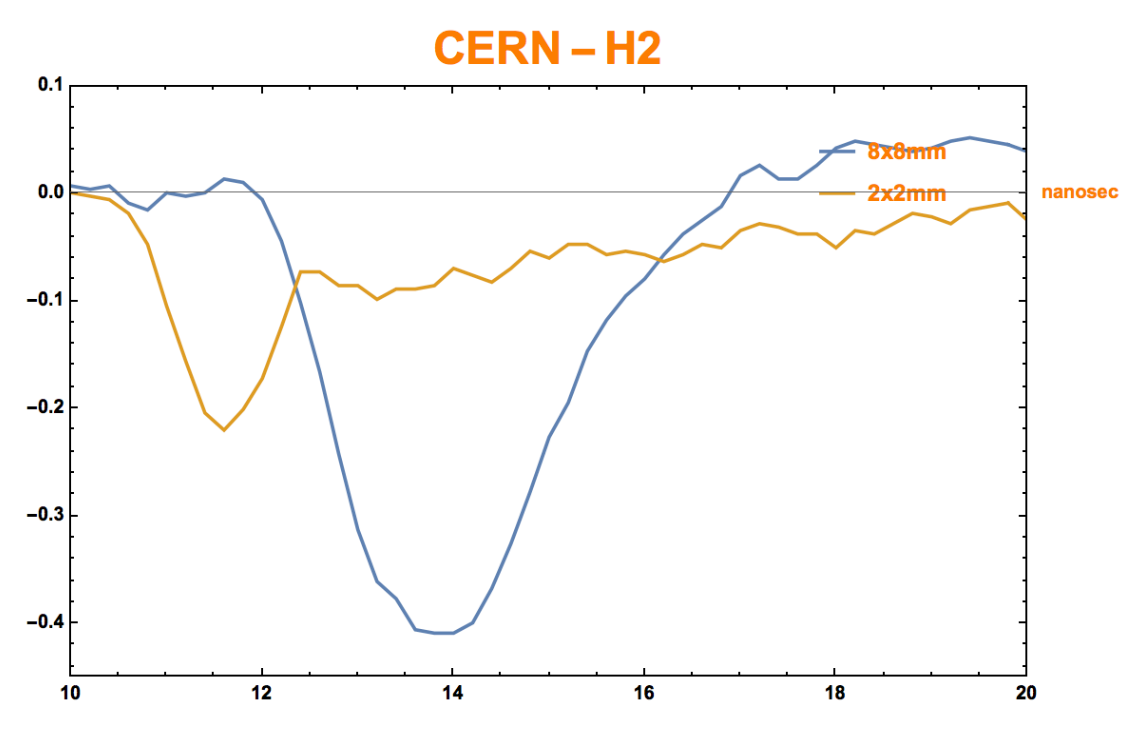
Expected timing performance relative to Diamond Detectors- SNW, July 11, 2015

There was a talk on diamond detector timing (for TOTEM) this Friday. Their MIP timing performance is, by now, well known- 90 picosec rms for MIP. We are doing ~6 times better. To me the puzzling thing is that we are not doing still better than this (ie >10 better than diamond)- at least from electronics considerations.

Our signal risetime (and fall time for the 8x8) is typically ~1 nsec (10-90%). This also happens to be the calculated risetime for an RC of 50 Ohm*25 pF(1.25nsec). See figure here from recent H2 run (8x8 channel is using a Wenteq preamp):



In order not to degrade the signal, preamp and scope bandwidth should be greater than the 300 MHz corresponding to this bandwidth. According to Shannon-Nyquist a sampling frequency of >1-2 GSa/s should be adequate.

In the H2 run we use 13 dB Mini-Circuits amp(for trigger) and Wenteq(50 dB) and Cividec(40 dB) on the 8x8 detectors. Since diamond people tend to use Cividec we can estimate performance using that.

What input noise should we expect? For a 50 Ohm resistor at Room Temperature the noise voltage is 1nV/Sqrt[Hz]. Taking a BW of 500 MHz (the full BW with Cividec is 2GHz) we then expect , for an amp gain of 100, an output noise of 2.2 mV. The Cividec data sheet specifies an output noise of 2.5 mV rms, which is pretty close to this ideal.

Relative signal (Si vs. diamond): The expected MIP signal from diamond is ~18k e-h pairs for a 500 micron sensor. For our Si APD we expect ~4k e-h pairs. But with an APD gain of 200 (we operated at 1750V bias) we obviously have a much large signal into the amplifier than with diamond.

For the pulse shape in the above figure for the 8x8mm APD (ie 4 nsec base) and equating the area to the total charge from above we calculate ~400 mV peak amplitude for an amp gain of 100 (40dB). In the case of the above figure, however, the amplifier is a Wenteq with a gain of ~300 (50 dB). This is related to the discussion over the last week of whether or not the detector capacitance is costing us in peak amplitude.

To estimate the approximate time jitter we could use the rule of thumb that $dt=t_{Rise}/SNR$ and we would obtain ideally a ballpark figure of 1nsec*(2.2mV/400 mV)= 5-6 picoseconds.

Instead, for the H2 data, we had an output noise of 6-8 mV. This is roughly consistent with the fact that we need G=300 rather than 100 to get 400 mV signal amplitude and the expected time jitter is then not far from we we've been measuring for the electronics noise contribution.

The typical diamond detector capacitance used by TOTEM is 2 pF, which is definitely less than ours.

But if we simply assumed we could scale timing performance by the signal input amplitude and take the 90 picosecond jitter reported by TOTEM we should expect ours to be 4 picoseconds.

My conclusion is that we should definitely be able to do better on time jitter due to electronics than we are doing now. It still seems like detector capacitance is our issue.

(btw. Since we are pushing for >100 in SNR we will have to keep from being limited by the 8 bit scope resolution we have with the Lecroy model.)