Test of a new Fast Waveform Digitizer for PMT signal read-out from liquid Argon Dark Matter detectors

A.M. SZELC (Yale University)*,N. CANCI (INFN-LNGS),
F. CAVANNA (L'Aquila University), A. CORTOPASSI (CAEN),
G. MINI (CAEN), F. PIETROPAOLO (INFN-PD), A. ROMBOLI (CAEN),
E. SEGRETO (INFN-LNGS), M. D'INCECCO (INFN-LNGS), R. ACCIARRI
(L'Aquila University)

*previously at L'Aquila University and IFJ PAN

Liquid Argon as a Dark Matter Detector

Liquid noble gases are definitely a strong competitor in Dark Matter searches. Xenon is going strong, but argon has great possibilities as well.

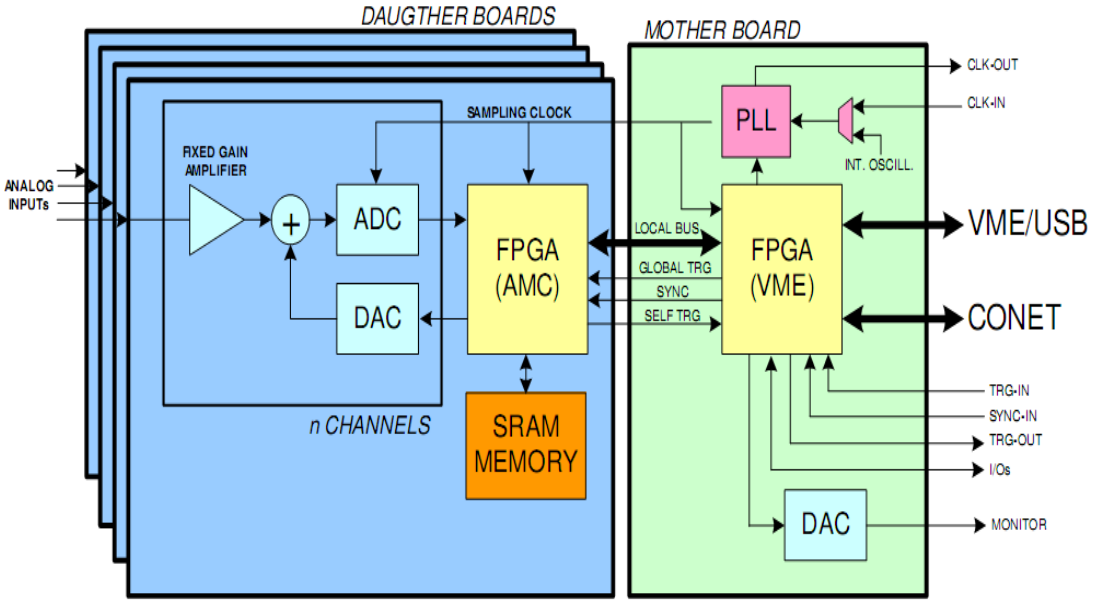
- argon is capable of Pulse Shape Discrimination (PSD) – see talk by N. Canci
- PSD is based on differentiating between two components of scintillation light with different decay times (~5-7ns and 1.3 - 1.5 us). How well do we need to see the signal?
- So far WArP has used electronics with 20MS/s,100MS/s (integrated) and 1GS/s (previous generation wvfm digitizer – since 2006)
- We used the new generation **CAEN V1751** board (recently developed and introduced in 2010/2011) in real working conditions for PMT signal readout and recording in an actual DM detector (WArP 2.3 liter chamber).

The new CAEN V1751 board

CAEN V1751 is a VME board housing a 8 channel 10 bit 1 GS/s Flash ADC waveform digitizer. The V1751 can also interleave couples of channel through the Dual Edge Sampling mode, acting as a 4 channel10 bit 2 GS/s digitizer.

- 6U VME
- with analog bandwidth of 500 MHz
- input dynamic range of 1 Vpp.
- DC offset changeable via an internal 16-bit DAC in the range –1/+1 V.

Modifying the input amplifiers, the dynamic range has been reduced to 204 mVpp preserving the analogue bandwidth.



V1751's pros and cons

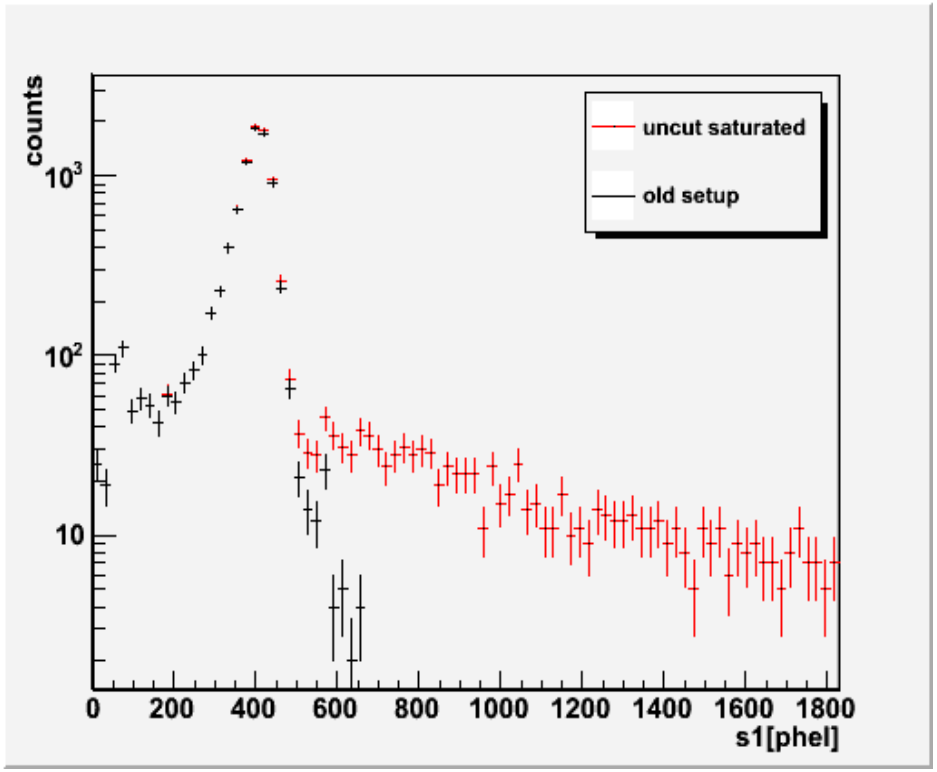
- 10bit range
- Only 1 Vpp FS – but can be customized.
- Bandwidth
- possible to go to 2Gs (do we need to?)
- optical fiber connection – fairly easy to setup but need another board A2818 (or A3818 – up to 4 optical links).

