Quo Vadis, Theory?

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Disclaimer

'This is just my humble opinion'

- Physics is a experimental science and there are still several aspects of particle physics that we are not satisfied with.

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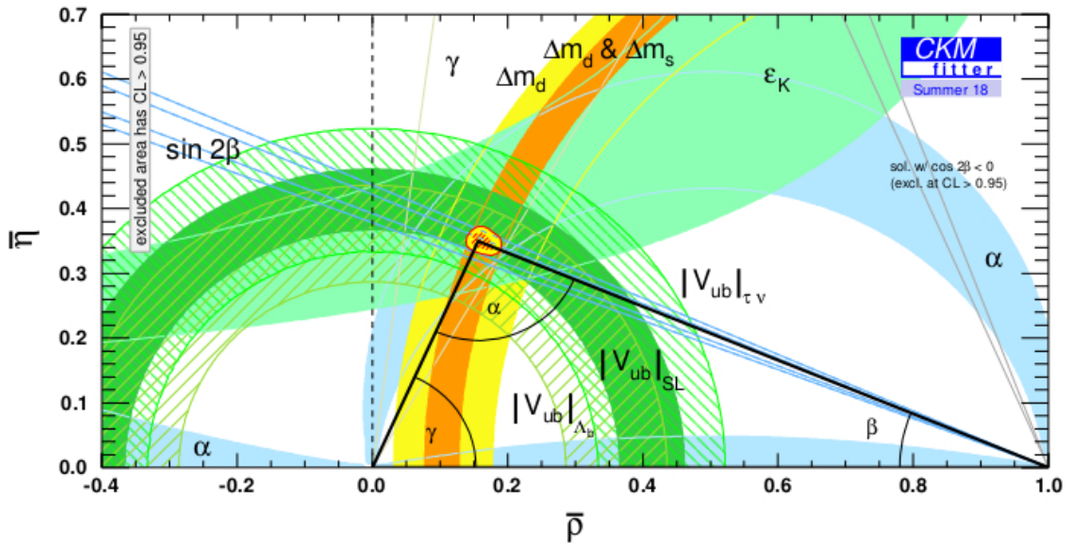
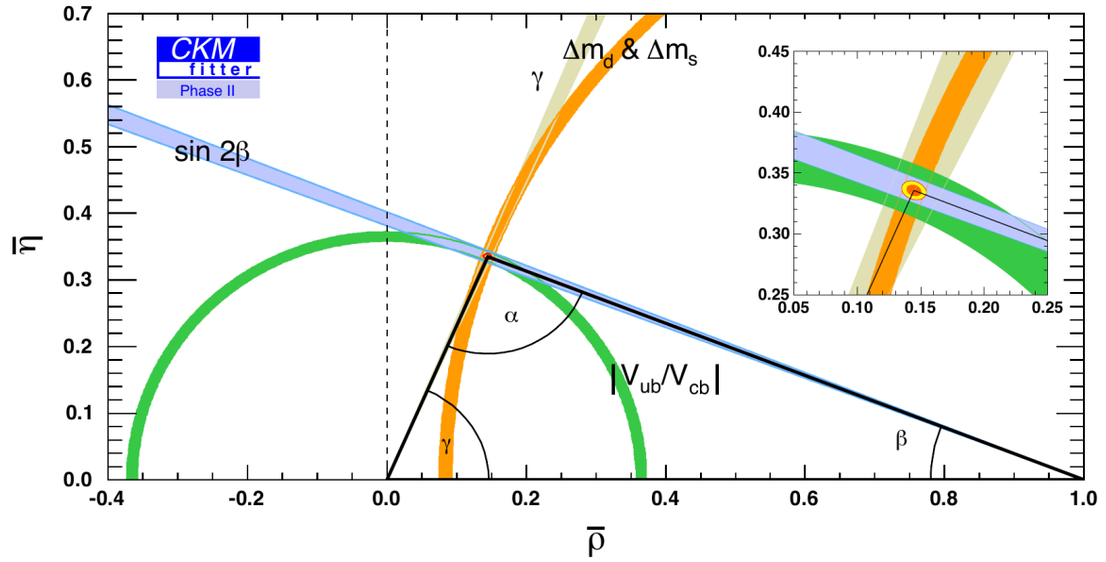
- NB: Except DM all of them (naturalness, flavor, flatness problem, matter-antimatter,…) can just be related to initial conditions.

Flavor

- **Current**

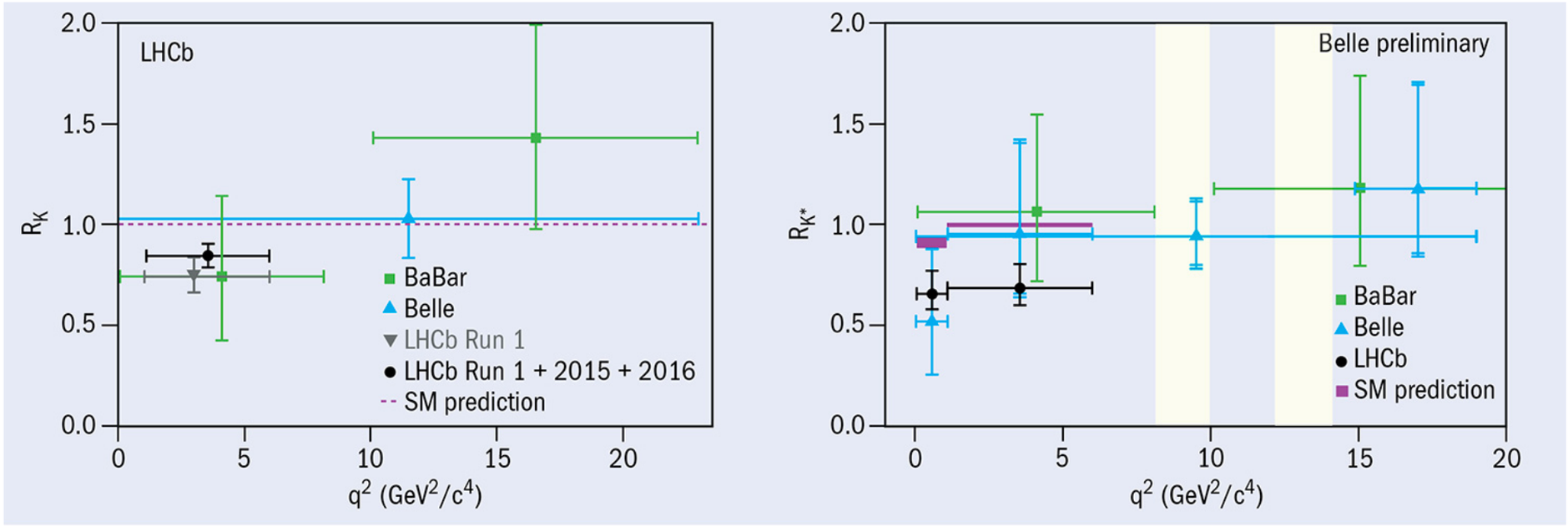


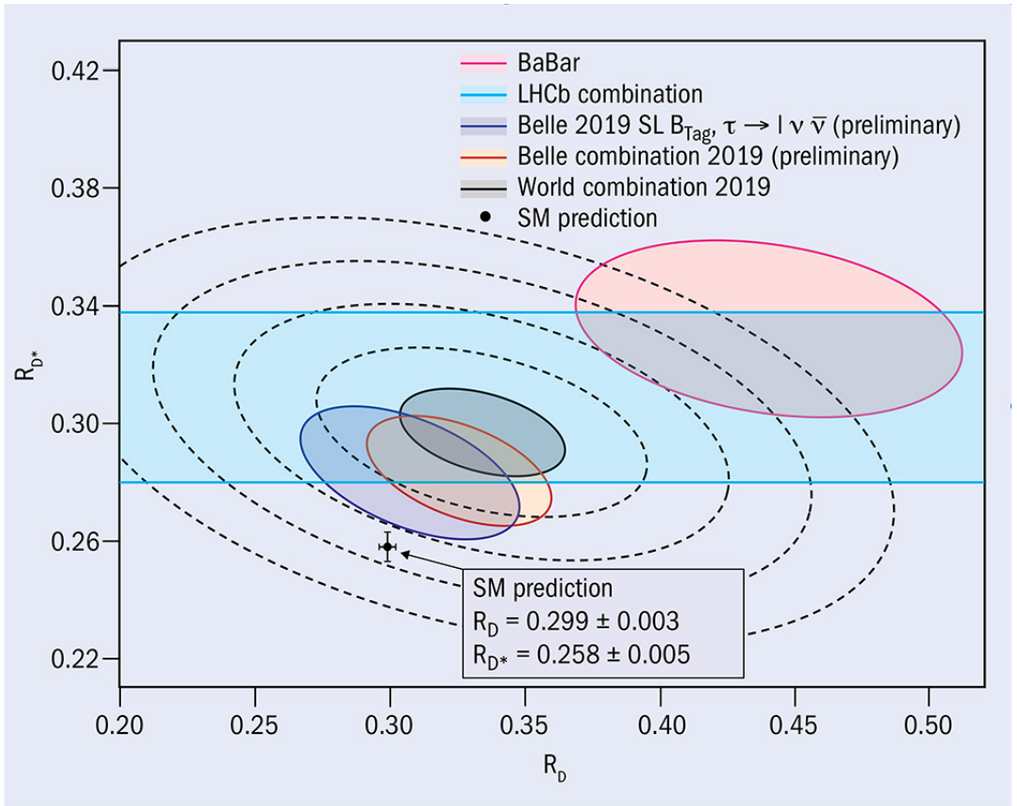
- **Projection HL-LHC only**



"Opportunities in Flavour Physics at the HL-LHC and HE-LHC", A. Cerri *et al.*, arXiv: 1812.07638

