

IPA Interplay between Particle and Astroparticle Physics

Looking for new physics

Veronica Sanz (Sussex)

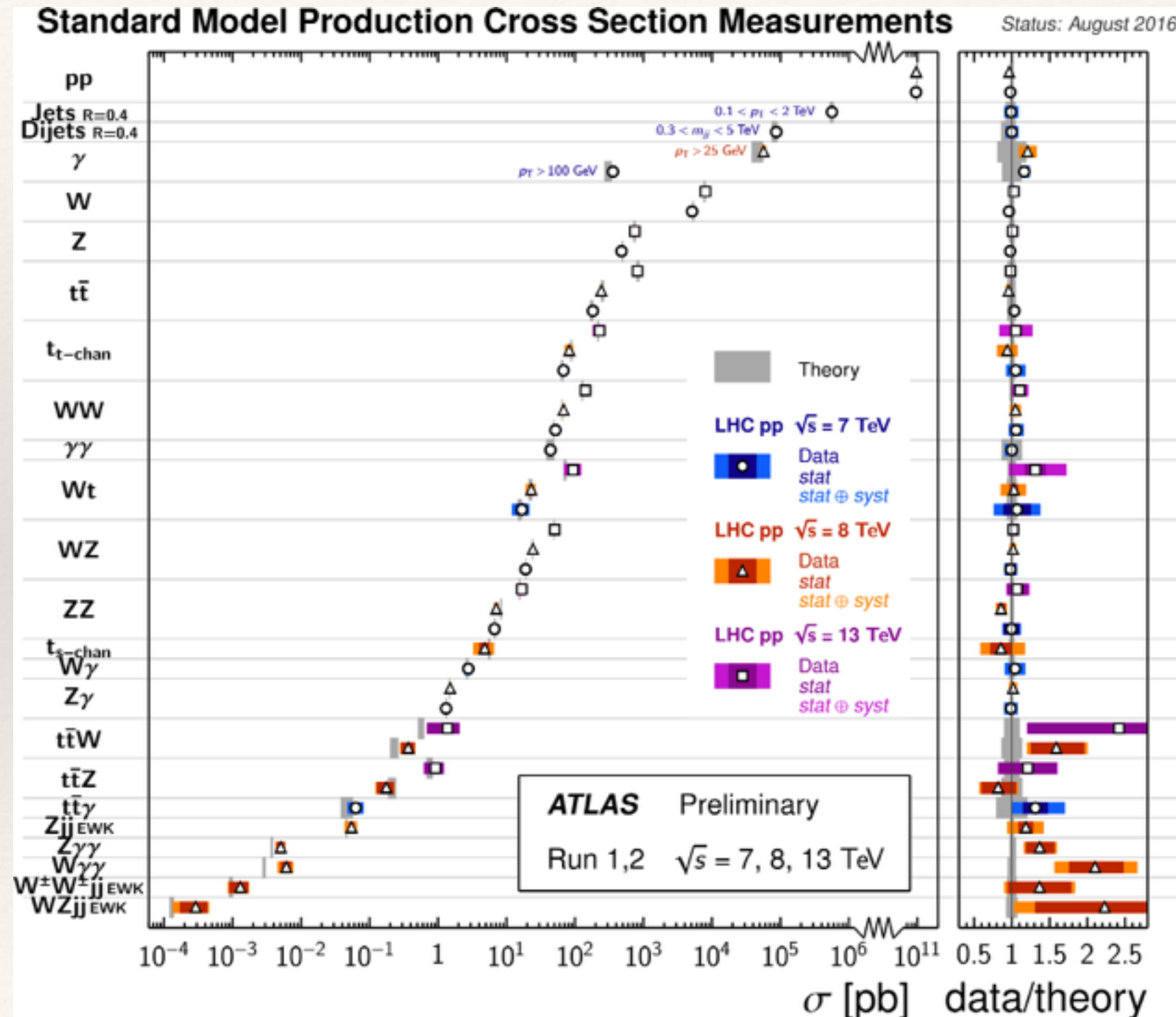
LAL, Orsay
September, 2016

The Standard Model

The Standard Model

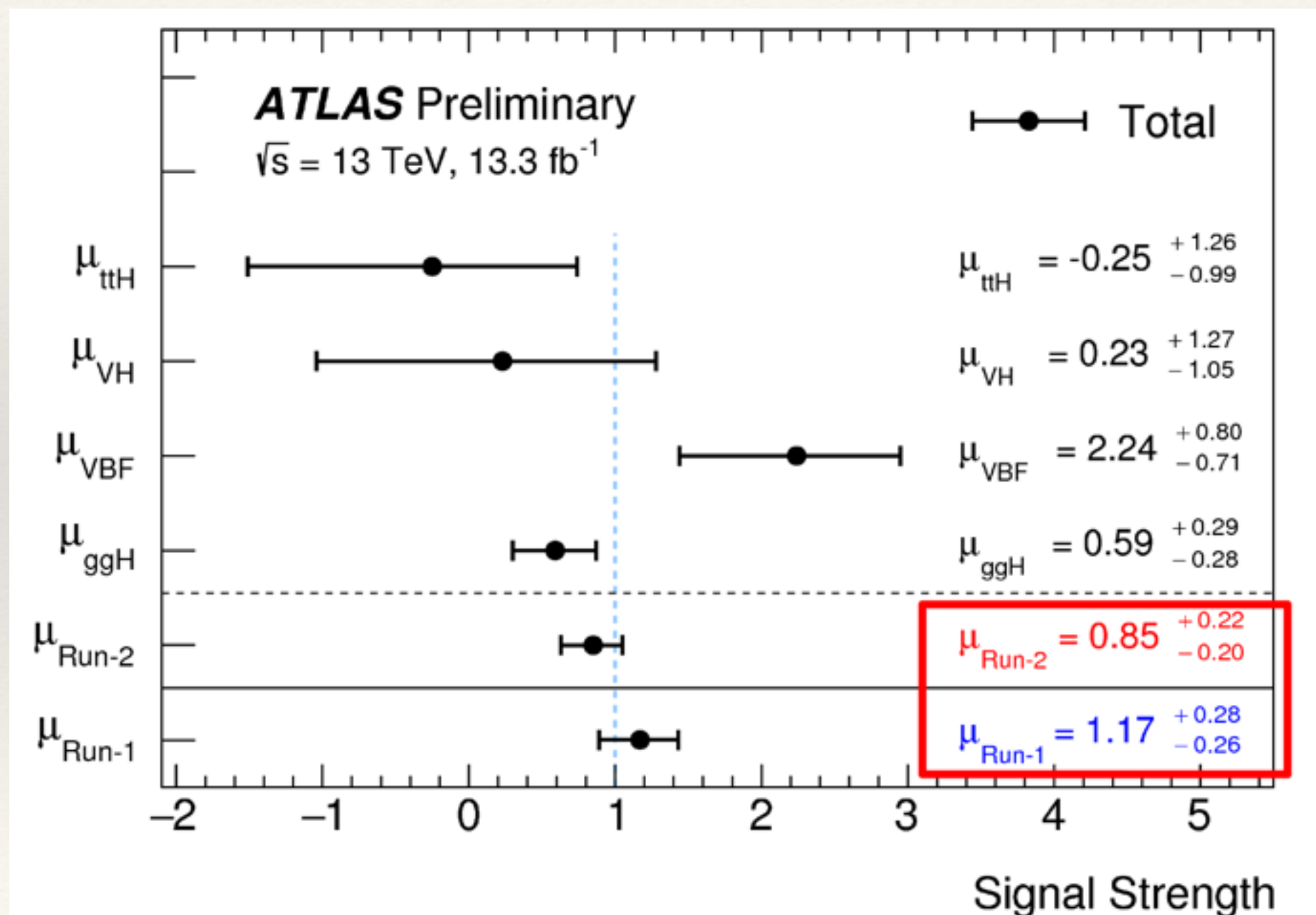
Predictive, successful paradigm
being tested to highest precision
at the LHC

