Model independent searches for extra scalars produced in association to a Z boson at the ILC

Teresa Núñez - DESY

- Previous studies
- Current analysis:
  - motivation
  - analysis flow
  - preliminary results
- Conclusions and outlook

ILD Software and Analysis Meeting (2-10-24)

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Previous studies

Higgs factories are specially suited for searching at new scalars in the process $e^+e^- \rightarrow ZS^0$

Model independent searches are based on the recoil of the new scalar against the Z

Independent fo the S^0 decay mode

Studies were performed using the full detector simulation and reconstruction procedures of the ILD at the ILC for $\sqrt{s}$ = 250/500 GeV

- Detector and beam conditions were not the current ones
- Focused on the decay of the Z to two muons

arxiv:1902.06118

arxiv:2005.06265

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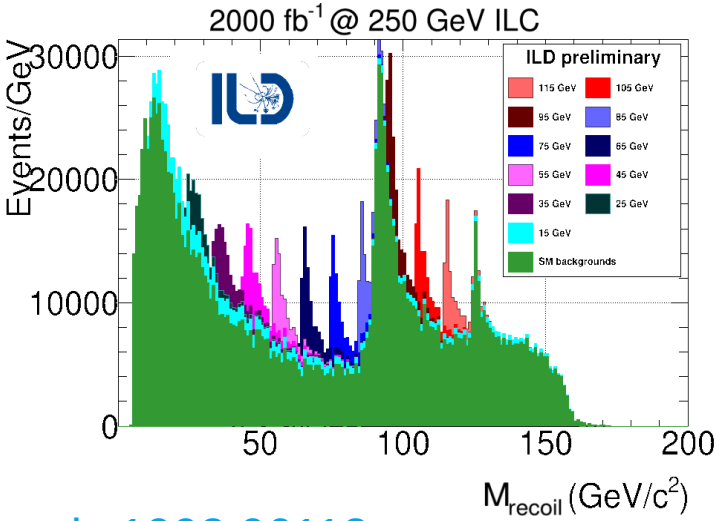
Previous studies (ctd.)



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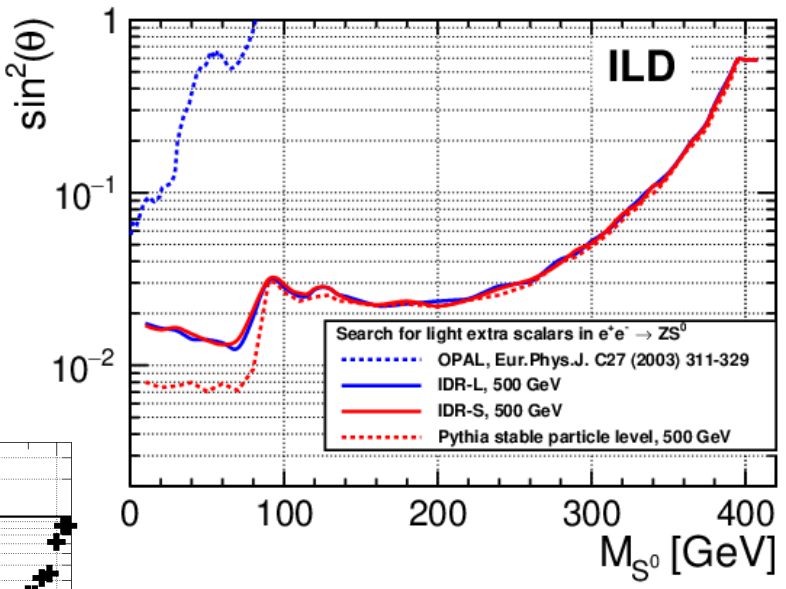
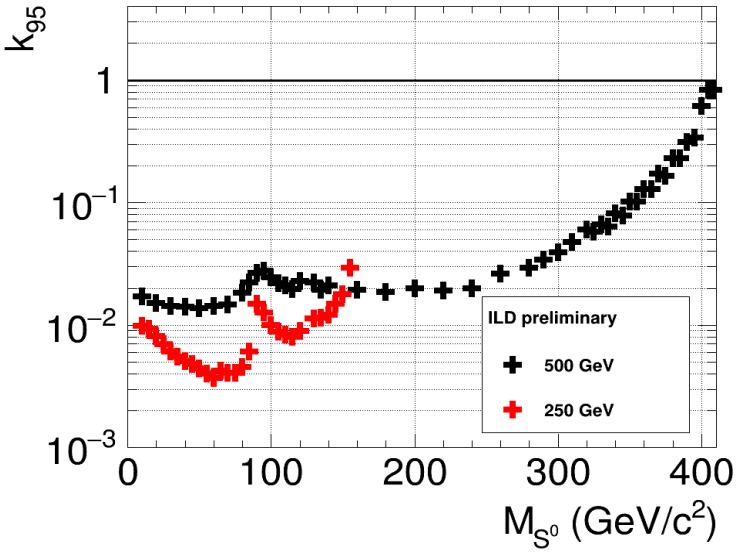
$e^+e^- \rightarrow Z' \rightarrow ZS^0 \rightarrow \mu^+\mu^- S^0$





Expected sensitivities at 95% CL for the cross section scale factor with respect to the SM Higgs,$\sin^2(\theta)$, for scalars masses between 10 and 410 GeV

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Motivation and conditions current studies

Reimplementation of previous analysis with current experimental conditions and full simulation software

Full detector simulation and reconstruction procedures of the ILD at the ILC for $\sqrt{s}$ = 250 GeV

Different Z decays modes want to be covered

Samples:

- Background using new SM 250 GeV samples generated with Whizard v.2.8.5, the SetA beam-spectrum, simulation and reconstruction with the ILD_l5_o2_v02 model, and ILCSoft v02-02-01
- Signal generated with Whizard v.2.8.5, the SetA beam-spectrum, detector simulation done by sgv.

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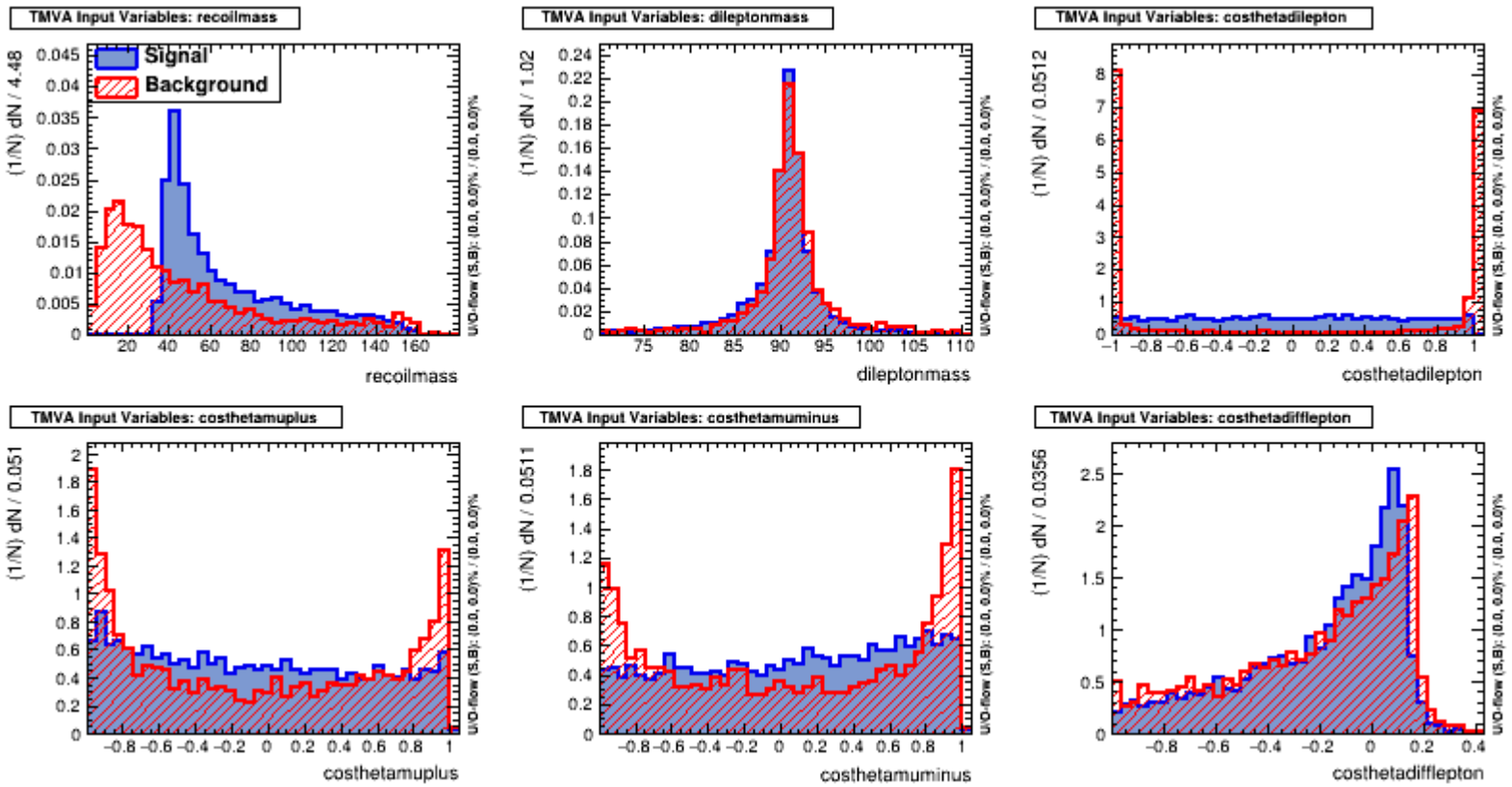
Event selection

$e^+e^- \rightarrow Z' \rightarrow ZS^0 \rightarrow \mu^+\mu^- S^0$

- Identification of ISR photons (IsolatedPhotonTaggingProcessor)
- Select events without high-energetic ISR photon:
  - none or $E\gamma < 100$ GeV for $|\cos\theta| < 0.95$ or $E\gamma < 75$ GeV for $|\cos\theta| > 0.95$
- Identification of isolated leptons (IsolatedLeptonTaggingProcessor)
- Select events with two isolated muon candidates and di-muon and recoil masses in defined ranges
  - $M_{\mu^+\mu^-} \in [M_z - 40, M_z + 40]$, $M_{rec} \in [0,250]$ GeV
- Perform isolated lepton pairing (LeptonPairing)
- Cuts on kinematic variables (FSR corrections applied), accepted if
  - $M_{\mu^+\mu^-} \in [70, 110]$ GeV
  - $P^T_{\mu^+\mu^-} \in [0, 120]$ GeV
- Cuts on output of two BDTGs, 2f-MTVA and 4f-MTVA, trained against 2 fermion and 4 fermion backgrounds, respectively.
  - Input variables: M_{recoil}, $M^{FSR}_{\mu^+\mu^-}$, $\cos\theta^{FSR}_{\mu^+}$, $\cos\theta^{FSR}_{\mu^-}$, $\cos\theta^{FSR}_{\mu^+\mu^-}$, $\cos\theta\mu - \mu^{FSR}$, $\pi - (\phi_{\mu^+} - \phi_{\mu^-})$
  - cut limits depends on scalar mass
- Additional cut on M_{recoil} depending on M_{scalar}

Training against 2f background (2f-mtva)

Exotic Scalar mass 40 GeV



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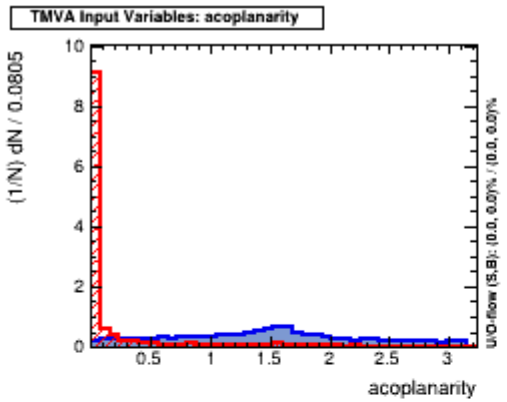

