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Possibility to Investigate the Energy Correlators and their Ratio for High Multiplicity Events with pile-up background at 14 TeV

J. Budagov, Y. Kulchitsky[1], J. Manjavidze[2], N. Russakovich, A. Sissakian

JINR, Dubna, Russia

Abstract

We present the results of the study of the energy correlators $K_2(n)$, $K_3(n)$ and their ratio $R_3(n)$ in dependence on the hadron multiplicity at the LHC. The PYTHIA generator has been used. The PYTHIA predicted that $R_3(n)$ does not depend on multiplicity. The $K_2(n)$, $K_3(n)$ and $R_3(n)$ ratio can be studied at ATLAS.

[1] also B.I. Stepanov Institute of Physics, National Academy of Sciences of Belarus, Minsk, Republic of Belarus

[2] also Institute of Physics, Tbilisi, Georgia

1 Introduction

The investigation of very high multiplicity (VHM) events is a very important task for high energy physics [1, 2]. The purpose of this study is to calculate the energy correlators $K_2(n,s)$, $K_3(n,s)$ and the ratio $R_3(n,s) = |K_3(n,s)|^{2/3}/|K_2(n,s)|$ as a function of the hadron multiplicity for the future ATLAS experiment at the LHC [3, 4]. The theory predicts that the $R_3(n,s)$ ratio has tendency to equilibrium for the VHM events [1].

2 Phenomenology of VHM events

We will call the very high multiplicity events the ones for which the condition $n(s) \gg \bar{n}(s)$ is fulfilled, where n is the number of hadrons in an event, $\bar{n}$ is the mean multiplicity of hadrons, and $\sqrt{s}$ is the c.m.s. energy.

Fig. 1 shows the distribution of $\langle n\rangle P(n)$, where $P(n) = \sigma_n/\sigma_{tot}$, as a function of the secondary particles multiplicity represented in the units of mean multiplicity. The points are the results of the E735 (FNAL) experiment at 1.8 TeV with $\langle n\rangle = 44$. The **A** region corresponds to the multi peripheral kinematics, where $n \sim \bar{n}(s)$. The **B** region is the thermodynamical region corresponding to the approximation of the non-interacting gas where $n \to n_{max}(s)$. The maximum possible number of hadrons is equal to $n_{\max}(s) = \sqrt{s}/m_\pi$, where m_π is a pion mass. The **C** region corresponds to the VHM events. The cross section of such a process is significantly smaller than $10^{-7}\sigma_{tot}$.

The thermodynamical description of the final state events in the high energy physics is possible at fulfillment of the condition of N.N. Bogolyubov's principle of the vanishing of the correlators [6]:

$$R_l(n,s) = |K_l(n,s)|^{2/l}/|K_2(n,s)| \ll 1,$$

where $l = 3,\ 4,\ \ldots,\ K_l(n,s)$ is the l-particle energy correlator for the n-particle event. Two and three particle correlators are defined as

$$K_2(n,s) = \langle([\varepsilon_1;n,s] - \langle\varepsilon;n,s\rangle)([\varepsilon_2;n,s] - \langle\varepsilon;n,s\rangle)\rangle,$$

$$K_3(n,s) = \langle([\varepsilon_1;n,s] - \langle\varepsilon;n,s\rangle)([\varepsilon_2;n,s] - \langle\varepsilon;n,s\rangle)([\varepsilon_3;n,s] - \langle\varepsilon;n,s\rangle)\rangle,$$

where ε_i is the energy of the i-particle and $\langle\varepsilon;n,s\rangle$ is the mean energy.

