Do new experimental results indicate a consistent framework?

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WHAT IS ν?: from new experimental neutrino results to a deeper understanding of theoretical physics and cosmology,

GGI, June 20, 2012

Motivation: new data from many different experiments

- Neutrino flavour physics - large θ_{13} measured
  - Why all nontrivial mixing angles are related to the Cabbibo angle?
    $\theta_{12} \sim \pi/4 - \theta_c, \qquad \theta_{13} \sim \theta_c/\sqrt{2}$
- LHC
  - Higgs boson
  - SUSY
  - New resonances, extra dimensions etc
- DM direct detection
  - WIMPs - Xenon100 (new results coming very soon!)
  - Axion experiments become sensitive to DM parameters
- DM indirect detection - Fermi 130 GeV gamma ray peak

Is there a consistent emerging picture of new physics?

Meetings like this are meant to encourage discussions

The “standard" paradigms of NP beyond the SM

SUSY

- Hierarchy problem is solved by SUSY
- There is a desert between M_Z and M_{GUT}
- Flavour physics generated at M_P
- RH neutrino/leptogenesis mass scale 10^{12} GeV is obtained as $M_N = y_\tau M_{GUT}$
- After imposing R-parity DM is the lightest neutralino

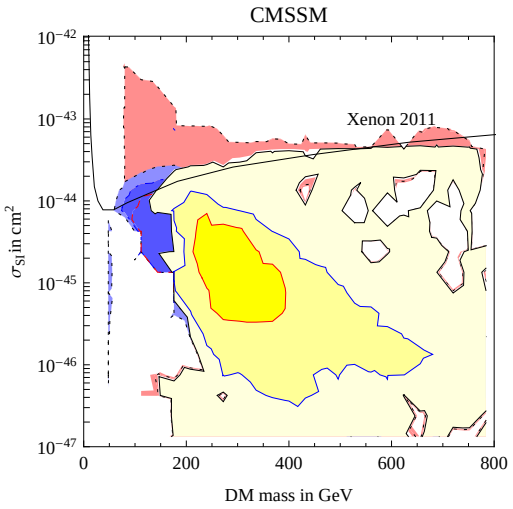
Alternatively

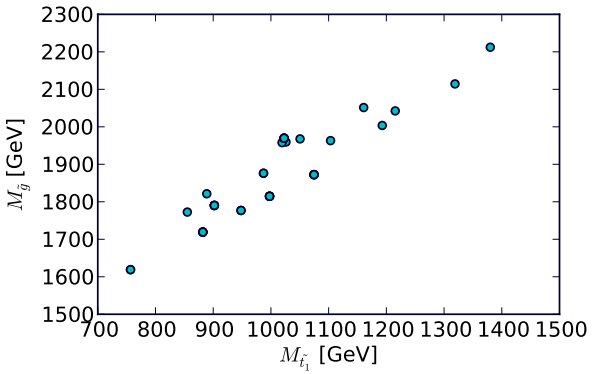
- Extra dimensions to solve hierarchy/flavour/DM problems
- New strong interactions: composite Higgs and higgsless models
- Split SUSY & anthropic principle

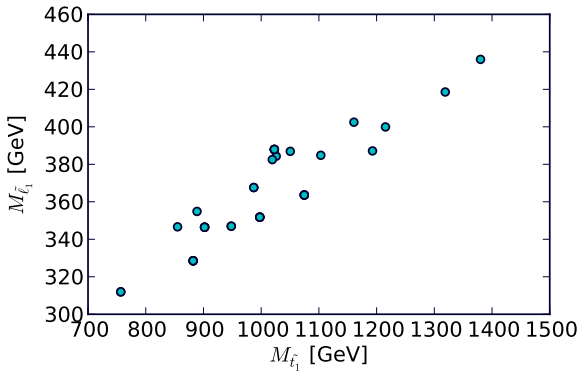
Lessons to learn from collider searches

CMSSM before 125 GeV Higgs
arXiv:1104.3572

CMSSM after 125 GeV Higgs
arXiv:1112.3647







Naturalness/mathematical beauty etc seem not to be good arguments. LHC:

- After Moriond 2012 $M_{1/2} = m_0 > 1.5$ TeV
- New Z' type and KK resonances above 3-4 TeV
- New strongly interacting resonances above multi-TeV

Does model building without solid physical measurement make sense?