Based on QFT, symmetries
(global/gauge) and consistent
ways to break them
Foundation from which we
develop BSM theories



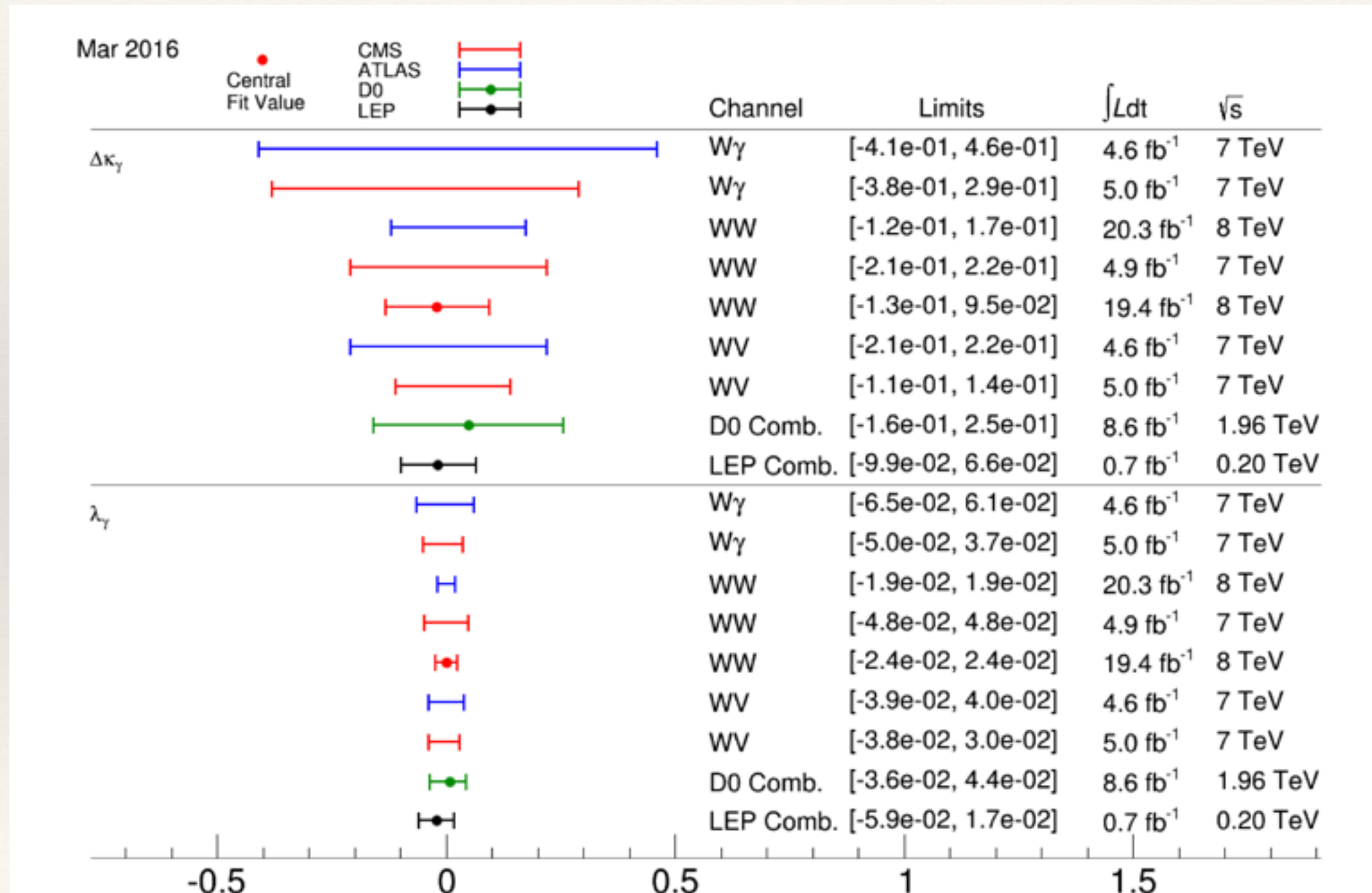
