Zprime Searches at 13TeV in pp Colliisions

Dongshuo Du,Jianxin,Feng,Xiaofei Guo,Yang Xu, Menglin Xu

The 3nd International Summer School
20/07/2016

Outline

- Motivation
- Experimental status
- Simple research
- Summary

Motivations

- String/GUTS
  - Harder to break U(1)' factors than non-Abelian
  - Supersymmetry:SU(2) ×U(1) and U(1)' breaking scales both set by SUSY breaking scale
  - μ problem
- Alternative electroweak model/breaking(TeV scale):DSB, Little Higgs, extra dimensions, left-right symmetry
- Connection to hidden sector(weak coupling, SUSYbreaking/mediation)
- Extensive physics implication, especially for TeV scale Z'
- Important test of SM
  - Possible contribution from New physics

Search for Z'

- Direct searches
- Carried out at hadron colliders since these give access to the highest energies available.
- Looks for high-mass dilepton resonances,which will be produced by quark-antiquark annihilation and decay to e-e+ or a pair of opposite-charged muons.
- The LHC has excluded the appearance of large Z' resonances over most of the range of proposed 3TeV lepton colliders.

- Indirect searches
- Carried out at e-e+ colliders, since these give access to high-precision measurements of the properties of Z boson.
- Constraints come from mixing between the Z' and the Z, and they depend not only on the Z' mass but also its mixing with the Z.
- ILC will extend this reach up to 5 to 10 GeV

- Since the Z' couplings conserve baryon and lepton numbers, the mass of the Z' may be well below the GUT(Grand Unified Theories) or string models, as low as TeV.

- In many supersymmetric GUT and the string models, the Z' mass is tied to the soft supersymmetry breaking scale, expected to be at the TeV scale. The movitation for a TeV-scale Z'is particularly strong in supersymmetric models with additional particles that are singlets of the SM SU(2)*U(1).

