山东大学 SHANDONG UNIVERSITY

Department of Physics, Shandong University

Compressed EWK study(ISRC1N2)

Chengxin Liao
liaocx@ihep.ac.cn

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Tasklist

- ~~Summary for the SR in C1N2ISR~~
- BSc thesis: https://www.overleaf.com/project/674e7119837a2580151a0868
- ABCD method note/bkg estimation: any note or paper I can follow/ref?

Outline

1. Hyperparameters optimization
    - 1.1 LH channel
    - 1.2 HH channel
2. Performance of Model
    - 2.1 LH channel
    - 2.2 HH channel
    - 2.3 SR definition
3. Backup

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Hyperparameters Optimization

Hyperparameters optimization(LH)

Input(LH-Channel):

Sample:

Sig: ISRC1N2(mass_C1 = 100GeV, mass_N2 = 70GeV)->21225 entries
Bkg: 1703476 entries

All input data(C1N2_100_70 and Bkg) already passed pre-selection

```
Signal     -- training events            : 12735
Signal     -- testing events             : 4245
Signal     -- training and testing events: 16980
Background -- training events            : 1022092
Background -- testing events             : 340692
Background -- training and testing events: 1362784
```

Strategy:

method: BDTG
Separate sig(bkg) into five folders, one for test, the other three for train, and last one for validation set,then traverse all possibilities.

Pre-Selection

$$lep\text{-}had\ \ channel: nTaus \geq 1, nLeps \geq 1$$
$$pass\ MET\ trigger;\ MET \geq 200$$
$$1 \leq nBaseJet \leq 8$$
$$b - Veto$$
$$OS$$

Hyperparameters optimization(LH)

Variables(30):

Obj kinematics
- nBase_Jet
- mt_lep
- e_lep(energy of tau2)

Angular correlations
- dPhitt
- dRtt
- dRt1x
- dPhiMin_xj
- dPhiMax_tj

Event kinematics
- Mll(Invariant Mass of tau1 and tau2)
- METsig
- MT2_50
- Mwh(Invariant Mass of tau1 and MET)
- Mwl(Invariant Mass of tau2 and MET)
- MCT(Transverse Mass Squared)
- Proj_j(Projection of pt jet on zeta)
- Proj_tt(Projection of tau1+tau2 on zeta)
- mtx_tau
- Mtx_lep
- ht_tau
- mt_quad_sum
- mt_sum
- frac_MET_tau1
- frac_MET_tau2
- frac_MET_tt
- frac_MET_sqrtHT_40
- frac_jet_tau1
- frac_jet_tau2
- frac_jet_tt
- MT_taumin
- pt_Vframe

High importance at shiyi's feature

Note:

zeta is bisector direction of tau1 and tau2[PhyUtils::bisector(tau1, tau2)]

Hyperparameters optimization(LH)

Grid Search:

Ntrees: 200, 300, 400, 500
Max Depth: 6, 8, 10, 12
MinNodeSize: 1%, 2%, 3%
Learning Rate: 0.01, 0.05, 0.1

Binned significance: $Z = \sqrt{2((s_i + b_i)\log\left(1 + \frac{s_i}{b_i}\right) - s_i)}$

Show top Zn

	Model Name	Binned Significance	Max Zn	Max Zn Bin
12	400_8_1_001	15.6795	4.31391	192
79	400_10_1_001	15.6755	4.26908	192
92	400_12_1_001	15.6890	4.21178	192
77	400_10_2_001	15.3196	4.11376	191
52	500_10_1_001	15.8304	4.11162	194
13	500_12_1_001	15.8210	4.05346	194
120	400_12_1_01	16.0665	4.02939	199
113	500_10_3_001	15.3232	4.02306	192
0	300_12_1_005	16.1734	4.01739	198
139	400_12_1_005	16.2126	4.00753	199
123	500_12_3_001	15.3067	4.00343	192
118	500_12_1_01	16.0441	4.00080	199
24	500_8_1_01	15.9307	3.99007	199
133	500_8_3_001	15.3061	3.97695	192
97	400_6_3_001	15.0010	3.97216	190
26	300_10_1_01	16.0095	3.96339	199
136	300_12_1_01	16.0204	3.94916	199
128	400_8_3_001	14.9962	3.93255	190
107	200_12_1_005	16.0375	3.93002	197
45	400_12_2_001	15.2724	3.92019	191
88	400_12_3_001	14.9991	3.91396	190

Shiyi's result of LH channel

Top Sig

	hy	sig	zn
400_10_2_0.05		15.3225	3.72536
300_11_1_0.05		15.3127	3.87694
500_10_2_0.05		15.3099	3.60778
400_6_1_0.05		15.3075	3.91373
500_8_1_0.05		15.2990	3.58389
400_8_2_0.05		15.2980	3.74427
300_6_1_0.05		15.2929	4.09837
500_8_2_0.05		15.2891	3.63322
200_11_1_0.05		15.2849	3.92924
300_11_2_0.05		15.2804	3.85617
400_11_2_0.05		15.2780	3.68484
300_8_1_0.05		15.2753	3.82506
300_10_1_0.05		15.2733	3.71921
400_11_1_0.05		15.2701	3.60863
500_6_1_0.05		15.2593	3.84429
200_6_1_0.1		15.2559	3.90950
400_12_1_0.05		15.2554	3.58328
500_10_1_0.05		15.2493	3.49410

