Dark Matter from the <u>10</u> of SO(10)

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Goal

Construct a DM model with the smallest representation of SO(10); the **10**.

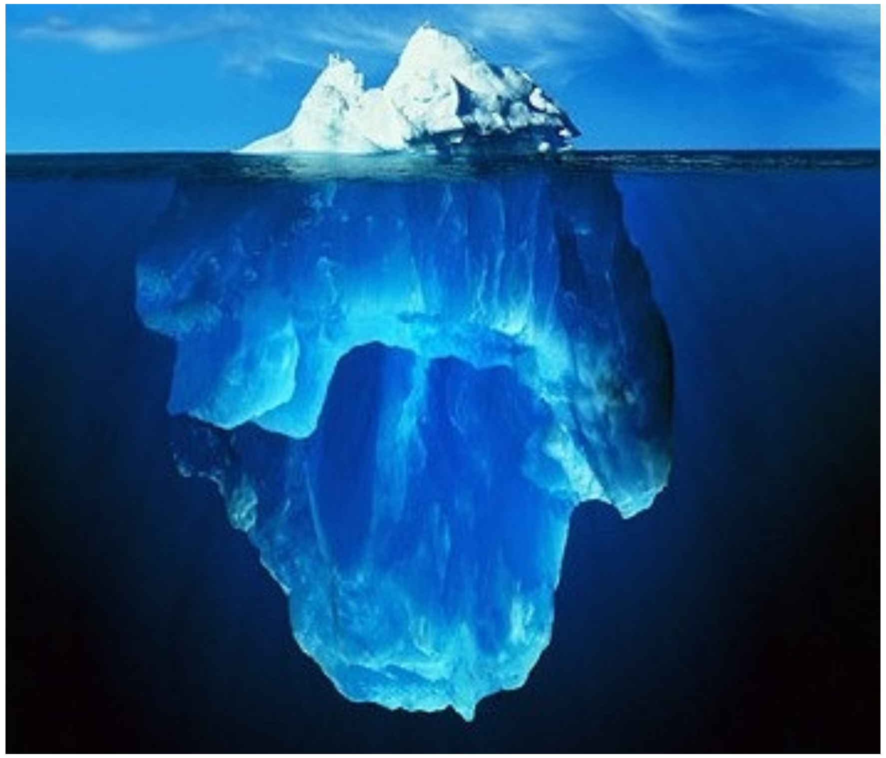
What are the pheno consequences?

Part I
Motivations

Known knowns about DM

An acceptable candidate should not only reproduce observed abundance but also be

- neutral-ish,
- cold-ish
- quasi-stable
- OK with BBN and astro
- collisionless
- OK with search limits



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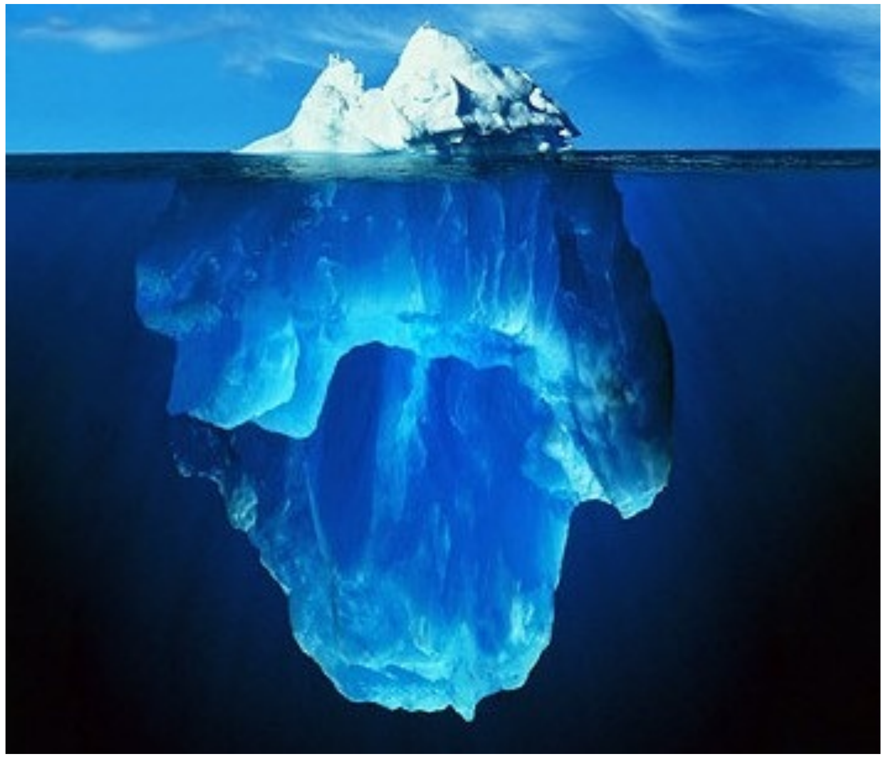

