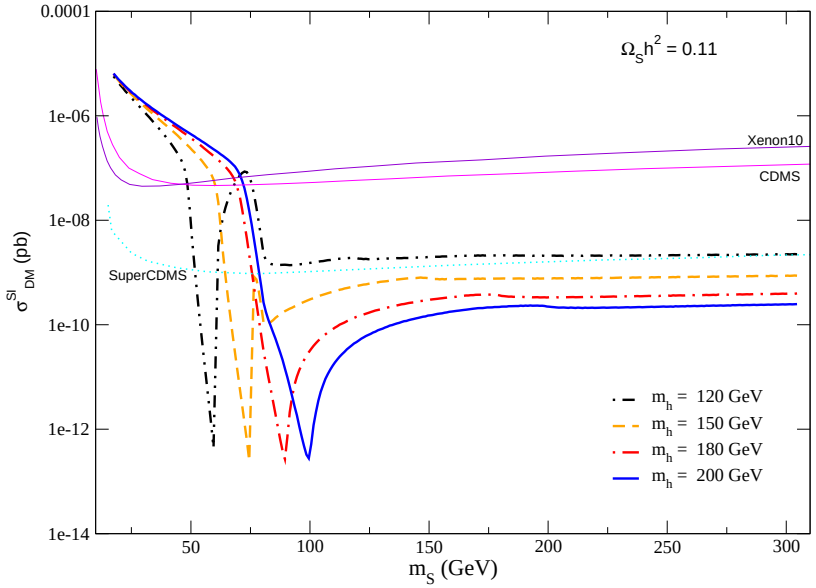
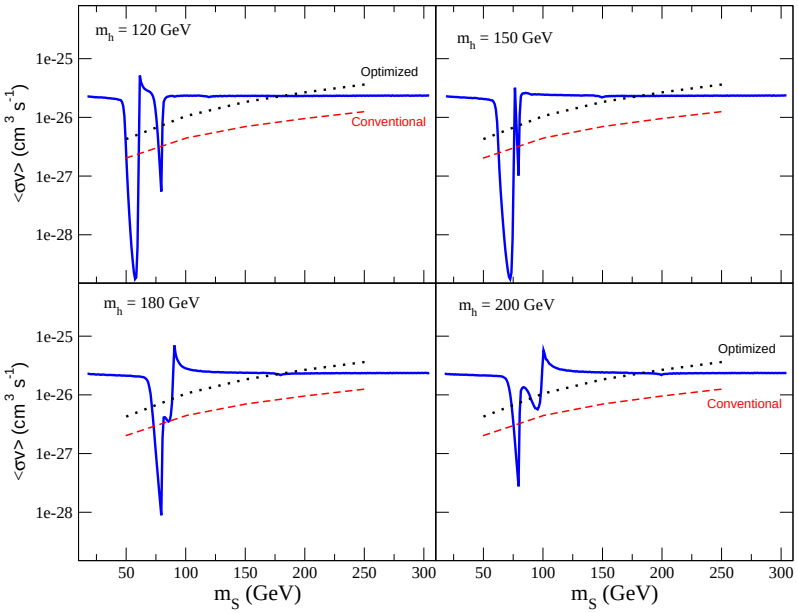
Detection of singlet scalar dark matter

Yaguna, JCAP 0903:003,2009
Goudelis, Mambrini and Yaguna, `arXiv:0909.2799`





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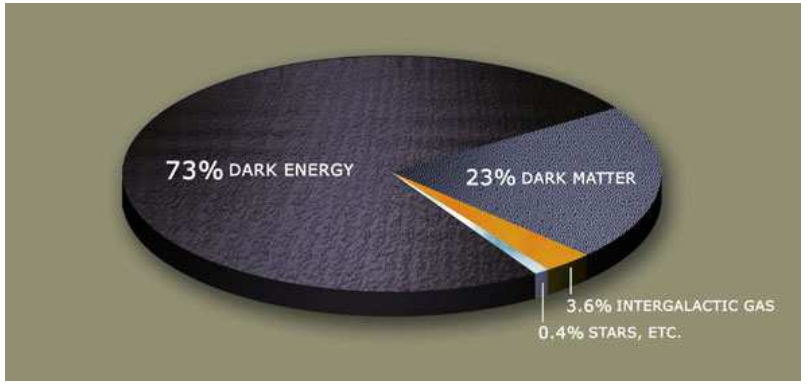
The singlet scalar model is a simple extension of the SM that can explain the dark matter

The SM is successful but it cannot account for the DM



Let us extend the SM with one additional field: S

S is a singlet scalar

And a discrete symmetry Z_2 to render it stable

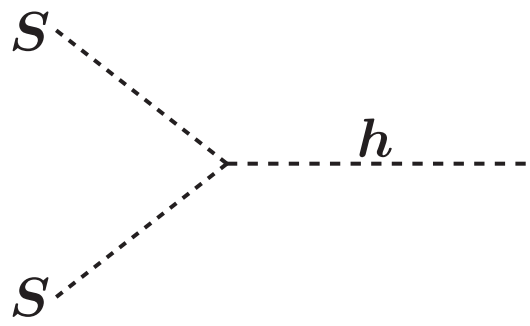
$$\mathscr{L} = \mathscr{L}_{SM} + \tfrac{1}{2}\partial_\mu S \partial^\mu S - \tfrac{1}{2} m_0^2 S^2$$
$$- \lambda S^2 H^\dagger H - \tfrac{1}{4}\lambda_S S^4$$

