Minimal consistent models for systematic Dark Matter exploration

Alexander Belyaev

Southampton University & Rutherford Appleton Laboratory

Corfu 2021 , the 6th of September

Workshop on the Standard Model and Beyond
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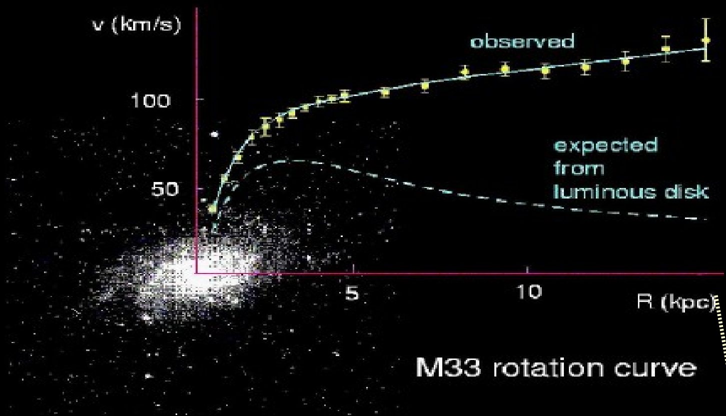
Collaborators & Projects

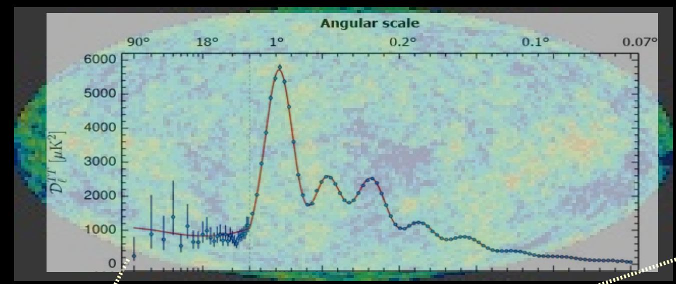
- U.Blumenschein, A. Freegard, D.Gupta, S.Moretti, AB arXiv:**2109.xxxxx**
- **G.Cacciapaglia, D.Locke, AB** **arXiv:2109.xxxxx**
- I.Ginzburg, D.Locke, A. Freegard, T. Hosken, A.Pukhov, AB arXiv:**2109.xxxxx**
- S.Prestel, F.Rojas-Abate,J.Zurita, AB arXiv:**2008.08591**
- G.Cacciapaglia, J.McKay, D. Marin, A.Zerwekh, AB arXiv:**1808.10464**

The existence of Dark Matter is confirmed by several independent observations at cosmological scale

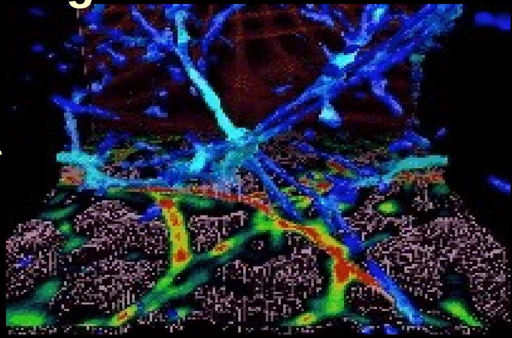
Galactic rotation curves

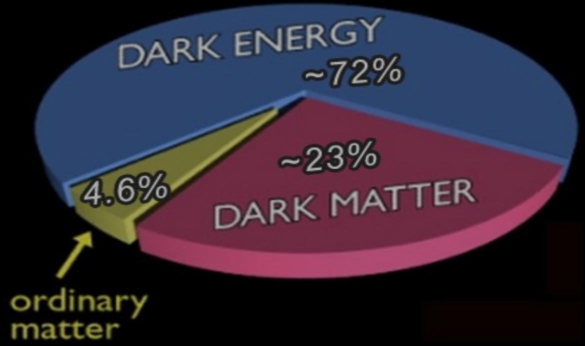


CMB: WMAP and PLANCK

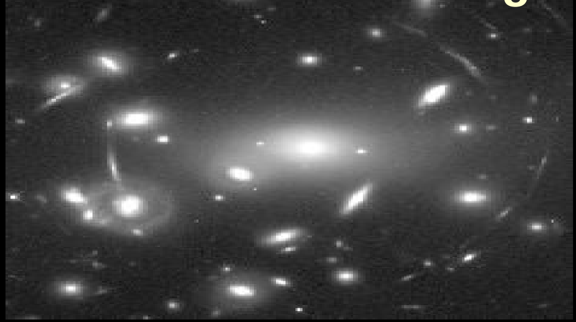


Large Scale Structures



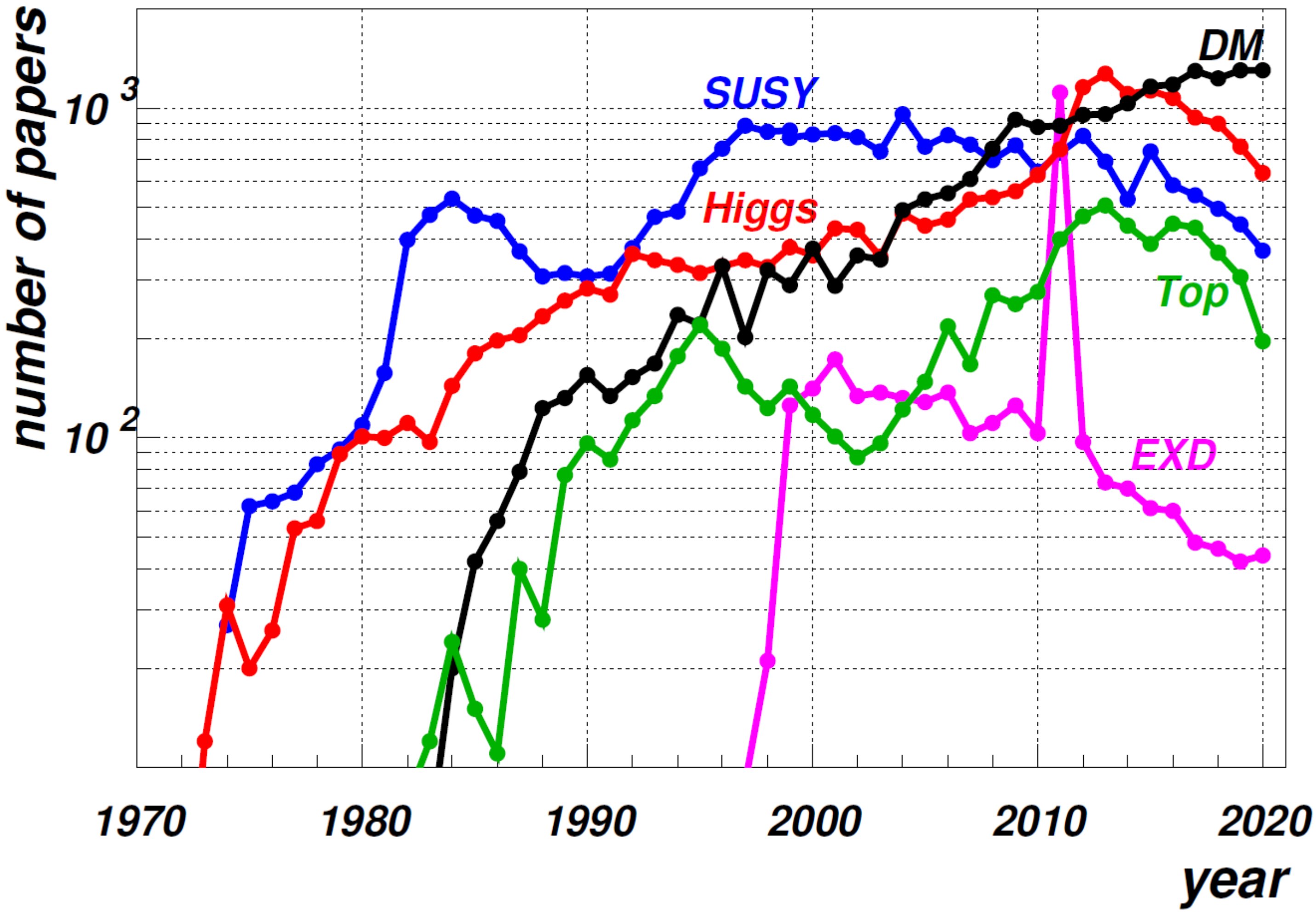


Gravitational lensing



Bullet cluster

The evidence for Dark Matter is a very appealing argument for BSM



DM is very appealing even though we know almost nothing about it!

Spin ?

Mass ?

Stable

Yes ? No ?

symmetry behind stability ?

Couplings

gravity	V
weak	?
higgs	?
quarks/gluons	?
leptons	?
New mediators	?

Thermal relic

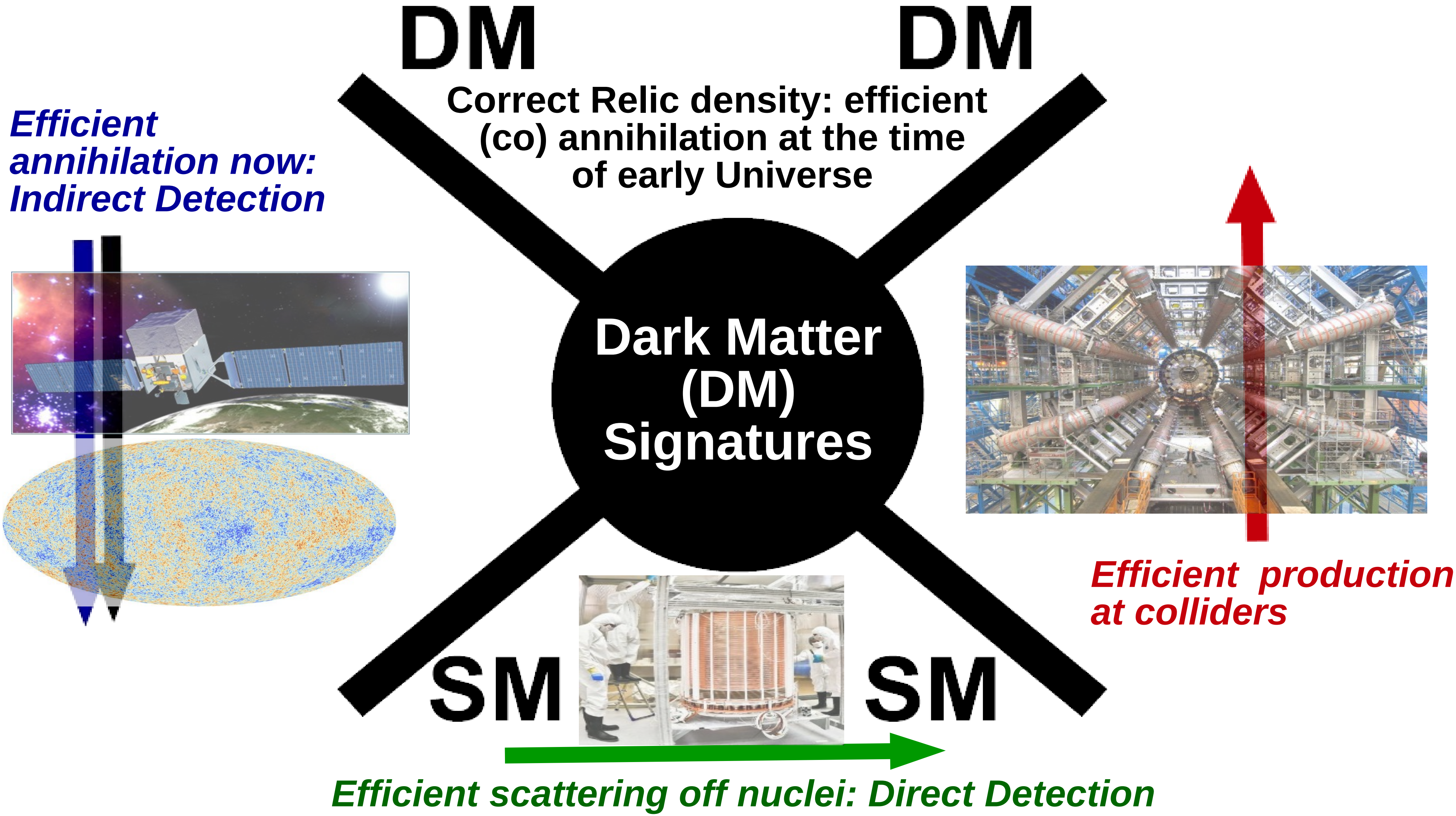
Yes ? No ?

How we can decode the fundamental nature of Dark Matter?

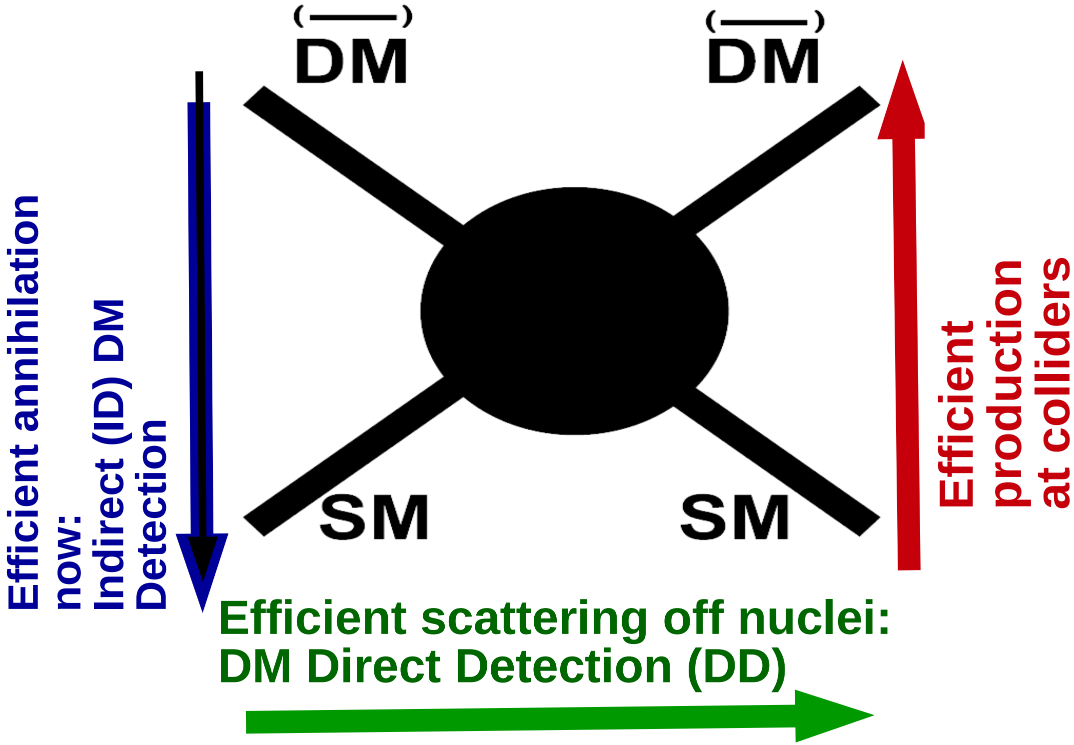
We need a DM signal first!

