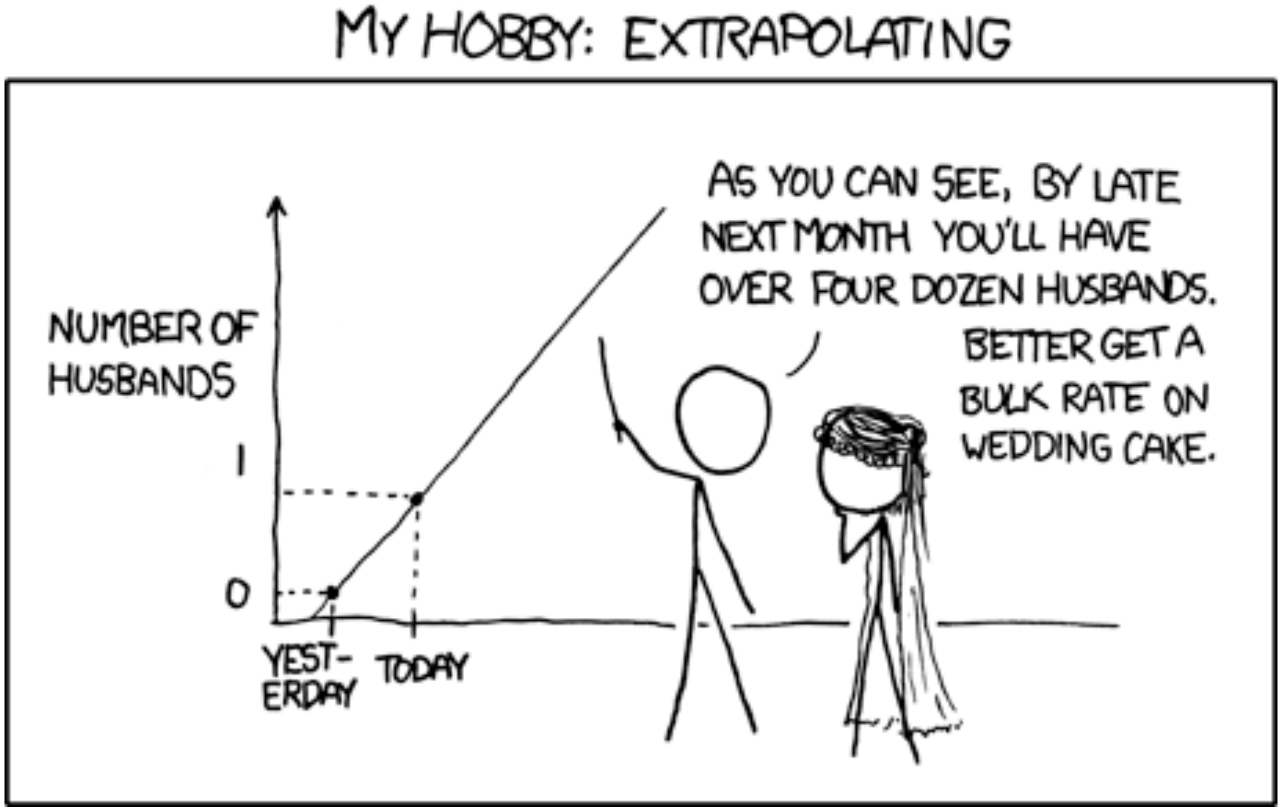
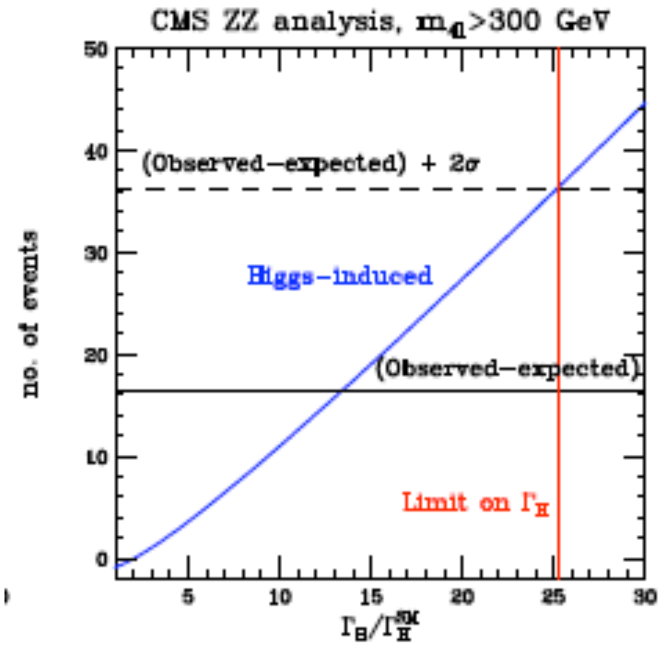
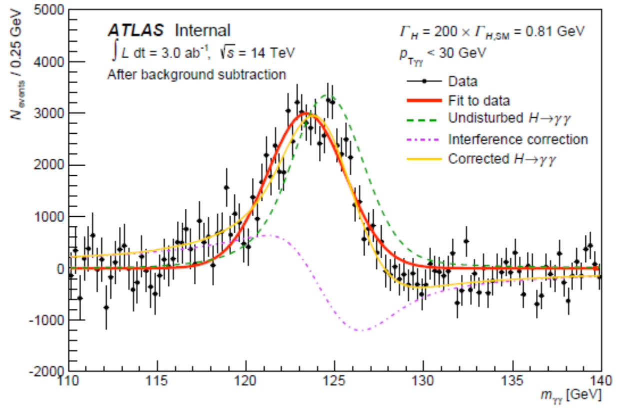
