Theory Summary of T-channel Models

LHC DMWG Meeting – Sept 2016

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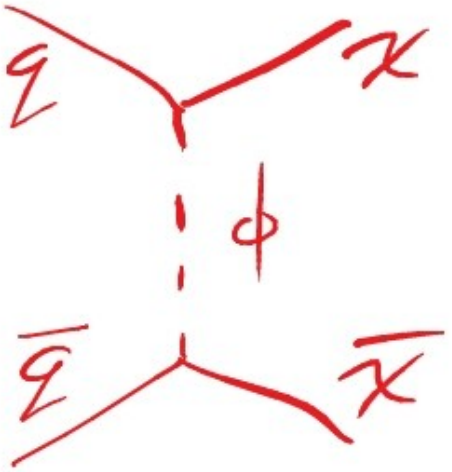
T-Channel Models

$$\mathcal{L} \sim g[SM][DM][med]$$

Gives unique t-channel DM production at LHC

$$\text{e.g.} \quad [SM] = \text{quark}, \; [DM] = \chi, \; [med] = \phi$$

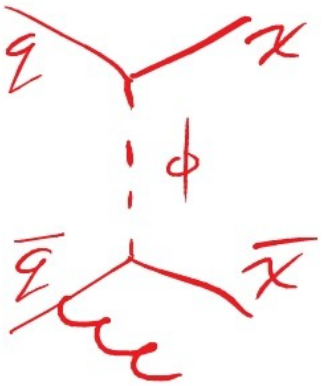


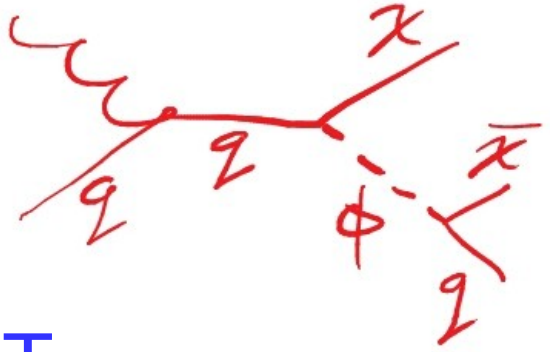
Must make this gauge invariant

Mediator must be a color triplet, at the very least

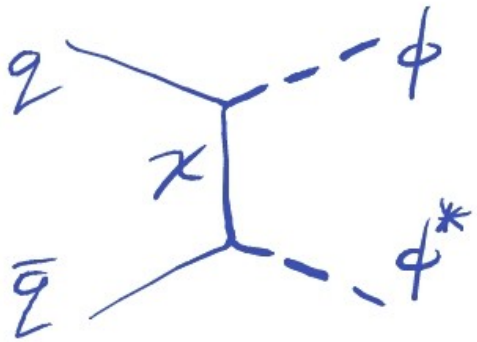
Collider Searches

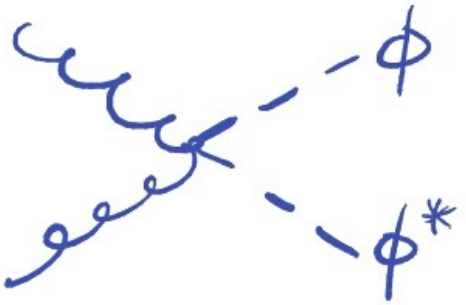
Mono-jet





Di-jets + MET





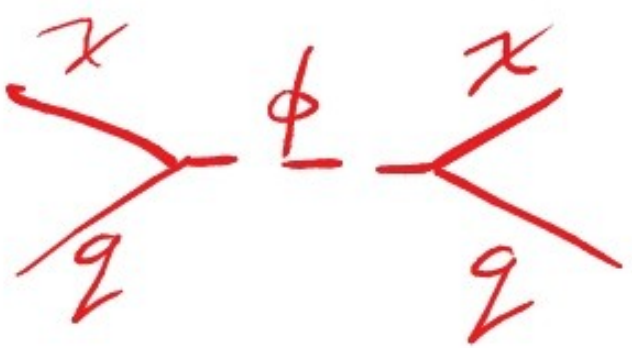
Produced entirely through QCD. Can exclude some some regions in the DM-mediator mass plane!!

