中国科学院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences

ATLAS
EXPERIMENT

AIs for the HBSM pre-approval

Abdualazem Fadol for the analysis team

November 10, 2022

Documentation

- ☐ Glance link ⇒
- ☐ The analysis TWiki ⇒
- ☐ Supporting note in the CDS ⇒
- ☐ Recent communication through the CDS ⇒
- ☐ Pre-approval slides on October 27, 2022.

List of AIs to address before unblinding

☐ **Required for unblinding**

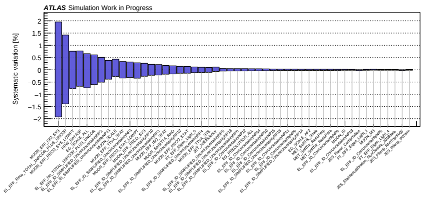
(1) Add pull/ranking plots for the CR and MET > 200 GeV
(2) Signal Cutflow starting from raw number.
(3) Strategy for re-interpretation of analysis: RECAST
(4) Signal injection tests
(5) Replying to comments and questions on the CDS before the unblinding.
(6) You should have a clear strategy on how to deal with large widths in the signals, and how much of your parameter space affects.

☐ **Follow-up questions during the pre-approval talk**

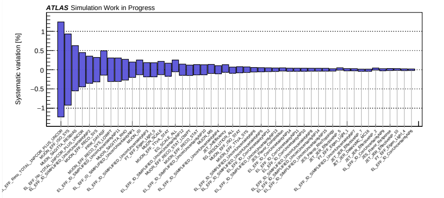
(1) Why the resolution up/down is much wider than the nominal? Why is the resolution not getting better? Why is the peak much lower for both Scale up/down?
(2) Are the sub-regions orthogonal?
(3) Understanding the asymmetric uncertainties for the signal shape systematic.
(4) Could you plot the ratio so that we compare and if we could justify the increase in the sensitivity by a higher signal effxacc?
(5) Description of the 2HDM numbers.

AI(1): Systematic uncertainties on the CR region

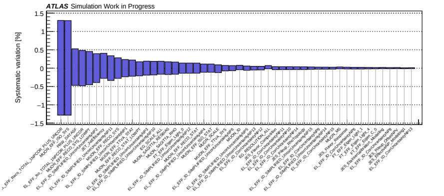
- Control region: $80 < m_{4\ell} < 170$ GeV; only experimental uncertainties are considered.



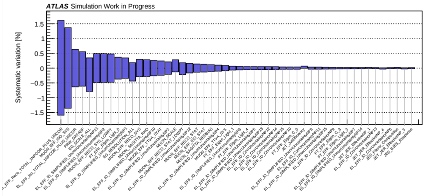
$q\bar{q} \to ZZ$



VVV



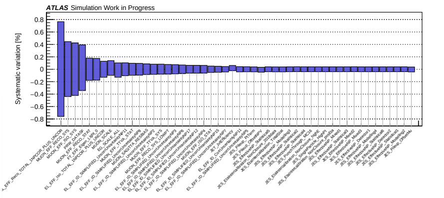
$gg \to ZZ$



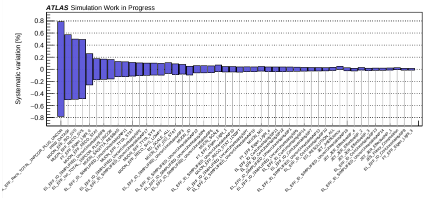
others

AI(1): Systematic uncertainties on the $m_{4\ell} > 200$

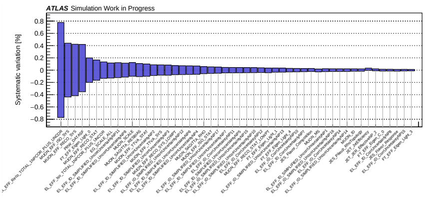
- For $m_{4\ell} > 200$ GeV; only experimental uncertainties are considered.
- Comparable to the inclusive $H \to ZZ \to 4\ell$ analysis (High mass) note.



