Signatures of new scalar particles at future e^+e^- colliders

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1. MOTIVATION

A number of astrophysical observations based on gravitational interactions point to the existence of dark matter (DM) in the Universe, which can not be described with the Standard Model (SM). Many of the proposed extensions of the SM, which can provide a dark matter candidate, involve extended scalar sectors and new scalar particles which could be produced at future e^+e^- colliders. Many different BSM scenarios, production channels and signatures can be considered. While it is not feasible to put constrains on all theoretical scenarios, one can consider a model-independent approach, where cross section limits are set for different signal signatures.

2. INERT DOUBLET MODEL

We studied the case of the Inert Doublet Model (IDM) in detail,[1,2] where pair-production of new neutral or charged scalars is possible already at 250 GeV collision energy,[3] and the expected signature is mono-Z or W-pair production (where Z or W can be on- or off-shell, depending on the model parameters) and large missing energy. For low mass benchmark scenarios, high statistical significance of signal observation is expected for the leptonic signature, see Fig. 1. For high scalar masses, the semi-leptonic final state should be considered, as it provides much higher statistics of signal events.[4] Heavy charged IDM scalars could be observed at high energy CLIC stages up to the masses of about 1 TeV, see Fig. 2.

3. HIGGS PORTAL MODELS

In the Higgs-portal models existence of additional fundamental scalars of the "hidden sector" is assumed. As they mix with the SM Higgs, they could be produced in e^+e^- collisions in the process corresponding to the Higgs-strahlung process in the SM. We studied the possibility of constraining production of new scalar particles at CLIC running at 380 GeV and 1.5 TeV, assuming their invisible decays.[5] In Fig. 3 the expected CLIC sensitivity is compared to the existing limit from LEP and the expected sensitivity of ILC running at 250 GeV and 500 GeV.[6]

4. PLANS FOR SNOWMASS 2021

We plan to consider other models with extended scalar sectors, as eg. 2HDM+a model,[7] where new interesting signatures are expected. New scalars can be produced singly or in pairs, in association with the Z boson, W^+W^- pair, SM Higgs boson, top-quark pair or pair of b quarks. From the experimental point of view, cross section limits can be set separately for each considered production channel and signature. These cross section limits can be used as an input to further analysis, to set limits on different extensions of the Standard Model.

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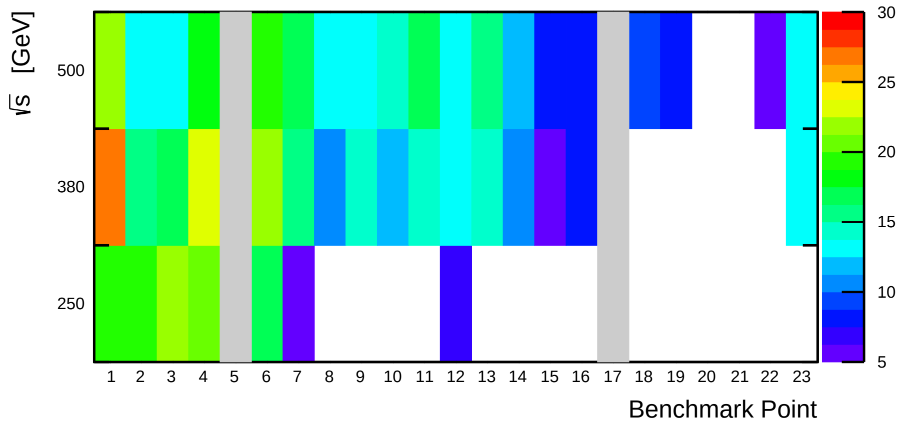

Figure 1. Significance of the deviations from the Standard Model predictions, expected for $1\,\mathrm{ab}^{-1}$ of data collected at centre-of-mass energy of 250 GeV, 380 GeV and 500 GeV, for events with two muons in the final state, for low mass IDM benchmark scenarios.[3] Only significances above 5σ are shown.

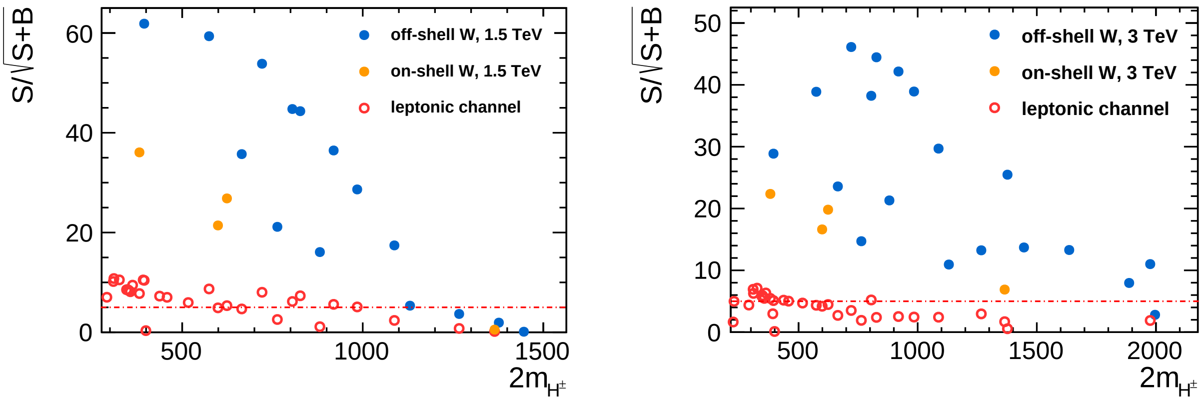

Figure 2. Expected statistical significance for different IDM scenarios,[4] as a function of charged scalar mass, for CLIC running at 1.5 TeV (left) and 3 TeV (right), both for the scenarios with on-shell $W^{\pm}$ boson and off-shell (orange) $W^{\pm}$ boson (blue). Open red circles show the expected results for the leptonic channel,[2] and the red dotted line denotes the 5σ threshold.

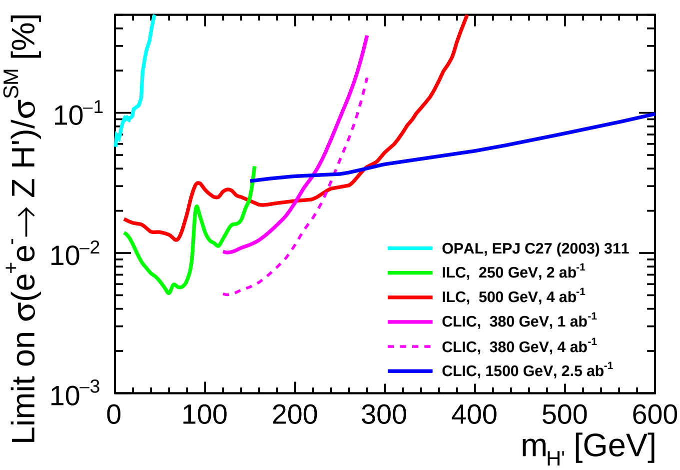

Figure 3. Expected sensitivity of CLIC running at 380 GeV and 1.5 TeV compared to the existing limit from LEP and the expected sensitivity of ILC running at 250 GeV and 500 GeV.[6] Limits on the production cross section of the new scalar H', relative to the expected SM Higgs production cross section, are shown as a function of its mass. For CLIC limits, new scalar is assumed to have invisible decay channel only, BR(H'→inv) = 100%, while LEP and ILC results are decay-mode independent.