Mono-W/Z

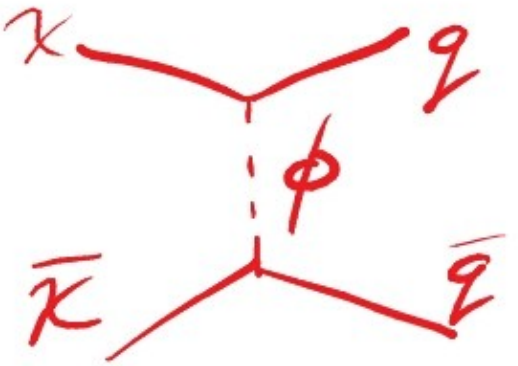
DM and/or mediator carry EW charges, non-trivial contributions to other mono-X channels

[Bell, Cai, Leane arxiv:1512.00476]

Direct Detection and Relic



S-channel
Direct Detection



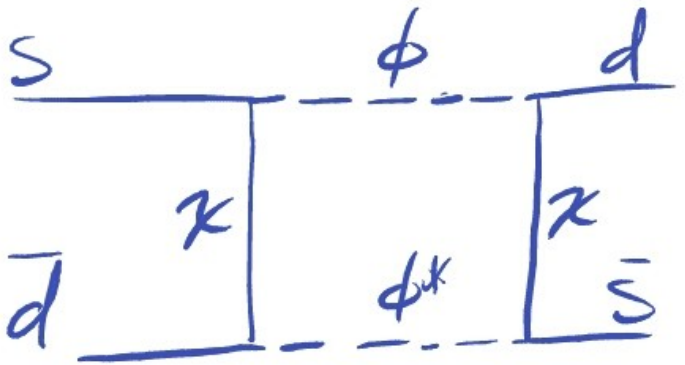
T-channel
Relic/Annihilation

Model Possibilities

Required: Mediator is colored

Options for mediator and DM:

- One boson, one fermion
- Either/both carry EW charges
- Flavor structure → MFV!



K-$\bar{K}$ oscillation

Models: Colored Scalars

- Squark-like: [Chang et.al. 1307.8120, An et.al. 1308.0592, Bai et.al. 1308.0612, Ko et.al. 1605.07058]

  mediator transforms exactly as corresponding quark as well as their flavor structure:

$$\tilde{u} : (3,1)_{2/3} \quad \tilde{d} : (3,1)_{-1/3} \quad \tilde{q} : (3,2)_{1/6}$$

$$g_{ij}\tilde{u}_i^*\bar{\chi}P_R u_j \qquad g_{ij}\tilde{d}_i^*\bar{\chi}P_R d_j \qquad g_{ij}\tilde{q}_i^*\bar{\chi}P_L q_j \qquad (+h.c)$$

- Flavored DM: [Agrawal,Blanchet,Chacko,Kilic arXiv:1109.3516]

  move flavor indices to DM field instead

$$\text{e.g.} \quad g_{ij}\tilde{u}^*\bar{\chi}_i P_R u_j$$

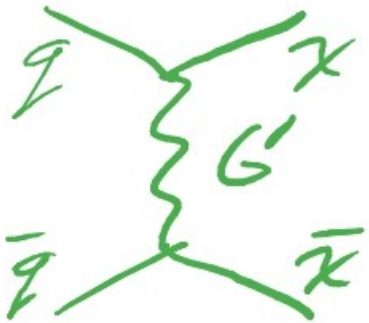
Models: Colored Vectors

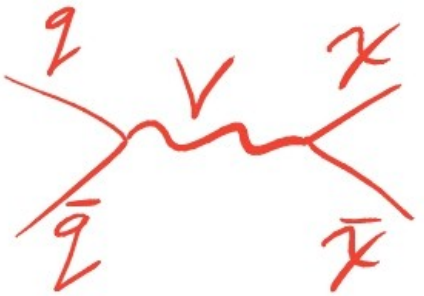
$$\mathcal{L} \sim g_{ij} G'^{\mu} \bar{\chi}_i \gamma_\mu q_j$$

