Update on the extra scalar searches based on recoil mass

Teresa Núñez - DESY
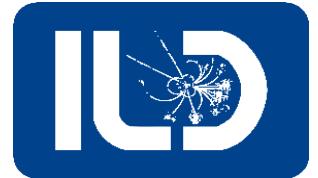
- Motivation and conditions
- Updated analysis flow
- Further checks in the analysis
- Scalar search sensitivity for ILC @ 250 GeV
- Conclusions and outlook

ILD Software and Analysis Meeting (25-01-25)

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Motivation and conditions

- **Reimplementation of previous analysis with current experimental conditions**
- **Redefine cut flow**
- **Use standard Marlin processors if possible**

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)
- 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: $M_{\mu+\mu-}^{FSR}$, $\cos\theta_{\mu+}^{FSR}$, $\cos\theta_{\mu-}^{FSR}$, $\cos\theta_{\mu+\mu-}^{FSR}$, $\cos\theta_{\mu-\mu}^{FSR}$, $\pi - (\phi_{\mu+} - \phi_{\mu-})$
  - cut limits depends on scalar mass
- Limits computed based on fractional event counting using the M_{recoil} histograms

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Why do not add dimuon energy in training ?

Legend:
- Extra scalar (black)
- 2f_l (magenta)
- 4f_l (red)
- 4f_sl (blue)
- SM Higgs (green)

x-axis labels: $\cos\theta_{\mu-\mu}$, P_{dimuon} [GeV], Energy$_{dimuon}$ [GeV]
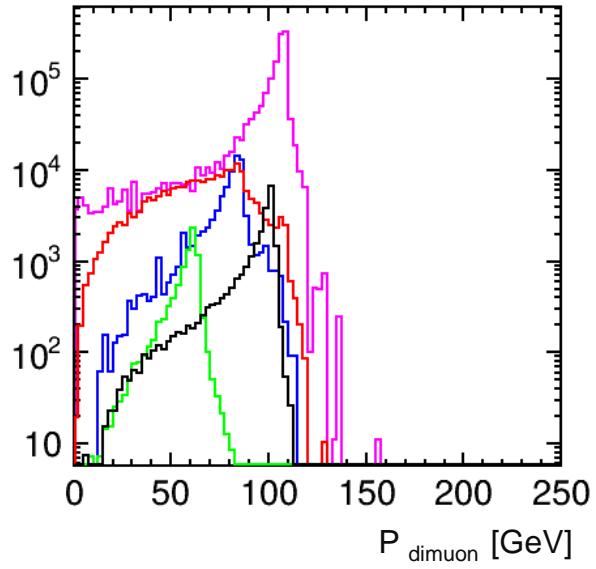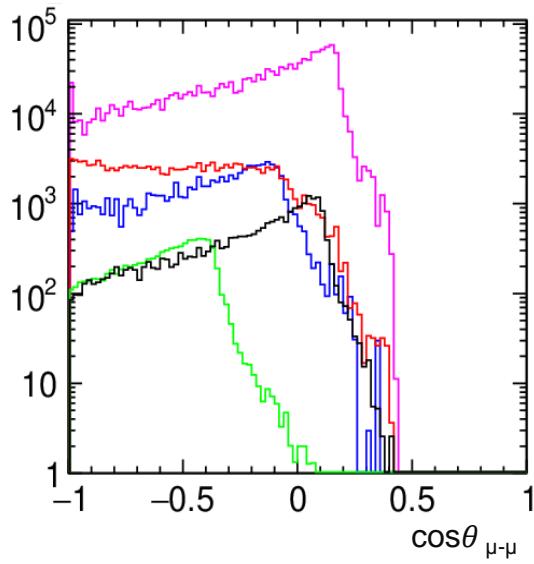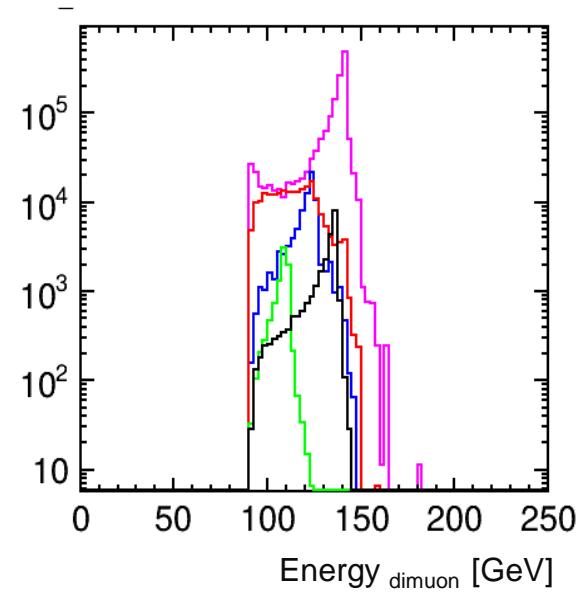
Redundant with the angular distribution already included

