Reconstrução do ZPrime e Machine Learning utilizando dados de ATLAS

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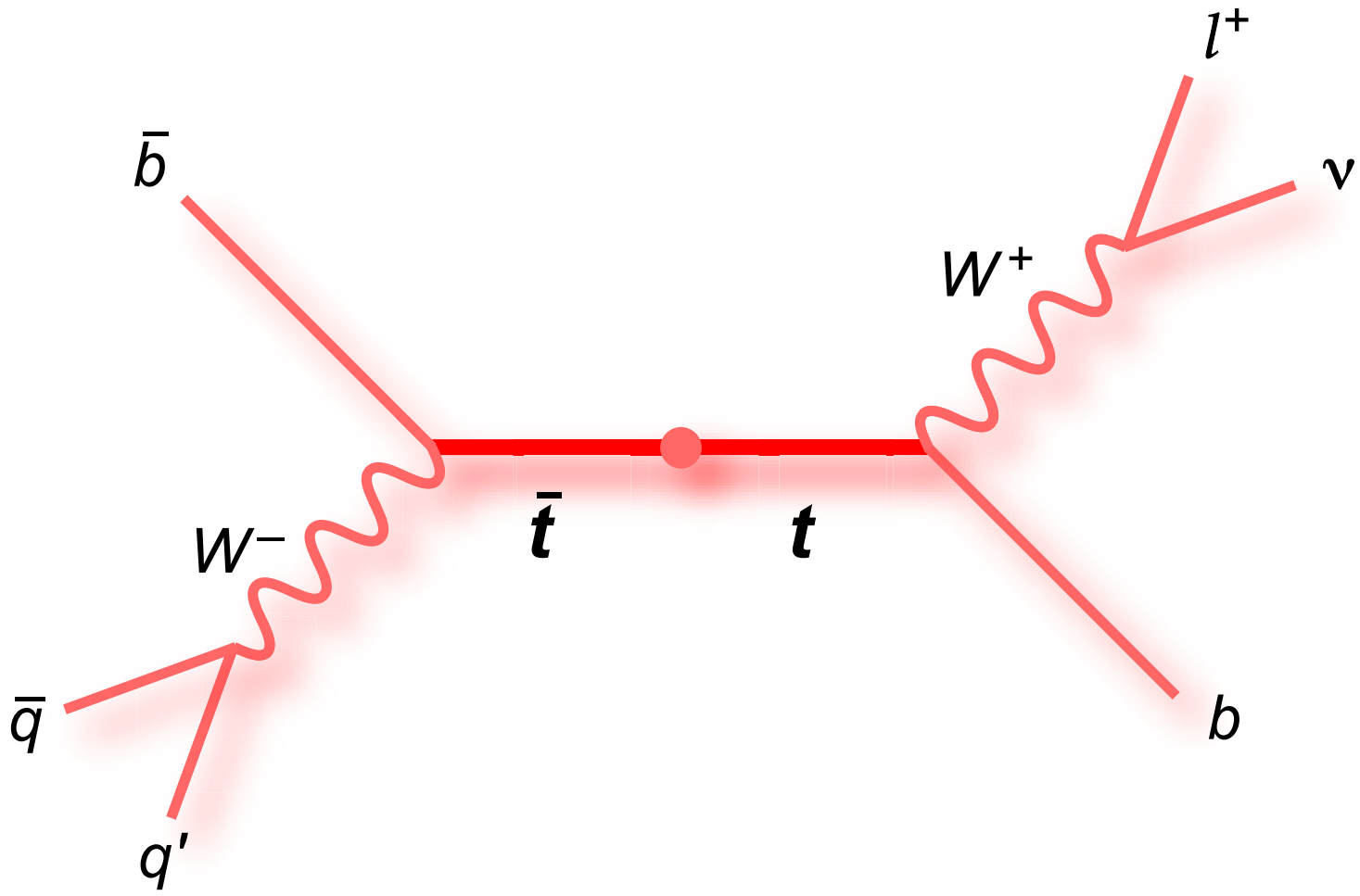
LIP - UMinho

Decaimento TTbar



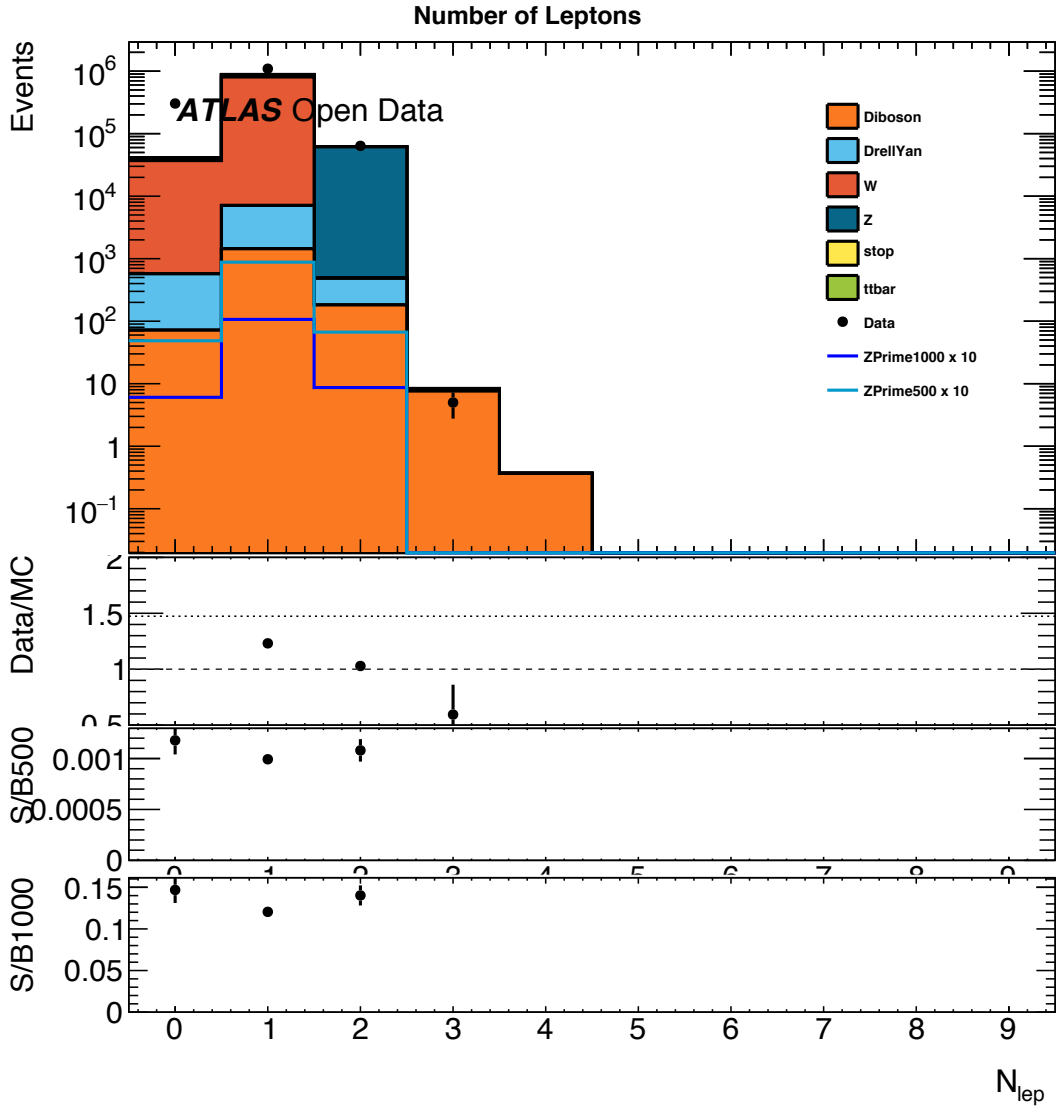
Sumário

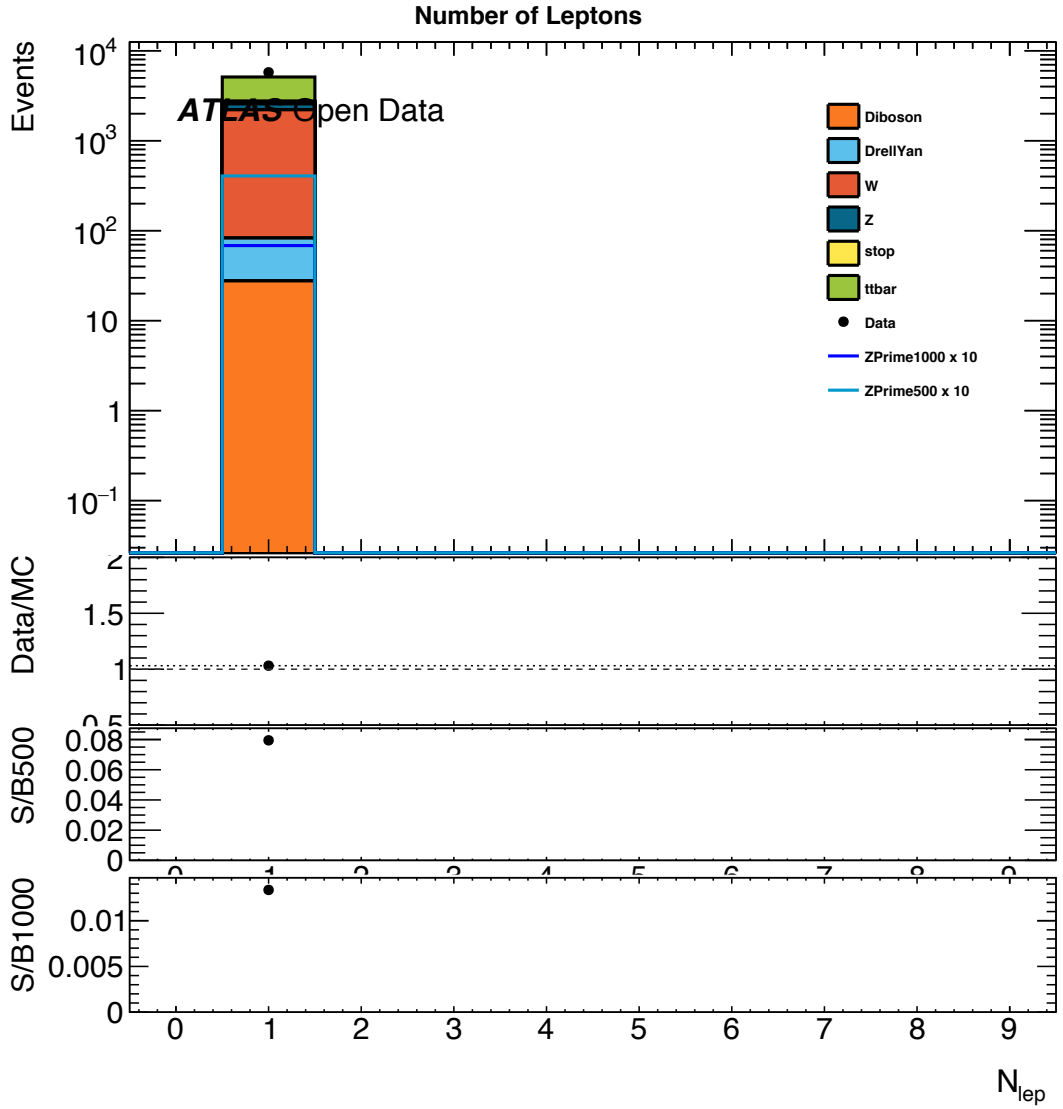
- Análise do decaimento do Z’, aplicando os cortes necessários
- Reconstrução do Z’ a partir das partículas do decaimento
- Escolha das melhores features para utilizar em Machine Learning
- Exportação para um ficheiro csv
- Treino e validação da rede neuronal
- Estudo das correlações entre variáveis

Análise (cortes)

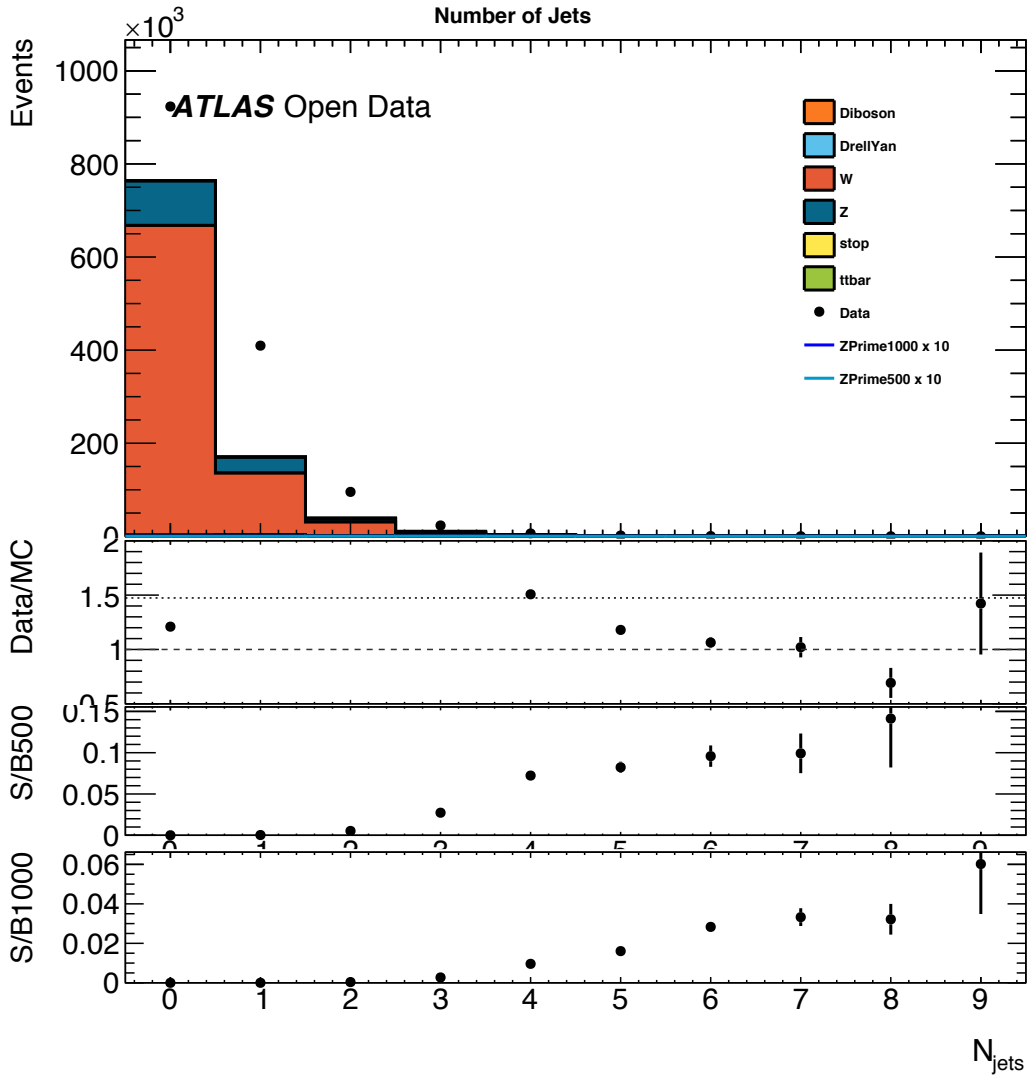
- Standard Cuts
- Corte no número de leptões = 1
- Corte no número mínimo de jatos >= 4
- Corte no número mínimo de quarks >= 2

