The existing VBF category designed by Tyler Burch resulted in a lower global HH significance (see Kunlin's presentation here):
W/ VBF category: HH limit @95%CL: 5.85 × SM
W/o VBF category: HH limit @95%CL: 5.52 × SM

This may be due to the training of the category done on the previous set of samples (EMTopo jets, older ggF selection ...). Changqiao and qui-Ping have demonstrated here that a retraining of the BDT could lead to further improvement.

In the light of having a more C2v=0 exclusion oriented design 2 approaches were developed by Chen and Kunlin

2 types of training: either with A/ SM VBF or with B/ C2v=0 sample
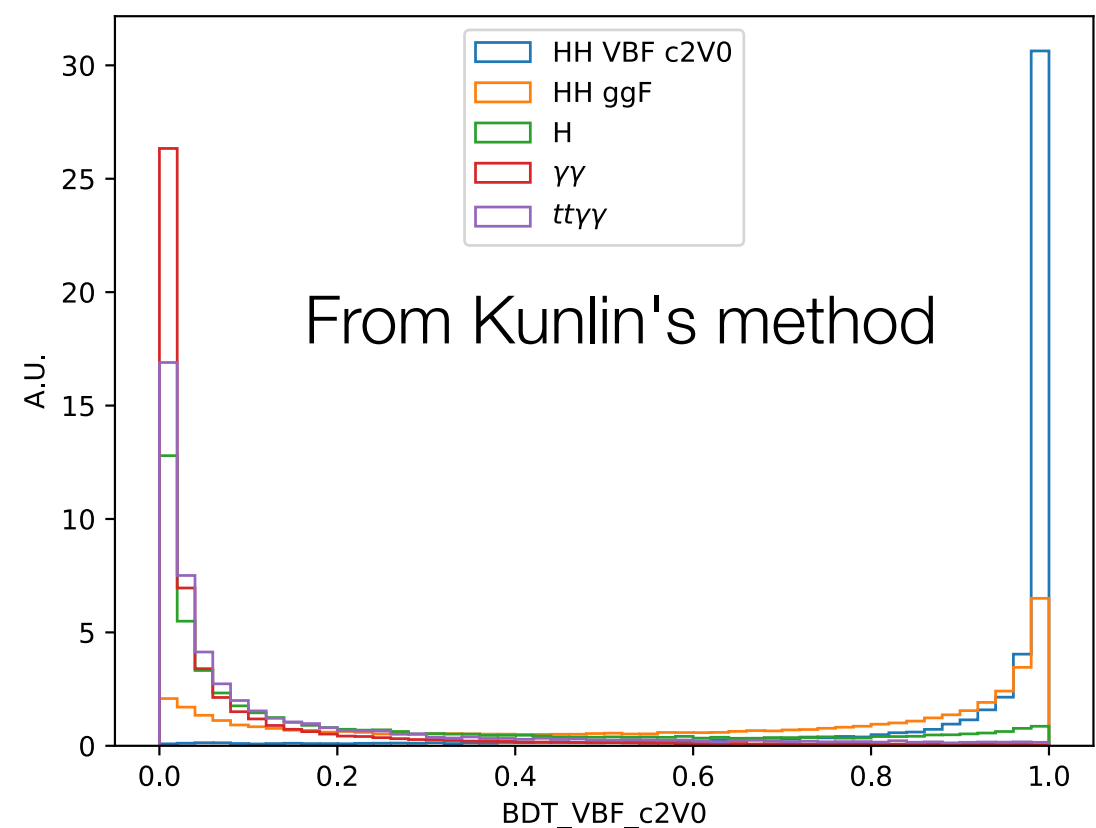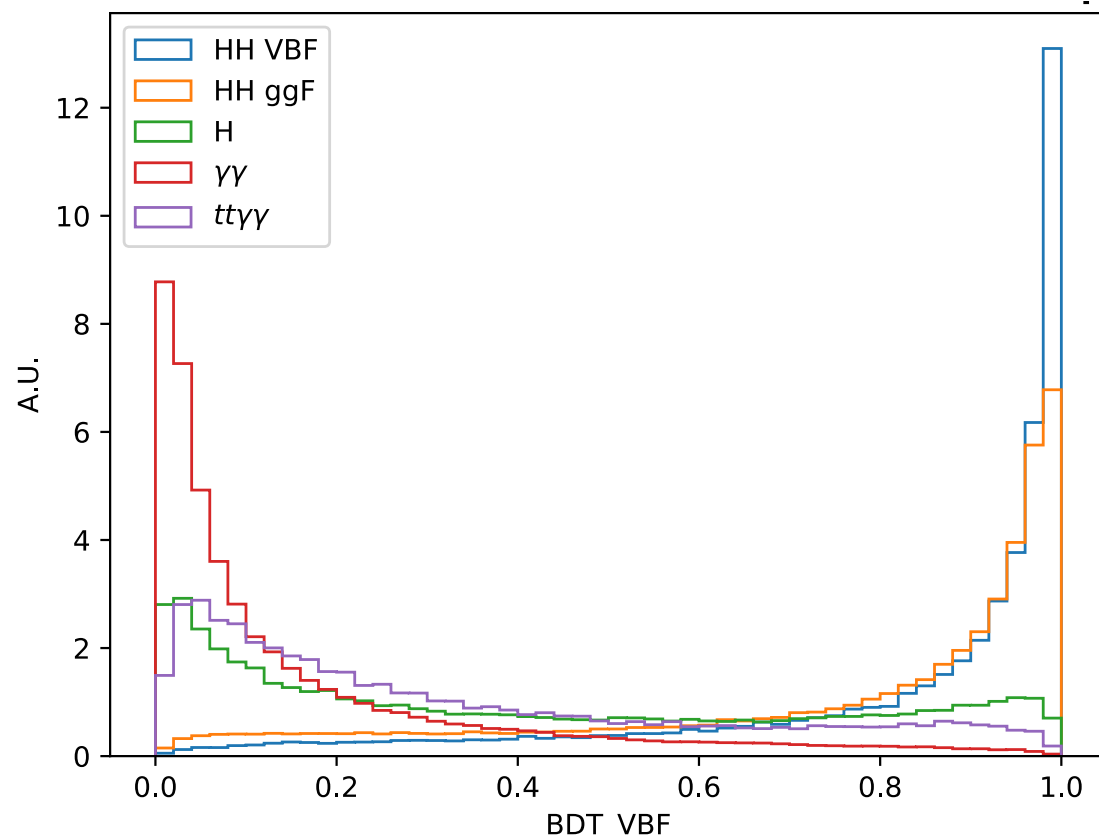
This has resulted in improved C2V=0 limit but with some degradation of the overall HH limit.
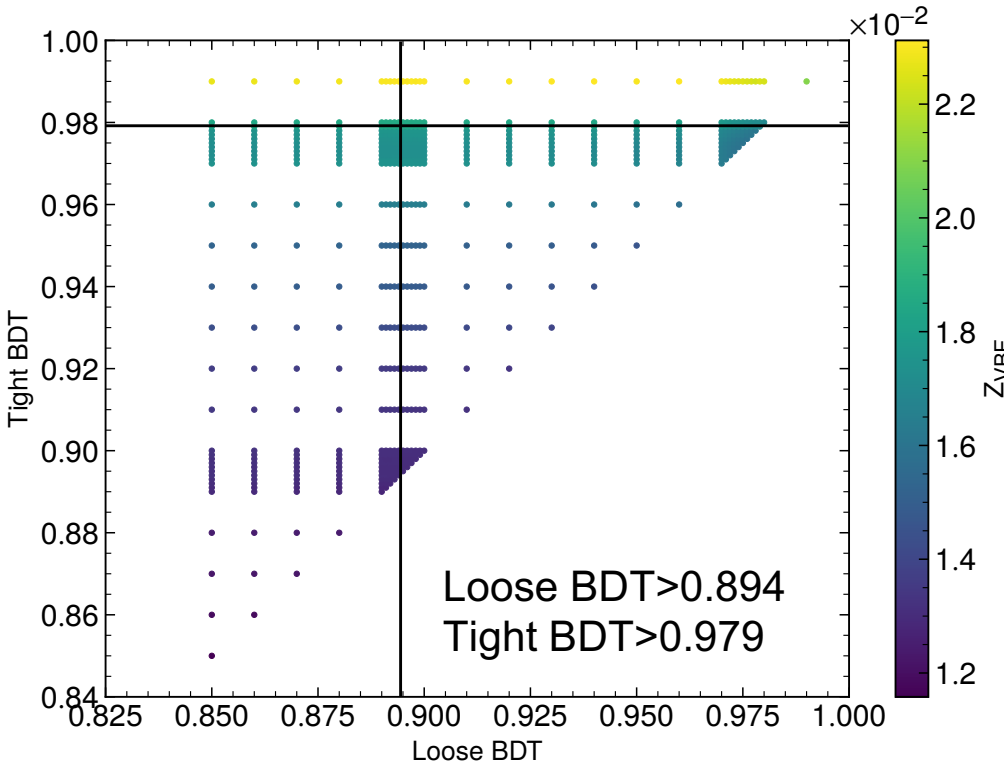
Kunlin

Limit	ggF only cat	ggF + old VBF	ggF + SM VBF	ggF + c2v=0 VBF
HH	5.52	5.85	5.61	5.75
SM VBF		294	155	187
C2v=0 VBF		5.47	3.37	3.16

Chen

Limit	ggF only cat	ggF + old VBF	ggF + SM VBF	ggF + c2v=0 VBF
HH		5.32	5.16	5.32
SM VBF		242	148	157
C2v=0 VBF		6.98	5.26	5.07

Slight differences in the numbers due to a different approach in the computation, but consistent improvement in terms of C2v=0 limit.

