



Light Nonthermal Dark Matter and the Collider Monotop Chirality

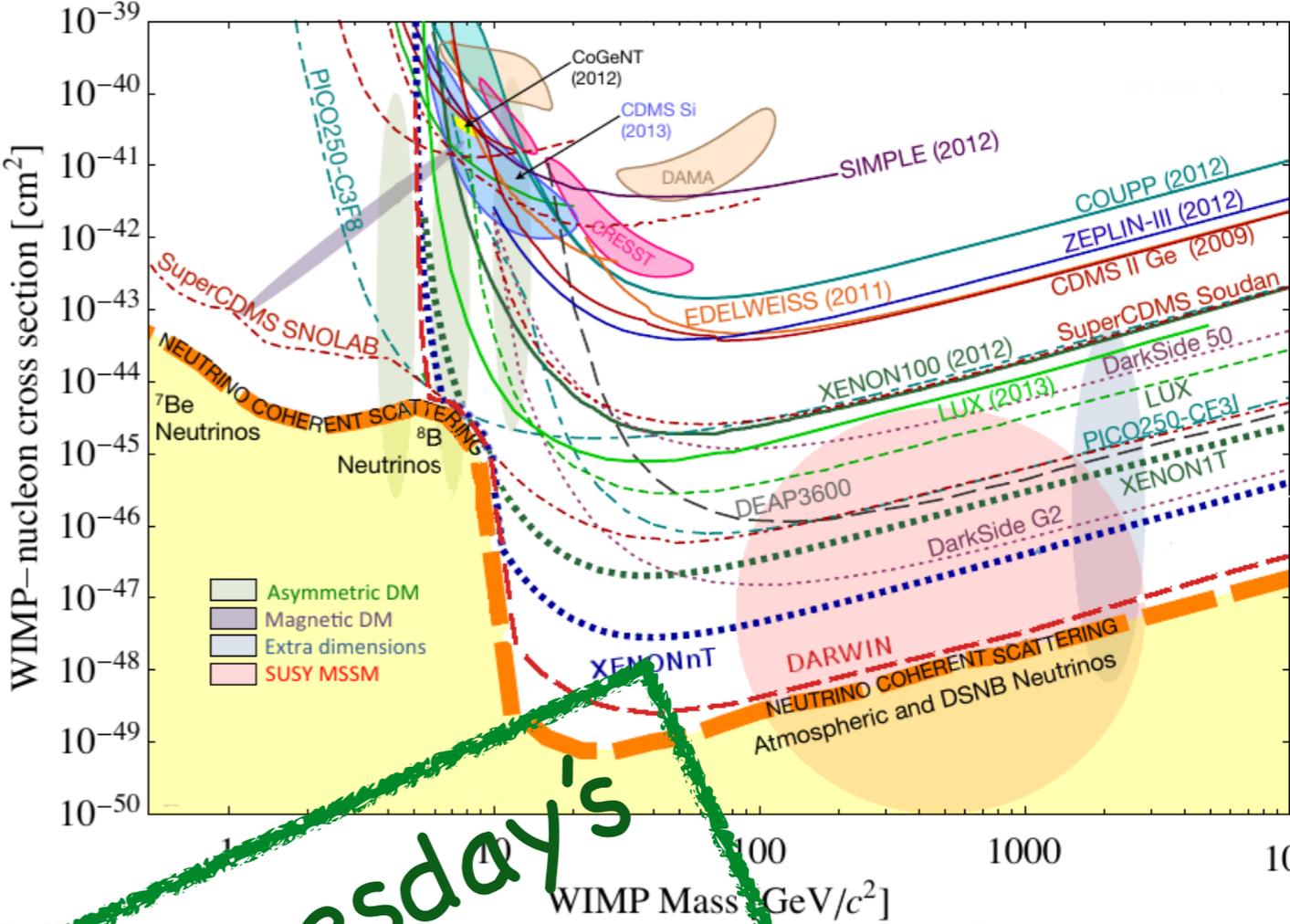
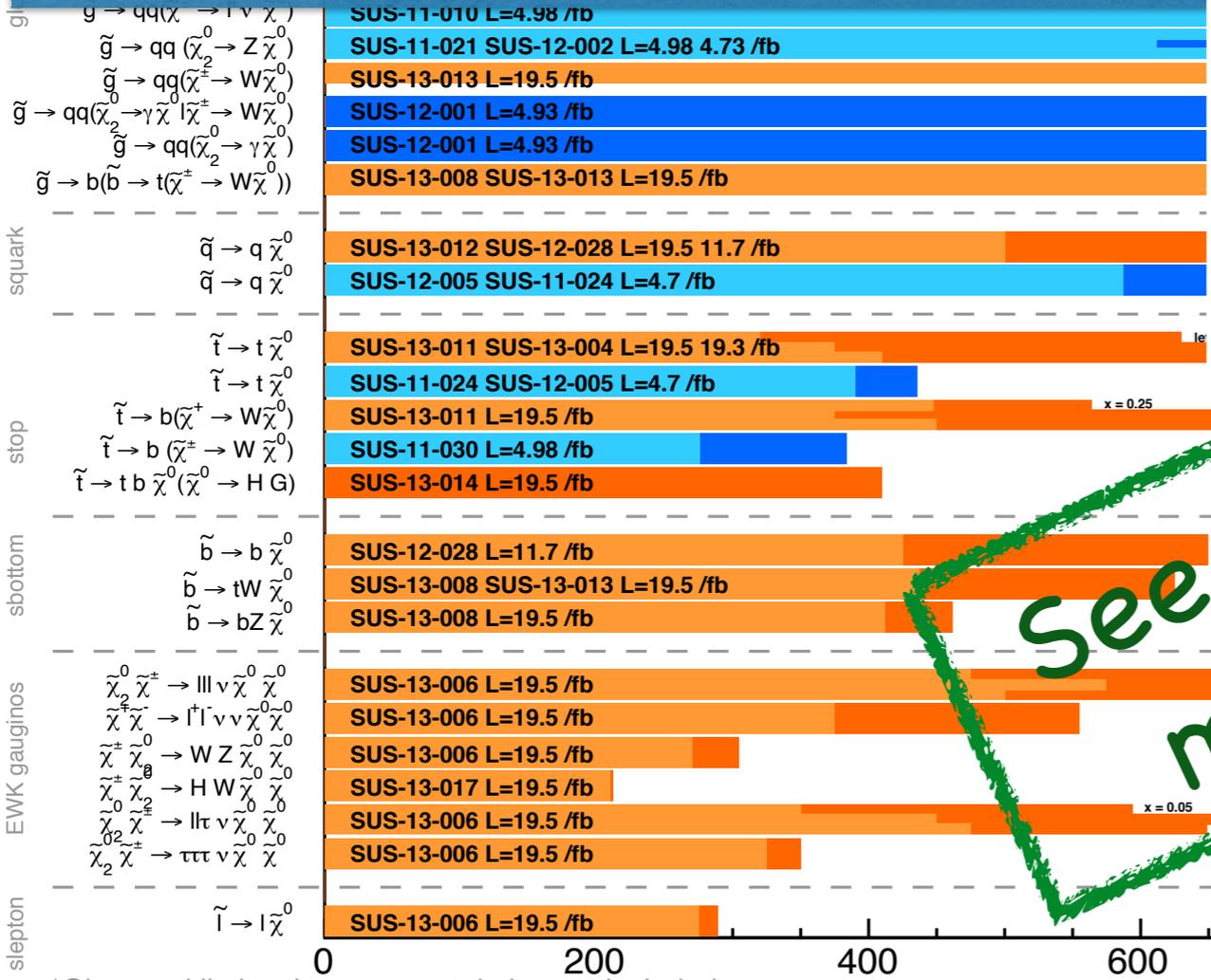
(work in progress)

