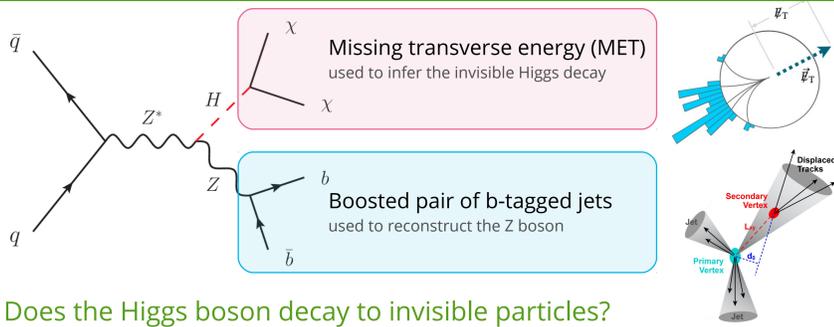




# Search for invisible Higgs decays in the associated ZH production modes with Z decays to a pair of bottom quarks in 8 TeV pp collisions at CMS

Jia Fu Low (Univ of Florida)  
on behalf of the CMS Collaboration

## 1. Introduction



**Does the Higgs boson decay to invisible particles?**  
Higgs invisible branching fraction is predicted to be  $\sim 0.1\%$  by the standard model, but a lot larger by many theoretical models (supersymmetry, dark matter, etc).

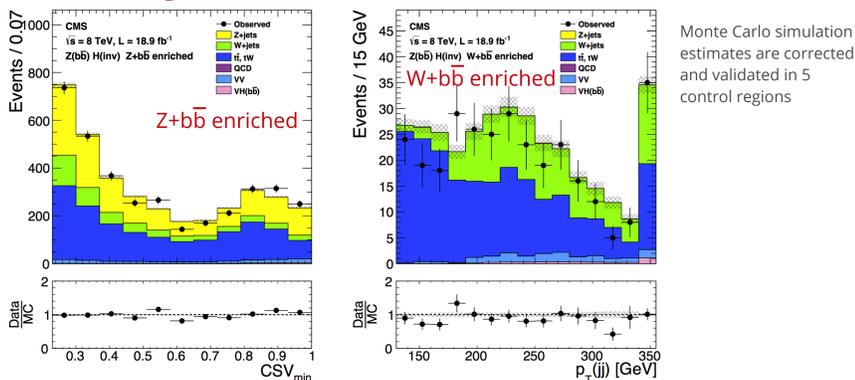
**How does an invisible Higgs decay show up in the detector?**  
Invisible Higgs decay can be "detected" as MET  $\equiv$  recoil against a Z  $\rightarrow b\bar{b}$  system, when produced in the ZH associated production mode.

**What is b tagging? Why boosted jets?**  
Due to longer lifetime, b jets can have displaced tracks and a secondary vertex. Boosted ZH event topology can be triggered; high MET and a boosted  $b\bar{b}$  pair also significantly reduces background contamination.

## 3. Background estimation & Systematics

Significant background come from W/Z+jets ( $\sim 60\%$ ), and diboson ( $\sim 30\%$ ). Minor background from top and QCD also contribute.  $Z(\nu\bar{\nu})H(b\bar{b})$  contribution is negligible.

### Control regions

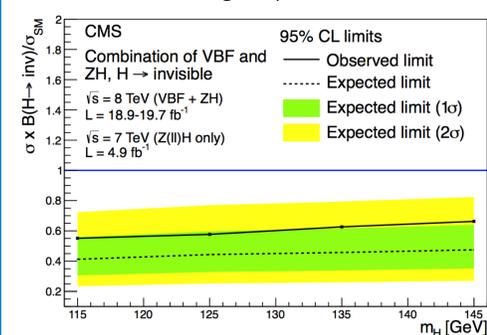


### Systematic uncertainty

Type	Source	Background uncertainty(%)	Signal uncertainty(%)
Norm.	Luminosity	0.9	2.6
	Factorization/renormalization scale and PDFs	—	7
	Signal $p_T$ boost EW/QCD corrections	—	6
	Background data/MC scale factors	8	—
Shape	Single-top-quark cross section	1	—
	Diboson cross section	4	—
	Trigger	1	5
	Jet energy scale	4	3
	Jet energy resolution	3	3
	$E_T^{\text{miss}}$ scale	1	2
	b tagging	7	5
	MC statistics	3	3
MC modelling (V+jets and tt)	3	—	

## 5. Combined cross section limits

CMS has performed two other invisible Higgs searches in the VBF and  $Z(\ell\ell)H$  channels. The combined **observed** (expected) upper limit on  $\mathcal{B}(H \rightarrow \text{inv})$  for  $m_H = 125 \text{ GeV}$  is **0.58** (0.44), assuming SM production cross section.



