$B_c^+ \to \tau^+ \nu_\tau$ Analysis

Taifan

Basic statistics

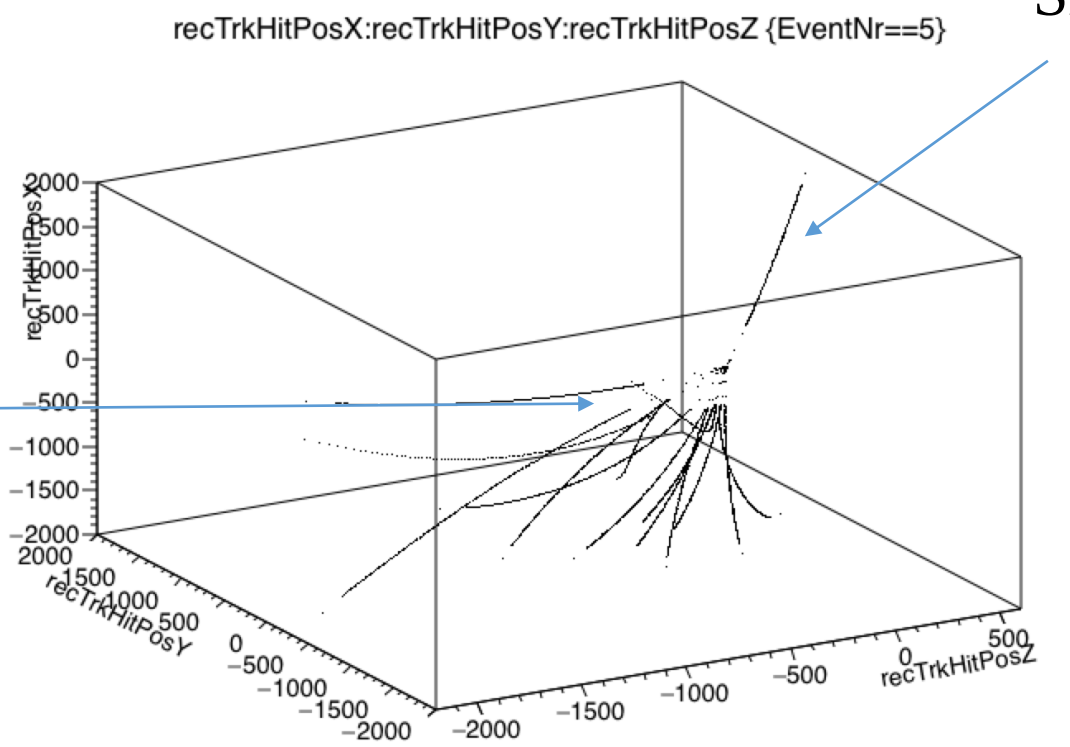
The following studies are done assuming 1×10^{11} Z bosons are produced. → 7.5×10^{5} $B_c^+ \to \tau^+\nu_\tau$ & 1×10^{6} $B^+ \to \tau^+\nu_\tau$

What we want to find

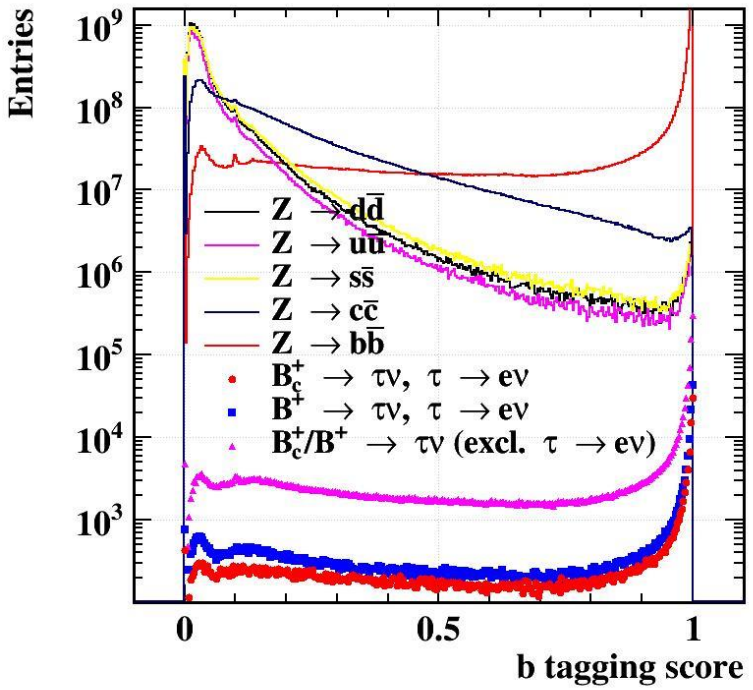
$B_c^+ \to \tau^+\nu_\tau, \tau^+ \to e^+\nu_e\overline{\nu}_\tau$ at Z pole.

