WG3 Summary

The 17th Workshop of the LHC Higgs Working Group

11/11/2020

WG3: Anna Goussiou (ATLAS), David Sperka (CMS),
Zhen Liu & Pietro Slavich (TH)

07:00	**Introduction**	*Anna Goussiou et al.*	
	Online only	07:00 - 07:05	
	MSSM Subgroup Updates	*Emanuele Angelo Bagnaschi*	
	Online only	07:05 - 07:20	
	MSSM Subgroup Updates	*Artur II Darovic Gottmann*	
	Online only	07:20 - 07:35	
	NMSSM Subgroup Updates	*Milada Muehlleitner*	
	Online only	07:40 - 07:55	
08:00	**NMSSM Subgroup Updates**	*Janek Bechtel*	
	Online only	07:55 - 08:10	
	Extended Higgs Sector Subgroup Updates	*Rui Santos*	
	Online only	08:15 - 08:30	
	Extended Higgs Sector Subgroup Updates	*Lidija Zivkovic*	
	Online only	08:30 - 08:45	
	Exotic Higgs Decays Subgroup Updates	*Georgia Karapostoli*	
09:00	*Online only*	08:50 - 09:15	
	bbH Subgroup Updates	*Abdollah Mohammadi*	
	Online only	09:20 - 09:40	
	Tea/Coffee Break		
10:00	*Online only*	09:50 - 10:10	
	On the yb sensitivity of bbH	*Davide Pagani*	
	Online only	10:10 - 10:25	

Thanks all for the excellent summary talks with progress and future plans!

Charged by the SC, I will focus more on the future plans.

Organization of the BSM-Higgs Working Group (WG3)

Anna Goussiou (ATLAS), David Sperka (CMS), Zhen Liu & Pietro Slavich (TH)

Anna Goussiou (ATLAS), Jan Steggemann (CMS), Zhen Liu & Pietro Slavich (TH)

- Extended Higgs Sector (neutral + charged)

  Xiangyang Ju (ATLAS, 0), Jana Schaarschmidt (ATL
  Raffaele Gerosa (CMS, 0), Jan Steggemann (CMS
  Heather Logan, Rui Santos & Shufang Su (TH

  Lidija Zivkovic (ATLAS, 0), Jana Schaarschmidt (ATLAS, ±)
  Raffaele Gerosa (CMS, 0), Jan Steggemann (CMS, ±)
  Heather Logan, Rui Santos & Shufang Su (TH)

- MSSM

  Tim Barklow (ATLAS), Andrew Gilbert (CMS)
  Stefan Liebler, Pietro Slavich & Michael Spira (T

  Tim Barklow (ATLAS), Artur Gottmann (CMS)
  Emanuele Bagnaschi, Pietro Slavich & Michael Spira (TH)

- NMSSM

  Nikos Rompotis (ATLAS), Nadjieh Jafari (CMS)
  Ulrich Ellwanger & Margarete Mühlleitner (TH)

  Nikos Rompotis (ATLAS), Janek Bechtel (CMS)
  Ulrich Ellwanger & Margarete Mühlleitner (TH)

- Exotic Higgs Decays

  Lily Morvaj (ATLAS), Cécile Caillol (CMS), Lorenzo Sestini
  Zhen Liu & Jessie Shelton (TH)

  (ATLAS), Georgia Karapostoli (CMS), Lorenzo Sestini (LHCb)
  Matthias Konig & Brian Shuve (TH)

- bbH/bH associated production process

  Lei Zhang (ATLAS), Abdollah Mohammadi (CMS
  Michael Spira & Marius Wiesemann (TH)

  Lei Zhang (ATLAS), Abdollah Mohammadi (CMS)
  Michael Spira & Marius Wiesemann (TH)

[red = departed/depa

[green = arrived/arriving]

WG3's unique task: BSM Higgs

- Target space is huge (BSM)
- Pathway not clearly defined (in contrast to WG1: Higgs XS&BR; and WG2: Higgs Properties;)

WG3's uniqueness deems huge span of tasks, prioritization procedures, and form of services

