Upgrade of the Time of Flight system of the CMD-3 detector

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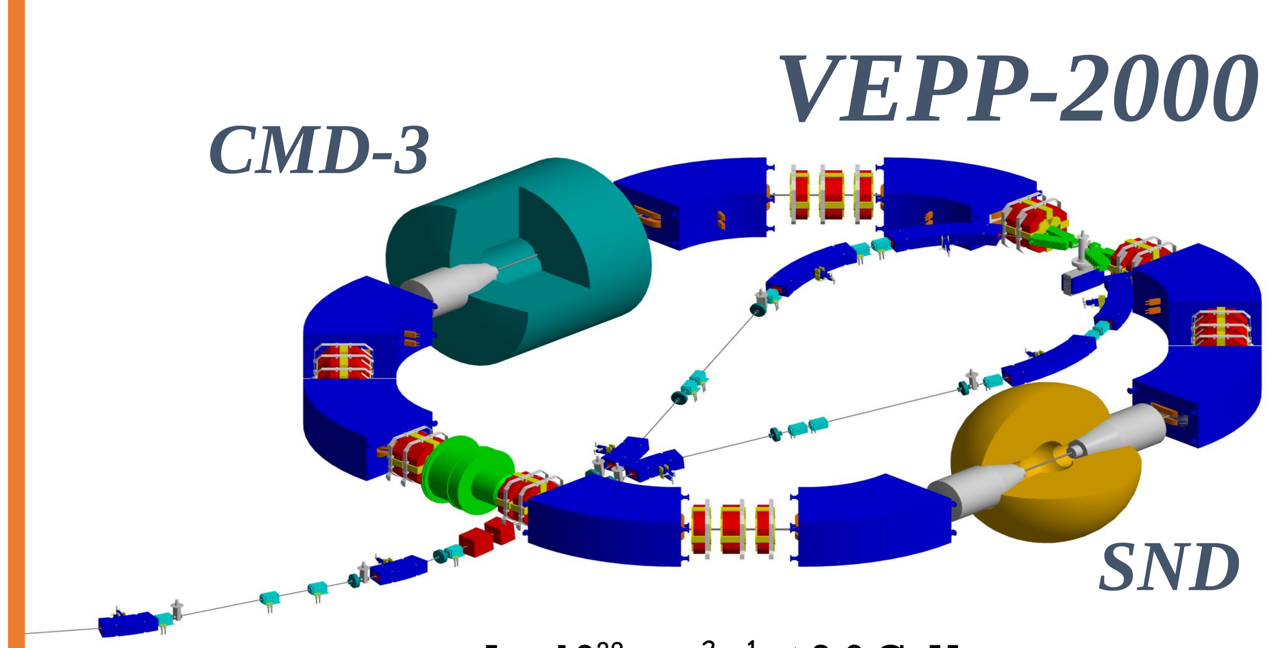
Abstract

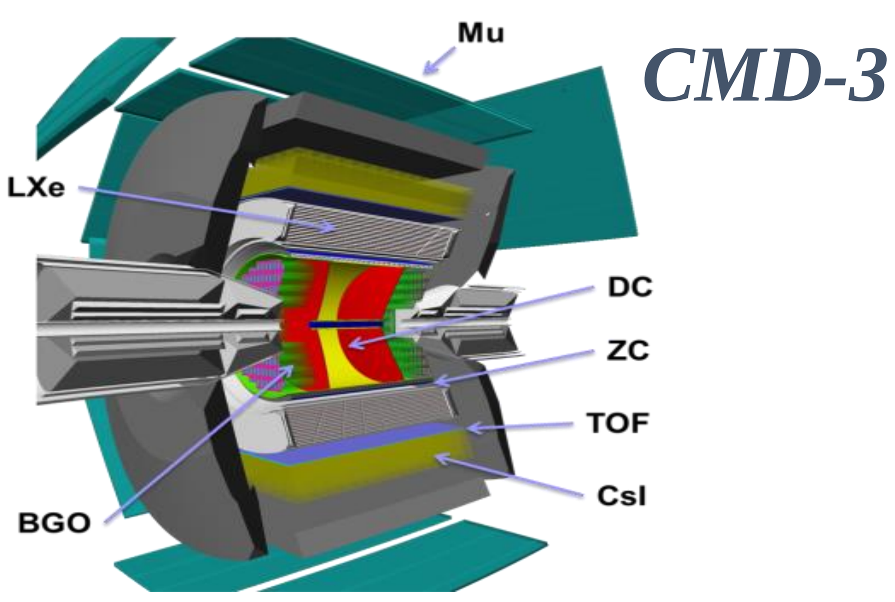
Upgrade of the Time of Flight (TOF) system of the CMD-3 detector is described. The TOF is located inside the narrow gap between two layers of the cylindrical calorimeter based on the liquid Xe and CsI crystals. The TOF system is made from thin plates of plastic scintillator and is intended for measuring the time of flight of particles through the detector, in particular to detect products of antineutron annihilations in the calorimeters. Due to low velocities of antineutrons, the average times of annihilation in the calorimeters have a typical delay time about 4-10 ns with respect to the beam collision.