Signal side

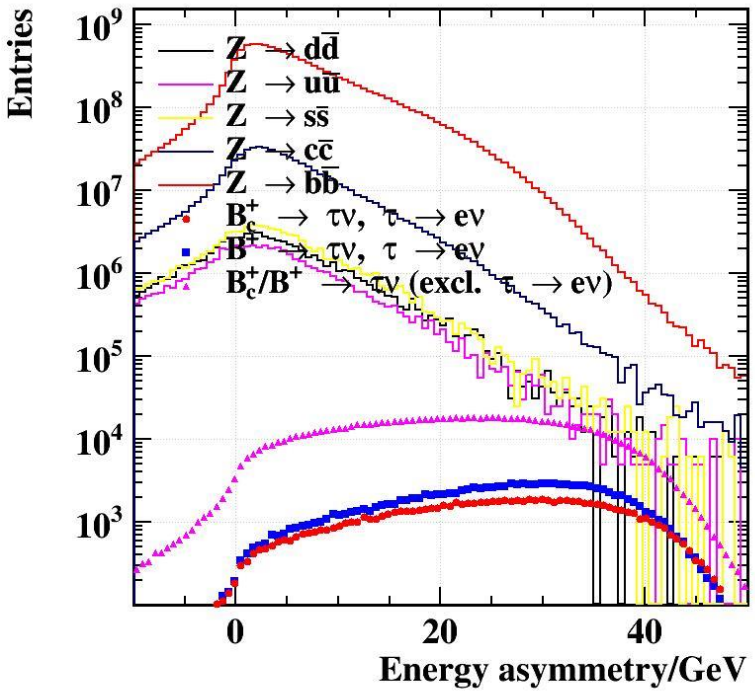
Recoil side



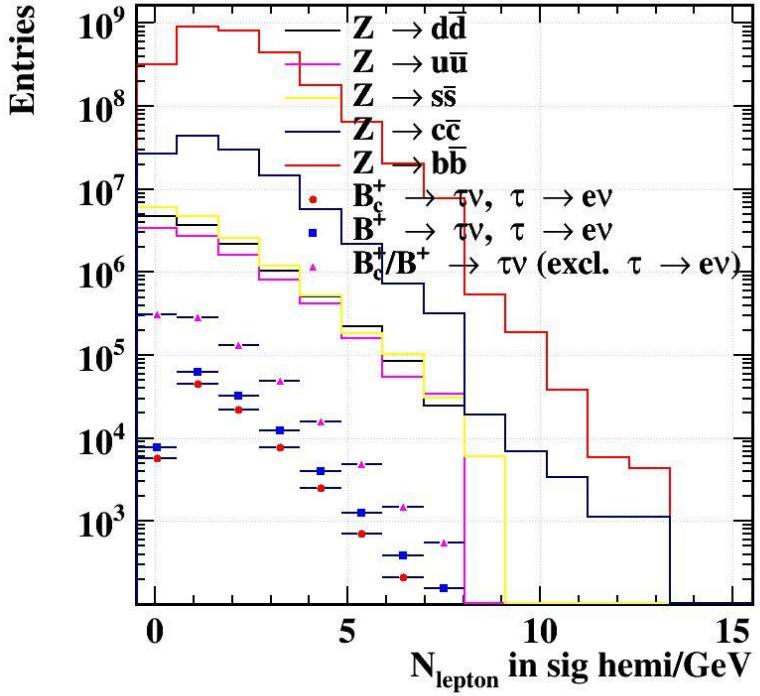
Parameter distribution (simple scaling)



