

The 4 Yellow Reports

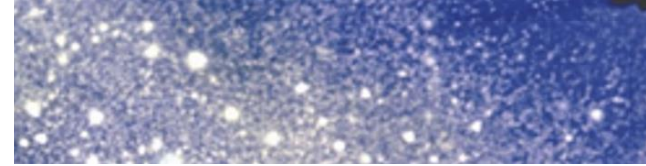


The 20th workshop of the LHC Higgs (XS) WG - Chiara Mariotti

A bit of history

- In 2008 Giampiero Passarino had the idea of the group for the first time, underlying the urgency, since a discovery could come sooner than expected!
- In August 2009 we met at the cafeteria of B40 (Passarino, Mariotti, Murray, Nisati, Qian and Stoeckli)
- In Torino, in November 2009 (the exact day LHC delivered the very first pp interaction !) the group was formed and the program was discussed.
- Jan 2010 the experiments formally recognize it.





Short Minutes of the Tuesday 24-November Round Table in Torino of the Higgs Circle.

- After a short introduction we went through the points raised in our preliminar *short note*. As a consequence:
1. There has been a long discussion on the future of these meetings. To proceed we need some sort of formal approval by the Collaborations. We will try to reach a solution in the next 10 - 15 days. In the mean time we keep working.
 2. Next meeting: possibly around March in Freiburg (Markus Schumacker is organizing it)
 3. There is a general consensus on the first topic: we plan to analyze *signal cross - sections* and BR;
 - we plan to use NNLO programs; at the moment the candidates are HNNLO by M. Grazzini et al, Fehip by C. Anastasiou et al. (TBC) and Higlu by M. Spira (TBC).
 - for MSSM we plan to use use Feynhiggs and Higlu.

We will set up a small group from each experiment with a corresponding contact person. The theoreticians involved are: Grazzini, Heinemeyer (they were present and agree) plus, possibly, Spira. For the choice of the PDF and α_s A. Vicini (also present) will be the contact person. We also discussed the involvement of Tevatron Working Groups (looking for one person for each experiment) in order to develop a consistent level of communication from now on.
 4. We need to set up a repository/database with numbers, program versions etc. that everybody can have access to. Jianming will look into a possibile technical solution.
 5. Background cross sections: we plan to make a list of processes for all relevant final states; for them we want to study and compute:
 - the interference of the signal with the background;
 - the background cross sections (at the highest, available perturbative order); for the moment we start with the di-bosons final states. G. Passarino will start to organize this group.
 6. Definition of pseudo-observables will follow (hopefully) from the previous point.
 7. There has been a long discussion on I/O, especially for the benchmark value of the top mass: 172.5 ± 2.5 GeV. For the bottom mass the recommended value is 4.2 GeV.

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- 24 November 2009 at 14:00

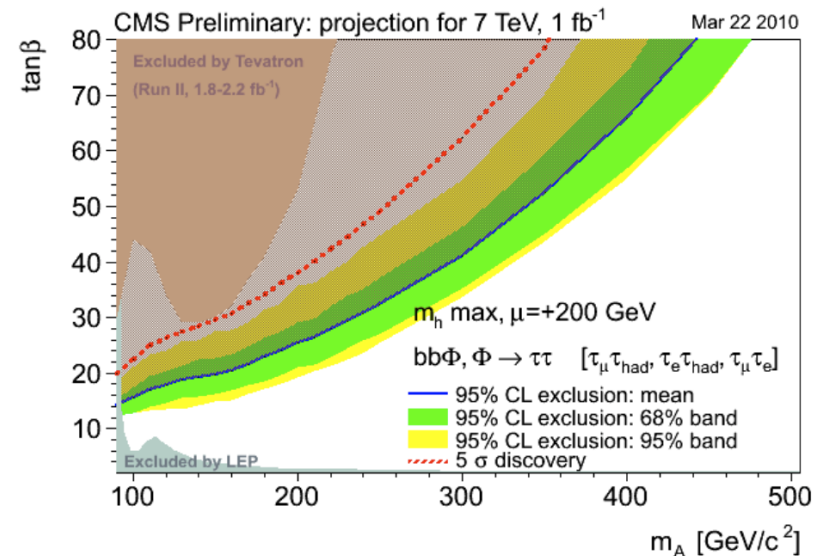
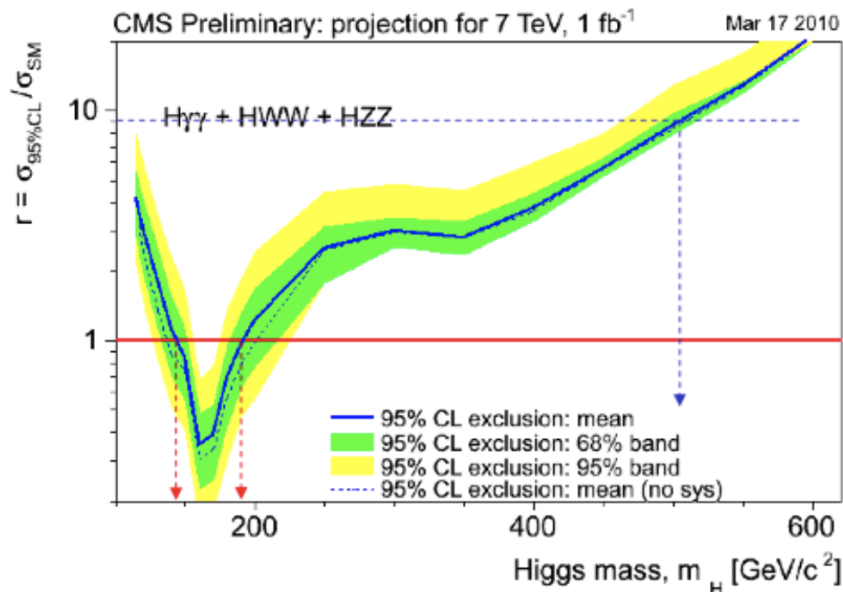


1 meeting, Freiburg, April 2010

Why?

