Prospects of the High Luminosity LHC from CMS and ATLAS

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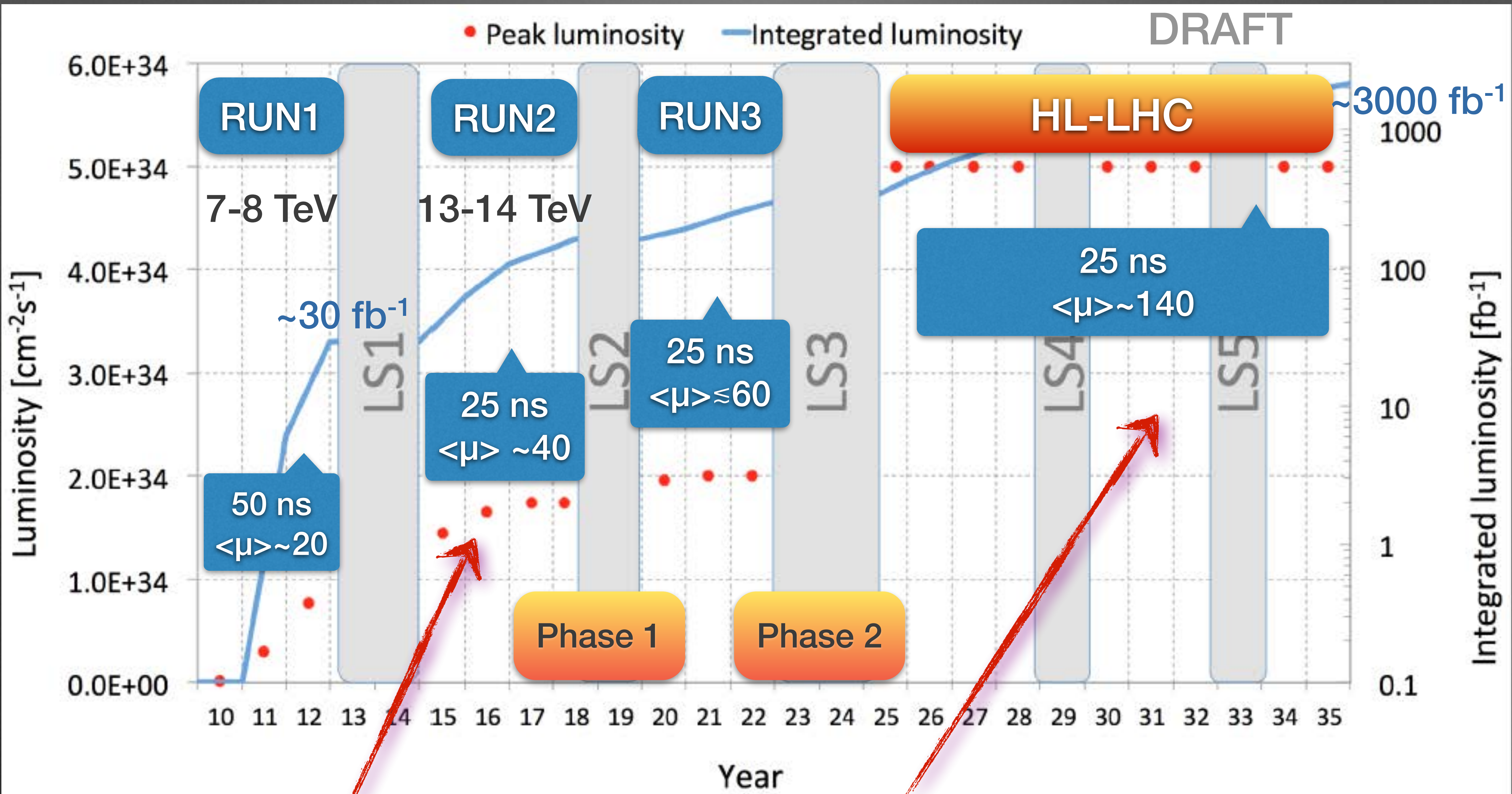
The Past-Present-Future of LHC



We are here!

We want to go there...

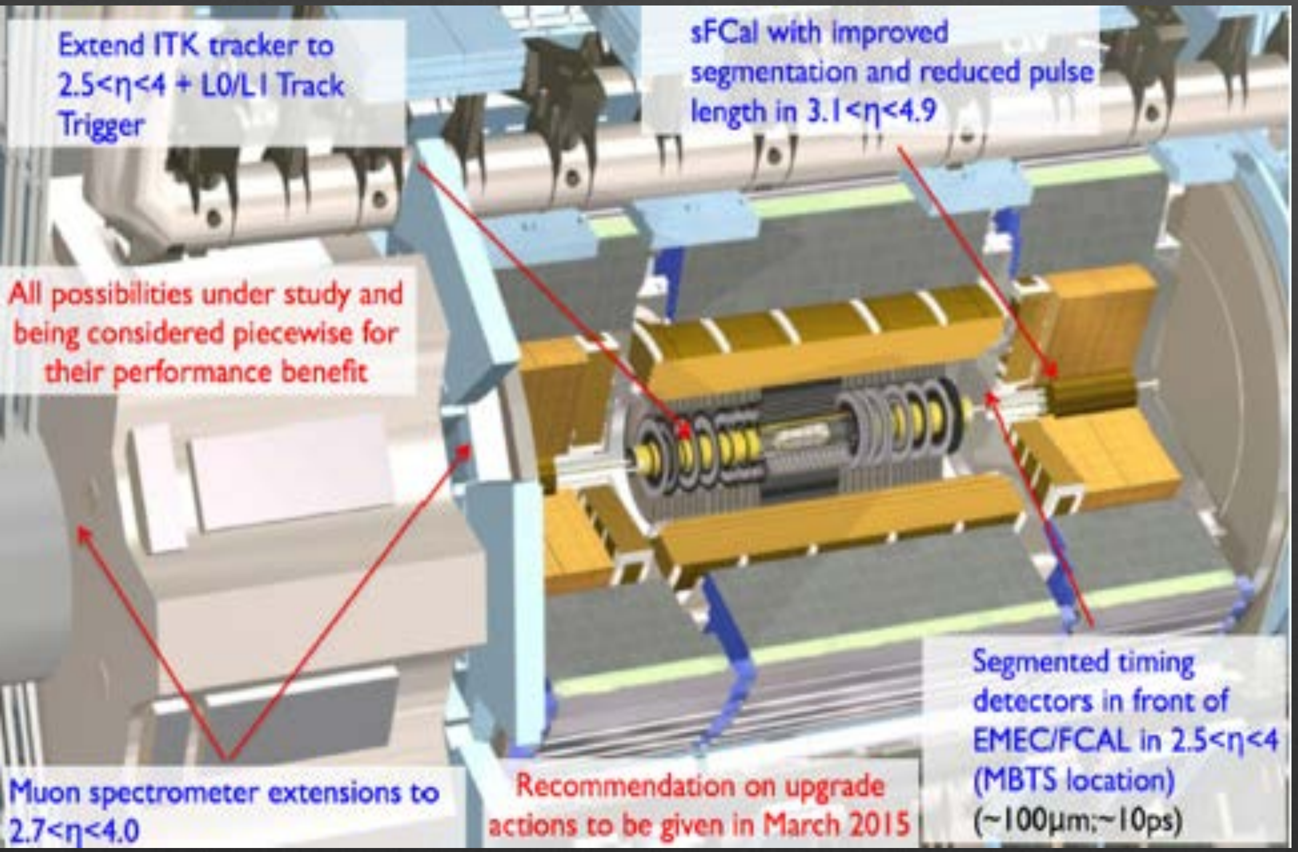
ATLAS & CMS Detector upgrade

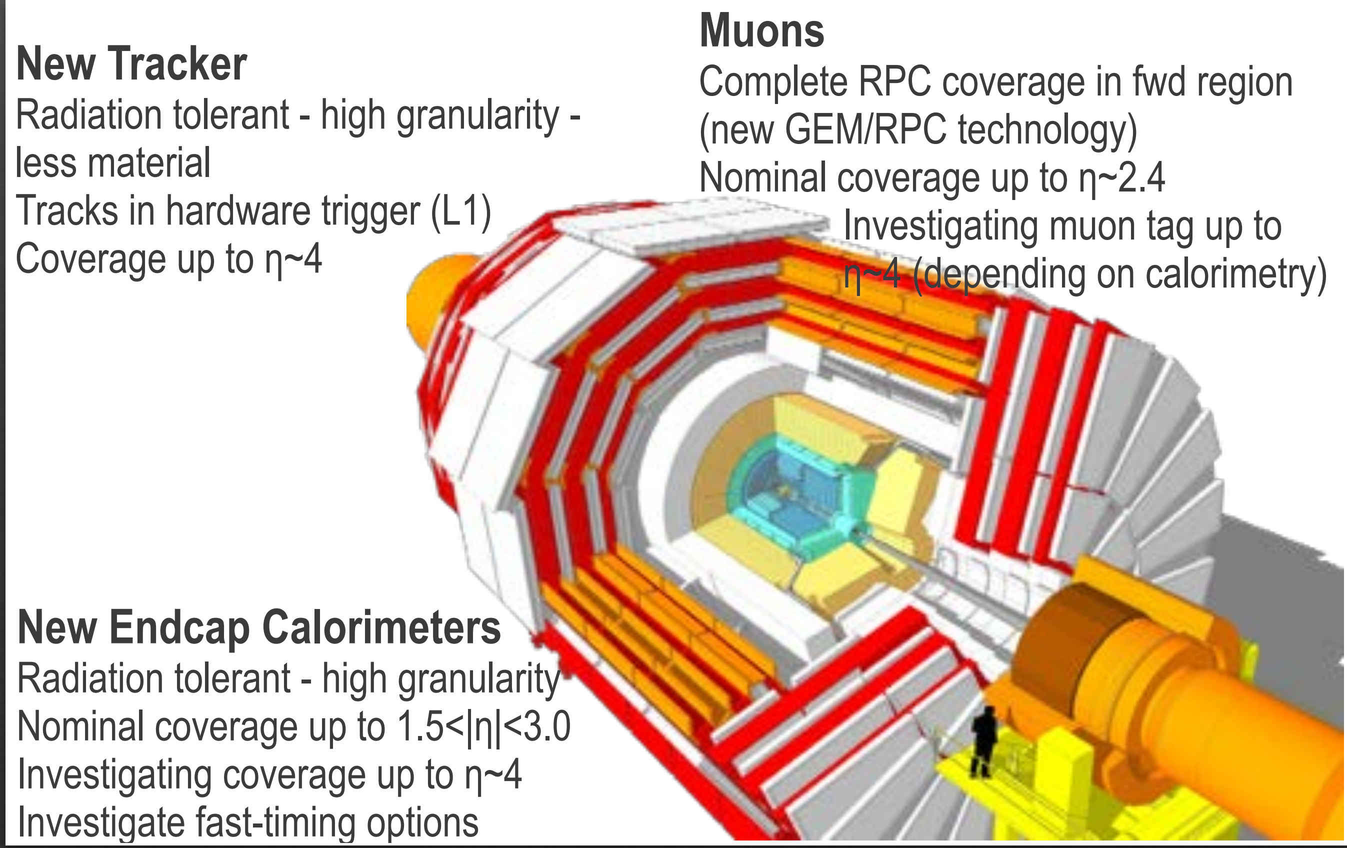
Must cope with:
High pile-up
High radiation level

Lot of talks in the Detector session

Different technologies will be used in the Phase-II upgrade, but common strategy:

- ➡ Re-visit the L1 trigger logic to keep leptons p_T thresholds and L1 trigger rates low
- ➡ New Tracker with high granularity and radiation resistance and extended η coverage
- ➡ Extension of detectors coverage to increase acceptance and improve performances

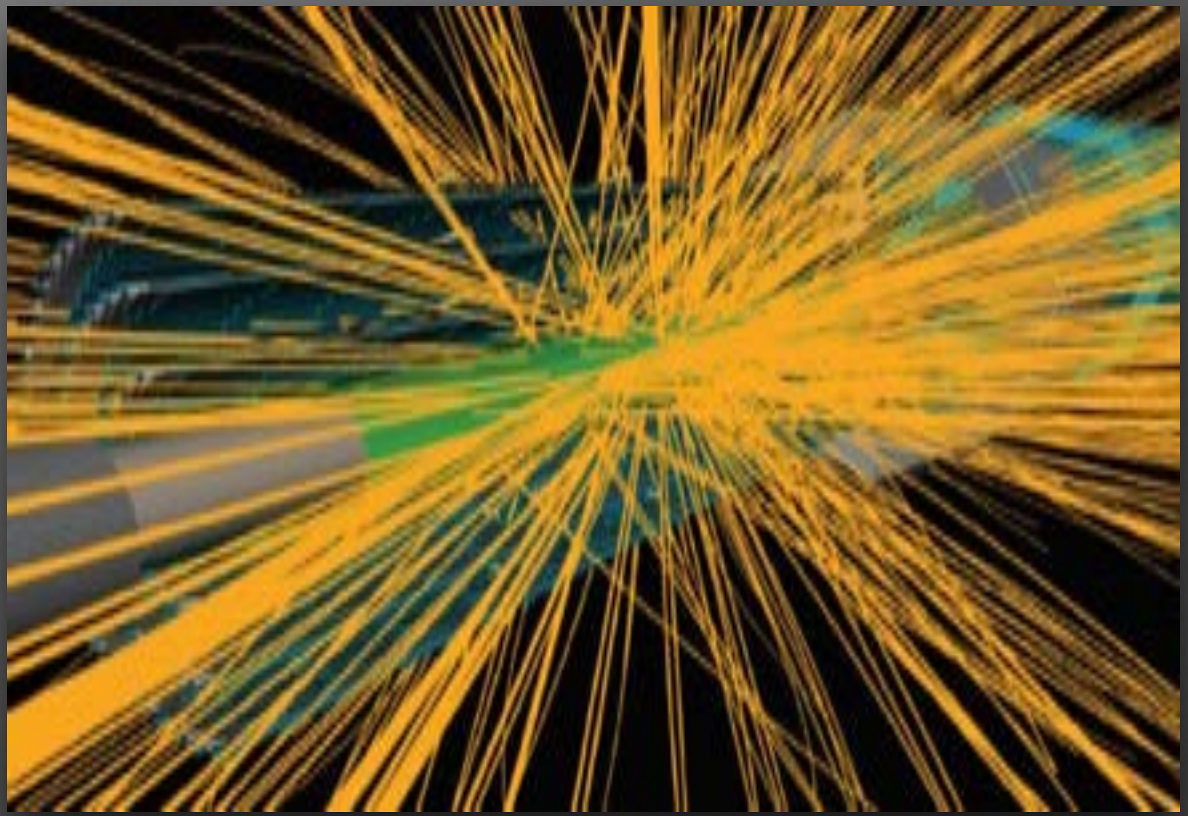




Physics program at HL-LHC

Huge Physics program addressing

- ★ Precision studies of the 125 GeV Higgs boson (couplings, rare decays, etc.)
- ★ Searches/studies for BSM Physics
  - ➡ Higgs
  - ➡ SUSY
  - ➡ Vector Boson Scattering (VBS)
  - ➡ Exotics
  - ➡ DM



ATLAS Performance studies

Performance assessed in benchmark channels using full simulation

- ★ Run 2 detector and <μ>=60, 300 fb^{-1}
- ★ New tracker (ITK) in Run 1 Calorimeter and Muon system, with varying <μ> up to 2000 and for 3000 fb^{-1}
- ★ Physics reach (mostly) based on generator level studies with parameterized performance

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/UpgradePhysicsStudies

CMS Performance studies

Performance assessed in benchmark channel using full simulation

- ★ Phase 1 detector and <μ>=50, 300 fb^{-1}
- ★ Phase 1 detector (aging but pixel) and <μ>=140, 1000 fb^{-1}
- ★ Phase 2 detector and <μ>=140, 1000 fb^{-1}

Physics reach (mostly) based on extrapolation under different assumptions on uncertainties or Delphes

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsFP

Prospects for Higgs Physics

HL-LHC: a Higgs factory!

★ Enable precision measurements:

- ➡ Signal strength
- ➡ Spin/parity
- ➡ Couplings

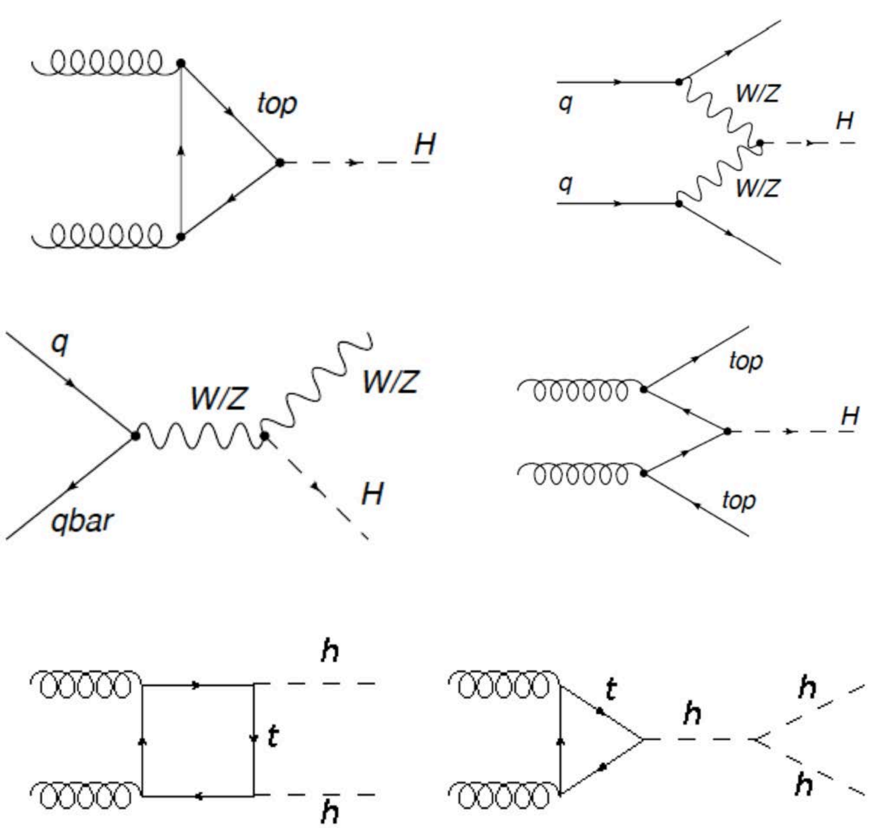
★ New measurements:

- ➡ Rare decays (H→μμ, H→Zγ)
- ➡ Double Higgs boson production (self couplings)
- ➡ Higgs portal to New Physics

Higgs bosons at $\sqrt{s}$=14 TeV 3000 fb^{-1}

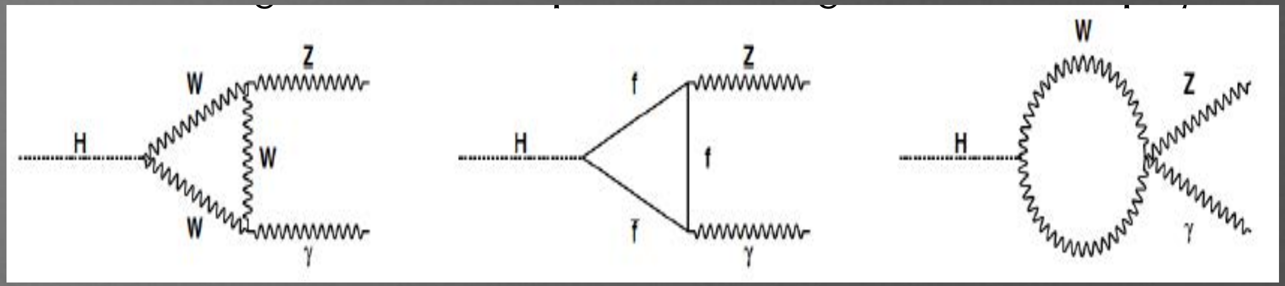
HL-LHC total	170 M
VBF (main decays)	13M
ttH (main decays)	1.8M
H→Zγ	230k
H→μμ	37k
HH (all)	121k

Given cross sections from LHCHXSWG



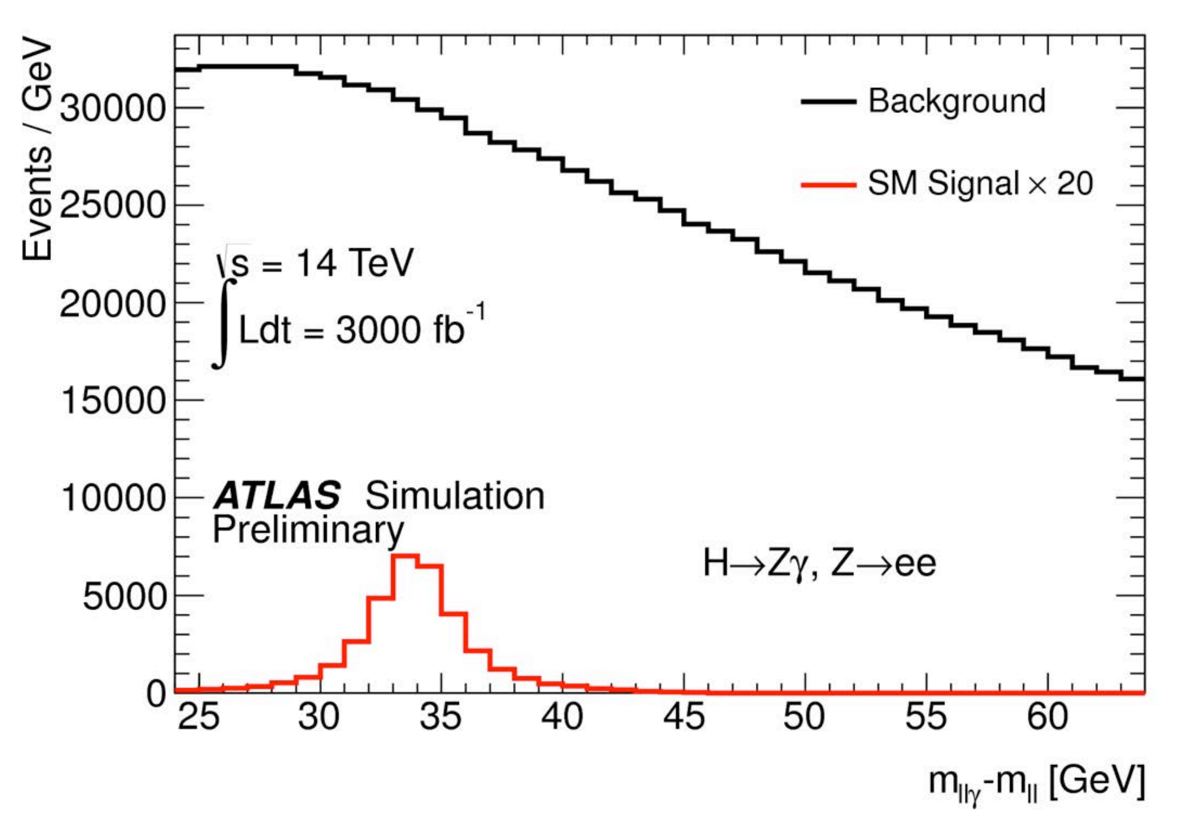
Higgs rare decays: H→Zγ

- Largely benefit from dataset increase due to HL
- In the SM the decay proceeds entirely via loops
- Sensitive to New Phyics (i.e. Higgs composite models)



