SPECTROMETRIC DETECTION PROBE
Model 310

Operator's manual

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1. INTRODUCTION

The Spectrometric Detection Probes Model 310 (SDP310) are miniature portable gamma-ray detection devices used for measurement of gamma ray spectra in a range of an energy registered more then 50 keV.

The SDP310 contains a single CZT detector, charge sensitive preamplifier and stainless steel housing of 0.8 cm external diameter connected in a watertight manner to a cable of 0.6 cm in diameter. Small external diameter of the SDP310 allows make measurements in out-of-the-way places. Small probe design also allows the detector to be well shielded and collimated for application in strong radiation fields.

There are the next main types of the SDP310:

SDP310/Z/01

SDP310/Z/05

SDP310/Z/20

SDP310/Z/60

Outward appearance of the SDP310 probes are shown in fig. 1.

Fig. 1 – Spectrometric Detection Probes Model 310.

2. SPECIFICATIONS

Basic

- detector type
  all modifications .... CZT quasi hemispherical detector
- detector sensitive volume
  for SDP310/Z/01 .... 0.8 mm^3 ... 1.5 mm^3
  for SDP310/Z/05 .... 4.0 mm^3 ... 6.0 mm^3
  for SDP310/Z/20 .... 12 mm^3 ... 20 mm^3
  for SDP310/Z/60 .... 50 mm^3 ... 62 mm^3
- detector high voltage ....up to 600 V
- detector high voltage polarity .... positive
- output signal polarity .... negative
- cable driving capability ....up to 30 m
- output impedance .... 50 Ω

Performance

- energy resolution (FWHM) at 662 keV line (at operation temperature of +22 °C),
  for SDP310/Z/01 .... < 2,3 %
  for SDP310/Z/05, SDP310/Z/20 .... < 1,5 %
  for SDP310/Z/60 .... < 2,0 %
- peak-to-Compton ratio at 662 keV line
  for SDP310/Z/01, ... > 1,5
  for SDP310/Z/05, SDP310/Z/20 .... > 2,5
  for SDP310/Z/60 .... > 3,0
- output signal rise time .... < 150 ns
- conversion coefficient .... ≥ 0.1 mV/keV
- integral nonlinearity (60 keV ... 1.3 MeV) .... < 0.2 %
- shift peak position in range of operation temperatures .... < 0.02 %/°C
- shift peak position for 8 hours of continuous operation .... < 0.2 %

Power Requirements ....+ 12 V, ≤ 12 mA; - 12 V, ≤ 8 mA

Operation Temperature .... 0 to 50°C

Dimensions

- length of a fixed connecting cable ....up to 30 m
- length of removable probe ....83 mm
- diameter of removable probe ....8 mm

Connectors

- for probes SDP310/Z
  5-pin LEMO, type .... FGG.2B.704.CLAD62 type
- for probes SDP310/LC
  low voltage .... single 9-pin D type
  output .... BNC
  detector bias voltage .... SHV

Spectrum of ^{137}Cs obtained with the SDP310 is shown on fig. 2.