VEPP-2000 collider and CMD-3 detector

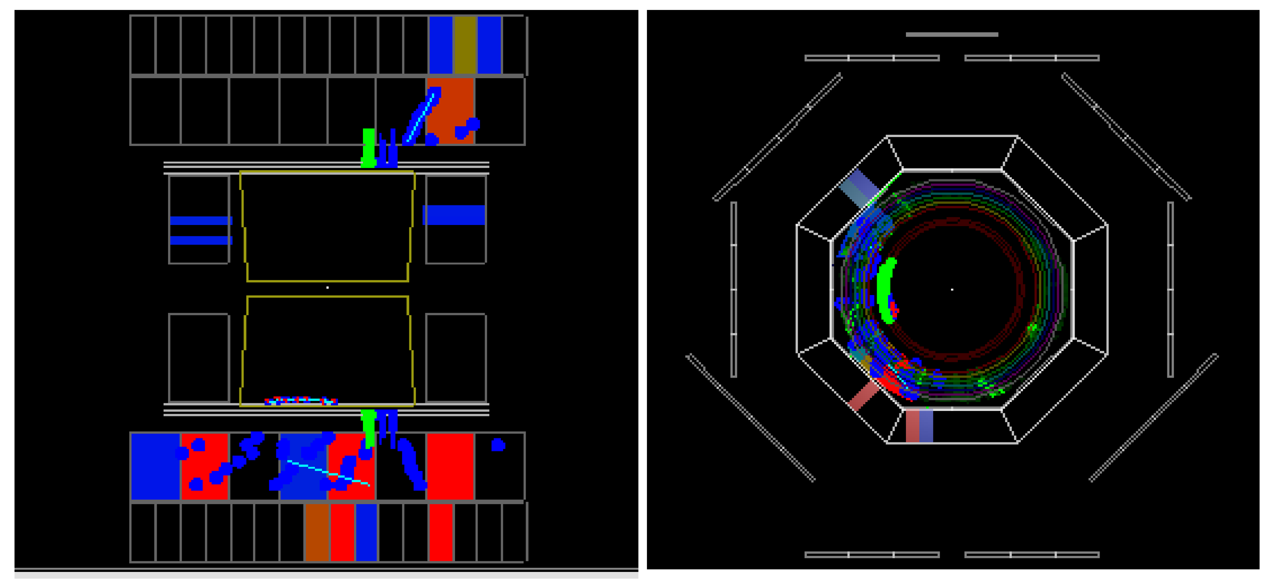


L = 10^{32} $cm^{-2}s^{-1}$ at 2.0 GeV
Lpeak = $2\cdot10^{31}$ $cm^{-2}s^{-1}$ at 1 GeV

Since 2010 the CMD-3 detector has been collecting data at the VEPP-2000 e^+e^- collider. CMD-3 is a general purpose detector designed to study e^+e^- annihilations into hadrons in the center of mass energy range from 0.3 up to 2 GeV.



