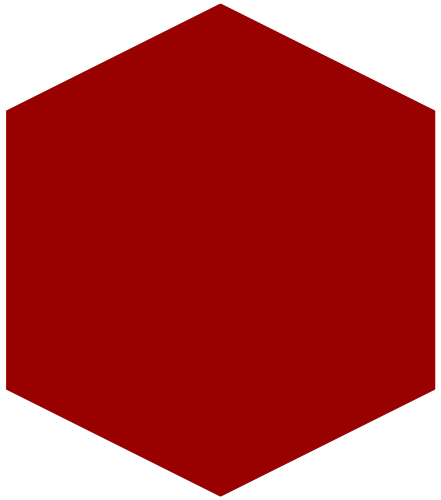

SIMPLIFIED TEMPLATE CROSS SECTIONS: SENSITIVITY TO DIMENSION-6 INTERACTIONS AT THE LHC

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MOTIVATION

THE USE OF SIMPLIFIED TEMPLATE CROSS-SECTIONS (STXS) IS BECOMING INCREASINGLY POPULAL FOR LHC EXPERIMENTS

- THE AIM OF STXS IS TO BE A ROBUST INTERFACE BETWEEN EXPERIMENTAL RESULTS AND GLOBAL FITS.

ON THE OTHER HAND, OPTIMAL OBSERVABLES FOR A GIVEN (SET OF) EFFECTIVE FIELD THEORY OPERATOR(S) INVOLVE THE WHOLE EVENT KINEMATICS

- SOME INFORMATION MAY BE LOST WHEN PROJECTING ONTO THE STXS SPACE.

MOTIVATION (2)

AS PART OF THE LES HOUCHES WORKSHOP WE SET UP AN EXERCISE WITH TWO GOALS

ASSESS THE LOSS OF INFORMATION COMING FROM THE USE OF STXS VS FULL EFT INFORMATION

CHECK FOR MODEL DEPENCENCE IN THE STXS EXTRAPOLATION

SET UP AND BENCHMARKS

FOCUS ON ASSOCIATED ZH PRODUCTION

- STUDY THE EXPERIMENTAL SENSITIVITY TO ONE PARTICULAR DIM-6 OPERATOR

$$\mathcal{O}_{HW} = \frac{ig}{2\Lambda^2}\left[D^\mu \varphi^\dagger \sigma_k D^\nu \varphi\right] W^k_{\mu\nu}$$

- LEP + RUN I BOUNDS ON THE WILSON COEFFICIENT

$$c_{HW} \equiv \frac{m_W^2}{\Lambda^2} C_{HW} \in [-0.07,\ 0.03] \ \text{ at } 95\%\ \text{C.L.}$$

- BENCHMARKS $c_{HW} = \pm 0.03$ and $\pm\ 0.01$

SET UP AND BENCHMARKS (2)

