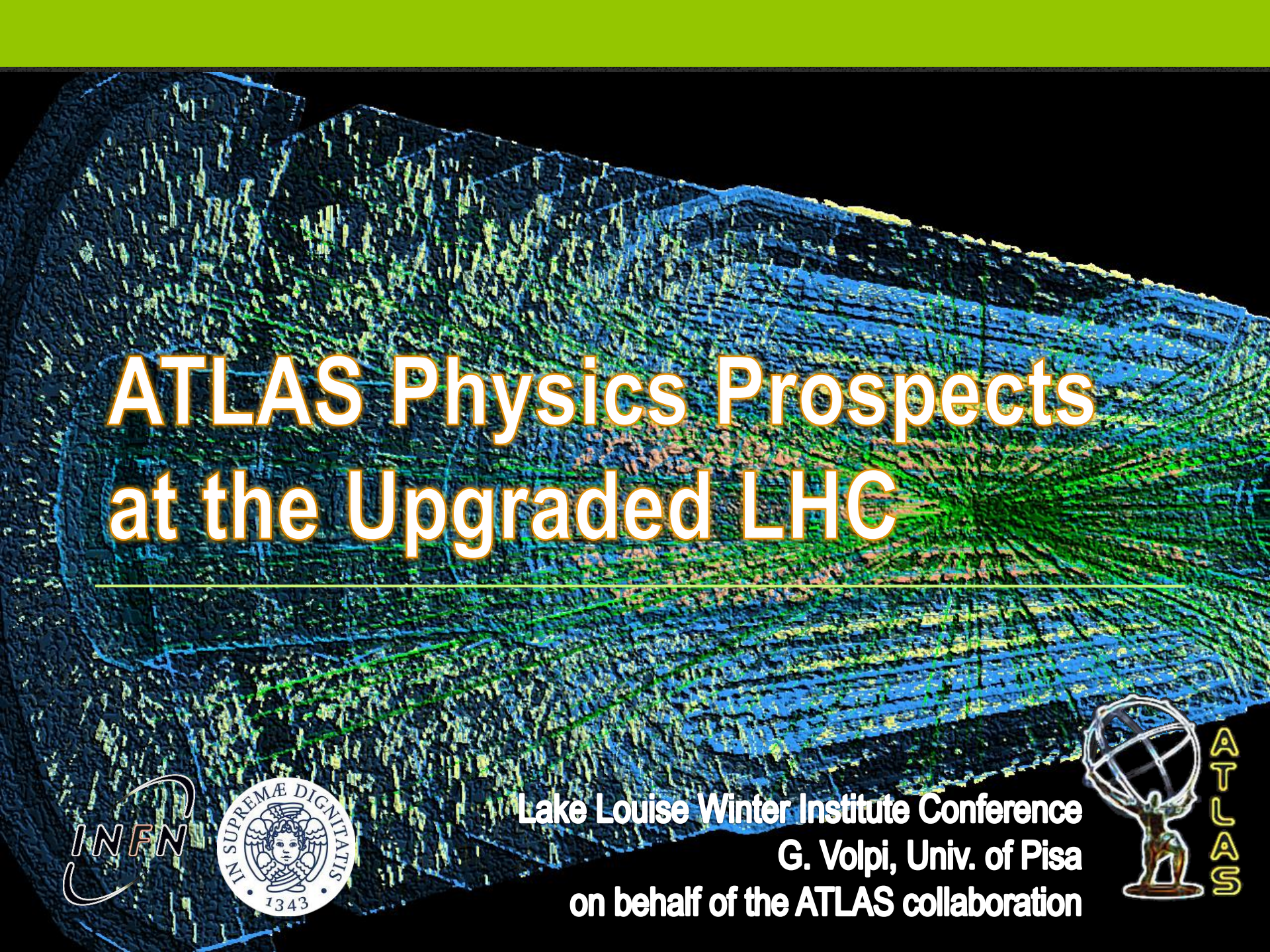


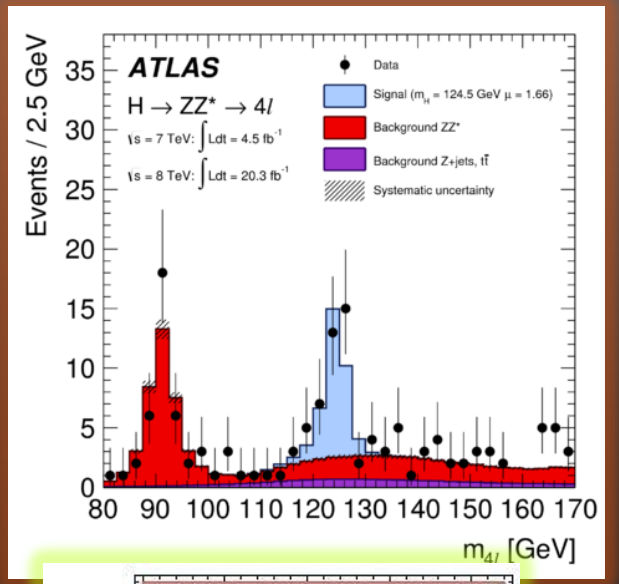
ATLAS Physics Prospects at the Upgraded LHC

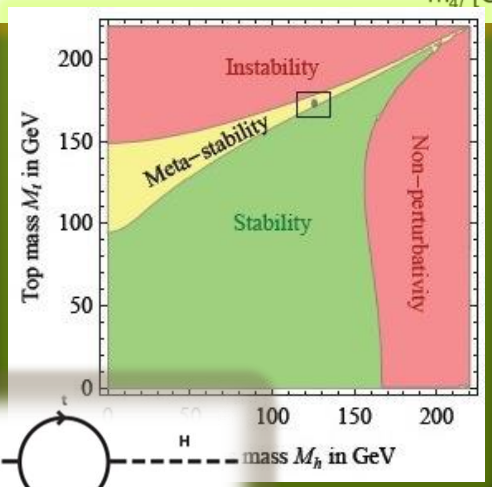
Lake Louise Winter Institute Conference
G. Volpi, Univ. of Pisa
on behalf of the ATLAS collaboration

Introduction

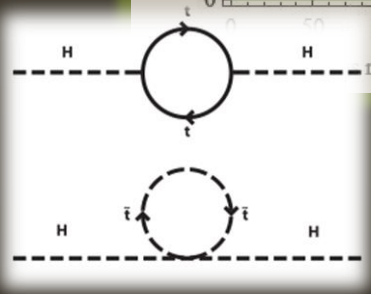
- ATLAS and the LHC achieved important results
  - Higgs boson discovery
  - Strong constraints on new physics phenomenon
- Still many questions remain unsolved
  - Dark matter candidate
  - Baryogenesis
  - Naturalness of the Higgs boson
- The next LHC runs will offer the opportunity to continue to explore the standard model
- On this talk I'll focus on the ATLAS evolution, physics prospect for the Higgs and beyond standard model measurements