Mykhailo Dalchenko



Physics motivation

- We need an explanation for baryogenesis
- Astrophysical observables push WIMPs towards the EWK scale
- However, such scenarios are heavily restricted by LHC results



See Wednesday's morning talks

CMS Preliminary

For decays with intermediate mass,
 $m_{\text{intermediate}} = x \cdot m_{\text{mother}} - (1-x) \cdot m_{\text{LSP}}$

*Observed limits, theory uncertainties not included
 Only a selection of available mass limits
 Probe *up to* the quoted mass limit

Nonthermal scenario

Add a minimal extension to the SM:

- scalar color triplet(s)
- a fermionic DM candidate

R. Allahverdi and B. Dutta, PRD 88 (2013) 023525
 B. Dutta, Y. Gao, and T. Kamon, PRD 89 (2014) 096009

$$\mathcal{L}_{int} = \lambda_1^{\alpha, \rho\delta} \epsilon^{ijk} X_{\alpha, i} \bar{d}_{\rho, j}^c \mathbf{P}_R d_{\delta, k} + \lambda_2^{\alpha, \rho} X_{\alpha}^* \bar{n}_{DM} \mathbf{P}_R u_{\rho} + C.C.$$

- At least two scalar X are needed for the successful baryogenesis
- X couples to two d -quarks or u -quark and DM
- DM isn't protected by parity $\rightarrow |m_{DM} - m_p| < m_e$

New interaction terms and production mechanism are implemented in **MadGraph 5**

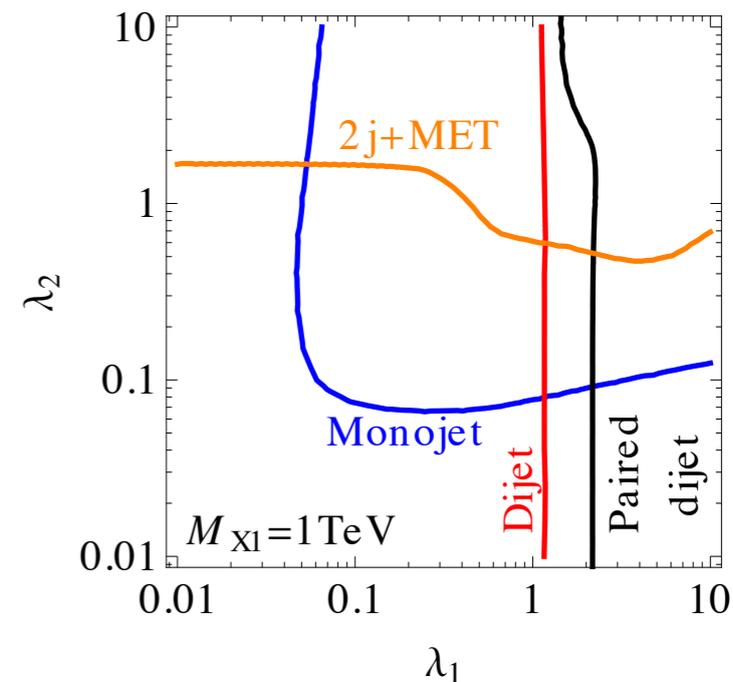
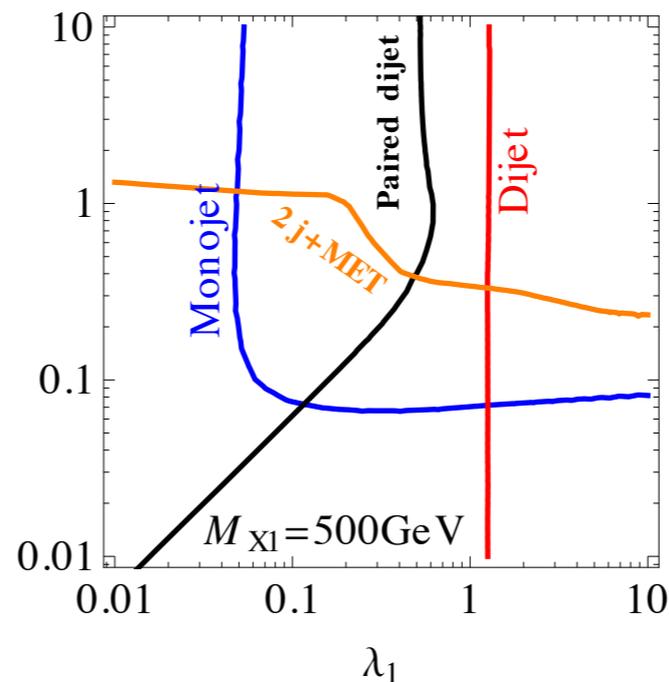
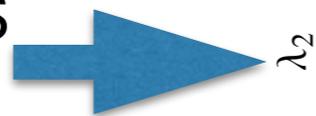
$$\mathcal{L}_{int} = \lambda_1^{\alpha, \rho\delta} \epsilon^{ijk} X_{\alpha, i} \bar{d}_{\rho, j}^c \mathbf{P}_R d_{\delta, k} + \lambda_2^{\alpha, \rho} X_{\alpha}^* \bar{n}_{DM} \mathbf{P}_R u_{\rho} + C.C.$$

$$\lambda_1^{\alpha, \rho\delta} = \lambda_1 \times \lambda_{1X}^{\alpha} \times \lambda_{1R}^{\rho\delta}$$

$$\lambda_2^{\alpha, \rho} = \lambda_2 \times \lambda_{2X}^{\alpha} \times \lambda_{2R}^{\rho}$$

ATM A minimal parametrization

Various final states limits estimation



Our focus:

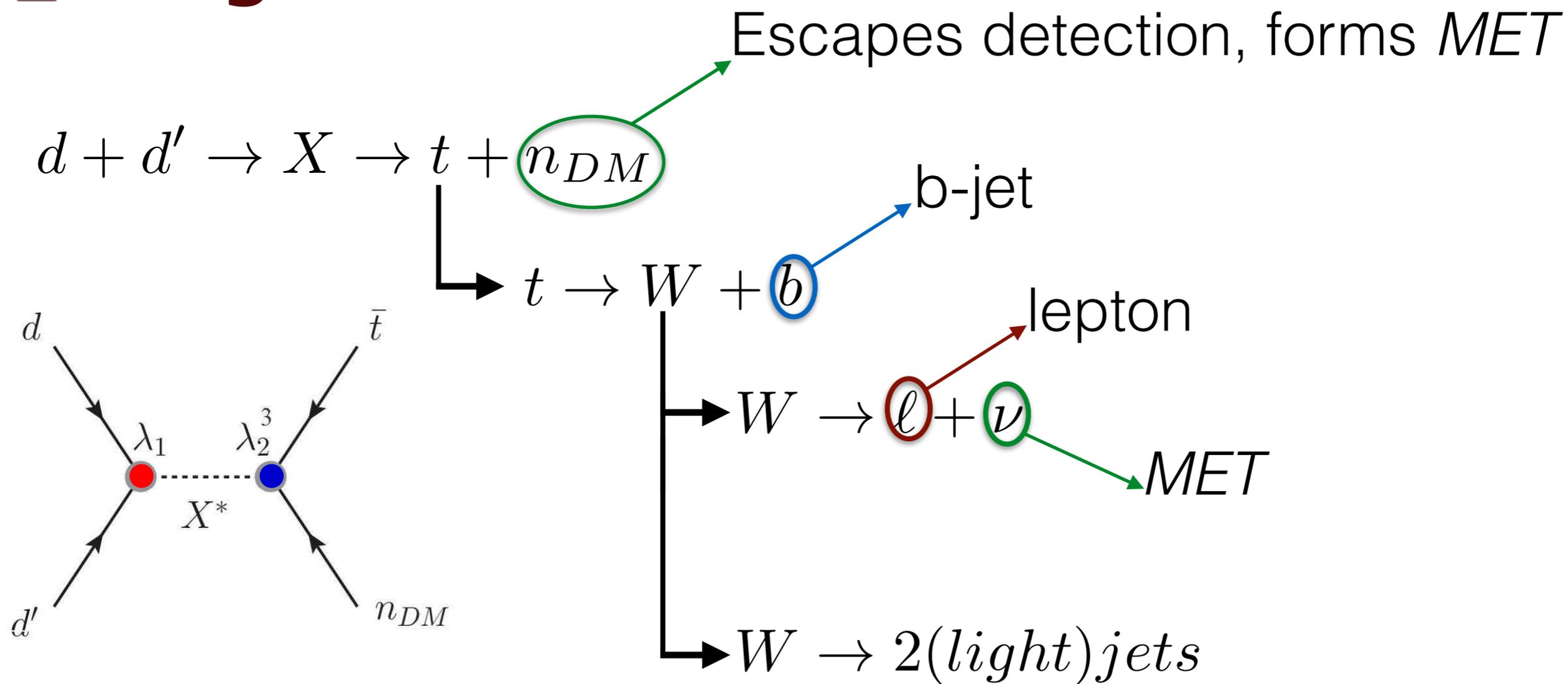
☑ $\lambda_{2R}^\rho = (1, 1, 1)$ allows to probe the coupling to top quark

