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Optimization of the gas system in the CMS RPC Detector at the LHC

Jiwoong Seo for the CMS Collaboration

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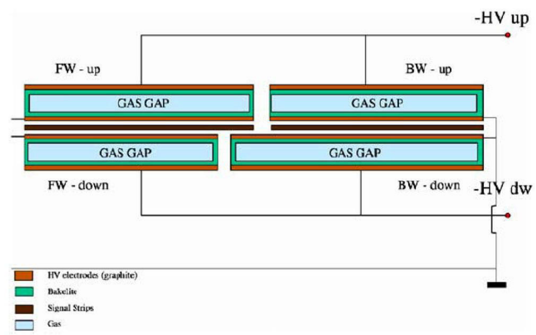

Fig. 1. Resistive Plate Chambers (RPC) design. It consist of two gaps and filled up gas mixture.

I. Introduction

In the middle of February 2013, the Large Hadron Collider (LHC) went into a long maintenance stop. Running will resume in 2015 with increased collision energy and luminosity. The 2013/2014 Long Shutdown-1 (LS-1) is a chance for its experiments to upgrade their detectors.

The muon system of the Compact Muon Solenoid (CMS) experiment is composed of a central barrel and two closing endcaps. The Resistive Plate Chambers (RPCs) system is part of the muon detection system in the CMS and is used for triggering purposes. RPCs have been chosen because of their fast time resolution (about 2 ns) and high granularity, which permit a fast and efficient triggering of muons over large areas [1]. They also contribute to the identification, reconstruction and tracking of the muons [2].

RPCs are ionizing-particle detectors consisting of two gaps filled up with gas. They are used as dedicated trigger detectors but they also contribute to the muon reconstruction at CMS. The CMS RPC detectors are divided in three regions which are two endcaps and a central barrel, in total there are 480 RPCs in the Barrel region, and 432 RPCs in the endcap regions covering more than 3000 m^2.

Figure 1 shows the Resistive Plate Chambers (RPCs) design. RPCs consist of two partially overlapped double gaps. Each double gap is made by two single gaps with common pick-up conductive strips in between. The gaps are filled with non-flammable gas mixture, it consist of 95.2% $C_2H_2F_4$ (Freon), 4.5% iC_4H_{10} (isobutene) and 0.3% SF_6 (sulfur hexafluoride).

The RPC gas system uses a recirculation (closed loop) gas system developed by the CERN gas group because of high costs and huge volumes of the Freon-based gas mixture used. With a fresh injected amount of gas limited to only 10%, the collection of contaminants could be a serious problem that must be monitored. Thus, the closed loop is a critical component of the CMS RPC system.

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II. THE GAS LEAK TEST

We prepared a method and portable system to find the leaks in the RPC chambers, and to measure the leak rates. In the cavern where is 100 m underground, there are the five gas racks with the purpose of gas supply and return for the wheels in the barrel region. Each gas rack has 50 channels, distributed in the manifolds.

The total leak rate on the barrel increased between 2011 and 2012 while the endcaps was negligible during the same period, therefore we focused on the barrel region. In order to setup a leak detection system at the cavern, the pre-campaign for the known leaky chambers was performed during May and June 2013. A bottle of N_2H_2 gas has been installed in the cavern to search a leak, and the Argon gas could be directly provided through the gas rack to measure the leak. The leak rates were measured by using the leak box which is a special tool supported by CERN gas group.

A. *Identifying leaks on the RPC chambers*

To find the leak location, inject Argon gas to each RPC channels using the leak box, get pressure logs and classify the potentially leaky chambers. Figure 2 shows the pressure logs if the similar trend of the magenta or the red line after investigation it is a potential leak chamber. For the investigation on the known leaky chambers, skip this process.

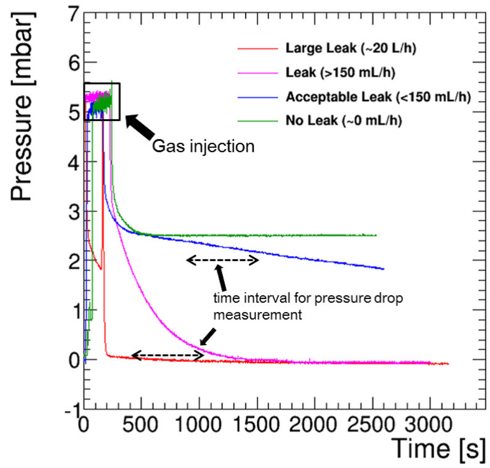

Fig. 2. Pressure vs. Time log examples. This figure shows four different kinds of RPC gas leaks. These are the raw data examples taken with the gas leak box. The green line shows a stable leak. The blue line shows an acceptable leak. The magenta line shows a bigger leak than the blue line. The leak rates were calculated after a stabilization time of maximum 10 minutes, they were calculated using pressure drop intervals of 10 minutes. The red line shows a very large leak, this leak cannot be measured with the leak box. Instead that kind of leak was estimated using the input rate of the gas.

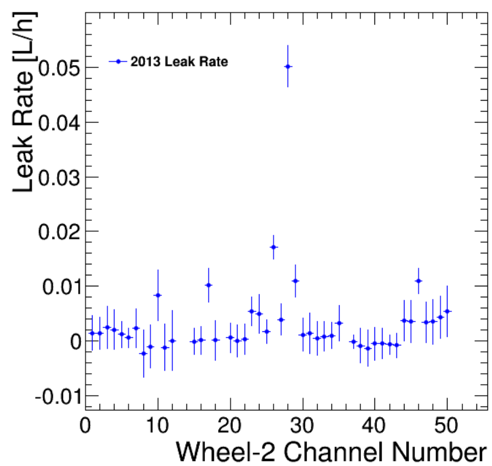

Fig. 3. Leak rates vs. Wheel -2 channel numbers. This shows the calculated average leak rates and their assigned errors for wheel -2 channels. Channels 13, 14, 19 and 36 had large leaks, therefore they were excluded from the plot. This is a typical example for leak rates.

