Status report on H->$\mu^-+\mu^+$ at CEPC

Zhenwei Cui,Qiang Li,Lei Wang,Gang Li,Manqi Ruan,Xin Mo

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OUTLINE

1.Introduction

2.Signal and background

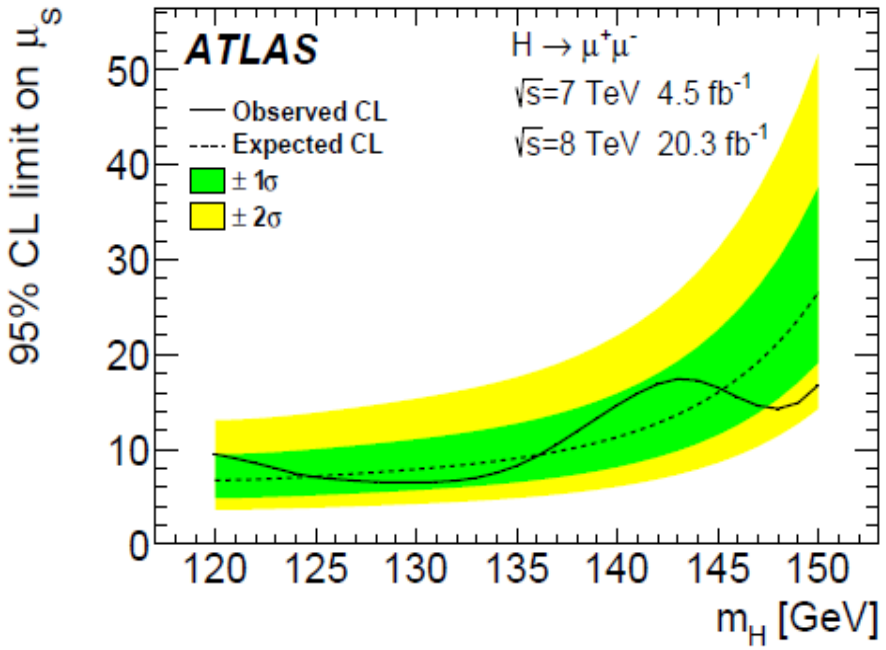
3.Cut-base optimization

4.BDT optimization

5. Summary

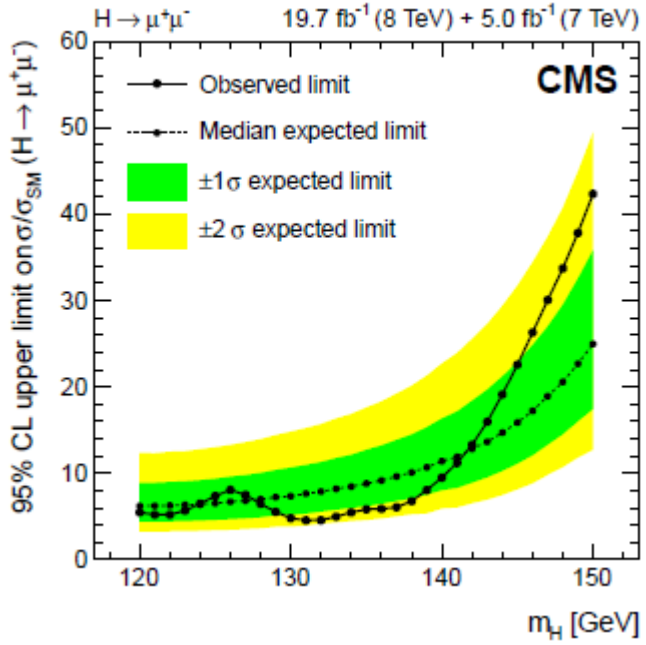
Introduction

"Search for the Standard Model Higgs boson decay to $\mu^-\mu^+$ with the ATLAS detector" **30 Jun 2014**



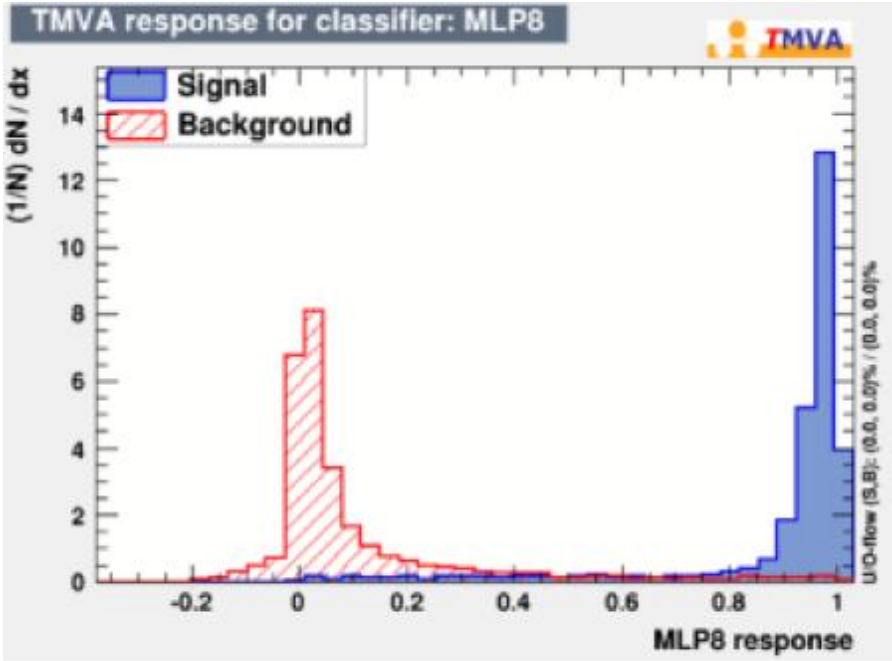
upper limit at the 95% confidence level is 7.0 times.

"Search for a standard model-like Higgs boson in the $\mu^-\mu^+$ and e^-e^+ decay channels at the LHC" **22 Apr 2015**



the observed upper limit at the 95% confidence level is 7.4 times.

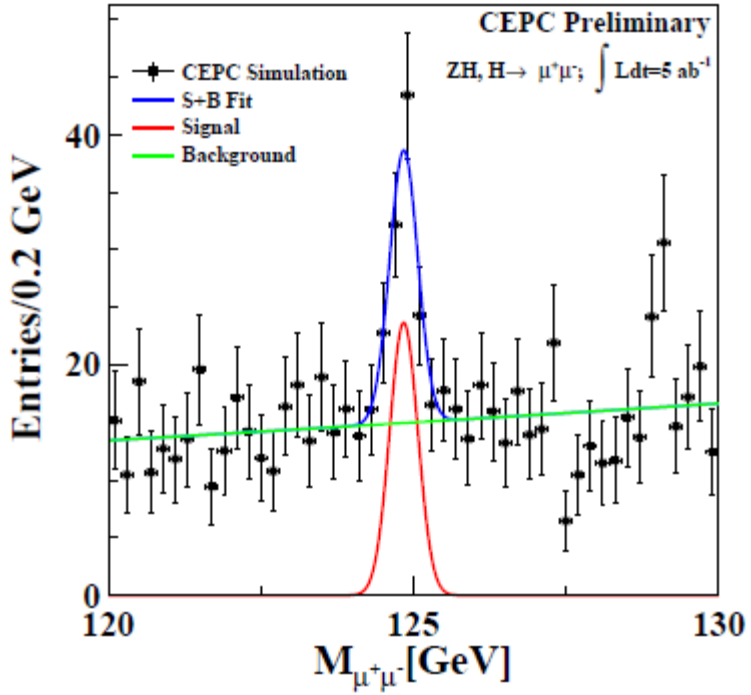
“H→ μ⁻μ⁺ at ILC Talk presented at the International Workshop on Future Linear Colliders” 11 2015



Artificial Neural Network

1TeV 500fb^{-1}
Significance is 2.75σ

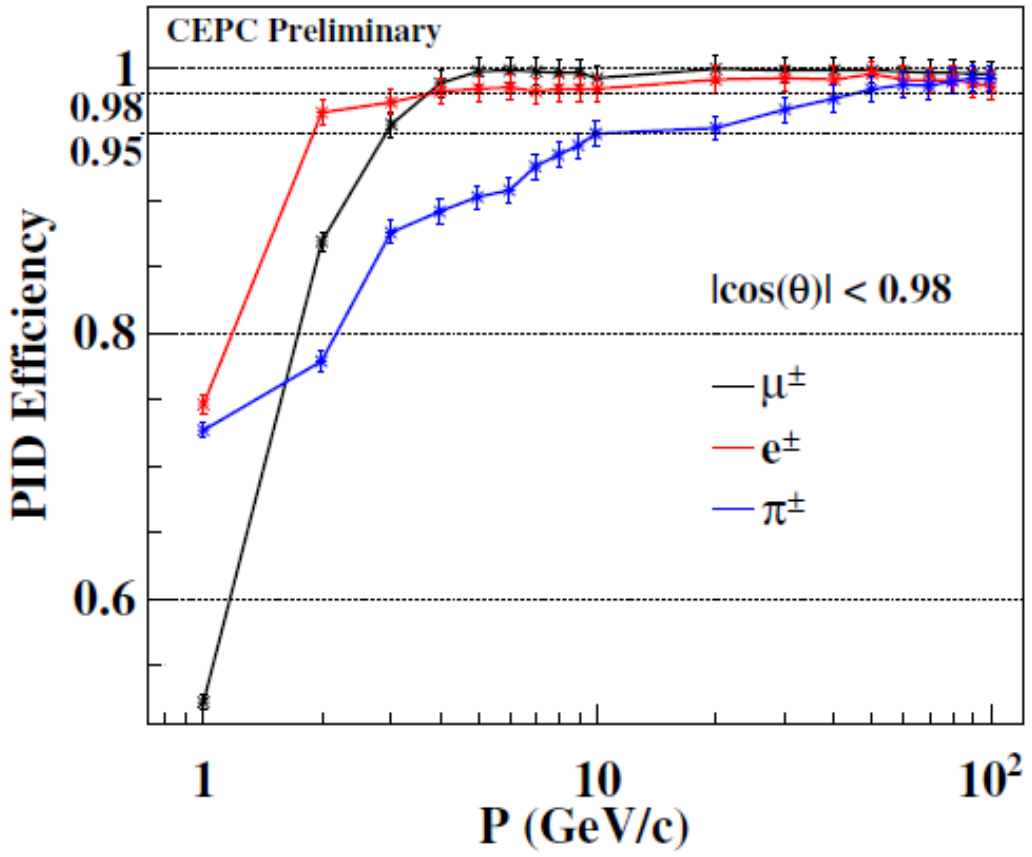
“CEPC-SPPC Preliminary Conceptual Design Report Volume I – Physics & Detector” 3 2015



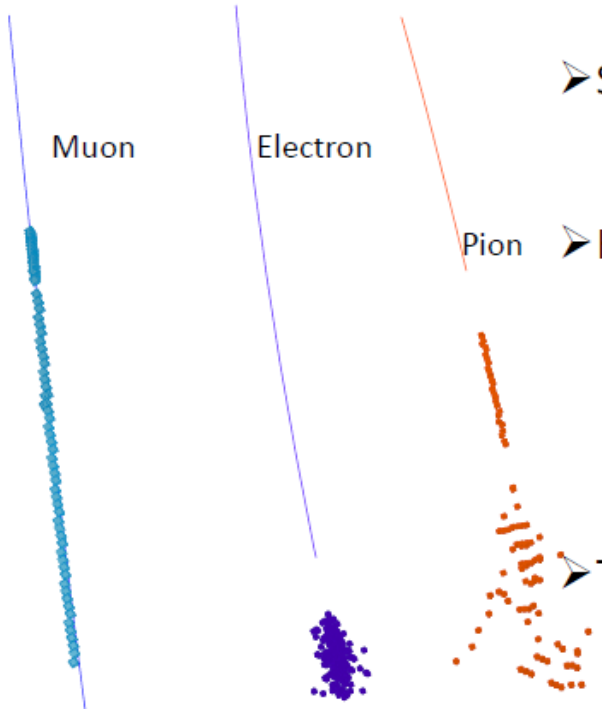
250GeV 5000fb^{-1}
Significance is 6.89σ

Normalization is wrong.

