Probing Dark Matter at the LHC Using Vector Boson Fusion Processes

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Probing Dark Matter at the LHC Using Vector Boson Fusion Processes

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Vector boson fusion processes at the Large Hadron Collider (LHC) provide a unique opportunity to search for new physics with electroweak couplings. A feasibility study for the search of supersymmetric dark matter in the final state of two vector boson fusion jets and large missing transverse energy is presented at 14 TeV. Prospects for determining the dark matter relic density are studied for the cases of wino and bino-Higgsino dark matter. The LHC could probe wino dark matter with mass up to approximately 600 GeV with a luminosity of 1000 fb^{-1}.

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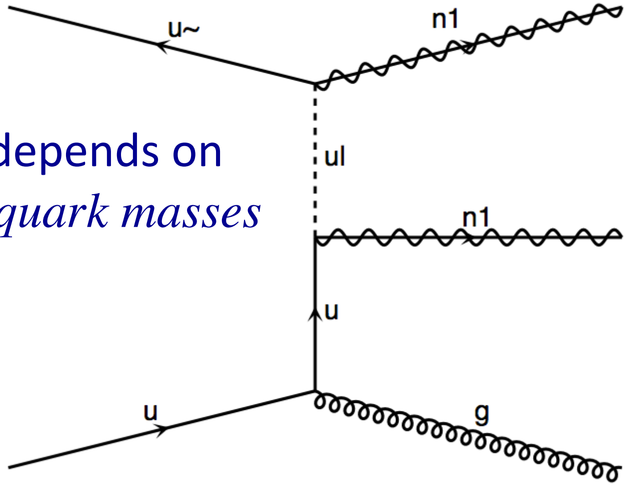
C. Clément