Top Zn

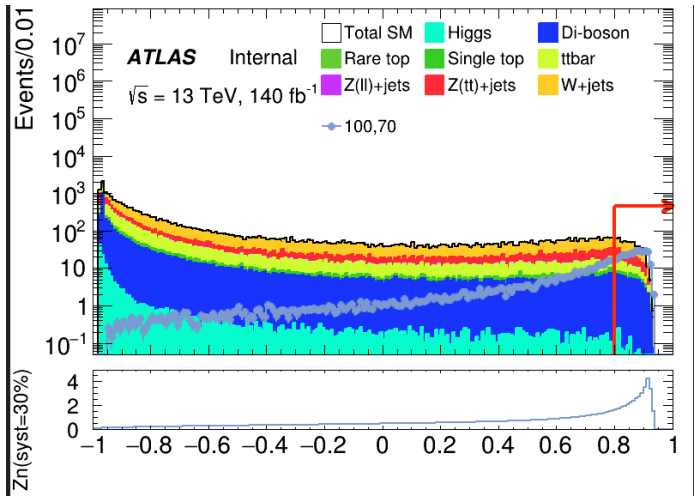
	hy	sig	zn
200_6_3_0.05		15.0164	4.29022
200_6_1_0.05		15.0755	4.10077
300_6_1_0.05		15.2929	4.09837
200_10_2_0.05		15.1606	4.09228
200_12_2_0.05		15.1803	4.04800
200_8_2_0.05		15.0857	4.01373
200_8_3_0.05		14.9662	4.01324
200_6_2_0.05		14.9743	3.94396
200_11_1_0.05		15.2849	3.92924
300_6_2_0.05		15.1858	3.91508
400_6_1_0.05		15.3075	3.91373
200_6_1_0.1		15.2559	3.90950
200_12_1_0.05		15.2279	3.90380
400_8_1_0.01		14.6829	3.90189
300_11_1_0.05		15.3127	3.87694
200_8_1_0.05		15.1285	3.85623
300_11_2_0.05		15.2804	3.85617
500_6_1_0.05		15.2593	3.84429

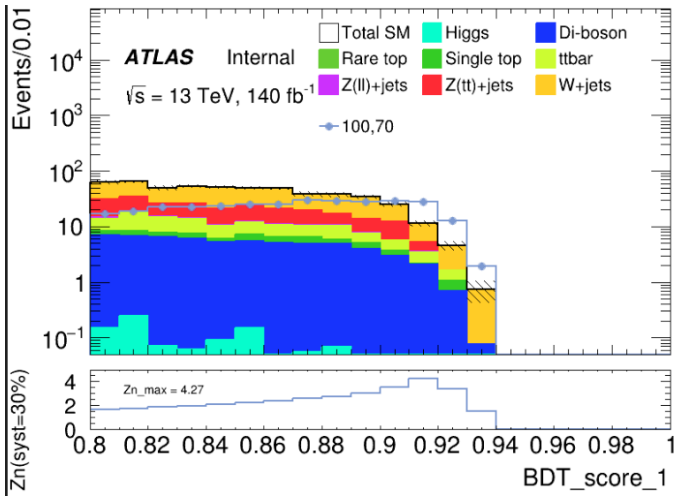
```
400_10_1_001,15.6755,4.26908,192,200
400_10_1_001,15.4762,3.53693,96,100
400_10_1_001,15.1985,3.40439,49,50
400_10_1_001,15.3013,3.53693,39,40
400_10_1_001,14.8172,3.40439,25,25
400_10_1_001,15.06,3.53693,20,20
400_10_1_001,13.9532,1.6563,10,10
```

```
400_12_1_001,15.689,4.21178,192,200
400_12_1_001,15.4949,3.52564,97,100
400_12_1_001,15.2434,3.52564,49,50
400_12_1_001,15.3089,3.52196,39,40
400_12_1_001,14.8653,3.52564,25,25
400_12_1_001,15.0506,3.52196,20,20
400_12_1_001,13.9276,1.6473,10,10
```

Hyperparameters optimization(LH)

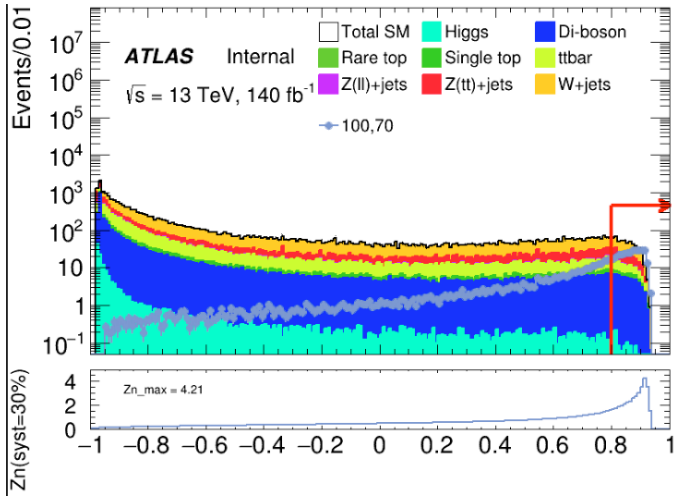
hyper parameter: NTrees=400, learning rate=0.01, max depth=10, MinNodeSize=1%(default)

