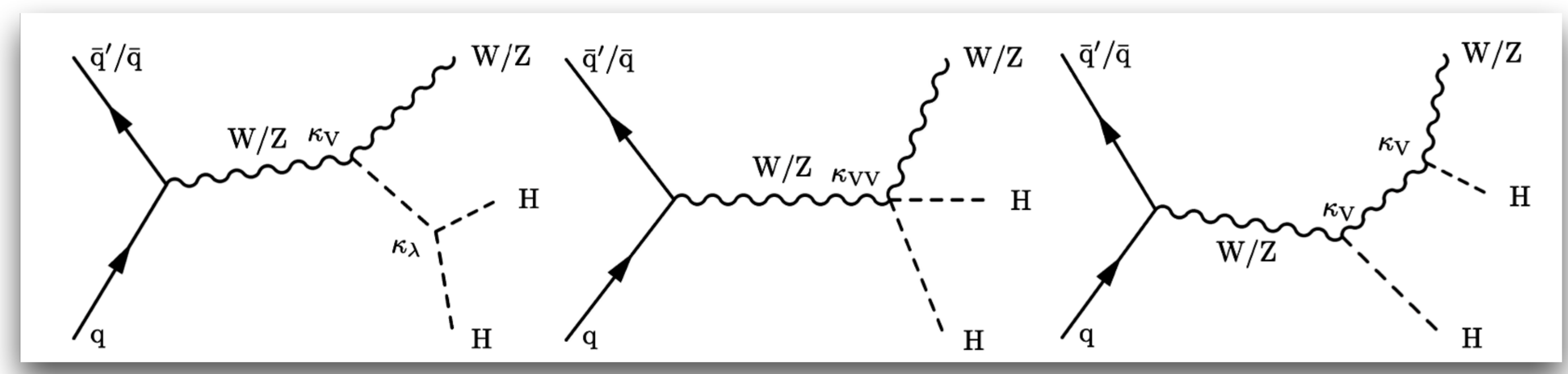


Search for Higgs boson pair production with one associated Vector boson at CMS

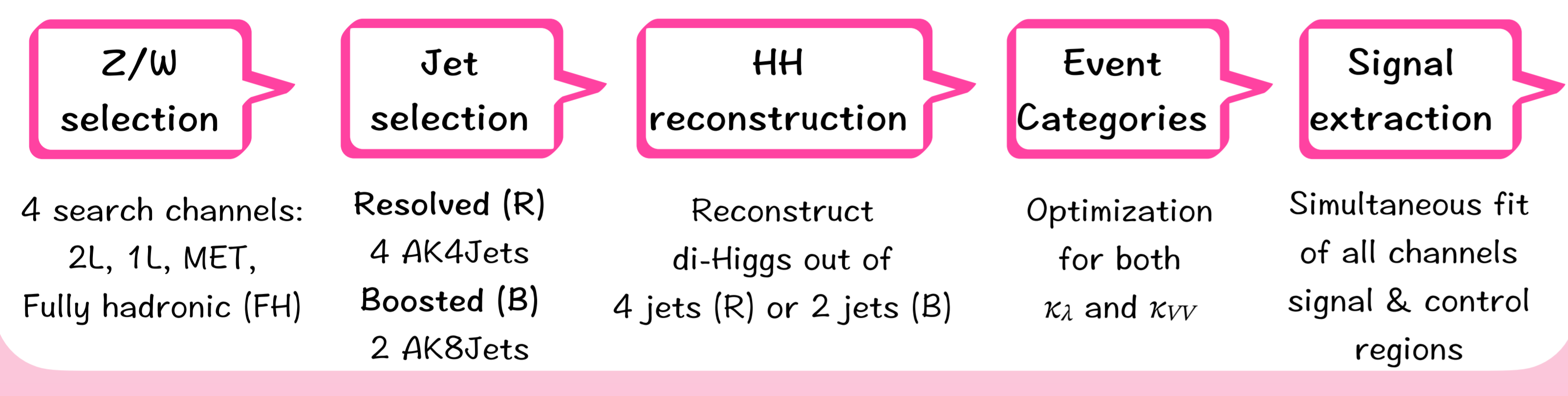
Chayanit Asawatangtrakuldee (Chulalongkorn U.) on behalf of CMS Collaboration
Reference : CMS PAS HIG-22-006



A search for Higgs boson pair production (HH) associated with a vector boson V (W or Z boson) is presented. The search is based on 138 fb⁻¹ of proton-proton collisions at a center-of-mass energy of 13 TeV, collected with the CMS detector at the LHC. The processes in this search include pp → ZHH and pp → WHH production. All hadronic decays and leptonic decays of W and Z bosons involving electrons, muons, and neutrinos are utilized. Higgs bosons are searched for in the bbb channel.