light jets → (1, 1) (1) → *top*

☑ Suppose X_1 be lighter than X_2

☑ Make a flavor-blind coupling structure for simplicity

ATM Signatures



Possible final states:

- ☑ High MET + b-jet + lepton
- ☑ High MET + b-jet + 2 other (preferably light) jets

Naive sensitivity estimation gives ~ 1 event/fb for 50% efficiency and $\lambda_1 \approx \lambda_2 \sim 0.1$, $m_X \sim 1\text{TeV}$



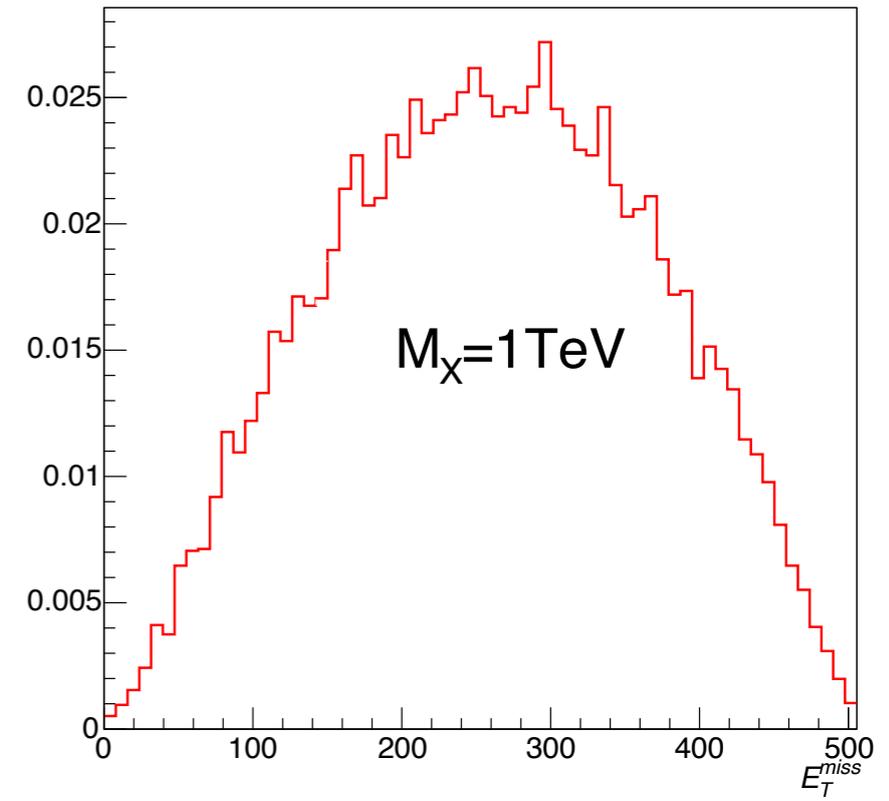
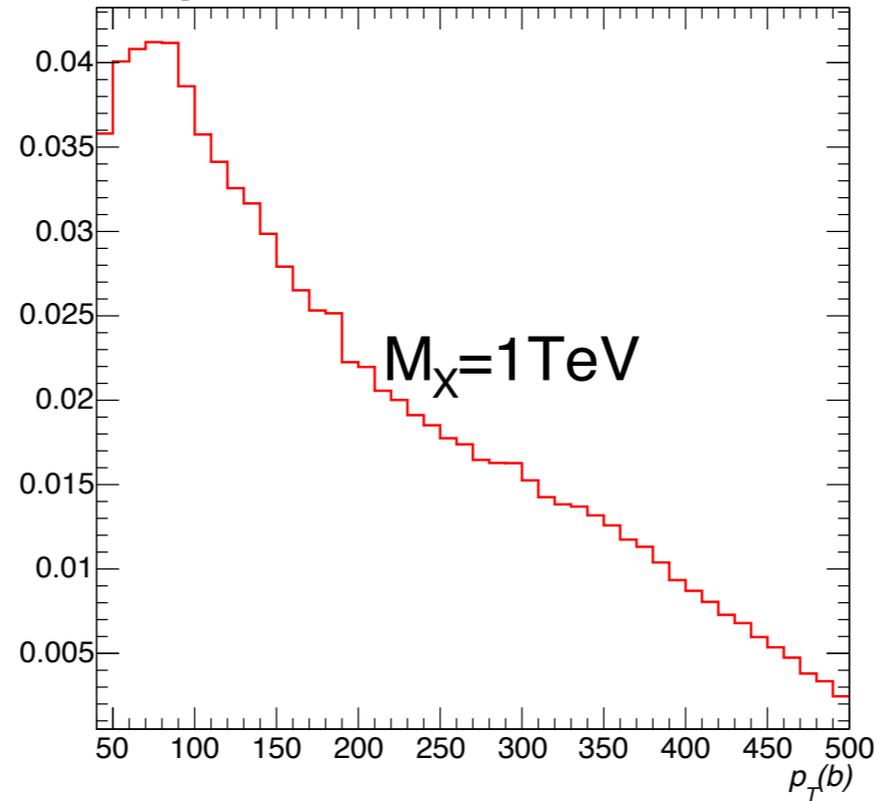
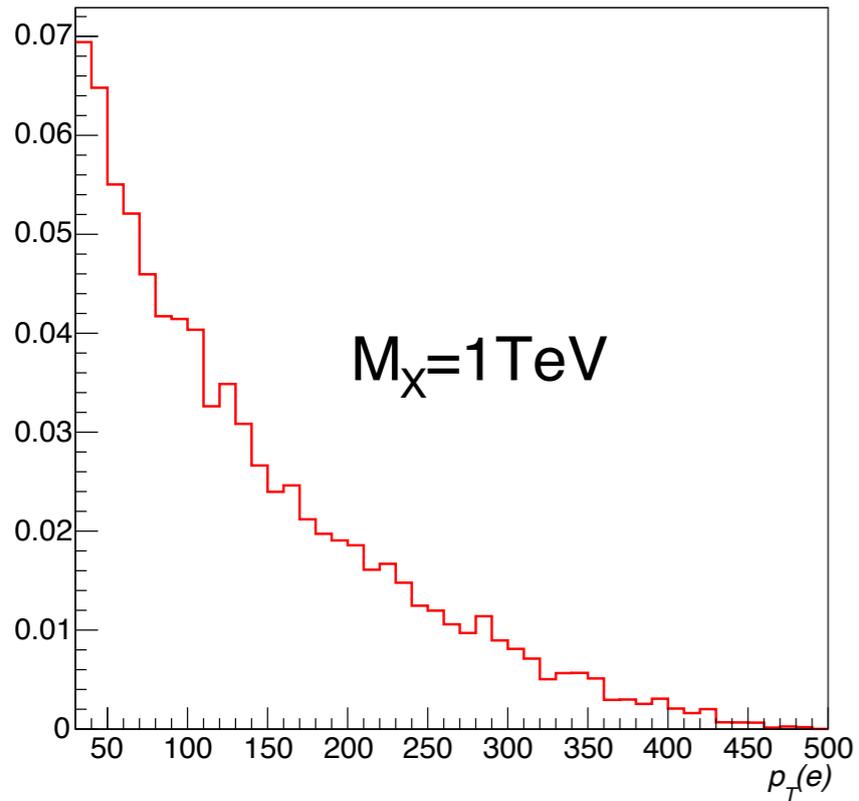
Events generation and detector simulation

