ISTEP2016　Project

Zprime Searches at 13TeV PP Collider

李博洋、张育飞、韩大伟、何显科、王梦真、王妙

Introduction

- Various extensions of the Standard Models predict the existence of new kinds of heavy gauge bosons .
- Due to their simplicity and clean signature in leptonic decay, searches for Z' and W' serve as the benchmark to examine the potential of future high energy colliders.
- In this study, we are particular interested in the Sequential Standard Model

The Lagrangian of SM

$$\mathcal{L} = -\frac{1}{4}F_{\mu\nu}F^{\mu\nu} + i\bar{\psi}\not{D}\psi + h.c.$$
$$+ \psi_i y_{ij} \psi_s \phi + h.c. + |D_\mu \phi|^2 - V(\phi)$$

The gauge bosons appear in the covariant derivative

$$\begin{pmatrix} \frac{g'}{g} B^{\mu} + W_{\mu}^{3} & W_{\mu}^{1} - iW_{\mu}^{2} \\ W_{\mu}^{1} + iW_{\mu}^{2} & \frac{g'}{g} B^{\mu} - W_{\mu}^{3} \end{pmatrix}$$

The w^3 and B bosons mix ,give Z and photon A

$$Z_{\mu} \equiv \cos\theta_{w} W_{\mu}^{3} - \sin\theta_{w} B_{\mu}$$

$$A_{\mu} \equiv \sin\theta_{w} W_{\mu}^{3} + \cos\theta_{w} B_{\mu}$$

The SSM (Sequential Standard Model)

- Z' is a carbon copy of SM Z boson with the same couplings with a heavier mass

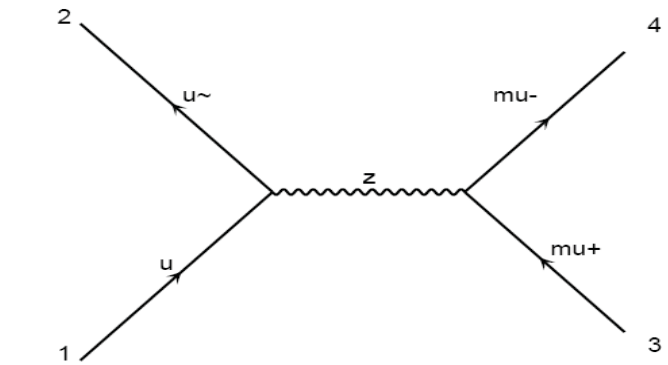
- Z' is created through qqbar annihilation and decays in SM final states.

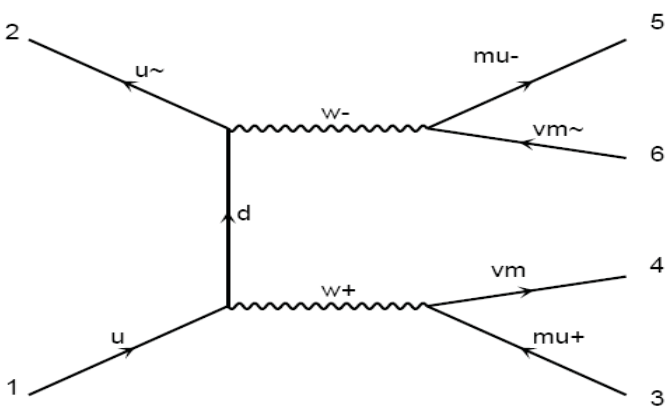
- ATLAS high-mass ditau: exclude Z'_{SSM} masses below 1.4 TeV($4.6fb^{-1}$ at $\sqrt{s} = 7$TeV) and 1.9 TeV($19.5fb^{-1}$ at $\sqrt{s} = 8$TeV).
- ATLAS high-mass ditau: exclude Z'_{SSM} masses below 1.4 TeV($4.6fb^{-1}$ at $\sqrt{s} = 7$TeV) and 1.9 TeV($19.5fb^{-1}$ at $\sqrt{s} = 8$TeV). The CMS results :exclude Z'_{SSM} masses below 1.4 TeV($4.9fb^{-1}$ at $\sqrt{s} = 7$TeV) and 1.3 TeV($19.7fb^{-1}$ at $\sqrt{s} = 8$TeV(in τ lepton pairs decaying into final states with an electron and a muon)
- The most stringent mass limits on Z'_{SSM} production in the decay channel of the Z' to a pair of electrons or muons amount to 3.4 TeV in the case of ATLAS and 3.2 TeV in the case of CMS,at $\sqrt{s} = 13$TeV.

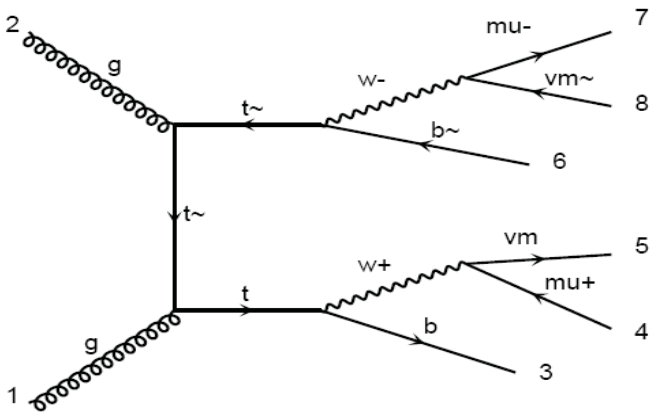
Discovery research at 13 TeV @LHC

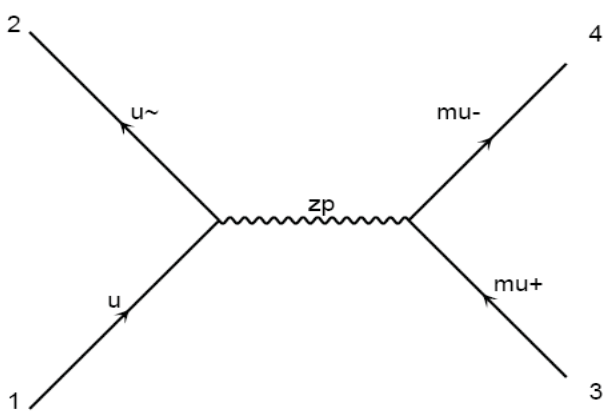
Relevant processes in our study are Drell-Yan, TTbar, Diboson, Single top, and our Zprime signal .the final states are dimuon.

