A short report on the Performance of BARC HMCs for INO detectors

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1. Introduction

Resistive Plate Chambers (RPCs) will be used as the active detector elements for a 50 kton neutrino detector which is proposed to be built by the India-based Neutrino Observatory (INO) collaboration. RPC produces a negative polarity signal at its anode and a positive polarity signal at its cathode. The RPC can be operated in the *streamer* or *avalanche* modes. In the streamer mode, the RPC produces large enough signals and therefore donot require any external amplification. While in the avalanche mode, typical pulse height and rise time of these signals across a 50Ω load are 0.5-4mV and 1nS respectively. We plan to operate the RPCs in avalanche mode in our detector. Thus we preferably need a fast (rise time under 2nS), high gain (more than 100) and low noise (a few mV) preamplifiers to process these signals faithfully. Low power design will carry an obvious advantage.

2. BARC hybrids

Electronics Division (ED), BARC has designed and developed four types of preamplifiers listed below. Discrete versions of these circuits were tested and characterised using pulser inputs at BARC and TIFR as well as on the RPC detectors at TIFR. The preamplifiers were then produced at BEL, Bangalore as Hybrid Micro Circuits (HMCs), the part numbers of which are shown in brackets in the list. This pilot production chips were tested on test benches at BARC and TIFR and were finally tested on the RPC detectors at TIFR. Based on these studies and other considerations, it was decided to mass produce 1500 chips each of two out of the four types, namely BMC1595 and BMC1597. The production chips were first tested at BEL, using a jig provided by the ED, BARC and were finally tested on the RPC detectors at TIFR.

1. Negative Input Negative Output (BMC1595)
2. Positive Input Positive Output (BMC1596)
3. Positive Input Dual Output (BMC1597)
4. Negative Input Dual Output (BMC1598)

We will use BMC1595 chips for the negative signals produced at the RPC's anode and BMC1597 chips for the positive signals produced at the RPC's cathode. In the latter case, we will use inverted output.

3. Design specifications of the HMCs

Parameter	BMC1595	BMC1596	BMC1597	BMC1598
Input impedance	50Ω	50Ω	50Ω	50Ω
Input range	-100mV	400mV	-200mV	100mV
Nominal gain	10	10	10	10
Output range	-1000mV	4000mV	±2000mV	±1000mV
Rise rime	< 2nS	< 2nS	< 2nS	< 2nS
Bandwidth	350MHz	350MHz	350MHz	350MHz
Power supplies	±6VDC	±6VDC	±6VDC	±6VDC
Power dissipation	140mW	108mW	122mW	139mW

