LHC searches relevant to the LZ event

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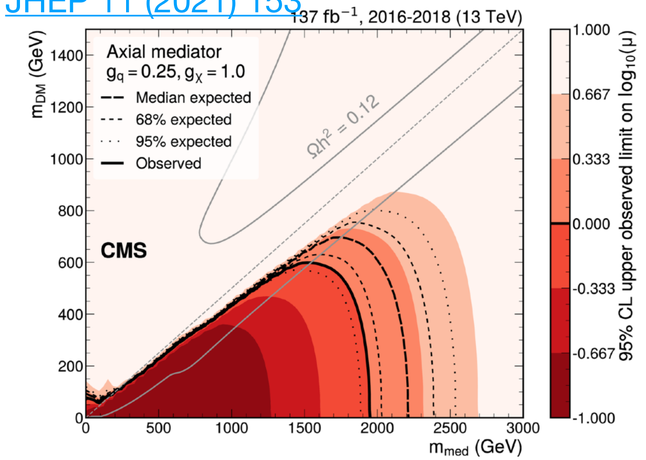
The LZ event

- The anomalous LZ event reported was discussed with some possible dark matter scenarios:
  - **Elastic dark matter:**
    - Spin-independent: almost impossible to generate the recorded recoil
    - **Spin-dependent**: mass above 100 GeV (according to the interpretation in the LZ paper)
  - **Inelastic dark matter:**
    - Mass above 400 GeV
    - Mass gap between the excited and stable DM states of O(100 keV)

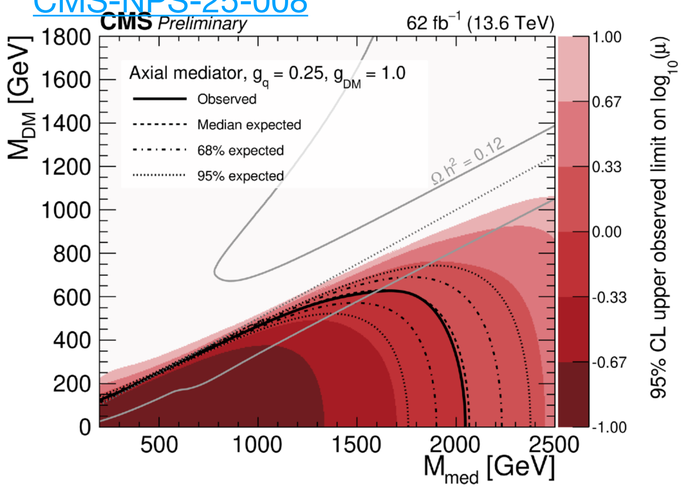
LHC searches for DM

- Searches at the LHC usually uses missing energy to search for DM
  - Different assumptions are made to design the exact signatures to search for
- **Generic — The “monojet” search:**
  - Jet from the initial state radiation + significant missing energy
  - Sensitive to a large range of DM models, suffer from relatively high background rate
- **The DM production cross section might be too low to be detected (if they are produced in the collisions at all)**

