Higgs in Perspective III: concrete BSM

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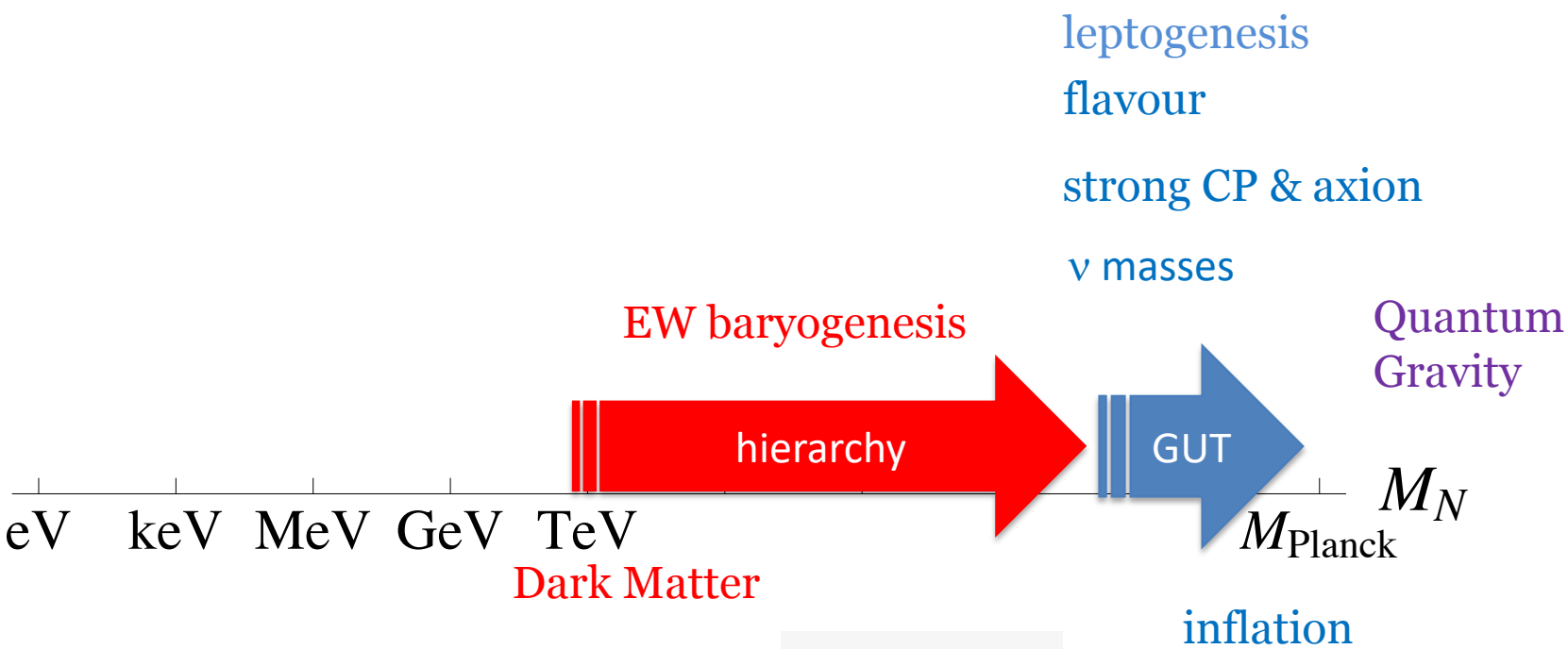
The concrete BSM way...
(not longer just top-down)

Which BSM ?

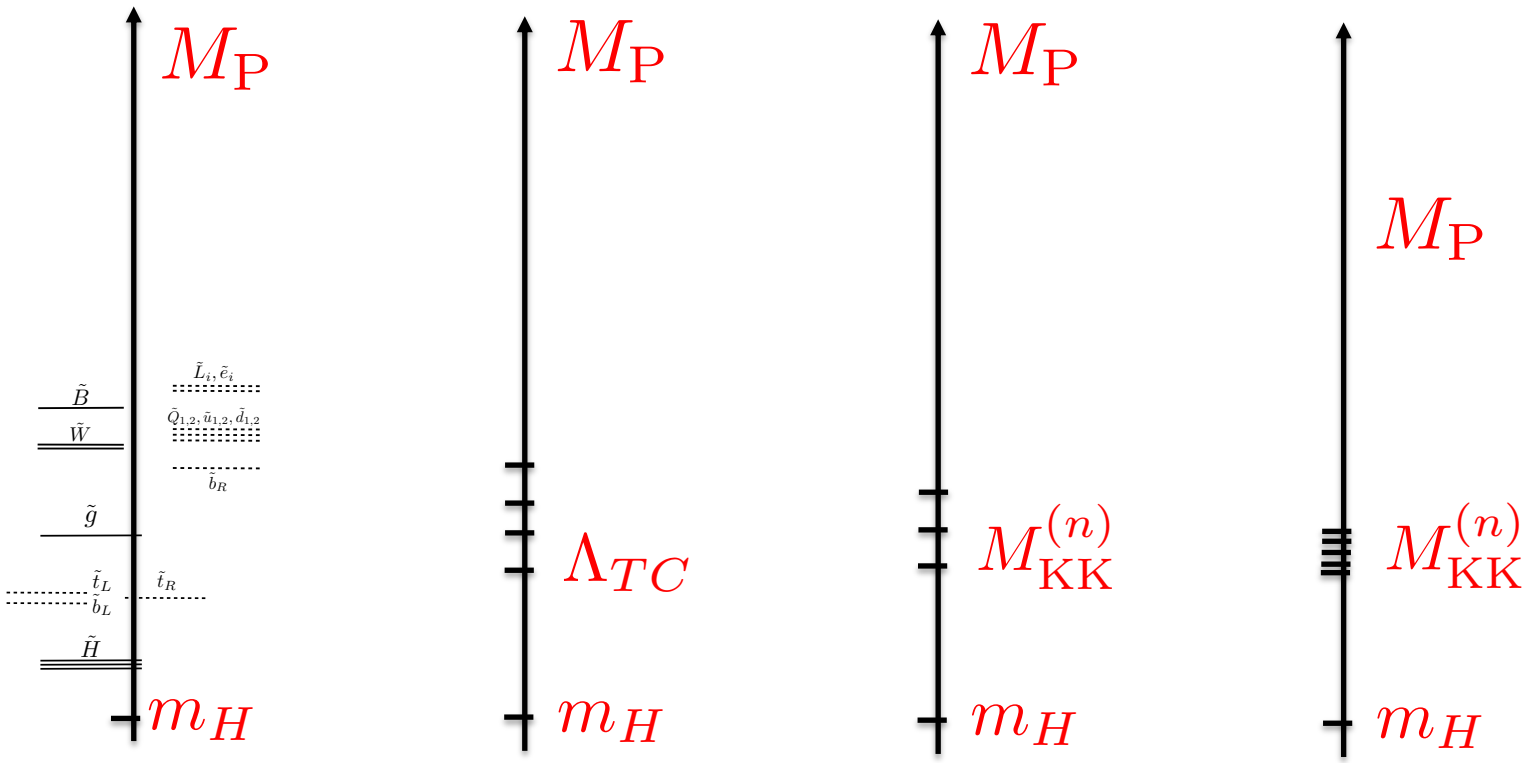
In the "good old days", we had a grand scheme:



Hierarchy problem and dark matter

EW Hierarchy problem ?

An enormous brain effort has been devoted to solving this problem, ie. understanding the separation between $M_{Higgs} << M_{Planck}$



