Novel Experimental Techniques for Higgs boson Measurements in ATLAS

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on behalf of the ATLAS Collaboration

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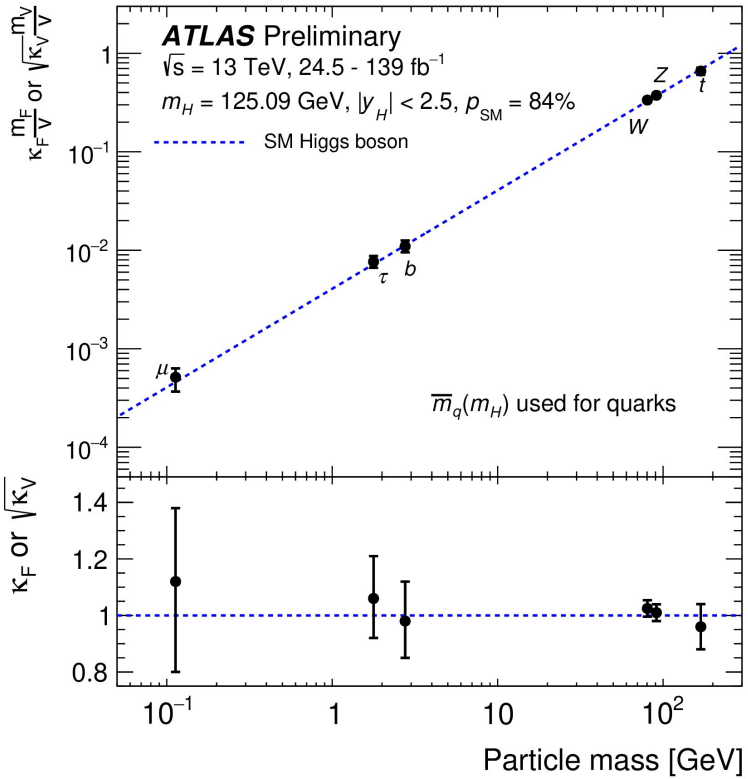
Higgs Properties

- Necessary to develop new techniques for many measurements, which may be applicable to other physics analyses or experiments

- In this talk, focus on details from a few key Higgs measurements
  - VH, H→cc
    →c-tagging, MC statistical uncertainty
  - VH, H→bb
    →systematic uncertainties, MC statistical uncertainty
  - VBF H→bb
    →Z background estimation
  - H→ττ
    →Z background estimation
  - ttH(multilepton)
    →non-prompt lepton rejection
  - H→llγ
    →Close-by electron identification