- ggF, VBF, VH, ttH production
- Challenging study due to high Z+γ/Z +jet background
- Not-Higgs mediated bkg

$\Delta m = m_{\ell\ell\gamma} - m_{\ell\ell}$ as signal discriminant



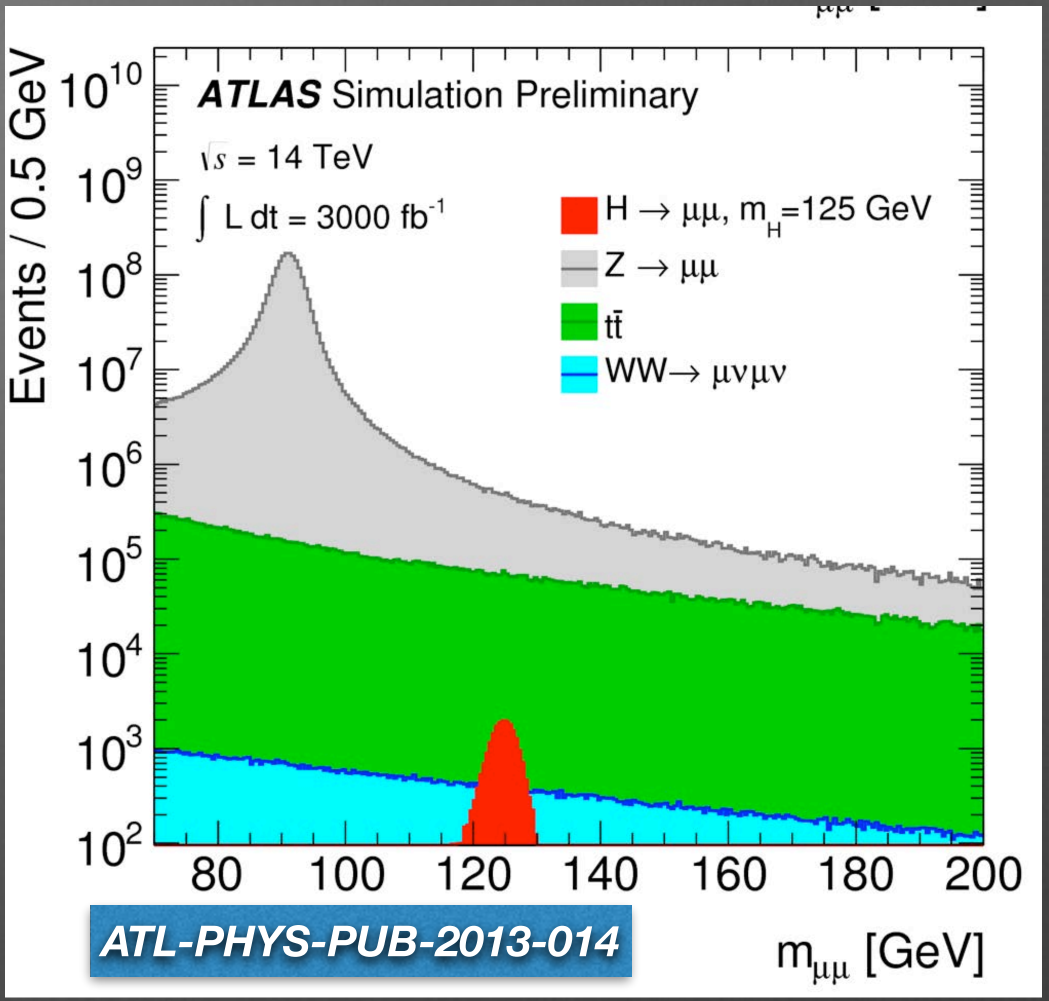
- ★ Z in ee/μμ considered
- ★ 3.9σ expected
- ★ CMS expects 20/24% uncertainty with scenario 2 *(1/2 th. uncert.)*/1 *(same RUN1 th uncert.)*
- ★ ATLAS expects 30% uncertainty
- ★ Signal strength error dominated by statistical one

ATL-PHYS-PUB-2014-006

CMS NOTE-13-002

Higgs rare decays: H→μμ

- ➡ Largely benefit from dataset increase due to HL
- ➡ *Probe the 2nd generation couplings*
  - ➡ BR O(10^{-4})
  - ➡ ggF, VBF, VH, ttH production
  - ➡ Backgrounds: **Zjets, $t\bar{t}$, WW**
  - ➡ excellent di-muon mass resolution is crucial



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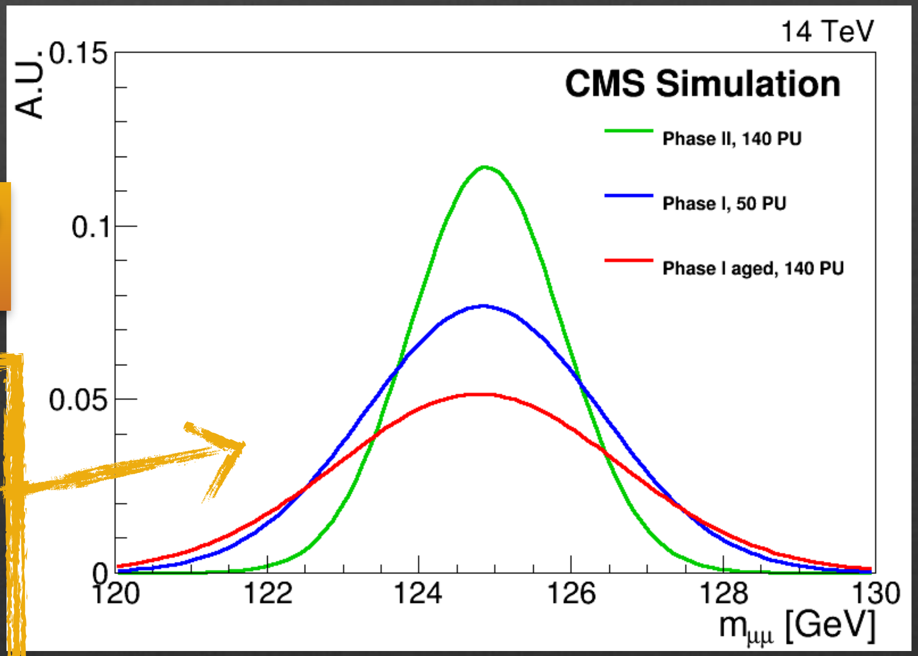
Expects observation with > 7.0σ

		μ-hat error	
	$\mathscr{L}$ (fb^{-1})	Scenario 1	Scenario 2
ATLAS	300	± 0.39	± 0.38
CMS	300	± 0.42	± 0.40
ATLAS	3000	± 0.16	± 0.12
CMS	3000	± 0.20	± 0.14

ATLAS scenarios: 1- full sys 2- no theory sys
CMS scenarios: 1- run-1 sys 2- reduced sys

CERN-LHC-2015-010
CMS NOTE-13-002

Phase2: 40% better mass resolution, 20% higher efficiency wrt aged-Phase1



Higgs couplings fit

$$\frac{\sigma \cdot B(gg \to H \to \gamma\gamma)}{\sigma_{SM}(gg \to H)\cdot B_{SM}(H \to \gamma\gamma)} = \frac{k_g^2 \cdot k_\gamma^2}{k_H^2}$$

The hashed areas indicate the increase of the estimated error due to current theory systematic uncertainties (CERN-2011-002, CERN-2012-002)

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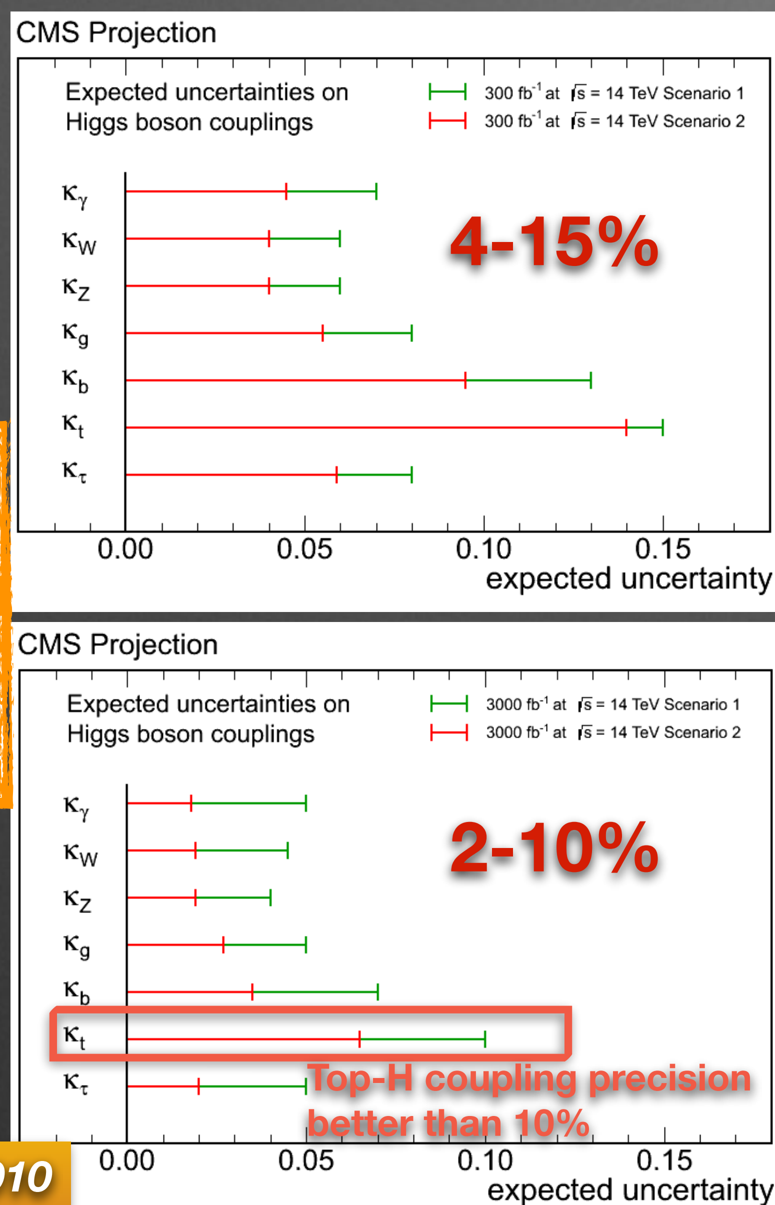
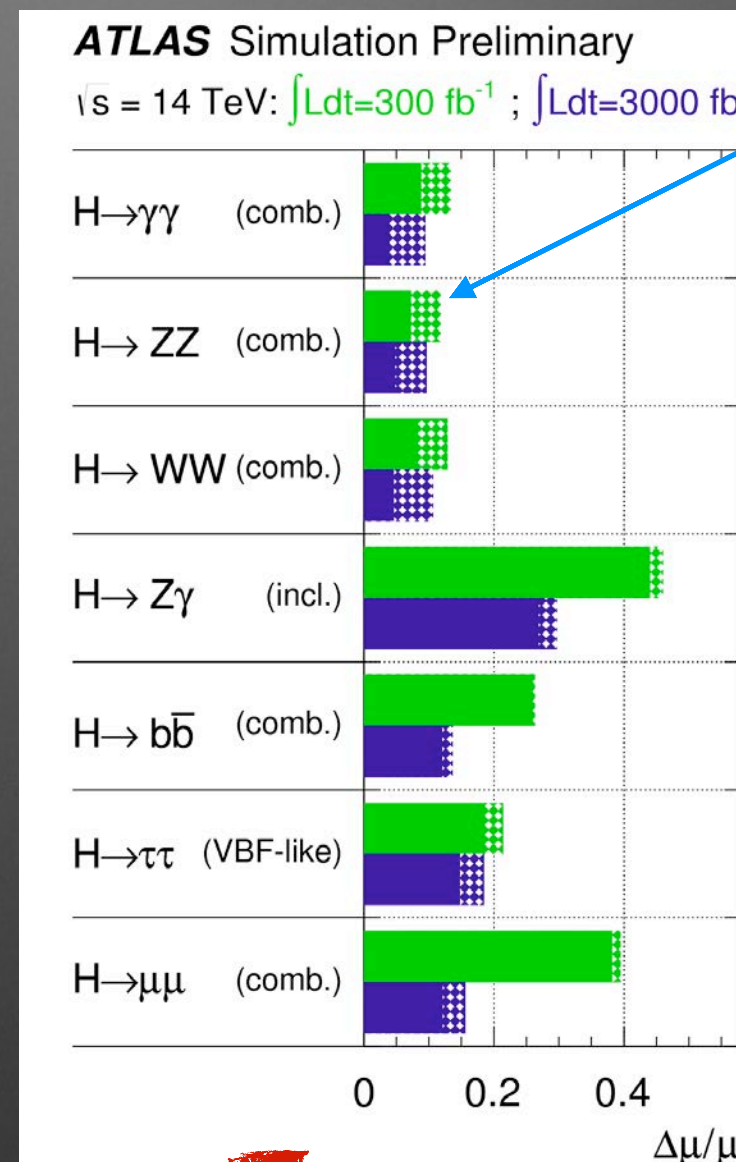
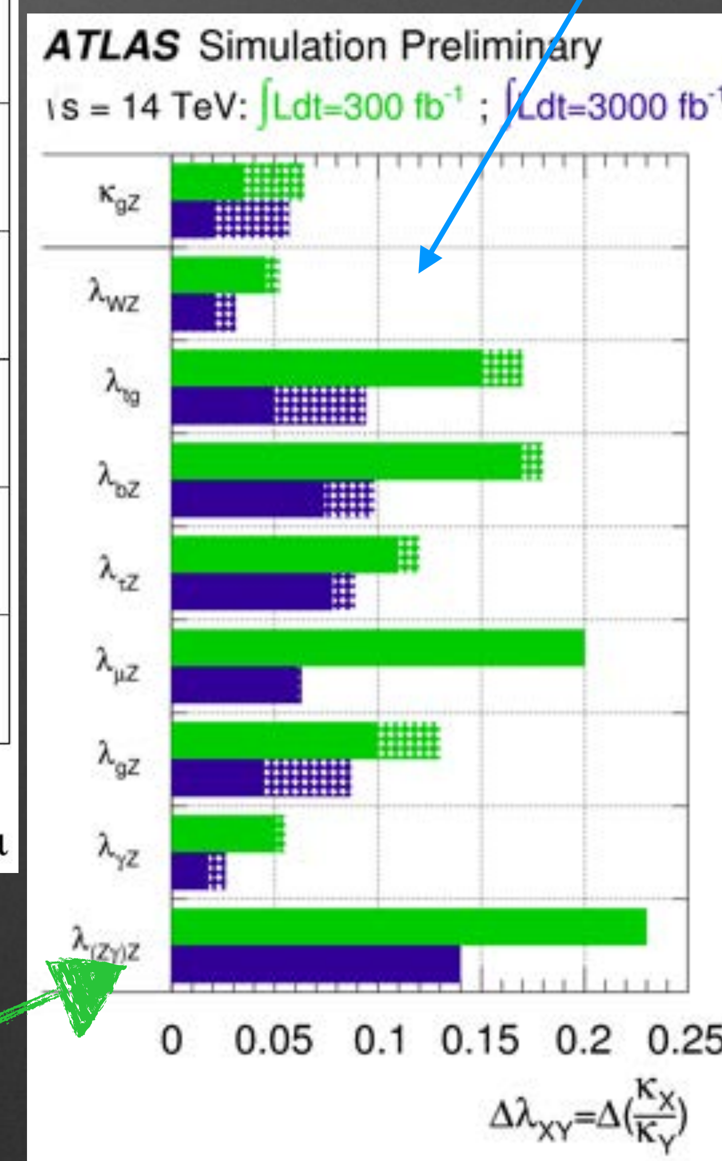
Scenario 1: systematics as in RUN1

Scenario 2: theory uncert x 1/2, exp. uncert x 1/√∫L







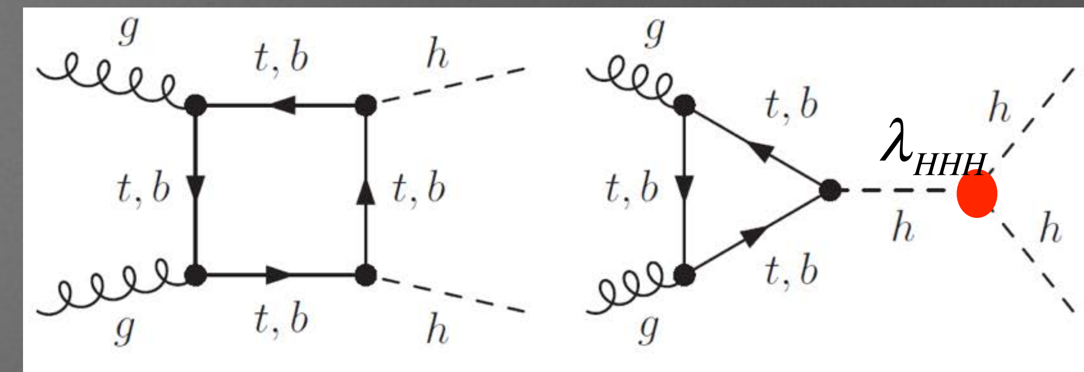
CERN-LHC-2015-010
CMS NOTE-13-002

Assumptions:

- ➡ Single resonance @ m_H=125 GeV
- ➡ Narrow width approximation
- ➡ If width constrain removed only coupling ratios $\lambda_{XY} = k_X/k_Y$

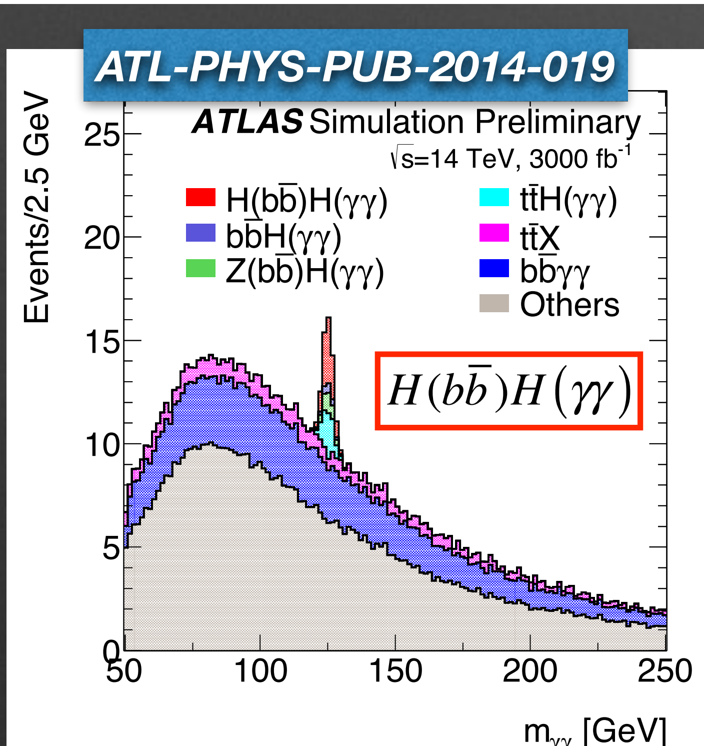
H pair production

- One of the exciting prospects @ HL-LHC:
  - Higgs self-coupling
  - accessing the Higgs potential
  - sensitive to BSM Physics



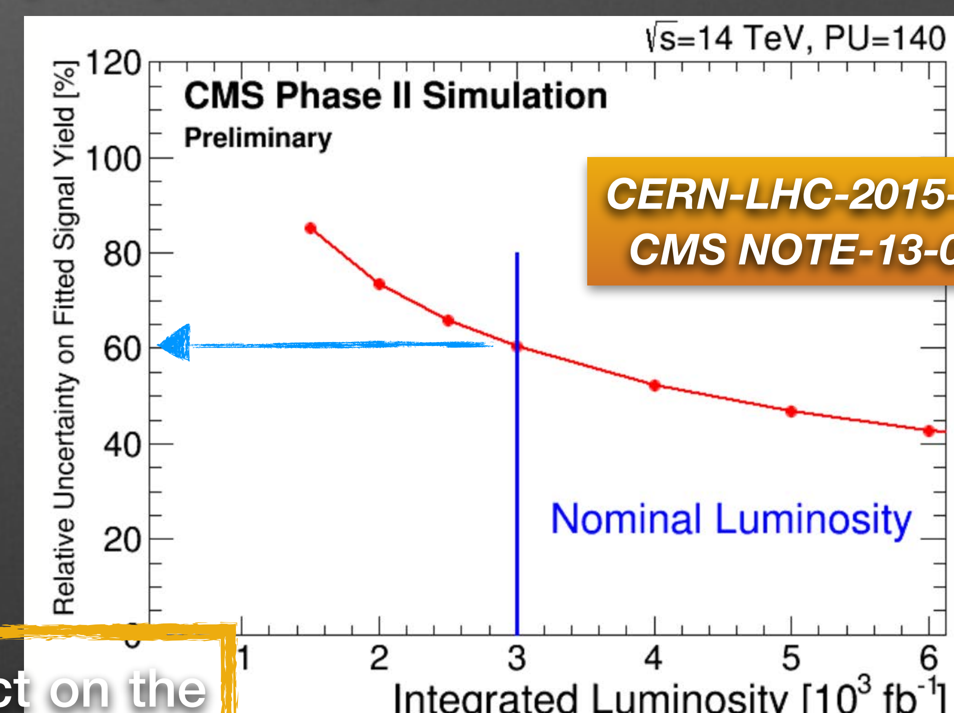
Decay Channel	Branching Ratio	Total Yield (3000 fb^{-1})
$b\bar{b}+b\bar{b}$	33%	40,000
$bb+W^+W^-$	25%	31,000
$b\bar{b}+\tau^+\tau^-$	7.3%	8,900
$ZZ+b\bar{b}$	3.1%	3,800
$W^+W^-+\tau^+\tau^-$	2.7%	3,300
$ZZ+W^+W^-$	1.1%	1,300
$\gamma\gamma+b\bar{b}$	0.26%	320
$\gamma\gamma+\gamma\gamma$	0.0010%	1.2