DM is <u>very</u> stable!

DM should be at least older than the Universe:

$$\tau_{\rm DM} \gtrsim H^{-1} \sim 10^{18}{\rm s}$$

However, it usually emits *gammas, e+, p,* etc, and to avoid bounds, the limit becomes:

$$\boxed{\tau_{\rm DM} \gtrsim 10^{26}{\rm s}}$$

How to stabilize DM?

From HEP viewpoint, this stability points to a new preserved symmetry. Straightforward solution is to impose a parity by hand. However, more motivated mechanisms have been proposed where the stability could be, e.g.,

- accidental, Cirelli et al. 05';...
- due to a new (unbroken) gauge group, Ackerman et al. 08'; Foot at al. 06'-10'; Pospelov et al. 07'; ...
- remnant from a flavour symmetry, Hirsch et al. 10'; SB et al. 11'-12'; ...
- **remnant from SO(10) GUT** Mohapatra 86'; Martin 92'; Frigerio-Hambye 09'; Kadastik et al. 09'

[For a short review, see Hambye's 1012.4587]

Why SO(10) ?

SO(10) is a group of rank 5; SM gauge group is rank 4 → 1 extra U(1). If charges are chosen carefully, a spontaneously broken U(1) leaves a remnant discrete symmetry

$$U(1) \xrightarrow[\text{[with N units of charge]}]{\phi} Z_N$$

In SO(10) this U(1) is identified with $U(1)_{B-L}$, and the smallest *irreps.* with *N*>1 is **126**, therefore:

[Think of seesaw I and II from **16.126.16**]

$$\boxed{U(1)_{B-L} \xrightarrow{\langle 126 \rangle} Z_2 \equiv (-1)^{3(B-L)}}$$

The possible dark *reps.* are:

	SO(10) reps.	DM candidate (SM)	Z2
Fermions	**10,** **45, 54, 210** **126** **...**	**(1,2,1/2)** **(1,1,0)+(1,3,0)** **(1,1,1/2)**	**+**
Scalars	**16, 144** **...**	**(1,1,0)**	**-**

[From **16.10.16**, with **16** odd and **10** even:
new fermions (scalars) are stable if even (odd)]

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	45, 54, 210	**(1,1,0)+(1,3,0)** Frigerio, Hambye 09’
	126	**(1,1,1/2)**
	...	
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	...	

See also:
Mambrini et al. 15'
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Part II
The model

Particle content

The model consists of a minimal SO(10) fields content: 3 generations of fermion **16**, and scalars in **126** and complex **10** (where the Higgs lives), augmented by fermionic **10** and a scalar **45**.

The breaking proceeds through

$$
\begin{aligned}
SO(10) \quad & \xrightarrow{\mathbf{45}_H} \quad 3_C 2_L 2_R 1_{B-L} \\
& \xrightarrow{\mathbf{126}_H} \quad 3_C 2_L 1_Y \otimes Z_2 \\
& \xrightarrow{\mathbf{10}_H} \quad 3_C 1_Y \otimes Z_2
\end{aligned}
$$

Bidoublet DM

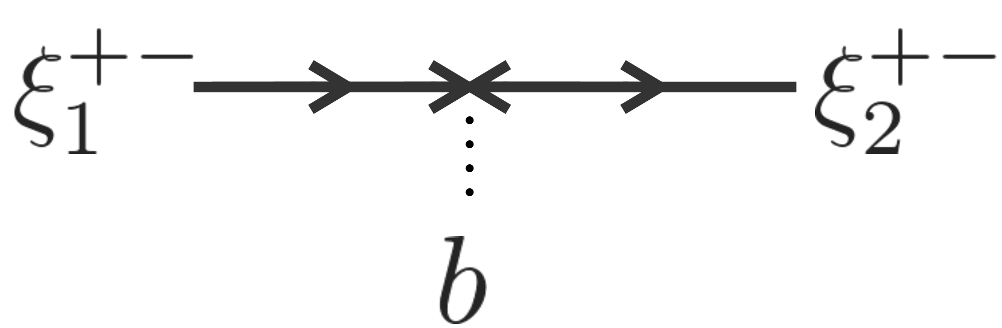
We are interested in the colorless part of the **10**, i.e,

