1 The model

An excess is seen in the ATLAS monojet analysis [1, 2] around leading jet p_T of 300-400 GeV. This excess is seen in the signal region (SR) but also to a lesser extent in the control region (CR). While this is suggestive of systematic issues with respect to the background, this could also arise from new physics which populates both signal and control regions. For example, the processes shown in Fig. 1. Where we have the following particle content:

- ϕ: color-triplet scalar
- $\chi^{0,\pm}$: electrically charged and neutral fermions which share the same mass
- inv: invisible scalar

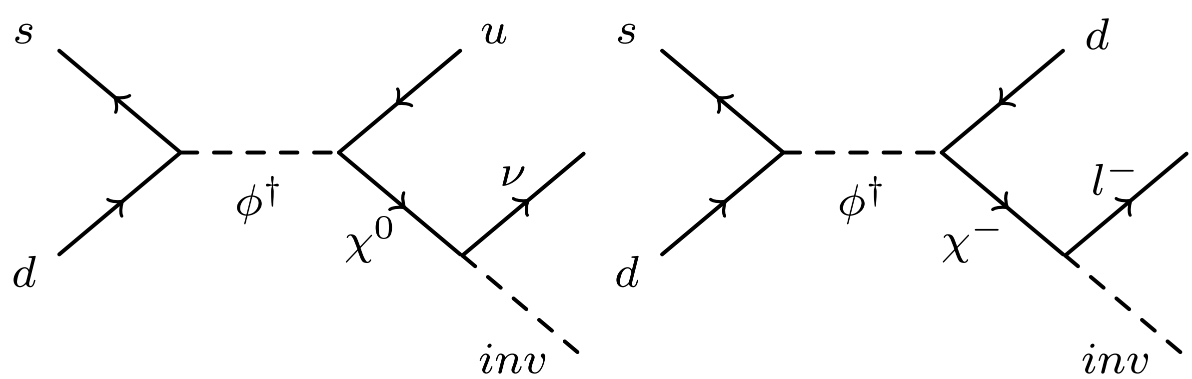

Figure 1: Diagrams for our signal model. The left (right) diagram will attempt to explain the excess in the SR (CR). The colored scalar ϕ is produced resonantly, decays to a jet and either a neutral fermion (χ^0) or a charged fermion (χ^+). The neutral state decays into an invisible scalar and a neutrino, thus it is entirely invisible. The charged state decays into the invisible scalar and a charged lepton.

The colored scalar ϕ is resonantly produced via an RPV-like vertex. It decays to a jet and either χ^0 or $\chi^\pm$ with a 50/50 branching ratio. Finally, χ^0 decays to a neutrino and the invisible scalar, while $\chi^\pm$ decays to a charged lepton and the invisible state. The former process contributes to the SR while the latter contributes to the CR.

2 Explaining the Excess

As a proof-of-principle, we focus on the single muon control region, where the excess is more pronounced compared to the other control regions, by assuming the charged lepton in the decay of the $\chi^\pm$ is a muon. In this case, the number of excess events in the single muon CR is about 25% of that in the SR. See Table 1 for a summary of these events.

	Observed	Background	Excess
SR	99001	93674	5327
CR 1μ	42511	41144	1367
CR $1e$	26590	25966	624

Table 1: The observed, post-fit background, and difference in events in the SR and two CRs with $300 < p_T(j^1) < 400$ GeV.

This CR is intended to be rich in the $W(\mu\nu) + jets$ background, by requiring events to fall in a $30 < M_T < 100$ GeV window and by requiring a single muon. Thus this proposed signal must "fake" a W sufficiently often to simultaneously explain all of the excess events in the SR and CR. Since the M_T variable assumes that both daughters are massless, such as is the case for the W, the M_T distributions can be very broad and therefore cut out many signal events since the invisible state in our model can be quite massive. See Fig. 2, for normalized M_T distributions for the W+jets background and for various mass points in our model.

