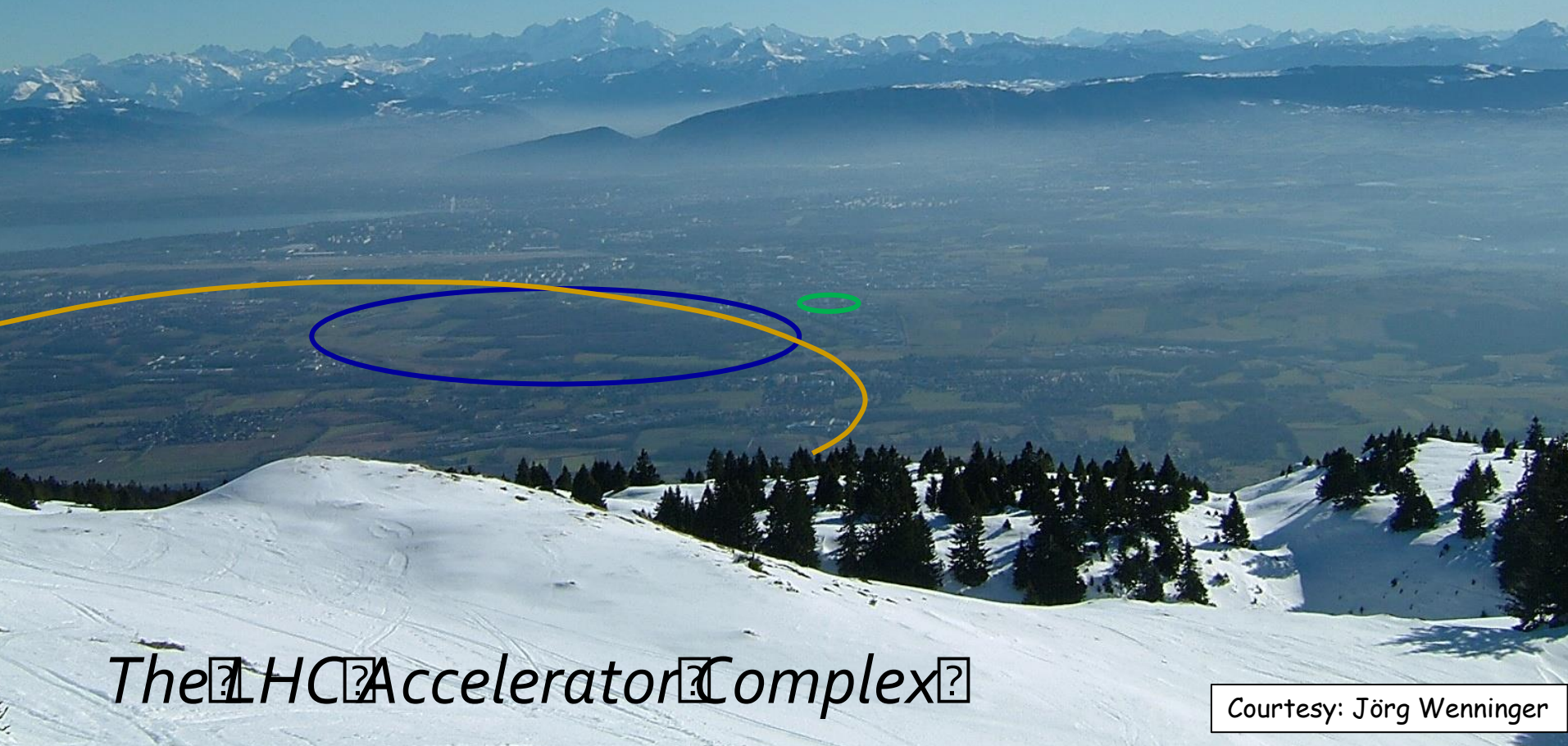


The Physics Landscape

Fabiola Gianotti (CERN, Physics Department)
RLIUP Workshop, 29 October 2013



The LHC Accelerator Complex

Courtesy: Jörg Wenninger

What did we accomplish so far with the LHC ?

What are the outstanding questions ?

How can the HL-LHC address them ?

Note: here only ATLAS and CMS

→ see R. Jacobsson's talk for ALICE and LHCb

What did we accomplish so far ?

Three main results from LHC Run-1

We have consolidated the Standard Model
(wealth of measurements at 7-8 TeV, including the rare, and very sensitive
to New Physics, $B_s \rightarrow \mu\mu$ decay)
→ it works BEAUTIFULLY ...

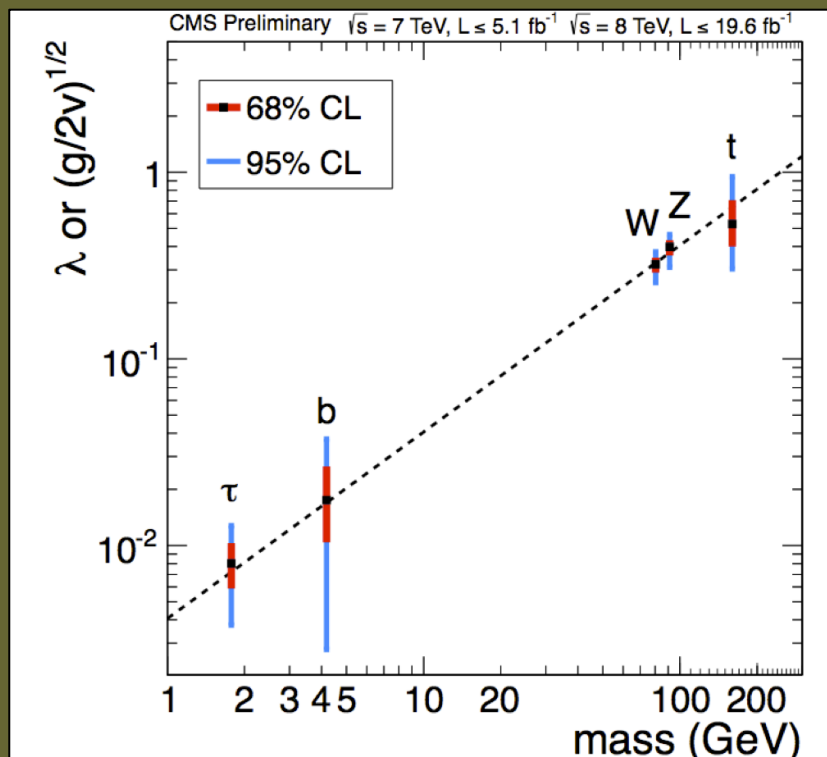
We have completed the Standard Model: Higgs boson discovery
(almost 100 years of theoretical and experimental efforts !)

Is the new particle a Higgs boson ?

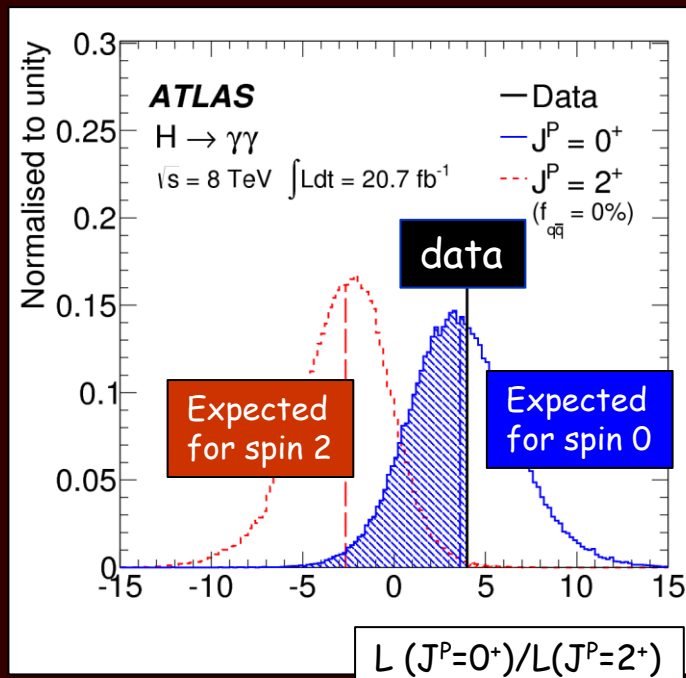
YES !

ATLAS and CMS have verified the two "fingerprints"

1) To accomplish its job (providing mass) it interacts with other particles (in particular W, Z) with strength proportional to their masses



2) It has spin zero (scalar)



Hypothesis	Rejection (C.L.)
0^-	97.8%
1^+	99.97%
1^-	99.7%
2^+	99.9%

Is the new particle a Higgs boson ?

YES !

ATLAS and CMS have verified the two "fingerprints"

Revolutionary:

The first elementary scalar observed in Nature

→ consequences also for Universe evolution (according to cosmology, inflation was triggered by a scalar field)

Traditional:

Until now, fermions (c, b, t, τ) discovered in the US,
bosons (W, Z, H) in Europe ...

What did we accomplish so far ?

Three main results from LHC Run-1

We have consolidated the Standard Model
(wealth of measurements at 7-8 TeV, including the rare, and very sensitive
to New Physics, $B_s \rightarrow \mu\mu$ decay)
→ it works BEAUTIFULLY ...

We have completed the Standard Model: Higgs boson discovery
(almost 100 years of theoretical and experimental efforts !)

We have NO evidence of new physics

Note: the last point implies that, if New Physics exists at the TeV scale and is discovered at $\sqrt{s} \sim 14$ TeV in 2015++, its spectrum is quite heavy → it will require a lot of luminosity (→ HL-LHC 3000 fb^{-1}) and energy to study it in detail → implications for future machines (e.g. most likely not accessible at a 0.5 TeV LC)

This is VERY puzzling



On one hand, the LHC results imply that the SM technically works up to scales much higher than the TeV scale, and limits on new physics seriously challenge the simplest attempts (e.g. minimal SUSY) to fix its weaknesses

On the other hand: there is strong evidence that the SM must be modified with the introduction of new particles and/or interactions at some energy scale to address fundamental outstanding questions, including the following

Why is the Higgs boson so light (so-called “naturalness” or “hierarchy” problem) ?

What is the nature of the matter-antimatter asymmetry in the Universe ?

Why is Gravity so weak ?

And perhaps the most disturbing one ...



The DARK Universe (96%):
73% Dark Energy
23% Dark Matter



Only 4% is ordinary (visible) matter

DARK ... MATTERS !

Some of the outstanding questions ...

Why is the Higgs boson so light (so-called “naturalness” or “hierarchy” problem) ?

What is the nature of the matter-antimatter asymmetry in the Universe ?

Why is Gravity so weak ? Are there additional (microscopic) dimensions responsible for its “dilution” ?

What is the nature of Dark Matter and Dark Energy ?

.... and the “unknown unknown” ...

In addition:

Higgs sector (and the Electroweak Symmetry Breaking mechanism): less known component (experimentally) of the Standard Model → lot of work needed to e.g. understand if it is the minimal mechanism predicted by the SM or something more complex (e.g. more Higgs bosons)

What can the HL-LHC do to address these (and other) questions ?