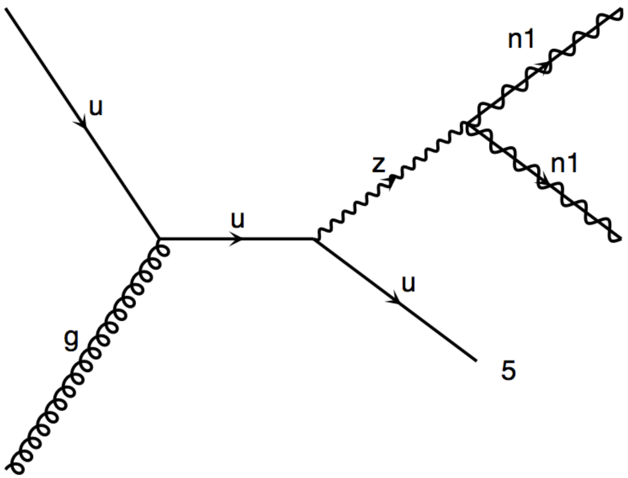
OKC Dark Matter Meeting

DM monojet search

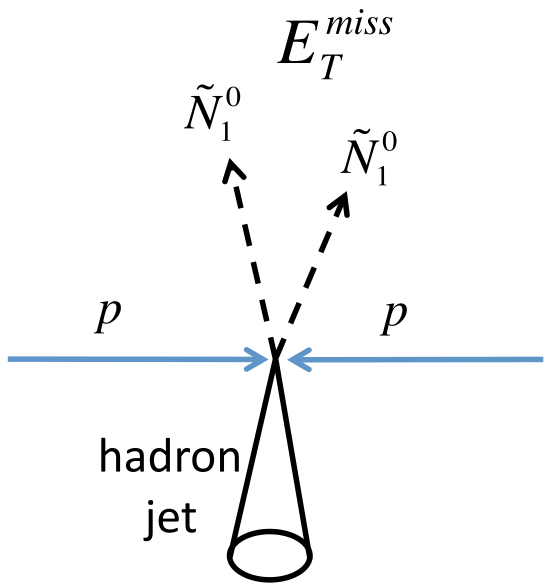
Feynman

here depends on
some squark masses



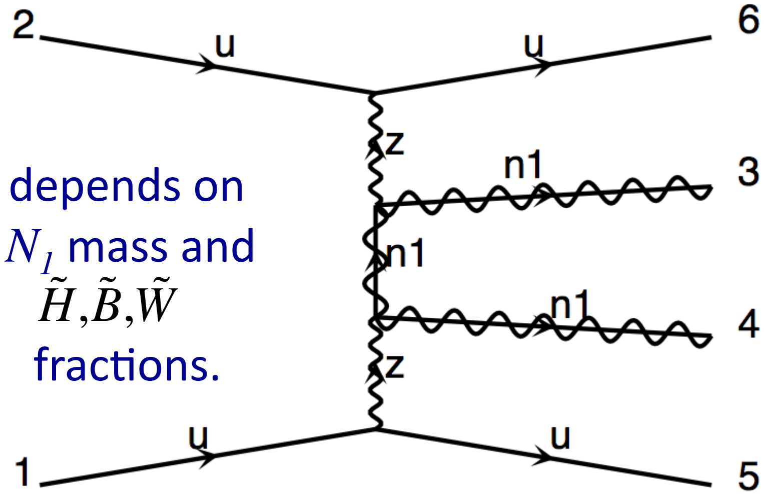


Detector

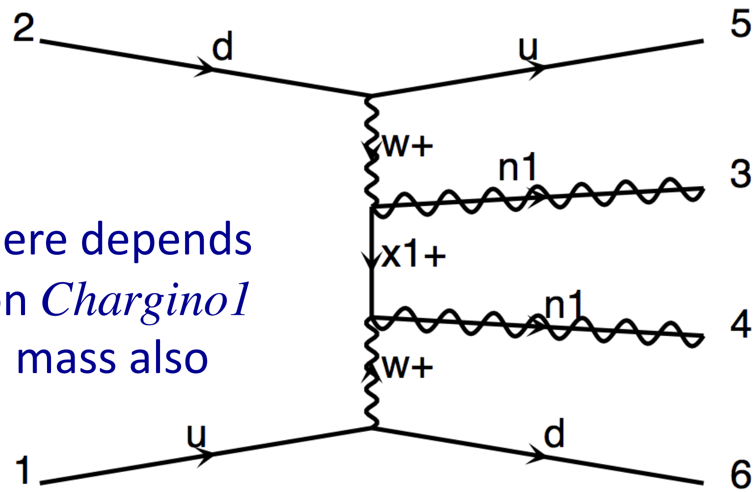


DM VBF search

Feynman

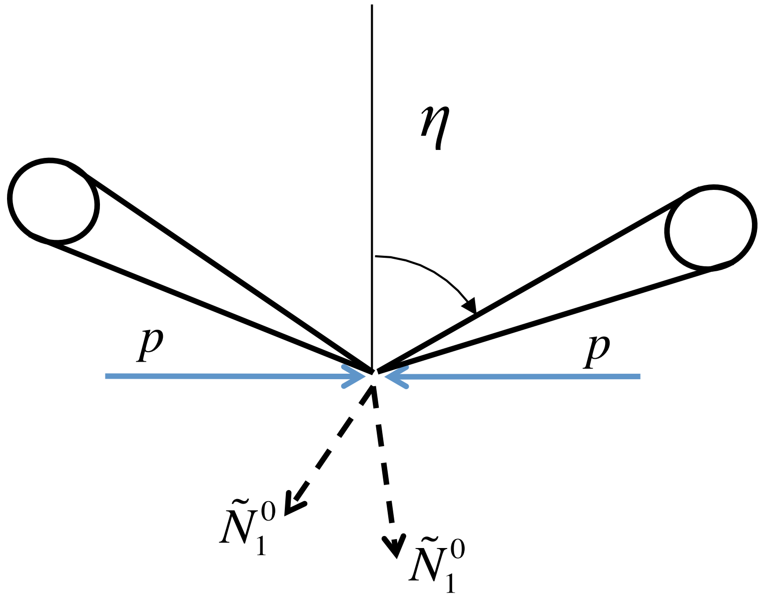


depends on N_1 mass and $\tilde{H},\tilde{B},\tilde{W}$ fractions.



here depends on *Chargino1* mass also

Detector



Two high p_T forward jets
high $\Delta\eta$
with high invariant mass $m(j_1,j_2)$

also consider in this paper

$\tilde{\chi}_1^0\tilde{\chi}_1^0, \tilde{\chi}_1^0\tilde{\chi}_1^\pm, \tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$

Select VBF with two jets fullfilling

$m(j_1,j_2)>1500$ GeV
$\Delta\eta > 4.2$
$\eta_1 . \eta_2 > 0$

"VBF cuts"