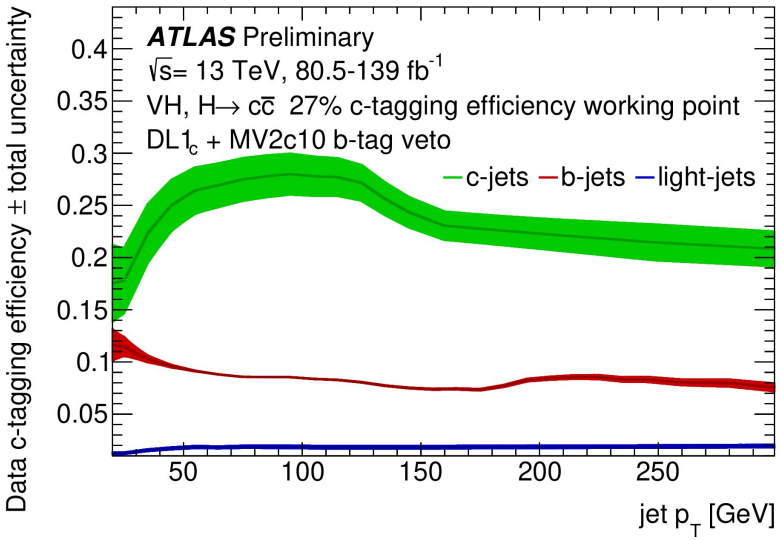


ATLAS-CONF-2020-027

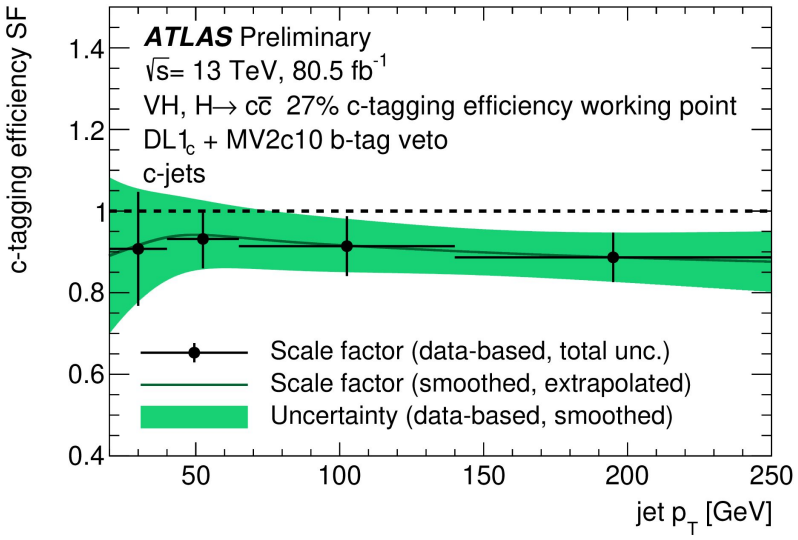
Charm-tagging in VH, H→cc

- c-jet-tagging is a challenge, in terms of performance and calibration
- Necessary to have high charm efficiency to measure H→cc, due to the low cross-section, while also rejection b-jets, to suppress H→bb and to have orthogonality with the VH(bb) measurement

Efficiency for true **c-jets**, **b-jets**, and **light-jets**



Example data/MC for true c-jets

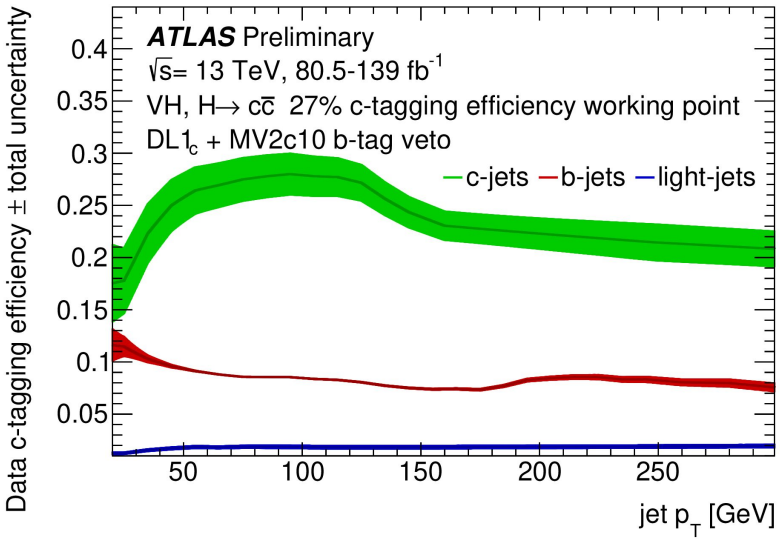


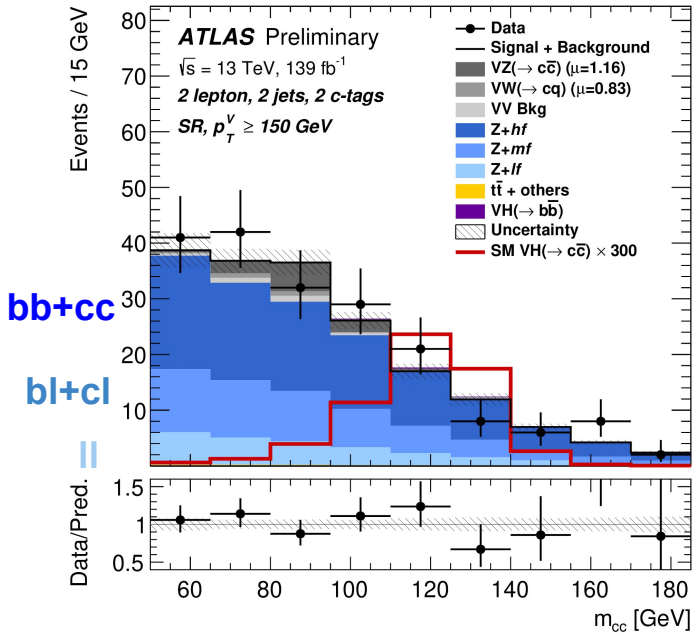
ATLAS-CONF-2021-021

Truth-tagging in VH, H→bb/cc

- VH(bb/cc) has backgrounds from difficult-to-model regions of phase-space
- MC statistical uncertainties large, particularly for event with true c- or light-jets mis-tagged as b-jets
- Rely on parameterized flavor-tagging efficiencies and apply as event-weights with uncertainties to dramatically improve sample statistics