UV completion: embed SM into a larger gauge group which breaks spontaneously

$$\mathbb{G} \to SU(3)_C \times \mathbb{H}$$

- Breaking generates:
  - Massive colored vectors: $\sim G'^{\mu} \bar{\chi}_i \gamma_\mu q_j$
  - Massive uncolored vectors: $\sim V^{\mu} \bar{q}_i \gamma_\mu q_j, V^{\mu} \bar{\chi}_i \gamma_\mu \chi_j$





[Tait, Fornal 1511.07380, Goyal, Kumar 1609.03364]

Squark-like Mediator

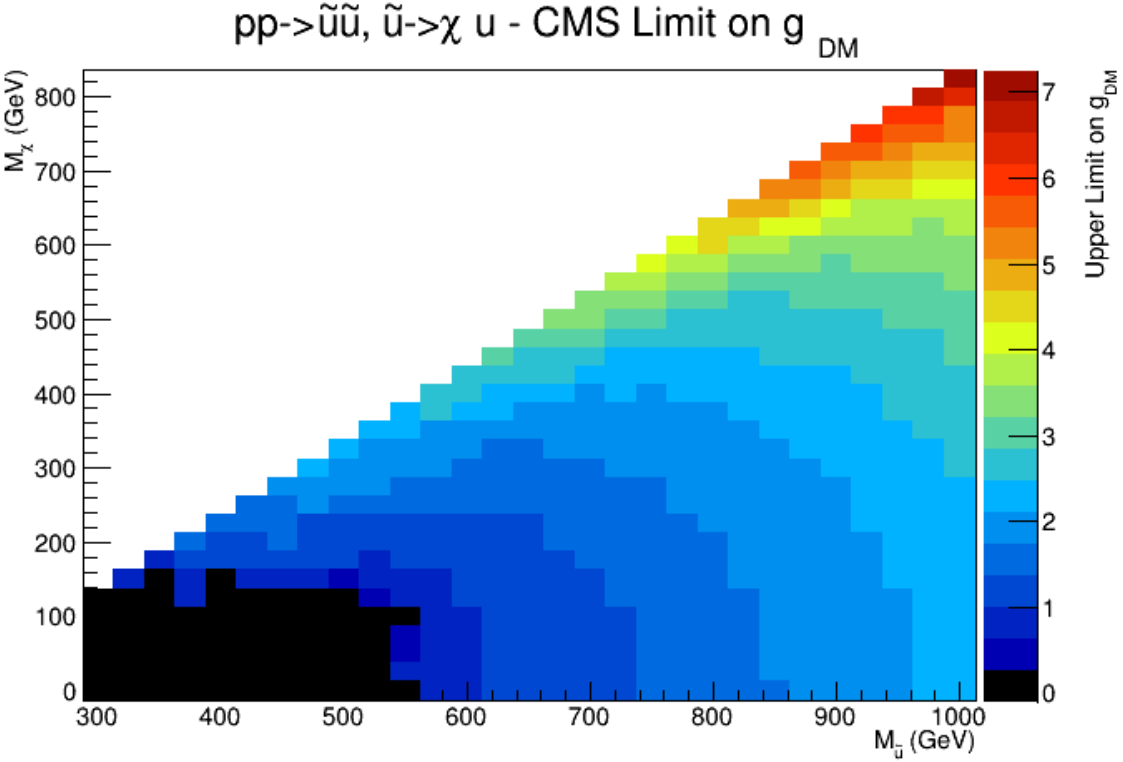
[AD, Tait, Rajaraman, Nagao arXiv:1308.2679]

