Finding our way to new physics

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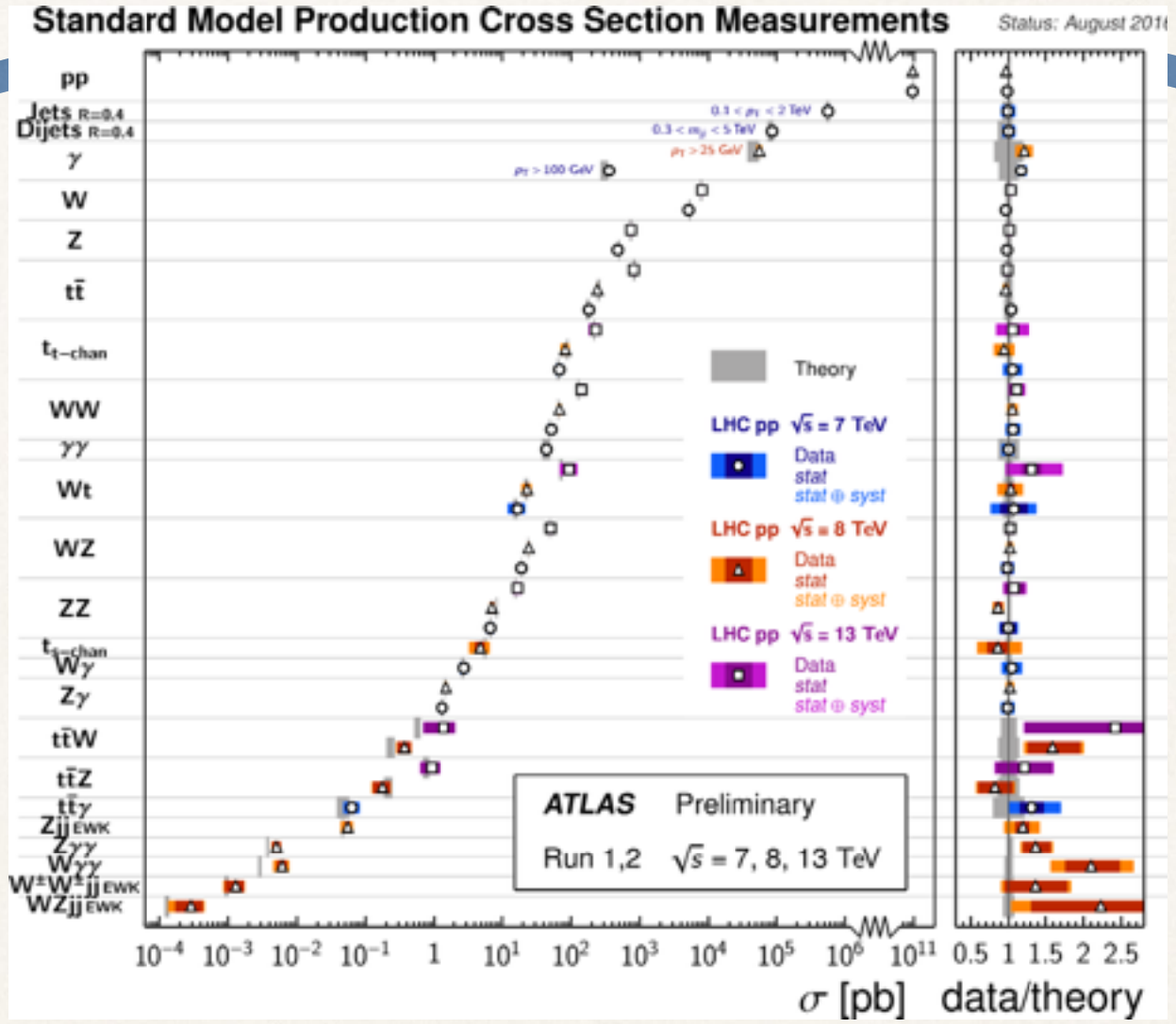
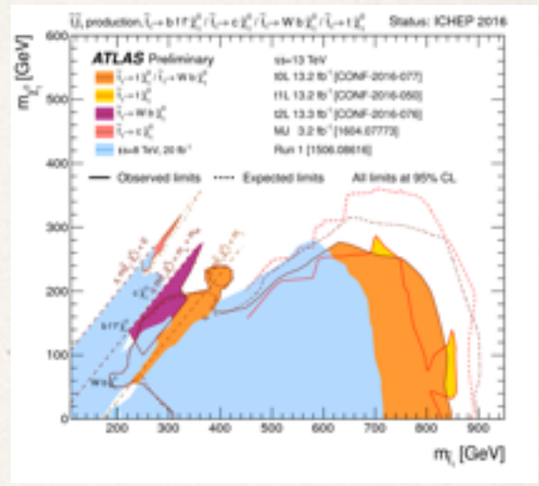
Let's start with the LHC

The LHC is in a mature stage, already providing precision tests for the SM in most channels (excl the Higgs)

Precise tests of the full structure of the SM, based on QFT, symmetries (global/gauge) and consistent ways to break them non-trivial tests of perturb.->non-perturb. QCD