Efficiency for true **c-jets**, **b-jets**, and **light-jets**





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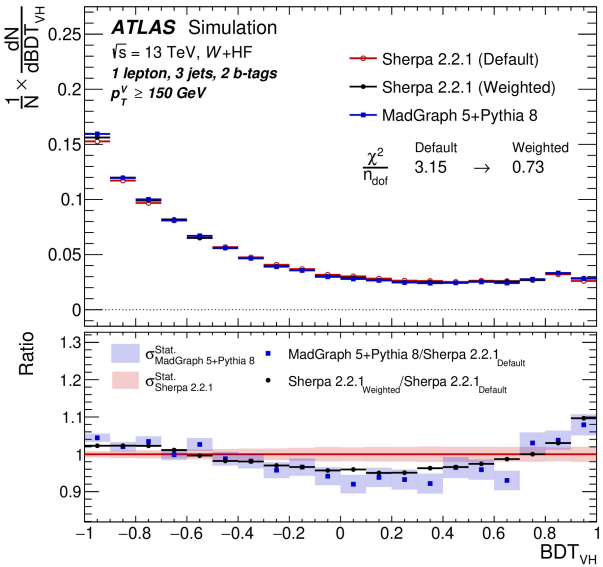
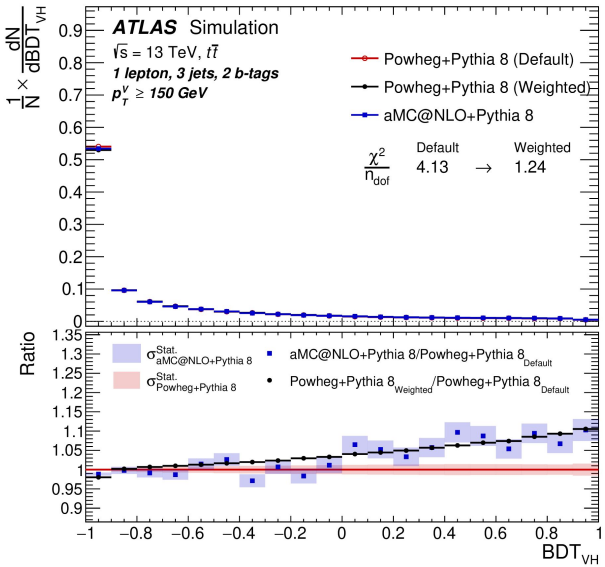
2-Point Systematics in VH, H→bb

- Comparisons of truth-level samples commonly used to evaluate systematic uncertainties (e.g. comparison of samples produced with different generators)
- Train BDT to discriminate two MC samples, and propagate BDT comparison from truth to reconstructed samples
- Allows for propagating effect of comparison on many kinematic variables through 1D reweighting

