On the stability of particle Dark Matter

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DM is astonishingly stable!

$$\tau_{DM} > \tau_U \sim 10^{18}\,\text{sec}$$

$$\tau_{DM} \gtrsim 10^{26}\,\text{sec}$$ ⇐ in most models not to produce $e^+,\ \bar{p},\ \gamma,\ \ldots$ fluxes larger than observed

in many models: stability assumed by hand

⇓

ad hoc global symmetry assumed, e.g. a Z_2

e.g. gravity is expected to violate any global symmetry but not gauge symmetries

How could DM be stable from first principles?

high energy stabilization mechanism

low energy stabilization mechanism

$\Downarrow$

so that DM stability origin could be determined experimentally

$\Downarrow$

as for all stable particles in the Standard Model!

γ

massless (due to exact $U(1)_{em}$ gauge symmetry)

e^-

lightest charged particle under exact $U(1)_{em}$ sym.

ν

lightest fermion (Lorentz sym.)

p^+

accidental B sym. due to gauge SM sym. and particle content

I. High energy stabilization mechanisms

MSSM neutralino DM

- χ is stable due to the assumed R-symmetry

$$R_m = -1 \qquad \psi_L,\, \psi_Q,\, \psi_{l_R},\, \psi_{u_R},\, \psi_{d_R}$$
$$R_m = +1 \qquad \psi_{H_u},\, \psi_{H_d}$$

⇓

the lightest susy particle is stable

$$R_{parity} = R_m \cdot (-1)^{2 \cdot spin}$$

- R-symmetry to prevent proton decay
  - but for proton decay B conservation is enough

⇓

χ not a good DM candidate anymore: decays fastly

⇒ could we make R-parity less ad hoc???

R-symmetry from a gauge symmetry: $U(1)_{B-L}$

Mohapatra 86', Martin 92'

$R_m = (-1)^{3(B-L)}$ ⇒ R-symmetry is a Z_2 subgroup of $U(1)_{B-L}$

⇓

a subgroup of $SO(10)$

⇒ if $U(1)_{B-L}$ (or $SO(10)$) is a gauge symmetry and is broken only by vev of fields with even B-L: R-symmetry remains as an exact symmetry!

→ $10,\ 45,\ 54,\ 120,\ 126,\ 210,\ \ldots$

→ conserved by UV physics too

→ high energy explanation of R-symmetry ⇐ not experimentally testable (directly)

Aulakh, Melfo, Rasin, Senjanovic 98'
Aulakh, Bajc, Melfo, Rasin, Senjanovic 01'

DM stability in non-susy SO(10) setups

non-susy $U(1)_{B-L}$ (or $SO(10)$) gauge theories broken by only even B-L field vev also leaves a Z_2 symmetry

SM fermions are in the 16 of $SO(10)$ which is B-L odd

SM Higgs doublet is in the 10 of $SO(10)$ which is B-L even

the lightest component of an extra B-L odd scalar $SO(10)$ representation is stable

$16,\ 144,\ \ldots$

Kadastik, Kannike, Raidal 09'

the lightest component of an extra B-L even fermion $SO(10)$ representation is stable

$10,\ 45,\ 54,\ 120,\ 126,\ 210,\ \ldots$

Frigerio, TH 09'

DM stability in non-susy SO(10) setups: scalar case

Kadastik, Kannike, Raidal 09'

add a16 scalar representation:

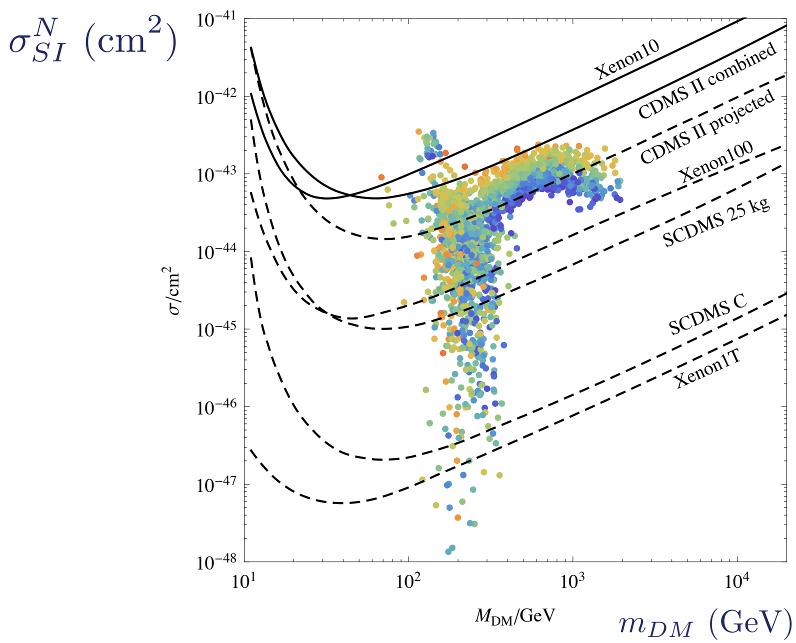
DM is a combination of a scalar doublet and a scalar singlet

inert doublet

similar phenomenology with additional constraint: $m_{DM} \gtrsim 100\,\mathrm{GeV}$

not for DAMA, CoGeNT

direct detection:



Huitu, Kannike, Raccioppi, Raidal 10'

+ long lived DM partners at LHC

DM stability in non-susy SO(10) setups: fermion case

Frigerio, TH 09'

add a 45 or 54 fermion representation:

DM is the neutral component of a fermion triplet $\Sigma^+, \Sigma^0, \Sigma^-$

$\Downarrow$

advantage that the DM triplet can drive gauge coupling unification

$\Downarrow$

as in split susy but without susy

low energy pheno is as for a generic fermion triplet:

- relic density requires $m_{DM} \simeq 2.7\,\mathrm{TeV}$ Cirelli, Fornengo, Strumia 06'
- $\sigma_{SI}^N \sim 10^{-45}\,\mathrm{cm}^2$
- indirect detection:
  - too many antiprotons for explaining e^+ excess of Pamela
  - $DM\,DM \to \gamma\gamma$ expected to give γ-lines with a rate than can be probed at atmospheric Cerenkov telescopes

Hisano et al 04'; Cirelli, Franceschini, Strumia 08'

II. Low energy stabilization mechanisms:

what are the chances we have to understand experimentally why DM is stable?

DM stability from unbroken U(1) gauge group

as for the e^-: stable because lightest charged particle under a U(1)

the simple adjunction of a new QED structure
for a single fermion gives a viable DM candidate!!

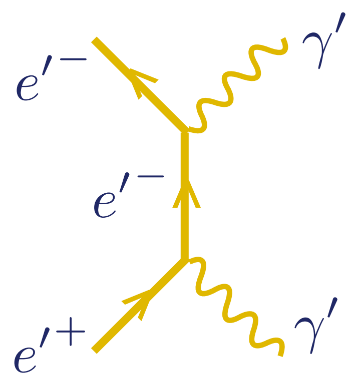
Ackerman, Buckley, Carroll, Kamionkowski 08'
Feng, Tu, Yu 08'; Feng, Kaplinghat, Tu, Yu 09'
Foot at al. 06'-10'

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{QED'}$$

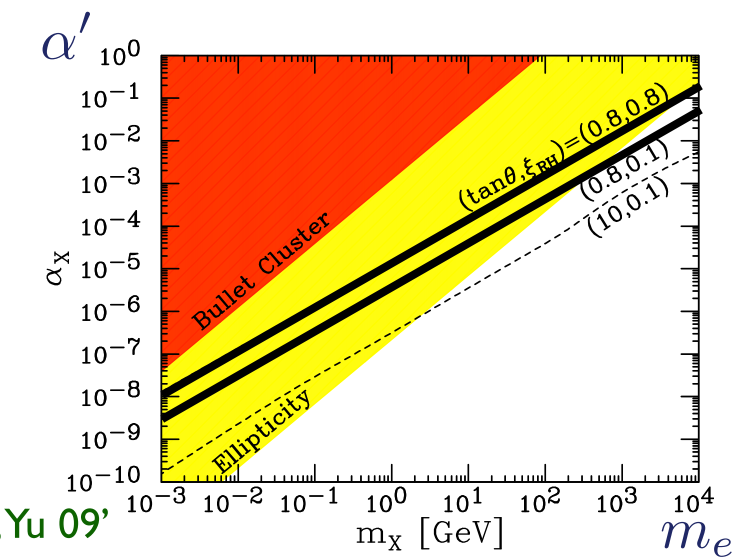
$$\mathcal{L}_{QED'} = \overline{\psi}_{e'}(i\partial\!\!\!/ - e A\!\!\!/_{\gamma'} - m_{e'})\psi_{e'}$$

