# Overload Recovery in the ATLAS Muon Electronics

P. O'Connor, A. Kandasamy (BNL)

Sept. 28, 2001

We have simulated the effect of very large ionization charge deposition in the front-end electronics of the ATLAS muon system. This was done in response to concerns about the high background of neutrons expected in ATLAS, with the realization that ionization from neutron hits can be much higher than for muons. High charge depositions well in excess of the maximum expected muon charge may result in long recovery times, depending on the electronics configuration. Measurements on the CSC front-end chip confirm the simulation results.

## *Simulation Setup*

The CSC, MDT, and TGC front-end preamplifiers were studied using the commercial circuit simulator *PSPICE*. Fig. 1 shows the circuits that were simulated. For the CSC, the complete front end (CMOS preamplifier/7$^{th}$ order shaper) was simulated, while for the other two systems only the preamplifier was studied. The circuit schematics were taken from ATLAS design review documentation available on the Web. No attempt was made to model the input protection networks of the ICs. For the CSCs we studied two circuit configurations, corresponding to the first and second design iterations of the preamp/shaper chip.

MOS transistor models were available for the CSC and MDT preamplifiers, both fabricated in the Agilent 0.5 micron CMOS technology available through MOSIS. For the TGC preamplifier simulation, the bipolar transistors of the Sony analog masterslice process were approximated using models available for the high frequency transistor array HFA3046.

Simple low-frequency equivalent circuit models were used to represent the detectors. For the CSC, the cathode strips were modeled as a pure capacitance of 75 pF. The MDT anodes were modeled as a 60 pF capacitor with a 470 pF/380 Ω termination and a 470 pF AC-coupling capacitor to the preamp input. For modeling slow recovery effects, it is not necessary to include the transmission line properties of the anodes. The TGC anodes and cathodes were represented as pure capacitve 200 pF sources.

Charge injection was simulated by delta-function current sources. The total charge was varied from 100 fC (well within the linear range of all three detectors) up to 300 or 1000 pC. For the TGCs, both polarities of input charge were used since the TGC-ASD circuit will be used to read out both the anodes and cathode strips. Recovery time was specified as the time needed to recover the small-signal gain to within 5% of its initial value.

## *Results*

Figure 2 shows the recovery times as a function of the input charge Qin. The “old” CSC preamp/shaper showed the longest recovery behavior, extending to almost 30 μs at an input charge of 30 pC (about 300 times the most probable charge of one MIP). Measurements on one sample of the circuit were in good agreement with the simulation numbers. The “new” design iteration recovers about four times faster at each charge level.

The MDT preamplifier recovers quickly from overload, less than 1 μs even at 300 pC input charge.

For the TGC preamplifier, an asymmetry is seen between the anode and cathode polarity. Large charge deposition in the anode direction (current flow away from the preamp) results in longer recovery times than for the cathode polarity. In the cathode polarity, the input NPN transistor’s base-emitter junction will turn on to absorb the overload charge, resulting in fast and nearly-constant recovery times. No evidence was seen for extremely long overload recovery in either polarity, however.

## *Discussion*

The preamplifier must remove the overload charge from the detector capacitance. When overloaded, saturation of the preamplifier breaks the feedback loop and changes the input impedance of the circuit. The overload charge must be removed via the feedback components themselves, which can have high DC impedance in the saturated condition.

Both the MDT and TGC preamps have passive resistors in feedback, in the range of 10 kΩ. When the preamp saturates, the voltage across these resistors is 1 – 3 V and so they can carry currents of several hundred microamperes. The input node is thus discharged at a rate of $10^{-4}$ C/s, or 100 pC in 1 μs. The results for the MDT and TGC (anode) in Figure 2 are consistent with this recovery rate. As already mentioned, the TGC (cathode) configuration has an additional charge removal mechanism, the turn-on of the input transistor’s base-emitter junction, which greatly speeds up the recovery.

