Decay-mode independent searches for new light scalars at future Higgs factories

Teresa Núñez - DESY

- Previous studies
- Current analysis:
  - motivation
  - analysis flow
  - preliminary results (work in progress)
- Conclusions and outlook

Third ECFA Worshop on e+e- Higgs/Top/EW Factories
Paris, October 2024

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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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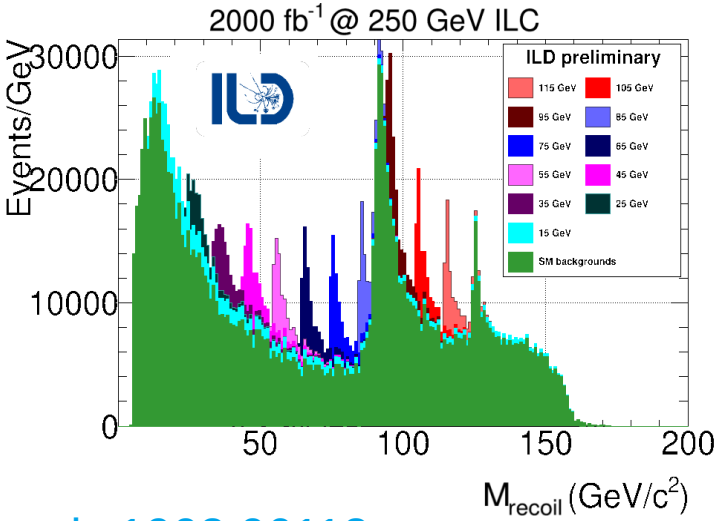
Previous studies (ctd.)



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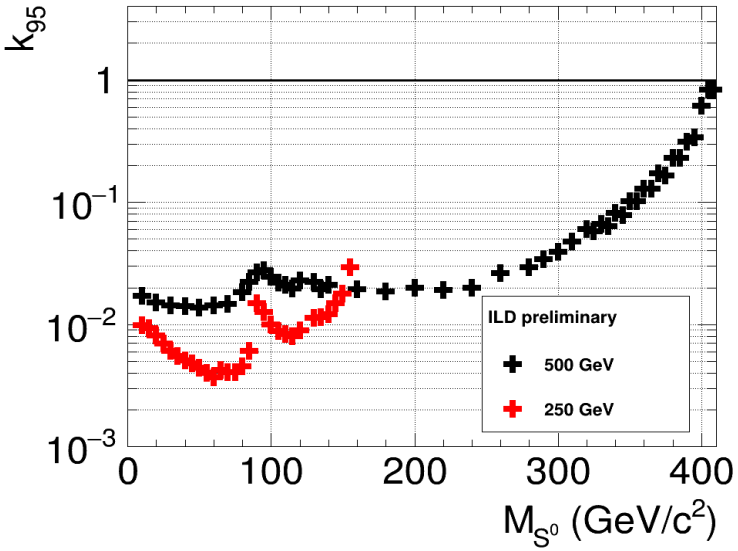
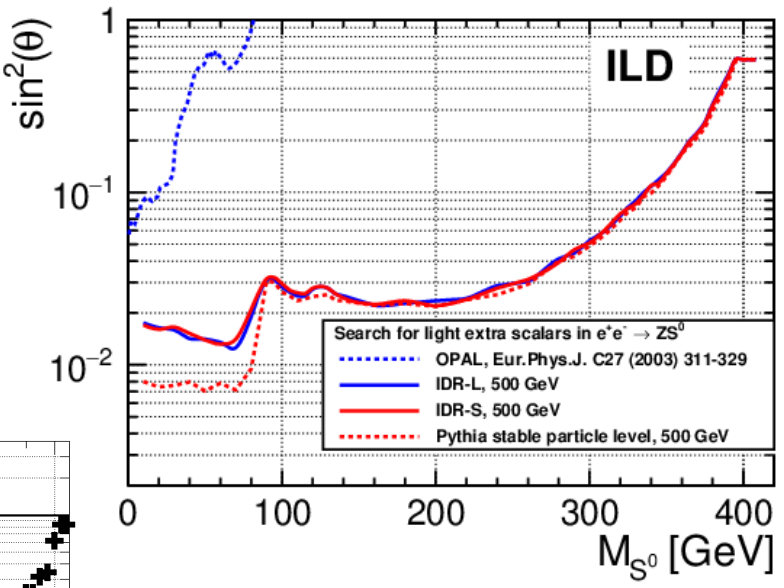


$e^+e^- \rightarrow Z' \rightarrow ZS^0 \rightarrow \mu^+\mu^- S^0$



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}, $M_{\mu^+\mu^-}^{FSR}$, $\cos\theta_{\mu^+}^{FSR}$, $\cos\theta_{\mu^-}^{FSR}$, $\cos\theta_{\mu^+\mu^-}^{FSR}$, $\cos\theta\mu - \mu^{FSR}$, $\pi - (\phi_{\mu^+} - \phi_{\mu^-})$
  - cut limits depends on scalar mass
- Additional cut on M_{recoil} depending on M_{scalar}

