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ATLAS NOTE

January 30, 2015

Test of the VMM1 Address in Real Time (ART) output using ≥ 0.8 GeV$/c^2$ cosmic muons

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Abstract

We present the results of a study of the time distribution and spatial resolution of the VMM1 ART output using cosmic muons. Our findings are compared with the NSW TDR expectations.

1 Experimental setup

The VMM1 ART outputs provide signals for the NSW trigger. They consist of a time flag, the leading edge of which (AFT) corresponds to the earliest time at which a micromega strip-signal passes the VMM1 threshold. The ART output also includes the hardwired address of the earliest channel (ADDR), consisting of six bits the level of which is latched when this channel goes over theshold. The ART outputs are LVDS signals.

In Ref. [1], we have emulated the performance of the ART output by selecting the channel with the largest TDO in the chip processing micromega signals produced by incident muons. In this case, the earliest time (ETDO) is derived by using the peaktime and not the time-at-threshold as required by the NSW trigger. The channel number of the ETDO strip is referrred to as EADDR. In that study we find that the ETDO distribution covers 8 LHC bunch crossings and not 2-3 as stated in the NSW TDR [2]. Motivated by this discrepancy, we have added the ART output to our data acquisition system.

The implementation is done converting ART LVDS signals into ECL signals and feeding them to a Lecroy 3377 multi-hit TDC, which has a 0.15 ns resolution. The TDC information is acquired through the CAMAC crate part of the data acquisition system [1]. We have tested the LVDS-ECL converter using the VMM1 on-board test-pulser firing one channel at the time. The time jitter of the ART output plus converter with respect to the test pulser is less than 1 ns. However, when using the pulser, address bit 0 was never set in any of the four VMM1 chips we tested; bit 1 worked only in 1 out of 4 chips. This remains a mystery since all bits work when taking muons data.

Muon data have been collected with the setup in which muons have angles of incidence between 0 and 25° [1] in six 5° steps with a 1.5 ° RMS deviation as determined by the increasing y coordinate of the bottom scintillator counters. Since the micromega strip number also increases with their y coordinate, the highest-number strip in a cluster collects the ionization with the shortest drift path, which in turn should be the one providing the ART signal.

We have collected 79131 events with one good muon in which 24143 events have a micromega signal. We use a gain of 9 mV/fC, a TAC scale of 1000 ns, a peaktime of 200 ns, and no neighbor-enable option. The ART signal is generated at time-over-threshold.

