

# Singlet-triplet fermion dark matter

## LLP processes

### Abstract

This file contains a list of the processes which are expected to give interesting LLP signatures in our model [1], possible backgrounds and signal features.

## 1 Two displaced leptons

The production goes through Z-boson, leading to a signature with two displaced leptons of the opposite sign (Fig. 4). The displacement is caused by the mixing angle suppression  $\theta \approx \mu/(m_T - m_S)$ , the mass splitting between the charged and the light neutral states is  $\Delta m_{c\ell} = 15 - 30$  GeV. The lifetime of the charged state varies in the range  $\tau_+ \simeq 0 - 1.5(4)$  cm in the scalar(pseudo-scalar) scenario and the portal coupling is  $\mu/v \lesssim 3 \times 10^{-5}$  ( $3 \times 10^{-4}$ ) in the scalar (pseudo-scalar) model.

### 1.1 Main backgrounds expected

- 2015 CMS  $e - \mu$ -search for the opposite sign leptons with large impact parameters  $d_0 = 0.02 - 2$  cm,  $\tau_{\tilde{t}} = 10^{-2} - 10^2$  cm [2]: HF states with  $\tau \simeq 0.05$  cm/c and  $Z \rightarrow \tau\tau$  decays with  $\simeq 0.0087$  cm/c (Fig. 1).
- 2016 CMS  $e - \mu$ -search for the opposite sign leptons with  $d_0 = 200 \mu\text{m} - 10$  cm,  $\tau_{\tilde{t}} = 10^{-2} - 10^2$  cm [3]: decays of leptons and B or D mesons with  $c\tau_{\tau} \simeq 87 \mu\text{m}$ ,  $c\tau_B \simeq 500 \mu\text{m}$ ,  $c\tau_D \leq 100 \mu\text{m}$  (Fig. 2).
- 208 CMS soft prompt oppositely charged (e or  $\mu$ ) leptons [4]: “The main backgrounds arise from events in which one of the leptons is not prompt (mainly from W+jets events), events from fully leptonic tt decays ( $t\bar{t}(2l)$ ), and Drell–Yan (DY) processes with subsequent decays  $\gamma/Z^* \rightarrow \tau\tau \rightarrow ll\nu_l\nu_l\nu_\tau\nu_\tau$ . Smaller backgrounds are from tW production (tW) and the diboson processes WW and  $ZZ^*$ , with  $Z^* \rightarrow ll$  and  $Z\nu\nu$  (VV). Processes such as  $t\bar{t}W$ ,  $t\bar{t}Z$ ,  $WWW$ ,  $ZZZ$ ,  $WZZ$  and  $WWZ$  as well as processes including the Higgs boson have very small contributions, and are grouped together as “Rare”. ”