A LOT: as answers to some of the above questions expected at the TeV scale whose exploration JUST started ... 3000 fb⁻¹ are crucial in several cases

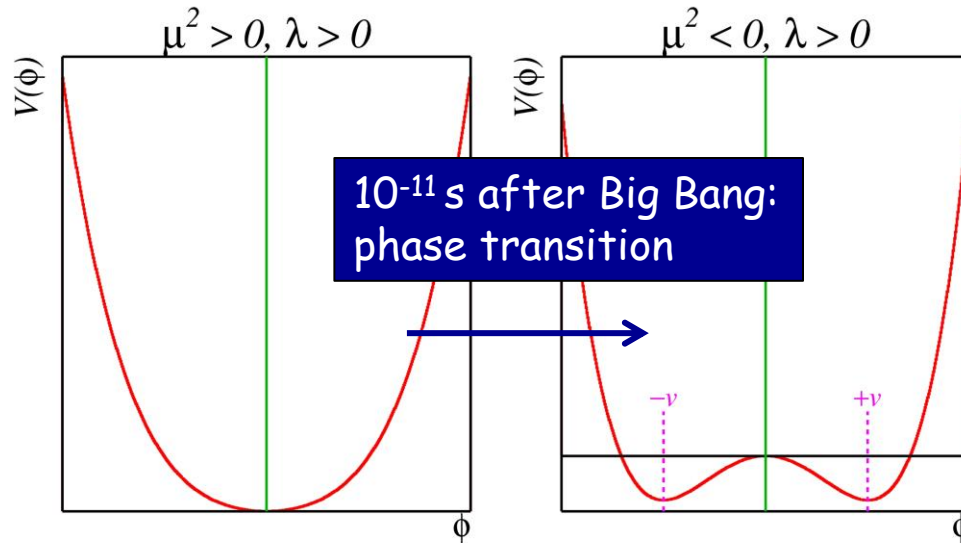
The Brout-Englert-Higgs (Electroweak Symmetry Breaking) mechanism (an oversimplified view ...)



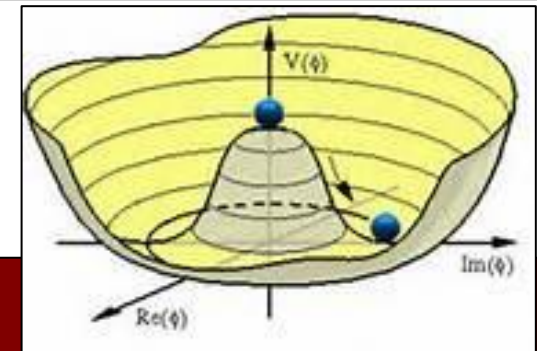
How do elementary particles acquire mass ?
In the SM without Higgs all particles are massless.

Add Higgs potential to SM equations:

$$V(\phi^\dagger \phi) = \mu^2 \phi^2 + \lambda \phi^4 \quad \mu^2 < 0$$



- Just after the Big Bang:
 $\mu^2 > 0 \rightarrow$ ground state (minimum of the potential): $V(\phi)=0$ for $\phi=0$
 \rightarrow no field
 \rightarrow particles are massless (speed=c)
- About 10^{-11} s after Big Bang:
 $T \rightarrow$ below $T_c \rightarrow$ phase transition:
 from $\mu^2 > 0$ to $\mu^2 < 0 \rightarrow$ minimum of potential becomes $\neq 0$: $V(\phi) = -1/4 \lambda v^2$
 for $\phi = \sqrt{-\mu^2/\lambda} = v \sim 250 \text{ GeV}$
 \rightarrow particles interacting with a non-zero field acquire a mass (and are slowed down: $c < 0$)



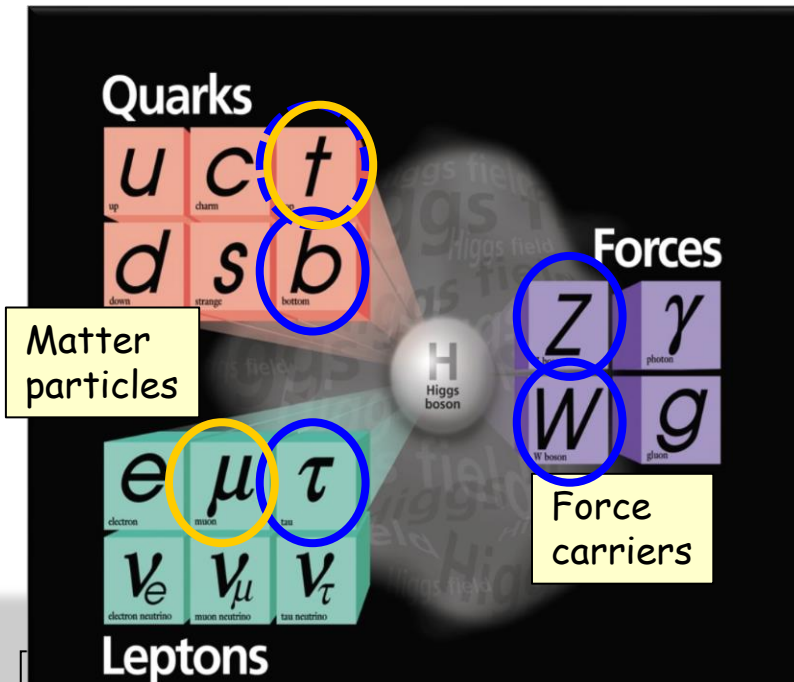
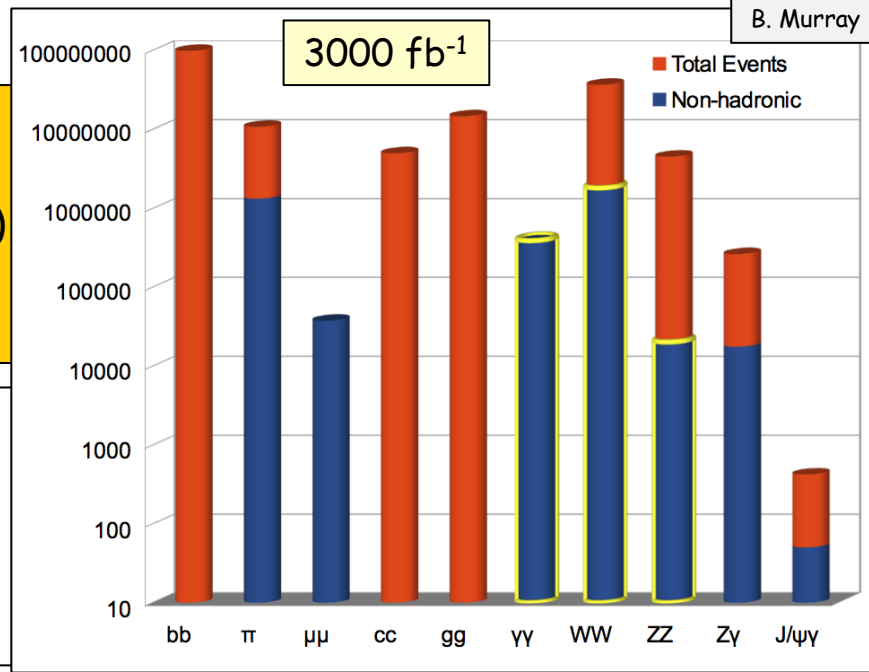
Note:

- Since then (10^{-11} s after the Big Bang) vacuum is not empty
- Electroweak symmetry (i.e. symmetry between weak and electromagnetic interactions) is broken: W and Z acquire mass from interactions with Higgs field, whereas photon remains massless (does not interact with Higgs field) \rightarrow range of forces very different !

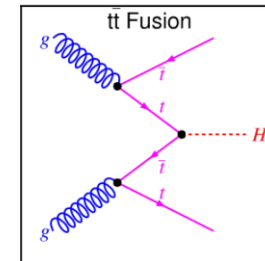
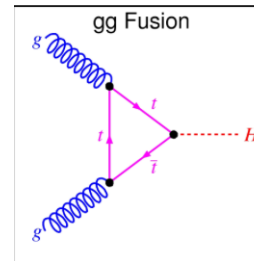
- Measure as many Higgs couplings to fermions and bosons as precisely as possible
- Measure Higgs self-couplings (give access to λ)
- Verify that the Higgs boson fixes the SM problems with W and Z scattering at high E

HL-LHC (3000 fb⁻¹): **THE Higgs factory**:

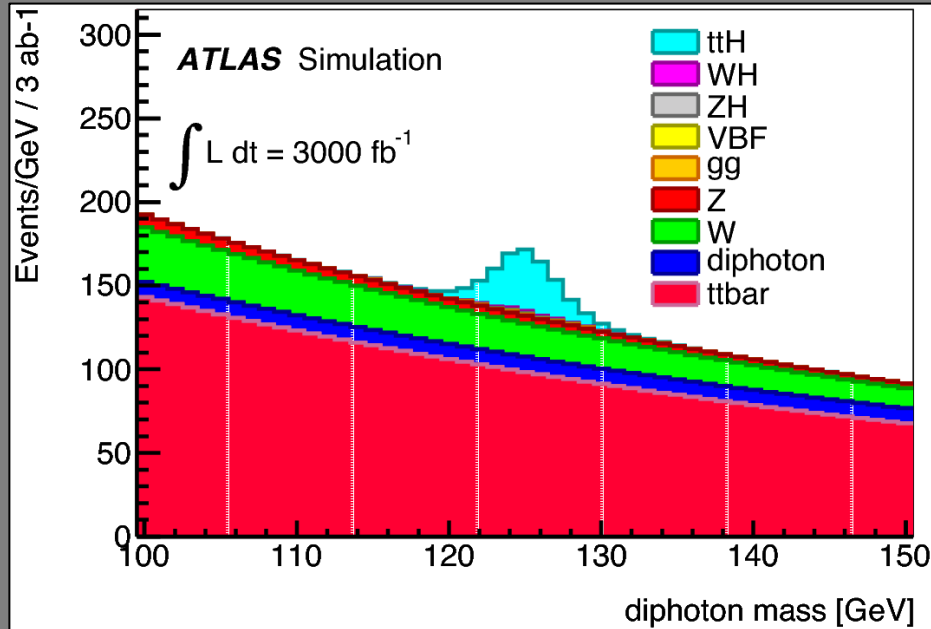
- > 170M Higgs events produced
 - > 3M useful for precise measurements more than (or similar to) ILC/CLIC/TLEP
- Note: today ATLAS+CMS have 1400 Higgs events



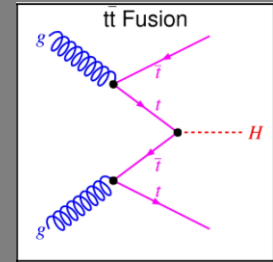
Observed/measured until now (note: top-Higgs coupling indirectly through gg -fusion production)