btag>0.6

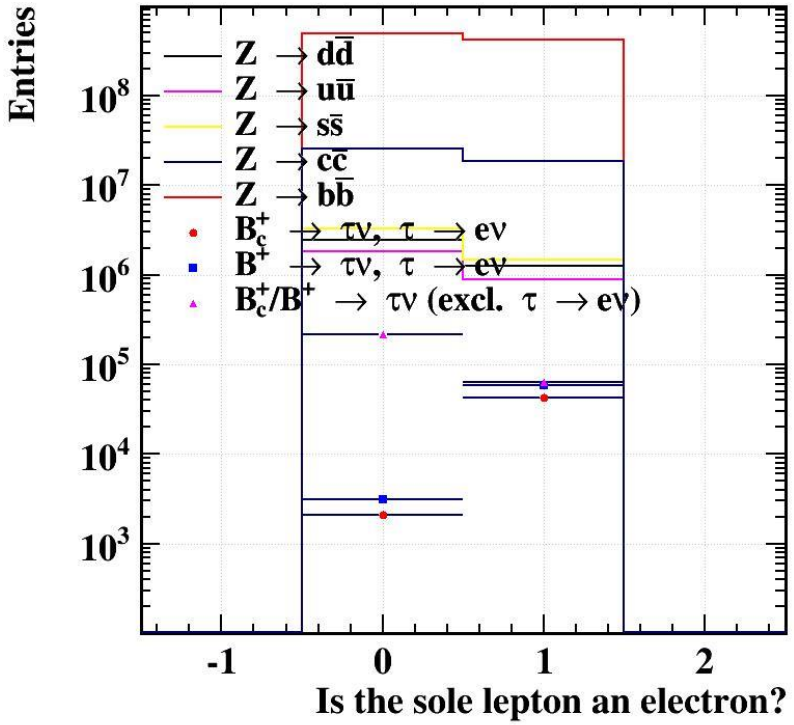


Recoil side en – signal side en > 10 GeV

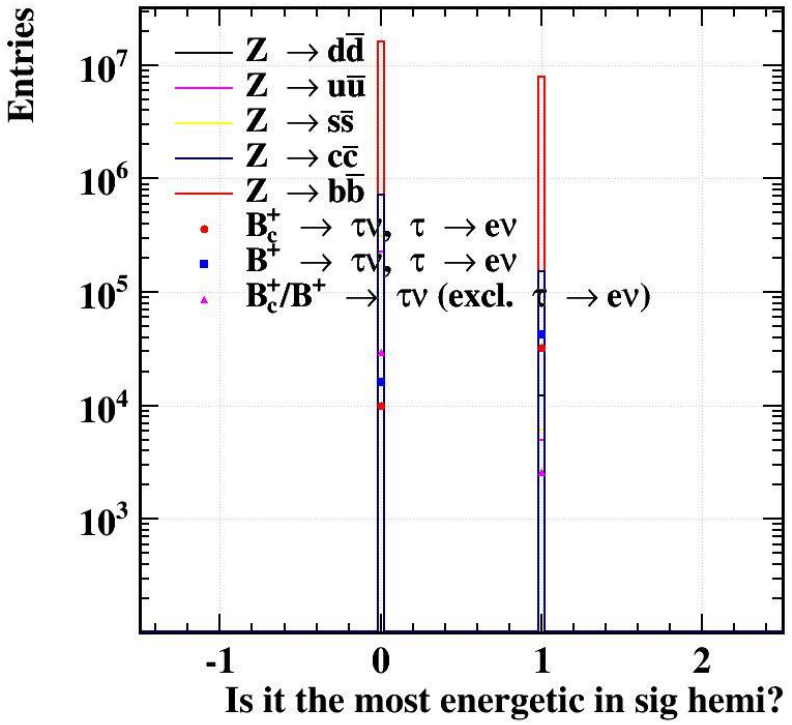


Only one lepton in the signal hemisphere

Parameter distribution (simple scaling)