10bit Full Scale range

In our previous setups with many PMTs and lower Light Yield the higher Full Scale was not necessary.

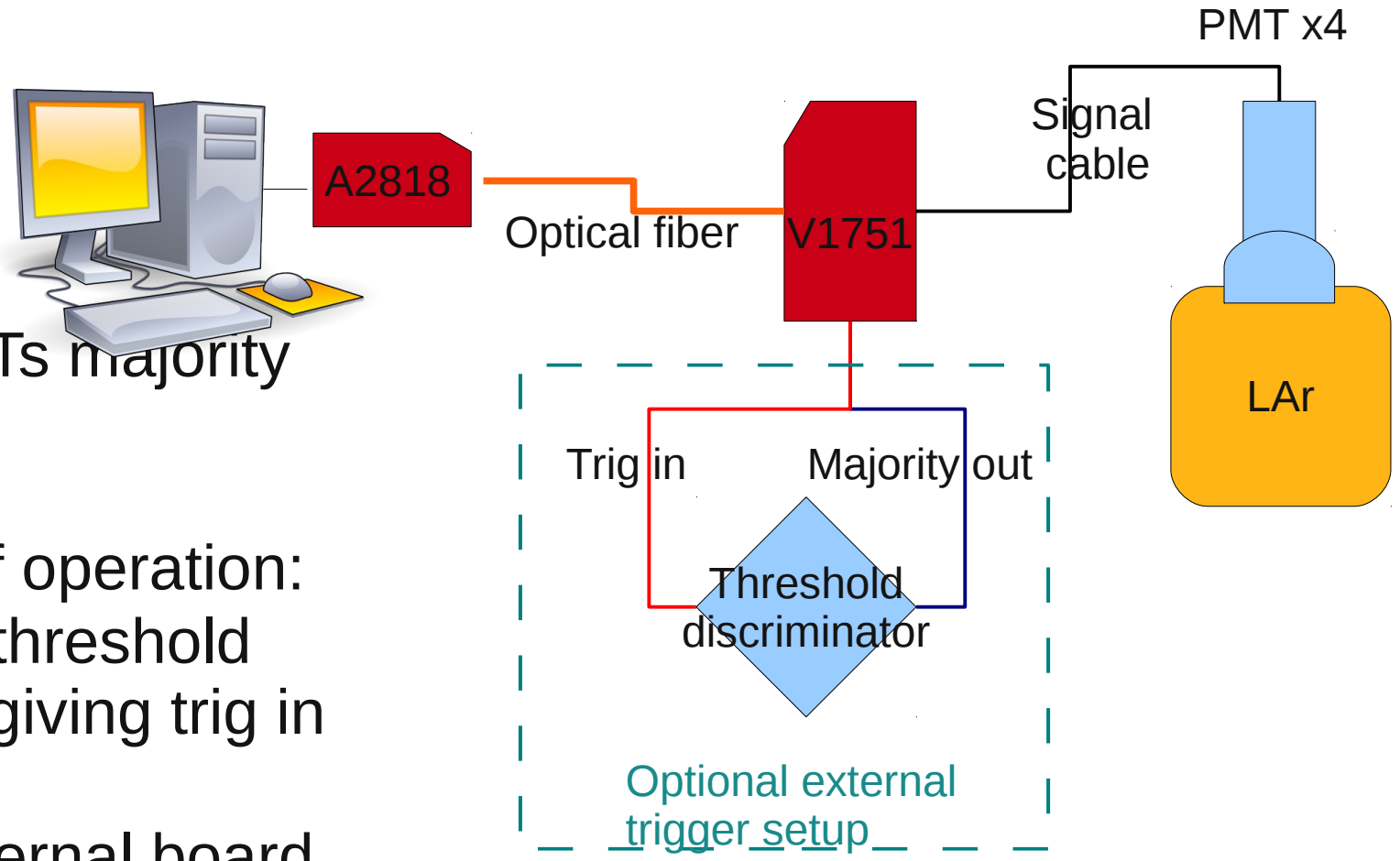
But with small setups (few PMTs) and a high LY (see talk by E. Segreto) it becomes useful :

It is especially come in handy when looking at recoil like events (see talk by N. Canci)



The Experimental Setup

first use of the V1751 in working experimental conditions



3 out of 4 PMTs majority requested.