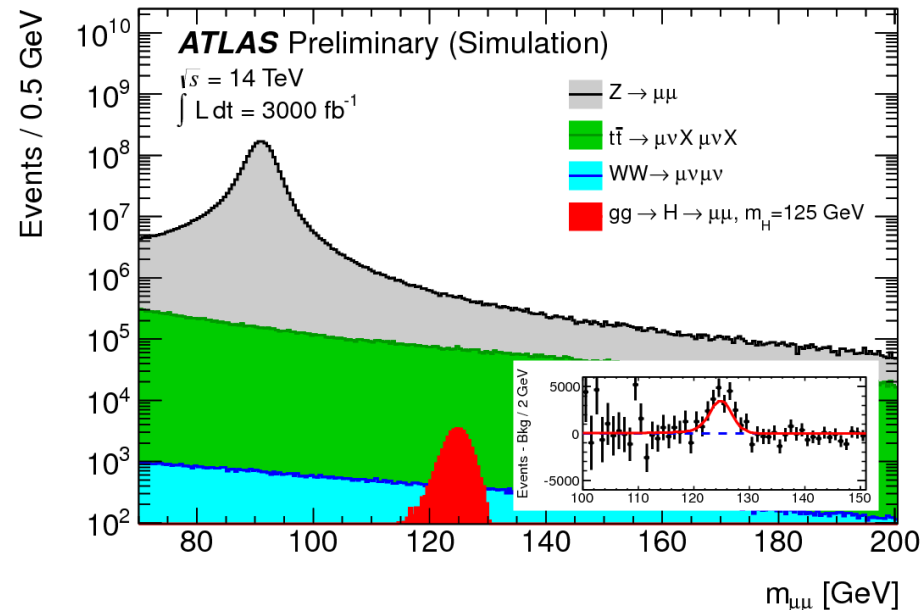
Become accessible with 3000 fb⁻¹: coupling to muons ($H \rightarrow \mu\mu$) and direct coupling to top quark (mainly through $ttH \rightarrow tt\gamma\gamma$)



ttH production
with $H \rightarrow \gamma\gamma$

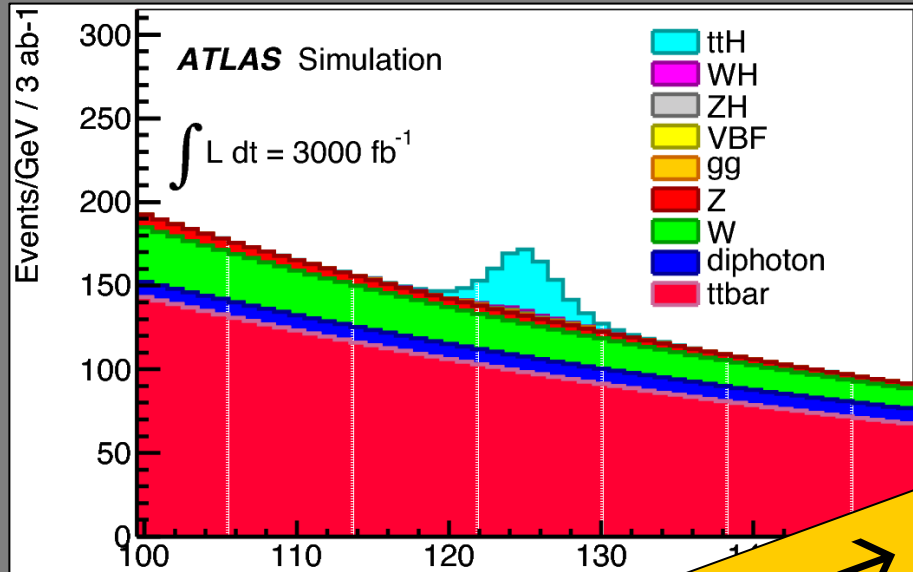


- Gives direct access to Higgs-top coupling (intriguing as top is heavy)
- Today's sensitivity: 6xSM cross-section
- With 3000 fb⁻¹ expect 200 signal events ($S/B \sim 0.2$) and $> 5\sigma$
- Higgs-top coupling can be measured to about 10%

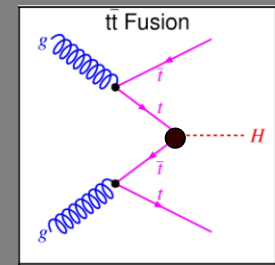


$H \rightarrow \mu\mu$

- Gives direct access to Higgs couplings to fermions of the second generation.
- Today's sensitivity: 8xSM cross-section
- With 3000 fb⁻¹ expect 17000 signal events (but: $S/B \sim 0.3\%$) and $\sim 7\sigma$ significance
- Higgs-muon coupling can be measured to about 10%

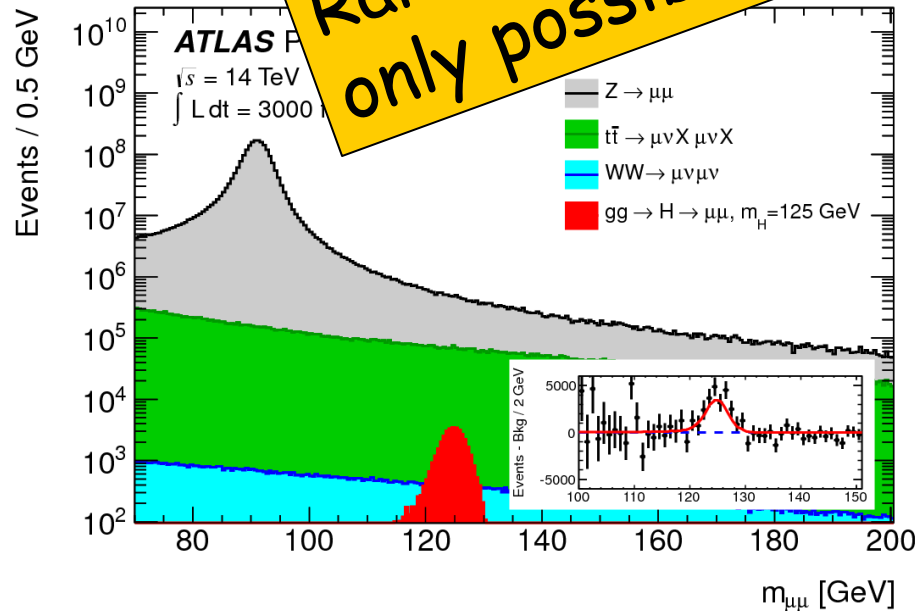


ttH production
with $H \rightarrow \gamma\gamma$



Rare processes \rightarrow sensitive studies
only possible with 3000 fb^{-1}

- Gives direct access to Higgs-top coupling (if top is heavy)
- Today's sensitivity: 8xSM cross-section
- With 3000 fb^{-1} expect 200 signal events
- Higgs-top coupling can be measured to about 10%



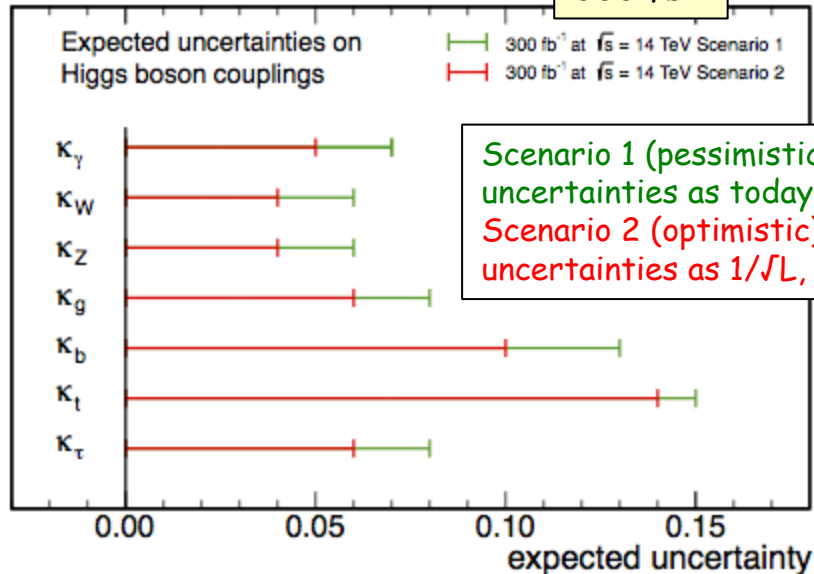
$H \rightarrow \mu\mu$

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Measurements of Higgs couplings

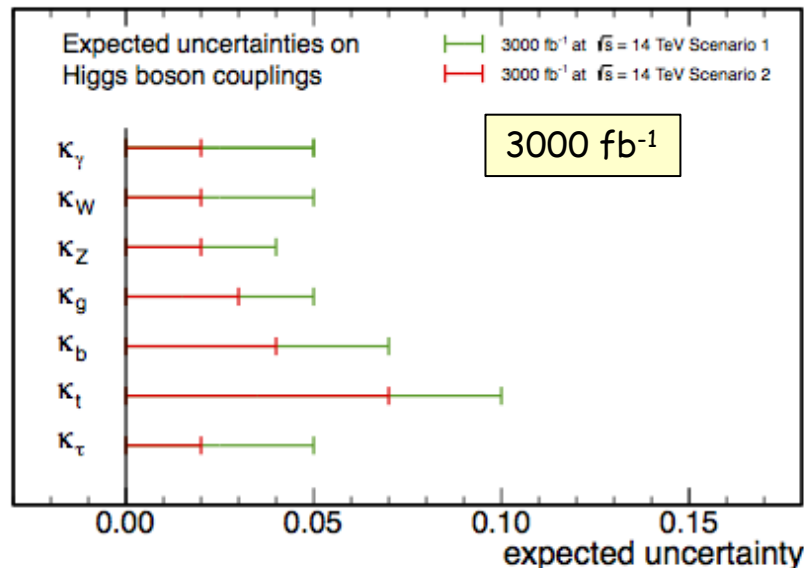
CMS Projection

300 fb⁻¹



CMS Projection

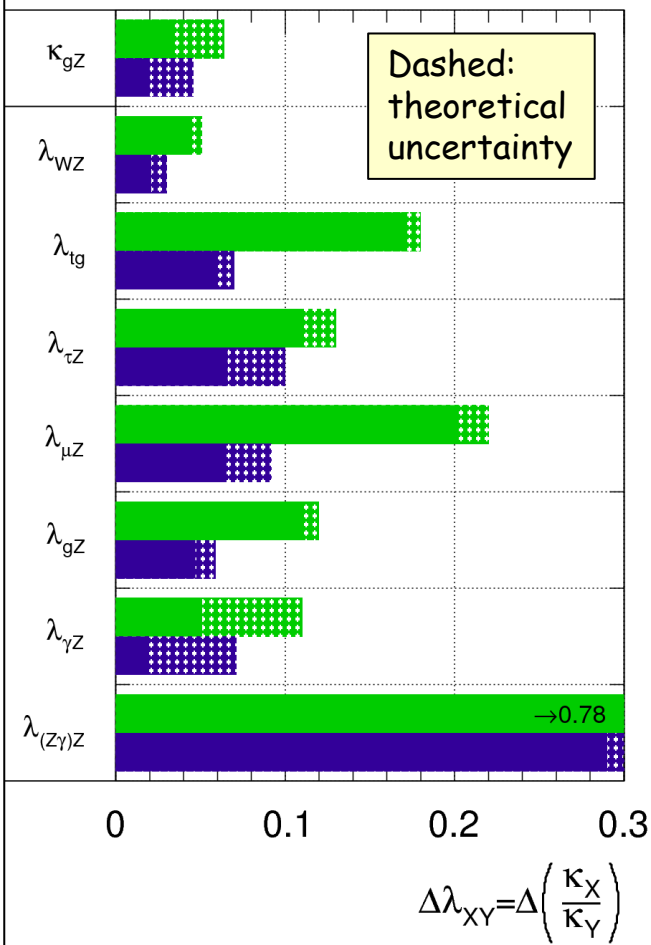
3000 fb⁻¹



k_i = measured coupling normalized to SM prediction
 $\lambda_{ij} = k_i / k_j$

ATLAS Simulation Preliminary

$\sqrt{s} = 14$ TeV: $\int L dt = 300 \text{ fb}^{-1}$; $\int L dt = 3000 \text{ fb}^{-1}$



Main conclusions:

- 3000 fb⁻¹: typical precision 2-10% per experiment (except rare modes)
→ 1.5-2x better than with 300 fb⁻¹
- Crucial to also reduce theory uncertainties

How well should the Higgs couplings be measured ?

