Towards a white paper on t-channel models

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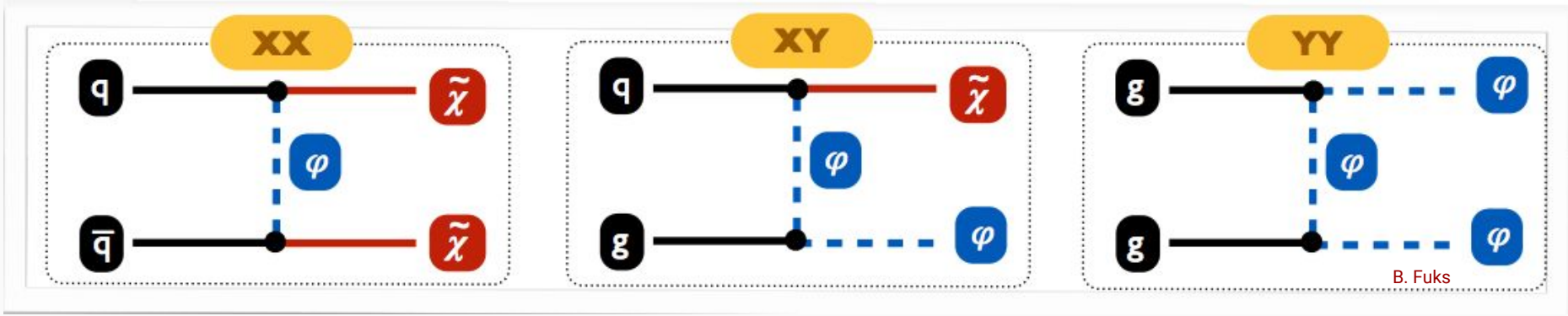
with input from Oleg Brandt

April 28, 2020

Introduction

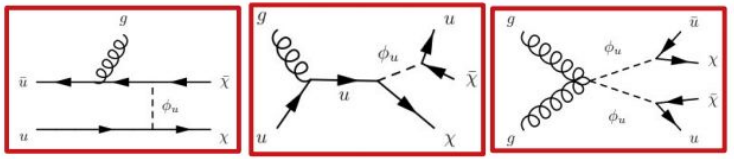


- Goal: white paper on DM t-channel models for DM@LHC.
- Earlier today:
  - Tutorial on generic t-channel UFO (collider, relic).
  - UFO overview (L. Mantani).
- This talk: discussion on specific goals and timeline for white paper results (collider-centric).
  - We think having the paper ready fast will only be beneficial: DM@LHC is the ideal place to make it public, and Run-2 monojet analyses can cite it.

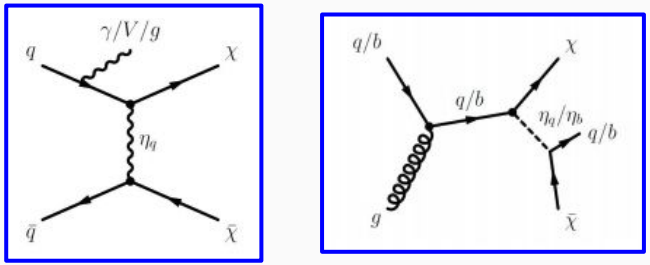
See previous agendas

Previous t-channel models

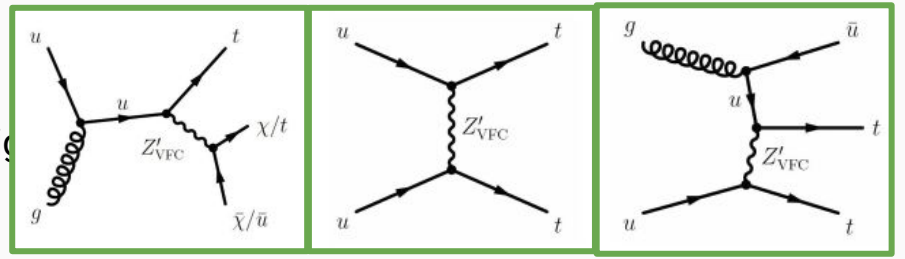
- Fermion portal DM [1]
  - CMS monojet.
  - Coincides with S3D_uR UFO restriction.