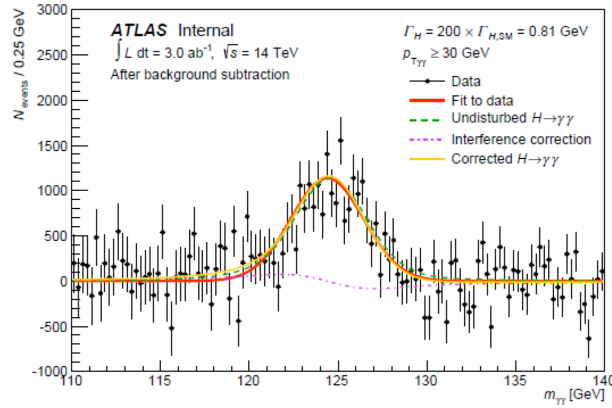
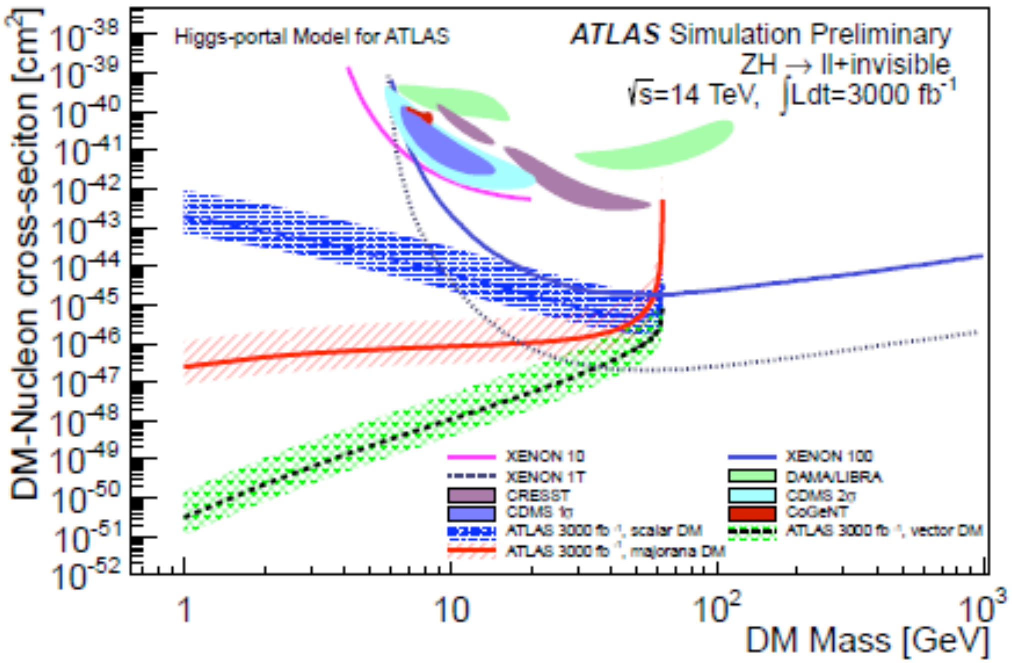
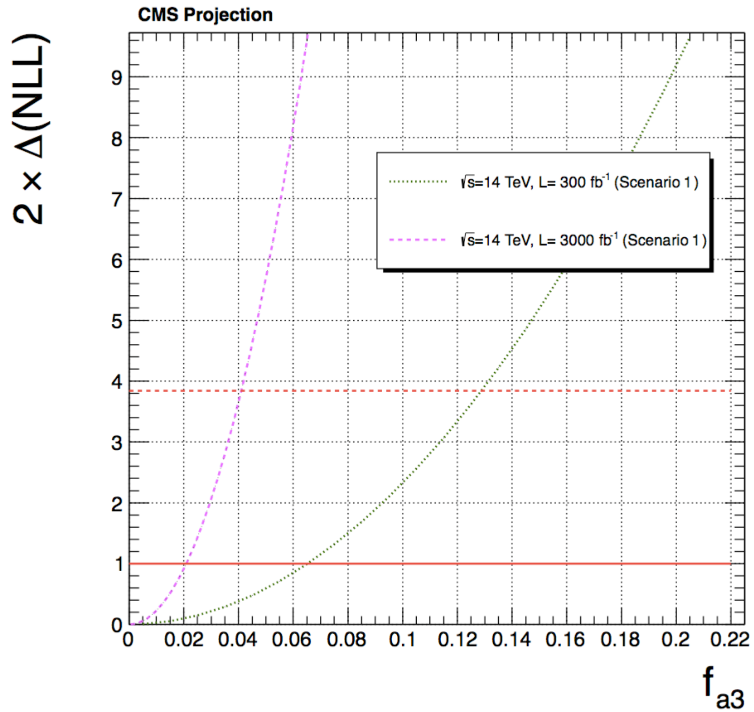