Relevant Feynman diagrams:





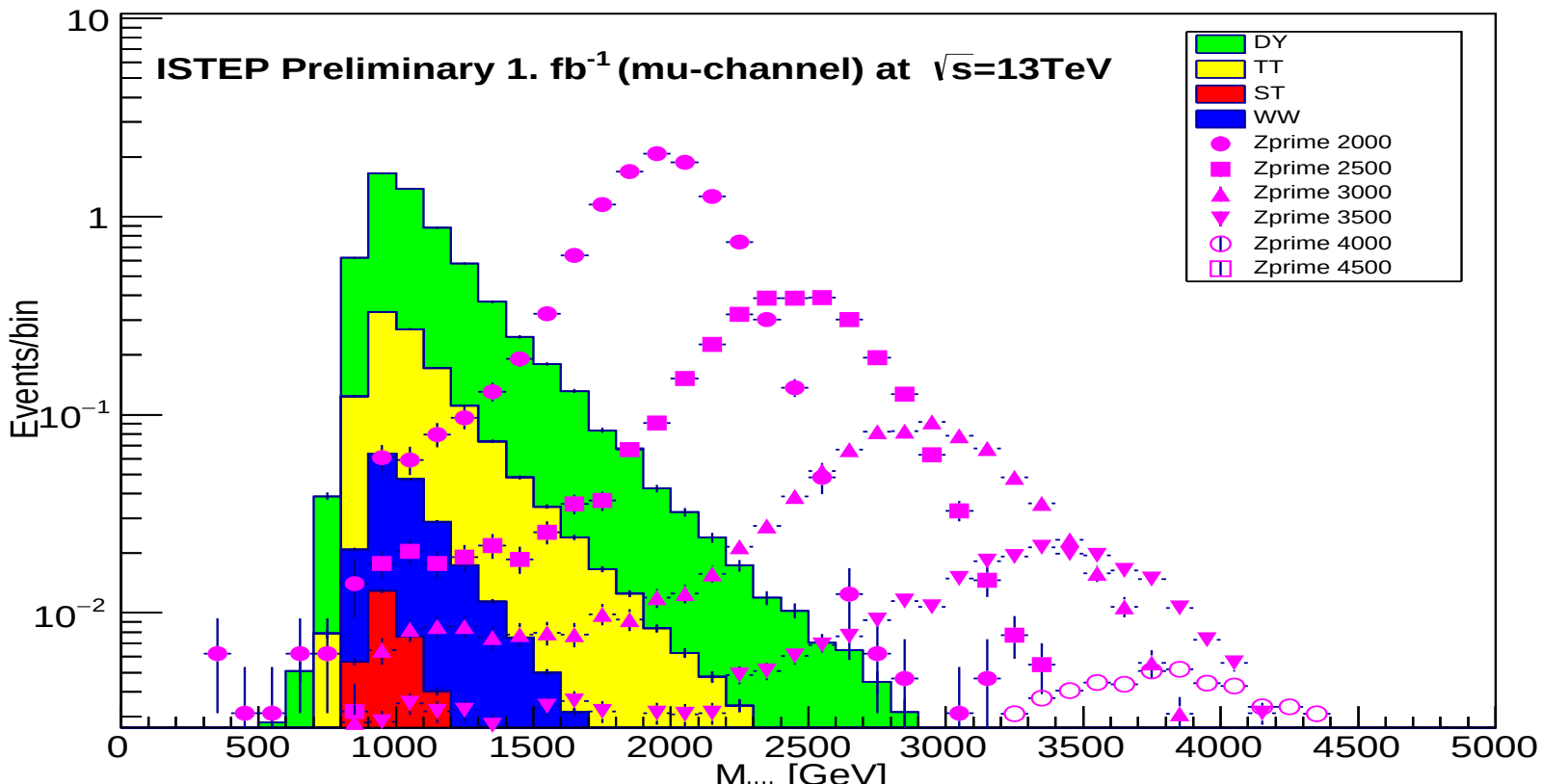




Cross sections of bkg and signal

Background/Signal	Cross section
DY	5.14615
ST	0.0361963
TT	1.04458
WW	0.178684
ZP2000	10.9372
ZP2500	2.99436
ZP3000	0.880089
ZP3500	0.28073
ZP4000	0.0968058
ZP4500	0.0371262

Inv mass distribution of bkg and signal



Strategy

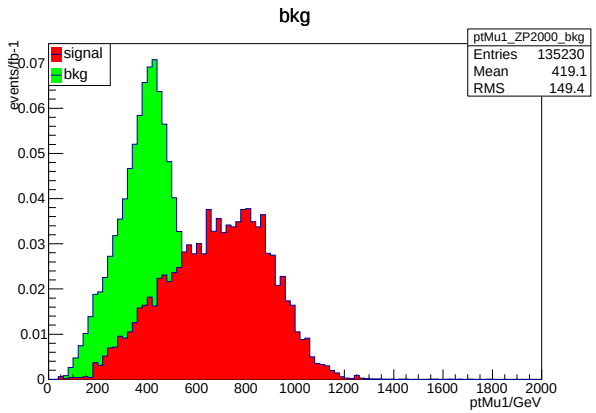
Loop for the best cut in the inv mass range[0,5000](GeV) to find the biggest q0 and significance .

