New gas distribution system for the ATLAS RPCs

Giulio Aielli^{a, c}, Enrico Pastori^{b, c, *}

^a *University of Roma Tor Vergata
Via della Ricerca Scientifica 1, Roma, Italy*

^b *INFN Roma Tor Vergata
Via della Ricerca Scientifica 1, Roma, Italy*

^c *on behalf of the ATLAS MUON collaboration*

E-mail: enrico.pastori@roma2.infn.it

ABSTRACT: a new gas distribution system for the ATLAS RPCs is developed aimed at equalizing the flow with respect to the average counting rate per gas volume. The system takes into account the expected luminosity foreseen in superLHC (sLHC) and the consequent increase of gas flow necessary for the proper operation.

KEYWORDS: Gas systems and purification; Resistive-plate chambers; Large detector systems for particle and astroparticle physics;

* Corresponding author.

Contents

1. Introduction	1
2. Gas flow equalization	2
3. Impedances for the gas distribution system	3
4. First check of the system and conclusions	5

1. Introduction

The Resistive Plate Chambers (RPCs) [1] detectors are used as muon trigger detectors in the ATLAS Experiment [2] at CERN-LHC accelerator. RPCs are gaseous detectors in which the quality of the gas mixture as well as the design of the gas supply system [3], play a fundamental role in their functioning.

The ATLAS RPC gas system consists of 2080 gas units with volumes ranging from 1.36 to 10.77 l. The first parameter for the gas-flow equalization is the number of volume exchanges. This parameter has driven the project of the existing gas-distribution system (Fig.1) [4] that was planned to increase total flow¹ with the increase of the ATLAS background. At the moment, as a consequence of some gas leaks, the gas-flow increase is practically impossible. Almost all of the gas-gap problems noticed until now are related to insufficient gas flow. We also realized that almost all of the found gas leaks are greater than expected due to a misbehaviour of the gas distribution at the existing gas-flow rate². For this reason and with a better understanding of the actual ATLAS background we considered the possibility to replace the old gas-distribution system.

Figure 1: Atlas RPC gas distribution system

¹ maximum design value 1 volume exchanges per hour

² due to a too small ΔP at current gas flow rate (section 3)

2. Gas flow equalization

The average value of the measured current in each RPC gas volume (Fig.2), cleaned from all detector systematic contributions, represents the average charge per second delivered in the gas gap due to the incident particle rate. With the data collected in more than one year at a luminosity up to $3 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ (about 1/3 of the LHC design value), and with a better knowledge of the LHC-induced background [5], it is possible to choose a better gas equalization taking into account the measured charge per gas volume flowing through the detectors.

Figure 2: The average current per m² measured. Notice the excess on chamber number 5 in both sides.

The flow needed in each RPC gas volume is proportional to the total charge rate delivered in the gas, which is in turn proportional to the electric current flowing through each RPC gap [6].

In any case as a precaution a minimum gas flow of 0.15 volume exchanges per hour has been granted to all the gas gaps irrespectively to the current, which corresponds to about one half of the total circulating flow.

Taking into account these two constraints, we have redistributed the total gas flow budget available to reduce the high tail of the deposited charge per unit volume distribution (Fig.4); this at the cost of providing a wider dynamic range through a completely new system of gas distribution (Fig.3). Indeed the charge deposited in the gas per unit volume inside the detectors is one of the most important parameters driving the RPCs to malfunctioning and faster ageing [7].

Figure 3: Gas flow distribution

Figure 4: Charge deposited inside each detector per unit volume.

3. Impedances for the gas distribution system

The starting point in designing the system of distribution of the gas flow is the Hagen–Poiseuille law:

$$\Delta P = \frac{8\mu L}{\pi r^4} \Phi \quad (1)$$

The equation (1) gives the pressure drop (ΔP) in a fluid with dynamic viscosity μ flowing through a cylindrical pipe of length L and radius r with the assumptions that the flow Φ is laminar, viscous and incompressible (in our case this is true because $\Delta P \ll$ atmospheric pressure) and the flow is through a hose of constant cross section and of a length substantially greater than its diameter. The flow of the fluid is turbulent for velocities above a threshold (Reynolds number greater than 2000), leading to larger pressure drops than those expected according to the Hagen–Poiseuille equation.

In the limit of validity of Hagen–Poiseuille law starting from a common manifold it is possible to distribute the gas in a certain flow in different gas layer by connecting a gas impedance of appropriate value in series with the assumption that the pressure drop in each gas layer is negligible compared to the pressure drop on the impedance.