Analysis Flow



Motivation

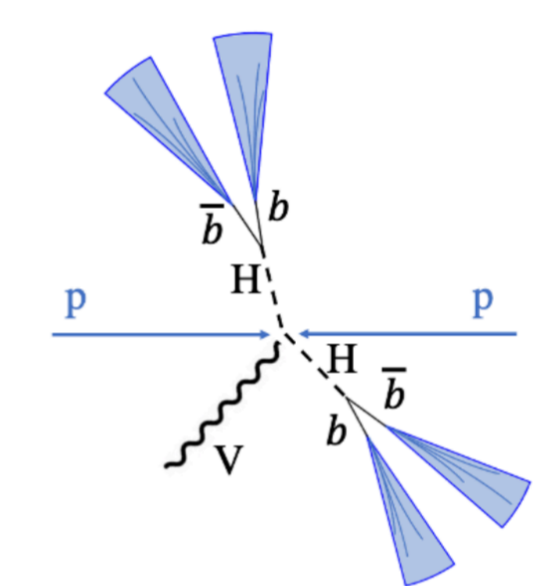
- ☆ Cross section enhanced by constructive interference
- ☆ Good triggers and cleaner background
- ☆ Decompose κVV to κWW and κZZ



Z/W selection (4 channels)

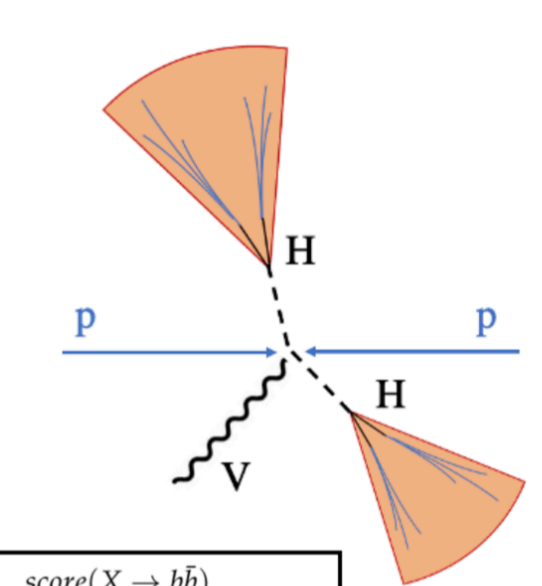
Channel	V selection
2L	Muon: p _T > 20 GeV Electron: p _T > 25 GeV(leading), p _T > 20 GeV(sub-leading) p _T (V) > 50 GeV
1L - R	Muon: p _T > 25 GeV
1L - B	Electron: p _T > 32 GeV(2017/2018), p _T > 28 GeV(2016) Δφ(lep, MET) < 2.0, p _T (V) > 125 GeV
MET - R	p _T (V) > 150 GeV
MET - B	p _T (V) > 250 GeV
FH	65 < m _V < 105 GeV

Jet selection & HH reconstruction



Resolved (4 AK4 Jets)

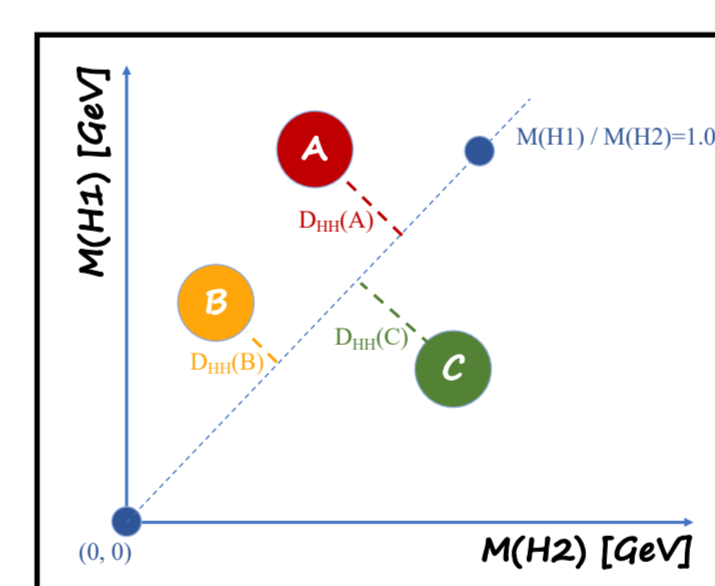
- ☆ GoodJets > 4
- jet without leptons, |η| < 2.5
- ☆ 4 leading DeepJet-scored GoodJets
- MET channel all 4 jets to pass loose WP
- ☆ p_T cut for all 4 jets
- MET: p_T > 35 GeV
- 1L: p_T > 25 GeV (j1-j3), p_T > 15 GeV (j4)
- 2L: p_T > 20 GeV
- ☆ 3/4 b-tagged events (DeepJet medium WP)



