Search for new long-lived particles at LHC with the CMS detector

Extensions of the Standard Model (SM) predict the existence of new particles which can be created in high-energy proton-proton (pp) collisions at the LHC. The lifetime of these new massive states is often a free parameter of the theory. If the new particle is long-lived, it will decay far from the pp interaction point and can interact directly with the detector while traveling through it. The experimental signatures of long-lived particles (LLPs) are usually striking but also very different from the short-lived ones, thus requiring dedicated analysis methods.

Searches for LLPs have been performed in a wide range of final states with the CMS detector and, so far, no evidence of these signals have been found. The CMS collaboration published 15 papers on this topic [1]. A large number of experimental signatures has been explored, as outlined in Fig. 1, including:

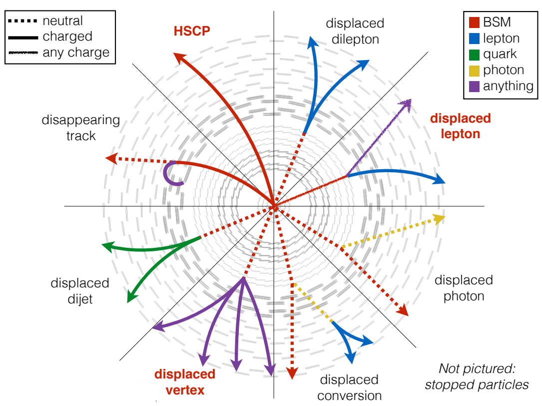

Figure 1: Experimental signatures of new long-lived particles (LLPs) in the CMS detector. LLPs are indicated with the label BSM (beyond the Standard Model). Image courtesy of Jamie Antonelli.

- **Heavy Stable Charged Particles (HSCP)**: at LHC these massive particles are typically produced with β significantly less than 1. They can be identified by unusual rate of energy loss via ionization in the inner tracker material or by their longer time-of-flight to the outer tracking detectors compared to light SM particles (such as muons). Recent results are reported in Ref.[1];

- **Stopped particles**: slow HSCPs ($\beta \ll 1$) can lose all their momentum via ionization and stop in the calorimeters. Their decays can be detected out-of-time with respect to the LHC collisions, even hours or days after the pp collision that produced them;

- **Displaced vertices**: the LLP can be a neutral particle decaying into SM charged particles (hadrons or leptons) within the inner tracker volume. They can be identified via the reconstruction of decay vertices displaced from the pp interaction point;

- **Disappearing tracks**: a disappearing-track signature can be produced by a charged LLP whose decay products are undetected;

- **Displaced photons**: a neutral LLP can decay to a photon and a weakly interacting particle. The photon arrival at the electromagnetic calorimeter (ECAL) is delayed, due to extra flight length added by the LLP decay. This time delay, unusual for photons generated by SM processes, can be measured taking advantage of the excellent ECAL time resolution. Displaced photons are foreseen for example by neutralino decays in Supersymmetry. The first search in CMS was performed by the Rome group using data at $\sqrt{s} = 7$ TeV and no deviation from the SM predictions was found [2]. Limits were set on the neutralino mass as a function of its proper decay length, as shown in Fig. 2, extending results from previous experiments.

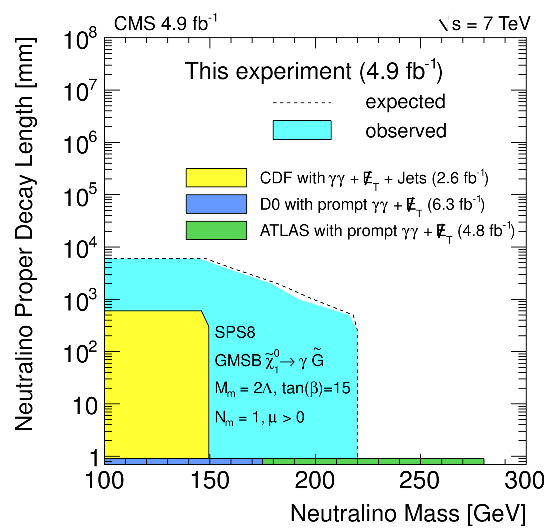

Figure 2: Excluded regions in the neutralino proper decay length ($c\tau$) vs mass plane.

In the next several years, LHC experiments will collect hundreds of fb^{-1} of data at a constant center-of-mass energy of 13-14 TeV. In this scenario of high integrated luminosity and no sign of new physics in the standard prompt decay channels, searches for the exotic signatures of LLPs are expected to become increasingly important.

References

1. The CMS Collaboration, Phys. Rev. D **94** 112004 (2016)

[1] http://cms-results.web.cern.ch/cms-results/public-results/publications/EXO/LLP.html

2. The CMS Collaboration, Phys. Lett. B **722** 273 (2013)

Authors
The CMS Rome Group

http://cms.web.cern.ch/