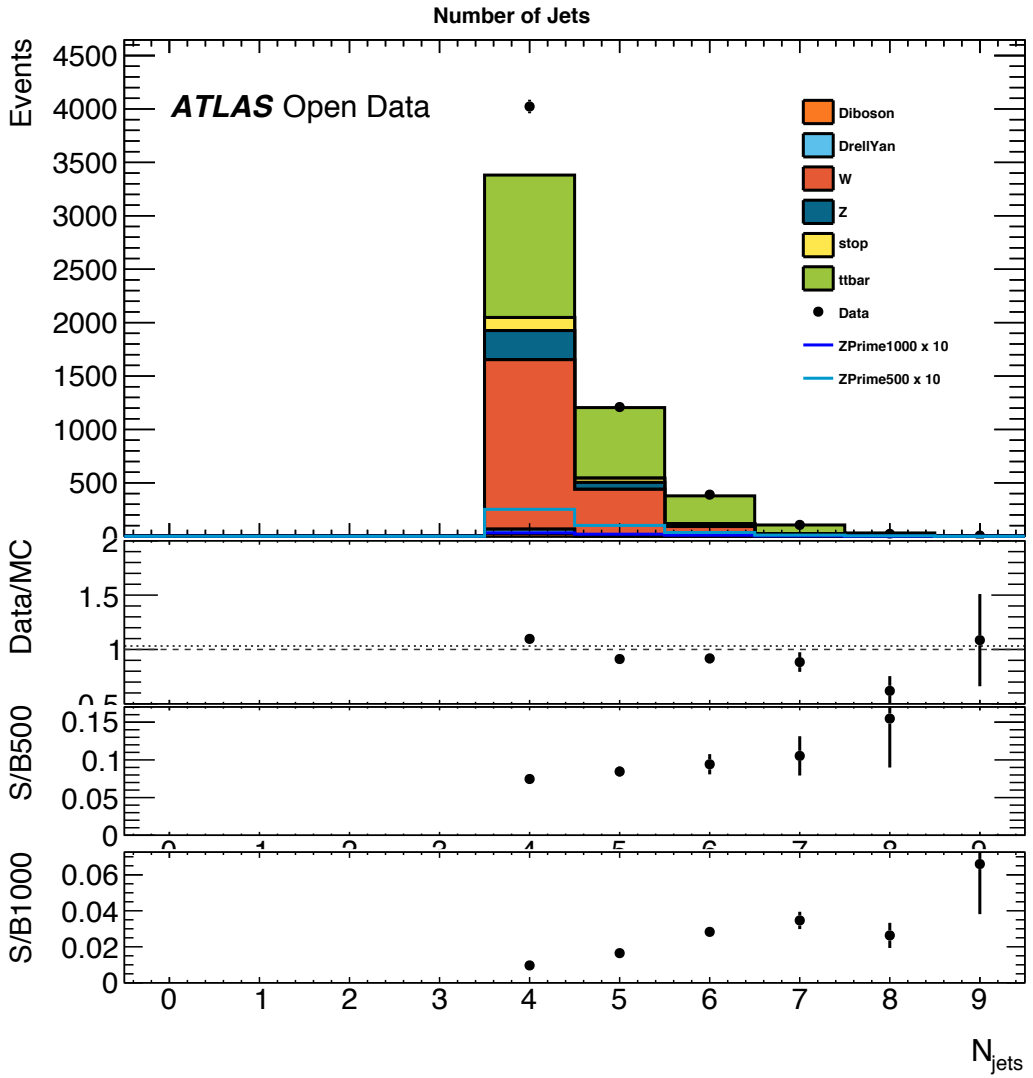
Leptões


Number of Leptons
Events
ATLAS Open Data
Diboson
DrellYan
W
Z
stop
ttbar
Data
ZPrime1000 x 10
ZPrime500 x 10
Data/MC
S/B500
S/B1000
N_lep


Number of Leptons
Events
ATLAS Open Data
Diboson
DrellYan
W
Z
stop
ttbar
Data
ZPrime1000 x 10
ZPrime500 x 10
Data/MC
S/B500
S/B1000
N_lep

Jatos


Number of Jets
×10^3
Events
ATLAS Open Data
Diboson
DrellYan
W
Z
stop
ttbar
Data
ZPrime1000 x 10
ZPrime500 x 10
Data/MC
S/B500
S/B1000
N_jets

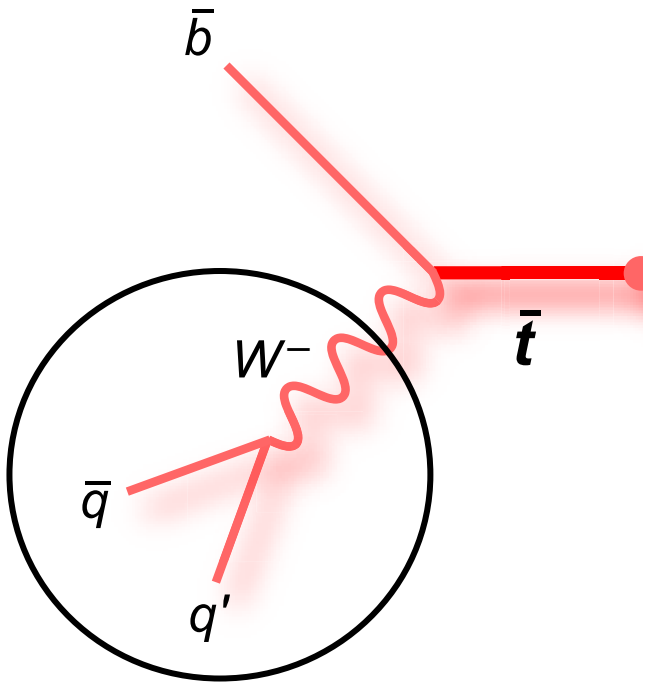

Number of Jets
Events
ATLAS Open Data
Diboson
DrellYan
W
Z
stop
ttbar
Data
ZPrime1000 x 10
ZPrime500 x 10
Data/MC
S/B500
S/B1000
N_jets

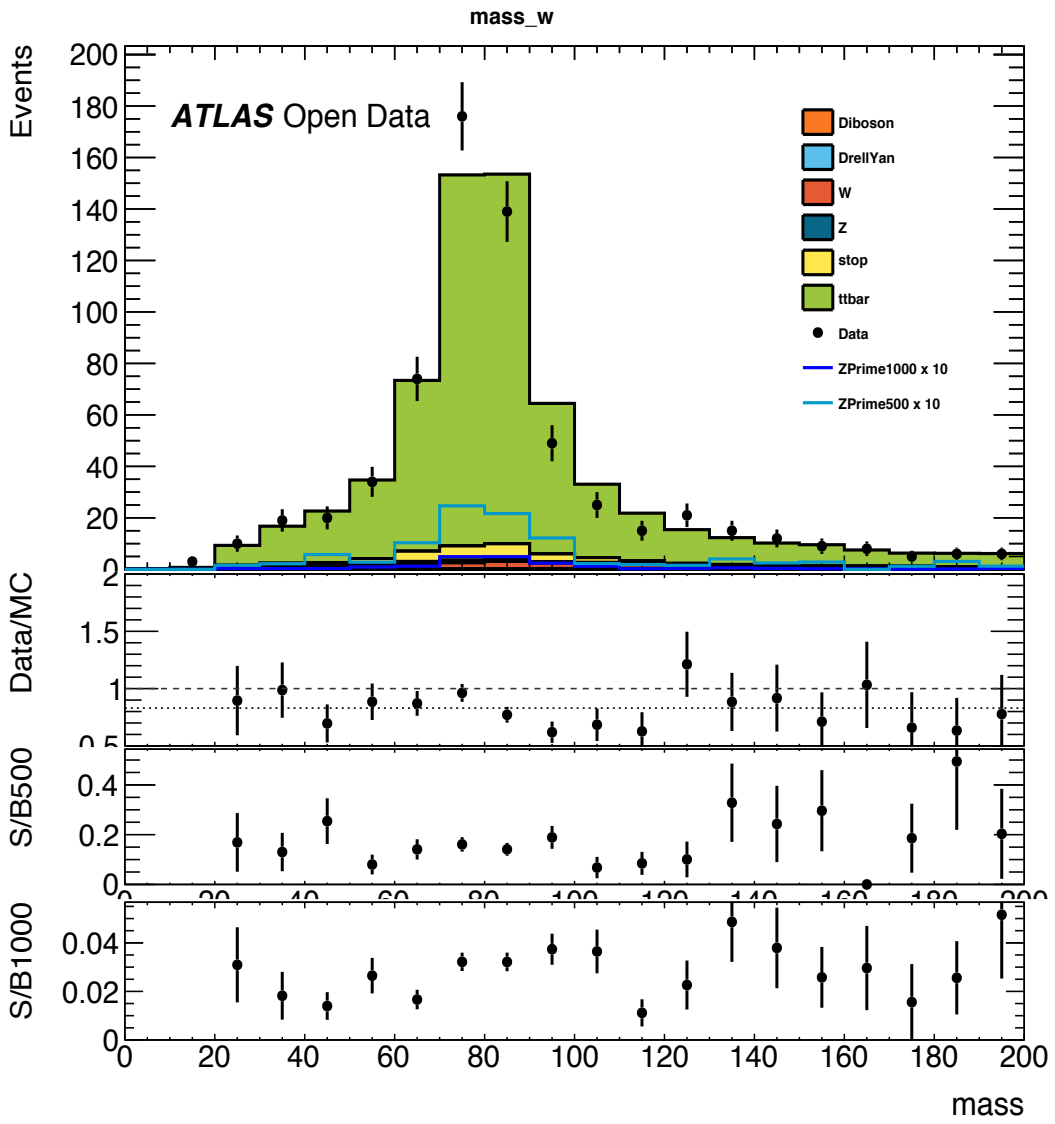
Reconstrução do Z Prime

- Reconstrução do W hadrónico
  - Construir o TLorentzVector dos quarks
- Reconstrução do W leptónico
  - Construir o TLorentzVector do leptão e neutrino (problema: o momento em z do neutrino está em falta)
- Reconstrução do Top hadrónico e leptónico a partir dos W e b's
- Reconstrução do Z' a partir dos Tops

Reconstrução W hadrónico

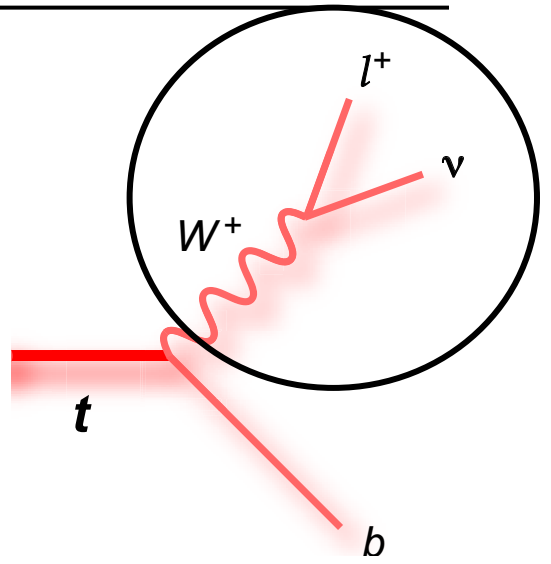
- TLorentzVector dos quarks
- Combinatórias da soma de dois TLorentzVector dos quarks
- Diferença entre a massa do W e a massa das combinações
- O mínimo corresponde ao W reconstruído
- Elimina-se estes quarks da lista para evitar usar novamente noutra reconstrução




mass_w
ATLAS Open Data
Diboson
DrellYan
W
Z
stop
ttbar
Data
ZPrime1000 x 10
ZPrime500 x 10
Events
Data/MC
S/B500
S/B1000
mass

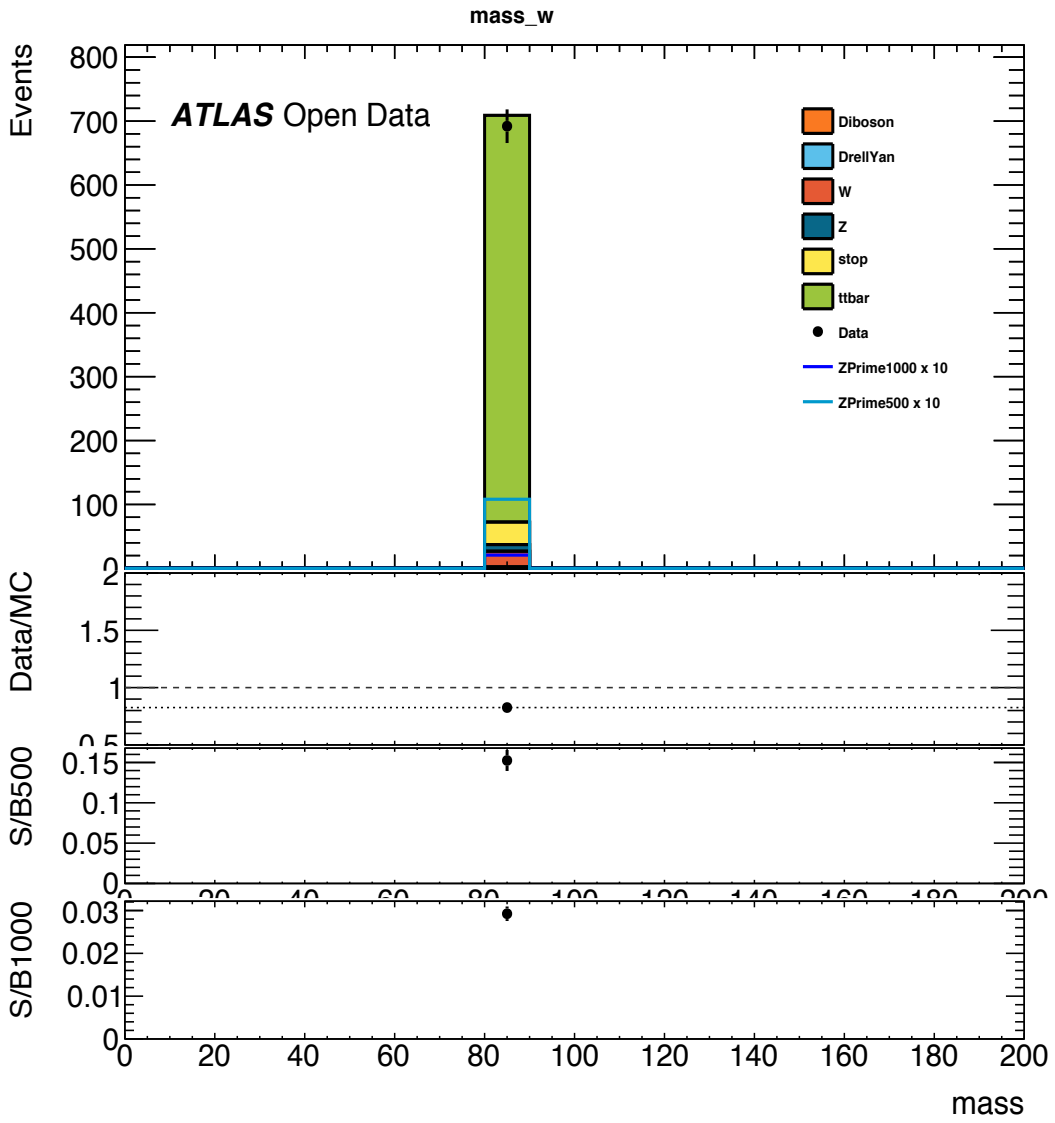
Reconstrução W leptónico

- Para sabermos o momento em z do neutrino:



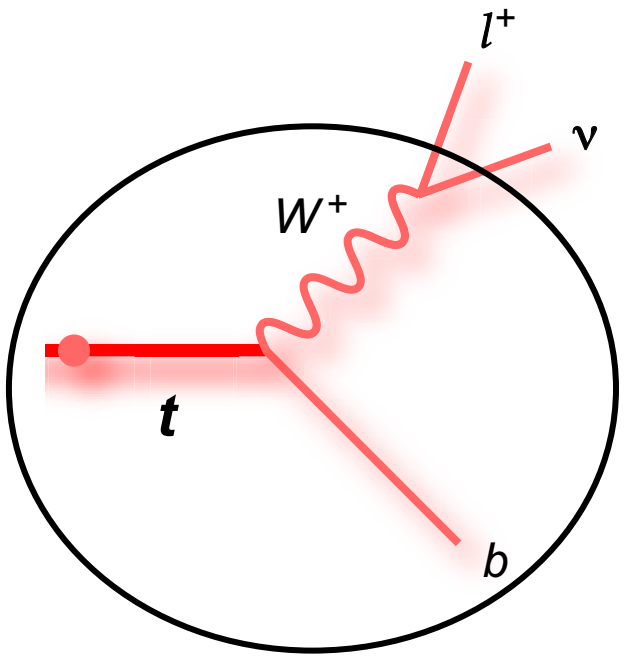
$$p_{\nu z} = \frac{2\vec{p}_T^{\,lep} \cdot \vec{p}_T^{\,\nu} p_z^{lep} + m_W^2 p_z^{lep}}{2(p_T^{lep})^2} \pm \frac{p^{lep} \sqrt{-4(p_T^{lep})^2 (p_T^{\nu})^2 + 4(\vec{p}_T^{\,lep} \cdot \vec{p}_T^{\,\nu})^2 + 4\vec{p}_T^{\,lep} \cdot \vec{p}_T^{\,\nu} m_W^2 + m_W^4}}{2(p_T^{lep})^2}$$

- TLorentzVector do leptão e do neutrino (a partir do momento em z e da energia em falta)
- Combinatórias da soma de dois TLorentzVector
- Diferença entre a massa do W e a massa das combinações
- O mínimo corresponde ao W reconstruído


mass_w
ATLAS Open Data
Diboson
DrellYan
W
Z
stop
ttbar
Data
ZPrime1000 x 10
ZPrime500 x 10
Events
Data/MC
S/B500
S/B1000
mass

