

Preliminary ATLAS results on the HH channel

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Introduction

- ◆ Three channels and combination
 - $b\bar{b}b\bar{b}$ and $b\bar{b}\tau\tau$ extrapolated from Run-2
 - include +8% in b-tagging efficiency (Pixel ITk TDR)
 - dedicated $b\bar{b}\gamma\gamma$ analysis following studies done for the Phase-2 TDRs

- ◆ Use of the [latest HH cross-section \(link\)](#)
 - direct impact on significance with respect to the results in the Phase-2 TDRs

- ◆ **Systematic** uncertainties: following the common ATLAS prescriptions for the YR (eg theory systematics divided by 2)

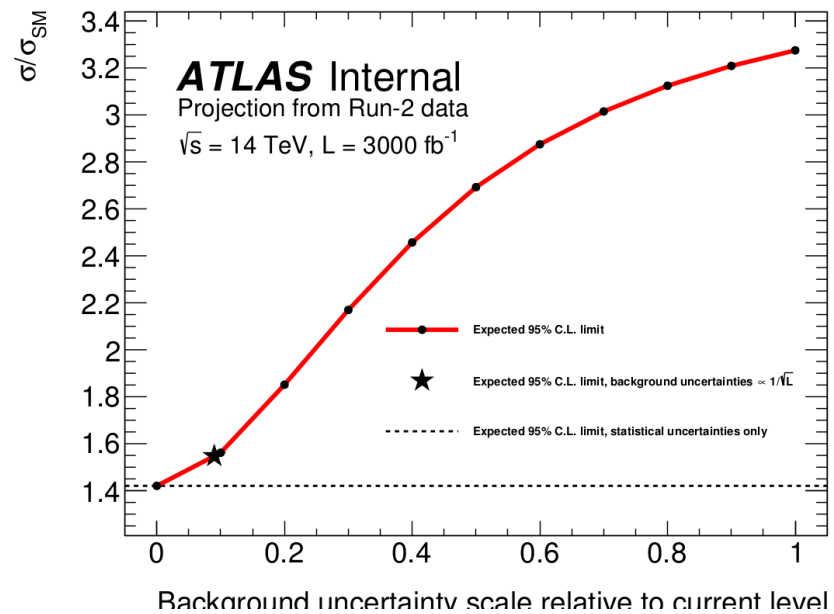
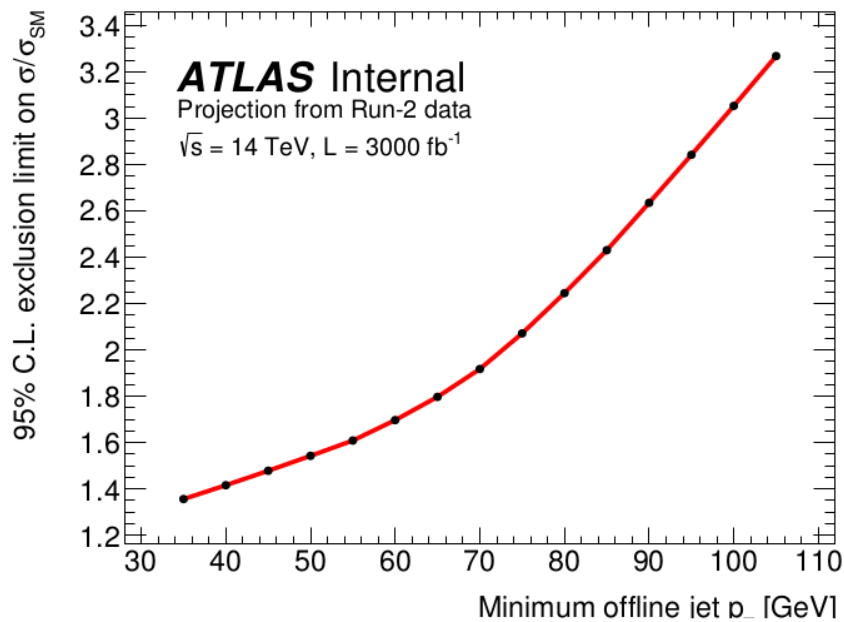
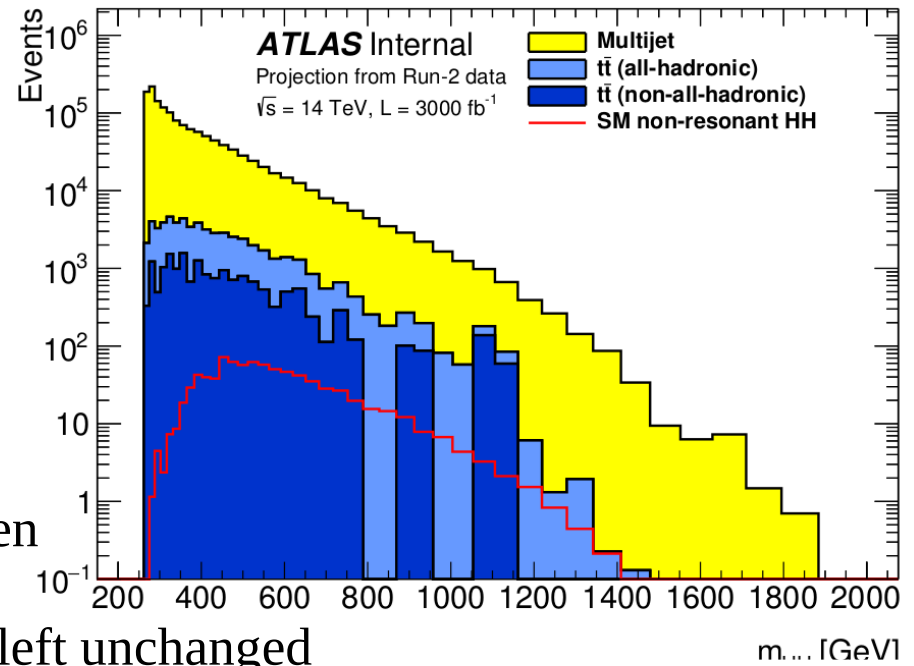
HH \rightarrow $b\bar{b}b\bar{b}$

