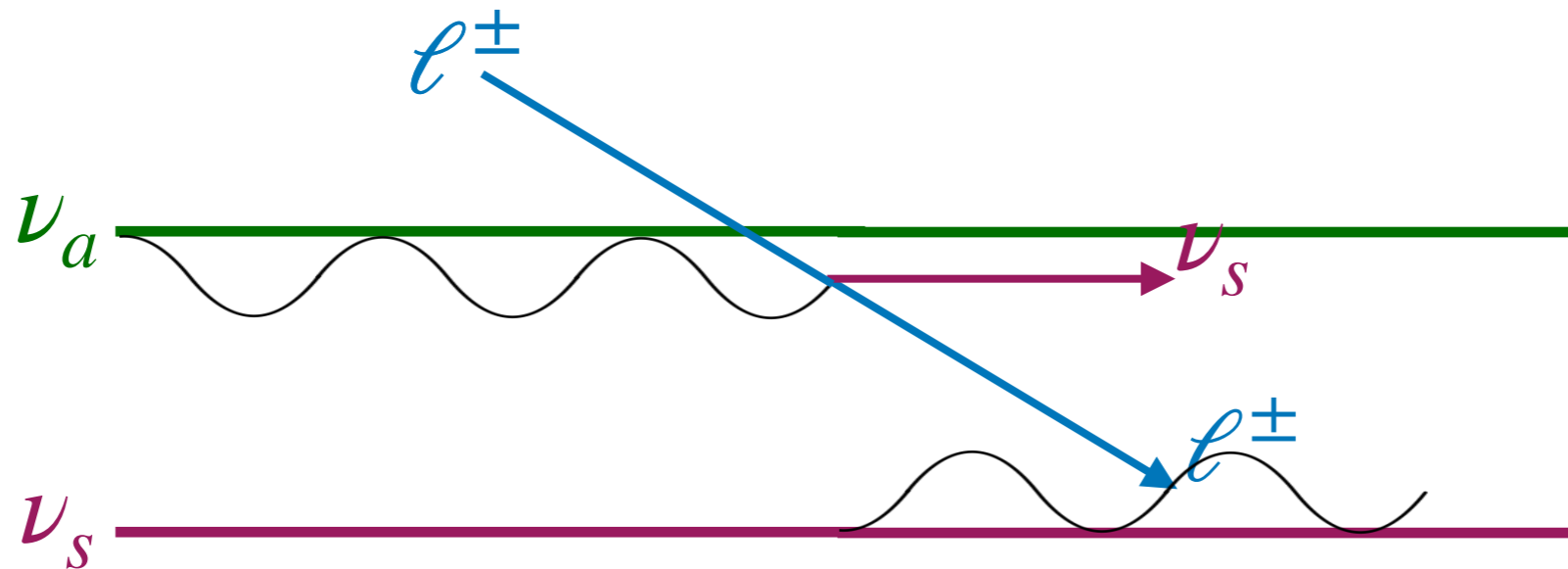
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