Search for VH,H→cc

(In the Resolved-Jet Regime at CMS)

DPF-PHENO Parallel Talk
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T. Russell[1] on behalf of the CMS Collaboration

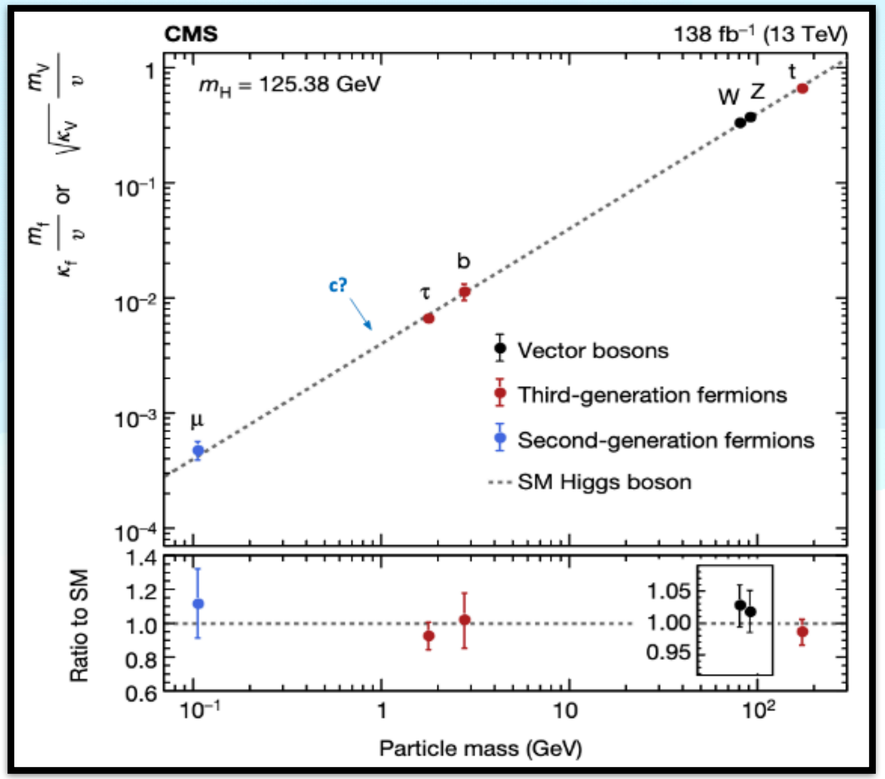
1. Brown University

VH(H→cc) Run 3 Analysis

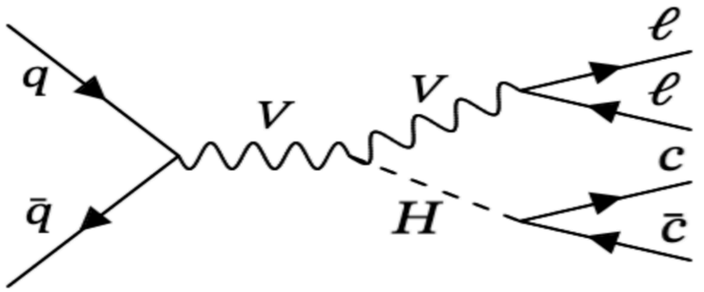
Motivation

- Higgs boson couplings to vector bosons and 3rd generation charged fermions have been established
- Yet to establish coupling with second generation quarks
  - H→cc branching ratio is 20x smaller than H→bb
  - Tagging charm jets is difficult
- Analysis with full Run 2 data
  - Vector boson (Z/W) decaying leptonically: 3 leptonic channels

arXiv: 2207.00043



Run 2 Results	Expected	Observed
σ(VH) x B(H→cc)	< 7.6 x SM	< 14 x SM
$\lvert\kappa_c\rvert$	< 3.4	[1.1,5.5]



VH(H→cc) Run 2 Analysis

Review

- Resolved-Jet Regime
  - Targets low and moderate ranges of the Higgs p_T
  - 2 small-radius (AK4) Jets
  - Covers ~95% of the signal phase space
  - Fit signal vs background BDT
- Merged-Jet Regime
  - Targets moderate and high ranges of the Higgs p_T
  - 1 large-radius (AK15) Jet
  - Fit regressed Higgs mass
  - Contributes comparatively more to sensitivity
    - Exploits correlations between charm jets
    - Benefits from lower backgrounds