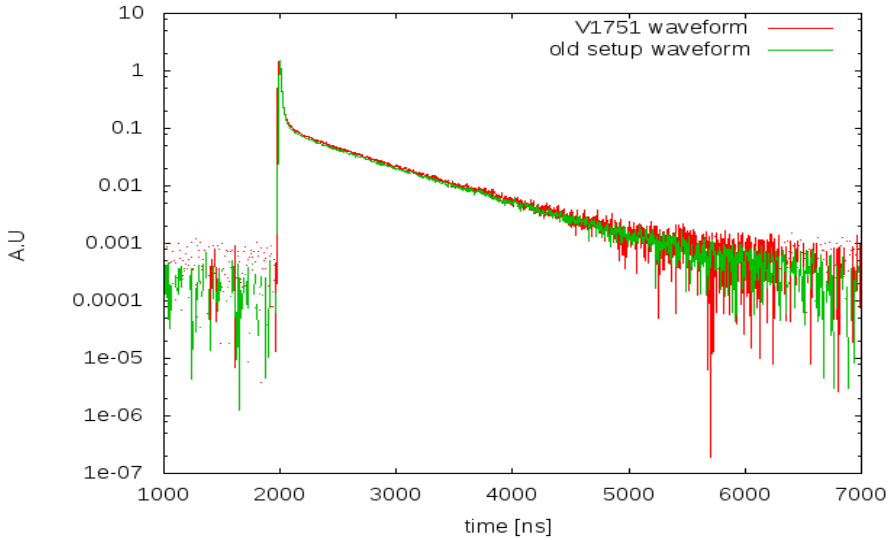
Two modes of operation:
1st - external threshold discriminator giving trig in signal.
2nd – using internal board register to check majority.
(possible fully internal majority trigger)

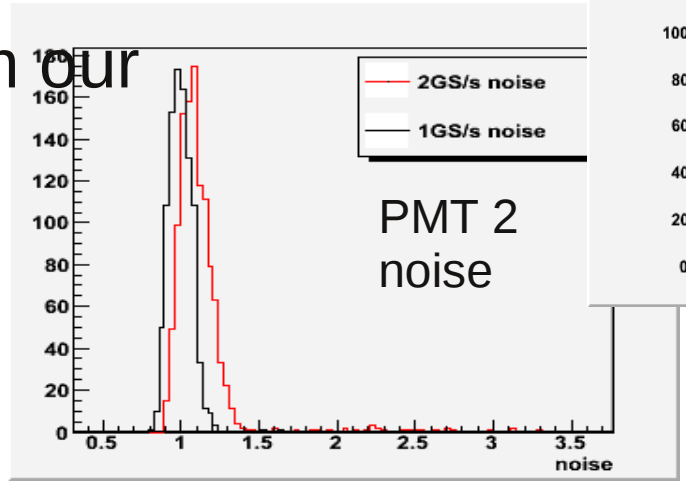
PMTs operating at **High Gain – 0.8e6** In order to see single phel wvfms.

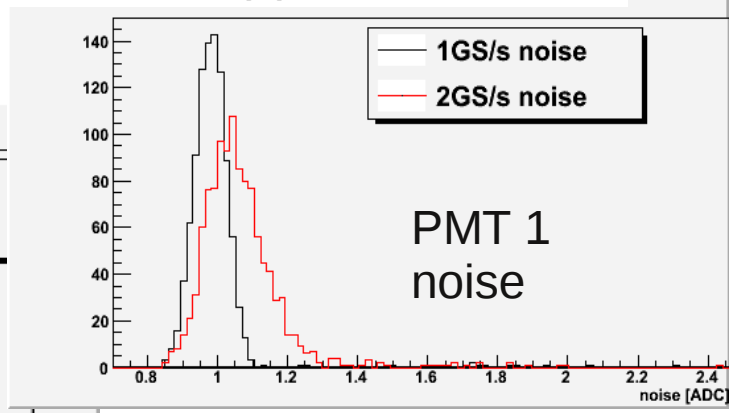
First tests: checking the basics

Intrinsic board noise, calculated as RMS of the baseline before the trigger, is under control and ~ LSB

The average waveform and single waveforms are compatible with data from our previous DAQ setup.







First tests: quirks of the board and data transfer.

A “dephasing” in the average waveform has been observed – possibly due to the way the ADC sends out the samples (pairs) – this effect is under 1 ADC, so insignificant for single events.

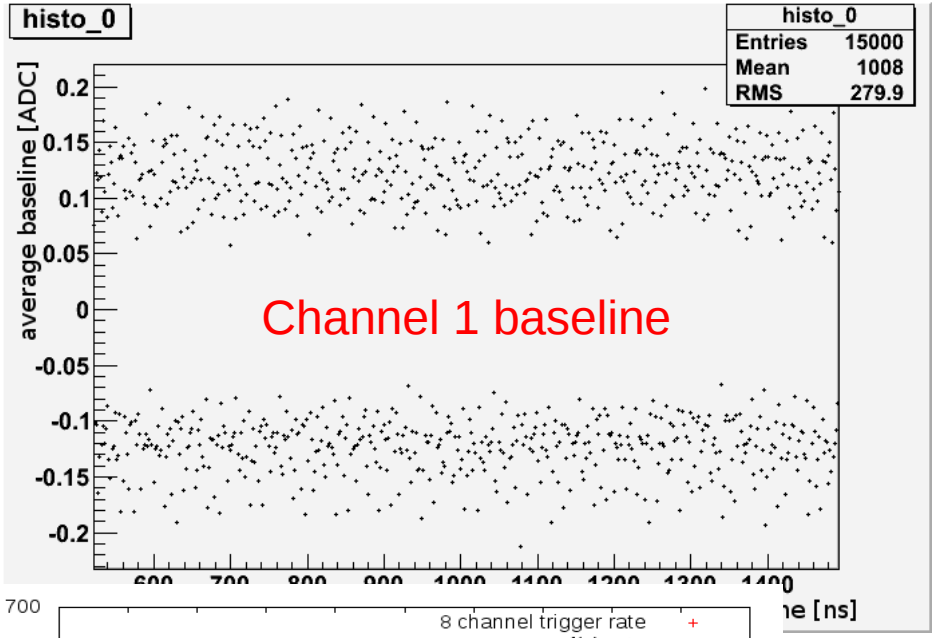
checking throughput of the board especially at longer wvfms (up to 400 us – needed for larger double phase chambers) yields