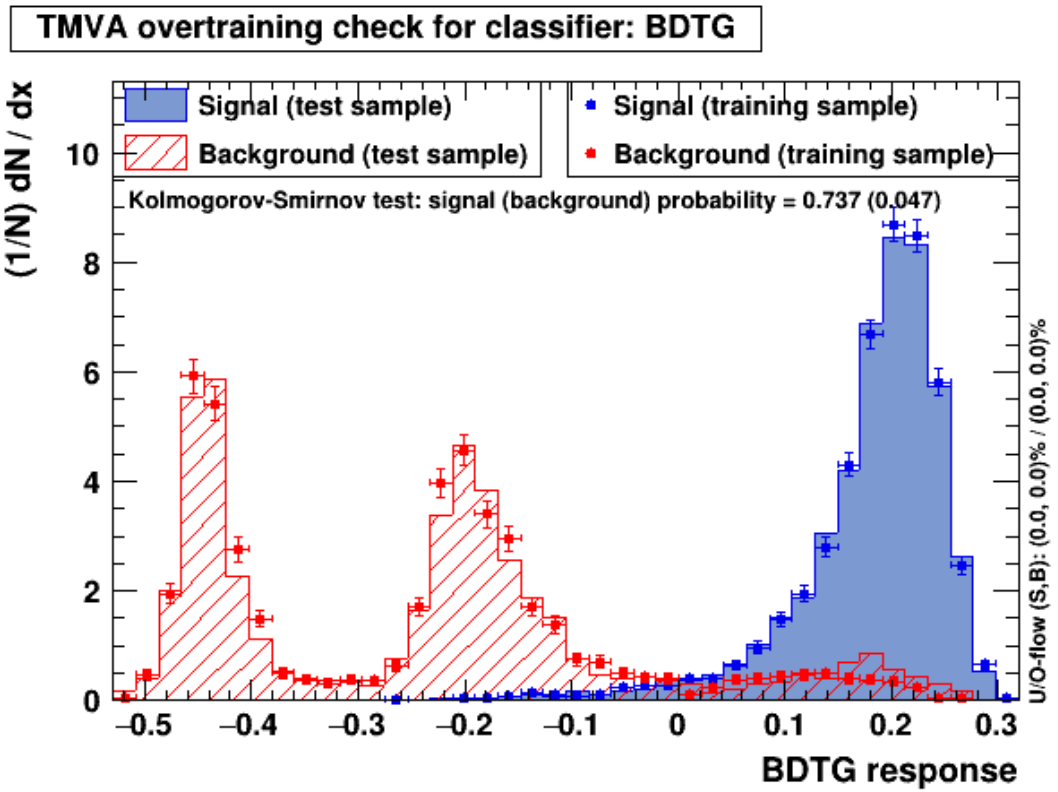

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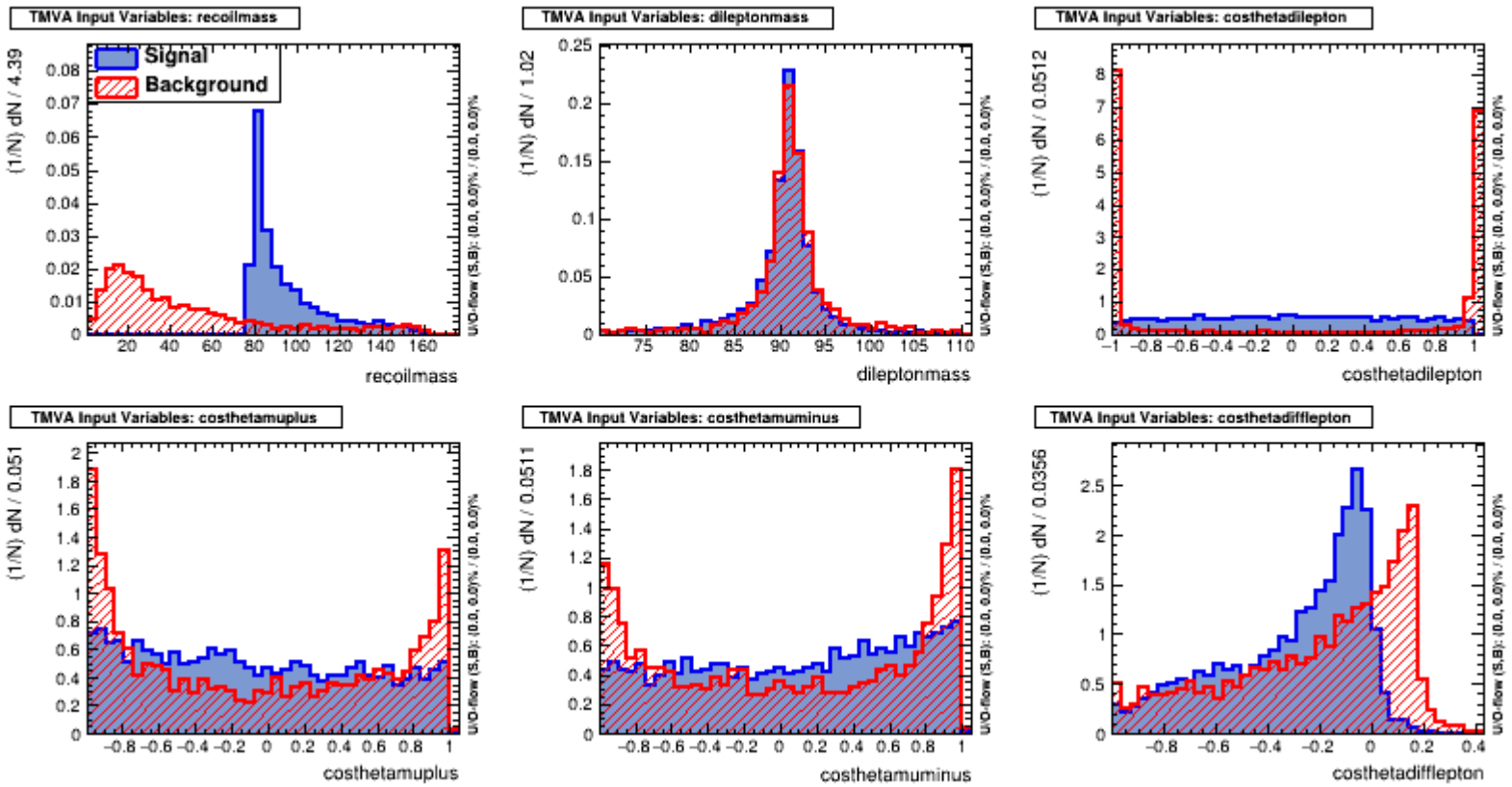

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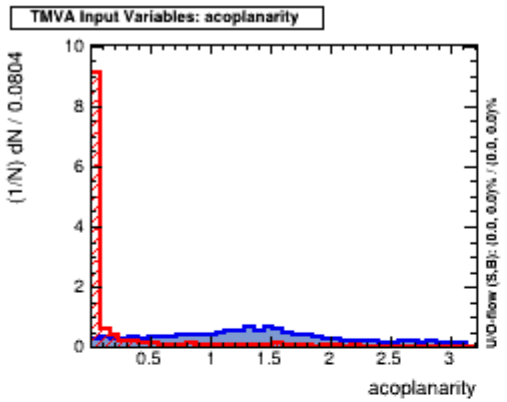

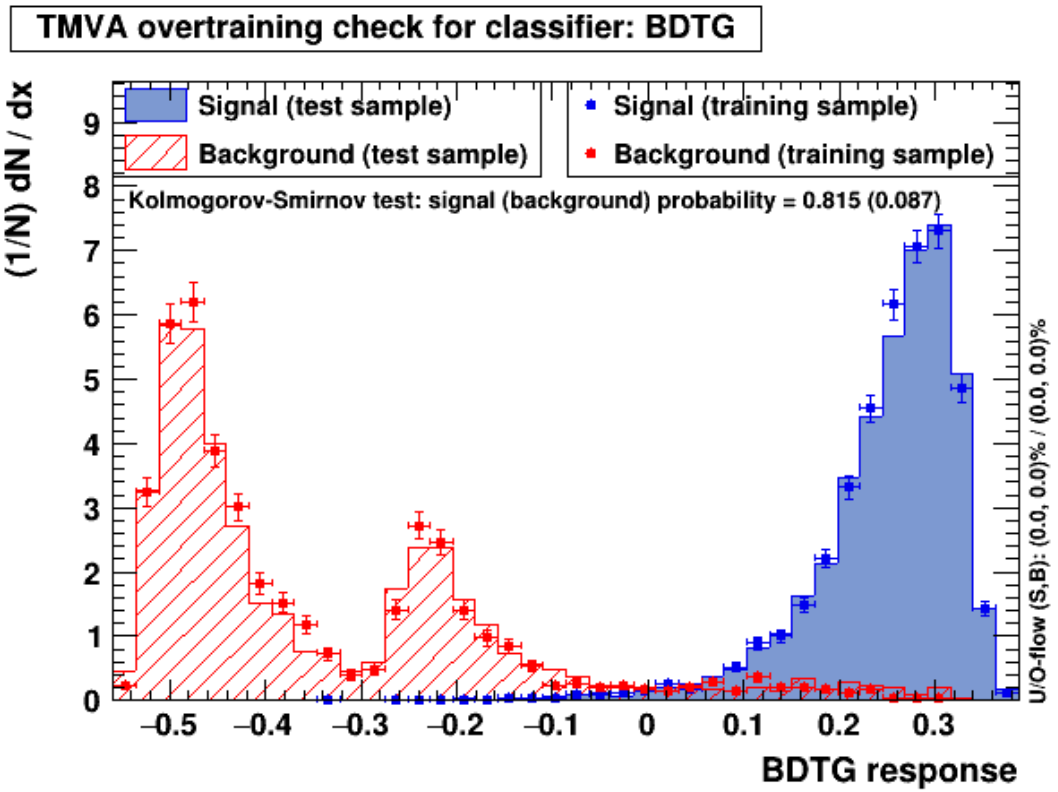

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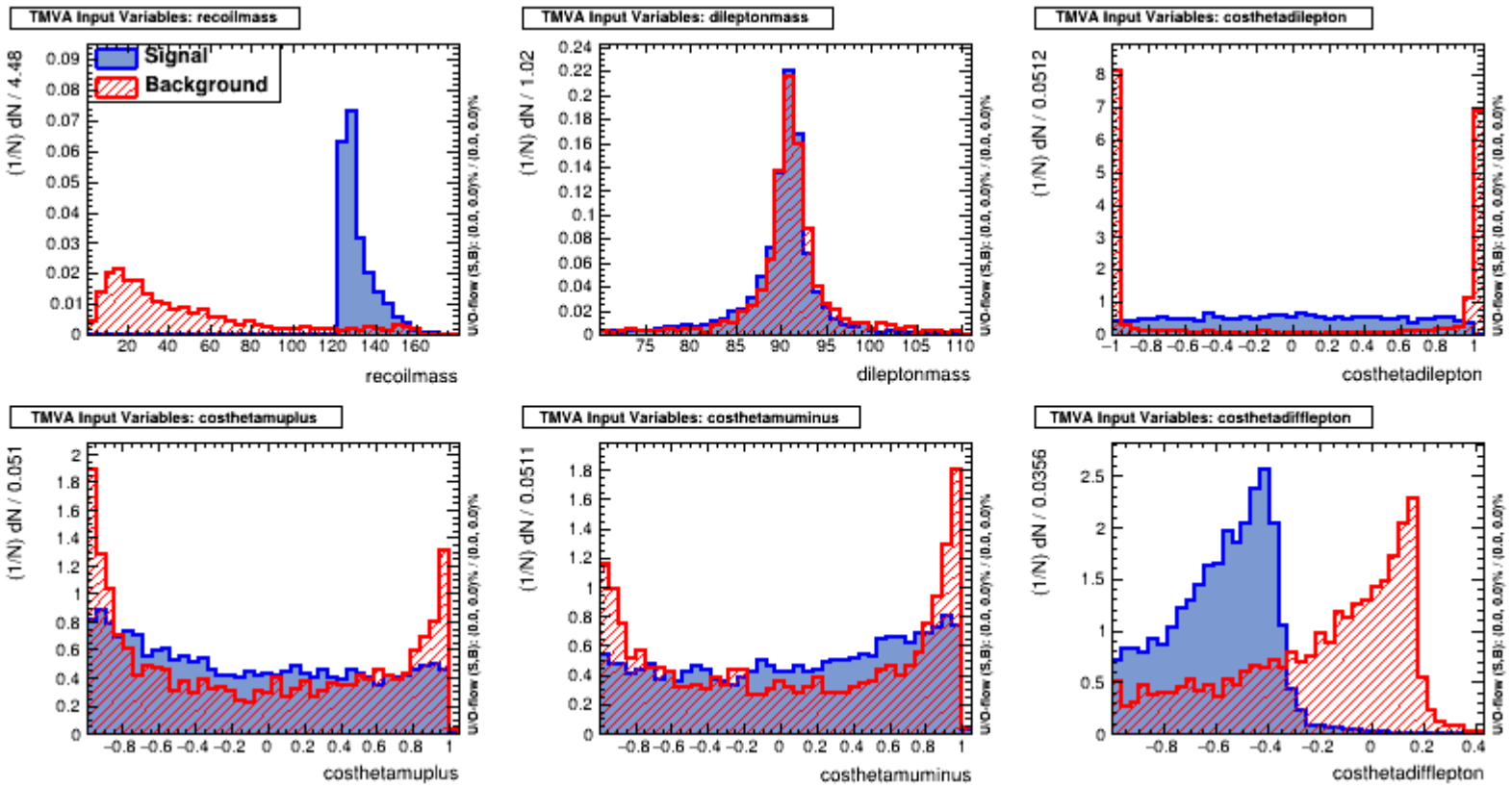
Training against 2f background (2f-mtva)

Exotic Scalar mass 125 GeV



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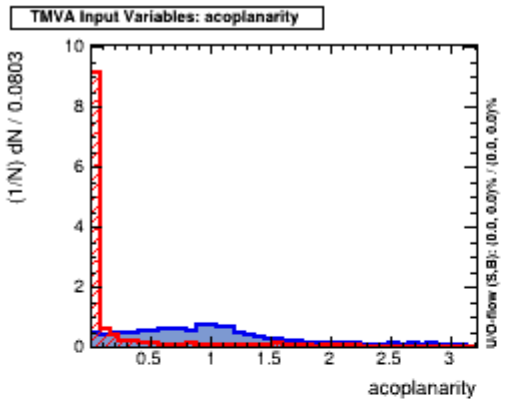

