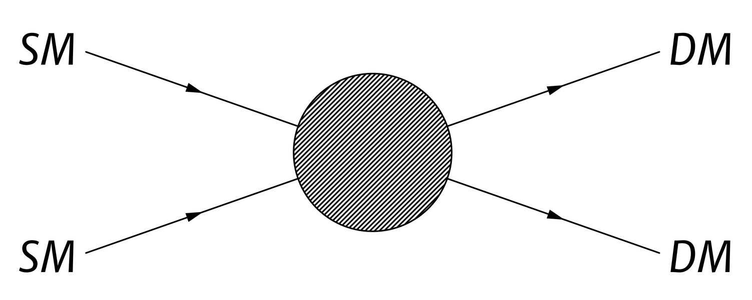
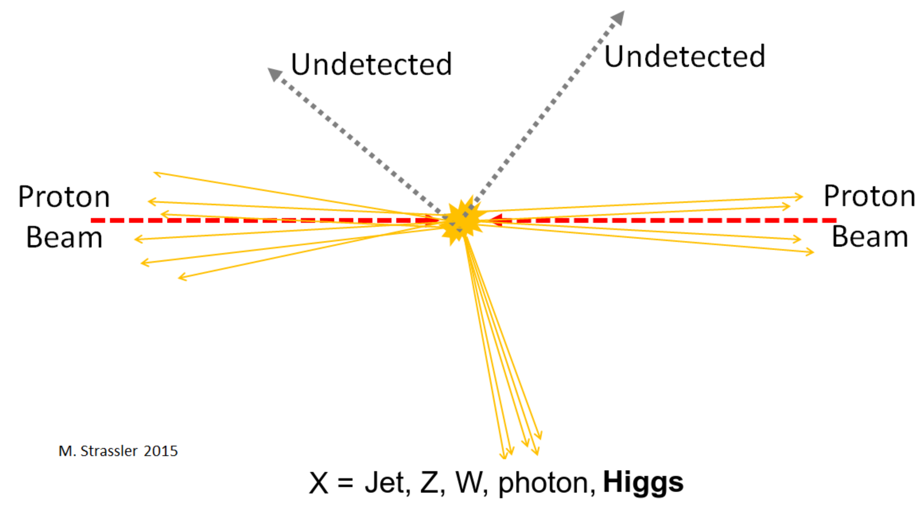
Search for dark matter produced in association with a Higgs boson decaying to a pair of W bosons at CMS

Nicolò Trevisani *(IFCA - CSIC - UC) on behalf of the CMS collaboration*

Searching for Dark Matter at LHC

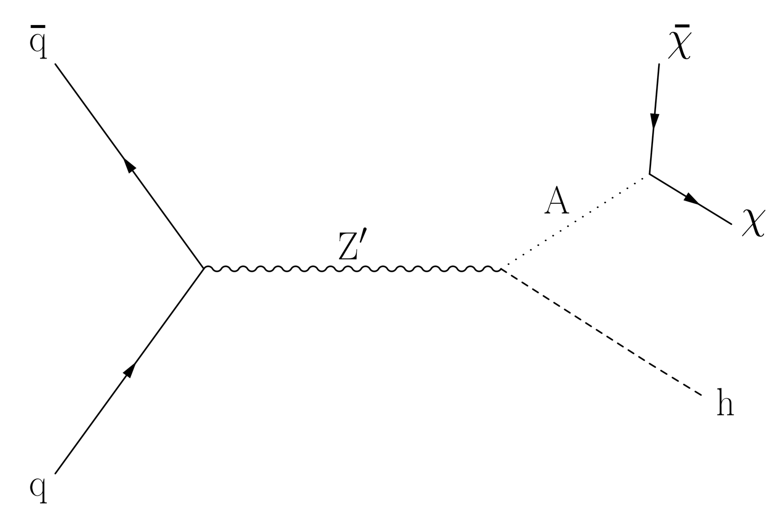
- Dark Matter particle nature is unknown and cannot be explained within Standard Model
- At a hadron collider have to assume interaction between Standard Model and Dark Matter candidate particles
- Main candidate: **Weakly Interacting Massive Particle**
- Final state with two Dark Matter particles and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

