NATIONAL CENTRE FOR SCIENTIFIC RESEARCH "DEMOKRITOS"
INSTITUTE OF NUCLEAR & PARTICLE PHYSICS

The LHC at 18: the legacy

or, how these 18 years changed the way we think of the LHC and of the open issues in particle physics

20 October 2026



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LHC: the Large Hadron Collider

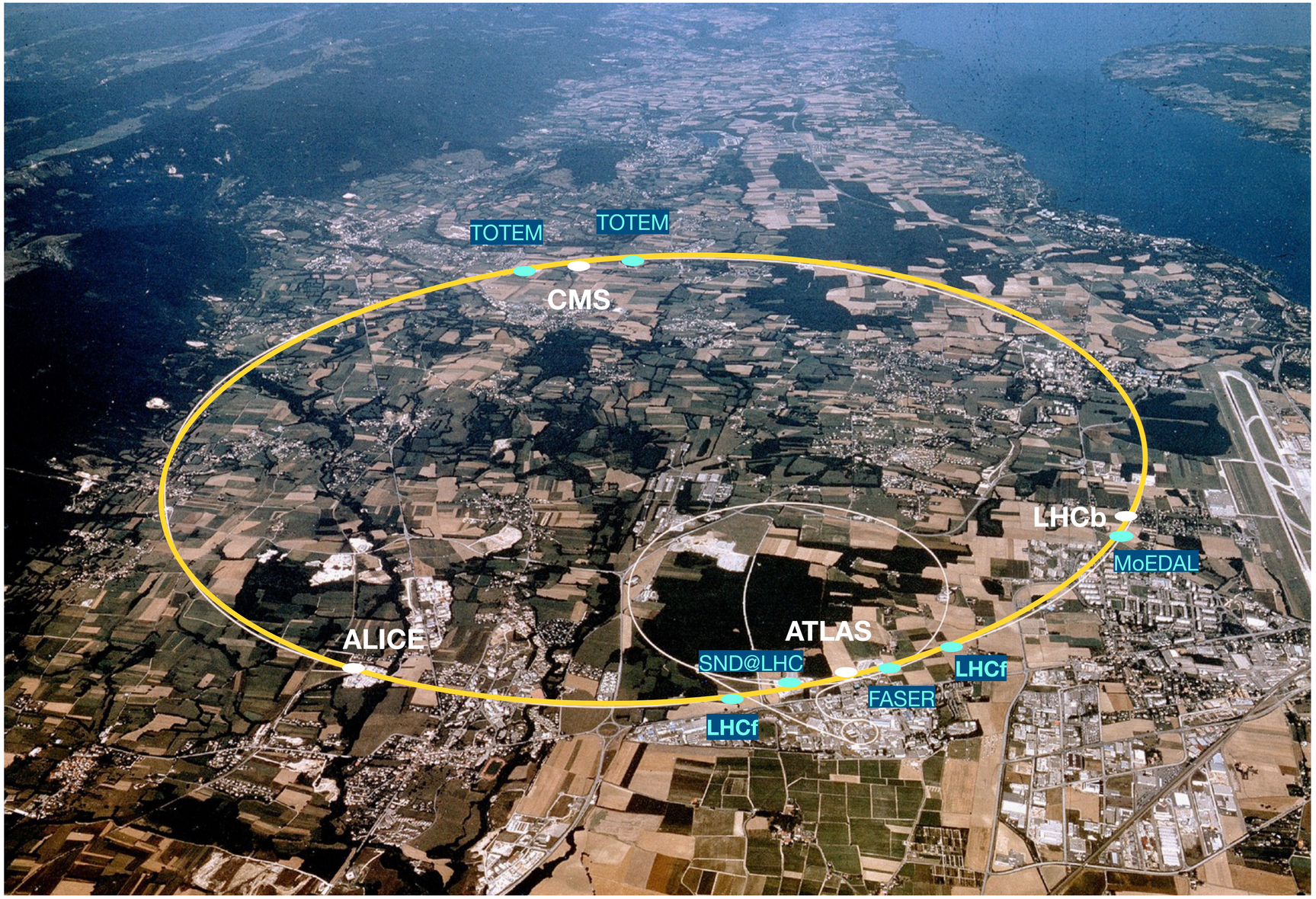
- 27 km tunnel, instrumented with NbTi magnets with B up to ~9T, to steer protons up to E=7 TeV
- proton-proton, proton-ion and ion-ion collisions, up to ECM(pp) = 14 TeV

Experiments:

ATLAS, CMS
O(3000) physicists; general purpose, optimized for high-pt physics

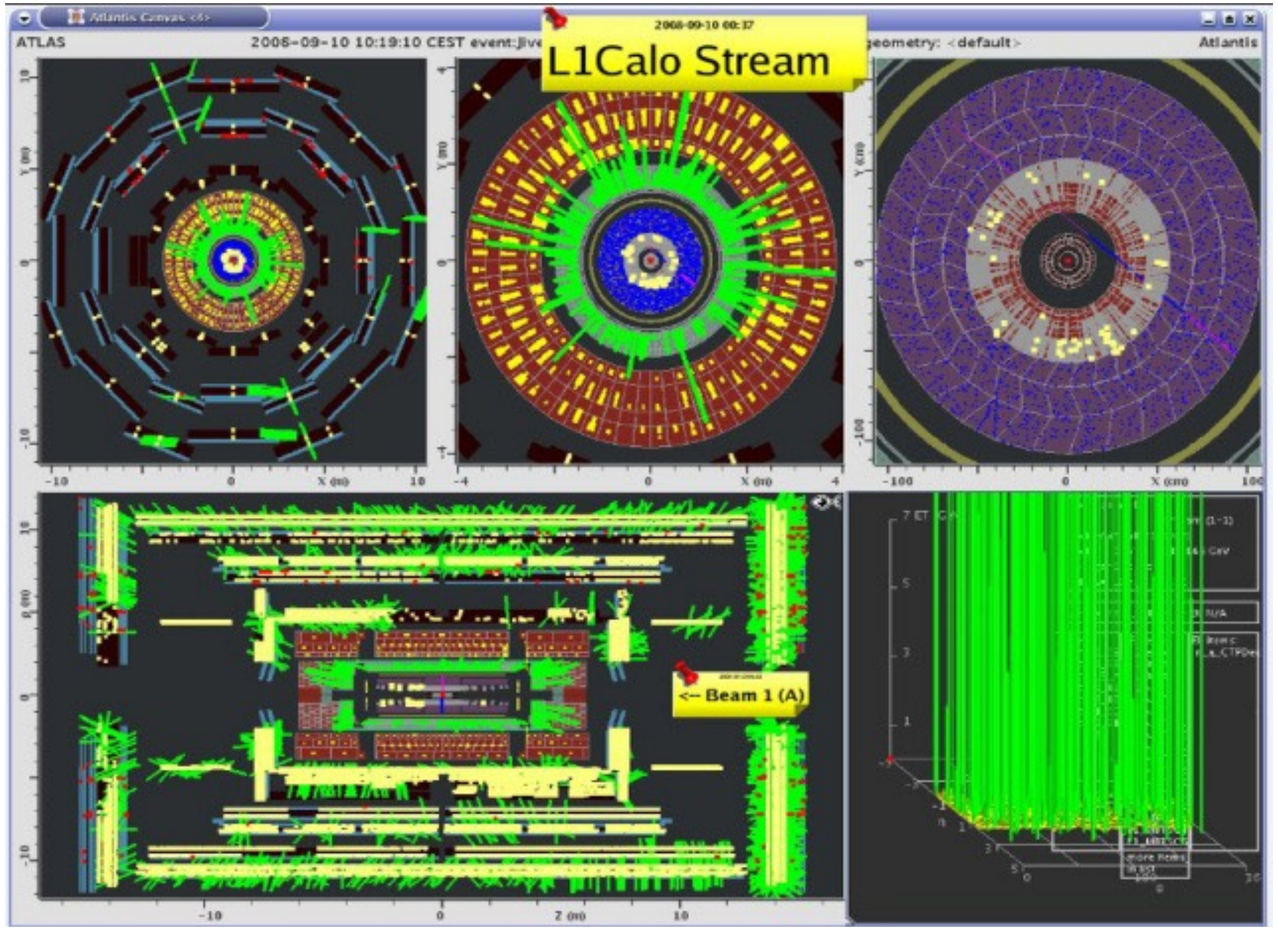
ALICE, LHCb
O(1000) physicists; general purpose, optimized for heavy ion collisions and flavour physics, resp)

Smaller (O(100) physicists):
TOTEM, LHCf (hadronic forward physics, modeling of cosmic ray showers),
MoEDAL (magnetic monopole and highly-ionizing particle searches),
FASER, SND@LHC (neutrino interactions and searches for long-lived weakly interacting particles)

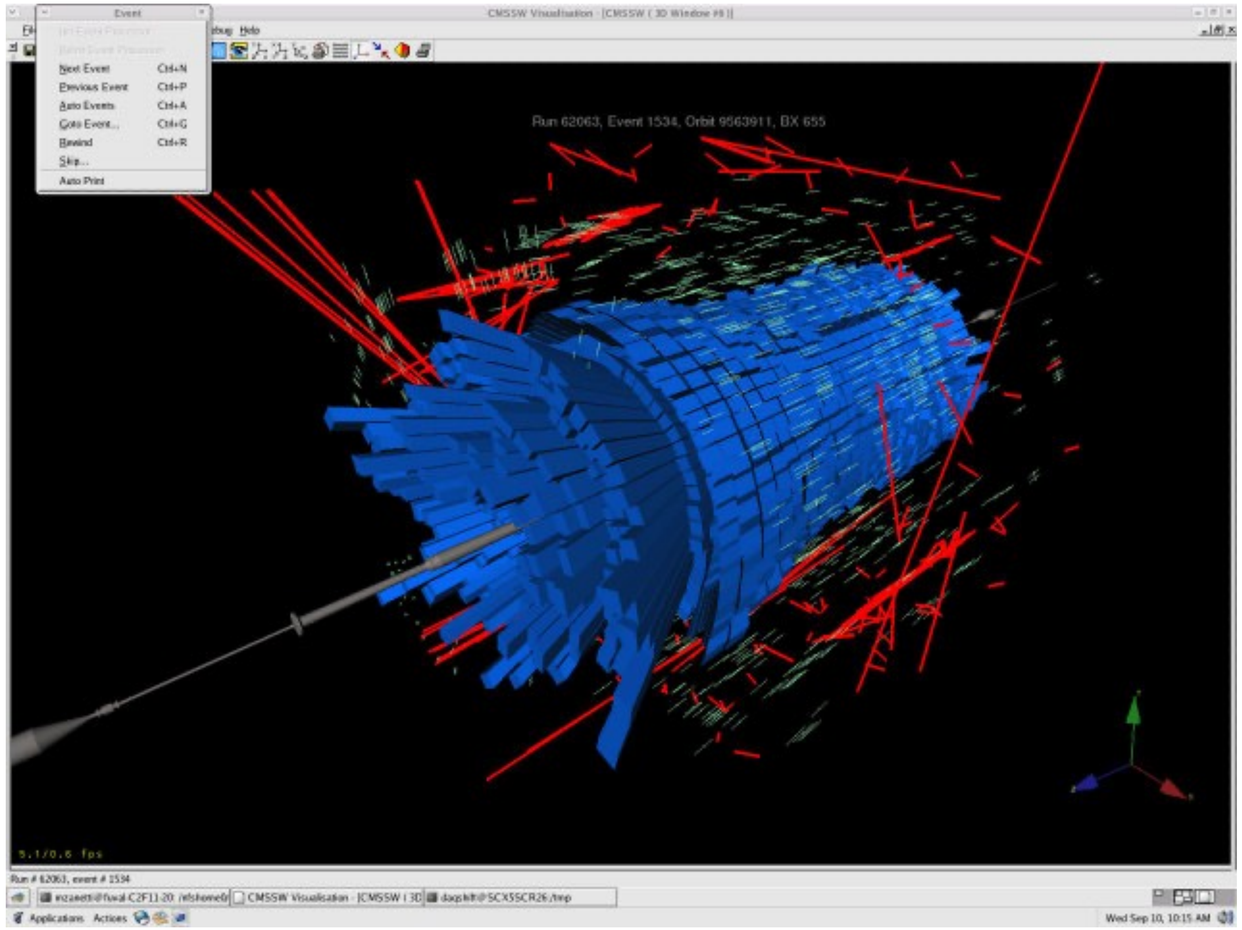


10 September 2008: first protons circulating in the LHC

ATLAS beam splash events



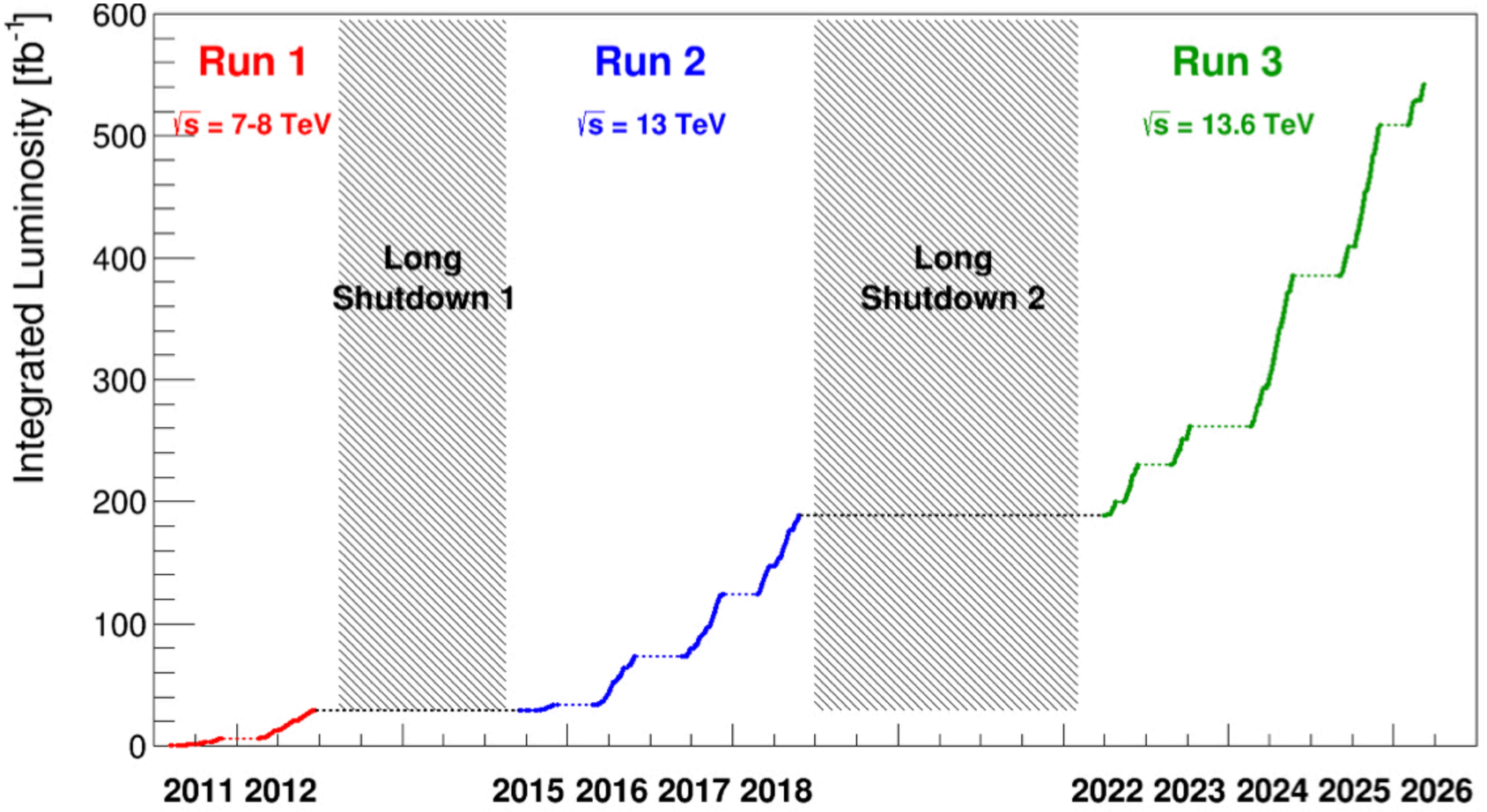
CMS beam splash events



8 days later, an incident stopped the commissioning of proton collisions, postponing the first collisions to the end of 2009 …

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since then, the accelerator performance far exceeded the expectations (over 500 fb^{-1} wrt the 300 initial target)



Run period	Total delivered luminosity (fb^{-1})
Run 1: 2010-12	~30
Run 2: 2015-18	~160
Run 3: 2022-26	~350
Full	over 500

General perspective, expectations and prejudices leading to the LHC start

Target	Key Goals
Higgs	discovery of Higgs or alternative EW symmetry breaking manifestations below the TeV scale
BSM	search&discovery of new particles/interactions predicted by a variety of new physics scenarios related to the origin of the Higgs, of dark matter, CP violation, etc
SM	• improved measurements of SM parameters like m_{top}, m_W • EW studies at the TeV scale (eg WW scattering) • QCD tests at multi-TeV energies and exploration of the proton/quark structure
Flavour	search for new sources of CP violation with improved mapping of CPV phenomena (eg CPV in the charm sector), within and beyond the SM; observation of rare FCNC processes (eg $B_S \rightarrow \mu\mu$); …
Heavy Ions	consolidation of QGP phenomenology, esp with new probes such as charm and bottom quarks, jets and EW gauge bosons

on BSM

Guido Altarelli, lectures at the HCP school 2008

Is it possible that the LHC does not find the Higgs particle?

Yes, it is possible, but then must find something else

Is it possible that the LHC finds the Higgs particle but no other new physics (pure and simple SM)?

Yes, it is technically possible but it is not natural

Is it possible that the LHC finds neither the Higgs nor new physics?

No, it is essentially impossible

on the discovery prospects of Higgs vs BSM

F.Gianotti and M.Mangano: LHC physics, the first 1-2 yrs, https://arxiv.org/pdf/hep-ph/0504221 ,
a.k.a. "Mangianotti"

9. Conclusions

The LHC offers the potential for very interesting physics and major discoveries right from the beginning. We note that for some standard physics processes, a single day of data taking at $L = 10^{33}$ cm^{-2} s^{-1} corresponds, in terms of event statistics, to ten years of operation at previous machines. SUSY may be discovered quickly, a light Higgs boson will be much more difficult to observe, unexpected scenarios and surprises may also be round the corner at an unprecedented collider exploring a completely new territory.

on the potential for a programme of precision physics

- Leaving aside the Higgs discovery and measurements, and marginal improvements in the measurements of fundamental SM parameters (eg W and top mass), there is nothing new to be learned about the SM dynamics at the LHC
- LHC pp environment too dirty for precise measurements ⇒ pointless to invest on major theory calculations
- Higher-order precision calculations for pp are anyway close to impossible

Let’s see what Nature ended up giving to us …

2012

Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Observation of a new particle in the search for the Standard Model Higgs boson with the ATLAS detector at the LHC ☆

ATLAS Collaboration *

This paper is dedicated to the memory of our ATLAS colleagues who did not live to see the full impact and significance of their contributions to the experiment.

