UNIVERSIDAD DE ANTIOQUIA

1803

Simplest Fermion Vector-Like Portal Dark Matter model:

Search in the compressed mass region at the CMS experiment

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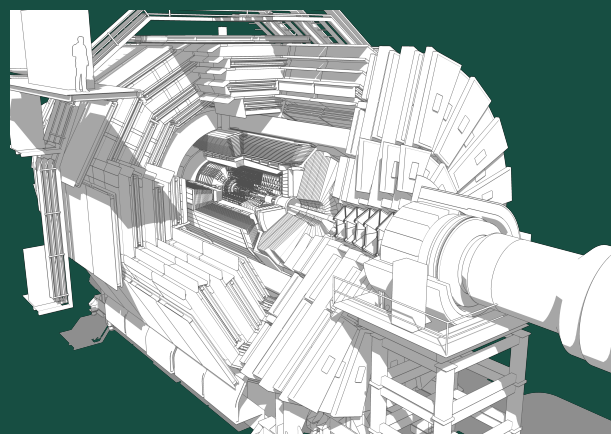

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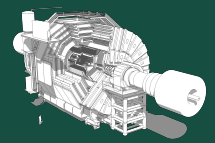
Introduction



Dark Matter (DM) constitutes one of the main unsolved problems in fundamental physics. Ever since it was proposed to explain the rotation curves of galaxies, some other astronomical observations left little doubt of its existence.

Whatever DM is, the Standard Model (SM) is not able to produce a candidate that have, at the present time in the universe, stability and also interact very little or not at all with known matter, proven properties of DM.

Rotational Velocities

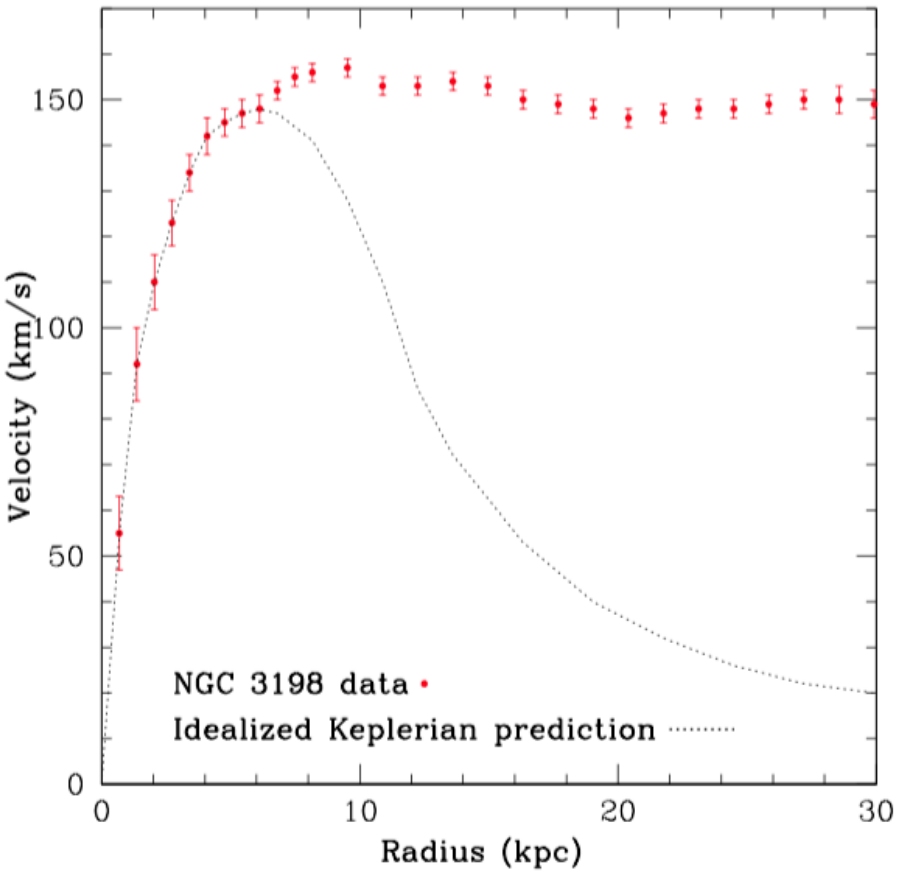


Figure 1.1: Measured rotational velocities of HI regions in NGC 3198 compared to an idealized Keplerian behavior [Astron. and Astrophys. 223, 47-60]