The CSC system uses position interpolation and therefore a longer shaping time is used to get a high signal-to-noise ratio. Because of this long shaping, a higher effective feedback resistance is used in parallel with the preamplifier feedback capacitance. This resistance is synthesized using a MOSFET biased in the triode region, since physical resistors of the required high value are impractical in the integrated circuit process. The feedback transistor has a width-length ratio of 0.9μm/28.8μm in the “old” design, and can carry approximately 1 μA of current in the preamp’s saturated condition. This is consistent with the observed recovery time of 10 μs for 10 pC input charge, as shown in Figure 2. In the revised design, the W/L ratio of the feedback transistor was changed to 0.9µm/7.2µm, and the corresponding discharge current increases by a factor of 4; this leads to a fourfold decrease in recovery times as seen in Figure 2.

Although the MDT and TGC preamplifiers show quick recovery from overload, there may be other circuit blocks in the front-end ICs that can have much longer recovery times. In particular, the TGC front end employs a baseline restorer with a long time constant. Its behavior under overload has not been studied yet.

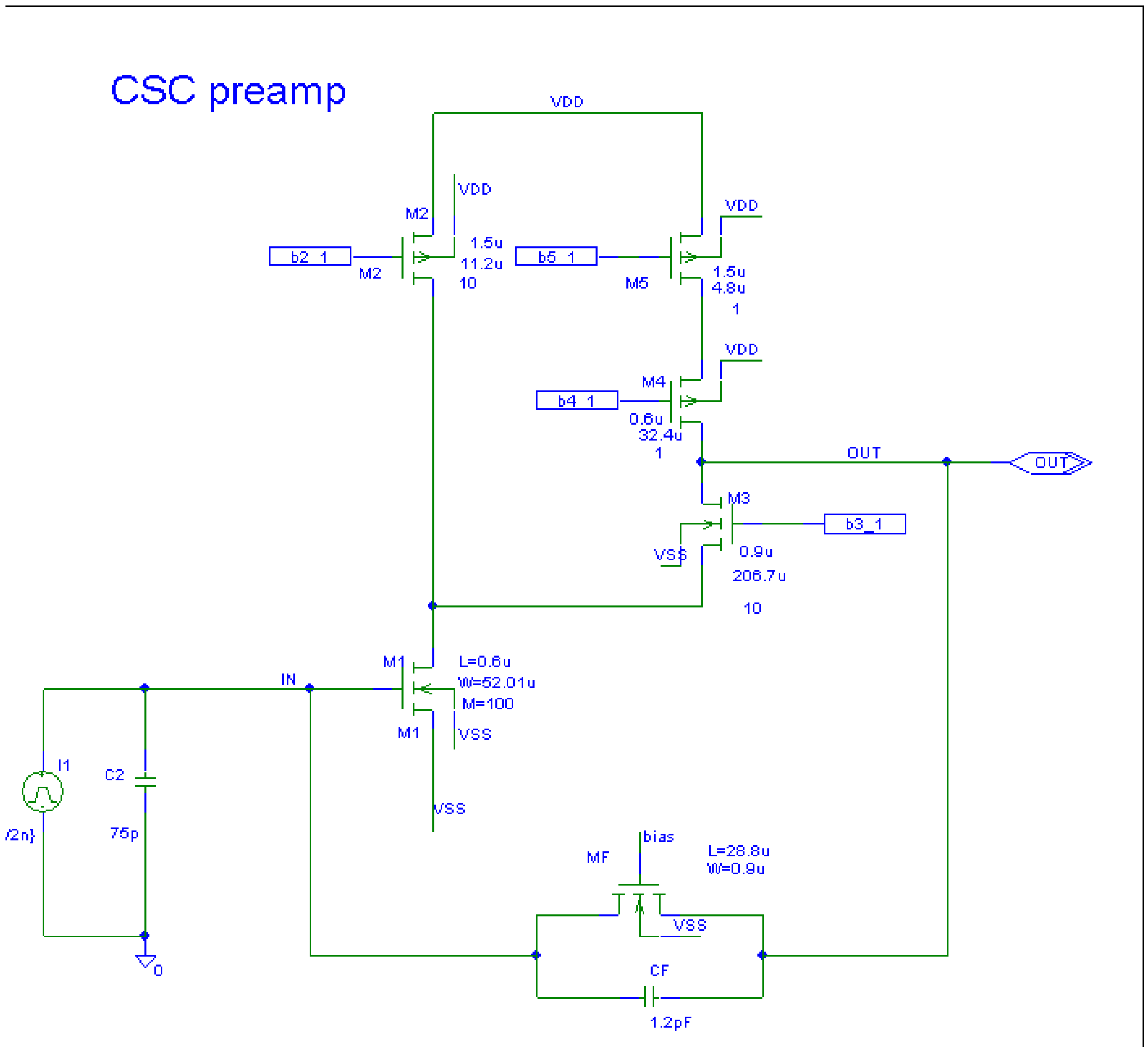


Fig. 1(a): CSC preamp

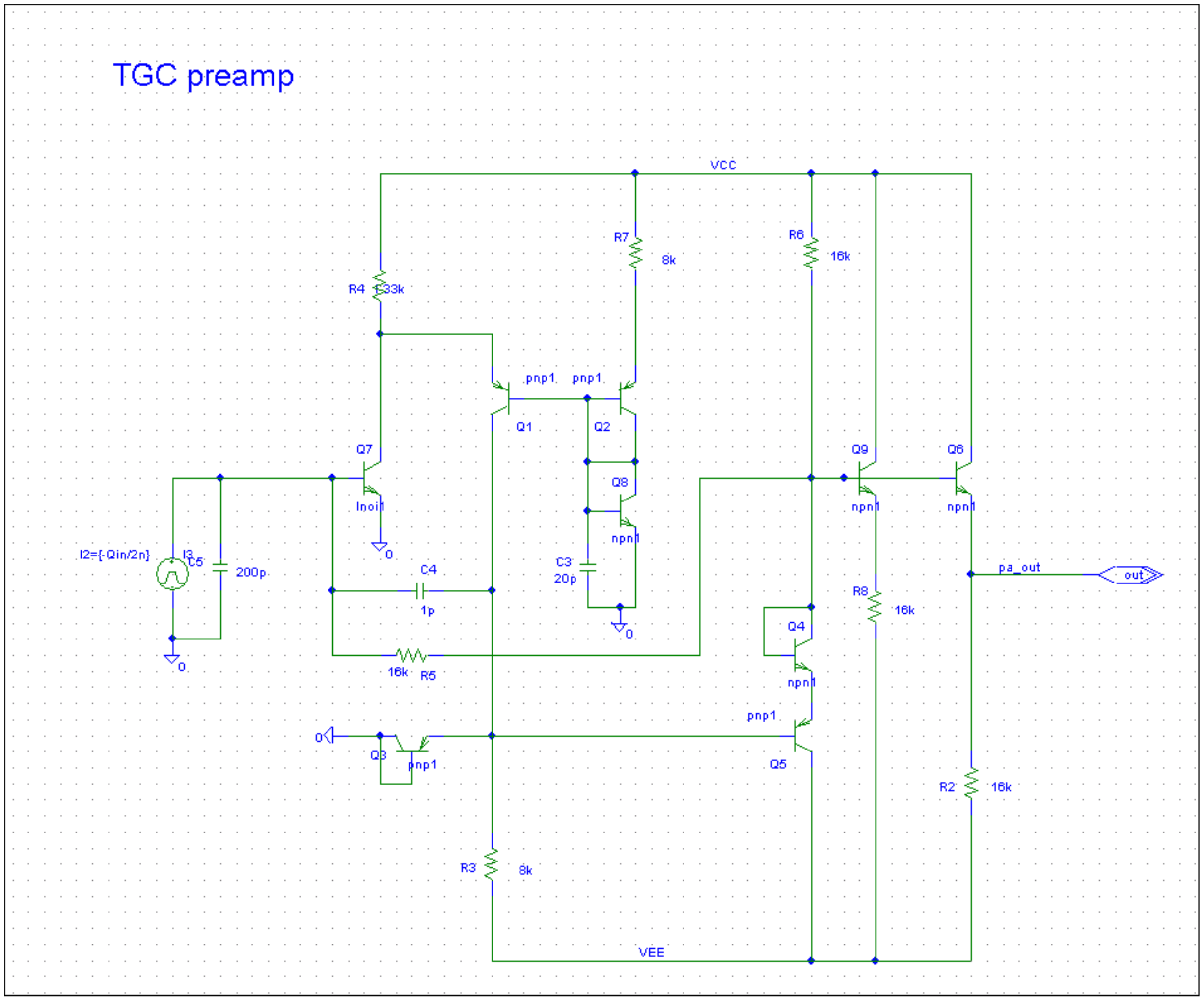


Fig. 1(b): TGC preamp

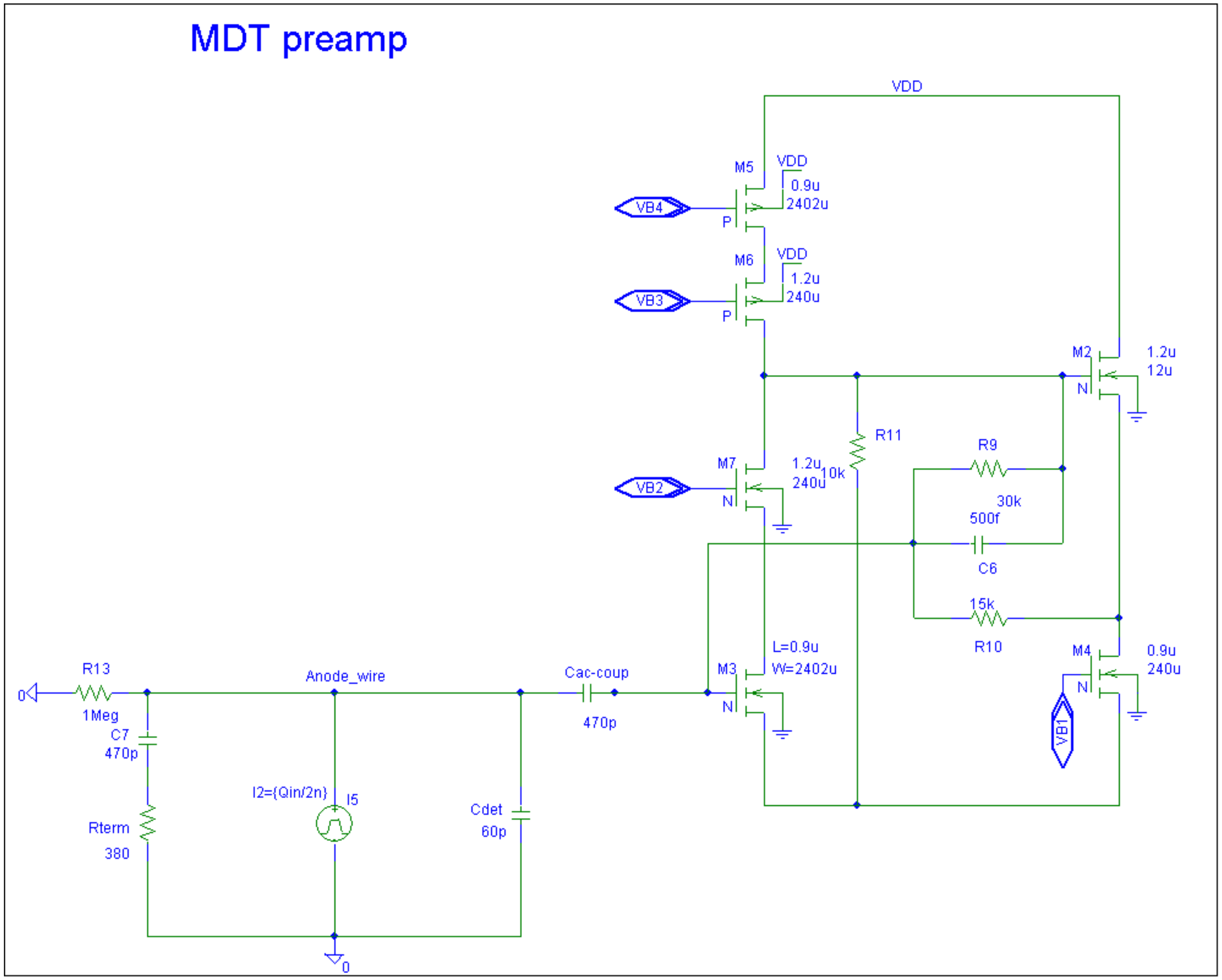


Fig. 1(c): MDT preamp

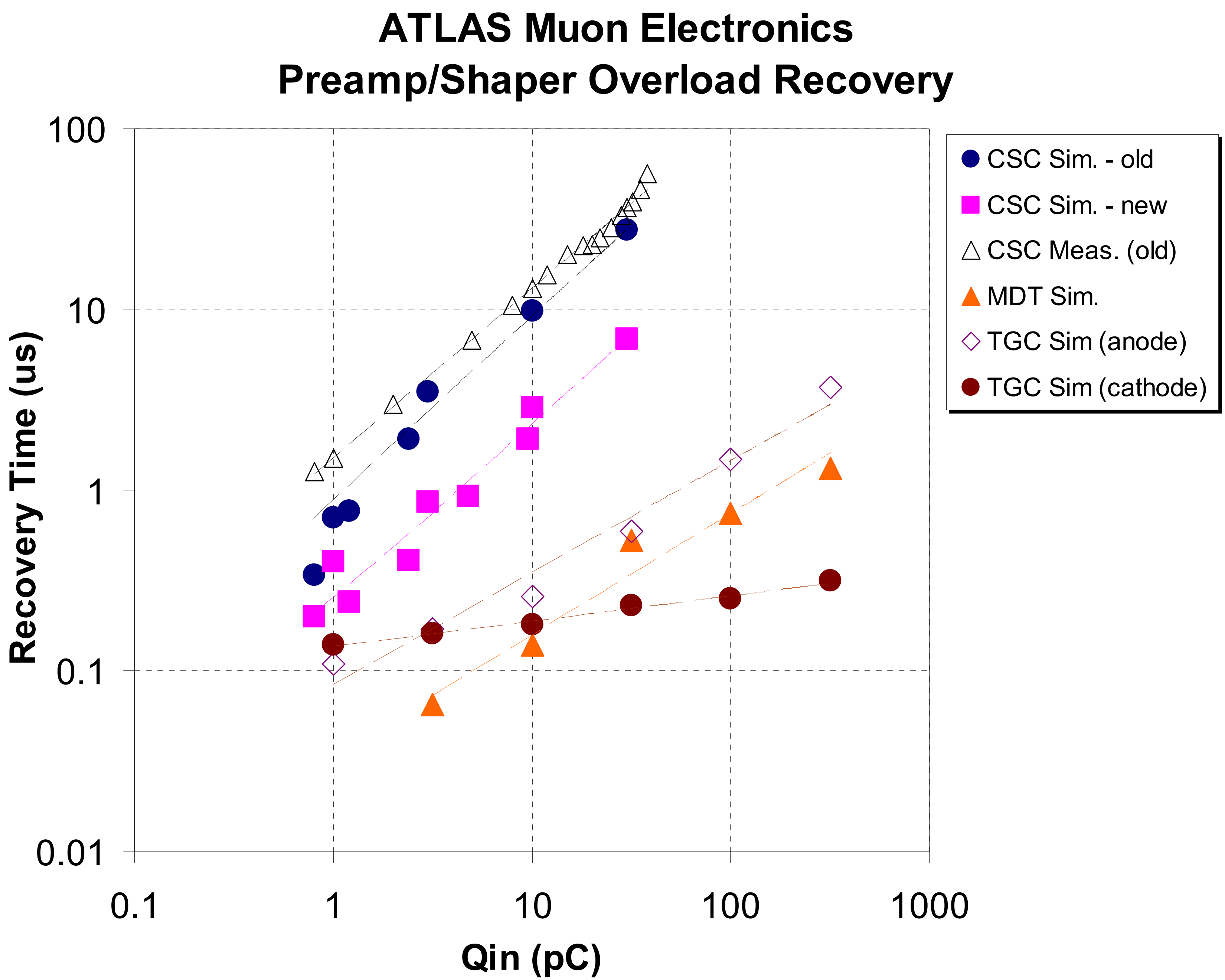


Fig. 2 Overload recovery time of the three front ends.