BSM collider phenomenology

PhysTeV 2023

Conveners:
Manuel Szewc*, Tamara Vazquez Schroeder, Jure Zupan
szewcml@ucmail.uc.edu, zupanje@ucmail.uc.edu,
tamara.vazquez.schroeder@cern.ch

* acting convener in place of JZ till Saturday

Organization

Currently, all participants that expressed interest have received an email from Tamara and access to a Google Drive shared folder. Already a lot of interesting input collected in the “Topics of interest” gDoc!

We will develop each of the projects/ideas inside the Google Drive (separate gDocs per project), and in parallel make a summary of the projects in the Les Houches wiki.

We’ll switch to the wiki, but it was an easy way to start. We’ll define a few projects and interest today and put them in the wiki

List of people: if you don’t see yourself but want to gain access please let us know!

Balazs, Buttazzo, Cacciapaglia, Crivellin, Dermisek, Desai, El Faham, Flacke, Gascon-Shotkin, Greljo, Grosso, Hong, Isidori, Jourd'huy, Kraml, Kvellestad, Lee, Lim, Da. Liu, Di Liu, Z. Liu, Mantani, Mariotti, Morales Alvarado, Moreau, Pagès, Pandini, Procter, Ricci, Riembau, Rigo, Sekmen, Sengupta, Son, Spira, Srivastava, Szewc, ter Hoeve, Torre, Ubiali, Vazquez Schroeder, Waltenberger, Xiao, Zupan, Zurita

experimentalists

Anomalies / Excesses

- Update on existing results
- Consistent explanations
- Underlying question: a better way to assess the relevance of an anomaly?

For more insight on latest results, check out the EXP/TH summary talks at Moriond EW [EXP, TH], Moriond QCD [EXP, TH], and LHCP [EXP, TH] 2023!

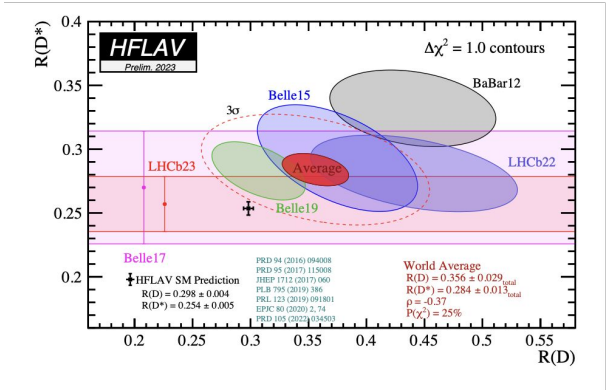
Flavour anomalies

- Flavour physics provides great potential to explore physics beyond the SM
- Hints for lepton flavour universality violation observed in **charged** and **neutral** current processes in B-physics

τ vs e/μ

$$R(D^{(*)}) \equiv \frac{\mathcal{B}(B^0 \to D^{(*)+}\tau\nu)}{\mathcal{B}(B^0 \to D^{(*)+}\ell\nu)}, \quad \ell = \mu, e$$

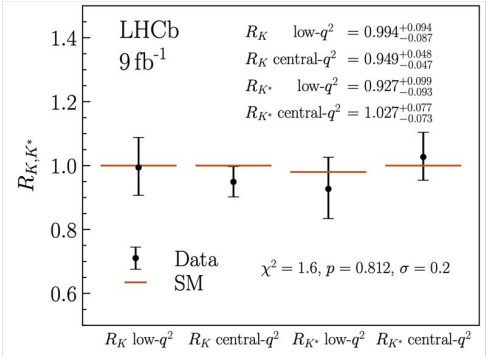
3.2σ excess in R_D and R_{D^*} combination