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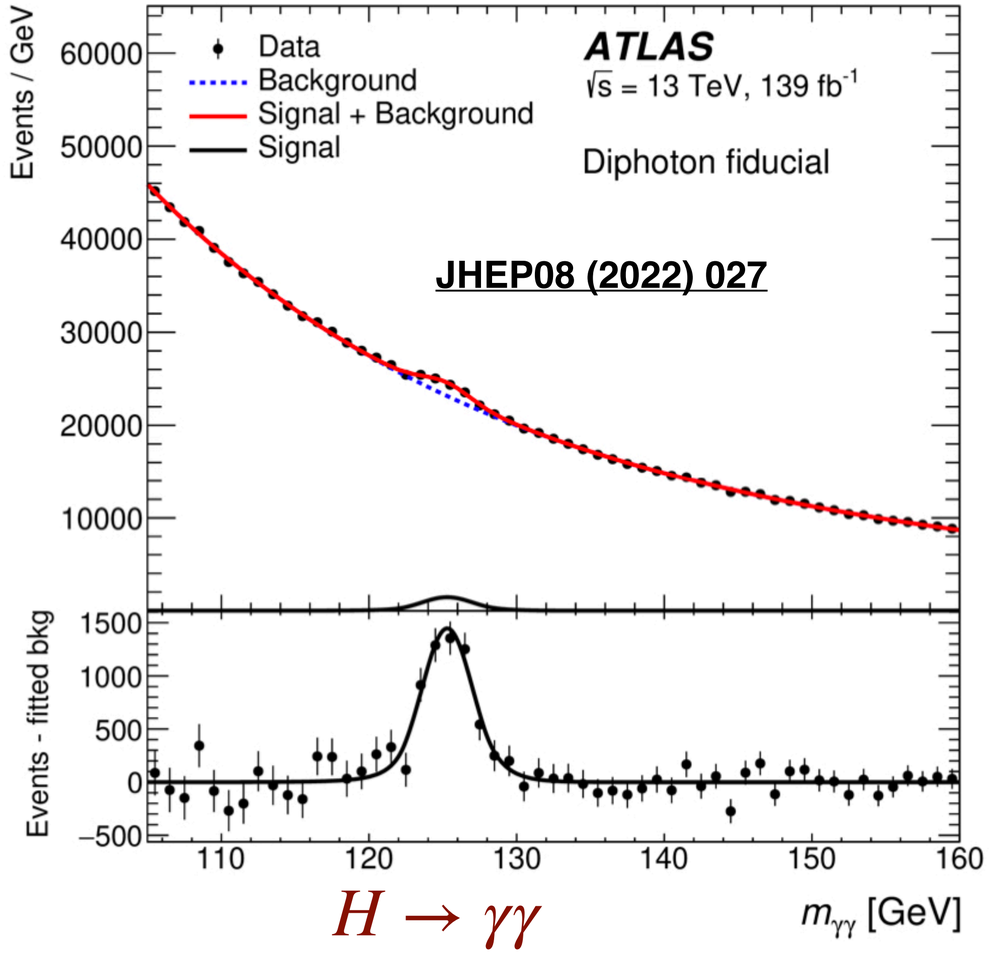
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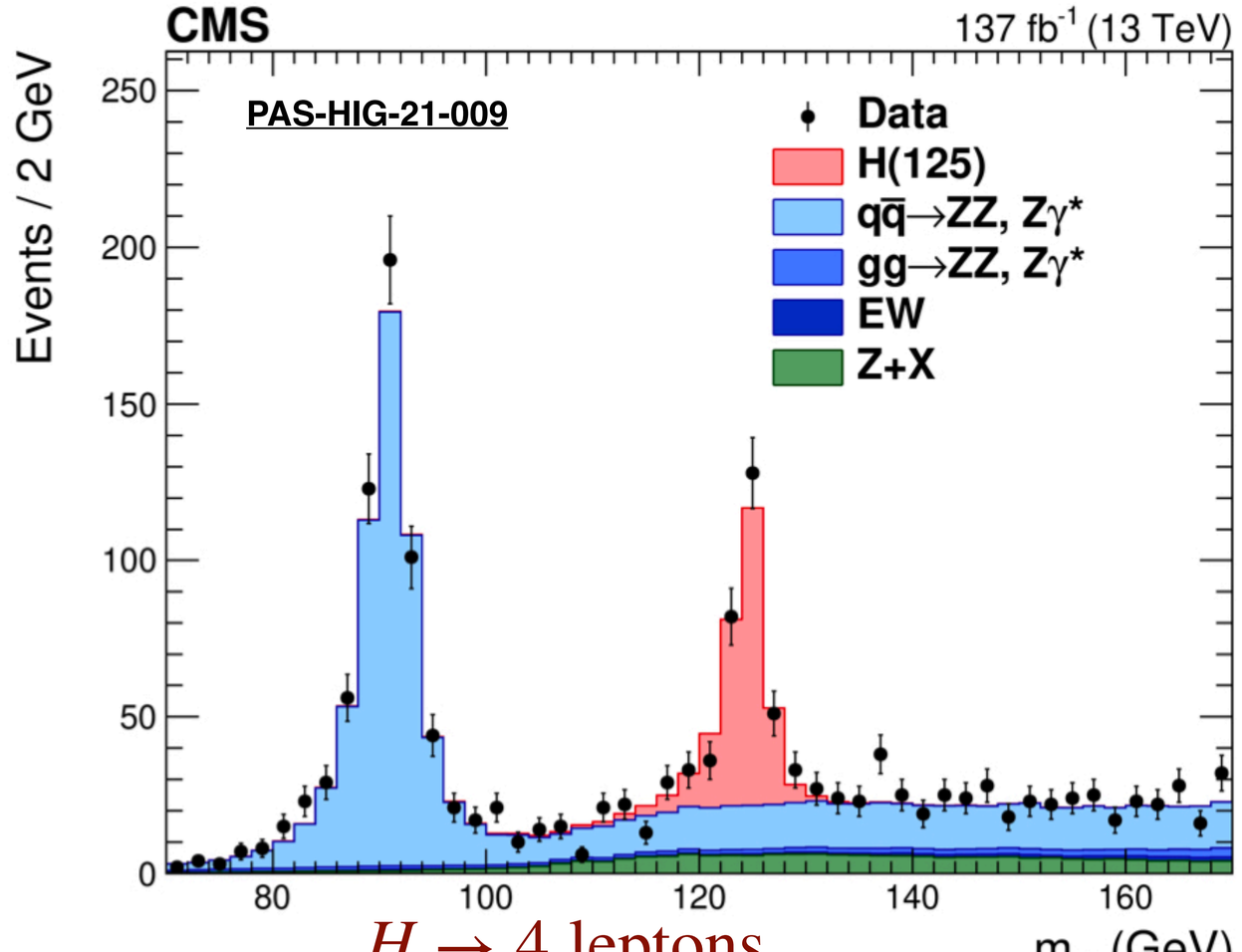
Observation of a new boson at a mass of 125 GeV with the CMS experiment at the LHC ☆

CMS Collaboration *

2023

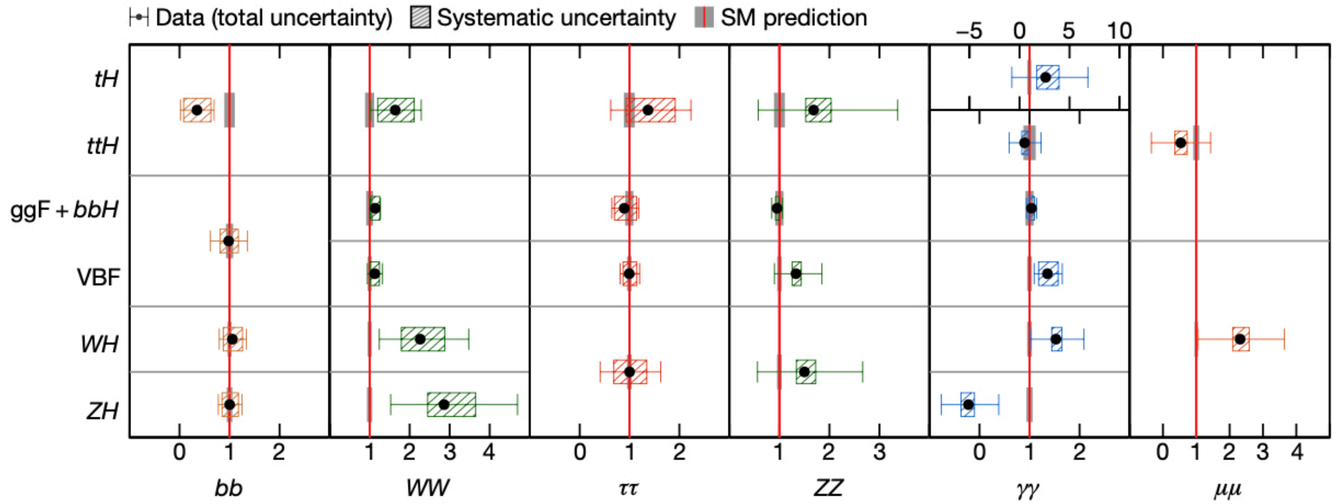


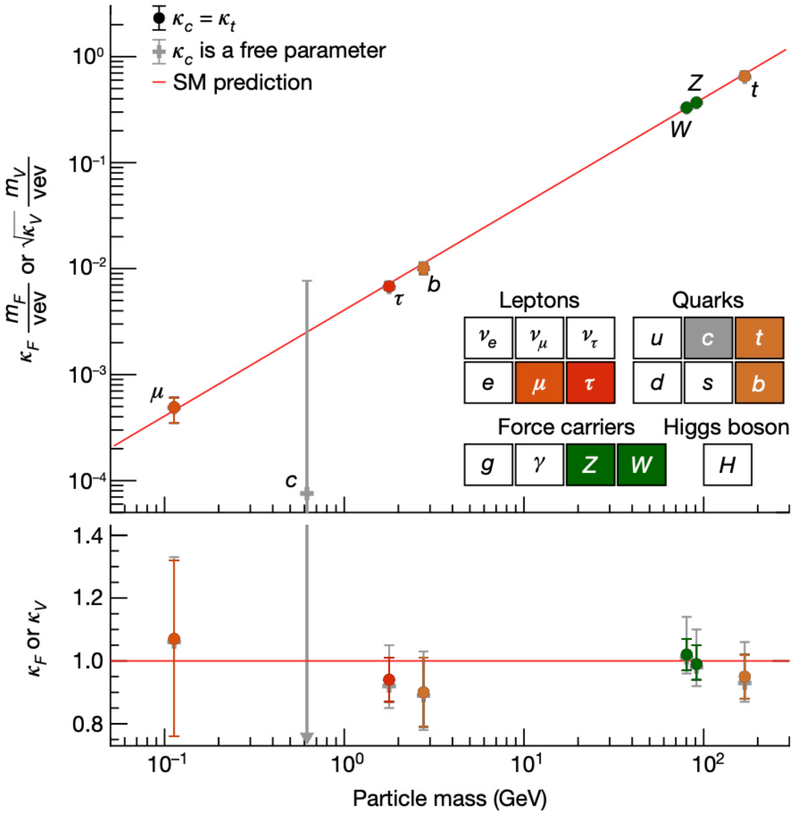
$H \to \gamma\gamma$

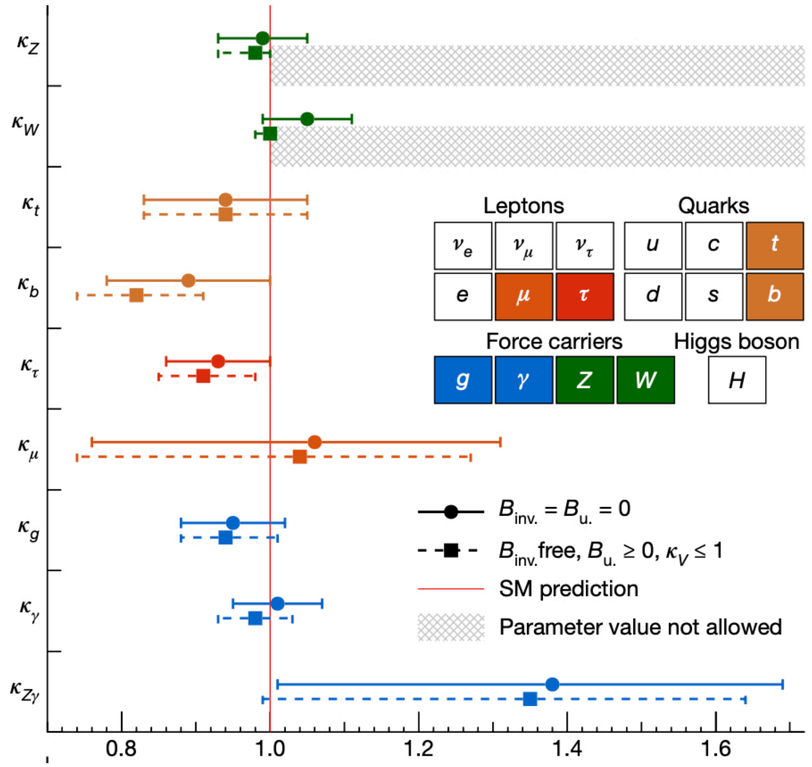


$H \to 4$ leptons

today:
general properties and couplings are consistent with the SM







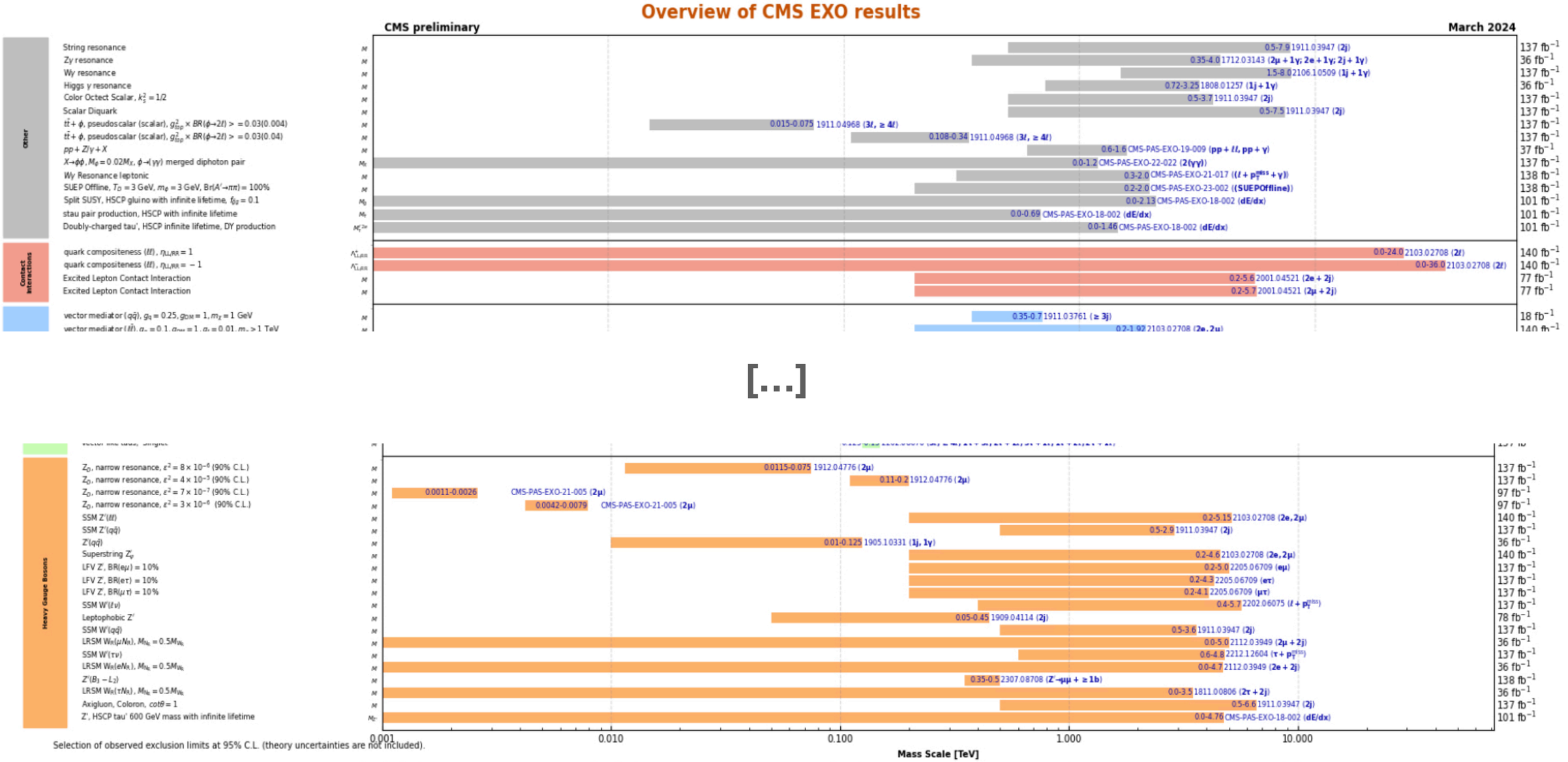
The ATLAS Collaboration
Nature, 607, 52–59 (2022)

The CMS Collaboration
Nature, 607, 60–68 (2022)

For recent global updates, see **ATLAS** arxiv:2608.07332 and **CMS,** arxiv:2602.18611

In parallel, no *conclusive* signal of physics beyond the SM

new gauge interactions, heavy or excited fermions, extra-dims, RPV, DM, SUSY, …



[…]

0.001 0.01 0.1 1 10

Mass scale (TeV)

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Theory

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a set of ideas and numbers that ***describe*** the past, present, or future state of something

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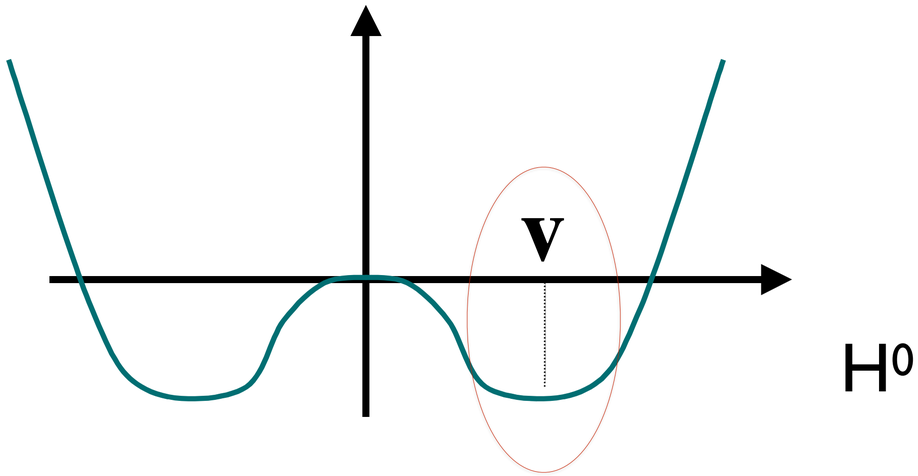
So, I’d rather stick to **Model….**

But there is a deeper reason why I believe the SM **still is** a model.