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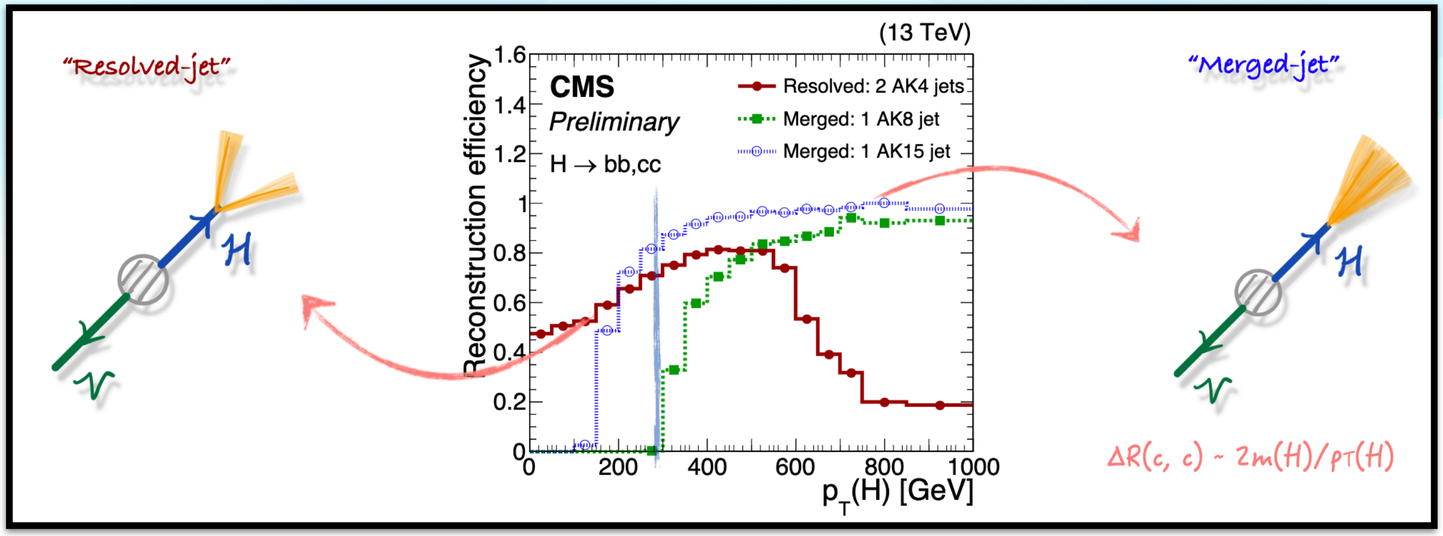
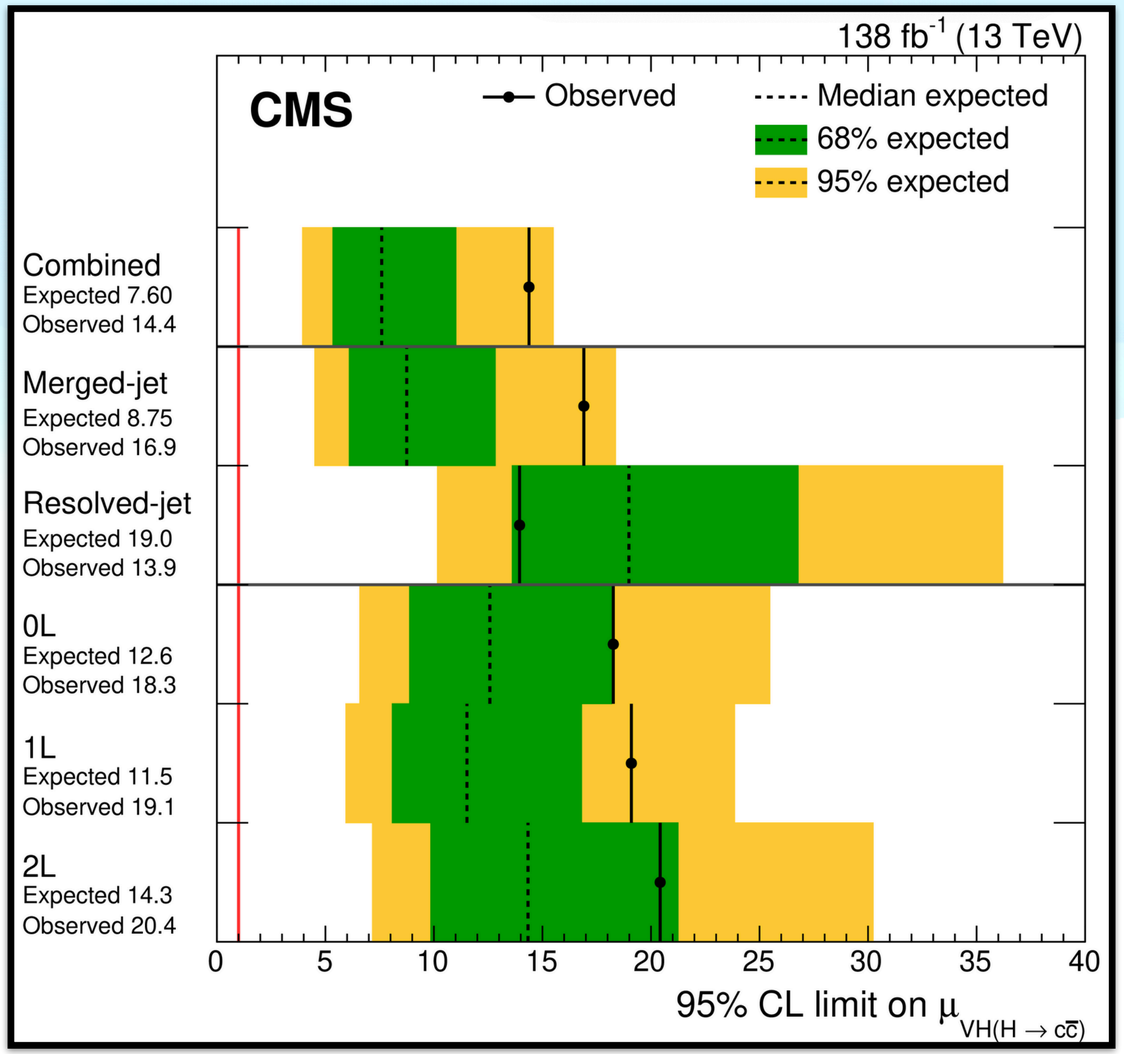