◆ Extrapolation from Run-2 analysis

- fit of m_{4j} distribution
- $p_T^{\text{jet}} > 40$ GeV, **different thresholds** tested

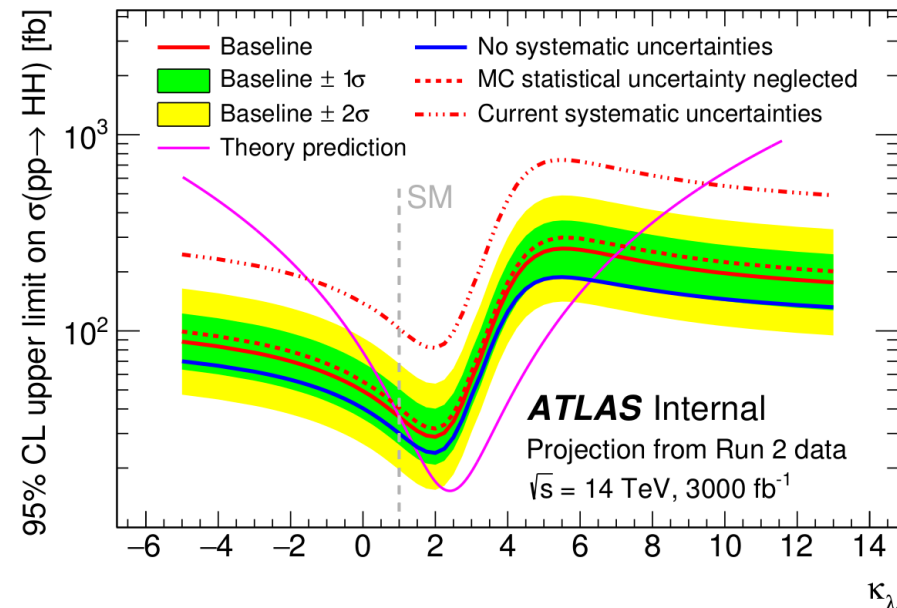
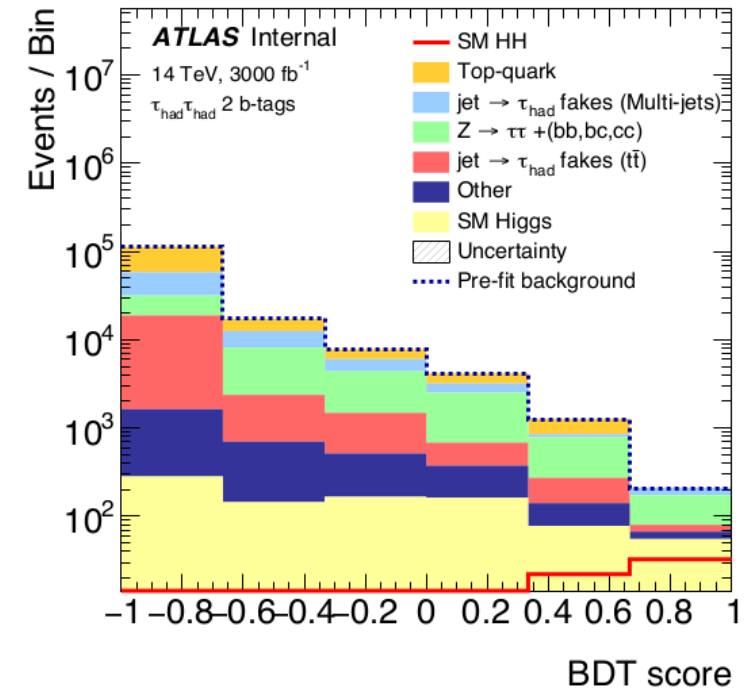
◆ Systematics

