Higgs Prospects at the HL-LHC

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- Physics programme after the 125 GeV Higgs boson discovery
- The LHC luminosity upgrade
- Expected physics performance of ATLAS and CMS detector upgrade
- Higgs Prospects
- VBS
- Conclusion

Issues for the Future *(Starting now!)*

1. What is the agent of EWSB? *There is a Higgs boson!* Might there be several?
2. Is the Higgs boson elementary or composite? How does it interact with itself? What triggers EWSB?
3. Does the Higgs boson give mass to fermions, or only to the weak bosons? What sets the masses and mixings of the quarks and leptons? *(How) is fermion mass related to the electroweak scale?*
4. Are there new flavor symmetries that give insights into fermion masses and mixings?
5. What stabilizes the Higgs-boson mass below 1 TeV?

C. Quigg, seminar at this conference

Issues for the Future (Now!)

6. Do the different CC behaviors of LH, RH fermions reflect a fundamental asymmetry in nature's laws?
7. What will be the next symmetry we recognize? Are there additional heavy gauge bosons? Is nature supersymmetric? Is EW theory contained in a GUT?
8. Are all flavor-changing interactions governed by the standard-model Yukawa couplings? Does "minimal flavor violation" hold? If so, why?
9. Are there additional sequential quark & lepton generations? Or new exotic (vector-like) fermions?
10. What resolves the strong CP problem?

C. Quigg, seminar at this conference

Issues for the Future (Now!)

11. What are the dark matters? Any flavor structure?

12. Is EWSB an emergent phenomenon connected with strong dynamics? How would that alter our conception of unified theories of the strong, weak, and electromagnetic interactions?

13. Is EWSB related to gravity through extra spacetime dimensions?

14. What resolves the vacuum energy problem?

15. (When we understand the origin of EWSB), what lessons does EWSB hold for unified theories? … for inflation? … for dark energy?

C. Quigg, seminar at this conference

Issues for the Future (Now!)

16. What explains the baryon asymmetry of the universe? Are there new (CC) CP-violating phases?
17. Are there new flavor-preserving phases? What would observation, or more stringent limits, on electric-dipole moments imply for BSM theories?
18. (How) are quark-flavor dynamics and lepton-flavor dynamics related (beyond the gauge interactions)?
19. At what scale are the neutrino masses set? Do they speak to the TeV scale, unification scale, Planck scale, …?

20. How are we prisoners of conventional thinking?

C. Quigg, seminar at this conference

Higgs Physics Programme

1. Measurement of couplings to elementary fermions and bosons
2. Precision measurement of the mass and width of this new particle
3. Determination of the quantum numbers: spin and CP properties
4. Measurement of the self-coupling (di-Higgs boson production)
5. Search for possible partners (neutral and/or charged) of this boson
6. Fundamental/composite particle
7. Strongly associate to this: Vector Boson Scattering

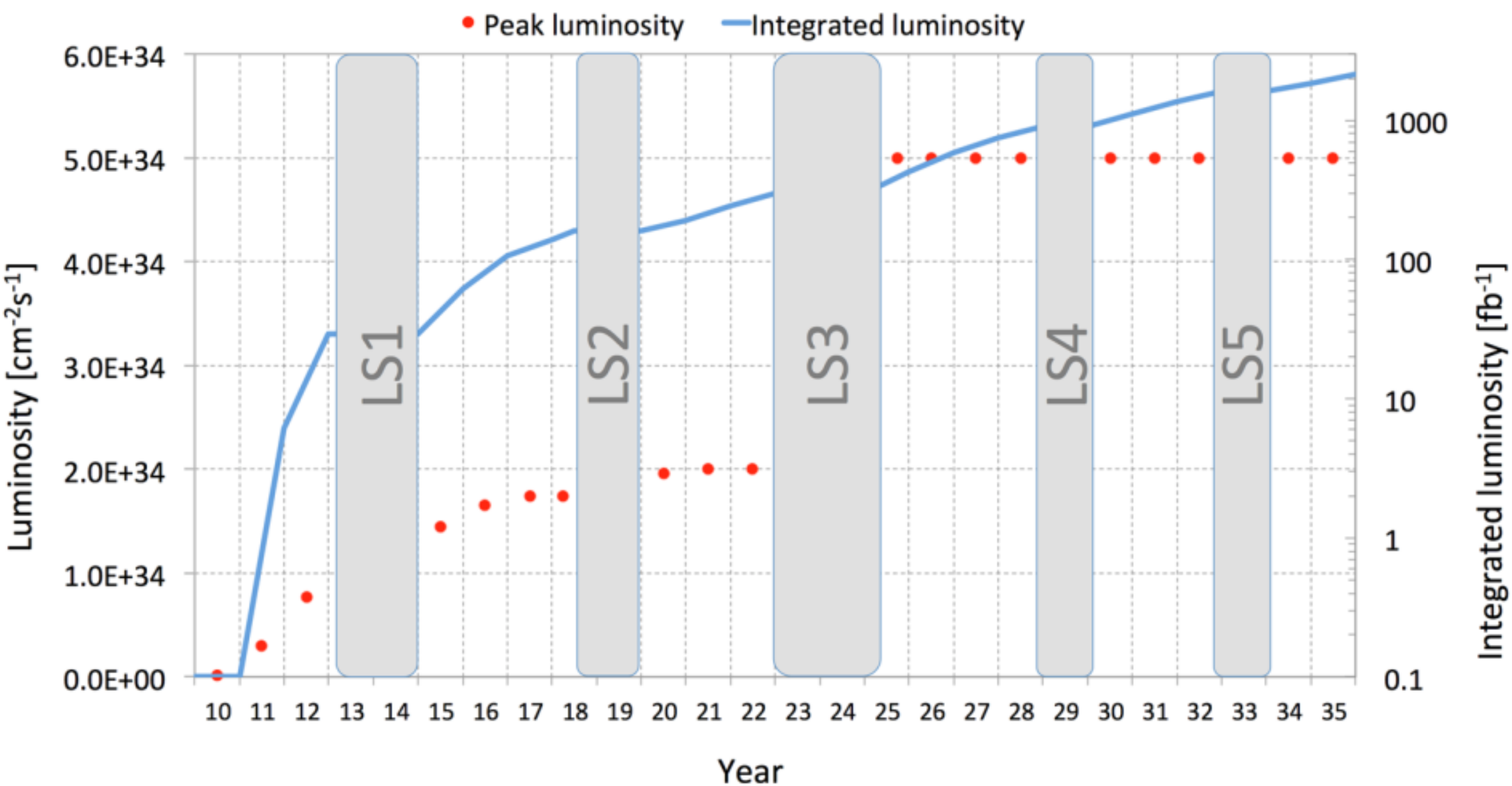
HL-LHC Physics goals

- HL-LHC will be alone, in the near future for sure, exploring multi-TeV
  - There will be a wide physics programme
  - Higgs physics plays a central role

HL-LHC Benchmark scenario

- Approved running to deliver 300 fb^{-1} by ~2021
  - With 20x Higgs boson production so far
- Post LS3 operation at $5x10^{34}cm^{-2}s^{-1}$ (lumi leveling)
  - 25 ns bunch spacing
  - 140 events per bunch crossing
  - 3000 fb^{-1} over 10 years
- Detector upgrades needed
  - to cope with radiation damage and pileup
  - aim to maintain/enhance physics performance
- Trigger is a key component:
  - Thresholds not too dissimilar to today
  - Mandated by need to study the Higgs boson

HL-LHC timeline



- M. Lamont @ Recontre workshop, Vietnam, Aug 2014
- O. Bruning @ ECFA HL-LHC Workshop, Aix-Les-Bains, 2014

LHC Upgrade Goals: Performance optimization

Luminosity recipe (round beams):

$$L = \frac{n_b \cdot N_1 \cdot N_2 \cdot \gamma \cdot f_{rev}}{4\pi \cdot \beta^* \cdot \varepsilon_n} \cdot F(\phi, \beta^*, \varepsilon, \sigma_s)$$

- ➔ 1) maximize bunch intensities ➔ Injector complex
- ➔ 2) minimize the beam emittance LIU ⇔ IBS
- ➔ 3) minimize beam size (constant beam power); ➔ triplet aperture
- ➔ 4) maximize number of bunches (beam power); ➔ 25ns
- ➔ 5) compensate for 'F'; ➔ Crab Cavities
- ➔ 6) Improve machine 'Efficiency' ➔ minimize number of unscheduled beam aborts

- O. Bruning @ ECFA HL-LHC Workshop, Aix-Les-Bains, 2014

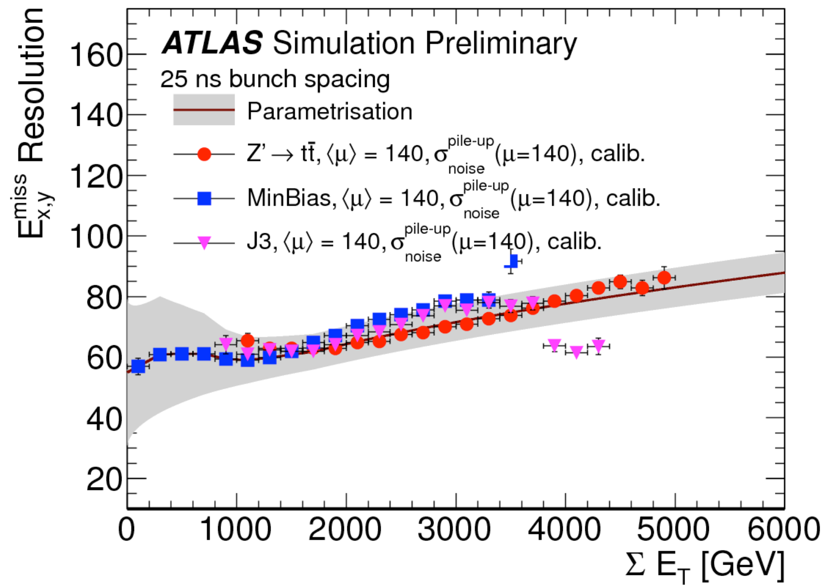
Simulation methods

- ATLAS:
  - Efficiency and resolution functions are applied to physics objects
  - Performance of the new detector will not be worse than the current detector at Run I conditions
- CMS:
  - Scale signal and background yields of current analyses
  - Two scenarios for systematic uncertainties
    - Scenario 1: Systematic uncertainties remain the same
    - Scenario 2: Theoretical uncertainties scaled by ½, other systematic uncertainties scaled by $1/\sqrt{L}$

Full simulation object studies

- Parametrization of object performance in the HL-LHC pile-up environment
- Some examples here:
  - ATLAS E_T^{miss} resolution with parametrization overlayed
- ATLAS b-tag fake rate for 70% efficiency compared with rate assumed for ES studies
  - ITK brings enhanced tracking
  - Mistag below 0.5% for <μ>=140 p_T=100 GeV

MET



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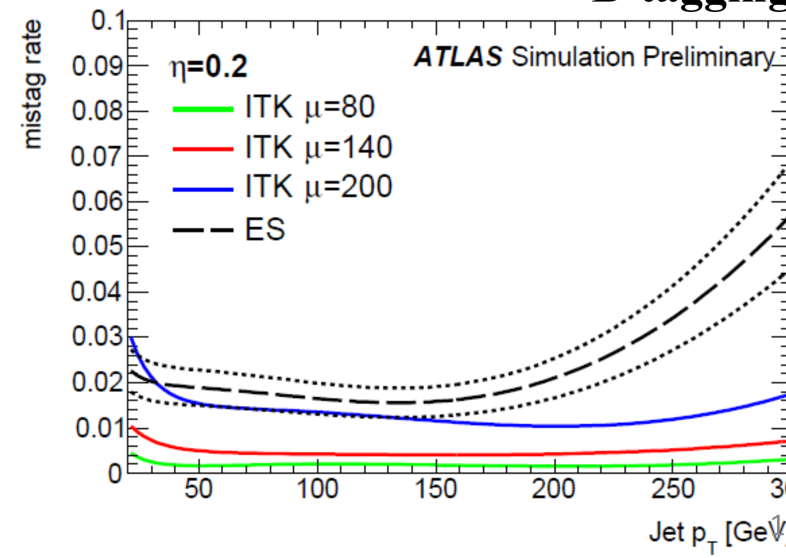
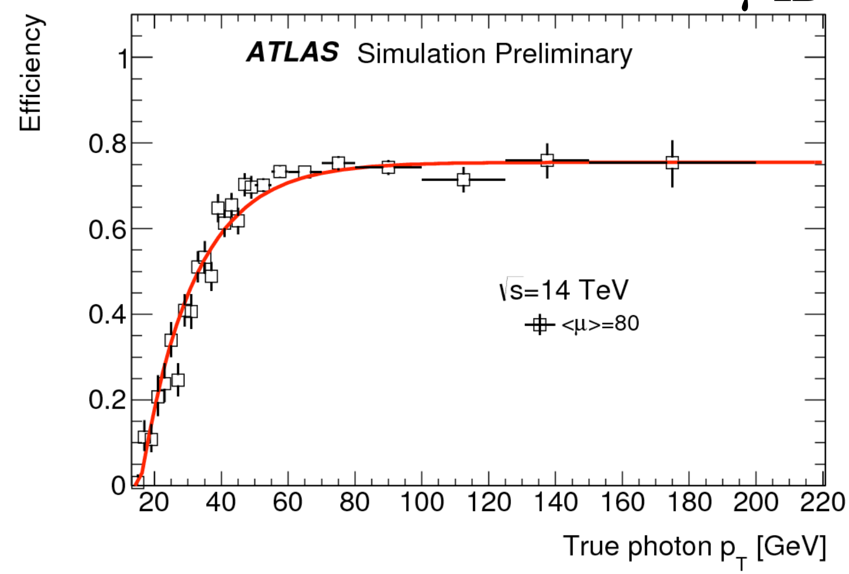
B-tagging