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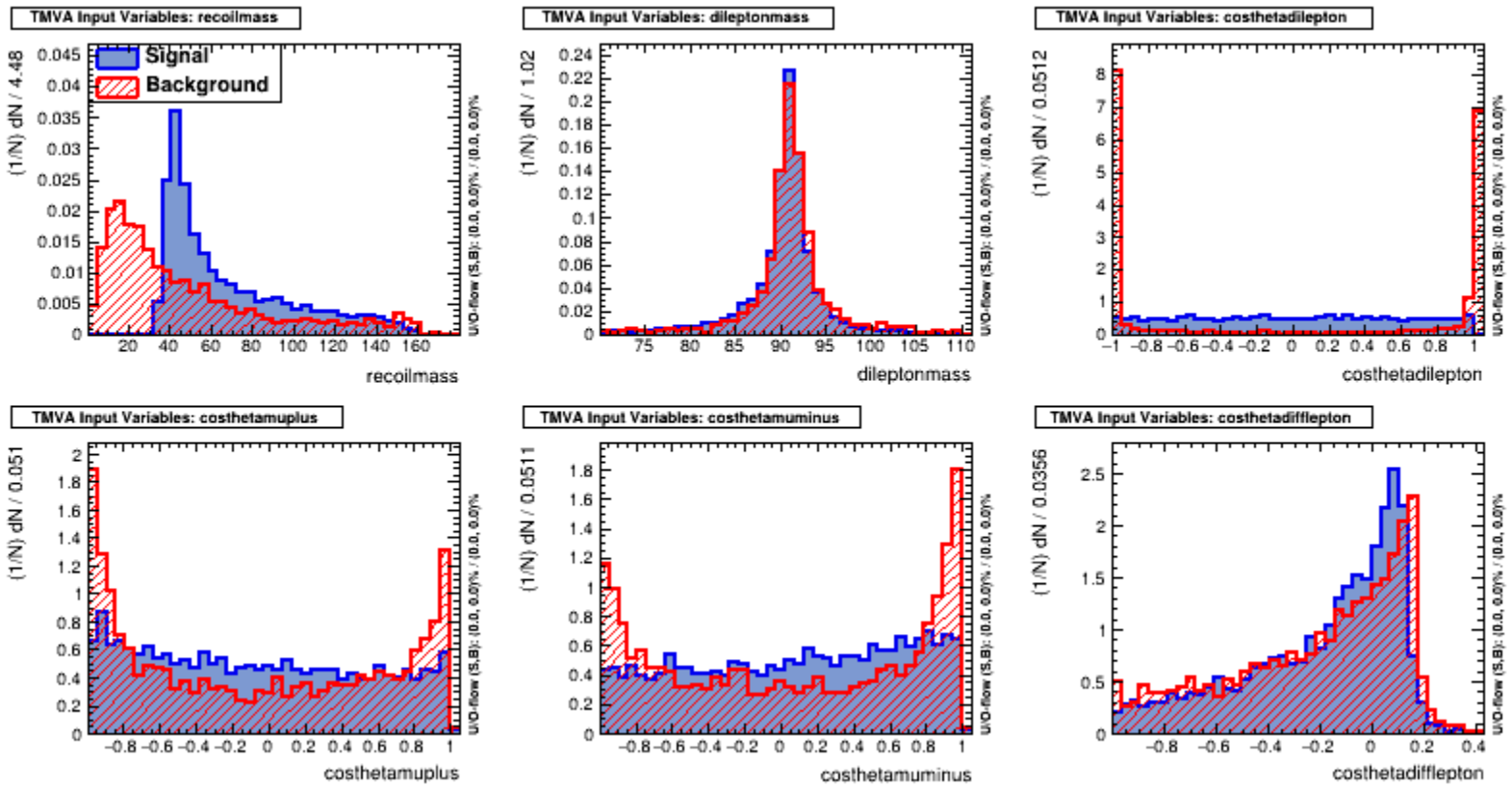
Training against 2f background (2f-mtva)

Exotic Scalar mass 40 GeV



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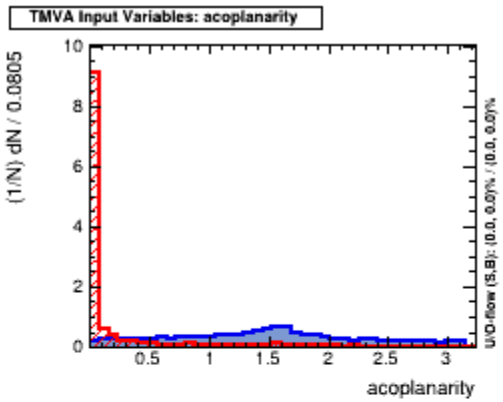