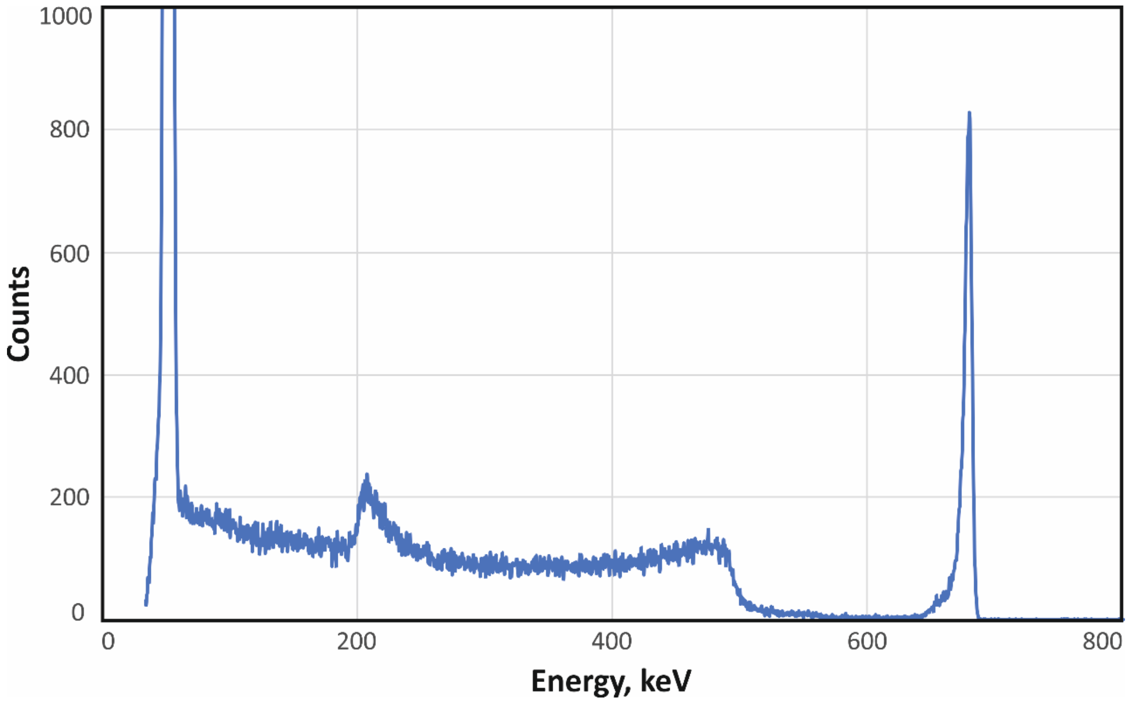

Fig. 2 – Spectrum of ^{137}Cs obtained with the SDP310/60.

3. DESIGN FEATURES

There are the following main types of the SDP310:

SDP310/Z/01

SDP310/Z/05

SDP310/Z/20

SDP310/Z/60

Availability of the letter “Z” in name means using of the CZT detector.

The last figures in the name of modification mean average value of a sensitive volume of the used detector.

Appearance of the SDP310 was shown in fig. 1.

Details, such as main modified probe dimensions and location of the detector inside of a probe case are given in fig. 3, 4.

The SDP310 can be used with extension connecting cable, fig. 5.

