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LHC Dark Matter Working Group: Potential topics for future work

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Horizon 2020
European Union funding
for Research & Innovation

LHC Dark Matter Working Group (2015-)

http://lpcc.web.cern.ch/lpcc/index.php?page=dm_wg

The LHC Dark Matter Working Group (LHC DM WG) brings together theorists and experimentalists to define guidelines and recommendations for the benchmark models, interpretation, and characterisation necessary for broad and systematic searches for dark matter at the LHC.

The LHC DM WG develops and maintains close connections with theorists and other experimental particle DM searches (e.g. Direct and Indirect Detection experiments) in order to help verify and constrain particle physics models of astrophysical excesses, to understand how collider searches and non-collider experiments complement one another, and to help build a comprehensive understanding of viable dark matter models.

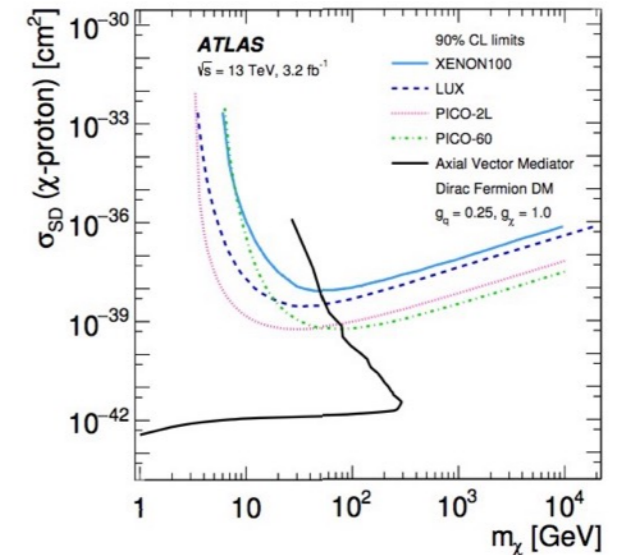
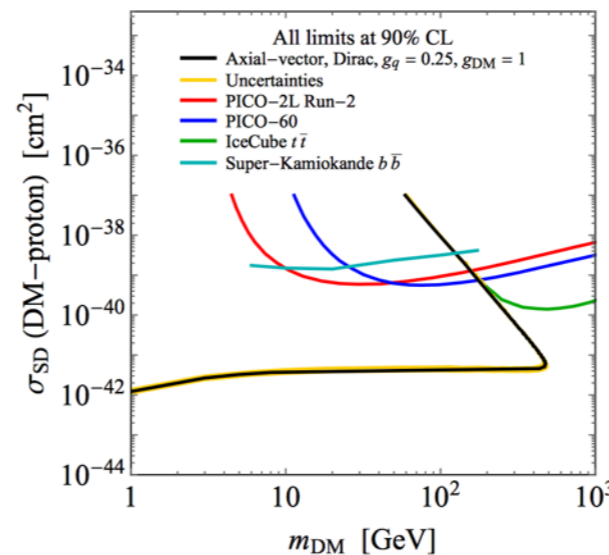
First project: translation of LHC simplified model results into DM-nucleon cross-section plane (DD/ID)

<http://arxiv.org/pdf/1603.04156.pdf>

CERN-LPCC-2016-001

Recommendations on presenting LHC searches for missing transverse energy signals using simplified s -channel models of dark matter

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What next for LHC DM searches?
long-term statement will also
depend on DD/ID reach



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How to proceed

- The DMWG works on focused efforts: selected topics leading to arXiv write-up
- Goal of this meeting: choose one topic to develop towards our next public meeting
 - Past few weeks: open editing of a [google document](#) containing suggestions
 - Today: short presentations on some of the potential topics
 - Until the end of June: add suggestions and discussion to google doc
 - Decision on topic will be taken jointly after discussion on the mailing list below
- Discussion encouraged on new mailing list: lhc-dmwig-contributors@cern.ch
 - higher volume list for day-to-day discussions in detail
 - everyone registered with the mailing list has posting rights and can contribute to the exchanges or raise questions or issues to the attention of the group
- Today: discuss the possibility of introducing a more general scope: shall we have shorter periodic, Vidyo-based meetings to discuss developments and updates on previous topics?

