



Dark Matter Searches at the LHC: Full Analysis for Leptophobic Mediators

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1. Introduction
2. General Results
3. Towards UV completions
4. Conclusions



1. Introduction

Approach at the LHC for DMSMs: example for spin-1 mediator

Spin-1 mediator

- Interaction Lagrangian mediator-DM

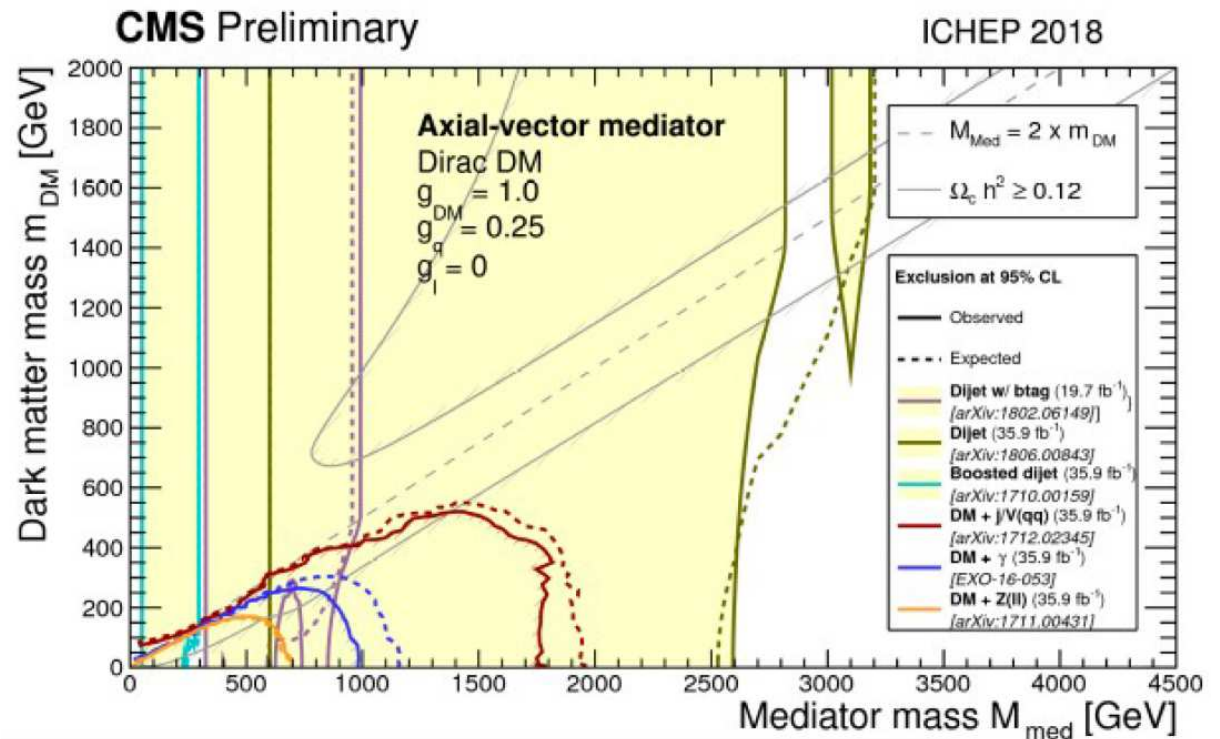
$$\mathcal{L}_{X_D}^{Y_1} = \bar{X}_D \gamma_\mu \left(g_{X_D}^V + g_{X_D}^A \gamma_5 \right) X_D Y_1^\mu.$$

- Interaction Lagrangian mediator-quarks

$$\mathcal{L}_{quarks}^{Y_1} = \sum_{i,j} \left[\bar{d}_i \gamma_\mu \left(g_{d_{i,j}}^V + g_{d_{i,j}}^A \gamma_5 \right) d_j + \bar{u}_i \gamma_\mu \left(g_{u_{i,j}}^V + g_{u_{i,j}}^A \gamma_5 \right) u_j \right] Y_1^\mu$$

- Interaction Lagrangian mediator-leptons

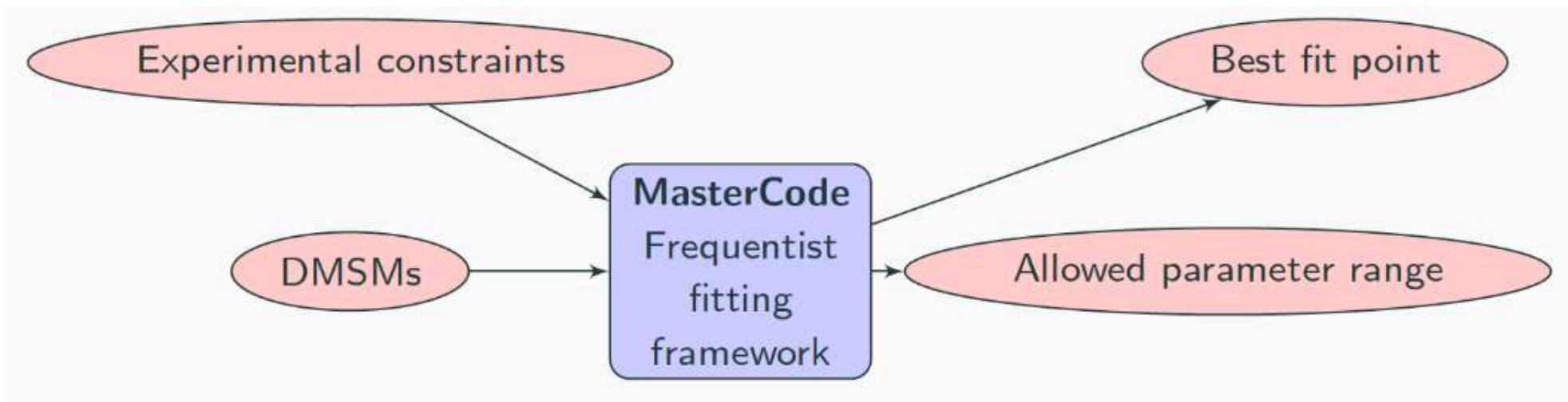
$$\mathcal{L}_{leptons}^{Y_1} = \sum_{i,j} \left[\bar{l}_i \gamma_\mu \left(g_{l_{i,j}}^V + g_{l_{i,j}}^A \gamma_5 \right) l_j \right] Y_1^\mu$$



- simplifying assumptions on the Lagrangian (more soon)
- Results for fixed values of m_{med} , m_{DM} , g_{SM} , g_{DM}
- overlay results from mono-jet search
- overlay results from di-jet searches
- . . .

MasterCode approach

Fit to the full Lagrangian (some simplifying assumptions)



Included into the fit:

- DM relic density
- DM direct detection limits
- LHC mono-jet searches
- LHC di-jet searches

⇒ global picture of status and prospects

The Lagrangians

- We consider DMSMs with a spin-1 (Y_1) s-channel mediator.
- The dark matter candidate is a Dirac fermion (X_D).
- We use the model files provided by the DMSIMP package for our implementation.

Spin-1 mediator

- Interaction Lagrangian mediator-DM

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Scenarios

- Leptophobic, $g_{l_{i,j}}^V = g_{l_{i,j}}^A = 0$ (no constraints from dilepton searches).
- Flavor diagonal, $g_{u/d_{i,j}}^{V/A} = 0$ if $i \neq j$.
- Flavor blind, $g_{u_{i,j}}^{V/A} = g_{d_{i,j}}^{V/A}$.

$$1. \quad \begin{aligned} g_{X_D}^V &\equiv g_{DM} & g_{X_D}^A &= 0 \\ g_{u/d}^V &\equiv g_{SM} & g_{u/d}^A &= 0, \end{aligned}$$

pure vector.

$$2. \quad \begin{aligned} g_{X_D}^V &= 0 & g_{X_D}^A &\equiv g_{DM} \\ g_{u/d}^V &= 0 & g_{u/d}^A &= g_{SM}, \end{aligned}$$

pure axial-vector.