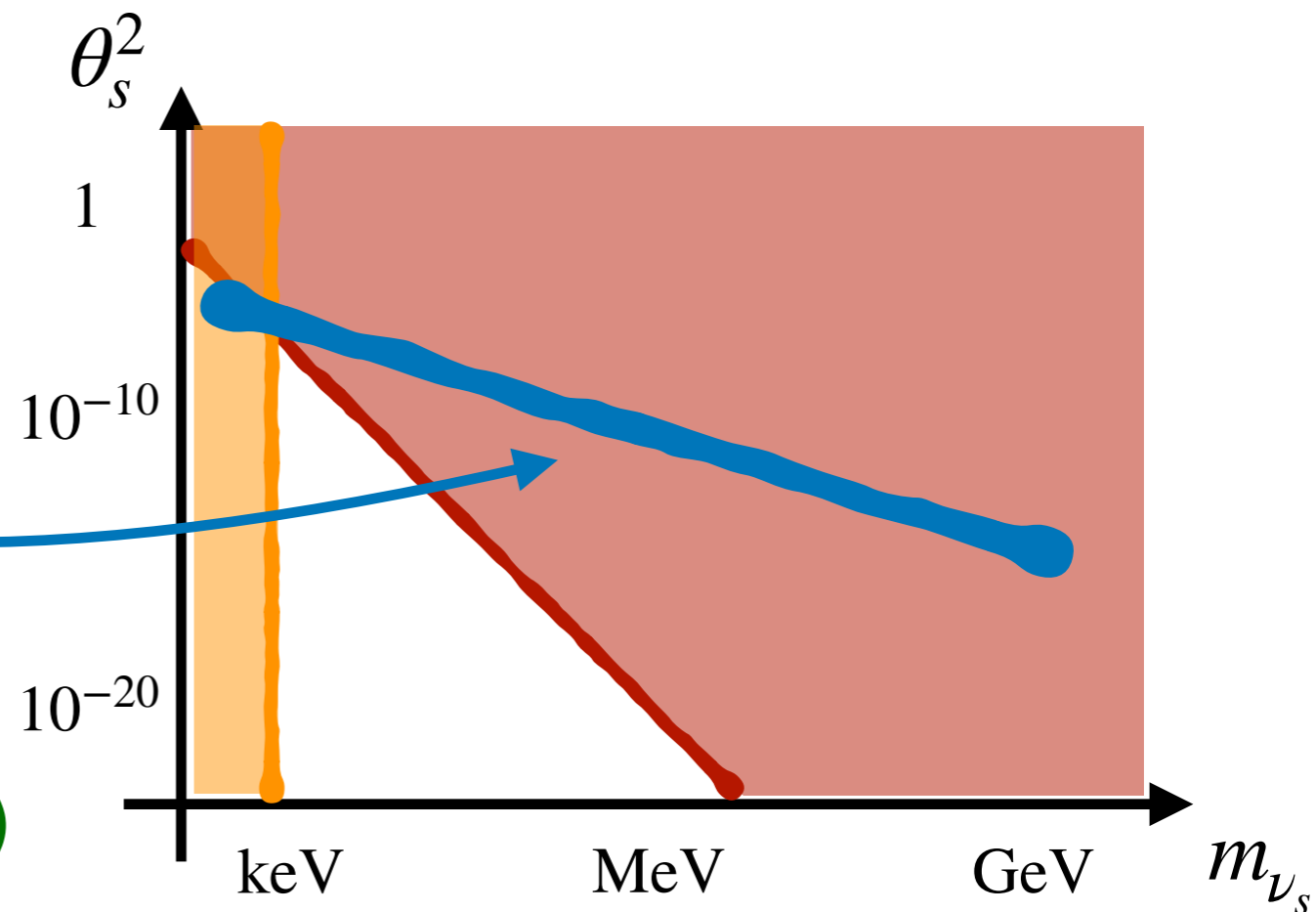
Production rate

