What Are We Doing Here?

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We and our colleagues have had many good discussions about simplified models for how dark matter interacts with the Standard Model, and there's been a lot of work done.

The point of this forum is to bring theorists and Run 2 experimenters together to put these ideas into practice.

Mandate

Full text here.

As Run 2 data–taking rapidly approaches, it is important to narrow the scope and timescale of this forum to quickly achieve the following goals:

1. *A prioritized, small set of benchmark simplified models should be agreed upon by both collaborations for Run-2 searches.* **As soon as possible.**

2. *The matrix element implementation of the simplified models should be standardized, and other common technical details (order of the calculation, showering) harmonized as much as practical. It would be desirable to have a common choice of LO/NLO, ME–parton shower matching and merging, factorization and renormalization scales for each of the simplified models. This will also lead to a single set of theory uncertainties, which will be easier to deal with when comparing results from the two collaborations.* **End of February.**

3. *On the same timescale, the forum could also discuss the conditions under which the EFT interpretation may still be desirable.*

4. *An arXiv document should be prepared summarising these items, suitable both as a reference for the internal ATLAS and CMS audiences and as an explanation for theory and non-collider readers.* **End of March.**
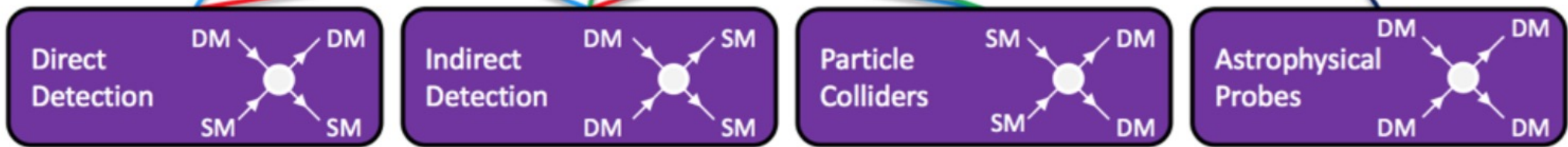
The document may also address how to compare the collider results to non-collider experiments.

Practical limitation: data-taking in summer means signal MC production must start in late winter/early spring.

Reminder: EFT for 7 TeV
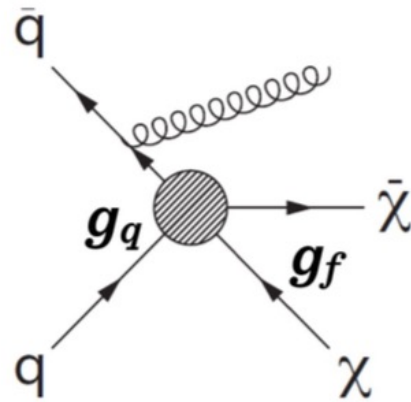
$M_* = M/\sqrt{(g_q\, g_f)}$, the suppression scale of the contact interaction

"The most powerful results are from the mono-jet analyses, and the greatest gains come from the combination of the independent analyses from ATLAS and CMS, though the other final states make a non-negligble improvement."

Phys.Rev. D87 (2013) 9, 095013

TABLE V: 90% CL limits on $\sigma(pp \to \chi\bar{\chi} + X)$ for $m_\chi = 10$ GeV, theory prediction for $M_\star = 1$ TeV, and limits on $M_\star$ using the D5 operator. In the case of the $Z + \not{E}_T$ final state, the prections include the $Z \to \ell\ell$ branching fraction.

Channel	Limit σ (fb)	Pred. (fb)	Limit $M_\star$ (GeV)
ATLAS jet+$\not{E}_T$	1,700	370	685
CMS jet+$\not{E}_T$	1,140	370	750
ATLAS $\gamma + \not{E}_T$	33	3.7	580
CMS $\gamma + \not{E}_T$	35	3.7	570
ATLAS $Z + \not{E}_T$	36	0.5	340

} 785
} 645
} 795

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Forum Topics

Forum topic 1: list of simplified models and assumptions

- EFT provided a systematic way to think about the possibilities for collider dark matter searches.
  - A menu of all possible operators allowed under a reasonable set of assumptions
  - A set of signatures (defined by possible ISR in the Standard Model)

  but problems at LHC for smaller UV couplings, high mass WIMPs.

- Simplified models: replace contact interaction with explicit light mediator.
  - New parameters to be scanned: mass and total width of mediator.
  - More model dependence.

