Journal club minutes and notes: Dark Matter - Part 1

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May 16th 2018 - Journal club meeting minutes
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Neha chairs, Karol guides. First session of Dark Matter paper and part of PDG review.

Topics:

- Evidence for DM
- Dark energy diagrams (figure 1)
- How sensitive experiments are to the various couplings and masses in these diagrams

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Details:

- Karol tells us why he chose this paper: there are several schools of thought in DM searches at LHC: one that looks for SUSY signal models that have candidates that just so happen to look like DSPs. Then there is also the exotics group that look for DM directly with largely model independent searches, e.g. the mono-X searches and diet searches. And we also have the direct detection experiments, just tubs of water essentially. This paper connects the LHC experiments with the dedicated DM experiments and hence gives a nice overview of the search. Karol advises we ignore the equations and look at the plots as there is a lot of stuff happening there.
- Neha motivates our reading of the paper with evidence for DM: Classic galaxy rotation curves. Bullet cluster. CMB measurements and the gravitational lensing.
- Karol reminds us that the key thing here is the relic density.
- We discuss the stop and neutralino mass curve and how it is constrained.
- We know DM interacts gravitationally is non-relativistic and the relic density gives us the cosmological constraint - but that's effectively all we know. We hope it weakly interacts so we can actually see it.
- If we think about the limit where the effective field theory is correct, this is not very useful at the LHC. The reason for this, Xiangyang explains, is because in the CI case the mediator mass cannot be very close to the centre of mass production energy.
- Why though, is because you'd be off-shell if the mass is too low and this limits the cross-section.
- The tasi lectures (in table in commons page) show you how to calculate the branching ratio of the Z, ends with the breit-wigner equation. Karol recommends this nice review paper to refresh our memories on how cross-sections and BR are calculated from on-shell decays, etc.
- Why does the WIMP not couple to leptons as effectively as to quarks? Is it just because of the stronger experimental limits on dilepton searches? From an experimental view: yes. And possibly the theorists just adapt to the experiments.

- We then go through the diagrams in Figure 1.
    - The first diagram is indirect detection.
    - The second is direct detection (all those tubs-of-water models). The properties of DM matter the experiments are sensitive to is large mass DM, to give a measureable nuclear recoil for example.
    - The third is an ISR mono-something diagram. But NOT mono-higgs! The Higgs production requires something else, e.g. coupling to a vector boson like in this link: https://www.researchgate.net/figure/Feynman-diagrams-for-athe-EFT-and-bthe-Z-2HDM-models-The-ch-is-the-DM-particle-The_fig7_301482616 .
    - The fourth is a dijet resonance, which would produce jets with a resonance at the mediator mass,
    - And the fifth is diet associated production - a similar story to the above.
- The LHC fills in the lower masses that the direct-detection measurements aren't sensitive to because they don't need to depend on the DM masss as long as it's lighter than the mediator.
- They added an extra mediator in the case of this review, rather than just the DM particle, which isn't as generic as the EFT but it is more physically correct. So you have 4 unknowns. The dark matter coupling, the mass of the DM, the mediator mass, and the mediator couplings.
- The diagrams d and e are simplified as we have more particles with more final states that we can look at. This is similar to SUSY, they look for signatures.
- Spin-independent and spin-dependent: a question of what the direct searches are sensitive to.
- We focus on axial coupling as that's where direct detection limits are weakest and that's where LHC is most useful.

N E X T W E E K
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mono-jet + diet (ie. Sections 4 & 5) but let's not read the atlas papers on these and focus on the overall goals of the review.
Karol advises we look at the figures, try and understand the features and then return to the plots afterwards.

Notes from paper
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1. [x] Introduction
2. [x] Simplified Interactions of a vector mediator
3. [x] Non-collider constraints
4. [ ] Monojet searches
5. [ ] Dijet searches