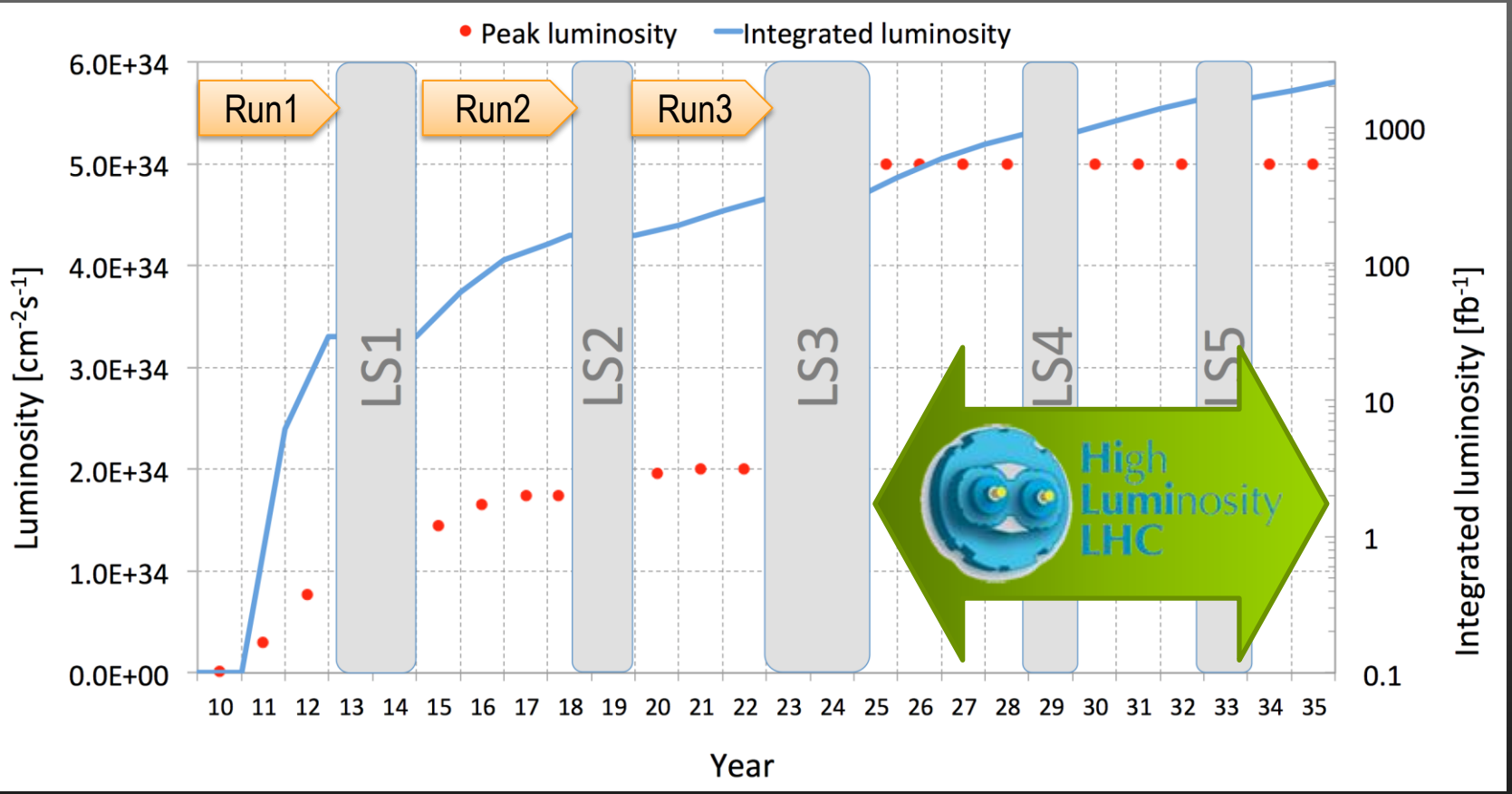
Phys. Rev. D 91, 012006 (2015)





arXiv:1205.6497





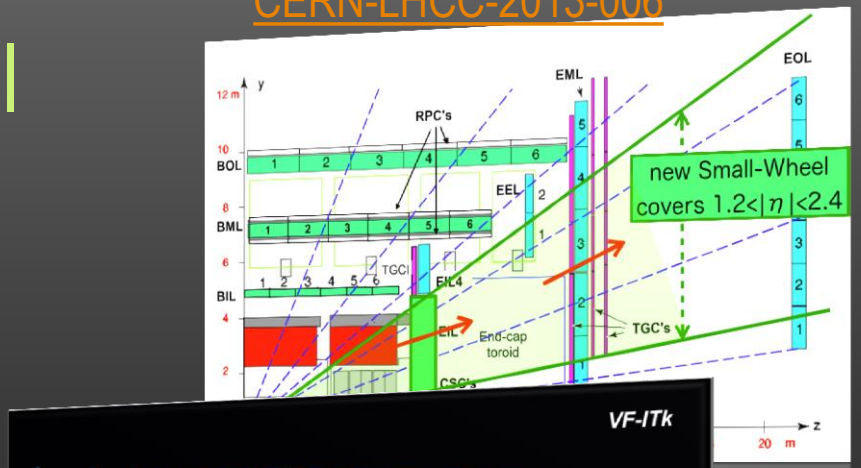
lhc-commissioning web-site

- LHC has brought 7-8 TeV collisions, 50 ns bunch crossing, about 20 overlapping collisions (pileup)
- LS1 consolidations will allow 13-14 TeV collision, 25 ns BC, nominal luminosity
- LS2 work will allow peak luminosities to reach 2-3x10^{34} $cm^{-2}s^{-1}$
  - 300 fb^{-1} expected for 2022
- LS3 will make the instantaneous luminosity grow to 5-7 times the nominal luminosity
  - Experiments are expected to collect up to 3000 fb^{-1} until 2035

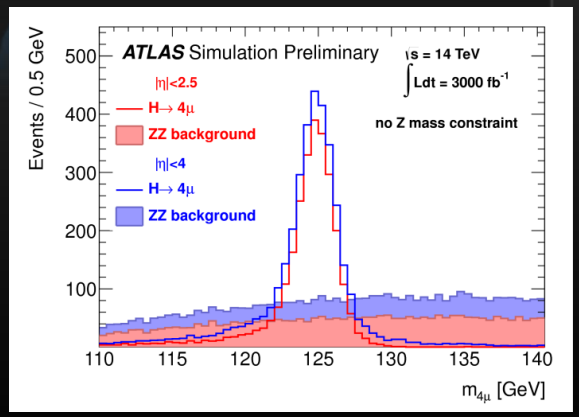
ATLAS Upgrades in a nutshell

- ATLAS plans upgrades to the detectors and the DAQ system
- During LS1 enhancements to the trigger and detector
  - Additional silicon layer (IBL)
  - New TDAQ computing architecture
  - Dedicated tracking processor (FTK)
- LS2 improvements to the muon trigger with the New Small Wheel
- LS3 the major improvements to the inner tracker
  - ITK will replace the current silicon and TRT tracker
  - Ability to reconstruct tracks at Level 1 and new TDAQ infrastructure
  - **Discussing the possibility to increase the eta coverage of the detector $|\eta| < 4$**