Higgs boson status

- I assume that the LHC evidence does correspond to some Higgs boson
- I assume that its mass is 125 GeV
- I allow its couplings to deviate from the SM predictions
- I shall be very surprised if Higgs not confirmed at ICHEP 2012

The Higgs mass 125 GeV is a very interesting one

There are two reasons why this Higgs mass is special

- From theoretical point of view $m_h = 125$ GeV is an uncomfortable value
  - This is well below the SM vacuum stability bound 130 GeV
  - This is almost too high for the MSSM Higgs boson motivating (i) unnaturally high SUSY scale or (ii) models beyond the MSSM

- From the LHC experiment's point of view $m_h = 125$ GeV is almost an ideal value
  - All decay branching fractions to the SM particles are sizable
  - Most of the interesting signal rates,

    $$\sigma \times BR,$$

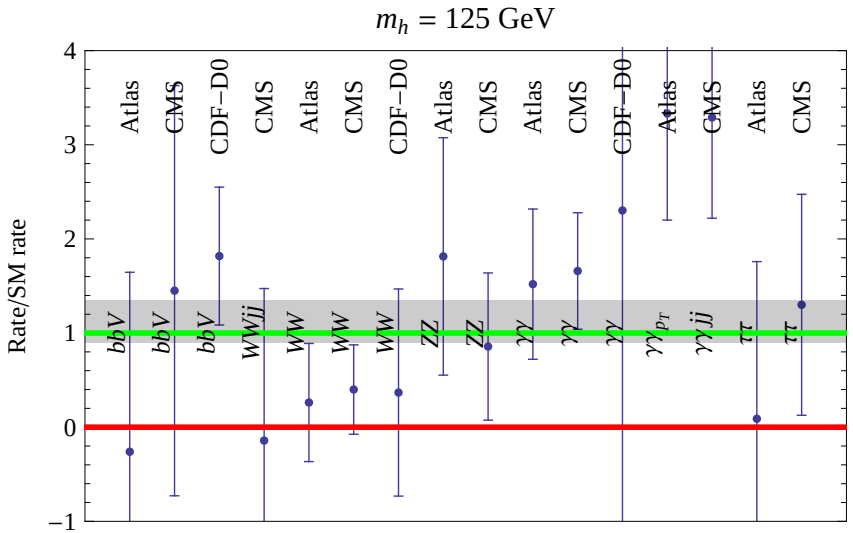
    are measurable

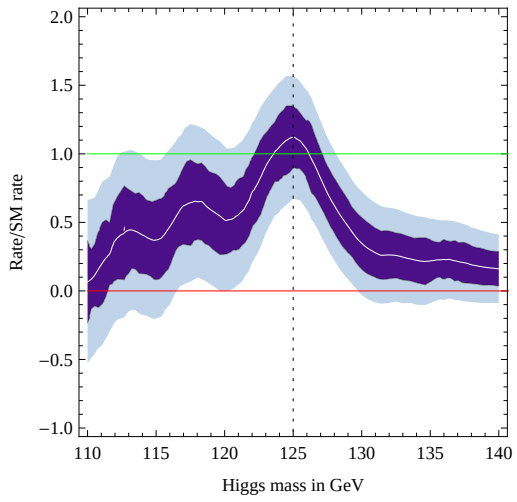
- The ideal situation for interesting physics

Is the Higgs boson standard?