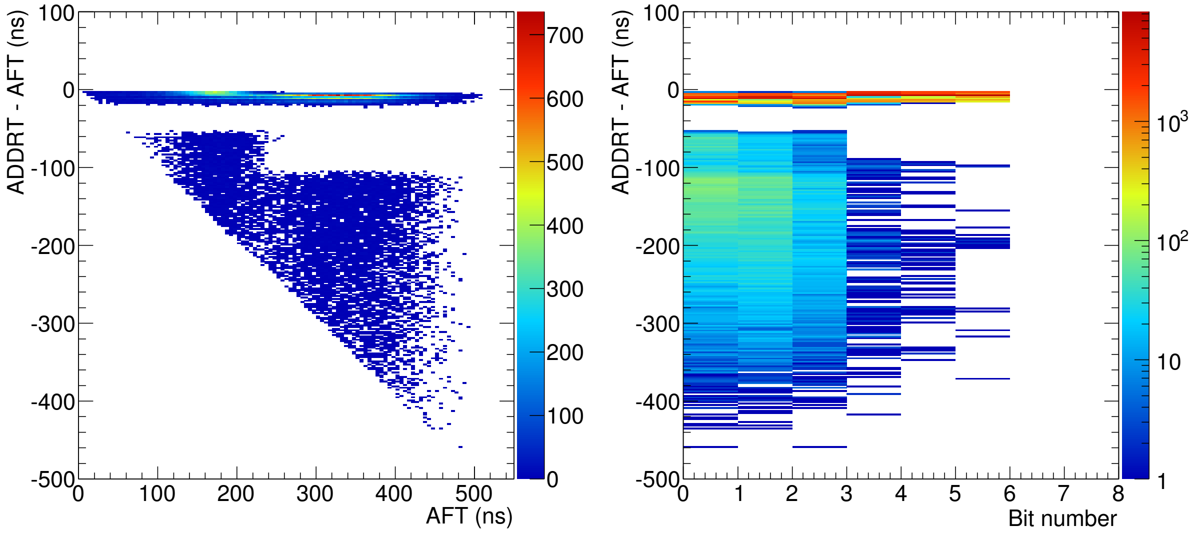
2 Study of the ART time distribution

In these events, we reconstruct AFT and the leading edge (ADDRT) of each address bit. The times AFT, ADDRT, and ETDO are measured with respect to that of the SP scintillator, part of the trigger system, which has a 1 ns resolution. Since times are measured with respect to a common stop, larger times indicate earlier occurrence.

In Fig. 1 a), we compare the time distributions of ADDRT and AFT. One sees that bit-addresses are set to 1 about 5 ns after the AFT; however, bit addresses not set to 1 have transient noise and flip to 1 at random times. As shown by Fig. 1 b), the least significant address-bits have the most random hits, which suggests that this type of noise is generated inside the VMM1 chips. We mitigate this problem by requiring that ADDRT and AFT are within 25 ns. In general, this noise will not cause problems if the VMM ART address is serialized within 25 ns from the AFT.

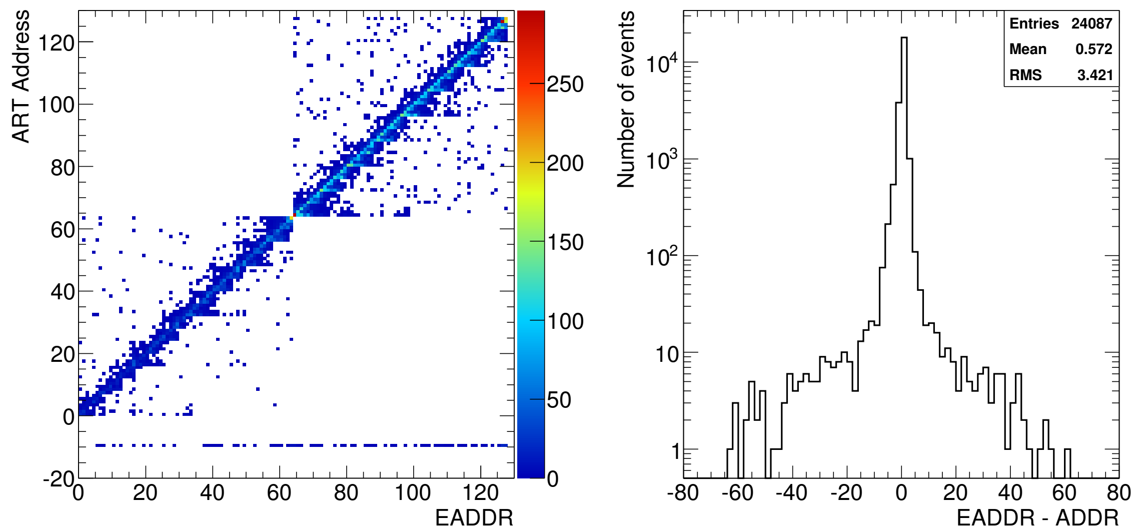
Two events in 20,000 have an ART signal and no TDO/PDO signal. In 0.5% of the events, the AFT arrives after the TDC stop and is recorded as a nil value. Figure 2 compares EADDR and ADDR distributions for all events with a micromega signal. In 98% of the events, they agree within a few channels; however, the RMS deviation is 3.4 strips. As shown in the next section, this RMS deviation is mostly caused by the uncertainty of the drift time inferred from the peaktime.