γ' $\qquad$ $e'^{\pm}$ $\Rightarrow$ stable

$\Rightarrow$ $e'^{\pm}$ relic density



depends on $m_{e'}$, α', $\xi \equiv T_{\gamma'}/T_\gamma$



Feng, Kaplinghat, Tu, Yu 09'

Connecting the unbroken U(1) gauge group with the SM

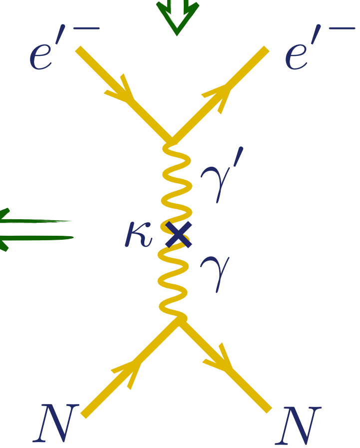
Frigerio, TH 09'

only one possibility: $\mathcal{L} \ni -\frac{1}{4}\kappa F^{Y}_{\mu\nu} F^{\mu\nu}_{QED'}$ ← kinetic mixing

$\kappa \lesssim 10^{-8}$ ← positronium

too small for any collider test

but large enough for direct detection



$\propto \frac{1}{E_r^2}$

Mirror models explanation of DAMA-CoGEnT data

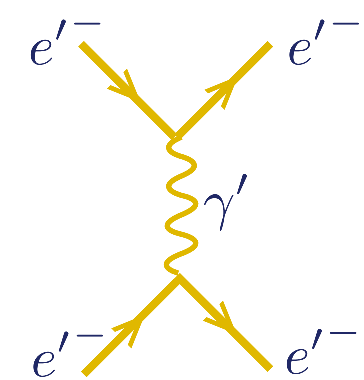
Foot at al. 06'-10'

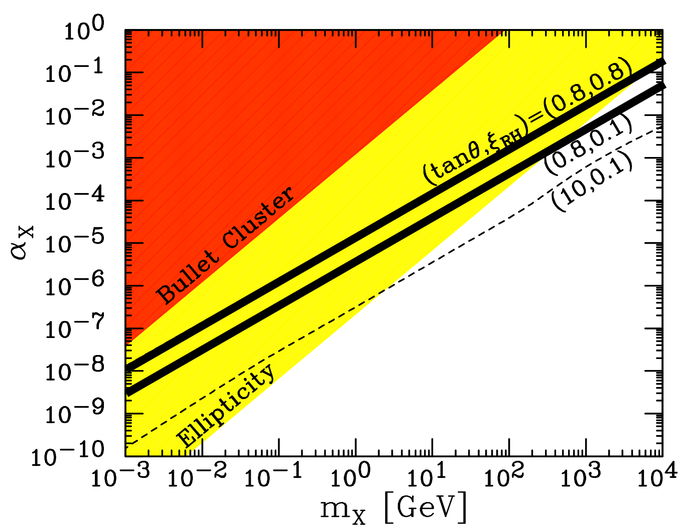
without Xenon limit problems: $E_r^{Xenon} > E_r^{DAMA-CoGeNT}$

Cosmological constraints on a new long range force

long range γ' exchange has many implications:

- damping of small scale structure due to lower kinetic decoupling
- galactic halo morphology modified by DM collisions through Rutherford scattering
- more collision in bullet cluster through Rutherford scattering
- ...





$\Longrightarrow m_{DM} \gtrsim (1 - 1000)\,\mathrm{GeV}$

depending on $\xi = T_{\gamma'}/T_\gamma$

Fermion charged under a broken U(1)

assume:
- a new U(1) gauge interaction → a massive Z'
- a charged scalar ϕ breaking it → a Higgs boson
- a charged fermion ψ (vector) → a massive fermion ψ
- all SM fermions are neutral under U(1)

$\Downarrow$

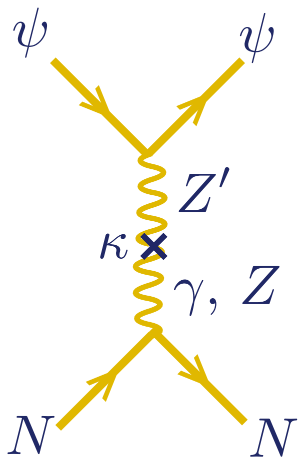
stable because lightest fermion of a secluded sector

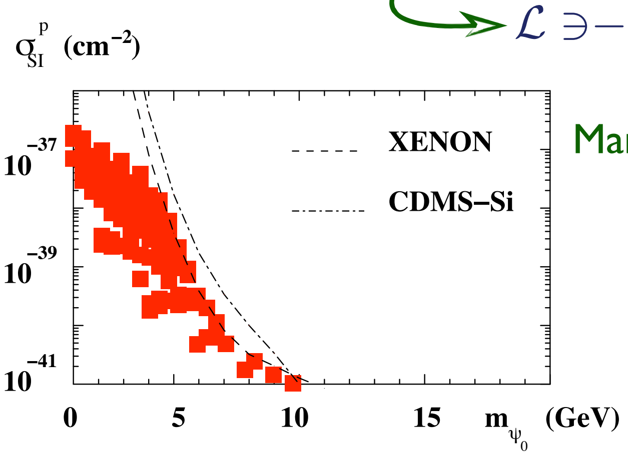
Pospelov, Ritz, Voloshin 07'
Gopalakrishna, Jung, Wells 08'
Gopalakrishna, Lee, Wells 08'

communication with SM through Higgs portal and kinetic mixing

$\mathcal{L} \ni -\lambda\, \phi^\dagger \phi\, H^\dagger H$

$\mathcal{L} \ni -\frac{1}{4}\, \kappa\, F^{Y}_{\mu\nu}\, F^{\mu\nu}_{QED'}$





Mambrini 10'

$\kappa \lesssim 10^{-(2-3)}$

can account for DAMA-CoGeNT
if $m_{DM} \sim m_{Z'}/2$ (resonance)

DM stability from accidental symmetry: Minimal Dark Matter

Cirelli, Fornengo, Strumia 06'
Cirelli, Strumia, Tamburini 07'

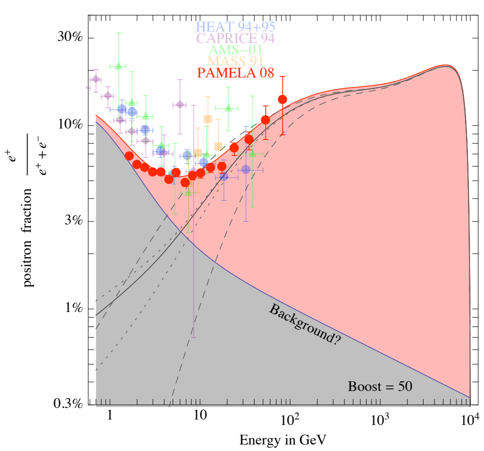
- as the p^+ in the SM
- without adding any new gauge group, large $SU(2)_L$ multiplet cannot have any renormalizable interactions with SM fields due to $SU(2)_L$ gauge invariance
  (or dimension-5)

a fermion quintuplet, septuplet, ...

a scalar septuplet, nonuplet, ...

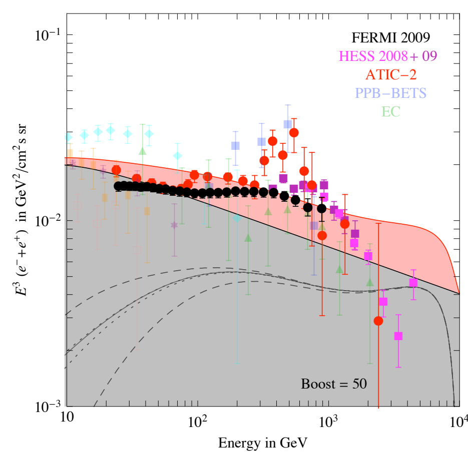
$$m_{DM} = (9.6 \pm 0.2)\,\mathrm{TeV}$$
$$\sigma_N^{SI} = 1.2 \cdot 10^{-44}\,\mathrm{cm}^2$$

nice fit of Pamela e^+ excess



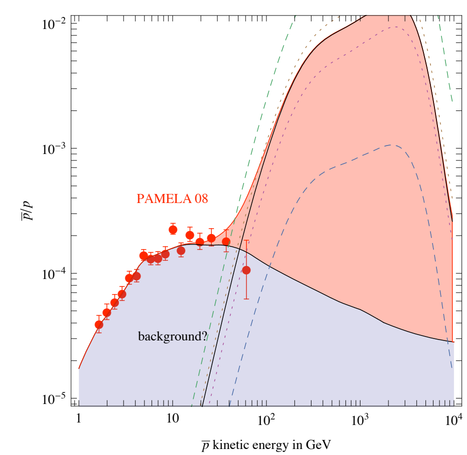
(large Sommerfeld resonance boost + need of ~ 50 astro boost)

