SEARCH FOR HIGGS INVISIBLE AND DARK MATTER MONO-Z SIGNATURE WITH Z($\ell\ell$)+MET FINAL STATE

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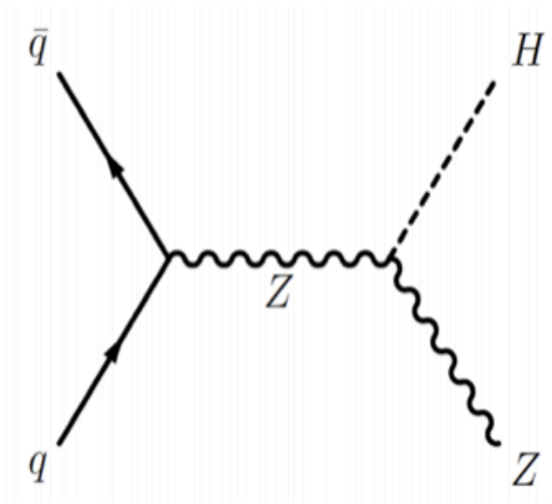
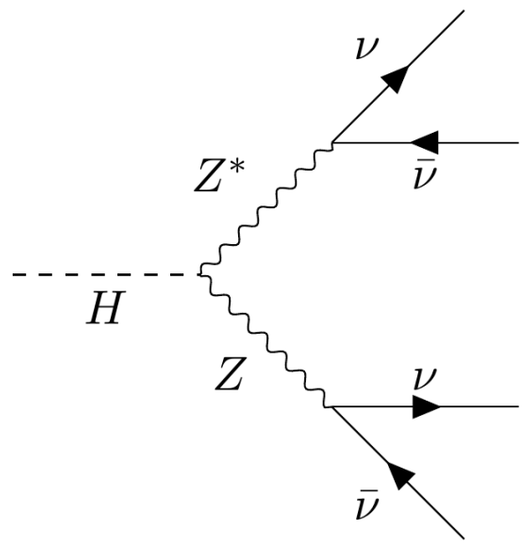
II+MET ANALYSIS

- The Higgs boson, in the Standard Model, can decay to insivible through $H \to ZZ^* \to \nu\nu\nu\nu$. The theoretical SM prediction is $BR_{H\to inv} = 1.06 \times 10^{-3}$ for $m_H = 125$ GeV.
- The final state targeted is $\ell\ell + E_T^{miss}$, given by the ZH production mode, with the Z decaying into two leptons;
- Previous results with 2015-2016 data (36.1 fb-1) for the ZH: $BR_{H\to inv} < 39\%$.



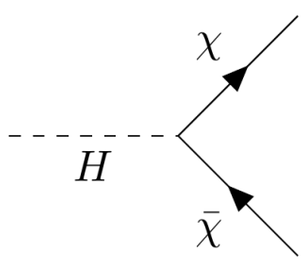
ZH production



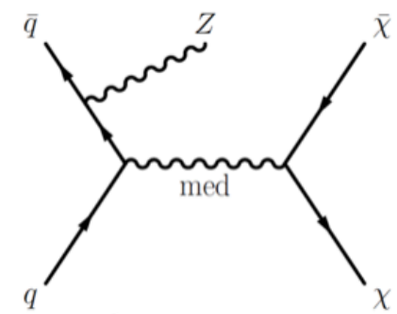
SM decay

ll+MET ANALYSIS

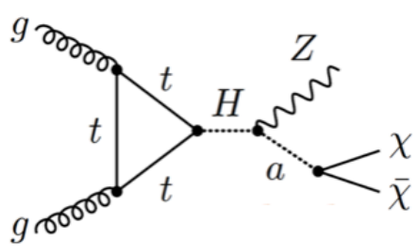
- The $\ell\ell+E_T^{miss}$ final state potentially can be produced also by Beyond Standard Model physics processes. Among these, there are:
  - The Higgs-portal models predict a larger $BR_{H\to inv,}$ in which the Higgs could decay into two Dark Matter (DM) particles.
    - If dark matter gets its mass from the Higgs boson and this is lower than about 10 GeV, H→*invisible* is the most likely place for a discovery.
  - axial-vector/vector simplified model;
  - 2HDM+a.