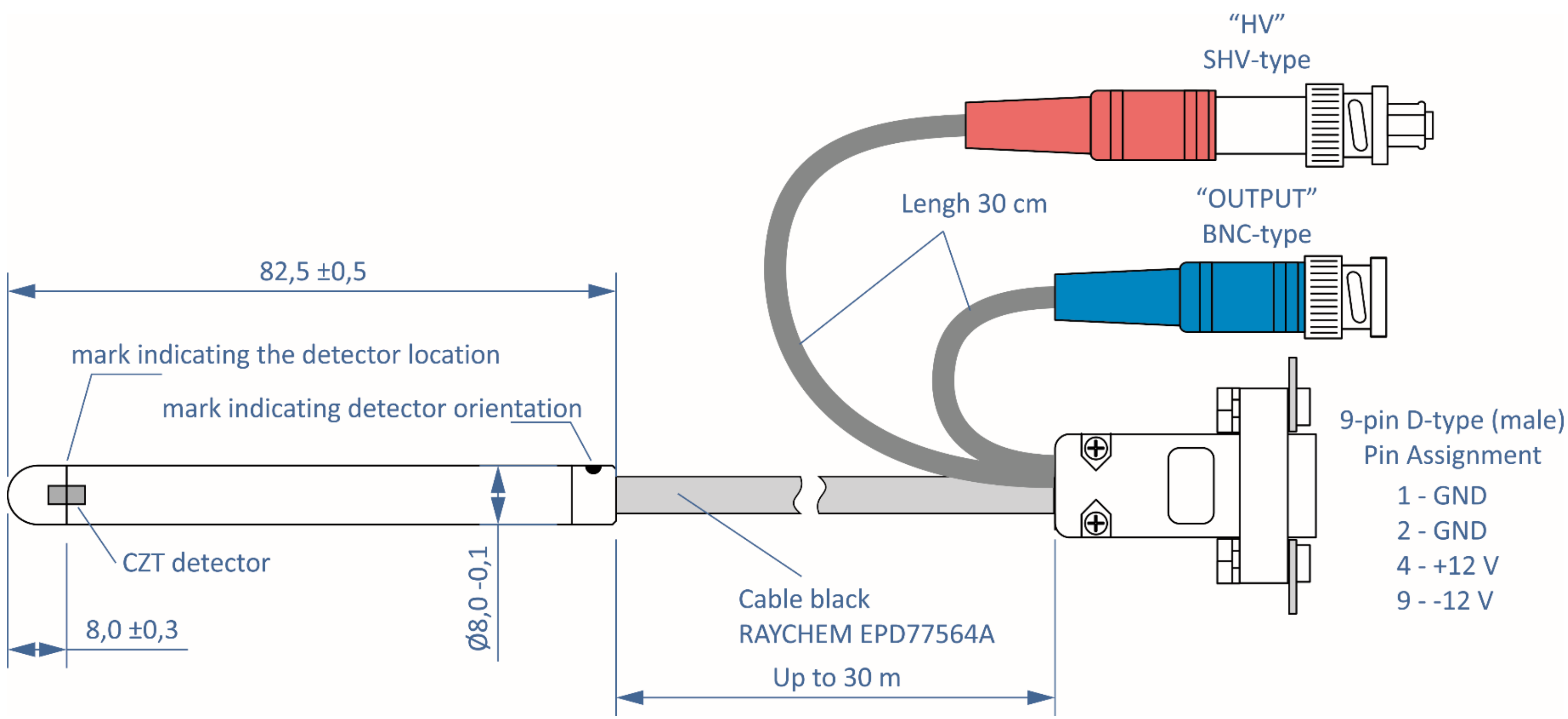

Fig. 3 – Design feature of the SDP310 with D-type connector.

