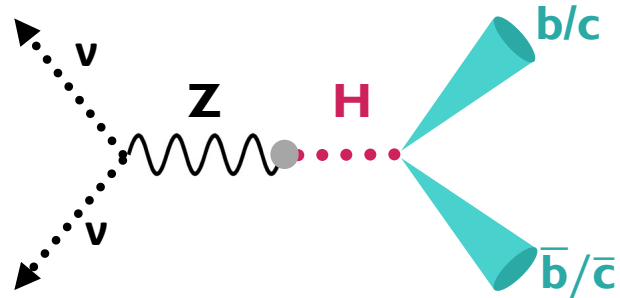# ATLAS Higgs activities for Snowmass

Maria Mironova for the ATLAS collaboration

Snowmass EF01 Working Group Meeting

Outline
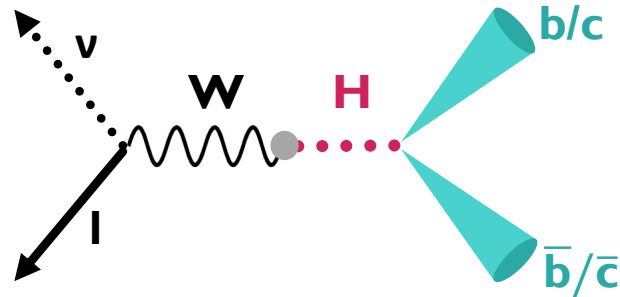
- **Summary of recent ATLAS Higgs physics activities for Snowmass**

- **Summary of VH(bb/cc) extrapolation [PUB note](#)**

- **Brief status update on Di-Higgs extrapolations for Snowmass**
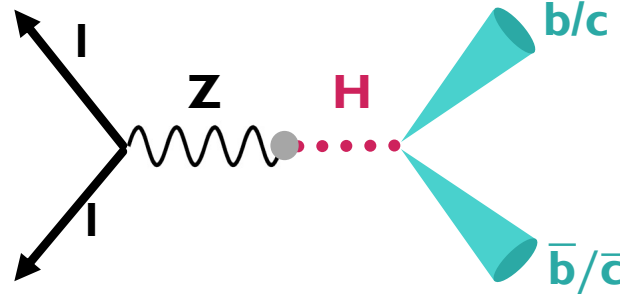
ATLAS VH(bb) and VH(cc) analysis

0 lepton

1 lepton

2 lepton

- Search in VH production
- Three lepton channels defined by decay of vector boson
- Split in several analysis categories by kinematics and flavour tagging
- Flavour tagging: use DL1 as a c-tagger, MV2c10 as b-tagger
- **VH(cc):** cut-based analysis, fit to m_{cc} of the two leading jets
- **VH(bb):** fit to BDT discriminant
- Extrapolation of VH(bb) and VH(cc) analyses, as well as VH(bb/cc) combination
- Consider increased luminosity and CoM energy
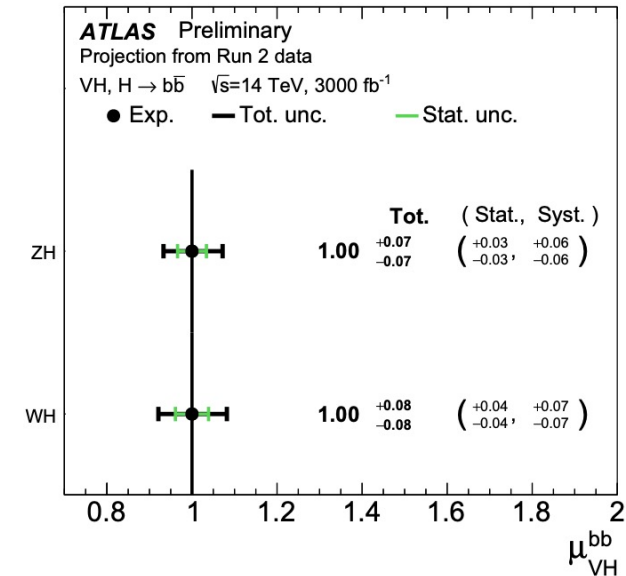- Reduce systematic uncertainties following expectations from CP groups

