Technical manual

NaI + PMT Gamma ray spectroscopy system

Designed and Developed at

Inter University Accelerator Centre,
New Delhi, India.

NaI + PMT Gamma ray spectroscopy system

Description:

The NaI + PMT Gamma ray spectroscopy system system contains various building blocks such as Integrated scintillation and PMT assembly, charge sensitive preamplifeir, shaping amplifier and multiple power supplies as shown in the Figure.1. The entire assembly is assembled in a die-cast aluminium box. The system optimised for Phonix MCA (multi channel analyser) and can be used with any other MCA. This assembly is tested for its functionality and test report is attached with representative screen capture.

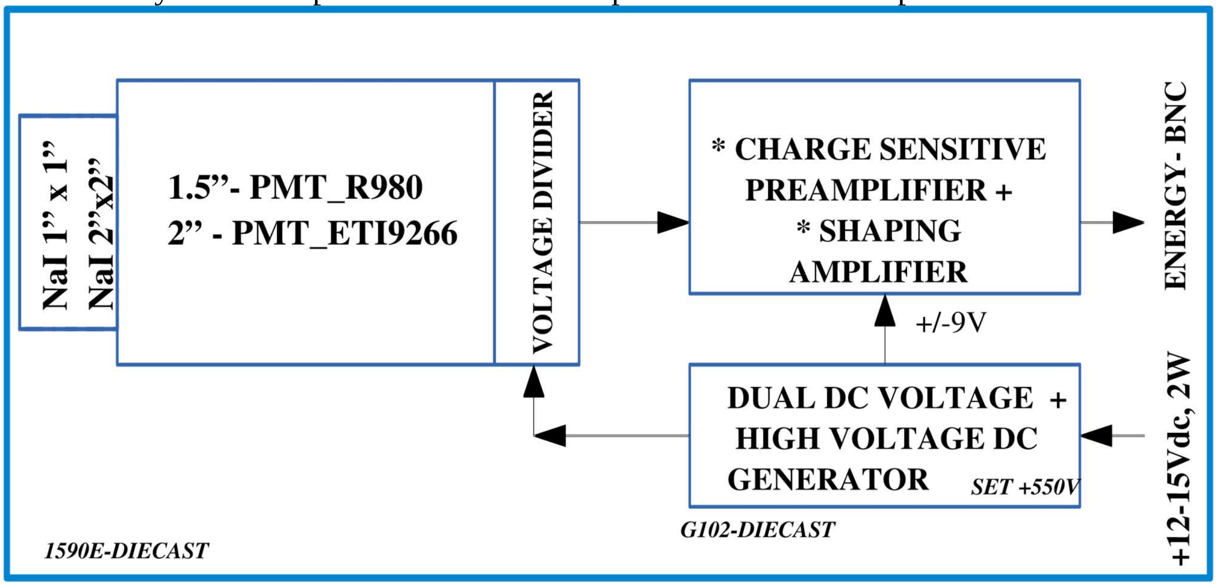

Fig:1. Block diagram

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Specifications	:	**NaI + PMT Gamma ray spectroscopy system**
Scintillation	:	M/s. Saint-Gobain crystals, 1M1/1.5 (NaI 1” X 1”) or **2M2/2** (2”x2”x2”) Integrated detection assembly
Input DC supply	:	+12V to 15V, ~0.2A [12V, 0.5A Wall mount adopter is used]
Dimension	:	188 x 120 x 82 (mm) die-cast Aluminium enclosure (1590E)
Output	:	BNC connector, Unipolar Semi-Gaussian **~ 0-5V /** 0-10V
Bias Power Supply		
High voltage Power supply	:	+650 KV/ ~1mA (Adjustable on PCB) factory set at +600V
Regulation Load	:	better than 0.1% at full load
Ripple	:	better than 0.005% at full load
Dimension	:	90 x 36x 30 (mm) die-cast aluminium enclosure (G102)
PMT Bias Network		
PMT Detector	:	10 stage, ETI-9266 2” PMT
Socket type	:	14 pin JEDEC B-14-38
Total resistance	:	~6 Mega ohm
Power Dissipation	:	~0.1W at **+600V**.
Application	:	Energy spectroscopy
Signal Output	:	Energy (2.2Mohms), with 100ms decay time.
Preamplifier		
Type	:	Charge sensitive preamplifier operational amplifier type
Conversion factor	:	**-1mV/MeV** (Si. Equ)
Decay time	:	~50 µS (+/-10%)
Output	:	DC blocked and 100 ohm capable
Protection	:	Input is over voltage protected against spikes
Power	:	+/-9V, 5mA
Dual voltage supply		
Type	:	Charge pump ICL7660
Output	:	+/-9V, 20mA each
Shaping Amplifier		
Output	:	P/Z, Baseline corrected unipolar, with overload recovery, Semi-gaussian type output pulse
Gain	:	**2.5MeV**, 5MeV respectively (Jumper select on board) for **0-5V**

Bold: default set

Descriptions

NaI + PMT Radiation detector and Assembly

The integrated assembly of Radiation detector assembly contains a NaI (Tl) scintillator of size 2”x2” is optically coupled to a 10 stage photomultiplier tube (PMT) and shielded with 'mu' metal as shown in the Figure 2. Such detector is used for converting incident gamma ray radiation energy into proportional electrical pulses of decaying type. This is a commercially available unit from M/s. Saint-Gobain Crystals, Bangalore [1]. Such detectors are commonly used for gamma ray spectroscopy, thyroid measurements and health physics applications. All the required electronics are placed within the die-cast Aluminium box with opening for radiation to enter the scintillation crystal as shown here. The circuits are interlinked with PTFE wires, and double shielded PTFE coaxial cable (2mm).