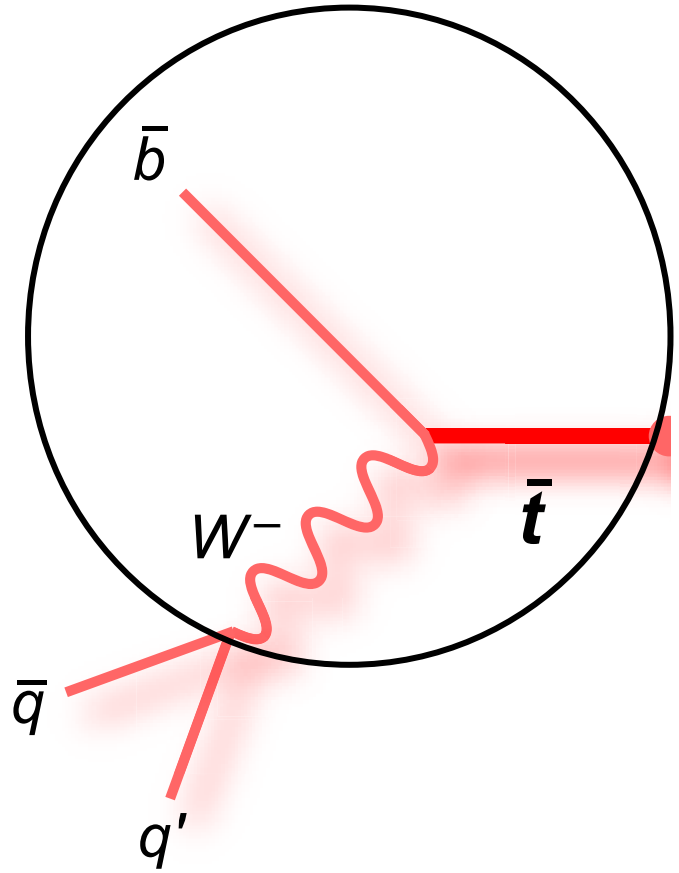
Reconstrução Top Leptónico

- Se nº btags maior que 2
  - TLorentzVector dos b's e do W
  - Soma dos TLorentzVector e usar o b que minimize a diferença entre a combinatória e a massa do top
- Se nº btags menor que 2
  - TLorentzVector dos quarks e do W
  - Soma dos TLorentzVector e usar o quark que minimize a diferença entre a combinatória e a massa do top



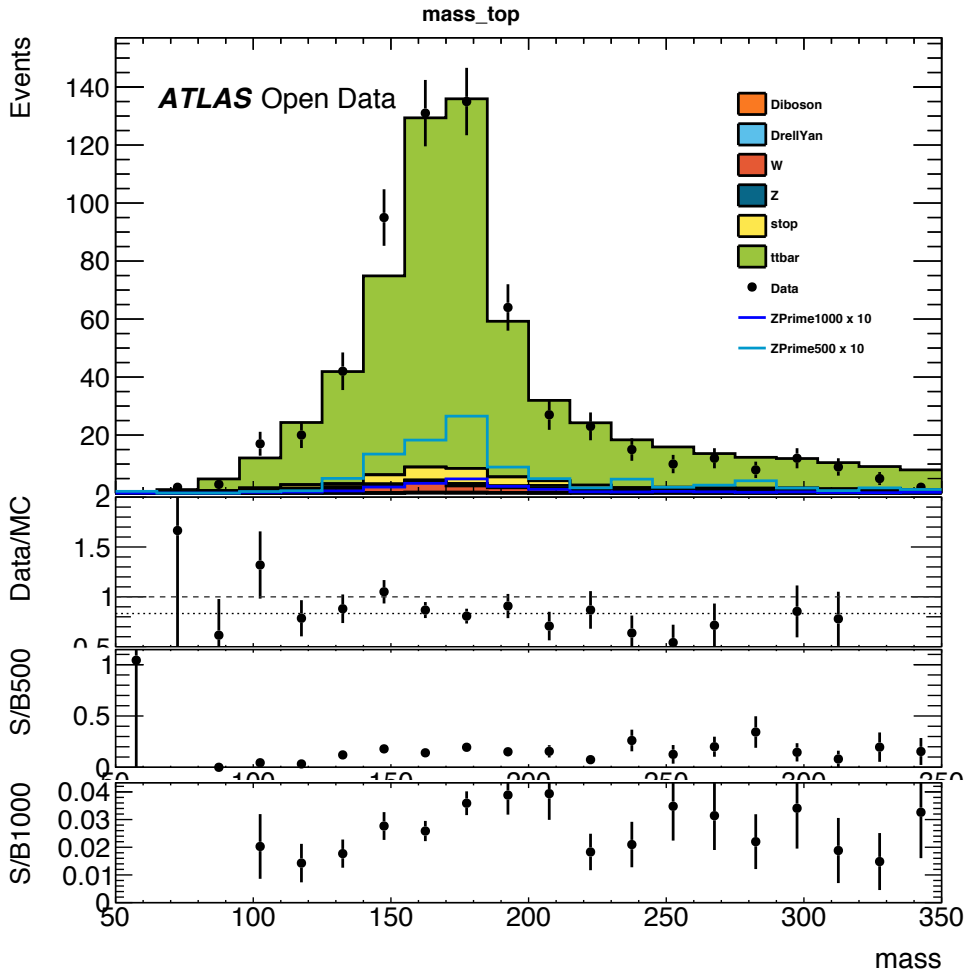
Reconstrução Top Hadrónico

- Se nº btags maior que 2
  - TLorentzVector dos b's e do W
  - Soma dos TLorentzVector e usar o b que minimize a diferença entre a combinatória e a massa do top
- Se nº btags menor que 2
  - TLorentzVector dos quarks e do W
  - Soma dos TLorentzVector e usar o quark que minimize a diferença entre a combinatória e a massa do top

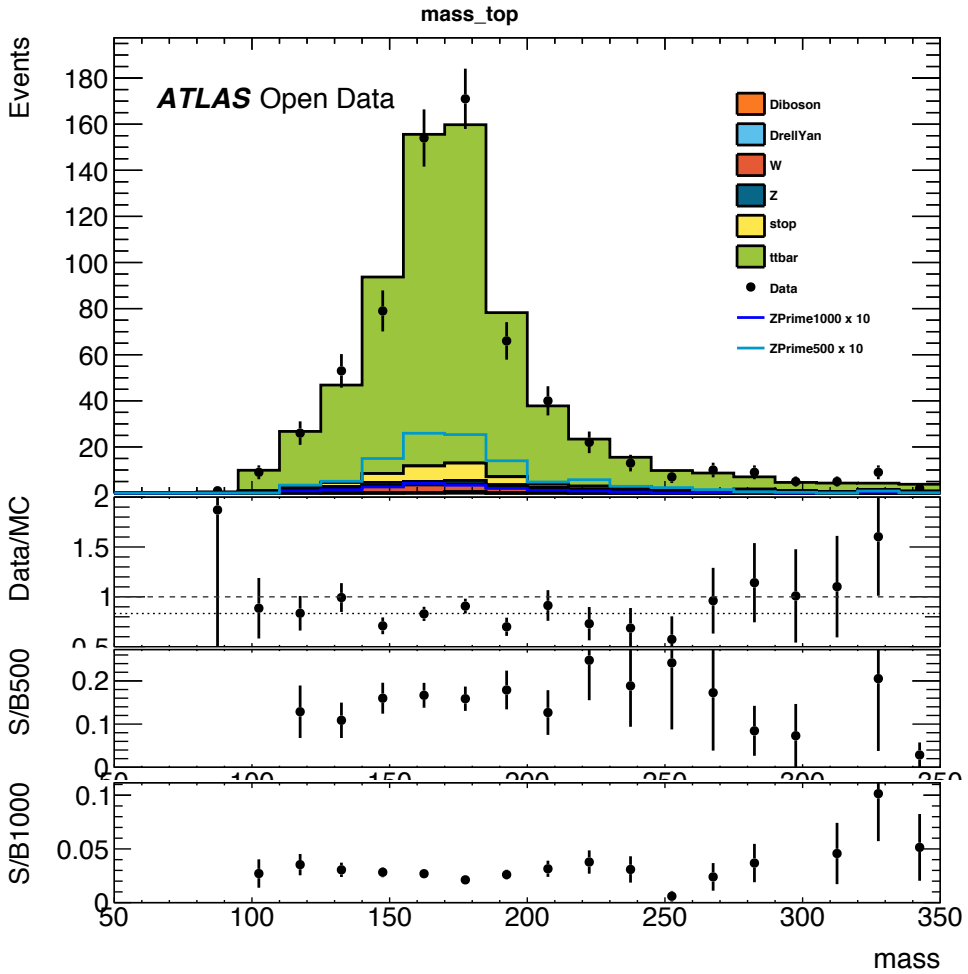


- Se forem utilizados os mesmos b’s ou quarks para ambos os tops
  - O segundo b (ou quark) que minimize a diferença entre a massa do top e as combinações deverá ser utilizado

Massa Top Had

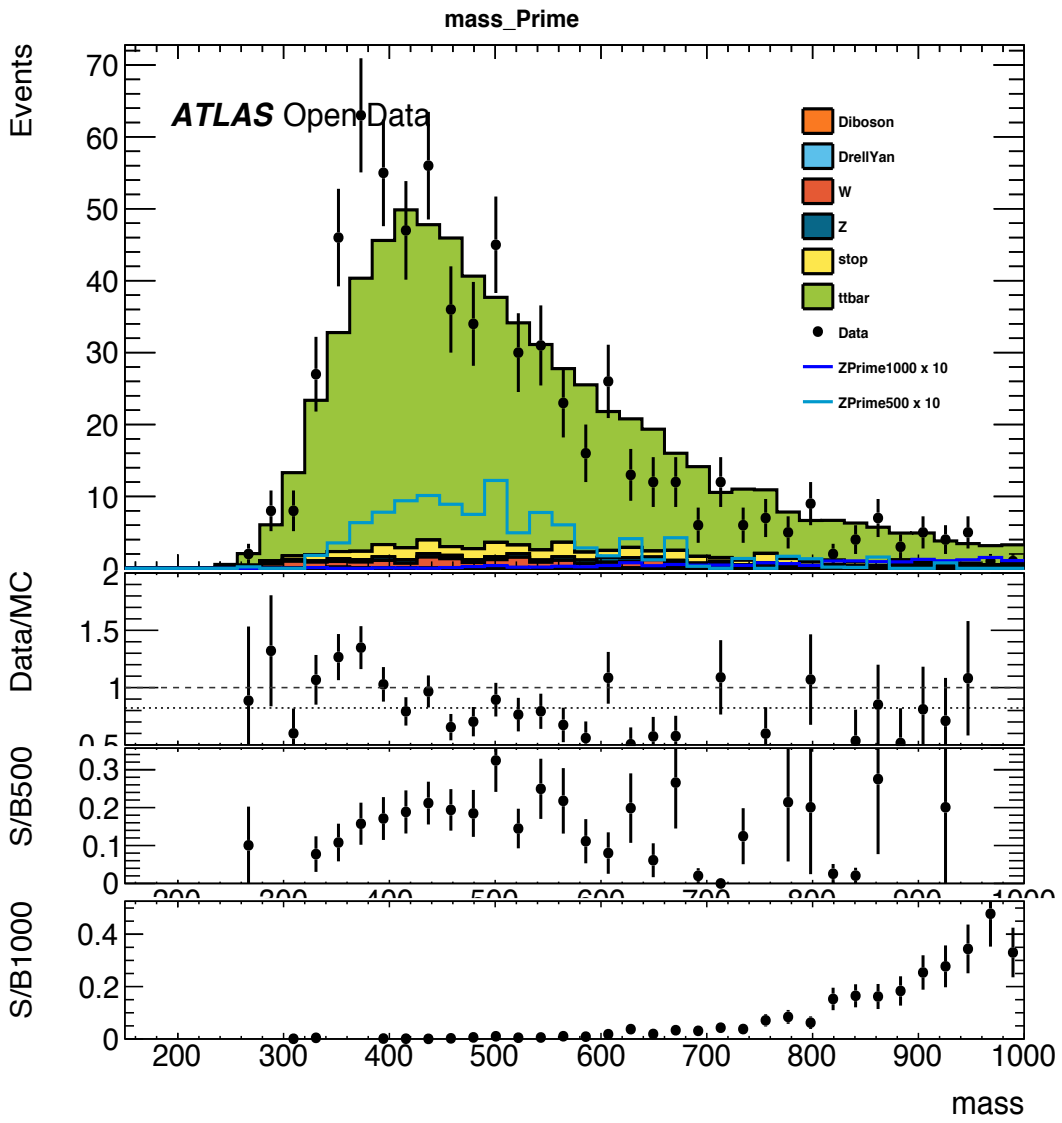


Massa Top Lep



Reconstrução do Z Prime

- Somou-se os TLorentzVector dos dois tops


mass_Prime
ATLAS Open Data
Diboson
DrellYan
W
Z
stop
ttbar
Data
ZPrime1000 x 10
ZPrime500 x 10
Events
Data/MC
S/B500
S/B1000
mass

Features

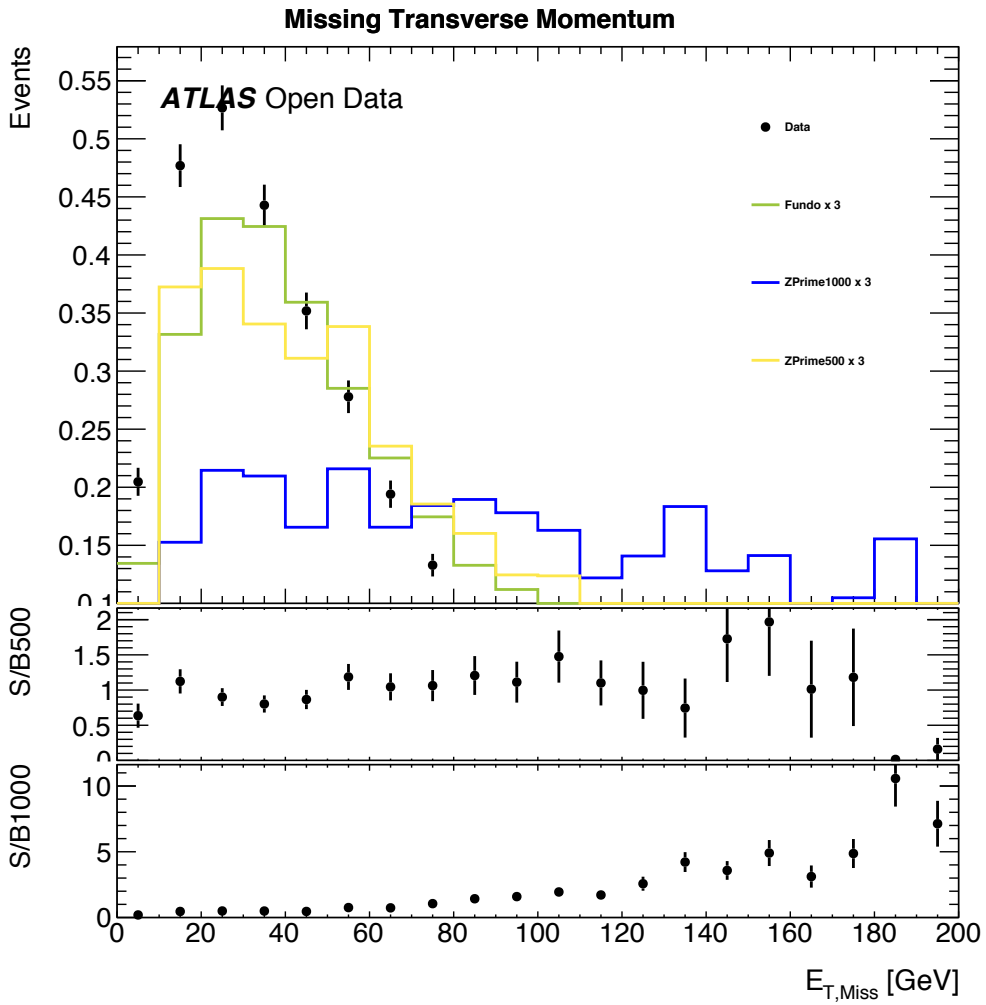
- Baixo nível:
  - Energia em falta (Etmiss)
  - Número de quarks b
  - Pseudorapidez do leptão
  - Pseudorapidez dos 4 jatos mais energéticos
  - Delta R
  - Delta Phi (entre jatos)
  - Delta eta (entre jatos)
- Alto nível:
  - Massa do Z Prime
  - Momento transverso do Z Prime
  - Soma escalar dos momentos transversos dos leptões e jatos finais (incluindo quarks b)