The Higgs of the SM

Run1 (and now Run2) indicates a very SM-like Higgs



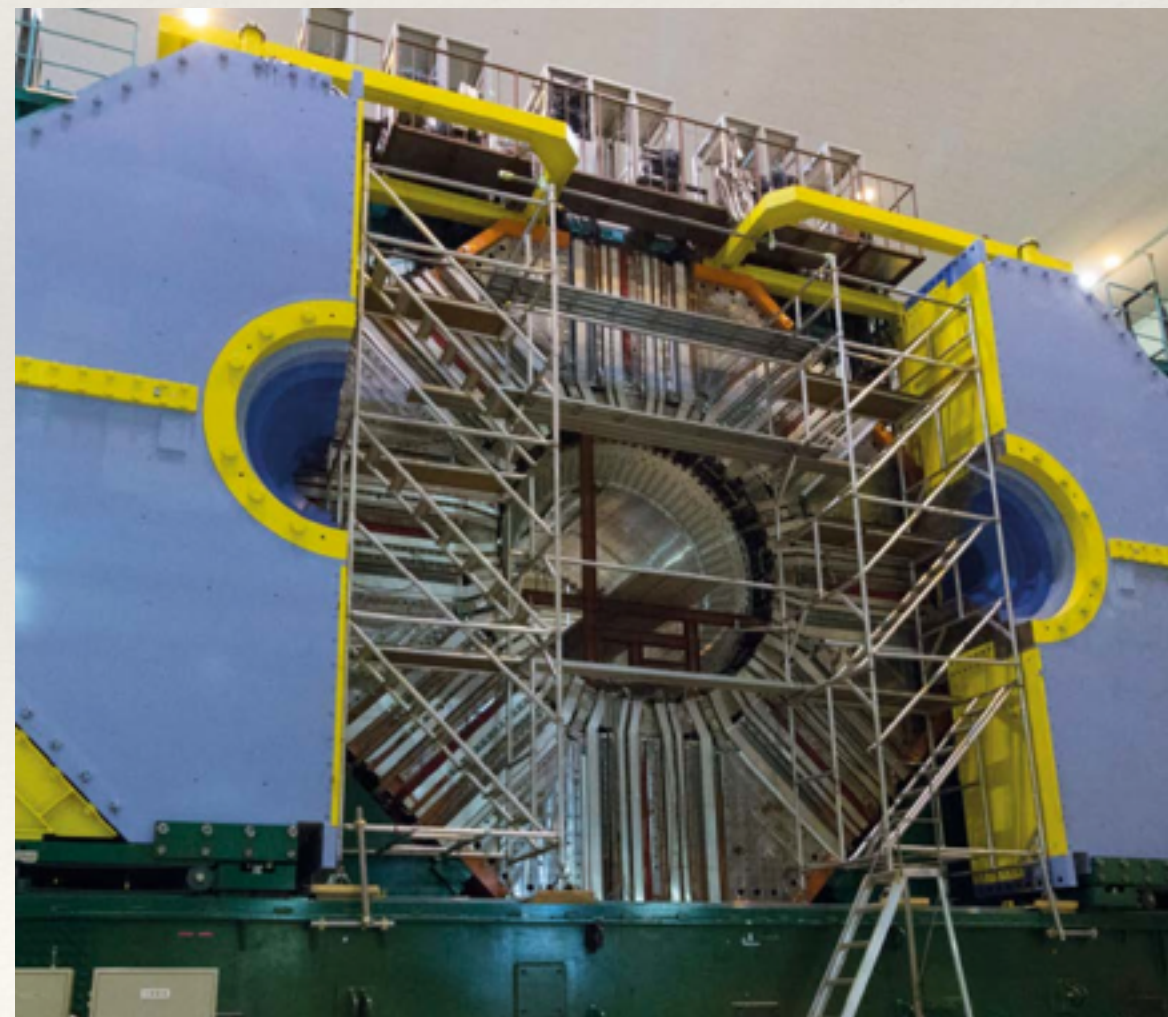
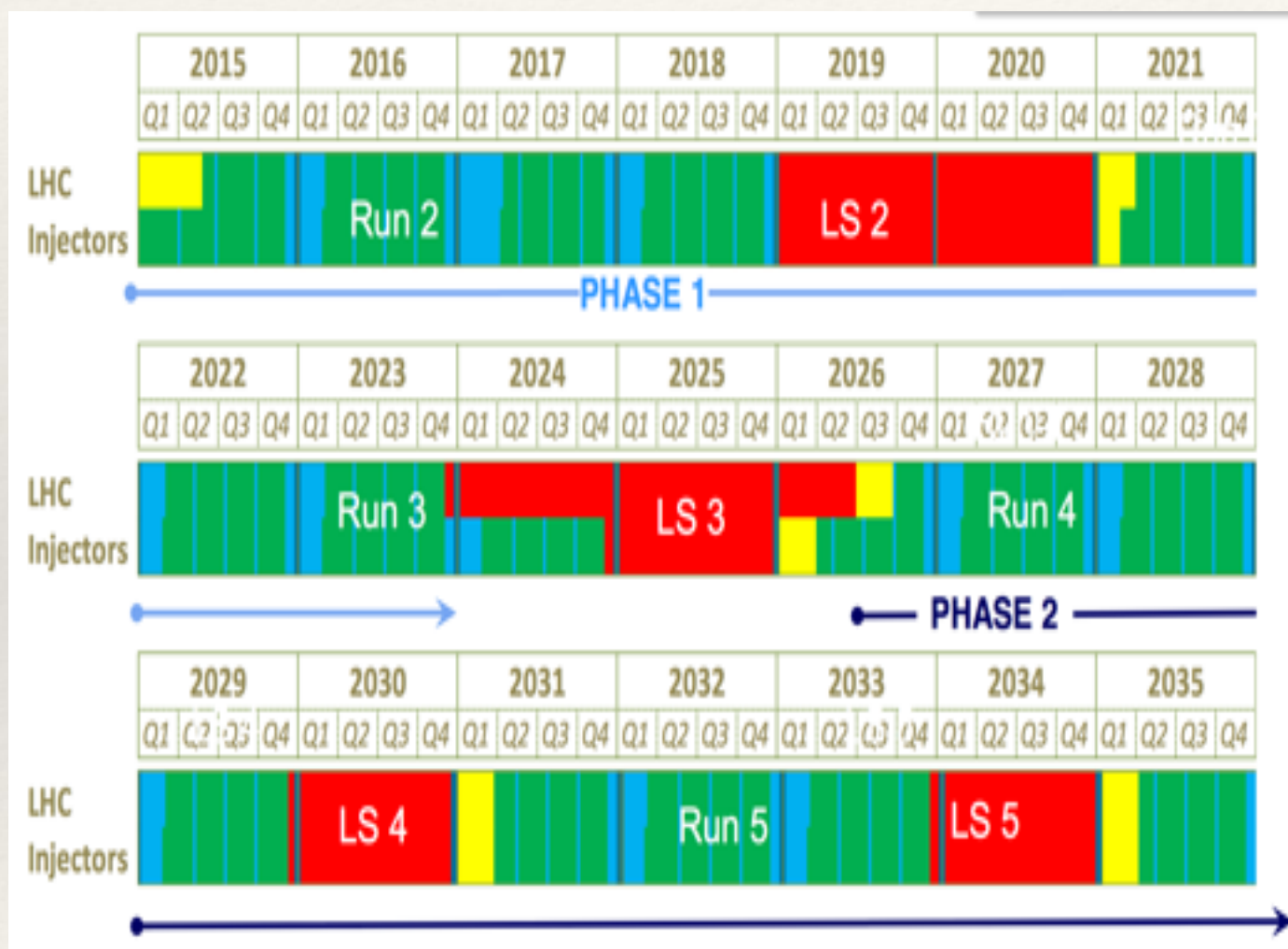
Massive Z,W