"Natural" SUSY

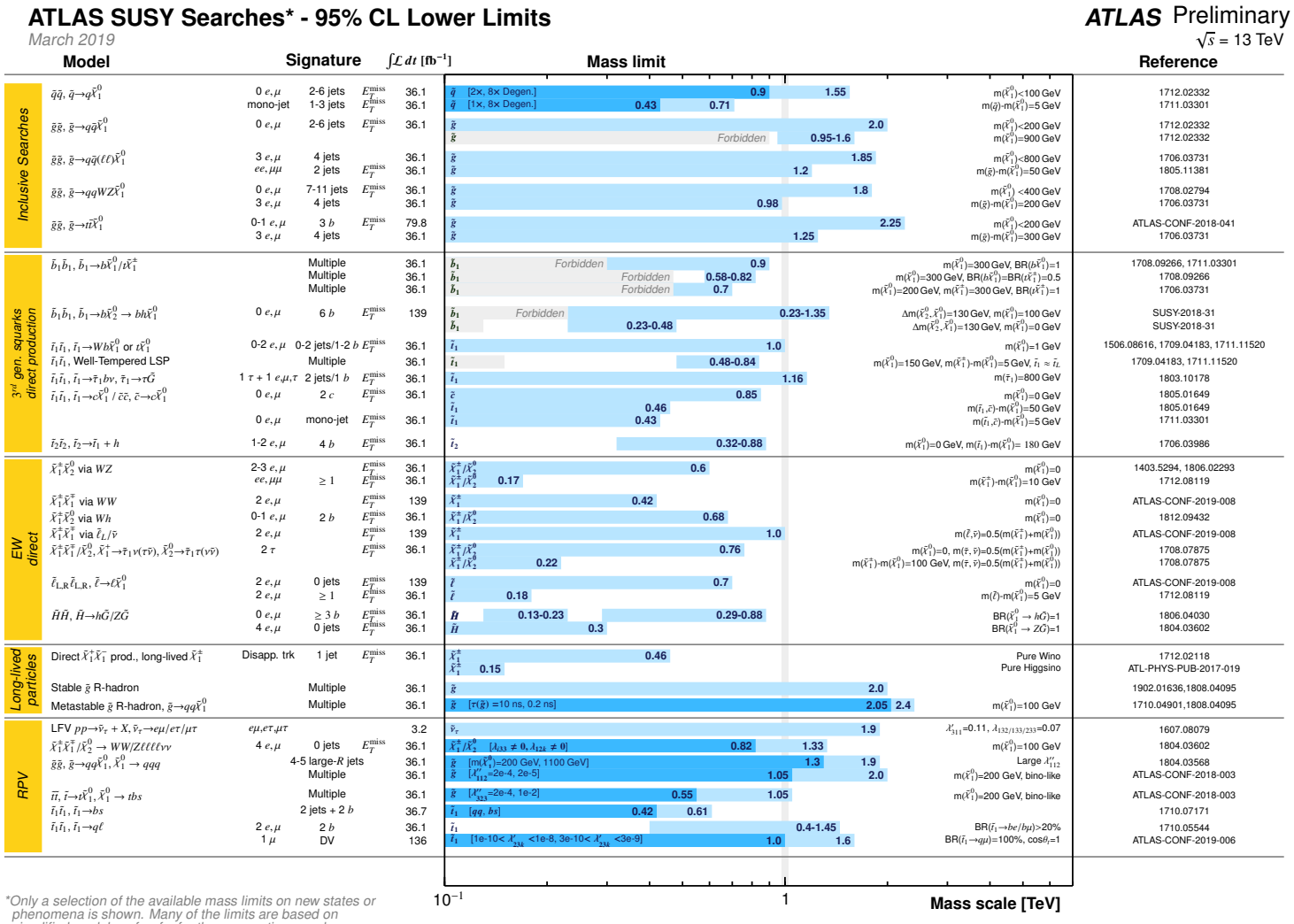
Higgs compositeness

ExtraD (RS)

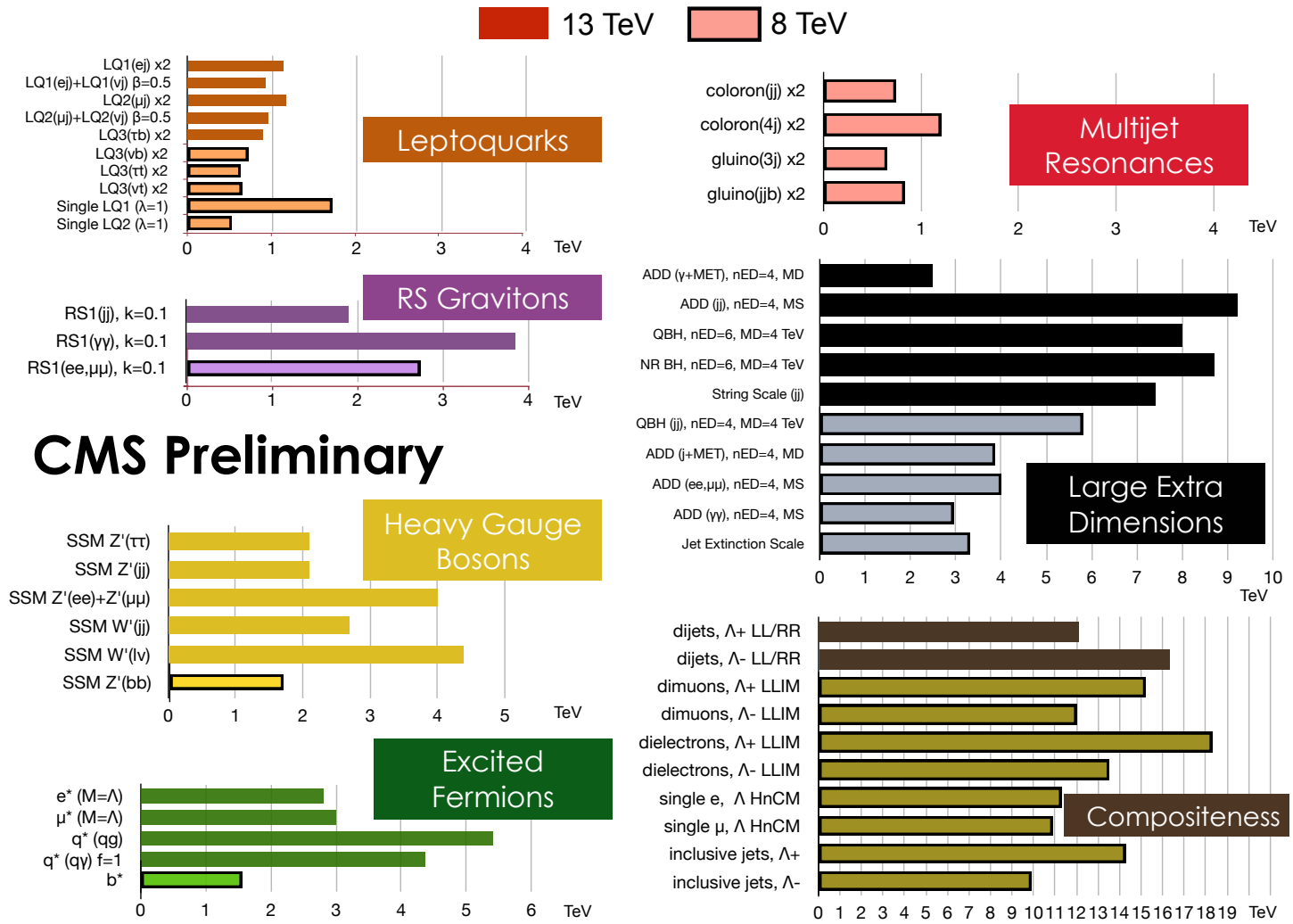
Clockwork

New states at TeV, top quark special

LHC EW hierarchy razor



LHC EW hierarchy razor



CMS Exotica Physics Group Summary – ICHEP, 2016

EW Hierarchy Problem ?

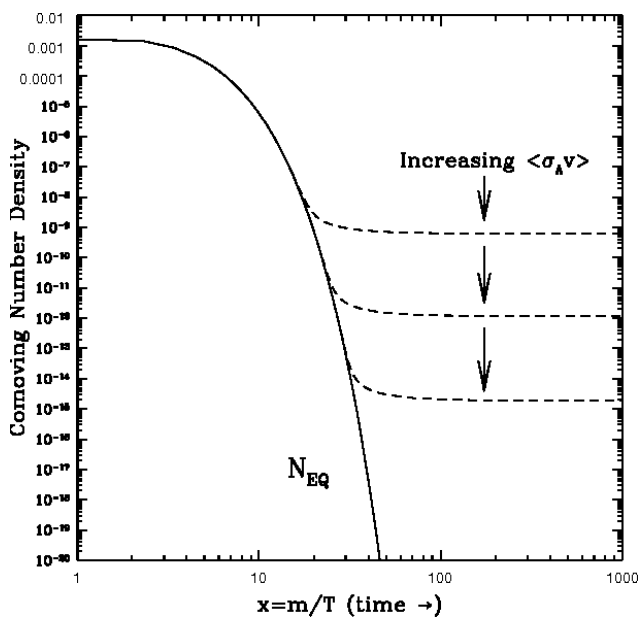
LHC has found no smoking gun for a solution to the big hierarchy problem and has enhanced the "Little hierarchy problem":

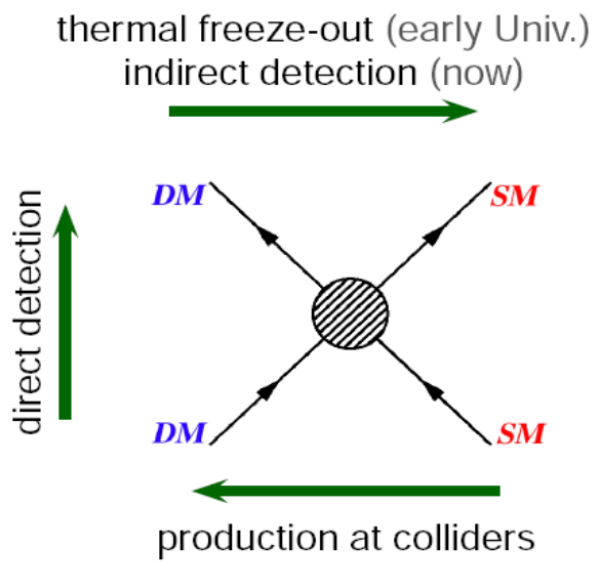
But O(10-100)TeV still an interesting scale to explore!