- By the end of the 7 TeV run, the luminosity collected will hopefully allow us to probe some Higgs-mass value

(exclusion, evidence - see Guillelmo talk)



→ We want to use the BEST of our knowledge to probe EWSB



The goal of the group

<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/CrossSections>

- Access the most advanced theory predictions for the Higgs Cross Section and Branching Ratio.
- Common and correlated theoretical inputs, like cross sections, PDF, SM inputs etc. are discussed in the group.
- Theoretical uncertainties.
- Experiments are/will coherently use the **COMMON INPUTS** based on the interaction with the TH community to facilitate the combination* of the individual results

*Higgs Combination Group



The LHC Higgs Combination Group

Initial Composition

Role	ATLAS	CMS
Higgs WG convener	Bill Murray	Vivek Sharma
Overall Contact	Kétévi A. Assamagan	Andrey Korytov
Statistical Com. Rep.	Eilam Gross	Gregory Schott
Higgs XS Rep.	Rei Tanaka	Chiara Mariotti

In addition:

ATLAS and CMS Spokespersons and Physics Coordinators

With the participation of relevant experts as needed

Towards YR1: Some of the arguments

PDF

Intense collaboration with PDF4LHC group

We need to come to the agreement on a common recipe of PDF errors:

- α_s value
- PDF + α_s error definition
- XS central value, envelope method or other methods ?
If no envelope, instead why not:
 - computing σ with different PDF sets, then take the average and correctly compute the error (correlated and non-correlated component)
- correlation between different Higgs production channels due to common PDF set

TH errors

- For signal XS:
 - **parametric errors** and their propagation
 - **EW corr**, renormalization scheme
 - **QCD \otimes/\oplus EW corr** (factorized or added) ?
 - **QCD scales** (ren: μ_R , fact: μ_F)
define central value and range and scan strategy
- PDF uncertainties
- Background treatment:
LO \times K factor or NLO, interference with signal, etc. ?
- Possible approximations ?

Note: TH errors

CONVERGE ON « PRESCRIPTIONS »

TH and Exp errors

To discuss

- list of
 - theoretical systematic errors
 - central values
 - and their uncertainties
- correlation between the experiments

Strategy:

Up to now, we concentrated on MSSM scenario.

- Shall we go beyond MSSM scenarios?
E.g. NMSSM, Higgsless, Fermiophobic, etc.



Publish or Perish

Yellow Report

- We agreed in Freiburg to write a **CERN Yellow Report**.
- Better to **start the writing now** in order to finalize it at Bari workshop, since the status of inclusive Higgs XS calculations is already well advanced.
(Then ATLAS and CMS can quote the paper.)
- We should compile all references relevant to the Higgs XS.

MAX 10 pages per group.

Precise instructions were given to the editors



Towards YR1, Bari, Nov 2010

Most important: the deadline

Nov 24, 2010

↪ after that no more results can be included, no changes are possible

A quote from <http://www.thefreedictionary.com/deadline> about

“deadline”:

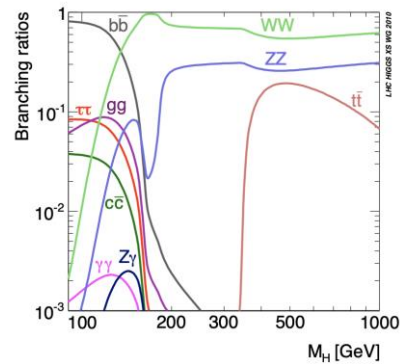
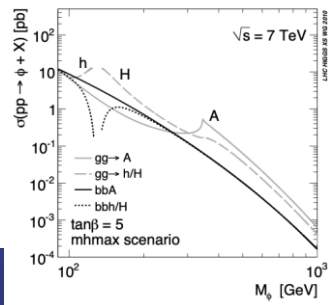
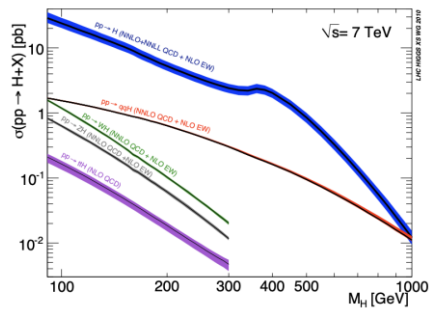
“1. A time limit, as for payment of a debt or completion of an assignment.”

“2. A boundary line in a prison that prisoners can cross only at the risk of being shot.”



New year's eve and ArXiv

<https://arxiv.org/abs/1101.0593>



CERN-2011-002
17 February 2011

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

Handbook of LHC Higgs cross sections:
1. Inclusive observables

Report of the LHC Higgs Cross Section Working Group

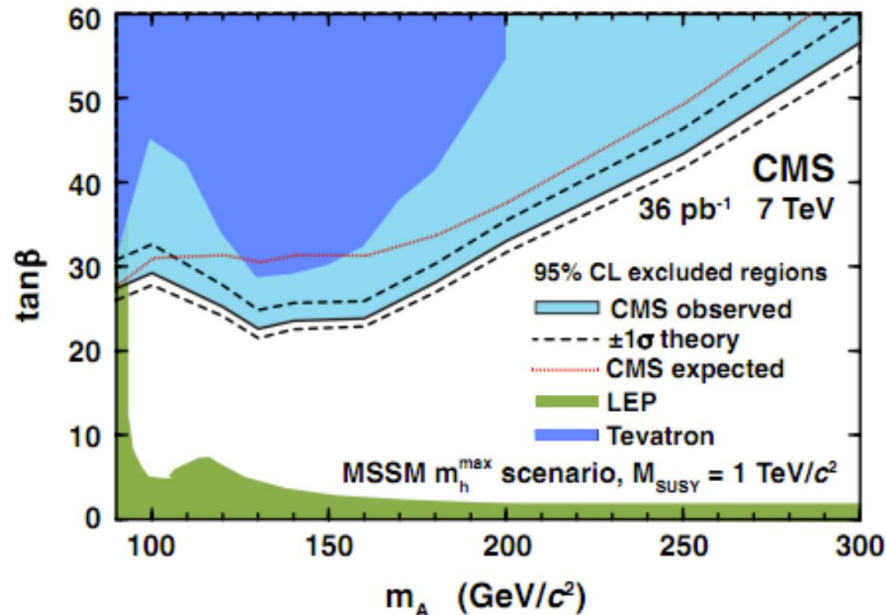
Editors: S. Dittmaier
C. Mariotti
G. Passarino
R. Tanaka