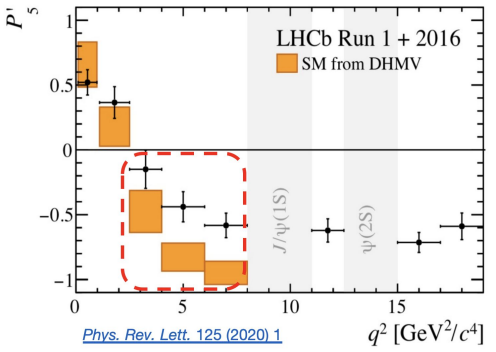
e vs μ

$$R(K^{(*)}) = \frac{\mathcal{B}(B \to K^{(*)}\mu^+\mu^-)}{\mathcal{B}(B \to K^{(*)}e^+e^-)}$$

No longer evidence of μ/e universality violation in updated full Run 1 + Run 2 result and revisited misidentified background estimation in electron mode [LHCb:2212.09153]



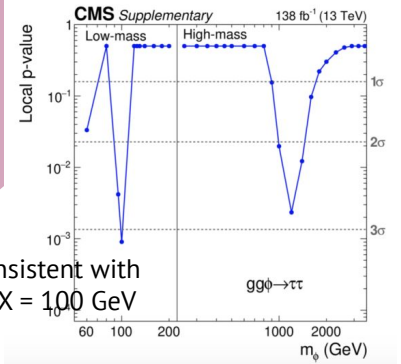
still tensions in angular observables and BRs of b→sμ+μ-



Tensions / Excesses to be understood

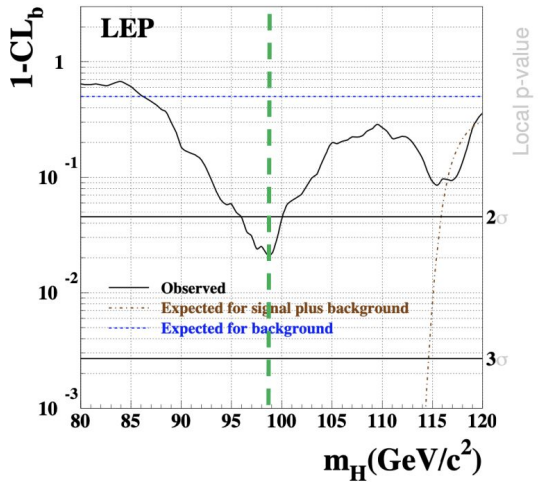
- Low γγ excess at 95 GeV (CMS) - much less significant in ATLAS