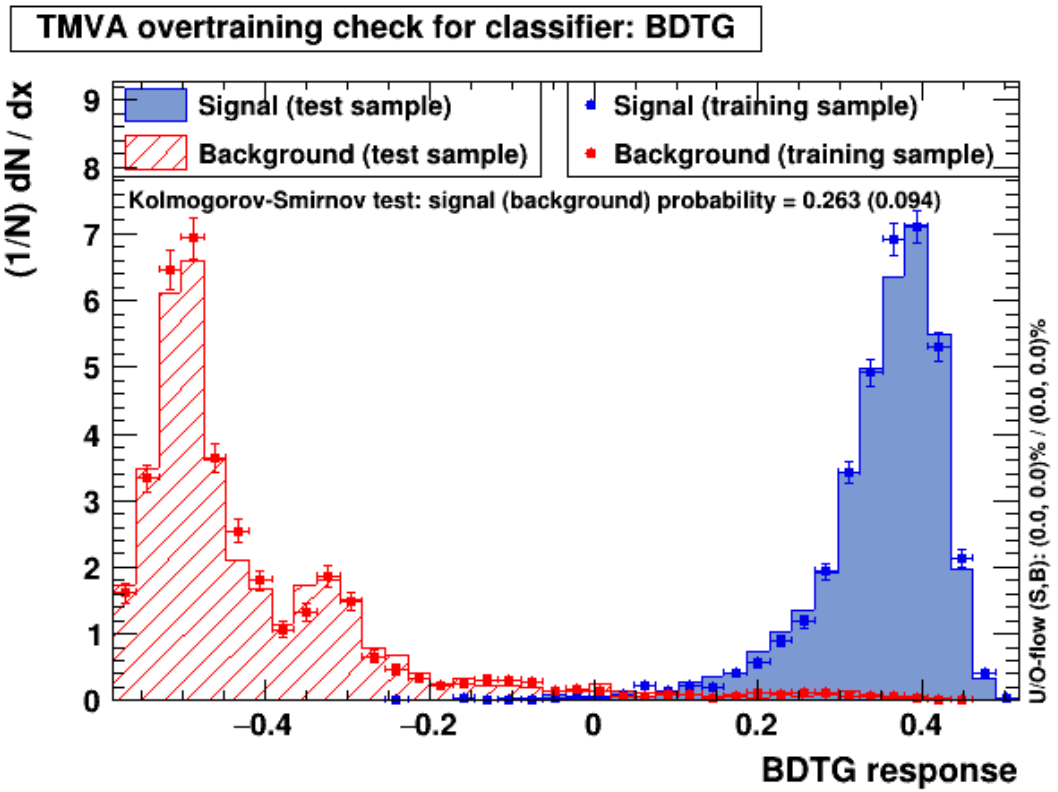

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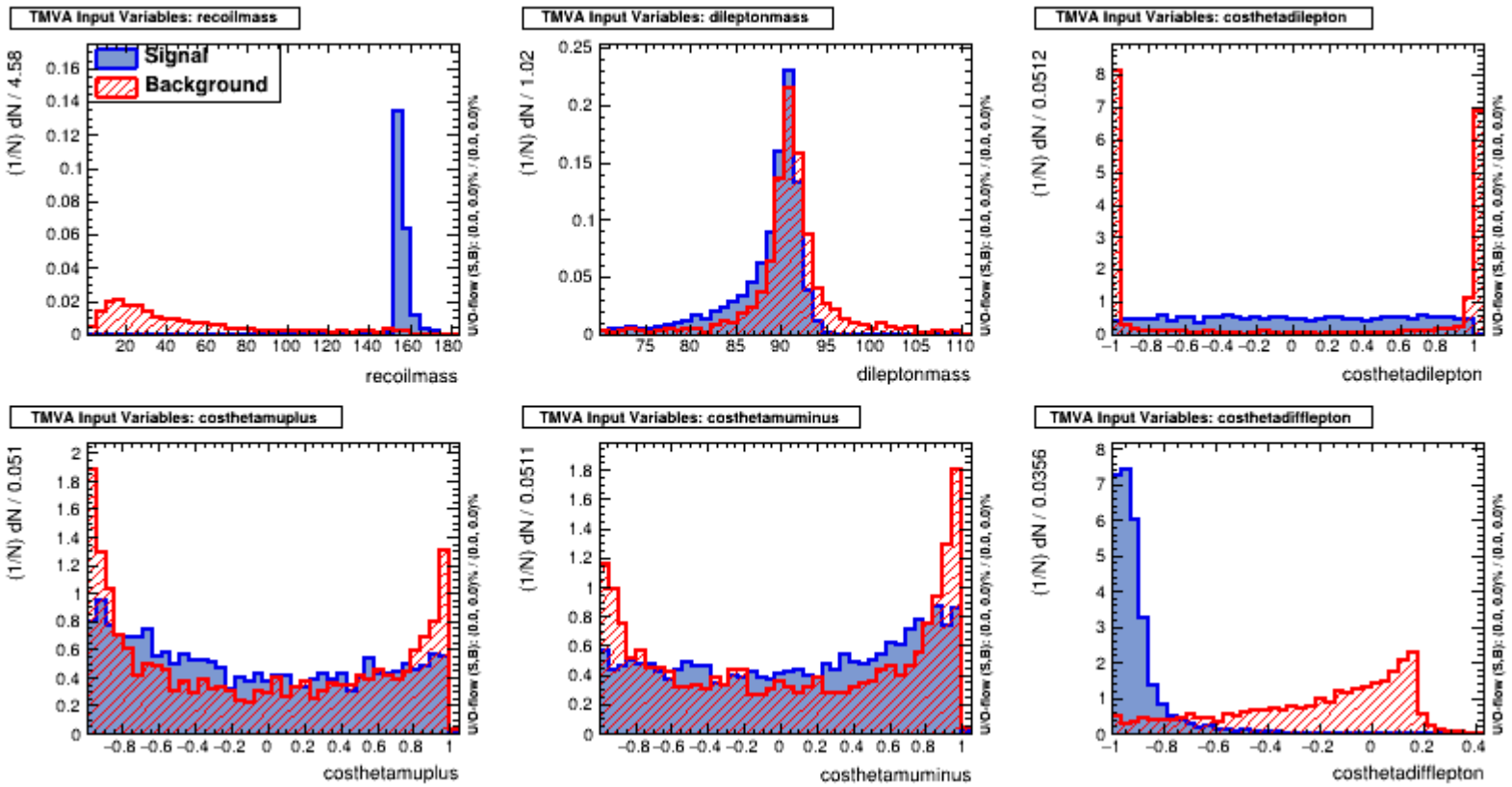
DESY.

Training against 2f background (2f-mtva)

Exotic Scalar mass 155 GeV



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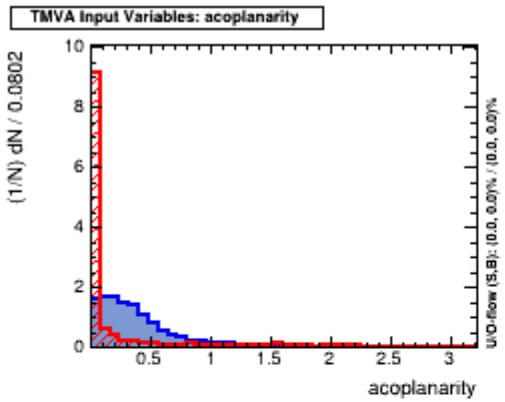

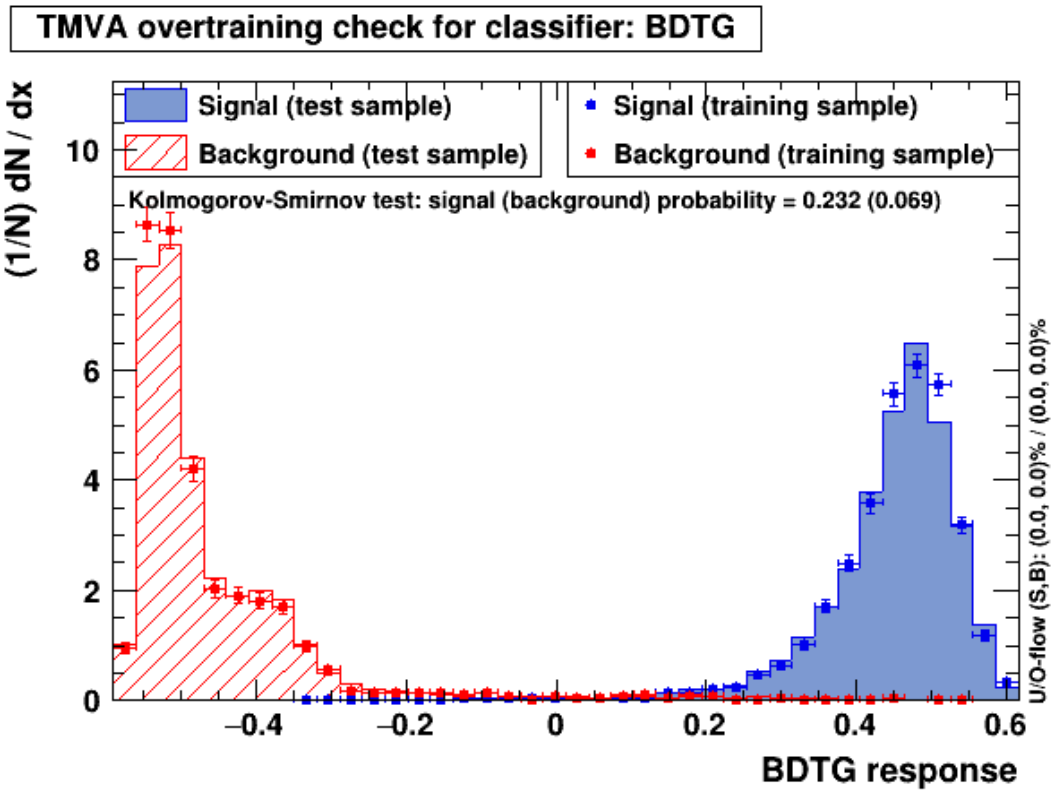

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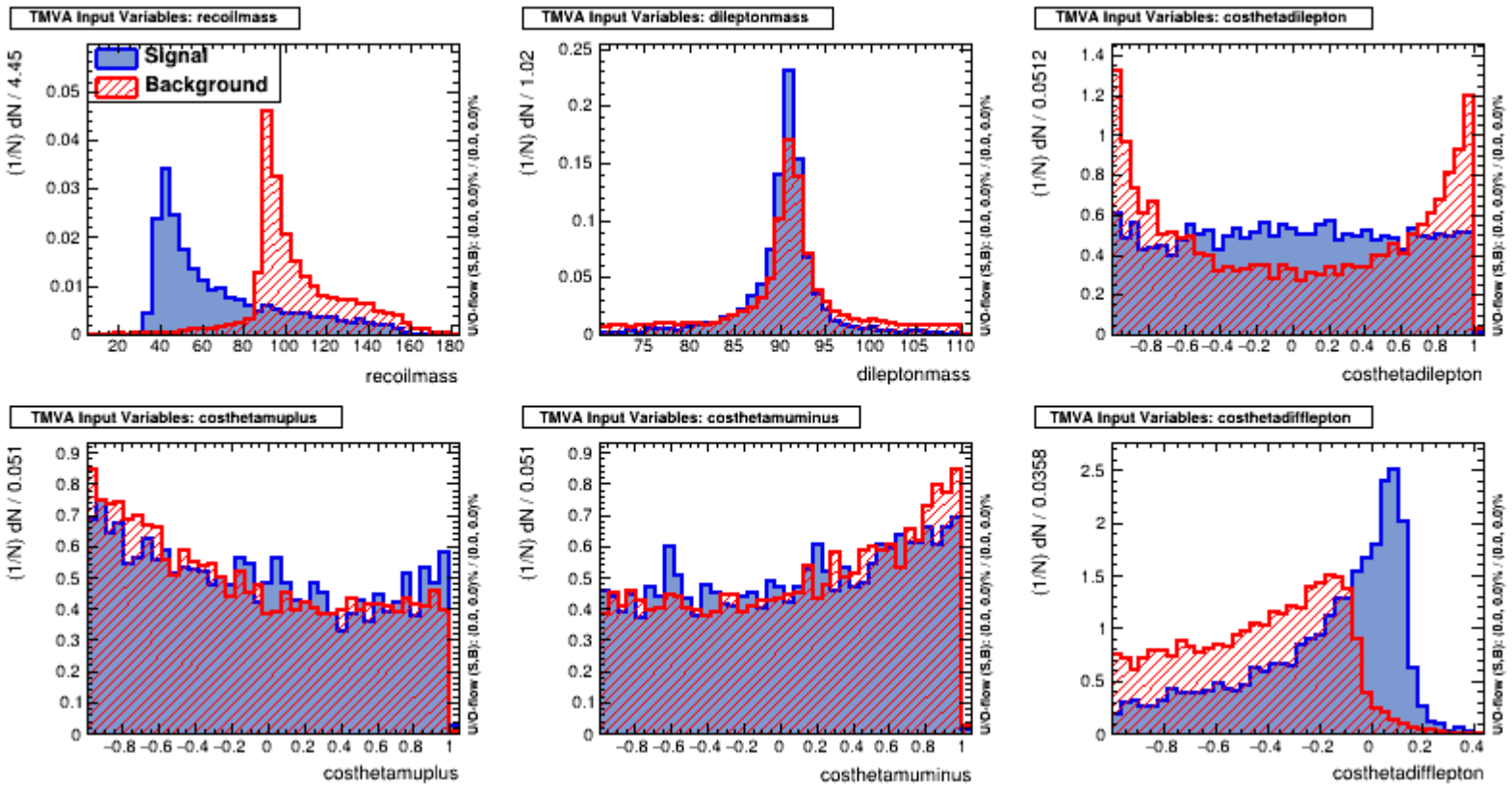
Training against 2f background (4f-mtva)

Exotic Scalar mass 40 GeV



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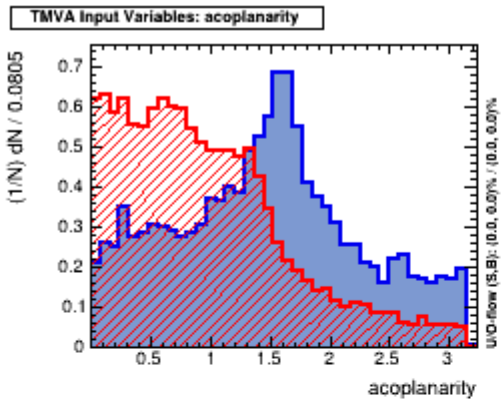