More precisely, I would actually define the SM as **the theory <u>of</u>** weak interactions, but just **a model <u>for</u>** electroweak symmetry breaking

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$$V(H) = -\mu^2 |H|^2 + \lambda |H|^4$$

Where does this come from?

The Higgs mechanism* , as implemented in the SM (*á la Weinberg, 1967*), provides the *minimal* set of *ingredients* required to enable a consistent breaking of the EW symmetry.

* Higgs, Brout, Englert, Guralnik, Hagen, Kibble 1964

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Eg, *is m_H calculable from 1st principles*?

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a historical example: superconductivity

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- The relation between the Higgs phenomenon and the SM is similar to the relation between superconductivity and the Landau-Ginzburg theory of phase transitions: a quartic potential for a bosonic order parameter, with negative quadratic term, and the ensuing symmetry breaking. If superconductivity had been discovered after Landau-Ginzburg, we would be in a similar situations as we are in today: an experimentally proven phenomenological model. But we would still lack a deep understanding of the relevant dynamics *(like Kepler vs Newton)*.

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- For superconductivity, this came later, with the identification of $e^- e^-$ Cooper pairs as the underlying order parameter, and BCS theory. In particle physics, we still don't know whether the Higgs is built out of some sort of Cooper pairs (composite Higgs) or whether it is elementary, and in both cases we have no clue as to what is the dynamics that generates the Higgs potential. With Cooper pairs it turned out to be just EM and phonon interactions. With the Higgs, none of the SM interactions can do this, and **we must look beyond.**

examples of possible scenarios

- **BCS-like**: the Higgs is a composite object … m_H can be calculated like the pion mass in QCD

- **Supersymmetry**: the Higgs is a fundamental field and
  - $\lambda^2 \sim g^2+g'^2$, it is not arbitrary (MSSM, w/out susy breaking, has one parameter less than SM!)
  - potential is fixed by susy & gauge symmetry
  - EW symmetry breaking (and thus m_H and λ) determined by the parameters of SUSY breaking

- …

Other important open issues on the Higgs sector

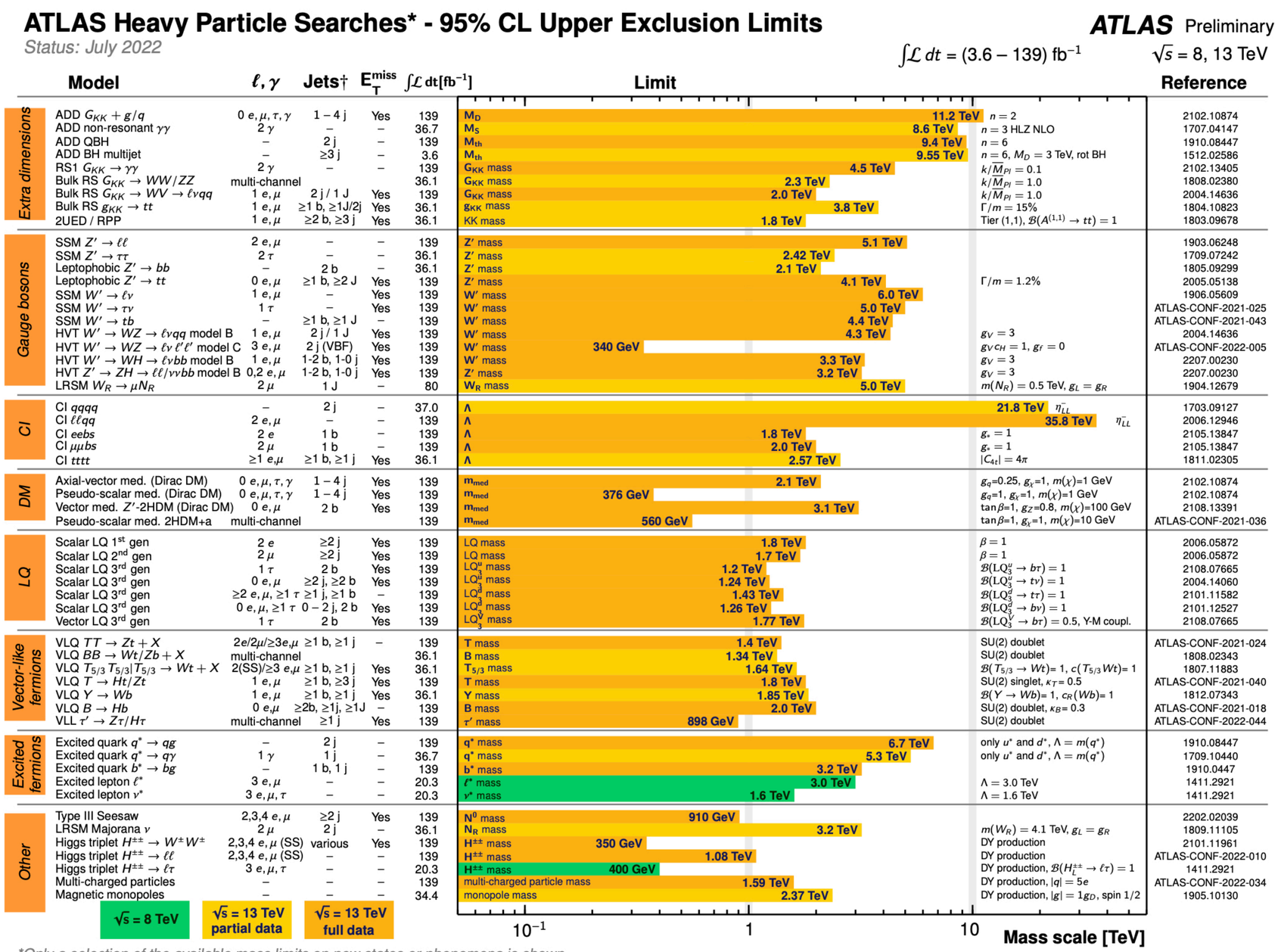
- Is the Higgs the only (fundamental?) scalar field, or **are there other Higgs-like states** (e.g. $H^{\pm}$, A^0, $H^{\pm\pm}$, ... , EW-singlets, ...) ?
  - Do all SM families get their mass from the **same** Higgs field?
  - Do I_3=1/2 fermions (up-type quarks) get their mass from the **same** Higgs field as I_3=–1/2 fermions (down-type quarks and charged leptons)?
  - Do Higgs couplings conserve flavour? $H \to \mu\tau$? $H \to e\tau$? $t \to Hc$?
- Is there a deep reason for the apparent metastability of the Higgs vacuum?
- Is there a relation among Higgs/EWSB, baryogenesis, Dark Matter, inflation?
- What happens at the EW phase transition (PT) during the Big Bang?
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➡ the Higgs discovery does not close the book, it opens a whole new chapter of exploration, based on precise measurements of its properties,
which can only rely on the LHC and a future generation of colliders

So far, no *conclusive* signal of physics beyond the SM



*Only a selection of the available mass limits on new states or phenomena is shown.

†Small-radius (large-radius) jets are denoted by the letter j (J).

How is the lack of evidence for new physics at the LHC changing our perspective on

A. the theoretical landscape?
B. the approaches to searching for new phenomena with the LHC and future colliders?

A bit of history …

~50 years ago, 1974 signalled the greatest before/after discontinuity in particle physics since its birth

before:

<1973:

- GWS model — Glashow Weinberg Salam
- GIM — Glashow Iliopulos Maiani
- renormalizability of gauge interactions — 't Hooft Veltman

1973:

- Discovery of neutral currents ⇒ SU(2)xU(1) gauge structure for weak interactions — Gargamelle @ CERN
- Asymptotic freedom ⇒ SU(3) gauge structure for strong interactions — Gross&Wilczek, Politzer
- Kobayashi-Maskawa CP violation with 3-generations ⇒ CKM flavour structure

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In 1974 the SM gets firmly established as the framework to understand all known phenomena in particle physics … we just needed a few Nobel prizes to be distributed, and further experimental exploration to work out the details …

after:

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- Supersymmetry — Wess Zumino

and the avalanche build-up ever since:

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- Naturalness and EWSB, composite Higgs, etc — WIlson,
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➡ explosion of BSM model building, phenomenology and exptl searches

By 1974 the SM is declared history, BSM searches become the new virgin territory of exploration, with theory providing guidance to experiments, rather than the opposite

The consolidation of the SM went hand in hand with the search for BSM phenomena.

Reliance on the SM framework, helped guiding the discovery of the missing pieces of the SM (the EW gauge bosons, the top quark, the Higgs), offering “no-loose” theorems that guaranteed those discoveries at suitably built colliders

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Lack of a new reference framework radically changed the perspective of the LHC and theoretical BSM programme, focusing on:

- more exotic/elusive signatures and models (dark sectors, ALPs, long-lived particles, …)
- model-independent searches/interpretations (simplified models, recasting, EFT, …)
- indirect probes of BSM via precision measurements, exploiting the evolution of the experiments, accelerator and theory precision, surpassing even the most optimistic expectations

Example 1: on the impact of precision measurements, when there is a framework

In the SM, the relation between M_W , M_Z and $\sin^2\theta_W$ is fixed at tree level. At the quantum level, the relation depends on input param's like m_{top} and m_H.

Precision measurements of M_W , M_Z and $\sin^2\theta_W$ at LEP/SLAC/Tevatron confirmed the deviation from tree level:

- ***is this BSM or a manifestation of radiative corrections to the SM prediction?***

  ➡ ***calculate m_{top} and m_H that describe data, use/build a collider to search for top and Higgs with these mass values, and check if SM is ok***

The moral of the story:

the SM provided a framework to interpret the results of precision EW measurements, giving direct guidance as to how dedicated experiments (in this case Tevatron and LHC for top and Higgs resp) could confirm its consistency, or expose new phenomena

Example 2: on the impact of precision measurements, when there isn't a framework

In the SM, a prediction exists for the anomalous magnetic moment of the muon, $a_\mu = (g-2)_\mu$ … all SM parameters enter here via radiative corrections. All SM parameters are known today with sufficient precision to calculate a_μ with the accuracy required to challenge the SM with experimental data (FNAL, BNL).

Current data indicate that the SM prediction * is off by 5.2σ … Options:

(A) the uncertainty of the SM result is underestimated (see eg recent lattice predictions)

(B) there is new physics

if (B), there is no BSM model, among the many considered, which can be singled out as a benchmark framework to interpret the origin of the a_μ anomaly, and plan for confirmation experiments/facilities

* *this is under new scrutiny, following disagreement between different theoretical approaches to the estimate of non-perturbative contributions*

Example 3: on the impact of direct discoveries, when there is/isn't a framework

suppose that: a jets+ missing ET signal is observed at the LHC

In the 90's this would have been immediately interpreted as a supersymmetric neutralino, calling for discovery of SUSY and DM

Today, many options could be on the table:

(A) SUSY

(B) invisible H decay (eg to axions, dark photons, etc)

(C) extra dimensions

(D) …

After the SM, interpreting discoveries and pinning down their origin is harder than just predicting possible manifestations of BSM models … even if we work with a specific class of BSM scenarios in mind

Bottom line

progress towards answering questions like the origin of EWSB requires a multitude of probes and perspectives, whose interplay and role cannot be anticipated as it will ultimately depend on what is the actual underlying framework.

This is where the huge breadth of the overall LHC physics programme plays a key role: don't leave any stone unturned, starting from the fullest exploration of the SM phenomena

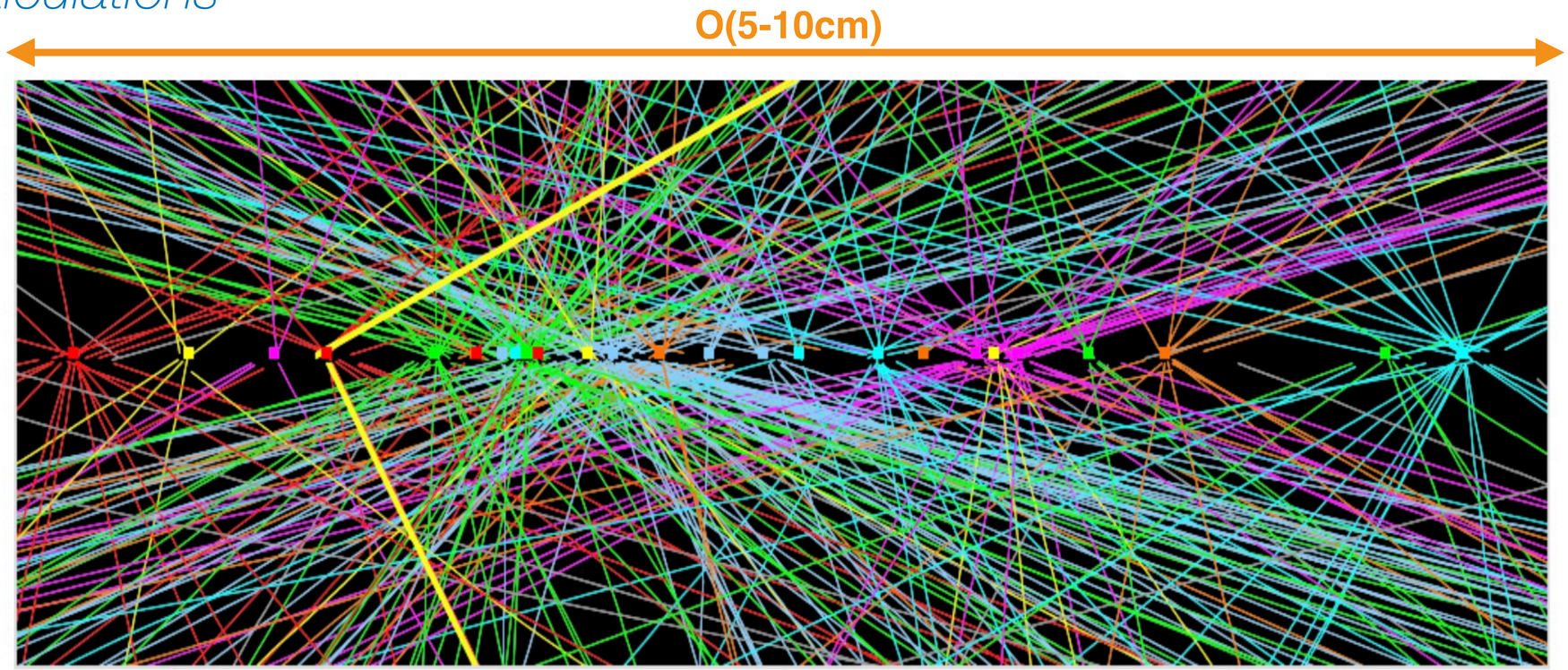
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The experimental and theoretical communities proved all these biases unfounded

- Precision of experimental measurements far exceeded even the most optimistic expectations:
  - ability to top-perform with up to O(70) pile up events
  - 1% knowledge of luminosity (cross sections = event rate / luminosity)
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  - NNLO results available for most processes of interest, and first key NNNLO results
  - Improved understanding of resummation, merging with MCs, shower evolution, tuning, etc.etc.etc.

These developments have redefined the potential and focus of the physics programme

LHC scientific production:
a role model of scientific diversity

Over 4000 papers published/submitted to refereed journals by the 7 experiments that operated in Run 1 and 2 (ALICE, ATLAS, CMS, LHCb, LHCf, TOTEM, MoEDAL)… and the first papers are appearing by the new experiments started in Run 3 (FASER, SND@LHC)

Of these:

~10% on Higgs (15% if ATLAS+CMS only)

~25% on searches for new physics (30% if ATLAS+CMS only)

~60% of the papers on SM measurements (jets, EW, top, b, HIs, …)

Not only Higgs and exotic searches !

Flavour physics

- B(s) $\rightarrow \mu\mu$
- D mixing and CP violation in the D system
- Measurement of the γ angle, CPV phase ϕs, …
- Lepton flavour universality in charge- and neutral-current semileptonic B decays

QCD dynamics

- Countless precise measurements of hard cross sections, and improved determinations of the proton PDF
- Measurement of total, elastic, inelastic pp cross sections at different energies, new inputs for the understanding of the dominant reactions in pp collisions
- Exotic spectroscopy: discovery and study of new tetra- and penta-quarks, doubly heavy baryons, expected sensitivity to glueballs
- Discovery of QGP-like collective phenomena (long-range correlations, strange and charm enhancement, …) in "small" systems (pA and pp)

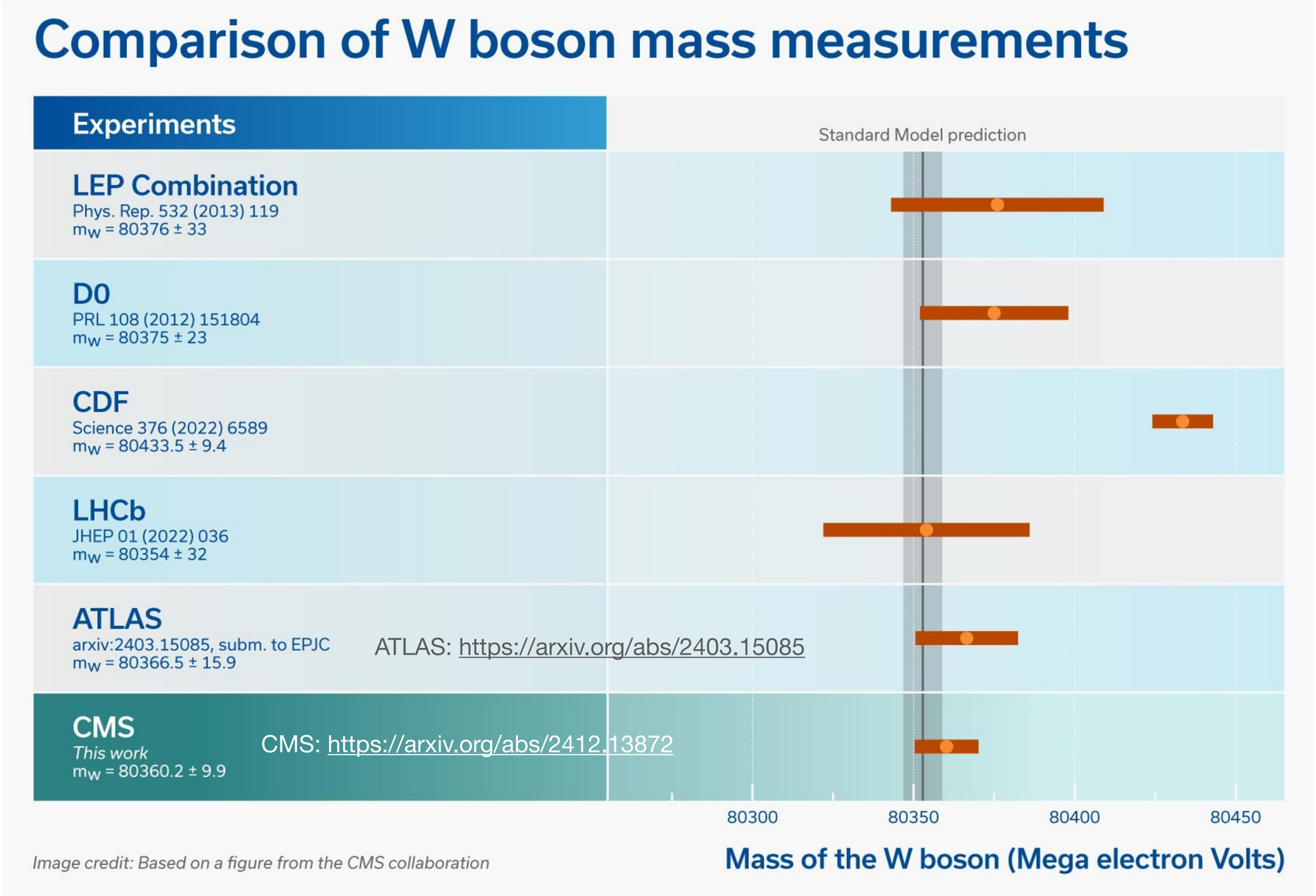
EW param's and dynamics

- m_W, m_{top}, $\sin^2\theta_W$ measured to unprecedented precision
- EW interactions at the TeV scale (DY, VV, VVV, VBS, VBF, Higgs, …)