Brock/Peskin, Snowmass 2013

Facility	LHC	HL-LHC	ILC500	ILC500-up	ILC1000	ILC1000-up	CLIC	TLEP (4 IPs)
\sqrt{s} (GeV)	14,000	14,000	250/500	250/500	250/500/1000	250/500/1000	350/1400/3000	240/350
$\int \mathcal{L} dt$ (fb $^{-1}$)	300/expt	3000/expt	250+500	1150+1600	250+500+1000	1150+1600+2500	500+1500+2000	10,000+2600
κ_γ	5 – 7%	2 – 5%	8.3%	4.4%	3.8%	2.3%	–/5.5/<5.5%	1.45%
κ_g	6 – 8%	3 – 5%	2.0%	1.1%	1.1%	0.67%	3.6/0.79/0.56%	0.79%
κ_W	4 – 6%	2 – 5%	0.39%	0.21%	0.21%	0.13%	1.5/0.15/0.11%	0.10%
κ_Z	4 – 6%	2 – 4%	0.49%	0.24%	0.44%	0.22%	0.49/0.33/0.24%	0.05%
κ_ℓ	6 – 8%	2 – 5%	1.9%	0.98%	1.3%	0.72%	3.5/1.4/<1.3%	0.51%
κ_d	10 – 13%	4 – 7%	0.93%	0.51%	0.51%	0.31%	1.7/0.32/0.19%	0.39%
κ_u	14 – 15%	7 – 10%	2.5%	1.3%	1.3%	0.76%	3.1/1.0/0.7%	0.69%

Scenarios with no new particles observable at LHC

HL-LHC (3000 fb $^{-1}$): percent level
 → some sensitivity to physics beyond SM

ILC/TLEP: sub-percent level
 Note: hard to believe that New Physics will manifest itself through tiny effects on Higgs couplings and nothing else ...unless very heavy (but then how to interpret the observed deviations ?)

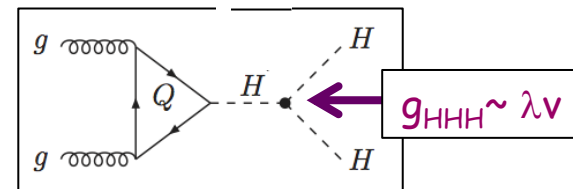
	κ_V	κ_b	κ_γ
Singlet Mixing	~ 6%	~ 6%	~ 6%
2HDM	~ 1%	~ 10%	~ 1%
Decoupling MSSM	~ –0.0013%	~ 1.6%	< 1.5%
Composite	~ –3%	~ –(3 – 9)%	~ –9%
Top Partner	~ –2%	~ –2%	~ –3%

How well should the Higgs couplings be measured ?

Brock/Peskin, Snowmass 2013

Facility	LHC	HL-LHC	ILC500	ILC500-up	ILC1000	ILC1000-up	CLIC	TLEP (4 IPs)
\sqrt{s} (GeV)	14,000	14,000	250/500	250/500	250/500/1000	250/500/1000	350/1400/3000	240/350
$\int \mathcal{L} dt$ (fb $^{-1}$)	300/expt	3000/expt	250+500	1150+1600	250+500+1000	1150+1600+2500	500+1500+2000	10,000+2600
κ_γ	5 – 7%	2 – 5%	8.3%	4.4%	3.8%	2.3%	–/5.5/<5.5%	1.45%
κ_g	6 – 8%	3 – 5%	2.0%	1.1%	1.1%	0.67%	3.6/0.79/0.56%	0.79%
κ_W	4 – 6%	2 – 5%	0.39%	0.21%	0.21%	0.13%	1.5/0.15/0.11%	0.10%
κ_Z	4 – 6%	2 – 4%	0.49%	0.24%	0.44%	0.22%	0.49/0.33/0.24%	0.05%
κ_ℓ	6 – 8%	2 – 5%	1.9%	0.98%	1.3%	0.72%	3.5/1.4/<1.3%	0.51%
κ_d	10 – 13%	4 – 7%	0.93%	0.51%	0.51%	0.31%	1.7/0.32/0.19%	0.39%
κ_u	14 – 15%	7 – 10%	2.5%	1.3%	1.3%	0.76%	3.1/1.0/0.7%	0.69%

HL-LHC (3000 fb $^{-1}$): percent level
 \rightarrow good sensitivity to physics beyond SM
 ILC/TLEP: sub-percent level
 Note: hard to believe that New Physics will manifest itself through tiny effects on Higgs couplings and nothing else
 ...unless very heavy (but then how to interpret the observed deviations ?)



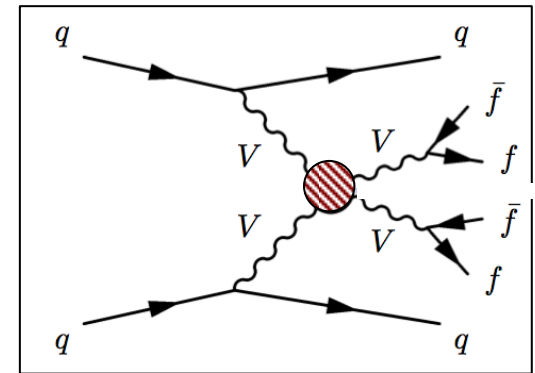
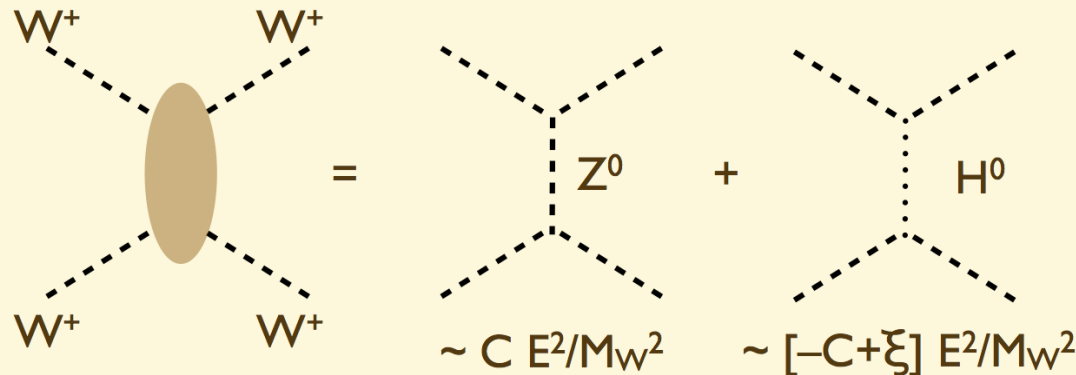
Higgs self-couplings difficult to measure at any facility (energy is mainly needed ..)

	HL-LHC	ILC500	ILC500-up	ILC1000	ILC1000-up	CLIC1400	CLIC3000	HE-LHC	VLHC
\sqrt{s} (GeV)	14000	500	500	500/1000	500/1000	1400	3000	33,000	100,000
$\int \mathcal{L} dt$ (fb $^{-1}$)	3000	500	1600 †	500/1000	1600/2500 †	1500	+2000	3000	3000
λ		83%	46%	21%	13%	21%	10%	20%	8%

HL-LHC studies not completed yet ... ~30% precision expected, but need 3000 fb $^{-1}$

Vector-Boson ($V=W, Z$) Scattering at large m_{VV} \rightarrow insight into EWSB dynamics

M. Mangano



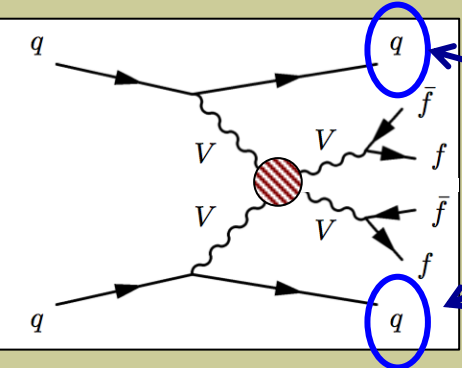
First process (Z exchange) becomes unphysical ($\sigma \sim E^2$) at $m_{WW} \sim \text{TeV}$ if no Higgs, i.e. if second process (H exchange) does not exist. In the SM with Higgs: $\xi = 0$

CRUCIAL "CLOSURE TEST" of the SM:

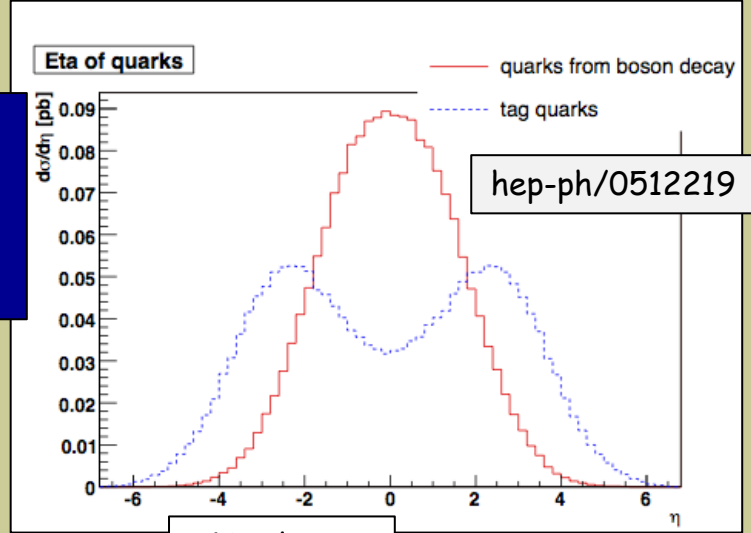
- ☐ Verify that Higgs boson accomplishes the job of canceling the divergences
- ☐ Does it accomplish it fully or partially? I.e. is $\xi = 0$ or $\xi \neq 0$?

