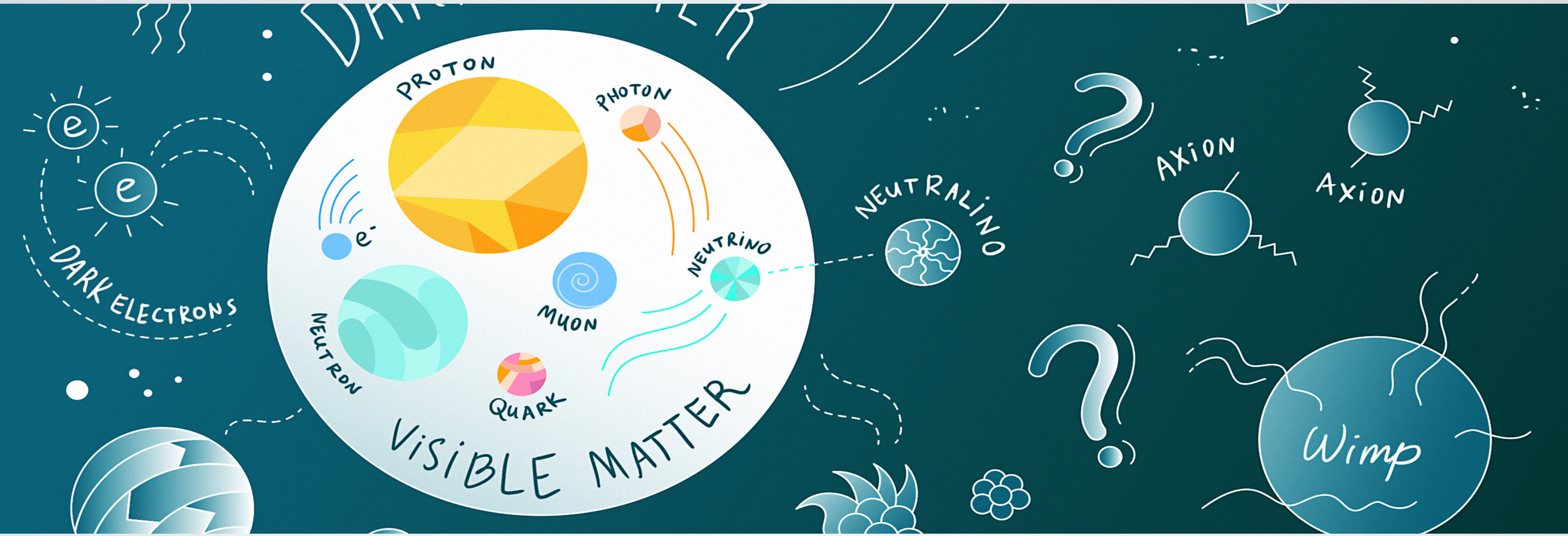
SIMP model at NNLO in ChPT



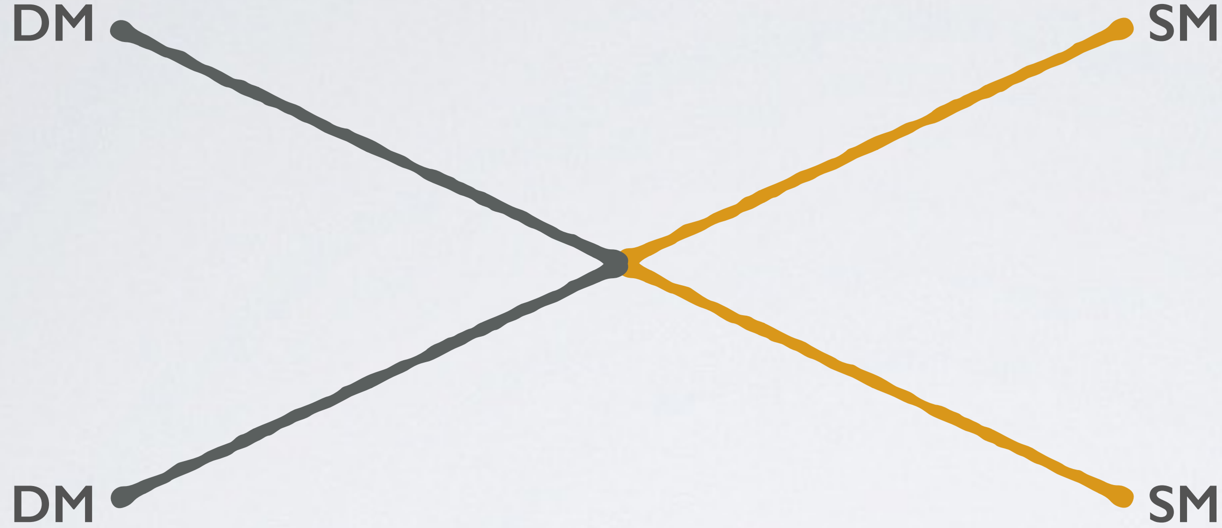
Kasper Langæble
Martin Hansen, Francesco Sannino

