2.2 LHCb
Probing physics beyond the Standard Model

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During 2014 the LHCb detector was prepared for the upcoming Run 2 of the LHC at a higher beam energy of 13 TeV and a more frequent collision rate of 40 MHz. At the same time, the data collected in 2011 and 2012 were further analysed, in particular to search for signals from physics beyond the Standard Model. The results of three of these searches, with leading contributions of the Nikhef group, are summarised here.

Search for new matter vs antimatter asymmetries
The phenomenon of Charge-Parity (CP) violation is required to explain the absence of antimatter in the universe. Although the Standard Model with three generations of particles offers an elegant explanation for the existence of matter-antimatter asymmetries in particle physics via the so-called CKM mechanism, it falls short by many orders of magnitude to explain the cosmic absence of antimatter. The goal of the LHCb CP violation program is on the one hand to precisely measure the CKM model parameters, and on the other hand to search for signatures that cannot be explained with the Standard Model CKM picture. A beautiful measurement of the CKM parameter γ is performed through the detection of beauty-strange meson particles decaying to a charmed meson and a kaon in the decay $B_s^0 \rightarrow D_s K$.

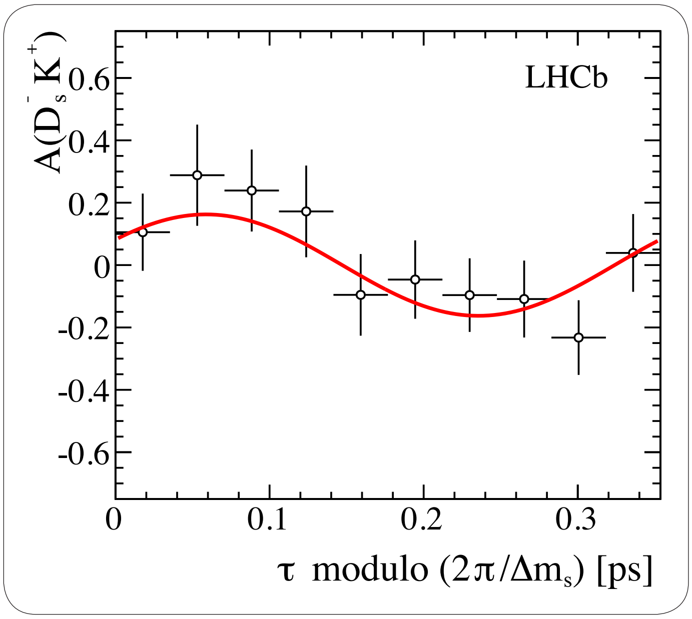

Figure 1. The asymmetry between B_s^0 and $\overline{B}_s^0$ decays into a final state of $D_s^- \pi^+$ in the 2011 LHCb dataset. The decay rate distribution is folded into a single period of a B_s^0-$\overline{B}_s^0$ oscillation. The black points are the data and the red line is the fitted curve. The amplitude of the oscillation curve is a measure for the amount of CP violation.

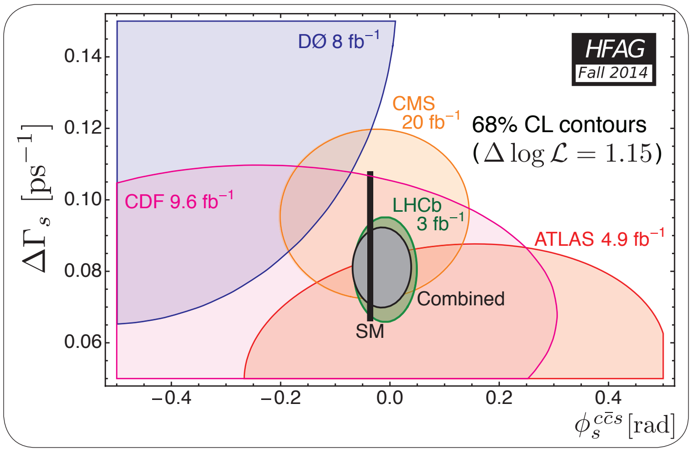

Figure 2. The result of the measurement of the B_s^0 oscillation parameter $\Delta\Gamma_s$ vs the CP violation parameter φ_s, comparing the measurement of LHCb (the green oval) with that of other experiments. The grey oval is the combined average and the black bar represents the Standard Model prediction.