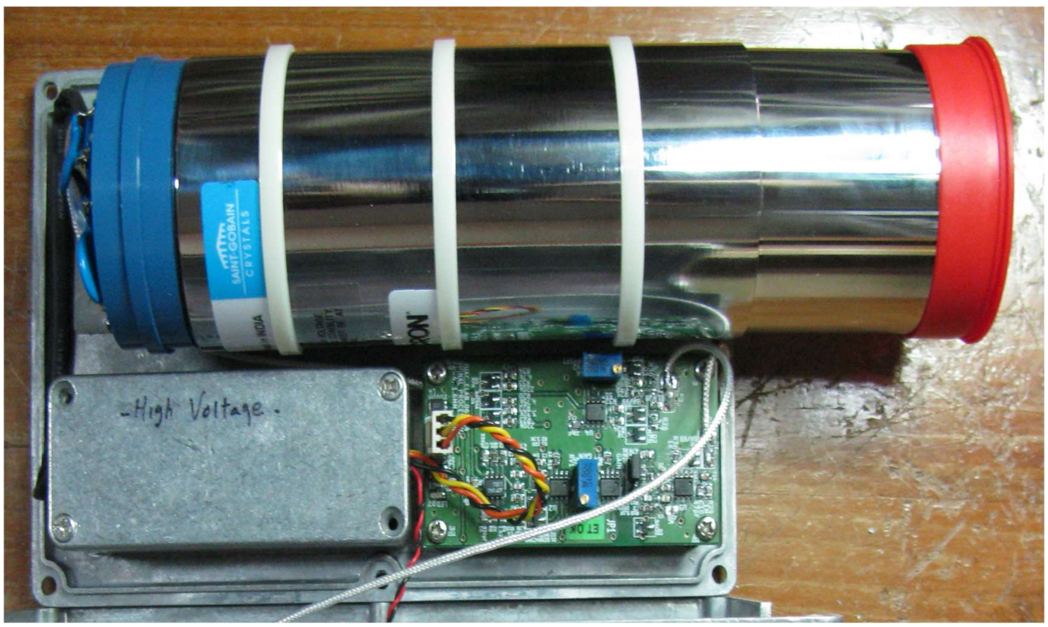


Figure 2: Internal view of the spectroscopy unit

PMT voltage divider network

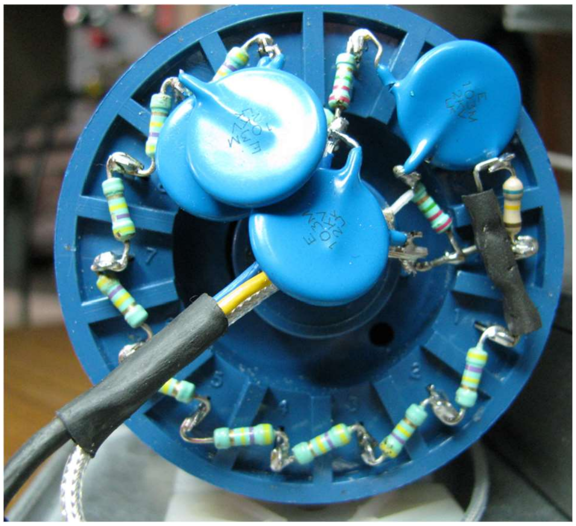


Figure 3: PMT socket views

The 10 stage PMT electrodes are biased through PMT high voltage bias network as shown in the Figure.3 & 4. The PMT anode is supplied with +600V through load resistor of 2.2Mohms (R2). The potential across each dynode is approximately 40 to 50Volts as recommended in the voltage distribution ratio table for the PMT R980 [2, 3]. The divider network is fabricated on a PCB with SMD components and socket mounted for easy construction. Optional voltage monitor across the cathode can be used to monitor the PMT bias voltage supplied. The current pulse from anode is dropped across 2.2Mohm load resistor and DC coupled, The decay time constant selected to be around 100mS (C1 X R1).

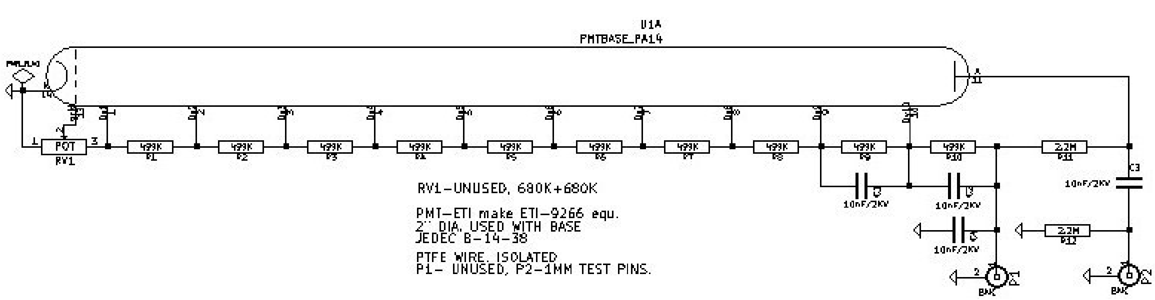


Figure 4: Schematic of PMT high voltage bias network

Signal processing electronics

The signal from the anode of PMT is buffered with on board charge sensitive preamplifier (U5) having charge sensitivity of -1mV/ MeV (47pF, 1M) (Si. Equ), and decay time constant of 50uS. The preamplifier signal is DC blocked and fed to a pole-zero correction network for smooth baseline recovery of amplified signal. The block diagram of signal processing electronics is shown in Figure 5:

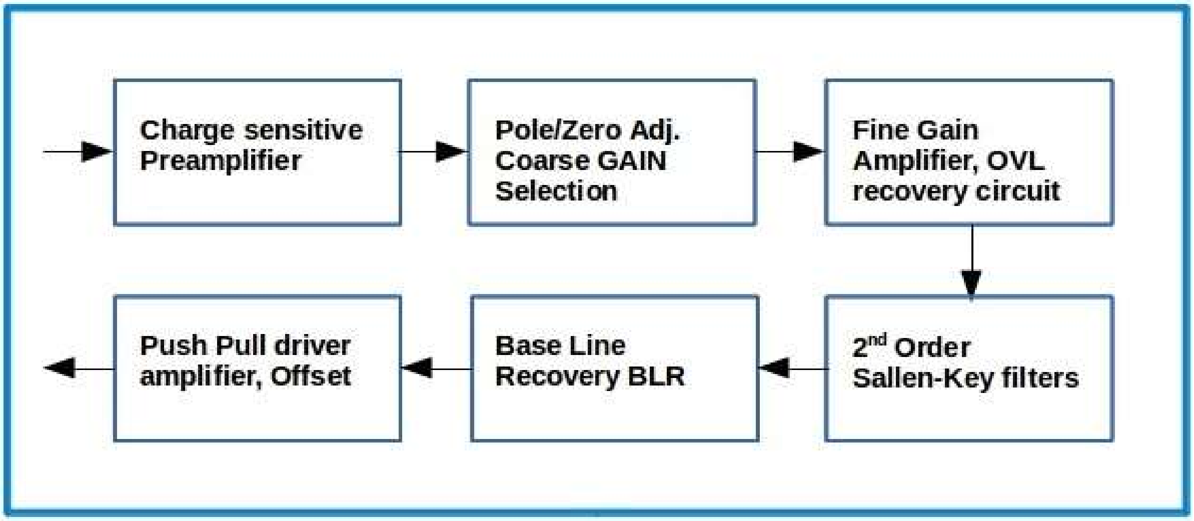


Figure 5: Block diagram of signal processing electronics

The signal from preamplifier is further amplified with a low noise, broadband operational amplifier (U1) and desired gain selection (COARSE gain) is done in this stage. Further amplification (FINE gain) as well as over load recovery (OVL) takes place in the next stage (U2, D2). The signal level in this stage is clamped to a desired level, so that the over all amplified signal does not exceed the desired level in order to protect the following stages. This circuit also helps to recover the amplifier quickly from pileup of events at the input due to increased radiation intensity. The signal is shaped for a desired time constant (2uS) with 2 stages of 2^{nd} order low pass filters in cascade (U3A &B). The slow varying baseline or DC offset is corrected in the following stage with twin diode Robinson baseline recovery circuit (BLR) (Q1,D4,Q4). Further the signal is amplified and buffered for an optimum load in the last stage (U4, Q2,Q3). The required DC (+/-9V) supply is tapped from power supply unit through 3 pin CFU connector. The signal processing PCB is mounted on the diecast aluminium box, and the output is made available on the BNC connector for further digitisation.

Typical shaped energy output signal is shown in Figure 8.

Power supply Unit

The high voltage power supply is an independent unit, as shown int the Figure 6: and is enclosed in a die-cast aluminium box. The high voltage PCB also contains a dual DC voltage supply (charge pump) circuit, required for the signal processing electronics circuits. The incoming supply is zener regulated to +9.0 volts and fed to a switched capacitor type charge pump circuits (U3, U4) to generate +/-9V supplies. Whereas the high voltage DC generator works on Cock croft-Walton principle. The step up transformer (T1) is fed with pulses of 50% duty cycle at 25KHz, from a pulse width modulator (PWM) circuit (U1). The primary voltage of transformer is controlled through the voltage regulator circuit (U2), to set the required output voltage through a feedback mechanism. A 6 -stage Cock craft-Walton half bridge high voltage multiplier circuit generates required high output voltage (~550-600V). The output voltage is sampled through a high ohmic resistor chain to generate negative feedback voltage for a on board regulator (LM723). The CRC filter (C10, R4, C12) is used as a low pass filter, as well current limiter. The high voltage supply circuit can be shut down with jumper (JP1) selection. The output voltage is set to +550Volts, for this application, and can be adjusted within +/-5% with control provided on PCB. The ripple voltage at the output is measured when it is fully loaded and is measured to be 14 mV_{rms} (<0.003%).

