Cheers and Thank You!

and Blabla

Tilman Plehn

Universität Heidelberg

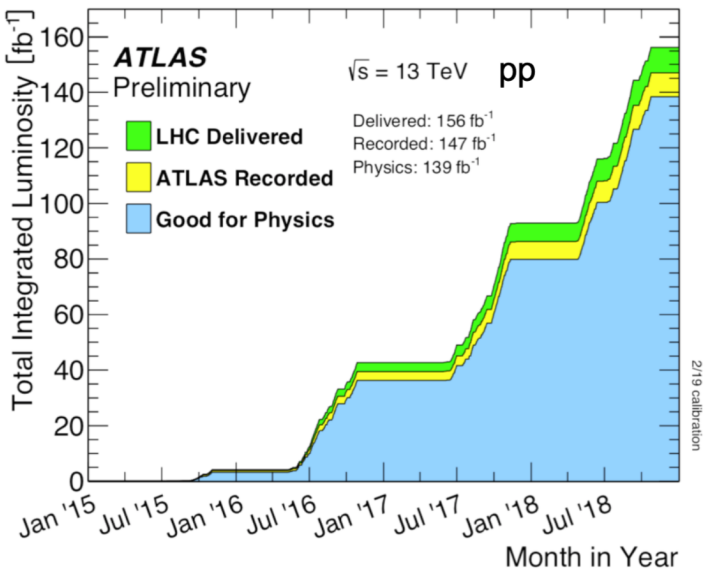
Higgs, October 2020

The things we are all missing

The things we are all missing

Run 2 great and over...

LHC Run 2



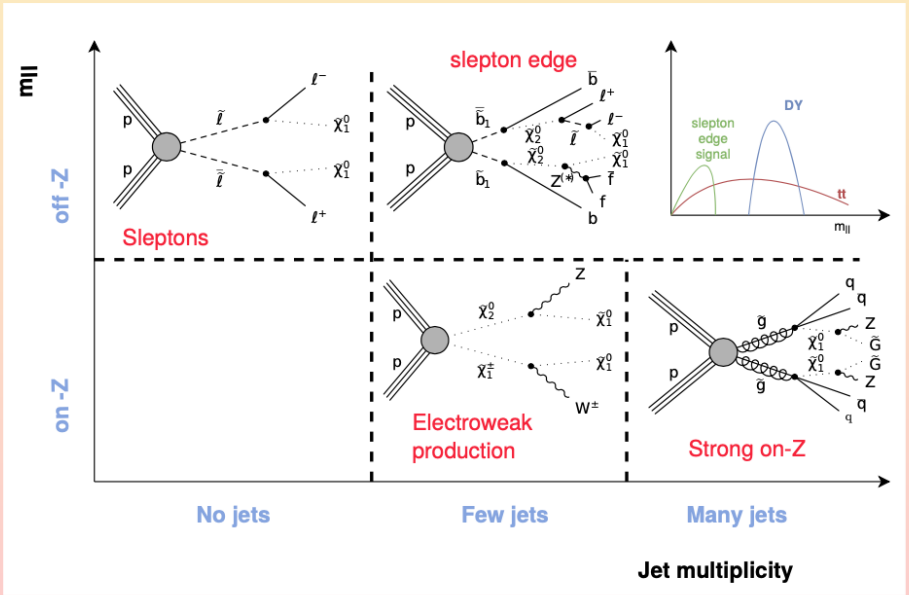
- The performance of the LHC and ATLAS in Run 2 (2015-2018) was outstanding
  - Delivered: 156 fb^{-1}
  - Recorded: 147 fb^{-1}
    (Data taking efficiency 94.2%)
  - Good for Physics: 139 fb^{-1}
    (Efficiency 94.6%, high data quality)
- Total luminosity know to precision of 1.7%
- Over 100 papers produced with Run 2 data
  - I will present some of the more recent results.

