Exploring Multilepton Signatures From Dark Matter at the LHC

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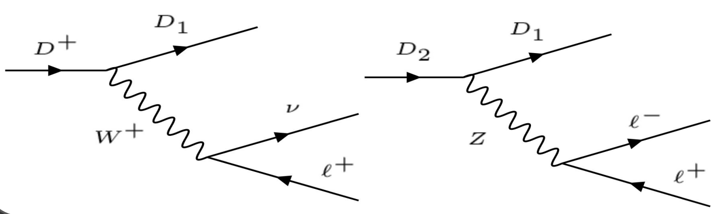
Abstract

The most general DM signature at colliders, mono-X, has limitations.
This study is devoted to the generic class of DM models, where DM is a part of the electroweak multiplet

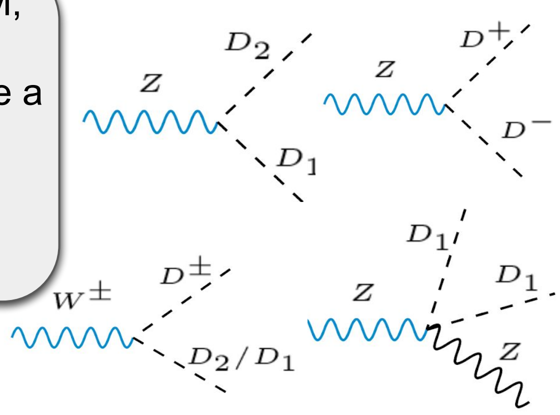


$$r = \frac{\sigma_{DM}}{\sigma_{95}}$$

Inert Two Higgs Doublet Model (i2HDM)

$$\mathcal{L}_\phi = |D_\mu \phi_1|^2 + |D_\mu \phi_2|^2 - V(\phi_1, \phi_2)$$

$\mathbb{Z}_2$ symmetric extension to SM, with two scalar doublets. New SU(2) doublet does not require a VEV and does not couple with fermions. We assume "Higgs funnel", DM coupling to Higgs: $\lambda_{345} \sim 0$



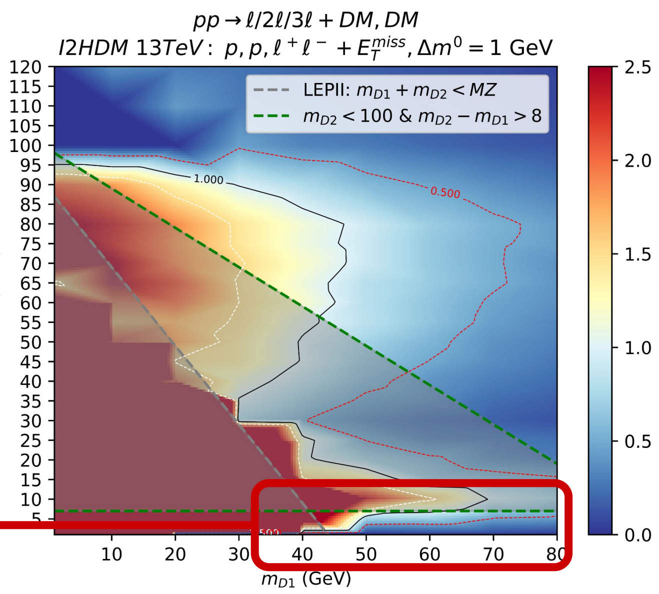
$$\Delta m^0 = m_{D2} - m_{D+}$$
$$\Delta m^+ = m_{D+} - m_{D1}$$
$$[m_{D1}, m_{D+}, m_{D2}, \lambda_2, \lambda_{345}] \rightarrow [m_{D1}, \Delta m^+, \Delta m^0]$$

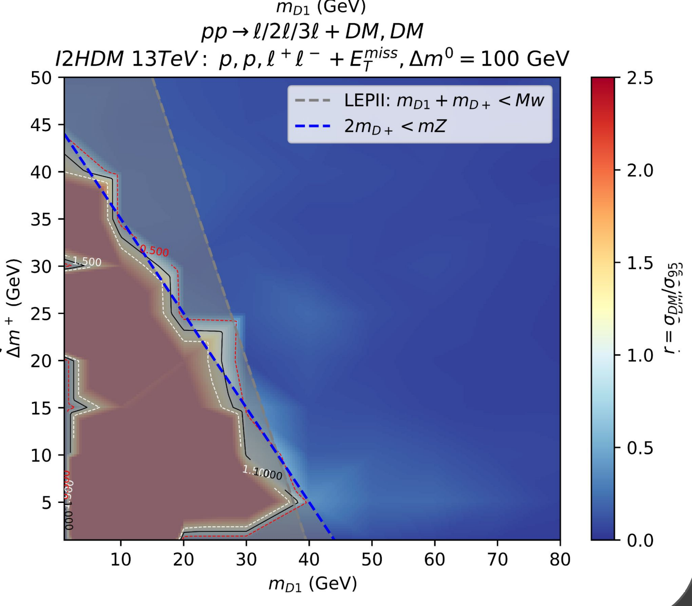
Small wedge around $m_{D1} > 50$ GeV and $\Delta m^+ < 8$ GeV still allowed by LEP

Δm^+ is a better variable than m_{D+}, results not dependent on m_{D2}, only require plane of 2 variables

Important contributions from 3-lepton (up to 70%) which could be combined with 2-lepton

Increasing Δm^0 to 100 GeV means the Z veto $m_{\ell\ell}$ > 100 GeV in analyses can no longer be fulfilled, as production cross-section of the heavier states has fallen