If $\xi \neq 0 \rightarrow$ new physics (resonant and/or non-resonant deviations) \rightarrow important to study as many final states as possible (WW, WZ, ZZ) to constrain the new (strong) dynamics

Requires energy and luminosity \rightarrow first studies possible with design LHC, but HL-LHC 3000 fb^{-1} needed for sensitive measurements of SM cross section or else more complete understanding of new dynamics



Tagging these forward quarks (jets) is crucial signature to distinguish this process from SM QCD background

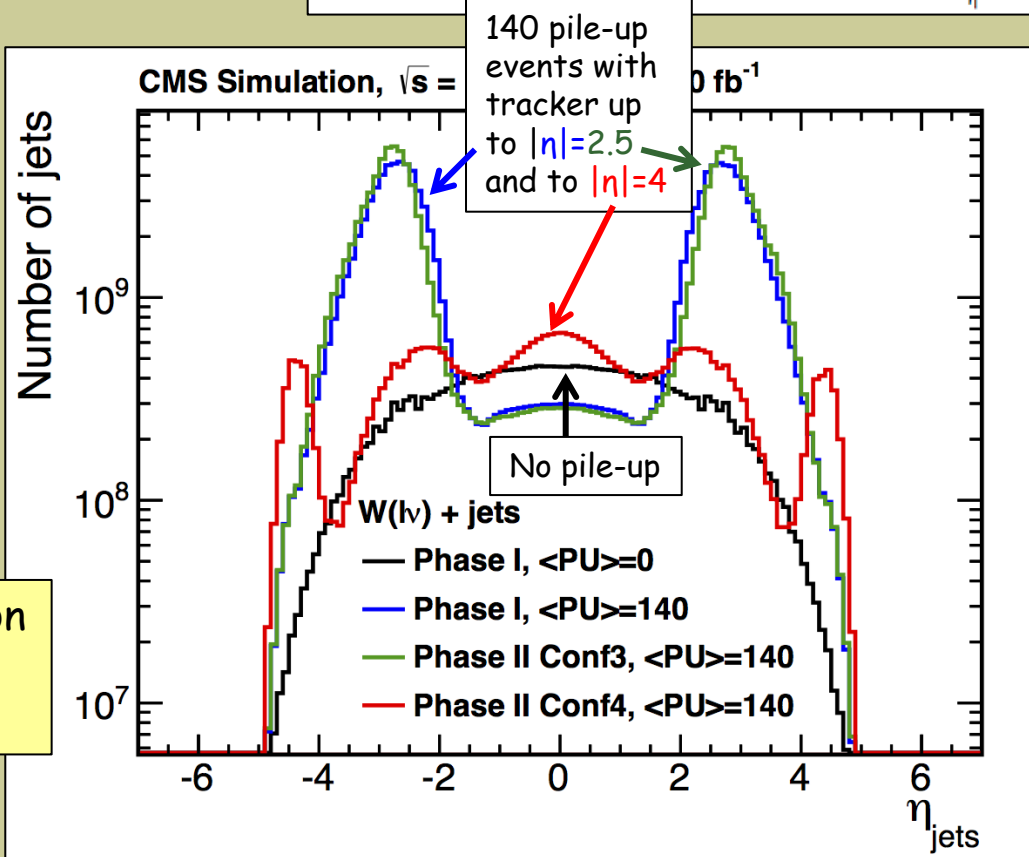


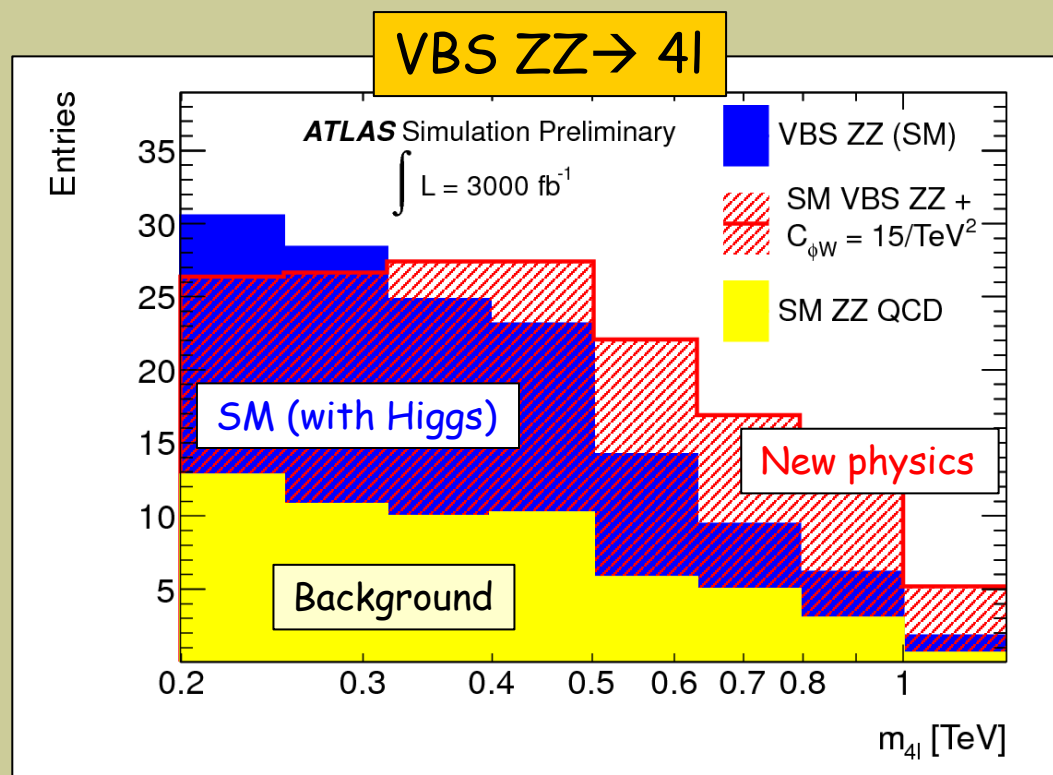
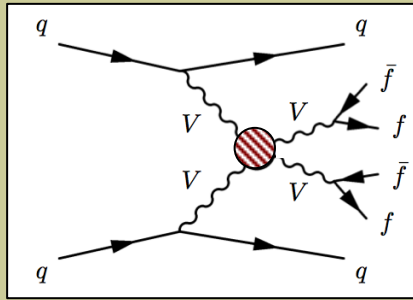
However: huge pile-up in the forward regions

Extension of HL-LHC trackers from $|\eta| \leq 2.5$ to $|\eta| \leq 4$ (considered by both experiments) to reject pile-up jets (not associated to the primary vertex)

Jets rapidity distribution in $W \rightarrow l\nu$ events (i.e. no VV contribution)

$p_T(\text{jet}) > 30 \text{ GeV}$





CONCLUSIONS

If no new physics: good behaviour of SM cross section (i.e. no divergence thanks to Higgs contribution) can be measured to 30% (10%) with 300 (3000) fb^{-1}

If new physics exists: sensitivity increases by factor of ~ 2 (in terms of scale and coupling reach) between 300 and 3000 fb^{-1}

→ HL-LHC is crucial for a sensitive study of EWSB dynamics

The problem of the stability of the Higgs mass a.k.a "naturalness"

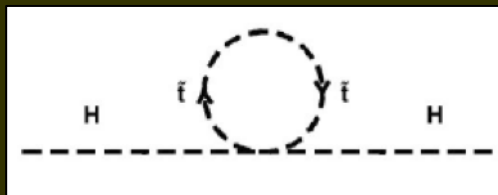
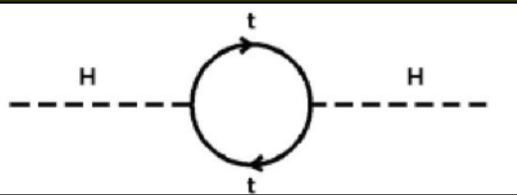
As any other particle (e^\pm , ...) in quantum mechanics Higgs mass receives radiative corrections

$$M_H^2 = M_{\text{bare}}^2 + \left(\text{Higgs loop} \right) + \left(\text{top quark loop} \right) + \left(\text{W/Z loop} \right)$$

Mostly small, except top contribution: $\sim m_t^2 \Lambda^2$
 Λ^2 = energy scale up to which the SM is valid
 (or, equivalently, new physics sets in)

2 solutions

- 1) "Naturalness": Higgs mass stabilized by new physics that cancel the divergences.
 E.g. SUSY: the contribution of the supersymmetric partner of the top (stop) gives rise to the same contribution with opposite sign \rightarrow cancellation



BUT: cancellation only works if stop mass not much larger than top mass \rightarrow this is one of most compelling motivations for SUSY (or new physics) at TeV scale

- 2) "Fine tuning": the bare mass cancels the radiative corrections \rightarrow this becomes more and more "acrobatic" the higher the scale Λ up to which SM is valid (w/o new physics)

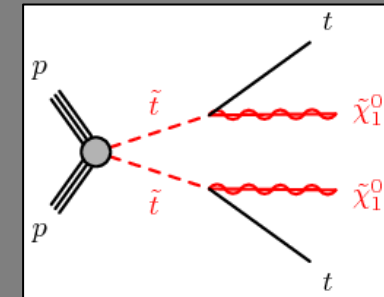
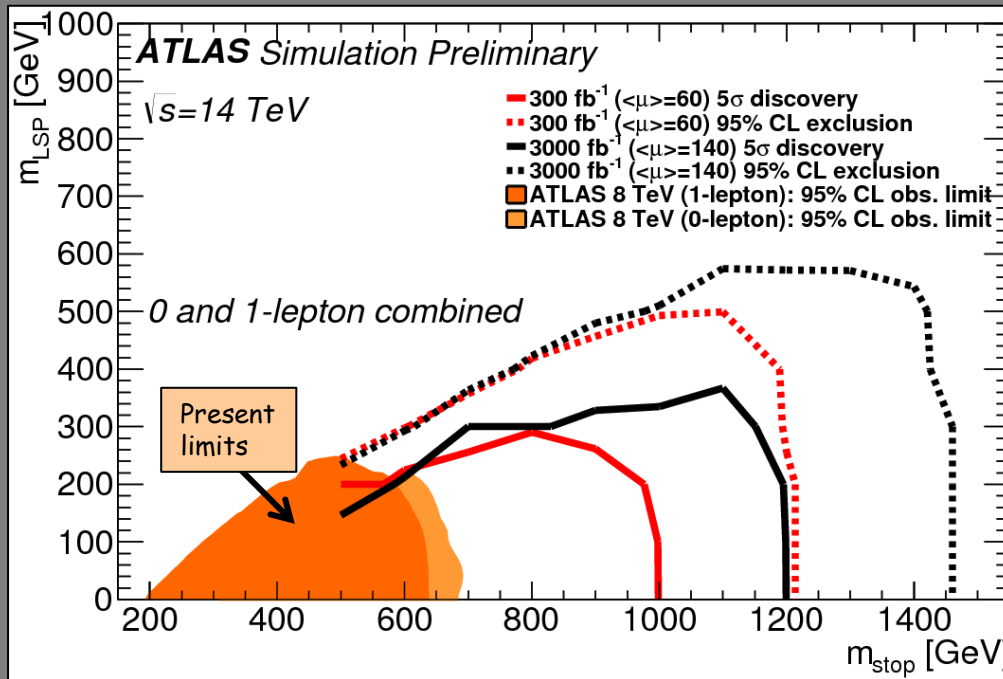
E.g. $\Lambda = 10 \text{ TeV} \rightarrow M^2(\text{rad. corr}) = 8265625 \text{ GeV}^2 \rightarrow$ need fine-tuned $M_{\text{bare}}^2 = 8281250 \text{ GeV}^2$
 to get $M_H^2 = (125 \text{ GeV})^2 = 15262 \text{ GeV}^2$