Bullet cluster

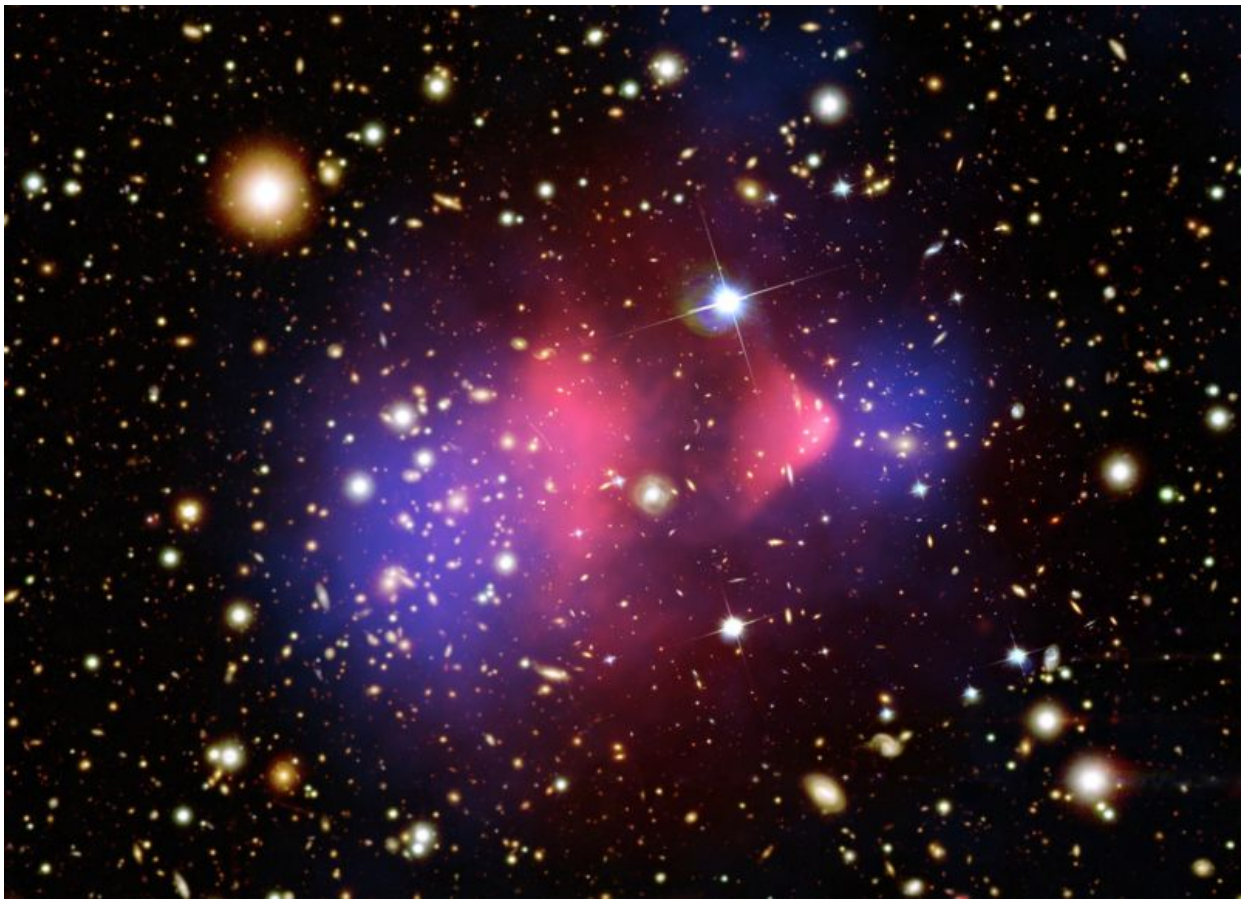


Figure 1.2: The Bullet cluster, the result of a subcluster (the "bullet") colliding with the larger galaxy cluster 1E 0657-56 [arXiv:1711.02117]