This model has only two relevant parameters: the singlet mass and the higgs-singlet coupling

λ_S does not affect the phenomenology

$$\mathscr{L} = \mathscr{L}_{SM} + \tfrac{1}{2}\partial_\mu S \partial^\mu S - \tfrac{1}{2} m_0^2 S^2$$
$$-\lambda S^2 H^\dagger H - \tfrac{1}{4}\lambda_S S^4$$

S interacts with SM fields through h

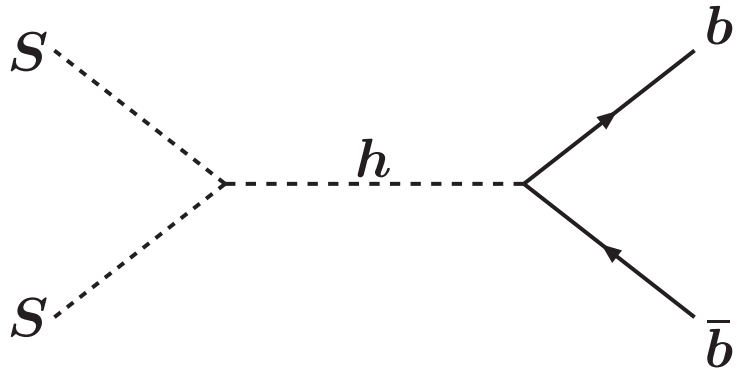


We take λ and m_S as the free parameters

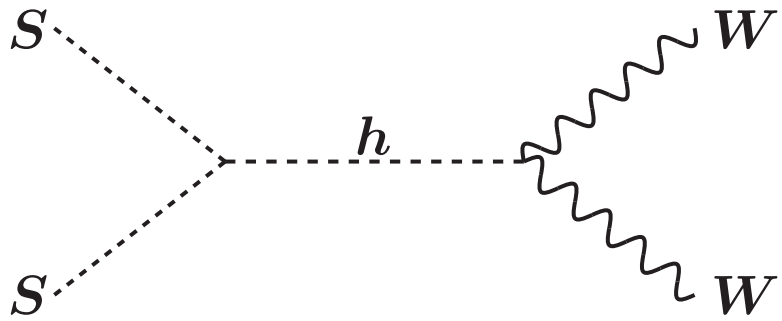
$$m_S^2 = m_0^2 + \lambda v_{EW}^2$$

Singlets annihilate mainly through s-channel higgs boson exchange