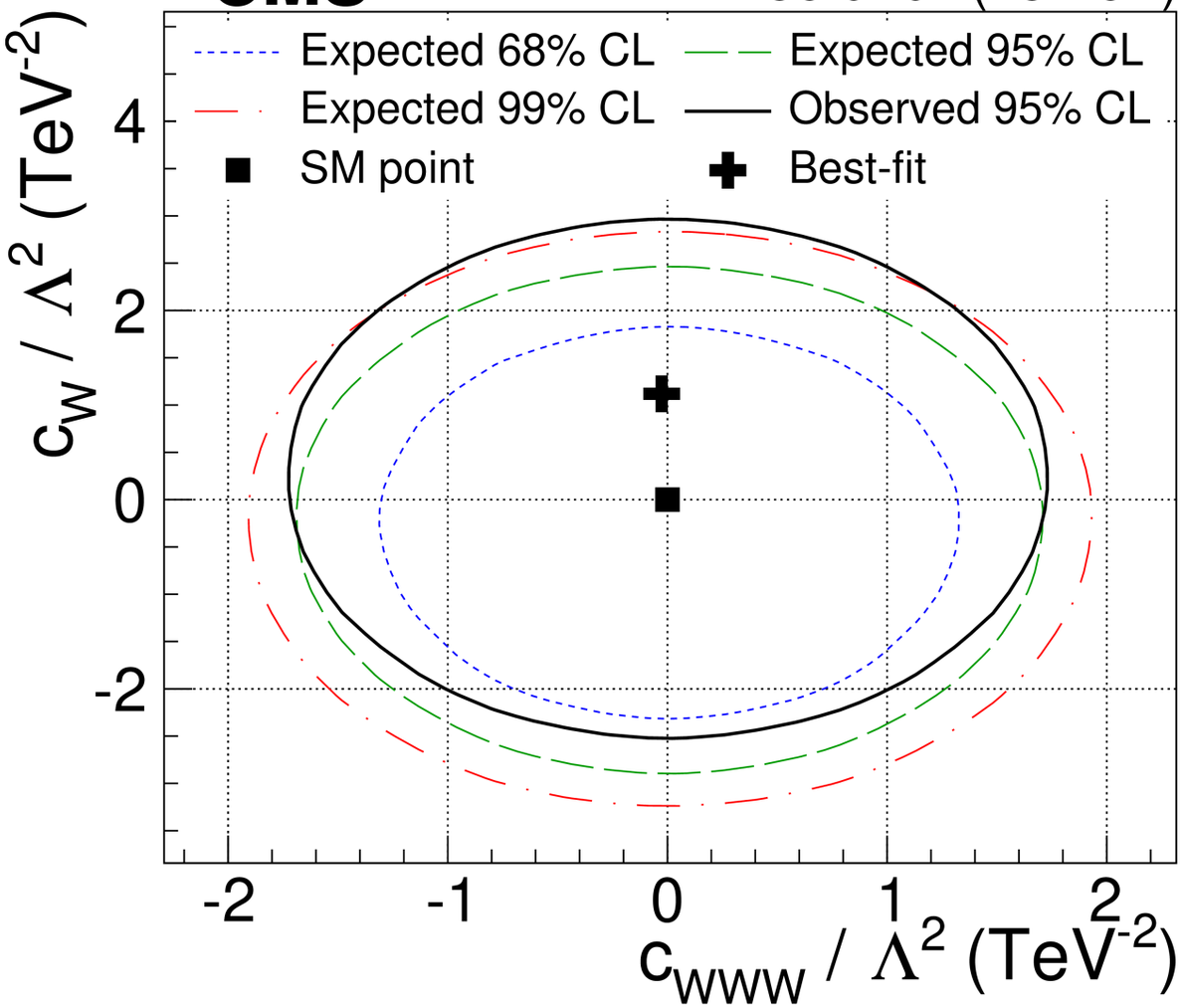
Lepton universality

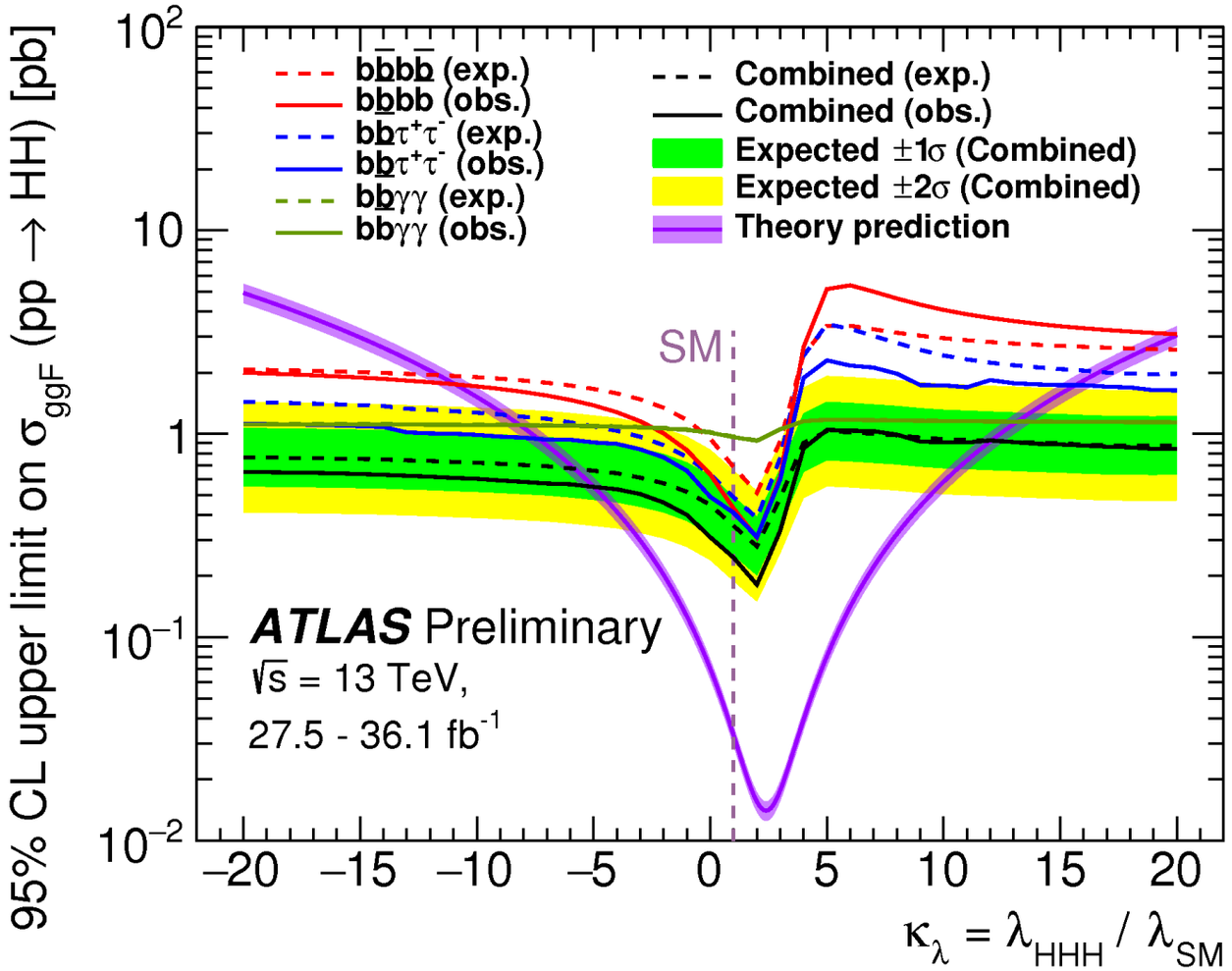




G. Caria @ Moriond EW 2019 (arXiv:1904.0879)

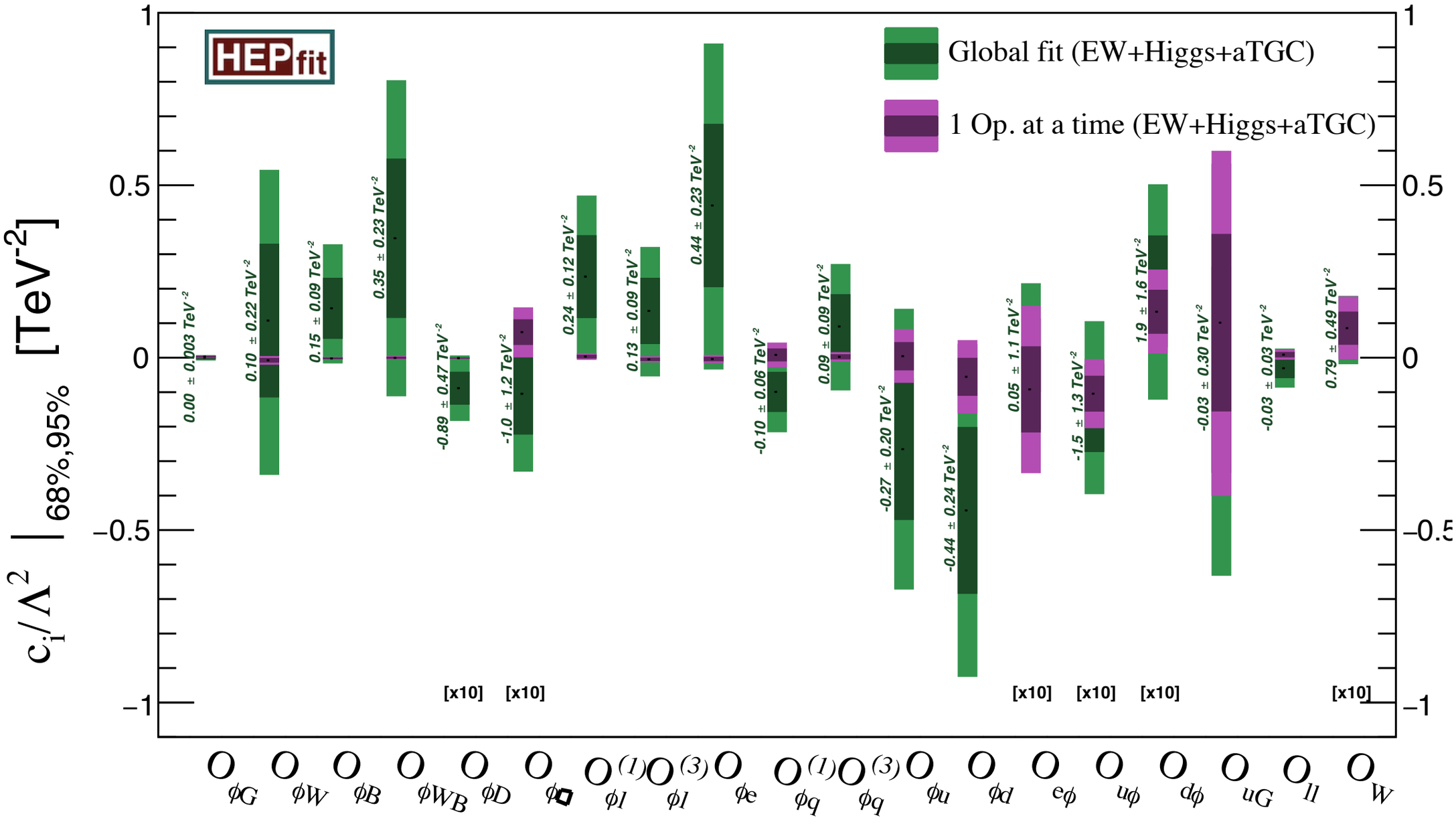
SM predictions/deviations





