System Description (2-4)

Gains from single photo-electrons in vacuum at room temperature (5-8)

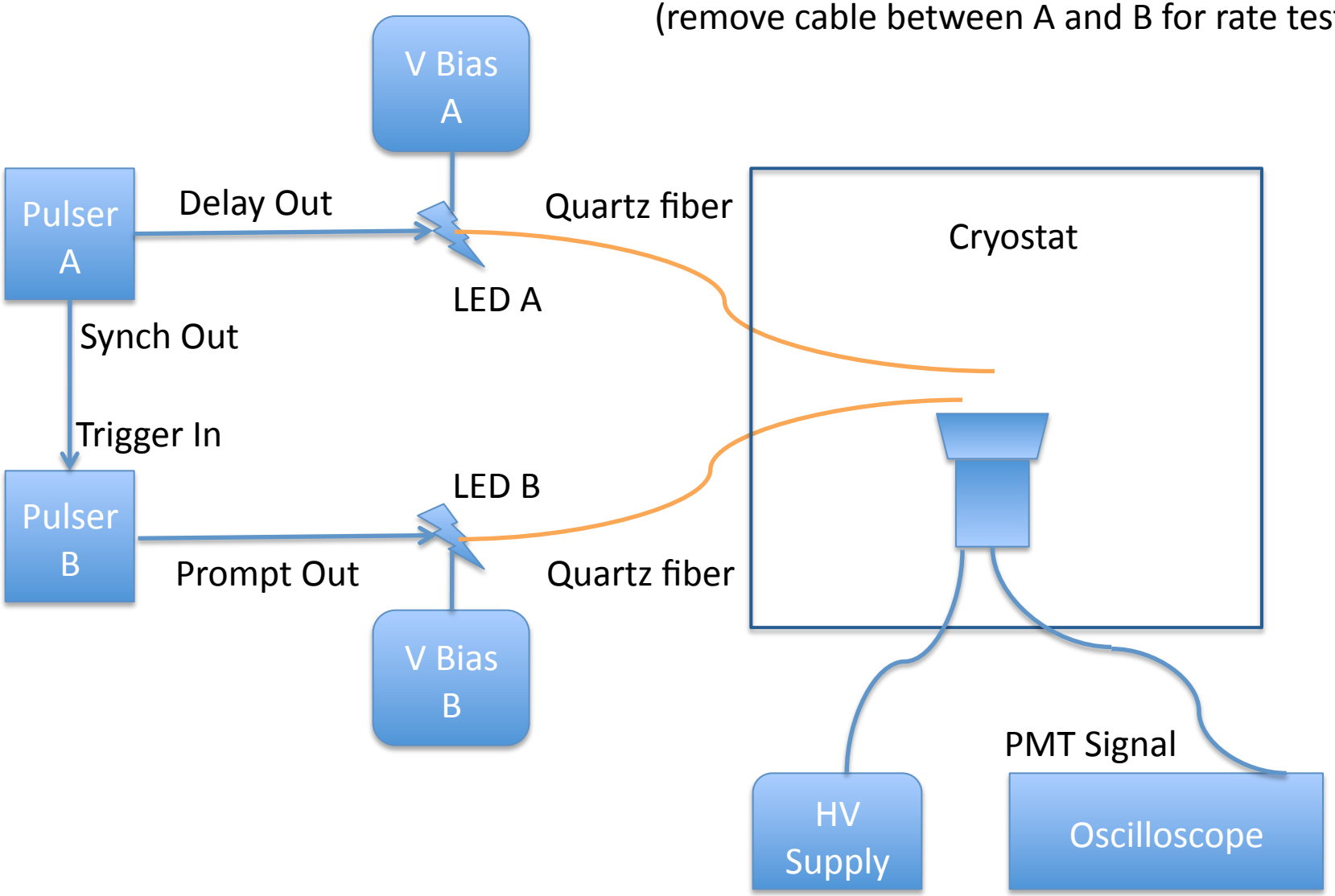
Linearity Test at +1400 V in vacuum at room temperature (9-11)

Gains from single photo-electrons in liquid (12-14)

Linearity test in liquid at +1400, +1300 and +1200 (15-18)

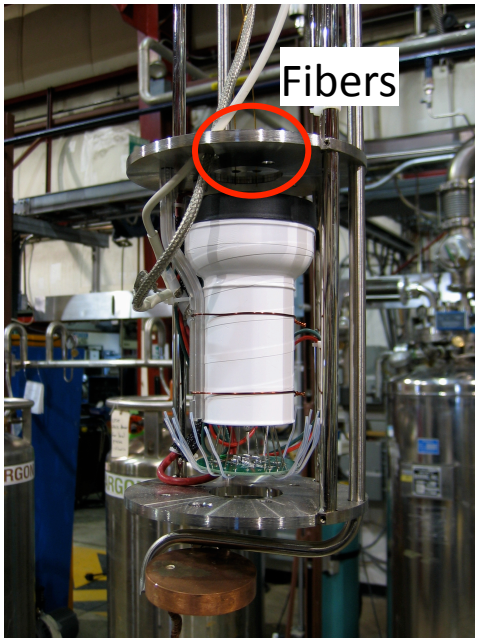
Background rate test at +1200 (19-20)

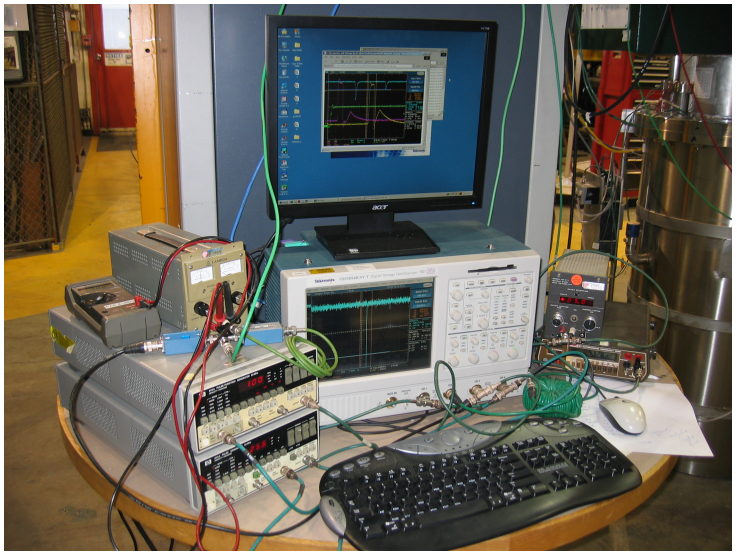
Set up for linearity test
(remove cable between A and B for rate test)



All control signals pass by the oscilloscope (see next page)

