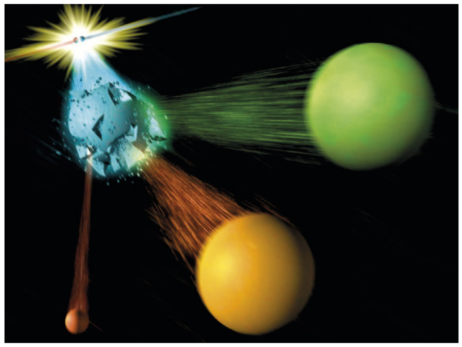
LHCb
excitement in the physics of quarks

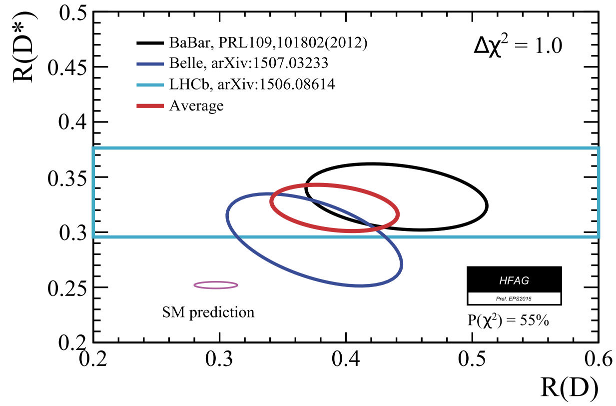
In the year 2015 the LHCb experiment welcomed back the LHC beams, this time with proton-proton collisions at a world record energy of 13 TeV. After a two-year break the experiment was in excellent shape and collected its data with a remarkably high efficiency. At the same time as the new data was being collected, the analyses of data from run 1 (2011–2012) was finalized and intriguing observations were made, resulting in a number of press releases during the year.

Rare decays under inspection

The highlight is without doubt the observation of decays of B-mesons to two muons, leading to a publication in Nature together with the CMS experiment. The work was partly done by a PhD student of Nikhef, Siim Tolk, with supervision from a former Nikhef postdoc. The decay concerns a very rare quantum process, in jargon a very rare decay process, in which a b-quark and an s-quark annihilate each other. For B_s^0 mesons, this process is seen to occur with a rate of about 3 times in a billion! The main excitement, however, was that in the same analysis also evidence for the annihilation of a b-quark and a d-quark annihilation was seen. This mirror process, of B_d^0 mesons, is expected to be even a factor 10 more rare, and since evidence for its existence arrived earlier than expected, theorists speculated about quantum effects due to new, yet undiscovered, particles such as a Z-prime.

Left: Artist's view of a B→D* τ ν decay process.
Right: Measurements of Babar, Belle and LHCb of the R(D*) quantity in comparison with the Standard Model prediction.





Management
prof.dr. M. Merk

Such speculations had already appeared earlier to explain an observation in another, less rare, process: the decay of a B-meson into a kaon particle (carrying a strange quark) together with two muons. The physics of this process is a variant of the transition of a b-quark to an s-quark. Here, there are two puzzling aspects observed. The first one is that the angles under which the particles are produced in the detector are not distributed as they were predicted from calculations. The second is referred to as 'the R_K-puzzle': various decays resulting from the 'b-to-s' transition process (referred to as 'Penguins') seem to occur at a lower rate together with two muons than when they are produced with two electrons. Again, a possible quantum effect of a Z-prime particle was debated.

An anomaly in beauty to charm decays

Another unresolved issue, now called 'the R_D puzzle', is related to an earlier observation of the BaBar experiment, involving so-called semi-leptonic decays of B-mesons to charmed D-mesons and leptons. In particular the decay $B \rightarrow D^* \tau \nu$ was observed to have a different decay rate as the mirror decay $B \rightarrow D^* \mu \nu$, where the only difference is the type of lepton (τ or μ) in the final state. The so-called concept of lepton universality predicts that decay rates should be equal. Such decays, with a tau-particle and a neutrino in the final state were long considered to be one step too far for the dense environment of LHC collisions. However, Nikhef postdoc Greg Ciezarek showed that a very careful analysis made this measurement possible. He obtained a result was in agreement with the earlier measurement of the BaBar experiment, also hinting at a deviation from the Standard Model. Including finally a recent measurement of the Belle experiment results in a measurement that deviates by 3.9 sigma from the Standard Model. A comparison of the results of the three experiments and their average with the expected value is shown in above, together with an artist view of the decay process. In this case speculations are made, among others, on a possible existence of charged Higgs particles.