Feynman Diagram

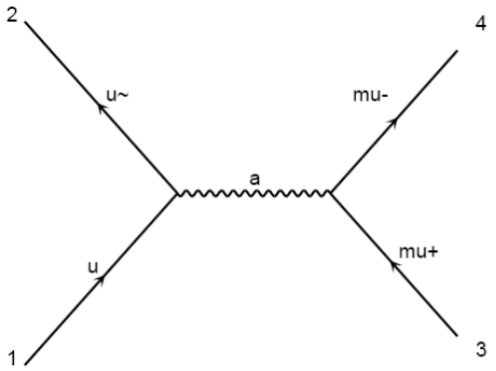


diagram 1 QCD=0, QED=2

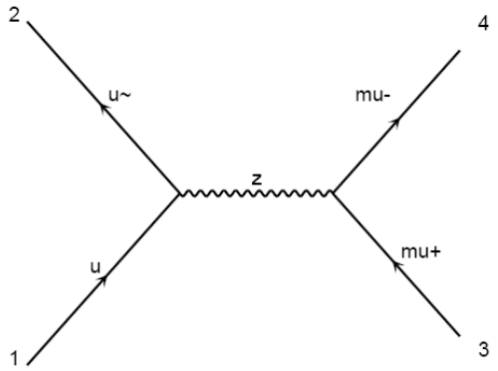


diagram 2 QCD=0, QED=2

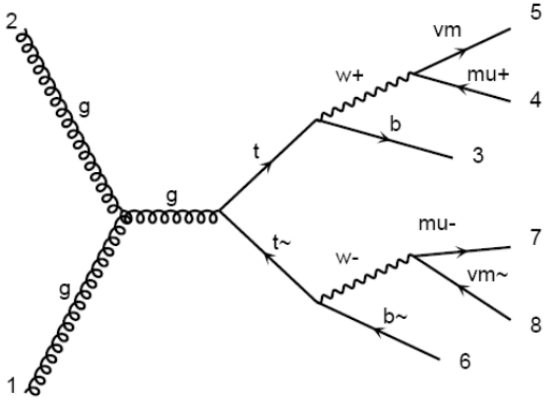


diagram 1 QCD=2, QED=4

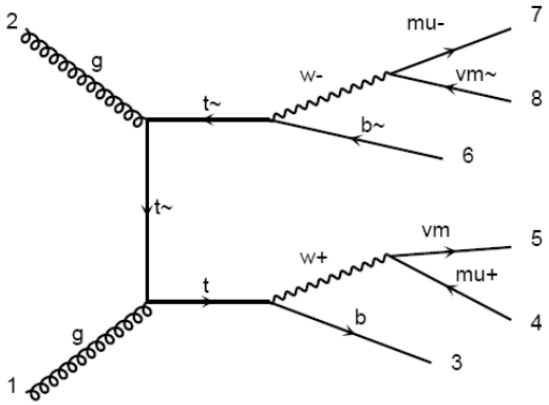


diagram 2 QCD=2, QED=4

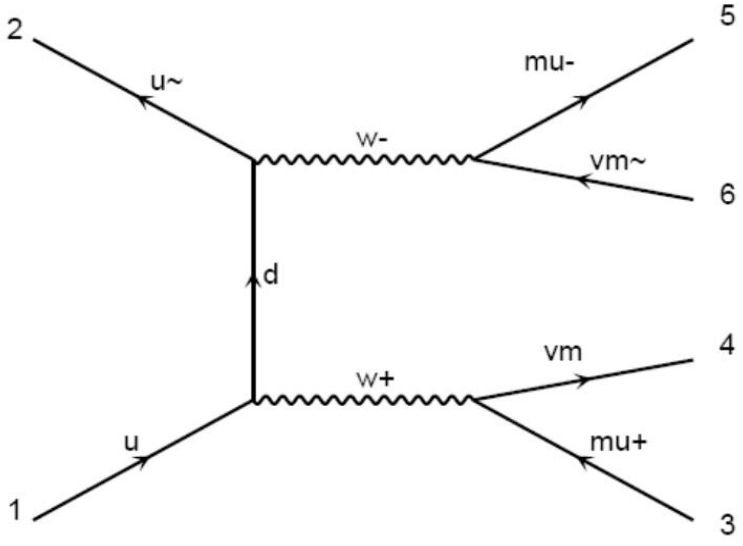


diagram 3 QCD=0, QED=4

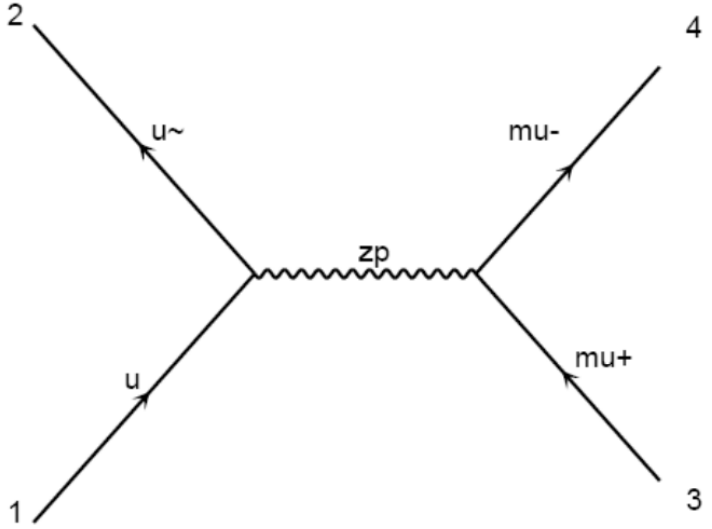


diagram 1 QCD=0, QED=2

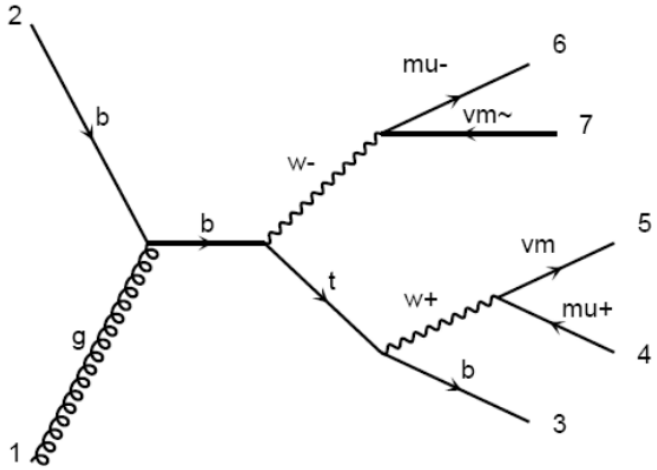


diagram 1 QCD=1, QED=4

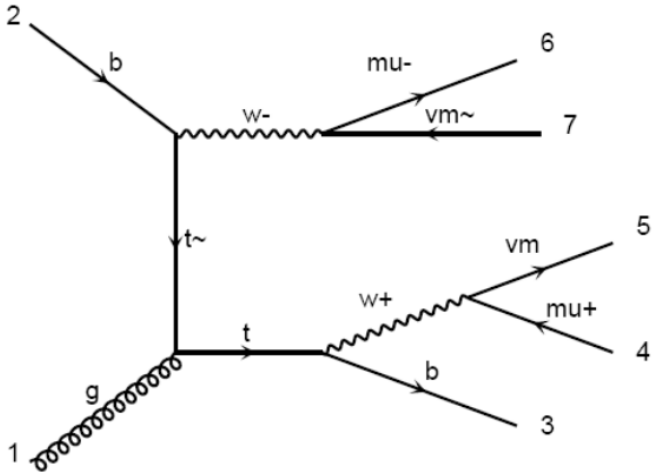
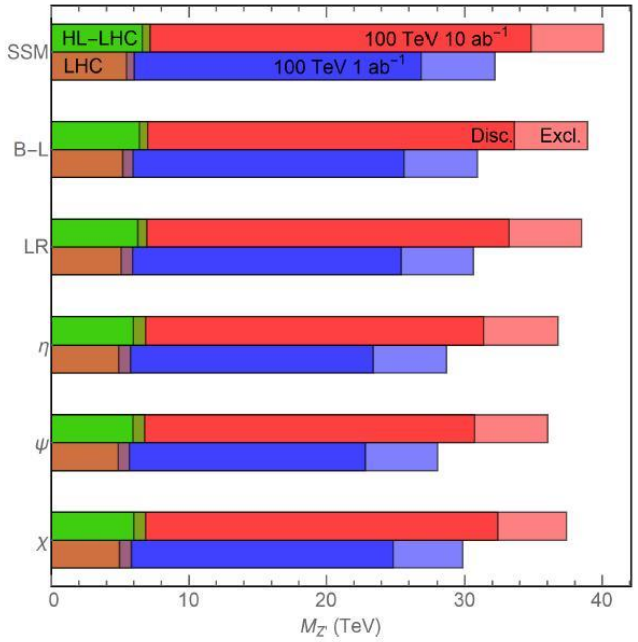


diagram 2 QCD=1, QED=4

Experimental status

- ILC
- 500 GeV – 1 TeV Sensitive to Z’ at √s<<Mz’
- Reach of a 500 GeV ILC exceeds the LHC reach in most models, while a 1TeV ILC will significantly improve on the LHC performance in all cases, with sensitivity well above 10 TeV in many models.
- Measure couplings to SM fermions (if Z' is discovered) to complete the characterization of this particle.With a polarized electron beam, only a twofold polarized improvs the results further.
- Z’ couplings to quarks can be obtained from final states(once the leptonic couplings are measured)
- High luminosities would improve the range for the Z’ couplings only by a factor 0.84 increasing the center-of-mass is more efficient

CEPC - SPPC



The discovery and exclusion reaches of Z' at SPPC 100 TeV at $1ab^{-1}$(blue) and 10 $ab^{-1}(red)$ and LHC 14 TeV at 300 fb^{-1}(brown) and 3000 $fb^{-1}(green)$ through dilepton(e,μ) channels.

Motivation: Higgs and Z pole measurements @pp colliders

Center of mass energy: 50-100 TeV

At 1 ab^{-1} the 100 TeV SPPC could discover(exclude) up to 23-26(28-32) TeV Z' for various benchmark models.

These discovery(exclusion) reach will invrease to 30-34(36-40) with a higher luminosity of 10 ab^{-1}.

Simple Research

- Data samples: $pp \to Z' \to \mu^+\mu^-$@13TeV
- Integrated luminosity :1 fb^{-1}
- Measuring Method: $q_0 = -\frac{2lnL(0)}{L(\hat{s})} = 2\left(nln\frac{n}{b} + b - n\right)\ for\ n > b$
- Data Generator:

  PYTHIA event generator

  CTEQ6L1 parton distribution function
- PreCut : PTI>10GeV ,|etal|<3. MII>900GeV

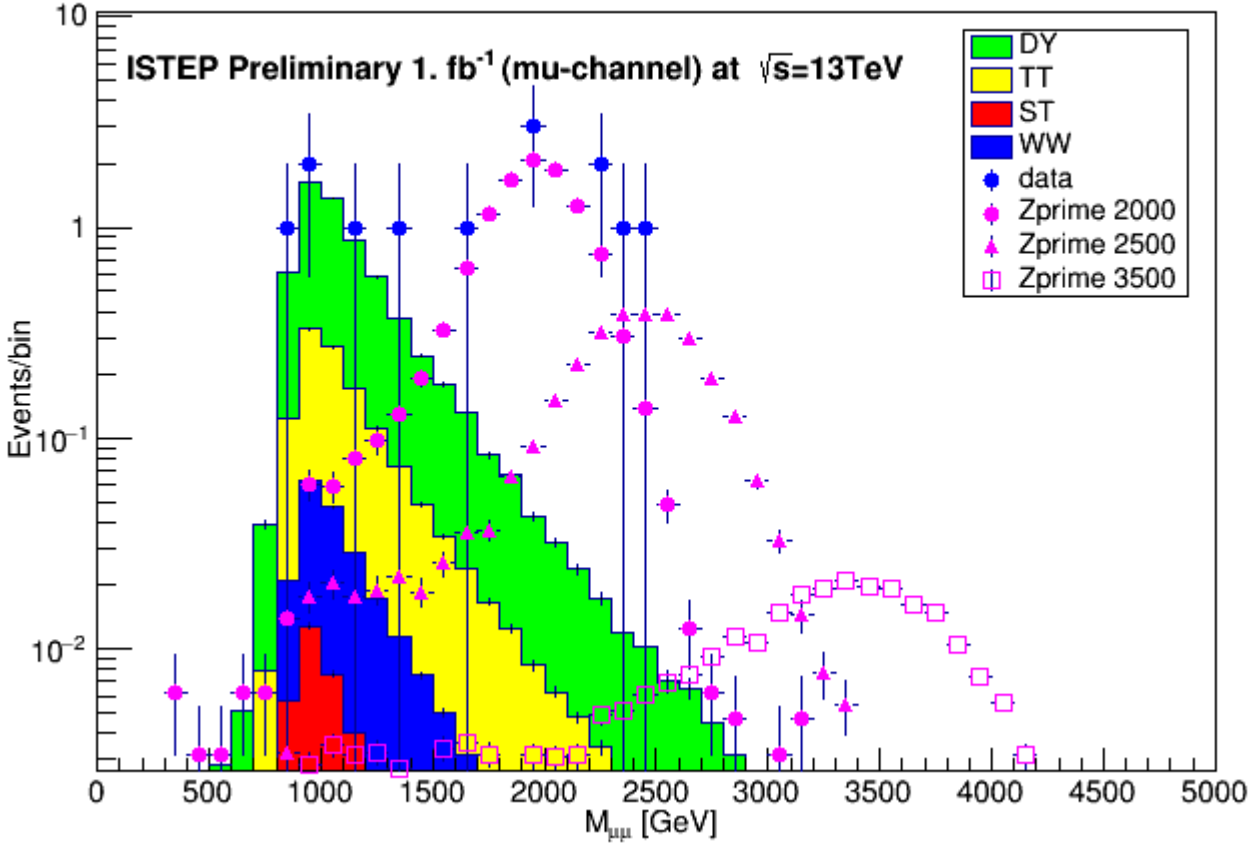
MC Samples

MZ'(GeV)	Width(GeV)	Xsec (pb)
2000	59.8	59.8 0.01558 ± 2.035e-05 pb
2500	74.8	0.004547 ± 6.202e-06 pb
3000	89.9	0.001466 ± 2.782e-06 pb
3500	104.9	0.0005123 ± 1.173e-06 pb
4000	119.9	0.0001894 ± 3.144e-07 pb
4500	134.9	7.523e-05 ± 1.546e-07 pb

