# SHORT TERM SCIENTIFIC MISSION (STSM)
# SCIENTIFIC REPORT

**This report is submitted for approval by the STSM applicant to the STSM coordinator**

**Action number: CA15108**
**STSM title: Collider Physics of Long-lived Multiply-charged Particles - Future Searches and Constraints**
**STSM start and end date: 20/01/2019 to 31/01/2019**
**Grantee name: Sandra Kvedaraite**

## PURPOSE OF THE STSM:

Starting a follow-up project to our work on bounds and prospects for stable multiply charged particles at the LHC (arXiv:1812.03182 [hep-ph]). In this new project we aim to study how the high luminosity LHC upgrade (in particular the new timing detectors) could improve the bounds and the discovery potential of the stable multiply charged particles.

## DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

We have focused on studying the paper on Identification of Long-lived Charged Particles using Time-Of-Flight Systems at the Upgraded LHC detectors by O. Cerri *et al* (arXiv:1807.05453 [hep-ex]). In this paper the authors proposed a way to extract the particles' mass from its velocity ($\beta$) and momentum by using the new timing detectors and a vertex time reconstruction algorithm leading to a 30 ps timing detector resolution as opposed to the 160 ps bunch crossing time. Thus, the authors described two search scenarios: one involving the new algorithm and $H_T > 150$ GeV trigger and the other without the algorithm and with $H_T > 350$ GeV trigger and studied how the bounds on stops' mass could improve.

During the STSM, we have recomputed the cross sections for the multiply charged particles at c.o.m energy of 14 TeV using Madgraph and Pythia. We have studied the $\beta$ resolution this new detector has. We have also written a C++ code implementing the trigger and other selections proposed in this paper. We have reproduced efficiencies in this paper using both of the triggers proposed by the authors for single and both particles passing the selections. We have used the code to obtain the efficiencies of the multiply charged lepton-like and colored scalar particles. We have also obtained the efficiencies specifically for the two differently charged hadrons that could be formed from the colored scalar particles hadronizing. Finally, by scaling the efficiency used in obtaining the bounds for stops' mass in this paper, we have obtained new bounds on the multiply-charged lepton-like and scalar particles' mass at c.o.m energy of 14 TeV and integrated luminosity of 1 $ab^{-1}$.

## DESCRIPTION OF THE MAIN RESULTS OBTAINED

During the STSM we have found that the $\beta$ resolution is one to three orders of magnitude better than in the searches considered in our previous work. The new selection criteria yielded significantly better efficiencies for larger charge and larger mass particles as compared to our previous work. Due to the significantly larger amount of background, however, the bounds that we have obtained on the colored scalar and lepton-like particles' mass proved to be significantly weaker as compared to our previous 13 TeV analysis.

## FUTURE COLLABORATIONS (if applicable)

Even though this analysis has not yielded stronger mass bounds for the stable multiply charged particles it serves as a starting point for this follow-up project. The new timing detectors provide us with an opportunity to discriminate these particles before they enter the calorimeters and the muon systems which are the main sources of the ionization energy loss and hence poor efficiency in detecting these particles. The main problem with triggering at such an early stage of the detector is the large background. Therefore, we plan to look into ways to reduce the background, in particular using an ionization energy discriminator and the improved $\beta$ resolution. We hope that by building onto the search studied in the previous work, we can improve it by adding the new timing and ionization loss information and thus devise a search that would yield stronger bounds and better discovery potential for the stable multiply charged particles.