For light singlets $b\bar{b}$ is the dominant final state



For heavier singlets W^+W^- becomes dominant



Resonance effects can be important

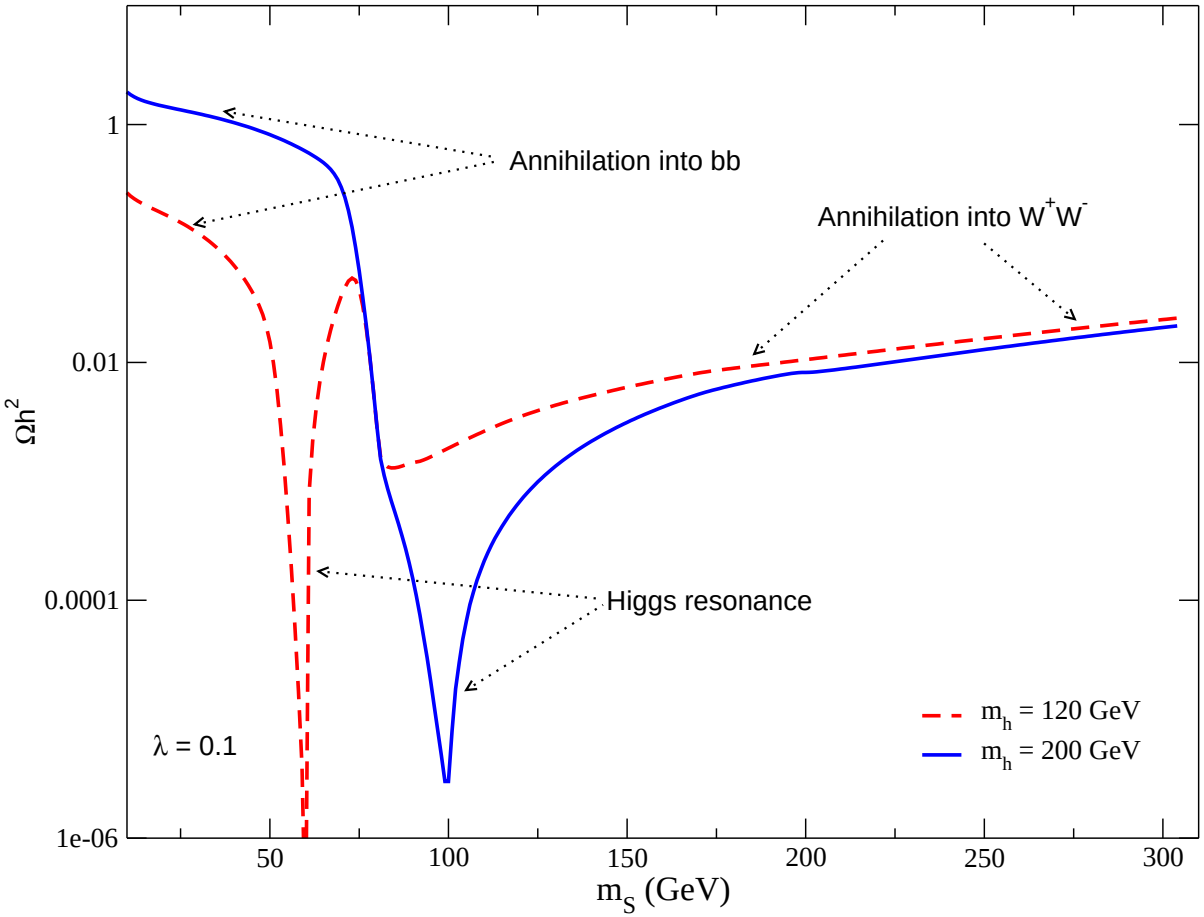
In the region $2m_S \sim m_h$

The singlet relic density depends on three parameters: λ, m_S, m_h

Three regions can be distinguished

Ωh^2 tends to be larger for light singlets

At the higgs resonance Ωh^2 is suppressed

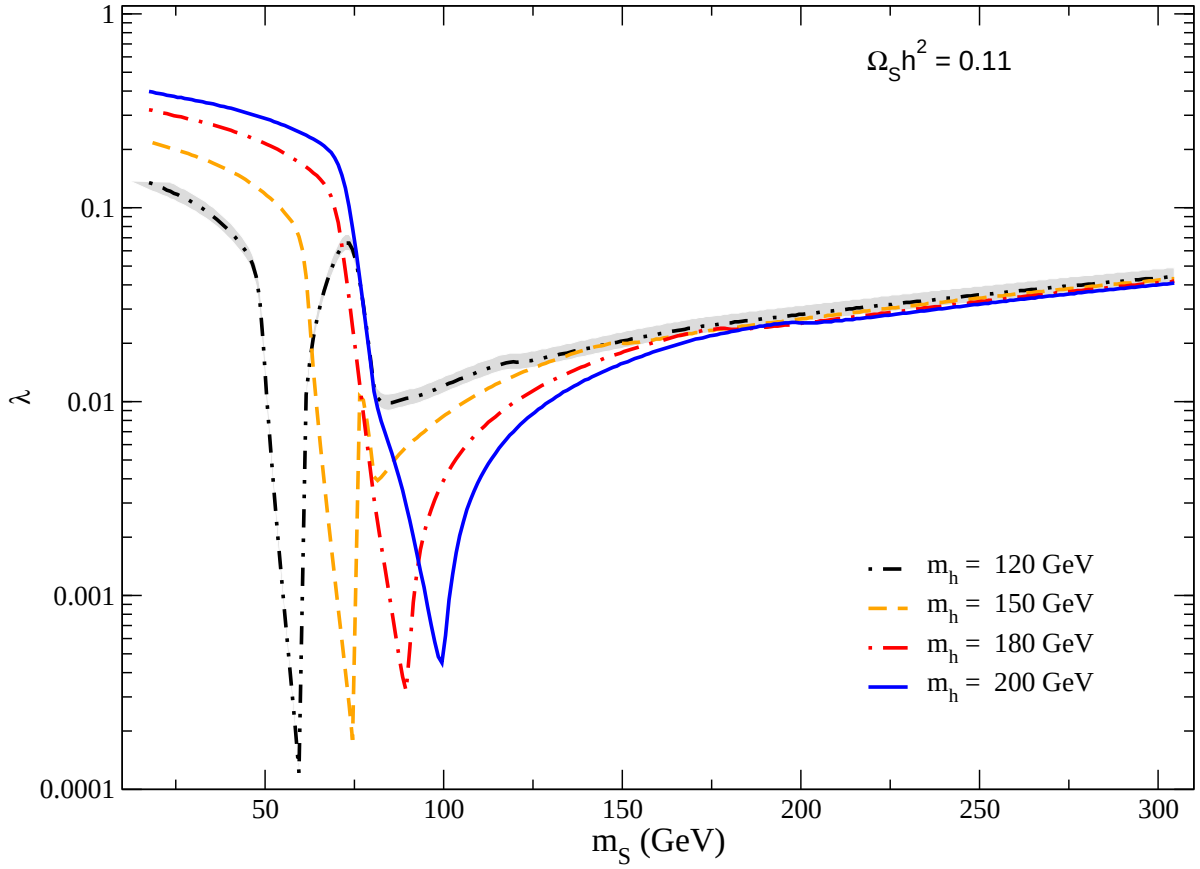


The relic density constraint leaves m_S as the only new parameter of the model