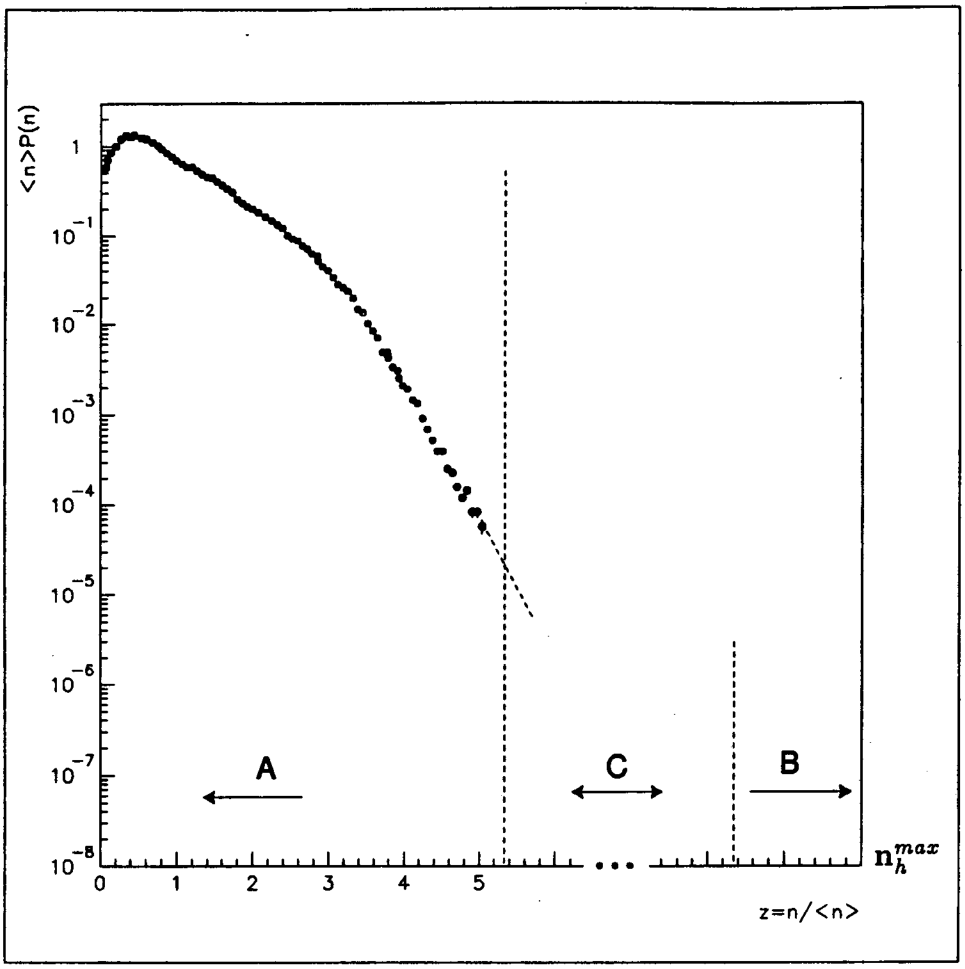

Figure 1: Multiplicity distribution $\langle n \rangle P(n)$ in the KNO scaling form at 1.8 TeV.

3 Energy correlators and their ratio

The PYTHIA has been used for this investigation [7]. The hard processes have been used for the simulation of the trigger events: $q_i\ q_j \rightarrow q_i\ q_j$, $q_i\ \bar{q}_i \rightarrow q_j\ \bar{q}_j$, $q_i\ \bar{q}_i \rightarrow g\ g$, $q_i\ g \rightarrow q_i\ g$, $g\ g \rightarrow q_i\ \bar{q}_i$, $g\ g \rightarrow g\ g$ where q are quarks and g are gluons.

The main background for the VHM events at the LHC will be soft processes. There will be ≈ 23 pp-interaction in the 25 ns of one interaction of bunches at the full LHC luminosity ($10^{34}\ cm^{-2}s^{-1}$). The time of data collection will be 125 ns, for example for the electromagnetic calorimeter. Therefore, there will be written about 115 soft background events, which