Hadron vs lepton collider



What's next for the SM ?

HL-LHC (High-Luminosity) LHC approved, to deliver 3000 inverse fb of data.
Funding ensured until 2035.



Plus other collider experiments testing SM
e.g. super-B factory

Challenging times

Light Higgs

Inflation

Neutrinos

Matter/Antimatter

Unification

CP QCD

Dark Matter

Dark Energy

Quantum Gravity

finding our path through

SYMMETRIES & DYNAMICS

aiming for a

UNIFIED FRAMEWORK

Example of unified framework: Supersymmetry

Unifies concept of bosons and fermions

Light scalar bosons

Candidates for Dark Matter

Unification of strong / EM / weak forces

Matter / Antimatter asymmetry

Component of Quantum Gravity

New mechanisms

Inflation, Neutrinos and Dark Energy

The discovery of SUSY at LHC
first step to understand many
aspects of Nature

Alas! SUSY nowhere to be seen

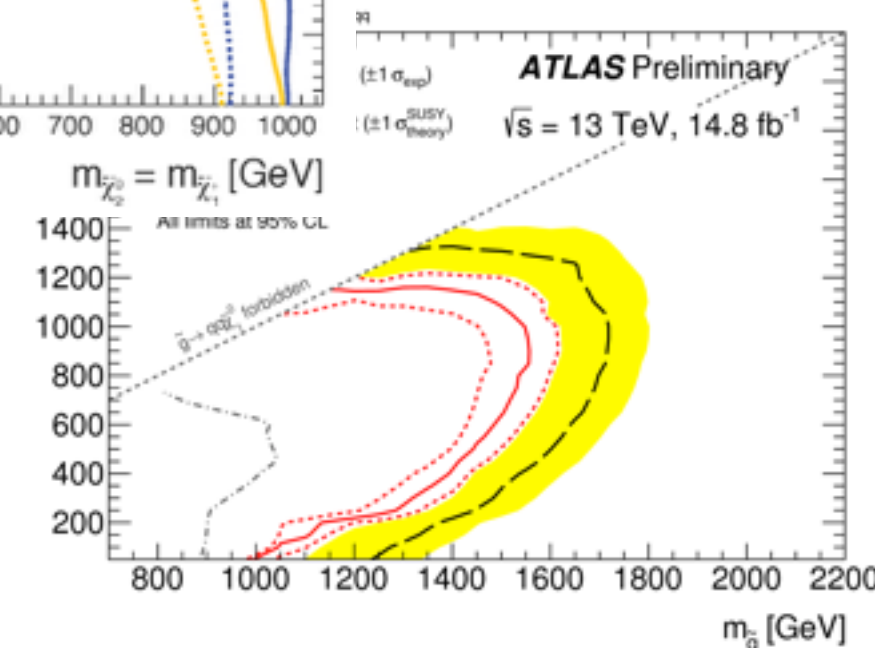
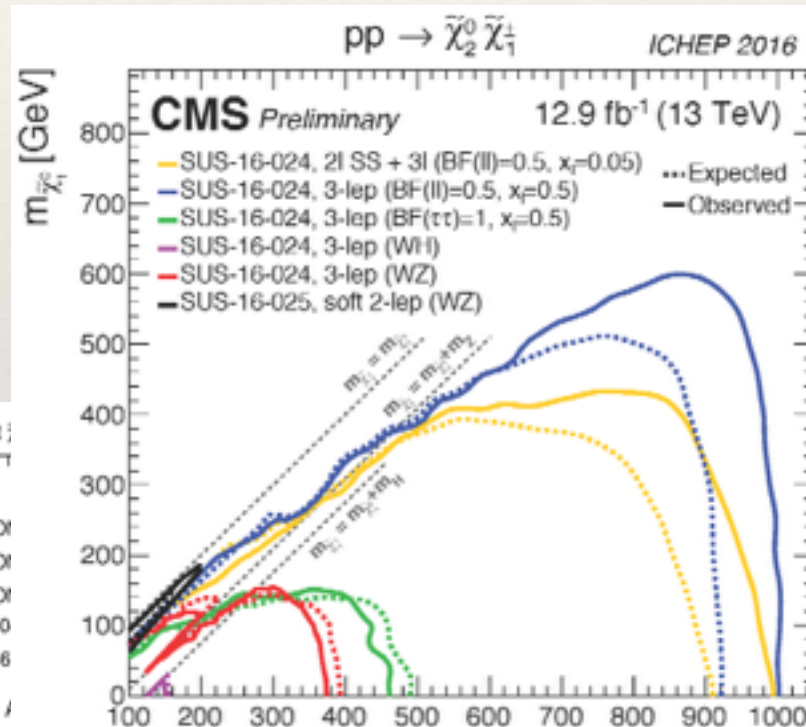
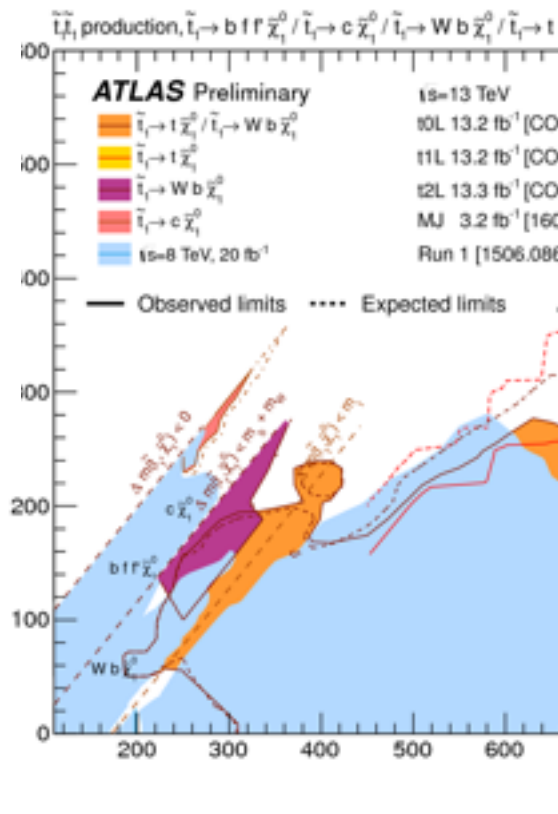
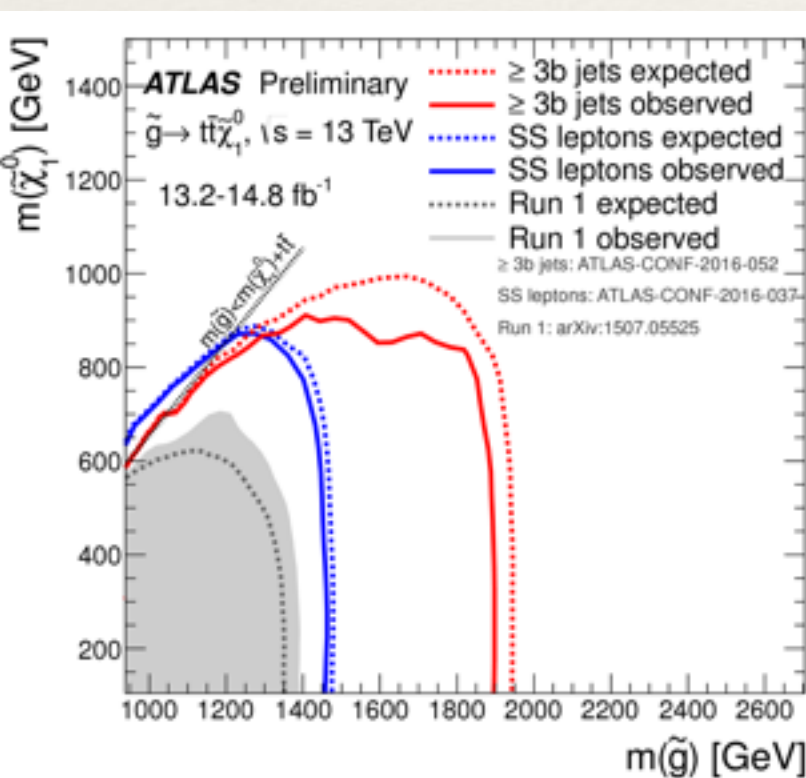
The 13 TeV data (~13 ifb) already undermining hopes energy increase could unveil new coloured states

Vanilla SUSY

Natural SUSY

EW SUSY

some-SUSY



some have a feeling of doom

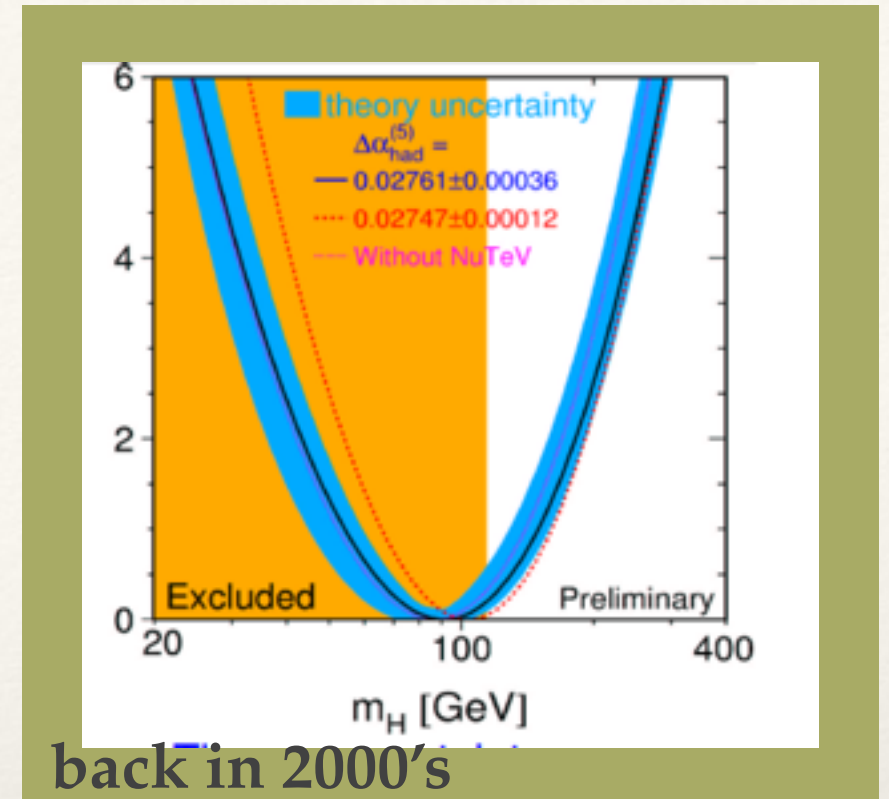


which I don't share, yet

Where is New Physics?