At the higgs resonance λ is small

If $m_S < m_W$ λ must be larger than about 0.1

If $m_S > m_W$ λ has to be of order 0.01

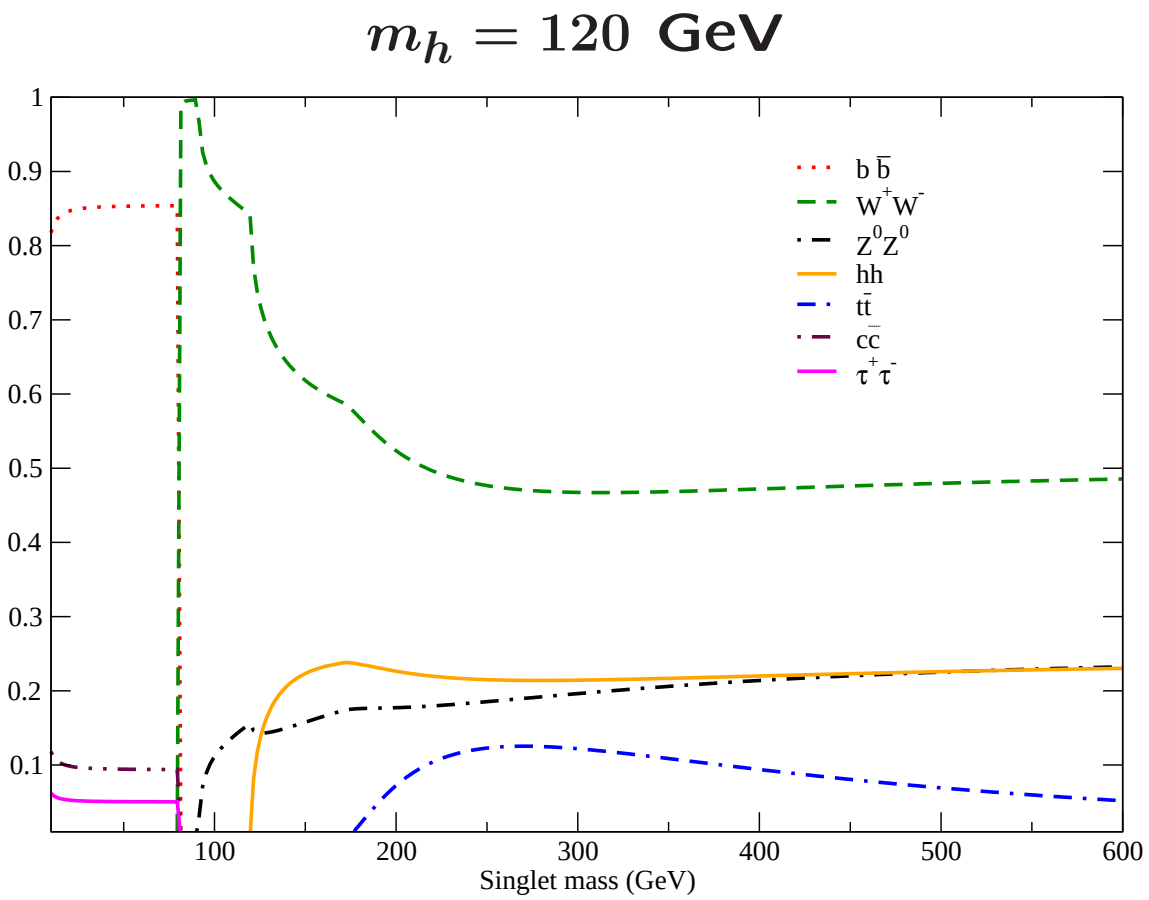


The singlet annihilation branching fractions are determined for given m_S and m_h

Light singlets annihilate into fermions

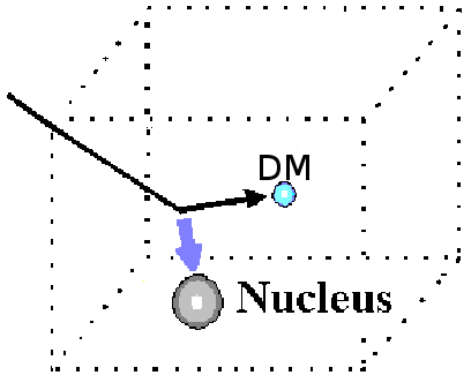
Heavy singlets annihilate into gauge bosons

Dependence with m_h is very weak

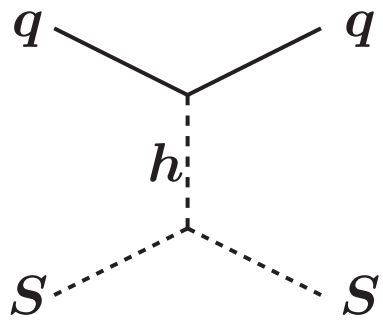


Dark matter particles can be directly detected through their elastic scattering with matter

