R&D Proposal for the Purification of the RPC gas Mixture.

18/09/2006

DT1:
M. Capeans, A. Gonidec, F.Hahn and S. Haider

With the Participation of:
G. Iaselli (CMS RPC), R. Santonico (ATLAS RPC)

Introduction

RPC chambers use a gas mixture of 94-96% of $C_2H_2F_4$, 3-5% of iC_4H_{10} and 0.5 SF_6. The design philosophy of the gas systems for the ATLAS and CMS RPC's foresees to re-circulate the gas mixture in a 95 to 99% closed loop circulation. This concept is based on economical grounds and related to the large chamber size, the need for high gas flows and the relatively high cost of the gas (today approx. 70 CHF/m^3).

However, in the amplification process in the chamber gas molecules are ionised, dissociated or fragmented; afterwards they recombine to new stable objects which are either deposited in the chamber or leave the chamber with the gas flow. At the LHC, RPC chambers are operated in a high radiation environment, conditions for which large amount of impurities in the return gas have been observed in earlier studies. Due to the complex gas composition the species created are very numerous and many are chemically exceedingly reactive. They are potentially dangerous for materials in the detector and in the gas system.

In a re-circulating gas system one tries, of course, as much as possible, to remove these impurities in the purifiers in order to keep the gas purity near the level of the fresh gas quality. Conversely, recent measurements from CMS indicate that the achievable re-circulation rate for the RPC's could be far more limited (due to impurities) than previously expected. At the moment this is preventively compensated for by an increased purification capacity (factor two now, plus an option for a future increase in 2008) and by more frequent regenerations of the absorbers.

However, the problem may not be fully solved because higher luminosities at the LHC will increase the impurity concentration further. Furthermore, chemical reactions between the absorber and the impurities are not well understood, and it is thought that there could be unwanted secondary reactions degrading the absorber materials themselves. In view of the more frequent regenerations, it must be considered that the absorber capacity deteriorates with time or that some absorbers excrete new pollutants into the gas.

Results from earlier R&D studies

This new R&D effort is, in fact, a continuation of measurements that were done in the years 2003 and 2004. Although these earlier studies were focused mainly on ageing of the chambers where the gas system parameters were kept mostly stable, the major findings were the following:

- RPC chambers can sustain long-term operation under radiation. Both, ATLAS and CMS accumulated an equivalent charge of 5 to 8 years of LHC operation without visible degradation of the signal.
- The RPC chambers require a level of hygrometry in the gas mixture of approximately 9'000 to 12'000ppm to maintain a stable resistivity of the bakelite.

- To operate stably in radiation the gas flows should not be much lower than one volume change per hour.
- Numerous impurities were found in the return gas, when the chambers were operated under radiation.
  a. In a typical chromatogram, more than 12 extra peaks with concentrations > 10 ppm were found; they were identified as mainly perfluoro, hydrofluoro or hydrocarbon compounds, in saturated or non saturated form.
  b. Important quantities of F^- ions (originating from HF molecules) were found in the return gas.
  c. The amount of contamination in the return gas increases with signal current.
  d. The most abounding compounds are removed in the purifiers, if four absorbers are used in series: molecular sieve, BASF CuO-ZnO catalyst R3-12, BASF CuO R3 11G, Leuna NiAlO3 catalyst. The absorption capacity for the various contaminants was not studied.
  e. A problem in the gas purification has immediate impact on the noise level of the chamber.

(For more details see: http://indico.cern.ch/conferenceDisplay.py?confId=a045466)

R&D Proposal:

In our view it is necessary to start a new R&D effort that involves DT1, CMS, ATLAS, ALICE (tbc) and TS-MME (chemistry experts).

This new R&D proposal will focus more on the gas system aspects and should study in particular the impurities produced in the chambers, and the properties of possible absorbers. More precisely we expect to understand:

- What kind of impurities are produced and in what concentrations?
- Which are the harmful impurities that degrade the signal or cause dark currents?
- What is the dependence of the impurity concentrations on the gas flow and the degree of re-circulation?
- Which absorbers can be used to remove what pollutant?
- What is the capacity and the lifetime (ageing of the product) of the absorbers?

During the first phase (~ 1year) we expect to run RPC chambers in the ISR without significant radiation (ohmic currents only), in a second phase we propose to repeat the same measurements in a radiation environment (e.g. in GIF).

Schedule and Resources

We believe that this Study could start in the first half of 2007 and we estimate that it will take approximately 2 to 3 years of R&D effort:

- 1st year for setting up and first phase (data taking without radiation)
- 2nd year for data talking in radiation environment
- 3rd year reserve.

The set-up required will be:

- Closed loop gas system (2 systems existing)
- Chambers + all equipment to run them (HV, LV, read-out, etc.). (supplied by CMS + ATLAS)
- Purifier materials, cartridges, regeneration facility (supplied by DT1)
- On-line gas analysis equipment (Hygrometer, GC, MS,…). (Existing DT1)
- On-line HF analysis: fluorine electrode to measure the free fluorine in aqueous solutions (not existing cost ~4-5 KCHF)
- Offline chemical analysis of the gas (HPLC, HF measurements, etc.) and of cleaning agents. (Done in collaboration with TS/MMS, Universities of Pavia and Bari, INFN Fracscati).

The manpower needed is estimated to be 4-5 man-years (approximately 2 FTE's in the first year, 1.5 FTE's the second year and 1 FTE the third year). In order to ensure a good continuity for the project it is important to have at least one person following up the study for a significant amount of his time, therefore we propose to allocate one fellow for 75% of his time to this project (~1.5 man-years). The remaining 3.5 man-years will be shared between the different parties: ATLAS=1 man-year, CMS=1 man-year, DT1 = 1 man-year and 0.5 man-years for dedicated analysis (TS/MMS).

The operating cost (mainly gas and absorber materials, chemical analysis) are estimated as 20 to 25 kCHF per year.

The test could be made in the ISR IP4 area (currently used by CMS). In the second year the tests will require access to an irradiation facility, e.g. GIF.