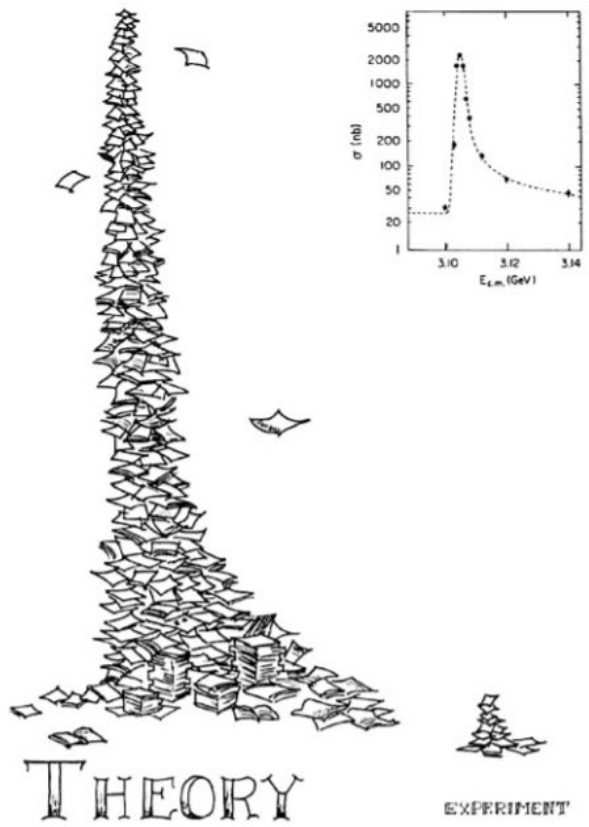

Figure 5: Cartoon from the cover of *CERN Courier*, April, 1975.

Every success has many parents.

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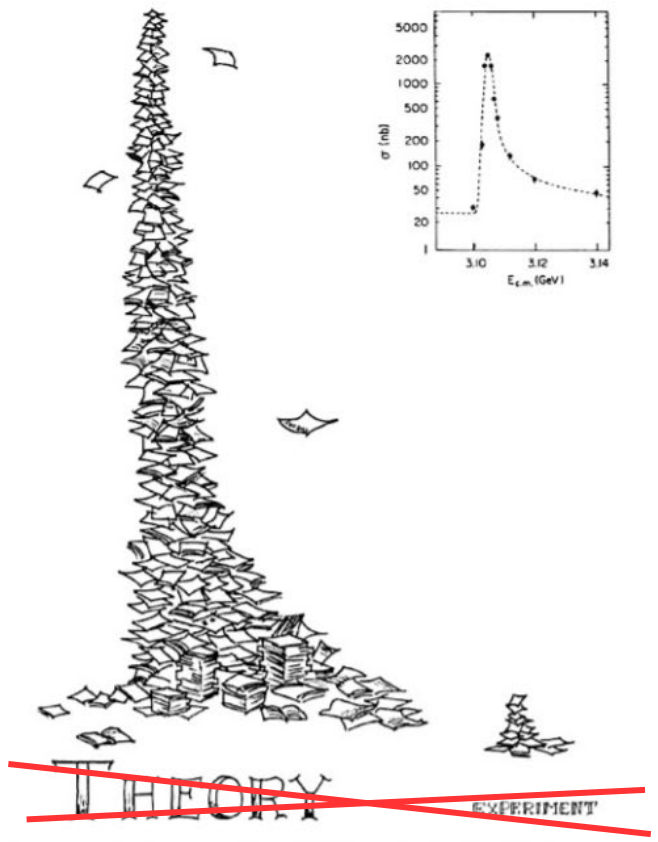

Or: Data Search Results

Figure 5: Cartoon from the cover of *CERN Courier*, April, 1975.

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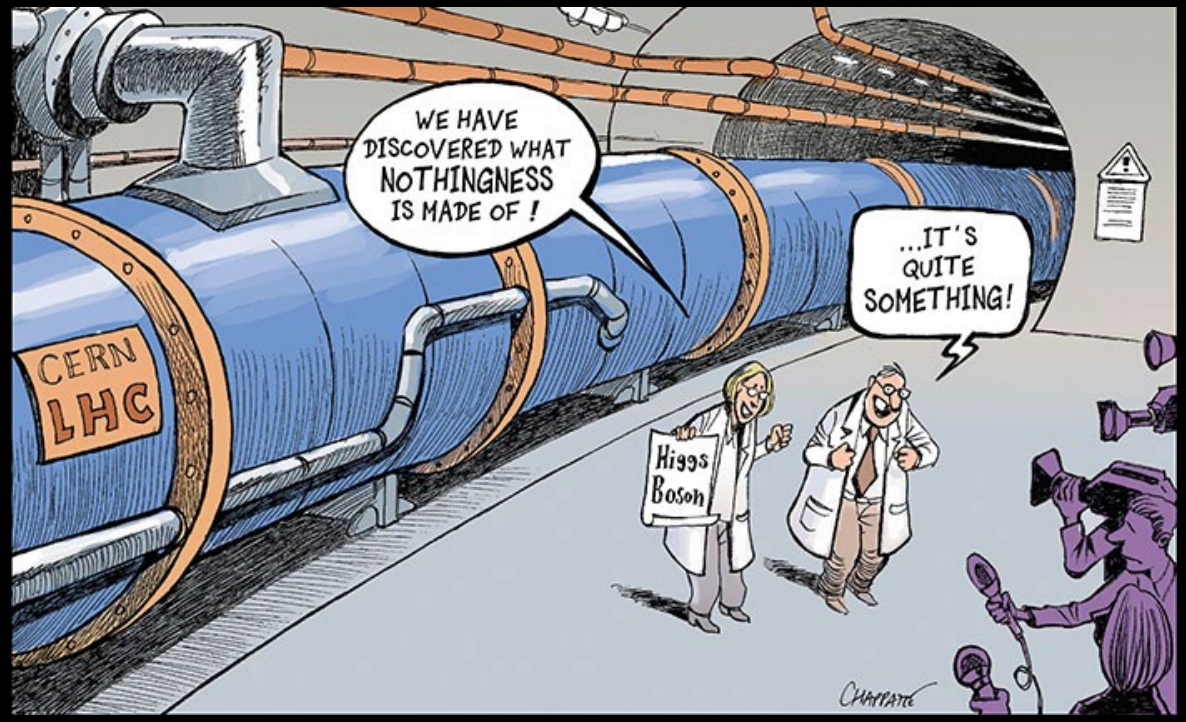
To accelerate, ensure not-to-miss, the opportunities for new physics at the LHC