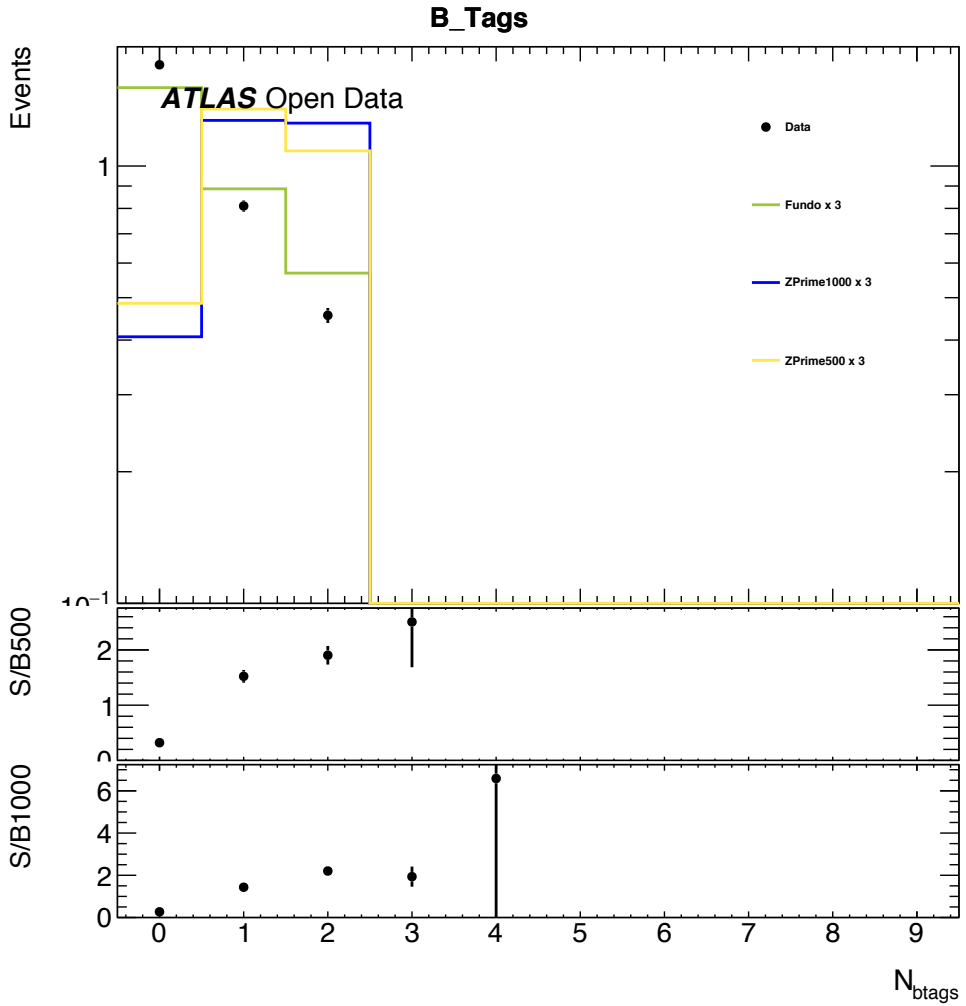
$$\Delta\eta = \sqrt{\Delta\Phi^2 + \Delta\eta^2}$$

$$\Delta\Phi = \phi_1 - \phi_2$$

Etmiss

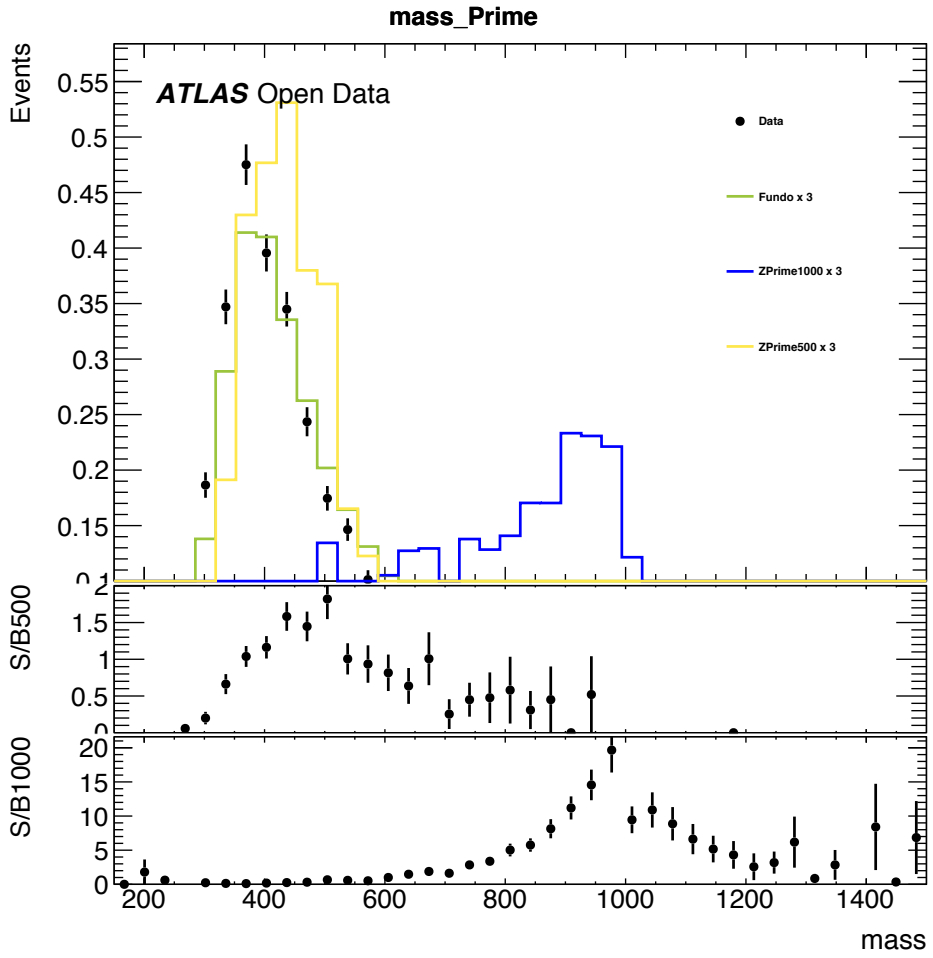
BTags

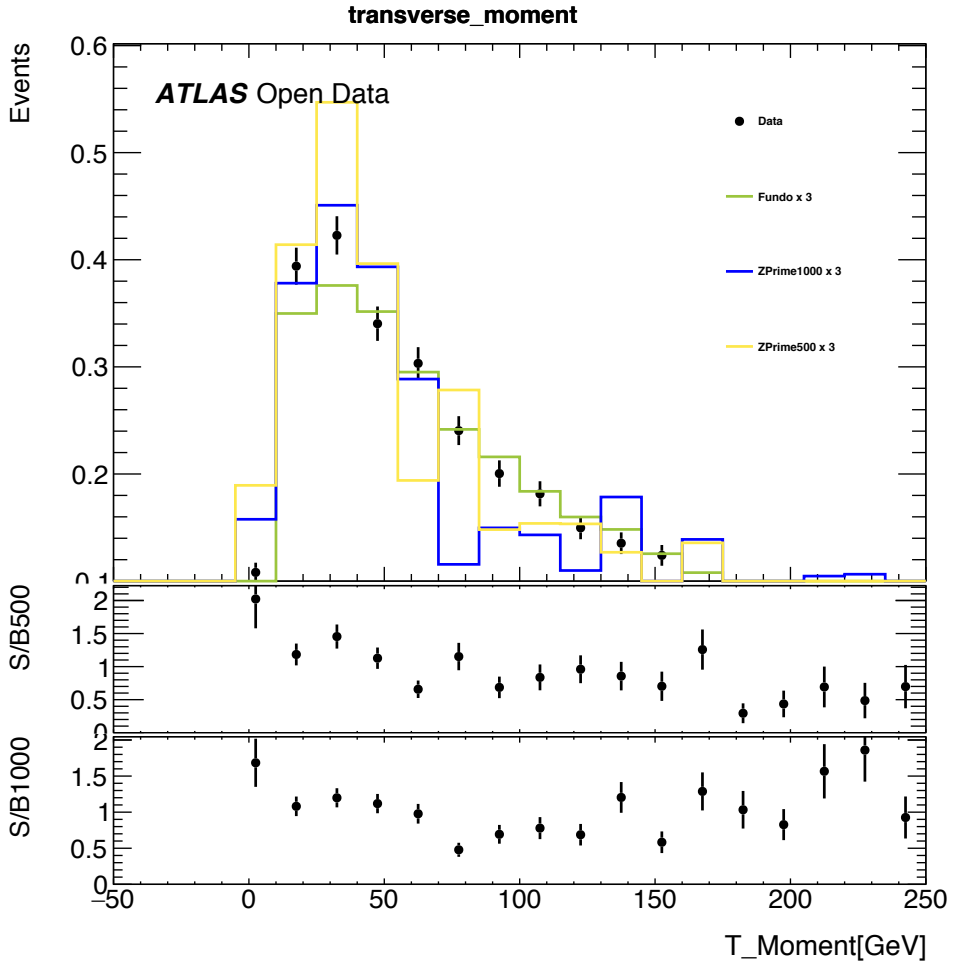




Massa ZPrime

PT ZPrime



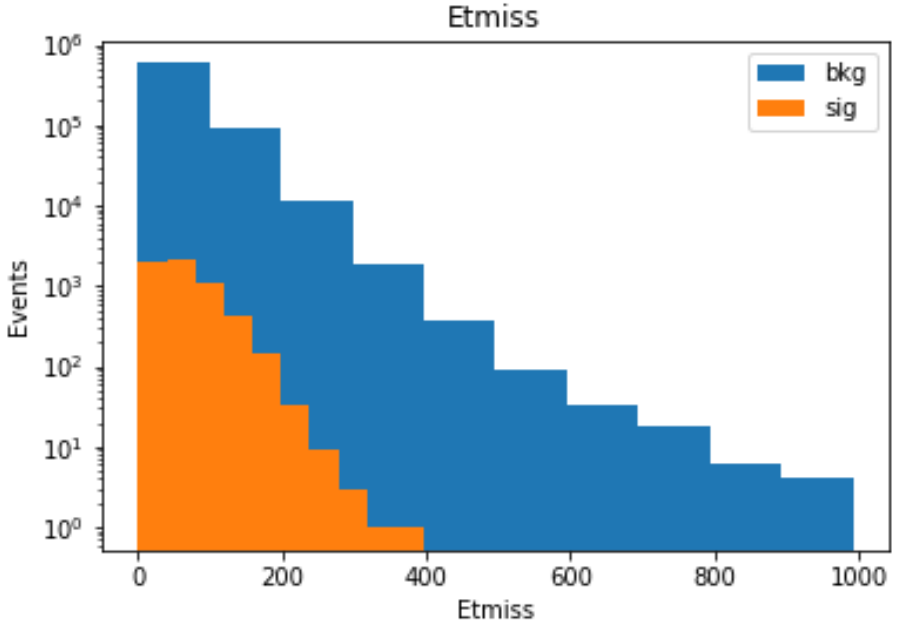


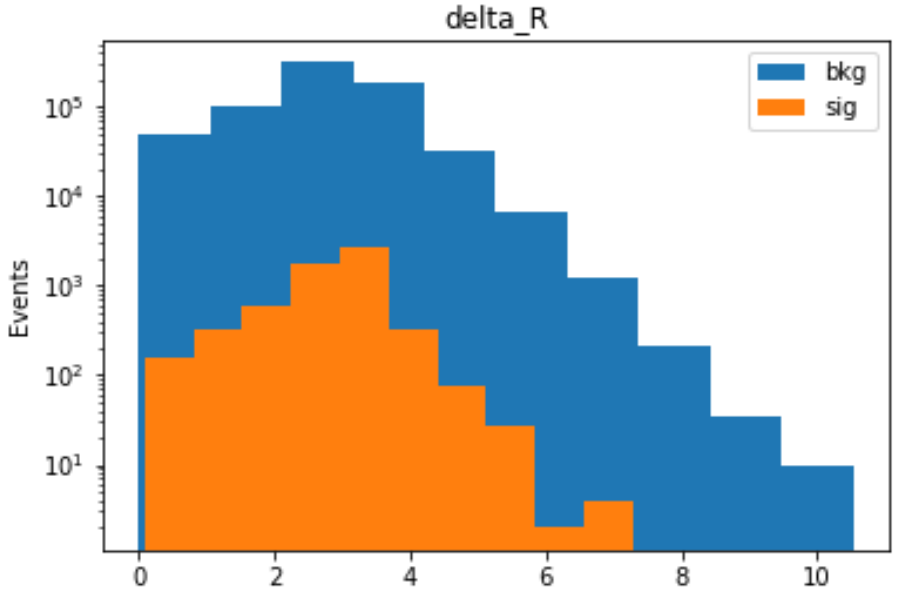
Treino e validação da rede neuronal

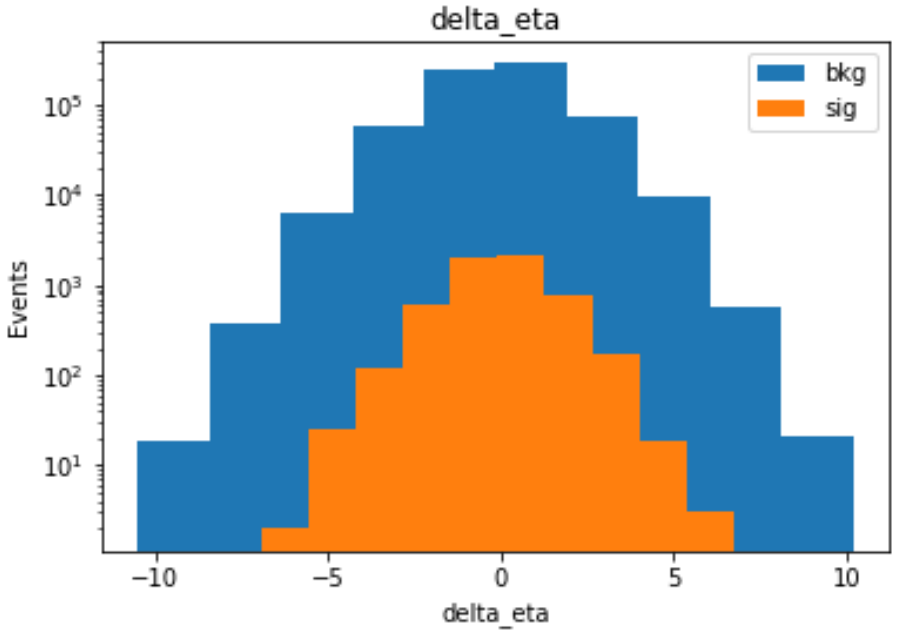
```
model = Sequential()
model.add(Dense(100, activation='relu', input_shape=X_train.shape[1:]))
model.add(Dense(100, activation='relu'))
model.add(Dense(1, activation='sigmoid'))
```

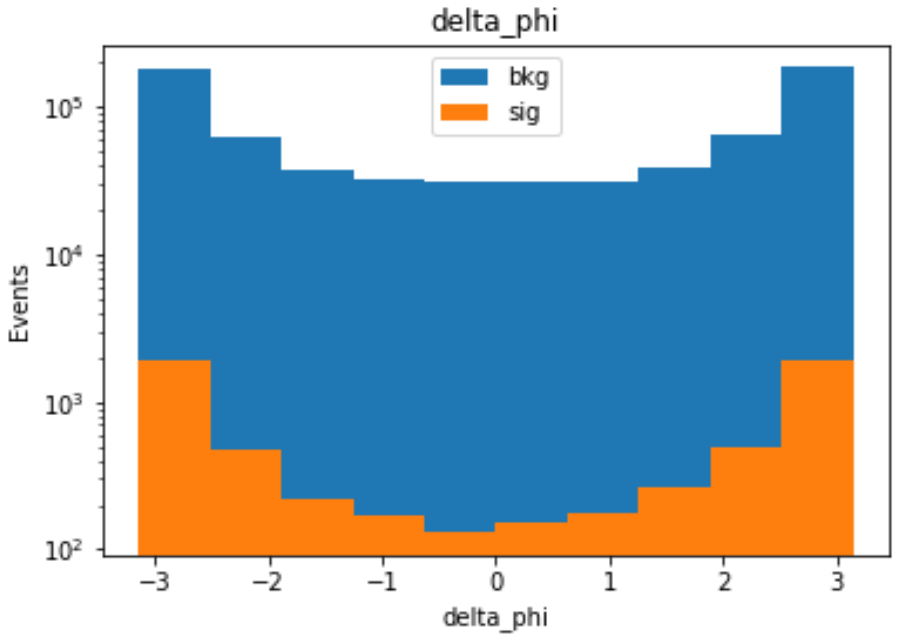
```
earlyStop = EarlyStopping(monitor='val_loss', patience=5, verbose=1, mode='auto') #Setup early stopping
saveBest = ModelCheckpoint("train_weights/best.h5", monitor='val_loss', verbose=1, #Save best performing network
                           save_best_only=True, save_weights_only=True, mode='auto', period=1)

adam = Adam(lr=0.00001, beta_1=0.9, beta_2=0.999, epsilon=None, decay=0.0, amsgrad=False)
model.compile(loss='binary_crossentropy',
              optimizer=adam)
```