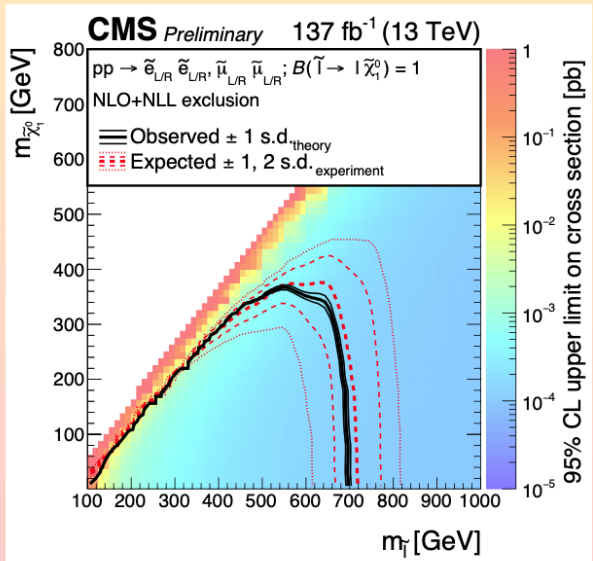
...SUSY alive and kickin'...

SUSY s-leptons (and ewkinos and s-quarks)

CMS-PAS-SUS-20-001

- Probe both electroweak and strong production with dilepton final states
  - Moderate $E_{\mathrm{T}}^{\mathrm{miss}}$ requirements to target invisible particles
  - Per-model signal regions
- Backgrounds estimates:
  - Flavour-symmetric ($t\bar{t}$, WW, also with taus): estimate in opposite-flavour sideband, apply in same-flavour
  - Drell-Yan: model $E_{\mathrm{T}}^{\mathrm{miss}}$ from γ+jets events (for s-leptons, extrapolate from Z peak)
- Neutralino (chargino) masses excluded up to 750 (800) GeV (+100 GeV w.r.t. previous searches)
- Light-flavour (bottom) s-quark masses excluded up to 1800 (1600) TeV (+300 GeV in bottom)
- **Direct s-lepton production excluded up to 650 GeV (+200 GeV)**

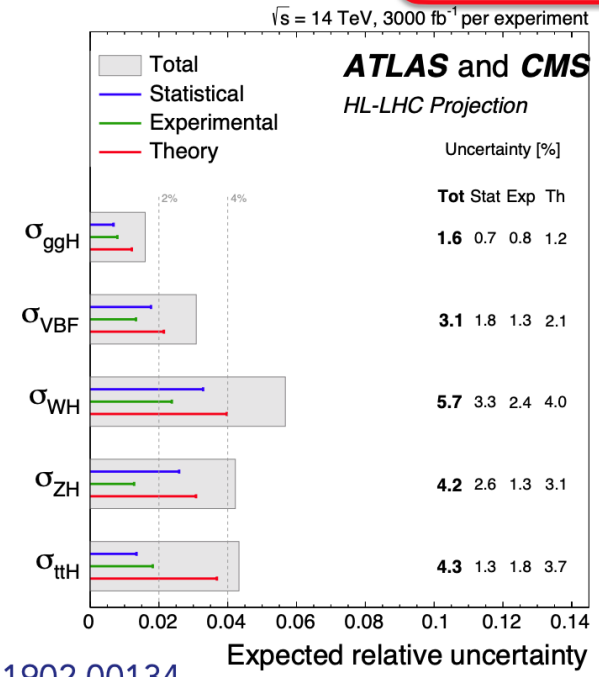


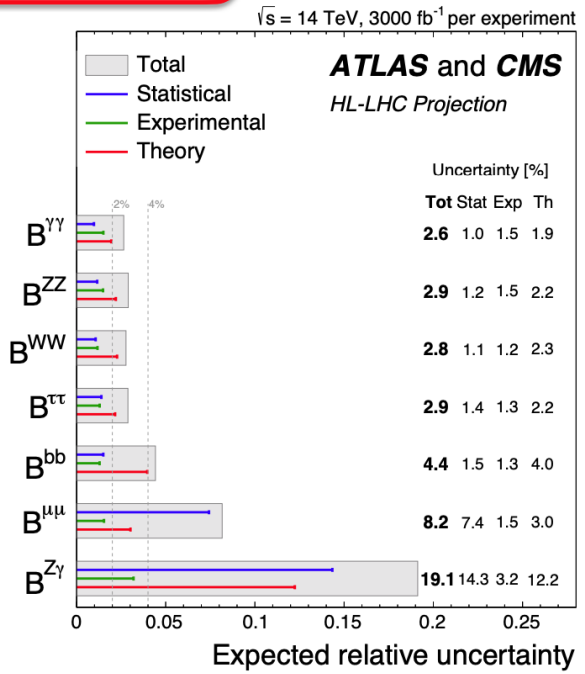


...precision delivered...

