JAVIER DUARTE (UCSD),
NAN LU, SI XIE (CALTECH),
ARTUR APRESYAN, CRISTIÁN PEÑA (FERMILAB)

SNOWMASS JOINT EF01 & EF02 DISCUSSION

MAY 27, 2020

BOOSTED HADRONIC HH

OUTLINE

- Context and Existing Studies
- New Higgs Tagging Techniques
- Goals of the Snowmass Study

CONTEXT AND EXISTING STUDIES

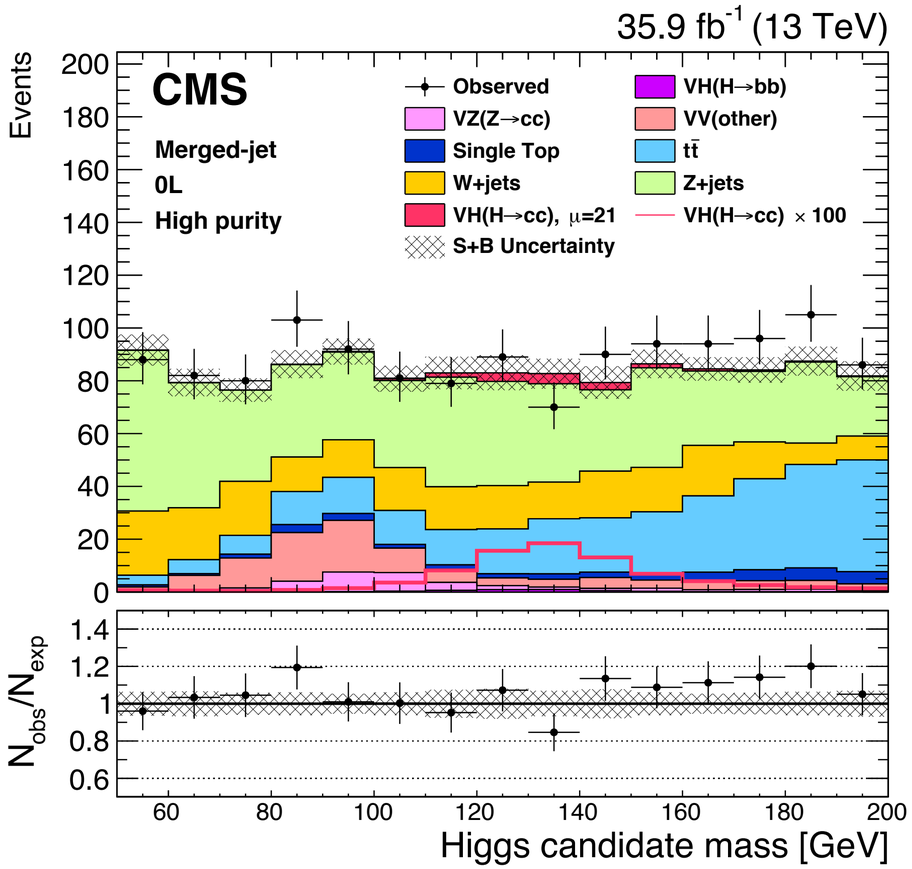
- European Strategy Briefing Book [arXiv:1910.11775,arXiv:1905.03764]
  - Comparison of future collider reach for SM nonresonant HH
- HH white paper, including HH+jet studies at 100 TeV [arXiv:1910.00012, arXiv:1802.01607]
  - Notes importance of HH+jet channel for accessing low m(HH)
- ML for H(bb) Tagging [arXiv:1807.10768,arXiv:1909.12285]
- HH(4b) with ML and jet substructure [arXiv:2004.04240]
  - Detailed projection of 4b final state for HL-LHC
- Many others…
- Existing studies do not fully explore hadronic H(VV) modes
- For H(bb) and H(VV) tagging, new ML methods have emerged recently

