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IRRADIATION TESTS OF READOUT CHAIN COMPONENTS OF THE ATLAS LIQUID ARGON CALORIMETERS

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Various readout chain components of the ATLAS liquid argon calorimeters have been exposed to high neutron fluences and γ doses at the irradiation test facility of the IBR-2 reactor of JINR, Dubna. Results of the capacitance and impedance measurements of coaxial cables are presented. Results of peeling tests of PC board samples (kapton and copper strips) as a measure of the bonding agent irradiation hardness are also reported.

The investigation has been performed at the Laboratory of Particle Physics, JINR

Радиационные тесты компонент считывающих цепей жидкоаргоновых калориметров детектора ATLAS

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Различные компоненты считывающих цепей жидкоаргоновых калориметров детектора ATLAS облучались до высоких нейтронных флюенсов и гамма-доз на облучательной установке реактора ИБР-2. Представлены результаты измерений емкости и сопротивления коаксиальных кабелей, а также результаты тестов на отслаивание до и после облучения.

Работа выполнена в Лаборатории физики частиц ОИЯИ.

1. DESCRIPTION OF THE SETUP

The irradiation test facility has been constructed at the beam-line No. 3 of the IBR-2 reactor of JINR, Dubna. A detailed description of the facility can be found in Refs. 1,2. It has a large beam acceptance (20×40 cm^2) and high dose rates ($2 \cdot 10^{10}$ cm^{-2}·s^{-1}). The facility is operating since 1993. The facility was completed in 1998 by the installation of a cryostat and associated cryogenics which allow one to carry out radiation hardness tests of different materials and electronics at cryogenic temperatures. The cryostat is installed on a support frame at the head of a movable shield platform. The bended tube inside the platform could be used for the samples transportation and their irradiation in parasitic mode. Measurements of various parameters of the tested samples may be carried out either «on-line» during the

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reactor operation or after the run in a laboratory room of the experimental hall located 25 m from the irradiated zone.

2. CAPACITANCE OF THE KAPTON CABLES

A bunch of 64 coaxial cables made of polyimide kapton (AXON France, P511543) with two connectors on both sides was delivered to Dubna to be irradiated at high neutron dose. Unfortunately, lack of time prevented «zero-dose» measurement of all the cables prior to irradiation. That is why the bunch was cut into two parts — one part was positioned in the beam area for irradiation and the other one was kept outside the beam for the reference measurements. In order to separate the bunches, the cables were cut at one connector and another connector was broken into two pieces.

The length of the bunch was about 400 cm. The length of the cables in the bunch was uniform with a spread within the range of $(1 \div 2)$ cm. Two cables were dismounted during the connector cutting, and one cable was damaged mechanically elsewhere outside Dubna. The capacitance of these cables was not measured.

The cables were irradiated during the December'98 run at the IBR-2 reactor. They were taken to the experimental hall two weeks after the irradiation run, and the cable capacitance was measured for both parts (irradiated and nonirradiated) of the bunch.

2.1. Neutron Fluence Measurements. A standard method for the fast neutron fluence measurement was applied as described in detail in Ref. 1. To protect the cables from activation by thermal neutrons, the bunch to be irradiated was covered with a cadmium foil. Four nickel dosimeters were mounted at different locations on the cable coil to monitor the integral fluence of the fast neutrons ($E_n \geq 100$ keV). The neutron fluence was found to be $(1.8 \pm 0.2) \cdot 10^{16}$ cm^{-2} by averaging over all the dosimeters. The accompanying γ dose was estimated to be (300 ± 50) kGy, based on results of previous experiments.

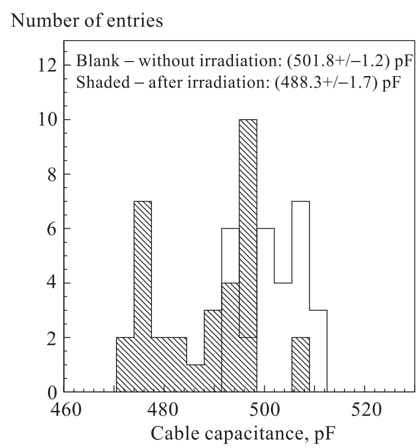

Fig. 1. Cable capacitance measured for the group of cables irradiated to the fluence $1.8 \cdot 10^{16}$ cm^{-2} (shaded area) and for the nonirradiated group of reference (blank area)

2.2. Capacitance Measurements. The cable capacitance was measured at the frequency of 1 MHz by means of a LRC-meter E7-12 which allows the measurement of the inductance, capacitance and resistance with good accuracy. The air humidity in the laboratory room was about 60 %. The measurements were repeated three times and averaged. The spread of the capacitance value was within the range of ± 0.1 pF for each cable.

The results for two groups of cables are presented in Fig. 1. The histogram shows the capacitance values of the nonirradiated group of cables of reference (blank area) and of the group of cables irradiated to the fluence $1.8 \cdot 10^{16}$ cm^{-2} (shaded area).

The distribution of the irradiated cables capacitance values became wider and was shifted to lower values by $\sim$13 pF when compared with the reference group data. The capacitance averaged over each group is (501.8 ± 1.2) pF and (488.3 ± 1.7) pF for the nonirradiated reference group and irradiated cables, respectively.

Thus, a 2 % degradation of the kapton cable capacitance is observed after irradiation of the cables to a high neutron fluence and γ dose.

3. TEST OF COAXIAL CABLES IMPEDANCE

A set of readout chain elements of the ATLAS hadronic end-cap calorimeter was exposed to a total fluence of fast neutrons ($E_n > 100$ keV) of $9 \cdot 10^{15}$ cm^{-2} and to a γ dose of 55 kGy. The irradiated elements were: striplines (made of Duraver PD, by Korsten and Goossens), 16 pins adapters of polyester fibers (Samtec), coaxial cables of PEEK (Habia, HF1 260) and coaxial cables of polyimide (Axon, AWG3401 Kapton).