Exotic Scalar mass 50 GeV

Correlation mva response 2f vs 4f
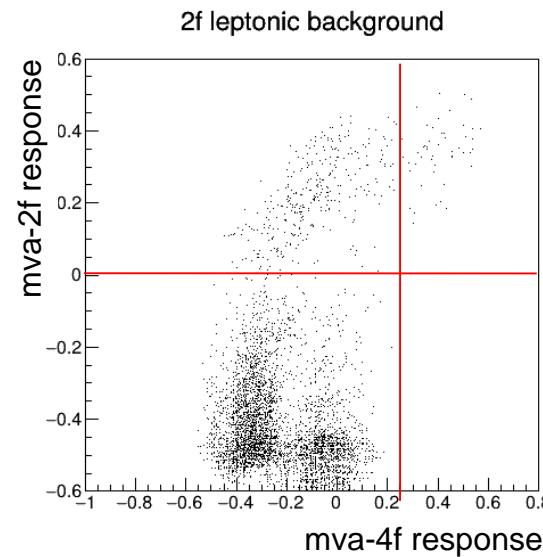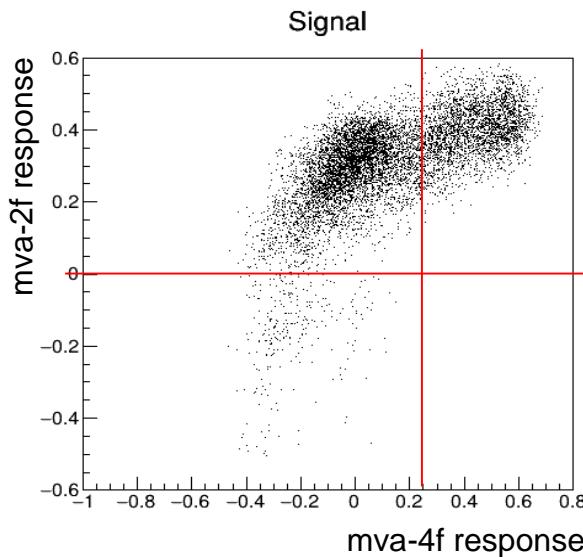
Exotic Scalar mass 50 GeV
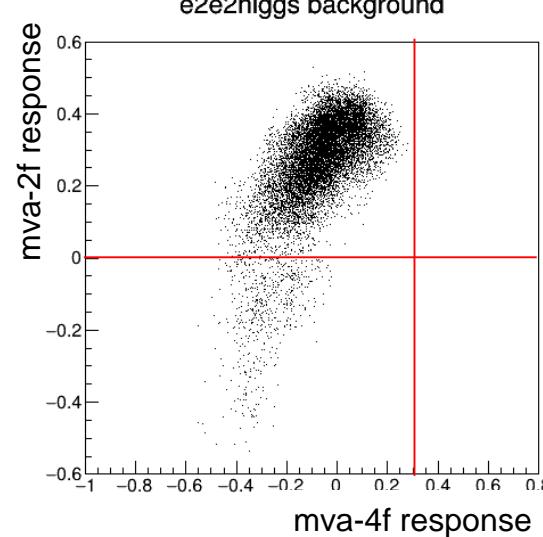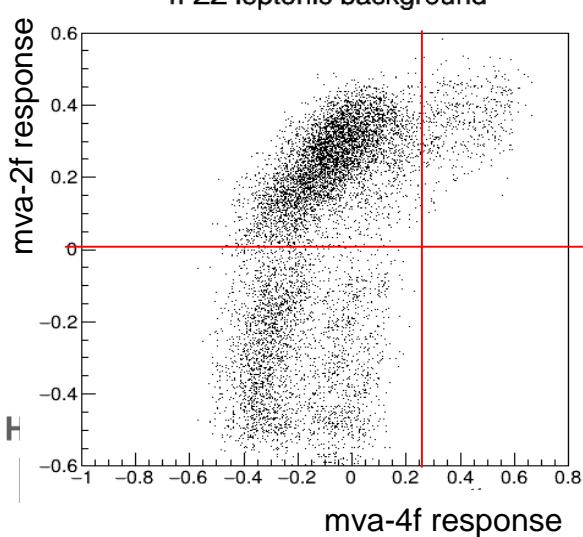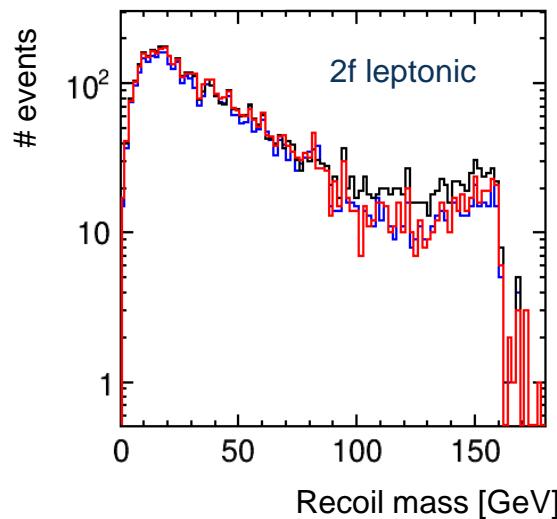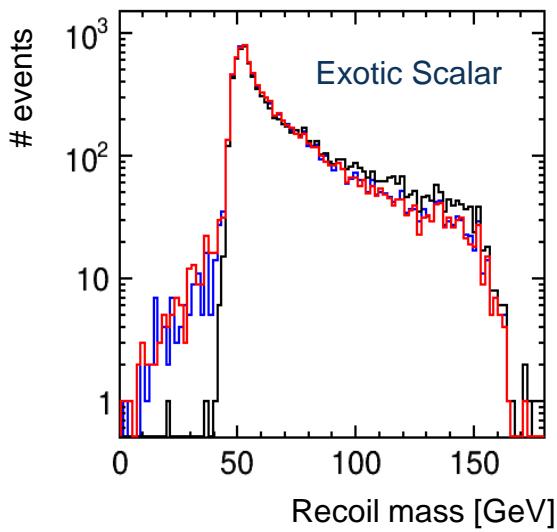
ISR correction in recoil mass