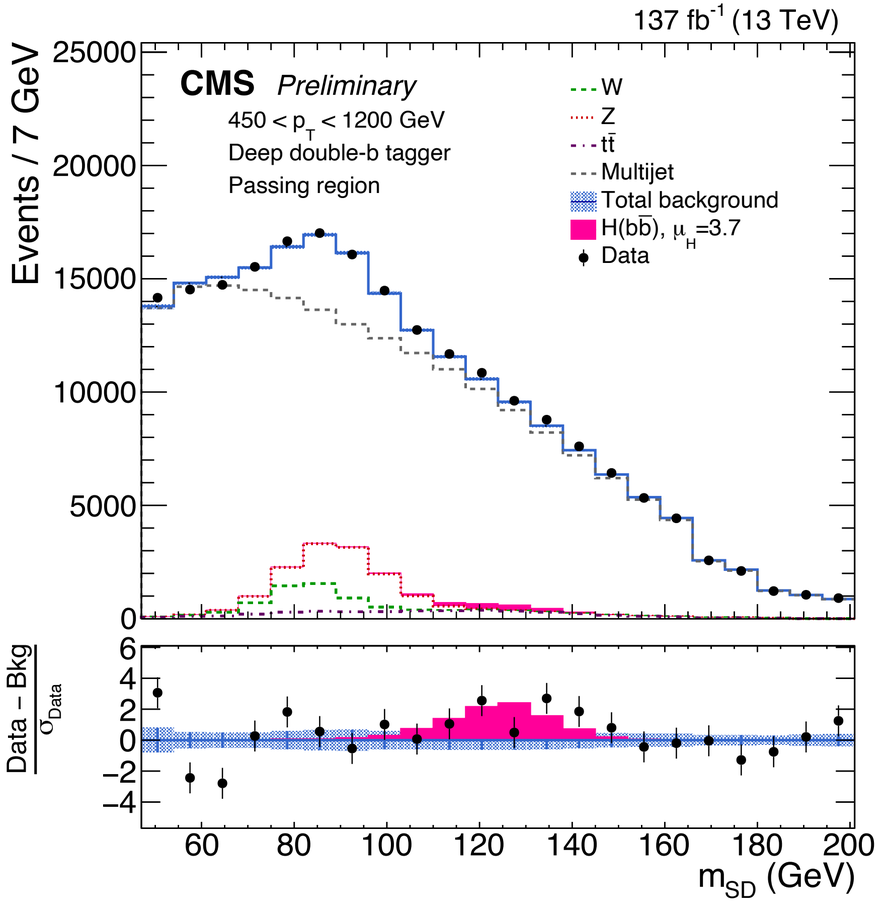
HADRONIC HH BRANCHING FRACTIONS

- Many hadronic HH channels are not fully explored
- Branching fractions for HH decays:
  - bbγγ : 0.26%
  - **bbbb** : 33.9%. 130× more signal than bbγγ
  - **bbWW** : 24.9% 98× more signal than bbγγ
  - **bbZZ** : 3.0% 12× more signal than bbγγ
  - **VVVV** : 5.8% 22× more signal than bbγγ
- After requiring both Higgs with $p_T > 400$ GeV
  - **bbbb** : 5.2× signal yield of bbγγ
  - **bbWW** : 4.3× signal yield of bbγγ
  - **VVVV** : 0.9× signal yield of bbγγ