$\Lambda = 10^{19} \text{ GeV} \rightarrow$ need fine tuning of M_{bare} to the 33rd digit !! \rightarrow UNNATURAL

We expect Nature to be "natural" → naturalness is one of the main motivations for expecting new physics at TeV scale, hence for the LHC



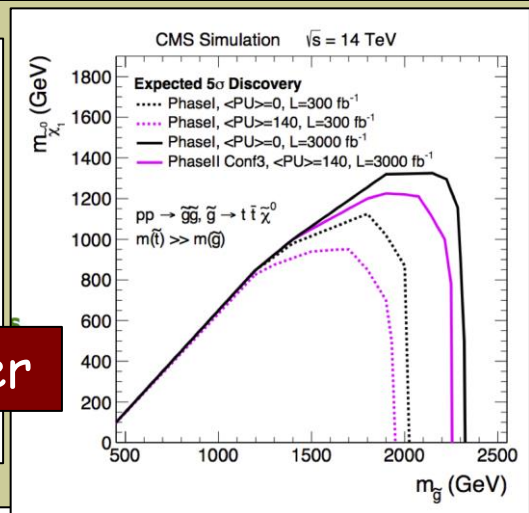
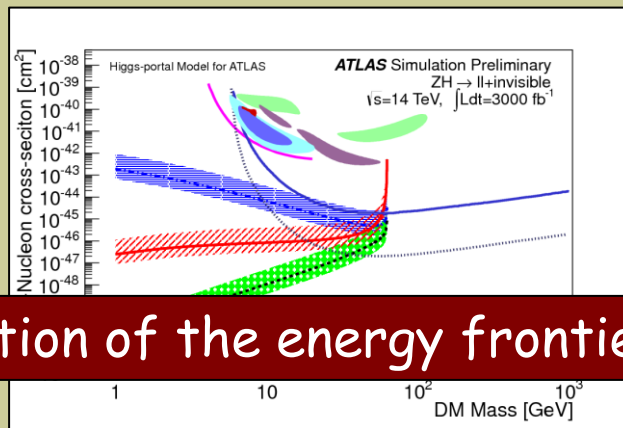
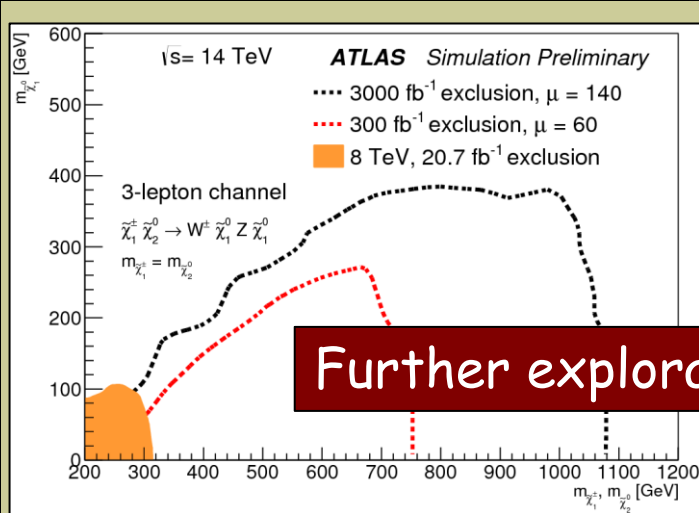
SUSY searches: to stabilize the Higgs mass, the stop should not be much heavier than $\sim 1\text{-}1.5$ TeV (note: the rest of the SUSY spectrum can be heavier)



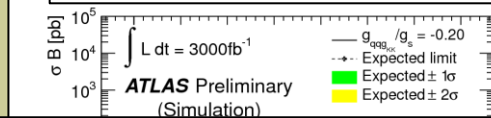
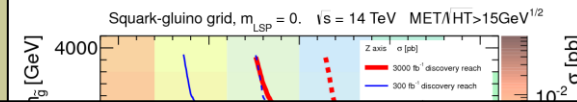
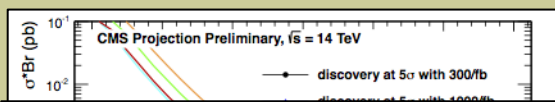
Mass reach extends by ~ 200 GeV from 300 to 3000 fb⁻¹
→ most of interesting mass range will be covered !

Philosophical/metaphysical discussions (for the coffee break ...):

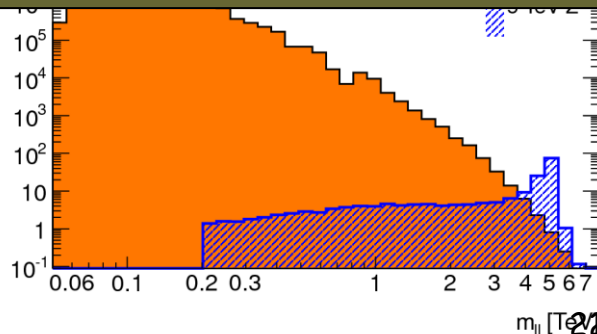
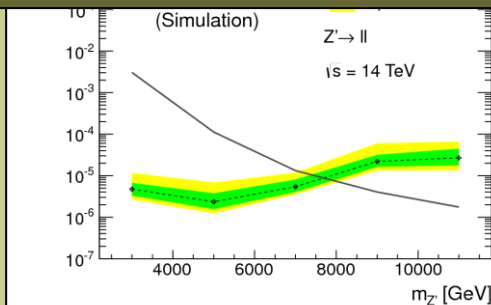
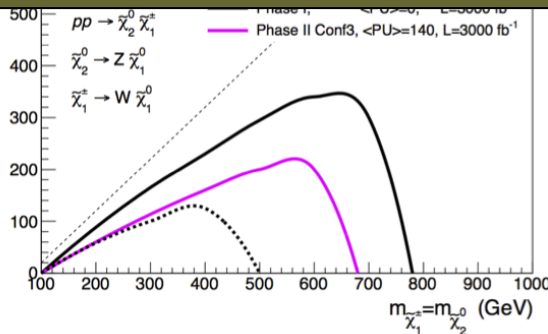
- ❑ Question for the next high-E machine: how much fine-tuning are we ready to swallow before giving up on naturalness ?
- ❑ Maybe naturalness is a good concept for us and not for Nature → Anthropic principle: of all possible worlds, we live in a fine-tuned one as otherwise we could not exist



Further exploration of the energy frontier



- For a given \sqrt{s} , searches for heavy physics require the largest integrated luminosity, as cross-sections go as $\sim 1/s$ for heavy particles
- With 3000 fb^{-1} mass reach can be extended by typically 30-50% (compared to 300 fb^{-1}), depending on scenario.
- In some cases, the reach with 3000 fb^{-1} is ~ 1 TeV larger than with 1000 fb^{-1}
- In particular: if new physics discovered LHC in 2015++ \rightarrow HL-LHC with 3000 fb^{-1} is expected to help complete the heavier part of the spectrum and to allow precise measurements of the new physics



Conclusions

The discovery of a (the ?) Higgs boson is a giant leap in our understanding of fundamental physics and the structure and evolution of the universe

After almost 100 years of superb theoretical and experimental work (in particular from accelerator-based particle physics), the Standard Model has been completed.

However: we also know that the SM is not the ultimate theory of particle physics, because of the many outstanding questions, including:

- ☐ Why is the Higgs boson so light ("naturalness" problem) ?
- ☐ What is the nature of the dark part (96% !) of the universe ?
- ☐ What is the origin of the matter-antimatter asymmetry ?
- ☐ Why is gravity so weak ?

There are compelling reasons to believe that answers to some of the above questions lie at the TeV scale, whose exploration JUST started ...

→ The STRONG physics case for the HL-LHC with 3000 fb⁻¹ comes from the imperative necessity of exploring this scale as much as we can with the highest-E facility we have today (note: no other planned machine, except a 100 TeV pp collider, has a similar direct discovery potential). Likely, and perhaps more importantly, the HL-LHC will also tell us what are the right questions to ask and how to continue.

More powerful accelerators will be needed in the future to advance our knowledge of fundamental physics, requiring new ideas, ingenuity, new developments in order to provide higher energy at affordable costs.

THANK YOU !



SPARES

So what do we need to measure in order to know more about EWSB ?

From the non-zero Higgs potential in the SM equations and a few transformations

$$V(\phi^\dagger\phi) = \mu^2\phi^2 + \lambda\phi^4 \quad \mu^2 < 0$$

Interactions of Higgs field with W and Z \rightarrow W, Z masses and H-W, H-Z couplings

$$\frac{1}{2}\partial^\mu H\partial_\mu H + \left[\left(\frac{gv}{2}\right)^2 W^{\mu+}W_\mu^- + \frac{1}{2} \frac{(g^2 + g'^2) v^2}{4} Z^\mu Z_\mu \right] \left(1 + \frac{H}{v}\right)^2$$

Higgs couplings to W, Z: $2M_{W,Z}^2/v$

$$M_W = \frac{1}{2} gv$$

$$M_Z = \frac{1}{2} v\sqrt{g^2 + g'^2}$$

Interactions of Higgs field with fermions \rightarrow fermions masses and H-fermion couplings

$$\sqrt{\frac{1}{2}} \Lambda_f v \bar{f}f \left(1 + \frac{H}{v}\right)$$

Higgs couplings to fermions: M_f/v

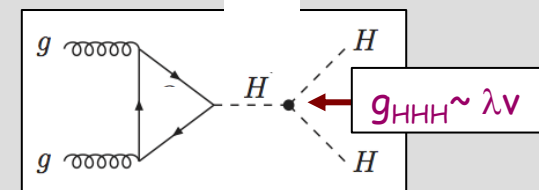
$$M_f = \sqrt{\frac{1}{2}} \Lambda_f v$$

Higgs mass and self-interaction

$$-\lambda v^2 h^2 - \left[\lambda v h^3 - \frac{1}{4} \lambda h^4 \right]$$

$$M_H = 2 \lambda v^2$$

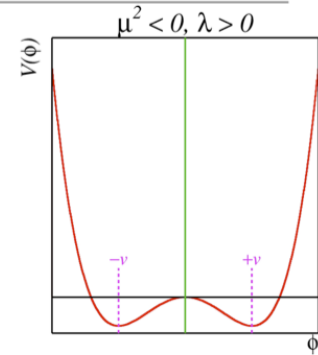
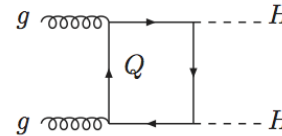
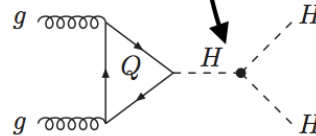
Higgs self-couplings