- HL-LHC projections ~20 years from now!

(S2) TH uncertainties scaled down by factor 2, EXP scaled according to $\sqrt{\mathscr{L}}$



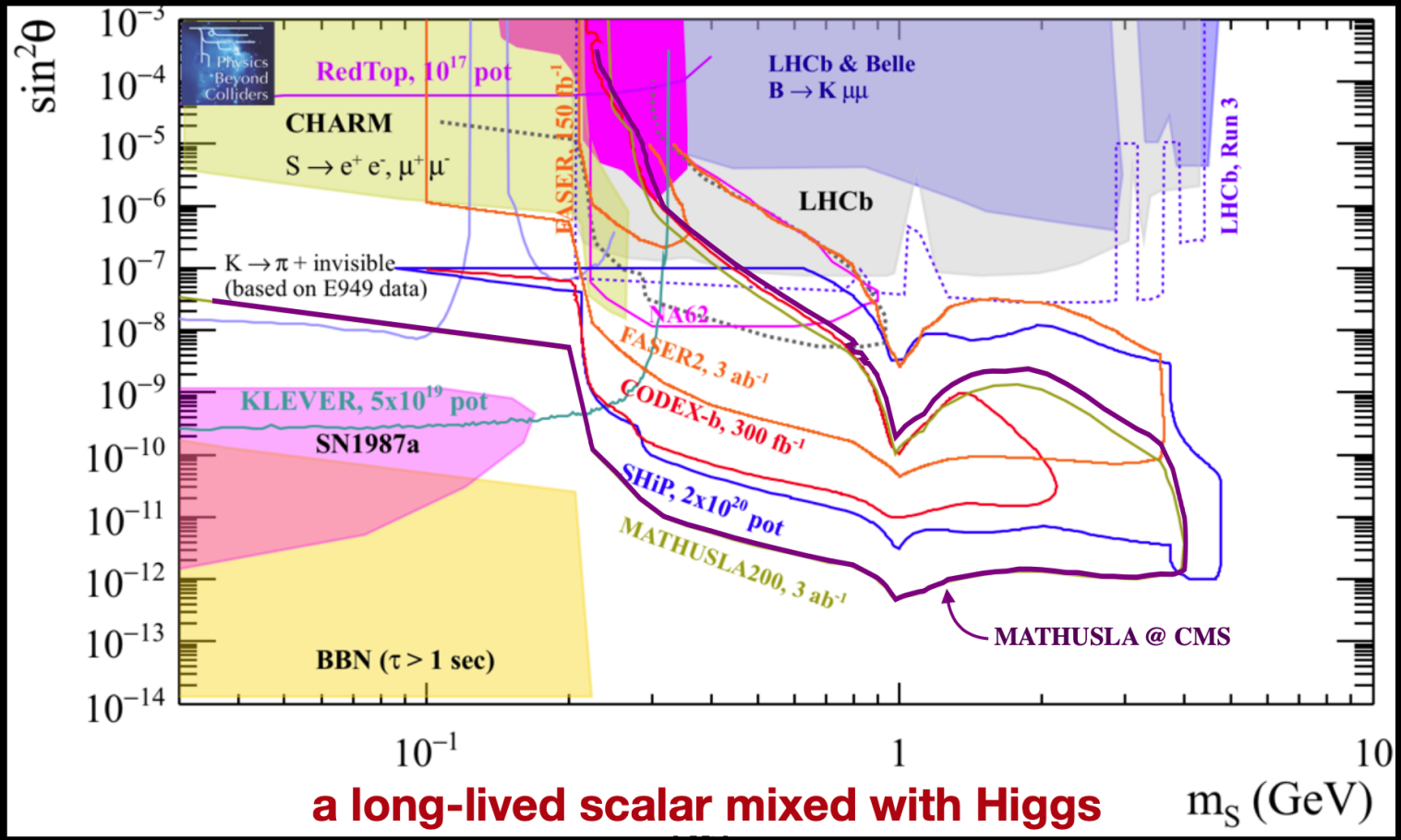


1902.00134

- Theoretical uncertainties on SM predictions generally largest component
- Precision becomes critical
- TH: can we improve calculations? Where? How?