WIMP Dark Matter

Thermal relic (freeze-out):

neutral and stable Weakly Interacting Massive Particle related to the physics that solves the hierarchy problem (eg. SUSY LSP)



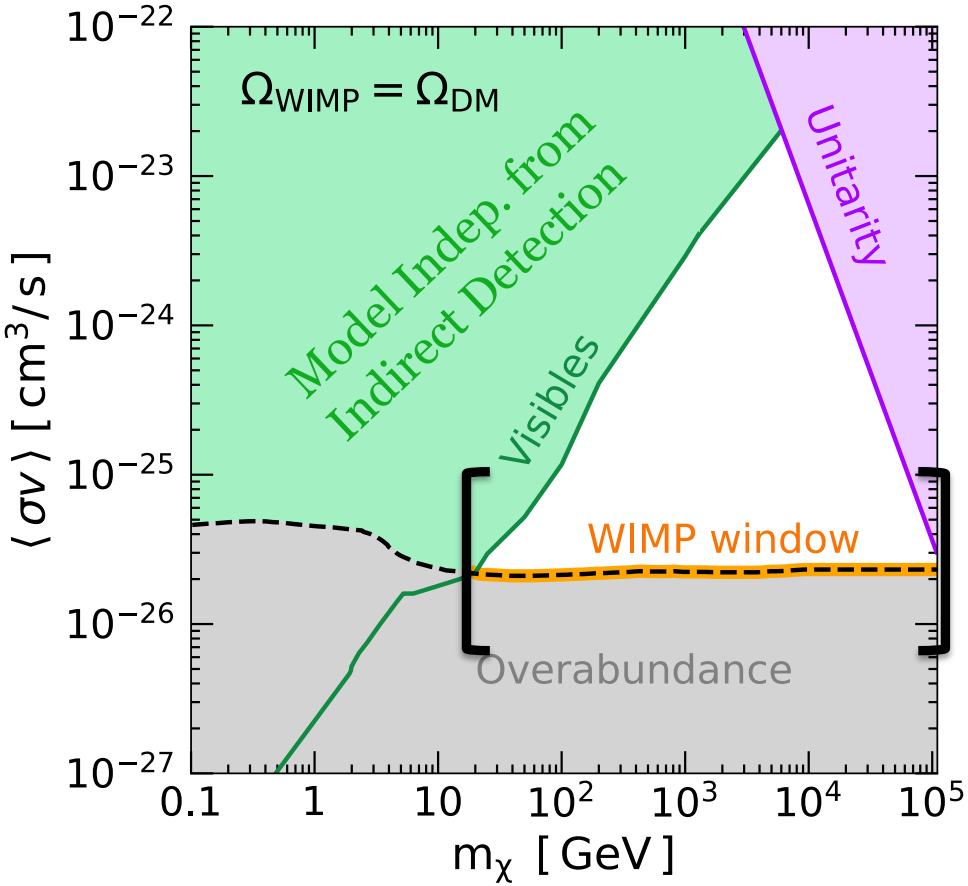


$$\Omega_{DM} h^2 \propto \frac{1}{\langle \sigma v \rangle}$$

$$\begin{aligned} \langle \sigma v \rangle &\sim 10^{-26} cm^3/s \\ &\sim \alpha^2 \left(\frac{m_\chi}{100\mathrm{GeV}}\right)^{-2} \end{aligned}$$

WIMP Dark Matter

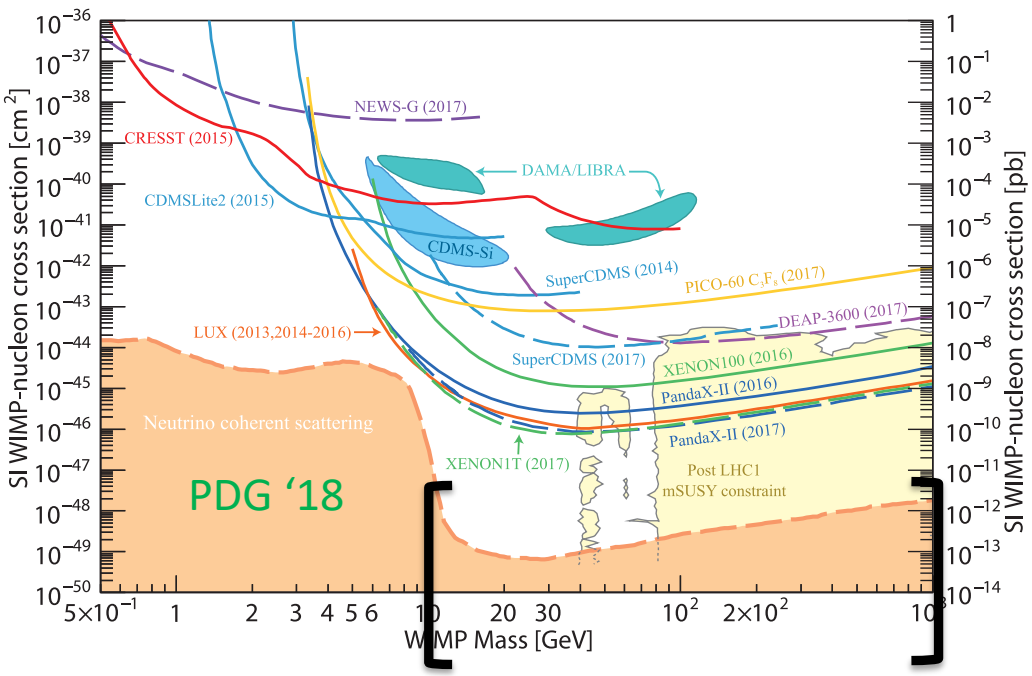
Vanilla WIMP getting squeezed but a clear motivation to explore the [10GeV-100TeV] !