That lepton is electron

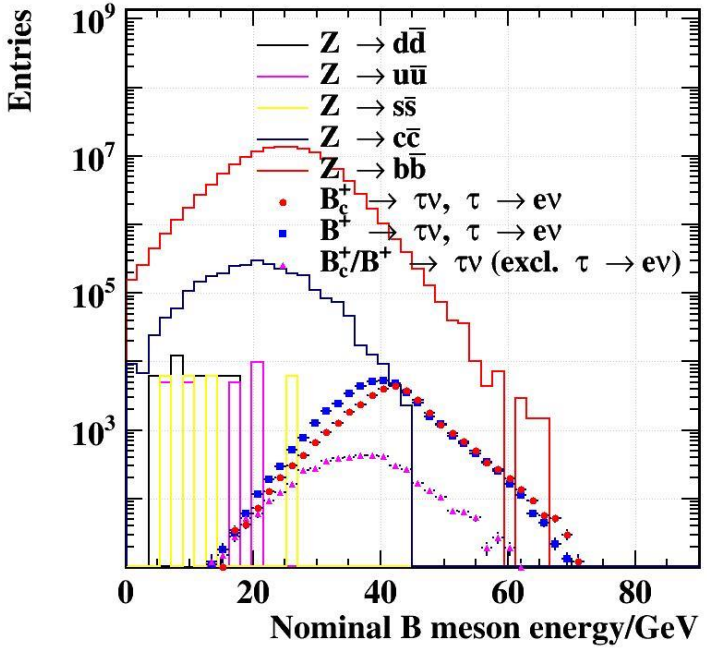


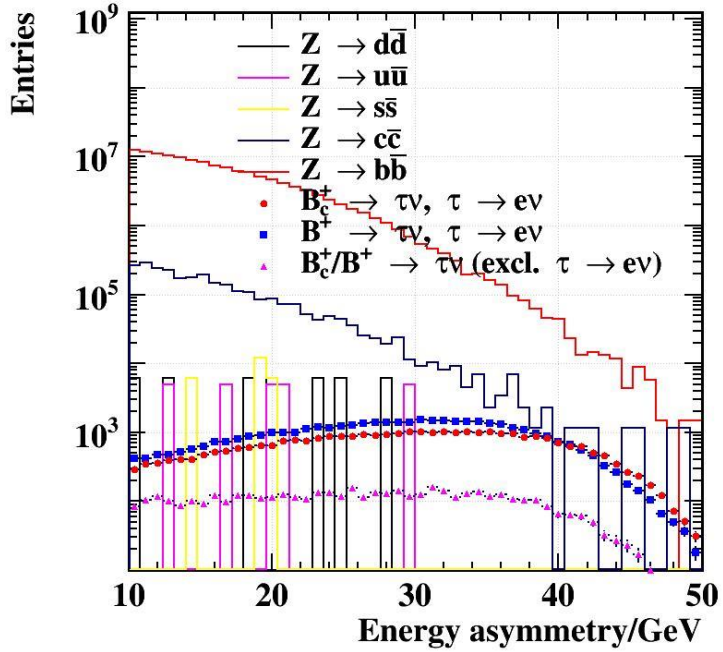
And it’s the most energetic particle in the signal hemisphere

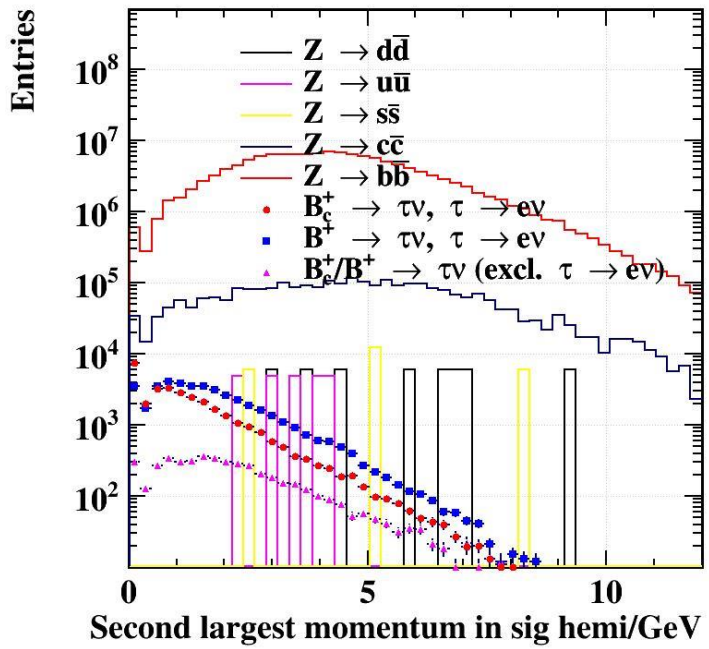
Cut chain

			1/6100	1/4900	1/6100	1/1100	1/1500
	$B_c^+ \to \tau^+\nu_\tau/\tau^+ \to e$	$B^+ \to \tau^+\nu_\tau/\tau^+ \to e$	dd	uu	ss	cc	bb
All	625177/134681	797230/195570	2530406	2415827	2531430	10414223	10532756
b-tag > 0.6	437048/94370	536144/133336	12495	11559	14920	590417	7885422
Energy asymmetry > 10 GeV	361063/83338	433750/119520	2048	1857	2525	108464	1892666
One lepton in sig hemi	127468/44500	153697/61805	610	549	784	38263	623432
Which is electron	32044/42386	30916/58652	206	181	245	16107	287334
And it's the most energetic one	2569/32458	2173/42475	8	5	4	2449	93945