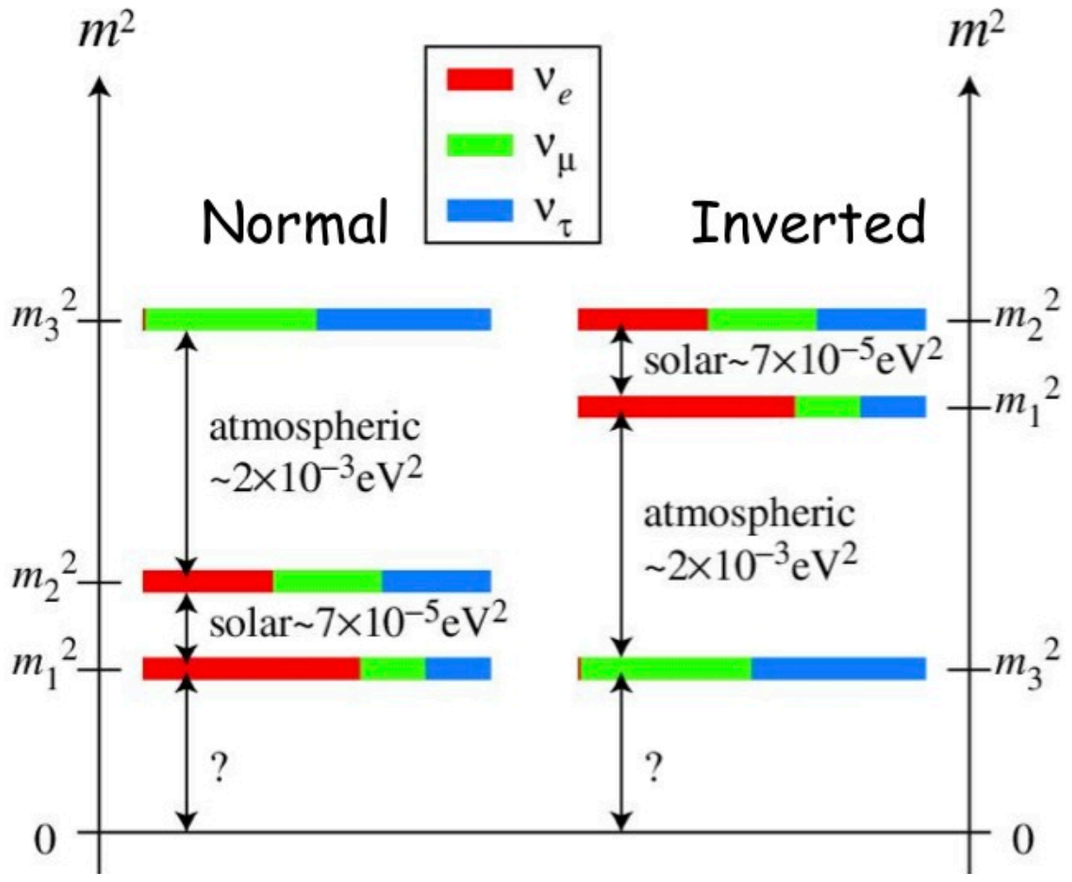
EFT approach

arXiv:1910.14012

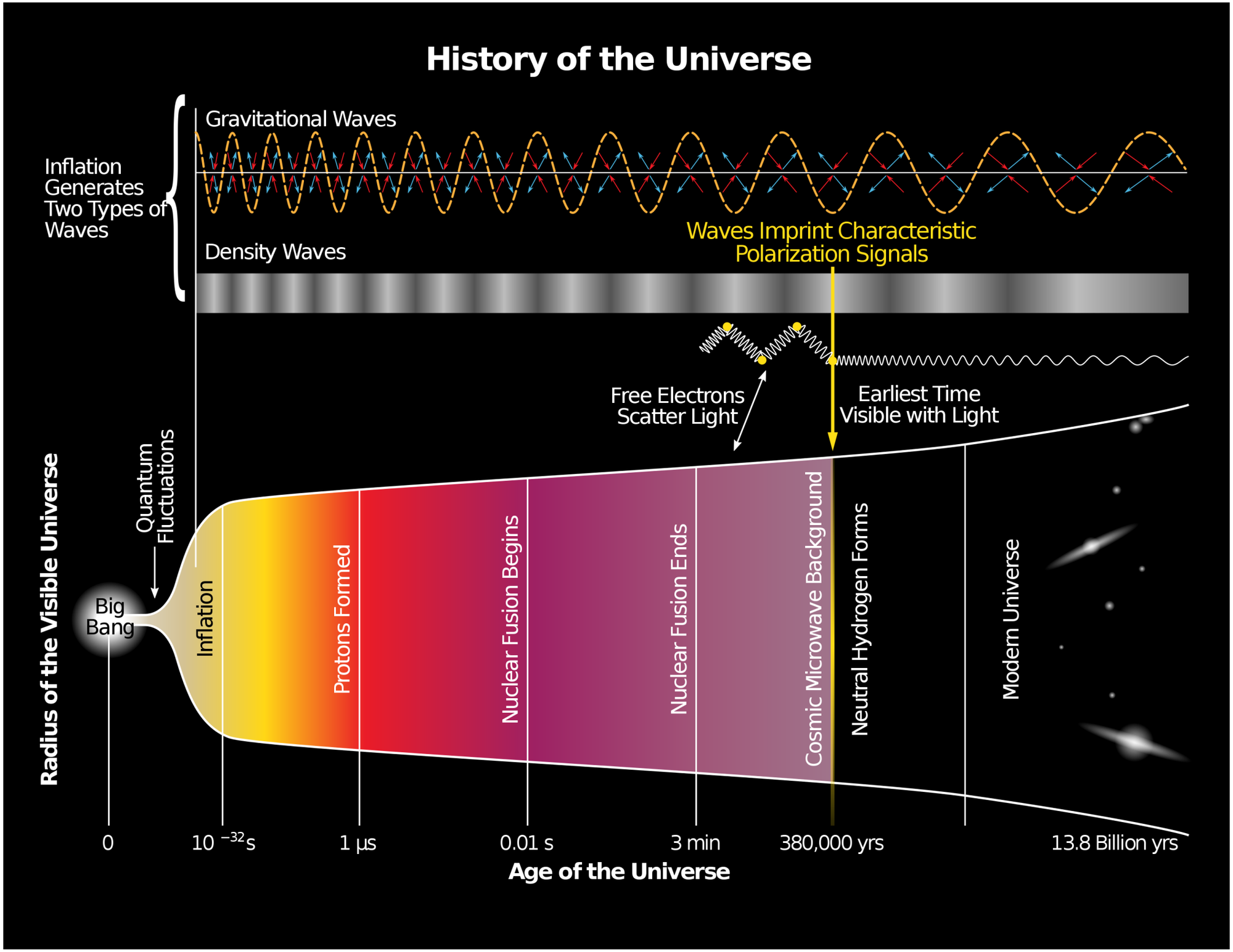


Neutrinos

- We need to know the hierarchy
- We need to know the nature (majorana vs Dirac)
- We need to know if there are sterile neutrinos