- ☑ Generate parton level events with Madgraph 1.5
- ☑ Hadronize events with Pythia 8
- ☑ Simulate the detector with Delphes:
 - ☑ Use standard CMS configuration card
 - ☑ Reconstruct jets with FastJet package using anti-Kt
 - ☑ B-tagging efficiency $\sim 70(60)\%$ in the barrel(endcaps)
 - ☑ Apply $p_T(b) > 60 \text{ GeV}$ and $p_T(jet) > 20 \text{ GeV}$ selection for jets in hadronic final state
 - ☑ Apply $p_T(b) > 30 \text{ GeV}$ and $p_T(\ell) > 30 \text{ GeV}$ selection in leptonic final state

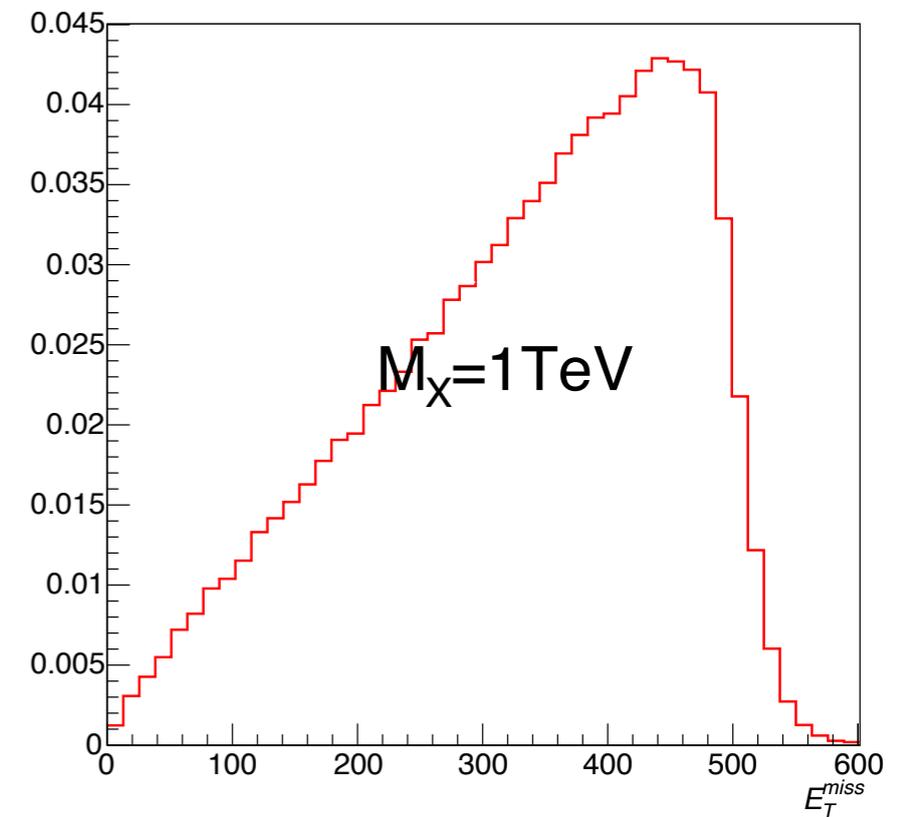
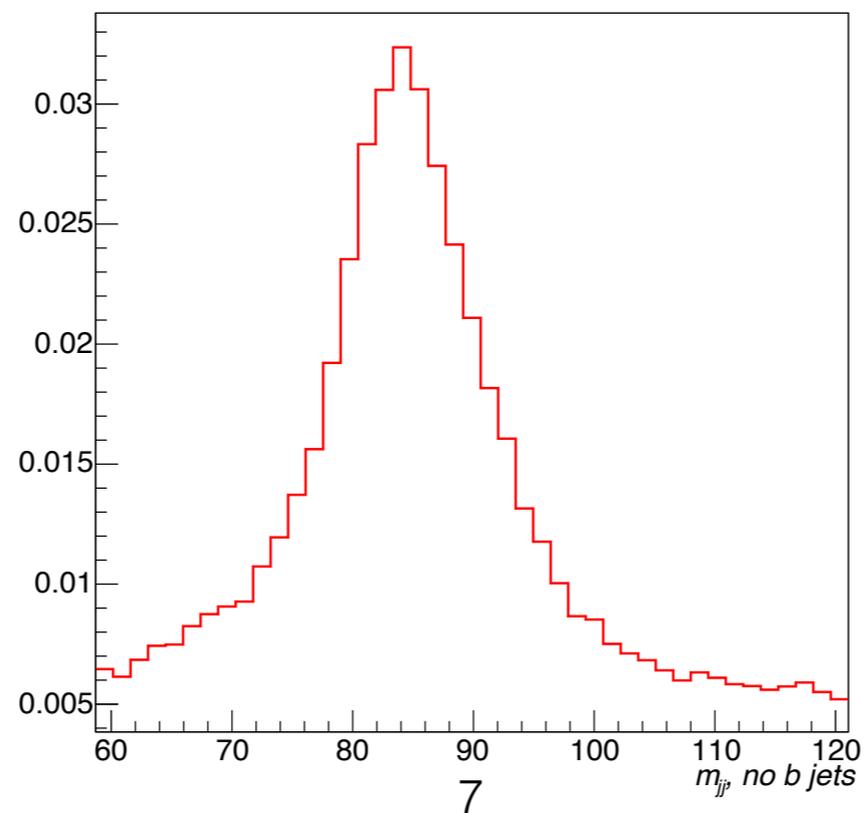
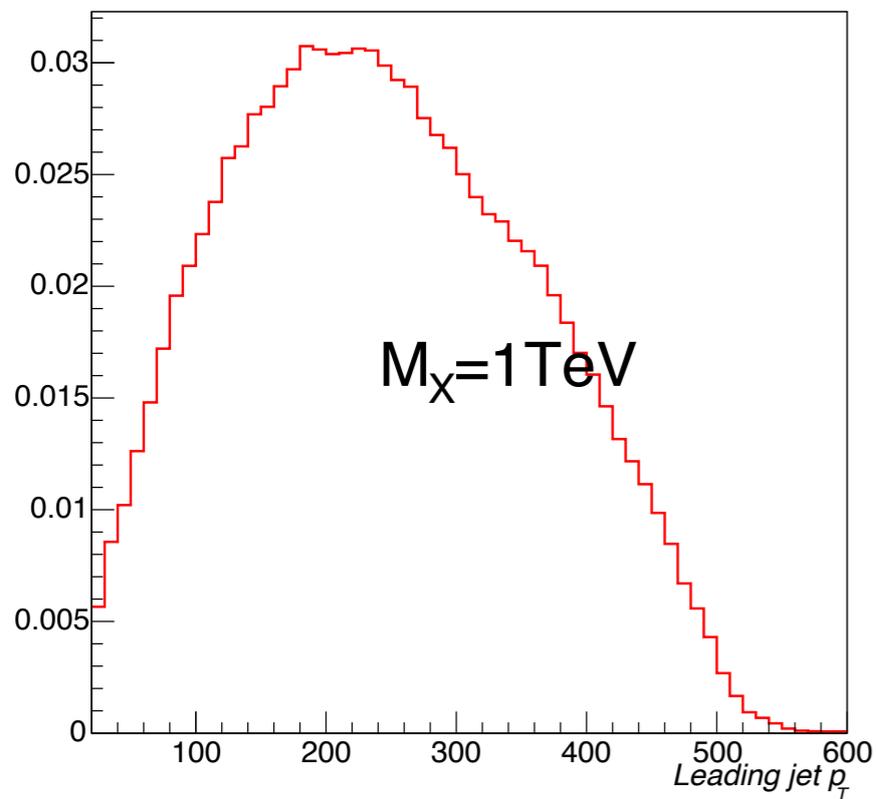