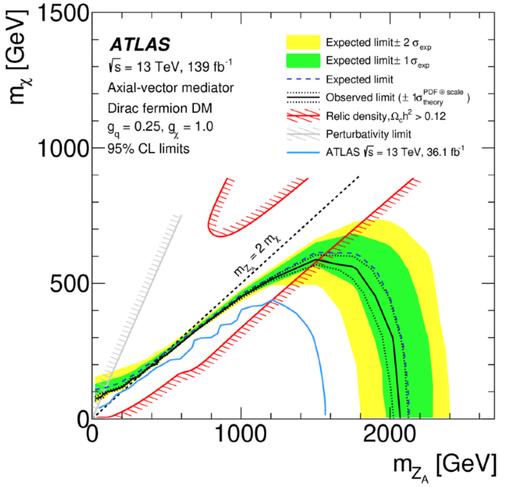
JHEP 11 (2021) 153



CMS-NPS-25-008



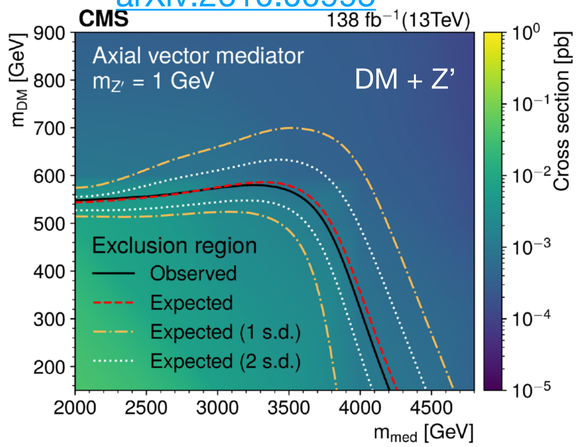
Phys. Rev. D 103 (2021) 112006



LHC searches for DM — CMS

- Additional assumptions are added to searches to enhance the sensitivity for more specific DM scenarios
- **The assumptions might be too restrictive for the DM model to satisfy**

arXiv:2610.00995



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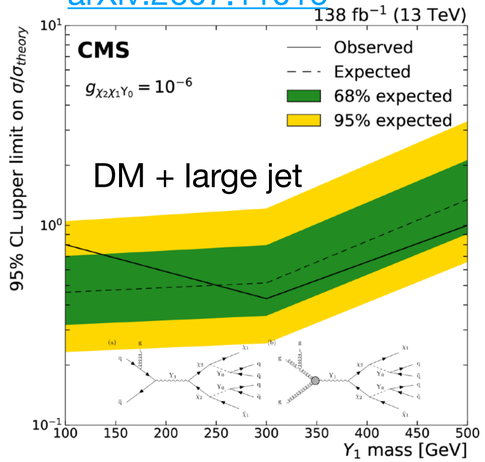
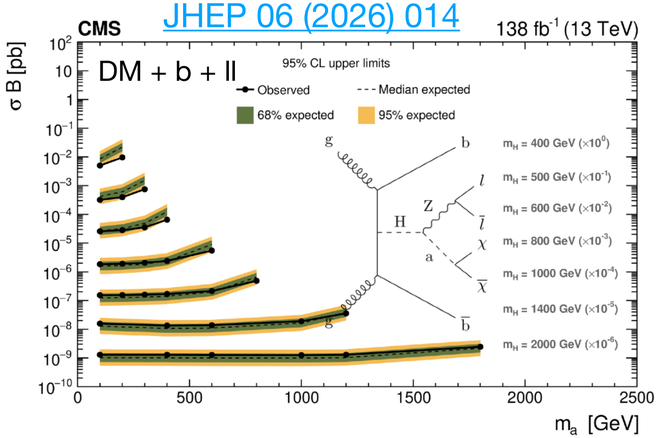
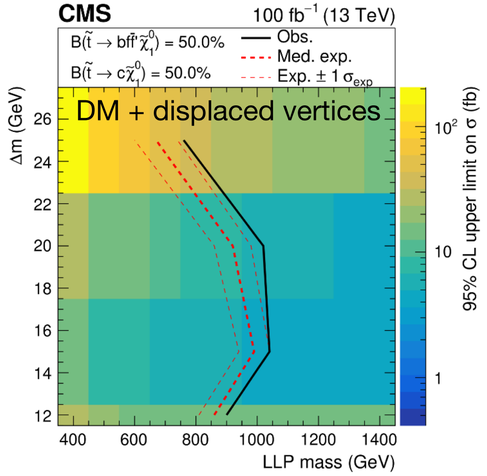


