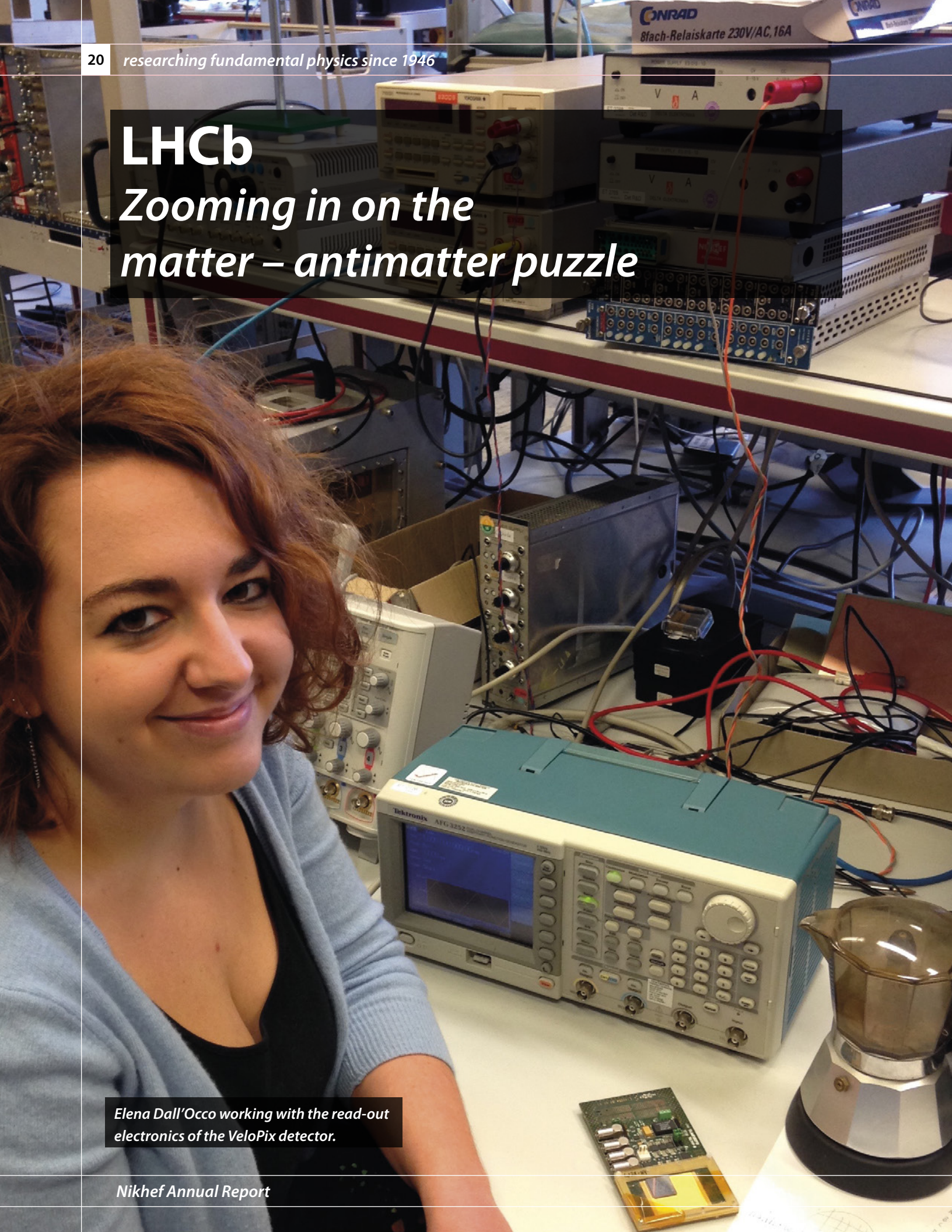
LHCb
Zooming in on the matter – antimatter puzzle



Elena Dall'Occo working with the read-out electronics of the VeloPix detector.