$e^+ + e^-$ total flux



(m_{DM} too high for HESS cutoff)

$\bar{p}$ flux



(m_{DM} high enough to avoid low energy excess)

prefers an isothermal profile for compatibility with galactic center and dwarf galaxy γ flux

DM stability from accidental symmetry: Hidden vector DM

- spin-1 gauge boson DM
- accidental non-abelian global symmetry
- the stability can be “understood” only from the low-energy point of view as for the proton in the SM
- accidental symmetry $\Rightarrow$ slow DM decay with specific pheno

  ↪ intense γ-ray line

Custodial symmetry $\Rightarrow$ DM stability

T.H. 08'

simplest example: a gauged SU(2) + a scalar doublet ϕ

$$\mathcal{L} = -\frac{1}{4} F^{\mu\nu a} F^a_{\mu\nu} + (D^\mu \phi)^\dagger (D_\mu \phi) - \mu_\phi^2 \phi^\dagger \phi - \lambda_\phi (\phi^\dagger \phi)^2$$

$\Downarrow$

ϕ gets a vev v_ϕ

$$\phi = \begin{pmatrix} \phi^+ \\ (\eta + i a_0 + v_\phi)/\sqrt{2} \end{pmatrix}$$

$\Rightarrow$ spectrum: - 3 degenerate massive gauge bosons V_i: $m_V = \dfrac{g_\phi v_\phi}{2}$

- one real scalar η: $m_\eta = \sqrt{2\lambda_\phi}\, v_\phi$

This lagrangian has a custodial symmetry $SU(2)_C$ or equivalently a $SO(3)_C$: $(V_1^\mu, V_2^\mu, V_3^\mu) =$ triplet and $\eta =$ singlet

$\Rightarrow$ the 3 V_i are stable! $\leftarrow$ $V_i \to \eta\eta, \ldots$ forbidden

Communication through the Higgs portal

$$\mathcal{L} = \mathcal{L}_{SM} + \mathcal{L}_{Hidden\,Sector} + \mathcal{L}_{Higgs\,portal}$$

$SU(2)_{HS}$

$$\mathcal{L}_{Hidden\,Sector} = -\frac{1}{4}F^{\mu\nu a}F^{a}_{\mu\nu} + (D^{\mu}\phi)^{\dagger}(D_{\mu}\phi) - \mu^{2}_{\phi}\phi^{\dagger}\phi - \lambda_{\phi}(\phi^{\dagger}\phi)^{2}$$

