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EVALUATION AND FIRST MEASUREMENT OF THE GAS PRESSURE DROP OF THE CMS MICROSTRIP GAS CHAMBERS

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Abstract

In order to better specify the requirements on the gas distribution system foreseen for the MSGC of the central tracker of CMS the pressure drop in detectors and tubing have been calculated and measured. The results are discussed.

1. Introduction

The central Tracker of CMS [1] is composed of layers of silicon microstrip detectors and Microstrip gas chambers (MSGC). In the volume of the tracker a particle will traverse first 9 layers of silicon detectors and then *16 layers* of MSGC precisely positioned. The support frame envisaged at present is a large *wheel* 2.6 m in diameter and 25 cm thick. The coverage of the solid angle must be as large as possible and the material present should be kept to a minimum to avoid multiple scattering. The detectors with a sensitive area of $\approx 25 \times 11.5cm$ will be precisely positioned in slots, and distributed with some overlap on spiral arms ideally stemming from the center of the wheel and reaching the outer diameter. The support will be called *the wheel* in what follows (see fig 1). Each wheel will house 456 MSGC (Micro Strip Gas Chamber). 9 adjacent identical wheels will constitute at the central part of the tracker.

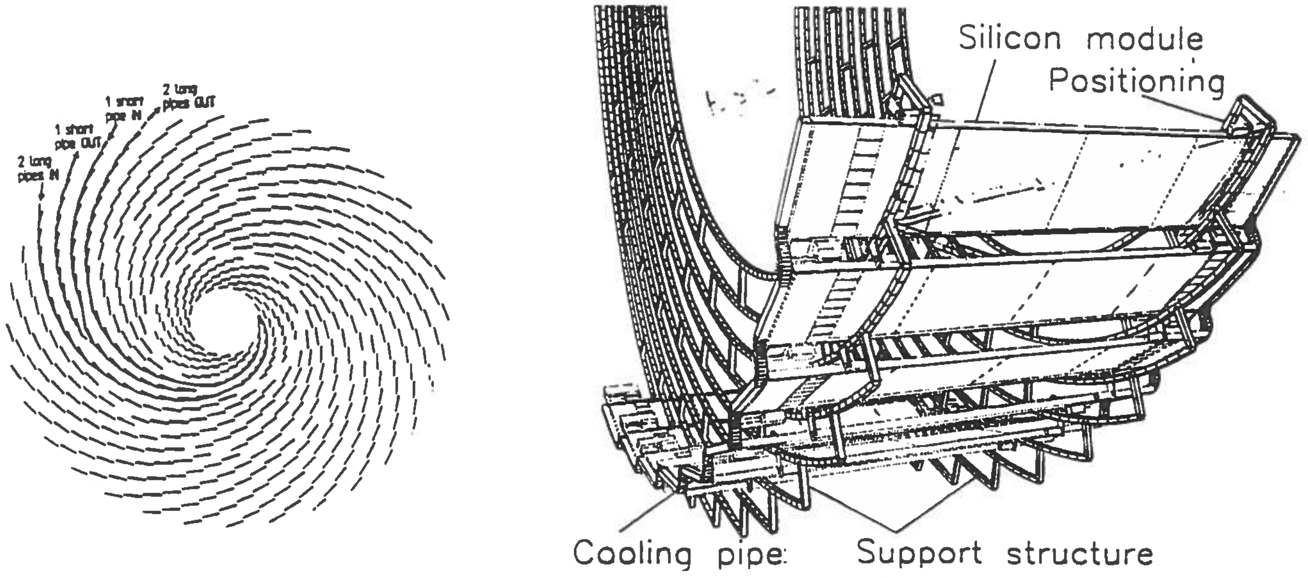

Figure 1: *The wheel structure of the CMS tracker. 9 wheels will be assembled parallel to each other to complete the tracker in the* z direction.

This layout, together with other features, offers an original solution to the problem of connecting the detectors to the R/O and control system without requiring any dead space (which would inevitably appear if the cables were to traverse the detector layers, radially for example). One of the crucial items for the proper functioning of the MSGC is the gas distribution: the gas mixture that fills the chambers has to be renewed regularly. The measurements described in the following were performed to check the feasibilty of joining a certain number of detectors **in series** for what concerns the gas distribution. In this way one would exploit fully the *spiral* configuration of the layout.

There are drawbacks to be carefully evaluated in making series of detectors.

- Gas flowing through the detector results in a *pressure drop* due to hydraulic resistance. Connecting detectors in series is equivalent, from the hydraulic point of view, to simply put *resistances* in series. The first chamber will experience the largest pressure with respect to the outside. The increased gas pressure probably does not affect the working characteristics of the detectors, however it has to be considered when calculating the safety margins for the construction of the detectors.