Absence of excesses: interpreted as new physics exclusions



exclusions: rather impressive, many at the TeV

searches: outstanding coverage of possible topologies

any hints: (like in flavor) extremely tempting

So here we are

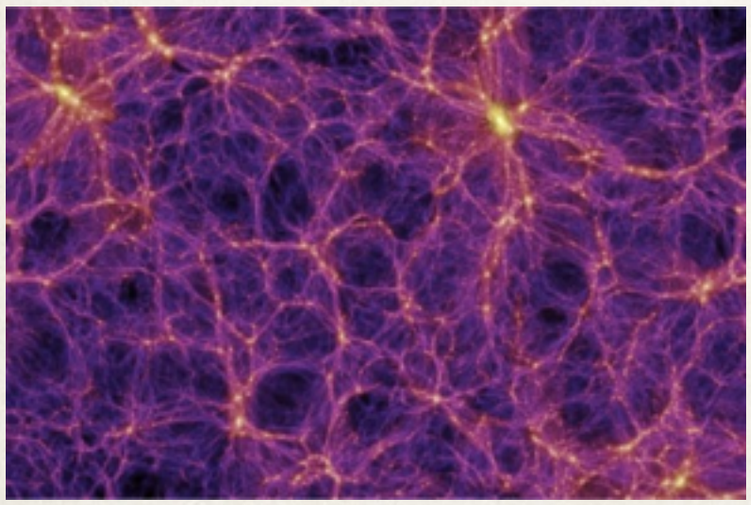
What we would hope for

Special relativity
+
equivalence principle

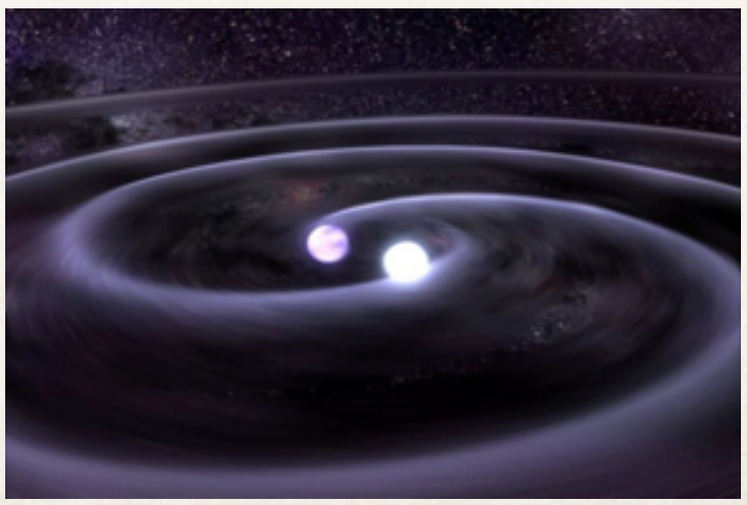
development of new, sophisticated mathematical framework

General relativity

Universe's evolution



gravitational waves



black holes

Some years ago

String theory, *the* final theory

Mathematical consistency (anomalies, SUSY)

+guiding principles (QGrav, unification,3 families)

trickle down to the SM, a boundary condition

Light Higgs

Inflation

Neutrinos

fermion puzzles

Unification

Matter/Antimatter

CP QCD

Dark Matter

Dark Energy

Quantum Gravity

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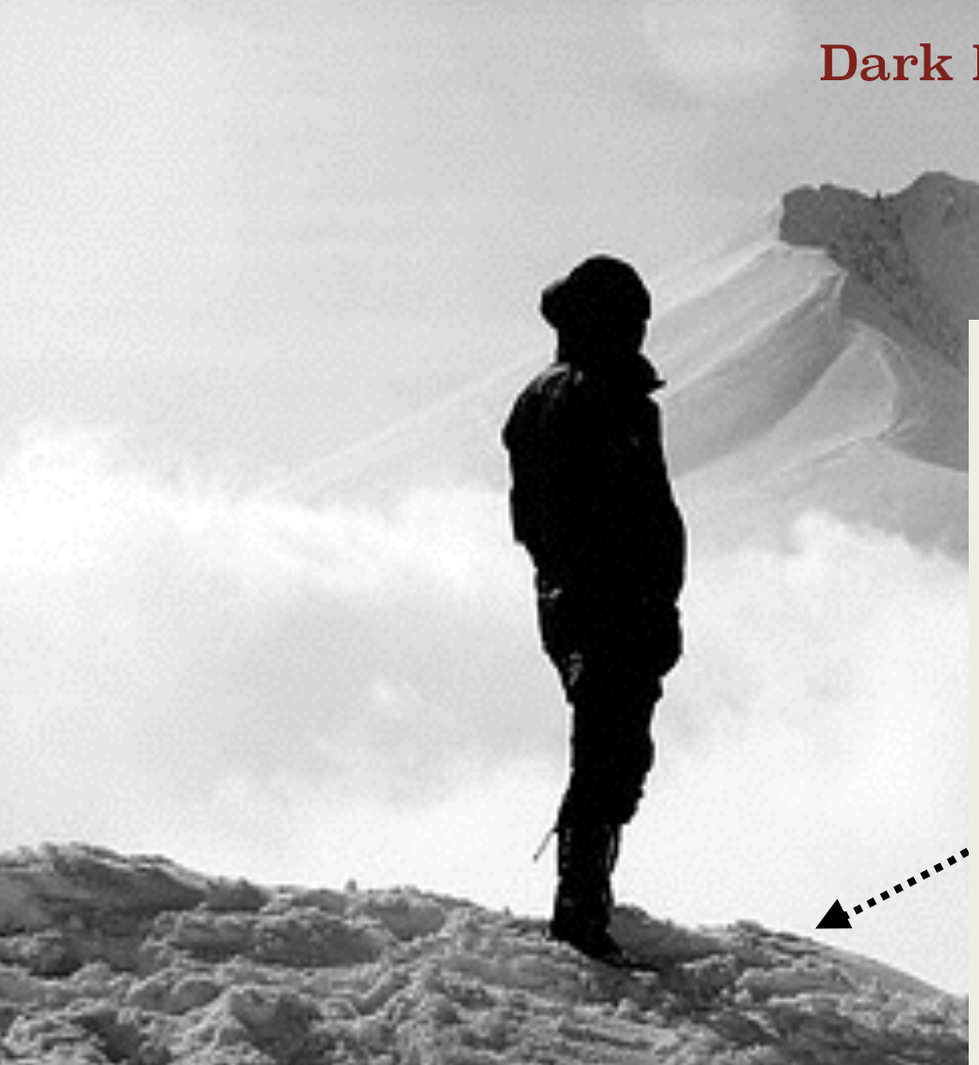