MY HOBBY: EXTRAPOLATING
AS YOU CAN SEE, BY LATE NEXT MONTH YOU'LL HAVE OVER FOUR DOZEN HUSBANDS.
BETTER GET A BULK RATE ON WEDDING CAKE.
NUMBER OF HUSBANDS
1
0
YEST-ERDAY
TODAY


CMS ZZ analysis, m4l>300 GeV
(Observed−expected) + 2σ
Higgs−induced
(Observed−expected)
Limit on ΓH
no. of events
ΓH/ΓH SM


ATLAS Internal
∫L dt = 3.0 ab-1, √s = 14 TeV
After background subtraction
ΓH = 200 × ΓH,SM = 0.81 GeV
pTγγ < 30 GeV
Data
Fit to data
Undisturbed H→γγ
Interference correction
Corrected H→γγ
Nevents / 0.25 GeV
mγγ [GeV]


ATLAS Internal
∫L dt = 3.0 ab-1, √s = 14 TeV
After background subtraction
ΓH = 200 × ΓH,SM = 0.81 GeV
pTγγ ≥ 30 GeV
Data
Fit to data
Undisturbed H→γγ
Interference correction
Corrected H→γγ
Nevents / 0.25 GeV
mγγ [GeV]

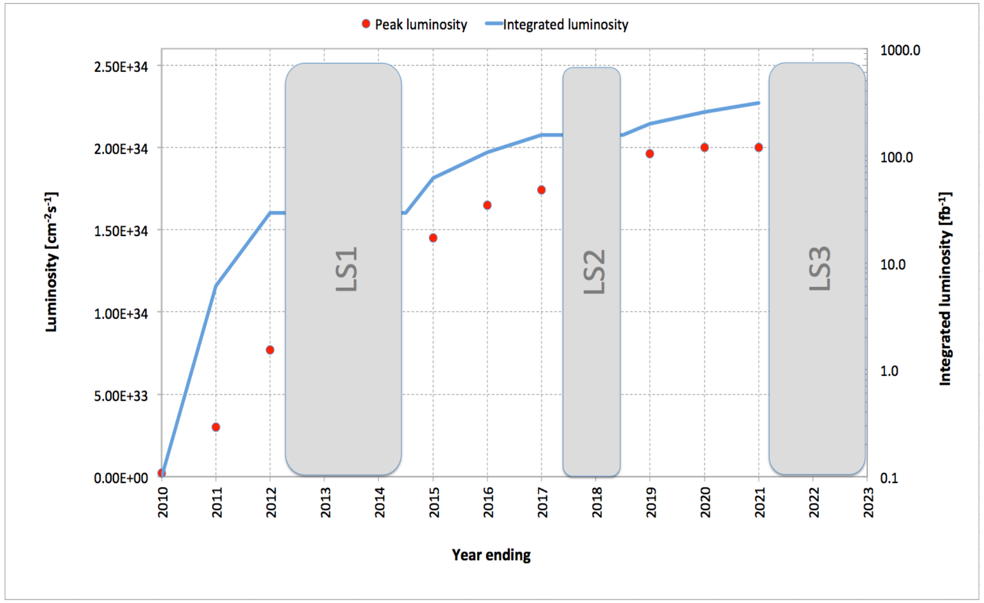

Higgs-portal Model for ATLAS
ATLAS Simulation Preliminary
ZH → ll+invisible
√s=14 TeV, ∫Ldt=3000 fb-1
XENON 10
XENON 1T
CRESST
CDMS 1σ
ATLAS 3000 fb-1, scalar DM
ATLAS 3000 fb-1, majorana DM
XENON 100
DAMA/LIBRA
CDMS 2σ
CoGeNT
ATLAS 3000 fb-1, vector DM
DM-Nucleon cross-seciton [cm2]
DM Mass [GeV]


