

Searching for inelastic dark matter with future LHC experiments. [2201.12253]

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In collaboration with with Enrico Bertuzzo and Marco Taoso

June 2, 2022

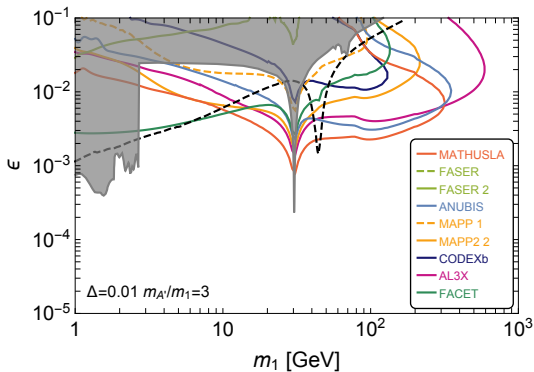
Istituto Nazionale di Fisica Nucleare, Sezione di Torino, via P. Giuria 1, I-10125 Torino, Italy



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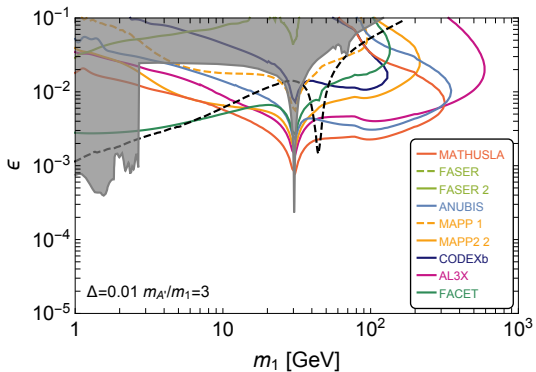
The Dark Universe:
A Synergic Multimessenger
Approach

Overview



$$pp \rightarrow \chi_1 \chi_2 \rightarrow \chi_1 f \bar{f} \quad (\sqrt{s} = 14 \text{ TeV})$$

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- ▶ Almost degenerate inelastic states \Rightarrow suppressed DM-Nuclei interactions. Evade current direct detection constraints.
- ▶ Coannihilations in the early Universe determine Relic abundance which are suppressed at later times
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Our inelastic dark matter model

$$\mathcal{L}_{int} = \frac{\epsilon}{2 \cos \theta_w} A'_{\mu\nu} B^{\mu\nu}$$

- ▶ Consider a dark sector containing two states coupled to the Standard Model through a dark photon mediator:

- ▶ Fermionic

$$\mathcal{L}_{int}^X = ig_d \bar{\chi}_2 \gamma^\mu \chi_1 A'_\mu$$

- ▶ Scalar

$$\mathcal{L}_{int}^\phi = g_d (\partial^\mu \phi_1 \phi_2 - \phi_1 \partial^\mu \phi_2) A'_\mu$$

- ▶ SM-DP

$$\mathcal{L}_{int} = e\epsilon A'_\mu \sum_f \bar{f} Q_f \gamma^\mu f$$

- ▶ Mass splitting

$$\Delta = \frac{m_2 - m_1}{m_1}$$

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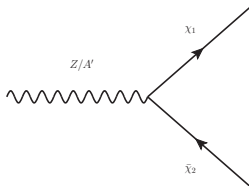
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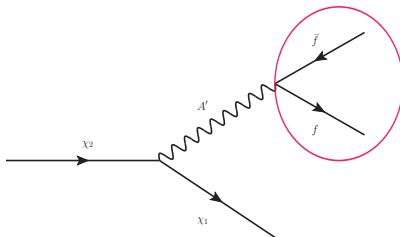
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Observable channels

- ▶ Dominant production channels Drell-Yan:



- ▶ Detection:



Forecasting sensitivity

- ▶ Expected number of signal events in detector volume:

$$N = \sigma_{pp \rightarrow \chi_1 \chi_2} \cdot \mathcal{L} \cdot f_{\text{signal}}$$

- ▶ f_{signal} detector dependent:

$$f_{\text{signal}} = \langle p_{\text{dec}} \epsilon_{\text{det}} \rangle$$

Computed averaging over all the possible kinematical configurations of the χ_2 : MadGraph5_aMC@NLO.

- ▶ Probability of χ_2 decaying within detector volume

$$p_{\text{dec}} = e^{-L_{\text{entry}} / \bar{L}} - e^{-L_{\text{exit}} / \bar{L}}$$

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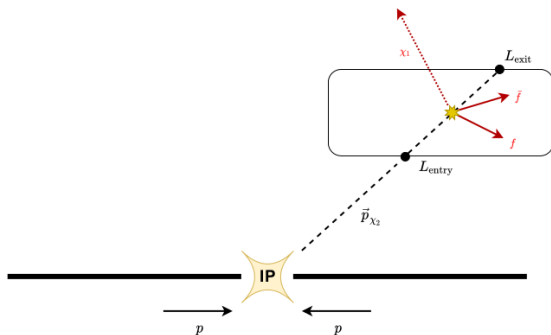
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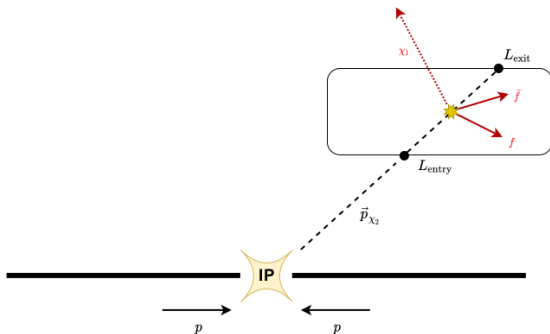
- ▶ L_{entry} and L_{exit} determined by simulating realizations of $\chi_2 \rightarrow \chi_1 \bar{f} f$ and determining \vec{p} trajectories.
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Experimental geometries we considered

