Extended Dark Matter EFT(s)

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December 3rd

MAX-PLANCK-INSTITUT
FÜR KERNPHYSIK
HEIDELBERG

INTERNATIONAL MAX PLANCK RESEARCH SCHOOL FOR PRECISION TESTS OF FUNDAMENTAL SYMMETRIES

PT FS

Overview

1. Towards Dark Matter Models for the LHC

2. Extended DM EFT

3. Flavor and DM from the EW scale

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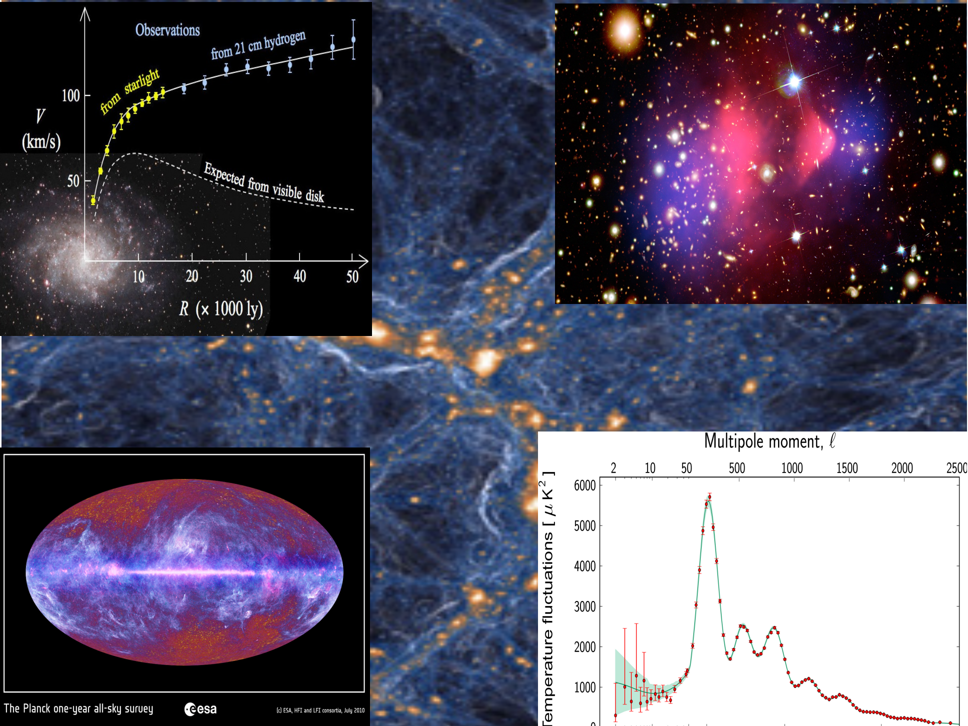
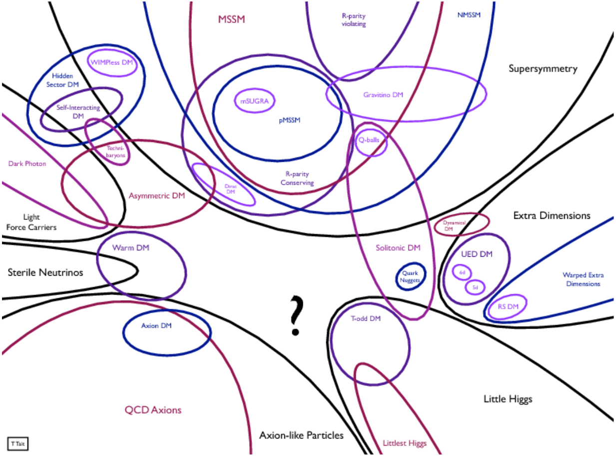
2. Extended DM EFT

3. Flavor and DM from the EW scale



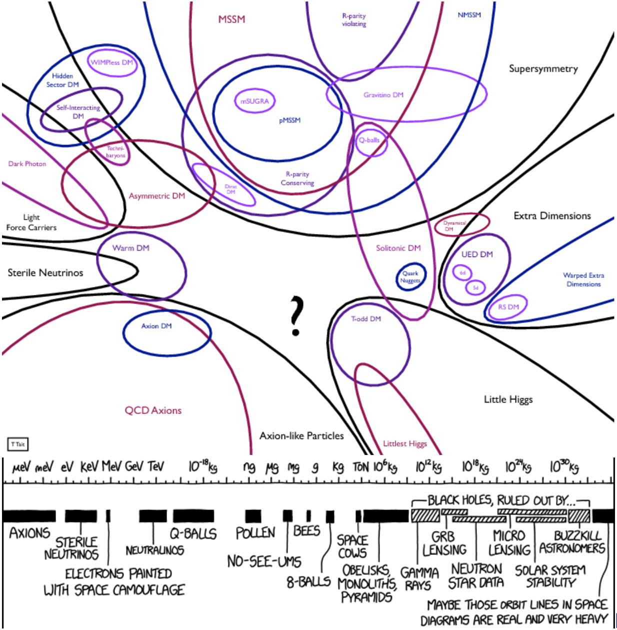
Observations
from 21 cm hydrogen
from starlight
100
50
V
(km/s)
Expected from visible disk
10
20
30
40
50
R (× 1000 ly)
The Planck one-year all-sky survey
esa
(c) ESA, HFI and LFI consortia, July 2010
Multipole moment, ℓ
2
10
50
500
1000
1500
2000
2500
6000
5000
4000
3000
2000
1000
Temperature fluctuations [μK²]