- Look at right handed up-type scalar

$$g_{DM}\delta_{ij}\tilde{u}_i^*\bar{\chi}P_R u_j$$

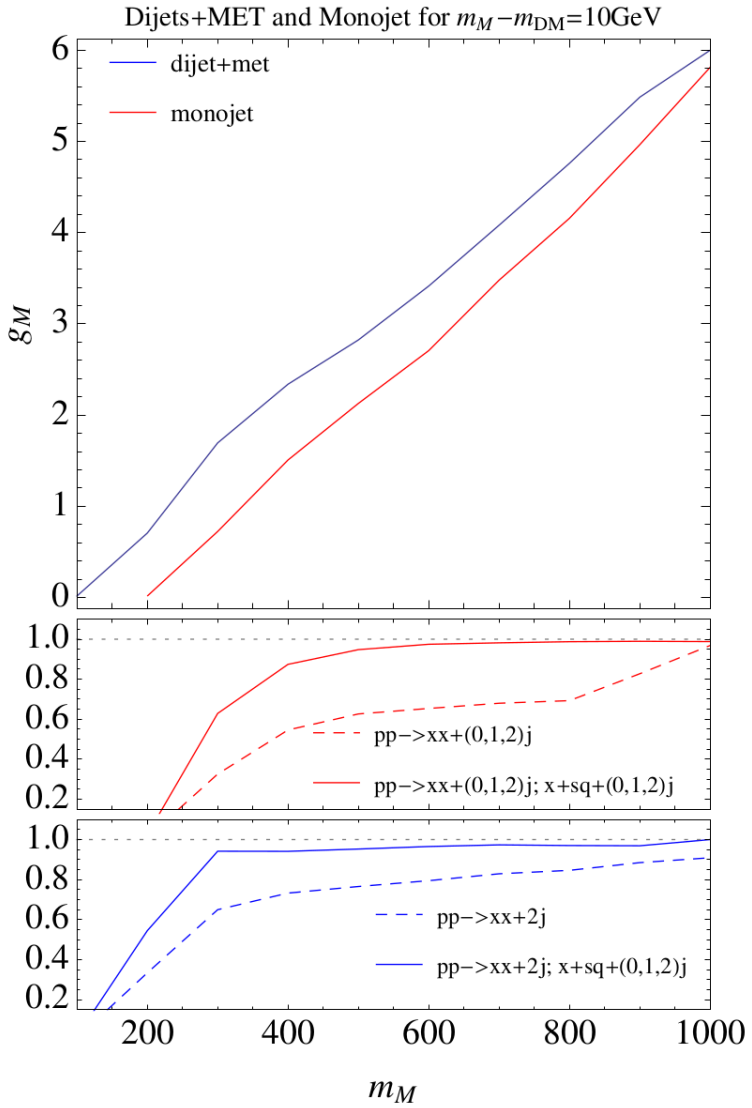
- With Dirac DM
- explore dijet+met channel

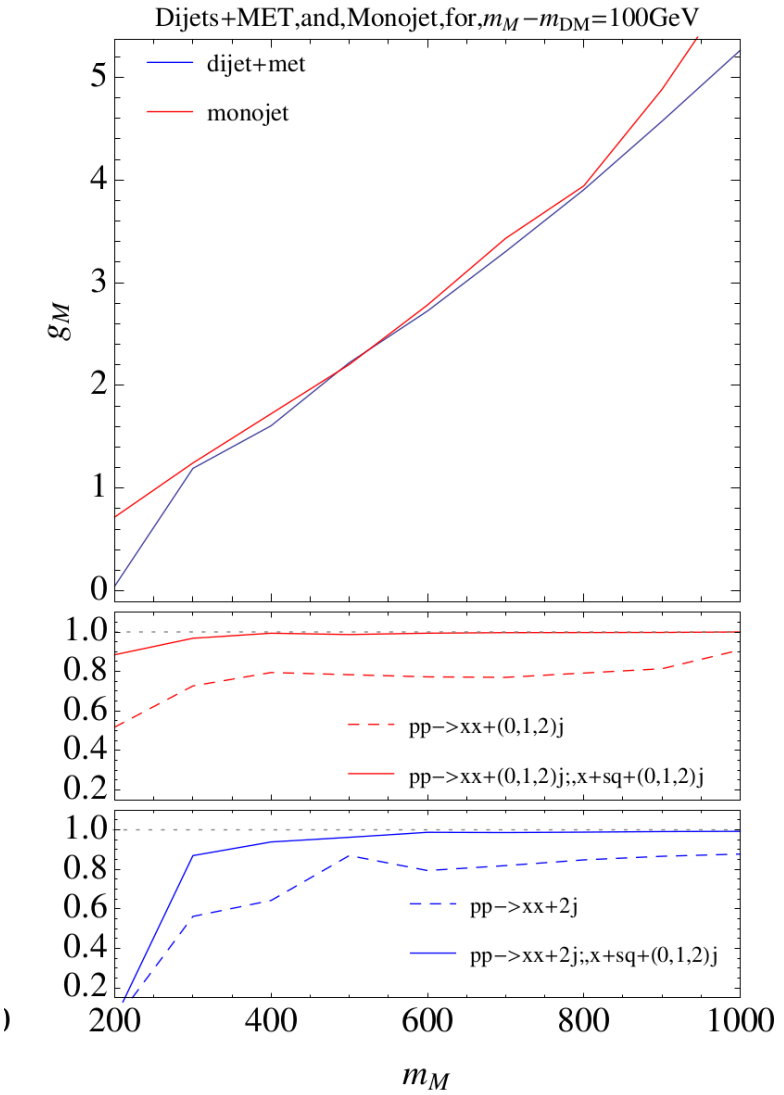
[CMS arXiv:1303.2985]



