

NLO predictions for Dark Matter production at the LHC

Mathieu PELLEN

Institute for Theoretical Particle Physics and Cosmology, RWTH Aachen

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In collaboration with:
M. Backović, M. Krämer,
F. Maltoni, A. Martini, K. Mawatari

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Outlook

- 1 Introduction
- 2 The models
- 3 Importance of NLO corrections
- 4 Other features
- 5 Conclusion

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Introduction

The models

Importance of NLO corrections

Other features

Conclusion

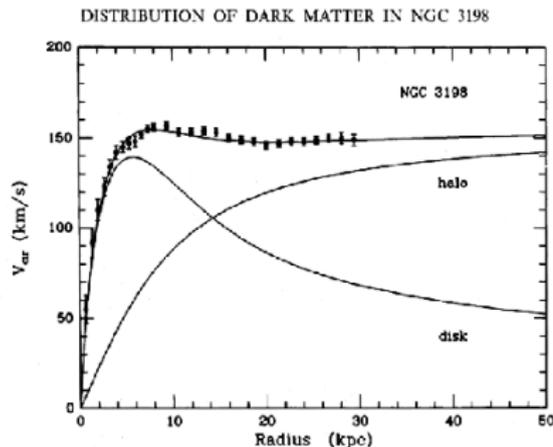
Dark Matter: Evidences and Theories

Review

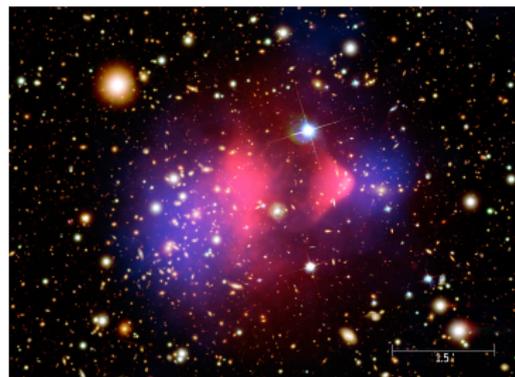
Method of computation



Evidences for Dark Matter



[Rubin, Ford, Kent]



[Clowe, Gonzalez, Markevitch, astro-ph/0312273]

And **more**: CMB, weak lensing, large scale structure ...

→ Weakly Interacting Massive Particles (**WIMPs**)

What theory for Dark Matter?

- Plethora of models
- Need for model independent tools

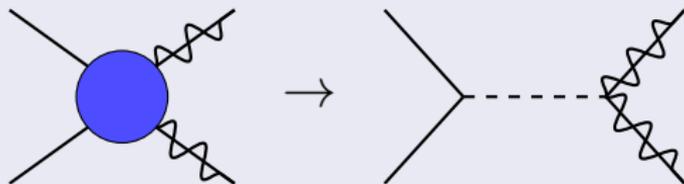
What theory for Dark Matter?

- Plethora of models
- Need for model independent tools
- Effective Field Theory (EFT)
 - The mediator is integrated out
 - Problematic at energies probed by the LHC [Busoni et al., 1402.1275]
 - Hard to compare bounds from different search strategies (direct, indirect, collider)

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→ Simplified models:



Review - Searches

Detection of dark matter at the LHC:

→ MET + mono X (= jet, photon, W, Z, h), di-jets or top pair

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Studies in simplified model:

- Mono-jet + MET [Buchmueller et al., 1308.6799, 1407.8257]
- Di-jet + MET [Chala et al., 1503.05916]
- Top pair + MET [Haisch and Re, 1503.0069]

→ Dark matter Forum: [Abercrombie et al., 1507.00966]

Review - Computations

Precise predictions:

- NLO QCD correction to dark matter production ...
 - ... in association with gauge boson
[Wang et al., 1107.2048], [Huang et al., 1210.0195], [Mao et al., 1403.2142], [Neubert et al., 1509.05785]
 - ... for mono-jet for EFT [Fox and Williams, 1211.6390],
- Matched to parton shower [Haisch et al., 1310.4491]
- Loop induced [Haisch et al., 1208.4605], [Harris et al., 1411.0535], [Buckley et al., 1410.6497], [Mattelaer and Vryonidou, 1508.00564]