Figure 3 shows the AFT and ETDO time distributions. As expected because the muon-induced strip signals fluctuate by a factor of 50 [1] and the signal risetime is about 200 ns, the time-over-threshold



(a) (b)

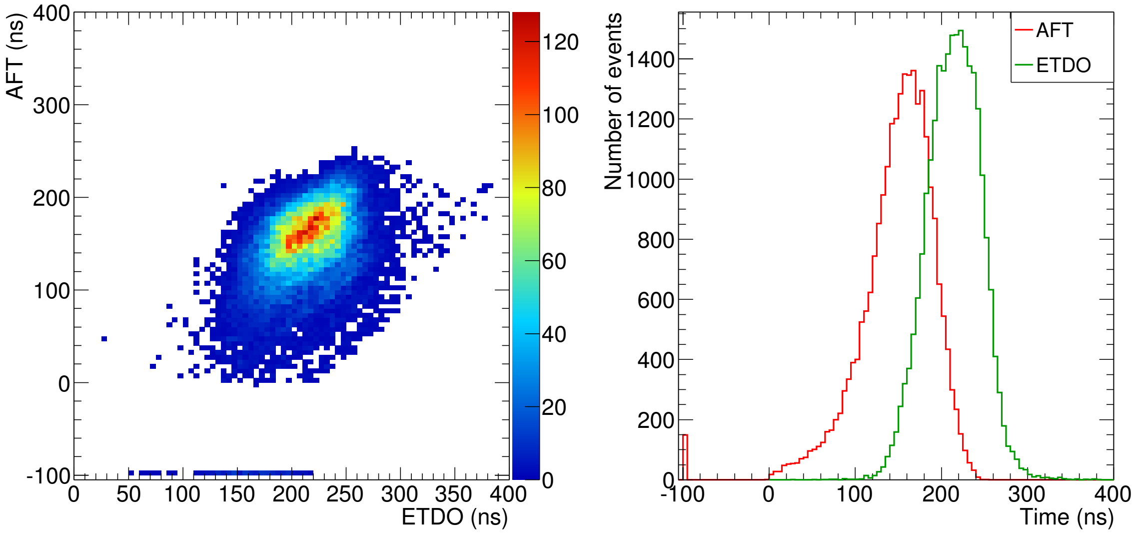
Figure 1: (a) Distribution of the difference between the leading edge of the address-bit (ADDRT) and AFT as a function of AFT; (b) the same difference as a function of the address-bit number.



(a) (b)

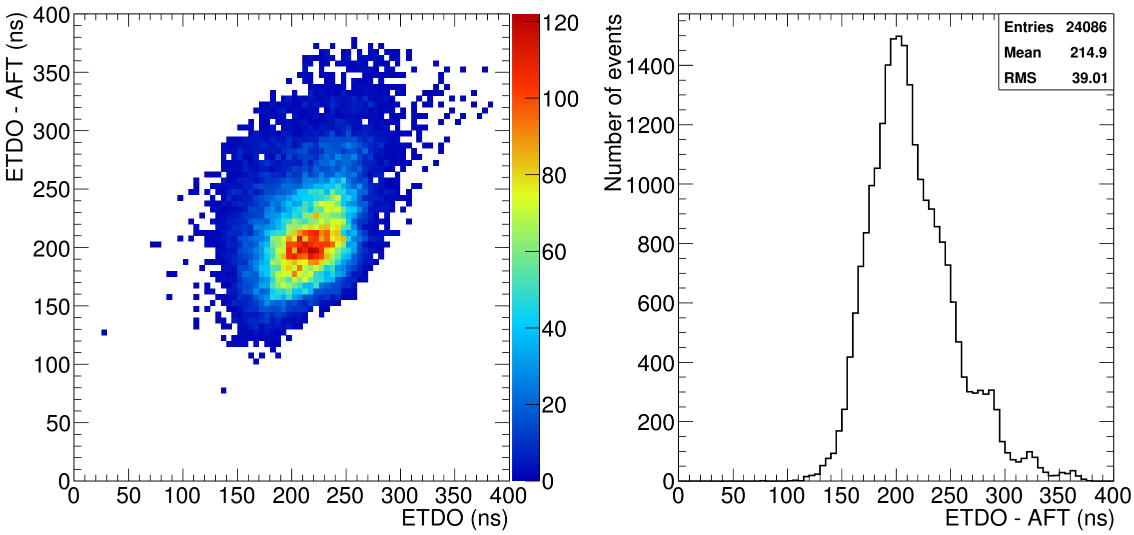
Figure 2: (a) Distribution of the ART address versus EADDR, the channel number with the earliest TDO in each events; (b) distribution of their difference.

