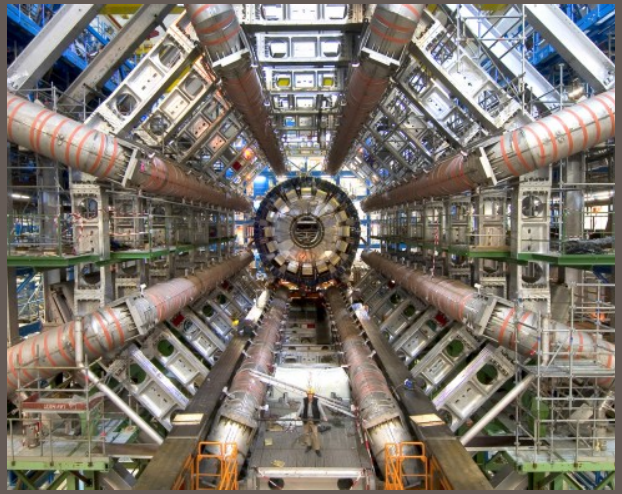
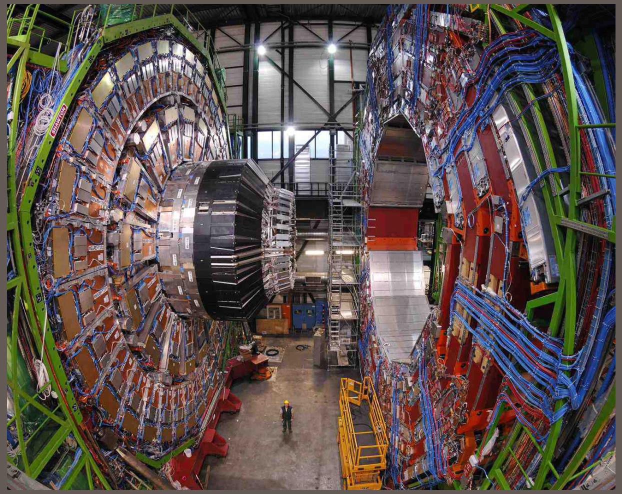
TRIUMF

Canada's national laboratory for particle and nuclear physics
Laboratoire national canadien pour la recherche en physique nucléaire et en physique des particules

Selected Highlights from the LHC and HL-LHC Physics Program



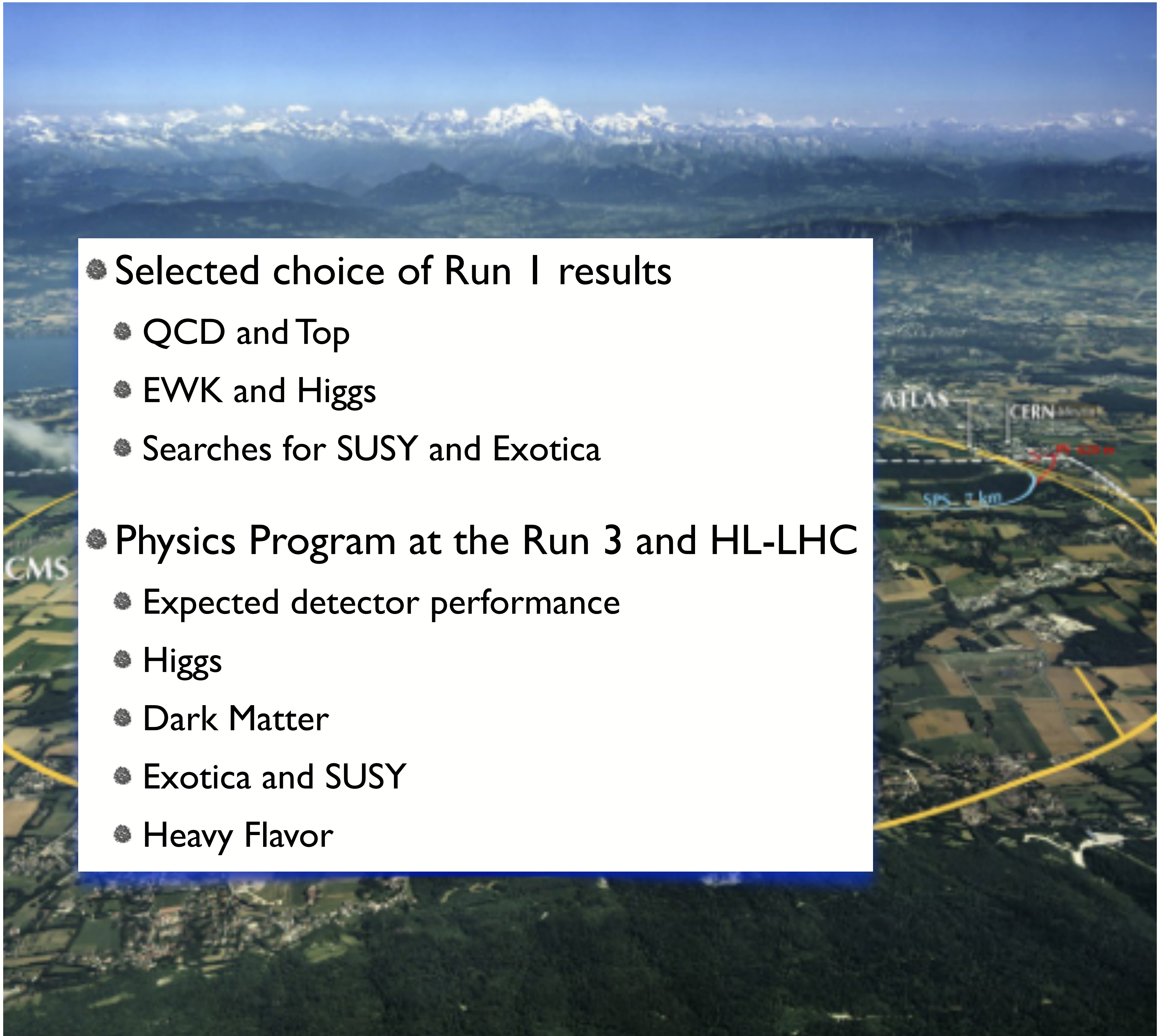


Exploring the Physics Frontier with Circular Colliders

January 26th - February 1st, 2015
Winter Aspen Meeting

Anadi Canepa | TRIUMF

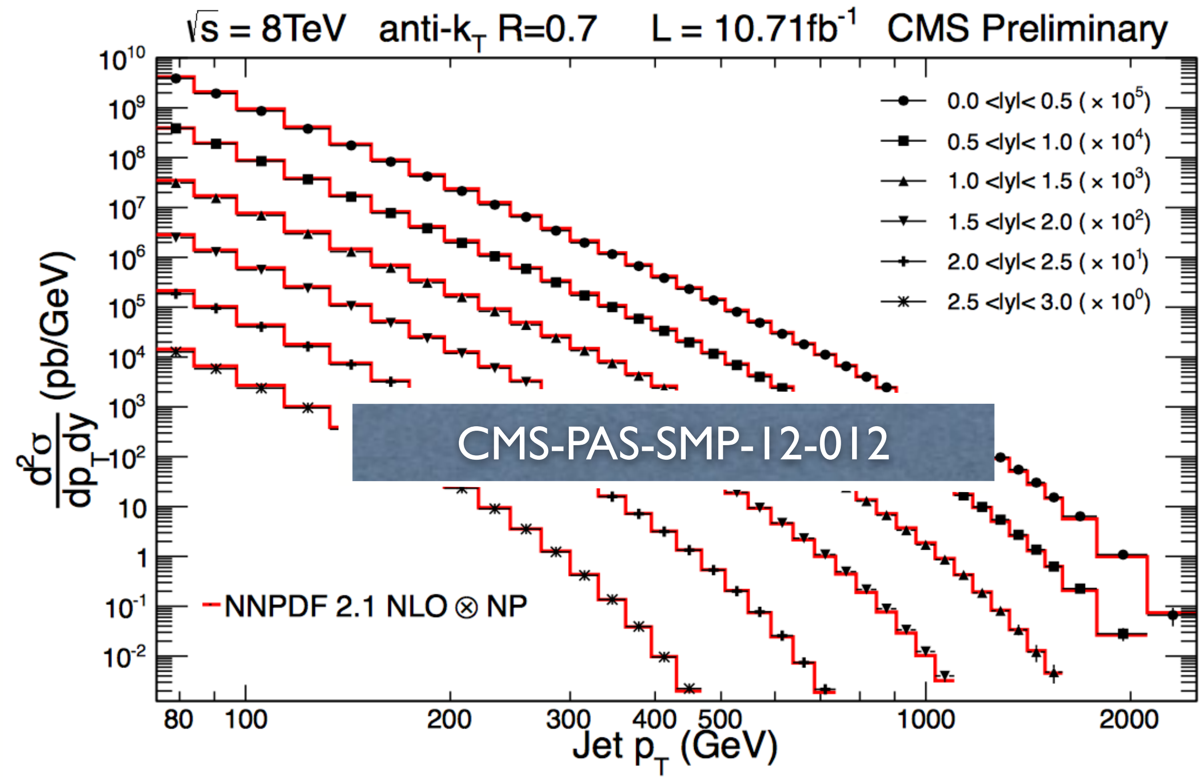
Talk Outline



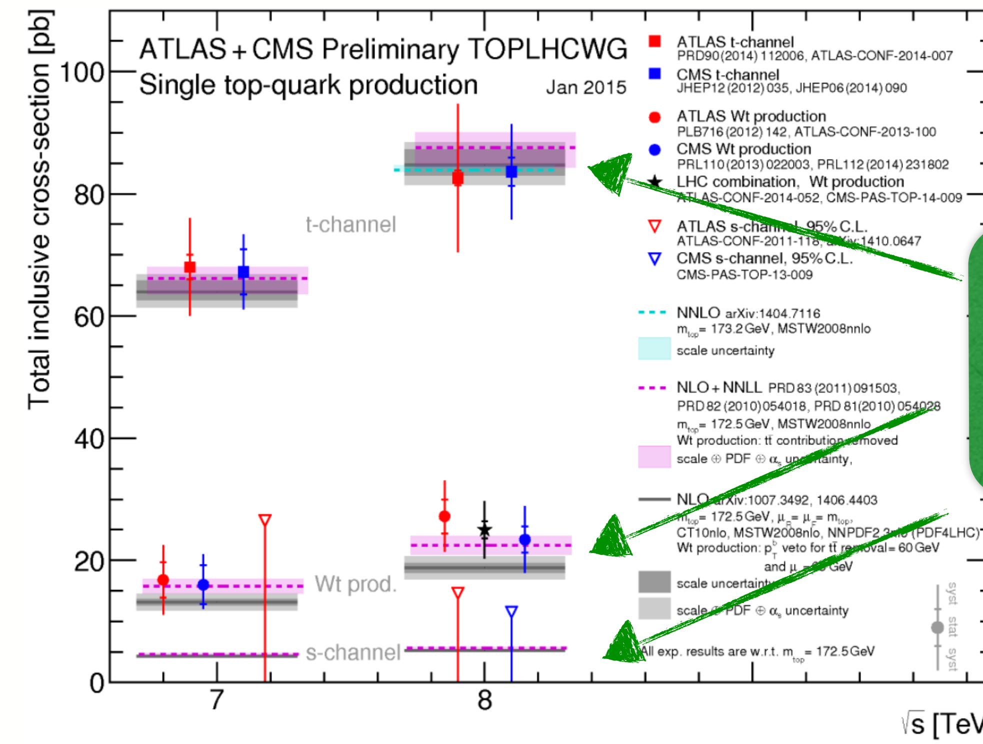
- Selected choice of Run 1 results
  - QCD and Top
  - EWK and Higgs
  - Searches for SUSY and Exotica
- Physics Program at the Run 3 and HL-LHC
  - Expected detector performance
  - Higgs
  - Dark Matter
  - Exotica and SUSY
  - Heavy Flavor

Highlights of QCD and Top Physics at Run I

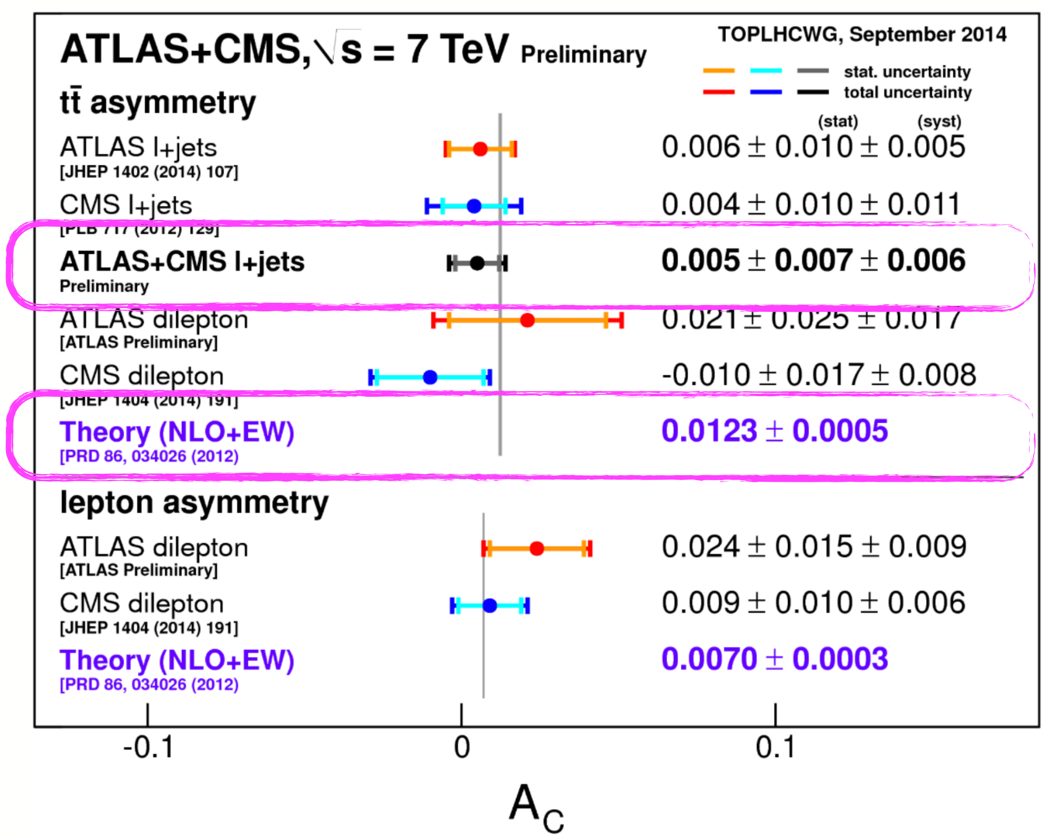
- Agreement with the NLO pQCD predictions over several orders of magnitude

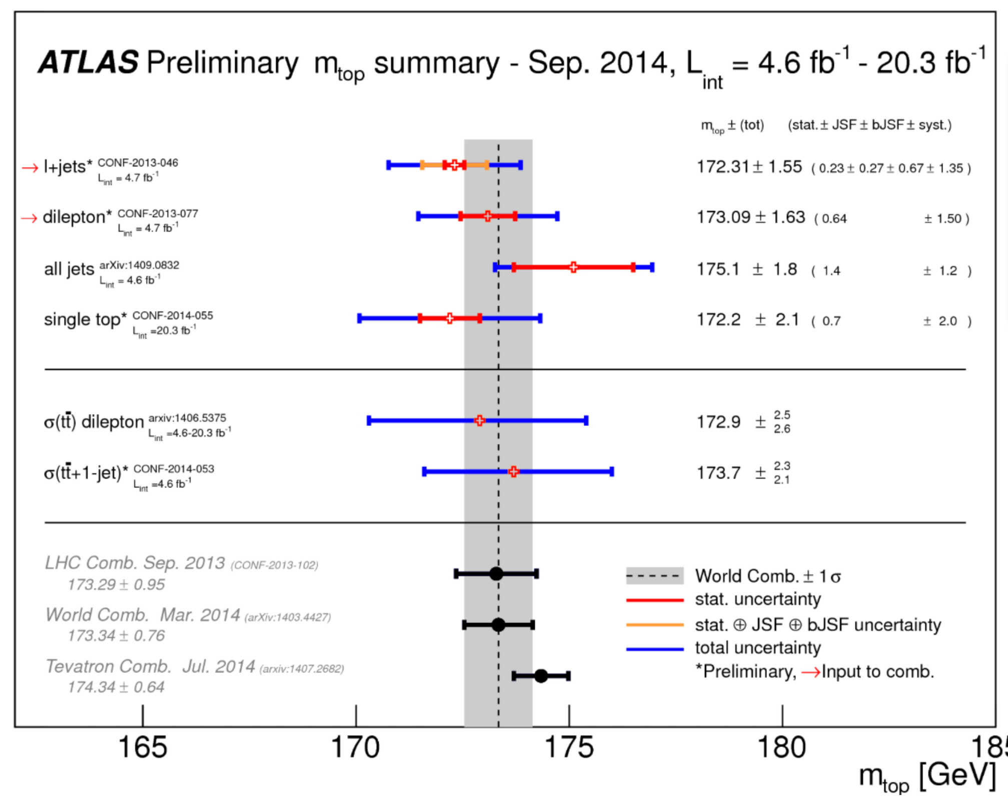


- The LHC is a top factory
  - extensive program of precision measurements



t-channel
Wt-channel
s-channel





World Combination
173.34±0.76 GeV
(0.4%)

CMS update:

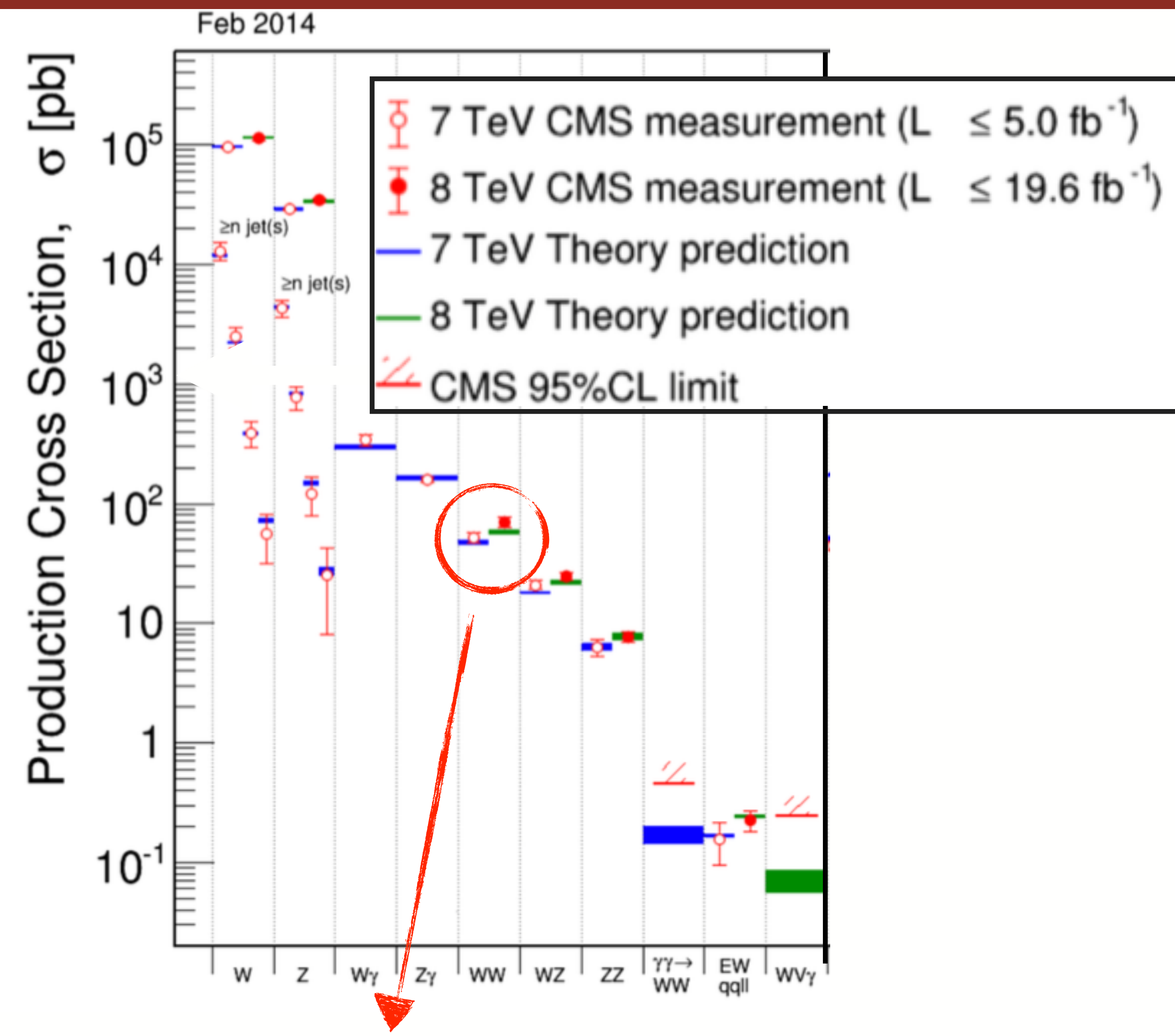
(September14)

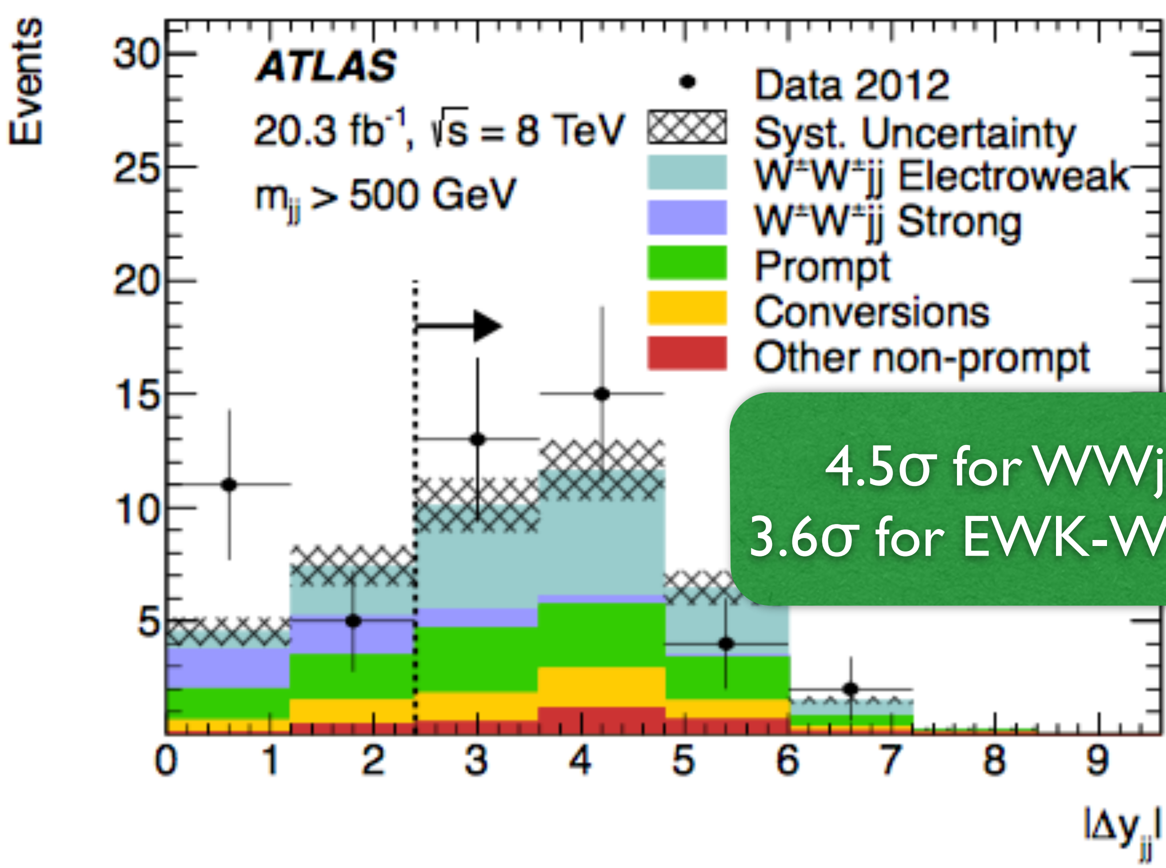
172.38±0.10±0.65 GeV

Highlights of EWK Physics at Run 1

- Measurements agree with the SM predictions
  - single boson for tune modeling and input to proton structure
  - diboson to test EWK predictions and aTGC
- Evidence of VBS and EWK-only VBS
  - final state with two same sign Ws and jets

1410.6315, CMS   1405.6241, ATLAS





4.5σ for WWjj
3.6σ for EWK-WWjj

- <u>Measurement of WW cross section</u>
  - ATLAS (CONF-2014-033)
    $71.4^{+1.2}_{-1.2}$ (stat) $^{+5.0}_{-4.4}$ (syst) $^{+2.2}_{-2.1}$ (lumi)~pb
  - CMS (Phys. Lett. B. 721 2013 290)
    $69.9 \pm 2.8\,(\text{stat.}) \pm 5.6\,(\text{syst.}) \pm 3.1\,(\text{lum.})$ pb
  - (MCFM 58.7 + 3.0 - 2.7 pb)

Highlights of Higgs Physics at Run 1

From a "Higgs-like" particle to "a Higgs" boson:
entering the precision era of Higgs physics at the LHC
Spin/parity 0+ favored and couplings measured in 2012 compatible with the SM

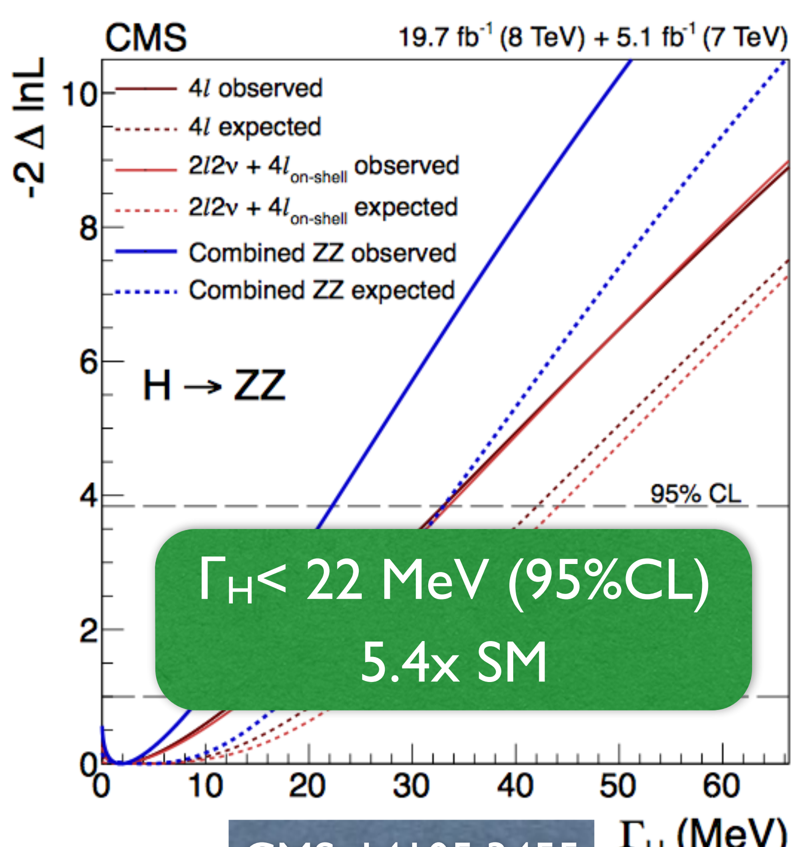
- **Comprehensive program including measurements of cross-section and BR in a variety of modes**
- **Measurements of the mass**
  - $m_H = 125.36 \pm 0.37 \pm 0.18$ GeV — 1406.3827, ATLAS
  - $m_H = 125.02\,^{+0.26}_{-0.27}\,\text{(stat)}\,^{+0.14}_{-0.15}\,\text{(syst)}$ GeV — 1412.8662, CMS
- **Measurement of the width**
  - using its relative on-shell and off-shell production and decay rates to a pair of Z

$$\sigma^{\text{on-shell}}_{gg\to H\to ZZ^*} \sim \frac{g^2_{ggH} g^2_{HZZ}}{m_H \Gamma_H}$$

$$\sigma^{\text{off-shell}}_{gg\to H^*\to ZZ} \sim \frac{g^2_{ggH} g^2_{HZZ}}{(2m_Z)^2}$$

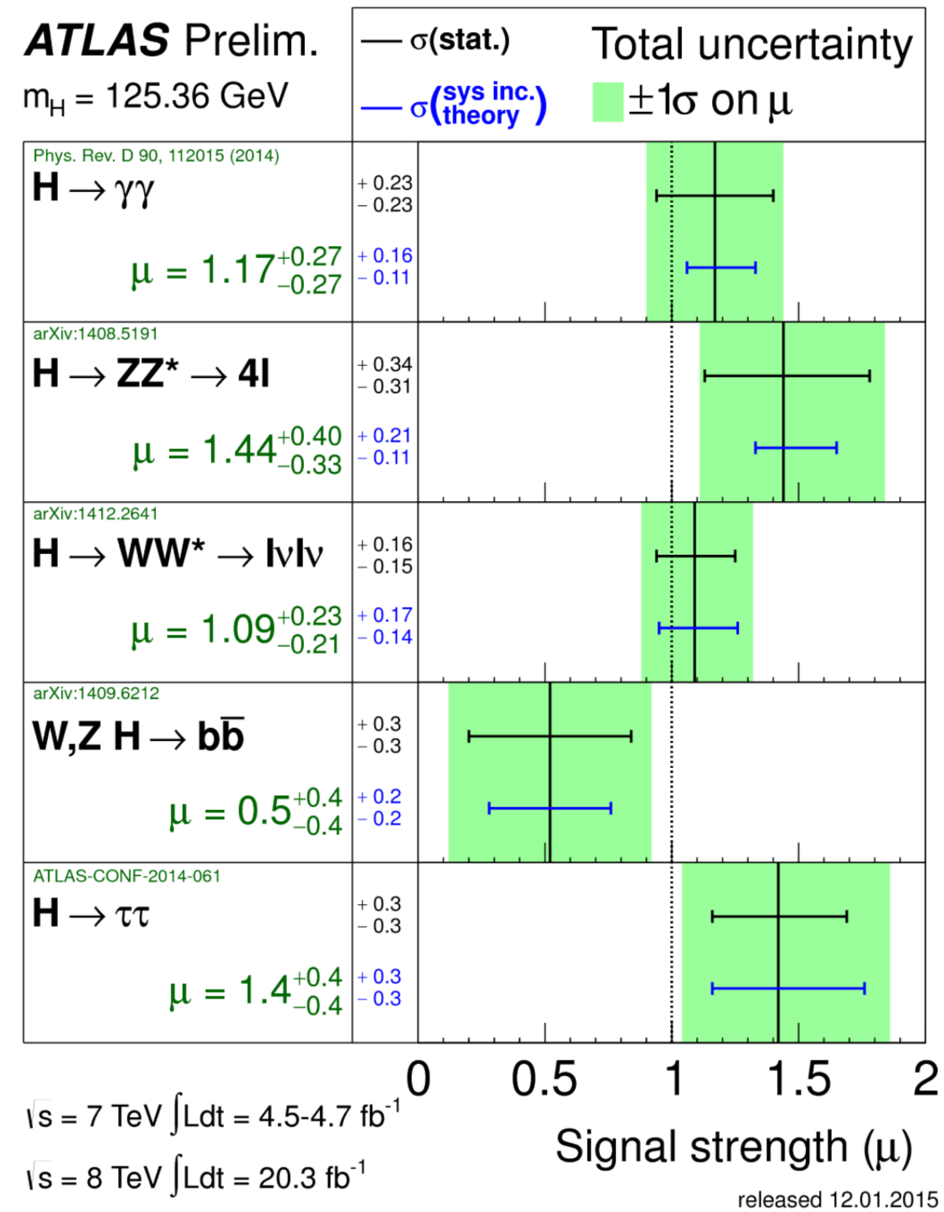
$4.8 < \Gamma_H/\Gamma^{SM}_H < 7.7$ (95%CL)