Here, CP violation manifests itself through a time-dependent modulation of the decay rate, as shown for the 2011 dataset in Fig. 1. The combination of this measurement with similar other decays has resulted in the measurement of the CKM parameter, $\gamma=(73\pm10)°$.

At the same time a precision study of alternative decays of beauty-strange mesons to hidden charm and strangeness mesons, $B_s \rightarrow J/\psi\varphi$, has been completed on the combined dataset of 2011 and 2012. For this particular decay the CKM mechanism of the Standard Model predicts the absence of any CP violation, making this decay a sensitive probe for contributions from alternative sources. This measurement involves the search for a time-dependent oscillation in the decay rate as well. The result is expressed with the CP violation parameter $\varphi_s=(-0.6\pm2.3)°$. The LHCb measurement is compared with that of other experiments in Fig. 2.

Search for Forbidden decays
The occurrence of decays of neutral beauty mesons (both B^0 and B_s^0) into a final state of two muon particles is heavily suppressed in the Standard Model. As such, a more frequent occurrence of these so-called forbidden decays directly points to the existence of physics beyond the Standard Model. Following earlier reports of LHCb results, a common analysis of LHCb and CMS data was recently performed. The result of this analysis is shown in Fig. 3. This establishes the existence of the decay $B_s \rightarrow \mu^+\mu^-$ at 6σ standard deviations, while at the same time there is a 3σ hint for the decay $B^0 \rightarrow \mu^+\mu^-$. The latter result is somewhat surprising as it was not quite expected from the Standard Model prediction. The

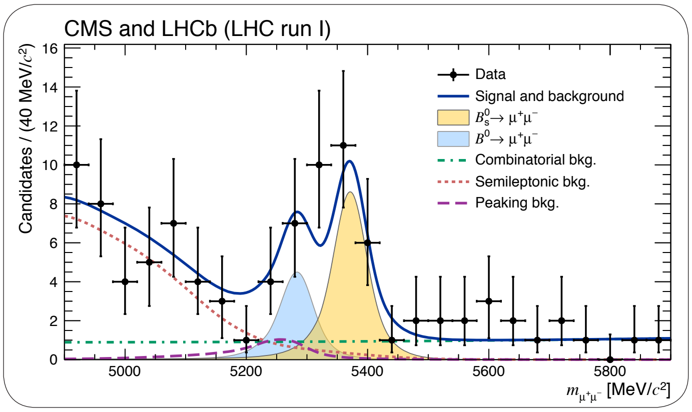

Figure 3. The combined LHCb and CMS invariant mass distribution of selected events with two oppositely charged muons in the final state. The black points are the data, the blue curve is the fitted lineshape of the mass spectrum including the B_s^0 resonance (yellow shaded area), the B^0 resonance (blue shaded area) and several backgrounds (coloured dotted lines).

relative occurrence of the corresponding ratio B^0 over B_s^0 decays is a stringent future test for the Standard Model, and at currently deviates slightly more than 2σ from its prediction.

Search for long-lived massive particles

Nature provides us with meta-stable massive particles that decay after travelling a macroscopic distance in our detectors. Similarly, various New Physics models predict in addition the existence of similar, but even heavier particles. LHCb is particularly suited to filter out decays of such metastable particles from the huge collision background, when they decay a distance between a fraction of a millimeter up to several tens of centimeters. A particularly interesting class of these particles are so-called Hidden Valley particles, also called v-pions. A search has been carried out to try and reconstruct decays of v-pions producing hadronic jets into the spectrometer. A candidate event is shown in Fig. 4. However, no signal was found in the data of 2011 and exclusion limits on the production rate of various different masses of hypothetical v-pion particles have been set.