PMT on mount before installation

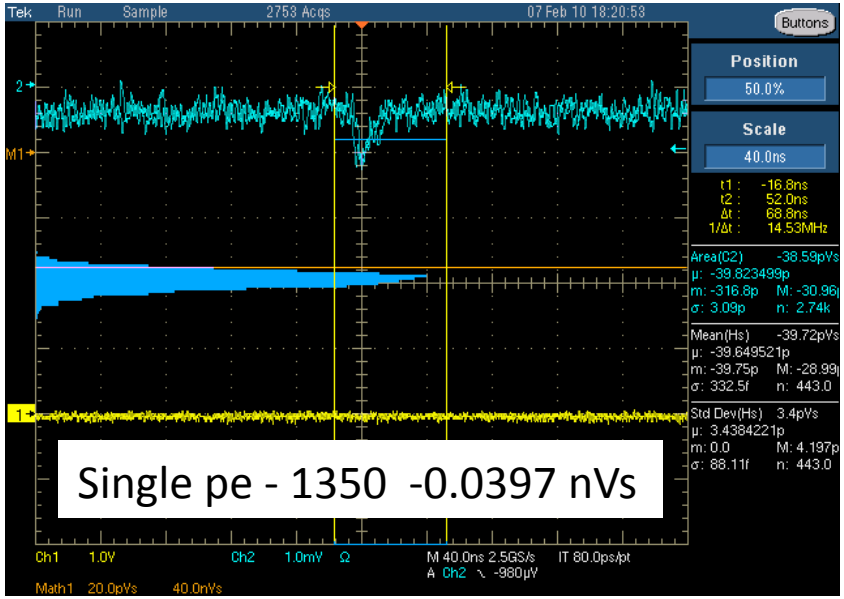


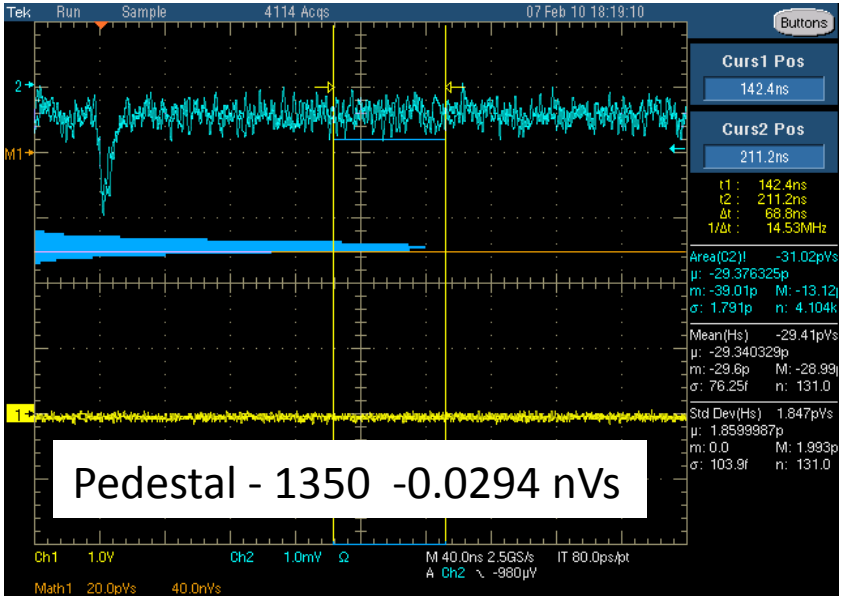


Electronics and Oscilloscope

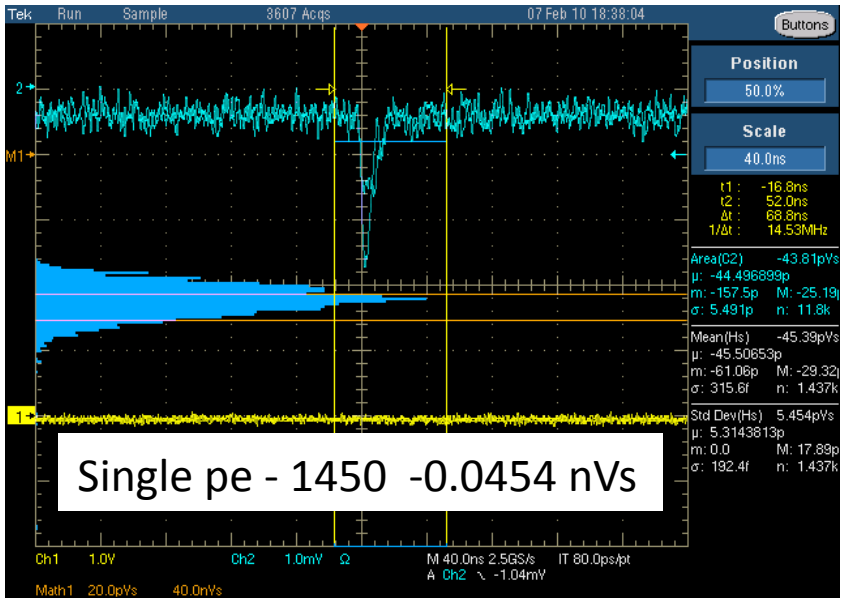
Cryostat

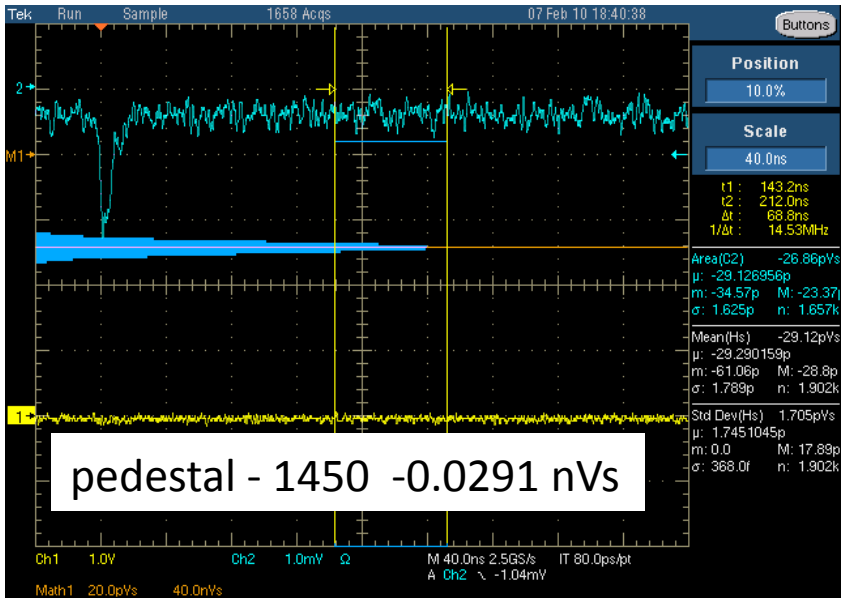
Gains from single photo-electron pulse-height spectra



