The gamma-quantum registration system of SVD setup

Sergey Golovnya,[a] **Journal of Instrumentation, v.9 (2014), p9-16**.

[a] *On behalf of the SVD-2 Collaboration*
Institute for High Energy Physics,
Protvino, Russia
E-mail: Sergey.Golovnya@ihep.ru

ABSTRACT: The gamma - quantum registration system is the part of the SVD setup at the U-70 accelerator (IHEP) exposed in experiments: SERP E-184 (An experiment for studying mechanisms of charmed particle production and decays in pA-interactions at 70 GeV/c) and SERP E-190 (Production of particles in pp-interactions in high multiplicity events at 50 GeV/c). The system consists of two detectors - the hodoscope detector of 1532 (48x32) cherenkov full absorption counters with a lead glass absorber (DEGA) and the soft photons calorimeter of 49 (7x7) counters with BGO crystals (SPC). The following subsystems are described: the high-voltage power system, the DEGA platform positioning control system for detector calibration in an electron beam, the DEGA LED monitoring system. The description of the soft photons calorimeter is also provided. This subsystem is focused to detecting the gamma quantum in energy range of tens MeV. The test results of SPC, obtained during its first operation in the accelerator run of 2013 year, are presented, the energy spectrum of photons are given.

KEYWORDS: SVD collaboration, gamma-detector; BGO, soft photons.

Contents

1. Introduction

The Spectrometer with vertex detector (SVD) [1] is situated in the beam of the U-70 (IHEP, Protvino) accelerator and exposed in the experiments SERP-E-184 and SERP-E-190 by the collaboration of three institutes: IHEP (Protvino) – SINP MSU (Moscow) – JINR (Dubna). The installation includes the gamma - quantum registration system that consists of two detectors: hodoscopic detector with 1532 cherenkov full adsorption counters of lead glass (DEGA) and 49-channel scintillation calorimeter of soft photons with BGO crystals (SPC).

2. The Gamma – Detector (DEGA)

2.1 The construction design of gamma - detector

The detector is the array of Cherenkov counters with total weight of 6 tons. The geometry of the detector working area limited by the MC-7 magnet working aperture and fits it. Dimensions of a single counter are a compromise between the energy resolution and spatial precision of the detector and equal to 38x38x505 mm^3. The detector active area is 1.9x1.3 m^2 and consists of 48x32 counters coupled with FEU-84-3 PMT ‘s. The DEGA is able to detect the gamma quantum from 300MeV/s with the spatial precision up to 2-3 mm. The geometrical detection efficiency for single π^o mesons from L^+_c and D decays in the forward hemisphere varied from 20% to 30%. The DEGA platform position control system [2] provides movement the whole detector array in two directions with the precision of 3 mm

The tape bandage is used for counter assembling. It consists of two pre-strained 100 μm thick metallic tapes. These tapes crossed on the front side and welded to the flange on the rear side. The flange is the base for the PMT cartridge. The 5 mm diameter hole in the cross-point of tapes is made for mounting the LED holder of the monitoring system. There is the internal (reflecting) layer of the counter with metal plated Mylar film.

2.2 The high voltage power system

The digitally controlled Cockcroft – Walton scheme based multiplier – distributor is used for powering the PMT’s. The common design of this multiplier is mostly standard for such kind of scheme. The voltage value sets by 10-bit DAC up to 1800 V with 1.8 V step. On the rear side of the multiplier board the flat cable plug, 4-bit address coder and address selector test pins are mounted. It is allowed to use up to 16 boards with one cable. The common bus scheme is used to pass control codes and bias power. Each bus consists of 10-wires flat cable with wires separated by ground wires. The following signals: “Select”, “Strobe”, ”Data” and power “+6V”, ”-6V”, “-90V” are passed to multiplier boards. The end of the bus is terminated by the special board – bus terminator, forced to signal lines pull-up to “+5V”. At the connection point to the bus driver each 4 buses is coupled together in one 40-wires flat cable. The working voltage value is individual for each multiplier board and assigned by sending the series of control codes in format of “Address’+”Data”. If the “Address” code is equal to the address, previously set by the address selector on the rear side of the board, the “Data” part of the control word is passed to DAC and a new voltage value appears at the PMT distributor. The creation of control pulses sequence – exchange protocol is made by programmable logic ALTERA chip.