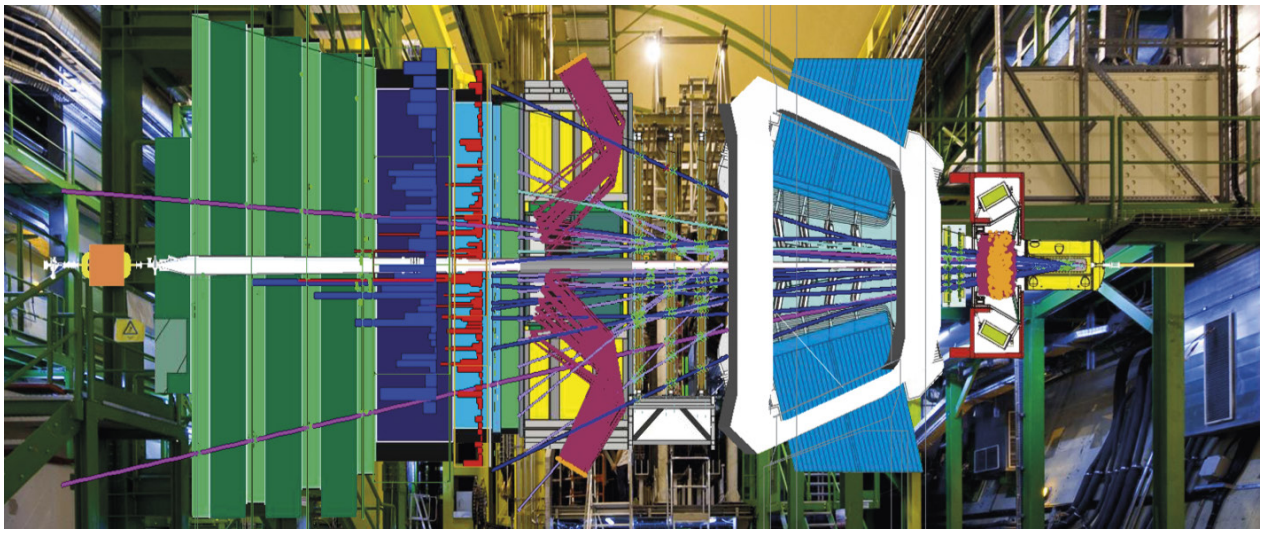


Figure 1. Display of a reconstructed LHCb collision superimposed on the detector in the LHCb hall.

Management
prof.dr. M. Merk

The year 2016 was a year of smooth data taking for the LHCb experiment during which a wealth of data was collected. An example of a reconstructed event is shown in Fig. 1. Whereas in 2015 LHCb attracted the main attention on various observations of so-called 'forbidden decays', the year 2016 saw exciting new results on the topic of CP-violation: the riddle of the asymmetry in the laws of nature between matter and antimatter particles. Members of the Nikhef group were involved in several of these analyses involving transition between beauty particles and antiparticles and their decays.

Matter – antimatter oscillations

Neutral B_d and B_s mesons are particles that consist of an exotic anti b-quark together with a d-quark and an s-quark respectively. Due to virtual quantum processes these mesons have the possibility to change their nature from particle to anti-particle with an extremely high frequency of 80 thousand million Hz for the B_d and 3 million-million Hz for the B_s. Vidi laureate Jeroen van Tilburg together with PhD students Jacco de Vries and Laurent Dufour performed a precision measurement to test whether the transition rate from B_s to anti-B_s particle occurs at a different speed compared to the reverse process from anti-particle to particle. Their results, shown in Fig. 2, demonstrate that these transition rates are identical to a precision of 0.5% and that no CP-violation occurs in this process, in contradiction with a previous, more indirect, measurement of the DØ collaboration.

Matter vs antimatter particle decays

Although no CP violation is observed in the particle–antiparticle oscillation process, Nikhef researcher Niels Tuning and PhD student Lennaert Bel studied an alternative mechanism that involves the quantum processes of oscillation and decay. They chose the decay mode where a neutral B_s particle decays to a D_s particle (c-quark plus anti s-quark) and a Kaon (anti-s quark and u-quark). An intricate quantum interference of direct and indirect decays leads to matter–antimatter differences of the rate at which this process occurs, depending on the time each individual B_s-decay occurs. This process is considered to be a standard reference for the so-called Cabibbo

Kobayashi Maskawa explanation of CP violation. The measurement resulted in the first evidence for the existence of decay-time dependent CP violation for B_s mesons and was presented at the international beauty conference in Marseille.

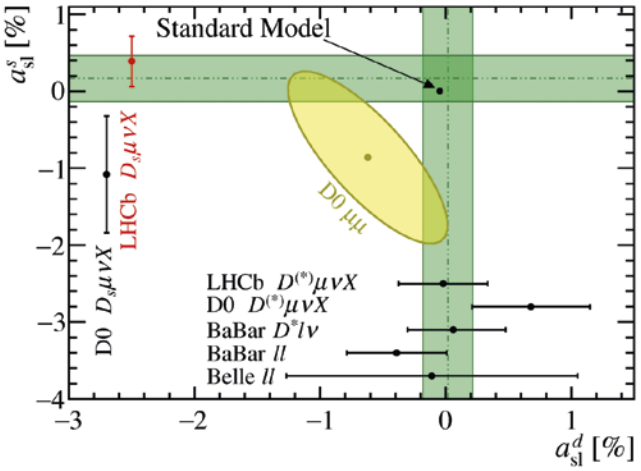


Fig 2. The relative B_s – anti-B_s oscillation asymmetry (vertical axis) and the B_d – anti B_d mesons oscillation asymmetry (horizontal axis). The red data point is the recent measurement of the Nikhef group; in black additional measurements and in yellow the so-called di-muon measurement of the D0 collaboration.