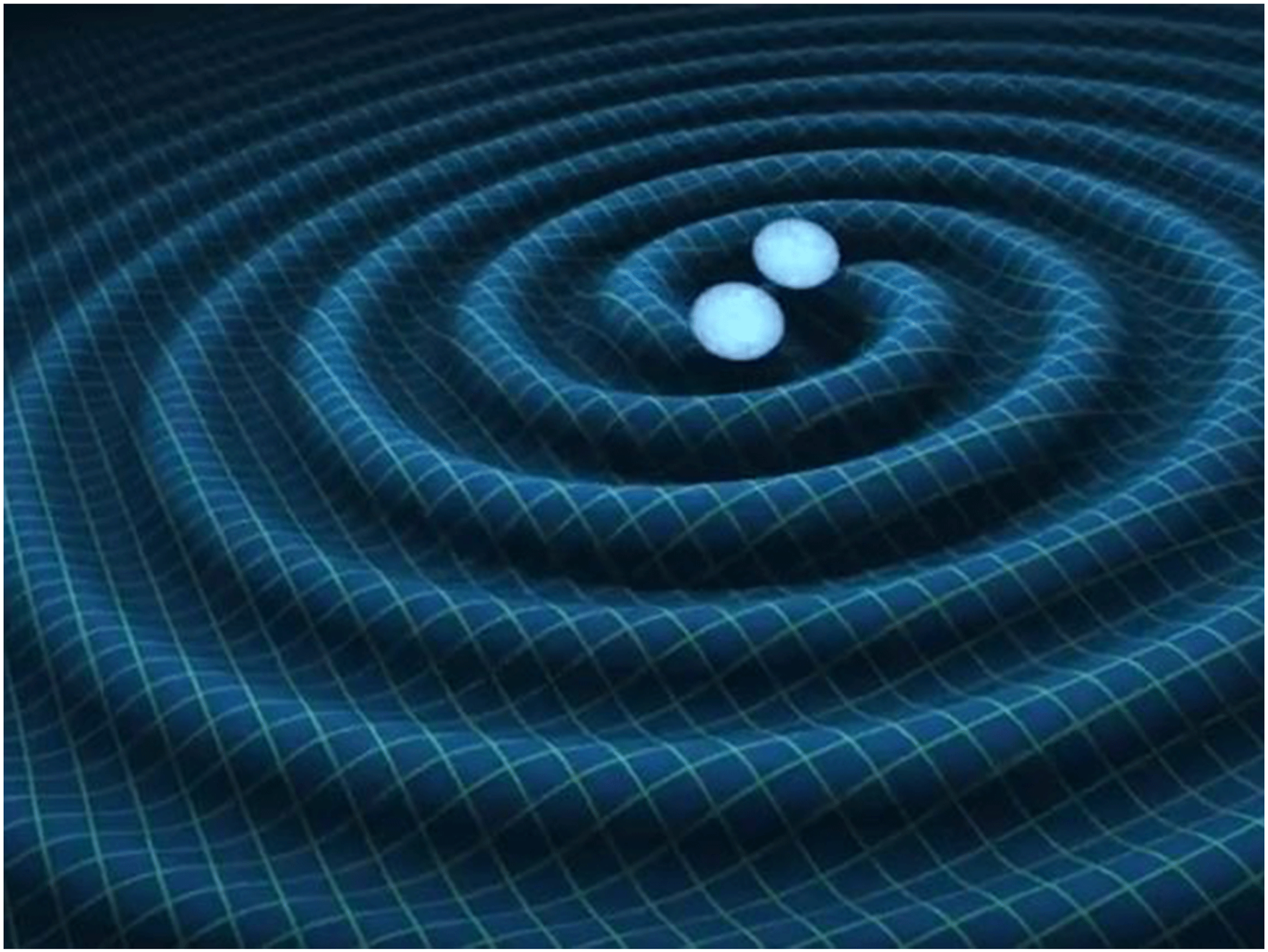


Cosmology


History of the Universe
Inflation Generates Two Types of Waves
Gravitational Waves
Density Waves
Waves Imprint Characteristic Polarization Signals
Free Electrons Scatter Light
Earliest Time Visible with Light
Radius of the Visible Universe
Quantum Fluctuations
Big Bang
Inflation
Protons Formed
Nuclear Fusion Begins
Nuclear Fusion Ends
Cosmic Microwave Background
Neutral Hydrogen Forms
Modern Universe
0
10 −32s
1 μs
0.01 s
3 min
380,000 yrs
13.8 Billion yrs
Age of the Universe

- There are several open problems in cosmology.
- Is ΛCDM enough?
- Inflation?
- Structure formation?
- matter-antimatter
- CP?

Gravitational Waves



- Apart from being a new way of ‘seeing' the universe which can change the astrophysics
- eLisa could be sensitive to an stochastic background of GW coming from phase transitions in the early universe

Open problems in theory:

- Amplitudes……
- Strong CP-problem
- Quantum Gravity: WGC, Swampland

Theory input for new colliders

- Precision calculations
- MC generators
- Parton showering
- Detector simulation

Naturalness

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- …and the reason to build a new collider