- Destructive interferance
  - SM cross-section decreases
  - Cross section at $\sqrt{s}$ = 14 TeV is **40.7 fb** [NNLO] (Phys. Rev. Lett. 111 (2013) 201801)



bbγγ

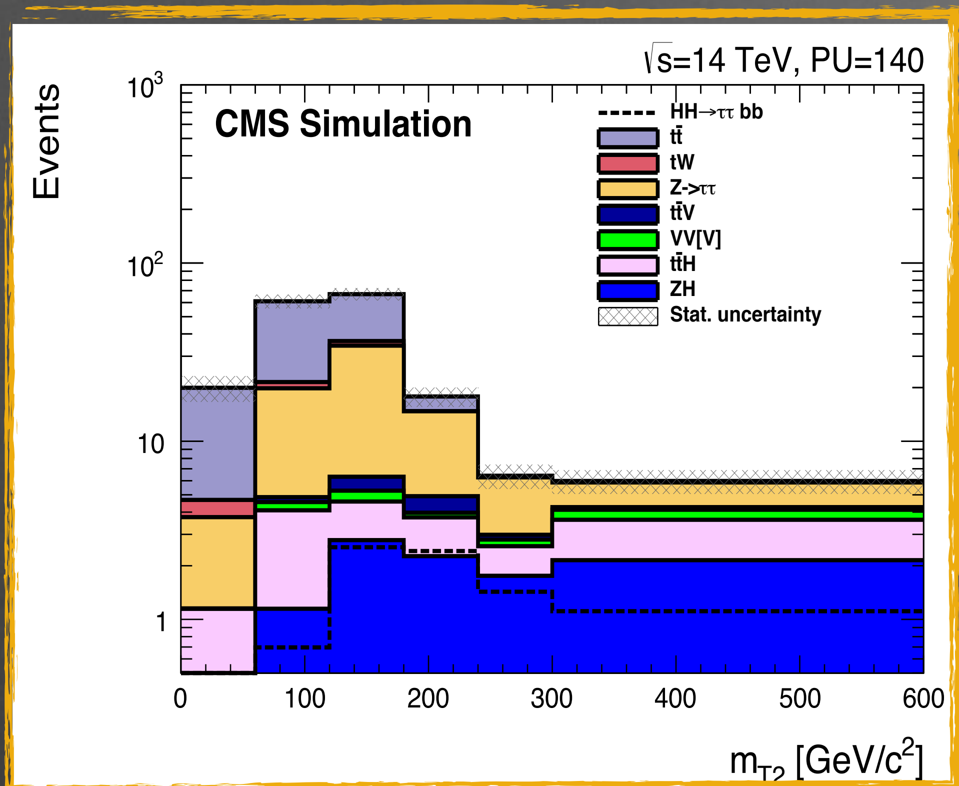
Small cross-section and huge resonant (single H) and non resonant bkg

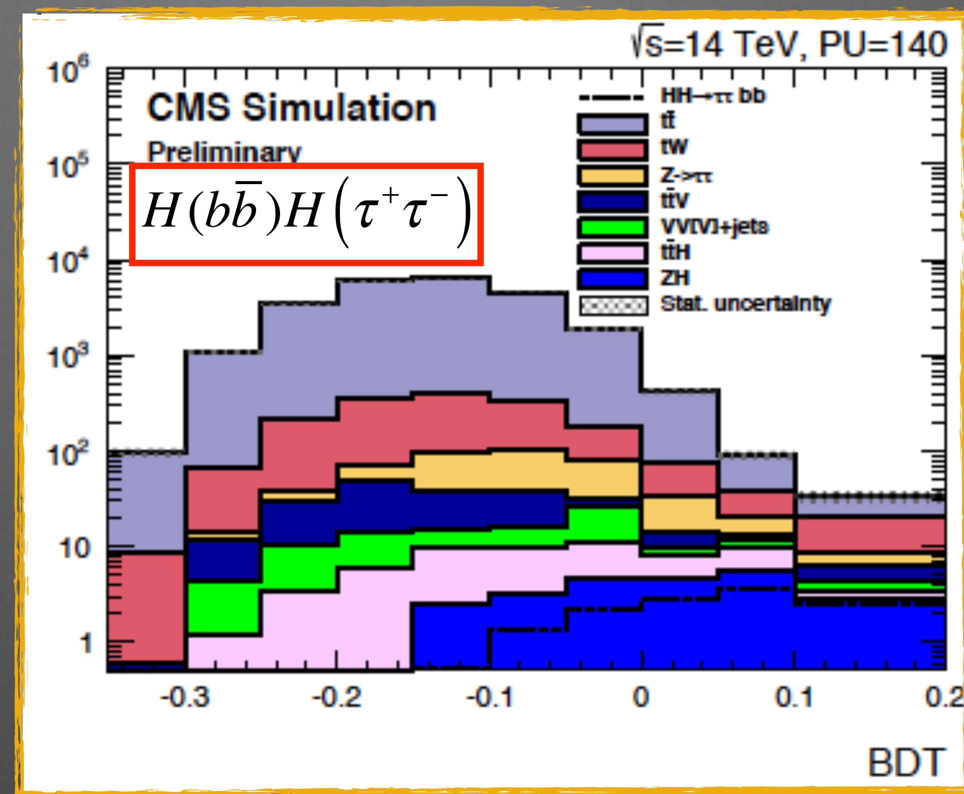


CMS has evaluated the impact on the analysis as the b-tagging and photon identification efficiencies change

ATLAS and CMS expects ~ 8-9 events after trigger and event selections corresponding to a signal significance of ~1.3σ per exp for the SM scenario

H pair production





CMS also studied bbττ channel in $\tau_\mu\tau_h$ and $\tau_h\tau_h$ final states and expects a combined signal significance of 0.9σ in bbττ channel

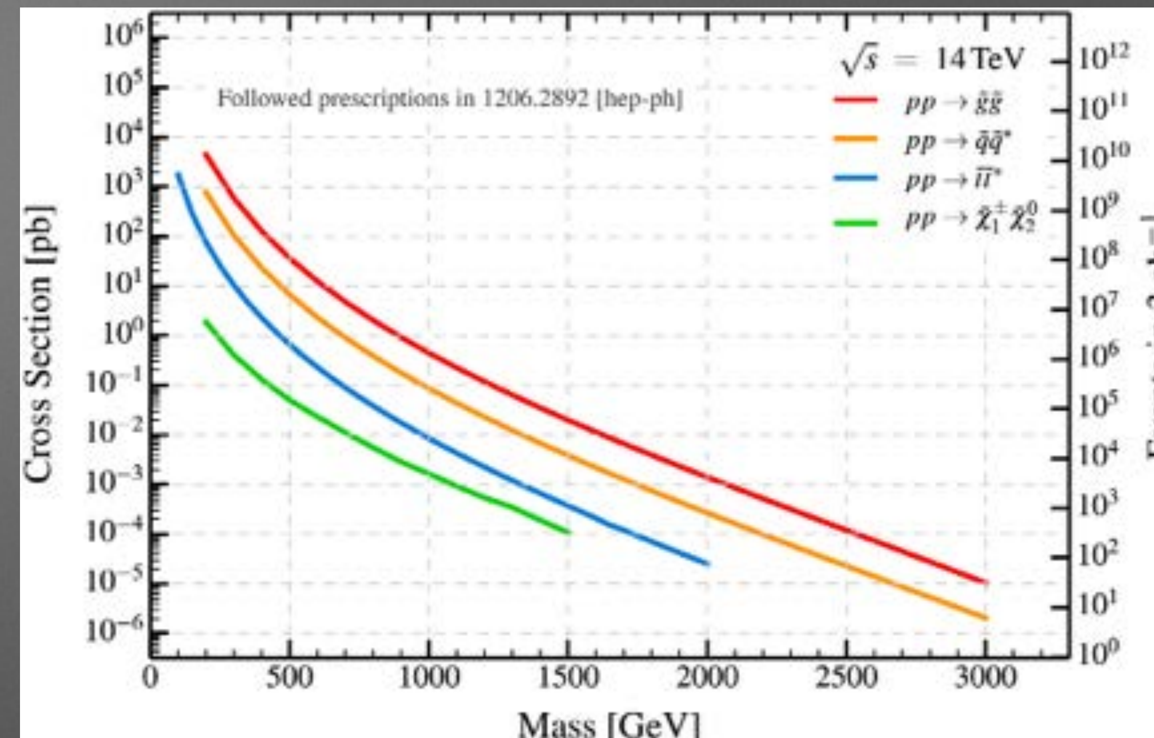
CERN-LHC-2015-010
CMS NOTE-13-002

Combining *bbγγ* and *bbττ* final states CMS expects 1.9σ significance with an uncertainty of ~ 54%

Significant improvements in future studies of di-H signatures are expected by ATLAS and CMS by combining more channels and also using MVA analysis technique

Prospects for SUSY @ HL-LHC

- ➡ Search for SUSY is a major goal for Run2 & HL-LHC
  - ★ Higgs discovery poses new urgency to the hierarchy problem
  - ★ Candidate for DM
  - ★ Gauge unification
- ➡ Prospects for SUSY using
  - ★ ATLAS: Simplified SUSY Models and benchmark configurations
  - ★ CMS: Simplified SUSY model and Full Spectrum models (new!)
    - ➡ Five phenomenological models motivated by naturalness explored through a number of signature-based searches
    - ➡ Models differ by nature of the LSP (bino-, higgsino-like), EWK-inos and sleptons hierarchies
    - ➡ STC (stau) and STOC (stop) co-annihilation models satisfy dark matter constraints



Analysis	Luminosity (fb^{-1})	Model NM1	NM2	NM3	STC	STOC
all-hadronic (H_T-H_T^{miss}) search	300				$< 3\sigma$	$3-5\sigma$
	3000				$3-5\sigma$	$> 5\sigma$
all-hadronic (M_{T2}) search	300	$3-5\sigma$	$> 5\sigma$	$> 5\sigma$		
	3000	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$		
all-hadronic $\tilde{b}_1$ search	300	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$	$3-5\sigma$	$< 3\sigma$
	3000	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$	$> 5\sigma$	$< 3\sigma$
1-lepton $\tilde{t}_1$ search	300	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$3-5\sigma$	$< 3\sigma$
	3000	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$
monojet $\tilde{t}_1$ search	300					$3-5\sigma$
	3000					$3-5\sigma$
$m_{\ell^+\ell^-}$ kinematic edge	300	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$		
	3000	$> 5\sigma$	$< 3\sigma$	$< 3\sigma$		
multilepton + b-tag search	300	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$3-5\sigma$	
	3000	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	
multilepton search	300	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$	
	3000	$3-5\sigma$	$3-5\sigma$	$< 3\sigma$	$3-5\sigma$	
ewkino WH search	300		$< 3\sigma$			
	3000		$3-5\sigma$			

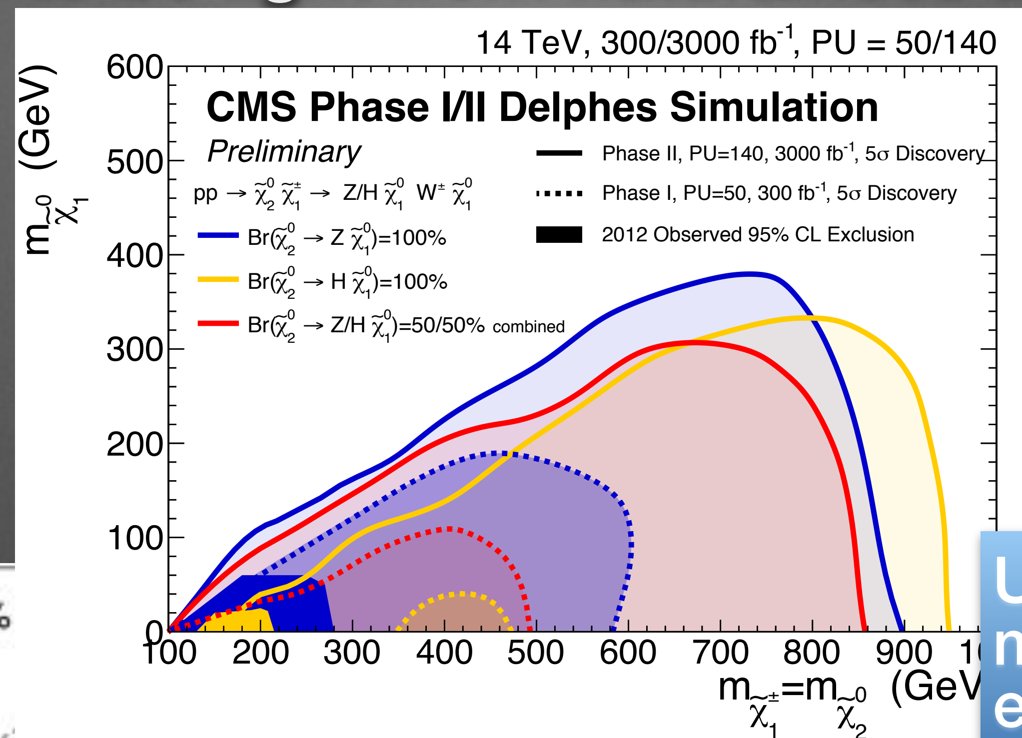
$< 3\sigma$ | $3-5\sigma$ | $> 5\sigma$

$\chi^{\pm}\chi^{0}$ searches @ HL-LHC

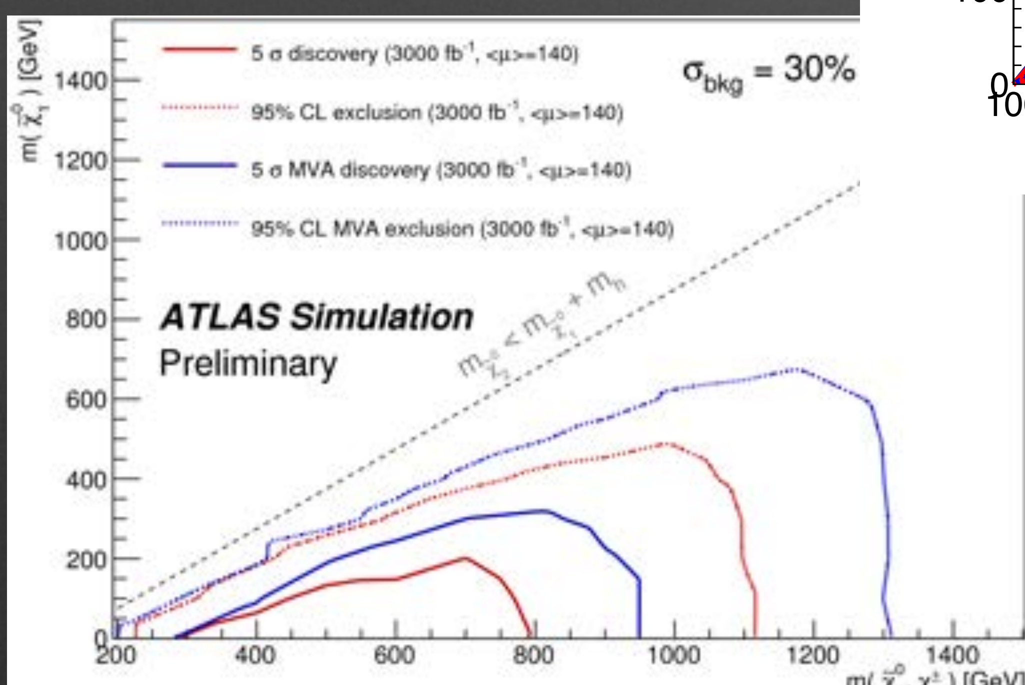
Factor 10x in luminosity essential to probe pair production of EWK-inos expected to be light from naturalness arguments

WZ (3l)
WH (1l2τ, 3l, 1lbb)
channels studied

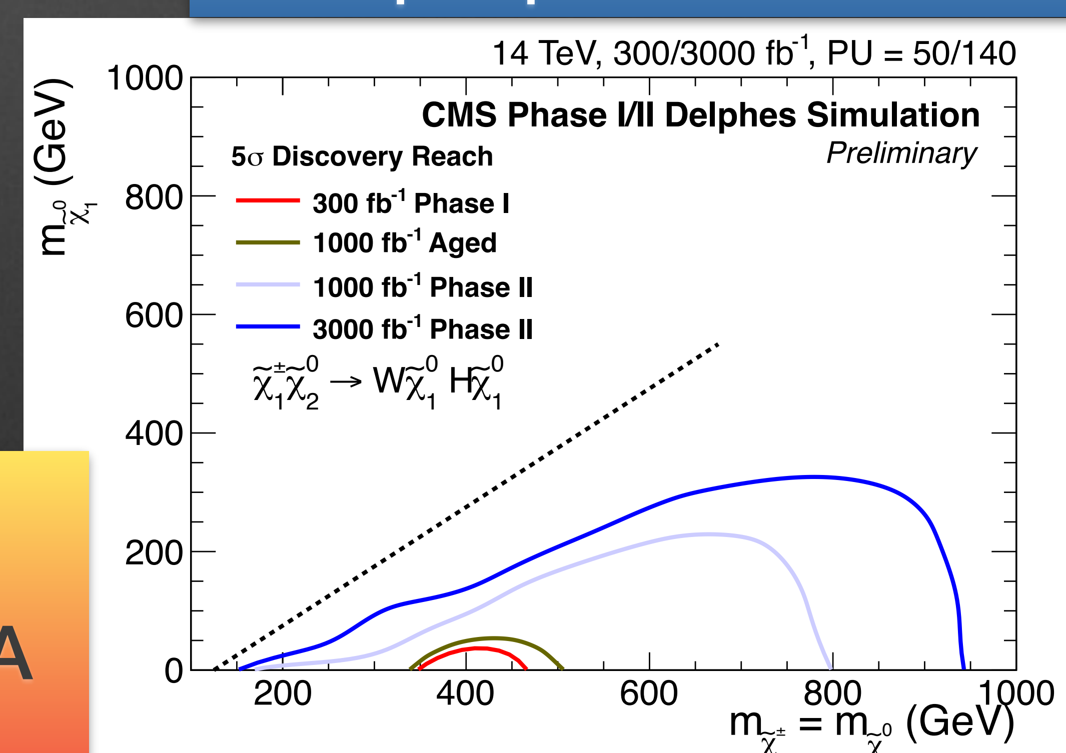
ATL-PHYS-PUB-2015-032



CMS PAS SUS-14-012

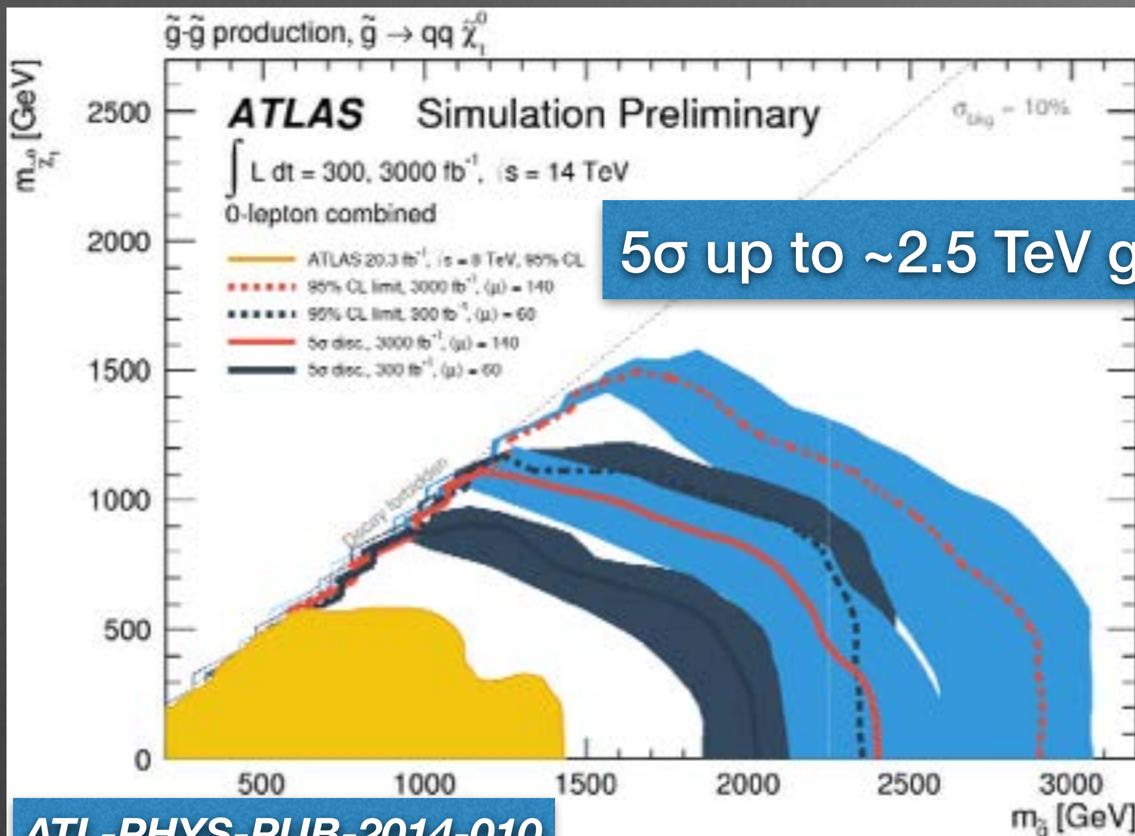


Upgrade of the detector mandatory to significantly enhance discovery region wrt RUN2 perspectives



5σ up to ~850-950 GeV in both WZ-WH depending on the decay channel
Extensions up to above 1000 possible with MVA technique and better cyst understanding