$$\mathcal{L}_{Higgs\,portal} = -\lambda_m \phi^{\dagger}\phi H^{\dagger}H$$

$$\ni -\lambda_m v_{\phi}\, v\, h\, \eta$$ → $h - \eta$ mixing

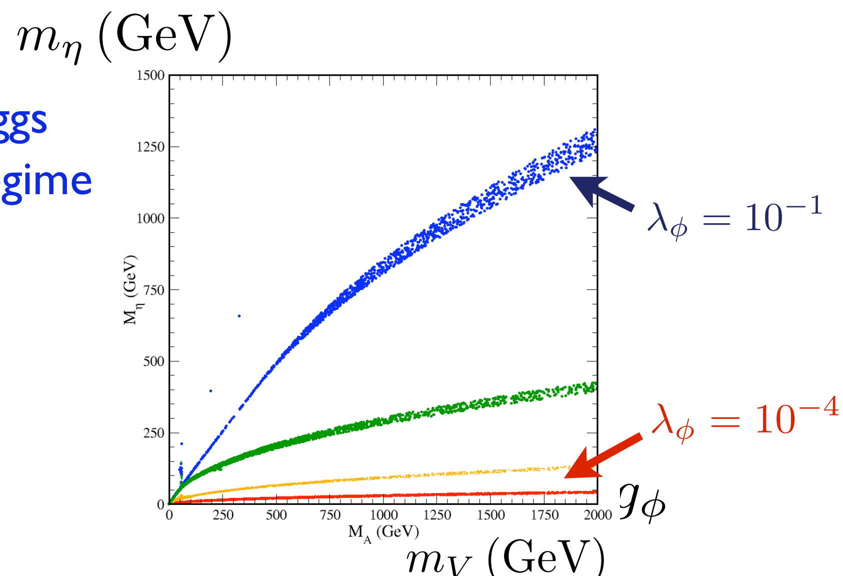
⇓

doesn't spoil the stability of the V_i^{μ}

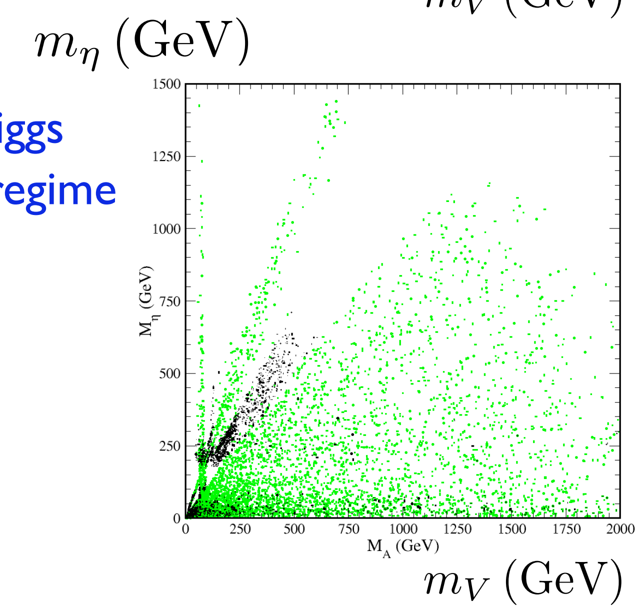
Hidden vector: relic density

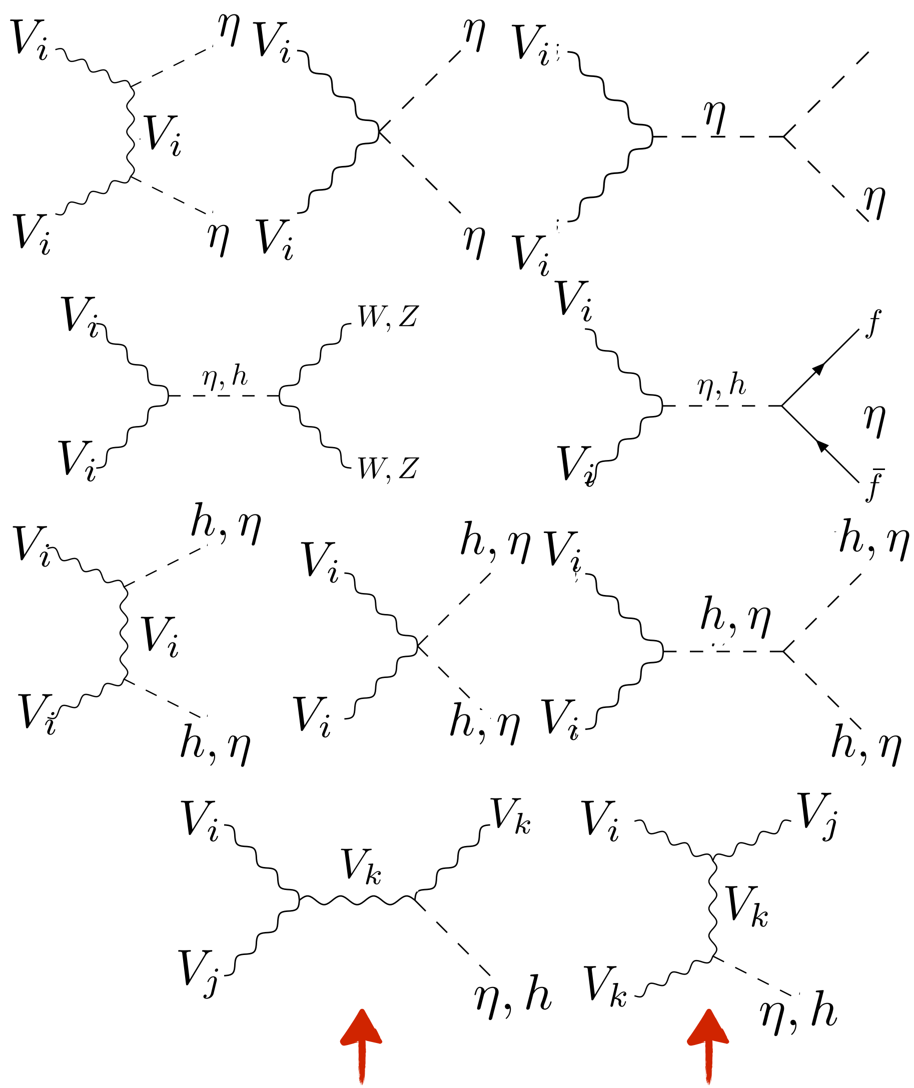
relic density from thermal freezeout

small Higgs portal regime



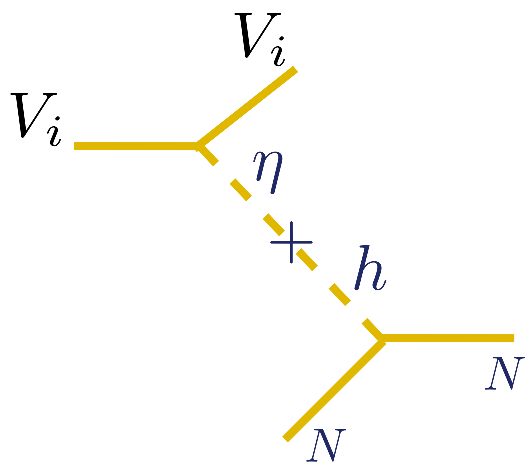
large Higgs portal regime

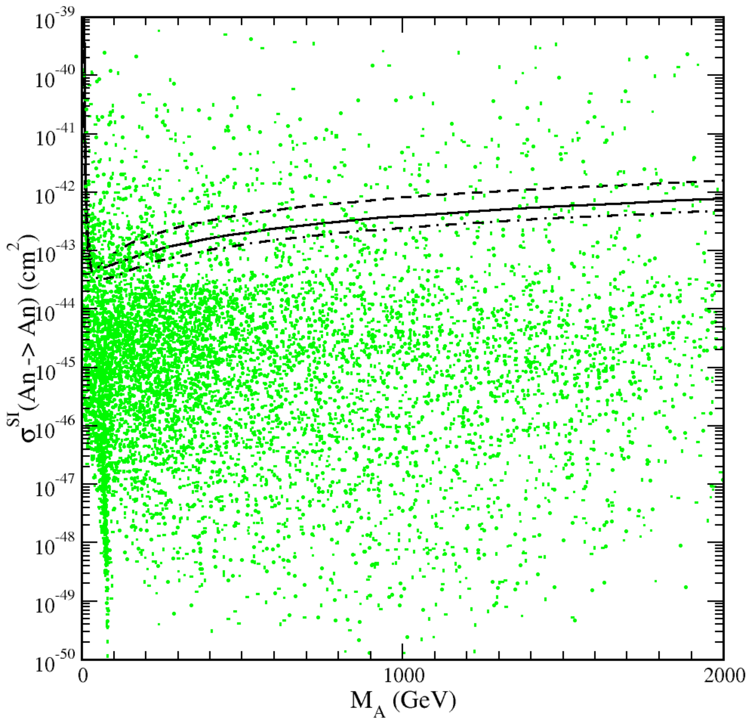




$$1\,\mathrm{MeV} < M_{DM} < 10\,\mathrm{TeV}$$

Hidden vector: direct detection





Monochromatic γ-ray lines: a smoking gun for DM

$DM\,DM \to \gamma\gamma\,,\,\gamma Z$ annihilation leads to a monochromatic γ-ray line

(not expected in astrophysics background)

e.g. obtained at one loop level $\Rightarrow$ rather suppressed

$\Downarrow$

e.g. needs for large boost factor or a TeV DM mass

Bergstrom, Ullio, 97' 98';Bern, Gondolo, Perelstein 97';
Bergstrom, Bringmann, Eriksson, Gustafsson 04', 05';
Boudjema, Semenov, Temes 05';
Jackson, Servant, Shaughnessy, Tait, Taoso 09', ...
one tree level exception: Dudas, Mambrini, Pokorski, Romagnoni 09'

But what about a γ-ray line from DM decay?????

has been considered from gravitino decay through R-parity violation

Buchmuller, Covi, Hamagushi, Ibarra, Tran 07';
Ibarra, Tran 07'; Ishiwata, Matsumoto, Moroi 08';
Buchmuller, Ibarra, Shindou, Takayama, Tran 09';
Choi, Lopez-Fogliani, Munoz, de Austri 09'

A scenario for large γ-ray lines through DM decays

C. Arina, T.H., A. Ibarra, C. Weniger 09'

If DM stability results from an accidental symmetry (as proton in SM)

$\Downarrow$

we expect higher dimensional operators destabilizing the DM to be generated by higher scale physics

a dim-5 operator leads to $\tau_{DM} << \tau_{Universe}$

$\Uparrow$

even if $\Lambda \sim M_{Planck}$

but a dim-6 operator leads to a γ-ray flux of order the experimental sensitivity if $\Lambda \sim M_{GUT}$

in particular off the galactic plane!

as for other cosmic rays:

Eichler; Nardi, Sannino, Strumia; Chen, Takahashi, Yanagida; Arvanitaki, Dimopoulos et al.; Bae, Kyae; Hamagushi, Shirai, Yanagida; ...

$\Longrightarrow$ DM model based on accidental symmetry decaying to γ from dim-6 operator

Dimension-6 operators breaking the custodial symmetry

C. Arina, T.H., A. Ibarra, C. Weniger 09'

(A) $\frac{1}{\Lambda^2}\mathcal{D}_\mu\phi^\dagger\phi\,\mathcal{D}_\mu H^\dagger H$

(B) $\frac{1}{\Lambda^2}\mathcal{D}_\mu\phi^\dagger\phi\,H^\dagger\mathcal{D}_\mu H$

(C) $\frac{1}{\Lambda^2}\mathcal{D}_\mu\phi^\dagger\mathcal{D}_\nu\phi\,F^{\mu\nu Y}$

(D) $\frac{1}{\Lambda^2}\phi^\dagger F^a_{\mu\nu}\frac{\tau^a}{2}\phi F^{\mu\nu Y}$

all give 2-body decay to γh or $\gamma\eta$

examples of branching ratios:

Benchmark	M_A	g_ϕ	v_ϕ	M_η	M_h	$\sin\beta$
1	300 GeV	0.55	1090 GeV	30 GeV	150 GeV	≈ 0
2	600 GeV	0.6	2000 GeV	30 GeV	120 GeV	≈ 0
3	14 TeV	12	2333 GeV	500 GeV	145 GeV	≈ 0
4	1550 GeV	2.1	1457 GeV	1245 GeV	153 GeV	0.25

operator A & B

Benchmark	$\eta\eta$	$h\eta$	hh	$\gamma\eta$	$Z\eta$	γh	Zh
1	-	0.09	-	0.04	0.02	0.65	0.20
2	-	0.04	0.62	0.002	0.003	0.15	0.18
3	-	0.04	0.80	3×10^{-6}	0.002	0.0003	0.16

operator C

Benchmark	$Z\eta$	$\gamma\eta$	Zh	γh
1	0.19	0.81	0	0
2	0.22	0.78	0	0
3	0.23	0.77	0	0
4	0.028	0.79	0.041	0.14

operator D

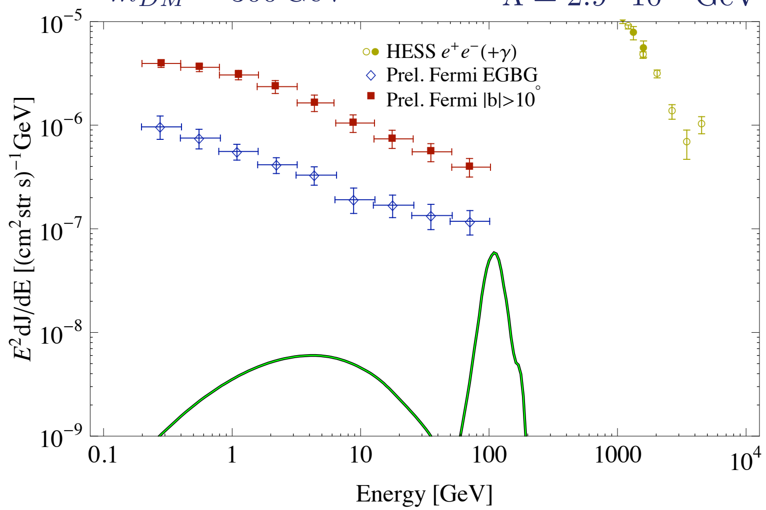
Benchmark	$Z\eta$	Zh	$\gamma\eta$	W^+W^-	$\nu\bar{\nu}$	e^+e^-	$u\bar{u}$	$d\bar{d}$
1	0.01	0.005	0.04	0.02	0.09	0.39	0.29	0.15
2	0.019	0.004	0.036	0.014	0.072	0.35	0.39	0.12
3	0.22	0.0002	0.73	0.0005	0.003	0.016	0.018	0.005