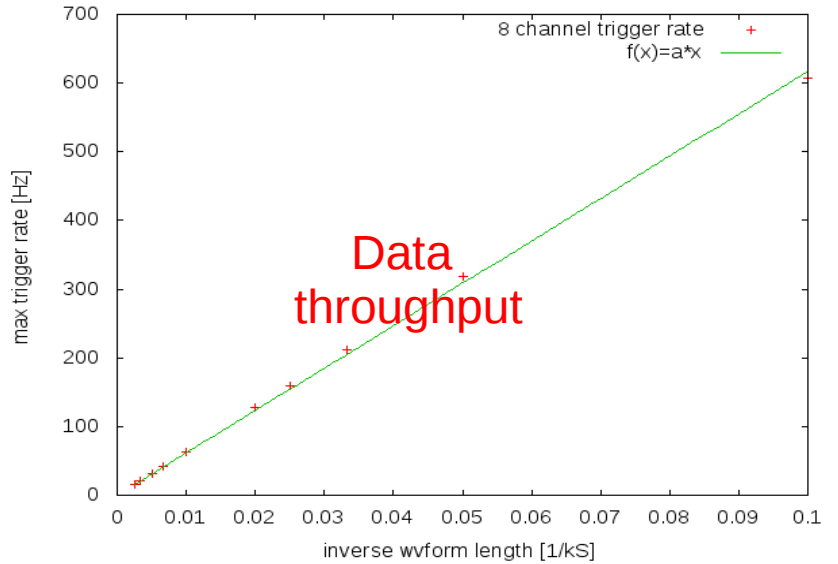
~6.2 (*8) MS/s –> ~ 17 Hz @400kS

(Declared limits with CONET 2 - > up to 80MB/s per link)

– reasonable for low background measurements.

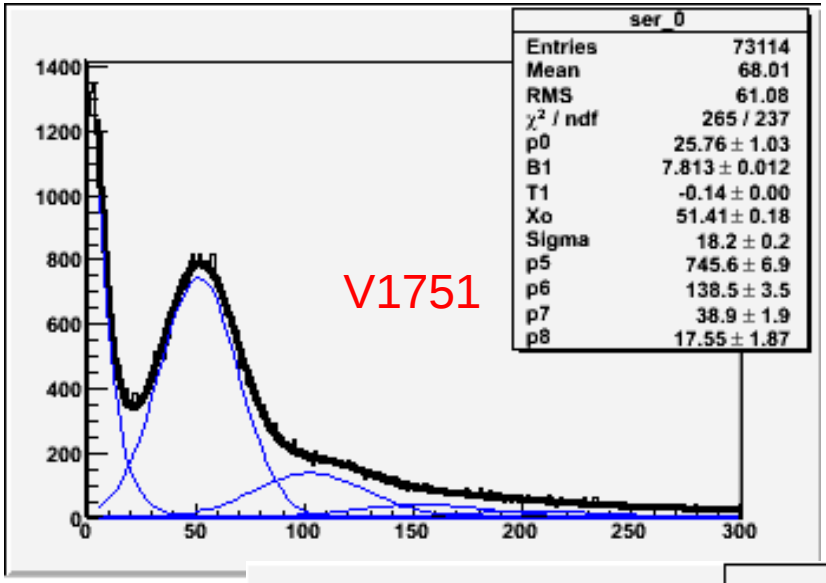
Using the onboard FPGA for a second level trigger may be necesssary.