Higgs-portal to DM decay



axial-vector/vector simplified model



2HDM+a

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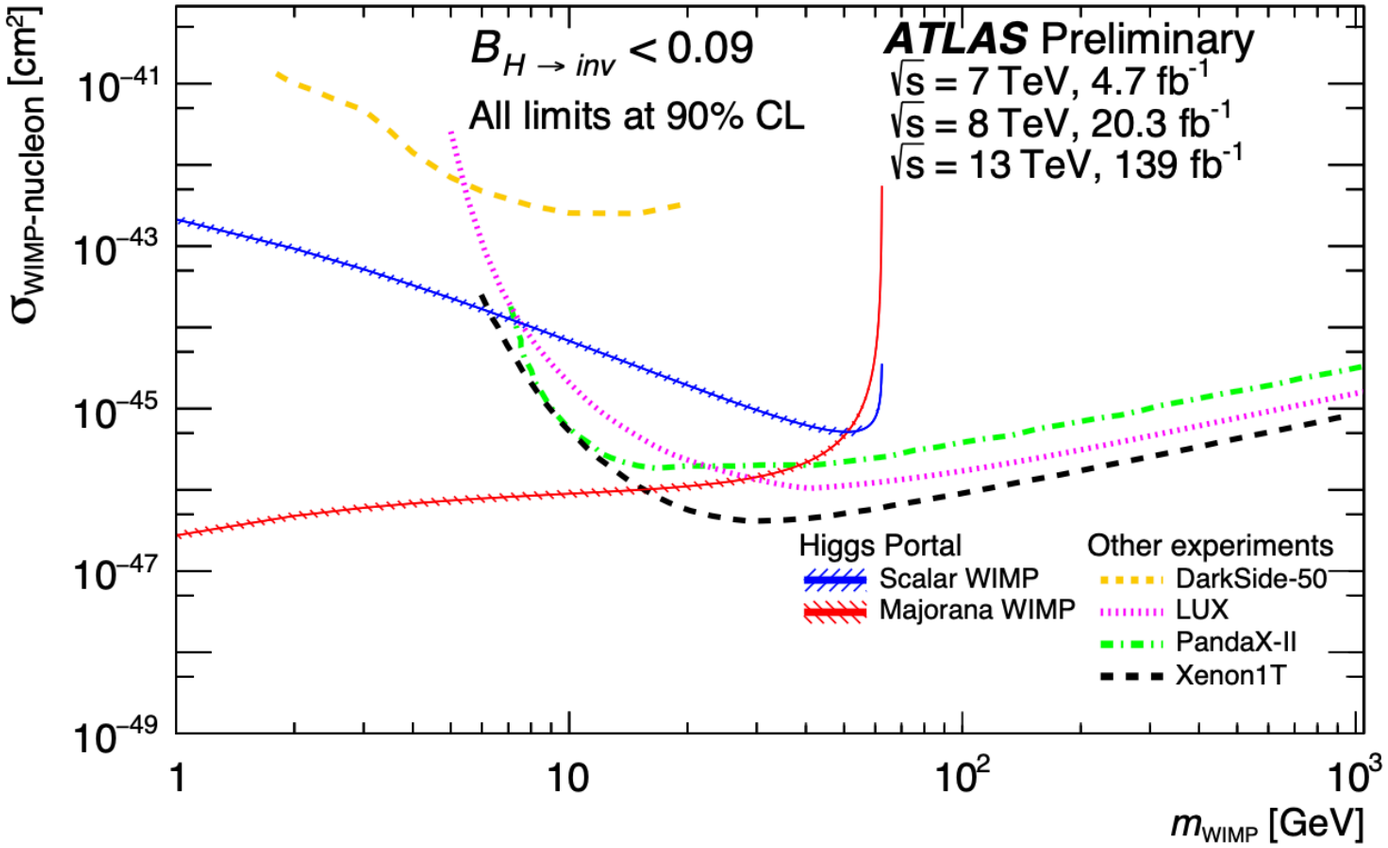
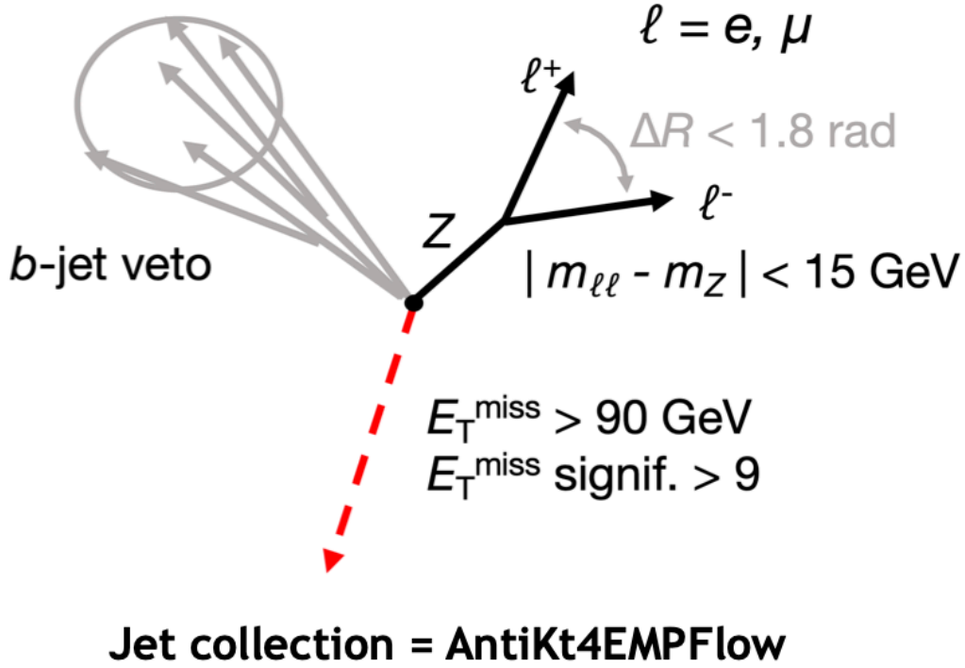