VH(H→cc) Analysis

Run 3 Goals

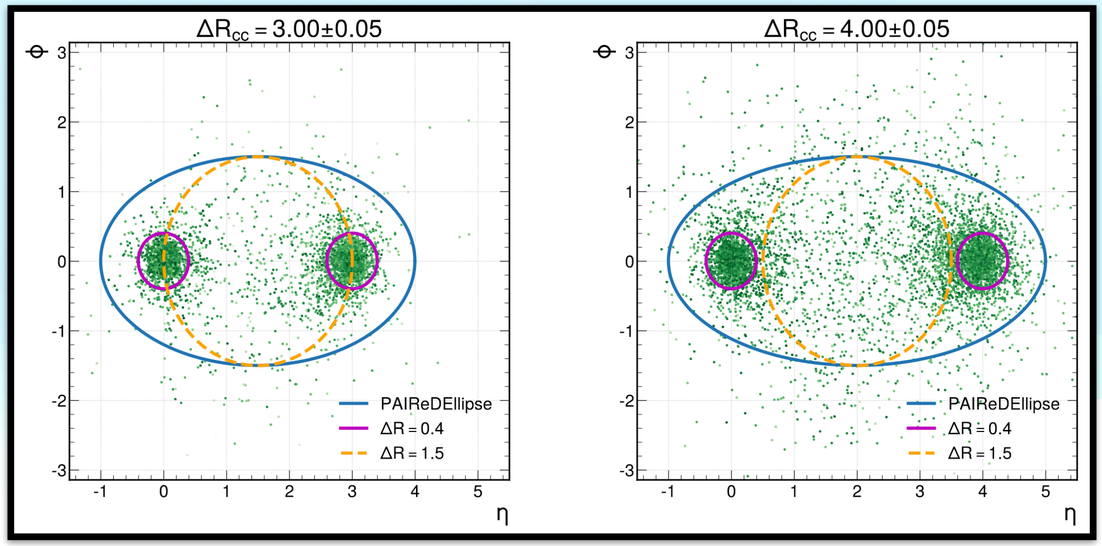
- Improve the limits in the resolved-jet regime set in the Run 2 Analysis
- Move toward an integrated strategy between merged and resolved regimes