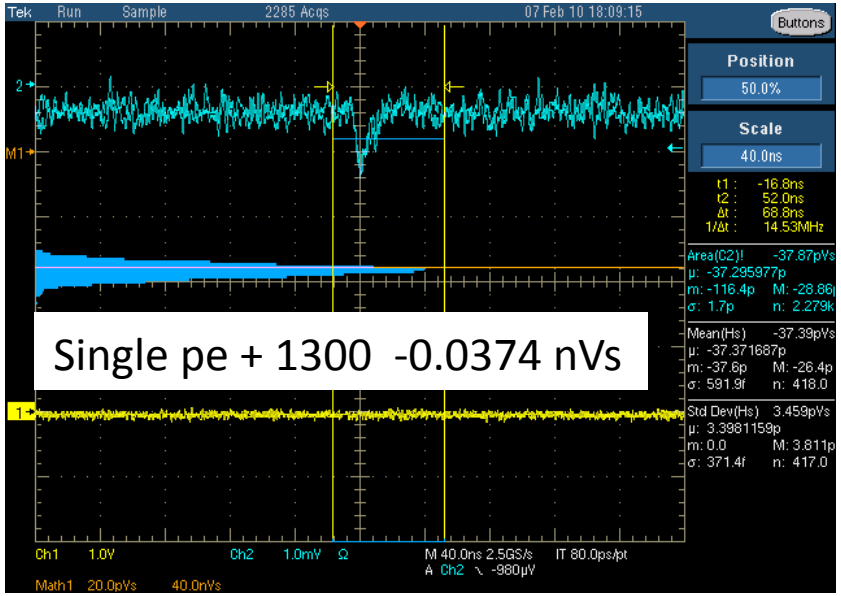


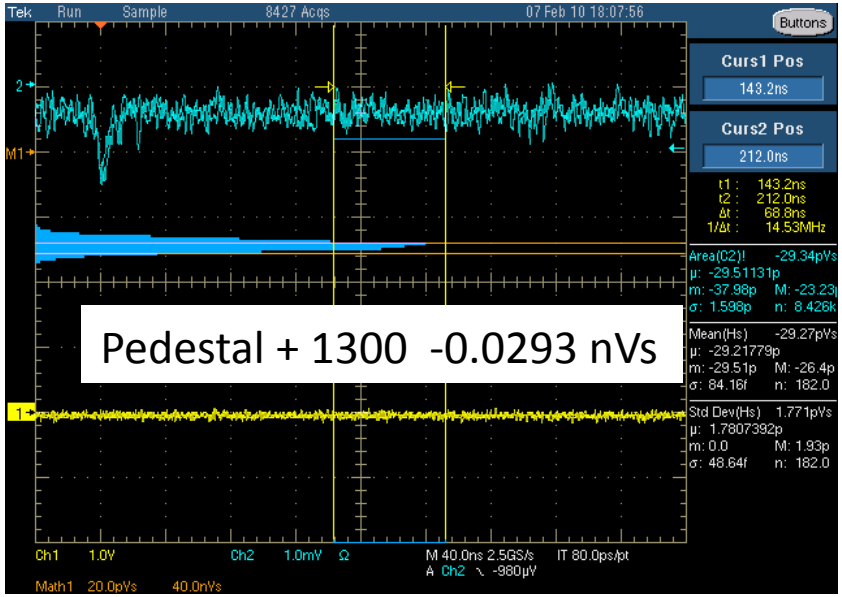
Room Temperature



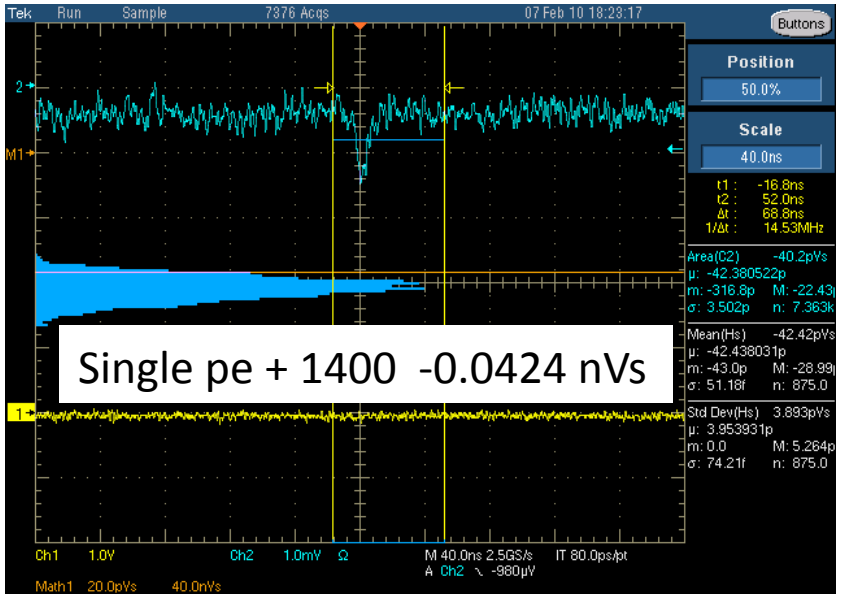


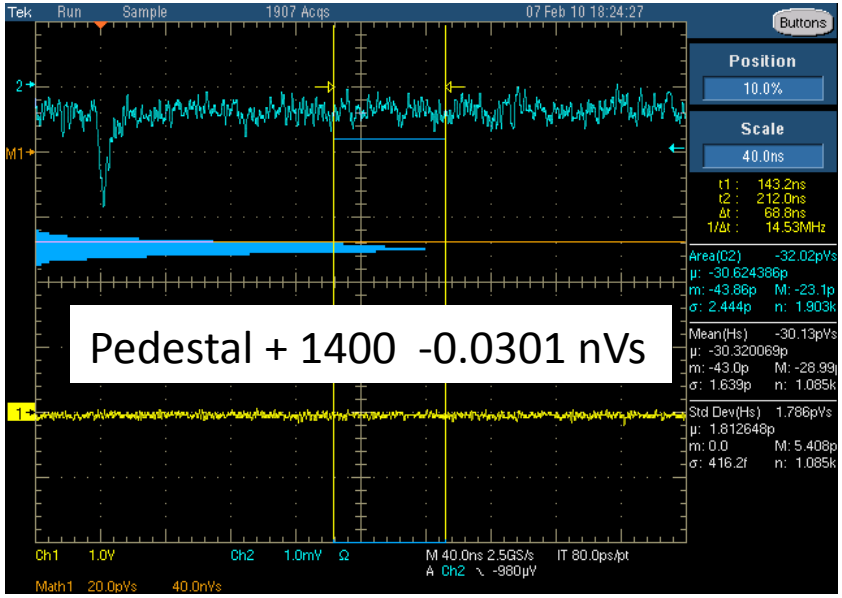
More gains from single photo-electron pulse-height spectra



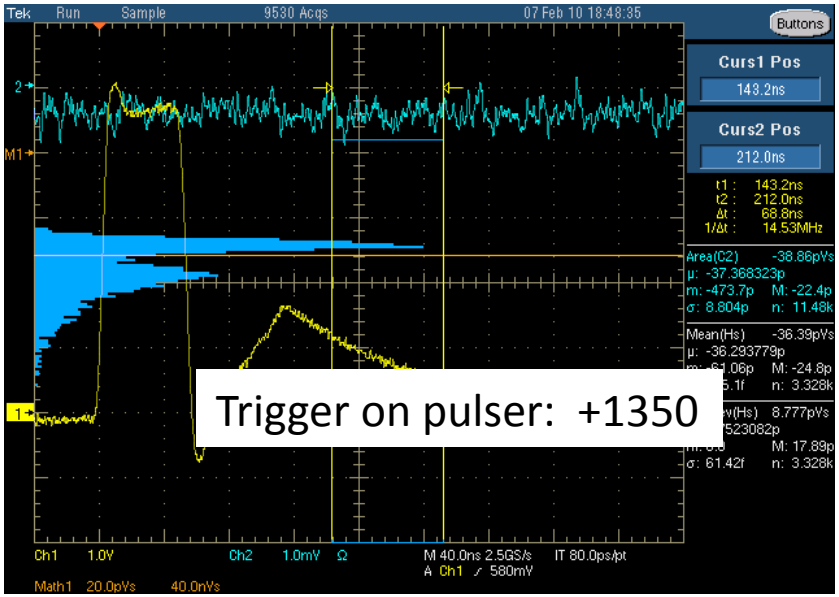


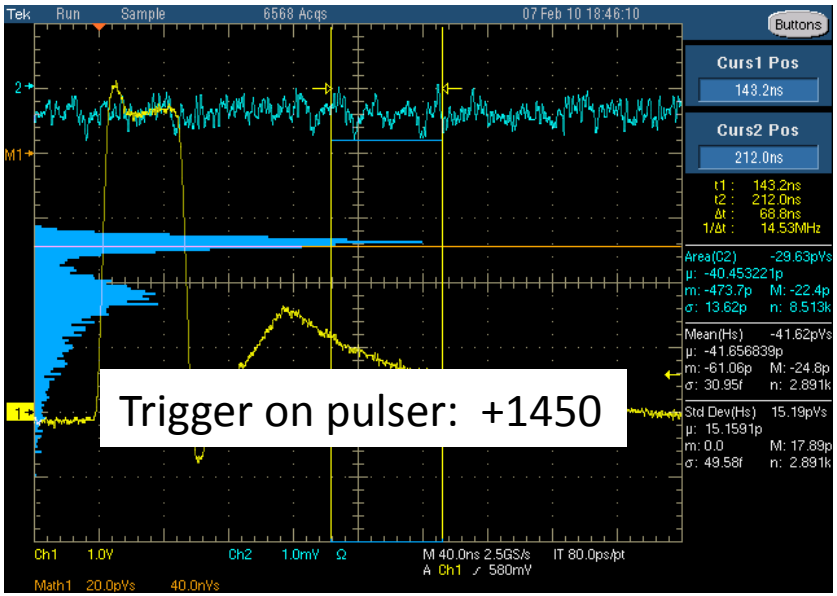
Room Temperature





Set LED bias to give ~ 1 pe on average; gives similar results to triggering on single pe signal





Gain vs Voltage from single pe at room temperature

Volts	Pulse Int (nVs)	Ped Int (nVs)	Diff (nVs)	Gain
1300	-0.0374	-0.0293	-0.0079	2E6
1350	-0.0397	-0.0294	-0.0103	2.5E6
1400	-0.0424	-0.0301	-0.0123	3E6
1450	-0.0454	-0.0291	-0.0163	4E6

Linearity Test:
A and B are two completely independent light pulsers –
(except plugged into the same AC power circuit)