SCALARS 2015

UNIVERSITY OF SOUTHERN DENMARK.DK

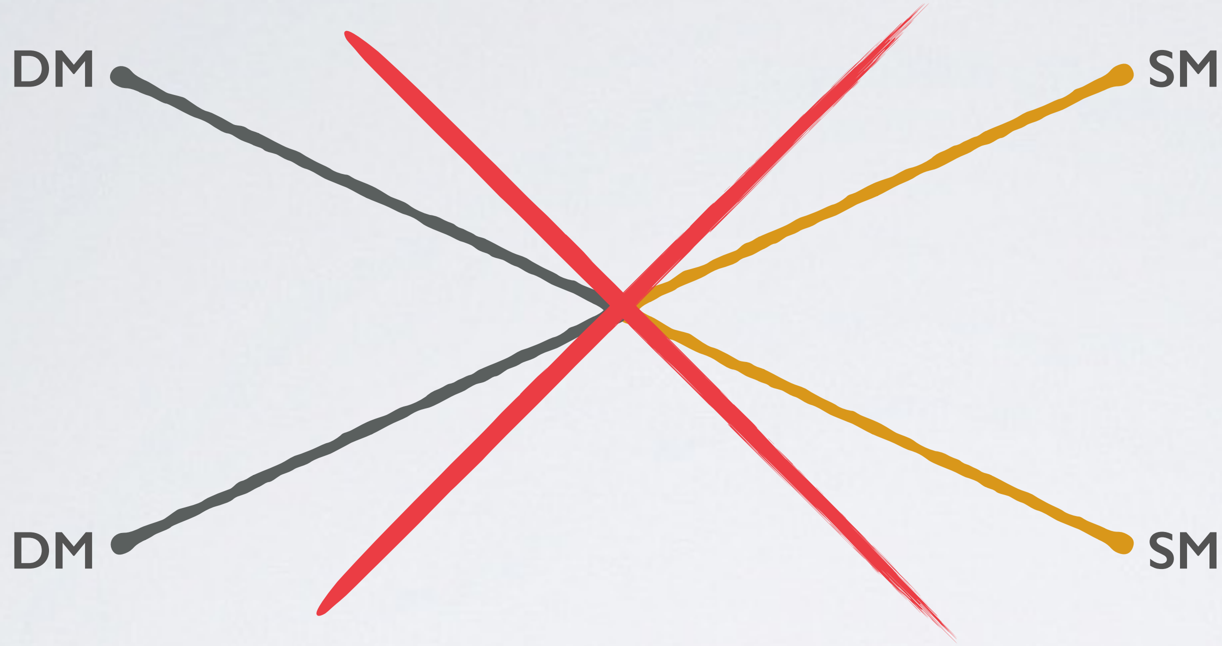
CP3 Origins
Cosmology & Particle Physics