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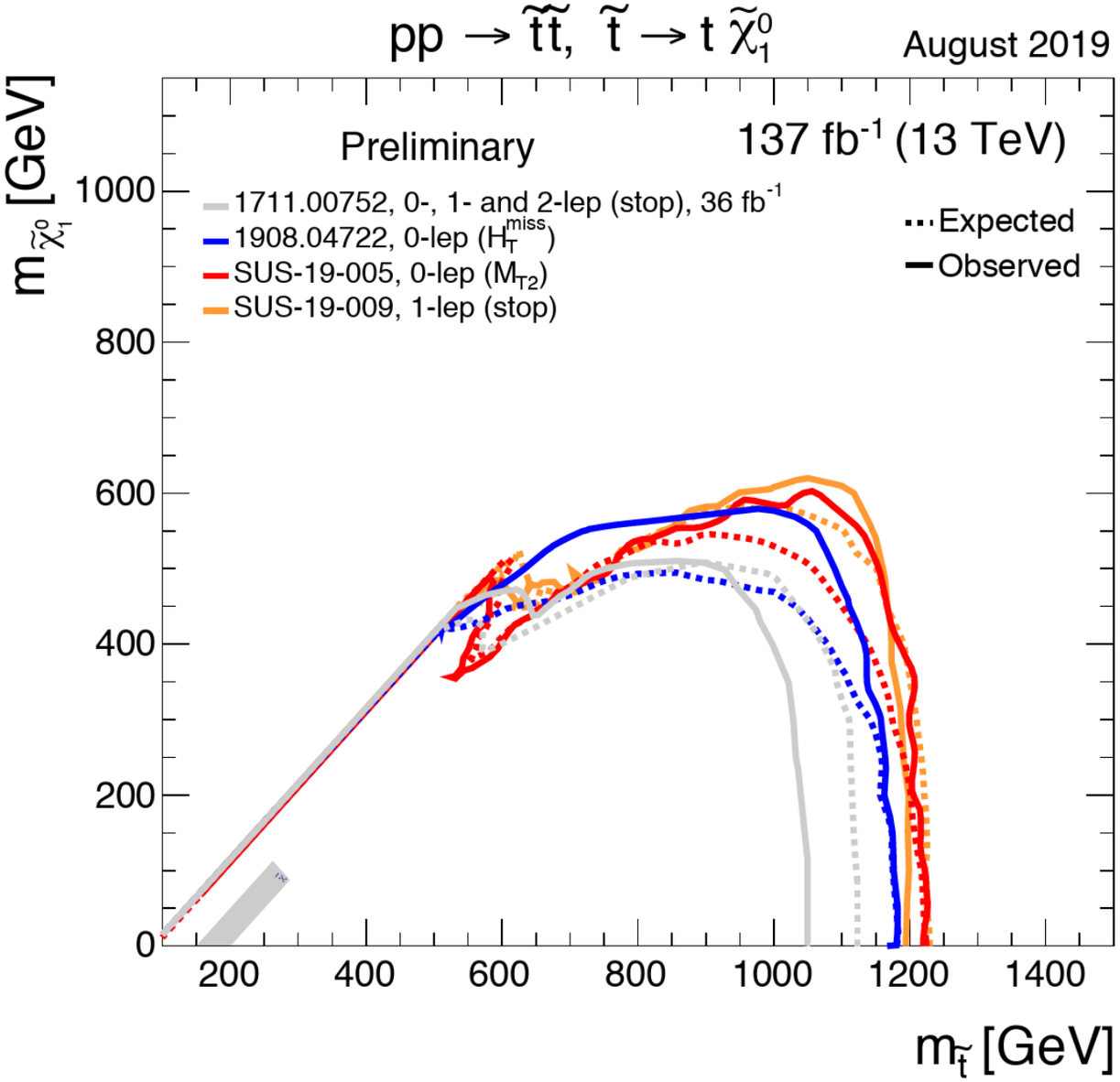
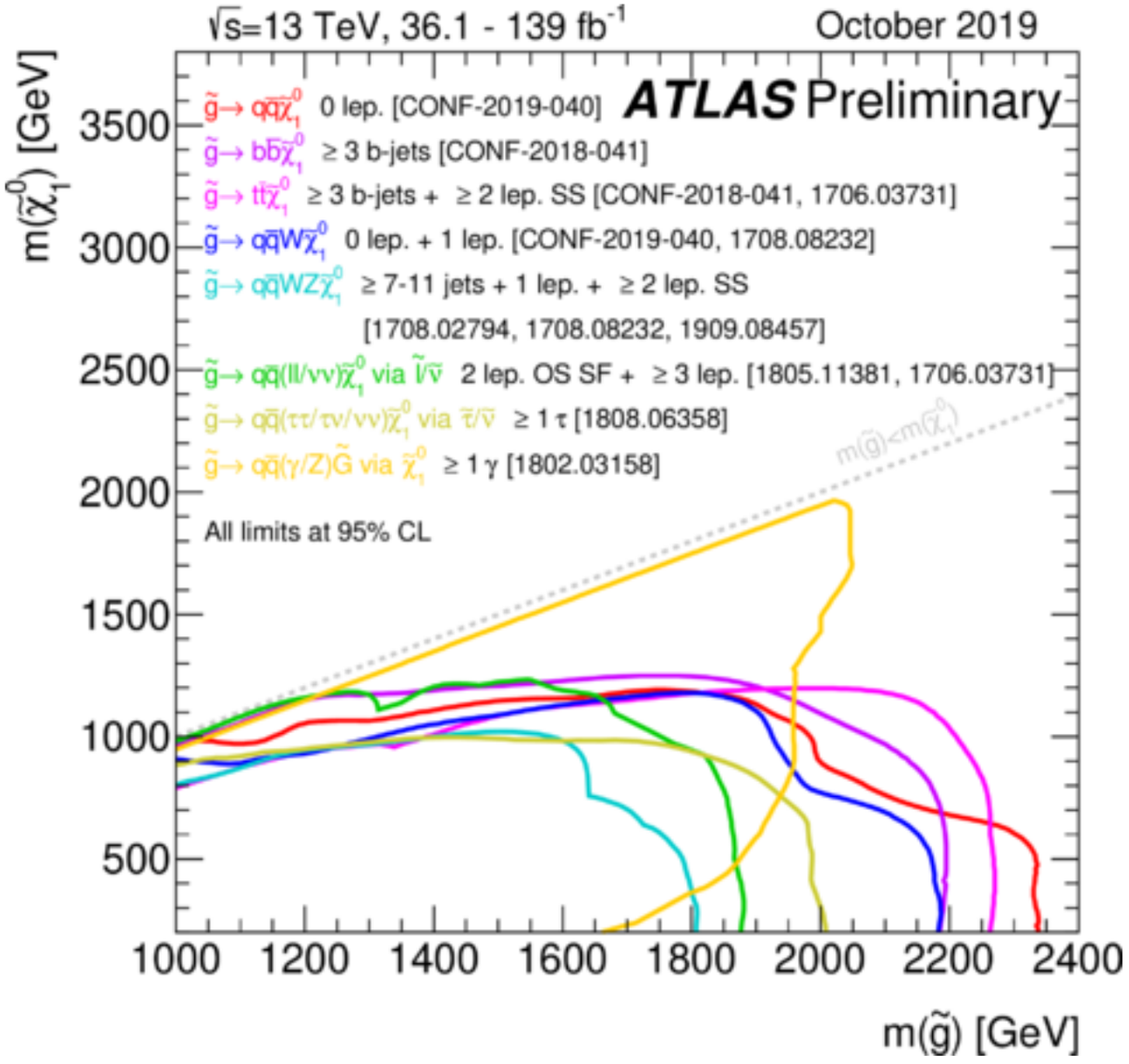
- We need to know if naturalness have something to do with the value of the EW scale
- …or is just an accident.
- Any theory that address naturalness requires new particles that necessarily will modify Higgs couplings…..another argument to measure with precision!!!!!!


pp → t̃t̄, t̃ → t χ̃⁰₁
August 2019
Preliminary
137 fb⁻¹ (13 TeV)
1711.00752, 0-, 1- and 2-lep (stop), 36 fb⁻¹
1908.04722, 0-lep (H_T^miss)
SUS-19-005, 0-lep (M_T2)
SUS-19-009, 1-lep (stop)
Expected
Observed
m_χ̃⁰₁ [GeV]
m_t̃ [GeV]

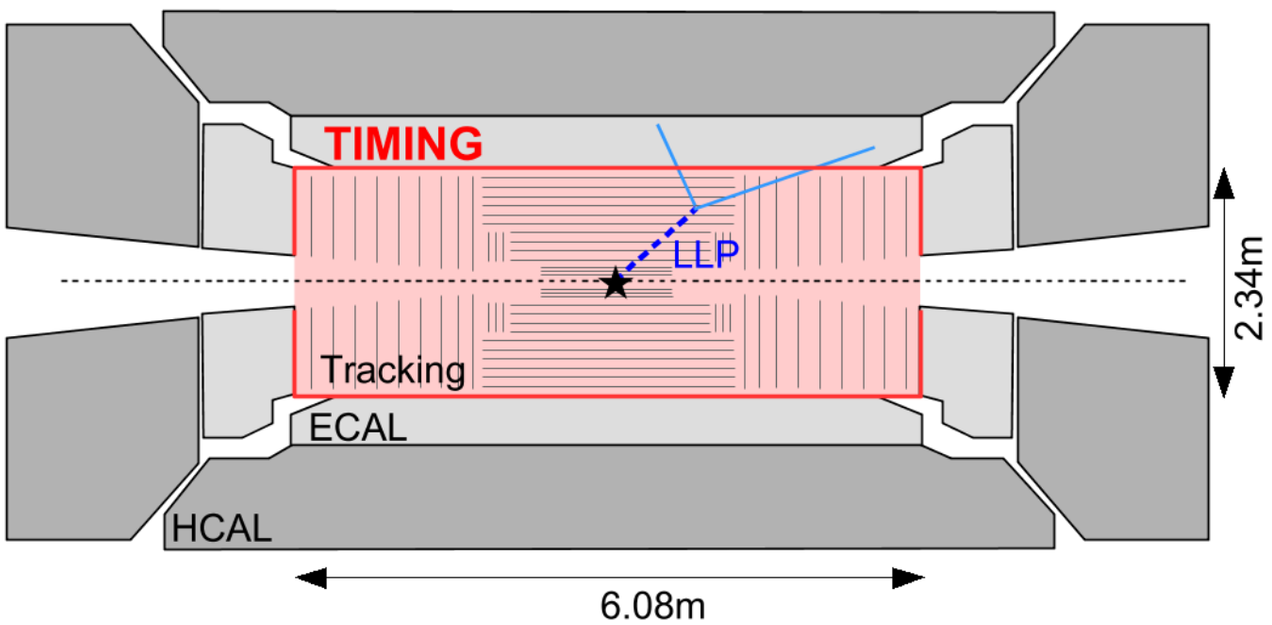

√s=13 TeV, 36.1 - 139 fb⁻¹
October 2019
ATLAS Preliminary
g̃→ qqχ̃⁰₁ 0 lep. [CONF-2019-040]
g̃→ bbχ̃⁰₁ ≥ 3 b-jets [CONF-2018-041]
g̃→ ttχ̃⁰₁ ≥ 3 b-jets + ≥ 2 lep. SS [CONF-2018-041, 1706.03731]
g̃→ qqWχ̃⁰₁ 0 lep. + 1 lep. [CONF-2019-040, 1708.08232]
g̃→ qqWZχ̃⁰₁ ≥ 7-11 jets + 1 lep. + ≥ 2 lep. SS
[1708.02794, 1708.08232, 1909.08457]
g̃→ qq(ll/νν)χ̃⁰₁ via l̃/ν̃ 2 lep. OS SF + ≥ 3 lep. [1805.11381, 1706.03731]
g̃→ qq(ττ/τν/νν)χ̃⁰₁ via τ̃/ν̃ ≥ 1 τ [1808.06358]
g̃→ qq(γ/Z)G̃ via χ̃⁰₁ ≥ 1 γ [1802.03158]
All limits at 95% CL
m(g̃)=m(χ̃⁰₁)
m(χ̃⁰₁) [GeV]
m(g̃) [GeV]