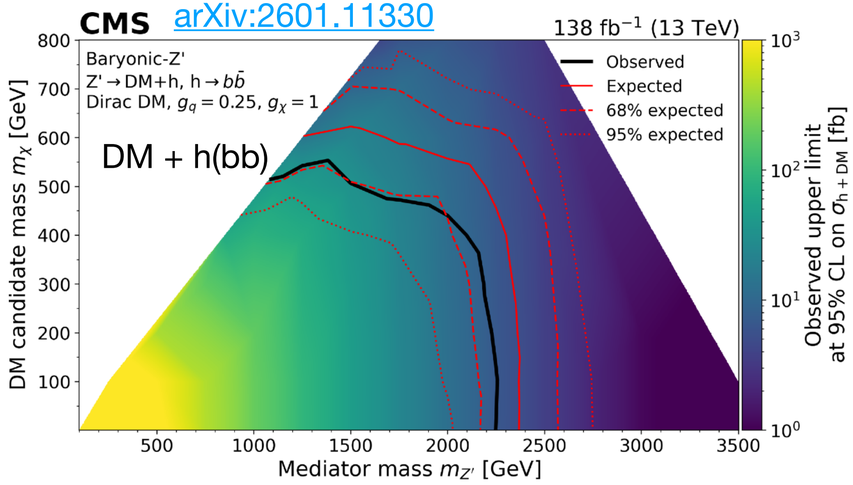
JHEP 06 (2026) 014



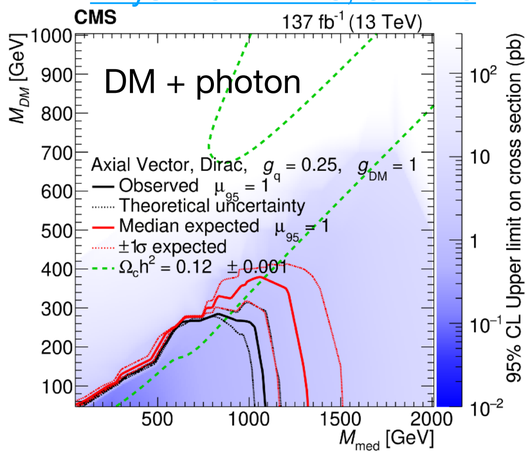
JHEP 05 (2026) 191



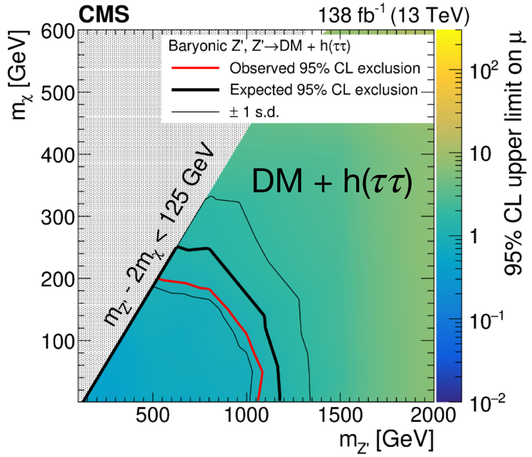
arXiv:2601.11330



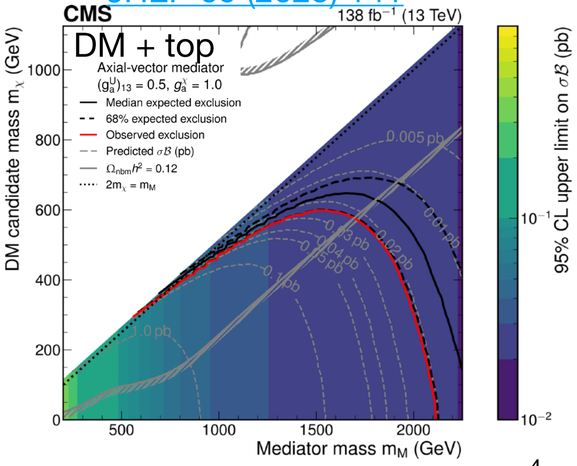
Phys. Rev. D 113, 072020



JHEP 10 (2025) 170



