Upgrade of the MDT Readout Chain for the SLHC

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Problems of the MDT electronics at very high luminosity

The readout electronics of the MDT system was designed to cope with data rates and radiation levels corresponding to five times the simulated ("nominal") level of neutrons and gammas in the UX15 hall. An additional safety factor of two had been foreseen, so the readout would be expected to work up to ten times the nominal value over 10 years of operation.
Beyond this level, the most exposed chambers (i.e. in the high-η range of the endcaps) would suffer from data loss due to various storage and bandwidth limitations along the readout chain. Also, after years of operation malfunction or permanent failure of CMOS components would have to be feared as soon as the limiting radiation dose was reached. While this component failure due to radiation could in principle be cured by routine replacement of the critical modules, data loss could only be avoided by the use of more performant components in the readout chain and/or improved readout strategies. In summary, a major upgrade of the readout chain would be needed, requiring new ASICs and possibly new processors. Such an upgrade program could be be expected to take several years before components could be certified for volume production.

The occurrence of both types of problems, bandwidth as well as radiation damage, depends, of course, on the actual background levels encountered in ATLAS. The relevant numbers will probably be known some time in 2008/2009 when machine parameters approach their nominal values and operation becomes stable. It may turn out -in our favor- that background levels are considerably lower than anticipated (less that 5 * nominal), increasing the margin for the MDT readout to operate at high luminosity.

The idea of this proposal is to *not* wait until these numbers become known, but to start R&D already now, in 2007, assuring sufficient time for simulation, system architecture, design and prototyping.

Limitations of the readout due to high tube occupancies

Fig. 1 shows a simplified diagram of the MDT readout chain. At high occupancy of the tubes, i.e. above about 150 kHz/tube, the following limitations are expected:

a) TDC and link to the CSM: the storage capacity of the internal buffers, accumulating hits for later readout, may be exceeded, leading to uncontrolled data loss. Limitations of the transfer rate to the CSM may fill up the derandomizing buffers, with the same consequences.
b) CSM: the flexibility of this device, being fully programmable, allows to increase buffer space if needed. The clocking speed limitation of the present FPGA, on the other hand, would be an obstacle for higher transfer rates (towards TDC and MROD).
c) CSM-MROD link: the limitation of the effective transfer rate to about 1.2 Gbit/s may lead to data loss.
d) MROD: limitations due to processor speed and storage capacity.

Technical options for the upgrade

Refering to the list of the previous paragraph the following improvements could be envisioned.

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a) Redesign of the TDC for higher storage capacity, faster clocking and processing speed. Using more modern technologies, possibly migrating to a full-custom ASIC solution, would automatically lead to higher radiation tolerance.- The link to the CSM may then be operated at higher speed (80→160 MHz?). Alternatively, more than one LVDS line may be used for data transmission to the CSM.
b) CSM: upgrade of the XILINX-FPGA to the latest family (e.g. Virtex-II → Virtex-IV), which, among other advantages allows for faster clocking.- The tolerance of these devices w.r.t. irradiation would have to be verified, in particular SEE sensitivity.
c) CSM-MROD optical link: the possibility of higher clocking rates, leading to higher bandwidth, should be explored. Alternatively, a duplication (or even multiplication) of the existing links would have to be foreseen.- New technologies, like multi-frequency transmission should be checked for feasibility, as this may be the most cost effective solution, in particular, if radiation tolerant drivers were commercially available.
d) MROD: In a duplication scenario a MROD would serve three MDTs instead of six. To optimize this configuration, however, a redesign of the MROD would most likely be necessary.

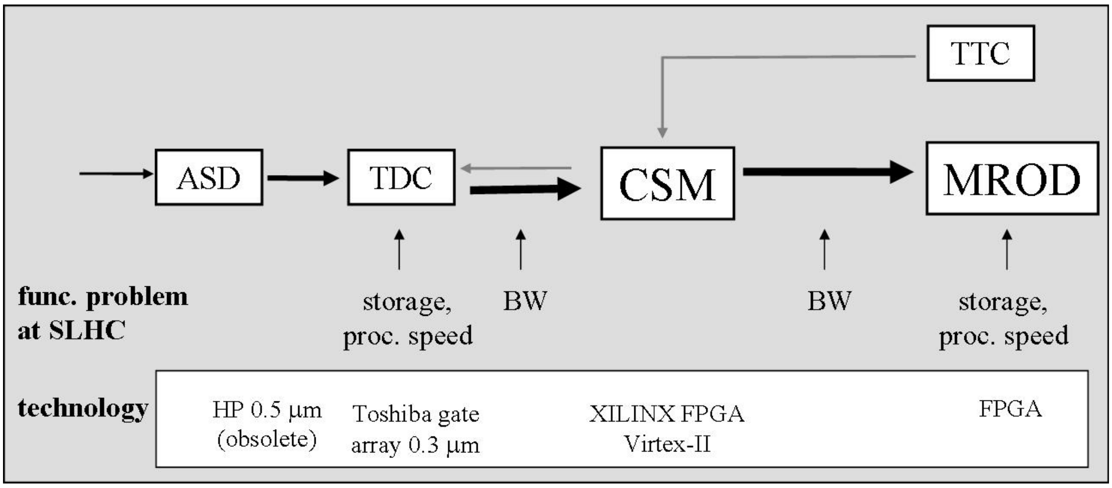

Fig. 1 Schematic diagram of the MDT readout chain. The Chamber Service Module (CSM) collects and formats the data on each chamber and sends them to the MROD via an optical link.

These modifications have to be carefully matched to each other to optimize the performance of the complete chain. A detailed simulation of the data flow must therefore be the first step.

The proposed project requires considerable human and financial resources. A participation of several institutions from the muon community is therefore a necessity. Beyond this, synergy from common development projects with other LHC upgrade programs, e.g. in chip development, should be pursued.

It has been observed that the large majority of MDT data, read out to the MRODs, is discarded at the LVL2, containing no tracks, the average number of muons per event being very small (about 1,5). For the average event not more than about 15-20 chambers are actually needed for further data processing and analysis, while all 1200 MDTs are read out in the present scheme.

The possibility of a selective readout of the *few relevant chambers*, leading to a reduction of the data volume by about two orders of magnitude, could therefore be pursued as an alternative approach to the *complete chamber readout*, the latter leading to the costy upgrade of fibers and processors described above. In this szenario the information from the fast trigger chambers would be the crucial element to guide the readout. This complementary readout concept is discussed in a separate EoI.