ATLAS-CONF-2014-042



$\Gamma_H < 22$ MeV (95%CL)
5.4x SM

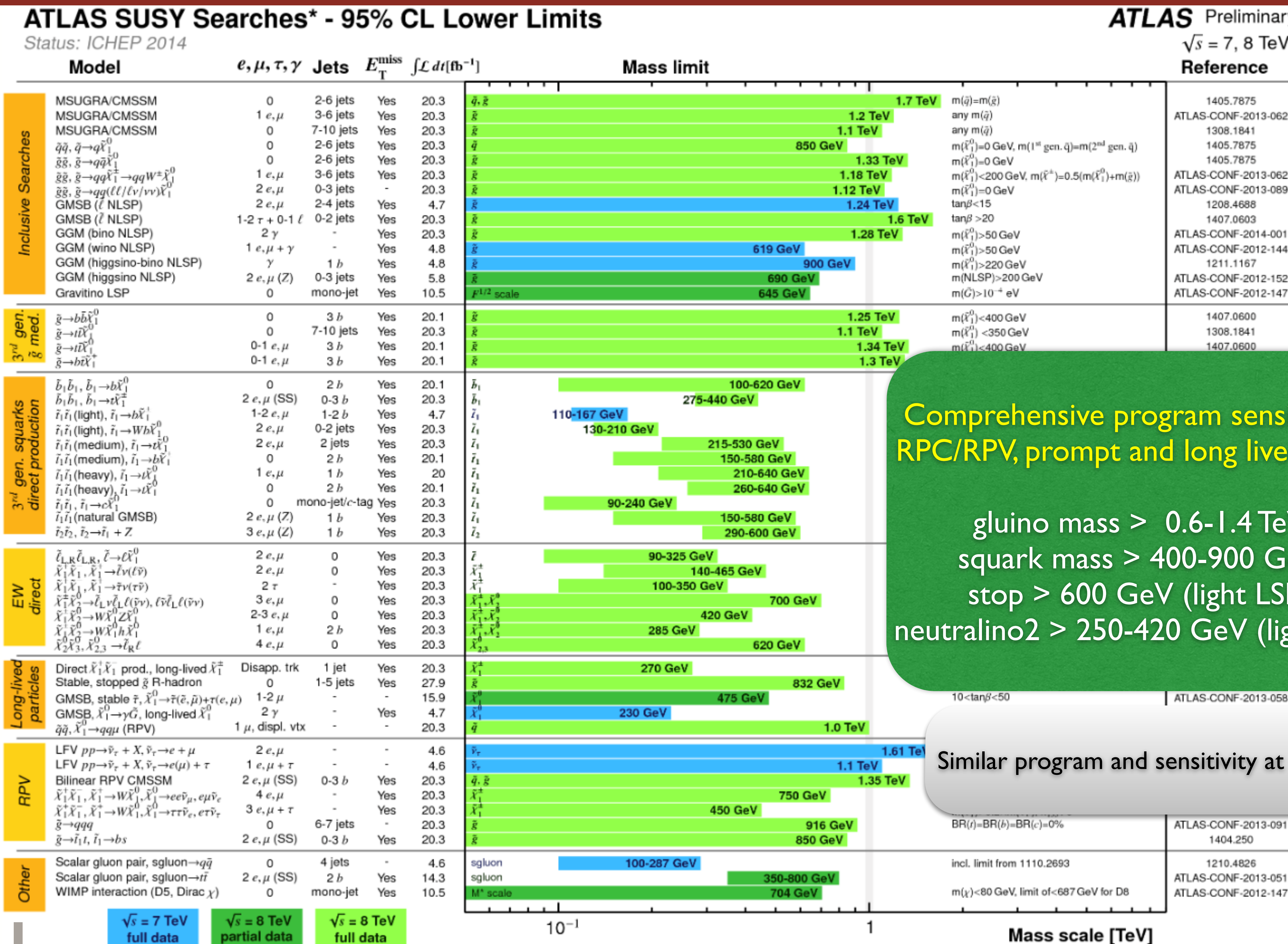
CMS, 14105.3455



New H→ττ!
$\mu = 1.43\,^{+0.43}_{-0.37}$

1501.04943

SUSY at Run I

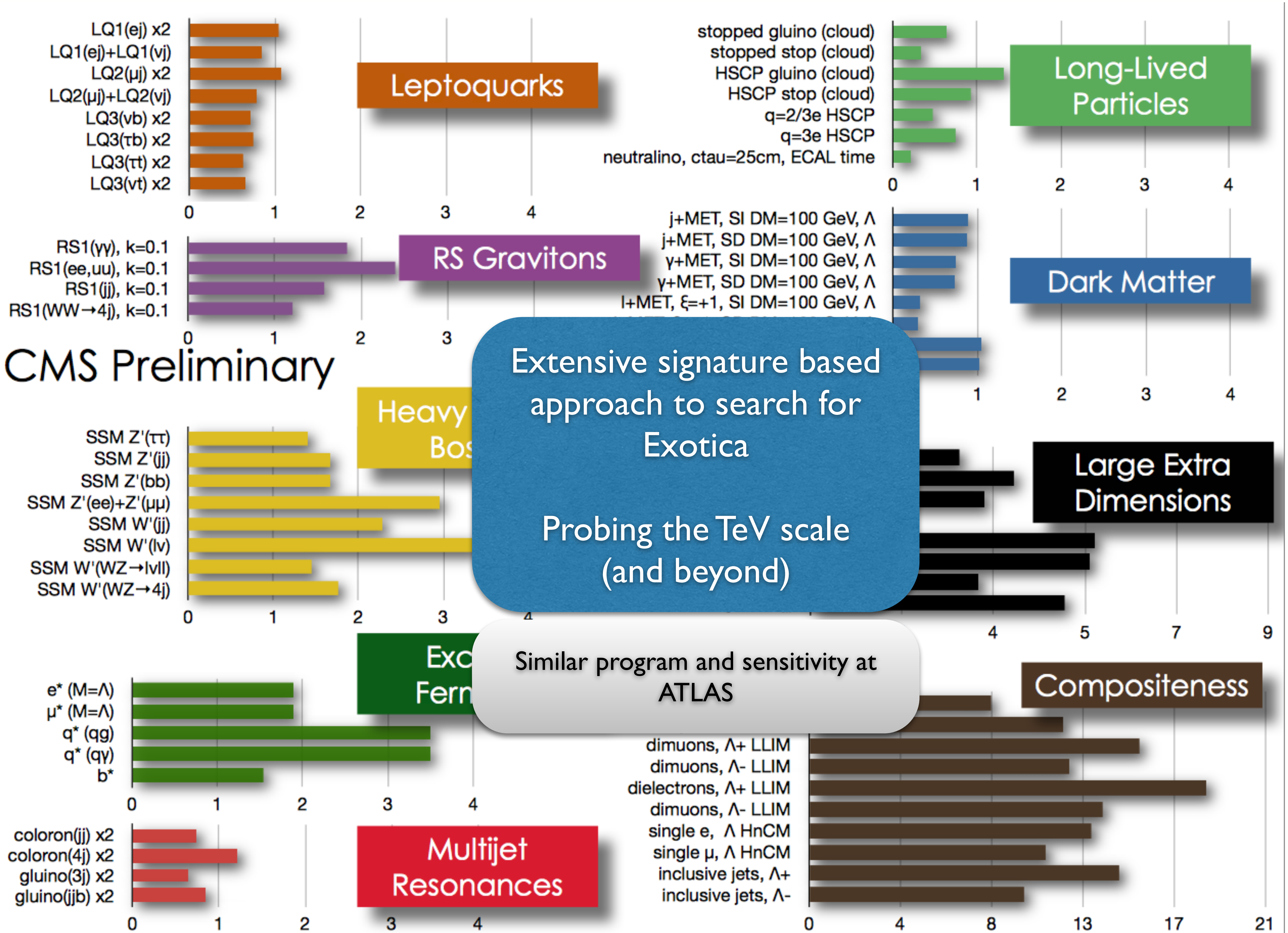


Comprehensive program sensitive to RPC/RPV, prompt and long lived SUSY

gluino mass > 0.6-1.4 TeV
squark mass > 400-900 GeV
stop > 600 GeV (light LSP)
neutralino2 > 250-420 GeV (light LSP)

Similar program and sensitivity at CMS

Exotics at Run I

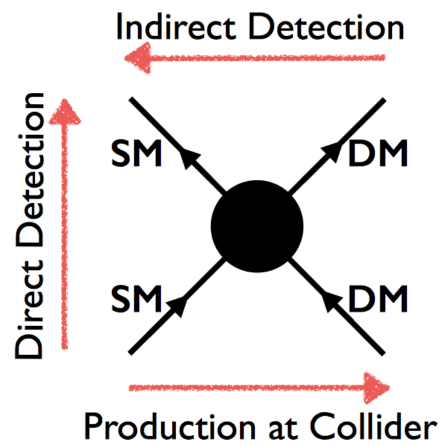


Extensive signature based approach to search for Exotica

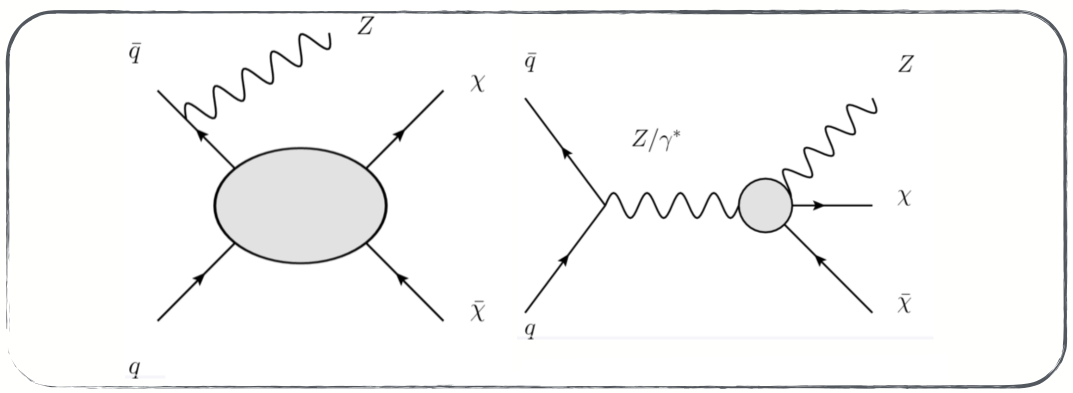
Probing the TeV scale (and beyond)

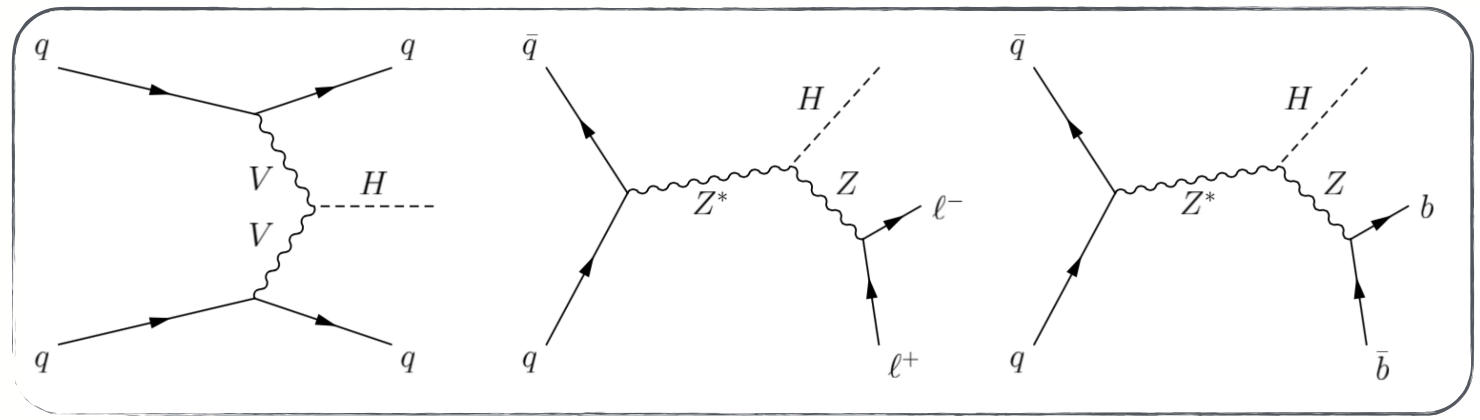
Similar program and sensitivity at ATLAS

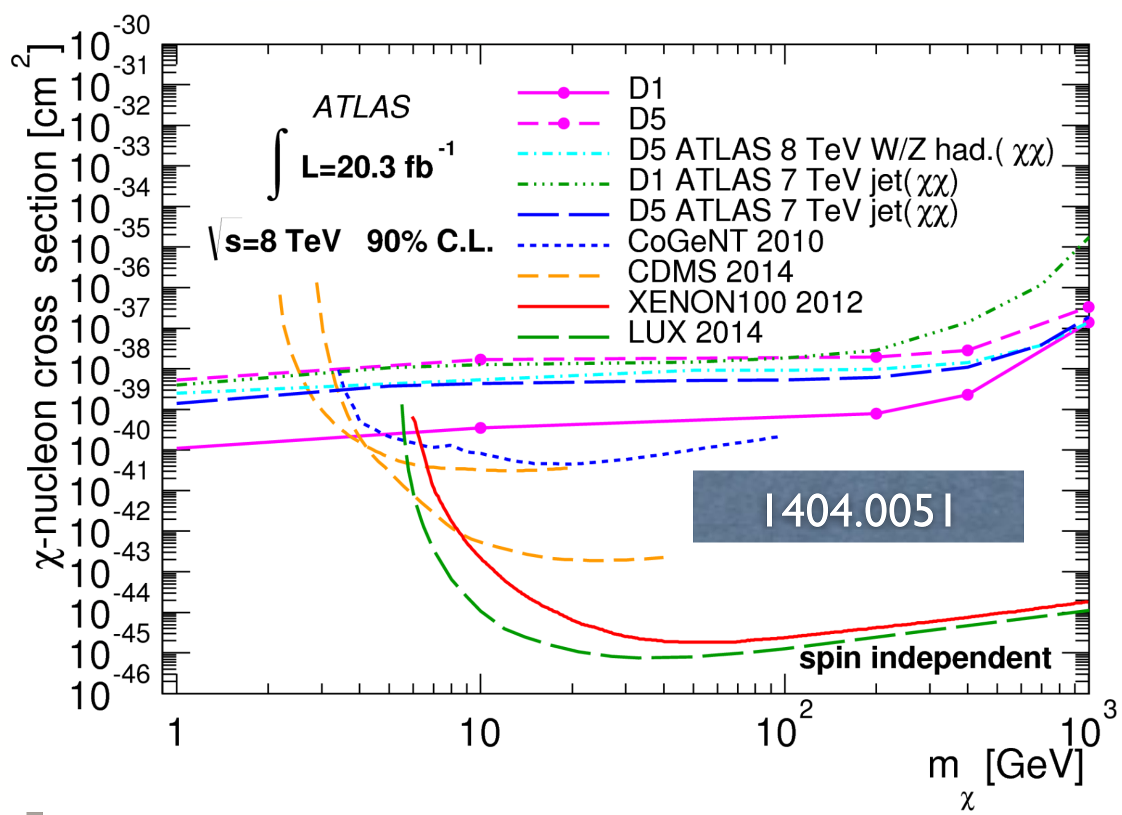
Dark Matter Search in Run 1: Highlights

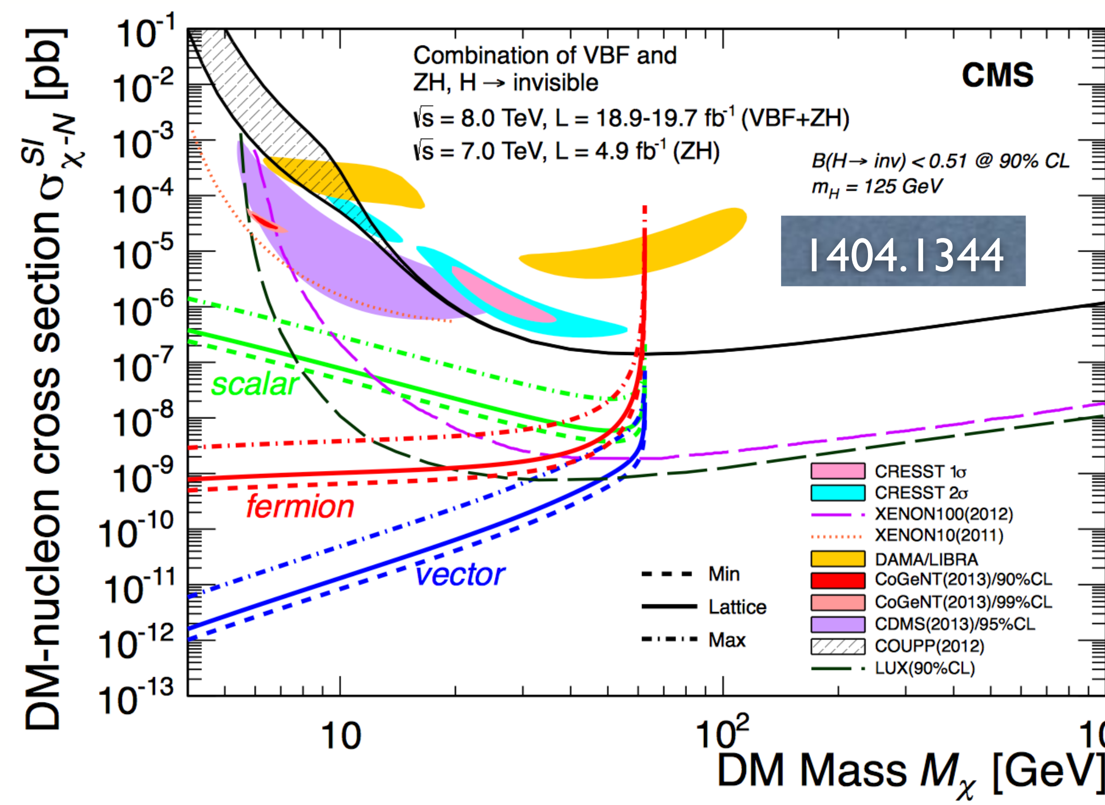


- Mono-X (X=jet, photon, W, Z, top) approach adopted to search for the production of Dark Matter at the LHC
  - results interpreted in EFT and simplified models
- Dark Matter also originating from Higgs decays

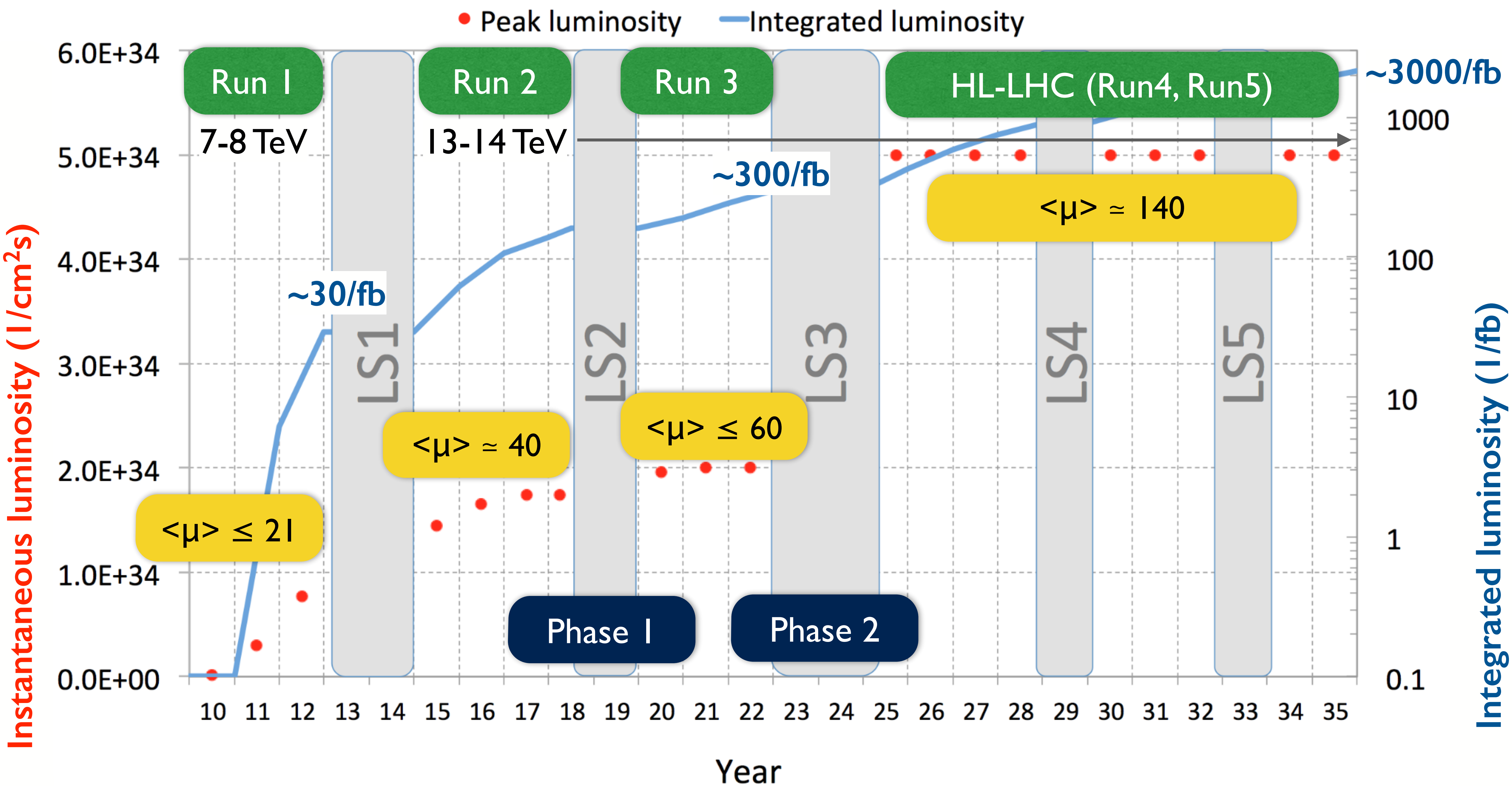




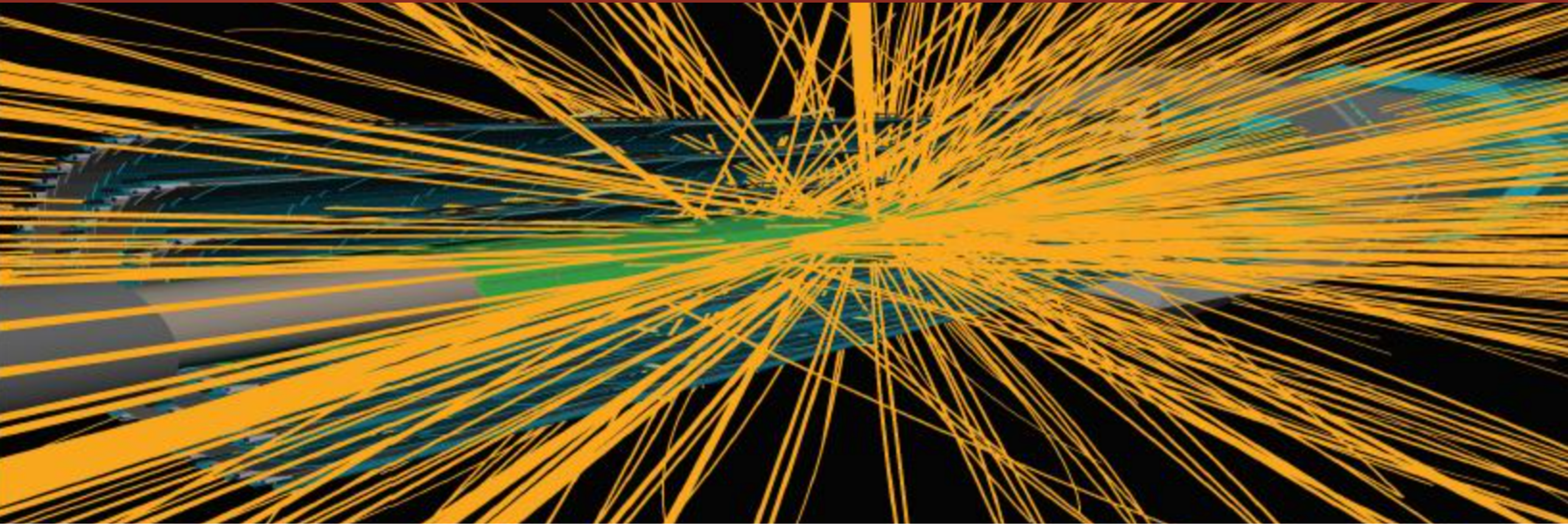




The Future


Peak luminosity
Integrated luminosity
Run 1
7-8 TeV
Run 2
13-14 TeV
Run 3
HL-LHC (Run4, Run5)
LS1
LS2
LS3
LS4
LS5
~30/fb
~300/fb
~3000/fb
<μ> ≤ 21
<μ> ≃ 40
<μ> ≤ 60
<μ> ≃ 140
Phase 1
Phase 2
6.0E+34
5.0E+34
4.0E+34
3.0E+34
2.0E+34
1.0E+34
0.0E+00
1000
100
10
1
0.1
10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
Year
Instantaneous luminosity (1/cm²s)
Integrated luminosity (1/fb)

The Physics Program at the HL-LHC



- **ATLAS Physics Prospects**
  - Performance assessed using full simulation
    - Run 2 detector and <μ>=50, 300/fb
    - New tracker (ITK) in Run 1 Calorimeter and Muon system, with varying <μ>
  - Physics reach (mostly) based on generator level studies with parameterized performance

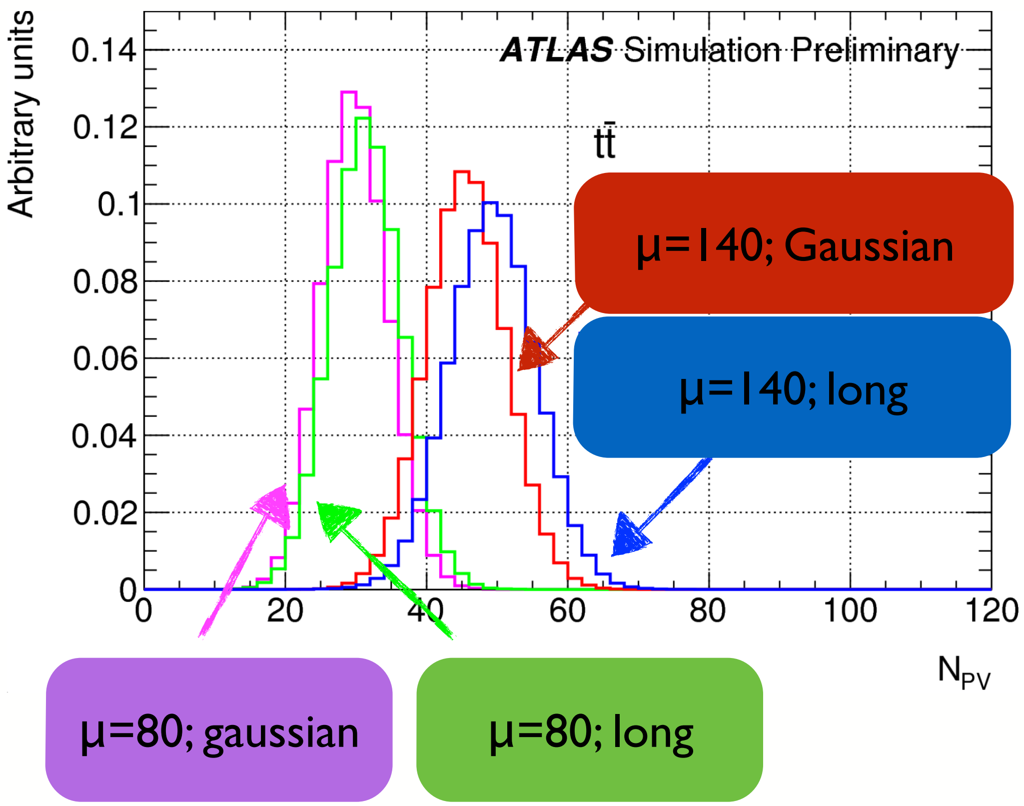
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/UpgradePhysicsStudies