The SIMP Mechanism

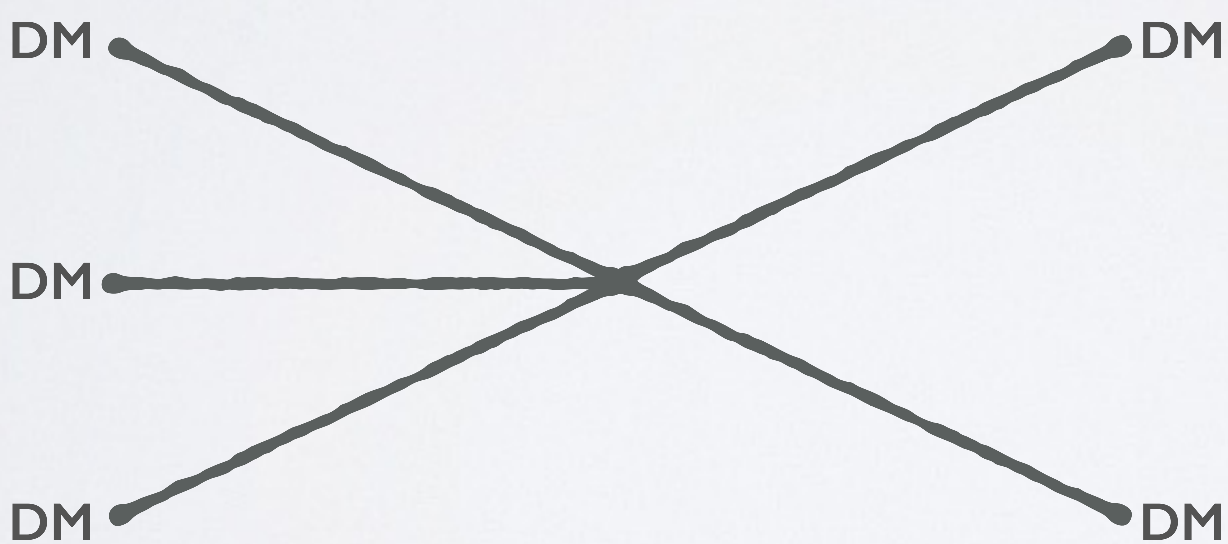


$2 \rightarrow 2$ annihilation

The SIMP Mechanism



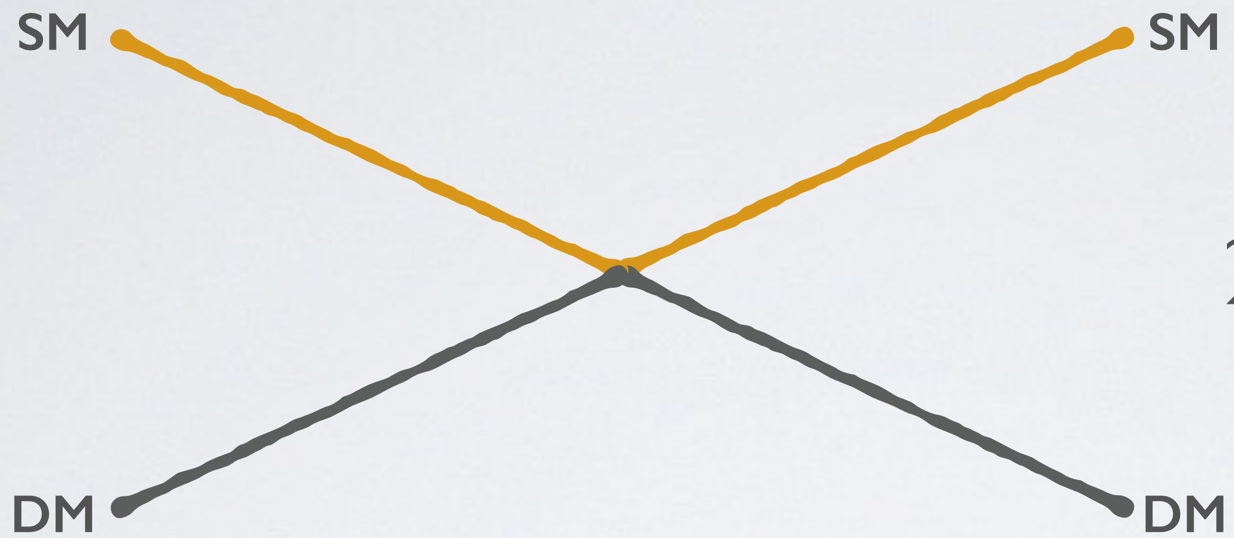
$2 \rightarrow 2$ annihilation



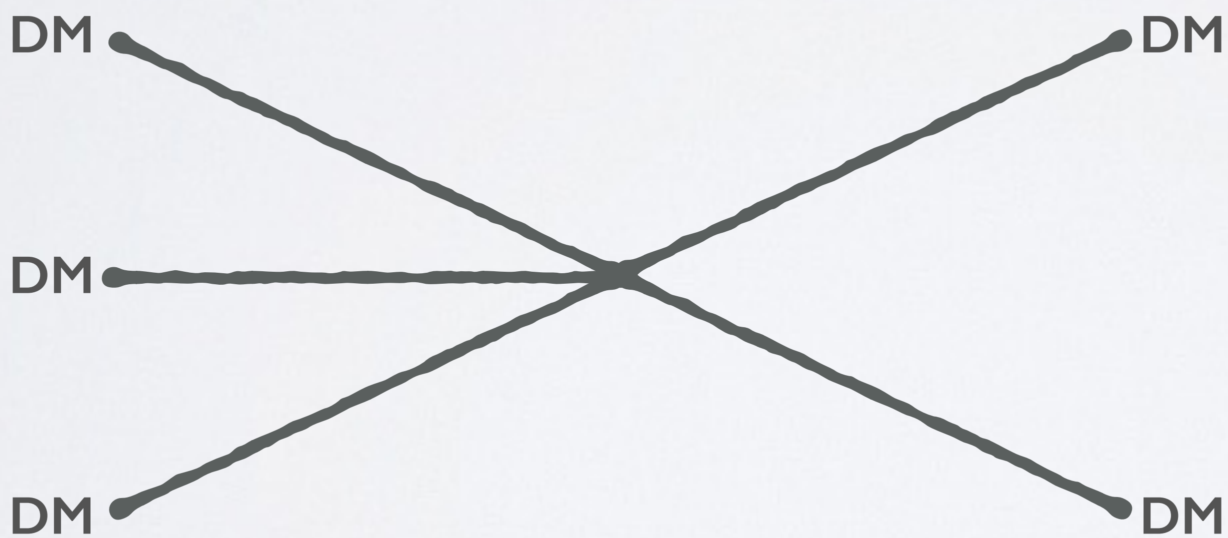
$3 \rightarrow 2$ annihilation

Y. Hochberg *et al*: Phys.Rev.Lett. 113 (2014) 171301

The SIMP Mechanism



2 → 2 scattering



3 → 2 annihilation

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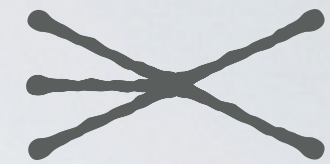
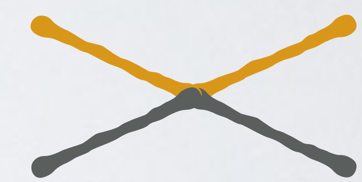
Relevant processes

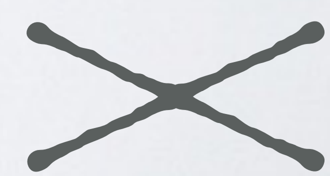
- The 3 → 2 process fixes the DM coupling constant by solving the Boltzmann equation.



- The 2 → 2 scattering process between DM and SM particles keeps the DM particles in thermal equilibrium with the SM bath until freeze-out.



- The 2 → 2 scattering process between DM particles are constrained by observations.



Features

- SM-DM coupling constraints

$$\langle \sigma v \rangle_{kin} = \frac{\epsilon^2}{m_{DM}^2} \qquad 1 \times 10^{-9} \lesssim \epsilon \lesssim 3 \times 10^{-6}$$

- Boltzmann equation

$$\dot{n} + 3Hn = -(n^3 - n^2 n_{eq})\langle \sigma v^2 \rangle_{3\to 2}$$

- Expected mass

$$m_{DM} \sim 100 \text{ MeV}$$

Realisation via ChPT

SIMPlest Miracle

- Y. Hochberg *et al*: Phys.Rev.Lett. 115 (2015) 021301
- Analysis to lowest non-vanishing order

SIMPlest Miracle

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- Analysis to lowest non-vanishing order
- The topological WZW term leads to a 5-point interaction

$$\mathcal{L}_{WZW}^{(4)} = \frac{N_c}{240\pi^2} \int_0^1 d\alpha \int d^4x \; \epsilon^{abcde} \langle u_a u_b u_c u_d u_e \rangle$$