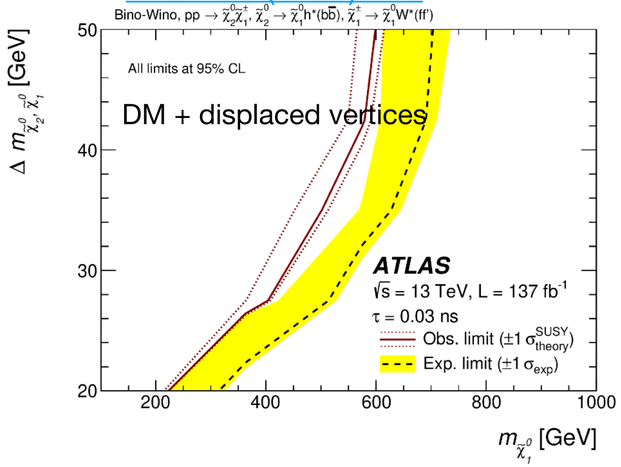
JHEP 09 (2025) 141



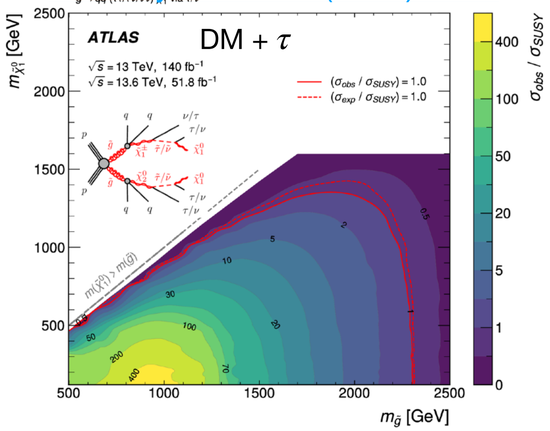
LHC searches for DM — ATLAS

- Additional assumptions are added to searches to enhance the sensitivity for more specific DM scenarios
- **The assumptions might be too restrictive for the DM model to satisfy**