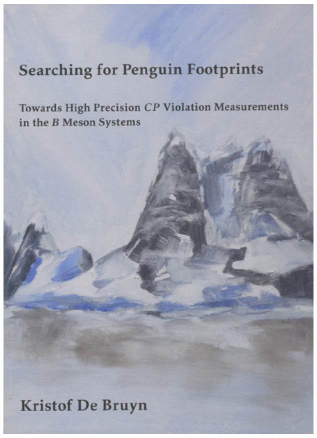
Five quarks for Muster Mark…

That LHCb not only studies weak interactions of quark decays, but also strong interactions between quarks became evident by the announcement of the discovery of the pentaquark. While investigating a specific B-particle decay process, that of B-baryons to a proton, a charmed J/ψ-meson and a kaon, LHCb researchers noticed a so-called resonance behaviour in the J/ψ + proton production. A temporary state of matter of five quarks is formed, consisting of up, up, down, charm and anti-charm quarks!

The existence of such a state of matter has been discussed several times before in history, but the LHCb observation finally settles it. In fact, two states are observed: the so-called $P_c^+(4450)$ and the $P_c^+(4380)$; both with a very large statistical significance. Whether these quarks are internally tightly bound by the strong interaction or rather resemble more a sort of 'quark-molecule system' remains to be seen.