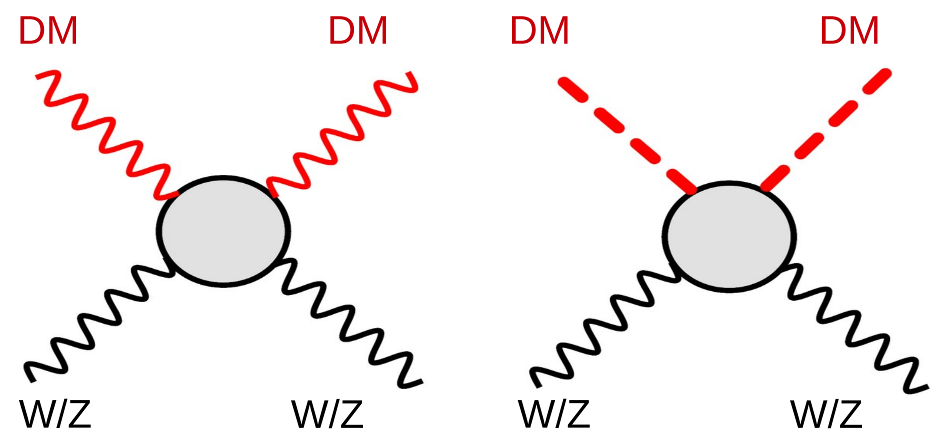
But at the moment we can:

- understand what kind of DM is already excluded
- explore theory space and prepare ourselves to
- discovery and decoding of DM


DM
DM
Correct Relic density: efficient (co) annihilation at the time of early Universe
Efficient annihilation now: Indirect Detection
Dark Matter (DM) Signatures
Efficient production at colliders
SM
SM
Efficient scattering off nuclei: Direct Detection

Complementarity of DM searches





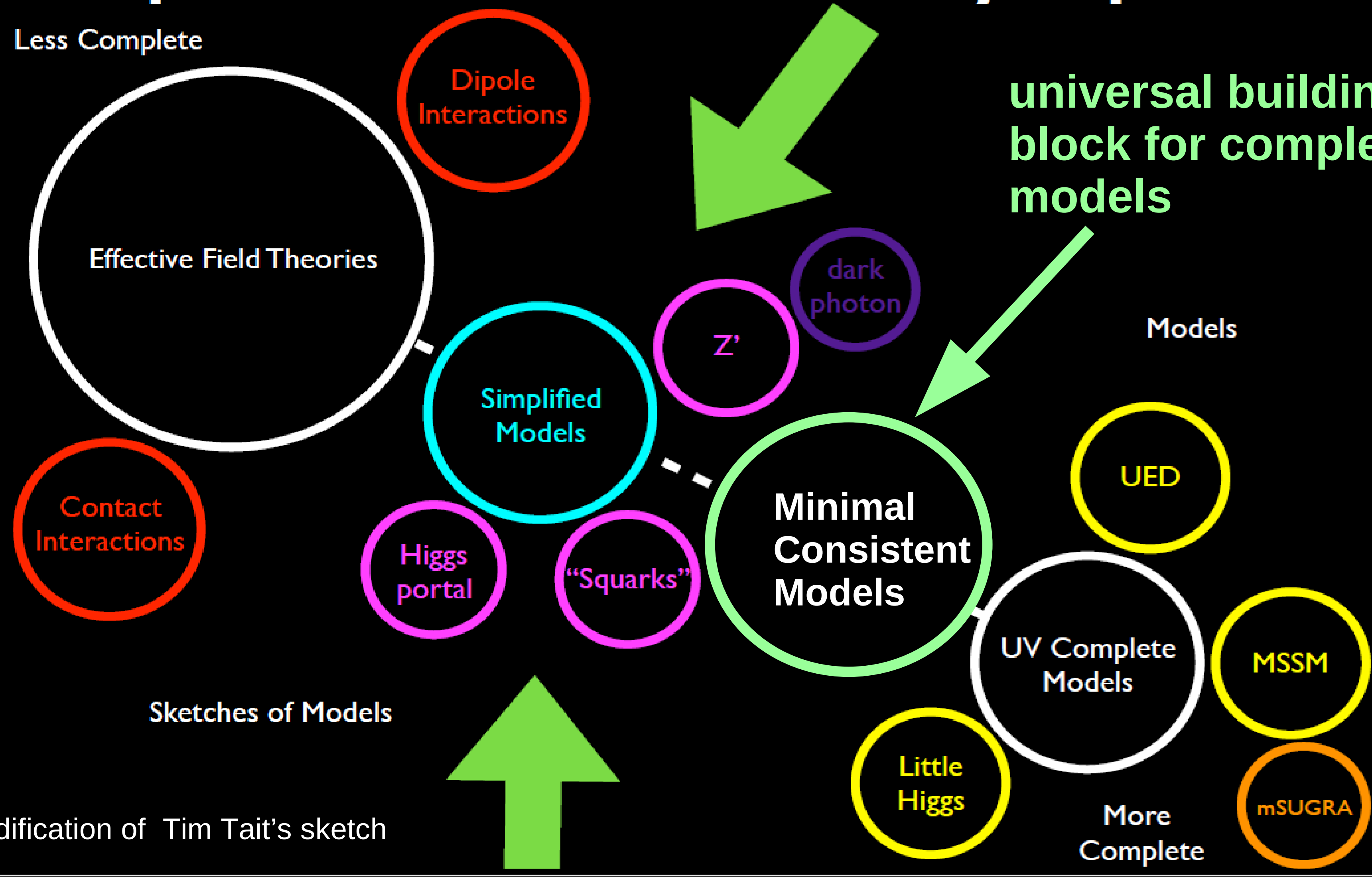
Example of DM interactions with negligible/suppressed DD rates

Important: there is no 100%correlation between signatures above. E.g. the high rate of annihilation does not always guarantee high rate for DD!

Actually there is a great complementarity in this:

- **In case of NO DM Signal – we can efficiently exclude DM models**
- **In case of DM signal – we have a way to determine the nature of DM**

Spectrum of Theory Space



modification of Tim Tait's sketch

Minimal Consistent DM (MCDM) Models

Properties

- gauge-invariant
- renormalisable
- anomaly-free
- can also be a building block of a bigger theory (e.g. SUSY)

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Classification is important for systematic DM exploration

- DM is a part of EW multiplet
- at most one mediator multiplet
- very important for consistent exploration of DM theory space

Z_2 odd or even

spin → $\tilde{X}^{i}_{y}$ ← isospin, hypercharge

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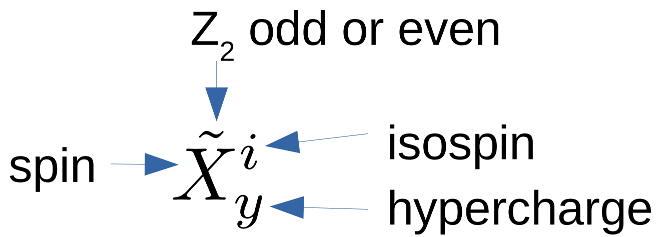


Spin of Mediator \ Spin of Dark Matter	0	1/2	1
spin 0 even mediator	$\tilde{S}^I_Y S^{I'}_{Y'}$	$\tilde{F}^I_Y S^{I'}_0$	$\tilde{V}^I_Y S^{I'}_{Y'}$
spin 0 odd mediator	$\tilde{S}^I_Y \tilde{S}^{I'}_{Y'}$	$\tilde{F}^I_Y \tilde{S}^{I'}_{Y'}$ $\tilde{F}^I_Y \tilde{S}^{I'c}_{Y'}$	$\tilde{V}^I_Y \tilde{S}^{I'}_{Y'}$
spin 1/2 even mediator			
spin 1/2 odd mediator	$\tilde{S}^I_Y \tilde{F}^{I'}_{Y'}$ $\tilde{S}^I_Y \tilde{F}^{I'c}_{Y'}$	$\tilde{F}^I_Y \tilde{F}^{I\pm 1/2}_{Y\pm 1/2}$	$\tilde{V}^I_Y \tilde{F}^{I'}_{Y'}$ $\tilde{V}^I_Y \tilde{F}^{I'c}_{Y'}$
spin 1 even mediator	$\tilde{S}^I_Y V^{I'}_0$	$\tilde{F}^I_Y V^{I'}_0$	$\tilde{V}^I_Y V^{I'}_{Y'}$
spin 1 odd mediator	$\tilde{S}^I_Y \tilde{V}^{I'}_{Y'}$	$\tilde{F}^I_Y \tilde{V}^{I'}_{Y'}$ $\tilde{F}^I_Y \tilde{V}^{I'c}_{Y'}$	$\tilde{V}^I_Y \tilde{V}^{I'}_{Y'}$

G.Cacciapaglia, D.Locke, AB to appear

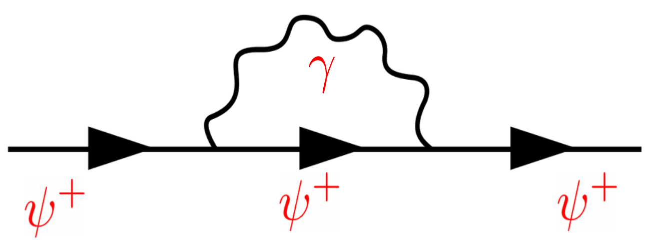
DM multiplet only

$$\mathcal{L} = i\bar{\psi}\gamma^{\mu}D_{\mu}\psi - m_D\bar{\psi}\psi$$

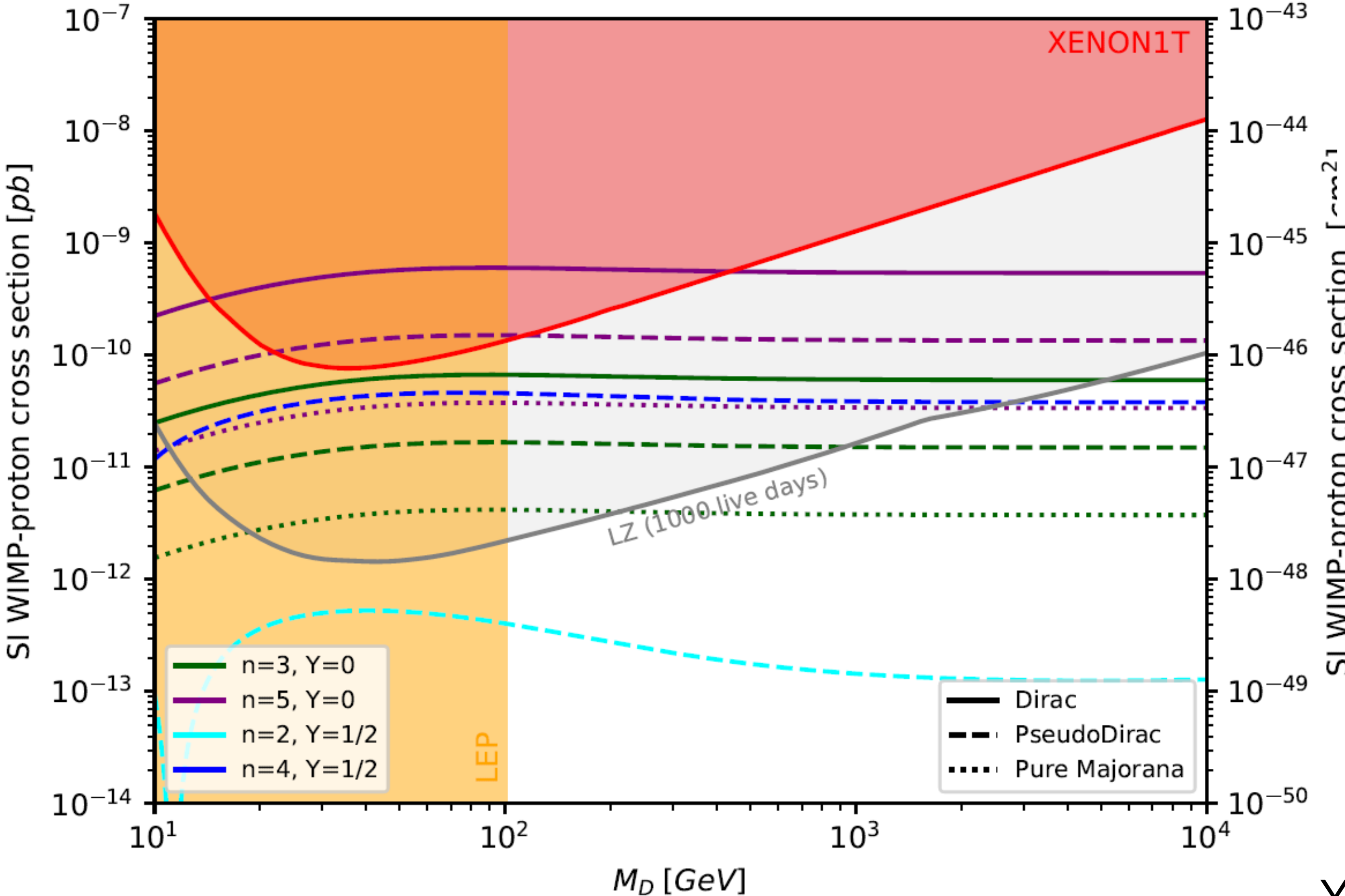
$$\psi = \begin{pmatrix} \psi^{n+} \\ \vdots \\ \psi^{+} \\ \psi_0 \\ \psi^{-} \\ \vdots \\ \psi^{m-} \end{pmatrix}$$

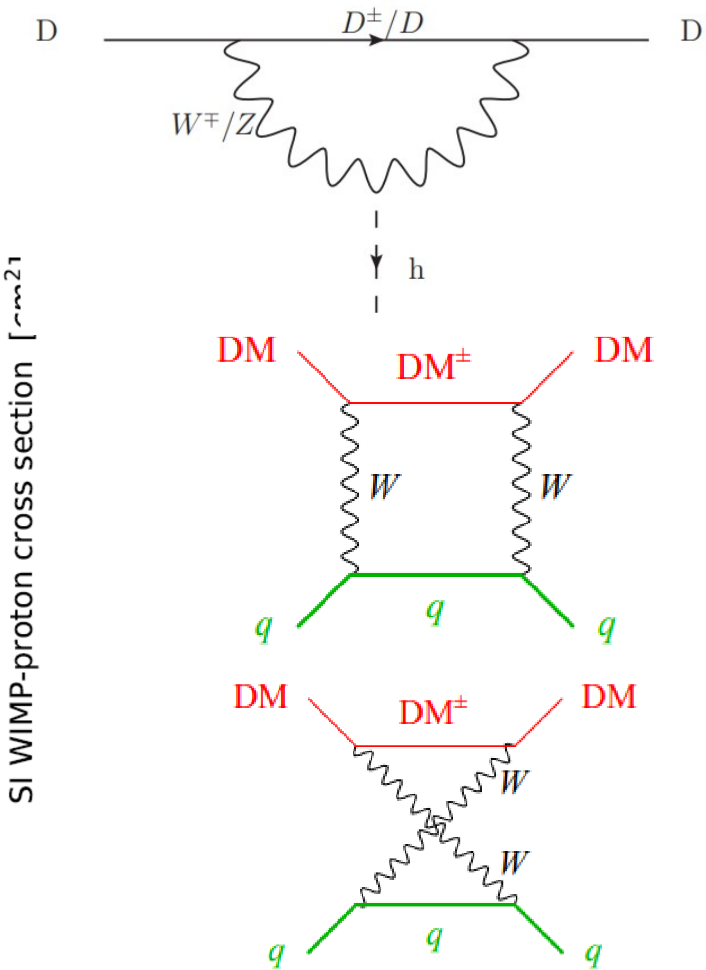
Cirelli,Fornengo,Strumia hep-ph/0512090 (Minimal Dark Matter)

- **{I,Y}={0,0}, {½,½}, {1,0}**
- Z_2 forbids yukawa couplings
- {0,0} – no gauge-interactions – invisible to direct detection and collider but over(under) abundant if thermal (non-thermal)
- $Y \neq 0$ (Dirac DM) Is excluded by direct detection or requires additional sector – which splits the mass of ψ
- Radiative mass split – very important for the phenomenology