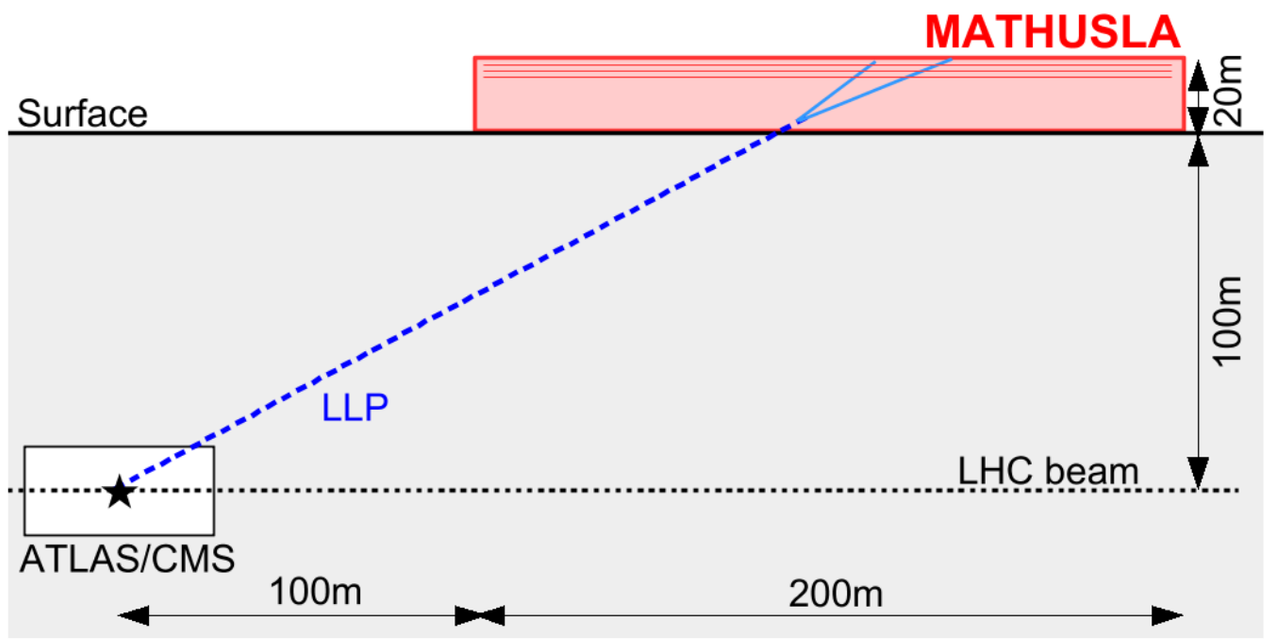

You're just going to keep looking under this light?
Well, I literally can't see anything in the dark, so yeah.
@redpenblackpen

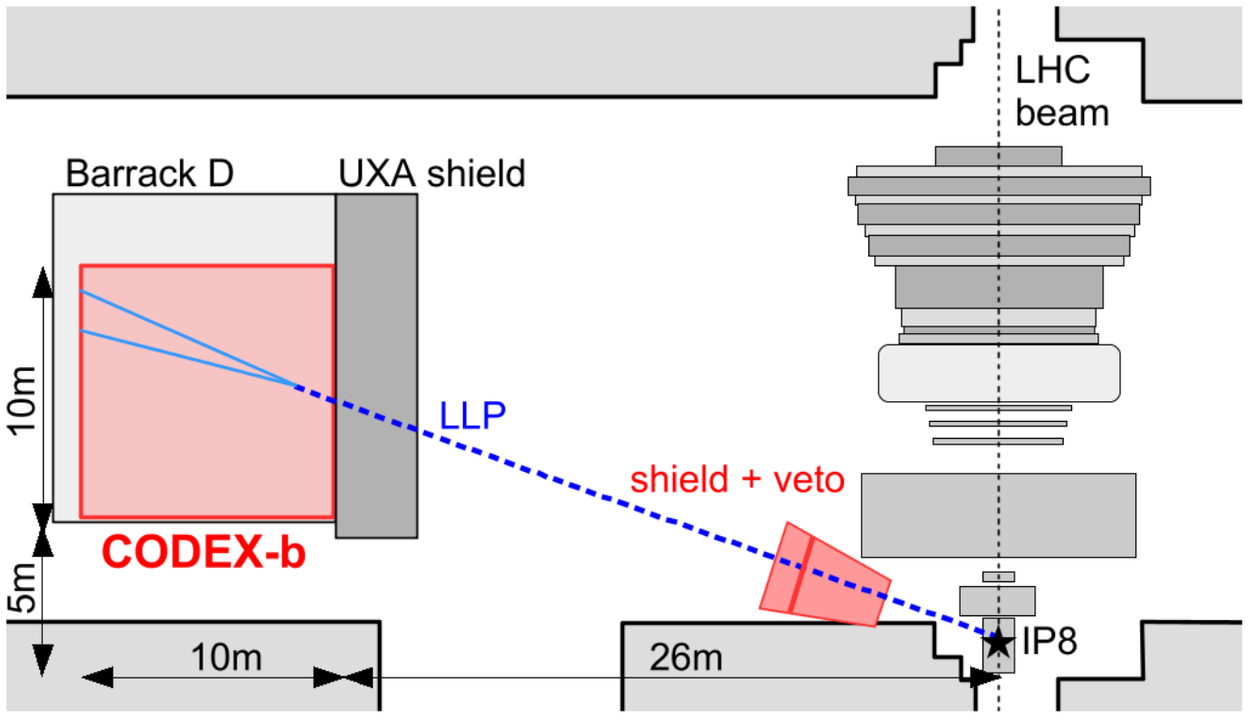
- But there are several alternative to susy or strongly coupled higgses without color partners

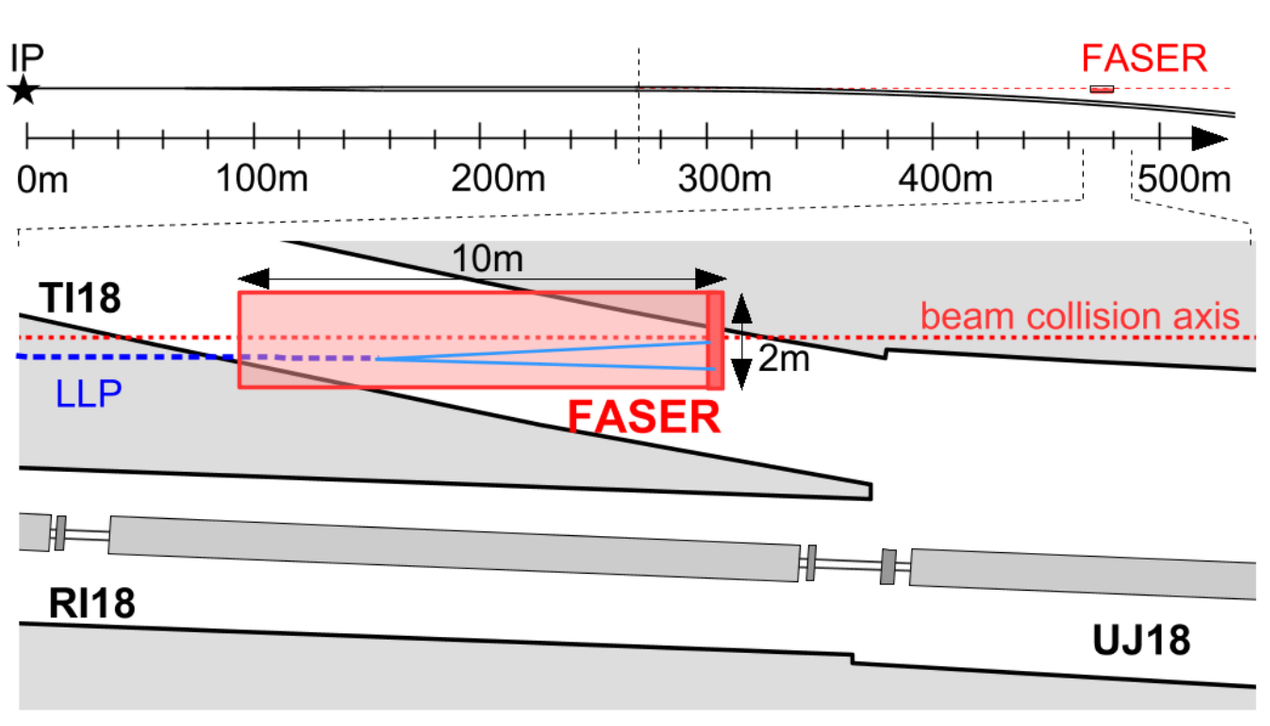
- We need to be prepared to look for the unexpected