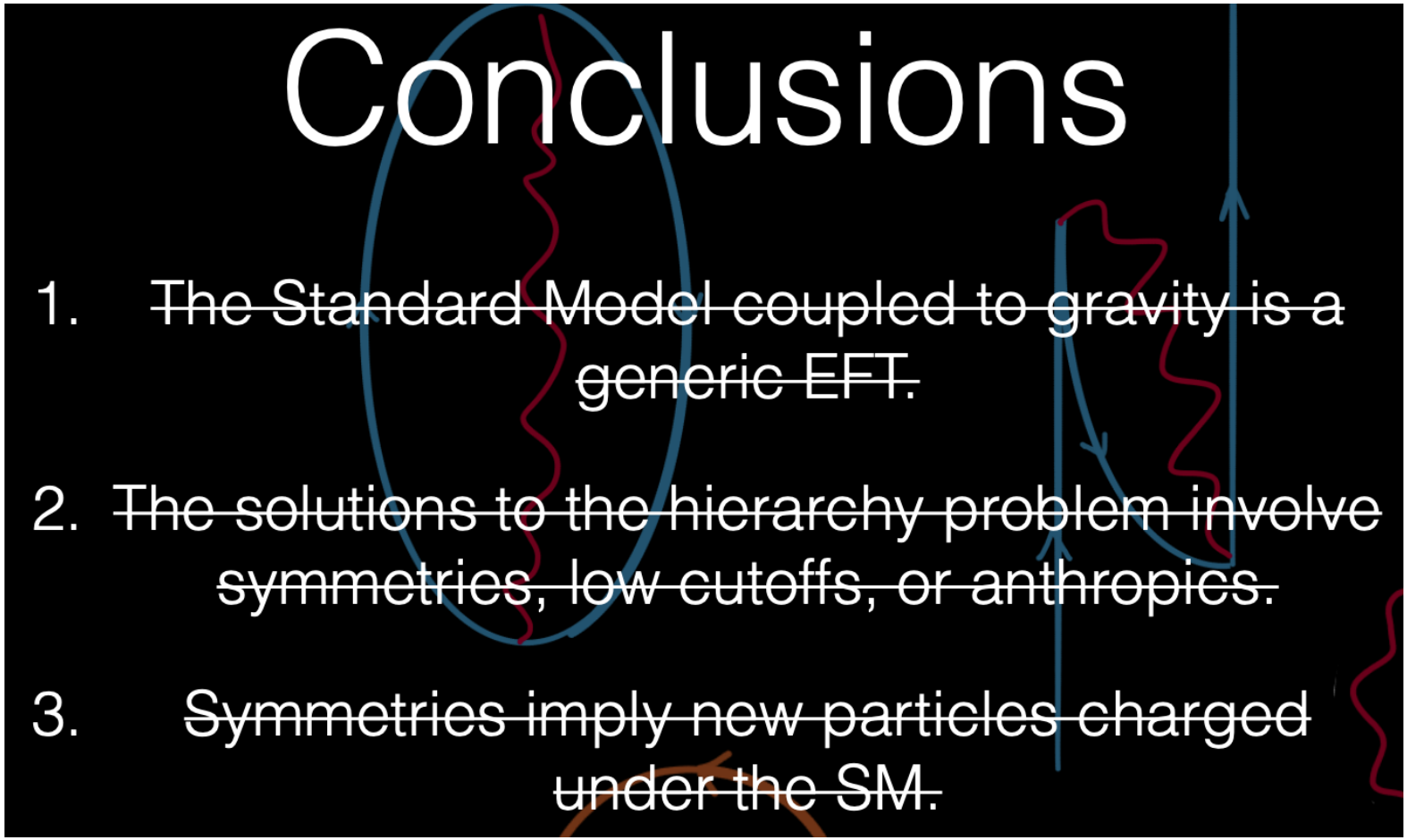
...so give us next collider!

need studies for ILC



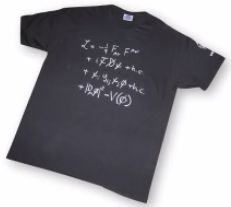
ILC opportunities for new particles that couple to leptons and photons

BSM motivation puzzling



What does SM mean, anyway?

Laws and Constitutions: What is the SM?

SM =  ?