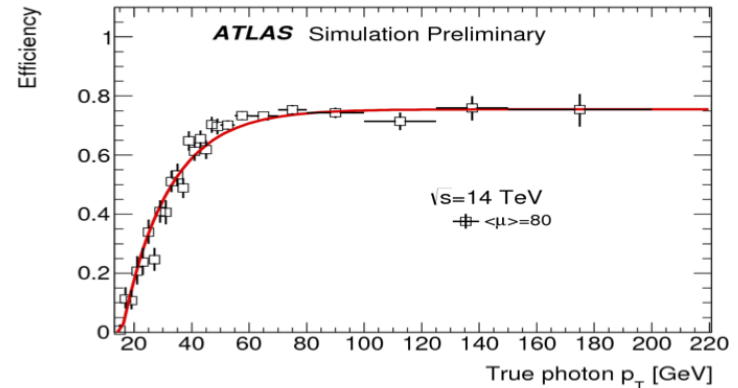
Higgs pair production

- Higgs self-coupling is an important parameter of SM
 - Test through di-Higgs production*
- Experiments are still working on projections of precision
 - Critically dependent on detector many aspects of detector performance*
 - b-tagging, resolution, fake rates**
- Small cross-section, large backgrounds
 - Clearly needs full HL-LHC luminosity*
 - And detectors that maximize the experimental efficiency*

$$M_H^2 = \lambda v^2 \quad g_{hhh} \equiv 3\lambda v = \frac{3M_H^2}{v}$$



Expected events	
bbWW	30000
bbττ	9000
WWWW	6000
γγbb	320
YYYY	1



Instead of asking with what precision can observe di-Higgs, easier (and maybe more useful) might be to set detector requirements to make $N \sigma$ measurement

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \left[\frac{a_i}{\Lambda} \mathcal{O}_i^{(5)} + \frac{c_i}{\Lambda^2} \mathcal{O}_i^{(6)} + \frac{e_i}{\Lambda^4} \mathcal{O}_i^{(8)} \dots \right]$$

Observation of **anomalous quartic gauge coupling** would indicate **new physics in the electroweak symmetry breaking sector!**

- HL-LHC enhances discovery range for new higher-dimension electroweak operators by more than a factor of two

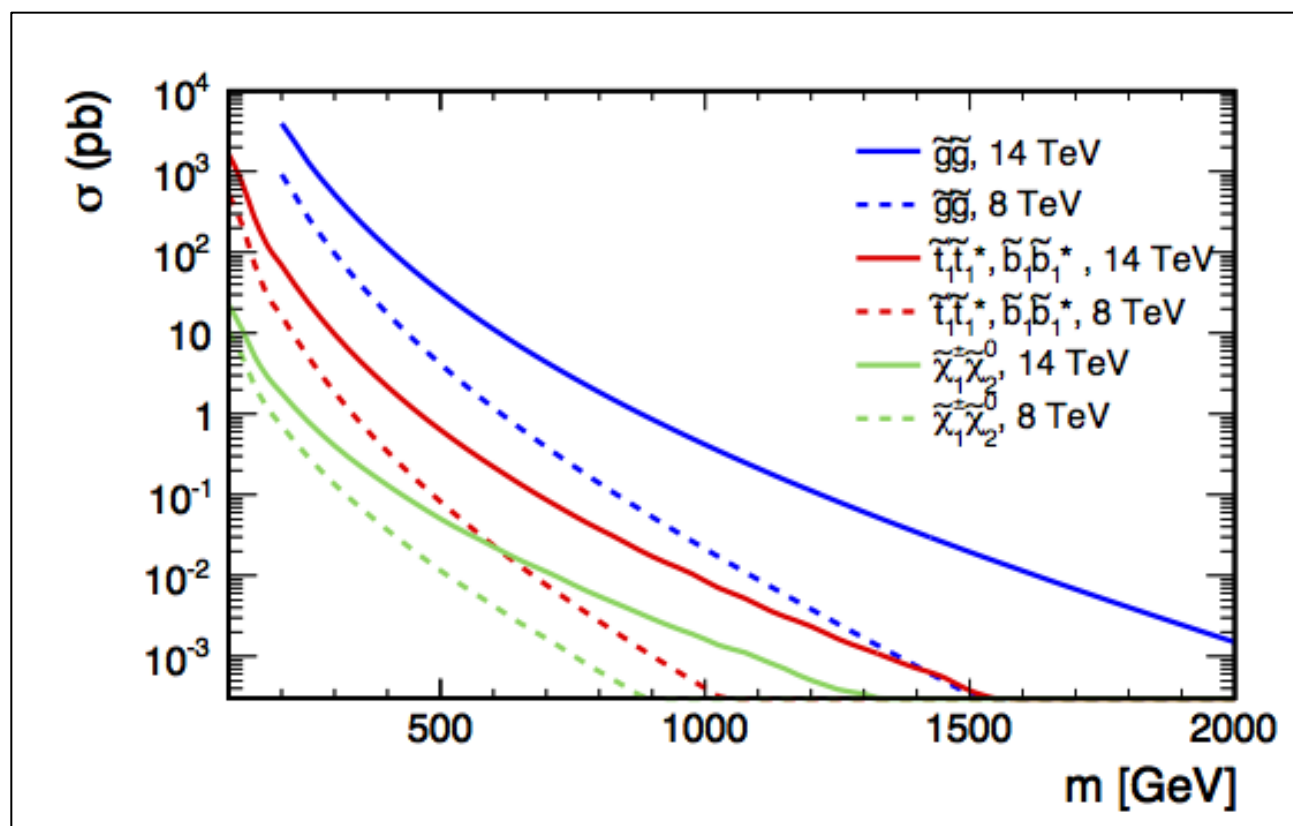
Parameter	dimension	channel	Λ_{UV} [TeV]	300 fb ⁻¹		3000 fb ⁻¹	
				5 σ	95% CL	5 σ	95% CL
$c_{\phi W}/\Lambda^2$	6	ZZ	1.9	34 TeV ⁻²	20 TeV ⁻²	16 TeV ⁻²	9.3 TeV ⁻²
f_{S0}/Λ^4	8	$W^\pm W^\pm$	2.0	10 TeV ⁻⁴	6.8 TeV ⁻⁴	4.5 TeV ⁻⁴	0.8 TeV ⁻⁴
f_{T1}/Λ^4	8	WZ	3.7	1.3 TeV ⁻⁴	0.7 TeV ⁻⁴	0.6 TeV ⁻⁴	0.3 TeV ⁻⁴
f_{T8}/Λ^4	8	$Z\gamma\gamma$	12	0.9 TeV ⁻⁴	0.5 TeV ⁻⁴	0.4 TeV ⁻⁴	0.2 TeV ⁻⁴
f_{T9}/Λ^4	8	$Z\gamma\gamma$	13	2.0 TeV ⁻⁴	0.9 TeV ⁻⁴	0.7 TeV ⁻⁴	0.3 TeV ⁻⁴



Λ_{UV} : unitarity violation bound corresponding to the sensitivity with 3000 fb⁻¹

SM discovery expected with 185 fb⁻¹

BSM contribution at TeV Scale might be observed at 300 fb⁻¹!
If BSM discovered in 300 fb⁻¹ dataset, then the coefficients on the new operators could be measured to 5% precision with 3000 fb⁻¹