The high voltage control system logically divided in two separate parts – bus driver block serviced by a specially designed crate controller situated near the detector in so-called “Down” crate and the CAMAC register board, placed into the CAMAC crate in the control room and linked to PC by Q-Bus. These two parts were linked by 50 m of SFTP cable using LVDS protocol. The “Down” crate hosts the crate controller and consists of LVDS receiver module used for from serial to parallel code conversion and 6 separate bus driver boards for code transmission to Cockcroft-Walton multipliers.

The bus driver board serves up to 256 multipliers connected by 4 40-wires flat cables. All boards installed into double-size CAMAC modules placed in and powered by standard CAMAC crate. The +90V power potential, used in Cockcroft – Walton multipliers sourced from separate power supply unit, placed in the control room for electrical safety reason and connected to driver boards by shielded cable.

Special software DEGA-HV was developed to manage the high voltage power system. The program can communicate with the complete multiplier array or with the specific multiplier in it as selected by the operator and to set the high voltage code into the multipliers. The program can also store and load the high voltage codes into the multipliers in an automatic mode, renewing DAC codes.

2.3 The DEGA LED monitoring system

The LED monitoring system [3] is used for channel – by – channel slow control of the detector counters to determine the possible drift of the PMT amplification and to correct this drift in off-line data processing, for on-line detection and localization of the electronic faults, for fast drop of the PMT power. The LED monitoring system is logically divided into three separate branches. Each of them serves of 16x32=512 counters of the detector. The system consists of the following set of modules:

1. Master Modules (MM-GD), placed into CAMAC crate in the control room.
2. Signal Converters (SC) placed on the detector platform. The distance between the DEGA and the control room is near 20 m.
3. Control Modules (CM64), twenty four of it are mounted on the front side of the detector.

The MM-GD module mounted in the CAMAC double size station and used for setting the LED index, flash amplitude and operation mode. Each module is able to serve up to 8 CM64 boards, i.e. can control up to 512 LED's. For LED index and light pulse amplitude transmission the special buses under SPI protocol are used. The LED flash is hardware synchronized with trigger pulse, incoming to the MM-GD's front panel from the SVD setup trigger subsystem.

The CS module is also build as a double size CAMAC station and uses CAMAC crate as a power source only. It houses a plug for SFTP cable connection to MM-GD module, plug for the flat cable connection to CM64 boards and a power supply plug for the +20V for flash voltage. The control signals, after conversion from LVDS to TTL levels passed to CM64 boards by flat twisted cable. The length of the cable is 10 m. In addition to control signals, the +20V power for LED flash passed by this cable also. The CM64 boards are powered by the own power supply.

The CM64 board is designed to house the LED drivers array and to manage the LED flash pulse shape. It is made as a square shape board with the size of 304x304 mm^2 and contains the array of 8x8 LED drivers, controlled by the single 8-bit DAQ. The drivers forms the LED pulse and its amplitude in range from 0 to 18 V according the code, loaded in DAQ. The SPI exchange protocol conversion, DAQ protocol generation, decoding the LED index, LED selection and flashing are included into CPLD ALTERA MAXII chip. The CM64 module logic structure is the following – four identical groups with sixteen LED's in each group. For the LED selection the group index and the index of the LED in the specific group is used. There is the common mode of operation, when the four LED's can be flashed simultaneously and with identical amplitude.

Besides the system provides the following operation modes:

1. LED flash (one-off or continuously) by the internal (software) trigger
2. LED flash (one-off) by the external trigger
3. LED flash by the external trigger with fixed number of pulses.