Squark/gluino searches @ HL-LHC



5σ up to ~2.5 TeV gluinos

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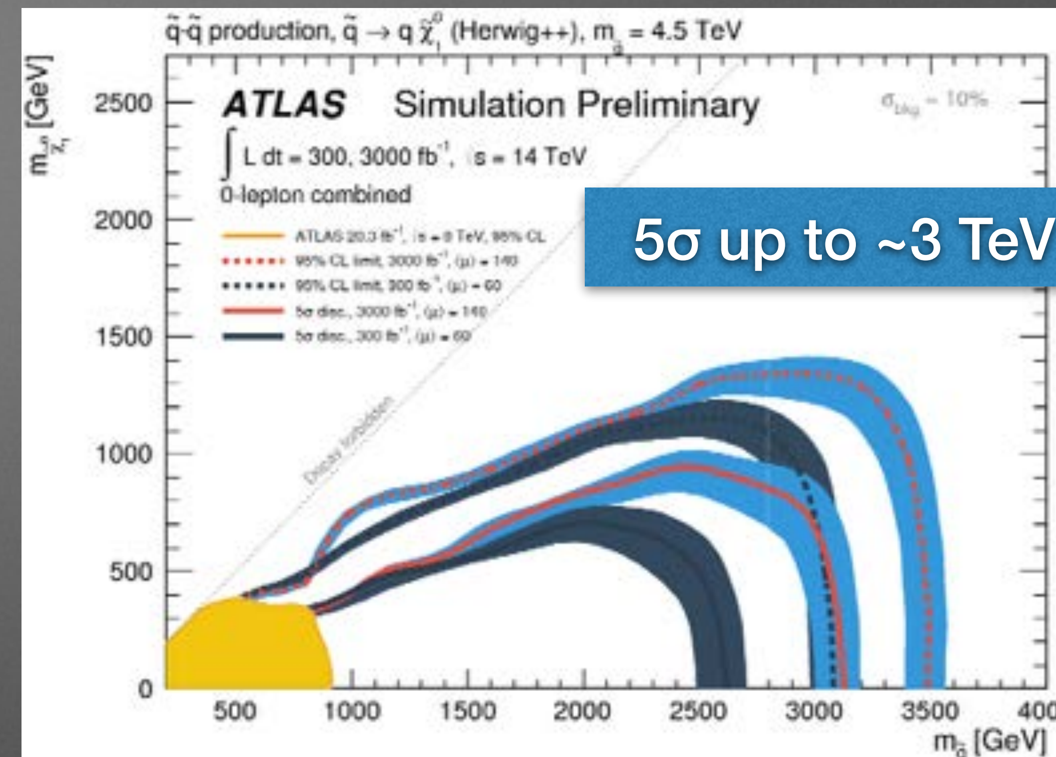
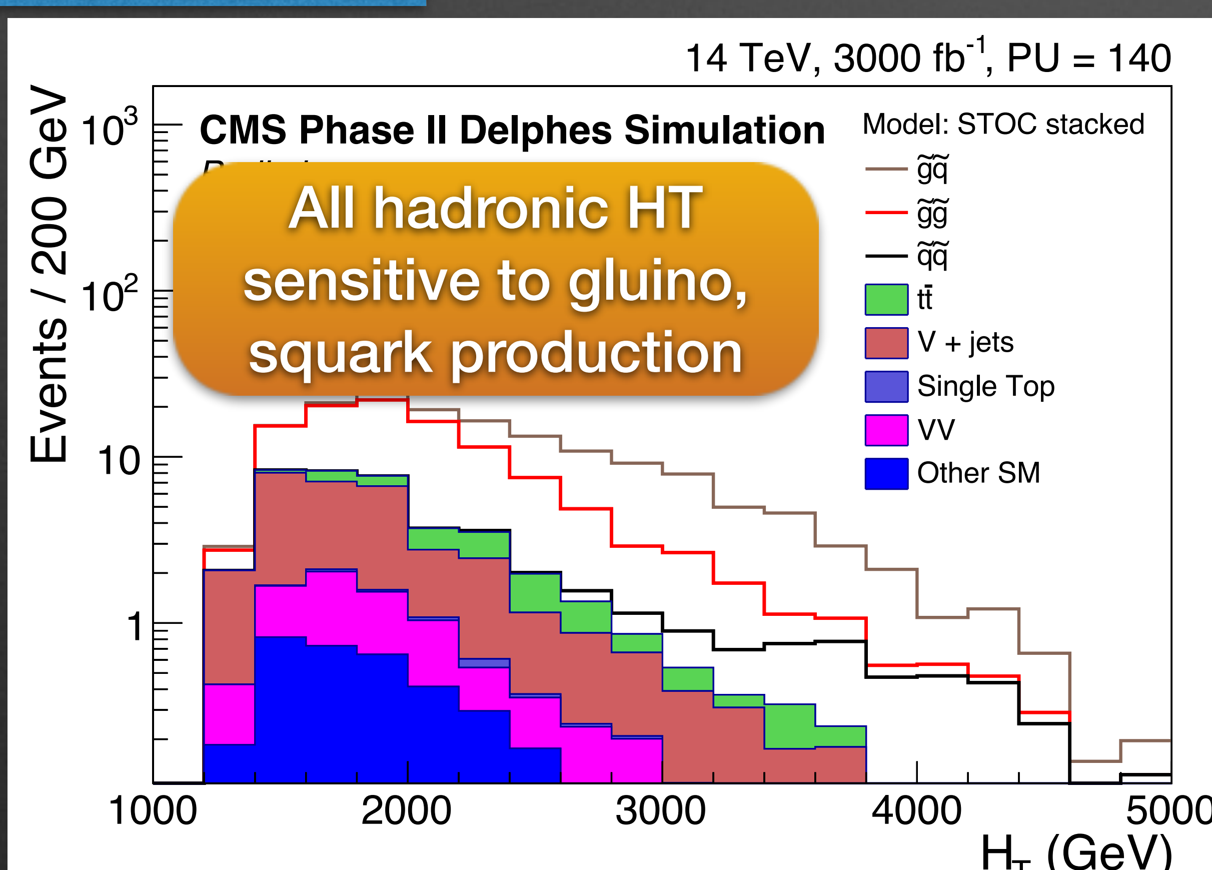
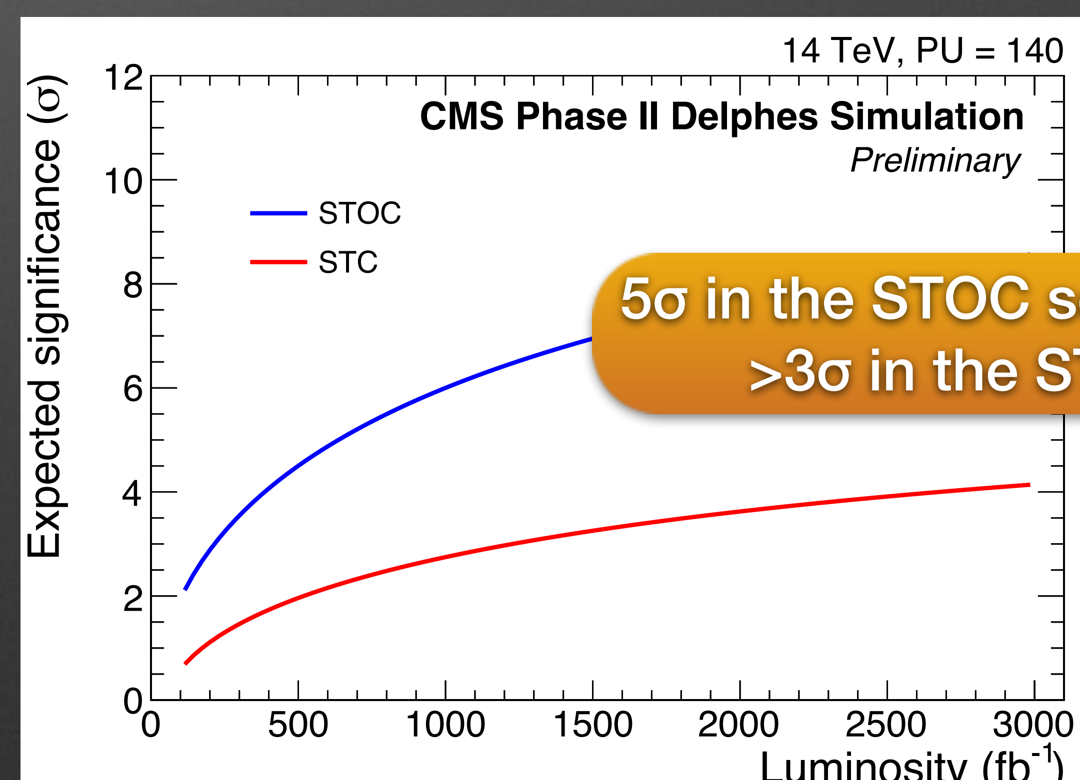


5σ up to ~3 TeV squark



All hadronic HT sensitive to gluino, squark production



5σ in the STOC scenario >3σ in the STC

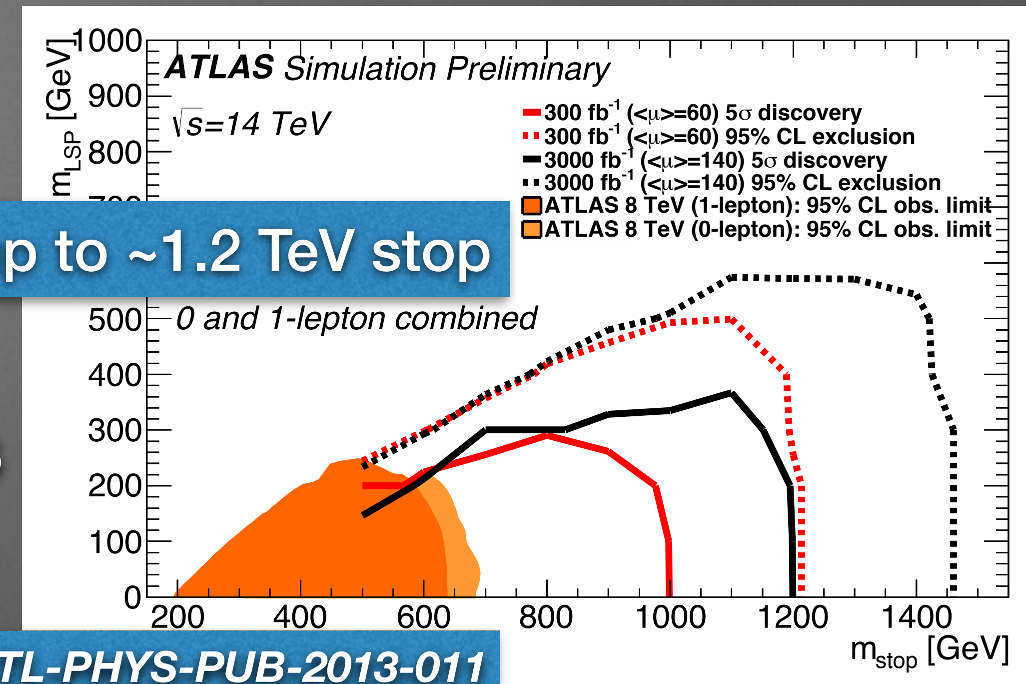
CMS PAS SUS-14-012

Stop/sbottom searches @ HL-LHC

Naturalness arguments require light third generation squark

Discovery could be accessible @ 300/fb

With 3000/fb increase sensitivity to heavy stop/sbottom and/or measure their properties



5σ up to ~1.2 TeV stop

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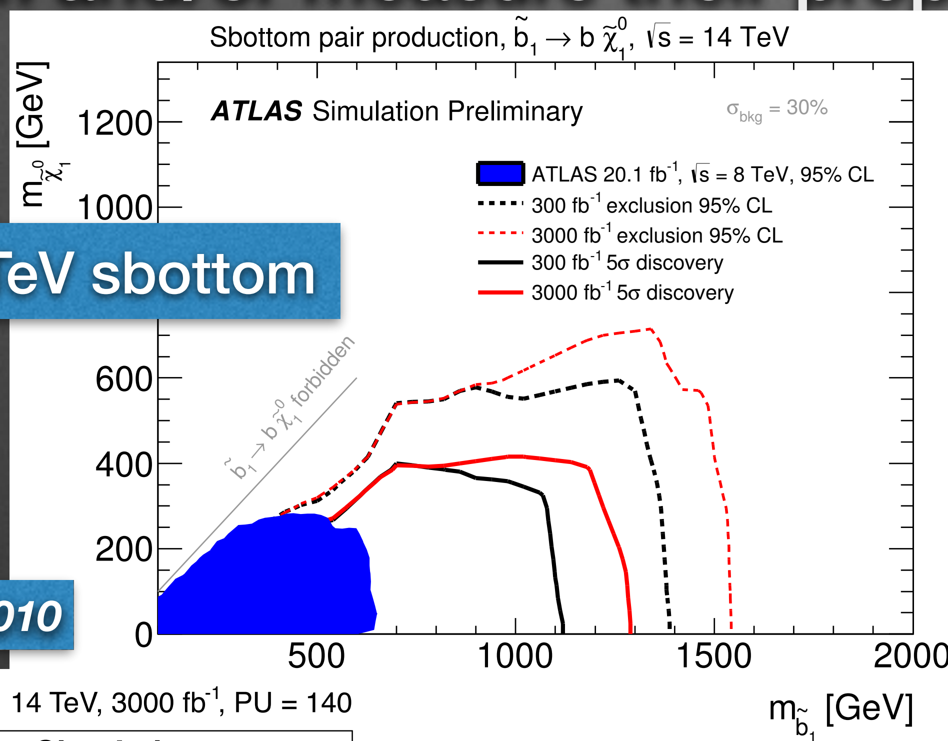

5σ up to ~1.3 TeV sbottom

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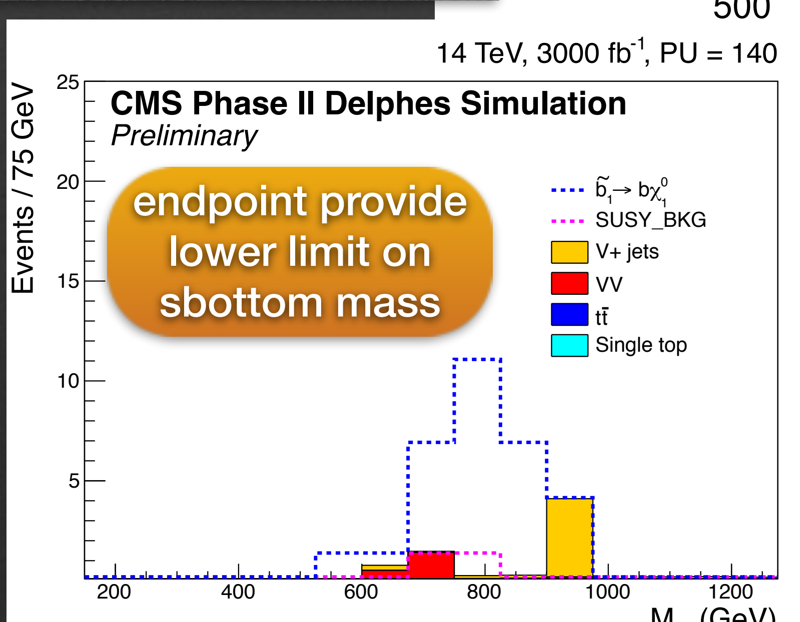
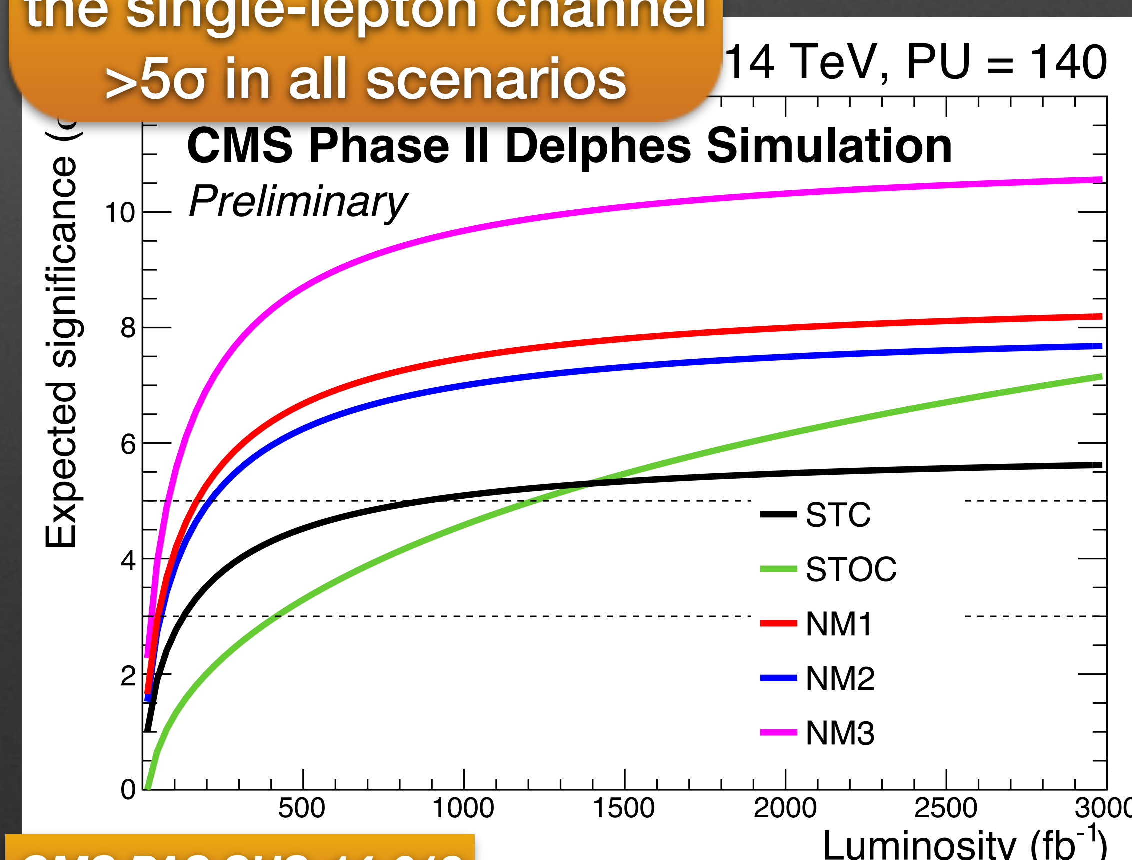


endpoint provide lower limit on sbottom mass

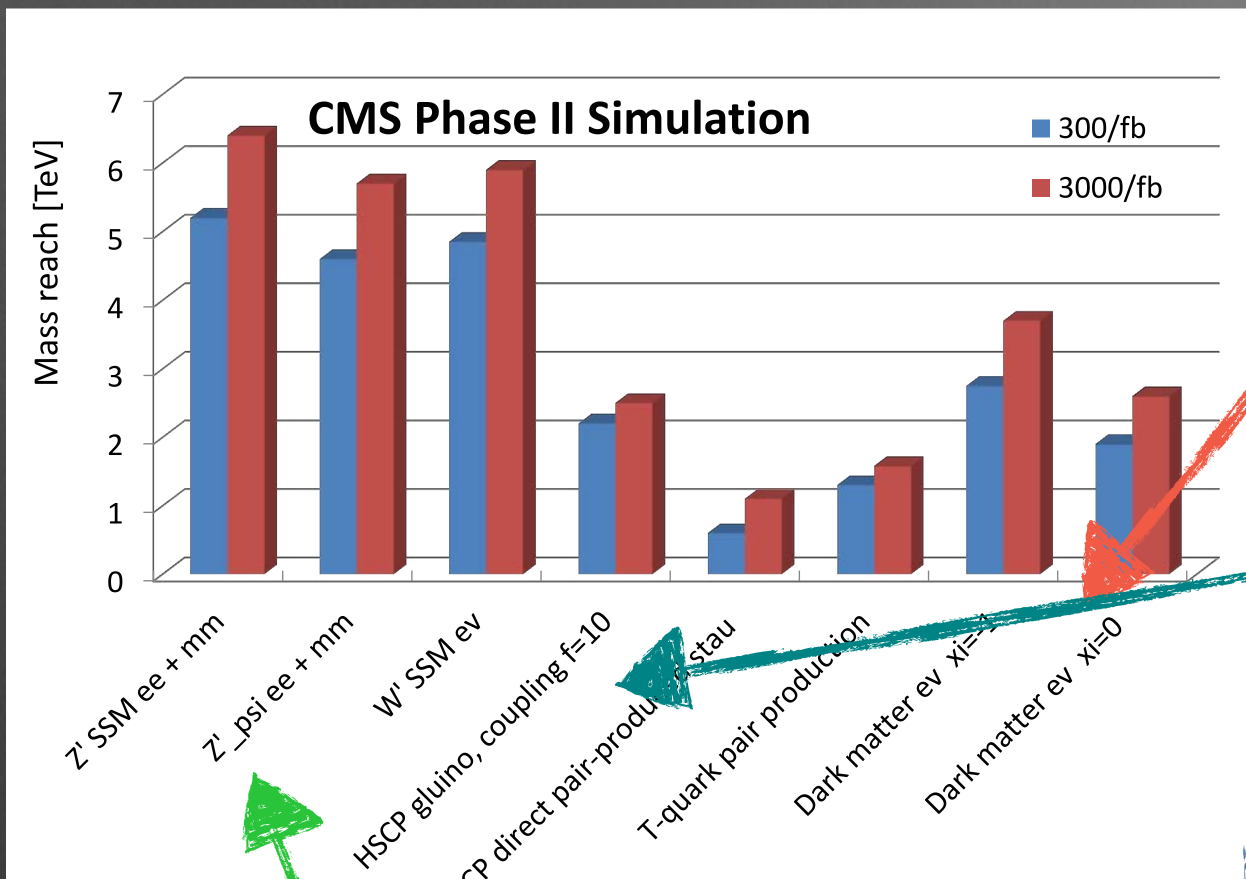


direct stop production in the single-lepton channel >5σ in all scenarios

CMS PAS SUS-14-012

Exotica @ HL-LHC

A broad range of models can benefit of increased statistics



CERN-LHC-2015-010

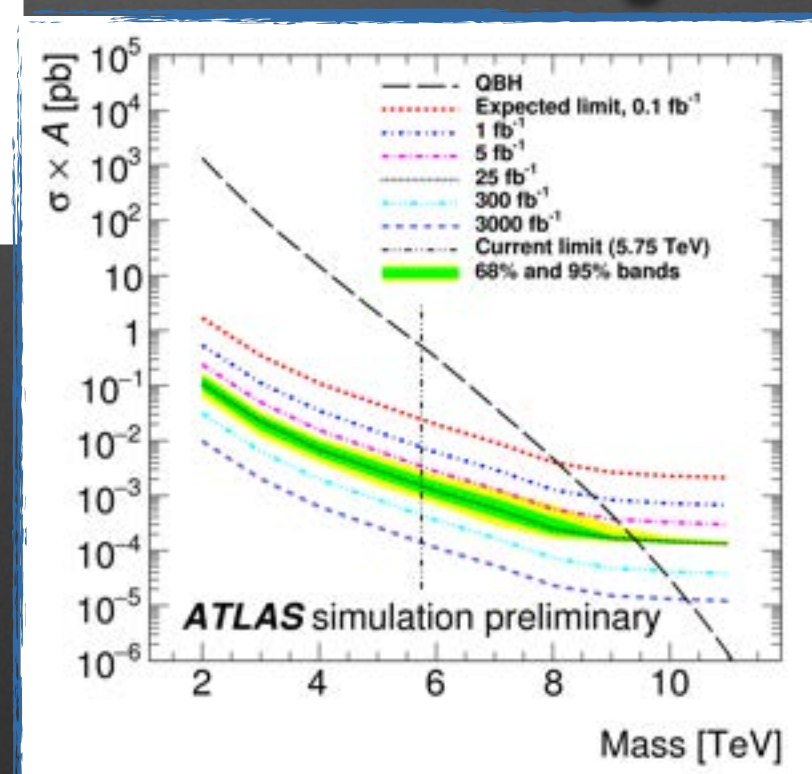
Looking for an excess in mono-lepton or mono-jet channels

Looking for anomalous dE/dx, displayed secondary vertices, slow moving tracks…for massive stable or long-lived particles

Looking for modification of di-lepton (Z', KK-gluon) or di-jet invariant mass (q*, QBH)

ATLAS @14 TeV	Z' → ee SSM 95% CL limit	g_{KK} → t t RS 95% CL limit
300 fb^{-1}	6.5 TeV	4.3 TeV
3000 fb^{-1}	7.8 TeV	6.7 TeV

