Dark Matter via t-Channel Production: Leptophilic Models

Michael J. Baker

LHC DM WG t-channel Kickoff Meeting
20 February 2023

Outline

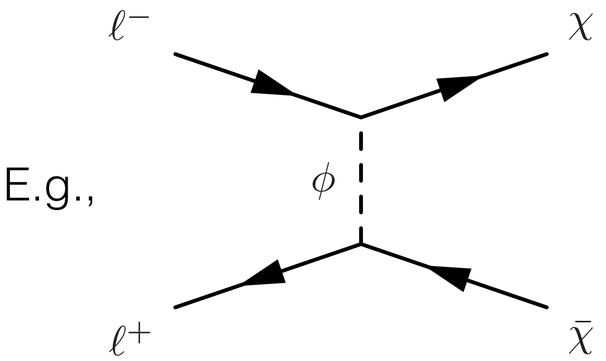
- Classification
- Phenomenology
- Scope of Contribution

Leptophilic Models: Classification

Leptophilic t-channel models:

DM **only** couples to SM leptons via a t-channel diagram

E.g.,



RH Model Parameters:

- m_χ
- $\Delta = (m_\phi - m_\chi)/m_\chi$
- y_R^i

- DM can couple to RH and/or LH e, μ and/or τ
- DM is gauge singlet $\Longrightarrow$ charged mediator
- Fermionic DM $\Longrightarrow$ bosonic mediator and vice versa
- DM could be a real or complex scalar, a Majorana or Dirac fermion or a real or complex vector
- The mediator must be complex/Dirac

$$\mathcal{L} \supset y_R^{ij}\phi^j\overline{\chi}\ell_R^i + y_L^{ik}\varphi^k\overline{\chi}L_L^i + h.c.$$

Field	$(su(3)_C, su(2)_L, u(1)_Y)$	Spin
ℓ_R	$(1, 1, -1)$	$1/2$
L_L	$(1, 2, -1/2)$	$1/2$
χ	$(1, 1, 0)$	$0, 1/2, 1$
ϕ	$(1, 1, 1)$	$1/2, \{0, 1\}, 1/2$
φ	$(1, 2, 1/2)$	$1/2, \{0, 1\}, 1/2$

Leptophilic Models: Phenomenology

Phenomenology depends on

Mass Regime

- Decoupled: $0.3 \lesssim \Delta$
- Coannihilation: $0.02 \lesssim \Delta \lesssim 0.3$
- Quasi-degenerate: $\Delta \lesssim 0.02$

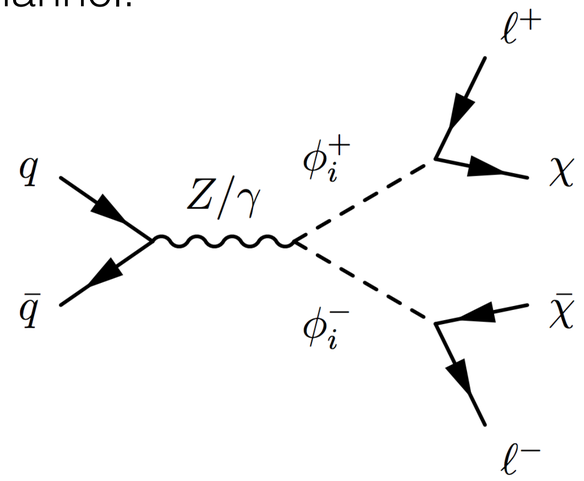
DM Production Mechanism (3 → 2 parameters)

- Freeze-out
- Freeze-in
- Other
- Undefined (3 parameters)

DM Particle Identity

- Real scalar and Majorana fermion has velocity suppressed freeze-out, direct detection and indirect detection processes
- Not directly relevant at LHC, but important when comparing with other searches or using production as constraint

Main LHC channel:



Two (SF) OS leptons + MET

(Also one lepton + MET in LH models from $W^\pm \to \phi^0 \phi^\pm$)

Mass Regimes:

- Decoupled: $\Longrightarrow$ hard leptons
- Coannihilation: $\Longrightarrow$ soft leptons (ISR boost?)
- Quasi-degenerate and small couplings: $\Longrightarrow$ long-lived mediator

Leptophilic Models: Scope of Contribution

- Brief model classification
- Brief summary of mass regimes and DM production mechanisms
- Collection of existing limits and (up-to) HL-LHC projections
- Brief comparison with other experimental approaches (direct and indirect detection)

Thank you!