diphoton

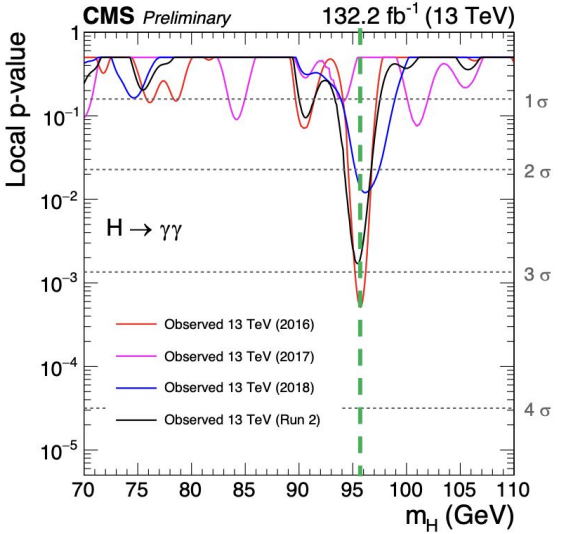


CMS excess consistent with ggF X->**ττ** at mX = 100 GeV

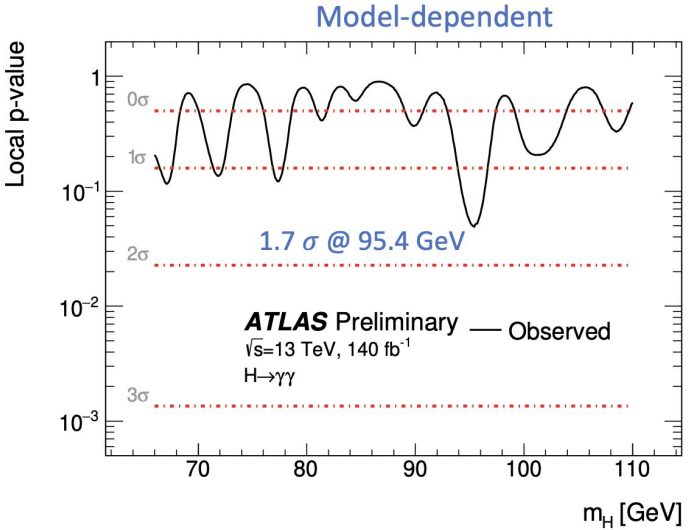
Phys.Lett.B565:61-75,2003



CMS-PAS-HIG-20-002



local (global) significance of **2.9 (1.3) σ** @ 95.4 GeV



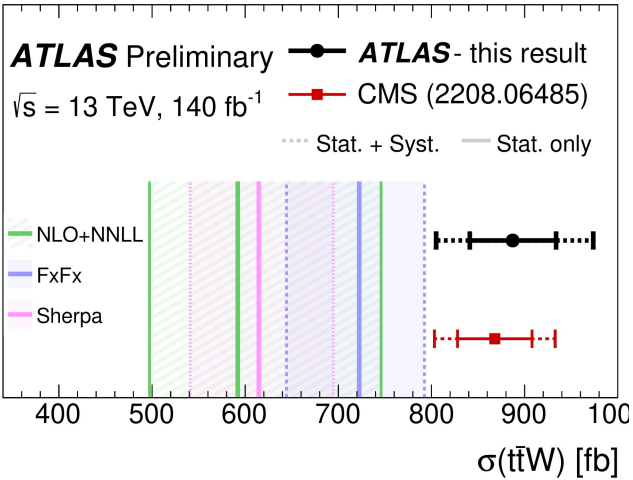
ATLAS-CONF-2023-035

Tensions / Excesses to be understood

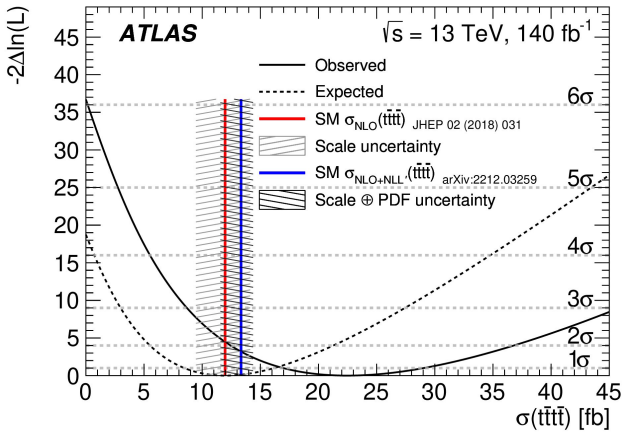
multilepton & multibjets & asymmetric

- 4tops, tt̄W (-like?)

ATLAS-CONF-2023-019/

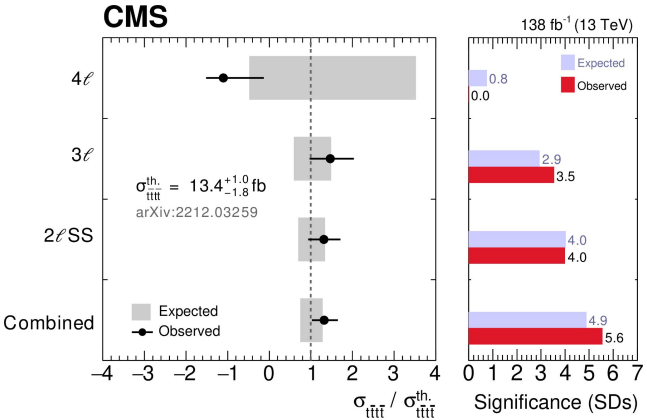


arXiv:2303.15061



Observed tt̄tt̄ cross section in ATLAS = 22.5 +6.6 -5.5 fb consistent with the SM prediction of 12.0 ± 2.4 fb within 1.8σ