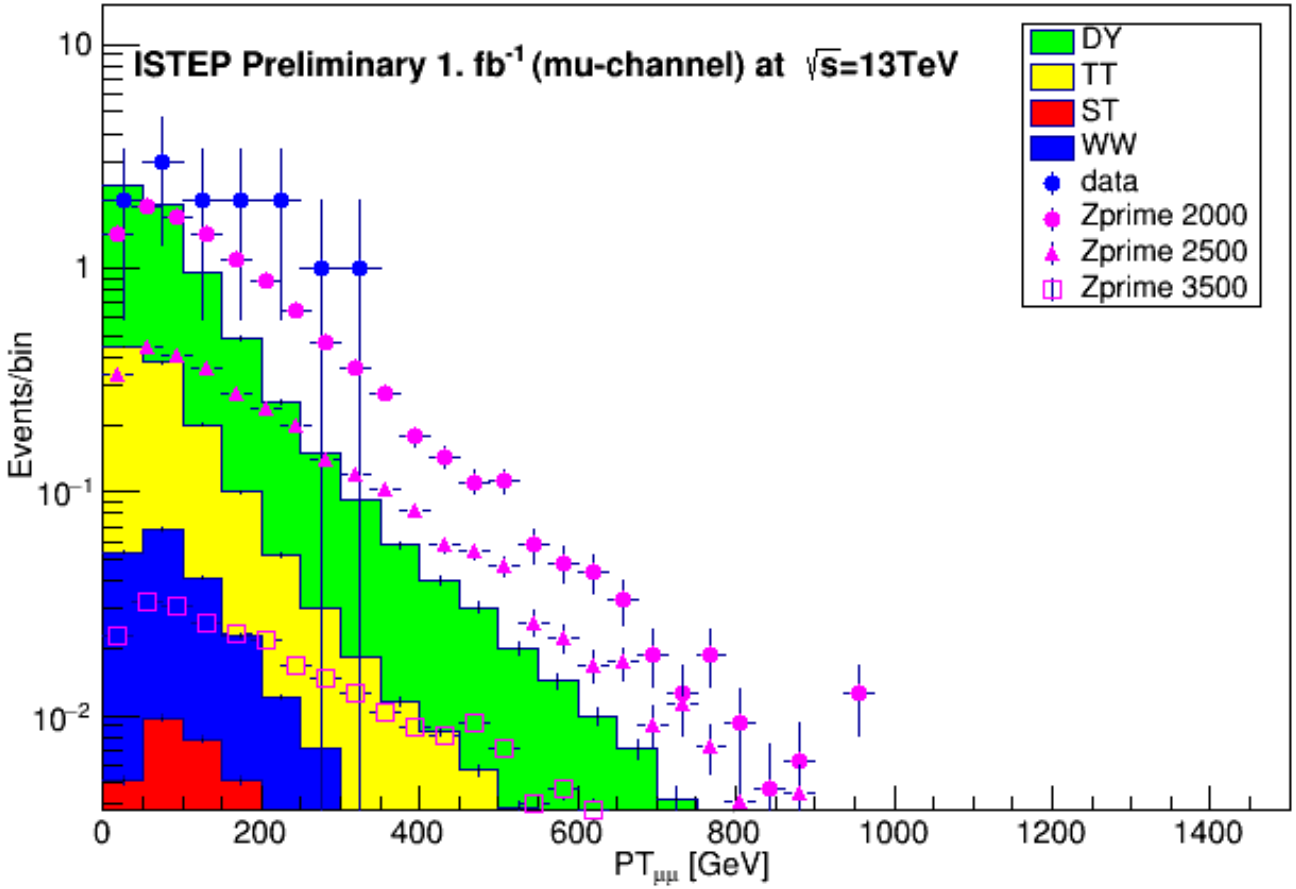
Bkg Samples

Model	Number	Xsec (pb)
DY	80K	**0.007476±6.427e-06 pb**
TTbar	40K	**0.0007598±1.198e-06 pb**
TW	10K	**8.888e-05±2.135e-07 pb**
WW	40K	**0.000338±3.497e-07 pb**