NEW HIGGS TAGGING APPROACHES

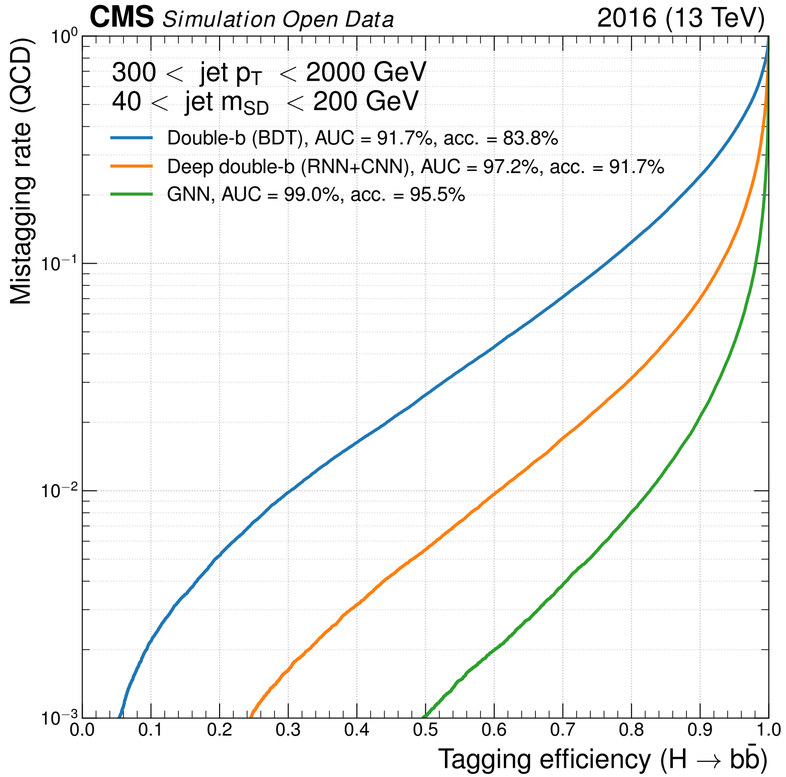
- ATLAS [arXiv:1906.11005] and CMS [arXiv:1712.07158,arXiv:2004.08262] developed techniques for tagging boosted large-radius H(bb), H(cc), H(4q)
- Methods used in CMS VH(cc) and ggH(bb) searches

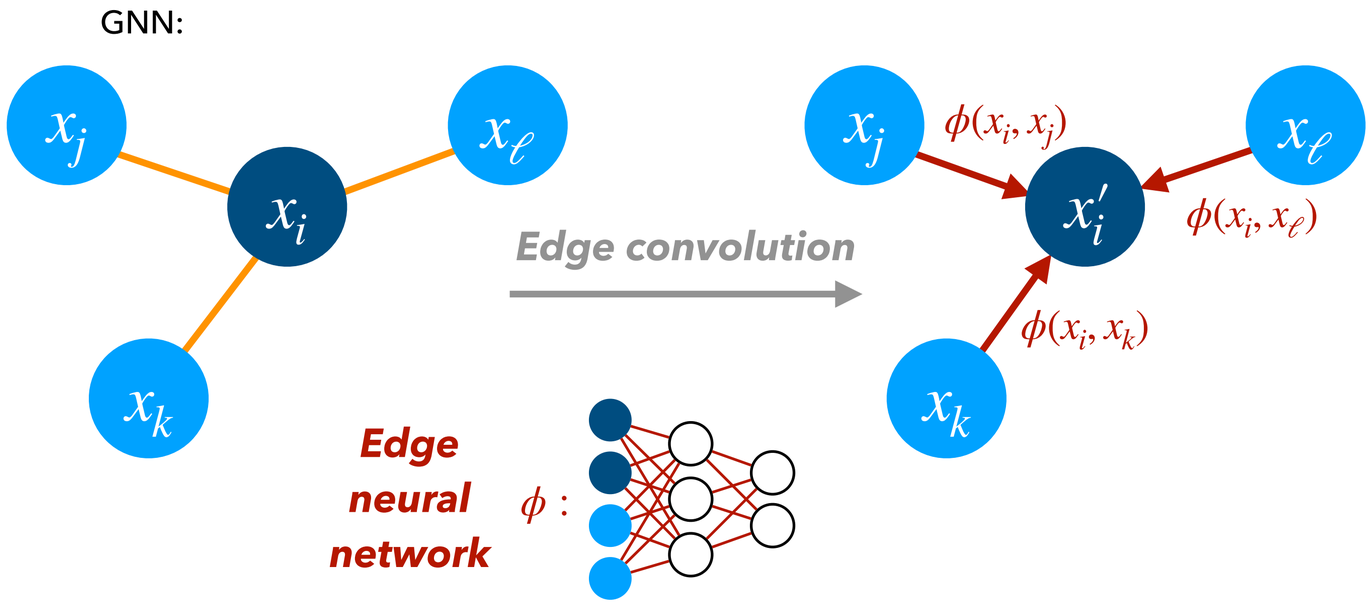




EXAMPLE: GRAPH NEURAL NETWORKS

- Graph neural networks for jet tagging
  - ParticleNet [arXiv:1902.08570], based on Dynamic Graph Convolutional Neural Network (DGCNN) [arXiv:1801.07829]
  - JEDI-Net/HiggsInteractionNet [arXiv:1908.05318,arXiv:1909.12285], based on Interaction Network [arXiv:1612.00222,arXiv:1806.01261]