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$$\mathcal{L}^{(2)} = \frac{f^2}{4}\langle u^\mu u_\mu + \chi_+\rangle$$

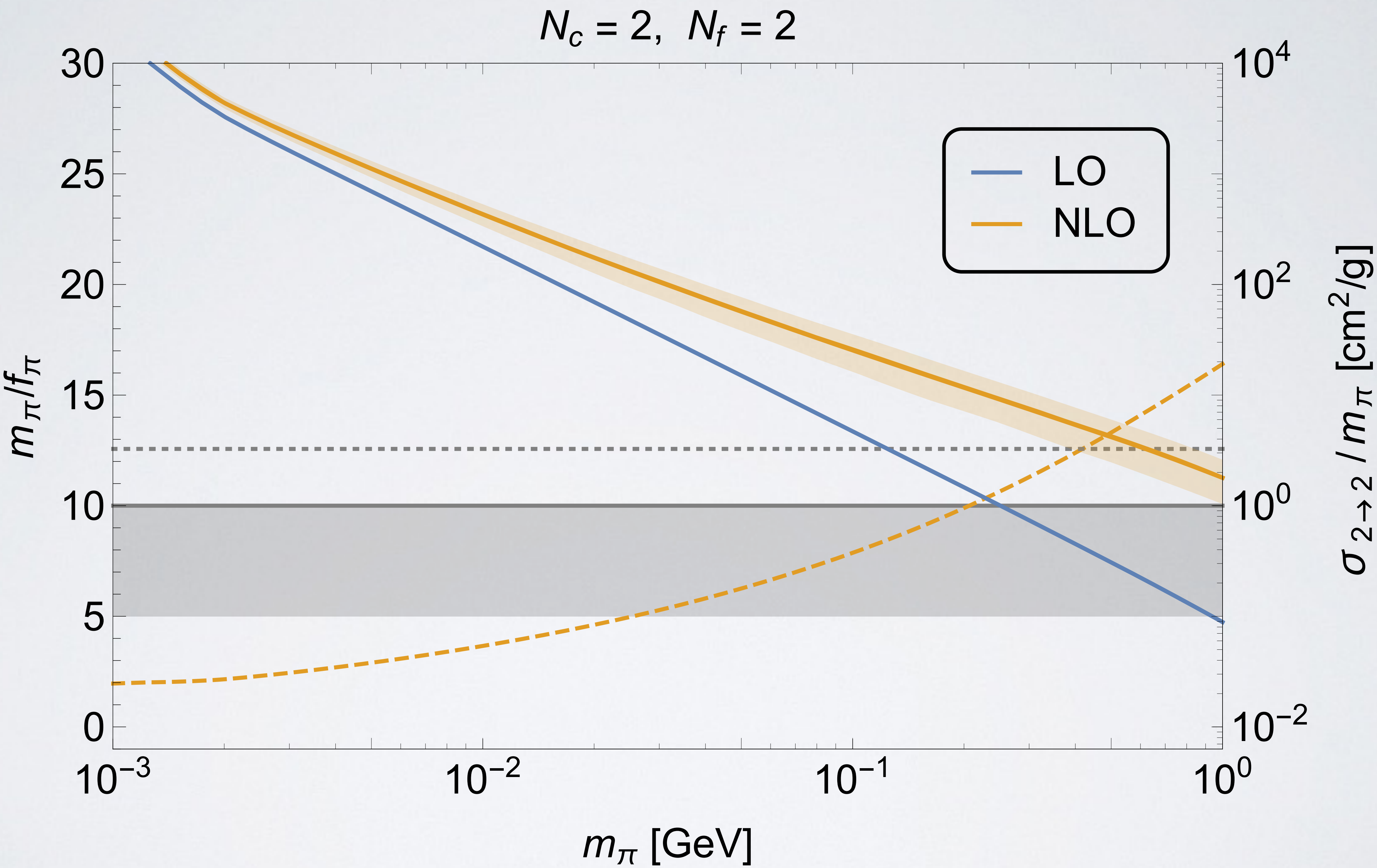
ChPT

- We always work with the *physical* values for the mass and decay constant.