Discoveries and new avenues in SM physics: a random handful of examples

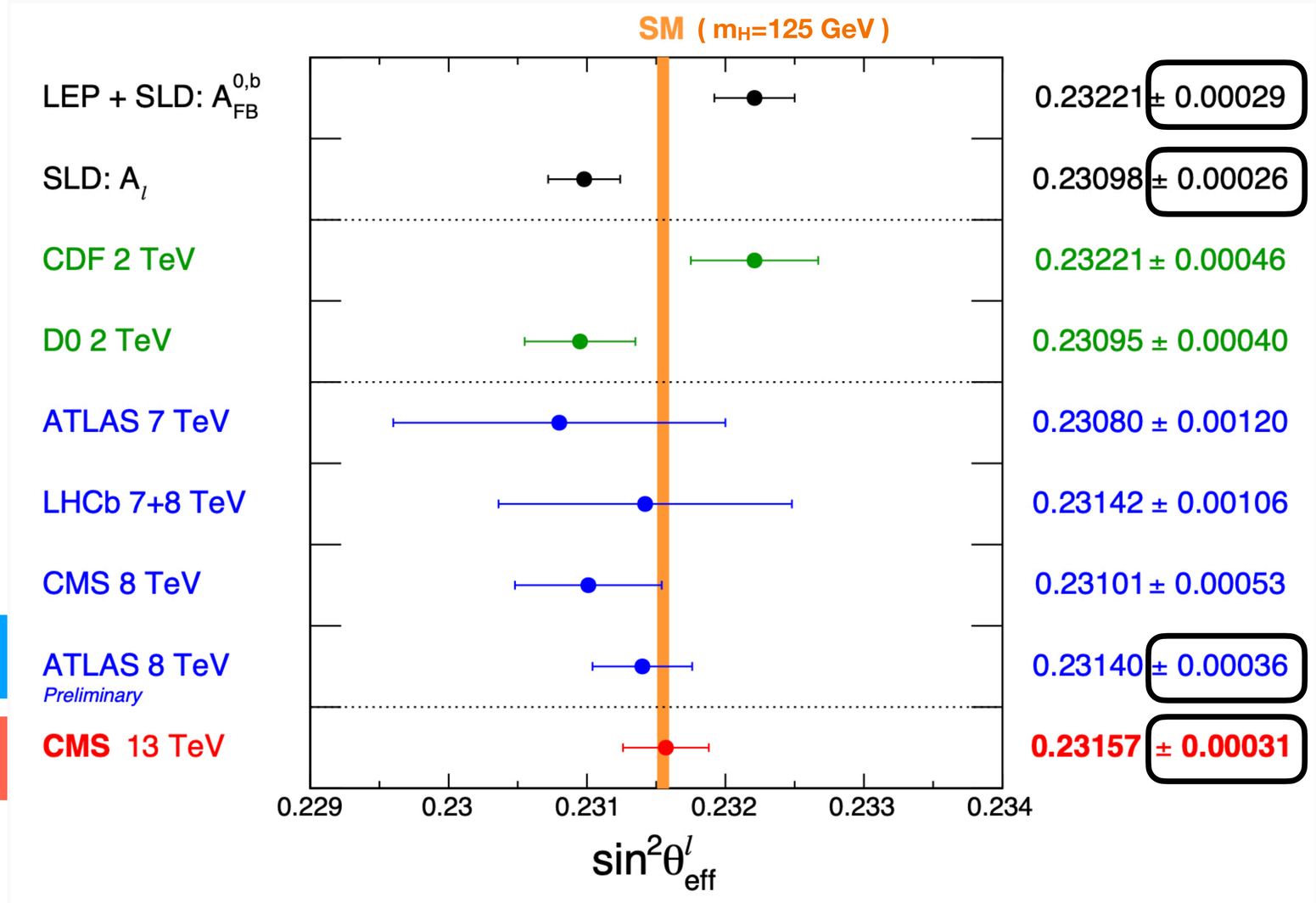
Precision EW physics

The W mass


Comparison of W boson mass measurements
Experiments
Standard Model prediction
LEP Combination
Phys. Rep. 532 (2013) 119
m_W = 80376 ± 33
D0
PRL 108 (2012) 151804
m_W = 80375 ± 23
CDF
Science 376 (2022) 6589
m_W = 80433.5 ± 9.4
LHCb
JHEP 01 (2022) 036
m_W = 80354 ± 32
ATLAS
arxiv:2403.15085, subm. to EPJC
m_W = 80366.5 ± 15.9
ATLAS: https://arxiv.org/abs/2403.15085
CMS
This work
m_W = 80360.2 ± 9.9
CMS: https://arxiv.org/abs/2412.13872
80300
80350
80400
80450
Mass of the W boson (Mega electron Volts)
Image credit: Based on a figure from the CMS collaboration

Effective leptonic weak mixing angle

$$\frac{g_V^\ell}{g_A^\ell} = 1 - 4\sin^2\theta_{eff}^\ell$$



$$\Rightarrow m_H = 175^{+99}_{-66}\,\text{GeV}$$

$$\Rightarrow m_H = 76^{+54}_{-33}\,\text{GeV}$$

ATLAS,
ATLAS-CONF-2018-037

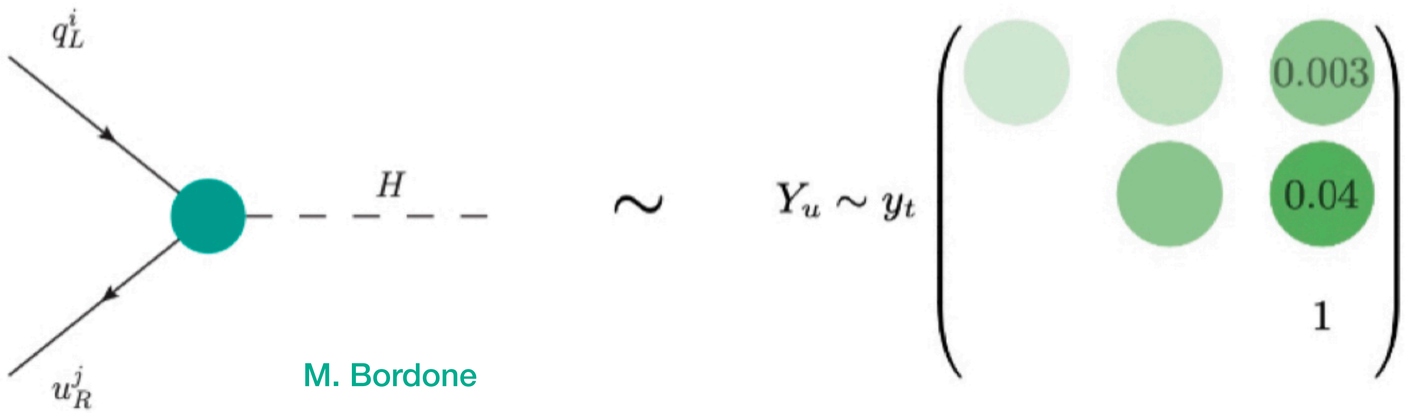
CMS,
Phys. Lett. B 866 (2025) 139526

$$\sin^2\theta_{\text{eff}}^\ell = 0.23157 \pm 0.00010(\text{stat}) \pm 0.00015(\text{syst}) \pm 0.00009(\text{theo}) \pm 0.00027(\text{pdf})$$

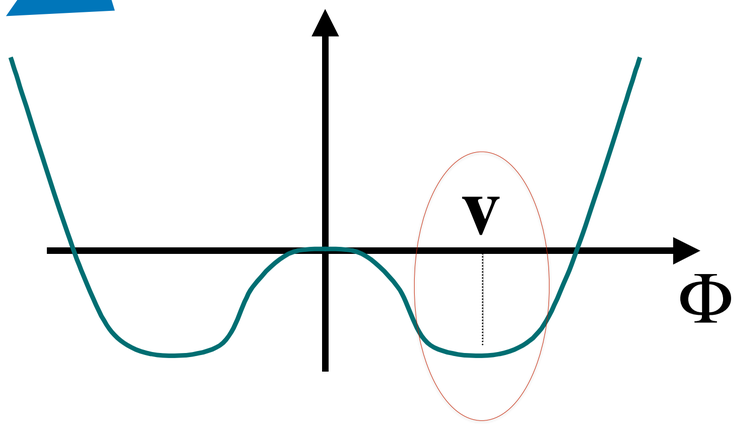
$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\psi}D\psi + h.c.$$

$$+\Phi\,\bar{\psi}_i^L\, y_{ij}\,\psi_j^R + h.c. + |D_\mu\Phi|^2 - V(\Phi)$$

Who ordered this?



M. Bordone



$$V(\Phi) = -\mu^2|\Phi|^2 + \lambda|\Phi|^4$$

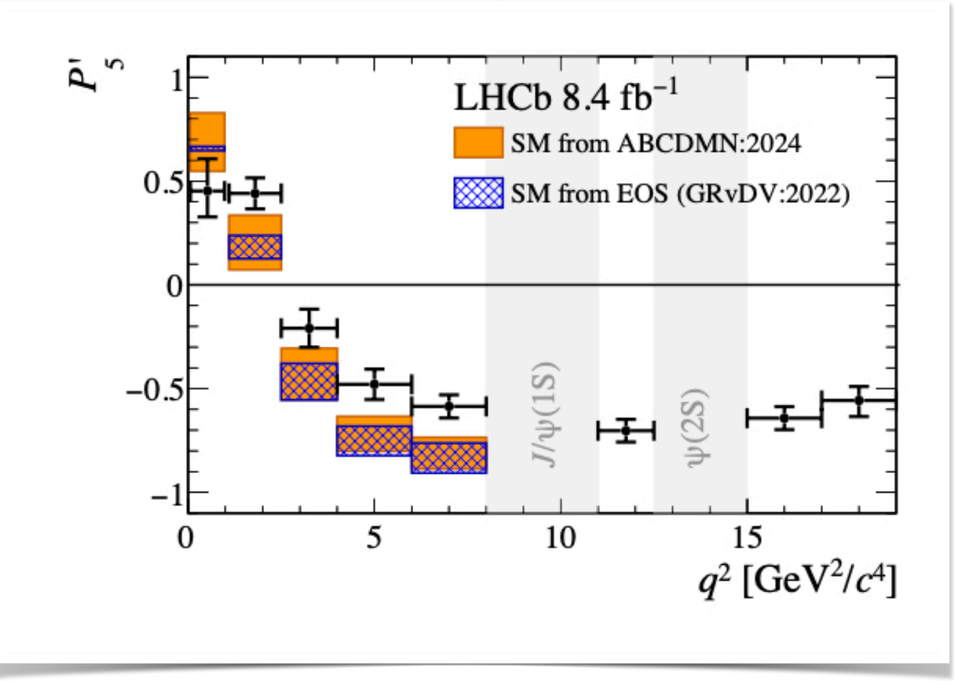
Who ordered that?

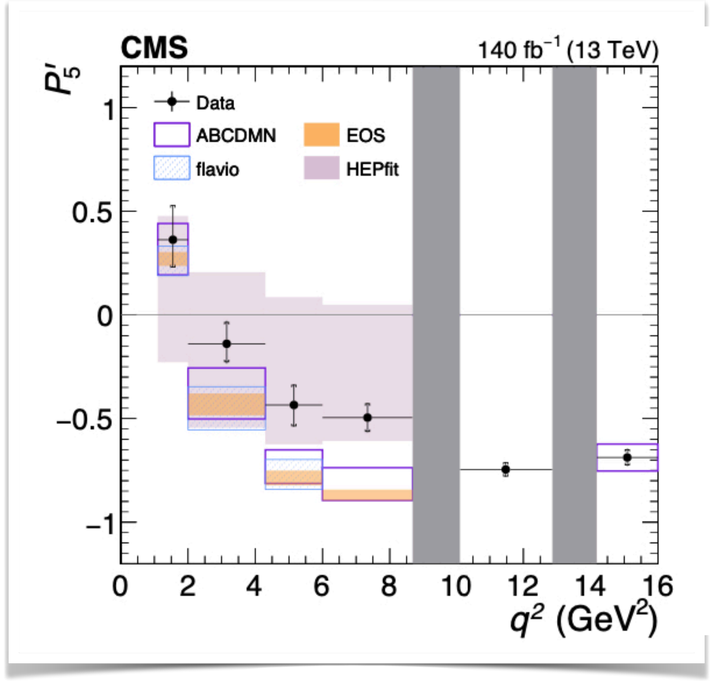
The origin of EWSB and the origin of flavour are two facets of the same grand puzzle:

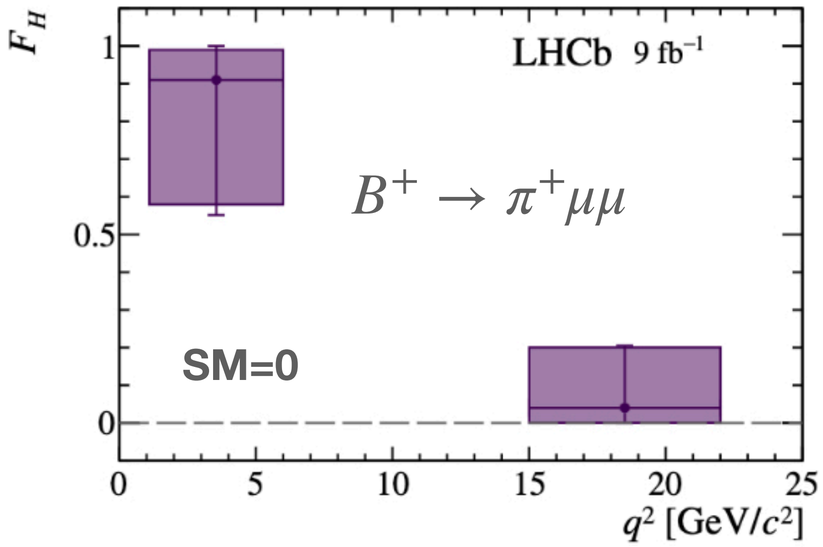
where does the Higgs come from?

Exploring flavour and exploring the Higgs run in parallel, and go hand in hand in addressing particle physics' most misterious challenge

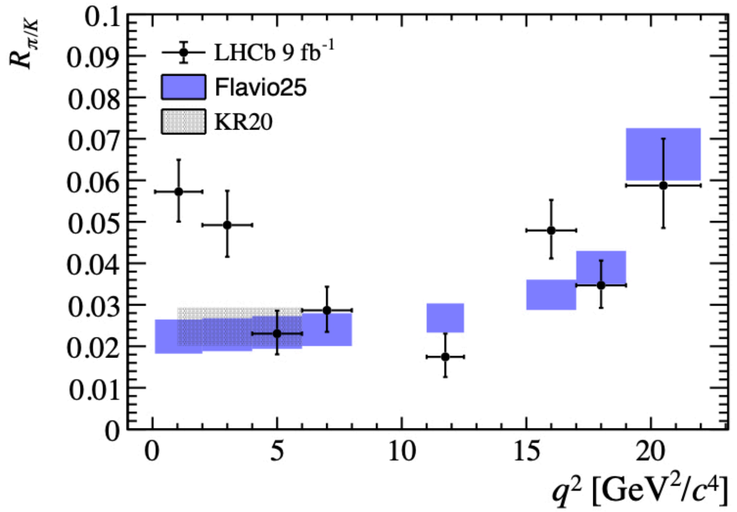
It is not surprising that flavour is giving us signals of a potential breakdown of SM predictions … few examples out of several:







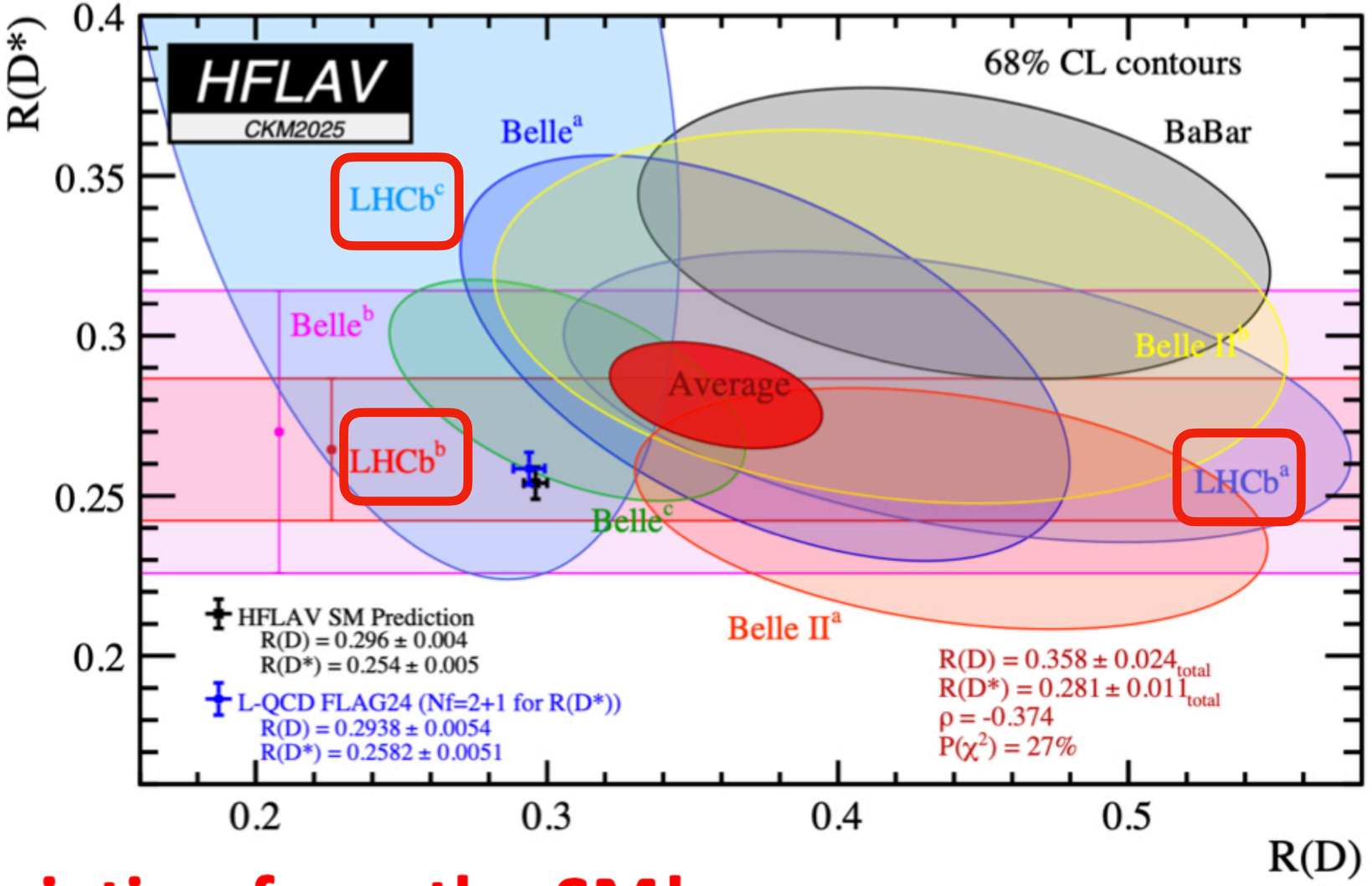
New LHCb for LHCP26:
https://arxiv.org/abs/2604.21987



$$(B^+ \to \pi^+\mu\mu)/(B^+ \to K^+\mu\mu)$$

New LHCb for LHCP26: LHCb-PAPER-2026-016

$$\mathcal{R}(D^{(*)}) = \frac{\mathcal{B}(B^0 \to D^{(*)-}\tau^+\nu_\tau)}{\mathcal{B}(B^0 \to D^{(*)-}\mu^+\nu_\mu)}$$