The role of loops in DM DD



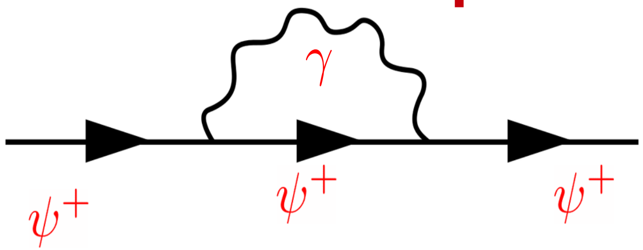


G.Cacciapaglia, D.Locke, AB to appear (preliminary)

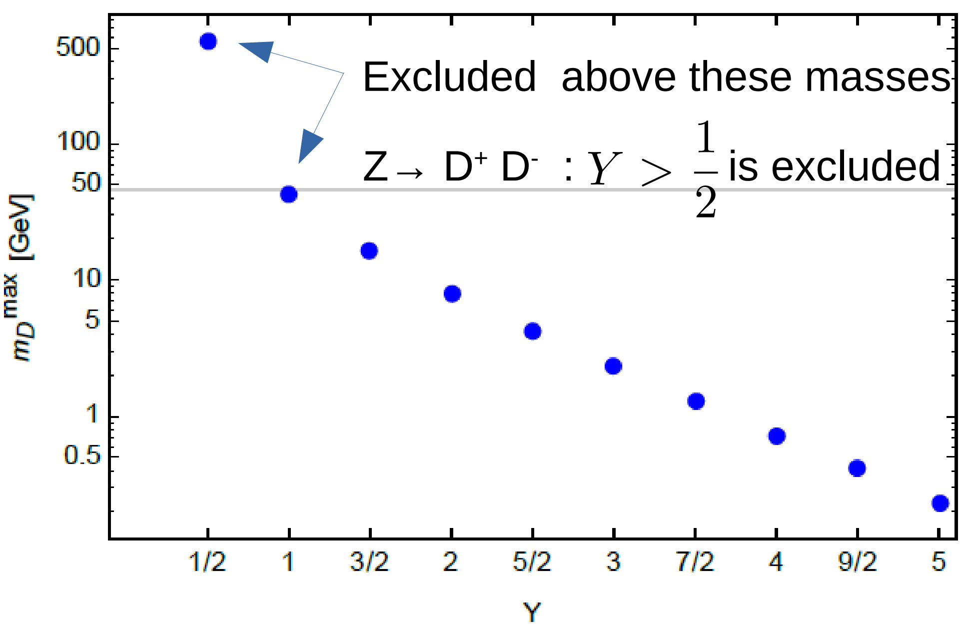
Y=0 minimal candidates may be discovered or ruled out at next generation of DD experiments

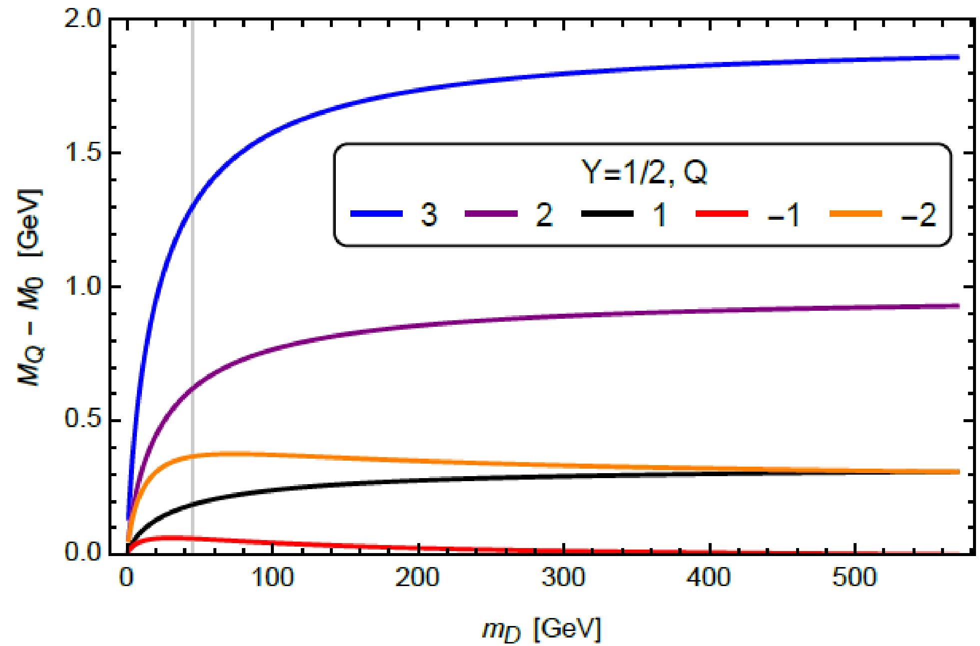
Radiative mass Split

simplest models with Y>1/2 are excluded



$$M_Q - M_{Q'}\big|_{m_D \gg m_W} \approx \frac{\alpha m_W}{2(1+c_W)}\left[(Q^2 - Q'^2) + \frac{2Y(Q-Q')}{c_W}\right]$$





Left: maximum value of m_D above which the lightest particle has charge Q = -1 for various values of Y

Right: spectrum for a generic multiplet with Y = 1/2, with mD < 570 GeV.

The vertical line shows $m_D \sim m_Z/2$, below which the model is excluded by the Z decays

Long Lived Particles (LLPs)

- LLPs appear in the minimal DM models with DM being the part of the EW multiplet: **the radiative mass split** of charged and neutral components is of the order of pion mass
- The **hypercharge of the multiplet**
  - a) should be zero, otherwise the the model is excluded by DM DD constraints from Z-boson exchange
  - b) or neutral component (DM) of the multiplet should be split by additional (e.g.Yukawa) interactions, which eliminate DM-DM-Z
  - c) multiplet for non-zero hypercharge can not be large – negatively charged component becomes the lightest particle

$$\begin{pmatrix} D^+ \\ D^0 \\ D^- \end{pmatrix} \longrightarrow \quad \Delta M = M_{D^\pm} - M_{D^0} \sim m_\pi$$

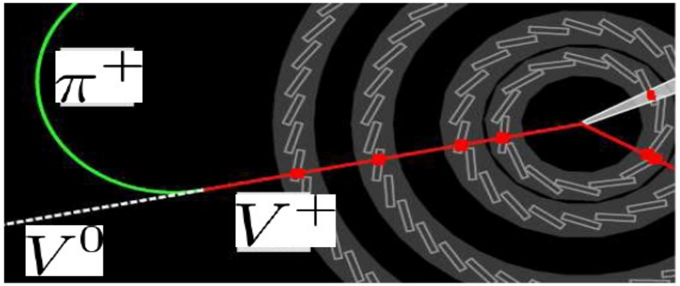
$$M_Q - M_{Q'}\big|_{m_D \gg m_W} \approx \frac{\alpha m_W}{2(1+c_W)}\left[(Q^2 - Q'^2) + \frac{2Y(Q-Q')}{c_W}\right]$$

Cirelli, Fornengo,Strumia 2005 (scalar and femion DM)

$$\Delta M = \frac{5 g_W^2 (M_W - c_W^2 M_Z)}{32\pi}$$

AB, Cacciapaglia, McKay, Marin, Zerwekh 2018 (vector DM)

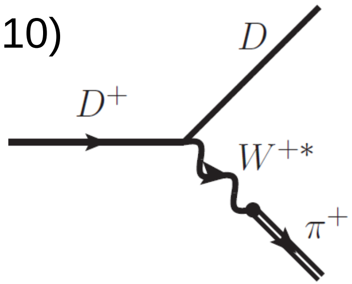
$D^+ \to D^0 \pi^+$ is the dominant decay, D^+ is LLP

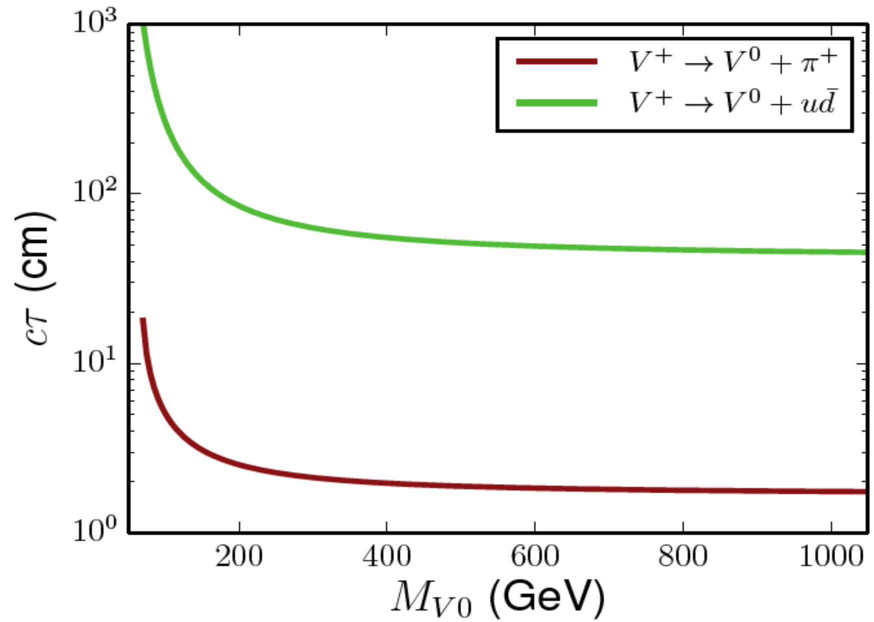


This small mass gap (~ pion mass) provides disappearing track signature

D^+ (charged partner of DM multiplet) decay

- D^+ life-time should be properly evaluated using W-pion mixing (otherwise overestimated by factor of 10)





$$\mathcal{L}_{W\pi} = \frac{g f_\pi}{2\sqrt{2}} W^+_\mu \partial^\mu \pi^- + \text{h.c.}$$

$$\mathcal{L}^{\text{i2HDM}}_{D^+D\pi^-} = -\frac{g^2 f_\pi}{4\sqrt{2}M_W^2}[(p_D - p_D^+)\cdot p_{\pi^-}]D^+D\pi^- + \text{h.c.}$$

$$\mathcal{L}^{\text{MFDM}}_{D^+D\pi^-} = -\frac{g^2 f_\pi}{4\sqrt{2}M_W^2}\cos(\theta_{DD_3}) p^\mu_{\pi^-} D^+\gamma^\mu D\pi^- + \text{h.c.}$$

$$\mathcal{L}^{\text{MSSM}}_{D^+D\pi^-} = -\frac{g^2 f_\pi}{4\sqrt{2}M_W^2} p_{\pi^- \mu} D^+ \left[g_L\gamma^\mu P_L + g_R \gamma^\mu P_R\right] D\pi^- + \text{h.c.}$$

$$\mathcal{L}^{\text{VDM}}_{D^+D\pi^-} = -\frac{g^2 f_\pi}{2\sqrt{2}M_W^2}\left[(p_D - p_{D+})^\mu g^{\nu\rho} - p^\nu_D g^{\mu\rho} + p^\rho_{D+} g^{\mu\nu}\right] p_{\pi^- \mu} D^+_\nu D_\rho \pi^- + \text{h.c.}$$

AB, Prestel, Rojas, Zurita [arXiv 2008.08581]

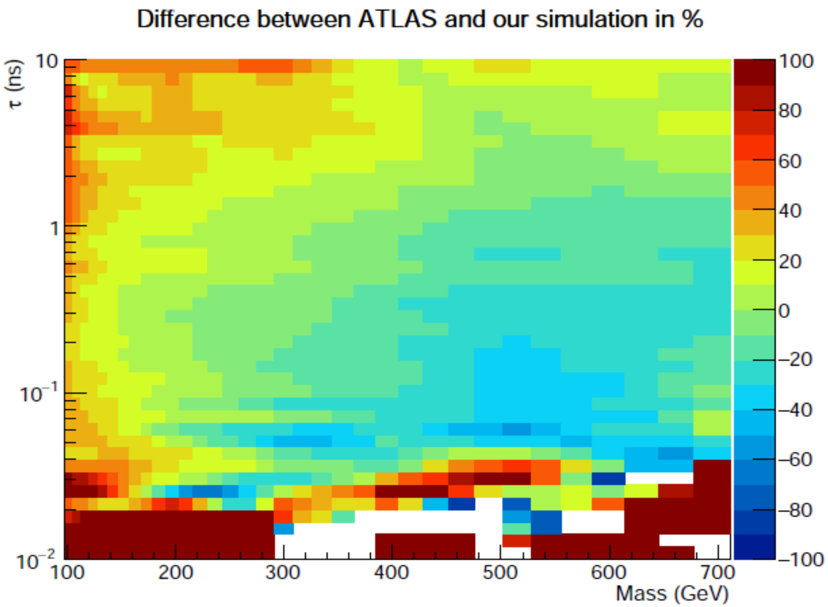
Disappearing track signature (DT) for DM probes

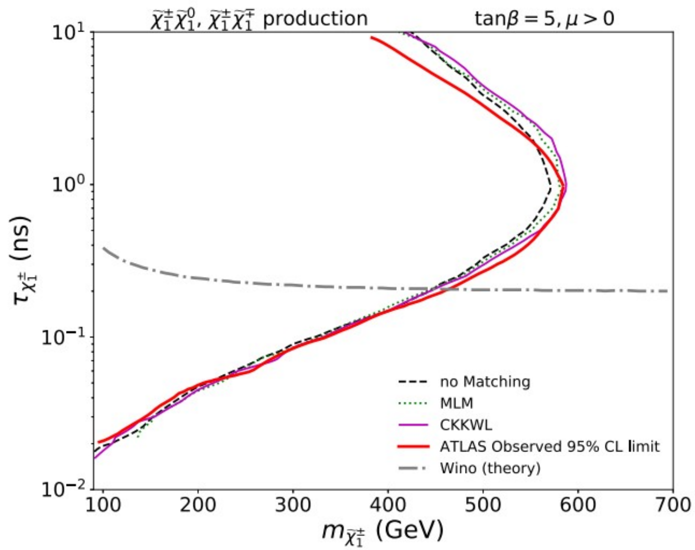
- We reinterpret ATLAS disappearing track search [arXiv:1712.02118] for long-lived charginos with disappearing-track signature for generic models with DM of different spins: 0, ½, 1

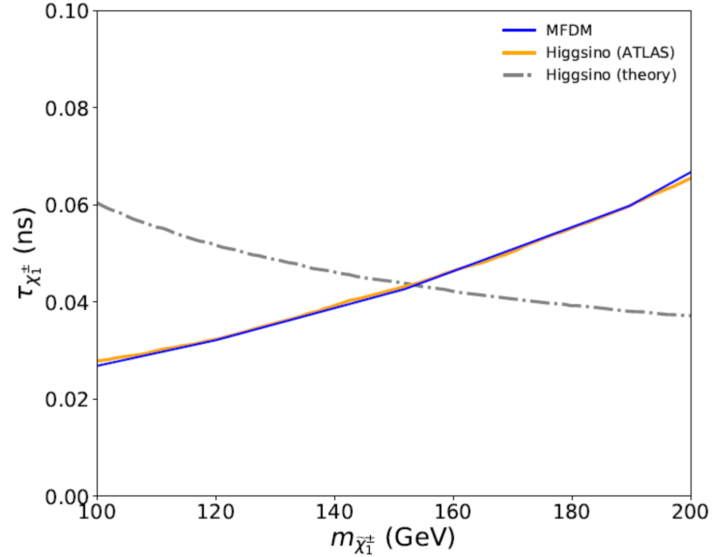
- Our stragegy [arXiv:2008.08581]
  - LanHEP → CalcHEP (LHE) → PYTHIA 8.245 (Latest CKK merging) → Delphes 3.4.1 → analysis code
    - LanHEP/CaclHEP: i2HDM, MFDM, VTDM models with the correct W-pion mixing, models are public at HEPMDB https://hepmdb.soton.ac.uk/ (0820.0330, 0820.0329, 0820.0331)
    - PYTHIA 8.245: improved CKK merging (Stefan Prestel)
    - Delphes 3.4.1: ATLAS card, in particular, to simulate correctly MET from visible ET leptons and jets
    - analysis code (Felipe Rojas): implements ATLAS cuts and efficiency “heatmap” for tracklet ID, evaluates efficiencies and limits for general models
  - Validate our code by comparing with ATLAS limits
  - Find new limits for generic DM models with spin 0, ½ , 1
  - Provide publicly the code and efficiency/limits map in (MDM-τ) plane