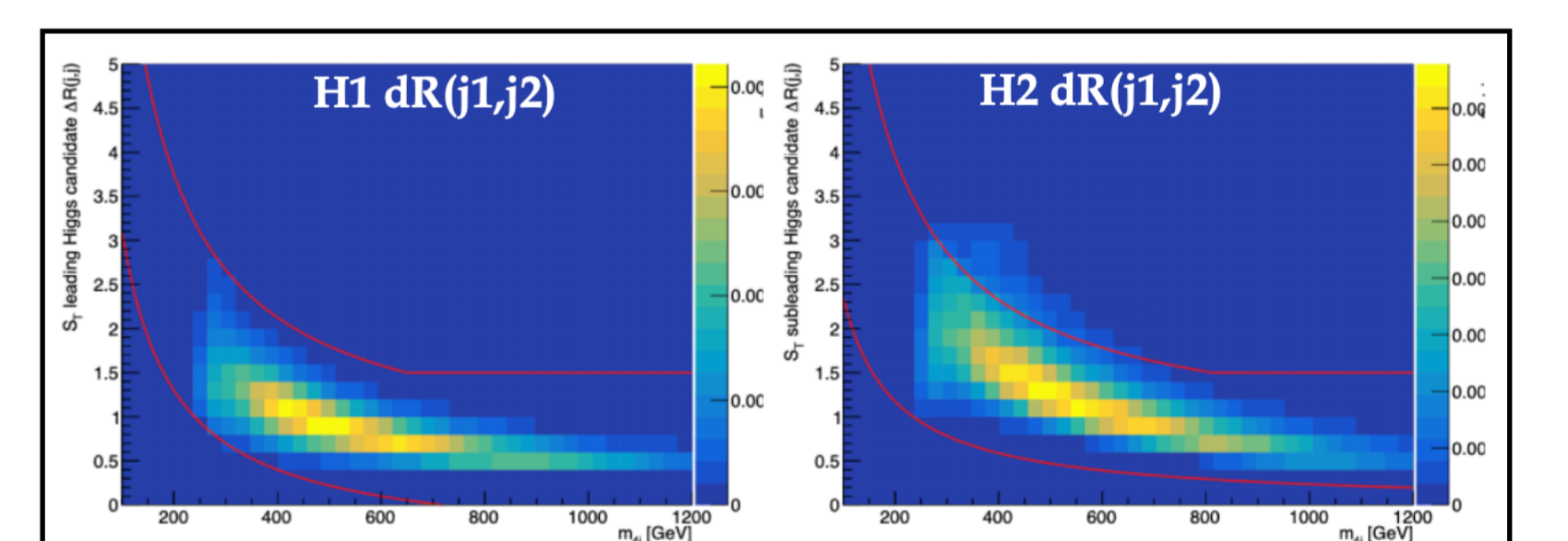
Boosted (2 AK8 Jets)

- ☆ 2 leading AK8 jets (sorted by D_{bb}, derived from ParticleNet score) that pass the following selections
- ☆ p_T > 200 GeV, |η| ≤ 2.5,
- ☆ ParticleNet mass > 50 GeV, dR(jet,lep/MET) > 0.8
- ☆ m_{HH} > 300 GeV