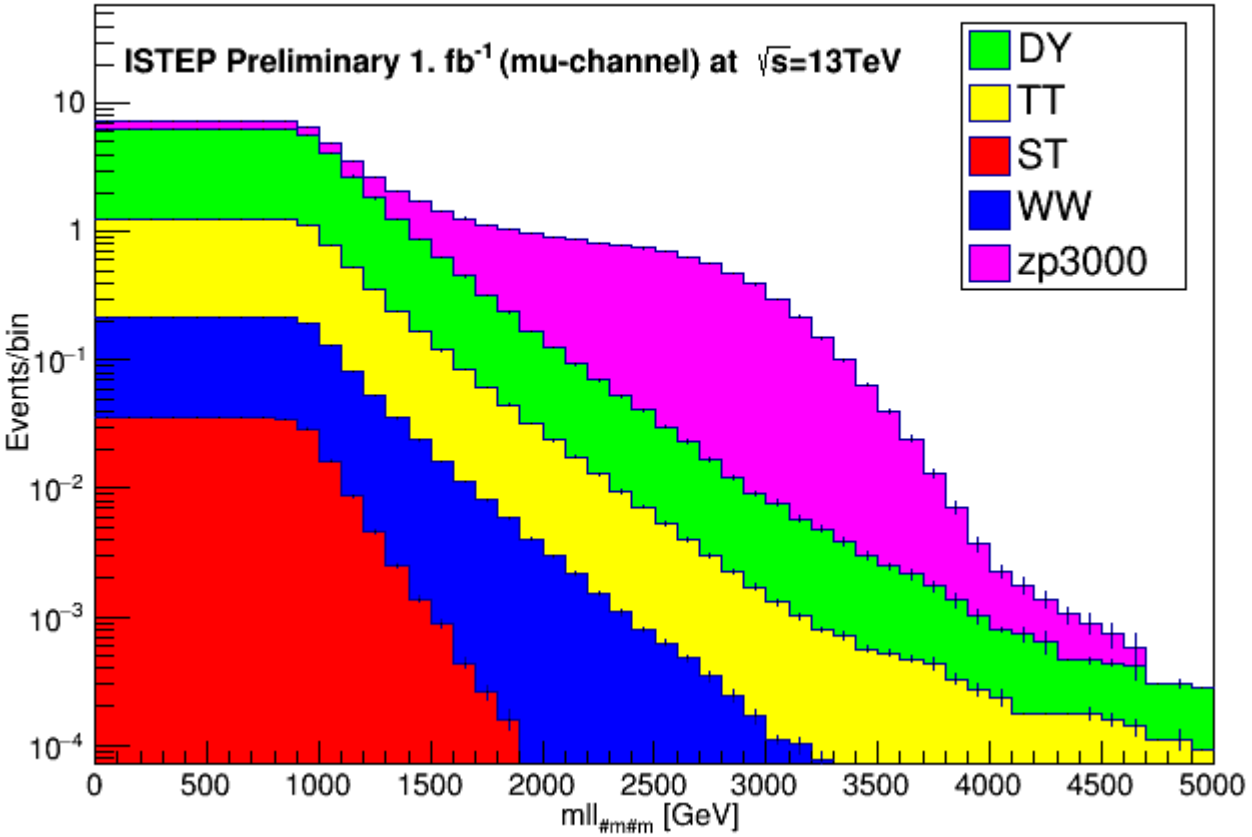
Mass Distribution



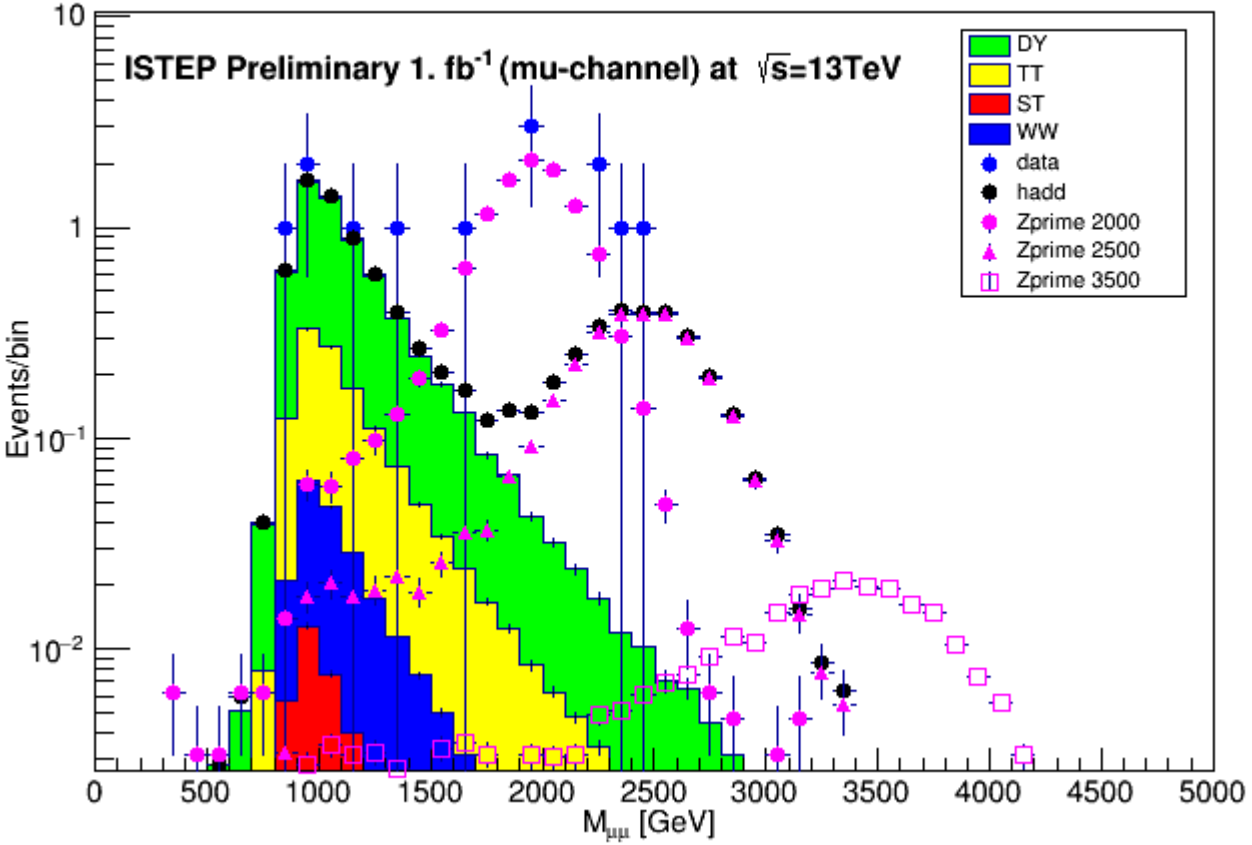
PT Distribution



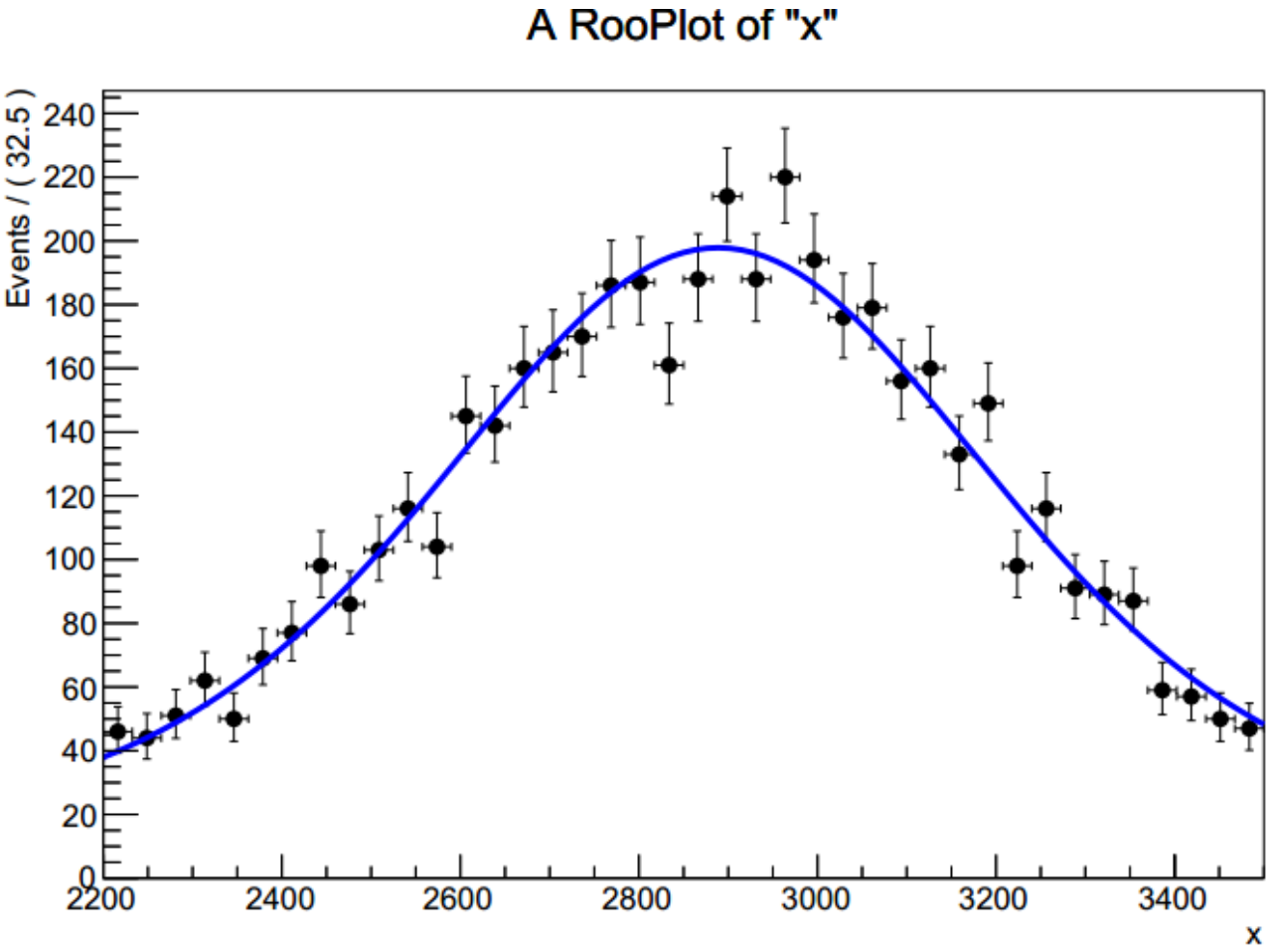
Cumulative Mass Distribution



Bkg Impact


ISTEP Preliminary 1. fb-1 (mu-channel) at √s=13TeV
DY
TT
ST
WW
data
hadd
Zprime 2000
Zprime 2500
Zprime 3500
Events/bin
10
1
10-1
10-2
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
Mμμ [GeV]

Gauss Fit

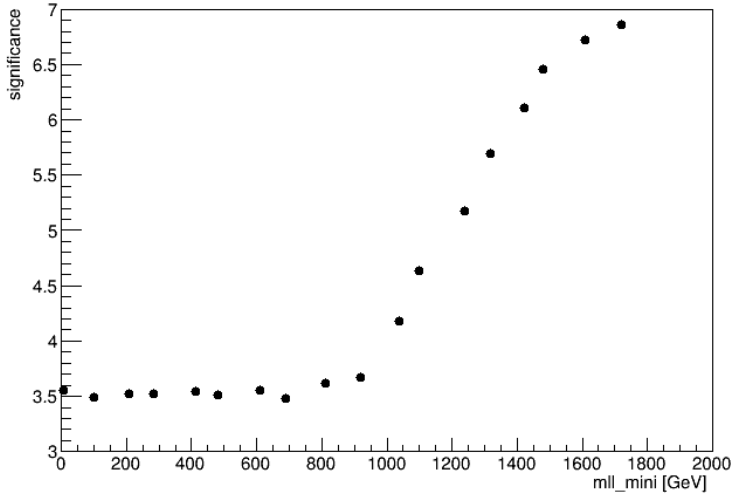


mean=2888.63 width=479.183
sigma=201.94 nsig=4873
Fit chi square/dof = 0.987281

First Method (Rang Cut)

