IL NUOVO CIMENTO Vol. 31 C, N. 4 Luglio-Agosto 2008
DOI 10.1393/ncc/i2009-10319-6

The TOF detector of ALICE experiment: Analysis of the first cosmic data

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(ricevuto il 9 Gennaio 2009; approvato il 9 Febbraio 2009; pubblicato online il 20 Marzo 2009)

Summary. — ALICE@LHC is an experiment optimized for study of heavy-ions collisions (Pb-Pb up to 5.5 ATeV). The main aim is the search for a new state of matter (called QGP) where quarks and gluons are deconfined. Particle identification is guaranteed by a set of detectors: one of these, the time-of-flight system plays an important role in the identification of charged hadrons (π, K, p) in the momentum range [0.5, 4] GeV/c. The first data-taking periods with cosmic rays have been a great chance to check the performance of the experimental apparatus and of the developed software for description, simulation, recostruction, visualization and analysis. A preliminary time resolution study on this cosmic rays data is presented.

PACS 25.75.-q – Relativistic heavy-ion collisions.
PACS 25.75.Nq – Quark deconfinement, quark-gluon plasma production, and phase transitions.
PACS 12.38.Mh – Quark-gluon plasma.

1. – Introduction

ALICE (A Large Ion Collider Experiment) [1] is, amongst the LHC experiments, the only one mainly devoted to ions-ions collisions and its goal will be the search of hints of a new state of matter, the so-called *Quark Gluon Plasma* [2].

ALICE is conceived as a general-purpose detector, in which the most part of hadrons, leptons and photons produced in the interactions can be measured and identified.

Particle tracking and identification in the central rapidity region ($-0.9 < \eta < 0.9$) of ALICE, relies on a system of complex detectors immersed in a moderate solenoidal magnetic field $B = 0.2$–0.5 T. Detection and identification of muons are performed by the forward muon arm ($2.4 < \eta < 4$).

In particular the time-of-flight (TOF) system [3] of the ALICE experiment is a high-resolution array dedicated to particle identification (PID): it has been optimized to identify charged hadrons in an intermediate momentum range, *i.e.* below about 2.5 GeV/c for pions and kaons, up to 4 GeV/c for protons.

The performance of such a detector is of crucial importance for the experiment since the majority of the charged particles are produced in this momentum range.

The TOF system, covering an area of $155\,\mathrm{m}^2$, is confined inside a cylindrical shell, of polar acceptance $|\theta - 90°| < 45°$ and full coverage in ϕ (the azimuthal angle). The internal radius is 370 cm and the external radius is 399 cm (with respect to the beam axis). The structure is subdivided in 18 sectors in the azimuthal angle and 5 segments in the longitudinal coordinate along the beam axis. At both ends of each sector, special crates contain the readout and the slow control system [4].

The TOF basic sensitive unit is a gas detector, the 10-gap double-stack Multigap Resistive Plate Chamber (MRPC) strip [5], 122 cm long and 13 cm wide. The single strip has an active area of $120 \times 7.4\,\mathrm{cm}^2$ subdivided into two rows of 48 pads, each of $8.8\,\mathrm{cm}^2$ area.

The TOF strips have been arranged inside the modules following, with respect to the interaction vertex, a particular geometry designed to minimize the transversal path of the incident particles through the MRPC strips and reduce the sharing of the charge, produced by the ionization taking place in the gas volume of the MRPC, among adjacent pads. The MRPC strips are then placed, in each sector, transversely to the beam direction. In particular their angle with respect to the axis of the cylinder is progressively increasing from 0° in the central part ($\theta = 90°$) of the detector to 45° ($\theta = 45°$ and 145°) in the extreme part of the external module.

Tests with cosmic rays have been performed on one of the first sectors installed in the ALICE apparatus during December 2007. In February 2008 tests with cosmic rays have been performed with six TOF sectors taking data.

In this paper we will describe the results of a time resolution analysis performed on data taken during these periods.