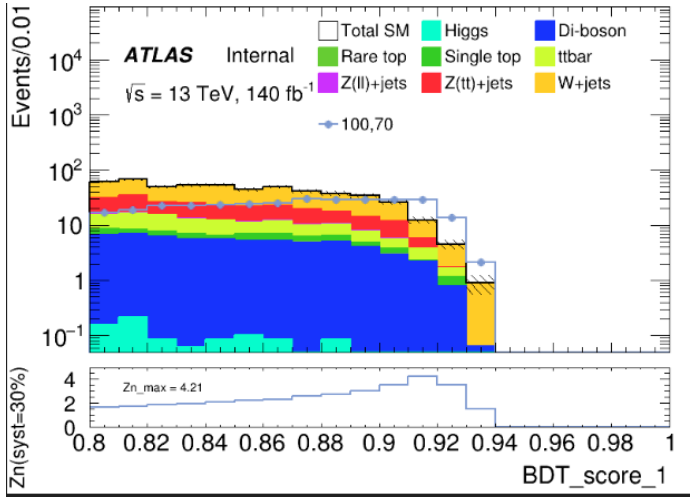




Cut at BDT_score = 0.8

hyper parameter: NTrees=400, learning rate=0.01, max depth=12, MinNodeSize=1%(default)





Hyperparameters optimization(HH)

Input(HH-Channel):

Sample:

Sig: ISRC1N2(mass_C1 = 100GeV, mass_N2 = 70GeV)->12180 entries
Bkg: 513850 entries

All input data(C1N2_100_70 and Bkg) already passed pre-selection

Strategy:

method: BDTG
Separate sig(bkg) into five folders, one for test, the other three for train, and last one for validation set,then traverse all possibilities.

```
Number of training and testing events
-------------------------------------------------------
Signal     -- training events            : 7311
Signal     -- testing events             : 2436
Signal     -- training and testing events: 9747
Background -- training events            : 308329
Background -- testing events             : 102770
Background -- training and testing events: 411099
```

Pre-Selection

$$had\text{-}had\ \ channel: nTaus \geq 2, nLeps = 0$$
$$pass\ MET\ trigger;\ MET \geq 200$$
$$1 \leq nBaseJet \leq 8$$
$$b - Veto$$
$$OS$$

Hyperparameters optimization(HH)

Variables(26):

Obj kinematics

Pt_tt

Angular correlations

dPhit1x
dEtatt
dPhiMax_xt
dPhiztt
dPhitt
dPhizxe
dPhiMin_xt
dPhit2x
dPhiMin_tj1
dRt2x
dRMax_xt
dRMin_tj
dRtt
sum_cos_dphi

Event kinematics

Mll(Invariant Mass of tau1 and tau2)
MIA
MT2_150
MET_Tau
Proj_tt
MstauA
MCT
frac_MET_tt
frac_MET_tau1
frac_MET_MeffInc_40
frac_MET_Meff

These vars are selected based on the importance

Hyperparameters optimization(HH)

Grid Search:

Ntrees: 200, 300, 400, 500
Max Depth: 6, 8, 10, 12
MinNodeSize: 1%, 2%, 3%
Learning Rate: 0.01, 0.05, 0.1

Binned significance: $Z = \sqrt{2((s_i + b_i)\log\left(1 + \frac{s_i}{b_i}\right) - s_i)}$

Show top Zn

	Model Name	Binned Significance	Max Zn	Max Zn Bin
500_12_1_005		14.2770	3.83857	199
300_10_1_01		13.9648	3.76965	198
200_6_1_01		13.9250	3.74940	198
500_6_3_01		14.2740	3.72616	199
400_10_1_01		13.9553	3.70167	199
300_6_2_01		13.9366	3.69620	199
300_10_2_01		14.0094	3.67743	199
300_8_1_01		14.0434	3.67624	198
200_8_1_01		14.1925	3.67005	198
400_12_1_005		14.1384	3.66529	199
200_6_2_01		14.2209	3.65978	199
200_6_3_01		13.7197	3.64427	199
500_10_1_01		13.8227	3.63722	198
500_8_1_01		13.8369	3.61405	198
400_10_2_01		14.2001	3.60950	199
500_6_1_005		14.0399	3.60132	197

Rebin result

```
Model Name,Binned Significance,Max Zn,Max Zn Bin,bin num
500_12_1_005,16.0862,3.8635,198,200
500_12_1_005,15.9967,3.62563,99,100
500_12_1_005,15.9318,3.62563,50,50
500_12_1_005,15.6612,3.07372,40,40
500_12_1_005,15.3086,2.45396,25,25
500_12_1_005,15.0825,2.20391,20,20
```