GENEVA
2011

What did work, few examples

YR1 Jan 2011

- First result who used ALL the prescriptions from the LHC H XS wg:



ggH+bbH in MSSM neutral H

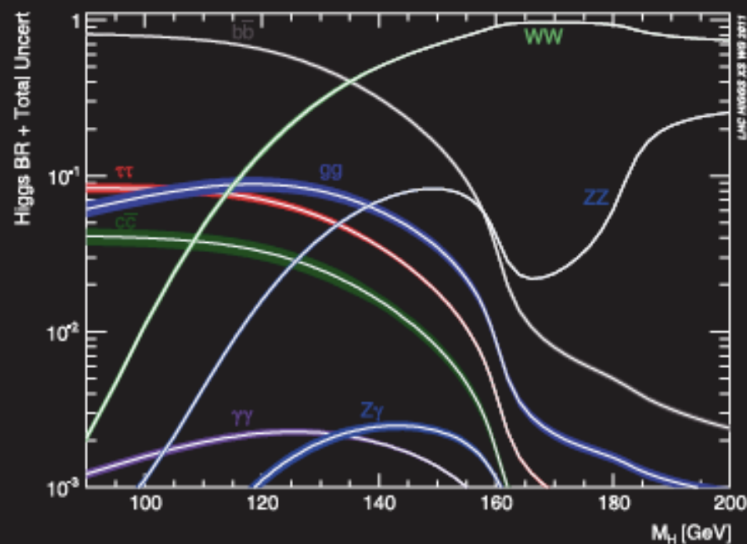
Total THU =
Envelope of the scale Unc +
sum in quadrature of PDF+ α_s Unc

(it has been checked that the sum in quadrature of the PDF+ α_s Unc error is a good approx of the PDF Unc. on the sum of the XS)

- After -> “Santander accord” to use the best from the 4FS and 5FS

BR

Numbers
used also
by Tevatron



Higgs branching ratios and their uncertainties for the low mass range.
From LHC Higgs Cross Section Working Group: Standard model Higgs-boson branching ratios with uncertainties



HqT , Powheg and more

- Rescaling $p_T(H)$ from Powheg with HqT done **BY ALL**
- Powheg for $ZZ^{(*)}$ promised in Bari and now used in Atlas and CMS !
- Jet-bin uncertainty : “BNL accord” used!
- Heavy Higgs Lineshape error uncertainty recommended and adopted in the EXPs results.
Next: correct Lineshape will be used.
- UE uncertainties quoted in most of the analyses



What did not work

- The conveners were not equally active and the burden was **on few**.
 - The Theoretical Uncertainty was not used properly by the Higgs Combination Group:
 - the message did not pass clearly
 - there was un-understandable reluctance
- **Total THU = Linear Sum of
{Scale Unc. + Parametric Unc.}**
- **Scale Uncertainties** have flat distributions: envelope method.
 - All **Parametric Uncertainties** (PU), like PDF, α_s , ... will be added in quadrature (gaussian distr.)



Towards YR2: Differential Distributions

PS + NLO

This area will become important as our next step for exclusive calculations:

- 1 differential distribution for Higgs signal, for example Higgs p_T
- 2 comparison between LO PS MC and NLO MC, how to normalize to NNLO ?
- 3 Can this be studied within the existing working framework ? Study $\gamma\gamma$, WW , ZZ in ggF group, or re-organize the group?

Specific final states

- combine production and decay tools for precision analyses
- dedicated subgroups formed for $H \rightarrow \gamma\gamma, ZZ^{(*)}, WW^{(*)}, \tau\tau, b\bar{b}$ and H^\pm
→ talks this afternoon

First background issues

- signal-background interference for $gg \rightarrow$ heavy Higgs $\rightarrow WW/ZZ \rightarrow 4f$
→ talk by Giampiero
- WH/ZH background, e.g. via $pp \rightarrow Wb\bar{b}$, etc.
- more to come

PDF activities

- more pragmatic/acceptable/reasonable PDF4LHC recipe ?
- update of PDF, $PDF \oplus \alpha_s$ error correlations

→ talk by Stefano

2h for exclusive Higgs XS calculations

- For which Higgs decay channel should we use **PS-MC**?
- How to define **jets, b-jet/ τ , isolation, jet-veto** etc?
- How to use these results in expts with different exp details?
- Prepare tools? Parametrisation? Which distributions are most relevant for which channel(reweightings)?
- How to include signal and background interference effects? With **LO MC**? Then, how to extrapolate to higher order? (e.g.. $qq/gg \rightarrow \gamma\gamma, qq/gg \rightarrow WW/ZZ \rightarrow l\nu/l\nu$ etc.
- How to organize future work and milestones with a careful planning of the interaction **production** groups \otimes **decay** groups?