- Scalar color-charged (SCC) models [1, 2, 3, 4]
  - ATLAS monojet, b(b)+MET, t+MET.
  - Not as easily mapped onto existing restrictions, e.g. LH couplings.



- Vector flavor-changing (VFC) model [1]
  - ATLAS [1,2]/CMS mono-t, same-sig tt.
  - Z'-u-t and Z'-x-x couplings.

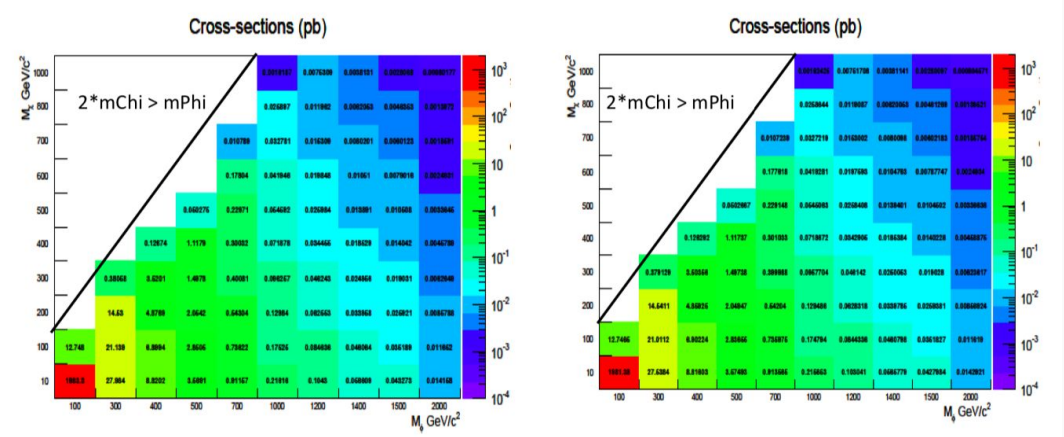


Not possible with existing UFO

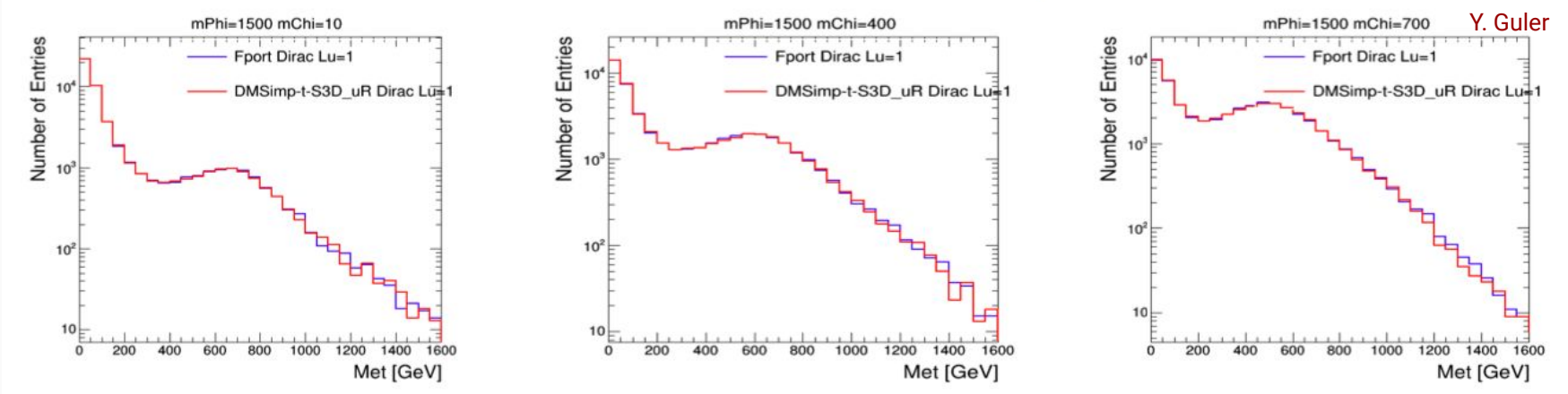
A. Albert, E. McDonald

Fermion portal == S3D_uR

- Previously: comparison of CMS fermion portal model with S3D_uR restriction (Y. Guler).
  - Identical cross sections, MET distributions.
  - LO only.



