# New analysis methods

3 slides of comparison
Thanks to Yanping Huang and Alessandro Calandri

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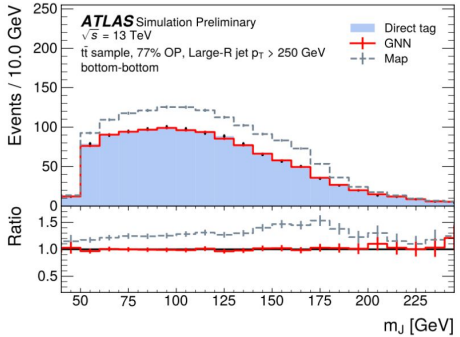
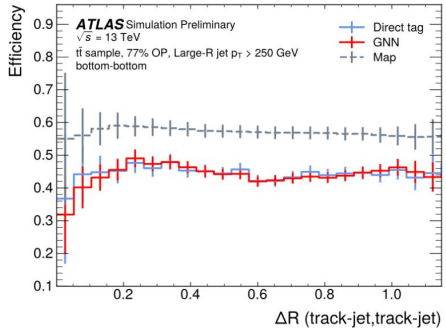
Higgs Hunting 2023  11-13/9/2023


# Flavour tagging & boosted topologies

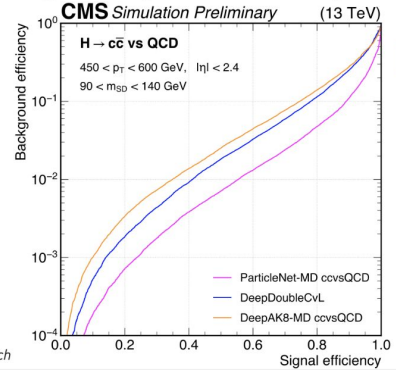
**Boosted VH, H→bb: closure**



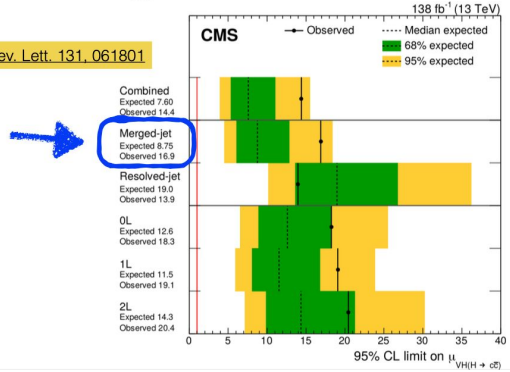



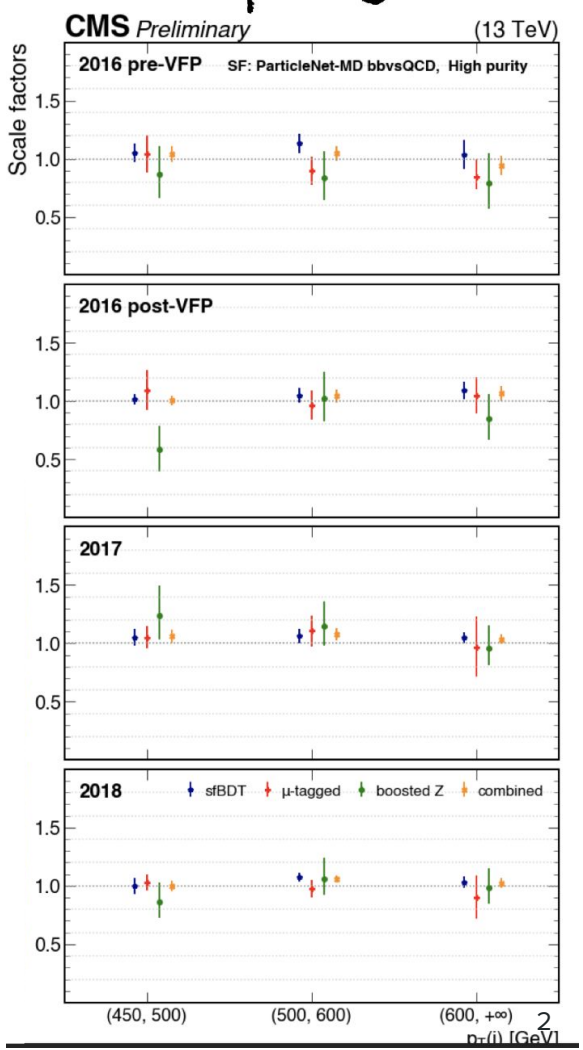

Graph NN used to emulate tagger & gain in MC statistics in tail

➡ **Significant leap in sensitivity in H→cc thanks to ParticleNet tagger performance and merged analysis - most stringent constraints on Higgs-charm Yukawa at LHC**