BUT we are talking about going

From the Higgs, a particle with known couplings and a mass in a definite range

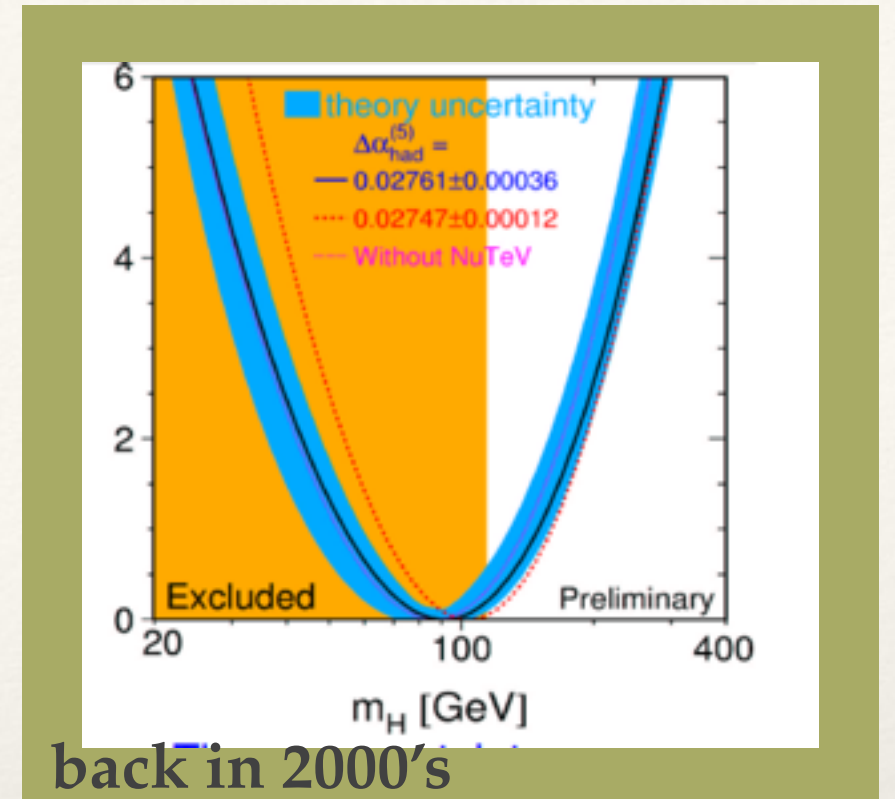


To the unknown



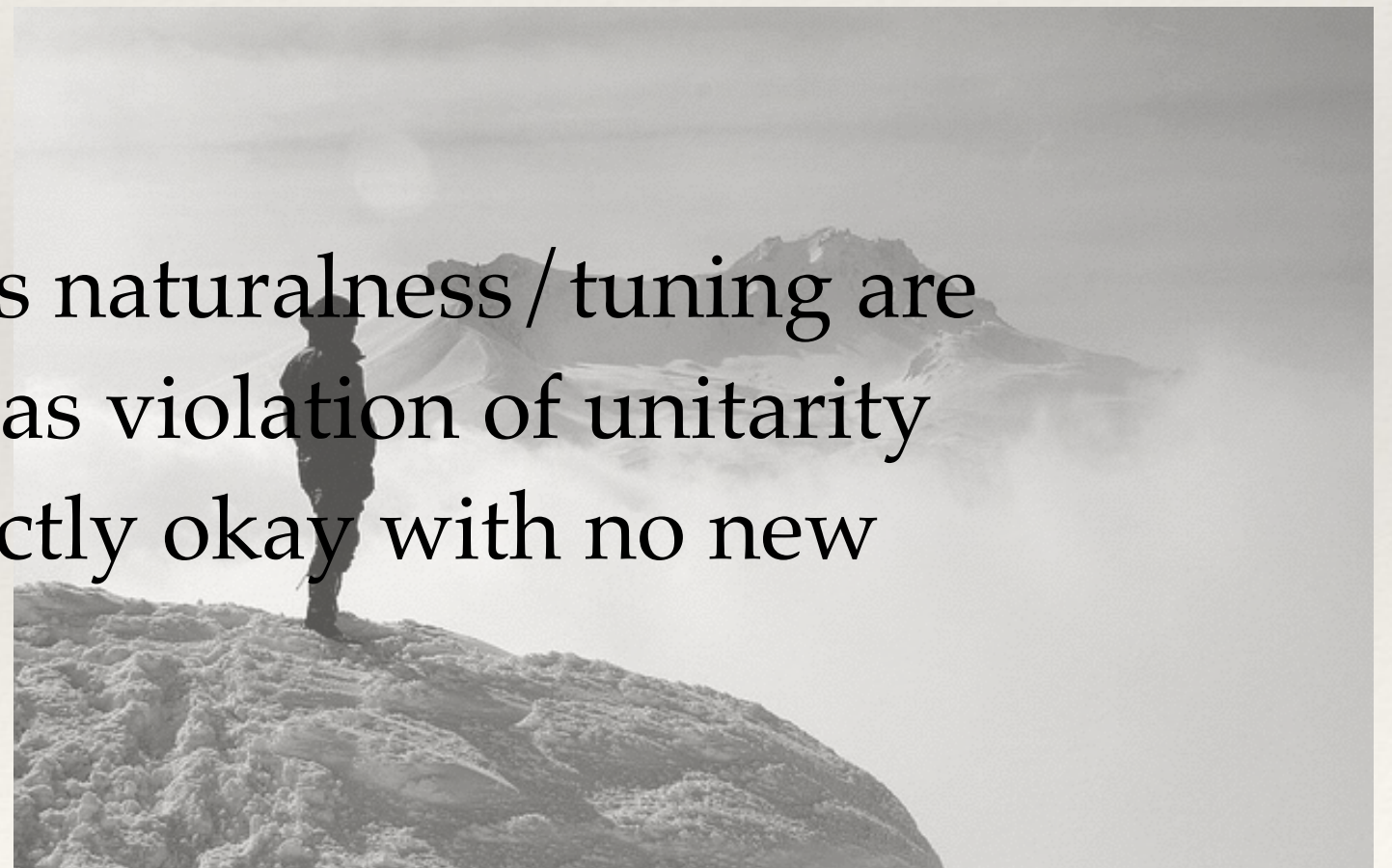
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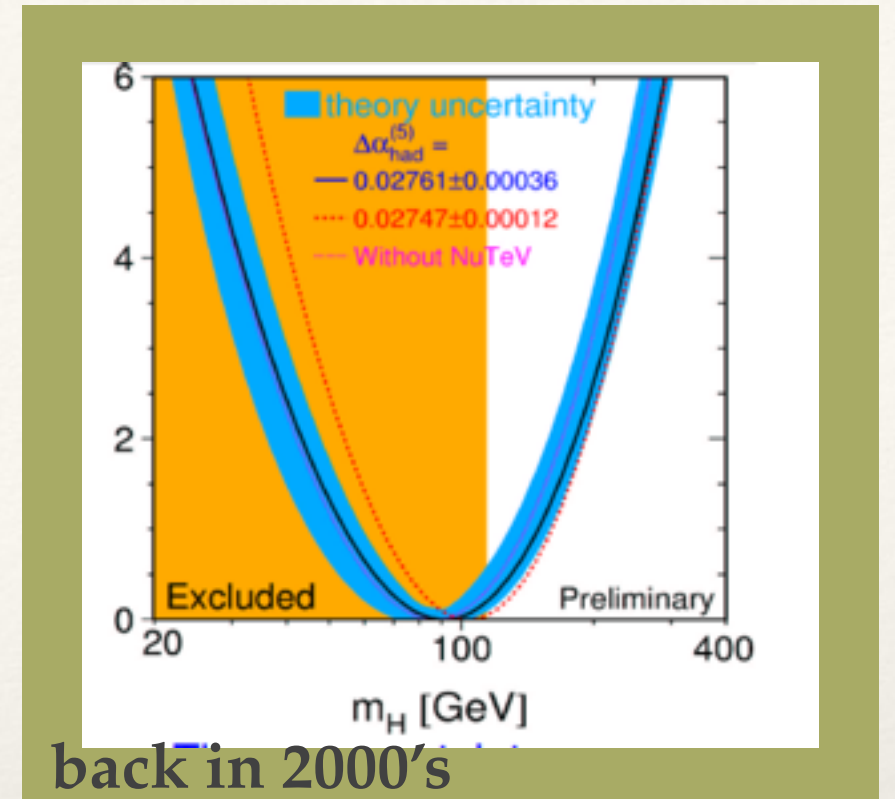
To the unknown

aesthetical arguments as naturalness / tuning are not on the same footing as violation of unitarity
precision tests are perfectly okay with no new physics at the EW scale