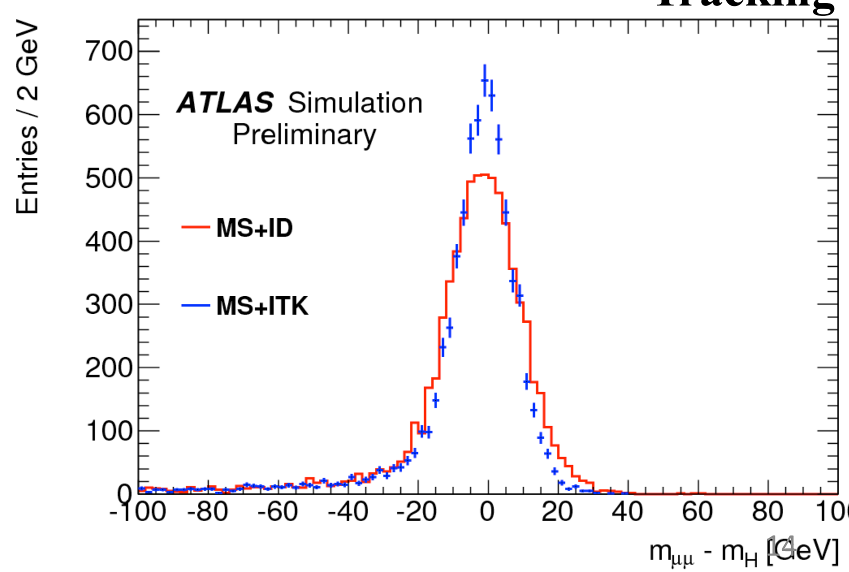
Full simulation object studies

- The efficiency of the photon identification and isolation requirements as a function of the true photon p_T. Fitted parametrisation is superimposed.
  - Simulation corresponds to an average value of $\langle\mu\rangle$=80. It assumed also for $\langle\mu\rangle$ = 140.
- Distribution of the difference between the reconstructed and true mass for a 400 GeV Higgs-like resonance for the current ID configuration (MS+ID) and for the Phase-II configuration (MS+ITK).

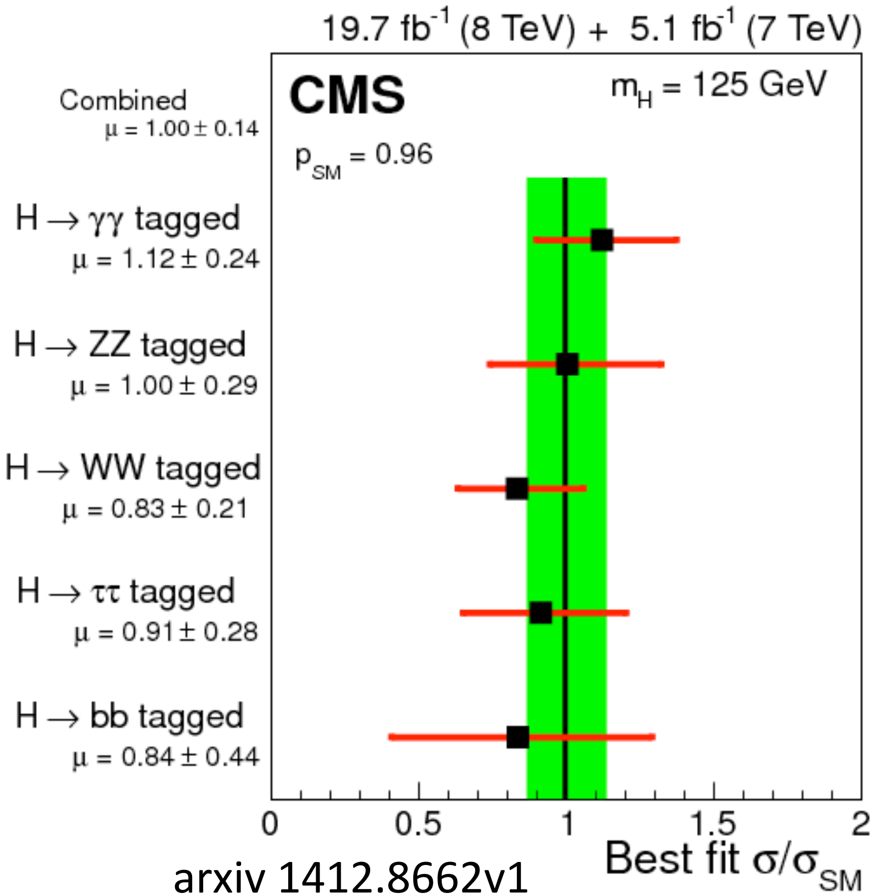
γ-ID



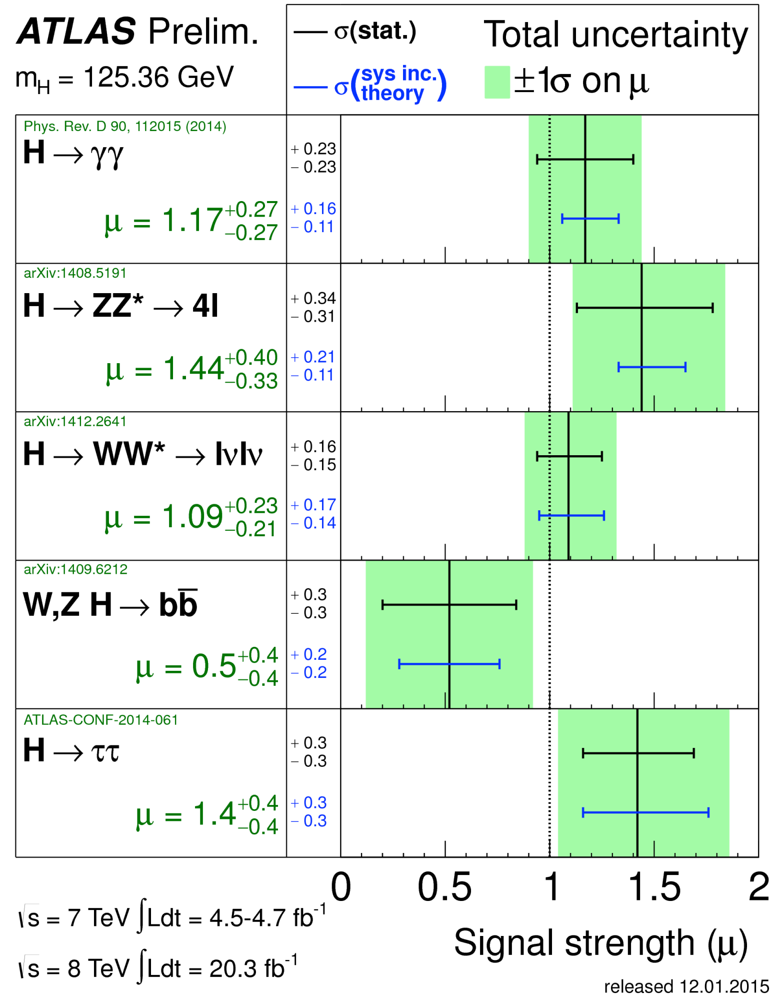
Tracking



Higgs results @ LHC Run-I



arxiv 1412.8662v1



- The sensitivity of the main 5 decay channels differs only by a factor ~3
- Rich Higgs sector programme at HL-LHC

H→ZZ*→4l

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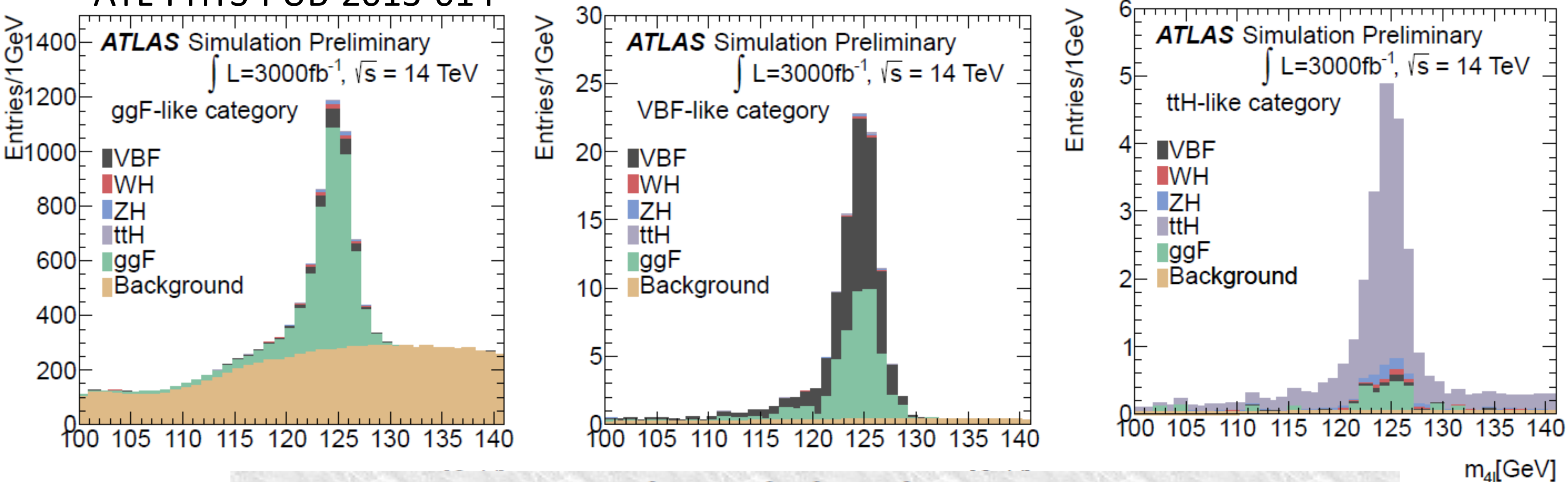