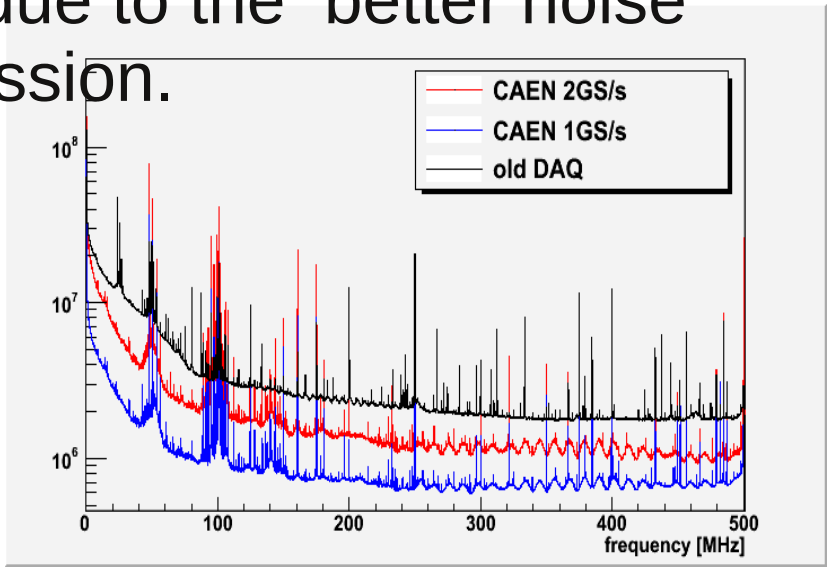


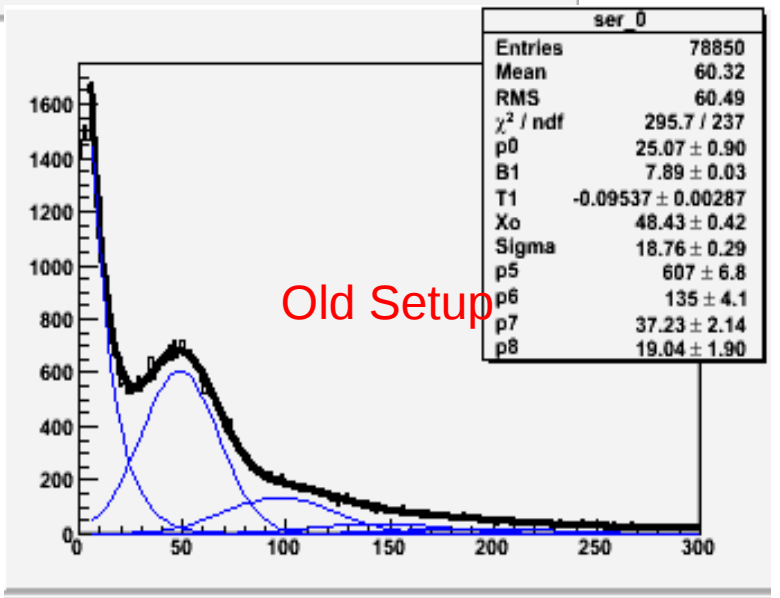
First tests: SER peak resolution

The SER peak obtained with the new board is much cleaner due to the better peak to valley ratio.



Likely due to the better noise suppression.