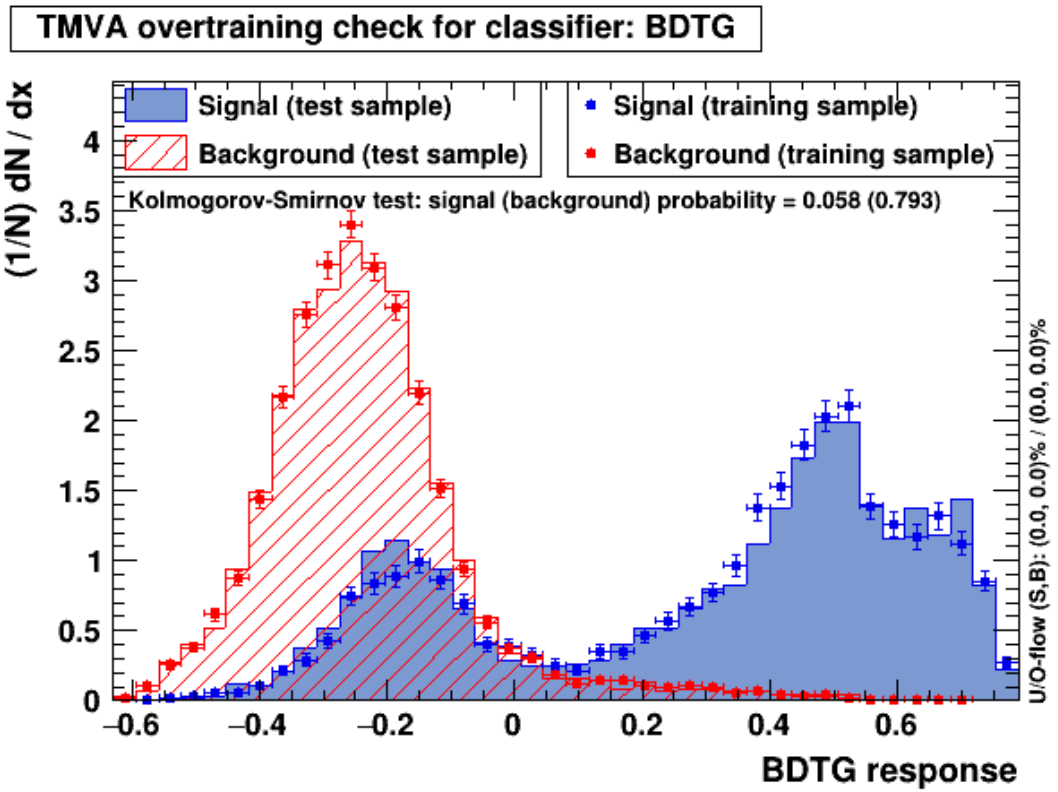

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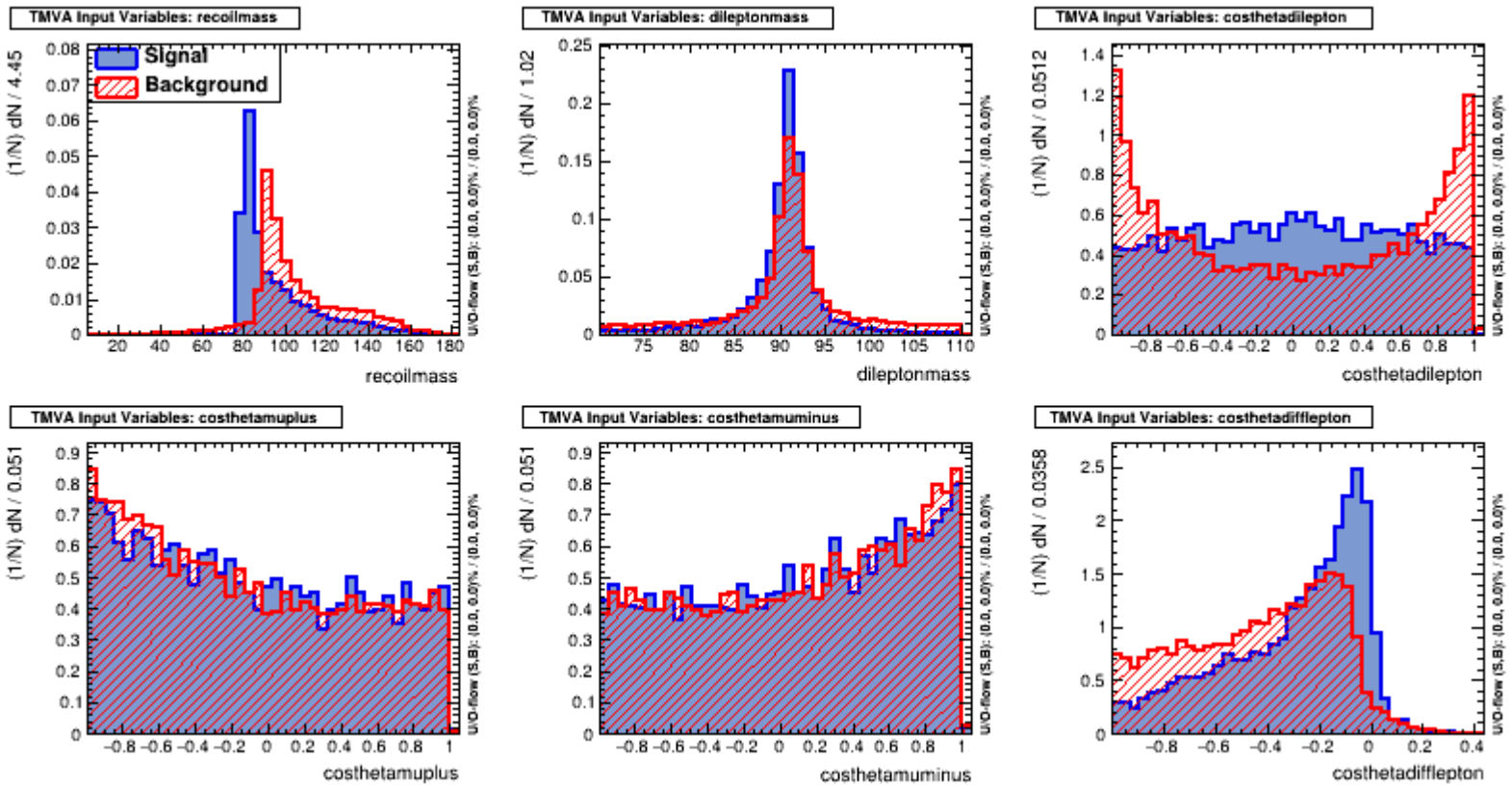

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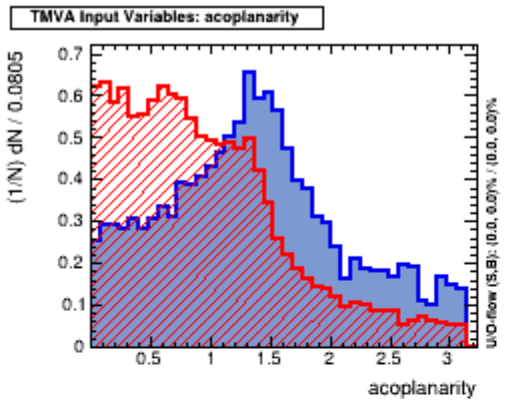

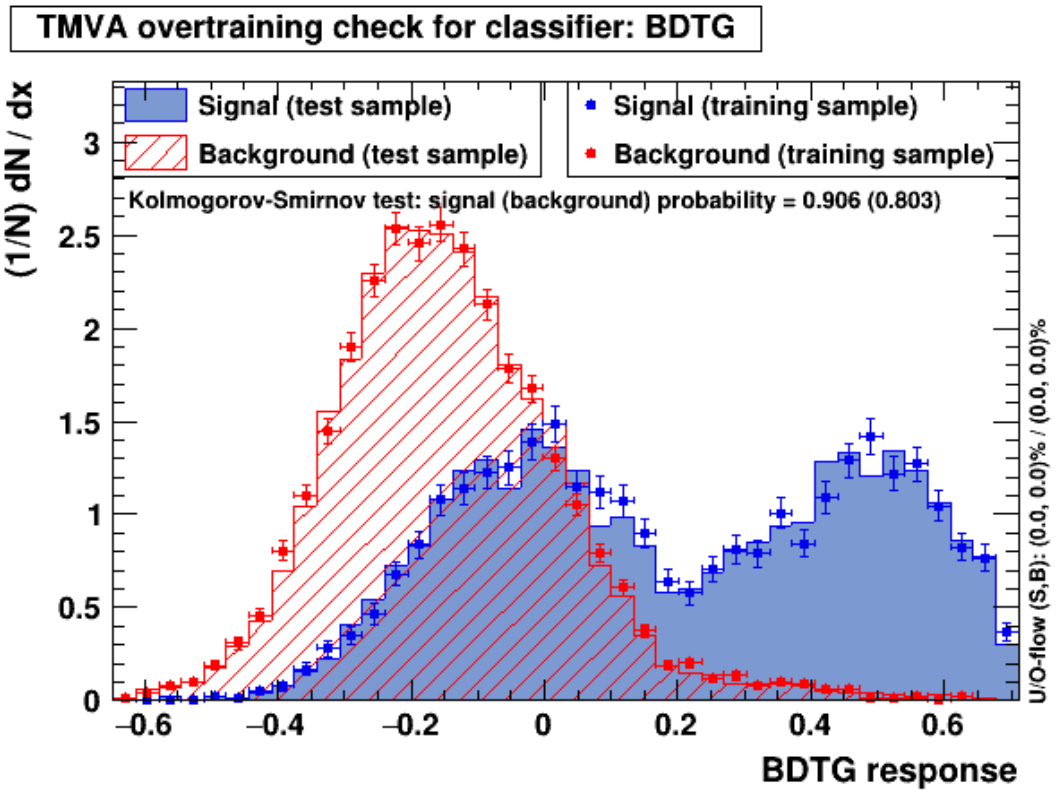

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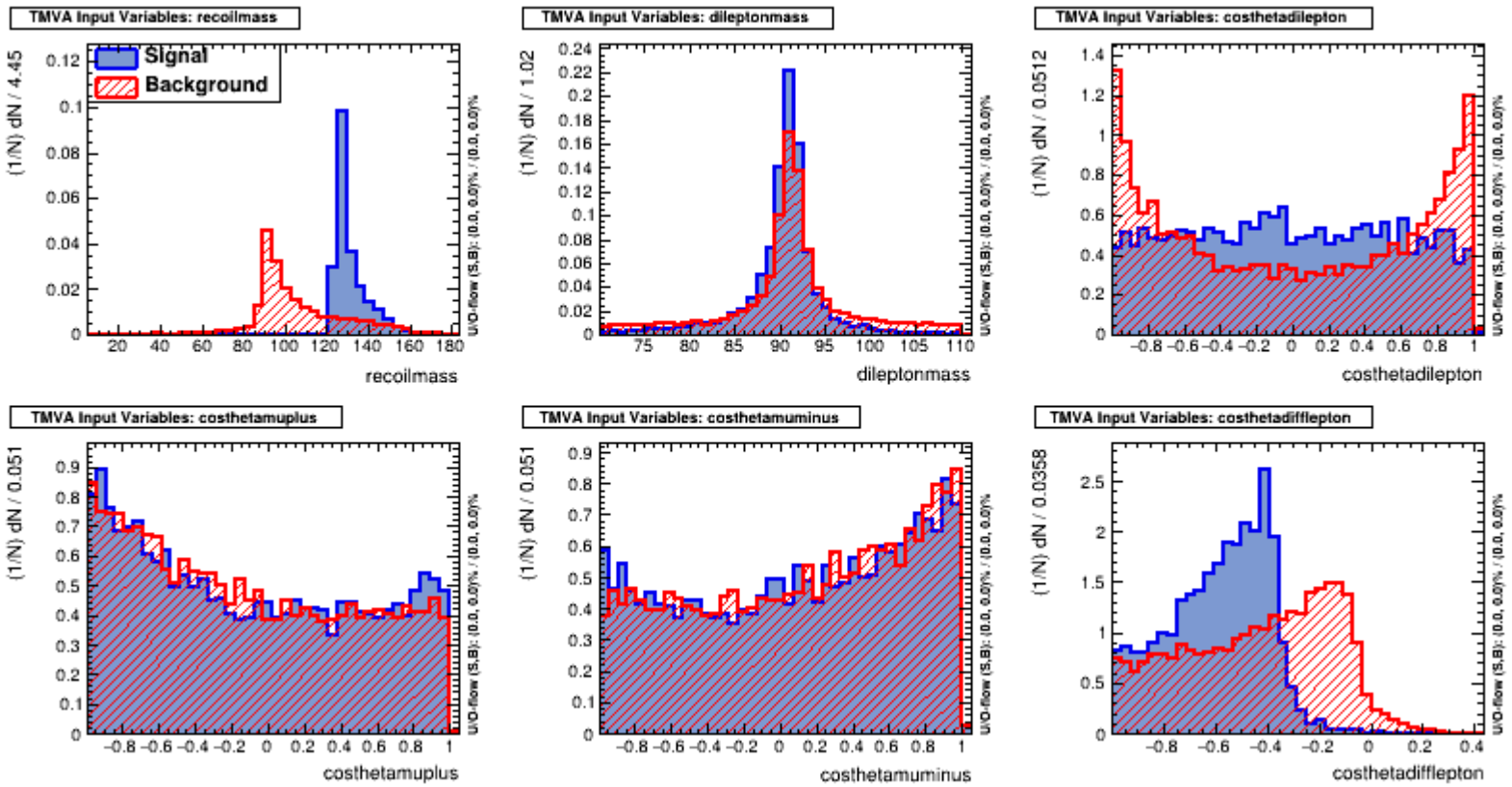
Training against 2f background (4f-mtva)

Exotic Scalar mass 125 GeV



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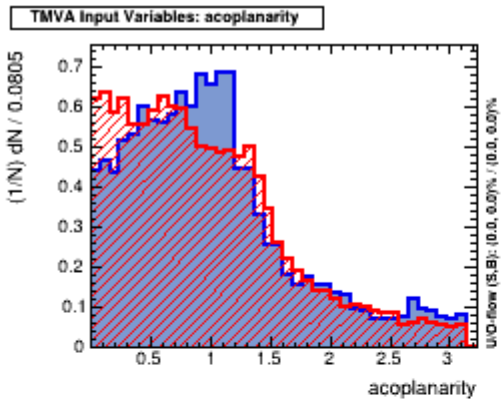