  Is it possible to have a set of simplified models to share most of the advantages of the EFT?
  - Cover the best-motivated possibilities
  - Allow community to build new interpretations from them
  - Minimal, practical for experiments, consensus of a broad set of theorists

High Energy Physics – Phenomenology

Simplified Models for Dark Matter and Missing Energy Searches at the LHC

Jalal Abdallah, Adi Ashkenazi, Antonio Boveia, Giorgio Busoni, Andrea De Simone, Caterina Doglioni, Aielet Efrati, Erez Etzion, Johanna Gramling, Thomas Jacques, Tongyan Lin, Enrico Morgante, Michele Papucci, Bjoern Penning, Antonio Walter Riotto, Thomas Rizzo, David

High Energy Physics – Phenomenology

Constraining Dark Sectors at Colliders: Beyond the Effective Theory Approach

Philip Harris, Valentin V. Khoze, Michael Spannowsky,

High Energy Physics – Experiment

Interplay and Characterization of Dark Matter Searches at Colliders and in Direct Detection Experiments

Sarah A. Malik, Christopher McCabe, Henrique Araujo, Alexander Belyaev, Celine Boehm, Jim Brooke, Oliver Buchmueller, Gavin Davies, Albert De Roeck, Kees de Vries, Matthew J. Dolan, John Ellis, Malcolm Fairbairn, Henning Flaecher, Loukas Gouskos, Valentin V. Khoze,

High Energy Physics – Phenomenology

Scalar Simplified Models for Dark Matter

Matthew R. Buckley, David Feld, Dorival Goncalves

(Submitted on 23 Oct 2014)

- Make conscious decisions about what models we ought to use and what models should be left out. Explain why.

  - What are the right assumptions? (MFV? types of DM particles? types of interactions?)
  - How to handle tricky details (e.g. gg vertex)
  - What are the free parameters of the models and what ranges of the parameters makes sense? (e.g., non-minimal width of the mediator).
    * Computational limits: what granularity? what regions of parameters produce qualitatively different signals, vs what are purely re-interpretation rather than re-optimization of the analysis cuts?
  - What are the constraints from other searches (e.g., dijet resonances)?
  - How to fit subsequent developments into this framework? (and where do other ideas like lepton portal DM fit?)
  - What searches ought to be done? (mono-jet, mono-γ, mono-$W/Z/H$, bottom/top + MET, ...)

- Don't re-invent the wheel.

  - Start from one of the proposals (DM@LHC?) and build up with missing pieces?
  - Enumerate all possibilities systematically and then pare down to best-motivated?

Forum topic 2: MC implementation

- Experiments need more than a Lagrangian to simulate the models!
  - Choice of event generators (MadGraph, Powheg)
  - Desired order of calculation (LO/NLO)
  - Matrix element / parton shower matching
  - Choice of scales (renormalization, factorization) for central value and systematic uncertainties
- And theorists would like some help as well, for ease of reinterpretation and comparison:
  - Consistent implementation of the models with no arbitrary differences
  - Consistent decisions about the matching/showering/LO vs NLO/etc.
  - Consistent treatment of common uncertainties
  - Comparison of technical choices (sanity check, up to generator level plots)

We would also like you to help collecting the simplified model files implementation tools into a common repository for ATLAS and CMS, accessible by both collaborations and anyone who is interested in reproducing the results.

Forum topic 3: legacy of EFT results

- Address criticism of past LHC results

  - One needs a UV completion to make any definite statements about how to correct the EFT results

  - ATLAS procedure developed with the authors of PLB728 (2014) 412-421, JCAP 1406 (2014) 060, JCAP09(2014)022 : truncate the cross section

- See talk later today.

- Should both collaborations use this procedure?

Forum topic: presentation of collider limits in context

- What does the wider community need to put LHC searches in their broader context?

  - Concise justification for the decisions made
  - Well-explained caveats

- Decide how to portray complementarity between collider results and non-collider experiments (or: what do our results mean for the overall search for dark matter?)

- Show collider limits on DD plots, or vice-versa, or both?

  - Focus on complementarity, not competition
  - Provide central tools for making comparison plots, if possible

- How to incorporate LHC searches for dijets, dileptons, and others?

- Whether/how to incorporate relic constraints

Write-up

A comprehensive document of the work. Important that it is not just a pile of ideas, but that it is coherent and convincing.

- Provide a reference for the internal ATLAS and CMS audiences (experts and newcomers)

- Explain our choices to theory and non-collider readers (defend our work as clearly as we can, and carefully point out its limitations)

- Ask a limited number of additional theorists for internal peer-review (collaboration with all interested theorists sought from the start)

- Provide all model details necessary to reproduce/re-interpret our work (common generator parameters / configurations on a CERN-hosted website)

- Provide any public, common tools, such as translation between DD and collider limits

Experiments need theorists help with all of these points!

- If we're not comprehensive, if some analyses are left to invent an interpretation scheme on their own,

- If we don't flesh out all the tools,

- If we don't address criticism of EFT/past results and give analyzers the tools they need to make their case for LHC results,

- If we don't explain ourselves well and do work that can be built upon,

then the work already done on simplified models won't have the impact it deserves.

Role of today's meeting and subsequent talks

- Collect ideas.

- Understand who can work on what, when.

- Decide how to divide the work.

- Identify where more effort is needed.

Organization, Schedule, and Plan

Twiki to collect reference material, lists of contributors, schedule and plan
Mailing list lhc-dmf@cern.ch e-group
Organizers: lhc-dmf-admin@cern.ch