

Testing the working background grouping

Use the existing selected events while additional MC is being generated

Question

Are generator samples assigned to the same background category sufficiently similar for a common training strategy?

Metrics

For each analysis variable: Jensen–Shannon (JS) distance.
(JS = 0 means identical normalized shapes; larger JS means stronger shape differences)

Key diagnostic for grouping: $\Delta JS = \max_i JS(HH, B_i) - \min_i JS(HH, B_i)$. Small ΔJS means the components behave similarly relative to the signal, even if they are not identical to each other.

First useful test case: $\ell\ell bb = ee bb + \mu\mu bb + \tau\tau bb$ (11,224 selected events).

Two complementary tests

- Component vs component: compare normalized shapes inside each group.
- Signal vs component: compare how each component separates from HH.

eebb: global signal-separation picture

The three components are not identical, but their separation from HH is often similar

component	selected	median JS(HH,B _i)	largest JS	variable
eebb	2,590	0.482	0.891	pairing χ^2
$\mu\mu$ bb	5,942	0.369	0.853	pairing χ^2
$\tau\tau$ bb	2,692	0.402	0.884	pairing χ^2

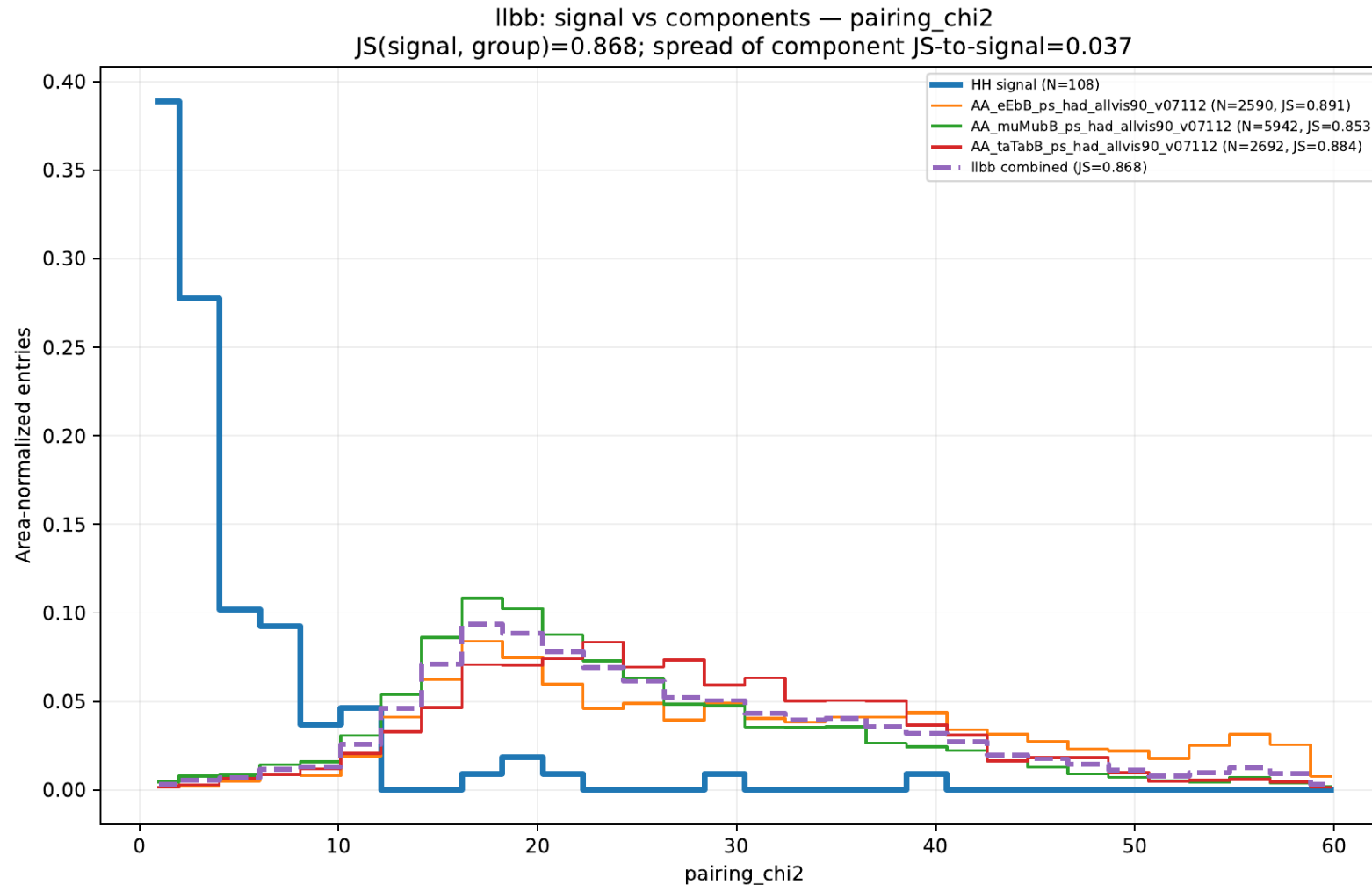
Variables with the largest spread in JS(HH, component)