Flux of monochromatic γ-rays

$$0 \leq l \leq 360^\circ,\ 10^\circ \leq |b| \leq 90^\circ$$

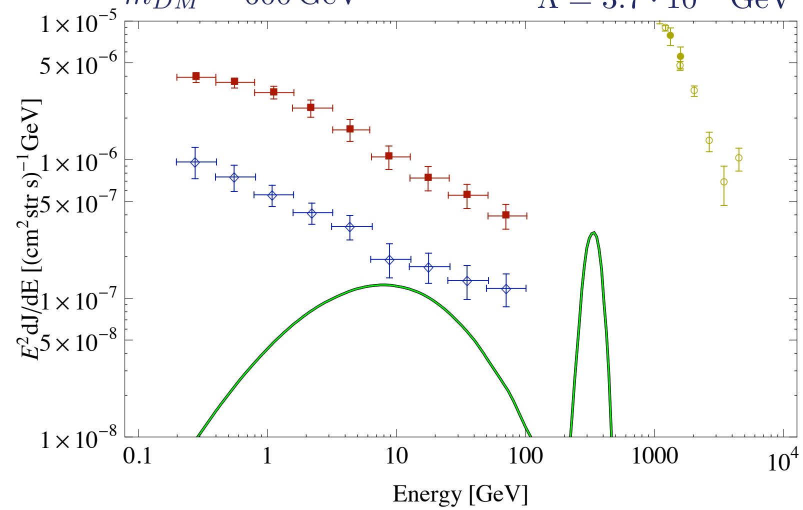
operator A & B

$m_{DM} = 300\,\text{GeV}$ $\Lambda = 2.9 \cdot 10^{15}\,\text{GeV}$



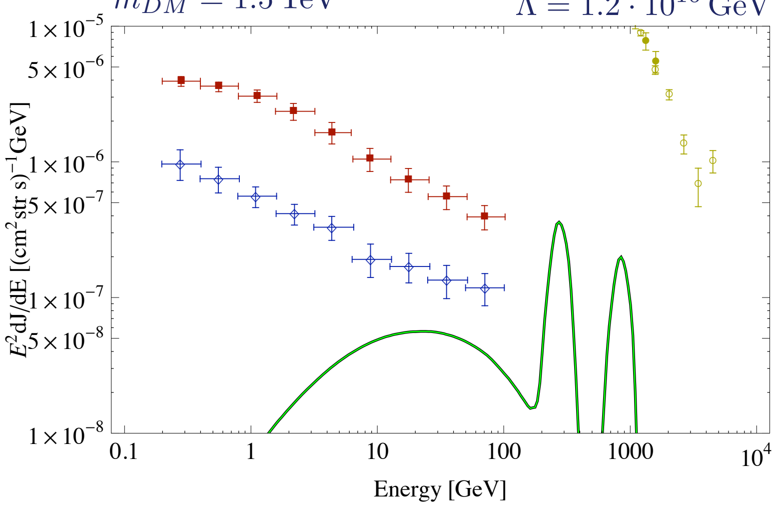
operator A & B

$m_{DM} = 600\,\text{GeV}$ $\Lambda = 3.7 \cdot 10^{15}\,\text{GeV}$ $\leftarrow \tau_{DM} = 1.6 \cdot 10^{27}\,\text{sec}$



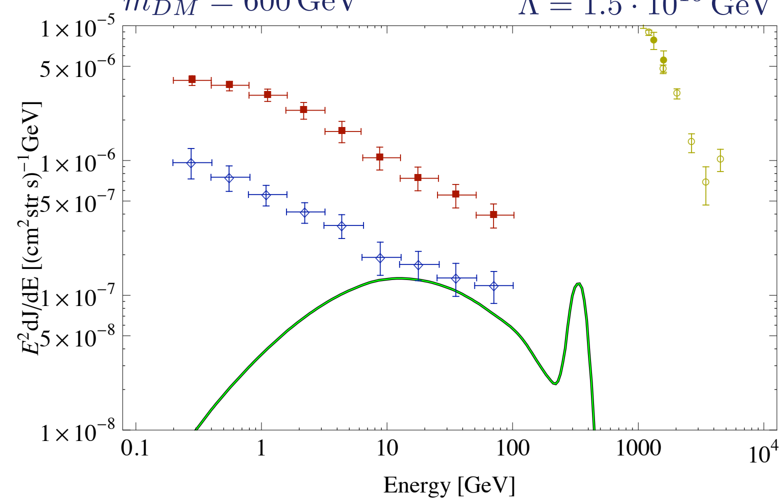
operator C

$m_{DM} = 1.5\,\text{TeV}$ $\Lambda = 1.2 \cdot 10^{16}\,\text{GeV}$



operator D

$m_{DM} = 600\,\text{GeV}$ $\Lambda = 1.5 \cdot 10^{16}\,\text{GeV}$



C. Arina, T.H., A. Ibarra, C. Weniger 09’

DM stability from accidental symmetry: Weakly interacting stable pions

Bai, Hill 10'

- QCD interactions conserve G-parity: $\underset{+}{\rho} \to \underset{-\,-}{\pi\pi}$ but $\rho \not\to \pi\pi\pi$
- pions would be stable if there were only QCD
- but G-parity is not conserved by
  - weak interactions ($V-A$ structure)
  - hypercharge interactions

⇒ assume a new QCD structure with new quarks ψ with
- no hypercharge
- vector weak interact.

⇓

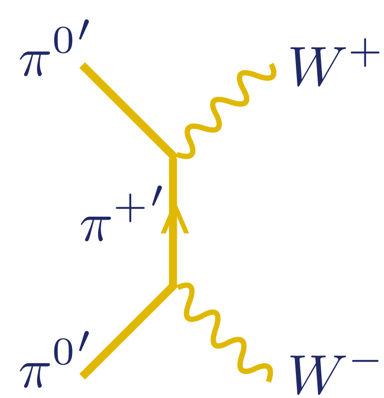
$\psi_L =$ doublet
$\psi_R =$ doublet

⇓

G-parity is exactly conserved

⇓

the $\pi^{0\prime}$ is stable and is a WIMP



$m_{DM} = 100\,\mathrm{GeV} - 2\,\mathrm{TeV}$

$\sigma_N^{SI} \sim 10^{-45}\,\mathrm{cm}^2$

but dim-5 operators breaking G-parity are allowed ⇒ DM decay would be too fast

Other naturally stable DM candidates

- DM stability from small couplings (suppressed by heavy scale) and/or small DM mass:

    - axion — P. Sikivie's talk
    - KeV right-handed neutrino — F. Bezrukov's talk
    - gravitino
    - ...

- KK parity in Universal Extra Dimension models (assuming orbifold,...) — Servant, Tait 06', ...

- $U(1)_{B'}$ in technicolor models — Gudnason, Kouvaris, Sannino 06'

- DM stability from a flavour symmetry — Hirsch, Morisi, Peinado, Valle 10'

- .....

Very brief summary

The origin of particle DM stability is a fundamental question!

Each UV or low energy scenario requires a very specific pattern in term of type of particle needed, energy scale, ..., and leads to definite phenomenology in term of DM mass, direct detection, astrophysics, cosmic ray fluxes from DM decay, ...