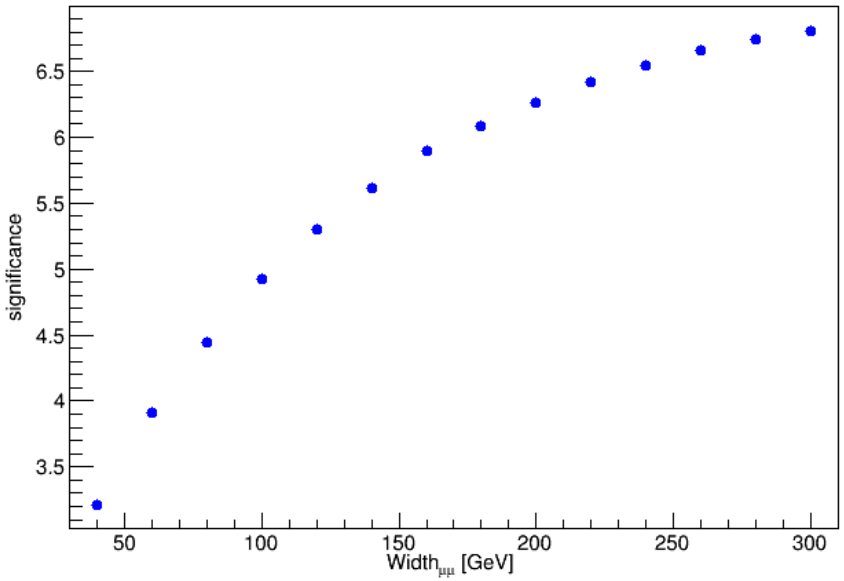
- $q_0 = -\frac{2lnL(0)}{L(\hat{s})} = 2\left(nln\frac{n}{b} + b - n\right)\ for\ n > b$
  - Significance = $\sqrt{q_0}$
  - $n = IntegralAndError(mll\_minus, 50, sigError)$
  - $b = IntegralAndError(mll\_minus, 50, bkgError)$

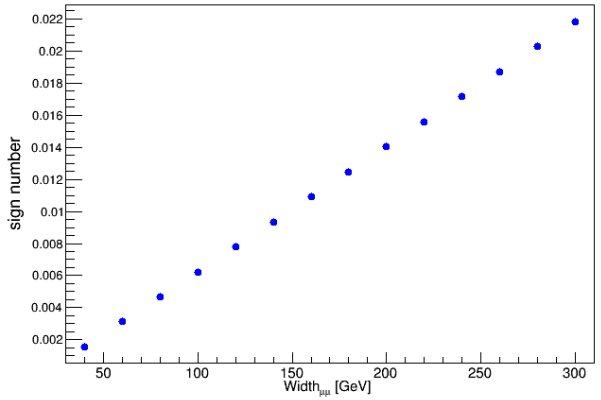
Cut Range(GeV)	sign number	Bkg number
M>100	10.9371	6.40541
M>500	10.9277	6.40059
M>800	10.9426	6.35393
M>1000	10.8374	4.08573
M>1300	10.6021	1.24908
M>1500	10.2796	0.630953
M>1700	9.31987	0.319254
M>1800	8.17007	0.235874

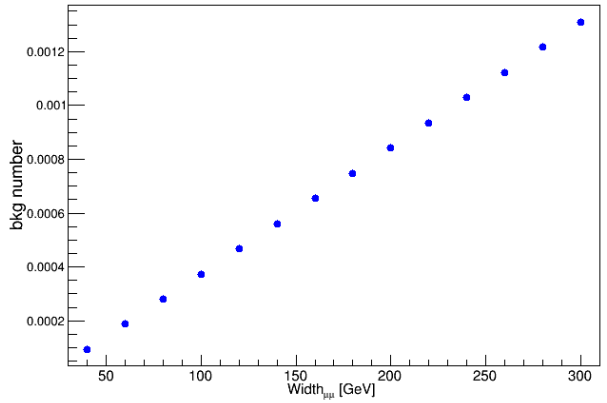


Second Method (Width Cut)

- $q_0 = -\frac{2lnL(0)}{L(\hat{s})} = 2\left(nln\frac{n}{b} + b - n\right)\ for\ n > b$
  - Significance = $\sqrt{q_0}$
  - sum_sig+=SF*lumi
  - sum_bkg+=SF*lumi
  - Lumi=1

