

Status of dark matter searches at colliders

Sarah Alam Malik Imperial College London



	2011	2012	2015	2016
Energy	7 TeV	8 TeV	13 TeV	13 TeV
Integrated Iuminosity	5 fb ⁻¹	20 fb ⁻¹	~4 fb ⁻¹	40 fb ⁻¹

LHC

- The 2016 proton-proton
 physics run has ended (26th
 October).
- The final integrated luminosity
 ~40 fb⁻¹ in ATLAS and CMS
- The target for the whole year was 25 fb⁻¹!







LHC

- ◆Reached peak luminosity of ~ 1.4x10³⁴cm⁻²s⁻¹
 - 40% above design luminosity

Mean # of pp collisions in 2015: ~14

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Mean # of pp collisions in 2016: ~24





LHC

• Expect ~40-50 fb⁻¹/year in 2017 and 2018 - total of ~ 130 fb⁻¹ by end of 2018

Thanks to efforts of accelerator division, LHC performing above expectation



Dark Matter at LHC





Dark Matter at LHC

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We don't know what nature has in store for us, cover broadest range of scenarios





Signatures for dark matter searches: Mono-X





Monojet/Mono-V search







Monojet/Mono-V search





One of the highest MET events in the analysis





✦ At the heart of all DM searches at LHC

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- Challenging quantity to measure
- Sensitive to mis-measurements, detector effects, backgrounds
- Numerous algorithms developed to deal with anomalous noise producing fake MET and leading to high tail in MET
- After cleaning, simulation describes the data well



CMS EXO-16-037



(a)

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Monojet/Mono-V search

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Excluding mediator mass of upto 2 TeV and DM mass up to 700 GeV

Mono-photon search

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Excluding mediator mass of upto 800 GeV and DM mass up to 300 GeV



Mono-Z search

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CMS EXO-16-038

Signature : Z(II) + MET



Excluding mediator mass of upto 600 GeV and DM mass up to 200 GeV

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Monotop

monotop production via (a) neutral flavor-changing current and (b) heavy colored, charged scalar

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Axial-vector mediator



Vector mediator





ICHEP summary of Mono-X searches

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ICHEP 2016 ICHEP 2016 $[200, 10^{-35}]$ 10^{-36} 0^{20} 10^{-37} $\begin{bmatrix} 10^{-33} \\ 10^{-34} \\ 0 \end{bmatrix} = \begin{bmatrix} 10^{-34} \\ 10^{-35} \\ 0 \end{bmatrix}$ **CMS** Preliminary **CMS** Preliminary Axial-vector med., Dirac DM Vector med., Dirac DM $g_a = 0.25, g_{DM} = 1$ $g_{_{_{_{_{}}}}} = 0.25, g_{_{DM}} = 1$ 10⁻³⁷ 10⁻³⁶ 10⁻³⁸ 10⁻³⁷ Pico 2L 10⁻³⁸ 10⁻³⁹ Pico 60 10⁻³⁹ CMS DM+Z₁[EXO-16-038] Super-K $\tau^+ \tau^-$ COMSLite 2015 10^{-40} 10⁻⁴⁰ CMS DM+y [EXO-16-039] CMS DM+Z₁₁ [EXO-16-038] IceCube T⁺1 CRESST-II 10⁻⁴¹∎ **10**⁻⁴¹ CMS DM+j/V_{aq} [EXO-16-037] CMS DM+y [EXO-16-039] 10⁻⁴² 10⁻⁴² 10⁻⁴³ 10^{-43} 10⁻⁴⁴ CMS DM+j/V_{aa} [EXO-16-037] LUX 2015 10^{-45} 10^{-44} PandaX 2016 10⁻⁴⁶ 10⁻⁴⁵ 10⁻⁴⁷ 10² 10^{3} 10 10³ 10² 10 m_{DM} [GeV] m_{DM} [GeV]







Search for narrow resonances decaying into a pair of jets, dijet mass spectrum smoothly falling distribution, no evidence of resonant production