Motivation

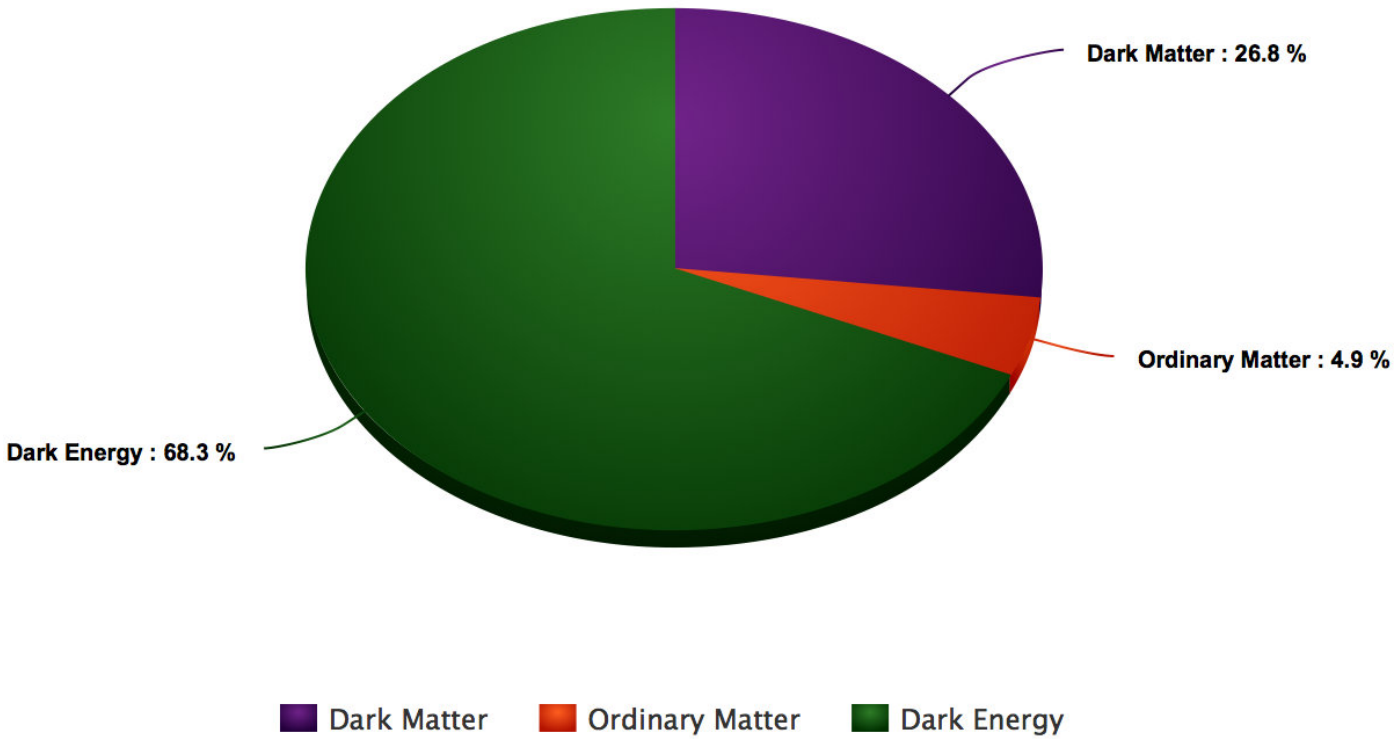


Figure 2.1: Simplified plot showing the estimate abundances

Detection Channels