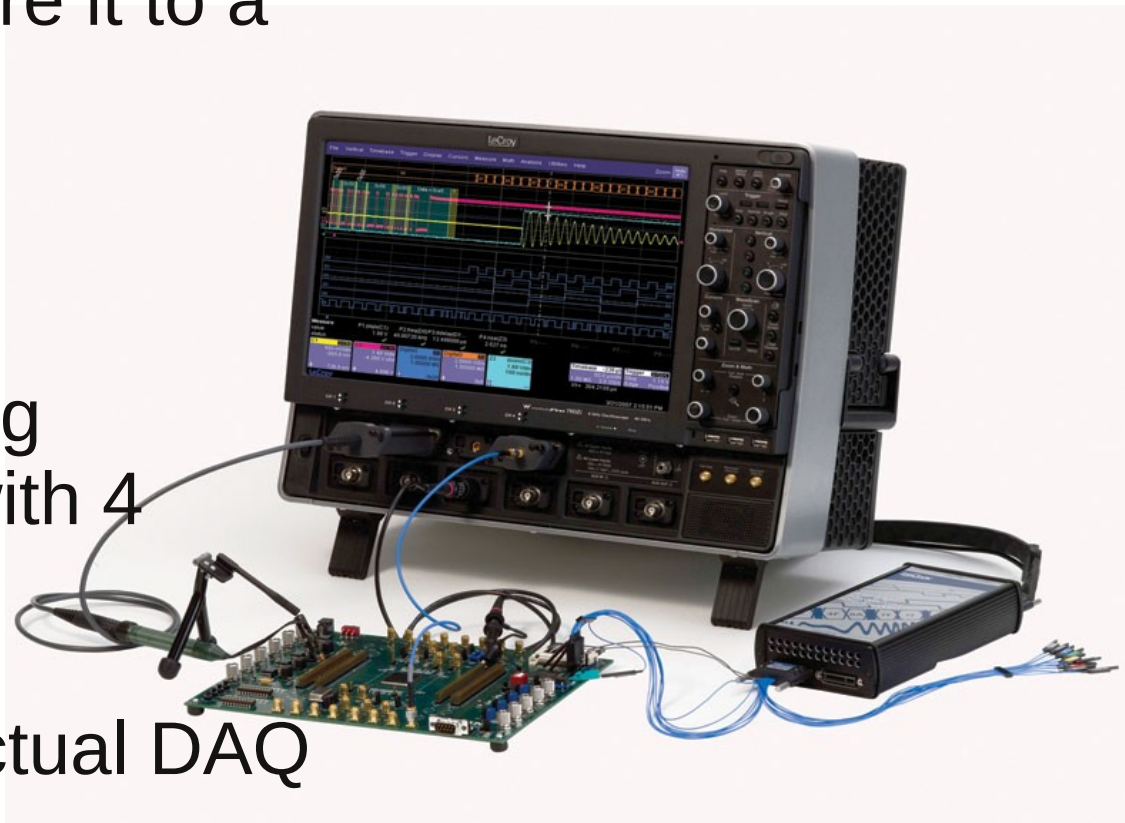


Defining the Context

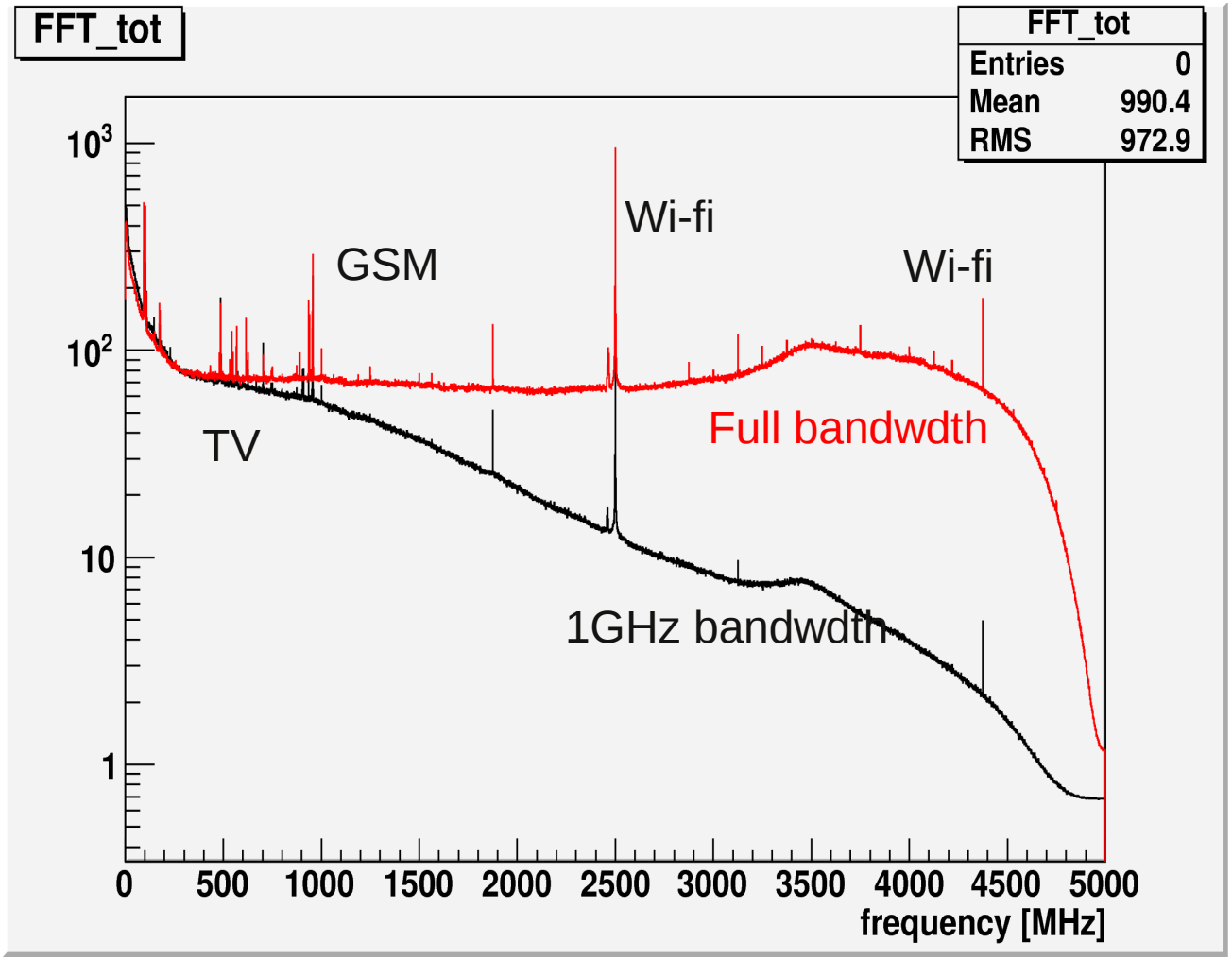
Comparing the board with one from an older generation is maybe not fair – so why not reverse and compare it to a "Monster":

Le Croy WavePro 735Zi oscilloscope :

- capable of 20GS/s sampling (50ps/bin) simultaneously with 4 channels;
- 3.5GHz analog bandwidth
- Pretty hard to use for an actual DAQ (price,data transfer etc...)



What can you see with the LeCroy?



- Wireless (4.4 GHz, 2.4GHz)
- cordless (1.9 GHz),
- GSM (900MHz),
- TV (52-890 MHz),
- Radio (170 MHz and 88-108 MHz)

Single phel waveforms

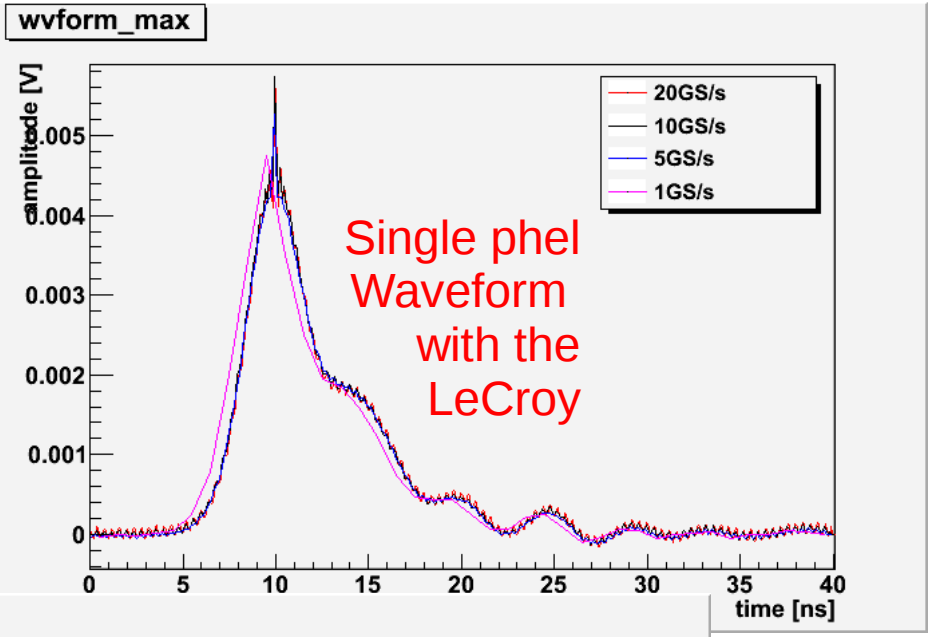
PMTs set at higher gain than usual operation focus on single phe spectra

