Interplay between dark matter and LHC data

Mikael Chala (DESY)

in collaboration with **F. Kahlhoefer, M. McCullough, G. Nardini,**

K. Schmidt-Hoberg and **A. Carmona.** Based on *1503.05916* and *1504.00332*.

DESY Theory Workshop, 2015

Outline

Mediators in models of dark matter

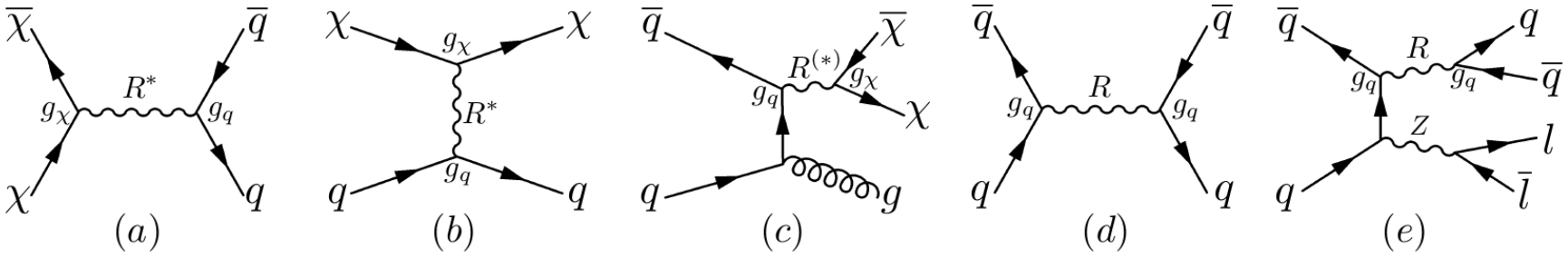
Complementarity between different searches

A concrete example: composite dark sectors

Mediators in models of dark matter

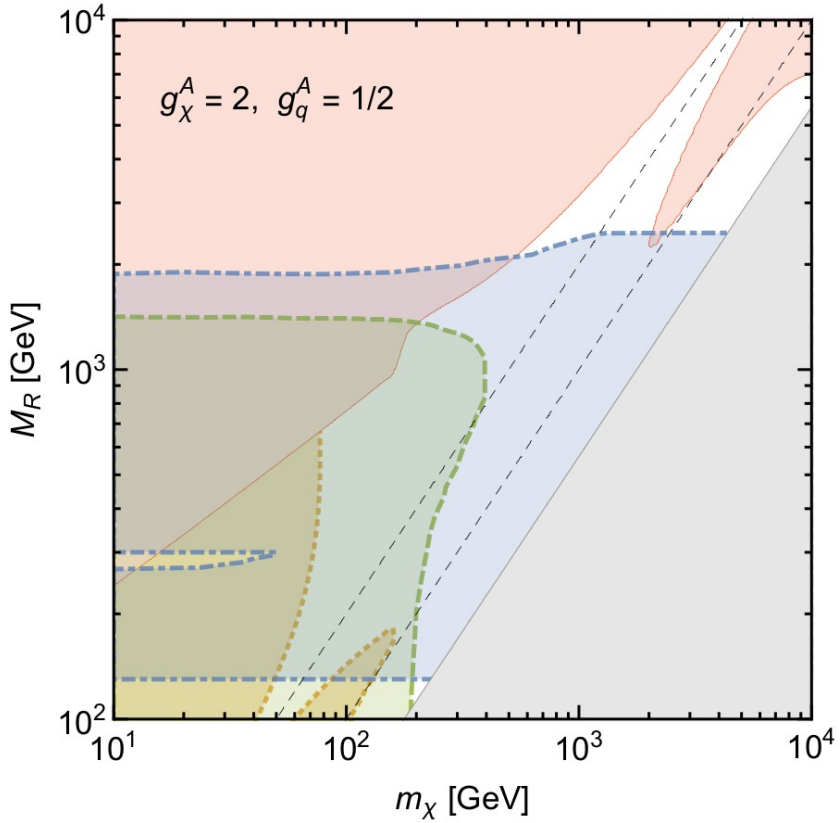
$$\mathcal{L}^R_{f\bar{f}} = \sum_{f=q,\ell} R_\mu \, \bar{f} \, \gamma^\mu (g^V_f - g^A_f \, \gamma^5) f$$