Ideas for focused topics

(effort limited in time, arXiv document as outcome)

Background estimates

- Estimation of the Z+jets background to the mono-X searches (dominant uncertainty for certain MET regions)
 - theory uncertainties on extrapolation from W+jets or photon+jets to Z+jets: current methods and improvements
 - How to reduce uncertainties on ratios of W/Z or photon/Z
- Review of how ATLAS and CMS estimate background uncertainties
- Recommendations for deriving and checking these uncertainties, with input from precision QCD experts
 - Scale choices and uncertainties
 - Analysis cuts and sensitivity to scale uncertainties (e.g. large logs)

Plan for discovery

- Is there anything we should do now to prepare for a signal in a MET tail?
 - Precision QCD/EW: how to exclude problems with the background estimate
- Is there anything we should do now to prepare for a signal in a direct detection or indirect detection experiment?

Refinement of the first Run 2 simplified models, additional models motivating new searches not yet done

- 'realism' but generality: did the Dark Matter Forum strike the right balance? Do they capture the right physics?
 - Mono-jet-like scalar model
 - Connection to models (e.g. 2HDM) used in Higgs searches?
 - Mixing of the scalar with the Higgs
 - vector/axial-vector
 - Is pure V and A the right basis?
 - Unavoidable theory issues: mixing with Z and dilepton constraints? Does how the Z' acquire mass affect the viable signals?
- Higgs portal / lepton portal / quark portal
 - Discuss problems with H→invisible interpretation for vector DM in light DM limit
 - Rare Higgs decays to dark sector particles
- Anything further to learn from W and Z measurements?
- identify missing searches beyond the mono-X 'resonance' s-channel simplified models with Dirac DM
 - Further discussion of t-channel models (squark-like, fermion portal)
 - e.g., <http://arxiv.org/abs/1605.07058>
 - Revisit motivation for mono-W searches
 - Motivation for VBF searches vs mono-jet/mono-W
 - Graviton mediator: does this provide another plausible and distinct signal?
 - Non-fermionic DM: any new signatures?
 - Beyond MFV: any new signatures?
 - Co-annihilation codex and other model surveys: can we identify large gaps in current searches?
 - E.g. <https://arxiv.org/abs/1510.03434> [Coannihilation codex and s-

channel [leptoquark mediator case study](#)]

- E.g. <https://arxiv.org/abs/1605.08056> [s-channel [diquark mediator case study](#)]
 - Minimal dark sectors/non-standard freeze-out scenarios: does this motivate emphasis on different signals?
- UV complete models: are there important classes of models not already targeted by any LHC searches?
 - SUSY searches: are pMSSM scans with astrophysical constraints sufficient?
 - What does SUSY not cover?
 - Example [electroweaking searches](#), no search covering "best fit" MSSM regions (see e.g. [arxiv 1602.00590](#) discussing MasterCode best fit regions), this is also an example of DM searches without MET (MET + anything would not see it)
- Relationship of models already discussed to models of dark sector signals for non-standard reconstruction (long-lived particles, displaced/disappearing jets, soft-stuff+X, etc.)
 - Very light mediator models
- Models beyond WIMP focus

New experimental searches motivated other than by simplified models

- Experimental problems E.g. additional ISR to improve signal/background of mono-jets
- Generic and systematic searches: MET+anything? (motivating MET+resonance/kinematic edge, etc.)

Measurements to improve LHC and non-LHC searches

- Possibility of low energy p-He for indirect detection (constrain cross sections for ISM interactions)

Combinations and combined constraints

- How to understand where effort should be targeted (combined constraints, global fits, pMSSM-style scans, simple comparisons of results without combination, etc.)
- When and where to combine searches, and when not to do this
 - Combinations across LHC channels?
 - Combinations with non-collider experiments?
 - astrophysical uncertainties in non-collider searches
- Theory issues with comparison to non-collider experiments
 - RG evolution of model parameters
- Astrophysical constraints
 - WIMP annihilation in gravitational wells (sun, galaxies, early universe)
- Benchmarks for comparisons of search channels
 - E.g. mono-jet vs dijet
 - Adding [dilepton](#), EW precision constraints
- Complementarity of searches for exotic higgs decays and searches for mono-Higgs signals
 - Similar to what is done in this paper - <http://arxiv.org/pdf/1404.3716v2.pdf> - but with a focus on how well the simplified models used for mono-H maps onto Figure 1

- Parameter scans: how to efficiently convey coupling dependence
- Morphing to interpolate between MC signal points

Ideas for standing topics (regular updates)

Discussion of experimental results

- q&a between experiments and with theory
- feedback on use of DMF models (1507.00966) and DM WG s-channel recommendations (arXiv:1603.04156)
- Discussion of feedback from conferences and workshops (Moriond, DM@LHC, ICHEP, Santander, Dark Interactions, etc.)