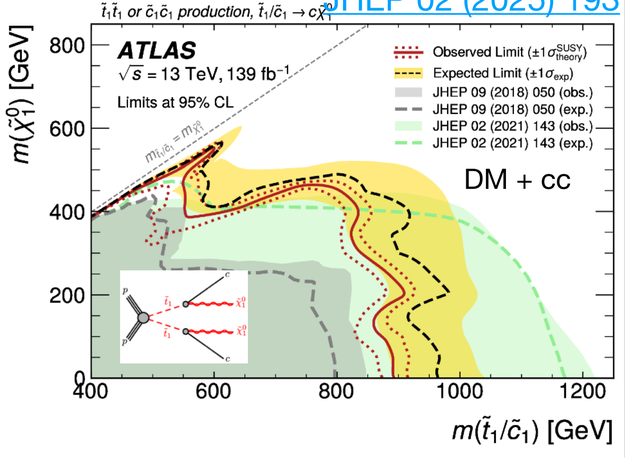
JHEP 08 (2026) 016



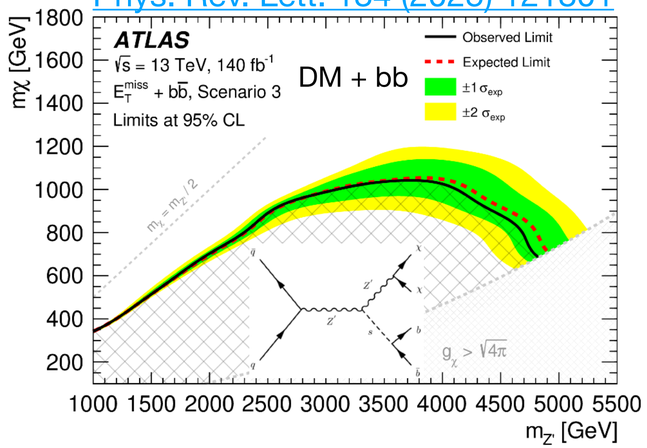
Eur. Phys. J. C 85 (2025) 1437



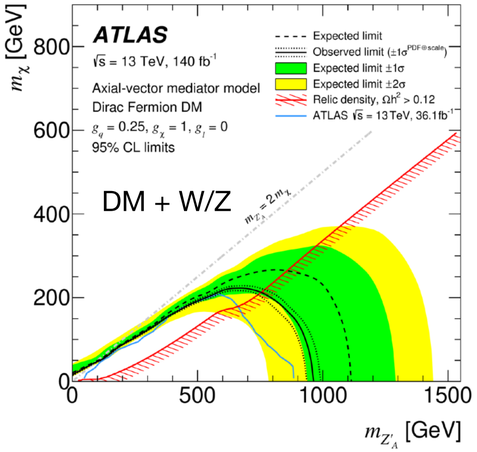
JHEP 02 (2025) 193



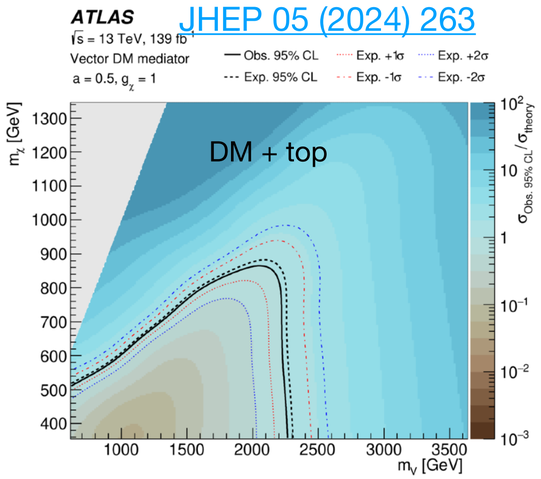
Phys. Rev. Lett. 134 (2025) 121801



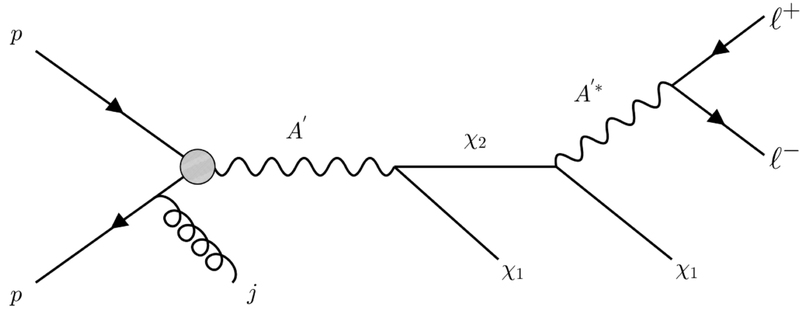
JHEP 11 (2024) 126



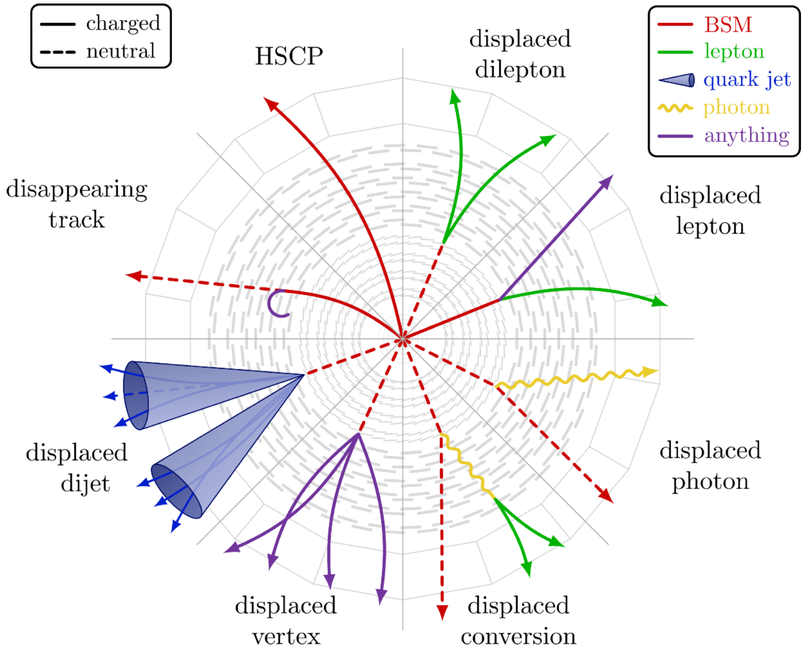