[taken from E. Bagnaschi]

MasterCode set-up :

- **Frequentist fitting** framework written in Python/Cython and C++
- **Multinest** algorithm is used to sample the parameter space
- **udocker** used for deployment

Scan ranges:

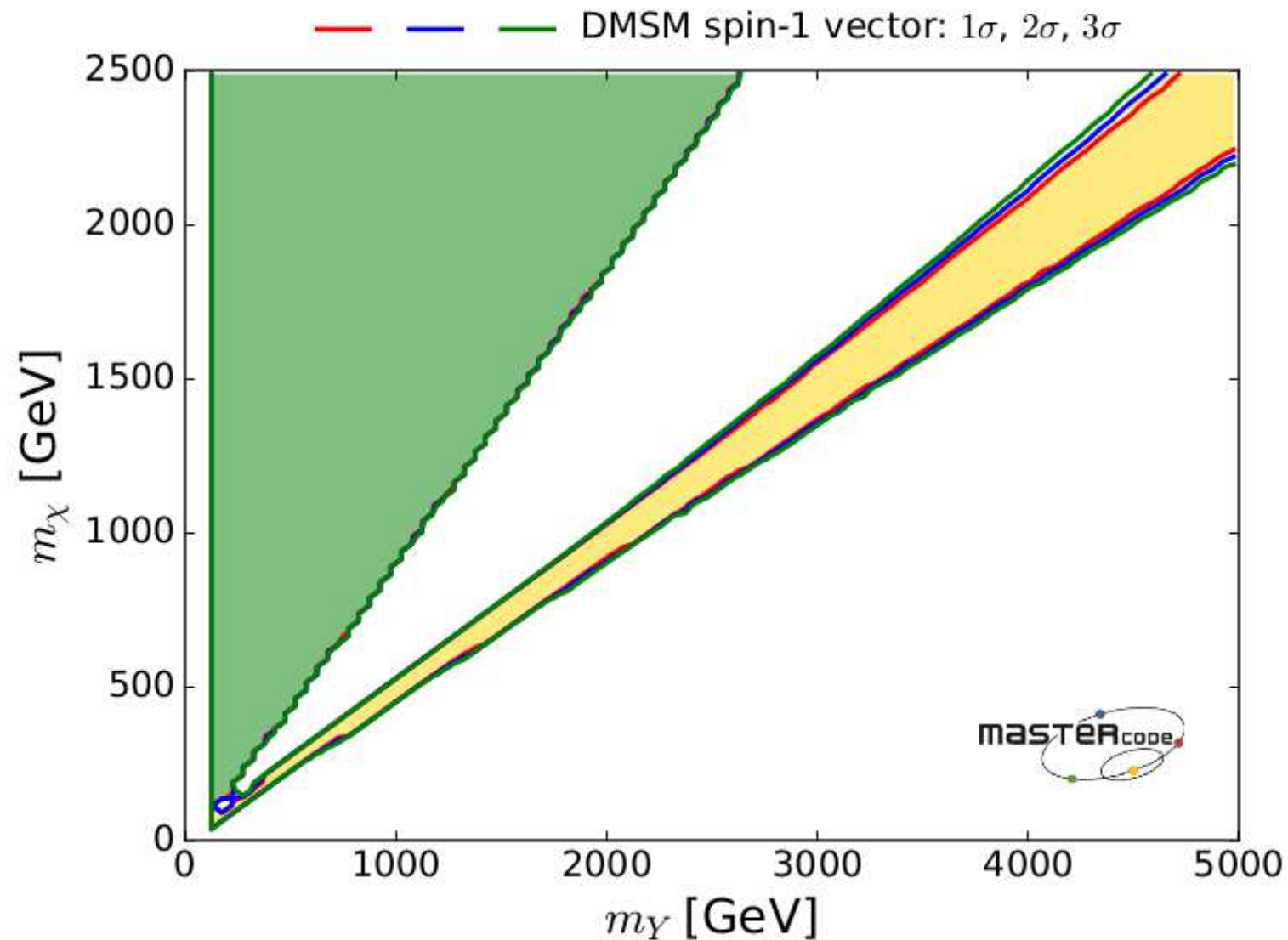
Parameter	Range	# of Segments
m_Y (mediator)	(0.1, 5) TeV	10
m_χ (DM)	(0, 2.5) TeV	8
g_{SM}	$(10^{-6}, \sqrt{4\pi})$	2
g_{DM}	$(10^{-6}, \sqrt{4\pi})$	2
Total # of segments		320

Constraints:

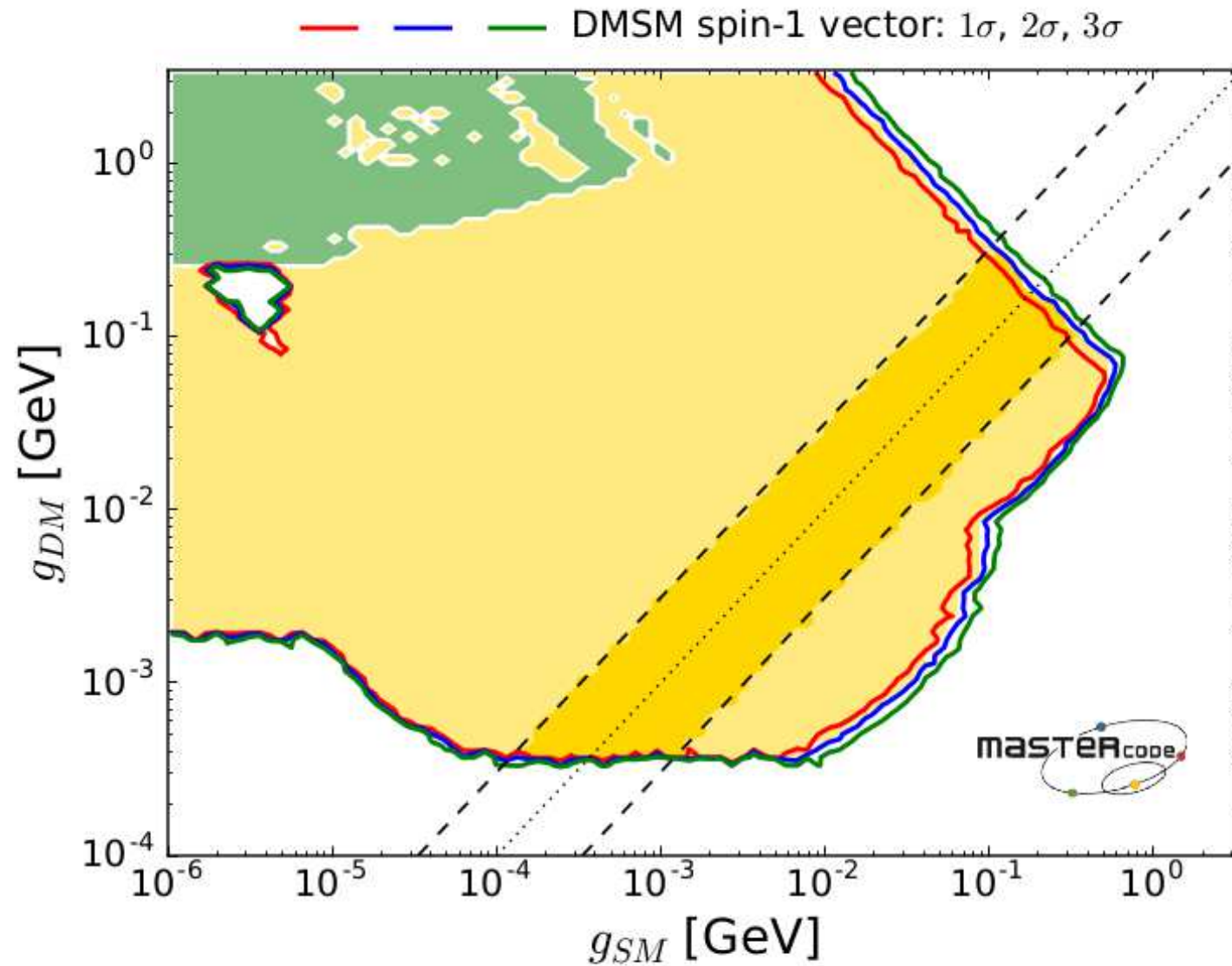
- DM constraints: relic abundance
⇒ full agreement with ATLAS/CMS results/implementations
 - DM constraints: direct detection
⇒ LUX, Xenon1T, PANDAX, PICO60
 - Mono-jet constraints
⇒ MC5 aMC(N)NLO, Fastlim approach
 - di-jet constraints
⇒ MC5 aMC(N)NLO, Fastlim approach
- details in the back-up