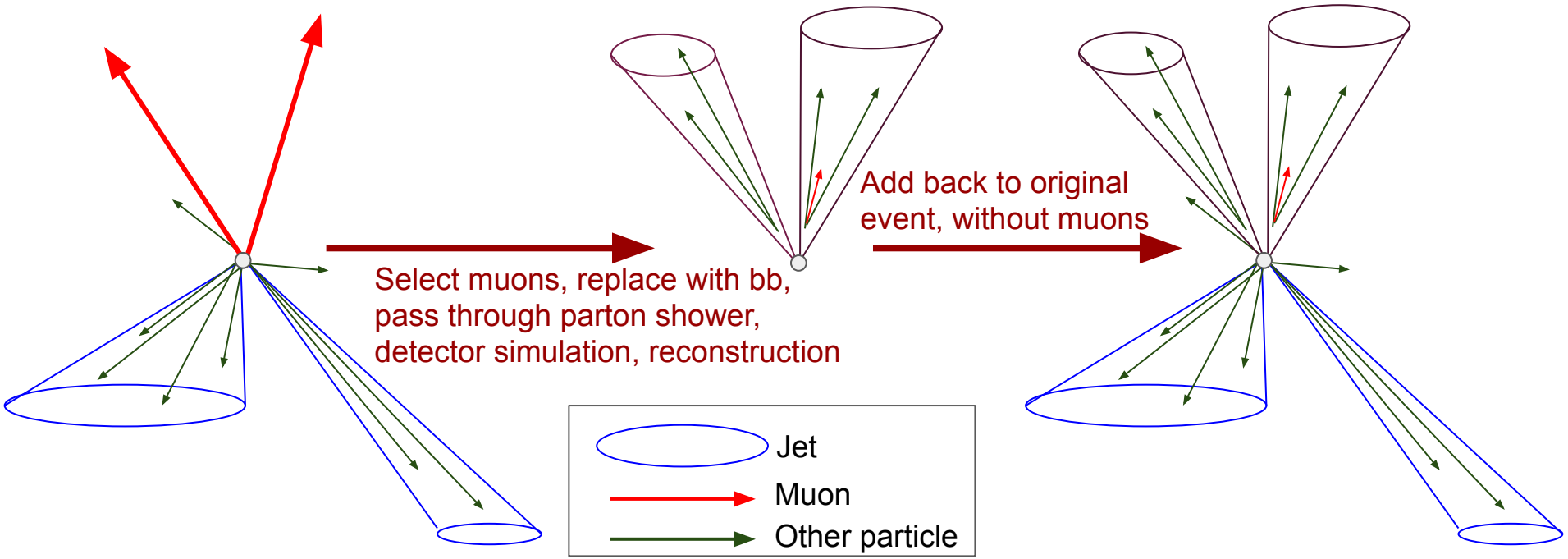




HIGG-2018-51

Z→bb Background in VBF H→bb

- Potentially significant mismodeling and systematic uncertainties
  →One of the main limiting factors in 2016 analysis
- Due to trigger limitations, cannot constrain Z in fits
  →Data-driven approach: estimate Z→bb from Z→μμ (embedding)