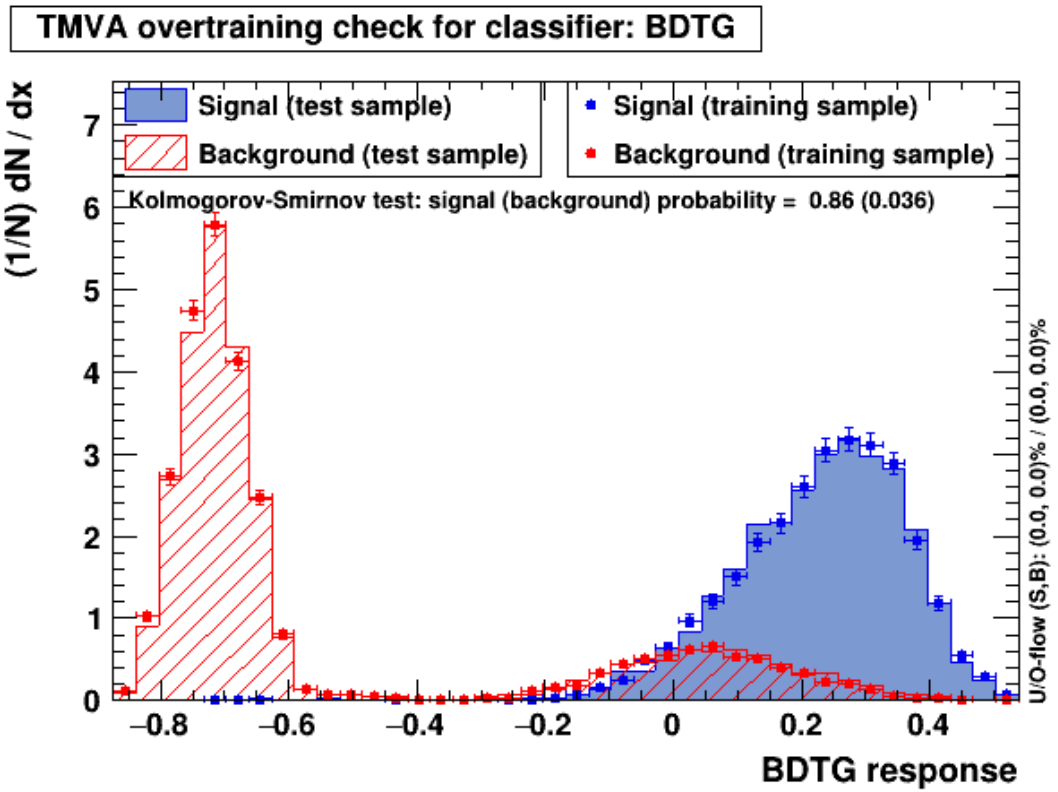

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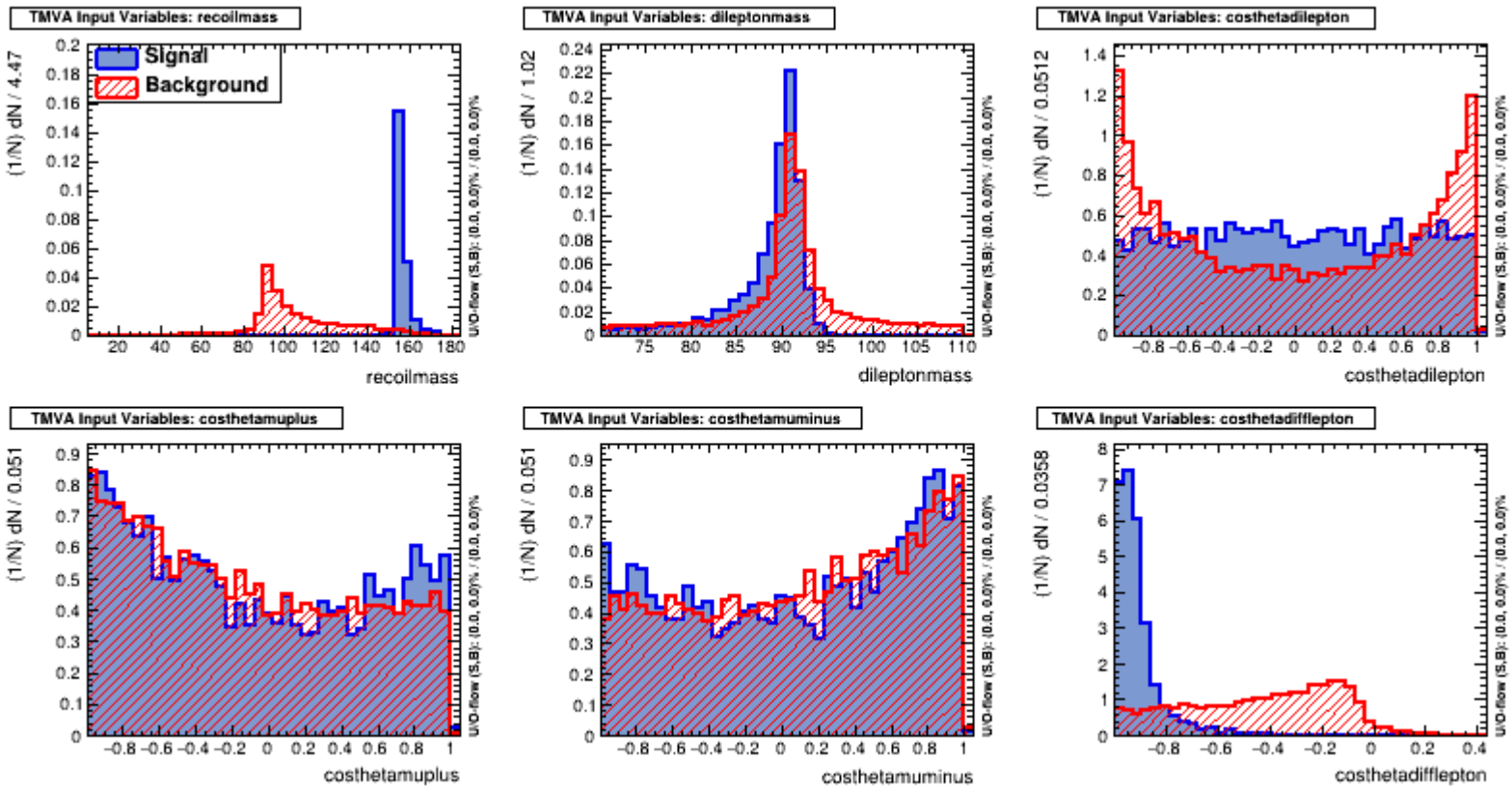

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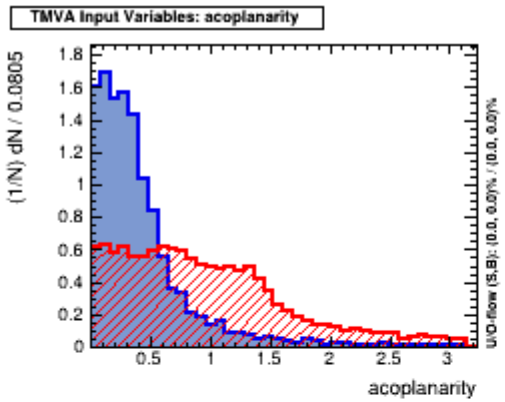

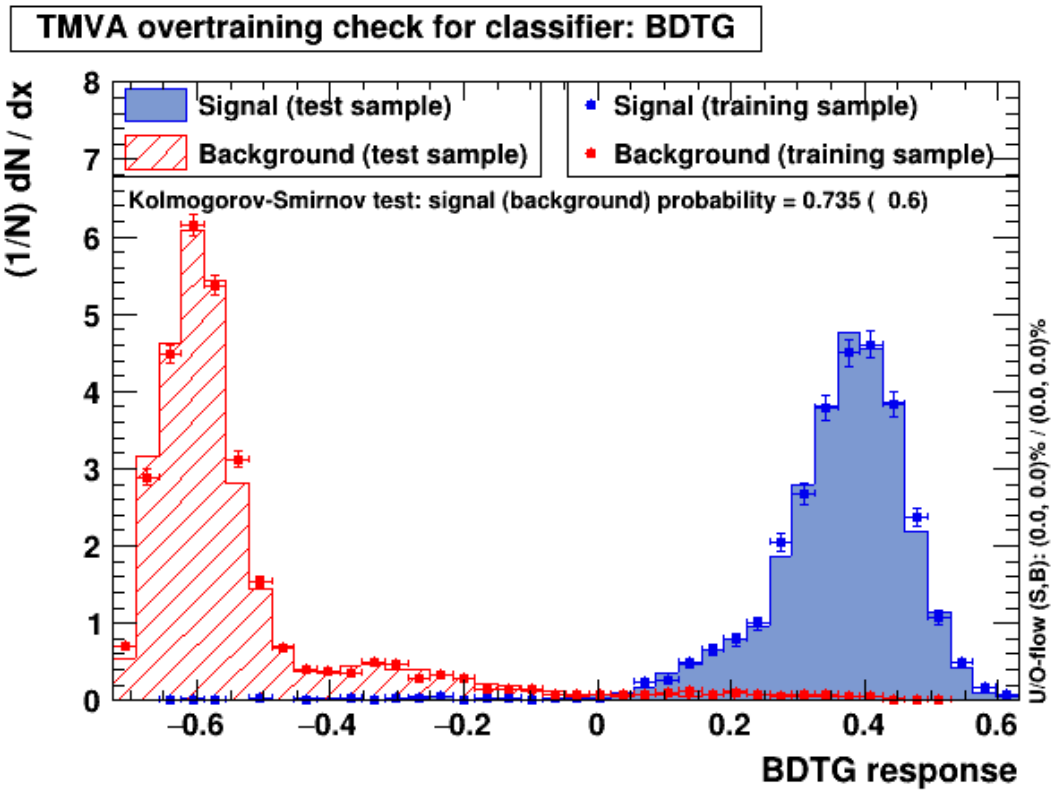

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Examples cut flow

Below Z boson mass

Scalar mass: 50 GeV

	Signal	e2e2Higgs	4f leptonic	4f semileptonic	2f leptonic
After preselection	23243	8382	123975	76947	1532470
After mva2f	19682	8124	38979	10599	42118
After mva4f	4372	0.7	0	0	0
After recoil	4372	0	0	0	0

Between Z and Higgs boson masses

Scalar mass: 90 GeV

	Signal	e2e2Higgs	4f leptonic	4f semileptonic	2f leptonic
After preselection	15580	8382	123975	76947	1532470
After mva2f	14737	8124	38979	10599	42118
After mva4f	6226	6602	9987	4527	14852
After recoil	3392	0	0	0	0

Examples cut flow (ctd.)

At Higgs boson mass

Scalar mass: 125

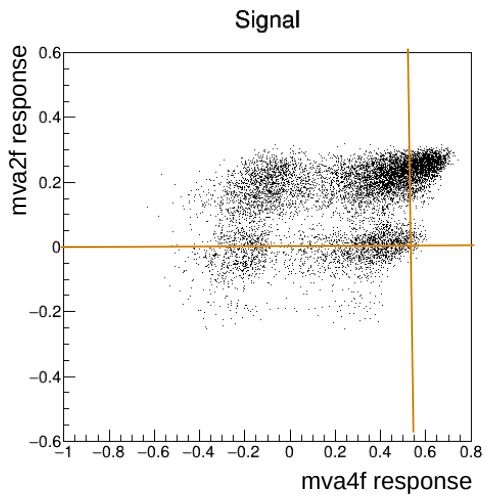
	Signal	e2e2Higgs	4f leptonic	4f semileptonic	2f leptonic
After preselection	8409	8382	123975	76947	1532470
After mva2f	8240	8124	38979	10599	42118
After mva4f	2408	2308	1000	670	1061
After recoil	1578	1581	545	363	265

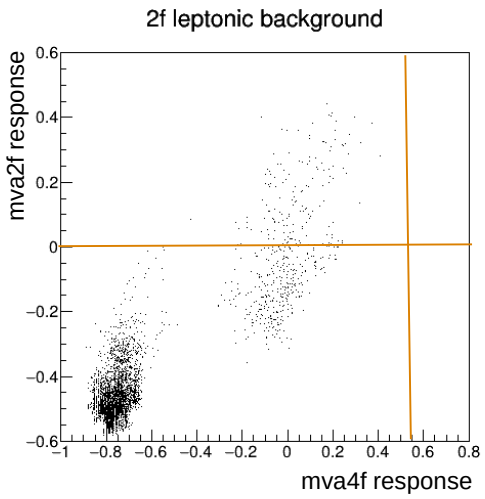
Above Higgs boson mass

Scalar mass: 145

	Signal	e2e2Higgs	4f leptonic	4f semileptonic	2f leptonic
After preselection	3885	8382	123975	76947	1532470
After mva2f	3853	8124	38979	10599	42118
After mva4f	856	468	107	120	243
After recoil	856	0	0	0	0

