DM@Collider summary plots for Snowmass

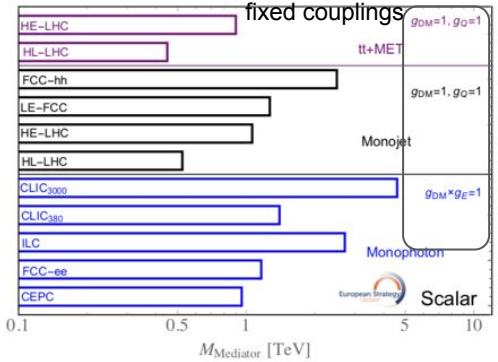
Plans for DM simplified models

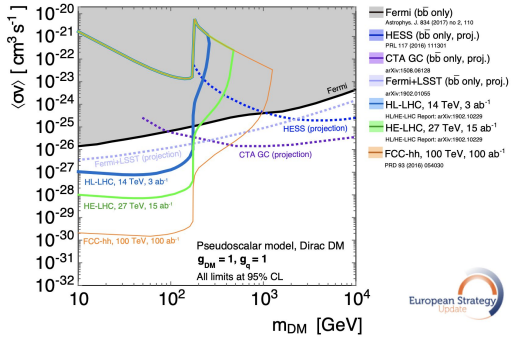
LOI: https://www.snowmass21.org/docs/files/summaries/EF/SNOWMASS21-EF9_EF10-RF6_RF0-CF1_CF3_Boyu_Gao-160.pdf
Authors: Antonio Boveia, Linda Carpenter, Caterina Doglioni, William Kalderon, Boyu Gao, Philip Coleman Harris, David Yu

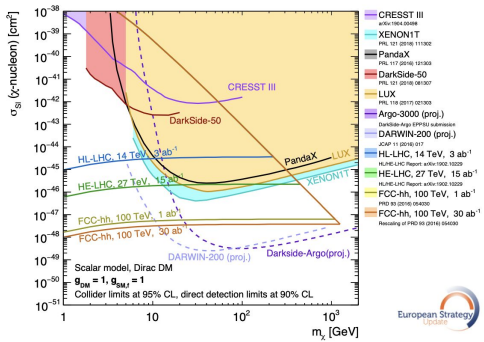
Our goal for DM@Collider plots for Snowmass

- Prepare Dark Matter summary plots like European strategy for HL-LHC and future colliders, with varying couplings → see K. Pachal's talk
  - Models used so far: from LHC Dark Matter Working Group [arxiv 1507.00966]
    - Vector/axial vector simplified model
    - Scalar/pseudoscalar simplified model
- Connect these plots to other experiments and Frontiers
  - Rare/precision Frontier: accelerator-based / fixed target experiments
  - Cosmic Frontier: indirect detection (bottom left) and direct detection (bottom right)
  - Will need to **agree on benchmarks models and presentation of results** with them

European Strategy: fixed couplings

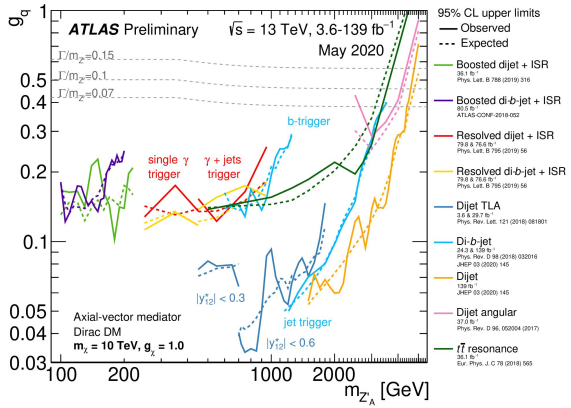


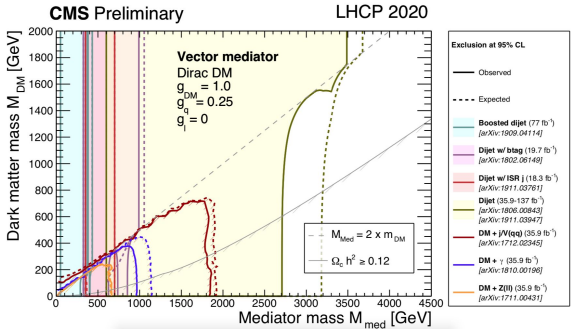




List of plots, analyses and collider options

- The list of plots we can to contribute to the Snowmass process
  - DM-SM coupling as a function of mediator mass (top figure)
  - DM mass - mediator mass plots (bottom figure)
  - Summary plots that include collider experiments
- The list of analyses we can put on these plots
  - Jet + MET
  - Photon + MET
  - ttbar + MET
  - Di-jet / di-lepton
- The list of colliders
  - HL-LHC
  - Future colliders (including muon collider)