CERN-LHCC-2013-006

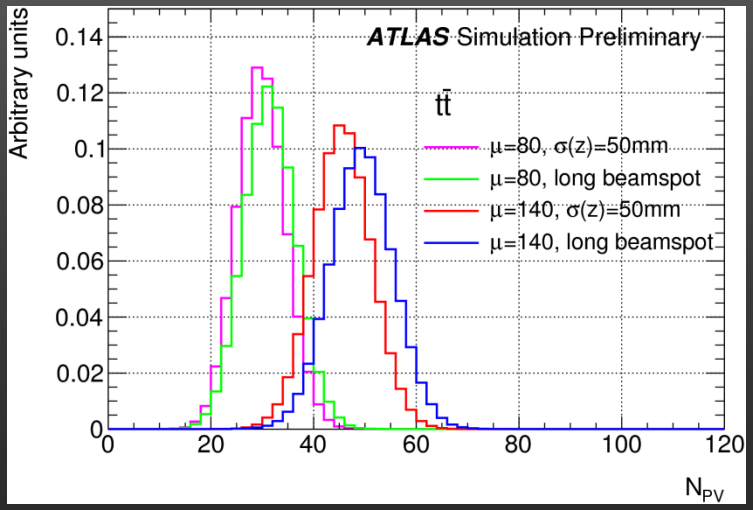


ITK Design

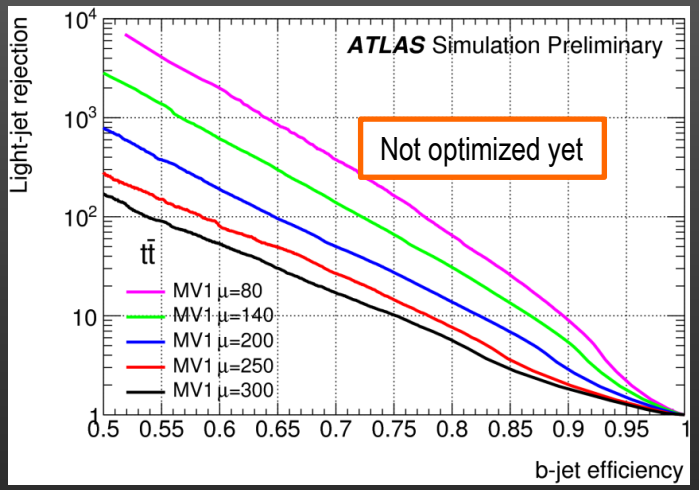


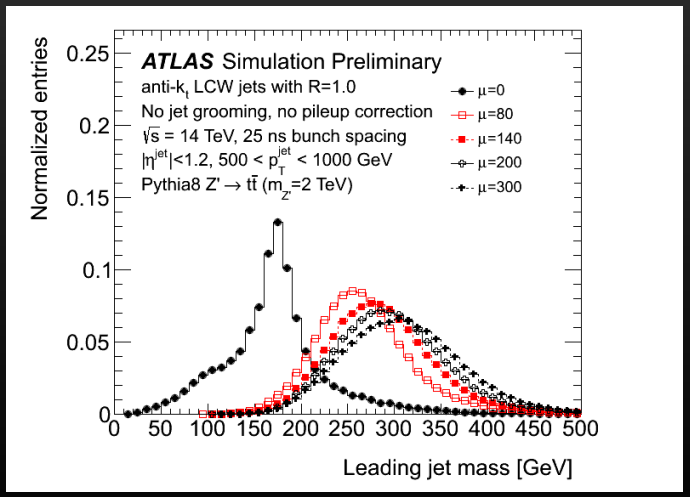
PLOT-UPGRADE-2014-002

Physics objects performance

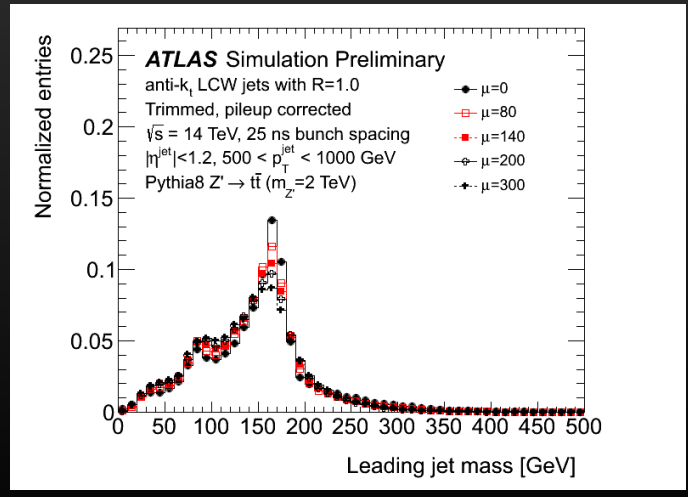


Vertexing and tracking related performance remain good in the various pileup and beam-spot conditions. (link)



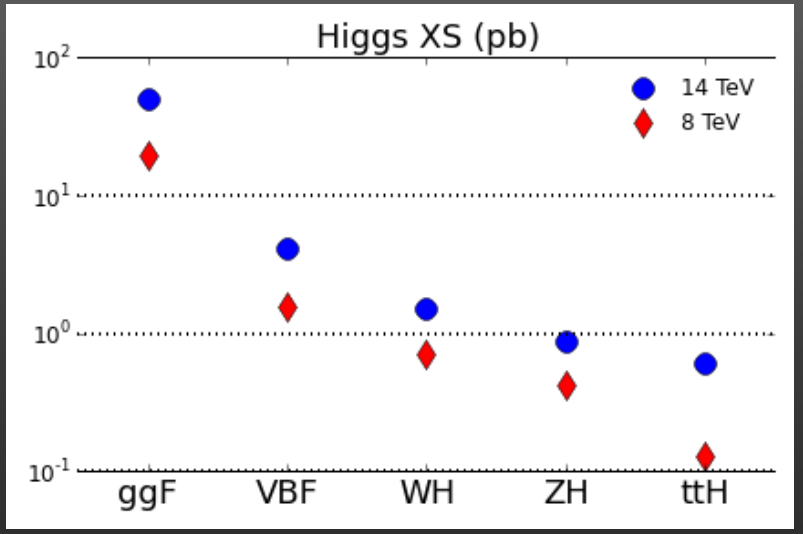


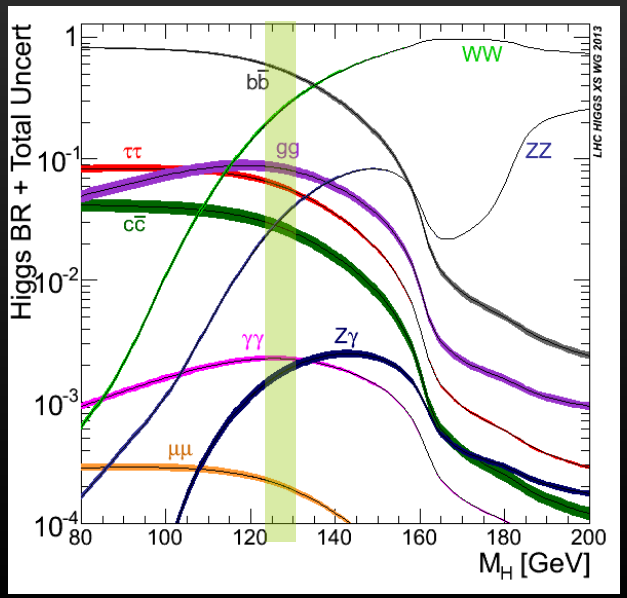
Efforts to mitigate pileup effects on jets.
Jet substructure can play a big role. (link)



HL-LHC as Higgs-factory

- The energy increase from 8 to 14 TeV will more than double the total cross section
  - ggF from 19 to 50 pb
  - ttH from 0.13 to 0.61 pb
- Large samples for all the relevant final states will be collected thanks to the high luminosity
- The most abundant channels will allow to perform precision measurements
- Possibility to explore rarer decay modes



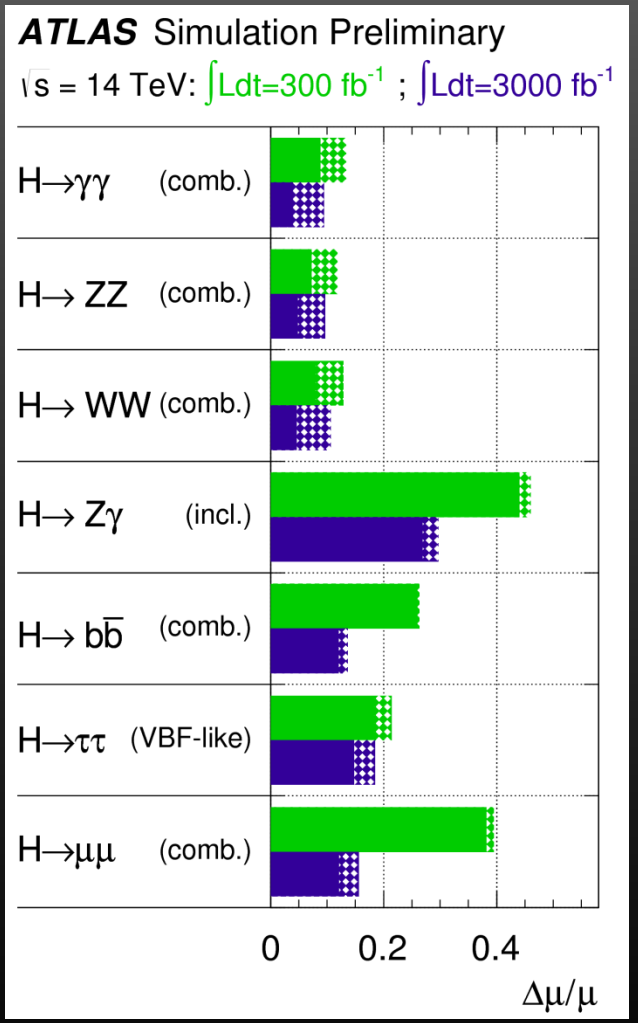


LHCHXSWG

Higgs decays prospects

- Most decays are studies through all production modes
  - H→WW doesn't include ttH
  - H→bb is only VH
- Most important modes include leptons in the final state
- Signal strength measured w.r.t. the standard model prediction
- Significance (Z) defined as excess of events w.r.t. bkg-only hypothesis