VH(bb) extrapolation

- Extrapolation based on <u>published</u> Run 2 VH(bb) analysis

Fit to WH(bb) and ZH(bb) signal strengths:

- **Uncertainties of 7% for ZH and 8% for WH**

- *Full Run 2 result: uncertainties of 25% for ZH and 26% for WH*

- Leading uncertainties: Signal modelling, followed by flavour tagging
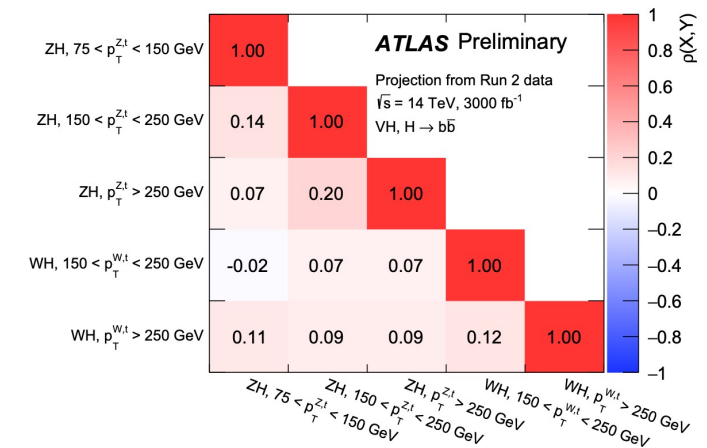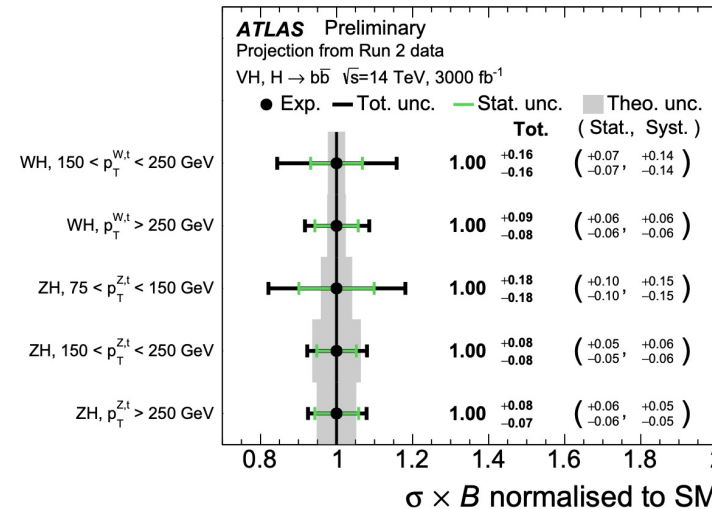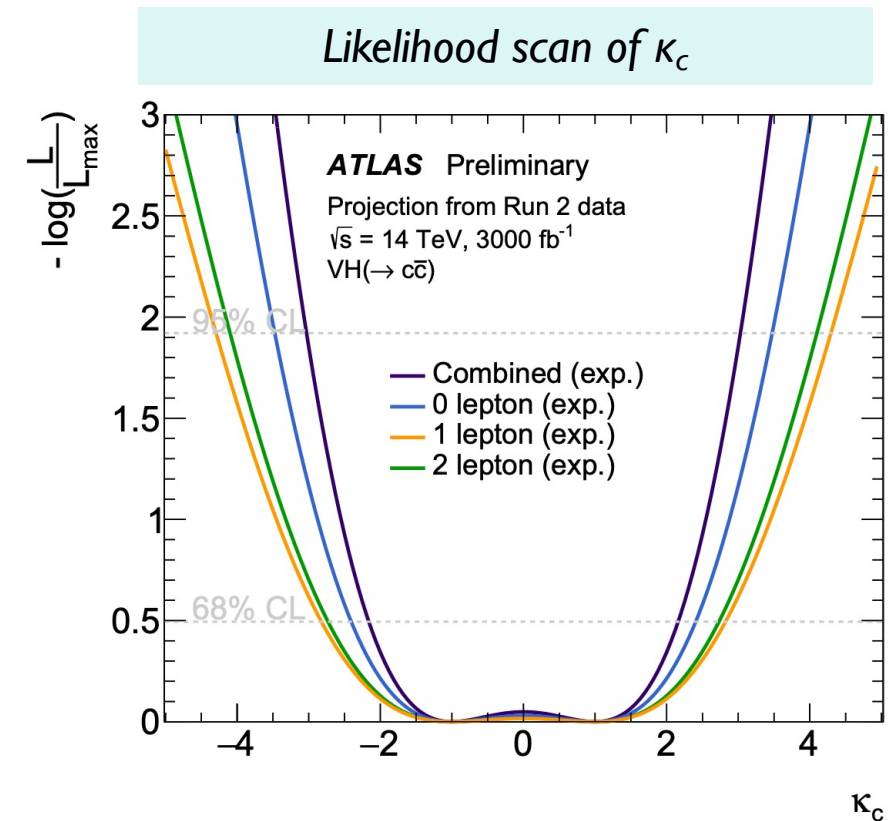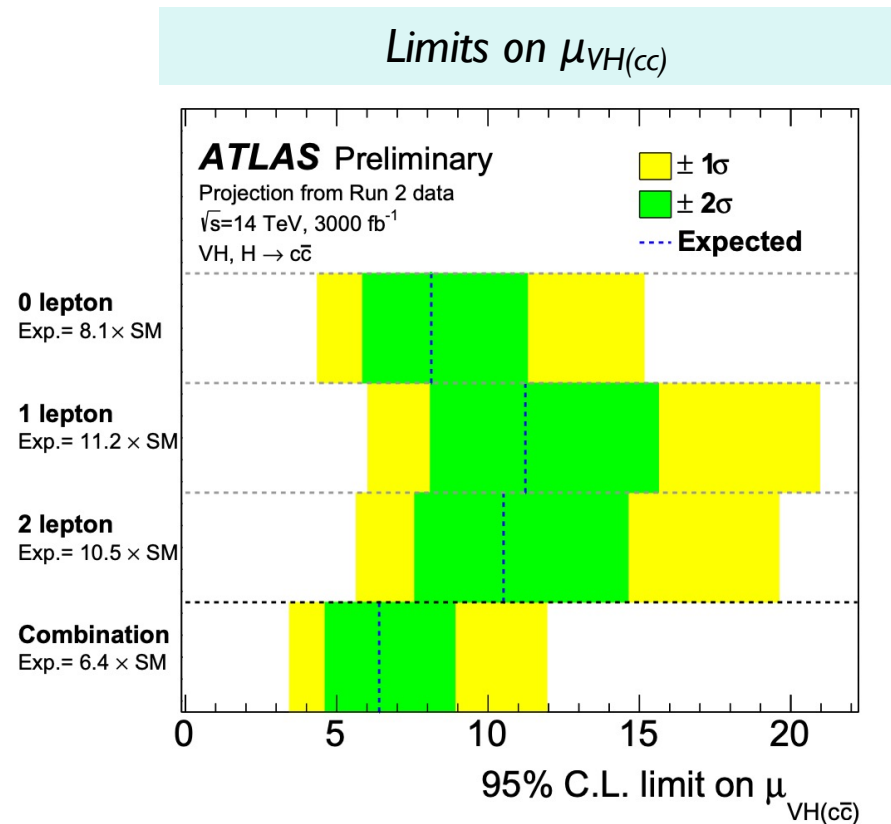
Fit to signal strengths in 5 STXS bins:

- **Uncertainties vary between 18% in the low p_T bins and 7% in the high p_T bins**
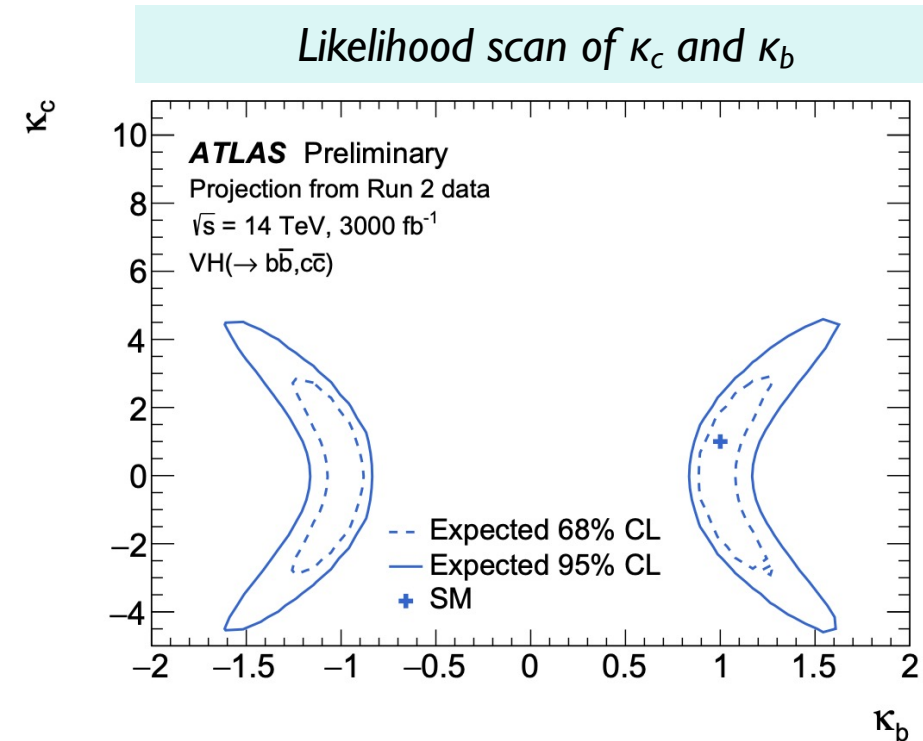- *Full Run 2 result: uncertainties between 30-60%*

WH/ZH extrapolation

VH(bb) STXS extrapolation

VH(cc) results

- Extrapolation based on public Run 2 VH(cc) analysis
- Expected upper limit on VH(cc) signal strength of 6.4 x SM and $|\kappa_c| < 3.0$
- Leading uncertainties from Z+jets modelling and flavour tagging

Limits on $\mu_{VH(cc)}$

ATLAS Preliminary
Projection from Run 2 data
$\sqrt{s}$=14 TeV, 3000 fb^{-1}
VH, H $\to$ c$\bar{c}$

☐ ± 1σ
☐ ± 2σ
---- Expected

0 lepton
Exp.= 8.1 × SM

1 lepton
Exp.= 11.2 × SM

2 lepton
Exp.= 10.5 × SM

Combination
Exp.= 6.4 × SM

95% C.L. limit on $\mu_{VH(c\bar{c})}$

Likelihood scan of κ_c

ATLAS Preliminary
Projection from Run 2 data
$\sqrt{s}$ = 14 TeV, 3000 fb^{-1}
VH($\to$ c$\bar{c}$)

95% CL
68% CL

—— Combined (exp.)
—— 0 lepton (exp.)
—— 1 lepton (exp.)
—— 2 lepton (exp.)