Next "quite something"



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Different subgroups have different emphasis amongst these tasks, for instance, the MSSM group and Exotic Higgs group

The (break down of) goals of WG3:

- Promote new, valuable theory development to experimental searches; (Th→Exp)
  - Provide recommendation of new search channels;
  - Provide recommendation of benchmarks & cross sections;
  - Develop/maintain/combine tools for the calculation of physical observables;
- Promote new experimental results and capabilities to the theory community; (Exp→Th)
- Address theory issues/questions raise by our experimental colleagues; (Exp→Th→Exp)
  - *Ensure a correct description of TH/PH issues in EXP publications;
  - E.g., review of the descriptions of MSSM benchmarks in a number of ATLAS/CMS publications
  - E.g., answer the heavy Higgs rate

Tim Barklow (ATLAS), Artur Gottmann (CMS)
Emanuele Bagnaschi, Pietro Slavich & Michael Spira (TH)

MSSM Subgroup Updates	*Emanuele Angelo Bagnaschi*	
Online only		07:05 - 07:20
MSSM Subgroup Updates	*Artur Il Darovic Gottmann*	
Online only		07:20 - 07:35

Tasks and Plans: MSSM subgroup

Subgroup mission

- To be a common ground for discussion between experimentalists and theorists.
- To clarify theoretical aspects important for experimental studies.
- To provide benchmark scenarios to be used by experimental collaboration.
- To discuss possible future developments on probing the MSSM Higgs sector at the LHC.

- A lot of ongoing work on the scenarios.
- Two updates of the ROOT files already scheduled.
- Ongoing activity on the Higgs $p_\perp^\phi$ framework.
- We plan to publish two working group notes.

Task	Status	Timescale ↑
Keep an eye on potentially missing signatures	In progress	Continuous
WG support to the release of experimental likelihoods	In progress	Continuous
Prioritize channels according to importance for end of LHC run2/3 or HL-LHC	In progress	Continuous
A/H decay to SUSY states and corresponding ROOT files	In progress	Beginning 2021
Higgs $p_\perp^\phi$ public note	In progress	Beginning 2021
Provide description and common tool for BSM Higgs $p_\perp^\phi$ calculation @ NLO+PS precision for gluon fusion	In progress	Beginning 2021
Public note describing the ROOT files	In progress	Beginning 2021
Release ROOT files with proper `HDECAY`⇔`FeynHiggs` matching	In progress	End 2020
Release ROOT files for mh125 variants with negative μ	In progress	Soon
Update of the ROOT files (SM BRs, `HDECAY` update, `FeynHiggs` proper version)	In progress	Soon
Provide updated ROOT files for end RunII analyses	Complete	End 2018
Provide benchmark scenario for low tan β using EFT approach	Complete	End 2018
Provide new MSSM benchmark scenarios	Complete	Sept 2018
Update SM parameters for MSSM calculations to be consistent with YR recommendations for SM calculations	Complete	Sept 2018

Types of Results provided/desired

Provided results, mostly also available on HEPData:

- Model-independent upper limits on the product of cross-section and branching fraction(s) ($\sigma \cdot BR$)
- Exclusion contours in a parameter space of a benchmark model (e.g. m_A, $\tan\beta$ of MSSM)
- Model-independent likelihood scans, e.g. in $\sigma \cdot BR$ and mass of the Higgs boson

Questions

- Do we agree on the parameter table on the slide before?
  $\longrightarrow$ Matches most the derived upper limits and exclusion contours of the analyses
- Further suggestions for parameterization?