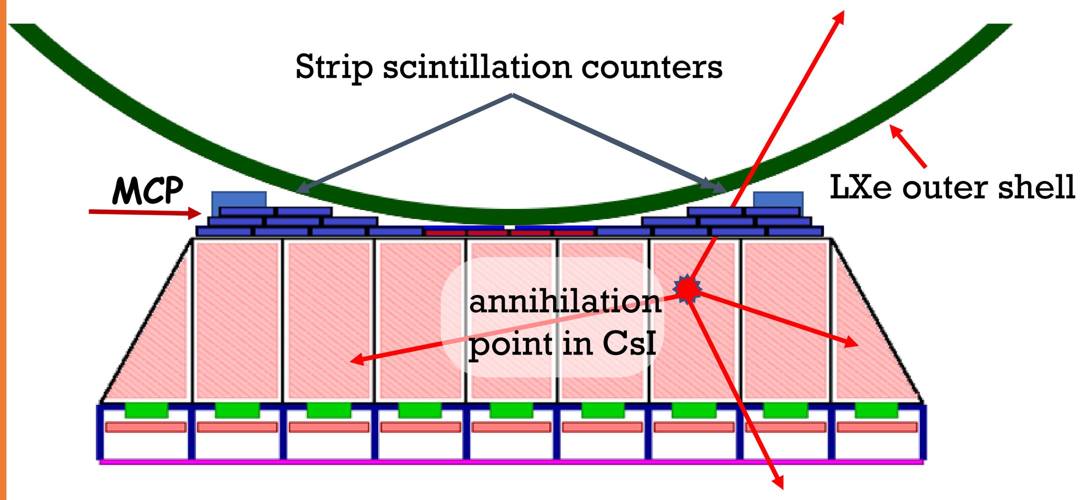
DC – 1218 hexagonal cells with sensitive wires, W-Re alloy 15 μ in diameter, coordinate resolution ~ 120 μ, z-coordinate – charge division technique (~ 2 mm)
Z-chamber – precise determination of Z coordinate ~ 500 μ, fast gas mixture (80%CF_4 + 20%C_4H_{10}), time resolution ~ 5 ns
TOF – 175 counters, time resolution < 1 ns
Muon range system – 8 octants, active cosmic veto, time resolution ~ 1 ns
Magnetic field ~1.3 T



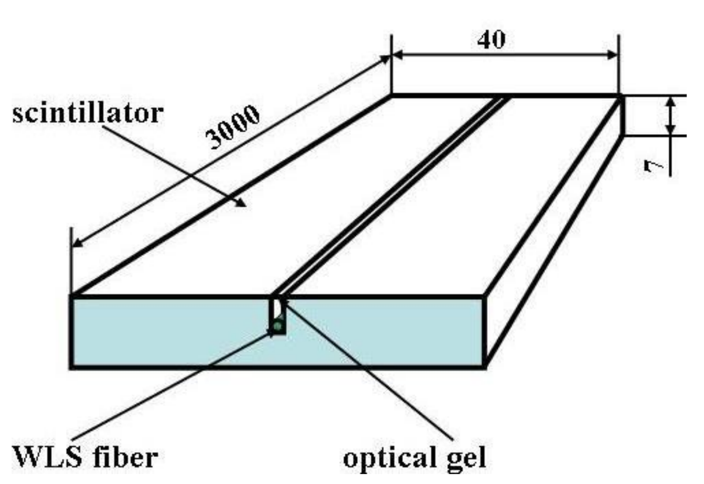
Candidate to n-nbar event in CMD-3, Ebeam = 950 MeV

- ✓ No tracks in DC coming from the beam interaction point
- ✓ Large energy deposition in calorimeters (LXe ~ 500 MeV, CsI ~ 600 MeV)
- ✓ No hits in outer muon range system to eliminate cosmic events
- ✓ Time delay ~ 8 ns with respect to the beam crossing

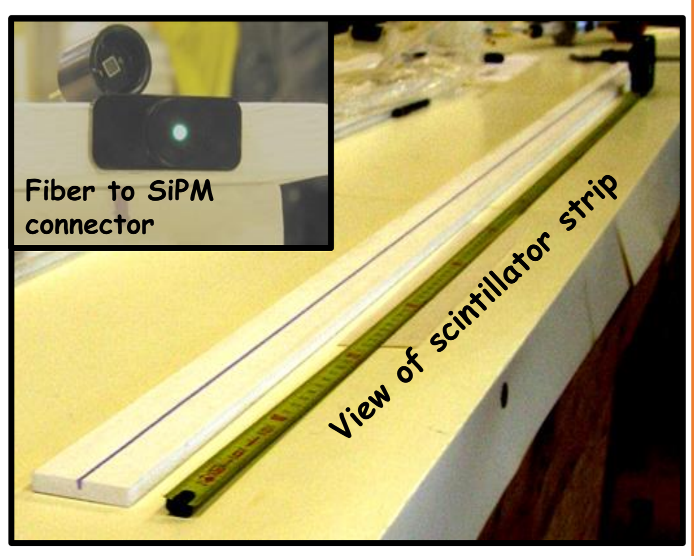
Time of Flight system structure



- Space between outer shell of the LXe calorimeter and CsI calorimeter surface filled with strip-counters
- Octant contains 23 strips: 11+2×(3+2+1)=23 (m=9.2 kg)
- All counters have identical sizes: 7(5)•40•950 mm^3
- Total number of counters: 8×22 - 1 = 175 counters