DM is detected through nuclear recoil



The singlet-matter interaction is mediated by h



Several experiments are searching for this signal

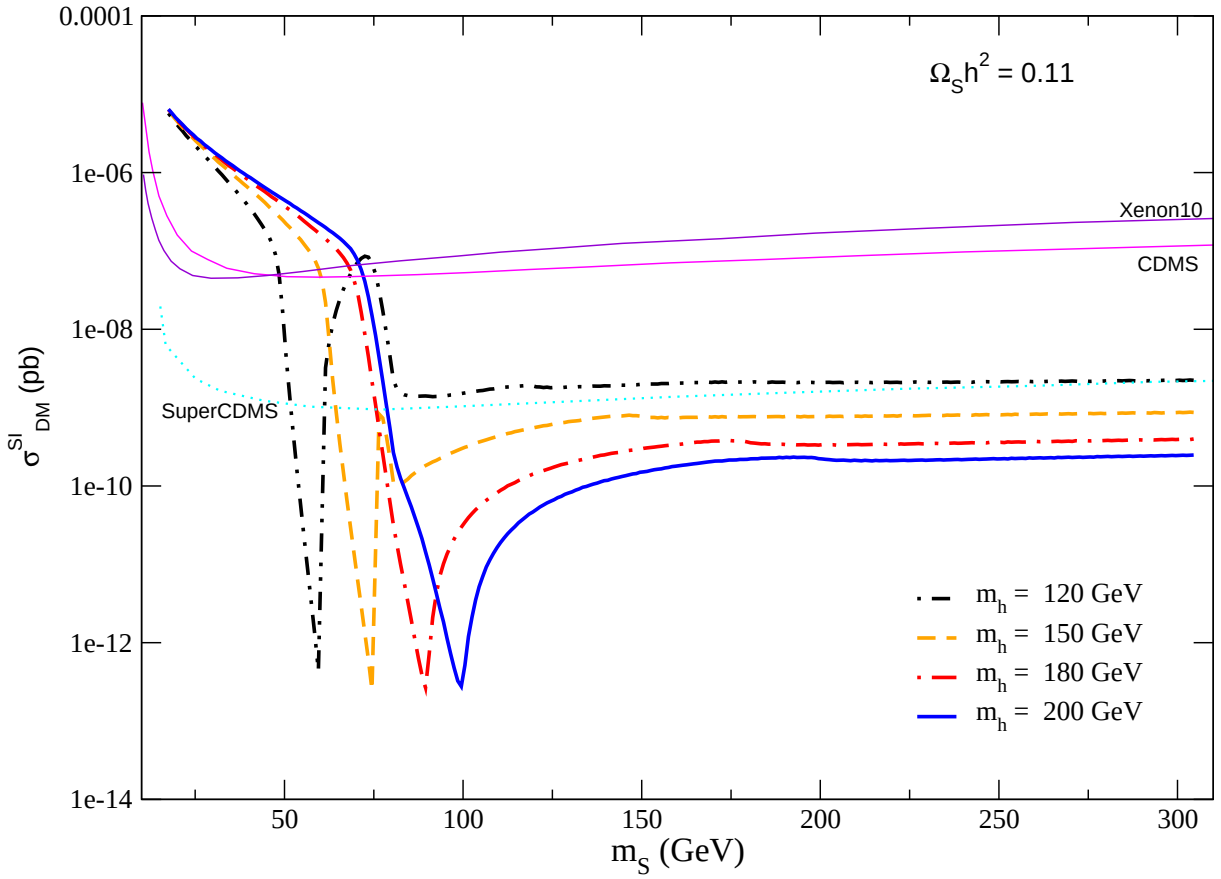
CDMS, Xenon

Direct detection constraints already require $m_S > 50$ GeV

Around the resonance σ_{SI} is suppressed

σ_{SI} decreases with the higgs mass

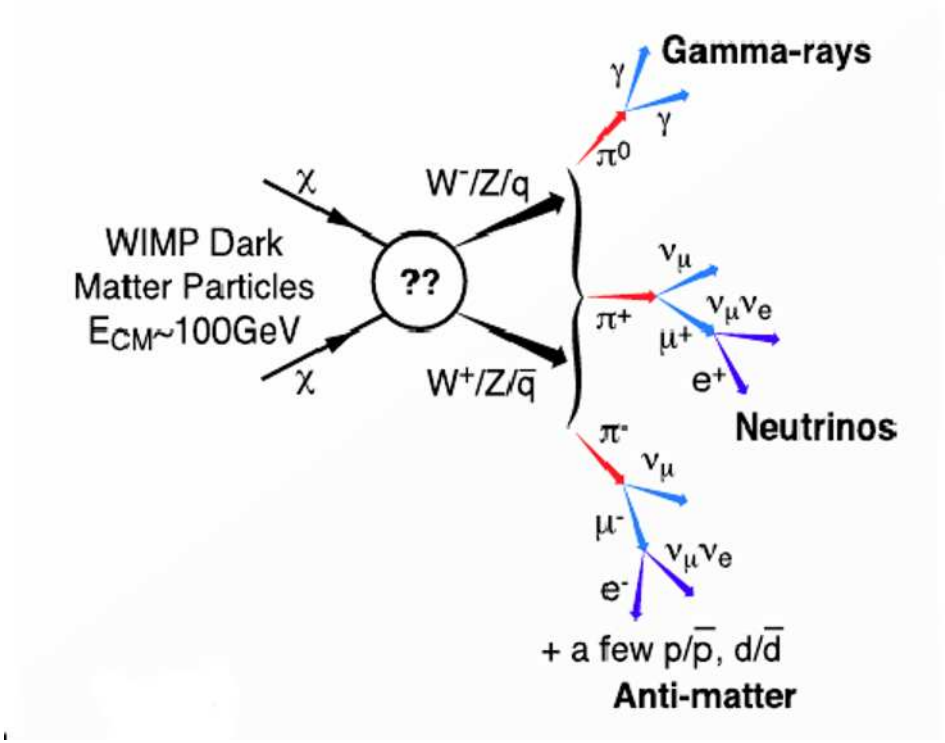
Current bounds rule out light singlets



Dark matter particles can also be indirectly detected through their annihilation products