JHEP 05 (2024) 263



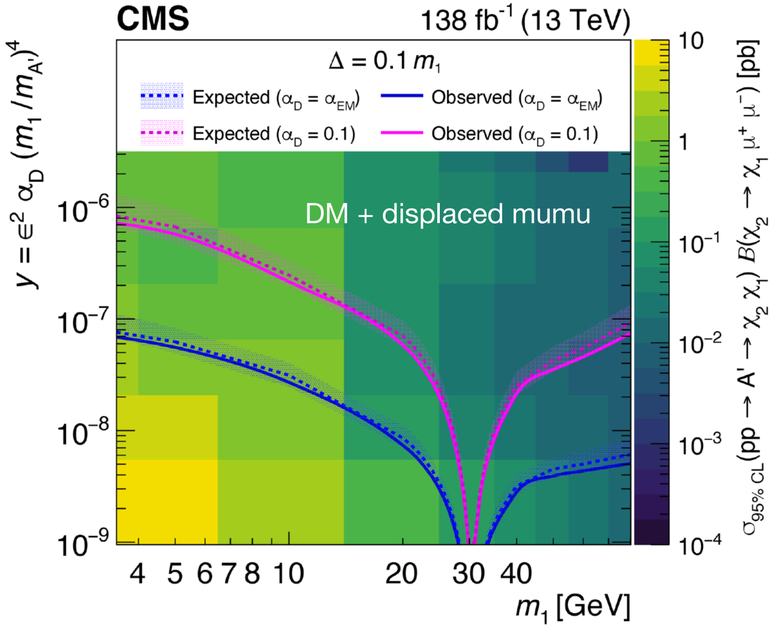
Inelastic dark matter



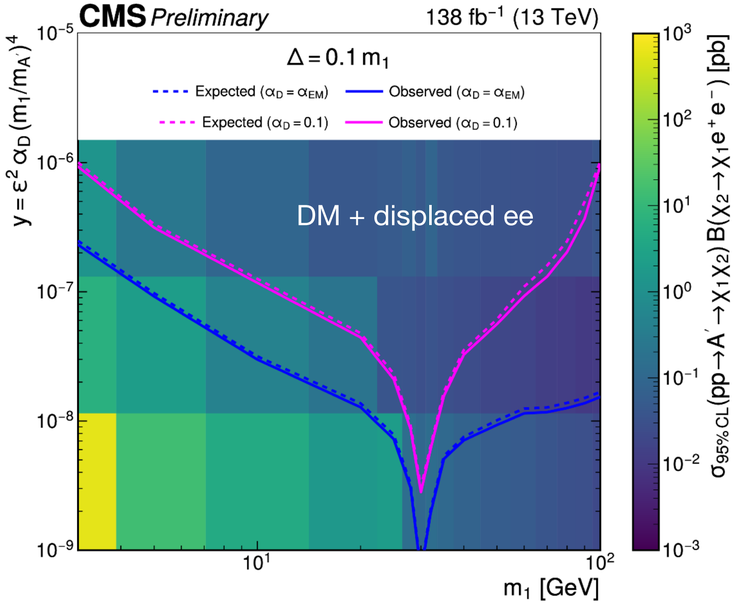
- There are CMS searches targeting inelastic dark matter models
  - Signatures include missing energy + displaced di-muon/di-electron
- Kinematically feasible when **mass splitting above** $2m_l$ — O(1MeV) >> recoil energy measured in the LZ event



