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Vacuum predictions and measurements for an internal Pellet Target at a storage ring

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Abstract

Measurements with low Z targets at internal experiments typically imply a gas load which deteriorates the vacuum of a storage ring. Future experiments need reliable estimates for the expected vacuum conditions in order to design 4π detectors closely surrounding the interaction area.

We present a method for the calculation of the resulting vacuum of such a complex system using a Pellet Target. In order to test the method, a vacuum system with diagnostic tools has been set-up and a Pellet Target was operated under realistic conditions. The results for the absolute vacuum agree within factors of two with the expected pressures.

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1. Introduction

Modern storage rings need a high vacuum throughout the whole ring to maintain the requirements on beam precision and lifetime. Internal experiments covering 4π acceptance have typically little space for vacuum pumps close to the interaction point. This is, however, the region where a high gas load is introduced if windowless gas, cluster, or Pellet Targets are used. When planning a new experimental facility the dimensions of the vacuum system have to be adjusted such that an acceptable pressure is reached inside the ring. In order to do this, it is crucial to have the means to predict the vacuum taking the geometry and gas load by the target into account.

In this paper we present a method to calculate the vacuum in such a system and compare it with measurements of the vacuum in a dedicated test stand. The measurements and calculations were done using a vacuum system which is similar to the one anticipated for the future PANDA experiment [1] and a Pellet Target as the source of gas.

A Pellet Target consists of micro-spheres (about 30 μm in diameter) of frozen gas called "pellets". Typically, hydrogen, deuterium, or noble gases are used. The pellets travel with speeds of 50–100 m/s and a spread of about 1 mrad. Thus the production can be metres away from the interaction point. Such a target was used at the CELSIUS/WASA experiment and is currently in operation at COSY [2,3]. A copy of the generator of this target was set-up as a testing facility at The Svedberg Laboratory (TSL), Uppsala, Sweden. The Pellet-Test Station (PTS) has been equipped with a full vacuum system in order to perform the measurements discussed below.

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2. Experimental set-up

The PTS is a fully operational target which has been built to test and further develop the Pellet Target at CELSIUS/WASA. It is a completely independent system and the pellet generator is largely a copy of the WASA target. The details of the pellet generation can be found in Ref. [2]. The basic principle is that gas, e.g. hydrogen, is liquefied in a first stage and small droplets are formed by vibrations with 50–100 kHz. These are then injected into vacuum which causes freezing. The point of vacuum injection is often referred to as the point of production, and we set our scale to it. To avoid large tails of the distribution of the pellet stream and to define the width at the interaction point, a skimmer is used at some point on the pellets' path. Typically rates of several thousand pellets per second are reached for a total width of the stream of about 2 mm at an interaction point about 2 m below the vacuum injection.

The PTS differs by the following items from the original WASA target [2]:

- The cold head has been improved, leading to lower vibrations, faster pumping, better temperature and vacuum control.
- The construction has been redesigned in order to allow for better access and faster exchange of parts on the generator, while keeping compatibility with the WASA system.
- A new vacuum system has been added, which is designed to simulate the interaction region of PANDA vacuum-wise. It allows vacuum measurements at five points and visual observation of the pellets on two levels. Here cameras, counters and a line-scan camera have been installed [4].

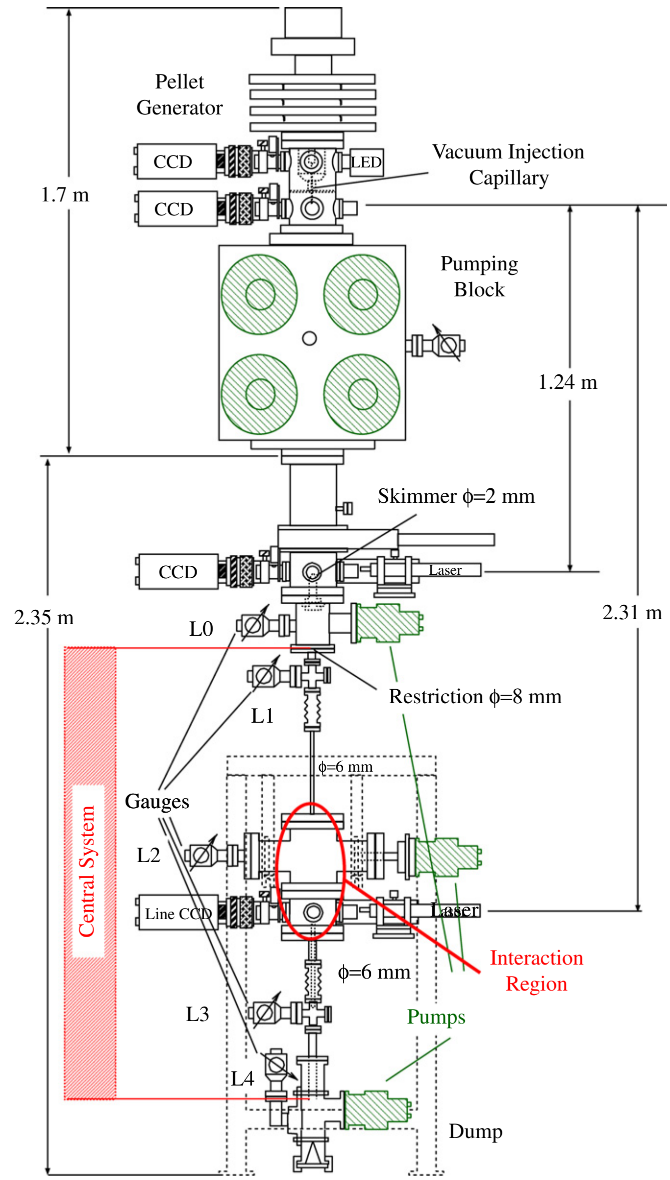

Fig. 1. Sketch of the Pellet-Test Station (PTS). The Pellet Generator (top) ejects pellets at the vacuum injection capillary, which pass a skimmer 1.24 m below and reach the *interaction region* about 1 m further below. Finally, they are collected in the Dump (see also Table 1). The vacuum system resembles the situation inside a 4π detector, where the beam would enter the interaction region horizontally.

A side view of the system is sketched in Fig. 1 and important parts and their distance to the production are listed in Table 1. The pellet-generation system is mounted on top of a block, which contains four turbo-molecular pumps with a pumping speed of 2800 l/s each. It should be noted that all the pumping speeds given in this document refer to the respective values for hydrogen, as this is the gas we consider here. During operation the pressure in the block is typically 10^{-5} mbar.

The skimmer, a cone with a hole of 2 mm that cuts the tails of the pellet distribution, is positioned below the Pumping Block. The upper observation chamber holding this skimmer is used to align the pellet stream such that a large fraction of the pellets pass through it. A side effect of such a skimmer is that some pellets are deflected only slightly when hitting the rim or inner surface. These continue with the stream and may produce large gas loads, where the system is narrow and difficult to pump. In order to remove these, a second restriction of 8 mm diameter is placed 27 cm below the skimmer. To pump the gas away, the chamber between is equipped with a turbo-molecular pump with 150 l/s and a vacuum gauge of Pirani type (L0).

When installing such a system at a large experimental set-up, the skimmer would be placed much further up, e.g. in the middle of the Pumping Block. In this case much more space would be available for detectors while leaving the properties of the pellet stream unchanged.[1]

Below this point the components which simulate the vacuum system inside a future detector follow. It is referred

[1]This is because the diameter of the skimmer can be changed accordingly. Studies with several skimmer sizes have confirmed the expected geometric relation without significant distortion.