variable	JS(HH,eebb)	JS(HH, $\mu\mu$ bb)	JS(HH, $\tau\tau$ bb)	Δ JS
MET / HT	0.154	0.153	0.490	0.337
sphericity	0.520	0.647	0.405	0.242
m4j	0.711	0.616	0.805	0.189
pairing χ^2	0.891	0.853	0.884	0.037

Important: a large JS is good signal/background separation; Δ JS tests whether the components differ in that separation.

A strong discriminant behaves almost identically across $\ell\ell b\bar{b}$

pairing χ^2 : large HH/background separation, very small component spread



pairing χ^2

$JS(HH, \ell\ell b\bar{b}) = 0.868$

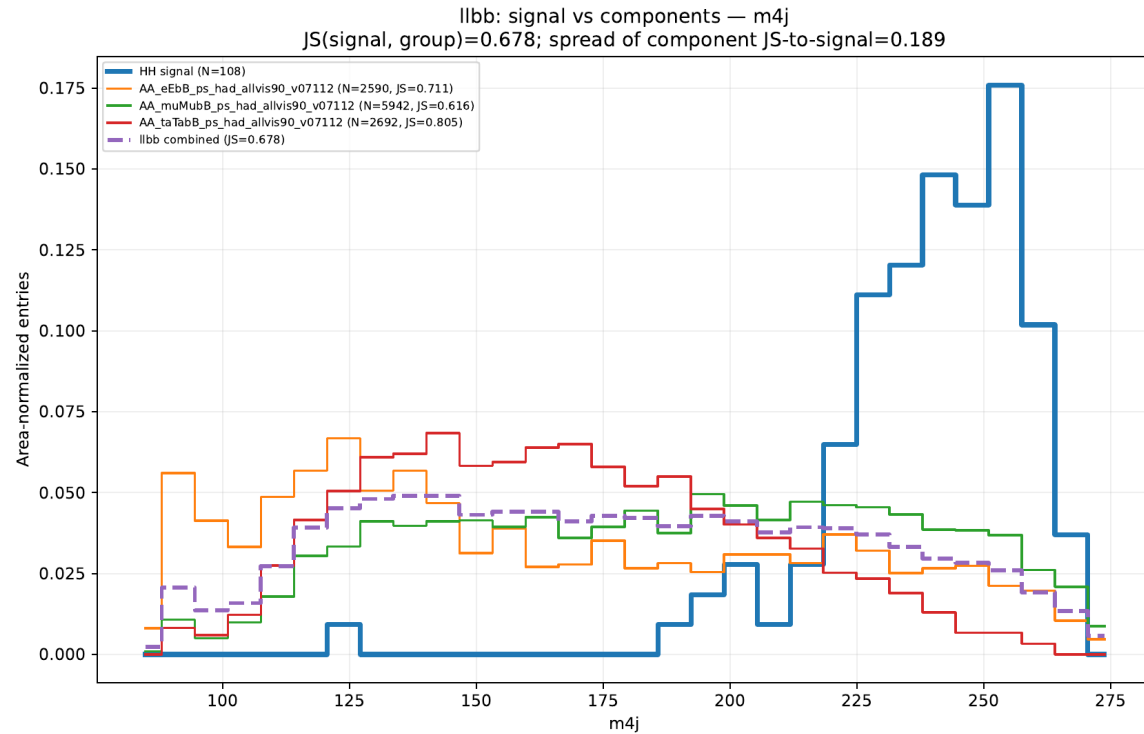
$\Delta JS = 0.037$

$e\bar{e}b\bar{b}$, $\mu\mu b\bar{b}$ and $\tau\tau b\bar{b}$ are all strongly separated from HH in essentially the same way.