ZPRIME500

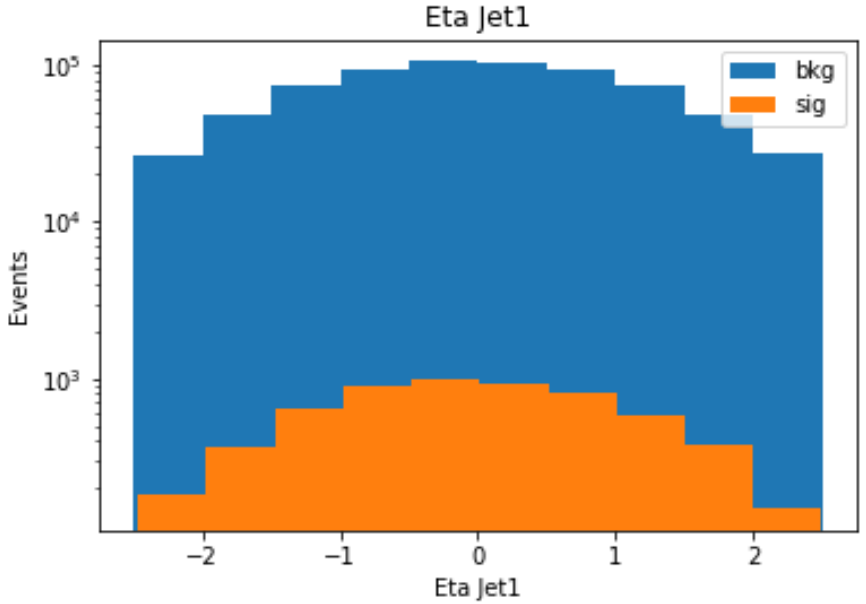

Etmiss
bkg
sig
Events
Etmiss

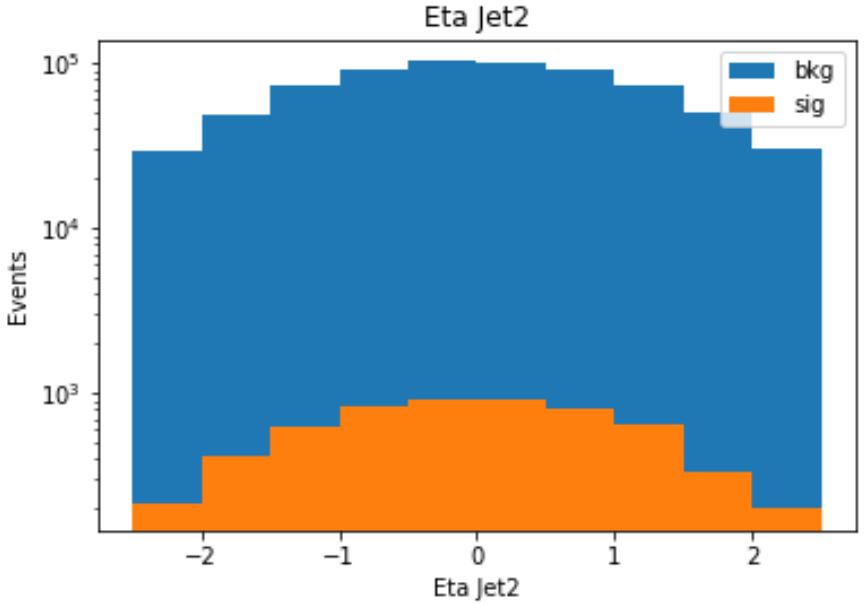

delta_R
bkg
sig
Events

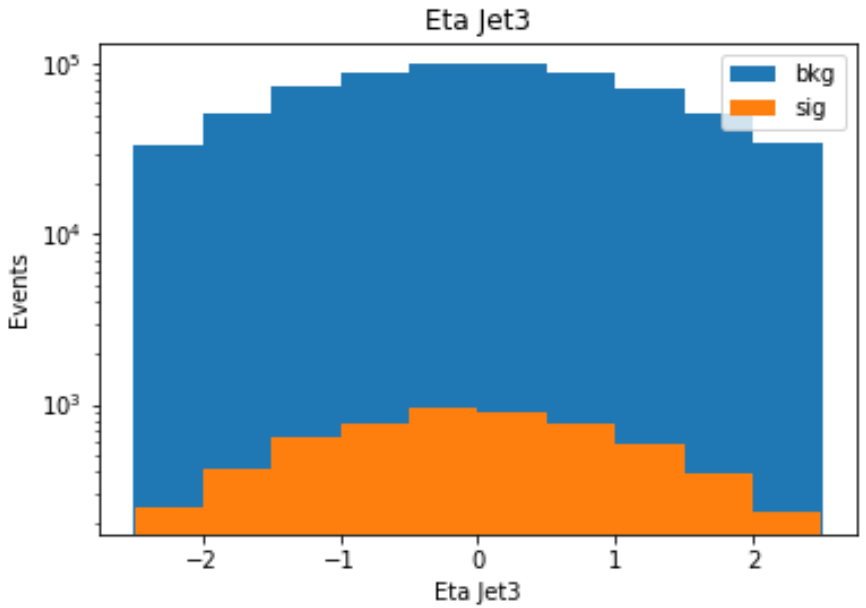

delta_eta
bkg
sig
Events
delta_eta


delta_phi
bkg
sig
Events
delta_phi

ZPRIME500


Eta Jet1
bkg
sig
Events
Eta Jet1


Eta Jet2
bkg
sig
Events
Eta Jet2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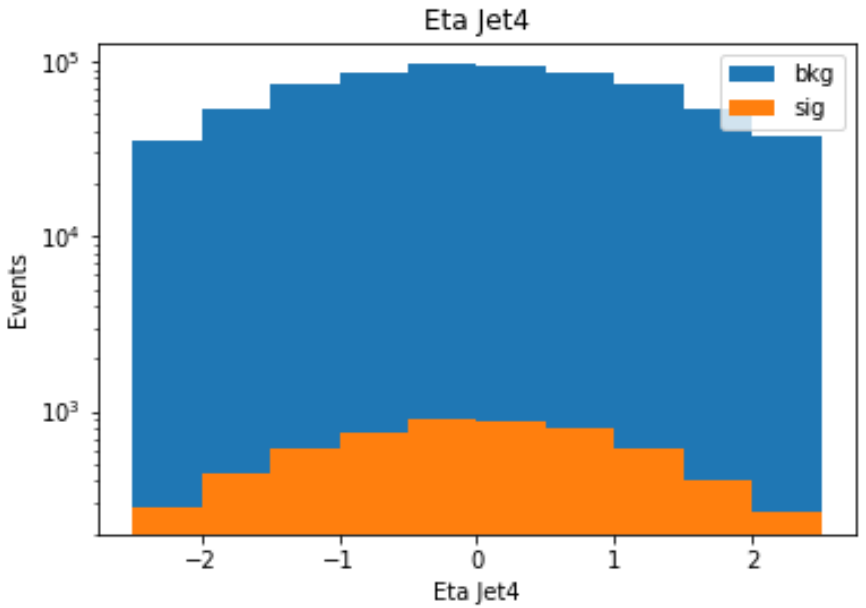
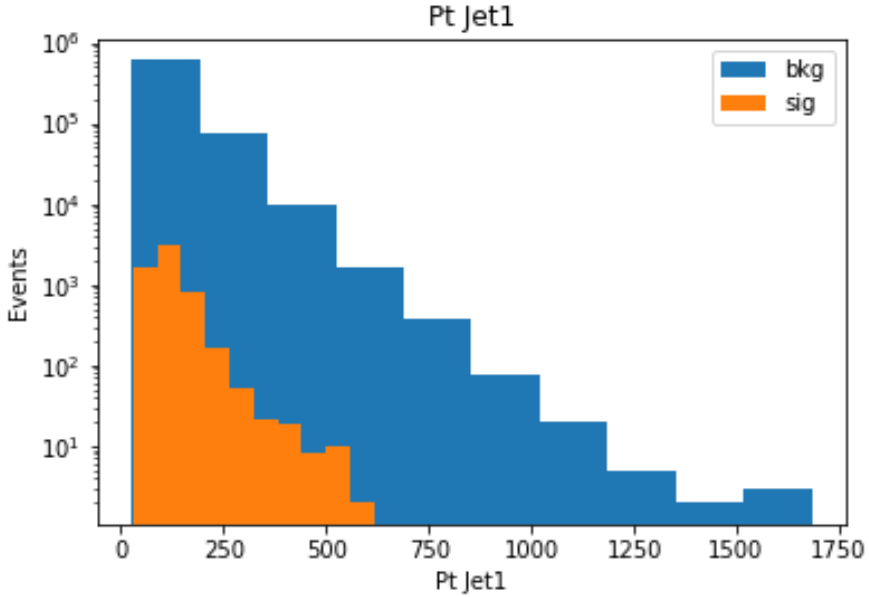
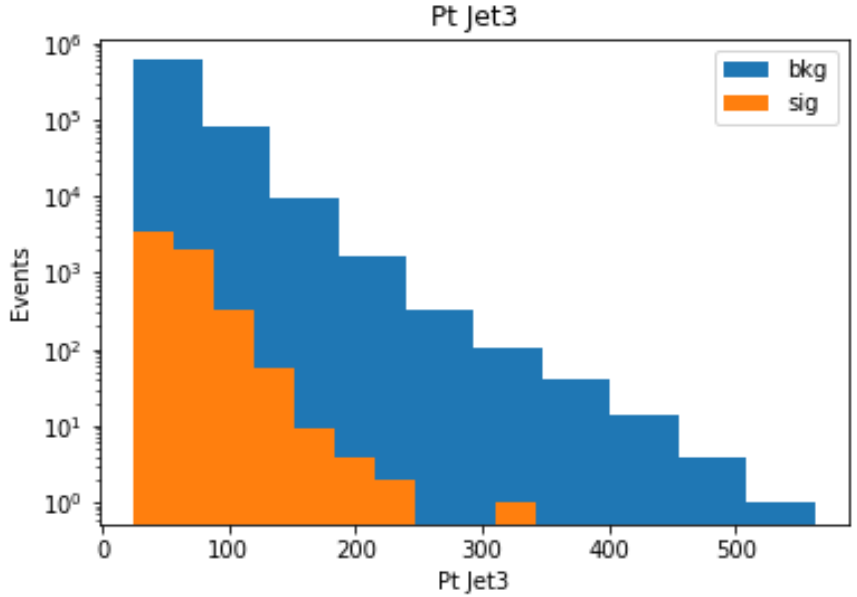
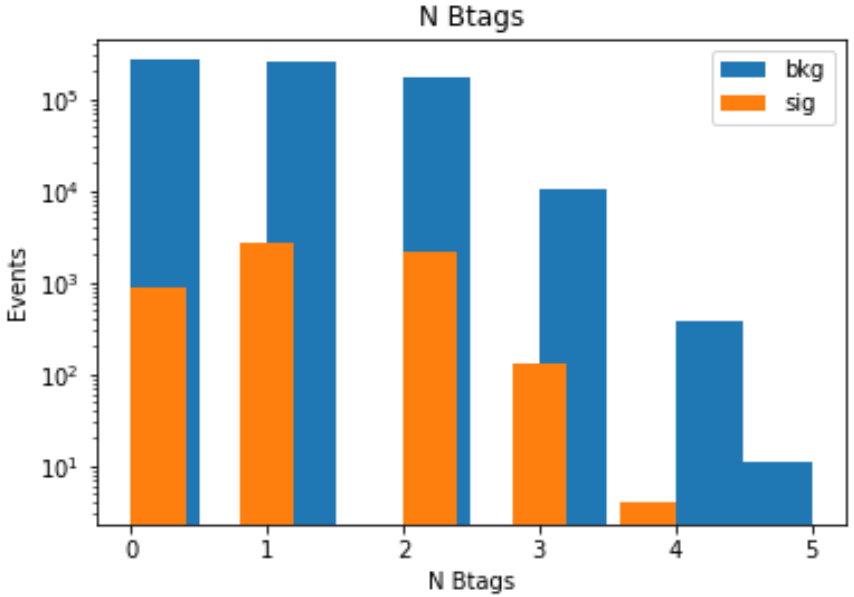
bkg
sig
Events
Eta Jet3