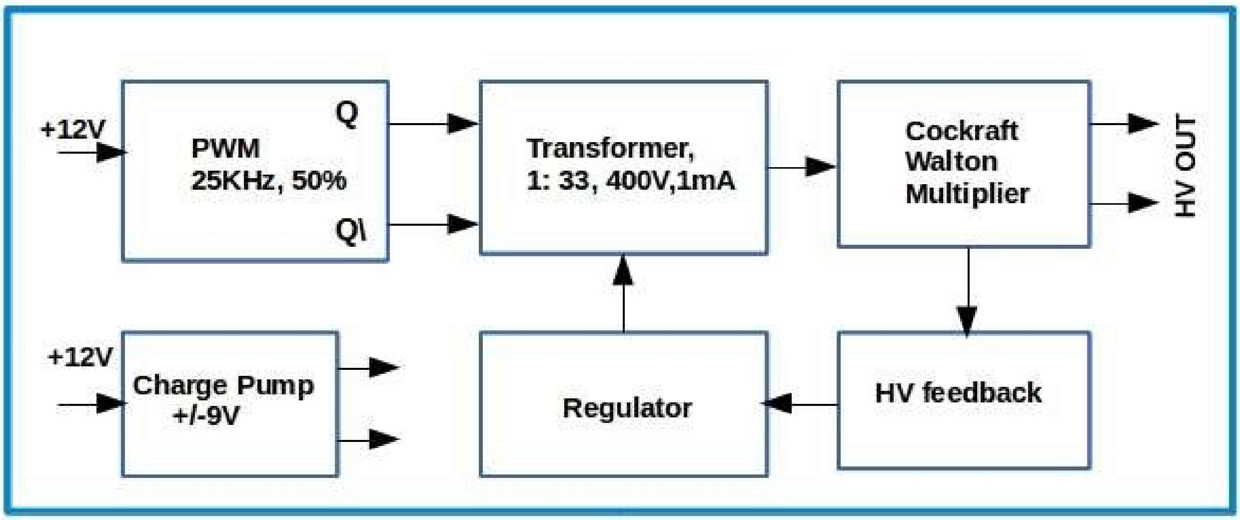


Figure 6: Block diagram of Power supply unit

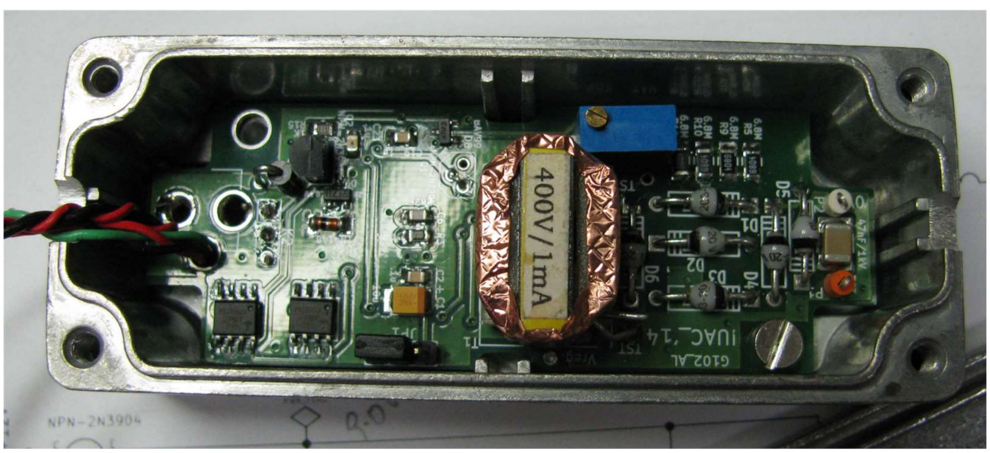


Figure 7: Internal view of power supply unit

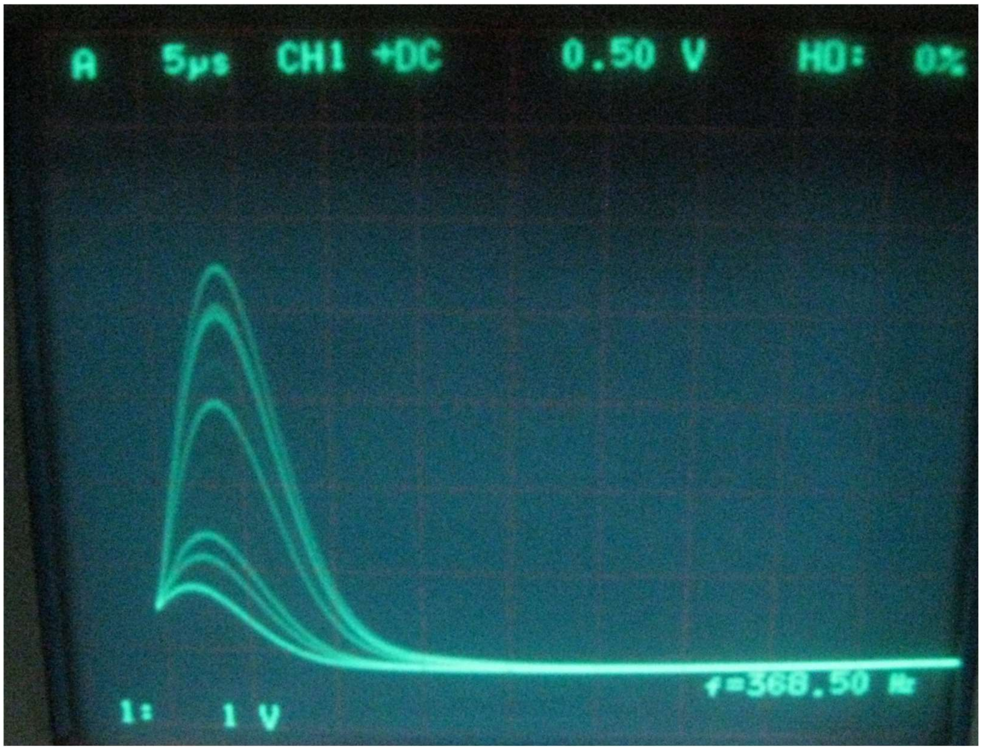


Figure 8. Energy output for ^{60}CO source

Setting up procedure:

Items required:

+12-15V/~0.5A wall mount adopter 1no.

NaI + PMT Gamma ray spectroscopy system 1 no. Cathode ray oscilloscope (CRO) 1 no. (optional)

Radiative source (laboratory grade) 137Cs / 60CO 1 no.

Multichannel Analyser (511/2K/4K/8K/16K), 0-5V¶ 1 no.

BNC-BNC coaxial cable 1M 1 no.

Procedure:

- ➔ Power the unit with wall mount adopter. LED must glow.
- ➔ Connect the output (Energy) to CRO through BNC cable. Set +ve edge "Trigger" threshold above +50mV DC.
- ➔ Set the horizontal (time) scale in 1us/div, vertical scale in 0.5V/div, observe randomly occurring gaussian shape signal with low count rate (~100Hz).