This program did not lead to identifying *the* theory

(see string lanscape)

instead, generated a **vast number of new ideas:**

reformulations of gravity and QFT

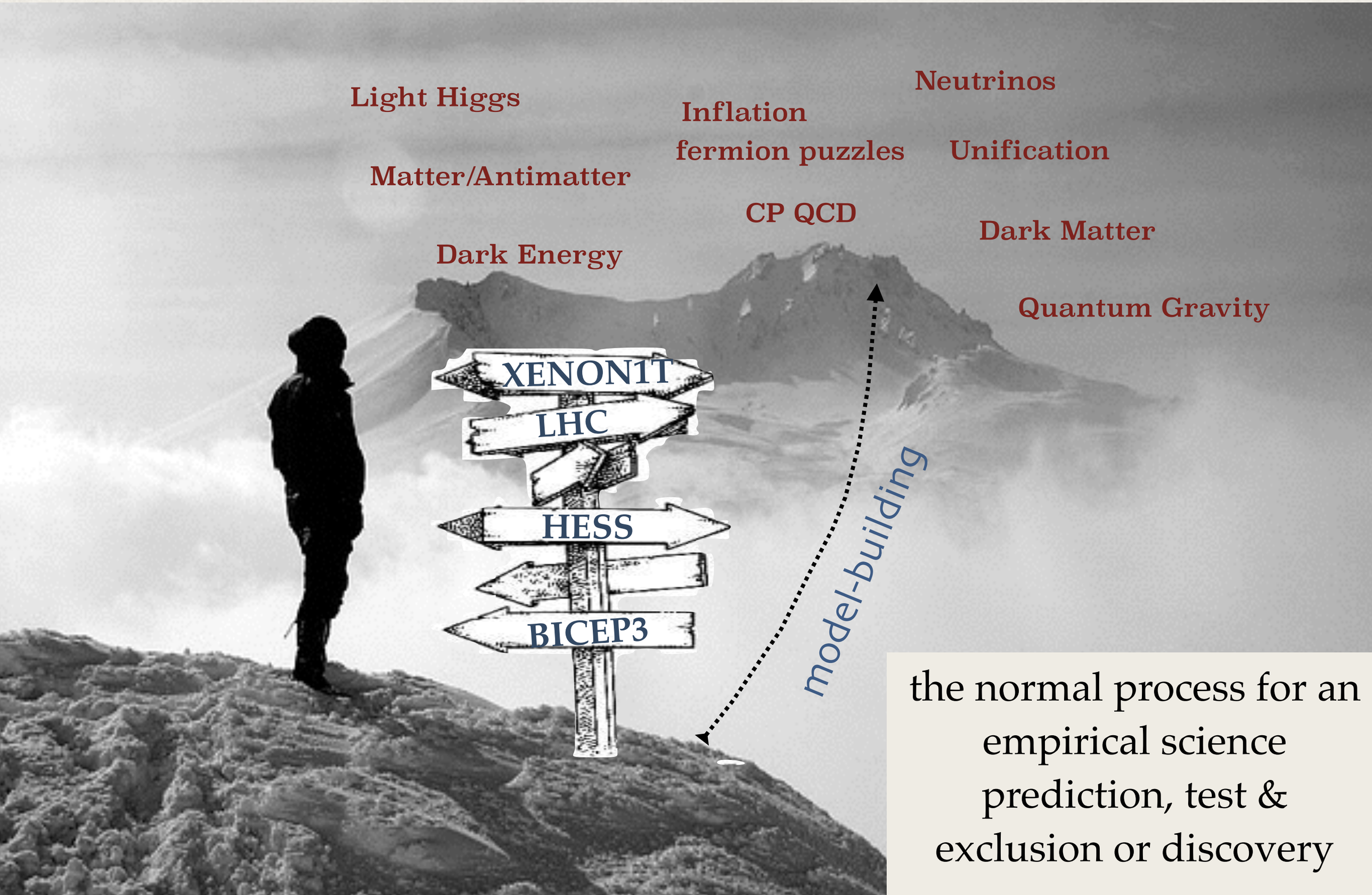
dualities incl AdS/CFT

new scenarios for model-building

incl duals of RS (composite higgs, clockwork),

models for inflation

So here we are again, post-LHC Run1

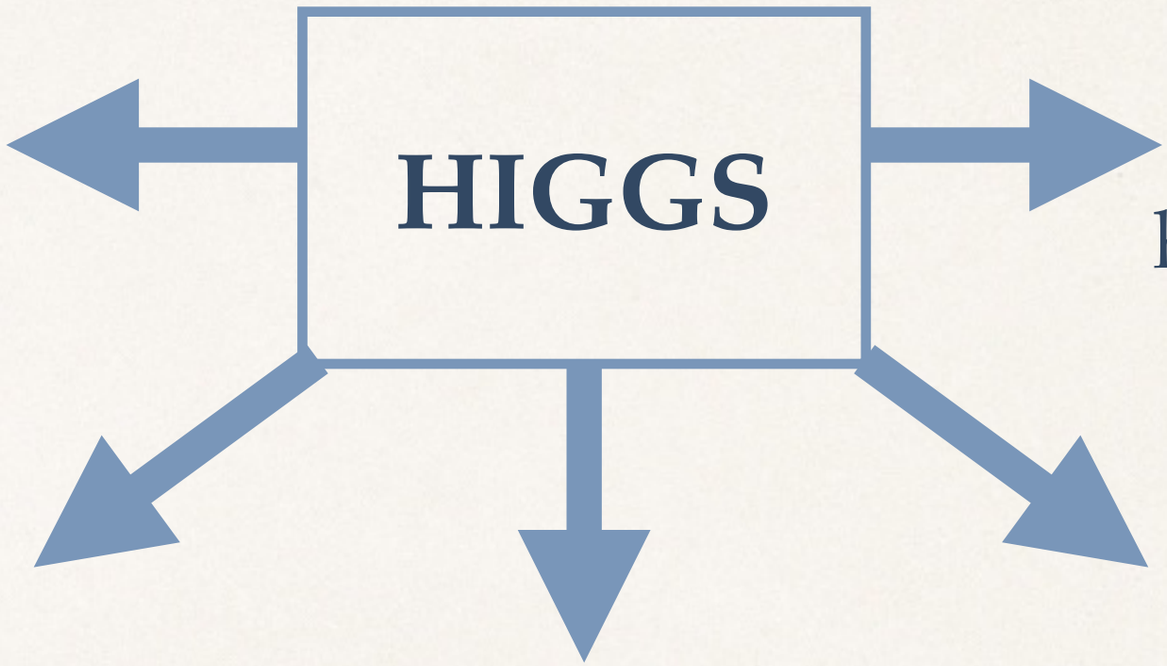


the normal process for an empirical science prediction, test & exclusion or discovery

Connecting ideas

A cosmological Higgs

Dark Matter
Higgs portal
Higgs DM mediator



UV sensitivity
Naturalness
heavy new physics
Relaxation

Inflation
Higgs inflation
Inflaton vs Higgs

Phase transitions
Baryogenesis
gravitational waves

Fate of the Universe
Stability

The LHC provides the most precise, controlled way of studying the Higgs and direct access to TeV scales
Exploiting complementarity with cosmo/astro probes