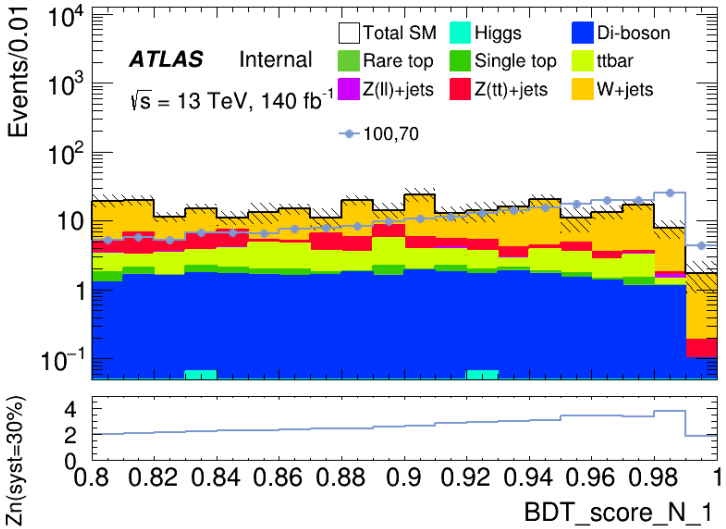
Compared with form result, there has a significant improvement in Zn

	Model Name	Binned Significance	Max Zn	Max Zn Bin
137	100_8_3_005	12.1380	3.27179	48
128	100_6_1_01	12.9663	3.24539	49
15	100_12_3_005	12.1254	3.22901	48
85	100_10_3_005	12.1150	3.20722	48
105	200_10_1_01	13.1608	3.19603	50
104	100_8_1_01	12.8853	3.18398	50
63	200_6_1_005	12.7673	3.17520	49
2	200_6_1_01	12.9052	3.17138	50
38	100_6_2_01	12.8248	3.16297	49
131	300_8_2_01	13.1256	3.16255	50
93	300_6_1_005	12.9703	3.14200	50
73	100_6_1_005	12.4457	3.14142	48
69	400_6_1_01	12.9285	3.14074	50
54	200_8_3_01	12.8685	3.13397	50
12	200_6_2_005	12.7035	3.12582	49
33	100_6_2_005	12.2453	3.11746	48
66	400_6_1_005	12.9369	3.10400	50
45	100_10_3_01	12.7388	3.10074	49
7	100_12_3_01	12.6318	3.10071	49
48	400_12_2_01	12.9393	3.09236	50
72	400_12_2_005	12.9179	3.06882	50
62	300_6_1_01	12.8501	3.06869	50
133	400_10_1_01	12.9846	3.06413	50
91	100_6_3_01	12.6291	3.06320	49
9	400_8_3_01	12.9337	3.06226	50
58	300_10_3_005	12.8854	3.05992	49
36	300_10_1_01	12.9906	3.05755	50
89	100_10_2_01	12.8406	3.05210	49
43	200_8_2_01	13.2400	3.04952	50
19	400_6_2_005	12.8263	3.04206	50

Hyperparameters optimization(HH)

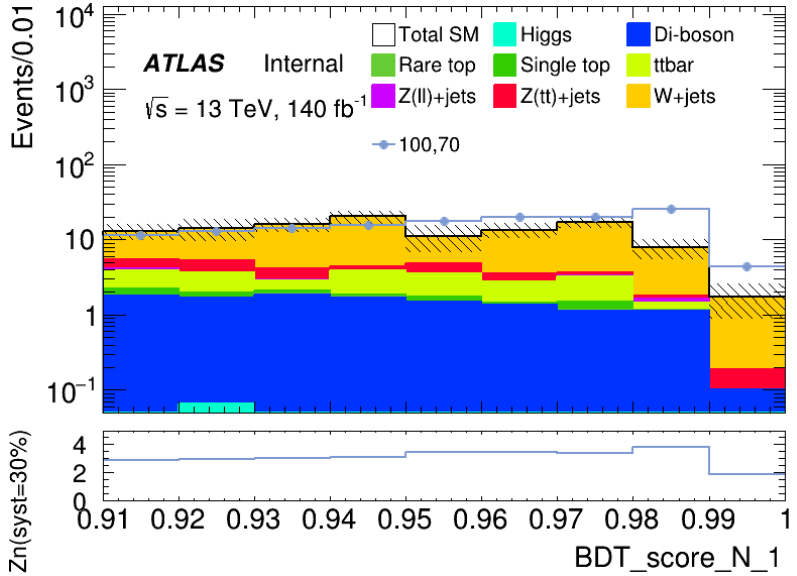
hyper parameter: NTrees=500, learning rate=0.05, max depth=12, MinNodeSize=1%(default)