SM is consistent (i.e. closed under radiative corrections and no pathology, except maybe hypercharge Landau pole).

We certainly know that the SM is not *complete* and it should be considered as low energy EFT, therefore there is no reason to stop at dim-4 operators. A better definition is then

— SM = SMEFT —

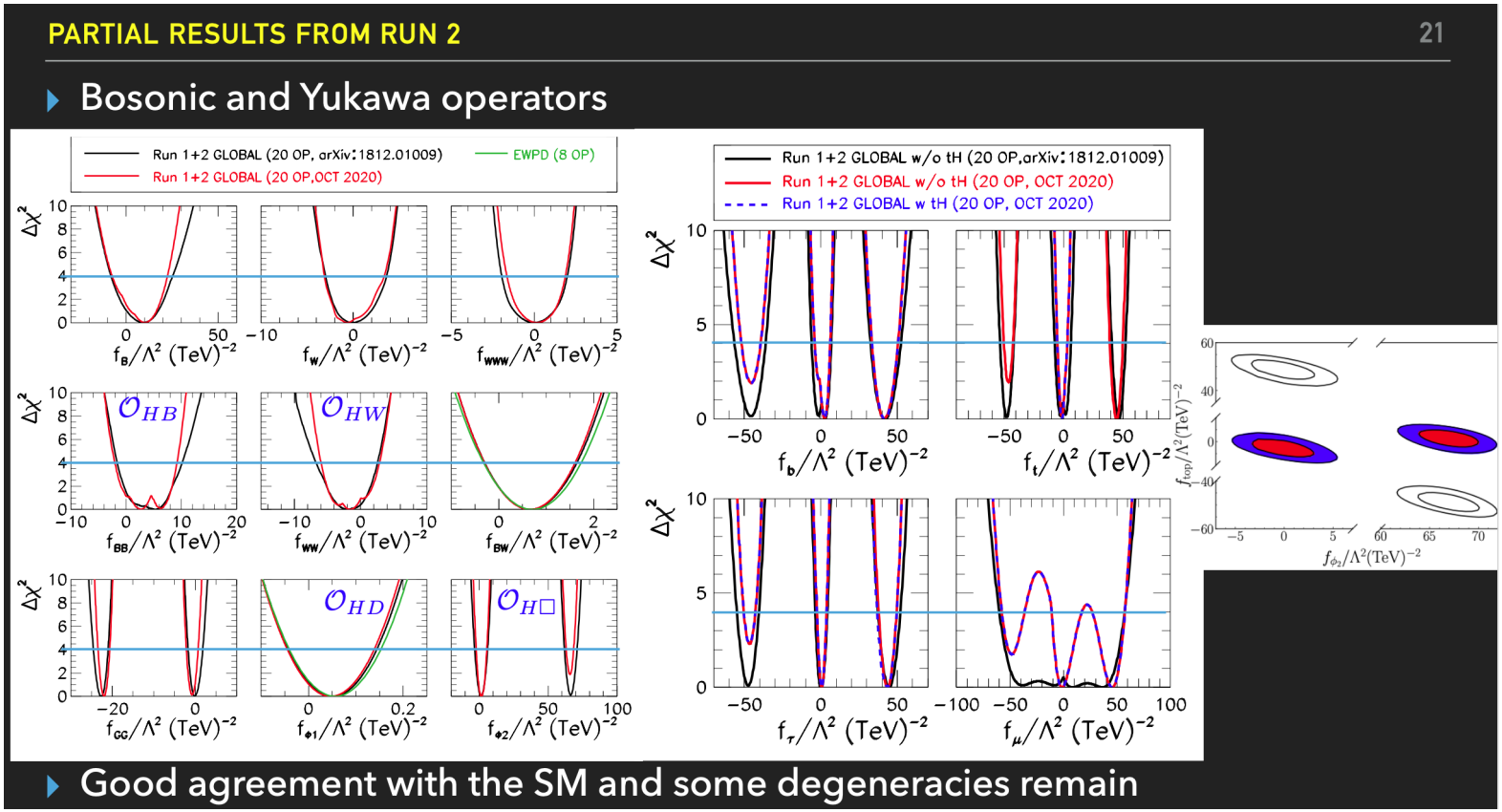
(i.e. particle content and gauge symmetries define SM)

— But this new view on the SM brings in new challenges/poses new questions —

1. all SM_4 couplings known, infinite interactions of the SM totally unknown. Which organising principles?
2. which symmetry? If Λ is not $>10^{16}$GeV, B and L cannot be accidental symmetries anymore, but they cannot exact symmetries of Nature either (quantum gravity forbids exact continuous global symmetry). Similarly, other structures of SM_4 now calls for further explanations (custodial protection/GIM-FCNC…)
3. and don't let neutrino physicists tell you that neutrino masses are BSM!