Validation of our code/results against ATLAS for DT

- Total acceptance x efficiency check in MDM-τ plane







- Compare Limits in MDM-τ plane for pure wino and higgsino models

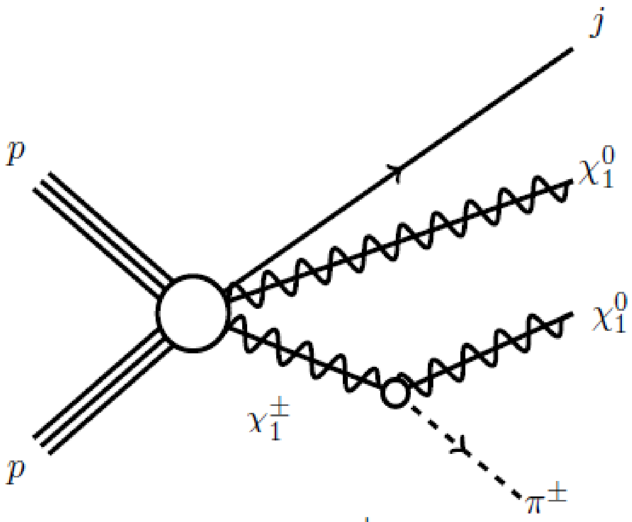
- The difference in limits on chargino mass is less than 5%

Using DT to probe minimal DM models

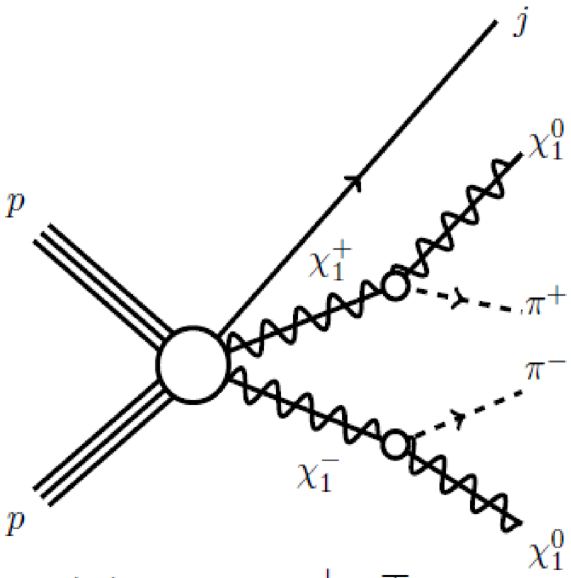
We apply our validated analysis to minimal consistent models

- Scalar: Inert two-Higgs doublet model (i2HDM)
- Minimal Fermion Dark Matter model (MFDM)
- Vector: Minimal Vector Triplet Dark Matter model (VTDM)

- Two classes of processes: D^+D^- and D^+D^0/D^-D^0 production mediated by s-channel Z/γ and W^+/W^- respectively



(a) $pp \to \chi_1^\pm \chi_1^0 j$



(b) $pp \to \chi_1^\pm \chi_1^\mp j$

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We apply our validated analysis to minimal consistent models

- Scalar: Inert two-Higgs doublet model (i2HDM)
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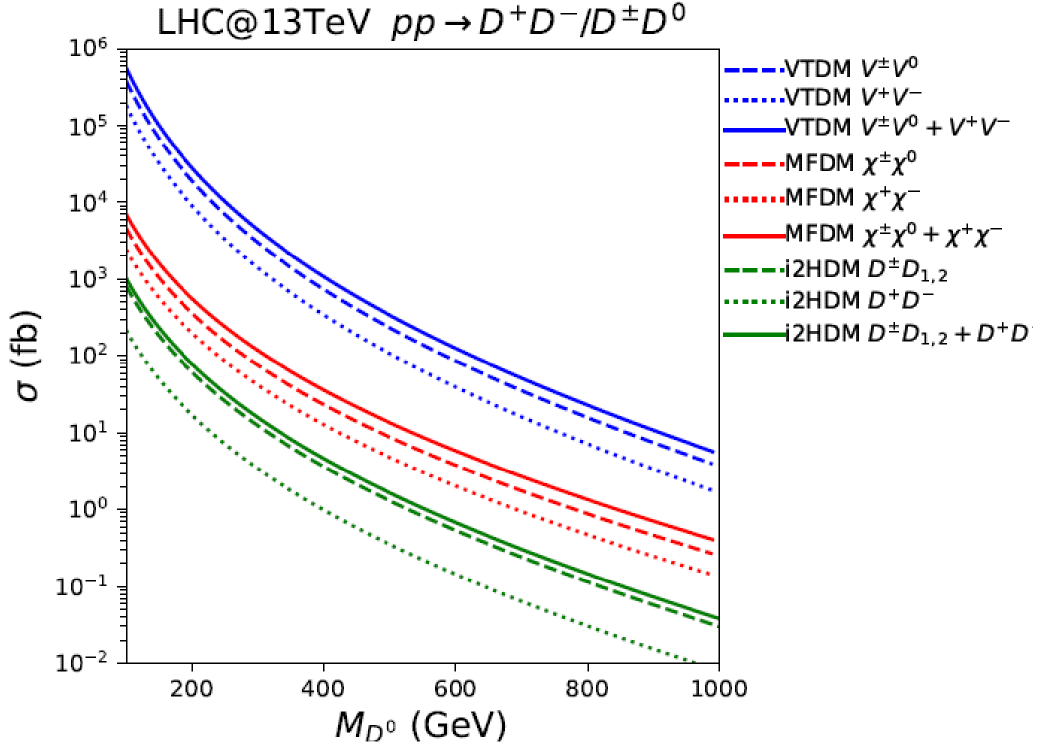
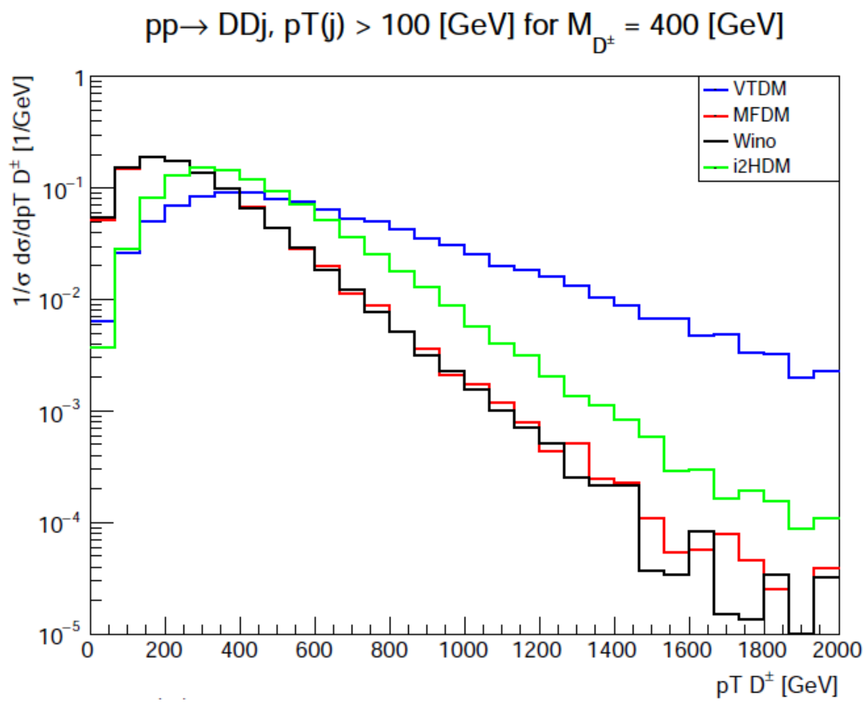
- Cross section and Transverse momentum distribution hierarchy: VTDM → MFDM → i2HDM defines the respective hierarchy of the efficiencies and the LHC sensitivity





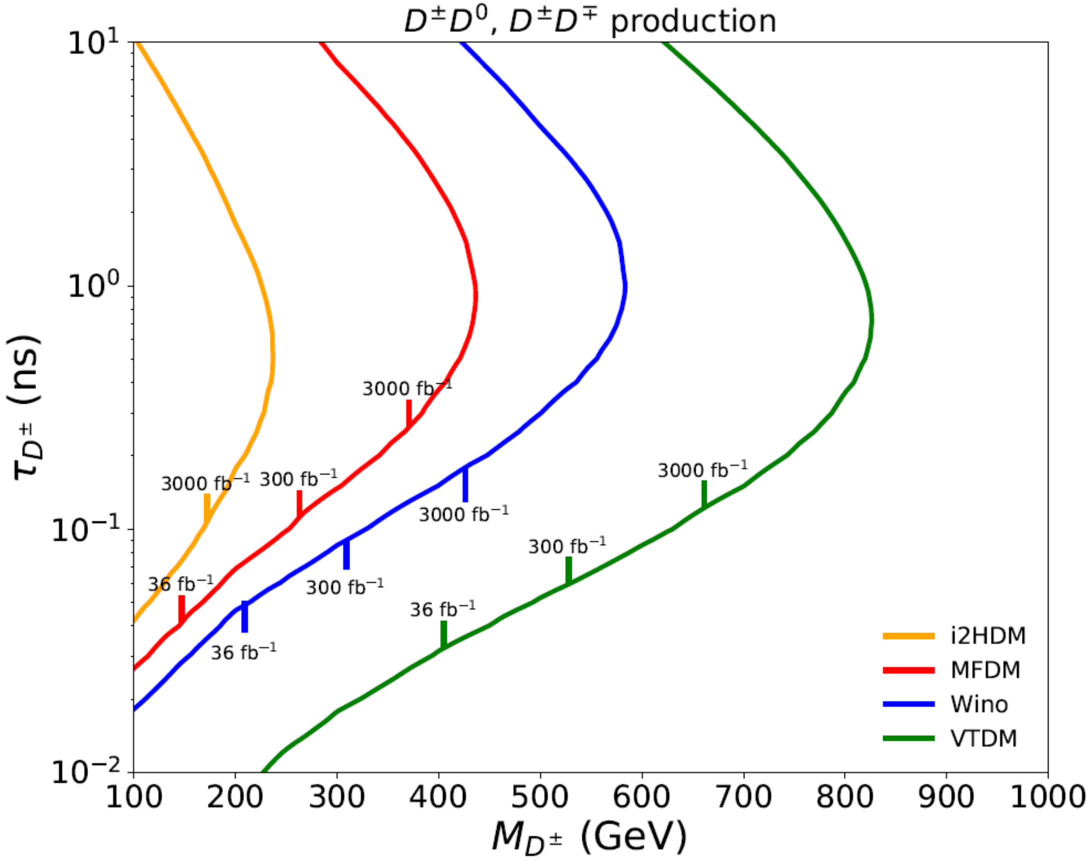
The power of DT for DM probe versus mono-jet limits

- New DT limits for DM models with different spin

- The limits are well beyond those from mono-jet signature analysis for $\tau \sim 1$ ns

Models	Mass (GeV)	tau (ns)
i2HDM	237	0.5
MFDM	436	0.9
VTDM	822	0.7
WINO	587	1.0

- VTDM → MFDM → i2HDM hierarchy is defined by CS and PT



AB, Prestel, Rojas, Zurita [arXiv 2008.08581]

$\widetilde{F}^{1/2}_{1/2}\widetilde{M}^{0}_{0}$

Z2 odd → $\widetilde{X}^{i}_{y}$ ← isospin

spin ↗ ↖ hypercharge

Minimal fermion DM model

+Mediator

Spin of Mediator \ Spin of Dark Matter	0	1/2	1
spin 0 even mediator	$\widetilde{S}^I_Y S^{I'}_{Y'}$	$\widetilde{F}^I_Y S^{I'}_0$	$\widetilde{V}^I_Y S^{I'}_{Y'}$
spin 0 odd mediator	$\widetilde{S}^I_Y \widetilde{S}^{I'}_{Y'}$	$\widetilde{F}^I_Y \widetilde{S}^{I'}_{Y'}$ $\widetilde{F}^I_Y \widetilde{S}^{I'c}_{Y'}$	$\widetilde{V}^I_Y \widetilde{S}^{I'}_{Y'}$
spin 1/2 even mediator			
spin 1/2 odd mediator	$\widetilde{S}^I_Y \widetilde{F}^{I'}_{Y'}$ $\widetilde{S}^I_Y \widetilde{F}^{I'c}_{Y'}$	$\widetilde{F}^I_Y \widetilde{F}^{I\pm1/2}_{Y\pm1/2}$	$\widetilde{V}^I_Y \widetilde{F}^{I'}_{Y'}$ $\widetilde{V}^I_Y \widetilde{F}^{I'c}_{Y'}$
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- **ILC:** D.Locke, A.Freegard, I.Ginzburg, T.Hosken, A.Pukhov, AB (to appear)
- **Drell Yan, VBF**: U.Blumenschein, A.Freegard, S.Moretti, AB (to appear)

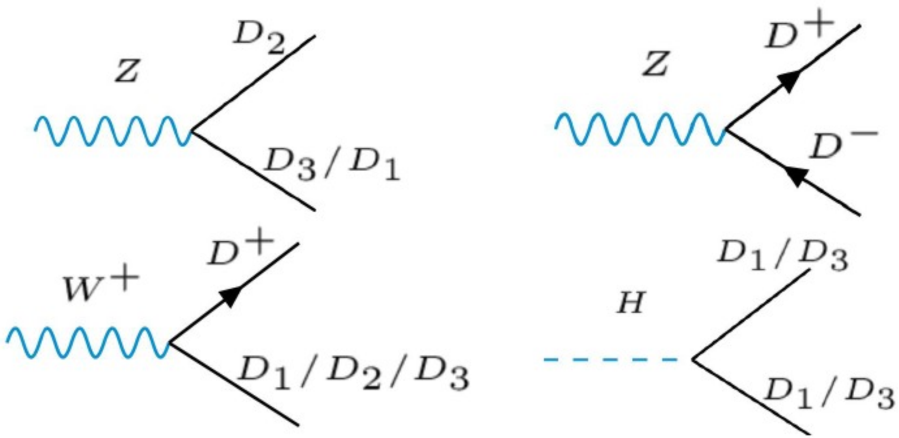
$\widetilde{F}^{1/2}_{1/2}\widetilde{M}^{0}_{0}$

Minimal fermion DM model (MFDM)

gives 2/3 -lepton signatures at the LHC

$$\mathcal{L}_{FDM} = \mathcal{L}_{SM} + \bar{\psi}(i\not{D} - m_\psi)\psi + \frac{1}{2}\bar{\chi}^0_s(i\not{\partial} - m_s)\chi^0_s - (Y(\bar{\psi}\Phi\chi^0_s) + h.c.)$$

$$\psi = \begin{pmatrix} \chi^+ \\ \frac{1}{\sqrt{2}}(\chi^0_1 + i\chi^0_2) \end{pmatrix}$$, additional Majorana singlet fermion χ^0_s



$$[M_{D1}, \Delta M_{D+}, \Delta M_{D3}]$$

only three parameters (effectively two for the LHC)