Similar story for Axions and ALPs, scalars are versatile

Many faces of Dark Matter

THEORY

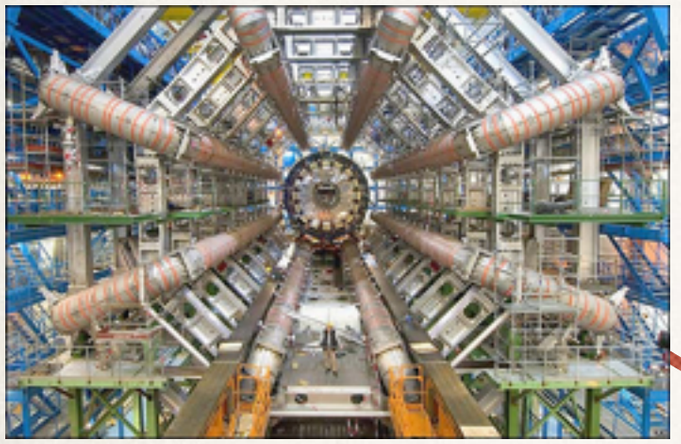
Discrete symmetries

Dynamical stability

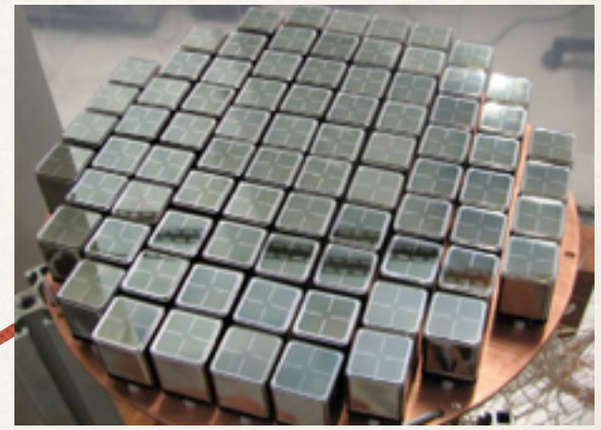
self-interactions