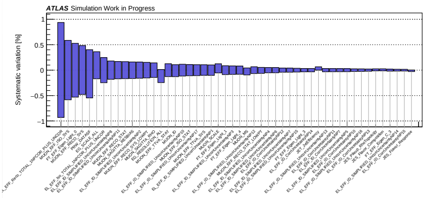
$q\bar{q} \to ZZ$



VVV

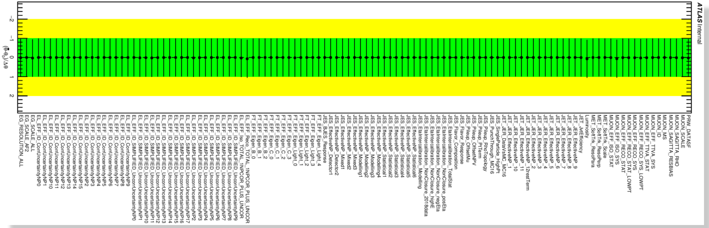


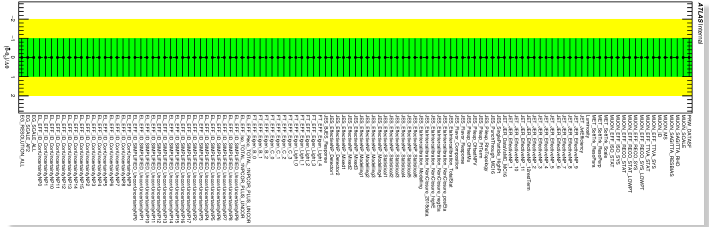
$gg \to ZZ$



others

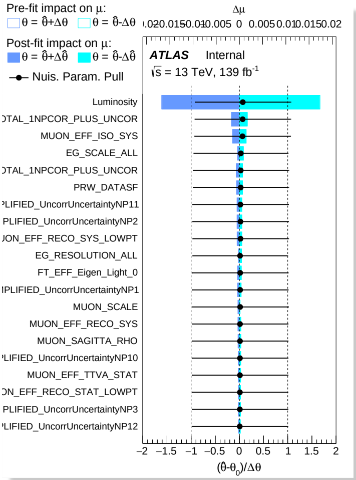
AI(1): Pull plot for the CR

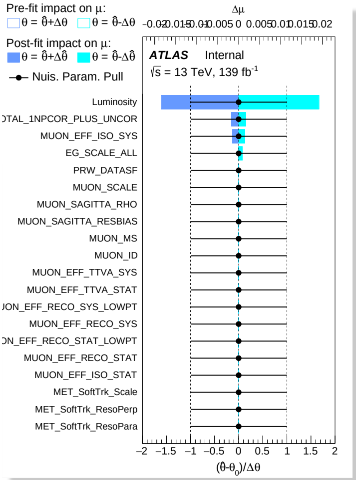




- ☐ Observed (top) and Asimov data (bottom) with POI fixed to one.

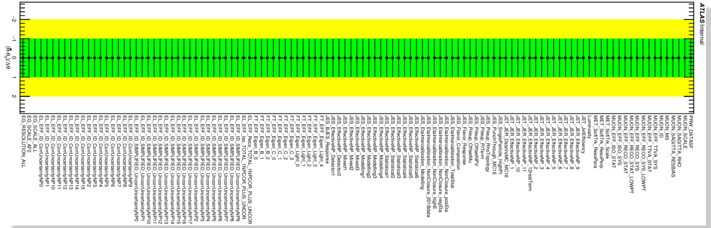
AI(1): Ranking plot for the CR

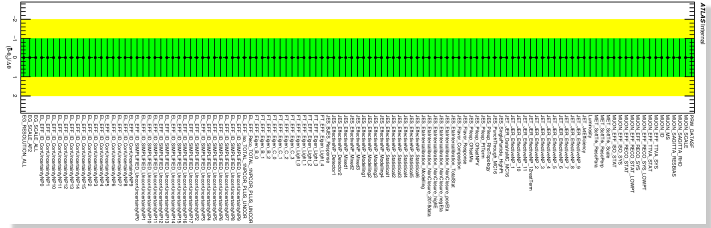




- Observed (left) and Asimov data (right) with POI fixed to one.