Selected signal event rates

	ttH	ZH	WH	VBF	ggH
3000fb^{-1}	35	5.7	67	97	3800

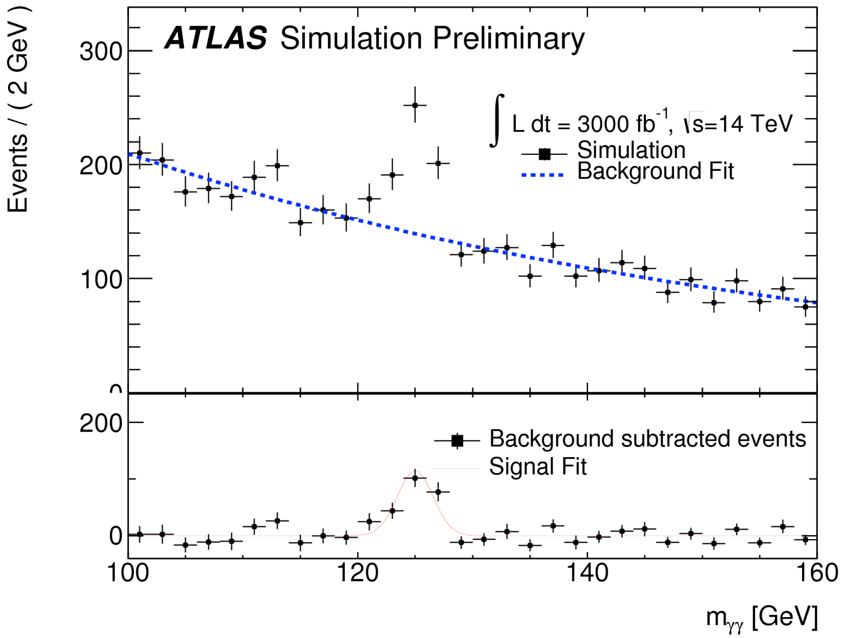
- Very high signal purity
- Separate into all 5 production modes
- WH, ZH use lepton tags

ttH only possible at HL-LHC

VH, H→bb

- Processes considered are WH→lνbb and ZH→llbb;
  - l = e,μ
  - The process ZH→ννbb should be investigated
- The analysis follows the general event selection strategy used for the analysis of $\sqrt{s}$ = 8 TeV collision, except for jet pT thresholds
- No direct simulation of pileup jets is performed, however jet p_T thresholds are set high to keep low their rate
  - the physics performance of objects account for pileup effects
- To validate the analysis method, the study has been performed assuming run-1 conditions (√s, L and pile-up) – reasonable agreement has been found (better than 5%)
- A **significance** of the H→bb signal from **8.8 to 9.6** can be obtained, depending on the JES systematic uncertainties that we can set at HL-LHC

ttH, H→γγ

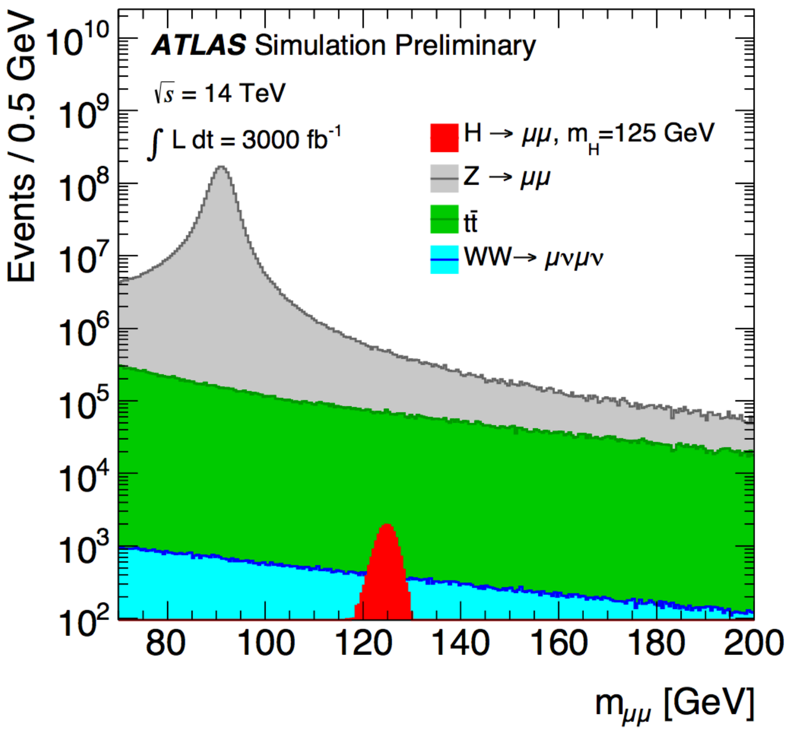


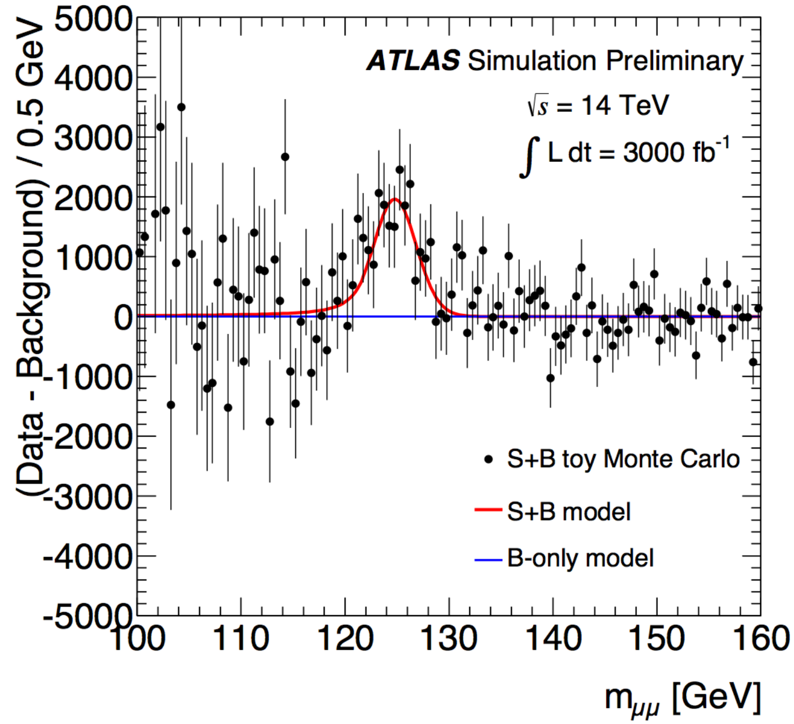
- Sensitive to top in both production and decay
- Yields top Yukawa coupling

ATL-PHYS-PUB-2014-012

Production mode	$\Delta\hat{\mu}/\hat{\mu}$ (%)			
	Total	Statistical	Experimental	Theoretical
$t\bar{t}H$	$^{+21}_{-17}$	$^{+13}_{-12}$	$^{+5}_{-4}$	$^{+17}_{-11}$
WH	$^{+26}_{-25}$	$^{+21}_{-20}$	$^{+13}_{-12}$	$^{+10}_{-8}$
ZH	$^{+35}_{-31}$	$^{+32}_{-29}$	$^{+7}_{-7}$	$^{+12}_{-8}$
ggF	$^{+19}_{-14}$	$^{+3}_{-3}$	$^{+1}_{-1}$	$^{+19}_{-14}$
VBF	$^{+29}_{-29}$	$^{+18}_{-18}$	$^{+1}_{-1}$	$^{+23}_{-23}$

H→μμ

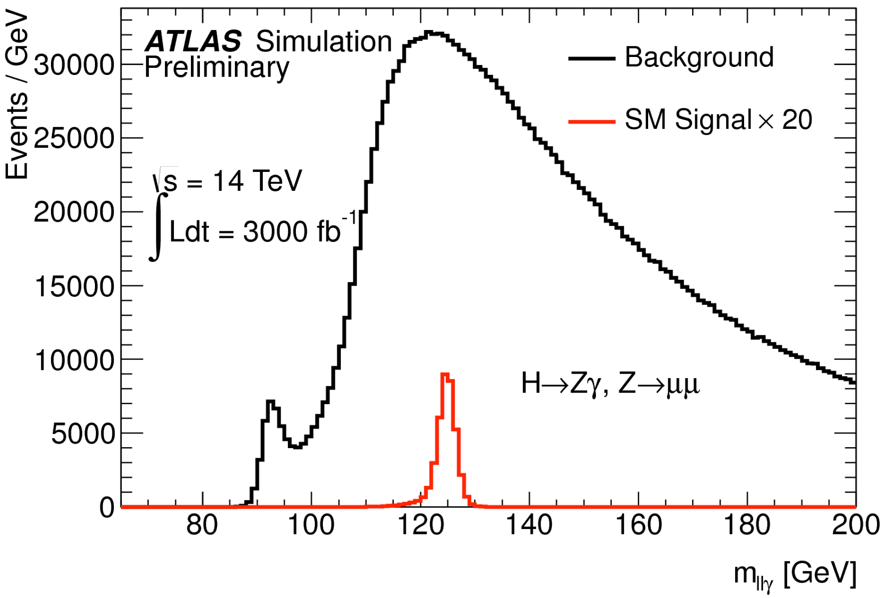


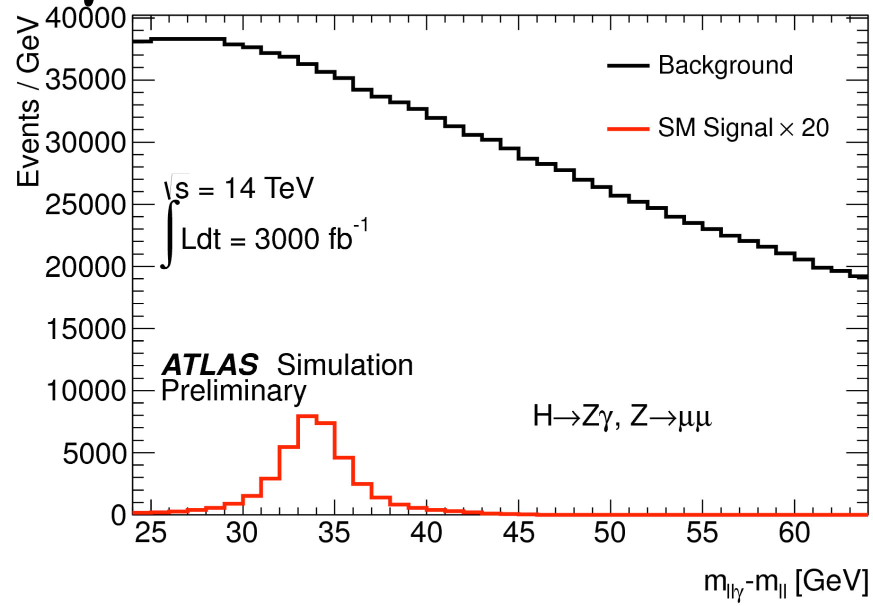


- Allows direct study of coupling to two different leptons
- Test lepton flavour-violation carefully
- Signal significance:

$\mathcal{L}$ [fb^{-1}]	300	3000
Signal significance	2.3σ	7.0σ
$\Delta\mu/\mu$	46%	21%

H→Zγ





Category	high p_{Tt}		low p_{Tt} low $\|\Delta\eta_{Z\gamma}\|$		low p_{Tt} high $\|\Delta\eta_{Z\gamma}\|$	
Final states	$ee\gamma$	$\mu\mu\gamma$	$ee\gamma$	$\mu\mu\gamma$	$ee\gamma$	$\mu\mu\gamma$
S	602	721	703	839	138	165
B	$2.56 \cdot 10^4$	$3.05 \cdot 10^4$	$1.09 \cdot 10^5$	$1.30 \cdot 10^5$	$2.56 \cdot 10^4$	$3.06 \cdot 10^4$
S/B (%)	2.4	2.4	0.64	0.64	0.54	0.54
$S/\sqrt{B}$	3.8	4.1	2.1	2.3	0.86	0.94

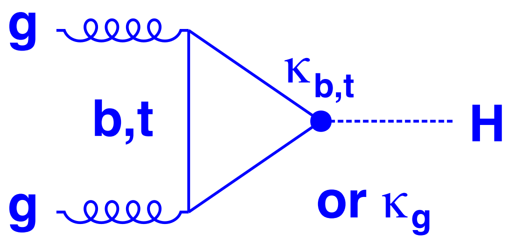
- Tests loop structure
- Small Signal to background ratio
- But a measurement is possible

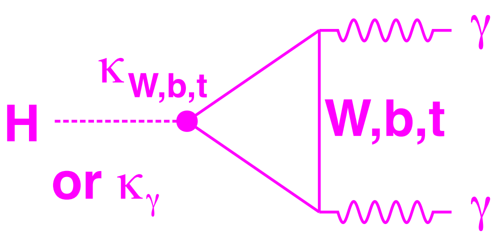
From signal rates to Higgs couplings

- The cross section times branching ratio for initial state i and final state f is given by

$$\sigma \cdot Br(i \rightarrow H \rightarrow f) = \frac{\sigma_i \cdot \Gamma_f}{\Gamma_H}$$

- The total width Γ_H is too narrow to measure
  - Assume it is the sum of the visible partial widths – no additional invisible modes
- Cross sections and branching ratios scale with κ^2 ($\rightarrow \Delta\kappa \sim 0.5\ \Delta\mu$)
- Gluon and photon couplings can be assumed to depend on other SM couplings, or to be independent to allow for new particles in the loop





Higgs Couplings

- New: VH->bb included in ATLAS, updates for H->Zγ, VH/ttH->γγ (*)
- No BSM Higgs decay modes assumed

–Comparable numbers for κ_W,κ_Z, κ_t, and κ_γ between the experiments

–Couplings can be determined with 2-10% precision at 3000fb^{-1} (for CMS Scenario 2)