Link to Higgs…

COLLIDERS

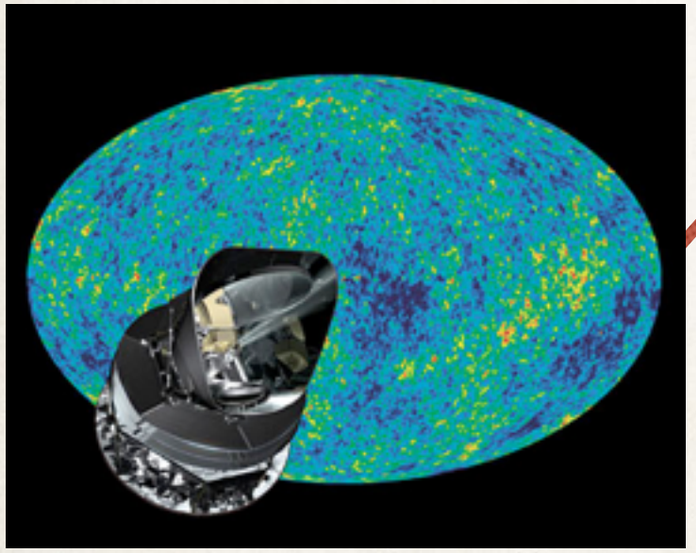


DIRECT DETECTION



DARK MATTER

CMB: relic, tilt

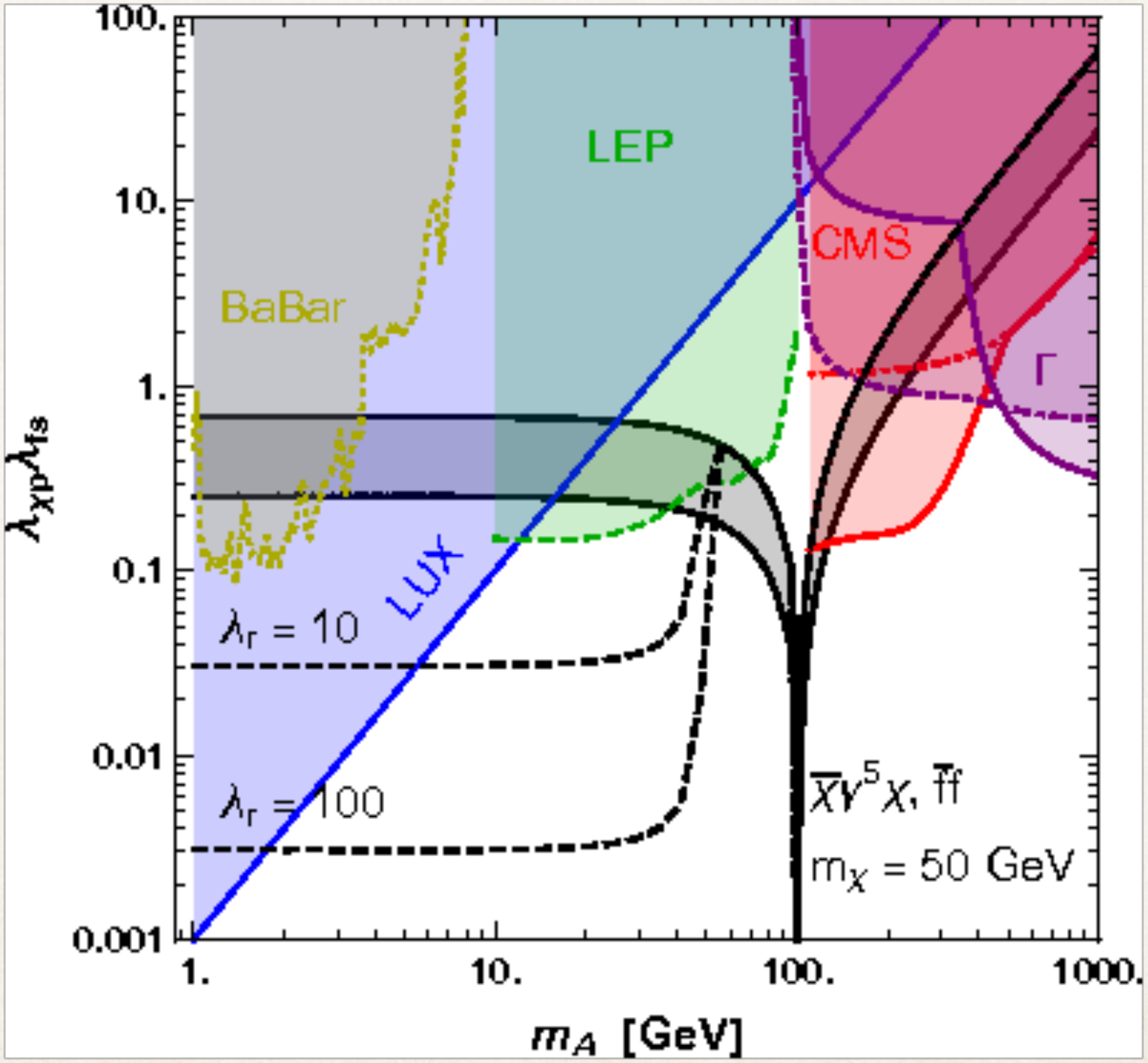


SIMULATIONS

INDIRECT DETECTION

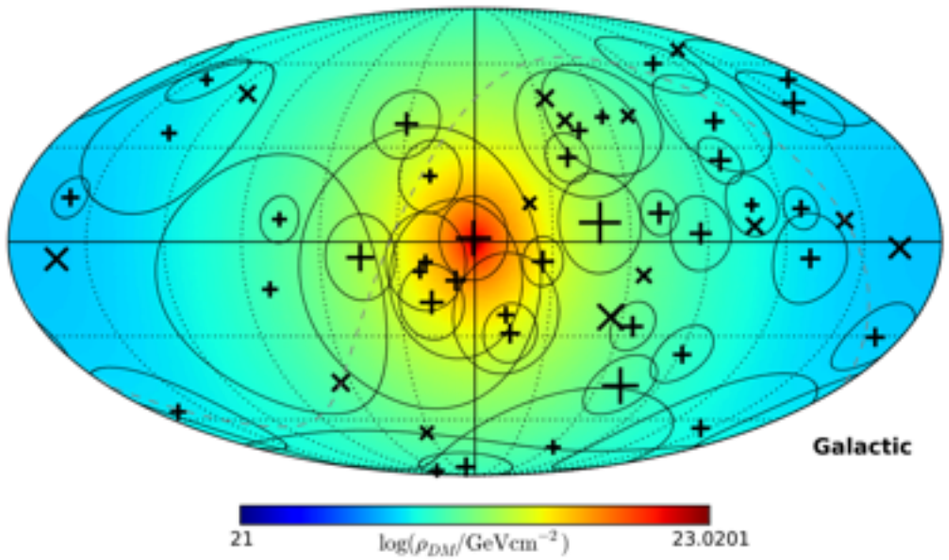
Complementarity