Their phasing can be adjusted and they can turned on and off independently (the synch output continues even when the Delay Output is turned off)

Page 9 shows all the signals and page 10 shows the 4 measurements taken:
pedestal, pulse A, pulse B and both (A & B) simultaneously

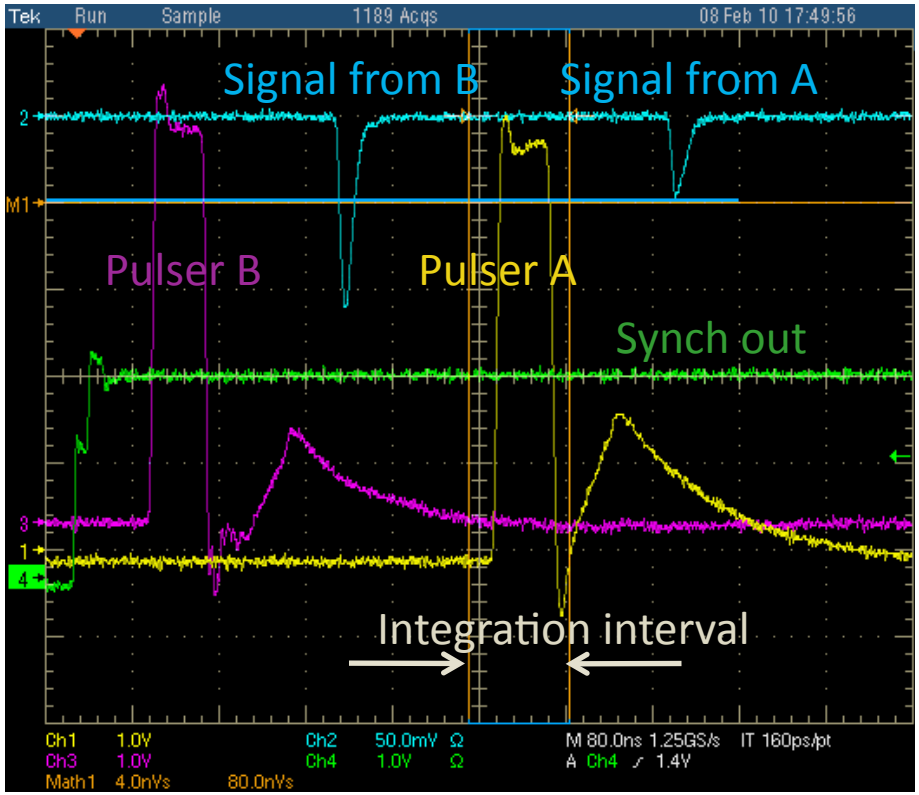
The scope gives the integral (volts x seconds) between the two vertical lines
to get charge recognize that the voltage is across 25 ohms (50 ohms back termination and 50 ohms at scope)

The horizontal histogram shows the distribution of values.

For the case shown on page 10 (they are all like this)
pulse A = -3.91 nVs (read from right of scope display)
pulse B = -5.35 nVs
pedestal = -0.71 nVs
both = - 8.36 nVs
A + B pred = -3.91 – 5.35 + 0.71 = - 8.55 nVs => both – pred = 0.2 nVs (out of 8.5 nVs))

There are obvious non-linearities at slightly larger pulse-height.