PID Efficiency at CEPC

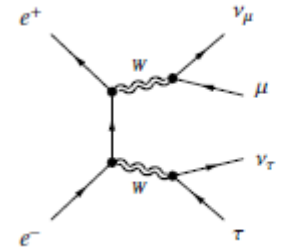
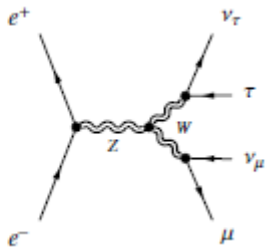
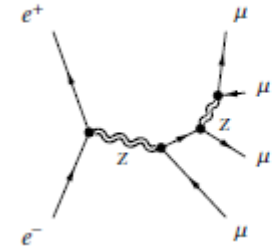
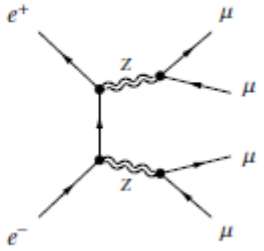
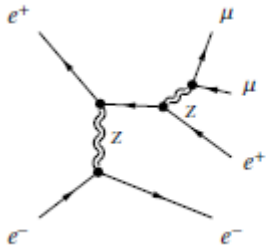
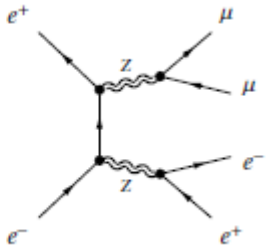


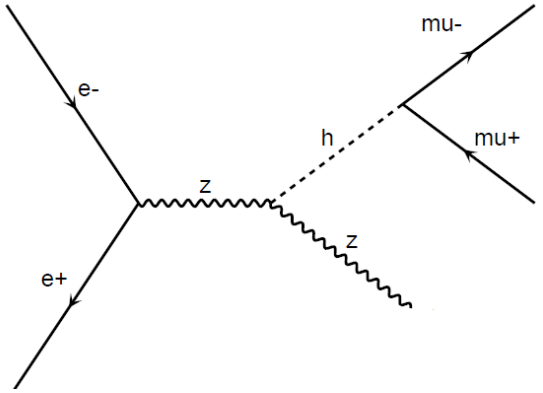
Different variables used in the PID



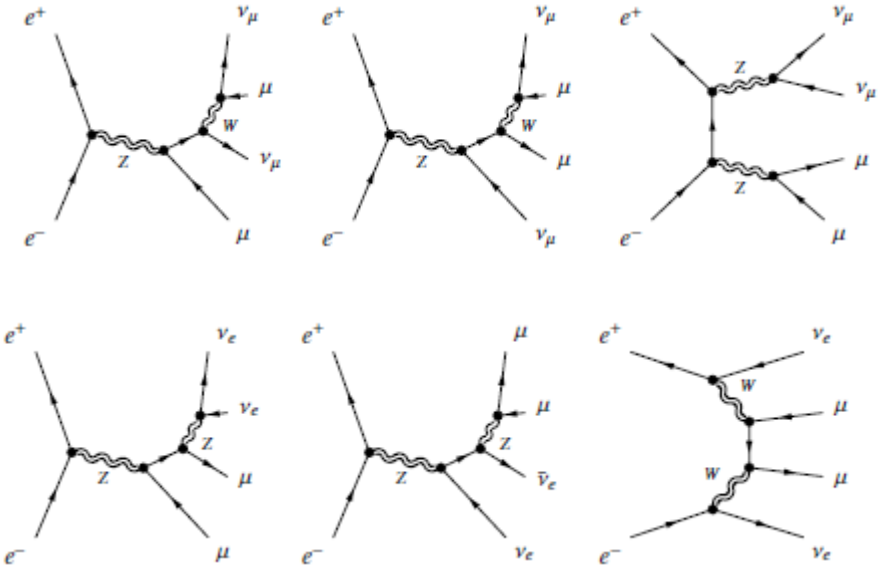
- Shape information
  - ✓Depth: CluDepth
  - ✓Width: avEnDisHtoL
- Hit information
  - ✓Numbers: NH_ECAL, NH_HCAL
  - ✓Energy: Eclu, EEClu, EHClu, EEClur
  - ✓Position: SDTheta
  - ✓Distribution: Fractal Dimention
- Track information: dE/dx

Components of Signal and Background



MC sample	
Signal: Higgs →μ⁺+μ⁻ full	
Bkg: fast	4f_ZZ
	4f_WW(SW)
	4f_SZ
	4f_ZZorWW
	2f

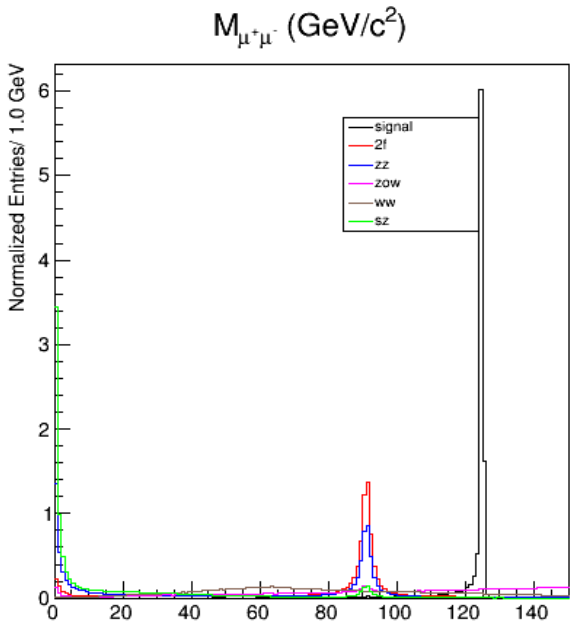


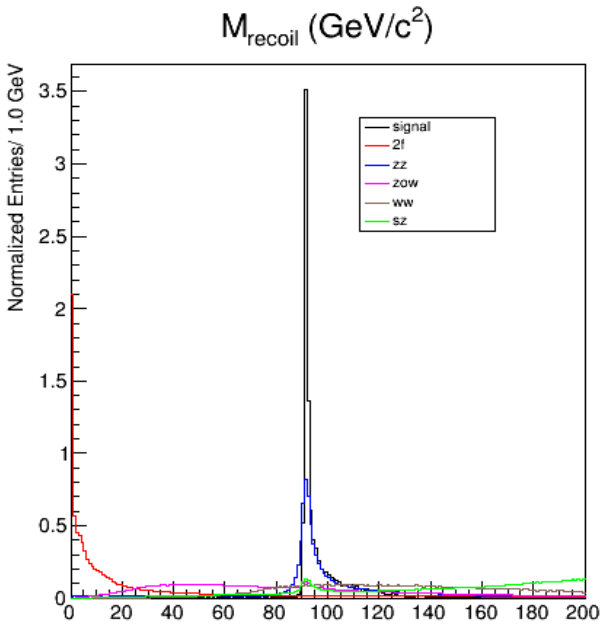
Event generator:WHIZARD 1.95

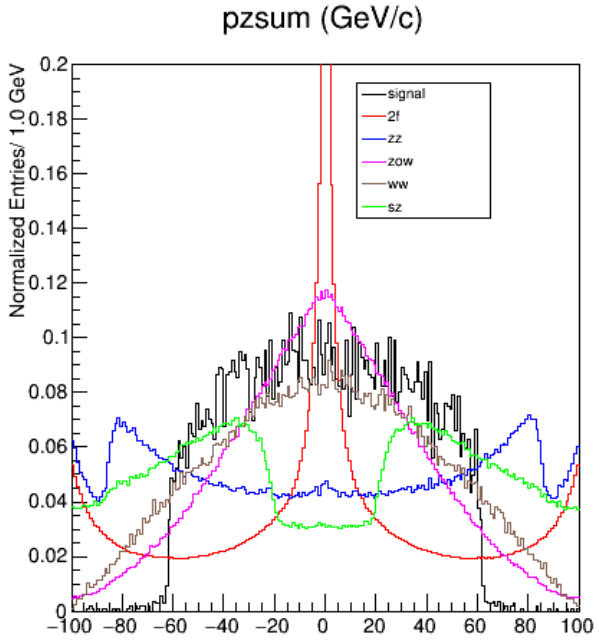
Detector simulation: MOKKA(cepc_v1 model)

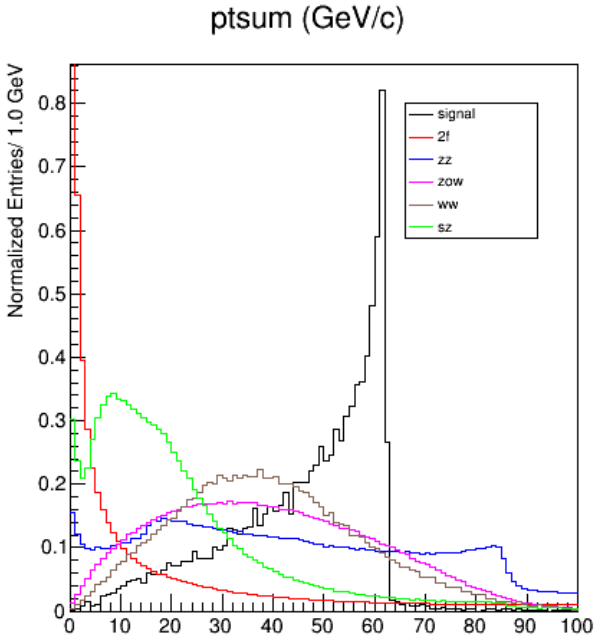
Particle reconstruction: arbor_v1

InvMass	di-moun’s invariant mass
RecMass	di-moun’s recoil mass
Ptsum	Transverse momentums of di-muon system
Pzsum	Z direction momentums of di-muon system

