Dark matter search at LHC in the Mono Higgs channel with the CMS detector

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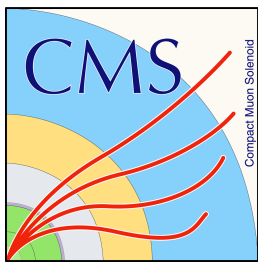

IFCA – CSIC – UC

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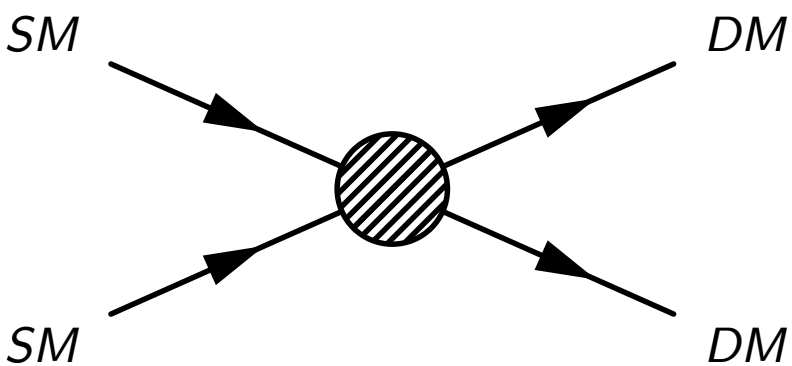
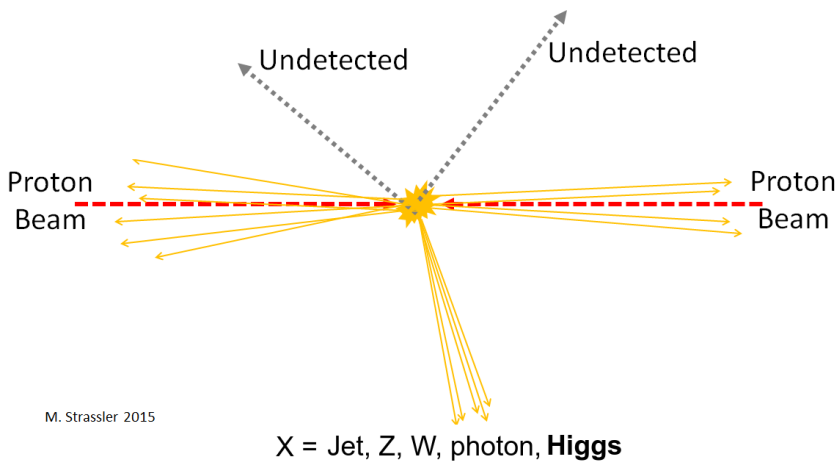
Searching Dark Matter at LHC

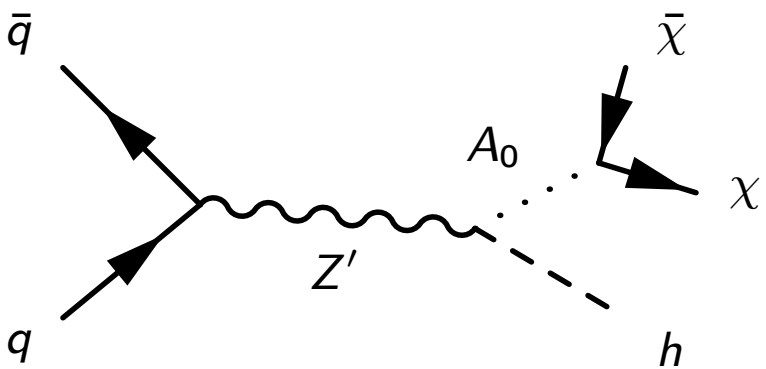
- Dark Matter particle nature is unknown and cannot be explained within Standard Model
- At a hadron collider have to assume interaction between Standard Model and Dark Matter candidate particles
- Main candidate: **Weakly Interacting Massive Particle**
- Final state with two Dark Matter particles and SM particle(s)
  - Missing Transverse Momentum $(\mathbf{p}_T^{miss})$ + **X** signatures
  - In this case **X is a Higgs boson**