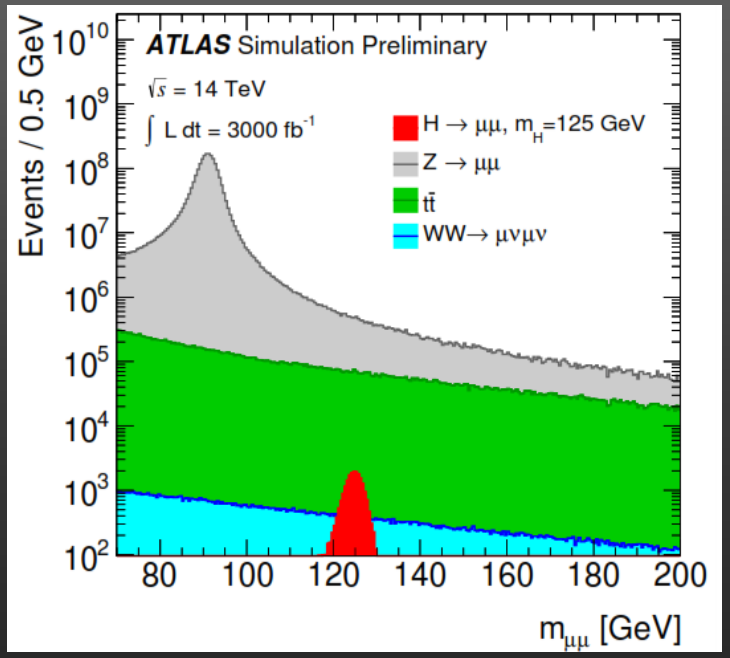
Process	Value	Now	300 fb-1	3000 fb-1
H->γγ	Δμ/μ	20%	13%	9%
H->ZZ		27%	11%	9%
H->WW		30%	13%	11%
H->ττ	Z	4.1 σ	6.9 σ	
	Δμ/μ	31%	21%	19%
H→bb	Z	-	3.9 σ	8.8 σ
	Δμ/μ	100%	26%	14%



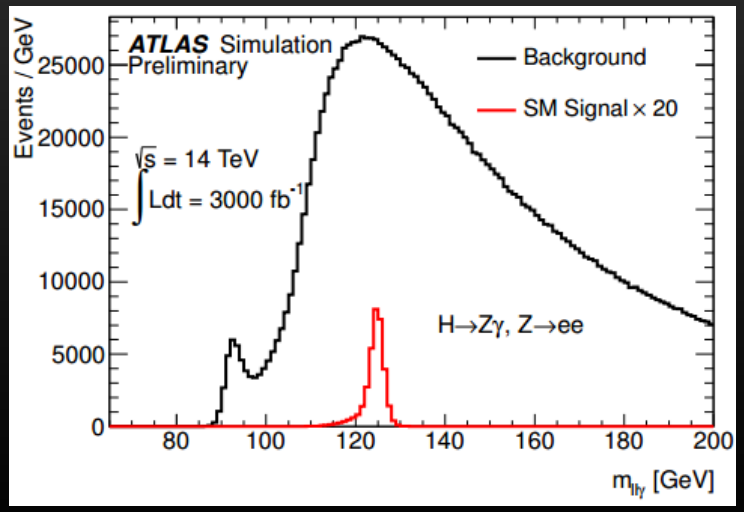
ATL-PHYS-PUB-2014-016

New Higgs measurements

- H→μμ can be observed in all the production modes
  - Clean measurements: peak over smooth background
  - Probe for the coupling to the 2nd generation fermions
  - Significance of 7σ and strength of 16% at 3000 fb^{-1} (2.3σ at 300 fb^{-1})
- H->Zγ detected through ggF and VBF
  - Sensitive to new particles in the loop
  - Significance of 3.9 σ and strength of 30% with 3000 fb^{-1} (2.3σ at 300 fb^{-1})



ATL-PHYS-PUB-2013-014

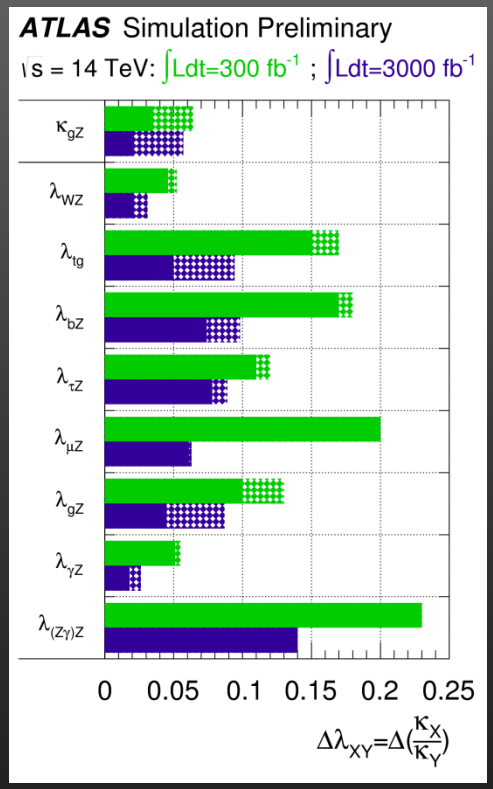


ATL-PHYS-PUB-2014-006

Higgs Couplings

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

- Single 125 GeV resonance, CP-even state
  - Tensor contributions ignored
- Prediction on minimal coupling hypothesis
- Prediction on the ratio between couplings sensitive to new particles in the loop



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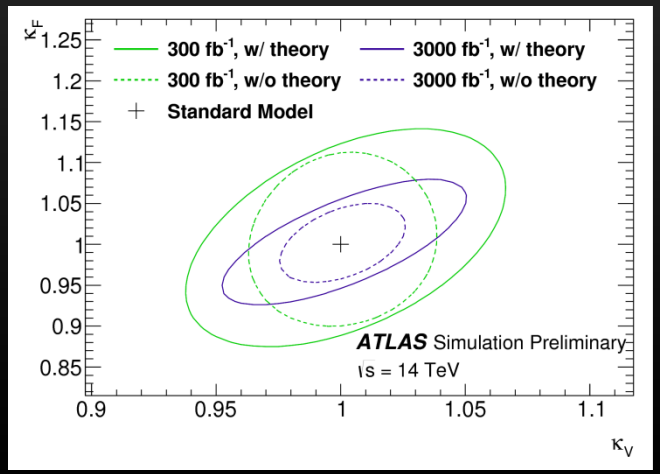
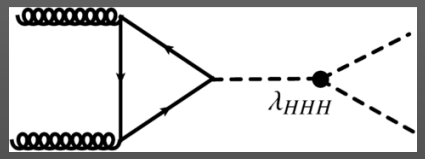
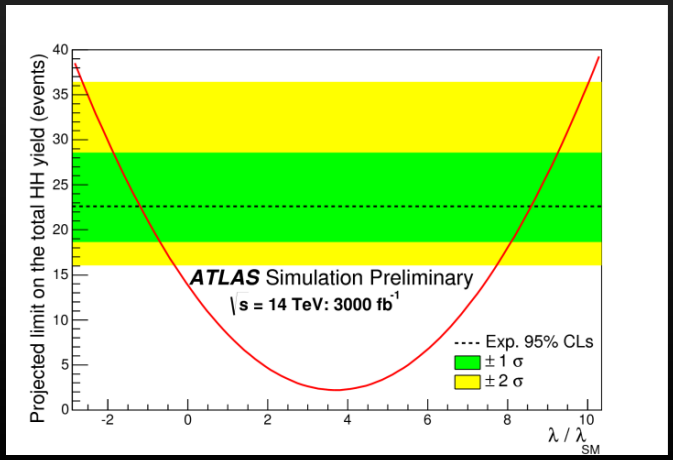
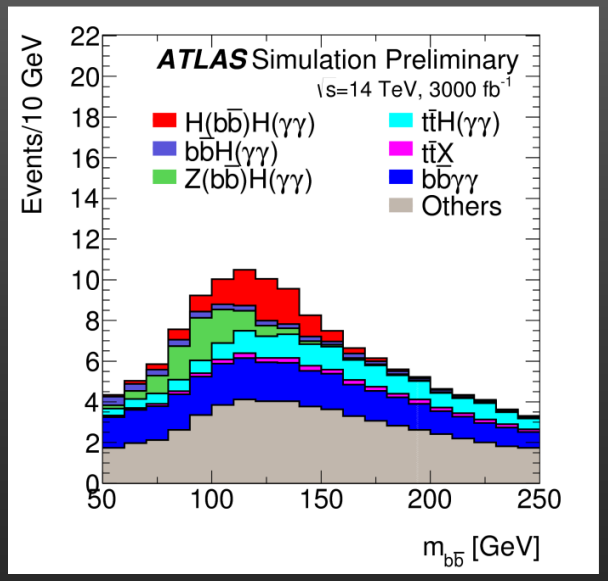