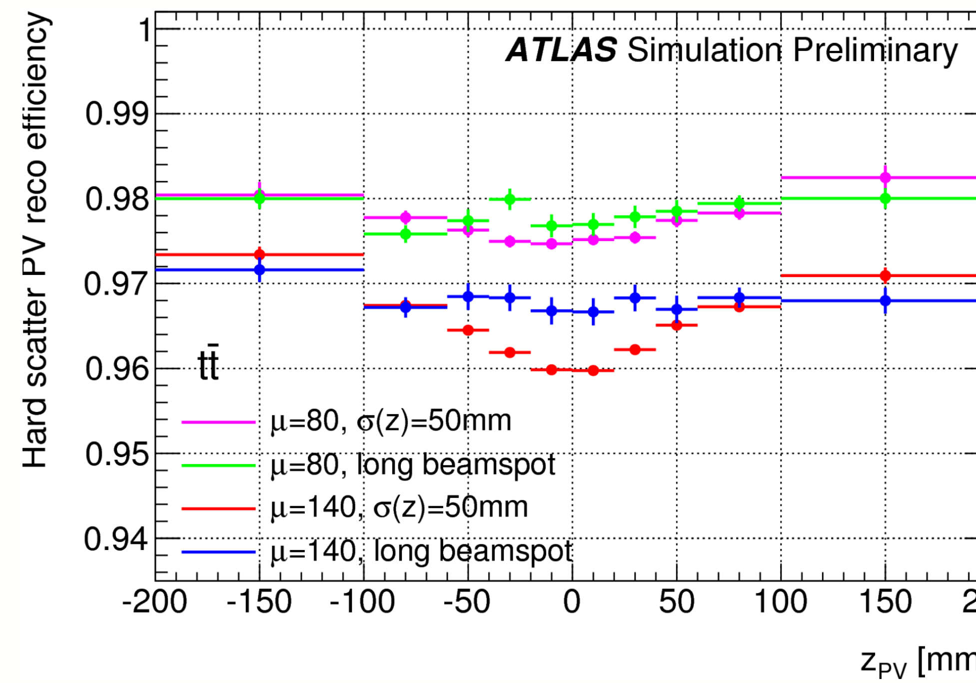
- **CMS Physics Prospects**
  - Performance assessed using full simulation
    - Phase 1 detector (no aging) and <μ>=50, 300/fb
    - Phase 1 detector (aging except pixel) and <μ>=140, 1000/fb
    - Phase 2 detector (aging except barrel calorimeter) and <μ>=140, 1000/fb
  - Physics reach (mostly) based on extrapolation under different assumptions on uncertainties or Delphes

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

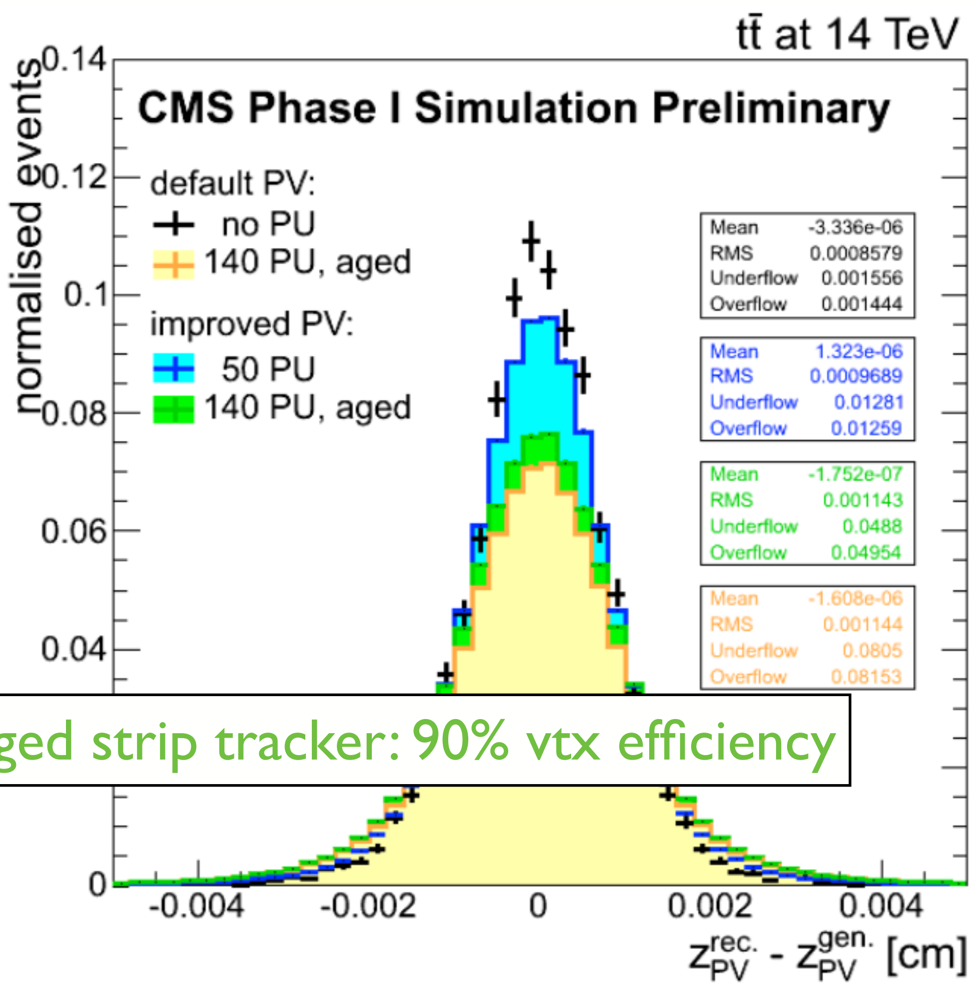
Vertexing

- Long-flat beam configuration might mitigate effects from pile-up

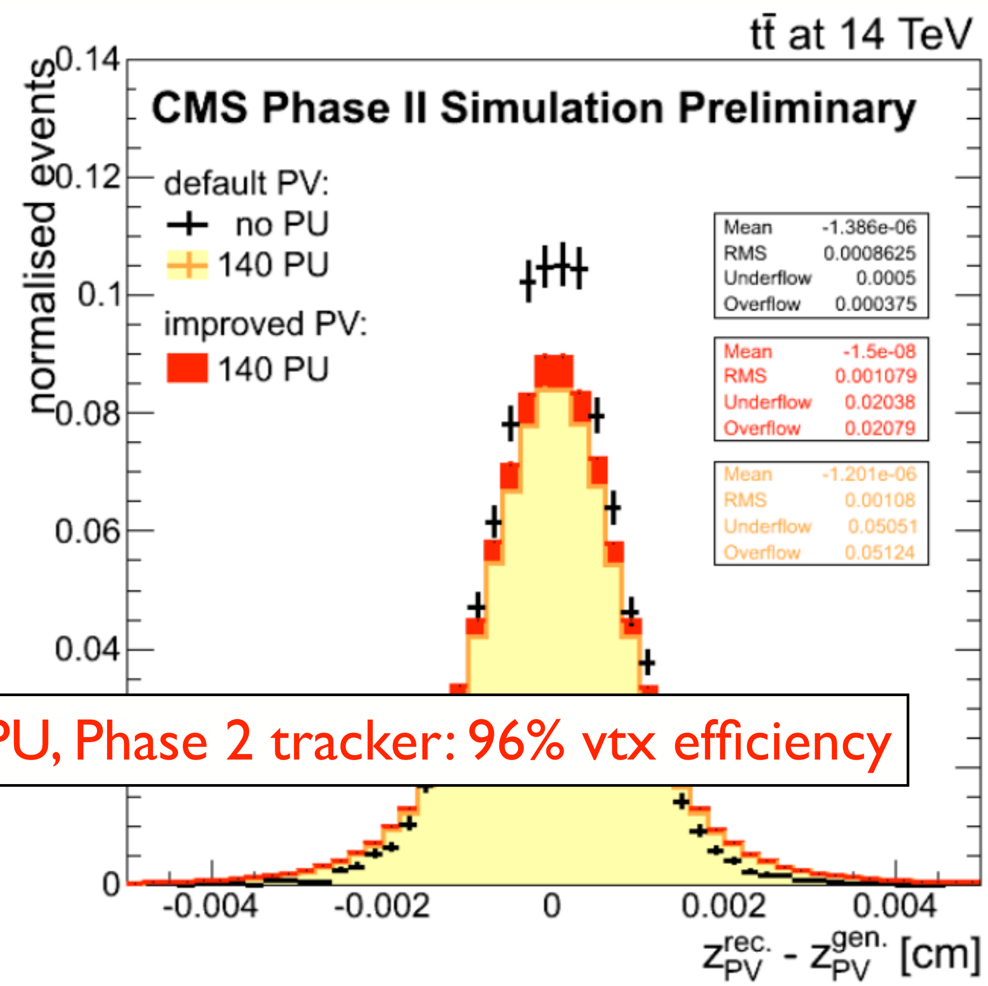




PLOT-UPGRADE-2014-003



140 PU, aged strip tracker: 90% vtx efficiency

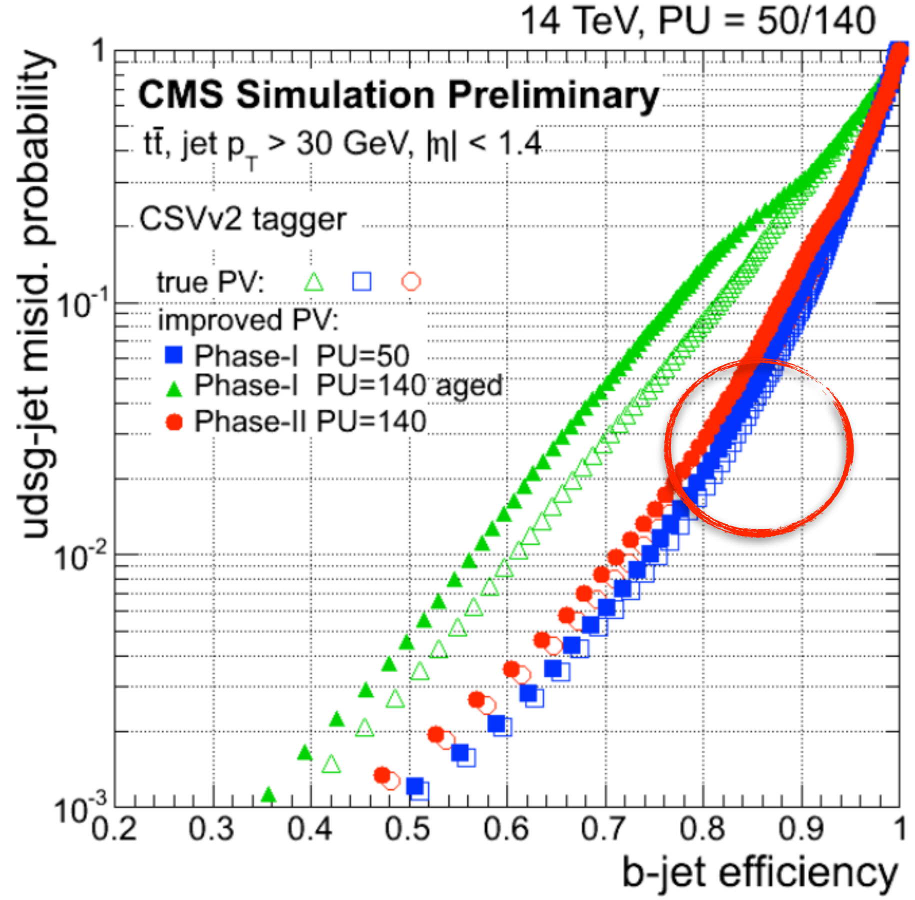


140 PU, Phase 2 tracker: 96% vtx efficiency

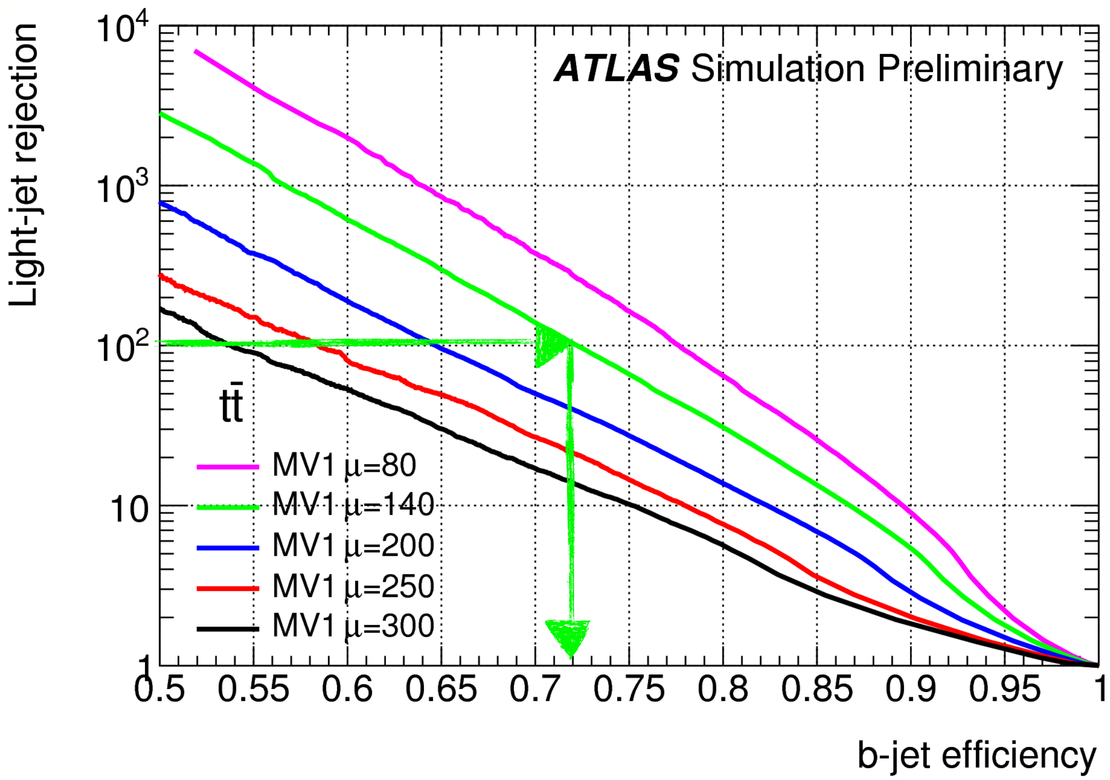
Physics Performance for 2nd ECFA workshop

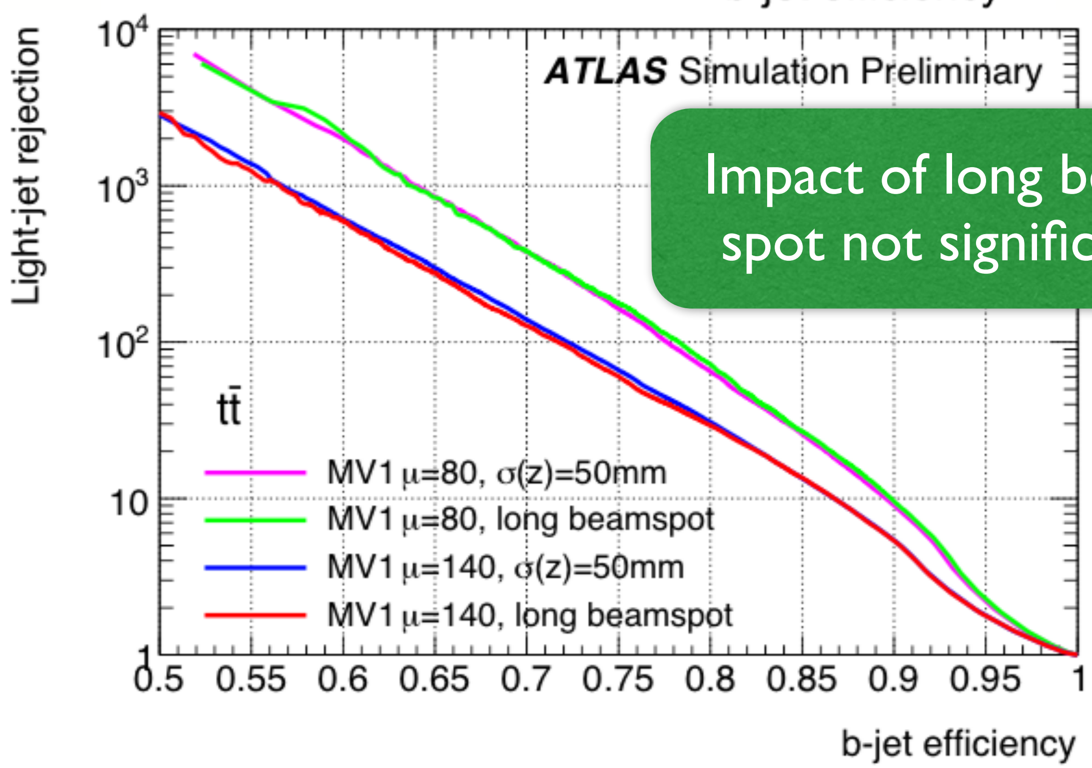
Tagging b-jets

- The capability of tagging b-jets critical to the success of the Higgs and BSM programs
- Detector aging and high pile-up lead to higher mis-identification probability for fixed b-tagging probability
- Phase 2 detectors recovering the b-tagging performance goals for Run 2



Physics Performance for 2nd ECFA workshop



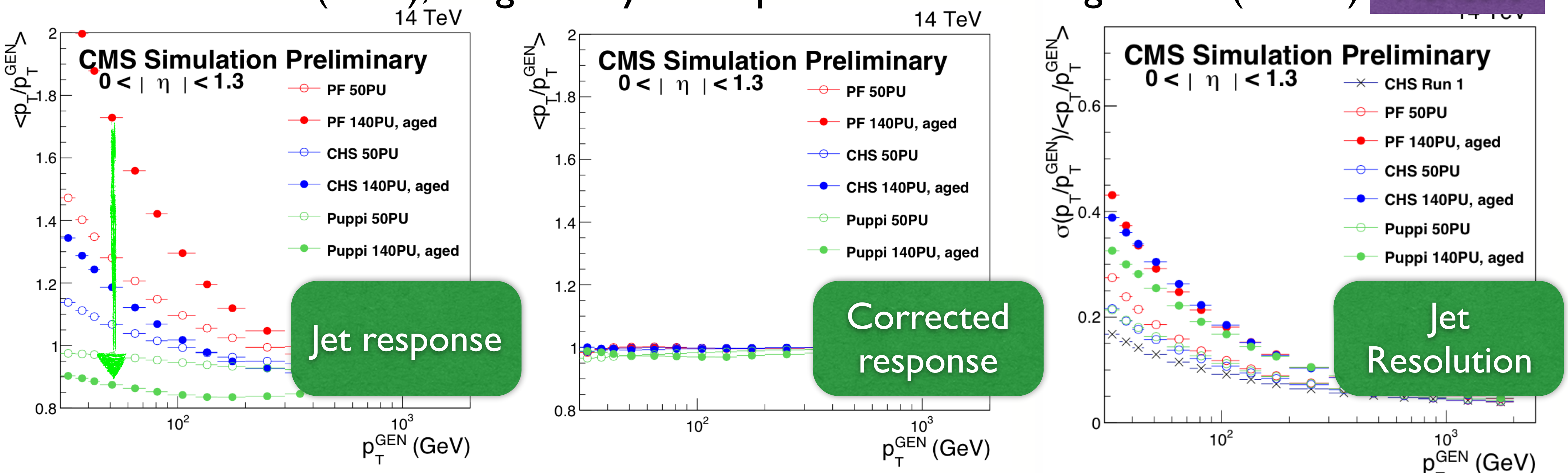


Impact of long beam spot not significant

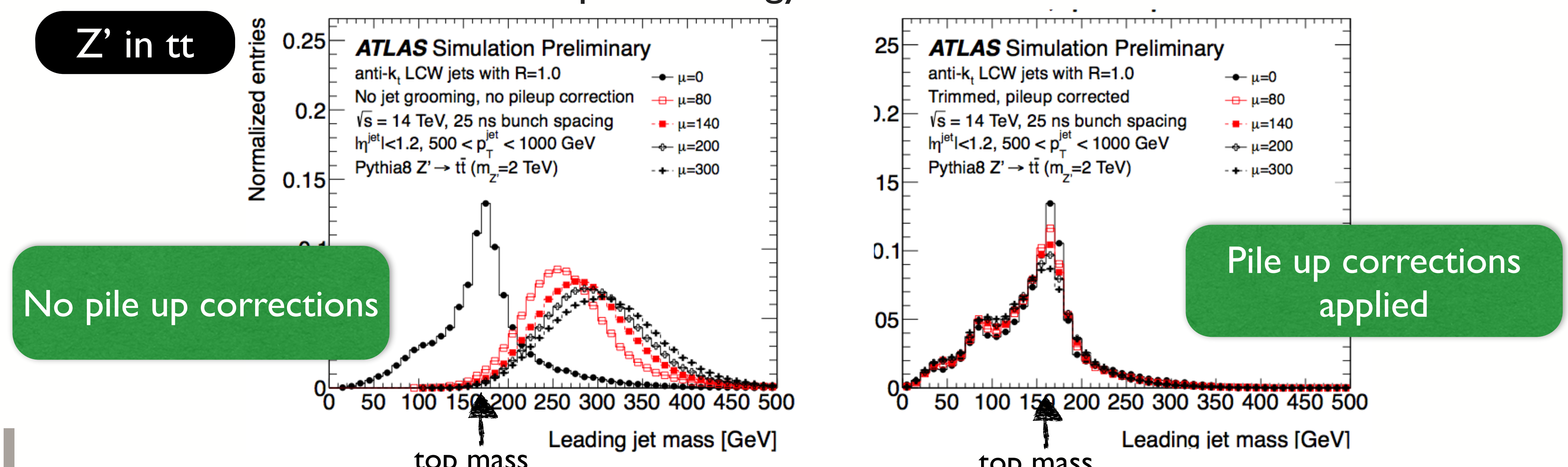
PLOT-UPGRADE-2014-003

Jet Reconstruction and Substructure

- In CMS, anti-kT jets reconstructed with R=0.4 from particle flow (PF), with additional rejection of hadrons from PU (CHS), weighted by "PileUp Per Particle Id" algorithm (PUPPI) 1407.6013



- In ATLAS, removal of low-pT R=0.3 subjects and pile-up corrections applied to hard-scatter jets with R=1.0 to restore scale and improve energy resolution

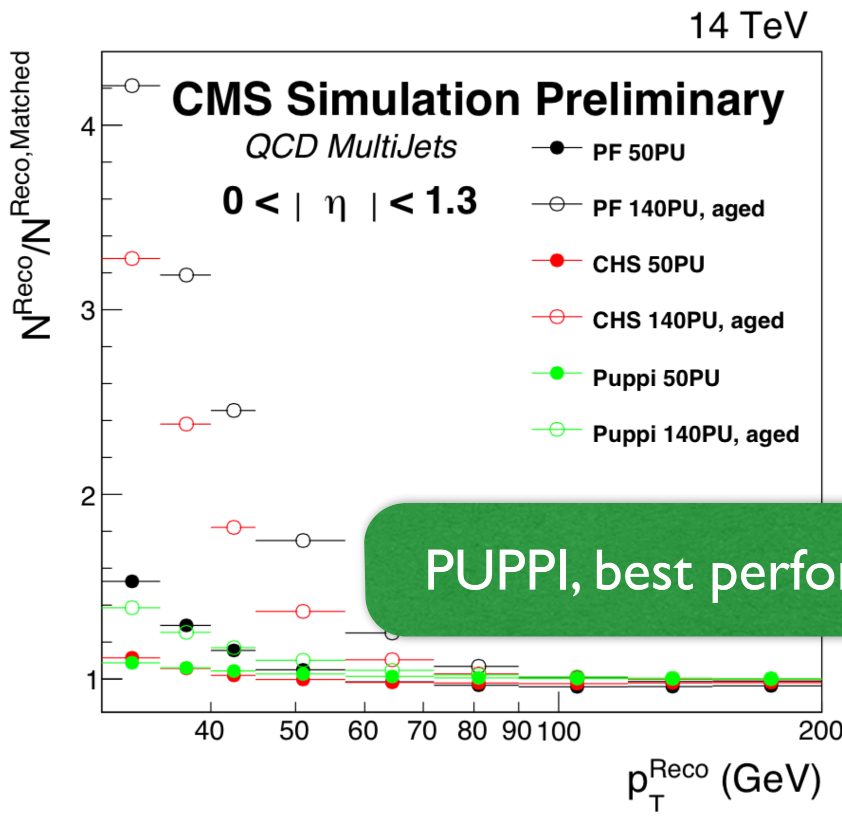


Physics Performance for 2nd ECFA workshop

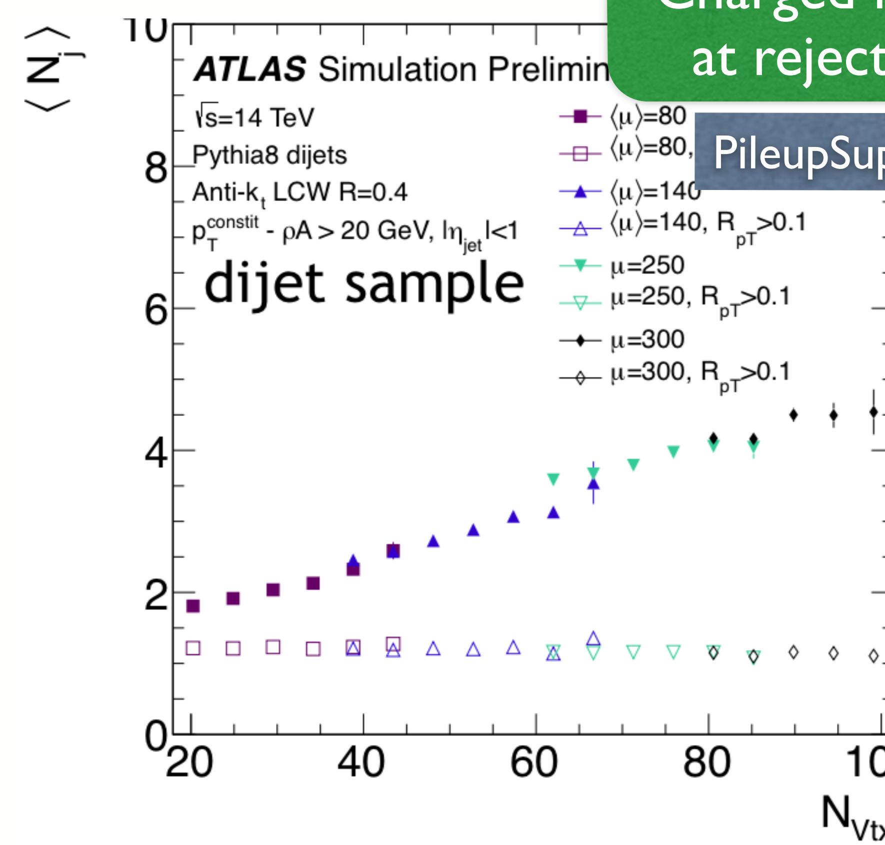
JetSubstructureECFA2014

Further Pile Up Mitigation

- Using track based information (ATLAS) and the PUPPI algorithm (CMS), pile up jets are discriminated from the hard scatter jets

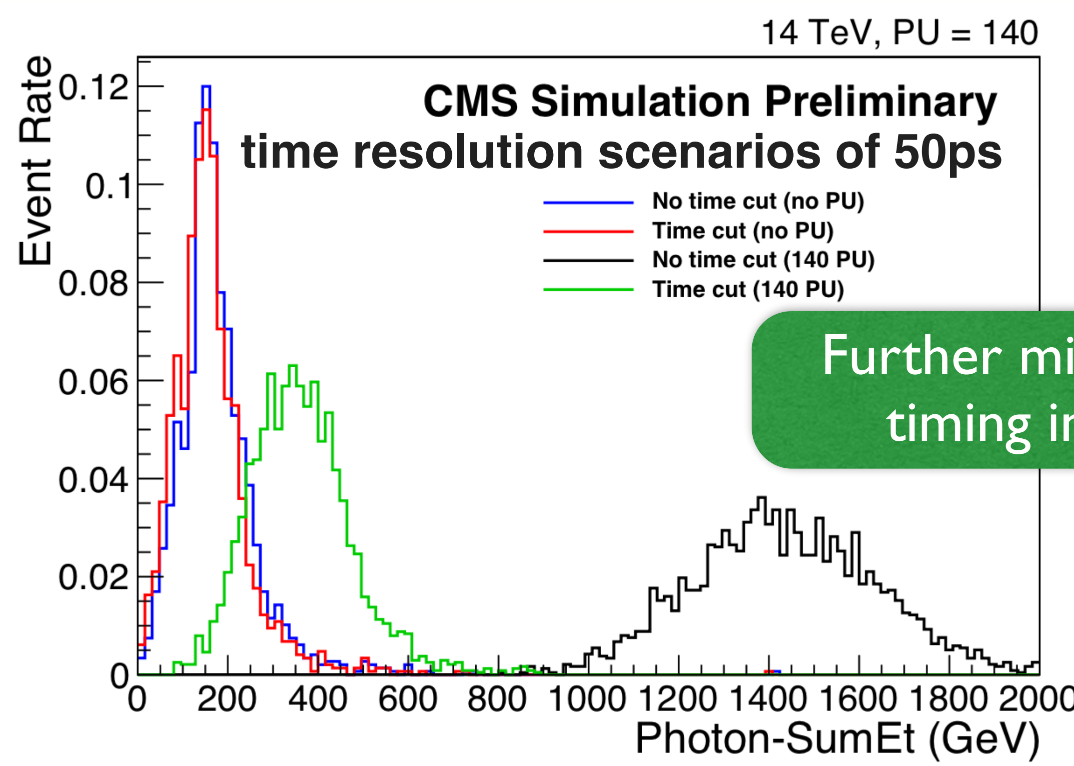


PUPPI, best performance



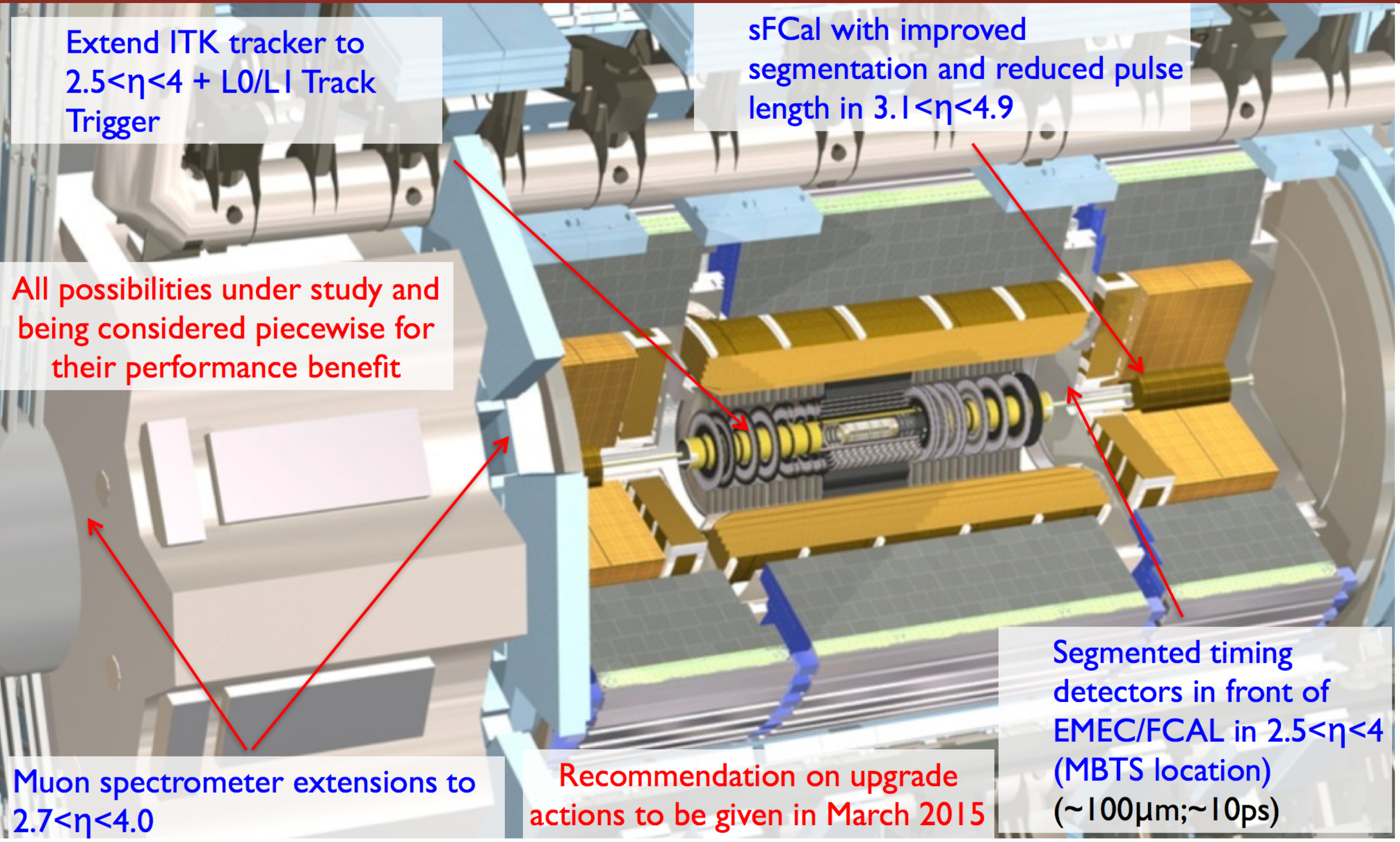
Charged fraction effective at rejecting pile up jets