PERFORM A MOCK-UP EXPERIMENTAL ANALYSIS

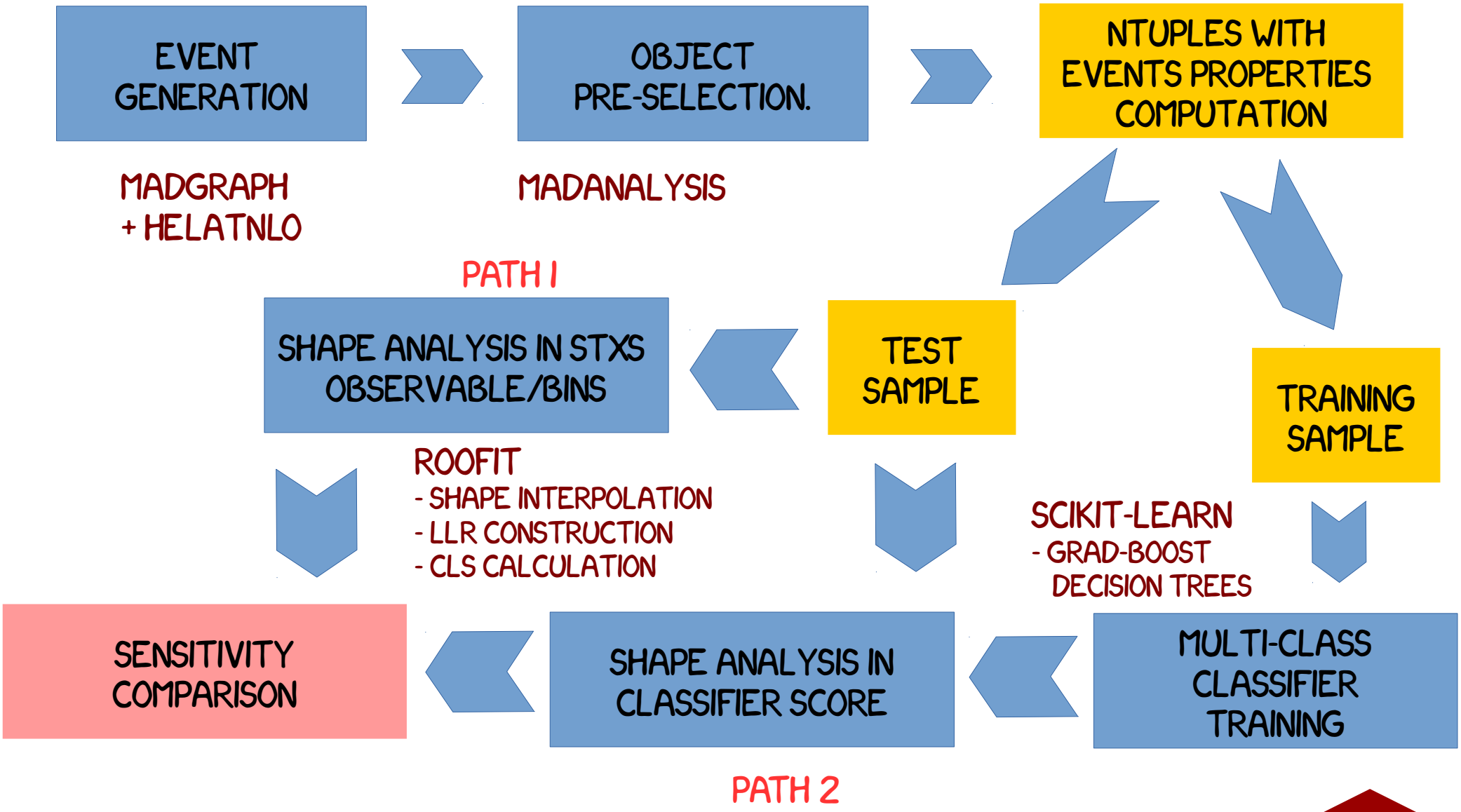
- CONSIDERED THREE CONTRIBUTIONS:
  - ASSOCIATED ZBB PRODUCTION
  - SM ZH(BB) PRODUCTION
  - BSM ZH(BB) PRODUCTION
- GENERATED AT LO USING MADGRAPG5_AMC@NLO, AND THE HELATNLO [1] FEYNRULES MODEL AND ANALYZED WITH MADANALYSIS.

COMPARED TWO PATHS

- PATH 1: KINEMATIC DISCRIMINANT FOR SM ZH(BB) VS ZBB PRODUCTION + STXS
- PATH 2: KINEMATIC DISCRIMINANT FOR SM ZH(BB) VS BSM ZH(BB) VS ZBB PRODUCTION
- KIN DISCRIMINANTS APPROXIMATED WITH BOOSTED DECISION TREES.

[1] De Grande et al., EPJC77 no. 4 (2017)

