Luminosity measurement of the LHC accelerator in CERN using ALFA detector

On March 30, 2011 at 13:06 CET, the first high-energy collision between proton beams was realized on a new Large Hadron Collider (LHC) at the European Organization for Nuclear Research CERN near Geneva. This event began the very expected research programme in particle physics, the aim of which is to allow the people to explore the secrets of nature being still hidden to us.

The main aims of research programmes, which are carried out on LHC, belong to the field of recognizing underlying phenomena of the matter. The objective of this concern is to seek for and consequently find the Higgs particle, nature of the dark matter, supersymmetry issues, studying the physics under conditions close to these, which took place immediately after the Big Bang event, and finally, during the collisions in LHC, it is also expected to uncover secrets which we nowadays only suspect.

The accelerator alone, together with its detectors, shows the top scientific technological level of the human race of the 21st century. The LHC accelerator was constructed in a circle tunnel approximately 100 metres under the ground level at the Swiss-French border and its perimeter is approximately 27 km. There are two tubes in which the proton or the lead ions beams are accelerated against each other at energies up to 14 TeV. There are four places where the accelerated beams are directed against each other and around them there are, in huge underground spaces, four huge detectors – ATLAS, CMS, ALICE and LHCb. The first mentioned detector having dimensions of 44x22x22 metres and weight of 7000 tonnes is recognized as the biggest detector ever constructed. The objective of the detectors is to catch as many particles as possible – these particles are generated during the collisions between accelerated protons or lead ions.

The Czech Republic actively takes part in the experiments which are being carried out on LHC. The most significant part plays the Academy of Sciences of the Czech Republic, Czech Technical University in Prague and Charles University in Prague. In January 2010, Palacký University in Olomouc represented by the RCPTM became one of the ATLAS project members. Our research division takes place in simulations, measurements and data evaluation on so called the primary ALTAS detector, which is intended for the absolute luminosity (intensity) calibration of the proton beams for the ATLAS detector.

ALFA detector is the scintillation trace detector designed for absolute luminosity evaluation. Detector monitors proton trajectory elastically deviated at the angles in microradians in the interaction point of the ATLAS detector, in other words in the forward field of the interaction point. ALFA detector consists of four stations, two on each side from the interaction point in the distance of 240 metres (see Figure 1). Each station constitutes of a pair of so called upper and lower Roman pot (see Figure 2). Every Roman pot consists of a set of scintillation fibres (Figure 2b) which are used for recording tracks of the scattered protons. The characteristics of the proton beam is unknown in this field and to make a reasonable description, it is necessary to place the Roman pots with accuracy up to 10 μm.

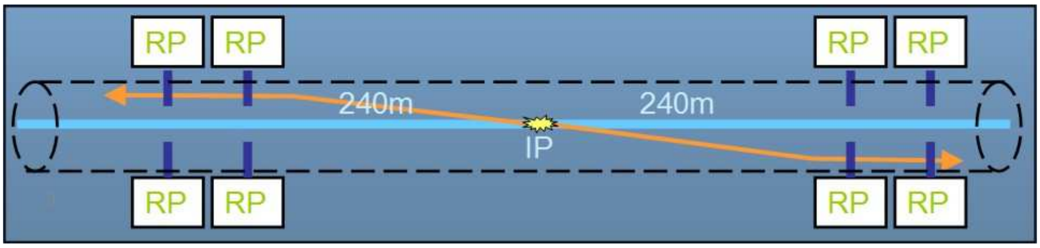

Figure 1 – Arrangement of stations in the ALFA detector.