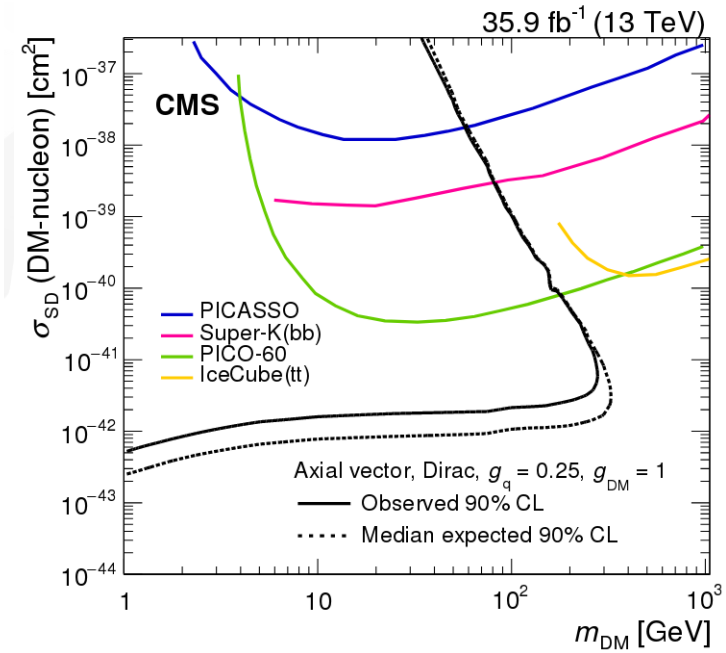


Leane, Slatyer, Beacom,Ng '18

WIMP Dark Matter

Strong (and complementary) constraints from direct detection and colliders





Many ideas in the market to target the low mass region in direct detection

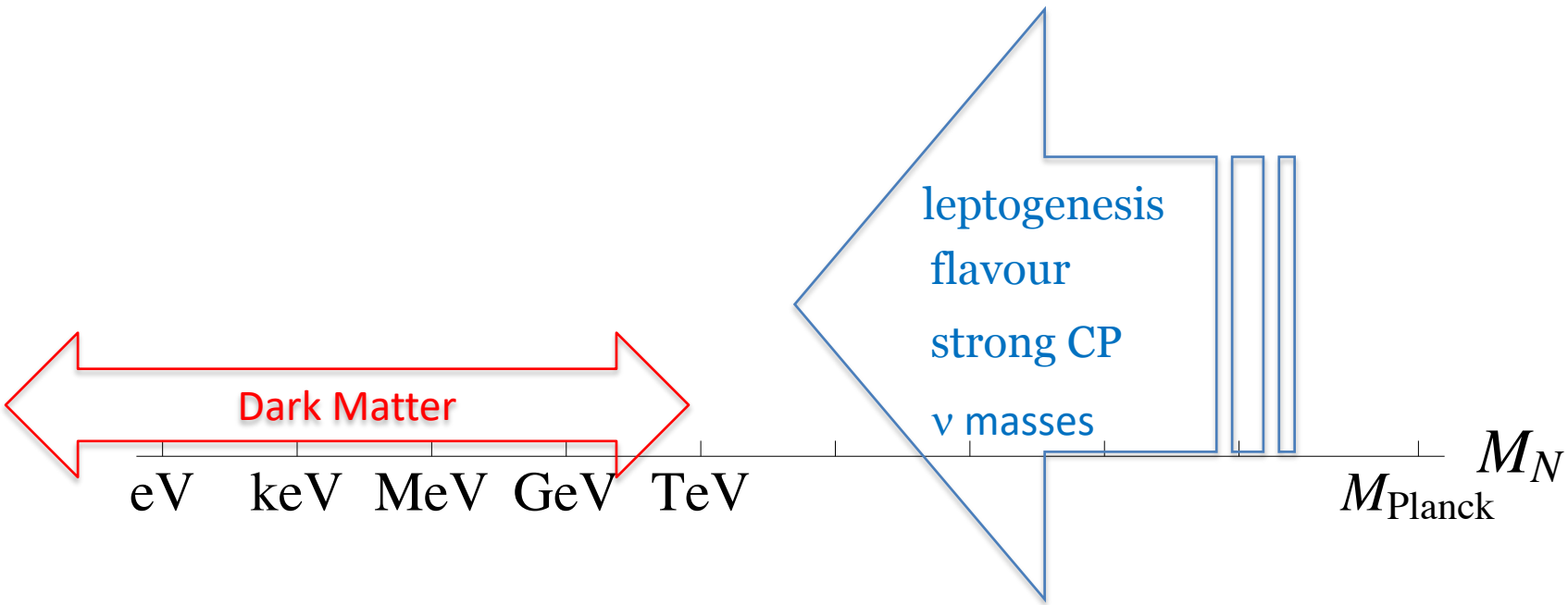
Several anomalies: DAMA-LIBRA, CDMS and also astrophysical 3.5keV, GeV excess…

What if solving the hierarchy problem is not the right lead ?

...we still need to understand data: DM, neutrino masses, Matter-antimatter asymmetry

Motivational Toolkit beyond EW hierarchy

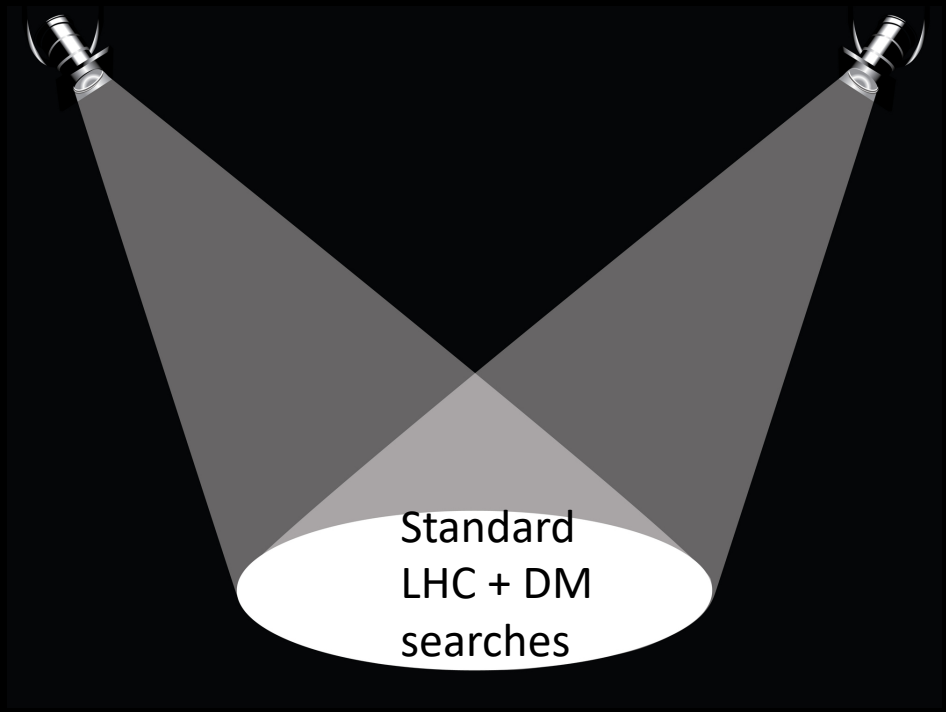
I. Avoid hierarchy problem & improve testability



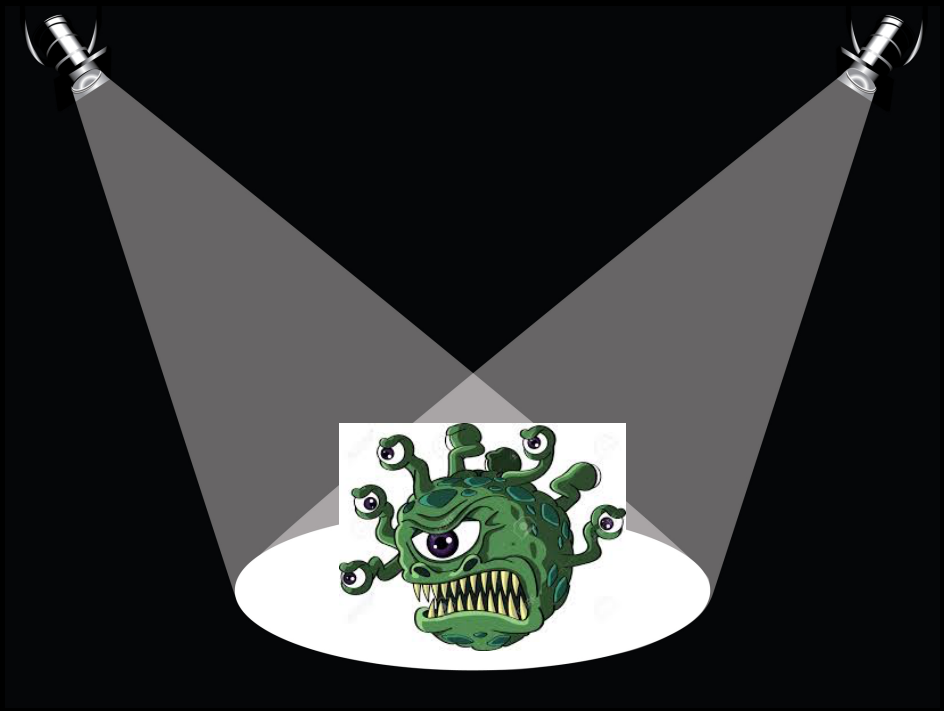
new DM production mechanism
(FIMPs, asymmetric Dark Matter...)