- ➔ When the radiation source is brought closer to the scintillation side of the detector, the signal intensity increases. The amplitude of the observed signal is entirely depended on the incident energy as shown in Figure 8.
- ➔ Ensure that the Energy output should not have any DC offset, and maximum amplitude shall not exceed +5V.
- ➔ Setup the MCA available as suggested. (Phonix or any commercial MCA can be used)
- ➔ Now the BNC cable can be connected to the MCA input for further data collection and interpretation as suggested in the MCA manual.

¶ **The internal circuit is capable of delivering the output across dynamic range of 0 – 10V, with 50 ohm load. Present circuit is wired for +5V with suggested DC power source.**

Warning:
The HIGH VOLTAGE for biasing PMT is exposed inside this unit.
Do not attempt to change the settings unless suggested by the manufacturer / supplier.
Any malfunctioning of this unit shall be reported with symptoms noticed.

Test results

The gamma ray spectroscopy system is repeatedly tested with standard radiation sources and pulse height distributions have been studied using different multichannel analyser (MCA). The energy resolution recorded is around 65KeV (~6% in 1173KeV) with radiation sources ^{60}CO and ^{137}Cs as shown in figure 9,10 which were obtained with 511 channels (Phoenix).

Figure 9: Energy distribution for ^{137}Cs source obtained with "PHOENIX"- MCA

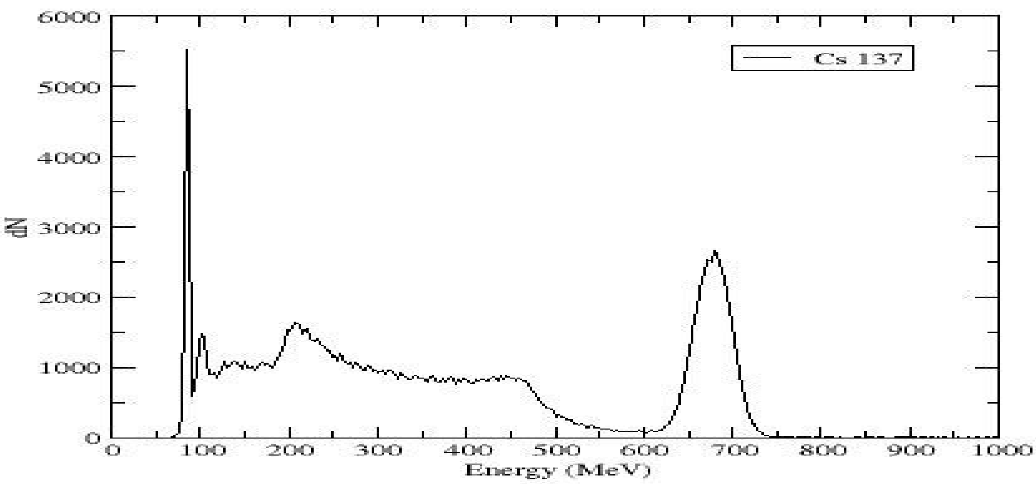
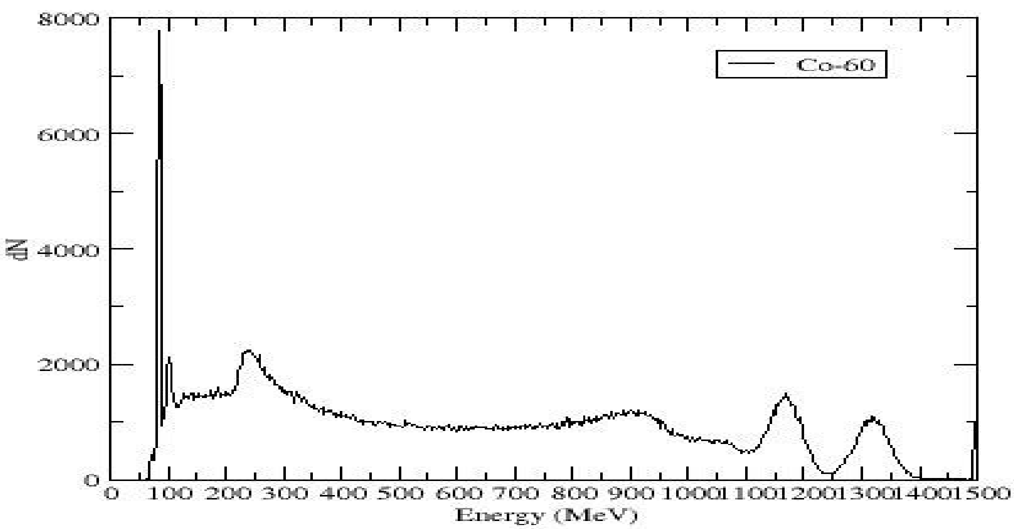
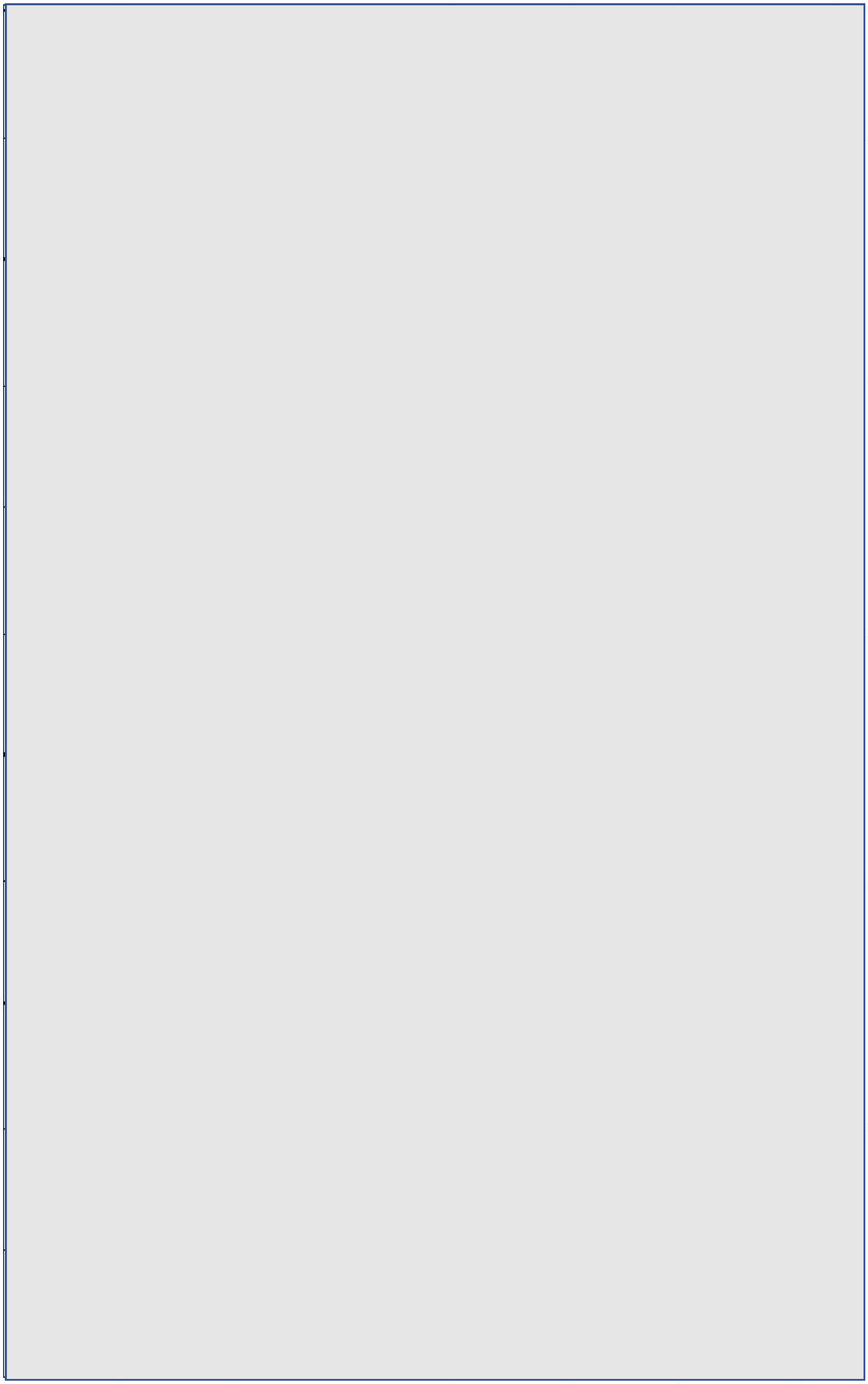