Event kinematics

leptonic final state



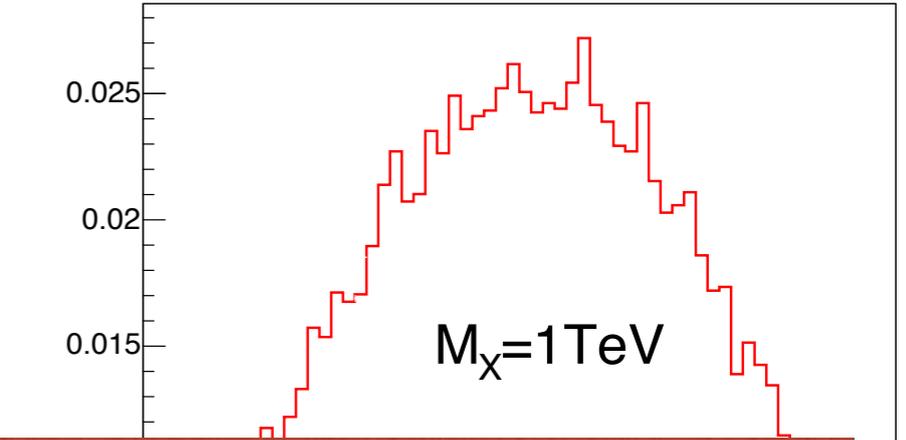
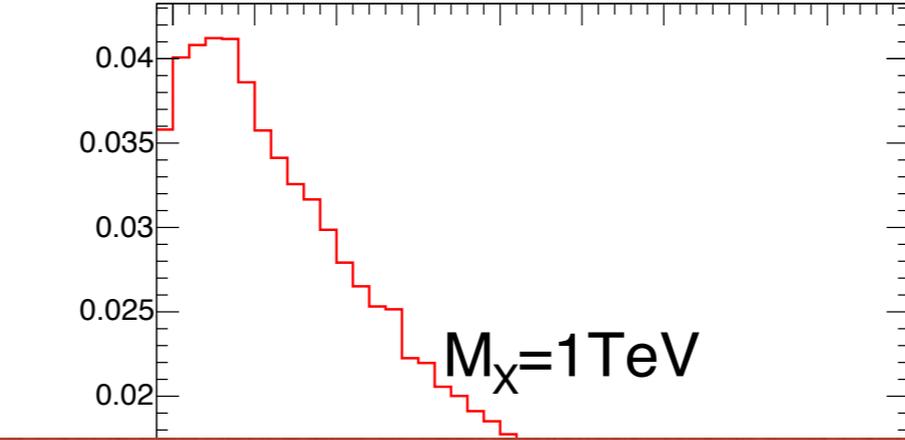
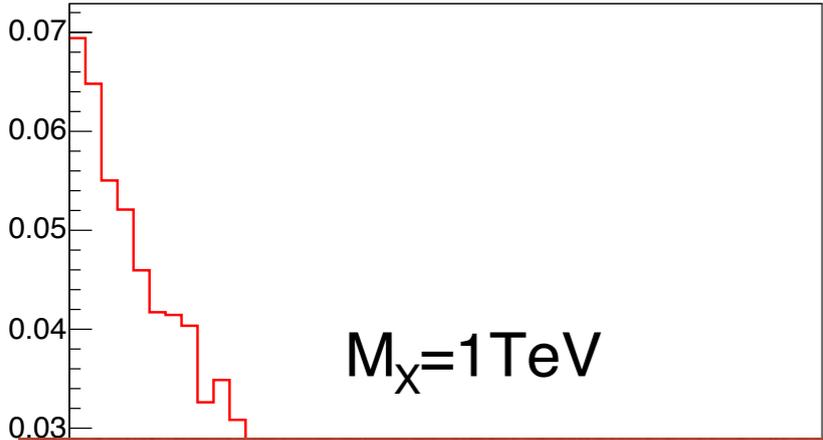
hadronic final state



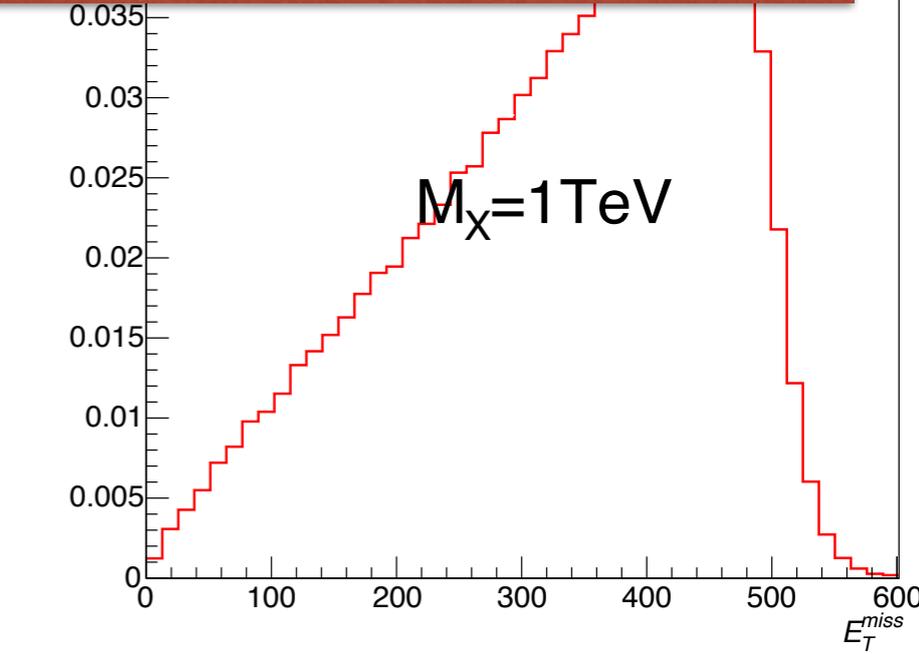
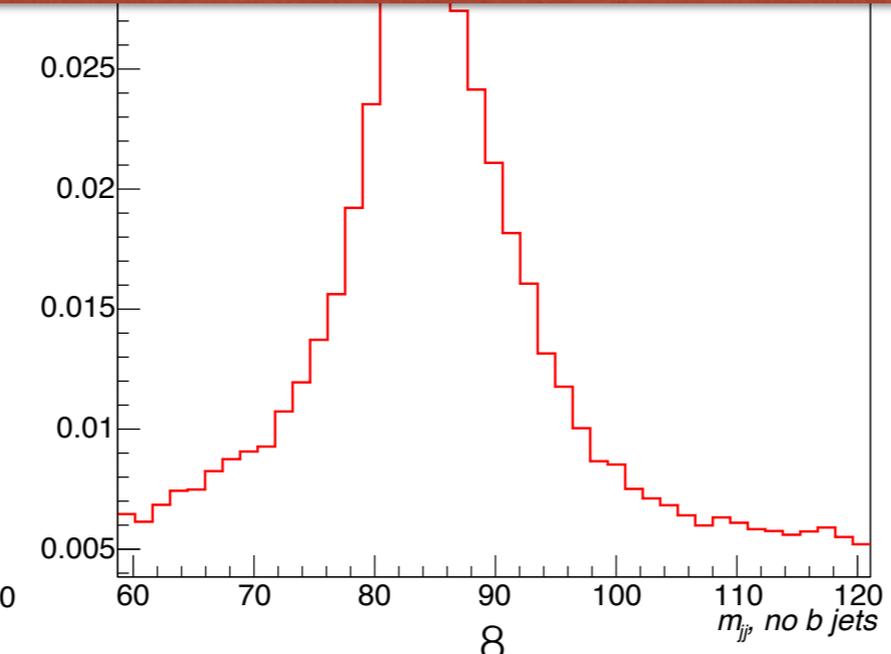
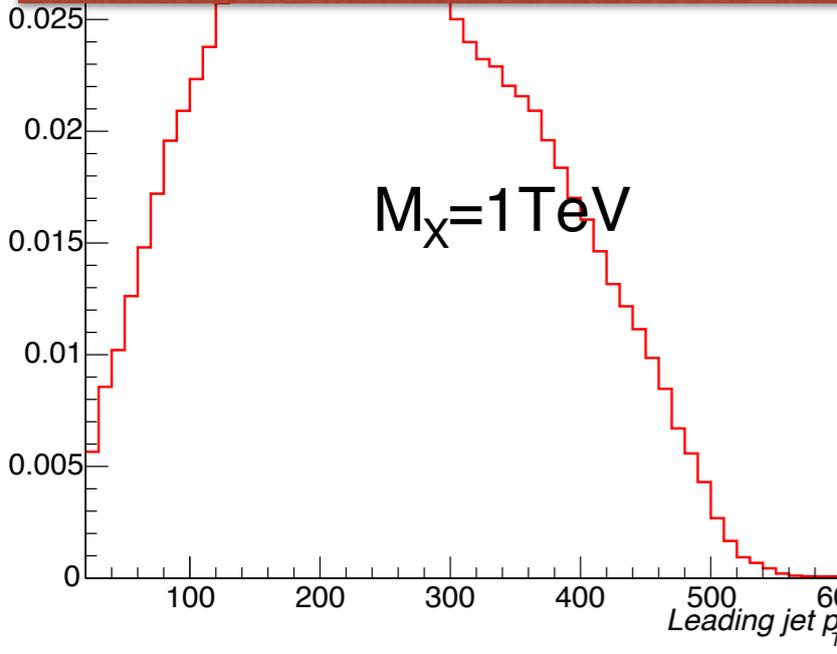