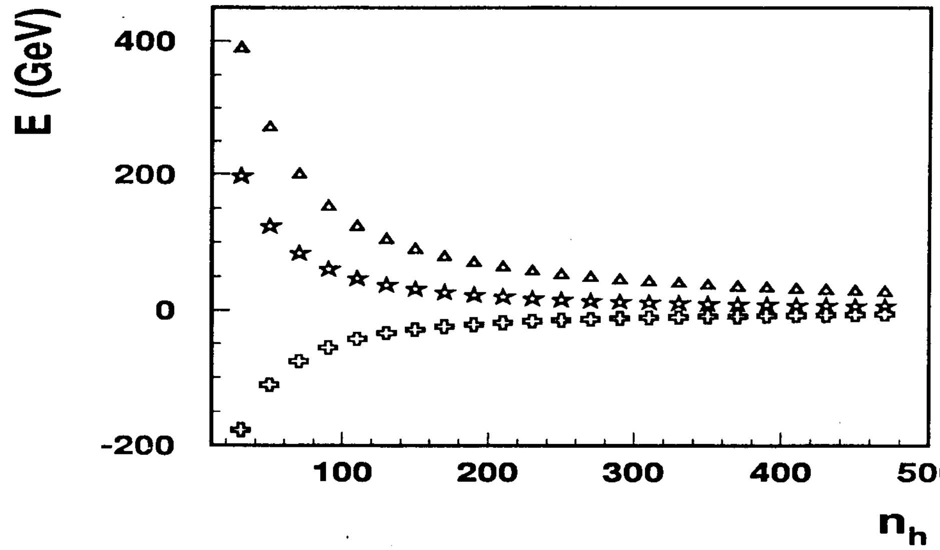

Figure 2: The average energy [△], the correlators $\sqrt{K_2(n)}$ [✠], $\sqrt[3]{K_3(n)}$ [★] as a function of the multiplicity at 14 TeV.

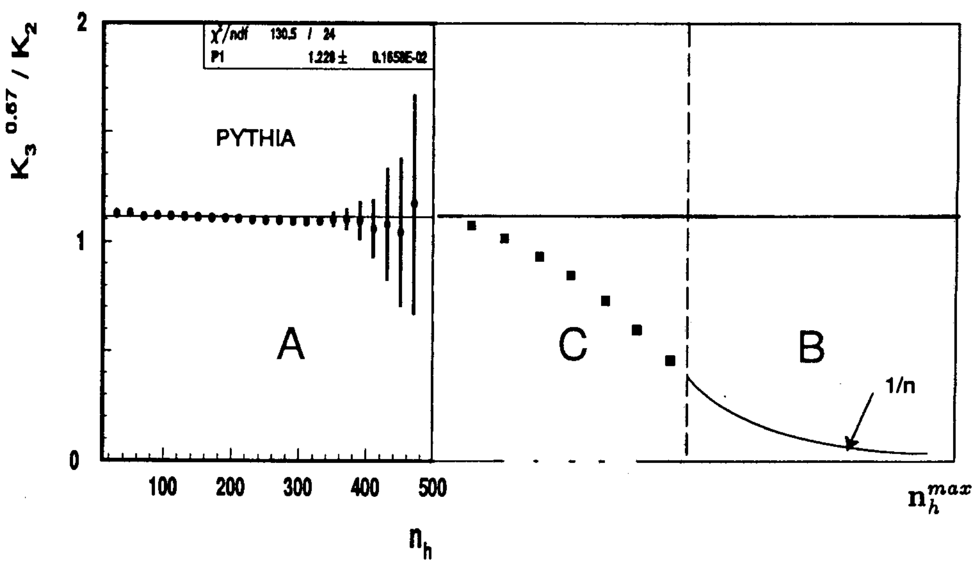

Figure 3: The $R_3(n)$ ratio [•] as a function of the multiplicity at 14 TeV.

are called pile-up, simultaneously with the trigger event. The inelastic processes have been used for the simulation of the pile-up events.

Fig. 2 shows the results of calculations of the average energy and the correlators $\sqrt{K_2(n)}$, $\sqrt[3]{K_3(n)}$ in the GeV scale as a function of the hadrons multiplicity at 14 TeV. The values of $\sqrt{K_2(n)}$ have signs of $K_2(n)$. As can be seen the $K_2(n)$ and $K_3(n)$ trend to zero at $n_h \to 500$. The dependence of the $R_3(n)$ ratio on n_h is given in Fig. 3. The PYTHIA predictions are given for the **A** region shown in Fig. 1. The average value of the $R_3(n)$ ratio does not depend on the hadron multiplicity and equals to 1.23. There is no trend to equilibrium in this region. This can be understood as the PYTHIA is based on the multiperipheral model [1].

Taking into account the experimental trigger conditions harder events have been selected which increase the hadron multiplicity. The requirement on the transverse parton momentum $p_t^q \geq p_t^{q,\ min}$ has been used, where $p_t^{q,\ min} \geq 500$ GeV. This has led to multiplicity increasing to ≈ 800. However, the tendency to equilibrium is not observed although the $R_3(n)$ ratio decreases to 1.1 for $p_t^q \geq 2000$ GeV.