Issues in MSSM predictions

- Optimal combination of tools for XSs and BRs predictions



The controversial subject:

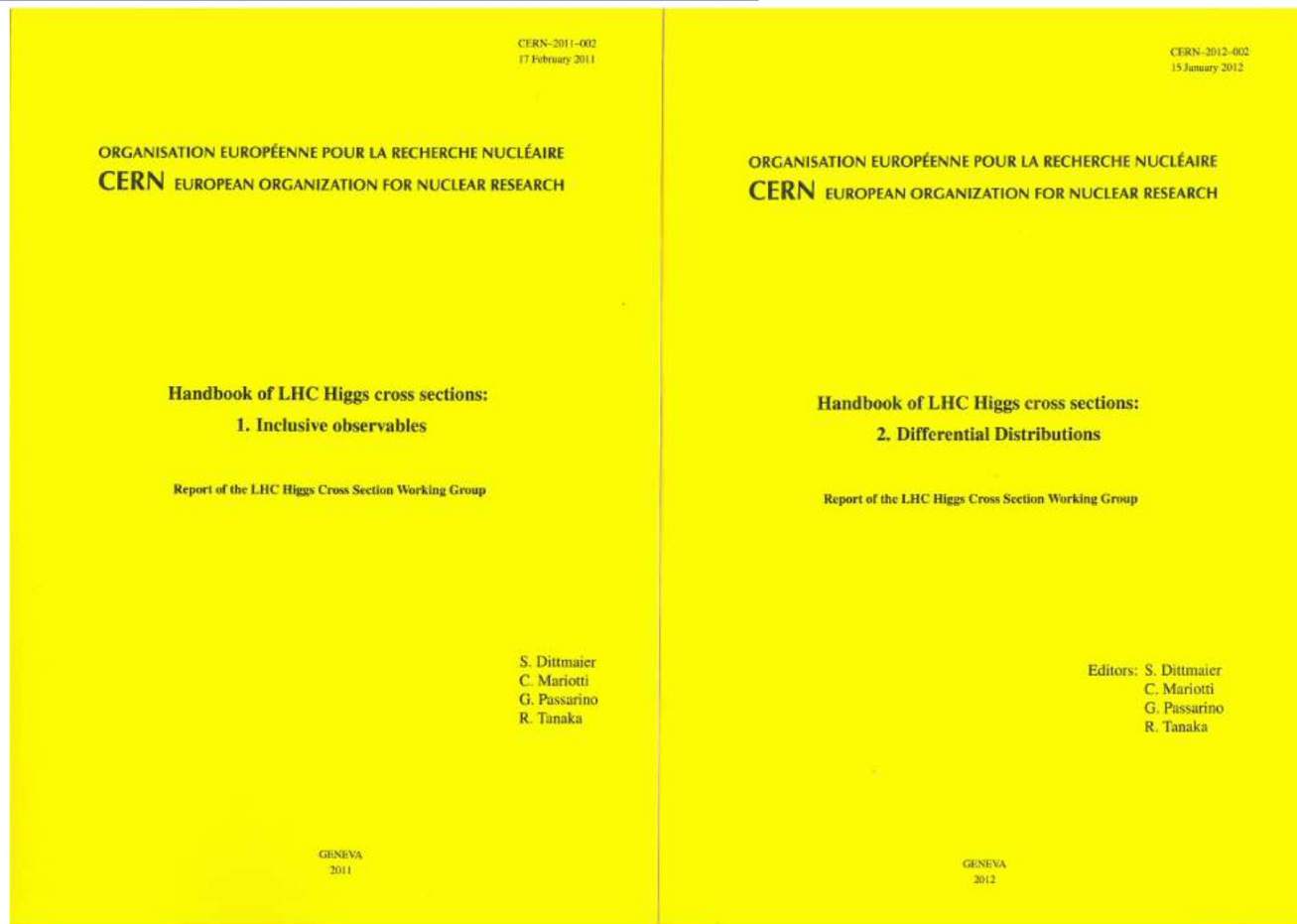
conservative LO improvements \longleftrightarrow rescaled state-of-the-art SM predictions via effective MSSM couplings

- **charged Higgs**: combination of 4FS and 5FS a la Santander ?!
- **ultimately**: solid state-of-the-art predictions for $pp \rightarrow b\bar{b}H$ beyond ad hoc combinations of 4FS/5FS
- **explicit results** beyond m_h^{\max} scenario ?

→ talks by Daniela, Sven

Published the 15-Jan 2012, 1 year after YR1

We should be proud of our achievements!



