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A study for the production viability of dark bosons at high-energy colliders

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INTRODUCTION

Several studies have been proposed to investigate the dark matter (DM), trying to uncover its origin and nature. Distinct approaches aims to understand how DM interacts and what are the possible mechanisms for detecting it. Theories beyond the Standard Model of the Elementary Particles (SM) investigate the possible couplings of DM with conventional matter in order to measure its interaction in the laboratory.

Our work aims to investigate the differential production cross section for dark matter (DM) particles in a process with a Z′ boson mediator in proton-proton collisions at a centre-of-mass energy of 14 TeV. The production of scalar, fermionic, and vector DM pairs via quark-antiquark annihilation into the new boson is investigated evaluating the differential cross section for on-shell production.

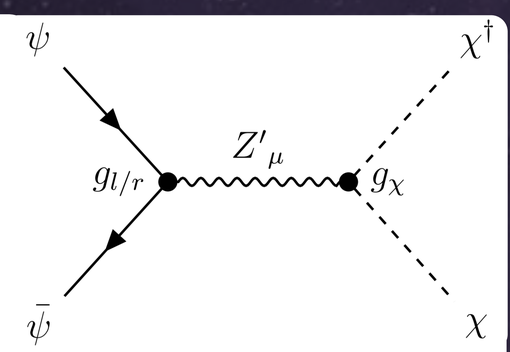
OBJECTIVES

The main goal of this study is to probe the limits and analyze parameters for the thermal production of DM, through a process that involves an interaction of the standard model with the dark sector mediated by a **new** massive boson mediator (Z'_μ) as a Breit-Wigner resonance peak.

METHODS

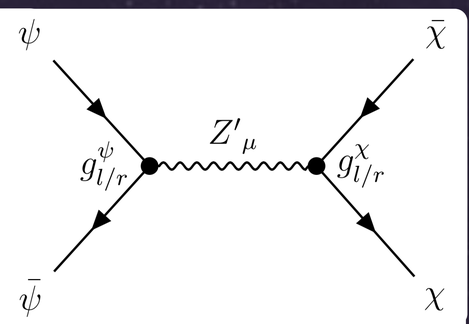
In this work we investigate three possible DM candidates, i.e. scalar, fermion, and vector DM particles. Making use of the Feynman rules, we compute the total cross sections for the following diagrams and its respective Lagrangians [1]:

SCALAR DM



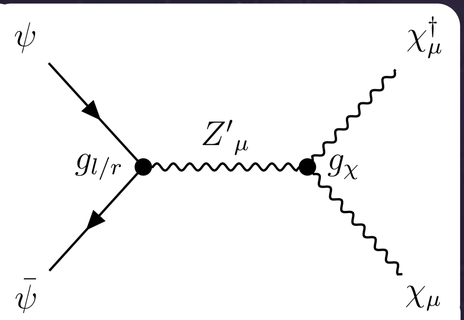
$$\mathcal{L}_{\text{int}} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + \frac{1}{2}M_\Omega^2 Z'^\mu Z'_\mu + \bar{\psi}\gamma^\mu\left(g_l P_L + g_r P_R\right)\psi Z'_\mu + g_\chi\left(\chi^\dagger\partial_\mu\chi - \chi\partial_\mu\chi^\dagger\right)Z'^\mu$$

FERMION DM



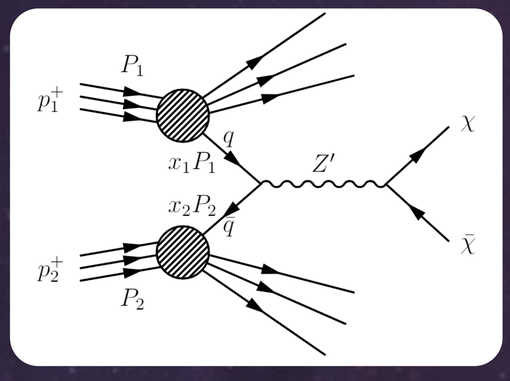
$$\mathcal{L}_{\text{int}} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + \frac{1}{2}M_\Omega^2 Z'^\mu Z'_\mu + \left[\bar{\psi}\gamma^\mu\left(g_l P_L + g_r P_R\right)\psi + \bar{\chi}\gamma^\mu\left(g_l P_L + g_r P_R\right)\chi\right]Z'_\mu$$

VECTOR DM



$$\mathcal{L}_{\text{int}} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} + \frac{1}{2}M_\Omega^2 Z'^\mu Z'_\mu + \bar{\psi}\gamma^\mu\left(g_l P_L + g_r P_R\right)\psi Z'_\mu - ig_\chi Z'_\mu\chi^\dagger_\nu\left(\partial^\mu\chi^\nu - \partial^\nu\chi^\mu\right) + ig_\chi Z'^\mu\chi^\nu\left(\partial_\mu\chi^\dagger_\nu - \partial_\nu\chi^\dagger_\mu\right) - ig_\chi\left(\partial^\mu Z'^\nu - \partial^\nu Z'^\mu\right)\chi^\dagger_\mu\chi_\nu,$$