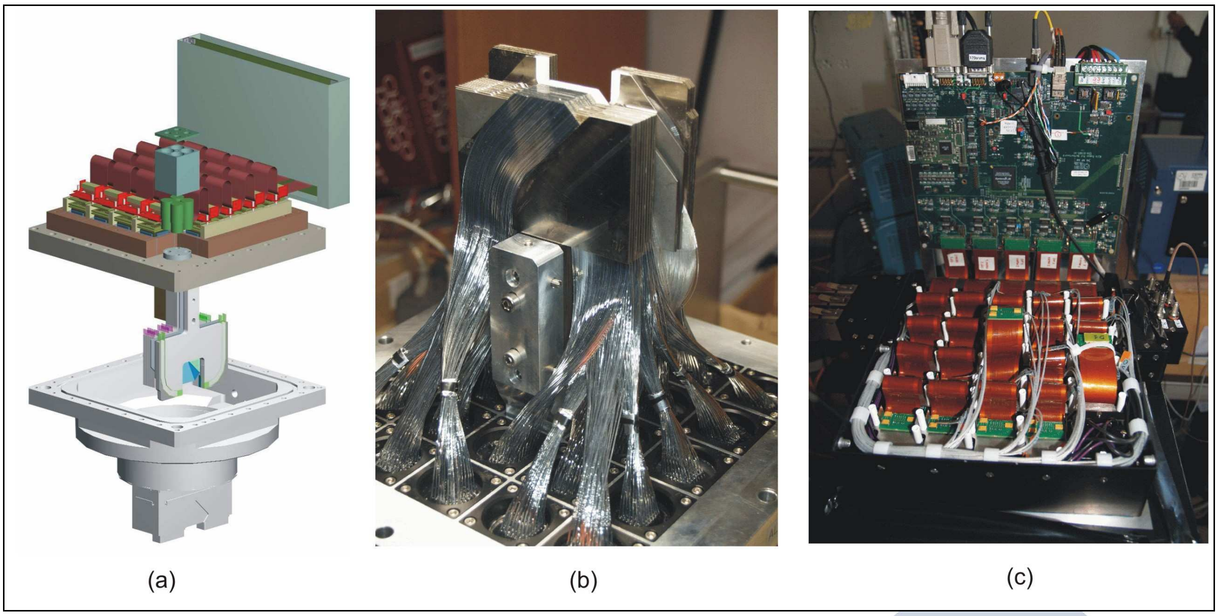

Figure 2 – (a) Roman pot scheme, (b) set of scintillation fibres, (c) electronics overview.

Our workplace works on modeling separate detectors in a unified ATHENA software environment, in which the whole ATLAS project operates, and construction of evaluative algorithms for the data processing. In the case of modeling, we work on introducing the ALFA detector geometries to the measuring system including their material properties and real metrology. This modeling is necessary not only for understanding the physical processes occurring in the forward field of the ATLAS detector but also for accurate track reconstruction of the proton beam during luminosity measurements. Moreover, we also work on several evaluative algorithm types for reconstruction and analysis of proton tracks, which are being used for determination of detector resolutions and luminosity.

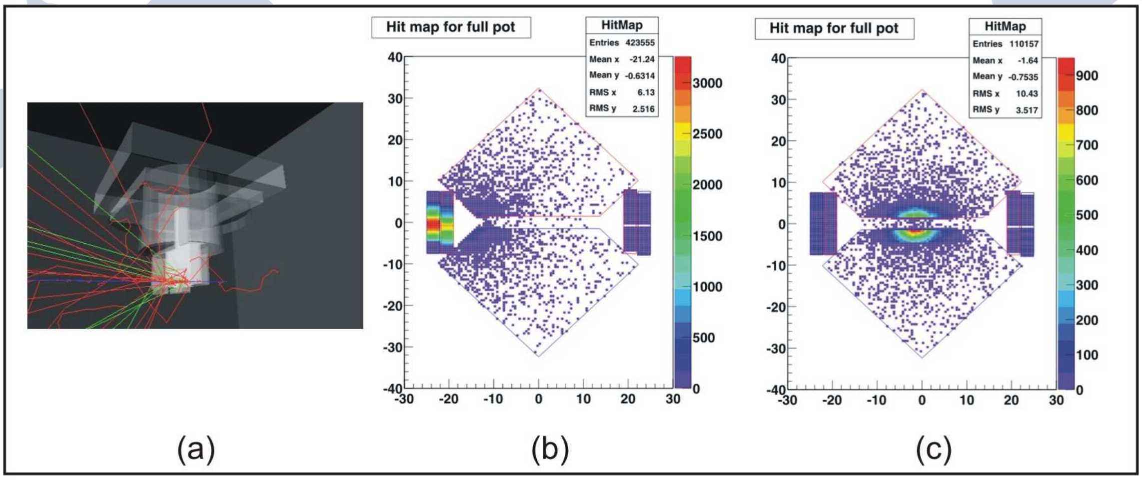

Figure 3 – (a) Example of visualization, (b)-(c) examples of proton beam reconstruction during testing.