Dark Matter - Candidates



T.Tait

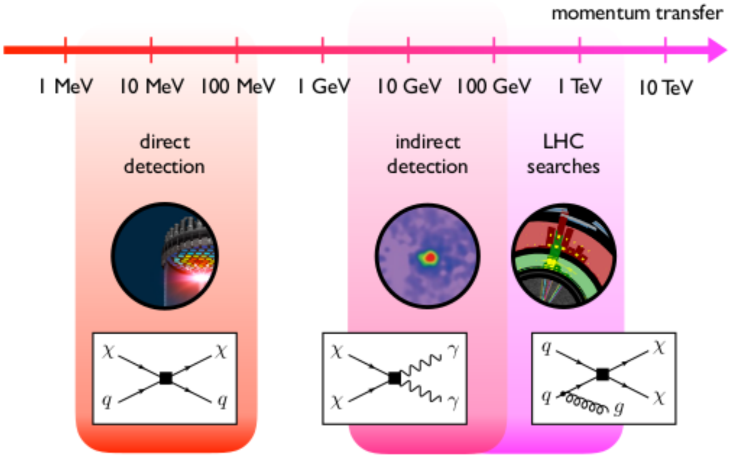
Dark Matter - Candidates



T.Tait

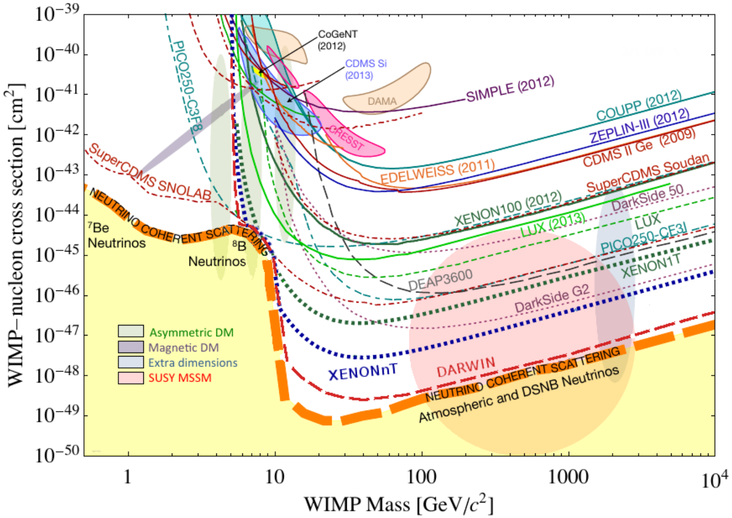
https://xkcd.com/2035

Dark Matter - Search Strategies



1810.09420

Direct Detection

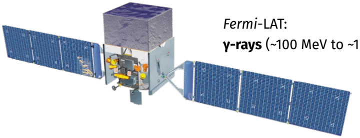


1310.8327, 1408.4371, 1805.12562 (Latest Xenon1t results)

Indirect detection ingredients

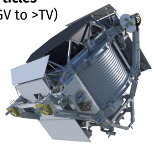
"Search for Standard Model products after self-annihilation, decay, or any other (exotic) interaction of naturally present particle dark matter outside the Earth"

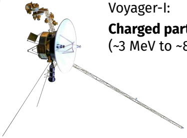
- Detect particles from space:



Fermi-LAT:
γ-rays (~100 MeV to ~1 TeV)

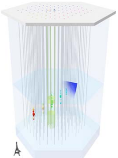
AMS-02:
Charged particles
(rigidity ~2 GV to >TV)





Voyager-I:
Charged particles
(~3 MeV to ~80 MeV)

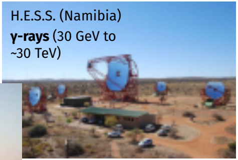
CREAM (stratosphere)
Charged particles
(TeV to PeV)



IceCube (South Pole)
Neutrinos (~100 GeV to >PeV)

VERITAS (USA)
γ-rays (85 GeV to ~30 TeV)

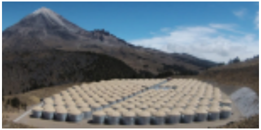
MAGIC (Spain)
γ-rays (30 GeV to ~30 TeV)



H.E.S.S. (Namibia)
γ-rays (30 GeV to ~30 TeV)

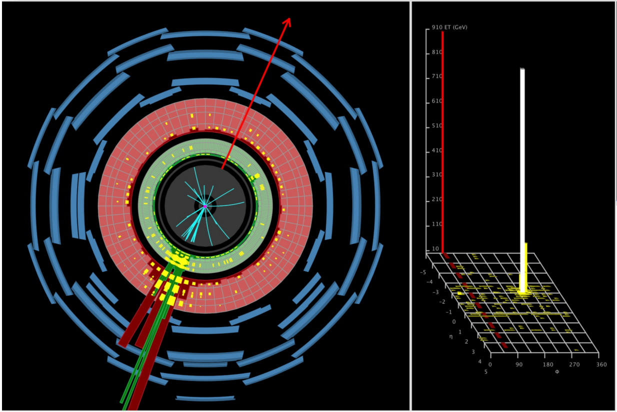
CTA (Future)
γ-rays (20 GeV to 300 TeV)

HAWC (Mexico)
γ-rays (~ 3TeV to >100 TeV)



Antares (Mediterranean Sea)
Neutrinos (~10 GeV to PeV)

Collider Searches



ATLAS EXPERIMENT

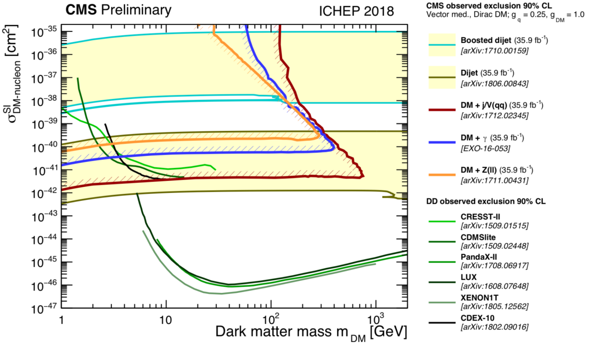
Run Number: 279284, Event Number: 606734214

Date: 2015-09-14 12:05:34 CEST

1 jet with p_T
of 973 GeV
balanced
by
MET of 954 GeV

Theory for DM Collider Searches

Need models for LHC searches
Prefer general models that can account for many UV theories
In addition compare different DM searches