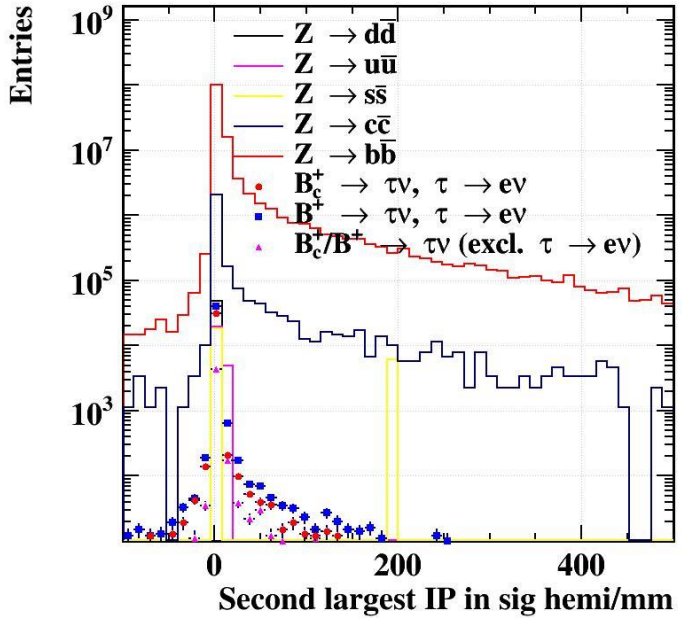
BDT variables (simple scaling)

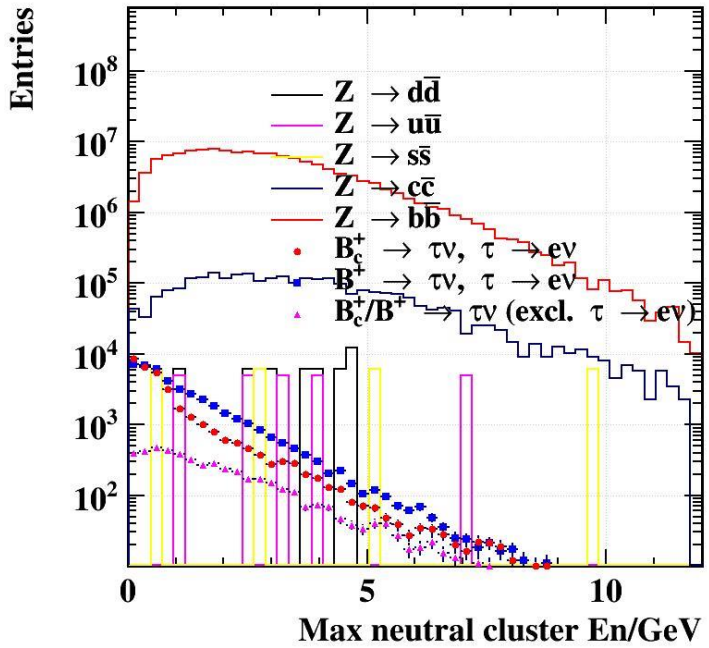


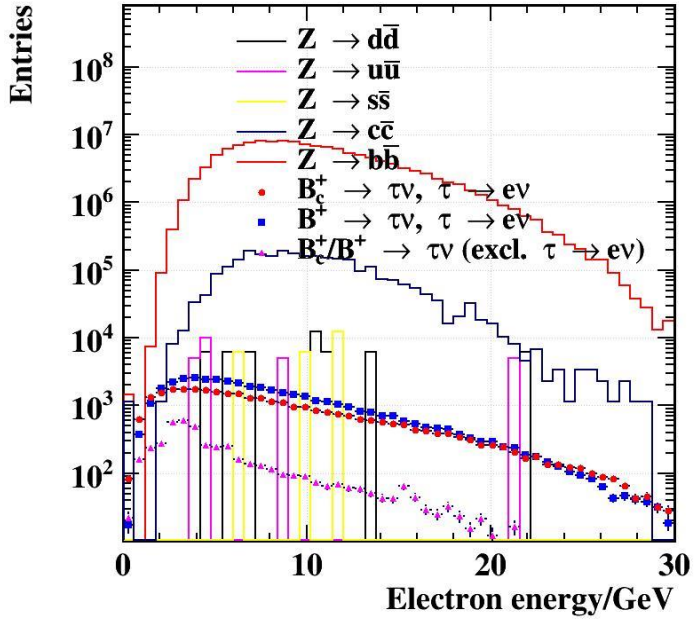




BDT variables (simple scaling)