Leptonic channel: minimal D_{HH}

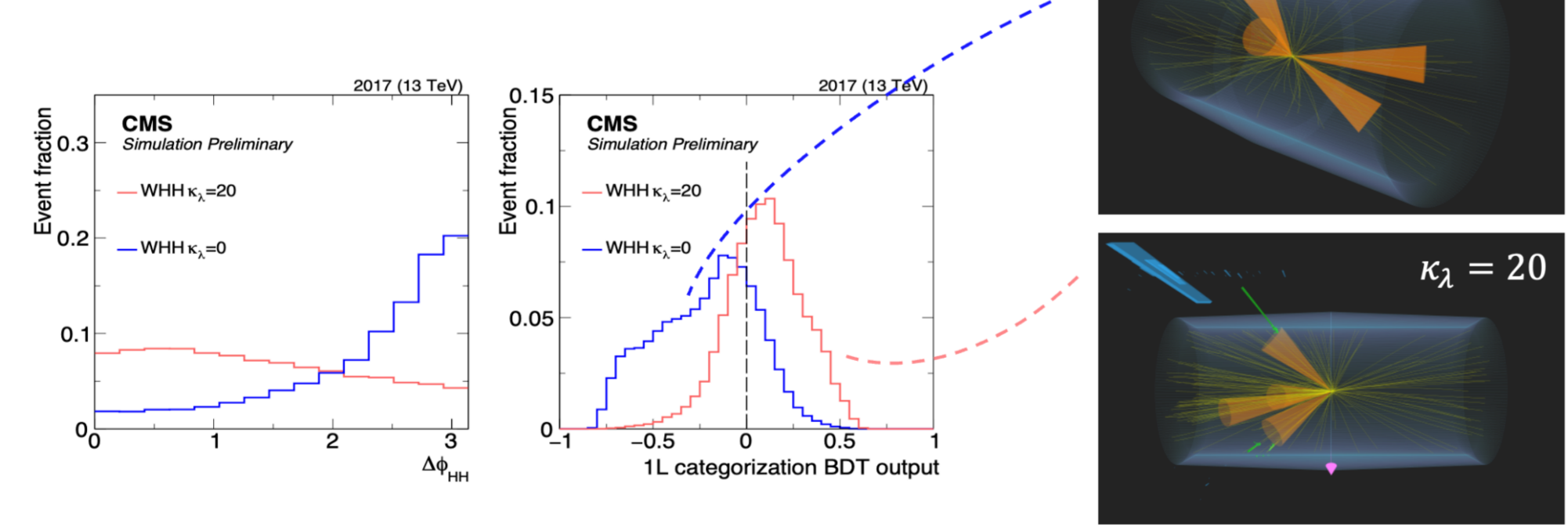


FH: ΔR(j1, j2) criteria



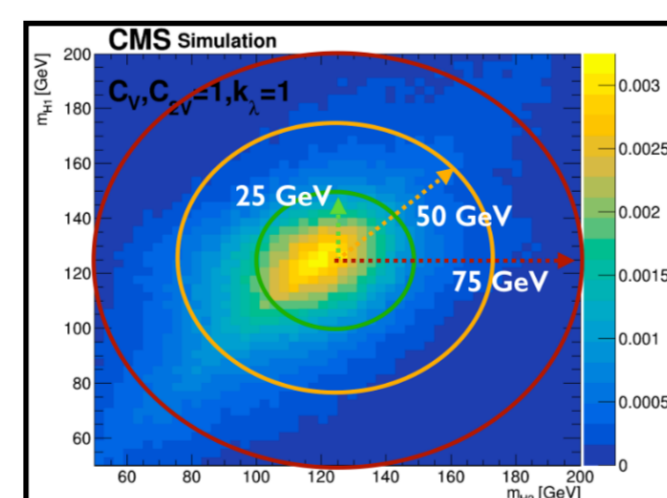
Event categorization

Separating signals with a categorization BDT



$r_{HH} = \sqrt{(m_{H1} - 125)^2 + (m_{H2} - 125)^2}$
 SR : r_{HH} ∈ [0, 25] GeV; CR : r_{HH} ∈ [25, 50] GeV
 SB : r_{HH} ∈ [50, 75] GeV