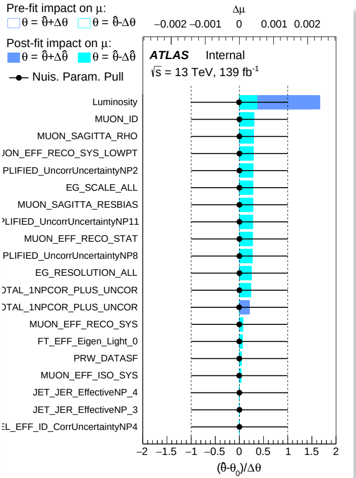
AI(1): Pull plot for the $m_{4\ell} > 200$ GeV region

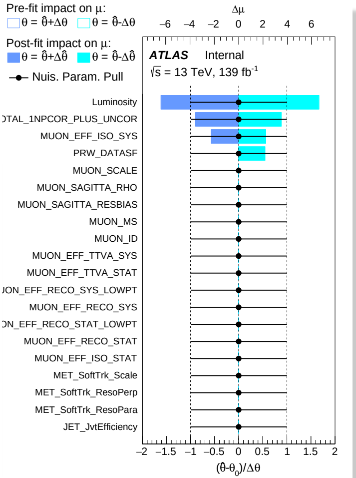




- Observed (top) and Asimov data (bottom) with POI fixed to one.

AI(1): Ranking plot for the $m_{4\ell} > 200$ GeV region





- Observed (left) and Asimov data (right) with POI fixed to one.

AI(2) Signal Cutflow starting from raw number

	2e2mu	2mu2e	4e	4mu
Total	30000.0	30000.0	30000.0	30000.0
DataPreselection	30000.0	30000.0	30000.0	30000.0
Preselection	20682.0	20682.0	20682.0	20682.0
Trigger	20620.0	20620.0	20620.0	20620.0
Lepton	9013.0	9013.0	3614.0	5489.0
SFOS	4242.0	4657.0	3486.0	5471.0
Kinematics	4237.0	4651.0	3483.0	5464.0
TriggerMatch	4237.0	4651.0	3483.0	5464.0
Z1Mass	4285.0	4673.0	6242.0	9932.0
Z2Mass	4167.0	4606.0	4626.0	7347.0
DeltaR	4151.0	4578.0	4621.0	7295.0
Iso	3689.0	4172.0	4246.0	6434.0
D0Sig	3633.0	4099.0	4234.0	6276.0
Vertex	3626.0	4094.0	4224.0	6259.0
Final	3624.0	4084.0	3156.0	4675.0

- For (390, 220) GeV sample (mc16a)

AI(3): Strategy for re-interpretation of the analysis

- This is still work in progress.

AI(4) Signal injection test

- For the $A \to ZH \to 4\ell + X$ signal model:

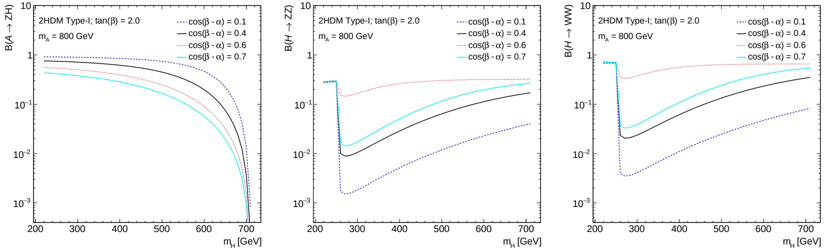
$(m_A,\ m_H)$	Upper limits at 95%			
	No-signal hypothesis	signal=1.0	signal=2.0	signal=10.0
(320, 220)	0.284	1.333	2.415	11.029
(500, 400)	0.173	1.261	2.318	10.728
(2090, 1000)	0.036	1.178	2.270	10.030