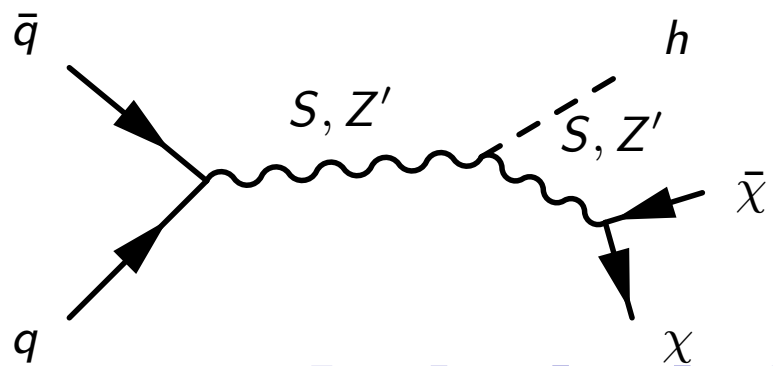




Mono-Higgs Physics Models

- The benchmark models inspected and their parameters have been chosen following **LHC DM Working Group** recommendations
  - **Z'-2HDM**
  - **Z'$_B$**
- Two **Higgs decay channels** already public using 2.3 fb^{-1} of 2015 Data interpreted in the **Z'-2HDM** benchmark **[arXiv:1703.05236]**
  - h $\rightarrow$ bb: higher branching ratio, lower m$_h$ resolution
  - h $\rightarrow \gamma\gamma$: lower branching ratio, higher m$_h$ resolution
- At **IFCA** we are studying **h $\rightarrow$ WW** final state
  - Following the tradition of SM WW and SM H $\rightarrow$ WW analyses





h→ bb Analysis Strategy

Two categories to enhance the sensitivity of the analysis

Resolved (low Higgs boost)	Merged (high Higgs boost)
Two b-tagged AK4 jets with $p_T > 30$ GeV	One AK8 jet with $p_T > 200$ GeV with two b-tagged sub-jets
$p_T^{miss} > 170$ GeV	$p_T^{miss} > 200$ GeV

- **Multi-jet** rejection
  - $\Delta\phi(\text{AK4}_{jet}, \vec{p}_T^{miss}) > 0.4$
  - $\Delta\phi(\vec{p}_T^{miss}, \vec{p}_{T,trk}^{miss}) < 0.7$
- **Semi-leptonic top** and **W + jet** rejection
  - Lepton (e, μ, τ) veto
  - No additional b-jets
  - No more than 1 additional AK4 jets

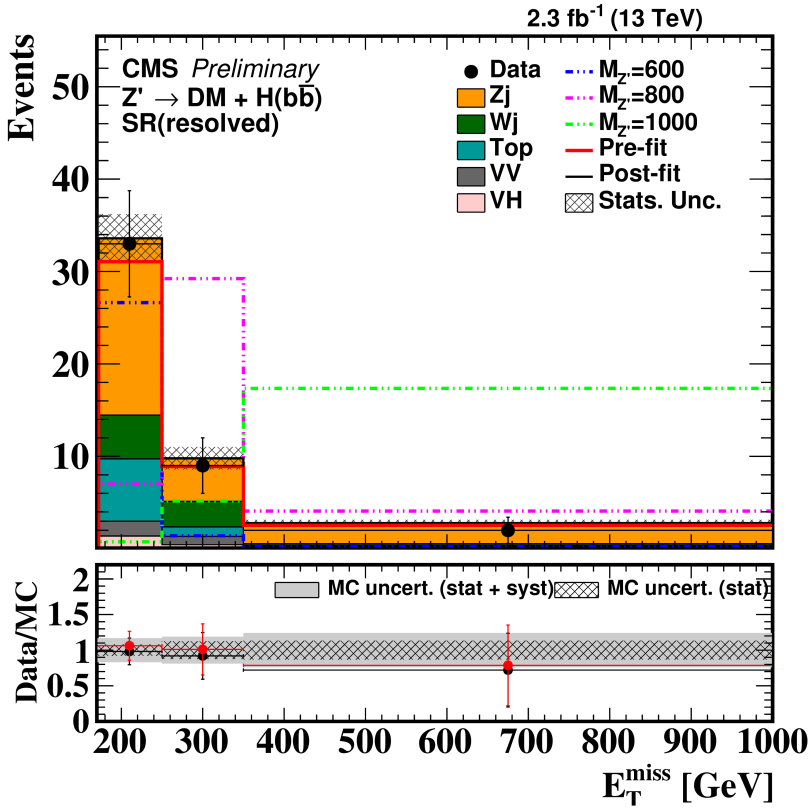
Main backgrounds (Z→ $\nu\nu$ + jets, Top, W + jets) normalized in **control regions**