changing paradigms: lighter and
more feably coupled,

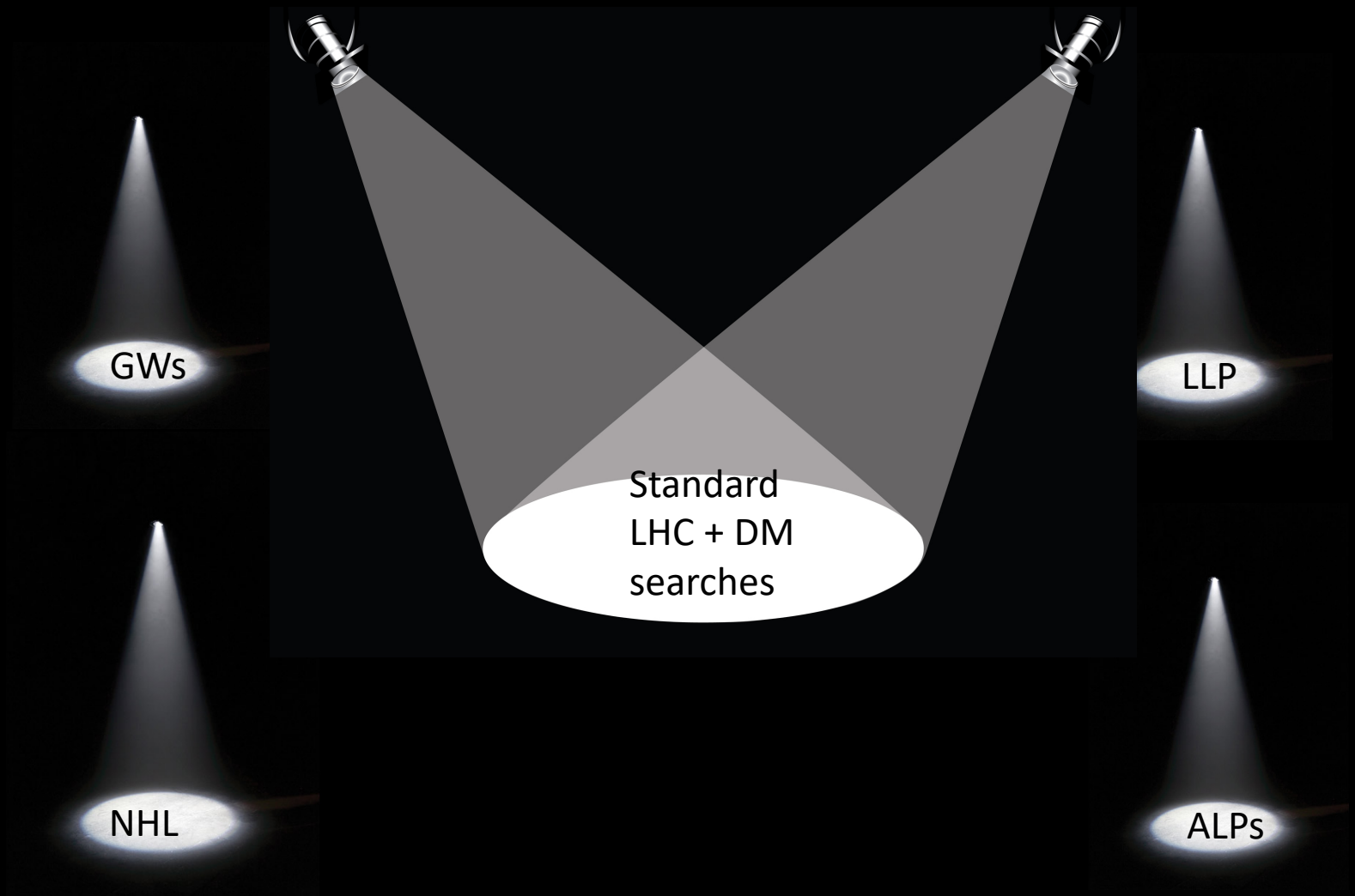
Models for the spotlight ?



Models for the spotlight ?

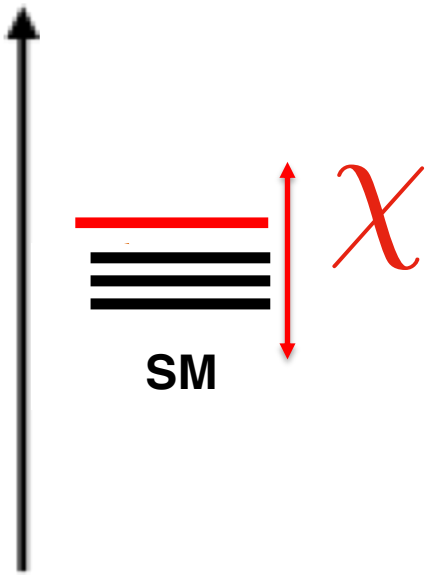


New spotlights for well motivated models



Motivational Toolkit beyond EW hierarchy

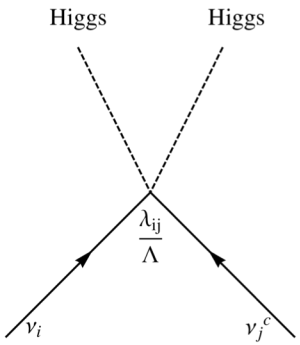
II. Occam's Razor

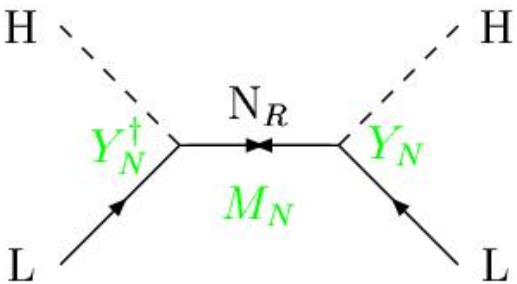


Example: heavy majorana neutrino<-> type I seesaw

$$\chi = N$$

Origin of neutrino mass:

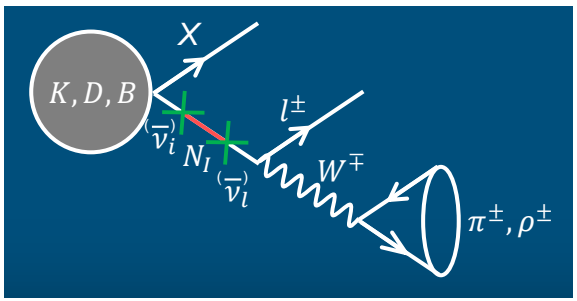


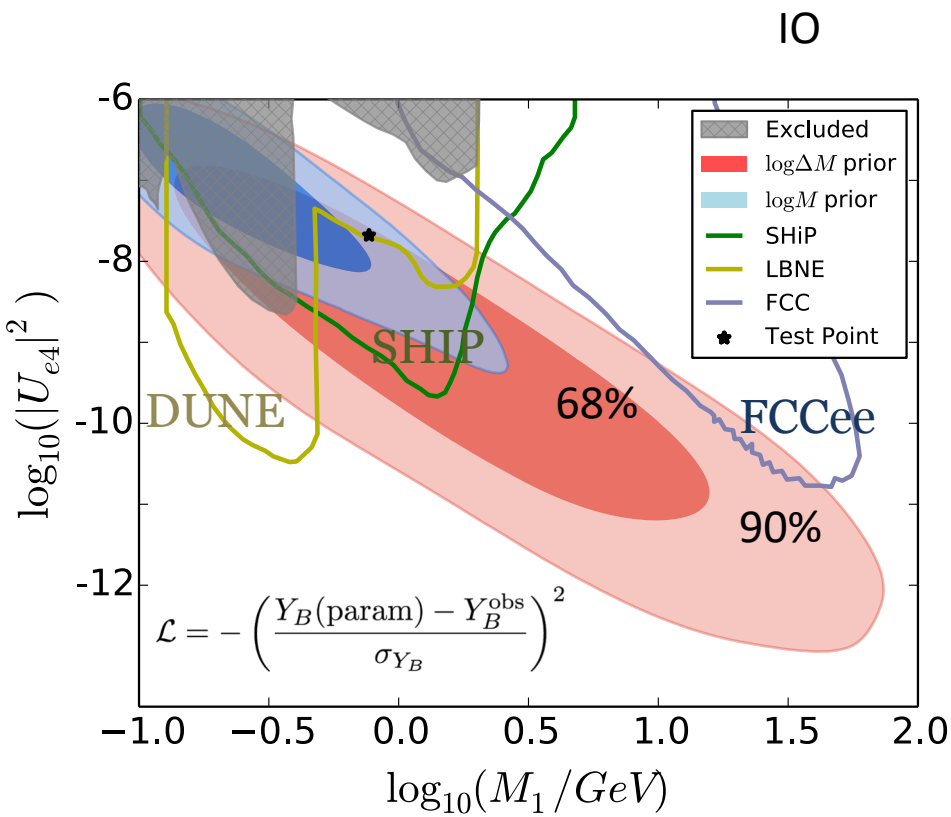


+ Origin of matter-antimatter asymmetry for M_N > O(100)MeV

BSM: Neutrino mass-Leptogenesis

New spotlights: beam dump and collider searches of neutral heavy leptons





The measurement of the mixing to e/μ of the sterile states, ββ0ν and δ in neutrino oscillations have a chance to give a prediction for Y_B