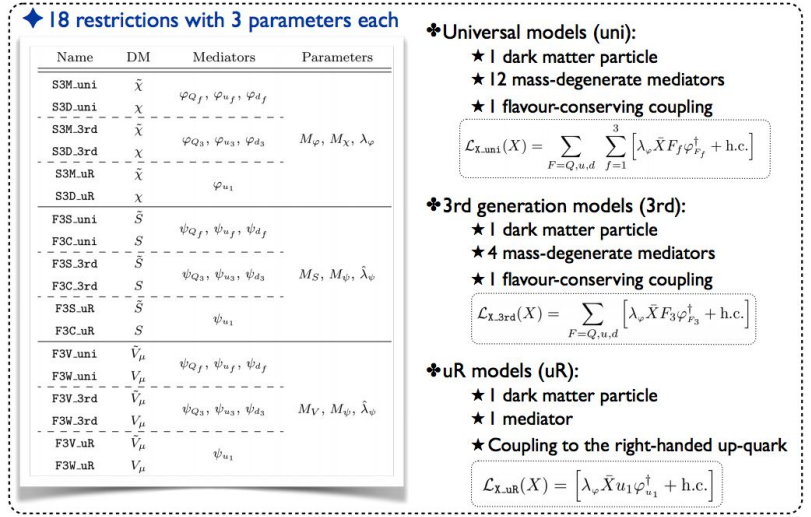
Y. Guler



First thoughts on parameter scans

Towards a parameter scan proposal

- Systematically study phenomenology / signatures of different coupling choices:
  - **First generation couplings:** establish baseline S3D_uR.
    - **Needed soon!** To be used by ongoing analyses.
    - LH couplings used by ATLAS?
  - 3rd generation couplings: b+MET, t+MET signatures!
  - Universal couplings

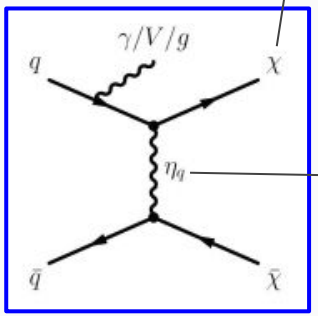


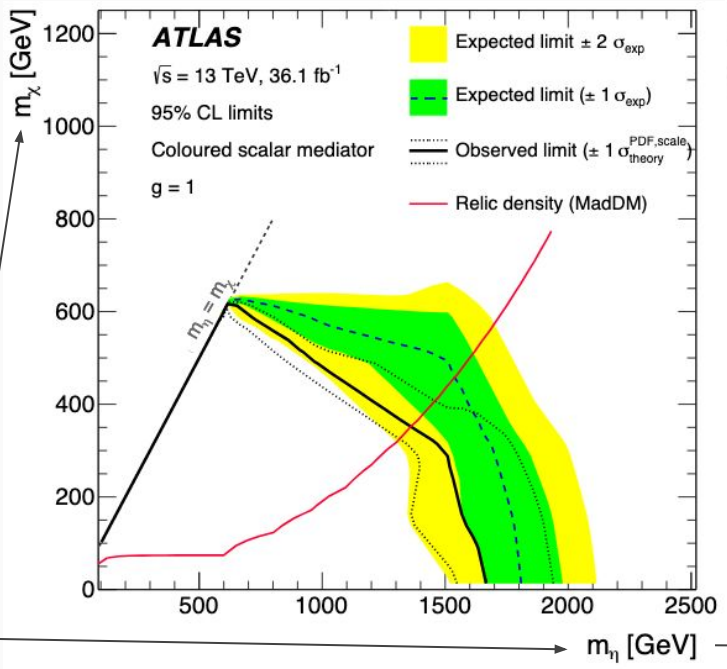
- Plan for determining parameter scan: evaluate NLO vs LO.
  - Generally, pheno & sensitivity studies computationally challenging (need to look at many points)
    - Evaluate NLO vs LO differences through differential k-factors
      - → if flat enough, LO for parameter scan definitions
- Impact of DM particles being Majorana/Dirac/scalar/vector DM options
  - More general models?