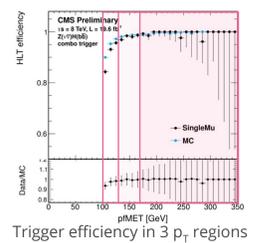
$m_H$ (GeV)	Observed (expected) upper limits on $\sigma \cdot \mathcal{B}(H \rightarrow \text{inv}) / \sigma_{\text{SM}}$		
	VBF	ZH	VBF+ZH
115	0.63 (0.48)	0.76 (0.72)	0.55 (0.41)
125	0.65 (0.49)	0.81 (0.83)	0.58 (0.44)
135	0.67 (0.50)	1.00 (0.88)	0.63 (0.46)
145	0.69 (0.51)	1.10 (0.95)	0.66 (0.47)
200	0.91 (0.69)	—	—
300	1.31 (1.04)	—	—

## 2. Search Strategy

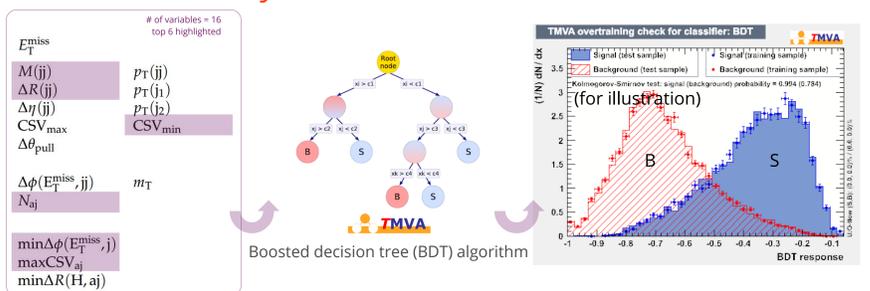
Similar strategy as in the  $Z(\nu\bar{\nu})H(b\bar{b})$  analysis is adopted (similar final state). Event selection is optimized individually for "low", "intermediate", "high"  $p_T$  regions.

### Event selection

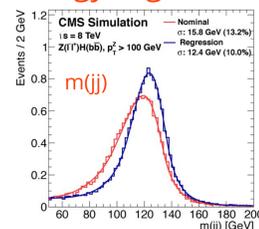
Variable	Selection
$E_T^{\text{miss}}$	[100 – 130] [130 – 170] > 170
$p_T(j_1)$	> 60
$p_T(j_2)$	> 30
$p_T(j_j)$	> 100
$m(j_j)$	> 130
$m(j_j)$	> 130
CSV <sub>max</sub>	< 250
CSV <sub>min</sub>	> 0.679
$N_{\text{aj}}$	> 0.244
$N_{\text{al}}$	< 2
$\Delta\phi(V, H)$	[-] [-]
$\Delta\phi(E_T^{\text{miss}}, j)$	> 2.0
$\Delta\phi(E_T^{\text{miss}}, \text{trk})$	> 0.7
$E_T^{\text{miss}}$ significance	> 0.5
	> 3



### Multivariate analysis



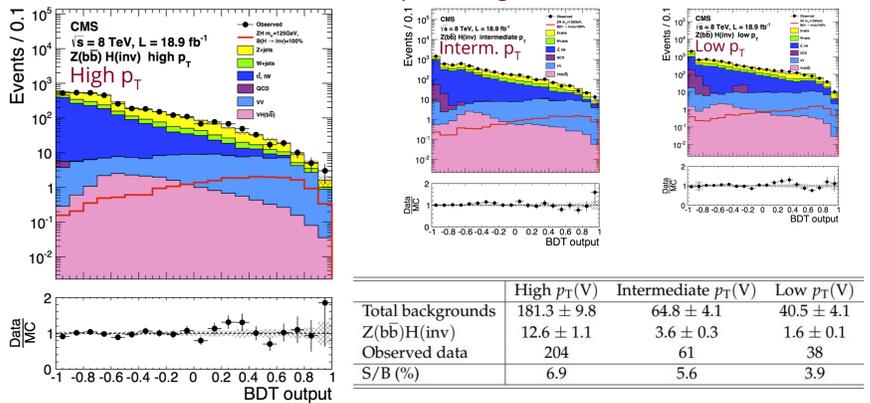
### b jet energy regression



Dijet mass resolution is improved with a multivariate regression technique trained specifically to correct b jet energies. This results in a resolution of  $\sim 10\%$ .

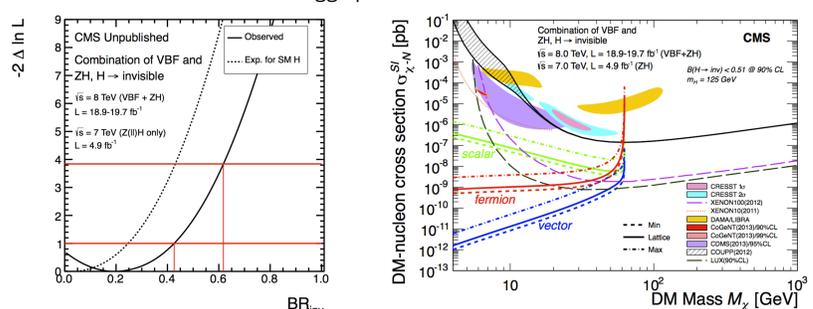
## 4. Signal fit

Signal fraction is extracted from a maximum likelihood fit, taking into account the uncertainties in normalizations and shapes. **No significant excess is observed.**



## 6. Result interpretations

Null result of invisible Higgs search can be included in the global fit of Higgs couplings, and is used to set limits in the Higgs-portal model of dark matter interactions.



## References

- CMS-HIG-13-030 "Search for invisible decays of Higgs bosons in the vector boson fusion and associated ZH production modes", submitted to Eur. Phys. J. C (2014), arXiv:1404.1344 [hep-ex]
- CMS-HIG-13-012 "Search for the standard model Higgs boson produced in association with a W or a Z boson and decaying to bottom quarks", Phys. Rev. D89 (2014) 012003, arXiv:1310.3687 [hep-ex]
- CMS-PAS-HIG-13-028 "Search for Higgs boson decaying to invisible particles and produced in association with a Z boson decaying to bottom quarks" (2013)