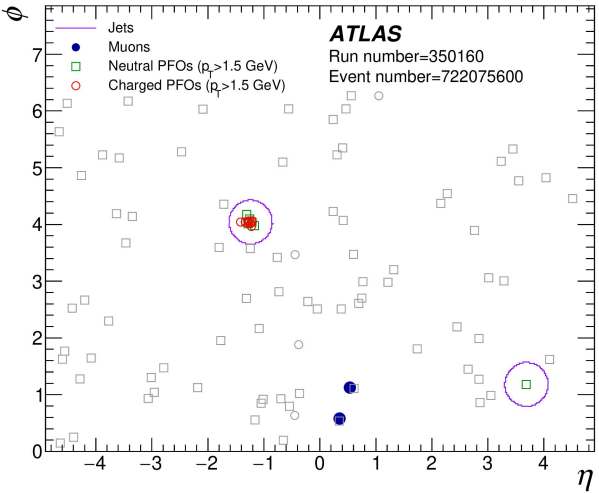


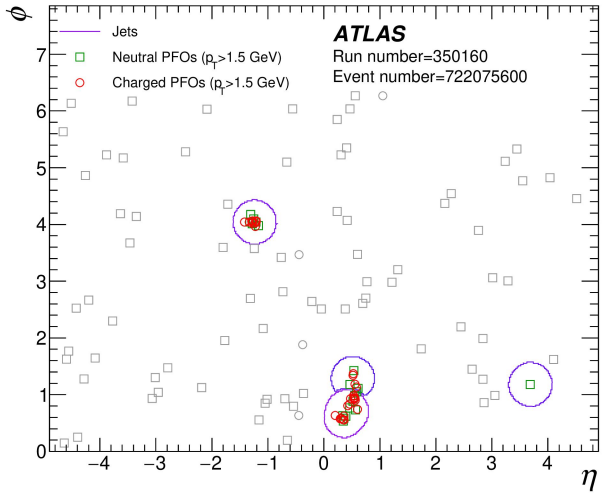
Z→bb Background in VBF H→bb

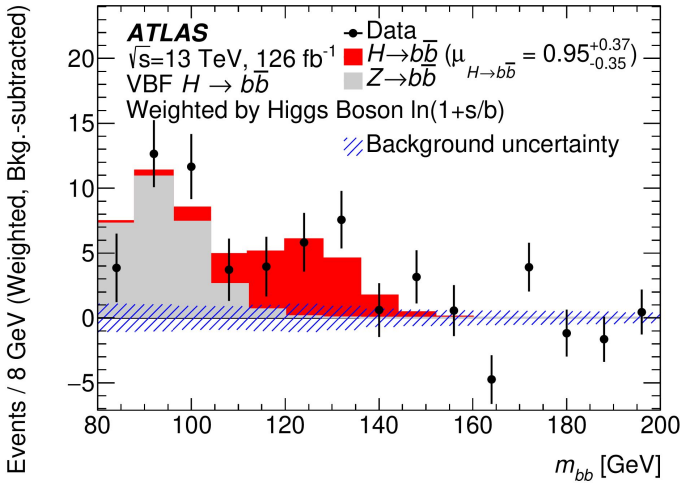
Start with Zμμ event

Produce Zbb event

Use as Zbb estimate, with uncertainties, to extract Higgs signal



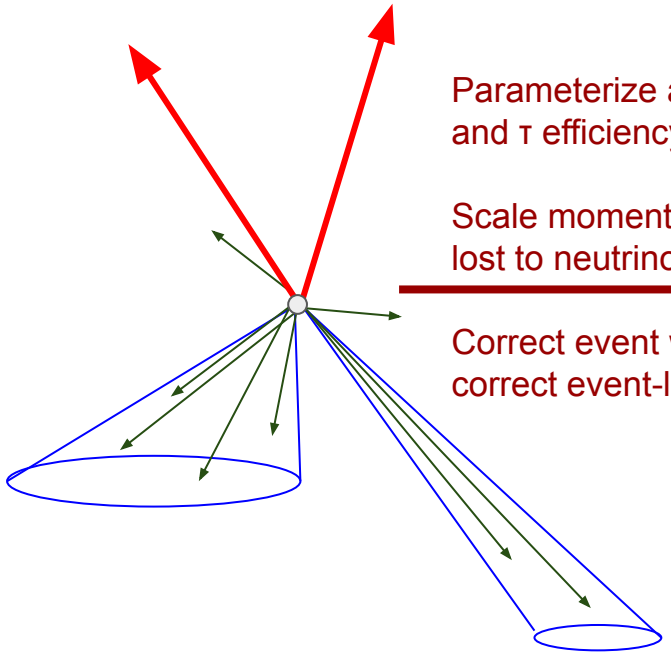




HIGG-2019-04

Z→ττ Background in H→ττ

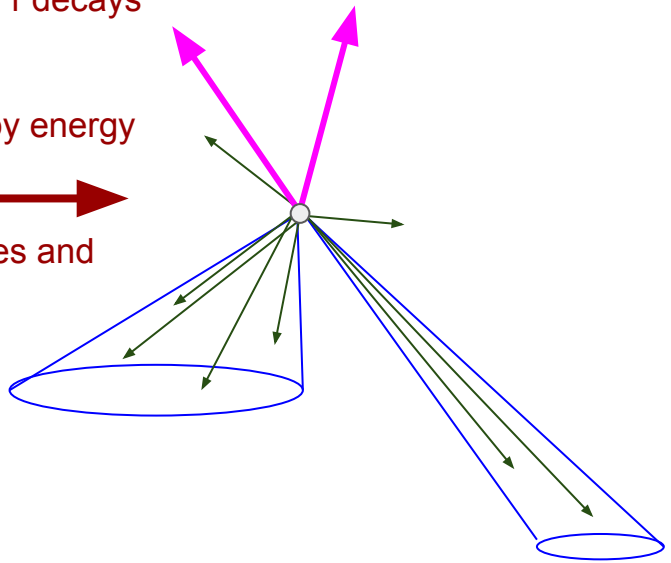
- Large Zττ background that overlaps with Hττ signal
- Simplified method with-respect-to what was done in Run 2
- Starts from Zee or Zμμ events to estimate Zττ background