DM particles annihilate into SM fields

ν's, e^+, $\bar{p}$, and γ's can be detected on earth



Several experiments are looking for such signals

Pamela, Fermi

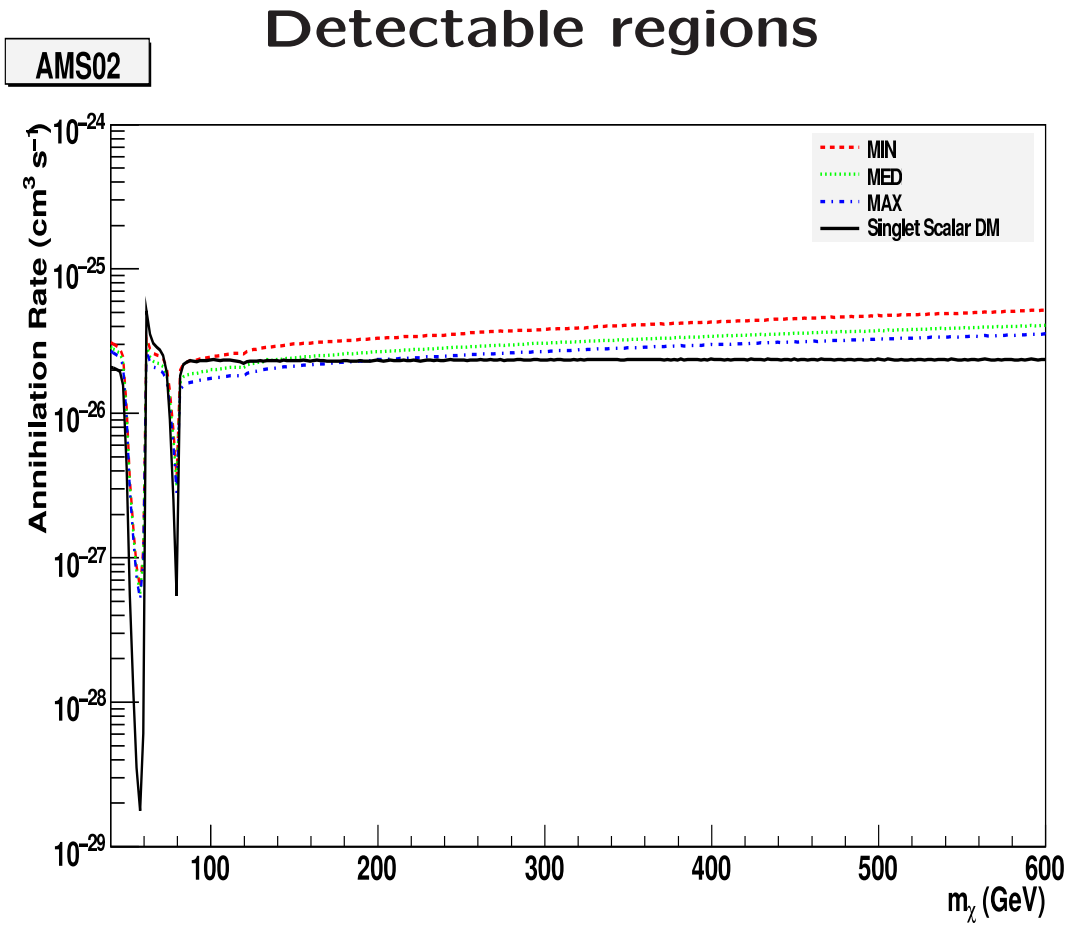
AMS-02

The positron signal is detectable at AMS-02 only for light singlets

Pamela and Fermi measured a large e^+ background

The detectable region depends on prop. model

$m_S \gtrsim 200$ GeV is beyond the reach of AMS-02

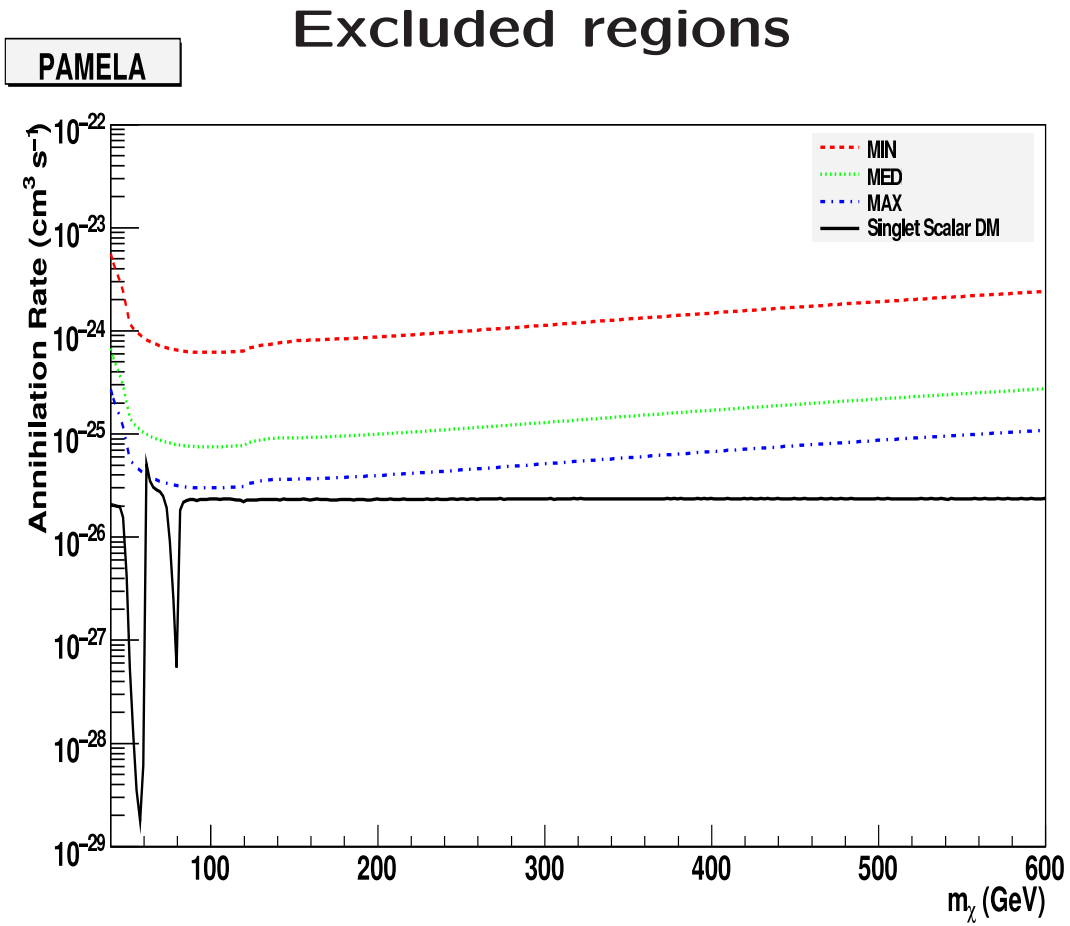