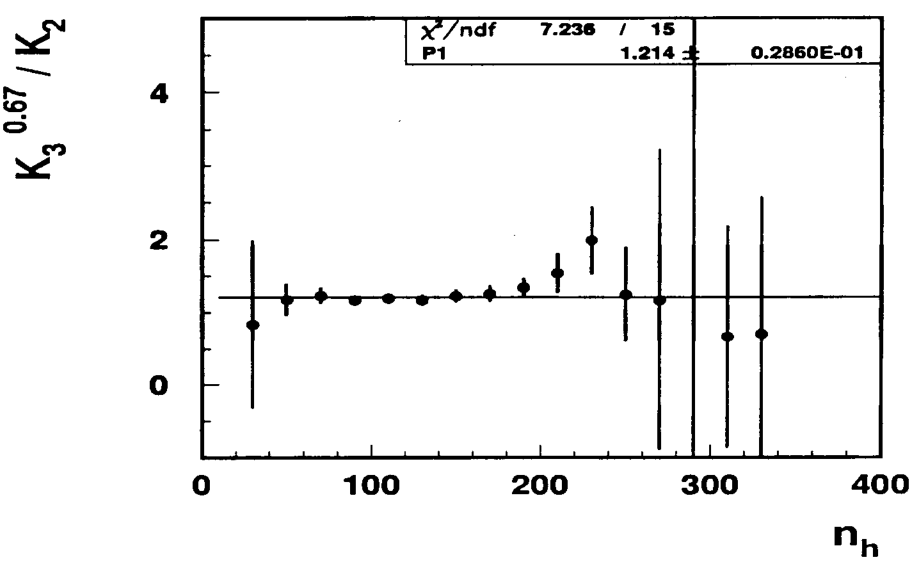

Figure 4: The $R_3(n)$ ratio [•] as a function of the multiplicity at 14 TeV taking into account the pile-up background.

The investigation of the behaviour of the VHM events is planned out at the ATLAS [3, 4] at $\sqrt{s} = 14$ TeV. Only charged particles with the transverse momentum more than ≈ 1.5 GeV reach the calorimeter because of the strong magnetic field (2 T) of the solenoidal magnet. Therefore, only the hadrons with $p_t \geq 2$ in the central region $|\eta| \leq 2.5$ have been selected. The physics events satisfied the condition $p_t^q \geq p_t^{q,\ min}$ for partons which have been simulated for the decreasing of the background pile-up events.

The obtained distributions of the correlators $K_2(n)$ and $K_3(n)$ as a function of multiplicity taking into account the pile-up events are similar to the ones shown in Fig. 2. As a result of using the cuts $p_t \geq 2$ GeV and $|\eta| \leq 2.5$ the maximum multiplicity decreases to ≈ 300 hadrons per event. As before, there is no trend to equilibrium for the $R_3(n)$ ratio, $R_3(n) = 1.21$ for $p_t^q \geq 2000$ GeV (Fig. 4).

It is important to note, that it is not necessary to take into account the detector acceptance because the correlations are small and equal to all particles in the VHM region.