$\widetilde{F}^{1/2}_{1/2}\widetilde{M}^{0}_{0}$

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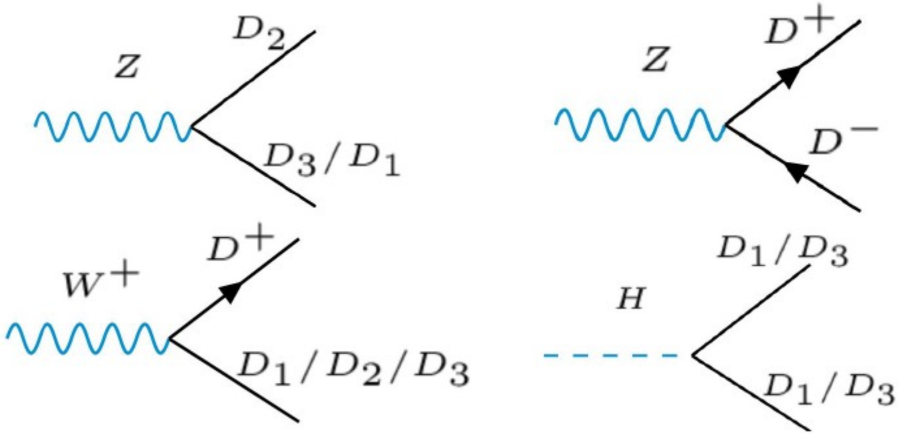

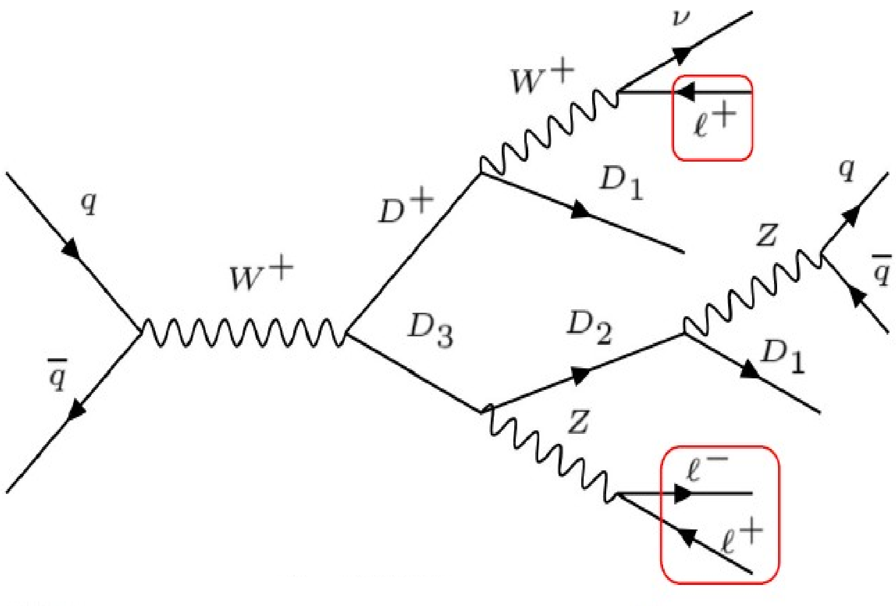

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$\widetilde{F}^{1/2}_{1/2}\widetilde{M}^{0}_{0}$

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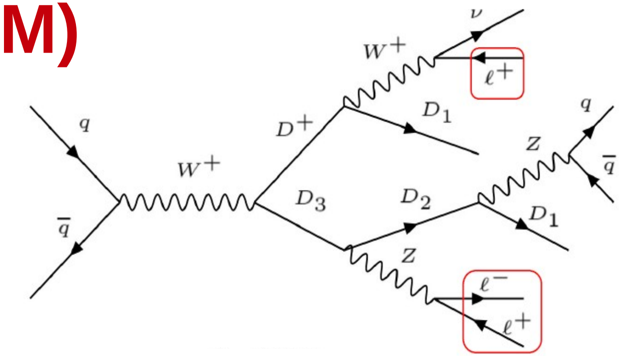

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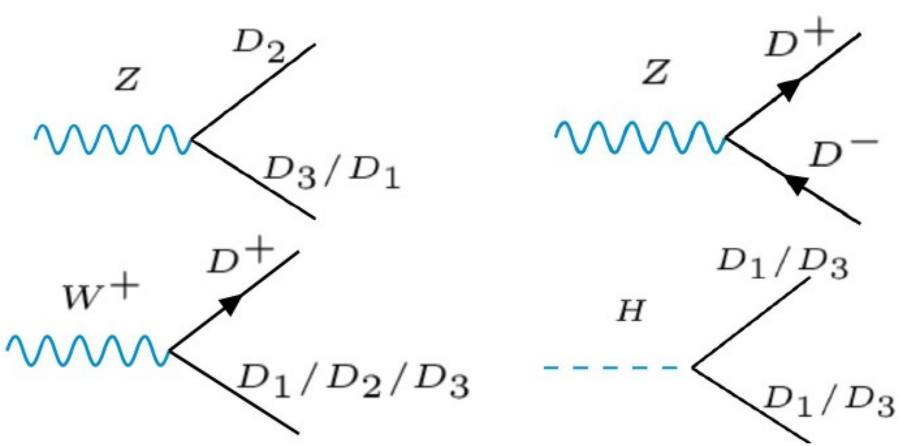
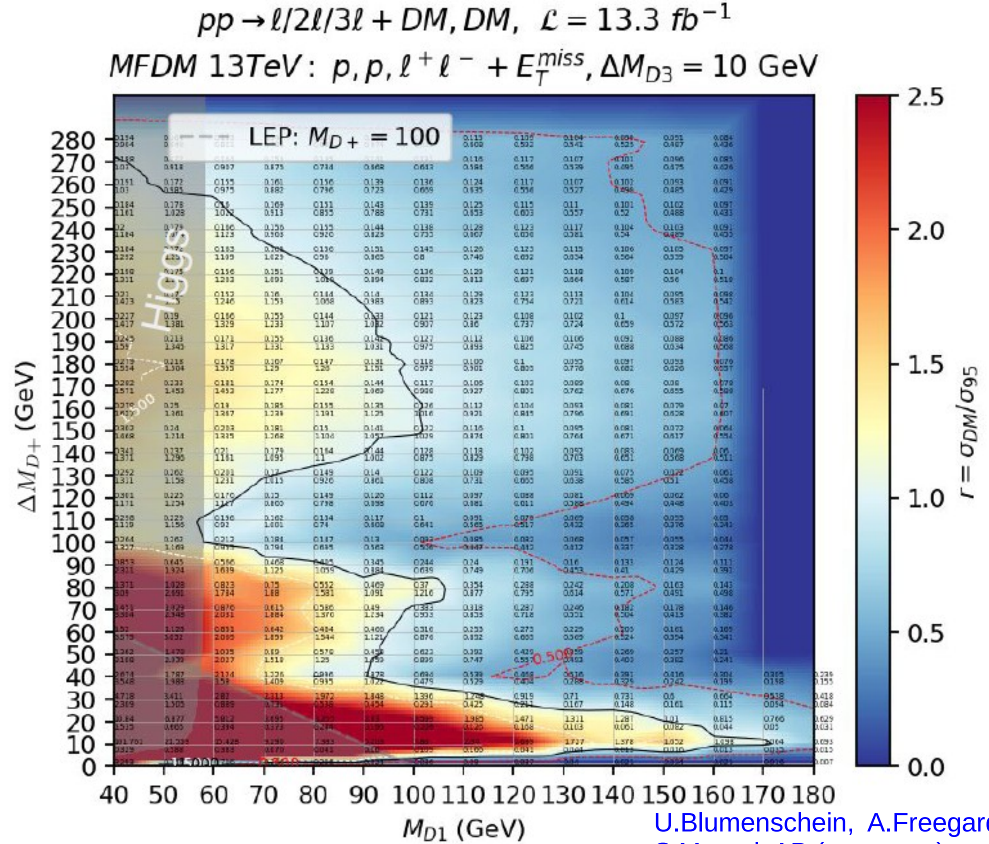


$$[M_{D1}, \Delta M_{D+}, \Delta M_{D3}]$$



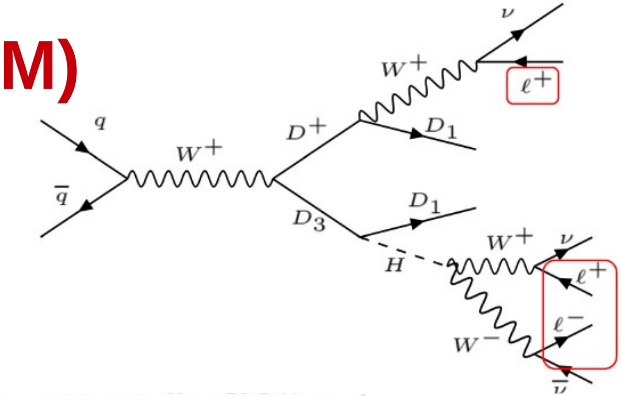
only three parameters (effectively two for the LHC)

U.Blumenschein, A.Freegard, S.Moretti, AB (to appear)

$\widetilde{F}^{1/2}_{1/2}\widetilde{M}^0_0$

Minimal fermion DM model (MFDM)

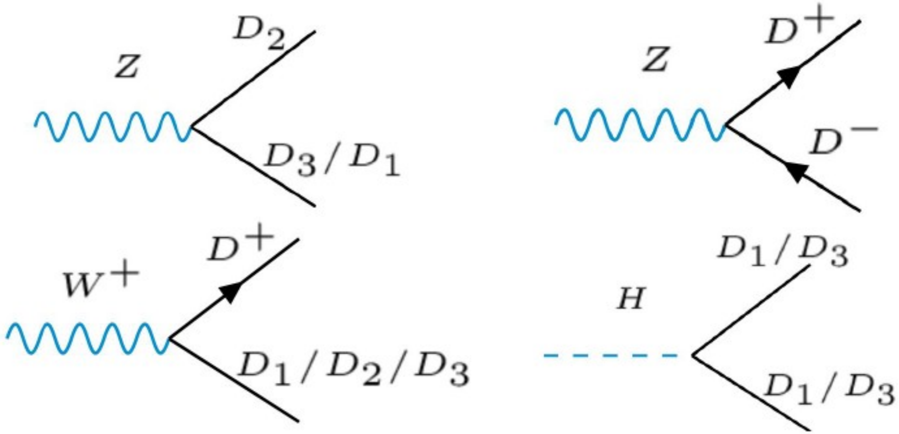
gives 2/3 -lepton signatures at the LHC



$$\mathcal{L}_{FDM} = \mathcal{L}_{SM} + \bar{\psi}(i\not{D} - m_\psi)\psi + \frac{1}{2}\bar{\chi}^0_s(i\not{\partial} - m_s)\chi^0_s - (Y(\bar{\psi}\Phi\chi^0_s) + h.c.)$$

$$\psi = \begin{pmatrix} \chi^+ \\ \frac{1}{\sqrt{2}}(\chi^0_1 + i\chi^0_2) \end{pmatrix}$$

, additional Majorana singlet fermion χ^0_s



$$[M_{D1}, \Delta M_{D+}, \Delta M_{D3}]$$

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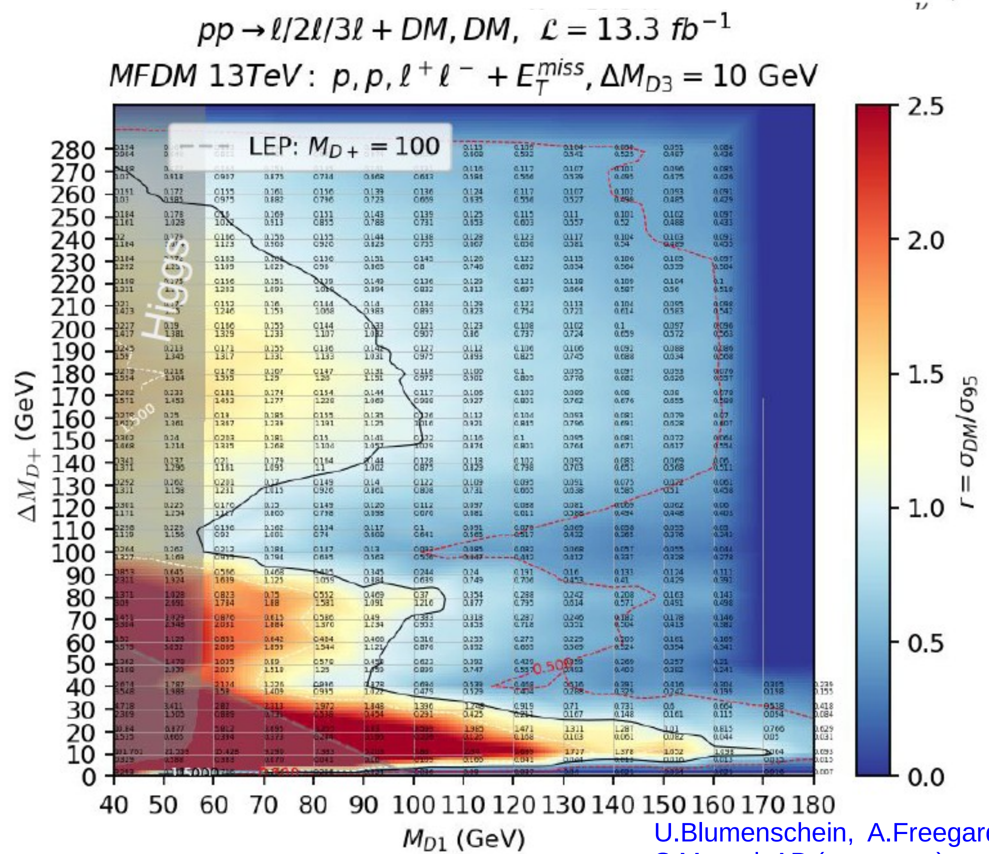
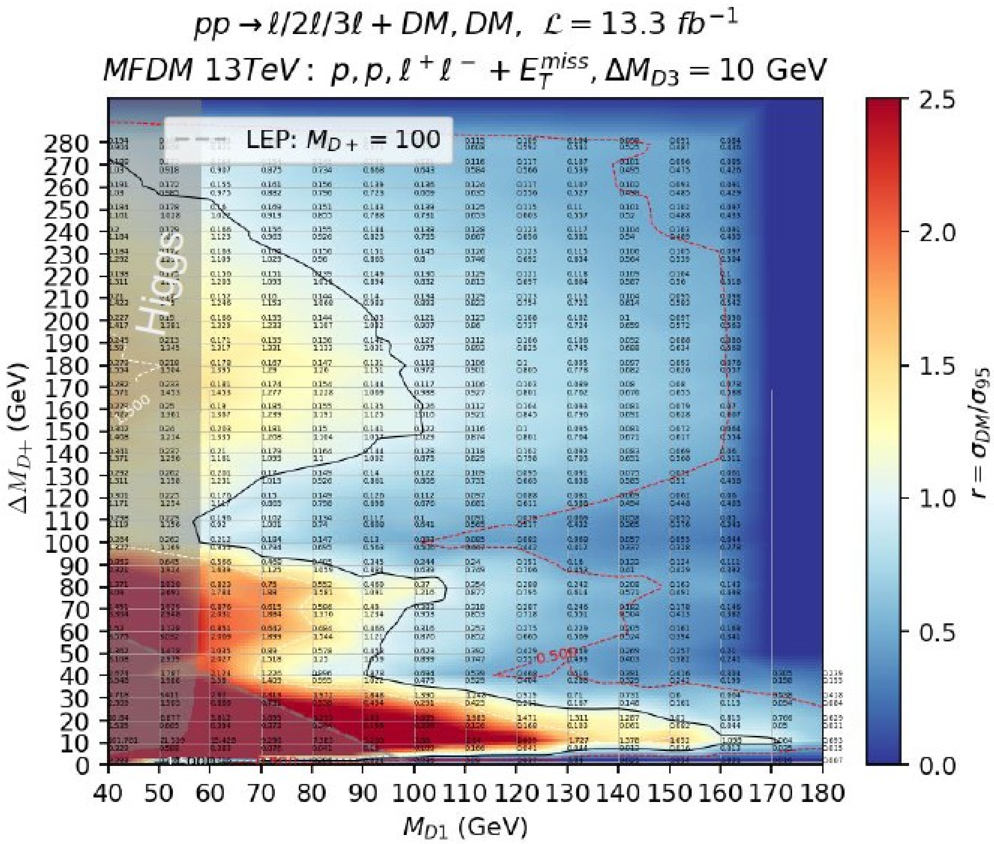
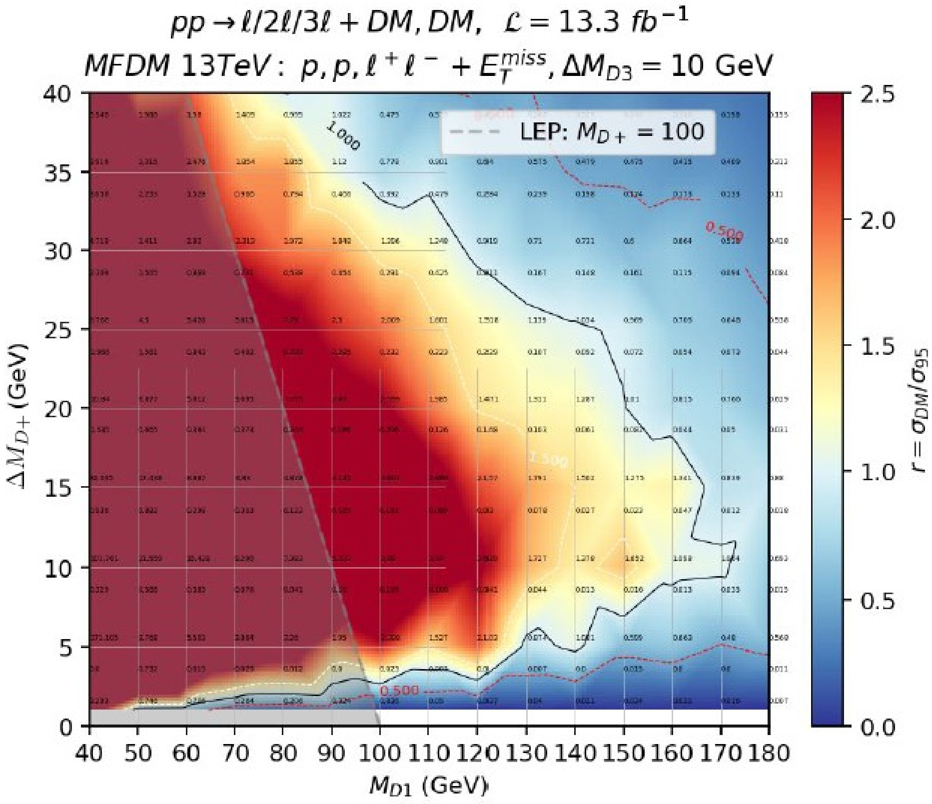