Event kinematics

leptonic final state



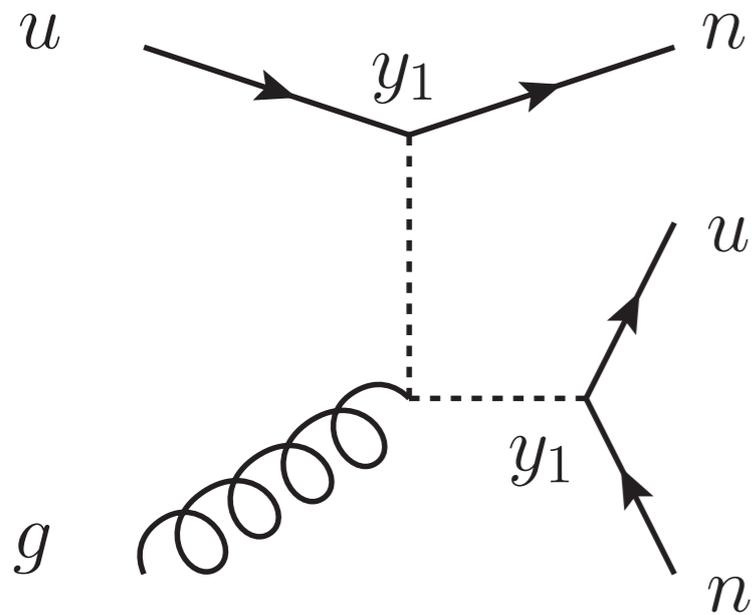
We have quite promising model with well recognizable final state, but how can we distinguish it from other similar models?



ATM An example of similar model

Let's use isospin doublet instead of isospin singlet

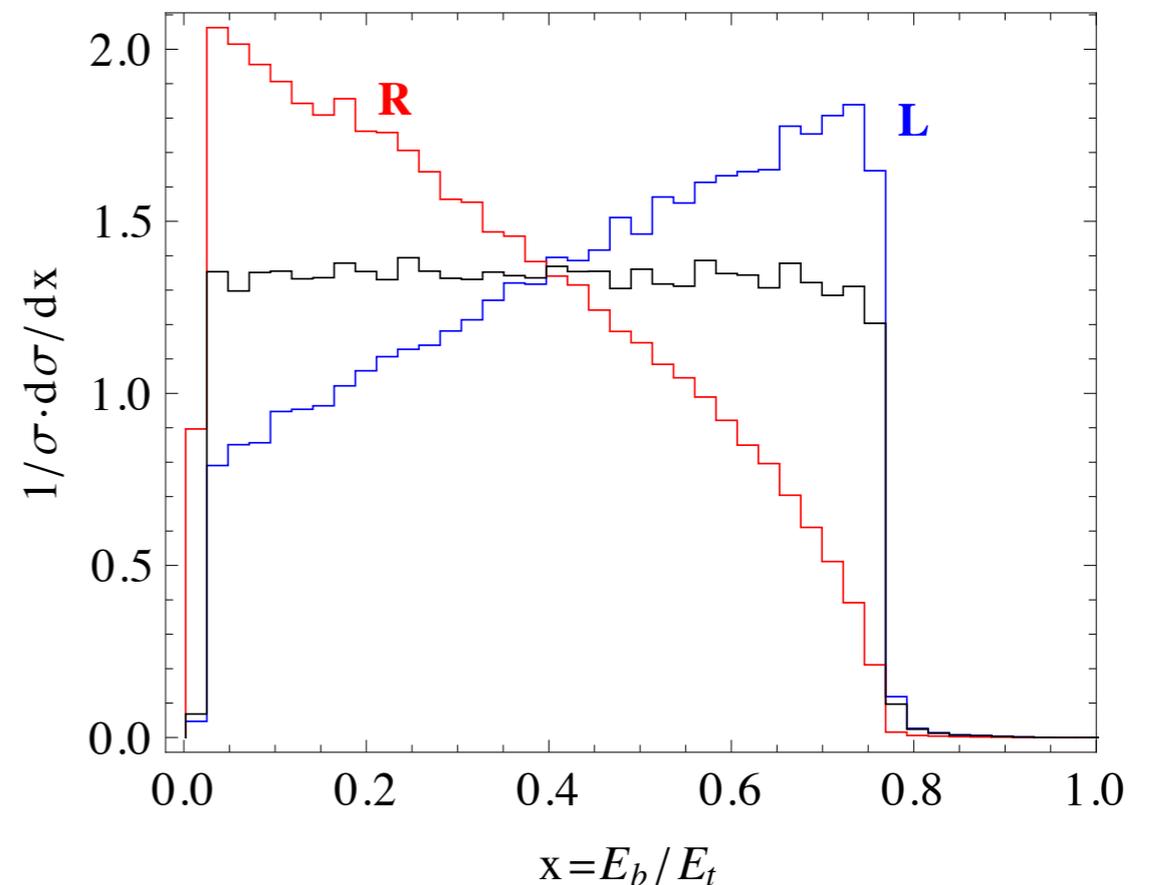
$$\mathcal{L}_D \supset y_1^{\alpha,i} \bar{Q}_i n X_\alpha + y_2^{\alpha,i} X_\alpha^\dagger \bar{Y} d_i + y_3^{\alpha,i} X_\alpha \bar{Y} u_i^c + \text{C.C.}$$



$$u + g \rightarrow X + n_{DM} \rightarrow t + n_{DM} + n_{DM}$$

The reconstructable final state is the same as in case of isospin singlet model

However, top quark chirality from X decay is opposite between the singlet and doublet cases.