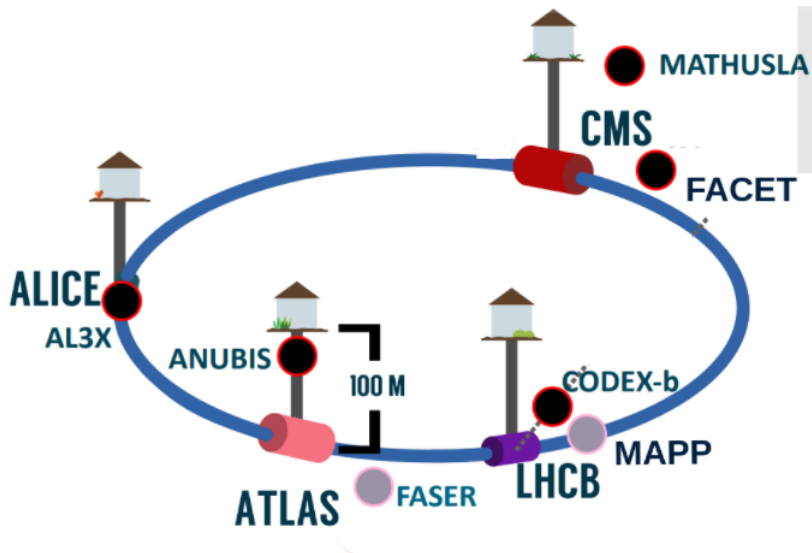
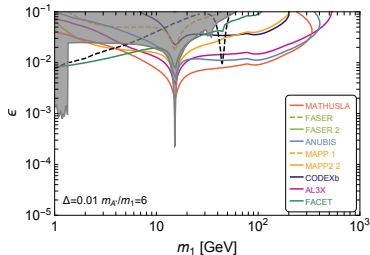
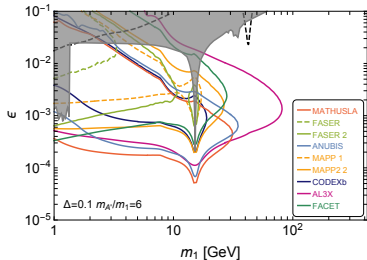
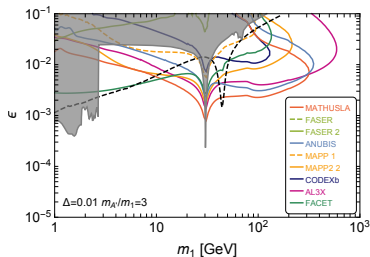
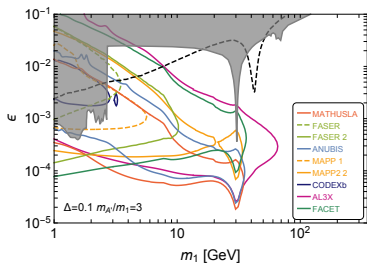


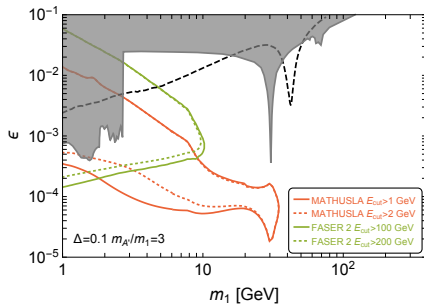
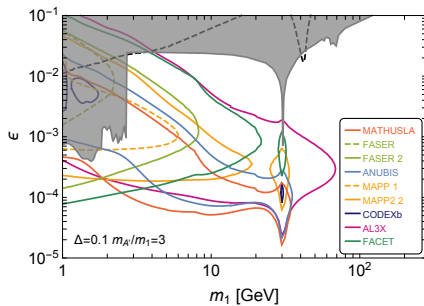
Figure 1: Image credit: Heather Russell

Results: Fermionic iDM

95% C.L ($N = 3$ events). Four benchmarks $[\Delta, m_{A'}/m_1]$.



Results: Scalar iDM and varying energy cut



Thank you!

Bonus slides

Experimental geometries we considered

Projected integrated luminosities and E_{cut} based on proposals

Experiment	\mathcal{L}	E_{cut}	Paper
MATHUSLA	3 ab ⁻¹	1 GeV	2009.01693
ANUBIS	3 ab ⁻¹	1 GeV	1909.13022
FASER	150 fb ⁻¹	100 GeV	1708.09389
FASER 2	3 ab ⁻¹	100 GeV	1901.04468
FACET	3 ab ⁻¹	10 GeV	2201.00019
MAPP 1	30 fb ⁻¹	1 GeV	1910.05772
MAPP 2	300 fb ⁻¹	1 GeV	1910.05772
CODEXb	300 fb ⁻¹	1 GeV	1911.00481
AL3X	250 fb ⁻¹	3 GeV	1810.03636

Handling final state quarks

- ▶ Contribution into leptons is straightforward to compute.
- ▶ For quarks we need to worry about the validity of perturbative QCD.
- ▶ Follow the strategy outlined in [2011.04735].
- ▶ Use a perturbative computation when $m_2 - m_1 > 2 \text{ GeV}$, while in the opposite case we use chiral perturbation theory and vector mesons matrix elements to capture the hadronic decays.