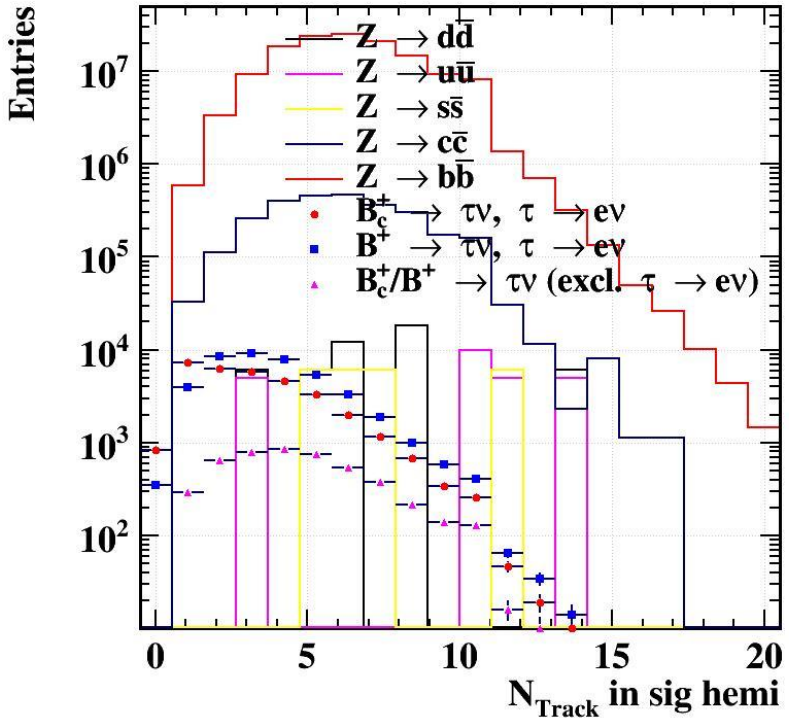






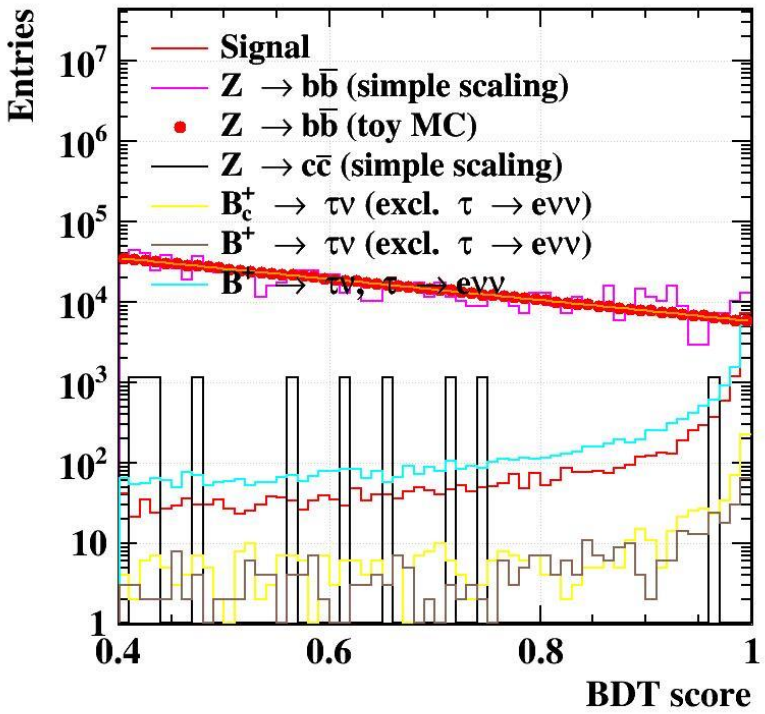
Max neutral cluster energy inside 30 deg cone around the thrust axis

BDT variables (simple scaling)