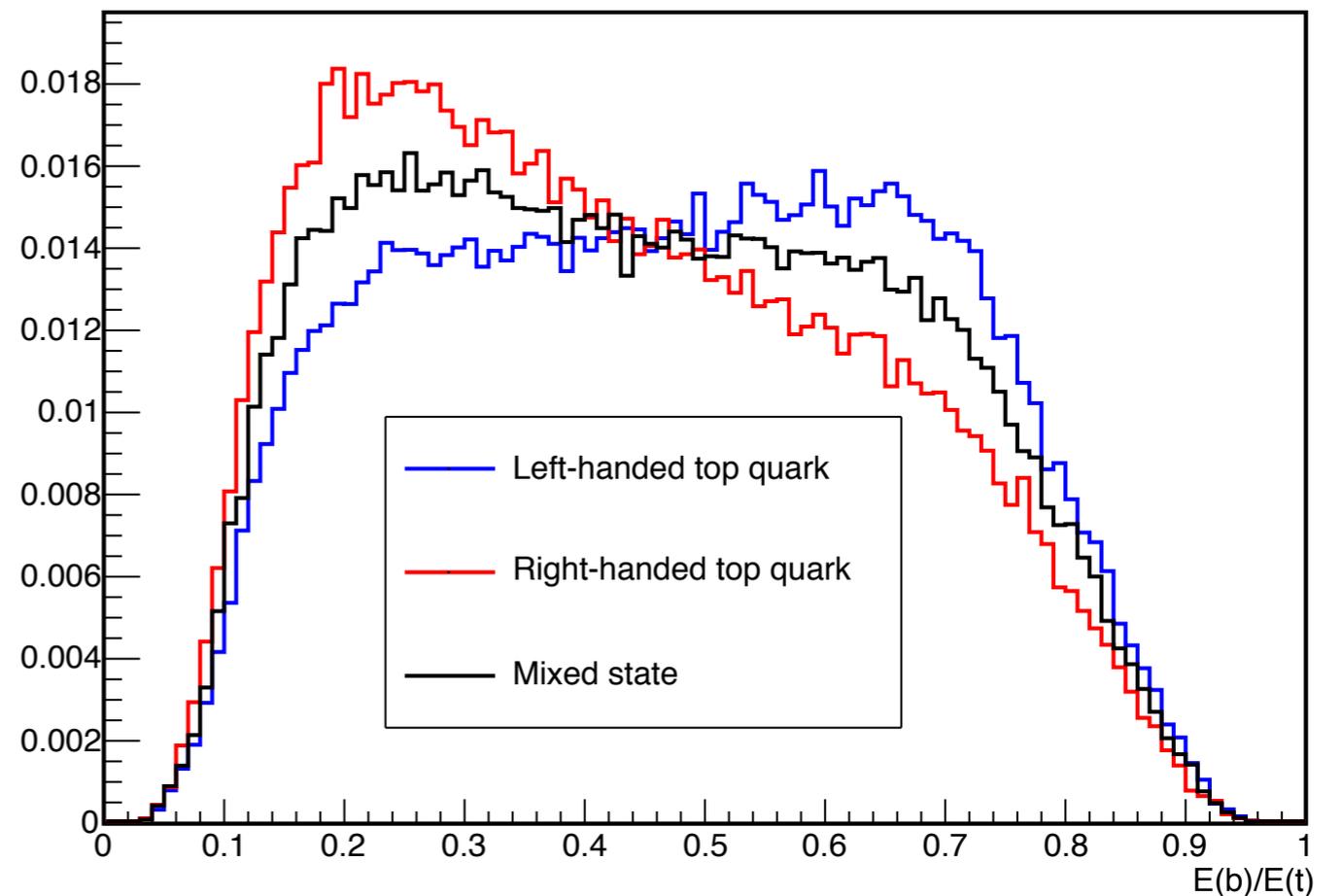
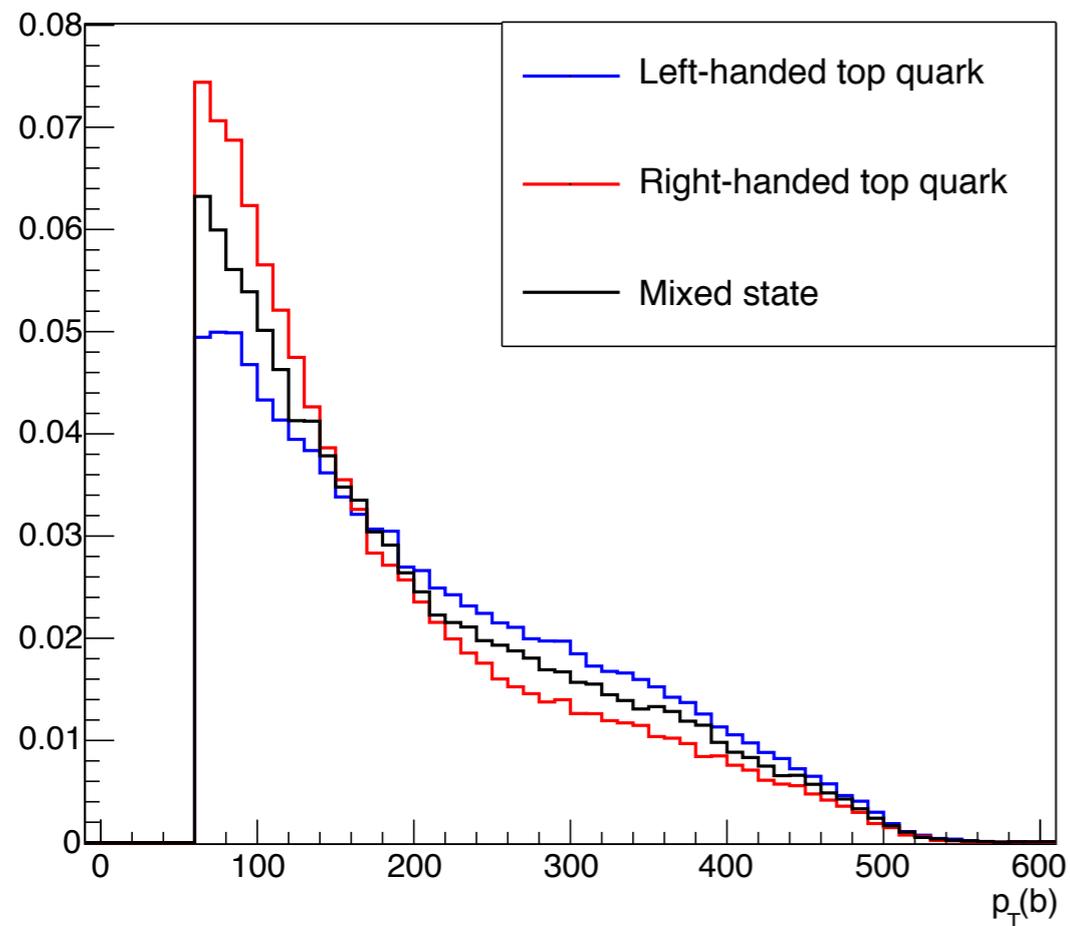




