A Barrel IFR Instrumented with Limited Streamer Tubes for BaBar Experiment

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Abstract

The new barrel Instrumented Flux Return (IFR) of the BABAR detector will be reported here. Limited Streamer Tubes (LSTs) have been chosen to replace the existing RPCs as active elements of the barrel IFR. The layout of the new detector will be discussed: in particular, a cell bigger than the standard one has been used to improve efficiency and reliability. The tubes are assembled in modules and installed in 12 active layers of each sextant of the IFR detector. R&D studies to choose the final design and Quality Control procedure adopted during the tube production will be briefly discussed. Finally the performances of the first two installed sextants will be reported.

1 The flux return geometry

As originally built, the muon and K_L^0 detection system for BABAR consisted of 19 layers of resistive plate chambers (RPCs) interleaved with the flux return iron in the barrel region and 18 layers in the forward and backward endcaps. Each detector gap contained a single layer of RPCs based on a bakelite and linseed oil design. During initial BABAR operations, the temperature in the iron increased to as much as 30^oC. Since that time efficiencies have continued to decline at the rate of approximately 1.2% per month. Efforts to reverse or halt the underlying decline in efficiency have not been successful. All the chambers in the forward endcap were replaced in the summer and fall of 2002 with RPCs built with more stringent quality control (the upgrade project foresaw also the replacement of 5 active layers with 2.5 cm thick brass plates to improve the pion rejection). In December 2002 BABAR decided to replace the RPCs with limited streamer tubes (LSTs) for the barrel upgrade.

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2 The LST Concept

A "standard" LST configuration [1] consists of a silver plated wire 100 μm in diameter, located at the center of a cell of 9x9 mm^2 section. A plastic (PVC) extruded structure, or profile, contains 8 such cells, open on one side. The profile is coated with a resistive layer of graphite, having a typical surface resistivity between 0.1 and 1 MOhm/square. The profiles, coated with graphite and strung with wires, are inserted in plastic tubes ("sleeves") of matching dimensions for gas containment. The signals for the measurement of one coordinate can be read directly either from the wires or from external strip planes attached on both sides of the sleeve.

3 R&D studies, Design and Performance

More than one year of R&D studies were made before choosing the final LST design. Our R&D program concentrated on several critical issues like: selection of safe gas mixture, rate capability, wire surface quality and uniformity, aging test and performance of the prototypes. Detailed studies concerning all these issues can be found at [2].
The LST tubes are somewhat fragile mechanically so careful design, handling, and operation are of paramount importance in preventing failures. The "mortality" of the LSTs depends on the cell size, on the care and attention given during construction and installation, and on the strictness of the acceptance tests. Given these constraints to build a highly efficient detector means: reduce tube mortality and/or introduce redundancy to decrease its effect on detector efficiency; arrange tubes into modules that can be extracted and replaced and to minimize the dead space; feed each tube with one or more independent HV channels and finally locate HV distribution boxes and front end electronics on the outside of the detector. Such indications led us to a 15x17 mm^2 cell design (which is more reliable and efficient) where each tube is composed by 7 or 8 cells and assembled in modules. We use wire readout for the azimuthal coordinate, ϕ, and strips plans for the z coordinate (along the beam direction). In order to obtain high performances and to respect the safety requirements a ternary gas mixture of $Ar/C_4H_{10}/CO_2$ (3/8/89)% has been chosen [3].

4 LST production and quality control

The LST production was commissioned to an external firm, the Pol. Hi. Tech. (PHT), which also assembled all the prototype used for R&D.
We worked together with PHT to improve the cleanliness of the tubes and

to set up a system of stringent quality control (QC) to guarantee the high performance of the product. The QC system was designed to check the quality of all mechanical components, the goodness and the resistivity of the graphite coating, the gas tightness of all assembled LSTs. Finally a set of electrical tests was applied to check the behavior and the performance of each LST under normal and critical electric (e.g. maximum allowed voltage) and physics (e.g. high particle rate simulated with a radioactive source) conditions. In order to be accepted for the installation into BaBar, each LST had to satisfy all stringent criteria required for each test.

5 Installation into BaBar

The first 2 sextants were installed during summer 2004, while the remaining four were installed in the period September-November 2006. Installation began with the insertion into each gap of a strip plane covering an entire gap. These strips were attached to the iron and supported by gravity. Then the modules were brought onto a supporting structure and inserted into the gap on top of the strip layer. The full installation and commissioning of the two sectors took less than 2 months and was completed on schedule. QC tests after installation certify the proper working of the apparatus.

6 Performance of the first two LST-sextants

The BaBar experiment began RUN5 on March 2005 and after 8 months of operation the LSTs are showing a very good performance with regard to the following items:

Mortality. Since the installation, the number of dead channels has been fairly constant over time, fluctuating around 0.2%. There are a total of 2 dead wires out of 1552 (0.1%) (mainly due to discharge in the cells or in the HV connectors) and 7 dead strips out of 2284 (0.3%) (mainly due to bad solder joints).

Plateau curves. Plateau curves are monitored monthly and all LSTs show a plateau width varying 300-600 V around a value of 5600 V.

Efficiency. The efficiency of the LSTs is calculated and monitored in two different ways. A daily monitoring of the efficiency, calculated via $\mu\mu$ pairs from colliding beams, shows very small fluctuations around an average value of 90% per sextant. A second monitoring is done every month and the efficiency, calculated with cosmic rays, results stable around an average efficiency of 92.5% per layer. The fluctuations of the efficiency are mostly related to the fluctuations on the number of dead channels, but no loss of efficiency for any single LST has been detected.

Muon ID and pion rejection. Comparing the results from LSTs and RPCs at different times it appears obvious that the LSTs are working better than the RPCs ever did. The LSTs introduced a significant improvement in pion/muon discrimination. For details see Fig. 3 of reference [4].

Rate and current versus luminosity. There is a linear correlation between rate/current of the installed LSTs and the instantaneous luminosity. The corresponding slope shows that LSTs will work properly also at the maximum estimated instantaneous luminosity of $2 \cdot 10^{34}$ cm^{-2}s^{-1}.

References

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