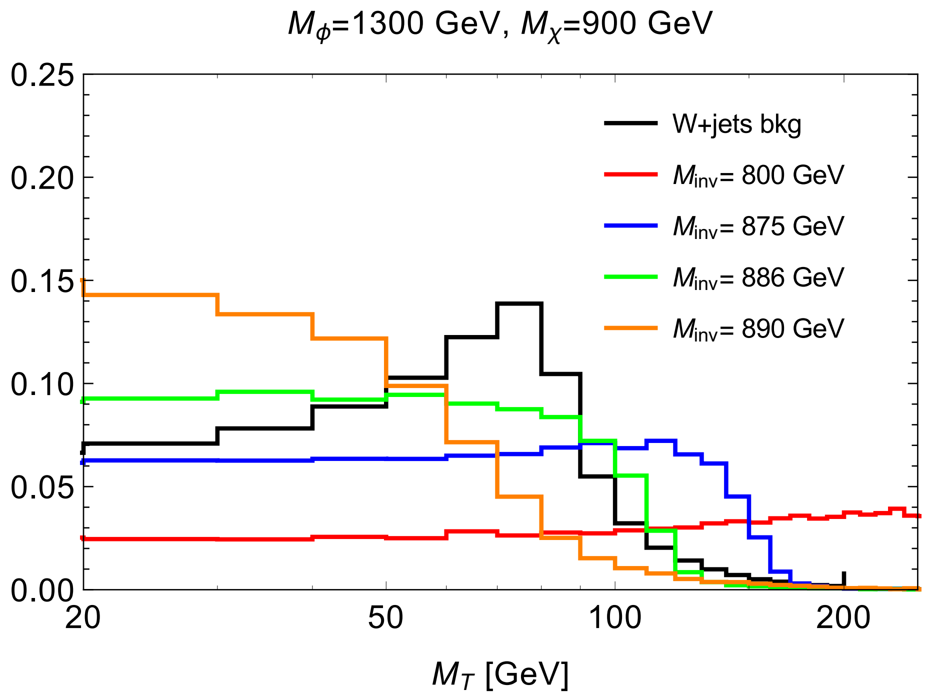

Figure 2: M_T distributions for the W+jets background and various masses for our signal model, with $M_\phi = 1300$ GeV and $M_\chi = 900$ GeV.

Here we find very broad distributions, but also notice that getting as many events into the $30 < M_T < 100$ GeV window as possible requires a mass splitting closer to 20 GeV, rather than 80 GeV as one may naively expect in order to fake a W boson. Also notice that the distribution is quite sensitive to the mass splitting. However, the major point here is that even though χ is quite heavy, it can fake a W boson sufficiently often with the correct invisible mass. In this case, the mass point $M_{inv} = 886$ GeV fits the most events into this M_T window.

A simple check that we can fit the excess better with this signal is to plot the data events minus the background and signal events. This residual should be flatter and closer to zero for a better fit. Fig. 3 shows this residual divided by the number of observed events for two different mass points in both the SR and CR. The dashed lines are the residuals without any signal injection.

The normalizations for background and signal are found by assuming a single correlated uncertainty in the background prediction and allowing their normalizations to float such that the combined signal and background provides the best fit in both the CR and SR simultaneously. More complete information on the uncertainties in the leading jet p_T spectra would be required for a more rigorous fit.

As expected, the SR residual is not very sensitive to M_{inv}, but in all cases remove many of the excess events. However, we see the residuals in the CR do depend on M_{inv} as this mass controls the efficiency for events to enter the M_T window. In the CR, we see that the mass point which is better optimized at passing the M_T cut ($M_{inv} = 886$ GeV) explains more of the excess events in the CR, compared to no signal injection and compared to the 800 GeV mass point.

References

[1] **ATLAS** Collaboration, M. Aaboud *et al.*, "Search for dark matter and other new phenomena in events with an energetic jet and large missing transverse momentum using the ATLAS detector," *JHEP* **01** (2018) 126, `arXiv:1711.03301 [hep-ex]`.

[2] M. G. Ratti, S. Resconi, and L. Carminati, "Searching for Dark Matter in the Mono-Jet and Mono-Photon Channels with the ATLAS Detector," 2018. http://cds.cern.ch/record/2307769. Presented 12 Feb 2018.