mode yields an AFT time-slewing larger than that of the peaktime, and the AFT distribution covers 10 LHC bunches. The fraction of events within a 75 ns window around the peak is 73%. Figure 4 shows the distribution of the difference between AFT and ETDO as a function of ETDO. We note the quite poor correlation between the two measurements that are plagued by uncorrelated uncertainties: the ETDO largest uncertainty comes from inferring the drift time from the peaktime whereas most of the AFT uncertainty is due to time slewing.



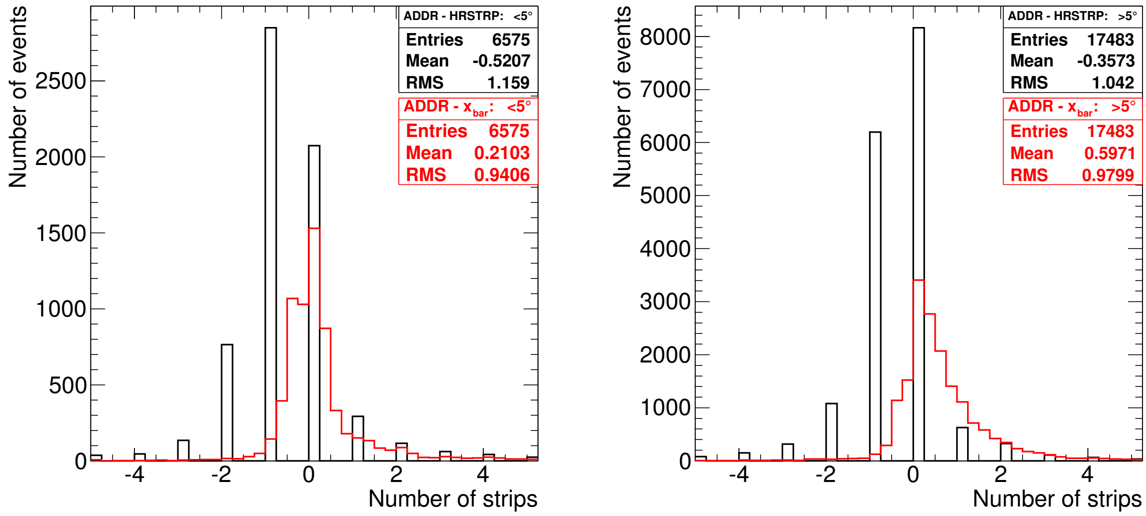
(a) (b)

Figure 3: (a) Distribution of AFT versus ETDO in each event; (b) projections on the vertical (AFT, red histogram) and horizontal axis (ETDO, green histogram).



(a) (b)

Figure 4: (a) Distribution of ETDO−AFT versus ETDO in all events; (b) projection on the vertical axis.



(a) (b)

Figure 5: (a) Distribution of ADDR-HRSTRP (see text) for muons with (a) $\geq 5°$ and (b) $\leq 5°$ angle of incidence. The distribution of ADDR$-x_{\mathrm{bar}}$ (red histogram) is also shown.