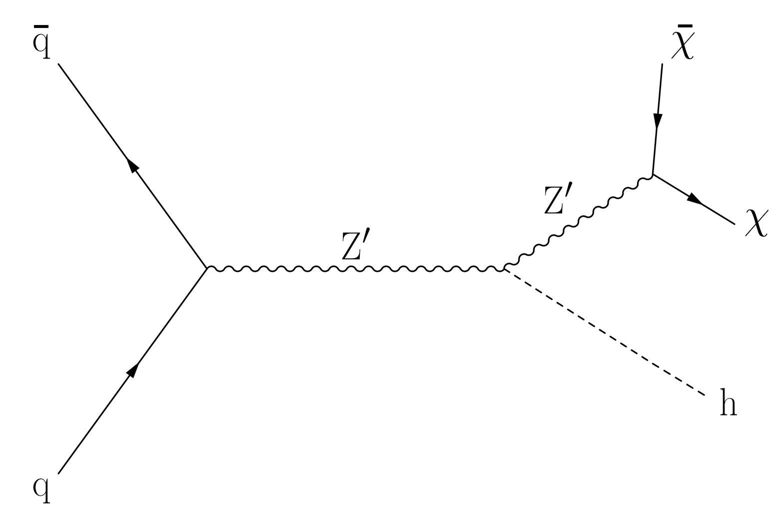




Mono-Higgs Physics Models

- The search exploits 35.9 fb^{-1} Data collected during 2016 by the CMS detector
- Two benchmark models inspected following **LHC DM Working Group** recommendations **[http://cern.ch/go/6FSK]**
  - **Z'-2HDM**: A vector boson mediator Z' decays into a Higgs boson and a pseudoscalar A
    - The A then decays into two dark matter particles **[arXiv:1402.7074]**
  - **Baryonic Z'**: A leptophobic mediator Z' radiates a Higgs boson and decays to pair of dark matter particles **[arXiv:1312.2592]**

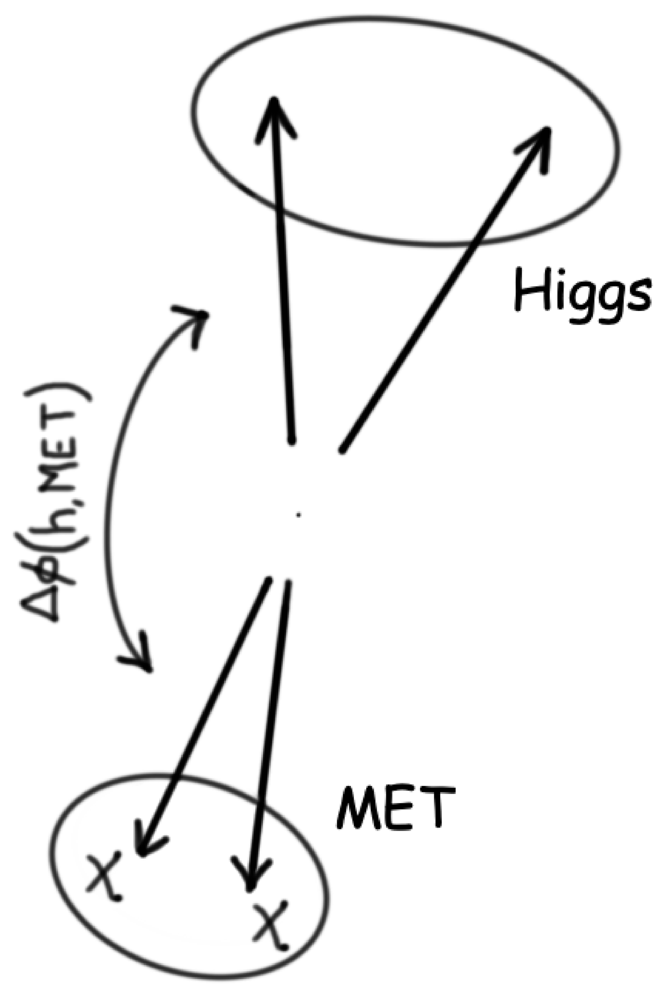




Typical Analysis Strategy

Typical strategy for mono-Higgs searches (bb, $\gamma\gamma$):