Paper does not show $\Delta\eta$ distribution

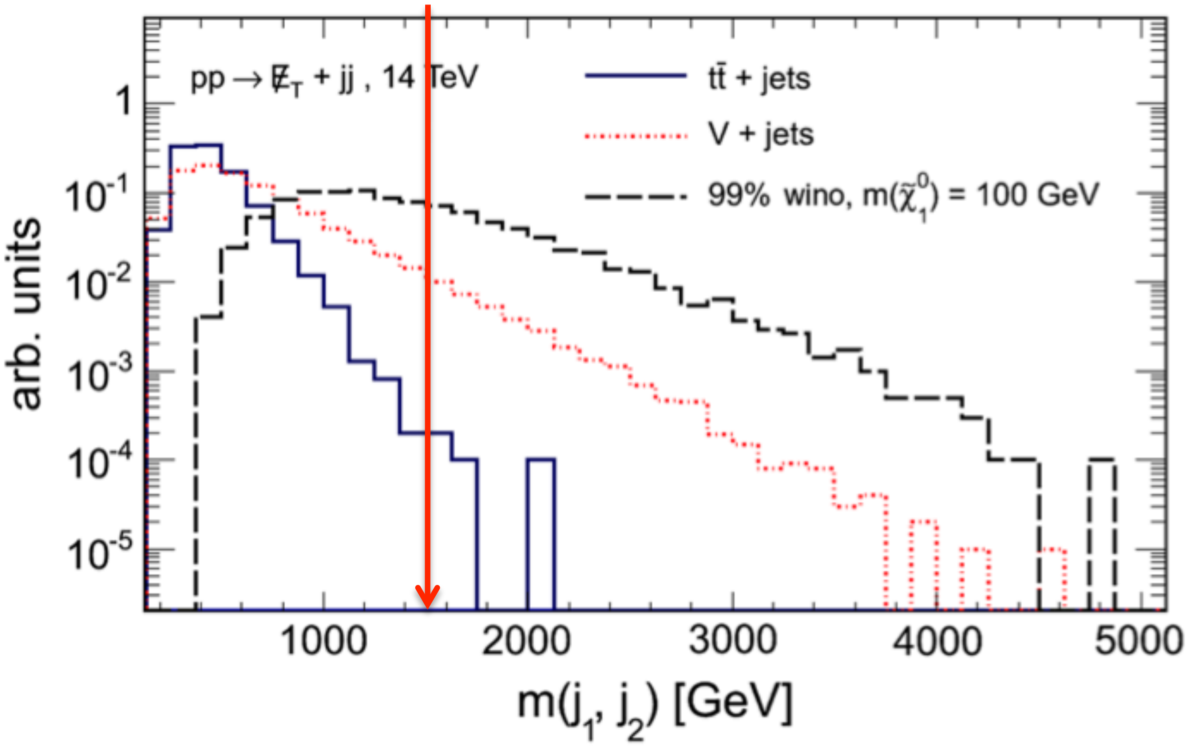


FIG. 2 (color online). Distribution of the dijet invariant mass $M_{j_1 j_2}$ normalized to unity for the tagging jet pair (j_1, j_2) and main sources of background after preselection cuts and requiring $p_T > 50$ GeV for the tagging jets at LHC14. The dashed black curves show the distribution for the case where $\tilde{\chi}^0_1$ is a nearly pure wino with $m_{\tilde{\chi}^0_1} = 50$ and 100 GeV. Inclusive $\tilde{\chi}^0_1\tilde{\chi}^0_1$, $\tilde{\chi}^{\pm}_1\tilde{\chi}^{\pm}_1$, $\tilde{\chi}^{\pm}_1\tilde{\chi}^{\mp}_1$, and $\tilde{\chi}^{\pm}_1\tilde{\chi}^0_1$ production is considered.

Paper discusses the reach with
High Luminosity LHC ie 1000 fb^{-1}

Question:
can we get started much earlier?

Cross section very sensitive to the Neutralino composition.