2. General Results

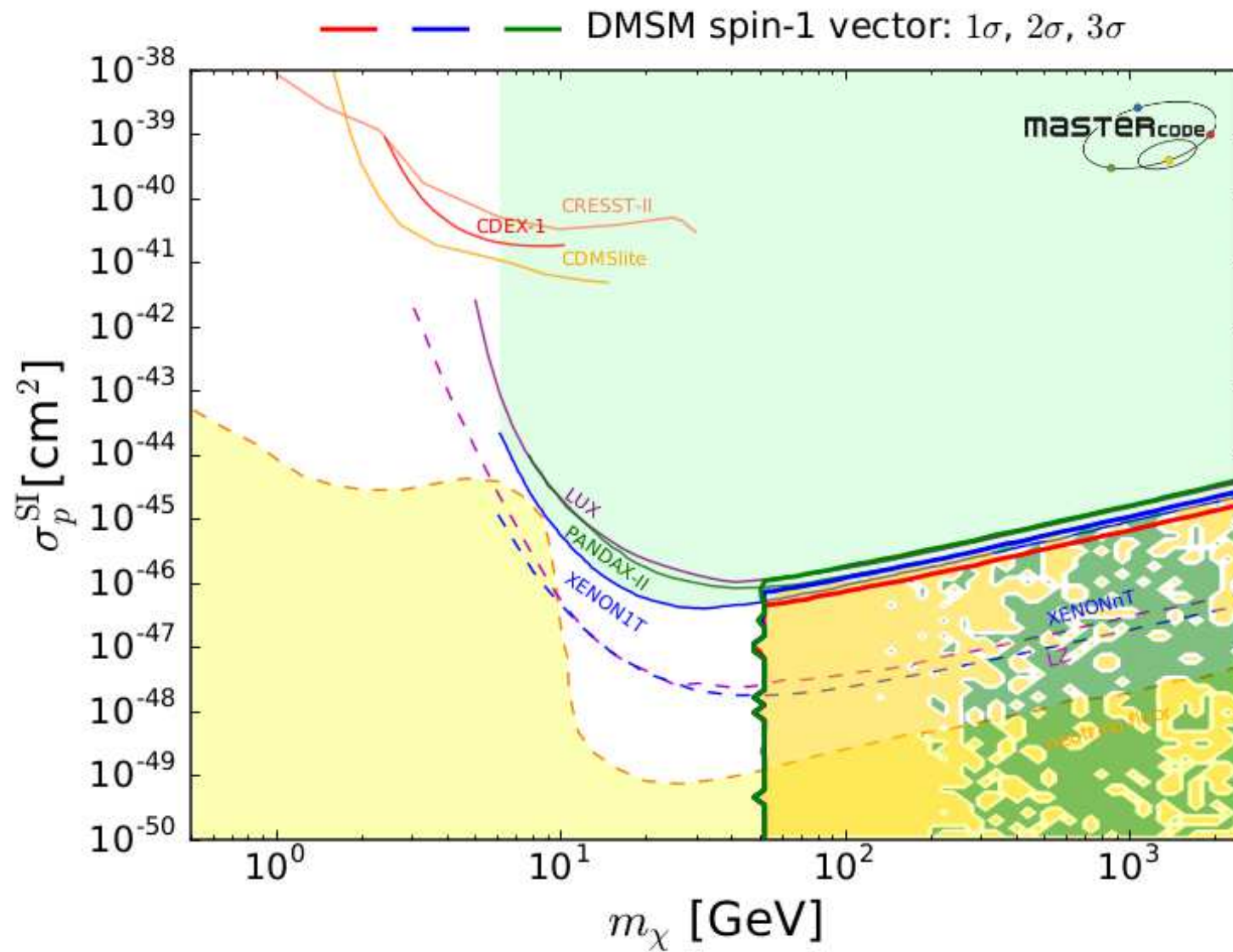
- Results for vector mediator model
- Results for axial-vector mediator model → back-up
- No restrictions on couplings or masses
- Color coding:
 - green: annihilation via t -channel χ exchange
into pairs of mediator particles Y that subsequently decay
into SM particles
 - yellow: rapid annihilation directly into SM particles
via the s -channel Y resonance



⇒ clear separation between s - and t -channel



⇒ large ranges allowed, t -channel only for $g_{DM} \gg g_{SM}$



⇒ mixed prospects, both for s - and t -channel case

3. Towards UV completions

So far no UV completion considered!

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In any UV completion the spin-one boson could be expected to have comparable couplings to SM and DM particles, modulo possible group-theoretical factors and mixing angles!

$$g_{\text{DM}}/g_{\text{SM}} = \mathcal{O}(1)$$

3. Towards UV completions

So far no UV completion considered!

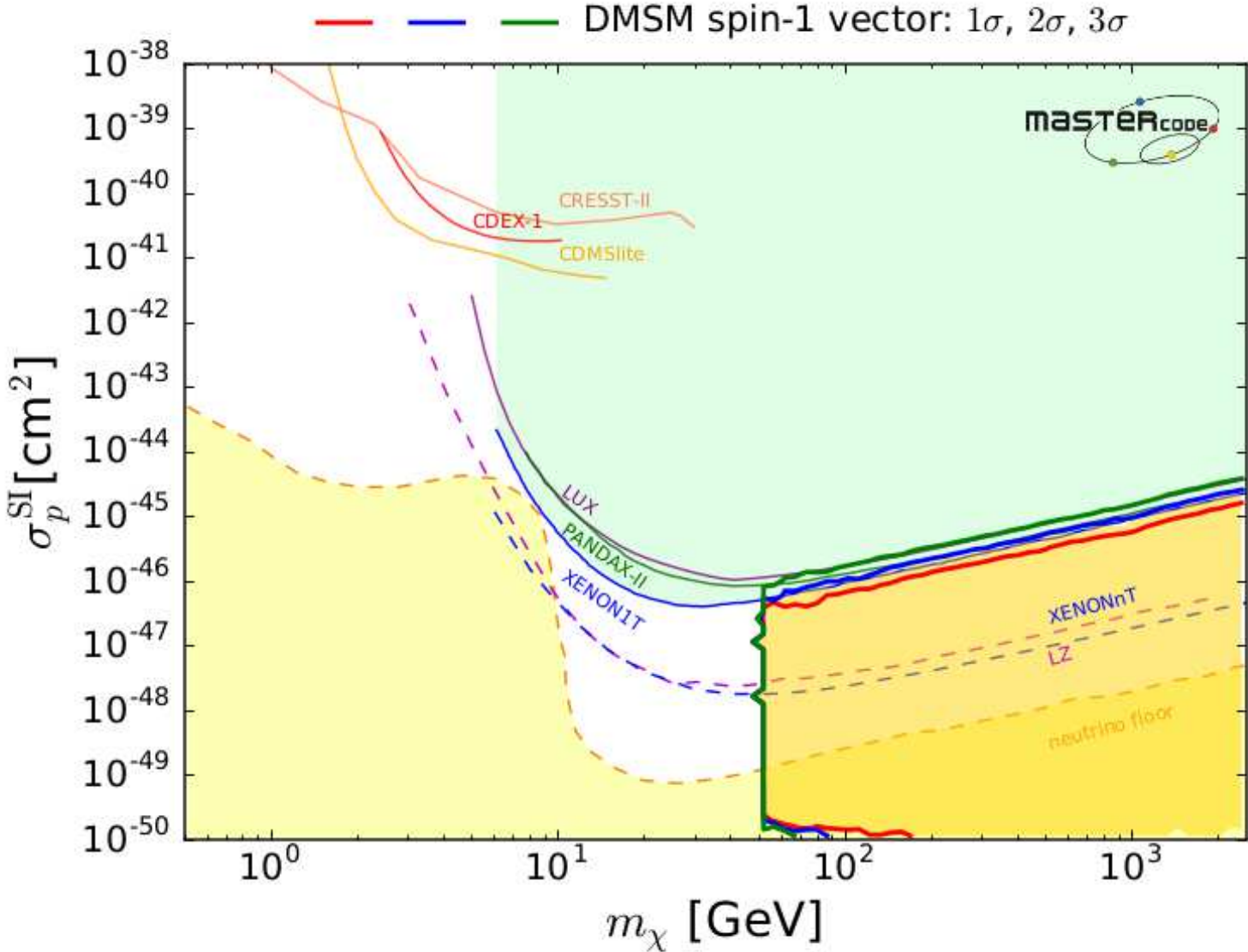
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$$g_{\text{DM}}/g_{\text{SM}} = \mathcal{O}(1)$$