WORKFLOW

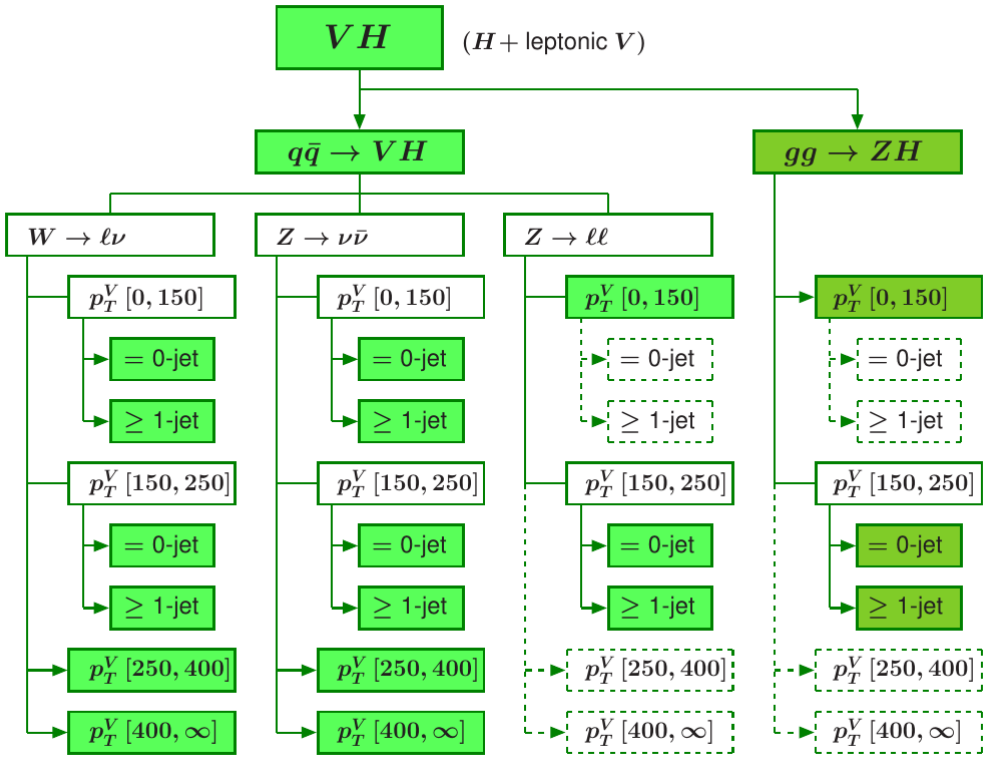

EVENT GENERATION
MADGRAPH + HELATNLO
OBJECT PRE-SELECTION.
MADANALYSIS
NTUPLES WITH EVENTS PROPERTIES COMPUTATION
TEST SAMPLE
TRAINING SAMPLE
PATH 1
SHAPE ANALYSIS IN STXS OBSERVABLE/BINS
ROOFIT
- SHAPE INTERPOLATION
- LLR CONSTRUCTION
- CLS CALCULATION
SCIKIT-LEARN
- GRAD-BOOST DECISION TREES
MULTI-CLASS CLASSIFIER TRAINING
SHAPE ANALYSIS IN CLASSIFIER SCORE
SENSITIVITY COMPARISON
PATH 2

REMINDER STXS

doi:10.23731/CYRM-2017-002 M. Dührssen, P. Francavilla, F.J. Tackmann, K. Tackmann

STXS ARE BINNED SIGNAL STRENGHTS.

- DEFINED AS CROSS SECTIONS (EXTRAPOLATED TO FULL ACCEPTANCE) IN KINEMATIC REGIONS DEFINED IN TERMS OF JETS, HIGGS AND ASSOCIATED BOSON KINEMATICS.



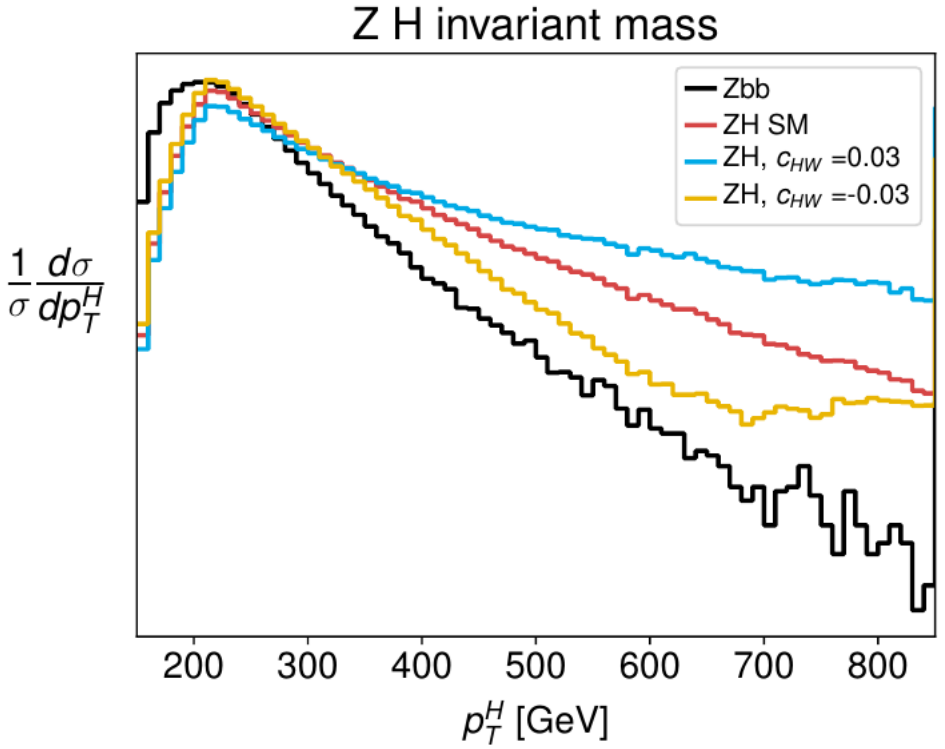
EVENT GENERATION

ROUGHLY 400K EVENTS PER PROCESS GENERATED (IN FID. PHASE SPACE)

