Dark Matter Reinterpretation using Razor Variables and Simplified Models

Lingxin Meng

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What is Dark Matter

- Evidence: astrophysics
  - Rotating speed of galaxy spirals
  - Thickness of galaxy discs
  - Anisotropies in CMB
  - Gravitational lensing of Bullet Cluster
- Criteria
  - Lifetime
  - No electromagnetic interaction
  - Relic mass density
- Candidates
  - Primordial black holes
  - Axions
  - Sterile neutrinos
  - **WIMPs**

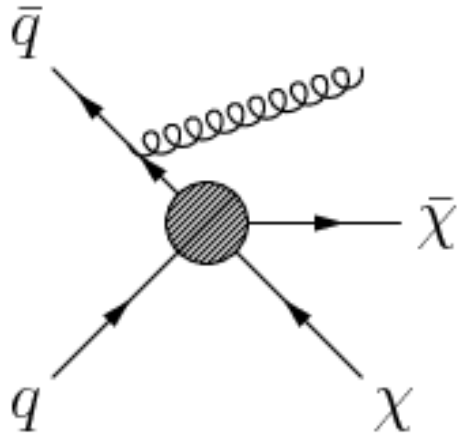
WIMPs

- Weakly Interacting Massive Particles (10 GeV – 10 TeV)
- Produced in the early Universe's "freeze-out"
- Relic density with self-annihilation cross-section $\widehat{=}$ weak scale
- MSSM prediction: weakly interacting particle with 100 GeV
  $\rightarrow$ "WIMP miracle"

Why LHC?

DM detection:

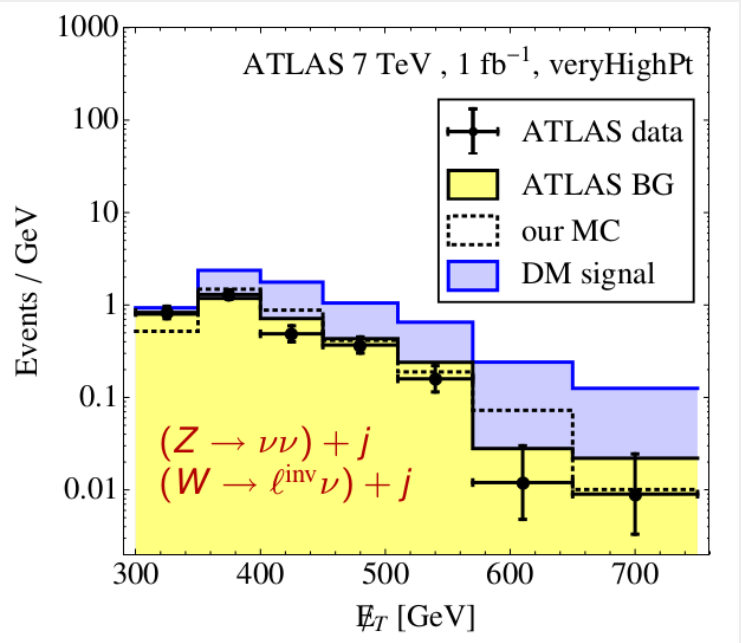
- Direct Search: nuclear recoil spectrum
  - Low recoil energy
  - Backgrounds
  - Local DM density
- Indirect Search: annihilation & decay products
  - CR background
  - DM halo density variation
- **Collider**
  - Independent from astrophysical assumptions
  - Complementary to direct and indirect searches
  - If couple to g or q, DM could be produced
  - Signature: missing transverse energy



Object and Constraints

Missing Energy

- ATLAS: nearly 4π
- No SM charge $\rightarrow$ escape
- Jet reconstruction
- $\not{E}_T = E_{tot} - E_{rec}$



Effective Field Theory vs. Simplified Models

- Momentum transfer in order of direct & indirect searches
- Contact interaction
- Momentum transfer $> M_{Med}$
- Underlying interactions

Razor Analysis

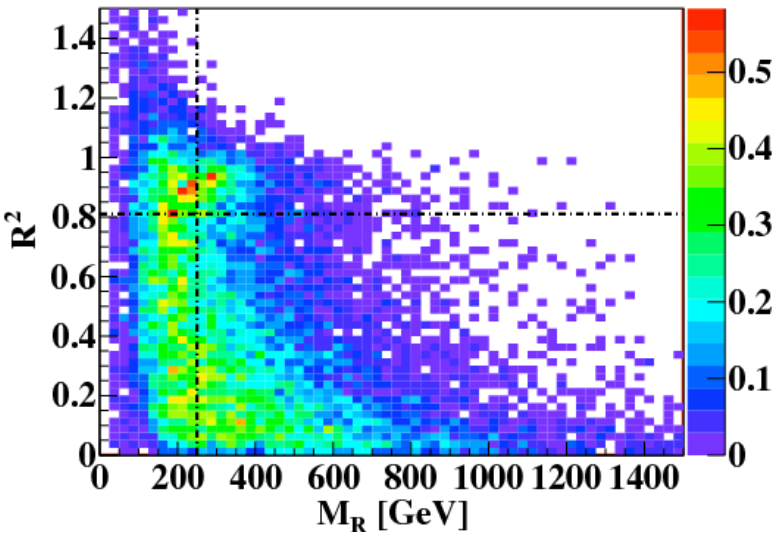
- Razor analysis on simplified models and EFT
- Discriminate heavy pair productions from SM backgrounds
- No assumption on $\not{E}_T$
- Backgrounds follow clean exponential distributions
- Two reconstructed objects in the final state
  $\rightarrow$ “megajets”, equal and opposite in the beam direction
- “Hemisphere”-algorithm
- Complementary dataset to monojet search

Razor variables:

$$M_R = \sqrt{(E_{j_1} + E_{j_2})^2 - (p_z^{j_1} + p_z^{j_2})^2}$$

$$M_R^T = \sqrt{\not{E}_T(p_T^{j_1} + p_T^{j_2}) - \vec{\not{E}}_T \cdot (\vec{p}_T^{j_1} + \vec{p}_T^{j_2})}$$

$$R = \frac{M_R^T}{M_R}$$



Event Selection

- Trigger on $\not{E}_T > 40\,\text{GeV}$
- Primary vertex and > 5 tracks
- Jets: $p_T > 60\,\text{GeV}$, $|\eta| < 3.0$
- e (μ): $p_T > 20(10)\,\text{GeV}$, $|\eta| < 2.5(2.1)$
- Include hadronically decaying τ that suffice jet definition
- Signal region: leading jet with high p_T and high $\not{E}_T$

Tools

- MadGraph 5 - event generator
- Pythia 8 - parton shower
- AToM - Automated Testing of Models
  - PGS - detector smearing
  - Rivet - analysis & histograms

Plan

- Collaboration with other summer students
- Write a monojet analysis
  - Use both EFT and simplified models for modelling of DM
  - Compare the limits
- Check the impact of the Razor analysis on signal selection