h→ bb Signal Extraction

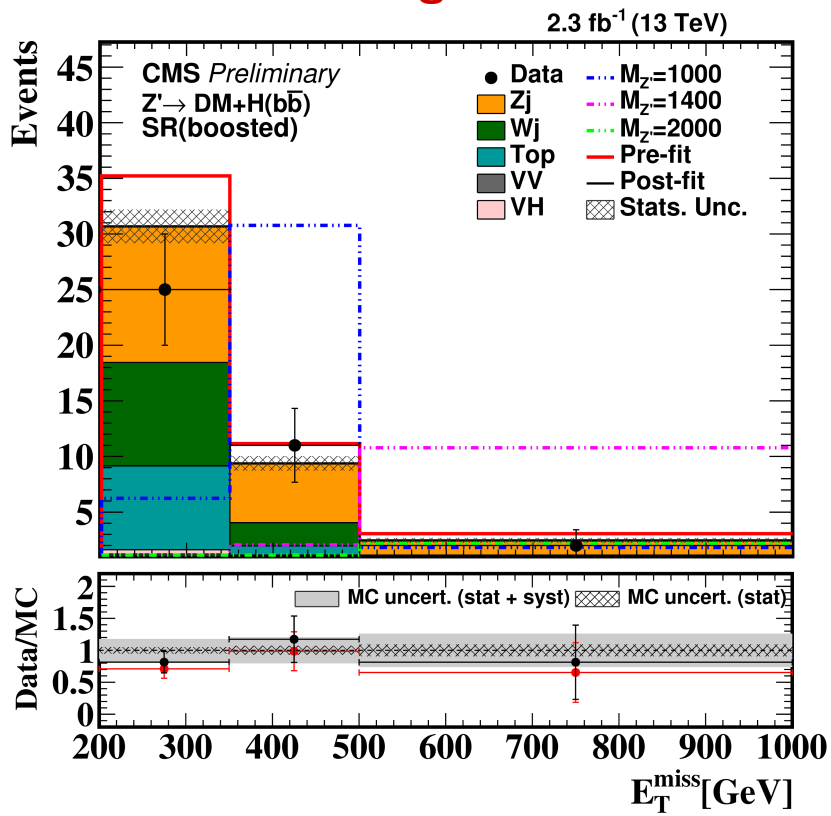
The signal is extracted with a **simultaneous fit of the signal region and the control regions**

- 100 GeV $< m_h <$ 150 GeV
- Fit is performed on a three-bin p_T^{miss} histogram