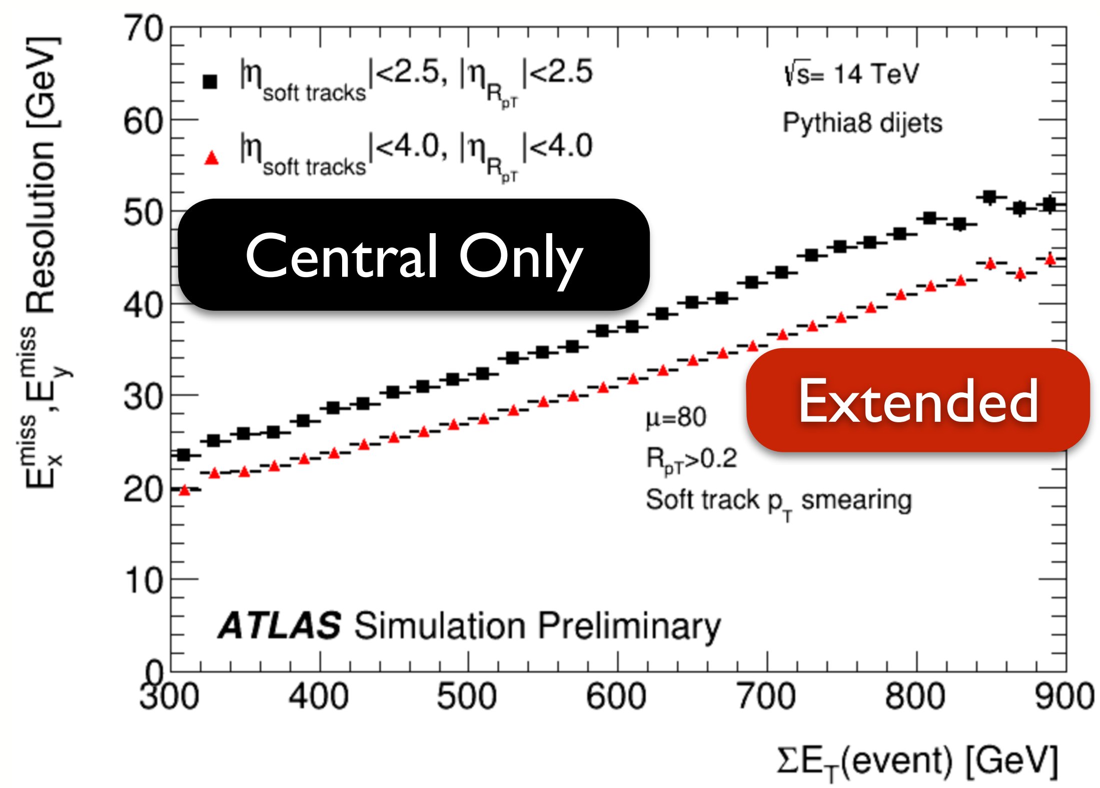
PileupSuppressionECFA2014



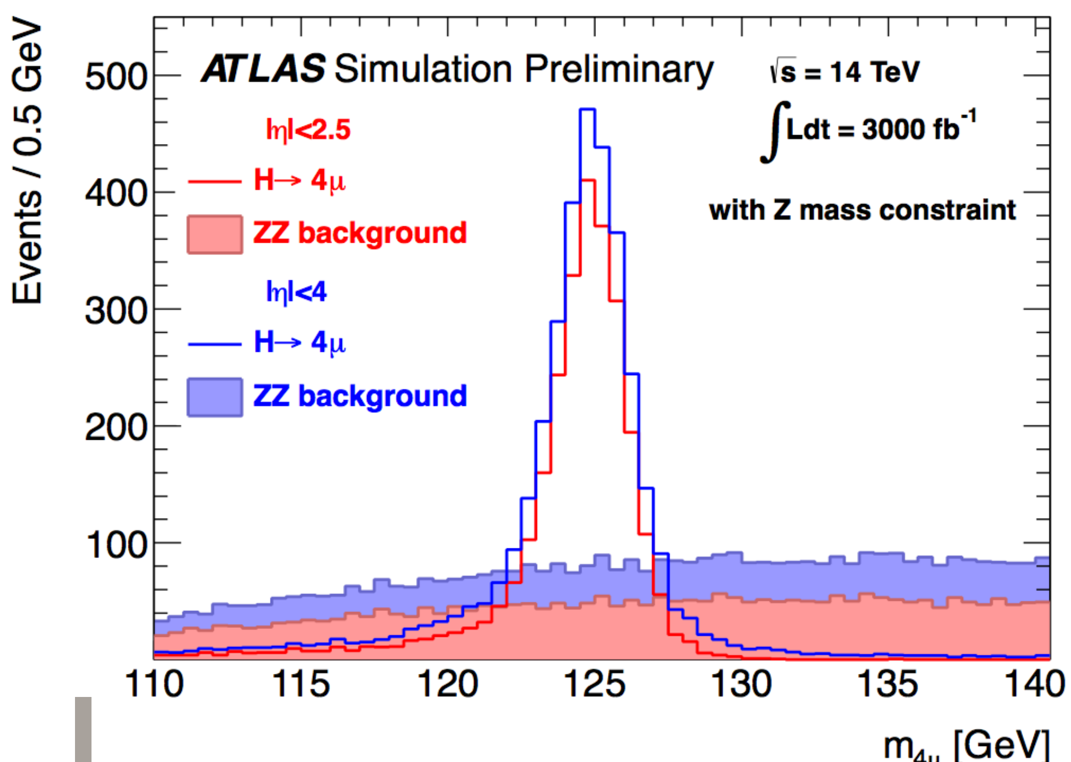
Further mitigation using timing information

Extension of ATLAS to large η



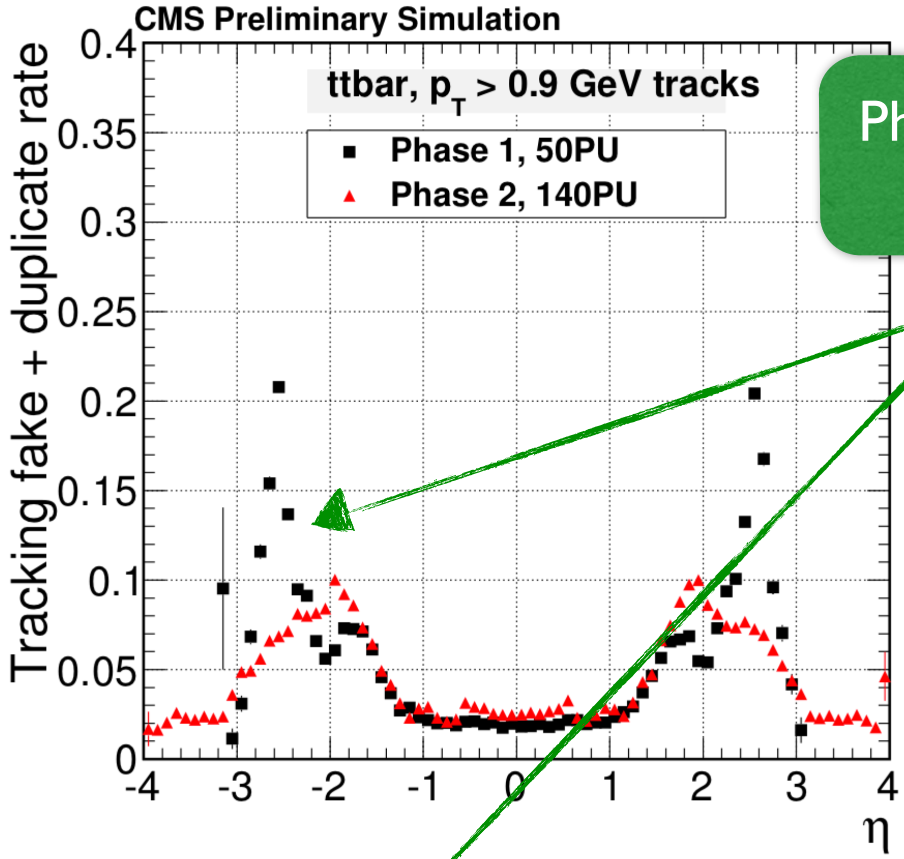


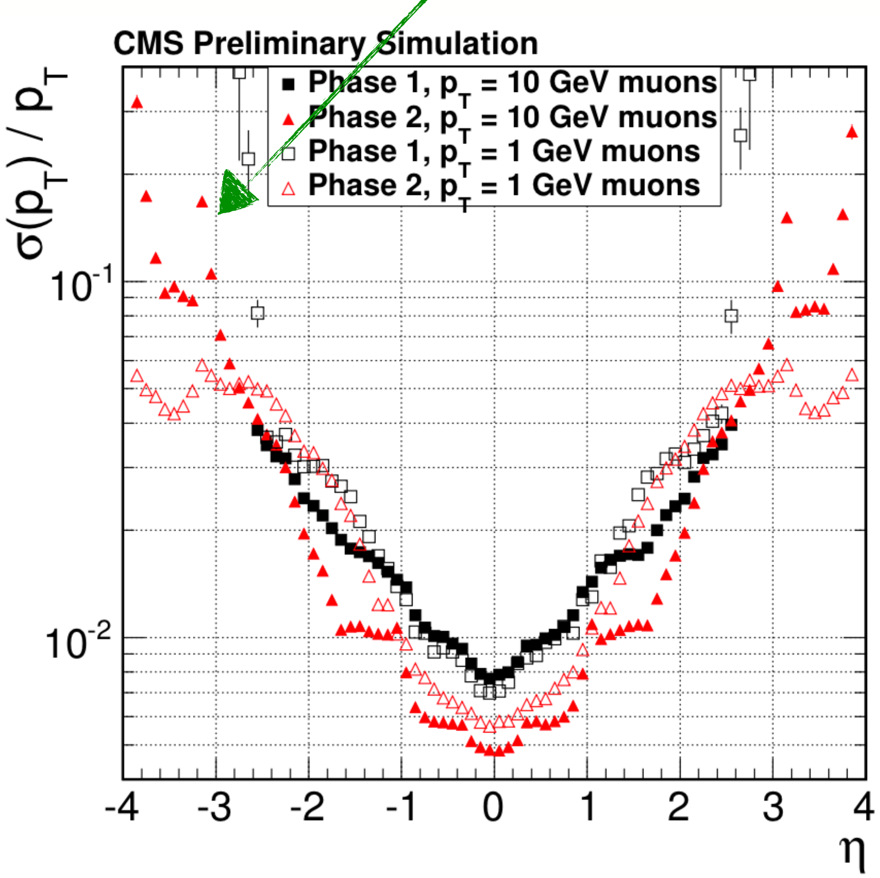
LargeEtaECFA2014



- The acceptance of H→ZZ in 4μ final states increases by ~35% assuming 100% muon reconstruction efficiency PLOT-UPGRADE-2014-002
- The expected signal strength uncertainty of the VBF $H\tau_l\tau_{had}$ signal improves by 3x if 90% pile up jet rejection probability ATL-PHYS-PUB-2014-018

Extension of CMS to large η





Phase 2 tracker performs as Run 2 in barrel and improves forward

New Tracker

- Radiation tolerant - high granularity - less material
- Tracks in hardware trigger (L1)
- Coverage up to η ~ 4

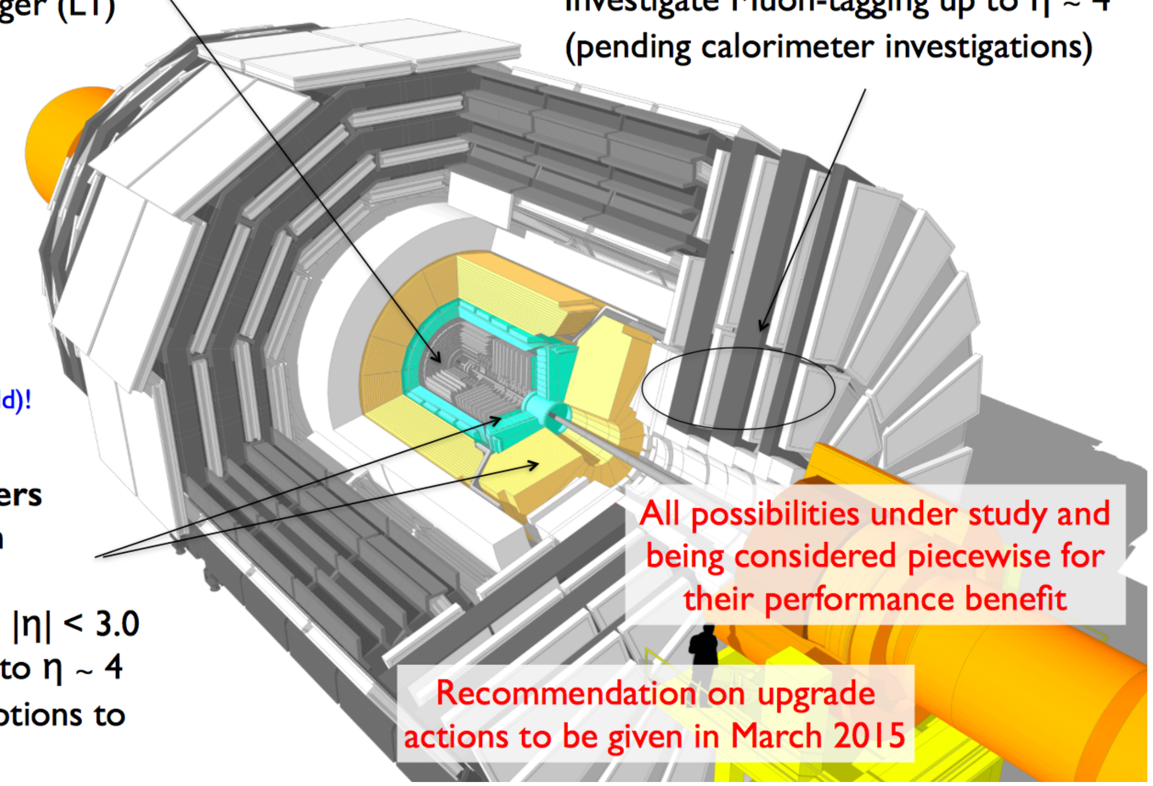
Muons

- Complete RPC coverage in forward region (new GEM/RPC technology)
- Nominal coverage to η ~ 2.4
- Investigate Muon-tagging up to η ~ 4 (pending calorimeter investigations)

See talks by:
Roger Rusack (Si HGCal),
David Petyt (Shashlik + HE Rebuild)!

New Endcap Calorimeters

- Radiation tolerant - high granularity
- Nominal coverage 1.5 < |η| < 3.0
- Investigate coverage up to η ~ 4
- Investigate fast timing options to augment Endcap



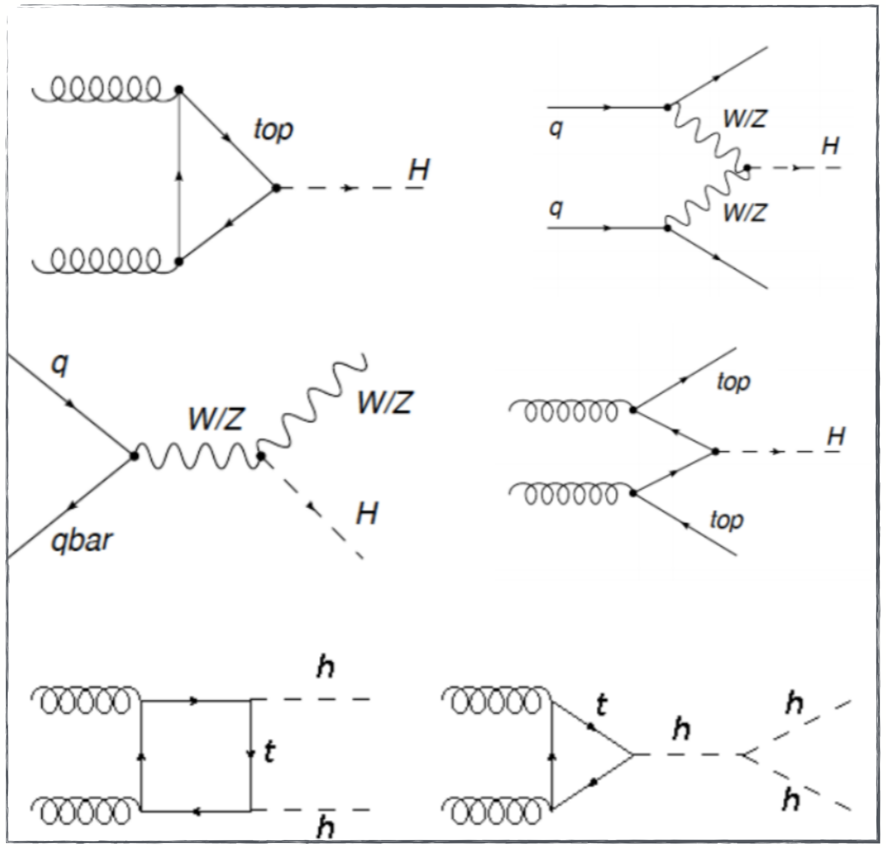
All possibilities under study and being considered piecewise for their performance benefit

Recommendation on upgrade actions to be given in March 2015

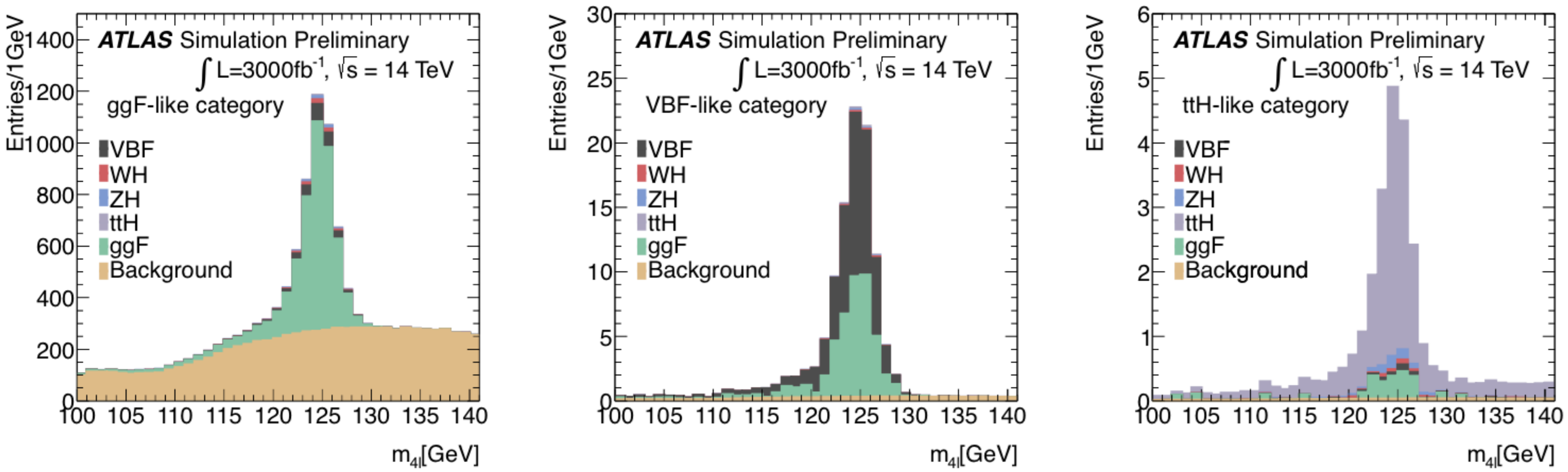
Physics Performance for 2nd ECFA workshop

The HL-LHC, a Higgs Factory

- Over 100 million SM Higgs bosons in total
  - access to rare decays like H in μμ and H in ZY; assessment of the top Yukawa coupling via ttH production
- **For example, H into ZZ measured with high purity in the various modes**
- Large sample allows to probe for CP structure of Higgs
  - Limits on the CP-even coupling g2 and CP-odd coupling g4



Category	True Origin					
	ggF	VBF	*WH*	*ZH*	*ttH*	Background
ttH-like	3.1 ±1.0	0.6 ±0.1	0.6 ±0.1	1.1 ±0.2	30 ±6	1.6 ±1.0
ZH-like	0.0	0.0	0.01 ±0.01	4.4 ±0.3	1.3 ±0.3	0.06 ±0.06
WH-like	22 ±7	6.6 ±0.4	25 ±2	4.4 ±0.3	8.8 ±1.8	13 ±0.8
VBF-like	41 ±14	54 ±6	0.7 ±0.1	0.4 ±0.1	1.0 ±0.2	4.2 ±1.5
ggF-like	3380 ±650	274 ±17	77 ±5	53 ±3	25 ±4	2110 ±50



ATL-PHYS-PUB-2013-014

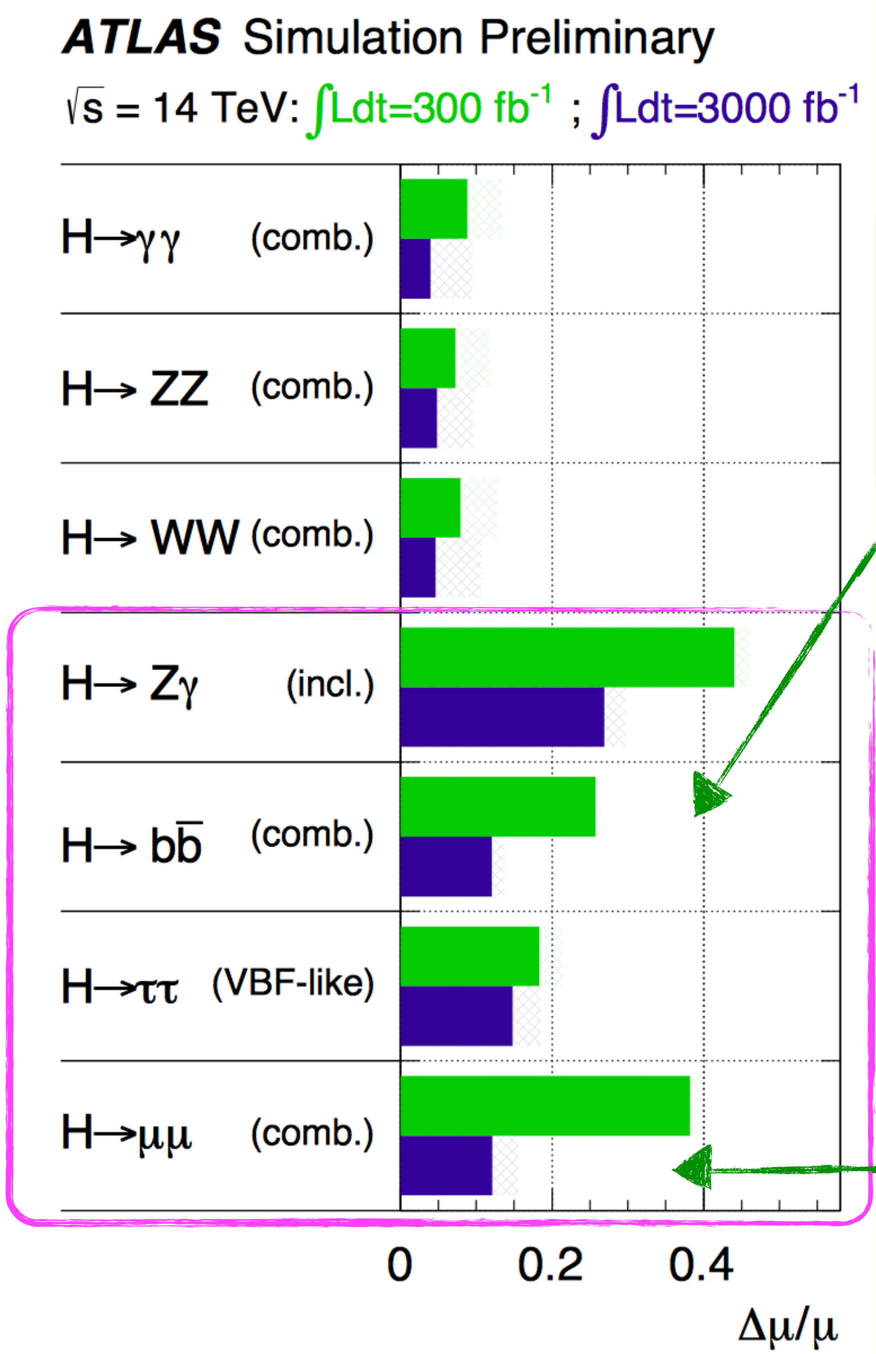
Luminosity	f_{g4}	f_{g2}
300 fb^{-1}	0.15	0.43
3000 fb^{-1}	0.037	0.20

ATL-PHYS-PUB-2013-013

Coupling Precision Measurement

- High precision on signal strength achieved by combining various production modes
- Measurements of the couplings is interpreted in the leading-order tree level *k* framework, e.g.:

$$\frac{\sigma \cdot B\,(gg \to H \to \gamma\gamma)}{\sigma_{SM}(gg \to H) \cdot B_{SM}(H \to \gamma\gamma)} = \frac{\kappa_g^2 \cdot \kappa_\gamma^2}{\kappa_H^2}$$

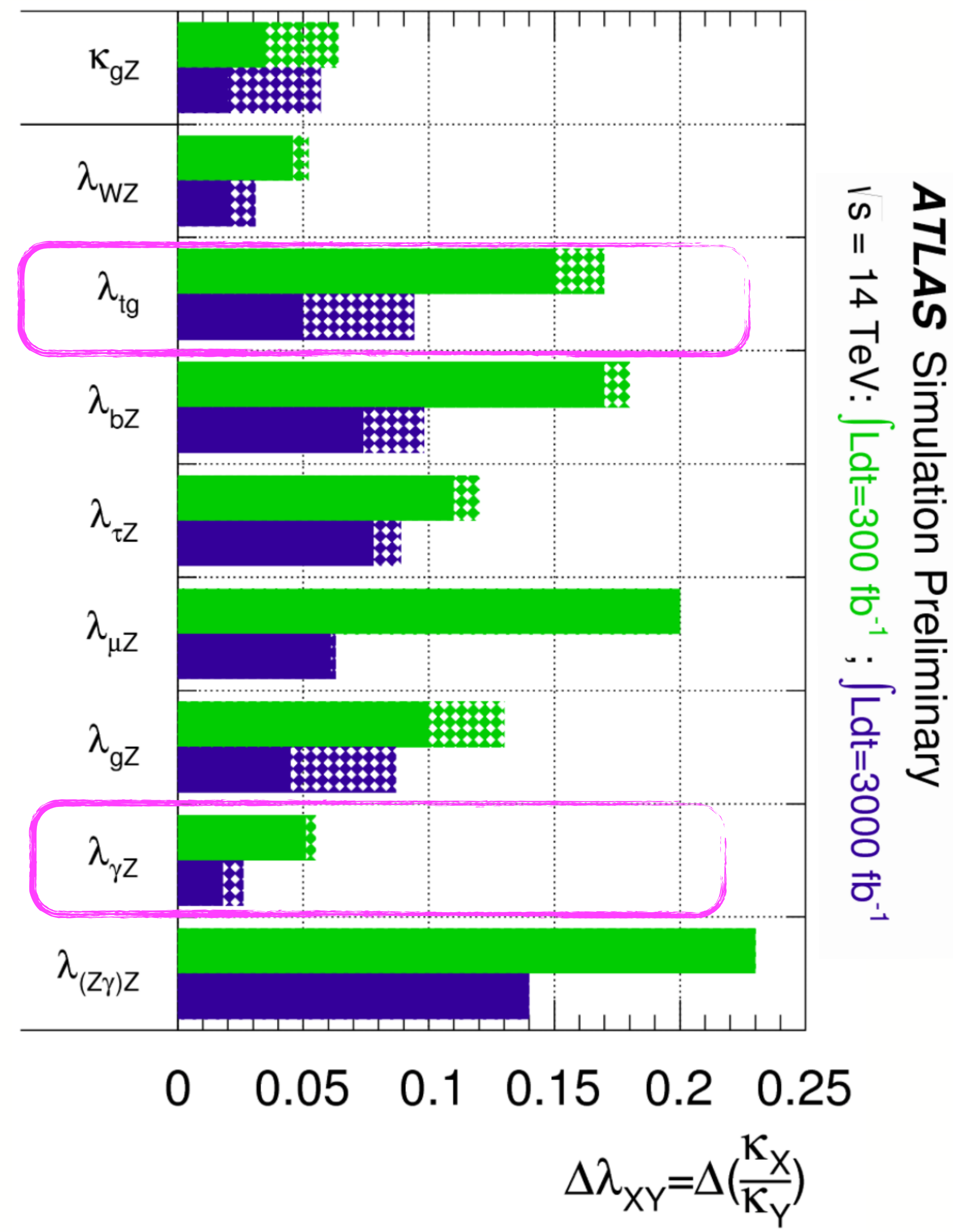


Significance for Hbb 3.9σ (8.8σ) for 300/fb (3000/fb)