- *baseline*: Run-2 JER, b-tagging and luminosity syst, stat unc on the data-driven multijet model scaled to follow Poisson distribution, systematic uncertainties are left unchanged
- **different bkg uncertainty** assumptions tested:



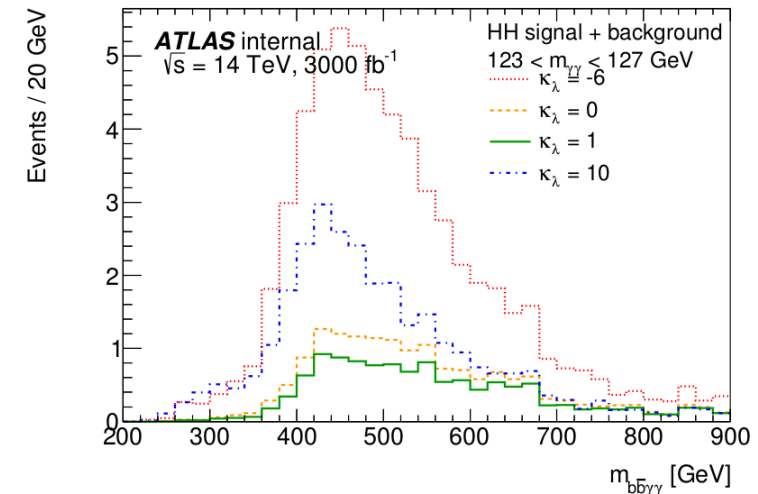
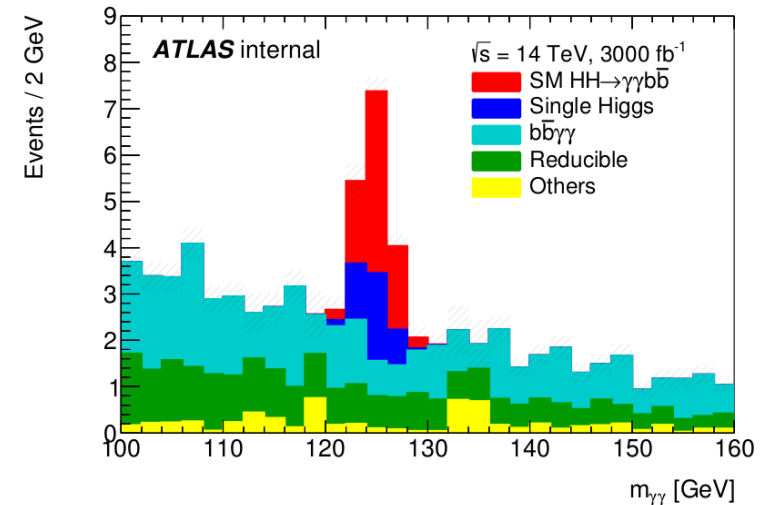
HH \rightarrow $b\bar{b}\tau\tau$

- ◆ **Extrapolation** from Run-2 analysis
- ◆ Three signal regions:
 - $\tau_{\text{lep}}\tau_{\text{had}}$ (Single Lepton Trigger)
 - $\tau_{\text{lep}}\tau_{\text{had}}$ (Lepton Tau Trigger)
 - $\tau_{\text{had}}\tau_{\text{had}}$ (Single Tau Trigger and Di-Tau Trigger)
- ◆ **BDT output** used as final discriminant
 - binning adapted to higher statistics
- ◆ Limit on κ_λ : LTT category not included and dedicated BDT trained on $\kappa_\lambda = 20$
- ◆ Systematics
 - *baseline*: 12% on $t\bar{t}$ and $Z+b\bar{b}$ scaled down with lumi, VH scaled to 5%, $t\bar{t}H$ to 10%, all cross-section uncertainties halved, MC stat uncertainty neglected, stat for data-driven bkg scaled to follow Poisson distribution
 - **different assumptions** for systematics tested



