Q&A

[1] Clarification on "Delphes" plots.

Delphes package was extensively used for various fast simulations predictions and many closure tests which compare the Delphes predictions with full simulation has shown a very good agreement between fast simulation and full simulation. See, for example, Fig.3 of http://arxiv.org/pdf/1307.6346v3.pdf for the jet energy resolutions between CMS and Delphes. The agreement is good for a feasibility study.

The FastJet algorithm used for the jet reconstruction is widely used by HEP community and shows very good performance.

As for the b-tagging efficiencies at high transverse momentum does not degrade. Please see the figure in the right taken from:
https://twiki.cern.ch/twiki/pub/CMSPublic/BoostedBTaggingPlots2014/btagperfcomp_Pt700toInf_FatJets_Subjets_StdJets_AK_Hadronic_top.png.


We didn’t study the background, since the goal of the paper is to propose E(b)/E(top) as an observable. We assume each experiment estimates the shape from all SM background sources and subtract them from “data”. An “excess” part is taken to be “signal” and we evaluate L-, R- or mixed cases. Further, we are using cross-sections ~ 30 fb for the monotop final state. After we introduce the m(3j) < 250 GeV cut on the background (to select the top), as given in Ref. 7 for 8-TeV data, it is reduced to 1 fb. The background at 14 TeV after the m(3j) < 250 GeV cut is about 4 fb (which can be perceived from the scaling of background cross-section). This is smaller than our signal as this cut only affects the signal monotop rate by a O(1) efficiency.

We would also like to comment on Ref.7 (PRL 114, 101801 for CMS; arXiv:1412.3629 for ATLAS):

(i) CMS paper: the difference between the model in CMS paper and our model is that CMS is testing non-resonant mono-top signal associated with vector DM, while we study mono-top events from a heavy mediator. Fig. 2 in the CMS paper is the 3-jet mass distribution for SM background and a vector DM signal (700 GeV) with no mediator. Fig. 2 shows the 3-jet mass *before* the top mass cut (< 250 GeV). We clearly see an excess over the SM background (if such a signal exists) for m(3j) < 250 GeV or so. Further, we can use a pT(top) distribution as a discriminator, since the top quark is from a heavy-mediator decay. With large luminosity, we expect the search will be very valuable.
CMS Fig. 1: Non-resonant mono-top signal associated with vector DM, while we study mono-top events from a heavy mediator.

CMS Fig. 2: 3-jet mass *before* the top mass cut (<250 GeV). We clearly see an excess over the SM background (if such a signal exists) for m(3j) < 250 GeV. One can further improve the significance by requiring the cut on pT(top) distribution in top quark from a heavy mediator.

(ii) ATLAS paper: it includes a resonance model (Fig.1(a)). Fig.3(a) shows a nice excess for 500 GeV scalar mediator over background in e/mu channels, while an excess from non-resonance case is hardly seen in Fig.3(b). We note this is for e/mu channel. But we expect ATLAS/CMS should provide both hadronic and leptonic channels.
ATLAS Fig. 1 shows resonance and non-resonance models; Fig. 3(a) shows MET distribution for data and SM background in e/mu channels along with 500 GeV scalar mediator, while an excess from non-resonance case is hardly seen in Fig. 3(b).

**[3] polarization analyzer**

We use mainly the bottom-quark energy in hadronic top decay as a polarization analyzer and also consider the semi-leptonic top decay. In general, the lepton in the semi-leptonic decay is the most efficient polarization analyzer in the case of inclusive top decays and a fully reconstructed top-quark frame, while the bottom-quark has limited analyzing power. However for monotop signal, the hadronic final state is most useful since the missing energy arises in the final state from new physics.

Let’s review the analysis of the $t\bar{t}$ system. The polar angle of the charged lepton, $\theta_{\text{lepton}}$, is determined by measuring the angle between the quantization axis and the charged lepton’s momentum direction in its parent top quark’s rest frame. The full reconstruction of each $t\bar{t}$ event is required to obtain the distribution of $\cos\theta_{\text{lepton}}$, where MET is assumed to be originated by neutrino(s). However, in leptonic channel of monotop event, MET is originated from a neutrino and DM. Thus, a reconstruction of top rest frame is not possible.

In the analysis of single top polarization, the key is a reconstruction of top rest frame. In the SM event, we assumed MET is originated by a neutrino in the top leptonic decay. In the monotop event, however, MET is mostly from DM. Thus, the reconstruction of top-quark rest frame is not straightforward.
Therefore, only fully hadronic decay of the top quark in the monotop event should have an access to the information of chirality and that is why we chose $b$ quark energy in hadronic top decay as a polarization analyzer.