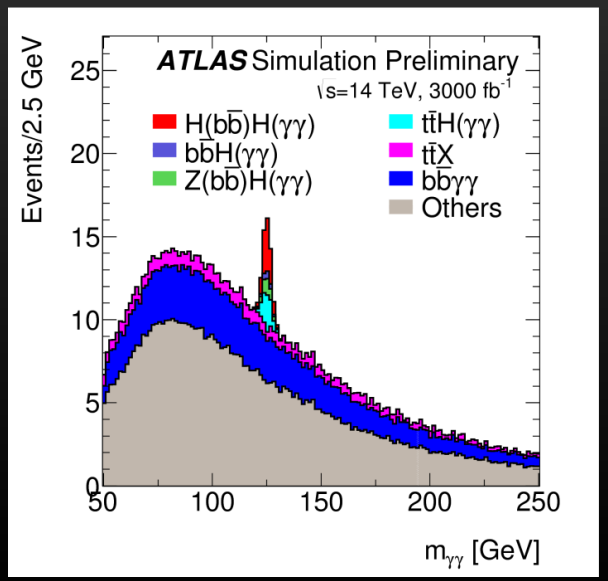


Search for HH production

- Higgs pair production allows direct measurement of the trilinear self-coupling λ_{HHH}
- Current extrapolation based on $HH \rightarrow \gamma\gamma b\bar{b}$ from ggF
- Expected significance 1.3 with 3000 fb-1
  - Possible to exclude BSM contribution with $\lambda/\lambda_{SM} \leq -1.3$ or $\lambda/\lambda_{SM} \geq 8.7$
- Improvements expected using MVA and combining other final states



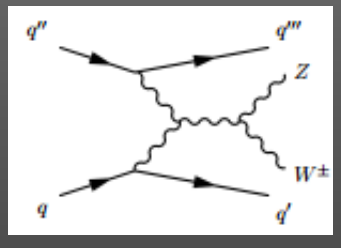


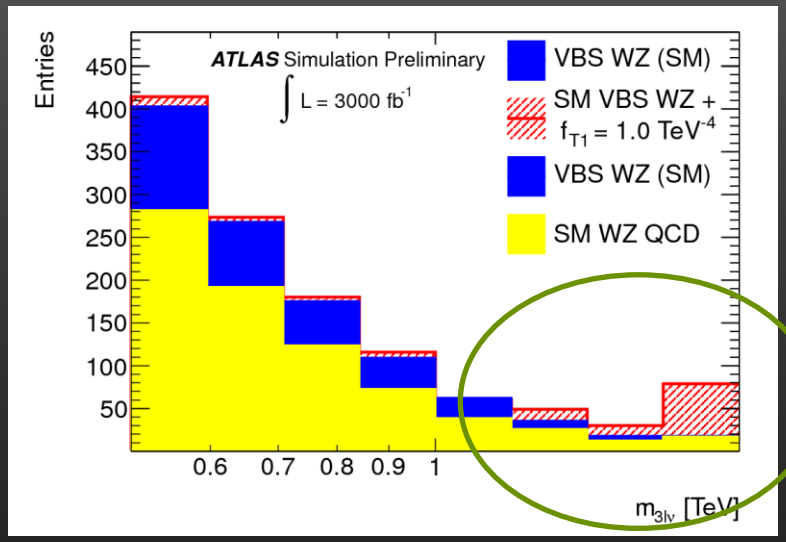


ATL-PHYS-PUB-2014-019

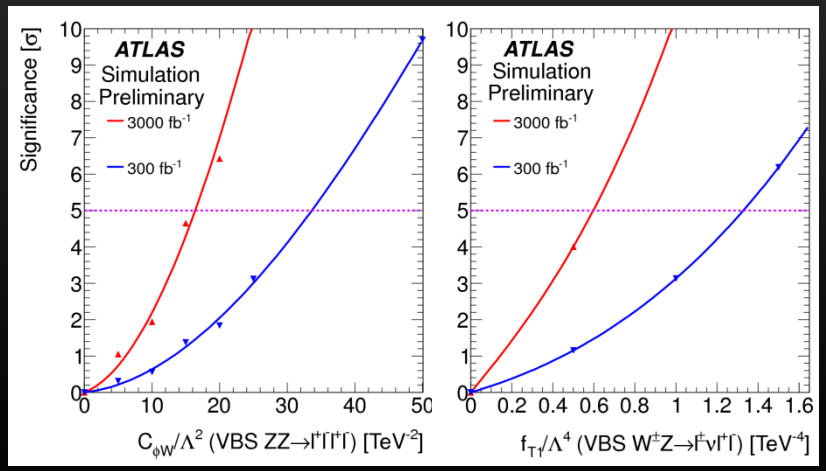
Vector Boson Scattering

- The SM prediction for the VBS are closely linked to the Higgs boson
- Selection similar to VBF Higgs search: **di-boson production and 2 forward jets**
- Predictions interpreted within an EFT approach
  - $C_{\phi W}/\Lambda^2$> 34 (16) TeV^{-2} for 300 (3000) fb^{-1} $ZZjj \rightarrow 4ljj$
  - f_{S0}/Λ^4> 10 (4.5) TeV^{-4} $W^{\pm}W^{\pm}jj \rightarrow l^{\pm}\nu l^{\pm}\nu jj$
  - f_{T1}/Λ^4> 1.3 (0.6) TeV^{-4} $W^{\pm}Zjj \rightarrow l^{\pm}\nu l^{\pm}l^{\mp}jj$
  - f_{T8}/Λ^4> 0.9 (0.4) TeV^{-4} $Z\gamma\gamma$
  - f_{T9}/Λ^4 > 2.0 (0.7) TeV^{-4} $Z\gamma\gamma$