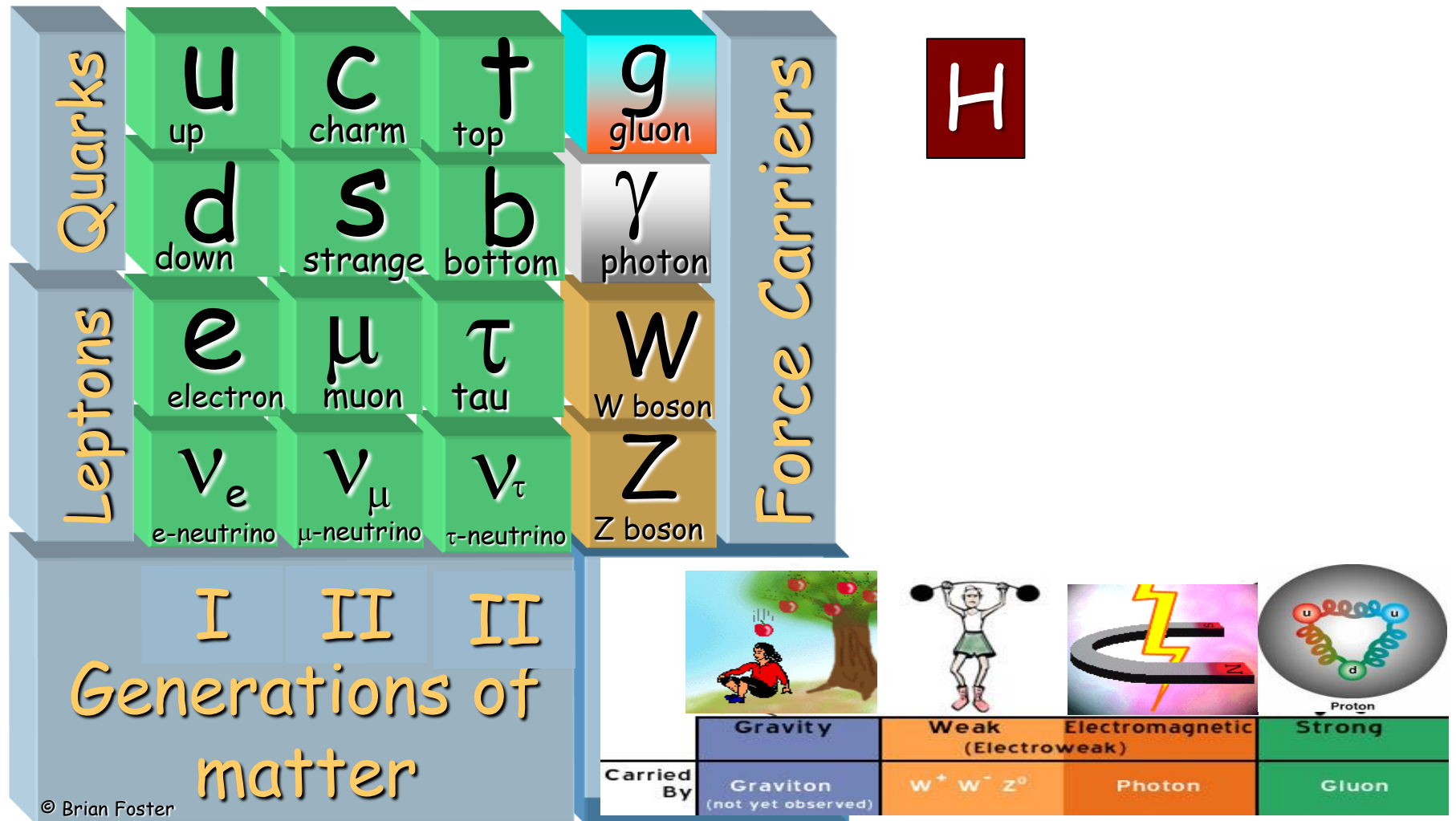


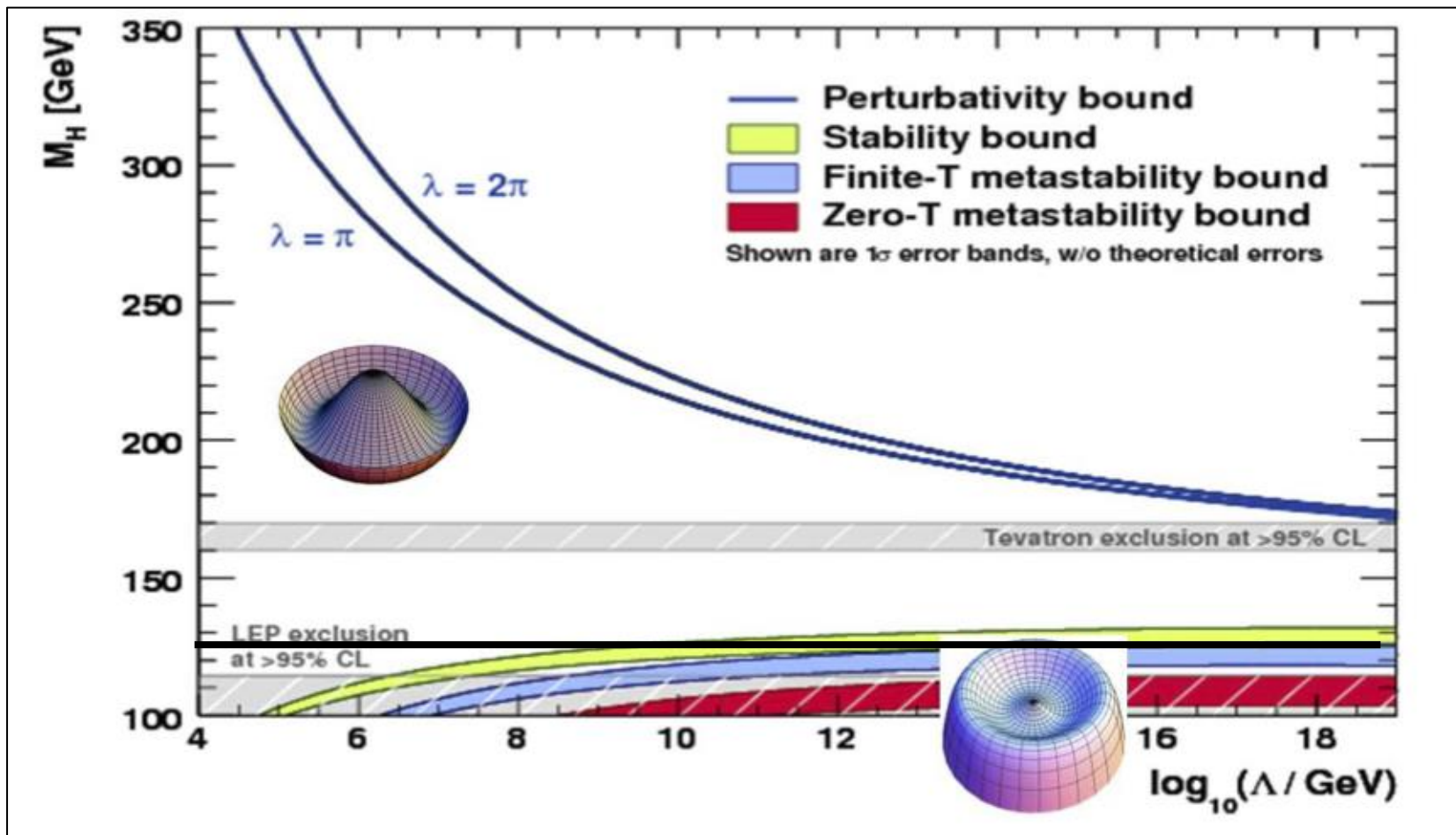
Search for top-antitop resonances in the lepton+ jet (dilepton) channel

ATLAS
simulation

model	300 fb^{-1}	1000 fb^{-1}	3000 fb^{-1}	(in TeV)
g_{KK}	4.3 (4.0)	5.6 (4.9)	6.7 (5.6)	
Z'_{topcolor}	3.3 (1.8)	4.5 (2.6)	5.5 (3.2)	

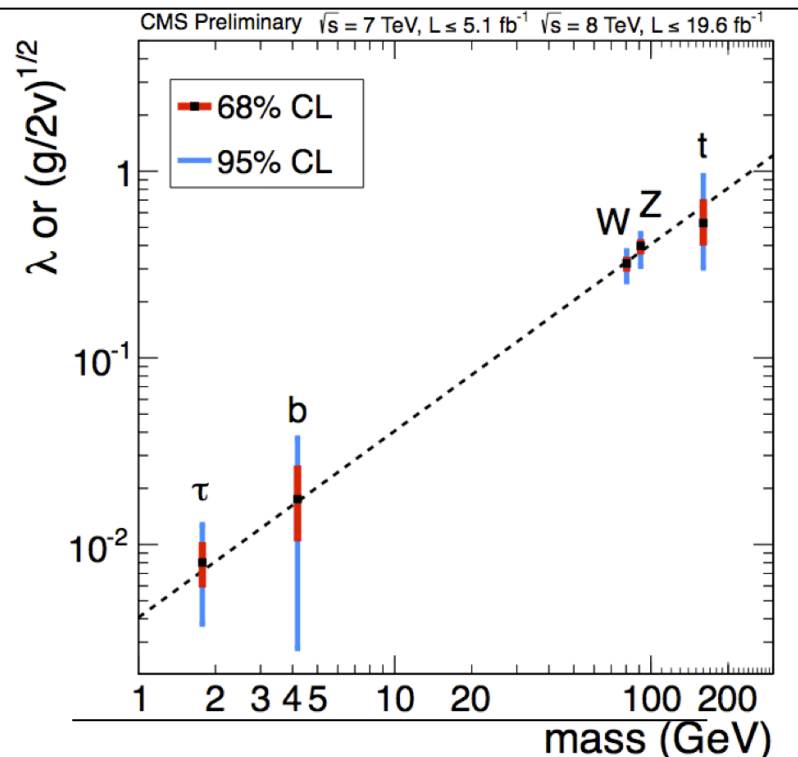
The world of elementary particles after 4 July 2012





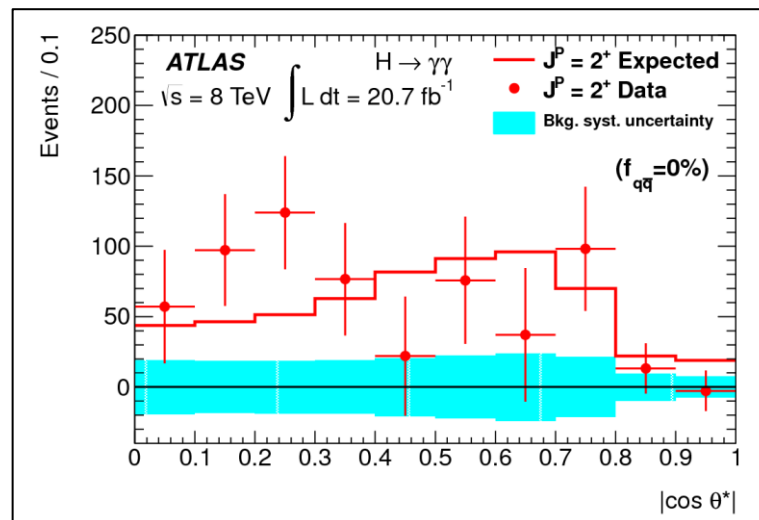
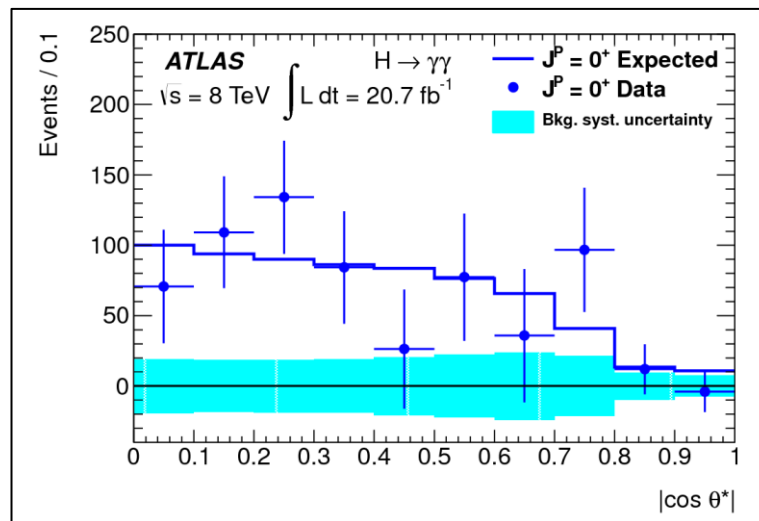
Is the new particle a Higgs boson ?

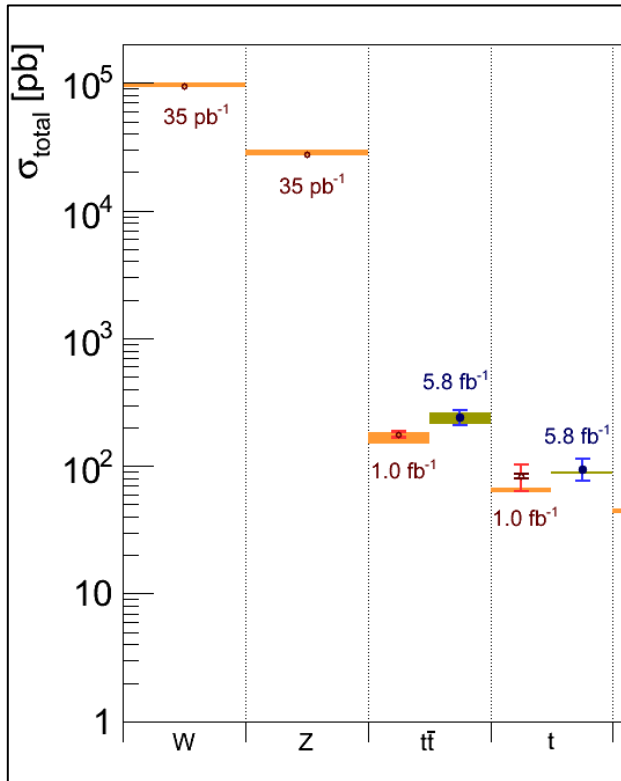
1) To accomplish its job (providing mass) it couples to other particles (in particular W, Z) with strength proportional to their masses



→ ATLAS and CMS have inspected the two "fingerprints"

2) It has spin zero (scalar)





ATLAS Preliminary

LHC pp $\sqrt{s} = 7 \text{ TeV}$

Theory

○ Data ($L = 0.035 - 4.6 \text{ fb}^{-1}$)

LHC pp $\sqrt{s} = 8 \text{ TeV}$

Theory

• Data ($L = 5.8 - 20 \text{ fb}^{-1}$)

The Standard Model works beautifully !

NO evidence for new physics so far ...

CMS EXOTICA 95% CL EXCLUSION LIMITS (TeV)