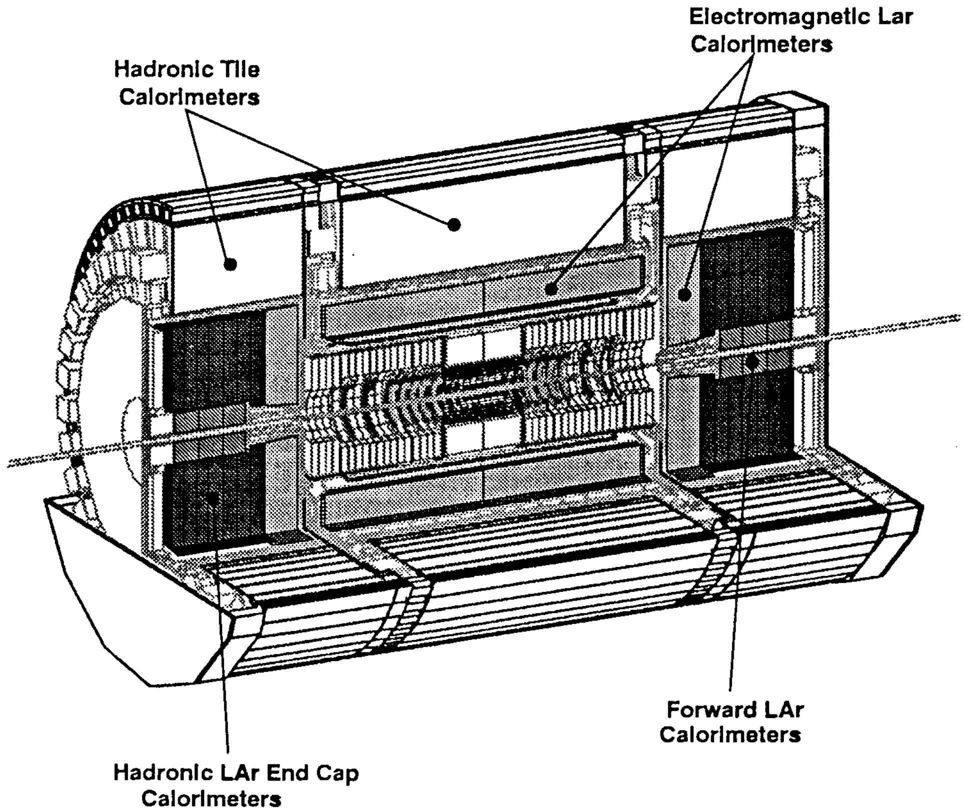

Figure 5: Three-dimensional view of the ATLAS calorimetry.

It is assumed to use the calorimetric [8, 9, 10] information for the determining of the energy correlators in the ATLAS experiment. This calorimeter (Fig. 5) has beautiful energy resolution $\sigma/E = (42\%/\sqrt{E} + 1.8\%) \oplus 1.8/E$ in the barrel region [11]. There is the projective geometry for ATLAS calorimeter towers. The initial transverse dimension of a hadronic calorimeter tower is equal to $\eta \times \phi = 0.1 \times 0.1$. The hadronic shower size is larger than one calorimeter tower size [12]. Signals from each tower have been used in the calculations separately. The ATLFAST [13] programme has been used for simulation.

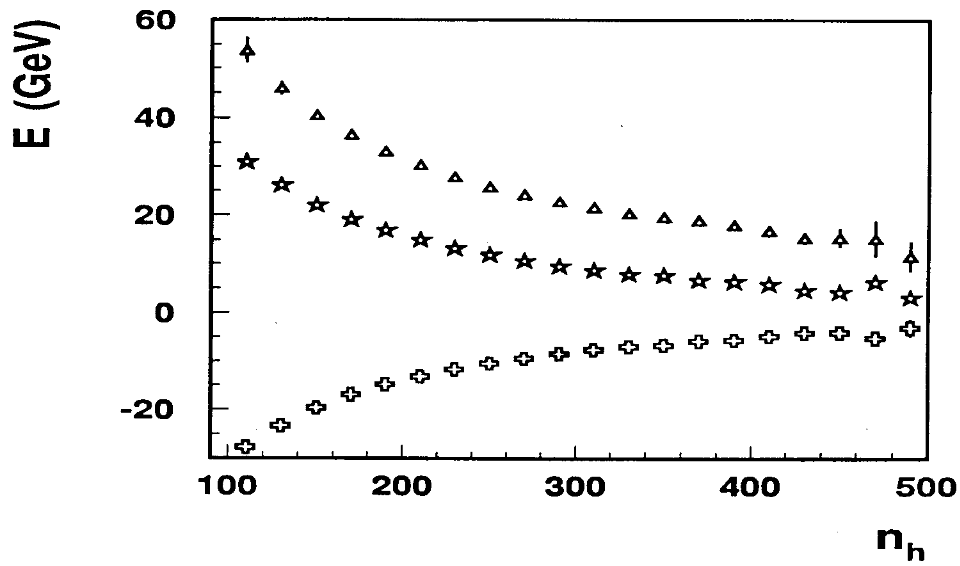

Figure 6: The average energy [Δ], the correlators $\sqrt{K_2(n)}$ [✠], $\sqrt[3]{K_3(n)}$ [★] for calorimeter towers as a function of the multiplicity at 14 TeV.

Fig. 6 shows the dependence of the average energy and the energy correlators $\sqrt{K_2(n)}$, $\sqrt[3]{K_3(n)}$ in calorimeter towers as a function of multiplicity of worked towers by using the cuts $p_t \geq 1.5$ GeV and $|\eta| \leq 3.5$. The values of the correlators lead to 5 GeV for $n_h \to 500$. The obtained distributions are also similar to the ones shown in Fig. 2. The dependence of the $R_3(n)$ ratio as a function of worked towers is shown in Fig. 7. There is no trend to decreasing the $R_3(n)$ ratio at n_h increasing. The value of this ratio is equal to 1.28 and coincides with the above obtained results (Fig. 3).