- NORM. CROSS SECTIONS COMPUTED WITH MG5_AMC@NLO + EHDECAY + ROSETTA

$pp \to b\bar{b}\ell^+\ell^-$	$\sigma_{\text{fid.}}[fb]$
ZH SM	2.72
$ZH\ c_{HW} = 0.03$	3.64
$ZH\ c_{HW} = -0.03$	2.21
$ZH\ c_{HW} = 0.01$	3.38
$ZH\ c_{HW} = -0.01$	2.50
$Zb\bar{b}$ SM	291.3

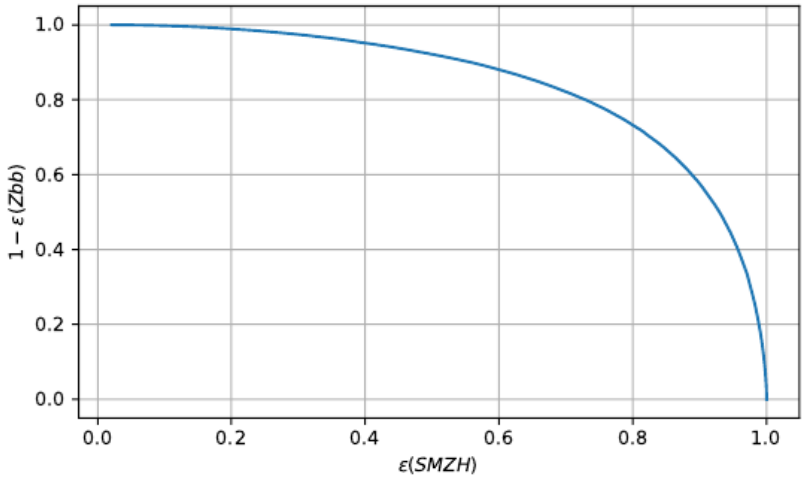
Fid. phase space
p_T(jet) > 20 GeV |η|<2.5
p_T(lep) > 25GeV |η|<2.5
n(lep) = 2
n(bjets) = 2 (ε(btag) = 0.7)
75 < M_{ll} < 105
60 < M_{bb} < 140

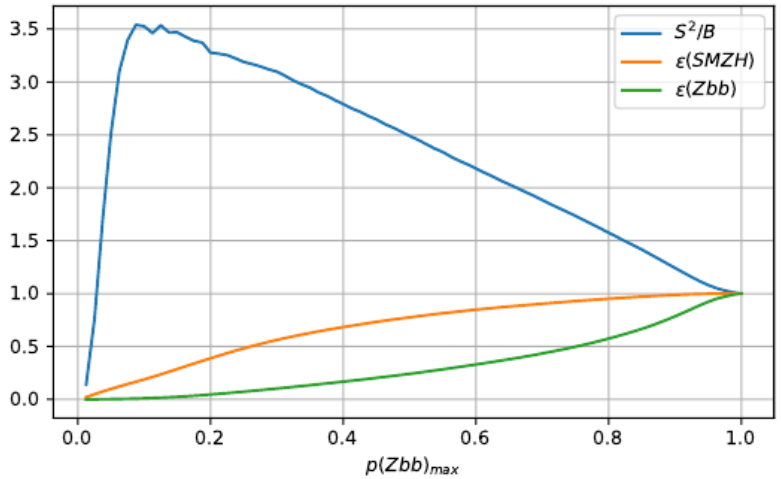


BDT TRAINING

KINEMATIC DISCRIMINANT TRAINED WITH BOOSTED DECISION TREES

- BDT SHOULD PROVIDE A REASONABLE APPROXIMATION OF THE "OPTIMAL OBSERVABLES", GIVEN THE TRAINING STATISTICS.
- 75% EVENT USED FOR TRAINING 25% RESERVED FOR ANALYSIS STEP.
- 5 DISCRIMINANTS TRAINED
  - STXS ANALYSIS: 2-CLASS BDT ZBB VS SM VH DISCRIMINANT
  - FOR EACH BENCHMARK: 3-CLASS BDT ZBB VS SM VH VS BSM VH
  - SELECTION CUT OPTIMIZED TO REJECT ZBB BACKGROUND.