The coaxial cables were inspected visually by means of a microscope with a magnification factor of 60. No damage was found for both types of cables although teflon was used as an isolation material for one of them.

The impedance of the cables was estimated using the impedance matching technique. The variable resistor value (R) was tuned in order to minimize the line reflection effects seen with the oscilloscope. The impedance (R) of each cable was measured ten times before and after irradiation and the results were averaged. For the PEEK cable, the values (51.5 ± 0.3) Ohm and (49.7 ± 0.5) Ohm were measured before and after the irradiation, respectively. For the kapton cable, the results were (48.7 ± 0.4) Ohm and (48.6 ± 0.5) before and after the irradiation, respectively. Only statistical errors are given as the «visual» method employed for the test makes hard the estimate of systematic effects. Thus, it is difficult to interpret some degradation of the PEEK cable impedance as an effect of irradiation.

The striplines were inspected visually and no damage was observed. Peeling tests were applied to polyimide glue and it was found to remain strong (it was impossible to peel out the copper foils without inflicting mechanical distortion). Also, the resistors of two types (loading and calibration types) mounted on the striplines did not change their resistance values. For various samples, the resistance remained stable after irradiation within the ranges of (51.5÷51.6) Ohm and (5.07÷5.08) kOhm for the loading and the calibration resistors, respectively.

The adapters were tested for inter-pin and pin-through resistance. The inter-pin resistance was always found higher than 50 MOhm (the multimeter scale upper limit) for all the samples tested. The pin-through resistance was identical for all the adapters and equal to 0.02 Ohm before and after irradiation.

4. PEELING TESTS OF BOARDS FOR THE ATLAS FCAL

A group of PC board samples for the ATLAS forward calorimeter (FCAL) was exposed to a fast neutron fluence of $7 \cdot 10^{15}$ cm^{-2} and a γ dose of 67 kGy at the IBR-2 reactor in May 1999.

The samples were immersed in the liquid argon cryostat during irradiation. Another group of boards, aimed to be used for reference measurements, was not irradiated. The material used for the PCB was KAPTON-HPP with 5 mm width copper strips laminated to each side with KAPTON-HPP as the bonding agent.

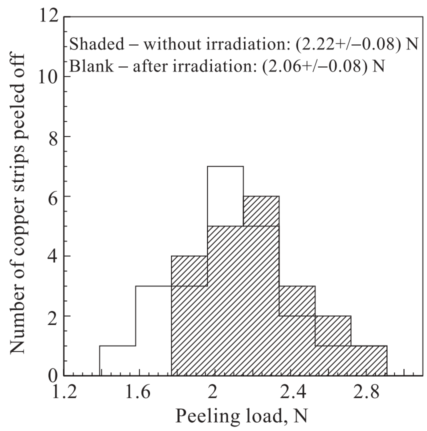

Fig. 2. Peeling load measured for the group of PC boards exposed to high neutron fluence (blank area) and for the reference group (shaded area)

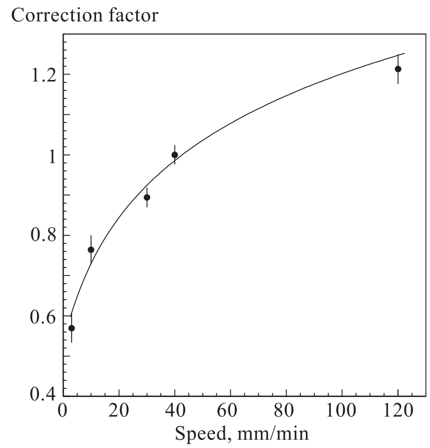

Fig. 3. Peeling load dependence on the value of peeling speed. Load is normalized to unity at a speed value of 40 mm/min

Two groups of samples were subjected to the peeling tests, after the run. In accordance to the Standard Tests Methods (*Designation D 5109-94*) the load was applied to the copper strip in the vertical plane and a constant reading of the needle indicator was recorded (at a peeling speed of 40 mm/min).

The results of the measurements for the two groups of samples are shown in Fig. 2. The averaged values of the peeling load are (2.06 ± 0.08) N and (2.22 ± 0.08) N for the irradiated and reference samples, respectively. Thus, a 6 % degradation of the bonding agent hardness have been observed. Nevertheless, the value of the peeling load after $7 \cdot 10^{15}$ cm^{-2} of neutron fluence and 67 kGy of γ dose is quite acceptable for application in the ATLAS FCAL.

The major bulk of measurements was carried out at a peeling speed of 40 mm/min. Figure 3 shows the peeling load dependence on the value of the peeling speed. The *Designation D 5109-94* requires a speed value of 50 mm/min. So a 5% correction factor has to be applied, approximately, to the peeling load shown in Fig. 2.

5. CONCLUSION

Various components of the readout chain of the liquid argon calorimeters of the ATLAS detector were exposed to high neutron fluences and gamma doses at the IBR-2 reactor of JINR, Dubna. Early results are presented in the Liquid Argon Calorimeter TDR [3].

Peeling tests of copper strips laminated to PC boards revealed a 6 % decrease of the peeling load after exposure to a neutron fluence of $7 \cdot 10^{15}$ cm^{-2} and a γ dose of 67 kGy. Also, a 2 % degradation of the kapton coaxial cable capacitance was found after cable exposure to a high neutron fluence of $1.8 \cdot 10^{16}$ cm^{-2} and an accompanying γ dose of 300 kGy.

Nevertheless, the variation of the measured parameters are at an acceptable level. This allows the application of the tested materials to liquid argon calorimetry in the ATLAS detector.

References

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