200 GeV N1 provides 10 fb
2015 ~20fb^{-1} –> 200 events
2015- 2017 ~ 100 fb^{-1} –> 1000 events

Large backgrounds from

$$pp \to Zjj \to \nu\nu jj$$

$$pp \to Wjj \to \ell\nu jj$$

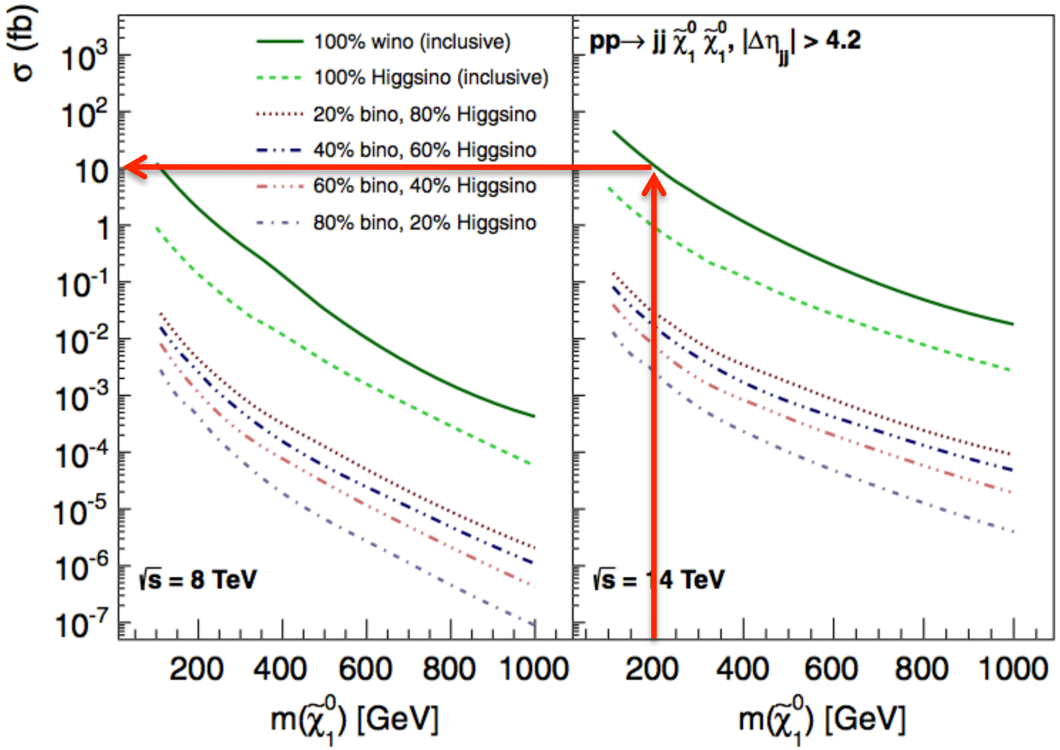


FIG. 1 (color online). Production cross section as a function of $m_{\tilde{\chi}_1^0}$ after requiring $|\Delta\eta(j_1, j_2)| > 4.2$, at LHC8 and LHC14. For the pure wino and Higgsino cases, inclusive $\tilde{\chi}_1^0\tilde{\chi}_1^0$, $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm}$, $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$, and $\tilde{\chi}_1^{\pm}\tilde{\chi}_1^0$ production cross sections are displayed.
(guessing from the text of the paper: jet pT cut > 30 GeV)

Veto events with isolated leptons (from Vector boson decays) and veto events containing b-jets (against top background).

Proposed cuts rely on E_T^{miss} but not very good discriminant here.