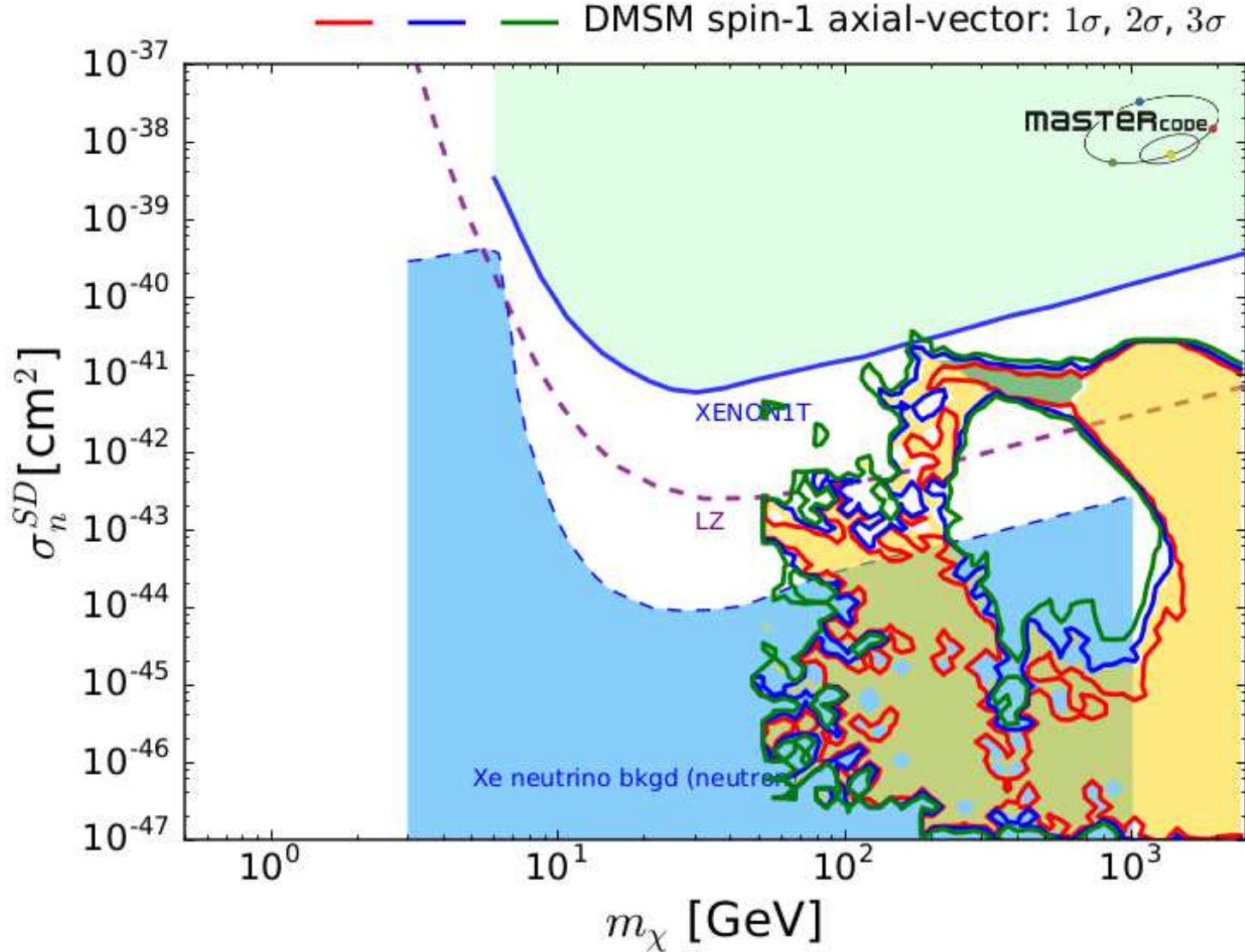
$$1/3 < g_{\text{DM}}/g_{\text{SM}} < 3$$

⇒ dark yellow regions

⇒ *s*-channel favored!



⇒ mixed prospects for discovery



⇒ *t*-channel can fully be probed, *s*-channel only partially

4. Conclusions

- EFT vs. **DMSM** vs. full theories
- Lagrangian for **vector** or **axial-vector** mediator
- So far results presented for **fixed values** for some of g_{SM} , g_{DM} , m_{med} , m_{DM} and other constraints (**mono-jet**, **di-jet**) overlaid
- **MasterCode approach: full fit of the model**, including
 - DM relic density
 - DM direct detection limits
 - LHC mono-jet searches
 - LHC di-jet searches
- Vector mediator: s - and t -channel separated, **mixed prospects** for DD
- Axialvector: s - and t -channel continuous, **mixed prospects** for DD
- UV-completions: $1/3 < g_{SM}/g_{DM} < 3 \Rightarrow s$ -channel preferred
 \Rightarrow prospects for DD **not improved**

