17 Mar 2005 PG
Update: 27 Oct 2005 (Appendix) PG

A first look at the FCAL noise data in March 2005 Cold Tests

Abstract

I have analyzed a fraction (5000 events) of the last noise run taken at ~16h on March 15, 2005. This document refers to the plots located in /afs/cern.ch/user/p/petr/public/ColdTests2005/ . The whole set of plots is packed in the zipped tar file FirstLook.tarz (1.1 MB) in the same directory. Use tar -xz to unpack the archive. The main observation is that the two edge FEBs (0 and 13) exhibit a sharply
higher coherent noise component. The individual channel noise in FEB0 is also higher than average and has a *mod(2)* structure.

1. Preamble

I have analyzed a fraction (up to 5000 events) of the last noise run taken at ~16h on March 15, 2005. The file is on Disk_1, `/noise/test14/noise_fcal_run14_000.data`

The conditions: are:

- LV(HEC) off
- HV(FCAL) off
- Calibration Board: disconnected, i.e., unpowered and lifted in the slot by ~1 cm[1]
- Environment in B.180: lights on, the crane working nearby, welding in the north part of B.180 ongoing

For reading the data, I used a modified version of Henric's dumpevt.c code. The modifications were only to speed up the processing (lookup tables to compute ADC/channel/cell numbers, discarding HBOOK calls for every sample and using two different numerical methods to compute running averages and spreads).

To present the coherent noise results, I used the same measure as the one we were using in the 2003 and 2004 beam tests: the ratio of the total rms noise for N summed channels (N=1...128) and the quadratic sum of individual rms noises for the same set of channels $\{A_i\}$:

$$rms(A_0 + ...A_N) \Big/ \sqrt{rms(A_1)^2 + ...rms(A_N)^2}$$

In the high statistics limit, this ratio must be 1 for a pure (incoherent) noise, for any N.

[1] Later, it turned out that I forgot to disconnect the board from the SPAC bus. The clock cable was disconnected.

2. The results

2.1. The two different numerical methods for computing the averages and spreads (see Appendix) give identical results. Both involve calculations in the "long double" precision. See plots

```
coh_50_acc.ps, coh_50_upd.ps, coh_200_acc.ps, coh_200_upd.ps,
coh_1000_acc.ps, coh_1000_upd.ps, coh_5000_acc.ps, coh_5000_upd.ps
```

The suffuxes "ups" and "acc" refer to the two methods. The numbers indicate the number of events processed. In each event, all 32 samples were used as independent measurements[2]

2.2. Several features are immediately seen in these plots:

- The two FEBs at the edges of the crate (FEB0 and FEB13) have a sharply larger coherent noise (up to ~120% in FEB0 and ~60% in FEB13, for a sum of all 128 channels). The noise "profile" is independent on the number of events.

- For the other FEBs, the coherent noise for all channels does not exceed 4%, 10% and 13%, for high, medium and low gains, respectively. The exception is FEB12, where the coherent noise is ~6% (high gain) and its "profile" is similar to the one in the adjacent "anomalous" FEB 13.

- The relative coherent noise increases when going from the high to low gain. IMHO, this as an indication that the source of the coherent noise is outside the cryostat (otherwise, it would go down for the low gain at which the thermal noise of the FEB electronics dominates);

- The coherent noise "profile" depends on the number of events used: it varies for short sets of events, before converging to a stable shape at 5000 events.

  NB: 5000 events were taken in about 20 minutes, with all delays and overheads. The peak rate was ~30 ev/s. 50 events were taken in about 2 s.

3. The time dependence of the coherent noise.

To study the time-dependence of the coherent noise profile, I analyzed consecutive sets of 50 events:

```
coh_50_0_acc.ps, coh_50_50_acc.ps, coh_50_100_acc.ps,
coh_50_150_acc.ps, coh_50_200_acc.ps, coh_50_250_acc.ps,
coh_50_300_acc.ps, coh_50_350_acc.ps, coh_50_400_acc.ps,
coh_50_450_acc.ps
```

The profiles for FEB1 (high gain) obtained for events 0-50, 250-300 and 400-450 are quite similar, which suggests that the noise source might have the peridic modulation of roughly 6-8 s. This is not
a very accurate statement, though, because the profiles observed for the medium gain on the same FEB do vary, as well, but I don't see any periodic pattern in these variations.

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[2] Admittedly, this is not quite correct.

4. The individual pedestal noise

The channel noise, averaged over 32 samples, is shown in the plots:

`ped50-0.ps, ped50-50.ps, ped50-100.ps, ped50-150.ps, ped50-200.ps, ped50-250.ps, ped50-300.ps, ped50-350.ps, ped50-400.ps, ped50-450.ps, ped5000events.ps`

Black. red and blue graphs correspond to high, medium and low gains.

These plots are obtained for different sets of 50 events and for the entire set of 5000 events. My only observation here is that FEB0 has visibly larger channel-to-channel fluctuations, exhibiting a clear mod(2) pattern (see the last plot in `ped5000events.ps`).

Appendix: computing averages and spreads

The two methods are:

A1. Trivial (running sums)

Accumulate $\sum_i x_i$ and $\sum_i x_i^2$, then, at any moment, after n events, compute

$$m_n = \langle x \rangle_n = \sum_{i=1}^{n} x_i / n \,; \qquad \langle x^2 \rangle_n = \sum x_i^2 / n \,; \qquad \mathrm{var}_n = \langle x^2 \rangle_n - \langle x \rangle_n^2$$

Main disadvantage: a sensitivity to rounding errors, especially if there is a large common baseline offset in all x-values. The way to overcome that are:

- Subtract a common offset (e.g., ~1000 for pedestals) from all x_i, then add it to m_n. Note that the variance estimate does not depend on constant offsets.
- Use extended precision, e.g. `long double`
- Both of the above

A2. Runnning means

Use a recurrent formula to compute running averages $m_n = \langle x \rangle_n$ and $v_n = \langle x^2 \rangle_n$, as well as the running estimate of the corresponding variance, var_n:

$$\begin{aligned} & m_0 = v_0 = 0; \\ & m_{n+1} = m_n + (x - m_n)/(n+1); \\ & v_{n+1} = v_n + (x^2 - v_n)/(n+1); \\ & \mathrm{var}_n = v_n / n - m_n^2 \end{aligned}$$

Features:

- less susceptible to rounding errors, no need to subtract the baseline offset;
- extended precision may still be required, for very long series.

A3. Computing coherent noise

To evaluate a coherent noise for a FEB, as function of the number of FEB channels involved, I was computing running averages/variances for two sets of 128 values per gain per FEB, for pedestal events:

- for individual channel noise x_j (j=1,..,128) and
- for the total noise of sums $\sum_{j=1}^{k} x_j$ of k channels (k=2,128).

The rms noise per channel is $r_j = \sqrt{\mathrm{var}(x_j)}$, and for a sum of k channels: $R_k = \sqrt{\mathrm{var}(\sum_{j=1}^{k} x_j)}$.

An estimate of a relative coherent noise contribution to the total noise of k channels (for the entire FEB in case of k=128) is

$$c_k = R_k / \sqrt{\sum_{j=1}^{k} \mathrm{var}(x_j)} - 1$$

It should be statistically compatible with zero for the case of a true uncorrelated random noise. It can also be zero if positive and negative correlations in the set of k channels compensate each other. Therefore, graphs $c_k(k)$ are useful to detect and investigate the coherent noise problems.