ATL-PHYS-PUB-2014-007



ATL-PHYS-PUB-2015-004

Summary

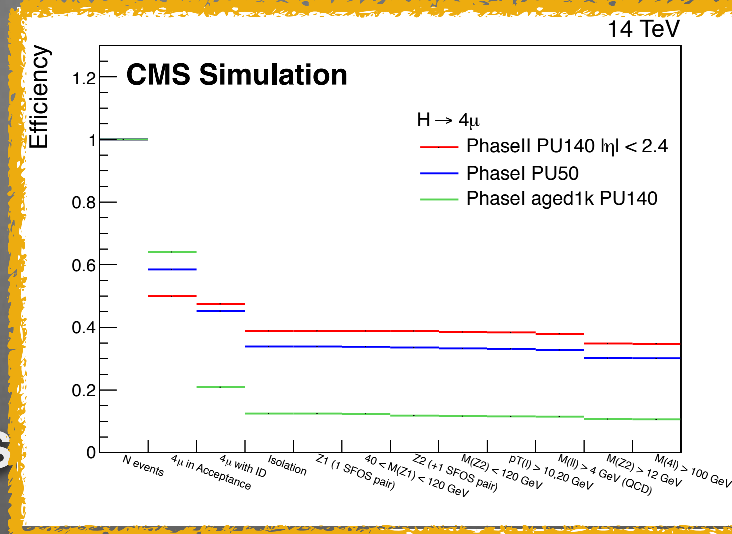
- The discovery of the Higgs boson at LHC-Run1 has opened the door towards a deeper understanding of particle Physics
- With the start of RUN2 with the unprecedented energy of 13 TeV we are now focussing even more in the searches for New Physics and precision Higgs studies
- The HL-LHC with a ten times more luminosity will offer unique opportunities to explore the Higgs sector and will represent an excellent probe for high scale New Physics
  - the 3000/fb dataset at 14 TeV will allow large gains in precision, discovery potential, and will make a number of important, low cross-section measurements possible
- Detector upgrade foreseen by ATLAS and CMS will ensure optimal performances despite the very hostile environment
- Lot of work is ongoing to be ready and well prepared for this new exciting LHC-era…

… The best maybe should still come…

Back-up

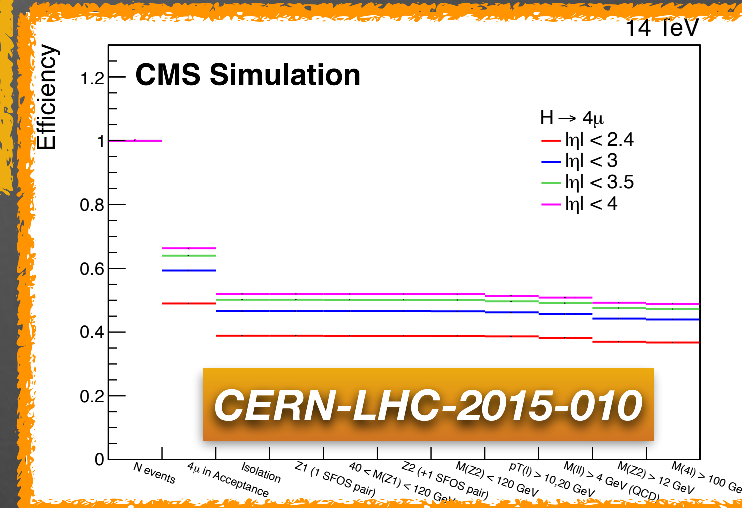
H→ZZ*→4ℓ

HL-LHC statistics allows
- ➡ measurement with high purity in the various modes
- ➡ precision ~4-10% on the signal strength (both ATLAS and CMS)
- ➡ probe CP-odd (CP-even) structures of the Higgs couplings g_4 (g_1, g_2)



Efficiency times acceptance for the signal vs selection criteria

Improvement due to increased muon coverage



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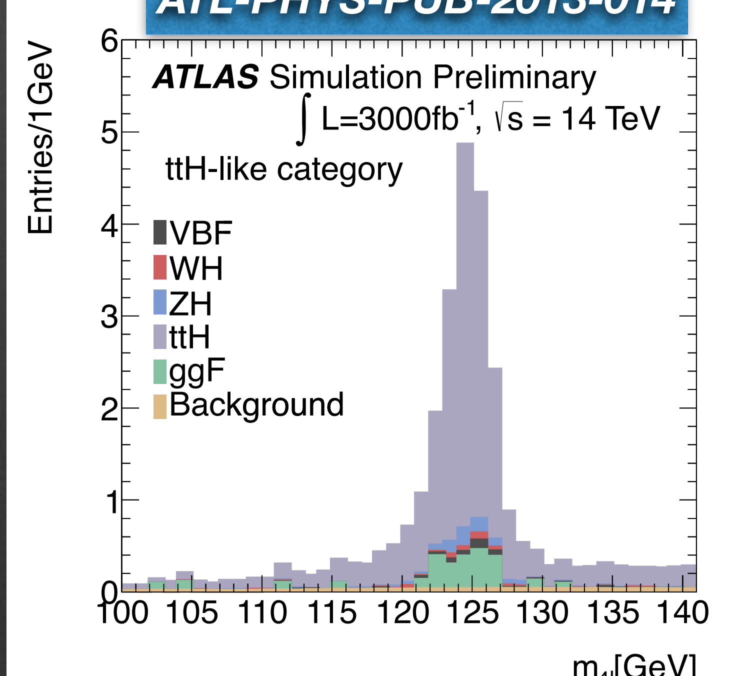
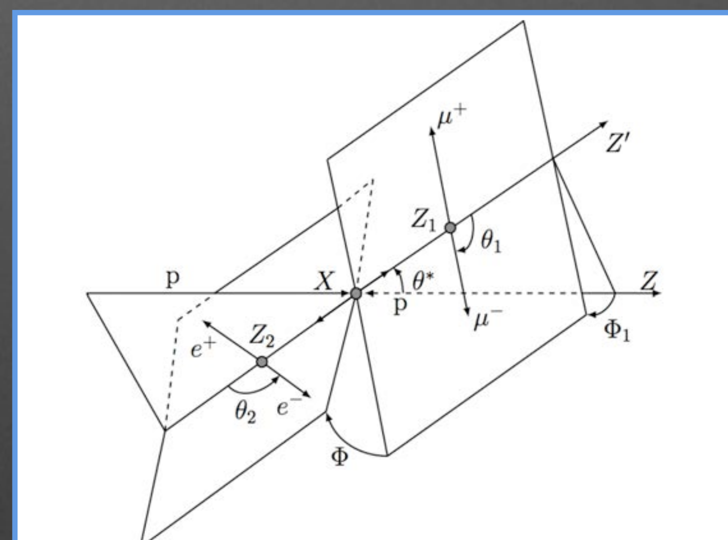
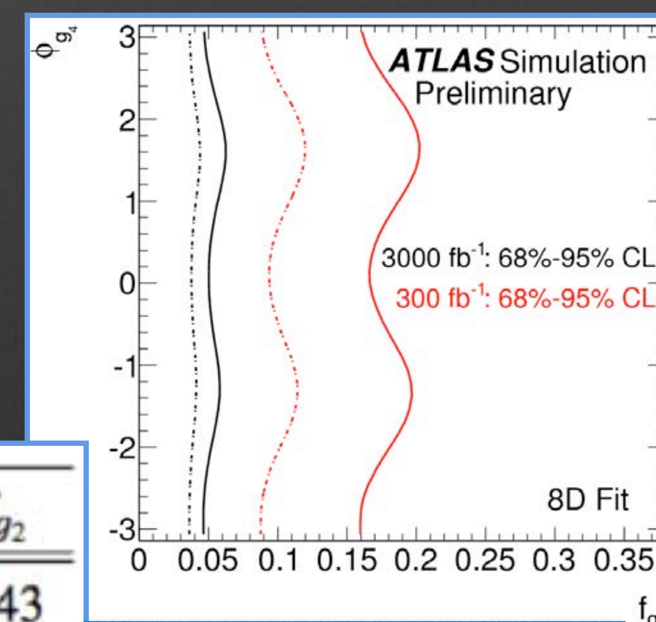






ATL-PHYS-PUB-2013-013

Error is dominated by theoretical uncertainty

Currently ~25% uncertainty on μ (ATLAS-CONF-2015-007, PHYSICAL REVIEW D89, 092007)

$\Delta\mu/\mu$	Total	Stat.	Expt. syst.	Theory
Production mode		300 fb^{-1}		
ggF	0.152	0.066	0.053	0.124
VBF	0.625	0.545	0.233	0.226
WH	1.074	1.064	0.061	0.085
$t\bar{t}$H	0.535	0.516	0.038	0.120
Combined	0.125	0.042	0.044	0.108
		3000 fb^{-1}		
ggF	0.131	0.025	0.040	0.124
VBF	0.371	0.187	0.225	0.226
WH	0.390	0.375	0.061	0.085
ZH	0.532	0.526	0.038	0.073
$t\bar{t}$H	0.224	0.184	0.034	0.120
Combined	0.100	0.016	0.036	0.093

Luminosity	f_{g_4}	f_{g_2}
300 fb^{-1}	0.15	0.43
3000 fb^{-1}	0.037	0.20

VH→bb, H→ττ

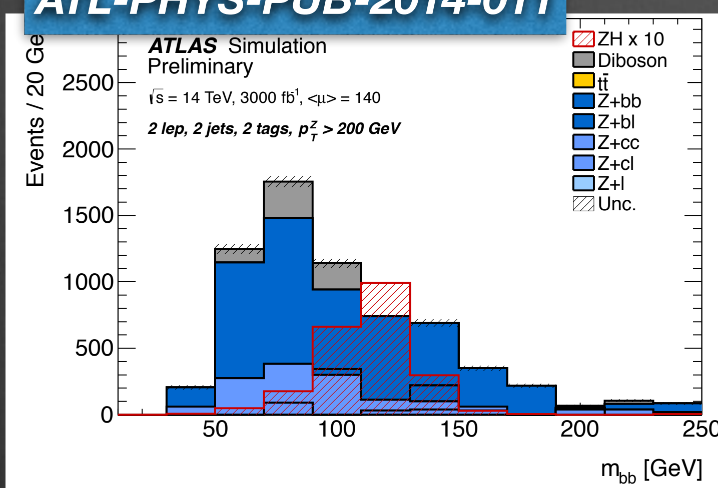
Important test of the coupling to third generations fermions

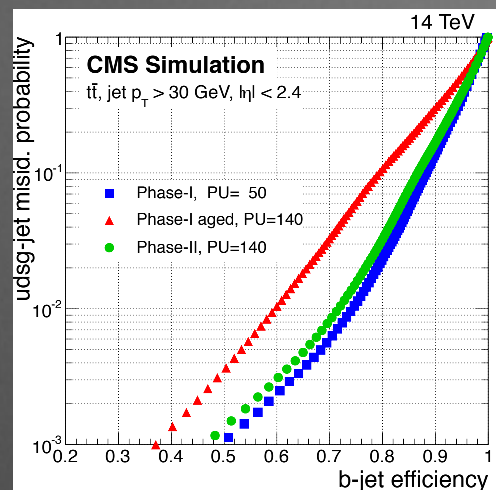
VH→bb, (V=W,Z)

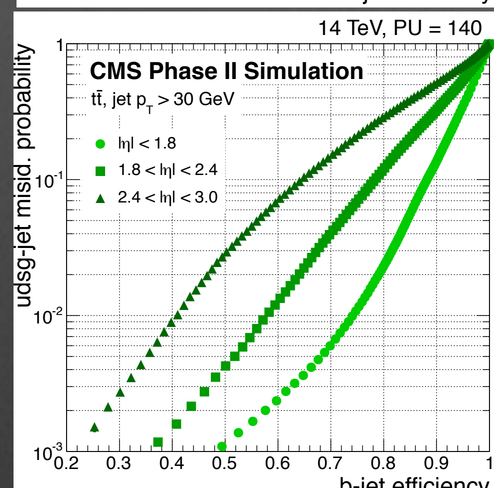
b-tagging performance are crucial

- ➡ degradation due to high-PU expected
- ➡ recovery due to upgraded detector mandatory

ATL-PHYS-PUB-2014-011







CMS expects a precision of 5/7% on the signal strength in scenario 2 (1/2 th. uncert.)/1(same RUN1 th uncert.)

		One-lepton	Two-lepton	One+Two-lepton
Stat-only	Significance	15.4	11.3	19.1
	$\hat{\mu}_{Stats}$ error	+0.07 −0.06	+0.09 −0.09	+0.05 −0.05
Theory-only	$\hat{\mu}_{Theory}$ error	+0.09 −0.07	+0.07 −0.08	+0.07 −007
	Significance	2.7	8.4	8.8
Scenario I	$\hat{\mu}_{w/Theory}$ error	+0.37 −0.36	+0.15 −0.15	+0.14 −0.14
10%JES uncert.	$\hat{\mu}_{wo/Theory}$ error	+0.36 −0.36	+0.14 −0.12	+0.12 −0.12
	Significance	4.7	-	9.6
Scenario II	$\hat{\mu}_{w/Theory}$ error	+0.23 −0.22	-	+0.13 −0.13
5%JES uncert.	$\hat{\mu}_{wo/Theory}$ error	+0.21 −0.21	-	+0.11 −0.11

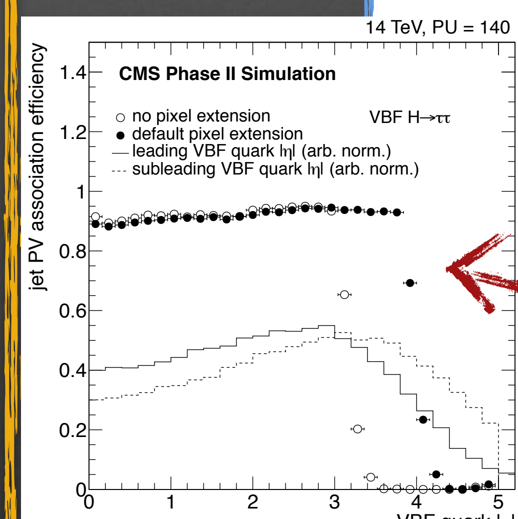
Run-I	μ-hat ± error
ATLAS	0.52 ± 0.40
CMS	1.0 ± 0.50

H→ττ *excellent probe for BSM Physics*

VBF production and τ_{lep} τ_{had} categories explored by both ATLAS and CMS

- ➡ All physics objects involved (e,μ,jets,E_{Tmiss},…)
- ➡ mitigation of high-PU mandatory

forward pile-up jet rejection	50%	75%	90%
forward tracker coverage		Δμ	
Run-I tracking volume		0.24	
$\vert\eta\vert < 3.0$	0.18	0.15	0.14
$\vert\eta\vert < 3.5$	0.18	0.13	0.11
$\vert\eta\vert < 4.0$	0.16	0.12	0.08



Extension of tracker would help in rejecting fake jets

Trigger acceptance increase by a factor 5 thanks to addition of track trigger capabilities

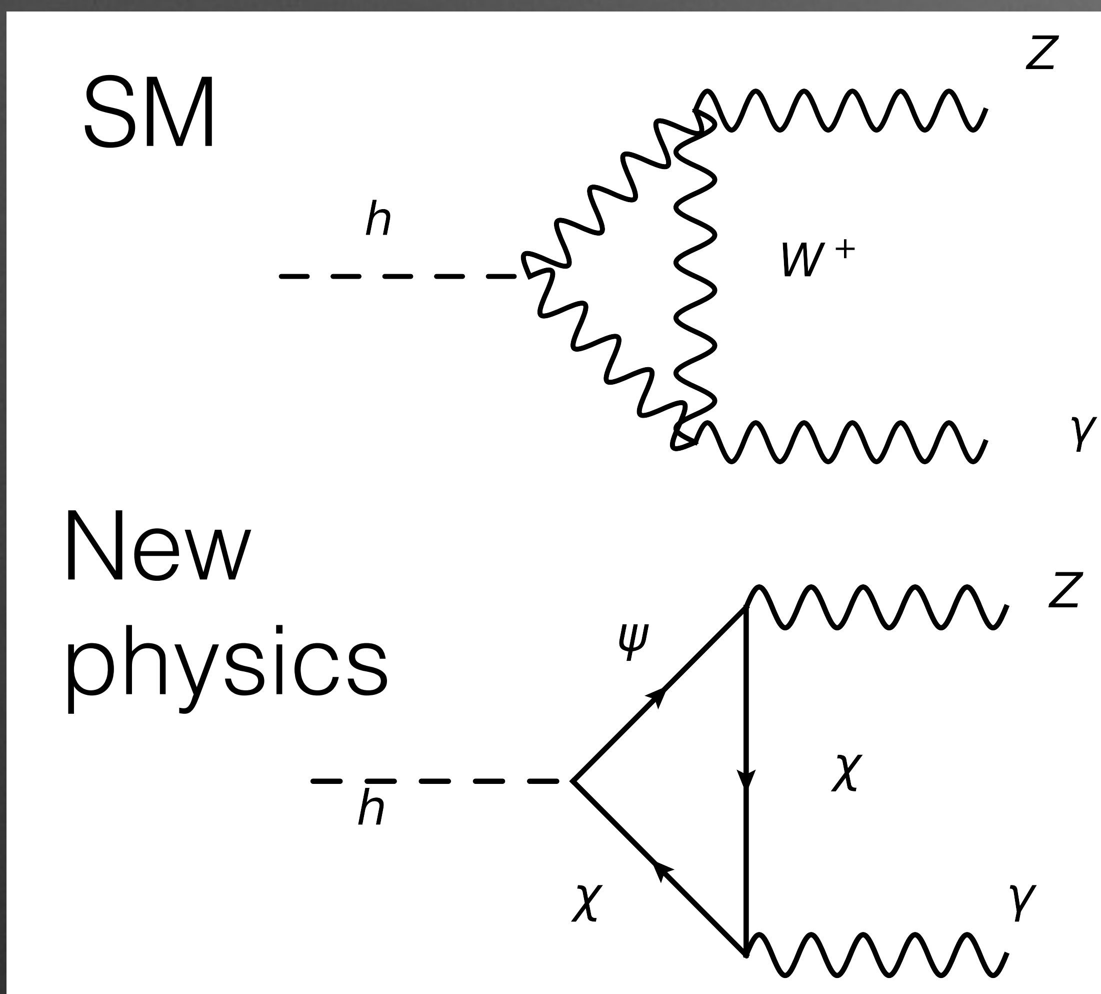
CERN-LHC-2015-010

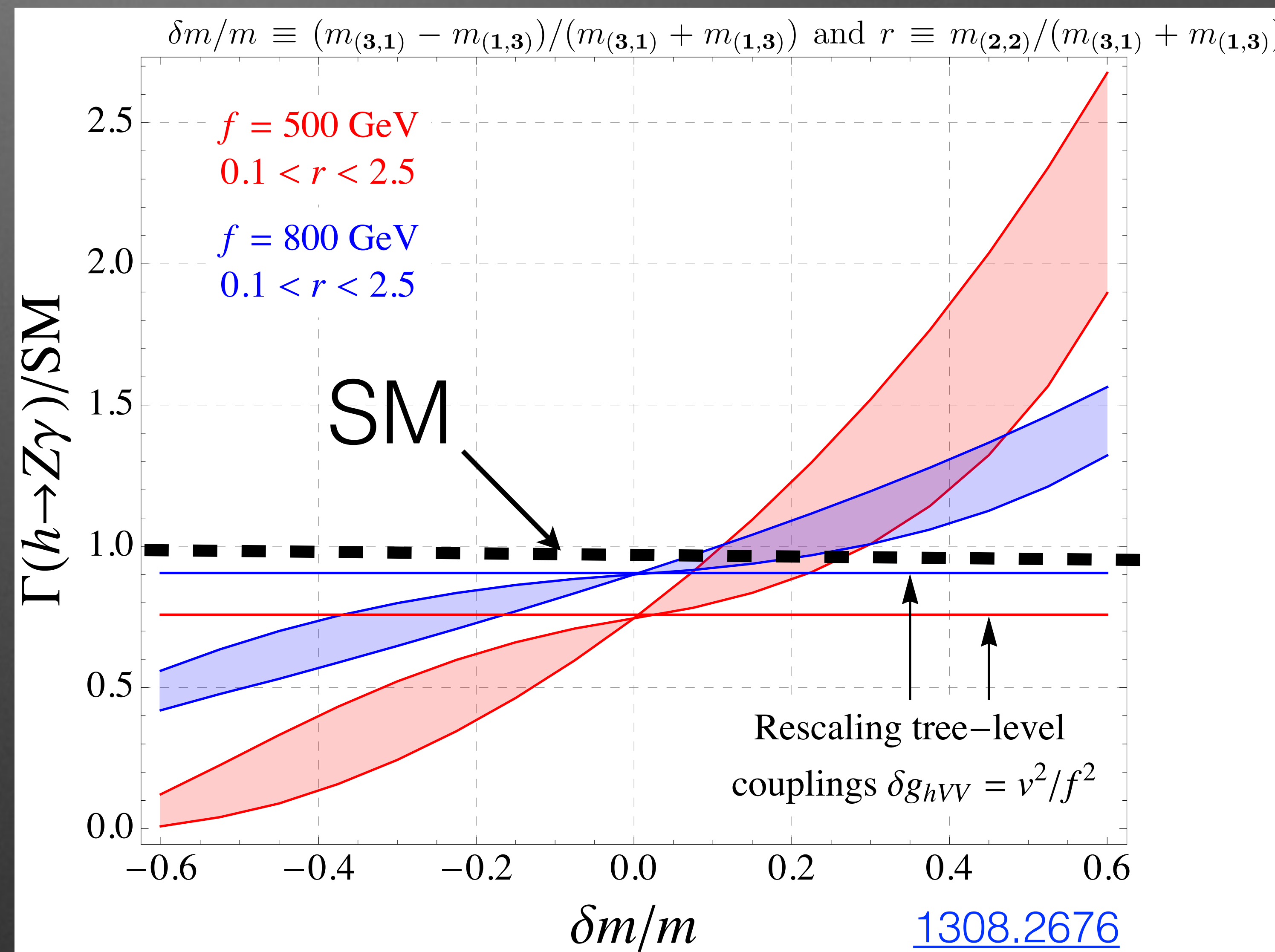
CMS expects a precision of 2/5% on the signal strength in scenario 2/1