U.Blumenschein, A.Freegard, S.Moretti, AB (to appear)

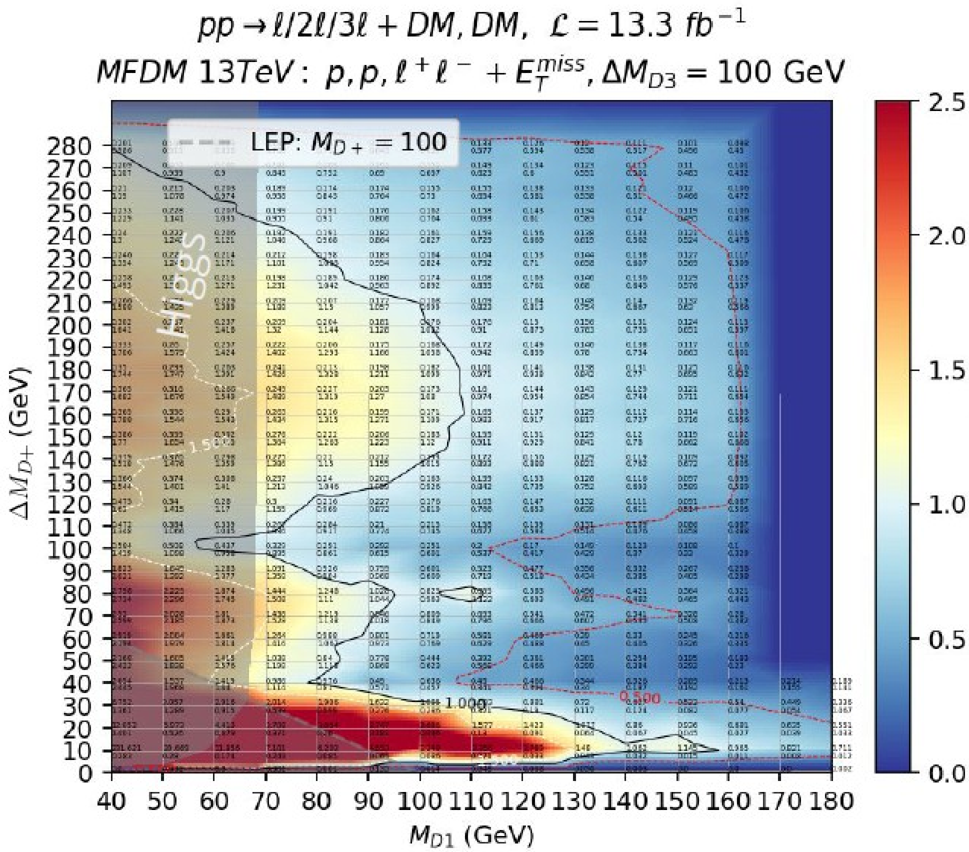
MFDM Results

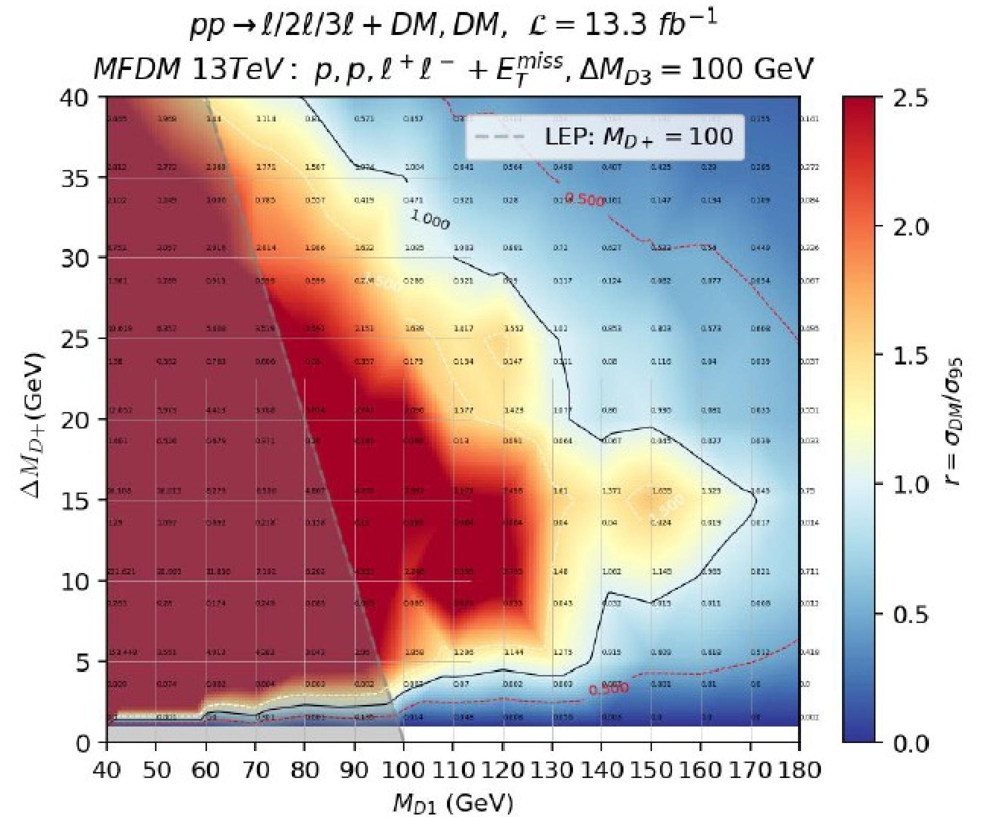




- As ΔM_{D3} increases, coupling between $D_1 - D^{\pm}$ increases, while heavy D_3 leads to suppressed production cross-section - 'no-lose' theorem

MFDM Results





- With increasing ΔM_{D3}, Higgs to invisible limit covers larger M_{D1} upto $M_{D1} = M_H/2$

$\tilde{F}^0_0 S^0_0 (CP-odd)$

Z2 odd

isospin

$\tilde{X}^i_y$

spin

hypercharge

Minimal fermion DM model with pseudo-scalar mediator

new model, has not been explored previously

two-component DM model (pseudoscalar is accidentally stable)

Spin of Dark Matter / Spin of Mediator	0	1/2	1
spin 0 even mediator	$\tilde{S}^I_Y S^{I'}_{Y'}$	$\tilde{F}^I_Y S^{I'}_0$	$\tilde{V}^I_Y S^{I'}_{Y'}$
spin 0 odd mediator	$\tilde{S}^I_Y \tilde{S}^{I'}_{Y'}$	$\tilde{F}^I_Y \tilde{S}^{I'}_{Y'}$ $\tilde{F}^I_Y \tilde{S}^{I'c}_{Y'}$	$\tilde{V}^I_Y \tilde{S}^{I'}_{Y'}$
spin 1/2 even mediator			
spin 1/2 odd mediator	$\tilde{S}^I_Y \tilde{F}^{I'}_{Y'}$ $\tilde{S}^I_Y \tilde{F}^{I'c}_{Y'}$	$\tilde{F}^I_Y \tilde{F}^{I\pm1/2}_{Y\pm1/2}$	$\tilde{V}^I_Y \tilde{F}^{I'}_{Y'}$ $\tilde{V}^I_Y \tilde{F}^{I'c}_{Y'}$
spin 1 even mediator	$\tilde{S}^I_Y V^{I'}_0$	$\tilde{F}^I_Y V^{I'}_0$	$\tilde{V}^I_Y V^{I'}_{Y'}$
spin 1 odd mediator	$\tilde{S}^I_Y \tilde{V}^{I'}_{Y'}$	$\tilde{F}^I_Y \tilde{V}^{I'}_{Y'}$ $\tilde{F}^I_Y \tilde{V}^{I'c}_{Y'}$	$\tilde{V}^I_Y \tilde{V}^{I'}_{Y'}$

G.Cacciapaglia, D.Locke, AB arXiv:**2104.xxxxx**

$\tilde{F}^0_0 S^0_0 (CP - odd)$

Minimal fermion DM model with pseudo-scalar mediator

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two-component DM model (pseudoscalar is accidentally stable)

Z2 odd

$\tilde{X}^i_y$

isospin

spin

hypercharge

$$\mathcal{L} \supset iY_\psi a \bar{\psi} \gamma^5 \psi - \frac{\lambda_{aH}}{4} |a|^2 \phi_H^\dagger \phi_H$$

Fermion DM Singlet

pseudoscalar

SM Higgs doublet

- a does not acquire VEV → no linear coupling to Higgs
- $m_a < 2m_\psi$ → “secluded DM”
- Model implemented in LanHEP, and numerical scan performed using micrOMEGAs.

4 relevant parameters:

$$m_\psi, \; Y_\psi, \; m_a, \; \lambda_{aH}$$

Spin of Mediator \ Spin of Dark Matter	0	1/2	1
spin 0 even mediator	$\tilde{S}^I_Y S^{I'}_{Y'}$	$\tilde{F}^I_Y S^{I'}_0$	$\tilde{V}^I_Y S^{I'}_{Y'}$
spin 0 odd mediator	$\tilde{S}^I_Y \tilde{S}^{I'}_{Y'}$	$\tilde{F}^I_Y \tilde{S}^{I'}_{Y'}$ $\tilde{F}^I_Y \tilde{S}^{I'c}_{Y'}$	$\tilde{V}^I_Y \tilde{S}^{I'}_{Y'}$
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spin 1 even mediator	$\tilde{S}^I_Y V^{I'}_0$	$\tilde{F}^I_Y V^{I'}_0$	$\tilde{V}^I_Y V^{I'}_{Y'}$
spin 1 odd mediator	$\tilde{S}^I_Y \tilde{V}^{I'}_{Y'}$	$\tilde{F}^I_Y \tilde{V}^{I'}_{Y'}$ $\tilde{F}^I_Y \tilde{V}^{I'c}_{Y'}$	$\tilde{V}^I_Y \tilde{V}^{I'}_{Y'}$

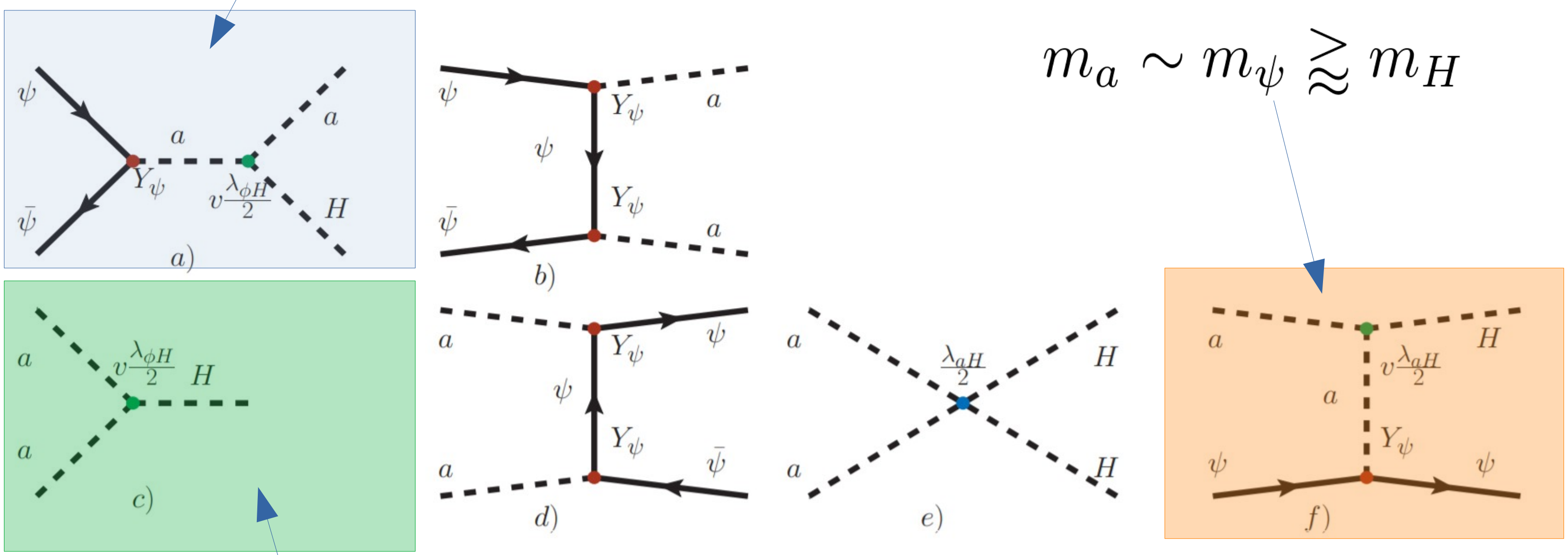
G.Cacciapaglia, D.Locke, AB arXiv:**2104.xxxxx**

Minimal fermion DM model with pseudo-scalar mediator:
rich phenomenology: relic density, DD, colliders