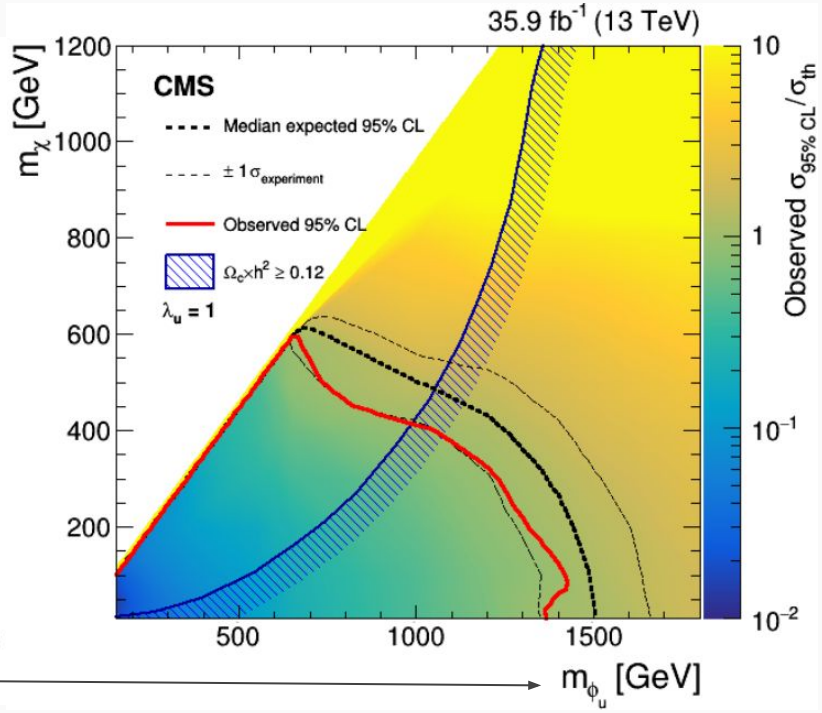
Up next: long-lived signatures, flavor

Scan: 1st generation couplings

- From previous studies (pheno/ATLAS/CMS), the signatures are driven by the kinematic parameters:



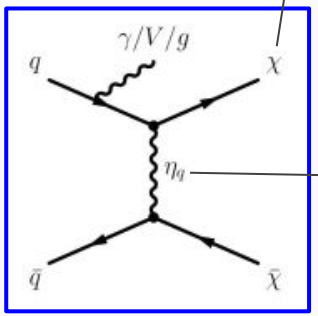


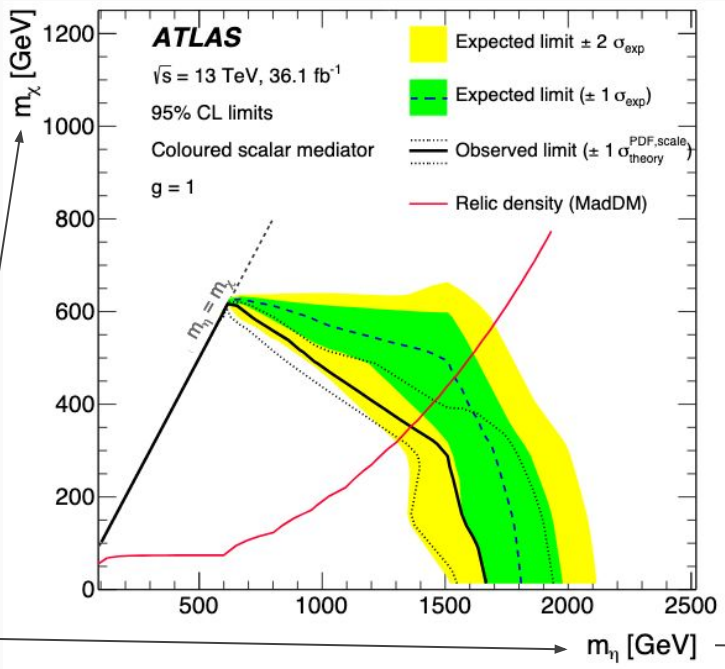


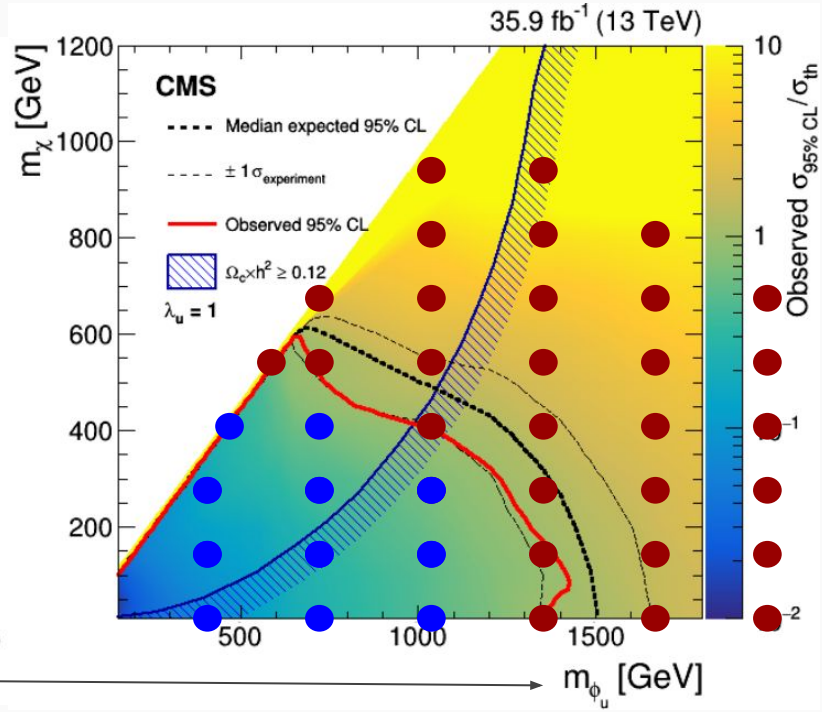
Both plots show generic features: kinematic boundary, sensitivity, balance
approximate of relevant diagrams → **scan in (mMed, mX) | mMed > mX?**

Scan: 1st generation couplings

- From previous studies (pheno/ATLAS/CMS), the signatures are driven by the kinematic parameters:



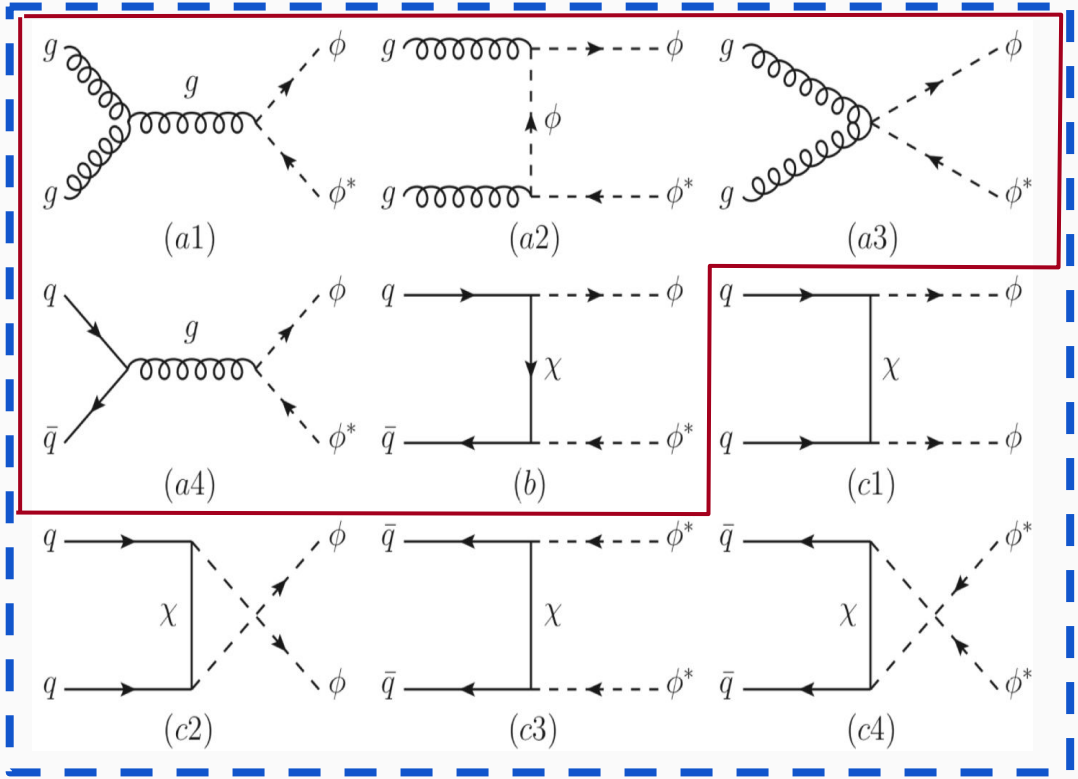




Both plots show generic features: kinematic boundary, sensitivity, balance
approximate of relevant diagrams → **scan in (mMed, mX) | mMed > mX?**

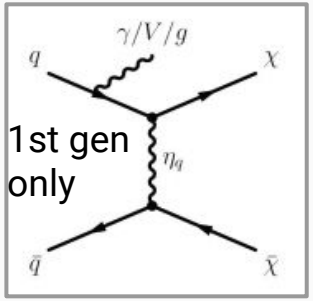
Scan: 1st generation couplings

- With the new UFO, can check impact of spin of DM particles
- Example →
  - Majorana DM has more diagrams
  - Quantify effect on which phase-space regions are relevant?
- Try out DM properties:
  - Dirac
  - Majorana
  - Scalar
  - Vector
- Easy to do for first generation RH couplings
  - DMSimp_t-S3D_uR (Dirac, tut.)
  - DMSimp_t-S3M_uR (Majorana)
  - DMSimp_t-F3C_uR
  - DMSimp_t-F3S_uR ?
  - DMSimp_t-F3V_uR
  - DMSimp_t-F3W_uR ?

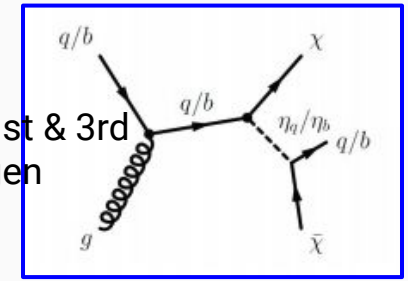


Scan: 3rd generation couplings

- **For b-quark production,** the signatures have a similar kinematic behaviour as first-generation →
  - Not surprising given they have a subset of diagrams from first-generation scenario:

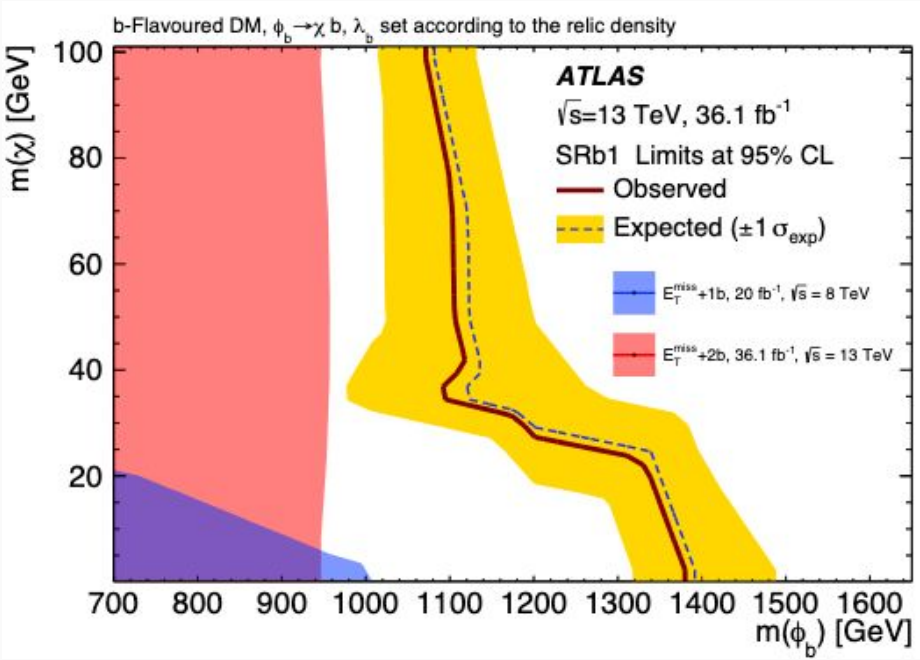


1st gen only



1st & 3rd gen

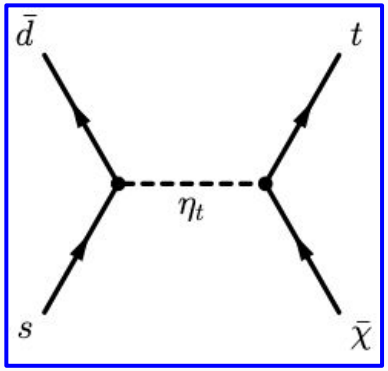
- In principle easy to implement
  - Benjamin's estimate: 30" (not 30')
- Maybe some subtle differences to 1st gen models?
  - b-quarks PDFs are small:
    - symmetry between u,d,c,s and b broken
- Don't think need additional studies about DM quantum numbers



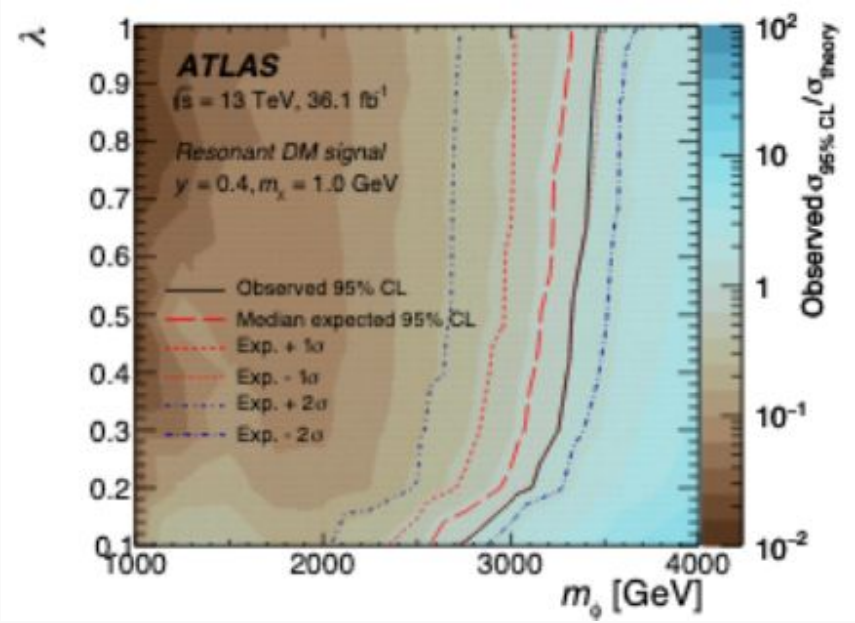
→ scan in (mMed, mX) | mMed > mX?

Scan: 3rd generation couplings

- **For t-quark production,** the signatures are qualitatively distinct from b-quark and 1st gen →



- It's not t-channel, but the mediator is coloured
  - Within the scope of this effort?
- Appropriate UFO restriction needs implementing
  - Will require implementation + testing
- Not-so-subtle differences to 1st gen models!
  - Exciting!
- Parallels to SUSY searches with RPV?
- Additional studies about DM quantum numbers?

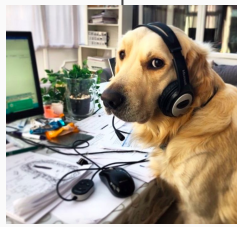


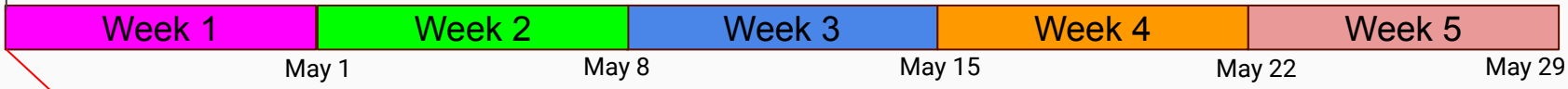
→ **scan parameters?**

Necessary steps & Possible roadmap

Today
Chat 0

2-5 June 2020
DM@LHC!!!