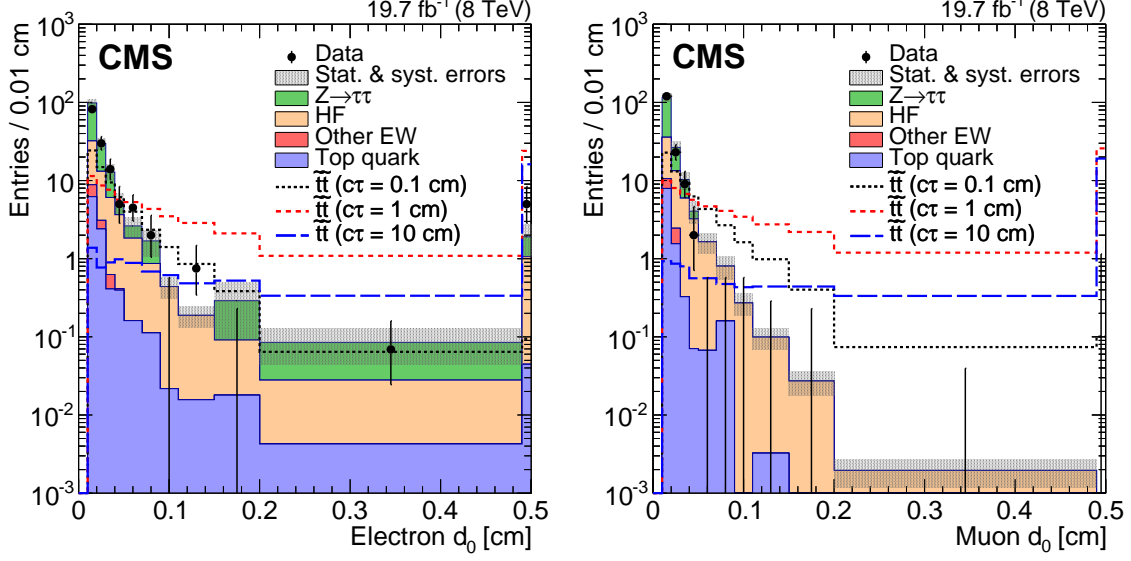


Figure 1: Backgrounds from [2]

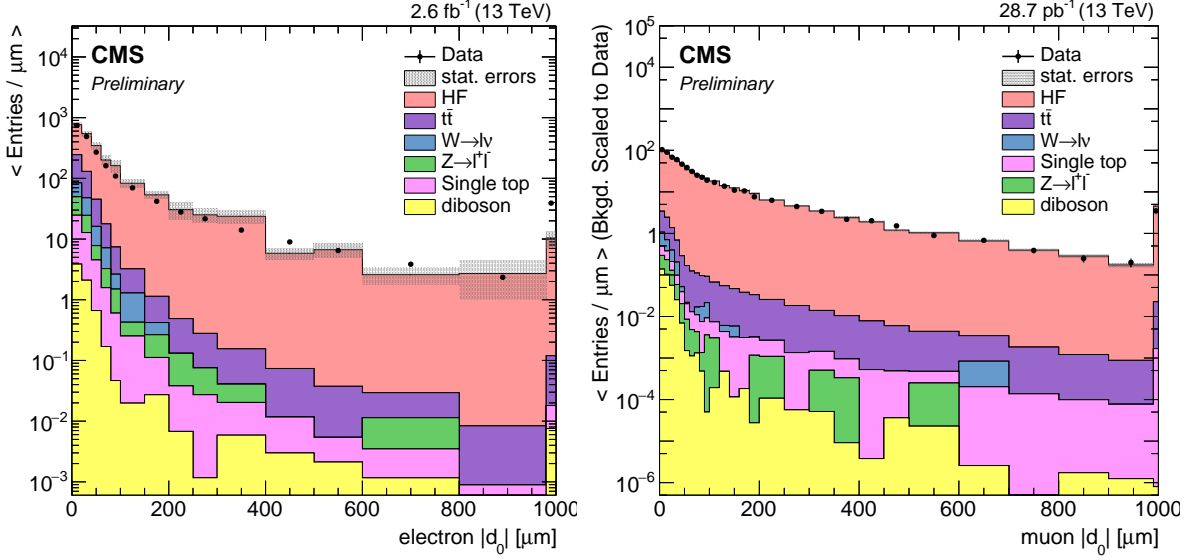


Figure 2: Backgrounds from [3]

## 2 One displaced and one prompt lepton

The production goes through W-boson, leading to a signature with one displaced and one prompt lepton of the same or opposite signs (4). The displacement on the long-branch side is caused by the mass splitting suppression  $\Delta m_{hc} = m_h - m_c \approx \mu^2 / (m_T - m_S) - 160 \text{ MeV}$ .<sup>1</sup>

<sup>1</sup>Caution: this approximate formula is valid only in the small  $\mu$  regime, however,  $\mu$  is sizeable in the considered case