Christophe Grojean 3 Higgs 2020, Oct. 30, 2020

EFT ideas already established



...but boring as hell...

Thank You!

Tilman Plehn

Brief summary

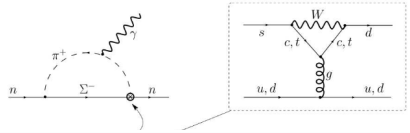
Wait!

Future

All old guys, but 59 inspiring parallel talks

Sources of CP violation

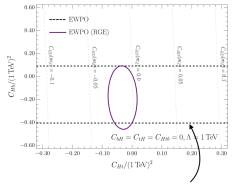
- QCD is CP invariant...
  - ...apart from possible θ term $\propto \epsilon_{\mu\nu\alpha\beta} G^{\mu\nu} G^{\alpha\beta}$
  - Neglect for the purpose of this talk
- Microscopic origin of CP violation:
  - Weak interactions
  - New Physics
- E.g. neutron EDM: SM contribution is tiny, $d_n^{\text{SM}} \sim 10^{-32}\, e\,\text{cm}$
  [Khriplovich & Zhitnitsky, PLB 109 (1982) 490]



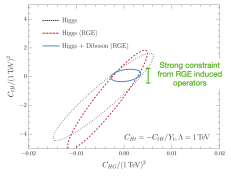
SM + VLQ Doublet Mixing with (t,b)

Generates C_{bH}, C_{tH}, C_{Hb}, C_{Ht}, C_{Htb}, C_{HG} at the matching scale

EWPO Constraints:



LHC Constraints:

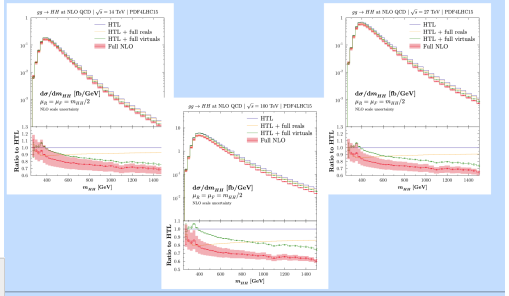


LEP sensitivity via Z to bb — flat direction broken by RGEs

Differential cross section

KIT

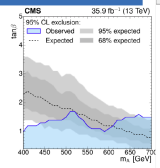
Differential cross section for different centre of mass energies

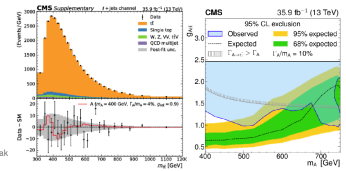


Seraina Glaus — Higgs 2020, 27.10.2020 — 9

H/A -> tt̄

- The search is performed over the mass range 400-750 GeV with total relative width of 0.5-25%.
- Event selections:
  - Basic semi/di-leptonic ttbar selections.
  - Special spin-sensitive variables.
- The interference with the SM ttbar BG is taken into account.
- A small peak-dip structure is observed at at the lowest masses tested with 1.9σ global significance.





L. Barak — Higgs 2020

Yukawa modifications in flavor models

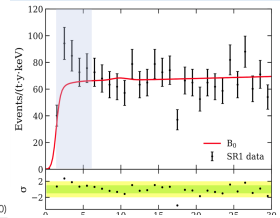
[FB, Brod, Uttayarat, Zupan: 1504.04022] – see also CERN YR4 Chap. IV.6 [1610.07922] + references therein for the specific models