BSM: Neutrino mass-Leptogenesis

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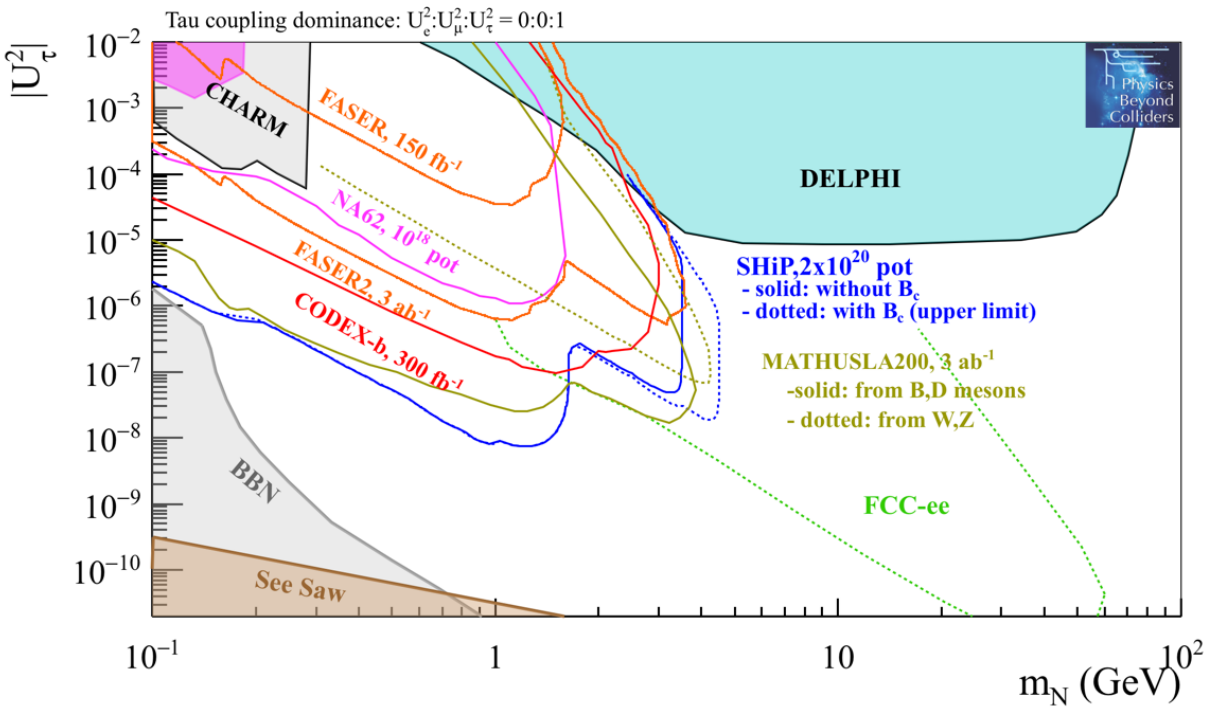

Motivational Toolkit beyond EW hierarchy

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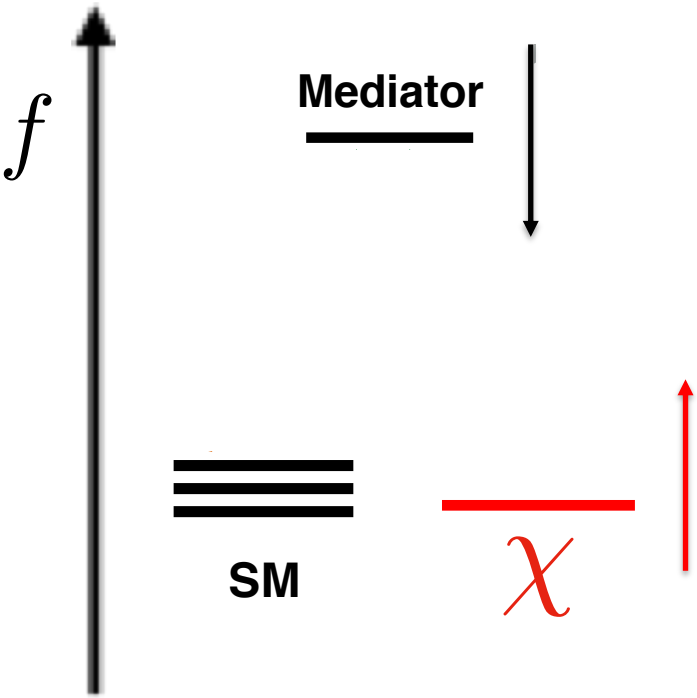
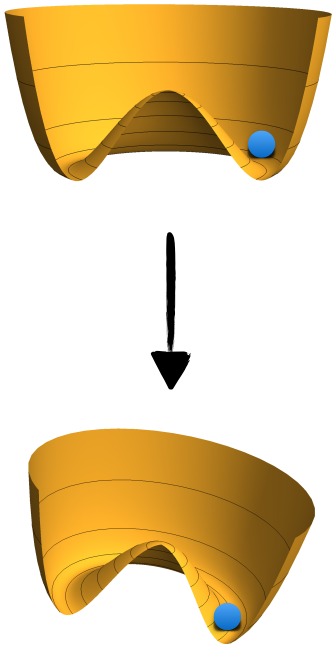


ALPs and more generally pNGB:
strong CP, dark matter, flavour,...