arXiv:1203.4254

Overview of Higgs data after Moriond 2012





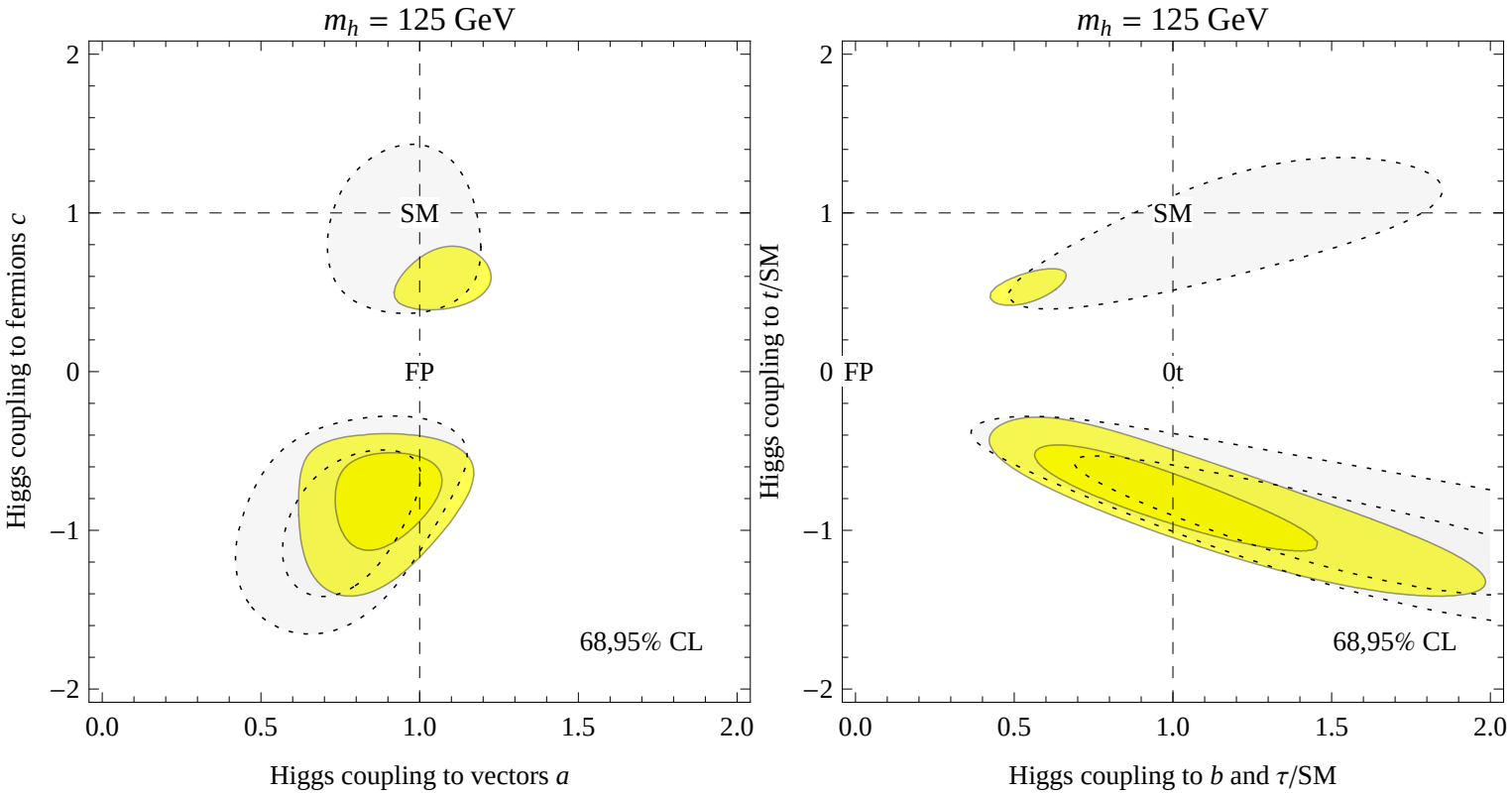
$$\frac{\text{observed rate}}{\text{SM rate}} = \begin{cases} 2.1 \pm 0.5 & \text{photons} \\ 0.5 \pm 0.3 & \text{vectors: } W \text{ and } Z \\ 1.3 \pm 0.5 & \text{fermions: } b \text{ and } \tau \end{cases}$$

- The SM fit is good: $\chi^2 \approx 17$ (15 dof), average rate is 1.1 ± 0.2
- Our results agree (semiquantitatively) with the ATLAS and CMS ones
- Is data fluctuating around the SM or is this first emerging signal of NP?