arXiv:2305.13439

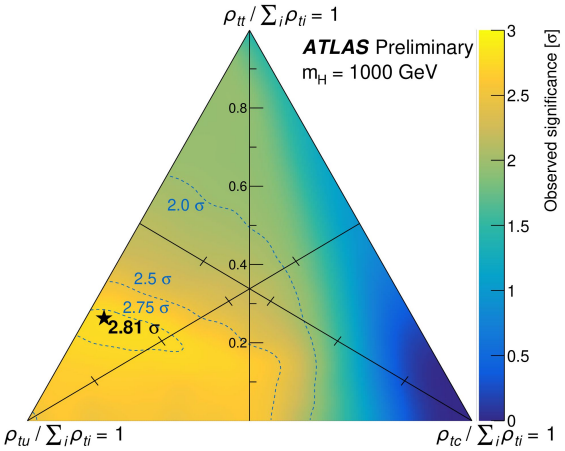


Observed tt̄tt̄ cross section in CMS = $17.7\ ^{+3.7}_{-3.5}$ (stat) $^{+2.3}_{-1.9}$ (syst) fb consistent with the SM prediction of $13.4\ ^{+1.0}_{-1.8}$ fb

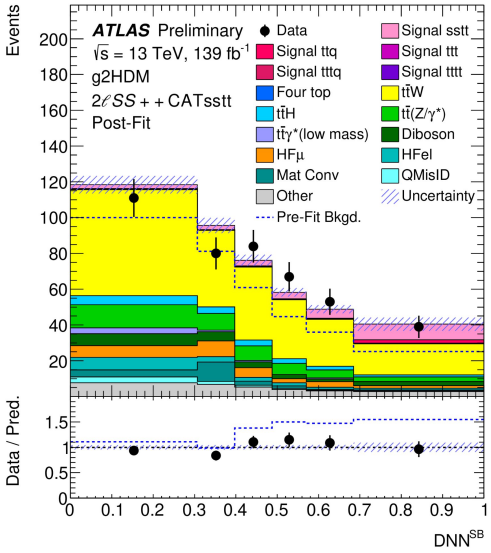
Tensions / Excesses to be understood

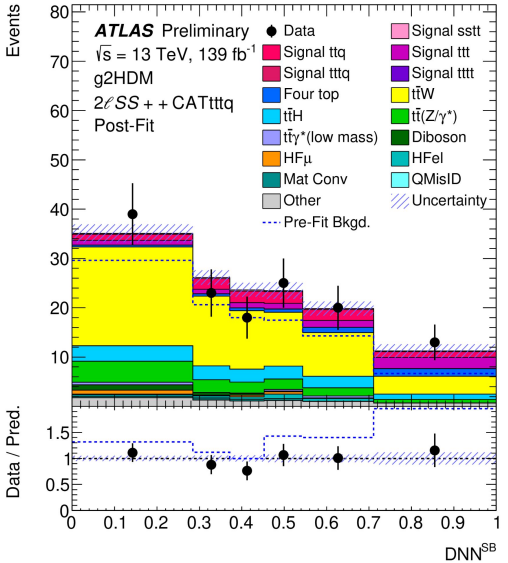
multilepton & multibjets & asymmetric

- g2HDM with flavour violating couplings (multilepton, multibjets)