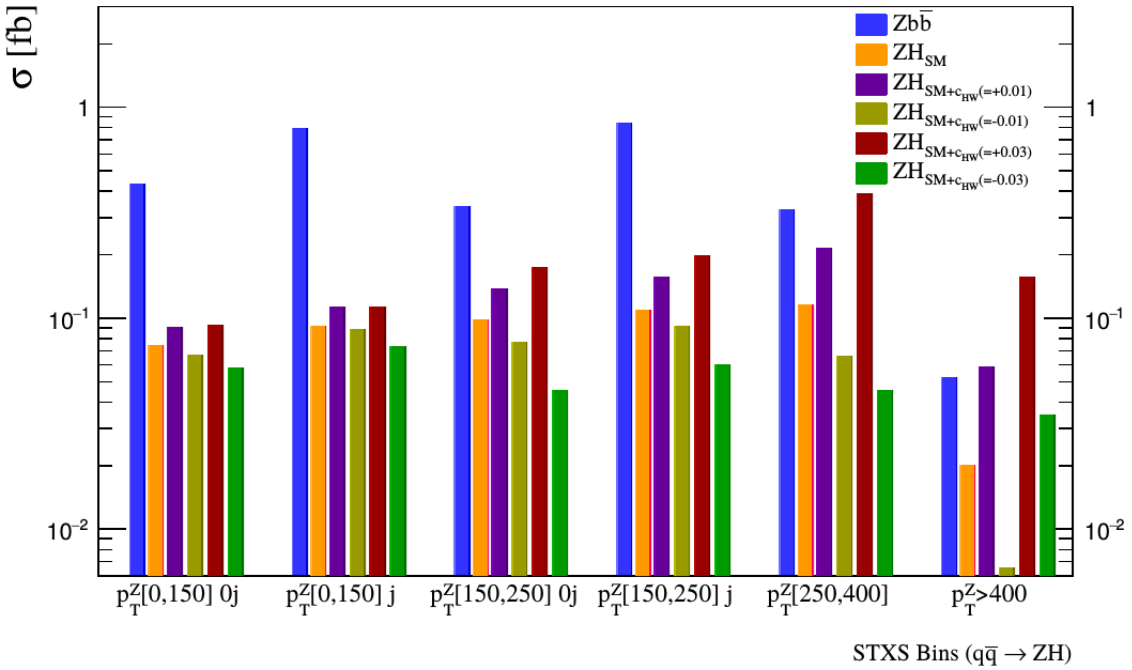




STAGE 1 AND STAGE 2 STXS BINNING IMPLEMENTED

- EVENTS BINNED AFTER ZBB REJECTION CUTS (AS IT WOULD BE DONE BY THE EXPERIMENTS.
- LARGE EFFICIENCY DIFFERENCE FOR DIFFERENT BENCHMARKS (BUT MUCH REDUCED WHEN RESTRICTED TO SINGLE BINS)

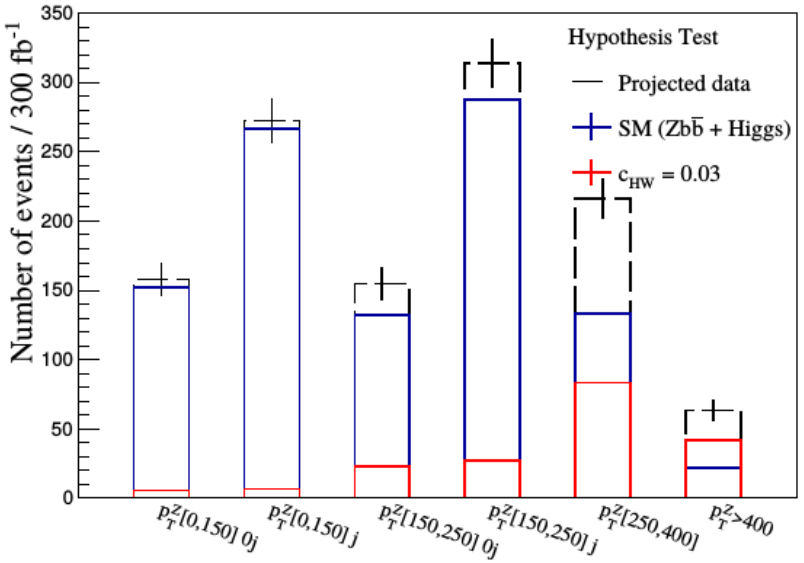
SAMPLE	SEL. EFFICIENCY
Zbb	<0.01
SM VH	0.19
c_{HW} = 0.03	0.31
c_{HW} = -0.03	0.14
c_{HW} = 0.01	0.23
c_{HW} = -0.01	0.16