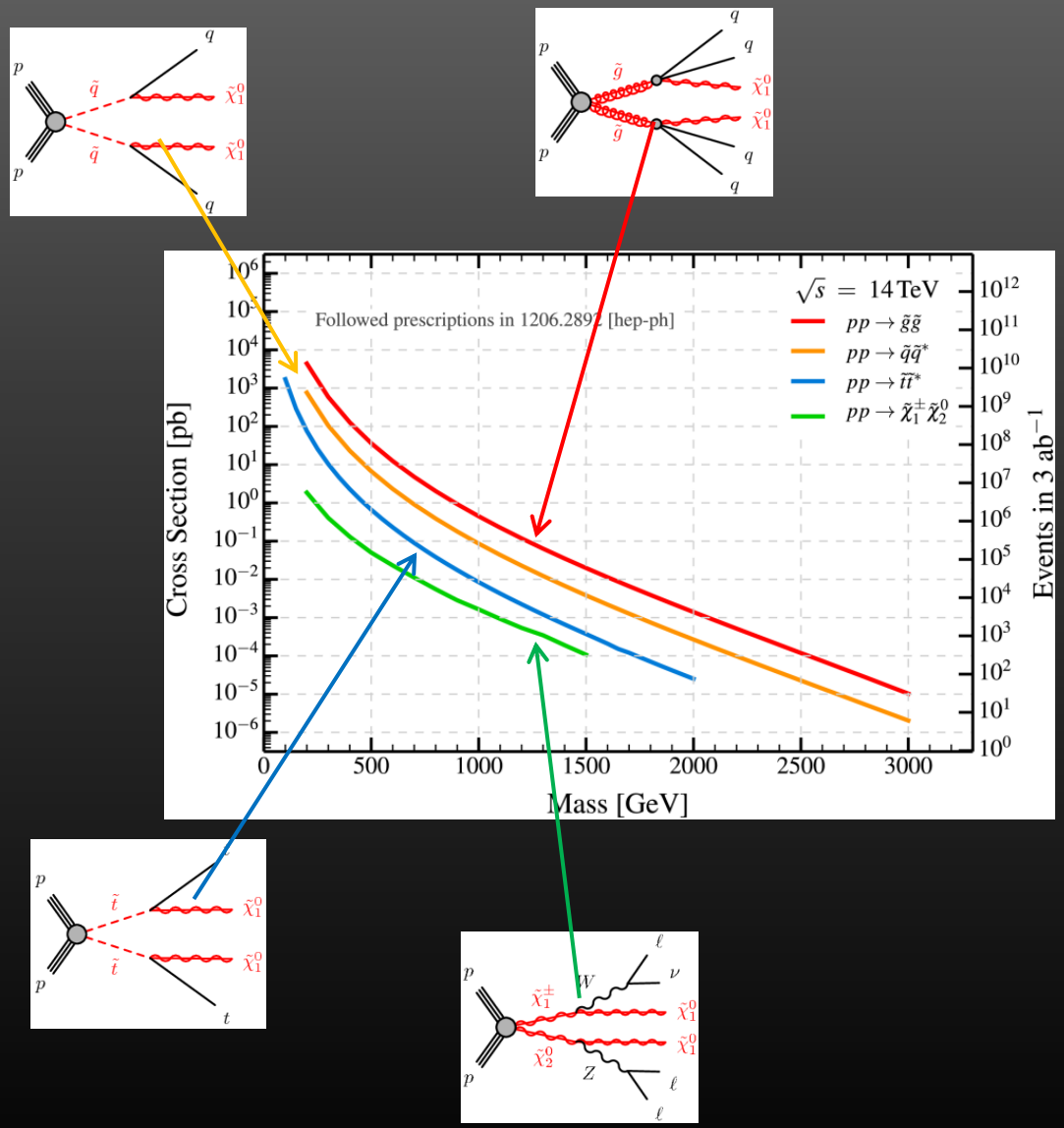


ATL-PHYS-PUB-2013-006

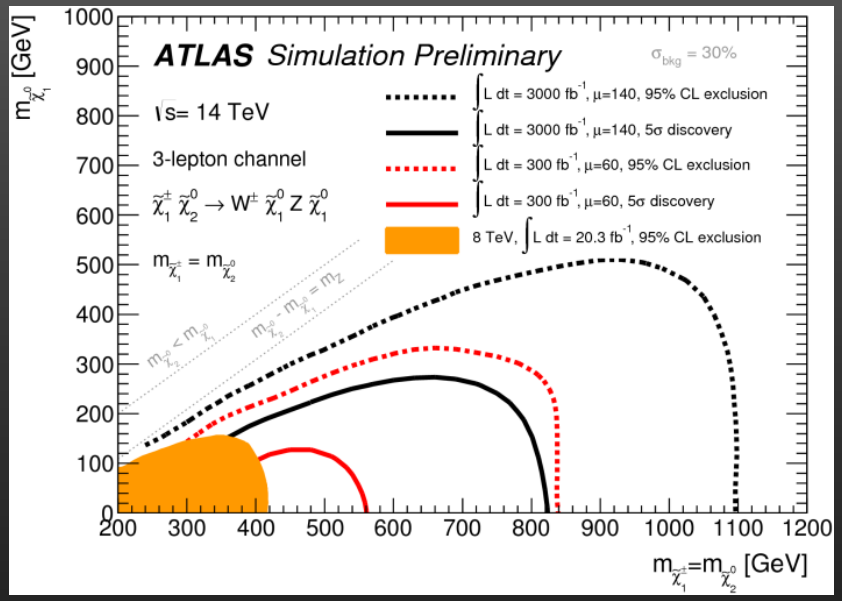


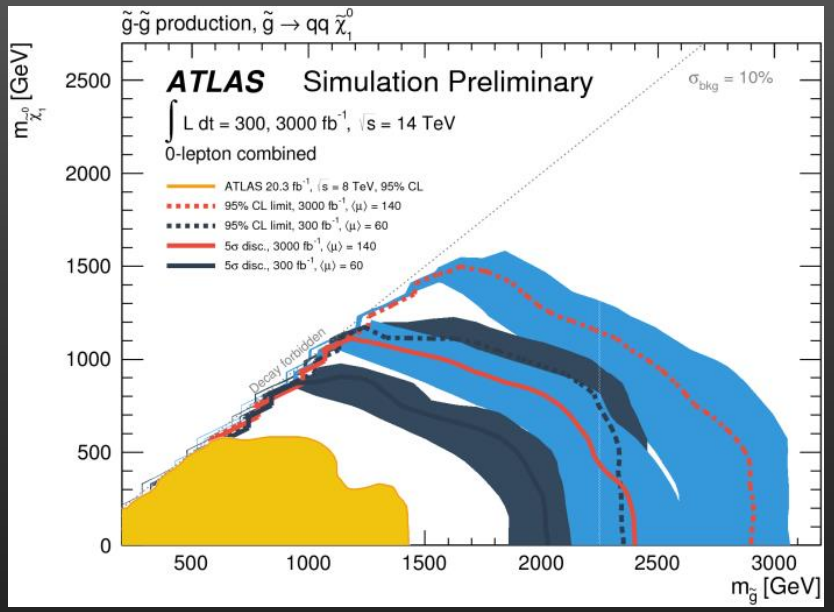
SUSY

- SUSY predicts a partner with spin ½ difference
- Has a natural mechanism that cancels Higgs mass divergence
- The model has a LSP (neutralino) under R-parity, good candidate for DM



SUSY expected results for 300 and 3000 fb^{-1}



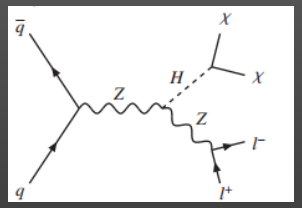


ATL-PHYS-PUB-2014-010

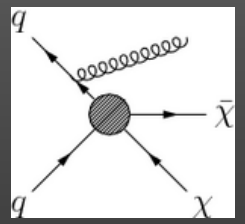
- Discovery of neutralino and chargino at 5 σ if mass below 560 (820) GeV at 300 (3000) fb^{-1}
  - Large exclusion ranges
- Current gluino limit (1.4 TeV) can be extended to 2.3 (3.0) TeV at 300 (3000) fb^{-1}
  - Discovery potential at 2.0 (2.3) TeV at 300 (3000) fb^{-1}