- For the $R \to SH \to 4\ell + E_{\mathrm{T}}^{\mathrm{miss}}$ signal model:

$(m_A,\ m_H)$	Upper limits at 95%			
	No-signal hypothesis	signal=1.0	signal=2.0	signal=10.0
(390, 220)	0.305	1.422	2.537	11.017
(500, 300)	0.135	1.289	2.401	11.090
(1340, 250)	0.090	1.253	2.341	10.896

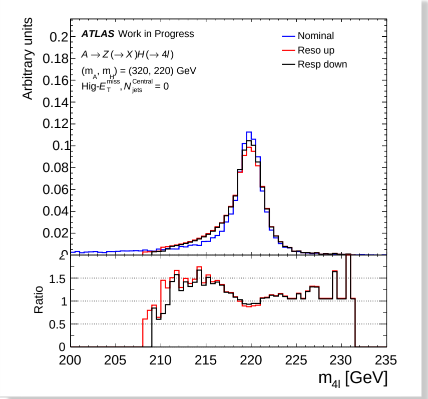
AI(6) Strategy on how to deal with large widths in the signals

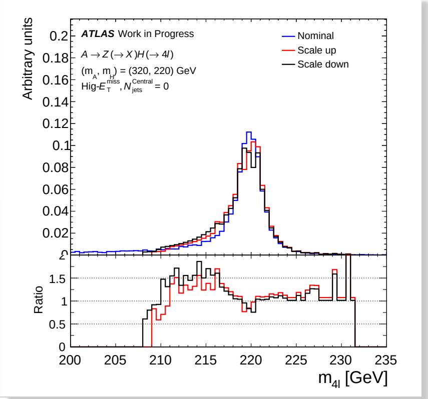
- The $\ell\ell bb$ (Eur. Phys. J. C. 81 (2021) 396) uses the following:
  - $\cos(\beta - \alpha) = 0$
  - H natural width of 1%
  - A natural width of 10% and 20%
  - Exclusion on the m_A-m_H
- For $\ell\ell WW$, exclude m_A-$\cos(\beta - \alpha)$
- In our case, we need to discuss with Nikos to decide what to do.



Follow-up questions

(1) Why the resolution up/down is much wider than the nominal? Why is the resol
getting better? Why is the peak much lower for both Scale up/down?

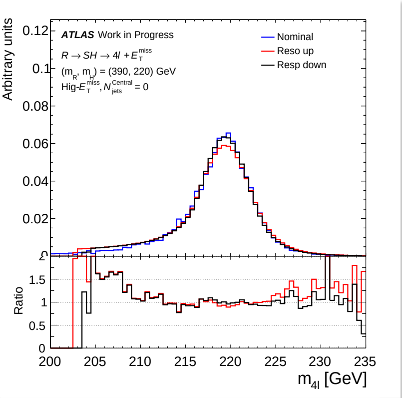


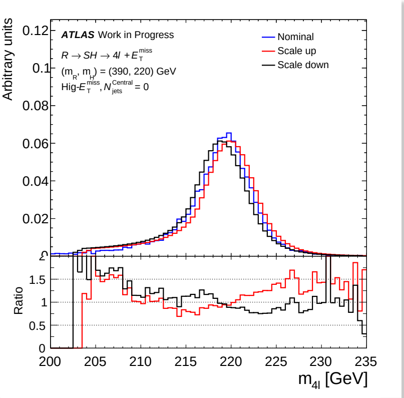


- ☐ Resolution: the σ is modified by 1.4%: $\text{nominal} \cdot (1 + 0.014)$ ($\text{nominal} \cdot (1 - 0.014)$) for up (down)
- ☐ Scale: the μ is modified by 0.23% (up/down)
- ☐ EG_RESOLUTION_ALL(RMS) & EG_SCALE_ALL(MEAN)

Follow-up questions

(1) Why the resolution up/down is much wider than the nominal? Why is the resol
getting better? Why is the peak much lower for both Scale up/down?