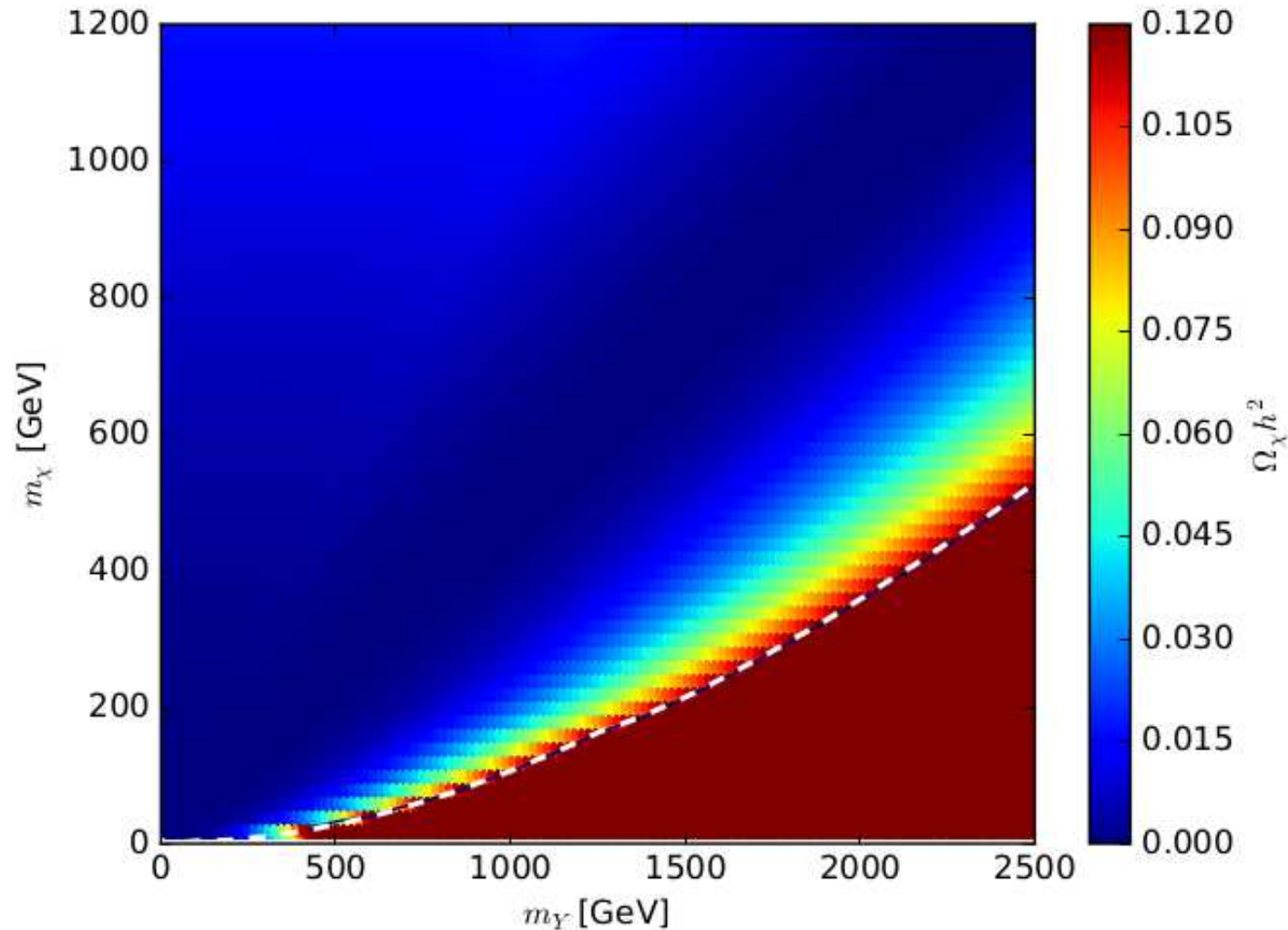
A photograph of a man with reddish hair looking up at a full-body Darth Vader costume. The scene is set in a dark, industrial environment with blue lighting from overhead fixtures. The text "Further Questions?" is overlaid in white on the left side of the image.

Further Questions?

DM constraints:

⇒ **micrOMEGAs** for relic density and DD cross sections

[2019]

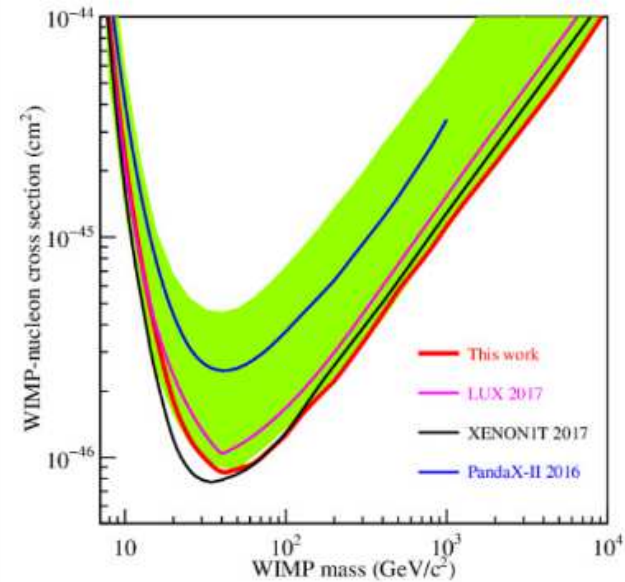
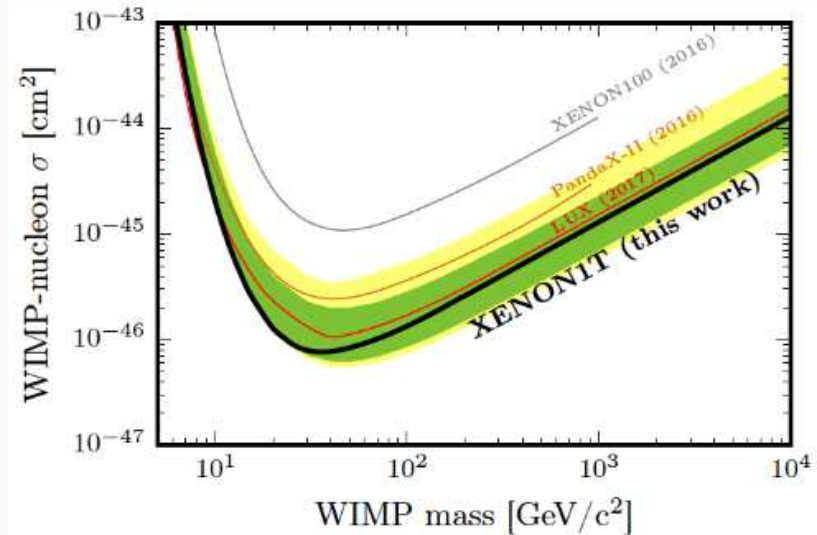
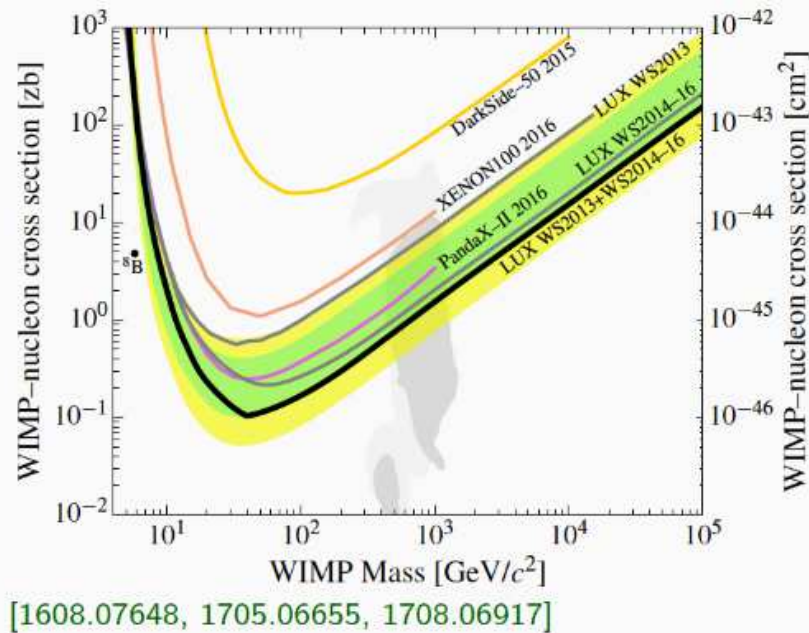


⇒ full agreement with ATLAS/CMS results (here: vector model)

Non-LHC constraints

Dark matter

- Relic density constraints from Planck.
- Direct detection constraints on σ_p^{SI} from LUX, XENON1T and PANDAX.
- Direct detection constraints on σ_p^{SD} from PIC060.