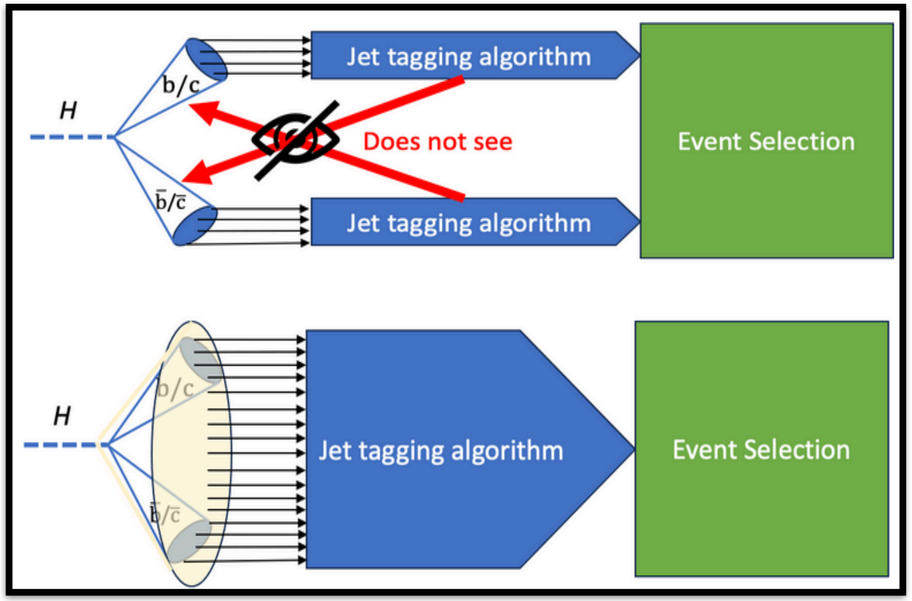
arXiv: 2205.05550



Jet Reconstruction Strategy

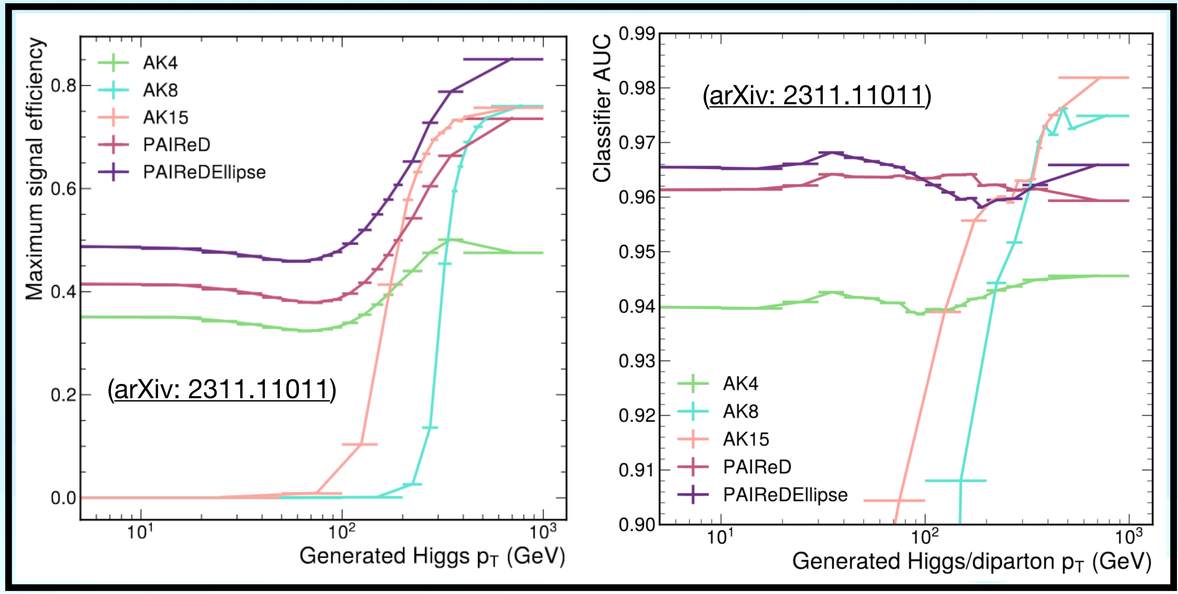
- **P**article **A**ngular-separation **I**ndependent **Re**sonant **D**ijet (PAIReD) [arXiv: 2311.11011]
  - New approach to reconstruct decays of heavy particles at a large range of Lorentz-boosts
- Instead of tagging AK4 jets individually, define an elliptical area in the η-ϕ plane based on a pair of AK4 jets
  - Run any tagging algorithm on the jet
  - Allows the tagger to leverage correlations between hadronization products