Exotic Scalar mass 50 GeV

Not corrected

ISR correction
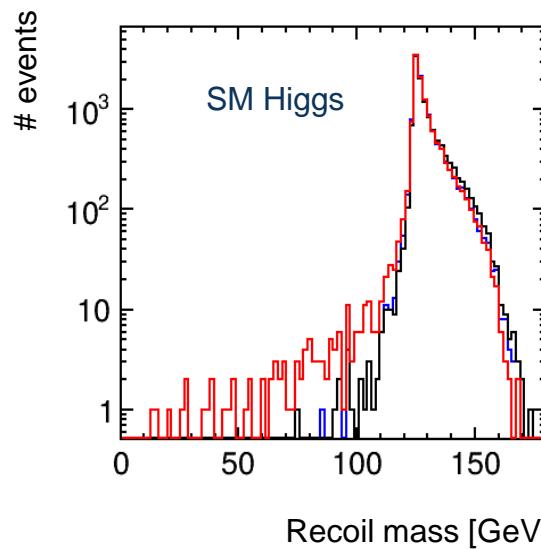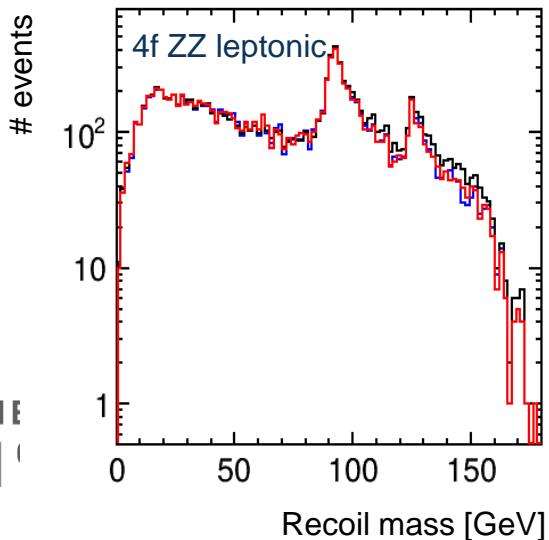
True ISR correction

ISR correction in recoil mass (ctd.)

Exotic Scalar mass 50 GeV

Not corrected

ISR correction

True ISR correction

$(M_{recoil} - M_{extra\_scalar})/M_{extra\_scalar}$

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Recoil mass spectrum: signal vs background

