Beam-Gas-Vertexing detector for transverse LHC beam profile measurement

Valdir Salustino Guimarães[1], on behalf of the BGV Collaboration

CERN and CBPF - Centro Brasileiro de Pesquisas Físicas[1]

Introduction

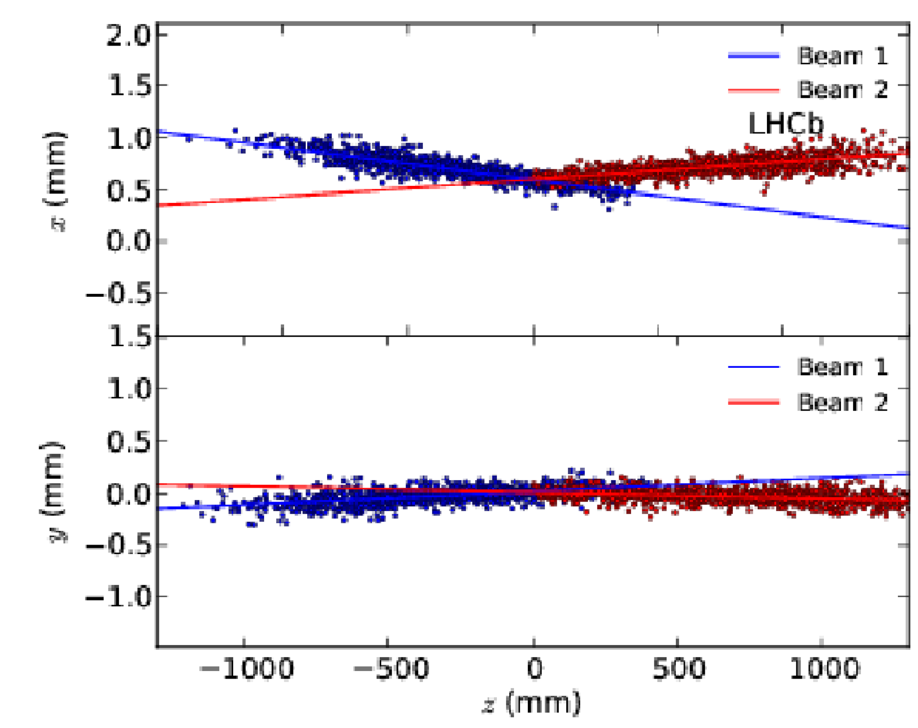
The Beam Gas Vertex (BGV) detector is foreseen as a non-invasive beam size measurement instrument for the LHC and its luminosity upgrade. This technique is based on the reconstruction of beam-gas interaction vertices, where the charged particles produced in inelastic beam-gas interactions are measured with high precision tracking detectors based on scintillating fibers (SciFi) read out by silicon photomultipliers (SiPM). The goal of the detector is to perform transverse beam profile measurements capable of providing the width measurements of each bunch with a ~ 5 % accuracy and of the whole beam with a ~ 2 % accuracy in about 1 minute. These target accuracies and measurement durations would allow meaningful measurements to be performed along the LHC energy ramp and a direct calibration comparison to be made with other beam profile monitors. Combined with an independent determination of the β functions of the magnetic lattice, the beam size σ depends on the emittance ϵ such that, $\sigma^2 = \epsilon\beta$, therefore the knowledge of the beam size will be used to provide precise values of the beam emittance (per bunch, or averaged over all bunches of one beam) throughout the LHC cycle.

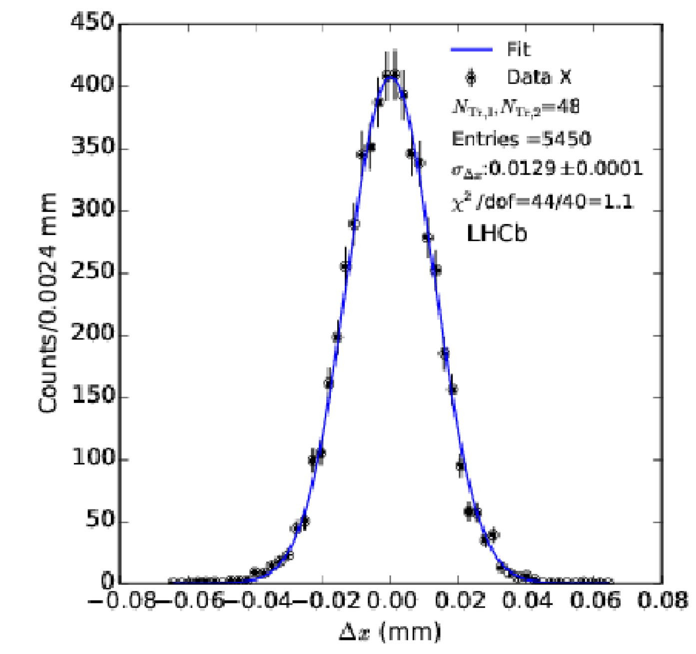
Strategy and previous experience

The chosen strategy is to demonstrate the capability of the beam-gas imaging technique for the LHC proton beam by using a prototype BGV system which was installed in the LHC ring 2.