- specially for long lived particles


TIMING
LLP
Tracking
ECAL
HCAL
2.34m
6.08m


MATHUSLA
Surface
20m
100m
LLP
LHC beam
ATLAS/CMS
100m
200m

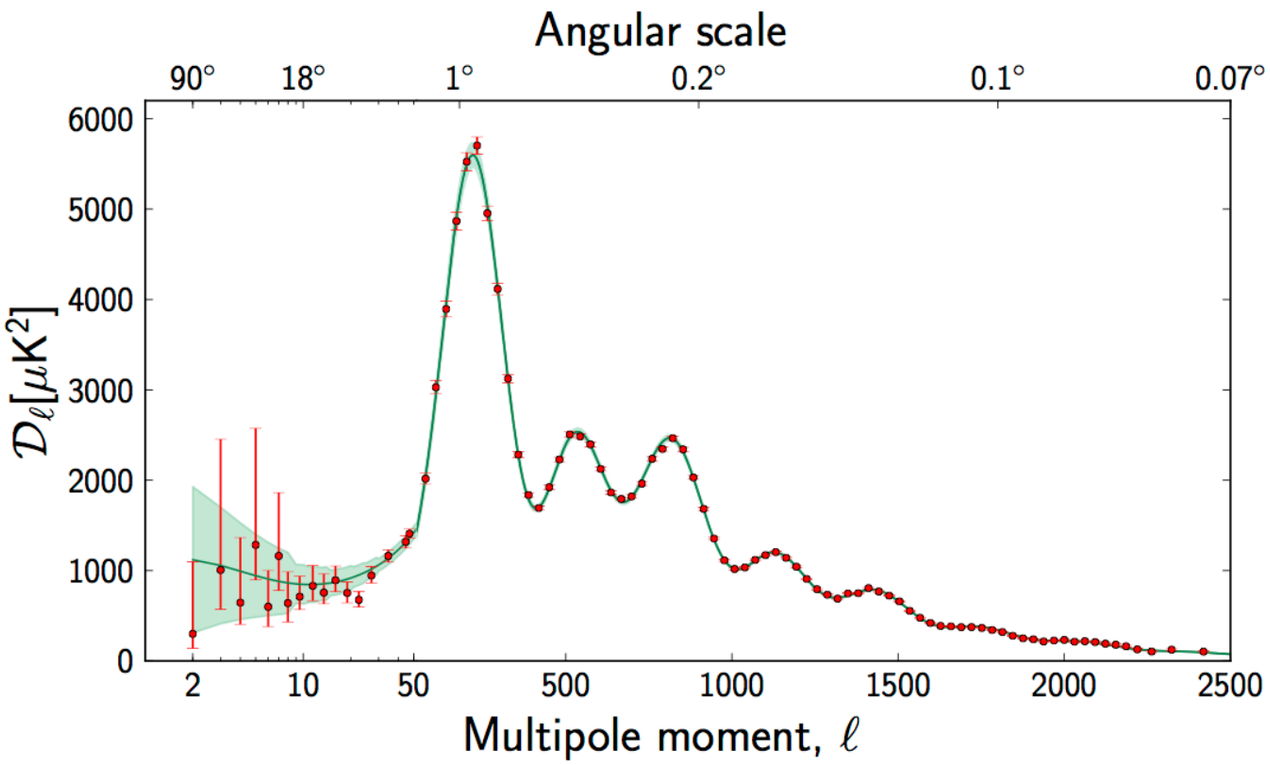

LHC
beam
Barrack D
UXA shield
10m
LLP
shield + veto
CODEX-b
5m
10m
26m
IP8

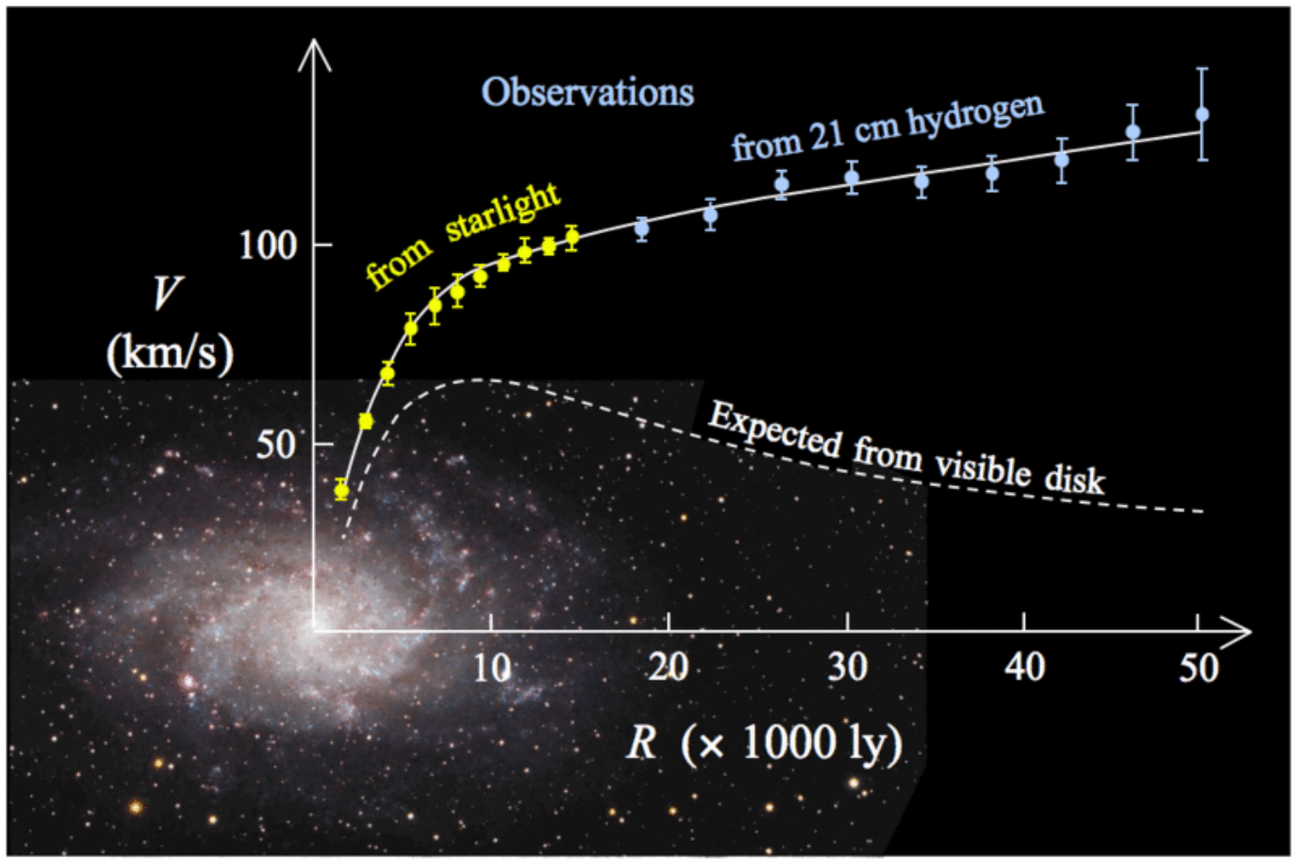

IP
FASER
0m
100m
200m
300m
400m
500m
10m
TI18
beam collision axis
2m
LLP
FASER
RI18
UJ18