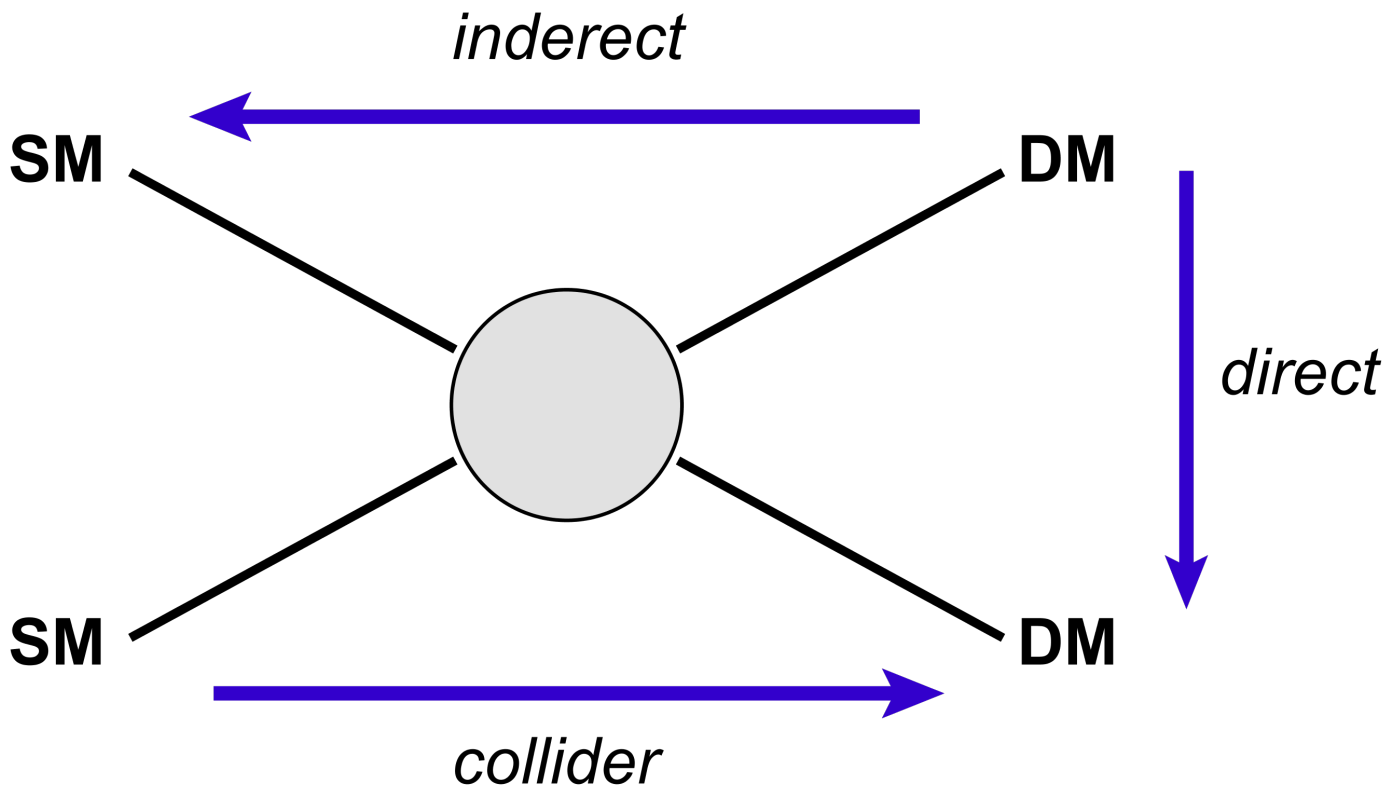
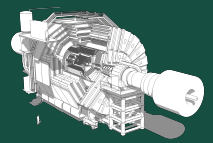


Figure 2.2: Schematic showing the possible dark matter detection channels.