Phys. Rev. Lett. 132 (2024) 041802

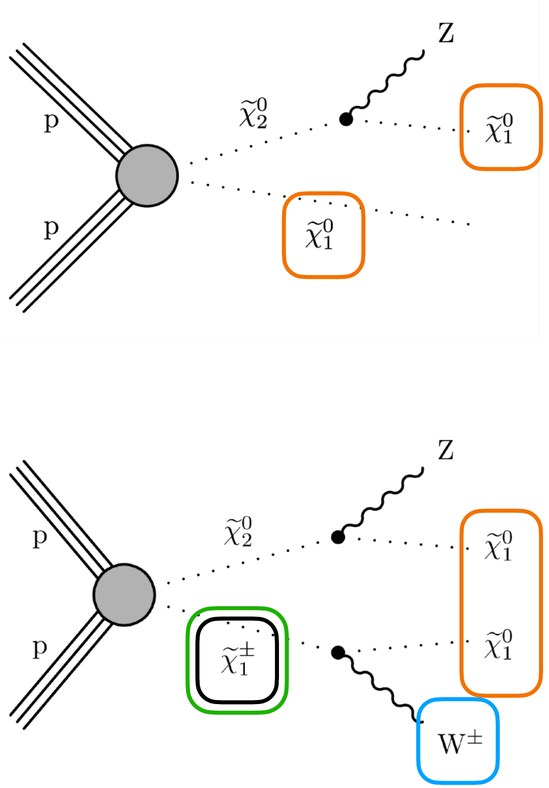


CMS-PAS-EXO-24-036



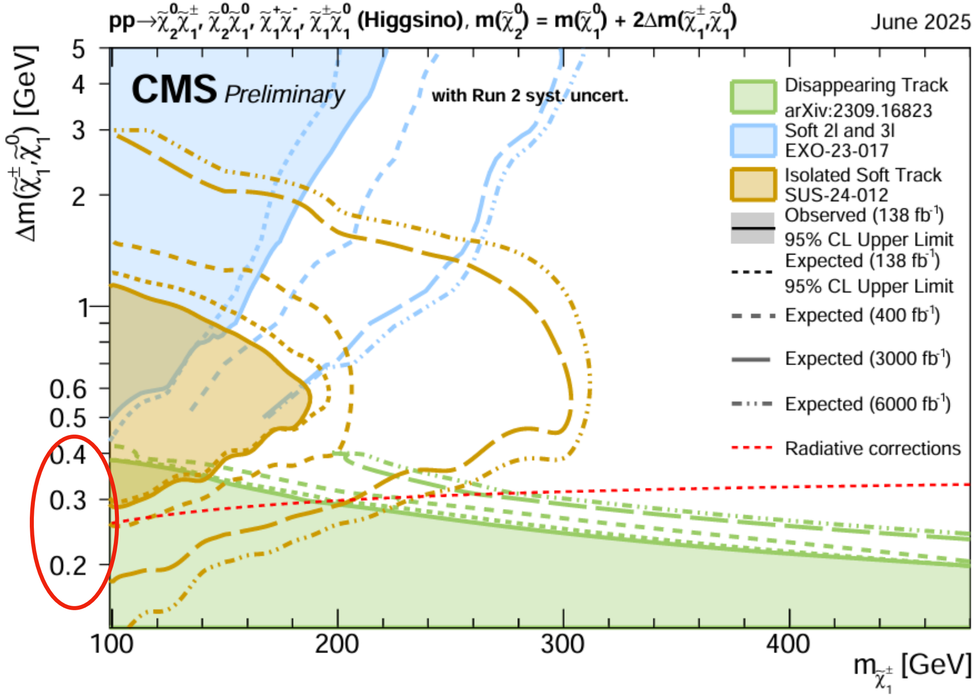
Inelastic dark matter

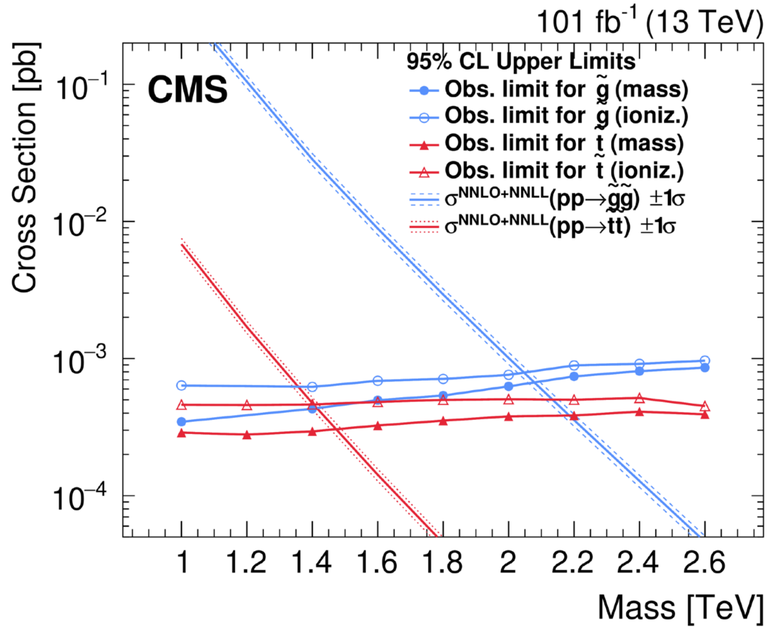
- The LZ event prefers inelastic DM with **mass splitting of O(100 keV)**
  - Higgsino models can be a good candidate
    - O(100 keV) mass splitting between $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$ — may not be detectable in LHC searches
    - **O(100 MeV) mass gap** between $\tilde{\chi}_1^0$ and $\tilde{\chi}_1^\pm$
    - Potentially **long-lived** $\tilde{\chi}_1^\pm$
- Signatures:
  - **Significant missing energy — "monojet" searches can be reinterpreted**
  - **Low-momentum (displaced) tracks / leptons**
  - **Disappearing tracks**
  - **Heavy stable charged particles**



