Pre-amplifier testing for old cylinderical MUSICs

July 2023

Relative gain test: A pulse generator of ORTEC model 448 was used together with the charge terminator to send an equal negative charge signal to the detector input of various pre-amplifiers (see sketch below). Furthermore, the resulting energy output signal was connected to an oscilloscope. Just to see how the timing signal looked on the oscilloscope, timing signal was also connected. The pulser signal information is as below:

Rise time (tr) = 50 nsec, *decay constant time* = 1000 nsec, and 50 Ώ termination in an oscilloscope with DC coupling. No change in signals has been observed with AC coupling with a 1 MΏ termination resister (50 Ώ termination with AC coupling was not enabled in the oscilloscope) except a shift of the signal in the y-axes.

Charge terminator: capacitor = 1 pf, voltage = 1 mV to mimic an anode signal with a charge signal of 1 fC

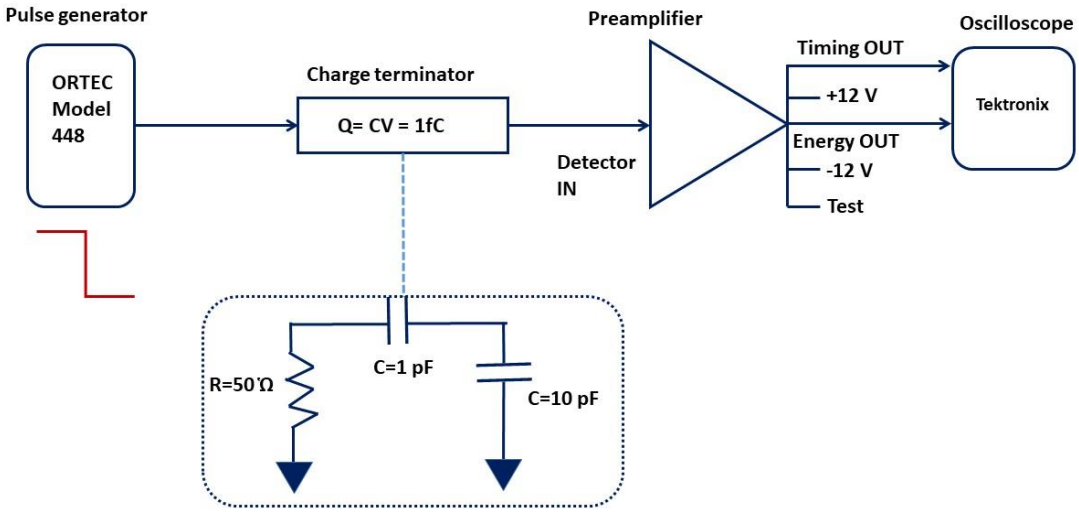


Table 1: Input pulse (in mV) from pulser, energy out, and gain (in mV/fC) are provided in the following table**.**