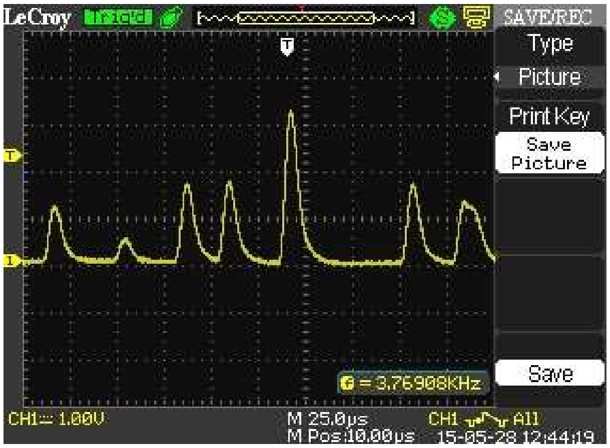
Figure 10: Energy distribution for ^{60} Co source obtained with "PHOENIX"- MCA



References:

1. Scintillation materials & assemblies, M/s.Saint -Gobain crystals.
   http://www.crystals.saint-gobain.com/
2. Photomultiplier tubes R980, Hamamatsu data sheet
3. Bases, Voltage Dividers, and Pre-amplifiers Accessories for Scintillation Detectors
   http://www.crystals.saint-gobain.com/

