Front end electronics cost estimate

This is a cost estimate for the cold front end electronics, the warm intermediate amplifier and the digitizer boards each of which couple to a readout board, together forming a 9U VME (?) module. The readout board is not included here.

Entries from the MicroBooNE costing table (Aug 7, 2012 edition), WBS 1-5.7.2, numbers in kUSD. Overhead is included but I don't know the level. Note, this WBS element is only for fabrication, not design.

	Total	Labor	Materials
CMOS construction	320	43	277
cold motherboard construction	72	21	50
warm electronics fabrication	221	83	138
feedthrough construction	244	17	226
power supply and cabling	300	33	267
TPC cabling	(212k, included above)		
digitizer board construction	273	27	246
testing	584	539	46
Total	2014		

Setting aside the testing, most of the cost is for M&S, with labor costs for "oversight" and preparing orders. The testing is all labor. The TPC cabling is included in 300k for "power supply and cabling". I think most costs scale linearly with the number of channel *except* the feedthrough, which I'll treat separately. The microboone readout is naturally quantized at the 64 channel level, since that's the channel count on the digitizer boards. There are a total of 8256 TPC channels in microboone, 516 CMOS chips (16 channels each), 258 intermediate amplifiers (32 channels each), and 129 digitizer boards. The total cost, neglecting the feedthrough and testing is 1186 kUSD or 9.2 kUSD per 64 channel block. NOTE, microboone surely made more than the minimum number of boards needed to service the detector, so my calculation effectively roles in whatever level of spares microboone decided on. This is perhaps a feature rather than a bug.

There are a total of 11 feedthroughs in microboone and each one (properly each "standard" one) serves 768 channels. There are also two spares. So, the cost per feedthrough is 18.8k.

Assuming 2000 channels (3mm spacing, 3m long, 2 views) one gets:

- 287k for the CMOS, cold motherboard, intermediate amplifier, digitizer and cables. This is 31.25 readout blocks.
- 56.4k for 3 feedthroughs, enough for 2304 channels. In principle, the third one could be made with fewer channels, which might yield a modest cost savings.
- 141k for the testing (scaled by 2000/8256)

Total cost for the TPC front end electronics: 484k.

Questions/statements:

- Do we need to do the same level of testing as microboone? Can we tolerate a higher bad channel fraction, or more swapping? Has/will microboone find that less testing was needed?
- Microboone needs 516 CMOS ASICs but ordered 384 spares. Are any of these potentially available?
- The assembly was done by vendors and supervised by BNL. We will certainly need the design from BNL and could obviously benefit immensely from their collaboration. I feel that some senior EE is needed to shepherd this part of the project. The cost for that is rolled into the budget (labor portion of the table).

Readout electronics

The readout system is from Nevis and consists of readout boards (FEMs) which couple to the digitizer boards. Each FEM has an FPGA which processes the raw data stream from 64 digitizer channels. Sixteen FEMs are housed in each 9U crate (VME?), for a total of 1024 channels/ crate. Each crate also has an transmit module (XMIT) which essentially manages readout of the FEMs, with data being passed FEM → XMIT over the backplane. The XMIT connects to a PC via two PCIe optical links. There is also a crate controller, used to configure the modules, also connected to the PC via a PCIe optical link. 9 crates are needed to readout the microboone TPC, with one additional crate for the PMT system. That additional crate has a few boards to shape the PMT signals, a FEM-like board to digitize them and a trigger module. The total cost is 408k (52k labor, 356k materials, WBS 1-11.3.2), which includes 10-20% spares and overhead. The rough cost is 41k/ full crate.

We would need two crates to read out a 2000 channel TPC at an estimated cost of 82k. Leslie Camilleri's CD3b review talk lists the following component costs (USD):

FEM	$1158
XMIT	$1531
crate controller	$721
PCIe card	$784

For a 16 FEM crate, with one XMIT, one controller and 3 PCIe cards, this comes to $23132 which doesn't match the $41k estimated above. But, I presume the cost of the crate itself is

included in the $41k and perhaps the numbers in the table above do not include overhead. If you assume a $5k crate and a 50% overhead you get to 42k. This issue could use clarification.

An additional crate is probably needed to service the PMT system and do beamline triggering. We'll assume the crate costs $5k, has a controller, a trigger module, one FEM, and one XMIT. I do not have the cost for the trigger module, but in microboone it's an FPGA hooked with LEMO inputs and outputs. I have a CAEN version of this sort of module, bought for $4200. The FEM in this crate could be used to read out beamline sensors since we will not have many PMT/SiPM channels. The sampling rate is 64MHz = 16ns sampling, probably fast enough for beamline signals though a little marginal (MINERvA had trouble with overlap from adjacent accelerator buckets, 28ns apart I think) and I'd prefer something even faster. We'd likely need a TDC for time of flight, $4500 for a CAEN v775. We'll also need to shape the PMT/SiPM signals to elongate them. That cost is probably lost in the noise, but let's estimate $1k.

I get a total cost of $20462 or roughly $30693k after a 50% overhead is applied.

Total cost for the readout system: $82k + $31k = $113k

DAQ system

Each crate is served by one sub-event computer (SEB). Each of these appears to cost $5.3k. There is also a master computer uBDPC which appears to cost $12.8k and a computer uBNPC which reads data from uBNPC and merges it with ACNET and other data and writes to enstore in root format. I cannot find this computer listed in the cost table so I'll assume $10k. The DAQ construction task also lists $42k for additional equipment and switches. I am going to leave that out, assuming that FNAL will provide it since all test beam users will want to setup their experiment on a reasonably fast private network.

Total cost for the DAQ: 3x$5.3k + $12.8k + $10k = $38.7k
Front end + readout + DAQ: $635.7k
The cost estimate above includes overhead but I don't know the rate. If I assume 50%, the "base cost" would be $424k.