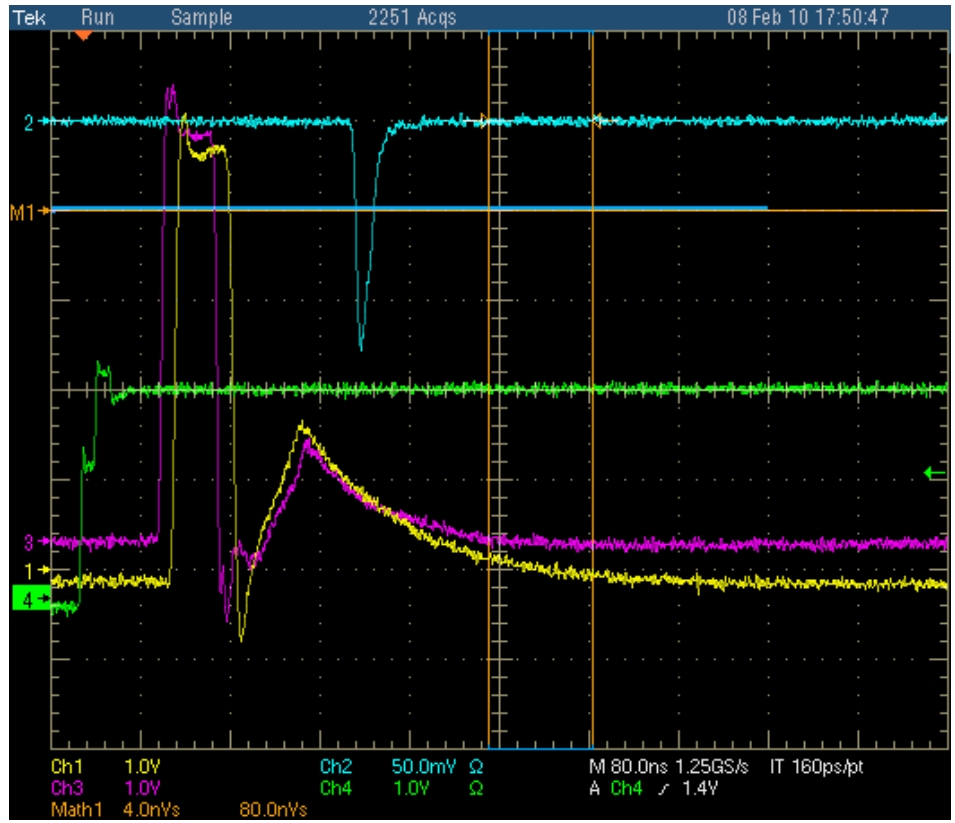
Signals Used



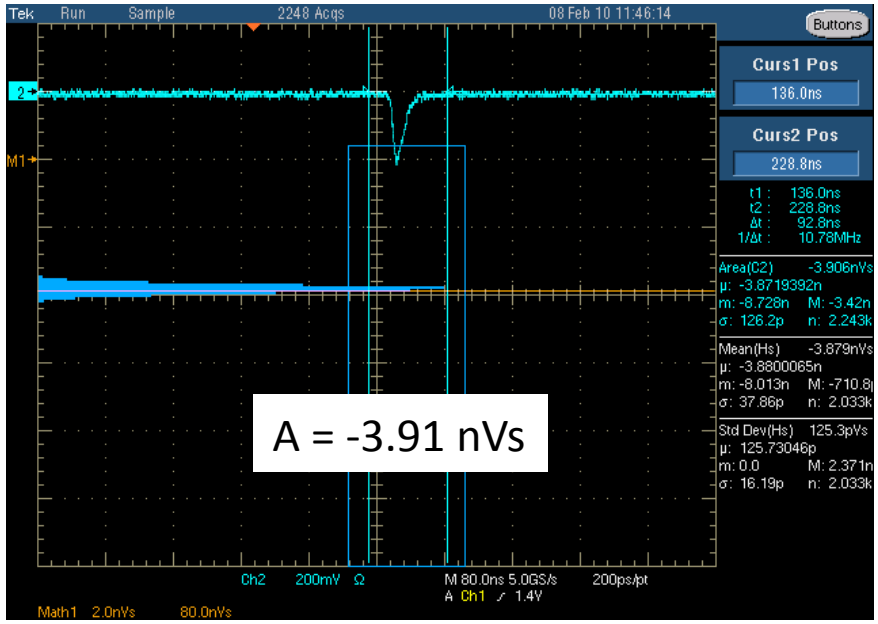
Signals offset in time

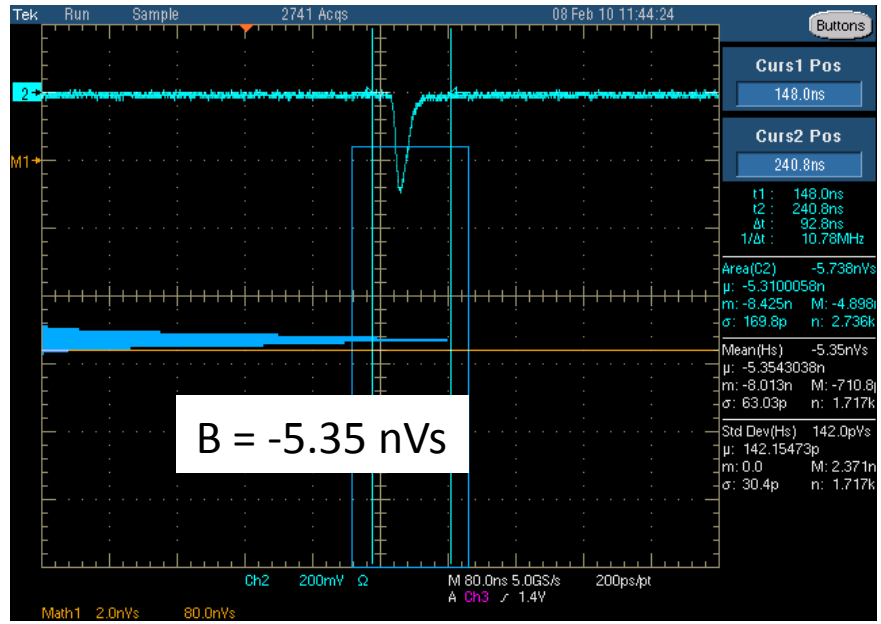
The scope gives the integral (volts x seconds) between the two vertical lines (this is into 25 ohms (50 ohms back termination and 50 ohms at scope)

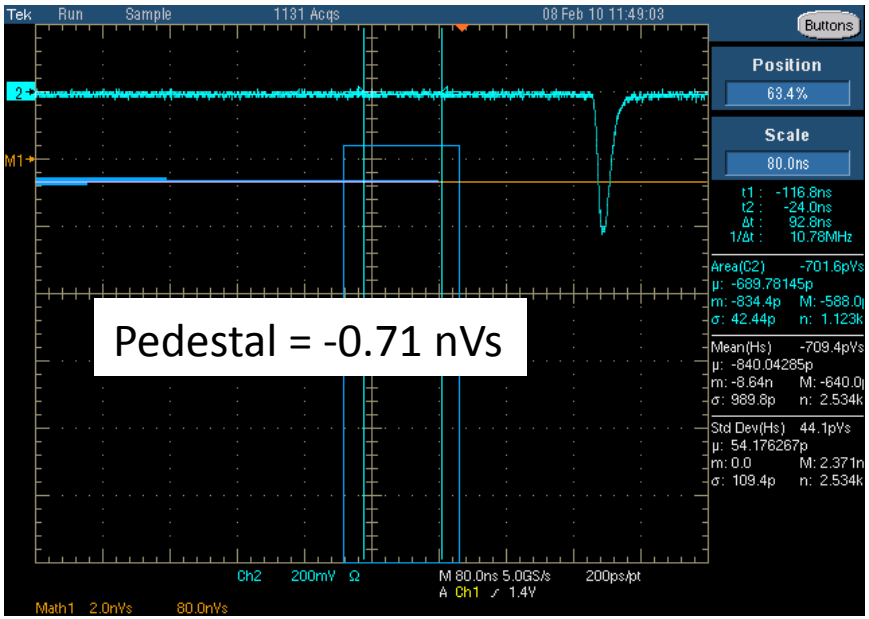
Signals aligned in time

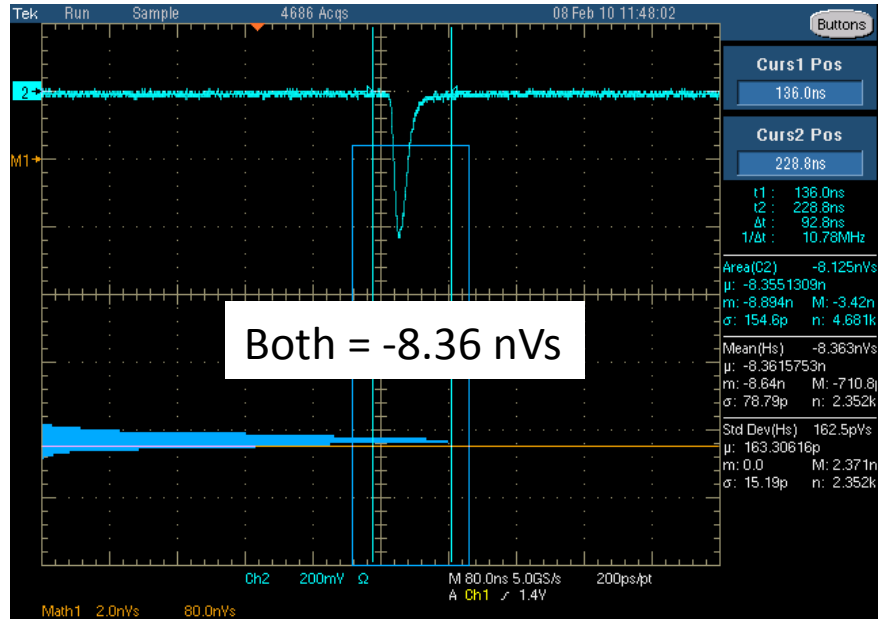


Example Set for Linearity Study









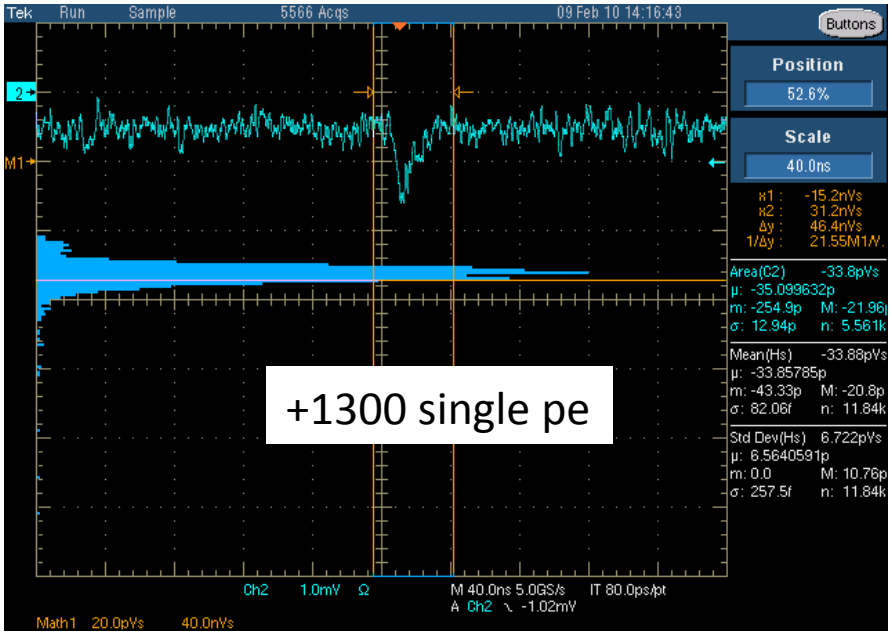
Linearity Study at +1400 volts in vacuum at room temperature