BUT we are talking about going

From the Higgs, a particle with known couplings and a mass in a definite range



To the unknown

The bottom-line
we do not know
what/where New
Physics is

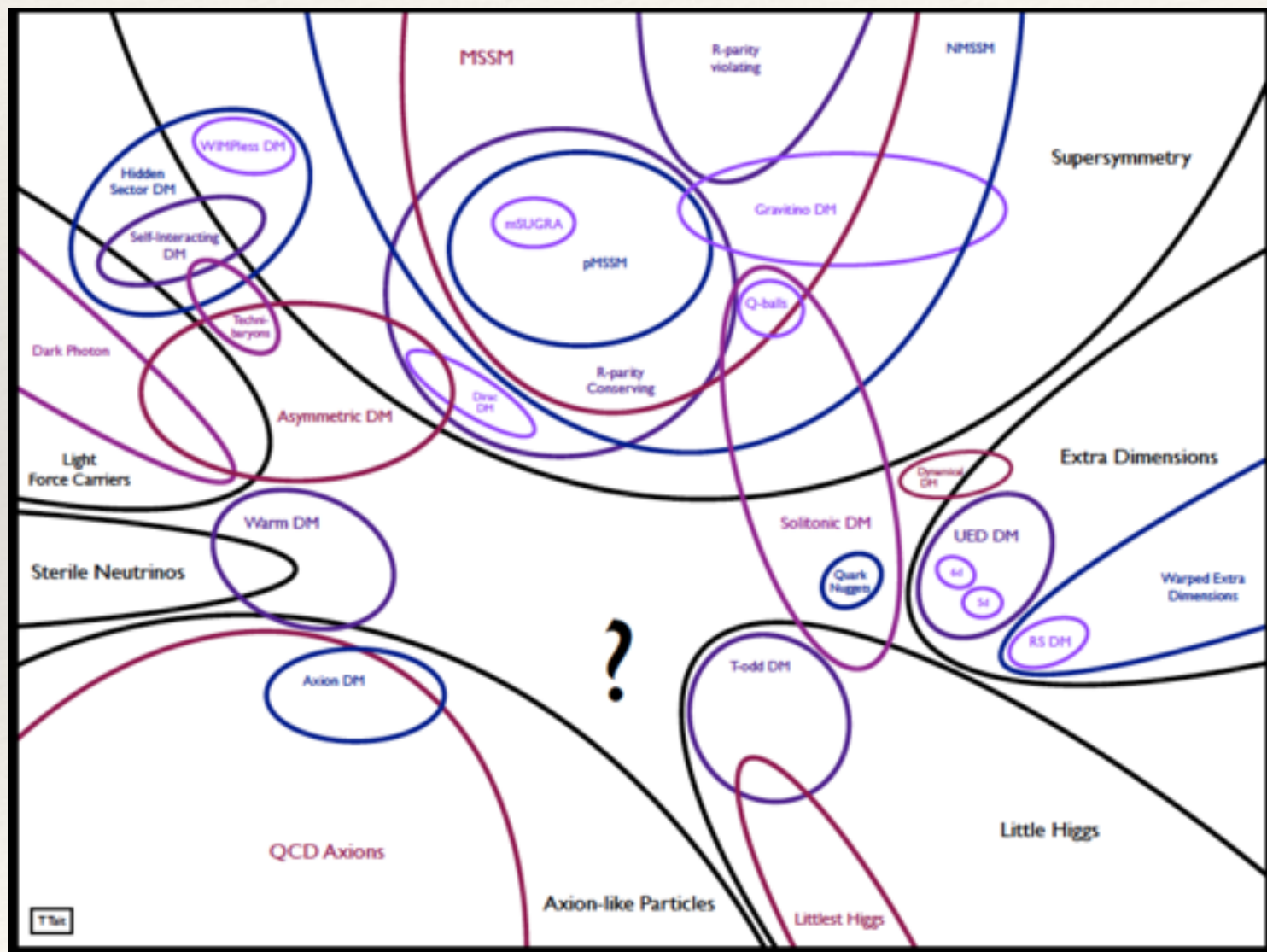


which is what makes this time so exciting

The landscape of theories

Each problem in the SM generates a plethora of new ideas

Example: **Dark Matter**



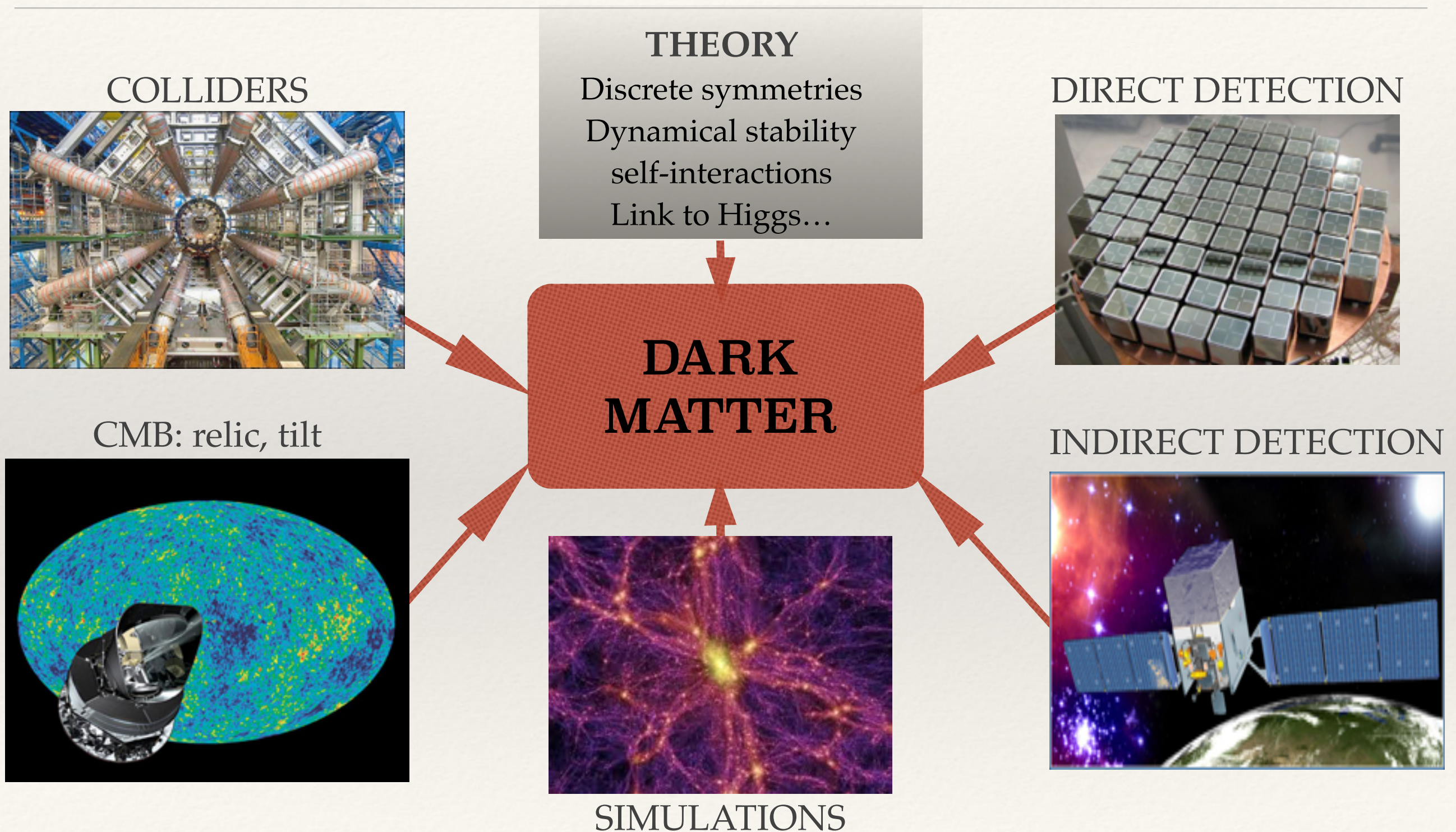
A snapshot of models for
Dark Matter

Popular models =
linked to solutions to other
problems in the SM

Discovery to characterization
of Dark Matter
leading to new discoveries

THANKS TO TIM TAIT

Multidimensional approach: Dark Matter



Looking above the fence

How do we probe the unknown with no compass?

Business as usual

test boundaries of the SM, looking for something unusual (cross-talk SM / BSM, precision)

Additionally we should work on ideas to use
non-LHC experiments / observations

Why?