CMS Projection
√s=14 TeV, L= 300 fb-1 (Scenario 1)
√s=14 TeV, L= 3000 fb-1 (Scenario 1)
2 × Δ(NLL)
fa3

BACKUP

- LHC is resuming (properly fixed) in 2015, with √s unlikely exceeding 13 TeV
  - Projections done assuming 14 TeV, little difference for analysis performance
- 25 ns bunch spacing instrumental for future physics reach
- Aim at 300 fb^{-1} by 2021

	n_B	Peak Lumi [$cm^{-2}s^{-1}$]	Pileup	Lumi [fb^{-1}]
25 ns	2760	9.2e33	21	24
25 ns low ε	***2508***	***1.6e34***	***43***	***42***
50 ns	1380	1.7e34 levelling 0.9e34	76 levelling 40	~45



- Instantaneous luminosity is limited by beam burn-off lifetime → level luminosity, L~5x10^{34} cm^{-2}s^{-1}.
- Taking 2012 as reference:
  - T=6.5x10^{6} sec, L=23fb^{-1} → <L>=3.7 nb^{-1}s^{-1}
- 10 years at L=50nb^{-1}s^{-1} would give **L=3000 fb^{-1}**
- Pileup (ATL-UPGRADE-PUB-2013-014)
  - σ_{Inel}=81mb, n_b=2808 (25 ns bunch spacing) → **μ_p>130**

- Major upgrades required on the LHC (replace more than 1.2 km):
  - New IR-quads Nb3Sn (inner triplets), new 11 T Nb3Sn (short) dipoles
  - Collimation upgrade
  - Cryogenics upgrade
  - Crab Cavities
  - …

- A real Higgs factory, a couple of Higgs events produced per sec
  - Compare to e^+e^- colliders ($L=10^{34}\ cm^{-2}s^{-1}$): <10 events per hour

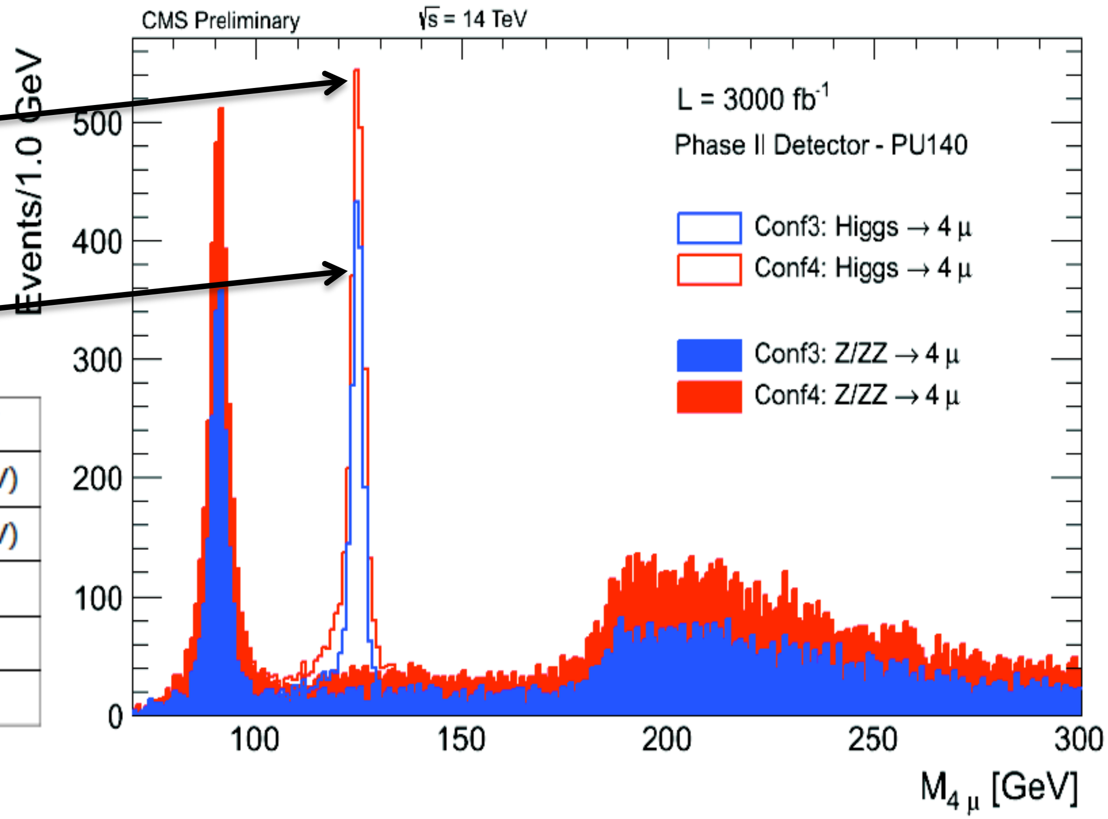
	σ(14 TeV) [pb]	Rate [Hz], L=50 $pb^{-1}s^{-1}$	Events, L=3ab^{-1}	Events, L=30fb^{-1}
ggH	50.4	2.52	150M	600K
VBF	4.2	0.21	13M	48K
WH	1.5	0.08	4.5M	21K
ZH	0.9	0.04	2.6M	12K
ttH	0.6	0.03	1.8M	4K