ll+MET ANALYSIS

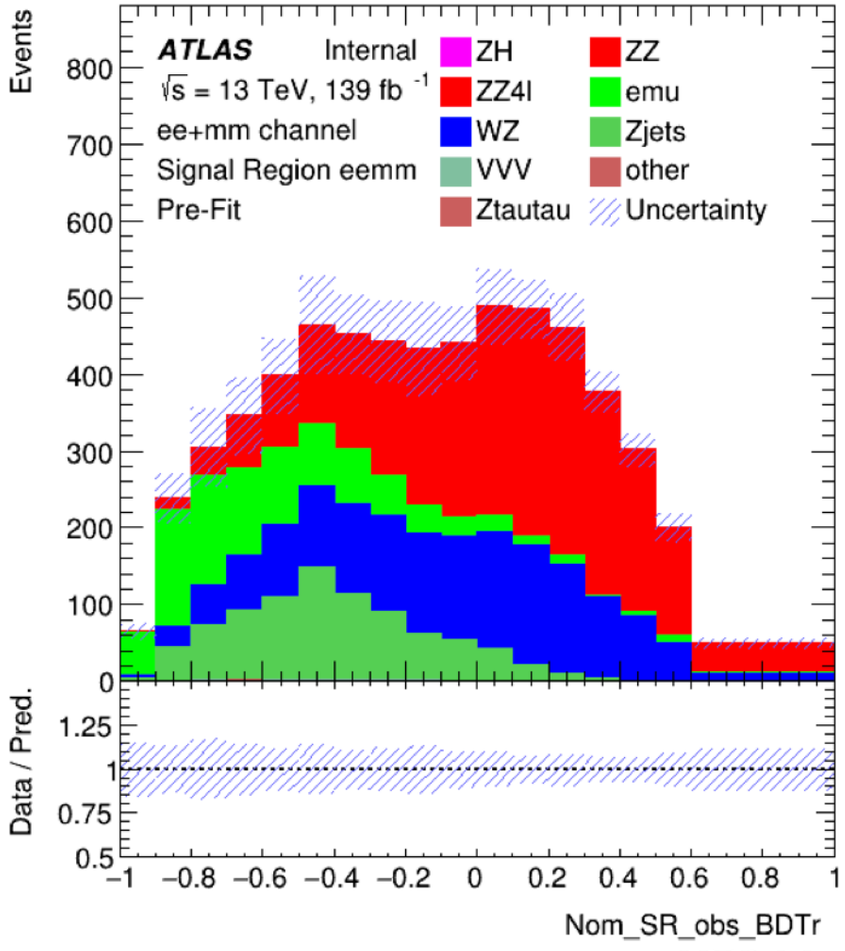
- The signal is represented by two isolated leptons from a Z boson decay and large missing transverse momentum due to an invisible Higgs boson decay or a WIMP pair ($\ell\ell+E_T^{miss}$), with ℓ=e, μ.