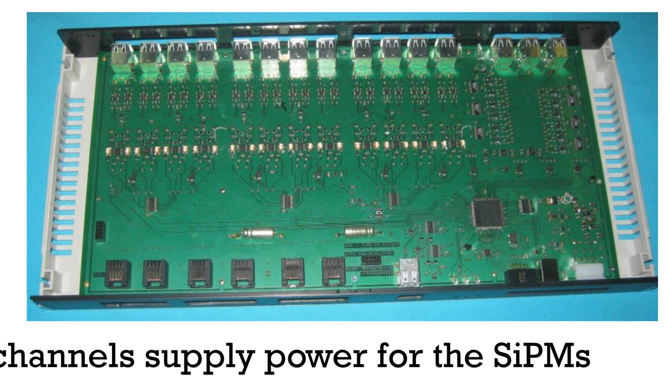
- Strip made from polystyrene based scintillator + 1.5% PTP + 0.25% POPOP, τ_{decay} ~ 5 ns ("Uniplast", Vladimir, Russia)
- WLS fiber (Kuraray Y11 1.2M, τ_{decay} ~ 8 ns) with 1.2 mm in diameter
- Fiber placed in a groove and viewed by 2 SiPM (PM1150, Germany) on both ends, sizes 1.3×1.3 mm²
- Groove depth is half of the strip thickness



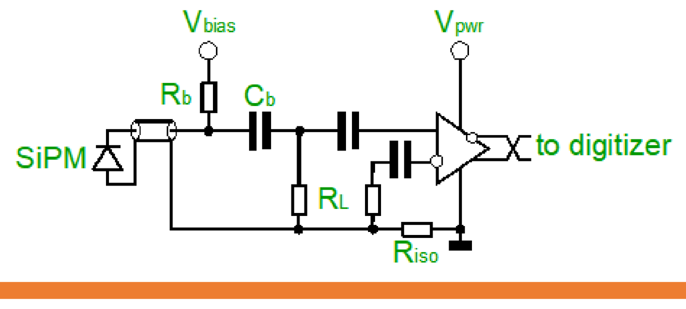
Electronics

SiPM bias source with preamplifier (FILIP)

The FILIP provides power for the SiPMs, amplification of signals from SiPM, and data transfer to the digitizer electronics. The bias voltage is controlled by a precision DAC, allowing precise and repeatable adjustment without large multi-turn potentiometers.

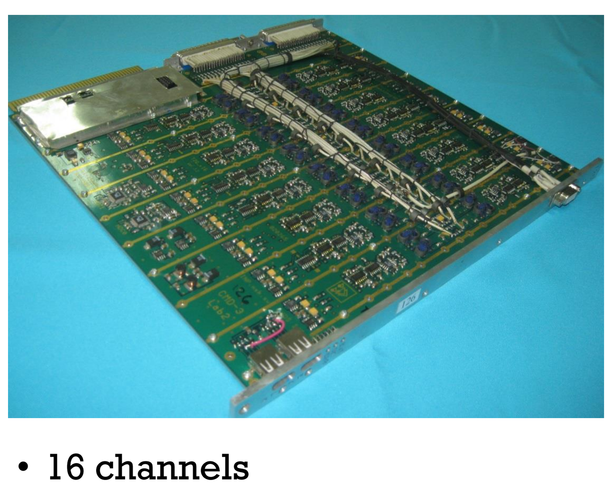


- 24 channels supply power for the SiPMs
- Regulated output voltage from 0 to 40 voltage
- Each channel includes a preamplifier
- Calibration circuits are onboard
- Form factor: 1U 19''
- USB and C-Link communication interface

