

# Searches for dark matter at CMS

**Norraphat SRIMANOBHAS** (Chulalongkorn U., Thailand) on behalf of the CMS Collaboration **DIS2016** 11 - 15 April 2016 **DESY, Hamburg, Germany** 

### Introduction to dark matter



### Dark matter searches



#### **Observe DM annihilation products**



#### **Dark Matter-nucleus scattering**



Laboratory production of DM particles







# Limit interpretations

Limits are quoted in terms of the WIMP-Nucleon cross-section



Contact interaction if

$$m_{Z^{'}} \gg Q = \sqrt{2m_n E_{\rm R}} \approx 50~{\rm MeV}$$

• Use of effective field theory (EFT) to place a limit on the contact interaction scale  $m_{Z'}$ 

$$\Lambda \equiv rac{m_{Z'}}{\sqrt{g_q g_\chi}}$$

 $\blacktriangleright$  EFT will be valid if  $~~m_{Z^{\prime}} \gg Q \sim ~~{
m TeV}$ 

# Limit interpretations

### **Effective Field Theory**

**Simplified Model** 





- Main interpretation used for 8 TeV analysis
- DM-SM contact interaction

- Explicit definition of the mediator
- LHC DM Forum: definition of a set of minimal benchmark simplified models to consider RunII DM searches

### Dark matter searches at CMS



# Monojet signal



### **Event selections**

- Large missing transverse energy
- One energetic central jet
- Lepton veto

### Background

- Z(->vv)+jets
- W(->lv)+jets; Lepton can't be

reconstructed, out of detector acceptance

- Data-driven to estimate background in signal regions
  - Dimuon, Dielectron, G+Jets => Z(nunu)
  - SingleMu,SingleElectron => W(->lv)+jets

#### http://cms-results.web.cern.ch/cms-results/ public-results/preliminary-results/EXO-15-003/



# Monojet signal

#### http://cms-results.web.cern.ch/cms-results/ public-results/preliminary-results/EXO-15-003/



#### **Results interpreted in terms of the simplified models**

- Results interpreted in terms of the different hypotheses of mDM - mMED considered
- 2D scan over different mass hypotheses of both mediator and dark matter masses

- Mediator couplings to SM and DM = 1
- Limits converted in terms of spinindependent DM-nucleon scattering cross section

### Dark matter associated with b-quarks

http://cms-results.web.cern.ch/cms-results/ public-results/preliminary-results/B2G-15-007/

### **Event selections**

- Large missing transverse energy
- b-tagged jet(s)
- Lepton veto
- 2 categories of signal-like events based on jet and b-tag multiplicity





### Background

- Z(->vv)+jets
- W(->lv)+jets
- ttbar



### Dark matter associated with b-quarks



- Results are interpreted in terms of Simplified Models
- 95% CL limits on DM heavy flavour production
  - On the scalar/pseudoscalar DM production wrt coupling gDM = 1

# Monotop signal

http://cms-results.web.cern.ch/cms-results/ public-results/preliminary-results/B2G-15-001/

- Monotop signature consists of single top quark and large missing energy
- FCNC or resonant models

### **Event selections**

- Use transverse mass of W as discriminating variable
- Signal region + 2 control regions
   (W-enriched, ttbar-enriched)

### Background

- ttbar
- W(->lv)+jets



# Monotop signal

http://cms-results.web.cern.ch/cms-results/ public-results/preliminary-results/B2G-15-001/

▶ 95% CL limits on the signal cross section for the non resonant and resonant cases



### **Search using razor variables**

### arXiv:1603.08914



Phys. Rev. D 86 (2012) 015010



Force events to be dijet+MET topology, two megajets are formed

Use momenta of two megajets to compute razor variables,

$$\begin{array}{lll} M_R &\equiv& \sqrt{(|\vec{p}_{J_1}|+|\vec{p}_{J_2}|)^2-(p_z^{J_1}+p_z^{J_2})^2} \;, \\ R &\equiv& \frac{M_T^R}{M_R} \;, \end{array}$$

with

$$M_{\rm T}^{\rm R} \equiv \sqrt{\frac{{\rm E}_{\rm T}^{\rm miss}(p_{\rm T}^{\rm J_1} + p_{\rm T}^{\rm J_2}) - \vec{\rm E}_{\rm T}^{\rm miss} \cdot (\vec{\rm p}_{\rm T}^{\rm J_1} + \vec{\rm p}_{\rm T}^{\rm J_2})}{2}}$$

### **Search using razor variables**

#### Events are classified according to the muon and b-tagged jet multiplicities



#### arXiv:1603.08914

### **Search using razor variables**



### Conclusions

- A lot of work has been done so far to search for dark matter produced from collider
  - Many channels are include: Jet, Lepton, Photon
  - Data-driven background techniques are used for background estimation
- No evidence for existence of dark matter production so far
  - Limits are quoted
- More results to come
  - Approval period for the first LHC Run II data
  - Waiting for the LHC 2016 run

# **Higgs portal to dark matter**

### EPJC 74 (2014) 2980





### mH=125GeV, and B(H→inv) < 0.51 at 90% CL, as a function of the DM mass.



# DM particles have the direct couplings to the SM Higgs sector, $H \rightarrow \chi \chi$

- Limits on branching fraction of Higgs to "invisible" particles used for limits on DM
- Can be scalar, vector or fermionic couplings
- Limits only up to DM mass  $M_{\chi} < M_{H}/2$

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# Monophoton signal

### **Event selections**

- Large missing transverse energy
- One energetic photon
- Veto on jets, leptons and and pixel seeds (hit pattern in the pixel detector)
- DeltaPhi(photon,MET)
- Reduce fake MET events







### Phys. Lett. B 755 (2016) 102

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# Monophoton signal



- Limits on the DM mediator mass
- Limits in term of DM-Nucleon cross section



# MonoZ signal

### arXiv:1511.09375



# MonoZ signal