A collaboration between CERN, EPFL Lausanne, and RWTH Aachen has been formed to design and develop this detector. The results and experience will be used to develop a more advanced BGV system which could be installed in the LHC during Long Shutdown 2 (2019).

LHCb beam profile measurements for luminosity calibration [1]:



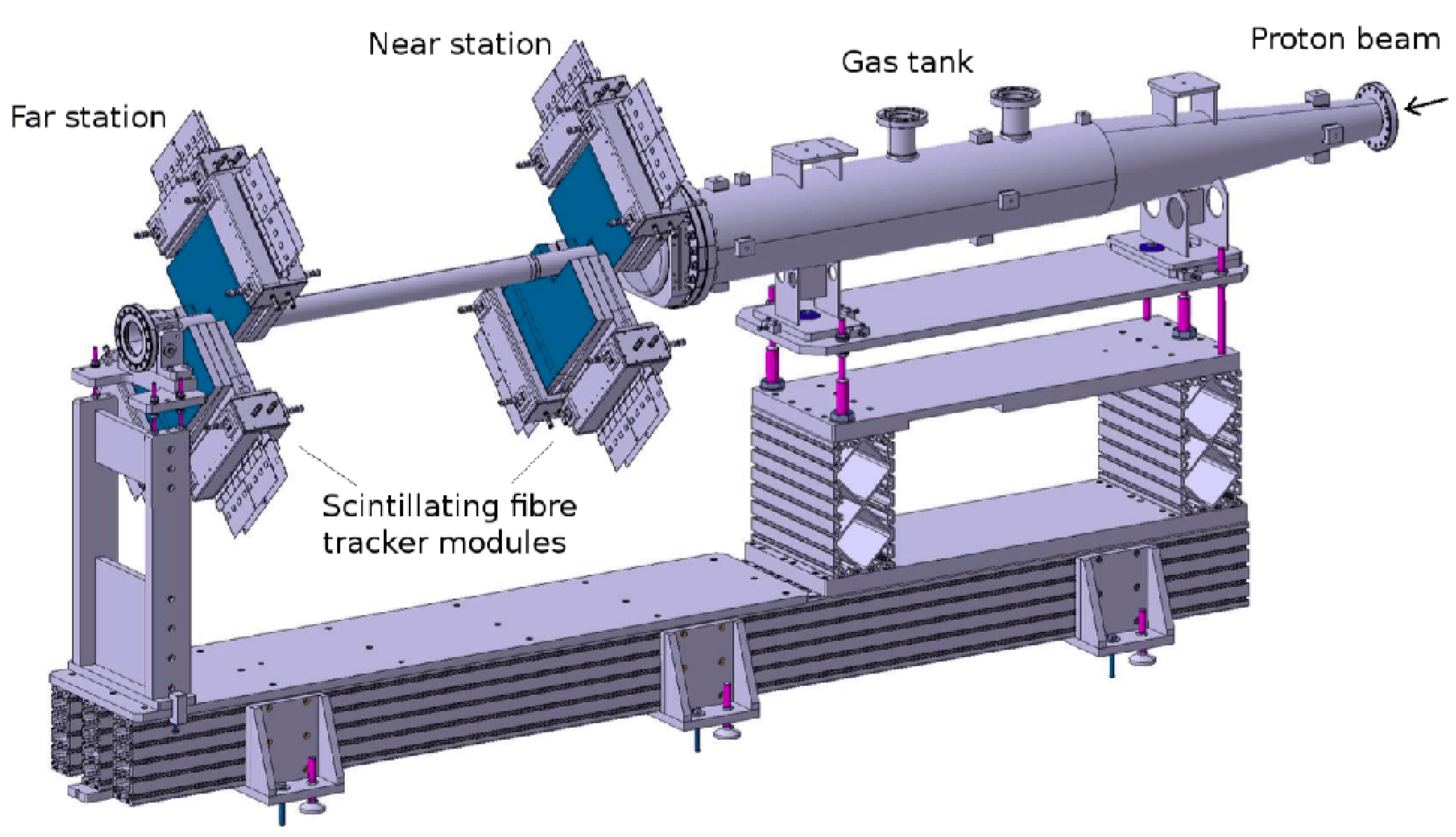


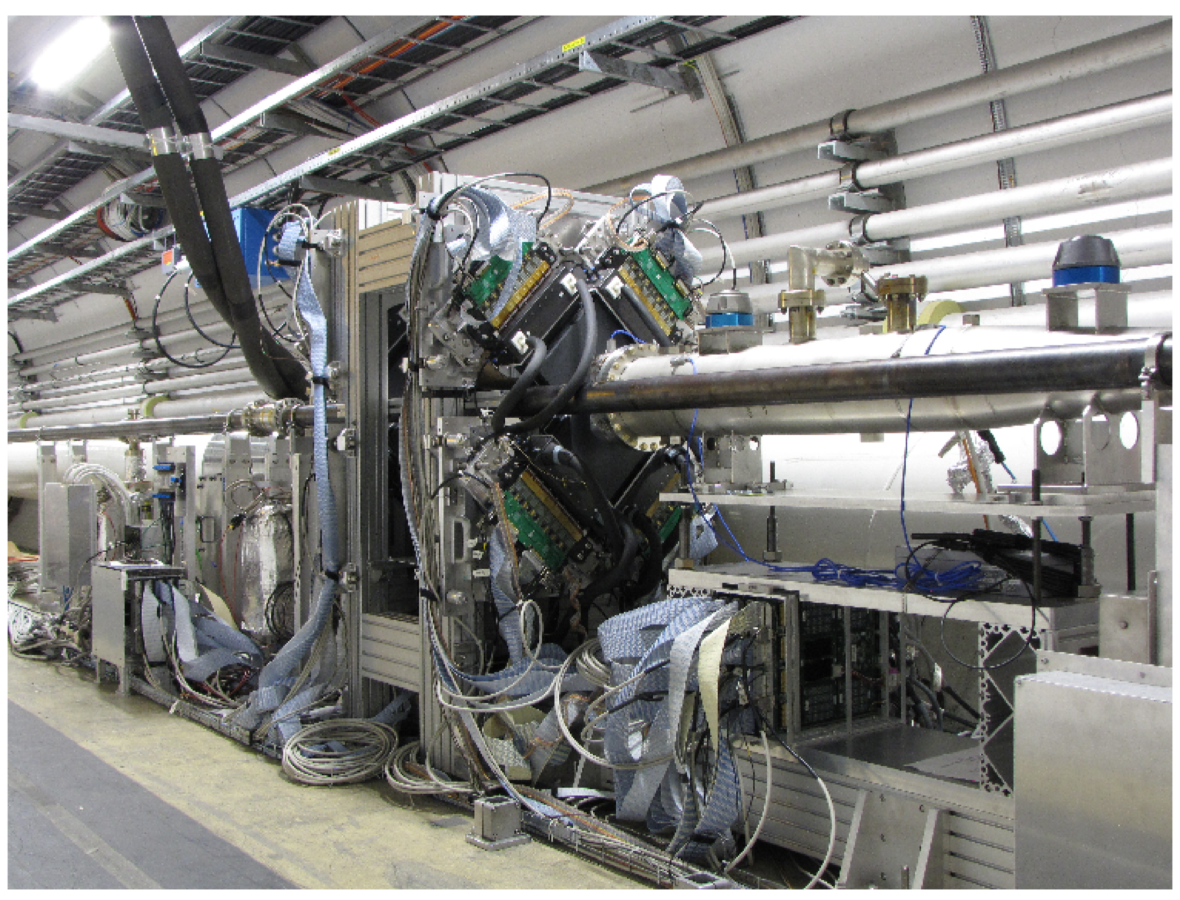
LHCb experiment pioneered the beam-gas vertexing technique by measuring geometrical properties of the LHC beam applied for determination of the absolute luminosity. The charged particles produced in inelastic beam-gas interactions are detected with high-precision tracking detectors to determine the interaction (vertex) positions. The beam-gas vertices reconstructed in a certain time interval are used to obtain an image of the beam.

The resolution of the measured beam profile depends on the beam-gas interaction rate (controlled by injecting a small amount of gas into the primary beam volume) and the measurement duration. The systematic uncertainty is dominated by the vertex resolution.

BGV Demonstrator

The BGV demonstrator was installed in 2015 and is currently being commissioned. It is situated at LHC point 4 and will measure the transverse beam profile of Beam 2. In addition, it can also be used to observe and measure ghost charges in the beam.