- Selection:

  - $E_T^{miss} > 90GeV$;
  - $E_T^{miss} Sig > 9$;
  - $\Delta R(\ell\ell) < 1.8$;
  - $b-jets$ veto;



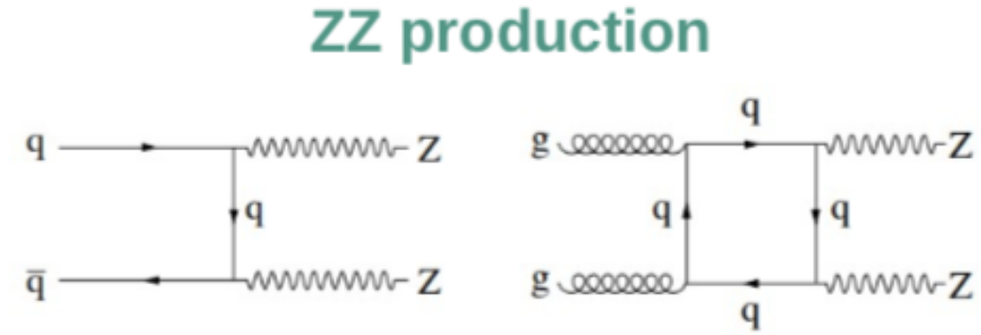
Background	Data-driven method	Contribution
ZZ	4ℓ and $Z\gamma$ control region	44%
WZ	3ℓ control region	26%
Z+jets	Sideband method	14%
Non-resonant $\ell^+\ell^-$	$e\mu$ control region	15%
W+jets	—	< 1%
$t\bar{t}V, t\bar{t}VV, VVV$	—	< 1%



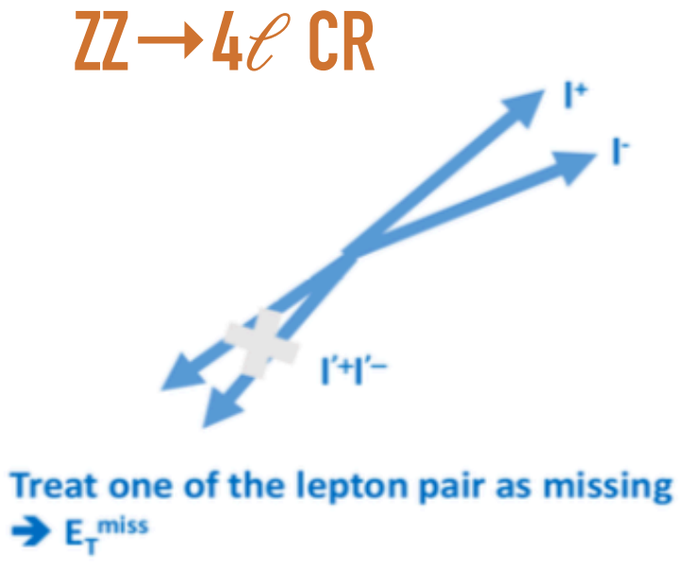
- BDT discriminant is used, built using kinematic variables such as E_T^{miss}Significance, angular distance between leptons, etc.. as input.

ZZ($\ell\ell$)+MET BACKGROUND

- The main backgrounds are estimated with the aid of data in control regions.