Model



The Lagrangian of the model reads

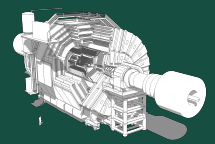
$$\mathcal{L} = \mathcal{L}_{SM} + m_F \bar{F} F + (Y_\ell S \bar{F} \ell_R + \text{h.c.}) + V(S, H) \; ;$$

m_F singlet fermion mass parameter, ℓ_R are the SM right-handed lepton fields, Y_ℓ are the Yukawa couplings. The contribution to the scalar potential is given by

$$V(S, H) = \frac{m_S^2}{2} S^2 + \frac{\lambda_S}{4} S^4 + \lambda_{SH} S^2 |H|^2 \; ,$$

with scalar mass parameter m_S and quartic couplings λ_S and λ_{SH}.

Model



We focus on scenarios where the vector-like portal for DM annihilation is dominant and, therefore, we set initially.

$$\lambda_{SH} = 0;$$

also we assume that the DM candidate does not couples to the electron.

$$Y_e = 0;$$

the remaining parameters, Y_μ,Y_τ , m_S and m_F are allowed to vary freely.
Also we are searching into the compress mass regime

$$\Delta m = m_F - m_S \lesssim 50 \text{ GeV}$$

Creation of DM in the Early Universe

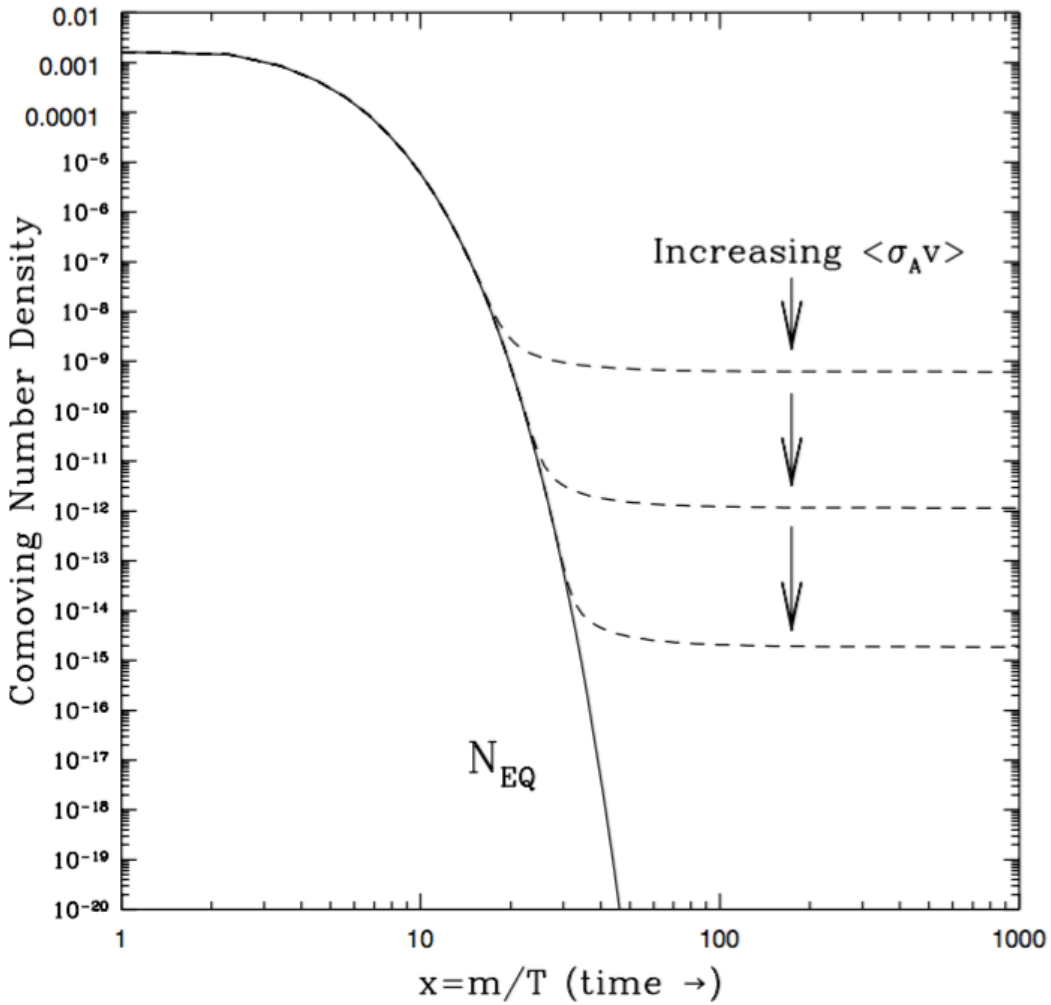
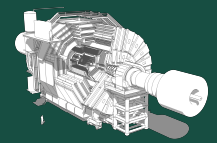