$$\mathbf{10} \supset (\mathbf{1},\mathbf{2},\mathbf{2},0) \equiv \xi = \begin{pmatrix} \xi^{+-} & \xi^{++} \\ \xi^{--} & \xi^{-+} \end{pmatrix} .$$

To separate it from colored states and give it mass we use a **45** à la Dimopoulos-Wilczek; $\mathcal{L}_{DM} = \mathbf{10}_1 \mathbf{45}_H \mathbf{10}_2$ with $\langle \mathbf{45}_H \rangle = \mathrm{diag}(a,a,a,b,b) \otimes i\tau_2 .$

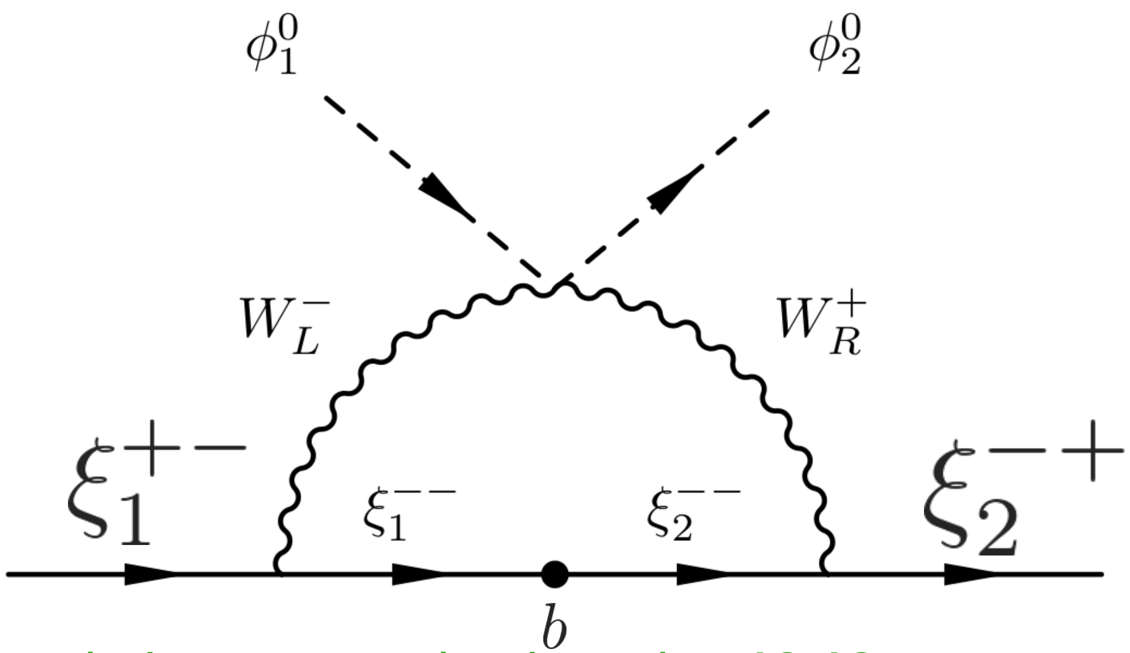
~GUT ~TeV

This leads, after EWSB to Dirac fermions of mass ~ *b*



Bidoublet DM

A fermion doublet DM is excluded by DD. However, if there's a mass gap of > ~200 keV in the Z transition, we can avoid these bounds: the model automatically takes care of this.