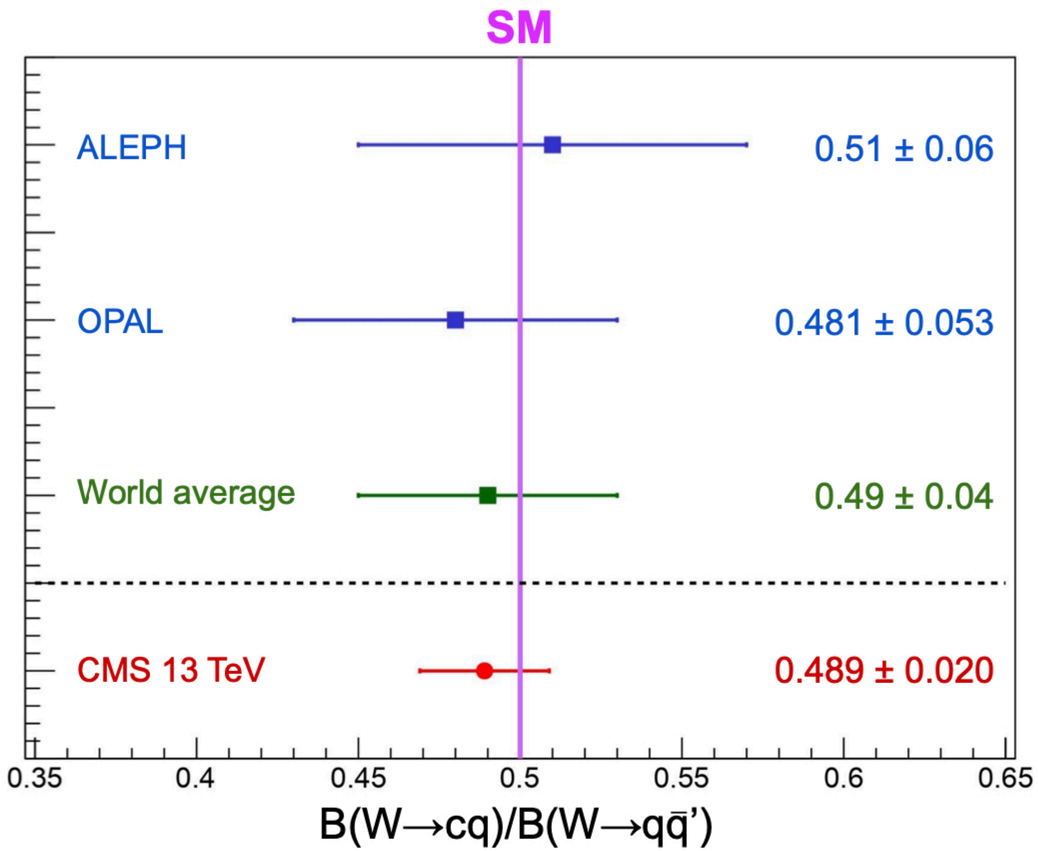
LHCb a key player

3.8σ-deviation from the SM!

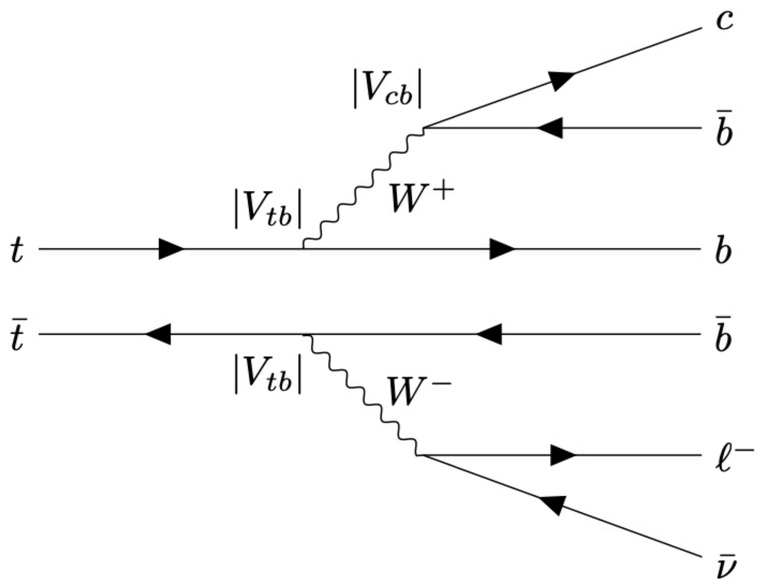
$t\bar{t}$ as a tool for precision EW and flavour measurements:

unbiased, inclusive W-decay samples from $t\bar{t} \to W^+bW^-\bar{b}$

CMS: Measurement of the W boson decay branching fraction ratio B(W → cq)/B(W → qq′), arxiv:2412.16296



Measurement of the $|Vcb|$ element of the CKM matrix



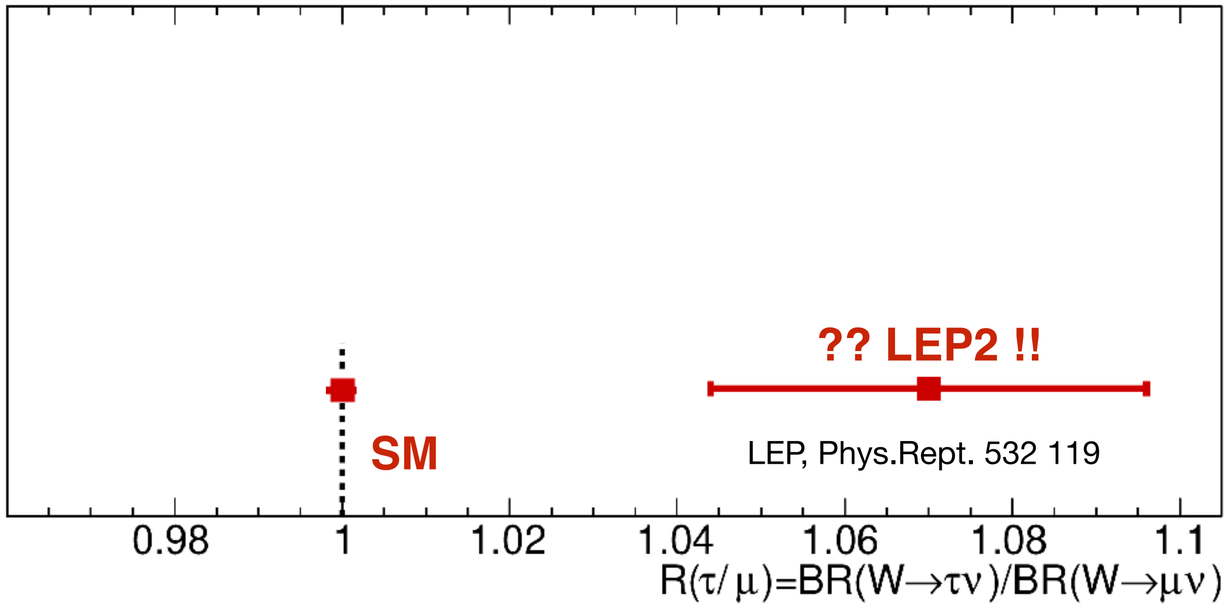
ATLAS: arxiv:2603.16414

$$|V_{cb}| = \left(50^{+11}_{-14}\right) \times 10^{-3}$$

CMS: CMS-PAS-TOP-2026-001

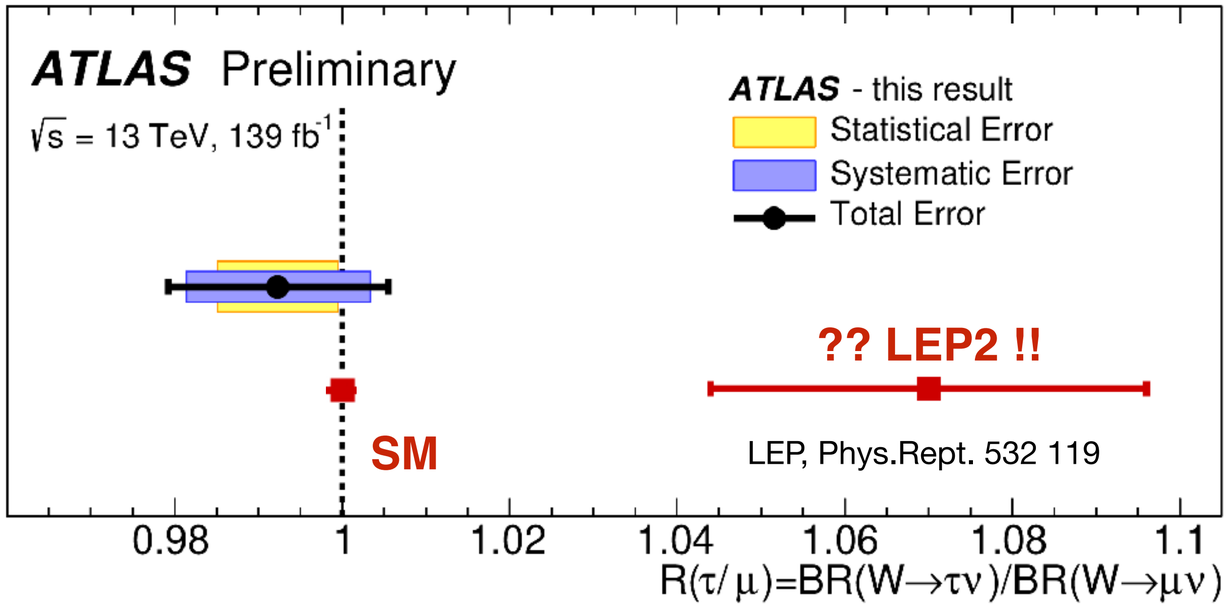
$$|V_{\mathrm{cb}}| = 4.59^{+0.44}_{-0.48}\,(\mathrm{stat})^{+0.64}_{-0.76}\,(\mathrm{syst}) \times 10^{-2}$$

Precision EW measurements, using W's from top decays: lepton universality of W couplings



Precision EW measurements, using W's from top decays: lepton universality of W couplings

ATLAS 2020: arXiv:2007.14040

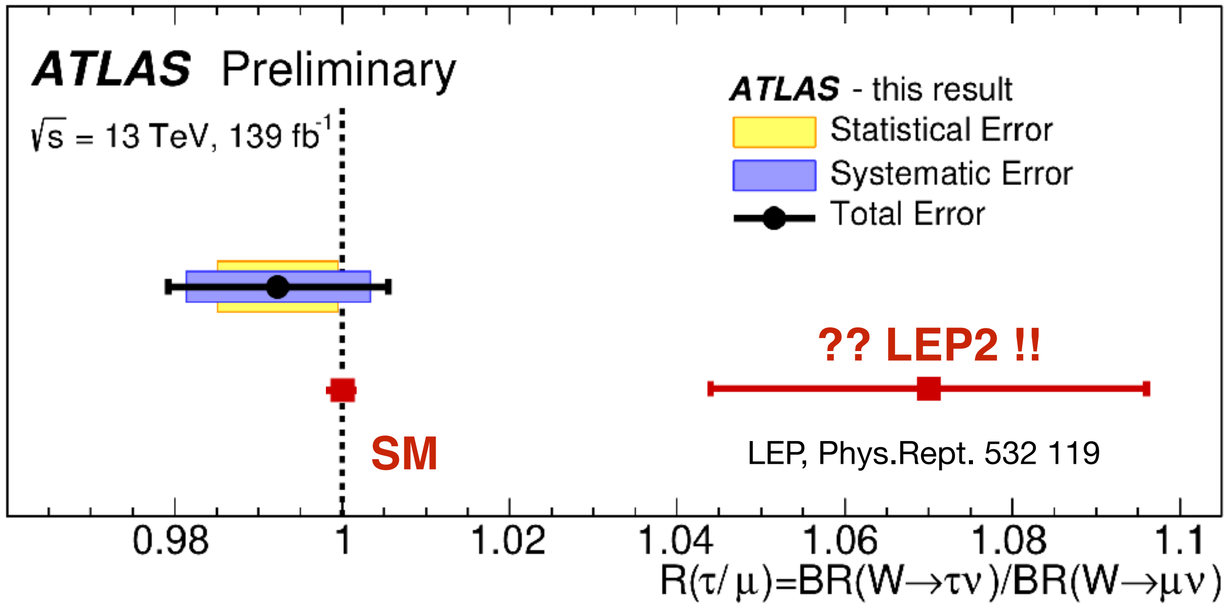


LEP:
***BR*(W→τν)/*BR*(W→μν) = 1.066 ± 0.025**

ATLAS:
***BR*(W→τν)/*BR*(W→μν) = 0.992 ± 0.013**

Precision EW measurements, using W's from top decays: lepton universality of W couplings

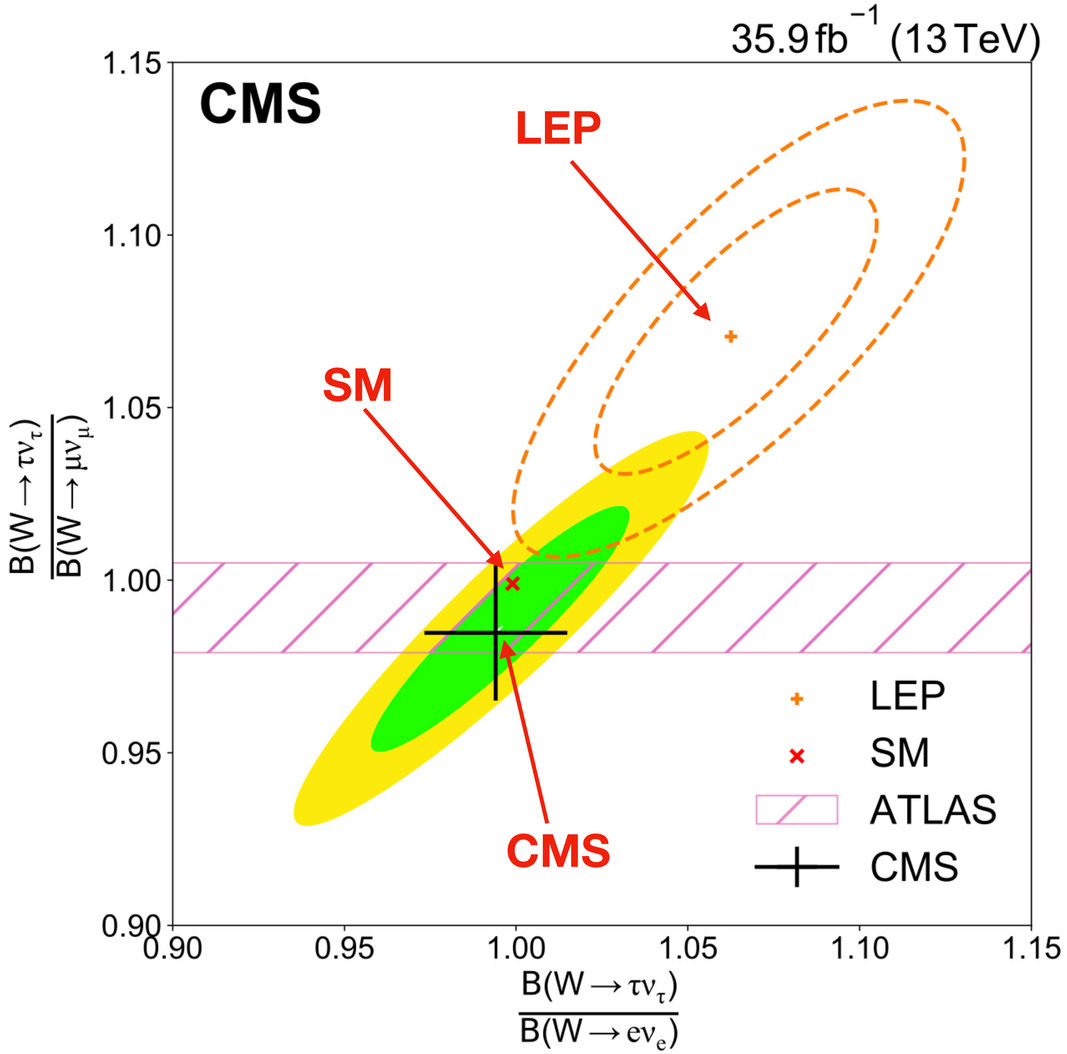
ATLAS 2020: arXiv:2007.14040



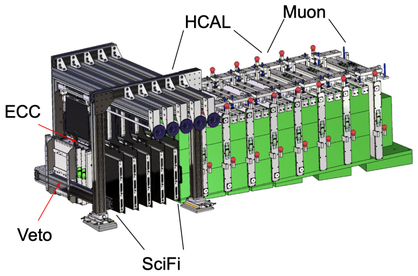
LEP:
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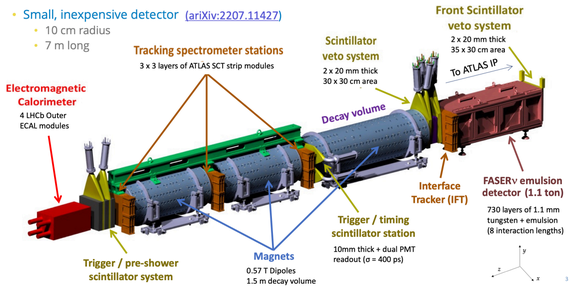
ATLAS:
***BR*(W→τν)/*BR*(W→μν) = 0.992 ± 0.013**