Hints of New Physics could come from the connection between colliders with other areas

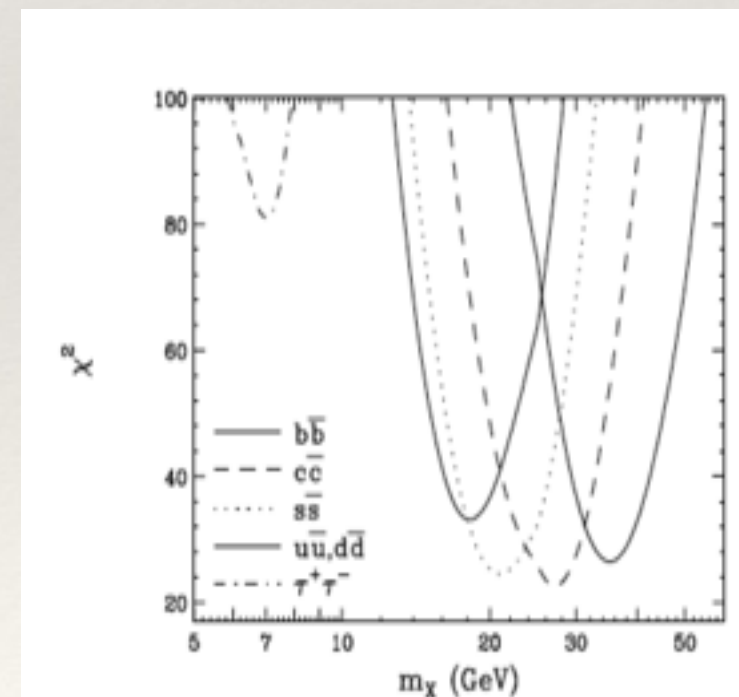
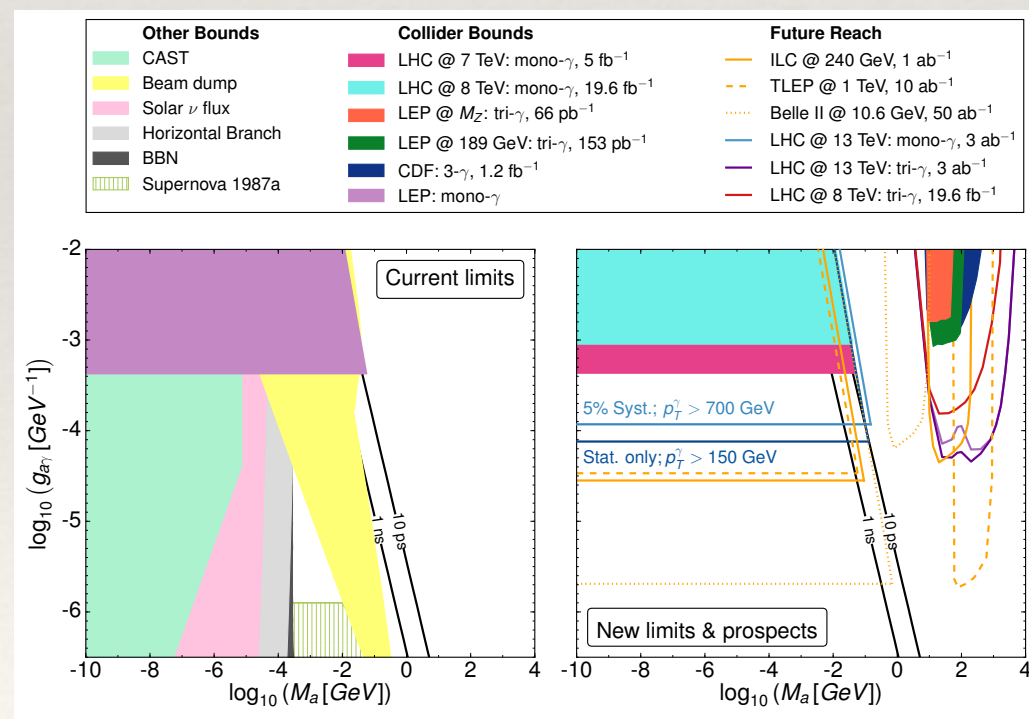
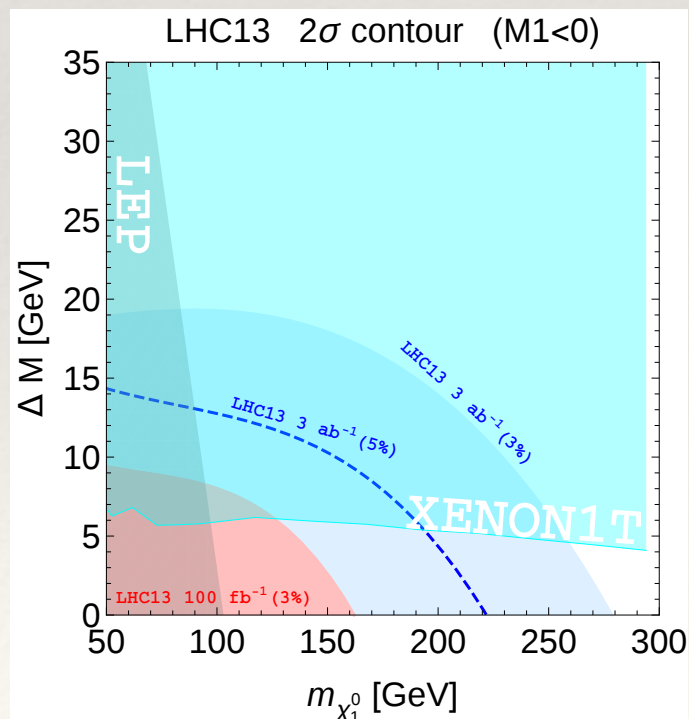
Ideas / techniques in Particle Physics may be useful to other areas

e.g. The Dark Universe connection

Relic abundance sets limits on precision required at colliders

Collider searches / CMB / direct detection are complementary:
EFT and in models

Excess in gamma-rays can be translated into a mass and a coupling to SM
particles \rightarrow colliders