$$\Gamma_s = \Gamma_a(T) \cdot \langle P_{a \rightarrow s} \rangle$$

where

$$P_{a \rightarrow s} = \left| 2\theta_s \sin(\omega t) \right|^2$$

Dodelson & Widrow (1994)



# Resonant production

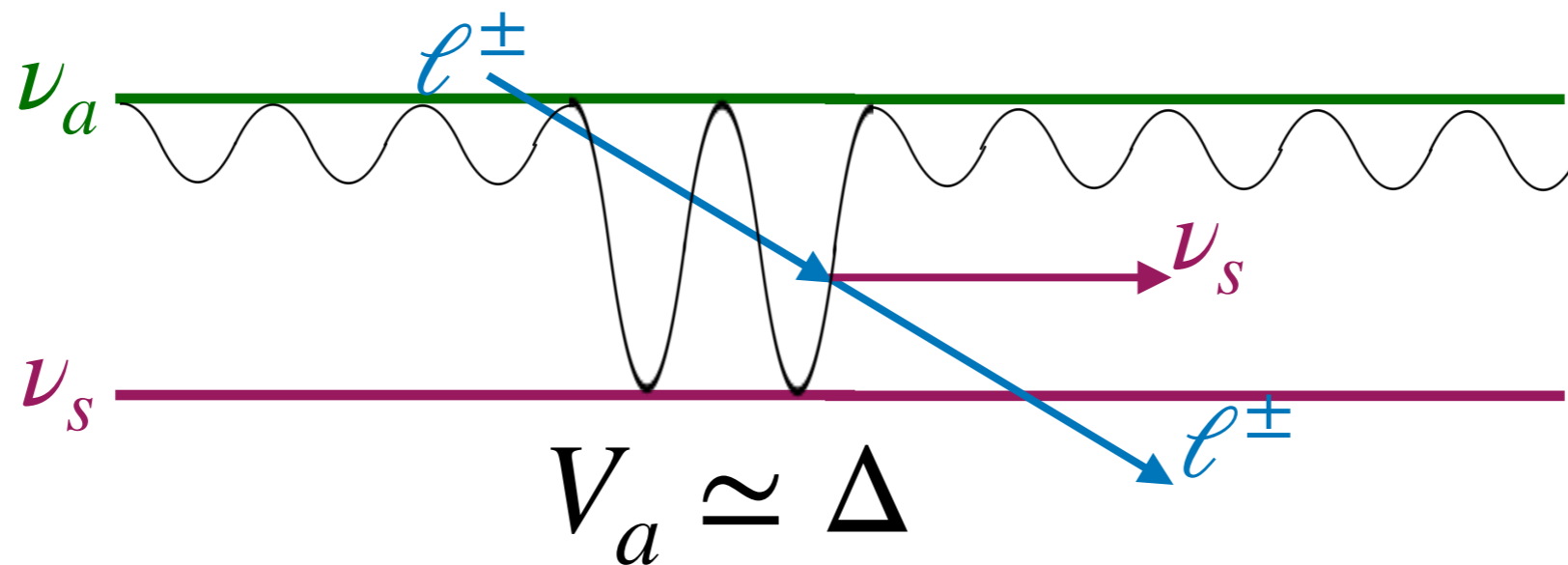
In the presence of matter effects

$$\langle P_{a \rightarrow s} \rangle \approx \frac{1}{2} \frac{4\Delta^2 \theta_s^2}{4\Delta^2 \theta_s^2 + \Gamma_a^2/4 + (V_a - \Delta)^2}$$

$$\Delta = \frac{m_s^2 - m_a^2}{2p} > 0$$

Decoherence  
by scatterings

Matter  
potential



Caveat:  $V_a < 0$  unless there is a huge lepton asymmetry  $L \sim 10^5 B$

# Neutrino gauge interactions

Gauge the anomaly-free lepton number symmetries

$$U(1)_{B-L}, \quad U(1)_{L_e-L_\mu}, \quad U(1)_{L_e-L_\tau}, \quad U(1)_{L_\mu-L_\tau}$$

SSB  
→

$A'$  becomes massive ( $m_{A'} \ll 1 \text{ eV}$ )

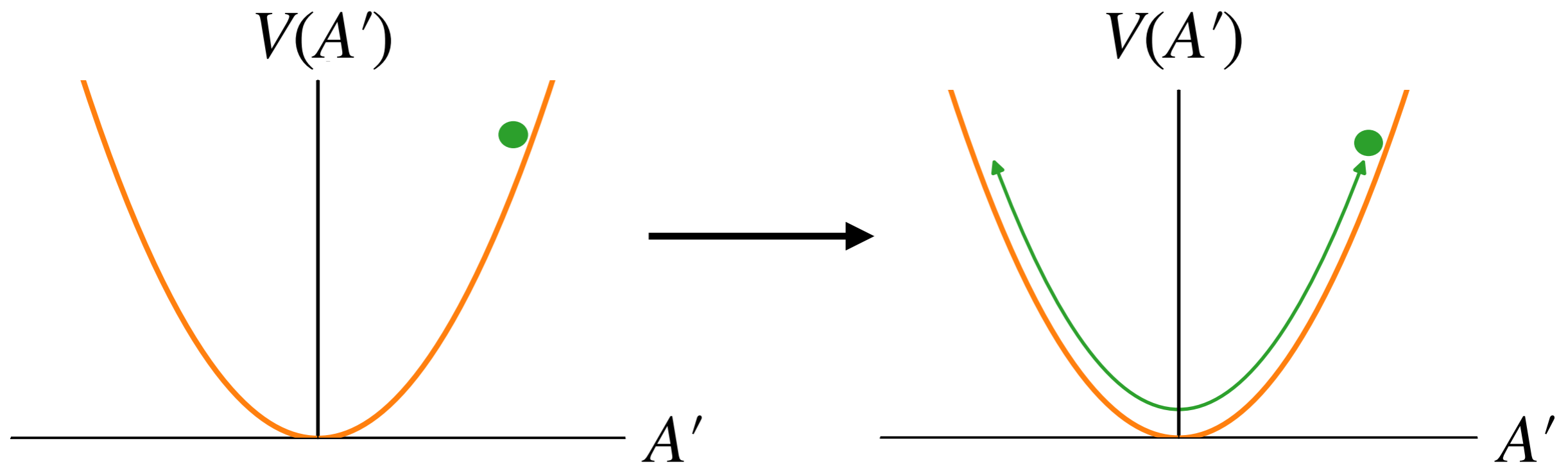
A dark “electromagnetic field” can modify the dispersion relation of active neutrinos