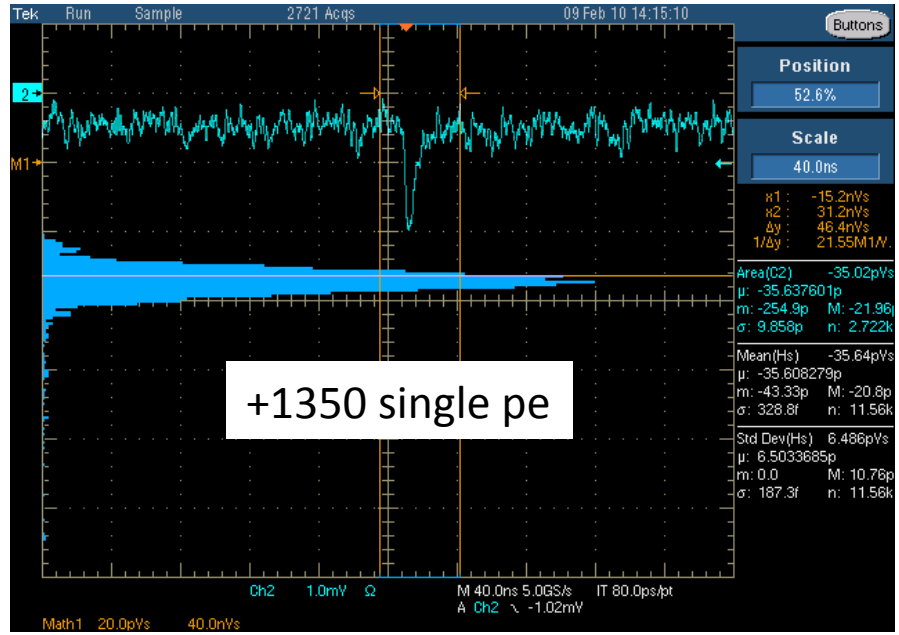
A (nVs)	B (nVs)	Pedestal (nVs)	Both (nVs)	Both – (A+B) (nVs)
-0.069	-1.43	-0.01	-2.12	-0.01
-2.01	-1.45	-0.01	-3.47	-0.02
-3.91	-5.35	-0.71	-8.36	+0.2
-6.22	-5.05	-0.35	-10.26	+0.66
-6.14	-12.31	-0.38	-15.71	+2.36

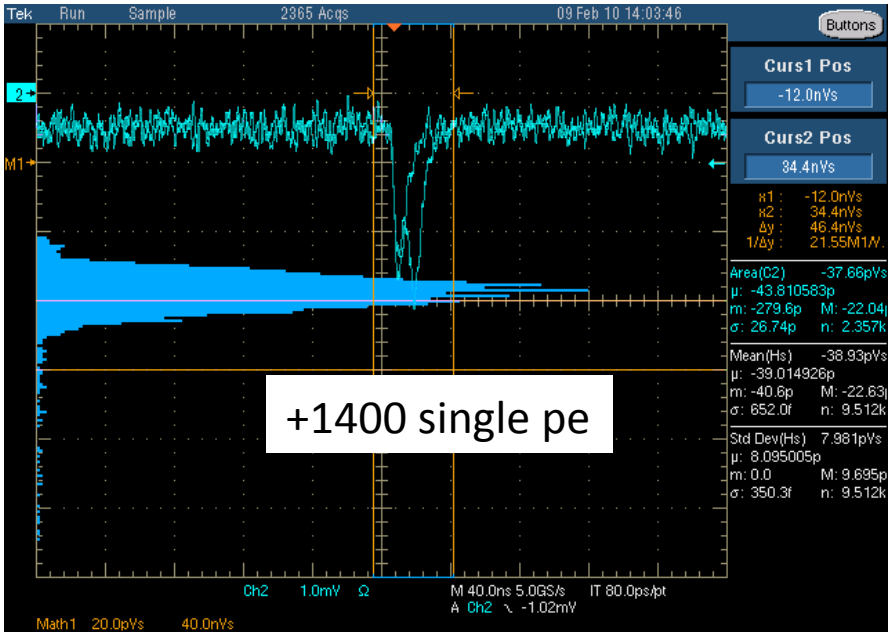
A, B, pedestal and Both are as read directly from the oscilloscope and not corrected for the pedestal. The comparison (column 5) is corrected for the pedestal (which without correction would appear twice in the sum (A+B) and only once in the measurement (Both))
The peak linear signal at 1400 volts corresponds to ~ 8 nVs which from page 4 is 8 nVs/0.016 nVs/pe = 500 pe's (only).

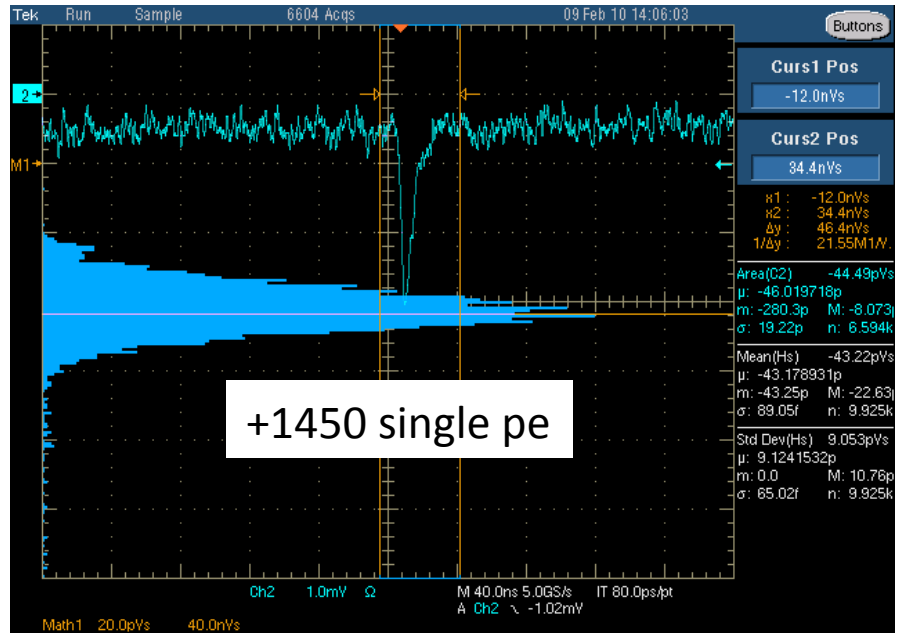
(The pedestals change at different scope sensitivities (mV/box))