Proposed cut $E_T^{miss} > 50$ GeV

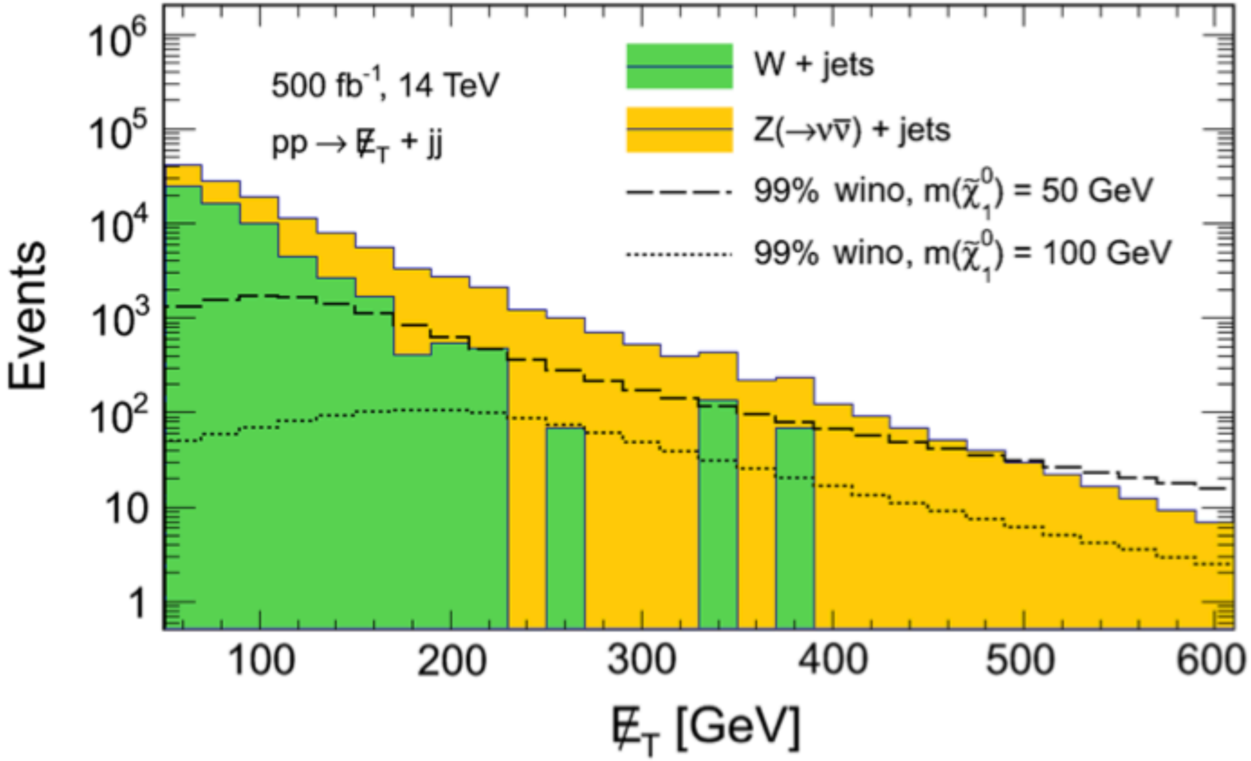


FIG. 3 (color online). The $\not{E}_T$ distributions for wino DM (50 and 100 GeV) compared to W + jets and Z + jets events with 500 fb^{-1} integrated luminosity at LHC14. The distributions are after all selections except the $\not{E}_T$ cut. Inclusive $\tilde{\chi}_1^0\tilde{\chi}_1^0$, $\tilde{\chi}_1^\pm\tilde{\chi}_1^\pm$, $\tilde{\chi}_1^\pm\tilde{\chi}_1^\mp$, and $\tilde{\chi}_1^\pm\tilde{\chi}_1^0$ production is considered.

Sensitivity measured as: $\dfrac{Nbr\ \ Signal\ \ Events}{Statistical\ \ Error\ \ on\ \ Signal\ + Background}$