Figure 3.1: Equilibrium (solid curve) and relic abundance (dashed curve) of WIMP particles. Figure is taken from arXiv:hep-ph/9506380

Collider searches for DM



Signals

1. Cascades of heavier particles to the DM candidate and SM.

2. DM production in association with other SM particles,

Experimental Signature

The simplest production and decay process at the LHC is pair-production of vector-like fermions, followed by their subsequent decay to a lepton and the DM scalar.
This process leads to the signature opposite sign leptons plus missing energy.

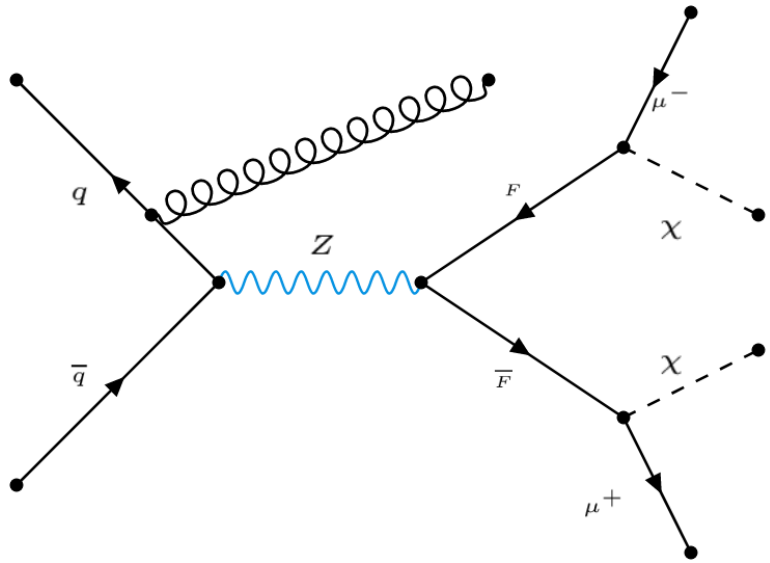


Figure 4.1: Pair-production of vector-like fermions ($pp \to F^- F^+$), in a Drell-Yan process, followed by their decay into a lepton and the DM particle ($F^- \to \ell^- S + \text{ h.c.},\ \ell = \text{e}, \mu, \tau$)