- The SM ZZ production is the dominant background in Z($\ell\ell$)+MET analysis;
- a 4ℓCR is used to constrain the predictions from Monte Carlo.
- Two dilepton pairs coming from the decay of two Z bosons.
- Treat one dilepton pair as invisible to mimic ZZ→$\ell\ell\nu\nu$.



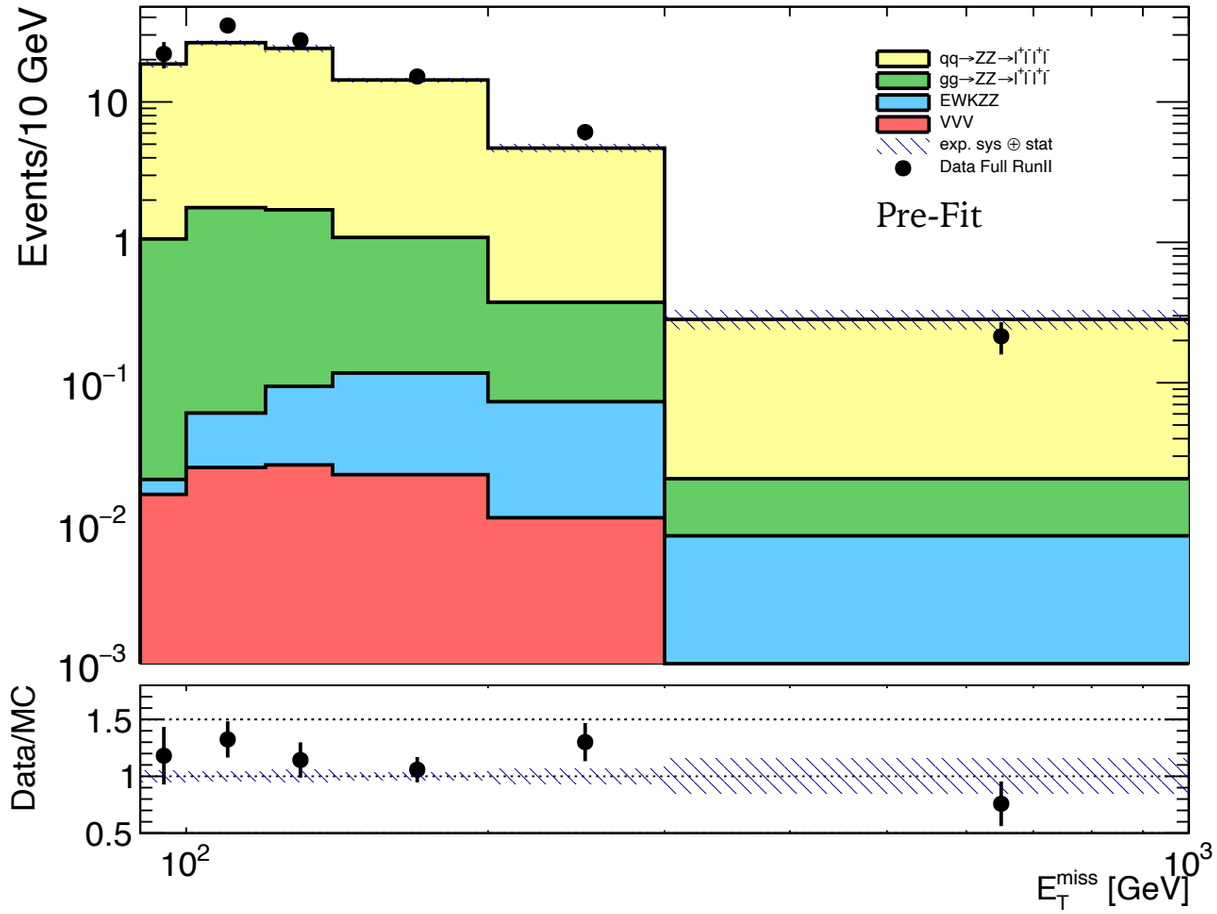
ZZ - 4ℓ CR

- Four leptons selected, with looser p_T requirement to increase the statistics, veto on 5th lepton.
- Pairing done using the following algorithm when the four leptons are all of the same flavour.