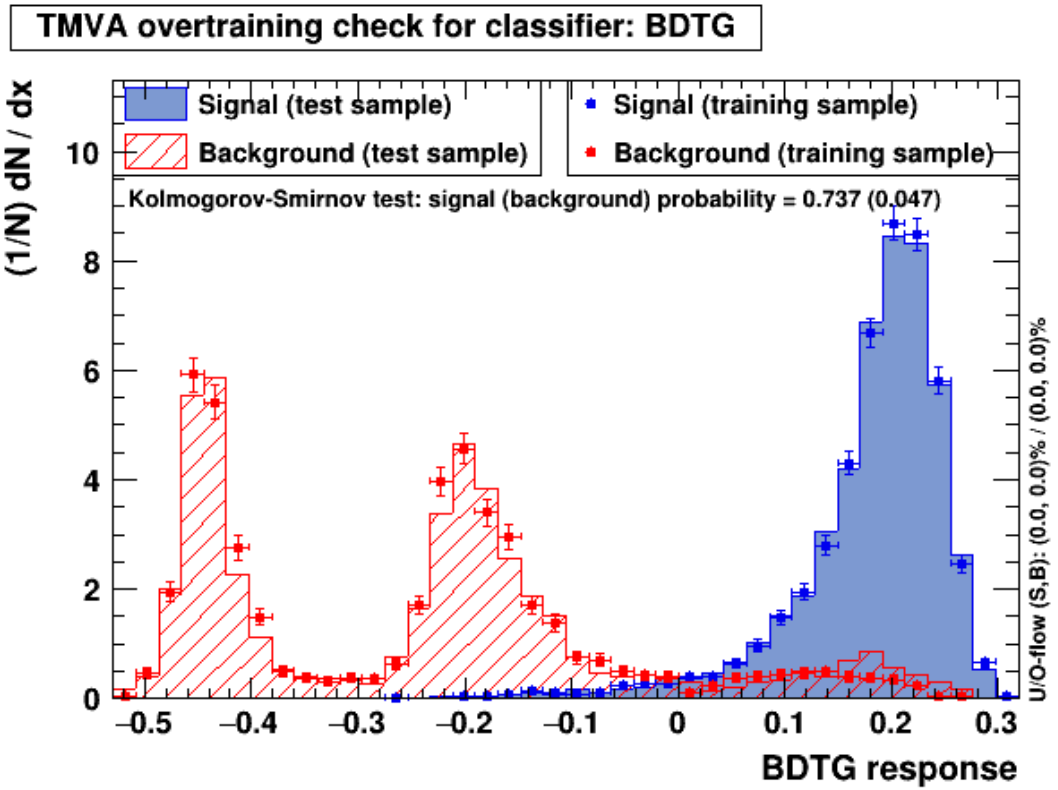

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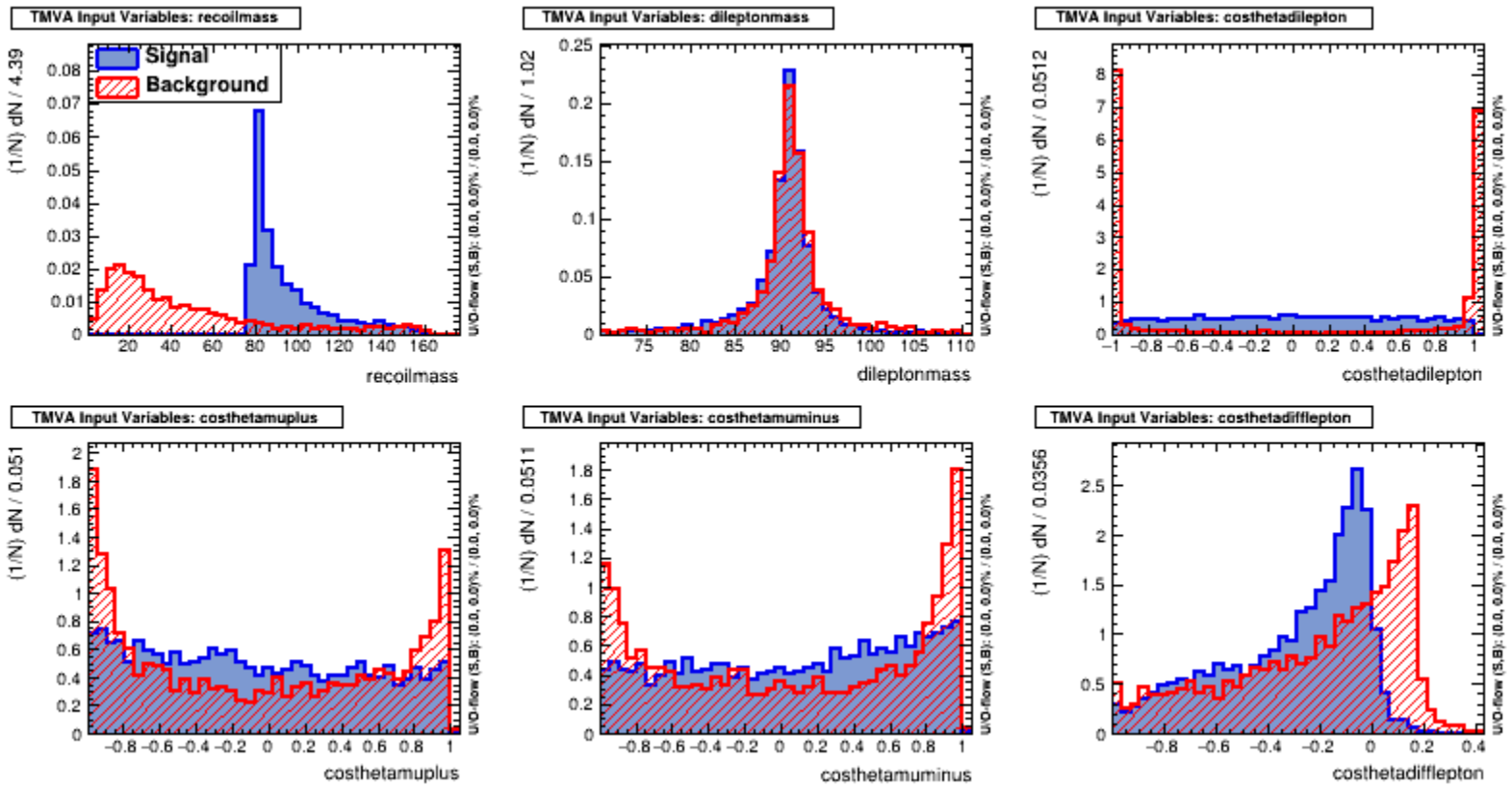

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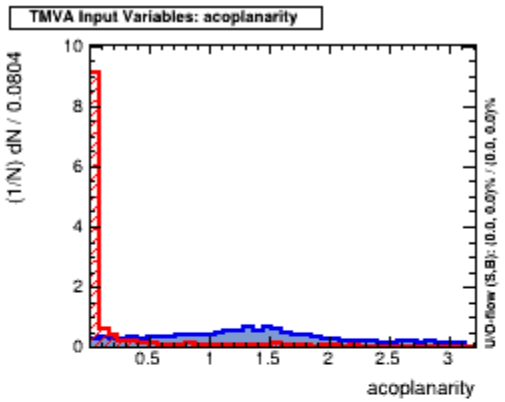