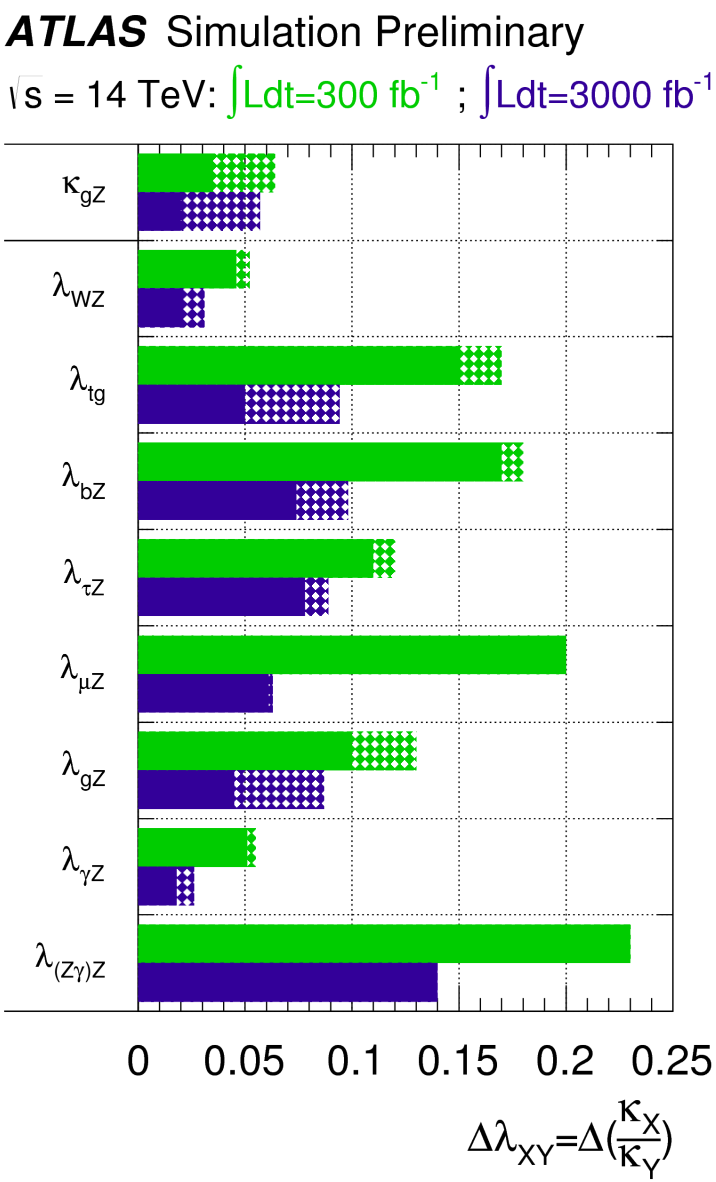
		κ_γ	κ_W	κ_Z	κ_g	κ_b	κ_t	κ_τ	$\kappa_{Z\gamma}$	κ_μ
300fb^{-1}	ATLAS	[9,9]	[9,9]	[8,8]	[11,14]	[22,23]	[20,22]	[13,14]	[24,24]	[21,21]
300fb^{-1}	CMS	[5,7]	[4,6]	[4,6]	[6,8]	[10,13]	[14,15]	[6,8]	[41,41]	[23,23]
3000fb^{-1}	ATLAS	[4,5]	[4,5]	[4,4]	[5,9]	[10,12]	[8,11]	[9,10]	[14,14]	[7,8]
3000fb^{-1}	CMS	[2,5]	[2,5]	[2,4]	[3,5]	[4,7]	[7,10]	[2,5]	[10,12]	[8,8]

–ATLAS: [no theory uncert., full theory uncert.]

–CMS: [Scenario 2, Scenario1]

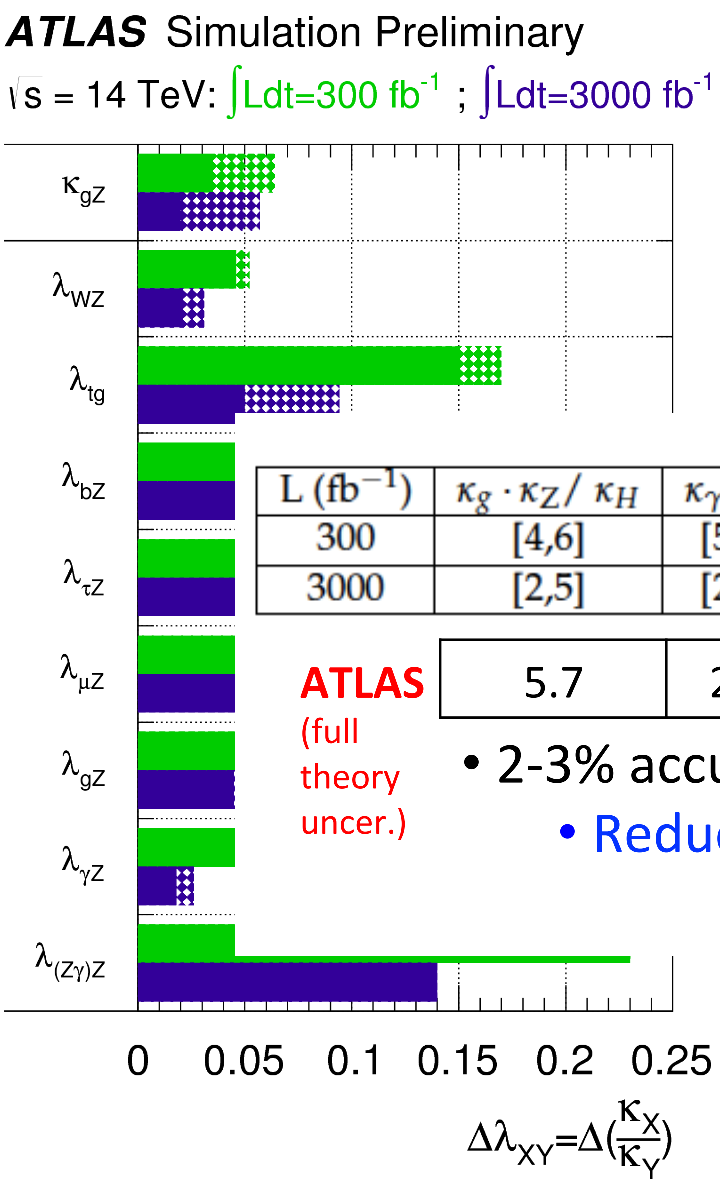
(*)
ATL-PHYS-PUB-2014-011
ATL-PHYS-PUB-2014-006
ATL-PHYS-PUB-2014-012
ATL-PHYS-PUB-2014-016

Higgs Couplings



- Remove the assumption on the total width
  - Only ratios of the coupling scale factors can be determined at LHC
  - Use given process as a reference

Higgs Couplings



CMS [Scenario2,Scenario1]

L (fb^{-1})	$\kappa_g \cdot \kappa_Z / \kappa_H$	κ_γ / κ_Z	κ_W / κ_Z	κ_b / κ_Z	κ_τ / κ_Z	κ_Z / κ_g	κ_t / κ_g	κ_μ / κ_Z	$\kappa_{Z\gamma} / \kappa_Z$
300	[4,6]	[5,8]	[4,7]	[8,11]	[6,9]	[6,9]	[13,14]	[22,23]	[40,42]
3000	[2,5]	[2,5]	[2,3]	[3,5]	[2,4]	[3,5]	[6,8]	[7,8]	[12,12]
ATLAS (full theory uncer.)	5.7	2.6	3.1	9.8	8.9	8.7	9.4	6.3	14

- 2-3% accuracy on few coupling constants at HL-LHC
  - Reduced theoretical uncertainties needed

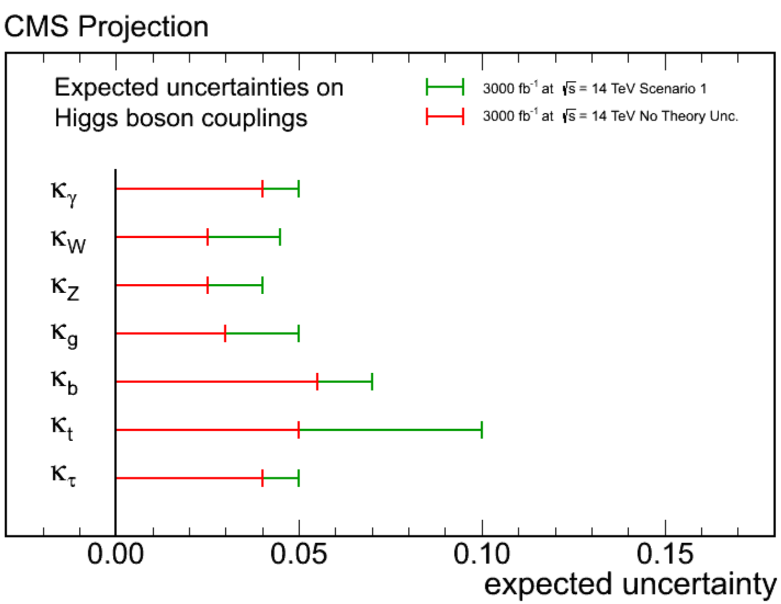
Effects of theory uncertainties

- Theoretical uncertainties limit the achieved precision
- Reducing the theoretical uncertainties is a worthwhile endeavor

CMS:

Scenario 1

No theory uncertainty

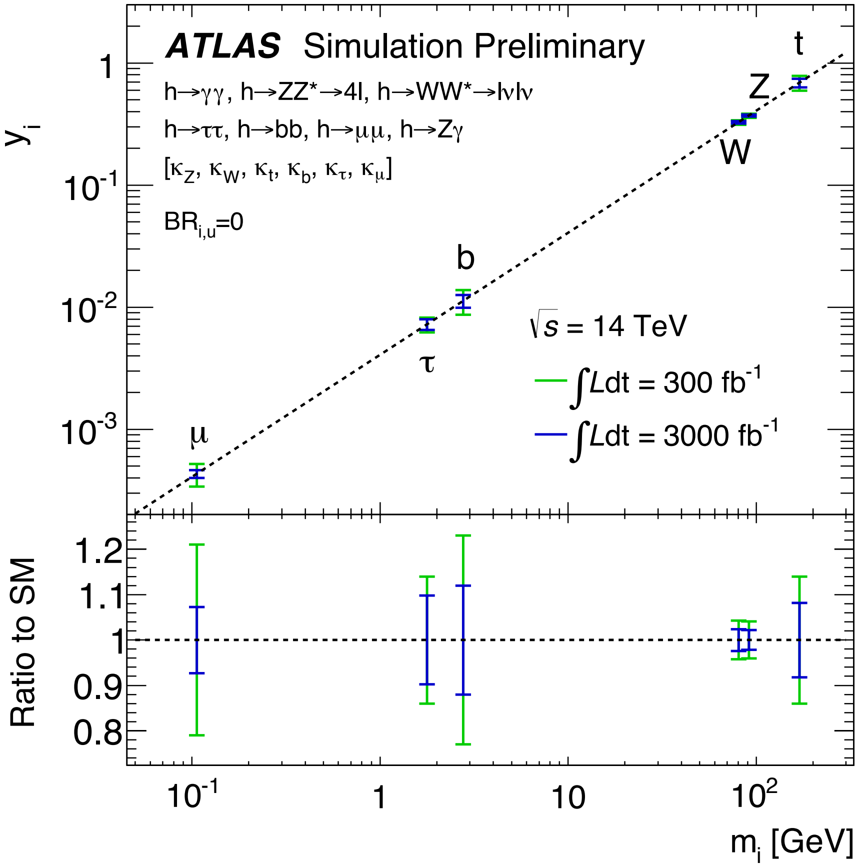


ATLAS: Deduced size of theory uncertainty to increase total uncertainty by <10% for 3000 fb^{-1}

Scenario	Status 2014	by $\lesssim$10% for 3000 fb^{-1}				
Theory uncertainty (%)	[10–12]	κ_{gZ}	$\lambda_{\gamma Z}$	λ_{gZ}	$\lambda_{\tau Z}$	λ_{tg}
$gg \to H$						
PDF	8	1.3	-	-	-	-
incl. QCD scale (MHOU)	7	1.1	-	-	-	-
p_T shape and 0j $\to$ 1j mig.	10–20	-	1.5–3	-	-	-
1j $\to$ 2j mig.	13–28	-	3.3–7	-	-	-
1j $\to$ VBF 2j mig.	18–58	-	-	6–19	-	-
VBF 2j $\to$ VBF 3j mig.	12–38	-	-	-	6–19	-
$q\bar{q}H$						
PDF	3.3	-	-	2.8	-	-
$t\bar{t}H$						
PDF	9	-	-	-	-	3
incl. QCD scale (MHOU)	8	-	-	-	-	2