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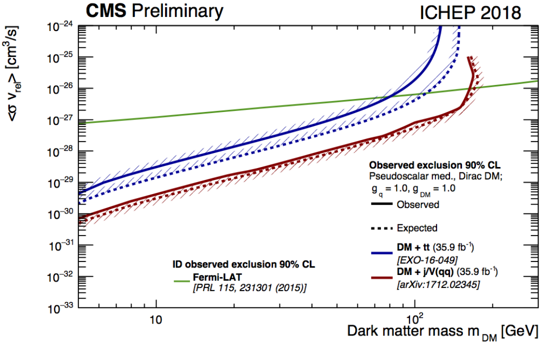

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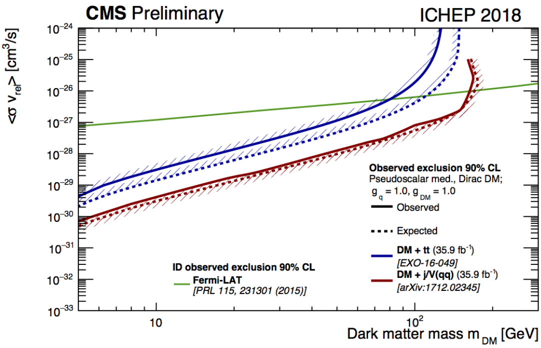
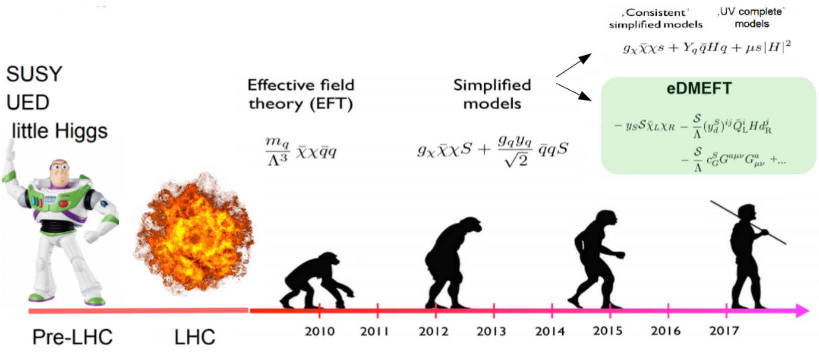


Quest for new observables: "Leave no stone unturned."
Open for new ideas, like displaced vertices!

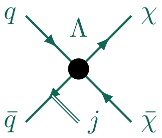
Theory Evolution



G. Polesello, U. Haisch, F.Goertz

DM EFT and Simplified Models

$$\mathcal{L}_{\mathsf{EFT}} = \frac{c_\chi}{\Lambda^2} \left(\bar{q}\,\Gamma^a q\right)\left(\bar{\chi}\,\Gamma'_a\,\chi\right)$$



$$p^2 \ll \Lambda^2$$

- \+ Valid for Direct Detection
- \+ Wide class of models
- − Break down @LHC
  → Restore Mediator

1008.1783, 1402.1275

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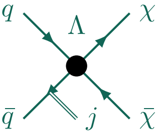

$$p^2 \ll \Lambda^2$$

+ Valid for Direct Detection
+ Wide class of models
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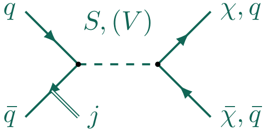
1008.1783, 1402.1275

$$\mathcal{L}_{\text{simp}} = g_q\,S\,\bar{q}q + g_\chi S\,\bar{\chi}\chi$$



$$\propto \frac{g_q\,g_\chi}{p^2 - M_S^2}$$

+ Improve LHC kinematics
− Not gauge invariant
− Rather specific
  → Need for improvement

1409.2893, 1507.00966 (ref. therein)

Consistent Simplified Models

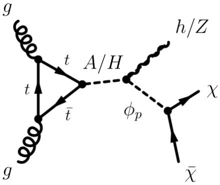
Recently discussed: $2\mathrm{HDM} +$ Mediator 1810.09420 (ref. therein)

$\rightarrow$ Gauge invariance restored + richer Phenomenology

(Most) Important case: $2\mathrm{HDM} + a$ 1701.07427, 1712.06597

Pseudoscalar $\rightarrow$ No Direct Detection limits

$$\mathcal{L} \subset \mathcal{L}_{2\mathrm{HD}} + \lambda_H a^2 H_1^\dagger H_2 - i\, y_\chi a\, \bar{\chi}\gamma_5\chi$$



New benchmark model: ATLAS-CONF-2018-52, CMS-PAS-16-050

Overview

Work in progress with
T.Alanne, G.Arcadi, F.Goertz, K.Tame-Navaez & S.Vogl
Based on: TA,FG, 1712.07626

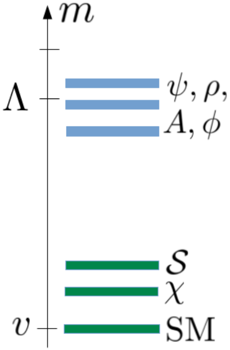
Extended Dark Matter EFT

Idea:
Combine advantages of both approaches
TA,FG, 1712.07626

Considered dof:
SM + Mediator $\mathcal{S}$ + Dark Matter χ

Allow for:
Lowest order of non-renormalizable operators

→ 4 Effective Lagrangian up to dimension 5
→ Small set of operators
→ Consistently include heavier new physics