Resolved

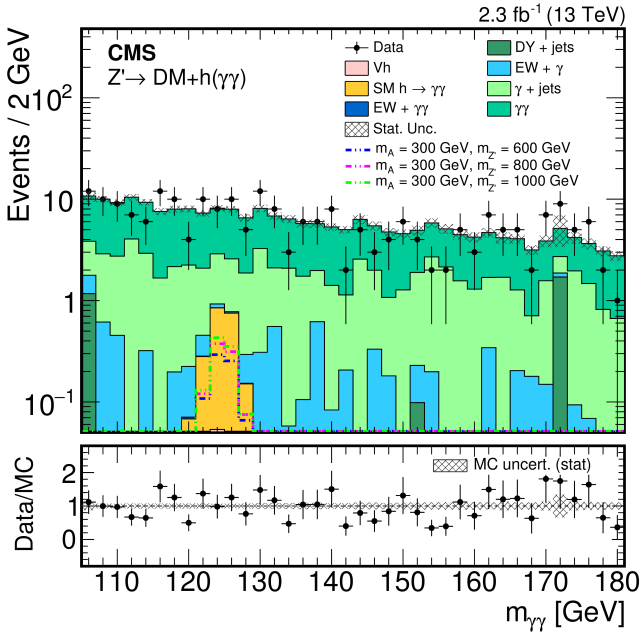


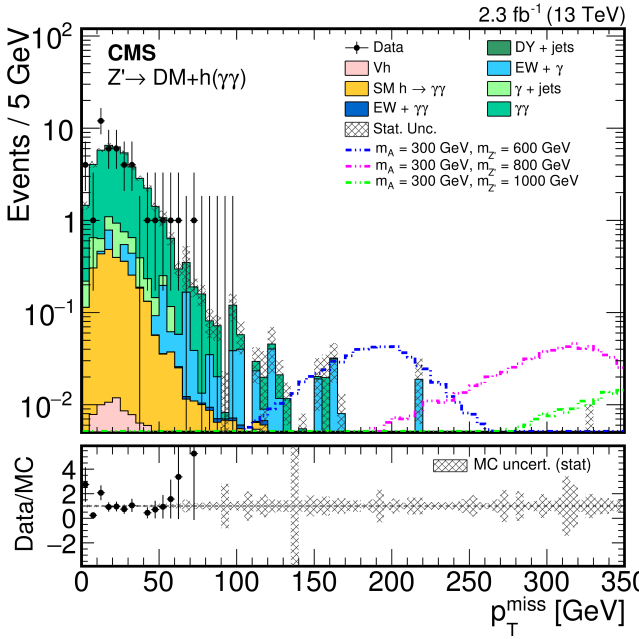
Merged



h→ γγ Analysis Strategy

- Reduce **jets faking photons** contribution
  - Low $\frac{E_{HCAL}}{E_{ECAL}}$
  - Isolation requirements applied
- Avoid **$m_{\gamma\gamma}$ spectrum distortion**
  - $\frac{p_T^{\gamma 1}}{m_{\gamma\gamma}} > 0.5$ and $\frac{p_T^{\gamma 2}}{m_{\gamma\gamma}} > 0.25$
- Reject **Mis-measured p_T^{miss}** events
  - $|\Delta\phi(\gamma\gamma, \vec{p}_T^{miss})| > 2.1$
  - $|\Delta\phi(\text{jet}, \vec{p}_T^{miss})| > 0.5$ for every jet with $p_T > 50$ GeV
- Reduce **EW background**
  - Veto events with muons or more than 1 electron
- Select events with a Higgs boson **recoling against $\vec{p}_T^{miss}$**
  - $p_T^{miss} > 105$ GeV
  - $p_T^{\gamma\gamma} > 90$ GeV