- The last MSGC will receive the gas which has already flown in the preceding ones: to ensure *clean* gas in the last detector it will be necessary to increase the flow from the one acceptable for a single MSGC (this last problem is being studied separately).

It is obvious that the simplest scenario sees all the detectors on one spiral connected in series: this number is 16. There are however *small* spirals every three large ones made of 9 detectors: if 16 turns out to be too large a number for series connection, the number of detector connected in series may be 8 (two series per spiral) and/or 9 for the small spirals.

2. The analytical approach

The fluid pressure losses for a gas flowing through a series of detectors can be calculated as the sum of two contributions[2]:

a) the frictional losses Δp_f due to momentum exchange between adjacent fluid layers moving at different velocities. These losses take place along the entire length of a pipe.

b) the local losses Δp_c due to sudden changes in channel cross section area, orifices, free discharge...

$$\Delta p_t = \Delta p_f + \Delta p_c \tag{1}$$

The frictional losses of a constant cross section straight tube can be evaluated by the following formula (`Darcy formula`):

$$\Delta p_f = \lambda \frac{l}{D_h} \frac{\gamma w^2}{2g} \tag{2}$$

where:

- λ is the wall friction coefficient
- l is the tube length
- D_h is the tube hydraulic diameter (ratio of the cross-section area to the cross-section perimeter)
- γ is the fluid specific weigth
- w is the fluid velocity

The local losses Δp_c can be evaluated using:

$$\Delta p_c \;=\; K_c\,\frac{\gamma w^2}{2g} \tag{3}$$

Where:

- K_c is the fluid local resistance coefficient (depends only on the geometry)
- $\gamma w^2 \;/\; 2g$ is the fluid dynamic pressure in the considered section.

The formula for local losses (3) shows a quadratic dependence of the local losses on the fluid velocity.
A rough calculation of the Reynolds number for the MSGC gas distribution system in the flow range expected in operating condition shows that the flow regime is `laminar`. *Re* (Reynold's number) is given by

$$Re \;=\; \frac{wD_h}{\nu}$$

ν being the kinematic viscosity of the fluid.

In laminar flow regime the friction coefficient λ is indipendent of the wall roughness and its value can be determined by the Hagen-Poiseuille law :

$$\lambda = \frac{64}{Re}$$

Combining the previous relations we obtain:

$$\Delta p_f \;=\; 64\frac{\nu l\gamma}{2gD_h{}^2}w \tag{4}$$

This last relation shows that in a pipe with fixed geometry in laminar flow regime the relationship between a frictional pressure drop and velocity is linear.
The pressure drop characteristic of an hydraulic circuit in laminar flow regime is then determined by two contributions:

$$\Delta p_t \;=\; \frac{\gamma}{2g}\left(K_c w^2 + \frac{64l}{D_h{}^2}w\right) \tag{5}$$

Equation 2 for a circular cross-section tube takes the form:

$$\Delta p_f \;=\; 256\,\frac{\nu\gamma Q}{2\pi g}\,\frac{l}{D_h{}^4} \tag{6}$$

where Q is the volumetric flow rate.

3. The test setup

The pressure drop was measured with a differential manometer filled with alcool. The gas flow rate was measured with a massflowmeter calibrated for Argon with a precision

of 0.1%, the differential manometer was connected at the entrance of the item under measurement. The gas at the exit of the item was let to flow freely in the athmosphere.
To perform the measurement we used the detectors that at present resemble most to the ones that will be used in the future in CMS (see figure 2): built fully in glass (to avoid problems with the DME gas) equipped with gas pipes 10cm long and of 3mm outer diameter, size proportioned with the dimension of the detector itself.