Zγ production

In composite Higgs models: large Zγ, while γγ and gg are small

Measurement of Zγ will profit of HL-LHC





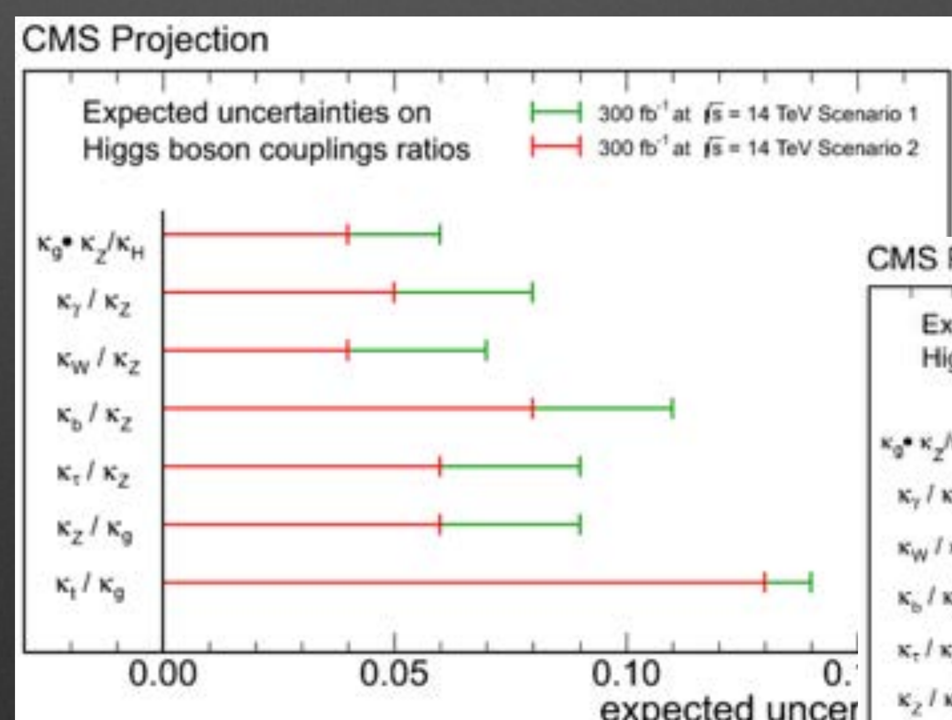
arXiv:1308.2676

Coupling uncertainties

ATLAS, estimate of the maximum theory uncertainty compatible with <10% increase of total uncertainty in 3000/fb

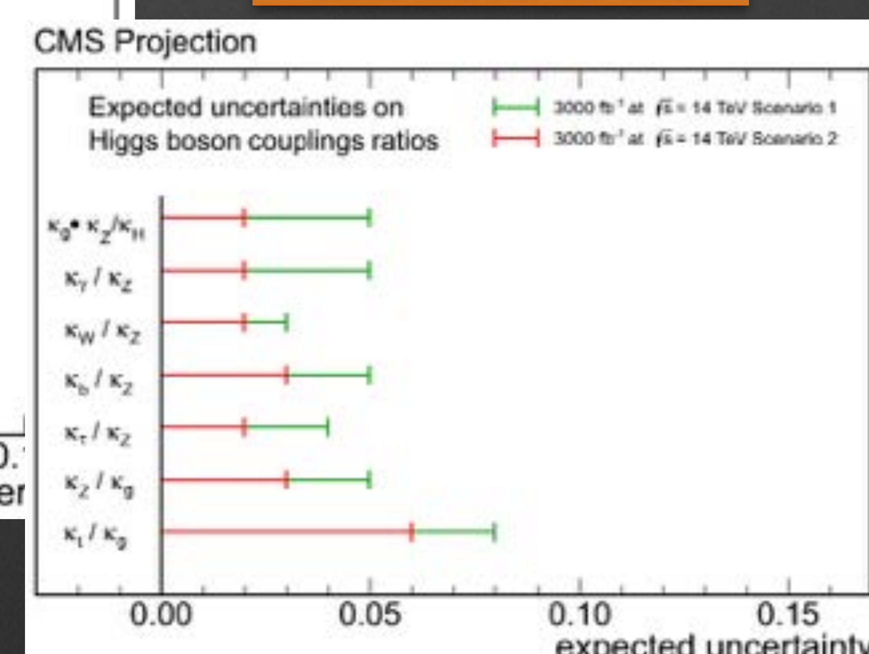
Scenario / Theory uncertainty (%)	Status 2014 [10–12]	Deduced size of uncertainty to increase total uncertainty by $\lesssim$10% for 300 fb^{-1}: κ_{gZ}	λ_{gZ}	$\lambda_{\gamma Z}$	by $\lesssim$10% for 3000 fb^{-1}: κ_{gZ}	$\lambda_{\gamma Z}$	λ_{gZ}	$\lambda_{\tau Z}$	λ_{tg}
$gg \to H$									
PDF	8	2	-	-	1.3	-	-	-	-
incl. QCD scale (MHOU)	7	2	-	-	1.1	-	-	-	-
p_T shape and 0j → 1j mig.	10–20	-	3.5–7	-	-	1.5–3	-	-	-
1j → 2j mig.	13–28	-	-	6.5–14	-	3.3–7	-	-	-
1j → VBF 2j mig.	18–58	-	-	-	-	-	6–19	-	-
VBF 2j → VBF 3j mig.	12–38	-	-	-	-	-	-	6–19	-
VBF									
PDF	3.3	-	-	-	-	-	2.8	-	-
$t\bar{t}H$									
PDF	9	-	-	-	-	-	-	-	3
incl. QCD scale (MHOU)	8	-	-	-	-	-	-	-	2

CMS, scaling of signal and background yields as:
Systematic uncertainties remain the same (scenario 1)
Theoretical uncertainties scaled by 1⁄2, other systematic uncertainties scaled by 1/√L (scenario 2)



ATL-PHYS-PUB-2014-016

LHCC-P-2015-08
CMS NOTE-13-002



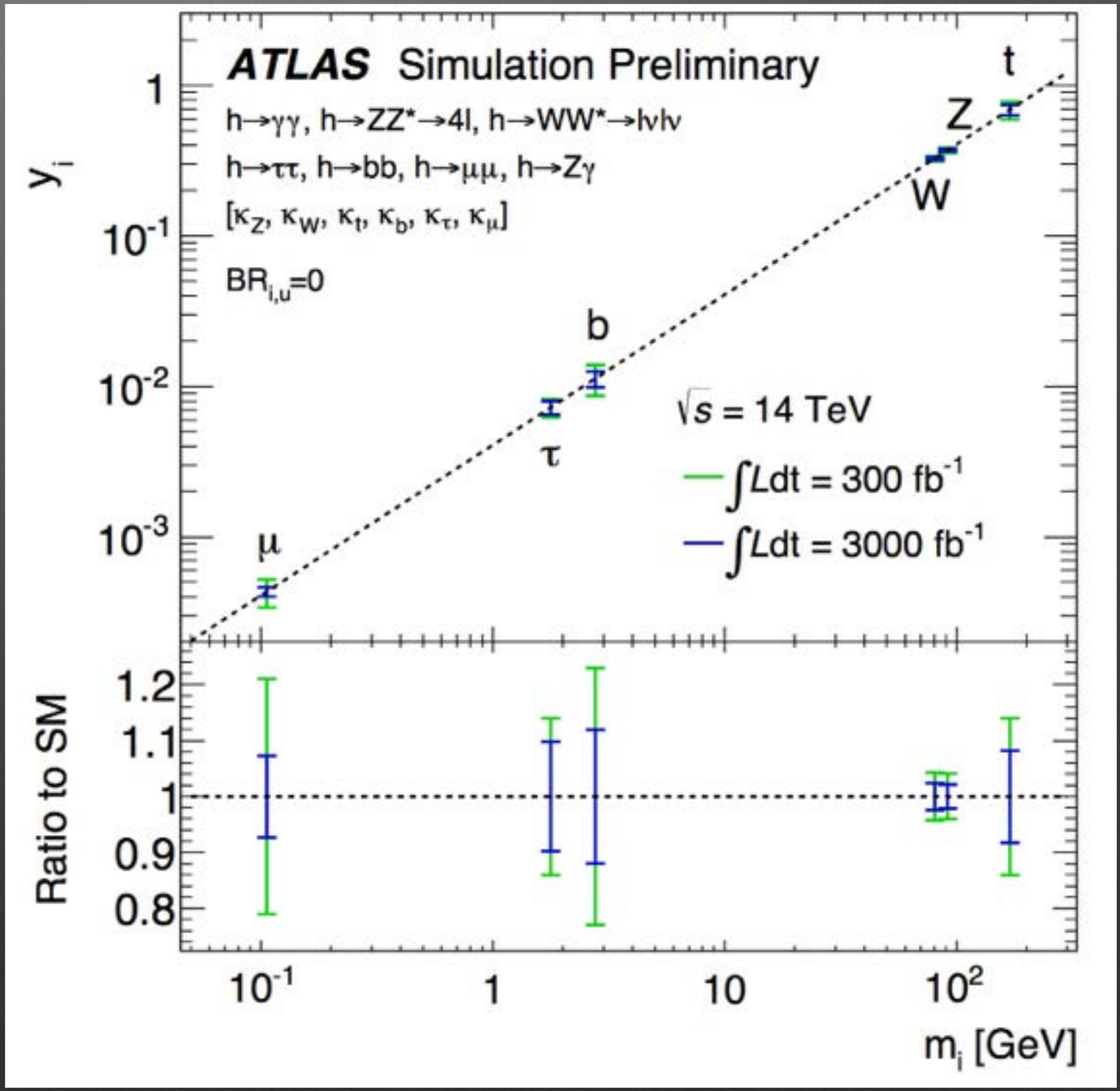
HL-LHC improves by 2-3x
2-3% uncertainty on ratios in scenario 2

Mass dependence of couplings

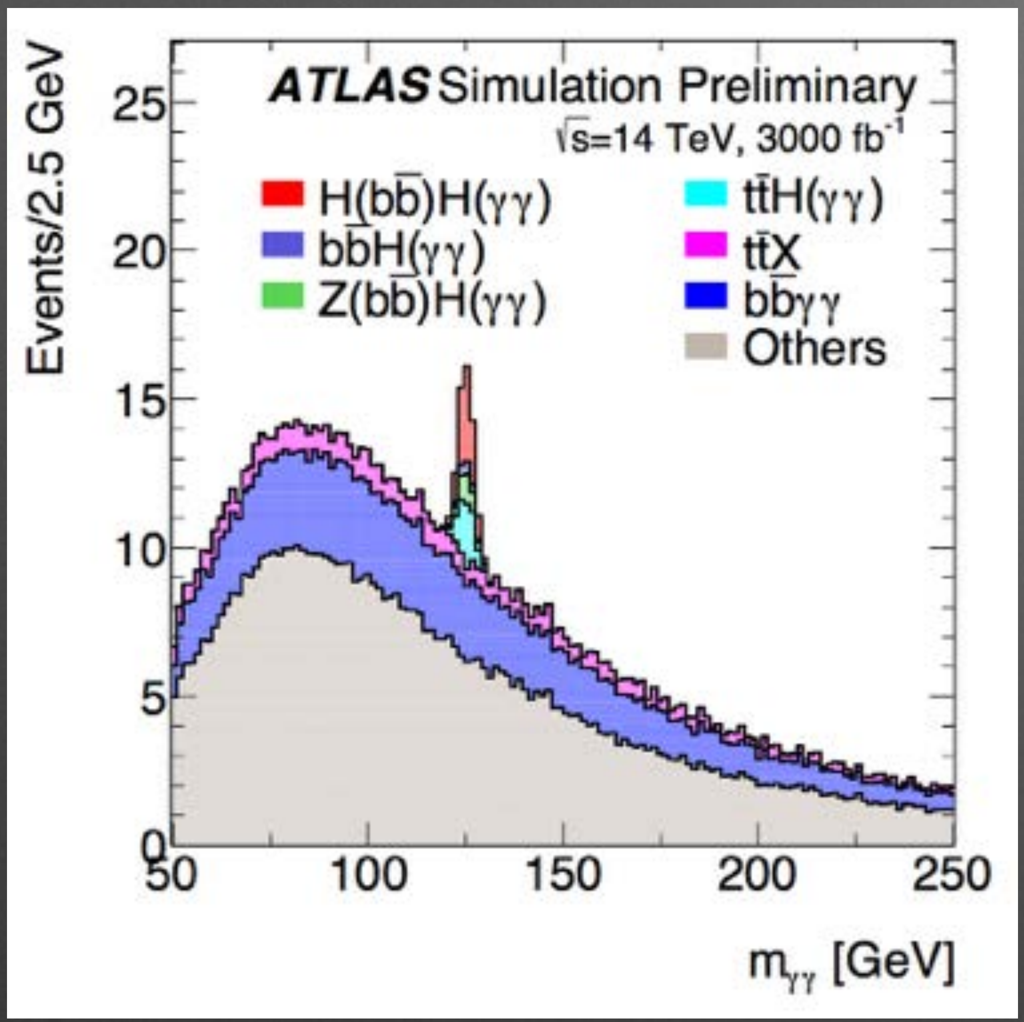
$$y_{V,i} = \sqrt{\kappa_{V,i}\frac{g_{V,i}}{2v}} = \sqrt{\kappa_{V,i}}\frac{m_{V,i}}{v}$$

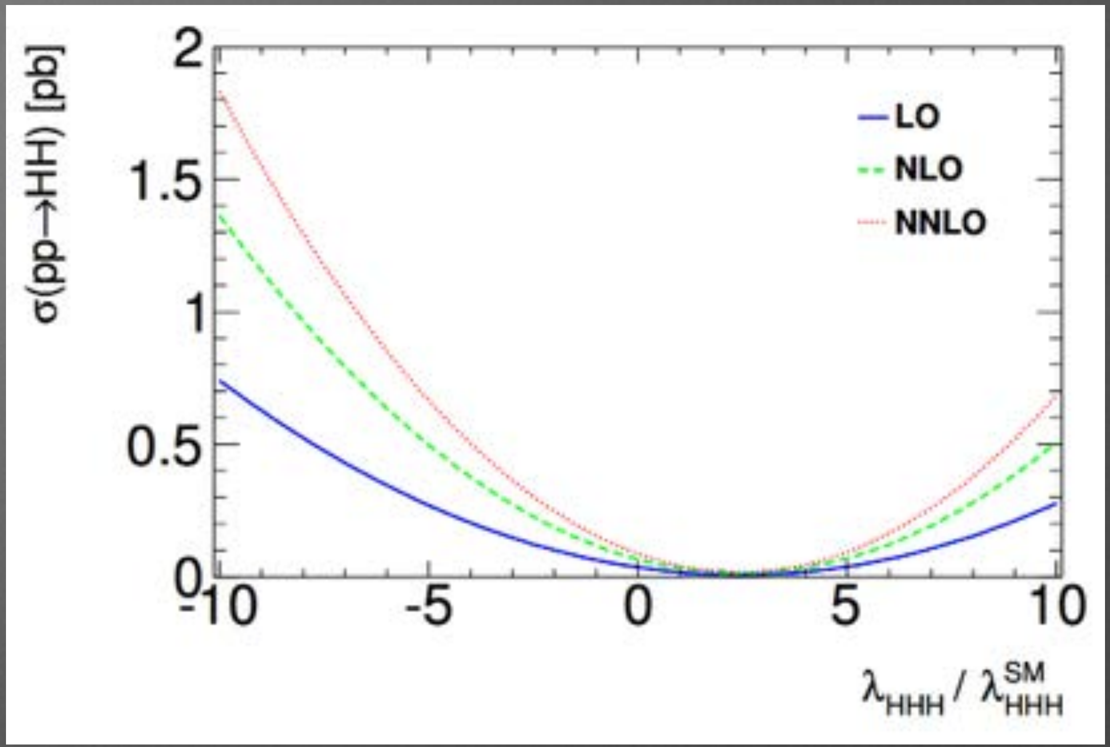
$$y_{F,i} = \kappa_{F,i}\frac{g_{F,i}}{\sqrt{2}} = \kappa_{F,i}\frac{m_{F,i}}{v}$$

ATL-PHYS-PUB-2014-016



HH→bbγγ @ ATLAS



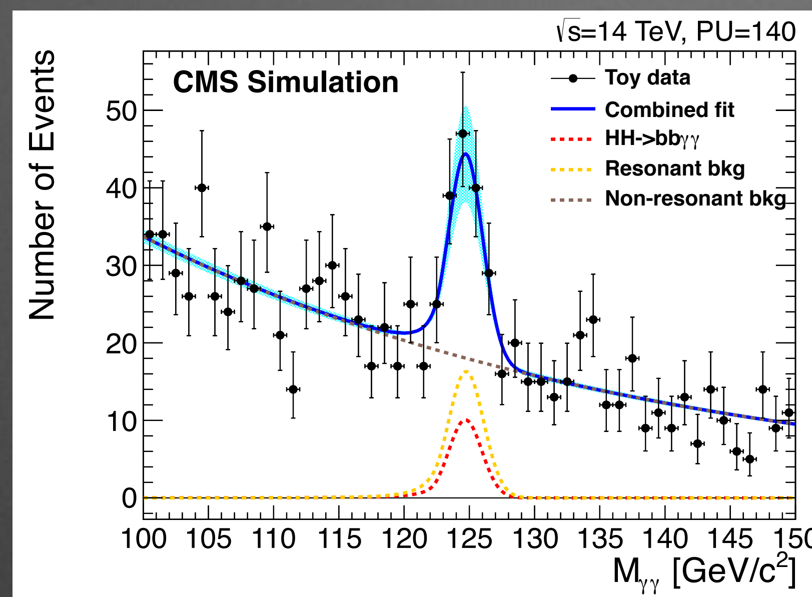


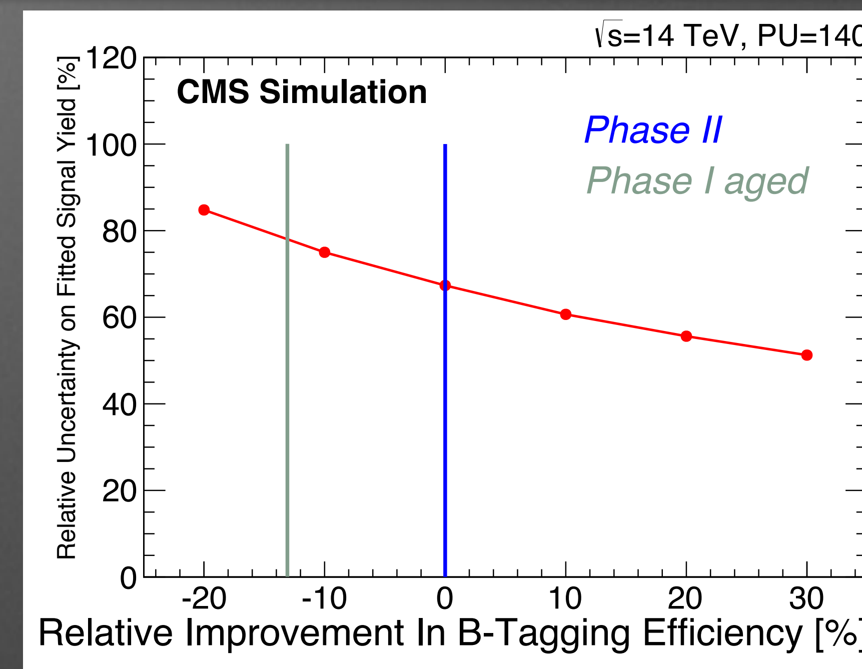
process	Expected events in 3000 fb^{-1}
SM HH→bbγγ	8.4± 0.1
bbγγ	9.7 ± 1.5
ccγγ, bbγj, bbjj, jjγγ	24.1 ± 2.2
top background	3.4 ± 2.2
ttH(γγ)	6.1 ± 0.5
Z(bb)H(γγ)	2.7 ± 0.1
bbH(γγ)	1.2 ± 0.1
Total background	47.1 ± 3.5
S/√B (barrel+endcap)	1.2
S/√B (split barrel and endcap)	1.3

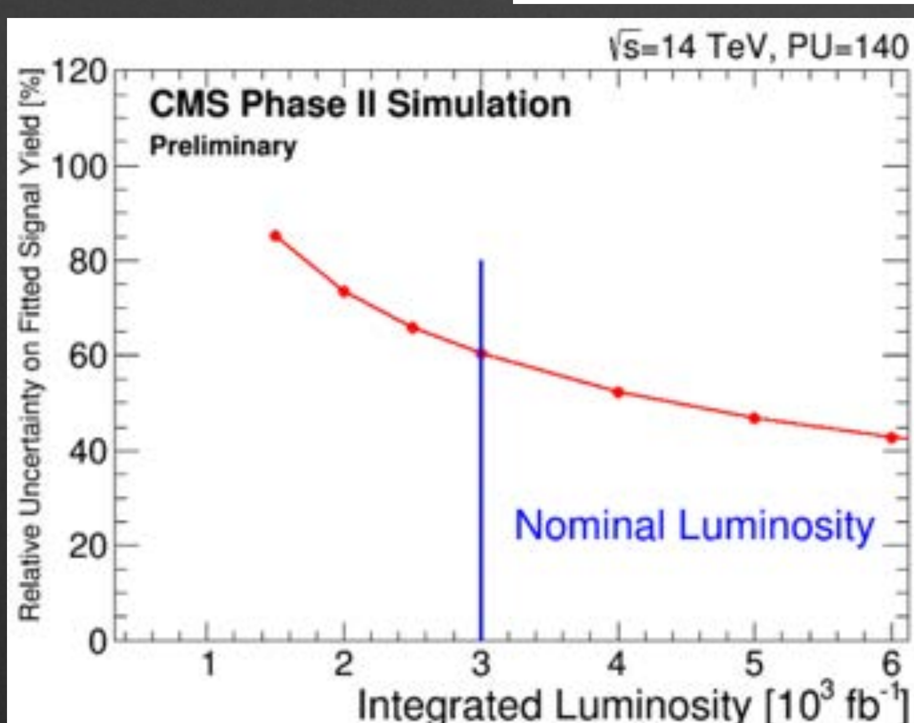
HH→bbγγ @ CMS

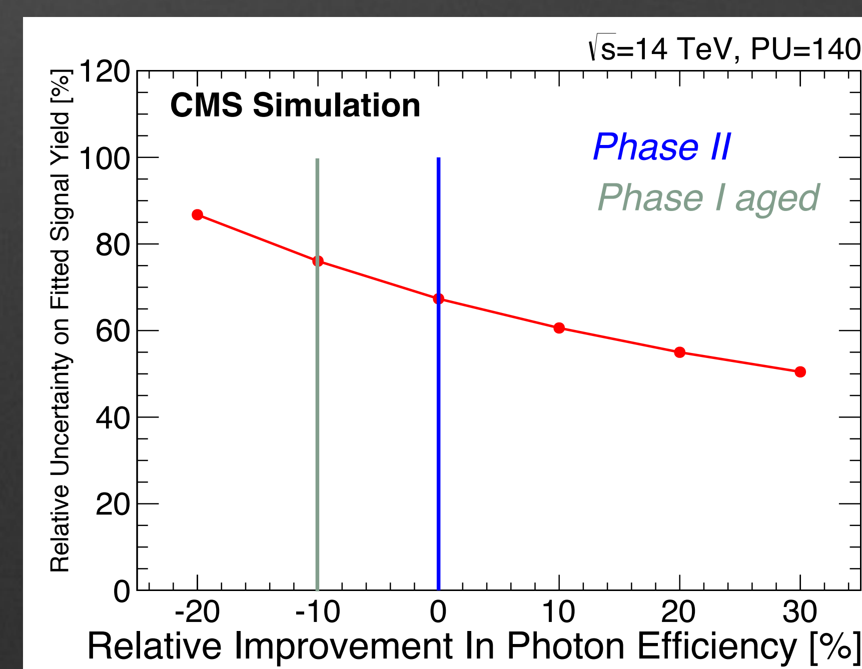
- Search approach based o 2D fit of M_{bb} and $M_{\gamma\gamma}$
- Parameterized object performance tuned to the Phase 2 detector