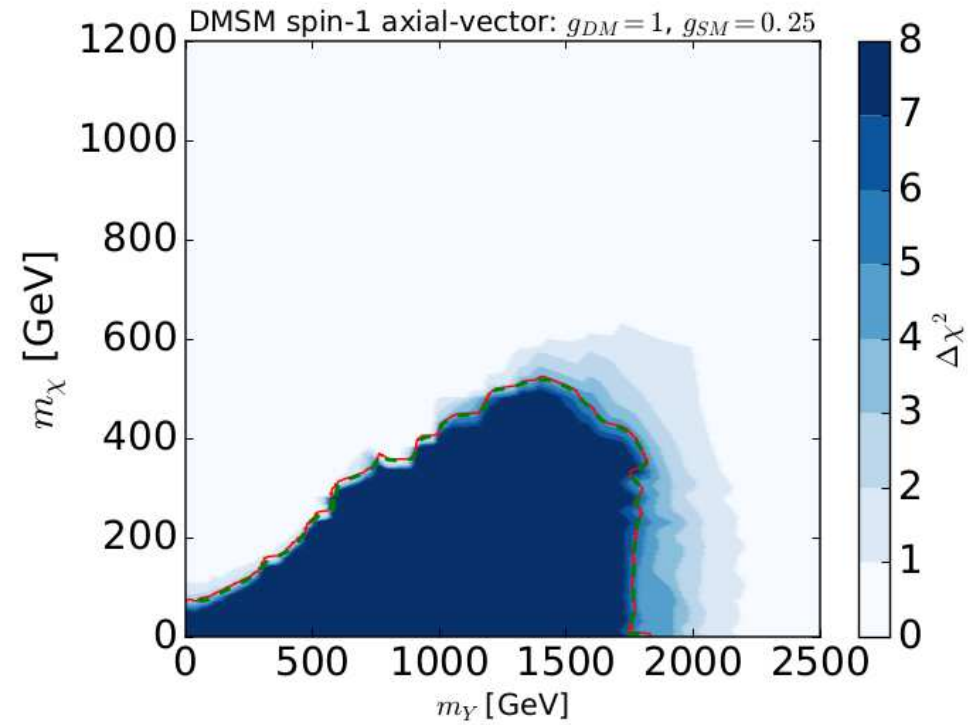
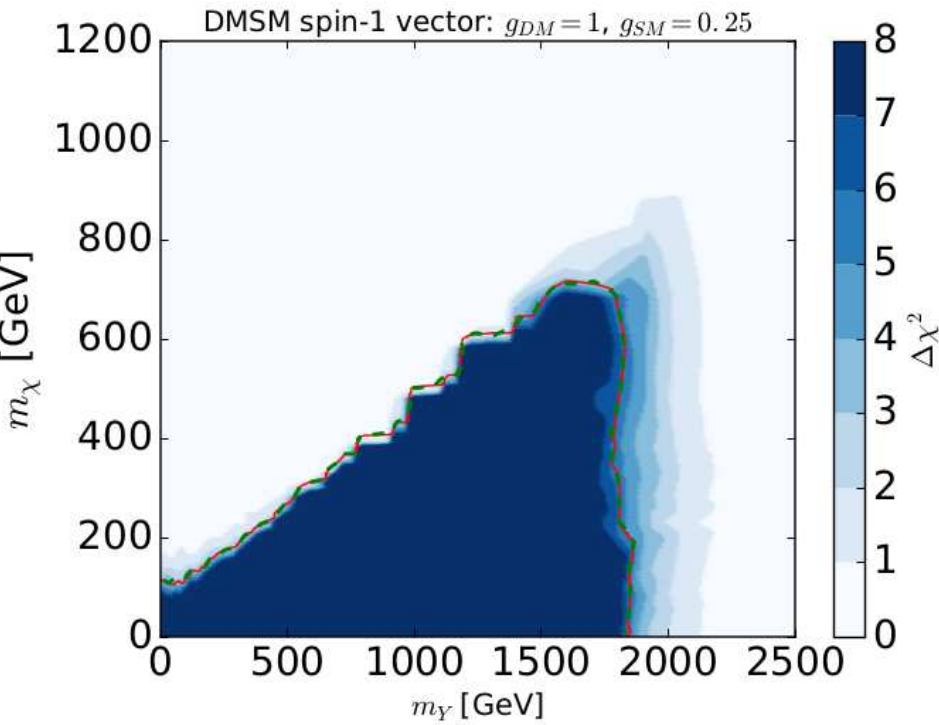


[taken from E. Bagnaschi]

Mono-jet constraints

[2019]

⇒ MG5 aMC(N)LO, Fastlim approach

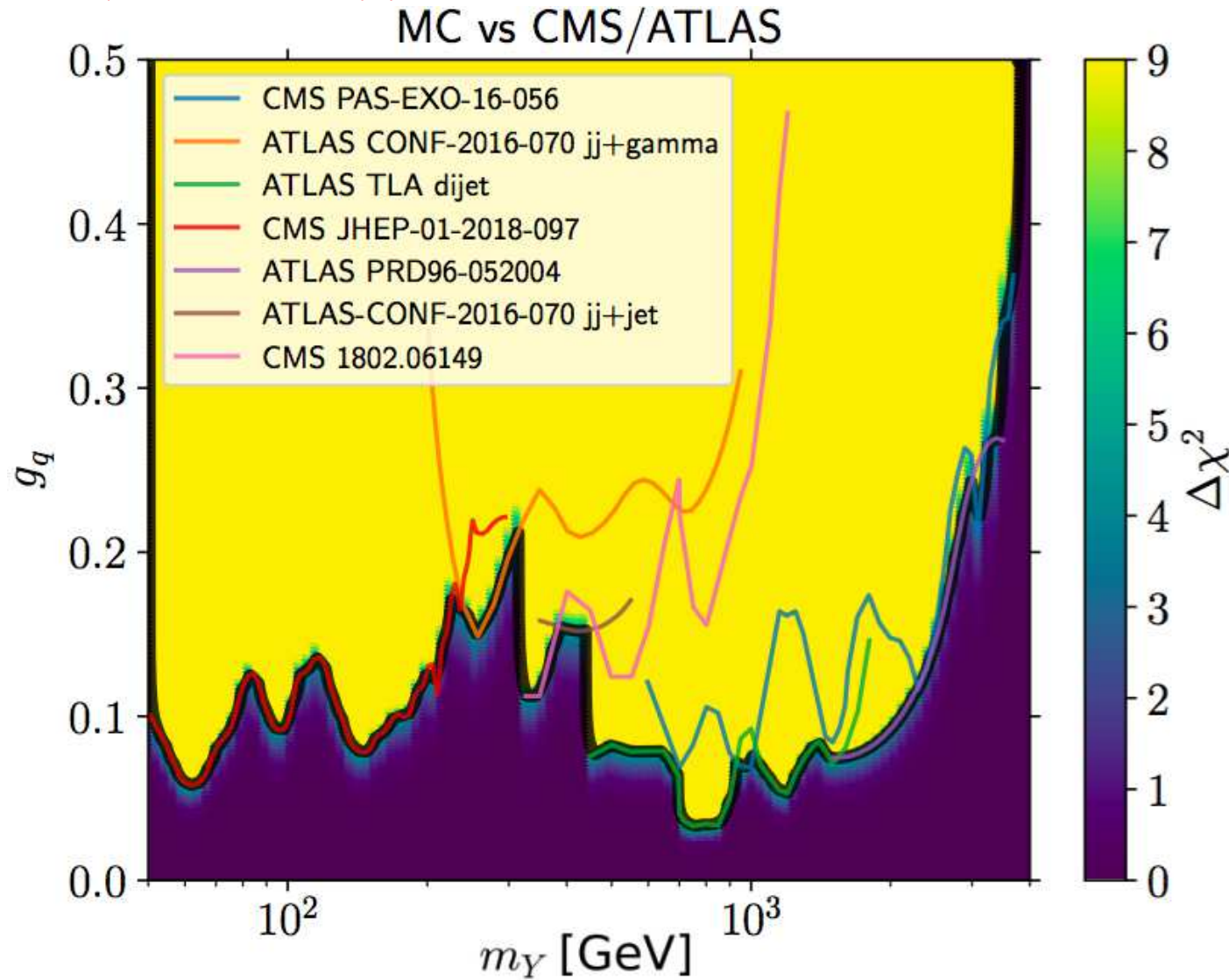


⇒ full agreement with ATLAS/CMS (red-dashed)