Fig 1: Design specifications of the new set of HMCs

4. Test results with pulser inputs

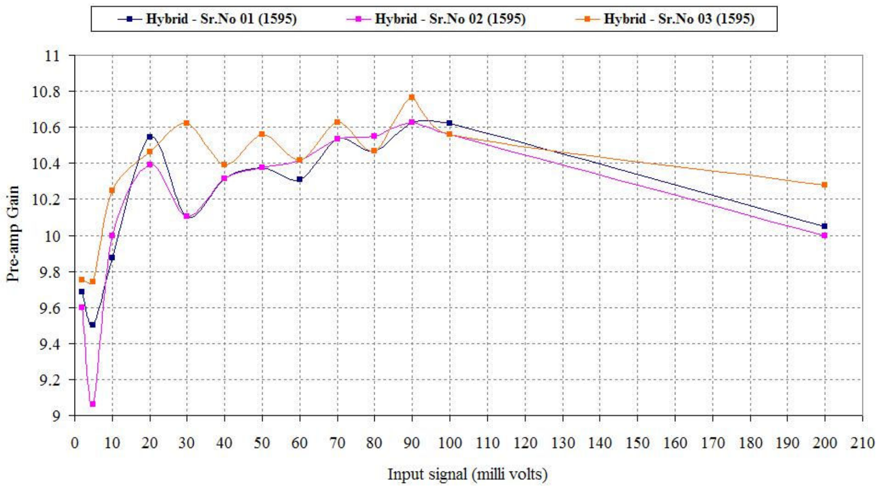

Fig 2: Gain plot of three BMC1595 chips as a function of input pulse height

Parameter	Input	Output		
		BMC1595	BMC1598	
			Inverted	Non-inverted
Signal amplitude	3-10mV	20-100mV	28-90mV	30-93mV
Rise time	1.5nS	2.4nS	4.5nS	2.5nS
Baseline shift	-1mV to 2mV	-5mV to 1mV	-1mV to 1mV	-1mV to 1mV
Noise band	1mV	2mV	2mV	2mV

Fig 3: Summary of test results for negative input chips

Parameter	Input	Output		
		BMC1596	BMC1597	
			Inverted	Non-inverted
Signal amplitude	3-24mV	40-100mV	30-108mV	20-106mV
Rise time	1.6nS	3.5nS	-	2.5nS
Baseline shift	-1mV to 2mV	-1mV to 2mV	-1mV to 2mV	-2mV to 1mV
Noise band	1mV	1mV	1mV	1mV

Fig 4: Summary of test results for positive input chips

5. Cascaded preamplifier

As mentioned earlier in the report, we need a preamplifier ideally with a gain of 100 or more. This allows us to set threshold at a comfortable level thus leaving good enough overhead for the comparator, which follows the amplifier and performs the logic pulse translation of the RPC signal. So, we have decided to cascade the BMC1595 or BMC1597 chips with BMC1513 to achieve an overall gain in our desired range. HMC BMC1513 was also earlier designed at the ED, BARC and produced at BEL, Bangalore.