Not MVA cuts
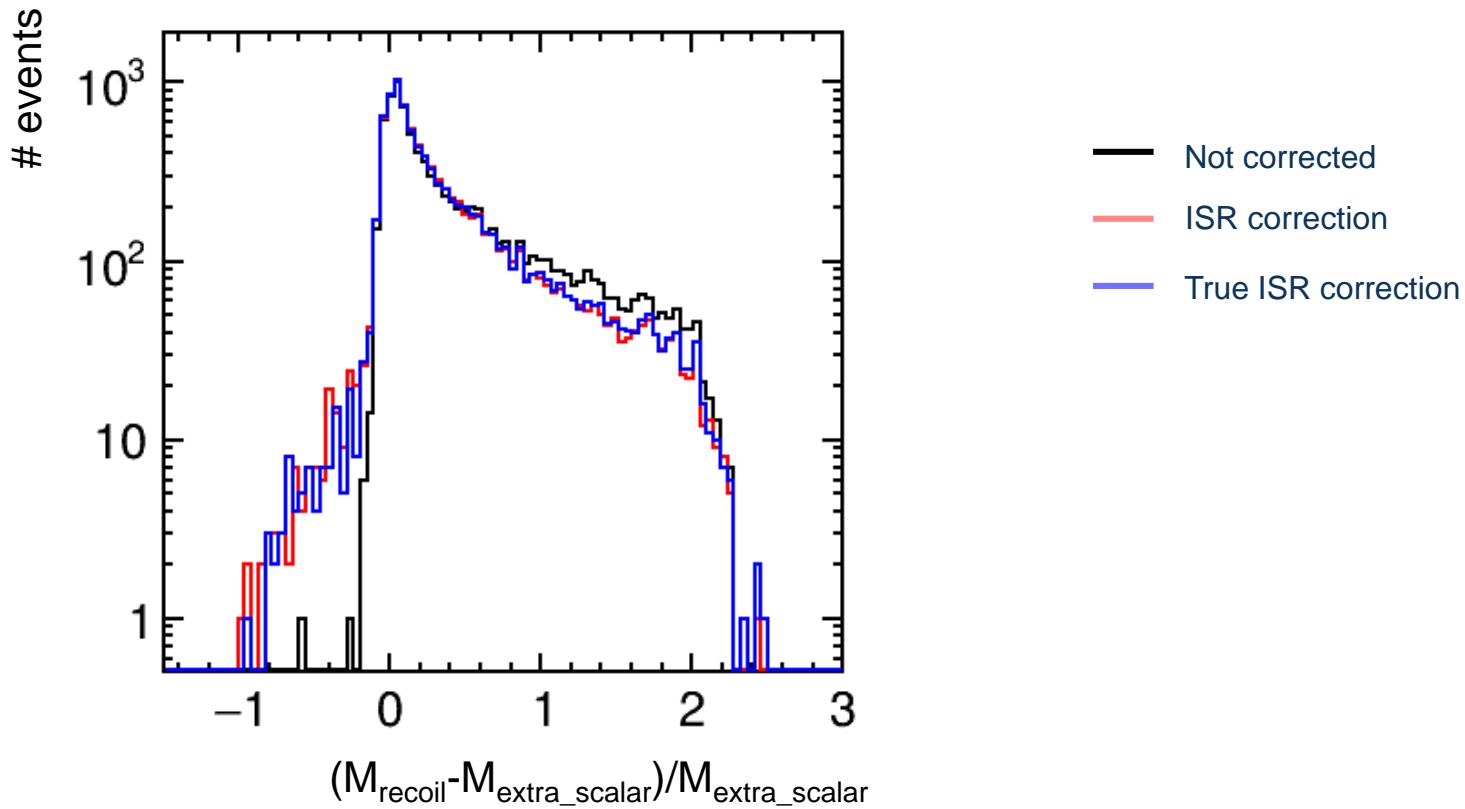
Extra Scalar (m = 50 GeV)
Background
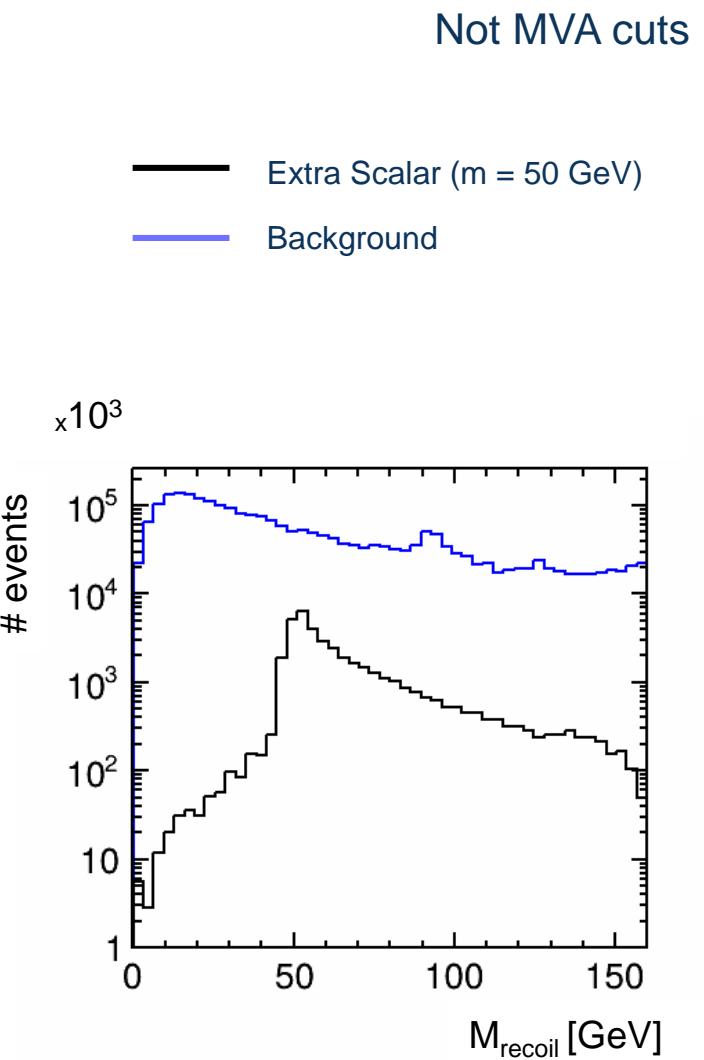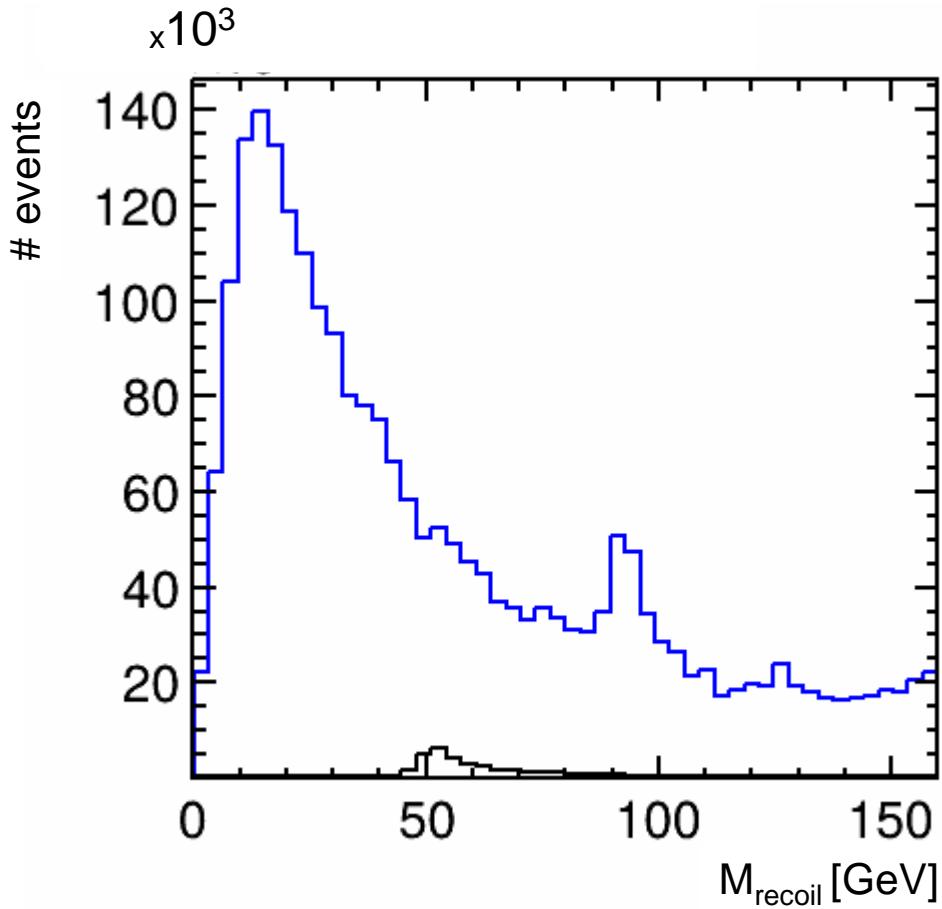
Recoil mass spectrum: signal vs background