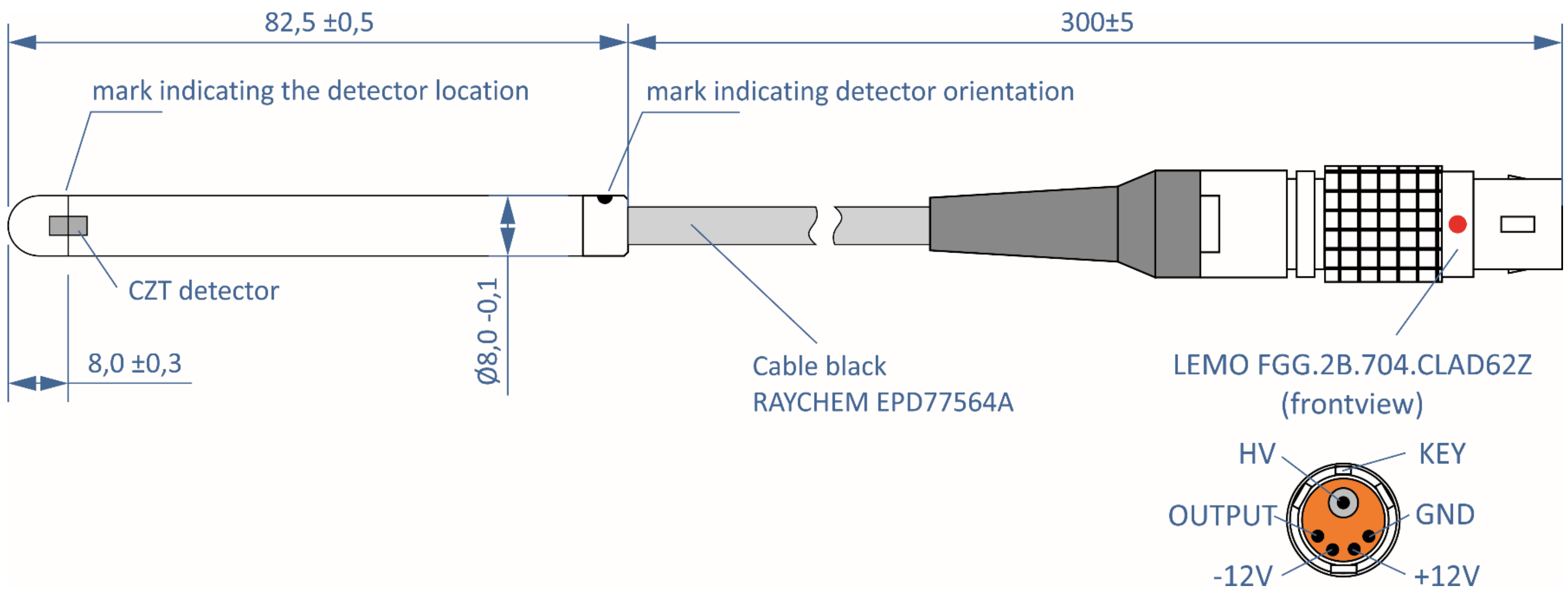

Fig. 4 – Design feature of the SDP310 with LEMO-type connector.