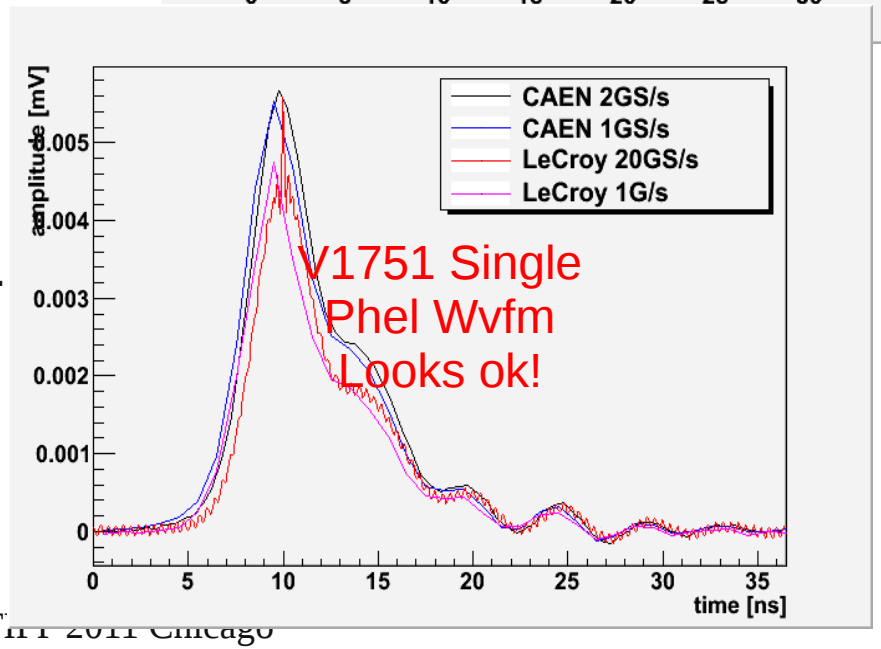
LeCroy – acquire from 5 to 7 us after trigger, 5k Events @ 20Gs/s, 10 GS/s, 5GS/s and 1GS/s. → (~10k phel used)

V1751 – acquire 15us waveforms off-trigger @ 1GS/s and 2GS/s (DES mode)

Single photoelectrons chosen based on SER position +/- 1 sigma and aligned on maximum.

Waveforms normalized to single phel amplitude in Volts.

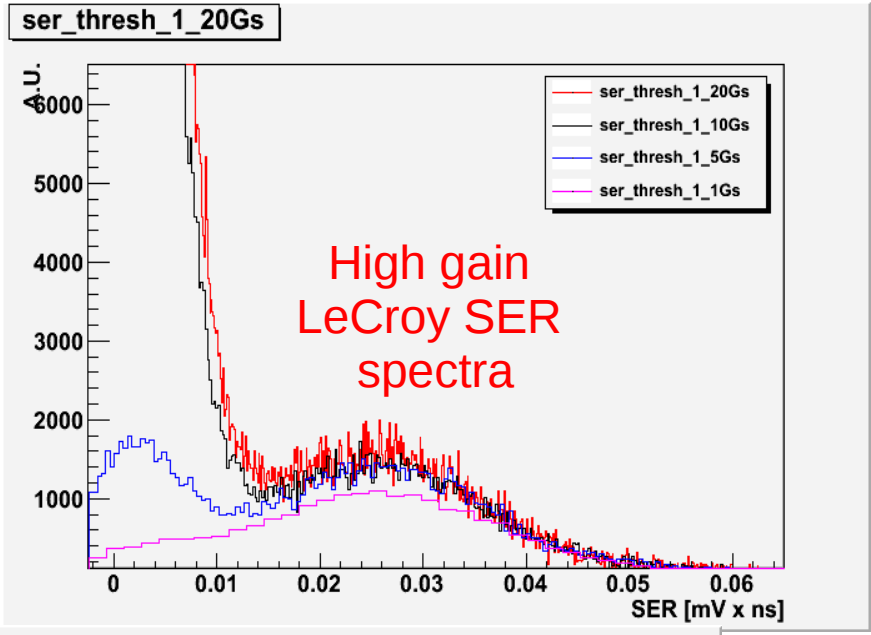




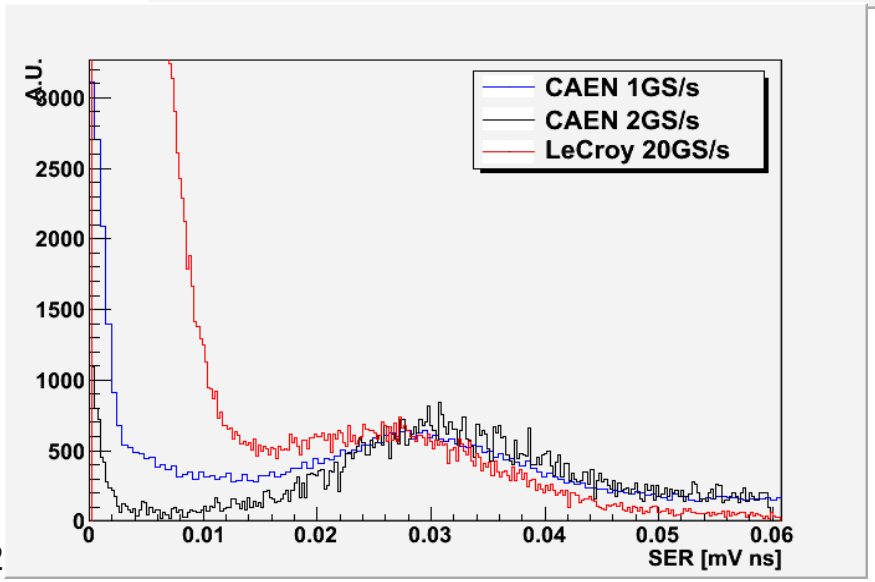
SER spectrum

In high gain data different sampling does not result in a loss of charge for the LeCroy.