Phys. Rev. Lett. 131, 061801



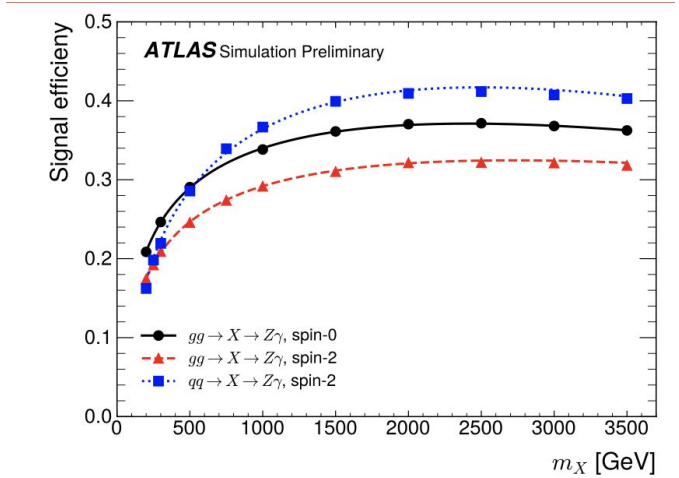



# Dedicated object reconstruction

The reach of Higgs analysis is increasing with data, opening the possibility for new signature and new needs from the objects.

As example from ATLAS High mass H->Zγ search => collimated di-leptons

- **Customized electron ID (MVA ID):**
  - MVA (XGBoost) using **shower shape variables** and **track-related variables** with **a signal efficiency of 99% @ 5TeV**
- **Mix-ID**: combine standard loose ID and MVA ID with a logical OR which improve the efficiency by 6.2% - 12.7%
- **eγ pair selection:** one of electrons is misreconstructed as a photon, and retrieve via tracking matching



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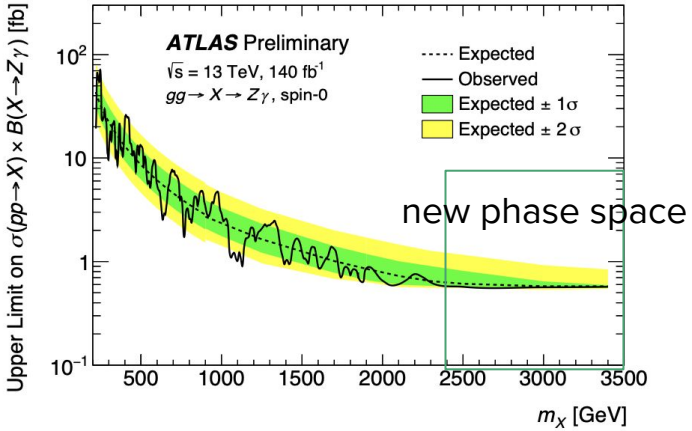
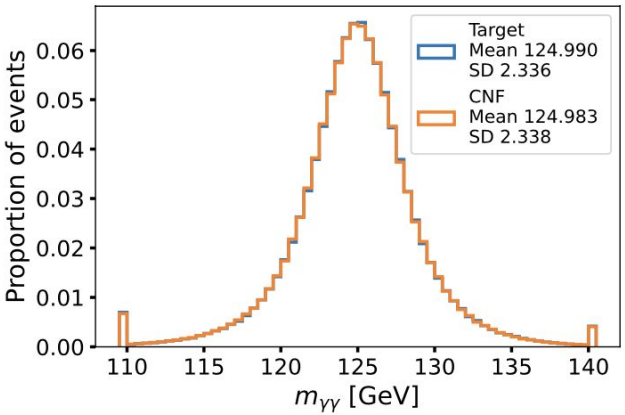
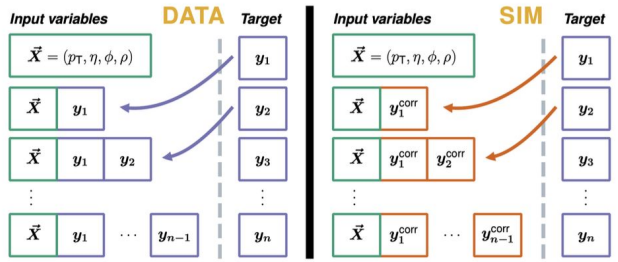