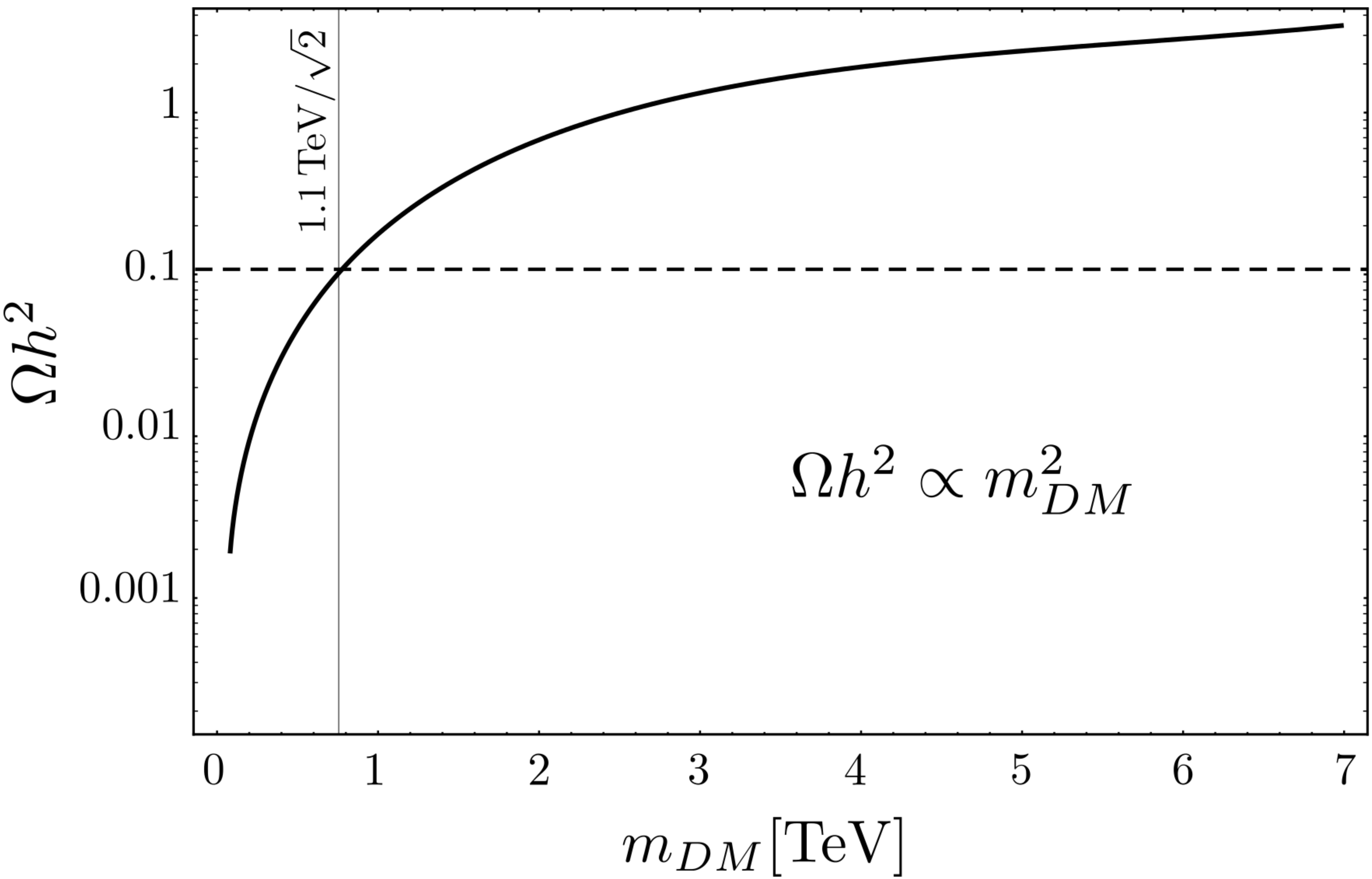
[In group th. languange, the insertion **10.10** acts as a **54**, which contains (**3**,**3**) of LR.]

At low energy, we end up with a fermion pair of masses: $b \pm \delta$, with a splitting O(MeV) for WR @ TeV.