We have set the pressure drop in each impedance to 6 mbar which is much greater than the pressure drop in each gas layer plus the return manifold pressure. The value of 6 mbar is situated well inside the range of values that can be set in the gas racks and is not so high as to become dangerous in the event of output block.

For the construction of these impedances, a set of commercial dosage needles (Tab.1) with a very strict tolerance of the inner diameter was chosen (the gas impedance depends on the fourth power of the inner diameter). In each needle the pressure drop at working point leads the gas velocity well below the turbulence point (Tab. 2).

Needle Type	1	2	5	6	7	8	9	10	11	12	13	15	16	17	18
DI (mm)	0,254	0,254	0,305	0,330	0,330	0,330	0,330	0,406	0,406	0,406	0,406	0,508	0,508	0,508	0,508
Length (mm)	11,80	18,20	19,20	11,80	18,20	30,80	43,10	11,80	18,20	30,80	43,10	11,80	18,20	30,80	43,10
Quadratic term	0,802	1,083	0,676	0,299	0,332	0,342	0,486	0,129	0,120	0,164	0,169	0,060	0,064	0,064	0,089
Linear term	2,920	4,073	2,731	1,051	1,813	2,570	4,120	0,649	0,775	1,325	1,868	0,291	0,368	0,610	0,735

Table 1: Type of needles used.

Gas Flow l/h	Needle Type															
	1	2	5	6	7	8	9	10	11	12	13	15	16	17	18	
3	1289	1289	1074	992	992	992	992	807	807	807	807	645	645	645	645	
4	1719	1719	1432	1323	1323	1323	1323	1076	1076	1076	1076	860	860	860	860	
5	2149	2149	1790	1654	1654	1654	1654	1344	1344	1344	1344	1075	1075	1075	1075	
6	2579	2579	2148	1985	1985	1985	1985	1613	1613	1613	1613	1289	1289	1289	1289	
7	3009	3009	2506	2316	2316	2316	2316	1882	1882	1882	1882	1504	1504	1504	1504	
8	3439	3439	2864	2647	2647	2647	2647	2151	2151	2151	2151	1719	1719	1719	1719	
9	3868	3868	3221	2977	2977	2977	2977	2420	2420	2420	2420	1934	1934	1934	1934	
10	4298	4298	3579	3308	3308	3308	3308	2689	2689	2689	2689	2149	2149	2149	2149	
12	5158	5158	4295	3970	3970	3970	3970	3227	3227	3227	3227	2579	2579	2579	2579	
14	6017	6017	5011	4632	4632	4632	4632	3765	3765	3765	3765	3009	3009	3009	3009	
18	7737	7737	6443	5955	5955	5955	5955	4840	4840	4840	4840	3868	3868	3868	3868	
22	9456	9456	7875	7278	7278	7278	7278	5916	5916	5916	5916	4728	4728	4728	4728	
25	10745	10745	8949	8271	8271	8271	8271	6722	6722	6722	6722	5373	5373	5373	5373	
30	12894	12894	10738	9925	9925	9925	9925	8067	8067	8067	8067	6447	6447	6447	6447	

Table 2: Reynold numbers for each needle, leading to laminar flow (light green background), leading to turbulent flow (dark red background).

A sample of each type of needles has been tested measuring the pressure drop, with an accurate differential electronic manometer, at different gas flow rate, set with a well calibrated thermal mass flow controller. The test result (Fig.5) differs from the Hagen-Poiseuille law for the presence of a quadratic term. This term is due to the sharp change in the gas velocity, as it happens in a bent pipe or in an abrupt change of the pipe diameter where any slight perturbation could cause an excursion to turbulence.

Figure 5: The measurements on a sample of needles of the same type. All measurements were done with pure TFE (μ very close to the actual ATLAS gas mixture) and temperature in the range: 19°C - 22°C

The wide gas flow spread needed in the system has requested 18 different types of impedance (Tab. 3) built with one or two needles in series.