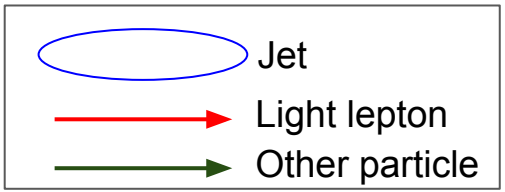


Parameterize average energy lost to neutrinos from τ decays and τ efficiency

Scale momentum of each light lepton in Zll events by energy lost to neutrino from τ decay of similar momentum

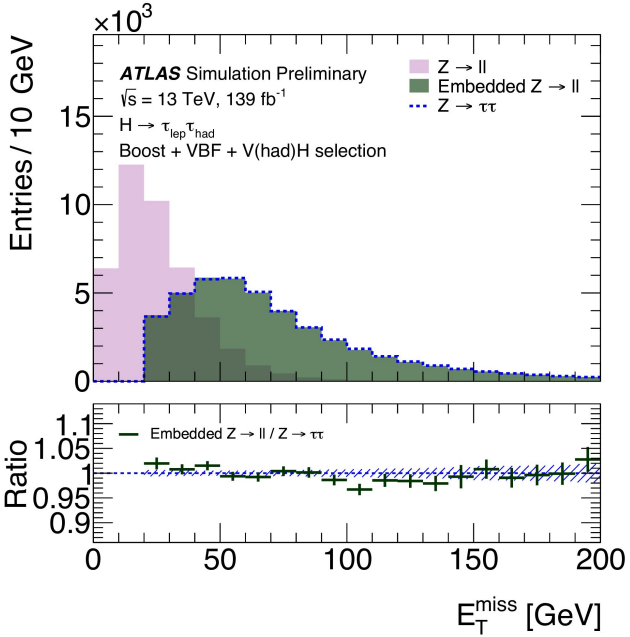
Correct event weights with parameterized efficiencies and correct event-level variables



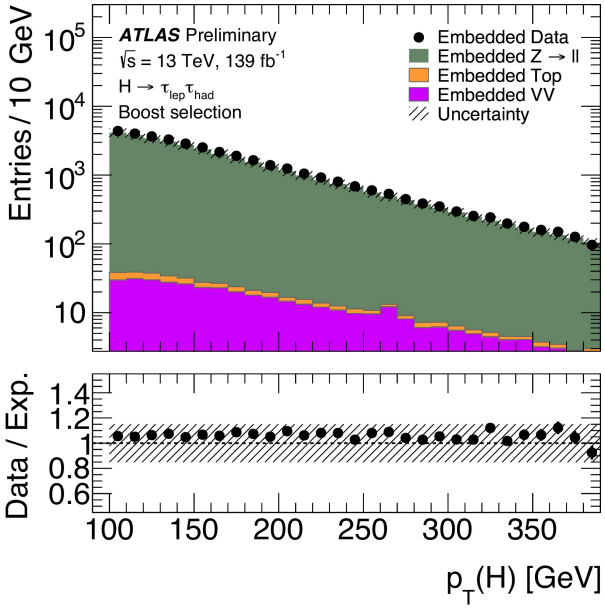


Z→ττ Background in H→ττ

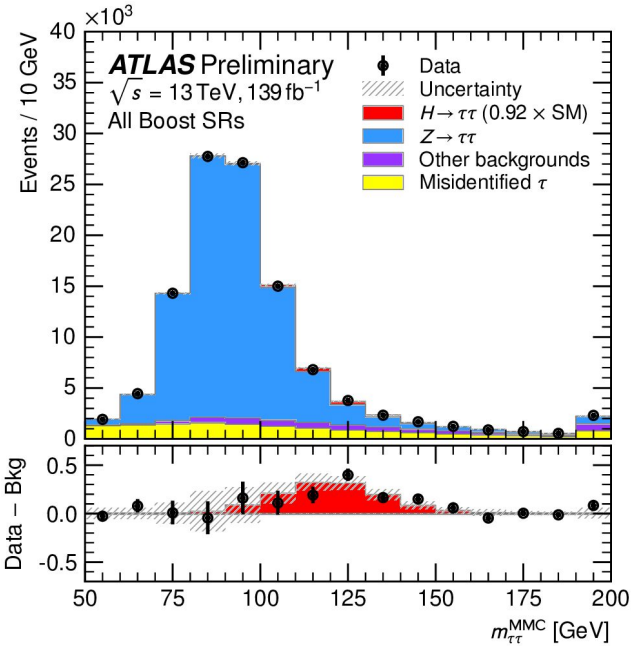
Closure test between Zττ and embedded Zll