Parameter Region

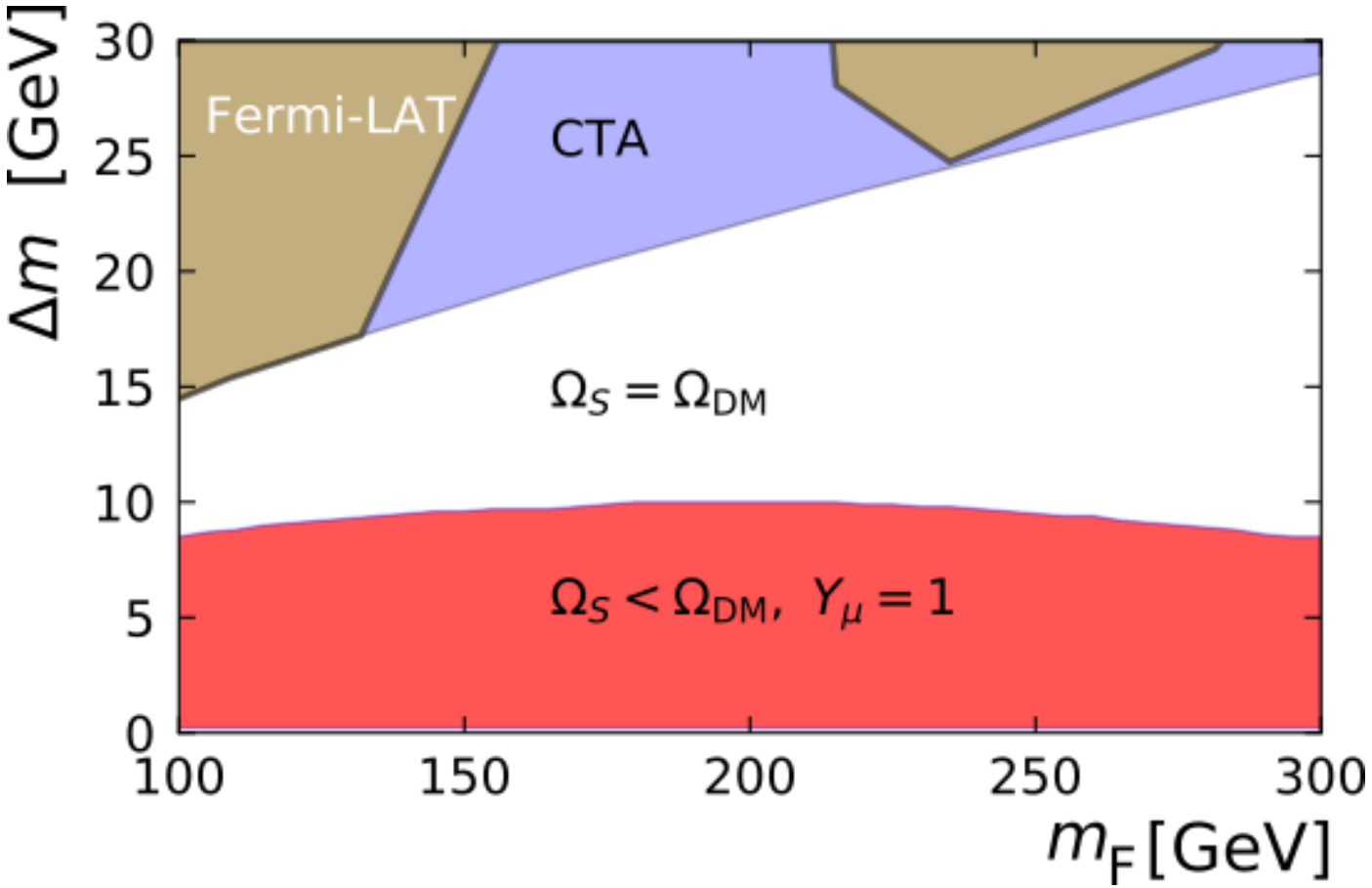
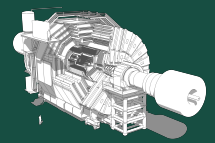


Figure 4.2: m_F vs Δm. The brown upper region is excluded by Fermi-LAT H.E.E.S, while the combined upper region with light and magenta are the prospects for Cherenkov Telescope Array.

Remarks



1. Although the model have been analyzed. there is still the region of the parameter space ($\Delta m = m_F - m_S \lesssim 50$ GeV) with exclusion potential.
2. The full dark matter content may be explained either by freeze-out at higher redshifts, or by another dark matter content.
3. We can obtain exclusion sensitivity over a large region of parameter has not yet been covered by any other search.

Thank You.

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