Antiproton data from PAMELA may soon start constraining the singlet model

The antiproton background is consistent with data

Propagation parameters affect the $\bar{p}$ flux

Future PAMELA data could constrain $m_S \lesssim 200$ GeV

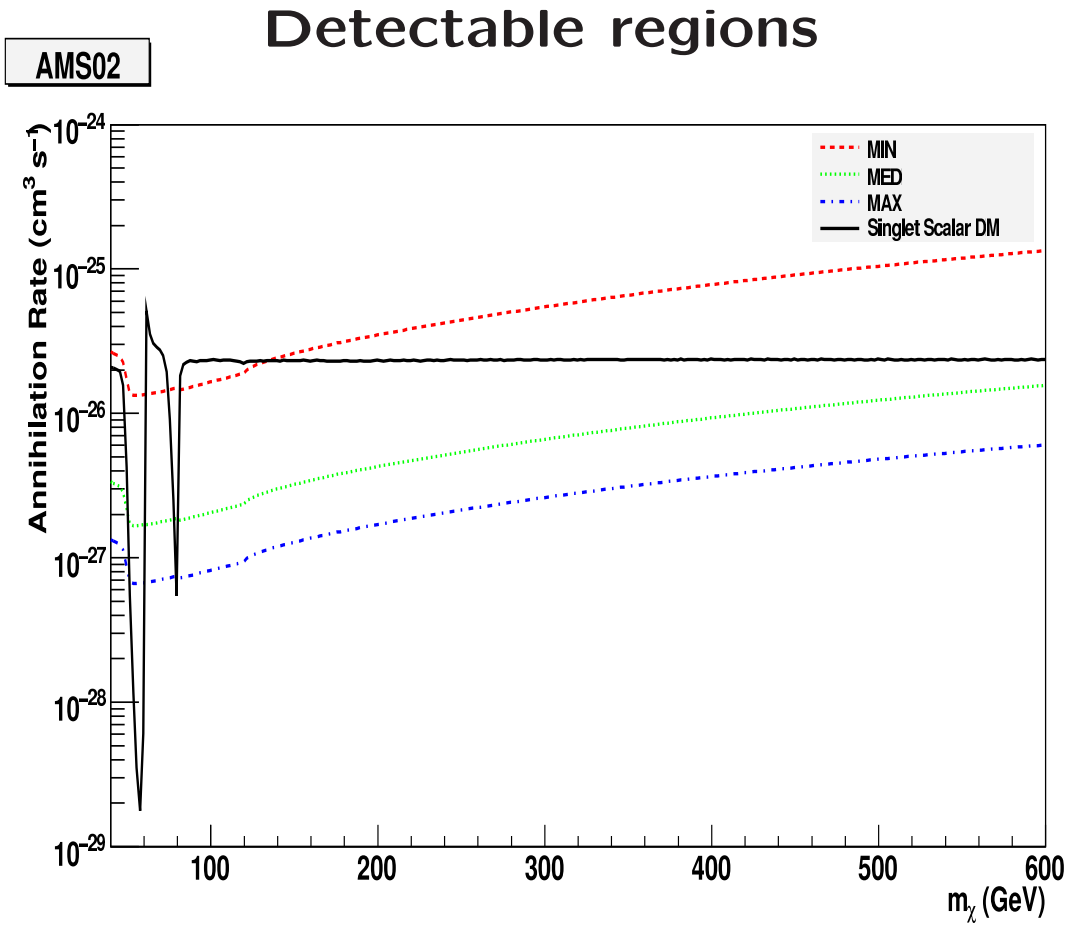


The antiproton signal seems to be a promising way to detect the singlet model at AMS-02

For the MIN model, light singlets can be detected

$m_S < 600$ GeV is detectable for MED and MAX