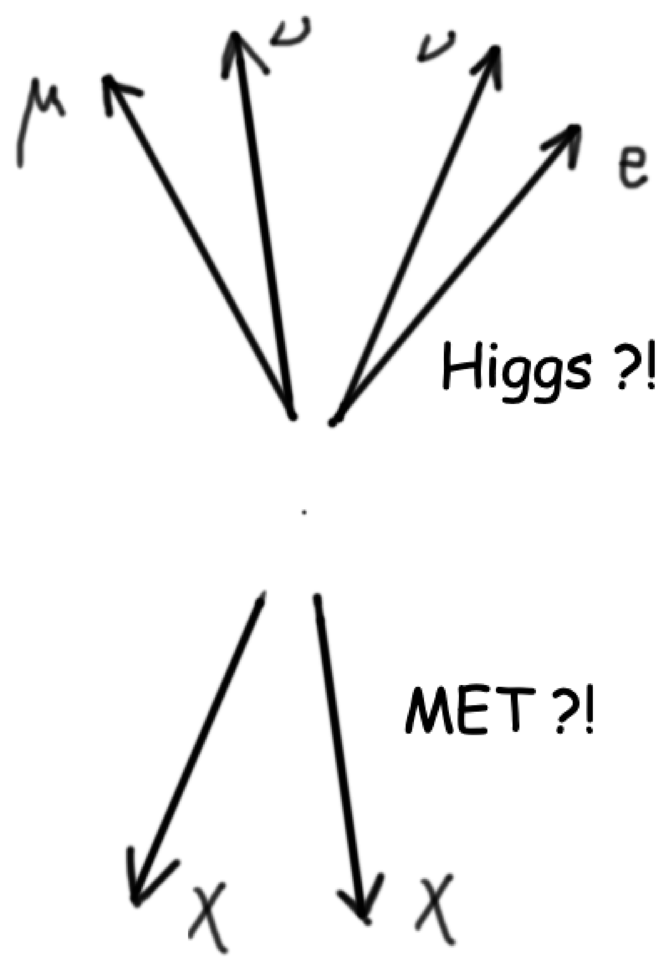
- **Tag** the presence of **the Higgs** boson
  - Through invariant mass requirements
- Ask for **large amount of p_T^{miss}** (MET)
  - Due to the presence of dark matter particles
- Select events with **large separation between the Higgs boson and the $\vec{p}_T^{miss}$**:
  - $\Delta\phi$(h,MET) $\sim \pi$



Strategy for WW Final State

The fully leptonic **WW final state**:

- **Large branching fraction**
  - BR(h→WW) $\sim$ 21%
- Selecting di-leptonic final state
  - Strong **background reduction**
  - Good control of systematic uncertainties
- **Two neutrinos** in the final state:
  - Invariant mass distribution does not peak at m_h
  - Both neutrinos and dark matter particles contribute to the p_T^{miss} distribution
  - Both module and direction of p_T^{miss} affected



Event Selection

Baseline selections aim to define a phase space enriched in **WW-like events**

- Two energetic leptons, **one electron and one muon**
- Large amount of MET: **p_T^{miss} > 20 GeV**
- Large transverse momentum of the di-lepton system: **$p_T^{\ell\ell}$ > 30 GeV**
- **No b-tagged jets** in the event

Specific selections for **mono-Higgs topology**

- Higgs invariant mass spoiled by the presence of neutrinos: **$m_{\ell\ell}$ < 76 GeV**
- Higgs boosted by the recoil against dark matter: **$\Delta R(\ell,\ell)$ < 2.5**