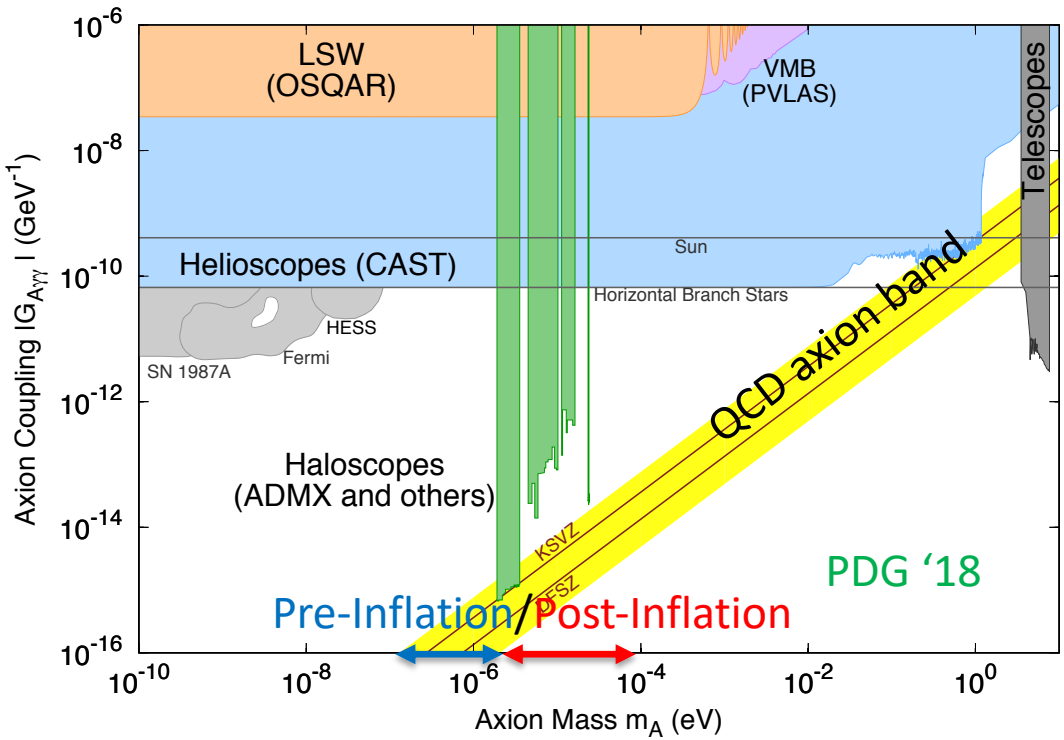
$$\chi = a$$

$$\phi = (f + s)e^{ia/f}$$



QCD axion: $m_A^2 f_A^2 \propto m_\pi^2 f_\pi^2$

Axion Dark Matter



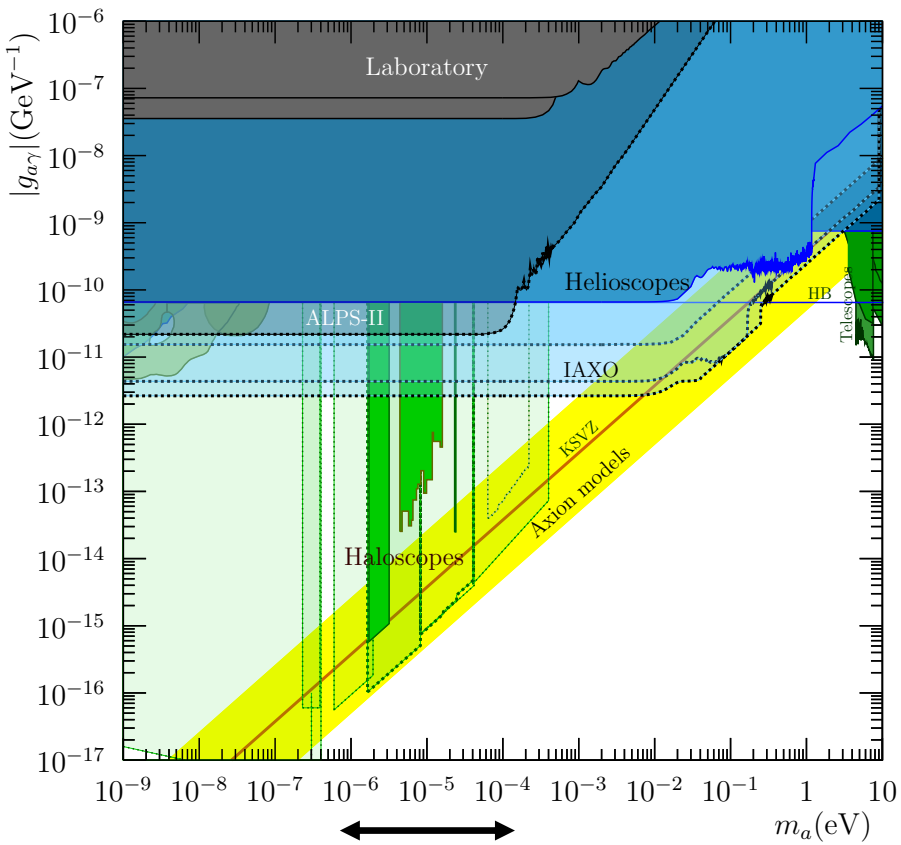
QCD Axion DM band

$$\Omega_A^{\rm vr} h^2 \approx 0.12 \left(\frac{f_A}{9\times 10^{11}\ \ {\rm GeV}}\right)^{1.165} F\,\bar{\Theta}_{\rm i}^2$$

$$\approx 0.12 \left(\frac{6\ \ \mu{\rm eV}}{m_A}\right)^{1.165} F\,\Theta_{\rm i}^2\,,$$

Axion Dark Matter

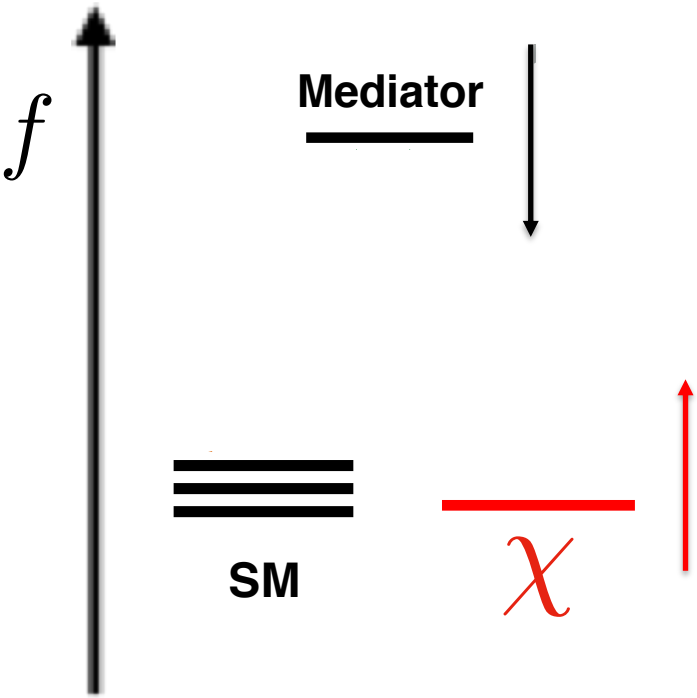
Bright prospect to explore the phase space of QCD axion models



Irastorza,Redondo '18

Motivational Toolkit beyond EW hierarchy

II. Occam's Razor



ALPs and more generally pNGB:
strong CP, dark matter, flavour,...

$$\chi = a$$

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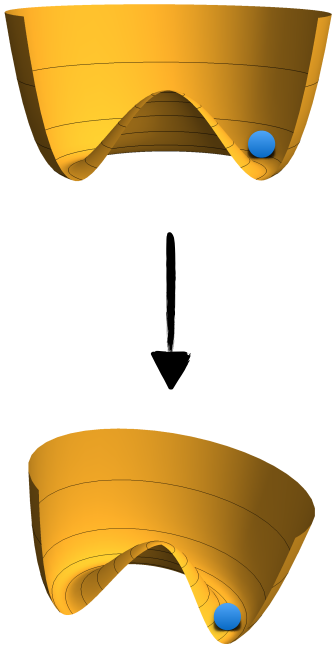
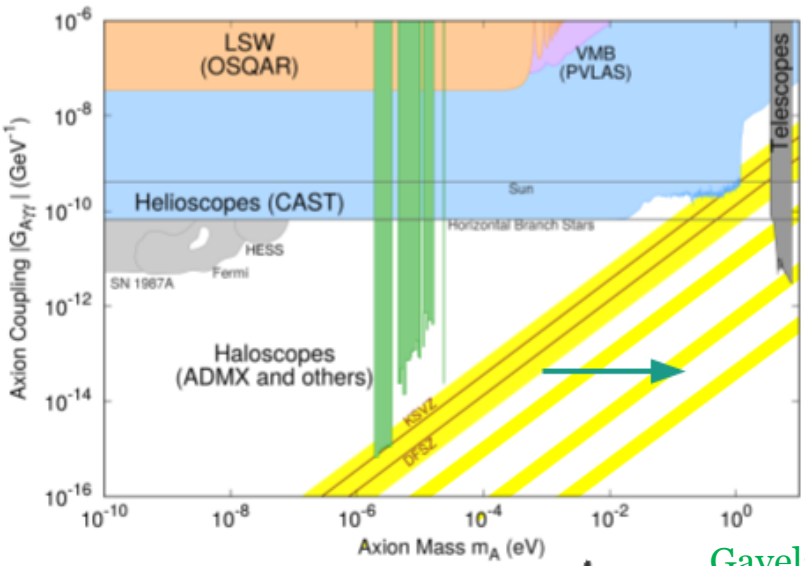
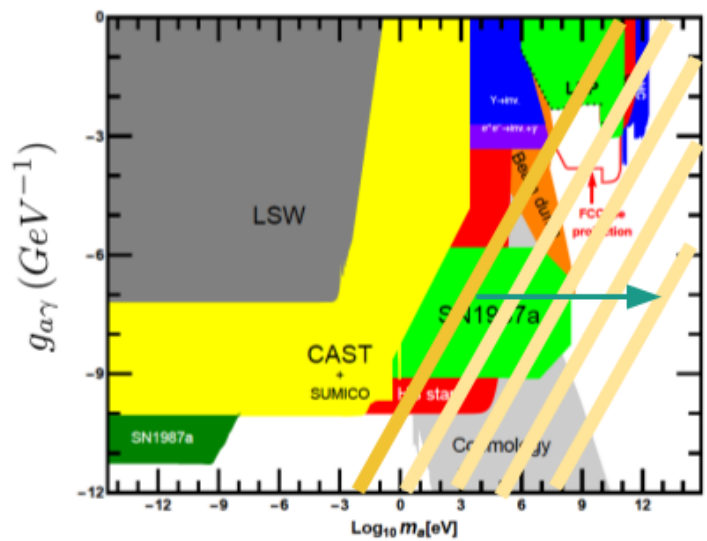