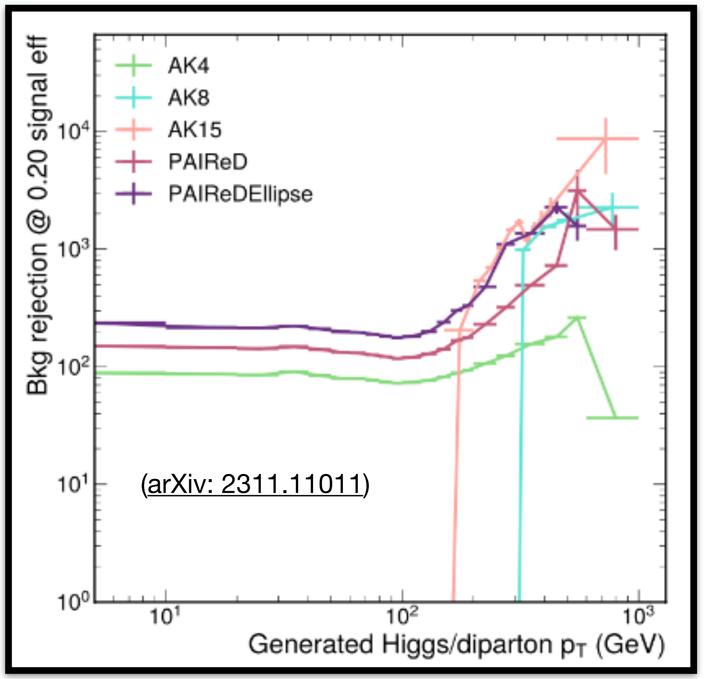




Advantages

- Better signal reconstruction
  - Higher signal reconstruction efficiency at all Lorentz boosts
  - 40-50% improvement at lower boosts
- Better tagging
  - Better flavor separation at low boosts
- Combined effect results in 2-4x rejection of V+jets background