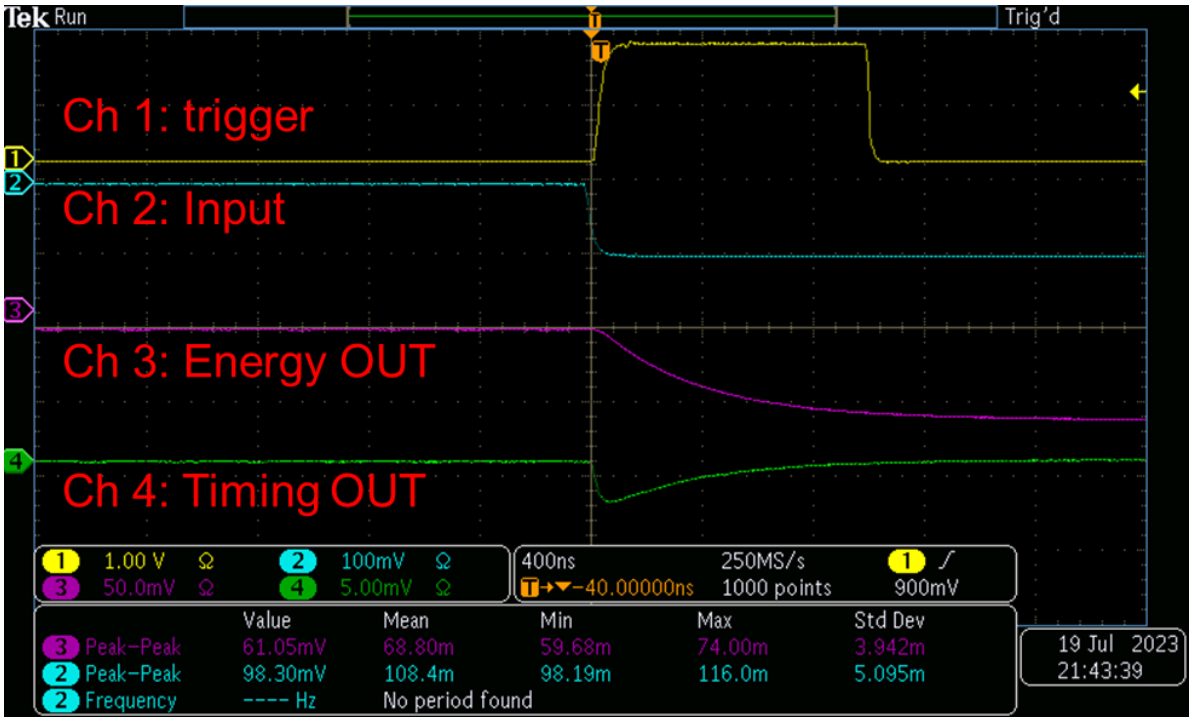
Types of pre-amp	Input (in mV) from pulsar	Input after charge terminator (in mV*pF =fC)	Output (in mV)	Gain (mV/fC)
CSTA-2, F21	98	98	20	0.20
CSTA-2, 2.1	99	99	89	0.90
CSTA-2, 2.3	98	98	61	0.62
CSTA-2, 2.4	99	99	76	0.77
CSTA-2, 113	99	99	82	0.83
CSTA-2, 114	99	99	88	0.89
CSTA-2, 115	99	99	81	0.82

CSTA-2, 116	99	99	86	0.87

- ❖ Input/output has been taken after averaging the signals in oscilloscope due to fluctuations.

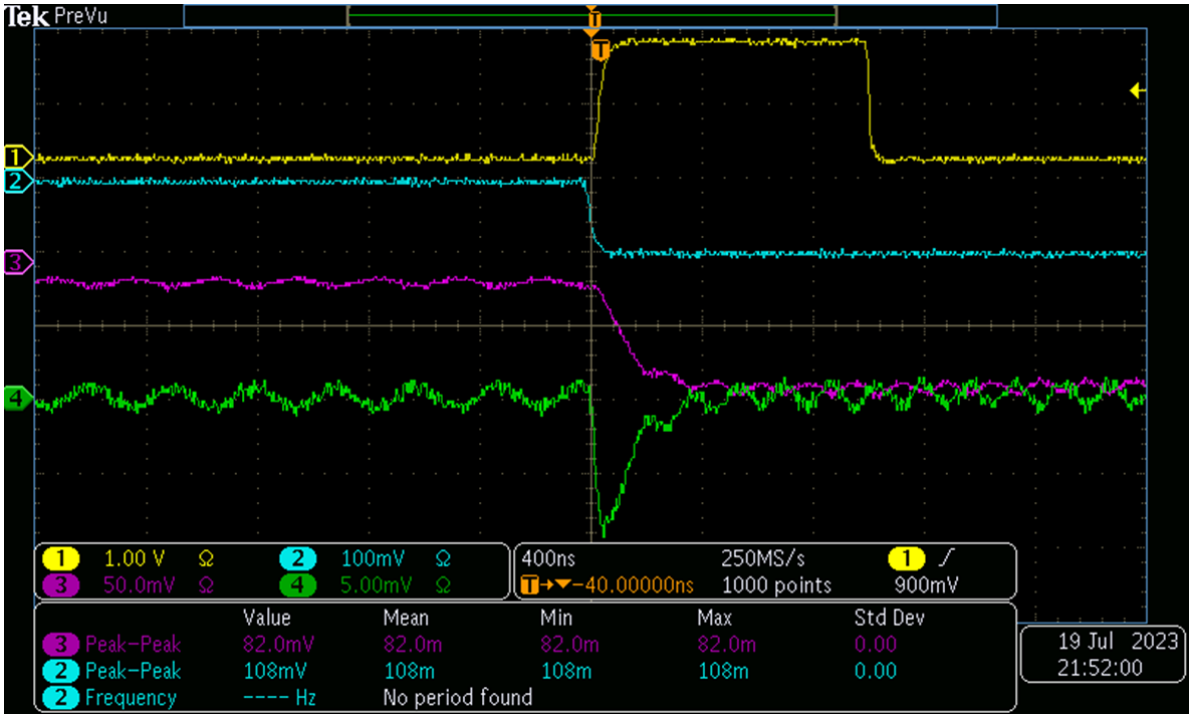
Example: For pre-amplifier CSTA-2, 2.3 [Number 76], the trigger signal, input from the pulser, and energy and timing out from the pre-amplifier are shown in the below figure:

(a) Input/output in oscilloscope when the averaging mode in oscilloscope



Gain = 0.62mV/fC

(b) Input/output in oscilloscope with single shot [screenshot]



Gain = 0.76 mV/fC

Note: the relative gain is within 15-20 % variation when we took average signal and single shot in oscilloscope.

How to decide the input voltage from pulser?

Using the LISE file **(**from Ritu's experiment**),** the energy loss in MUSIC was estimated as 5.73 MeV/u (913.11-907.38 MeV/u) using the 132Sn secondary beam.

Total energy loss in MUSIC is 5.73*132 = 756.36 MeV.
Energy deposited in P10 gas at each anode = 756.36/8 = 94.54 MeV
Energy required to create one ion-pair (in Ar gas) = 26 keV
Number of electrons (n_e) = $94.54*10^6/26 = 3636346$
Q = $3636346*1.6*10^{-16} = 5.8181*10^{-13}$ C
Furthermore, with a gauge capacitor of 1pF , the pulser input voltage can be calculated as following:
Q =CV, V^{pulser} = Q/C = 581.8 mV
However, we have considered different ranges of input voltages from the pulser to observe the effect of the input amplitude.

Signal to noise ratio (SNR) [Using oscilloscope]:

Pulsar info:
Module: ORTEC model 448
Rise time = 20 nsec, decay constant time = 10 µsec, pulse/sec = 100
Polarity = negative