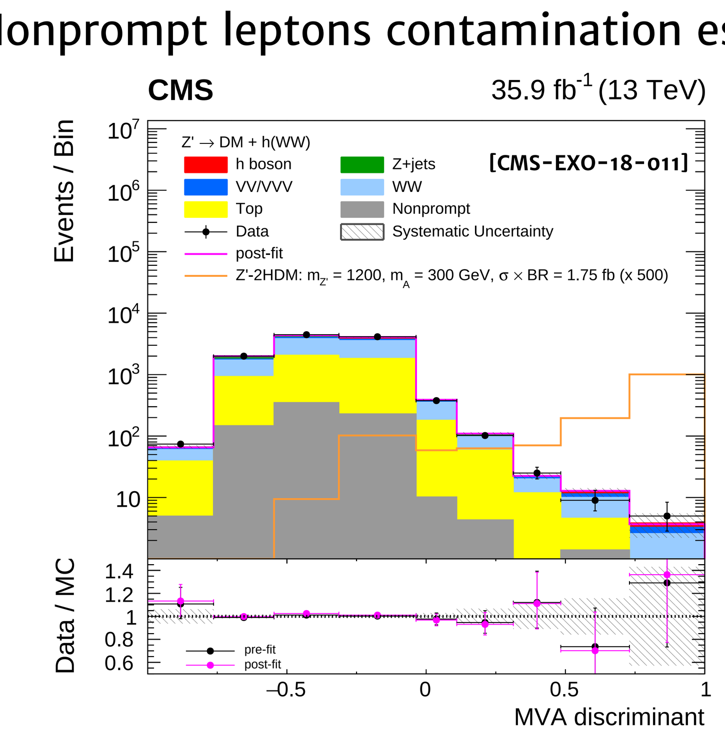
Sensitivity enhanced by using multivariate analysis techniques

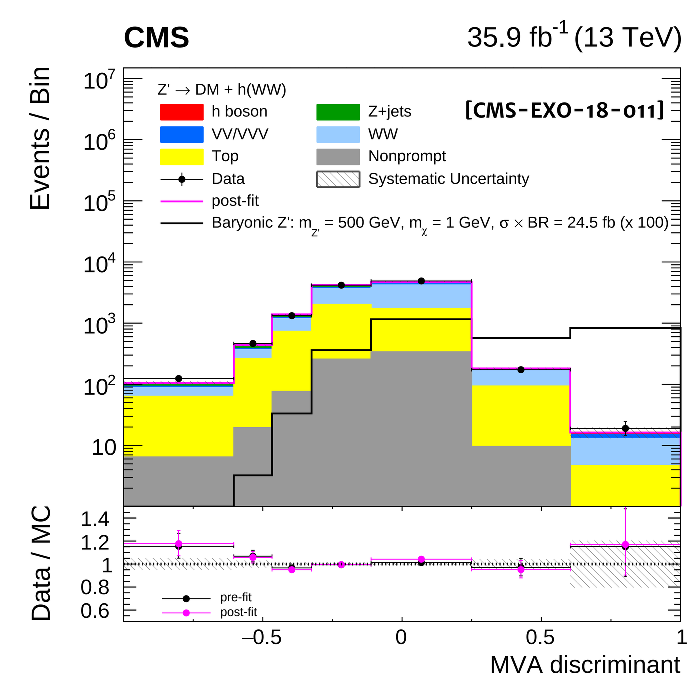
- **Boosted Decistion Trees** (BDTs)
- One set of BDTs for each of the two models
- Trained with several significant variables

Signal Extraction

Signal and background yields extracted through a **maximum likelihood fit**

- Using the **shape of the BDTs**
- Fitting simultaneously **signal region and control regions**
  - Control regions: WW, Top, and Z + jets
  - Nonprompt leptons contamination estimated with fake rate method