Data/MC modeling of embedded samples



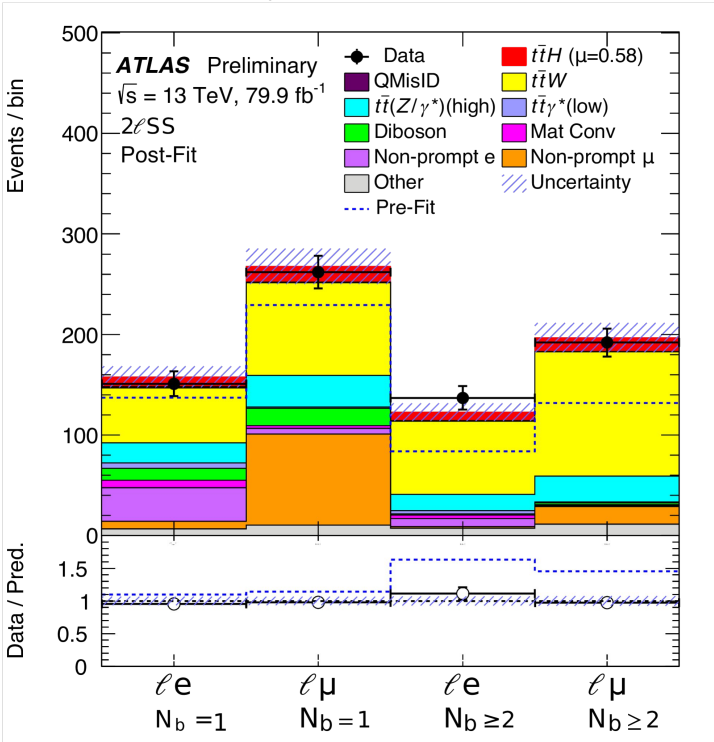
Example signal region, showing signal and embedded Z background



ATLAS-CONF-2021-044

Non-prompt Lepton Suppression in ttH(multilepton)

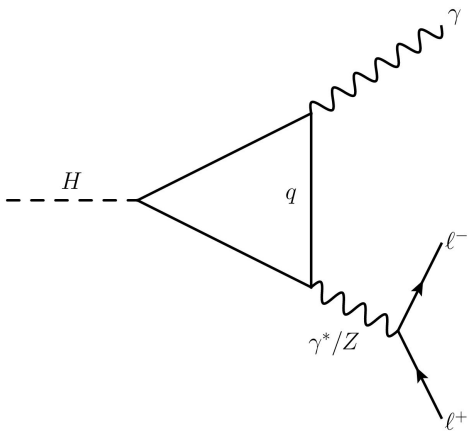
- B-hadrons commonly decay to leptons
- Can use track vertexing information to identify and reject leptons from heavy-flavor processes
- Dedicated lepton selection working points developed for this analysis and reoptimized after
- Compared to lepton isolation alone, tightest working point decreases non-prompt muon efficiency by 45%

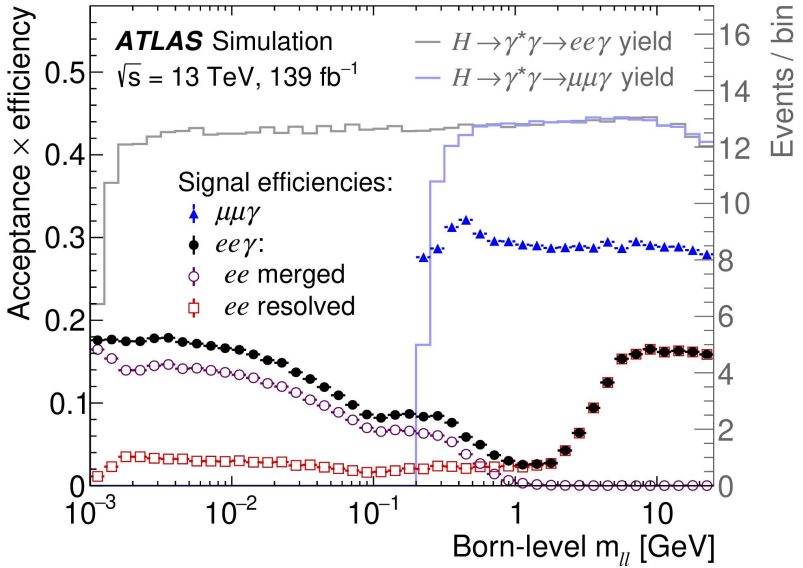


MUON-2018-03
ATLAS-CONF-2019-045

Merged Electrons in H→llγ

- Search for Higgs boson decays to photon and low mass lepton pair
- Normal electron reconstruction breaks down when two electrons are closeby - need dedicated trigger, reconstruction, and identification algorithms