$HH \rightarrow b\bar{b}\gamma\gamma$

- ◆ **Dedicated** analysis with smearing functions: upgraded detector geometry and performance functions
 - $m_{\gamma\gamma}$ resolution $\sim 1,6$ GeV, photon efficiency ~ 60 -85%, b-tagging eff from Pixel TDR
- ◆ Dedicated **BDT** trained to remove continuum background and main single-Higgs background ($t\bar{t}H$)
- ◆ Limit on κ_λ : use of the $m_{b\bar{b}\gamma\gamma}$ distribution for events with $123 < m_{\gamma\gamma} < 127$ GeV
- ◆ Systematics
 - *baseline*: cross-section uncertainties halved (in particular the 100% unc on ggF), egamma performance maintained, scale factors for jet unc
 - very **small impact** of systematics in general





Results and hypotheses

◆ Expected **significance** with and without systematics

– for $\kappa_\lambda = 1$:

Channel	Statistical-only		All Systematics	
	p_0	Significance	p_0	Significance
$HH \rightarrow b\bar{b}b\bar{b}$	0.0825	1.39	0.271	0.609
$HH \rightarrow b\bar{b}\tau\tau$	0.00686	2.46	0.0164	2.13
$HH \rightarrow b\bar{b}\gamma\gamma$	0.0180	2.10	0.0210	2.03
combined	0.000202	3.54	0.00197	3.02

– for κ_λ between -2 and 9

◆ Measurement of μ (SM signal injected):

◆ Maximum likelihood fits

– with and without systematics

– extract **limit on κ_λ** at 95% CL:

$$-0.4 \leq \kappa_\lambda \leq 7.3 \text{ with syst}$$

– extract **measurement of κ_λ** at 68% CL:

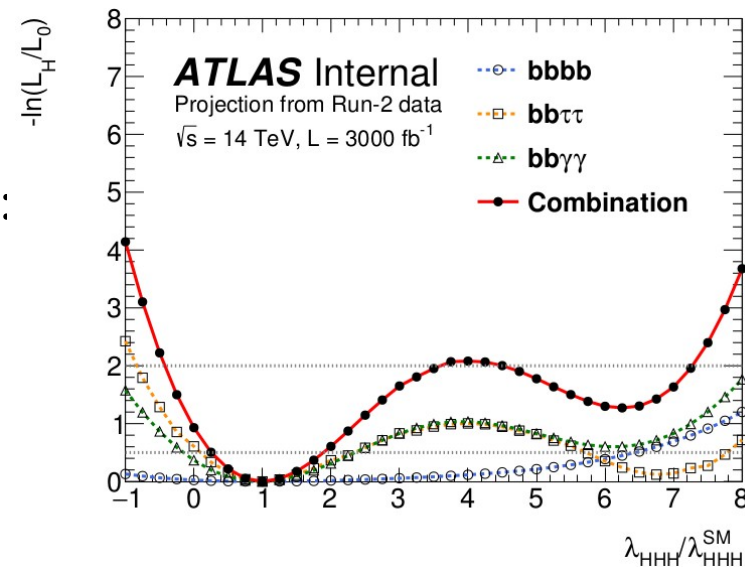
$$0.25 < \kappa_\lambda < 1.9 \text{ with syst}$$

– limit assuming $\kappa_\lambda = 0$

◆ Under discussion

– limit with $\sigma_{HH} = 0$ (as in Run-2)?

Channel	Measured μ (Statistical-only)	Measured μ (All Systematics)
$HH \rightarrow b\bar{b}b\bar{b}$	1.0 ± 0.6	1.0 ± 1.6
$HH \rightarrow b\bar{b}\tau\tau$	1.0 ± 0.4	1.0 ± 0.5
$HH \rightarrow b\bar{b}\gamma\gamma$	1.0 ± 0.6	1.0 ± 0.6
combined	1.00 ± 0.31	1.0 ± 0.4






- ◆ Analysis almost final
 - several ways to present the results under discussion
 - discussion with CMS last Friday
 - ATLAS PUB note under preparation
 - HE-LHC extrapolation: cf talk by M. Wielers

- ◆ YR status
 - preliminary short description in the current draft
 - more text will be written by the deadline, with numerical results to be added as soon as the PUB note is ready