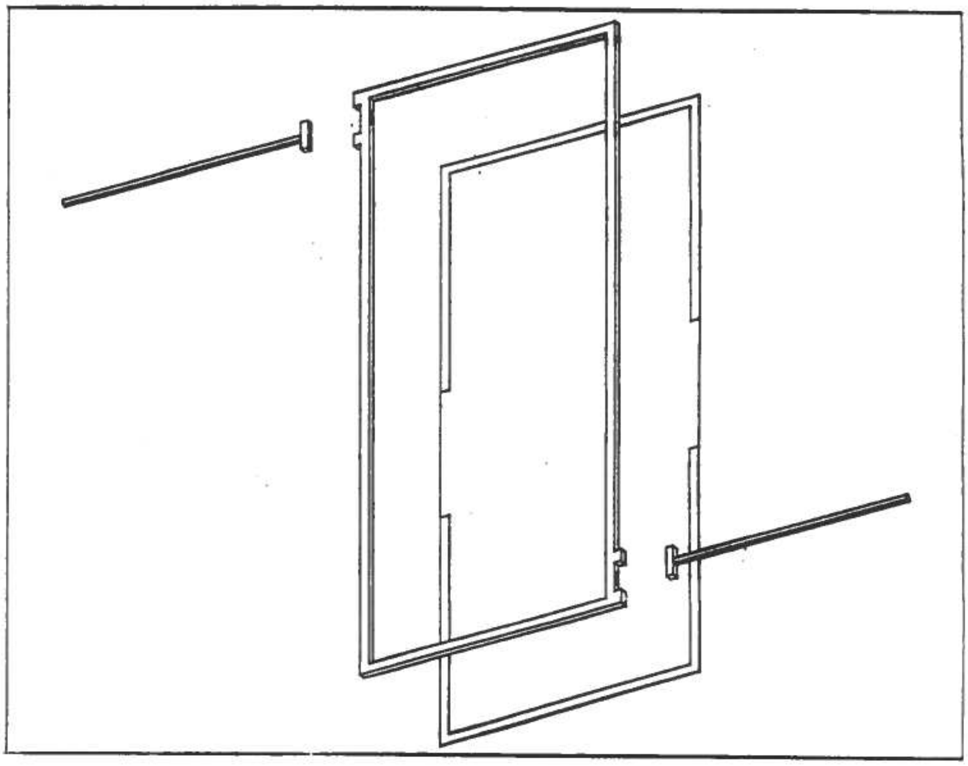

Figure 2: *The MSGC detector for CMS with details of the gas inlet and outlet*

The dimensions of the active volume of the detector are 250 × 115 × $3mm^3$, hence the volume is $\approx 90cm^3$. The measurements were performed on two detectors differing only in the details of the gas inlet and outlet geometry.
In order to separate the contribution of the detector from the one of the pipes, whose final length is not fixed at the moment, measurements were performed independently on sections of pipes of 3 mm outer diameter (2.5 mm inner diameter) and 20 cm long (total length of pipes on one detector).

The gas fittings mounted on the chamber required that the steel pipe be flattened to reduce its outer dimensions: since at the flows considered these pipes already show measurable pressure drop, we have measured also a configuration of a pipe of 20cm in length where one end was flattened for 25mm (equivalent to what was done for the two inlet/outlet of the detectors). These configurations are also analytically simple to calculate.

Since the pressures that one has to measure are very small (at the limit of the sensitivity of the manometer) we had to increase the flow of the gas trough the detector at a rate that will probably never be used in the real experiment. We measured at Argon flows (the most viscous gas amongst the candidate gases) ranging from $100cm^3/min$ to $400cm^3/min$ (i.e 1 to 5 volumes replaced in one minute).

4. The results

The measurements are shown in figure 3 and reproduced for completeness in table 1. The sensitivity of the measurements was of 0.5mm of alcool: this value should be taken as the uncertainty for all measurements.