Backup

Relic density

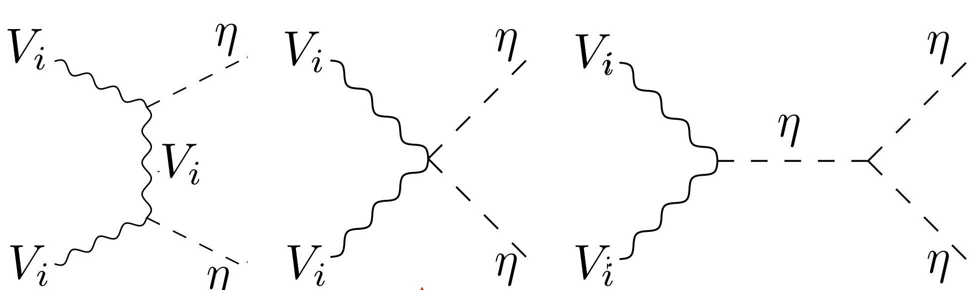
- $T \gtrsim m_V$: $V^{\mu}_{1,2,3}$ in thermal equilibrium with SM thermal bath

  η with h :due to λ_m coupling
  V_i with η :due to g_ϕ coupling

- $T < m_V$: $n_V^{eq.} \sim e^{-m_V/T}$ $\Rightarrow$ annihilation freeze out (WIMP)

to two real η:

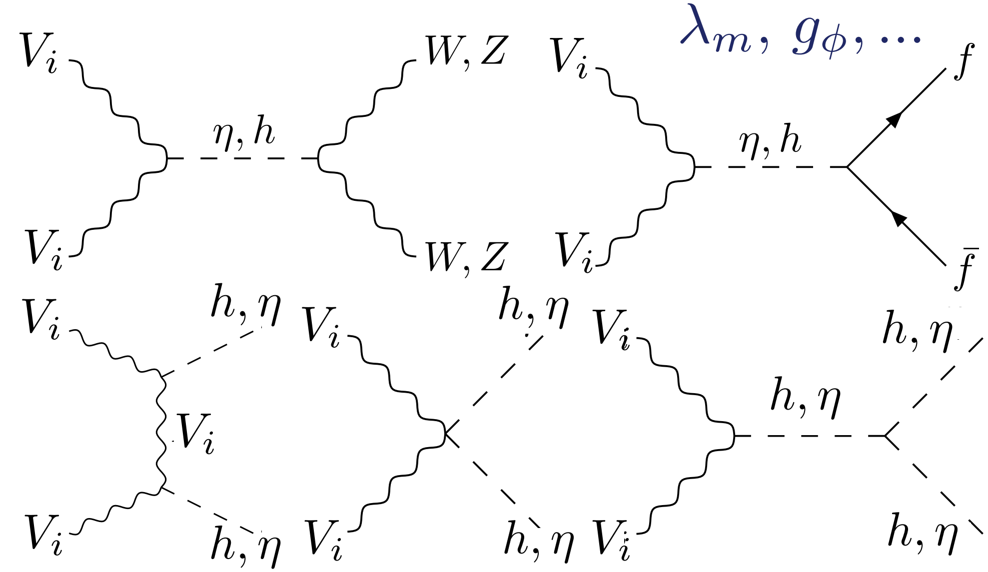
$g_\phi\ (+\lambda_\phi)$



with subsequent decay of η to SM particles via $h - \eta$ mixing

with at least one SM part. in final state:

$\lambda_m,\ g_\phi, \ldots$



Relic density: additional new type of contribution

non abelian trilinear gauge couplings:

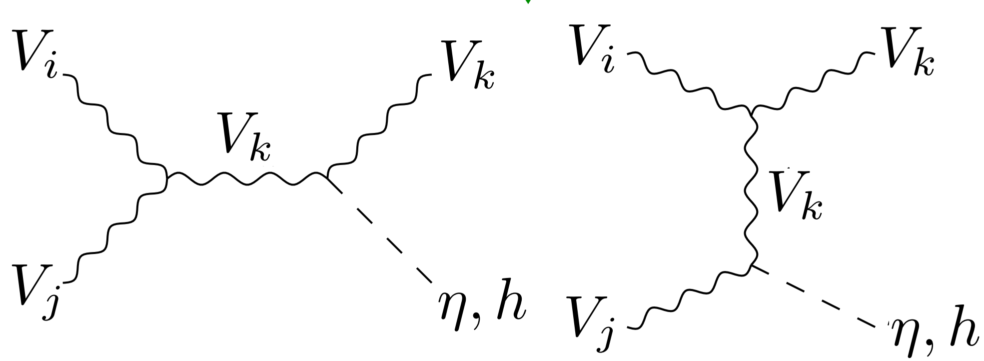
$$F^a_{\mu\nu}F^{\mu\nu a} \ni \varepsilon_{ijk}\partial_\mu A_{i\nu}(A^\mu_j A^\nu_k - A^\nu_j A^\mu_k)$$

do not lead to any V_i decay even if trilinear (carries 3 $\neq$ indices)

but induces two DM to one DM particle annihilation

$\Downarrow$

$\neq$ from the Z_2 case



$\Rightarrow$ no dramatic effect for the freeze out (same order as other diagrams)

Small Higgs portal regime

$\lambda_m \lesssim 10^{-3}$ ← (but larger than $\sim 10^{-7}$ to have thermalization with the SM bath)

$V_i V_i \to \eta\eta\,, V_i V_j \to V_k \eta$ dominant

depend only on $g_\phi\,, v_\phi, \lambda_\phi$ with $m_V = \frac{g_\phi v_\phi}{2}$, $m_\eta \simeq \sqrt{2\lambda_\phi}\, v_\phi$

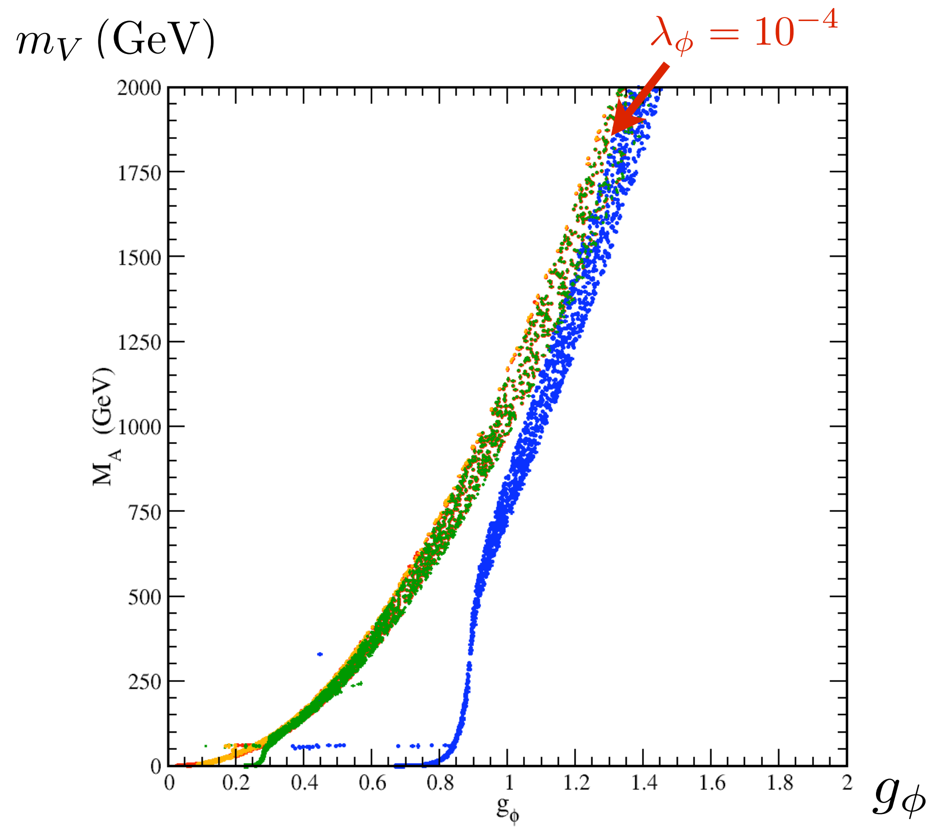
⇒ if λ_ϕ also small:

$$\sigma_{annih.} \sim \frac{g_\phi^4}{m_V^2} \sim \frac{g_\phi^2}{v_\phi^2}$$

⇓

$$m_V \propto g_\phi^2 \quad (\propto v_\phi^2)$$

⇒ $1\,\mathrm{MeV} \lesssim m_{DM} \lesssim 25\,\mathrm{TeV}$



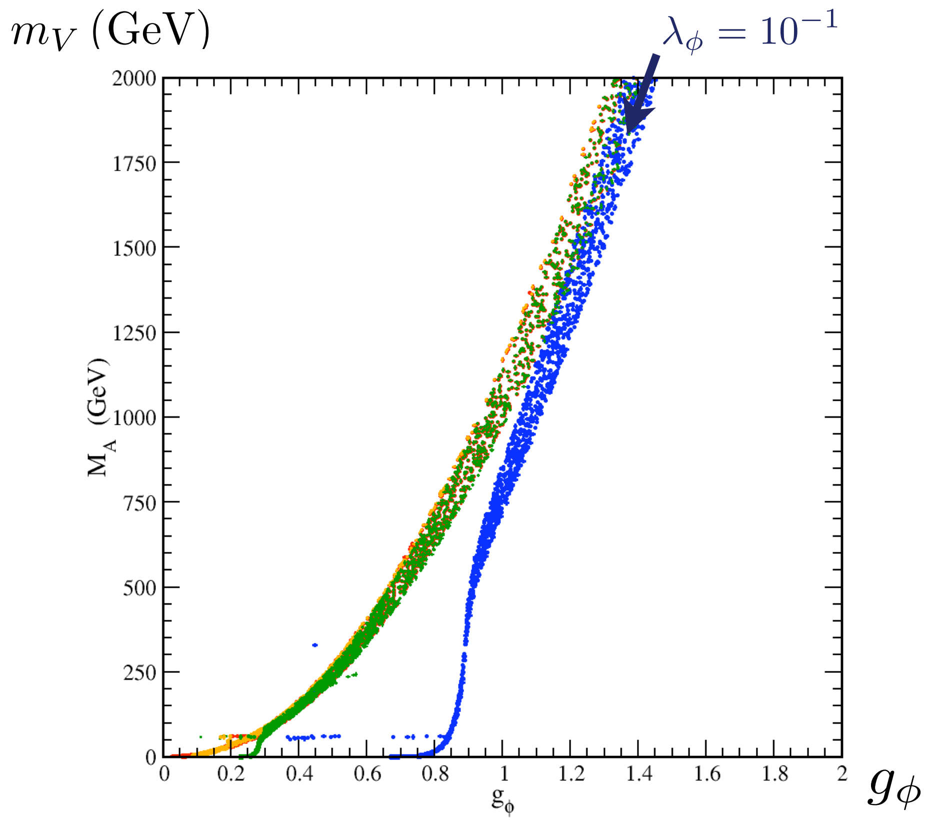
Small Higgs portal regime

$\lambda_m \lesssim 10^{-3}$ (but larger than $\sim 10^{-7}$ to have thermalization with the SM bath)

$V_i V_i \to \eta\eta \,, V_i V_j \to V_k \eta$ dominant

depend only on $g_\phi \,, v_\phi, \lambda_\phi$ with $m_V = \dfrac{g_\phi v_\phi}{2}$, $m_\eta \simeq \sqrt{2\lambda_\phi}\, v_\phi$

$\Rightarrow$ if λ_ϕ large:



Large Higgs portal regime

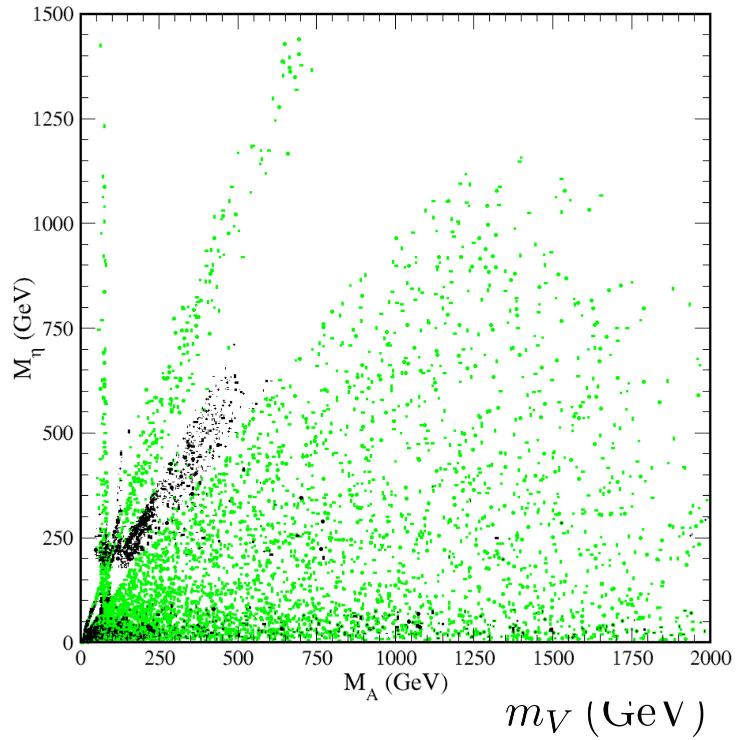
$\lambda_m \gtrsim 10^{-3}$ ⇒ large $\eta - h$ mixing ⇒ large hidden sector - SM mixing

can lead to the right Ω_{DM} even for maximal mixing

⇓

production at LHC of η just as for the Higgs in the SM but with possibly a larger mass

⇓



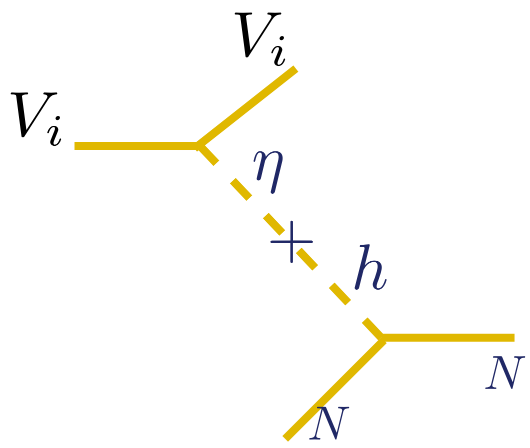
T parameter constraint:

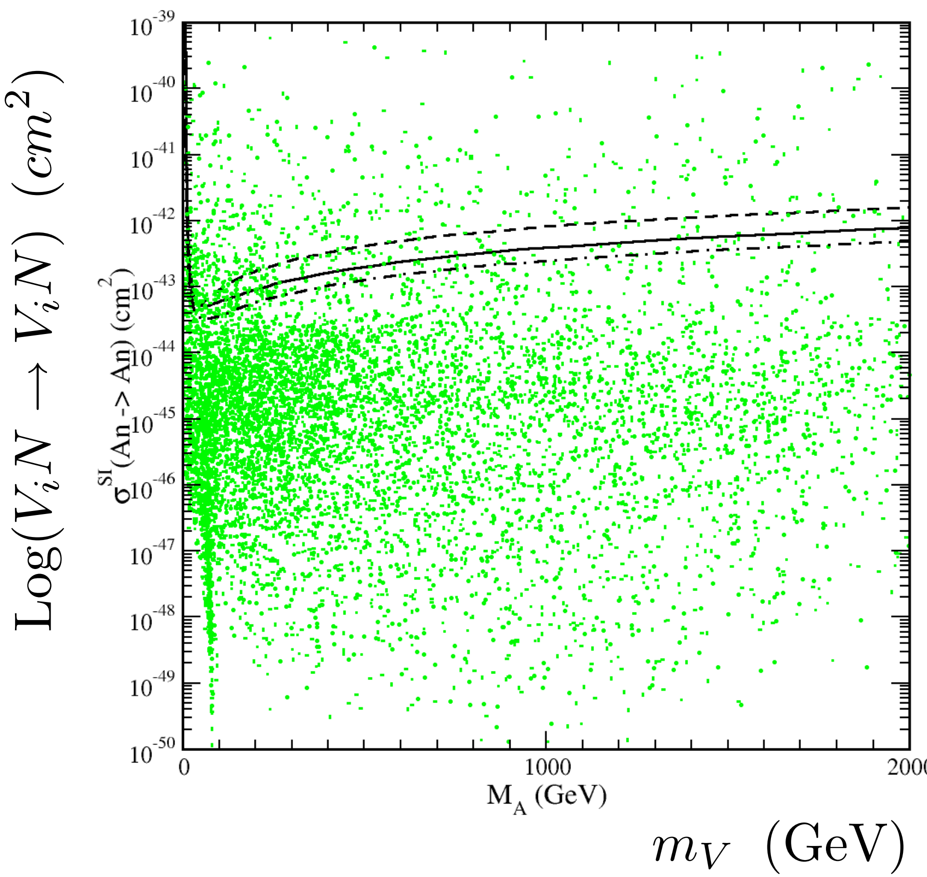
if $m_h = 120\,\mathrm{GeV}$ ⇒ $m_\eta <\sim 240$ GeV (3σ)

or larger if non maximal mixing

if $m_\eta = m_h$ ⇒ $m_h = m_\eta < 154$ GeV (3σ)