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→ Our work:

Fully automatised simplified model at NLO accuracy ...
... for arbitrary processes (also loop induced) ...
... matched to parton shower

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- Implementation of the model in FEYNRULES [Alloul et al., 1310.1921]

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→ UFO model publicly available

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- Calculation of arbitrary (also loop-induced) processes in MADGRAPH5_AMC@NLO [Alwall et al., 1405.0301]
- Can be used in MICROMEGAS [Belanger et al., 0803.2360] and MADDM [Bacaković et al., 1505.04190]

Outlook

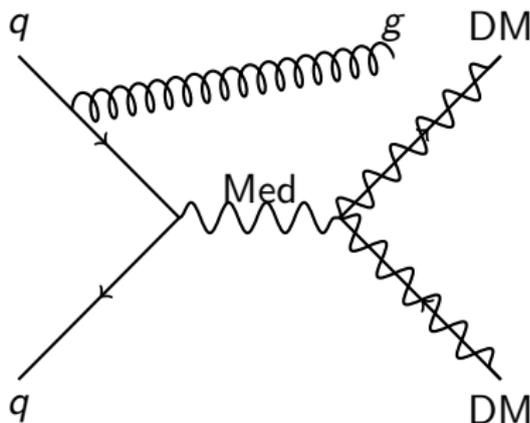
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- Vector mediator (Y_1)

$$\mathcal{L}_{X_D}^{Y_1} = \bar{X}_D \gamma_\mu (g_{X_D}^V + g_{X_D}^A \gamma_5) X_D Y_1^\mu$$

$$\mathcal{L}_{SM}^{Y_1} = \sum_{i,j} \left[\bar{q}_i \gamma_\mu (g_{qij}^V + g_{qij}^A \gamma_5) q_j \right] Y_1^\mu$$

→ Preferred signature: jet + MET

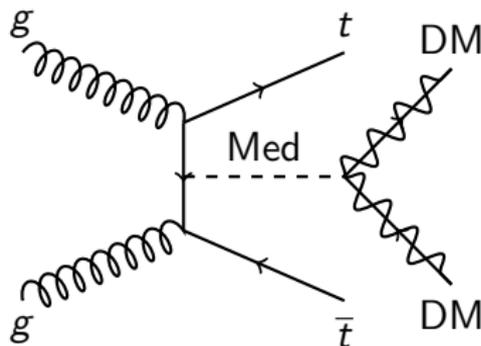


- Scalar mediator (Y_0)

$$\mathcal{L}_{X_D}^{Y_0} = \bar{X}_D (g_{X_D}^S + i g_{X_D}^P \gamma_5) X_D Y_0$$

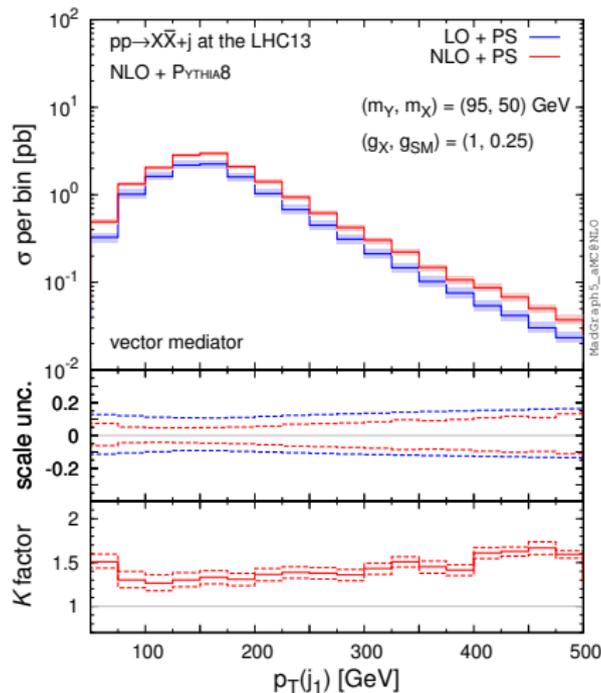
$$\mathcal{L}_{SM}^{Y_0} = \sum_{i,j} \left[\bar{q}_i \frac{y_{ij}^q}{\sqrt{2}} (g_{q_{ij}}^S + i g_{q_{ij}}^P \gamma_5) q_j \right] Y_0$$