$pp \to b(b)\phi + X \to b(b)bb + X$	m_ϕ	$\sigma(b(b)\phi) \cdot BR$
$pp \to \phi + X \to tt + X$	$m_\phi, \Gamma_\phi/m_\phi$	$g_{\phi \leftrightarrow tt}$
$pp \to \phi + X \to \mu\mu + X$	$m_\phi, \Gamma_\phi/m_\phi$	$\sigma(gg\phi) \cdot BR, \sigma(bb\phi) \cdot BR$
$pp \to tbH^\pm + X \to tb\{tb, \tau\nu\} + X$	$m_{H^\pm}$	$\sigma(tbH^\pm) \cdot BR$
$pp \to t + X \to bH^\pm + X \to b\{tb, \tau\nu\} + X$	$m_{H^\pm}$	$BR(t \to bH^\pm) \cdot BR$

Exotic Higgs Decays Subgroup Updates *Georgia Karapostoli*

Online only 08:50 - 09:15

Tasks and Plans: Exotic Higgs Decay Subgroup

Task	Involved persons	Status	Timescale
Provide a benchmark for interpretations of h->aa->4y/2g2y searches	Andrea Thamm	DONE	ALP benchmark
Add feasibility studies for h->2f+MET and develop benchmark scenarios predicting this type of signatures	All	planned	lower priority
List uncovered, but well motivated, Higgs decays searches involving one or more displaced vertices.	Brian Shuve	In progress	Spring 2021
What is the best way to present Higgs searches with displaced vertices to allow a simple recast by theorists?	Theorists	In progress	winter 2021
Reinterpret prompt decays results for LLP signatures	Experimentalists	In progress within collaborations	Full Run 2 papers
List of high priority channels for inclusion into BSM H fits and for which experimentalists are highly encouraged to publish likelihood scans (see p7-9). In the form of slides or a short document.	Theorists	In progress	Spring 2021
Parameter calculations for Higgs rare decays beyond gamma+J/Psi, gamma+phi, gamma+Upsilon	Matthias Koenig	DONE	Parameter_calculations
Provide final recommendations for h->W/Z+meson: link	Zhen Liu, Stefan Alte	under review	

Conclusions

- Higgs sector provide incredible tool for testing models of New Physics
- Exotic Higgs decay searches remain a top priority of the BSM search program, as we face new challenges and opportunities at HL-LHC
- Still a lot of room for new discoveries in signatures we have not covered yet!
- Exciting possibilities for full Run2 and Run3 analyses, with new searches and strategies, e.g.
  - Open to new benchmark ideas…
  - New trigger / reconstruction techniques for low p_T objects (boosted regimes, collimated decay products).
  - new Run 3 triggers being developed for LLP searches.
  - etc

Benchmark

Signature
H → ALPs
H(125)→aa (s →XXYY
H(125)→aa (s →XXYY
H(125)→hh
H(125)→h1h2
H(125)→hh
H(125)→2Zd–
H(125)→2Hd– lep
H(125)→aa (s →XXYY/invis

ark
g., ALP,
+gauge

wing.

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I apologize here of not covering all of the subgroups.

Beyond subgroup activities, we also have various cross-group activities with other groups, e.g., HH, LLP, etc.

WG3's unique task: BSM Higgs→ Issues (my personal view)

There is also a lack of activities, for many reasons:

- Lack of excitements; BSM theorists are very mobile, and wants quick results;
- BSM theorists already said what can be done in the coming years? (which I would not agree)
- Lack of recognition of efforts;

For instance (true case but I hide the names):

- Our Experimental colleagues conducting a search on a particular channel of Higgs exotic decays;
- Having trouble generating signal events efficiently, they turned to the theorists;
- The theorists who wrote the paper and model file are no longer interested in providing support (they are all busy/interests shifted/got cited anyway);
- No one responded for some time, so I provided some suggestions and ideas to circumvent the problem, but it failed (Oct. 2019);
- Our experimental colleagues kept on trying;
- Contacted the generator people and possibility identified it is the model file's problem and asked the authors and theory convenors again; again no one responded after a month.
- I would estimate the work, since it is subtle (but not suitable for a pheno paper), cost a theorist 2-8 weeks. It is non-trivial amuont of service. How do we encourage a new theorist to help solve this problem? (Does this qualify a CERN Pub? And is it attractive enough?)

*happen less often

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To accelerate, ensure not-to-miss, the opportunities for new physics at the LHC

- Keeping recruiting motivated people;
- Restructuring to excited areas (such as hidden sector or in connection with astro/cosmo)
- Exp recognizing theorists' services (in talks, documents, or co-authorship, etc.)

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