Allowing non-standard Higgs couplings to vectors and fermions

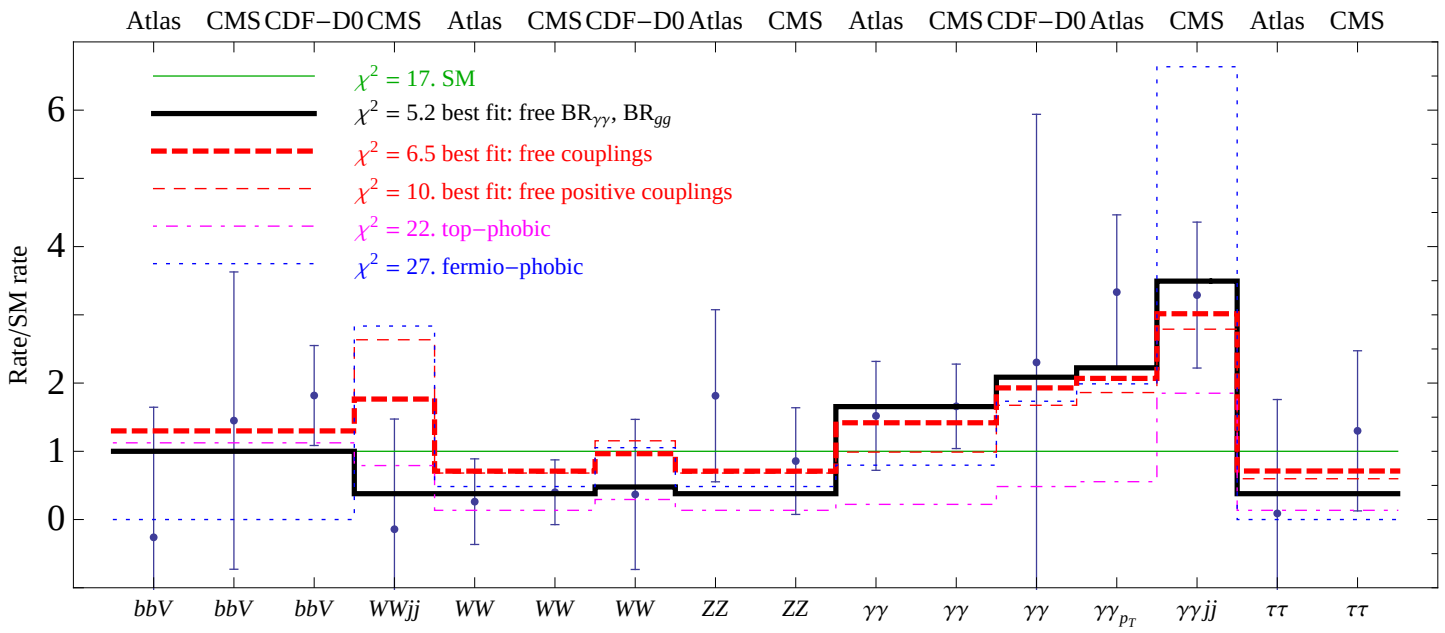
- Assume common deviation for gauge (a) and Yukawa couplings (c)

$$a = R_V \equiv R_W = R_Z, \qquad c = R_t = R_b = R_\tau$$



- Data prefers enhanced $h \to \gamma\gamma$ obtained for $y < -y^{SM}$ due to constructive interference between W and t loops

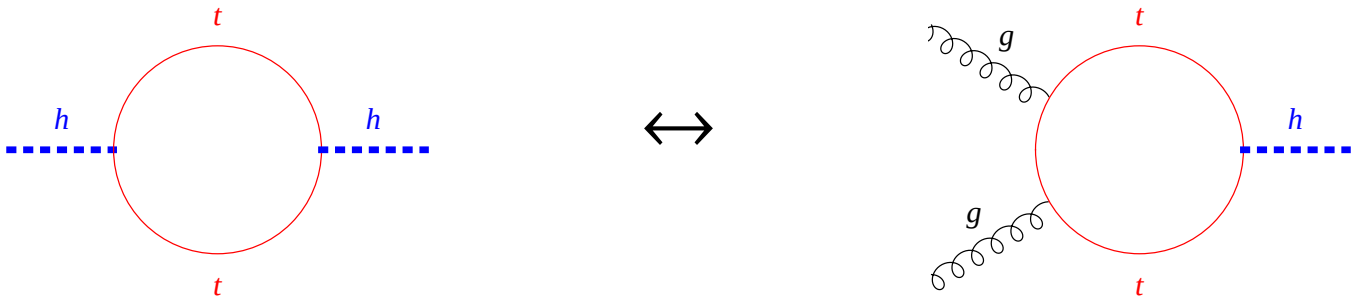
Summary of non-standard best fits



- The SM fit is good, the FP Higgs fit is as good, driven by new FP data
- We introduced two new variables to fit $\gamma\gamma$ excess and WW deficit
- Overfitting – χ^2 does not tell which scenario is preferred
- More data should show which model is realized in nature