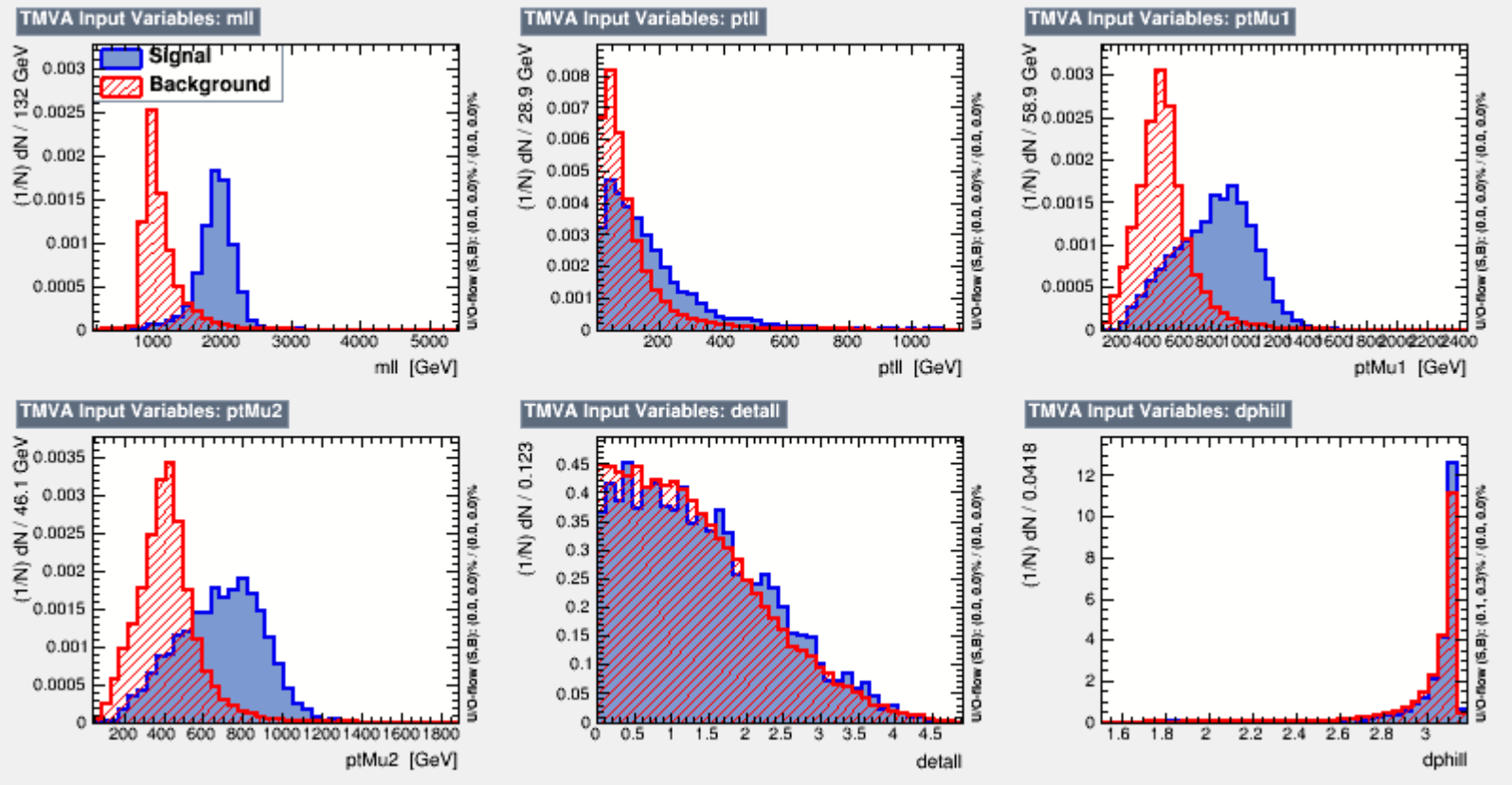




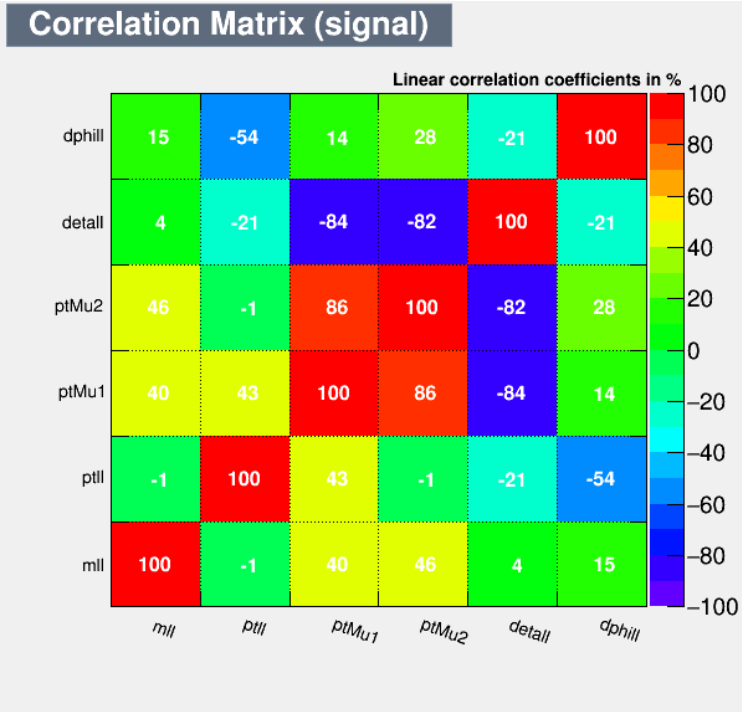


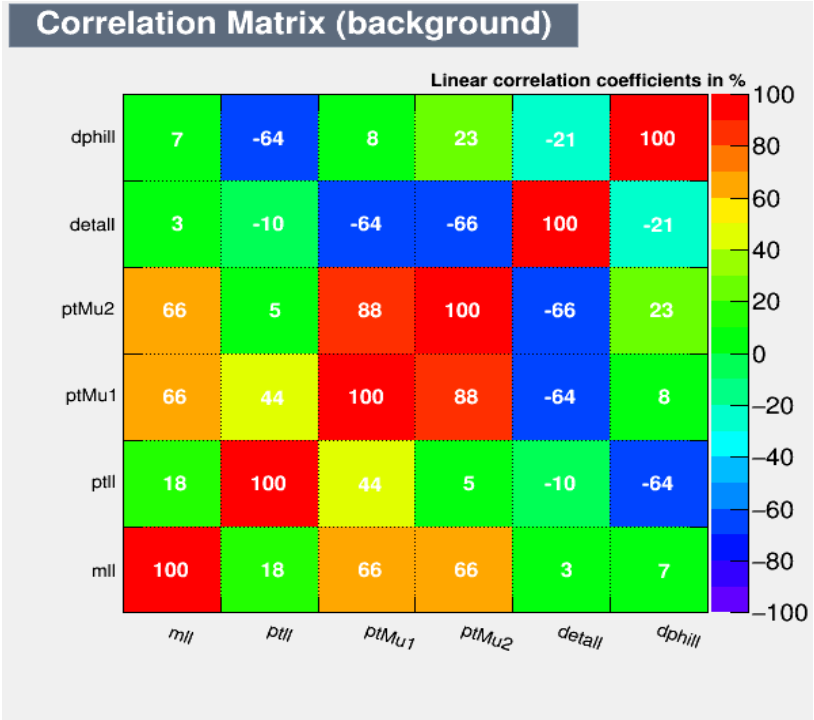
Third methods (multivariable analysis)

