Prospects for the search for HN in the CMS experiment using the lepton decay of the D_s meson into $\mu\nu$

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Abstract

It is well known that processes beyond Standard Model(SM) exist. One of the possible extensions of SM that explains these processes is the addition of one or more heavy neutrinos. We discuss the possibility of a search for said neutrinos in $D_s^+ \to \mu^+\mu^+\pi^-$ decay[1] using the BParking CMS dataset. We present a study of different D_s sources in the dataset, namely D_s coming from the primary collision vertex and D_s mesons coming from semileptonic B_s mesons decays, several possible reference channels and a number of channels forming the possible background. In this study we found around 1.7×10^6 D_s and 6.2×10^5 D candidates in the reference channel $B_s \to D_s^+(\to \phi(\to K^+K^-)\pi^+)\mu^+$ and 2.3×10^6 D_s and 7.9×10^5 D candidates in the reference channel $D_s^+ \to \phi(\to K^+K^-)\pi^+$.

[1]Throughout this report the inclusion of charge-conjugate processes is implied, unless otherwise stated

Introduction

There is a number of models that add heavy neutrinos(HN) to the SM. This research is based one of such extensions called νMSM[1] adding three singlet fermions. In this model, if the mass of the neutrino is between kaon mass and mass of charmed hadrons, D and D_s mesons dominate the neutrino production. Searches for HN were carried out by several collaborations[2], yet no neutrinos were found. To increase the amount of data, this research uses the latest CMS BParking dataset, where trigger requires a presence of a displaced muon track with a high momentum. Such muons usually come from b-hadron decays, which is why we probed both semileptonic B_s meson decays and prompt D_s as a source of D_s mesons.