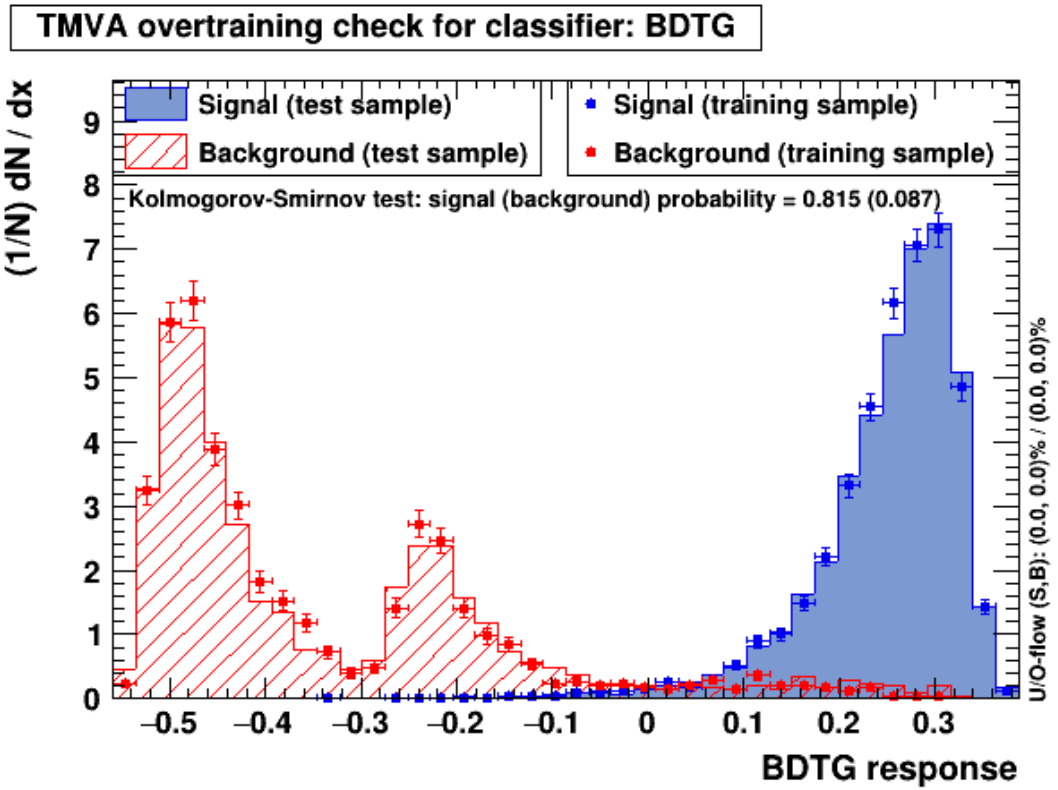

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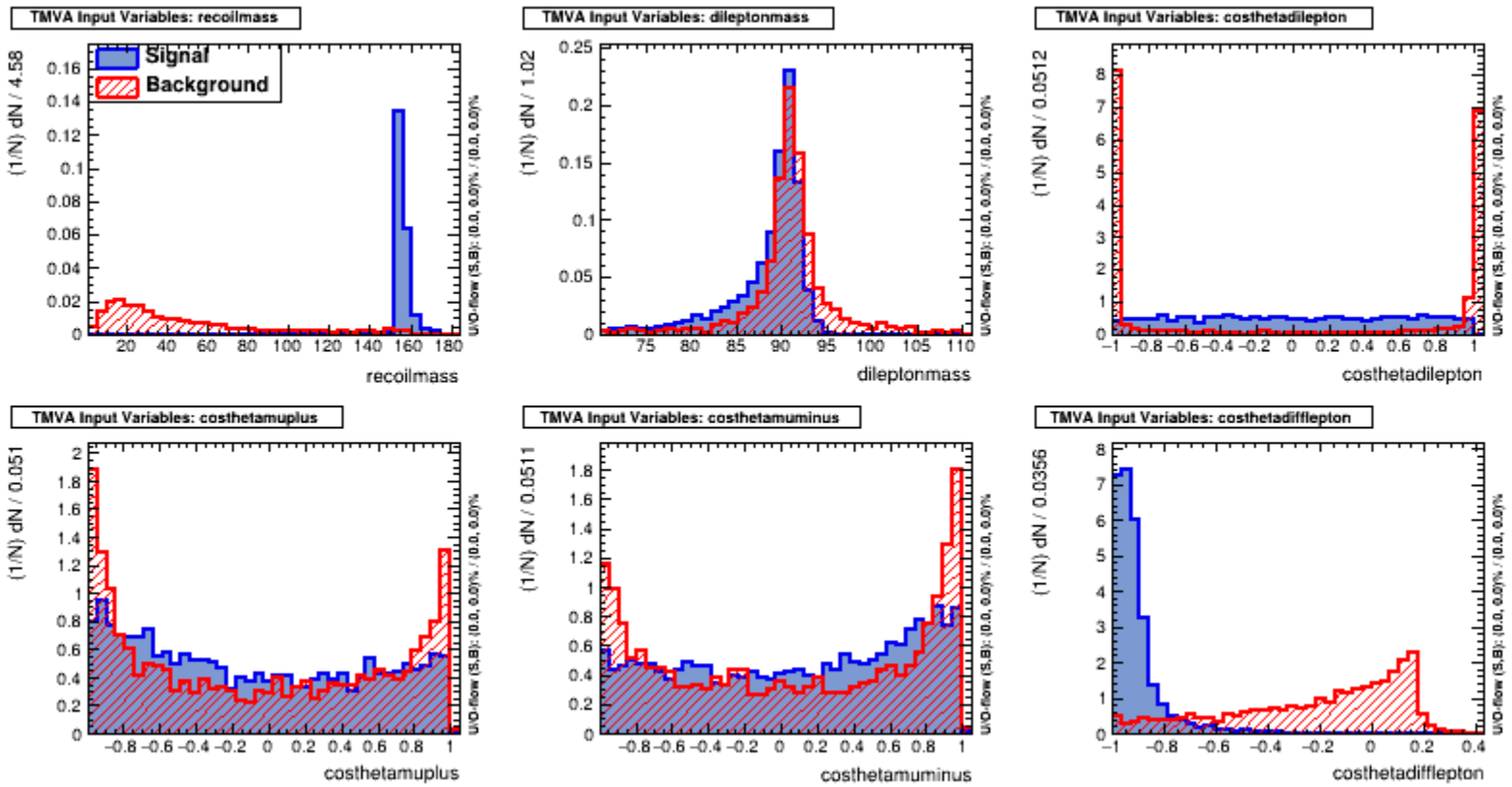
Training against 2f background (2f-mtva)

Exotic Scalar mass 155 GeV



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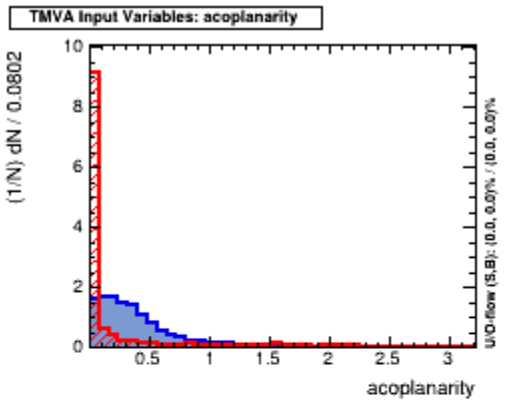