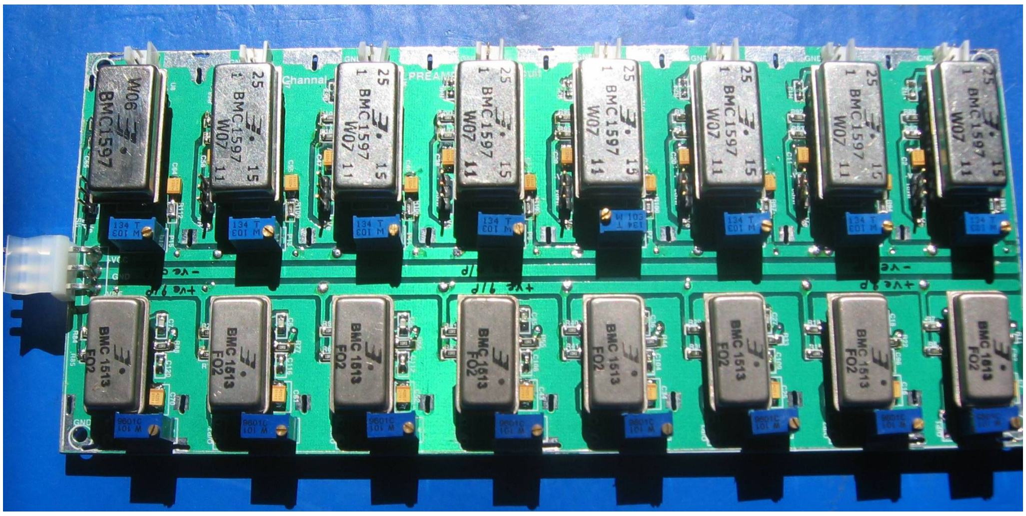

Fig 5: An 8-in-1 cascaded preamplifier board for positive inputs

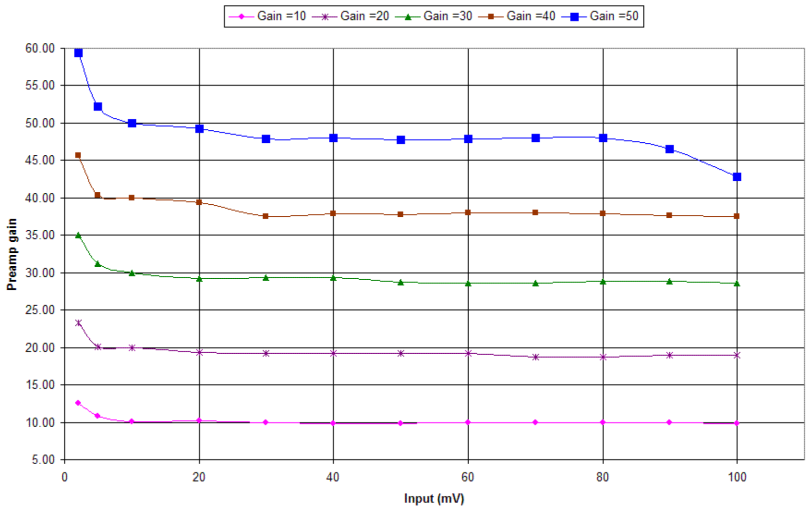

Fig 6: Gain plot of cascaded preamplifier as a function of input pulse height for different set gains

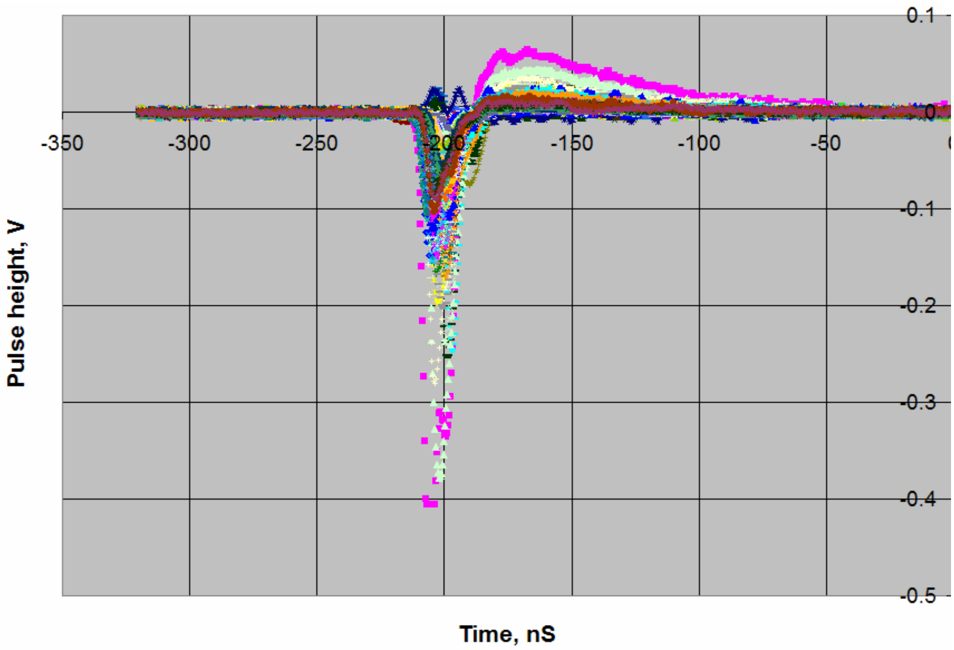

Fig 7: Superimposed traces of RPC pulses amplified by the cascaded preamplifier. The noise band recorded when used with RPC detector is about ±7mV.

6. Some characterisation studies of cascaded preamplifiers with RPC

Following are some of the characterisation studies done with the cascaded preamplifiers coupled to the RPC strips. The preamplifier output is fed to a leading edge discriminator for converting the analog signal into an ECL logic pulse. These plots further reinforce that the performance of the cascaded preamplifier stage is as per the design specifications.