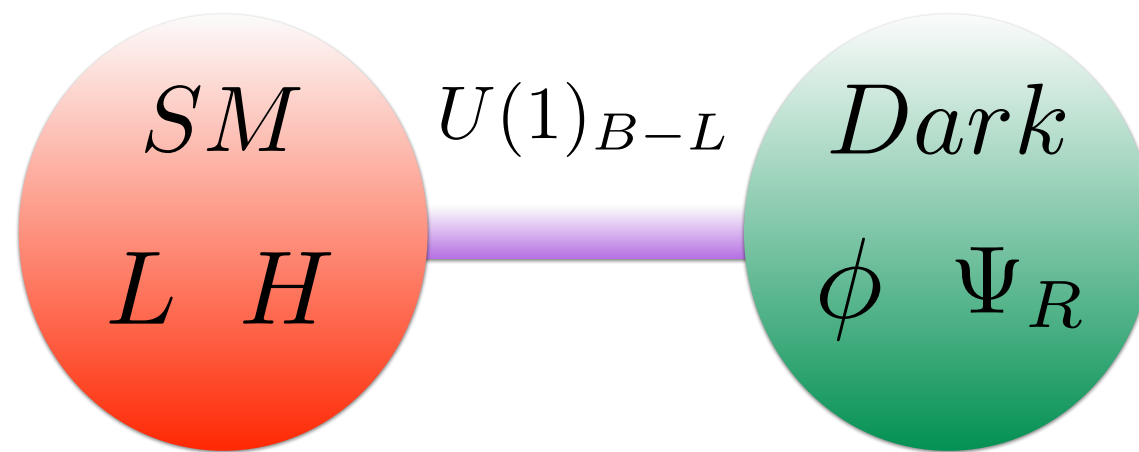


1402.6703

Dark Matter/Neutrino connection

with Escudero and Rius, 1606.01258

Propose and explore a paradigm



Neutrino mass
measurements

Self-interacting DM
lensing, simulations

Higgs invisible width
LHC, Higgs properties

DM to leptons
CMB

Direct detection
LUX, XENON1T

Gamma rays
HESS, Fermi-LAT

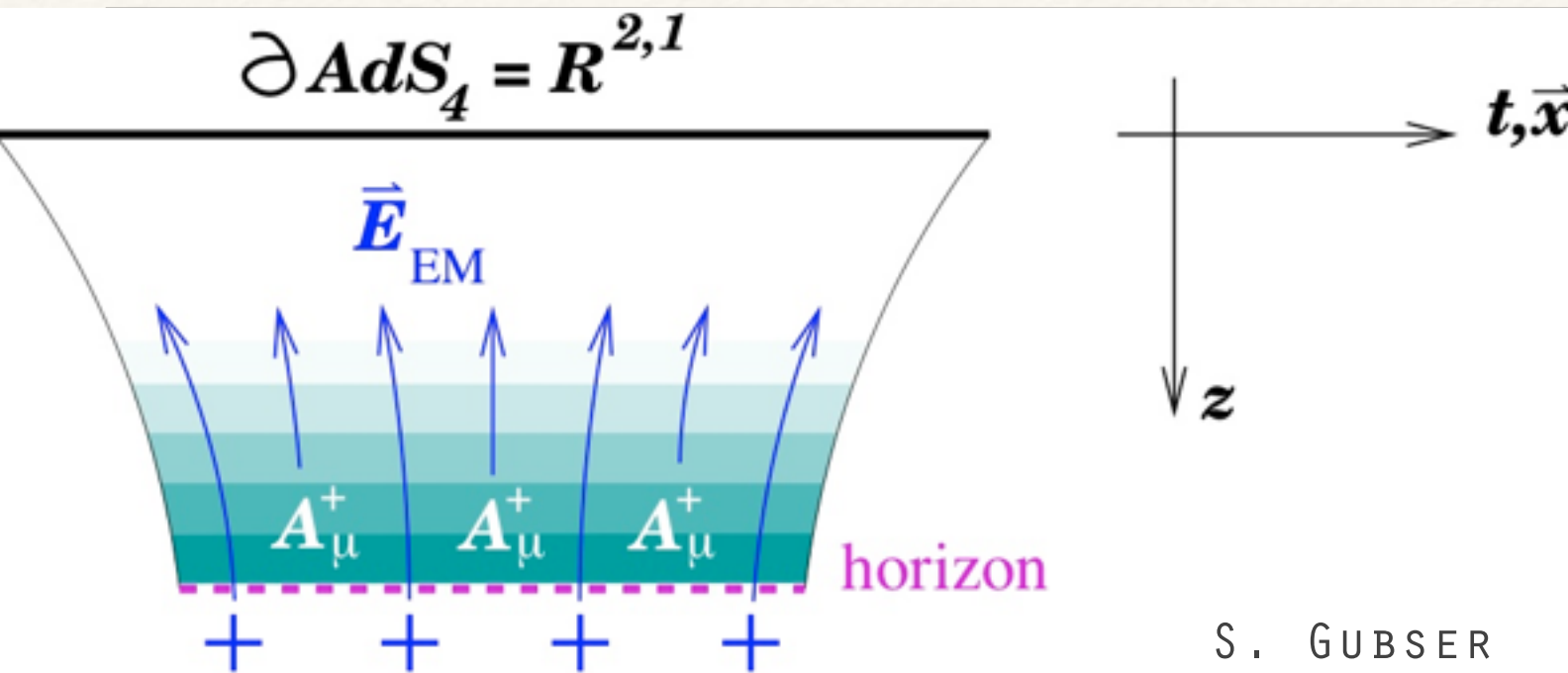
Higgs exotic decays
LHC, displaced vertices
indirect LFV, nuless beta-decay

Neff
CMB

Relic abundance
Planck

Neutrino telescopes
IceCUBE

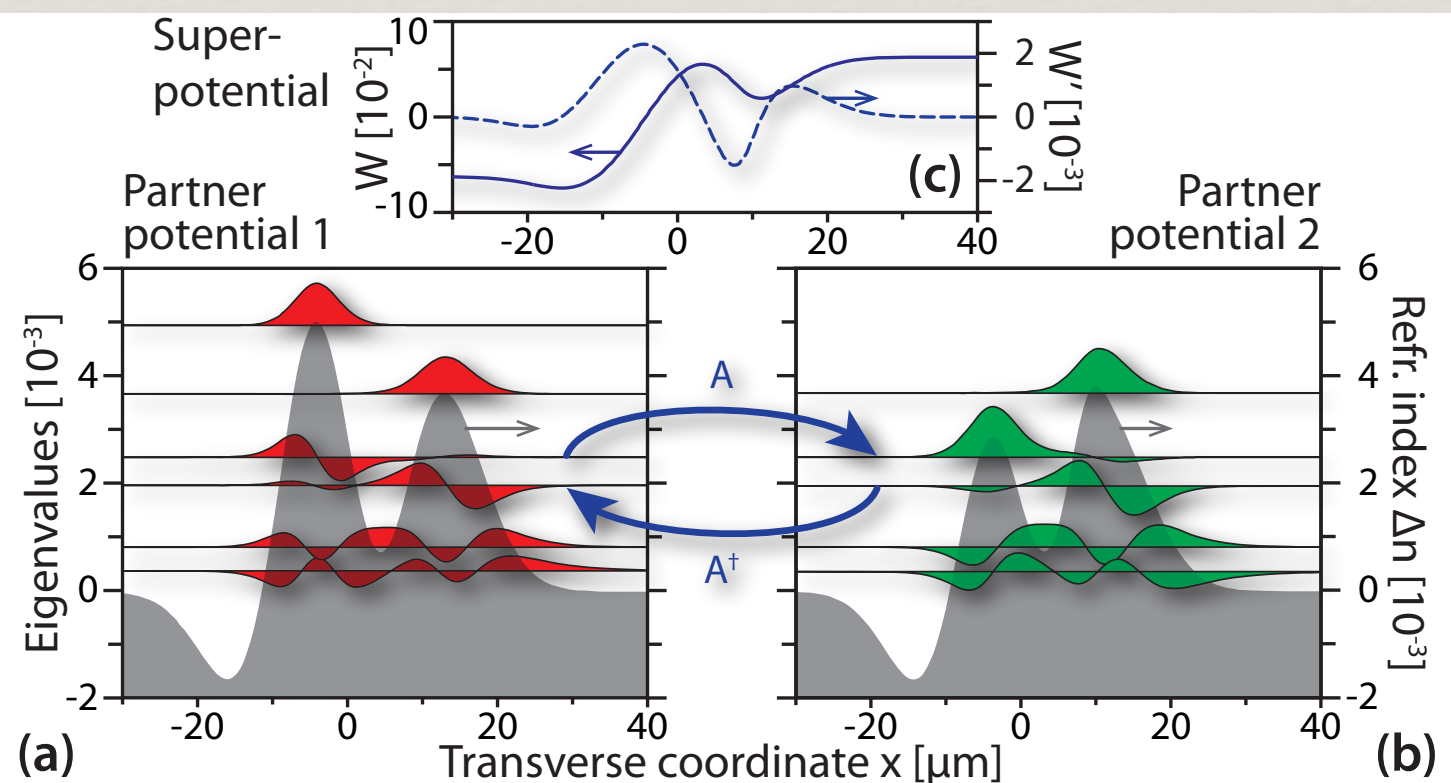
Don't forget: cross-pollination



Strong correlations:
Conductivity in high-Tc SCs
Superfluidity
Graphene

SUSY and
Hawking radiation in fiber optics

CHRISTODOULIDES ET AL. PRL(2013)



Summary

- ❖ Many facts about the Universe cannot be explained by the Standard Model, e.g. **Dark Universe, Inflation, Neutrinos...**
- ❖ We got many ideas, often based on symmetries and their breaking, which are / will be **tested in an array of experiments**: colliders, satellites, underground detectors, telescopes...
- ❖ **Exciting / confusing moment** for us: a number of experiments reaching sensitivity to models, and discovery of the Higgs as a key to unveil new phenomena. No discovery brings us to think out of the box: theory, model-building opportunities
- ❖ **Focus on ideas / paradigms** which can be tested from different sources, cross-pollination in between fields