ATLAS RPC off-line time calibration

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We applied an off-line calibration procedure to the ATLAS data recorded during 2011 in LHC p-p collisions at $\sqrt{s} = 7$ TeV to calibrate in time the entire RPC ATLAS detector [2] . Achieving the ultimate timing resolution of the RPC system is a very powerful way of extending the physics potential of ATLAS experiment, for example, in searches for particles moving with low velocity from the interaction point. In addition, good time resolution may be a key ingredient for background rejection, which may become of overwhelming importance in future scenarios of increased LHC luminosity.

The ATLAS Resistive Plate Chambers (RPC's) are planar large size gaseous detectors working in saturated avalanche regime with resistive electrodes and two orthogonal pick-up readout strip panels located outside a 2 mm-thick active gas volume. In the ATLAS experiment three layers of RPC detectors are used in the ATLAS Muon Spectrometer barrel ($|\eta| < 1.05$) to generate a hardware muon trigger signal.

The muon candidates are identified by fast geometrical coincidence pattern (trigger roads) in the two measurement views (η-ϕ). This allows to provide a Region of Interest $\Delta\eta\times\Delta\phi$=0.1×0.1 for the muon canditates, the highest among one of the six programmable transverse momentum thresholds, and the coarse measurement of the bending (η) and non-bending (ϕ) coordinates, useful to seed the next on-line trigger level, in addition to the bunch crossing identification number.

The RPC readout electronics, based on a 320 MHz clock [1] , allow to store a very granular time information, making the RPC system, potentially, the detector providing the most accurate time measurement in ATLAS. To fully exploit the intrinsic time resolution of detector and readout electronics, a careful calibration of the system is needed, involving about 330,000 channels. The on-line time alignment is done with tracks, both for trigger output signals and readout hits, in order to maximize trigger efficiency inside a 25 ns trigger window.

We assumed as off-line time calibration criteria that the arrival time of a relativistic track leaving the interaction point is on average equal to 100 ns. A simple calibration algorithm is employed strip by strip. The calibration constant per strip $\tau_{cal}$is defined as:

$$\tau_{cal} = t_c - MP[t_{raw} - t_{prop}], \quad (1)$$

where MP is the most probable value of the distribution of the strip time t_{raw}, minus the signal delay t_{prop}; t_c is conventionally set to 100 ns , which corresponds to the readout window center. In order to have a clean sample of tracks for the calibrations only RPC hits matched with muon tracks are considered in the time distribution.

Once the calibration constants are extracted from the data, the off-line calibrated time t_{cal} must be defined consistently as (see plots of Figure 1):

$$t_{cal} = t_{raw} - t_{prop} + \tau_{cal}. \quad (2)$$

Analogously, the real time of flight t_{TOF} is the calibrated time minus the 100 ns offset and plus the nominal time of flight given by the spatial hit position with respect to the interaction points d:

$$t_{TOF} = t_{cal} - t_c + c \cdot d, \quad (3)$$

where c is the speed of light. In fact, a ultra-relativistic particle leaving the interaction point at t=0 will have in average a calibrated time equal to zero and a time-of-flight equal to the nominal ones.

It is worth to notice that the signal delay must always be subtracted because it is a systematic time shift that adds to the real arrival time.
The 330,000 thousand calibration constants were measured adding together several runs of June 2011. The time measurement, as defined by equation 2, was stable for all channels and for all 2011 (corresponding to an integrated luminosity of about 4.8 fb^{-1}). The data selection is based on RPC clusters matched in both eta view and phi view with at least one extrapolated track reconstructed in the inner detector and in the muon spectrometer. It turns out that the time resolution obtained by on-line time alignment is of 4.7 ns, which corresponds to a resolution of 4.2 ns after signal time delay subtraction, and the time resolution obtained after off-line calibration is of 1.99 ns to be compared with the ideally expected 1.75 ns. The electronic noise and the time-walk introduced by analog and digital part coupling