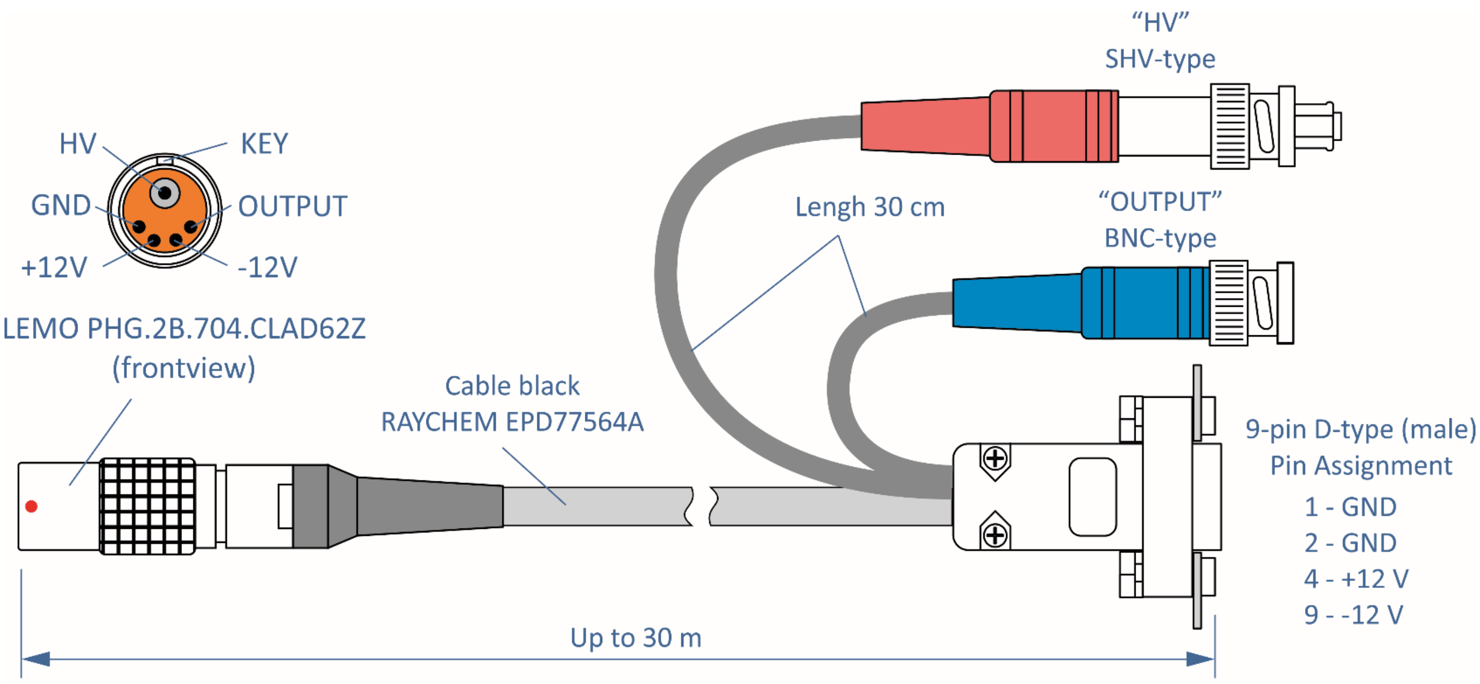

Fig. 5 – Connecting cable.

4. INSTALLATION

The installation procedure is the same for all modification of the SDP310. To complete a gamma-ray spectrometer a cable connects the preamplifier to either a multichannel analyzer (MCA) with amplifier, power and high voltage (HV) supplies or to a portable computer with internal MCA card or any other.

Laboratory Performance Test Procedure

This procedure is intended for performance monitoring of the SDP310 in the laboratory.

Equipment

Main:

- portable NIM bin power supply (CANBERRA model 1000 or similar);
- amplifier (ORTEC 572 or similar);
- MCA (VARRO or similar);
- high voltage power supply (TENNELEC TC 954 or similar);
- radioactive source: ^{137}Cs.

Additional:

- oscilloscope;
- micro voltmeter (UVM BN 12013 or similar).

Measurements

- Prepare and check all equipment.
- Connect the preamplifier cables; preamplifier power cable to outlet on the rear panel of the amplifier, the signal cable to the oscilloscope input and high voltage cable to HV supply, fig. 6.

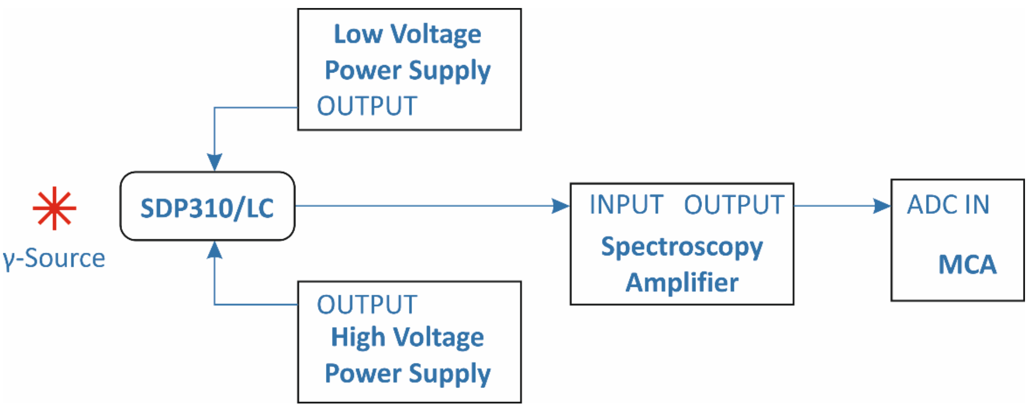

Fig. 6 – Test system for the SDP310.

- Turn on the NIM bin to supply preamplifier power.
- Turn on the HV supply and increase the voltage to the value given in the detector's certificate (or spread sheet). Wait for ten minutes before making measurements.
- Write down values of current drain for the SDP310 (mA) and noise V_{eff} (mV) (using the oscilloscope, measure the noise level from detector's output).
- Mount radioactive source ^{137}Cs at the marks on the probe case.
- Connect the signal cable to the amplifier input and the amplifier output to the MCA. Set the amplifier shaping time to 1 ?s and choose a suitable amplifier gain.
- Record spectrum. The number of pulses in the peak channel must not be less than 2000.
- Calculate spectrum parameters: energy resolution FWHM (***E2-E1***), ratio peak-to-Compton (***Nmax/Nc***), see fig. 7.