Alternative to QCD anomalous breaking: $m_a^2 f^2 \gg m_\pi^2 f_\pi^2$

ALPs searches

New spotlights: ALP searches @ colliders and beam dump experiments



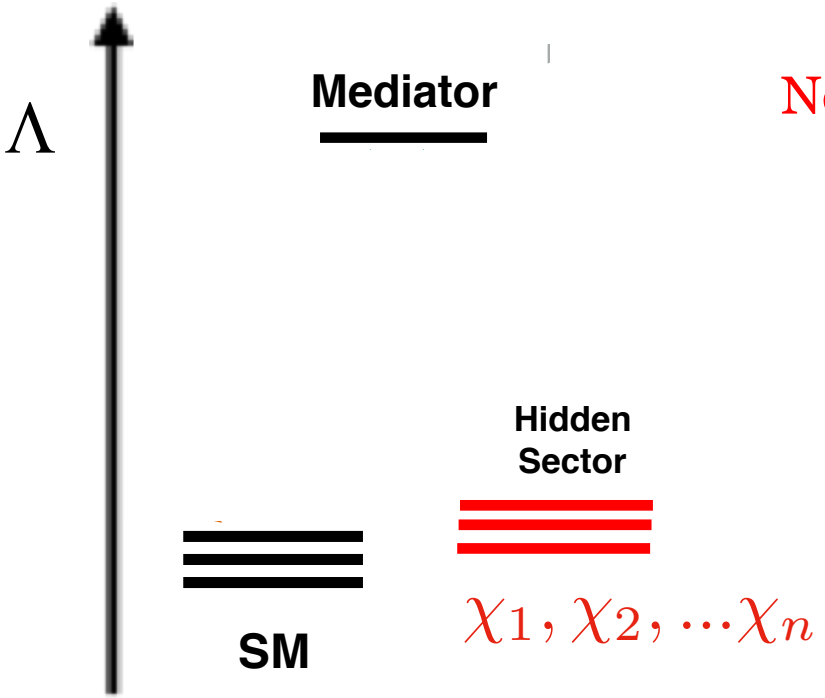


Gavela, Gaillard, Houtz, Quilez, del Rey

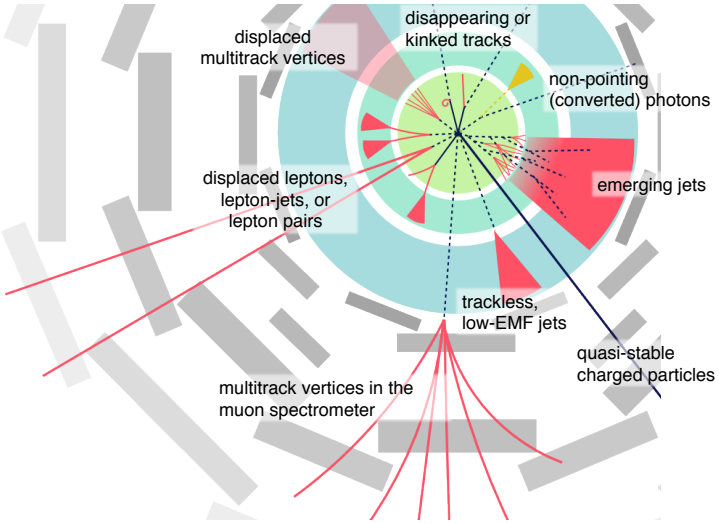
$$m_a^2 f_a^2 \gg m_\pi^2 f_\pi^2$$

Motivational Toolkit beyond EW hierarchy

II. Occam's Razor



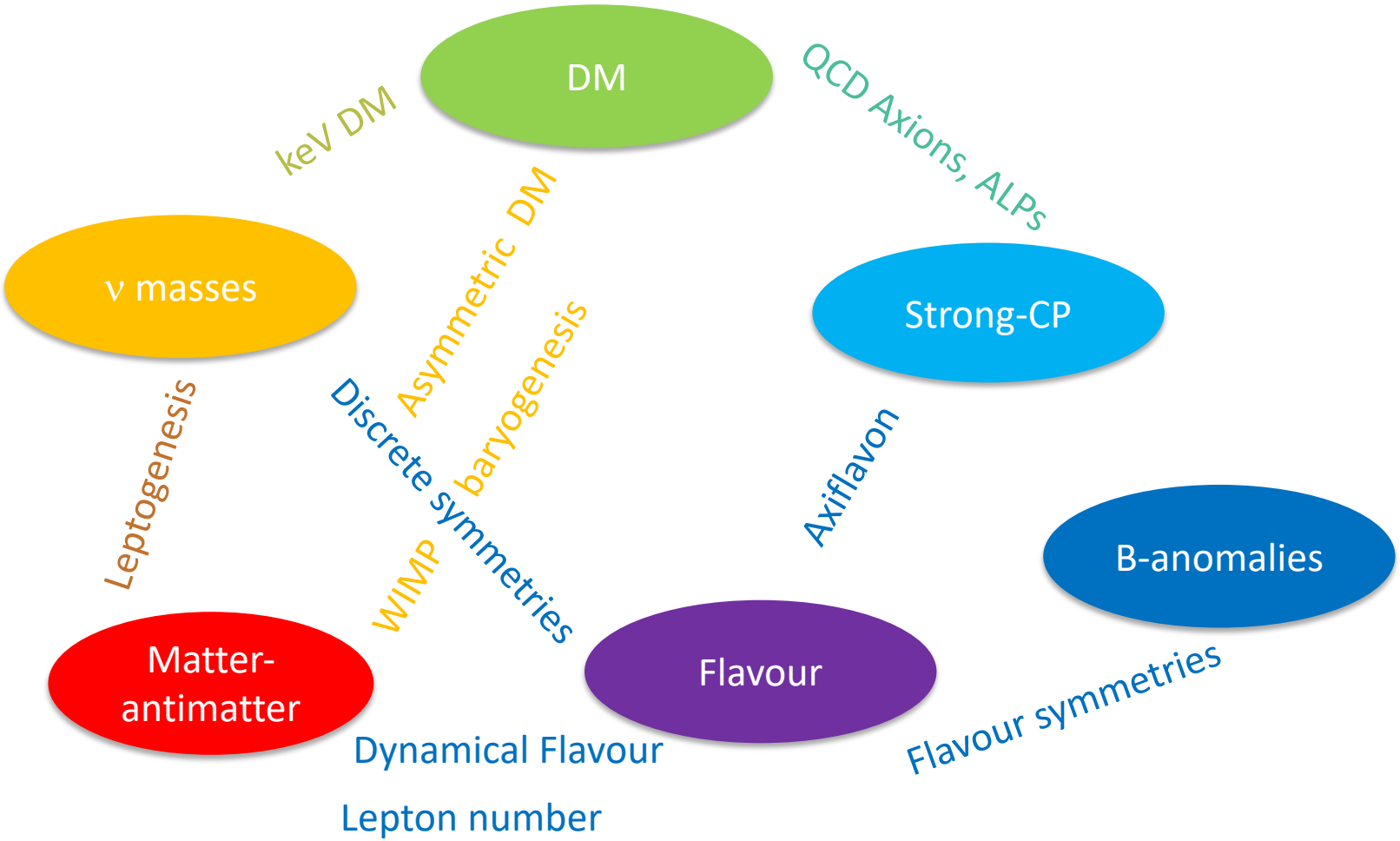
New spotlight: Long-Lived Particles



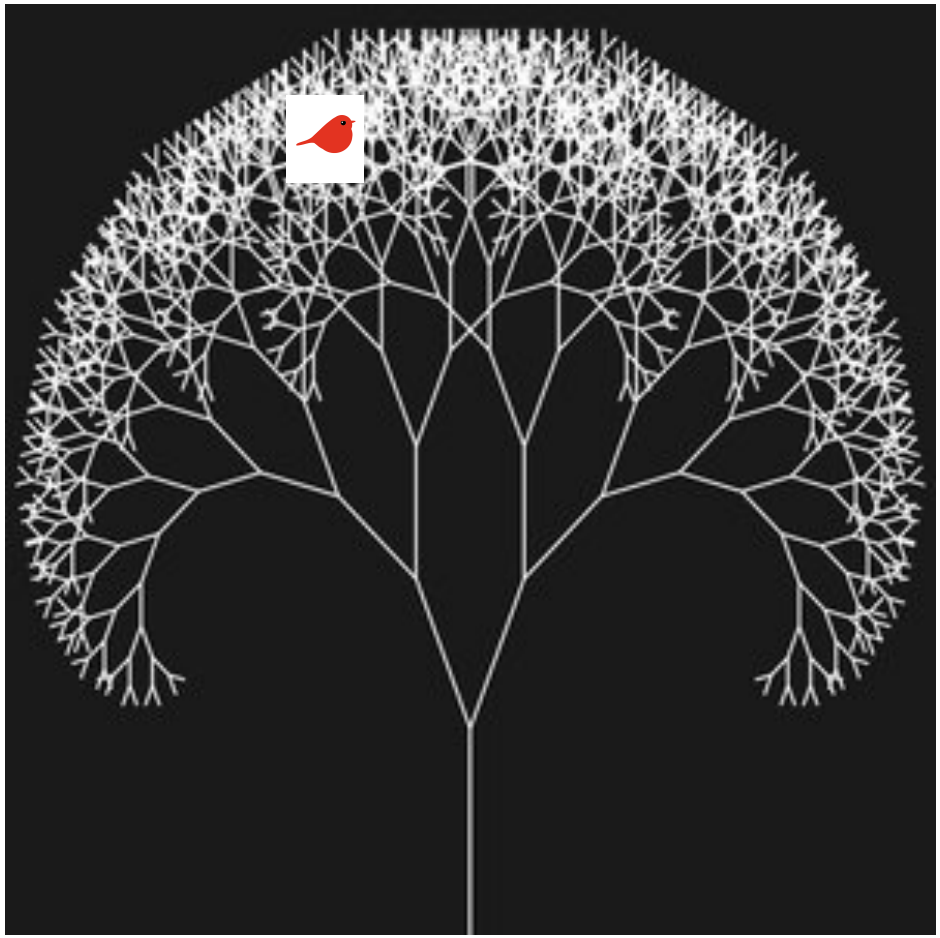
Many models of this type to explain Dark Matter: FIMPs, SIMPs, Mirror worlds...

Motivational Toolkit beyond EW hierarchy

III. Searching for connections: towards a new grand scheme



The BSM Landscape



“Truth is ever to be found in simplicity, and not in the multiplicity and confusion of things”

I. Newton