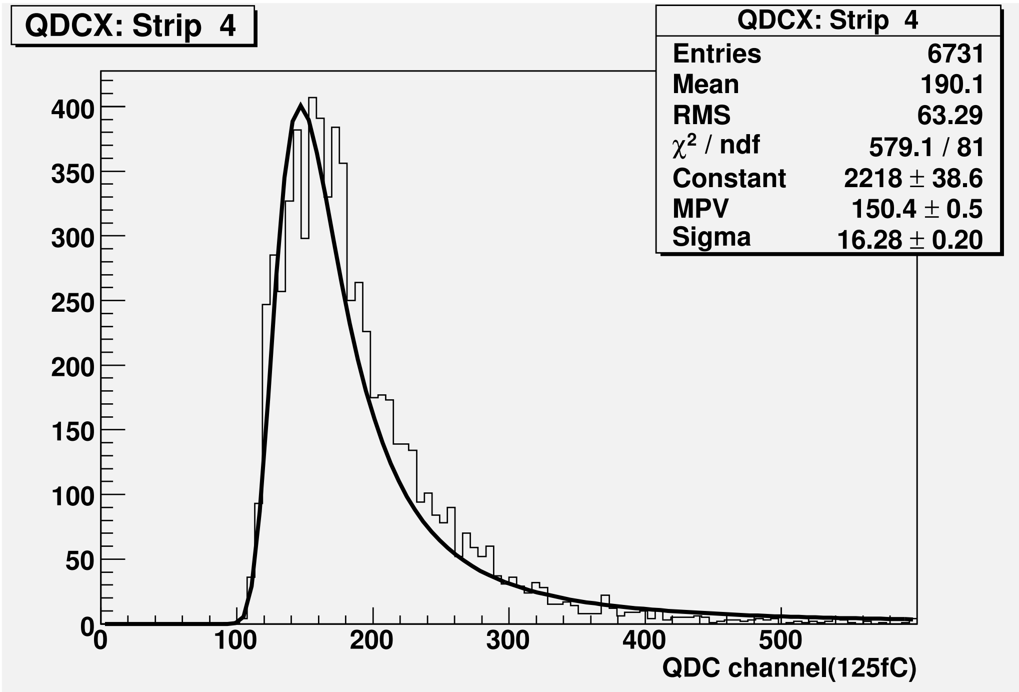

Fig 8: Distribution of charge produced typically for passage of cosmic ray muons through the RPC detector. RPC pulses are amplified by the cascaded preamplifier. From the above plot, we get a most probable charge of about 375fC by the RPC, which is a reasonable value in avalanche mode.

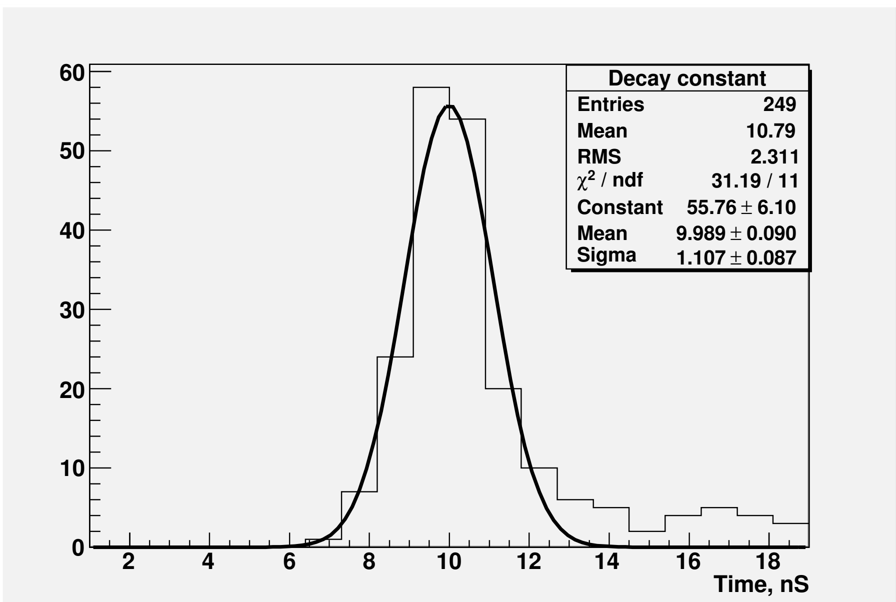

Fig 9: Decay constant distribution of the RPC pulses amplified by the cascaded preamplifier. These pulses are produced typically when cosmic ray muons were passed through the RPC detector. The mean value for the decay constant is about 10nS.