$$\omega_{\mathbf{p}_\nu}^2 - \mathbf{p}_\nu^2 = \Pi(\omega_{\mathbf{p}_\nu}, \mathbf{p}_\nu, A') \longrightarrow V_a$$

# Cosmological dark EM fields

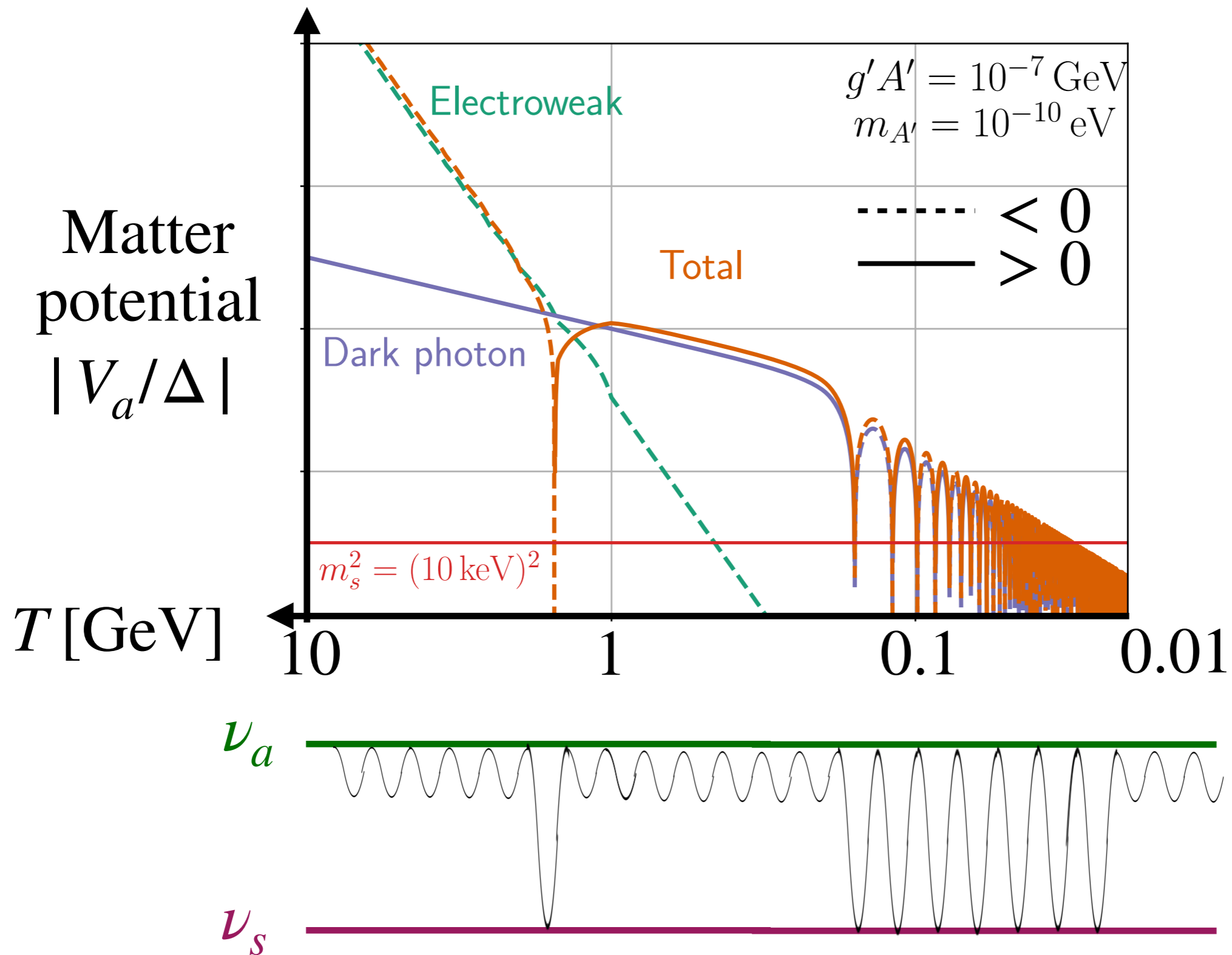
The dark photon can acquire a VEV ( $\sim$ misalignment mechanism)