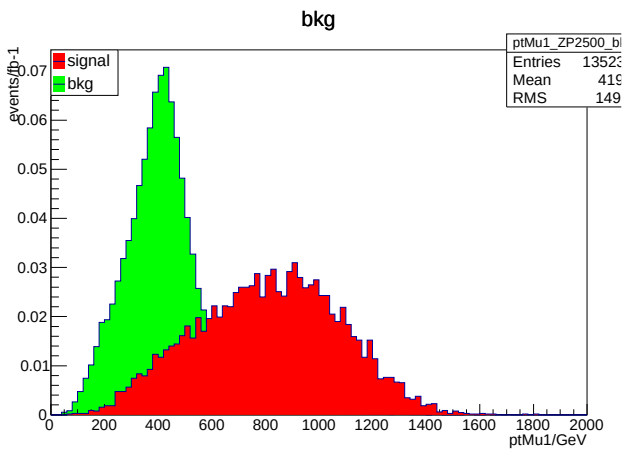
Numerical results:

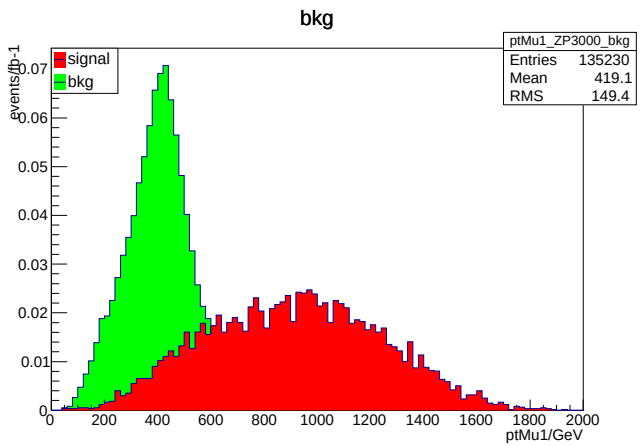
```
 ntuple

_2000 bestcut: mll > 1687      s/b = 28.2977   q0 = 47.2416    significance = 6.87325
_2100 bestcut: mll > 1792      s/b = 29.4672   q0 = 36.0959    significance = 6.00798
_2200 bestcut: mll > 1879      s/b = 30.1307   q0 = 27.7951    significance = 5.2721
_2300 bestcut: mll > 1980      s/b = 30.8831   q0 = 21.0462    significance = 4.58761
_2400 bestcut: mll > 2040      s/b = 27.3049   q0 = 15.0285    significance = 3.87666
_2500 bestcut: mll > 2089      s/b = 25.8521   q0 = 12.0276    significance = 3.46808
_2600 bestcut: mll > 2204      s/b = 27.2798   q0 = 9.287      significance = 3.04746
_2700 bestcut: mll > 2315      s/b = 27.8838   q0 = 6.86668    significance = 2.62043
_2800 bestcut: mll > 2323      s/b = 23.6783   q0 = 5.3584     significance = 2.31482
_2900 bestcut: mll > 2469      s/b = 25.4596   q0 = 4.02496    significance = 2.00623
_3000 bestcut: mll > 2532      s/b = 24.3289   q0 = 3.07578    significance = 1.75379
_3100 bestcut: mll > 2667      s/b = 26.5583   q0 = 2.35401    significance = 1.53428
_3200 bestcut: mll > 2733      s/b = 25.9467   q0 = 1.8214     significance = 1.34959
_3300 bestcut: mll > 2733      s/b = 21.7136   q0 = 1.42727    significance = 1.19468
_3400 bestcut: mll > 2908      s/b = 26.1264   q0 = 1.09868    significance = 1.04818
_3500 bestcut: mll > 3031      s/b = 27.1946   q0 = 0.852351   significance = 0.923229
_3800 bestcut: mll > 3152      s/b = 18.8727   q0 = 0.381508   significance = 0.617663
_4000 bestcut: mll > 3352      s/b = 17.6878   q0 = 0.215631   significance = 0.464361
_4500 bestcut: mll > 3916      s/b = 18.6937   q0 = 0.0502353  significance = 0.224132
```

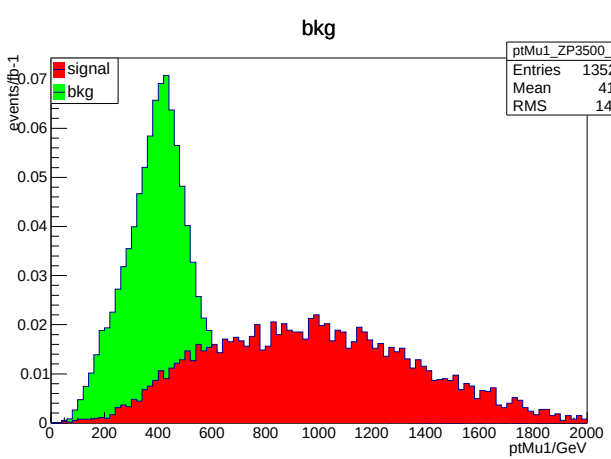
```
histogram

2000 bestcut: mll > 1800      s/b =29.1927    q0 = 47.0528    significance = 6.85951
2100 bestcut: mll > 1900      s/b =29.885     q0 = 35.8805    significance = 5.99004
2200 bestcut: mll > 2000      s/b =31.6202    q0 = 27.6043    significance = 5.25398
2300 bestcut: mll > 2000      s/b =25.7163    q0 = 20.8748    significance = 4.56889
2400 bestcut: mll > 2100      s/b =24.9379    q0 = 14.9637    significance = 3.86829
2500 bestcut: mll > 2200      s/b =26.3544    q0 = 12.0049    significance = 3.46481
2600 bestcut: mll > 2300      s/b =27.1207    q0 = 9.27824    significance = 3.04602
2700 bestcut: mll > 2400      s/b =26.7812    q0 = 6.8472     significance = 2.61672
2800 bestcut: mll > 2400      s/b =22.207     q0 = 5.30103    significance = 2.3024
2900 bestcut: mll > 2500      s/b =21.8934    q0 = 4.01219    significance = 2.00305
3000 bestcut: mll > 2600      s/b =22.1863    q0 = 3.04623    significance = 1.74535
3100 bestcut: mll > 2700      s/b =22.1446    q0 = 2.3212     significance = 1.52355
3200 bestcut: mll > 2800      s/b =23.3782    q0 = 1.79255    significance = 1.33886
3300 bestcut: mll > 2900      s/b =24.8995    q0 = 1.421      significance = 1.19206
3400 bestcut: mll > 3000      s/b =25.7655    q0 = 1.09681    significance = 1.04729
3500 bestcut: mll > 3000      s/b =21.3813    q0 = 0.849461   significance = 0.921662
3800 bestcut: mll > 3200      s/b =16.5955    q0 = 0.372618   significance = 0.610424
```