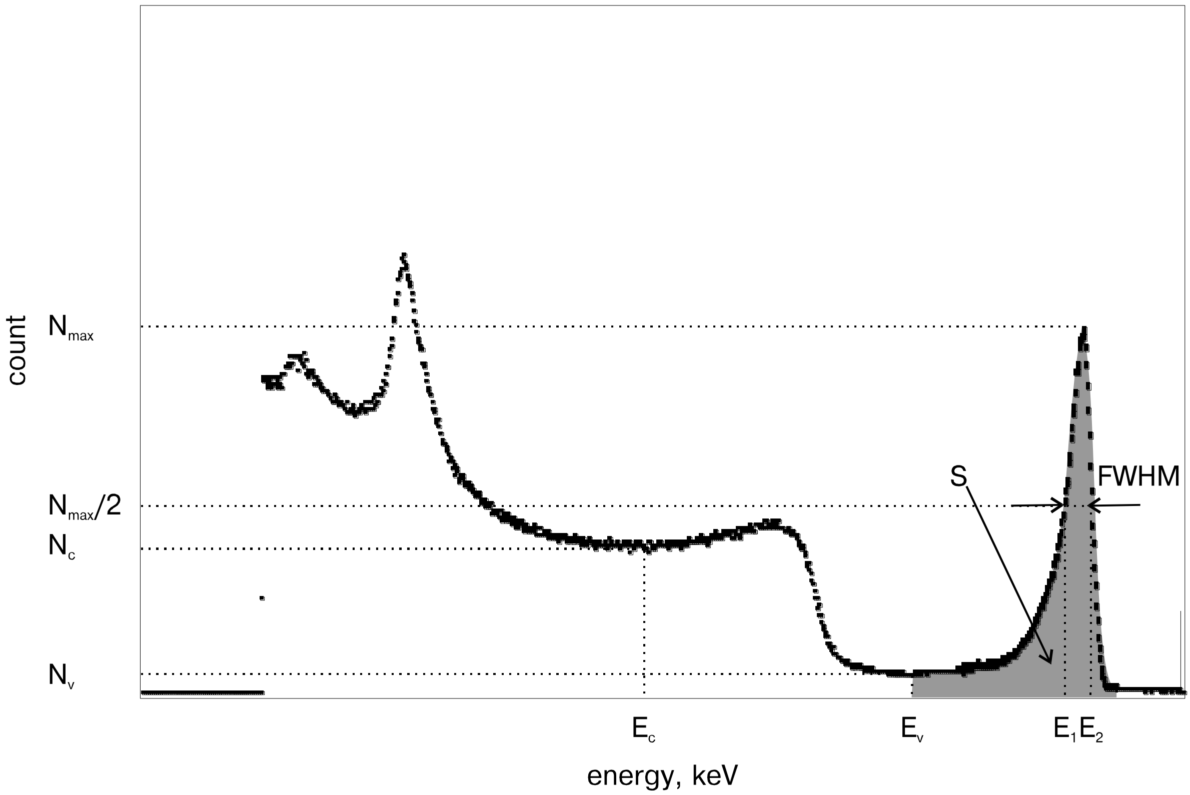

Fig. 7 – Quantities defined in the ^{137}Cs spectrum to calculate the performance values.

- Write these spectrum parameters in a spread sheet.
- If the difference between measured values and specified values is more than 10% it will be necessary to define a new operating voltage. It will be necessary to measure the dependence between energy resolution and high voltage. The voltage, after which no improvement in energy resolution is observed, should be established as the new operating voltage.
- Using the new operating voltage, check the stability of the detector's parameters during 12 hours of continuous operation.
- In the presence of instability in the detector's parameters, decrease the high voltage by 50 V and repeat the full performance test.
- Record the new operating voltage and the new detector parameters in the spreadsheet.
- Turn down the detector HV to zero and turn off the HV supply.
- Turn off the preamplifier power (the NIM bin).

