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Summary of NPS high voltage divider additional tests (April 2017)

1. Long-length cable test:

Following on a March 2017 tests of the NPS & COMPCAL high voltage divider, new tests were performed by Fernando Barbosa with an LED source with short and long cable using same setup (shown in Fig.1 of March 2017 report).

Fig.1 The NPS/COMCAL readout test setup

Test conditions:

LED source ➔ wavelength 420 nm, pulse width (FWHM) 20 ns, repetition rate 1 kHz;
Signal amplitude ➔ 300 mV (set via LED pulse generator);
PMT HV ➔ -1100 V;
Cable length ➔ RG-58 type, 10 ft and 65 ft. (10 ft + 55 ft). The RG-58 has a characteristic capacitance of 25.4 pf/ft. In the case of the 65 ft long cable a total load capacitance is ≈1.7 nF.

These simple tests show how long cable affects the signals driven from the HV divider and amplifier unit. A long cable run, as expected in the experimental halls, presents a relatively high capacitive output load to the preamp.
Fig.2 shows an average pulse after 10 ft (left panel) and 65 ft (right panel) cables.

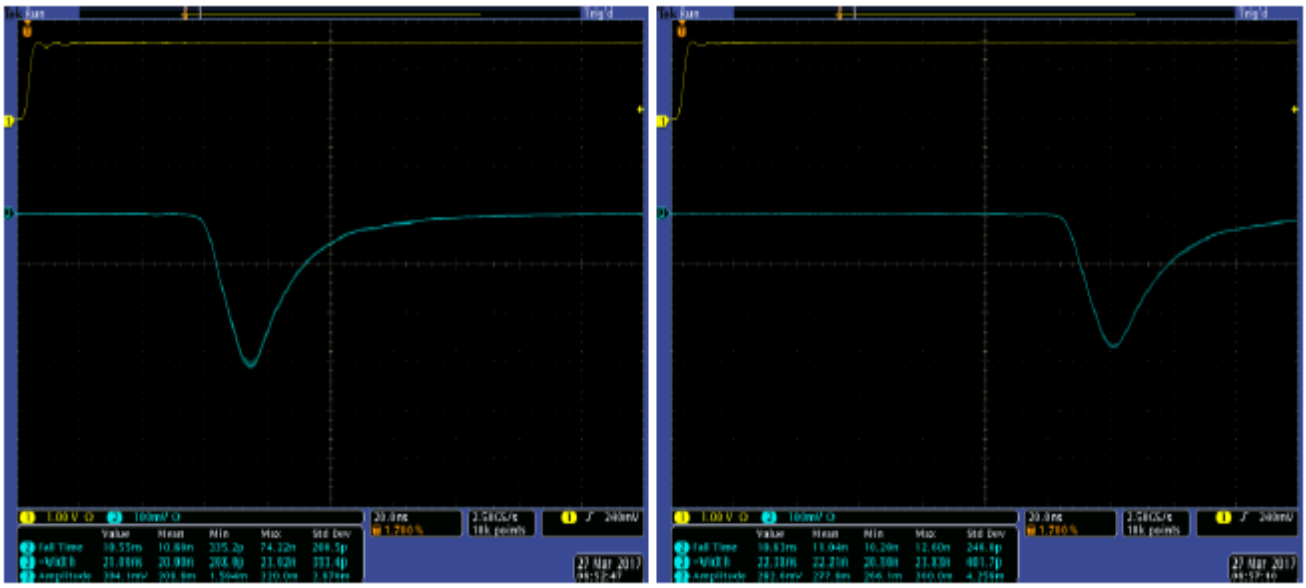

Fig. 2 Pulse output with 10 ft (left) and 65 ft (right) length RG-58 cable

Summary of test with long and short cables are presented in table 1.

Table 1: The output signal characteristics with 10 ft and 65 ft cables:

	Short Cable (10 ft)	Long Cable (65 ft)
Leading Edge (ns)	10.8	11.0
Pulse Width (FWHM)	20.9	22.2
Amplitude (mV)	309	278

- About 10% pulse amplitude attenuation due to ohmic losses in the long cable (which are not significant because these pulses have relatively slow characteristics);
- The pulses with short and long cables are very similar (aside from the delay due to different length).

2. Tests with fADC:

For this tests all setup (shown in Fig.1) have been moved in Hall D (to use all existing DAQ and electronics). For this test different type of LED was used, late we found it was defective. Most of test have been performed by Alexander Somov, only at last stage Fernando and me were involved. Three set of measurements at pulse amplitude 90 mV, 150 mV and 400 mV, and rates from 1 kHz to 2 MHz were performed. We found that the LED light intensity is rate dependent (increases as a function of the rate). In Fig.3 are shown examples of output signal peak distribution and pulse integral defined from fADC.