$$f_\pi = f\left[1+\frac{m^2}{f^2}(a_f L + b_f)\right]$$
$$m_\pi^2 = m^2\left[1+\frac{m^2}{f^2}(a_m L + b_m)\right]$$

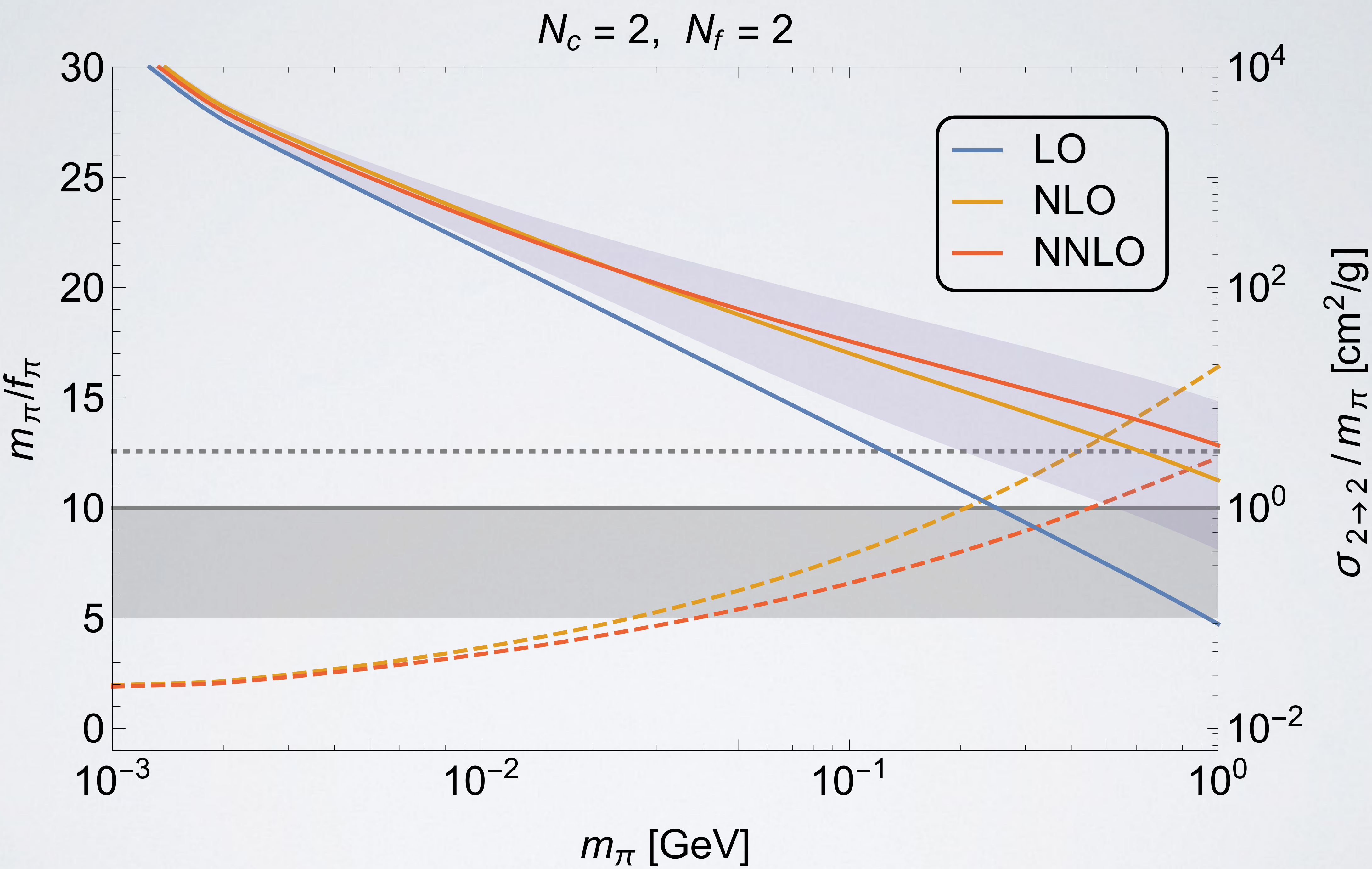
- The Boltzmann equation is solved by inserting the *physical* mass and it returns a value for the *physical* decay constant.
- These values are subsequently inserted in the cross section for the 2 → 2 scattering process to check with self-interaction constraints.