2. – Time resolution: A first approach

During December 2007 and February 2008 test, the trigger for the detection of cosmic muons has been mainly provided by the ACORDE detector, which is composed of several scintillator counters located in the three upper octants of the central magnet. The arrangement of these counters can be easily changed in order to obtain the most convenient geometry for specific measurements [6].

A simulation of the trajectory of a muon, crossing the active areas of the operating TOF sectors during the two cosmic runs, has been performed. The simulation showed that, with such trigger configuration, a single muon, crossing few adjacent TOF MRPC strips belonging to the same sector, could be revealed (fig. 1).

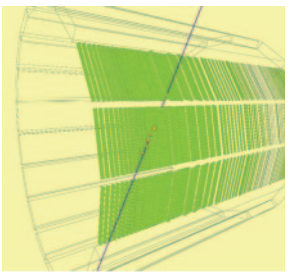

Fig. 1. – Visualization of the trajectory of a simulated muon crossing through the TOF sensitive volume.

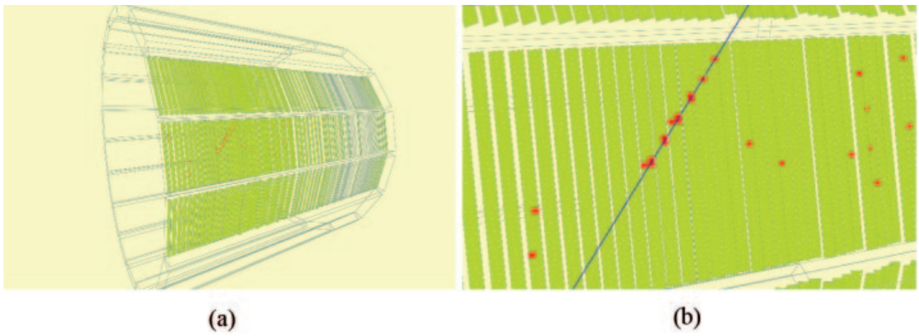

Fig. 2. – Visualization of the hit TOF pads by a cosmic muon. The line is the fit of their positions.

As a matter of fact, during these two cosmic runs, several events of this kind have been registered (fig. 2).

Using these first data a preliminary study of TOF time resolution has been performed. In the first step of the analysis a set of pads hit by a single muon has been taken into account and the deviation of the time measured on each pad with respect to the average measured time has been calculated. These deviations have been plotted and fitted with a Gaussian function (fig. 3).

The first estimate of time resolution with this method is $730 \pm 50\,\text{ps}$.

In order to improve this evaluation, for every set of hit pad (corresponding to a cosmic muon), the measured time (t_{meas}) on each pad has been plotted *vs.* the strip number; then a linear fit has been performed with the function (fig. 4a)

$$y = a + b * x.$$

So, the expected time for each strip has been calculated using the estimated parameter a and b from the linear fit

$$t_{\text{exp}} = a + b * (\text{strip number}).$$

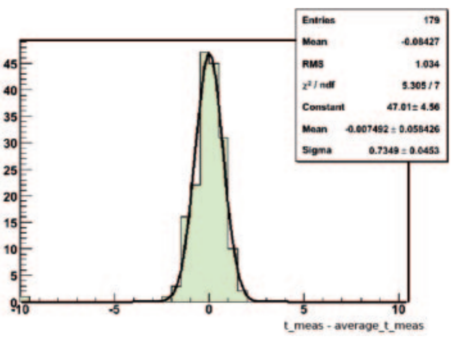

Fig. 3. – Distribution of the difference between measured time on each pad with respect to the average time of the set of pads hit by a single muon. The black line is Gaussian fit.