➢ BDT

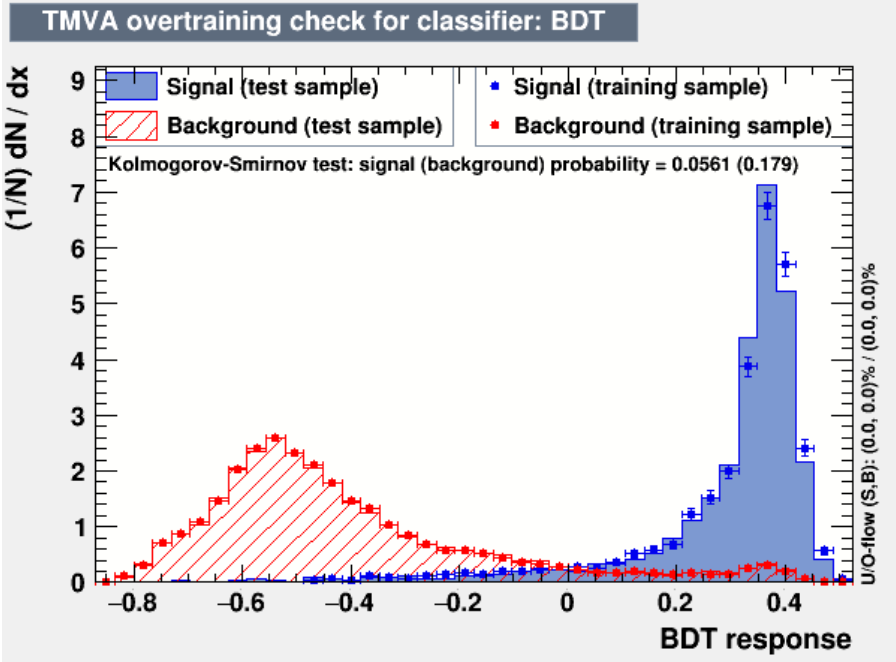


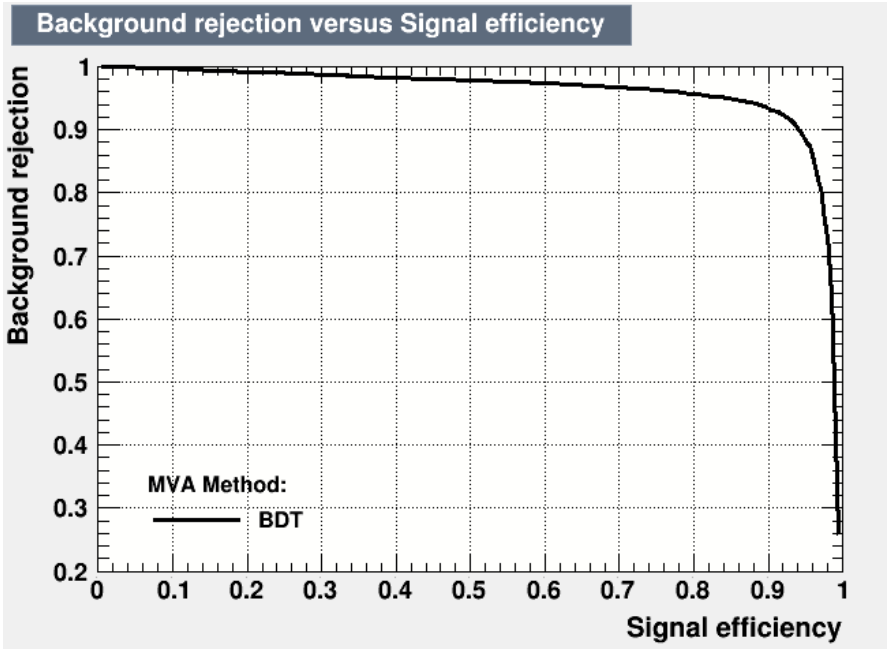
➢ Correlation Matrix





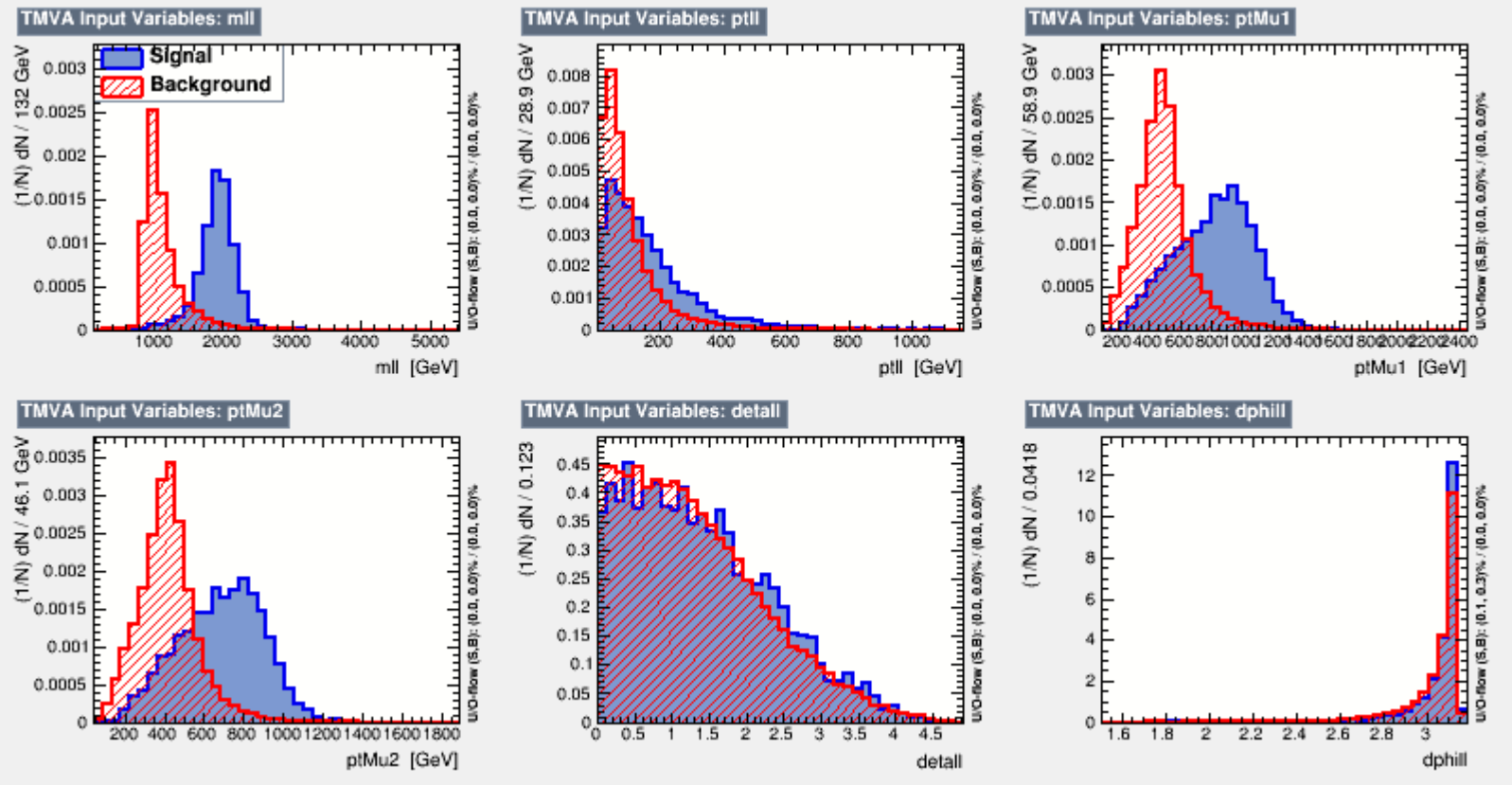
BDT Responces



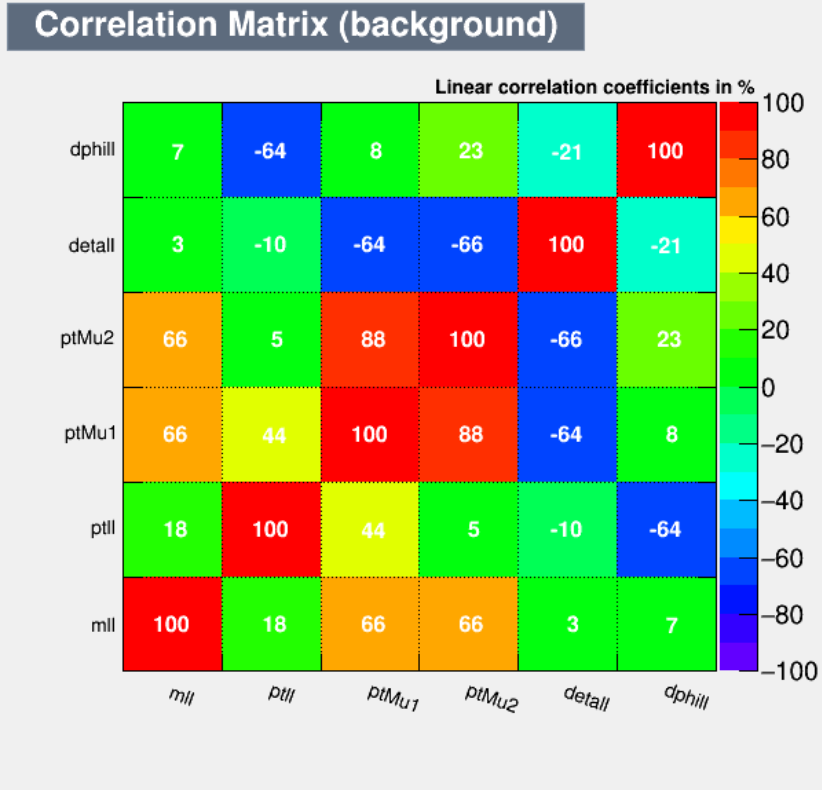


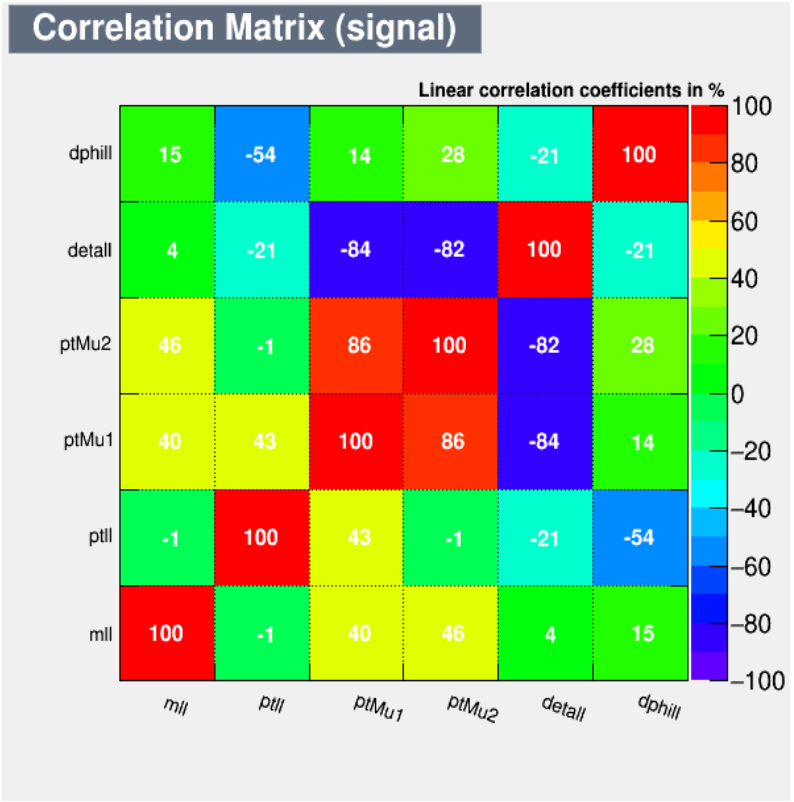
7.07312

➢ Fisher

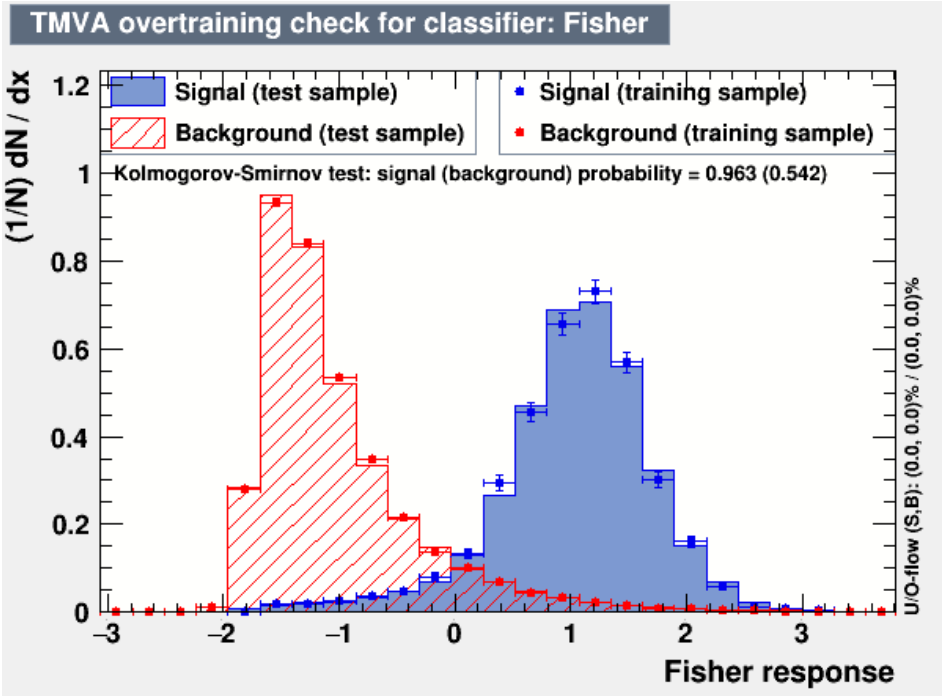

TMVA Input Variables: mll
Signal
Background
(1/N) dN / 132 GeV
mll [GeV]
TMVA Input Variables: ptll
(1/N) dN / 28.9 GeV
ptll [GeV]
TMVA Input Variables: ptMu1
(1/N) dN / 58.9 GeV
ptMu1 [GeV]
TMVA Input Variables: ptMu2
(1/N) dN / 46.1 GeV
ptMu2 [GeV]
TMVA Input Variables: detall