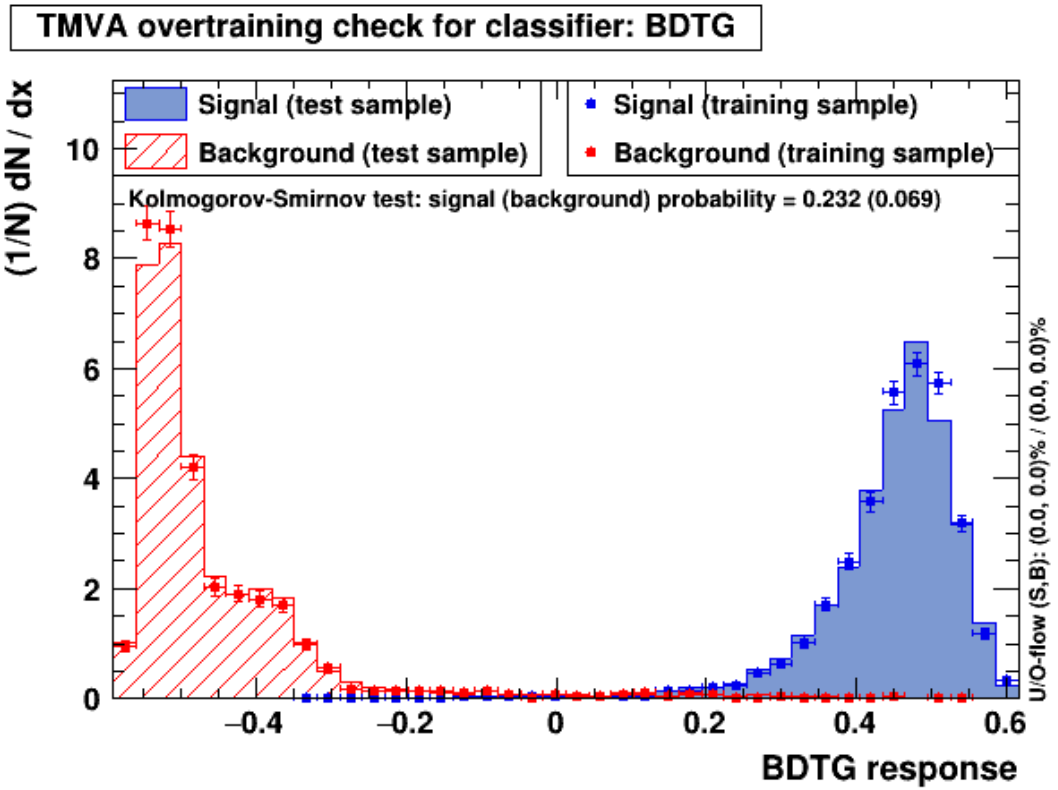

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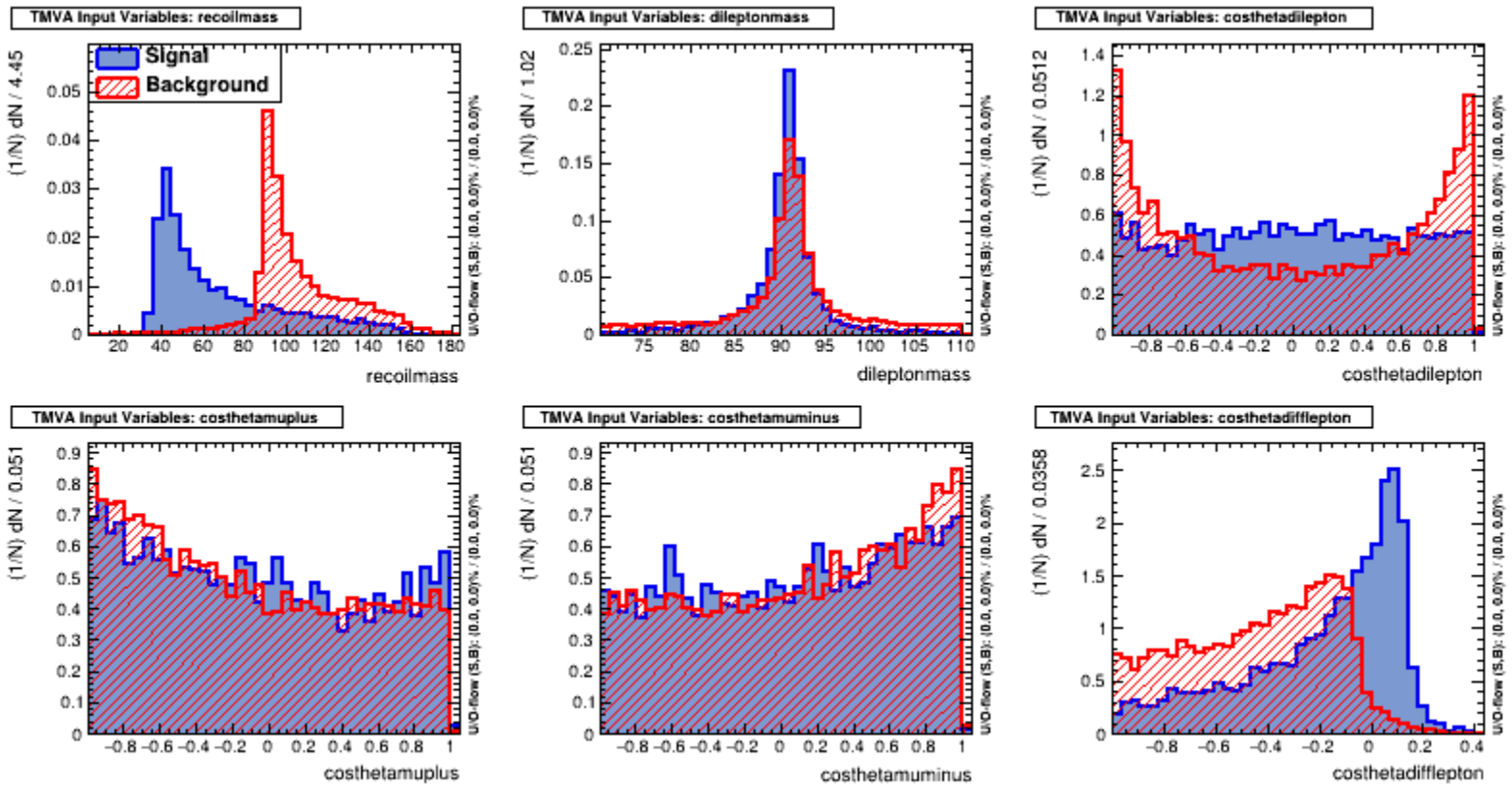
Training against 2f background (4f-mtva)

Exotic Scalar mass 40 GeV



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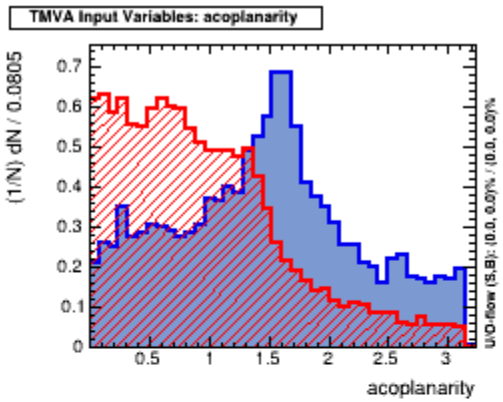