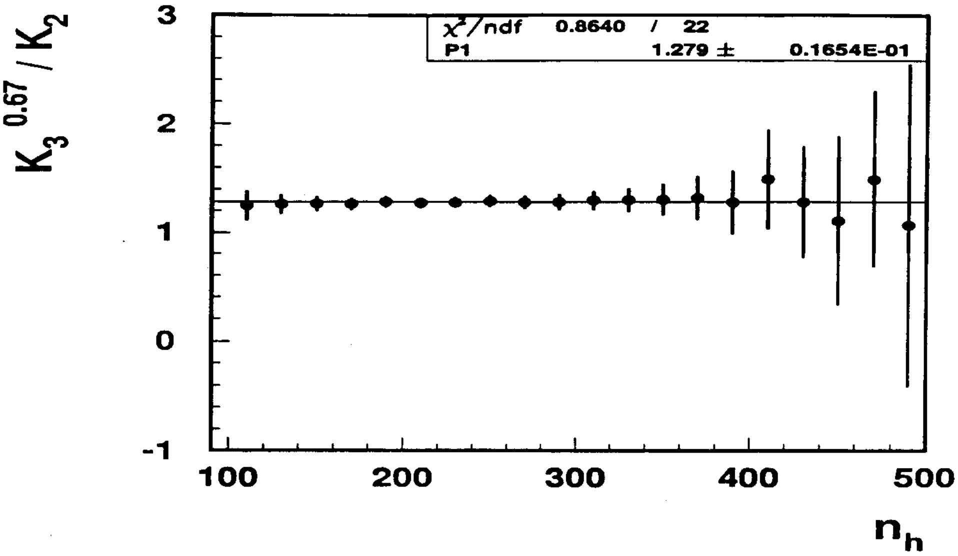

Figure 7: The $R_3(n)$ ratio [•] for calorimeter towers as a function of the multiplicity at 14 TeV.

4 Conclusion

The results of the study of the energy correlators $K_2(n)$, $K_3(n)$ and their ratio $R_3(n)$ as a function of hadron multiplicity at 14 TeV are represented. It is shown that the value of the ratio does not depend on multiplicity and is slightly more than unit. Thus, PYTHIA does not predict tendency to equilibrium, $R_3(n) \ll 1$, at high multiplicity. It is shown that the pile-up background and changing of the particle energy to the registered ones in the ATLAS calorimeter towers have a negligible effect on the $R_3(n)$.

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References

[1] J. Manjavidze, A. Sissakian, Phys. Rep. **346**, 1 (2001).

[2] J. Manjavidze, A. Sissakian, Bogolyubov Conf. "Problems of Theoretical and Mathematical Physics", Moscow-Dubna-Kiev, Ed. V.G. Kadyshevsky and A.N. Sissakian (1999); Part. & Nucl., 31 (2000) 104.

[3] ATLAS Collaboration, ATLAS Detector and Physics Performance Technical Design Report, v.1, CERN-LHCC-99-014, CERN, Geneva (1999).

[4] ATLAS Collaboration, ATLAS Detector and Physics Performance Technical Design Report, v.2, CERN-LHCC-99-015, CERN, Geneva (1999).

[5] T. Alexopoulos et al., Nucl. Phys. A544 (1992) 343.

[6] N.N. Bogolyubov, Studies in Statistical Mechanics, Amsterdam, 1962.

[7] T. Sjöstrand et al., Comp. Phys. Com., 135 (2001) 238.

[8] ATLAS Collaboration, ATLAS Calorimeter Performance, CERN-LHCC-96-040, CERN, Geneva (1996).

[9] ATLAS Collaboration, ATLAS Tile Calorimeter Technical Design Report, CERN-LHCC-96-042, CERN, Geneva (1996).

[10] ATLAS Collaboration, ATLAS Liquid Argon Calorimeter Technical Design Report, CERN-LHCC-96-041, CERN, Geneva (1996).

[11] S. Akhmadaliev et al., NIM A449 (2000) 461-477.

[12] P. Amaral et al., NIM A443 (2000) 51-70.

[13] E. Richter-Was et al., ATL-PHYS-98-131, CERN, Geneva, 1998.