(co)Annihilation channels

$$m_\psi \gtrapprox \frac{m_a + m_h}{2} \gtrapprox \frac{3m_H}{4} \sim 90GeV$$

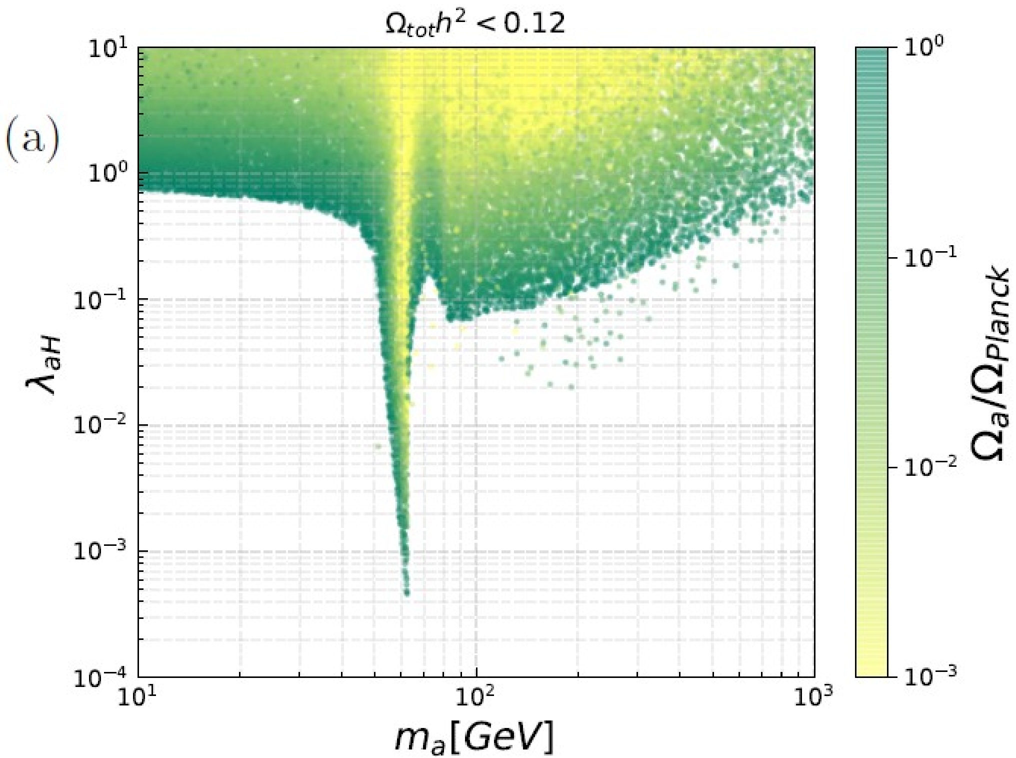
$$m_a \sim m_\psi \gtrapprox m_H$$

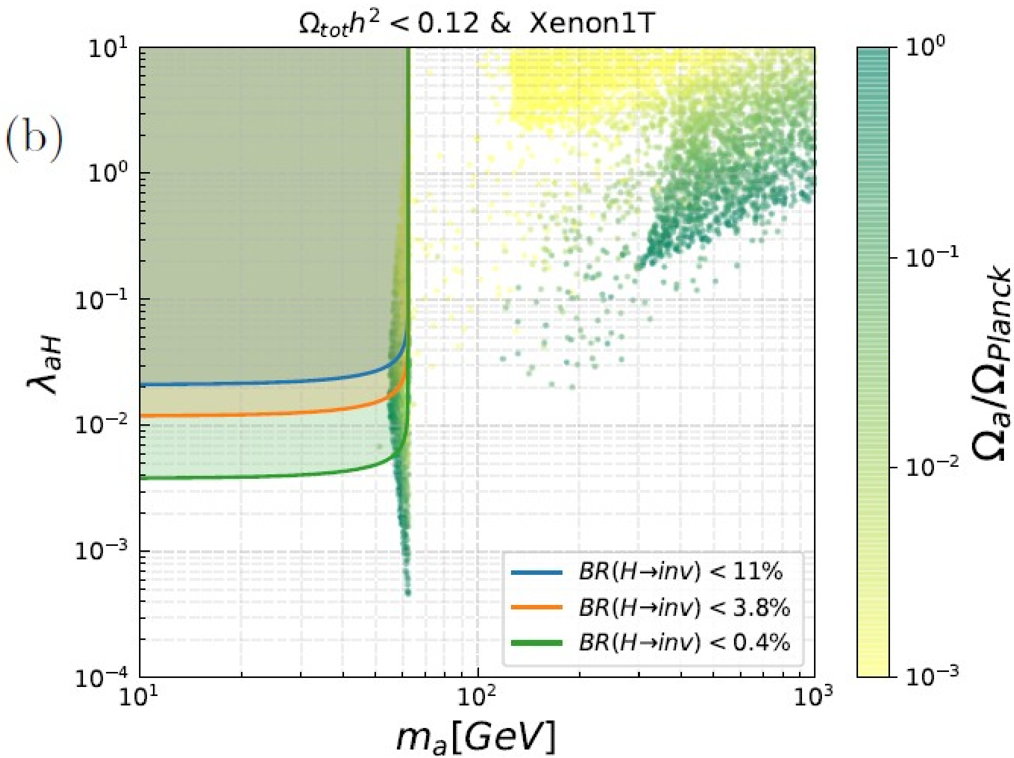


aa→WW
ma>80GeV
aa→ZZ
ma>90GeV
aa→tt
ma>173GeV

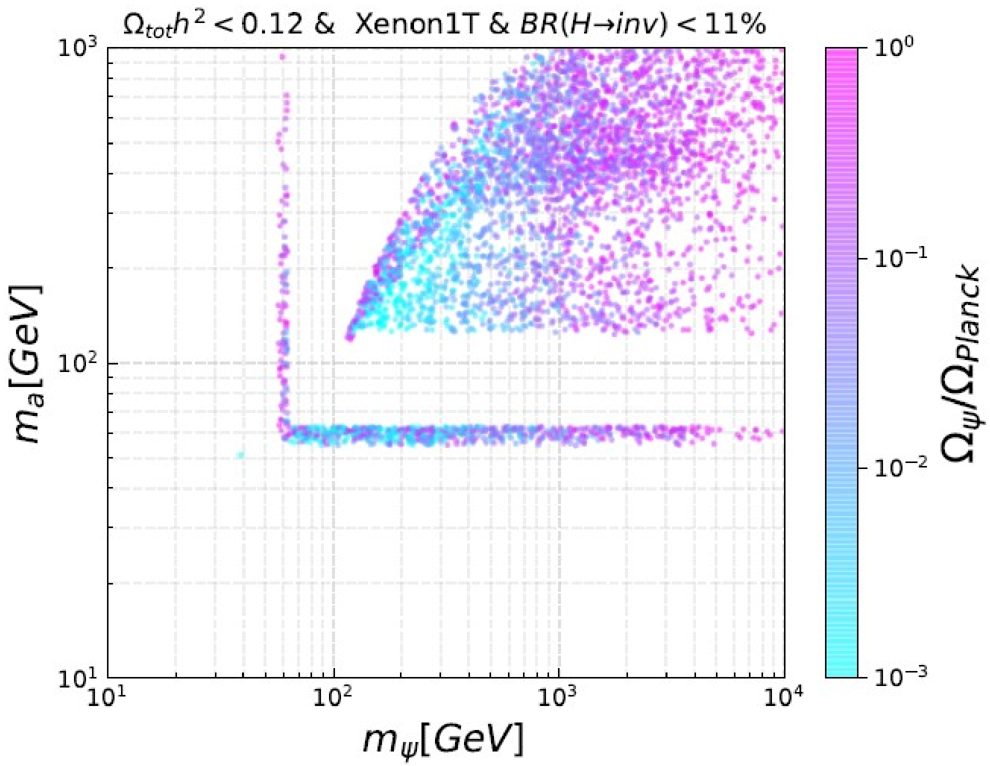
$$\sigma^{ann}_{aa\to ff}v \sim \frac{\lambda^2 m_f^2}{(4m_a^2 - m_H^2)^2 + m_H^2\Gamma_H^2)}$$

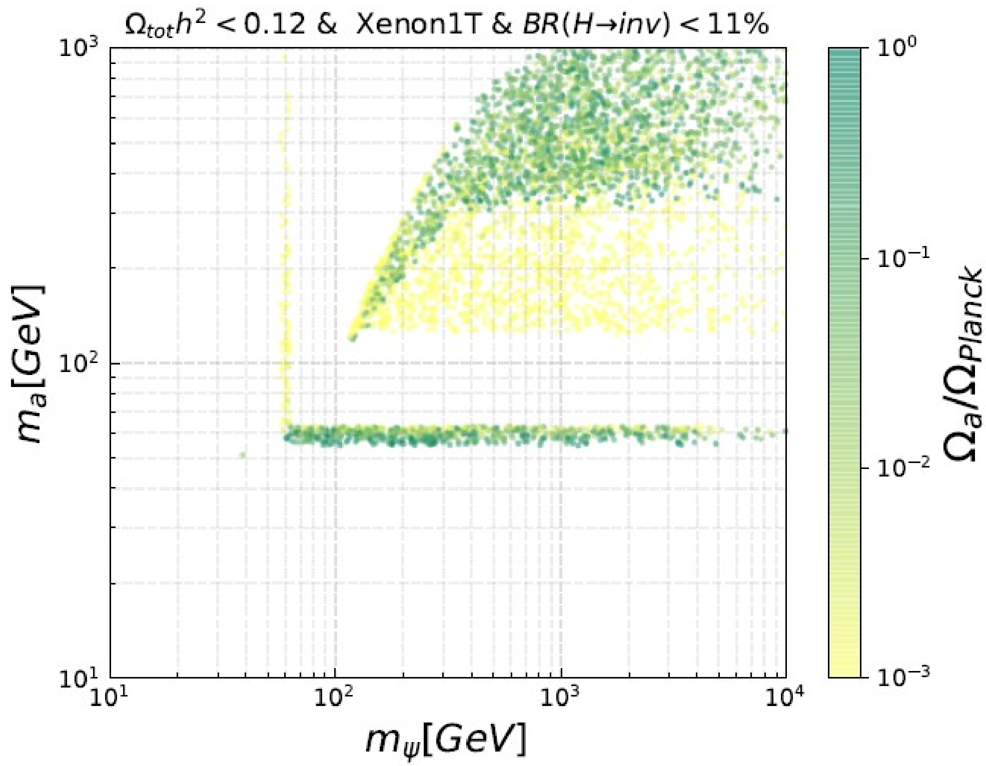
Minimal fermion DM model with pseudo-scalar mediator:
rich phenomenology: relic density, DD, colliders





Minimal fermion DM model with pseudo-scalar mediator:
Xenon1T vs LZ exclusion





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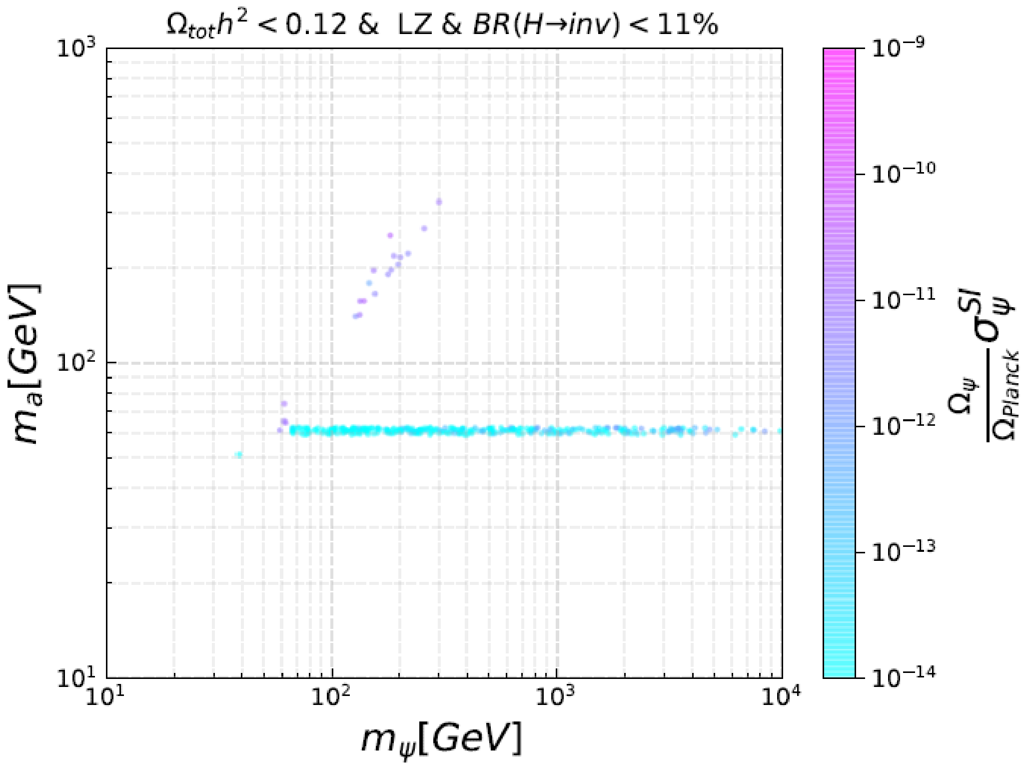
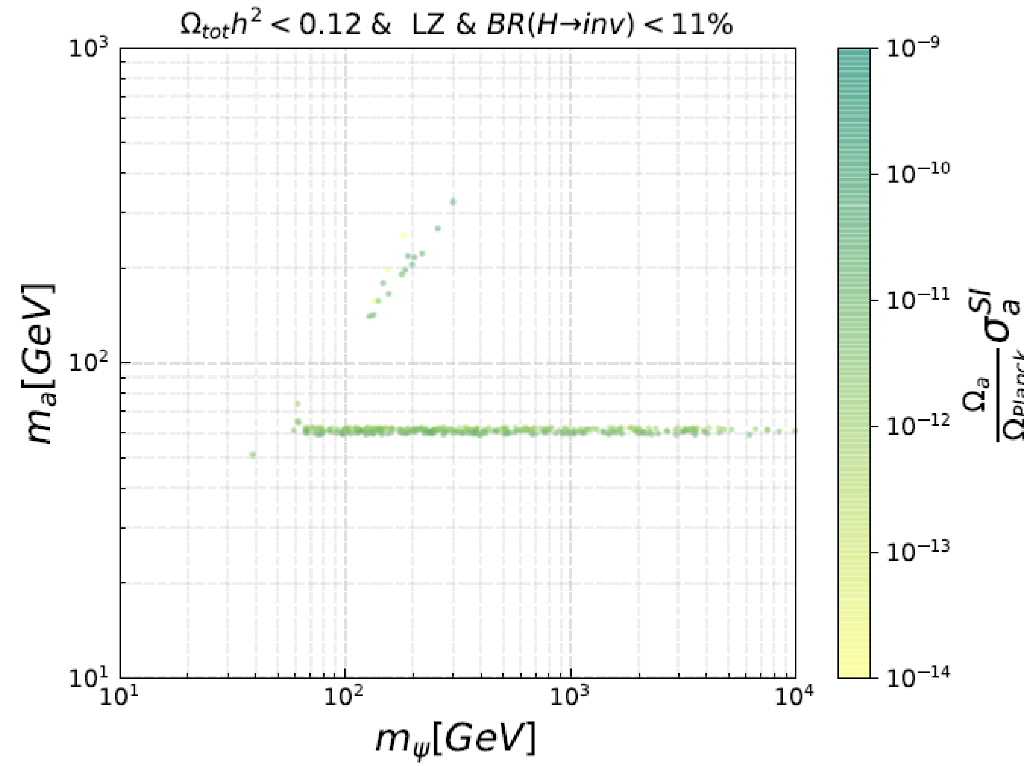
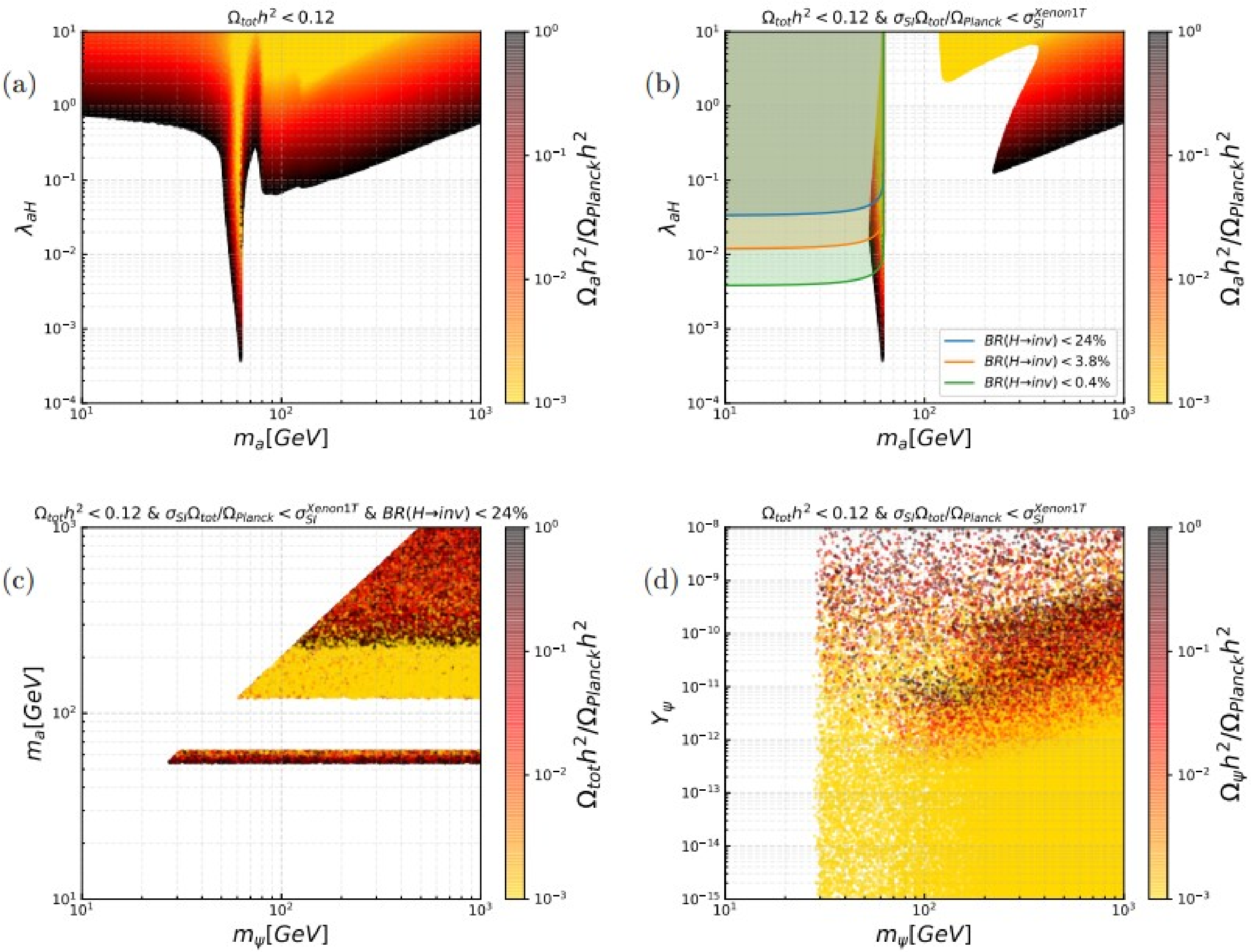
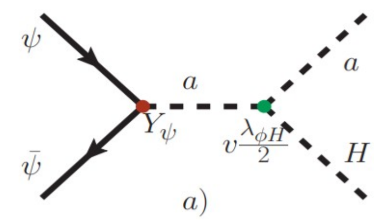