Extended Dark Matter EFT

Example: Scalar Mediator $\mathcal{S}$ + Fermionic DM χ

$$\begin{aligned}
\mathcal{L}_{\text{eff}}^{\mathcal{S}\chi} = & - \ \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{kin}} - V(\mathcal{S}) \\
& + \ \lambda'_{H\mathcal{S}} v |H|^2 \mathcal{S} - \lambda_{H\mathcal{S}} |H|^2 \mathcal{S}^2 \\
& - \ \frac{\mathcal{S}}{\Lambda} \left[c_{\lambda\mathcal{S}} \mathcal{S}^4 + c_{H\mathcal{S}} |H|^2 \mathcal{S}^2 + c_{\lambda H} |H|^4 \right] \\
& - \ y_{\mathcal{S}}\, \mathcal{S}\, \bar{\chi}\chi - \frac{y_{\mathcal{S}}^{(2)} \mathcal{S}^2 + y_H |H|^2}{\Lambda}\ \bar{\chi}\chi + \text{h.c.} \\
& + \ \frac{\mathcal{S}}{\Lambda} \Big[(y_d^{\mathcal{S}})^{ij} \bar{Q}_{\text{L}}^i H d_{\text{R}}^j + (y_u^{\mathcal{S}})^{ij} \bar{Q}_{\text{L}}^i \tilde{H} u_{\text{R}}^j \\
& \qquad\qquad + (y_\ell^{\mathcal{S}})^{ij} \bar{L}_{\text{L}}^i H \ell_{\text{R}}^j + \text{h.c.} \Big] \\
& - \ \frac{\mathcal{S}}{16\pi^2 \Lambda} \left[g'^2 c_B^{\mathcal{S}}\, B_{\mu\nu} B^{\mu\nu} + \ g^2 c_W^{\mathcal{S}}\, W^{I\mu\nu} W_{\mu\nu}^I \right. \\
& \qquad\qquad \left. + \, g_s^2 c_G^{\mathcal{S}}\, G^{a\mu\nu} G_{\mu\nu}^a \right]
\end{aligned}$$

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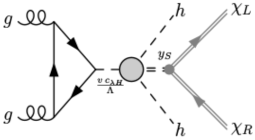
& - \;\; \frac{\mathcal{S}}{\Lambda} \left[c_{\lambda\mathcal{S}} \mathcal{S}^4 + c_{H\mathcal{S}} |H|^2 \mathcal{S}^2 + c_{\lambda H} |H|^4 \right] \\
& - y_{\mathcal{S}}\, \mathcal{S}\, \bar{\chi}\chi - \frac{y_{\mathcal{S}}^{(2)} \mathcal{S}^2 + y_H |H|^2}{\Lambda} 2 \\
& + \frac{\mathcal{S}}{\Lambda} \Big[(y_d^{S})^{ij} \bar{Q}_{\rm L}^i H d_{\rm R}^j + (y_u^{S})^{ij} \bar{Q}_{\rm L}^i \tilde{H} u_{\rm R}^j \\
& \qquad + (y_\ell^{S})^{ij} \bar{L}_{\rm L}^i H \ell_{\rm R}^j + {\rm h.c.} \Big] \\
& - \frac{\mathcal{S}}{16\pi^2 \Lambda} \Big[g'^2 c_B^{\mathcal{S}}\, B_{\mu\nu} B^{\mu\nu} + g^2 c_W^{\mathcal{S}}\, W^{I\mu\nu} W^I_{\mu\nu} \\
& \qquad + g_s^2 c_G^{\mathcal{S}}\, G^{a\mu\nu} G^a_{\mu\nu} \Big]
\end{aligned}$$

Higgs-Mediator Mixing
already at dim=4



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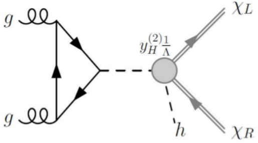
&- \frac{\mathcal{S}}{\Lambda} \left[c_{\lambda S} \mathcal{S}^4 + c_{HS} |H|^2 \mathcal{S}^2 + c_{\lambda H} |H|^4 \right] \\
&- y_{\mathcal{S}} \mathcal{S} \bar{\chi}\chi - \frac{y_{\mathcal{S}}^{(2)} \mathcal{S}^2 + y_H |H|^2}{\Lambda} \bar{\chi}\chi + \text{h.c.} \\
&+ \frac{\mathcal{S}}{\Lambda} \Big[(y_d^S)^{ij} \bar{Q}_{\text{L}}^i H d_{\text{R}}^j + (y_u^S)^{ij} \bar{Q}_{\text{L}}^i \tilde{H} u_{\text{R}}^j \\
&\qquad + (y_\ell^S)^{ij} \bar{L}_{\text{L}}^i H \ell_{\text{R}}^j + \text{h.c.} \Big] \\
&- \frac{\mathcal{S}}{16\pi^2 \Lambda} \Big[g'^2 c_B^S B_{\mu\nu} B^{\mu\nu} + g^2 c_W^S W^{I\mu\nu} W_{\mu\nu}^I \\
&\qquad + g_s^2 c_G^S G^{a\mu\nu} G_{\mu\nu}^a \Big]
\end{aligned}
$$

Dark-Sector Couplings



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& - y_{\mathcal{S}} \, \mathcal{S} \, \bar{\chi}\chi - \frac{y_{\mathcal{S}}^{(2)} \mathcal{S}^2 + y_H |H|^2}{\Lambda} \, \bar{\chi}\chi + \text{h.c.} \\
& + \frac{\mathcal{S}}{\Lambda} \Big[(y_d^{\mathcal{S}})^{ij} \bar{Q}_{\rm L}^i H d_{\rm R}^j + (y_u^{\mathcal{S}})^{ij} \bar{Q}_{\rm L}^i \tilde{H} u_{\rm R}^j \\
& \qquad + (y_\ell^{\mathcal{S}})^{ij} \bar{L}_{\rm L}^i H \ell_{\rm R}^j + \text{h.c.} \Big] \\
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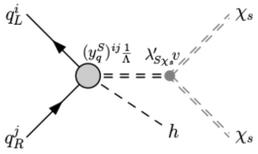
& \qquad + g_s^2 c_G^S \, G^{a\mu\nu} G_{\mu\nu}^a \Big]
\end{aligned}
$$