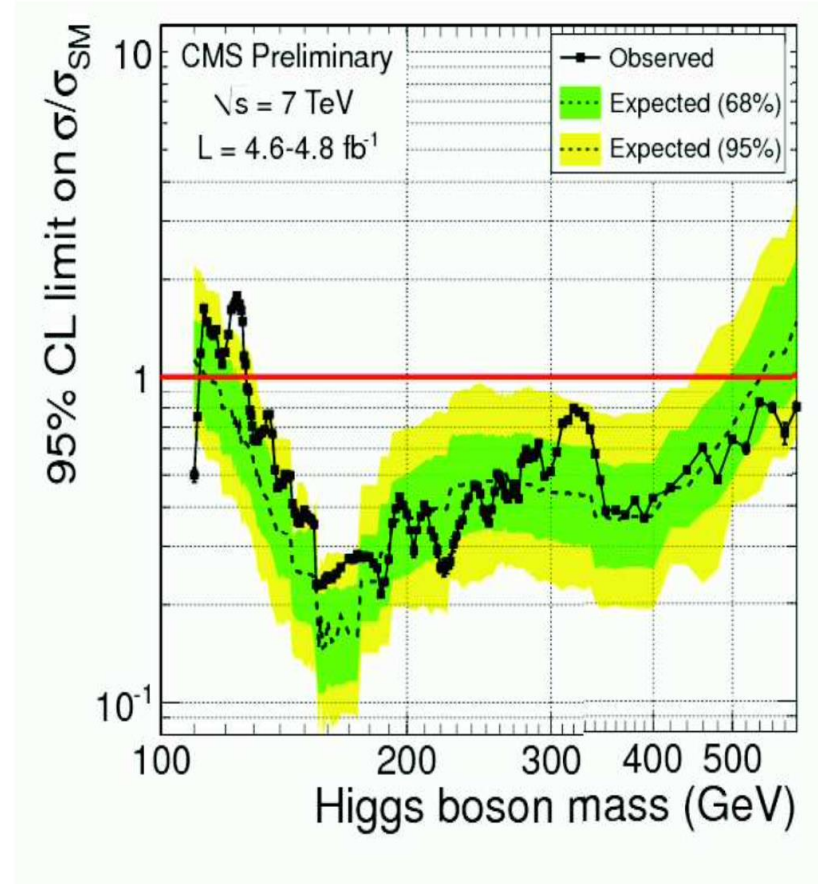
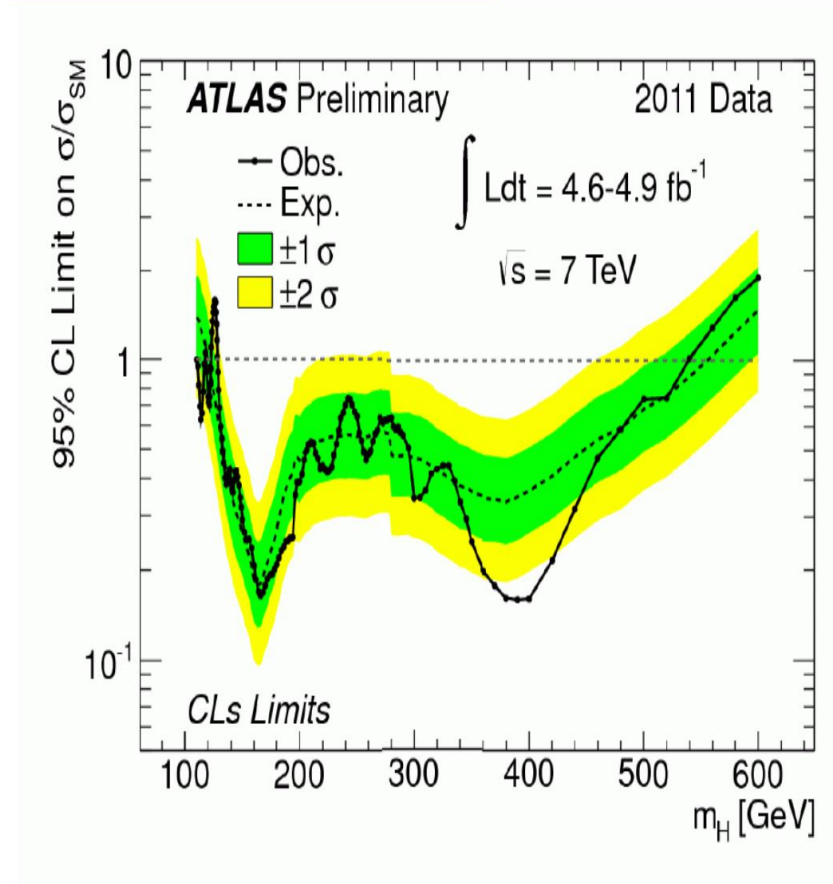
⇒ if you have not done so, pick up your copy!

Sven Heinemeyer, 6th LHC-Higgs-XS workshop, CERN, 24.05.2012



Getting very close !

Data drives priorities!



⇒ prepare property extraction around $M_H \sim 125 \text{ GeV}$



Preparing for YR3

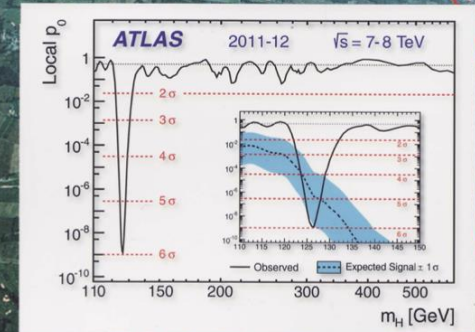
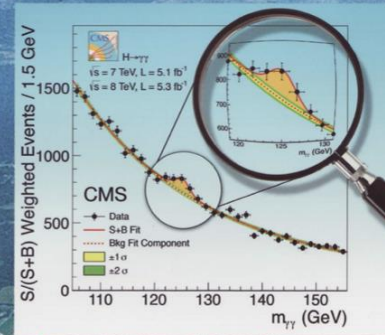
Priorities for 2013 (YR3):

- prepare for 8 TeV
- more on distributions?!
- prepare for property extraction
- improve MSSM and get it flexible
- prepare for heavy SM-like Higgs
- prepare for many B(MS)SM models ($M_H = ?$)
- make use of jets

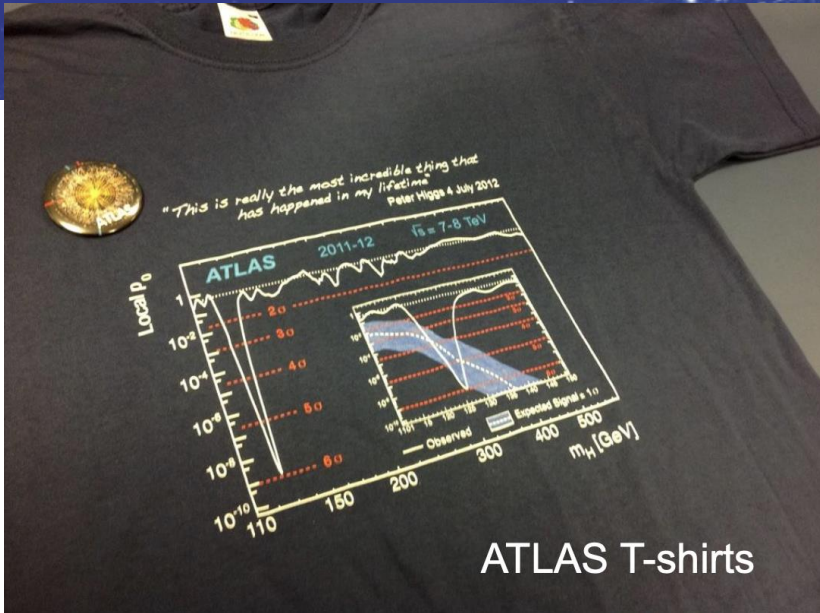




First observations of a new particle in the search for the Standard Model Higgs boson at the LHC