ATL-PHYS-PUB-2014-011

Significance for Hmm 2.3σ (7.0σ) for 300/fb (3000/fb)

ATL-PHYS-PUB-2013-014



ATL-PHYS-PUB-2014-016

More on the Impact of Uncertainties

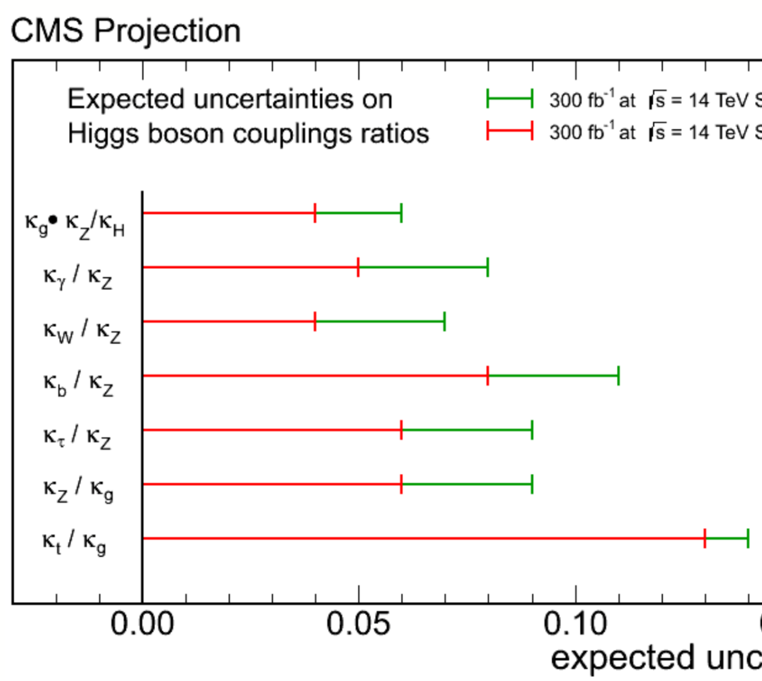
ATLAS, estimate of the maximum theory uncertainty compatible with <10% increase of total uncertainty in 3000/fb

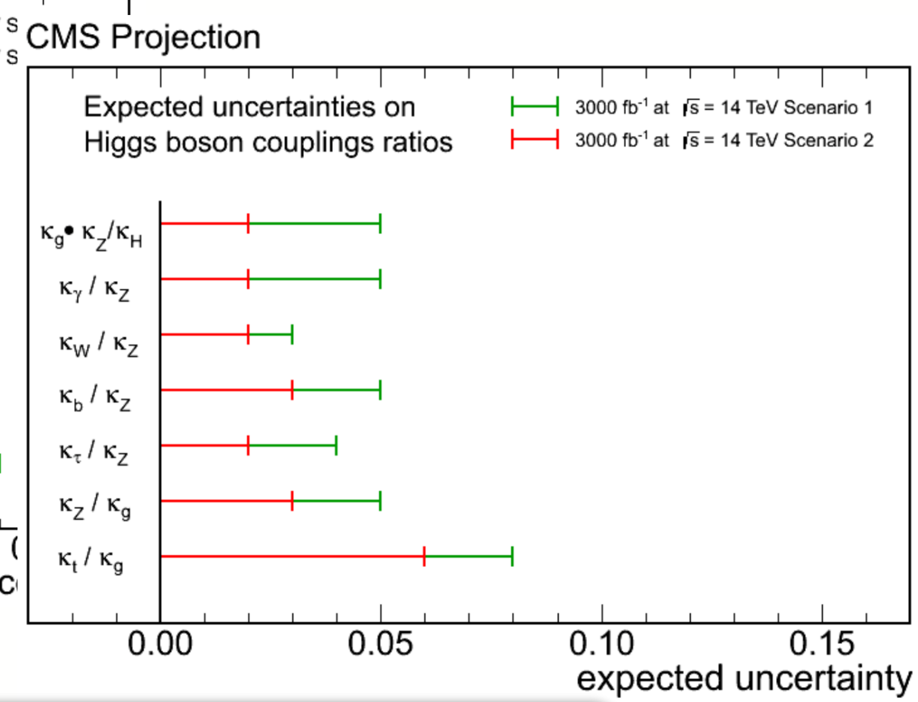
ATL-PHYS-PUB-2014-016

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 $1/\sqrt{L}$ (scenario 2)

HigSnowmass2013TWiki





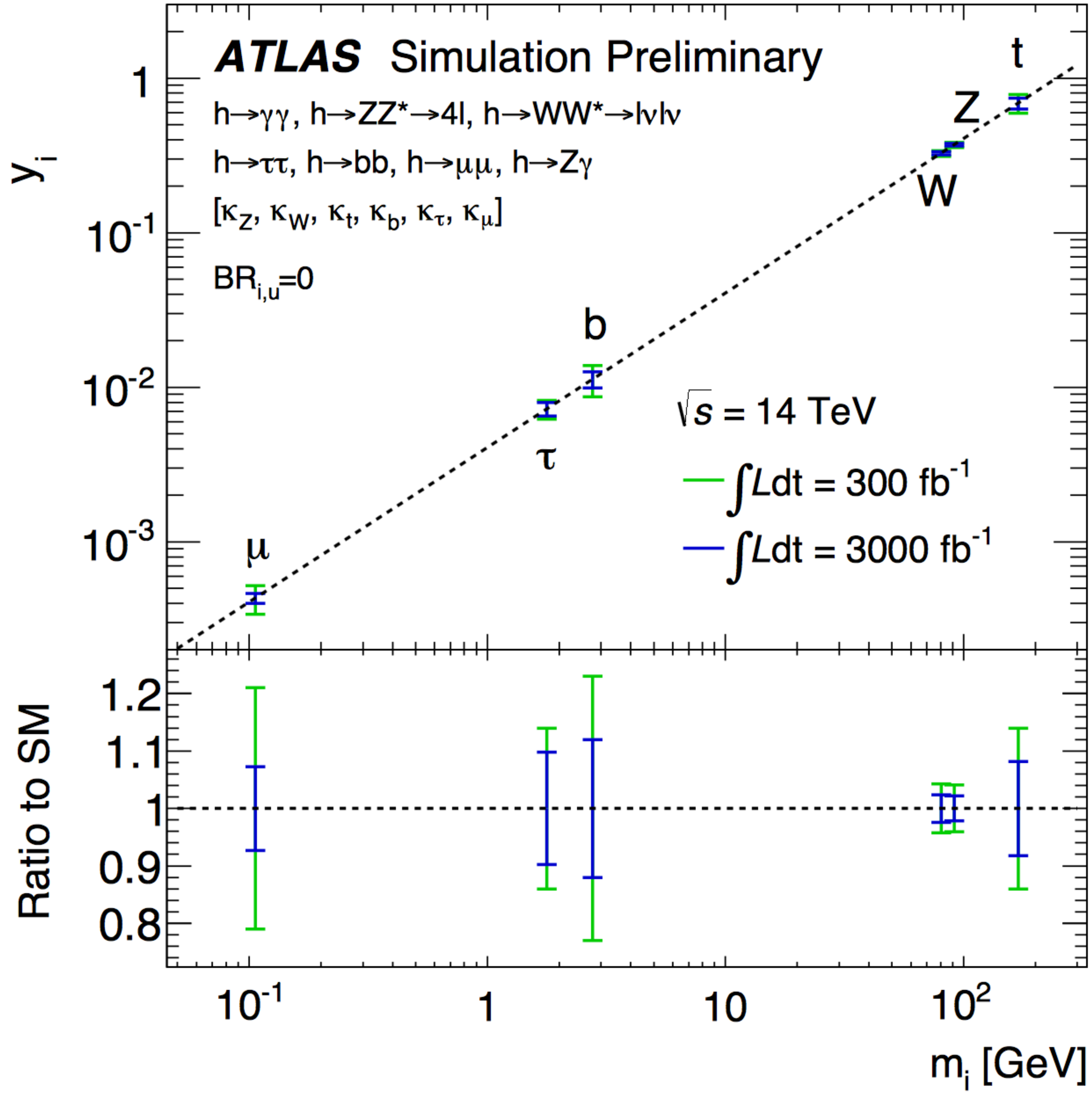
HL-LHC improves by 2-3x
2-3% uncertainty on ratios in scenario 2

Mass dependence on Couplings

- "Reduced" coupling scale factors yi defined to test the predicted relationship between the Higgs boson couplings and the SM particle masses

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

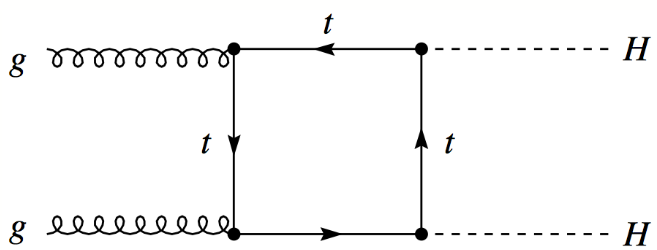
$$y_{F,i} = \kappa_{F,i}\frac{g_{F,i}}{\sqrt{2}} = \kappa_{F,i}\frac{m_{F,i}}{v}$$

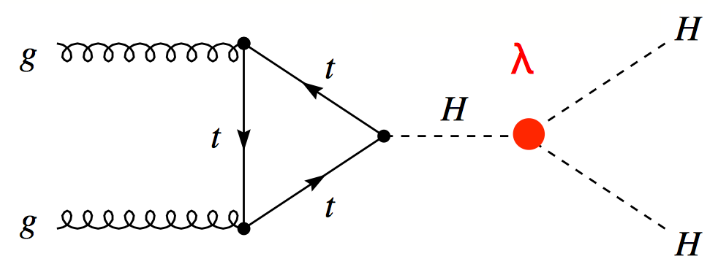


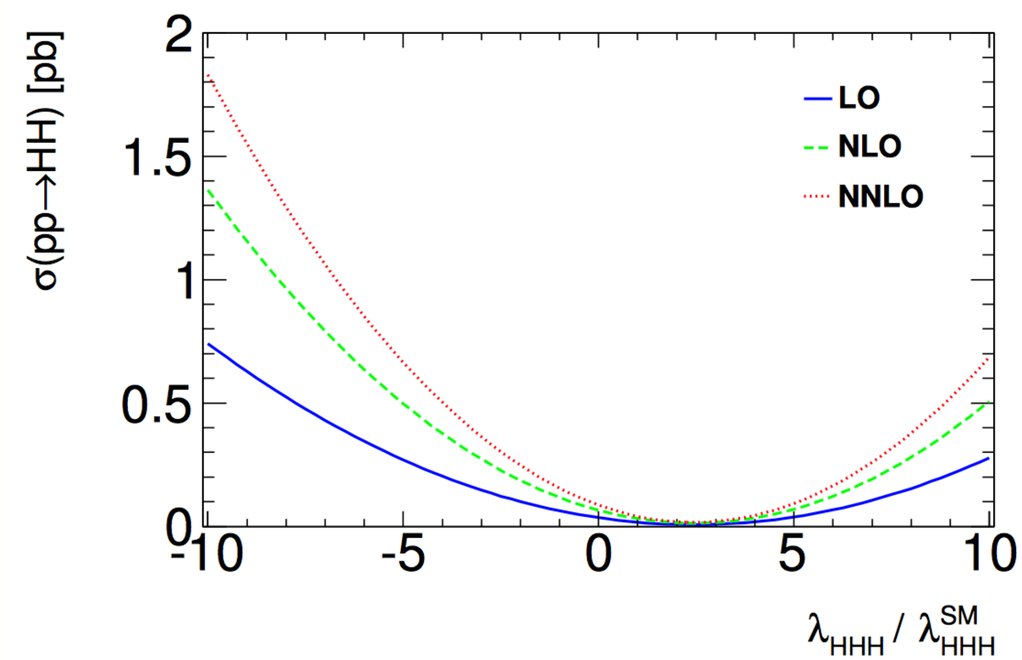
ATL-PHYS-PUB-2014-016

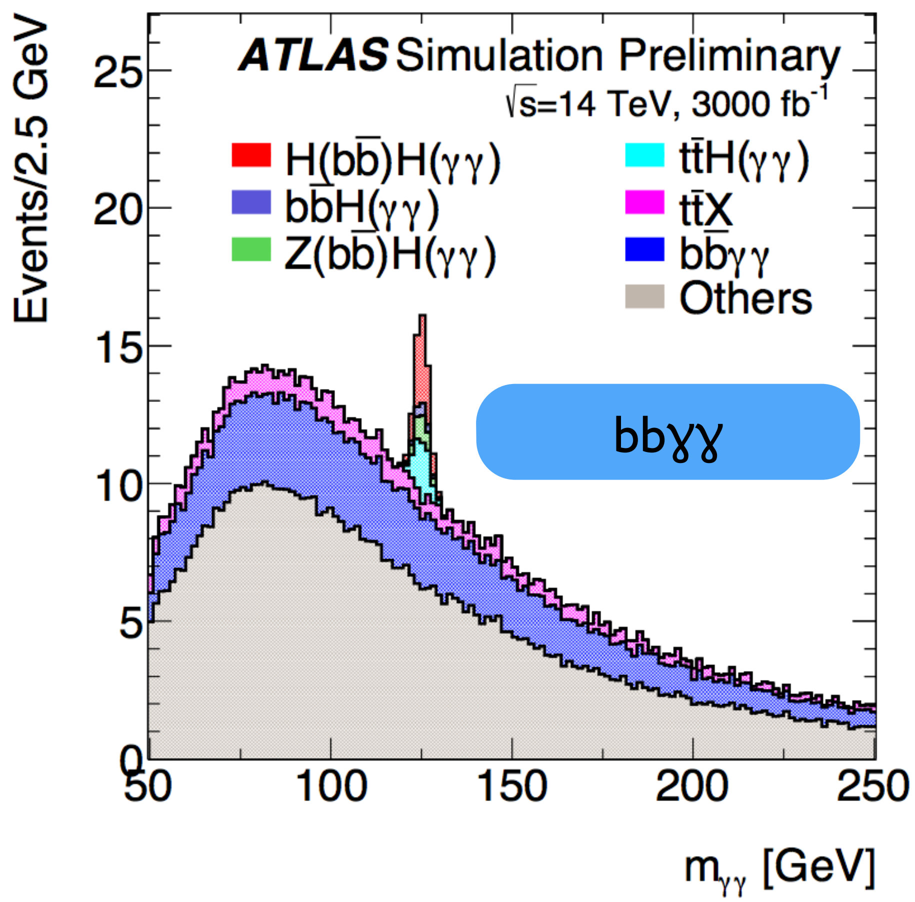
Higgs Pair Production in bbγγ at ATLAS

- Measurement of the Higgs pair production to probe the trilinear coupling and thus the Higgs potential
- Negative interference between the box and s-channel leading to suppression of event yield









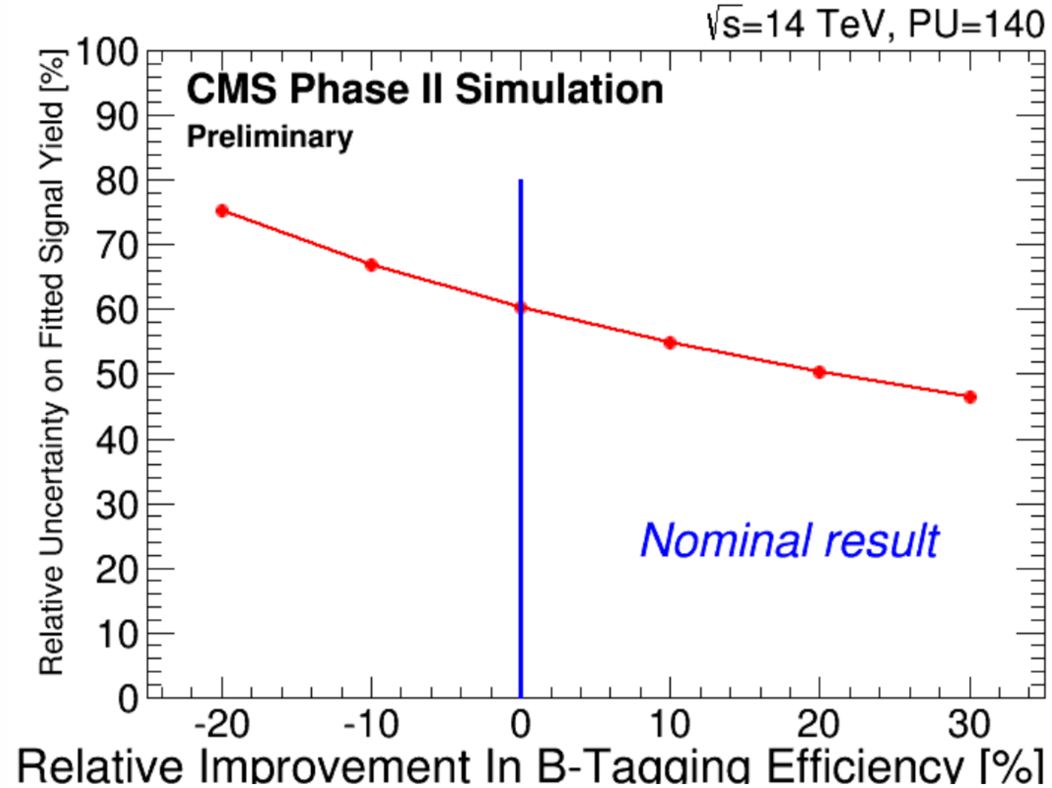
process	Expected events in 3000 fb^{-1}
SM HH→bbγγ	8.4± 0.1
bbγγ	9.7 ± 1.5
ccγγ, bbγj, bbjj, jjγγ	24.1 ± 2.2
top background	3.4 ± 2.2
ttH(γγ)	6.1 ± 0.5
Z(bb)H(γγ)	2.7 ± 0.1
bbH(γγ)	1.2 ± 0.1
Total background	47.1 ± 3.5
S/√B (barrel+endcap)	1.2
S/√B (split barrel and endcap)	1.3

ATL-PHYS-PUB-2014-019

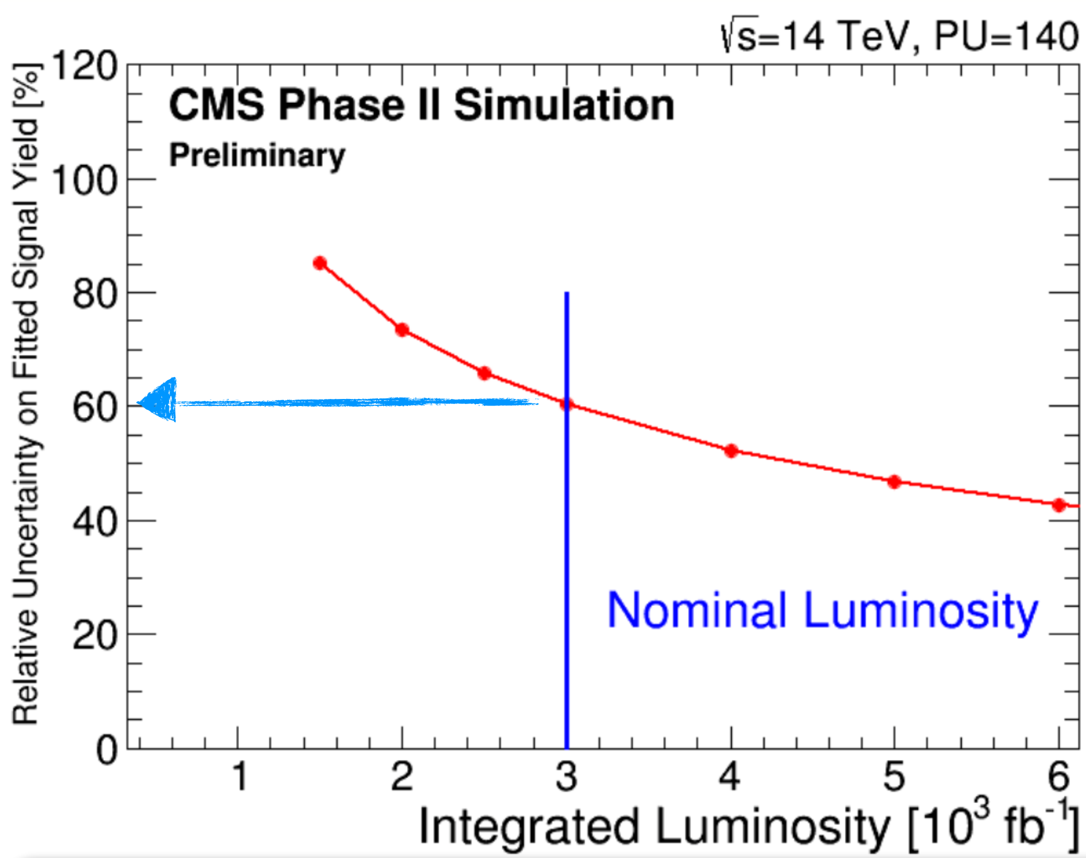
Higgs Pair Production in bbγγ at CMS

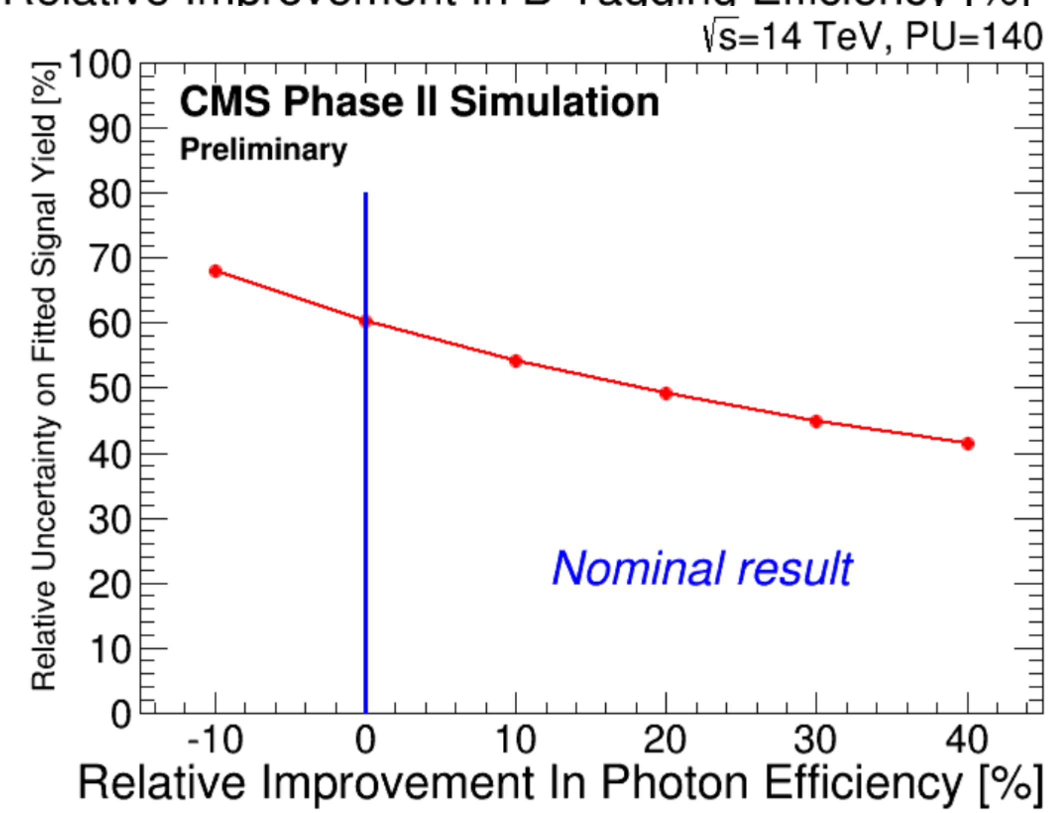
- Search approach based 2D fit of Mbb and Mγγ
  - parameterized object performance tuned to the Phase 2 detector

Process / Selection Stage	HH	ZH	$t\bar{t}H$	$b\bar{b}H$	$\gamma\gamma$+jets	γ+jets	jets	$t\bar{t}$
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



Physics Performance for 2nd ECFA workshop

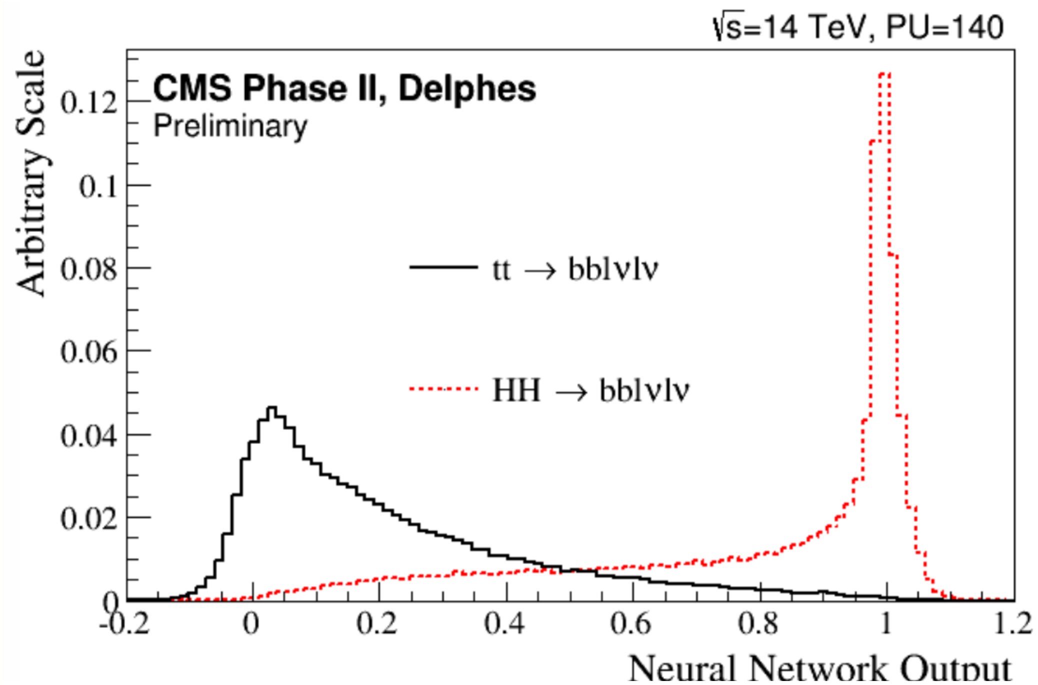


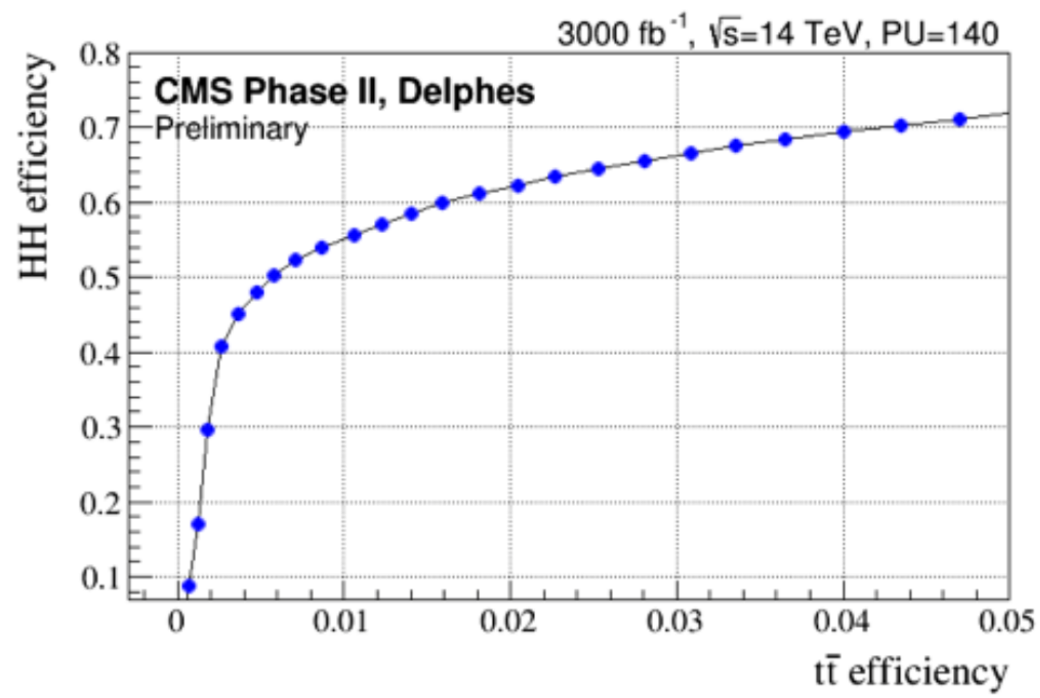


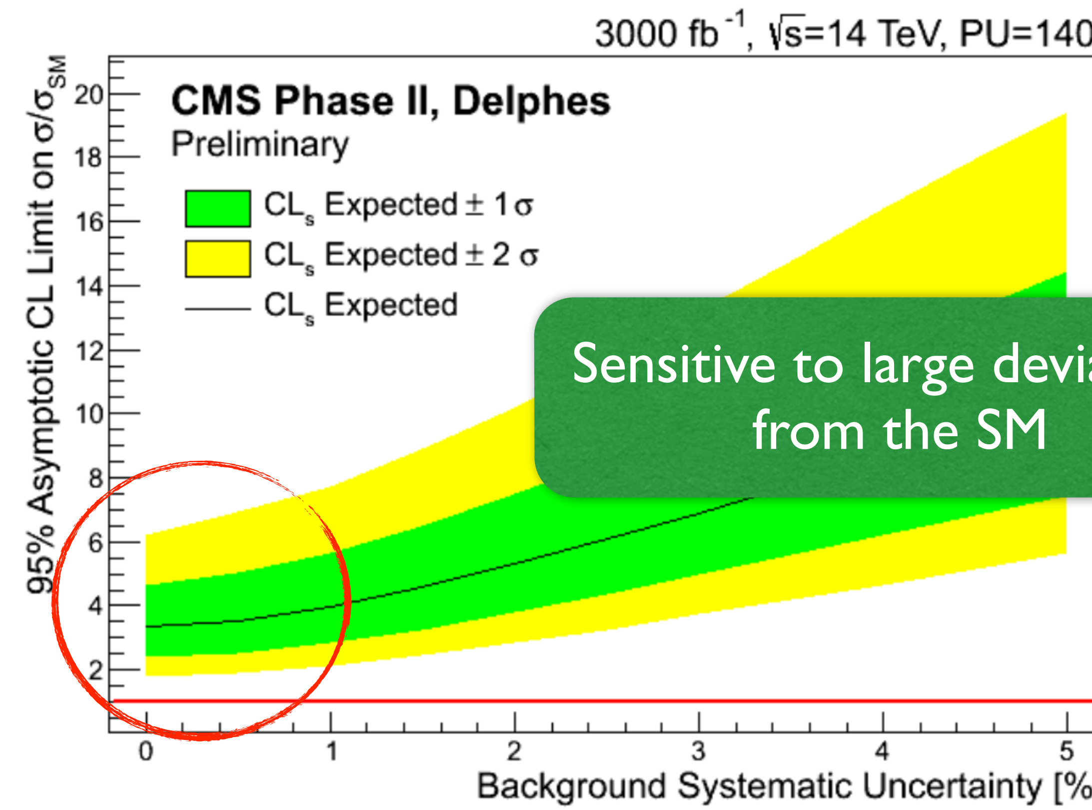
ATLAS and CMS are discussing the analyses to continue and better understand the remaining differences and explore avenues for sensitivity improvement

More searches for HH

- CMS search for HH in WWbb based on Delphes, tuned to Phase 2 detector
- only tt considered as background
- signal to background discrimination using NN
- observables used for NN training Mll, Mjj, ΔRll, ΔRjj, ΔRjl, MET, Δφll,jj, pjj, and MT







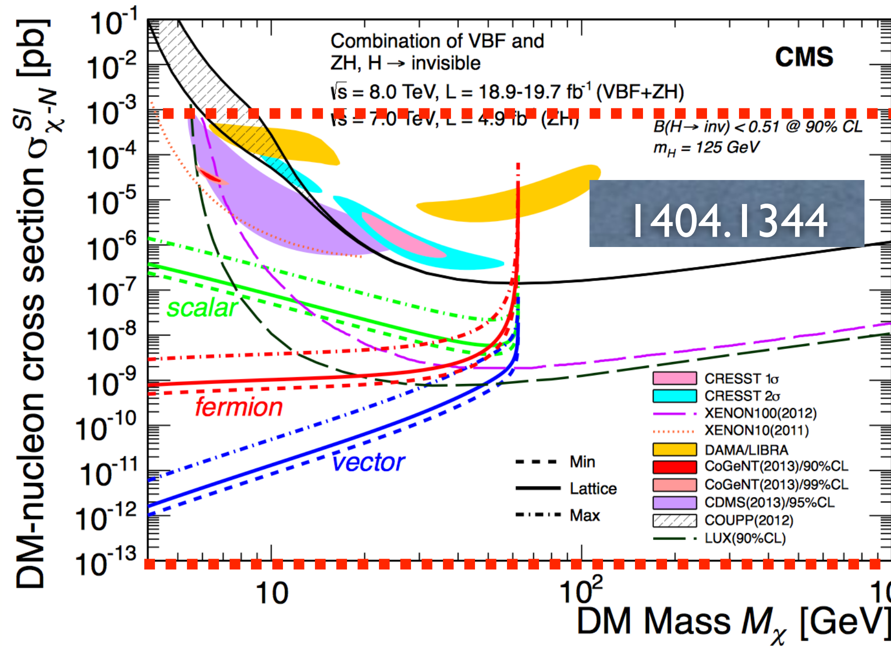
Sensitive to large deviations from the SM

HH is one of the exciting prospect for HL-LHC but it is a challenging measurement!