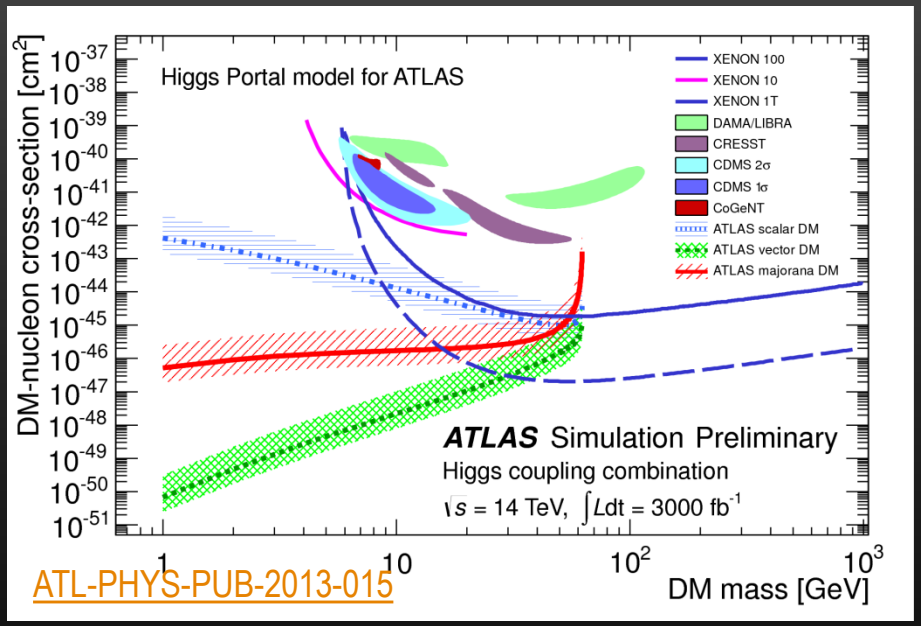
Dark Matter searches

DM search through ZH production

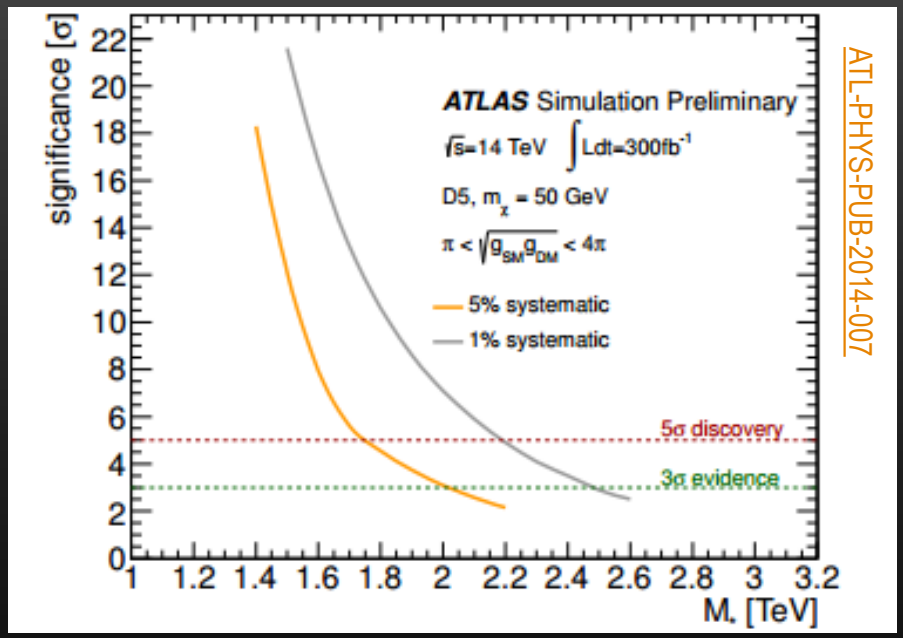


Contact interaction explored through mono-jet searches





Models where Higgs interact with DM particles make collider searches complementary to underground experiments.
Large exclusion regions are expected.



Mono-jet searches are also sensitive to DM.
Extrapolations interpreted within an EFT model.

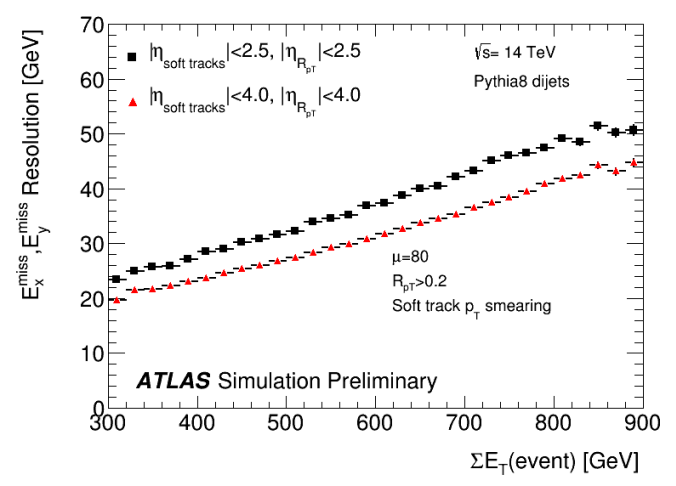
$$M^* = \frac{M_{med}}{\sqrt{g_{SM} g_{DM}}}$$

Conclusions

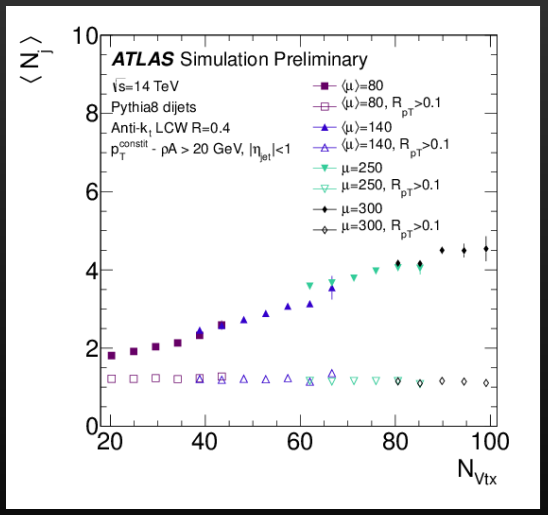
- Using the LHC data collected so far by the ATLAS experiment has been possible to reach important results
  - Higgs boson discovery, strong constraint on new physics models
- The coming runs promise more data and larger cross-section for all the relevant processes
  - The accelerator is expected to provide 10 times more data by 2022, 100 more data for 2035
  - Higgs production is expected between 2-4 times larger because the CoM energy increase
  - Increased sensitivity for heavier particles, predicted by many models
- The next runs will have important experimental challenge to take full benefit from the machine performance
  - The pileup will increase to a level of 140 for the HL-LHC
  - Mitigate the effect of the pileup is the major effort in the analysis preparation
  - New detectors and more modern infrastructure will be introduced during the scheduled shutdowns to improve the performance

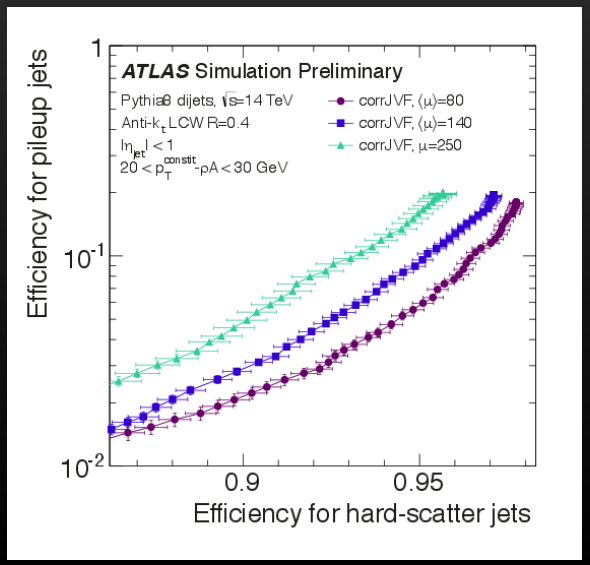
BACKUP

Jet reconstruction



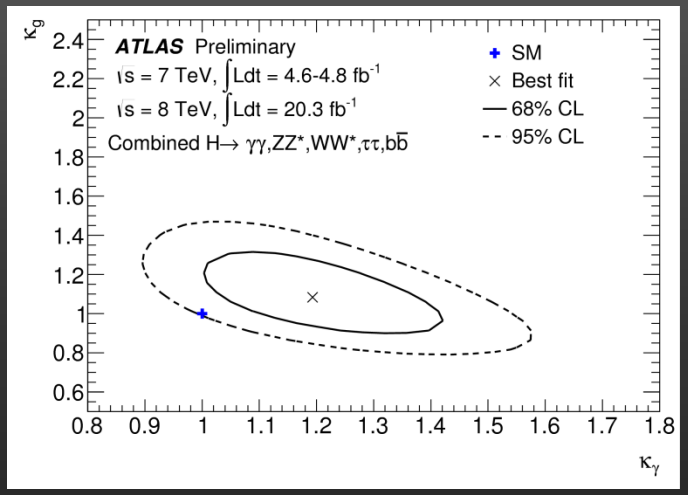
Further improvements can be achieved with the large eta extension (link)

