



# Search for dark matter produced in association with a Higgs boson decaying to a pair of bottom quarks in proton-proton collisions at $\sqrt{s} = 13$ TeV with the CMS detector



Shu-Xiao Liu on behalf of the CMS Collaboration

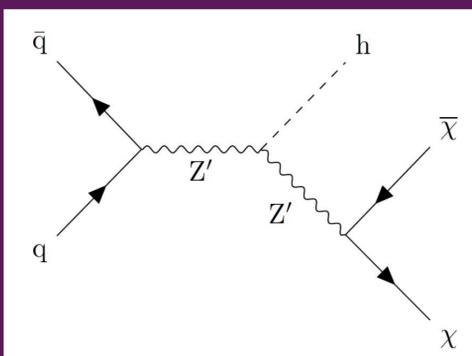
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## Introduction

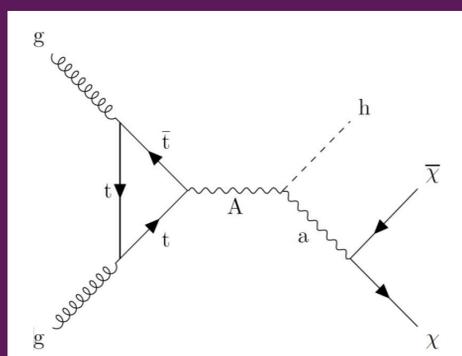
A search for dark matter (DM) produced in association with a Higgs boson decaying to a bottom quark-antiquark pair is performed in proton-proton collisions at a center-of-mass energy of 13 TeV collected with the CMS detector at the LHC. The analyzed data sample corresponds to an integrated luminosity of  $35.9 \text{ fb}^{-1}$ . The signal is characterized by a large missing transverse momentum recoiling against a bottom quark-antiquark system that has a large Lorentz boost. The number of events observed in the data is consistent with the standard model background prediction. Results are interpreted in terms of limits on parameters of various mono-higgs models.

## Model

Type-2 two-Higgs doublet model extended by an additional light pseudo-scalar boson  $a$  (2HDM+a model) and baryonic  $Z'$  model are searched for in this analysis. In this search, the SM-like Higgs boson decays to  $b\bar{b}$  final state and  $\chi$  denotes DM.



Baryonic  $Z'$  model



2HDM+a model

\* Higgs boson decays to  $b\bar{b}$

## Signal & Control Regions

	Main background	Iso AK4 b-tag jets	Leptons
<b>Signal region (SR)</b>	$Z + jet, t\bar{t}, W + jet$	0	0
<b>Control Region (CR)</b>			
Single-lepton	$W + jet, t\bar{t}$	0	1
Single-lepton + b-tagged	$t\bar{t}, W + jet$	1	1
Dilepton	$Z + jet$	0	2

## Selection

SR and CR have the same selection but they have different missing transverse momentum object. The missing transverse momentum object in SR is  $\vec{p}_T^{miss}$  and the one in CR is  $\vec{U}$  as defined below.

$$\vec{U} = \vec{p}_T^{miss} + \vec{p}_T^{l,l}$$

- One CA15 fat jet
  - $p_T > 200 \text{ GeV}$  and  $|\eta| < 2.4$
  - $100 < m_{SD} \text{ (GeV)} < 150$
- PUPPI  $\vec{p}_T^{miss} (\vec{U}) > 200 \text{ GeV}$  in SR (CR)
- Number of isolated AK4 jets  $\leq 1$ 
  - $\Delta\phi(\text{iso AK4 jet}, \vec{p}_T^{miss} \text{ or } \vec{U}) > 0.4$
- $\tau$  and photon veto
- $N_2^{DDT} < 0$
- Double-b tagger
  - SR: Pass
  - CR: Pass or Fail (measuring scale factors)

\*  $N_2^{DDT}$ : the designed decorrelating two-prong tagger and related to energy correlation function.

\* **Double-b tagger**: the algorithm to tag two b quarks within a fat jet.