ChPT



Phys.Rev. D92 (2015) 075036 (arXiv:1507.01590)

ChPT



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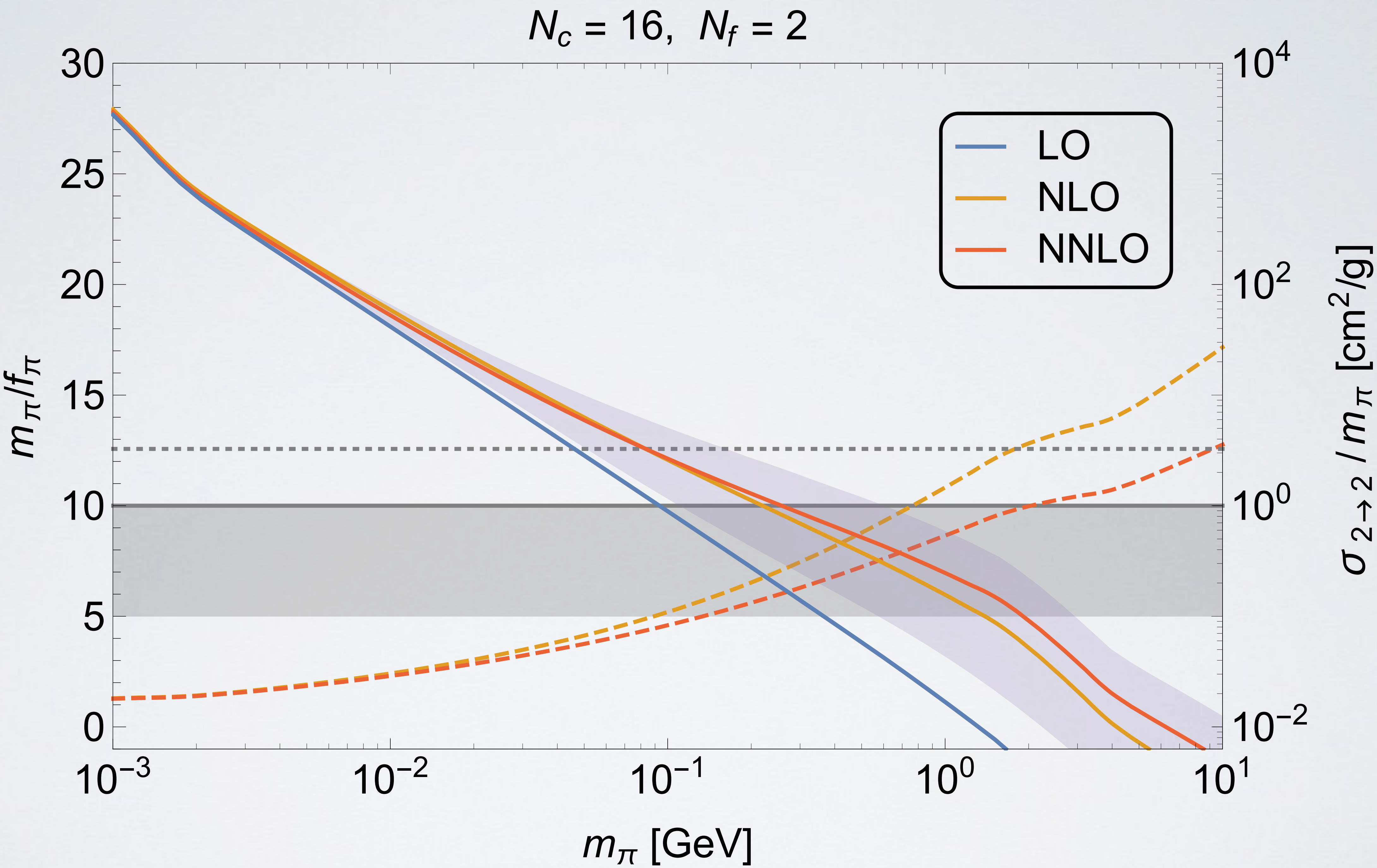

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Thank you!