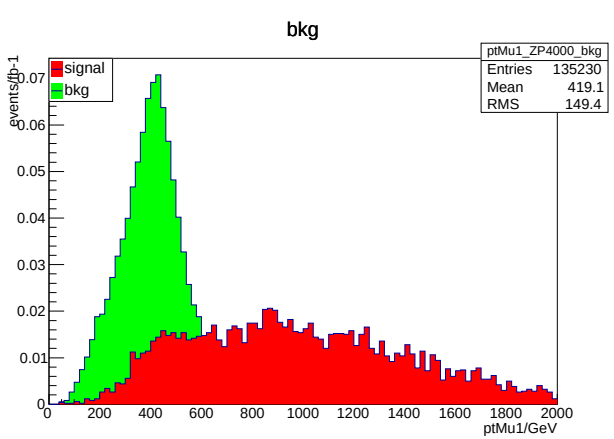
Pt distribution before inv mass cut

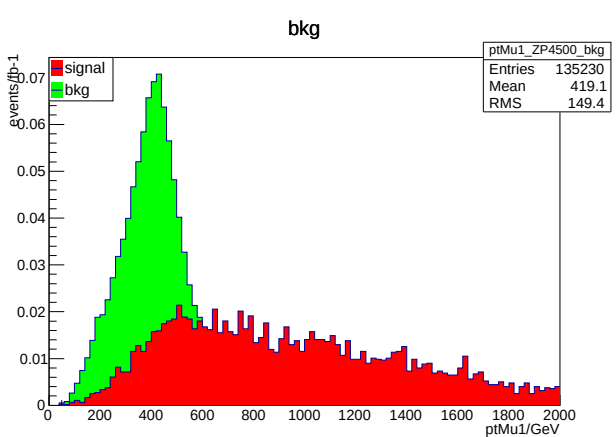




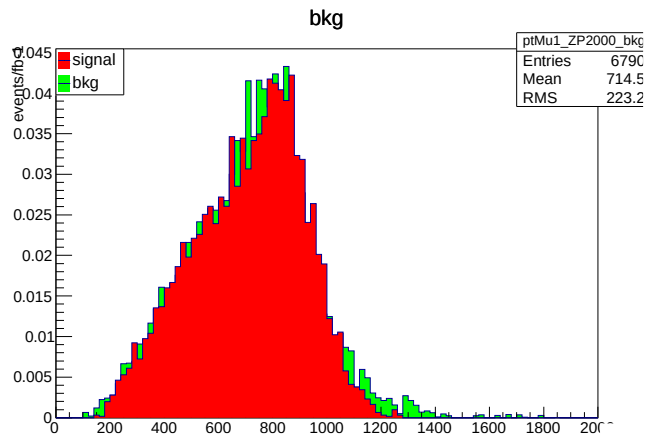


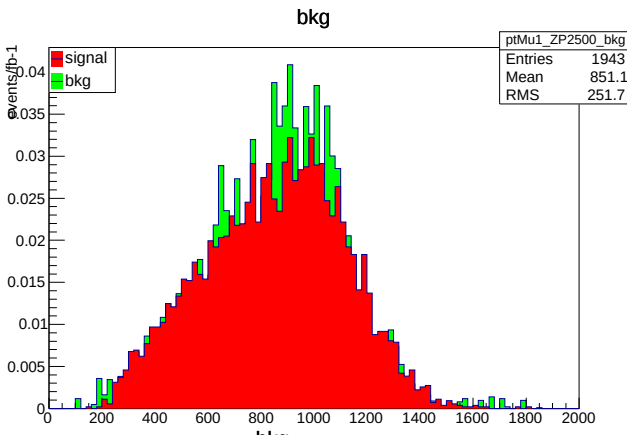


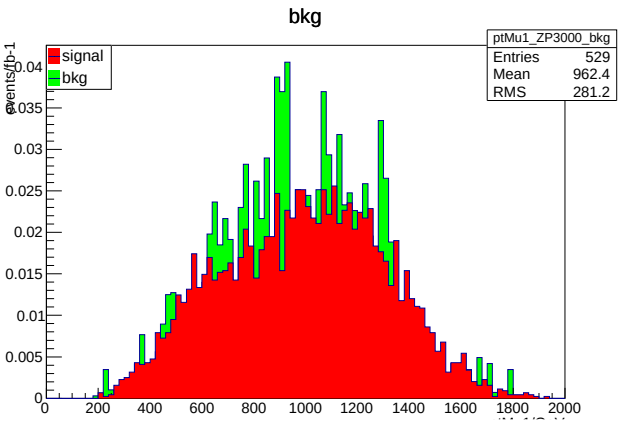


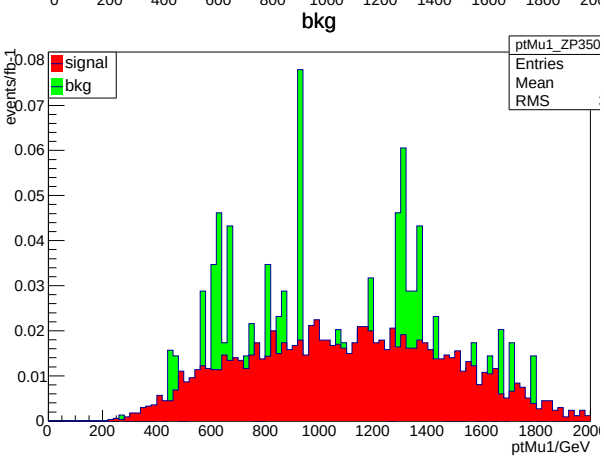


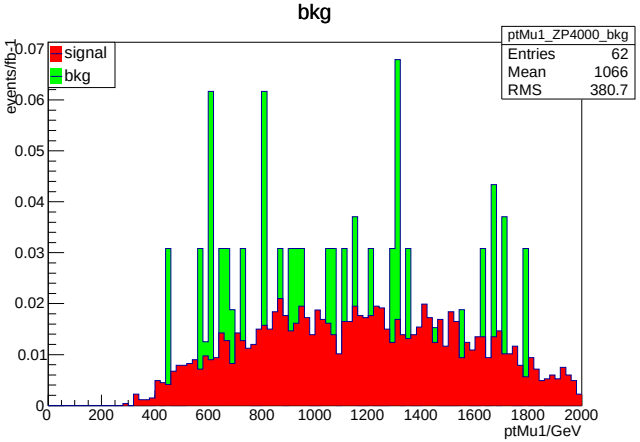
Pt distribution after inv mass cut

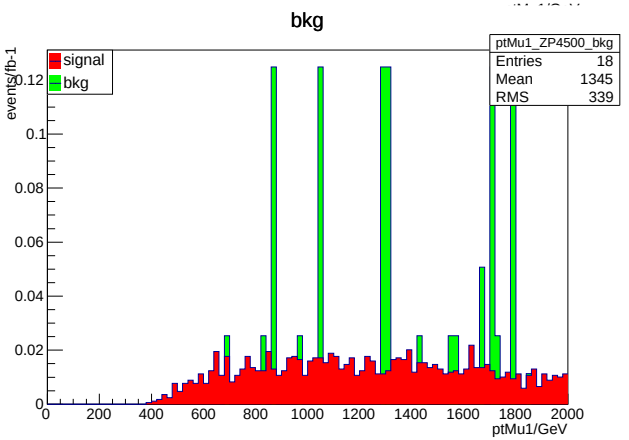




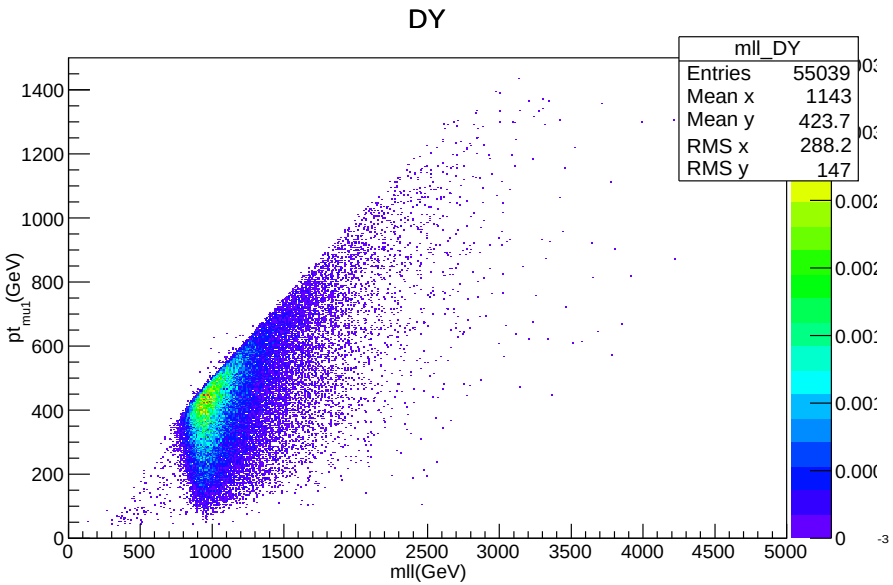


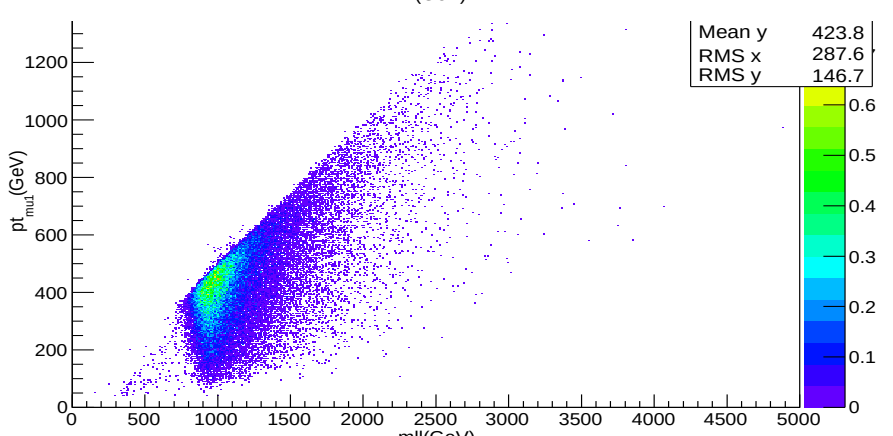


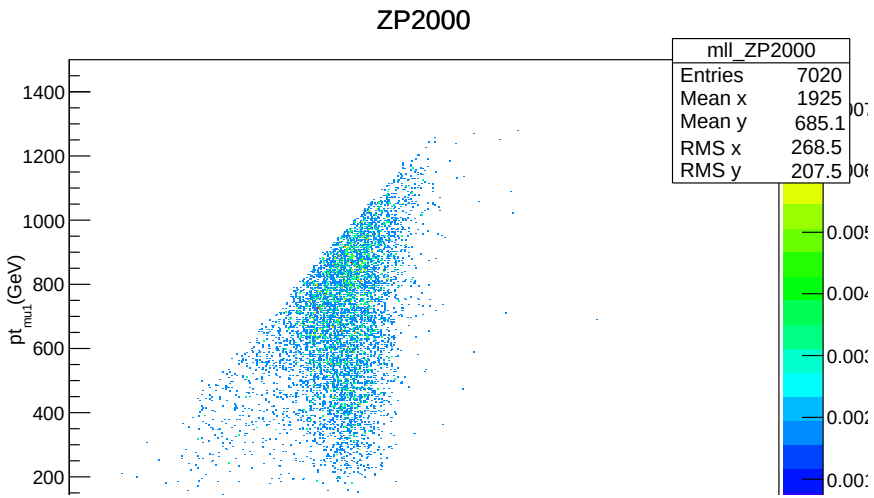


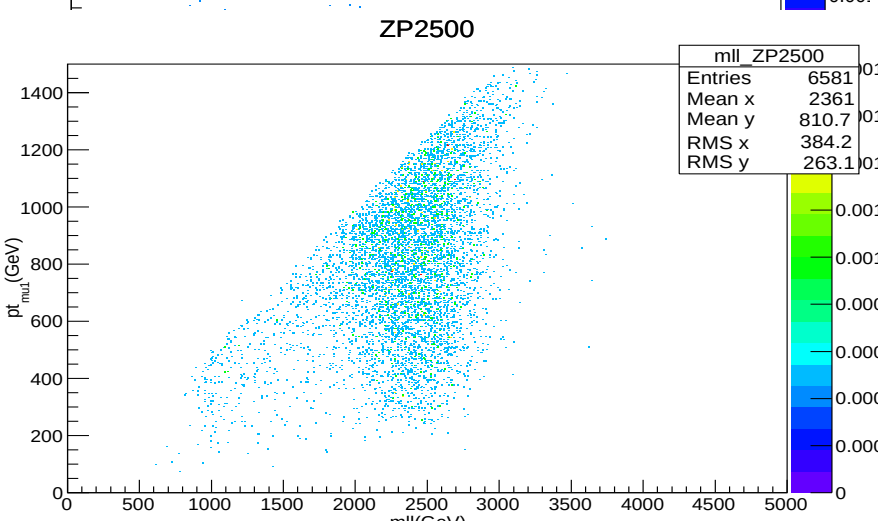


Two dimentional distribution of pt and mll