# Simulation modelling

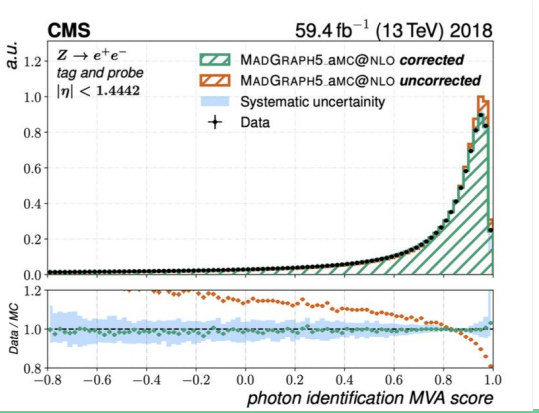
Few examples:

- Generative and conditional Normalizing flow used to model detector response and relax the request for large MC statistics (Hγγ in ATLAS)
- Correction on simulation to EM shower shapes and isolation to improve data MC modelling




JHEP07(2023)091



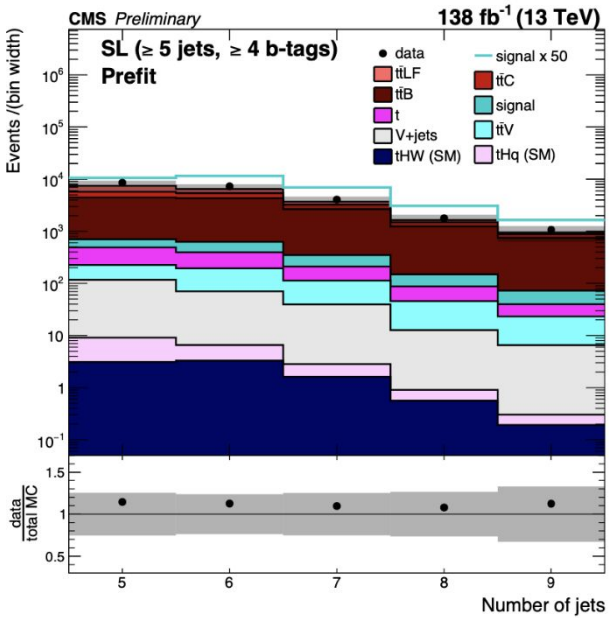
# Modelling of the backgrounds

Large large irreducible backgrounds =>
MVA techniques define sensitive regions
in very specific corner of the phase space.

BKG Modelling is crucial!

Important inputs:

- Improve the prefit modelling,
- reduce background modeling uncertainties and fit constraints: increased complexity of background model and improve prefit agreement with dedicated generators/tunings




| Uncertainty source | $\Delta\mu_{t\bar{t}H}$ (observed) | $\Delta\mu_{t\bar{t}H}$ (expected) |
|---|---|---|
| Total experimental | $+0.10/-0.10$ | $+0.11/-0.10$ |
| jet energy scale and resolution | $+0.08/-0.07$ | $+0.09/-0.09$ |
| b tagging | $+0.07/-0.06$ | $+0.06/-0.02$ |
| luminosity | $+0.02/-0.02$ | $+0.01/-0.01$ |
| Total theory | $+0.16/-0.16$ | $+0.18/-0.14$ |
| $t\bar{t}$ + jets background | $+0.15/-0.16$ | $+0.12/-0.11$ |
| signal modelling | $+0.06/-0.01$ | $+0.13/-0.06$ |
| Size of the simulated event samples | $+0.13/-0.12$ | $+0.10/-0.10$ |
| Total systematic | $+0.20/-0.21$ | $+0.23/-0.19$ |
| Statistical | $+0.17/-0.16$ | $+0.17/-0.17$ |
| background normalisation | $+0.13/-0.13$ | $+0.13/-0.13$ |
| $t\bar{t}B$ and $t\bar{t}C$ normalisation | $+0.12/-0.12$ | $+0.12/-0.12$ |
| QCD normalisation | $+0.01/-0.01$ | $+0.01/-0.01$ |
| Total | $+0.26/-0.26$ | $+0.28/-0.25$ |