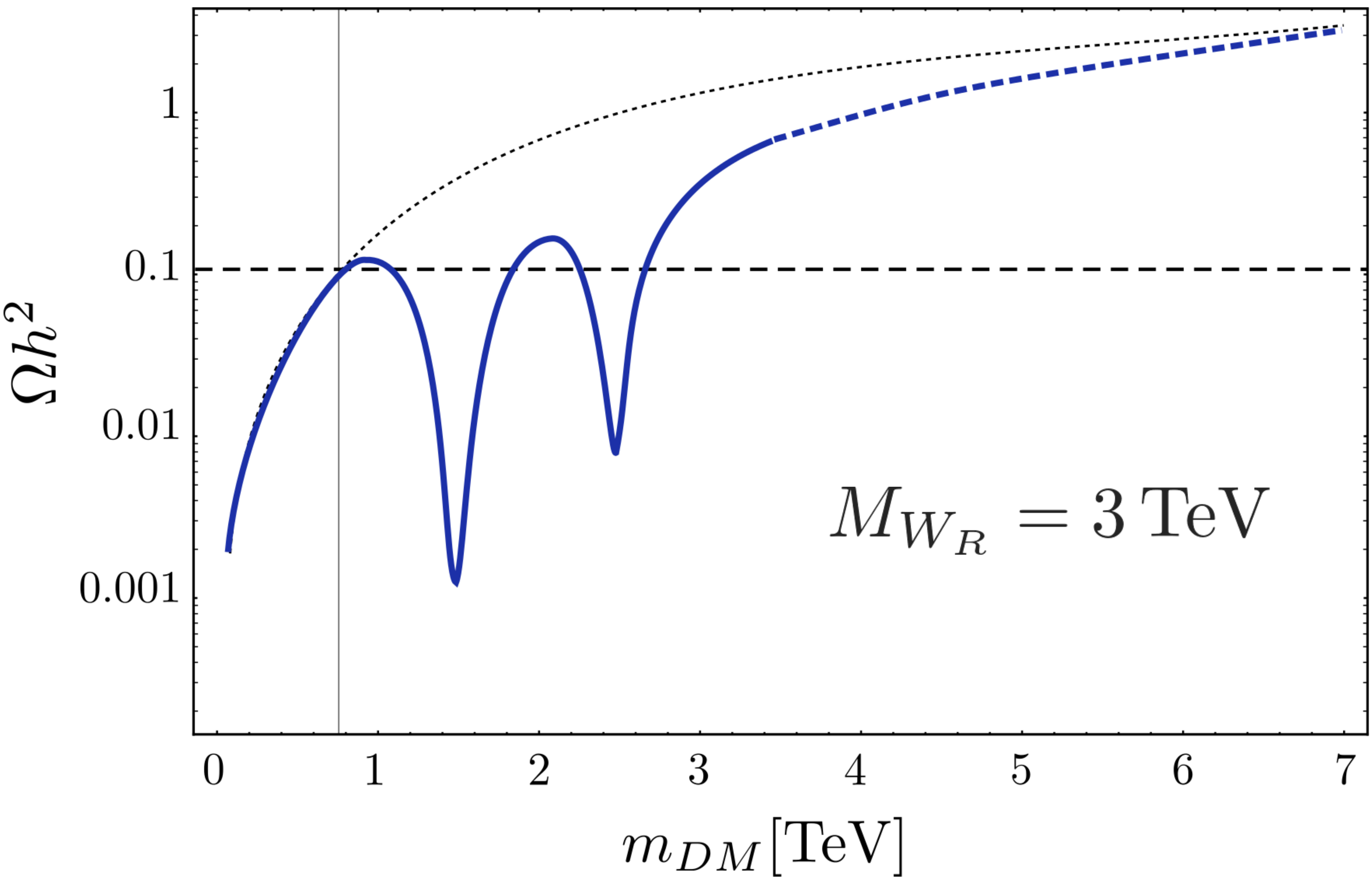
Interestingly, DD bounds *require* a low scale LR model:

$$\boxed{\delta > 200\,\mathrm{keV} \rightarrow M_{W_R} \lesssim 9\,\mathrm{TeV}}$$