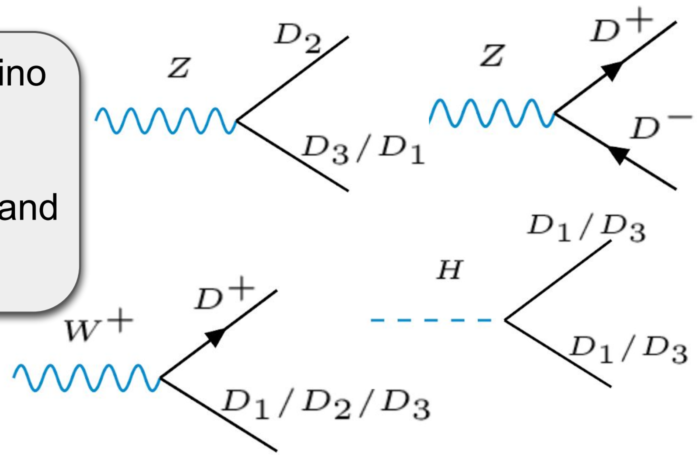
Minimal Fermion Dark Matter Model (MFDM)

$$\mathcal{L}_{FDM} = \mathcal{L}_{SM} + \bar\psi(i\not{D} - m_\psi)\psi + \frac{1}{2}\bar\chi_s^0(i\not\partial - m_s)\chi_s^0 - (Y(\bar\psi\Phi\chi_s^0) + h.c.)$$

$$\psi = \begin{pmatrix} \chi^+ \\ \frac{1}{\sqrt{2}}(\chi_1^0 + i\chi_2^0) \end{pmatrix} \qquad \chi_s^0$$

$$\Delta m^0 = m_{D3} - m_{D+}$$
$$\Delta m^+ = m_{D+} - m_{D1}$$

Inspired by Higgsino-Bino SUSY, introduces vector-like fermion SU(2) doublet and a singlet



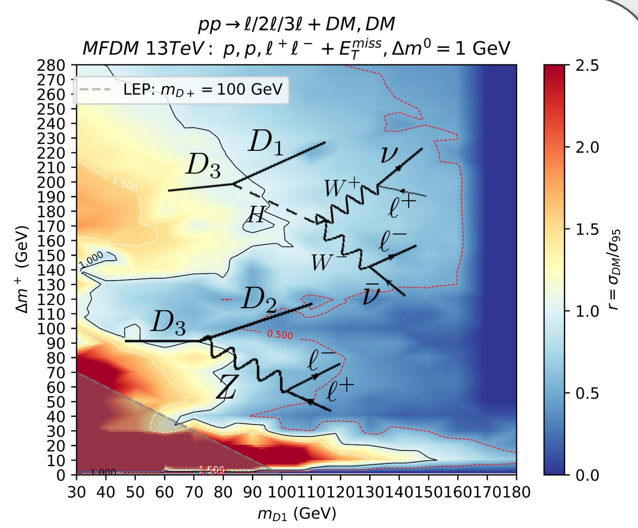
$$Y_{DM} = \frac{\sqrt{\Delta m^0 \Delta m^+}}{v}$$

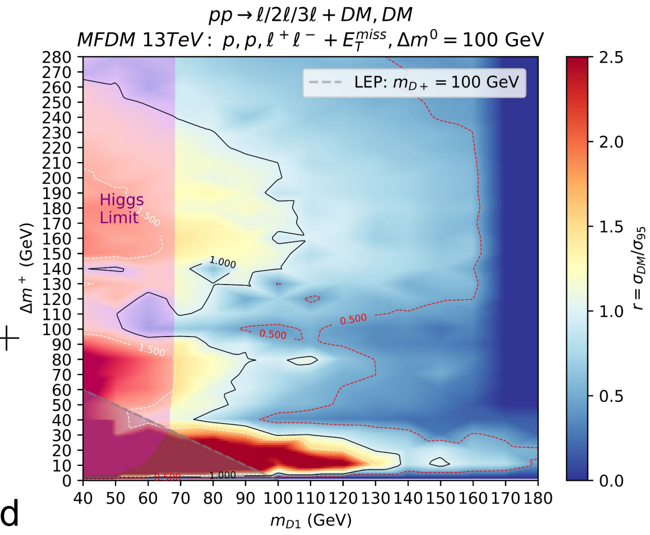
$$[m_{D1}, m_{D2} = m_{D+}, m_{D3}] \rightarrow [m_{D1}, \Delta m^+, \Delta m^0]$$

With large production of $D^\pm(\to \ell\nu D_1)D_3$, similar shapes to I2HDM, but 3-lepton channel sensitivity begins to dominate due to crossing from $D_3 \to \ell\nu D_1$ to $D_3 \to Z(\to \ell\ell)D_1$

Second shape due to 3-lepton channel sensitivity due to Higgs decay, from $D_3 \to Z(\to \ell\ell)D_1$ to $D_3 \to H(\to W^+W^-)D_1$, at $\Delta m^+ > 125$ Gev

'no-lose' theorem:
As Δm^0 increases, $D_1 - D^\pm$ coupling, thus $D+$ production increases, while heavy D_3 leads to suppressed production, leaving signal ~unchanged





Conclusions

For the representative minimal consistent DM models we have found new LHC sensitivity to DM mass beyond monojet limits from multilepton final states. We have demonstrated the importance of the 3-lepton channel, which becomes the leading one with the Δm^+ increase, especially due to the contribution from the Higgs decay channel

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