Tools

- Discussion of new developments in MC tools for phenomenology, signal generation, relic density (e.g. NLO in MadGraph5_aMC@NLO)

DM-specific aspects of re-interpretation of LHC results

- Model repository, reference cross sections
- Further standardization of relic density calculations, parameter grids, experimental uncertainties, etc.
- Tools for recasting (simplified models vs ATOM/Checkmate/MadAnalysis, Recast, etc.)
- Need of non-simplified (high parametric) model which is not MSSM, leading to very different phenomenology at LHC (maybe a different SUSY flavour (sneutrino DM) and high dimensional simplified DM model with/without co-annihilation included).
 - In principle any extension of the MSSM fulfils this criterion: NMSSM, U(1) extended MSSM, MSSM with inverse see saw, MSSM+sneutrino DM etc etc. It would be good to have some additional requirements to narrow down the possibilities.

EFT Truncation

- EFT models are not valid when the momentum transfer of a process (Q_{tr}) becomes comparable to the mass of the underlying non-specified mediator (M_{med}).
- The idea of truncation is to throw out events for which $Q_{tr} \geq M_{med}$. To do this, we need to figure out a form of M_{med} and Q_{tr} in terms of EFT parameters, such as Λ .
- Must assume underlying UV form. For examples, for some operators:
 - $\text{Sigma} \sim g_q^2 g_{\chi}^2 / [(Q_{tr}^2 - M_{med}^2)^2 + G_{med}^2]$
 $M_{med}^2 = 1 / \Lambda^4$
- If $M_{med} \gg Q_{tr}$ then $M_{med} = \sqrt{g_q g_{\chi}} \Lambda$
- So far in ATLAS results, we take $Q_{tr} = m_{\chi}$ and we take $g_q = g_{\chi} = 1$

or $g_q = g_{\chi} = 4 \pi$ (g_q and g_{χ} must be less than or equal to 4π)

- Then, to calculate the 95% CL limit on the cross section, we note that:
 - $\text{Sigma}_{95} = \text{sigma}(\Lambda) * A_{fiducial}(\Lambda) * A_{truncation}(\Lambda, \sqrt{g_q g_{\chi}}) * \text{efficiency}(\Lambda)$
- To calculate sigma_{95} then, we must iterate over Λ - this leads to a few different iterative truncation methods.
- Some are easier to implement than others, for example if efficiency is not a function of Λ , then a full simulation for the scan of Λ points is not necessary, and only a truth level simulation would suffice.
- Also note that the completion which gives $M_{med} = \sqrt{g_q g_{\chi}} \Lambda$ is only valid for some EFT operators.
- See the following presentation and the links to papers on slide 2 of the presentation for more information: https://indico.cern.ch/event/459037/contributions/1960015/attachments/1202708/1752598/run1_truncation.pdf

Today's agenda

13:15 → 15:30 Possibilities 

13:15

Simplified DM models: a case with t-channel colored scalar mediators

Speaker: Alexander Natale (Korea Institute for Advanced Study)

🕒 10m



13:30

Electroweak background predictions

🕒 10m



13:45

Parameter scans over couplings

Speakers: Thomas David Jacques (Scuola Int. Superiore di Studi Avanzati (IT)), Thomas Jacques (U)

🕒 10m



14:00

Refinements of scalar simplified models

Speakers: Giorgio Busoni (The University of Melbourne), Giorgio Busoni

🕒 10m



14:15

RG evolution of couplings

Speaker: Francesco D'Eramo (UC Berkeley)

🕒 10m



14:30

Monotop models

Speakers: Benjamin Fuks (Institut Pluridisciplinaire Hubert Curien (FR)), Giacomo Cacciapaglia

🕒 10m



14:45

MC tools

Speaker: Fabio Maltoni (Universite Catholique de Louvain (UCL) (BE))

🕒 15m




15:05

EFT Truncation

Speaker: Nikola Lazar Whallon (University of Washington (US))

🕒 10m



 eft_truncation.pdf