Initial conditions:  
inflationary fluctuations

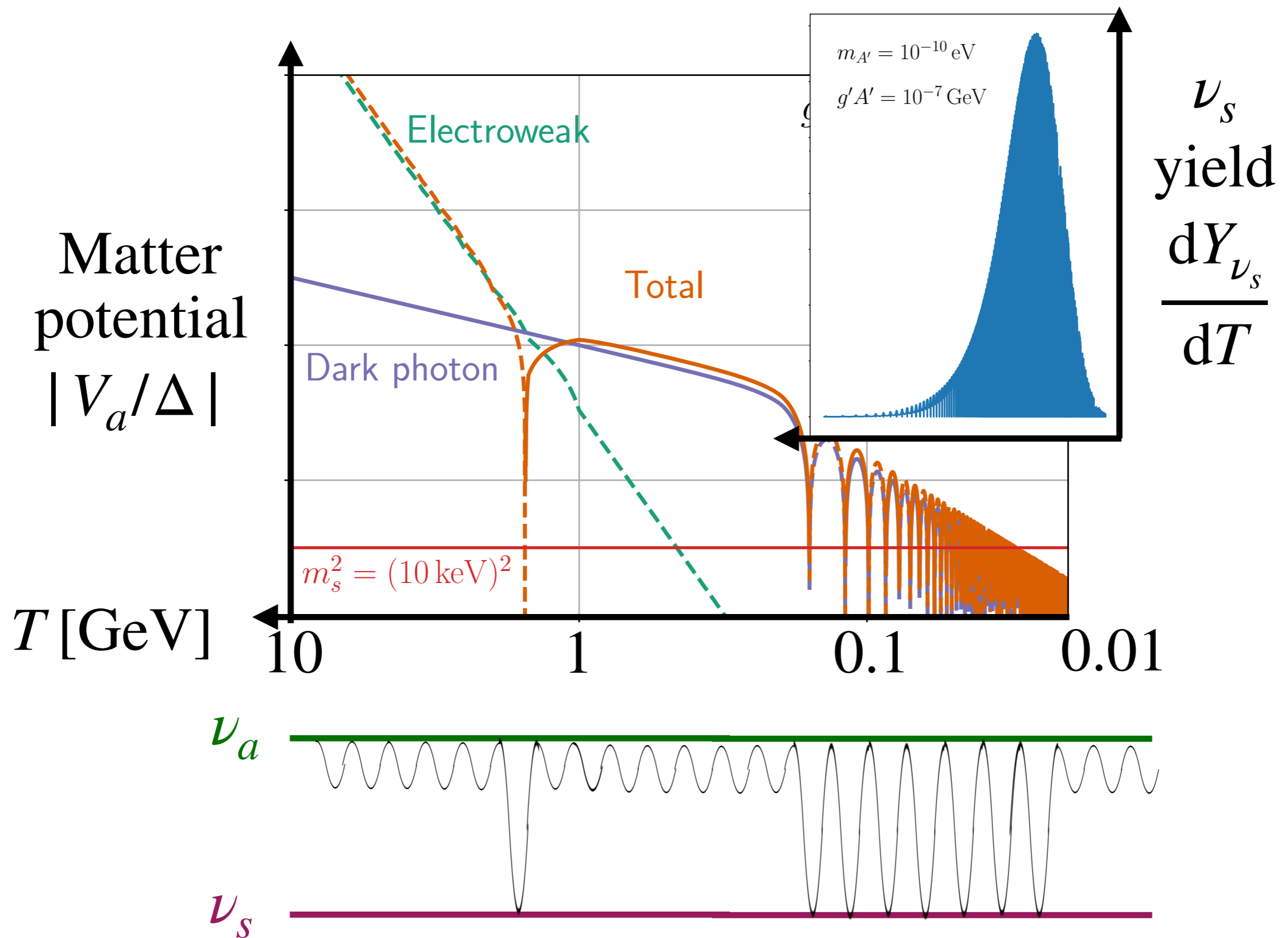


Late times:  
oscillations in the matter potential

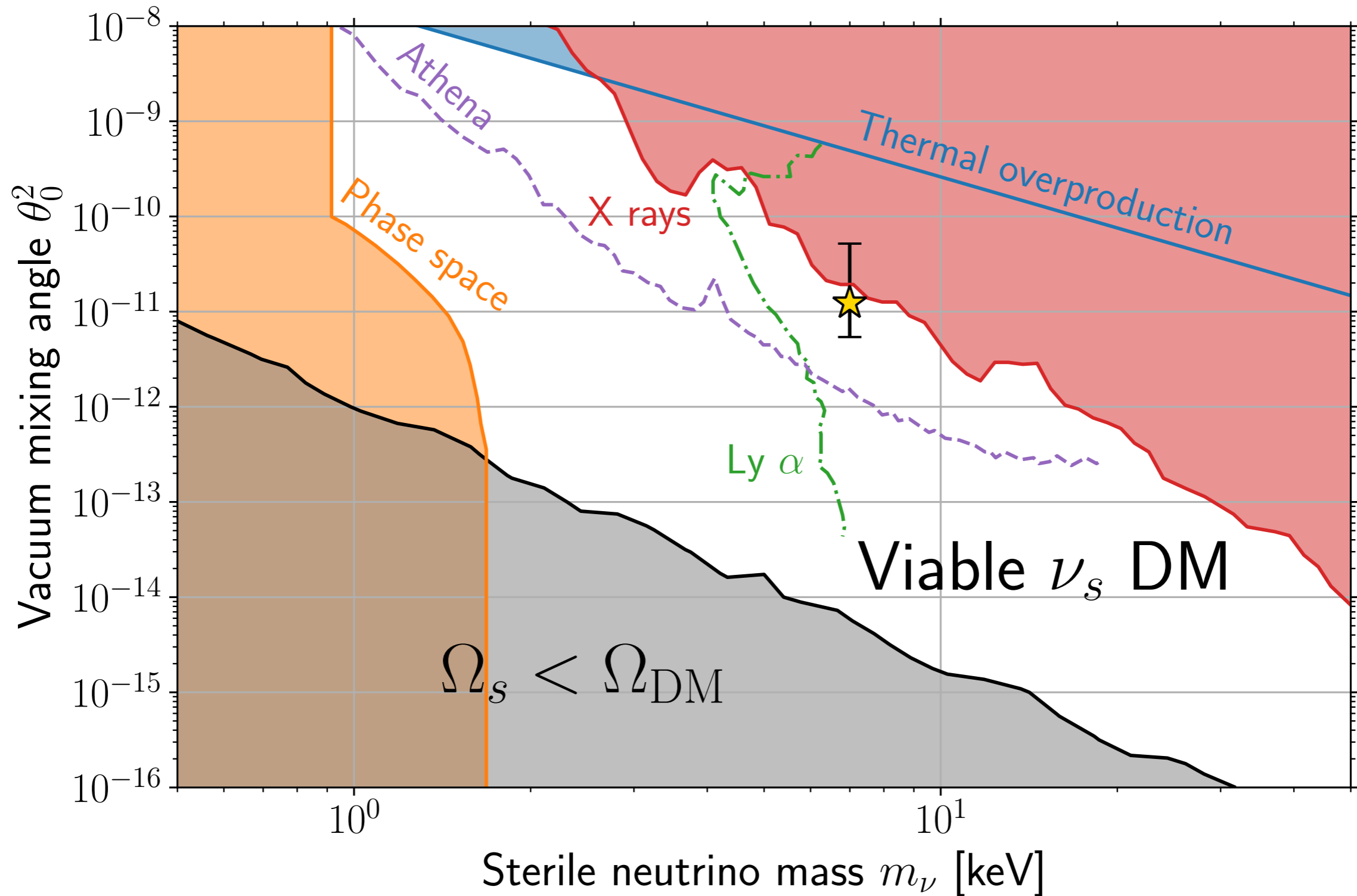
# (Multi-)resonant production



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# Parameter space



# Conclusions & outlook

- An  $L_\mu - L_\tau$  dark photon can mediate resonant keV sterile neutrino dark matter production
- Associated phenomenology:
  - Atmospheric neutrino oscillations
  - CMB & dark photon-induced  $\nu_a$  decay
  - Component of dark photon dark matter

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**Thanks!**

# Backup

# Dark photon parameter space