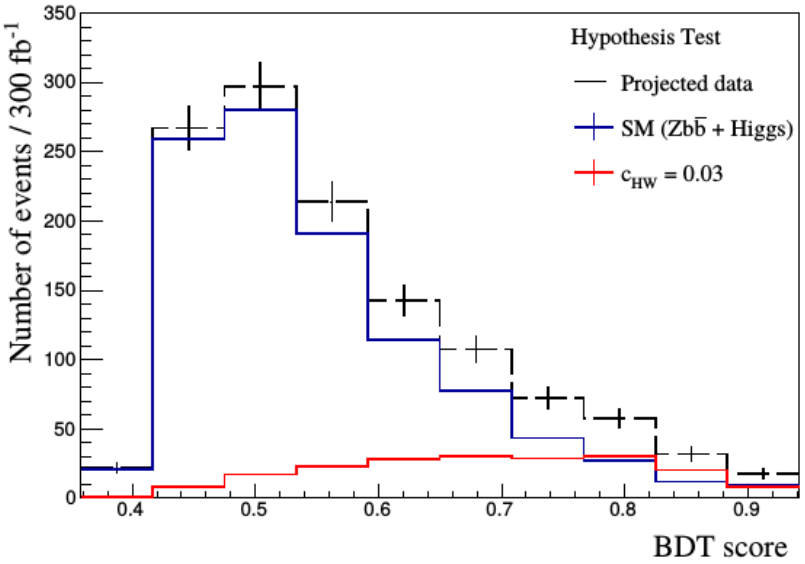


STAT ANALYSIS

TO ASSESS SENSITIVITY TO BSM SCENARIOS RUN 2- HYPOTESYS TEST FOR ZBB+SM ZH VS ZBB+BSM

- FOR STXS ANALYSES:
  - REJECT ZBB, BIN IN STXS BINS
- FOR BDT ANALYSES:
  - REJECT ZBB, BIN IN SM VS BSM BDT OUTPUT





RESULTS

LOSS IN SENSITIVITY DUE TO STXS PROJECTION

- ROUGHLY ~10% FOR SCENARIOS FAR FROM SM
- FOR SCENARIOS CLOSE TO THE SM LOSS IS AS LARGE AS 30-50%

Hypothesis test	Full Run-2 (150 fb^{-1})	LHC Run-3 (300 fb^{-1})	HL-LHC (3000 fb^{-1})
STXS: Higgs discovery	3.01	3.70	8.06
STXS: $c_{HW} = 0.03$	6.44	8.82	26.46
STXS: $c_{HW} = -0.03$	1.66	2.24	6.44
BDT: $c_{HW} = 0.03$ (STXS SM-acceptance)	6.29	8.58	25.61
BDT: $c_{HW} = -0.03$ (STXS SM-acceptance)	1.80	2.44	7.24
STXS: $c_{HW} = 0.01$	2.26	3.04	8.78
STXS: $c_{HW} = -0.01$	1.08	1.46	4.30
BDT: $c_{HW} = 0.01$	2.62	3.07	8.90
BDT: $c_{HW} = -0.01$	1.44	1.99	6.10

- CAVEATS
  - NO MODELLING UNCERTAINTIES CONSIDERED
  - BDT MAY STILL BE SUBOPTIMAL WRT THE OPTIMAL OBSERVABLES DUE TO FINITE STATISTICS OF THE TRAINING SAMPLE AND INPUT VARIABLE CHOICE

SUMMARY

- ASSESSED LOSS OF INFORMATION IN STXS FOR DIM-6 OPERATORS CONTRAINTS
- BENCHMARKED VH PRODUCTION UNDER ANOMALOUS HW COUPLING, IE A $2 \rightarrow 2$ PROCESS
- CONSTRUCTED AN ANALYSIS TO MOCH EXPERIMENTAL RESULTS
- STXS APPROACH SHOWS A 10-50% LOSS OF SENSITIVITY ON THE BENCHMARKS COMPARED TO A MULTIVARIATE ANALYSIS APPROACH
- PLAN TO INVESTIGATE MORE COMPLICATED TOPOLOGIES (SUCH AS VBF PRODUCTION), WHICH MAY SUFFER FROM LARGER LOSSES.