At low sampling the noise gets smoothed out and it's harder to fit the SER peak precisely.



At low gain setup the large bandwith of the LeCroy makes it hard to single out single phel.

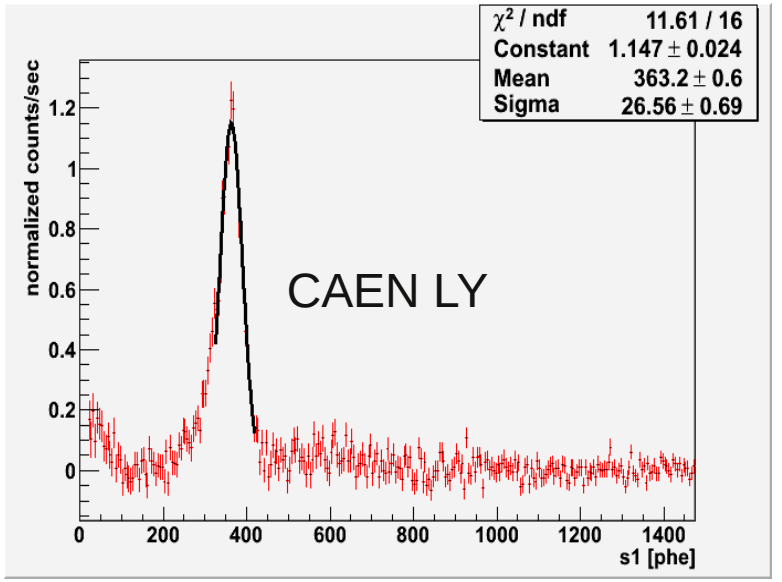


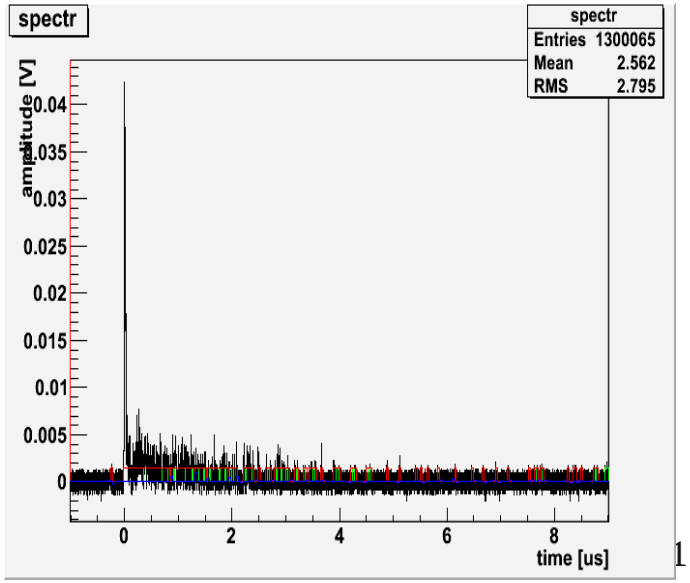
At High Gain CAEN SER peaks are in 10% agreement with the 20GS/s SER

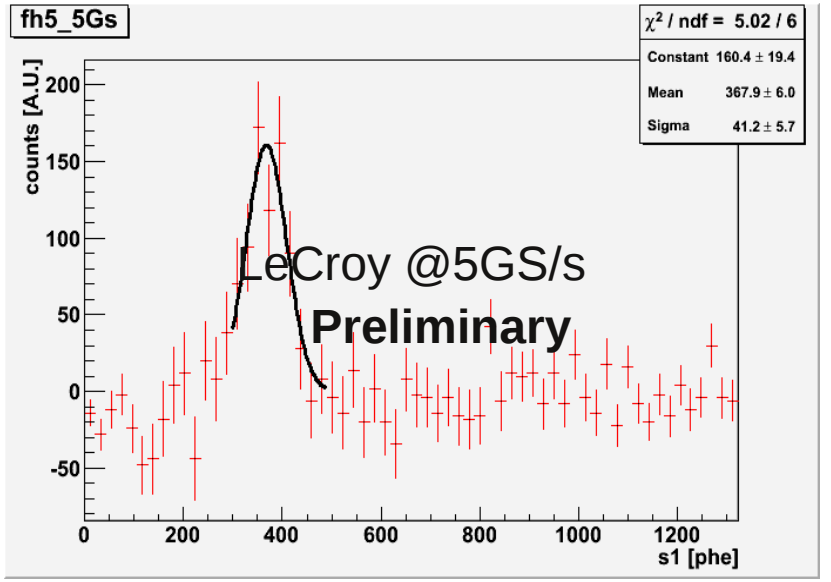
Light Yield test

Wvforms only @5GS/s (1GHz fBW)

Still some work to do, but the results seem promising – up to 3% agreement.







Conclusions

- The V1751 works and it works well.
- It is well suited to record data from low energy PMT signals like from a DM detector.
- Once set up it works stable.
- Capable of internal majority which is useful for small scale measurements (not too many PMTs).
- It seems a pretty good compromise price vs capabilities.
- It seems to hold its ground when compared to state of the art equipment.
- When looking at PMTs in LAr you should be ok with 1GS/s