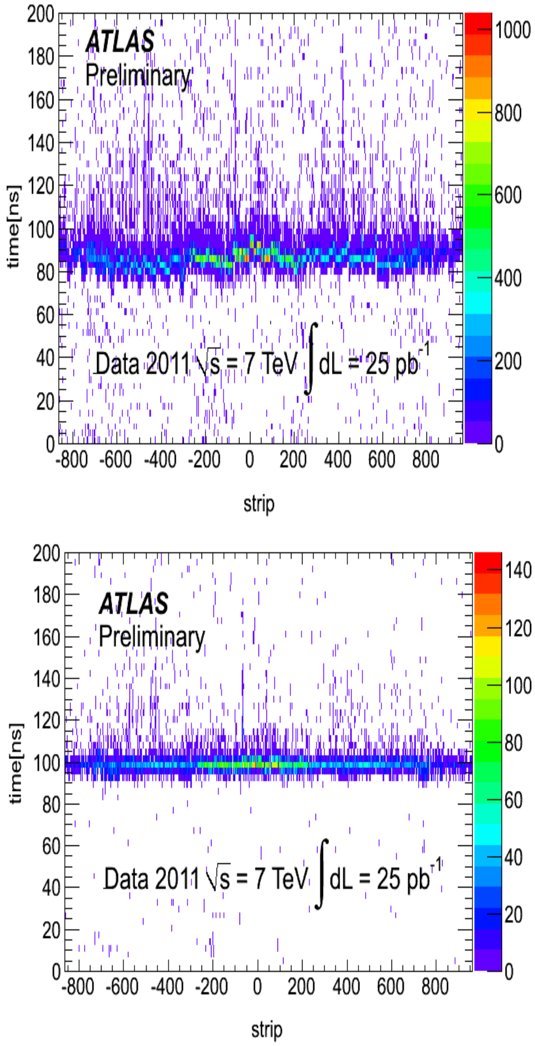

Figure 1. Upper: RPC cluster time corrected with signal time propagation along strip subtracted vs strip number for one layer before off-line calibration. Lower: The same as left plot but after off-line calibration.

are expected to make-up the rest of the time resolution and explain the difference between 1.75 ns and the 1.99 ns.

This is a very significant result because is obtained for the entire RPC system, using many months of data taking, using a small calibration sample also excluded from the plots. The RPC time resolution achieved by simple off-line calibration algorithms is very near to the single unit resolution and proves that RPC detector can easily operate in standalone mode thanks to its tracking and timing capability.

The achieved off-line time resolution is very effective in reducing correlated and un-correlated background such as: loopers, beam-gas, parasitic beam-beam, beam collimator interactions , cosmic rays, and cavern background (mainly neutrons and gammas). It is possible to see a long non Gaussian tail in the arrival time distribution also for hits matched with prompt tracks which can be identified by using RPC time information. The time spread of the Gaussian core is about 1.99 ns and the ratio of background events inside a ±3sigma window to the signal events in the Gaussian core is about 3%.

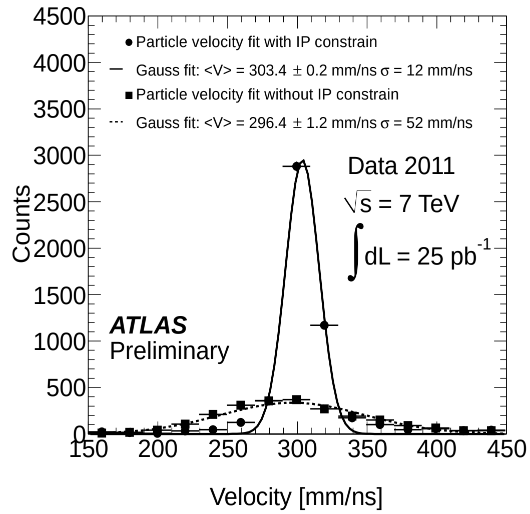

Figure 2. Distribution of velocity measured with RPC pointing track with interaction point constrain (circles) and without it (squares) using 7TeV pp collision data.

The velocity of particles was measured doing a linear fit between the incremental distance between spatially averaged space points and the average of the corresponding time-of-flight for each one of the 6 layers. In Figure 2 the distribution of velocity measurements is shown and for real data after off-line calibration. The redundancy in the RPC trigger system and its good tracking capability allow particle velocity measurement with a precision of about 4% with interaction point constrain and of about 17% without it.

REFERENCES

1. ATLAS Muon Collaboration, "ATLAS Muon Spectrometer Technical Design Report". CERN/LHCC/97-22 (1997).
2. "Off-line time calibration of the ATLAS RPC system" Chiodini G, Spagnolo S, On behalf of the ATLAS Collaboration. JOURNAL OF INSTRUMENTATION, ISSN: 1748-0221. IN PRESS.