2f-MVA cuts

Extra Scalar (m = 50 GeV)

Background

9
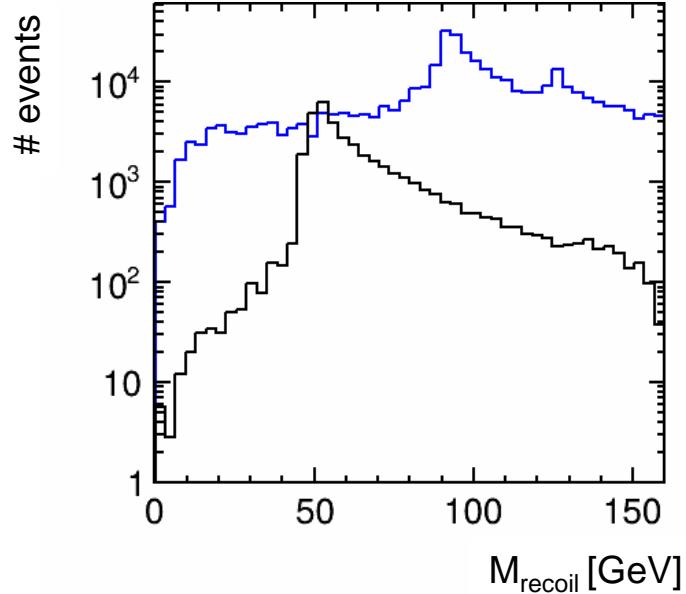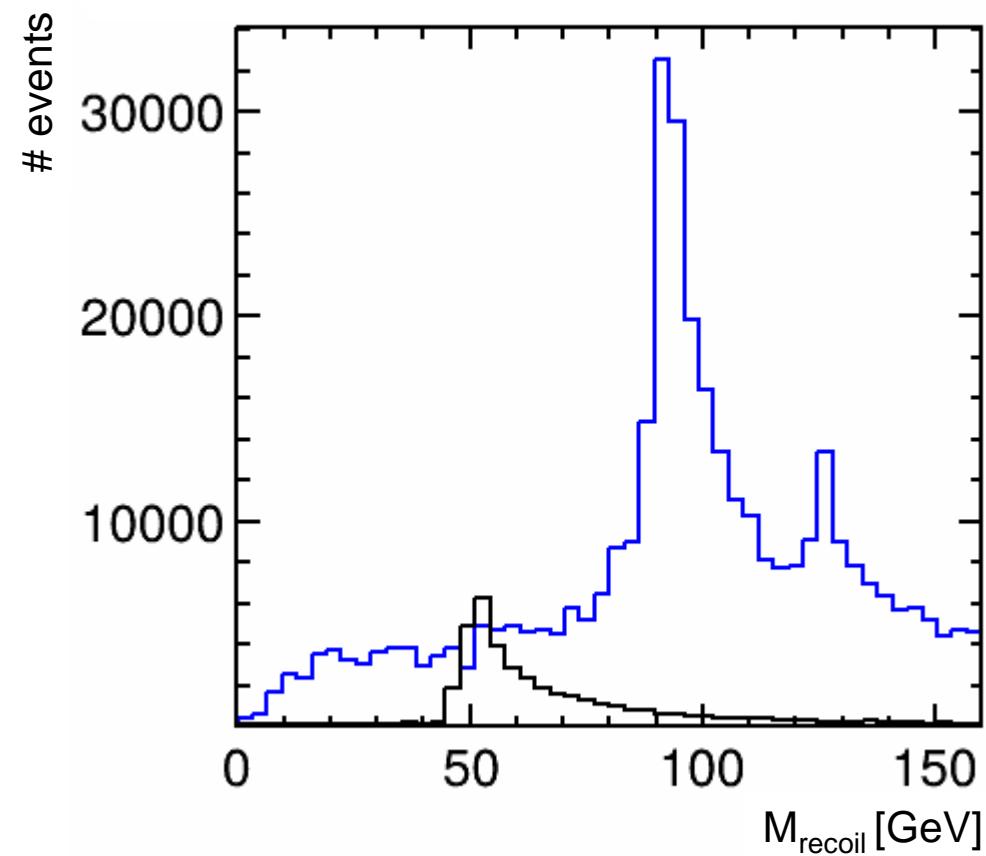
Recoil mass spectrum: signal vs background