DISCUSSION AND CONCLUSION

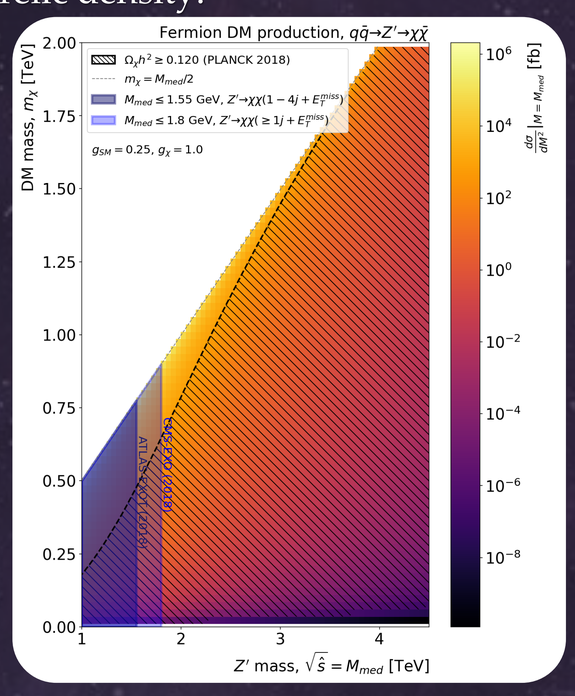


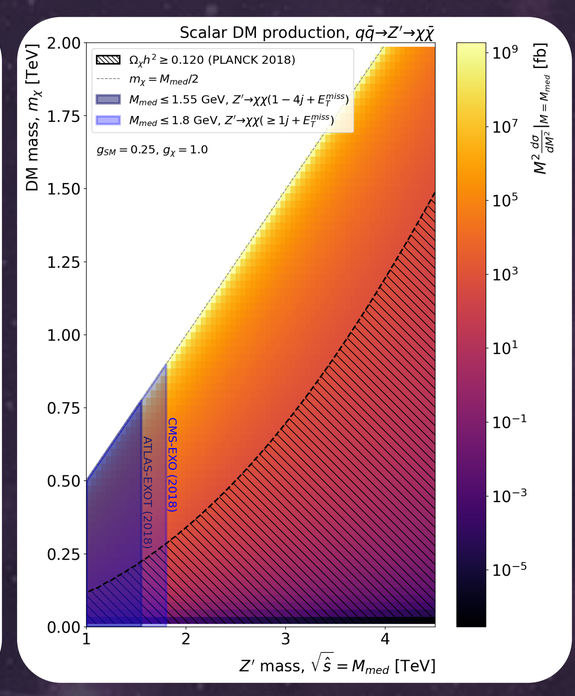
$$\tau = \frac{M^2}{s} \qquad x_1x_2\ s = \hat{s} \qquad \tau \equiv x_1x_2$$

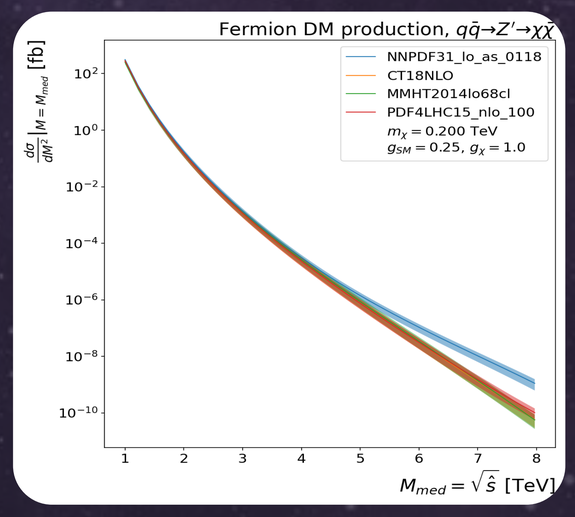
$$M^2\frac{d\sigma}{dM^2}\Big|_{M=M_{\text{med}}} = \tau F(\tau) = \tau\int_\tau^1 \frac{dx_1}{x_1}P_{q,\bar{q}}(x_1,\tau/x_1)\hat{\sigma}(\hat{s}=\tau s)\delta(\hat{s}-M^2)$$

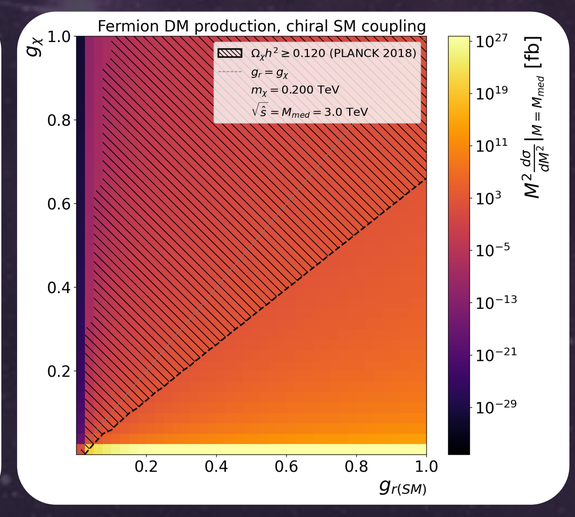
$$P_{q,\bar{q}}(x_1,x_2) = \sum_{q=1}^{N_f}\left\{f_q(x_1,Q^2)f_{\bar{q}}(x_2,Q^2) + f_{\bar{q}}(x_1,Q^2)f_q(x_2,Q^2)\right\}$$

Using a factorization as described in Ref. [2], we have developed a code to evaluate the differential cross section for DM (m_x) and mediator (M_{med}) mass ranges as employed in the literature, using the LHAPDF package [4]. Using data from Refs. [5-6], we are able to estimate exclusion limits for the proposed models. For observed DM density, we assume a scenario, with being the mass of the DM cold relic density.









As a result, we still seek to obtain the dependency of the coupling constants with the possible masses for the DM and the dark mediator for this simplified model, in addition to determining the observation limits in the LHC kinematic regime.

Additionally, we will be able to estimate the sensitivity of the experimental and phenomenological parameters, such as uncertainties in the partons distributions, favorable phase space regions towards the kinematics variables and detection uncertainties for production of initial- and/or final-state radiation.

SOME REFERENCES

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