ATLAS-CONF-2022-039

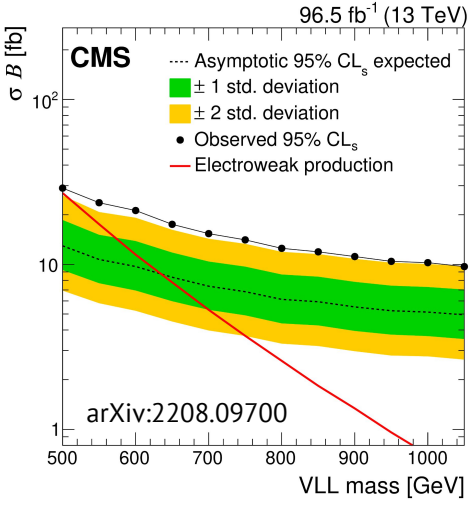




Mild excess observed over the SM with a local significance of **2.81σ** for a signal with **m_H = 1000 GeV** and **(ρ_{tt}=0.32, ρ_{tc}=0.05, and ρ_{tu}=0.85)**

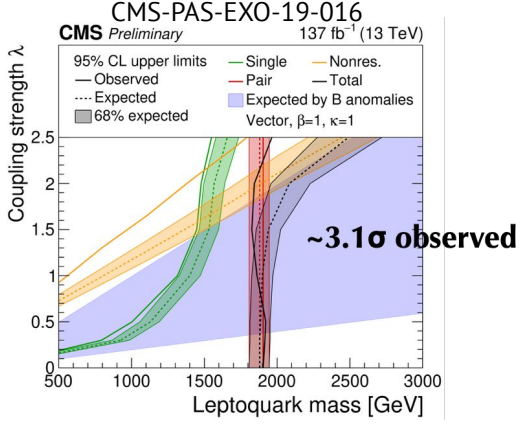
Tensions / Excesses to be understood

- VLL 4321 excess (CMS)
  - Largest tension with the SM at **τ**' mass = 600 GeV with **2.8 σ**

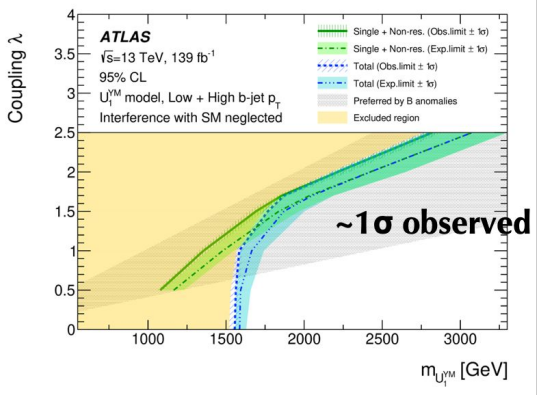


- LQ>b**τ** (CMS, excluded by ATLAS)