Process / Selection Stage	HH	ZH	$t\bar{t}H$	$b\bar{b}H$	$\gamma\gamma$+jets	γ+jets	jets	$t\bar{t}(\gamma)$
Object Selection & Fit Mass Window	23.8	30.5	184	6.5	3721	1619	287	597
Kinematic Selection	13.4	15.1	3.4	2.1	192	98	20	22
Mass Windows	9.0	3.4	1.6	0.8	13.0	6.3	1.1	1.2





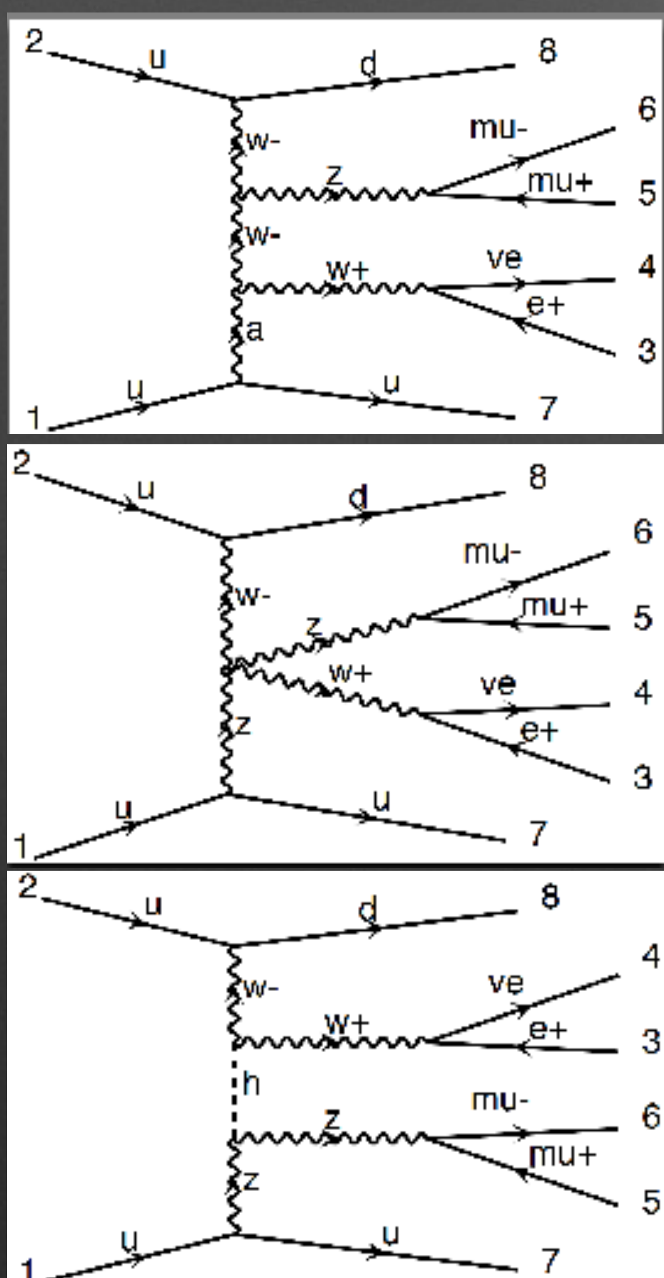


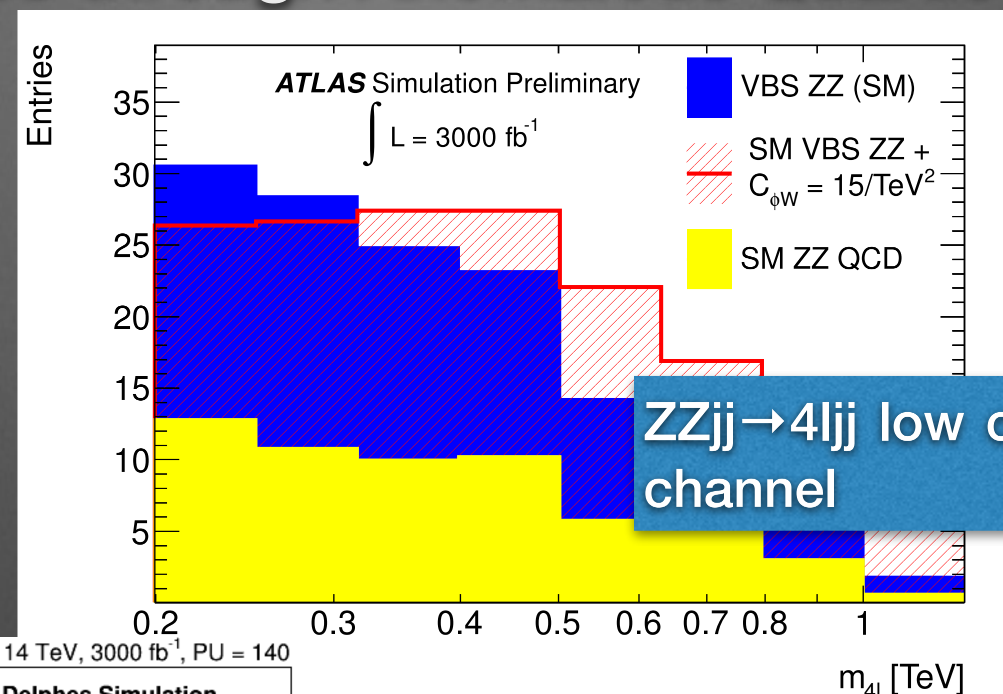


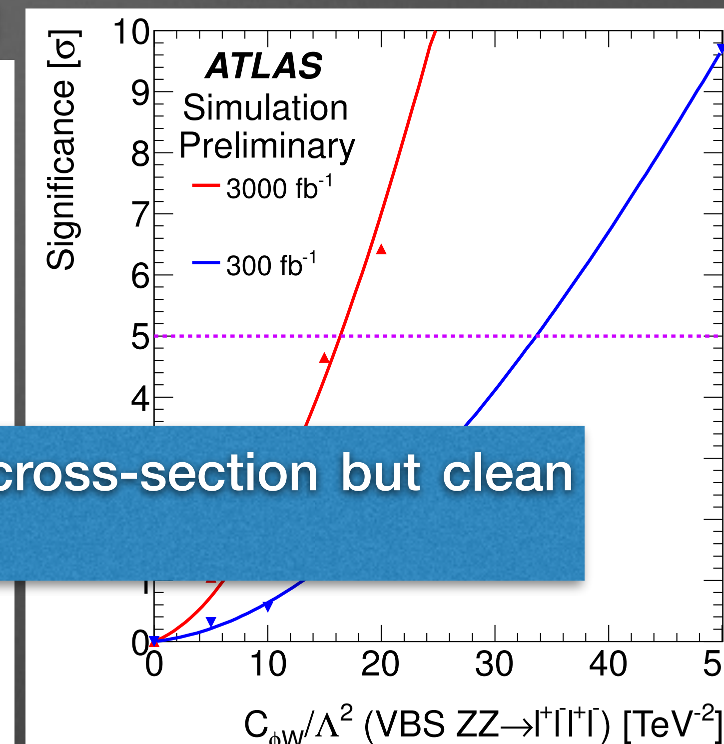
Vector Boson Scattering (VBS)

New Physics may appear in the unitarization of longitudinal VBS

Sensitive to New Physics also through Anomalous Quartic Gauge Couplings

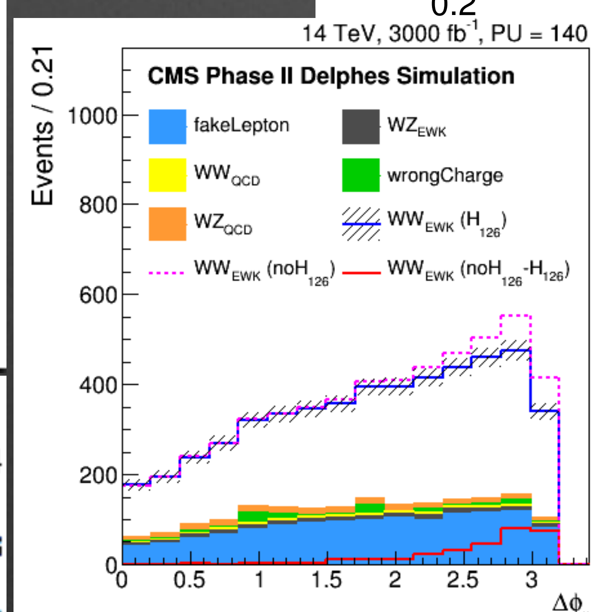


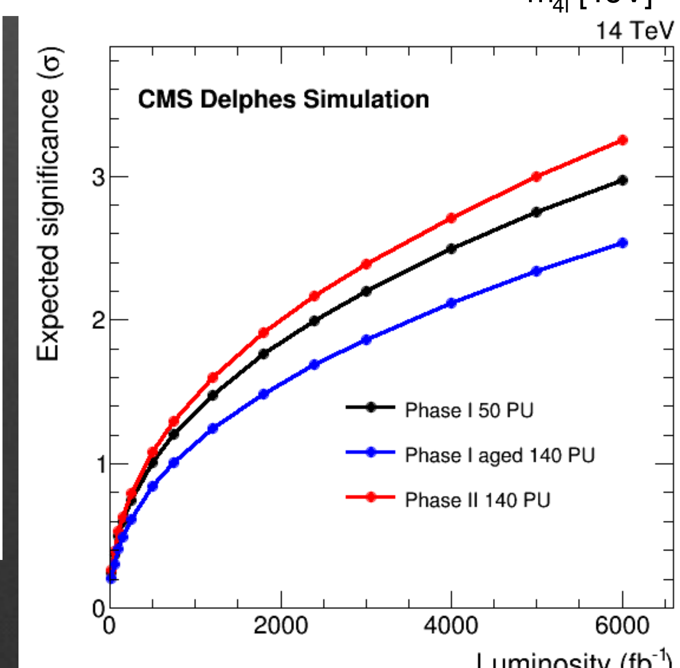




ZZjj→4ljj low cross-section but clean channel

ATL-PHYS-PUB-2013-006



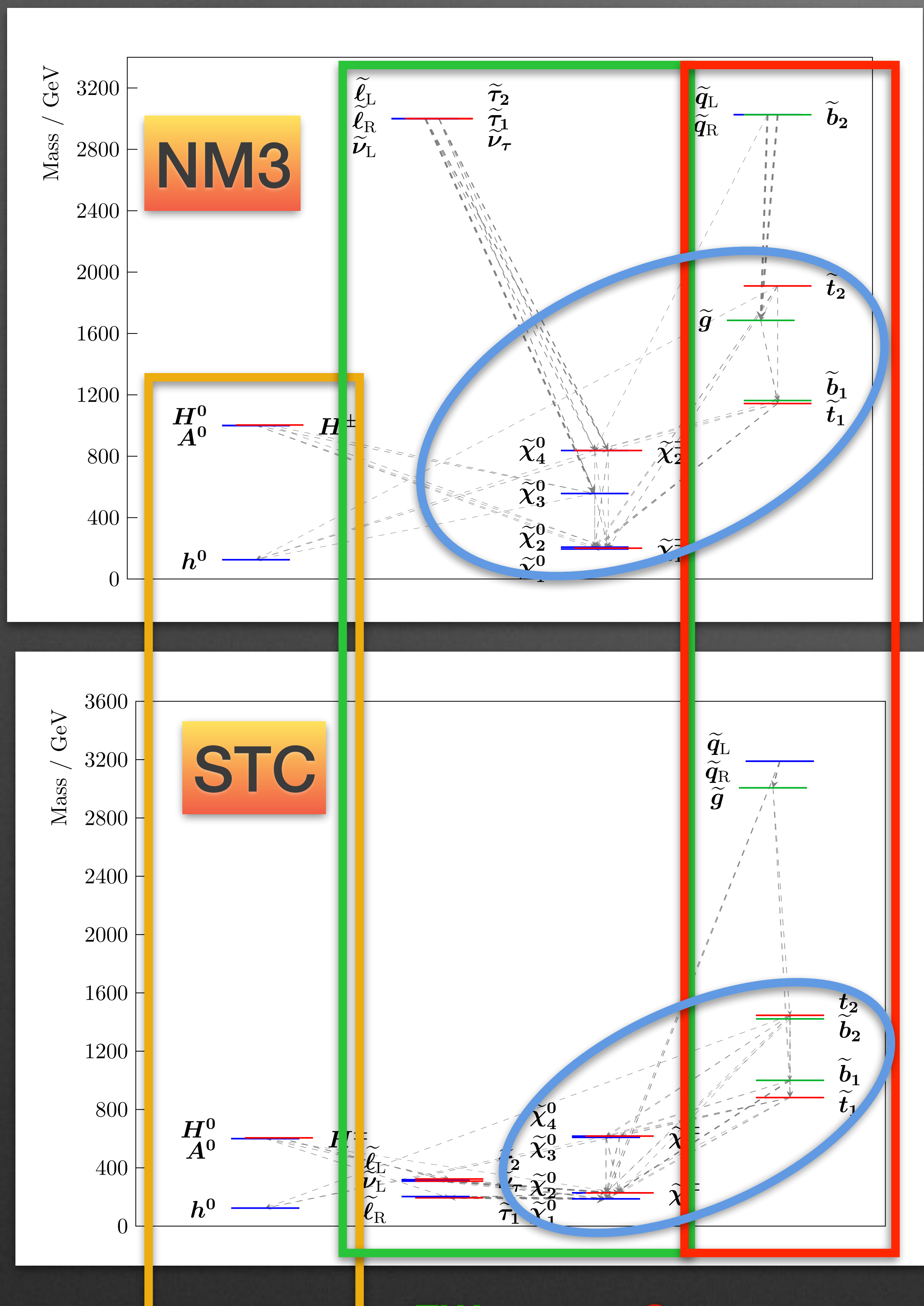


CERN-LHCC-2015-010

WW & WZ fully leptonic channel also studied and combined to increase sensitive to NP

$3000\ fb^{-1}$, 14 TeV	Phase-I	Phase-II	Phase-I aged
Higgsless 95% CL μ exclusion	0.14	0.14	0.20
$V_L\ V_L$ scattering significance	2.50	2.75	2.14

Full spectrum SUSY



EW sector Strong sector
Higgs sector with m_h=125 GeV
Light sbottom, stop, higgsino, gluino

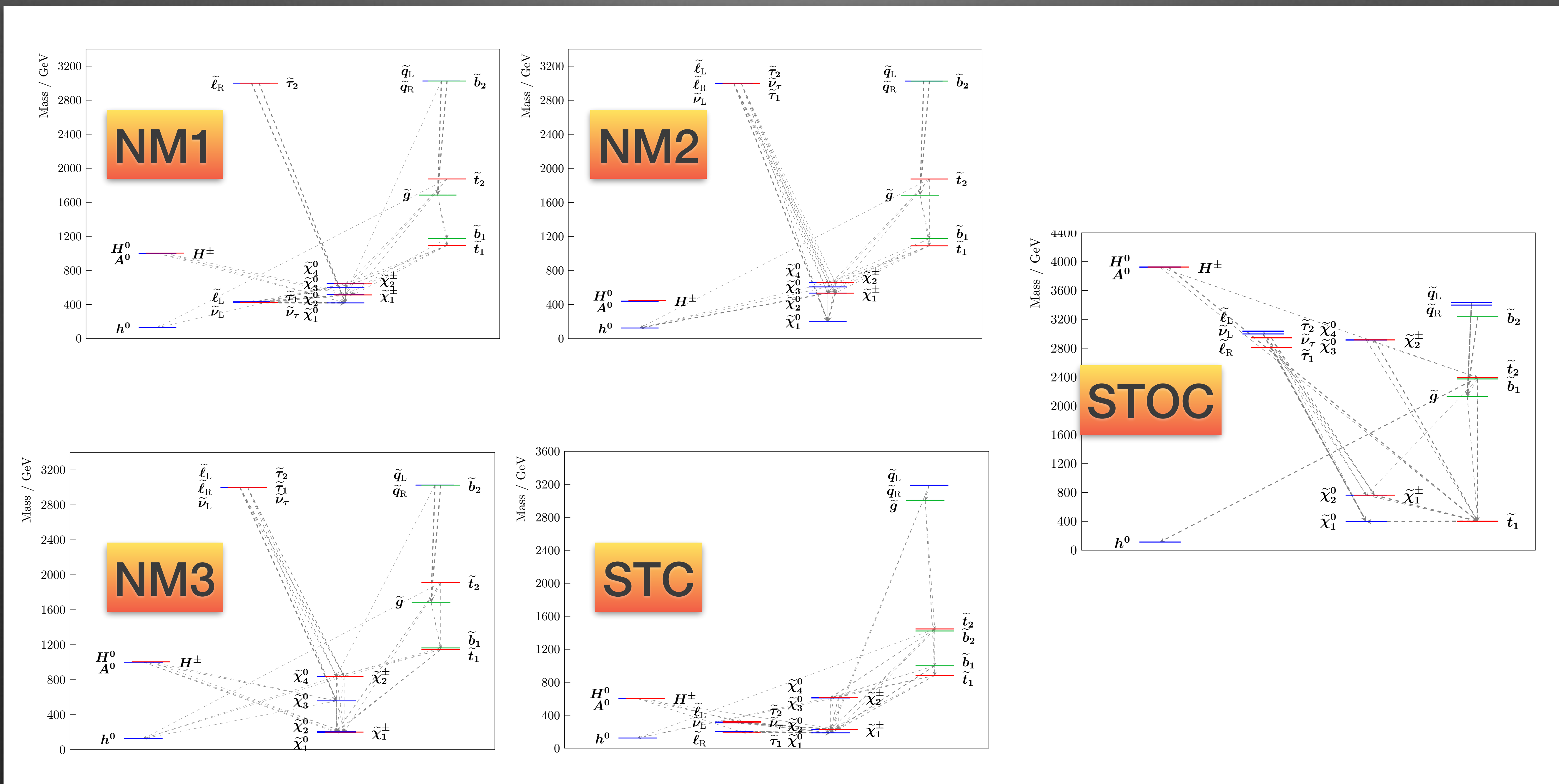
Analysis	Luminosity (fb^{-1})	Model NM1	NM2	NM3	STC	STOC
all-hadronic (H_T-H_T^{miss}) search	300				$< 3\sigma$	$3-5\sigma$
	3000				$3-5\sigma$	$> 5\sigma$
all-hadronic (M_{T2}) search	300	$3-5\sigma$	$> 5\sigma$	$> 5\sigma$		
	3000	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$		
all-hadronic $\tilde{b}_1$ search	300	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$	$3-5\sigma$	$< 3\sigma$
	3000	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$	$> 5\sigma$	$< 3\sigma$
1-lepton $\tilde{t}_1$ search	300	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$3-5\sigma$	$< 3\sigma$
	3000	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$
monojet $\tilde{t}_1$ search	300					$3-5\sigma$
	3000					$3-5\sigma$
$m_{\ell^+\ell^-}$ kinematic edge	300	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$		
	3000	$> 5\sigma$	$< 3\sigma$	$< 3\sigma$		
multilepton + b-tag search	300	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$3-5\sigma$	
	3000	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	$> 5\sigma$	
multilepton search	300	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$	$< 3\sigma$	
	3000	$3-5\sigma$	$3-5\sigma$	$< 3\sigma$	$3-5\sigma$	
ewkino WH search	300		$< 3\sigma$			
	3000		$3-5\sigma$			

$< 3\sigma$ | $3-5\sigma$ | $> 5\sigma$

CMS PAS SUS-14-012

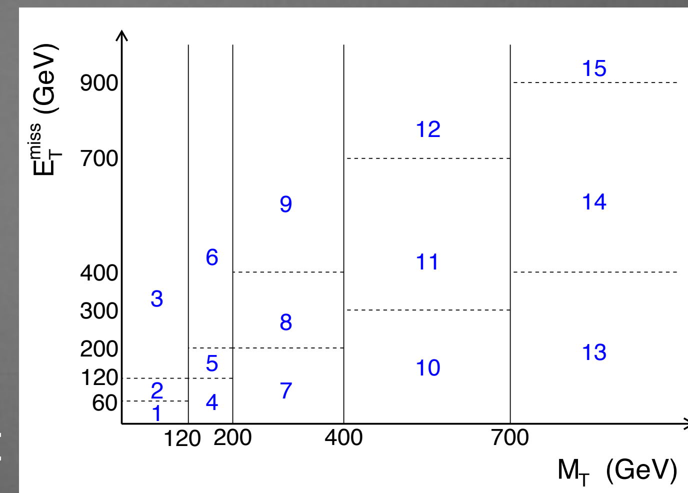
- Five phenomenological models motivated by naturalness explored through a number of signature-based searches
- Models differ by nature of the LSP (bino-, higgsino-like), EWK-inos and sleptons hierarchies
- STC (stau) and STOC (stop) co-annihilation models satisfy dark matter constraints