The first mode is used for detector electronics debugging and is very common to view an individual PMT signal on the oscilloscope. The LED flash by the external trigger is the main operation mode of the monitoring system. The additional test trigger pulses are inserted during the accelerator idle time to simulate the data collection start. The trigger pulse is hardware delayed to ensure the time demands of the data acquisition system. In this case the data of monitoring system is processed and stored together with other experimental data and the corrections of experimental data are possible in off-line procession in case of any instability.

2.4 The control of the LED monitoring system

The LED monitoring system is managed by recording binary codes into the control registers of the MM-GD modules. The codes follow the standard CAMAC rule NAF: "Number of module in crate", "Address of the control register in module", "Function" and "16-bit data word". Depending on the value of 15 bits in data word it is possible to set of the different combinations of LED flashing.

The special software package – SVD-LED was designed to manage the LED monitoring system. This program allows flash the requested LED (or group of LEDs) from the PC. The program has an advanced multitab interface and consists of a set of switched tabs for all operation modes.

3. The Soft Photons Calorimeter of SVD-2 installation

3.1 The construction design of the SPC

The Soft Photons Calorimeter (SPC) is the assembly of 49 scintillation counters, collected to the matrix of 7x7 (Fig. 1) [4].

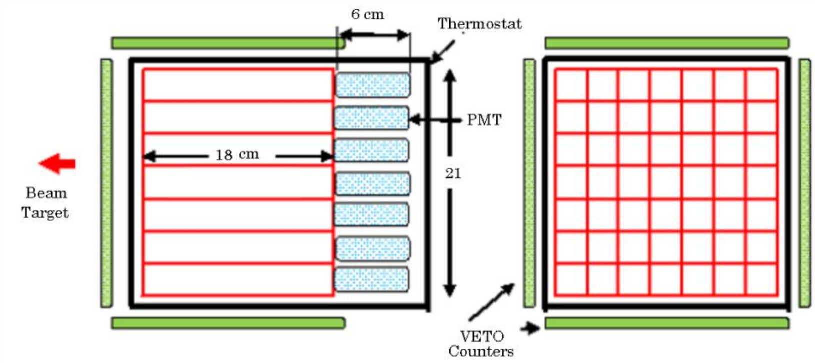

Fig.1 The design view of SPC with BGO crystals

The SPC counter consists of 30x30x180 mm^3 box shaped BGO crystal, viewed by a photomultiplier. The sides of the counter are coated by Tyvek film and the end-face is coated by high reflected VM2000 film. The photomultipliers type 9106S (build by ET Enterprises) are used. This photomultiplier have 8 dinodes and advanced quantum efficiency in green part of the absorbing spectrum. The diameter of the photocathode is 25 mm, the outer diameter of the PMT bulb does not exceed 29.5 mm. The PMT bulb is shielded by Permalloy layer. The optical connection between the PMT and BGO crystal is made by two components glue EPOTEK 301. Because of the SPC position in SVD-2 setup the calorimeter has to be as compact as possible. So the calorimeter material has to have the maximum density and minimum radiation length. By this reason, the BGO material was selected. The BGO crystal has (in comparison with NaI, for example) higher adsorbing ability, gives the possibility to minimize the detector sizes by a factor of ten. Besides the BGO crystal has low sensitivity to neutrons that can be useful for gamma rays measurements in experiments at U-70 accelerator. The BGO crystal is free of activator uniformity distribution in crystal body and has very low afterglow.

The preamplifier is based on low noise operation amplifier AD8014 as a current feedback amplifier. The PMT signal is coming to inverted input of the amplifier. The minimization of entrance capacitance provides the maximum signal-to-noise ratio. The capacitance is caused by the anode-to-dinod interval and equal to 6pF. The dynamic range of signals is more then 66dB.

The calorimeter powered by two power suppliers +12V and -12V with total current consumption of 1A at +12V and 50mA at -12V. The PMT photocathode is coupled to ground.

The SPC placed into thermostatic box. The temperature stabilization is based on using the Huber 006B chiller. The +18 °C was taken for the SPC operation.