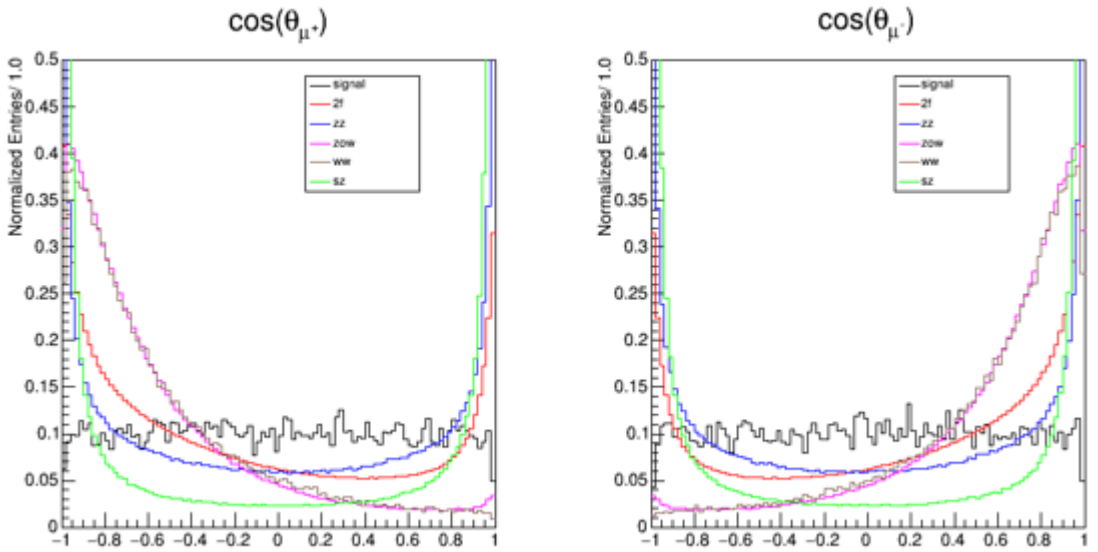


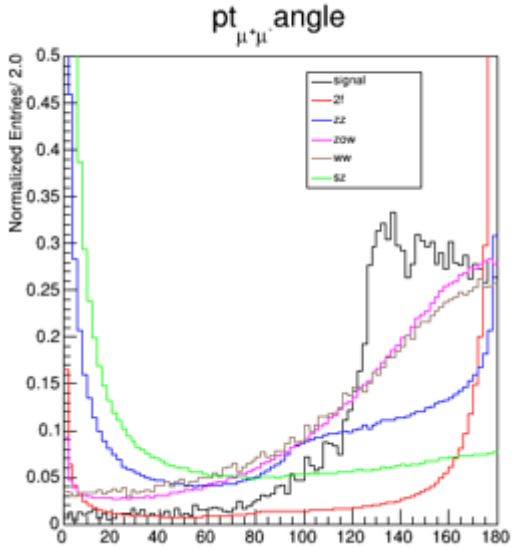






cosup	polar angle of μ^+
cosum	polar angle of μ^-
Ptuu	the angle between the muons' transverse momentums





Cut-base optimization

Divide the signal equally with random number.

Part A : Find sections.

Part B : Get test result.

All vars in Part A:

Z=S/sqrt(S+B)

Pre-section

Find the max Z

Section (End:Z_{old}>Z or ($cutL_{old}$-cutL)<e)

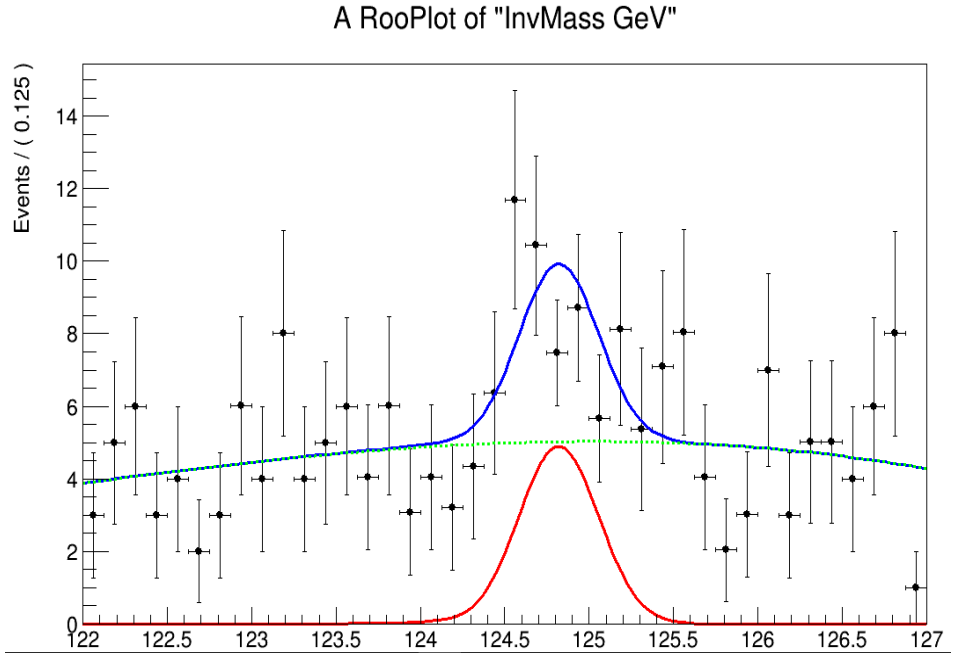
Part B: test and fit

Nsig : 250,000 fb^{-1}

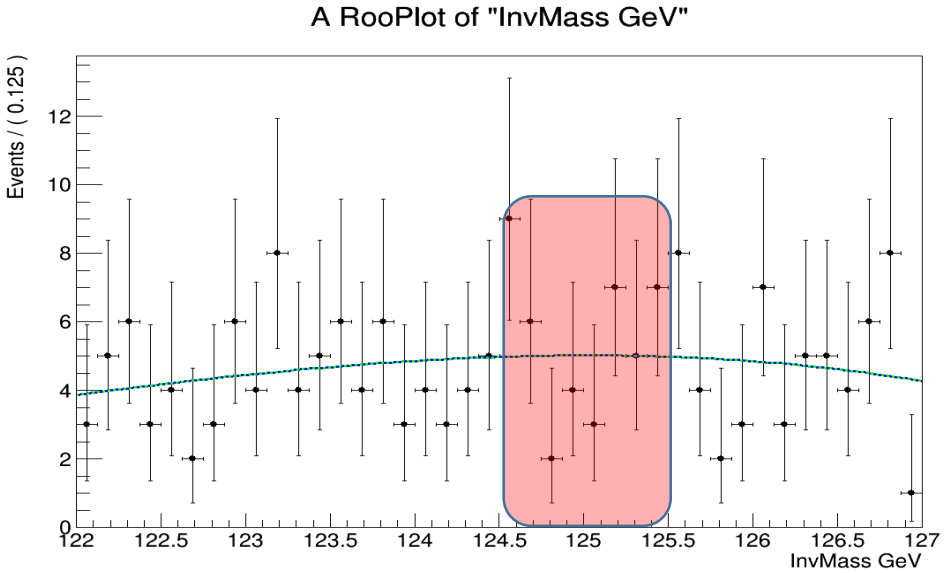
Nbkg : 5000 fb^{-1}

L=5000	zz	zzorww	sz	ww	2f	bg	signal
pre-section	390775	463361	101164	183751	9217194	10356245	217.64
122<Hmass<127	4653	31617	1130	9016	96095	142511	196.77
90.7<Recoilmass<92.5	466	769	65	318	436	2054	110.29
-55<Pzsum<52	363	607	47	226	141	1384	96.73
29.2<Ptsum<62	322	526	42	191	128	1209	91.18
-0.29<cosup<1	155	74	15	16	46	306	56.62
-1<cosum<0.20	113	40	9	9	31	202	48.93
0<arguu<178	112	40	9	9	17	187	47.75

cut	L	R	L	R	L	R	L	R
InvMass	122.0	127.0	122.0	127.0	122.0	127.0	122.0	127.0
RecMass	90.7	92.5	90.6	92.4	90.6	92.4	90.6	92.4
Pzsum	-55.0	54.0	-53.0	53.0	-55.0	56.0	-55.0	53.0
Ptsum	30.0	62.0	31.6	62.0	27.6	62.0	29.2	62.0
cosup	-0.27	1.00	-0.17	1.00	-0.27	1.00	-0.27	1.00
cosum	-1.00	0.17	-1.00	0.17	-1.00	0.20	-1.00	0.17
Ptuu	0.0	178.0	0.0	178.0	0.0	178.0	0.0	178.0
fb	580.0		562.7		460.0		570.0	
fb+fs	584.2		567.2		464.0		575.0	
Significance	2.43		2.54		2.35		2.71	
Nsig	47.7		48.1		45.3		48.0	
Nsig_fit	23.4±8.3		21.4±8.0		18.7±7.6		22.3±8.1	
Nbkg	187		182		155		184	



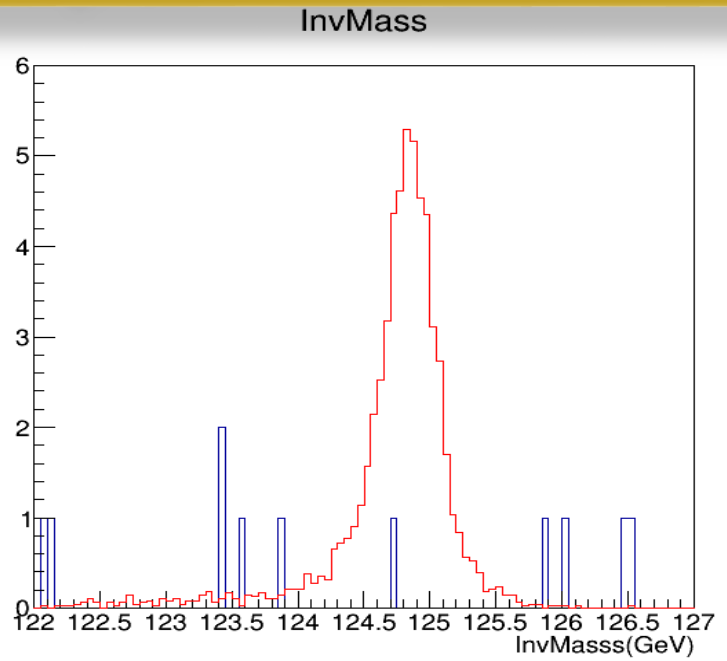
Thrid order Chebychev for Background pdf
Gauss for Signal pdf