Apply a rough cut at 0.80 to check the distribution



Precise cut at 0.91 to define signal region

It has a wider peak than LH signal region

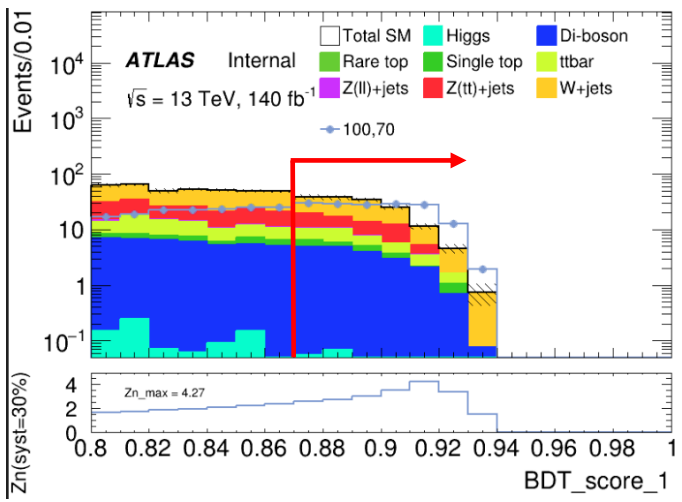


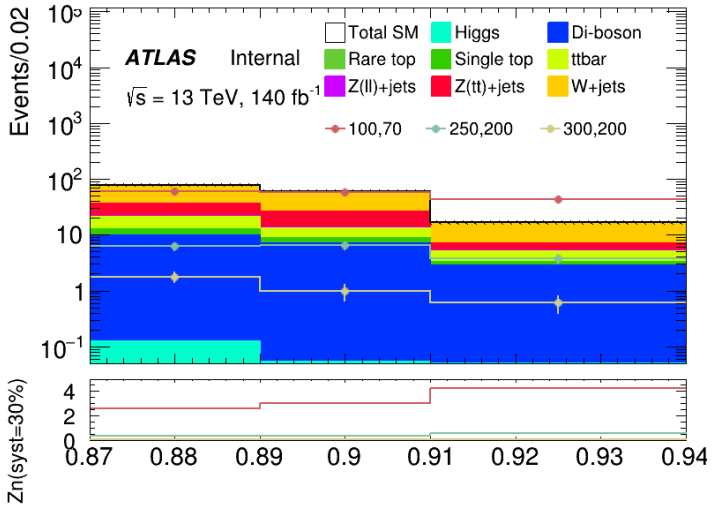
Rebin to: [0.91, 0.94, 0.97, 1.00]

Performance of Model

Performance of Model(LH)

hyper parameter: NTrees=400, learning rate=0.01, max depth=10, MinNodeSize=1%(default)





Apply BDT score cut at 0.87

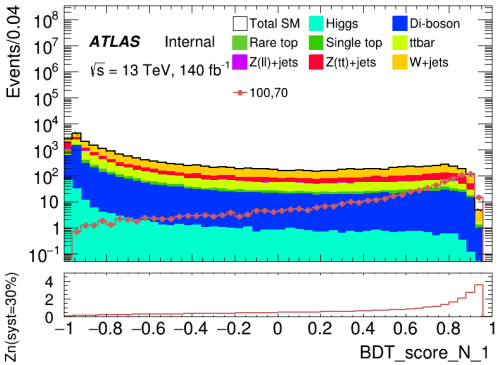
Root of square sum of Zn of each bin: 5.8479

Rebin to: [0.87, 0.89, 0.91, 0.94]

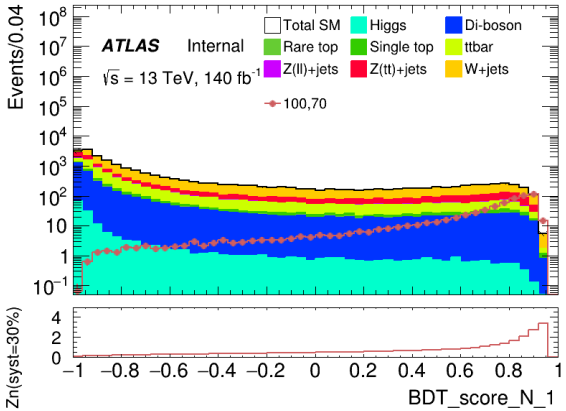
bin	max Zn	C1N2ISR (100,70)	bkg	Higgs	OtherTop	SingleTop	TopPair	VV	Wjets	Zlljets	Zttjets
(0.87-0.89)	2.59868	**59.238+-1.484**	**76.648+-5.530(7.21%)**	0.126+-0.034	0.033+-0.021	2.619+-0.548	8.311+-1.141	9.569+-0.520	**39.971+-5.074**	0.760+-0.130	15.259+-1.718
(0.89-0.91)	3.03656	**57.663+-1.447**	**59.803+-3.946(6.59%)**	0.053+-0.020	0.078+-0.030	1.761+-0.420	4.401+-0.823	6.851+-0.399	**33.586+-3.367**	0.453+-0.128	12.620+-1.792
(0.91-0.94)	4.26908	**42.715+-1.251**	**16.632+-1.683(10.11%)**	0.005+-0.004	0.006+-0.004	0.450+-0.202	1.819+-0.532	2.858+-0.249	**9.733+-1.536**	0.039+-0.020	1.722+-0.298