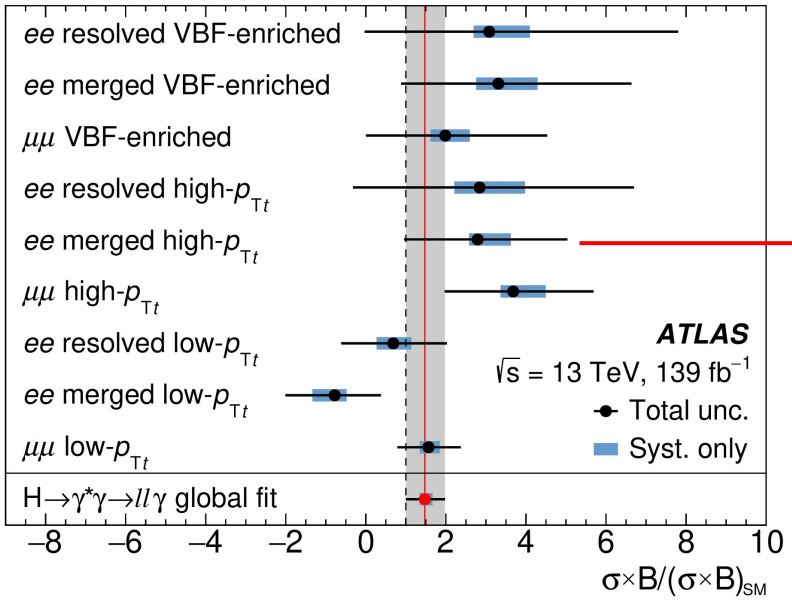


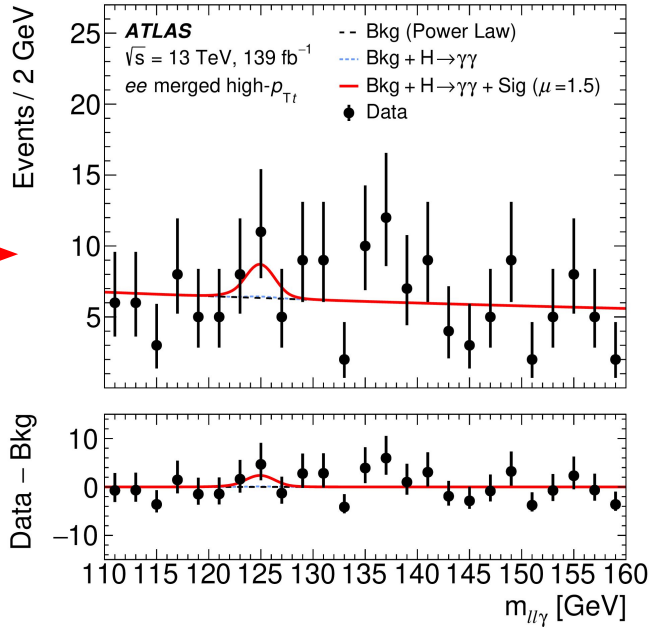


HIGG-2018-43

Merged Electrons in H→llγ

By including dedicated reconstruction technique, analysis found evidence of H→llγ at 3.2σ (expect 2.1σ)





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Conclusion

- Measurements of the Higgs boson thus far do not give strong indication of BSM properties

- There is still large room for BSM effects and many Higgs properties that have yet to be measured with sensitivity to the SM (e.g. the Hcc and HHH couplings) - developing new techniques is necessary

- For more information about individual measurements, see the following talks:
  - H→bb: Maria Giovanna Foti
  - H→cc: Maria Mironova
  - ttH: John Stakely Keller
  - H→ττ: Frank Sauerburger
  - H→llγ: Tom Neep