IN LIQUID ARGON

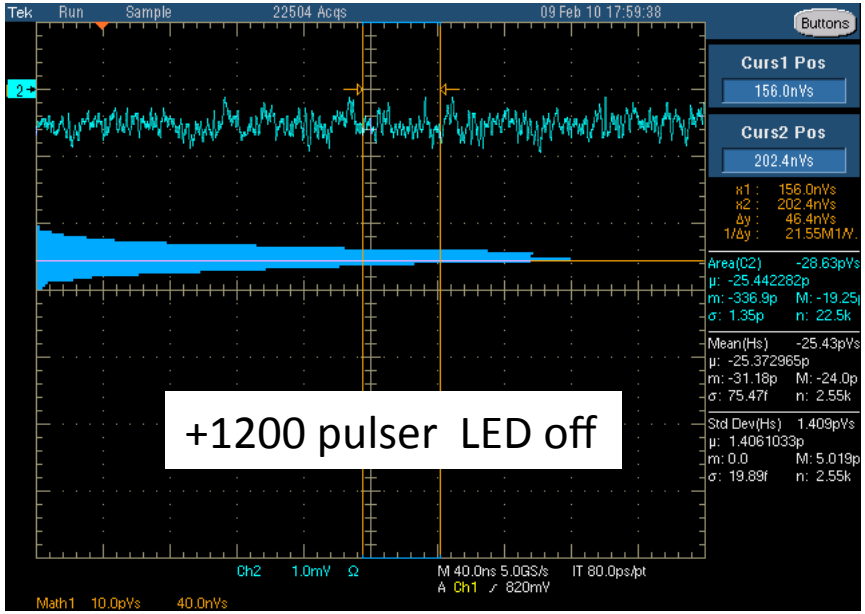


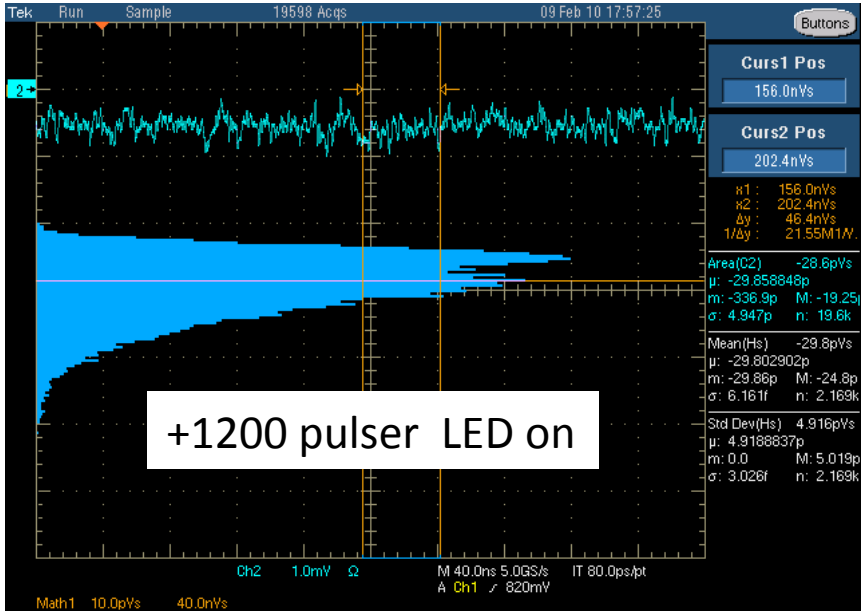






At 1200 volts single pe is not well separated from noise - so trigger on pulser





Gain vs Voltage from single pe **in liquid Argon**

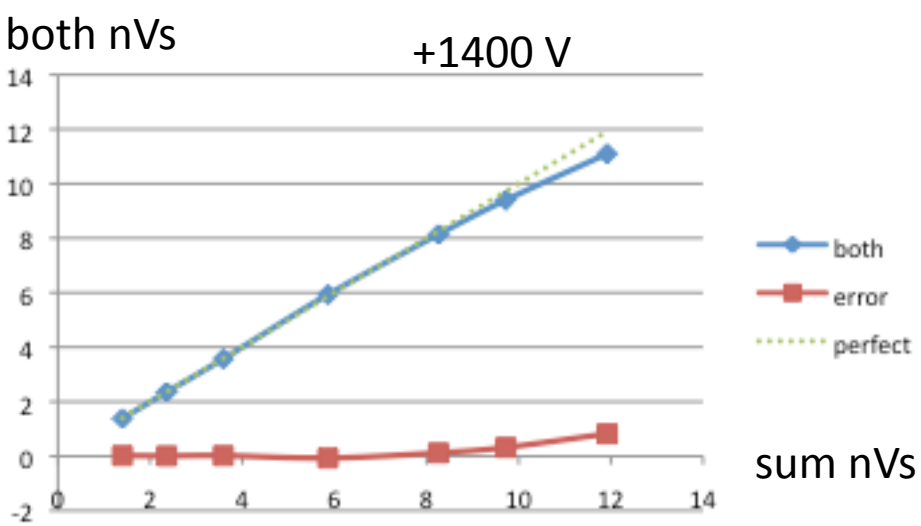
Volts	Pulse Int (pVs)	Ped Int (pVs)	Diff (pVs) (1 pe)	pC/pe	Gain
1200 *	-	-	-5	-0.2	1.3E6
1300	-34	-24.6	-9.4	-0.37	2.5E6
1350	-35.5	-23.4	-12.1	-0.48	3E6
1400	-39	-23.2	-15.8	-0.63	4E6
1450	-43	-23.5	-19.8	-0.79	5E6

Yes – 20% different from in vacuum at room temperature.
I don't know if this is real or a systematic.

* from gap between peaks on last plot on previous page (also see later)

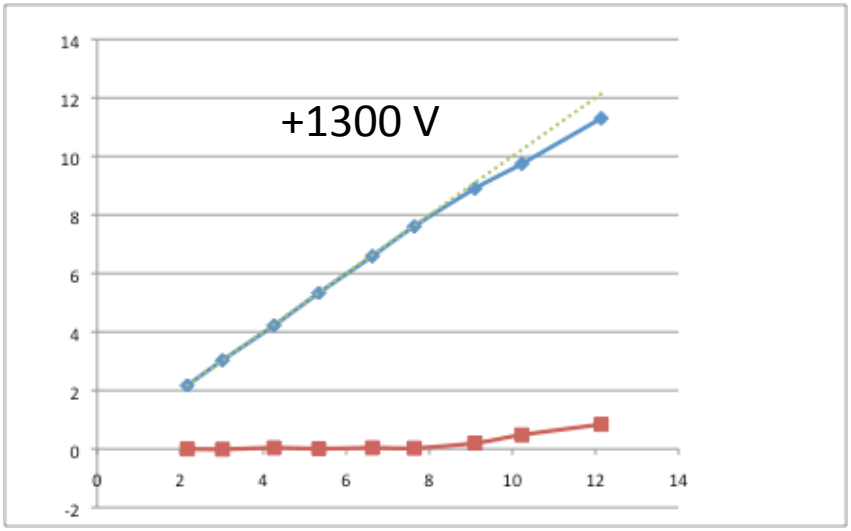
Linearity Study at +1400 volts in liquid

A (nVs)	B (nVs)	Pedestal (nVs)	Both (nVs)	(A+B) (nVs) - Pedestal	Both – (A+B) (nVs)	Photo-electrons (non-linearity)
-0.91	-0.50	-0.01	-1.38	-1.40	+0.02	90 (1)
-0.88	-1.49	-0.01	-2.35	-2.36	-0.01	150 (1)
-2.13	-1.47	-0.01	-3.57	-3.59	+0.02	225 (1)
-2.45	-3.76	-0.35	-5.93	-5.86	-0.07	320 (4)
-4.85	-3.76	-0.35	-8.14	-8.26	+0.12	500 (7)
-4.8	-5.27	-0.35	-9.4	-9.72	+0.32	580 (20)
-7.1	-5.16	-0.35	-11.1	-11.92	+0.82	725 (50)



Linearity Study at +1300 volts

A (nVs)	B (nVs)	Pedestal (nVs)	Both (nVs)	(A+B) (nVs) - Pedestal	Both – (A+B) (nVs)	Photo-electrons (non-linearity)
-1.16	-1.03	-0.02	-2.17	-2.17	0	230 (1)
-1.19	-1.85	-0.02	-3.03	-3.02	-0.01	320 (1)
-2.42	-1.86	-0.02	-4.22	-4.26	+0.04	450 (4)
-2.80	-2.89	-0.35	-5.33	-5.34	-0.01	530 (1)
-4.06	-2.92	-0.35	-6.59	-6.63	+0.04	670 (4)
-4.06	-3.94	-0.36	-7.61	-7.64	+0.03	770 (3)
-4.08	-5.38	-0.36	-8.9	-9.1	+0.2	930 (10)
-5.26	-5.33	-0.35	-9.75	-10.23	+0.5	1050 (55)
-7.26	-5.24	-0.35	-11.3	-12.14	+0.8	1250 (90)



Linearity Study at +1200 volts

A (nVs)	B (nVs)	Pedestal (nVs)	Both (nVs)	(A+B) (nVs) -Pedestal	Both – (A+B) (nVs)	Photo-electrons (non-linearity)
-2.59	-2.21	-0.36	-4.44	-4.44	0	830 (1)
-2.88	-2.87	-0.35	-5.41	-5.40	-0.01	1030 (2)
-2.89	-3.94	-0.36	-6.43	-6.47	+0.04	1250 (8)
-5.51	-3.94	-0.36	-8.80	-9.09	+0.3	1780 (60)