Here f.o.m. = S/√S+B

fom = 5 ~can be discovered

fom = 2 ~can be excluded at 95%CL

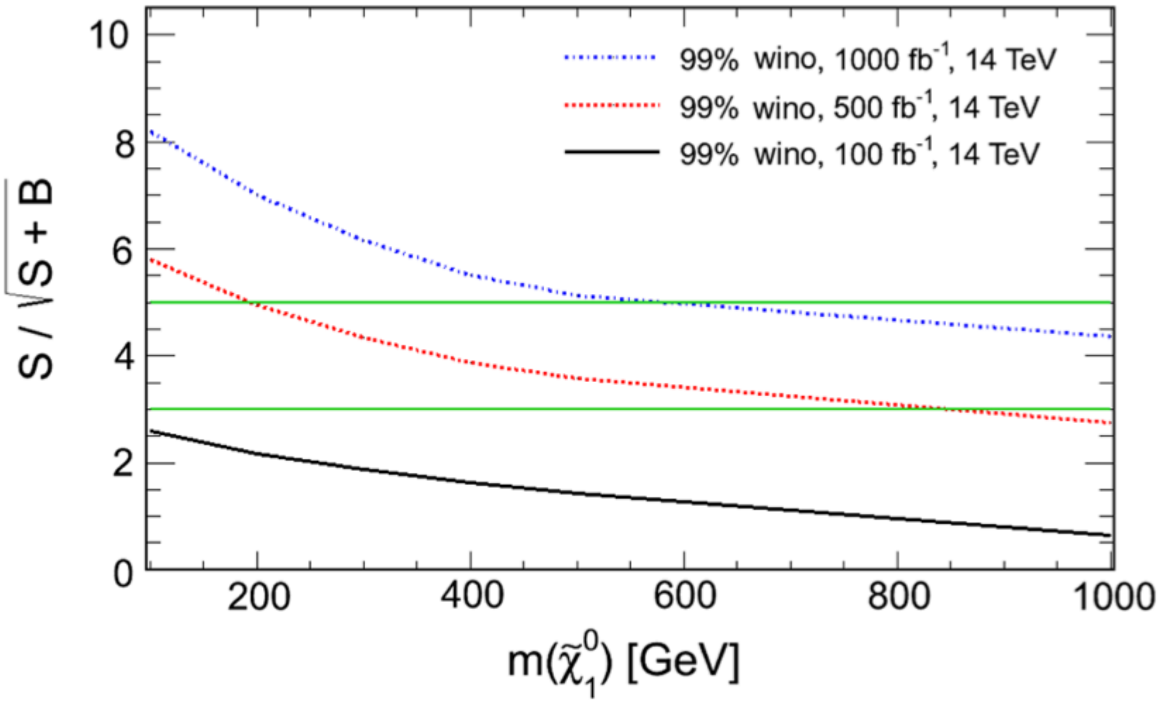


FIG. 4 (color online). Significance curves for the case where $\tilde{\chi}_1^0$ is 99% wino as a function of $m_{\tilde{\chi}_1^0}$ mass for different luminosities at LHC14. The solid gray (green) lines correspond to 3σ and 5σ significances.

Observables
- Rate
- Shape of E_T^{miss}

Are sensitive to
- Neutralino composition and
- Mass.

Paper does not offer much details.

–> Must rely in particular on some assumption for the rest of the SUSY spectrum.

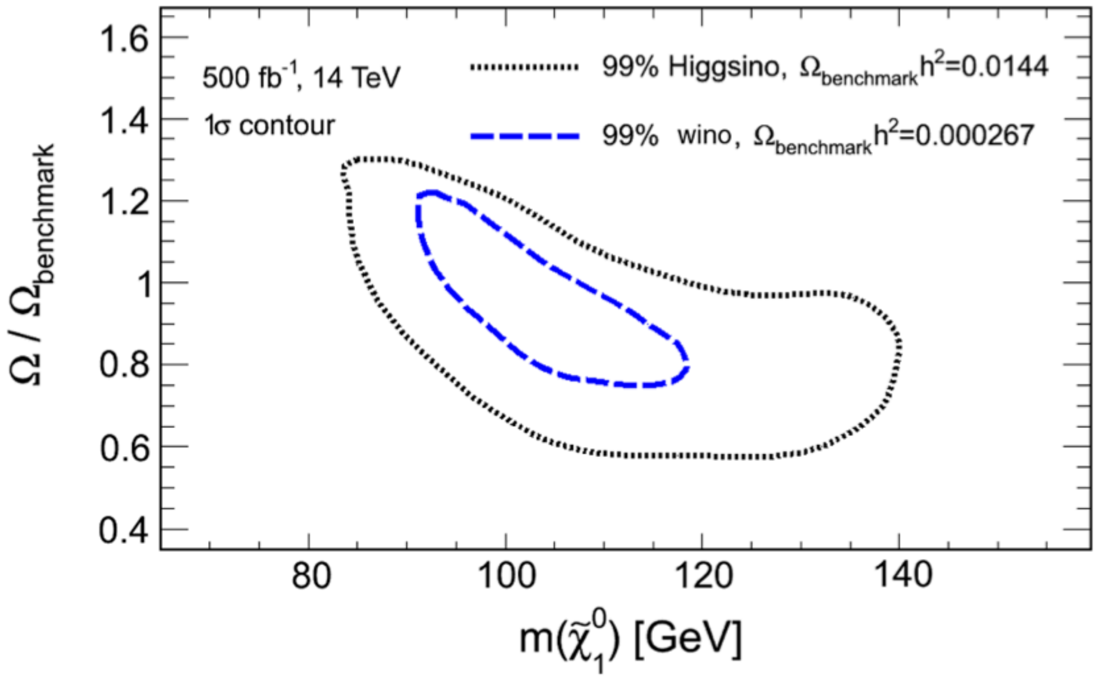


FIG. 5 (color online). Contour lines in the relic density-$m_{\tilde{\chi}_1^0}$ plane for 99% wino (blue dashed) and 99% Higgsino (gray dotted) DMs expected with 500 fb^{-1} of luminosity at LHC14. The relic density is normalized to its value at $m_{\tilde{\chi}_1^0} = 100$ GeV.

$\Omega_{benchmark}$

The relic density was normalized to a benchmark value $\Omega_{\text{benchmark}}$, which is the relic density for $m_{\tilde{\chi}_1^0} = 100$ GeV.