- Most of the exclusive final states accessible, including in particular very rare ones
  - 20K H->ZZ->4l, 30K H->$\mu\mu$, 50 H->J/ψ γ
- Possible to probe redundantly most of the coupling factors

- CMS:
  - Scale results of current analyses
    - Including those currently with little sensitivity, e.g. H->$\mu\mu$, ttH->$\gamma\gamma$, etc.
  - Two scenarios assumed reasonably covering the range of future performances:
    - Same systematic uncertainties as today (Scenario 1, conservative)
    - Experimental syst. scaled by $1/\sqrt{L}$, theory syst. halved (Scenario 2, ambitious)
  - Results supported by dedicated full simulation studies
    - Fast simulation (DELPHES) validated against full simulation too
- ATLAS:
  - Detector response functions derived using full simulation performed including pile-up events up to μ_p=140
    - signal and background MC events have been processed taking into account these functions.
  - 300 fb^{-1} scenario assumes 50 PU events on average
    - Includes IBL and LAr trigger upgrades
  - 3000 fb^{-1} scenario assumes 140 PU events
    - Includes Inner Tracker detector (under study for the upgrades)

Muons up to |η|=4

Muons up to |η|=2.4



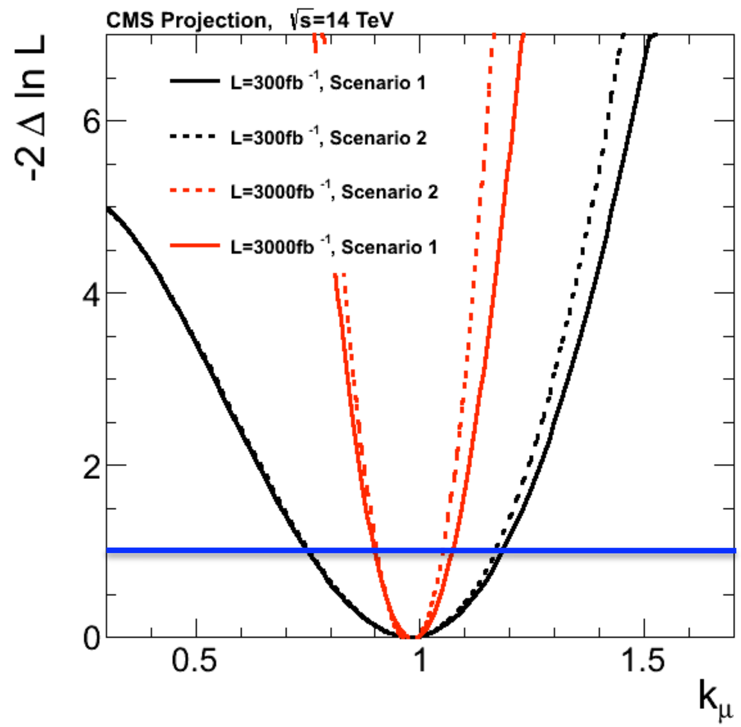
|η|	$1<p_T<10$ GeV	$10<p_T<100$ GeV	$p_T > 100$ GeV
<1.5	1.3%	2% (<200 GeV)	5% (>200 GeV)
1.5-2.5	1.5%	4% (<200 GeV)	5% (>200 GeV)
2.5-3.0	3%	5%	30%
3.0-3.5	4%	7%	30%
3.5-4.0	5%	20%	80%

- Tracking and muon system coverage extension from |η|=2.4 to |η|=4 under study
- Sizable impact on the H->ZZ->4μ acceptance: +45%!