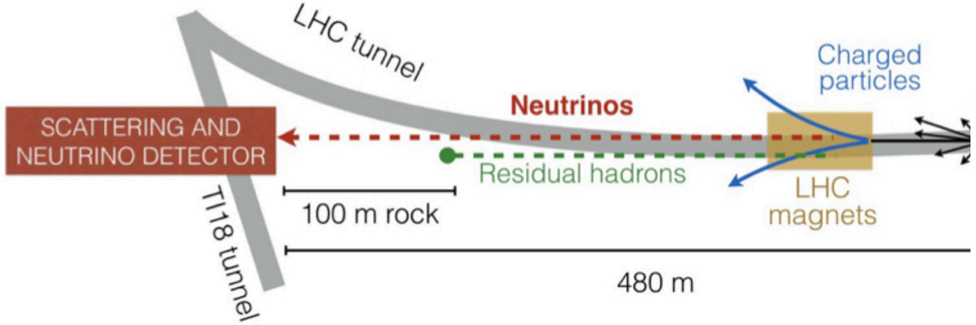
CMS 2022: arXiv:2201.07861

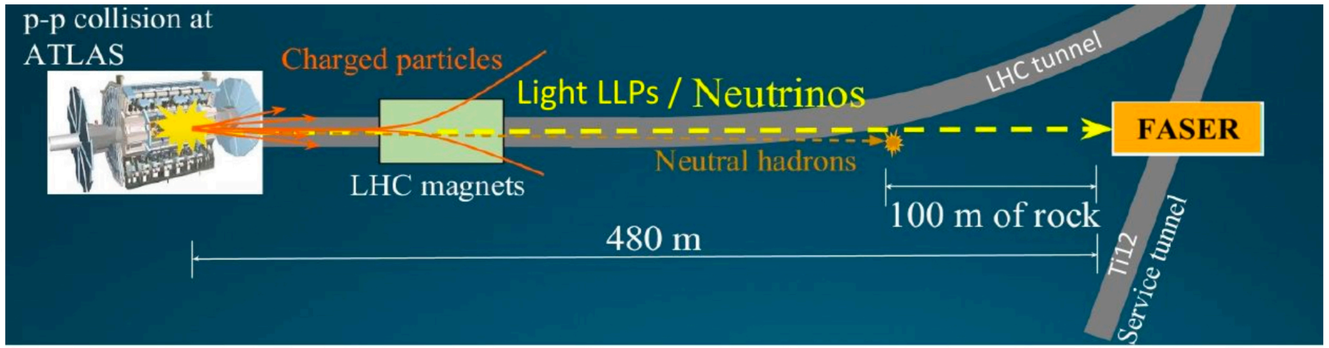


Neutrinos and LLPs: FASER & SND@LHC

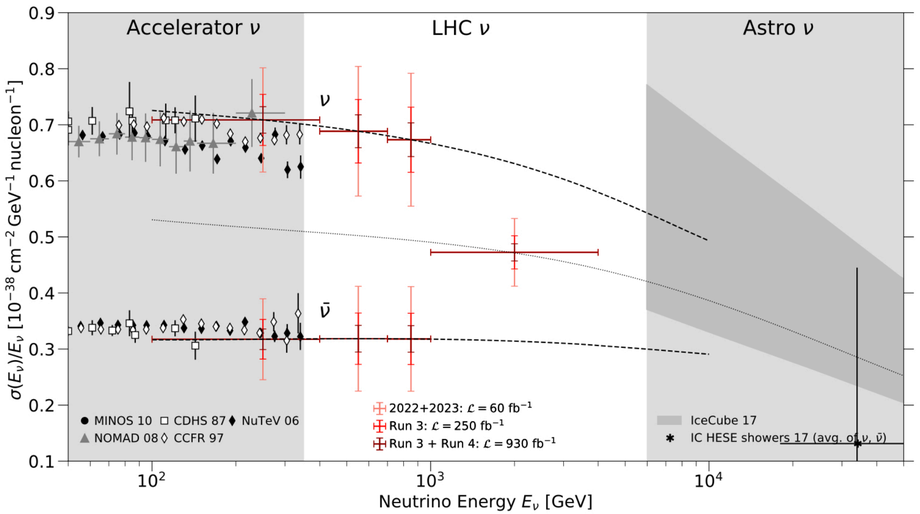




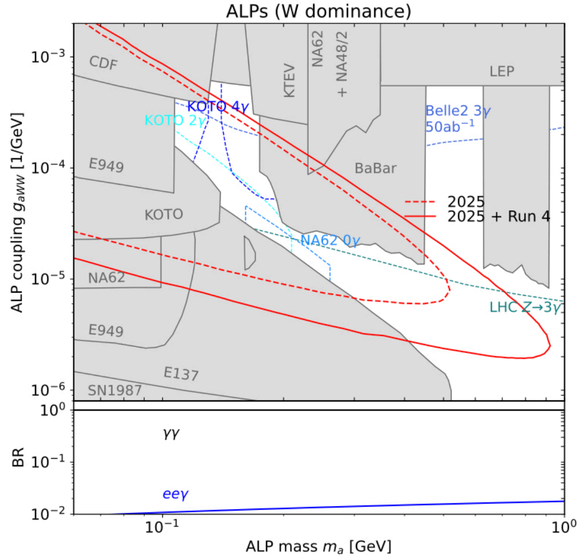




Measure ν cross sections in previously unchartered energy ranges



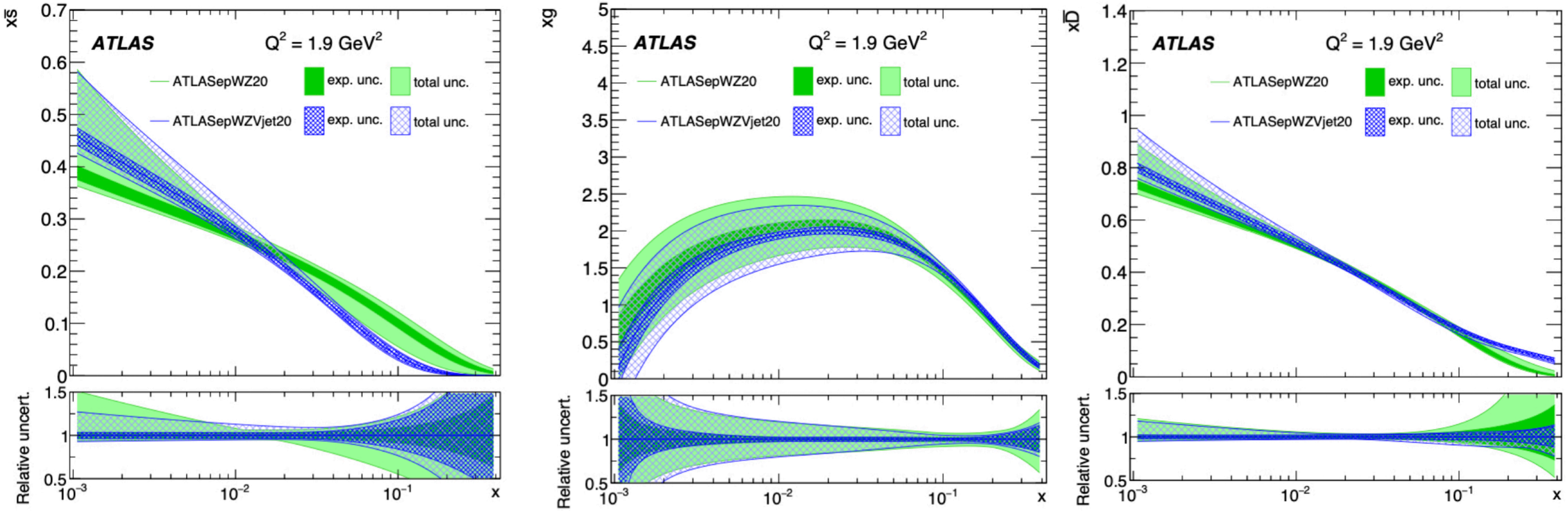
Explore BSM in unconstrained regions



Strong interactions

Z/W + jets data to improve PDF determinations

ATLAS, JHEP 07 (2021) 223



ATLASepWZ20: PDF fits using HERA ep and LHC W/Z inclusive production data

ATLASepWZVjet20: as ATLASepWZ20, plus W/Z+jets data

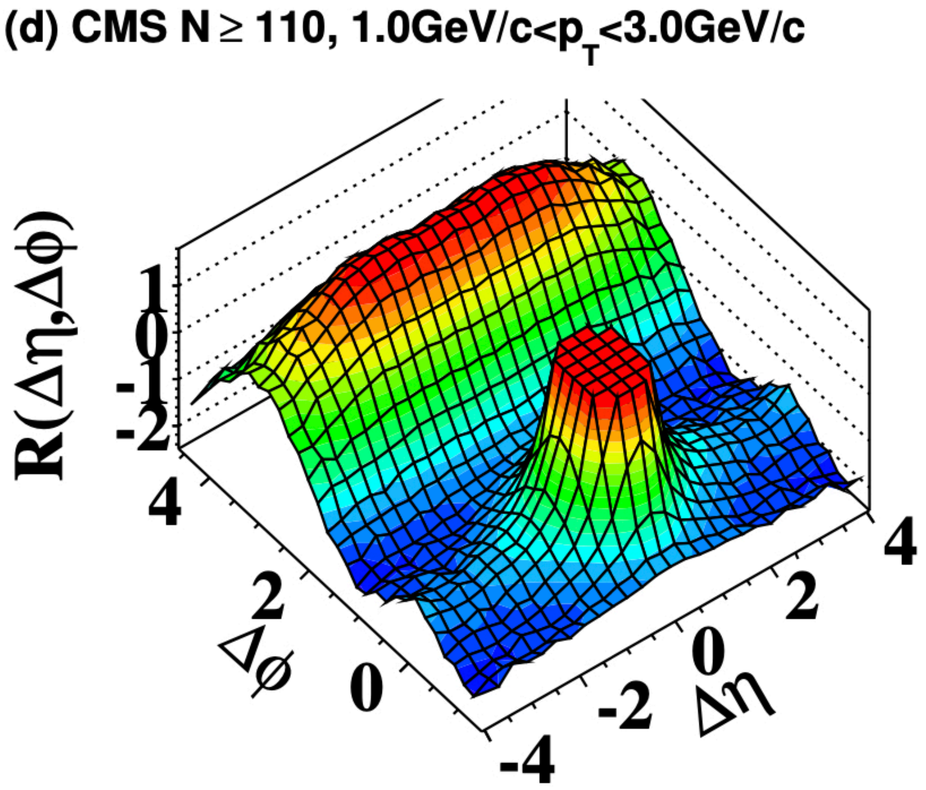
“***New physics***” is not just BSM particles or interactions. New physics must include SM phenomena, emerging from the data, which are unexpected, surprising, or simply poorly understood.

A discovery is everything that is not obviously predictable, or that requires deeper study to be clarified, even if it belongs to the realm of SM phenomena.

“New physics” is emerging every day at the LHC!

The ridge effect

CMS, *Observation of Long-Range, Near-Side Angular Correlations in Proton-Proton Collisions at the LHC*, https://arxiv.org/abs/1009.4122

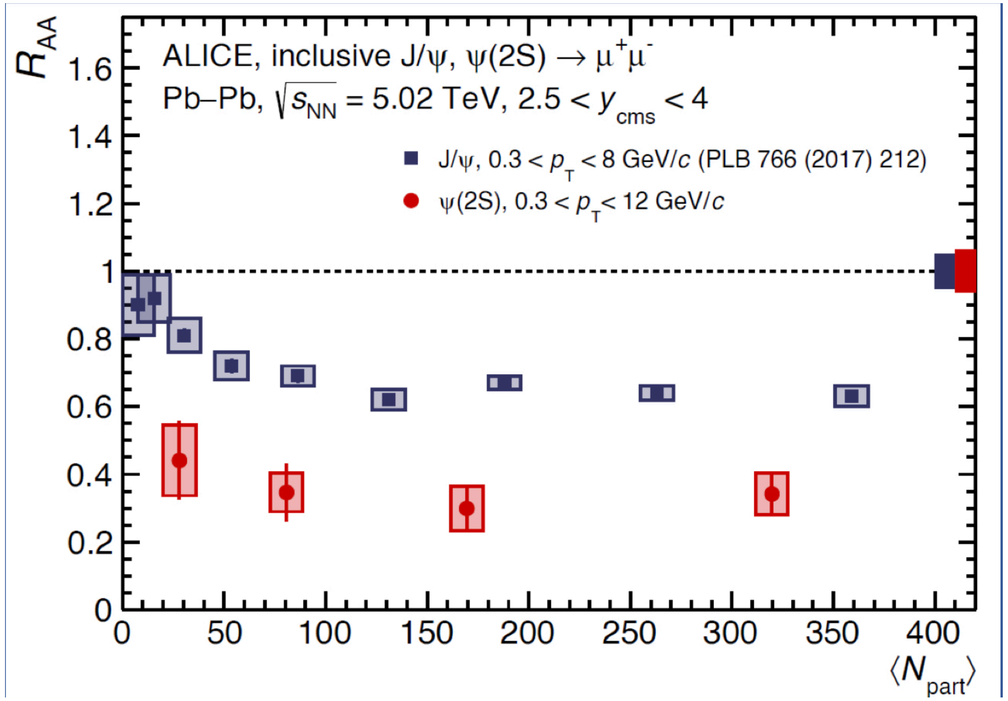


The first **discovery** at the LHC, the opening of a new exploratory domain for the LHC, namely **collective phenomena and long range correlations in small systems.**

This was the first glimpse of what remains today one of the biggest puzzles in the understanding (NB “understanding”, not just “modeling”) of strong-interaction dynamics

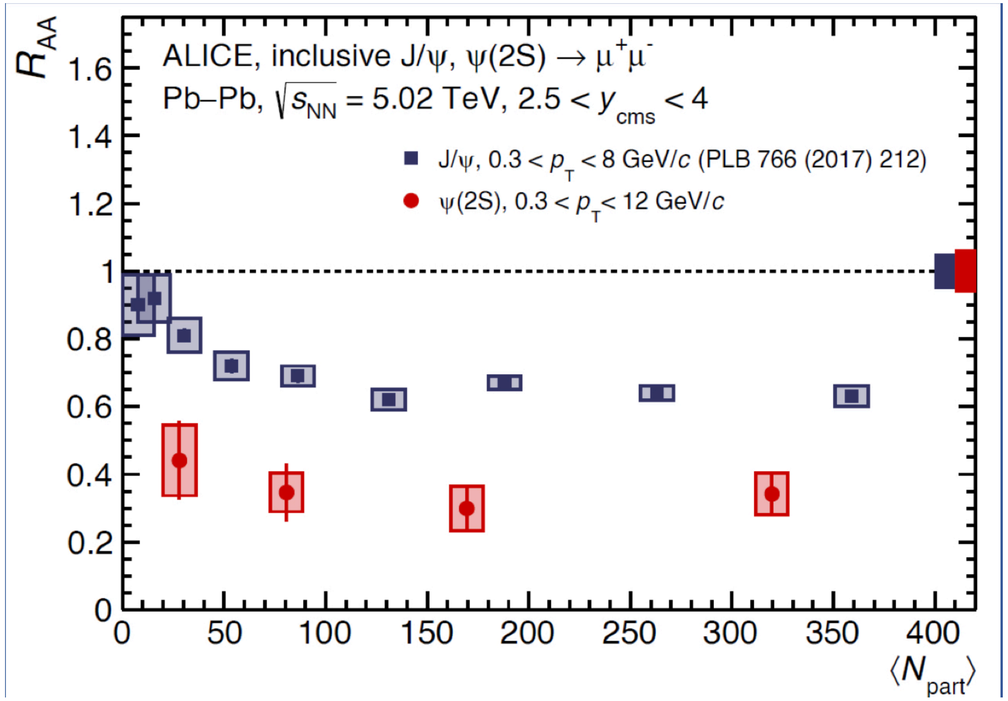
Collective QCD phenomena in high-T, high-density and other extreme environments

consolidation of known phenomena, with higher precision and broader coverage:
(ALICE, https://inspirehep.net/literature/2165947)

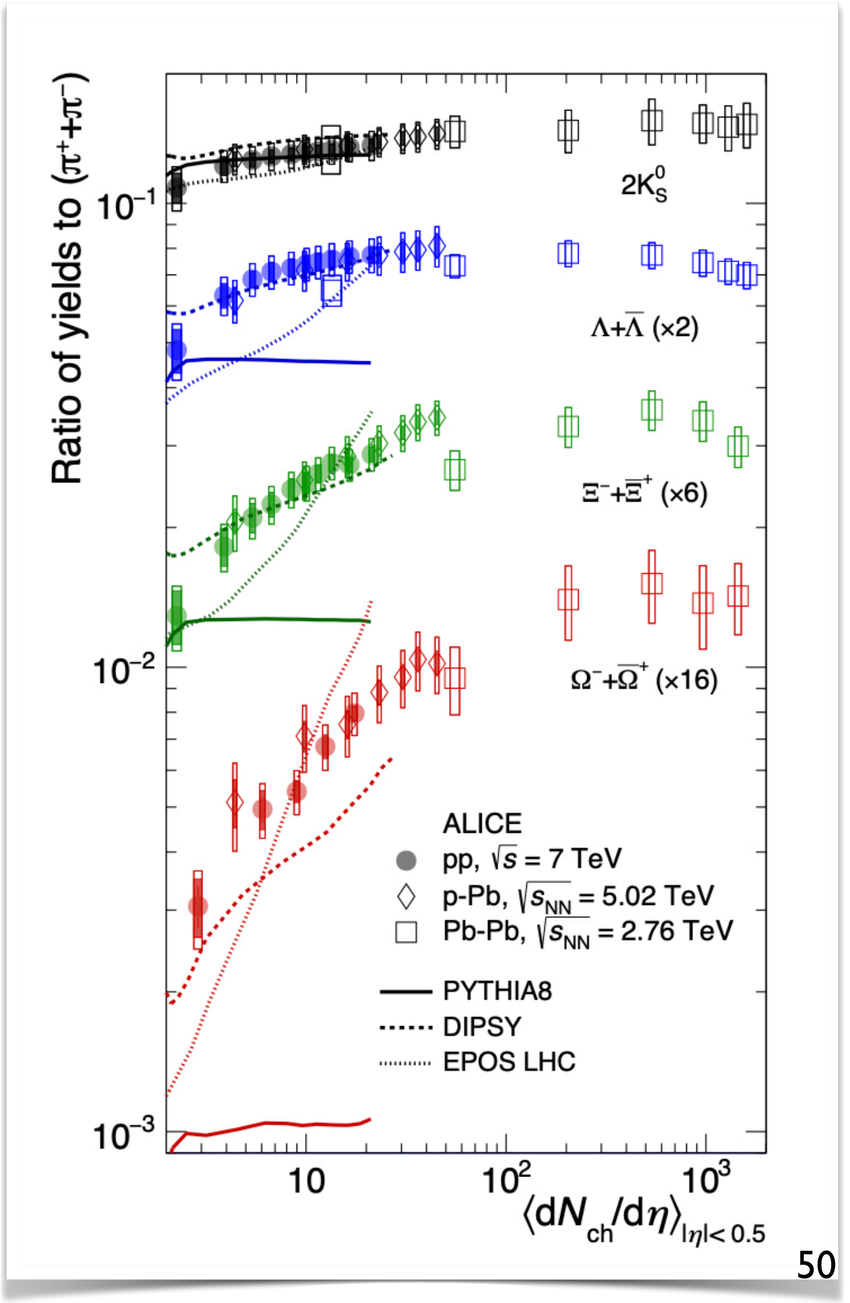


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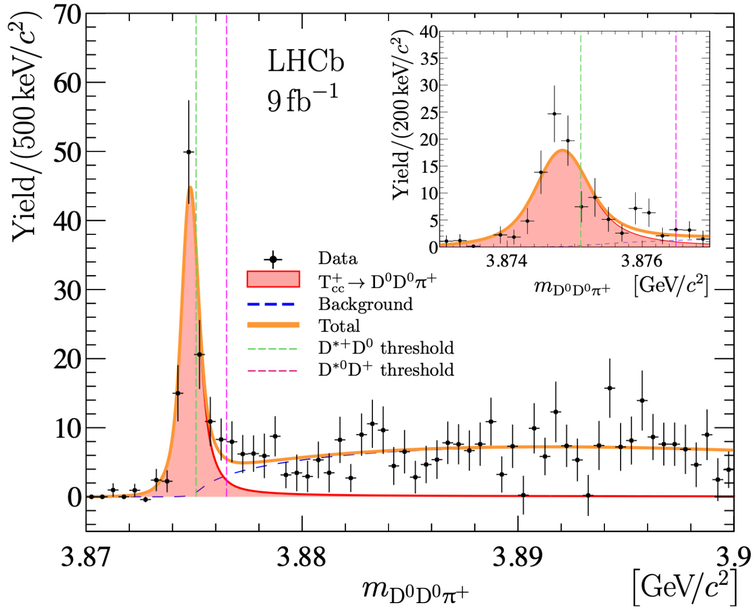


discovery of new dynamical behaviour, with collective phenomena typical of QGP appearing already in high-multiplicity final states of pp and pA