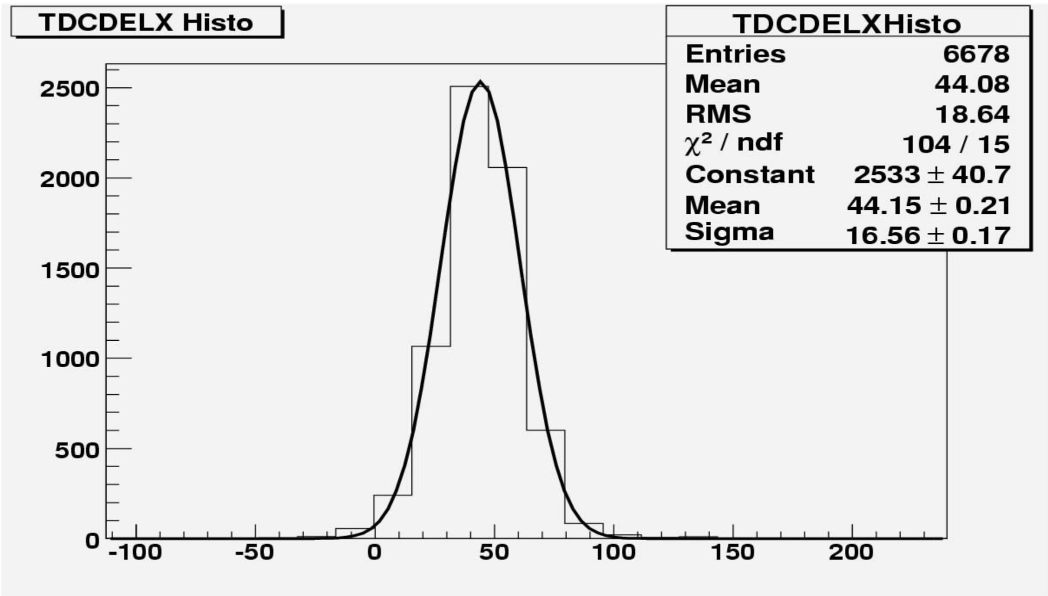

Fig 10: Relative timing distribution between two RPCs. The RPC pulses were amplified by cascaded preamplifiers. The data is acquired on a cosmic ray muon trigger produced by a coincidence of geometrically aligned scintillator paddles which are readout by PMTs. The combined timing resolution obtained from the RPCs and the electronics therefore is 16.56 bins or about 1.7nS.