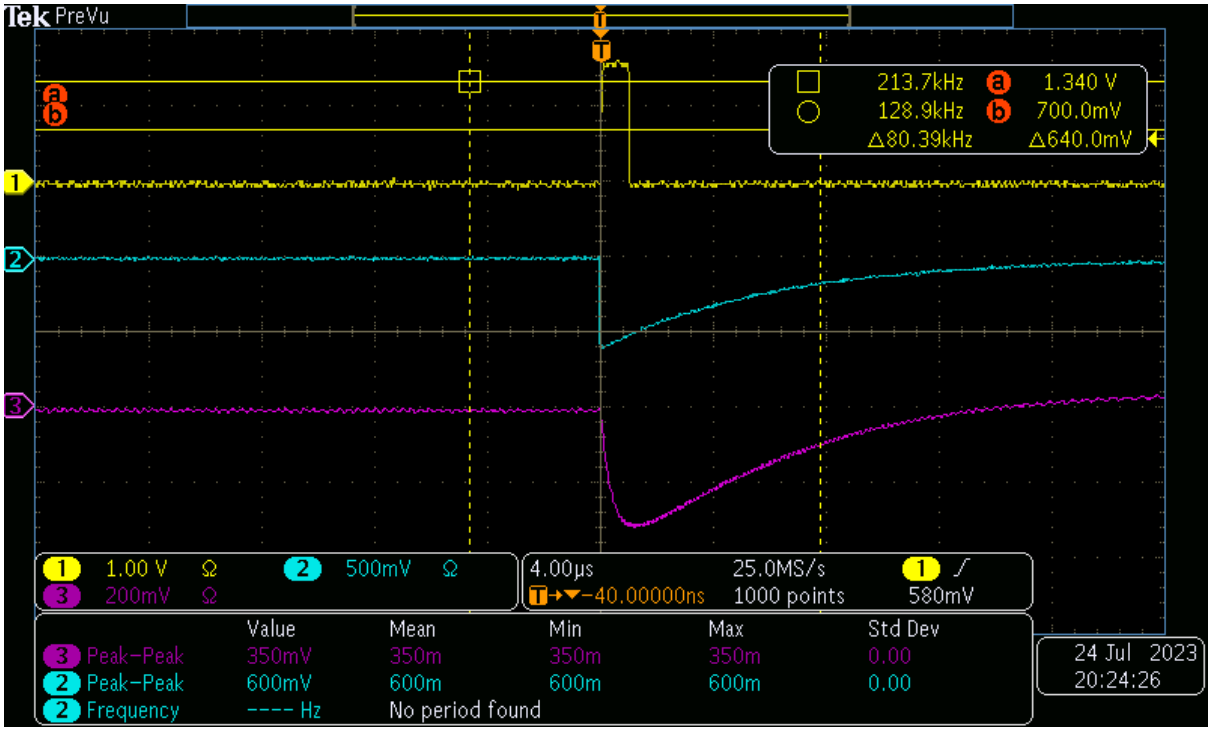
Shaping amplifier info:
Module: ORTEC 572, Shaping time = 1 µsec, coarse gain = 20, polarity = negative

- **The SNR is estimated using the energy out of pre-amplifier in oscilloscope. Signal to noise ratio is defined as follows:**