FastSim with Delphes

Hadronic top quark decay

- ✓ Flip the chirality and analyze the p_T spectrum



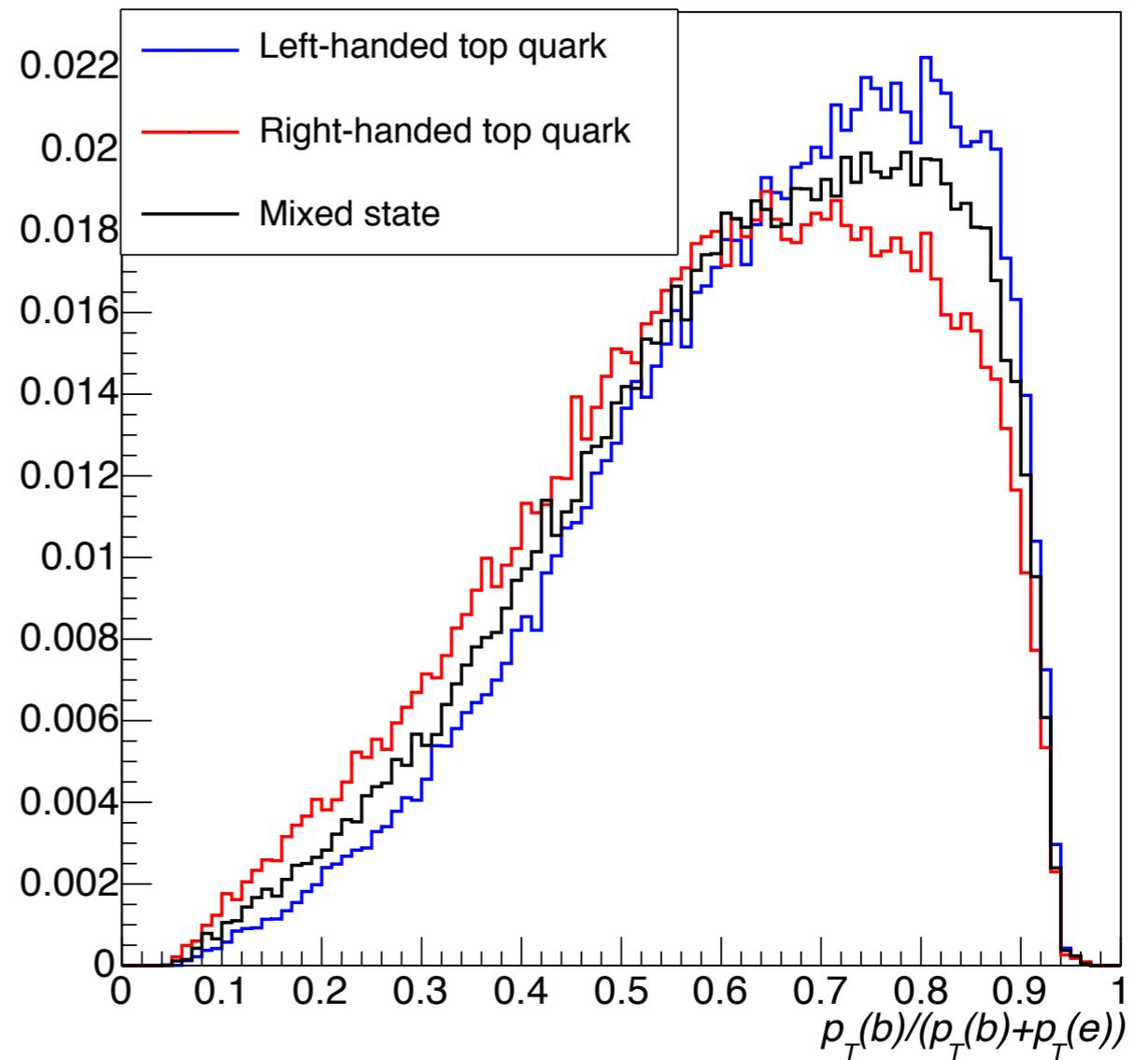
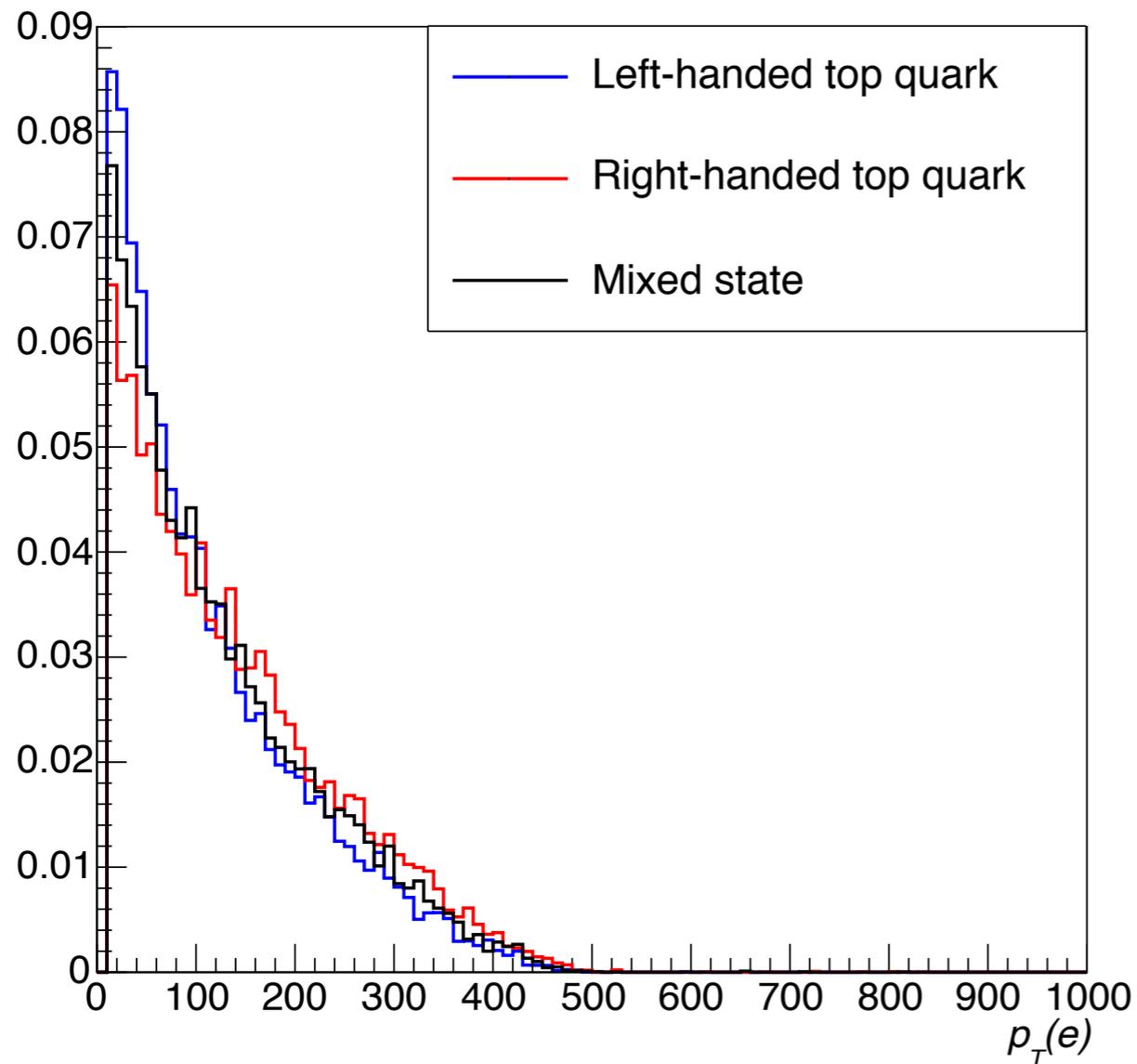
- ✓ There's a visible discrimination!



FastSim with Delphes

Leptonic top quark decay

✓ Flip the chirality and analyze the pT spectrum



✓ There's a visible discrimination!

Summary

- ☑ Light non-thermal DM model is well motivated by baryon asymmetry and current LHC bounds
- ☑ Good sensitivity with LHC Run II data is expected

- ☑ Top quark chirality reconstruction allows to distinguish between different NP models with single top quark in the final state
- ☑ Works for both hadronic and leptonic decay modes of the top quark
- ☑ Allows search for the anomalous weak couplings in SM events with single top quark in the final state