Squark-like: Dijet vs Mono-jet

[Papucci, Vichi, Zurek arXiv:1402.2285]





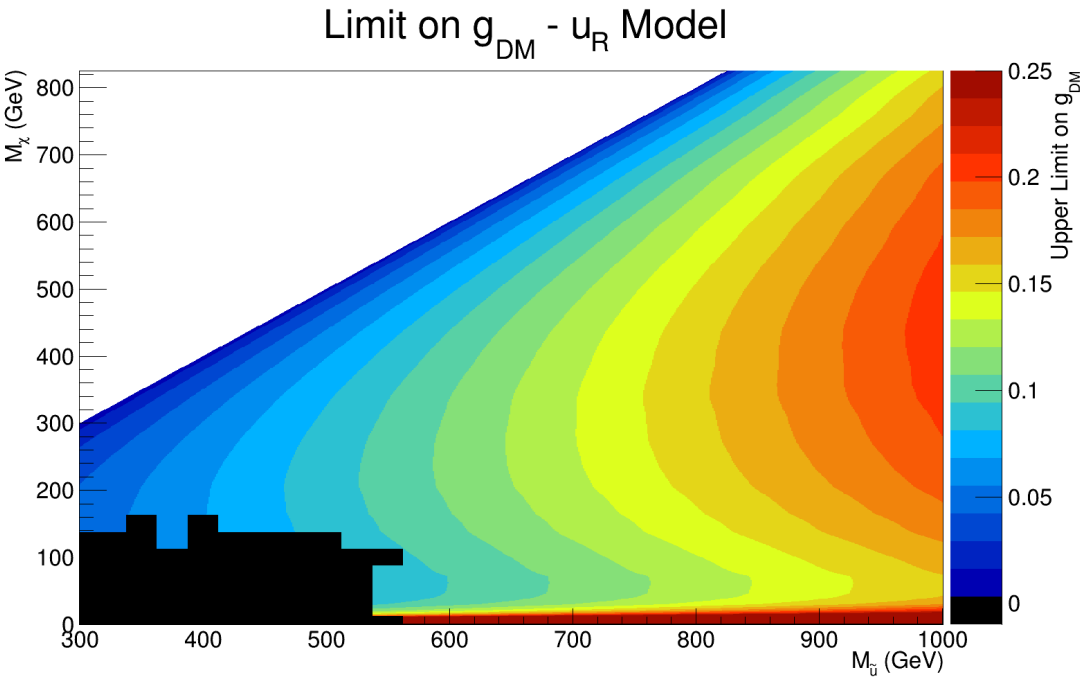
Squark: Direct Detection

$$\mathcal{M} = \frac{ig_{DM}^2}{8(M_{\tilde{u}}^2 - M_\chi^2)}[(\bar{\chi}\gamma^\mu\chi)(\bar{u}\gamma_\mu u) - (\bar{\chi}\gamma^\mu\gamma^5\chi)(\bar{u}\gamma_\mu\gamma_5 u)]$$