Performance of Model(LH)

hyper parameter: NTrees=400, learning rate=0.01, max depth=10, MinNodeSize=1%(default)

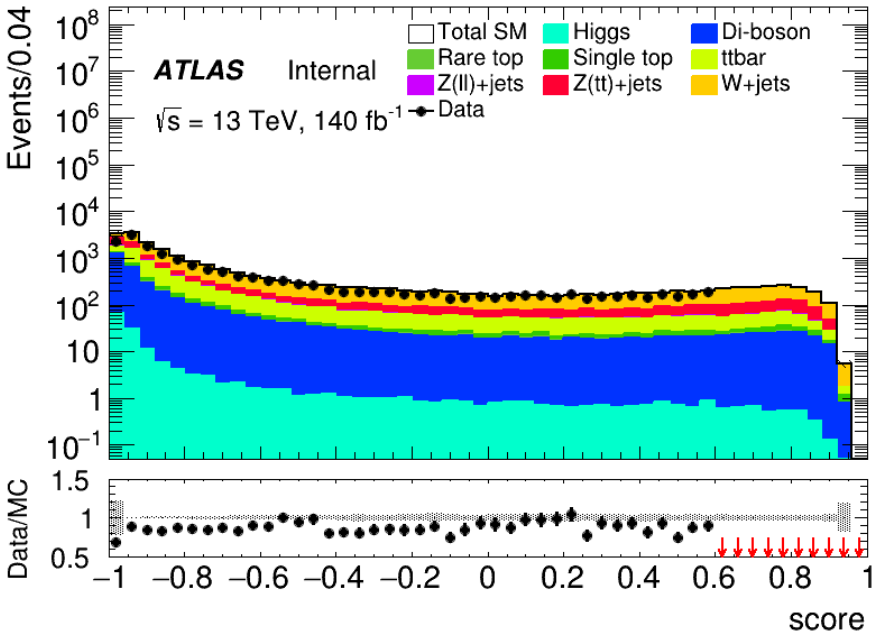


BDT score distribution of Validation set

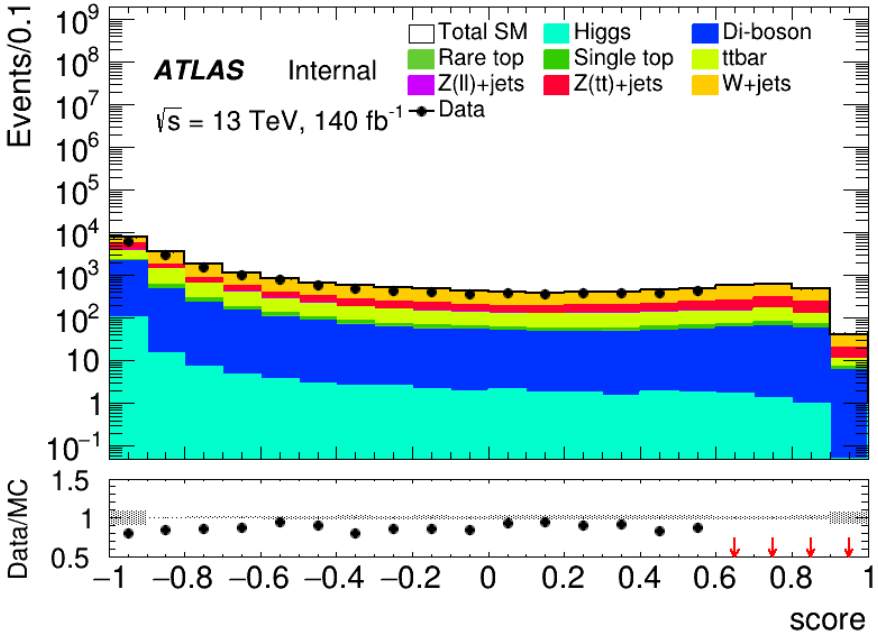


BDT score distribution of Test set

50 bins



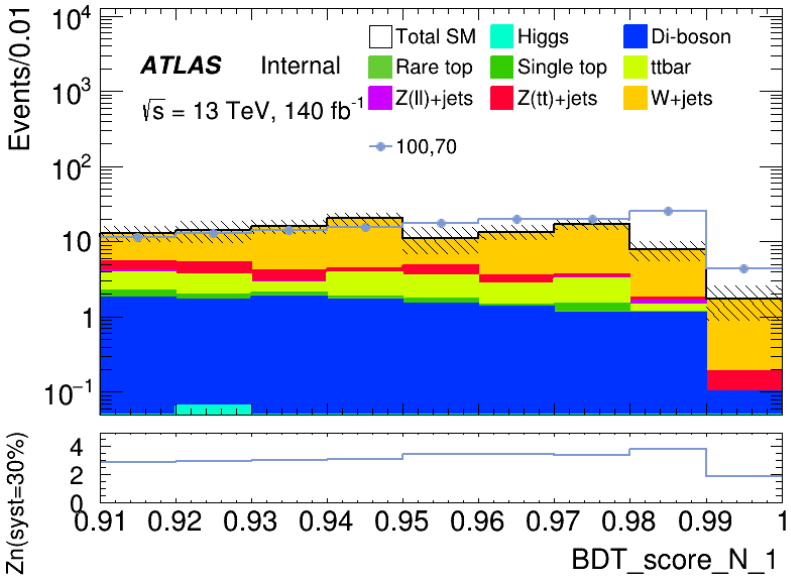
20 bins



BDT score distribution of test set and data
(Blind with events with score > 0.6)