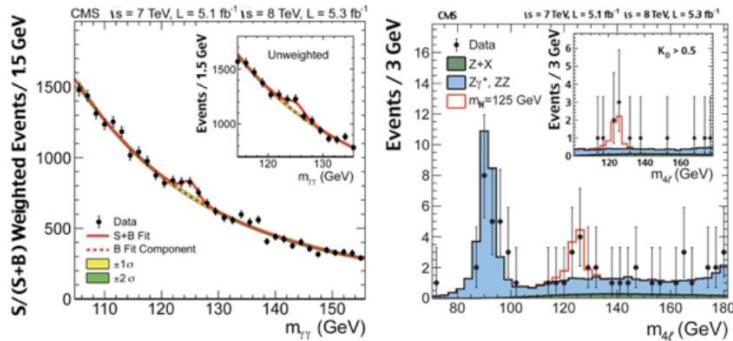


www.elsevier.com/locate/physletb



ATLAS T-shirts

I FOUND A NEW PARTICLE



CMS T-shirts



The 4 July 2012

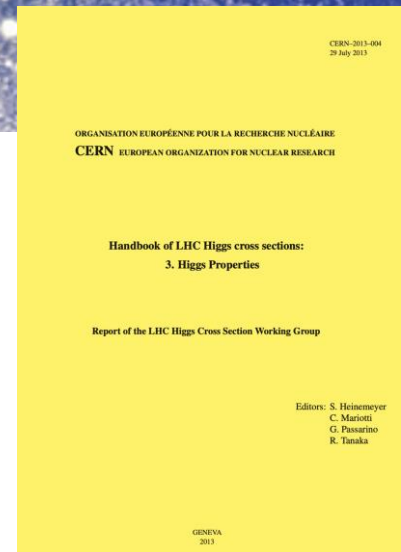
That day we could **compare** the results from ATLAS and CMS and we could claim that we had discovered an Higgs like particle, since we were all using coherently the inputs from the LHCHSWG.



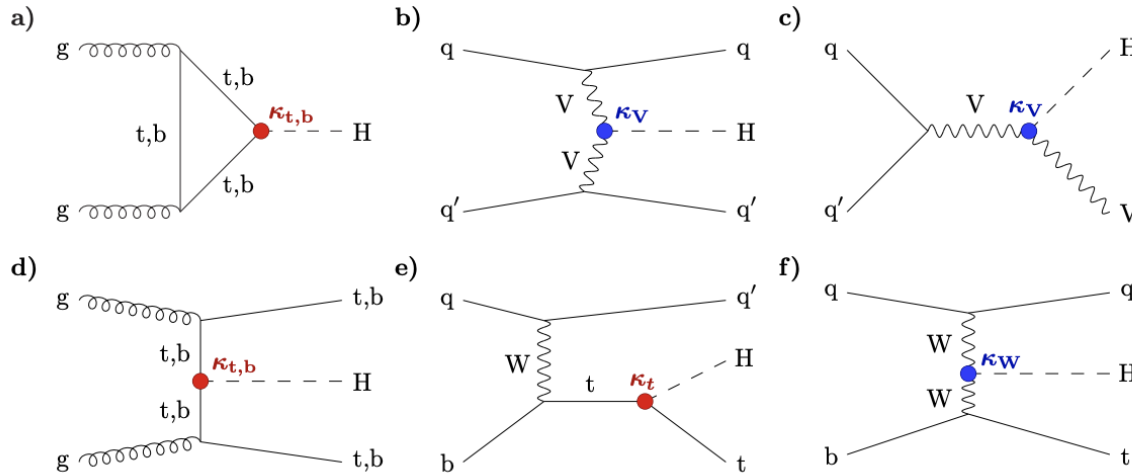
One of the success of the YR3 (2013)

The couplings & the coupling modifiers: the k framework.

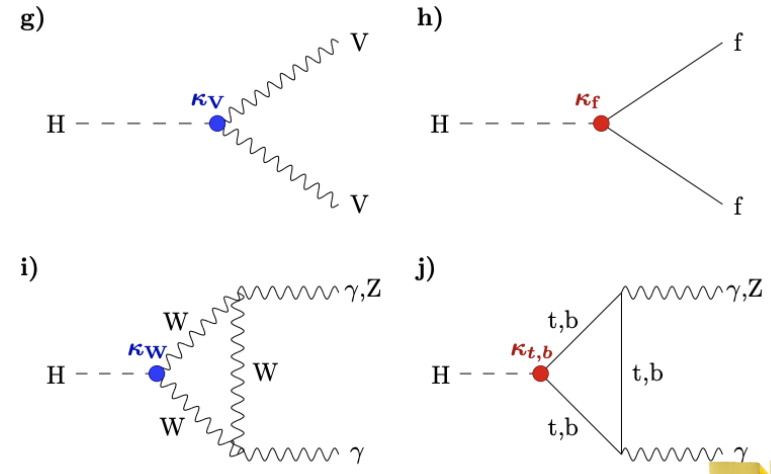
$$\kappa_j^2 = \frac{\sigma^j}{\sigma_{SM}^j} \quad \kappa_j^2 = \frac{\Gamma^j}{\Gamma_{SM}^j}$$