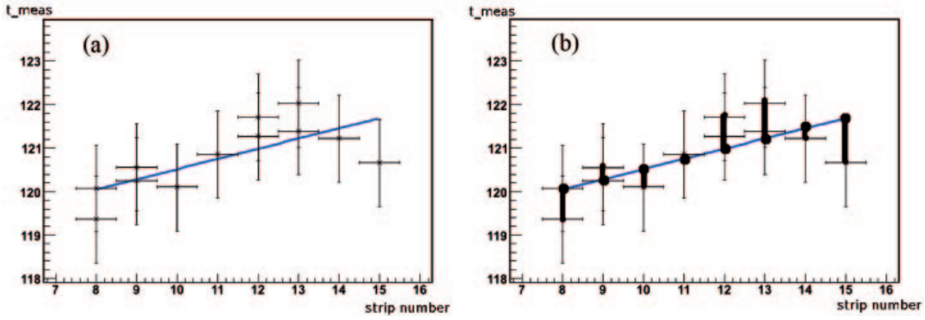

Fig. 4. – Measured time *vs.* strip number method: (a) t_{meas} *vs.* strip number: linear fit; (b) deviation t_{exp}-t_{meas} estimate.

Furthermore, the t_{exp}-t_{meas} deviation (fig. 4b) has been calculated for each point of the graph and the distribution of these deviations (for all cosmic revealed) has been plotted and fitted with a Gaussian function (fig. 5). The result for the TOF time resolution with this method is $530 \pm 30\,\mathrm{ps}$.

In the following step of the analysis, for every set of hit pad (a cosmic muon), the measured time on each pad *versus* the three Cartesian coordinates of the pad, separately, has been plotted and a linear fit has been performed with the function

$$y = a + b * k,$$

where k was in turn the X, the Y and the Z coordinate.

So, the expected time for each coordinate has been calculated in this way:

$$t_{\mathrm{exp}\,X} = a_X + b_X * X,$$
$$t_{\mathrm{exp}\,Y} = a_Y + b_Y * Y,$$
$$t_{\mathrm{exp}\,Z} = a_Z + b_Z * Z.$$

Then the mean (t_{exp}) of the three values $t_{\mathrm{exp}\,X}$, $t_{\mathrm{exp}\,Y}$, $t_{\mathrm{exp}\,Z}$ has been calculated and

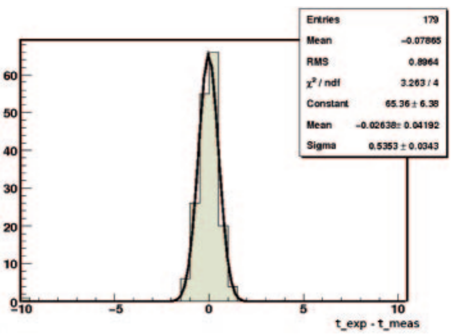

Fig. 5. – Deviation t_{exp}-t_{meas} distribution obtained with measured time *vs.* strip method. The black line is Gaussian fit.

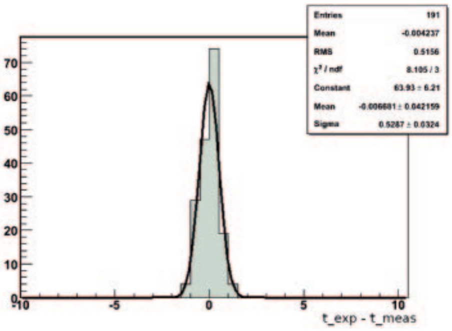

Fig. 6. – Deviation t_{exp}-t_{meas} distribution obtained with measured time *vs.* spatial coordinates method. The black line is Gaussian fit.

the deviation t_{exp}-t_{meas} has been extracted for each point of the graph. Moreover, the distribution of these deviations (for all cosmic muons revealed) has been plotted and fitted with a Gaussian function (fig. 6). The result for the TOF resolution with this method is 530 ± 30 ps.