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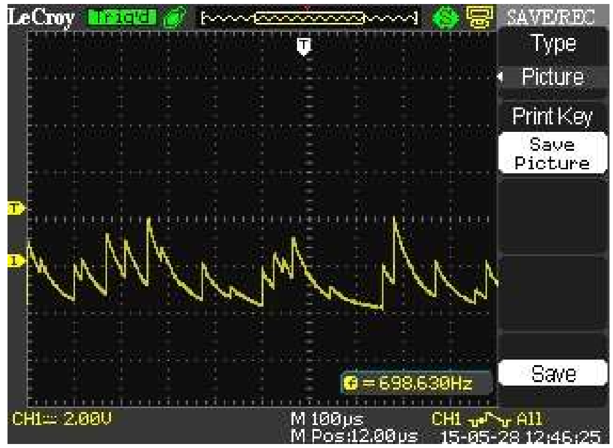
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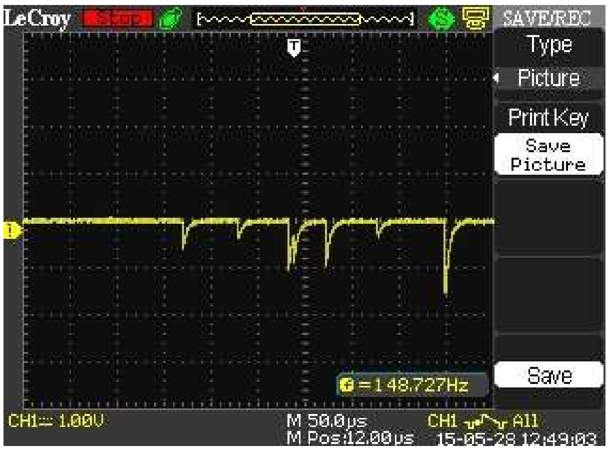
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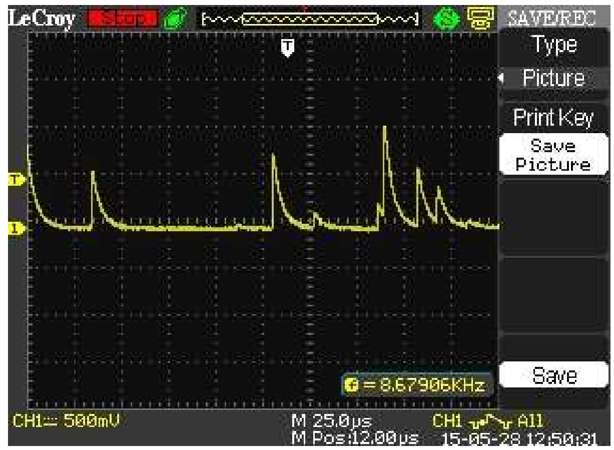
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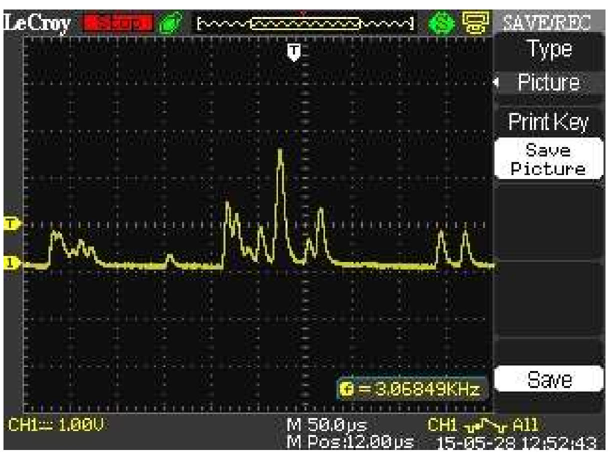
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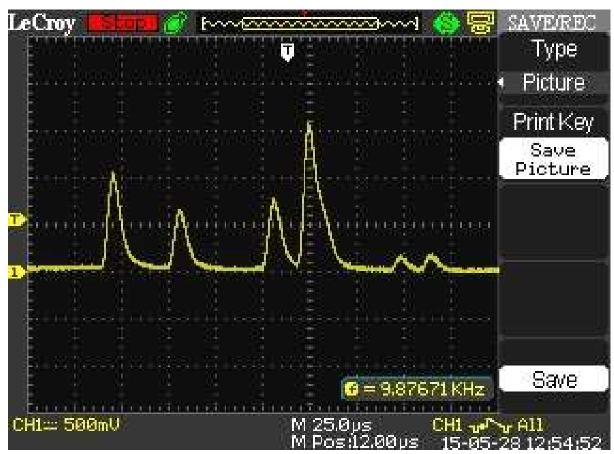