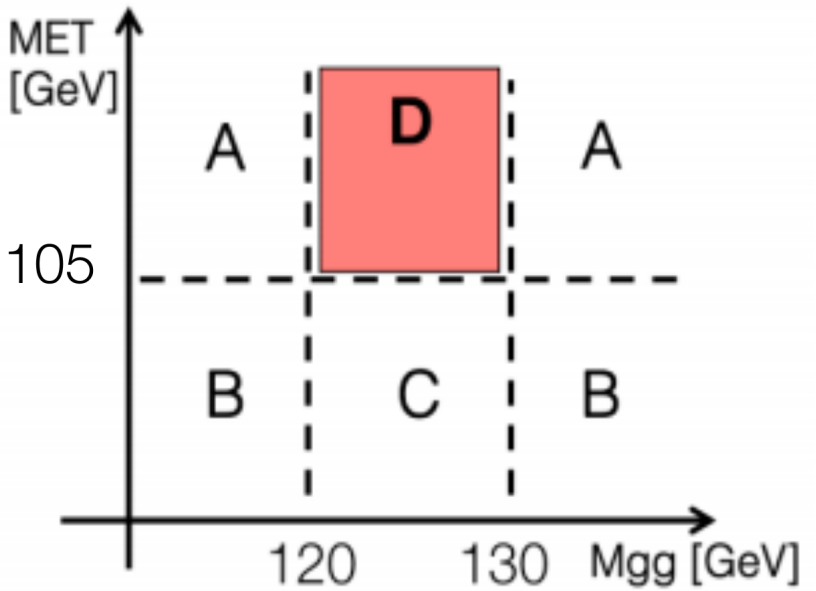


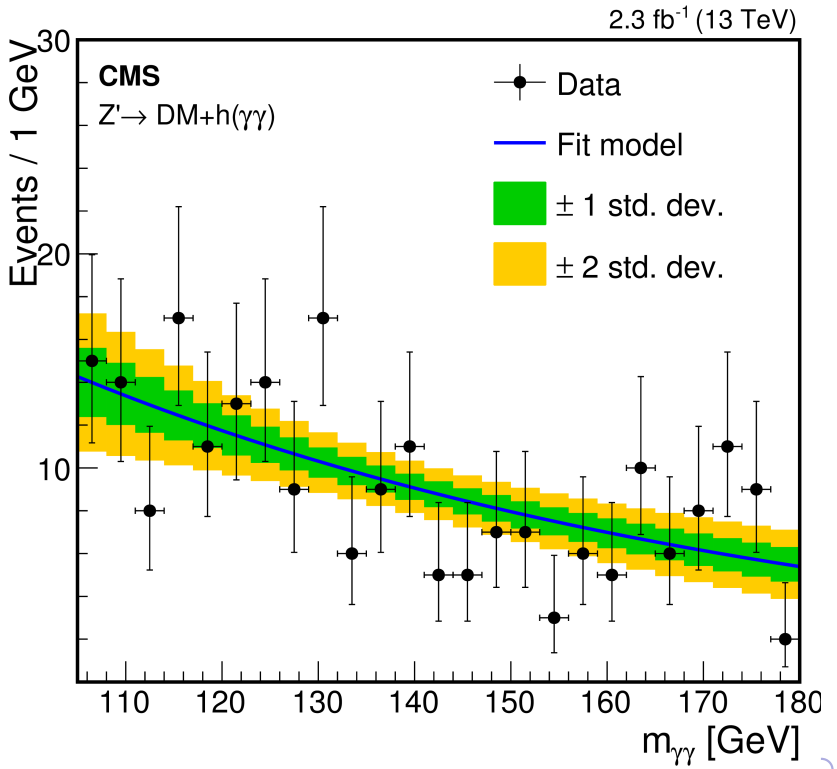


h→ γγ Signal Extraction

The signal is extracted by **counting the events in the Singal Region**

- **SM Higgs** contamination is taken from simulations
- **Non-resonant background** contribution in SR is estimated from Data
  - Transfer factor $\alpha = N_C / N_B = N_D / N_A$
  is **extracted in low p_T^{miss}** region
  - And then **applied in high p_T^{miss}** region: $N_D = \alpha \cdot N_A$





Mono-Higgs $\rightarrow$ WW Analysis

The **h $\rightarrow$ WW fully leptonic** final state is now under investigation at IFCA

- **Very clean** final state
- The presence of the neutrinos spoils the **p_T^{miss} and the m_H** distributions