Dim-5 Yukawa-like



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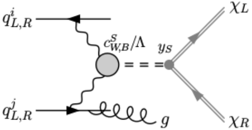
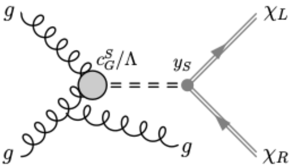
&- \frac{\mathcal{S}}{\Lambda} \left[c_{\lambda S} \mathcal{S}^4 + c_{HS} |H|^2 \mathcal{S}^2 + c_{\lambda H} |H|^4 \right] \\
&- y_S \, \mathcal{S} \, \bar{\chi}\chi - \frac{y_S^{(2)} \mathcal{S}^2 + y_H |H|^2}{\Lambda} \bar{\chi}\chi + \text{h.c.} \\
&+ \frac{\mathcal{S}}{\Lambda} \left[(y_d^S)^{ij} \bar{Q}_{\text{L}}^i H d_{\text{R}}^j + (y_u^S)^{ij} \bar{Q}_{\text{L}}^i \tilde{H} u_{\text{R}}^j \right. \\
&\qquad \left. + (y_\ell^S)^{ij} \bar{L}_{\text{L}}^i H \ell_{\text{R}}^j + \text{h.c.} \right] \\
&- \frac{\mathcal{S}}{16\pi^2 \Lambda} \left[g'^2 c_B^{\mathcal{S}} \, B_{\mu\nu} B^{\mu\nu} + g^2 c_W^{\mathcal{S}} \, W^{I\mu\nu} W_{\mu\nu}^I \ 1 \right. \\
&\qquad \left. + g_s^2 c_G^{\mathcal{S}} \, G^{a\mu\nu} G_{\mu\nu}^a \right]
\end{aligned}
$$

Dim-5 Gauge Boson Couplings

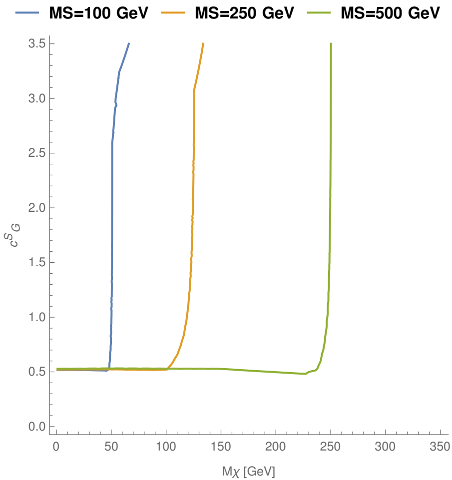


Mono-Jet Limits - Gluon Coupling

$$\mathcal{L}_{\text{eff}}^{\mathcal{S}\text{int}} \supset -y_{\mathcal{S}}\,\mathcal{S}\,\bar{\chi}\chi - \frac{g_s^2 c_G^S}{16\pi^2\Lambda}\,\mathcal{S}\,G^{a\mu\nu}G^a_{\mu\nu}$$



- ATLAS Mono-Jet
  1711.03301
- $\Lambda = 1$ TeV, $y_{\mathcal{S}} = 1$
- Use MadGraph5 + Phythia8 + CheckMATE



Preliminary Plot

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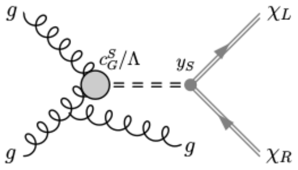

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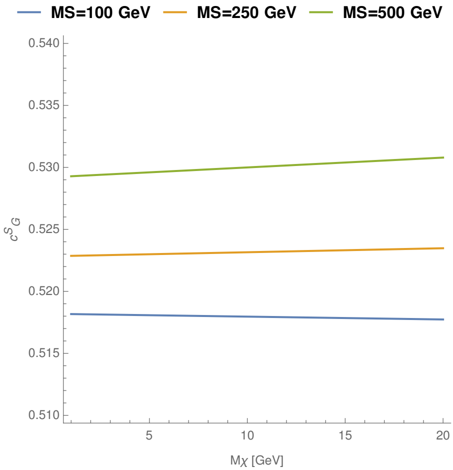
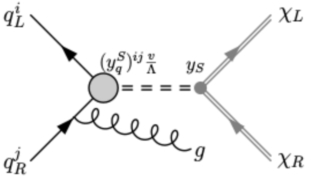


Preliminary Plot

Mono-Jet Limits - Yukawa-like Coupling

$$\mathcal{L}_{\rm eff}^{\mathcal{S}\rm int} \supset - y_{\mathcal{S}} \, \mathcal{S} \, \bar{\chi}\chi - \frac{\mathcal{S}}{\Lambda} \, (y_t^{\mathcal{S}})^{ij} \, \bar{Q}_{\rm L}^i \tilde{H} t_{\rm R}^j$$



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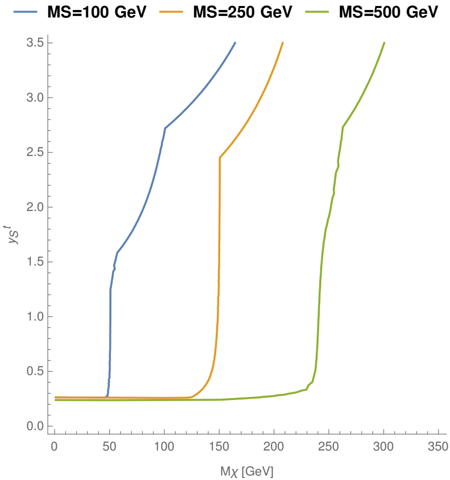
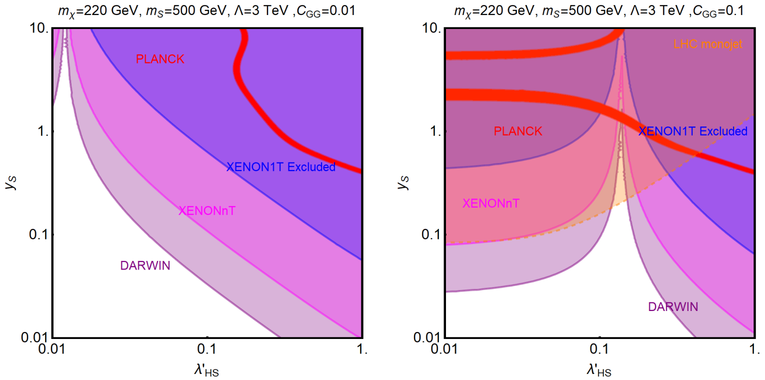


