Searching for Dark Matter at LHC

- Dark Matter particle nature is unknown and cannot be explained within Standard Model
- 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_Tmiss) + 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⁺
  - 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, γγ):
- Tag the presence of the Higgs boson
  - Through invariant mass requirements
- Ask for large amount of p_Tmiss (MET)
  - Due to the presence of dark matter particles
- Select events with large separation between the Higgs boson and the p_Tmiss:
  - ΔR(h,MET) ~ 4

Strategy for WW Final State

The fully leptonic WW final state:
- Large branching fraction
  - BR(h→WW) ~ 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_Tmiss distribution
  - Both module and direction of p_Tmiss 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_Tmiss > 20 GeV
  - Large transverse momentum of the di-lepton system: p_T > 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_h < 76 GeV
- Higgs boosted by the recoil against dark matter: ΔR(ℓ,ℓ) < 2.5

Sensitivity enhanced by using multivariate analysis techniques
- Boosted Decision 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

Combination

Results of the WW channel have been combined with other final states
- bb, γγ, ττ, and ZZ [CMS-EXO-18-011]
  - Sensitivity driven by bb channel due to much larger branching fraction
  - Z⁺→2HDM model: 500 GeV < m_A⁺ < 3200 GeV and 300 GeV < m_h < 800 GeV excluded
  - Baryonic Z⁺ model: 100 GeV < m_h < 1500 GeV and 1 GeV < m_A⁺ < 420 GeV excluded

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_A⁺ < 800 GeV and 300 GeV < m_h < 320 GeV excluded
  - Baryonic Z⁺ model: no sensitivity reached