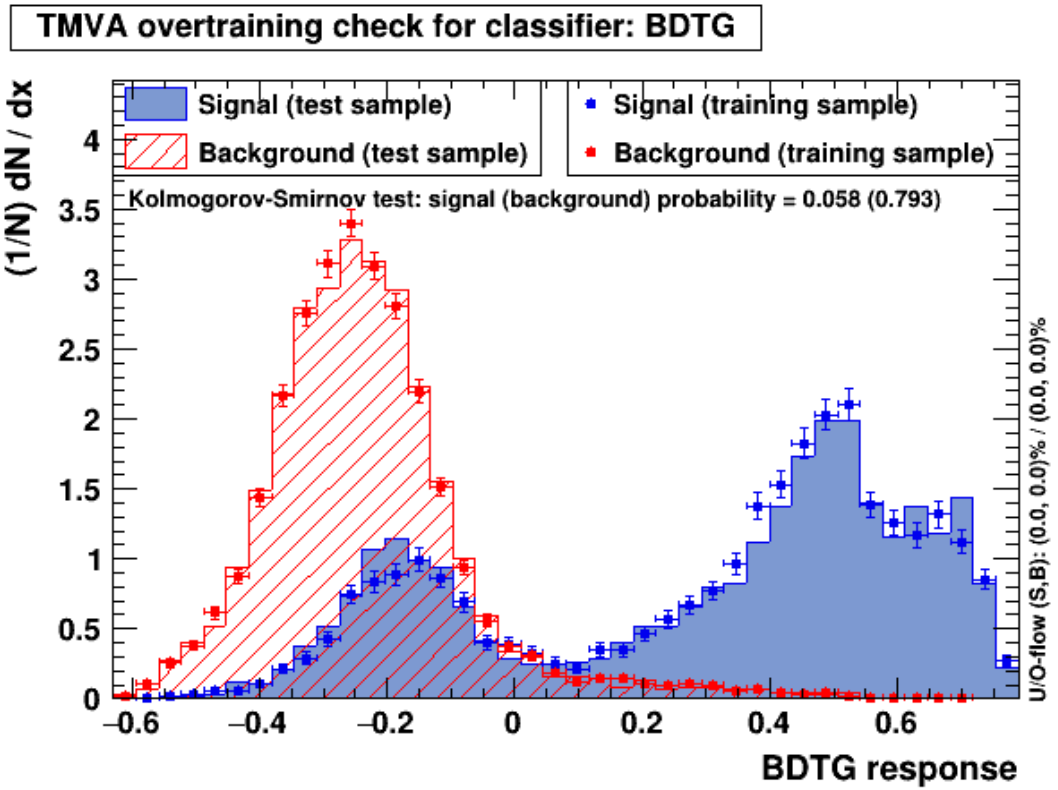

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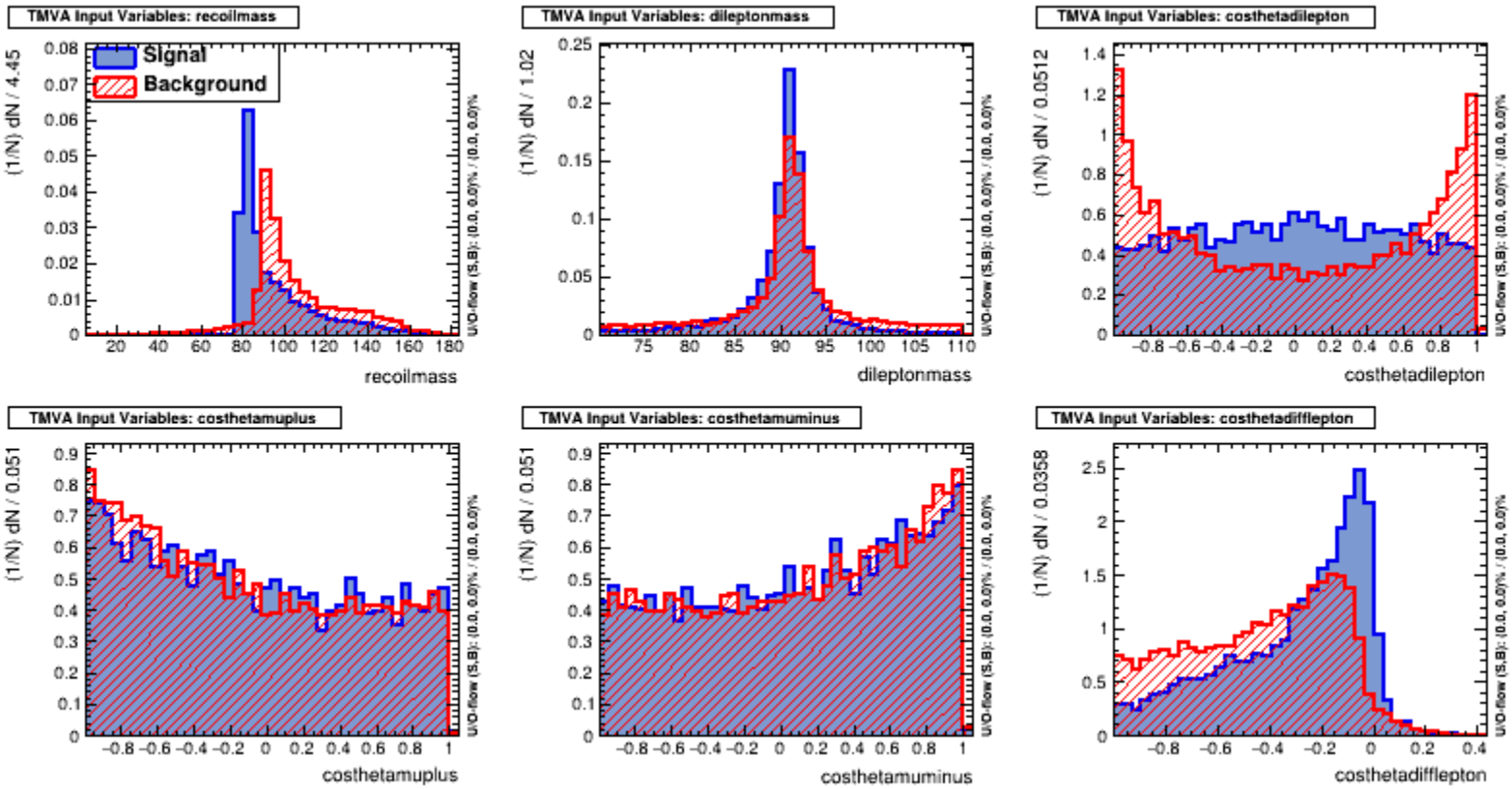

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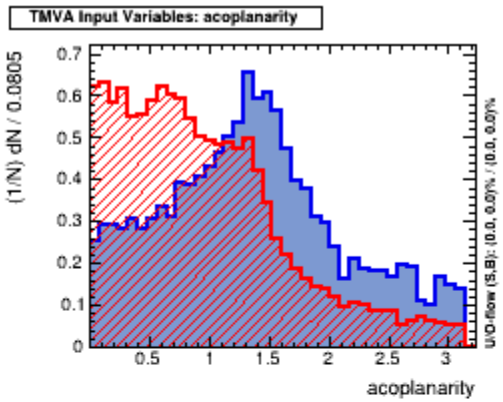