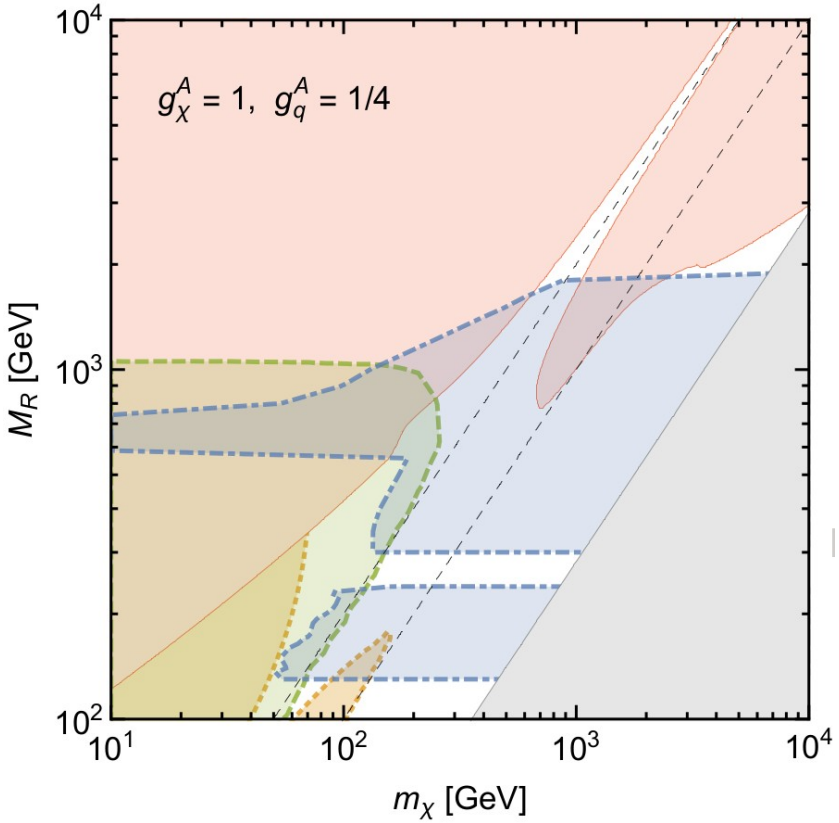
$$\mathcal{L}^R_{\rm DS} = R_\mu \, \bar{\chi} \, \gamma^\mu (g^V_\chi - g^A_\chi \gamma^5) \chi$$



Non-collider constraints:

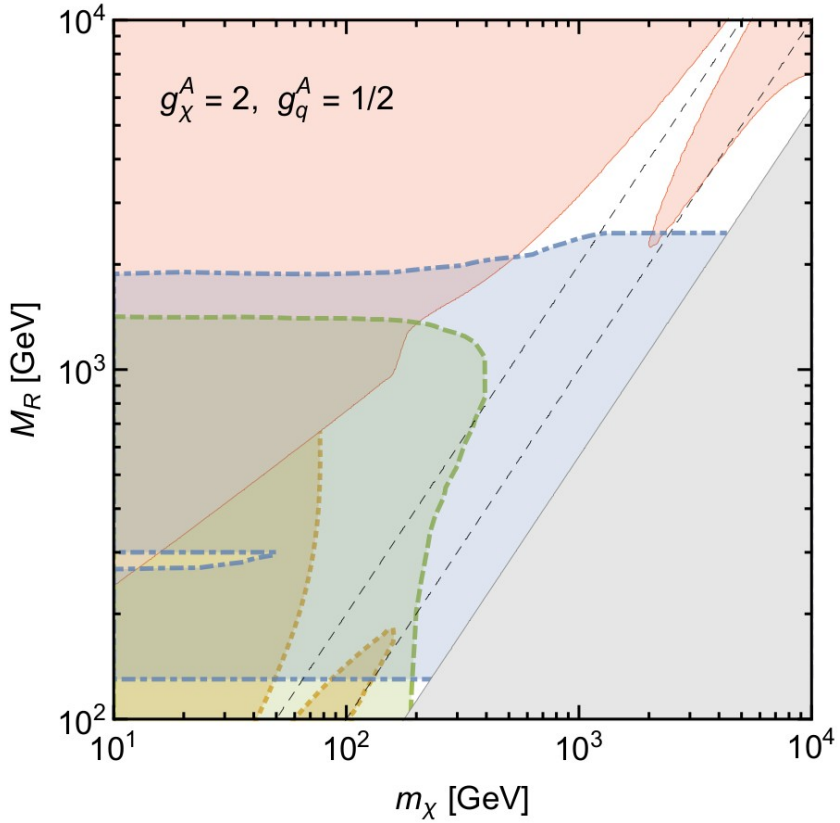
Relic density measurement (computed with micrOMEGAs) and **direct detection** (using results from the LUX experiment)

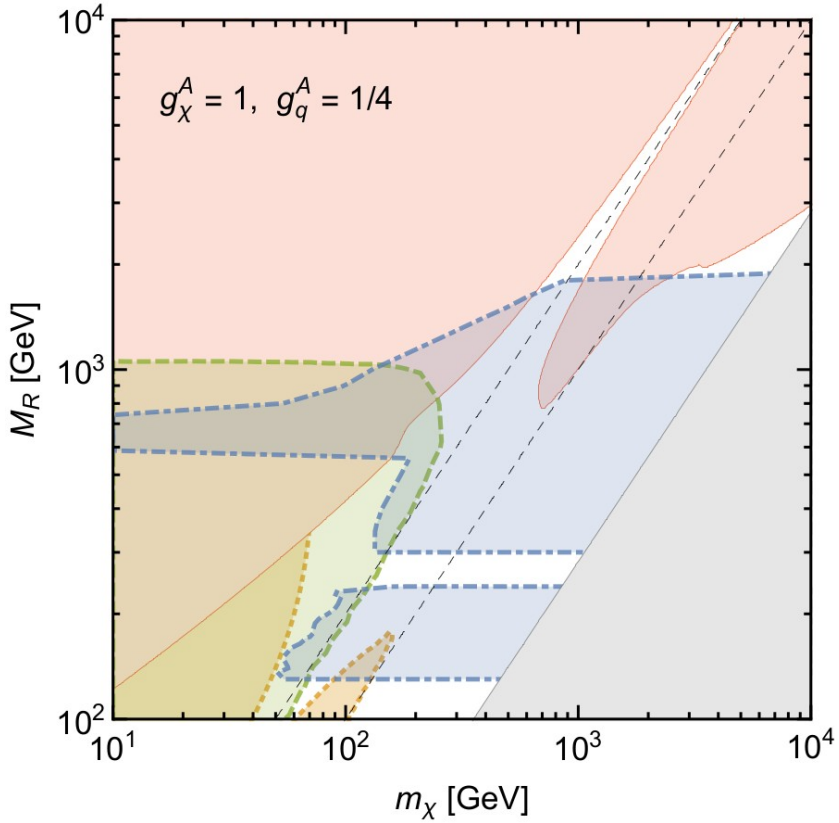




Collider constraints:

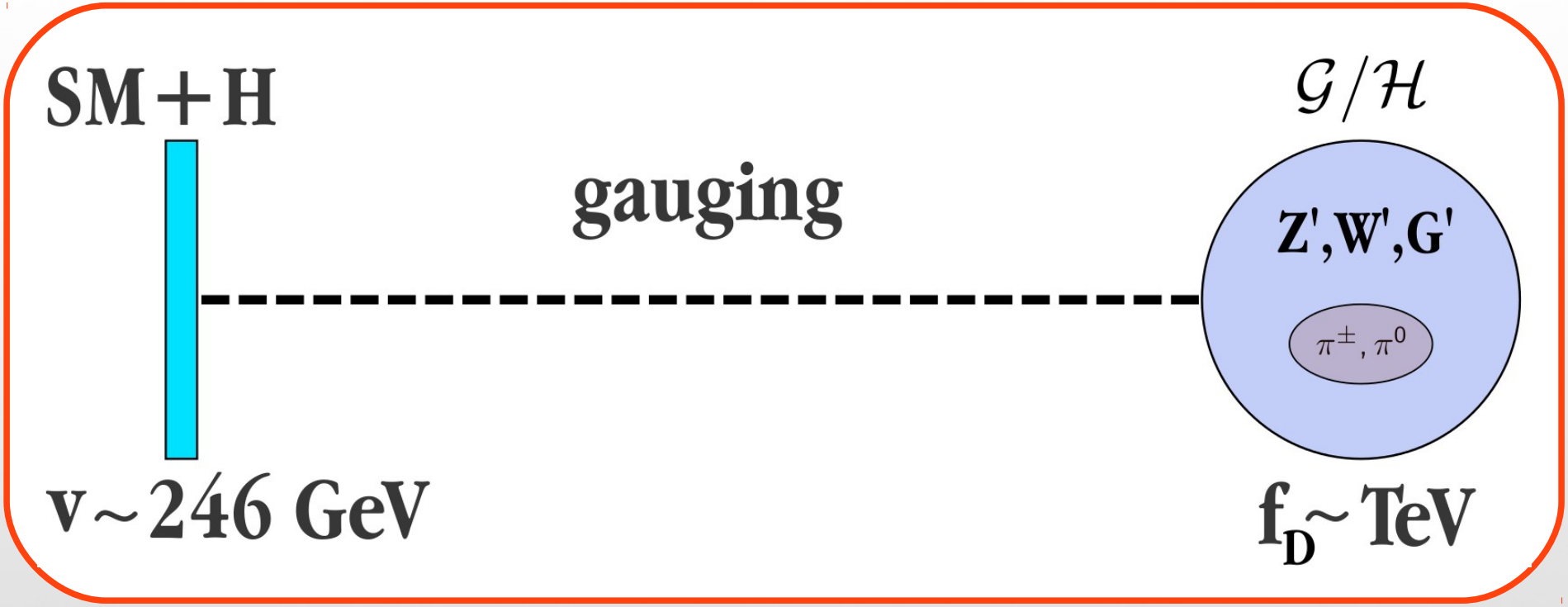
Monojet and **dijet searches** (including UA2, Tevatron and LHC data -combining both ATLAS and CMS results-)





A concrete example: composite dark sectors

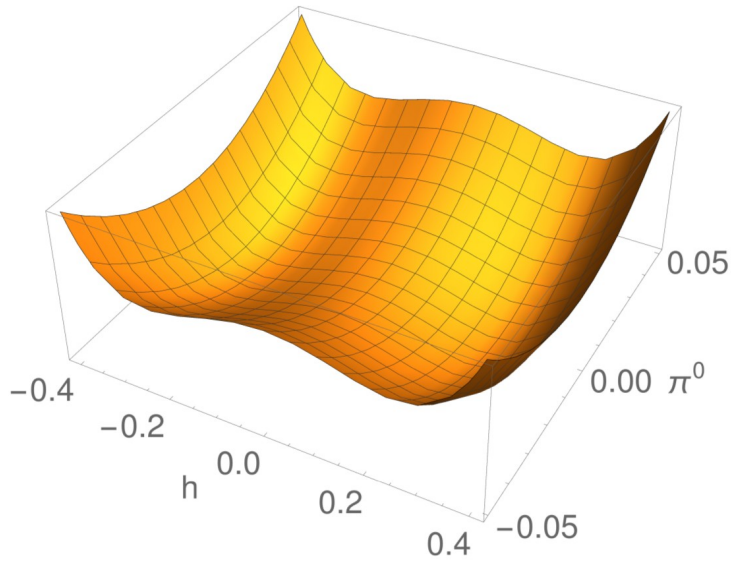
- Inspired on composite Higgs models. The Higgs boson is fully elementary. Fermion partners are no longer present.