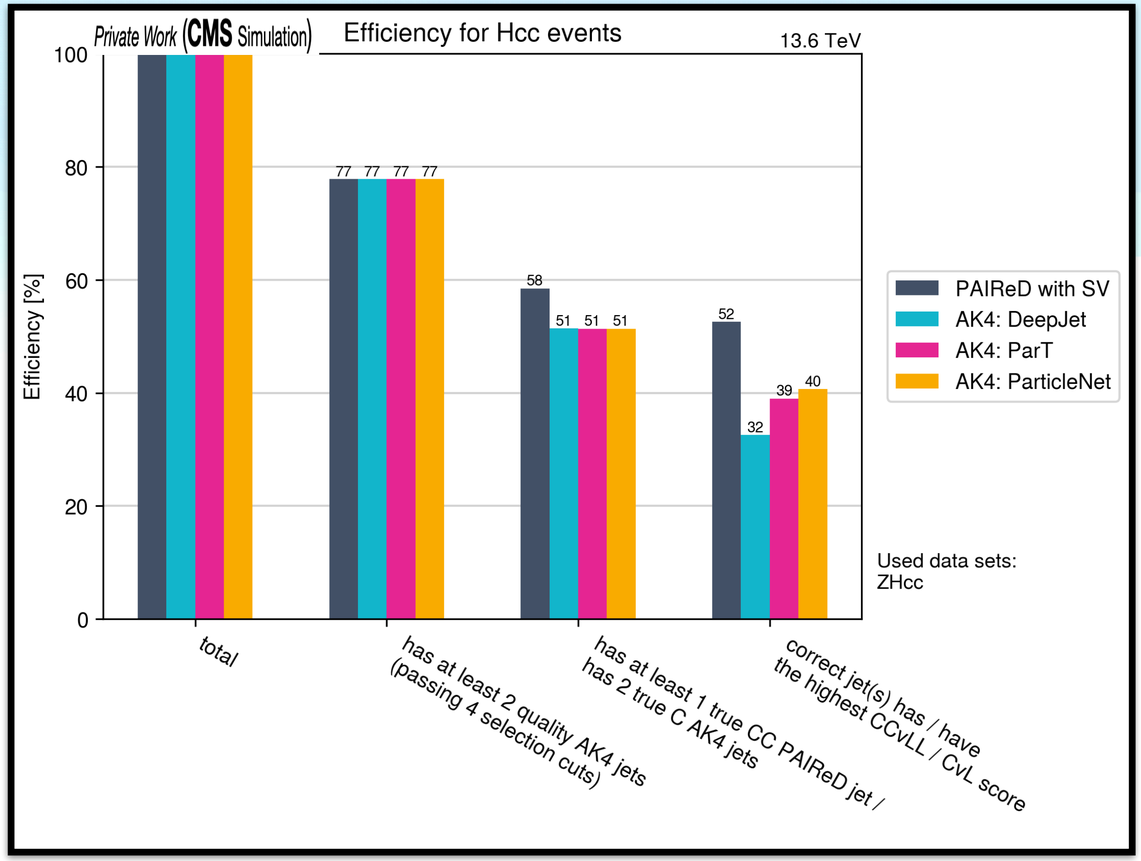


New VH(H→cc) Analysis Strategy

Description	Run 2 Resolved	Run 2 Merged	Run 3 (Resolved)
Higgs Reconstruction	2 AK4 Jets	1 AK15 Jet	1 PAIReD Jet
Tagging	Individual DeepJet Scores	ParticleNet	Particle Transformer on PAIReD
Signal Region Definition	Cut on Leading Jet Score	Cut on AK15 Jet Score + Signal vs Background Kinematic BDT	Cut on PAIReD Jet Score + Signal vs Background Kinematic BDT/NN
Fit Variable	Signal vs Background BDT	Regressed AK15 Jet Mass	Regressed PAIReD Jet Mass

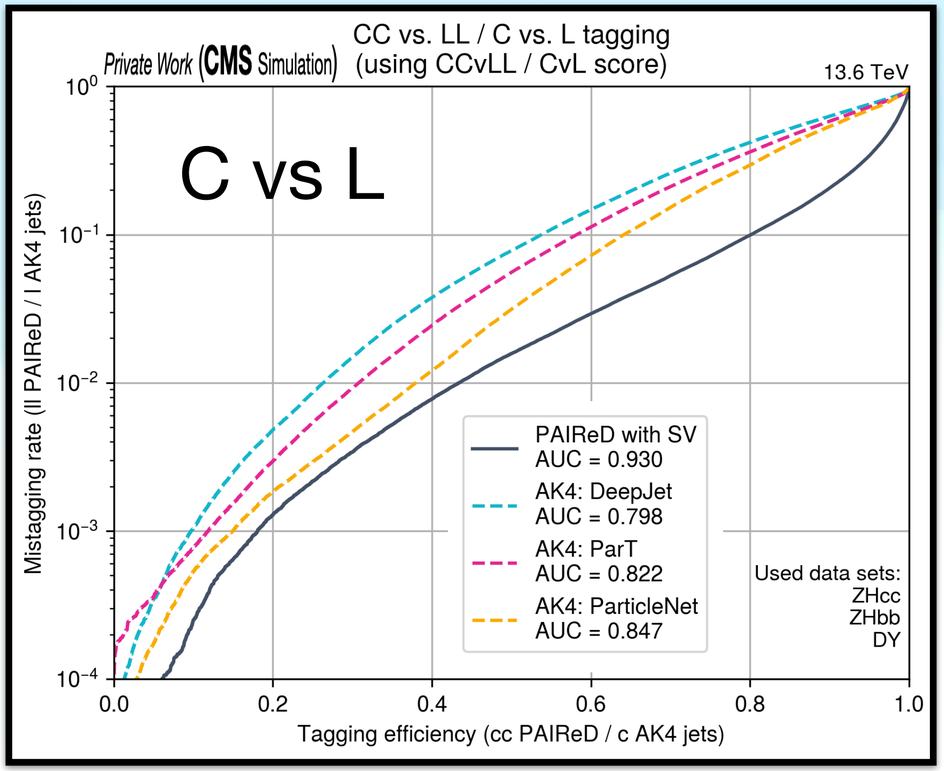
Implementation of Reconstruction Strategy in VH(H→cc) Run 3