2f- & 4f-MVA cuts

— Extra Scalar (m = 50 GeV)
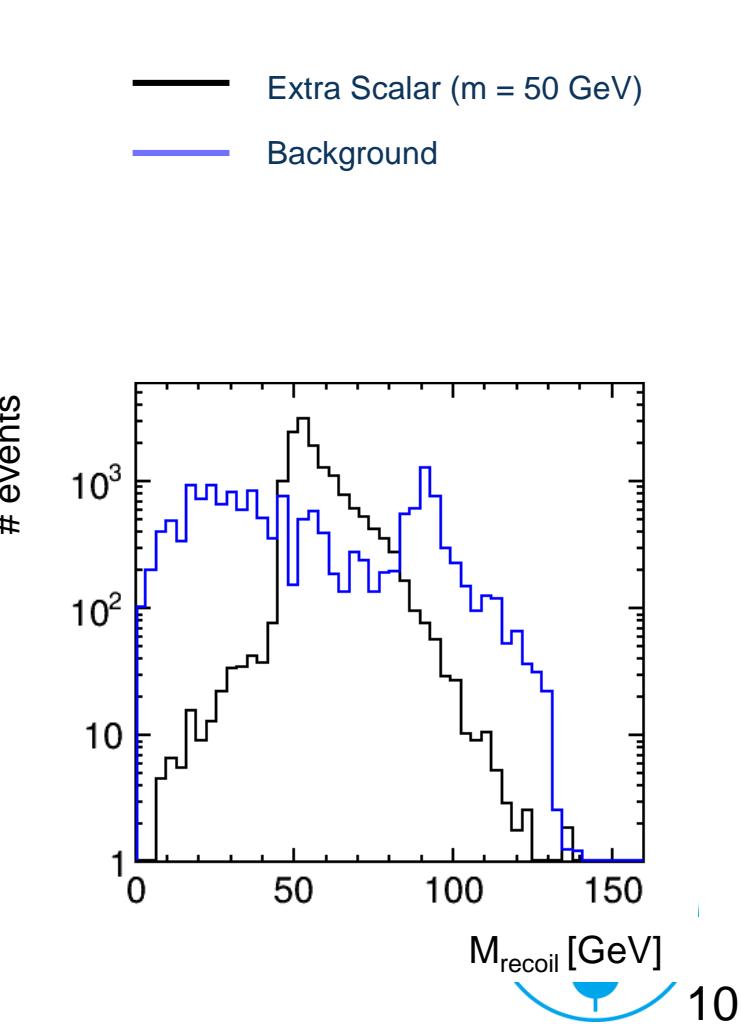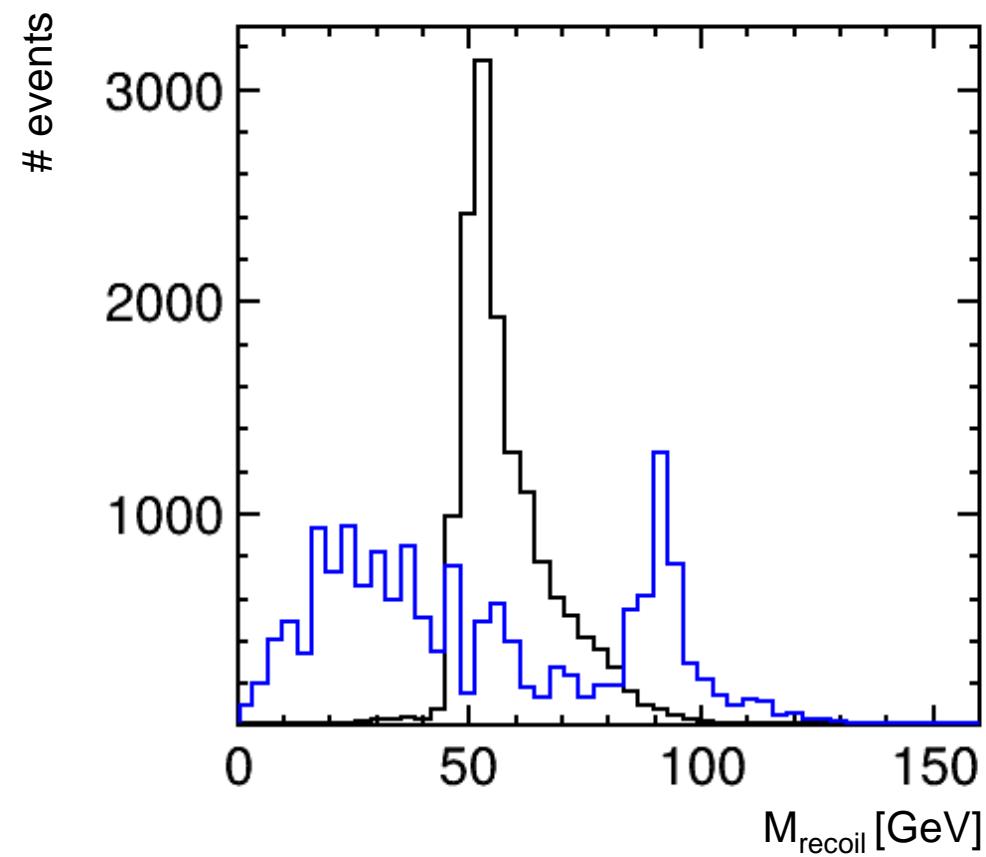
— Background

Cut flow (m_{extra_scalar} = 30 GeV)

Polarisation LR

|	Signal	mumuHiggs	4f leptonic	4f semileptonic	2f leptonic	Others	Total background	Significance
Total	31015.9	9277.43	2.20779e+06	1.67591e+07	1.16846e+07	3.14992e+08	3.45652e+08	0
ISR veto	30230.9	9272.88	2.00739e+06	1.65052e+07	9.98506e+06	2.66984e+08	2.95491e+08	1.8
Kinematic cuts	26853.5	8360.97	115915	76915.5	1.32907e+06	0	1.53026e+06	21.5
MVA 2f	25655.3	7829.75	98529.4	68656.8	93566.6	0	268583	47.3
MVA 4f	9509.7	0	1405.45	1521.5	13074.2	0	16001.2	59.5