The importance of top Yukawa - naturalness and Higgs boson couplings

- Quadratic divergences to the Higgs boson mass, δm_h^2 are dominated by top quark loops
- The same top Yukawa coupling enters into the dominant gluon-gluon fusion (ggF) Higgs production mechanism at the LHC, $gg \to h$



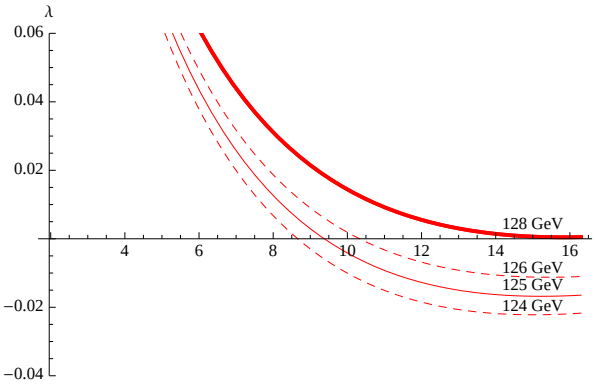
Exp. error in m_t measurement is now more important than any theoretical error - need to confirm that also fermions get a mass from the Higgs

Implications of the 125 GeV SM Higgs boson

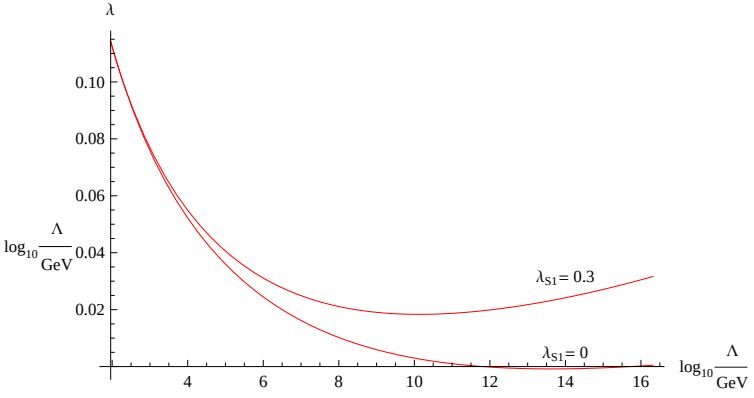
What is the fate of the Universe?

- RGE running makes the Higgs coupling $\lambda < 0$, destabilizing vacuum
- Does the SM Higgs $m_h = 125$ GeV correspond to $\lambda(M_{GUT}) = 0$?
  This would indicate/support a fundamental scale of BSM theories

NO, in the SM we would live in a metastable vacuum



The SM 2 loop RGEs



Singlet scalar DM, 1 loop RGEs

- NNLO computation exist, the SM vacuum stability bound is 130 GeV
- My favourite solution is that Higgs couples to scalar Dark Matter
- Adding a singlet scalar S with $\lambda_{S1}(S^\dagger S)(H^\dagger H)$ is enough to save us

Is there a new fundamental scale at 10^{12} GeV?

- $\lambda = 0$ can be associated with the new fundamental scale where scalars and flavour physics is generated
- It coincides with the seesaw and leptogenesis scale
- It agrees with the allowed axion decay constant window 10^9 GeV $< f_a < 10^{12}$ GeV