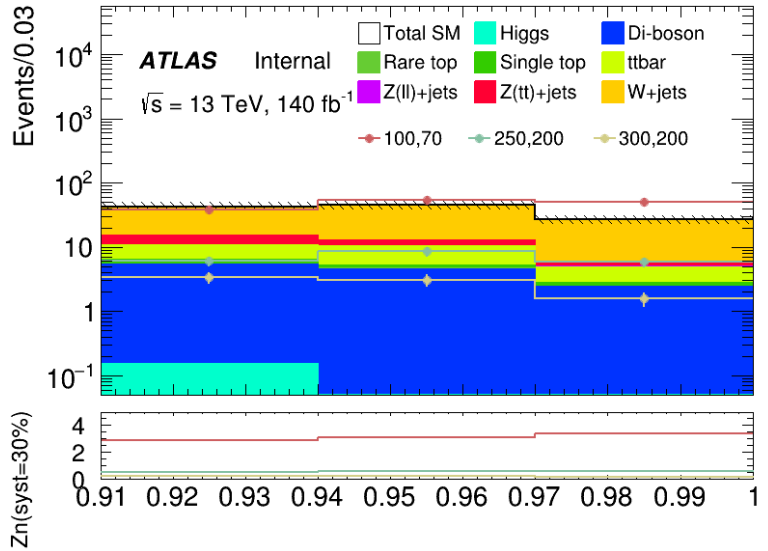
Performance of Model(HH)

hyper parameter: NTrees=500, learning rate=0.05, max depth=12, MinNodeSize=1%(default)



Root of quadratic sum of Zn = 5.3163

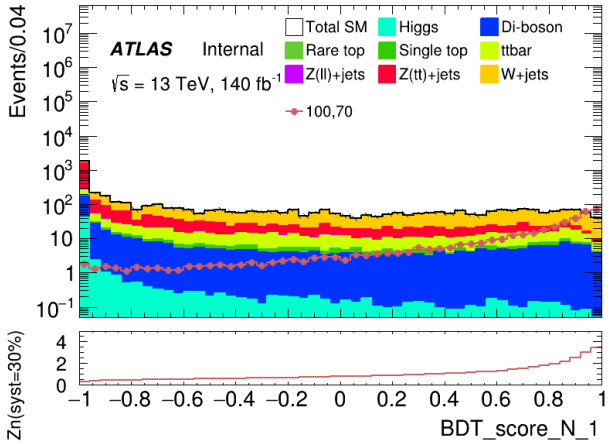
Rebin to: [0.91, 0.94, 0.97, 1.00]



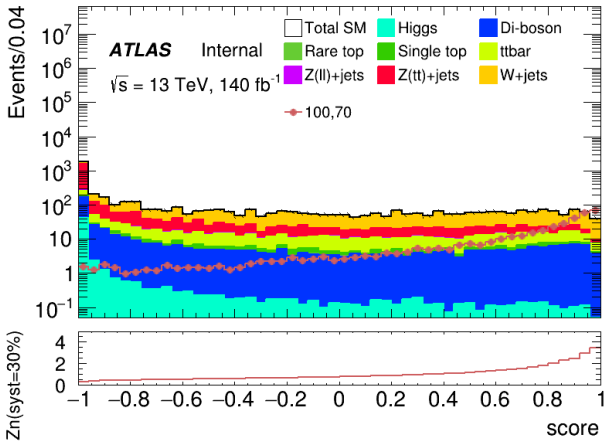
bin	Zn	C1N2ISR (100,70)	bkg	SingleTop	Zttjets	Wjets	OtherTop	VV	Zlljets	TopPair	Higgs
bin1	2.8678146	38.472+-1.192	42.986+-6.490(15.09%)	0.958+-0.303	4.090+-0.675	28.198+-6.388	0.026+-0.020	5.144+-0.289	0.265+-0.185	4.156+-0.802	0.150+-0.041
bin2	3.1193828	53.206+-1.399	44.788+-6.647(14.86%)	0.473+-0.239	2.435+-0.612	32.118+-6.547	0.033+-0.022	4.512+-0.303	0.040+-0.026	5.158+-0.888	0.019+-0.014
bin3	3.4088980	49.550+-1.350	26.640+-3.905(14.65%)	0.348+-0.184	0.600+-0.129	21.041+-3.850	0.034+-0.017	2.363+-0.189	0.196+-0.123	2.050+-0.570	0.007+-0.007

Performance of Model(HH)

hyper parameter: NTrees=500, learning rate=0.05, max depth=12, MinNodeSize=1%(default)