example: propose a solution to an astrophysical excess with a PP model

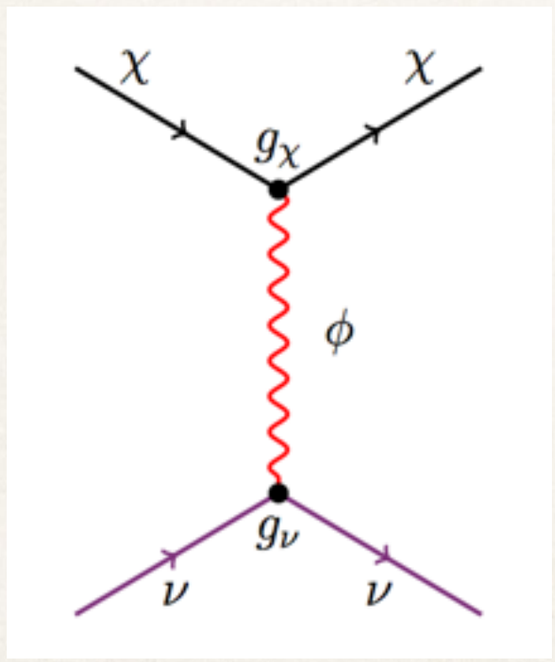


Escudero, Hooper, Witte. 1612.06462

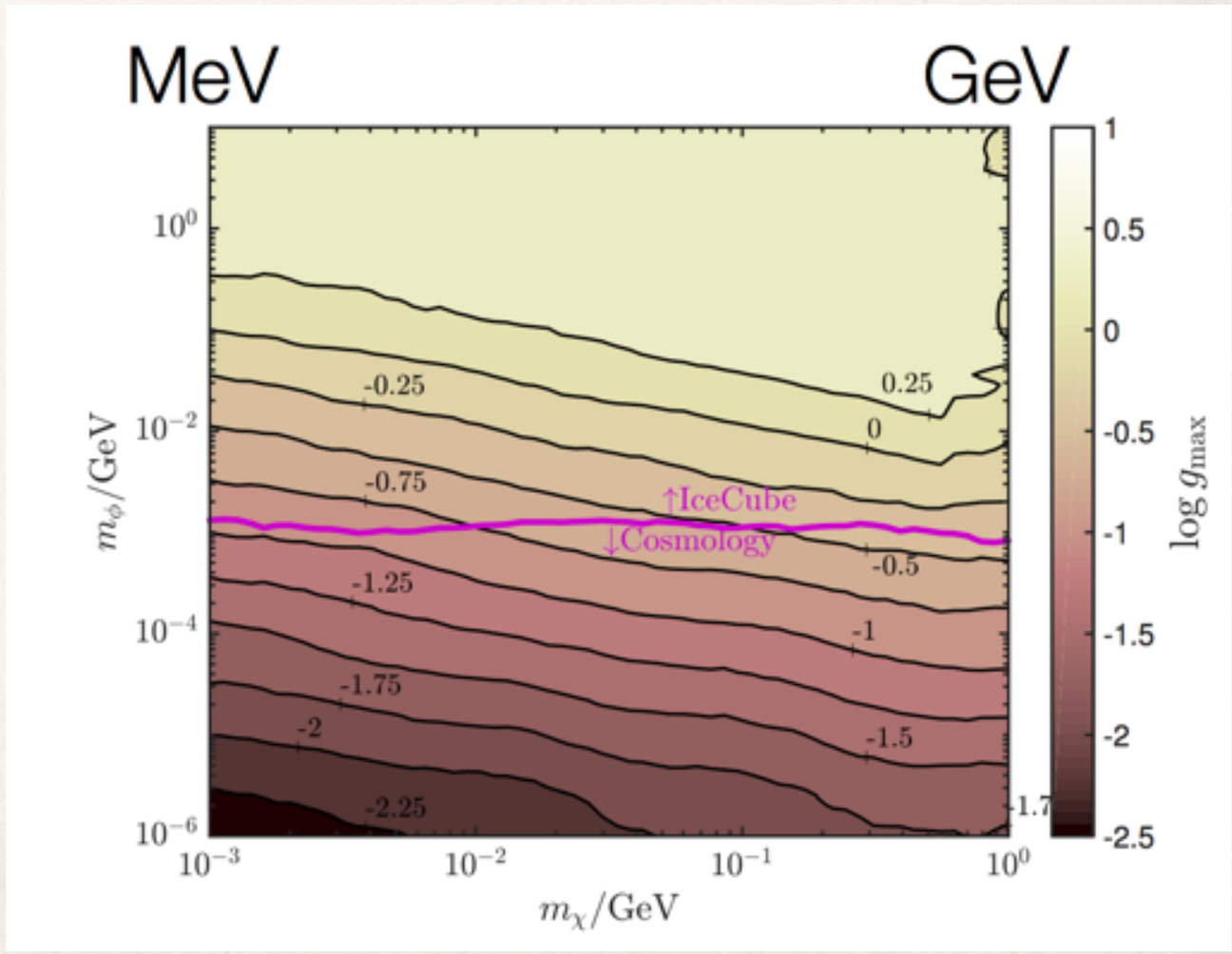
example: probe DM couplings to neutrinos