- What should be the scope of the paper?
- How do we want to weigh completeness vs. timeliness (full Run-2 monojet coming out soon)?

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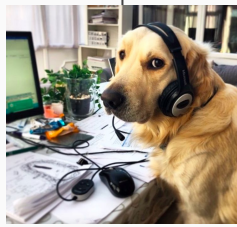

Week 1 | Week 2 | Week 3 | Week 4 | Week 5

May 1 | May 8 | May 15 | May 22 | May 29

get your Madgraph running

Necessary steps & Possible roadmap

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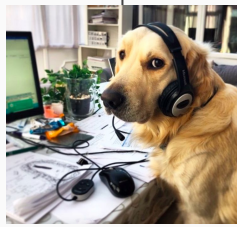

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get your Madgraph running

define quantum numbers & couplings, do sensitivity studies

make plots

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Chat 1

Who has what? What's missing?

2-5 June 2020
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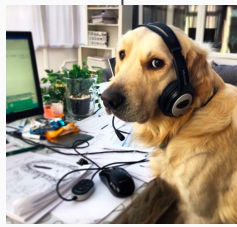

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make plots

- Stock-taking of what is there.
  - Sensitivity studies?
  - Benchmark points
  - Which plots are ready?
- What are the holes that need to be filled?

Necessary steps & Possible roadmap

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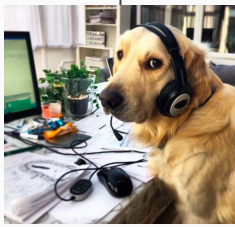
Who has what? What's missing?

2-5 June 2020
DM@LHC!!!



Week 1 | Week 2 | Week 3 | Week 4 | Week 5

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get your Madgraph running

define quantum numbers & couplings, do sensitivity studies

make plots

fill in the holes

start writing paper

Necessary steps & Possible roadmap

Today
Chat 0

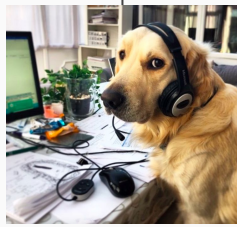
Chat 1

Who has what? What's missing?

Chat 2

First draft of paper

2-5 June 2020
DM@LHC!!!



Week 1 | Week 2 | Week 3 | Week 4 | Week 5

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get your Madgraph running

define quantum numbers & couplings, do sensitivity studies

make plots

fill in the holes

start writing paper

- First draft finished, is allowed to have placeholders and holes
- But most of the text should be there, and table of content should stand
- Sending it around for comments until end of that week

Necessary steps & Possible roadmap

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Chat 1

Who has what? What's missing?

Chat 2

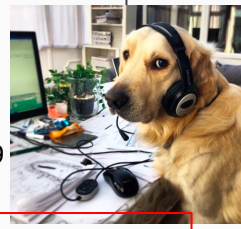
First draft of paper

Chat 3

Final paper draft

2-5 June 2020
DM@LHC!!!

Upload June 2



Week 1 | Week 2 | Week 3 | Week 4 | Week 5

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get your Madgraph running

define quantum numbers & couplings, do sensitivity studies

make plots

fill in the holes

start writing paper

circulate & review draft no. 1

implement comments

- Paper draft should be more or less final, allowing people to read through it over Pentecost
- Upload beginning of DM@LHC (Tuesday)

Necessary steps & Possible roadmap

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Chat 3

Final paper draft

2-5 June 2020
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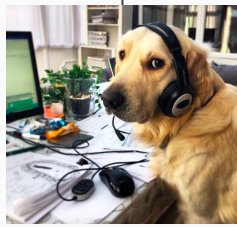

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Summary

- Can we wrap up the t-channel effort in a whitepaper in time?
- “In time”: ready for the next big conference on this topic - clearly DM@LHC
- “In time”: ready for mono-jet analyses on full Run-2 to refer to this paper and its benchmarks
- All the tools are there, first studies have been done, first scan proposals are on the table
- Requires work from everyone, but if we manage, that’s quite an achievement
- Eager to hear a discussion on it!