The SPC covered on lateral sides by “veto” scintillation counters to select SPC signals of background charged particles. The signals from these counters were digitized the same way with the calorimeter data and used in off-line analysis.

3.2 SPC in the beam line

The SPC view in the beam line is presented in fig.2. The passive neutron protection of polyethylene sheets of 8 cm thick placed around the SPC is not shown.

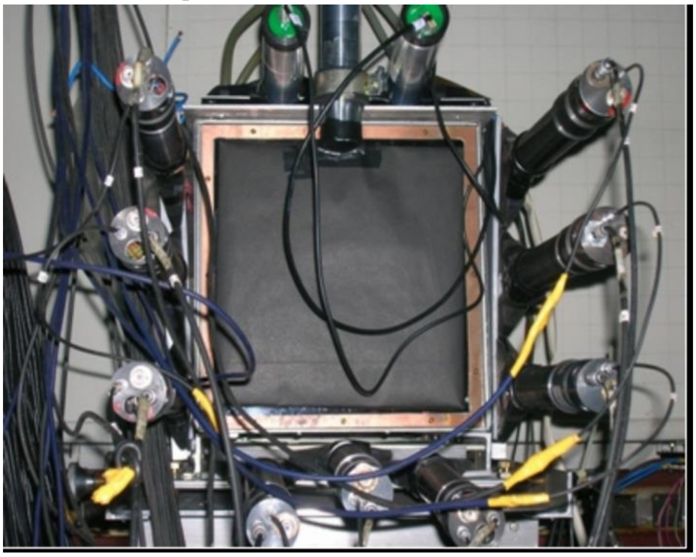

Fig.2. The SPC view in the beam line.

The calorimeter is placed in front of the gamma – detector (DEGA) at 5 degrees angle to the beam line at 10 m from the beam target at the DEGA support structure. It is possible to move SPC in angle range from 2 to 6 degrees that gives an opportunity to cover the cone from 0 to 50 degrees in CMS frame at the beam energy of 50 GeV.

The data coming from the SPC and veto counters are synchronized with DEGA data flow by the main SVD trigger.

The amplitude equalization of SPC signal channels was made by using the minimum ionization particles (MIPs) from the target. To select it, the following conditions were used:

- signal from frontal veto counter is close to MIP peak (see fig.3), the interval, limited by vertical lines;
- another veto counters have no signals;
- one signal from the SPC is taken only.

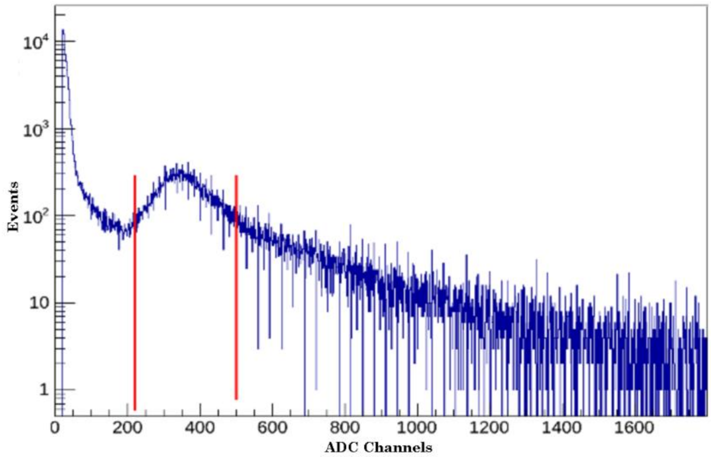

Fig.3. The amplitude distribution of signals in the frontal "veto" counter of SPC. The red vertical lines limit the region of MIPs.

Thus, the signals for all counters of the SPC were taken when the charged particle passed through the crystal in longitudinal direction. By the reference data (DPG), the energy loss in the BGO material for the minimum ionization particle is 8.92 MeV/cm, so the energy deposition of it in the crystal is 160 MeV. The corresponded SPC energy spectrum (after equalization) presented in fig.4.