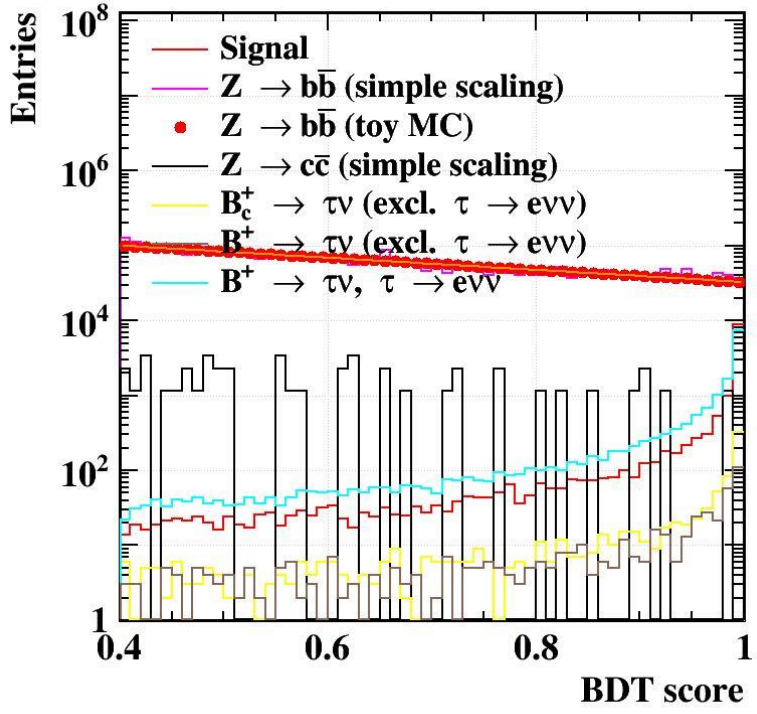
BDT

Variable	Importance
Nominal Bc energy	0.201
The second largest momentum in sig hemi	0.151
Maximum neutral cluster energy inside 30 deg cone	0.151
Energy asymmetry	0.148
Electron energy	0.123
Second largest IP in sig hemi	0.120
Number of tracks in sig hemi	0.106



root 5.34.07

I chose this & cut at 0.99



root 5.34.18

Set the weight to corresponding luminosity

Cut chain

			1/6100	1/4900	1/6100	1/1100	1/1500
	$B_c^+ \to \tau^+\nu_\tau/\tau^+ \to e$	$B^+ \to \tau^+\nu_\tau/\tau^+ \to e$	dd	uu	ss	cc	bb
All	625177/134681	797230/195570	2530406	2415827	2531430	10414223	10532756
b-tag > 0.6	437048/94370	536144/133336	12495	11559	14920	590417	7885422
Energy asymmetry > 10 GeV	361063/83338	433750/119520	2048	1857	2525	108464	1892666
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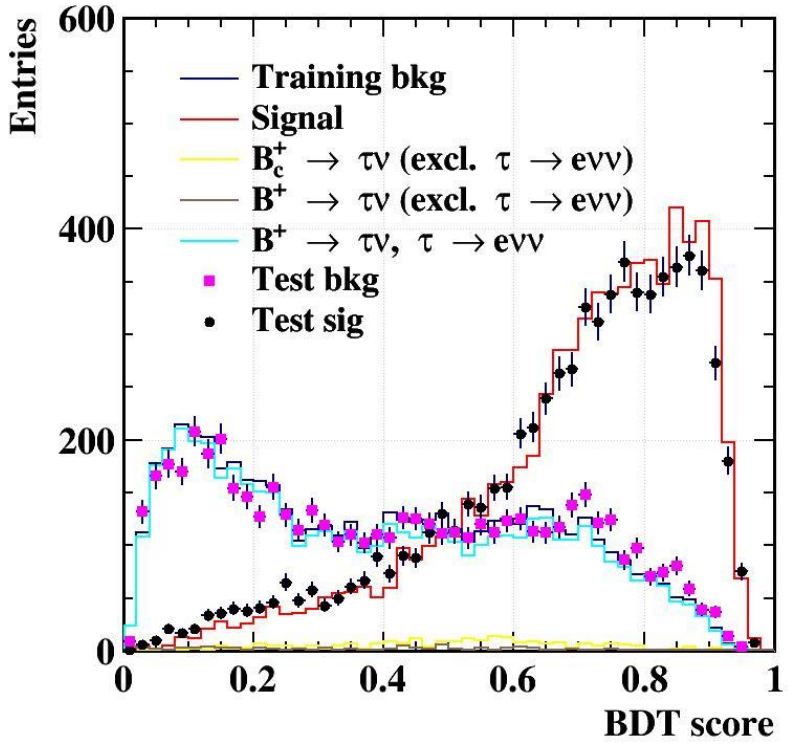
Which is electron	32044/42386	30916/58652	206	181	245	16107	287334
And it's the most energetic one	2569/32458	2173/42475	8	5	4	2449	93945
BDT > 0.99 (training data)	226/7226	65/5150	0	0	0	0	9 (5884)
BDT > 0.99 (test data)	223/7142	87/5178	0	0	0	1	8 (7441)