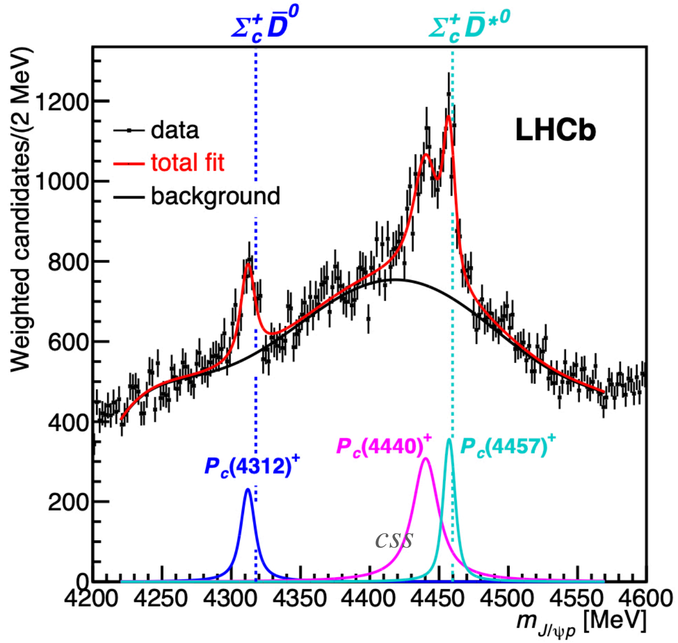


Tetraquarks, pentaquarks, double-heavy baryons, exotics, …

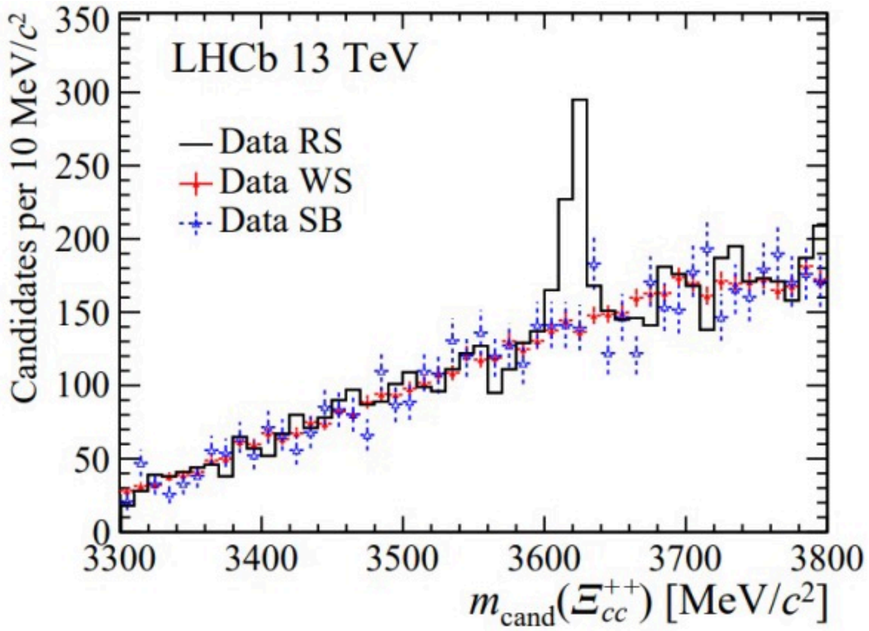
$ccū\bar{d}$



$duuc\bar{c}$



ccu



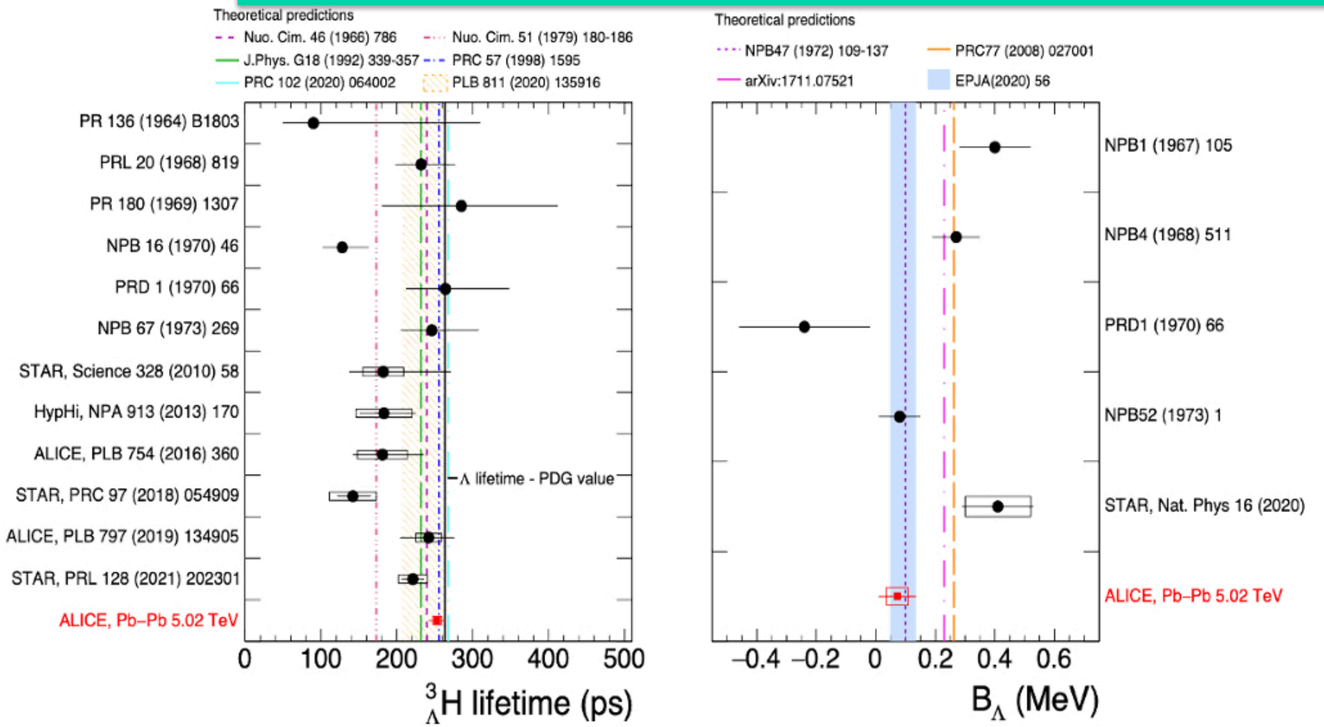
O(80) new hadronic states discovered … of which more than 20 exotic, most still waiting for a precise theoretical description

LIFETIME AND BINDING ENERGY OF HYPERTRITON

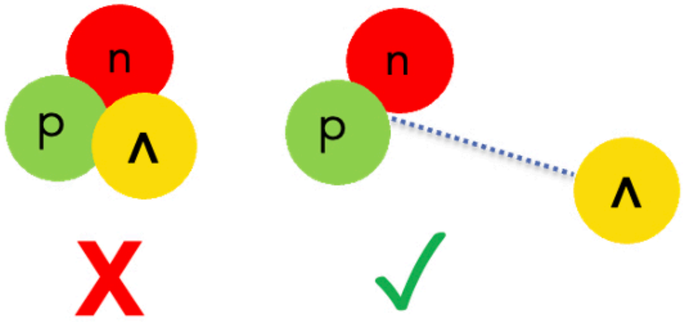
60 years after discovery, its properties were not yet well measured…

Unprecedented precision with Pb-Pb Run 2 data:

- Lifetime: is there a deviation from the free Λ lifetime? No!
- Binding energy B_Λ: is this really a loosely bound deuteron-Λ molecule? Yes!





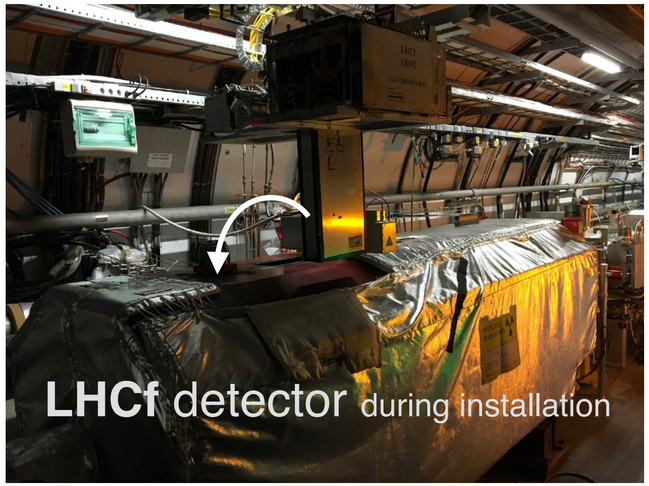


arXiv:2209.07360

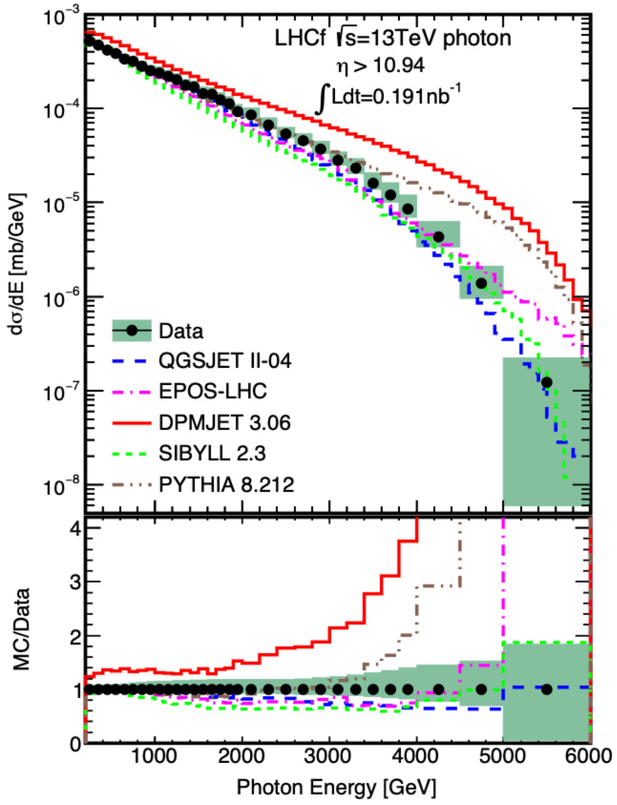
Impact on astroparticle physics

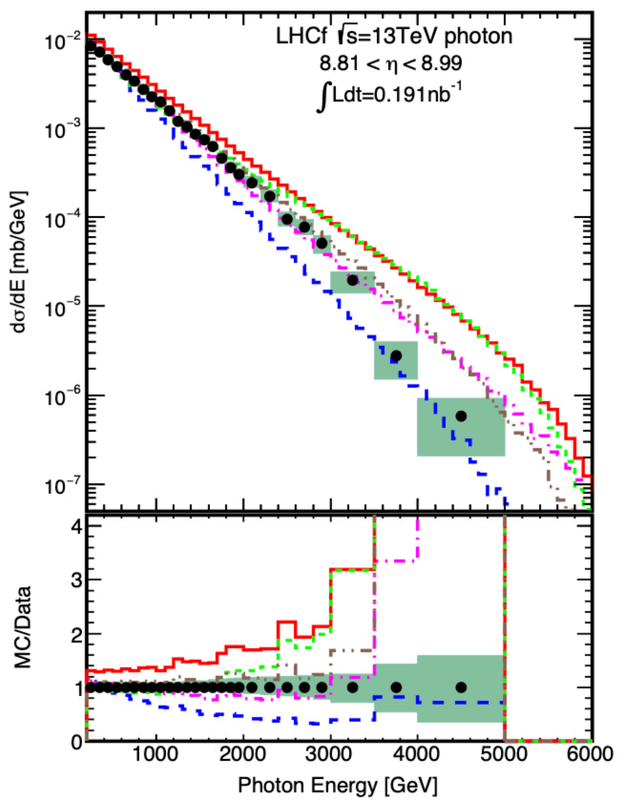
countless searches for dark matter candidates covering a huge domain of plausible model space

… plus:



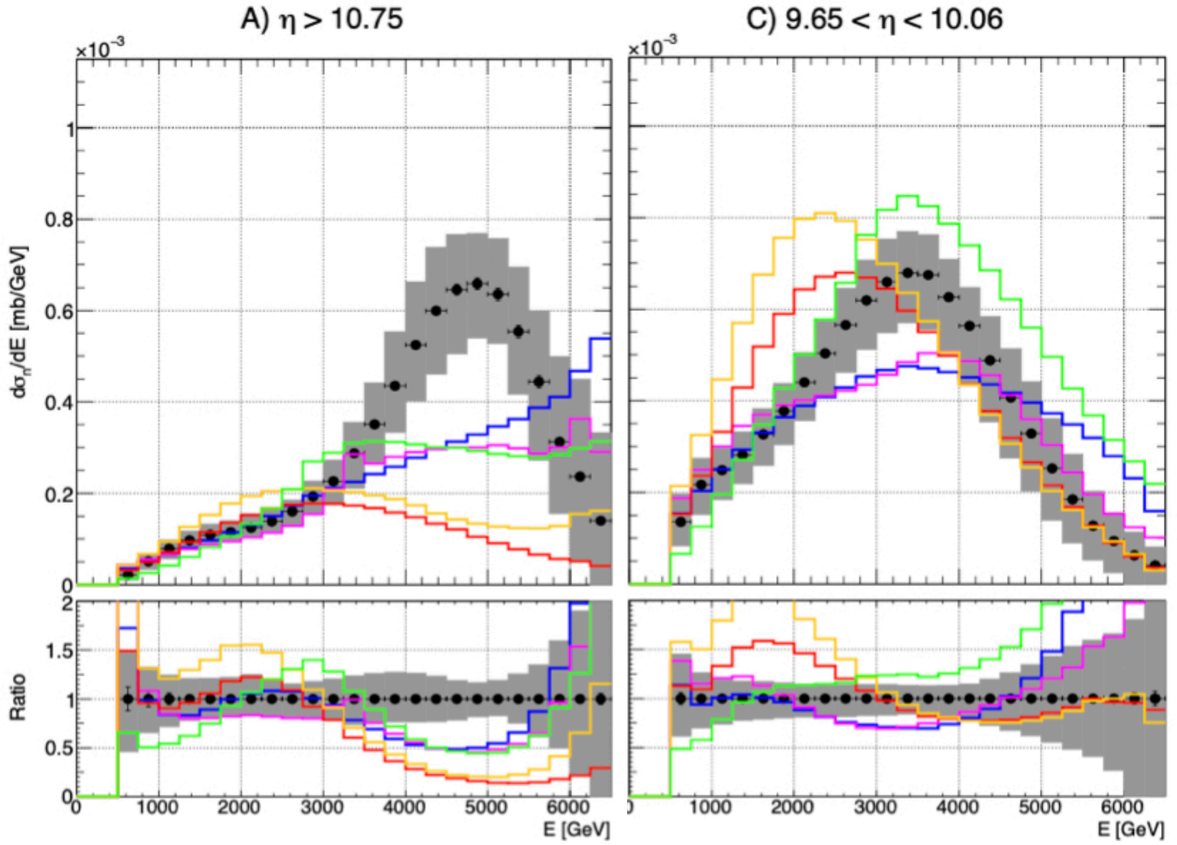
Probe spectrum of most energetic forward-produced particles => **model development of highest-energy cosmic ray showers in the atmosphere**





photons~π^0~π^{+-}

Phys.Lett.B 780 (2018) 233



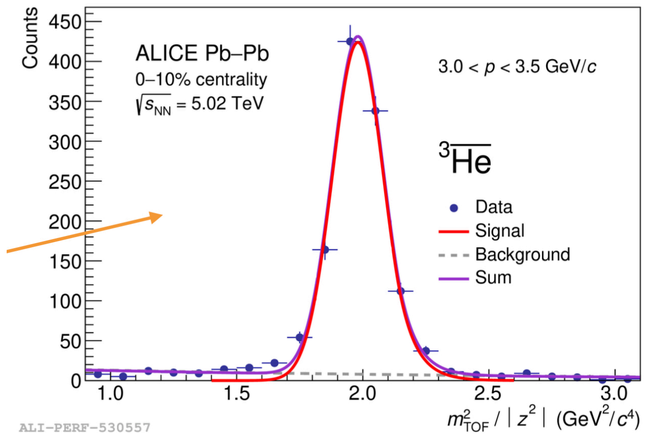
neutrons

JHEP 07 (2020) 016

Measurement of anti-^{3}He nuclei absorption in matter and impact on their propagation in the Galaxy