$$\textit{case 1:} \quad Z \to \ell_1^+\ell_2^-,\ Z \to \ell_3^+\ell_4^-$$
$$\textit{case 2:} \quad Z \to \ell_1^+\ell_4^-,\ Z \to \ell_3^+\ell_2^-$$

$$min \begin{cases} |m_{\ell_1^+\ell_2^-} - m_Z| + |m_{\ell_3^+\ell_4^-} - m_Z| \\ |m_{\ell_1^+\ell_4^-} - m_Z| + |m_{\ell_3^+\ell_2^-} - m_Z| \end{cases}$$

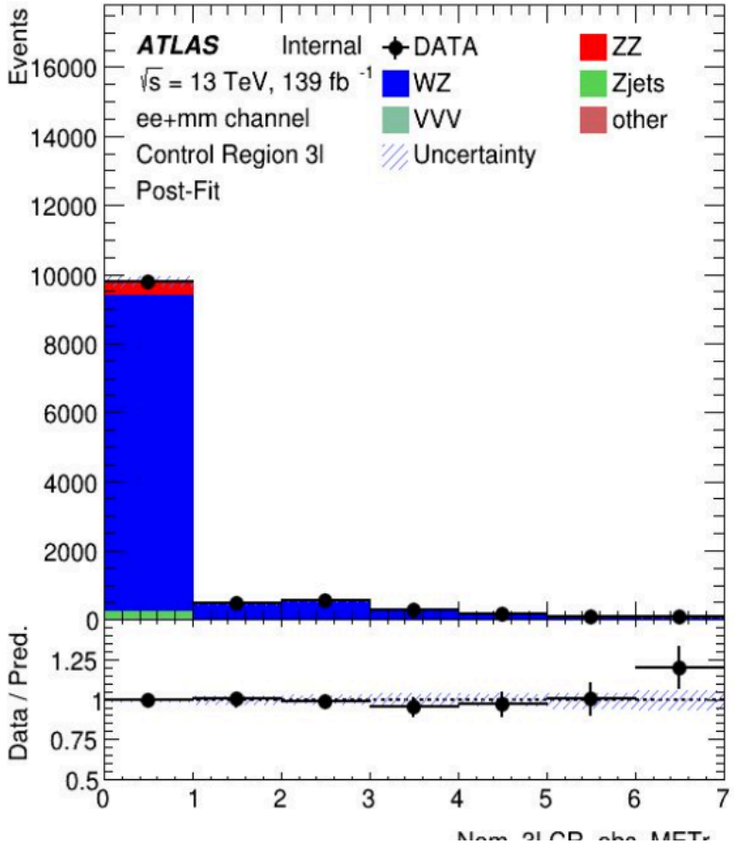
- Once the pairing is performed, the lepton pair to be treated as invisible is determined thourgh a 50-50 random choice.