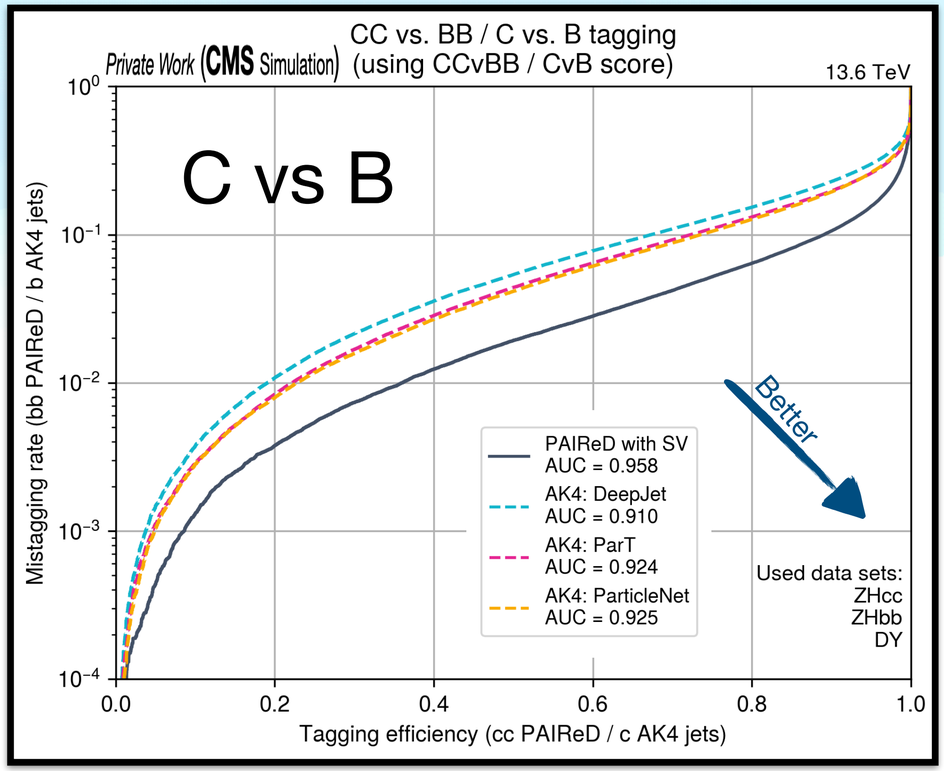
- Tagging with large-radius jets (e.g. AK15) lets one exploit correlations between decay products (as done in VHcc Run-2 merged-jet analysis)
  - Limited to high boosts only
- New strategy lets us extend this benefit to resolved-jet regime
- Retrained with CMS samples
- Added secondary vertex information to PAIReD Jets
  - Particle Transformer implementation
- Can also regress the Higgs mass and kinematics from the constituents
- Improved tagging efficiency and more synergy with the strategy in the merged-jet regime



Implementation of Reconstruction Strategy in VH(H→cc) Run 3

- Retrained tagger with CMS samples (PFNano/BTVNano)
  - **Added secondary vertex information to PAIReD Jets**
  - Particle Transformer implementation
- Can also regress the Higgs mass and kinematics from the constituents
- Improved tagging efficiency and more synergy with the strategy in the merged-jet regime