Illustration cuts on variable distributions

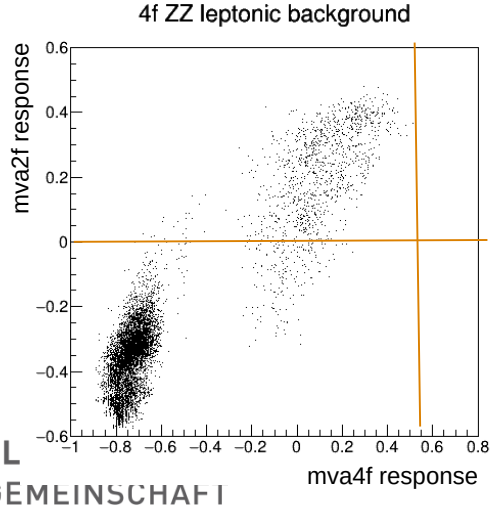


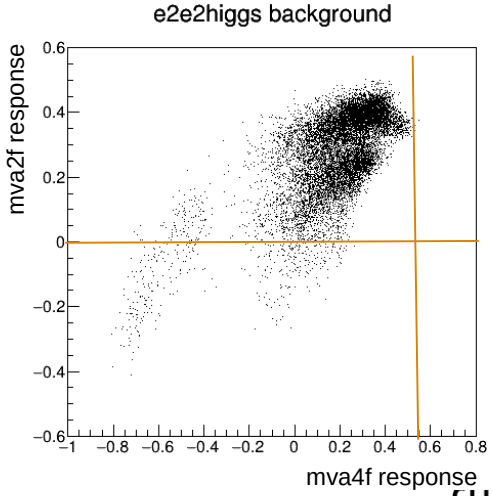


Cuts:

mva2f response > 0

mva4f response > 0.54

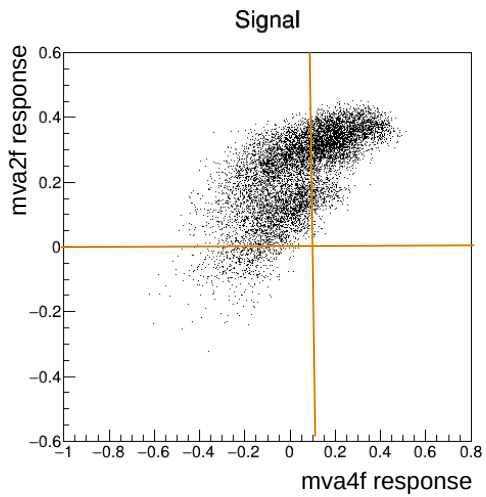


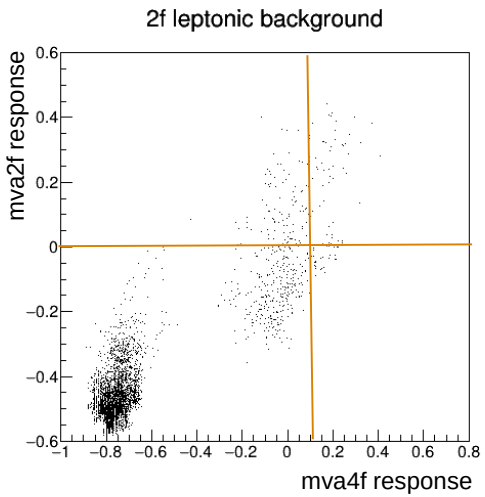


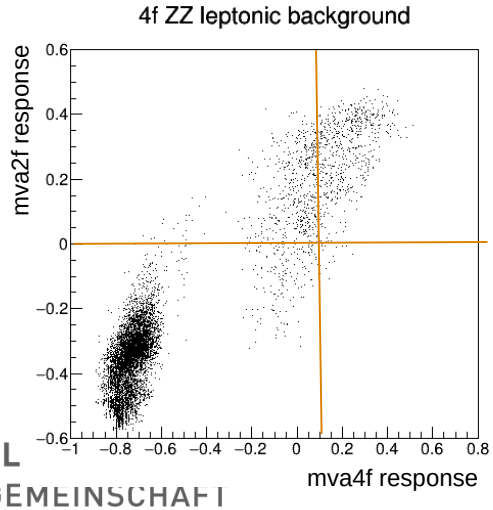
Background events killed after mva2f & mva4f cuts

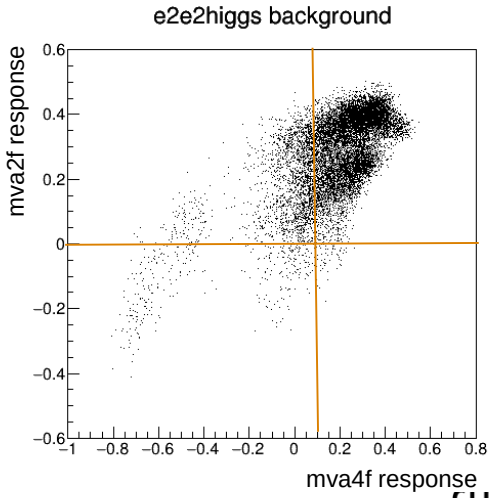
Scalar mass 50 GeV

Illustration cuts on variable distributions (ctd.)









Cuts:

mva2f response > 0

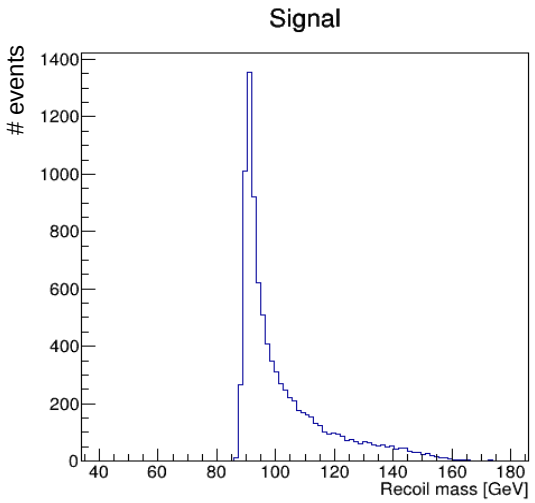
mva4f response > 0.1

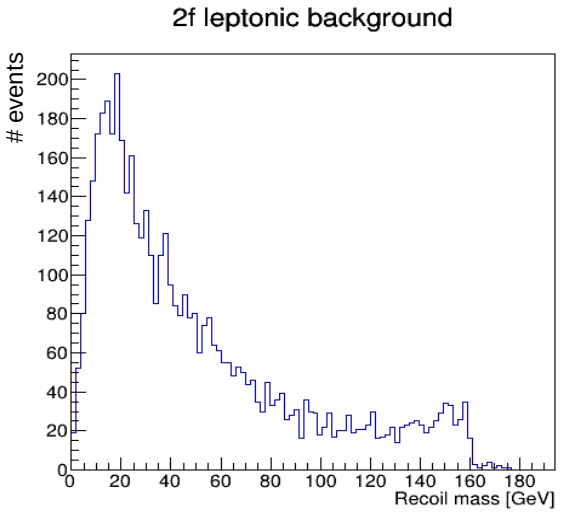
Recoil mass [90-3,90+3]

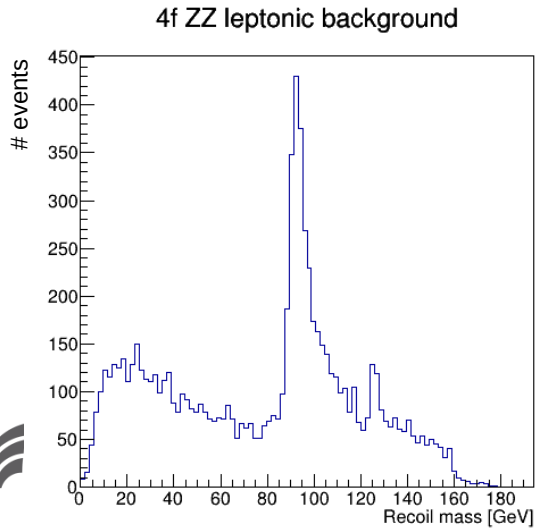
Background events killed after recoil mass cut

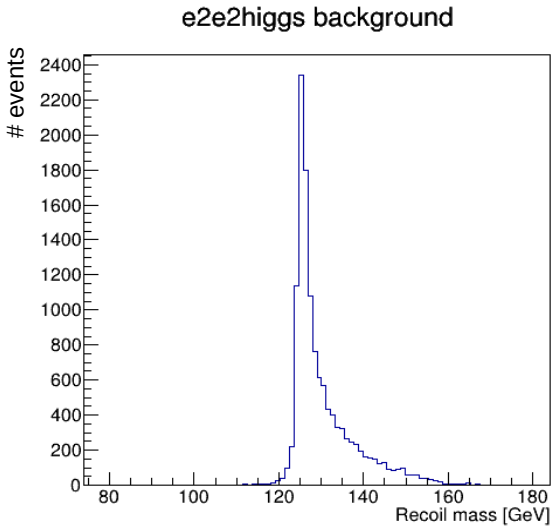
Scalar mass 90 GeV

Illustration cuts on variable distributions (ctd.)









Recoil mass distributions before mva cuts

Scalar mass 90 GeV

Cuts:

mva2f response > 0

mva4f response > 0.1

Recoil mass [90-3,90+3]

Background events killed after recoil mass cut

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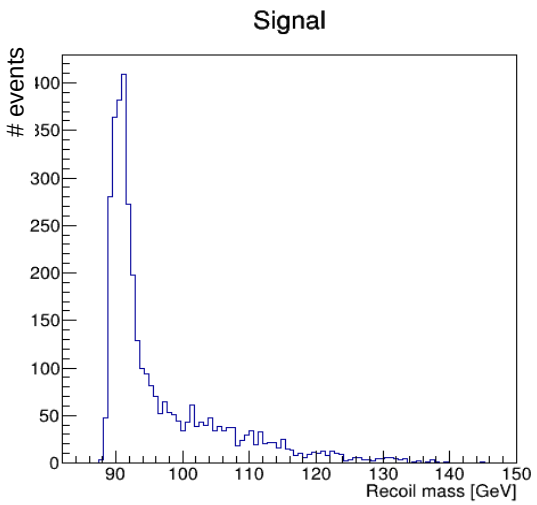
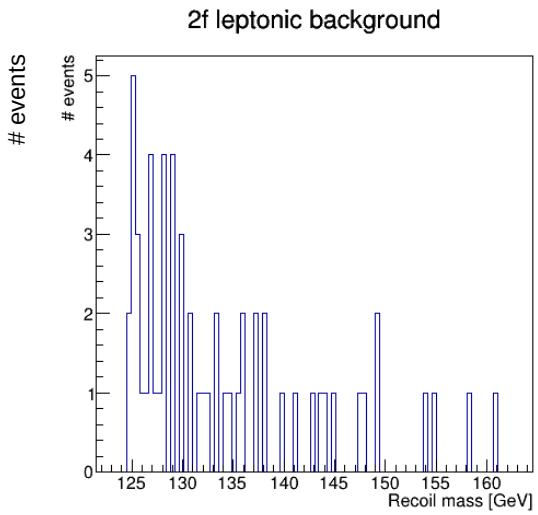
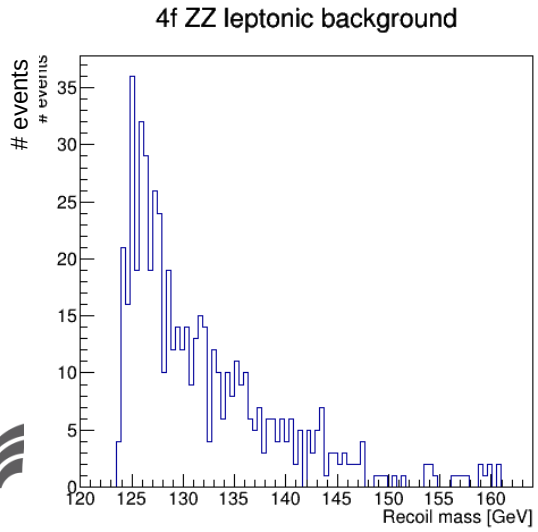
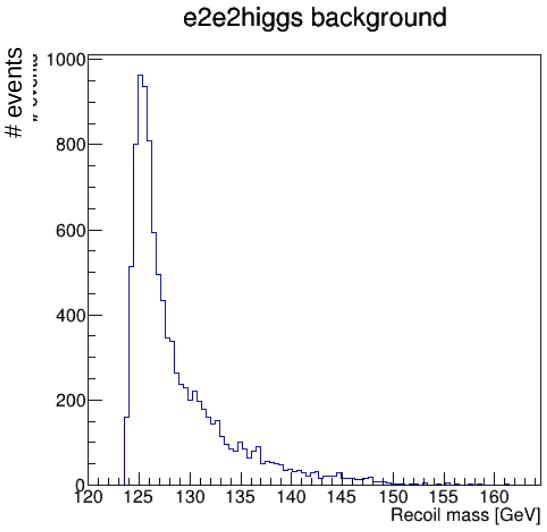
Illustration cuts on variable distributions (ctd.)









Recoil mass distributions after mva cuts

Scalar mass 90 GeV

Cuts:

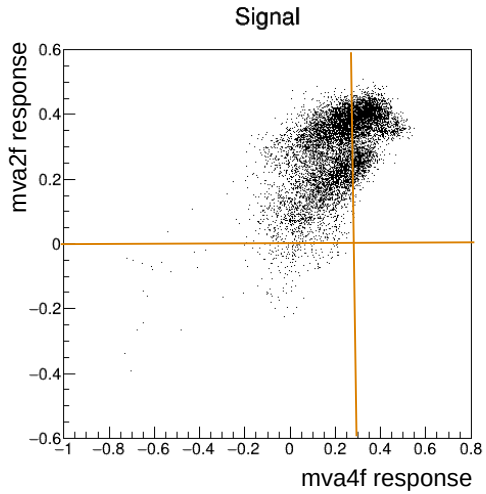
mva2f response > 0

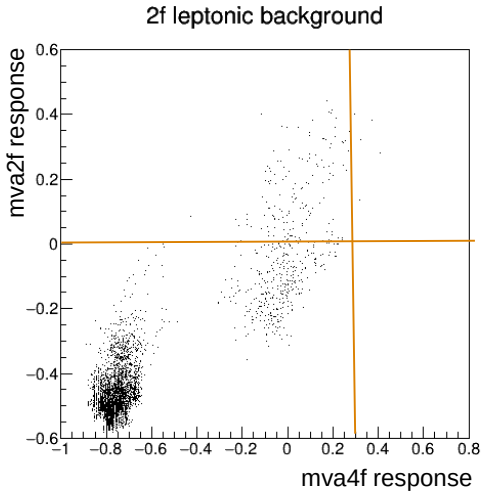
mva4f response > 0.1

Recoil mass [90-3,90+3]

Background events killed after recoil mass cut

Illustration cuts on variable distributions (ctd.)