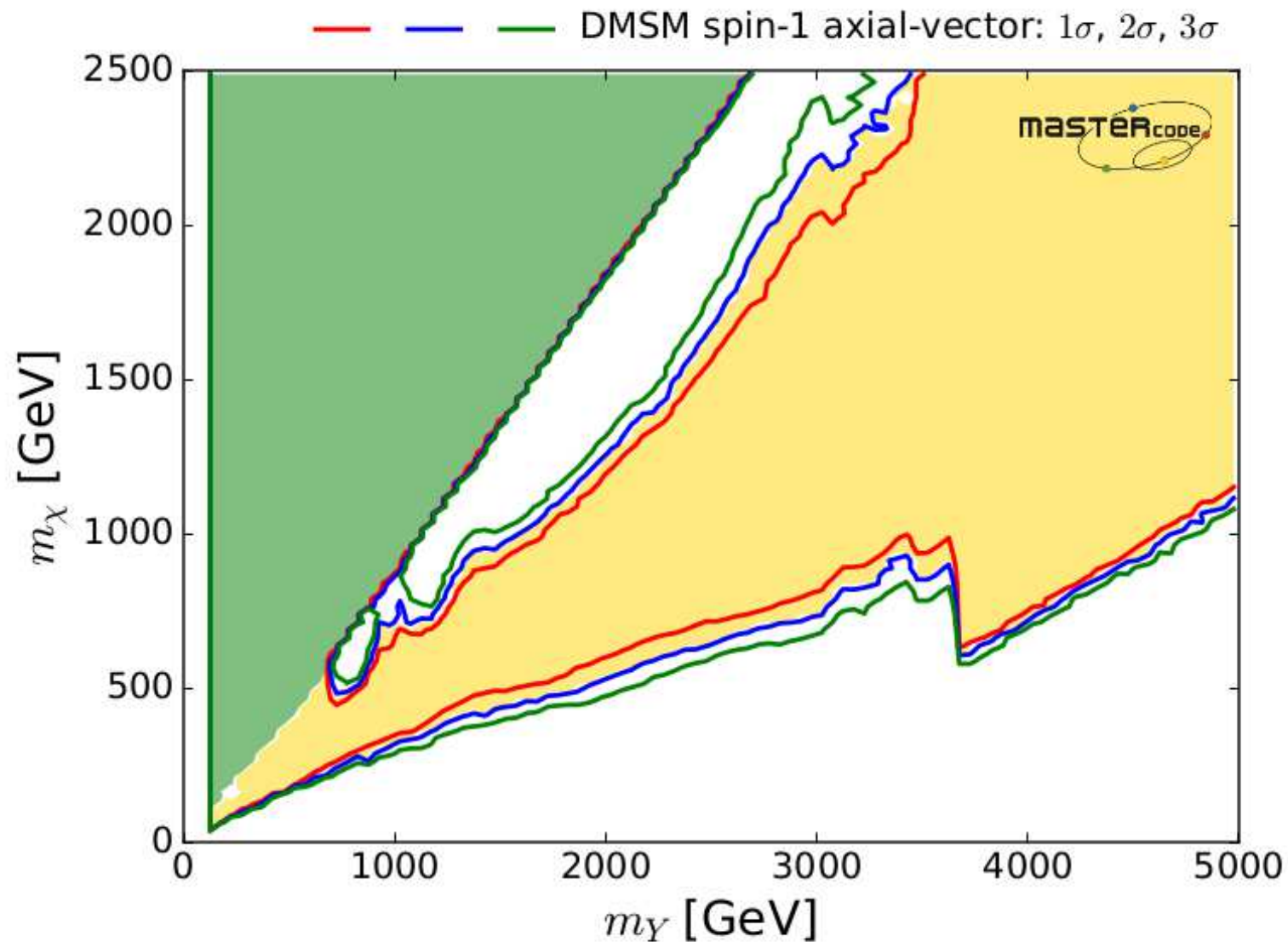
Di-jet constraints

[2019]

