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Prospects for Heavy Ion Physics with LHCb

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Abstract

We will discuss the potential of the LHCb experiment in the field of Heavy Ion physics. We will analyse three different scenarios which can be explored by the experiment, namely collisions of protons with lead, lead with lead and proton or lead beams with a gas injected in the interaction region. We will also show results in some of these configurations.

Keywords: Quark-gluon plasma, Quarkonia, Heavy-Flavour, SoftQCD, Electroweak, Cold Nuclear Matter, Fixed target

1. Introduction

Nucleus-nucleus collisions are a tool to reach ultra high energy densities where the properties of matter can be studied in a unique way. The quarks and gluons are usually bound together by the strong interaction and cannot be isolated. However when the nuclear matter density becomes very large, the matter is expected to transform into the quark-gluon plasma (QGP) state, in which quarks and gluons move freely. This phenomenon could be due to the colour screening of the strong force. At the Large Hadron Collider (LHC) at CERN we could be able to study the formation of QGP and observe the transition from "cold" regular matter to this "hot" nuclear matter (the QGP). While colliding protons is the default operation mode of the LHC, for about one month every operational year the LHC is configured to collide heavy nuclei head-on or with protons, in the attempt to recreate the QGP, which has been hunted for both in fixed target facilities at the CERN SPS and in heavy-nuclei collisions at RHIC and LHC. Although indications of QGP formation exist, the understanding of this unconventional state of matter is far from being complete and precise experimental data are needed.

The LHCb detector at the LHC at CERN could help to shed light on this issue. LHCb [1] had never before collected data in AB collisions (collisions of nucleus A with nucleus B), contrary to the other three large LHC experiments, and had participated in the proton-lead collisions run in 2013 collecting about 1.6 nb^{-1} of data. With the limited luminosity collected that time, LHCb did provide a number of interesting results [2, 3, 4, 5] with precision inaccessible to other experiments, revealing the potential of the experiment in this field.

For the present data taking period of the LHC, the LHCb physics programme has been extended to collect data in three different experimental scenarios: collisions of protons with heavy nuclei (pA) and of heavy nuclei (AB/AA, in two different operation modes). In addition to the proton-lead and lead-lead collisions delivered by the LHC, the LHCb experiment will also operate in a completely new "fixed-target" setup where proton or lead beams will be collided on a gaseous target and the data recorded. The fact that data can be taken in both colliding-beam and fixed-target mode is a key feature of the LHCb heavy ion programme.

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Table 1: Beam-target configurations and nucleon-nucleon centre-of-mass energies accessible for LHCb. Here “GAS” stands for the gas, Ar, Ne or He, injected in the LHCb fixed target running setup (SMOG). Data already exist for the configurations in bold.

E_{beam}(p)	pp	p-GAS	p-Pb/Pb-p	Pb-GAS	Pb-Pb
450 GeV	**0.90 TeV**				
1.38 TeV	**2.76 TeV**				
2.5 TeV	**5 TeV**	**69 GeV**			
3.5 TeV	**7 TeV**				
4.0 TeV	**8 TeV**	87 GeV	5 TeV	54 GeV	
6.5 TeV	**13 TeV**	**110 GeV**	8.2 TeV	**69 GeV**	**5.1 TeV**
7.0 TeV	14 TeV	115 GeV	8.8 TeV	72 GeV	5.5 TeV

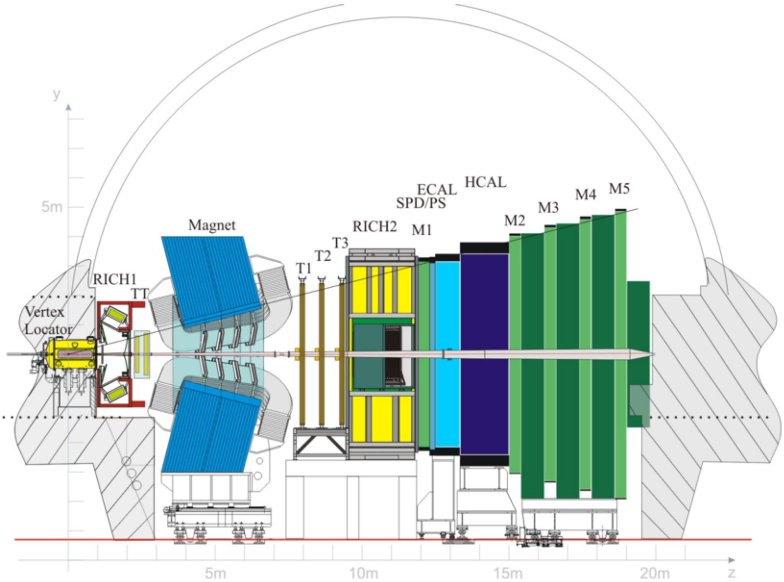

Fig. 1: View of the LHCb detector in the zy plane. The beam crosses the detector in the z direction, from left to right.

In fixed target mode a noble gas is injected in the interaction region. The system used for the injection, called SMOG (System for Measuring the Overlap with Gas), was originally designed for precise luminosity measurements in dedicated runs [6]. The novelty is the idea to use this system also to study collisions of protons or lead-ions with the nuclei of the noble gas over longer periods of time at different centre of mass energies, between 87 and 115 GeV(p-GAS) and 54-72 GeV(Pb-GAS), where GAS stands for He, Ne or Ar gas. The rapidity coverage in the nucleon-nucleon centre-of-mass frame is about $-3 < y < 1$. In two pilot runs in 2012 and 2013 LHCb looked at strangeness production in p-Ne and Pb-Ne collisions [7] and clear signals for strange mesons were observed in the detector.

Table 1 shows which beam target combinations and which nucleon-nucleon centre-of-mass energies are accessible for LHCb. The LHCb detector is shown in Fig. 1. An important feature of LHCb is its vertex locator detector (VELO) which is moved at about 8 mm from the beam pipe during operation mode, and allows us to achieve a resolution on the impact parameter measurements of about 20 μm. The LHCb kinematic coverage is shown in Fig. 2. A sizeable fraction of the phase space is covered by the detector, which compared to other experiments has the unique advantage to have precise tracking and vertexing, calorimetry and powerful particle identification in the full acceptance. In colliding beam mode the forward/backward