$-\log\left(\frac{L}{L_{max}}\right)$

κ_c

VH(bb/cc) combination

- Given the similarity of the VH(bb) and VH(cc) analyses it is straightforward to perform a simple statistical combination
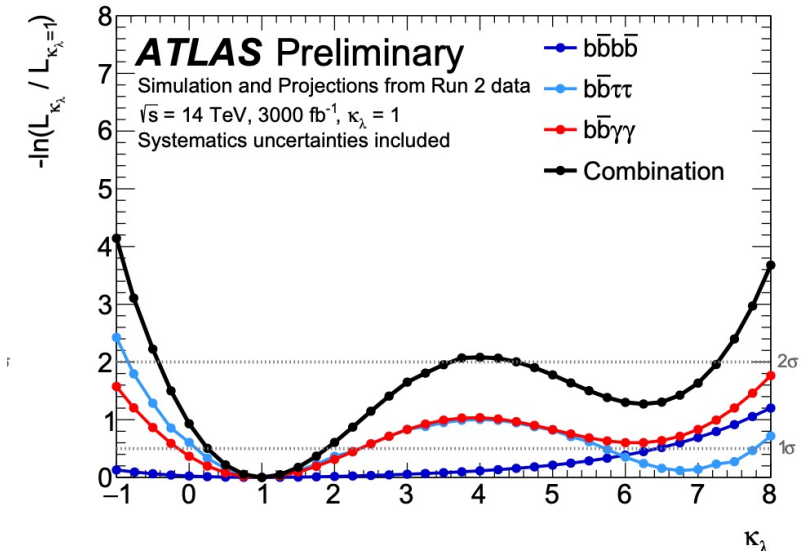
- At HL-LHC expect $\mu_{VH(bb)} = 1.00 \pm 0.06$ and $\mu_{VH(cc)} = 1.00 \pm 3.20$

- Expected constraint of $|\kappa_c/\kappa_b| < 2.74$ at 95% CL

Likelihood scan of $\mu_{VH(cc)}$ and $\mu_{VH(bb)}$

Likelihood scan of κ_c and κ_b
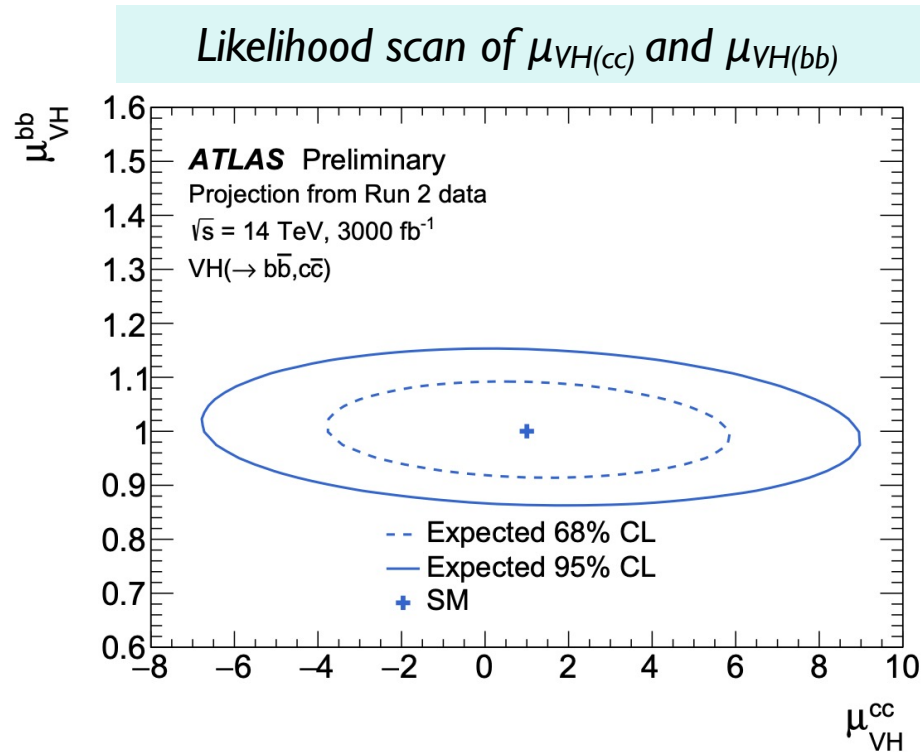
HH(bbɣɣ) extrapolation

- Previous extrapolation of bbɣɣ channel done in dedicated extrapolation analysis ([PUB note](#))

- ~2.0σ for the SM HH signal, κ_λ - constrained at 1σ to [-0.2, 2.5]

- Recent HH(bbɣɣ) results with full Run 2 dataset (139ifb) released as Moriond 2021 [CONF](#) note