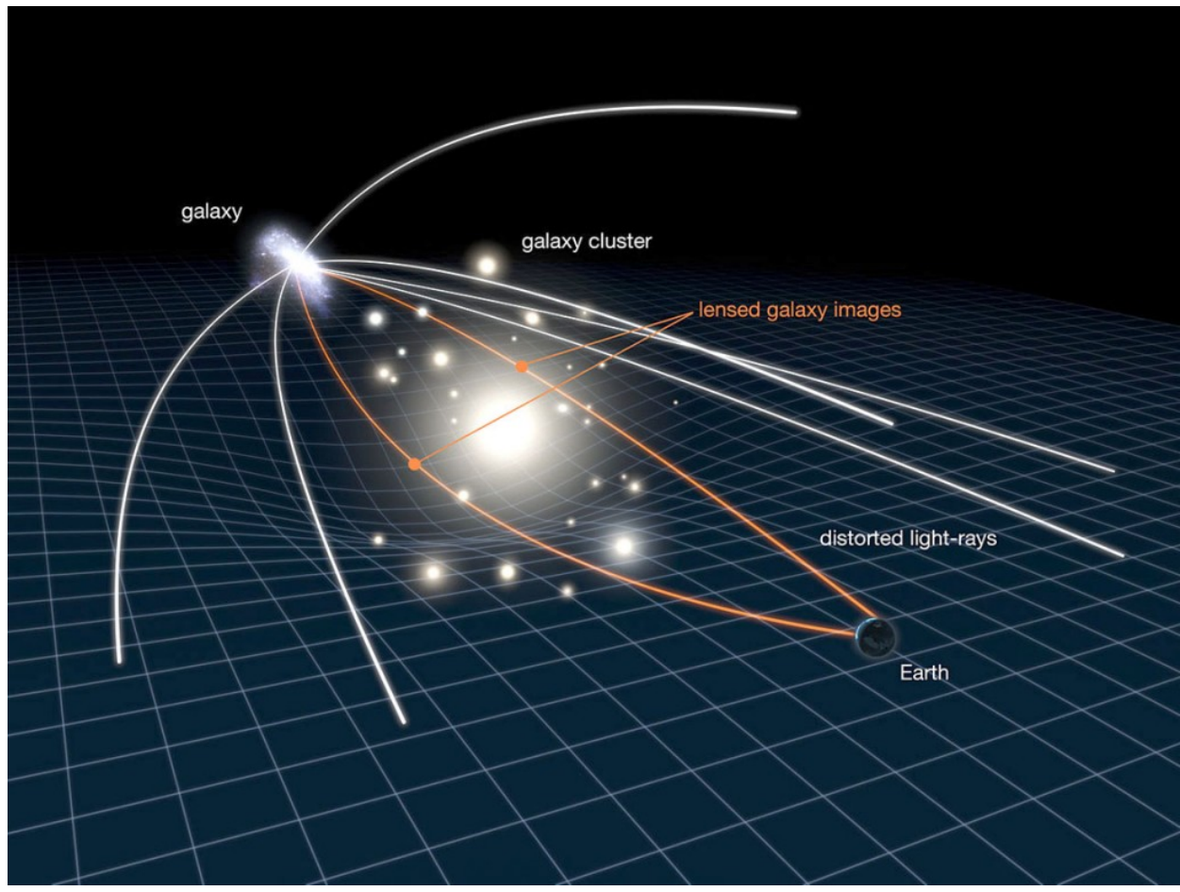
Dark Matter

- Dark matter is the most stablished reason for physics beyond the SM

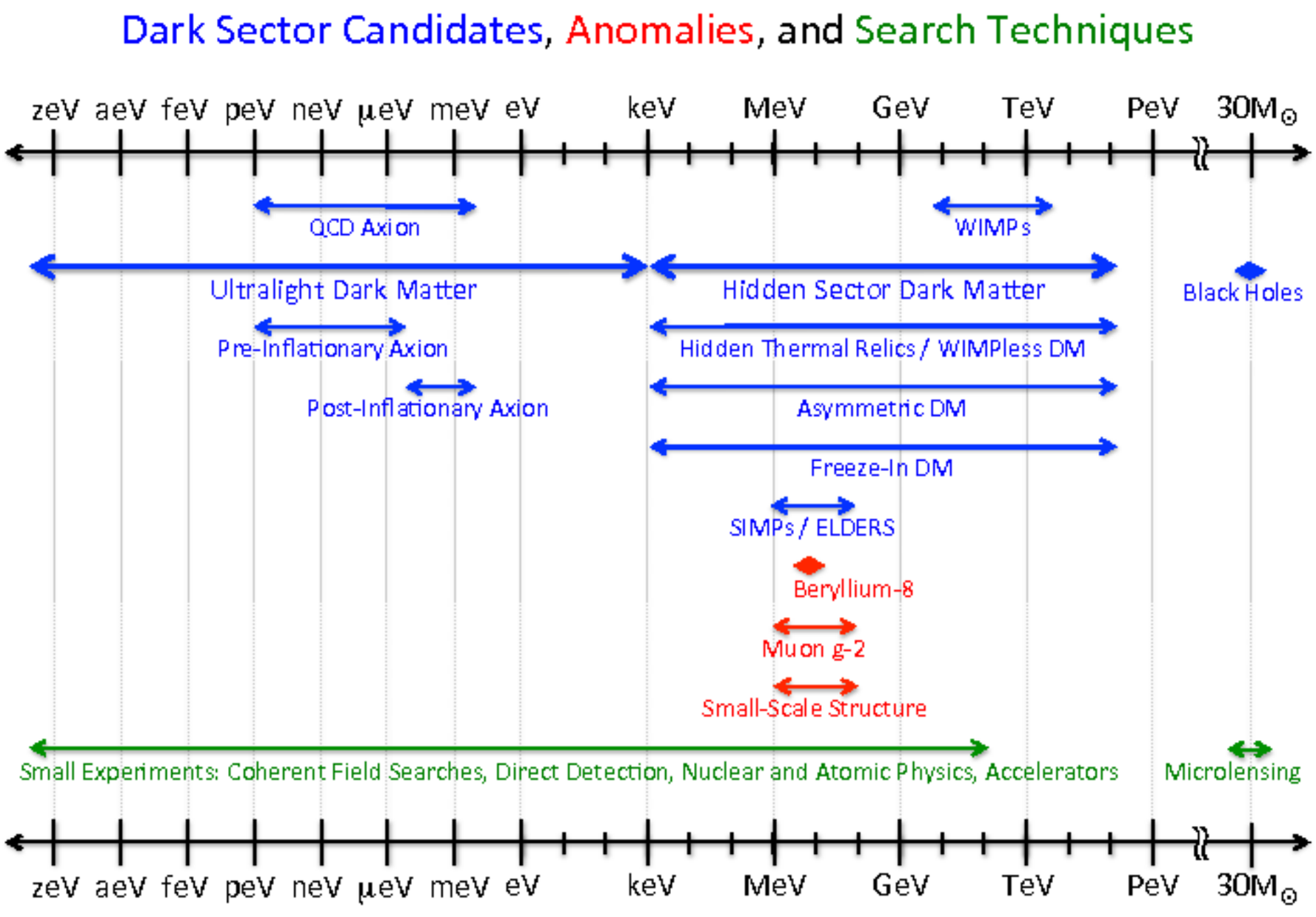
- We have evidence in several cosmological scales.


Angular scale
90°
18°
1°
0.2°
0.1°
0.07°
6000
5000
4000
3000
2000
1000
0
$\mathcal{D}_\ell[\mu K^2]$
2
10
50
500
1000
1500
2000
2500
Multipole moment, ℓ

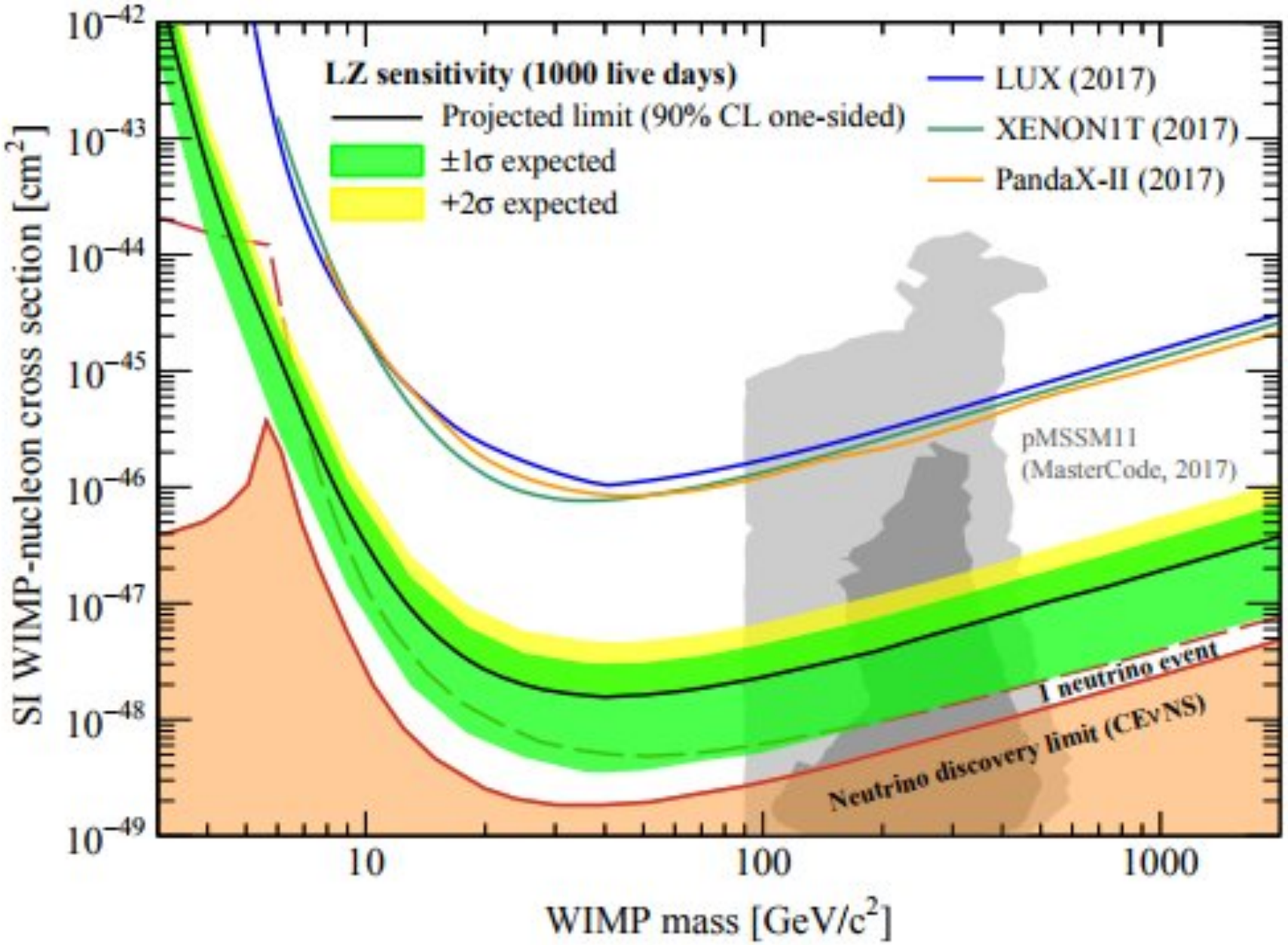

Observations
from 21 cm hydrogen
from starlight
100
50
V
(km/s)
Expected from visible disk
10
20
30
40
50
R (× 1000 ly)


galaxy
galaxy cluster
lensed galaxy images
distorted light-rays
Earth

But we have no idea what it is:



And a thermal relic is in somewhat trouble



- There are several wimp scenarios where DD is reduced:
  - Blind spots
  - Pure Higgisino
  - Gravitino
  - sterile neutrino

- There are several scenarios very different:
  - axions
  - fuzzy DM
  - Dark photons or dark sectors…..
  - primordial black holes??

Conclusions

- There are lots of open questions in theory, but the most important thing is to be open minded

- There are a lot of regions of parameters space unexplored by the LHC, DM searches or cosmological probes

- The Higgs was already an achievement


The best
Is yet
To come