A concrete example: composite dark sectors

Generic implications

- Phenomenology dictated by the symmetries and **only two free parameters**, namely f_D and g_D.
- The lightest neutral pNGBs are **naturally dark matter** candidates.
- (They do not even get EW VEV).
- In agreement with LHC data, and accessible at future colliders.



$$V = V(h, \pi^0) + V_{\rm SM}(h)$$

Minimal setup: $[SU(2)^2 \times U(1)]/[SU(2) \times U(1)]$

- Provides a dynamical realization of the **ITM**
- Dynamical realization of the **IDM** requires either $SU(3)/[SU(2) \times U(1)]$ or $SO(5)/SO(4)$

$$\mathcal{L} = g^2(\pi^0)^2 W_\mu^+ W^{\mu\,-} + \left[igW^{\mu\,+}(\pi^0 \overleftrightarrow{\partial_\mu} \pi^-) - \frac{1}{2} g^2 W_\mu^+ W^{+\,\mu} \pi^- \pi^- + \text{h.c.} \right]$$
$$+ g^2 W_\mu^+ W^{\mu\,-} \pi^+ \pi^- + \frac{g^2}{c_W^2}(s_W^2 - 1)^2 Z_\mu Z^\mu \pi^+ \pi^- + \frac{ig(1 - s_W^2)}{c_W} Z^\mu (\pi^+ \overleftrightarrow{\partial_\mu} \pi^-)$$
$$+ e^2 A_\mu A^\mu \pi^+ \pi^- + ieA^\mu (\pi^+ \overleftrightarrow{\partial_\mu} \pi^-) + \frac{2eg}{c_W}(s_W^2 - 1) A_\mu Z^\mu \pi^+ \pi^-$$
$$+ \left[egA_\mu \pi^0 W^{\mu\,+} \pi^- + \frac{g^2}{c_W}(s_W^2 - 1) W_\mu^+ Z^\mu \pi^0 \pi^- + \text{h.c.} \right] + \frac{1}{2 f_D^2} [\partial_\mu (\pi^0)^2] \partial^\mu (\pi^+ \pi^-)$$