GOALS OF THE SNOWMASS STUDY

- Show the relative importance of boosted, hadronic HH modes to cross section and Higgs self-coupling sensitivity
- Synthesize messages from existing studies
- Compare sensitivity in different collider scenarios (HL-LHC, FCC-hh)
- Explore analysis strategies and ways to measure ML-based Higgs tagging efficiency in data and control systematic uncertainties
- Provide input to future detector design for highly-boosted Higgs jets

- Connections to other working groups:
  - CompF3: Machine Learning

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BACKUP

BOOSTED HH SENSITIVITY TO K_λ

- Previous study by Banerjee et al. [arXiv:1802.01607] emphasized importance of studying HH+jet to increase acceptance to low HH mass and improve sensitivity to k_λ

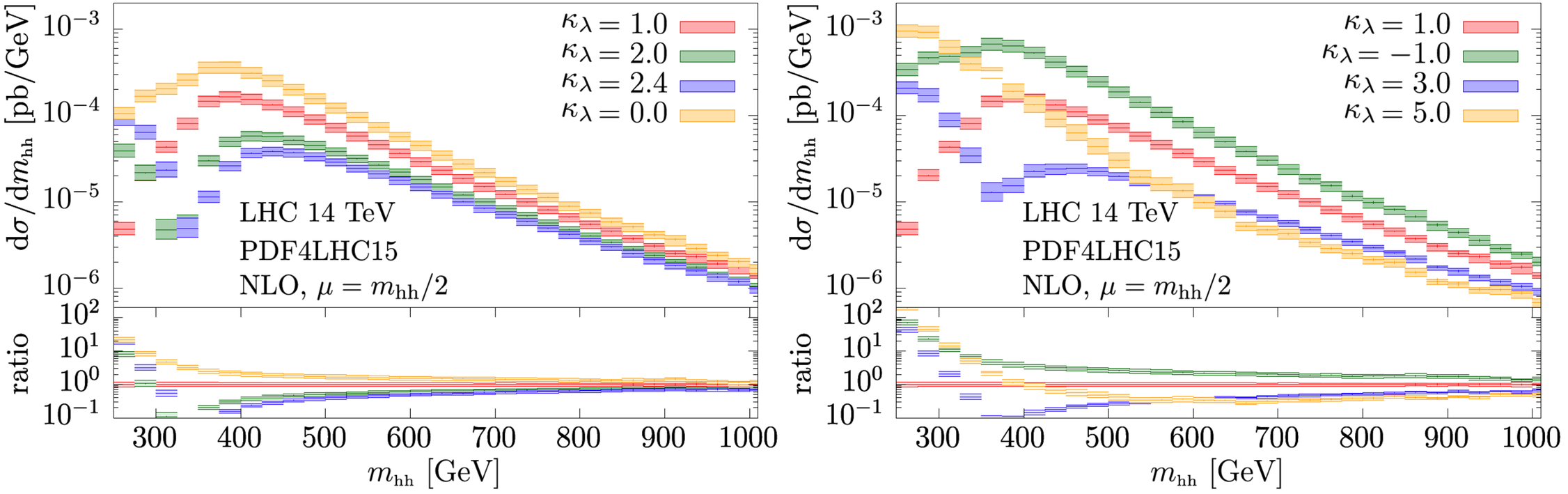

Figure 1.10: Higgs boson pair invariant mass distributions at 14 TeV for (left) positive small values of κ_λ and (right) larger or negative values of κ_λ [64]. [arXiv:1903.08137]