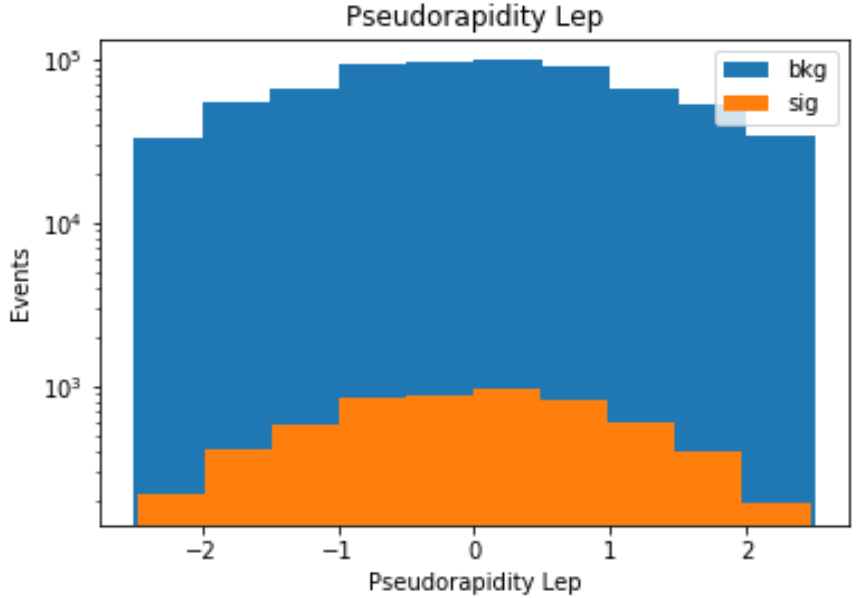

Eta Jet4
bkg
sig
Events
Eta Jet4

ZPRIME500

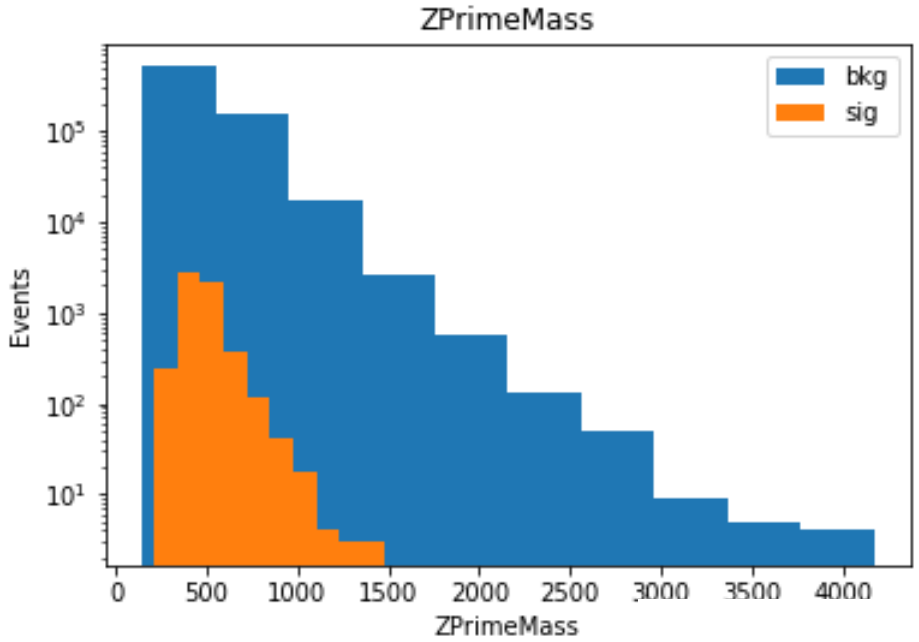

Pt Jet1
bkg
sig
Events
Pt Jet1


Pt Jet3
bkg
sig
Events
Pt Jet3


N Btags
bkg
sig
Events
N Btags


Pseudorapidity Lep
bkg
sig
Events
Pseudorapidity Lep

ZPRIME500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Events
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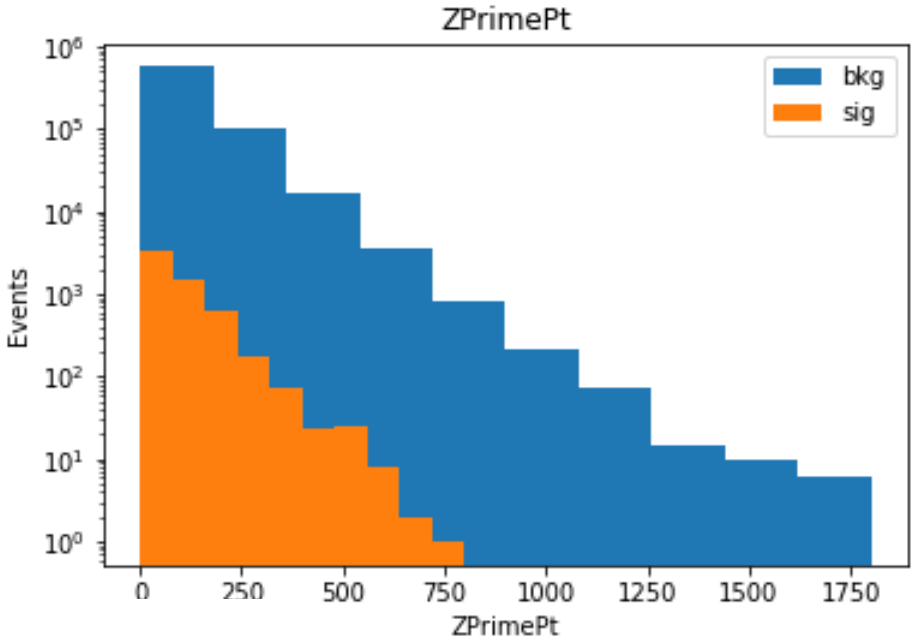
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Events
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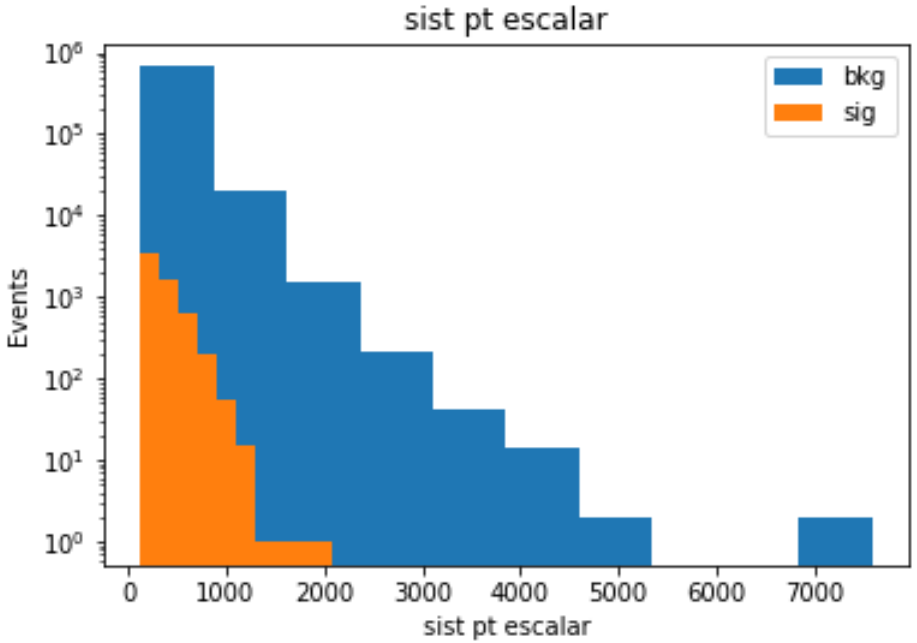
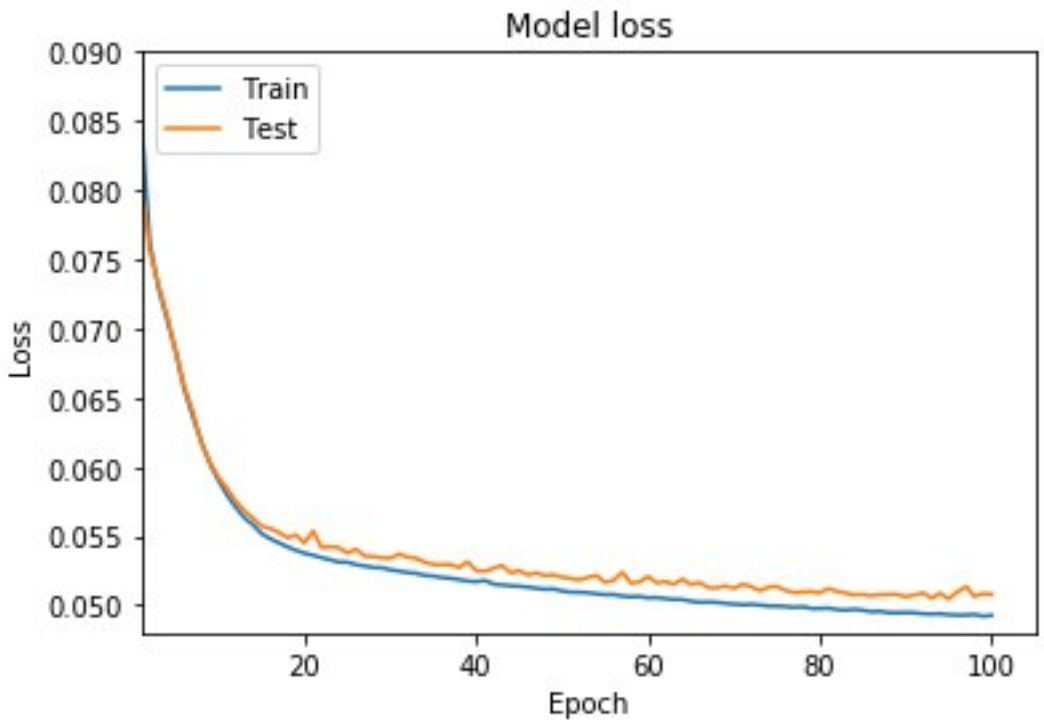
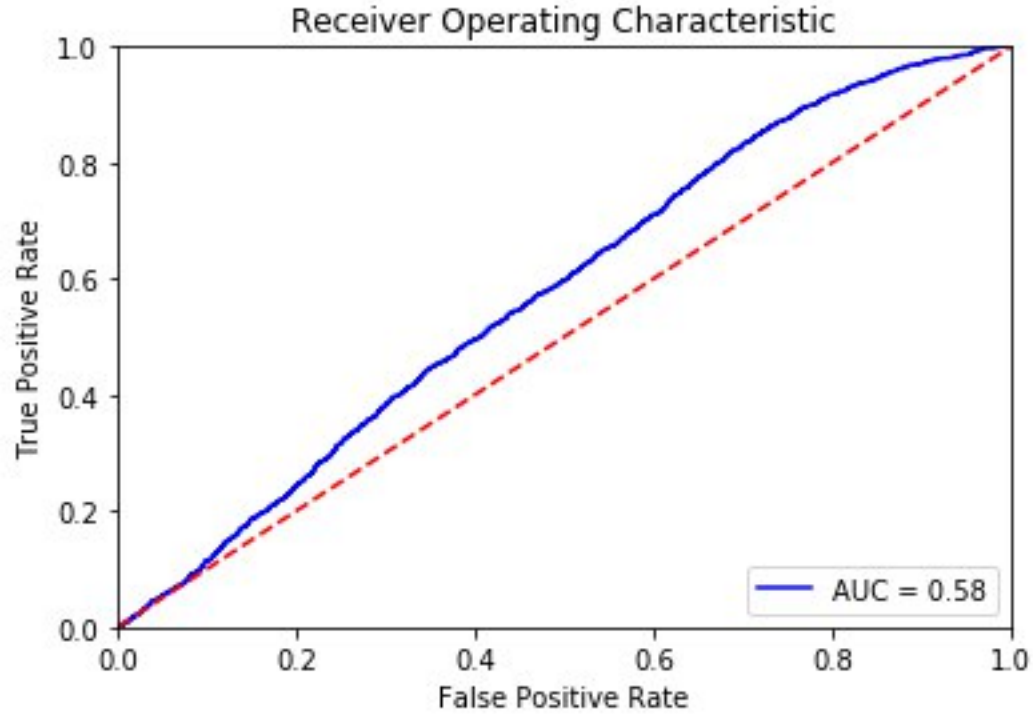
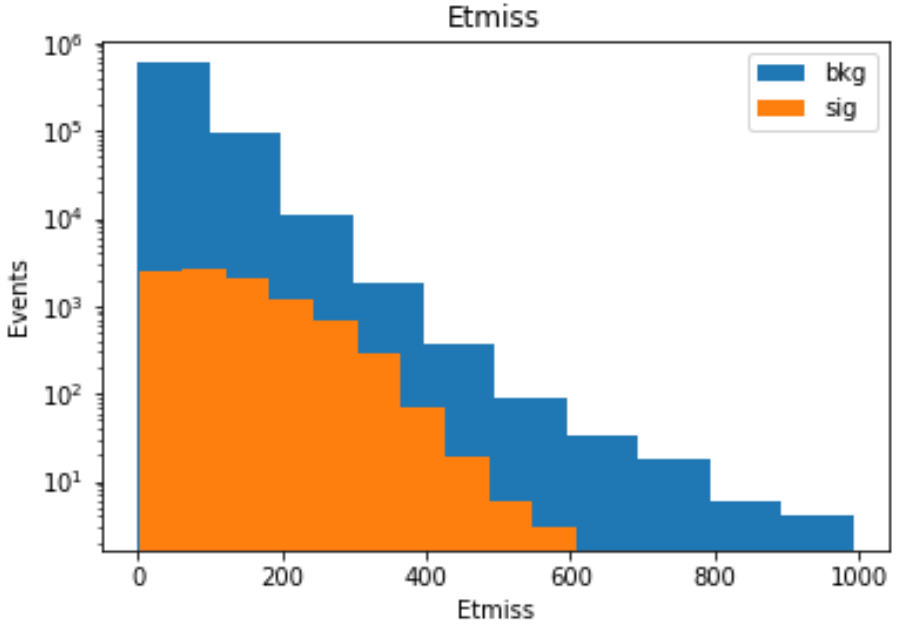

sist pt escalar
bkg
sig
Events
sist pt escalar

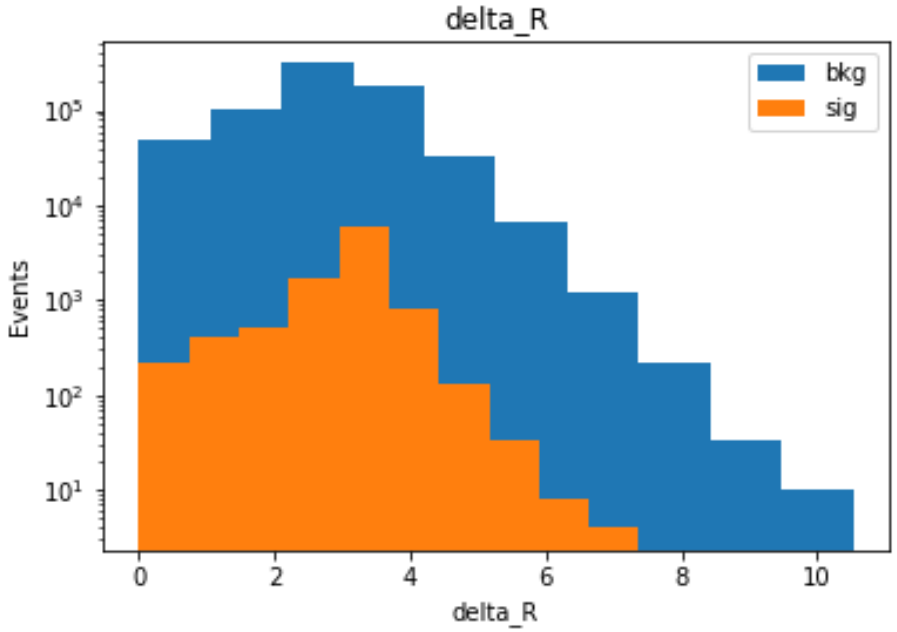
ZPRIME500

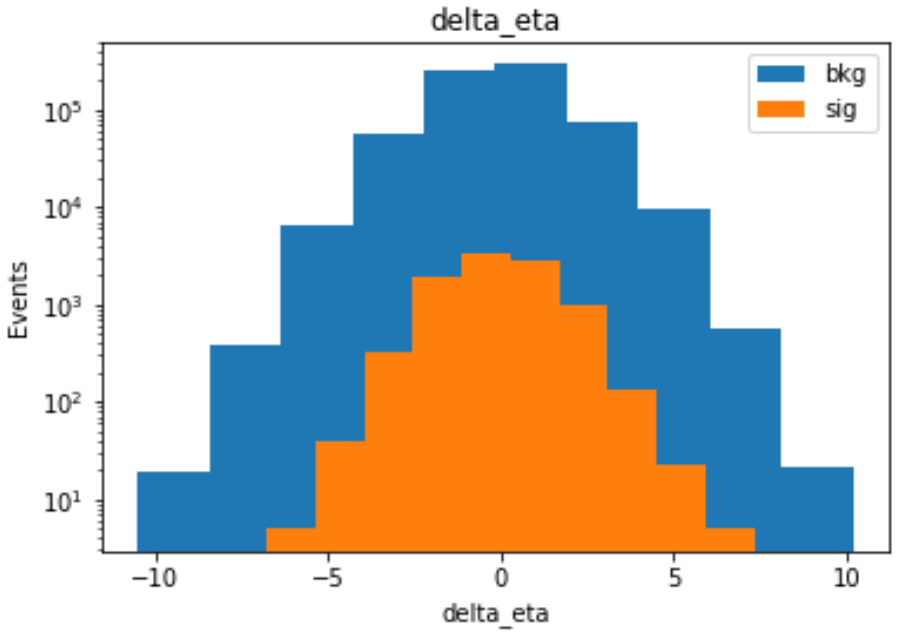

Model loss
Train
Test
Loss
Epoch
0.090
0.085
0.080
0.075
0.070
0.065
0.060
0.055
0.050
20
40
60
80
100


Receiver Operating Characteristic
True Positive Rate
False Positive Rate
AUC = 0.58
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0