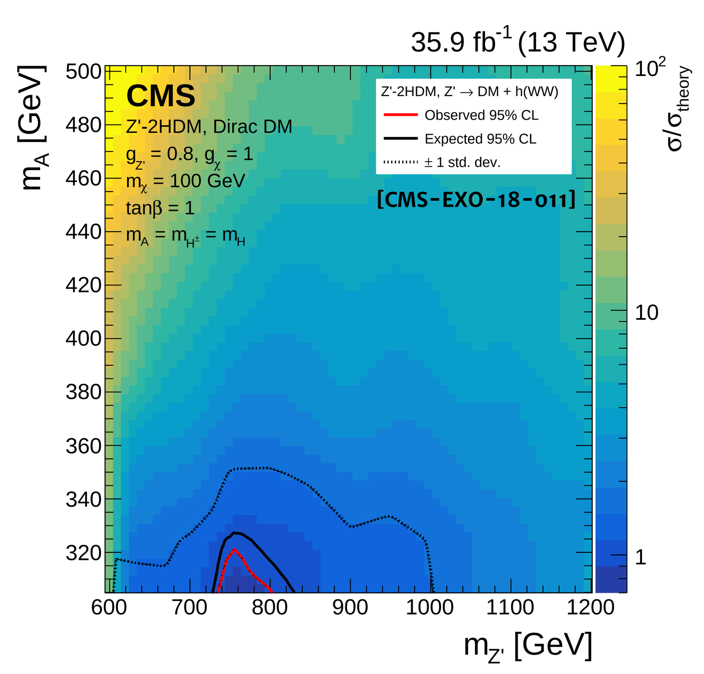


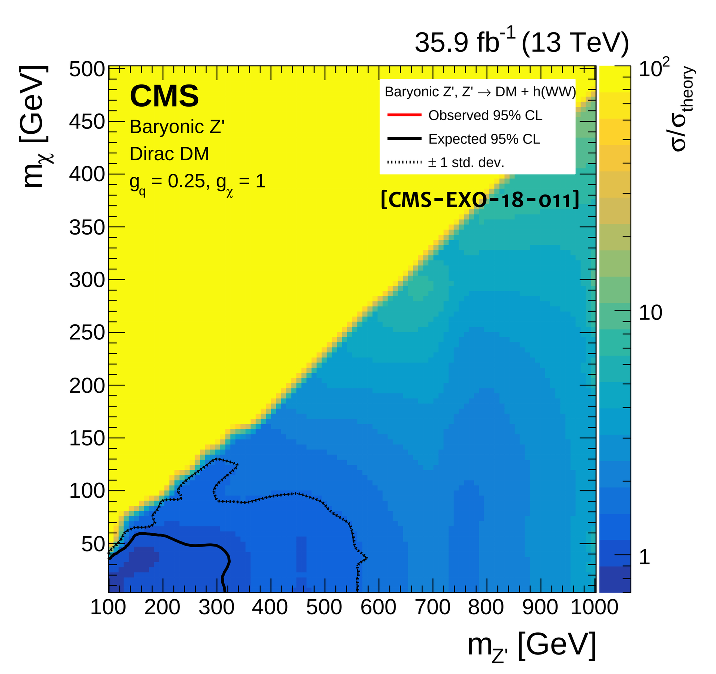


Results

No significant **discrepancies between data and the Standard Model** have been found

- **Limits have been set** on the dark matter production cross section
- Results dominated by statistical uncertainty
  - **Z'-2HDM** model: 740 GeV < $m_{Z'}$ < 800 GeV and 300 GeV < m_A < 320 GeV excluded
  - **Baryonic Z'** model: no sensitivity reached