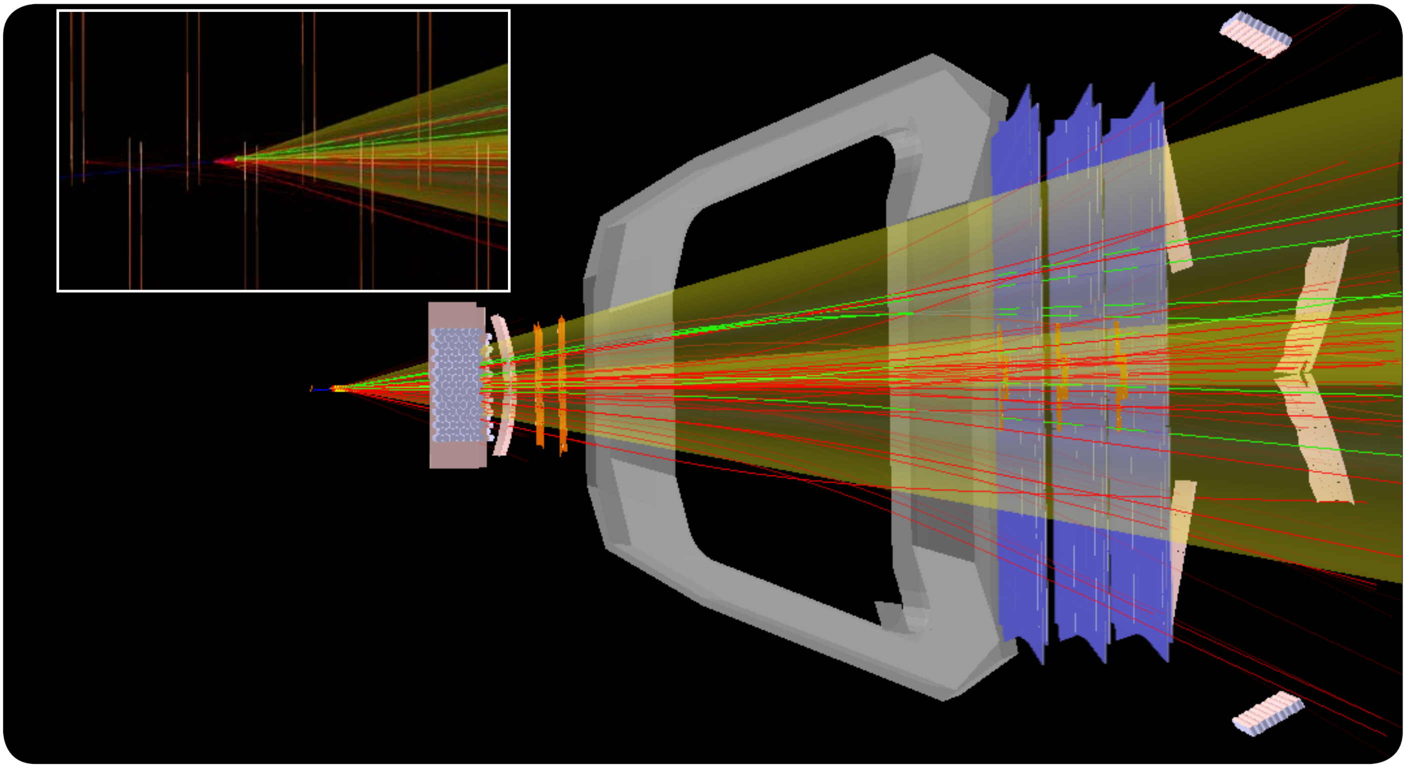

Figure 4. A candidate event of a reconstructed long-lived particle (blue line) and its decay products (green lines). The shaded yellow indicates the reconstructed jet and the red lines represent the additional particles produced in the collision. The insert shows a zoom-in on the production region.