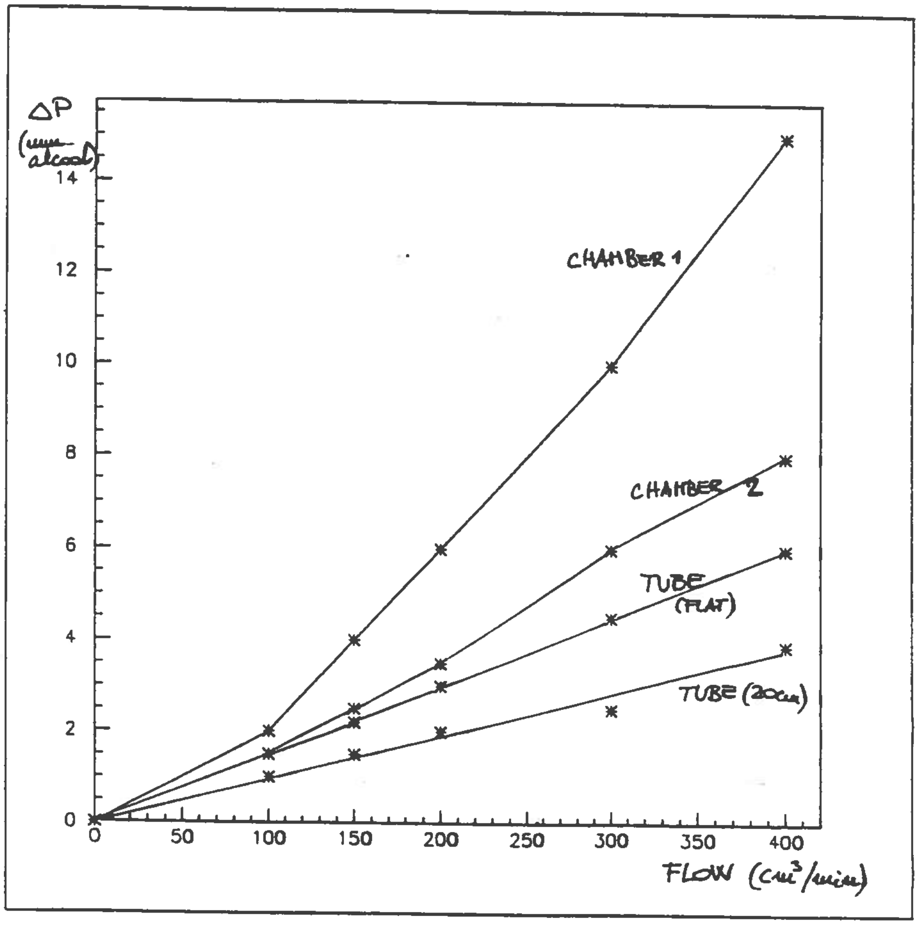

Figure 3: *The measurement performed on the two chambers and on a piece of tubing.*

Calculations show that the frictional pressure losses inside the active volume of the detector are orders of magnitude less than other losses in the system (as considered here) and then give only negligible contribution to the total pressure loss.
The measurements show a large difference between the values obtained for the two detectors: this difference is caused by the different geometries adopted for the gas inlet/outlet.

MEASUREMENTS (mm of alcool)					
Detector	Gas flow in ccm/min				
	100	150	200	300	400
Chamber 1	2	4	6	10	15
Chamber 2	2	2.5	3.5	6	8
tube (20cm)	1	1.5	2	2.5	3.9
tube (flat end)			3		6

Table 1:

More specifically the difference is in the aperture for the gas in the frame of the chamber, the metallic pipes used being identical for the two detector. The opening in chamber 2 is rectangular with dimensions of 8×0.8 mm^2 while in chamber 1 there are 4 holes of 1 mm diameter with a pitch of 2 mm. Gas in Chamber 1 has then to go through a smaller cross-section orifice than for Chamber 2 and the local losses due to inlet and outlet are higher. Chamber 1 was the first detector produced and the manufacturing possibilities had not been yet fully explored. Susequently we found it possible to make rectangular aperture of larger cross section: the improvement is evident.

As a consequence of this finding a particular care will have to be put in designing the details of the inlet/outlet geometry for the MSGC.

If now we concentrate on the findings of Chamber 2 it can be observed that friction losses in the pipes are dominant (≈ 60 *to* 70% of the total pressure drop). It may be expected that if one decreases the flow rate through the detector, the local losses tend to decrease with a quadratic law and then the relative importance of the frictional losses increases. In such a *regime* it will be easy to calculate the behaviour of the entire system using the analytical linear relationship for pipes referred to before.

The calculations reproduced in table 2 show good agreement with the measurement. The calculations themselves reflect the uncertainties on the pipe cross-section expecially for the flattened tube.

CALCULATIONS (mm of alcool)					
Detector	Gas flow in ccm/min				
	100	150	200	300	400
tube (20cm)	0.9	1.35	1.8	2.7	3.6
tube (flat end)	1.3		2.6		5.2

Table 2:

5. Conclusion

This work is very preliminary and many details can still be improved. It has to be considered as a first approach to the problem.
A few conclusions may be drawn: for 16 chambers connected in series with the geometry of chamber 2 the total pressure drop[1] is $\approx 25\ mm\ of\ H_2O$ for a gas flow rate of 100 cm^3/min of Argon.
At present it is not very well known how many volumes of gas per unit time will be needed in the experiment, and even if the flow used in our measurement seem to be on the high side, it is probably better to increase the cross section of the pipes rather than to decrease the flow to obtain a smaller pressure drop for the largest series of detectors conceivable.

References

[1] CMS collaboration, "Status Report and Milestones", CERN/LHCC 93-48, Geneva, 15 october 1993

[2] I. E. Idel'chik, "Handbook of hydraulic resistance" AEC-TR-6630 distributed by NTIS (1966)

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[1] the maximum pressure one chamber has to stand is equal to the total pressure drop and will manifest itself on the first detector of the chain