CMS-PAS-EXO-19-016



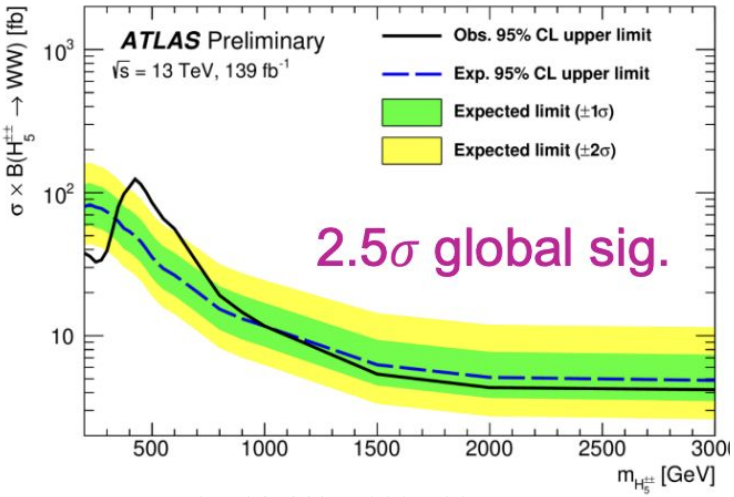
arXiv:2305.15962



tau leptons & multibjets

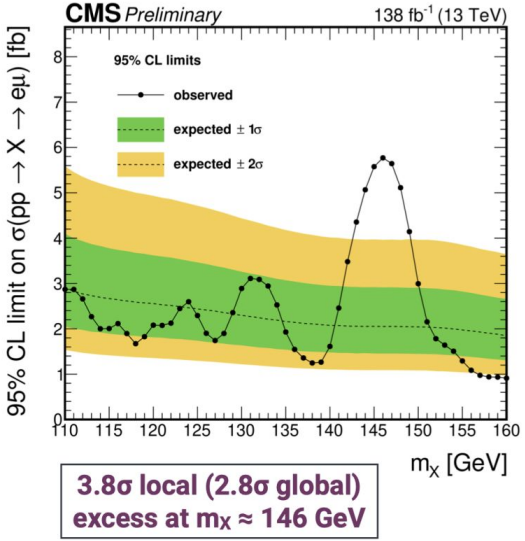
Tensions / Excesses to be understood

same sign WW scattering

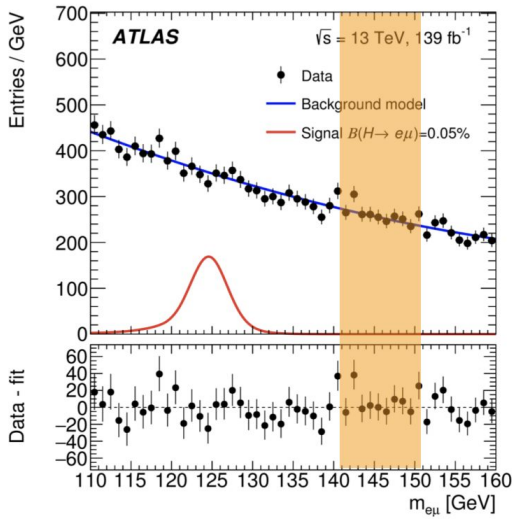


ATLAS-CONF-2023-023

X → eμ



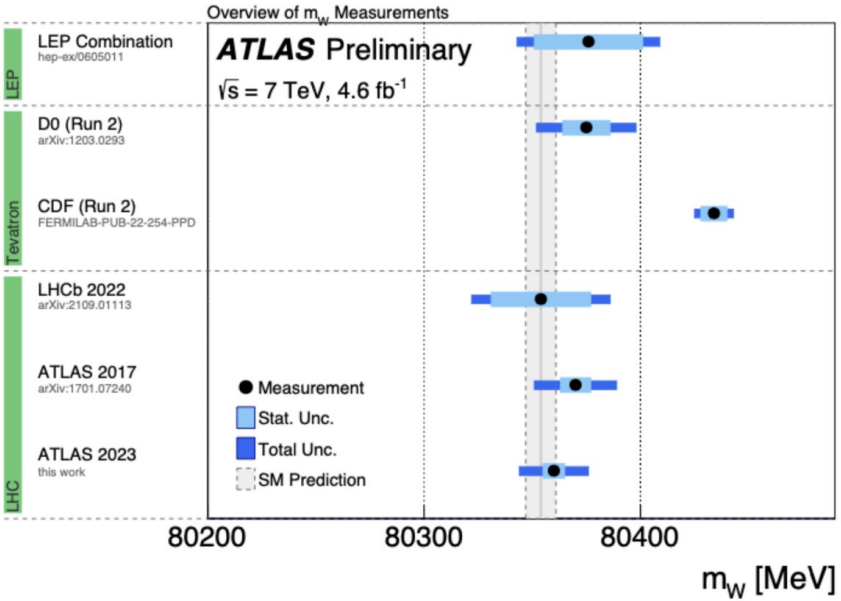
3.8σ local (2.8σ global) excess at $m_X \approx 146$ GeV