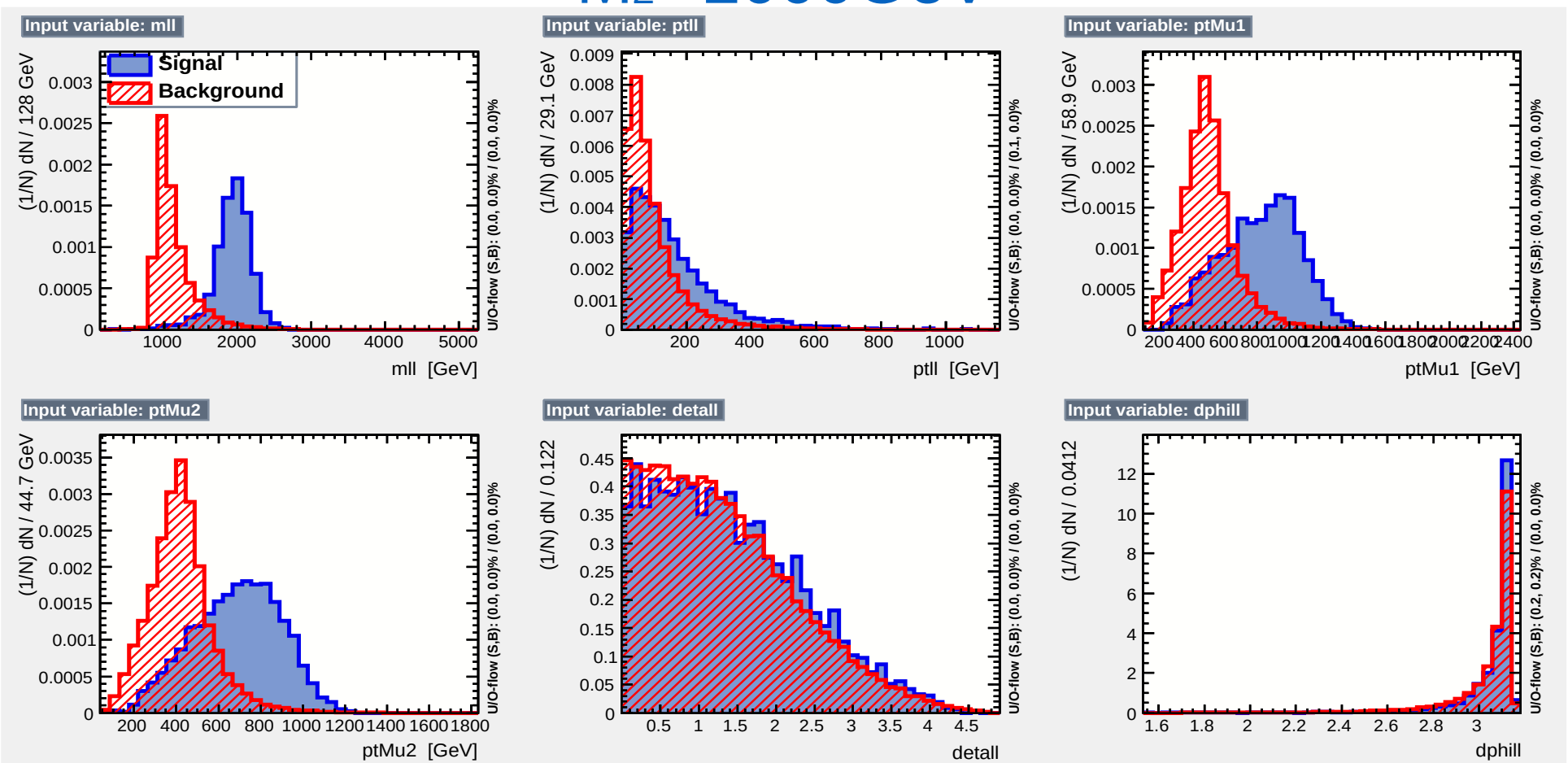




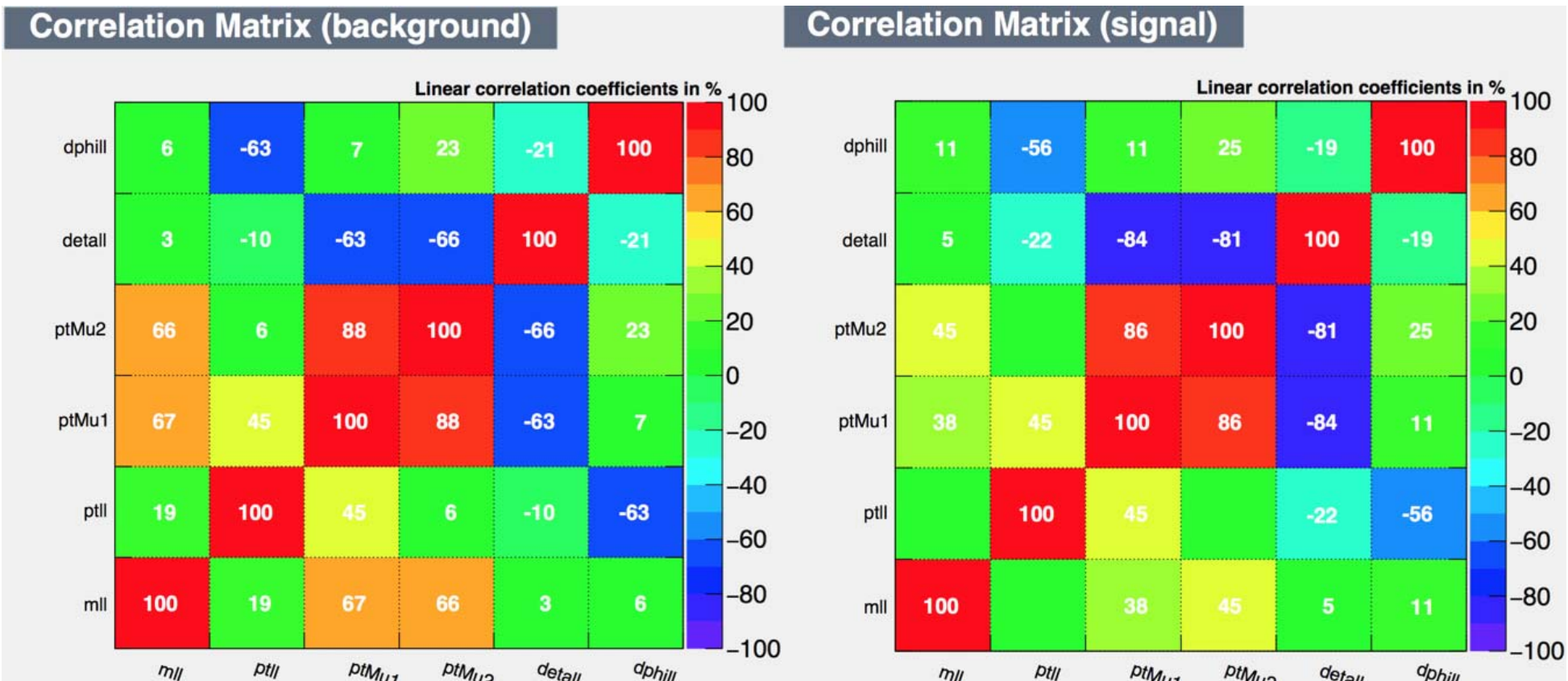




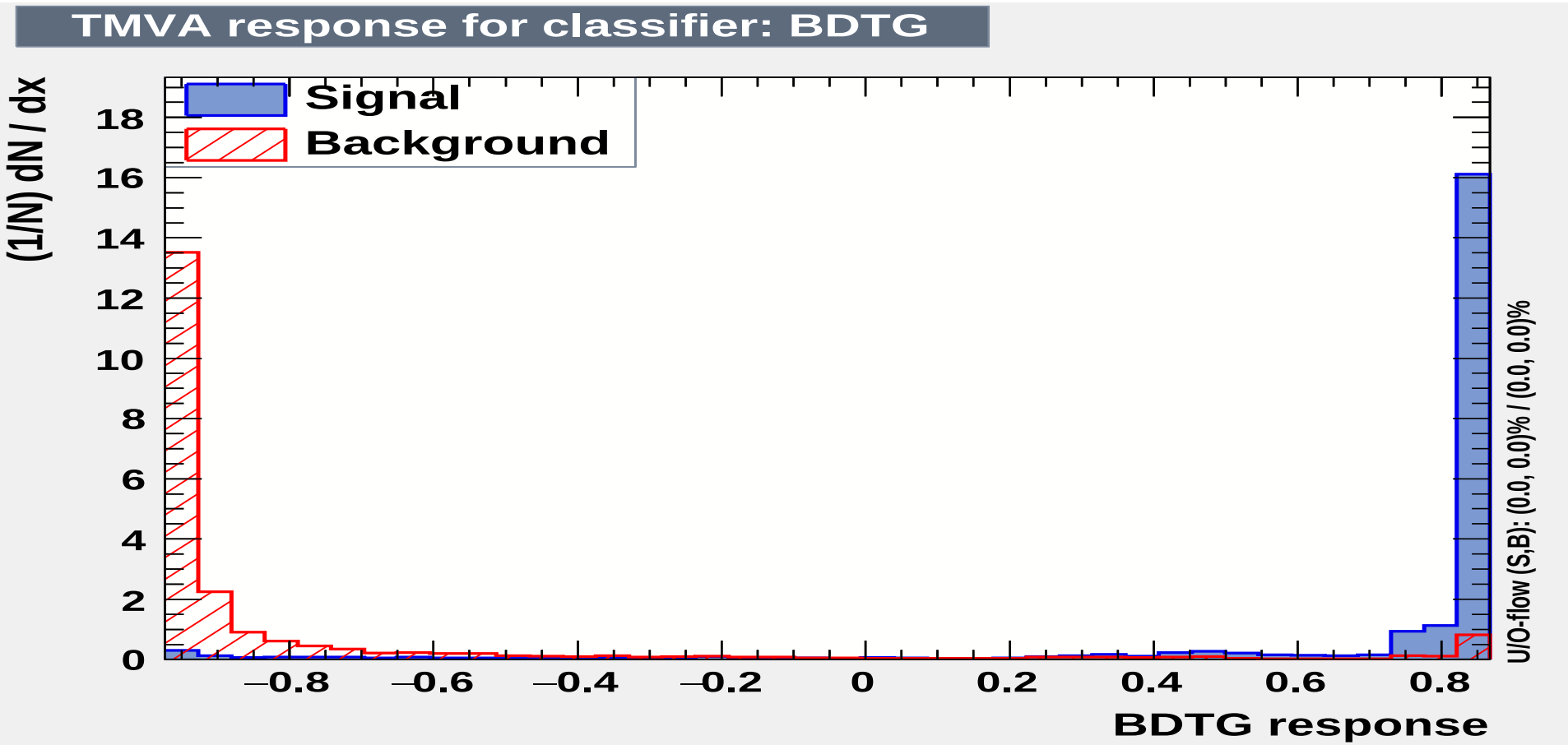
Probability Distribution function of BDT inputs for $M_{Z'}$=2000GeV



Correlation matrices of bkg and signal



BDT output of signal and bkg



Best cut on BDT and the significance

```
 BDT

_2000 bestcut: BDT > 0.5        s/b = 32.3391   q0 = 47.785     significance = 6.91267
_2100 bestcut: BDT > 0.63       s/b = 38.8304   q0 = 51.8015    significance = 7.19733
_2200 bestcut: BDT > 0.77       s/b = 49.5886   q0 = 55.6075    significance = 7.45705
_2300 bestcut: BDT > 0.87       s/b = 60.5191   q0 = 58.1805    significance = 7.62762