Higgs Couplings

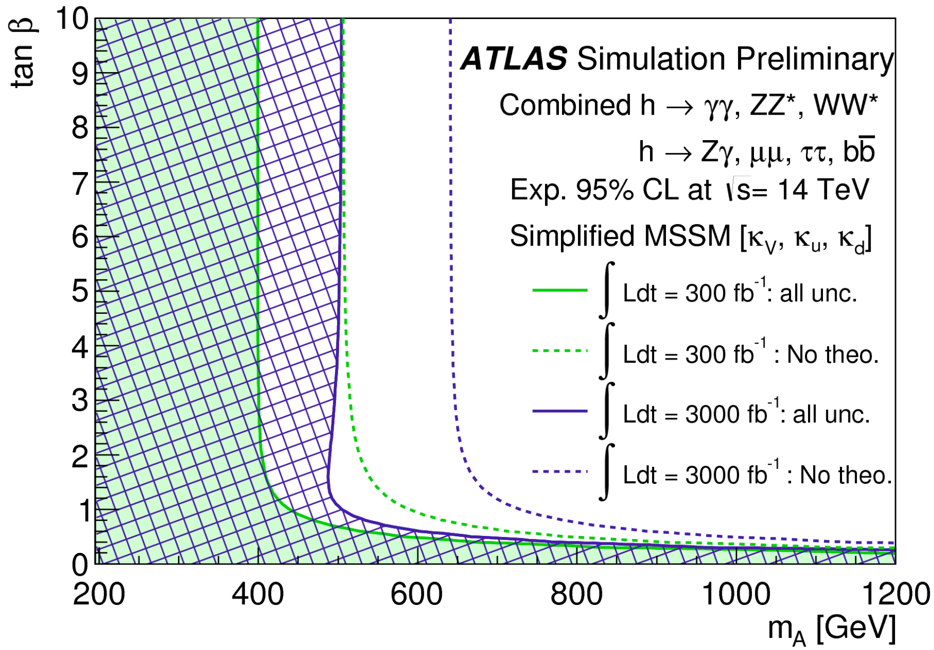
- Higgs boson couplings versus the SM particle masses
- Define 'reduced' coupling parameters



$$y_{V,i} = \sqrt{\kappa_{V,i}\frac{g_{V,i}}{2v}} = \sqrt{\kappa_{V,i}}\frac{m_{V,i}}{v}$$

$$y_{F,i} = \kappa_{F,i}\frac{g_{F,i}}{\sqrt{2}} = \kappa_{F,i}\frac{m_{F,i}}{v}$$

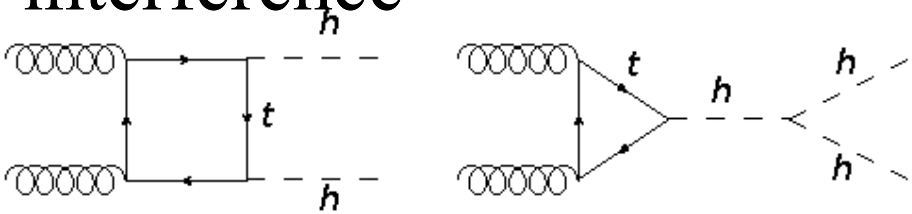
Simplified MSSM



- Second Higgs doublet present in many BSM models, such as MSSM
  - More in general one has 2HDMs, or extra EW singlet models
- Higgs boson couplings constraint heavy Higgs bosons from these models, depending on assumptions
- For tanβ > 2 expect limit on mA > 500 (600) GeV assuming 300 (3000) fb-1, if not limited by theory uncertainties
  - Current limit is 290 GeV

Di-Higgs production

- One of the exciting prospects of HL-LHC
  - Cross section at $\sqrt{s}$=14 TeV is 40.2 fb [NNLO]
  - Challenging measurement
    - New preliminary results from ATLAS and CMS
- Destructive interference



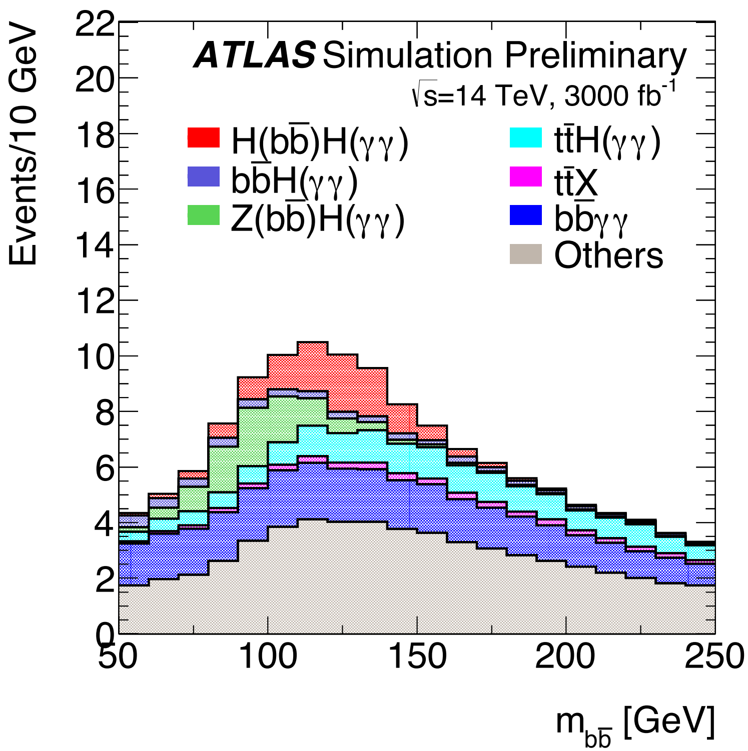
- Final states shown today
  - $bb\gamma\gamma$ [320 expected events at HL-LHC, 3000fb^{-1}]
    - But relatively clean signature
  - bbWW [30000 expected events at HL-LHC, 3000fb^{-1}]
    - But large backgrounds
- bbbb and $bb\tau\tau$ final states under consideration

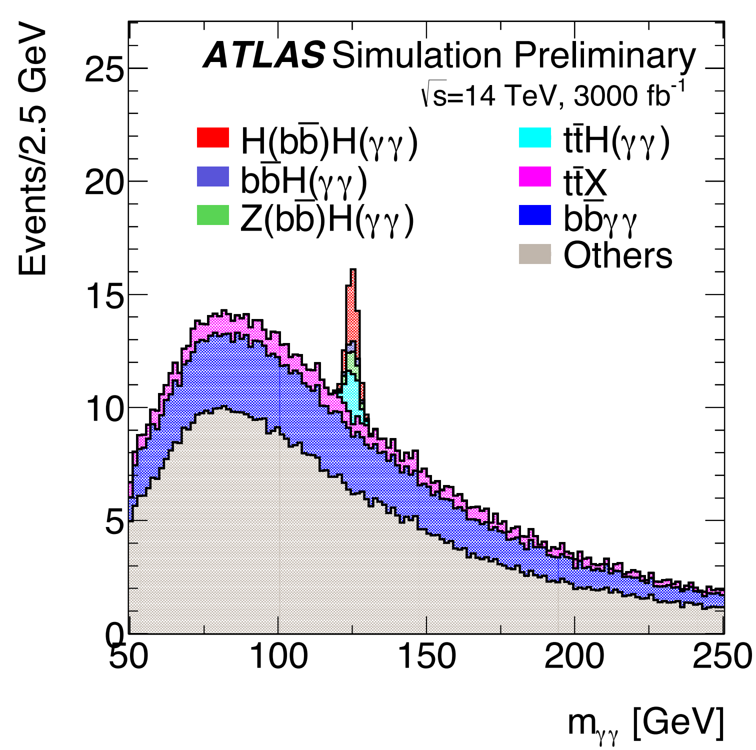
Di-Higgs production

–Nominal performance for Phase II scenario and $3000fb^{-1}$

- CMS:
  - Parameterized object performance tuned to CMS Phase II detector at <PU>=140
  - 2D fit of M_{bb} and $M_{\gamma\gamma}$ distributions
- ATLAS:
  - Parameterized object performance obtained from full simulation
  - Cut based analysis
  - Electron to photon misidentification probability of 2% (5%) in barrel (endcap) is assumed
  - ATL-PHYS-PUB-2014-019

Mass distribution





The distributions of m_{bb} / m_{bb} in 3000 fb^{-1} after applying all the selection criteria except for m_{bb}/ $m_{\gamma\gamma}$. The individual shaped of the contributions are obtained using the events surviving event selection before the mass criteria and angular cuts are applied, but normalized to the number of expected events after the full event selection. The *ttX* contribution includes *tt*(≥ 1 lepton) and *tt*γ, while 'Others' includes *cc*γγ, *bb*γ*j*, *bbjj* and *j j*γγ.

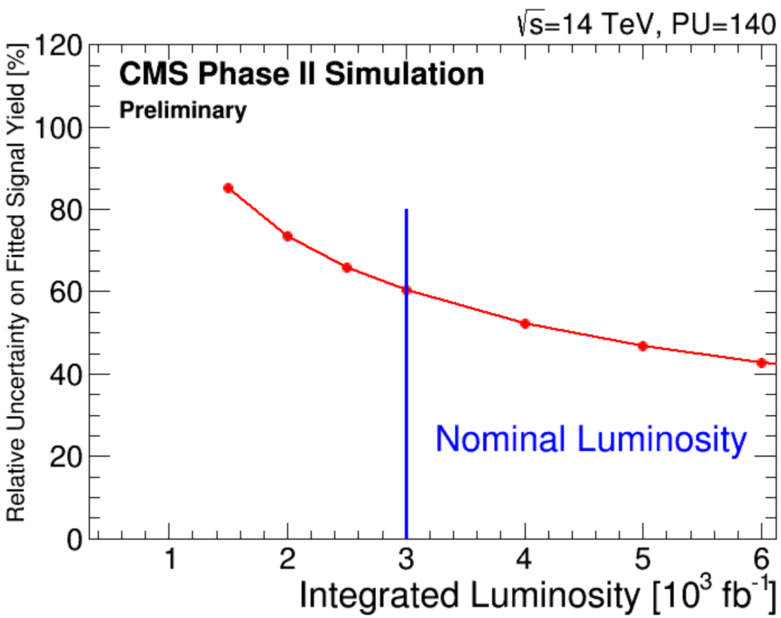
ATLAS prediction

process	Expected events in 3000 fb^{-1}
SM HH→bbγγ	8.4± 0.1
bbγγ	9.7 ± 1.5
ccγγ, bbγj, bbjj, jjγγ	24.1 ± 2.2
top background	3.4 ± 2.2
ttH(γγ)	6.1 ± 0.5
Z(bb)H(γγ)	2.7 ± 0.1
bbH(γγ)	1.2 ± 0.1
Total background	47.1 ± 3.5
S/√B (barrel+endcap)	1.2
S/√B (split barrel and endcap)	1.3

CMS results

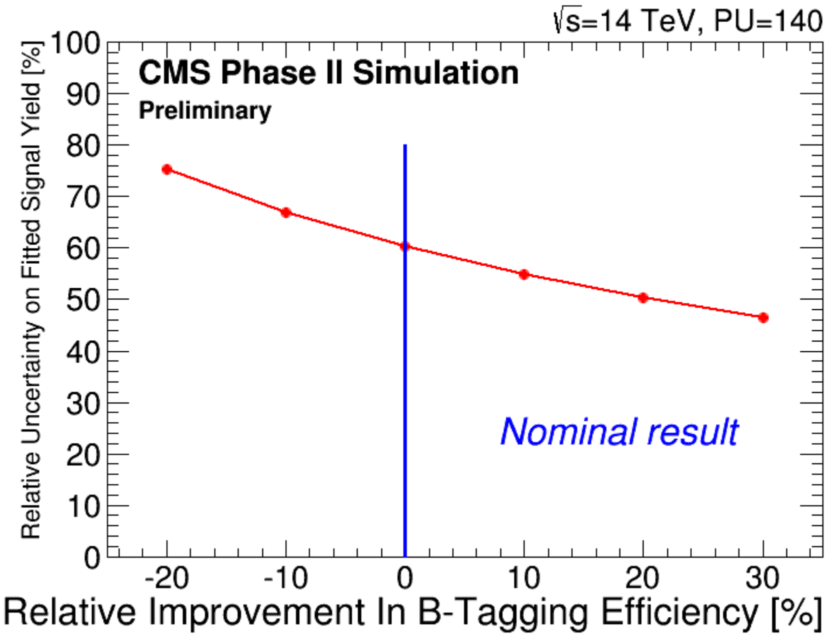
Process / Selection Stage	HH	ZH	$t\bar{t}H$	$b\bar{b}H$	$\gamma\gamma$+jets	γ+jets	jets	$t\bar{t}$
Object Selection & Fit Mass Window	22.8	29.6	178	6.3	2891	1616	292	113
Kinematic Selection	14.6	14.6	3.3	2.0	128	96.9	20	20
Mass Windows	9.9	3.3	1.5	0.8	8.5	6.3	1.1	1.1