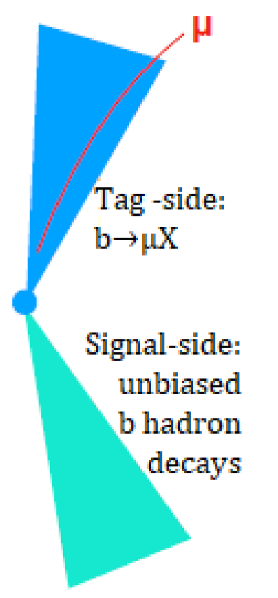

Figure 1: Illustration of BParking dataset trigger scheme

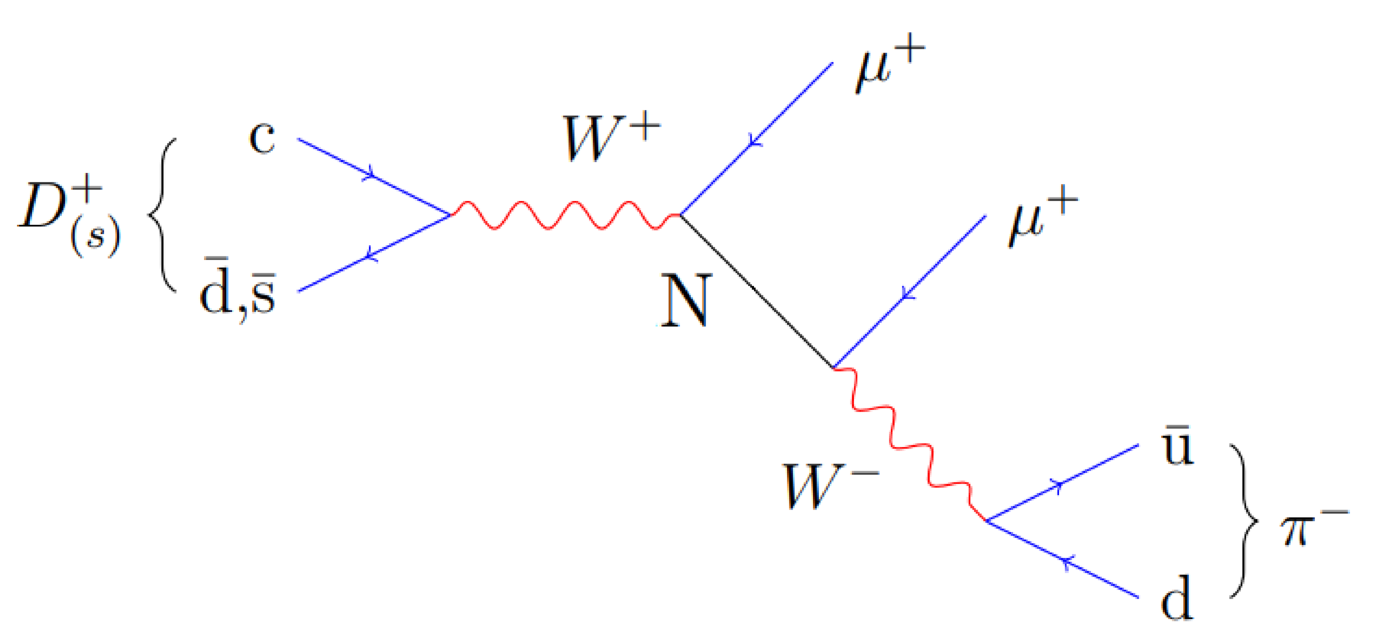

Figure 2: Diagram of the $D^+_{(s)} \to \mu^+\mu^+\pi^-$ decay with an intermediate heavy neutrino

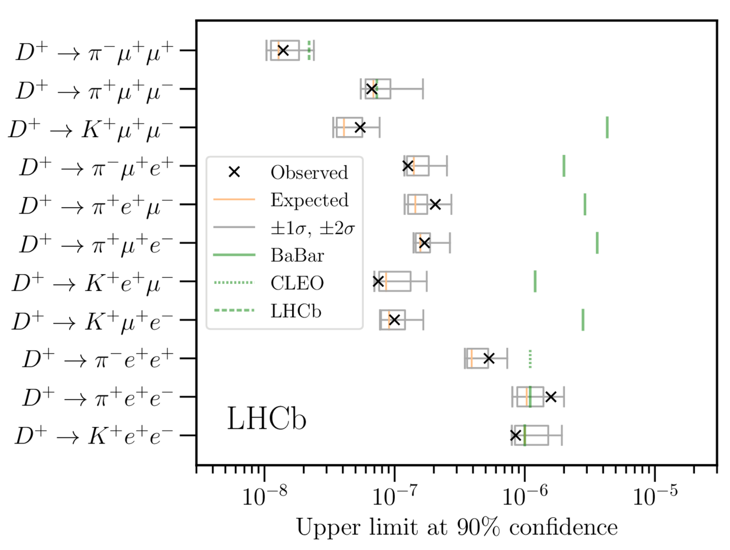

Figure 3: Latest results on different D meson decays

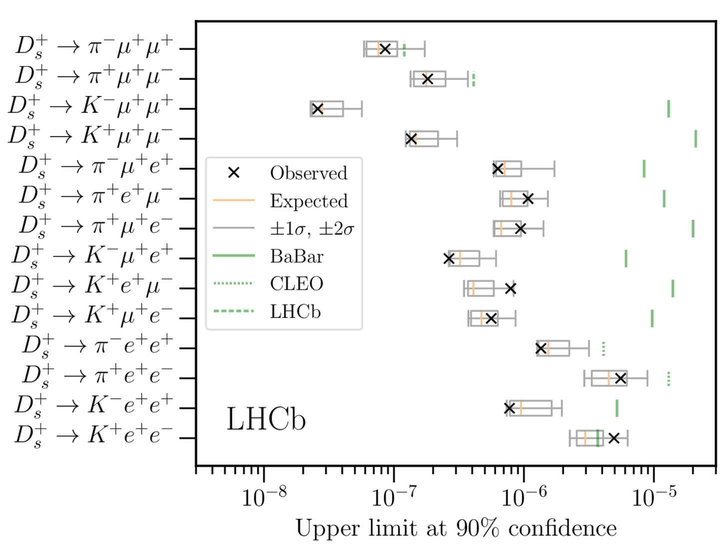

Figure 4: Latest results on different D_s meson decays

Reference channels

For the reference channels we probed D_s mesons coming from semileptonic decays of B_s mesons, as well as D_s mesons coming from the primary vertex. In both channels the produced D_s then decays as $D_s^+ \to \phi(\to K^+K^-)\pi^+$.