Preliminary Plot

Higgs Mixing + Gluon Coupling - Scalar

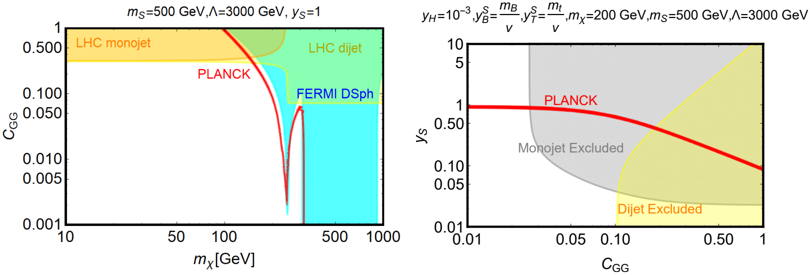
$$\mathcal{L}_{\text{eff}}^{\mathcal{S}\text{int}} \supset -\lambda'_{H\mathcal{S}} v |H|^2 \mathcal{S} - y_{\mathcal{S}}\, \mathcal{S}\, \bar{\chi}\chi - \frac{g_s^2 c_G^{\mathcal{S}}}{16\pi^2 \Lambda}\, \mathcal{S}\, G^{a\mu\nu} G^a_{\mu\nu}$$



Preliminary Plots

Yukawa-like + Gluon Couplings - Pseudoscalar

$$\mathcal{L}_{\rm eff}^{\tilde{S}\rm int} \supset -\frac{i\tilde{S}}{\Lambda}\left[y_b^{\tilde{S}}\bar{Q}_L H b_R + y_t^{\tilde{S}}\bar{Q}_L \tilde{H} t_R\right] - y_{\tilde{S}}\,\tilde{S}\,\bar{\chi}\chi - \frac{g_s^2 c_G^{\tilde{S}}}{16\pi^2\Lambda}\,\tilde{S}\,G^{a\mu\nu}\tilde{G}^a_{\mu\nu}$$



Preliminary Plots

Matching-Example: 2HDM + $\mathcal{S}$

$$\mathcal{L}_{2\mathrm{HDM}+\mathcal{S}} \supset \mathcal{L}_{2\mathrm{HDM}} + \lambda_{12}^{\mathcal{S}} v\, H_1^\dagger H_2\, \mathcal{S} + \lambda_{12}^{2\mathcal{S}}\, H_1^\dagger H_2\, \mathcal{S}^2 + y_{\mathcal{S}} \mathcal{S} \bar{\chi} \chi$$

$\downarrow$ H_2 heavy - motivated by Higgs signal strength

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↓ H_2 heavy - motivated by Higgs signal strength

$$\mathcal{L}_{\text{eff}}^{\mathcal{S}\text{int}} \propto \frac{-\lambda_{12}^{\mathcal{S}} v}{M^2} \, \mathcal{S} \left(Z_6 |H|^4 + \sum_{f=u,d,l} \frac{\eta_f \, y_f}{\tan\beta} \, \bar{F}_{\text{L}} H f_{\text{R}} + 2\lambda_{12}^{2\mathcal{S}} \mathcal{S}^2 |H|^2 \right)$$

$$- \frac{\mathcal{S} \; v}{16\pi^2 M^2} \left[c_B B_{\mu\nu} B^{\mu\nu} + c_W W^{i\mu\nu} W^i_{\mu\nu} \right] \text{1-loop}$$

$$c_{H\mathcal{S}} = \frac{-2\lambda_{12}^{\mathcal{S}} \lambda_{12}^{2\mathcal{S}} \, v}{M} \quad \bullet \quad c_{\lambda\mathcal{S}} = \frac{2 Z_6 \lambda_{12}^{\mathcal{S}} \, v}{M} \quad \bullet \quad y_q^{\mathcal{S}} = \frac{\lambda_{12}^{\mathcal{S}} \eta_q}{M \tan\beta}$$

Preliminary Result

Summary and Outlook I

- Increase applicability of Dark Matter EFT
- Allows matching of various UV theories
- Account for correlations by gauge symmetry
- Proper treatment of Higgs mixing and interaction

- Prepare FeynRules model database entry
- Extend LHC analyses to richer phenomenology
- Present constrains on the Wilson coefficients
- Provide matching of simpler (vector quarks, $2\mathrm{HDM} + \mathcal{S}$) and more complex theories (Composite Models, NMSSM, ...)

Overview

1. Towards Dark Matter Models for the LHC

2. Extended DM EFT

3. Flavor and DM from the EW scale

Work in progress with M.Bauer and F.Goertz

Flavor Hierarchy Problem

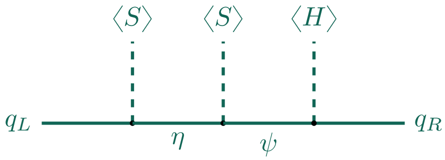
Explanation by Froggatt-Nielsen '79:

→ Fermions charged under spontaneously broken $U_F(1)$

→ Effective Yukawa couplings

→ Number of flavon insertions due to charges → Hierarchy

$$\mathcal{O} = y \left(\frac{S}{\Lambda}\right)^n \bar{Q}_L H q_R$$



Flavor Hierarchy Problem

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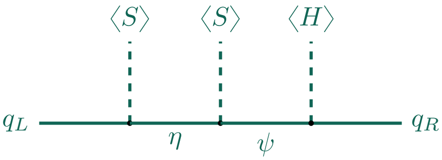
$\rightarrow$ Fermions charged under spontaneously broken $U_F(1)$

$\rightarrow$ Effective Yukawa couplings

$\rightarrow$ Number of flavon insertions due to charges $\rightarrow$ Hierarchy

$$\mathcal{O} = y \left(\frac{S}{\Lambda}\right)^n \bar{Q}_L H q_R \;\rightarrow\; y \left(\frac{\langle S \rangle}{\Lambda}\right)^n \bar{Q}_L H q_R$$

Scale of $\langle S \rangle$ and Λ is not determined!