Antimatter and time reversal symmetry

Proceeding even beyond CP-violation Jeroen van Tilburg together with Nikhef master students Maarten van Veghel and Yorgos Chatzikonstantinidis used B-particles to test the validity of combined CPT symmetry, de facto asking: *are antimatter particles identical to matter particles travelling backwards in time?* They examined whether decays of B-particles might be affected by the direction or magnitude of velocity of the particles in space, in a process called Lorentz symmetry violation. In a beautiful analysis they observed no sidereal effect due to the rotation of the earth and set a limit of Lorentz violating parameters that was a factor of ten better than previous results by the BaBar collaboration.

Preparing for the future

Simultaneously to the analyses of data collected with the LHCb experiment the Nikhef group steadily increased their activities toward the construction of the upgraded LHCb experiment. A team of physicists and technicians, under the leadership of Wouter Hulsbergen, designed modules for a novel Si pixel detector and its 'VeloPix' readout electronics. A major milestone was passed by Martin van Beuzekom and Elena Dall'Occo as they demonstrated that the novel pixel detectors together with the new VeloPix chip gave promising results in beam-tests at Cern. Fig. 3 shows the set-up of the experimental area.

A second team lead by Antonio Pellegrino constructed prototypes of modules for the large surface scintillating fiber tracker ('SciFi'). The team successfully managed to complete a challenging prototype of an end-piece of the detector module in which scintillating fibers are read out by Silicon Photomultipliers at a temperature of –50 °C.

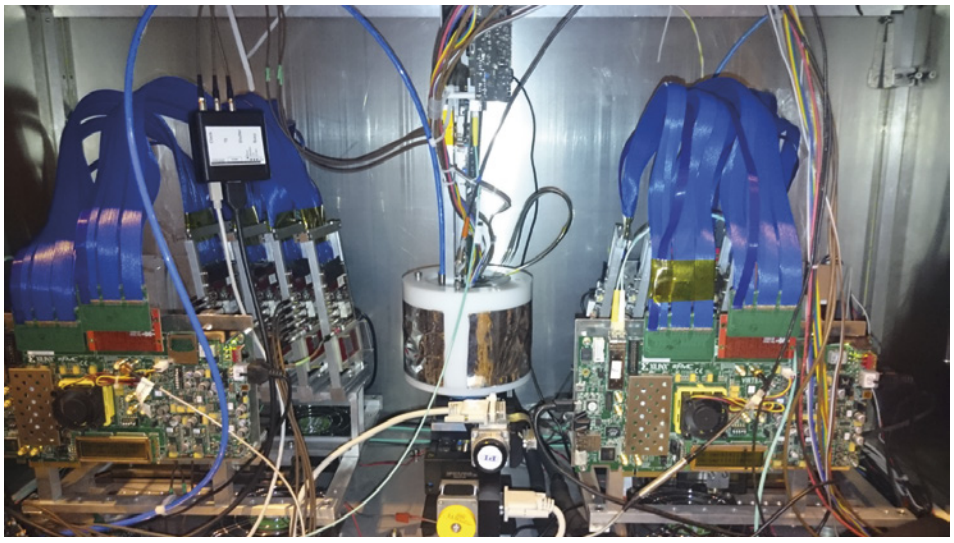
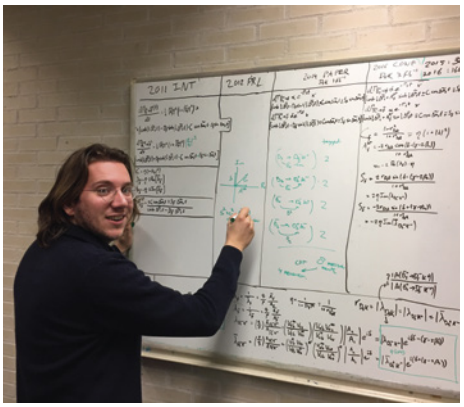


Fig 3. Picture of the beam test telescope at Cern used to test the prototypes of the upgrade Velo pixel modules.

Both the Velo and the SciFi teams are preparing to start the mass-production of detector modules in Nikhef cleanrooms in 2017.

Personal highlight of Lennaert Bel during finalization of angle gamma analysis

"Over the last year-and-a-half I've been working on a measurement of CP violation using the decay process $B_s \rightarrow D_s K$. I started off by sifting through all the LHCb data for this kind of events, as well as producing matching simulated data. Running these operations required immense computing power: I kept numerous computing nodes all across Europe busy, for weeks at a time! The next steps I worked on are a mass fit to properly separate the data from background, as well as a fit to the decay time of the B_s particles. The latter fit requires good knowledge of the accuracy of the decay time, for which I did an extensive study. It's very important to get this right, since it directly affects the measurement of the CP-violating parameters. In the end, we had to ensure that the numbers we got matched the quantities from the theory – as you can see, you need an entire whiteboard to work this out in full detail!"