ZPRIME1000


Etmiss
bkg
sig
Events
Etmiss
0
200
400
600
800
1000


delta_R
bkg
sig
Events
delta_R
0
2
4
6
8
10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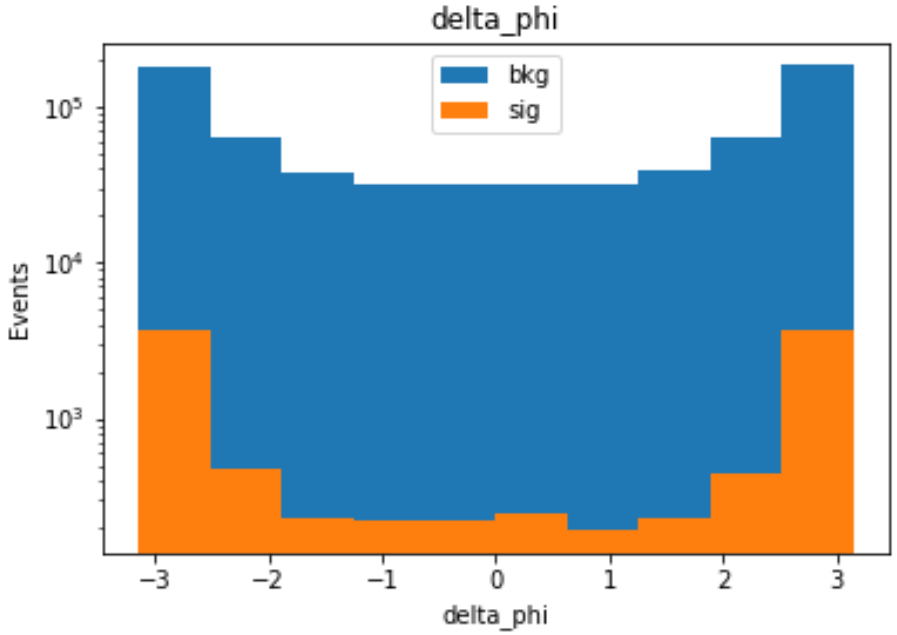
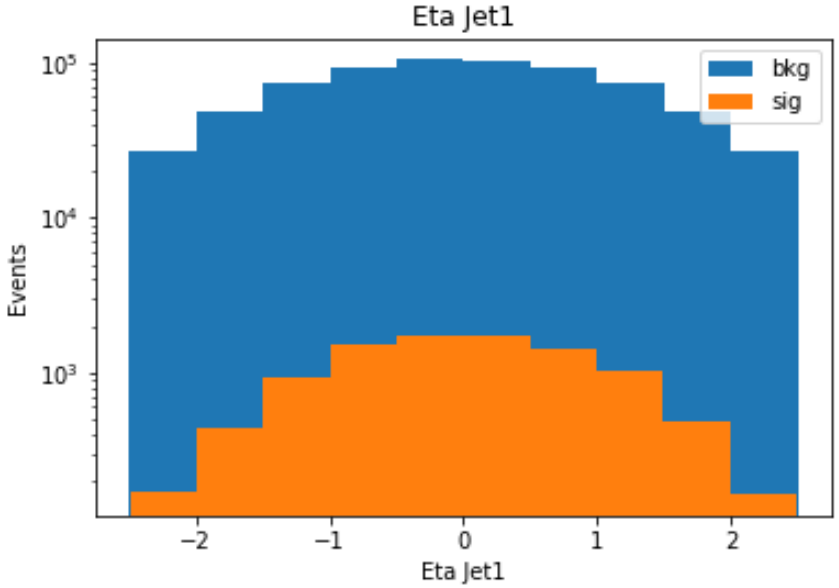
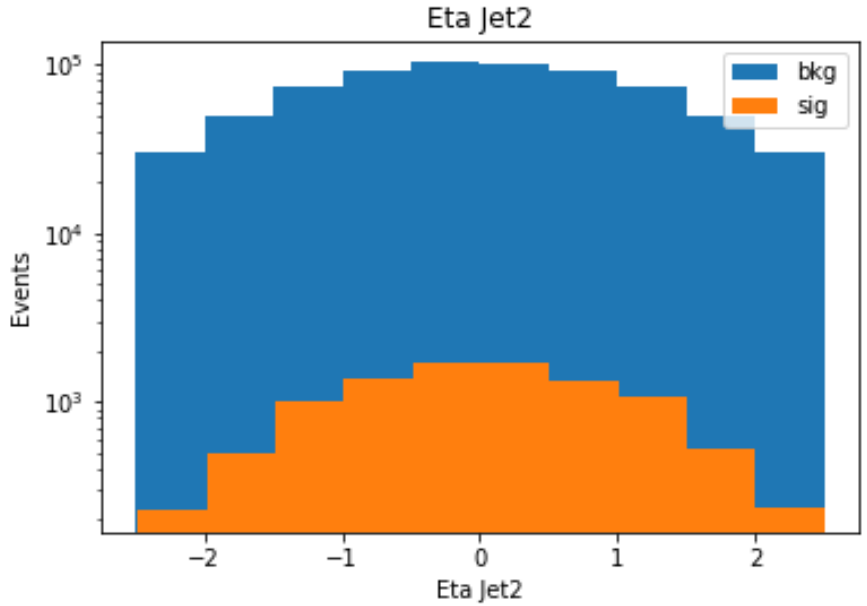
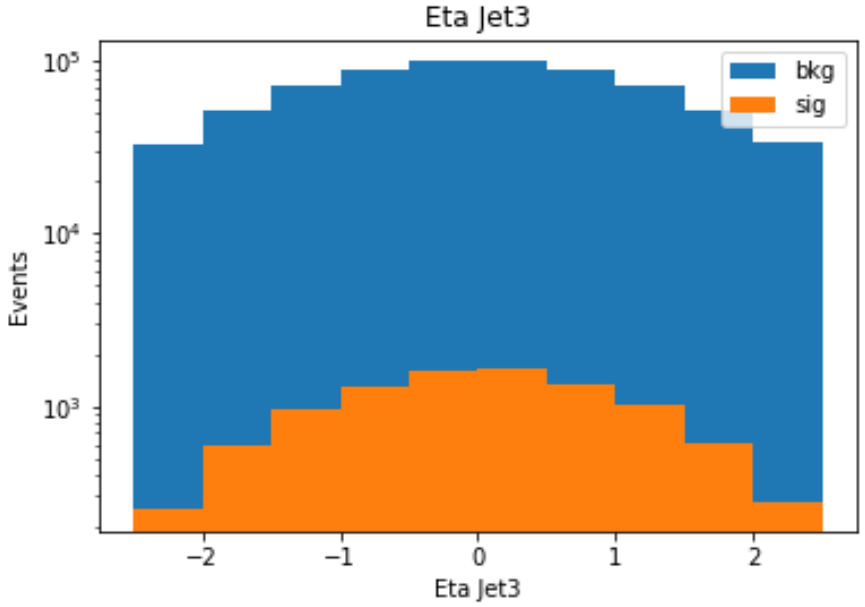
bkg
sig
Events
delta_eta
−10
−5
0
5
10