AMS-02 will probe the singlet model via $\bar{p}$



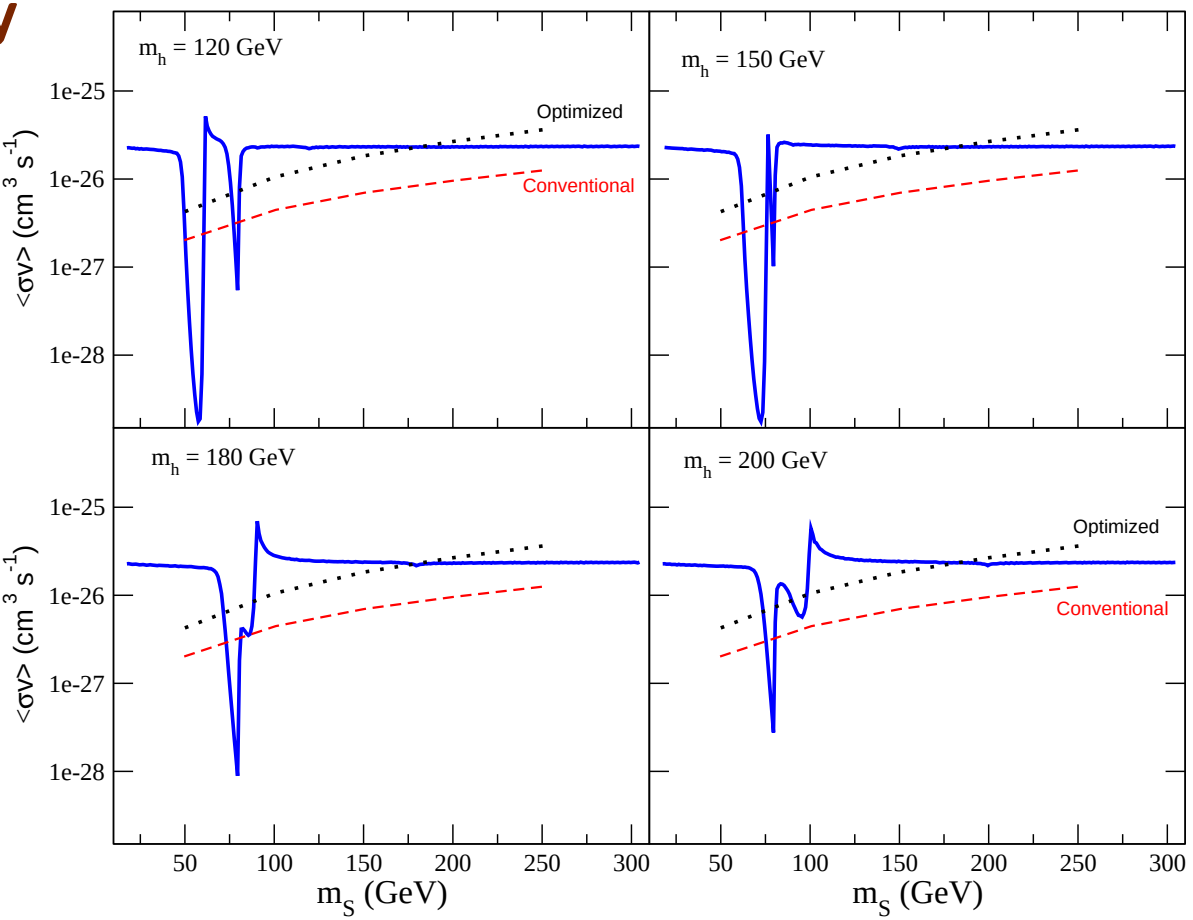
With 1-year of data, FERMI can probe a significant region of the parameter space

Constraints depend weakly on the halo profile

The conventional backg. is favored by Fermi

The γ-ray signal should be observed by Fermi

Detectable regions



A singlet scalar is an appealing and detectable dark matter candidate

The model is simple and very predictive

It can be tested via direct detection, $\bar{p}$'s, and γ's