- Follow recommendations and fit models described in Yellow Report 3 (arXiv:1307.1347)
- Signal cross section scaled w.r.t to SM predictions:

$$\sigma \cdot BR(ii \rightarrow H \rightarrow ff) = \sigma_{SM} \cdot BR_{SM} \frac{\kappa_i^2 \cdot \kappa_f^2}{\kappa_H^2}$$

- Not targeted to any BSM model, goal is to quantify possible (small) deviations w.r.t SM
- Global fits targeting the κ factors
  - Assign a modifier to each coupling constant
    - Do not resolve loops, effective coupling instead (κ_g, κ_γ and $\kappa_{Z\gamma}$)
  - Results reported in terms of 68% uncertainties (-2ΔLnL=1) on k



- Total width not trivial to assess at the LHC
  - E.g. not possible to measure directly a production cross section as at a e+e- collider
- It can be expressed as the sum of other SM couplings:
  - Assuming SM BRs for inaccessible decays (H->cc) and not other contribution from BSM
    - In this case H->bb is pivotal!
  - Allow extra BSM contributions (e.g. BRInv) and set an upper bound on κ_V (κ_V<1)
    - Eventually use bounds from direct search for invisible Higgs decay
- Alternatively use a given process as reference for the other coupling modifiers
  - Use ggH->ZZ signal strength, κ_{gZ}==κ_g*κ_Z/κ_T

- Fits performed assuming $\kappa_H = \Sigma \kappa_i BR_i$, only for *i* in SM
- ATLAS doesn't use H->bb channel, κ_b linked to κ_τ in the fit → all other couplings penalized
  - CMS up to a factor 2 better in several cases
- In an ambitious scenario, ultimate precision ~2% for couplings involved in the main decay modes

		κ_γ	κ_W	κ_Z	κ_g	κ_b	κ_t	κ_τ	$\kappa_{Z\gamma}$	κ_μ
$300 fb^{-1}$	ATLAS	[8,13]	[6,8]	[7,8]	[8,11]	N/a	[20,22]	[13,18]	[78,79]	[21,23]
	CMS	[5,7]	[4,6]	[4,6]	[6,8]	[10,13]	[14,15]	[6,8]	[41,41]	[23,23]
$3000 fb^{-1}$	ATLAS	[5,9]	[4,6]	[4,6]	[5,7]	N/a	[8,10]	[10,15]	[29,30]	[8,11]
	CMS	[2,5]	[2,5]	[2,4]	[3,5]	[4,7]	[7,10]	[2,5]	[10,12]	[8,8]

ATLAS: [no Th. syst., full Th. syst.] (same exp. syst.)

CMS: [Scenario2, Scenario1]

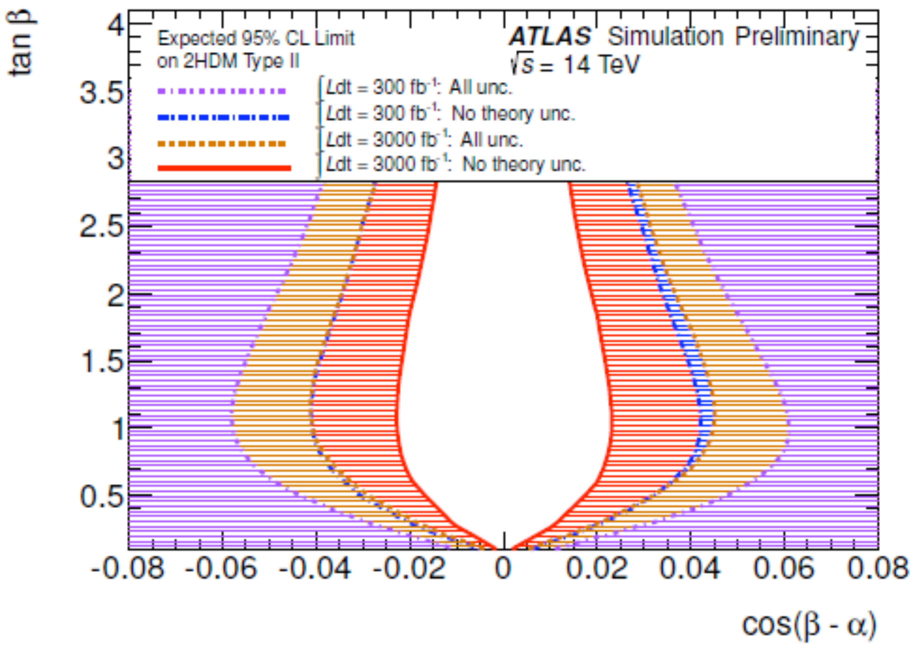
- Results are more directly comparable if total width absorbed by a reference scale factor
  - Performances of the two experiments very similar
- HL-LHC can lead to an accuracy of ~2% for many coupling constants