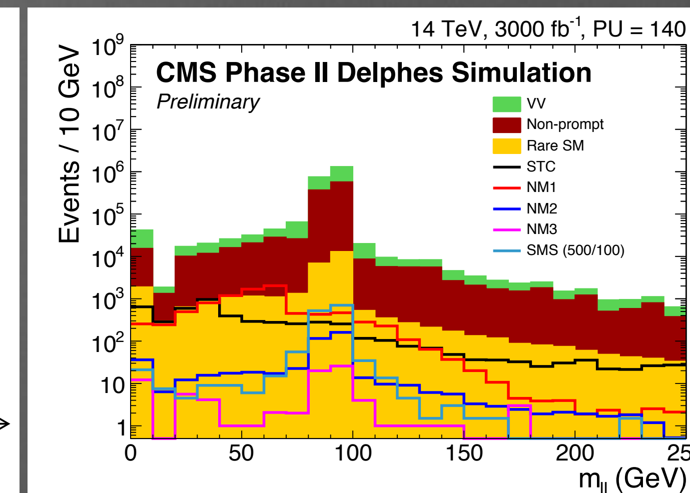
Natural Models

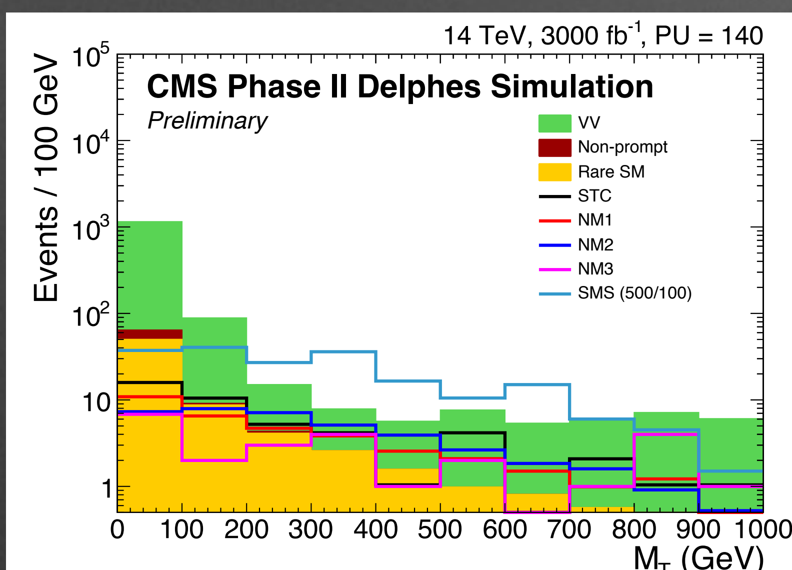


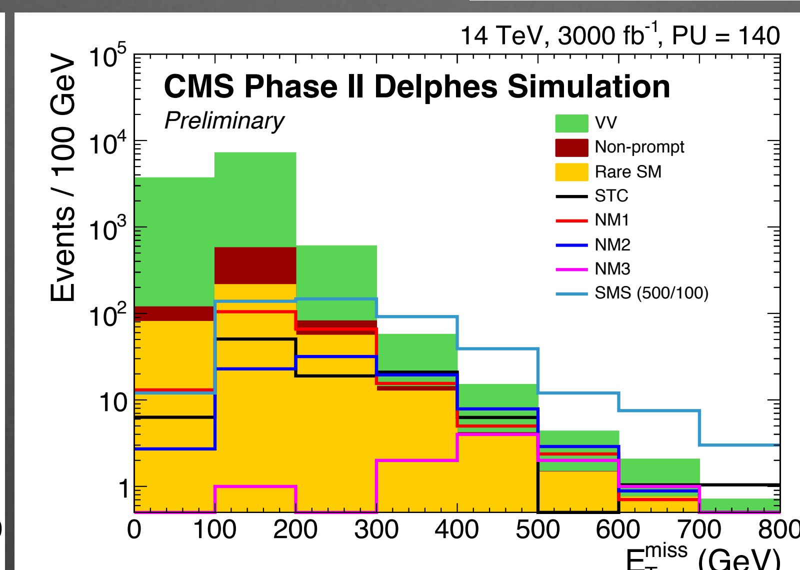
CMS $\chi^{\pm}\chi^{0}$ searches

Lepton candidates $p_T > 10$ GeV and $|\eta| < 4$
Leading lepton $p_T > 25$ GeV
Second leading lepton $p_T > 15$ GeV
One opposite-sign same-flavor (OSSF) lepton
Veto on events with 4 leptons or with a b-tagged jet

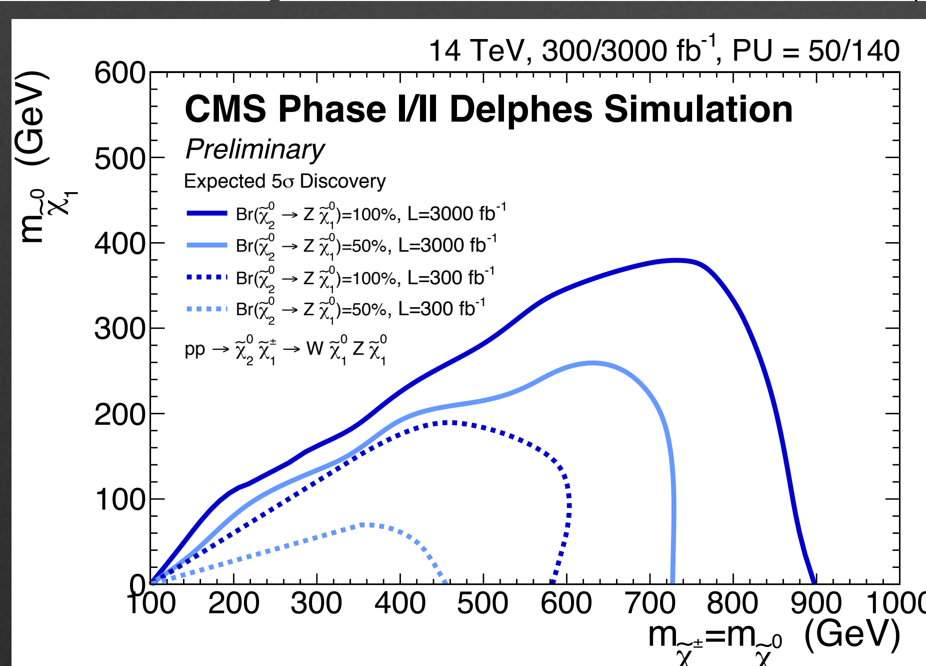


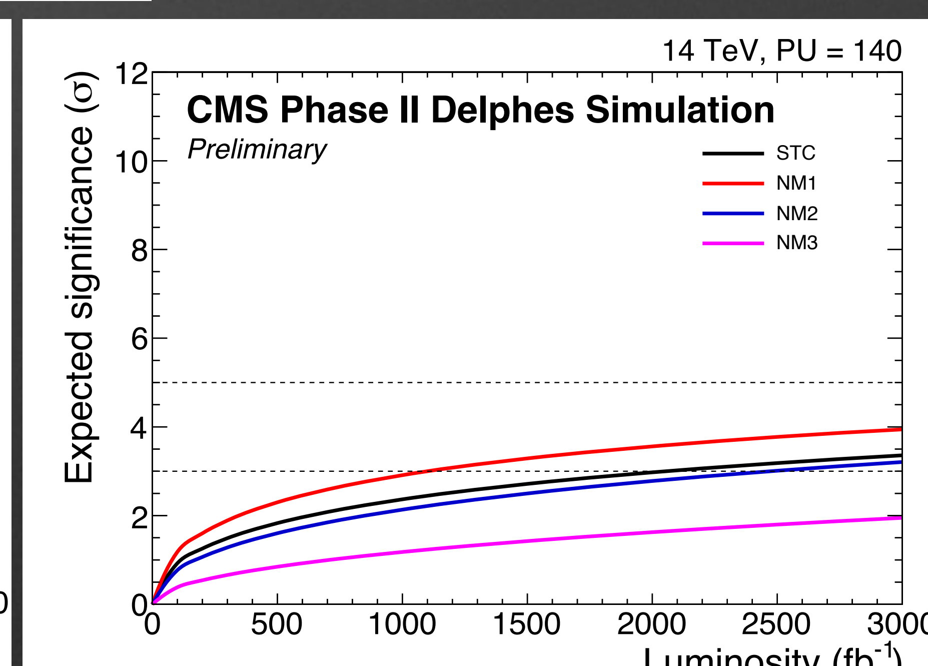






CMS PAS SUS-14-012





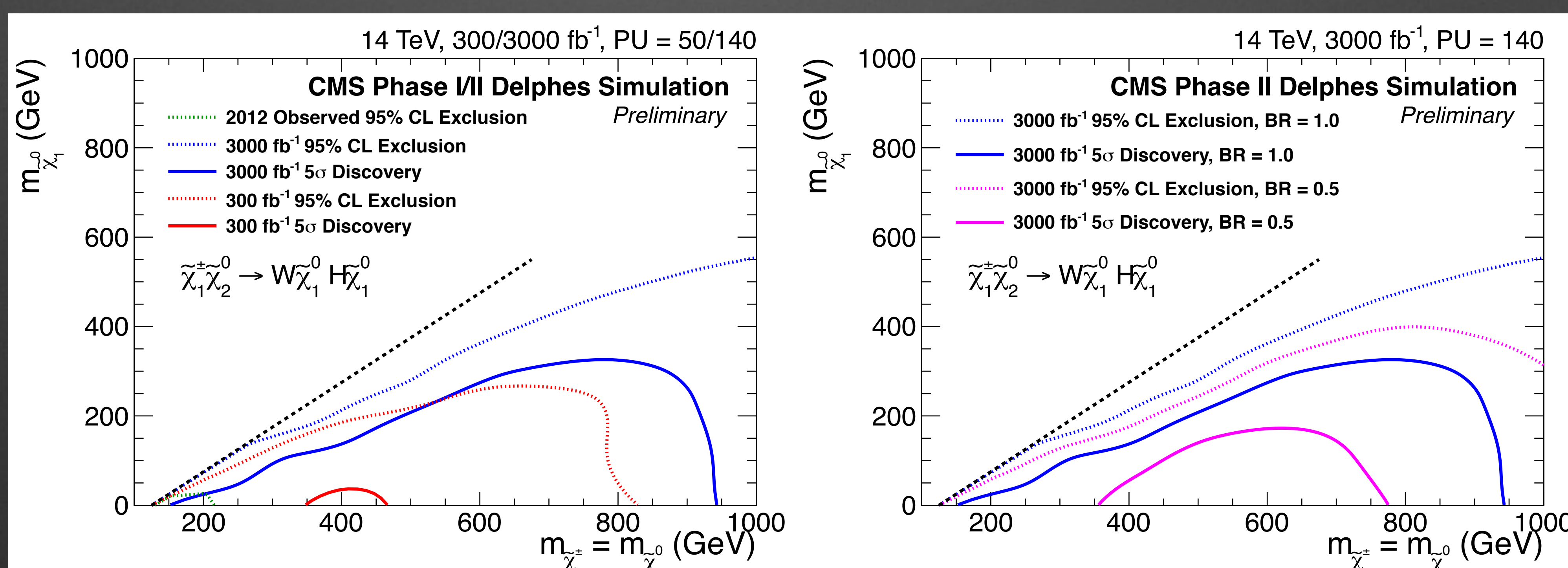
CMS $\chi^{\pm}\chi^{0}$ searches

300/fb

Sample	$E_T^{miss} > 200$ GeV	$E_T^{miss} > 300$ GeV	$E_T^{miss} > 400$ GeV
	25% Background Uncertainty		
WH signal (200,1)	1.7	1.8	1.5
WH signal (500,1)	1.4	2.9	3.9
WH signal (900,1)	-	0.4	1.3
Natural Model 2	0.6	1.2	1.3
	12.5% Background Uncertainty		
WH signal (200,1)	3.2	2.6	1.8
WH signal (500,1)	2.6	4.4	4.5
WH signal (900,1)	0.2	0.7	1.5
Natural Model 2	1.2	1.8	1.5

3000/fb

Sample	$E_T^{miss} > 200$ GeV	$E_T^{miss} > 300$ GeV	$E_T^{miss} > 400$ GeV	$E_T^{miss} > 500$ GeV
	25% Background Uncertainty			
WH signal (200,1)	2.8	1.9	4.3	5.5
WH signal (500,1)	1.4	3.0	7.6	6.9
WH signal (900,1)	-	0.4	2.5	4.7
Natural Model 2	0.6	1.3	2.9	2.4
	12.5% Background Uncertainty			
WH signal (200,1)	5.8	3.8	6.7	6.8
WH signal (500,1)	2.9	5.9	12	8.6
WH signal (900,1)	-	0.9	3.9	5.8
Natural Model 2	1.4	2.7	4.7	3.0



CMS PAS SUS-14-012

ATLAS $\chi^{\pm}\chi^{0}$ searches

WZ Selection

Selection	SRA	SRB	SRC	SRD
$m_{\rm SFOS}$[GeV]	81.2-101.2			
# b-tagged jets	0			
lepton p_T (1,2,3)[GeV]	> 50			
$E_{\rm T}^{\rm miss}$[GeV]	> 250	> 300	> 400	> 500
$m_{\rm T}$ [GeV]	> 150	> 200	> 200	> 200
$\langle\mu\rangle$ = 60, 300 fb^{-1} scenario	yes	yes	yes	–
$\langle\mu\rangle$ = 140, 3000 fb^{-1} scenario	yes	yes	yes	yes

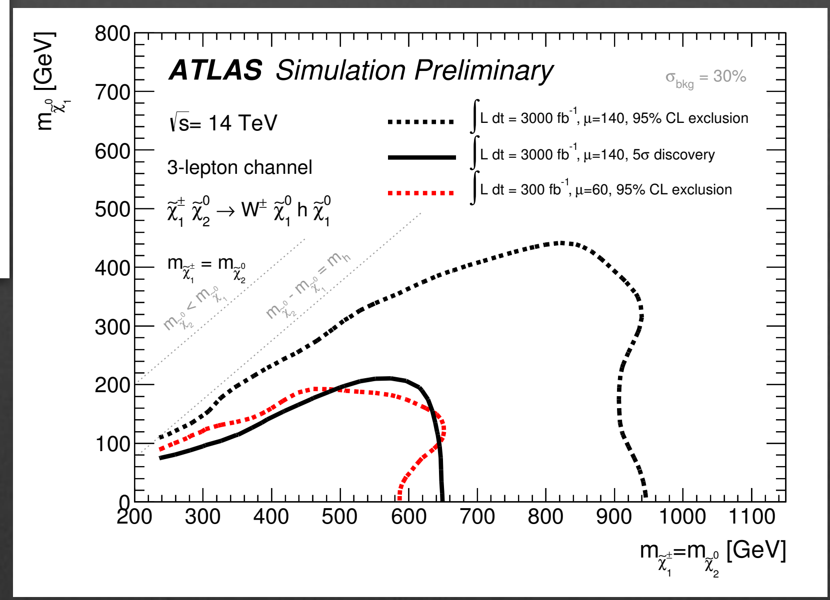
Sample Scenario	SRA 300 fb^{-1}, μ=60	SRB 300 fb^{-1}, μ=60	SRC 300 fb^{-1}, μ=60	SRA 3000 fb^{-1}, μ=140	SRB 3000 fb^{-1}, μ=140	SRC 3000 fb^{-1}, μ=140	SRD 3000 fb^{-1}, μ=140
WZ	9.60±0.32	4.59±0.22	1.91±0.14	200±5	59.4±2.5	22.0±1.5	8.3±1.0
ZZ	0	0	0	0	0	0	0
VVV	2.11±0.18	1.07±0.13	0.44±0.08	24.3±1.9	12.1±1.4	5.4±0.8	2.0±0.5
Wh	0	0	0	0	0	0	0
$t\bar{t}V$	0.67±0.19	0.23±0.12	0	14.4±2.8	4.2±1.6	0.31±0.31	0
$t\bar{t}$	0	0	0	0	0	0	0
Σ MC	12.4±0.4	5.89±0.28	2.35±0.16	239±6	75.6±3.3	27.7±1.8	10.3±1.1
WZ-mediated							
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^0)$=(400,0) GeV	38.5±0.6	20.1±0.5	5.47±0.23	407±6	224±5	67.9±2.6	19.7±1.4
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^0)$=(600,0) GeV	19.40±0.20	14.69±0.17	7.76±0.12	194.8±2.0	148.9±1.7	81.6±1.3	33.5±0.8
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^0)$=(800,0) GeV	6.97±0.06	5.90±0.06	4.21±0.05	69.6±0.6	59.1±0.6	42.4±0.5	25.2±0.4
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^0)$=(1000,0) GeV	2.31±0.02	2.05±0.02	1.64±0.02	22.94±0.19	20.42±0.18	16.36±0.16	11.55±0.14

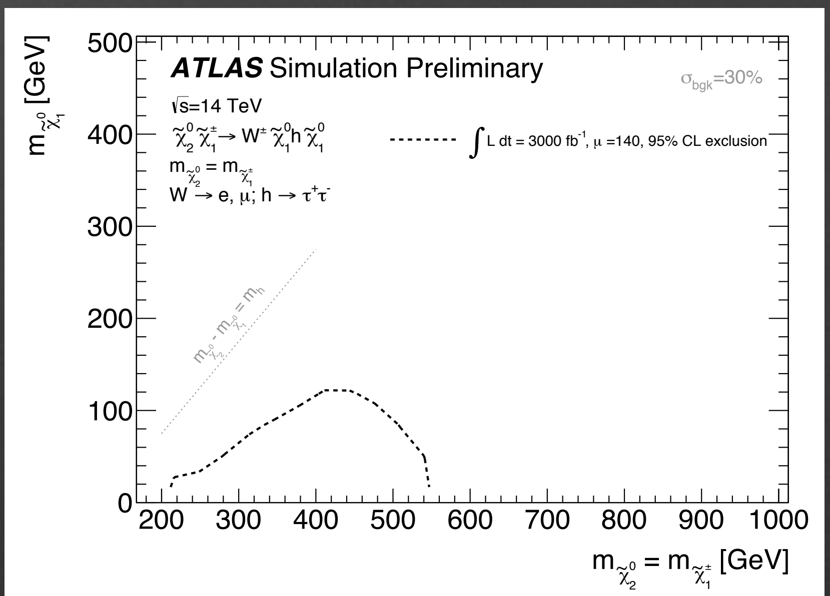
Wh Selection (3l)

Selection	SRE	SRF	SRG	SRH
SFOS pair	veto			
# b-tagged jets	0			
$E_{\rm T}^{\rm miss}$ [GeV]	> 100			
$m_{OS}^{\min\Delta R}$ [GeV]	< 75			
$m_{\rm T}(\ell_1)$ [GeV]	> 200	> 200	> 300	> 400
$m_{\rm T}(\ell_2)$ [GeV]	> 100	> 150	> 150	> 150
$m_{\rm T}(\ell_3)$ [GeV]	> 100	> 100	> 100	> 100
$\langle\mu\rangle$ = 60, 300 fb^{-1} scenario	yes	yes	yes	—
$\langle\mu\rangle$ = 140, 3000 fb^{-1} scenario	yes	yes	yes	yes

Wh Selection (1l2τ)

# e,μ	1
# τ	2 (OS)
# b-tagged jets	0
$E_{\rm T}^{\rm miss}$ [GeV]	> 250
$m_{\tau\tau}$ [GeV]	80-130
$\lvert p_T(\tau_1)\rvert + \lvert p_T(\tau_2)\rvert$ [GeV]	> 190
$m_{\rm T}(\ell)$ [GeV]	> 130



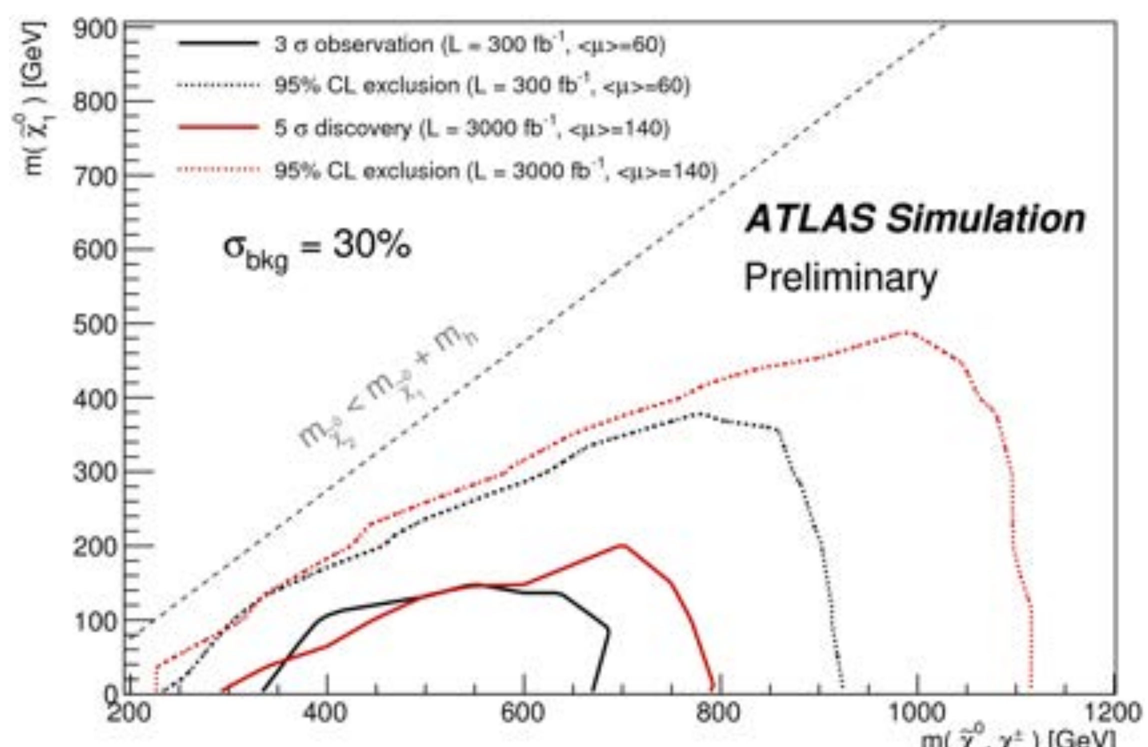


ATL-PHYS-PUB-2014-010

ATLAS $\chi^{\pm}\chi^{0}$ searches: Wh(bb)

Selection	SRA	SRB	SRC	SRD
# of leptons (e, μ)	1			
# b-tagged jets	2			
m_{bb} [GeV]	$105 < m_{bb} < 135$			
# jets	2 or 3			
m_{CT} [GeV]	> 200	> 200	> 300	> 300
m_{T} [GeV]	> 200	> 250	> 200	> 250
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	> 300	> 350	> 400	> 450
$\langle\mu\rangle$ = 60, 300 fb^{-1} scenario	yes	yes	–	–
$\langle\mu\rangle$ = 140, 3000 fb^{-1} scenario	–	–	yes	yes

	SRC	SRD
Expected events	30 ± 6	15 ± 4
$t\bar{t}$ events	18 ± 5	11 ± 4
single top events	5.4 ± 2.7	2.7 ± 1.9
$t\bar{t} + V$ events	3.8 ± 1.5	1.9 ± 1.1
Other SM events	2.8 ± 2.2	–
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^\pm)$ = 600 GeV, $m(\tilde{\chi}_1^0)$ = 0 GeV events	83.7 ± 3.3	51 ± 4
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^\pm)$ = 500 GeV, $m(\tilde{\chi}_1^0)$ = 300 GeV events	2.1 ± 0.9	0.8 ± 0.6
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^\pm)$ = 1000 GeV, $m(\tilde{\chi}_1^0)$ = 0 GeV events	20.0 ± 0.8	16.8 ± 0.7



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SR	Training Sample [GeV] $(m(\tilde{\chi}_2^0,\tilde{\chi}_1^\pm), m(\tilde{\chi}_1^0))$	BDT range
M1	(300,0)	> 0.22
M2	(800,400)	> 0.35
M3	(1300,0)	> 0.28

	M1	M2	M3
Expected events	73 ± 12	10 ± 4	10 ± 4
$t\bar{t}$ events	58 ± 11	4.7 ± 2.9	8 ± 4
single top events	4.1 ± 2.4	–	–
W+jets events	4.1 ± 2.9	4.0 ± 2.8	–
$t\bar{t} + V$ events	4.5 ± 1.5	1.8 ± 1.0	1.5 ± 0.9
Other SM events	2.5 ± 1.5	–	–
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^\pm)$ = 600 GeV, $m(\tilde{\chi}_1^0)$ = 0 GeV events	77 ± 5	69 ± 5	59 ± 4
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^\pm)$ = 500 GeV, $m(\tilde{\chi}_1^0)$ = 300 GeV events	9.1 ± 2.0	1.2 ± 0.7	1.2 ± 0.7
$m(\tilde{\chi}_2^0,\tilde{\chi}_1^\pm)$ = 1000 GeV, $m(\tilde{\chi}_1^0)$ = 0 GeV events	11.2 ± 0.4	15.7 ± 0.6	18.9 ± 0.7