3. – TOF clustering

As already mentioned, the TOF system consists of long MRPC strips with an active area subdivided into two rows of 48 pads, individually read out. A particle crossing an MRPC can produce hits on more than a single pad. In fact, the charge produced in the ionization occurring in the gas gaps can release a footprint on several neighboring pads (up to four) sharing in this way the total charge on a "cluster" of pads. This peculiarity has been exploited to produce an algorithm of weighted mean both of spatial position of hit pads and registered times by each hit pad. The weight used is the Time over Threshold (ToT) measure, *i.e.* the time interval in which the signal overcomes the threshold (which is strictly related to the measurement of the signal amplitude). With this method, it is possible to obtain, for each strip, a unique value of time and a unique value for the spatial coordinates of the cluster. For every set of hit pads (a cosmic muon), the weighted mean time on each pad has been plotted *vs.* the three Cartesian coordinates, separately, and a linear fit has been performed, as above, with the function

$$y = a + b * k,$$

where k was in turn the X, the Y and the Y coordinate of the cluster.

The expected time for each coordinate was calculated in this way:

$$\begin{aligned} t_{\mathrm{exp}\,X} &= a_X + b_X * X, \\ t_{\mathrm{exp}\,Y} &= a_Y + b_Y * Y, \\ t_{\mathrm{exp}\,Z} &= a_Z + b_Z * Z. \end{aligned}$$

Then the mean (t_{exp}) of the three values $t_{\mathrm{exp}\,X}$, $t_{\mathrm{exp}\,Y}$, $t_{\mathrm{exp}\,Z}$ has been evaluated and the t_{exp}-t_{meas} deviation has been calculated for each point of the graph, *i.e.* for each cluster. The distribution of these deviations (for all cosmic revealed) has been plotted and fitted

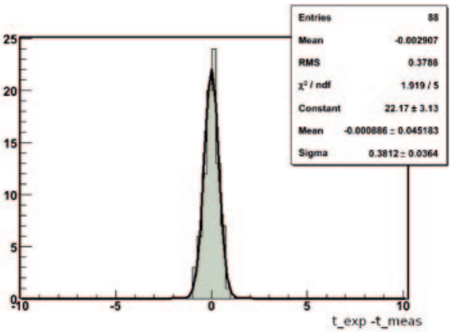

Fig. 7. – Deviation t_{exp}-t_{meas} distribution obtained with cluster method. The black line is Gaussian fit.

with a Gaussian function (fig. 7). The TOF time resolution obtained with this method is significantly improved to a value of $380 \pm 40\,\mathrm{ps}$.

4. – Conclusion

A preliminary study of time-of-flight system resolution on time measurement has been done on data taken during cosmic runs on December 2007 and February 2008.

Even neglecting some signal trasmission delay corrections, track momentum, TOF strip alignment and time slewing corrections [7] the obtained result for the TOF detector time resolution is $380 \pm 40\,\mathrm{ps}$.

REFERENCES

[1] ALICE Collaboration, *ALICE: Physics Performance Report, Vol. I*, *J. Phys. G: Nucl. Part. Phys*, **30** (2004) 1517.

[2] Karsch F. and Laermann E., *Thermodynamics and in-medium hadron properties from lattice QCD in Quark-Gluon Plasma 3* (World Scientific, Singapore) 2004.

[3] ALICE Collaboration, *Time Of Flight System, Technical Design Report, ALICE TDR 8*, CERN/LHCC/2000-12 (2000); ALICE Collaboration, *Addendum to ALICE TDR 8*, CERN/LHCC/2002-16 (2002).

[4] Akindinov A. *et al.*, *Nucl. Phys. Proc. Suppl. 1*, **158** (2006) 60.

[5] Cerron Zeballos E., Crotty I., Hatzifotiadou D., Lamas Valverde J., Neupane S., Williams M. C. S. and Zichichi A., *Nucl. Instrum. Methods A*, **374** (1996) 132.

[6] ALICE Collaboration, *ALICE: Physics Performance Report, Vol. II*, *J. Phys. G: Nucl. Part. Phys.*, **32** (2006) 1295.

[7] Akindinov A. *et al.*, *Nucl. Instrum. Methods A*, **533** (2004) 178.