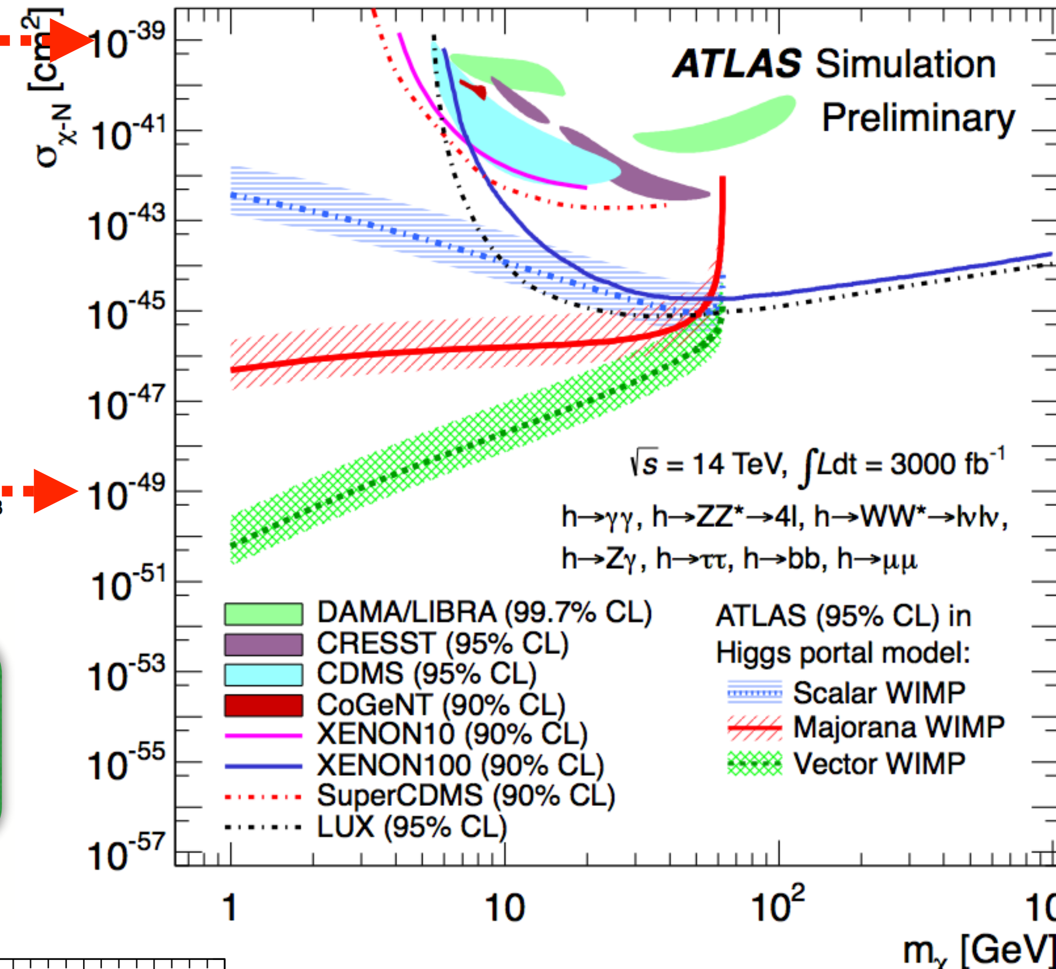
Both ATLAS and CMS are exploring more production modes (e.g. VBF , tthh) and decays (bbbb, bbττ)

Sensitivity to Dark Matter

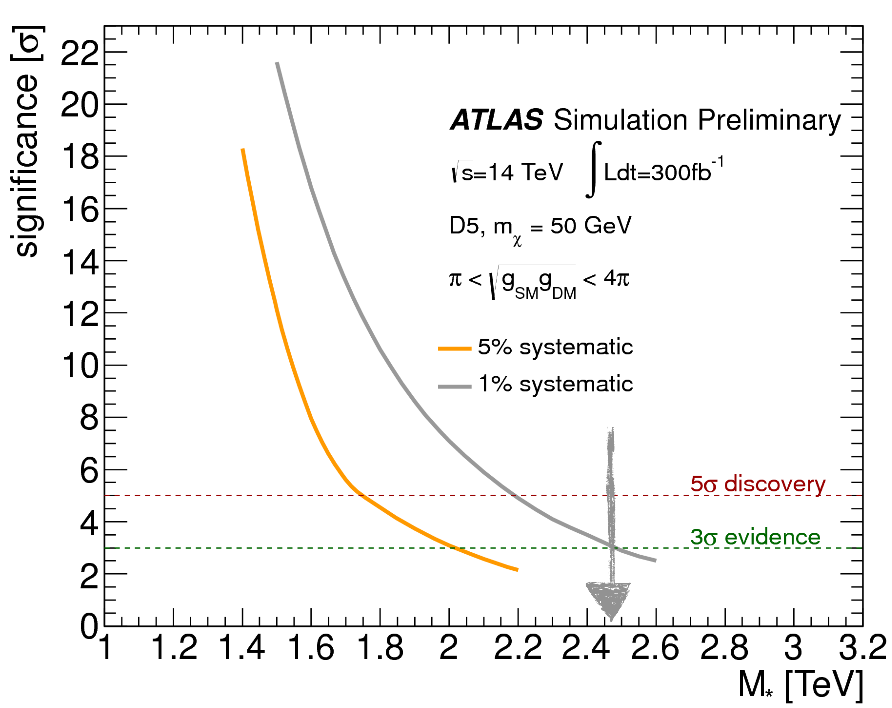
- BR of Higgs to invisible final states
  - ATLAS BR<0.13 (0.09 with no theory uncertainty)
  - CMS BR< 0.11 (0.07 in Scenario 2)

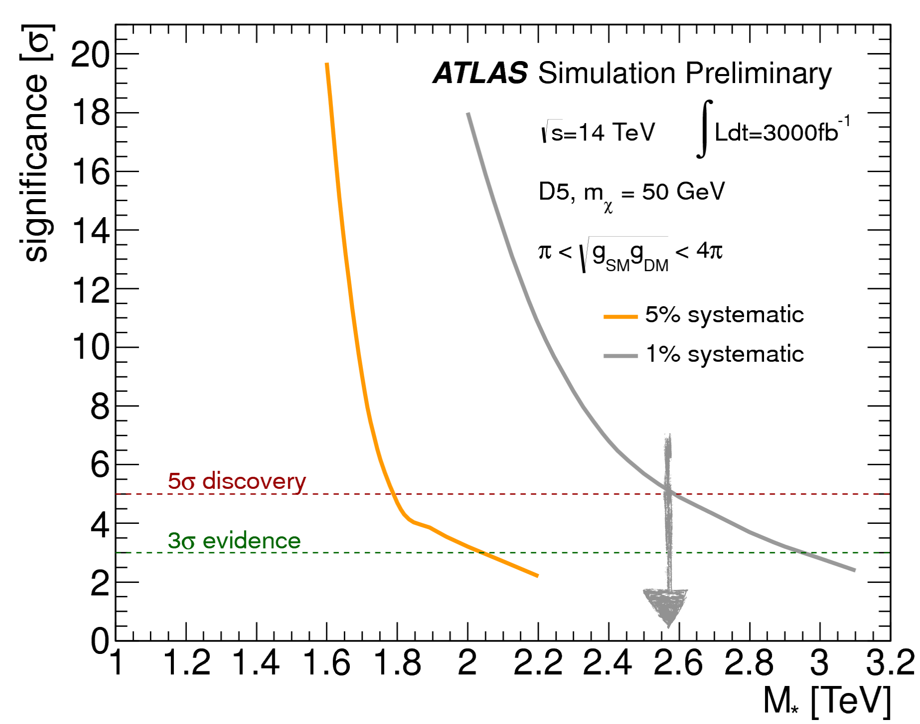


ATL-PHYS-PUB-2014-017



At the HL-LHC, improvement by 10x for any assumption on the Nature of the DM

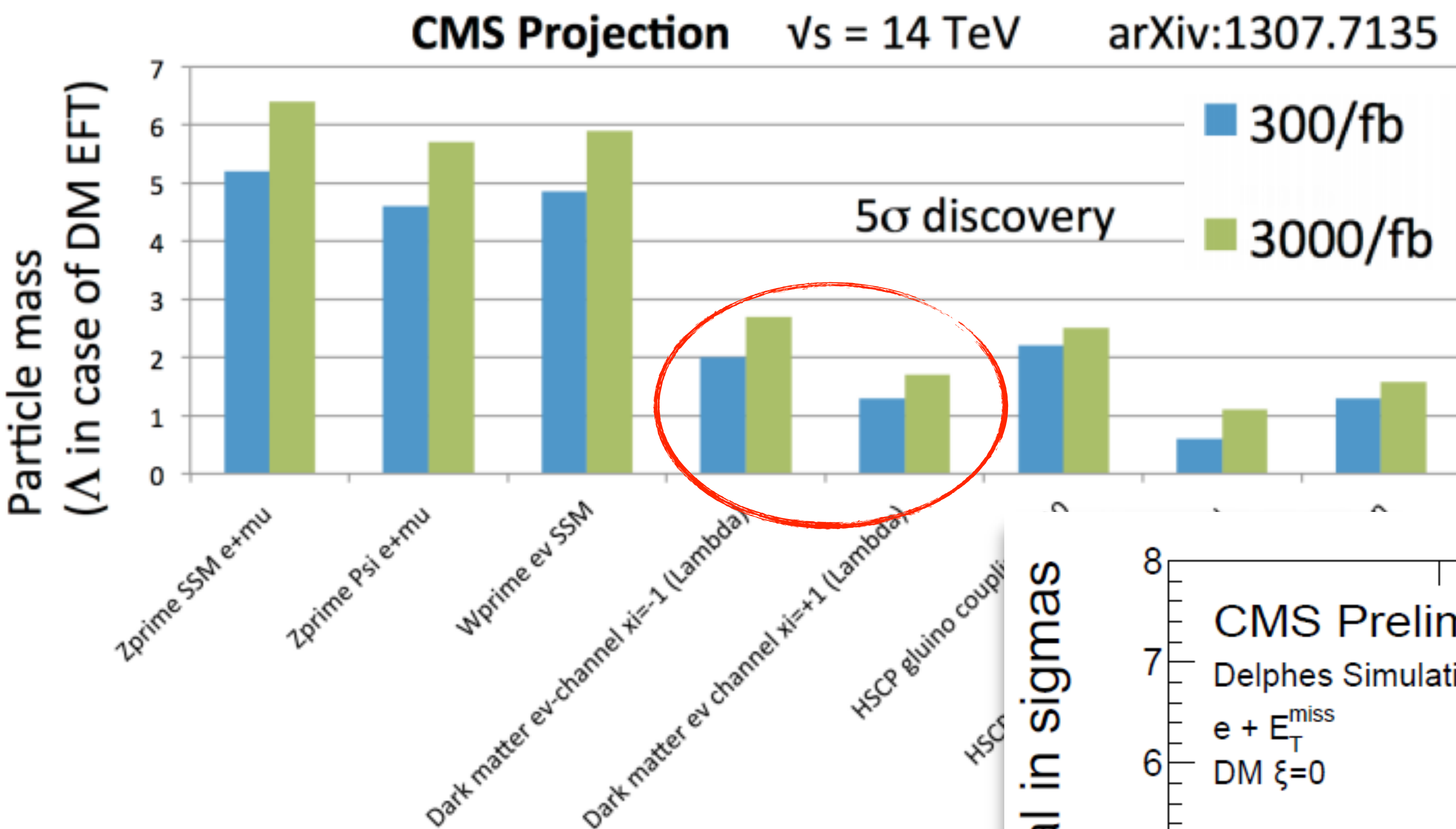




- Search for Dark Matter using mono-jet approach, EFT interpretation

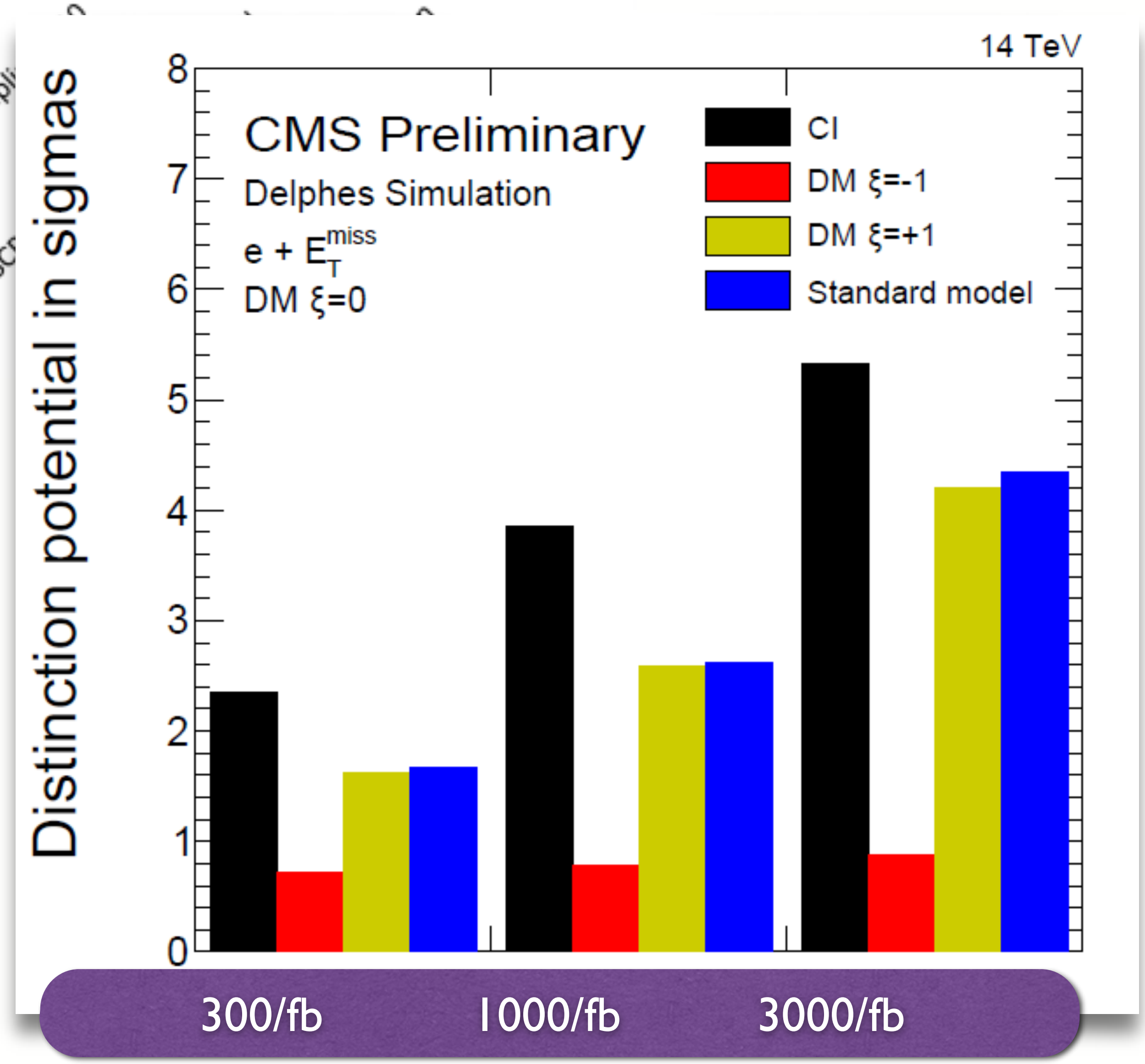
ATL-PHYS-PUB-2014-007

More Searches For Dark Matter



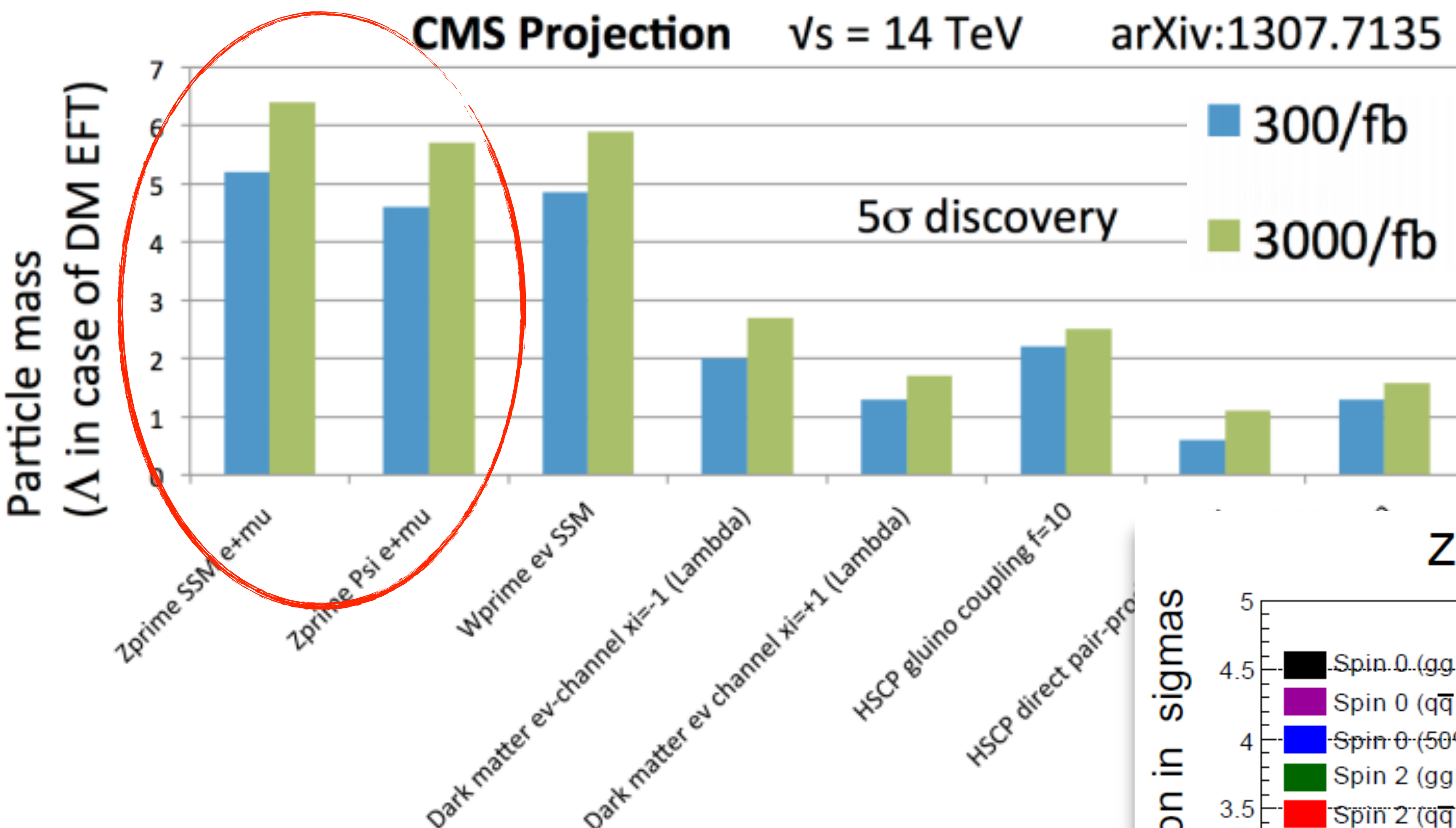
- Looking for an excess in the tail of the transverse mass in mono-W events
  - sensitivity to contact interactions and W' as well

HL-LHC essential to discriminate among hypotheses



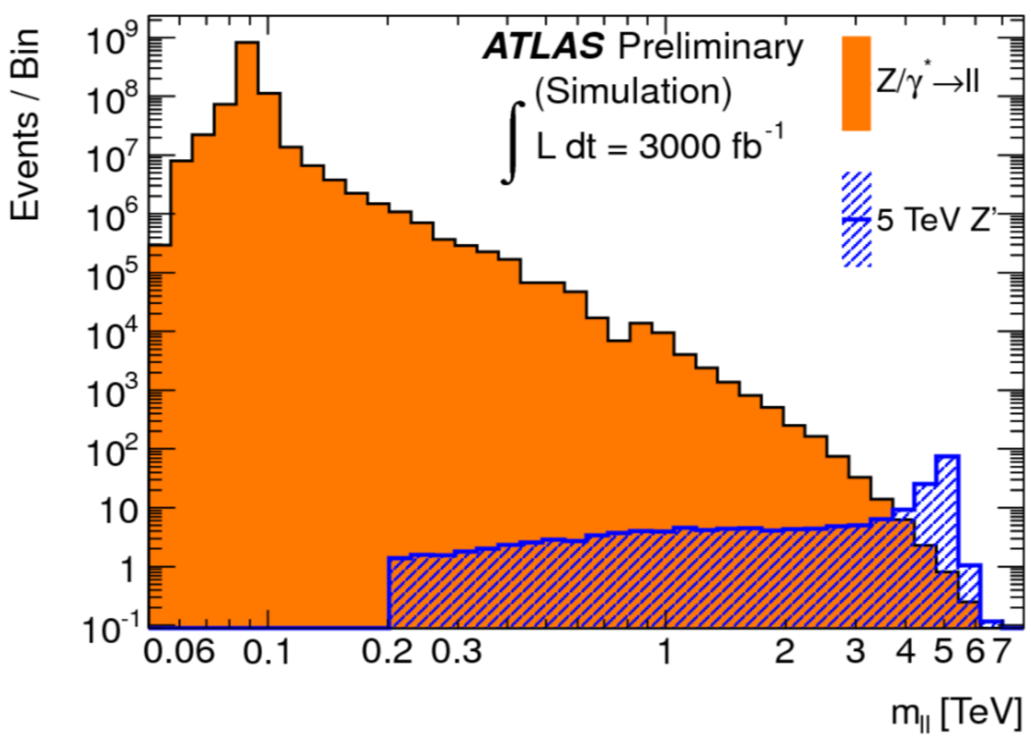
Physics Performance for 2nd ECFA workshop

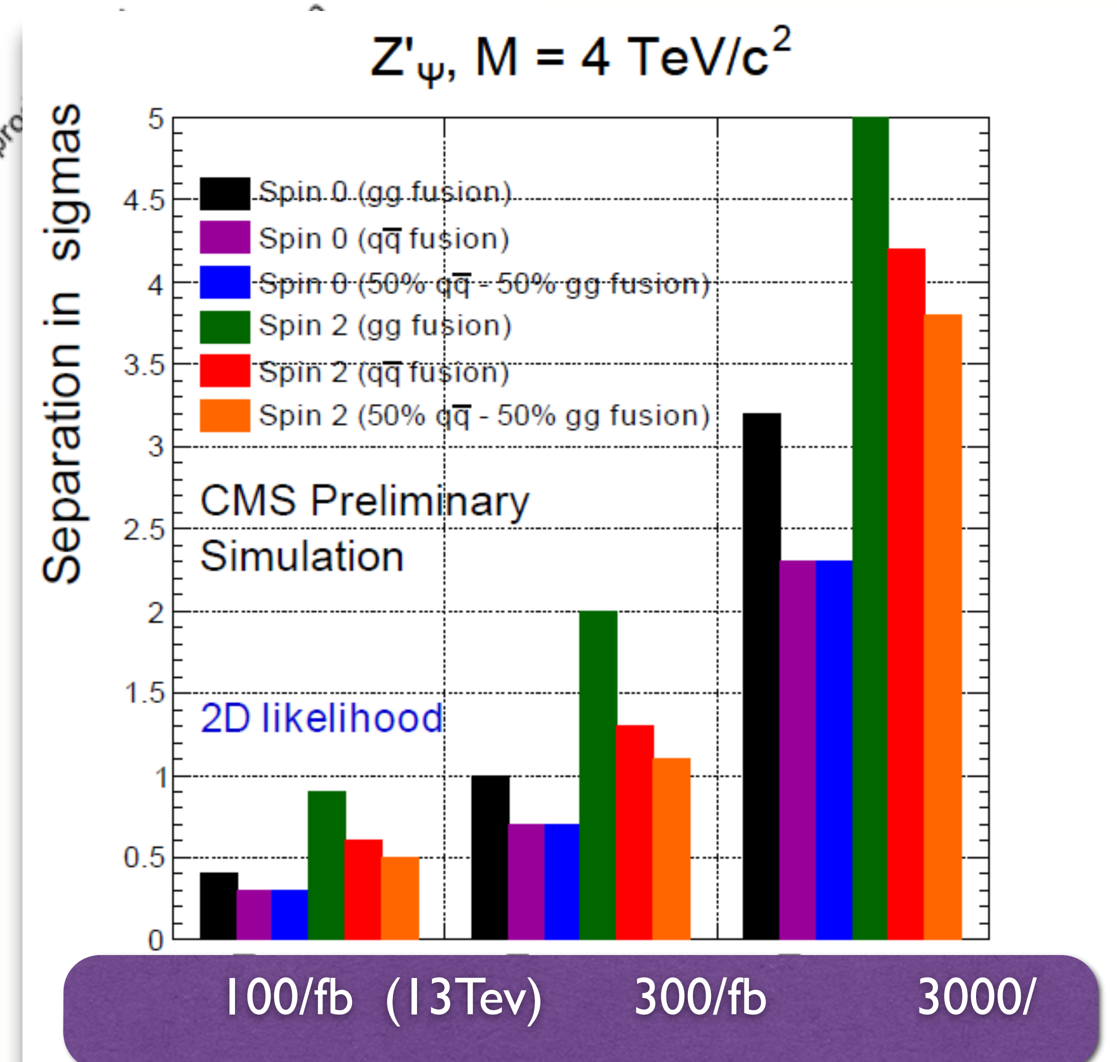
Discovering and Characterizing Resonances



- Looking for a heavy resonances (originating from Z', KK-gluon) in the tail of the di-lepton invariant mass