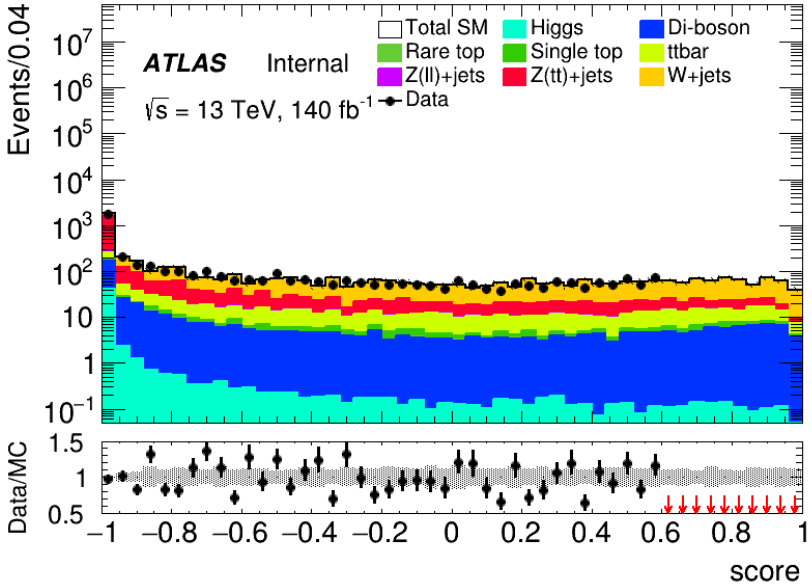


BDT score distribution of Validation set

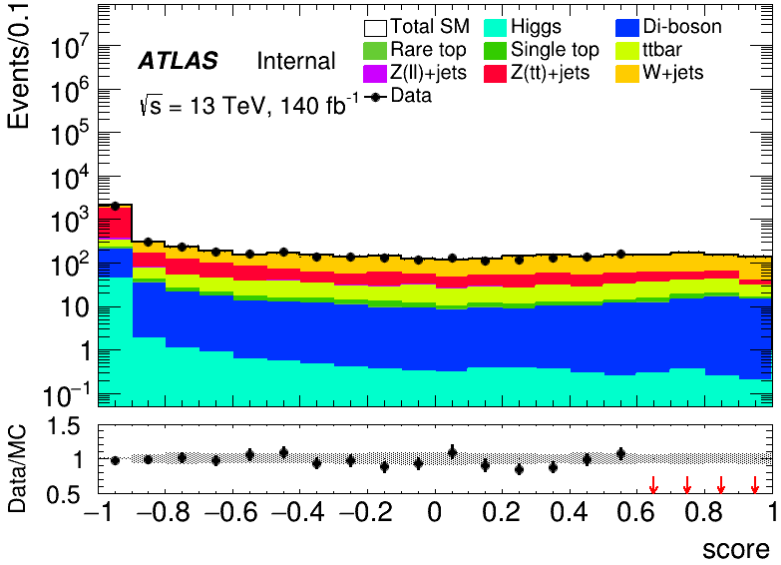


BDT score distribution of Test set

50 bins



20 bins



BDT score distribution of test set and data
(Blind with events with score > 0.6)

SR definition

Pre-Selection

- lep-had channel:nTaus$\geq$1;nLeps$\geq$1
- had-had channel:nTaus$\geq$2;nLeps=0
- MET$\geq$ 200; pass MET trigger
- $1 \leq nBaseJet \leq 8$
- b-veto
- OS

SR for HH channel

Pre-Selection + BDT score $\geq$ 0.91

SR for LH channel

Pre-Selection + BDT score $\geq$ 0.87

TODO

1. bkg estimation and define VR and CR

2. significance map

Backup

BackUp

An Interesting Method to Rebin

It can be proved that there are 2^{n-1} ways to rebin if histgram have n bins except 2 bins

2 bins

1. [0] [1] (separate)
2. [0+1] (merged)

Oredered the method and trun into binary number

3 bins

1. [0] [1] [2]
2. [0+1] [2]
3. [0] [1+2]
4. [0+1+2]

Based on Mathmatical Induction

2^{n-1} ways to rebin

4 bins

1. [0] [1] [2] [3]
2. [0+1] [2] [3]
3. [0] [1+2] [3]
4. [0] [1] [2+3]
5. [0+1+2] [3]
6. [0] [1+2+3]
7. [0+1] [2+3]
8. [0+1+2+3]

Example in 4 bins

000 (no walls): [0+1+2+3]

001 (wall at 2–3): [0+1+2] [3]

010 (wall at 1–2): [0+1] [2+3]

011 (walls at 1–2, 2–3): [0+1] [2] [3]

100 (wall at 0–1): [0] [1+2+3]

101 (walls at 0–1, 2–3): [0] [1+2] [3]

110 (walls at 0–1, 1–2): [0] [1] [2+3]

111 (all walls): [0] [1] [2] [3]

That's $2^3 = 8$ options (3 gaps).

BackUp

Feature_distribution