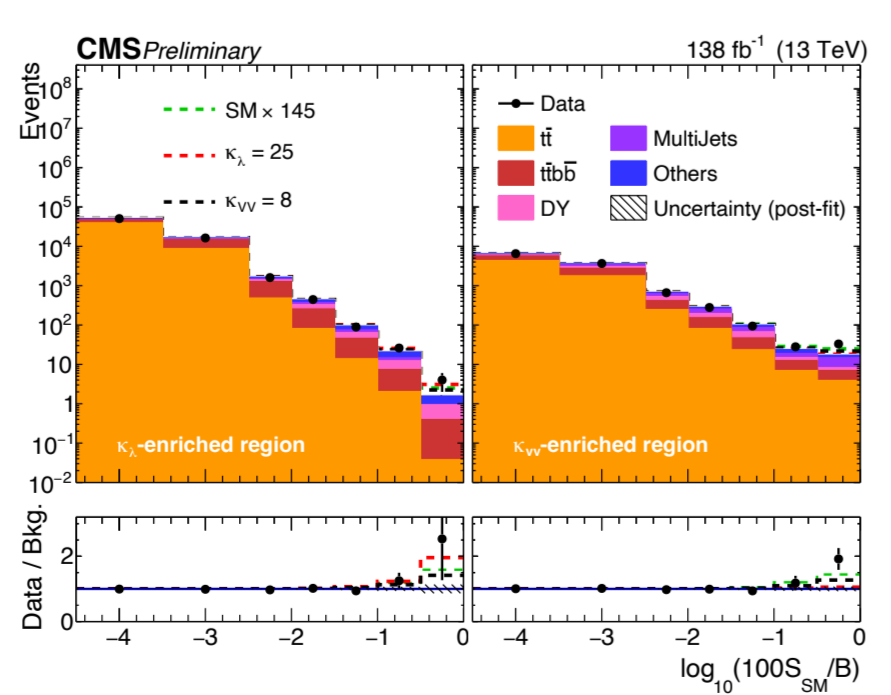
- SB observable: p_T(V) or m_{H2}
- SR, CR observable: machine learning score



Background estimation

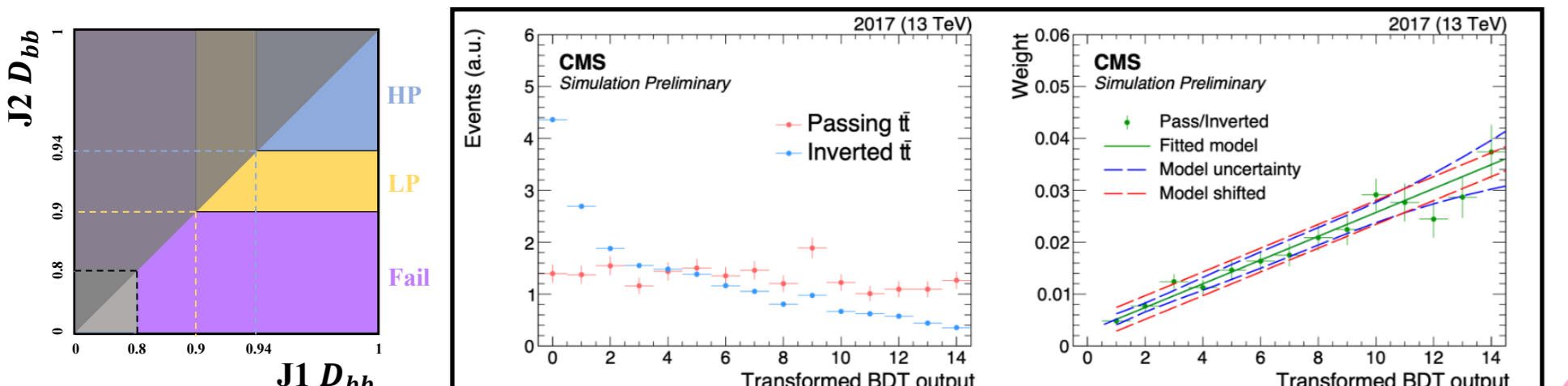
A. SvB classifier

- 1) Leptonic channel, BDTs
 - Common inputs: m_{HH}, p_T(HH), m_{H1}, p_T(H1), p_T(V)
 - Backgrounds modelled with MC
- 2) FH channel, machine learning score
 - Inputs: jet features (p_T, η, φ, m), dijet features (m, ΔR)
 - Data-driven multi-jets background