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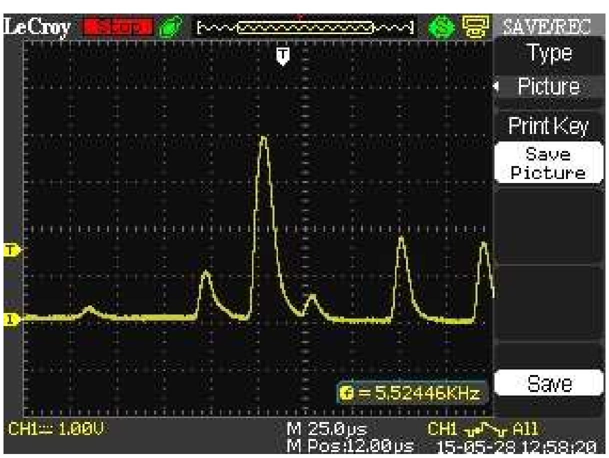
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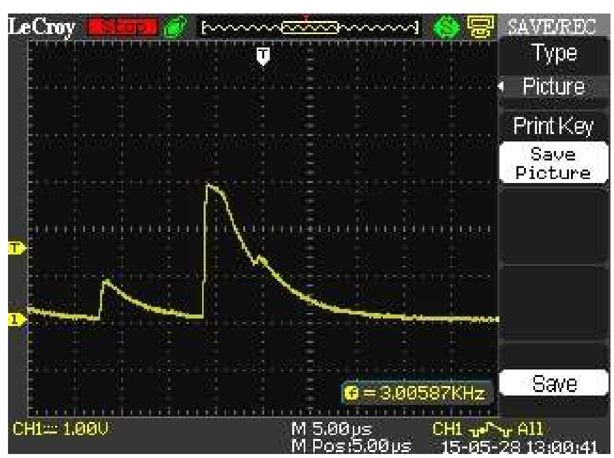
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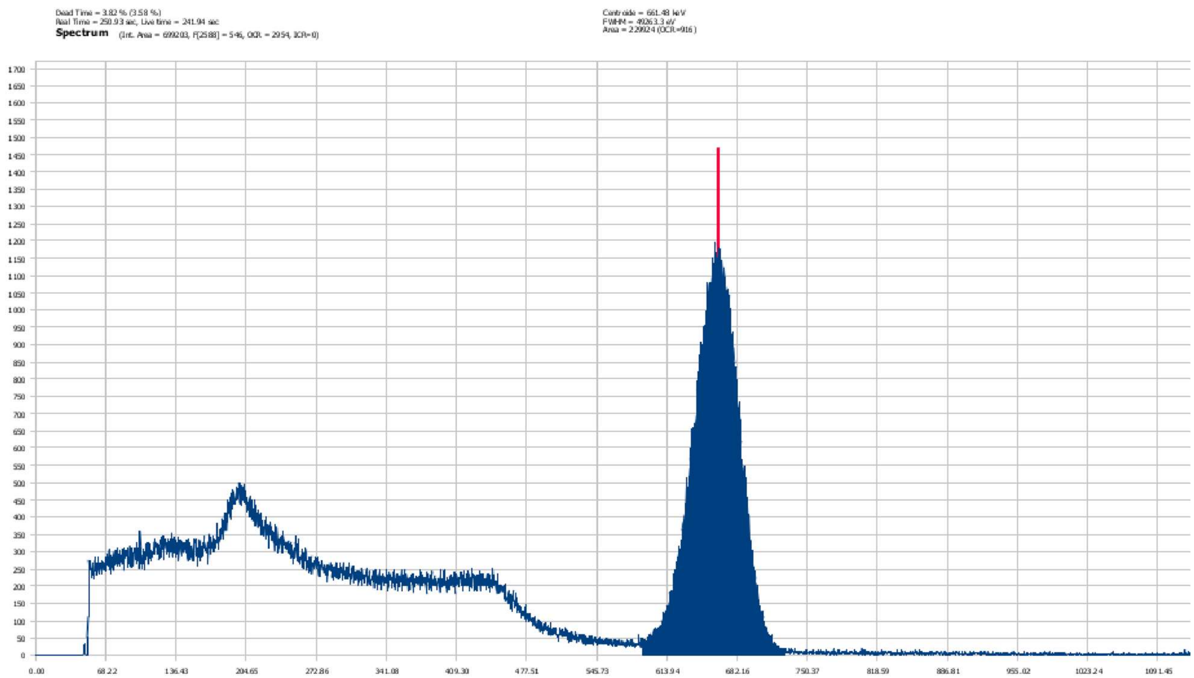
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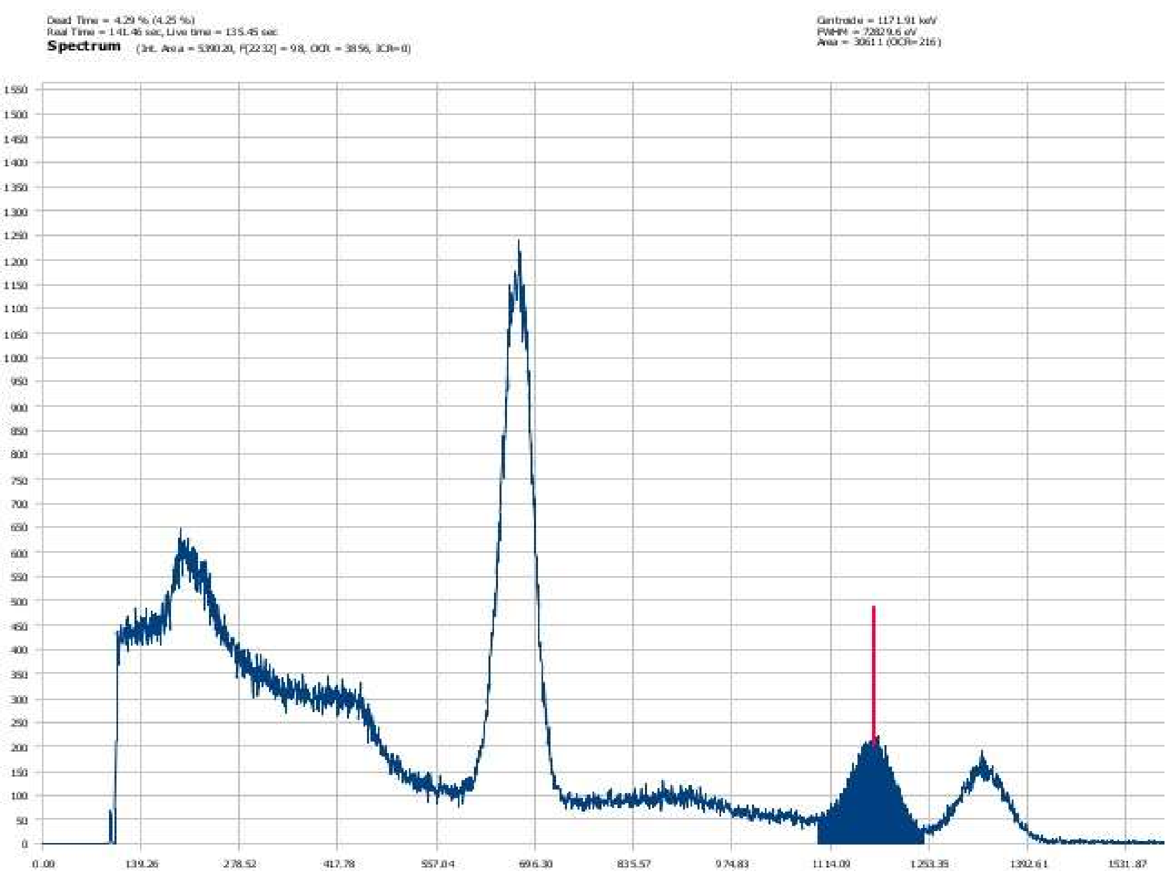
FWHM = 49263.3 eV
Area = 229924 (OCR=916)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FWHM = 72829.6 eV
Area = 30611 (OCR=216)