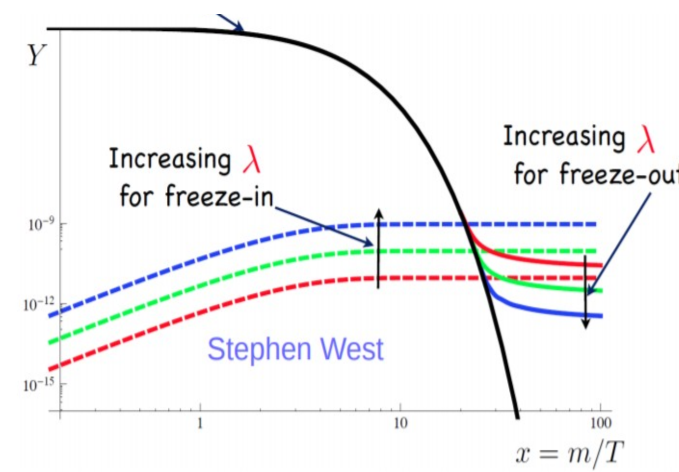


Minimal fermion DM model with pseudo-scalar mediator: non-thermal ψ

$$m_a < 2m_\psi$$





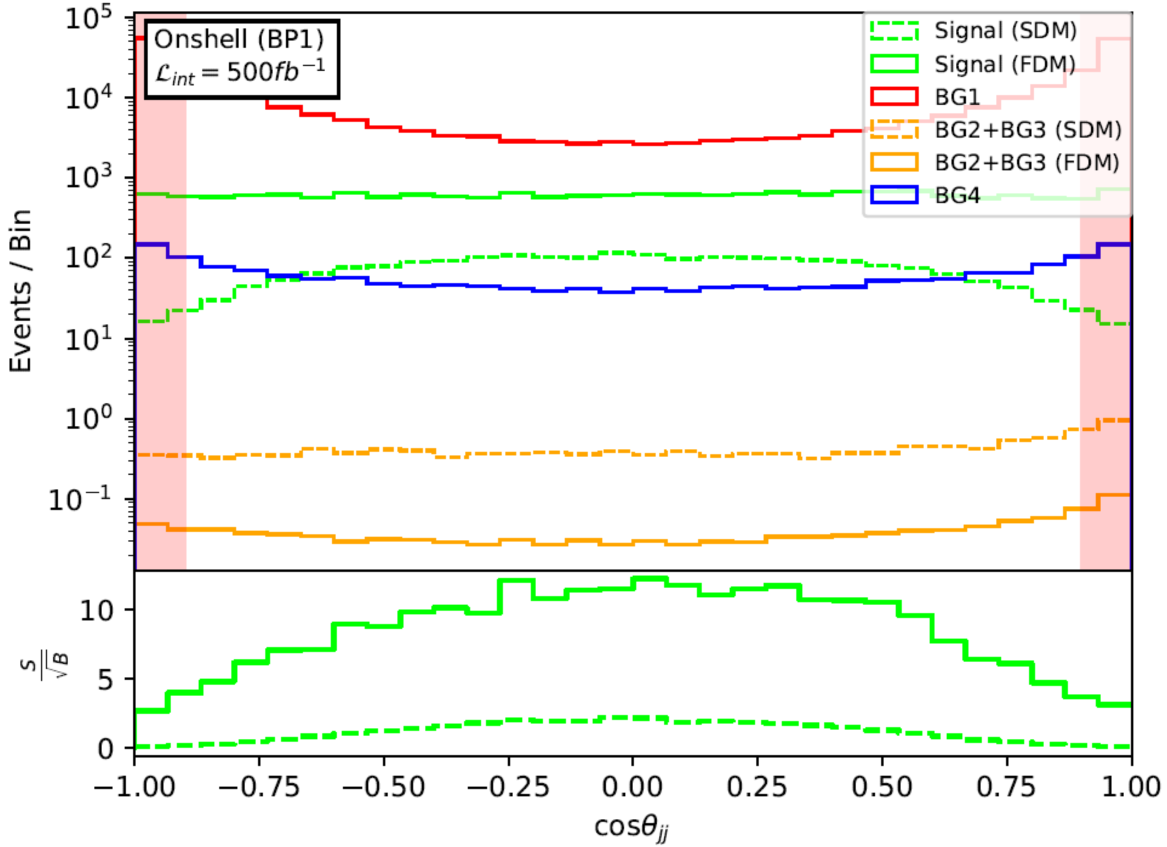


Small Y – FDM initially decoupled from SM+a bath, freezes in whilst a freezes out

Decoding the nature of DM at the ILC

muon spectrum from the models with scalar and fermion DM

e+e- → D+ D- → DM DM W+ W- → DM DM jj μ ν



Parameters \ Benchmarks		BP1
M_D		60
M_+		160
M_{D_2}		160.85
I2HDM parameters		
λ_{345}		6.5×10^{-4}
λ_2		1.0
DM observables		
Ωh^2	SDM	0.111
	FDM	0.108
σ^p_{SI}[pb]	SDM	6.17×10^{-13}
	FDM	1.67×10^{-11}

AB, Ginzburg, Locke, Freegard, Pukhov preliminary

Decoding Problem: Data → Theory link

- probably the most challenging problem to solve – **the inverse problem of decoding of the underlying theory from signal**
  - requires database of models, database of signatures
  - requires smart procedure based on machine learning of matching signal from data with the pattern of the signal from data

Decoding Problem: Data → Theory **link**

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- **HEPMDB (High Energy Physics Model Database)** was created in 2011 **hepmdb.soton.ac.uk**
  - convenient centralized storage environment for HEP models
  - it allows to evaluate the LHC predictions and perform event generation using CalcHEP, Madgraph for any model stored in the database
  - you can upload there your own model and perform simulation

Conclusions and Outlook

- **To decode the nature of DM** we need a signal first! But at the moment we can
  - understand what kind of DM is already excluded
  - systematically explore theory/parameter space and prepare to DM decoding
- **MCDM models:** consistent but simple – one can explore the entire parameter space
- **Systematic classification** is suggested: new models can be found even for simplest cases, e.g. 2-**component DM** with pseudoscalar mediator in $\tilde{F}_0^0 S_0^0 (CP-odd)$ model
- **Probing DM space**
  - non-singlets can be probed via DT searches or multi-lepton signatures at colliders.
  - DM DD is sensitive to the loop-induced diagrams but not exclude all models
  - sensitivity is highly dependent on mass-split
  - rich phenomenology
- **HEPMDB** (hepmdb.soton.ac.uk): the database for BSM models, including DM

Thank you!

Backup slides

Details on DT studies

Public source for the interpretation

- The reinterpretation code is public at https://github.com/llprecasting/recastingCodes/ [reads root file after LHE → PYTHIA → Delphes simulation]

- Tables of efficiencies and limits in MDM-τ plane allow to quickly find the reach for your own model in a simple code

tau	Mass (GeV)						
(ns)	100	200	300	400	500	600	700
0.01	1.37e-06	1.90e-07	5.64e-08	1.86e-08	1.17e-08	2.59e-11	2.41e-09
0.02	2.31e-05	9.19e-06	4.13e-06	2.26e-06	1.46e-06	6.29e-07	3.84e-07
0.03	8.67e-05	5.20e-05	3.10e-05	2.06e-05	1.43e-05	8.99e-06	6.72e-06
0.04	1.90e-04	1.43e-04	1.02e-04	7.52e-05	5.61e-05	4.06e-05	3.24e-05
0.05	3.19e-04	2.83e-04	2.27e-04	1.77e-04	1.42e-04	1.10e-04	9.33e-05

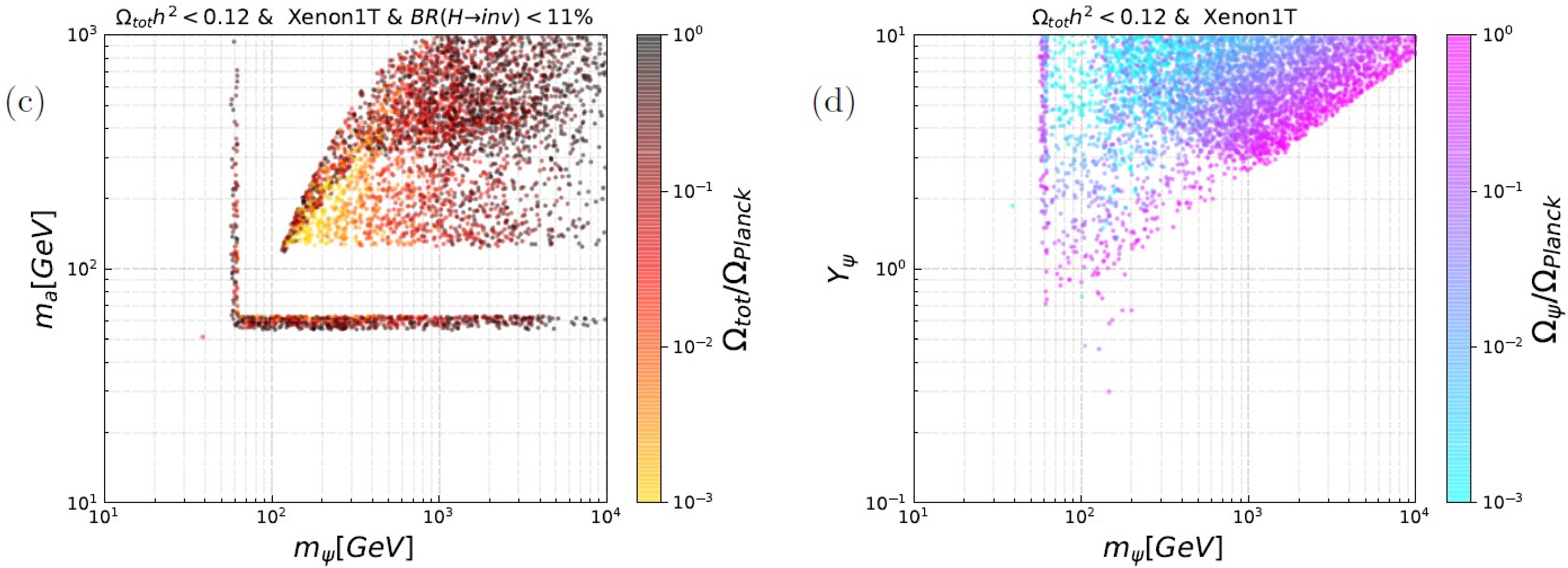
efficiencies

tau	Mass (GeV)							
(ns)	91	200	300	400	500	600	700	800
0.01	968.4	10390	63800	318700	1.44e+06	4.17e+06	2.08e+07	1.993e+09
0.02	187.4	753.3	2580	6434	15530	31210	64850	1.272e+05
0.03	99.06	256.7	649.0	1246	2324	3940	7094	11360
0.04	70.91	142.5	293.7	482.5	768.2	1179	1909	2814
0.05	58.26	97.35	173.7	259.1	377.6	538	797.9	1107
0.06	51.03	74.99	120.8	167.5	227.3	305.9	427.8	568.8

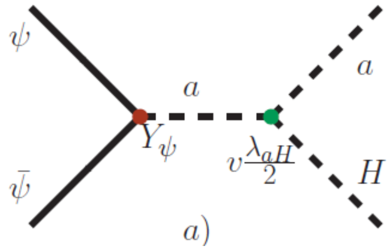
Limits in fb

  - available at zenodo https://zenodo.org/record/4288736 (thanks to Sabine for idea about zenodo)
  - efficiencies for separate channels of D^+D^- and D^+D^0/D^-D^0 production are important for more general interpretation – being produced now (thanks to Felipe Rojas)

Minimal fermion DM model with pseudo-scalar mediator:
rich phenomenology: relic density, DD, colliders



Parameter similar to that of typical portal models, however stable mediator causes "leakage" of points with FDM mass above ~90GeV caused by channel a) opening



MFDM parameter space: the current status