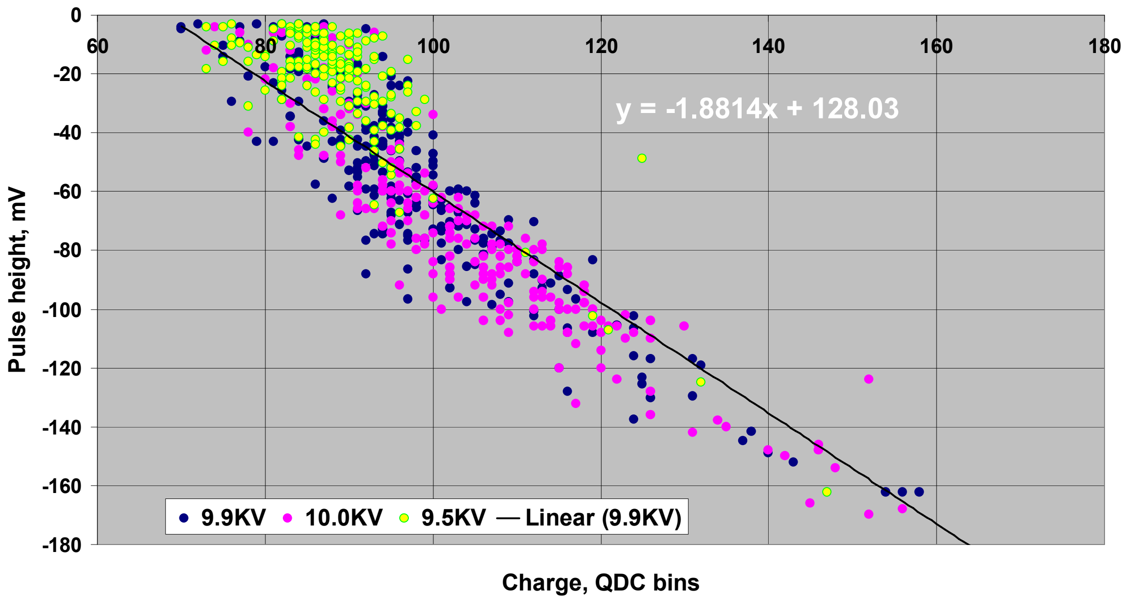

Fig 11: A scatter plot of RPC charge versus pulse height after amplification by the cascaded preamplifier. The data is obtained for the cosmic ray muon triggers. The charge is readout by a QDC unit. The preamplifier pulse profiles are recorded on a CRO. Pulse heights are derived from the profiles automatically. There is a good agreement between these data for charge/pulse height ranges provided by the RPC, by operating at different bias voltages.

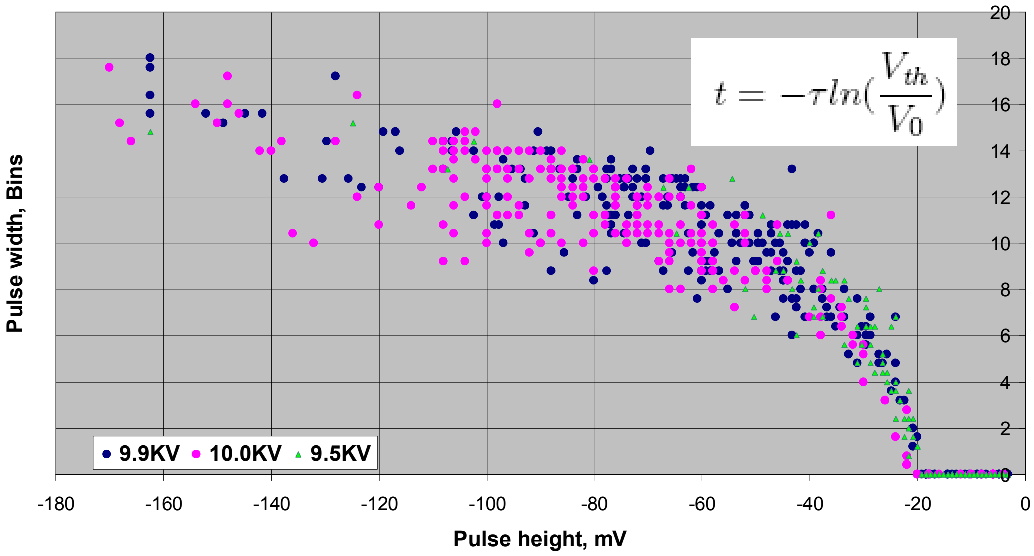

Fig 11: A scatter plot of RPC pulse height (V_0) after amplification by the cascaded preamplifier versus pulse width (t) of the logic pulse after translation. The data is obtained for the cosmic ray muon triggers. The preamplifier pulse profiles are recorded on a CRO. Pulse heights and widths are derived from the profiles automatically. There is a good agreement between these data for pulse height/width ranges provided by the RPC, by operating at different bias voltages. Threshold (V_{th}) set for the comparators is -20mV. τ is the decay constant of the amplifier pulse.