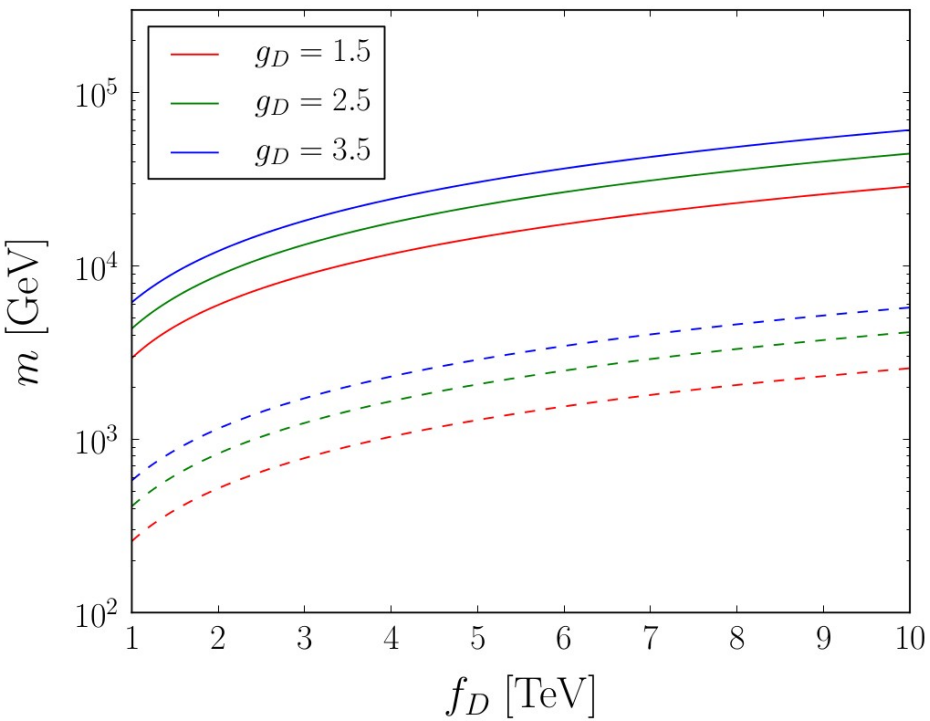
Potential

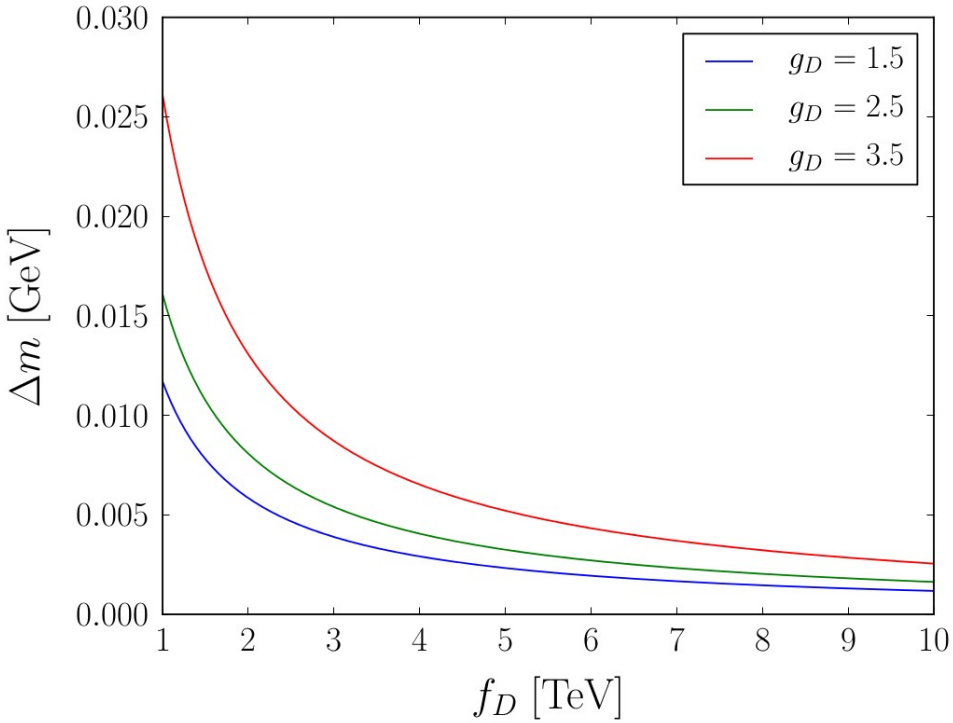
$$V(h,\pi^i) \approx \left[\lambda_0 + \lambda_2 \left(\frac{h}{f_D}\right)^2 + \lambda_4 \left\{1 + \right.\right.$$

$$\left.\left. + \frac{1}{2}\tan^2\hat{\theta}_W \frac{\pi^+\pi^-}{\Pi^2}\right\}\left(\frac{h}{f_D}\right)^4\right] \sin^2\left(\frac{\Pi}{f_D}\right)$$