Back-up



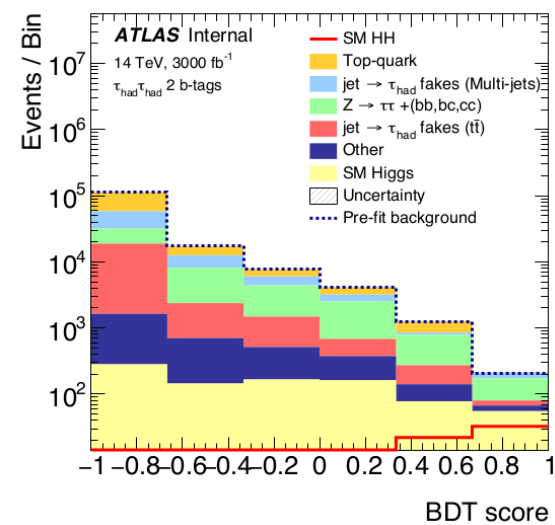
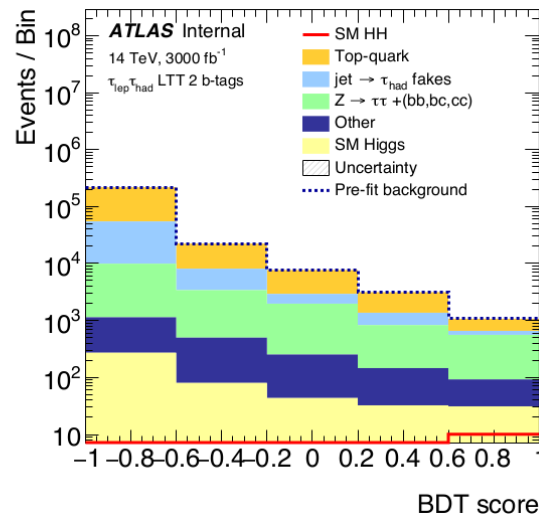
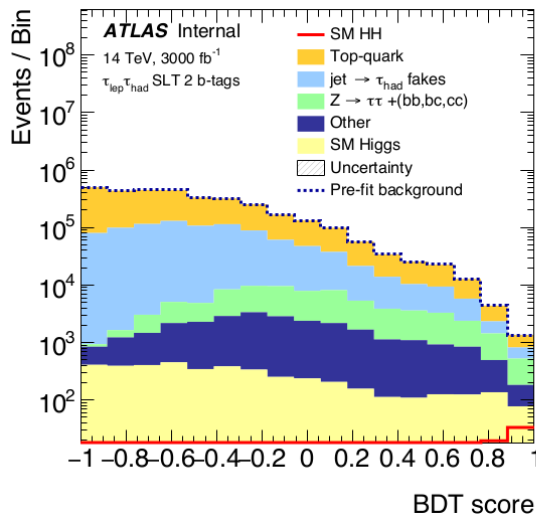
HH \rightarrow $b\bar{b}b\bar{b}$

- ◆ Extrapolation of the Run-2 publication: non-resonant di-Higgs using the “resolved” analysis method (not boosted, reconstruction of four b-jets)
 - same as previous PUB Note
- ◆ Event selection
 - four b-tagged $\Delta R=0.4$ jets ($p_T > 40\text{GeV}$, $|\eta| < 2.5$)
 - pair into two Higgs boson candidates
 - Higgs boson candidates satisfy requirements on p_T and $\Delta R(H,H)$
 - veto events with hadronic top candidates
 - masses of both Higgs boson candidates consistent with m_H
- ◆ Background estimation
 - dominated by multi-jet and $t\bar{t}$
 - difficult to model multi-jet background using MC simulation, using data-driven methods
- ◆ Fit m_{4j} spectrum

◆ Three signal regions:

- $\tau_{\text{lep}}\tau_{\text{had}}$ (Single Lepton Trigger)
- $\tau_{\text{lep}}\tau_{\text{had}}$ (Lepton Tau Trigger)
- $\tau_{\text{had}}\tau_{\text{had}}$ (Single Tau Trigger and Di-Tau Trigger)

◆ **BDT output** used as final discriminant



$HH \rightarrow b\bar{b}\gamma\gamma$

- ◆ Preselection: 2 photons and 2 b-jets
 - improved resolution from LAr TDR
 - improved b-tagging efficiency from Pixel ITk TDR
- ◆ Phase-2 TDRs: cut-based, new: BDT
- ◆ Use of $m_{b\bar{b}\gamma\gamma}$ to remove the degeneracy of the likelihood vs κ_λ :