→ Preferred signature: top pair + MET

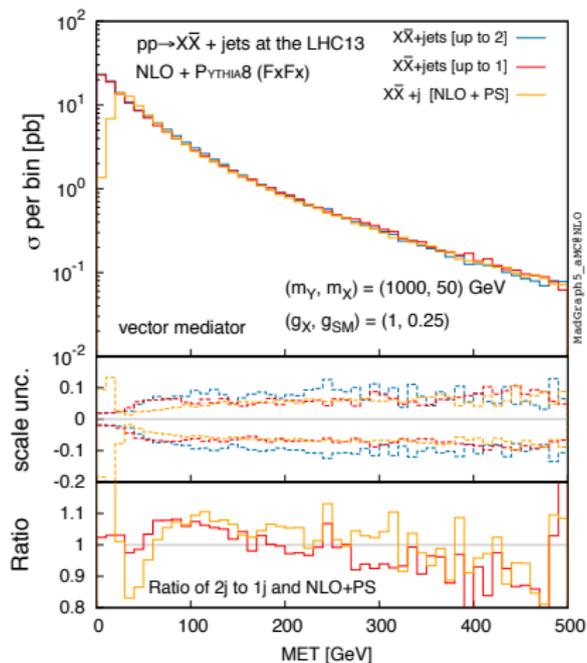


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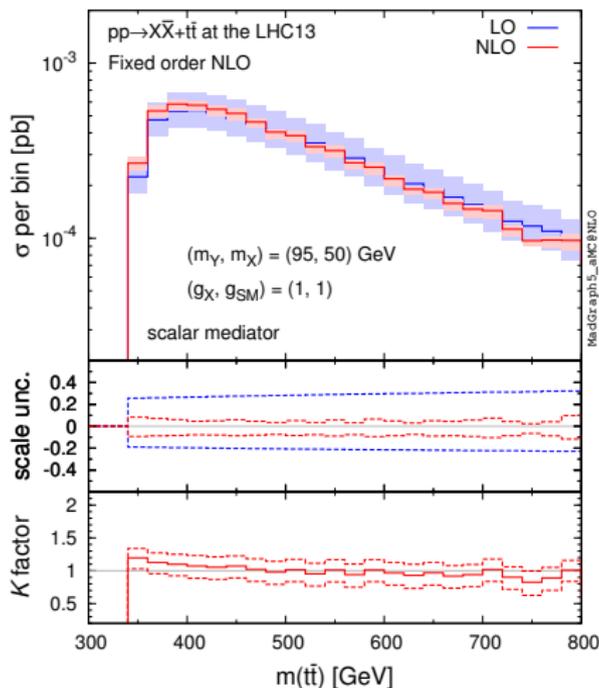
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→ Significant shape distortion