seems disfavoured by ATLAS

Tensions / Excesses to be understood

W mass



$m_W = 80360 \pm 5_{(stat.)} \pm 15_{(syst.)} = 80360 \pm 16$ MeV

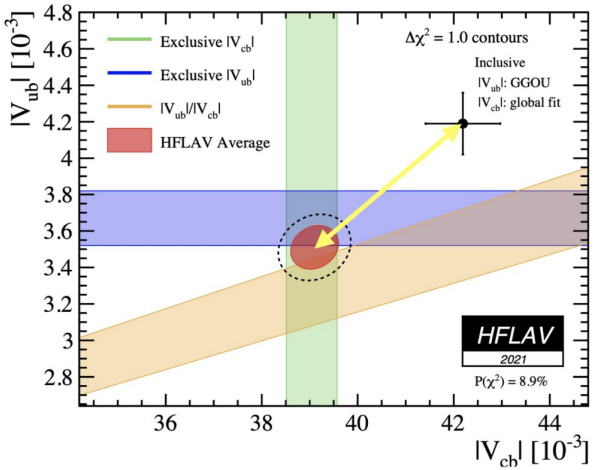
$m_W = 80370 \pm 19$ MeV

The tension with the CDF W mass is larger between ATLAS (only) and CDF 3.4σ now 4σ

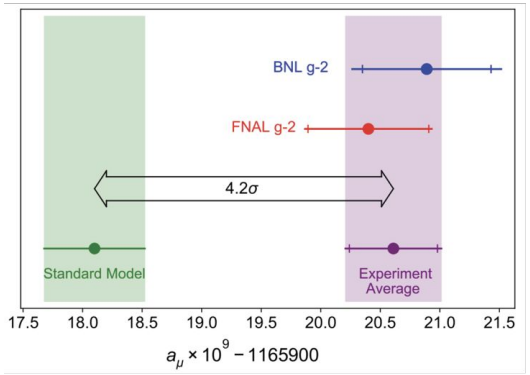
Tension of CDF measurement with the SM 7σ

Tensions / Excesses to be understood

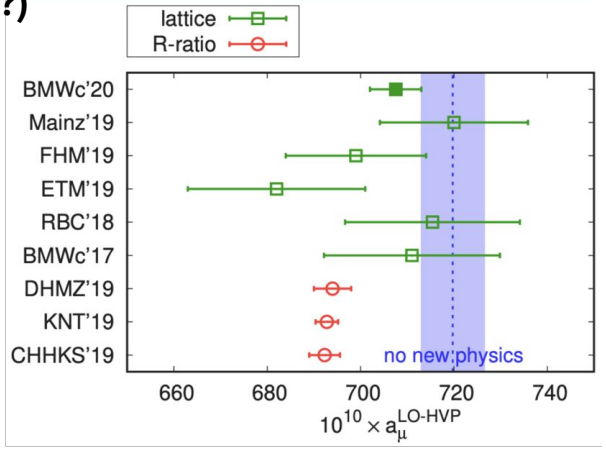
$|V_{ub}|$ - $|V_{cb}|$



$(g\text{-}2)_\mu$ (?)



[Muon g-2 collaboration, 2104.03281]



[Borsanyi et al., 2002.12347]

Possible signatures at the LHC and future colliders

- Di-higgs [N. Desai, J. Zurita,...]
- Long-lived, unconventional [N. Desai, J. Zurita, T. Srivastava,...]