ALICE https://doi.org/10.1038/s41567-022-01804-8

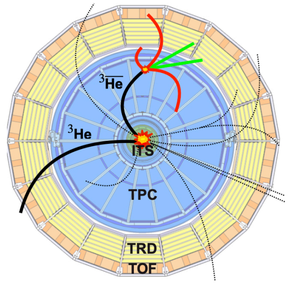
Laura Šerkšnytė CERN seminar



Method: ALICE as a target

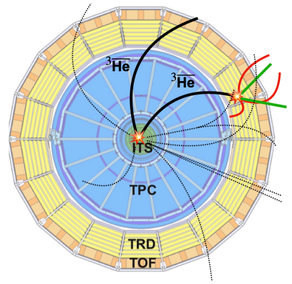
Antimatter-to-matter ratio

- Measure reconstructed $^3\overline{He}/^3He$ and compare with MC simulations



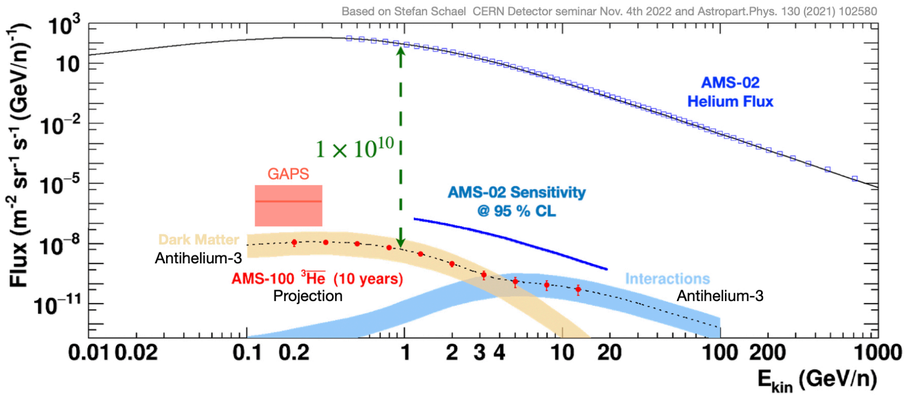
TOF-to-TPC-matching

- Measure reconstructed $^3\overline{He}_{TOF}/^3\overline{He}_{TPC}$ and compare with MC simulations



Measuring antinuclei fluxes

- AMS-02: Magnetic spectrometer on ISS; 9 antihelium candidates; not published yet
- GAPS: Antarctic balloon mission; low energy antinuclei; planned at the end of 2023
- AMS-100: Next generation magnetic spectrometer; x1000 sensitivity; estimated launch 2039



- Those 4000 papers reflects the immense potential of LHC to probe the fundamental dynamics of the SM. A diversity that historically would have required different detectors and facilities, built and operated by different communities

- On each of these topics the LHC expts are advancing the knowledge previously acquired by dedicated facilities

  - HERA→PDFs, B-factories→flavour, RHIC→HIs, LEP/SLC→EWPT, etc

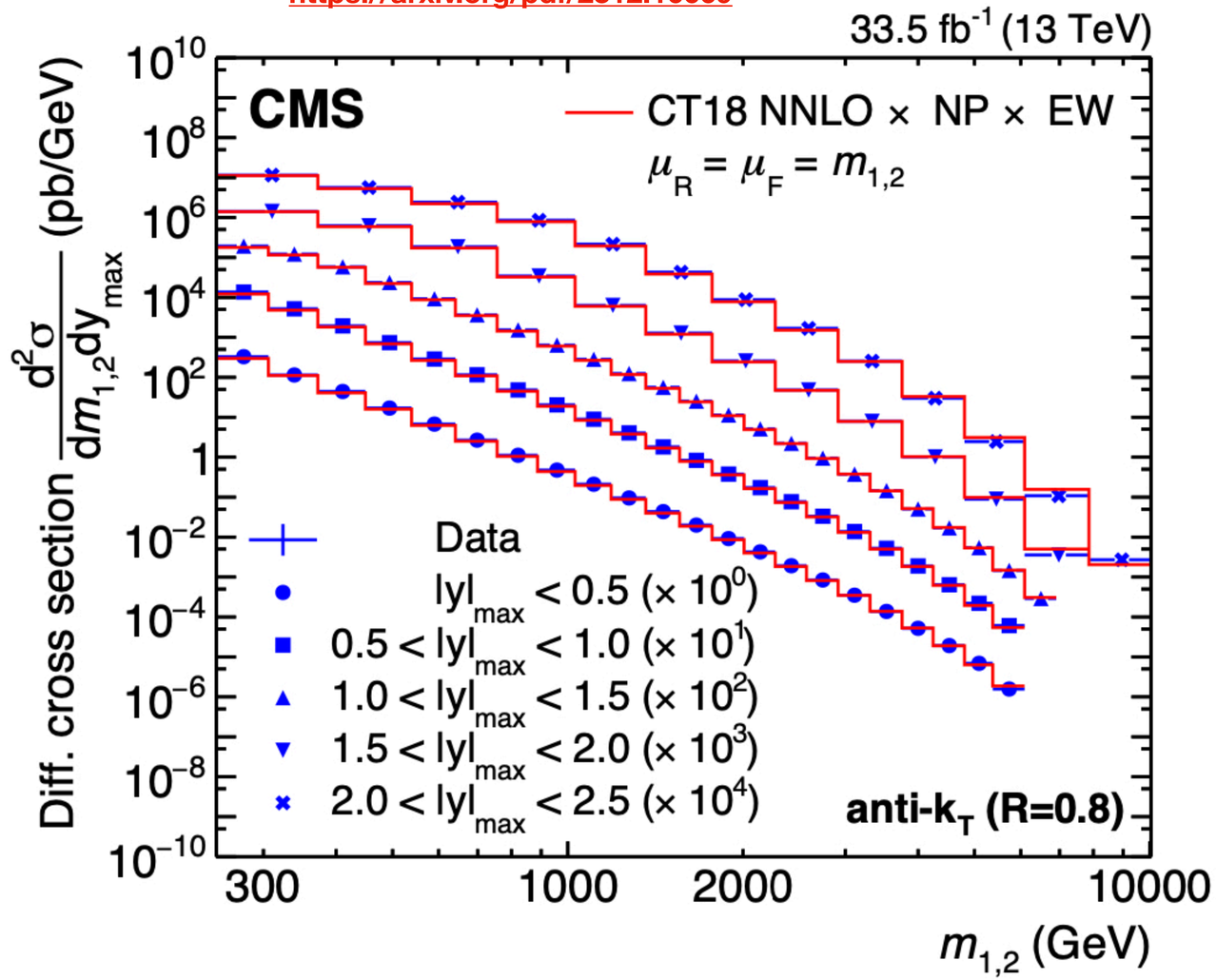
- Even in the perspective of new dedicated facilities, eg SuperKEKB or EIC, LHC maintains a key role of competition and complementarity

Last but not least:
the 10 TeV partonic CoM holy grail

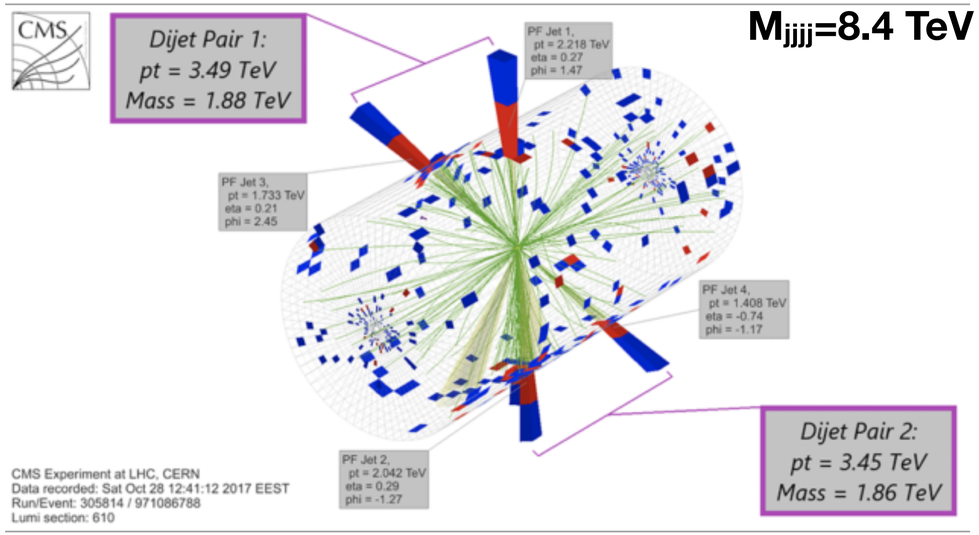
> ***"All options for a 10 TeV pCM collider are new technologies under development and R&D is required before we can embark on building a new collider"***
>
> *P5 Report (2023), p. 17*

The 10 TeV pCM holy Grail: how far are we from it, really? Not much actually, already at the LHC

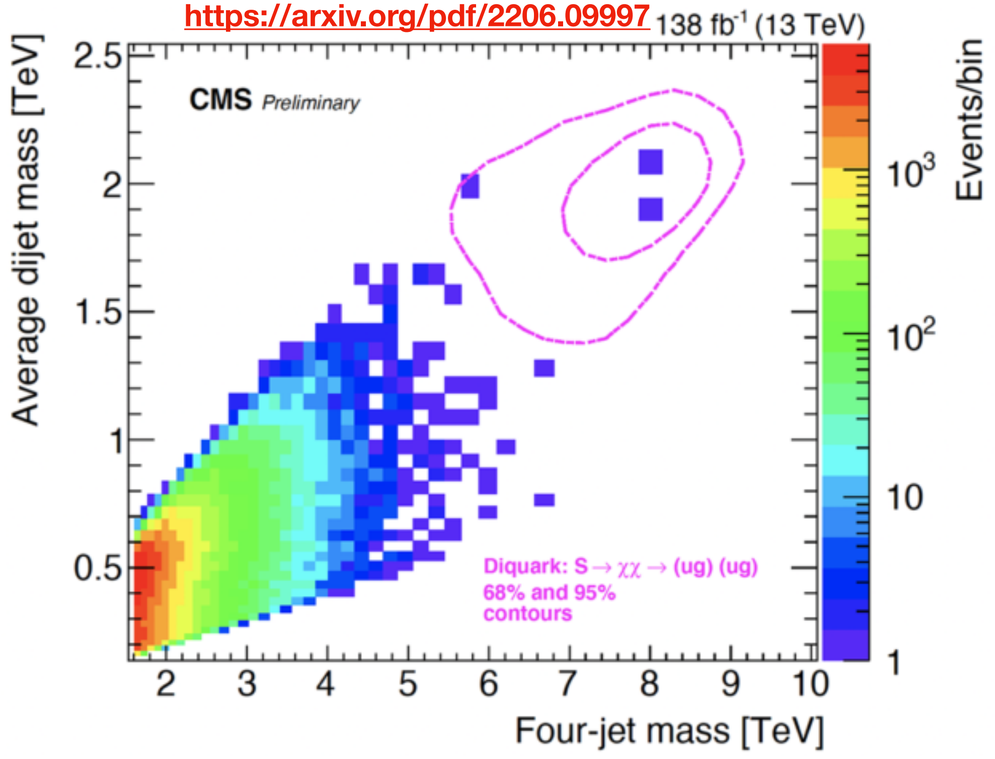
https://arxiv.org/pdf/2312.16669



https://arxiv.org/abs/1911.03947

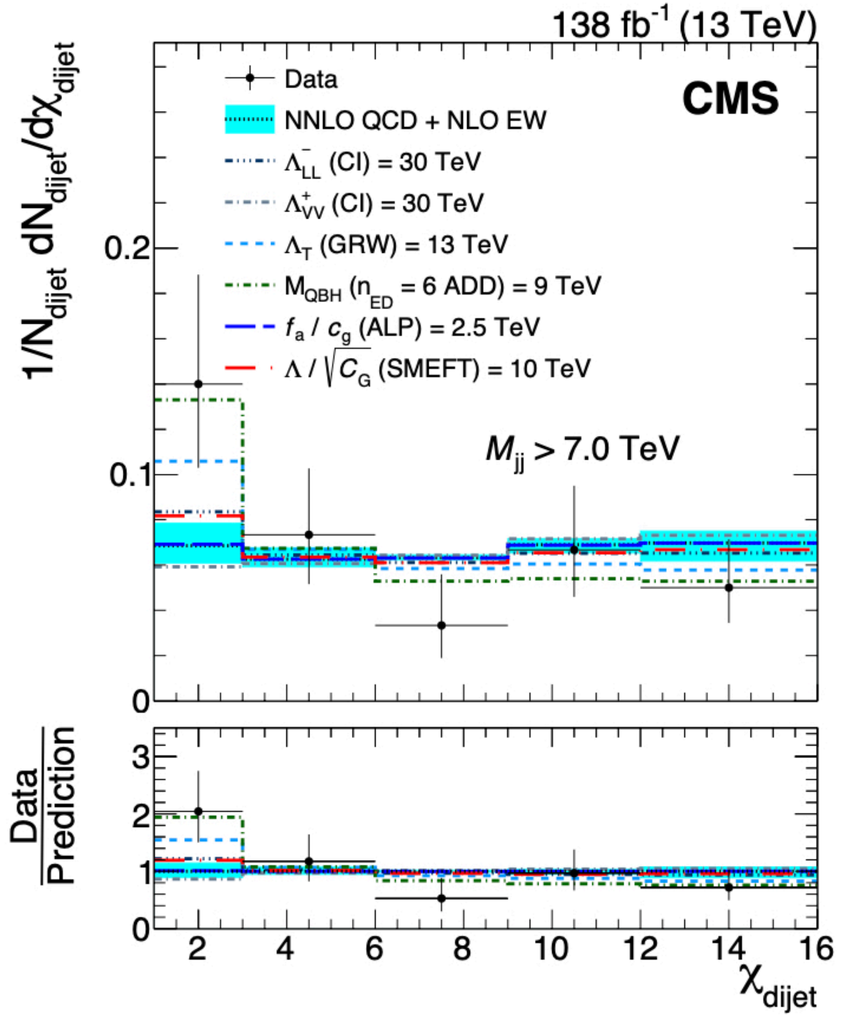


https://arxiv.org/pdf/2206.09997

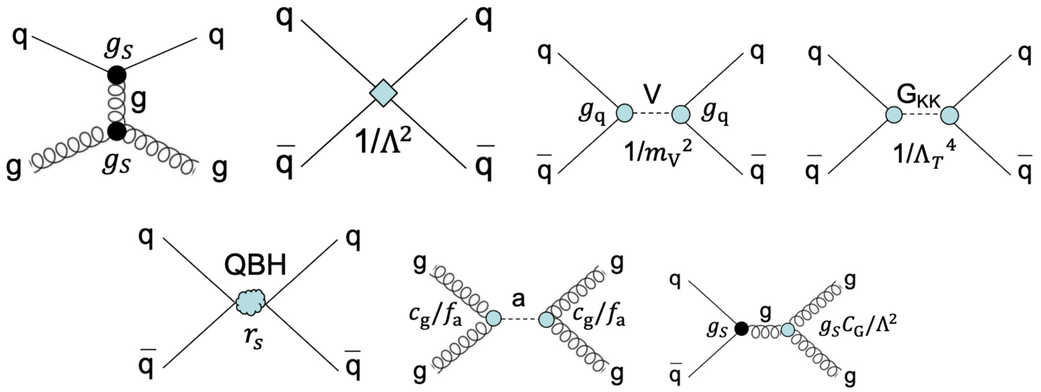


CMS, Measurement of dijet angular distributions and search for BSM,

https://arxiv.org/abs/2603.25458



50 events with M_{jj} > 7.0 TeV !!



Model	Observed limit	Expected limit
CI $\Lambda^{+}_{\mathrm{LL/RR}}$ (NLO)	17 TeV	18^{+20}_{-2} TeV
CI $\Lambda^{-}_{\mathrm{LL/RR}}$ (NLO)	37 TeV	34^{+8}_{-5} TeV
CI $\Lambda^{+}_{\mathrm{VV}}$ (NLO)	<19 and 27–31 TeV	41^{+17}_{-22} TeV
CI $\Lambda^{-}_{\mathrm{VV}}$ (NLO)	50 TeV	45^{+11}_{-7} TeV
CI $\Lambda^{+}_{\mathrm{AA}}$ (NLO)	19 TeV	39^{+16}_{-21} TeV
CI $\Lambda^{-}_{\mathrm{AA}}$ (NLO)	49 TeV	44^{+11}_{-7} TeV
CI $\Lambda^{+}_{\mathrm{(V-A)}}$ (NLO)	14.9 TeV	$14.0^{+1.8}_{-1.4}$ TeV
CI $\Lambda^{-}_{\mathrm{(V-A)}}$ (NLO)	15.7 TeV	$14.6^{+2.2}_{-1.6}$ TeV
ADD Λ_{T} (GRW)	13.4 TeV	14.2 ± 1.0 TeV
ADD M_{S} (HLZ) $n_{\mathrm{ED}} = 2$	15.0 TeV	16.0 ± 1.1 TeV
ADD M_{S} (HLZ) $n_{\mathrm{ED}} = 3$	15.9 TeV	16.9 ± 1.2 TeV
ADD M_{S} (HLZ) $n_{\mathrm{ED}} = 4$	13.4 TeV	14.2 ± 1.0 TeV
ADD M_{S} (HLZ) $n_{\mathrm{ED}} = 5$	12.1 TeV	12.8 ± 0.9 TeV
ADD M_{S} (HLZ) $n_{\mathrm{ED}} = 6$	11.3 TeV	11.9 ± 0.8 TeV
QBH M_{QBH} (ADD, $n_{\mathrm{ED}} = 6$)	8.5 TeV	9.1 ± 0.3 TeV
QBH M_{QBH} (RS1)	6.3 TeV	6.8 ± 0.4 TeV
DM mediator m_{med}	6.2 TeV	6.2 ± 0.8 TeV

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- Precision planetary measurements continued throughout the XIX century, revealing yet another SM deviation, in Mercury's motion. This time, it was indeed a beyond SM (BSM) signal: Einstein's theory of General Relativity!! Mercury's data did not motivate Einstein to formulate it, but once he had the equations, he used those precise data to confirm its validity!

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- … and who knows how important a given measurement can become, to assess the validity of a future theory?

    - the day some BSM signal is found somewhere, the available precision measurements, will be crucial to establish the nature of the signal, whether they agree or deviate from the SM

Conclusions

- **The diversity of the LHC programme is a key driver of progress in particle physics**
- **The initial big pillars of the program (Higgs and BSM searches) are now enhanced and strengthened by a multitude of fundamental scientific challenges stimulated by the data**
- **The LHC continues to have a radical impact on**
  - *Our thinking about the Standard Model and its extensions*
  - *The conceptual framework within which to perform and interpret searches for new physics*
  - *The perception of the relation/synergy/complementarity of “measurements” vs “searches”*
- **All of these elements will be strenghtened and extended with the next phase of its operations, at the HL-LHC**

The LHC opened new unexpected avenues and opportunities,
leaving us much richer than we could have ever hoped !

Long Term Schedule for CERN Accelerator complex