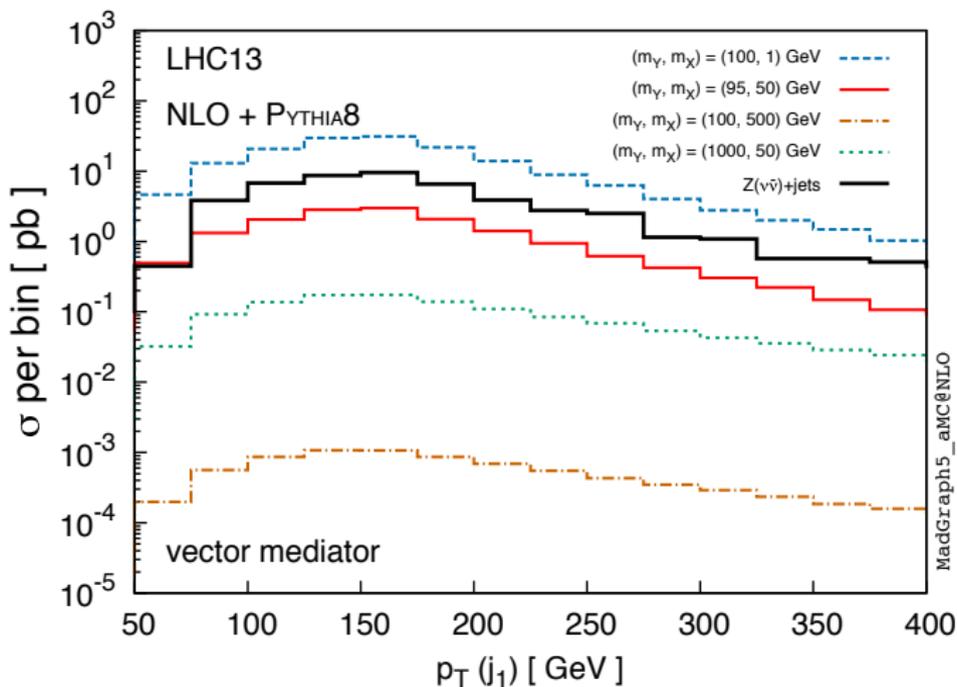
→ Possibility to merge different samples automatically



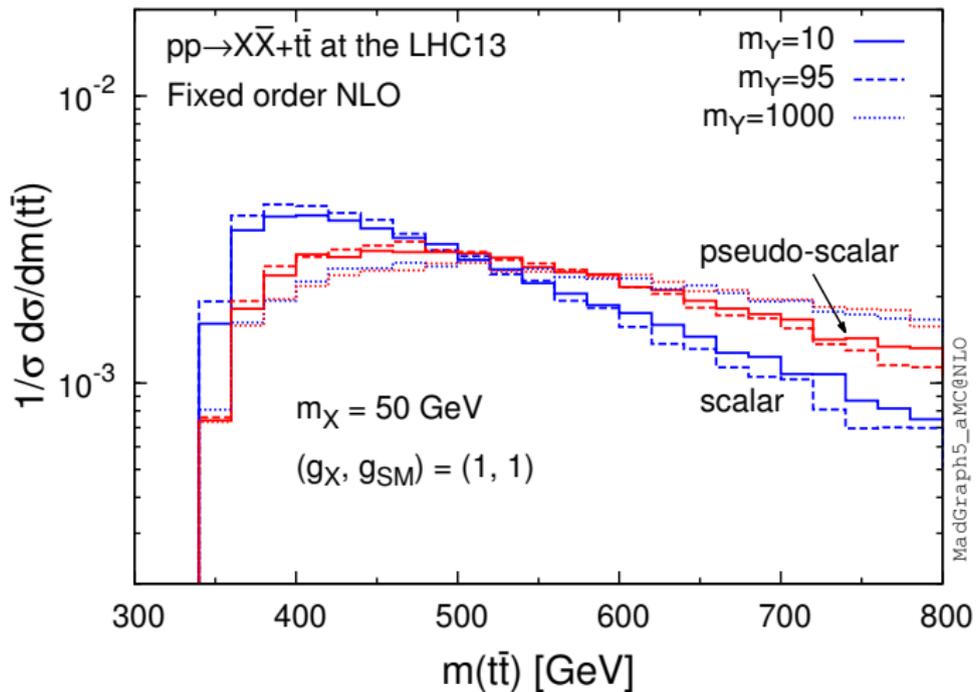
→ No significant shape distortion
 but huge reduction of the theoretical uncertainty

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→ Possibility to distinguish signal from background



→ Different shape for different coupling structure

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Summary

- Simplified models are key at the LHC
- NLO QCD effects are important
- Possibility of systematic studies in an uniform framework

Precise predictions for the Standard Model background ...
... and the Dark Matter signal are required

NLO model publicly available at:

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Back-up slides

BACK-UP