Spin-Independent Spin-Dependent

Spin-Independent Limits
XENON100 arXiv:1207.5988

DD is much more constraining here



Collider searches still necessary

1) Colliders not sensitive to astrophysical uncertainties like DD

2) Can reach below DD threshold

3) Many well motivated variations exist which suppress DD bounds

Squark: Majorana DM

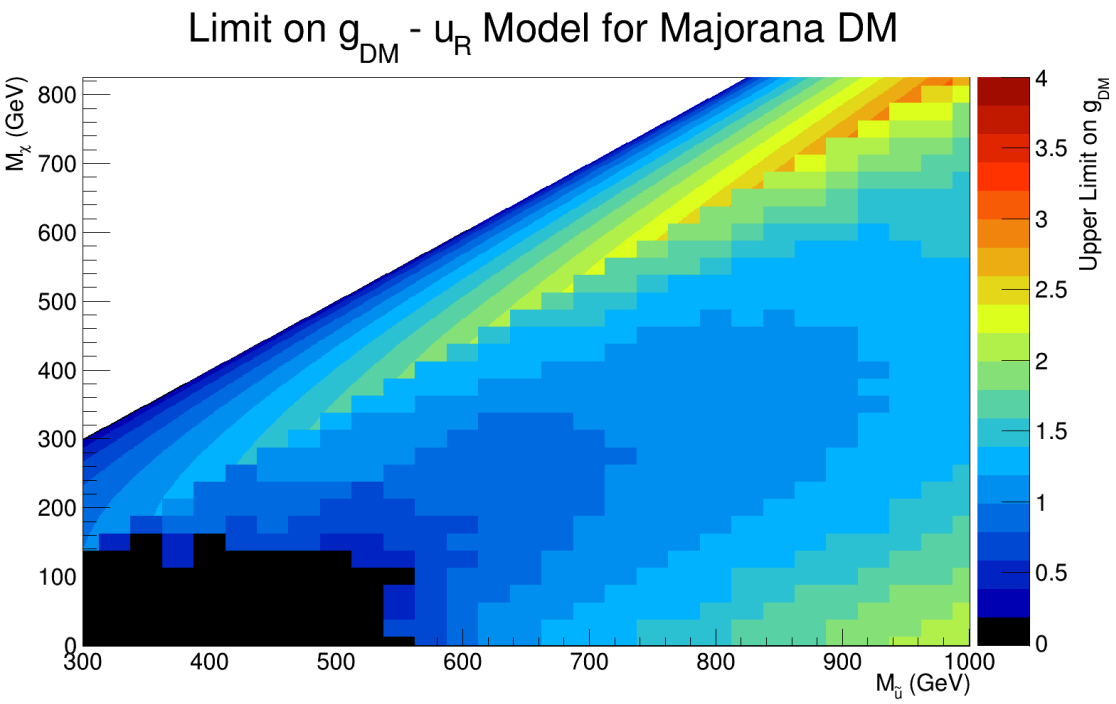
$$\mathcal{M} = \frac{ig_{DM}^2}{8(M_{\tilde{u}}^2 - M_\chi^2)}[(\bar{\chi}\gamma^\mu\chi)(\bar{u}\gamma_\mu u) - (\bar{\chi}\gamma^\mu\gamma^5\chi)(\bar{u}\gamma_\mu\gamma_5 u)]$$

Spin-Independent

Spin-Dependent

For Majorana DM, leading term vanishes. Only SD and velocity suppressed terms remain.