Follow-up questions

(2) Are the subregion orthogonal?

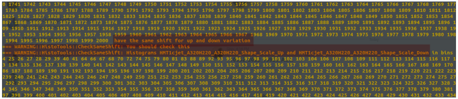

```
if(nbj77==0&&ncj==0&&pt4l>20&&metsig>2.0)          cat1_val[groupName][0]+=weight*scalefactor;
else if(nbj77==0&&ncj==0&&pt4l>10&&metsig>1.5)     cat1_val[groupName][1]+=weight*scalefactor;
else if(nbj77==0&&ncj>=1&&pt4l>10&&metsig>3.5)     cat1_val[groupName][2]+=weight*scalefactor;
else if(nbj77==0&&ncj>=1&&pt4l> 0&&metsig>2.5)     cat1_val[groupName][3]+=weight*scalefactor;
else if(nbj77>=1)                                  cat1_val[groupName][4]+=weight*scalefactor;
else if(ncj>=2&&fabs(m_cjj-mZ)<20)                 cat1_val[groupName][5]+=weight*scalefactor;
else if(ncj>=2&&fabs(m_cjj-mZ)>20)                 cat1_val[groupName][6]+=weight*scalefactor;
else if(ncj==1)                                    cat1_val[groupName][7]+=weight*scalefactor;
                                                   cat1_val[groupName][8]+=weight*scalefactor;
else{cat1_val[groupName][9]+=weight*scalefactor;}
```

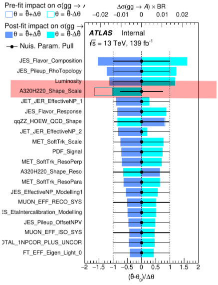
Categories			Representation	$Z_{\text{Sig}_1} = s/\sqrt{b}$	
				$A \to ZH \to 4\ell + X$	$R \to SH \to 4\ell + E_T^{\text{miss}}$
E_T^{miss} categories	$N_{\text{jets}}^{\text{Central}} = 0$	$p_T^{4\ell} > 20$ & E_T^{miss} significance > 2.0	High-E_T^{miss} & $N_{\text{jets}}^{\text{Central}} = 0$	1.10	3.11
		$p_T^{4\ell} > 15$ & E_T^{miss} significance > 1.5	Low-E_T^{miss} & $N_{\text{jets}}^{\text{Central}} = 0$	0.28	0.78
	$N_{\text{jets}}^{\text{Central}} \geq 1$	$p_T^{4\ell} > 10$ & E_T^{miss} significance > 3.5	High-E_T^{miss} & $N_{\text{jets}}^{\text{Central}} \geq 1$	1.35	5.66
		$p_T^{4\ell} > 0$ & E_T^{miss} significance > 2.5	Low-E_T^{miss} & $N_{\text{jets}}^{\text{Central}} \geq 1$	1.39	2.44
Jet categories	$N_{b\text{-jets}} \geq 1$		$N_{b\text{-jets}} \geq 1$	1.88	-
	$\lvert m_{jj}^{\text{Central}} - m_Z \rvert < 20$		$\lvert m_{jj}^{\text{Central}} - m_Z \rvert < 20$	2.05	-
	$\lvert m_{jj}^{\text{Central}} - m_Z \rvert > 20$		$\lvert m_{jj}^{\text{Central}} - m_Z \rvert > 20$	1.89	-
	$N_{\text{jets}}^{\text{Central}} = 1$		$N_{\text{jets}}^{\text{Central}} = 1$	1.13	-
Combined significance				4.19	6.90

- ☐ Yes, the subregion are orthogonal. The cuts are in a sequential order with "if" and "else if"