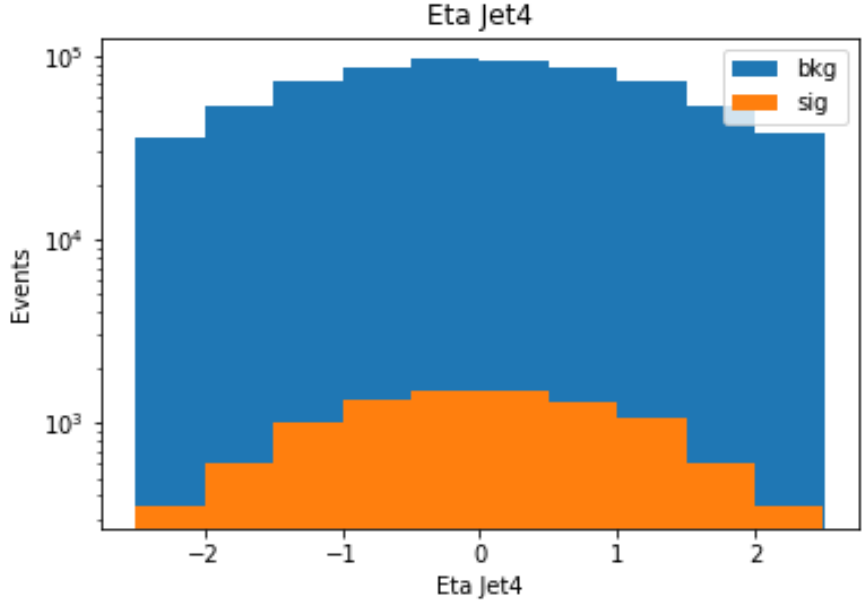

delta_phi
bkg
sig
Events
delta_phi
−3
−2
−1
0
1
2
3

ZPRIME1000

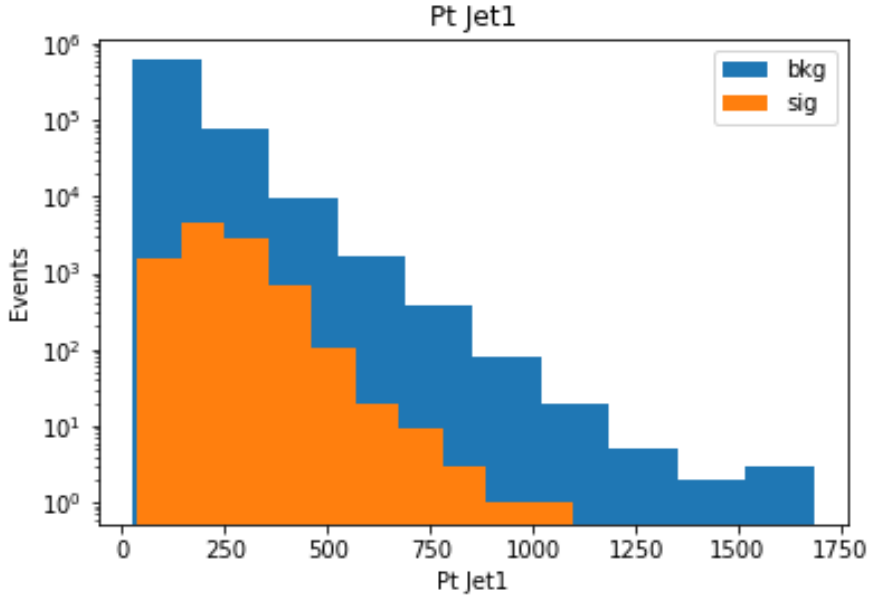

Eta Jet1
bkg
sig
Events
Eta Jet1

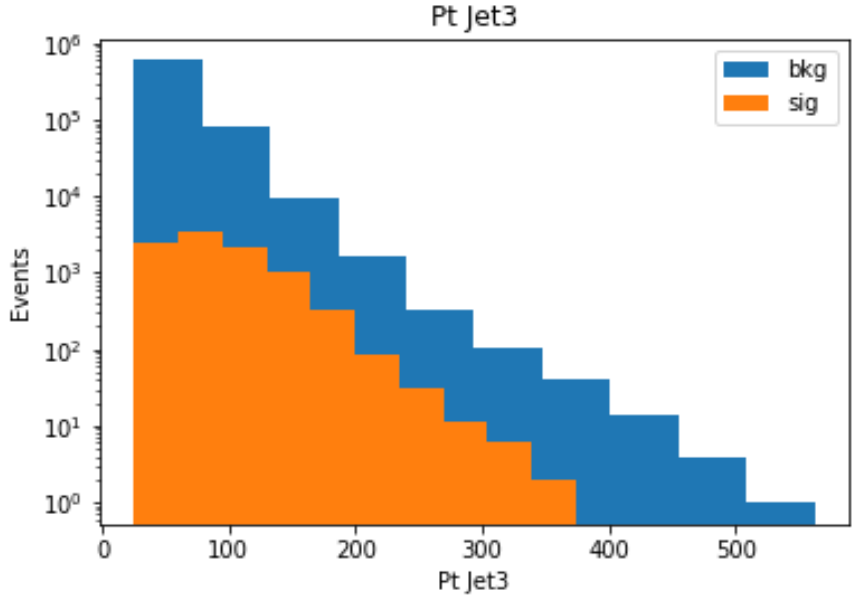

Eta Jet2
bkg
sig
Events
Eta Jet2

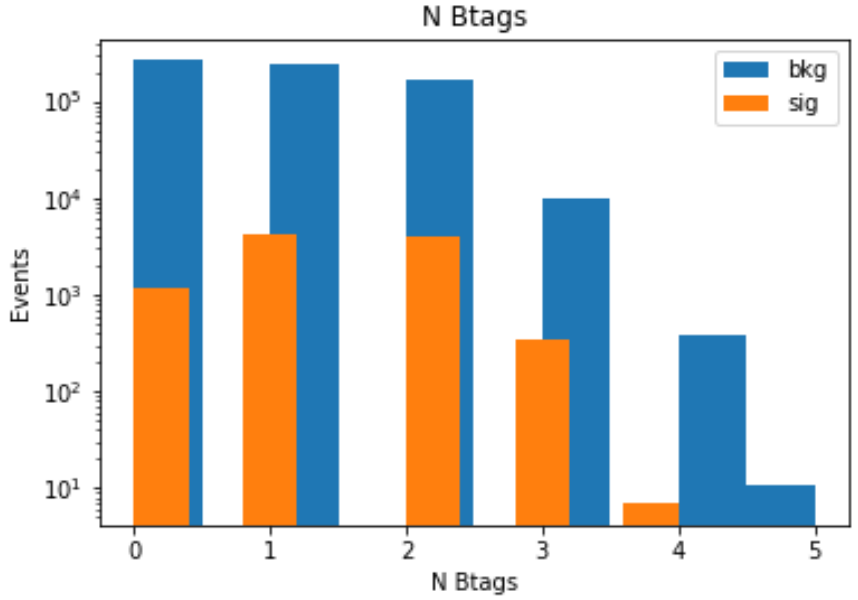

Eta Jet3
bkg
sig
Events
Eta Jet3

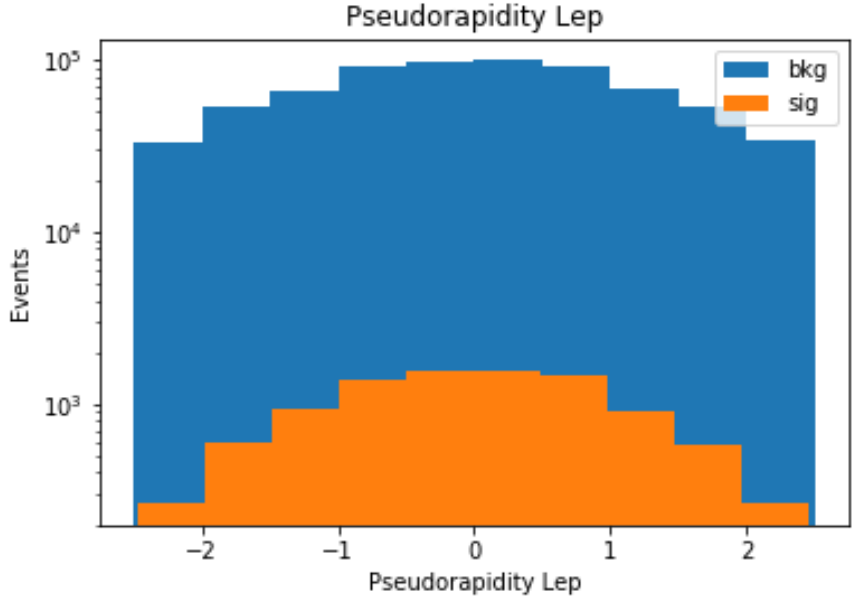

Eta Jet4
bkg
sig
Events
Eta Jet4

ZPRIME1000

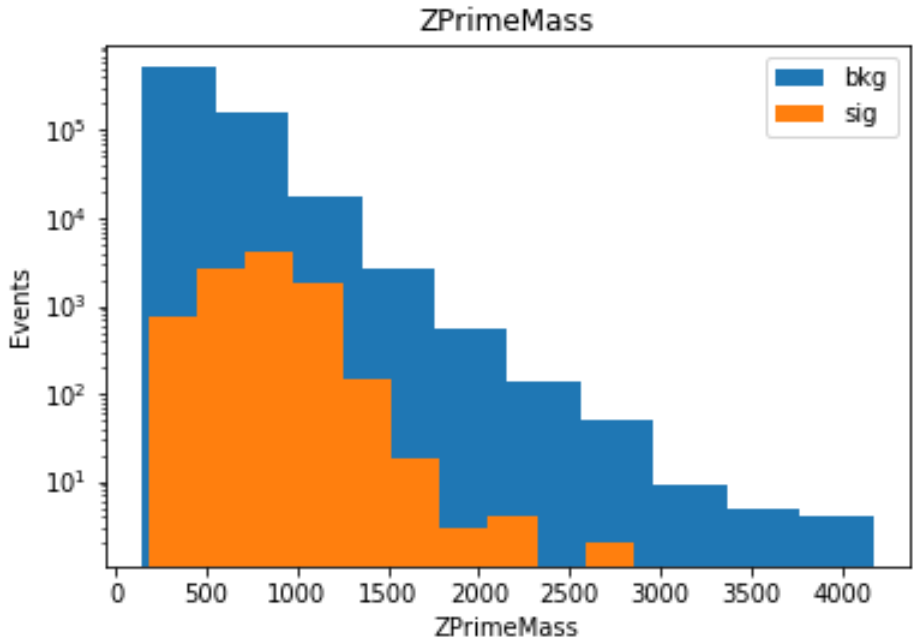

Pt Jet1
bkg
sig
Events
Pt Jet1

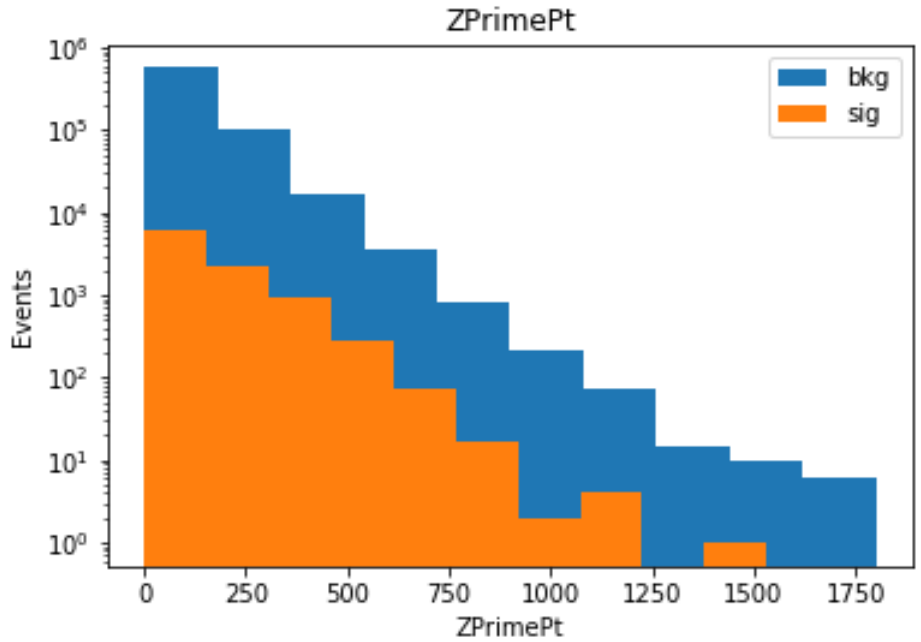

Pt Jet3
bkg
sig
Events
Pt Jet3

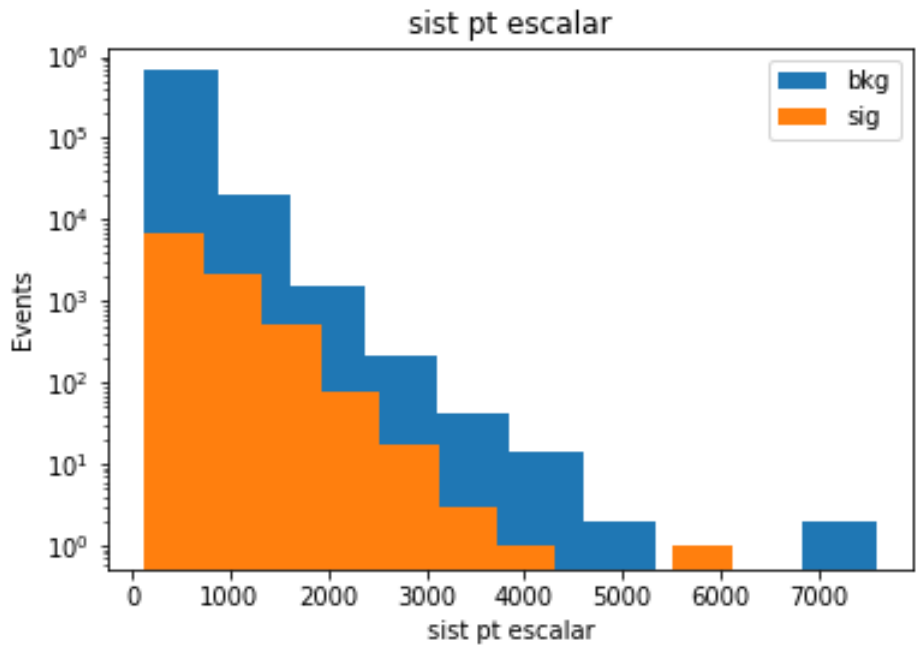

N Btags
bkg
sig
Events
N Btags


Pseudorapidity Lep
bkg
sig
Events
Pseudorapidity Lep

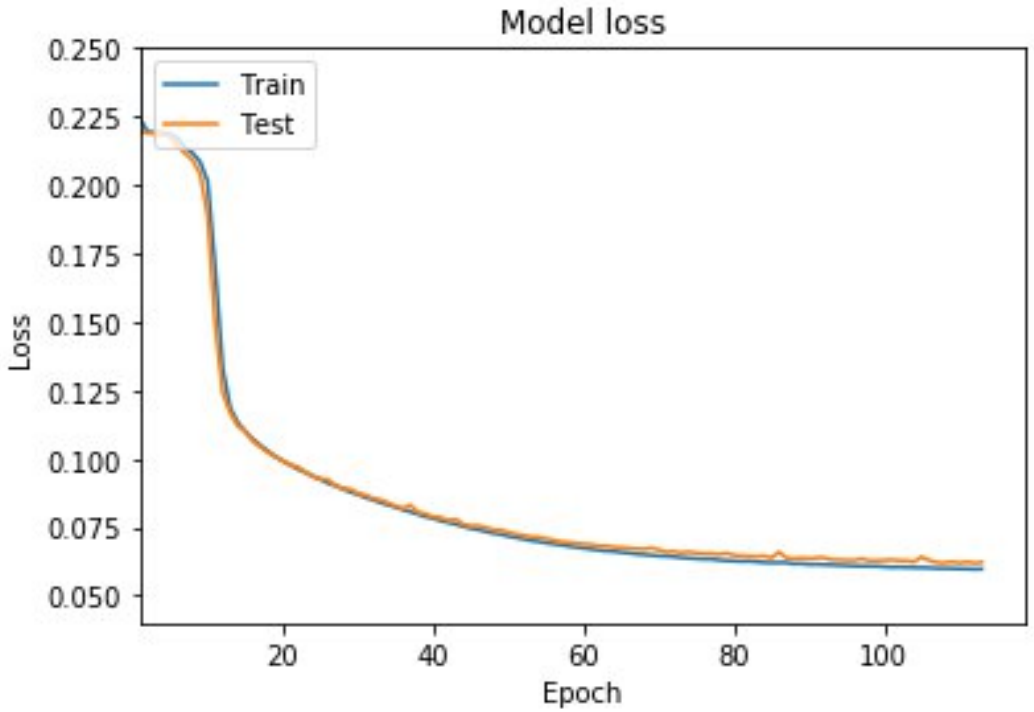
ZPRIME1000

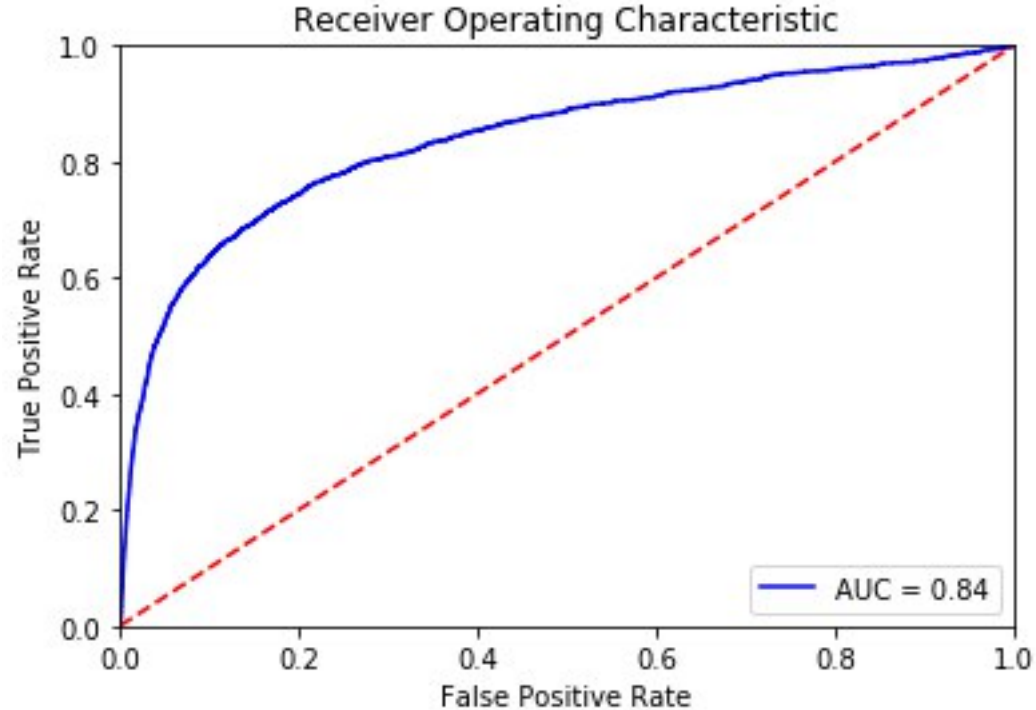

ZPrimeMass
bkg
sig
Events
ZPrimeMass


ZPrimePt
bkg
sig
Events
ZPrimePt


sist pt escalar
bkg
sig
Events
sist pt escalar

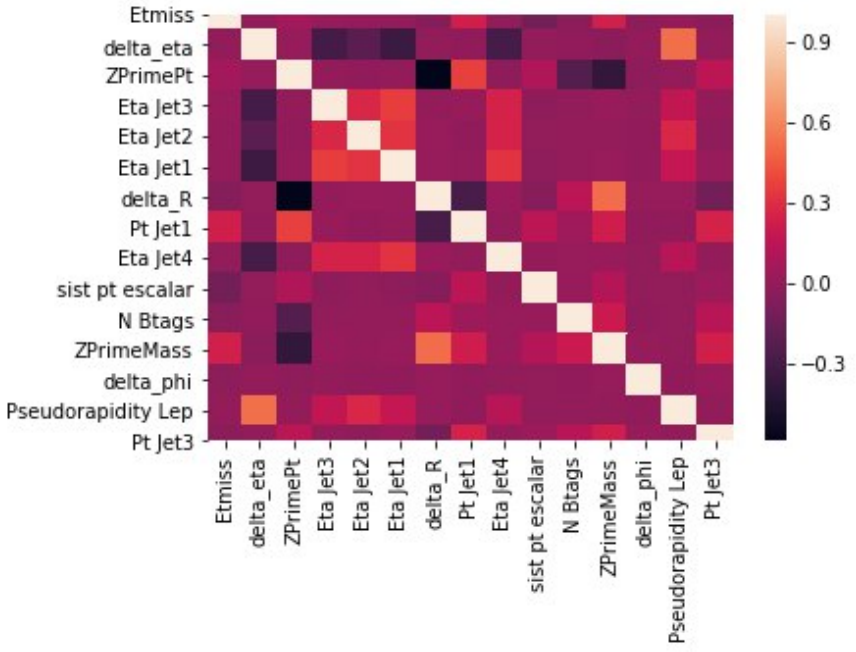
ZPRIME1000


Model loss
Train
Test
Loss
Epoch
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
20
40
60
80
100

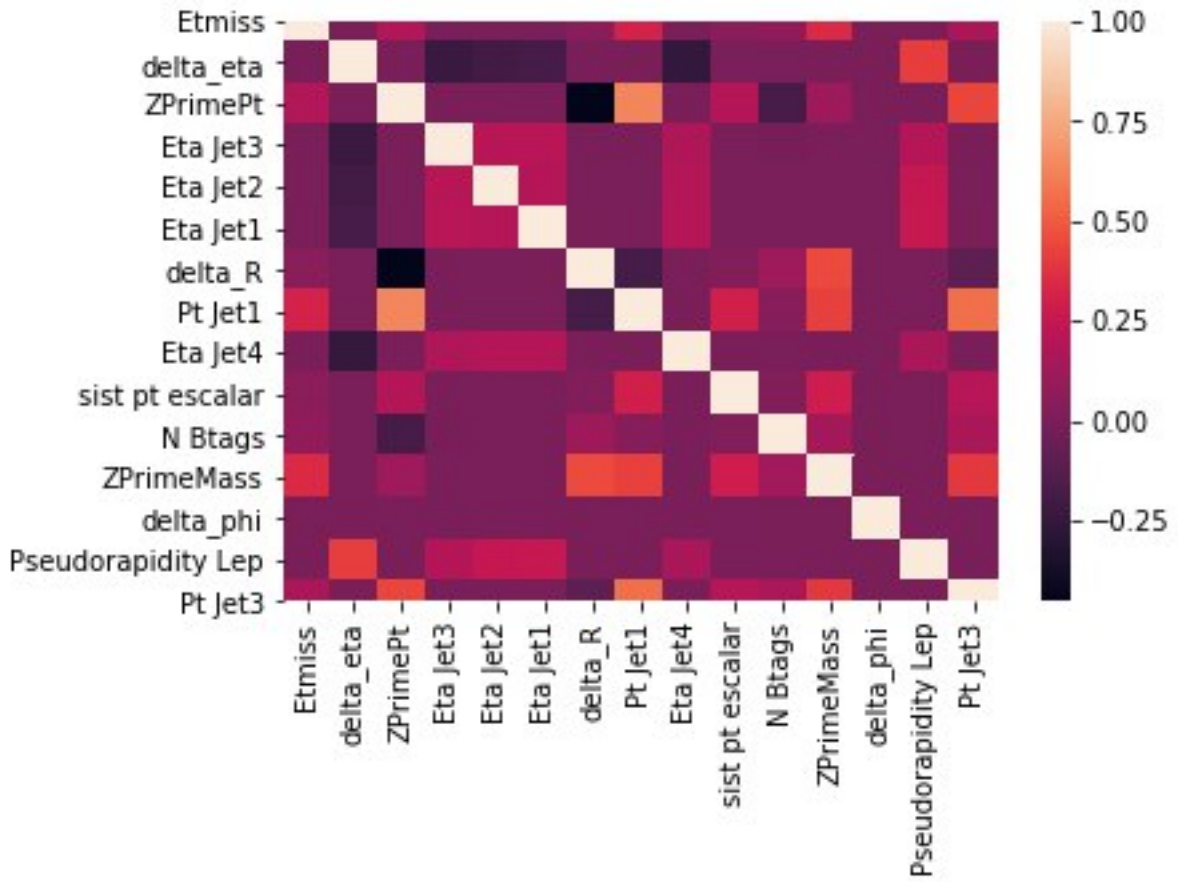

Receiver Operating Characteristic
True Positive Rate
False Positive Rate
AUC = 0.84
0.0
0.2
0.4
0.6
0.8
1.0

Correlações entre variáveis

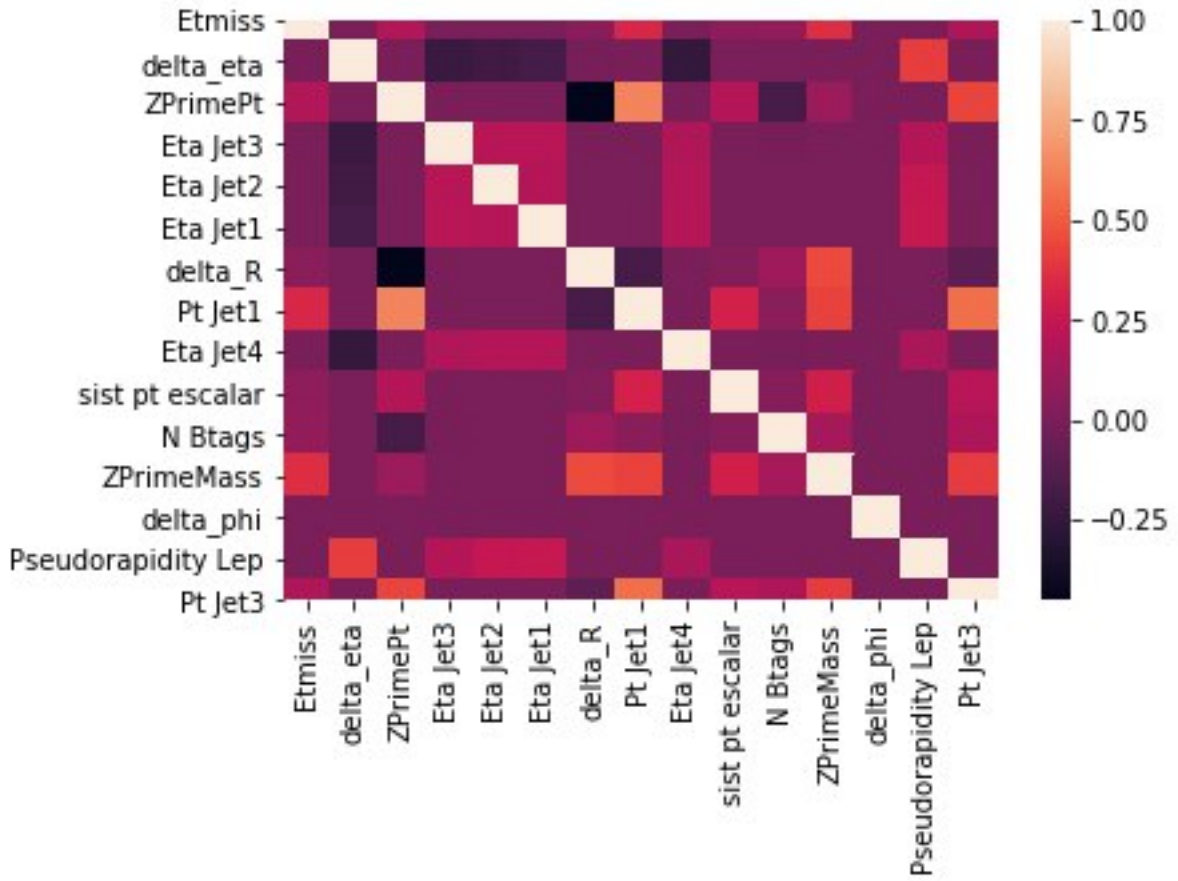
Correlações
Sinal



Correlações
Fundo



Correlações
Dados



Próximos objetivos

- Calcular limites a partir do output do classificador