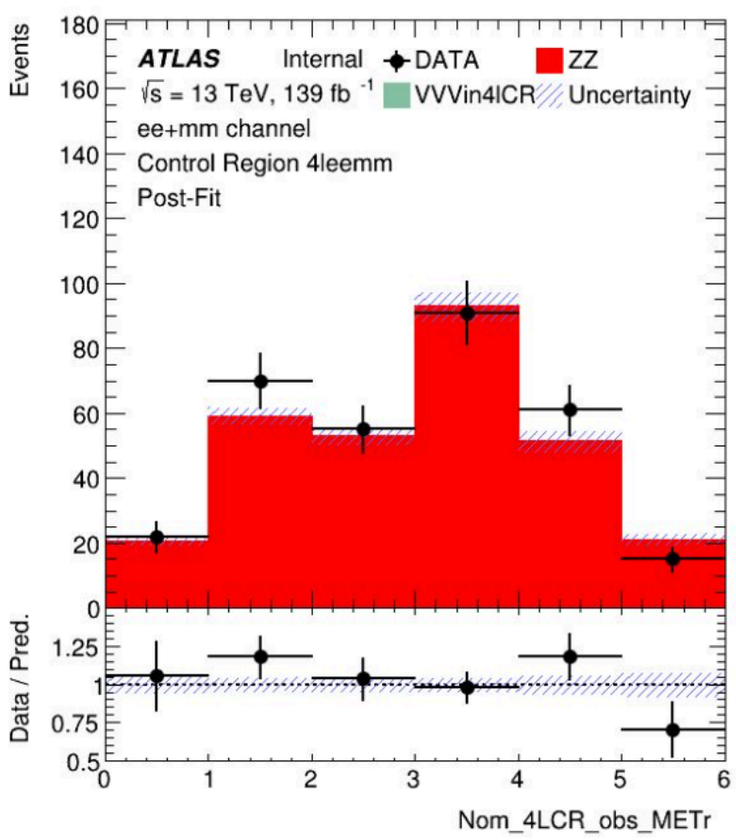


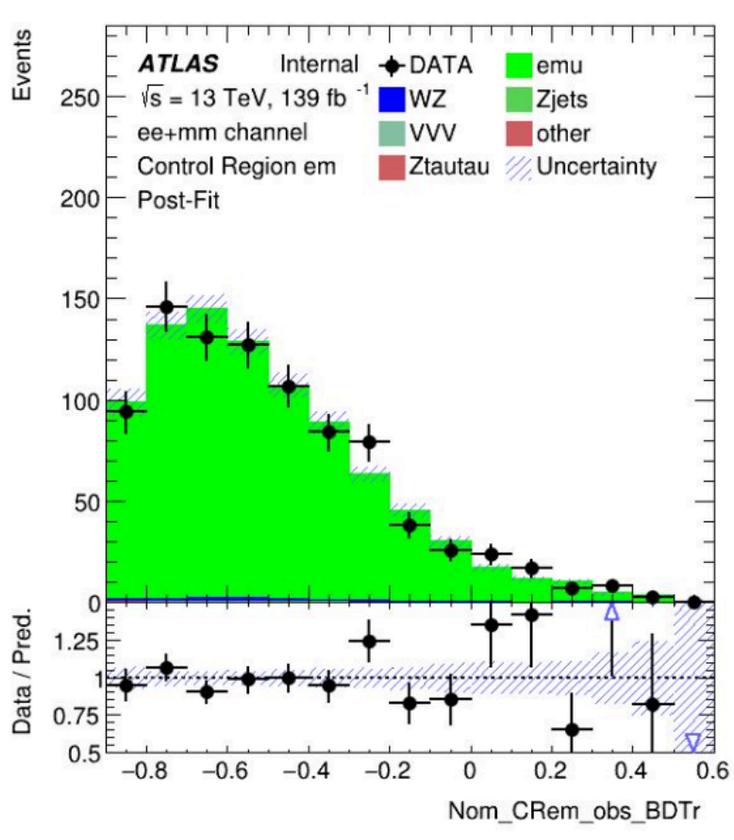
Channel	Data	MC Total	$qq \to \ell^+\ell^-\ell'^+\ell'^-$	$gg \to \ell^+\ell^-\ell'^+\ell'^-$	$qq \to \ell^+\ell^-\ell'^+\ell'^- jj$	VVV
ee	132 ± 11	125.03 ± 1.14	115.82 ± 1.14	8.09 ± 0.06	0.91 ± 0.03	0.201 ± 0.006
$\mu\mu$	182 ± 13	147.22 ± 1.19	136.72 ± 1.19	9.27 ± 0.07	0.99 ± 0.04	0.227 ± 0.006

SIMULTANEOUS FIT ZH(inv)

- Use a simultaneous fit to set limits on mono-Z and H→inv. branching ratio.
- Control regions (4ℓCR, 3ℓCR and eμCR) used to contraint the various backgrounds in the Signal Region.
- Fitted ee+$\mu\mu$ together.
- Improved the past BR limit by a factor of 2.
- Improved sensitivity for 2HDM and simplified models.