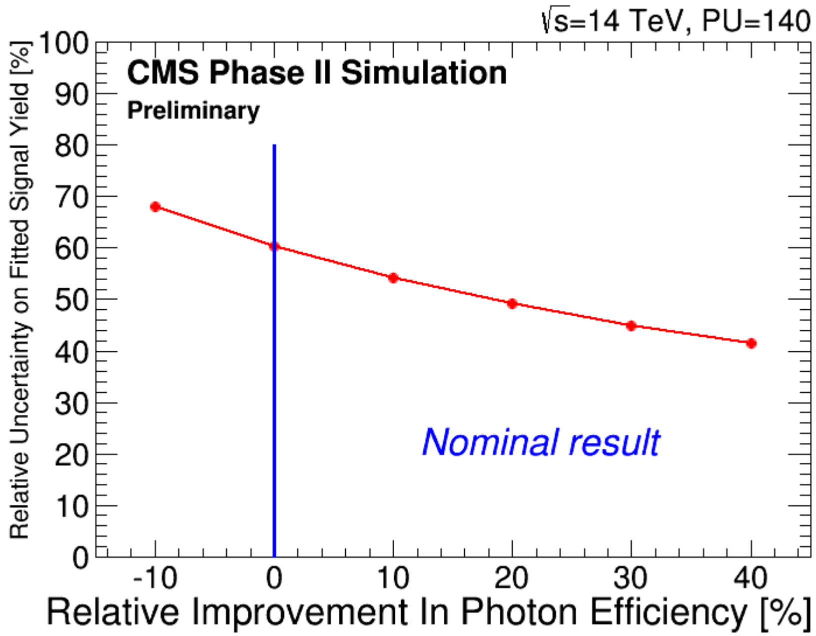
Table 3: The expected event yields of the signal and background processes for 3000 fb^{-1} of integrated luminosity are shown at various stages of the cut-based selection for the both photons in the barrel region. Mass window cuts are 120 GeV to 130 GeV for $M_{\gamma\gamma}$ and 105 GeV to 145 GeV for M_{bb}. A large fit mass window, 100 GeV to 150 GeV for $M_{\gamma\gamma}$ and 70 GeV to 200 GeV for M_{bb}, is used for the likelihood fit analysis. The statistical uncertainties on the yields are of the order of percent or smaller.



ATLAS and CMS are discussing the analyses to continue to better understand remaining differences and avenues for sensitivity improvement

CMS results

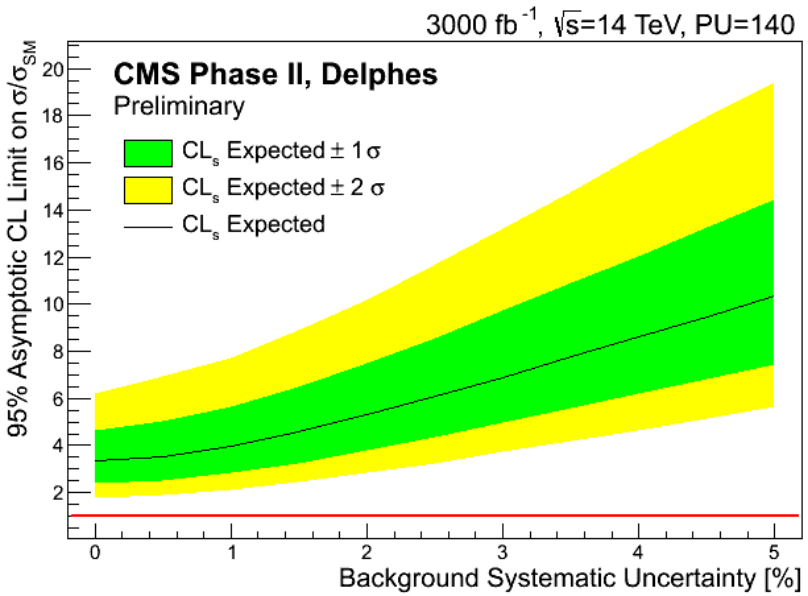


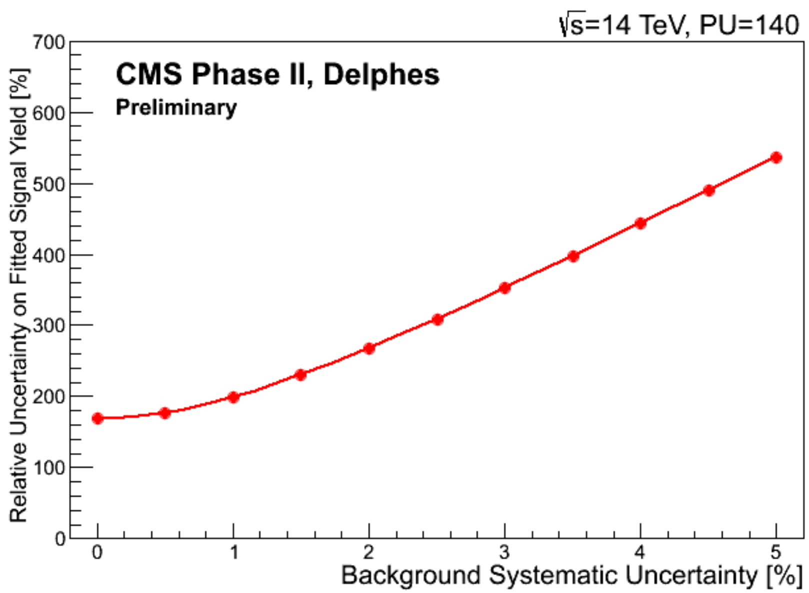


- The average expected relative uncertainty on the di-Higgs cross section measurement is shown as a function of the b-tagging efficiency (left) and the photon efficiency (right).

CMS: HH→WWbb

- Results are quoted as a function of the background systematic uncertainty
  - Data driven techniques will likely constraint the uncertainties to the percent level





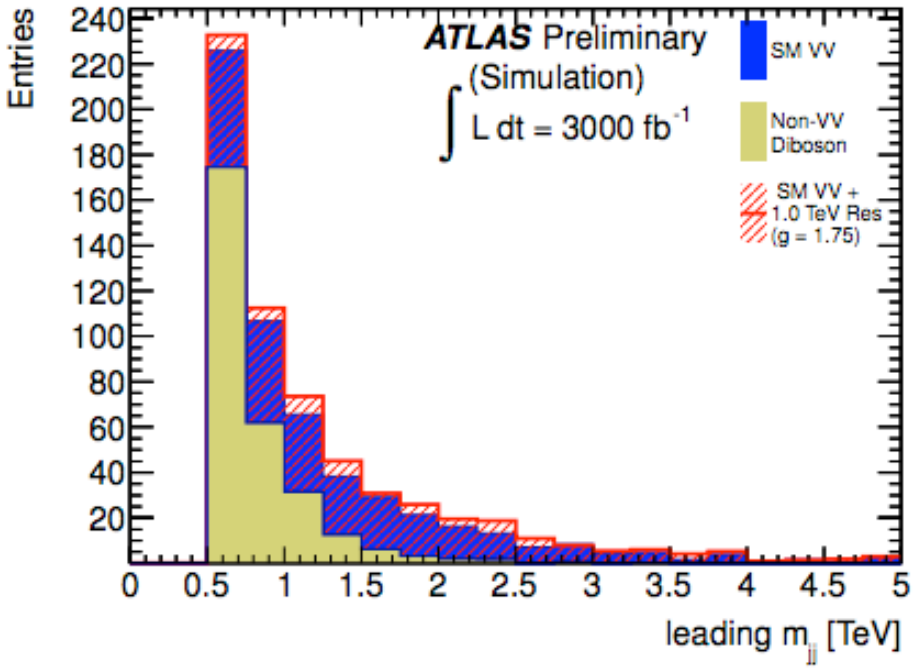
VBS → ZZ Final State

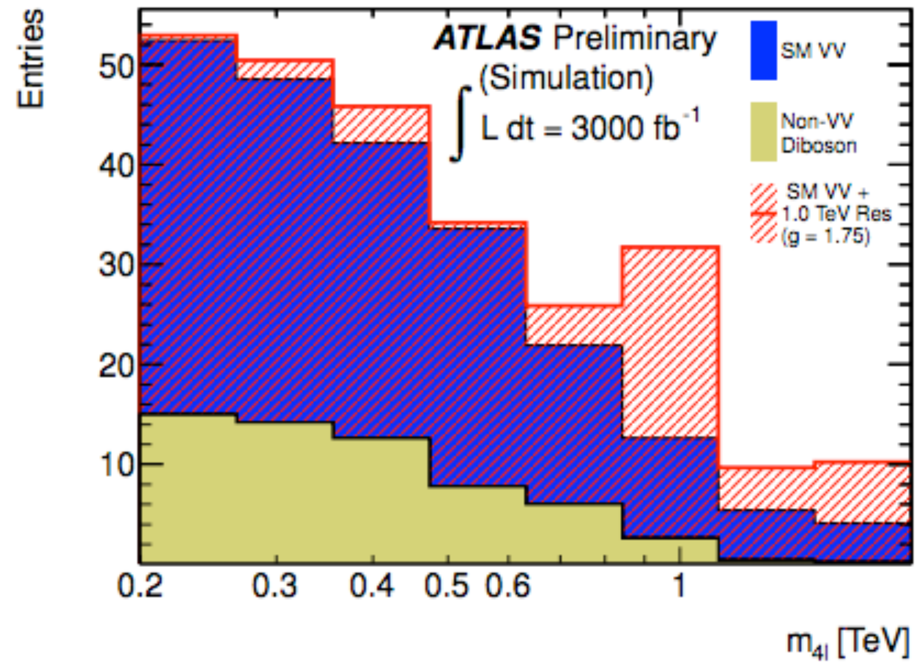
Kotwal, Pollard
Snowmass 2013

- Used EW Chiral Lagrangian using a minimal K-matrix unitarization method
- A. Alboteanu, W. Kilian, and J. Reuter, Resonances and Unitarity in Weak Boson Scattering at the LHC, JHEP 0811 (2008) 010, arXiv:0806.4145 [hep-ph].
- WHIZARD was used to generate
  - SM VV scattering prediction to the ZZ final state
  - Several VV resonances with various masses, couplings, and widths
- Other included backgrounds: diboson (Madgraph)
- Require 4 leptons, one trigger, and 2 jets

VBS → ZZ Final State

Kotwal, Pollard
Snowmass 2013





Expected stat-only Significance

model	$300\,\mathrm{fb}^{-1}$	$3000\,\mathrm{fb}^{-1}$
$m_{\mathrm{resonance}} = 500$ GeV, $g = 1.0$	2.4σ	7.5σ
$m_{\mathrm{resonance}} = 1$ TeV, $g = 1.75$	1.7σ	5.5σ
$m_{\mathrm{resonance}} = 1$ TeV, $g = 2.5$	3.0σ	9.4σ

Summary

- **30 fb^{-1}** of LHC data at $\sqrt{s}$ = 8 (and 7) TeV has allowed the Higgs discovery
- **300 fb^{-1}** at 14 TeV will allow lots of precision measurements in the Higgs sector, SM and continue NP searches
- **3000 fb^{-1}** will extends/complete the LHC Physics Programme:
  - LHC ultimate precision Higgs couplings to elementary bosons and fermions
  - Search for rare Higgs boson decays
  - Coupling structure
  - Di-Higgs boson production
- The physics possible at a hadron collider grows with experience: we'll surely exceed this physics programme!

backup

ECFA Workshop 2014

- Link to the agenda: https://indico.cern.ch/event/315626/
- Performance and Physics session:

14:20 - 15:00 Physics goals and performance reach
Conveners: Markus Klute (Massachusetts Inst. of Technology (US)), Aleandro Nisati (Universita e INFN, Roma I (IT)), Gavin Salam (CERN), Andreas Weiler (CERN)

14:20 **Pileup Mitigation at the HL-LHC** *15'*
Speaker: Pippa Wells (CERN)
Material: Slides