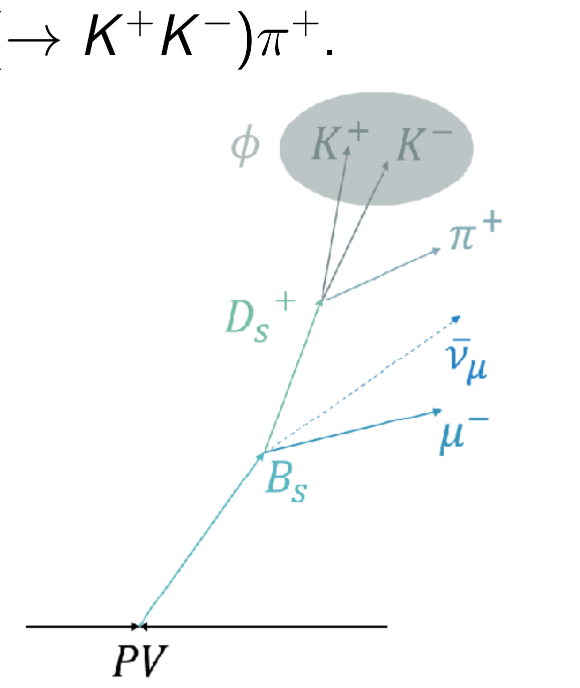

Figure 5: Topology of $B_s \to D_s^+(\to \phi(\to K^+K^-)\pi^+)\mu^-$

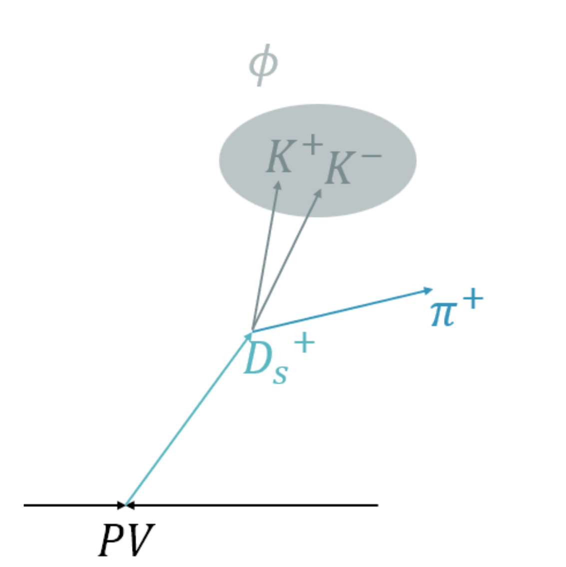

Figure 6: Topology of $D_s^+ \to \phi(\to K^+K^-)\pi^+$

Reference channels (continuation)

Both channels were recognised as viable sources of D_s mesons for further studies. D_s mesons from semileptonic B_s decays show much cleaner signals compared to prompt ones, while not losing much in terms of event number, which is why we consider it the most promising source of D_s mesons and a prime candidate for the reference channel. Due to the lack of Monte-Carlo simulation, the cut optimisation could not have been performed. Therefore, is possible that the signal clarity can be further improved.