B. Background reweighting

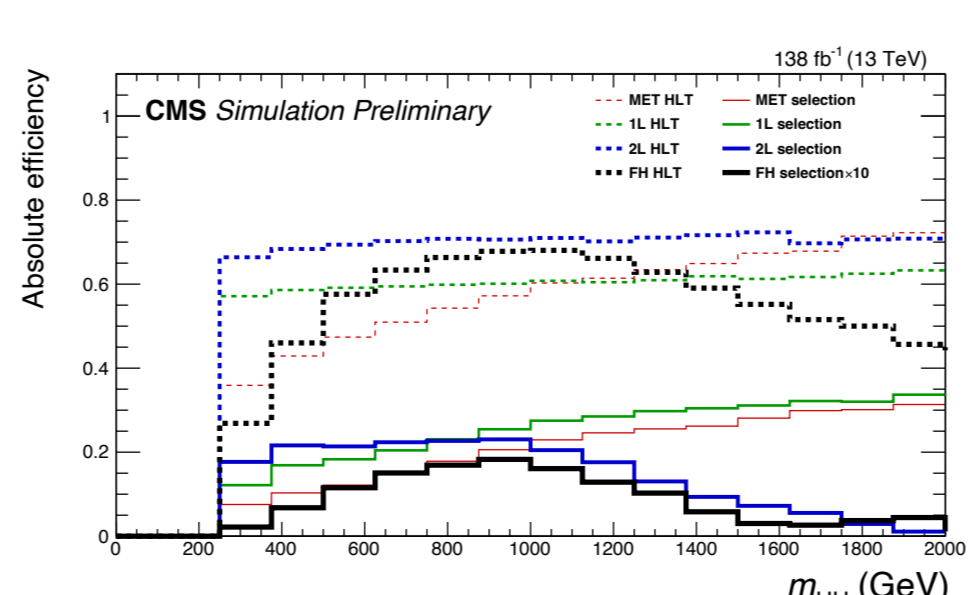
- Reweighting method used to accommodate low MC statistics



Systematics

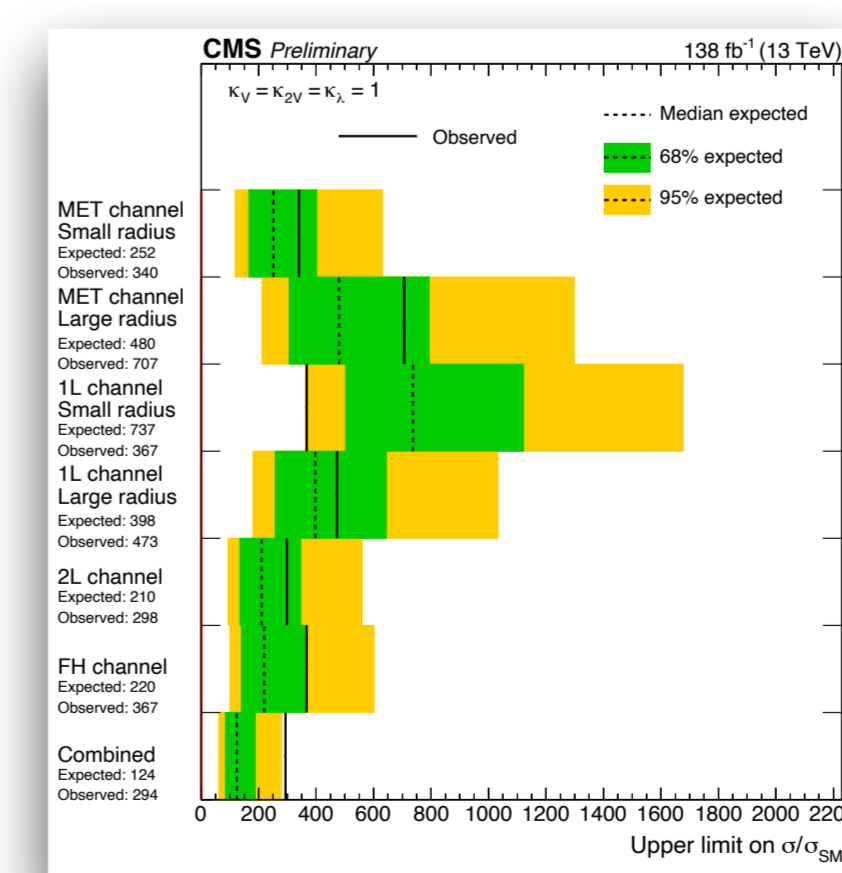
Source	Unc. /total Unc. [%]
Luminosity	+7.6/ -3.6
Theory	+17.6/ -7.0
JES/JEC	+26.3/ -15.0
B tagging	+61.7/ -34.1
Normalization	+58.6/ -31.4
Statistical	+74.4/ -90.1

Signal efficiencies



Results

Upper limits cross section (SM)



1D upper limit scans & constraints

	Observed	Expected
κλ	(-37.7, 37.2)	(-30.1, 28.9)
κVV	(-12.2, 13.5)	(-7.2, 8.9)
κV	(-3.7, 3.8)	(-3.1, 3.1)
κZZ	(-17.4, 18.5)	(-10.5, 11.6)
κWW	(-14.0, 15.4)	(-10.2, 11.6)