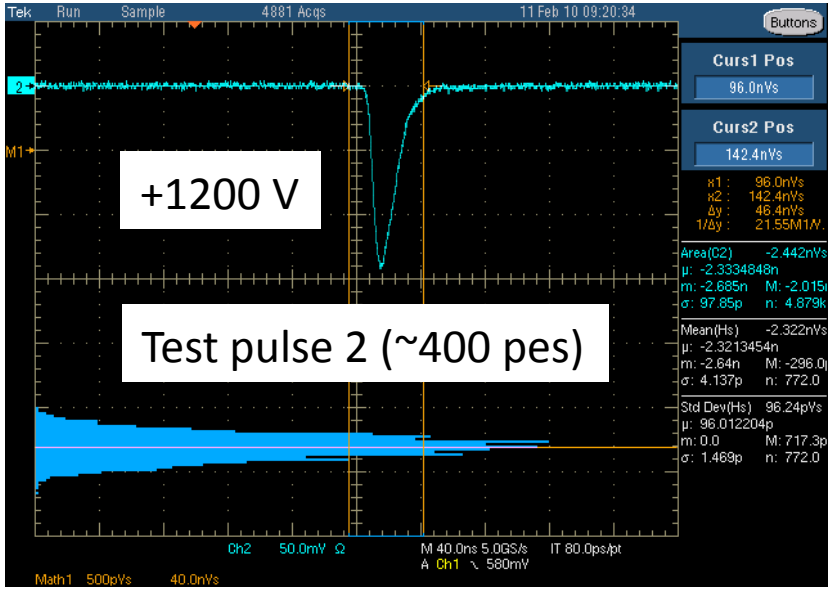
The third row here was taken with the same pulser settings as the last set at 1300 V where I calculate 1250 pe's. I use this to infer the other values in the table.The value for the single pe signal comes to 0.0047 nVs which is close to the 0.005 from the figure on page 12.
(Note one needs to subtract the pedestal from the Both value to get the nVs/pe)

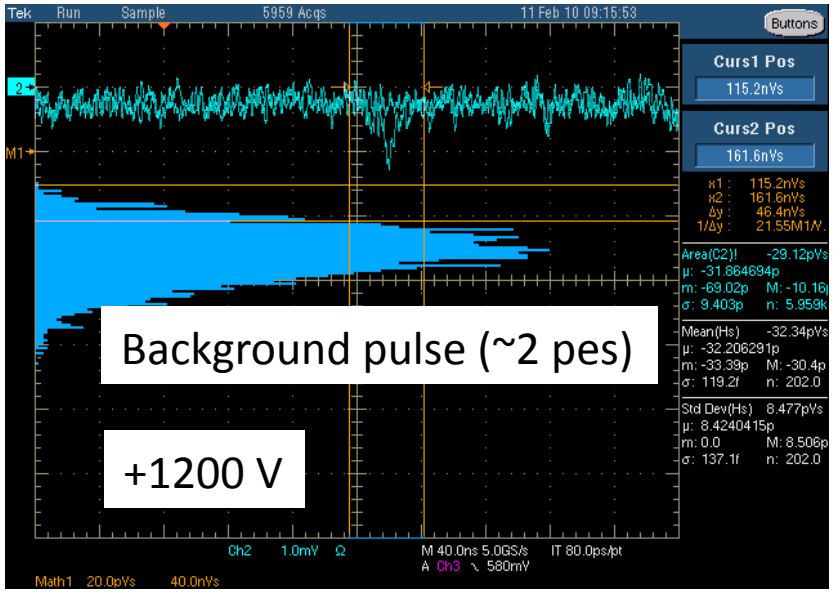
Conclusion from linearity study ..

Tube and base system is linear to an output of ~ 320 pC (8nVs/25 ohms) independent of voltage from 1200 to 1400 V.

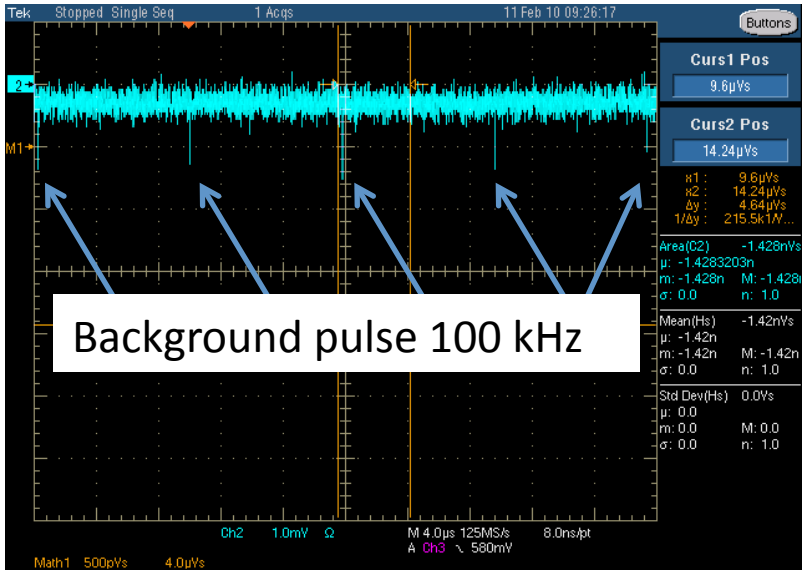
Linear range in photo-electrons will depend on how quiet we can make the system. Lower operating voltages give more range in number of photo-electrons, and the limit will be the noise in the system. It would be nice to operate at 1200 Volts (a gain of 1.25E6)

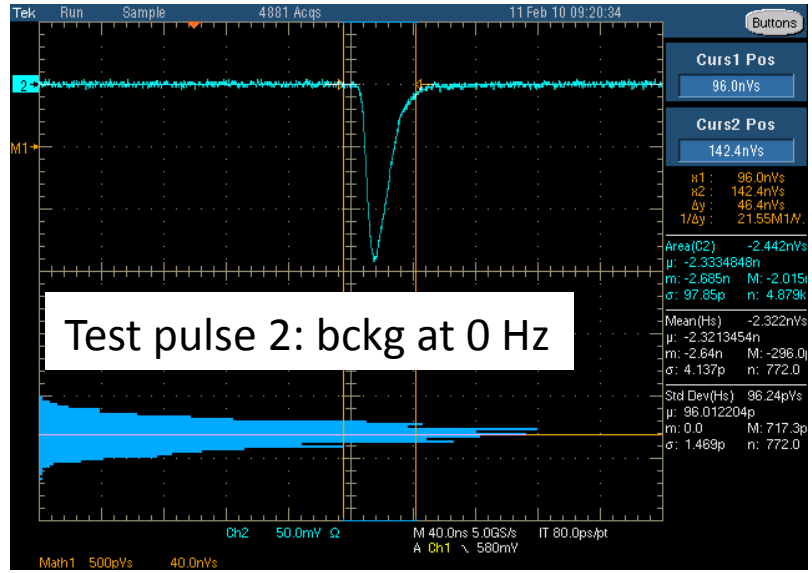
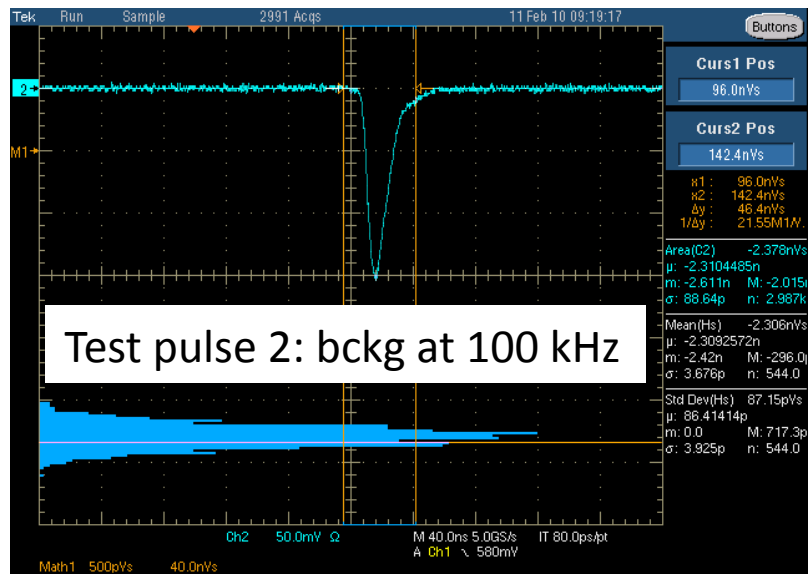
Rate Test – look at Test pulse as we change the rate of the Background pulse





Rate	Background Pulse (net) (pVs)	Test Pulse 1 (nVs)	Test Pulse 2 (nVs)
0		-0.255	-2.32
1 kHz	-19	-0.256	
10 kHz	-19	-0.258	-2.32
50 kHz	-13	-0.258	
100 kHz	-9.5	-0.256	-2.31





He’s/She’s a hero/shero