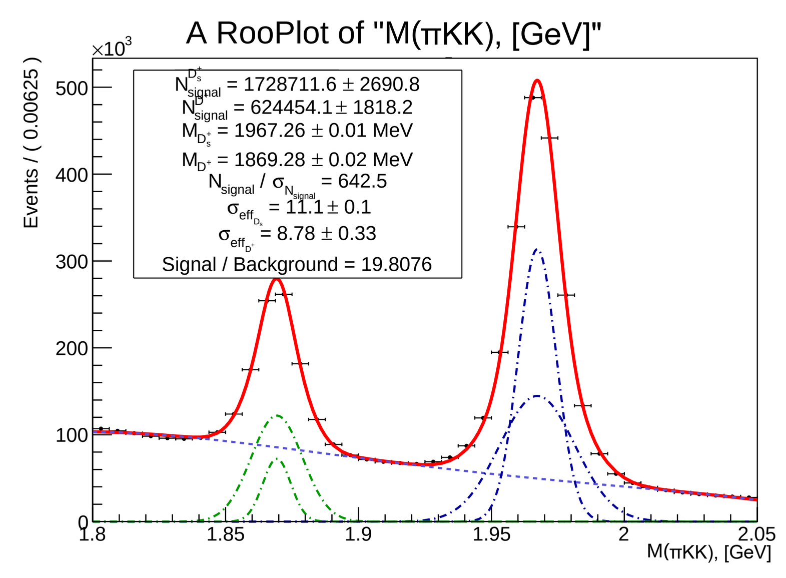

Figure 7: Invariant mass distribution of πKK in $B_s \to D_s^+(\to \phi(\to K^+K^-)\pi^+)\mu^+$ decay with exclusion of $B^0 \to D^-(\to K^+\pi^-\pi^-)\mu^+$ background process

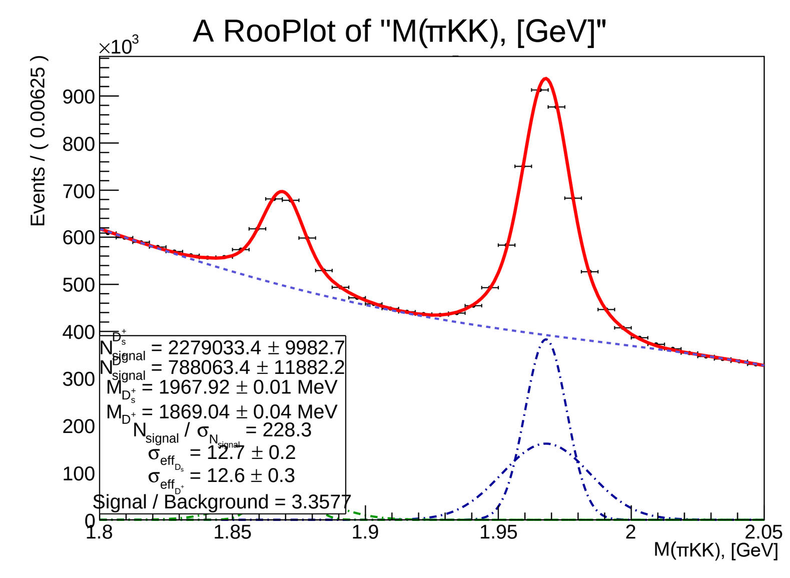

Figure 8: Invariant mass distribution of πKK in $D_s^+ \to \phi(\to K^+K^-)\pi^+$ decay

We found around 1.7×10^6 D_s and 6.2×10^5 D candidates in reference channel $B_s \to D_s^+(\to \phi(\to K^+K^-)\pi^+)\mu^+$ and 2.3×10^6 D_s and 7.9×10^5 D candidates in reference channel $D_s^+(\to \phi(\to K^+K^-)\pi^+)$.

Background channels

Due to the lack of particle identification systems in CMS, the process $D_s^+ \to \mu^+\mu^+\pi^-$ is similar in topology to many others. Namely, the $D_s^+ \to \pi^+\pi^+\pi^-$ and $D_s^+ \to \mu^+\mu^+\pi^-$ closely resemble our topology in case of short-lived heavy neutrino. To account for their inevitable presence in the background, a study of these channels has been performed. While the invariant mass distribution of $\pi\pi\pi$ in $D_s^+ \to \pi^+\pi^+\pi^-$ channel clearly shows the same two-peak structure as in the reference channel, the same cannot be said for the $D_s^+ \to \pi^+\mu^+\mu^-$ channel, where the structure forms only after applying ϕ mass restriction to the dimuon mass.