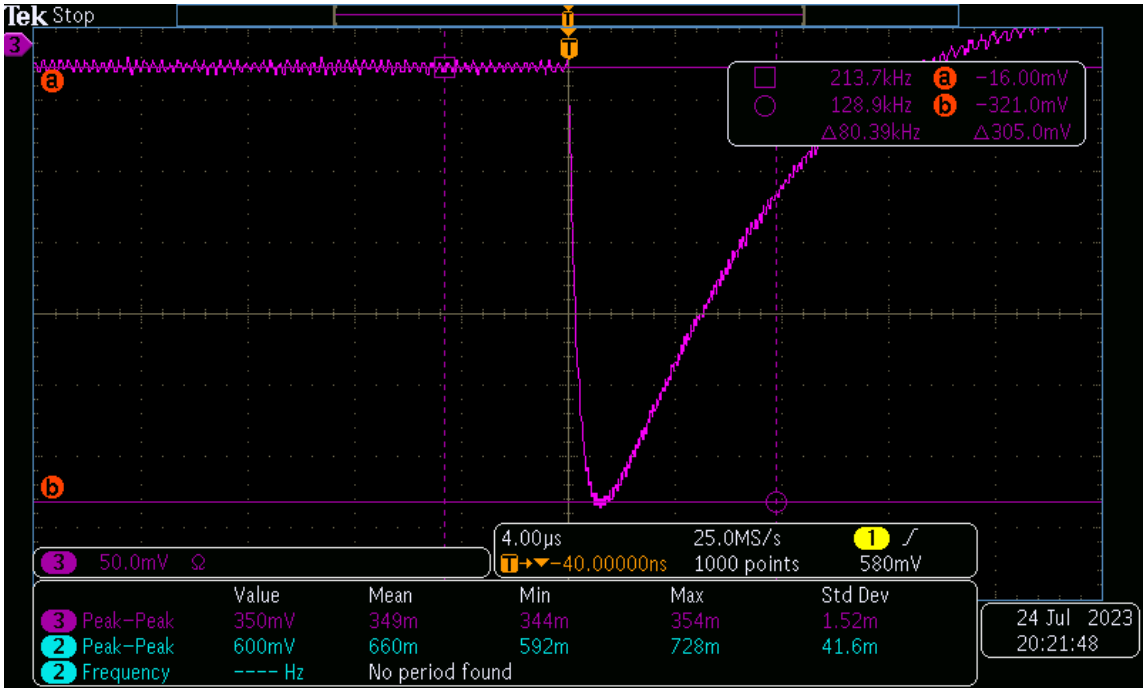
$$SNR = V_s/V_n,$$

where V_s and V_n are the signal amplitude and signal noise, respectively.

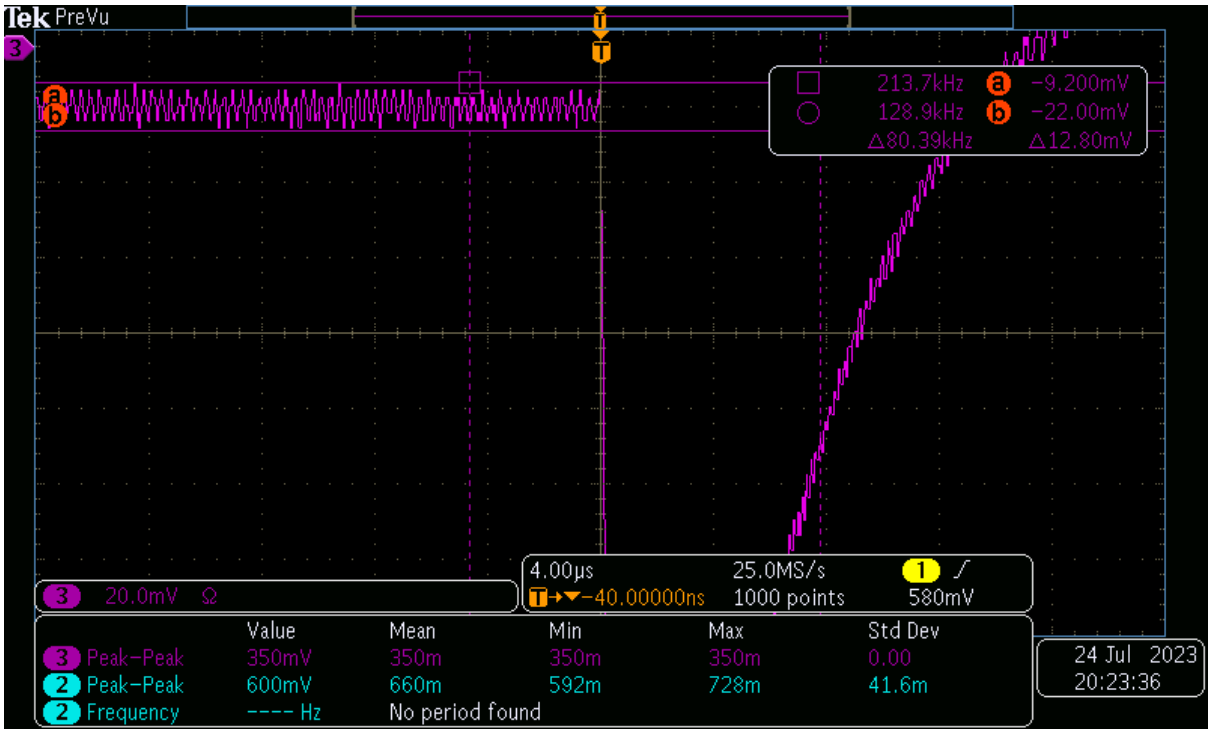
Example: For pre-amplifier CSTA-2, 2.3 [Number 76], apply the pulser peak voltage of 580 mV to charge terminator (gauge capacitor of 1pF) and connect it with the input detector of the pre-amplifier. Here is the trigger (yellow colour), input from the pulser (cyan colour), preamplifier energy out (purple colour) in the below figure.