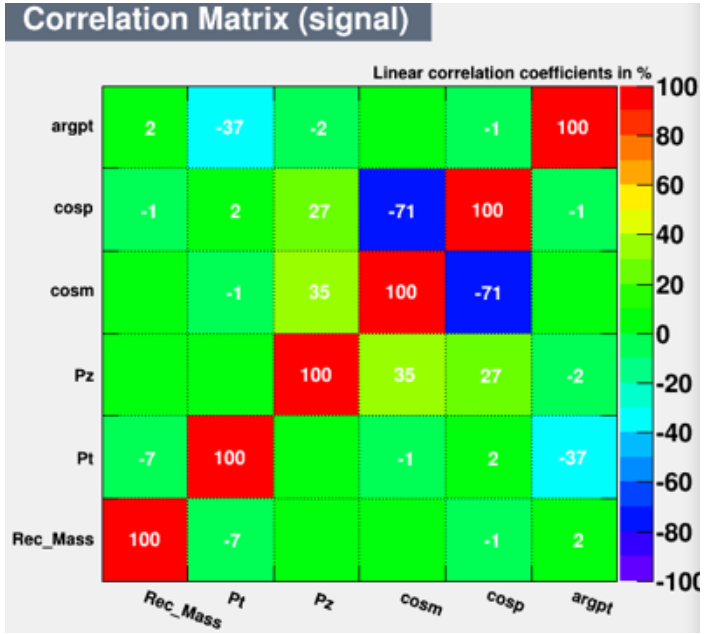
BDT optimization

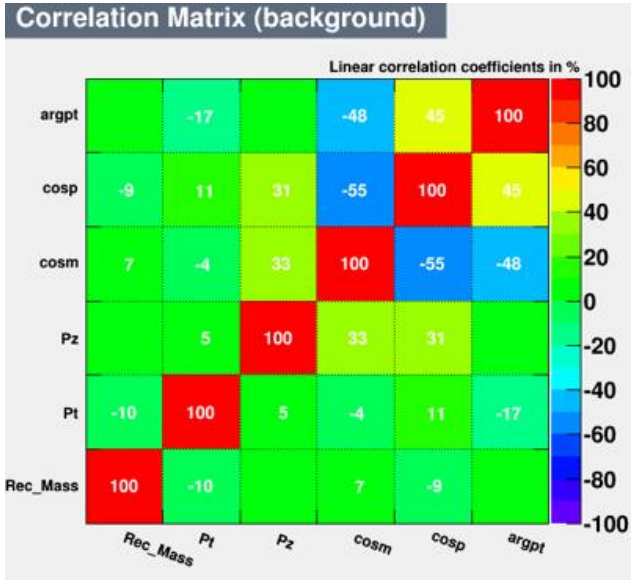
RecMass
Ptsum
Pzsum
cosum
cosup
Ptuu

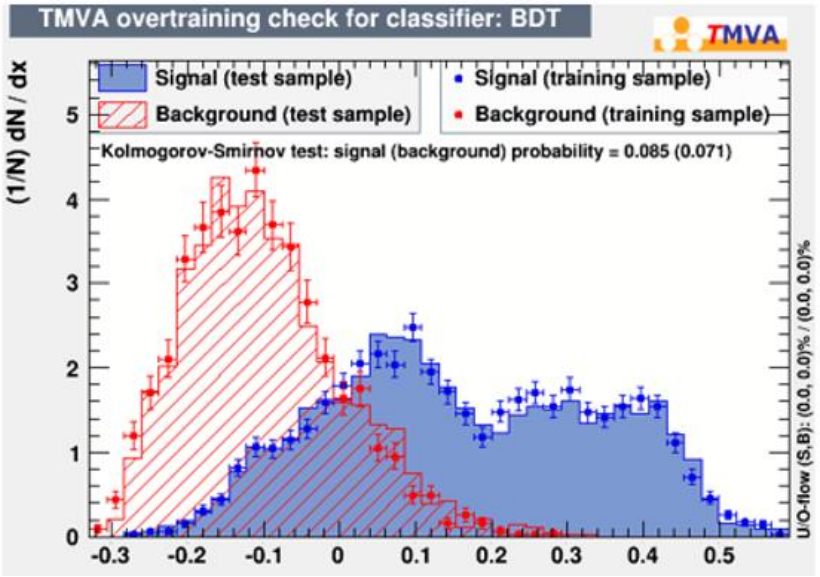
InvMass
BDT

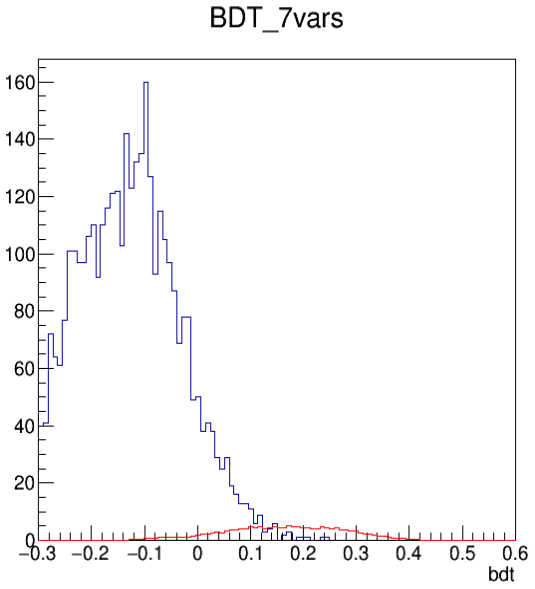


bdt>0.24
Nsig=59
Nbkg=11

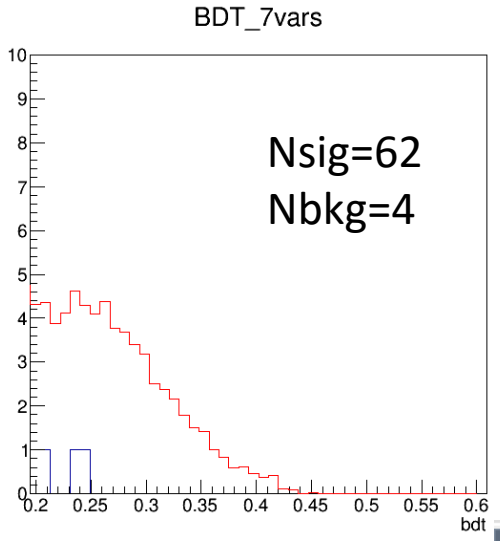






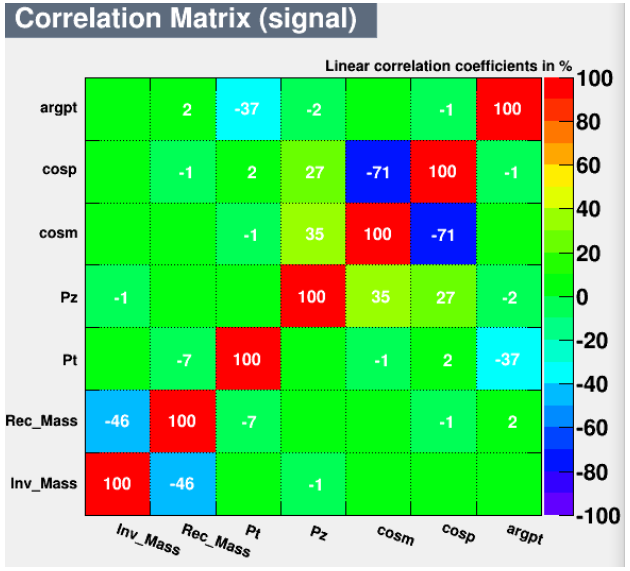


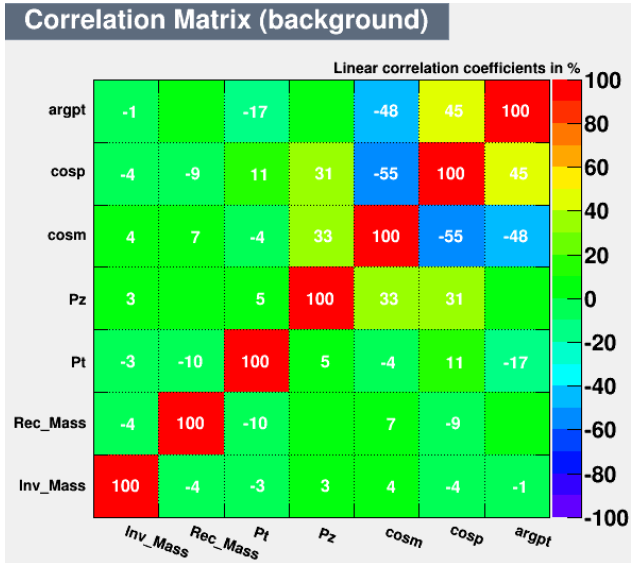
bdt>0.2

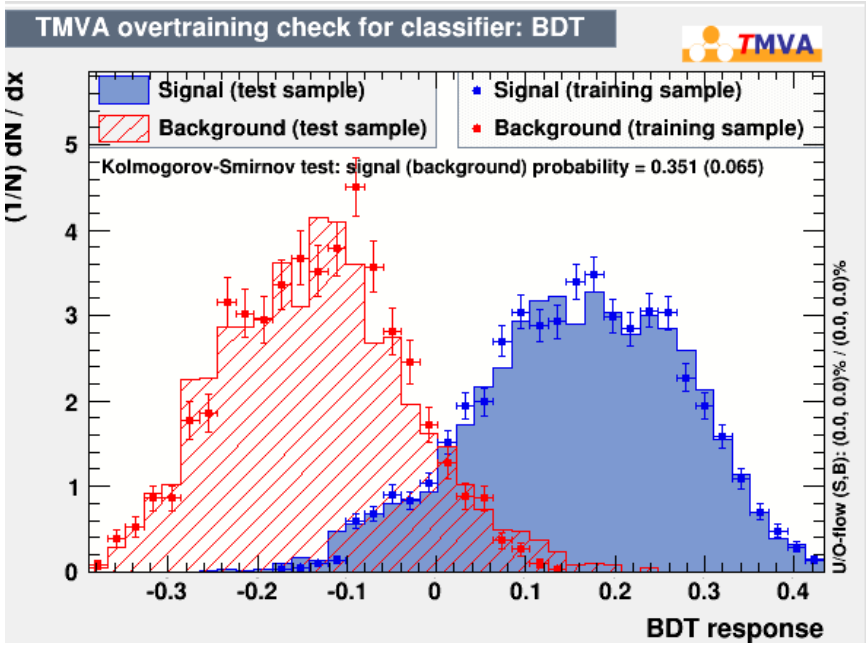


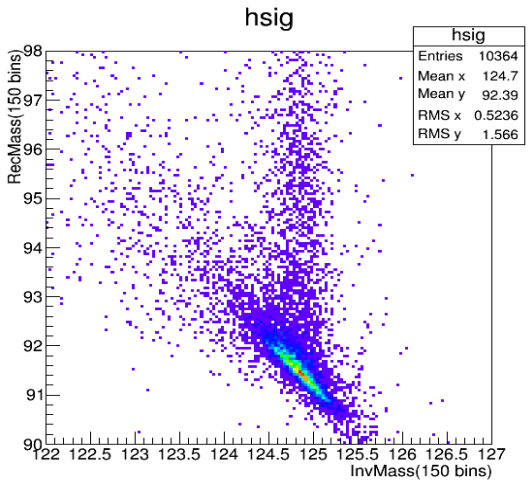
The important variables

- InvMass
- RecMass
- cosum
- cosup









Smooth(1)
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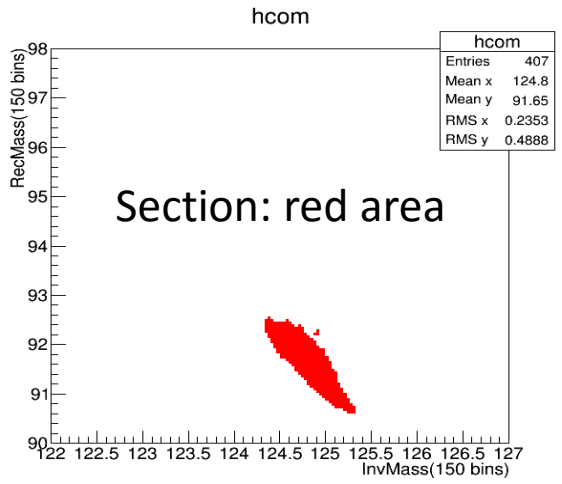
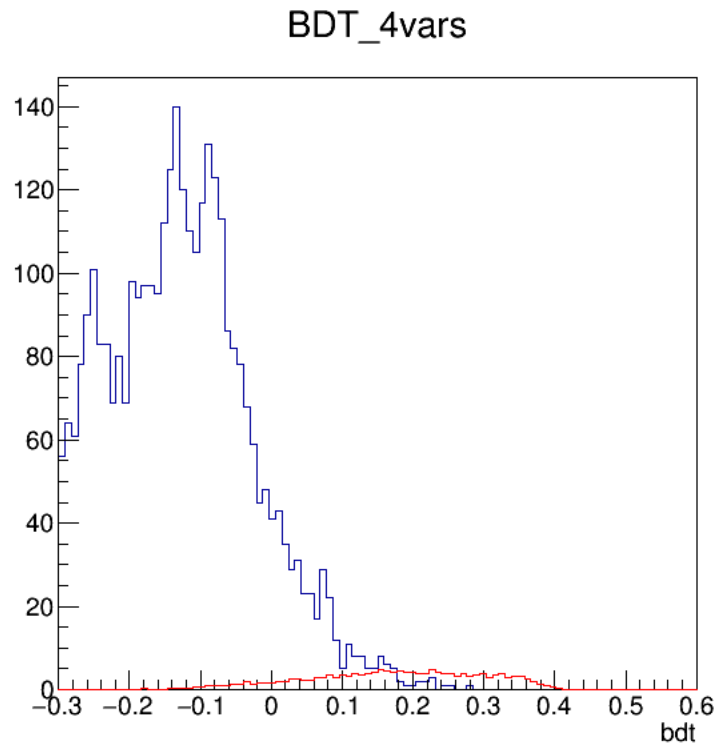
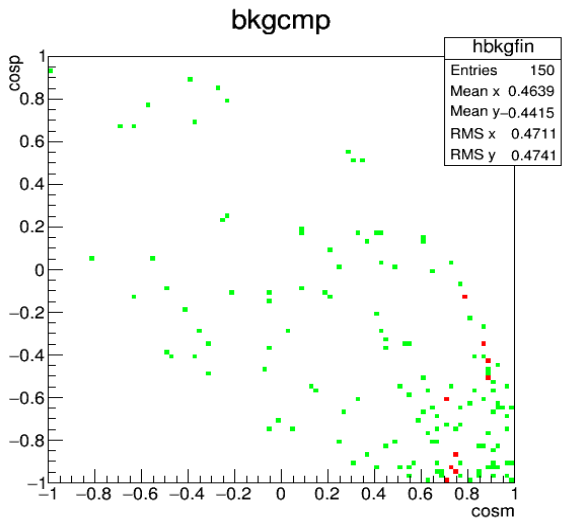
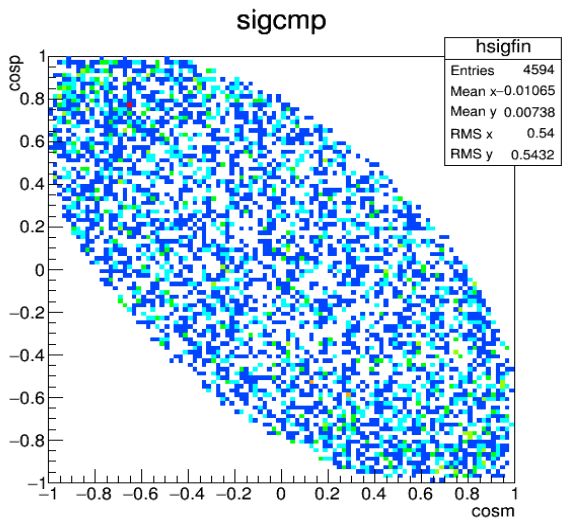