Polarisation RL

	Signal	mumuHiggs	4f leptonic	4f semileptonic	2f leptonic	Others	Total background	Significance
Total	20912.1	6257.16	1.87318e+06	2.33915e+06	9.28338e+06	2.56734e+08	2.70236e+08	0
ISR veto	20476.4	6255.59	929199	1.99034e+06	7.91776e+06	2.15993e+08	2.26836e+08	1.3
Kinematic cuts	18202.9	5660.63	30897.3	37916.8	899318	0	973793	18.3
MVA 2f	17394	5368.42	23829.1	33956.5	62037	0	125191	46.1
MVA 4f	6249.48	0	637.9	732.05	7626.9	0	8996.9	50.6

$$significance = \frac{s}{\sqrt{s+B}}$$

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Cut flow (m_{extra_scalar} = 50 GeV)

Polarisation LR

	Signal	mumuHiggs	4f leptonic	4f semileptonic	2f leptonic	Others	Total background	Significance
Total	25673.8	9277.43	5.24819e+06	1.67591e+07	1.16846e+07	3.14992e+08	3.48693e+08	0
ISR veto	25574.6	9277.40	3.58982e+06	1.65261e+07	1.00969e+07	2.72015e+08	3.02237e+08	1.47
Kinematic cuts	23243.3	8368.12	132412	76915.5	1.35870e+06	0	1.5764e+06	18.8
MVA 2f	22460.0	7922.28	113034	68241.4	110683	0	299881	39.6
MVA 4f	8680.21	20.78	3276.87	2628.59	18199.3	0	24125.5	47.9

Polarisation RL

	Signal	mumuHiggs	4f leptonic	4f semileptonic	2f leptonic	Others	Total background	Significance
Total	17312.0	6257.16	2.05509e+06	2.33915e+06	9.28338e+06	2.56734e+08	2.70418e+08	0
ISR veto	17219.3	6256.73	1.16572e+06	2.0274e+06	8.0073e+06	2.20701e+08	2.31907e+08	1.13
Kinematic cuts	15645.8	5663.22	32143.1	37916.8	917513	0	993236	15.6
MVA 2f	15123.6	5429.19	25240	34152.9	76423.8	0	141246	38.2
MVA 4f	5139.9	13.73	816.57	894.0	10235.9	0	11960.2	39.3

$$significance = \frac{s}{\sqrt{s+B}}$$

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Cut flow (m_{extra_scalar} = 90 GeV)

Polarisation LR

	Signal	mumuHiggs	4f leptonic	4f semileptonic	2f leptonic	Others	Total background	Significance
Total	17097.9	9277.4	2.20779e+06	1.67591e+07	1.16846e+07	3.14992e+08	3.45652e+08	0
ISR veto	17094.1	9272.9	2.00739e+06	1.65052e+07	9.98506e+06	2.66984e+08	2.95491e+08	1.0
Kinematic cuts	15576.7	8374.2	116063	76915.5	1.32907e+06	0	1.53042e+06	12.5
MVA 2f	15080.5	8011.4	100211	68448.3	86839	0	263510	28.6
MVA 4f	7975.2	2414.9	14327.6	21870.5	21699	0	60312	30.5

Polarisation RL

	Signal	mumuHiggs	4f leptonic	4f semileptonic	2f leptonic	Others	Total background	Significance
Total	11526.7	6257.2	1.87318e+06	2.33915e+06	9.28338e+06	2.56734e+08	2.70236e+08	0
ISR veto	11518.1	6255.6	929199	1.99034e+06	7.91776e+06	2.15993e+08	2.26836e+08	0.8
Kinematic cuts	10483.0	5669.6	30995.6	37916.8	899318	0	973900	10.6
MVA 2f	10190.9	5481.4	23348.7	33731.1	56473	0	1190 35	28.3
MVA 4f	4881.4	1855.7	4659.8	8212.1	10623	0	25351	28.1

$$significance = \frac{s}{\sqrt{s+B}}$$

# Scalar search sensitivity for ILC @ 250 GeV
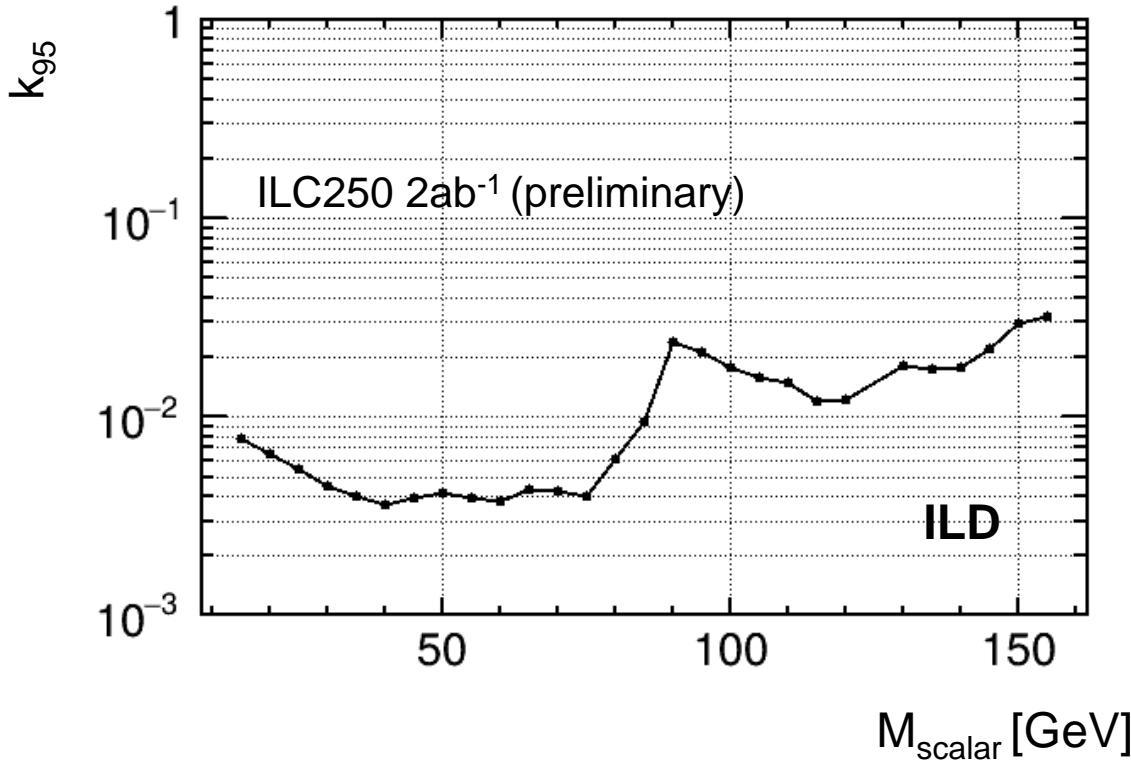
Scalar production cross section relative to SM Higgs boson production cross section at given mass