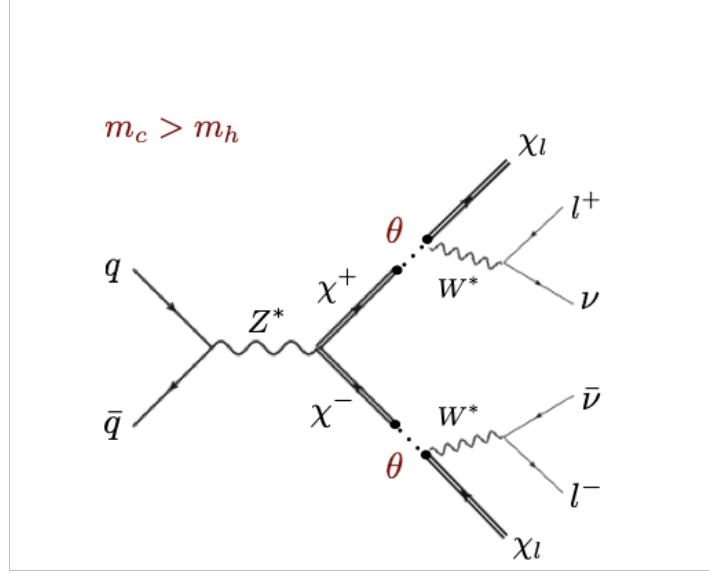


Figure 3: New signature of two displaced soft leptons at the LHC.

(we expect pion to be very soft, so that it is not observed), the second branch is prompt due to a relatively large mixing angle. The mass splitting between the charged and the light neutral states is again  $\Delta m_{cl} = 15 - 30$  GeV, and between the heavy neutral and the charge states:  $\Delta m_{hc} \simeq 160$  MeV. The lifetime of the charged state varies in the range  $\tau_+ \simeq 0 - 0.5$  cm and the portal couplings  $\mu/v \sim 10^{-2}$  ( $3 \times 10^{-2} - 10^{-1}$ ) in the scalar (pseudo-scalar) model.

## 2.1 Expeted backgrounds

Only non-symmetric processes:

- W+jets events (?)
- tW production (?)

## References

- [1] A. Filimonova and S. Westhoff, arXiv:1812.04628 [hep-ph].
- [2] V. Khachatryan *et al.* [CMS Collaboration], Phys. Rev. Lett. **114**, no. 6, 061801 (2015) doi:10.1103/PhysRevLett.114.061801 [arXiv:1409.4789 [hep-ex]].
- [3] CMS Collaboration [CMS Collaboration], CMS-PAS-EXO-16-022.
- [4] A. M. Sirunyan *et al.* [CMS Collaboration], Phys. Lett. B **782**, 440 (2018) doi:10.1016/j.physletb.2018.05.062 [arXiv:1801.01846 [hep-ex]].

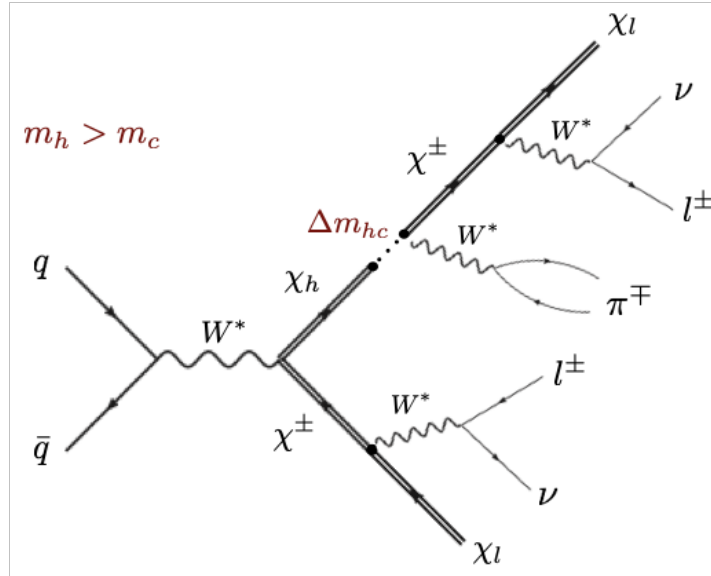


Figure 4: New signature of one displaced and one prompt soft leptons at the LHC.