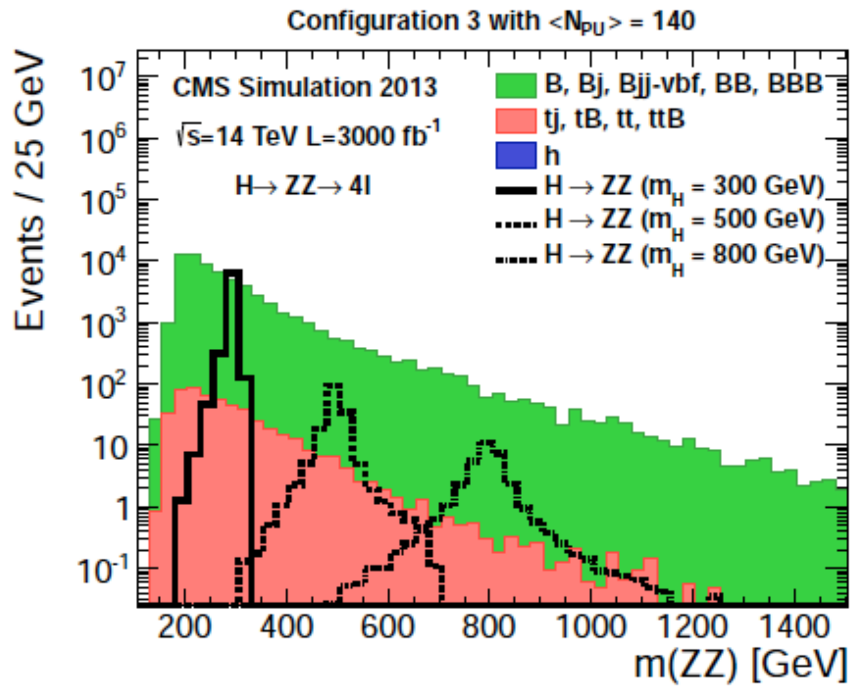
		$K_g \kappa_Z / \kappa_H$	K_W / κ_Z	K_γ / κ_Z	K_g / K_Z	K_b / K_Z	K_τ / K_Z	K_μ / K_Z	$\kappa_{Z\gamma} K_Z$	K_t / K_g
300fb^{-1}	ATLAS	[3,6]	[4,5]	[5,11]	[11,12]	N/a	[11,13]	[20,22]	[78,78]	[17,18]
	CMS	[4,6]	[4,7]	[5,8]	[6,9]	[8,11]	[6,9]	[22,23]	[40,42]	[13,14]
3000fb^{-1}	ATLAS	[2,5]	[2,3]	[2,7]	[5,6]	N/a	[7,10]	[6,9]	[29,30]	[6,7]
	CMS	[2,5]	[2,3]	[2,5]	[3,5]	[3,5]	[2,4]	[7,8]	[12,12]	[6,8]

ATLAS: [no Th. syst., full Th. syst.] (same exp. syst.)

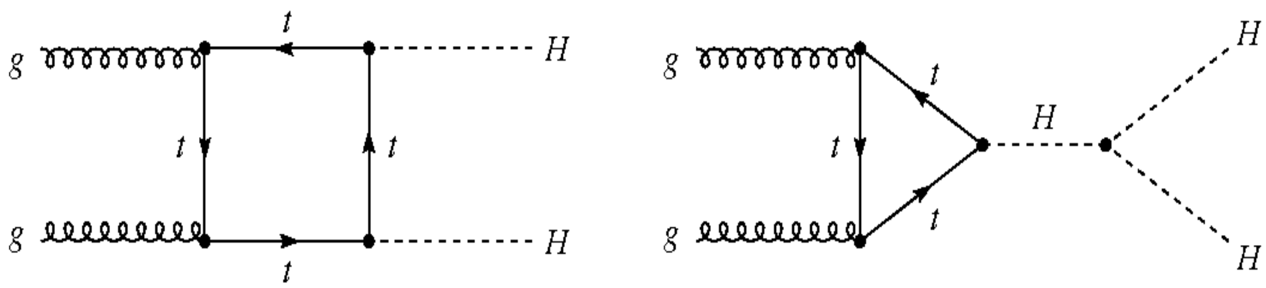
CMS: [Scenario2, Scenario1]

- A second Higgs doublet is present in many BSM models
- Additional Higgs fields can be searched for at high masses
- Both experiments performed full simulation analysis of ZZ and Zh resonances in Type I and II modes
  - Indirect constrains from SM coupling fits





- Double Higgs production among the main objectives of HL-LHC
- Tiny cross section, need very high integrated lumi
  - Problematic also at high energy e+e- machines
- Self coupling diagrams interferes destructively with double Higgs processes
  - Look for a deficiency in a small signal, rather tough indeed
- This process is very challenging, ATLAS and CMS studies are still on going