Spin-Dependent
XENON100, arXiv:1301.6620



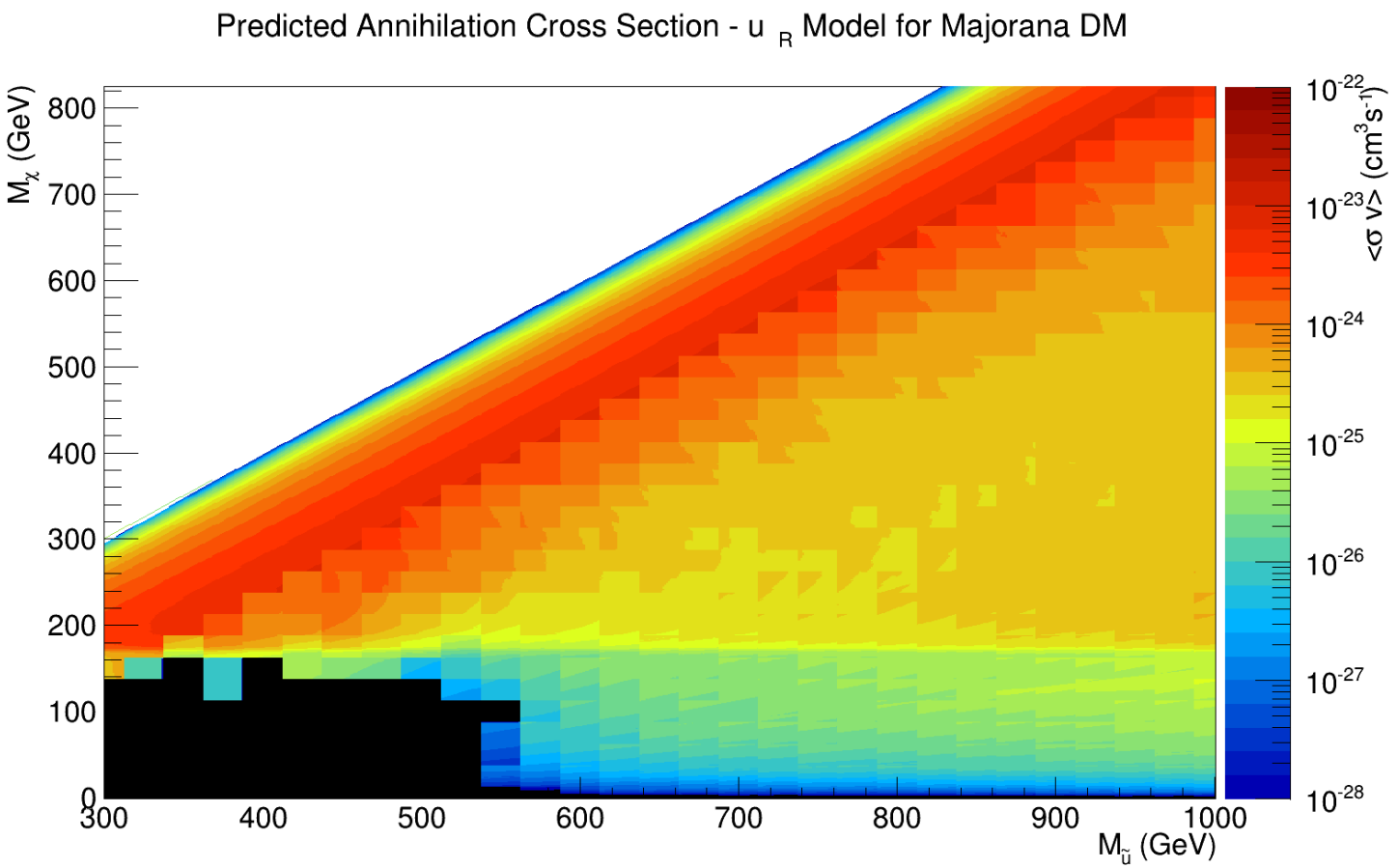
Top-philic models

- Top-flavored DM, light stops, etc
- Changes to Phenomenology:
  - DD is loop-level
  - No available tree-level mono-jet signature, only ttbar+met final state

Conclusions

- T-channel models are well motivated and distinct from other DM models
- This simplified model not only provides valid predictions for DM production at the LHC, it also predicts new phenomena to search for
- There's still rich phenomena to explore, especially in regards to flavor physics

Backup


Predicted Annihilation Cross Section - u R Model for Majorana DM
M$_\chi$ (GeV)
0
100
200
300
400
500
600
700
800
300
400
500
600
700
800
900
1000
M$_{\tilde{u}}$ (GeV)
10^{-22}
10^{-23}
10^{-24}
10^{-25}
10^{-26}
10^{-27}
10^{-28}
<σ v> (cm^{3}s^{-1})