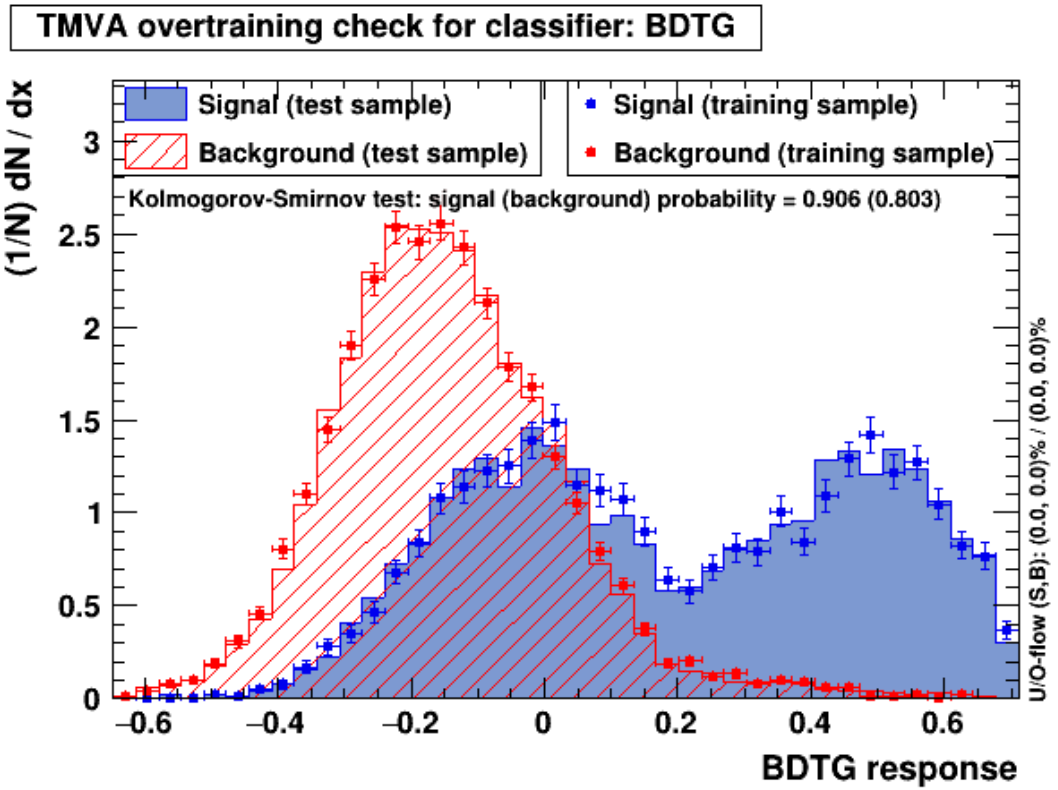

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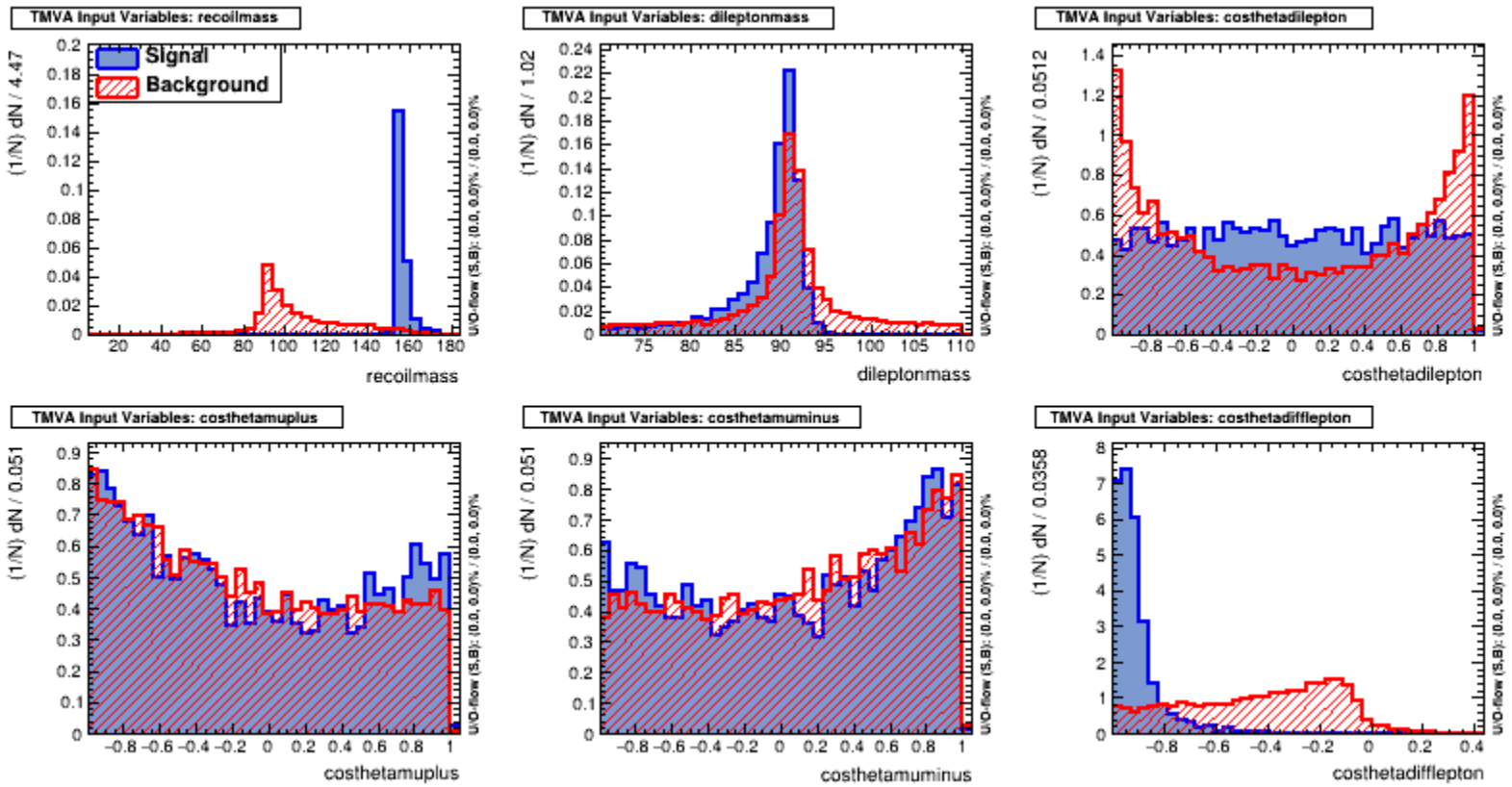

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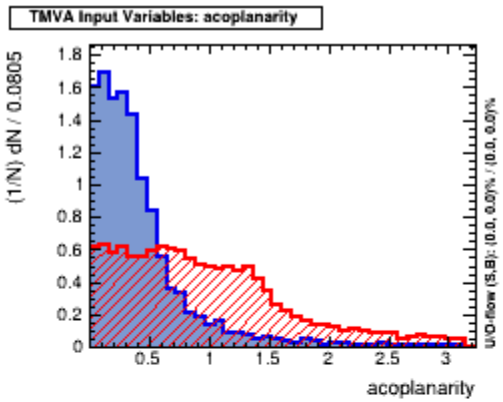