Limits based on fractional event counting using the M_{recoil} histograms

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Scalar search sensitivity for ILC @ 250 GeV (ctd.)

New vs previous results
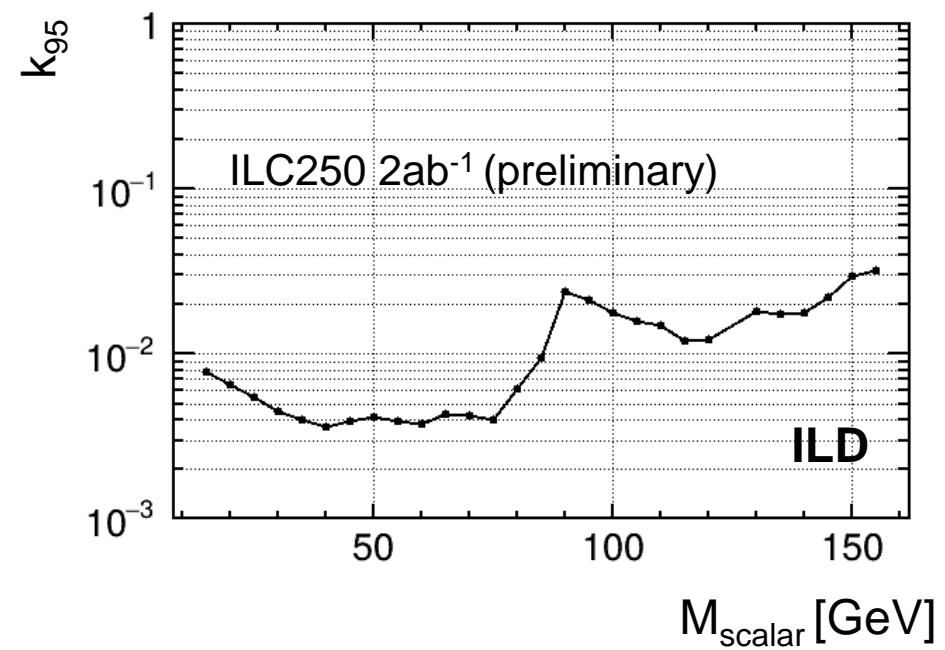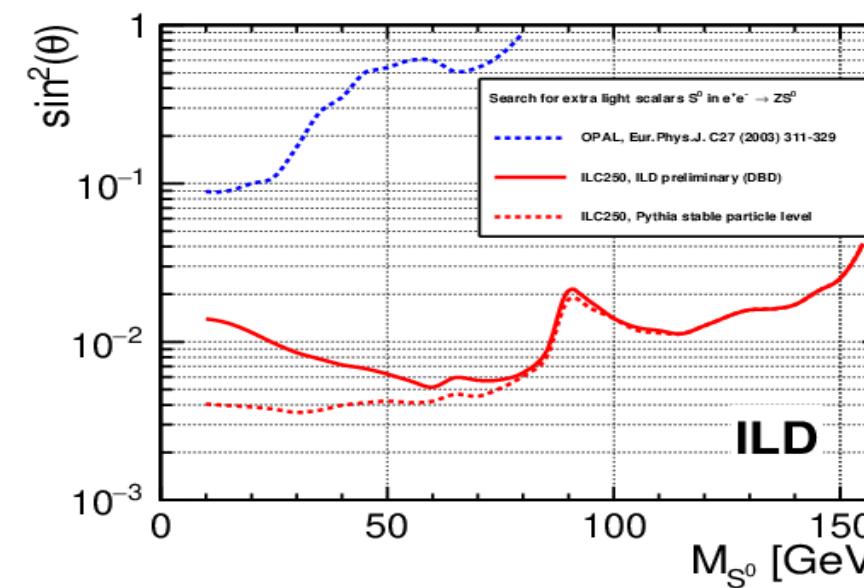
Conclusions and outlook

- 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
- Review of the cuts has being performed
- Calculation of the limits using fractional counting based on the recoil mass spectrum has been performed
- More statistics will be added
- Extension of the searches to other Z mode decays is forseen