

Search for Dark Matter with mono-X Signatures in CMS

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Dark matter

• Existence of dark matter (DM) known from astrophysics and cosmology.

• From Cosmology, 25% of universe is dark matter

• It rarely interacts with ordinary matter.

• Direct detection

• DM interacts with ordinary matters such as nucleons.

Indirect detection. $oldsymbol{O}$

• DM self-annihilate or decay in outer space.

Particle colliders. \bigcirc

Produce DM particles in a laboratory.

Dark Matter would not be detected directly at LHC, create a p_T^{miss} $p_{T^{miss}}$ = imbalance in the transverse momentum of all detected particles

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The multiple components that compose our univers















Dark matter detection at LHC

• mono-X search:

Standard model particle (jet, Z, γ , h, ...) recoil against missing energy.

- Tag from radiation or associated production
- Expect signal in the tail of missing energy distribution over the standard model background.
- Resonance search:
 - DM decays to standard model particle.
 - Expect signal peak in invariant mass of two visible final sate particle above the standard model background.
- Higgs portal:
 - Higgs decays to DM candidates.

Covered in previous talk by Raman

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Outline

Analyses for the talk:

- mono-J/V search
- mono-Z search
- **Dijet resonance search**
- Dilepton resonance search : <u>EXO-19-019(JHEP 07 (2021) 208</u>) -> full run2

• Full list of analyses are available here:

Public results

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: <u>EXO-20-004(arXiv:2107.13021</u>) -> full run2 : <u>EXO-19-003</u> (Eur. Phys. J. C 81 (2021) 13) -> full run2 : <u>EXO-19-012(JHEP 05 (2020) 033</u>) -> full run2



mono-J/V search



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mono-J/V search

Two major backgrounds: Z(vv)+Jets, W+Jets Backgrounds are estimated from Control regions Five control regions defined for background estimation





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Vector mediator Interpretation

Limits are set on dark matter particle production in the context of simplified models with vector mediator Comparison from direct-detection (DD) experiments



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Axial vector mediator Interpretation

Limits are set on dark matter particle production in the context of simplified models with axial-vector mediator Comparison from direct-detection (DD) experiments



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Axial vector mediator coupling limit

Exclusion limits in the plane of m_{med} and g_{χ}



For low mediator masses, values of g_q (g_x) as low as 0.018 (0.070) are excluded

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Exclusion limits in the plane of m_{med} and g_q





Scalar and pseudo-scalar mediator Interpretations

Scalar mediator



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Pseudo-scalar



Values less than 470 GeV are excluded



mono-Z(II) Search

Signature: Z(II)+MET

Model for interpretations:

- Simplified model
- ► 2HDM+a

 p_T^{miss} for simplified, m_T for 2HDM+a model

$$m_{\rm T} = \sqrt{2p_{\rm T}^Z p_{\rm T}^{\rm miss} (1 - \cos(\Delta \phi_{\ell \ell - \vec{p}_{\rm T}^{\rm miss}}))}$$

Basic selection:

- $p_{T(11)} > 25 \text{ GeV}, p_{T(12)} > 20 \text{ GeV}$
- $|m_{II} m_z| < 15 \text{ GeV}$
- p_T^{miss} > 100 GeV

Backgrounds:

- Drell-Yan, WZ, ZZ, VVV
- Dedicated Control regions to model the background

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10⁴

 10^{2}

10-1

10⁻²

 10^{-3}

Data/SM

Events / bin

10⁵

10⁴

10

10²

10

10⁻¹

3 -

2

Data/SM

Events



Vector mediator Interpretation

limit allowed for m_{med} > 870 GeV



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Compatible with direct ditection at low mass (Spin independent)







Axial vector mediator Interpretation

limit allowed for m_{med} > 800 GeV



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Best limits up to ~300 GeV (Spin dependent)











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Dijet resonance search

Bump hunt perfomed to find mediator 137 fb⁻¹ (13 TeV) dσ/dm_{jj} [pb/TeV] ۱0³ ^۲ Data CMS – Fit method χ^2 /NDF = 36.63 / 38 $|0^{2}|$ Ratio method χ^2 /NDF = 42.04 / 32 0 gg (2.0 TeV) qg (4.0 TeV) qq (6.0 TeV) 10 10^{-2} 10^{-3} 10^{-4} m_{ii} > 1.5 TeV [|η| < 2.5, |Δη| < 1.1 10^{-5} (Data-Prediction) Uncertainty 2 3 6 7 8 5 Dijet mass [TeV]



No peak is observed with respect to the SM background expectations.

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Boosted dijet (77 fb⁻¹ **Dijet w/ btag** (19.7 fb⁻¹ **Dijet w/ ISR j** (18.3 fb⁻¹) **DM + j/V(qq)** (137 fb⁻¹

Dilepton resonance search



Coupling to lepton introduced

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Bump hunt perfomed to find mediator



No peak is observed with respect to the SM background expectations





Interpretations



• $m_{med} < 1.92$ TeV excluded, for $m_{DM} = 0$, 1.04 TeV excluded

• Due to fluctuations in the observed limit, not all masses below that value are excluded

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Comparison

95% CL observed and expected exclusion regions in m_{Med}-m_{DM} plane for di-jet and dilepton searches



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- A brief summary of very exciting dark matter searches at CMS is presented.
- No excess observed in any of the analysis.
- The limits are set on Dark matter production.
- More results are coming soon.

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mono-photon and t/tt+DM [2016]



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Comparison



Vertical band : Results from Dijet searches Triangle shape: Results from mono-X searches

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95% CL observed and expected exclusion regions in mMed-mDM plane for di-jet searches and different MET based DM searches

(Assuming coupling to lepton is zero)

Boosted dijet (77 fb⁻¹) **Dijet w/ btag** (19.7 fb^{-1}) **Dijet w/ ISR j** (18.3 fb⁻¹) **DM + j/V(qq)** (137 fb⁻¹)