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

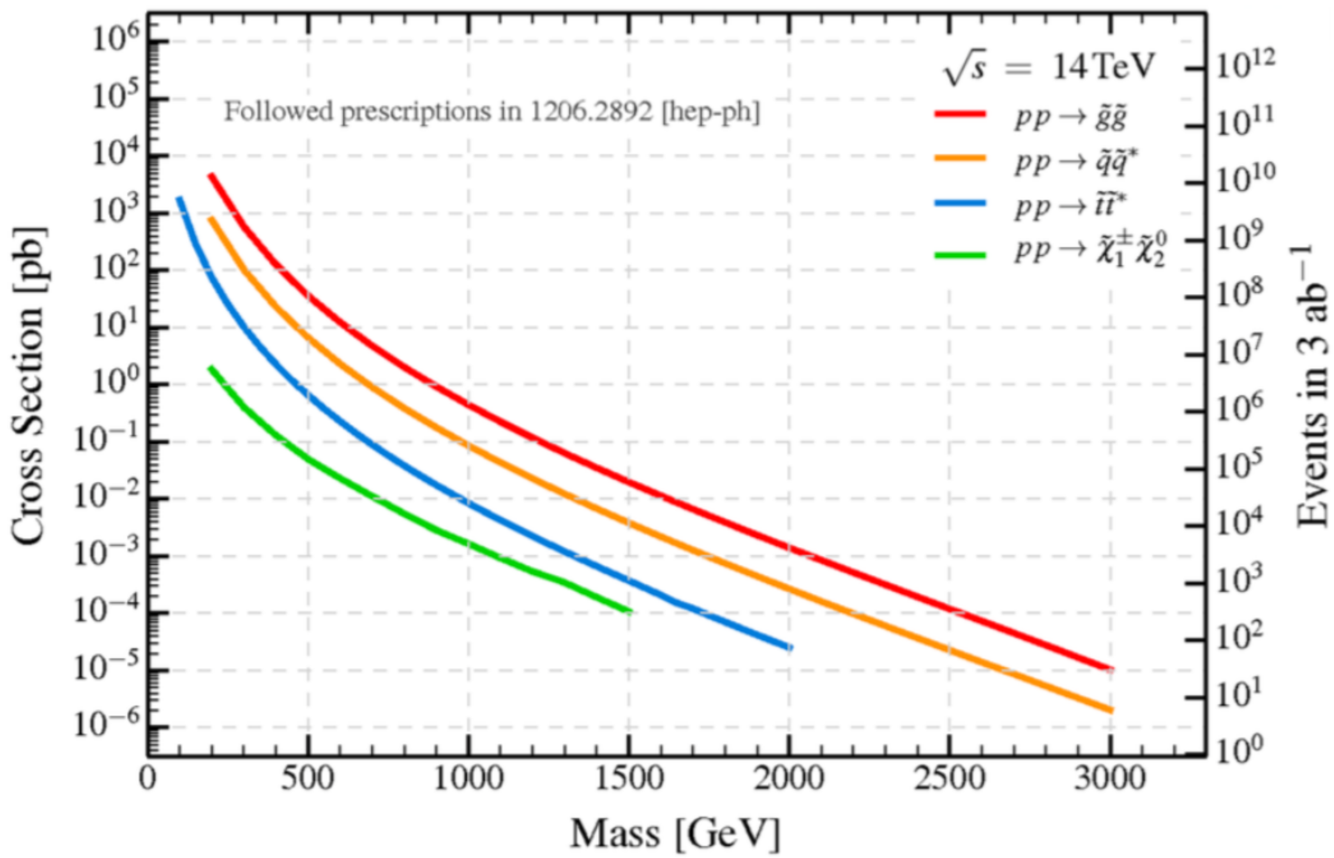


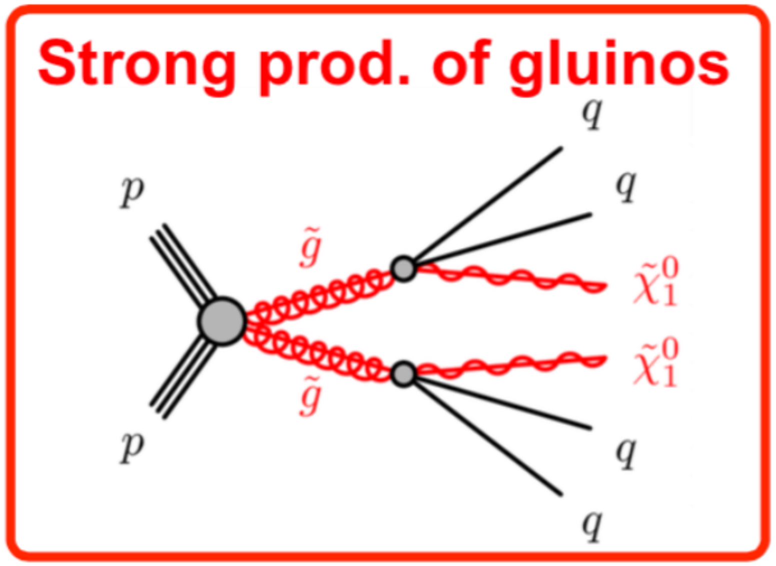


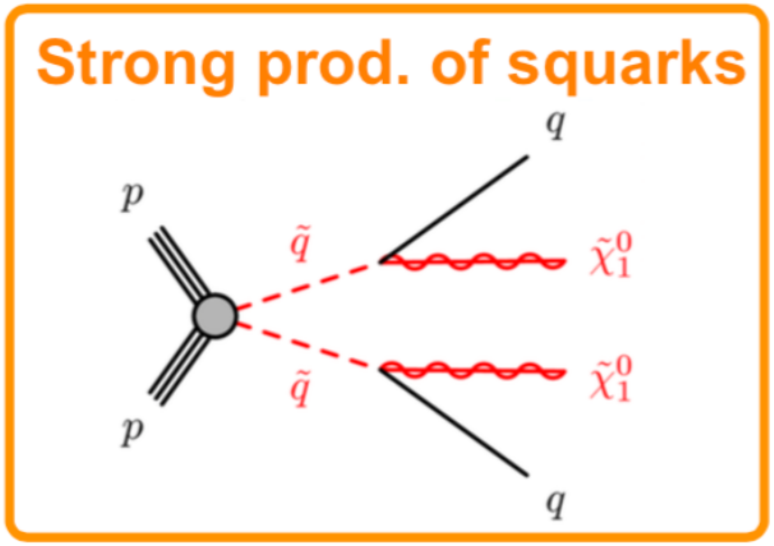
ATL-PHYS-PUB-2013-003

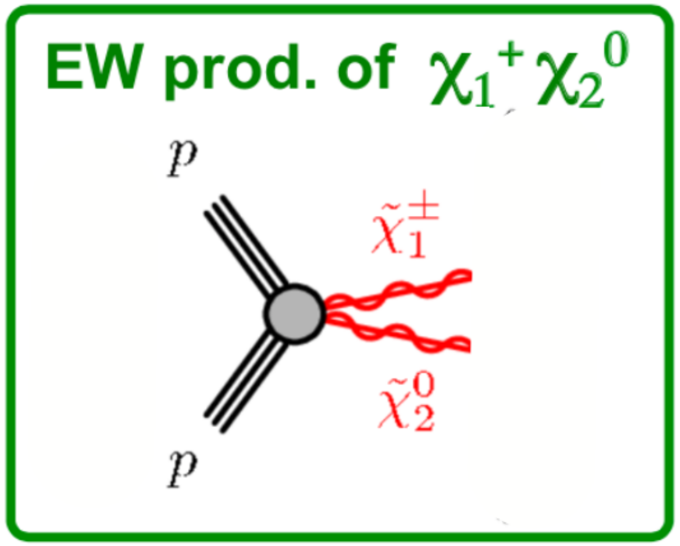
Physics Performance for 2nd ECFA workshop

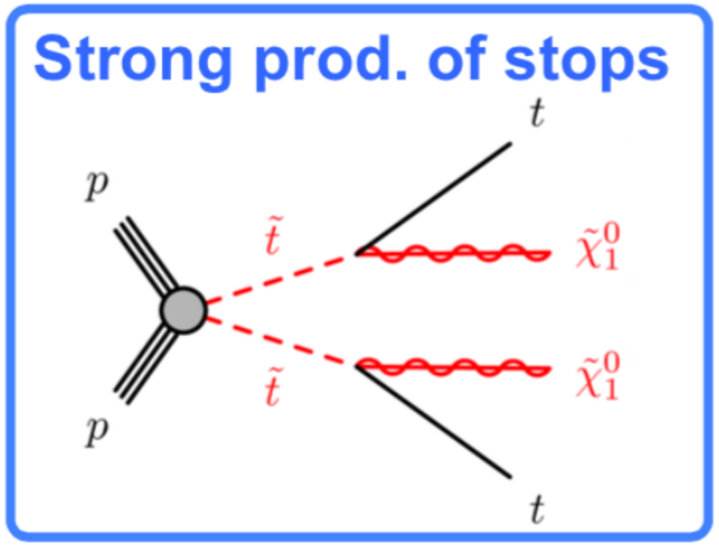
SUSY Reminder





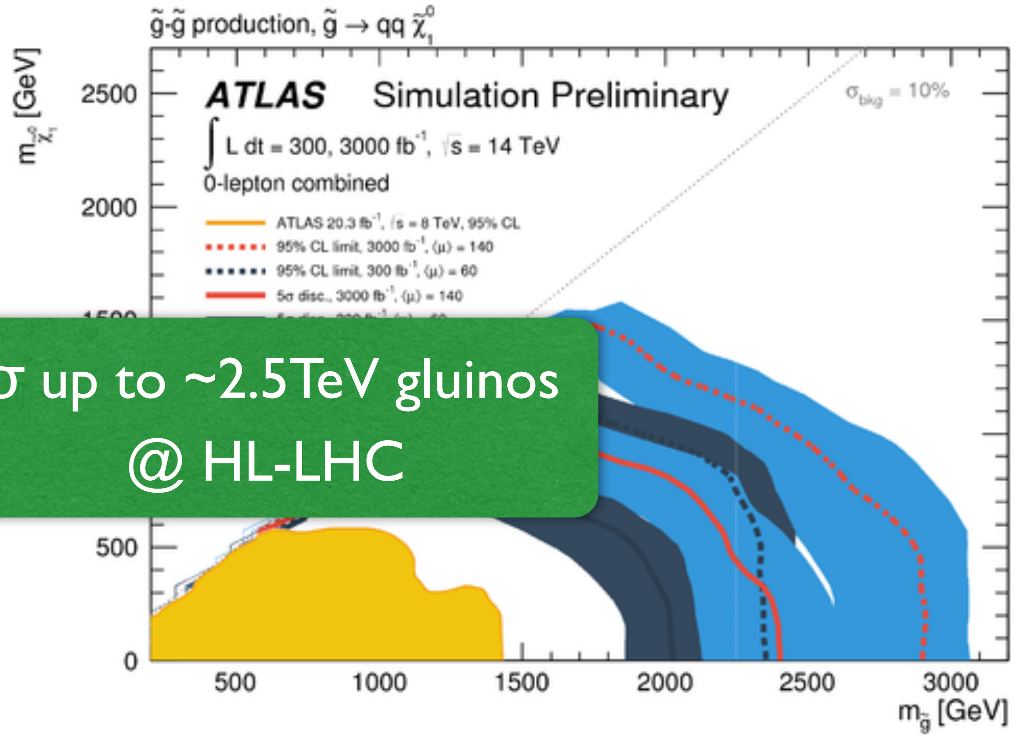




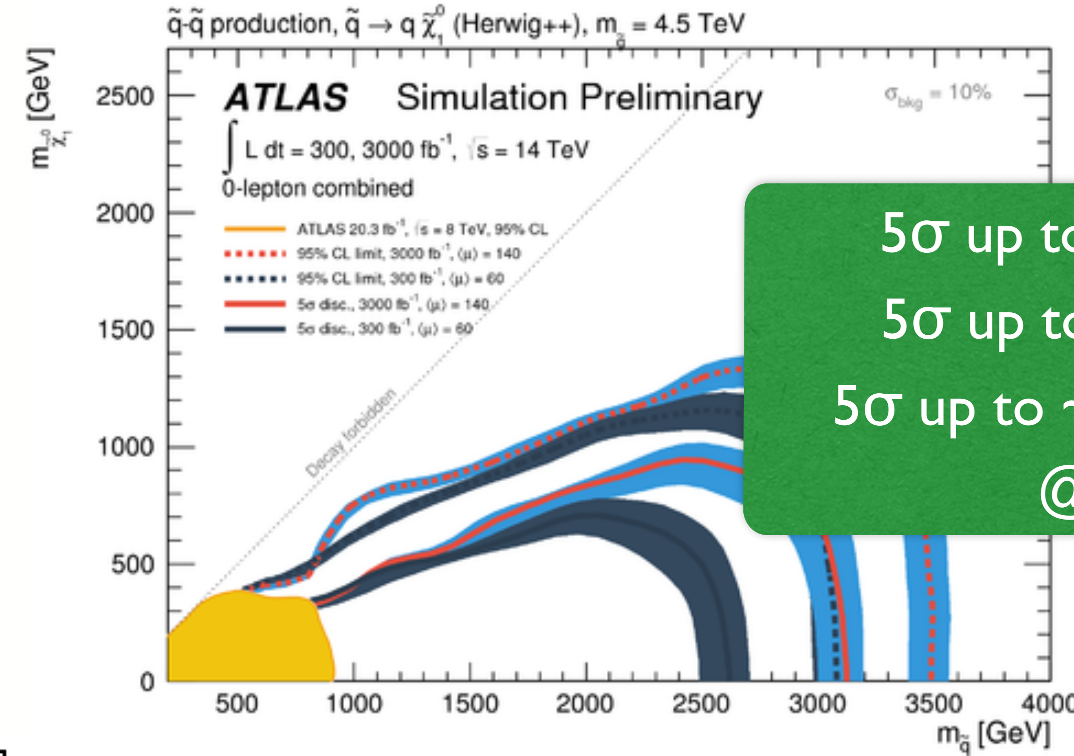


Strong SUSY at the HL-LHC

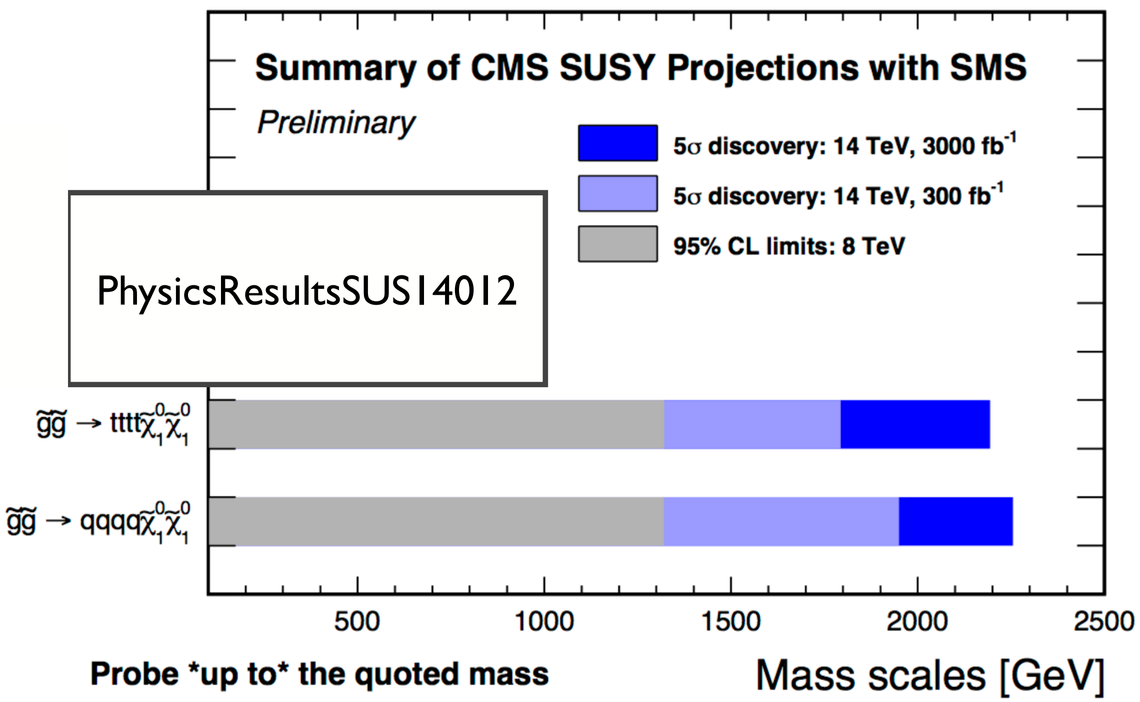
- Significant increase of discovery potential for strongly produced sparticle originates from the increase in center of mass energy



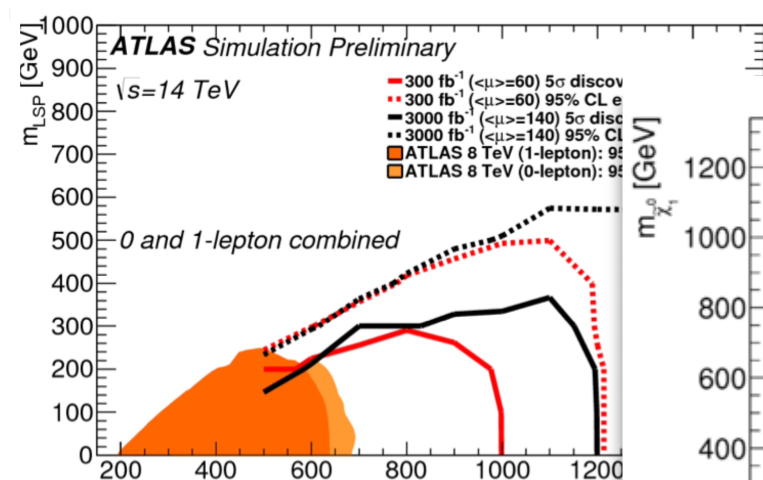
5σ up to ~2.5TeV gluinos @ HL-LHC

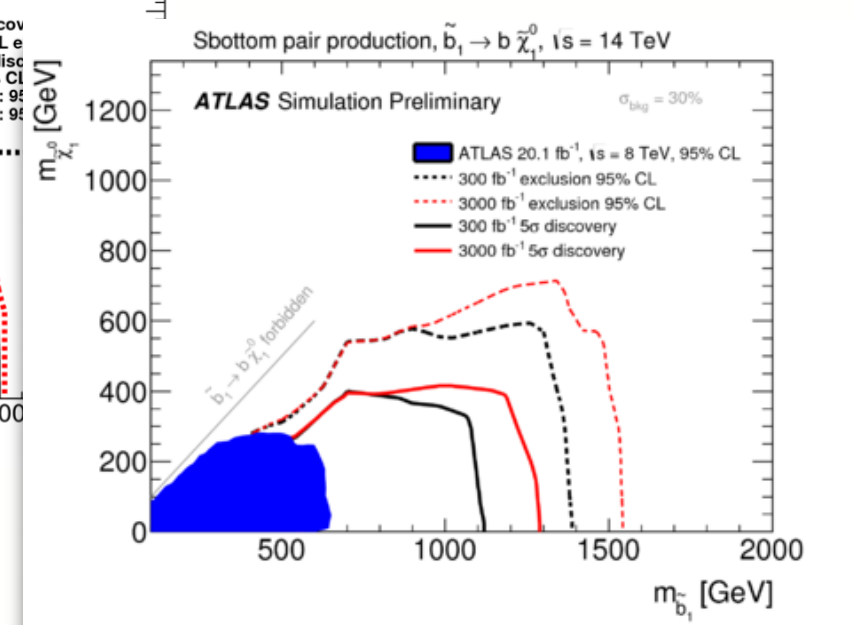


5σ up to ~3TeV squarks
5σ up to ~1.2 TeV stops
5σ up to ~1.3 TeV sbottoms
@ HL-LHC



PhysicsResultsSUS14012



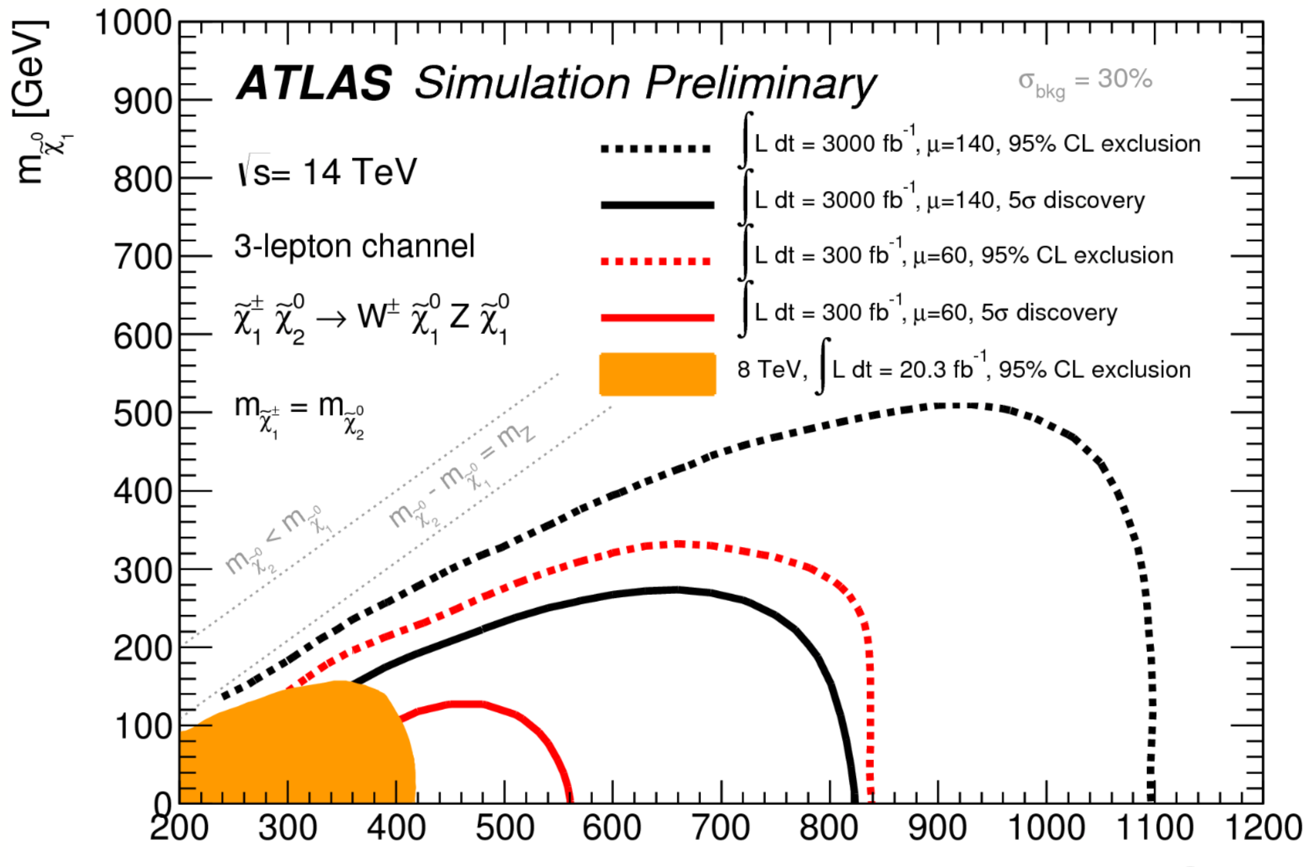


ATL-PHYS-PUB-2014-010 ATL-PHYS-PUB-2013-011

EWK-SUSY at the HL-LHC

TRIUMF

- Factor 10x in integrated luminosity essential to probe rare SUSY processes, e.g. the pair production of EWK-inos expected to be light from naturalness arguments



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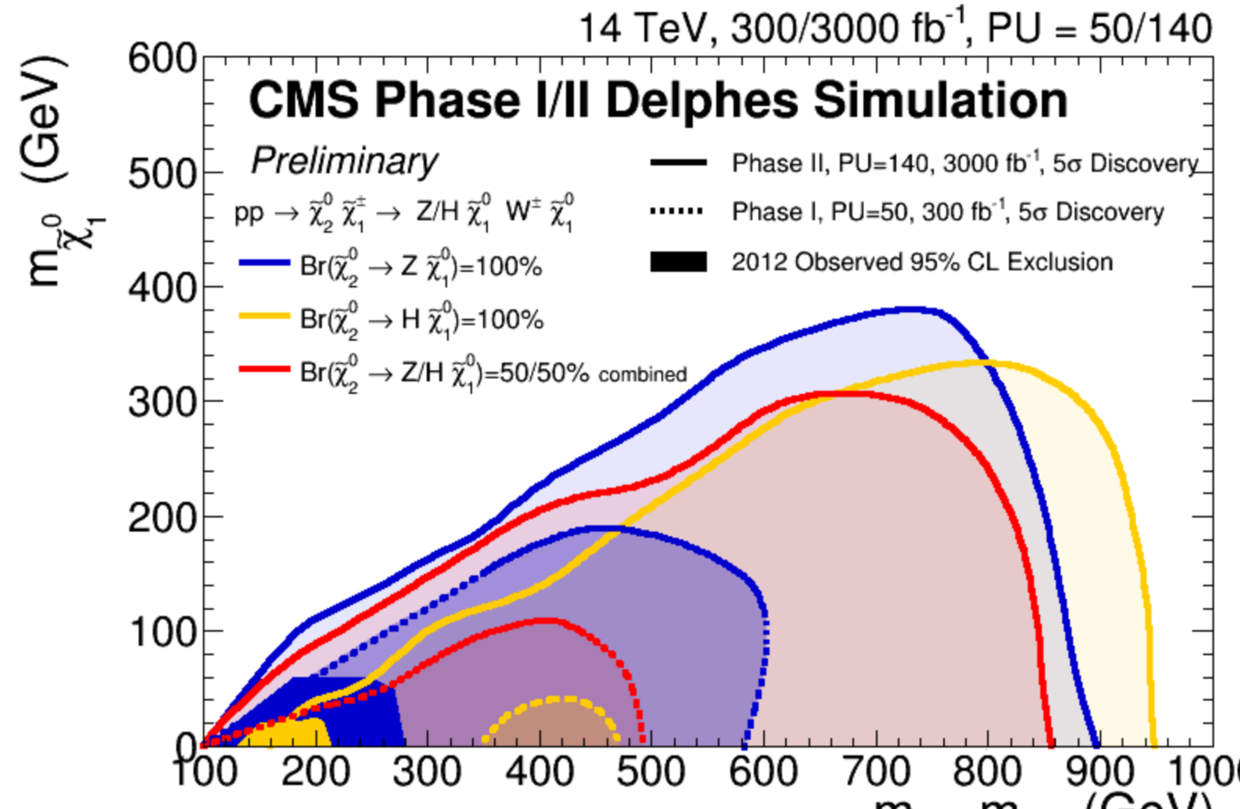
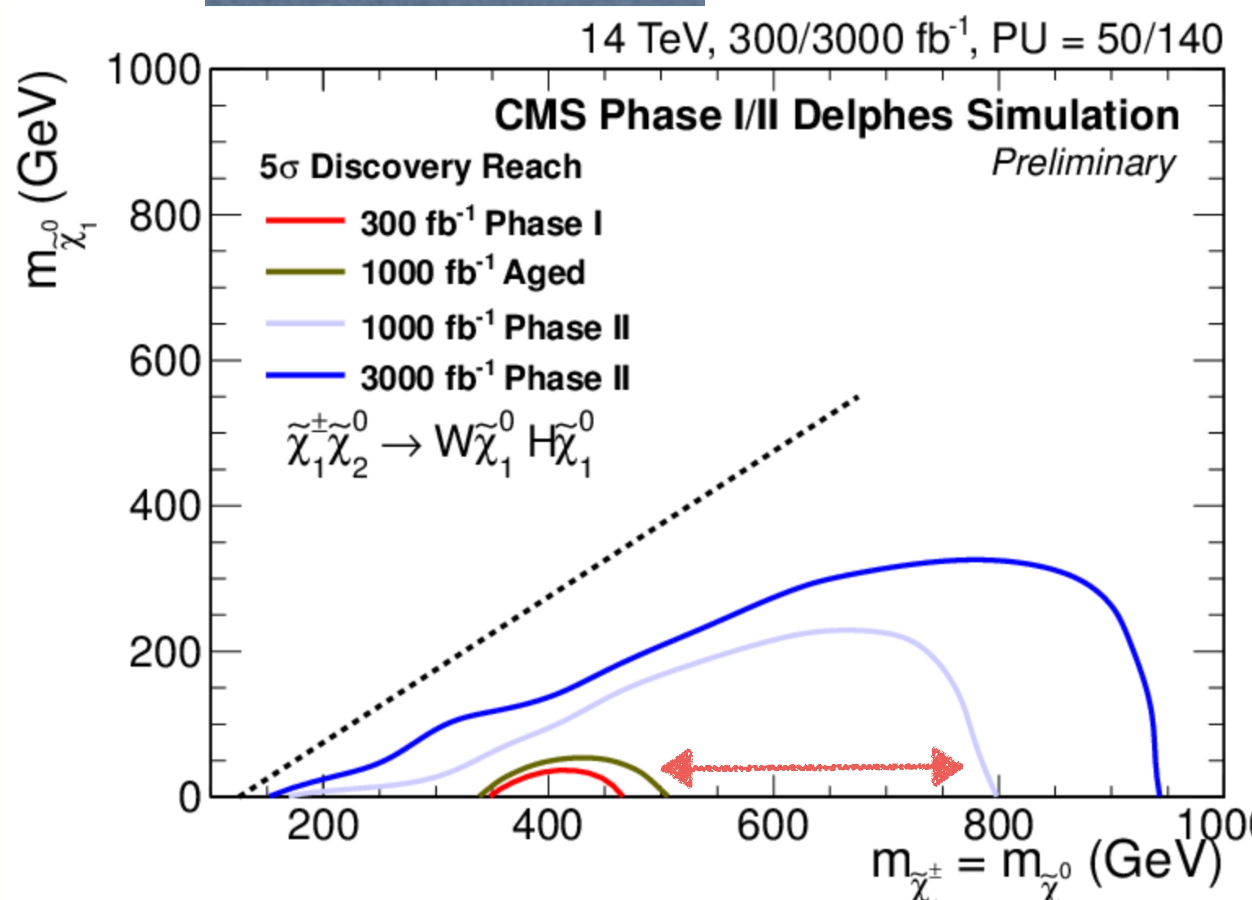


PhysicsResultsSUS14012

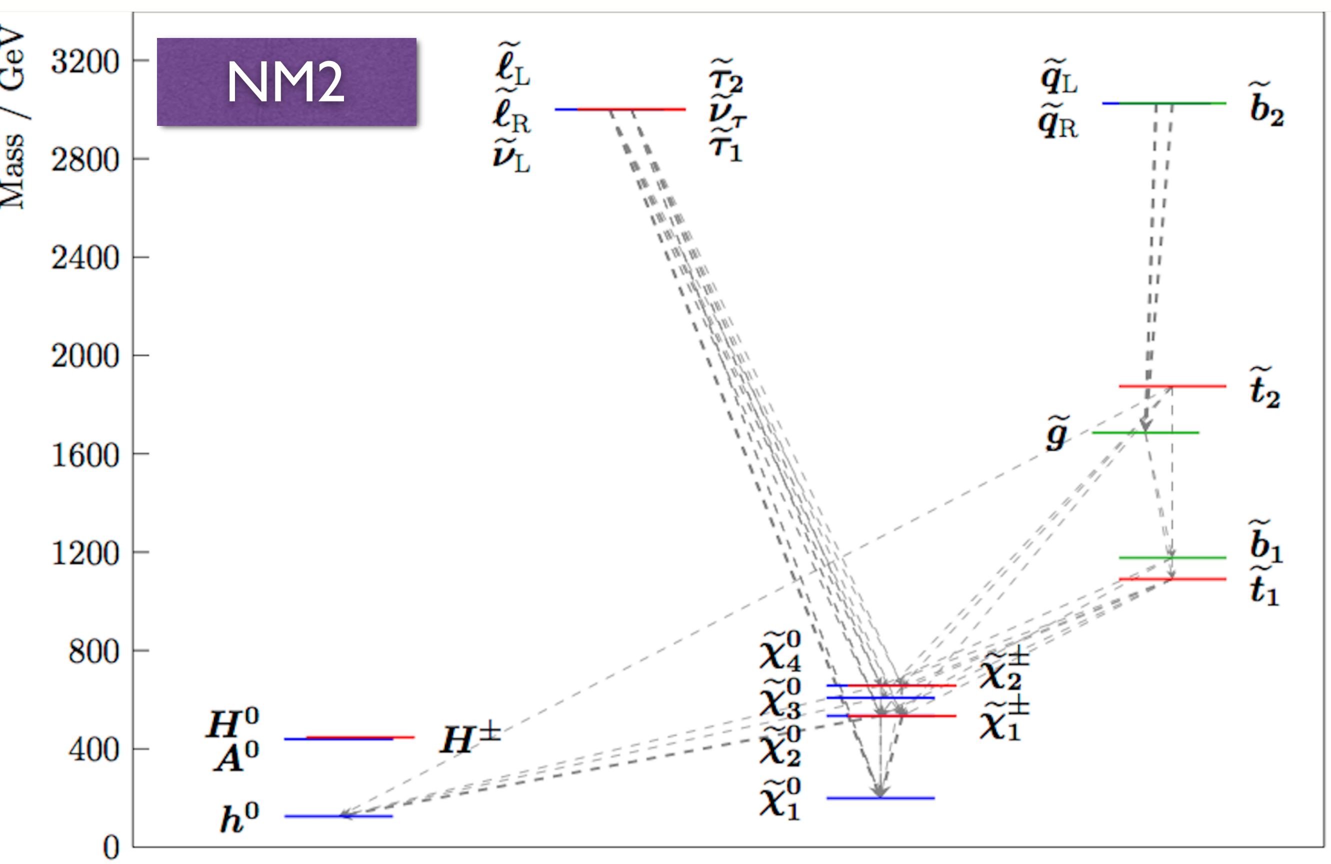


5σ up to ~800 GeV in both the WZ and Wh modes @ HL-LHC!