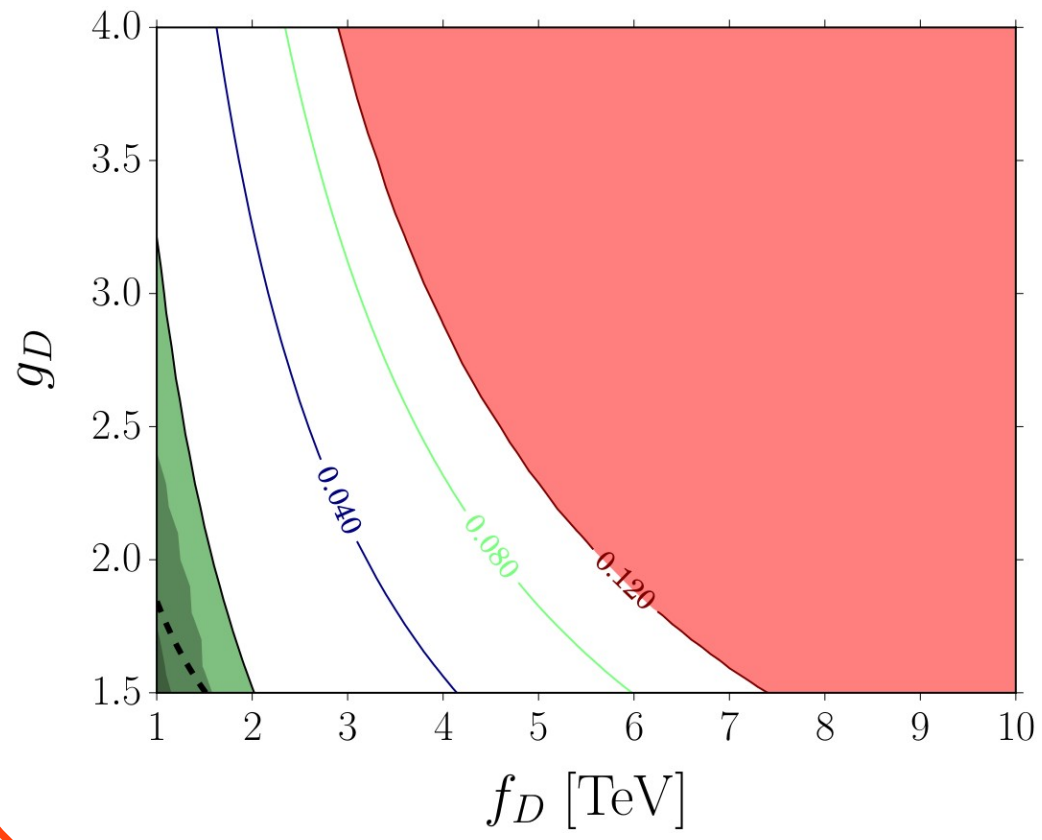
Computed in a 5-dimensional description with modified boundary conditions with respect to composite Higgs

Scalar (dashed) and vector resonance (solid) **masses** and **splittings**





Current constraints



- **Relic density** observation
- **Charged trace** searches
- Resonant **dijet searches**
- Resonant **ditop searches**
- **EW precision data**

Note:

Higgs and monojet searches, and direct detection experiments are not sensitive to this parameter space region

Conclusions

- Simplified model to illustrate the **compelling interplay** between different dark matter detection techniques.
- Relevant constraints from collider searches for **missing energy** and **resonances**, dark matter **direct detection** experiments, the **relic abundance** and perturbativity.
- These results can easily **guide model building**, as we have shown in a complete model of composite dark matter.
- This model provides scalar pNGBs with a parity symmetry not even broken in the EW phase.
- It turns out to be very predictive (only two free parameters).
- Dynamical realization of the Inert Triplet model.

Thank you for your attention!