EXO-16-032

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low mass region

high mass region





Searches for the mediator

EXO-16-032

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Mediator Mass [TeV]



Search for new resonances in a dijet system accompanied by a photon or jet Initial-State Radiation (ISR) excludes mediator masses starting from 200 GeV

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DM Mass [TeV]



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Higgs to invisible searches



DM mass [GeV]





Dark Matter at LHC











Dark Matter interpretation and comparison with DD

A lot of work/emphasis on interpretation of dark matter searches within framework of simplified models and their comparison with direct detection experiments

ATLAS-CMS Dark Matter Forum : Nov 2014 - Nov 2015
 LPCC Dark Matter Working Group : Nov 2015 - present

Report of	of the ATLAS/CMS Dark Matter Forum
June 22, 201	5
Nural Akchur Ece Akilli Un Juan Alcaraz (CIEMAT), S	rin Texas Tech University, USA liversité de Genève, DPNC, Switzerland : Maestre Centro de Investigaciones Energéticas Medioambientales y Tecnológicas ipain
Barbara Alva	CERN-LPCC-2016-00
	Recommendations on presenting LHC
	searches for missing transverse energy
	signals using simplified <i>s</i> -channel models
9	of dark matter
6v1 [hep-ex] 14 Mar 20	Antonio Boveia, ^{1,*} Oliver Buchmueller, ^{2,*} Giorgio Busoni, ³ Francesco D'Eramo, ⁴ Albert De Roeck, ^{1,5} Andrea De Simone, ⁶ Caterina Doglioni, ^{7,*} Matthew J. Dolan, ³ Marie-Helene Genest, ⁸ Kristian Hahn, ^{9,*} Ulrich Haisch, ^{10,11,*} Philip C. Harris, ¹ Jan Heisig, ¹² Valerio Ippolito, ¹³ Felix Kahlhoefer, ^{14,*} Valentin V. Khoze, ¹⁵ Suchita Kulkarni, ¹⁶ Greg Landsberg, ¹⁷ Steven Lowette, ¹⁸ Sarah Malik, ² Michelangelo Mangano, ^{11,*} Christopher McCabe, ^{19,*} Stephen Mrenna, ²⁰ Priscilla Pani, ²¹ Tristan du Pree, ¹ Antonio Riotto, ¹¹ David Salek, ^{19,22} Kai Schmidt-Hoberg, ¹⁴ William Shepherd, ²³ Tim M.P. Tait, ^{24,*} Lian-Tao Wang, ²⁵ Steven Worm ²⁶ and Kathryn Zurek ²⁷
Kiv:1603.0415	*Editor ¹ CERN, EP Department, CH-1211 Geneva 23, Switzerland ² High Energy Physics Group, Blackett Laboratory, Imperial College, Prince Consort Road London, SW7 2AZ, United Kingdom ³ ARC Centre of Excellence for Particle Physics at the Terascale, School of Physics, University of Melbourne, 3010, Australia ⁴ UC Santa Cruz and UC Santa Cruz Inst. Part. Phys. USA
ar	⁵ Antwerp University, B2610 Wilrijk, Belgium ⁶ SISSA and INFN Sezione di Trieste, via Bonomea 265, I-34136 Trieste, Italy

Summary

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- Searches in place to look for DM producing a variety of signatures within top-down models like SUSY and bottom-up models like EFT and simplified models.
- Searches for mediators (dijets) also coming into play and constraining potential mediators coupling SM to DM
- * Constraints on SM Higgs decays to invisible particles , upper limit on branching fraction 0.24
- Combination of all these searches could play vital role in determining the characteristics of a SM-DM interaction in case of discovery.
- Combined ATLAS-CMS-theory effort to benchmark a set of simplified models and accurately elucidate complementarity with direct detection experiments
- But so far, no sign of WIMPs. Are we missing something? Are there interesting signatures we're not looking for? Expecting ~130 fb⁻¹ of data by end of 2018, presents many opportunities.