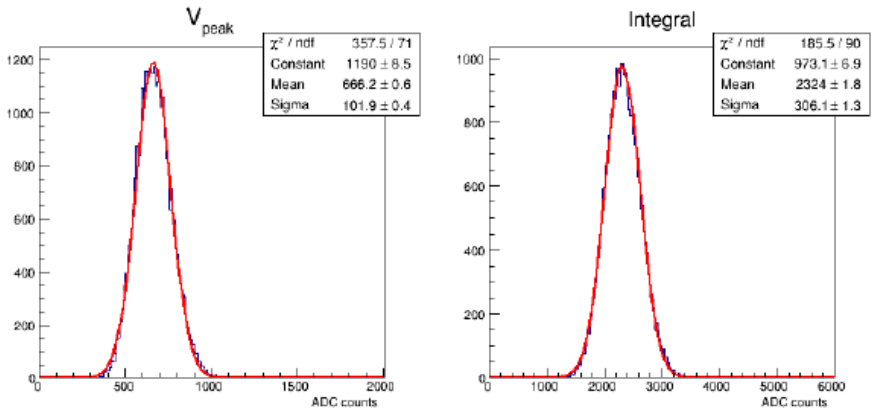

Fig.3 Example of signal peak value and pulse integral defined from fADC

If the pulse integral follows Gaussian statistics, which is not always the case, the Npe and the PMT Gain can be expressed in units of the pulse integral and sigma of this distribution: Npe = (Int/Sig)^2 and Gain = Sig*Sig/Int. The results of fADC tests are summarized in Table 2.

Table 2. Summary of fADC tests

V = 2.7 V

Rate	V (mV)	run	Vpeak	σ(Vpeak)	Int	σ(Int)	Npe	Gain		Int/Peak
1 kHz	90	31267	667	101.9	2324	306	57.7	40.3		3.48
100 kHz	117	31268	865.5	118.7	3061.6	361.8	71.6	42.7		3.53
1 MHz	138	31269	1039.2	129.2	3790.4	401.6	89.1	42.6		3.64
2 MHz	150	31270	1116.7	133.7	4129.9	417.6	97.8	42.2		3.69

V = 3.05 V

1 kHz	300	31271	2268.6	191.6	8787.4	611.9	206.2	42.6		3.87
100 kHz	324	31272	2481.1	198	9823.2	643.8	232.8	42.2		3.95
1 MHz	373	31273	2863.8	214.2	11686.8	707.9	272.6	42.9		4.08
2 MHz	387	31275	2942.4	217.8	11922	720.5	273.8	43.5		4.05

V = 3.23 V

1 kHz	440	31276	3338	229.2	13693	759	325.8	42	(sat)	
100 kHz	450	31277	3600	230.8	15126	782				
1 MHz	495	31278	3957	230.6	17133	770				
2 MHz	504	31279	3837	247.5	14554	833				

The gain calculated with such assumption seems to be rather stable, while the Npe increases with the rate indicating that the LED light is changing with rate.

To check that observed rate dependence of PMT output amplitude comes from the LED we have measured rate dependence at LED pulsar setting 3.23 V and 4.09 V. Each time we have optimized distance between fiber and LED to have same output amplitude ~300 mV at PMT HV=1100 V. Results show that PMT output signal amplitude variation with rate strongly depends on LED regime

LED set.	3,23 V				4.09 V			
LED rate	1 kHz	100 kH	1 MHz	2 MHz	1kHz	100 kHz	1 MHz	2 MHz
Output signal	321	355	409	411	330	344	366	360
Max Variation	~30%				~10%			

After all, we moved setup back to Fernando's Lab and tested divider with the LED and electronics which was used during March tests. All test show that divider within 1-2% operated linear up to rates 1-2MHz (like early test results). Then we replaced this LED with one which was used prior fADC tests and get strong amplitude variation with rate (similar what Alex observed).

Finally, we have tested divider again with fADC but now with the good LED and pulsar. In Fig. 4 are shown the dependency of the fADC amplitude (peak) as a function of the rate.

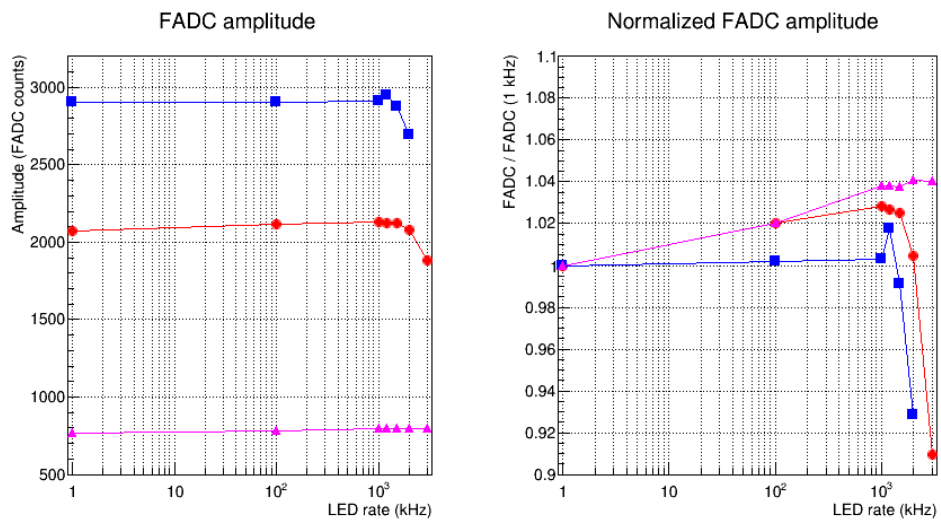

Fig. 4 The fADC amplitude (signal peak value) as a function of the rate.