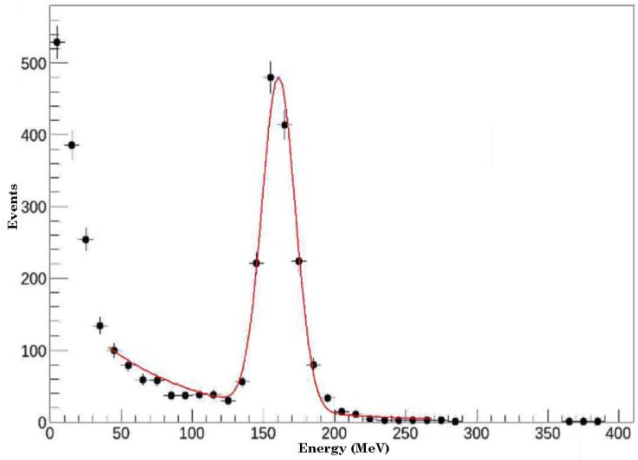

Fig.4. The energy spectrum of particles in BGO calorimeter corresponding to the peak in the front veto counter.

The fig.5 presents the crude energy spectrum of soft photons obtained with SPC in pp interactions at 50 GeV with the following conditions:

- veto counters have no signals;
- outer layer of the SPC counters have no signals;
- signals from internal part of the SPC (3x3 crystals) are summarized with individual weights, obtained during the equalization procedure.

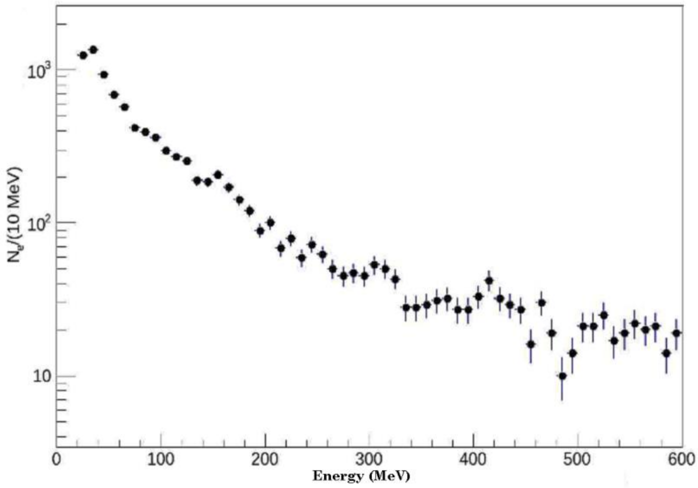

Fig.5. The energy spectrum of photons from the SPC. The corrections on the detection efficiency and spurious photons are not applied.

The preliminary data (Fig.5) from SPC show the huge enhancement of low energy photons, that maybe caused by the secondary interactions of particles in SVD setup. The further improvement of gamma –quantum registration system should be made to suppress this background (using TOF system, for example).

The gamma-quantum registration system working now in SVD setup has been productive used in number of experiments at U-70 accelerator. The further upgrade of it is foreseen.

References

[1] V. Avdeichekov at al, *Spectrometer with a Vertex Detector for Experiments at the IHEP Accelerator*, Instruments and Experimental Techniques, v.56, issue 9, 2013, pp 9-31.

[2] V. Golovkin at al, *A γ Detector Movement System of the Spectrometer with a Vertex Detector Setup*, Instruments and Experimental Techniques, v.57, issue 3, 2014, pp 274-278

[3] S. Golovnya at al, *The monitoring system of the Gamma-Detector of the SVD-2 setup*, Preprint IHEP2013-16 (in Russian). http://web.ihep.su/library/pubs/prep2013/ps/2013-16.pdf

[4] E. Ardashev at al, *The soft photons calorimeter of the SVD-2 experiment*, Preprint IHEP2013-17 (in Russian) http://web.ihep.su/library/pubs/prep2013/ps/2013-17.pdf