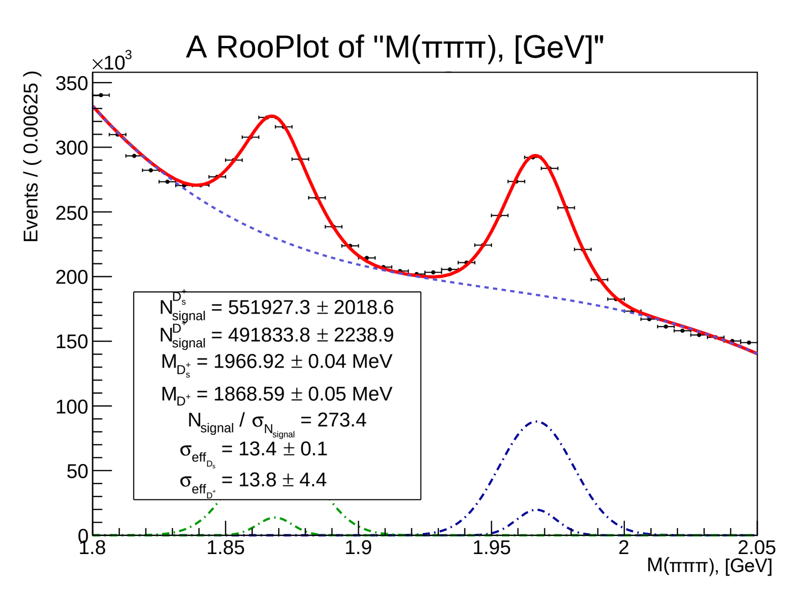

Figure 9: Invariant mass distribution of $\pi\pi\pi$ in $B_s \to D_s^+(\to \pi^+\pi^+\pi^-)\mu^-$

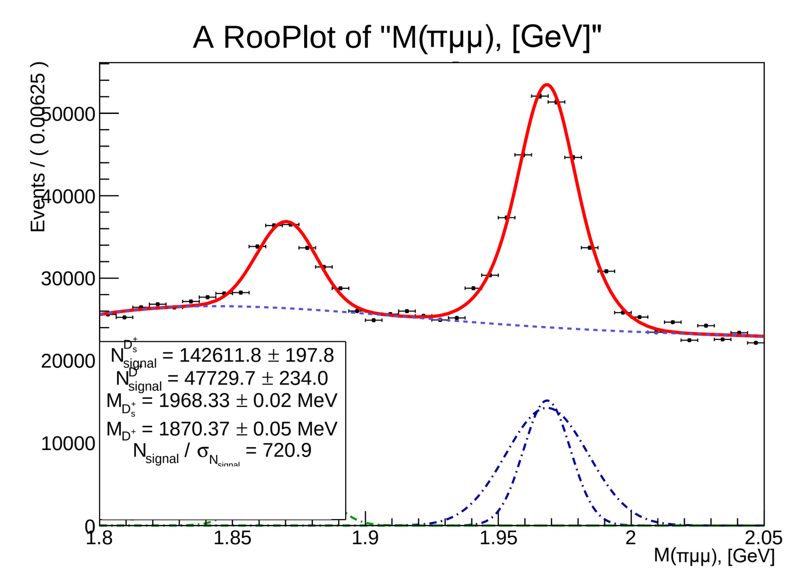

Figure 10: Invariant mass distribution of $\pi\mu\mu$ in $B_s \to D_s^+(\to \pi^+\mu^+\mu^-)\mu^-$ channel with applied ϕ mass restriction to the dimuon mass

Conclusion

In this work, different reference channels for the future search were examined and the event numbers in them were estimated. A study of background processes and their influence on target channel was performed. This paves the way for the subsequent NHL search in the future.

References

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