There is some small LED rate instability (the LED is more stable at larger amplitude). But overall, the amplitude change between 100 kHz and 1 MHz is less than 2 %. The divider seems to be stable up to 1.2 - 1.5 MHz at large current.

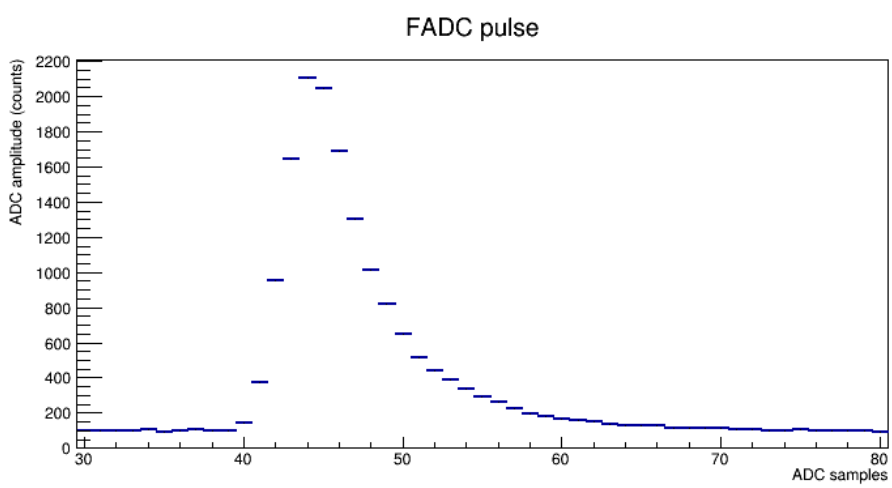

Fig.5 The signal pulse waveform reconstructed with fADC pulse waveform.

To be sure that small rate dependence observed with LED is due to light intensity variation with rate, we ask Fernando to do one more test with laser which very stable and don't have any variation of intensity with rate. To exclude any effects from the crystal (which observed during March tests) we ask Arthur dismount prototype.
This time we have tested the rate dependence for combination "PMT + divider" at light intensities corresponding to PMT output signal amplitude 100, 200, 300 and 400 mV at PMT high voltage 1100 V. Results shown in Fig.6 conform that divider linear up to rates ~2 MHz.

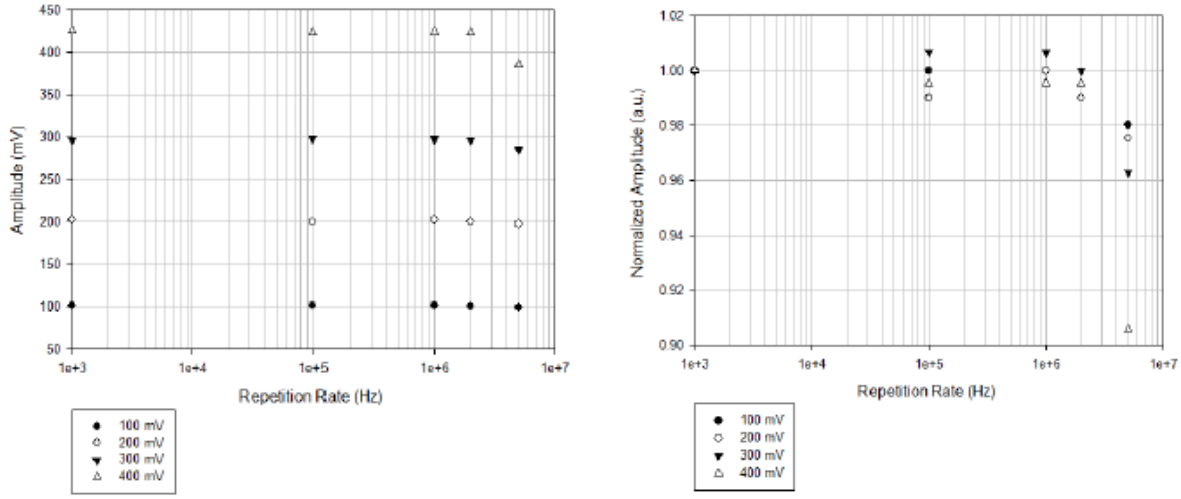

Fig.6 The PMT output signal amplitude (left) and normalized amplitude (right) with rate.

CONCLUSSION: NPS divider demonstrated linearly better than 2% for the rates up to 2 MHz for the signal amplitudes up to 400 mV at PMT HV 1100 V. For higher amplitude signals the PMT gain (HV) must be optimized to get similar performance.
(More details can be found in Fernando Barbosa reports).