# Modelling of the backgrounds

Large large irreducible backgrounds =>

M

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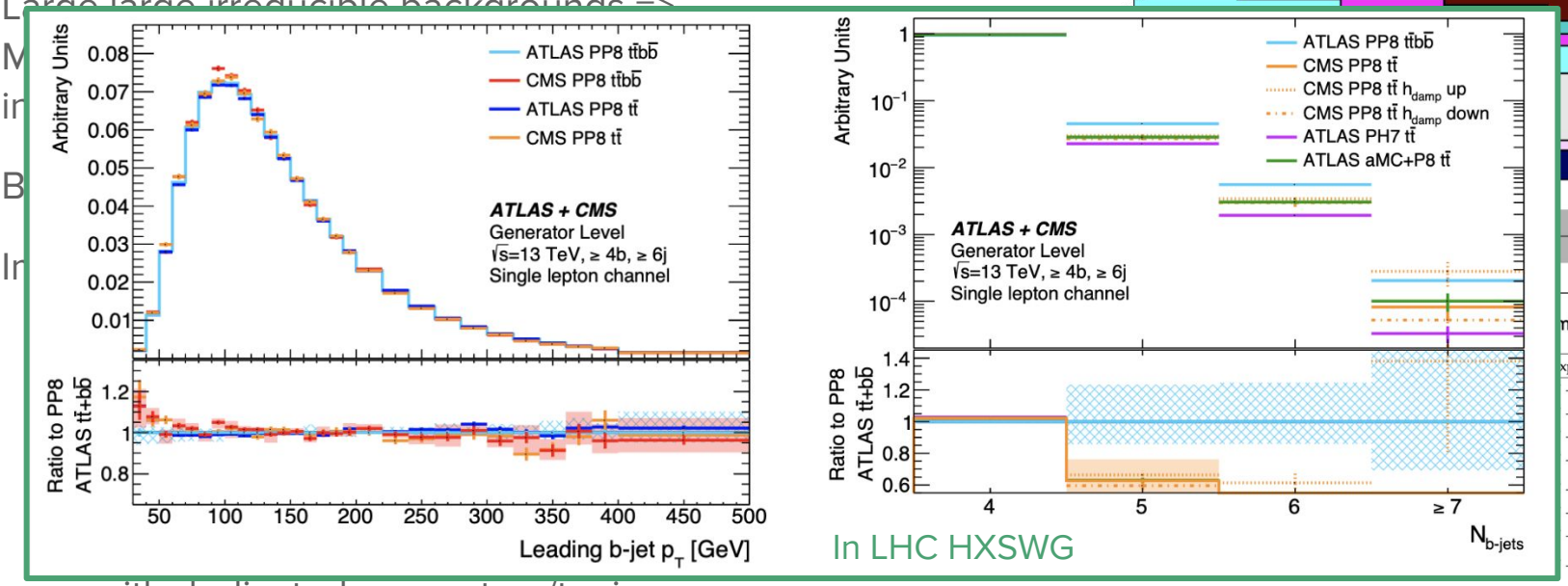
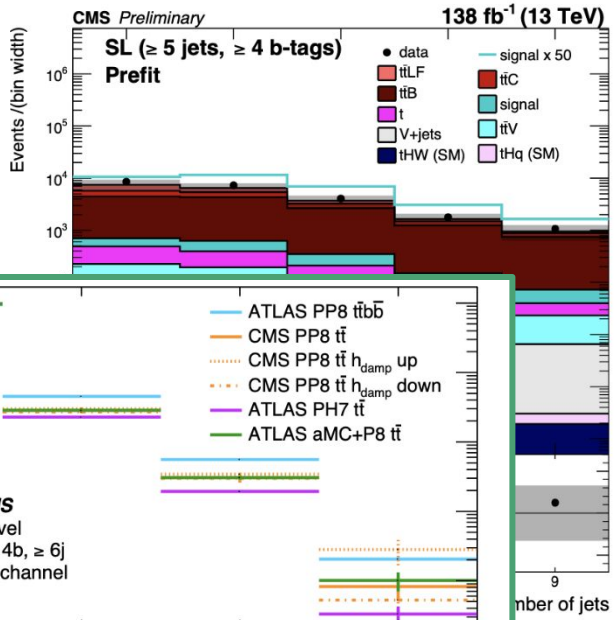
B