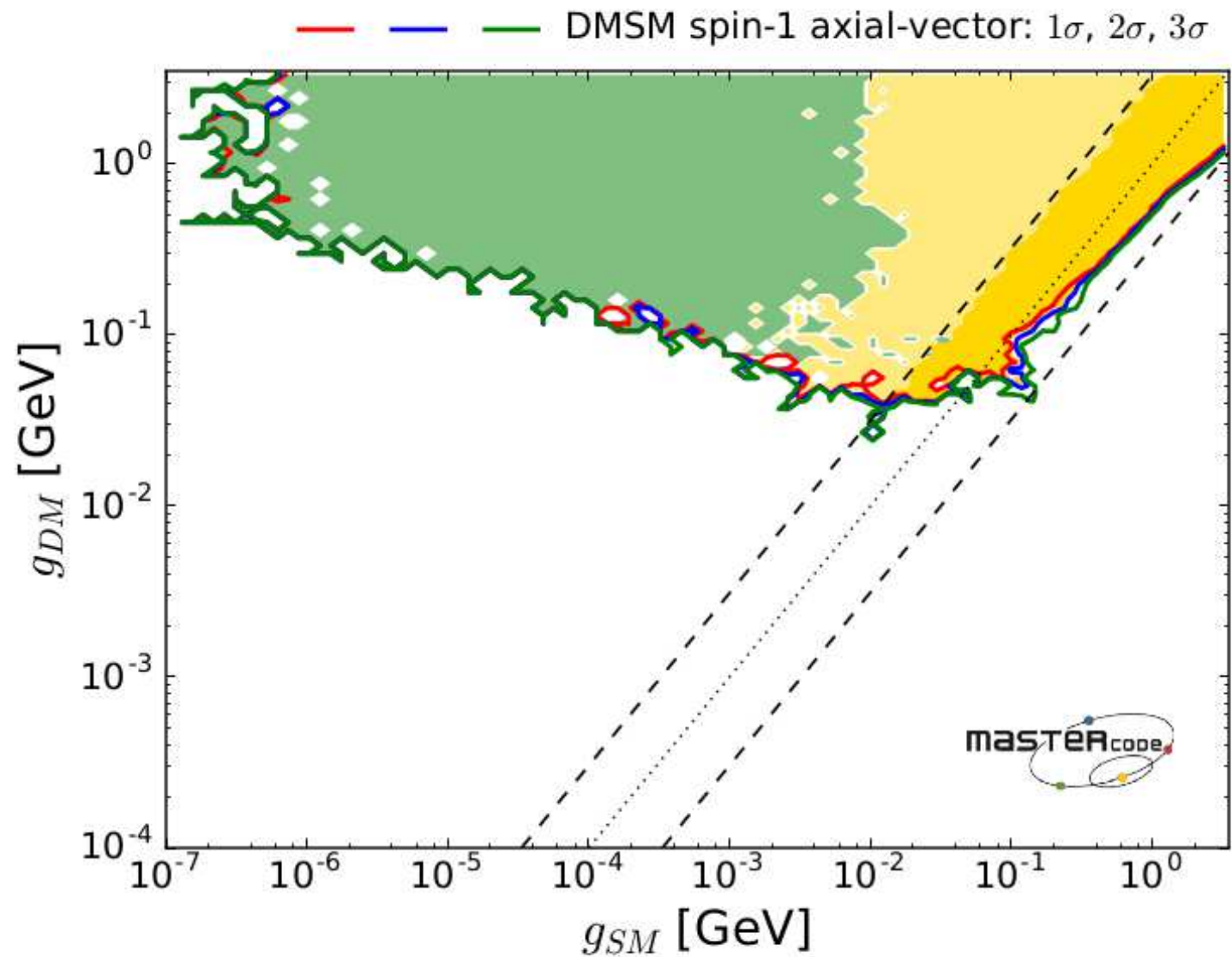
⇒ MG5 aMC(N)LO, Fastlim approach



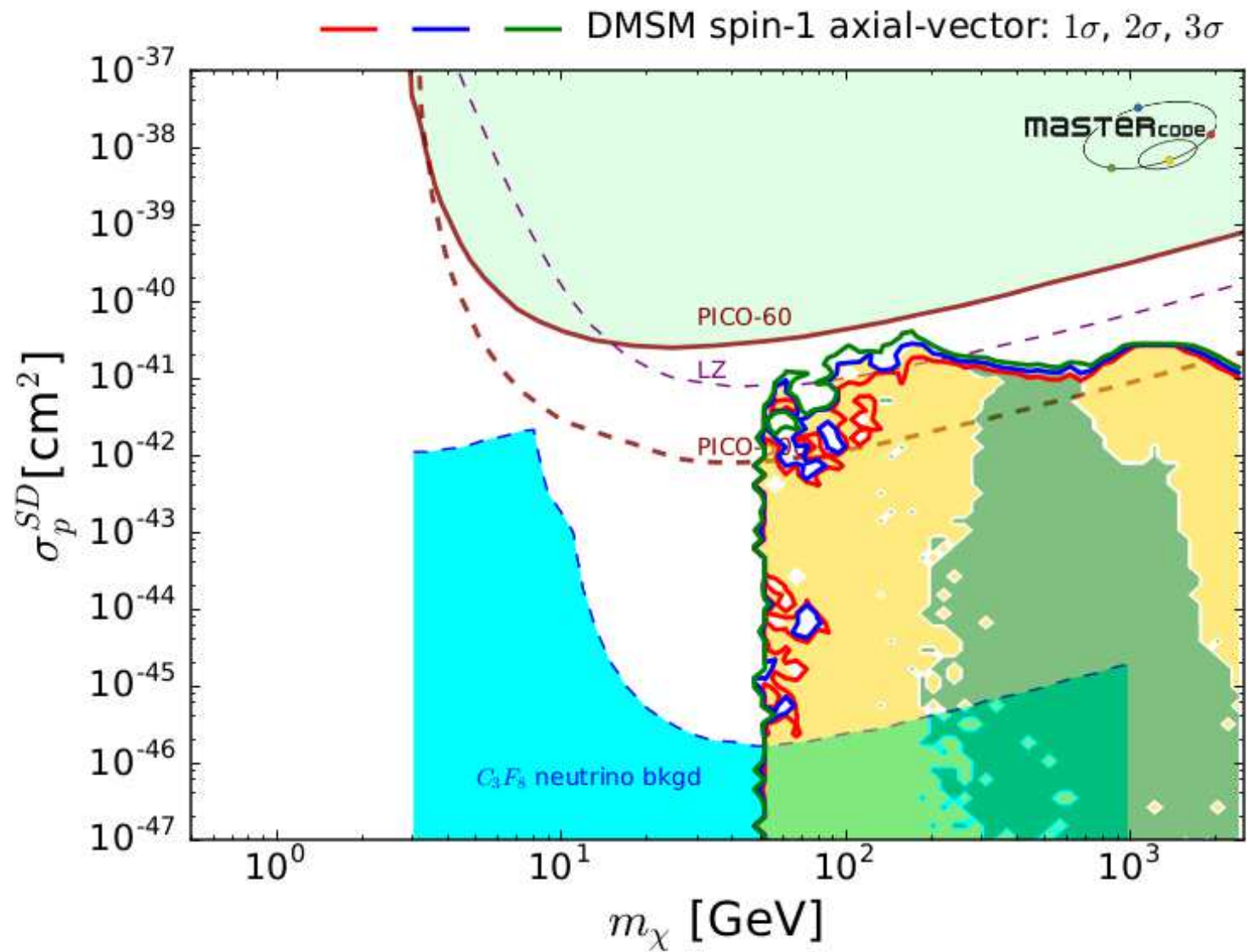
⇒ full agreement with ATLAS/CMS



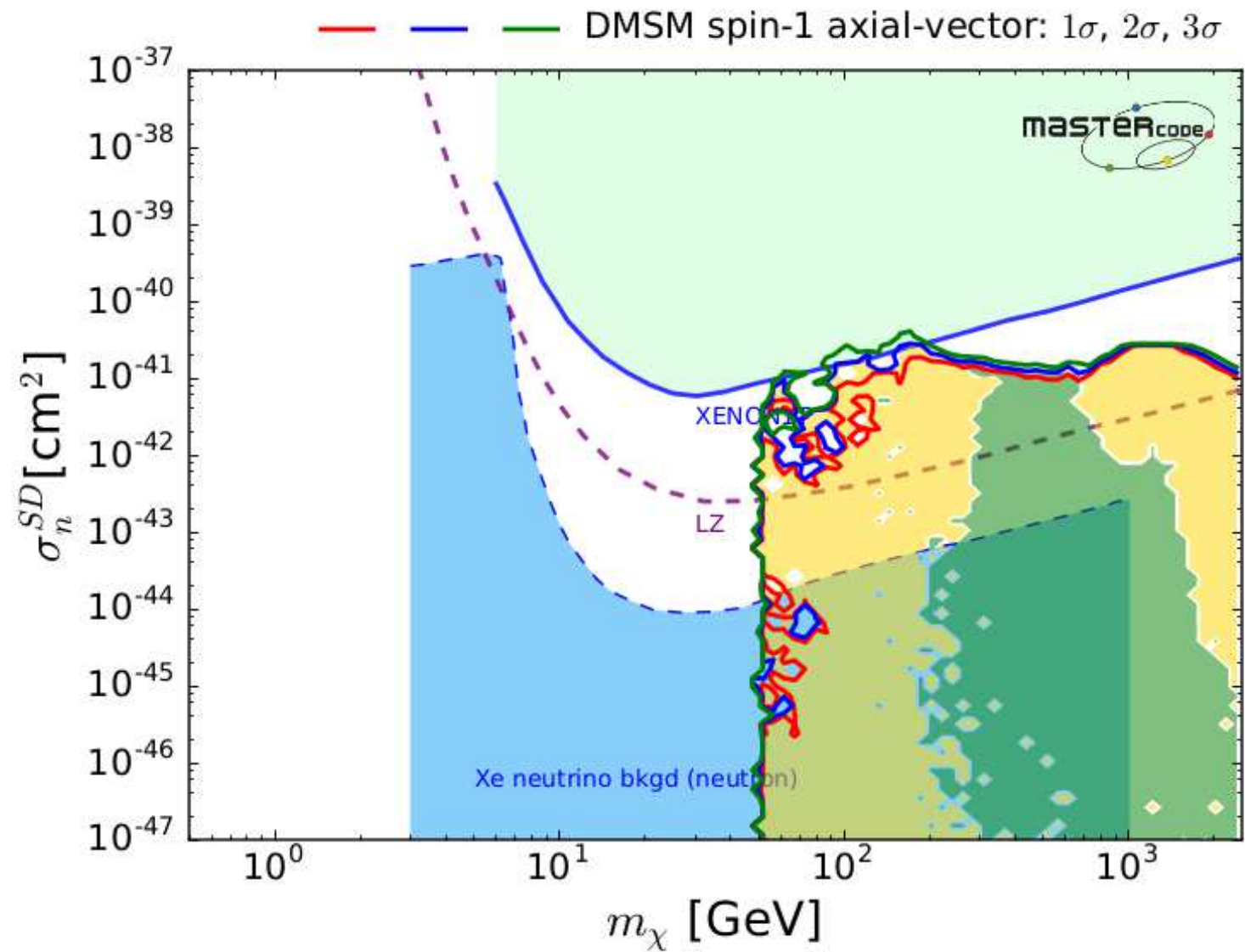
⇒ Larger s -channel region, continuous with t -channel



$\Rightarrow t$ - (s -)channel for $g_{SM} \lesssim (\gtrsim) 10^{-2}$



⇒ will not be easy for PICO!



⇒ neither for LZ!