Work plan

1. These plots need **individual inputs from future colliders**
    - With an analytical interpretation we can make plots for other couplings as well → procedure is the output of other LOI
2. After we agree on models with different communities (CF/RF), we will reach out to future colliders / HL-LHC to collect inputs from available searches
    - Ongoing work: validating Madgraph UFO and settings
        - Ongoing discussion with John Stupak III from MC task force
        - Plan is to give out models and instructions to future colliders if they want to provide analysis results to feature on these plots
    - Some results already there from European Strategy for hadron colliders, start with those
        - Lepton colliders: we will need to agree on benchmarks with lepton couplings
3. Connect to other frontiers and make summary plots
4. Contribute to the complementarity whitepaper, see this LOI
    - https://www.snowmass21.org/docs/files/summaries/CF/SNOWMASS21-CF2_CF7-EF10_EF0-RF6_RF0-TF9_TF0-150.pdf

Thank you!

Backup slides

European strategy briefing book: DM ID plot

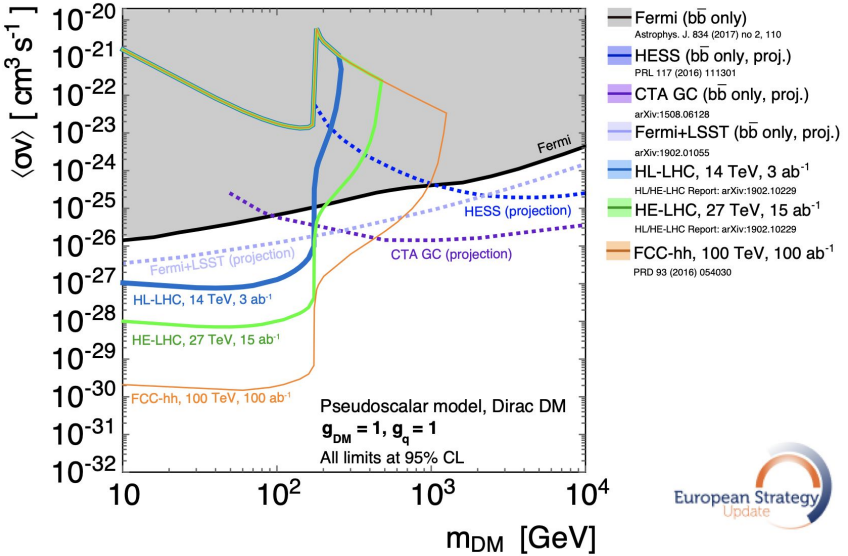
- Comparison of projected limits from future colliders with constraints from current and future indirect detection experiments (bottom right figure)
  - In the context of simplified s-channel pseudoscalar DM model
  - The collider limits are transferred via equations:
    - For quarks:

$$\langle \sigma v_{rel} \rangle_q = \frac{3 m_q^2}{2\pi v^2} \frac{g_q^2 g_{DM}^2 m_{DM}^2 \sqrt{1 - \frac{m_q^2}{m_{DM}^2}}}{(M_{med}^2 - 4 m_{DM}^2)^2 + M_{med}^2 \Gamma_{med}^2}$$

    - For gluons:

$$\langle \sigma v_{rel} \rangle_g = \frac{\alpha_s^2}{2\pi^3 v^2} \frac{g_q^2 g_{DM}^2 \mid \sum_q m_q^2 f(\frac{m_q^2}{m_\chi^2}) \mid^2}{(M_{med}^2 - 4 m_{DM}^2)^2 + M_{med}^2 \Gamma_{med}^2}$$

arxiv 1910.11775



European Strategy Update

European strategy briefing book: DM DD plot

- DM interacting with nucleon via t-channel with simp scalar mediator (SI case) has xsec of the form: $\sigma_{\rm SI} = \frac{f^2(g_q) g_{\rm DM}^2 \mu_{n\chi}^2}{\pi M_{\rm med}^4}$, where mu is reduce mass
- For scalar mediator
  - DM-nucleon coupling reads (the difference between proton and neutron can be ignored in this case):

$$f^{n,p}(g_q) = \frac{m_n}{v}\left[\sum_{q=u,d,s} f_q^{n,p} g_q + \frac{2}{27} f_{\rm TG}^{n,p} \sum_{Q=c,b,t} g_Q\right]$$

    - Finally this simplifies to: $f(g_q) = 1.16 \cdot 10^{-3}\, g_q$
  - Hence the size of typical xsec reads:

$$\sigma_{\rm SI} \simeq 6.9 \times 10^{-43}\ {\rm cm}^2 \cdot \left(\frac{g_q\, g_{\rm DM}}{1}\right)^2 \left(\frac{125\,{\rm GeV}}{M_{\rm med}}\right)^4 \left(\frac{\mu_{n\chi}}{1\,{\rm GeV}}\right)^2$$