cosum<0.38
cosup>-0.38

Nbkg=27
Nsig=52





bdt>0.2
Nsig=71.3
Nbkg=10

bdt>0.25
Nsig=48.3
Nbkg=2

pre-section	217.7	10356245
124.2<Hmass<125.5	163.2	30050
90.7<Recoilmass<92.5	105.6	419
-55<Pzsum<52	93.3	290
29.2<Ptsum<62	88.5	269
-0.29<cosup<1	55.2	69
-1<cosum<0.20	47.5	48
0<arguu<178	46.5	42

pre-section	214.2	285346
32.3<(InvMass-RecMass)<34.2	98.4	7008
215.95<(InvMass+RecMass)<216.66	79.1	158
-0.88<(cosup+cosum)<0.87	78.9	157
-1.92<(cosup-cosum)<0.40	48.9	40
-62.1<pzsum<58.5	47.9	37
10.0<ptsum<62.4	47.6	37
0<Ptuu<178	46.5	34

Summary

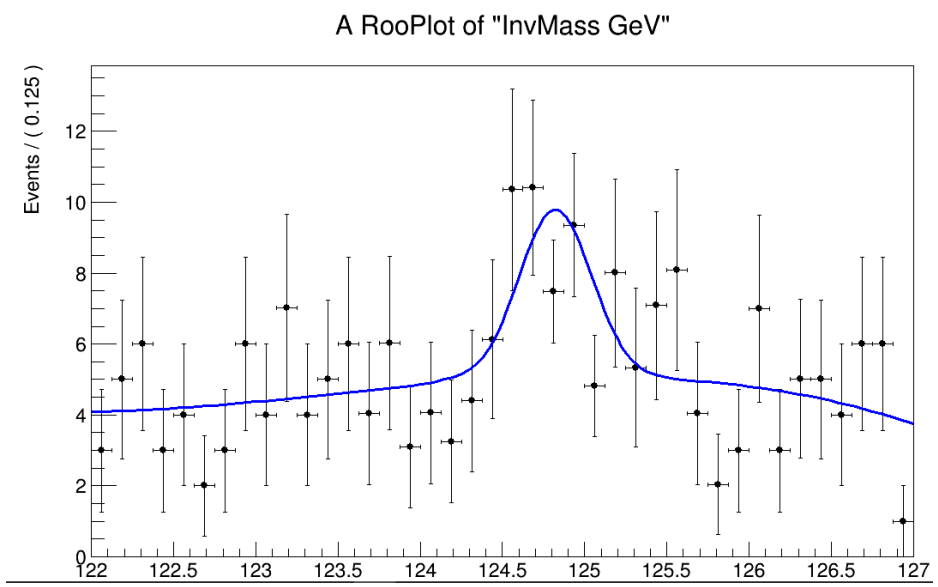
Higgs → $\mu^+ + \mu^-$ at CEPC

1 Cuts： Significance is less than 2.5

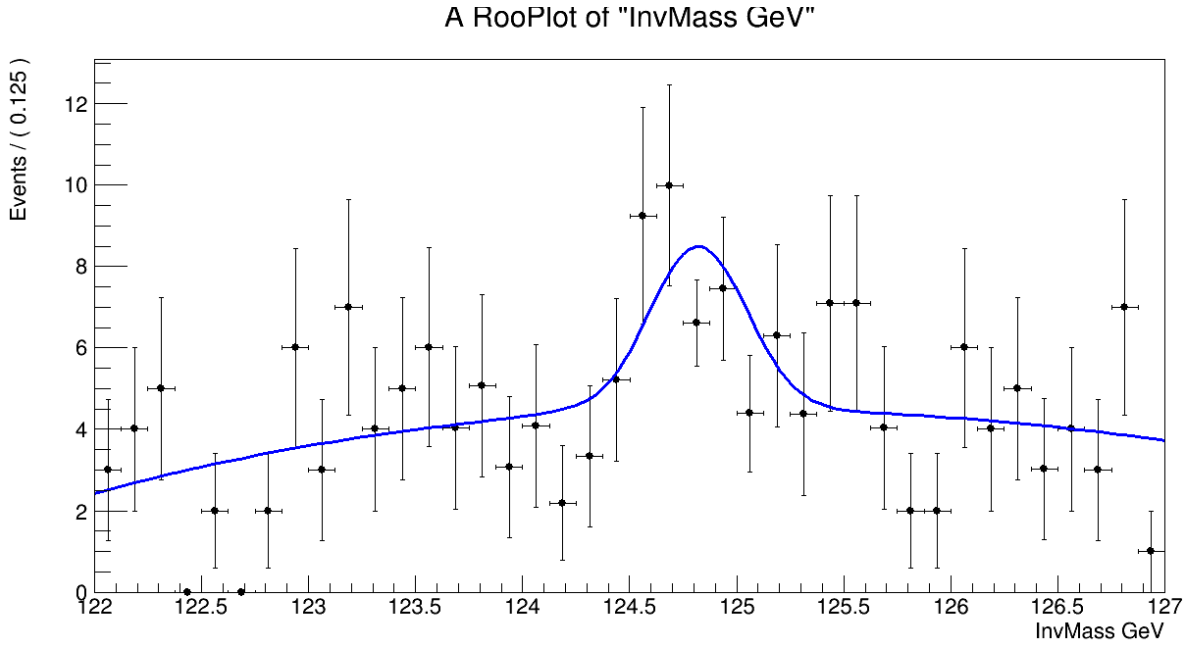
2 BDT: Signal and Background can be distinguished well