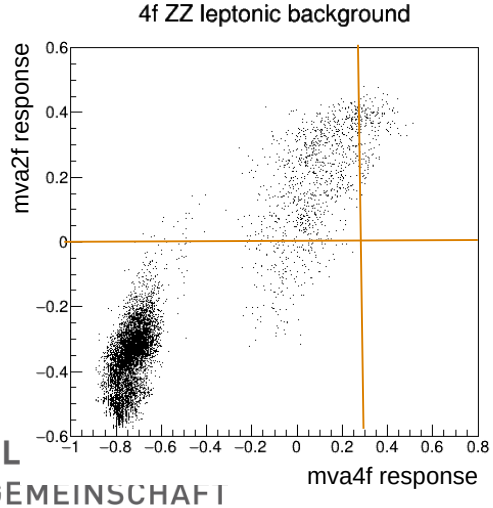
Cuts:

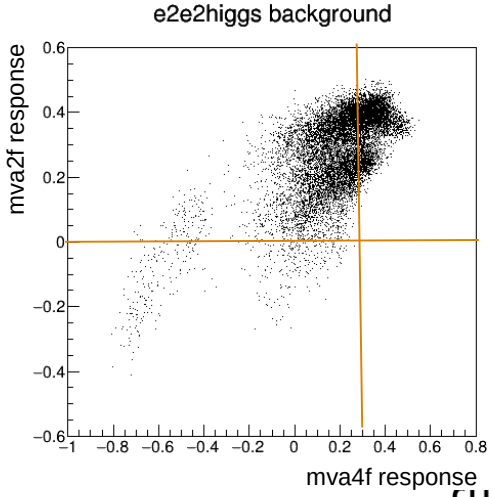
mva2f response > 0

mva4f response > 0.3

Recoil mass [125-2,125+2]

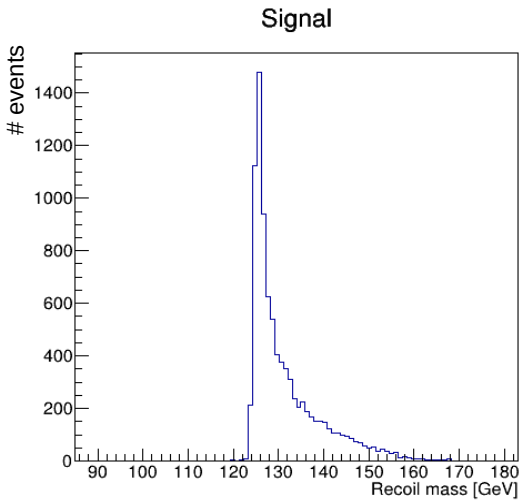
Background events survive after cuts

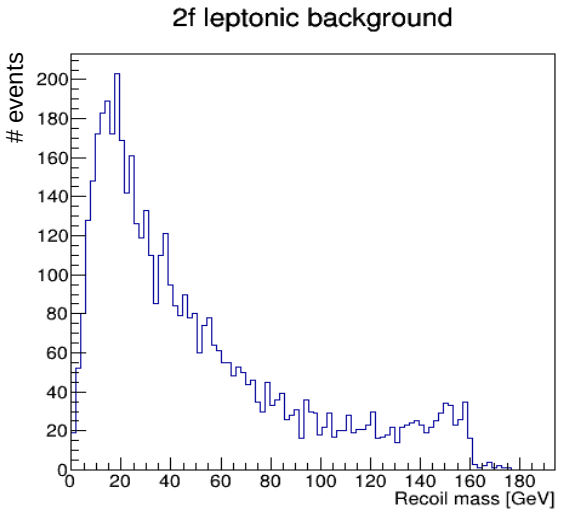


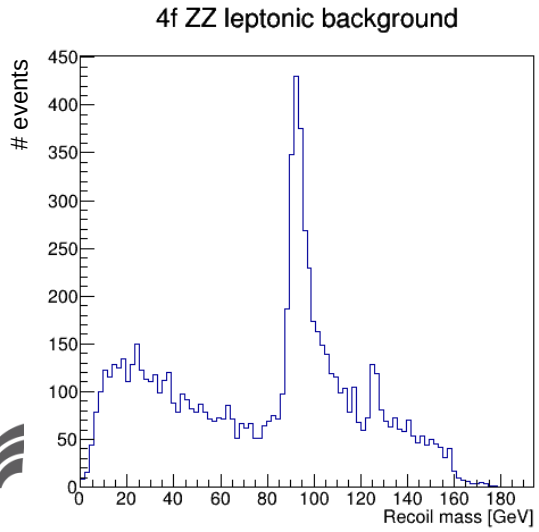


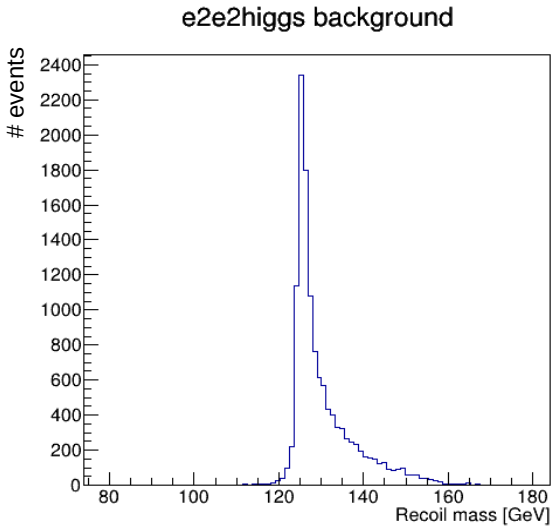
Scalar mass 125 GeV

Illustration cuts on variable distributions (ctd.)









Recoil mass distributions before mva cuts

Scalar mass 125 GeV

Cuts:

mva2f response > 0

mva4f response > 0.3

Recoil mass [125-2,125+2]

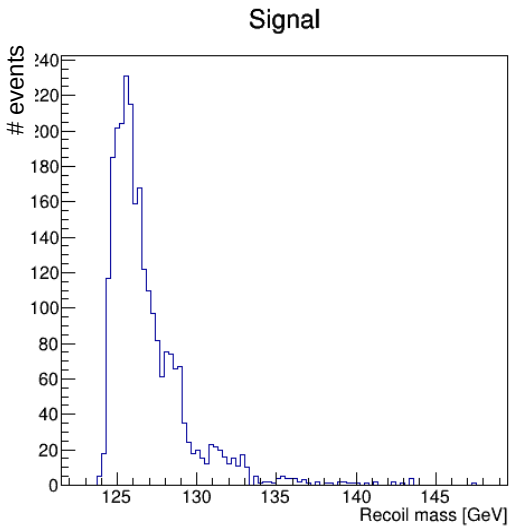
Background events survive after cuts

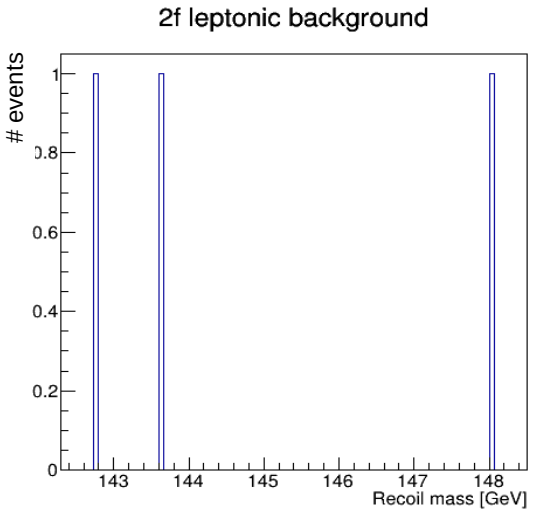
STER OF EXCELLENCE

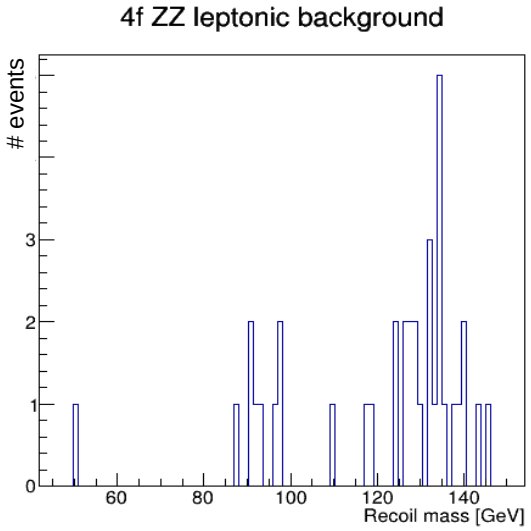
QUANTUM UNIVERSE

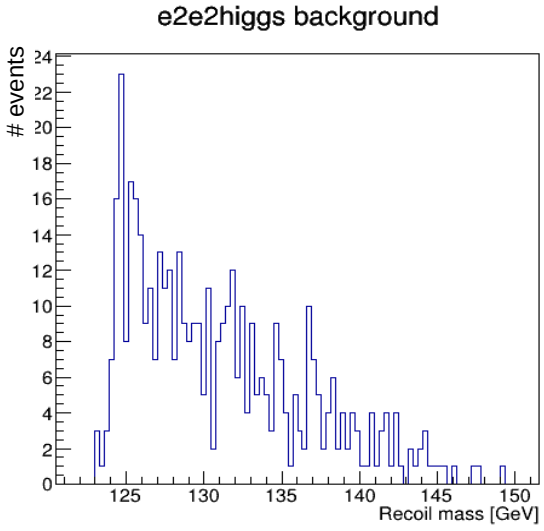
DESY.

Illustration cuts on variable distributions (ctd.)









Recoil mass distributions after mva cuts

Scalar mass 125 GeV

Cuts:

mva2f response > 0

mva4f response > 0.3

Recoil mass [125-2,125+2]

Background events survive after cuts

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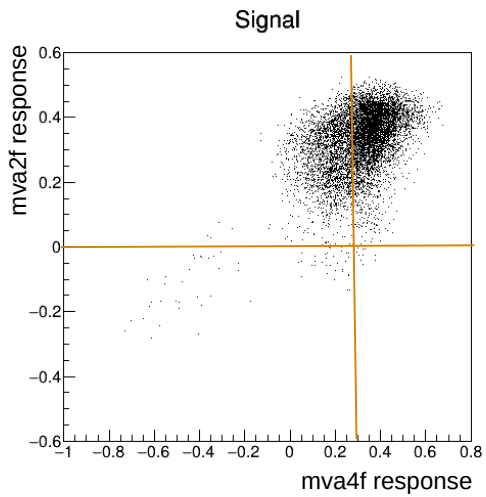
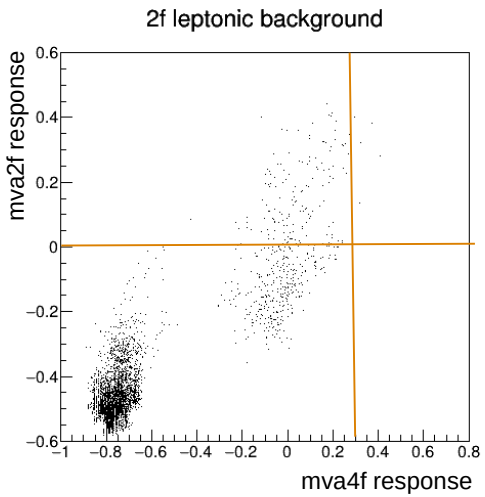
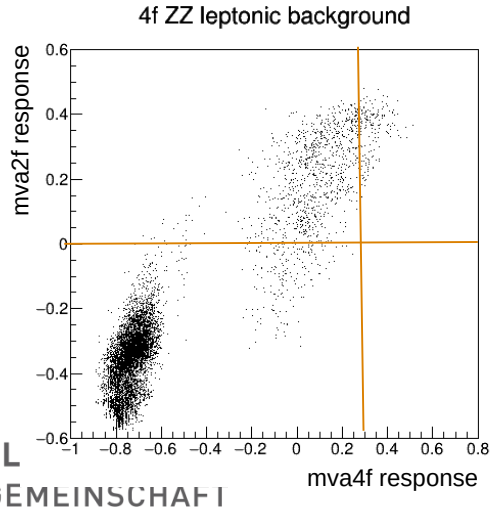
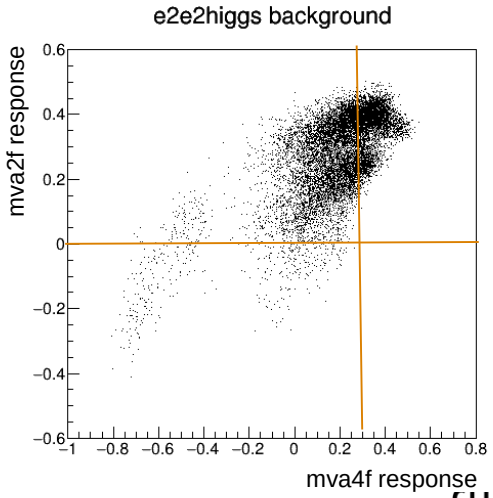
Illustration cuts on variable distributions (ctd.)