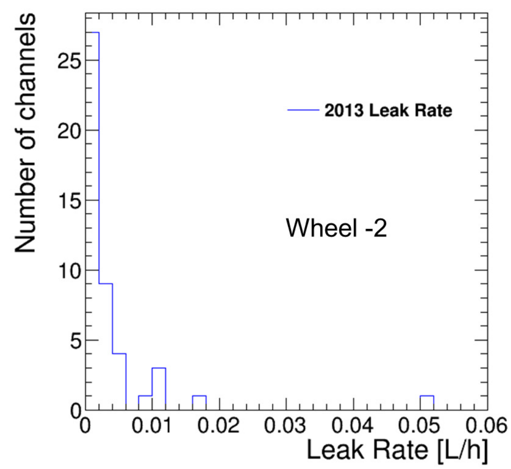

Fig. 4. Distribution of the leak rates for wheel -2. This shows the distribution of the leak rates for wheel -2 channels. This is a typical example too. Almost all channel-leak rates were less than 0.01 L/h. Channels with large leaks were excluded.

Stop the Argon gas injection after classification, followed by injection N_2H_2 gas to the potentially leaky chambers in order to localize leak using a sniffer. During the N_2H_2 flows, the patch panels, service blocks, and pipe connectors are checked. A sniffer makes beep sound once detect leak (external leak or internal leak). When the external leaks were located, some of them were repaired. Most of the leak were due to the external connectors. In spite of reparation, some leaks remained, these leaks were internal.

To measure the leak rates, inject Argon gas to each RPC channels using the leak box and wait until the RPC chambers are filled with Argon gas. Detected the bubbles in the backside of the leak box, it means the RPC chambers get over pressure and filled with Argon gas, therefore stop the gas flow and take the pressure log for 30 minutes. Save the data and calculate the leak rate using pressure drop intervals of 10 minutes.

B. Calculating the leak rates

After measuring the pressure of all channels or some channels, we can calculate the leak rates using a two point subtraction technique.

$$rate(t_i, t_f) = \frac{T_0}{P_0}\frac{Vol}{t}\left(\frac{atm_i - p_i}{T_i} - \frac{atm_f - p_f}{T_f}\right) \times 3600 \tag{1}$$

The unit of the equation is Liters per hours (L/h). Vol represents the volume of RPCs between 20 liters and 50 liters, and t represents $t_f - t_i$ commonly 10 mins. This equation gives only one stable value even though in some cases there is a time dependence. Therefore, the equation was improved to get a more descriptive value and a better error estimation.

$$rate = \frac{1}{n}\sum_{\Delta t=0}^{n} rate(t_i + \Delta t, t_f + \Delta t) \tag{2}$$

We took the average value of the leak rates as the central measurements, and the errors were assigned by taking the difference between the central values and the highest and lowest measured value. Figure 3 is the result of the Eq. 2. We can estimate errors and calculate the average value of the leak rate. Figure 4 shows distribution of the leak rates for wheel -2. We can see almost chambers has low leak rates less than 0.01 L/h.

C. Preliminary results of the gas leak campaign

We have investigated 21 known leaky channels in the barrel region. After investigation during summer 2013, we found that 18 channels were leaking internally. Unfortunately, 6 of these channels have leaks undetectable by a sniffer. One channel was fully repaired and two channels were partially repaired. The total leak rate was reduced by about 12% in the first year

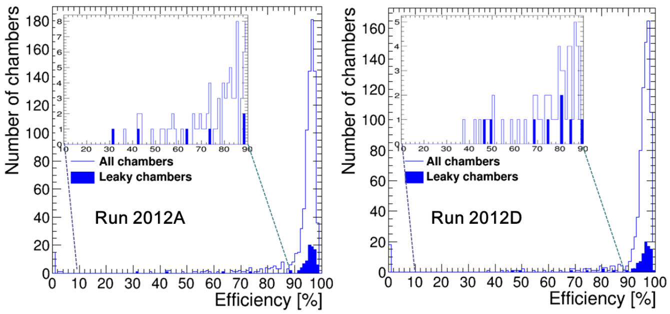

Fig. 5. Distribution of the efficiency in real data.

of the LHC LS-1 (2013) and further investigation of barrel and endcap regions is ongoing at the CMS.

III. RPC EFFICIENCY FOR THE LEAKY CHAMBERS

A study was performed to check whether any correlation between the detector performance and a gas leak is visible or not. We compared all chamber's efficiency with leaky chamber's efficiency using real data in 2012.

Figure 5 shows the distribution of efficiencies of the known leaky chambers (>150 mL/h) compared to all the chambers. There is no big difference in the efficiency between all the chambers and the leaky chambers. We conclude that the chamber efficiency is no hugely affected by a leak. Further studies are foreseens.

IV. CONCLUSIONS

During the Long Shutdown-1 (LS-1) started from the beginning of 2013, the RPC system will be upgraded and maintained. A gas leak test was setup in the CMS experimental cavern where is 100 m underground. The leak test was performed using a sniffer with N_2H_2 gas and a leak box with Argon gas. The total leak rate was reduced by about 12% in the barrel region during the first year of LS-1 (2013). The gas leak campaign was performed and the leak rates were measured with assigned conservative uncertainties. We conclude that the gas leaks do not affect the RPC detector performance significantly. The LHC LS-1 will continue until the end of 2014, hence the gas leak results will evolve accordingly.

ACKNOWLEDGMENT

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