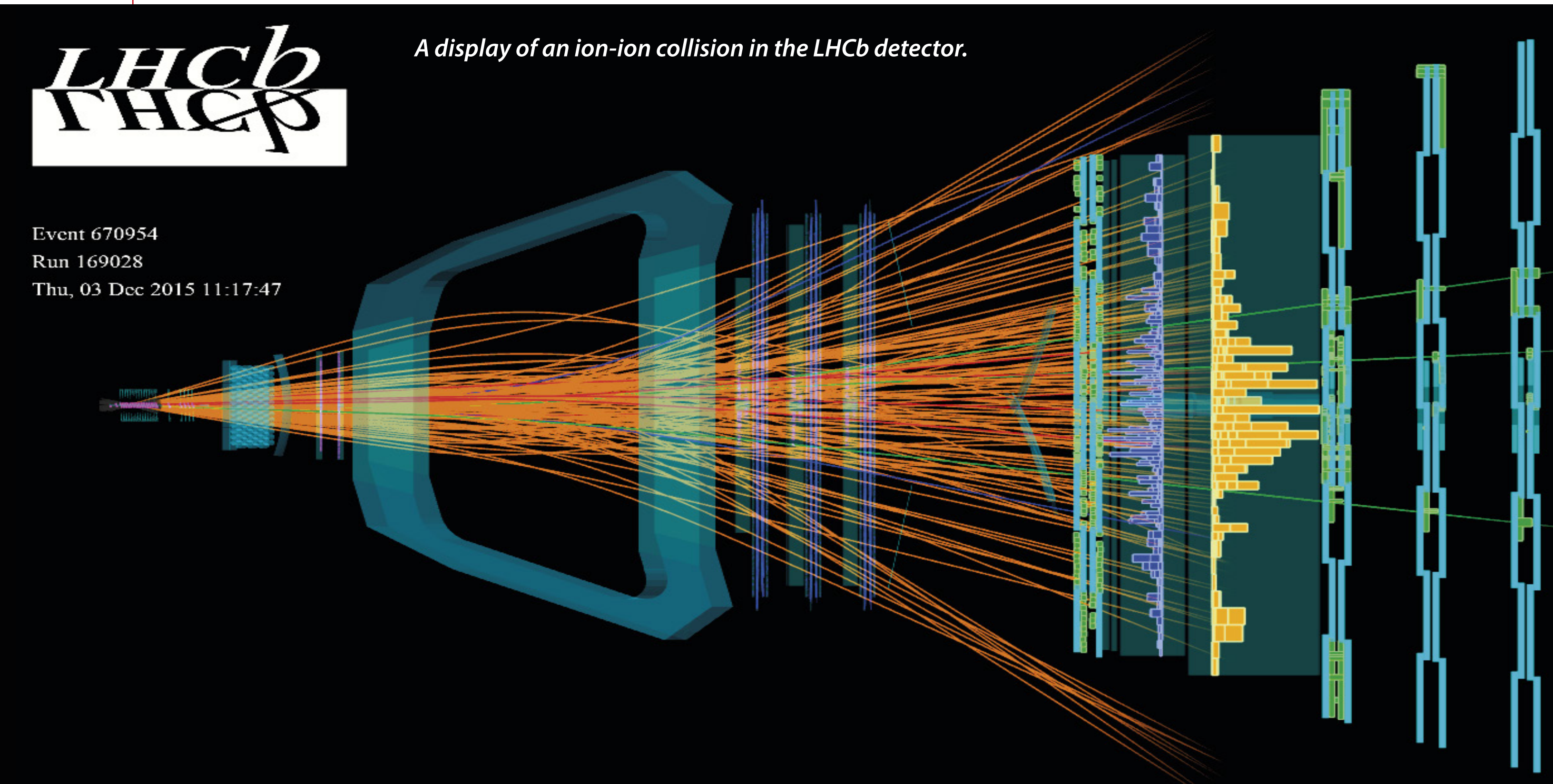
Excitement in heavy ion collisions

The studies for the strong interactions are taken further. Since the LHCb experiment has a unique coverage to detect particles of LHC collisions at small angles relative to the beam-pipe, physicists became interested to study small angle particle production in ion-ion collisions. Although the LHCb detector is not designed to take data under these very high multiplicity collisions, the detector was carefully switched on to record these collisions. After the trigger processes were adapted, a valuable dataset of events was obtained in a very smooth data taking period towards the end of the year. Analysis of these events is currently in progress. A typical heavy ion collision event is displayed below.



Kristof De Bruyn
8 October 2015

Rose Koopman
3 November 2015



A display of an ion-ion collision in the LHCb detector.

Serena Oggero
Nikhef alumna, PhD 3 October 2013

By Laetis Kuipers

As an innovator at TNO, Serena Oggero continues the search for 'beauty in data' that started at Nikhef when she prepared her dissertation entitled *"Beauty in the Crowd"*. With its publication in 2013, Serena presented first-time evidence of the disintegration of a B_s particle into two muons, something which was hailed as a very convenient way to probe New Physics models. Serena describes herself as a physicist with a drive for science, visual communication and a strong interest in diverse cultures. "While I was completing my thesis on data from the LHCb experiment," she says, "I found that my interests had become much broader than just particle physics, and that I also wanted to explore other fields in science. My time at Nikhef definitely helped me discover who I am and what I wanted to do: communicating scientific research to lead to a better society."

"I then learned about TNO's two-year trainee programme aimed at newly graduated Master's and PhD students," Serena continues, "and I decided to apply. This programme gave me the opportunity to span a number of TNO's departments and explore career options in the field of business development, strategy, consultancy and the valorization of innovations. And this made me aware that it's perfectly okay not to be exclusively focused on pure research, but that I could also produce highly valuable work when I concentrated on tasks involving communication and strategic thinking. To give you some examples, I worked in the Nano Instrumentation Department, where I contributed to B2B projects on contamination (nanoparticles) control for the semiconductor market. I also participated in the Climate, Air and Sustainability Group, where I worked on European projects on sustainable cities. My contribution involved data modelling activities for resource flow analysis and stakeholders management. Finally, I joined the Intelligent Imaging Group, where I focused on the development of applications in the field of visual pattern recognition and behaviour detection."

"All these beautiful new paths have led me to where I am today, in the Data Science department, collaborating with machine learning and computer vision experts to valorize their research in applications for society. I absolutely love working in multidisciplinary projects and discussing innovations with clients. My days at CERN and Nikhef, where an open environment and strong team work facilitated the exchange of perspectives from a wide range of cultures, have certainly prepared me for my current interdisciplinary tasks."