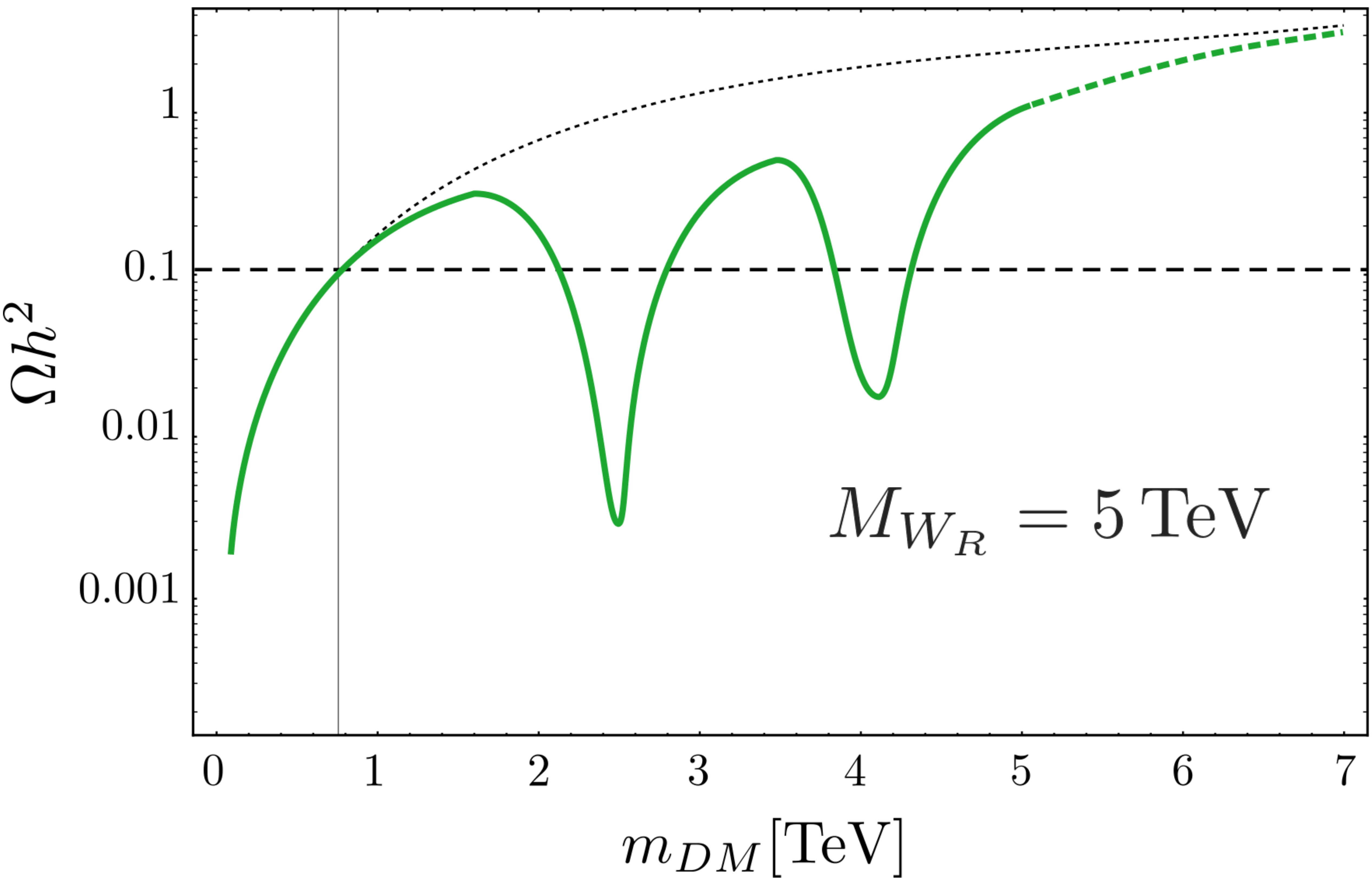
Part III
DM pheno



$1.1\,\mathrm{TeV}/\sqrt{2}$
1
0.1
0.01
0.001
Ωh^2
$\Omega h^2 \propto m_{DM}^2$
0
1
2
3
4
5
6
7
$m_{DM}[\mathrm{TeV}]$



Ωh^2
1
0.1
0.01
0.001
0
1
2
3
4
5
6
7
$m_{DM}\,[\mathrm{TeV}]$
$M_{W_R} = 3\,\mathrm{TeV}$



1
0.1
0.01
0.001
Ωh^2
$M_{W_R} = 5\,\mathrm{TeV}$
0
1
2
3
4
5
6
7
$m_{DM}\,[\mathrm{TeV}]$

Conclusions

- The smallest representation of SO(10), **10**, offers a viable DM candidate which makes sense at quantum level only.
- Stability follows from the gauge group itself.
- Direct detection bounds force the LR intermediate scale to be TeV-ish: testable scenario; interplay DD/ID - LHC.

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Thanks for your attention !