7. Deployment of HMC chips

We have started building 1m^2 area RPCs needed for the INO prototype detectors. These RPCs are stacked in a stand and are being operated to study their performance and long term stability. We have used about 100 chips each of BMC1595, BMC1597 and BMC1513 to fabricate the 8-in-1 preamplifier boards and started using them for the stack. In the process, we have also implemented some minor changes in the cascaded preamplifier circuit and are able to obtain higher gains.

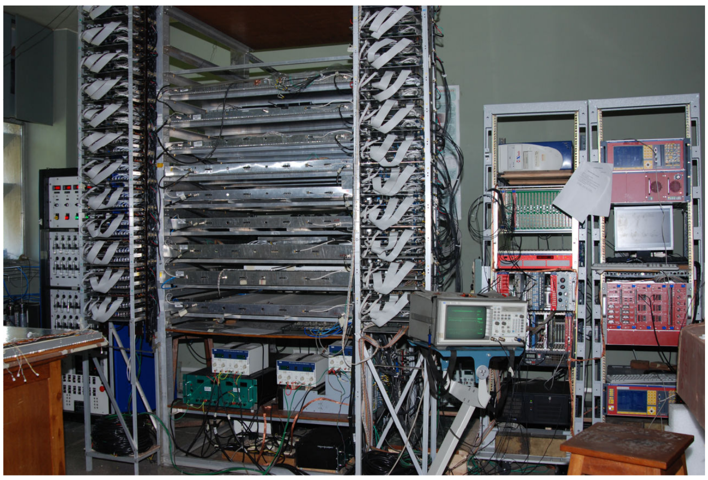

Fig 12: INO prototype detector stack in operation

The cascaded gain of the preamplifier shows good stability. This is indirectly inferred by the stability of RPC strip noise rate profiles monitored continuously. The rates donot show any variations except for the expected 24-hour cycles, caused by changes in ambient parameters such as temperature, relative humidity and barometric pressure, which affect the operation of RPC in a known manner.

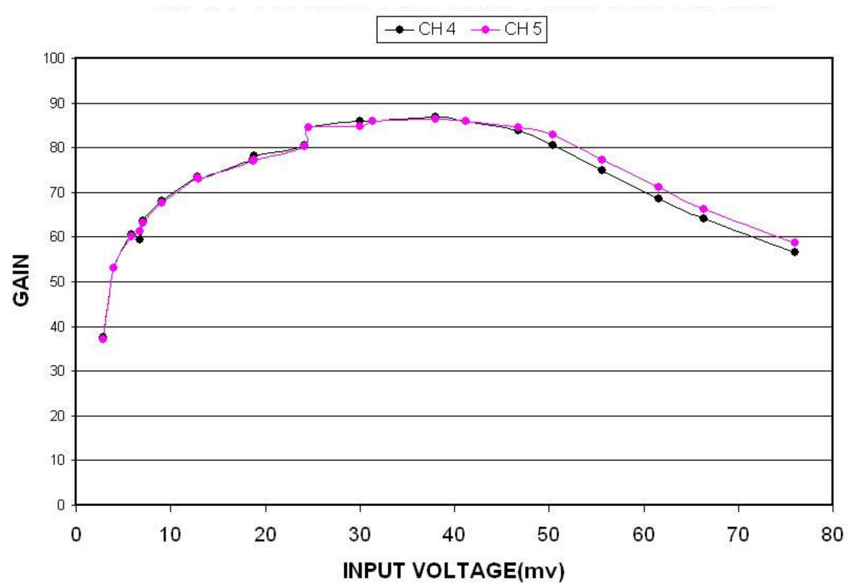

Fig 13: Improved cascaded gain with minor changes in the cascaded preamplifier circuit

8. Summary

The HMCs designed and produced by ED, BARC were tested and are being deployed in the INO detectors. They were found to satisfy their design specifications. We will need about 1300 chips each of types BMC1595 and BMC1597 and 2600 chips of the type BMC1513 to complete board production required for two prototype detectors, which were planned to be operational at VECC and TIFR soon.

3rd March 2008