14:40 **Forward Detector Performance at the HL-LHC** *15'*
Speaker: Lindsey Gray (Fermi National Accelerator Lab. (US))
Material: Slides

15:00 - 15:30 Coffee break

15:30 - 18:40 Physics goals and performance reach
Conveners: Markus Klute (Massachusetts Inst. of Technology (US)), Aleandro Nisati (Universita e INFN, Roma I (IT)), Gavin Salam (CERN), Andreas Weiler (CERN)

15:30 **Higgs Theory** *15'*
Higgs physics enters a precision era and the High Luminosity run of the LHC will reveal access to an uncharted territory of the Higgs landscape.
Not only will it probe new channels with multiple Higgs bosons, but it will also access rare corners of the phase space when the Higgs is produced in extreme kinematical conditions (high pT or far off-shell) or when it decays (exclusively or inclusively) into light quarks. The importance of these measurements are tantalizing since they will inform on some couplings that control the fate of the EW vacuum as well as the size of the quantum corrections to the Higgs mass and could tell if the Higgs boson is the only source of mass for the elementary particles.
Speaker: Christophe Grojean (ICREA/IFAE (Barcelona))
Material: Slides

15:50 **Prospects on Higgs Physics at the HL-LHC** *20'*
Speaker: Aram Apyan (Massachusetts Inst. of Technology (US))
Material: Slides

16:15 **SM Theory** *15'*
Speaker: Prof. Nigel Glover (IPPP Durham)
Material: Slides

16:35 **BSM Theory** *15'*
Speaker: Gilad Perez (CERN & Weizmann)
Material: Slides

16:55 **Prospects on Beyond the Standard Model Physics at the HL-LHC** *20'*
Speaker: Stephane Willocq (University of Massachusetts (US))
Material: Slides

17:20 **Heavy Flavour Theory** *15'*
Speaker: Gino Isidori (Istituto Nazionale Fisica Nucleare (IT))

17:40 **Heavy Flavour prospects at the HL-LHC** *15'*
Speaker: Vincenzo Vagnoni (INFN Bologna (IT))
Material: Slides

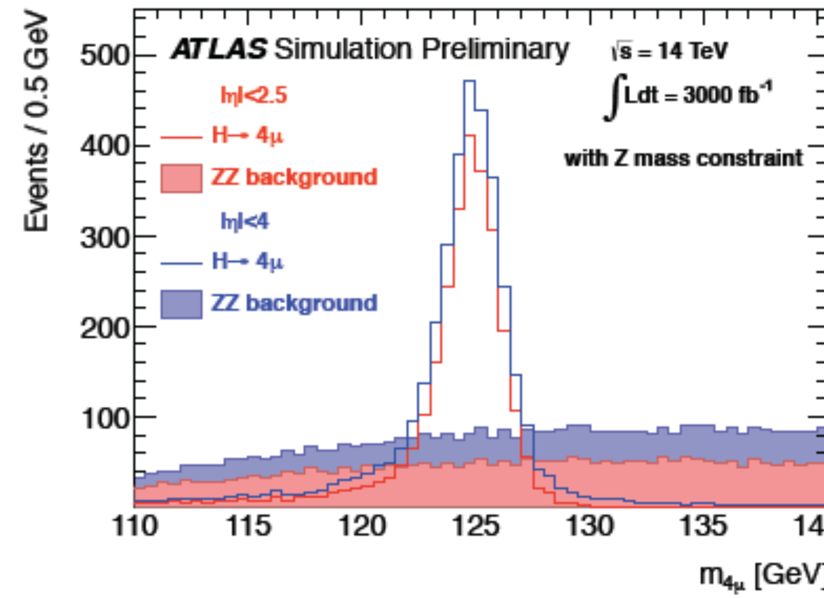
18:00 **Heavy Ion Theory** *15'*
Speaker: Urs Wiedemann (CERN)
Material: Slides

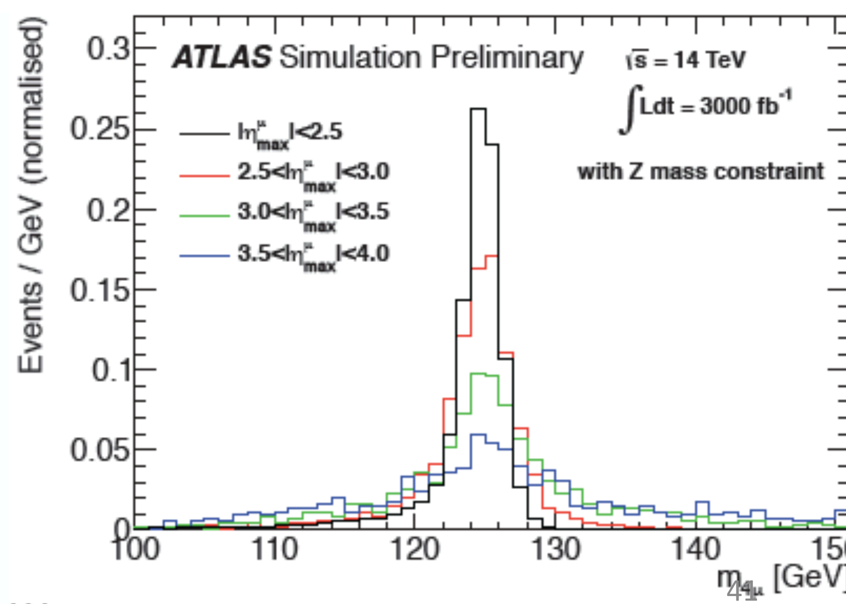
18:20 **Heavy ions at HL-LHC: experimental prospects** *15'*
Speaker: Andrea Dainese (INFN - Padova (IT))
Material: Slides

- New results on (single) Higgs studies since ECFA 2013: all from ATLAS!!
- New/first results on HH production from both collaborations on HH→bbγγ
- CMS presented exclusion limts also on (ggF) HH→bbWW

Higgs Studies & ATLAS Extended ITK

- Study impact of various ITK and MS p_T resolution and trigger acceptance scenarios
- Lepton requirements
  - p_T μ > 20,15,10,6 GeV
  - ΔR, m12, m34 as in Run1 analysis
- Using the best setup:
  - 7μm pixel reso., full muon upgrade
  - 35% Acceptance gain from nearly 100% efficient muon reconstruction
  - Mass resolution degrades quickly with η





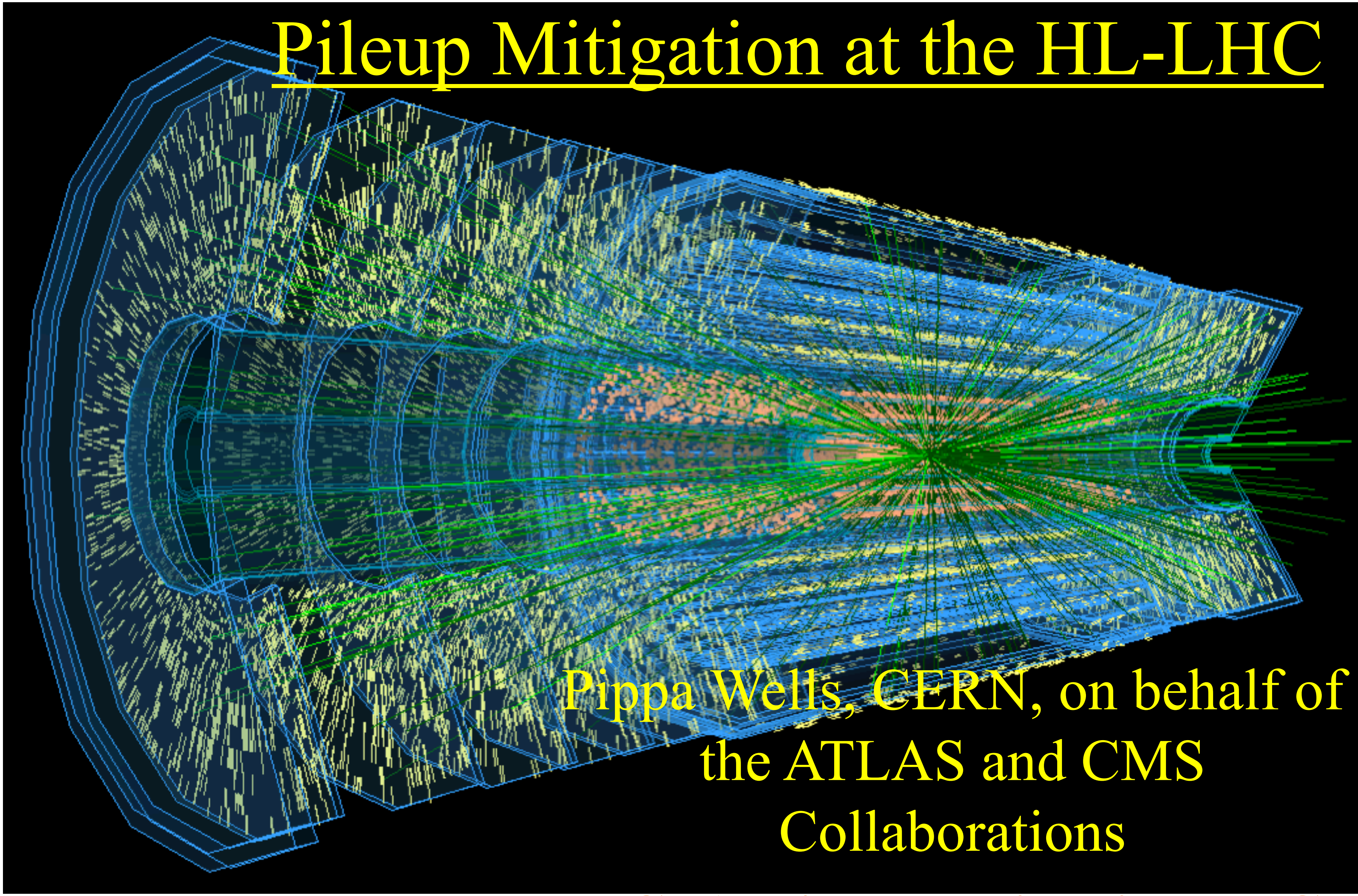
Higgs Prospects analyses

1. HH→bbγγ	ATL-PHYS-PUB-2014-019
2. SM H couplings interpretation	ATL-PHYS-PUB-2014-016
3. BSM H couplings interpretation	ATL-PHYS-PUB-2014-017
4. VBF H→ττ	ATL-PHYS-PUB-2014-018
5. H→4l large η plots	PLOT-UPGRADE-2014-002
6. H→Zγ	ATL-PHYS-PUB-2014-006
7. ttH/ZH,H→γγ	ATL-PHYS-PUB-2014-012
8. VH, H→bb	ATL-PHYS-PUB-2014-011

See details in

https://twiki.cern.ch/twiki/bin/view/AtlasProtected/HiggsProspects

Pileup Mitigation at the HL-LHC



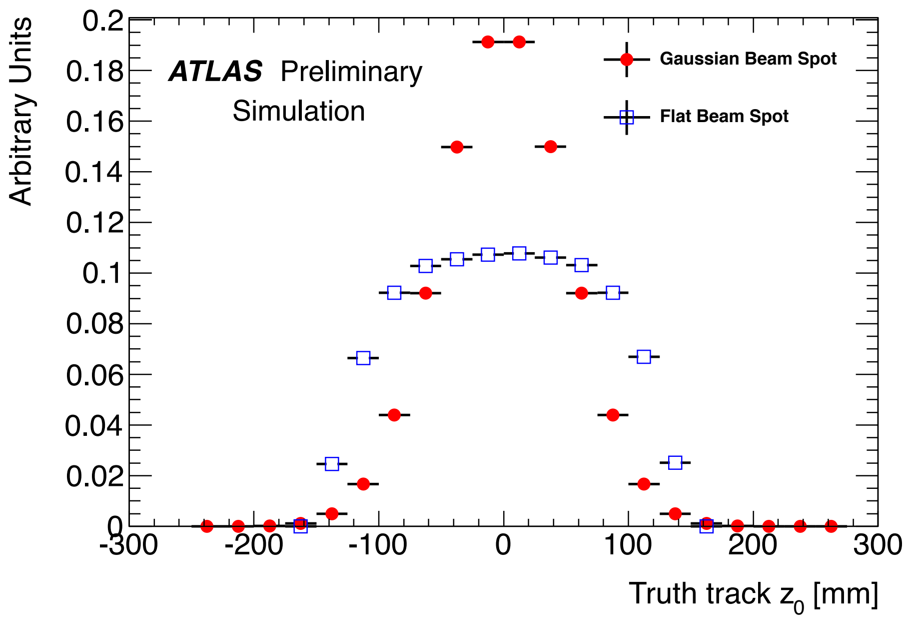
Pippa Wells, CERN, on behalf of the ATLAS and CMS Collaborations