For the later VBF dedicated result, attempt to have VBF only classification with 2 VBF categories (tight and loose) trained with the SM VBF (C2v=0) from Kunlin:
SM VBF HH limit @95%CL: 139 (168) × SM
C2v=0 VBF HH limit @95%CL: 3.47 (3.2) × SM

Loose BDT>0.894
Tight BDT>0.979

seline
ategory
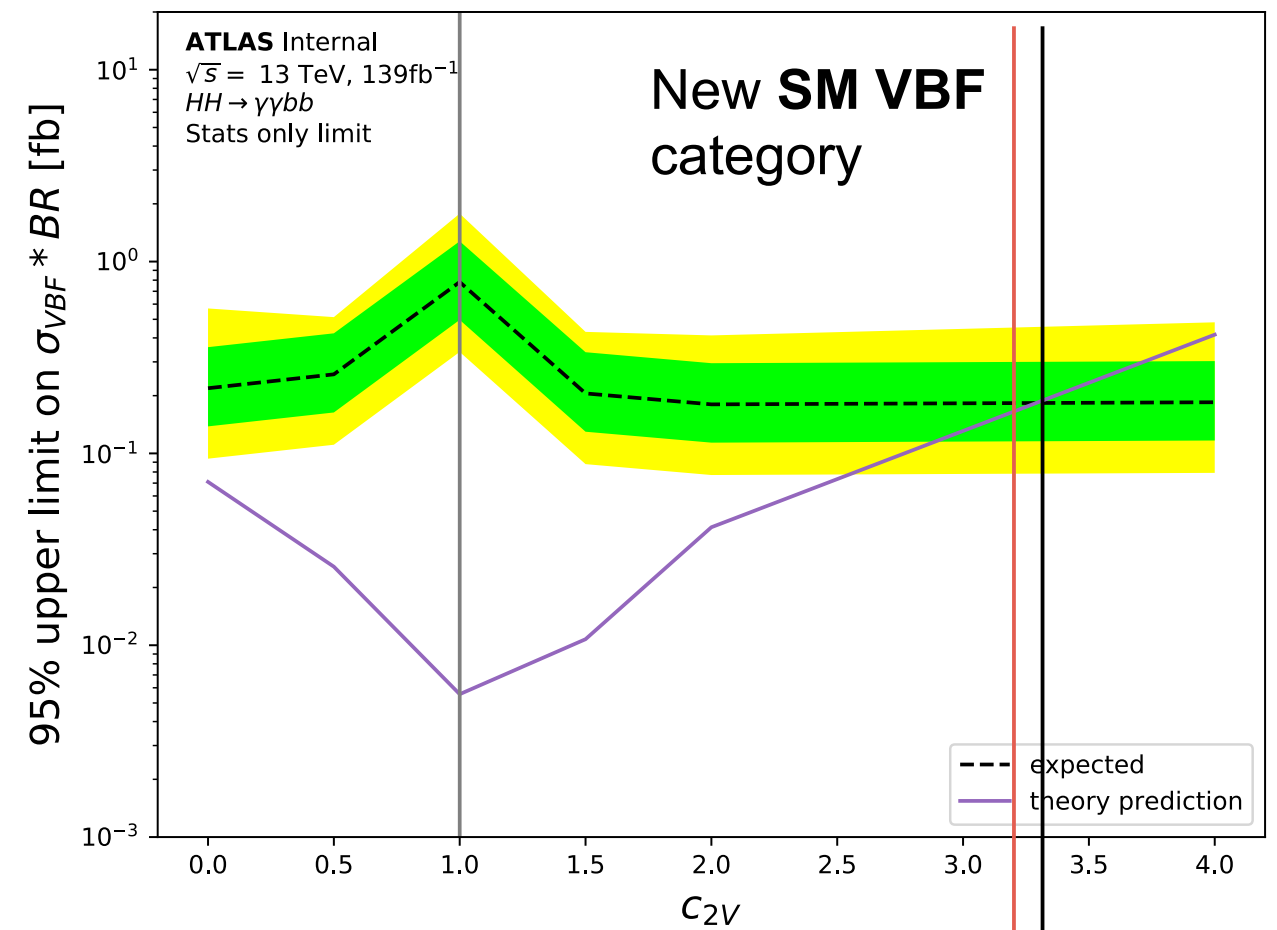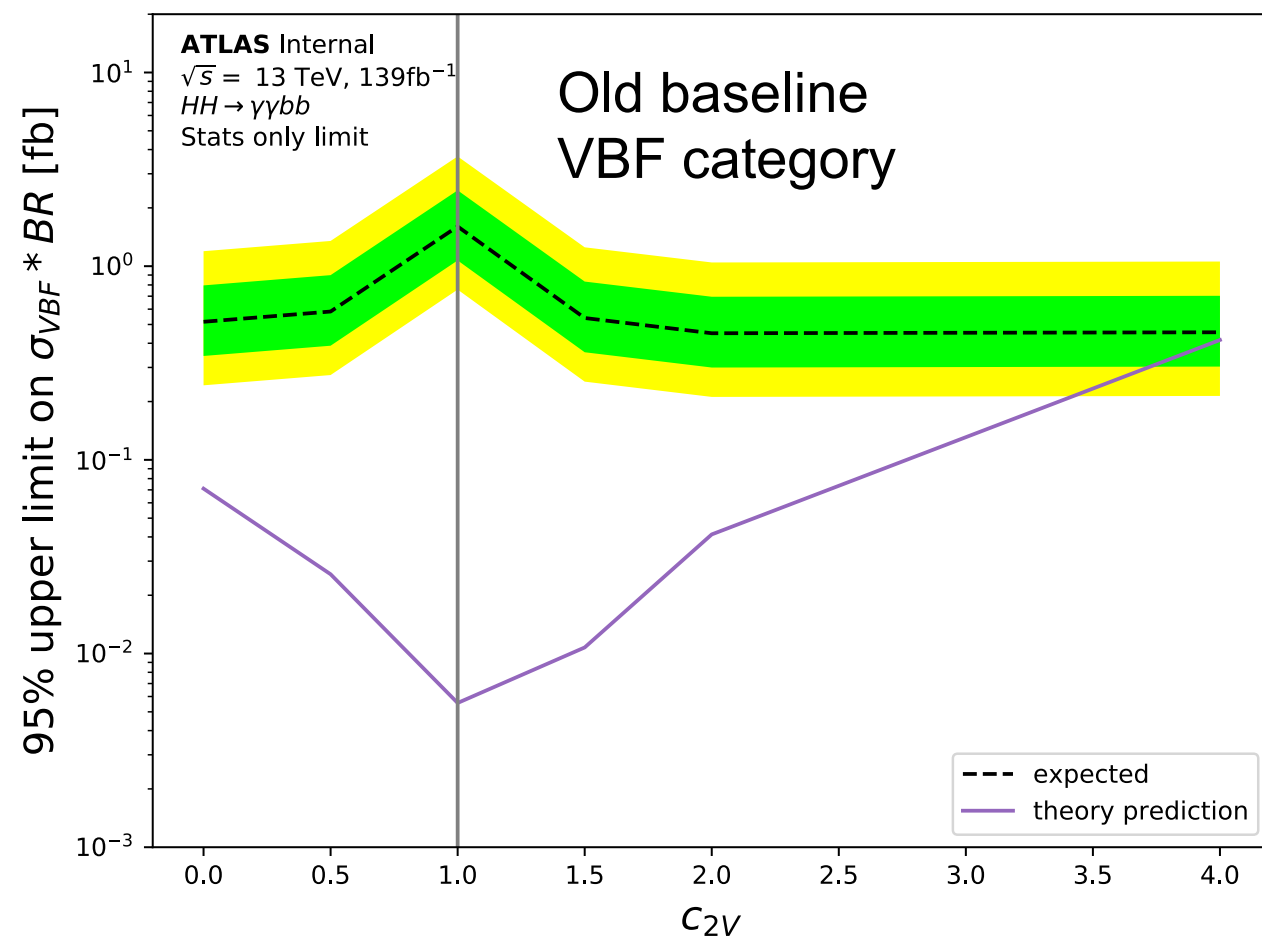
From Kunlin's categorisation

ATLAS Internal
$\sqrt{s} = 13$ TeV, 139fb^{-1}
$HH \to \gamma\gamma bb$
Stats only limit

New **SM VBF**
category

95% upper limit on $\sigma_{VBF} * BR$ [fb]

c_{2V}

- - - expected
—— theory prediction

ATLAS Internal
$\sqrt{s} = 13$ TeV, 139fb^{-1}
$HH \to \gamma\gamma bb$
Stats only limit

New **c2V0 VBF**
category

95% upper limit on $\sigma_{VBF} * BR$ [fb]

c_{2V}

- - - expected
—— theory prediction