Yields at $3ab^{-1}$

bbWW	30K
$bb\tau\tau$	9K
WWWW	6K
$\gamma\gamma bb$	320
$\gamma\gamma\gamma\gamma$	1

- Adopting model summarized in Table 50 of YR3 (pag 151)
  - Multi parameter model preferred by ATLAS
- Refer everything to ggHZZ signal strength ($\kappa_{gZ}==\kappa_{g}*\kappa_{Z}/\kappa_{T}$)
- 9 parameters in total
  - Including $\lambda_{\mu Z}$ and $\lambda_{Z\gamma Z}$

General parameterization allowing all gauge and third generation fermion couplings to float allowing for invisible or undetectable widths

Free parameters: $\kappa_{gZ}(=\kappa_g\cdot\kappa_Z/\kappa_H)$, $\lambda_{\gamma Z}(=\kappa_\gamma/\kappa_Z)$, $\lambda_{WZ}(=\kappa_W/\kappa_Z)$, $\lambda_{bZ}(=\kappa_b/\kappa_Z)$, $\lambda_{\tau Z}(=\kappa_\tau/\kappa_Z)$, $\lambda_{Zg}(=\kappa_Z/\kappa_g)$, $\lambda_{tg}(=\kappa_t/\kappa_g)$.

ggH	$\kappa_{gZ}^2\cdot\lambda_{\gamma Z}^2$	κ_{gZ}^2	$\kappa_{gZ}^2\cdot\lambda_{WZ}^2$	$\kappa_{gZ}^2\cdot\lambda_{bZ}^2$	$\kappa_{gZ}^2\cdot\lambda_{\tau Z}^2$
$t\bar{t}H$	$\kappa_{gZ}^2\lambda_{tg}^2\cdot\lambda_{\gamma Z}^2$	$\kappa_{gZ}^2\lambda_{tg}^2$	$\kappa_{gZ}^2\lambda_{tg}^2\cdot\lambda_{WZ}^2$	$\kappa_{gZ}^2\lambda_{tg}^2\cdot\lambda_{bZ}^2$	$\kappa_{gZ}^2\lambda_{tg}^2\cdot\lambda_{\tau Z}^2$
VBF	$\kappa_{gZ}^2\lambda_{Zg}^2\kappa_{VBF}^2(1,\lambda_{WZ})\cdot\lambda_{\gamma Z}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\kappa_{VBF}^2(1,\lambda_{WZ})$	$\kappa_{gZ}^2\lambda_{Zg}^2\kappa_{VBF}^2(1,\lambda_{WZ})\cdot\lambda_{WZ}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\kappa_{VBF}^2(1,\lambda_{WZ})\cdot\lambda_{bZ}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\kappa_{VBF}^2(1,\lambda_{WZ})\cdot\lambda_{\tau Z}^2$
WH	$\kappa_{gZ}^2\lambda_{Zg}^2\lambda_{WZ}^2\cdot\lambda_{\gamma Z}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\lambda_{WZ}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\lambda_{WZ}^2\cdot\lambda_{WZ}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\lambda_{WZ}^2\cdot\lambda_{bZ}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\lambda_{WZ}^2\cdot\lambda_{\tau Z}^2$
ZH	$\kappa_{gZ}^2\lambda_{Zg}^2\cdot\lambda_{\gamma Z}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\cdot\lambda_{WZ}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\cdot\lambda_{bZ}^2$	$\kappa_{gZ}^2\lambda_{Zg}^2\cdot\lambda_{\tau Z}^2$

$\kappa_i^2=\Gamma_{ii}/\Gamma_{ii}^{SM}$

Signal model parameters a (signal strength modifier μ can be one of them) are evaluated from a scan of the profile likelihood ratio $q(a)$:

$$q(a) = -2 \ln \frac{\mathcal{L}(\text{obs} \,|\, s(a) + b, \hat{\theta}_a)}{\mathcal{L}(\text{obs} \,|\, s(\hat{a}) + b, \hat{\theta})}, \tag{6}$$

Parameters $\hat{a}$ and $\hat{\theta}$ that maximize the likelihood, $\mathcal{L}(\text{obs} \,|\, s(\hat{a}) + b, \hat{\theta}) = \mathcal{L}_{\text{max}}$, are called the best-fit set. The 68% (95%) CL on a given parameter of interest a_i is evaluated from $q(a_i) = 1$ (3.84) with all other unconstrained model parameters treated in the same way as the nuisance parameters. The 2D 68% (95%) CL contours for pairs of parameters are derived from $q(a_i, a_j) = 2.3$ (6). One should keep in mind that boundaries of 2D confidence regions projected on either parameter axis are not identical to the 1D confidence interval for that parameter.