Back up

Cut2
182

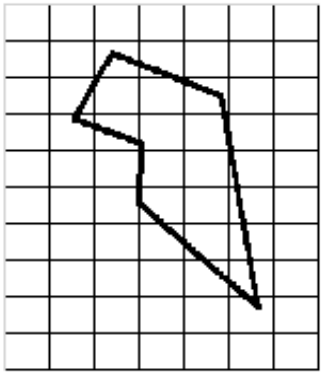


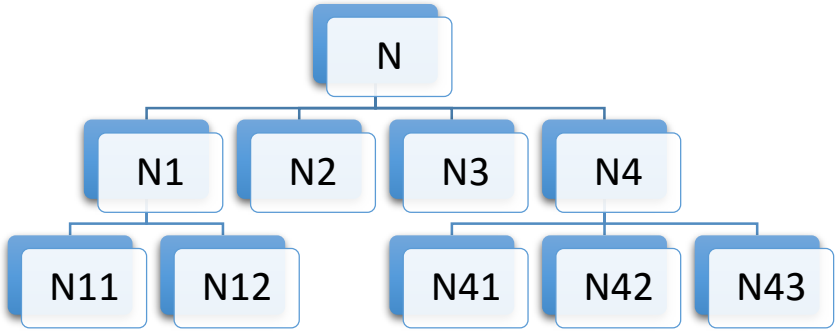
Cut3
155

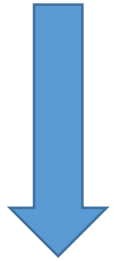


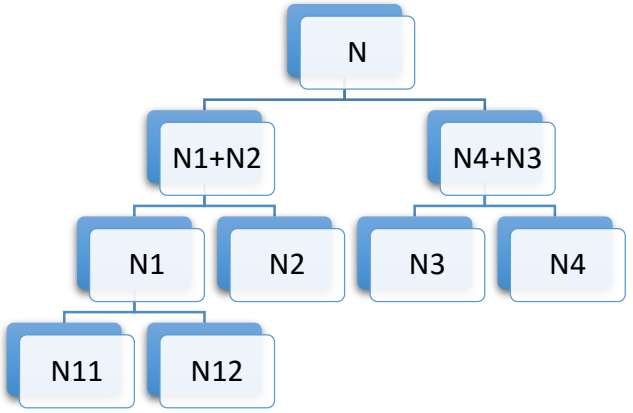
Rectangular Mesh Cut and DT

Decision tree's Construction





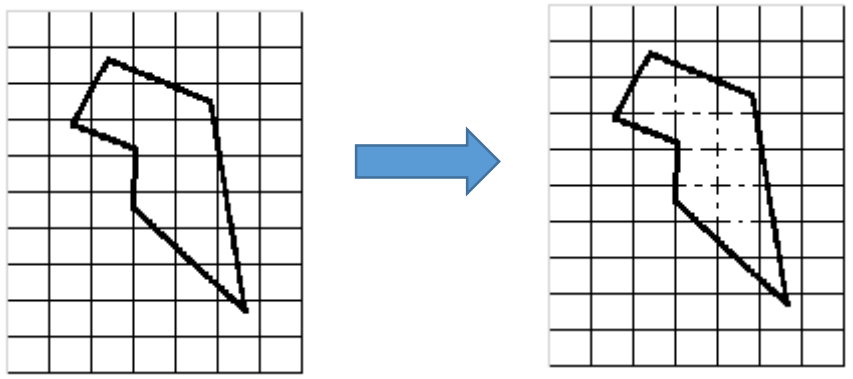


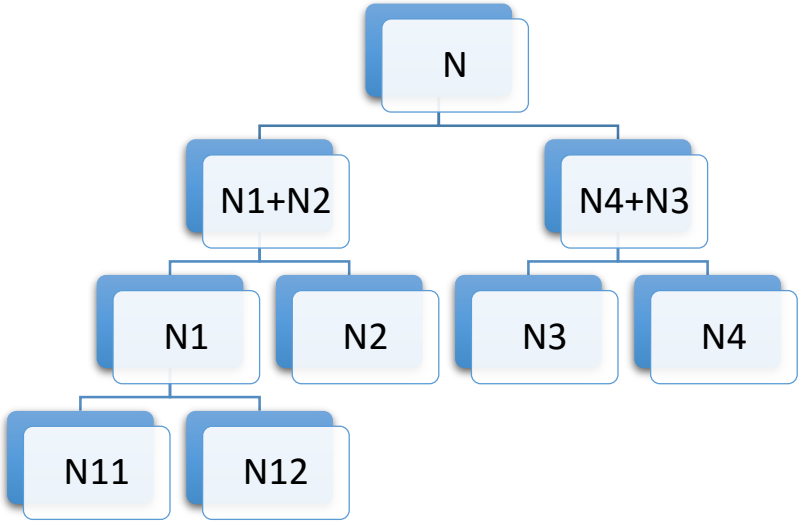


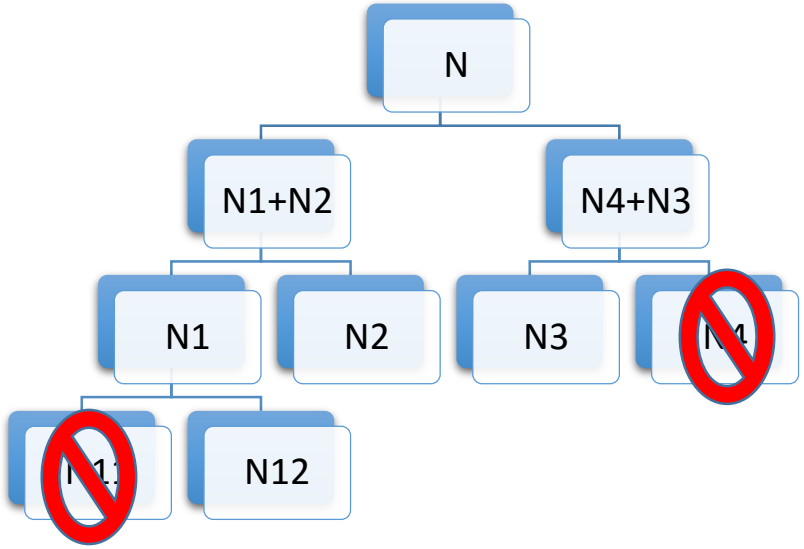
Ignore transformations

Rectangular Mesh Cut and DT

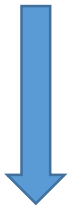
Decision tree's cut







Decision tree(DT)



Statistical fluctuation

1.Smooth
2.Random

Boosted Decision Trees(BDT)

So，

Describe the shape

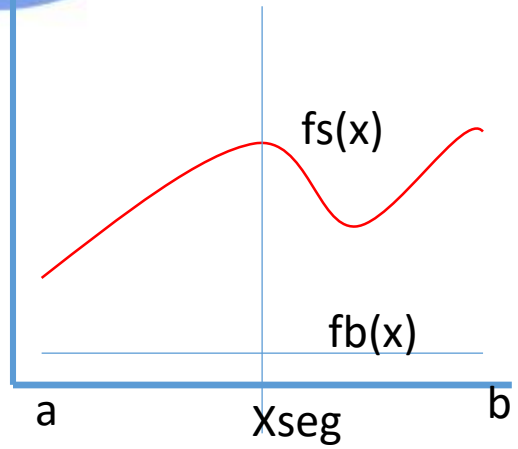
Rectangular or triangular mesh → FDM, BDT, FEA…

No mesh or background mesh And kore function → PDE approach, k-NN, MLM,…

Statistical fluctuation

Other methods or new methods

Decision tree



一组 (变量 + 阈值) 组合, 使得该节点的判别指数与它的两个子节点的判别指数的加权和的增量达到最大, 子节点的权值等于子节点的输入事例数除以母节点的输入事例数, 该增量 ΔI 用公式表示为

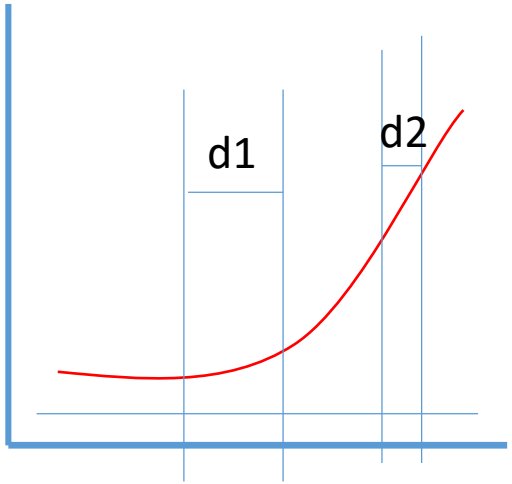
$$\Delta I = I - \left(\frac{n_1}{n_{\text{int}}} I_1 + \frac{n_2}{n_{\text{int}}} I_2\right), \qquad n_{\text{int}} = n_1 + n_2. \tag{4.2.6}$$

式中, I, I_1, I_2 分别为母节点和两个子节点的判别指数; n_{int}, n_1, n_2 分别为母节点和两个子节点的输入事例数.

fb(x) →0

Fs(a)=0

Xseg makes n1=n2



d1>d2

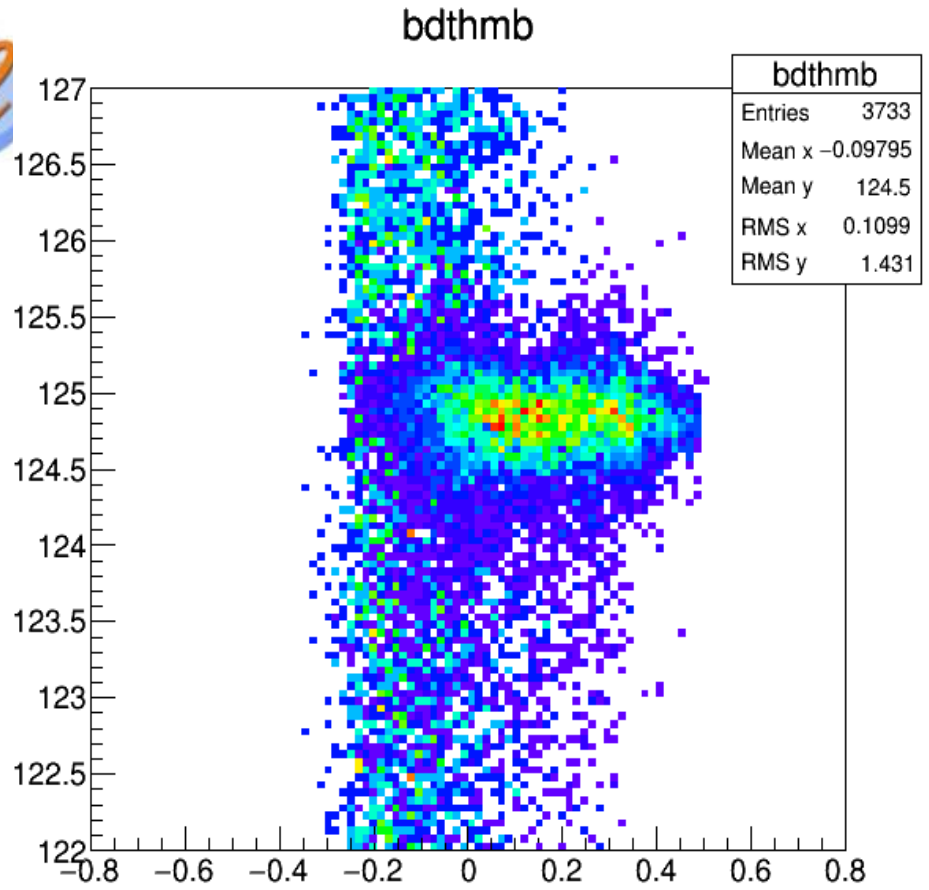
Adaptive Algorithm.

Reduce the overtraining effect.

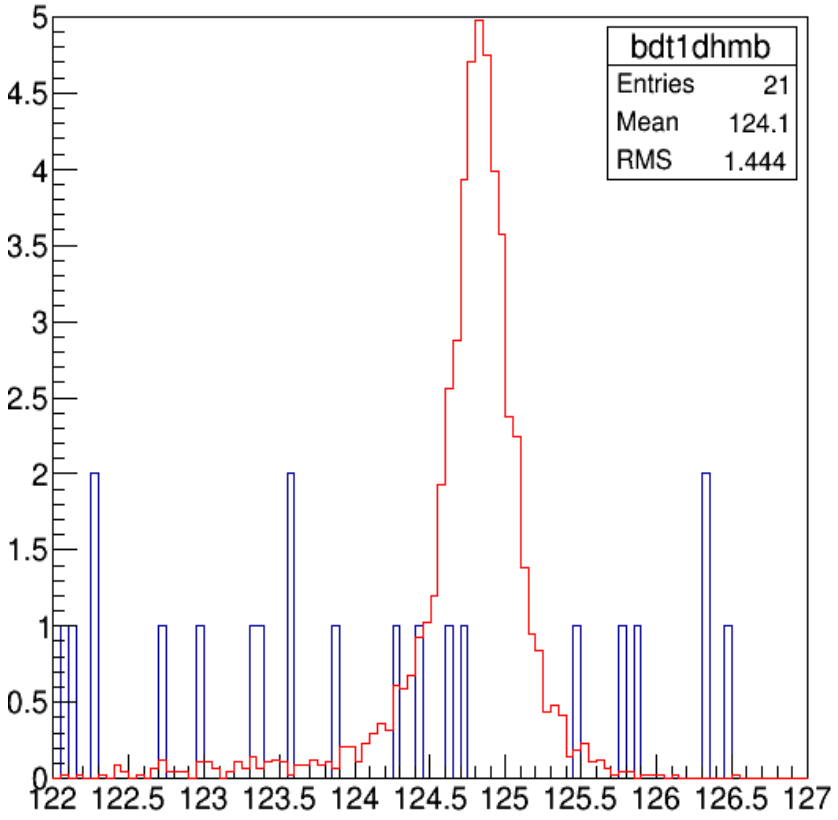
Like normal cut.