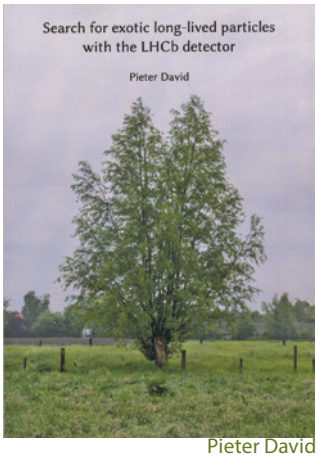
Lennaert Bel cross checking the mechanism of B meson oscillation and decay: was there a mistake with a minus sign?

Personal highlight of Elena Dall'Occo in Velo upgrade beam tests

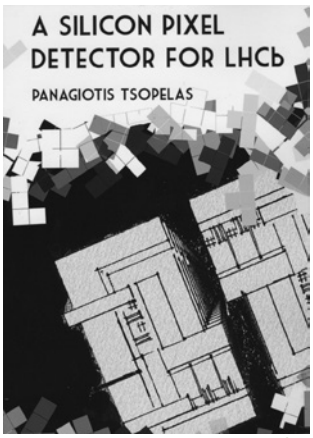
"As a PhD at Nikhef I have the great opportunity to contribute with my work to the upgrade of the LHCb experiment and specifically of the VErtex LOcator (VELO). From my point of view, the sensor characterisation project that I have been working on is a full experiment in its own right. The ultimate goal is to choose out of several prototypes the best sensor for the upgrade experiment, according to a series of beam tests and comparisons of their performance."

"The project allows me to learn how the experiment currently works and how we can improve it in the future. The tests are carried out using a beam of particles at the SPS (CERN) and a dedicated telescope (Timepix3 telescope) for tracking position and timestamp. When I started my PhD the telescope was already built and working beautifully, so I jumped directly in the middle of the operations. Doing shifts for the data taking was the best way for me to approach this new new subject and to see in reality what I had only read about on paper. The testbeam project has been a great and educational experience. Sitting in the control room in front of two screens with your co-shifter for many hours in a row requires more than pushing a button to start and stop the data acquisition. Every set of measurement is planned for a particular analysis and it is our duty to take the required amount of data and check their quality. As in each scientific experiment or analysis, there are always some issues, so it is important not to freak out but think calmly how to deal when problems occur and if you can't solve it by yourself: call the experts."

Jeroen van Leerdam
18 May 2016



Pieter David
7 July 2016



Panagiotis Tsopelas
21 November 2016

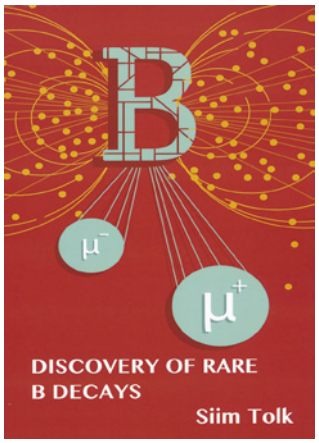
A testbeam involves working together not only with your colleagues, coordinating in the data taking and keeping track of the work done, but also with other groups/users on the same beam line and their needs. Of course being part of a great group of people makes it easier when there is a work related problem, but it is also a nice experience spending many hours together, including pizza/kebab breaks, and drinking litres of coffee to stay awake during the long nights waiting for the beam.

All in all I learnt a lot since I started, I keep learning at every shift and hope to continue in the future.

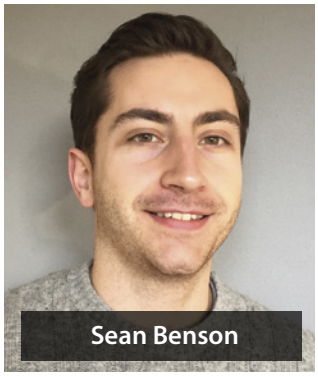
Jan Kluyver Prize Siim Tolk

Siim Tolk received the 2016 Jan Kluyver Prize for the best English summary of a Nikhef PhD thesis. The main result of his thesis with the title *"Discovery of Rare B Decays"* is the first ever observation of B_s meson decays into two muons.

The Jan Kluyver prize was established in 2010 by the Education Committee *(Onderwijscommissie, OWC)* of the Research School Subatomic Physics *(Onderzoeksschool Subatomaire Fysica, OSAF)*. The jury consists of the former directors of Nikhef.



Siim Tolk
8 April 2016


Sean Benson

LHCb Early Career Scientist Award

In September 2016, Sean Benson received the 'LHCb Early Career Scientist Award' for his contribution to the High Level Trigger, the so-called Turbo-stream.