ECFA High Luminosity LHC Experiments Workshop - 2014

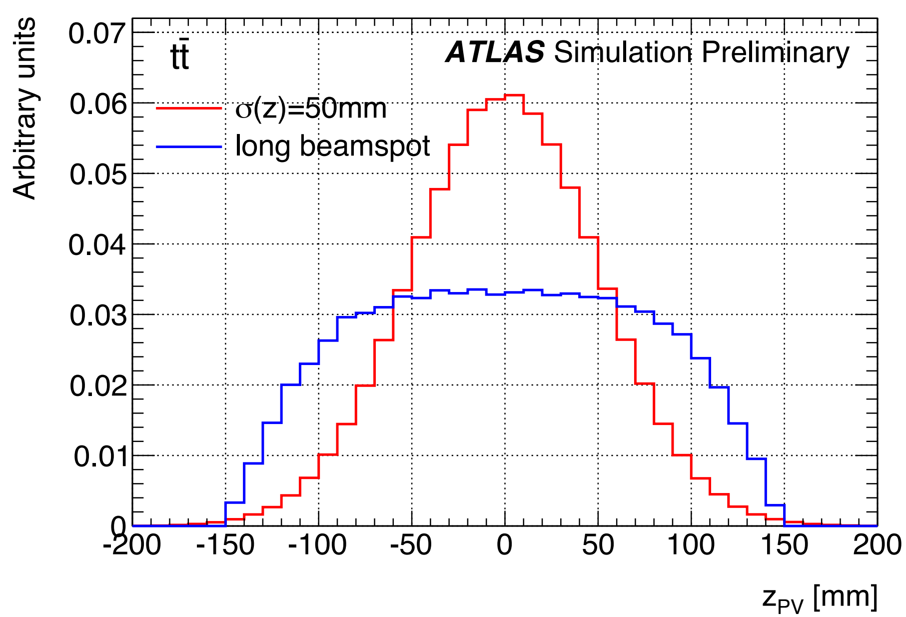
Effects of a longer beam spot

- Generate ttbar events with pileup, Phase II tracker, μ=140
  - Different longitudinal (z) beam spot profiles:
    Gaussian with σ=5cm or Long beam spot, ~flat to ±15cm

– Generated tracks



Reconstructed vertices

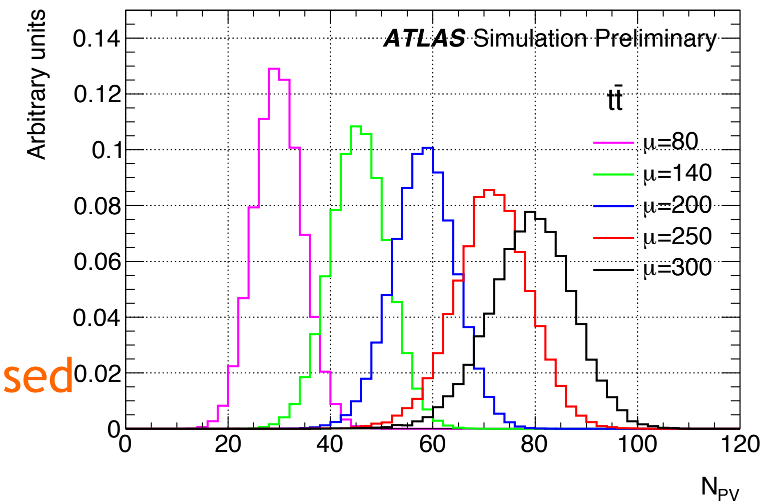


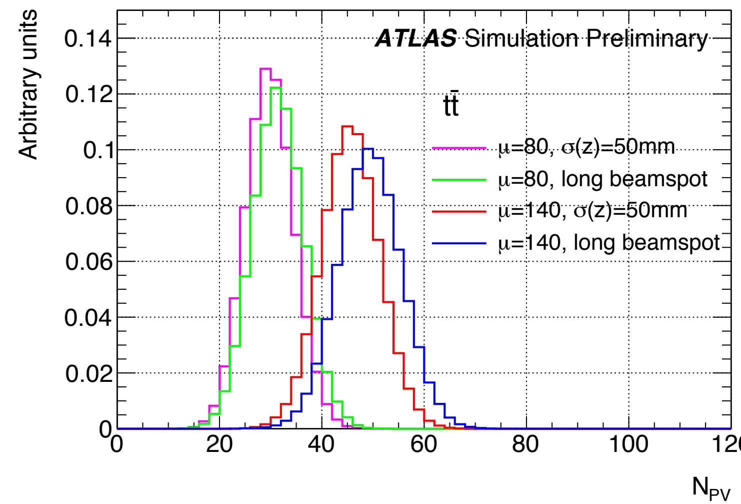
Effects of a longer beam spot

- ttbar events with varying pileup and beam spot z distributions
  - Gaussian, μ [80,300]   Varying shape, μ=80,140

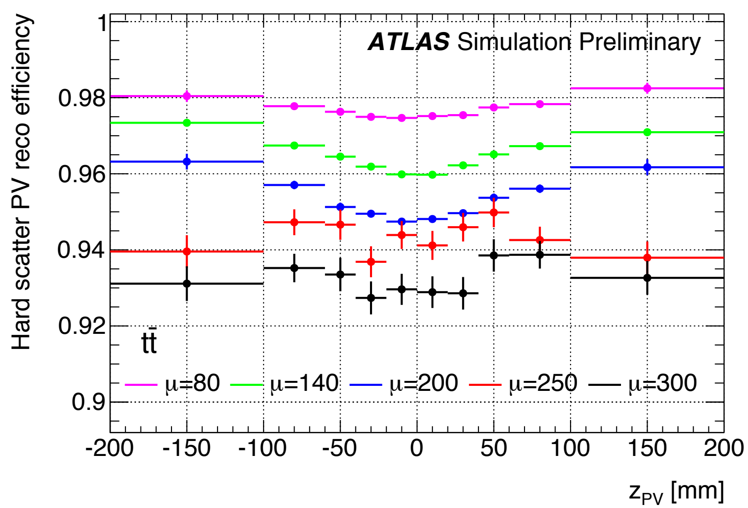
N reco primary vertices

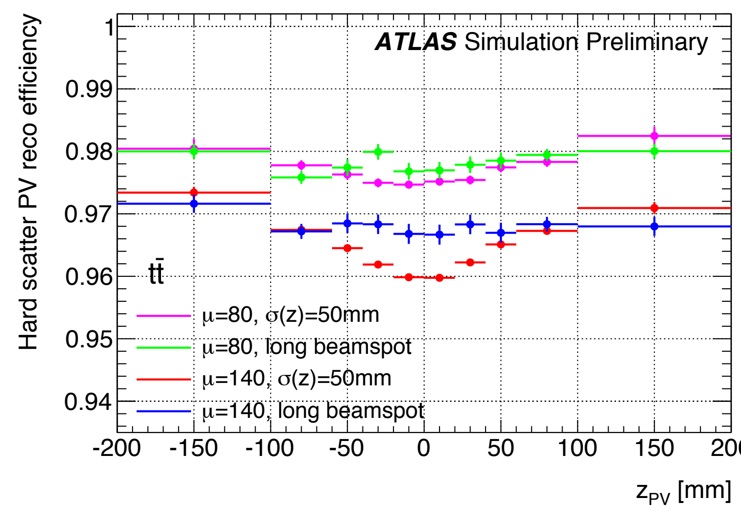
Non-optimised algorithms



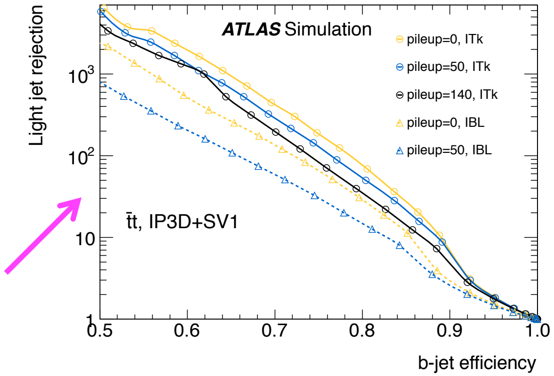


ttbar PV efficiency vs z

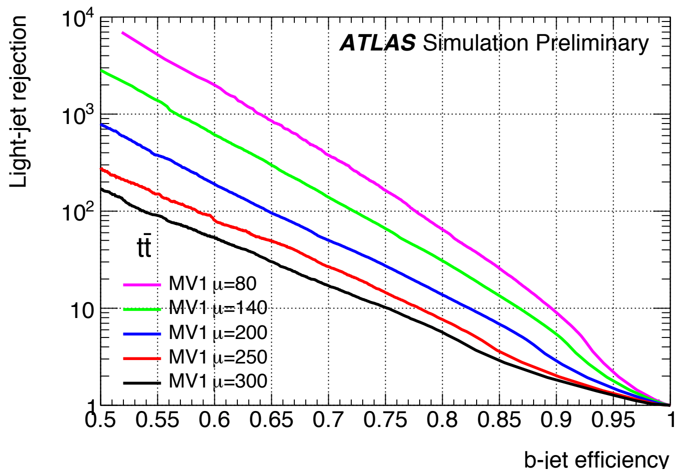


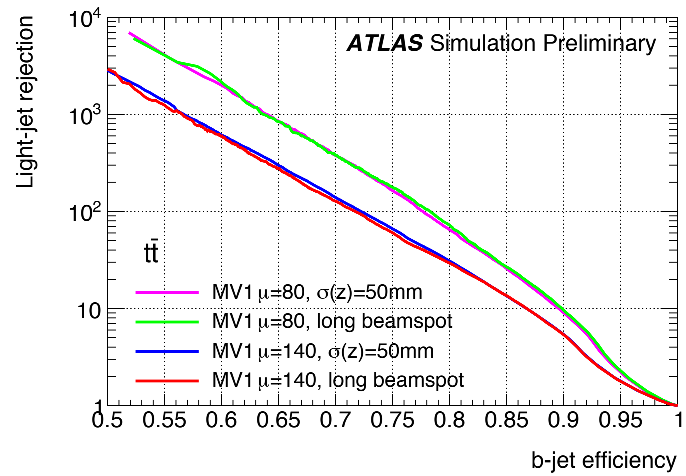


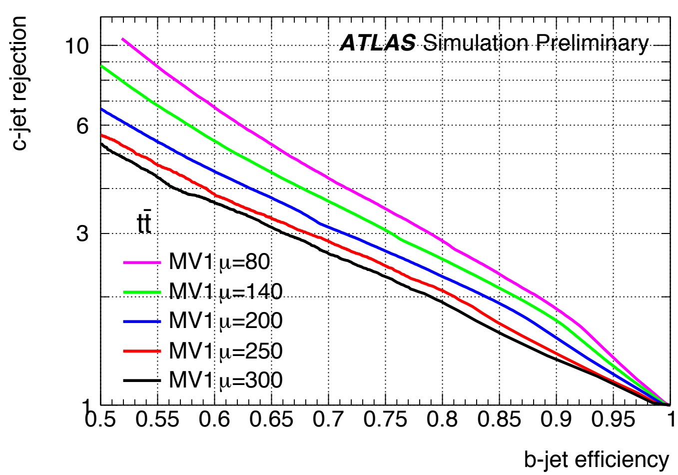
b-tagging – higher pileup



- ATLAS Phase II ITk performance with μ=140 better than Run 2 performance expected with μ=50 [LoI]
  - b-tagging degrades gradually with higher μ







- Only events with the correct primary vertex enter the plots
  - b-tagging is insensitive to beam spot shape IF the correct ttbar primary vertex is found
- NB: rejection = 1/(misid-prob)
- Non-optimised algorithms from Run 1

HEP Physics Programme

7. **Electroweak Symmetry Breaking**: is the 125 GeV particle the only responsible for the EWSB? Analyse the Vector Boson scattering cross section as a function of the VV invariant mass to study whether the cross-section regularization is operated by the Higgs boson (as predicted by SM) or by other objects.
8. **SM**: Very high precision test of the Standard Model parameters (high accuracy measurement of vector boson masses, top mass, $\sin^2\theta_W$, TGC, …)
9. **Naturalness problem**: continue the search for SUSY particles, in particular search for third generation squarks; also continue the search for gauginos and for 1^{st} and 2^{nd} generation squarks; similarly for Extra-Dimensions. Similarly test non-SUSY BSM models
10. **Dark Matter origin**