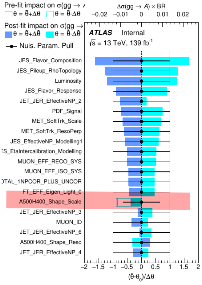
Follow-up questions

(3) Understanding the asymmetric uncertainties for the signal shape systematic

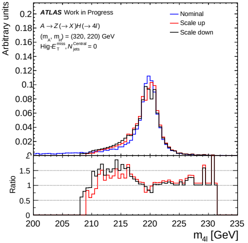


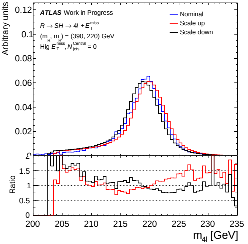


(a) $(m_A, m_H) = (320, 220)$



(b) $(m_A, m_H) = (500, 400)$ fb

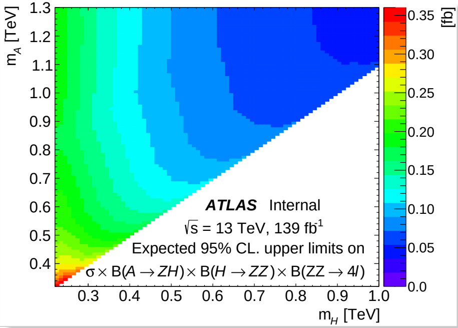


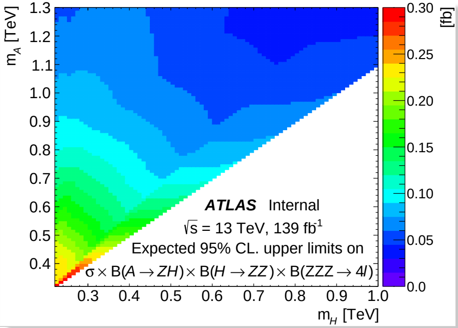


- ☐ Same shift for up and down variation in the $A \to ZH \to 4\ell + X$.

Follow-up questions

(4) Could you plot the ratio so that we compare and if we could justify the increase in the sensitivity by a higher signal effxacc?

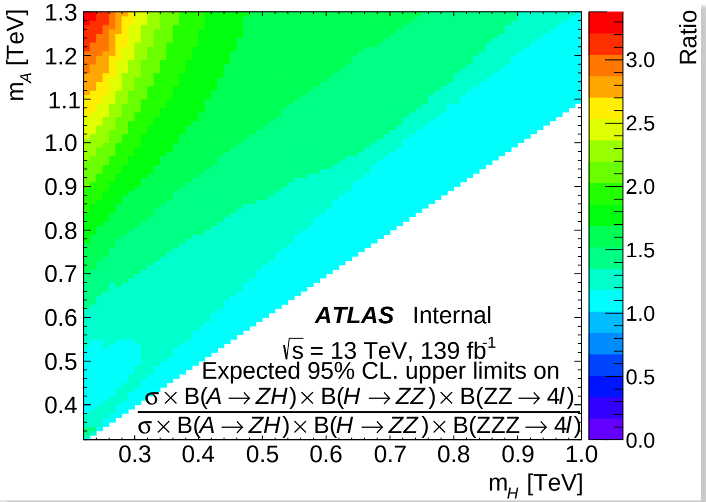




- Upper limits at 95% CL between [0.028 - 0.293] fb on (320, 1300) - (220, 1000) GeV.
- The $A \to Z(\to X)H(\to 4\ell)$ signal (left) and the total $A \to ZH \to 4\ell + X$ signal (right).

Follow-up questions

(4) Could you plot the ratio so that we compare and if we could justify the increase in the sensitivity by a higher signal effxacc?



- ☐ The ratio between $A \to Z(\to X)H(\to 4\ell)$ and $A \to ZH \to 4\ell + X$ is in the range of [1.014-3.365]

Summary

- We went through most of the AIs we discussed on the pre-approval talk.
- We replied to comments and question in the CDS, except the interpretation related comments.
- For these, we should discuss with Nikos to come up with an interpretation strategy.
- A new version of the note is uploaded to the CDS .

- To-do:
  - RECAST
  - CKKW/QSF
  - Inefficiency of the trigger
  - Interpretation strategy

Additional slides