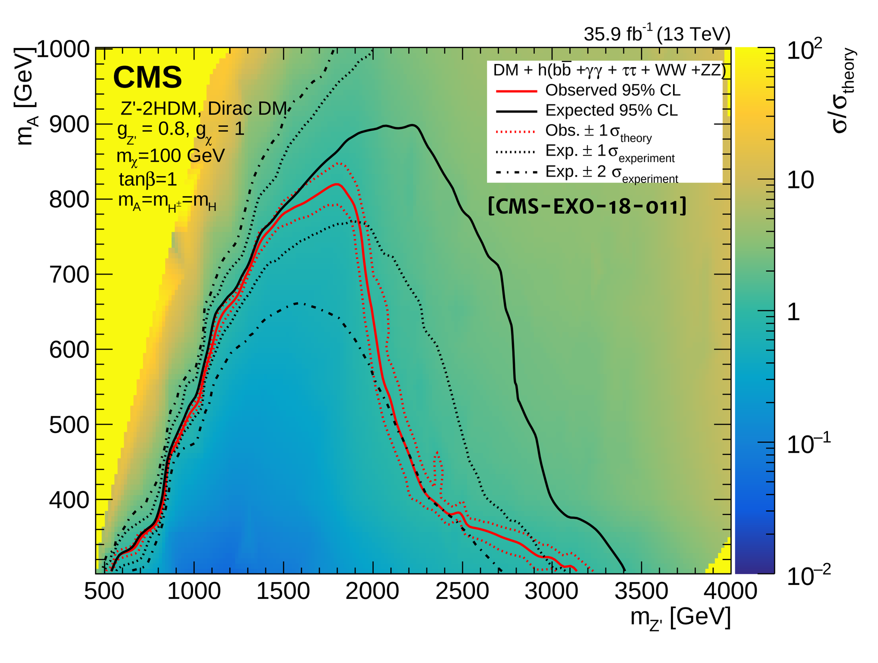


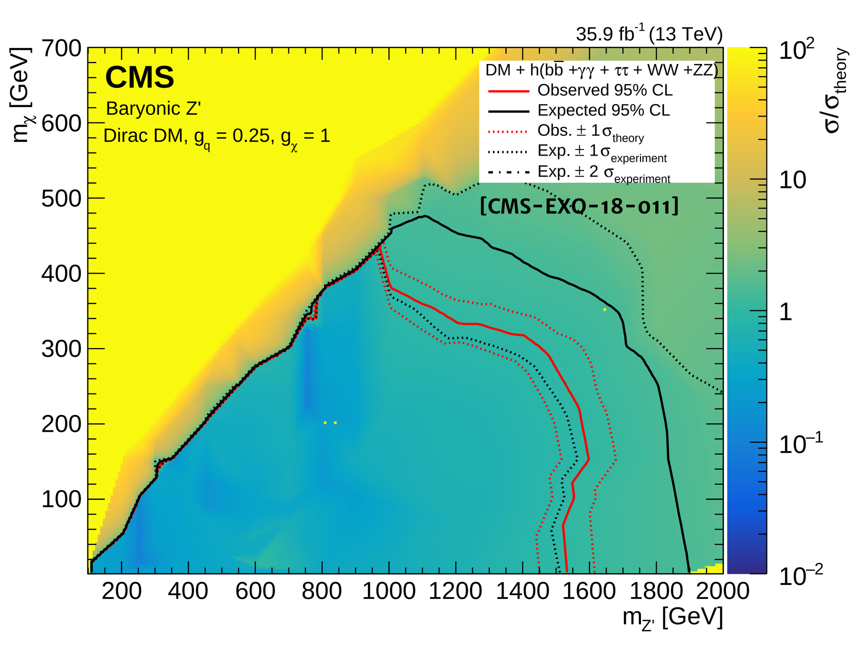


Combination

Results of the WW channel have been **combined with other final states**

- bb, $\gamma\gamma$, $\tau\tau$, and ZZ **[CMS-EXO-18-011]**
- **Sensitivity driven by bb channel** due to much larger branching fraction
- Z'-2HDM model: 500 GeV < $m_{Z'}$ < 3200 GeV and 300 GeV < m_A < 800 GeV excluded
- Baryonic Z' model: 100 GeV < $m_{Z'}$ < 1500 GeV and 1 GeV < m_χ < 420 GeV excluded





Posters@LHCC: Students' Poster Session at the 2019 Winter LHCC meeting, 27 Feb 2019, CERN, Geneva (Switzerland)