Regression

Multiclass

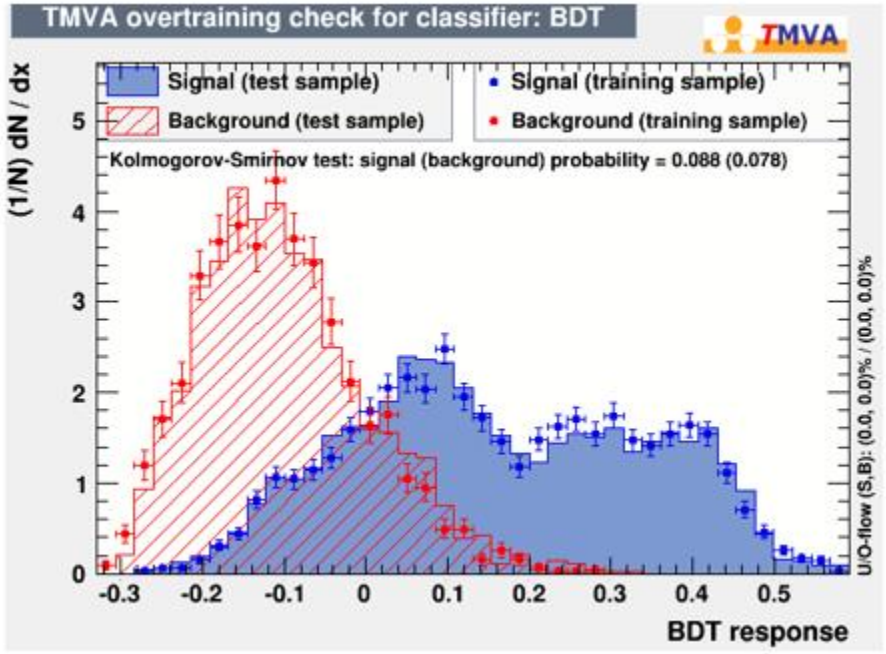


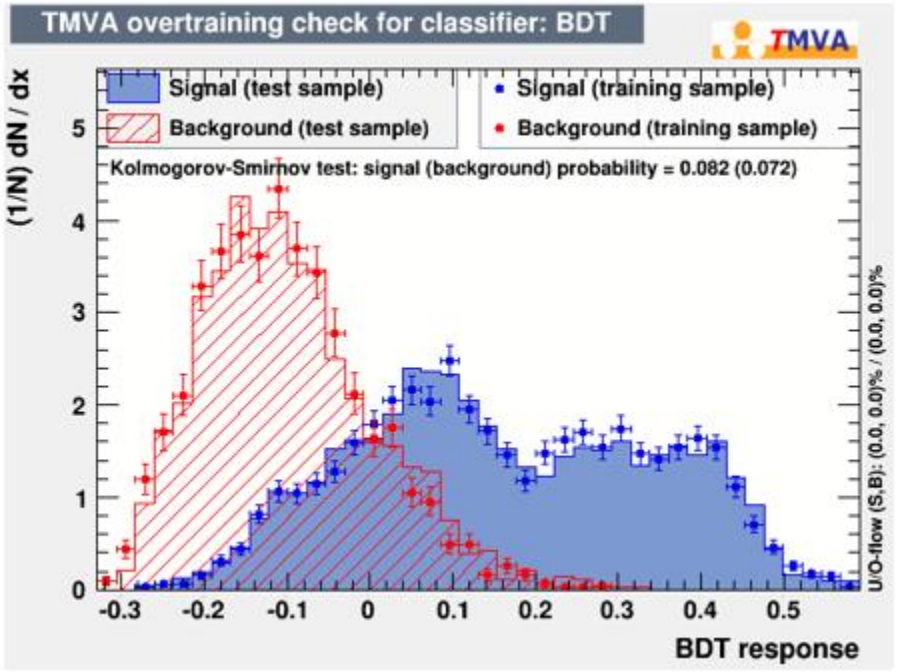
bdt>0.23



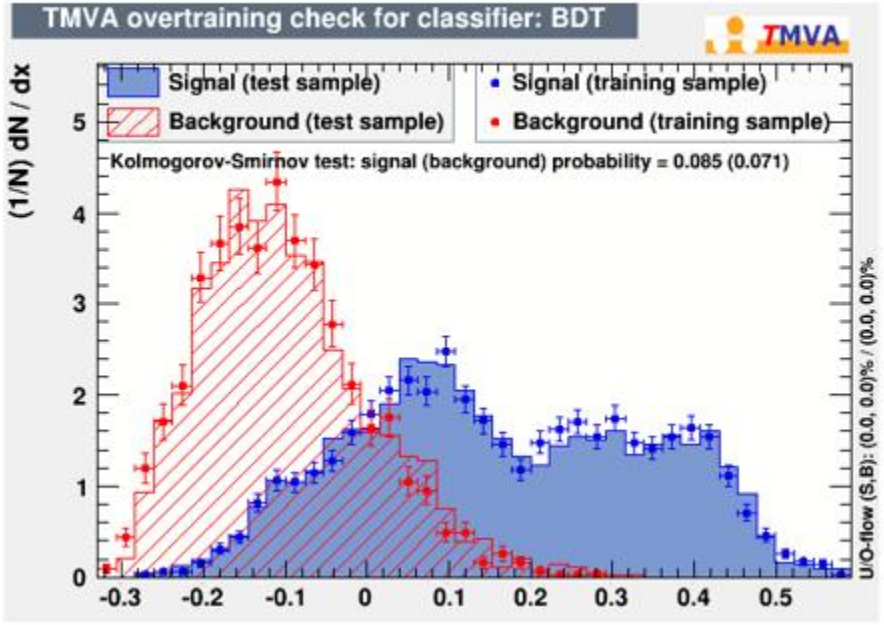
Signal： 59
BKG： 21

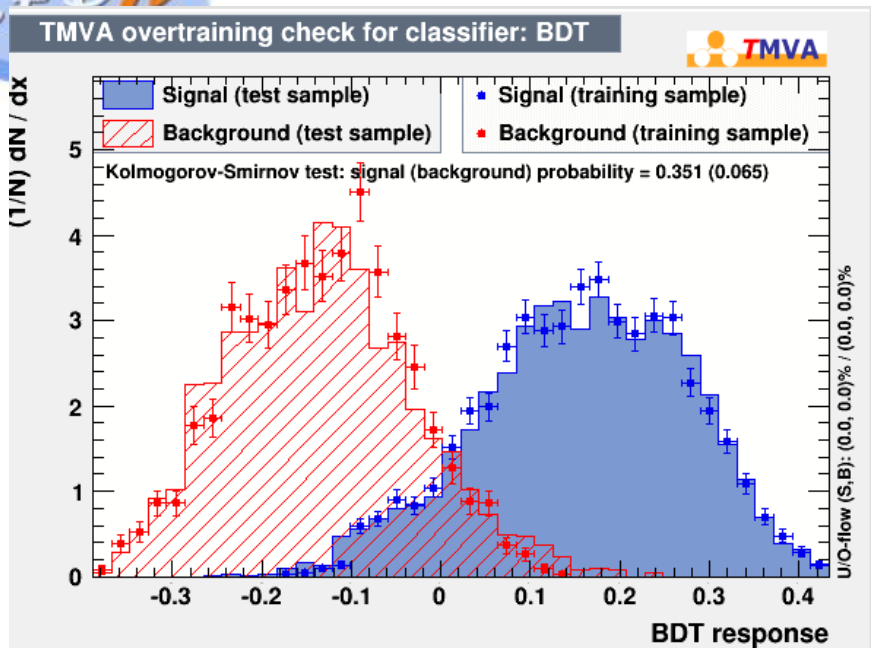
	L	R	L	R	L	R	L	R
InvMass	122.0	127.0	122.0	127.0	122.0	127.0	122.0	127.0
RecMass	90.7	92.5	90.6	92.4	90.6	92.4	90.6	92.4
Pzsum	-55.0	54.0	-53.0	53.0	-55.0	56.0	-55.0	53.0
Ptsum	30.0	62.0	31.6	62.0	27.6	62.0	29.2	62.0
cosup	-0.3	1.0	-0.2	1.0	-0.3	1.0	-0.3	1.0
cosum	-1.0	0.2	-1.0	0.2	-1.0	0.2	-1.0	0.2
Ptuu	0.0	178.0	0.0	178.0	0.0	178.0	0.0	178.0
fb								
fb+fs								
Significance								
Nsig								
Nsig_fit								

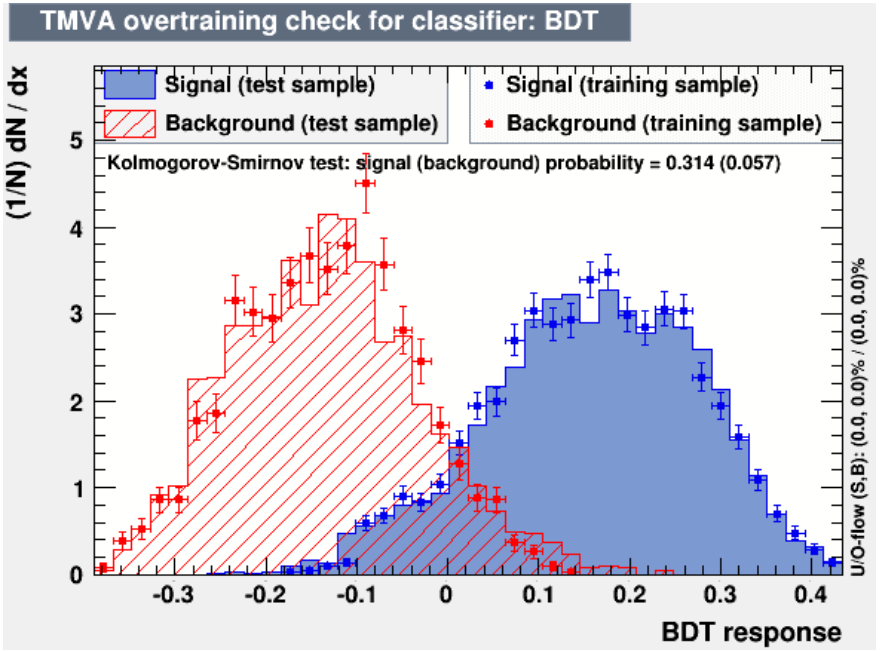

TMVA overtraining check for classifier: BDT
TMVA
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.088 (0.078)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDT response


TMVA overtraining check for classifier: BDT
TMVA
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.082 (0.072)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDT response

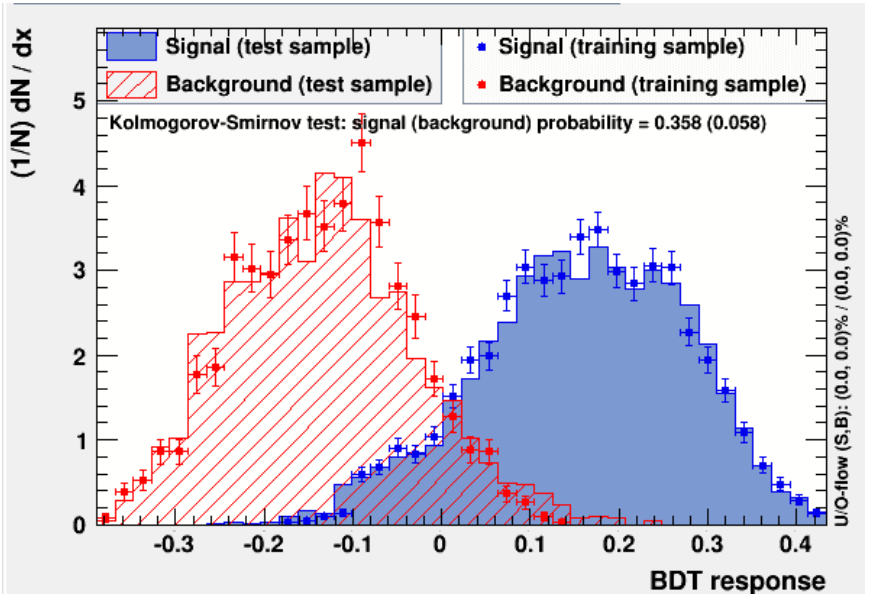
6vars


TMVA overtraining check for classifier: BDT
TMVA
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.085 (0.071)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%