Model	κ_t	$\kappa_{c(u)}/\kappa_t$	$\tilde{\kappa}_t/\kappa_t$	$\tilde{\kappa}_{c(u)}/\kappa_t$
SM	1	1	0	0
MFV	$1+\frac{\text{Re}(a_0 v^2+2b_0 m_t^2)}{\Lambda^2}$	$1-\frac{2\,\text{Re}(b_0)m_c^2}{\Lambda^2}$	$\frac{\text{Im}(a_0 v^2+2b_0 m_t^2)}{\Lambda^2}$	$\frac{\text{Im}(a_0 v^2)}{\Lambda^2}$
NFC	$V_{tu}\, v/v_u$	1	0	0
MSSM	$\cos\alpha/\sin\beta$	1	0	0
FN	$1+\mathcal{O}\left(\frac{v^2}{\Lambda^2}\right)$	$1+\mathcal{O}\left(\frac{v^2}{\Lambda^2}\right)$	$\mathcal{O}\left(\frac{v^2}{\Lambda^2}\right)$	$\mathcal{O}\left(\frac{v^2}{\Lambda^2}\right)$
GL2	$\cos\alpha/\sin\beta$	$\simeq 3(7)$	0	0
RS	$1-\mathcal{O}\left(\frac{v^2}{m_{KK}^2}Y^2\right)$	$1+\mathcal{O}\left(\frac{v^2}{m_{KK}^2}Y^2\right)$	$\mathcal{O}\left(\frac{v^2}{m_{KK}^2}Y^2\right)$	$\mathcal{O}\left(\frac{v^2}{m_{KK}^2}Y^2\right)$
pNGB	$1+\mathcal{O}\left(\frac{v^2}{f^2}\right)+\mathcal{O}\left(y_*^2\lambda^2\frac{v^2}{M_T^2}\right)$	$1+\mathcal{O}\left(y_*^2\lambda^2\frac{v^2}{M_T^2}\right)$	$\mathcal{O}\left(y_*^2\lambda^2\frac{v^2}{M_T^2}\right)$	$\mathcal{O}\left(y_*^2\lambda^2\frac{v^2}{M_T^2}\right)$

- Generally, modifications $\sim v^2/\Lambda^2 \ll \mathcal{O}(1)$ [Giudice, Lebedev: 0804.1753]
- Exception: GL2 (modified GL) where
  [FB, Brod, Uttayarat, Zupan: 1504.04022]
  [Carena, Gemmler, Bauer: 1506.01719, 1512.03458]

J. Alimena et al., 1903.04497, J.Phys.G 47 (2020)

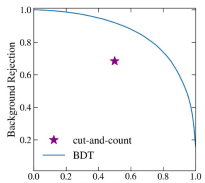
The Excess



Results

Determination of the *b*-yukawa coupling

Durham University — IPPP



CLs Limits

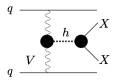
- Signal strength: $\mu = \frac{\sigma(pp \to hjj\gamma)\ \text{BR}(h \to b\bar{b})}{\sigma^{\text{SM}}(pp \to hjj\gamma)\ \text{BR}^{\text{SM}}(h \to b\bar{b})}$
- **Cut & count** limits at 95% CL:
  - μ<1.1 for ∫Ldt = 30.6 fb⁻¹
  - μ<0.4 for ∫Ldt = 300 fb⁻¹
  - μ<0.3 for ∫Ldt = 3000 fb⁻¹
- **BDT** limits at 95% CL:
  - μ<0.8 for ∫Ldt = 30.6 fb⁻¹
  - μ<0.25 for ∫Ldt = 300 fb⁻¹
  - μ<0.1 for ∫Ldt = 3000 fb⁻¹

ATLAS (2020)[4] μ = 1.3±1.0 @ 132 fb⁻¹

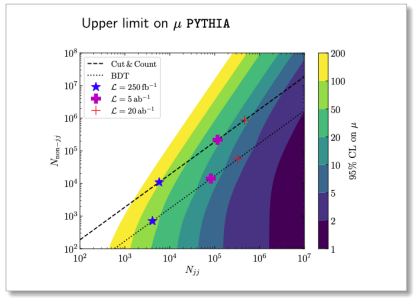
8

HIGGS + LONG-LIVED

- Higgs also presents trigger opportunities!



- Higgs produced in association with VBF jets or W/Z: can be used to trigger on otherwise difficult signals!
- So far, this approach only seems to have been used in one published analysis looking for $h \to ZA'$
  ATLAS, 1811.02542, PRL 122 (2019)
- Can low-mass tau triggers for Higgs studies be useful for low-mass, narrow displaced hadronically decaying LLPs?