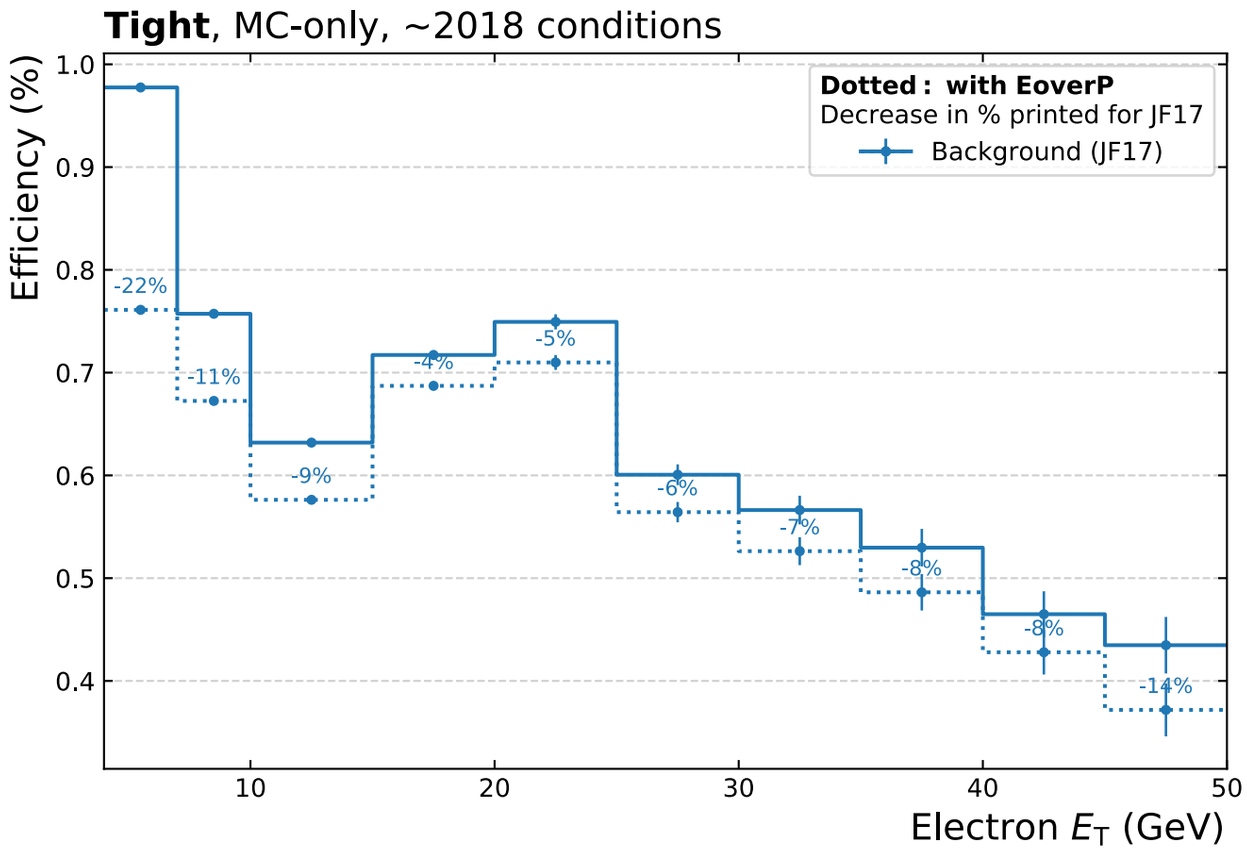






QUALIFICATION TASK

- Work done in the Electron Identification (ID) group.
- Maintened and improved sofware used to produce the idenfitication working point.
- Studies performed to estimate the impact of using different variables to derive the ID working points under different configuration of the ATLAS detector.
- Important to have a solid workflow to derive the working point for the Run 3 data taking.
- Keep contributing to the elctron ID effort.



CONCLUSION

This year:

- I have studied a method to improve the estimate of ZZ→$\ell\ell\nu\nu$ background using the ZZ→4ℓ channel;
- Based at DESY, I will (hopefully) be back in Liverpool in September;
- Became an ATLAS author, having done my Qualification Task on electron ID;

Plans:

- Keep working on the analysis, to be published soon.

Thank you for the attention!