3 Spatial resolution of the ART address

To determine the spatial resolution of the ART signal, we recontruct clusters in each event as in Ref. [1] and compare the highest-number strip in the cluster (HRSTRP) with the ART address. As said earlier, for muons with $\geq 5°$ angles of incidence this strip collects the ionization with the shortest drift path. For $\leq 5°$ angle of incidence, both the lowest or highest ranking strip in a cluster may correspond to the minimum drift path, and we also compare to the cluster barycenter position (x_{bar}). These comparisons are shown in Fig. 5. The RMS deviation of the ADDR−HRSTRP and ADDR$-x_{\mathrm{bar}}$ distributions is 1 strip. When adding a few outliers out of the histogram limits, the RMS deviation is 1.7 strips whereas the analogous distribution of EADDR−HRSTRP has a RMS deviation of 3 strips. Since the RMS uncertainty of the EADDR−ADDR distribution in Fig. 2 is 3.4 strips, it follows that the uncertainties of ADDR and EADDR are not correlated.

The ADDR ±1 strip uncertainty in finding the x-position of the strip collecting the ionization with the minimum drift path in a cluster does not account for those cases in which that strip does not pass the VMM threshold. We investigate this contribution by applying the μTPC method to each cluster. We fix the fit slope to be the muon angle of incidence inferred by the y position of the bottom trigger-counter. We use clusters with at least two strips, and, following the procedure of Ref. [1], we remove points if their fit residuals are larger than four [1]. From the fit, we extract the x position of the point with $z = 0$, $x_{z=0}$, and compare it to the ADDR value. The distribution of this difference is shown in Fig. 6.

The RMS deviation of this distribution is 0.6 mm (or 1.5 strips), which represents an upper limit to the spatial accuracy of ADDR since we believe the $x_{z=0}$ uncertainty to be negligible but we cannot prove it.

We compare this uncertainty to that measured with the 2012 test beam data by using eight micromegas with a lever arm of 60 cm. As reported in [3], a resolution of approximately 1 mrad was obtained. Having put the geometry of the test beam setup in a toy Monte Carlo, this angular resolution corresponds to an ADDR spatial resolution of 0.65 mm, consistent with our result.

[1] In the fit, the z error of each point is set to 0.25 mm. As shown by the residual distribution in [1], the correct error is 0.34 mm. This implies that the pruning removes all points with a residual larger than 3 σ.

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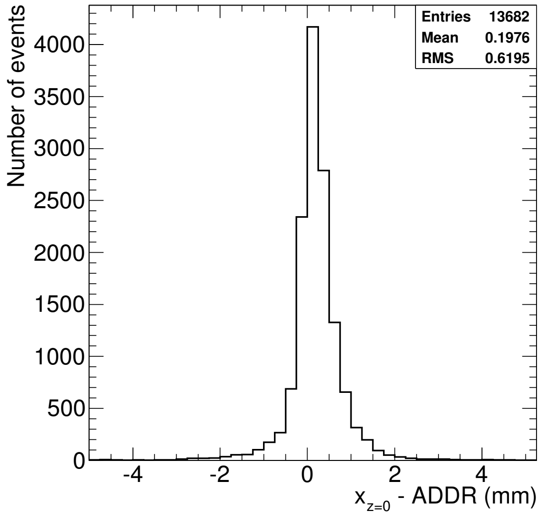

Figure 6: Distribution of $x_{z=0}$−ADDR (see text) for muons with a ≥ 5° angle of incidence.

When using an ADDR resolution of 0.6 mm, 8 micromegas positioned as in the NSW TDR provide a 4 mrad angular resolution. Fig. 12.14 of the NSW TDR shows a simulation result of a 0.7 mrad resolution using at least 5 out of 8 micromegas. Such a nice angular resolution requires an ADDR spatial uncertainty significantly better than 0.12 mm (strip width=0.4 mm/ $\sqrt{12}$).

References

[1] K. DiPetrillo *et al.,* ATL-COM-MUON-2014-038.

[2] ATLAS New Small Wheel Technical Design Report, ATLAS-TDR-020, CERN-LHCC-2013-006

[3] T. Alexopoulos *et al.*, *Performance of the first version of VMM front-end ASIC with resistive micromega detectors*, ATL-UPGRADE-PUB-2014-001