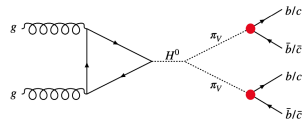
Higgs at LHCb

"Updated search for long-lived particles decaying to jet pairs"

LHCb — INFN Istituto Nazionale di Fisica Nucleare — Università degli Studi di Padova

EPJC 77 (2017) 812

- A Higgs boson could decay to a pair of Hidden Valley (HV) pions, which in turn decay to $q\bar{q}$ pairs



● displaced vertex

etc ... but way too much self-coupling!

Questions a la Tilman

How do we maintain that particle physics goes to Planck scale?

Classic pheno close to analyses is over, why?

LHC era means data-driven, do we use it best?

What kind of LHC-Higgs physics is fun?

It there an ex-th interface beyond precision-MC?

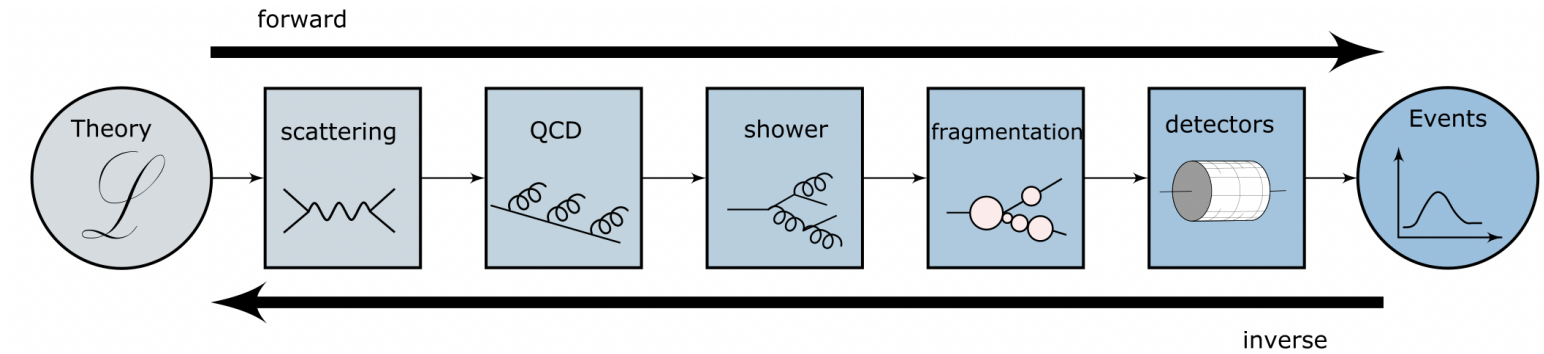
What are the great and cool ideas?

What can we learn from big data?

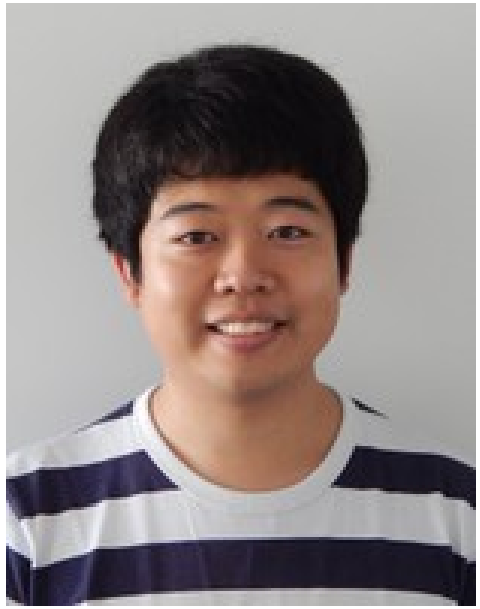
Alternative approaches to testing precision predictions? [like Kyle, Felix, StefanH]

Future collider politics good for young people?

...



Thank you to the vLOC!



More thanks and facts

zoom a success, even though hybrid would be nicer

record: 350 people for first plenary

parallels: 70-150 people each

only one slight glitch...

feedback welcome, personally, it's nicer with cameras on?

Paolo Meridiani (PC, go-to guy)

Sally Dawson (PC)

Maria Cepeda Hermida (PC)

Giacinto Pacquadio (PC)

James Wells (PC)

All chairs, especially extra-busy Karl Jakobs and Luca Malgeri

See you at Higgs 2021