Cuts:

mva2f response > 0

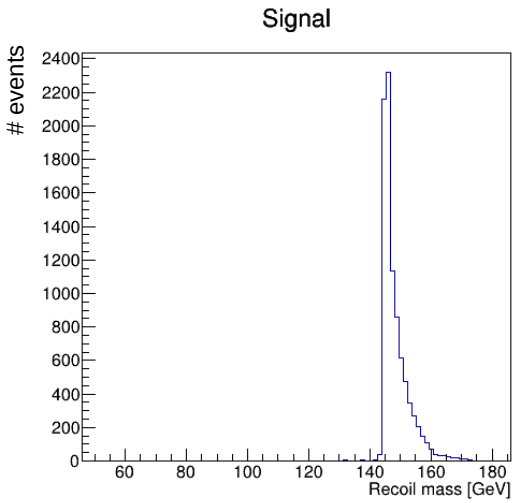
mva4f response > 0.3

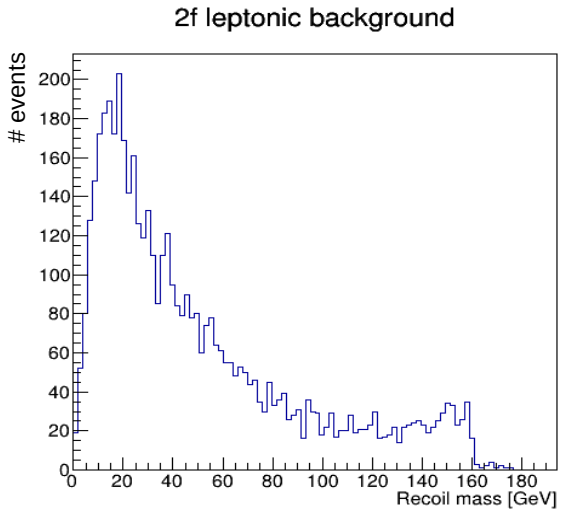
Recoil mass [145-5,250]

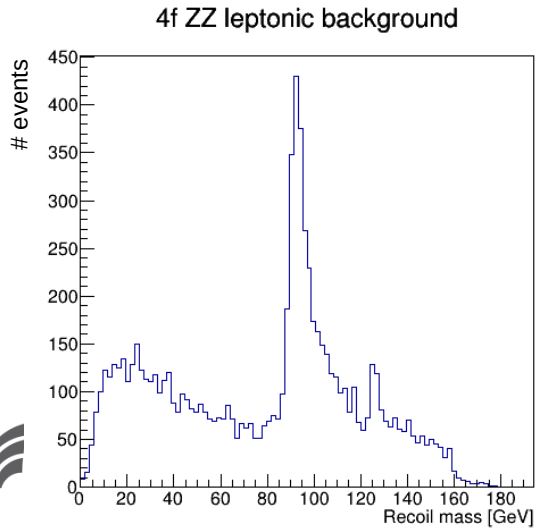
Background events killed after recoil mass cut

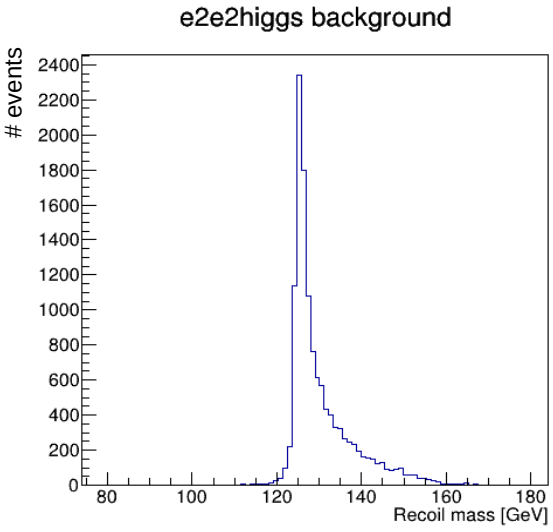
Scalar mass 145 GeV

Illustration cuts on variable distributions (ctd.)









Recoil mass distributions before mva cuts

Scalar mass 145 GeV

Cuts:

mva2f response > 0

mva4f response > 0.3

Recoil mass [145-5,250]

Background events killed after recoil mass cut

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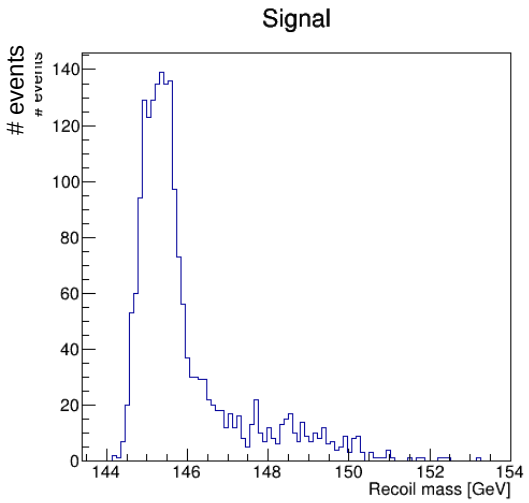
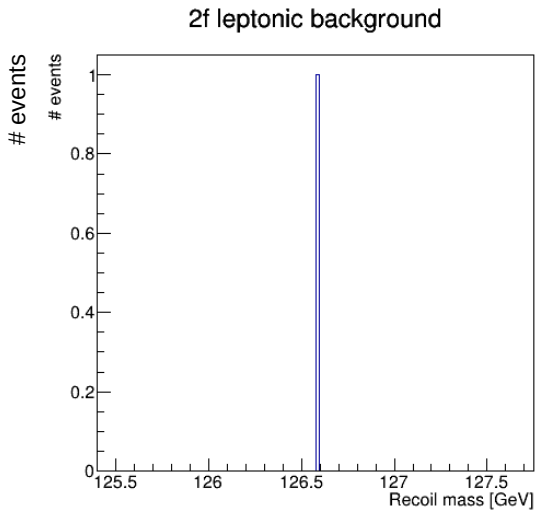
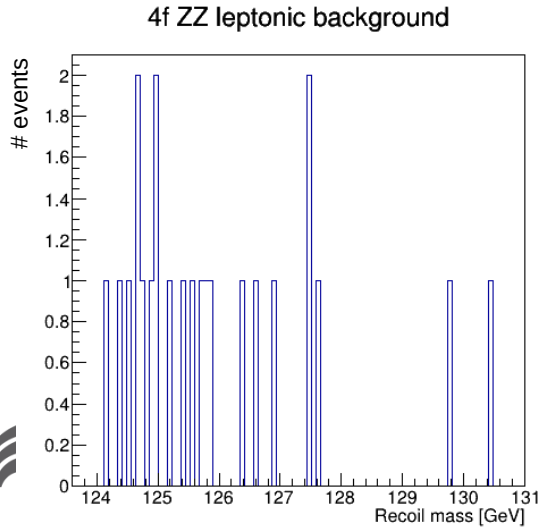
QUANTUM UNIVERSE

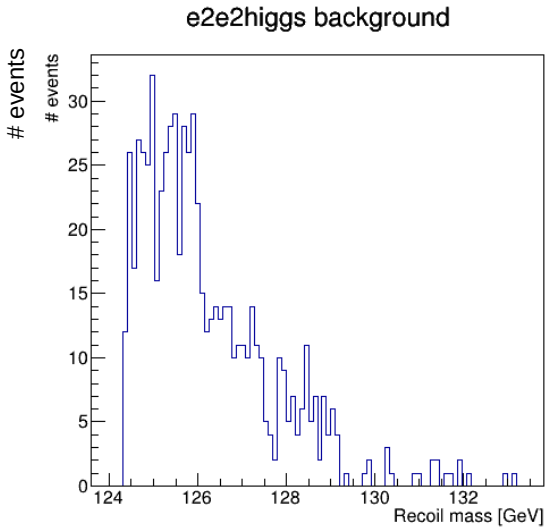
DESY.

Illustration cuts on variable distributions (ctd.)









Recoil mass distributions after mva cuts

Scalar mass 145 GeV

Cuts:

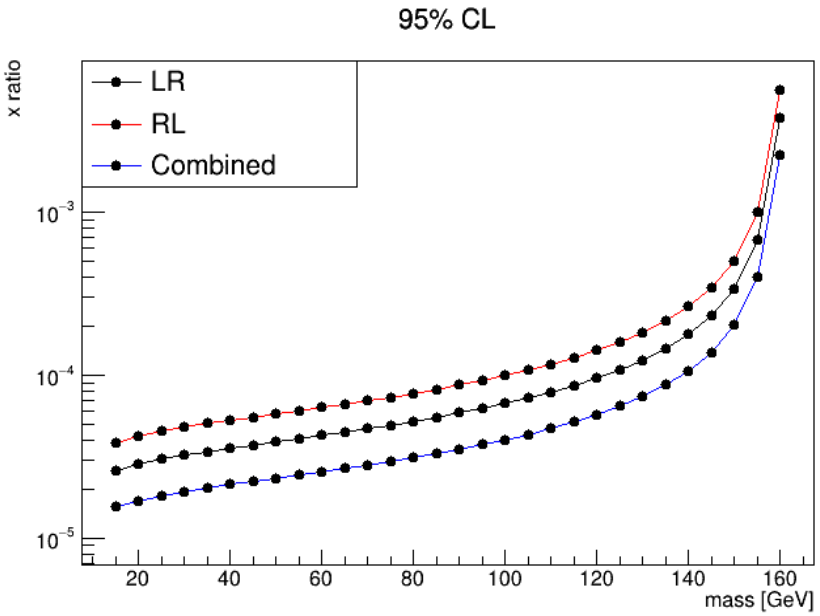
mva2f response > 0

mva4f response > 0.3

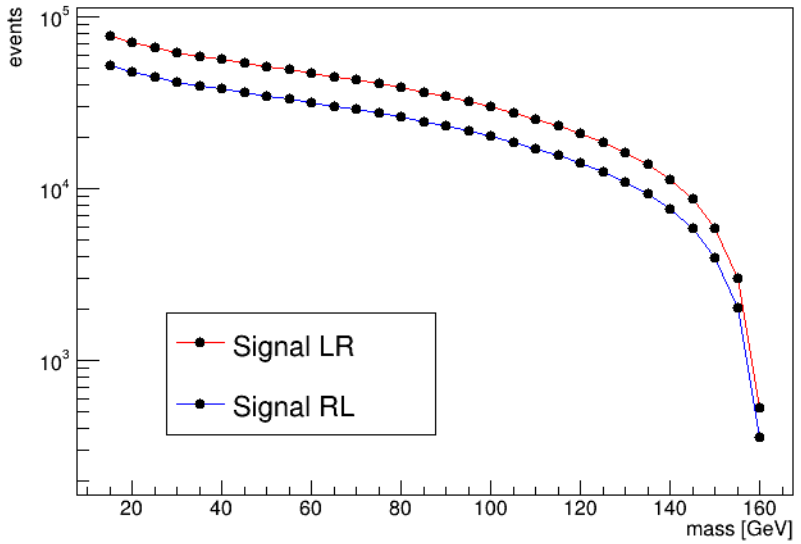
Recoil mass [145-5,250]

Background events killed after recoil mass cut

Limits assuming not background and 100% signal efficiency



- $\sqrt{s}$ = 250 GeV
- Luminosity 1.6 ab $^{-1}$ (0.8 ab^{-1} each polarisation)
- Limit computed from S/$\sqrt{S+B}$ exclusion



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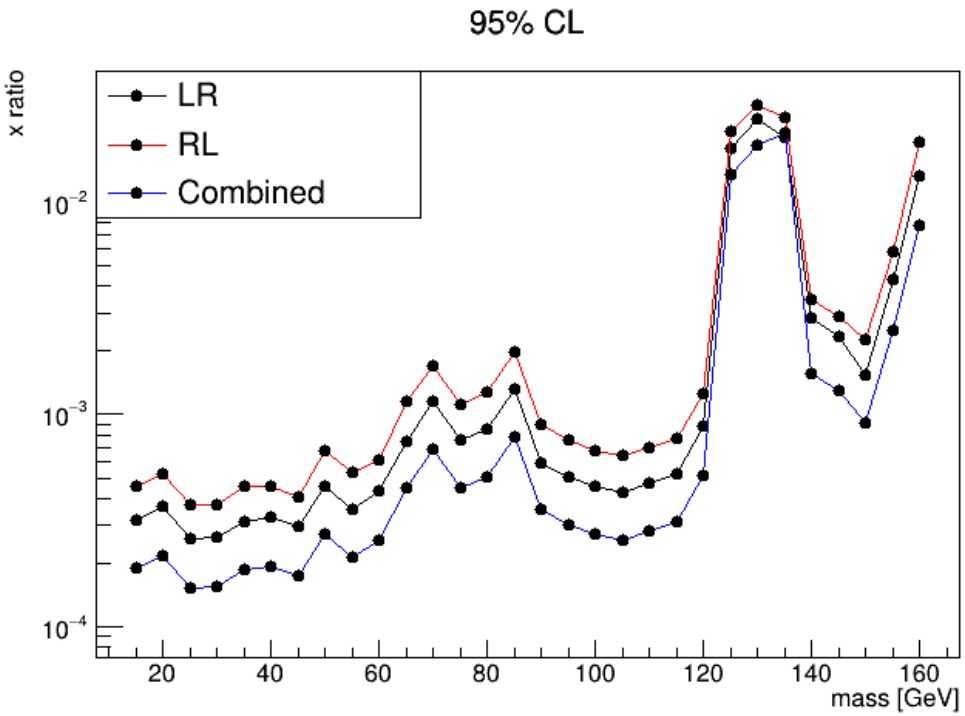
Preliminary limits



- $\sqrt{s}$ = 250 GeV
- Luminosity 1.6 ab $^{-1}$ (0.8 ab^{-1} each polarisation)
- 2f/4f/Higgs SM backgrounds
- Limit computed from S/$\sqrt{S+B}$ exclusion

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DESY.

Conclusions and outlook

- The model independent search for new scalars is reimplemented based on newest MC production and ILD software
- Cut flow is modified with respect to the previous analysis
- First results show an improvement with respect to previous limits
- Review and possible optimisation of the cuts is foreseen
- Detailed comparison with previous studies is needed
- Extension of the searches to other Z mode decays is on going

Results are promising but still very preliminary