Higgs boson production modes



Higgs boson decay channels



Importance to continue support and perform work (also) on the kappa-framework

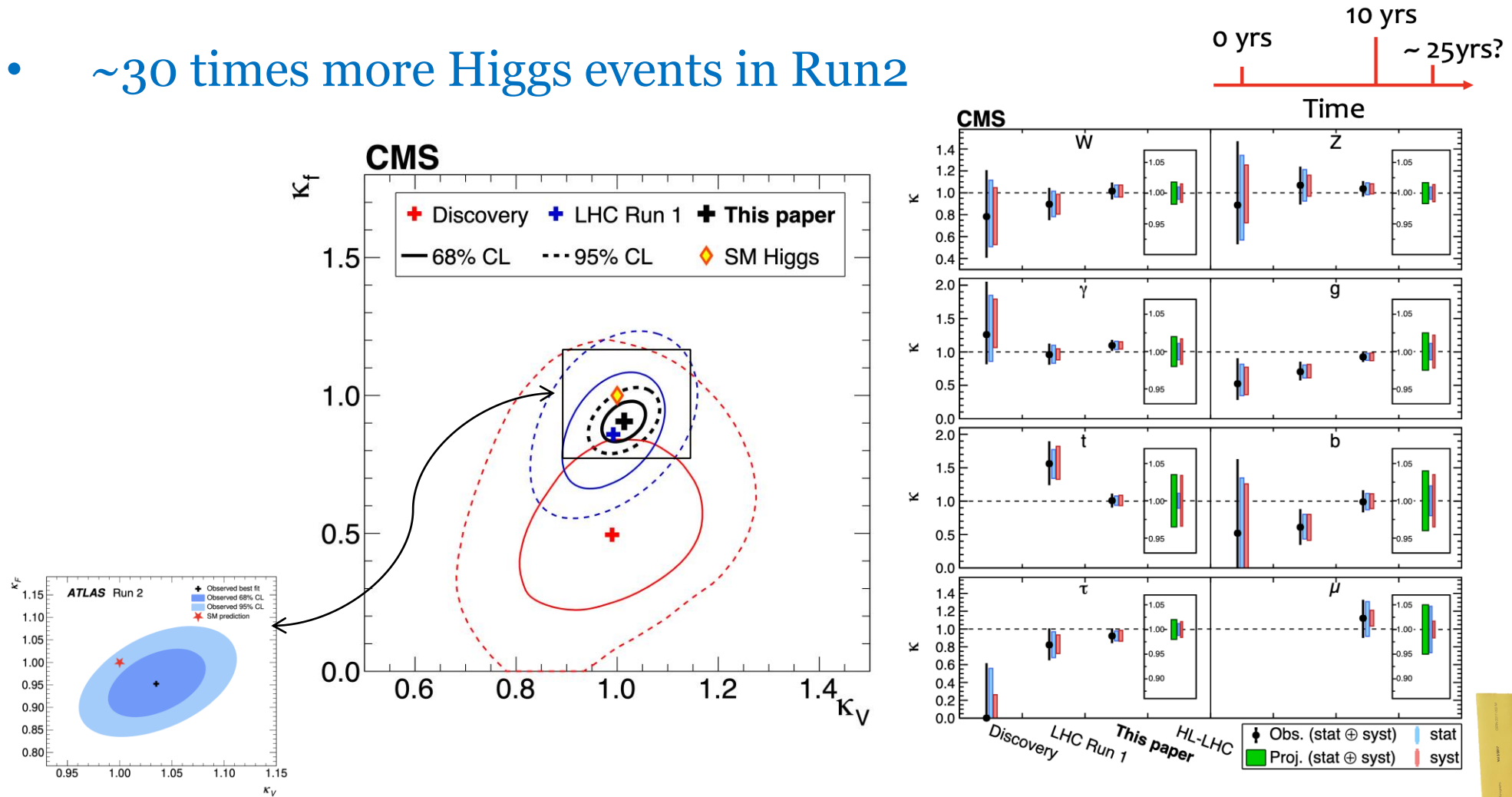
- The k-framework provides a simple language that allow access of the Higgs coupling studies to a wide community, much larger than the Higgs community
 - Easy and intuitive
- It is not in competition with EFT: in case of significant deviation from unity of the kappa parameters, the EFT is the correct framework to evaluate and investigate non-SM effects in Higgs couplings analyses
- It is important to produce the interpretation of Higgs results with the k-framework as part of the legacy studies of LHC, in view of the LHC high luminosity programme, HL-LHC.
- Last but not least, studies of Higgs boson couplings with LHC Run2+Run3 data also with kappa-framework are of paramount importance to prepare the input to the next update of the European Strategy (will take place in 2026-2027) and to update projections for HL-LHC. This input will be crucial to assist the discussion on the future collider strategy in Europe, and at CERN in particular.

A. NISATI



Luminosity, energy and ... ingenuity

- ~30 times more Higgs events in Run2

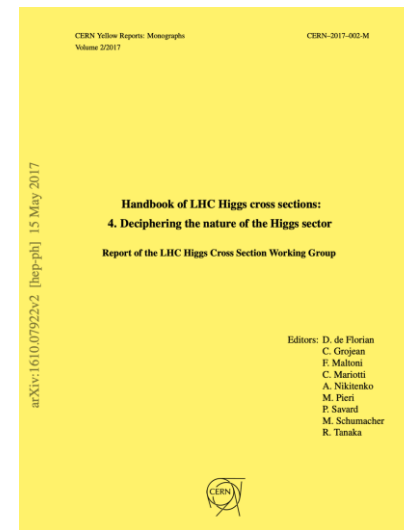


The YR4: a huge amount of work

Inputs		pag 3
PDF	the usual 10 pages	
BR	==	
Prediction at 13 TeV (ggF...) & with jets		pag 29
HH	pag	pag 187
Off-shell		pag 221
EFT		pag 283
PO		pag 399
STXS		pag 437
Fiducial XS		pag 449
BSM (many models)		pag 485