Impedance type	Needle 1	Needle 2	a1	b1	a2	b2	a-tot	b-tot	Flow l / h	Number needed
1	1	2	0.80	2.92	1.08	4.07	1.89	6.99	0.72	72
2	5	8	0.68	2.73	0.34	2.57	1.02	5.30	0.96	16
3	5	7	0.68	2.73	0.33	1.81	1.01	4.54	1.07	12
4	9		0.49	4.12	0.00	0.00	0.49	4.12	1.27	40
5	7	13	0.33	1.81	0.17	1.87	0.50	3.68	1.37	194
6	5		0.68	2.73	0.00	0.00	0.68	2.73	1.58	264
7	8		0.34	2.57	0.00	0.00	0.34	2.57	1.87	290
8	6	11	0.30	1.05	0.12	0.78	0.42	1.83	2.19	252
9	7		0.33	1.81	0.00	0.00	0.33	1.81	2.32	160
10	13		0.17	1.87	0.00	0.00	0.17	1.87	2.60	202
11	6		0.30	1.05	0.00	0.00	0.30	1.05	3.05	158
12	12		0.16	1.33	0.00	0.00	0.16	1.33	3.23	100
13	17	17	0.06	0.61	0.06	0.61	0.13	1.22	3.58	48
14	16	17	0.06	0.37	0.06	0.61	0.13	0.98	4.03	110
15	11		0.12	0.78	0.00	0.00	0.12	0.78	4.54	100
16	18		0.09	0.73	0.00	0.00	0.09	0.73	5.07	30
17	17		0.06	0.61	0.00	0.00	0.06	0.61	6.03	22
18	16		0.06	0.37	0.00	0.00	0.06	0.37	7.24	10
									TOT	2080

Table 3: The 18 combinations of one or two needles in series used for assembling the 2080 impedances needed. For each impedance, the linear and quadratic term of both needles and the flow obtained with input pressure of 6 mbar are shown

Even doubling the pressure drop from 6 to 12 mbar the ratio of flow rates for each needle is on average a factor of 1.6 and not 2 as expected (Tab 4). This limit is almost insurmountable and is caused by the quadratic term in the relation between the pressure drop, ΔP , and gas flow, Φ . To overcome this problem we are studying a different type of gas impedance made of many pipes assembled in a parallel configuration.

Needle Type	1	2	5	6	7	8	9	10	11	12	13	15	16	17	18
Flow(6mbar)	1,5	1,1	1,6	3,1	2,3	1,9	1,3	4,8	4,5	3,2	2,6	7,8	7,2	6,0	5,1
Flow(12mbar)	2,5	1,9	2,7	4,8	3,9	3,3	2,3	7,5	7,3	5,4	4,6	11,9	11,1	9,7	8,2
Flow(18mbar)	3,3	2,6	3,5	6,2	5,1	4,4	3,2	9,6	9,4	7,2	6,2	15,0	14,2	12,7	10,7
Flow(12mbar)/Flow(6mbar)	1,7	1,7	1,7	1,6	1,7	1,7	1,8	1,6	1,6	1,7	1,7	1,5	1,5	1,6	1,6
Flow(18mbar)/Flow(6mbar)	2,2	2,3	2,2	2,0	2,2	2,4	2,5	2,0	2,1	2,2	2,4	1,9	2,0	2,1	2,1

Table 4: The flow driven for each needle at different starting-point pressure (6 mbar is the design pressure).

4. First check of the system and conclusions

After a test performed on detectors connected to one single gas rack the new gas impedances were installed in the entire gas system and have been working since the end of January 2012. The gas pressure in the racks inlet has increased to 7.5 mbar (we expect 6 mbar on the new impedance and more than 1 mbar on the rack screw for line regulation). An accurate check was made on a large sample of chambers: the measured flow was compatible with the value of the installed impedance. With increasing luminosity of the LHC and the corresponding increase of the background, no problems have appeared in the chambers subject to lower irradiation where the gas flow was reduced. The chambers subject to higher irradiation are carefully monitored to ensure that the increase in gas flow in the new gas system is sufficient for a correct operation of the detectors.

We are confident that with this new gas distribution a good detector operation will be possible at the full-project sLHC luminosity without increasing the total gas flow more than a factor two.

References

- [1] R. Cardarelli and R. Santonico, *Development of resistive plate counters*, *Nucl. Instrum. Meth.* **A 187** (1981) 377;
- [2] ATLAS Collaboration, [2008 JINST 3 S08003](#)
- [3] De Asmundis, *Application of Gas Chromatographic analysis to RPC detectors in the ATLAS experiment at CERN-LHC*, *J. Instrum.* **2** (2007) T06001
- [4] ATLAS Muon Collaboration, “*Spectrometer Technical Design Report*”, [CERN/LHCC/97-22](#), (1997);
- [5] Aielli, G. *Cavern background measurement with the ATLAS RPC system*, [PoS \(RPC2012\) 025](#)
- [6] Aielli, G. An RPC gamma irradiation test, *Nucl.Instrum.Meth.* **A456** (2000) 82-86
- [7] G. Aielli et al., *Ageing test of the ATLAS RPCs at X5-GIF*, *Nucl. Instrum. Meth.* **A 533** (2004) 98.