Hidden vector: direct detection





$\Rightarrow$ can saturate the experimental bound easily

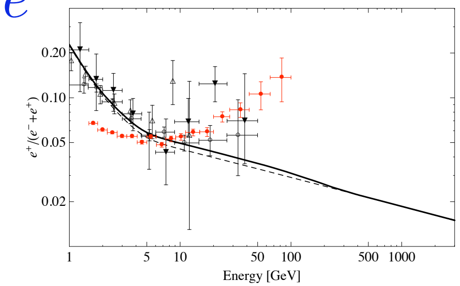
Hidden vector: cosmic ray fluxes

operator A & B

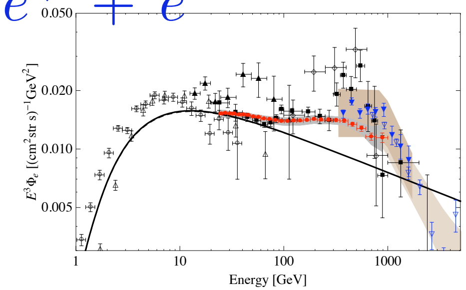
$m_{DM} = 300\,\mathrm{GeV}$

$\Lambda = 2.9 \cdot 10^{15}\,\mathrm{GeV}$

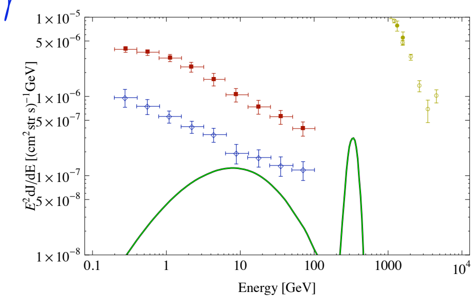
e^+



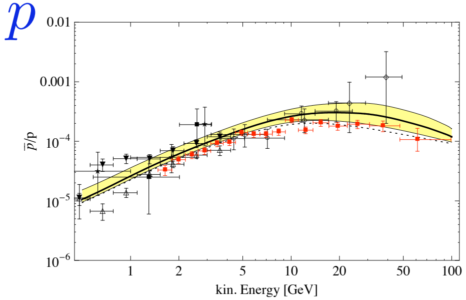
$e^+ + e^-$



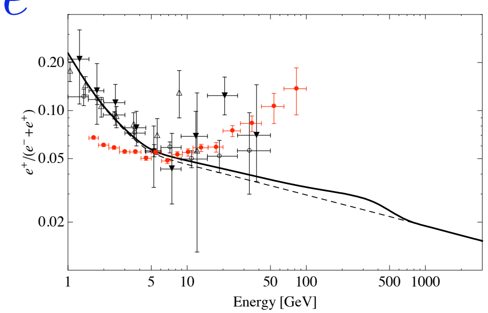
γ



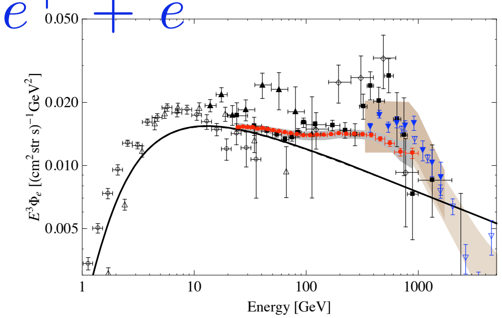
$\bar{p}$



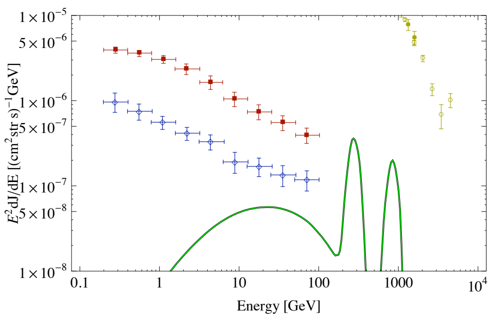
e^+



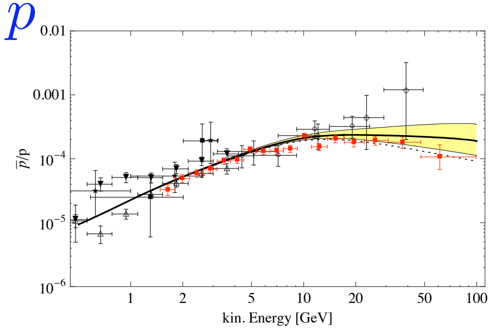
$e^+ + e^-$



γ



$\bar{p}$



operator C

$m_{DM} = 1.5\,\mathrm{TeV}$

$\Lambda = 1.2 \cdot 10^{16}\,\mathrm{GeV}$

What about the non-perturbative regime of this model?

T.H., M. Tytgat, arXiv:0907.1007

→ SU(2)$_{\text{Hidden Sect.}}$ confines automatically if $\Lambda_{SU(2)} >> v_\phi$

$\Lambda_{SU(2)}$ ↓ dynamical scale

v_ϕ ↓ perturbative breaking scale

→ but the custodial symmetry remains exact in this case too

't Hooft '98

$\Rightarrow$ ϕ confines: boundstates are eigenstates of the custodial sym.:

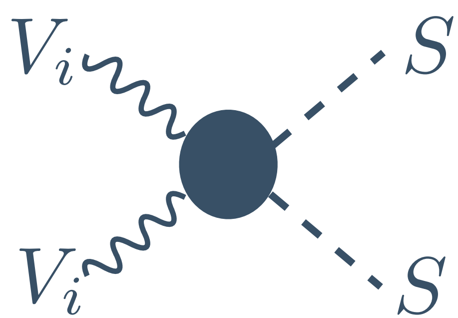
- scalar state: $S \equiv \phi^\dagger \phi$ singlet of SO(3) expected the lightest
- "charged" vector state: $V_\mu^+ \equiv \phi^\dagger D_\mu \tilde{\phi}$, $V_\mu^- \equiv \tilde{\phi}^\dagger D_\mu \phi$
- "neutral" vector state: $V_\mu^0 \equiv \dfrac{\phi^\dagger D_\mu \phi - \tilde{\phi}^\dagger D_\mu \tilde{\phi}}{\sqrt{2}}$

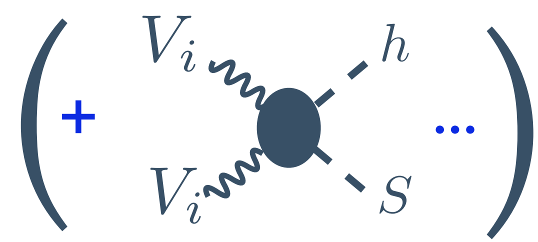
} SO(3) triplet $\Downarrow$ stable DM candidates!

Relic density in the confined regime

- strongly interactive massive particle (SIMP)
  - annihilation cross section cannot be calculated perturbatively

expected dominant channel:





if $S-h$ mixing is large (for large λ_m)

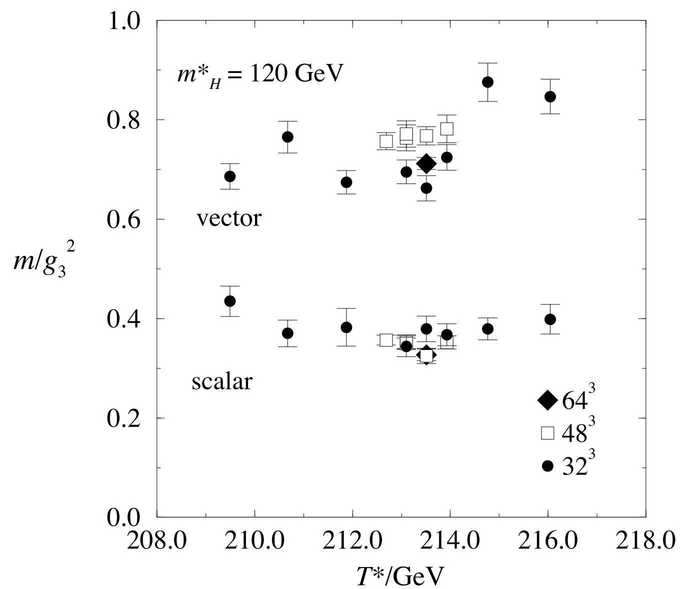
$A = 10 - 50$

$$\sigma_{annih.} \sim \frac{A}{\Lambda^2_{SU(2)}} \Rightarrow m_{DM} \simeq 20 - 120\,\mathrm{TeV}$$

⇒ confining non-abelian hidden sector coupled to the SM through the Higgs portal: perfectly viable DM candidate

Expected spectrum (in a similar case)

vector states e.g. expected heavier than scalar ones:



Kajantie, Laine. Rummukainen, Shaposhnikov '96

Possible effects on Electroweak Symmetry Breaking

contribution of the vev of the hidden scalar to the Higgs mass term:

$$\mathcal{L}_{Higgs\,portal} = -\lambda_m \phi^\dagger \phi H^\dagger H$$

$$\ni -\lambda_m v_\phi^2 H^\dagger H$$

$\Downarrow$

gives a contribution to the Higgs vev: $v^2 \propto \frac{\lambda_m}{\lambda_H} v_\phi^2 \propto m_{DM}^2$

$\Downarrow$

gives a hint for the m_{DM} versus v WIMP coincidence

see also T.H, M. Tytgat, arXiv 0707.0633, (PLB 659)