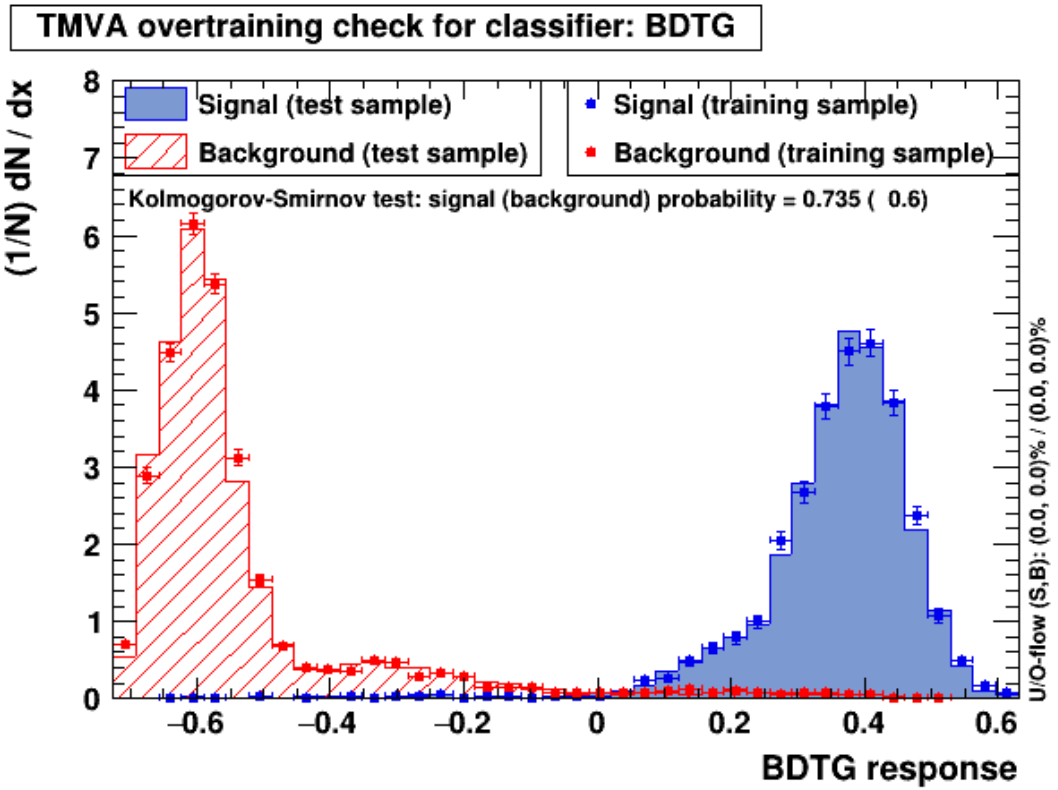

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Cut flow for scalar mass 90 GeV

Around Z boson mass

Scalar mass: 90 GeV

	Signal	e2e2Higgs	4f leptonic	4f semileptonic	2f leptonic
After preselection	15580	8378	117077	76915	13587e-3
After mva2f	14737	6845	69502	63869	48808
After mva4f	6226	1109	8023	13321	5267
After recoil mass	4630	1	4306	9108	1546

Cuts:

mva2f response > 0

mva4f response > 0.1

Recoil mass [90-3,90+10]

Limits:

LR	0.053
RL	0.059
Combined	0.040

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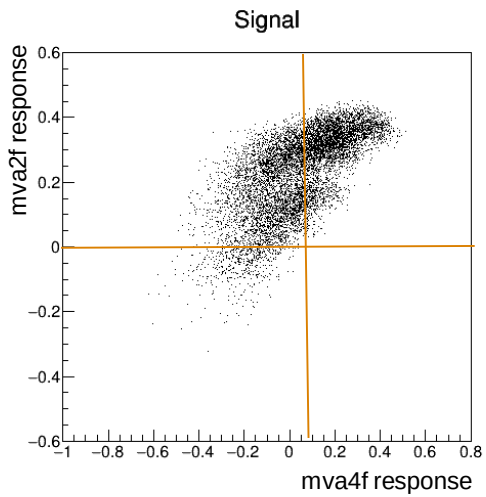
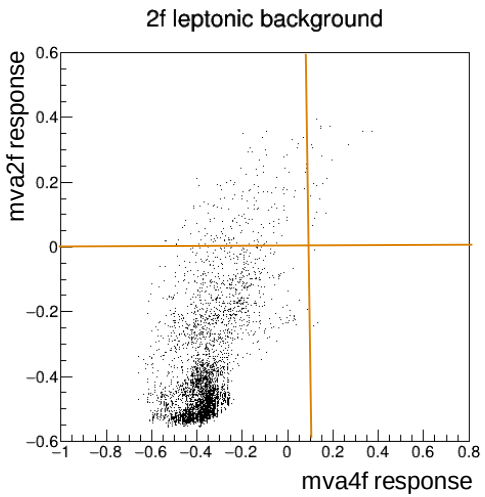
Illustration cuts on variable distributions





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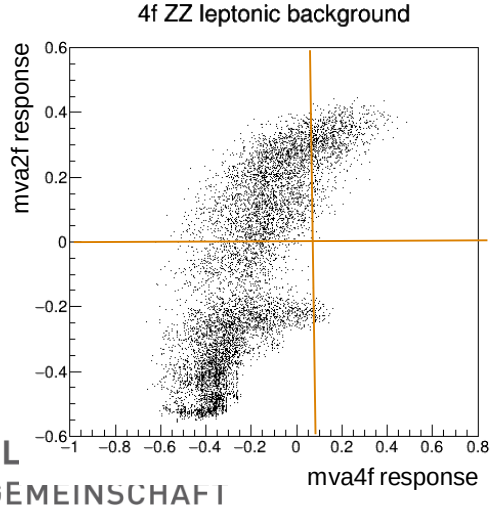

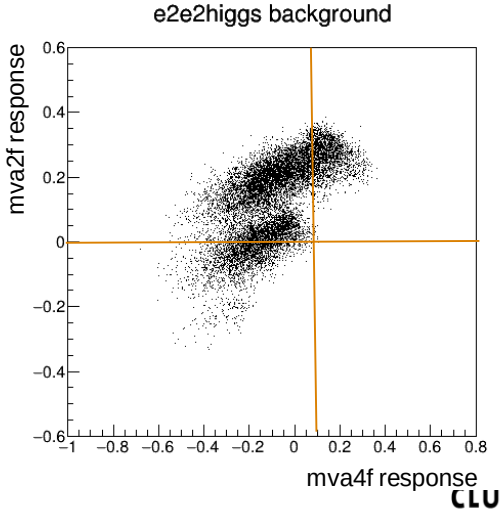

Scalar mass 90 GeV

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
- Extension of the searches to other Z mode decays is foreseen

Calculation of the limits is going on