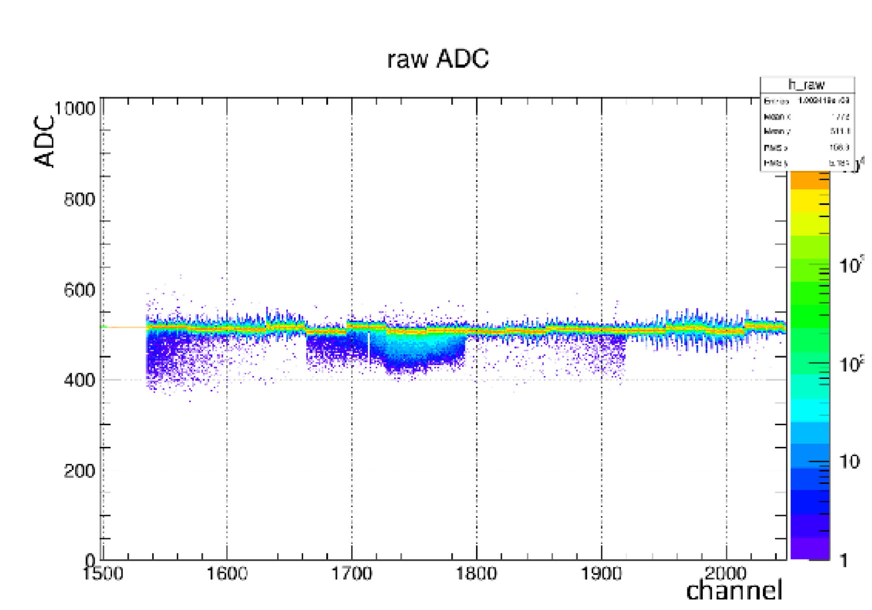
Expect first real-time beam profile measurements for 2017 *pp* runs.

Tracking detector: Two detector stations are situated downstream of the gas tank. They are made up of four modules each. The modules contain two scintillating fibre (SciFi) mats, rotated by 2° to each other for facilitated pattern recognition. The mats have 4 layers of fibres in the upstream detector modules, closer to the vacuum chamber and 5 layers in the downstream station. The fibre diameter is 250 μm. Two modules of each half station (upper or lower half) are installed one flat against the other, but with one module rotated by 90° such that each module measures an independent coordinate (X and Y). A particle is expected to leave 4 X- and 4 Y-hits, except in a small region of overlap between upper and lower halves where the number of hits is doubled.

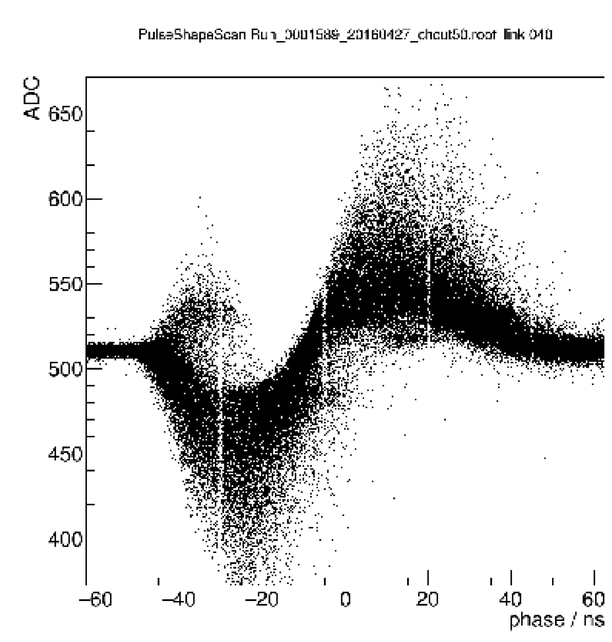
Gas target: The vacuum operates with neon gas injected with a pressure between 2×10^{-9} and 2×10^{-7} mbar. The expected interaction rate between the beam and the gas is of the order of 100 Hz per 10^{11} protons.

Redout: The detector is triggered by two sets of scintillating detectors. One set vetos beam-gas interactions occuring too far upstream of the gas tank. Each of the 16 SiPMs that readout the fibres is linked to a radiation hard Beetle chip [2]. The Beetle signals are amplified by repeater boards and then sent over 60m cables to the Tell1 readout boards [3], where data get digitised and then sent to the mini computing farm.

Performance under lab test Lab tests with radiation source and timing scan after installation.



raw ADC with Sr. source



pulse shape of the detectors

Challenge for 2017:

- Transport offline code to online system;
- Implement measurement algorithm in HLT farm;
- Setup communication with CCC;
- Implement a tracking alignment;

Reference

[1] The LHCb collaboration. Precision luminosity measurements at lhcb. *Journal of Instrumentation*, 9(12):P12005, 2014.

[2] M Agari et al. Beetle: A radiation hard readout chip for the LHCb experiment. *Nucl. Instrum. Methods Phys. Res., A*, 518:468–469, 2004.

[3] G. Haefeli, A. Bay, A. Gong, H. Gong, M. Muecke, N. Neufeld, and O. Schneider. The {LHCb} {DAQ} interface board {TELL1}. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, 560(2):494 – 502

Contact: vsalusti@cern.ch