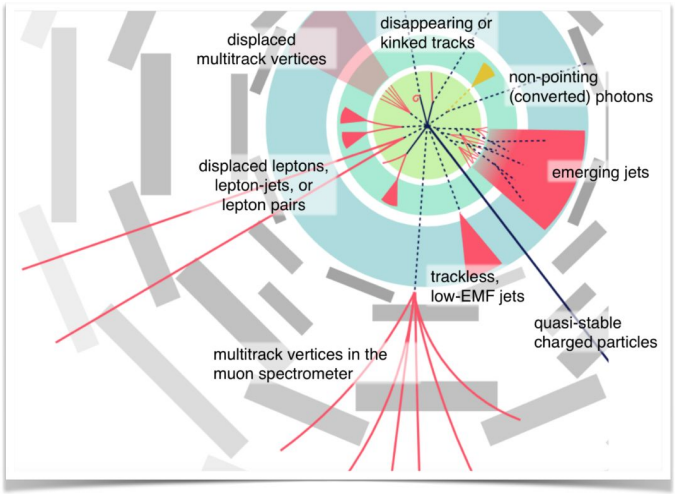
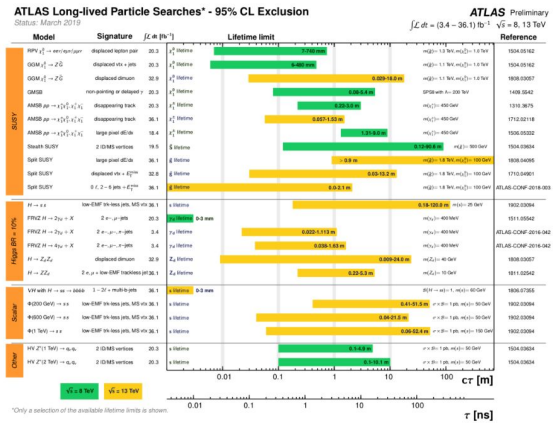


Image from H. Russel



Sample for ATLAS (same for CMS)

Relevant BSM models:

SUSY
Composite Higgs
Extra dimensions
Neutral naturalness
Relaxion models
Clockwork
NNaturalness
UV/IR mixing

WIMP
Axion DM
Dark sectors
Sterile neutrinos
Strongly interacting DM
Feebly interacting particles
Primordial black holes

Axions &
Axion-like-particles

Extended Higgs sectors

Effective field theories

Leptoquarks

S. Gori, TH summary LHCP 2023

Relevant BSM models:

The interplay between high-energy exclusions and low-energy excesses (although not all are at low-energy) yields a non-trivial flavor structure

Hard to accommodate all excesses (if one wanted to…) with a single heavy resonance. Usually multiple resonances are needed (see multiple LQs solutions or the need for extended higgs models). In particular, g-2 is in tension with other flavour observables in a big subset of BSM models (see G. Isidori et al. arxiv:2111.13724)

Also relevant studies to see correspondence between EFTs and non-resonant heavy physics (see L. Darmé et al, arxiv:2104.09512) and precision studies of 4-tops suggest it’s hard to get "model universal" results.

The question of most relevant model is non-trivial and very important to assign "scarce" resources.

Relevant BSM models:

- Interplay between VLL/VLQ/LQ [T. Vazquez Schroeder,...]
  - ...including other new bosons, spin-0 and spin-1. [G.Cacciapaglia, R. Dermisek,...]
- Extended Higgs models [C. Balazs,...]
- Soft BSM signals [M. Ubiali, J. Zurita,...]

Complementarity with other experiments

- High pT and flavour [J. Zupan,…]
- Dark sector (dark matter, dark forces, dark.. anything really), hidden sector (SUSY, GUTs, other BSM theories) [C. Balazs, N. Desai, T. Srivastava,…]
- Collider / gravitational wave detection complementarity [C. Balazs, N. Desai, T. Srivastava,…]
- Global BSM approaches: combinations of searches and measurements data from the LHC; EFT interpretations of the LHC data [S. Kraml,…]

Precision:

- Radiative corrections for BSM models [M. Spira,...]
- Interplay with PDFs [N. Desai, M. Ubiali,...]

As we delve deeper into low-statistic, non-resonant effects, precision corrections for SM and possible BSM contributions become more and more important.

Organizational issues

- To start the discussions/projects: **informal meetings tomorrow** to be decided after round table. e.g. Three possibilities from previous slides:
  - **Anomalies/Excesses**
  - **New signatures/Complementarity:** new BSM searches, signatures at HL-LHC and complementarity with other exps
  - **Precision:** precision SM/BSM phenomenology
- If you feel a talk on a specific topic would be useful, please contact us we can help organize and/or advertise it
- we will use mattermost for communication