5. SAFETY AND PRECAUTIONS

Equipment Precautions:

- The SDP must be connected to the POSITIVE HV outlet.
- The high voltage is set by the MCA or computer after a value is keyed in. An incorrect value could destroy the detector.
- The detector probe case has a thin wall and should not be strongly squeezed.
- When possible, use radiation shield and (or) collimator or maintain the SDP310 a distance from strong neutron-gamma sources for prevention of detector and connector’s insulator radiating damages.
- Decontamination or cleaning of the SDP310 can is carried out with water or other non-corrosive liquids.

Radiation Dose Caution:

- The detection probe should be routinely checked for contamination and decontaminated if necessary, after use to avoid possibility of radioactive contamination.

Electric Shock Safety:

- Check that all probes (detector probe, multichannel analyzer, computer, hoist controller/ are properly grounded. Use a multimeter between metal chassis and convenient grounds (pipes, etc.) to measure the resistance to ground. Resistance should be less than 1Ω.
- Do not touch the insides of connectors and cable ends while the high voltage is on and for 5 minutes after system is shut down.

6. THEORY OF THE HEMISPHERICAL DETECTOR OPERATION

The resolution of the wide band semiconductor detectors, such as CT or CZT detectors optimized by choosing a small hemispherical crystal geometry with a positive contact at the center of the flat surface and the outer spherical surface grounded (see fig. 4). The electric field is essentially radial and therefore much stronger near the positive contact. Assume first that only electron charge collection occurs with no appreciable electron carrier trapping. The pulse that is registered from a photoelectric event with a constant number of electrons produced would arise mainly from the induced charge from the electron carriers traversing the high field region. Even so, gamma photoelectric interactions in the lower field region (cross hatched) constitute the majority of the peak area (cross hatched) since this is where the majority of the detector volume resides. The electron carriers from throughout the detector volume drift toward the positive electrode reaching their highest velocity near the positive electrode. The electron collection time is less than 0.5 μs.

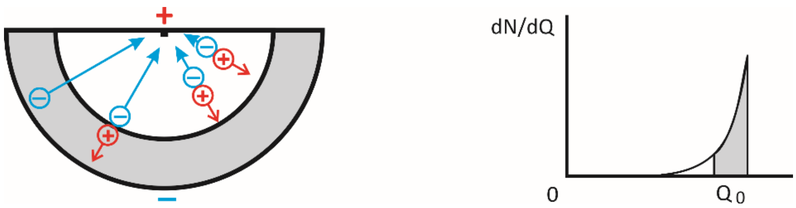

Fig. 8 – Cross sectional view of a hemispherical detector showing the drift of electrons toward a positive "point" electrode and the resulting induced charge pulse. The majority of the induced pulse arises from electrons originating in the cross-hatched region of the hemisphere.

The pulse height from a gamma interaction does not appreciably depend on holes collection due both to the hemispherical geometry and the short pulse shaping time. This is fortunate since hole drift velocities are an order of magnitude smaller causing hole collection time to be typically 5 μs and hole trapping to become important. The hole pulse height contribution tends to be very small since few holes traverse the high field region drifting rather toward the negative hemispherical surface electrode, thus a far smaller pulse is induced and the pulse shaping time of about 1 μs "clips" this pulse contribution well before it reaches its full height. The 1 μs shaping time does no clipping to the electron collection signal. The CZT or CdTe detector resolution is limited primarily by trapping of holes due to impurities and inhomogeneities in the crystal.

Manufacturing of detectors with ideal hemispherical geometry is labor-consuming process. Therefore, in detection units are used quasi-hemispherical detectors. The appearance of such detectors is shown in fig. 5. Researches have shown that the replacement of ideal hemispherical geometry of the detector on quasi-hemispherical a little bit worsens the spectrometer performance.

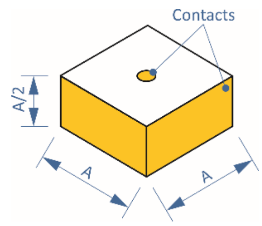

Fig. 9 – Appearance of a quasi-hemispherical detector.