Flavon at the Electroweak Scale

Proposed by Babu-Nandi and Giudice-Lebedev: 9907213, 0804.1753

$$\frac{S}{\Lambda} \to \frac{H^\dagger H}{\Lambda^2} \to \frac{v^2}{\Lambda^2}$$

Problems:

- Singlet under all gauge groups
  $\to$ Number of insertions n arbitrary
- Implies $g_{h\bar{b}b} = 3\, g_{h\bar{b}b}^{\mathsf{SM}}$
  $\to$ Excluded by Higgs measurements

Flavor from the Electroweak Scale

Use 2nd Higgs Doublet 1506.01719, 1512.03458

$$\frac{S}{\Lambda} \rightarrow \frac{H_u H_d}{\Lambda^2} = \frac{H_u^T (i\sigma_2) H_d}{\Lambda^2} \rightarrow \frac{v_u v_d}{2\Lambda^2}$$

$$\tan\beta = \frac{v_u}{v_d}$$

$$\frac{v_u v_d}{2\Lambda^2} = \epsilon \approx \frac{m_b}{m_t} \quad \rightarrow \quad \Lambda \approx 1.5\ \text{TeV} \sqrt{\frac{\tan\beta}{1+\tan^2\beta}}$$

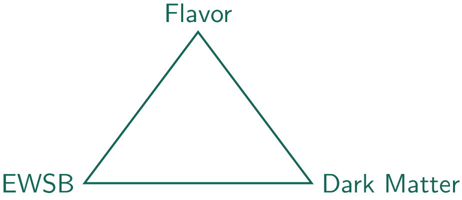
Advantages:

- Valid, predictable and testable model
- Connects flavor and the EW scale

Problems:

- Highly under pressure, especially by direct searches for new scalars

This Work

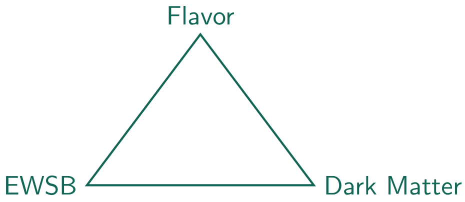


3 Phenomena: Dark Matter - Flavor - EWSB

$\rightarrow$ 3 Possible Scales

What if all this happens at one scale?

This Work



3 Phenomena: Dark Matter - Flavor - EWSB

→ 3 Possible Scales

What if all this happens at one scale?

Very predictive model with interesting phenomenology for Flavor, Collider and Dark Matter searches!

The Model

Extension of a $2\mathrm{HDM}$ type II

$$\begin{aligned}\mathcal{L} \;=\;& y^u_{ij}\left(\frac{H_u H_d}{\Lambda^2}\right)^{a_i - a_{u_j} - a_{H_u}} \bar{Q}_i\, H_u\, u_{R_j} \\ &+\; y^d_{ij}\left(\frac{H_u H_d}{\Lambda^2}\right)^{a_i - a_{d_j} - a_{H_d}} \bar{Q}_i\, H_d\, d_{R_j} \\ &+\; c_\chi\,\frac{H_u H_d}{\Lambda}\,\bar{\chi}\chi \;+\; c_5\,\frac{H_u H_d}{\Lambda}\,\bar{\chi}\gamma_5\chi \;+\; \mathrm{h.c.}\end{aligned}$$

Free physical Parameters:

$$M_A,\ M_H,\ M_{H^\pm},\ \tan\beta,\ \cos(\beta-\alpha),\ c_\chi,\ c_5,\ m_\chi$$

$$y^{u,d}_{ij} \in \mathcal{O}(1),\ a_i,\ a_{u.d_j},\ a_{H_{u,d}}$$

Higgs Couplings

$$g_{hff} = \kappa_f \, g_{hff}^{\mathsf{SM}}$$
$$g_{hVV} = \kappa_V \, g_{hVV}^{\mathsf{SM}}$$

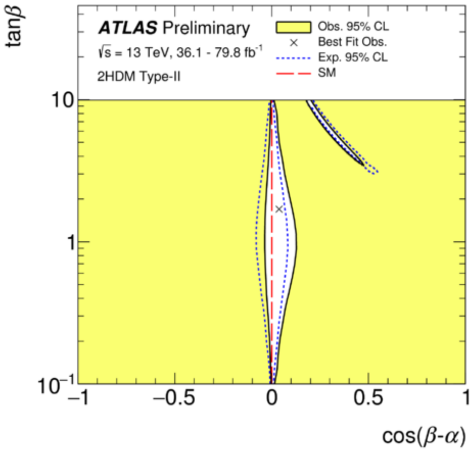
Here: Production as in 2HDM

$$\kappa_t = \frac{\cos\alpha}{\sin\beta}$$
$$\kappa_V = \sin(\beta-\alpha)$$

But:

$$\kappa_b = \left(2\frac{\sin\alpha}{\cos\beta} - \frac{\cos\alpha}{\sin\beta}\right)$$

→ Decay widths change!



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Higgs Signal Strength Fit

$$\mu_X = \frac{\sigma_{\text{prod}}}{\sigma_{\text{prod}}^{\text{SM}}} \frac{\Gamma_{h\to X}}{\Gamma_{h\to X}^{\text{SM}}} \frac{\Gamma_{h,\text{tot}}^{\text{SM}}}{\Gamma_{h,\text{tot}}}$$

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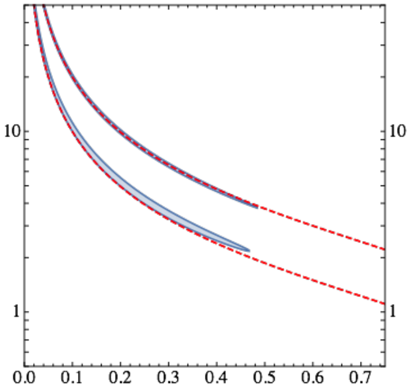


Preliminary Plot

- 2HDM of type II
- Restricted to $\kappa_b \approx \pm 1$
- Far from decoupling limit