The precisely measured preamplifier energy output pulse amplitude (305 mV) (Vs) is shown in figure below:



Here below is the energy signal noise (V_n):



Then we have estimated the SNR = 305/12.8 = 23.8 @ 580 mV input pulse for the CSTA-2, 2.3 preamplifier. Similarly, we have estimated the SNR at other input voltages for all preamplifiers and listed them in Table 2.

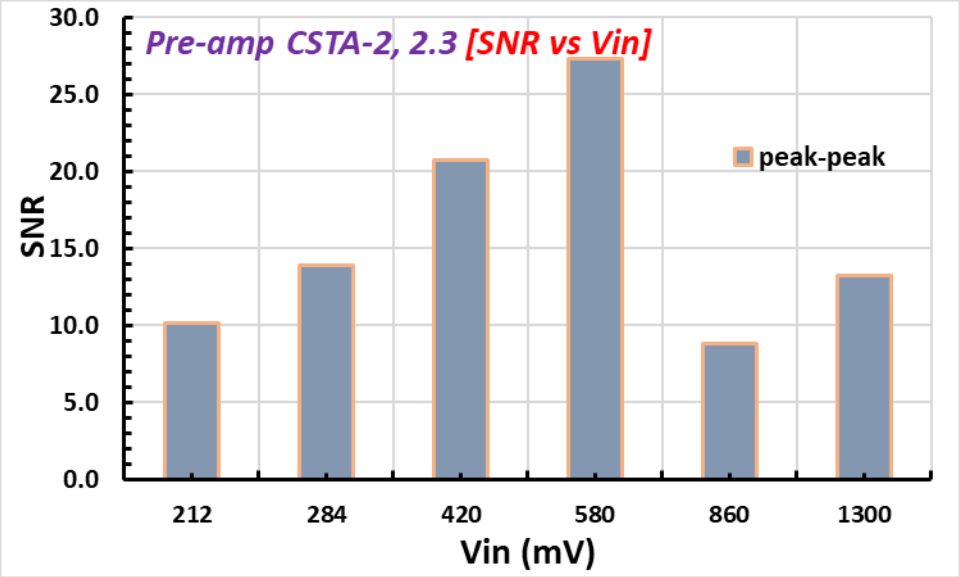
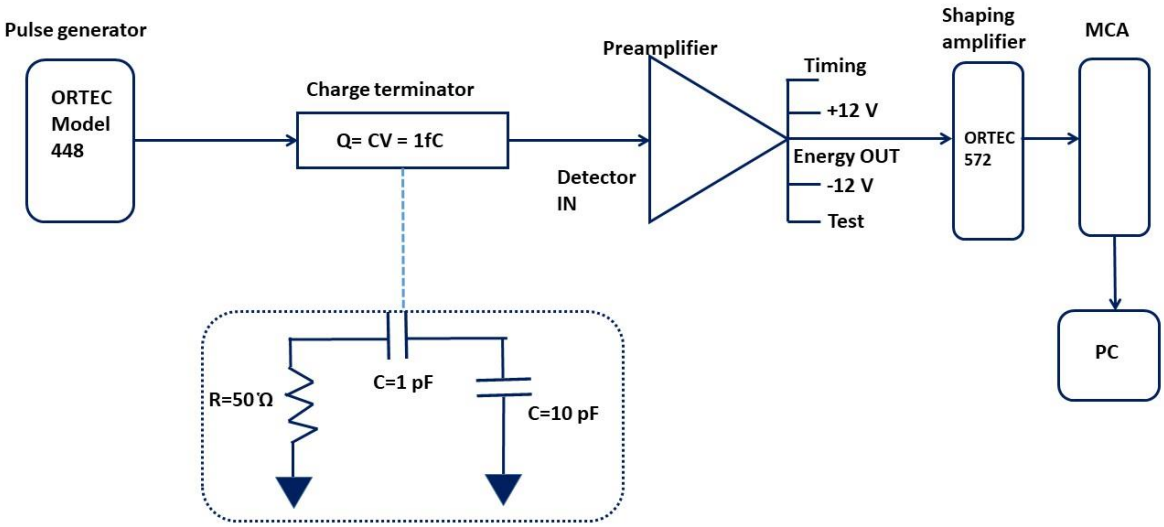


Figure 1: Signal to noise ratio (SNR) at different input voltages using oscilloscope for preamplifier CSTA-2, 2.3.