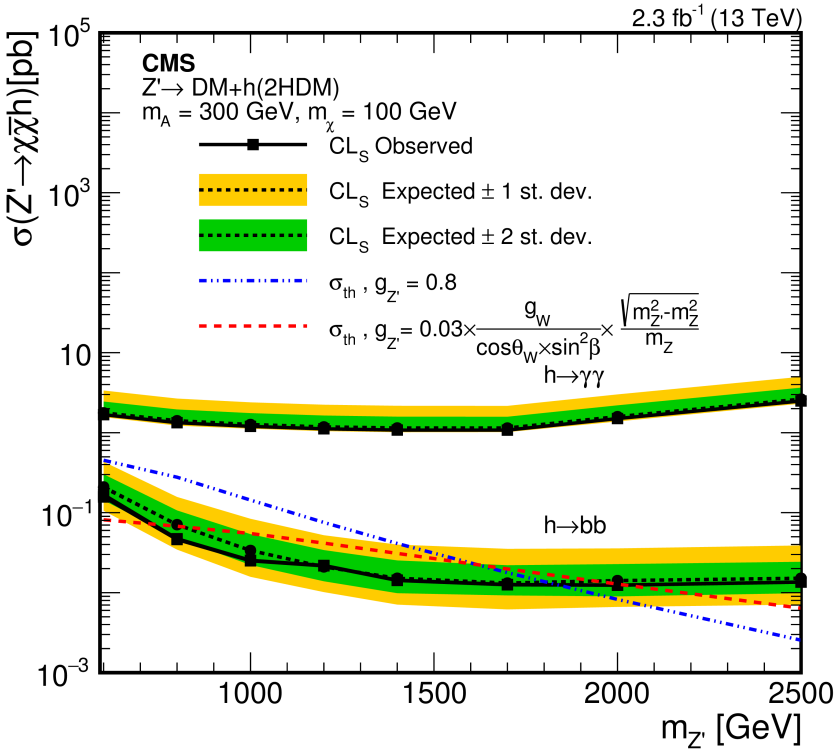
Analysis strategy

- Select two **well reconstucted and energetic** leptons (eμ and ee/$\mu\mu$ final states)
- Exploit a **multivariate analysis** to enhance signal vs background separation
  - m_T^H, $\Delta\phi(\ell\ell)$ ...
  - Take all **systematic uncertainties** under control!
- Estimate the main backgrounds in **control regions**
  - WW: $m_{\ell\ell} > 100$ GeV
  - Top: at least 1 b-tagged jet
  - Drell-Yan: $|m_{\ell\ell} - m_Z| < 15$ GeV

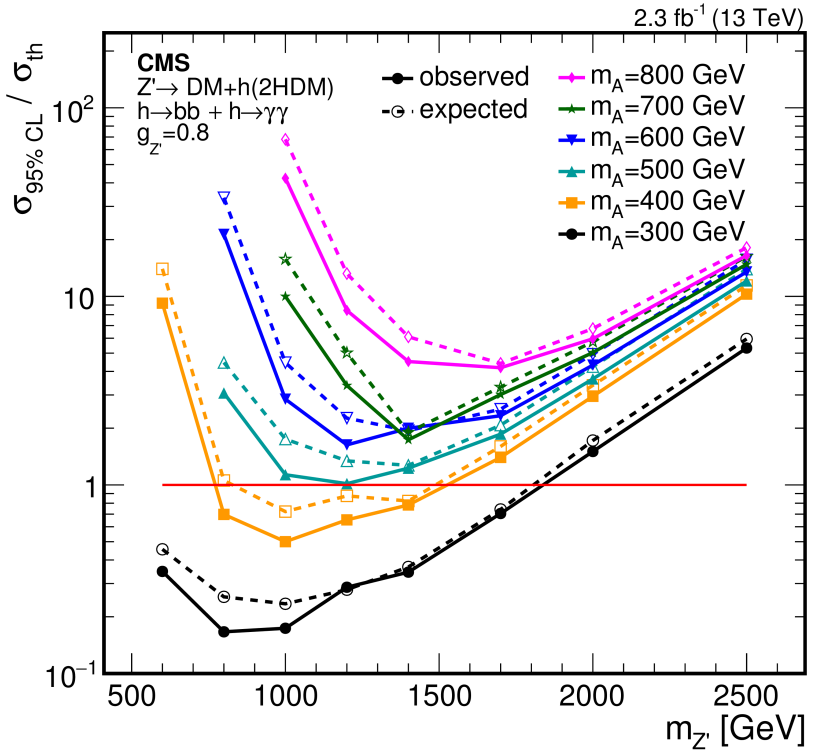
Combination of the public results

- Result intepreted in terms of **upper limits on the DM production** cross section via **Z'-2HDM** model since no excess wrt SM predictions observed
- Mass scan
  - $m_{Z'}$ = (600 GeV - 2500 GeV)
  - m_{A0} = (300 GeV - 800 GeV)
- Two Z'-A_0-h coupling constant $g_{Z'}$ values studied

h→bb and h→ γγ for m_{A0} = 300 GeV



Full Combination Results



Conclusions

CMS has already published results in the mono-Higgs channel

- The **2015 dataset** has been exploited
  - 2.3 fb^{-1} at $\sqrt{s} = 13$ TeV
  - h $\rightarrow$ bb and h $\rightarrow \gamma\gamma$ final states
  - The two **analyses have been combined** to enhance the exclusion limit
- Next steps
  - Exploit the **full 2016** luminosity
  - Extend the search to all main Higgs decay modes (in particular WW)
  - Include all **the final states** in the combination