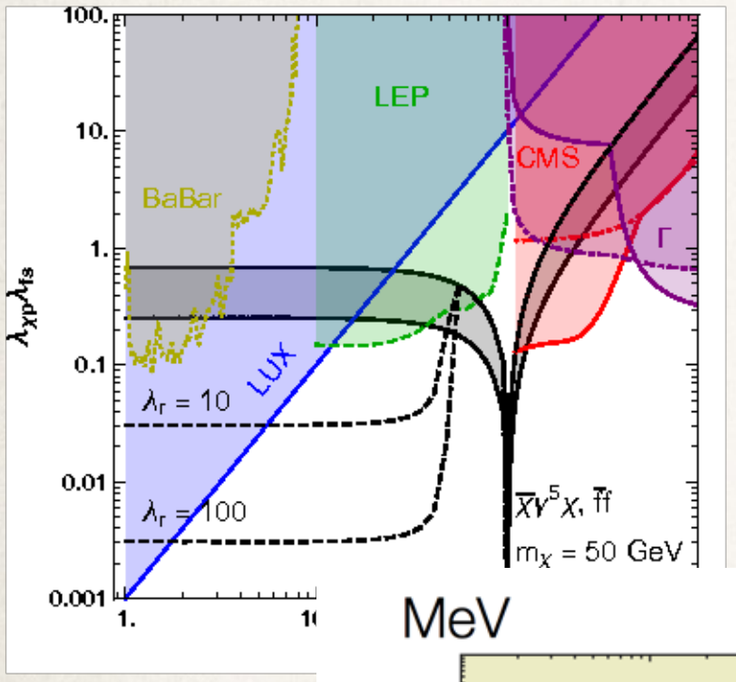
Icecube 53 events

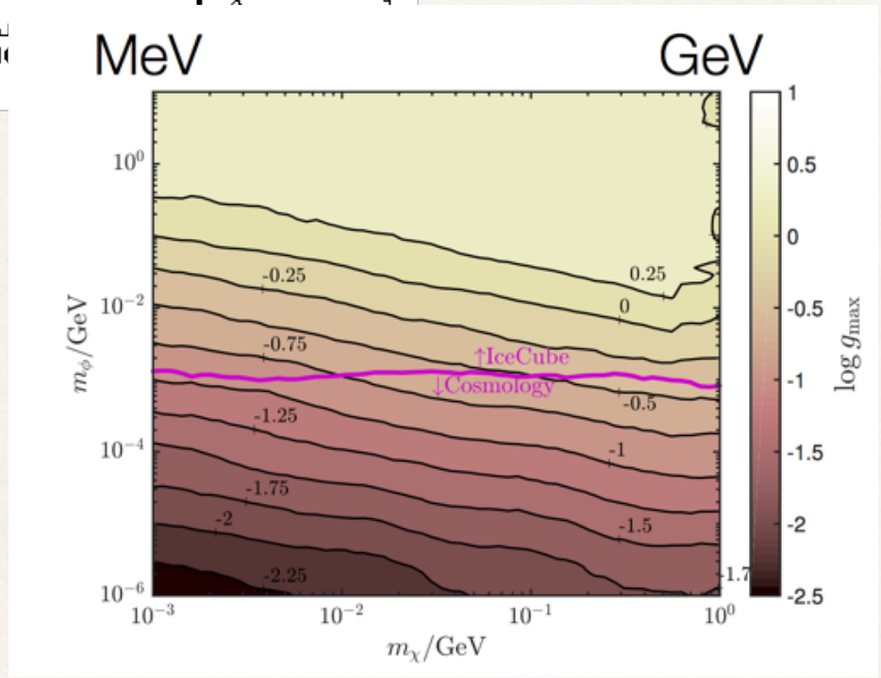


Arguelles, Keirandish,Vincent. 1703.00451



These days we think a lot more about **complementarity**





1. New experiments, ways they present results, access to data

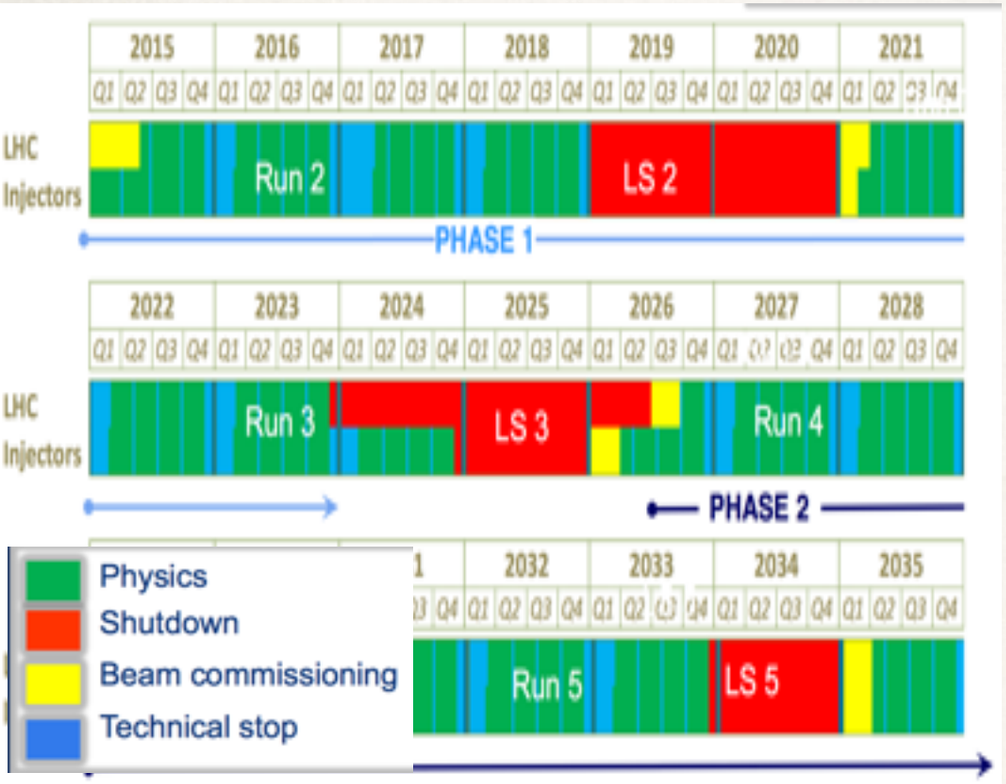
2. Simple straw-man models

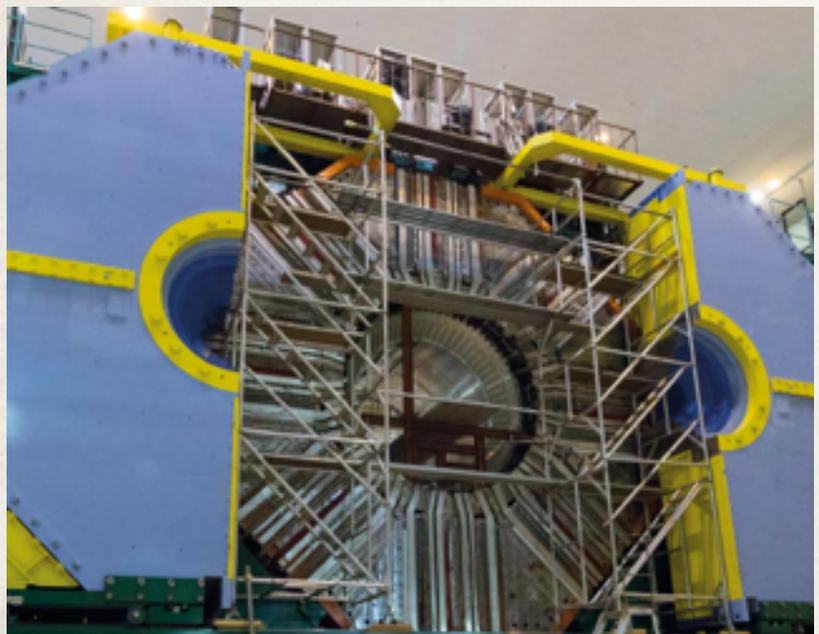
3. Development of public tools, or recasting, so we can tackle complex processes and focus on the fundamental ideas

Future

For the LHC, this is just the beginning

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





LHC hopefuls

gains from more data and better understanding of the environment

Testing non-standard kinematic features
Reaching high-precision in Higgs physics
Searches for invisible particles (monoX)
Blind spots (DV, disap. tracks, quirks)

and, of course, FLAVOR
with Belle-II, NA62 complementing LHCb

Smaller experiments may be key

Narrower focus

BUT

cheaper, shorter time-scale

develop creative experimental techniques

often enlarge the initial physics focus

New theoretical ideas

Experimental results challenge long-standing common lore in Particle Physics

e.g. SUSY& naturalness, WIMP

New **theoretical developments** are very much needed. Simplified models are good *proofs of concept* but don't bring the field very far

*Extend the current models with more features

e.g ALPs non-vanilla couplings

*Find a rationale for hidden sectors

* BE BOLD! this is the right environment for new ideas

And what about the cool/crazy stuff?

Dark Energy and its interaction with us

Alternatives to space-time symmetries (e.g. emergent gravity)

Very light dark matter (new exp techniques)

Dark moments in the Universe's history, pre-BBN

Connections between IR and UV physics, e.g. BHs

We need to *challenge* the well-stablished paradigms,
may be quickly ruled out
but one **always** learn something new from these explorations

Conclusions

- Here we are, looking for a way to advance our understanding of nature, to reach discovery

- Scaling back from an ambitious program to find *the* theory of everything. Facing the challenges/opportunities that more data brings

- Use of simplified models to organize/interpret searches, less model biased, and suitable to complementarity studies

- Yet theoretical advances require more than simplified models, asking difficult questions from model building

Remember progress doesn't always come from taking the direct route, wandering and having fun with ideas is key to our job

So, HAVE FUN!

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