Not all ended as
PRESCRIPTIONS

but maybe
we were asking to much



Twiki, plots, and YR

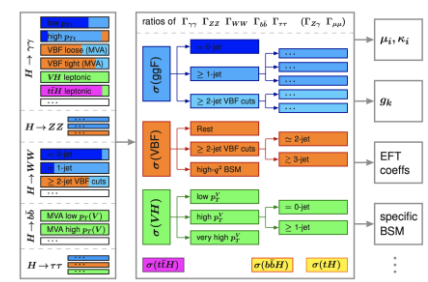
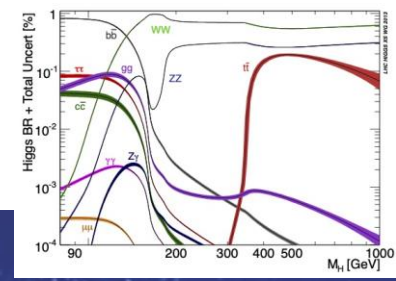
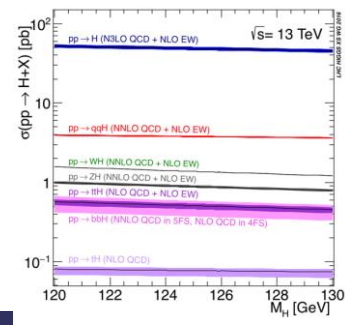
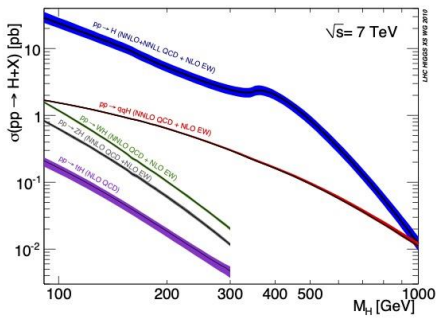
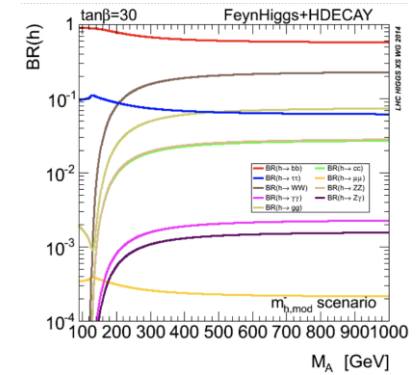
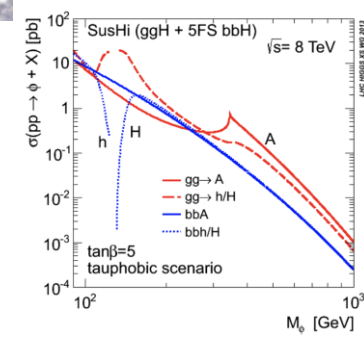
Summarising:

It has been very important to have the twiki pages with the numbers ready asap for the analyses

It has been very nice to have the plots of the LHCHXSWG – *it would be fun to count how many time those plots have been used in talks and paper...*

It has been very important to have all the INPUTS & PRESCRIPTIONS written down and collected in the YR

Yes, it is a lot of work (some period it was >100% of our time !!!) but it payed us back !



Many other followed our example:

“ About the LHC working groups: Yes, this is a very nice example. We astro-particle guys found it so convincing that we copied the initiative in ultra-high energy cosmic ray physics at a kick-off meeting in 2012 at CERN (UHECR2012).

It was the right thing to do at that time for very similar reasons that had motivated you to form e.g. the Higgs X-section WG.

We all learn from one another :-)

All the best, Karl-Heinz (2021)“

Similar for the neutrino group: **NuSTEC**

NuSTEC is a worldwide collaboration of theorists and experimentalists promoting and coordinating studies of neutrino nucleon/nucleus interactions for neutrino oscillation measurements.



THANKS SO MUCH !



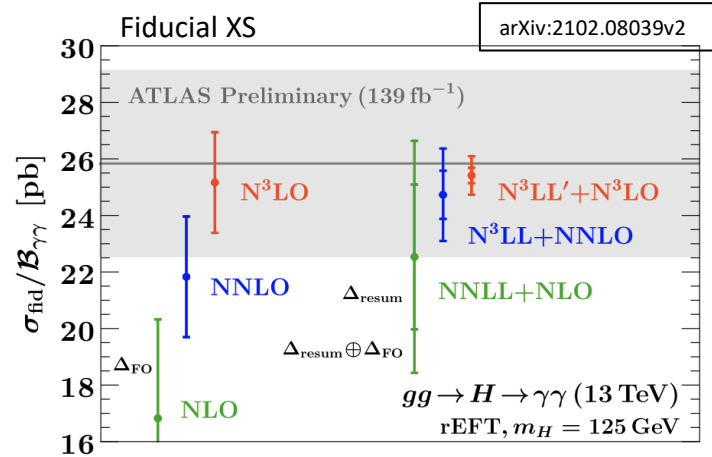
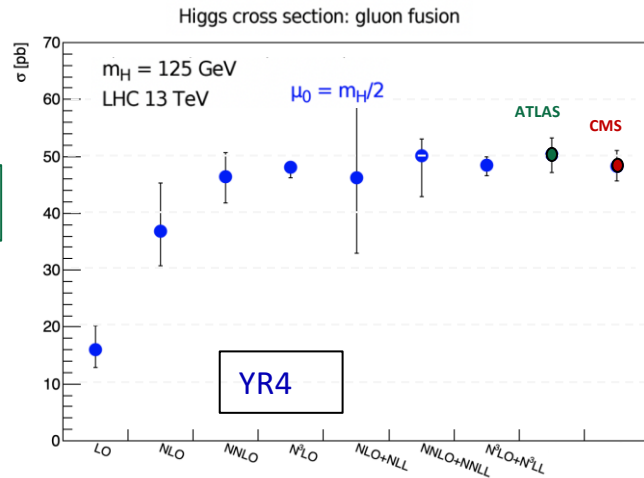
	Published	# Citations	Authors
YR1	Jan. 3, 2011	1,726 citations	64
YR2	Jan. 15, 2012	1,017 citations	141
YR3	July 4, 2013	1,740 citations	157
YR4	Oct. 25, 2016	2,046 citations	~350



2022/09/26

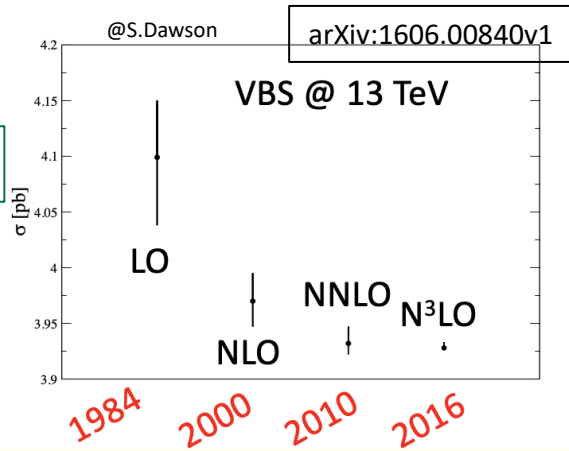
The huge leap of theoretical calculations

ggH



LHCHXSWG

qqH



PDF