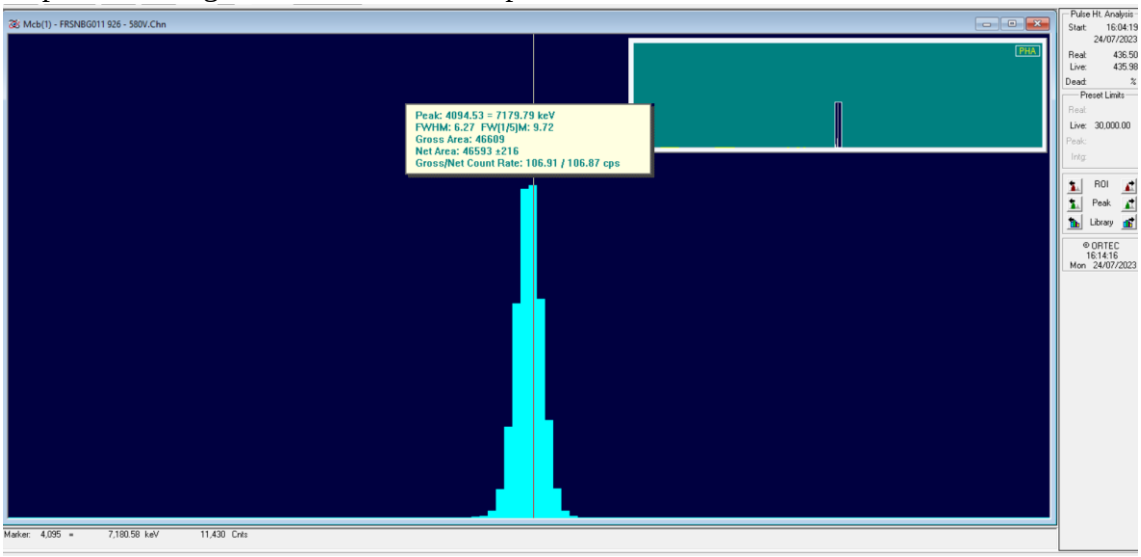
Noise measurement using Multi channel analyser (MCA):



Steps:

- Used the test circuit shown in the above figure to mimic the anode input of MUSIC with a pulse of known amplitude in conjunction with a charge terminator.
- Connected the preamplifier energy output to the shaping amplifier (ORTEC model 572) with the shaping time of 1 µsec.
- Connected the post shaping amplifier output to the MCA input.
- Calibrated the MCA (see excel sheet), channel to keV by observing the three peaks formed by three different known amplitude test pulses.

- Then, Full width at Half Maximum (FWHM) of a particular energy peak is read directly from MCA software using a PC.
- After that, % noise was measured using the relation as FWHM/mean peak energy of a particular energy peak.
  Example: One such example is shown here for the CSTA-2, 2.3 preamplifier at input amplitude voltage of 580 mV from the pulser.



Peak = 4095 (channel number) = 7179.79 keV, FWHM = 6.27
% noise = FWHM/peak energy = (6.27*100)/7179.79 = 0.09, similarly determined at other input voltages for different preamplifiers.