Inelastic dark matter

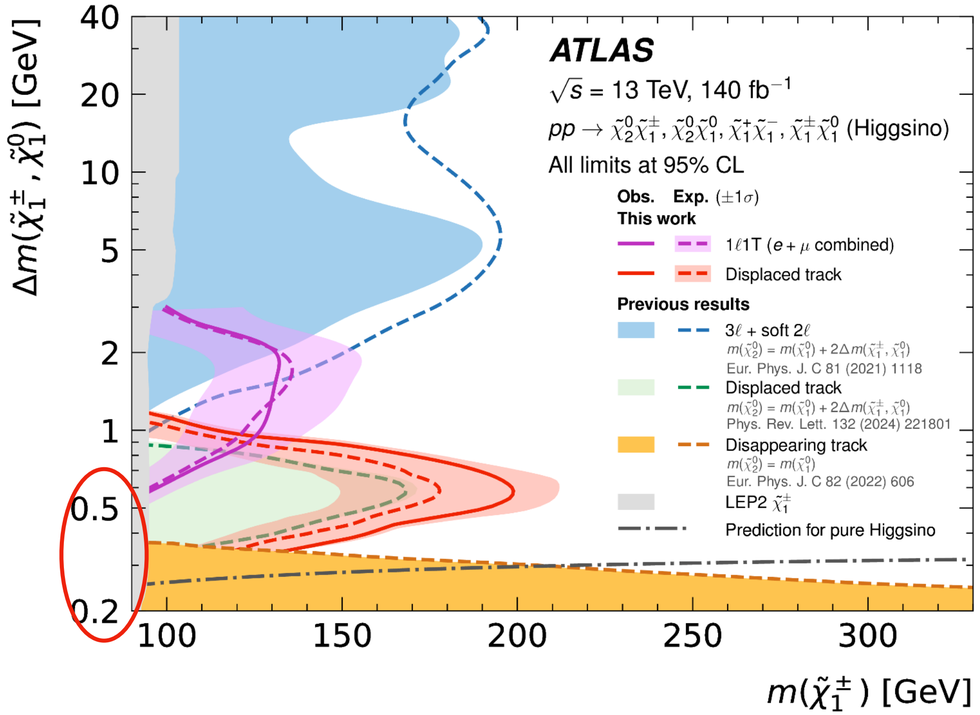
- **CMS-SUS-21-006**:
  missing energy + disappearing tracks
- **CMS-PAS-EXO-23-017**:
  missing energy + soft 2/3 leptons
- **CMS-SUS-24-012**:
  missing energy + isolated soft (displaced) track
- **CMS-EXO-18-002**:
  heavy stable charged particles

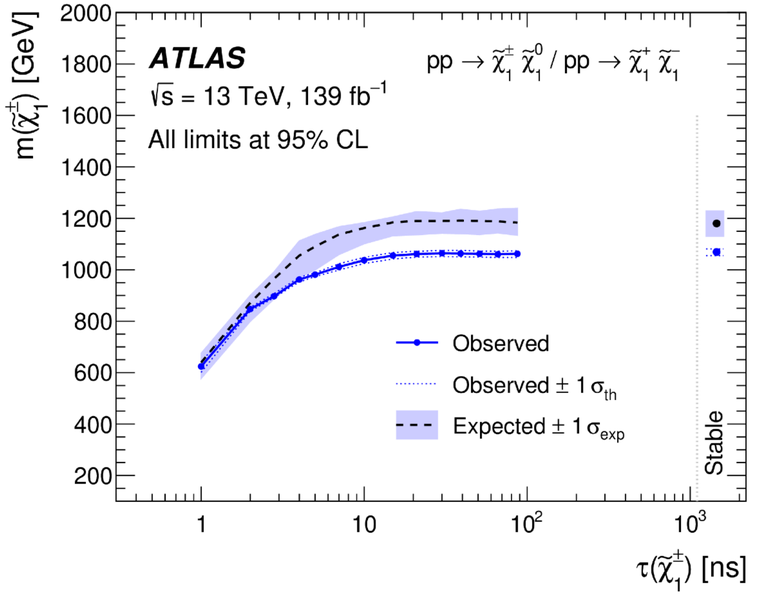




Inelastic dark matter

- **JHEP 06 (2026) 094**:
  missing energy + displaced track / soft leptons
- **Eur. Phys. J. C 81 (2021) 1118**:
  missing energy + soft leptons
- **Eur. Phys. J. C 82 (2022) 606**:
  missing energy + disappearing tracks
- **JHEP 06 (2023) 158**:
  heavy stable charged particles





Summary

- The LZ event suggests **spin-dependent elastic DM** or **inelastic DM**
- LHC has many searches with various assumptions on the DM models
  - **No tension found** so far at the LHC
    - The **production cross section** might be too low at the LHC
    - The **assumptions** might be inaccurate
- Might be helpful to **combine the searches** to get a better understanding