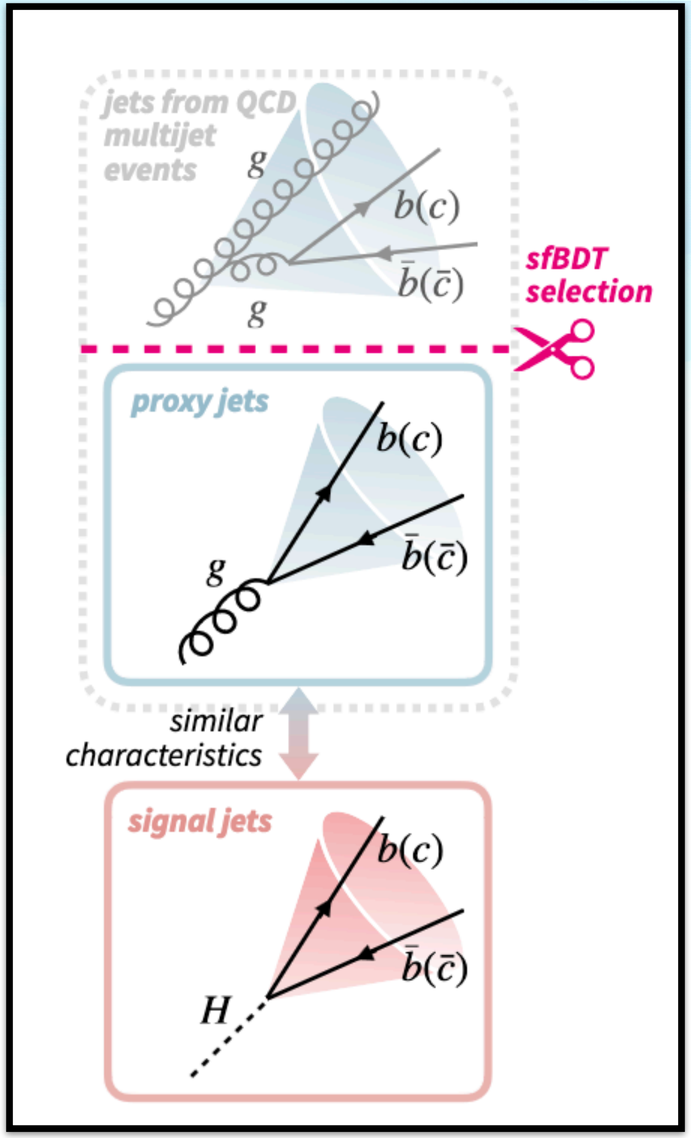


VH(H→cc) Run 3 Analysis

Calibration Plans

- PAIReD Jet energy corrections to be derived
- Will use boosted tagger calibration methods (sfBDT) to calibrate tagger
  - Use BDT to identify QCD jets similar to signal and derive scale factors with those

CMS DP



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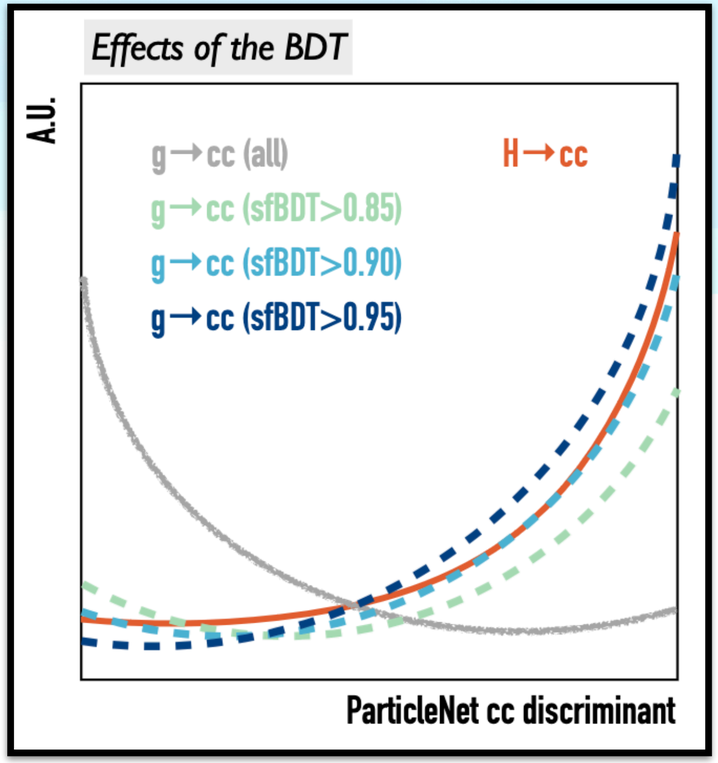

VH(H→cc) Run 3 Analysis

Summary

- New strategy allows taggers to take advantage of more information and achieve better efficiency
  - Applicable at all boosts
    - Main gain from lower boosts
  - Provides synergy with the merged-jet strategy
    - Wider acceptance coverage
    - Split between strategies can be tuned to maximize significance