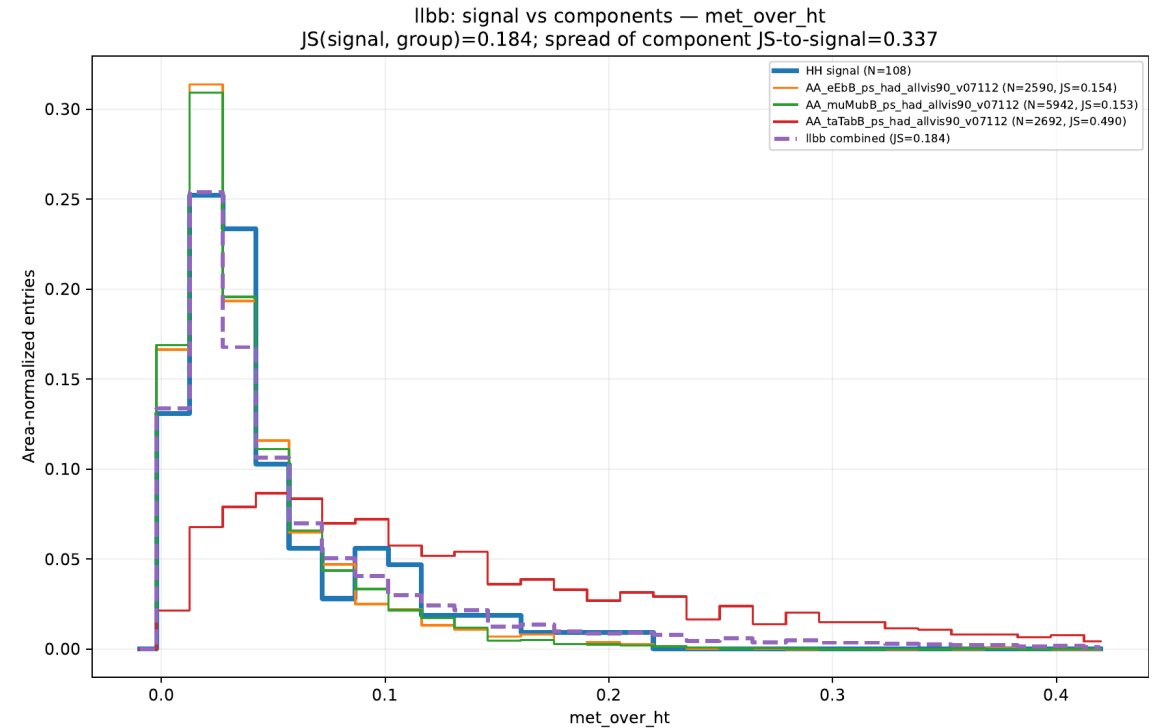
This is exactly the behavior we would like to see if they are to share one background category.

Where the $\ell\ell b\bar{b}$ components differ

m4j shows a moderate spread; MET/HT singles out $\tau\tau b\bar{b}$



m4j: JS(HH,group)=0.678; Δ JS=0.189



MET/HT: JS(HH,group)=0.184; Δ JS=0.337

$\tau\tau b\bar{b}$ is clearly different in missing-energy observables; m4j and sphericity should also be monitored in the first MVA.

Interim conclusion on background grouping

What we can already learn before the enlarged MC samples are ready

Keep $eebb + \mu\mu bb + \tau\tau bb$ as a common $\ell\ell bb$ category for the first MVA.

- The components are not kinematically identical — especially $\tau\tau bb$ in MET-related observables.
- However, several powerful HH/background variables show very similar separation for all three components.
- After the first classifier: compare the classifier-score distributions separately for $eebb$, $\mu\mu bb$ and $\tau\tau bb$.
- For $VVbb$, WZ , qq/mistag , ν +jets and rare EW, current statistics are too small for a robust grouping validation.

This study supports the working grouping, while identifying exactly what must be rechecked with more MC.