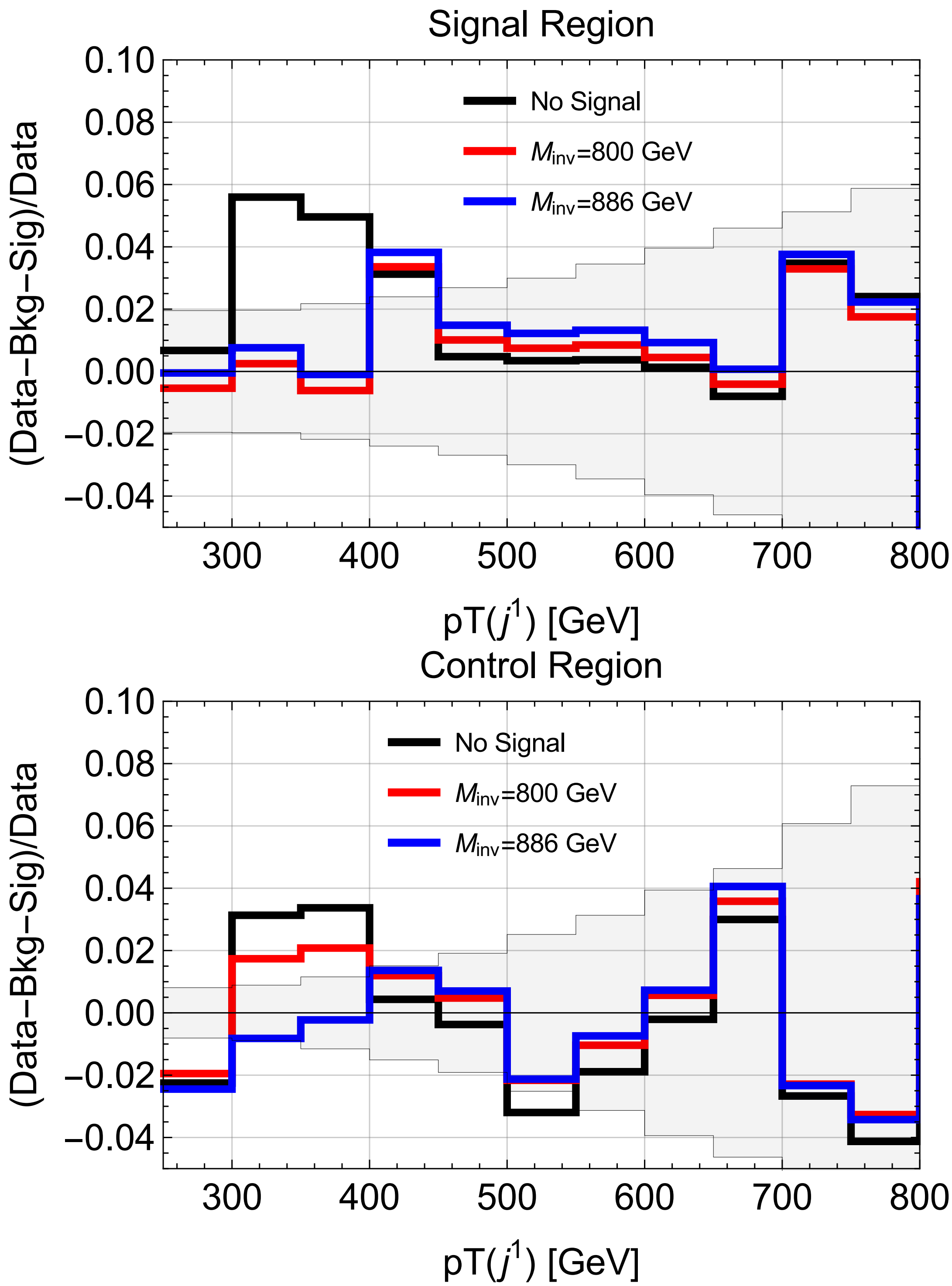

Figure 3: Relative residuals in the SR and CR in leading jet p_T for no signal injection and for two mass points. In the both cases, the other masses are taken to be $M_\phi = 1300$ GeV and $M_\chi = 900$ GeV. The gray bands here correspond to the combined post-fit systematic uncertainty and the statistical uncertainty associated with that bin.