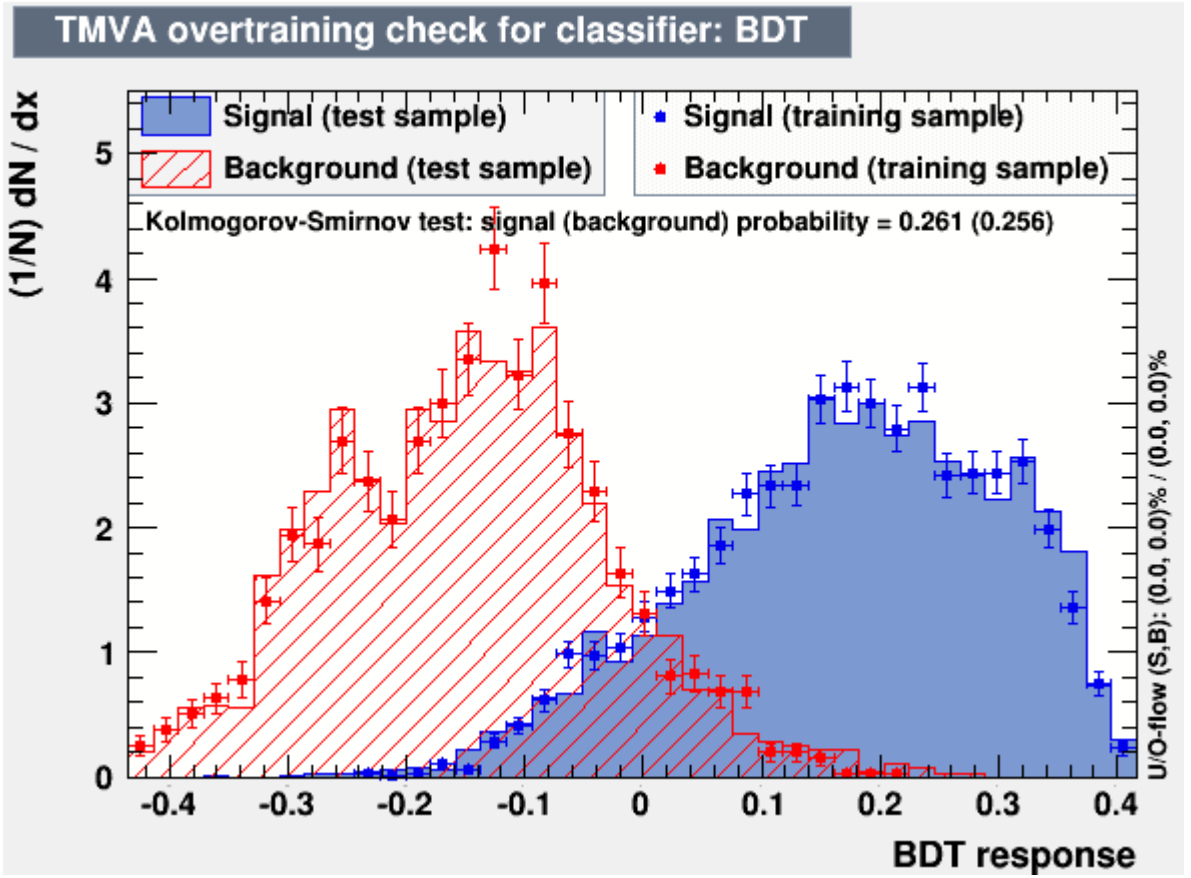

TMVA overtraining check for classifier: BDT
TMVA
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.351 (0.065)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDT response


TMVA overtraining check for classifier: BDT
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.314 (0.057)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDT response

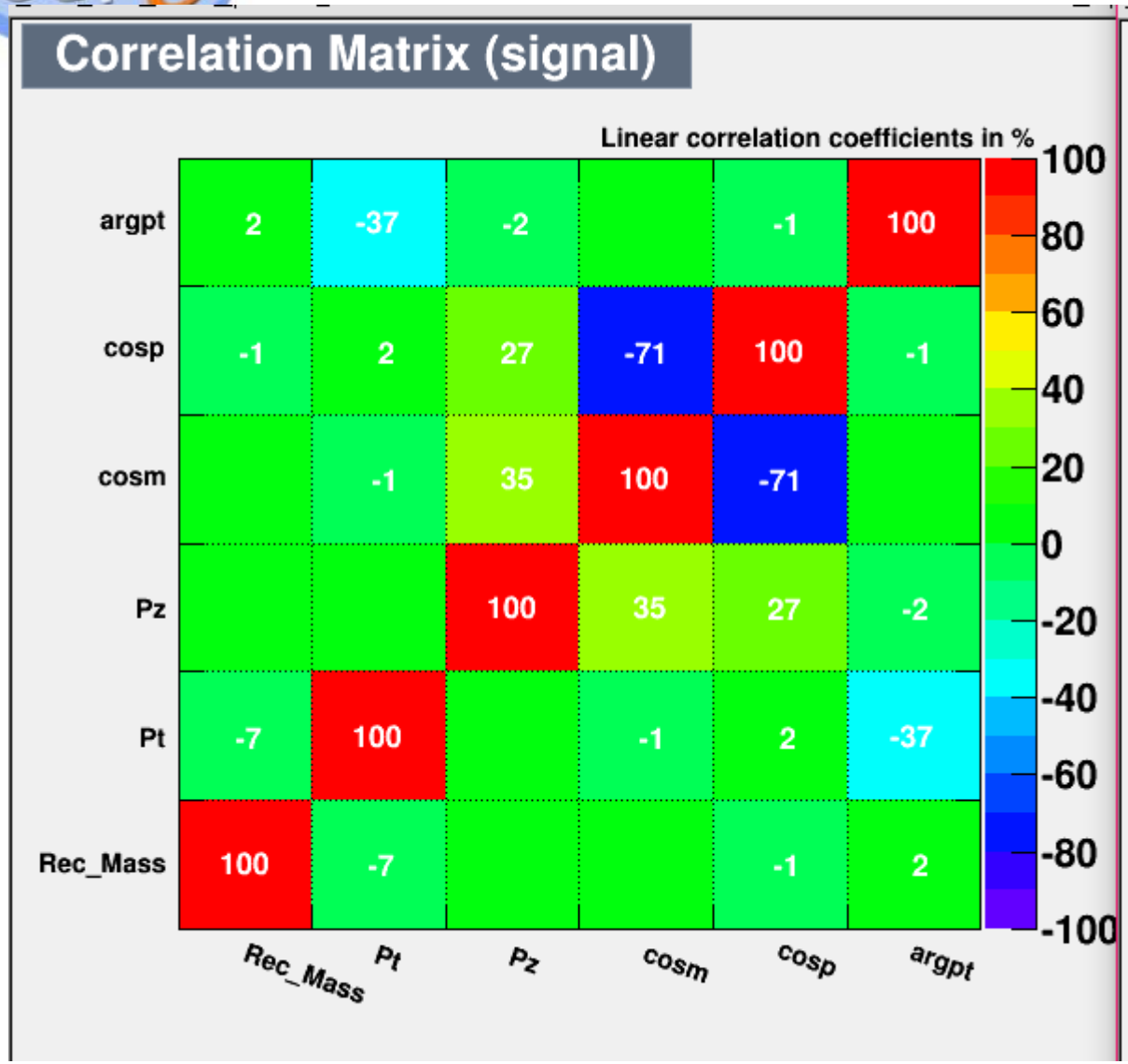
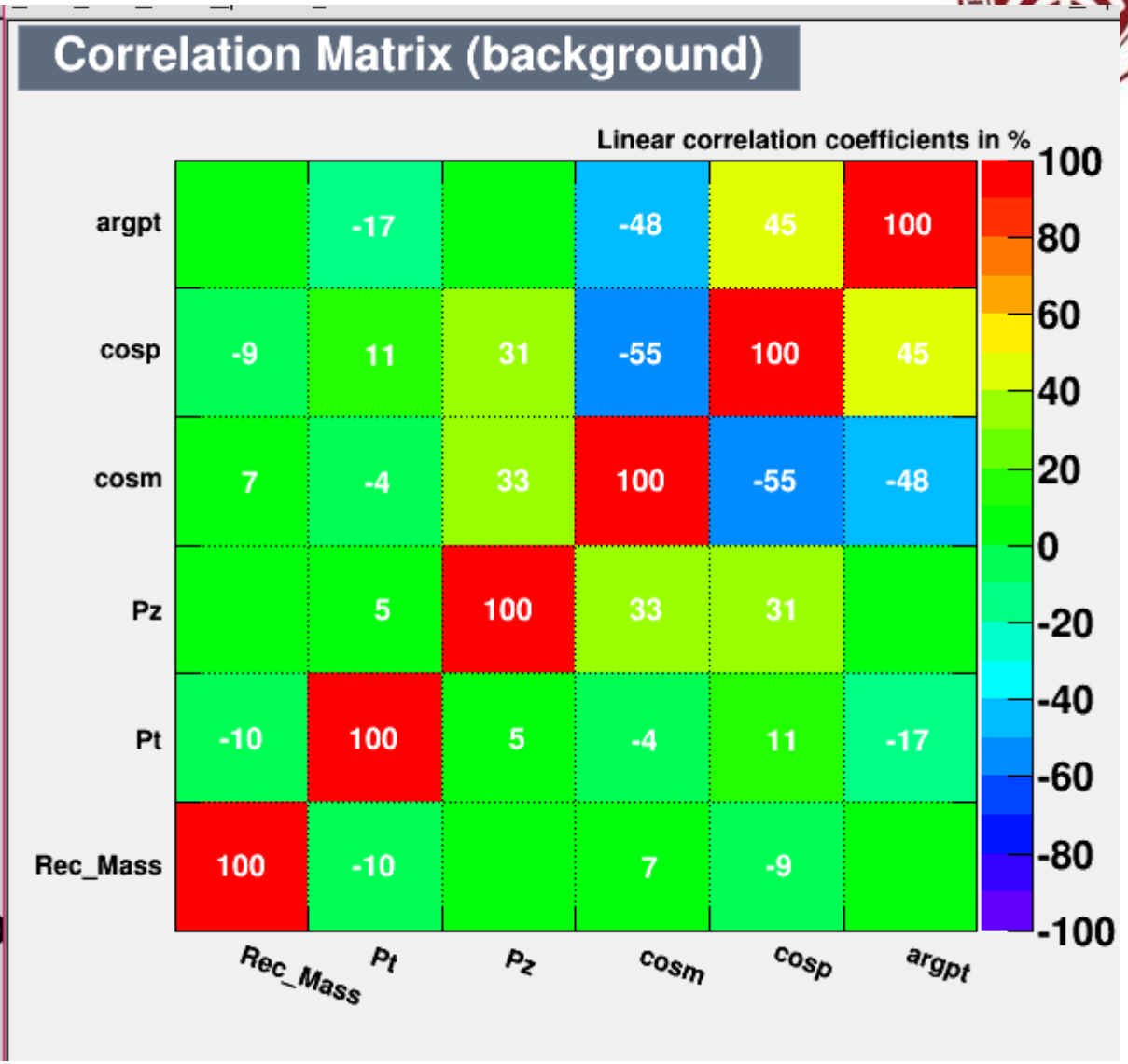
7vars


Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.358 (0.058)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDT response

4vars


TMVA overtraining check for classifier: BDT
Signal (test sample)
Background (test sample)
Signal (training sample)
Background (training sample)
Kolmogorov-Smirnov test: signal (background) probability = 0.261 (0.256)
(1/N) dN / dx
U/O-flow (S,B): (0.0, 0.0)% / (0.0, 0.0)%
BDT response
0
1
2
3
4
5
-0.4
-0.3
-0.2
-0.1
0
0.1
0.2
0.3
0.4

Correlation Matrix (signal)



Correlation Matrix (background)