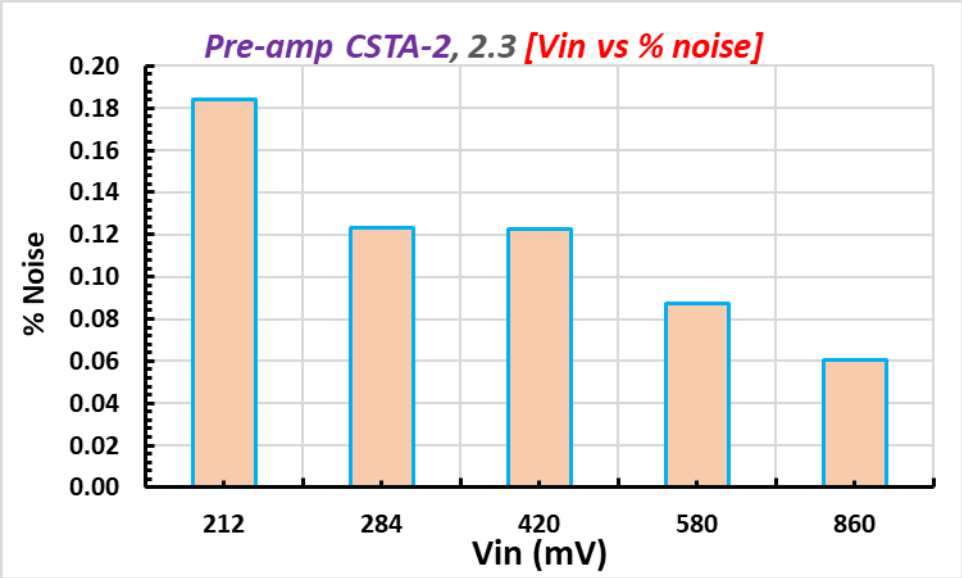


Figure 2: Noise (in %) at different input voltages using MCA for preamplifier CSTA-2, 2.3.

Table 2: Signal to noise (SNR) at different input voltages from the pulser for two different preamplifiers [Note: SNR for other preamplifiers is given in the Excel sheet.]

Preamp type	Input (in mV)	Output (peak-peak) (in mV)	Noise (in mV)	SNR
CSTA-2, 2.3	212	134	13.2	10.2
	284	236	17	13.9

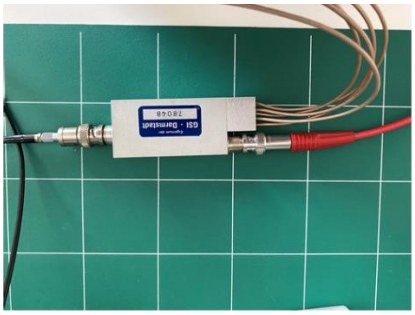
	420	352	17	20.7
	580	350	12.8	27.3
	860	580	66	8.8
	1300	820	62	13.2
CSTA-2, 2.4	212	192	24.8	7.7
	284	252	17.2	14.7
	420	368	24.8	14.8
	580	496	24.4	20.3
	860	740	82	9.0

Table 3: Noise (in %) measurement for different preamplifiers at different input voltages using a multi-channel analyzer (MCA) [% noise for other preamplifiers is given in the excel sheet.]

Preamp type	**Input (in mV)**	**Chnl number**	**Peak energy (keV)**	**FWHM**	**% noise = FWHM/peak**
CSTA-2, 2.3	212	1879	3441.01	6.34	0.18
	284	2607	4668.6	5.74	0.12
	420	2915	5189.69	6.37	0.12
	580	4095	7179.79	6.27	0.09
	860	6173	10688.32	6.44	0.06
	1300				
CSTA-2, 2.4	212	2120	3829.7	5.38	0.14
	284	2867	5107.7	5.32	0.10
	420	4175	7315.1	5.52	0.08
	580	5830	10108.6	6.96	0.07
	860	8139	14006.7	5.89	0.04

Conclusions:

- Almost all preamps are working fine.
- Relative gain is small for the CSTA-2, F21 preamplifiers as compared to others.
- Signal-to-noise ratio (SNR) is increasing with increasing input voltage, which is expected except in a few cases at higher input voltages [See figure 1].
- Noise (in %) is decreasing with increasing input voltages, which is also expected, and the noise is below 0.30 % for all the preamps within the studied input voltages [see figure 2].



Preamplifiers

Old cylindrical MUSICs