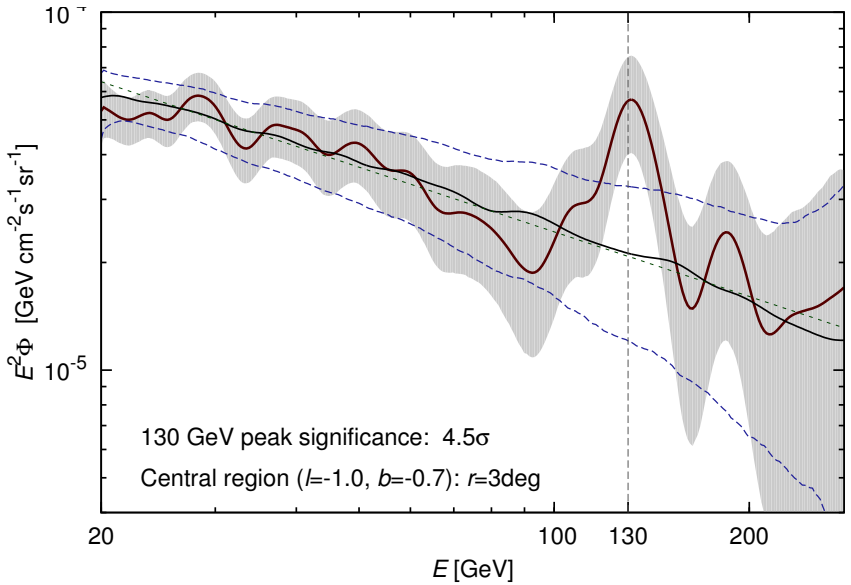
Alessandro Strumia advocates a scenario

- Higgs boson is a pseudo-goldstone of some tecnhicolour like theory at 10^{12} GeV
- DM is the axion
- Gauge couplings unification due to the new particles at that scale
- Anthropic principle/landscape explains the absence of naturalness

Experiments should decide whether the DM is a WIMP or an axion

New indirect evidence that DM is WIMP!

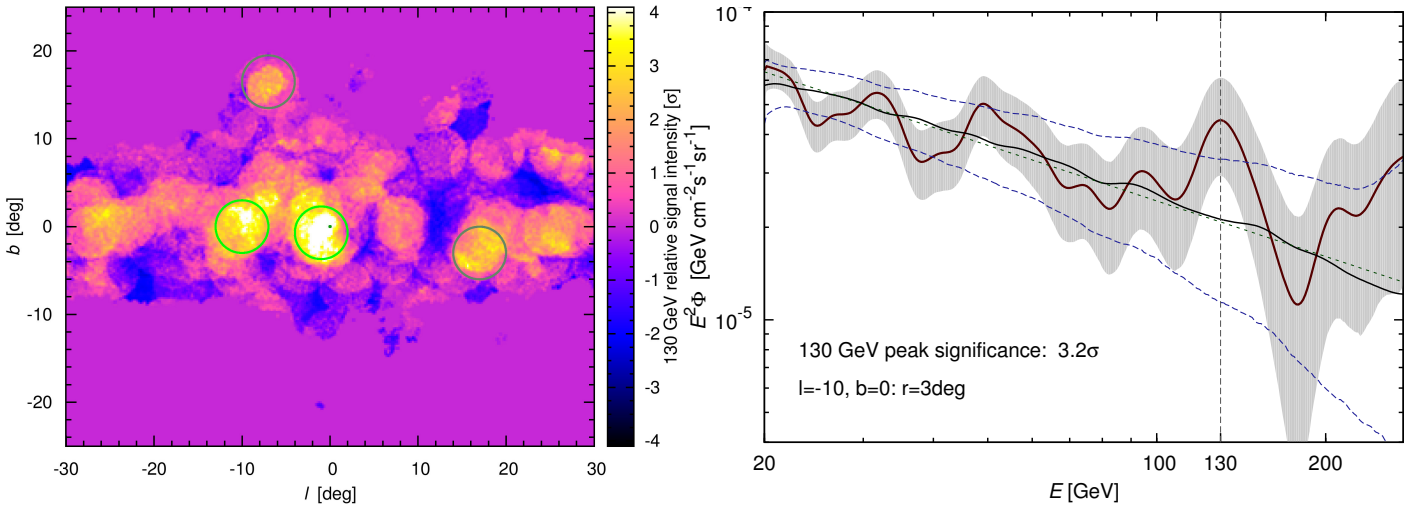
- C. Weniger discovered a monochromatic gamma-ray line in Fermi publicly available data coming from the center of Galaxy
- We confirmed in arXiv:1205.1045 the existence of a clear peak
- Data is consistent with DM annihilations with xc of 10% of the standard thermal cx



- Today there is no question whether the peak exists or not!
- Fermi collaboration has confirmed that. They check whether this is an instrumental artifact or physics!

DM substructure?

- The signal originates from small regions in the center of Galaxy



- Our preliminary results show the 130 GeV line also coming from galaxy clusters

Non-trivial model building is needed to couple DM to photons with such a cross section

Conclusions

- Intermediate scale 10^{12} GeV may play fundamental role in physics
- DM experiments should decide whether the DM is WIMP or axion motivate the intermediate scale
- LHC needs to test Higgs boson and top/bottom/tau couplings with better precision

- We are going to know much more after ICHEP 2012/Xenon100/Fermi new results
- The emerging picture may not be the standard one expected before LHC started
- We going to know a lot more just in two weeks