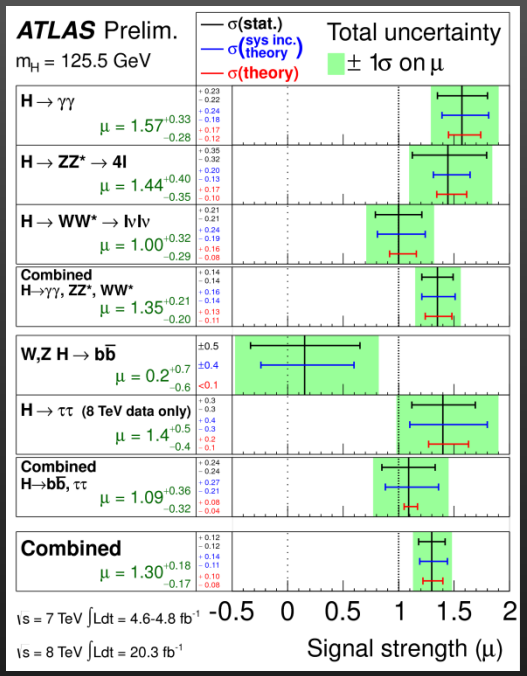


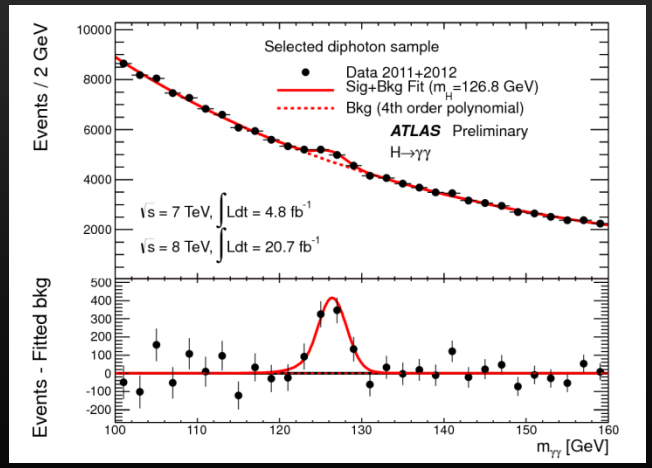


https://twiki.cern.ch/twiki/bin/view/AtlasPublic/PileupSuppressionECFA2014

Current Higgs results

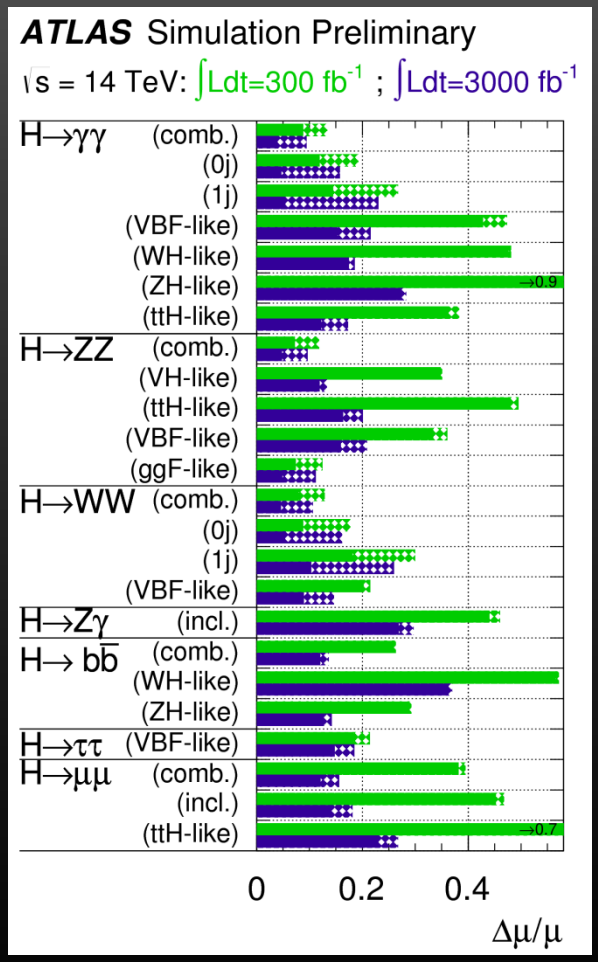


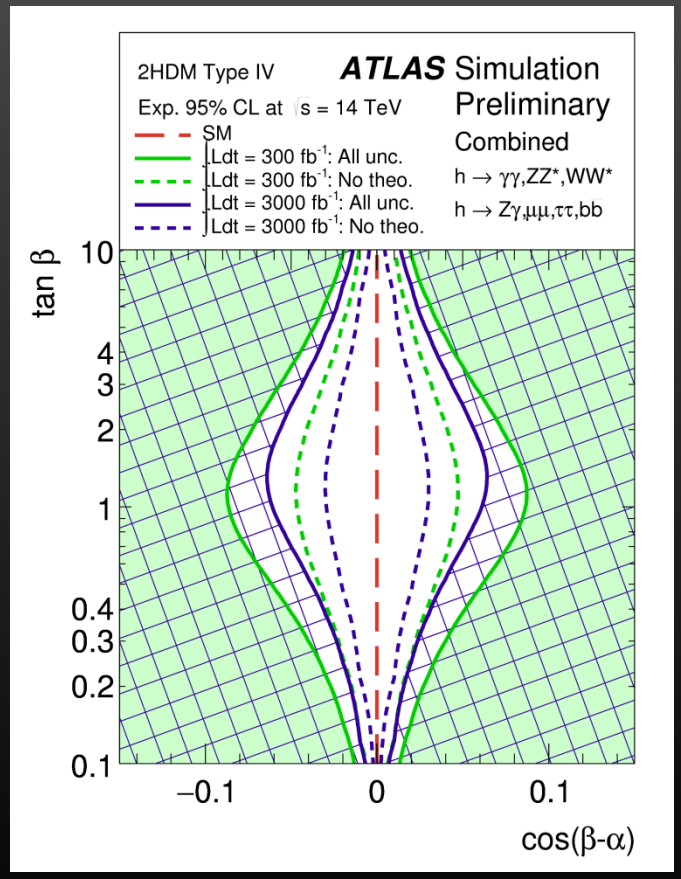




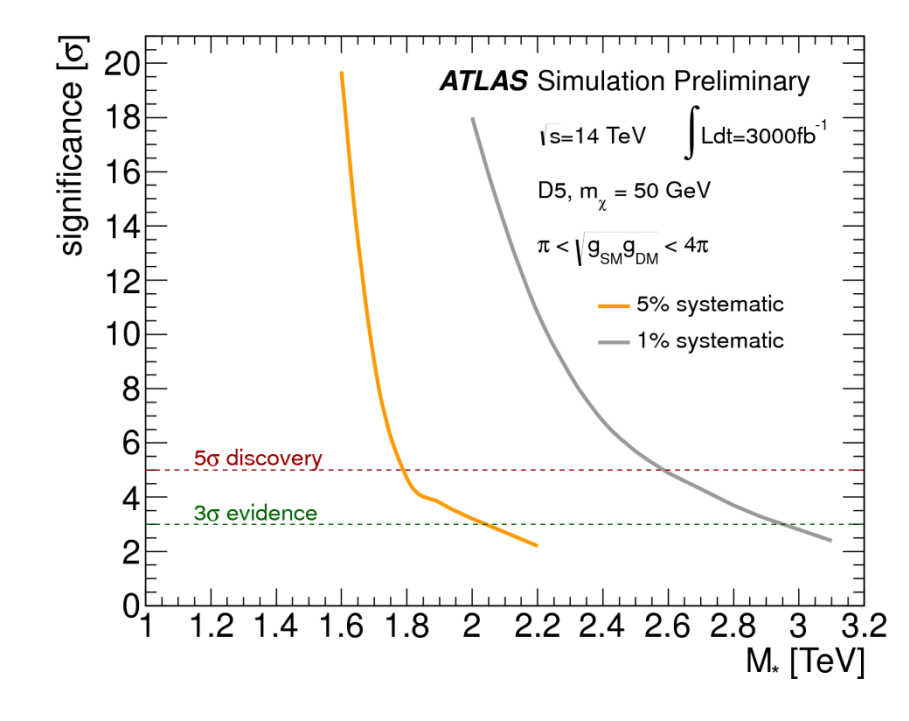
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/HiggsPublicResults

Higgs couplings and new phenomena





Mono-jet (2)


ATLAS Simulation Preliminary
√s=14 TeV ∫Ldt=3000fb-1
D5, mχ = 50 GeV
π < √gSMgDM < 4π
5% systematic
1% systematic
5σ discovery
3σ evidence
significance [σ]
M* [TeV]
0
2
4
6
8
10
12
14
16
18
20
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
3.2