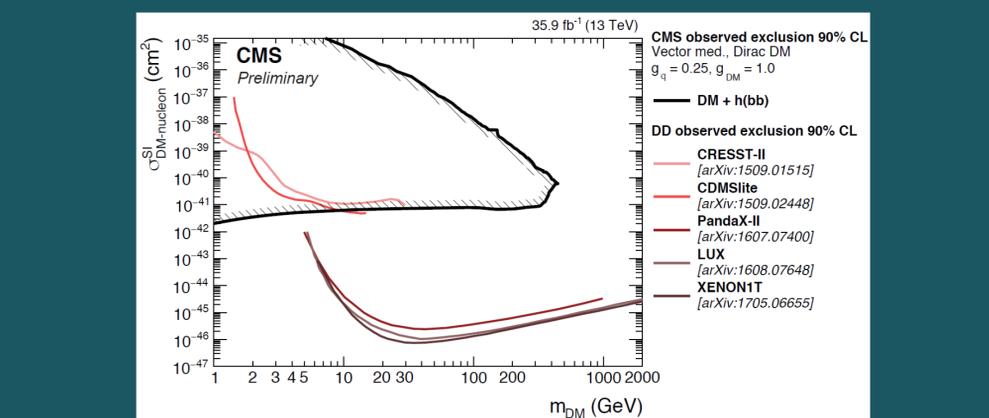
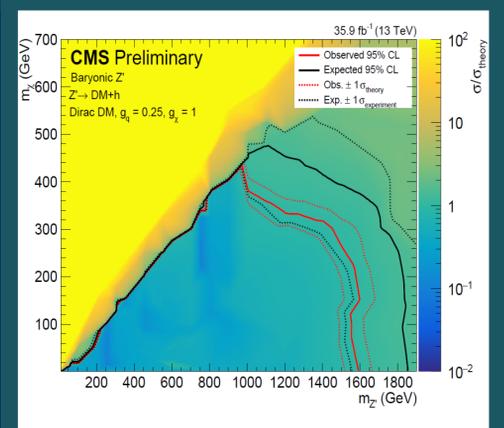
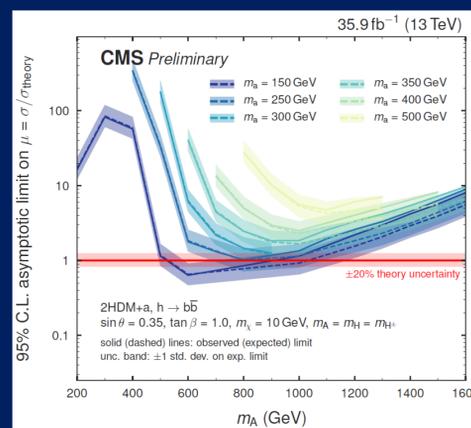
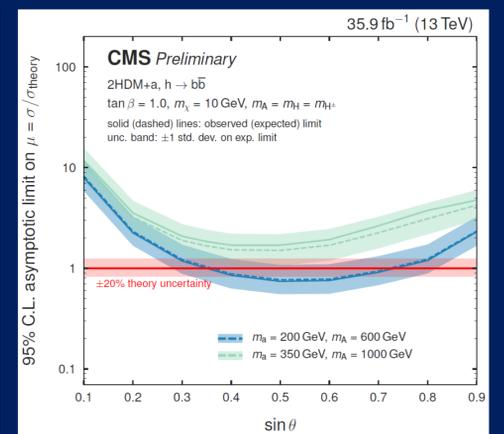
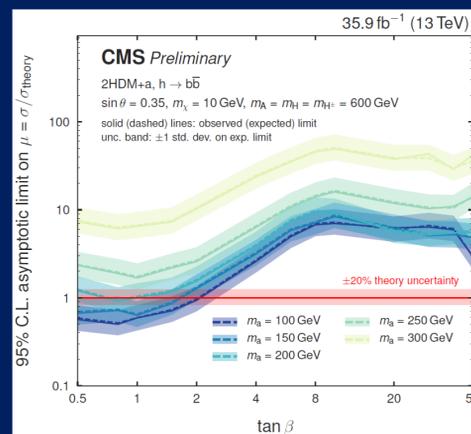
## Background Estimation

$$\text{Background} = \mu_{CR}/T$$

Background is estimated by CR events and transfer factor,  $T$ . Transfer factor which transfers event number in CR into the background in SR is given from the ratio of  $\vec{p}_T^{miss}$  bin in SR and corresponding  $\vec{U}$  bin in CR.  $\mu_{CR}$  is a freely float parameter included in binned likelihood fit to scale the contribution in CR.

## Result

The limit of 2HDM+a model is presented by varying one parameter while fixing the others.  $\sin\theta$  is the mixing angle of the two pseudo-scalars  $A$  and  $a$ .  $\tan\beta$  is the ratio of vacuum expectation values of the two Higgs doublets.



The observed limits on the production cross section of Baryonic  $Z'$  is presented as a function of  $m_{Z'}$  and  $m_\chi$ . The results are also compared with the direct detection (DD) experiments.