_2400 bestcut: BDT > 0.88       s/b = 62.961    q0 = 58.9143    significance = 7.67556
_2500 bestcut: BDT > 0.89       s/b = 66.021    q0 = 59.6537    significance = 7.72358
_2600 bestcut: BDT > 0.89       s/b = 66.528    q0 = 60.2436    significance = 7.76167
_2700 bestcut: BDT > 0.89       s/b = 64.4313   q0 = 57.8112    significance = 7.60337
_2800 bestcut: BDT > 0.9        s/b = 69.1303   q0 = 57.6854    significance = 7.59509
_2900 bestcut: BDT > 0.9        s/b = 68.079    q0 = 56.5616    significance = 7.52074
_3000 bestcut: BDT > 0.9        s/b = 65.618    q0 = 53.9466    significance = 7.34484
_3100 bestcut: BDT > 0.9        s/b = 65.0739   q0 = 53.3715    significance = 7.30558
_3200 bestcut: BDT > 0.9        s/b = 63.0705   q0 = 51.2639    significance = 7.15988
_3300 bestcut: BDT > 0.91       s/b = 73.5265   q0 = 50.7776    significance = 7.12584
_3400 bestcut: BDT > 0.91       s/b = 71.5197   q0 = 49.0102    significance = 7.00073
_3500 bestcut: BDT > 0.91       s/b = 70.9571   q0 = 48.5167    significance = 6.96539
_3800 bestcut: BDT > 0.91       s/b = 64.8606   q0 = 43.2285    significance = 6.57484
_4000 bestcut: BDT > 0.91       s/b = 61.1814   q0 = 40.0926    significance = 6.33187
_4500 bestcut: BDT > 0.91       s/b = 51.7707   q0 = 32.2812    significance = 5.68165
```

Summary

- We have analyzed the discovery significance of a new neutral gauge boson

- The BDT method is the best way to separate the signal and bkg .The significance obtained in such a way is higher than the traditional methods such as those based on the single inv mass cut.

Outlook

- suppress TTbar bkg
- We considered WW but not WZ or ZZ for the diboson contributions .the bkg from WZ or ZZ process.
- Shape Analysis instead of Cut/counting

工作量

- 李博洋(写code)
- 张育飞(算法，理论，PPT制作)
- 韩大伟(PPT制作)
- 何显科(图片后期处理)
- 王梦真(PPT制作)
- 王妙(文献查找)

Thank You