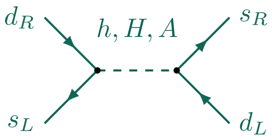
Electroweak Precision, Perturbativity, Unitarity

Deviation from decoupling limit + Perturbativity of potential of quartic couplings
$\rightarrow$ New Scalars not arbitrary heavy
$\rightarrow$ Mediator to Dark Matter can not decouple

Stability + Unitarity + Electroweak Precision tests
$\rightarrow$ Limits on mass splittings between the new states

$$M_A \approx M_H \approx M_{H^\pm} \lesssim 700 \text{ GeV}$$

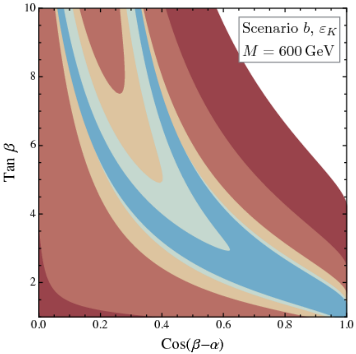
Flavor Bounds



Potentially dangerous FCNCs at tree-level

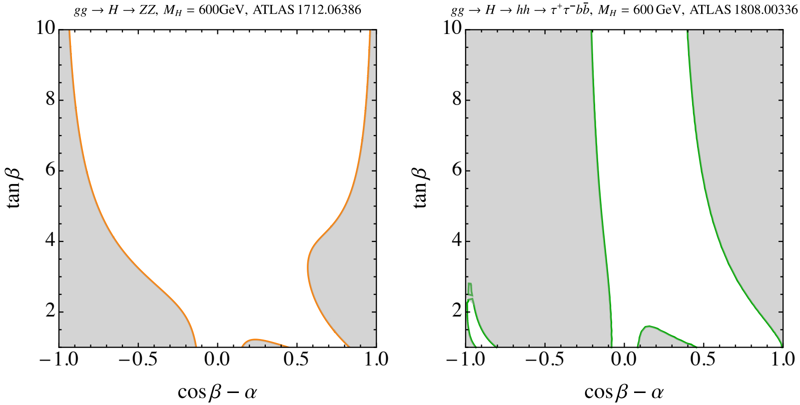
Under control due to several suppressions

$$|C_4^{sd}| \propto \frac{f^2(\alpha,\beta)}{m_h^2}\, g^2(y) \left(\frac{m_s}{v}\epsilon\right)^2$$
$$\propto f^2(\alpha,\beta)\, \frac{10^{-15}}{\text{GeV}^2}$$
$$\lesssim \frac{10^{-17}}{\text{GeV}^2} \quad \text{exp. bound}$$



1512.03458

Heavy Resonance Searches



Preliminary Plots

No longer relevant: $A \to hZ$

Consistent Model for Pseudoscalar Mediators

$$\mathcal{L}_\chi \supset c_5 \; \frac{H_u H_d}{\Lambda} \; \bar{\chi}\gamma_5\chi \; + \; h.c.$$

Pseudoscalar embedded in the 2nd Higgs Doublet 1712.06597

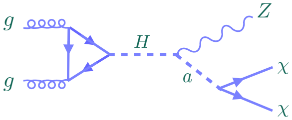
→ Minimalistic way to restore Gauge Invariance

→ Safe from Direct Detection 1711.02110

Coupling to DM via effective operators

→ Accounting for more complex dark sectors

→ Universal signal

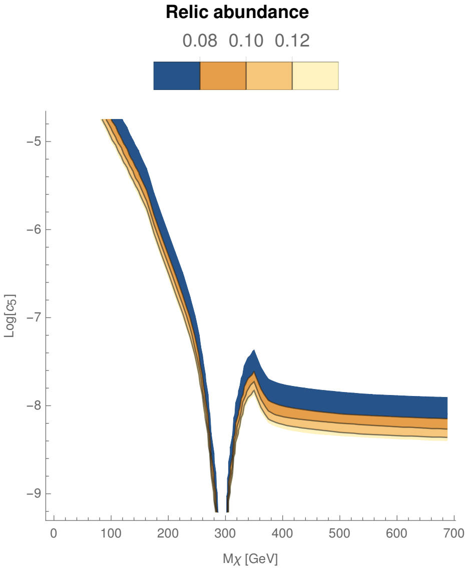


Mono-Z

Resonantly enhanced if

$M_H \geqslant M_A + M_Z$

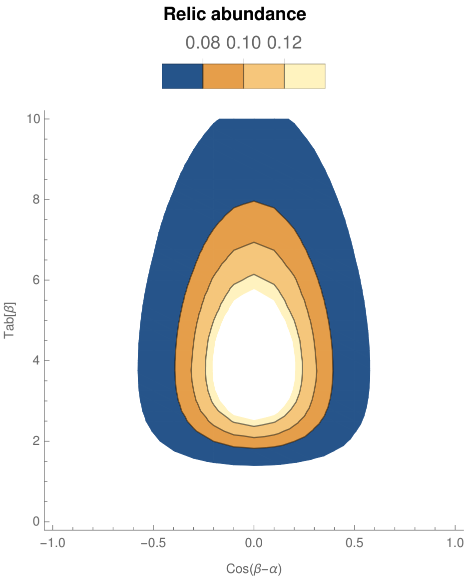
Relic Density



- $M_A = M_H = M_{H^\pm} = 600$ GeV
- $c_\chi = 0$
- $\tan\beta = 4$
- $\cos(\beta - \alpha) = 0.22$

Preliminary Plot

Relic Density



- $M_A = M_H = M_{H^\pm} = 600$ GeV
- $c_\chi = 0$
- $m_\chi = 140$ GeV
- $c_5 = 0.001$

Preliminary Plot

Summary and Outlook II

- Consistent model for Flavor and Dark Matter from the Electroweak Scale
- Flavor and Higgs constraints point to same parameter region
- Predicts new particles around 1 TeV
- Left over region testable by future LHC runs!

- More detailed analyses, projections for LHC27

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Thanks for your attention!