Strong dependence on detector performance

Full spectrum SUSY

- Five phenomenological models motivated by naturalness explored through a number of signature-based searches
  - models vary 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})	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		$3-5\sigma$			

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

PhysicsResultsSUS14012

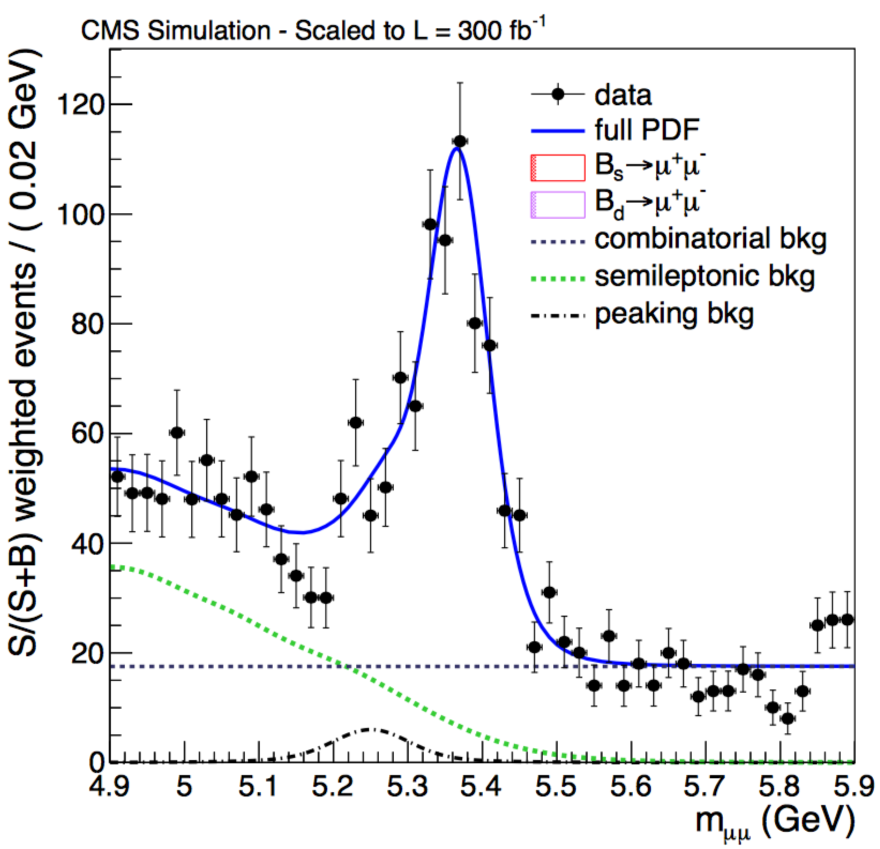
New Physics in the Heavy Flavor Sector

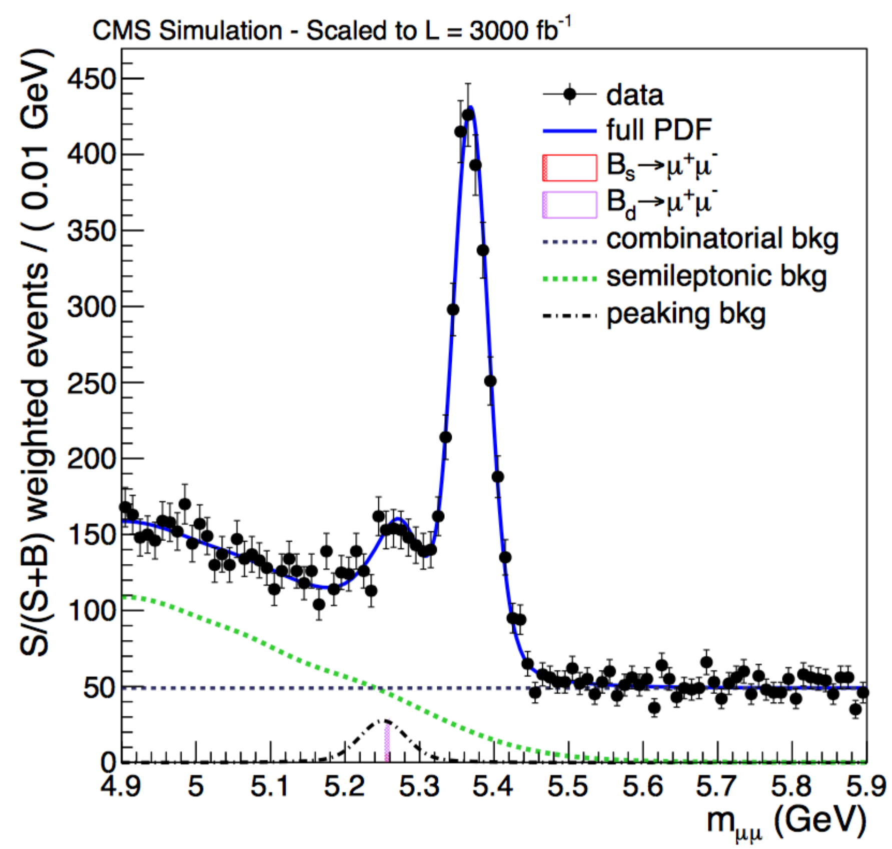
TRIUMF

- Rare decays $B^0_s \to \mu\mu$ and $B^0 \to \mu\mu$ only through FCNC, highly suppressed in the SM
  - modification to the BF predicted in several BSM scenarios (SUSY, non-SM Higgs,…)
- **Both CMS and LHCb observed the $B^0_s \to \mu\mu$ and achieved evidence of $B^0 \to \mu\mu$!**

1411.4413	$B^0_s \to \mu\mu$	$B^0 \to \mu\mu$
Significance	6.2σ	3.2σ
BF	$(2.8^{+0.7}_{-0.6})\times10^{-9}$	$(3.9^{+1.6}_{-1.4})\times10^{-10}$

L (fb^{-1})	No. of B^0_s	No. of B^0	$\delta\mathcal{B}/\mathcal{B}(B_s{}^0 \to \mu^+\mu^-)$	$\delta\mathcal{B}/\mathcal{B}(B^0 \to \mu^+\mu^-)$	B^0 sign.	$\delta\frac{\mathcal{B}(B^0\to\mu^+\mu^-)}{\mathcal{B}(B^0_s\to\mu^+\mu^-)}$
20	16.5	2.0	35%	>100%	0.0–1.5 σ	>100%
100	144	18	15%	66%	0.5–2.4 σ	71%
300	433	54	12%	45%	1.3–3.3 σ	47%
3000	2096	256	12%	18%	5.4–7.6 σ	21%





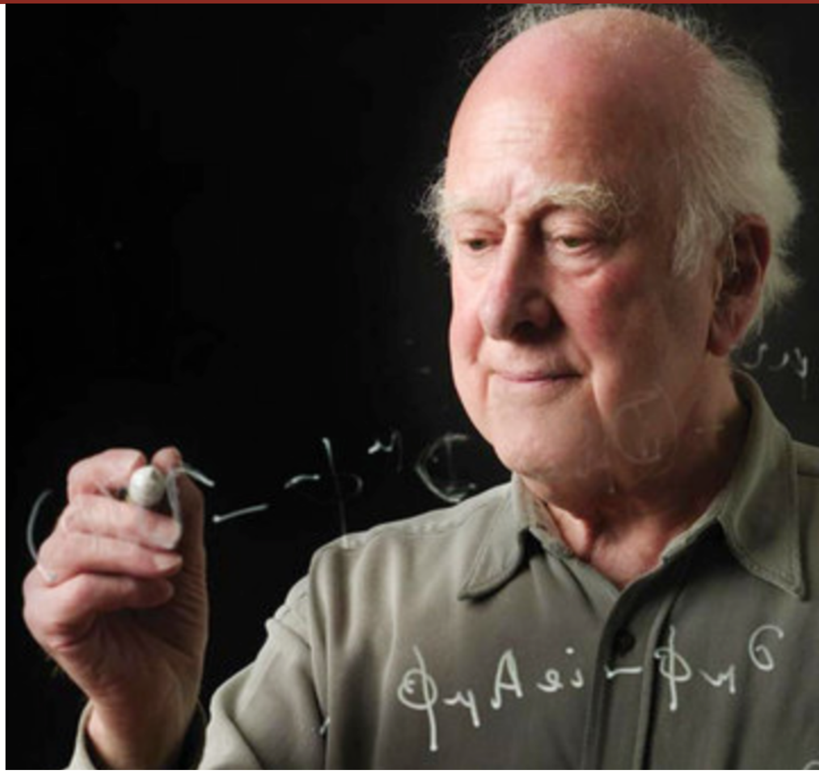
HL-LHC will allow for stringent tests of the $B^0_s \to \mu\mu$ and to observe the $B^0 \to \mu\mu$.

Excellent performance of the trigger and tracker is essential to the success of the program

FTR-13-022-pas

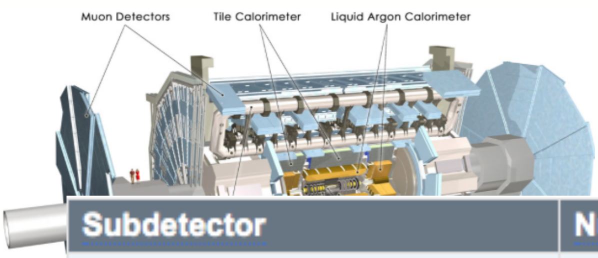
Summary and Outlook

- The LHC, ATLAS, and CMS exhibit a superb performance in Run 1
- One of the prime goals of the LHC, *i.e.* the discovery of a Higgs boson, has been achieved!
- The experiments are probing the TeV scale in searches for New Phenomena
- The High Luminosity upgrade is foreseen to extend from 300 to 3000/fb the dataset collected by the experiments at 14TeV
  - expected good detector performance despite the challenging conditions
- The High-Luminosity LHC will significantly improve the measurements of Higgs properties and will thus represent an excellent probe for high scale New Physics
- The High-Luminosity LHC extends the discovery reach of theoretically motivated scenarios e.g. low scale natural SUSY



Additional Material

ATLAS and CMS at the LHC



Operational fraction > 95%

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	95.0%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.9%
Tile calorimeter	9800	98.3%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	370 k	100%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	96.0%
RPC Barrel Muon Chambers	370 k	97.1%
TGC Endcap Muon Chambers	320 k	98.2%

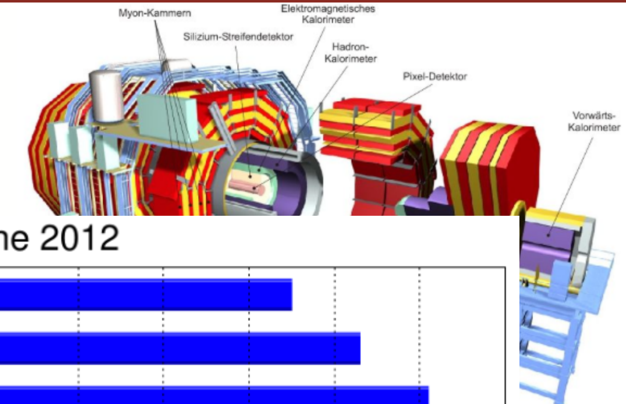
ATLAS p-p run: April-December 2012

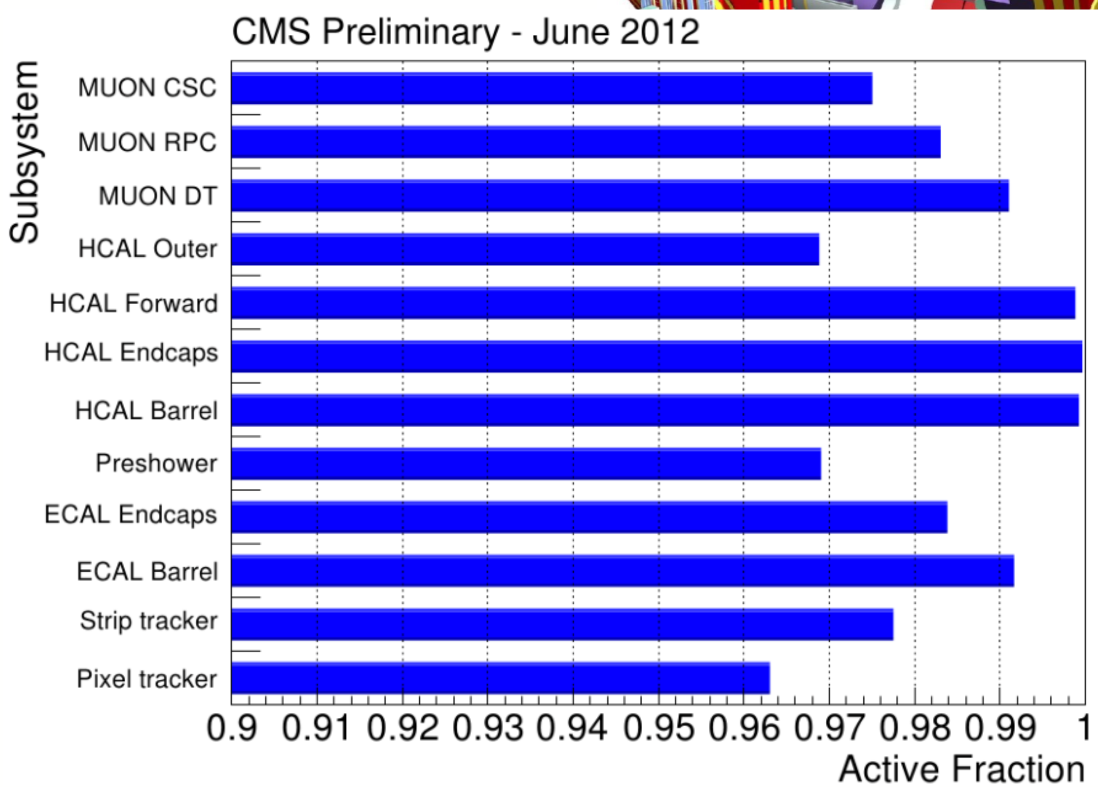
Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.1	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5

All good for physics: 95.5%

Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at √s=8 TeV between April 4th and December 6th (in %) – corresponding to 21.3 fb^{-1} of recorded data.

Good for physics > 98%





Operational fraction > 96%

- Excellent performance of both the ATLAS and CMS detectors
  - including trigger, data processing, data handling and distributions, reconstruction, simulation,….

CMS Upgrade

Courtesy of M. Klute

Baseline Upgrade Proposal

Muon System
- new DT FE electronics, CSC FEBs in inner rings
- extended η region (GEM & iRPC)
- investigate Muon-tagging up to η ~ 3

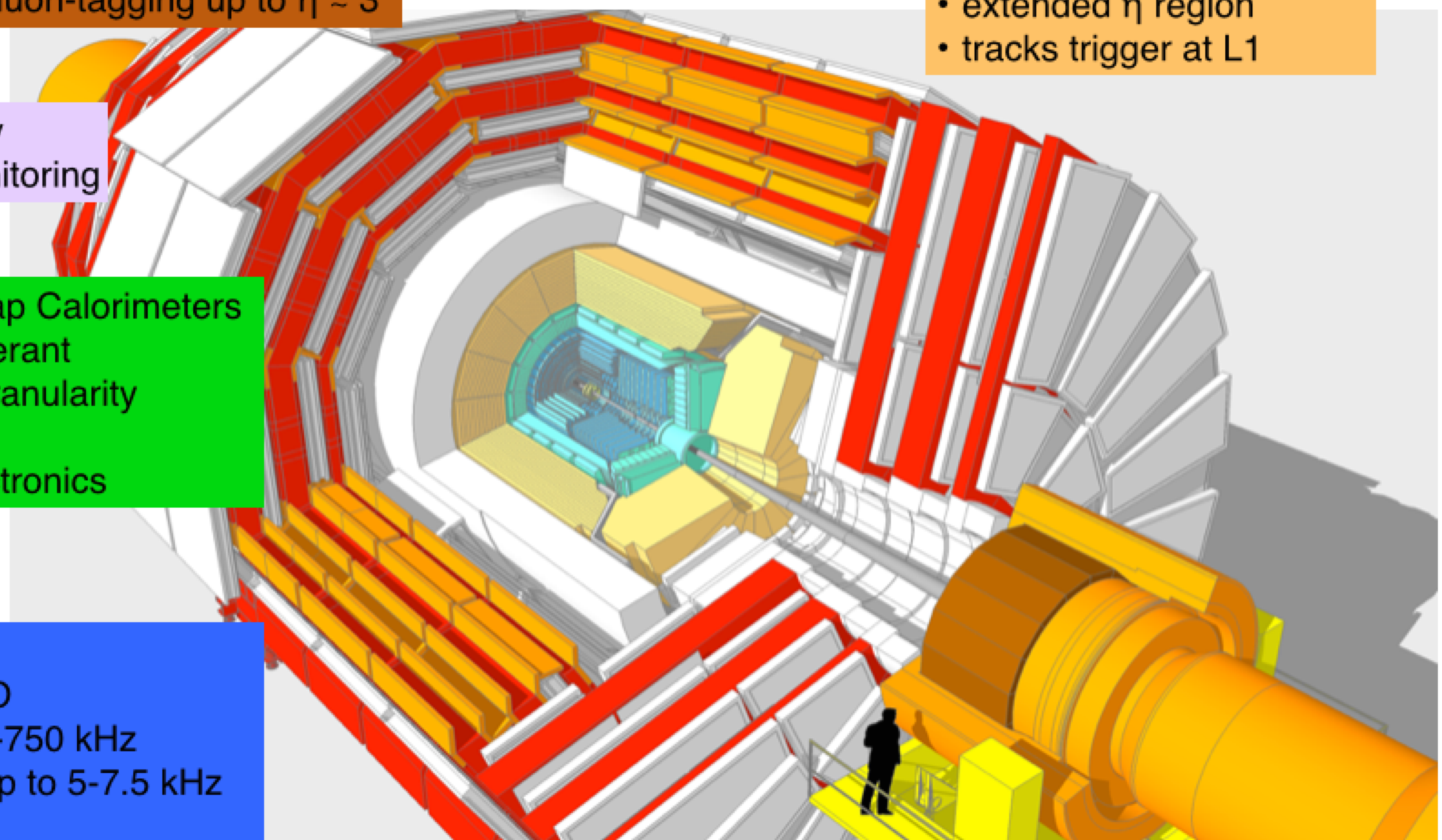
Tracker
- higher granularity
- less material
- better p_T resolution
- extended η region
- tracks trigger at L1

New luminosity and beam monitoring

Replace Endcap Calorimeters
- radiation tolerant
- increased granularity

Barrel ECAL
- new FE electronics

Trigger/DAQ
- new FE & RO
- L1 up to 500-750 kHz
- HLT output up to 5-7.5 kHz
- tracking @L1



ATLAS Upgrade

Courtesy of I. Gregor

Phase I

Selection of upgrades:

- Fast TracKing (FTK) input to HLT (already started)
- New Small Wheel (NSW) for the forward Muon Spectrometer
- Finer granularity LAr data to Level-1
- TDAQ Upgrades to Level-1/HLT
- Additional forward proton system (AFP)

Phase 2

Selection of upgrades:

- All new Inner Tracking Detector
- Introduction Level 0/1 trigger
- Level-1 track trigger
- Calorimeter electronics upgrades
- Upgrade muon trigger system and electronics
- DAQ upgrade
- Enhancements to high-eta region

Phase 2 ATLAS Trigger Upgrade

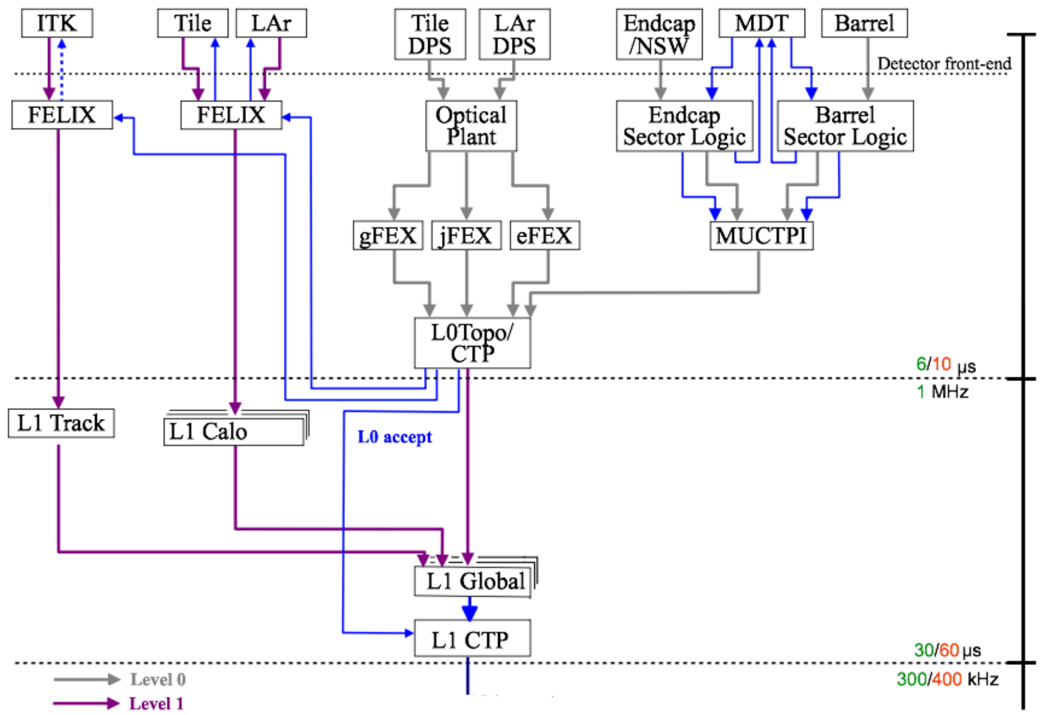
Courtesy of I. Gregor

Trigger system architecture

- New design for Phase-2
  - 2-level system, Phase-1 Level-1 becomes in Phase-2 L0; new L1 includes tracking
  - Make use of improvements made in Phase-1 (NSW, L1Calo) in L0
  - Introduce precision muon and inner tracking information in L1
    - Better muon p_T resolution
    - Track matching for electrons,…
  - An upgrade of the FE trigger processing will be required.

Will also have new timing/control links and LHC interface system

Level-0
Rate ~ 1 MHz, Lat. ~6 μs
Muon + Calo
Level-1
Rate 300-400 kHz, Lat. ~24 μs
Muon + Calo + Tracks



- Triggering sequence
  - L0 trigger (Calo/Muon) reduces rate within ~6 μs to 1 MHz and defines RoIs
  - L1 track trigger extracts tracking info inside RoIs from readout electronics

BSM Higgs: indirect and direct searches

- The combination of measurements from multiple production and decay channels used to probe for:
  - **composite Higgs models**
    - Pseudo-Nambu-Goldstone boson instead of elementary particle
    - couplings are modified with a scaling parameter $\xi = v^2/f^2$
  - **2 Higgs Doublets Model (e.g. SUSY)**

Model	300 fb^{-1}	
	All unc.	No theory unc.
MCHM4	620 GeV	810 GeV
MCHM5	780 GeV	950 GeV

	3000 fb^{-1}	
	All unc.	No theory unc.
	710 GeV	980 GeV
	1.0 TeV	1.2 TeV

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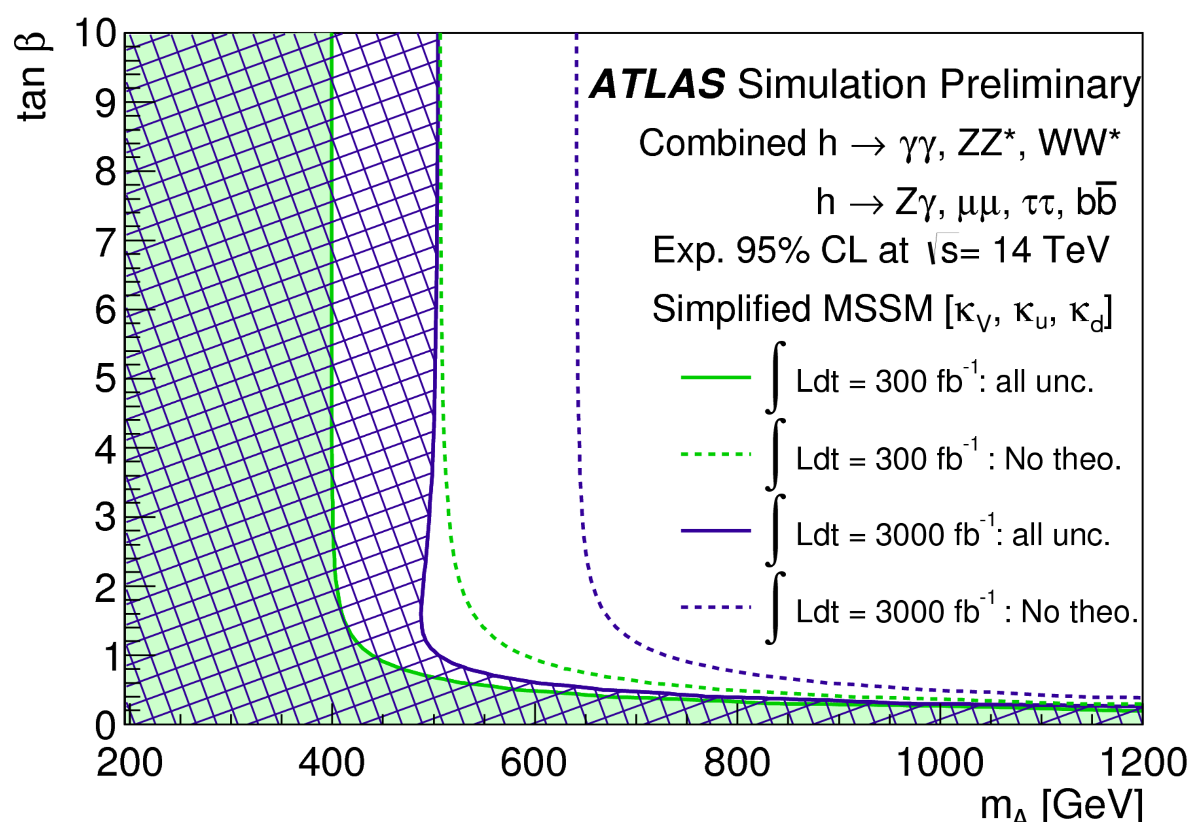

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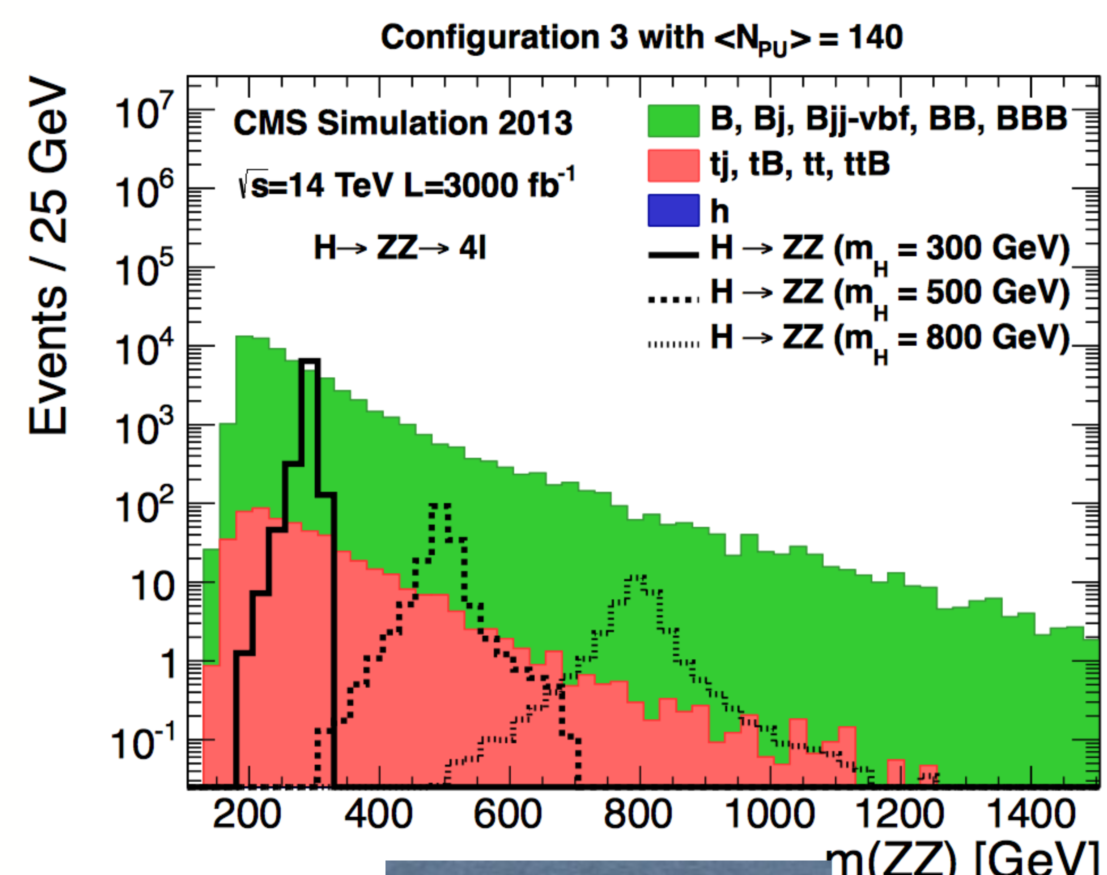

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