Ir

with dedicated generators/tunings

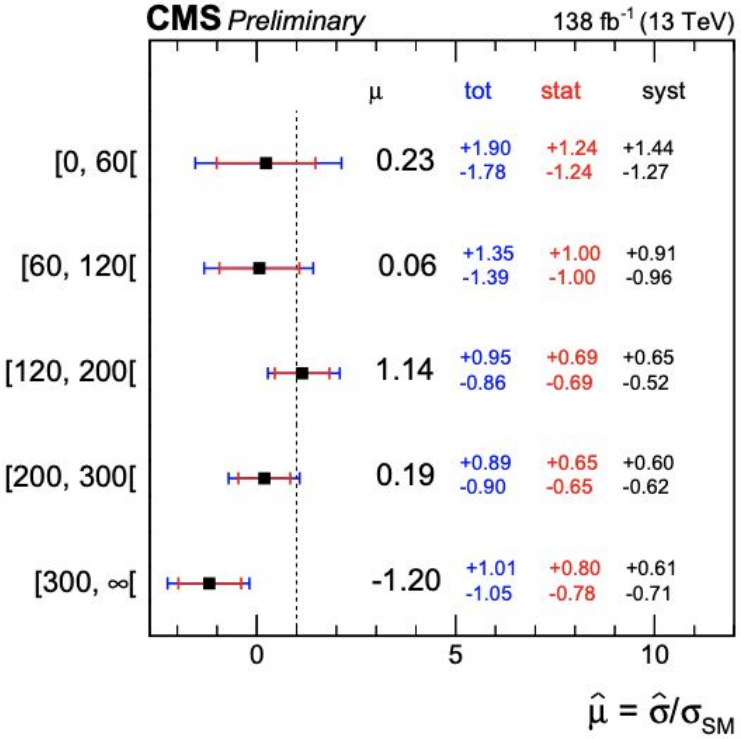


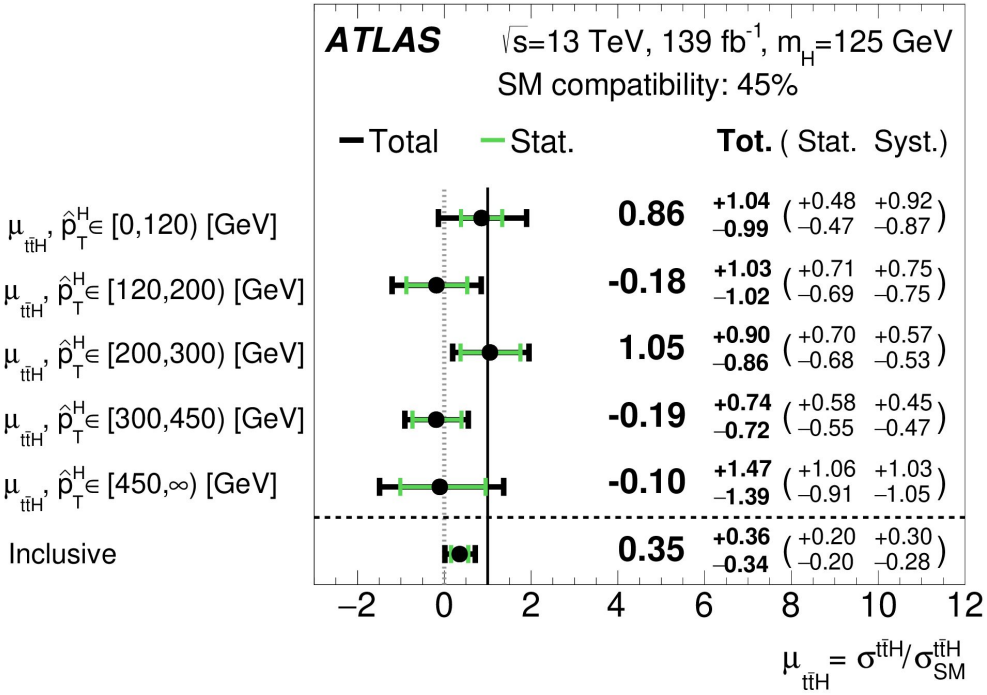

In LHC HXSWG




| | | |
|---|---|---|
| Total systematic | +0.20/ − 0.21 | +0.23/ − 0.19 |
| Statistical | +0.17/ − 0.16 | +0.17/ − 0.17 |
| background normalisation | +0.13/ − 0.13 | +0.13/ − 0.13 |
| tt̄B and tt̄C normalisation | +0.12/ − 0.12 | +0.12/ − 0.12 |
| QCD normalisation | +0.01/ − 0.01 | +0.01/ − 0.01 |
| Total | +0.26/ − 0.26 | +0.28/ − 0.25 |

# STXS comparison ttH(bb)




ATLAS ttH(γγ) for comparison