(1/N) dN / 0.123
detall
TMVA Input Variables: dphill
(1/N) dN / 0.0418
dphill

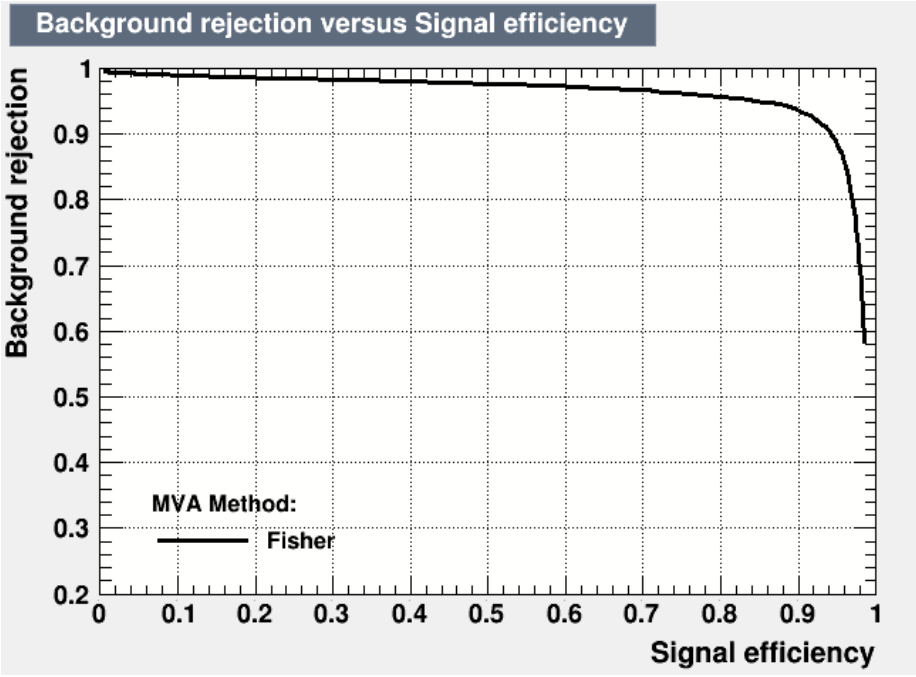
➢ Correlation Matrix





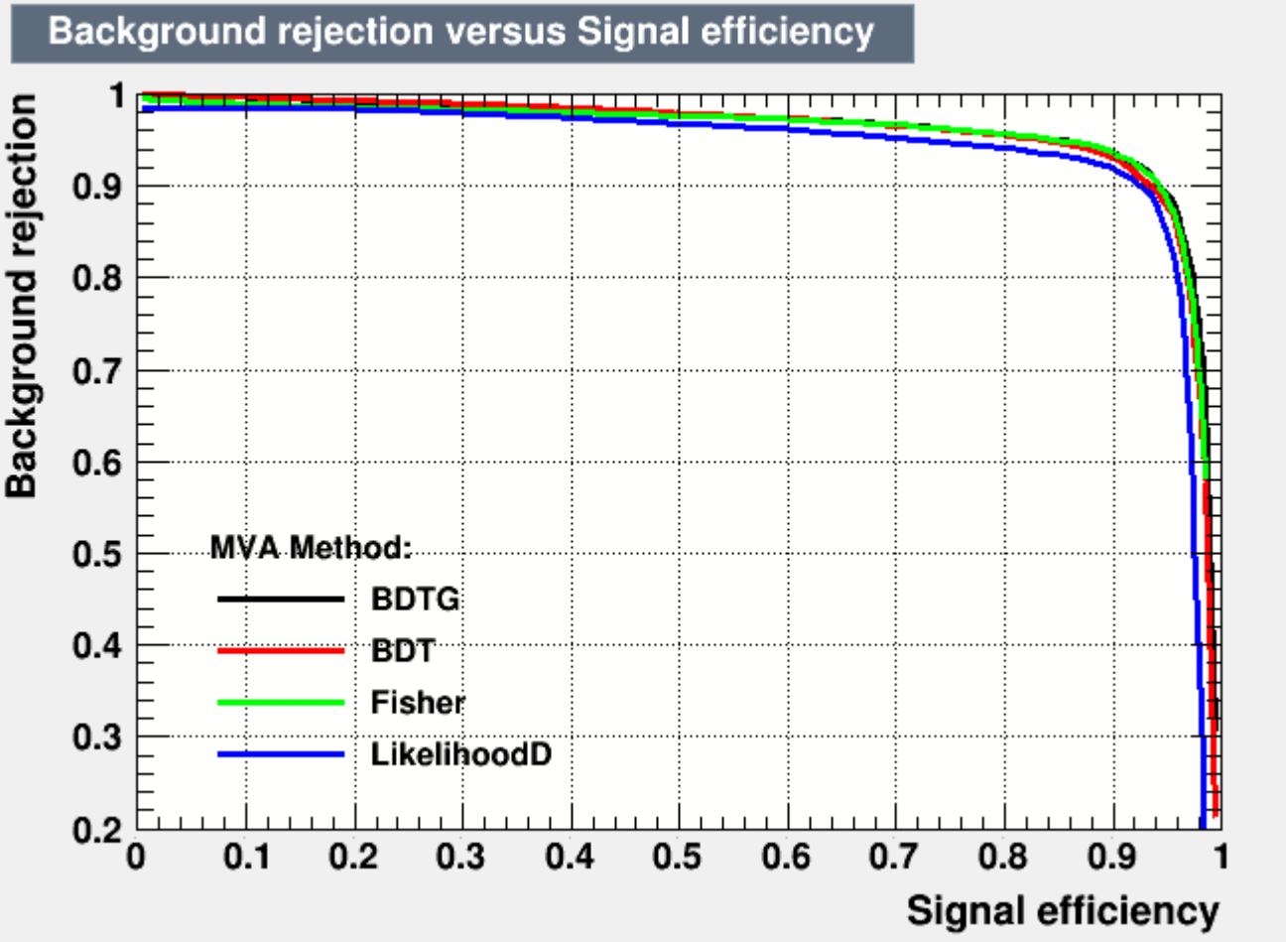
➢ Fisher Responces





6.95349

➢ comparison



BDT：7.07312
BDTG： 6.96335
Fiser：6.95349
LikelihoodD：6.61267

Summary

- No Z' signal was observed

- ATLAS: the benchmark Z'_{SSm} signal are 2.90 TeV @95%
- CMS : the benchmark Z'_{SSm} signal are 2.90 TeV @95%

(the benchmark Z'_{SSm} signal are 2.22 TeV @95%@7TeV)

- Expected to get best limit
  - With increasing statistics , may find Z' signal
  - Probe new physics