50/50 split between test and train samples

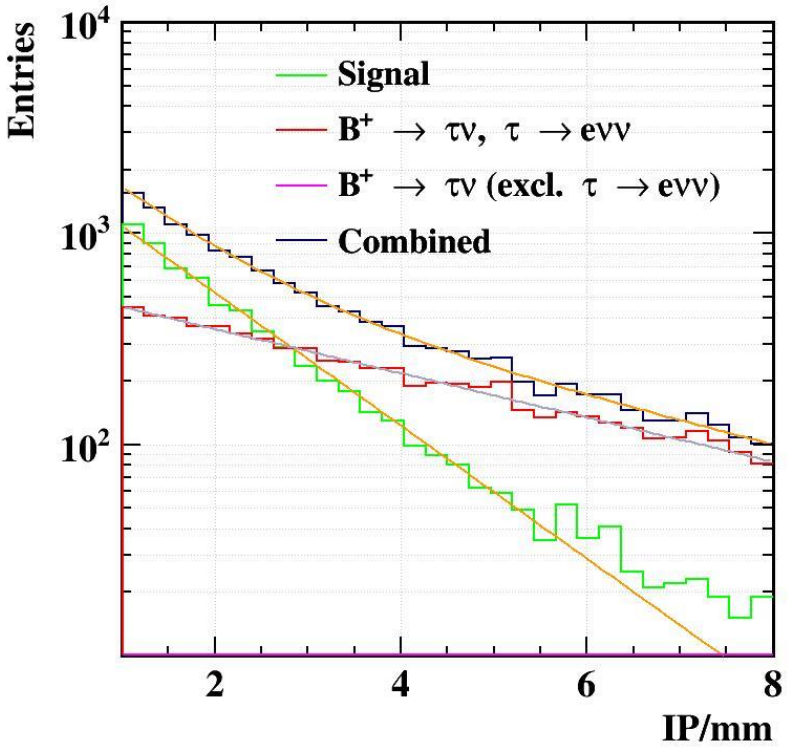
BDT

Using all of the previous variables + electron IP to do BDT again (ignore bb)

Variable	Importance
Electron IP	0.164
Electron energy	0.138
Nominal Bc energy	0.137
Energy asymmetry	0.134
Maximum neutral cluster energy inside 30 deg cone	0.133
The second largest momentum in sig hemi	0.127
Second largest IP in sig hemi	0.086
Number of tracks in sig hemi	0.082



Fit IP with exponential



Alternatively, we can fit the IP with exponential $C_1 \cdot e^{-E_1 x} + C_2 \cdot e^{-E_2 x}$(again, ignoring bb).

```
 EXT PARAMETER                                          STEP         FIRST
 NO.   NAME      VALUE            ERROR                 SIZE      DERIVATIVE
  1  C1           5.72575e+02   1.52615e+01   1.44289e-02  -7.51254e-06
  2  E1           2.41352e-01   6.62978e-03   6.26832e-06   1.43783e-02
FCN=67.8532 FROM MIGRAD    STATUS=CONVERGED      80 CALLS          81 TOTAL
                    EDM=5.09469e-08    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                          STEP         FIRST
 NO.   NAME      VALUE            ERROR                 SIZE      DERIVATIVE
  1  C2           2.24564e+03   6.53438e+01   1.14074e-01   1.07633e-05
  2  E2           7.25760e-01   1.12363e-02   1.96105e-05  -6.54741e-02
FCN=21.3704 FROM MIGRAD    STATUS=CONVERGED     327 CALLS         328 TOTAL
                    EDM=7.43106e-08    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                          STEP         FIRST
 NO.   NAME      VALUE            ERROR                 SIZE      DERIVATIVE
  1  C1           7.27399e+02   2.01951e+02   2.26757e-02  -5.88938e-06
  2  E1           2.49481e-01   3.81610e-02   6.94000e-06  -2.18549e-03
  3  C2           2.83089e+03   1.83058e+02   1.31003e-01  -4.50623e-06
  4  E2           9.38499e-01   1.24337e-01   2.44118e-05   1.31922e-02
```

Number of events predicted by fit results

	Truth	Individual fit	Combined fit
$B_c^+ \to \tau^+\nu_\tau, \tau^+ \to e$	6438	6525	8047
$B^+ \to \tau^+\nu_\tau / \tau^+ \to e$	6528	6375	5055