- Updated extrapolation based on these results in progress, following the usual ATLAS upgrade physics recommendations

- Improved κ_λ precision expected with respect to previous extrapolation, thanks to updated analysis strategy exploiting event categories based on di-Higgs mass

→ Public results expected by the end of the year

Previous HH extrapolation

Current HH(bbɣɣ) analysis
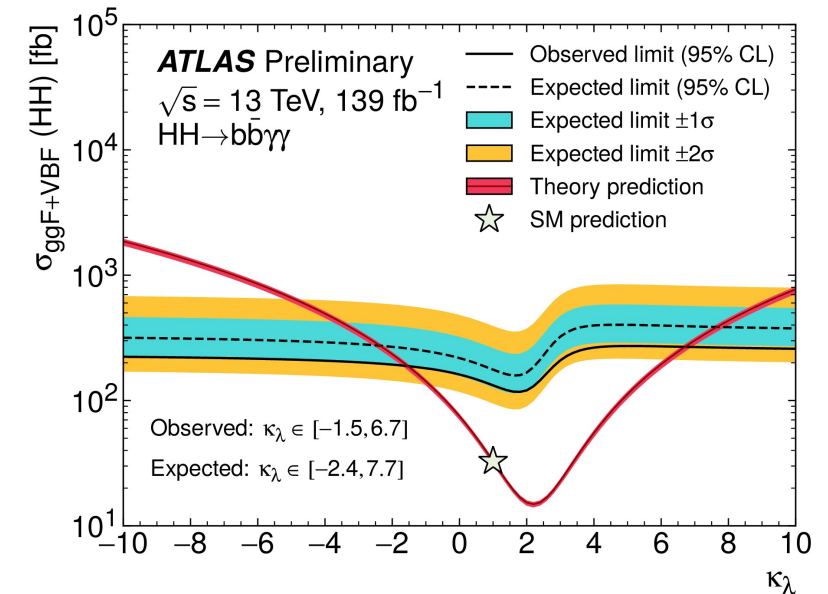
Summary

- **Summary of recent ATLAS Higgs physics activities for Snowmass**

- **Summary of VH(bb/cc) extrapolation [PUB note](#)**
→ Extrapolation of Run 2 VH(bb) and VH(cc) results and combination
→ $\mu_{VH(bb)} = 1.00 \pm 0.06$ and $\mu_{VH(cc)} = 1.00 \pm 3.20$, $|\kappa_c/\kappa_b| < 2.74$ at 95% CL

- **Brief status update on Di-Higgs extrapolations for Snowmass**
→ Update on HH(bbγγ) prospects expected by the end of the year
→ Other extrapolation activities ongoing, stay tuned!

Thank you!

Any questions?

Extrapolation setup

Step 1: **Scale MC samples from 139 fb⁻¹ to 3000 fb⁻¹**

Step 2: **Account for CoM increase 13 TeV → 14 TeV**

- Apply process-dependent (pTV inclusive) numbers

Step 3: **Add systematic uncertainties**

- Scale experimental uncertainties following CP group recommendations
- Reduce signal and background modelling uncertainties to 1/2
- Neglect uncertainties related to MC statistics

Step 4: **Perform fits on pre-fit Asimov dataset**

Parameters of interest:

- VH(bb): signal strengths of WH(bb) and ZH(bb), 5 POI STXS fit
- VH(cc): VH(cc) signal strength, κ_c
- Combination: $\mu_{VH(bb)}$ and $\mu_{VH(cc)}$, κ_c/κ_b

CoM scale factors	Scale factor
WH	1.10
qqZH	1.11
ggZH	1.18
ttbar, ggZZ	1.16
qqVV, V+jets, single top	1.10

Systematics scale factors		Scale factor
Experimental	MET	0.5
	Lepton	1
	Jet	1
	Luminosity	0.58
Flavour tagging	$c/b/\tau$ – jets	0.5
	l-jets (MV2c10)	0.5
	l-jets (DL1)	1
Modelling	Signal	0.5
	Background	0.5
MC stat	MC statistics	0
	Truth-tagging	0