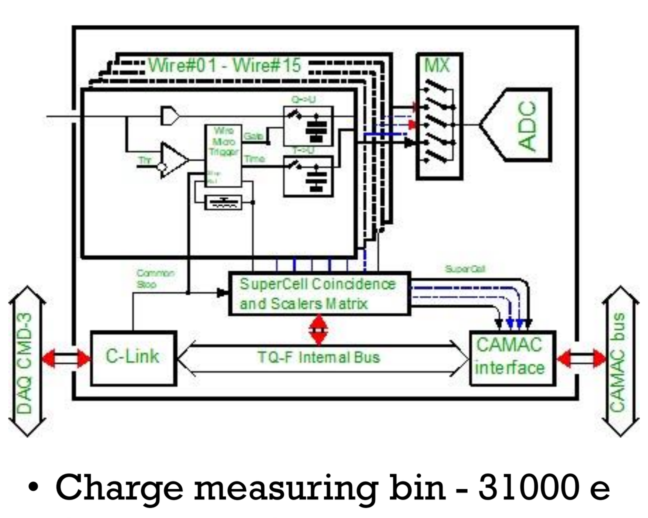


Digitizer electronics

To process SIPM signals a special TQ-F digitizing board was designed and produced. Each TQ-F board allows for the measurement of amplitudes and time for 16 independent channels.

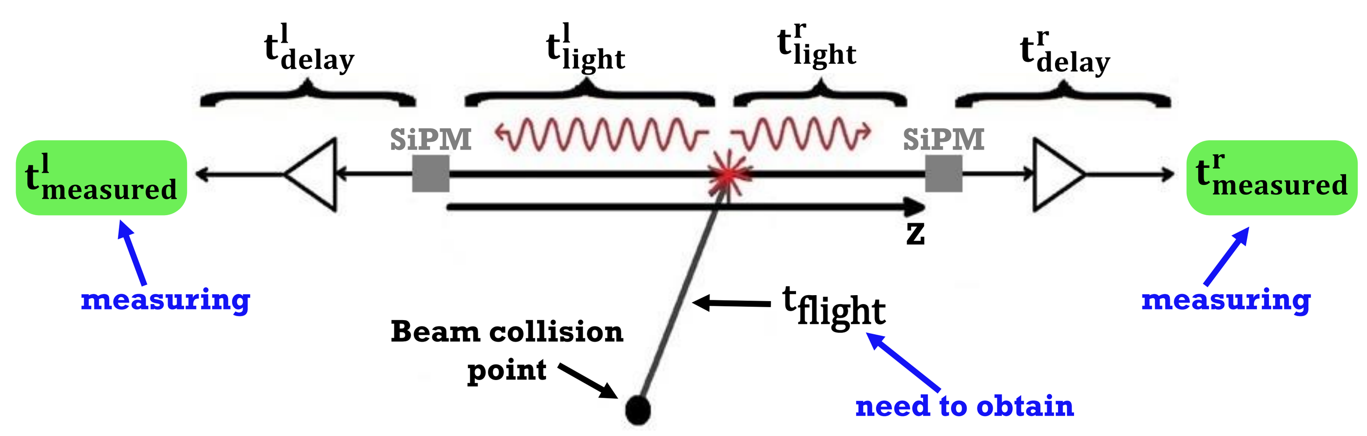


- 16 channels
- Differential input
- ADC Dynamic Range - 14 bit
- Event digitizing time is less then 40us
- Time measuring bin – 140 ps
- Time scale temperature drift ~ 0.01%/°C



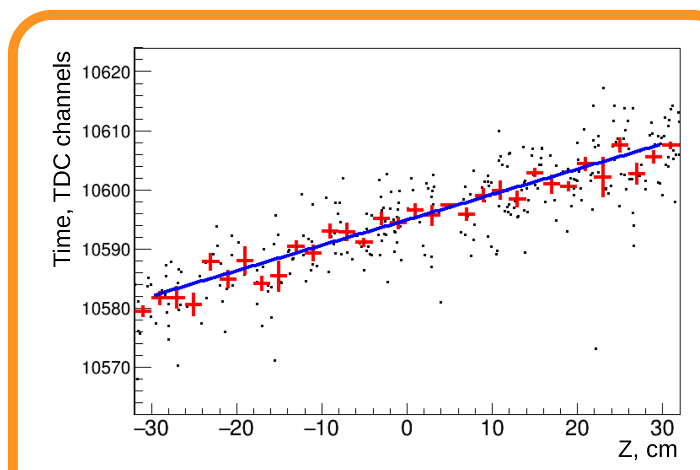
- Charge measuring bin - 31000 e
- Channel-to-Channel crosstalk – less then 0.1%
- CAMAC and C-Link communication interface
- Form factor: Big-CAMAC
- Power consumption +6V –0.43A, -6V –0.36A
- Built in unique board ID

Calibration and time resolution

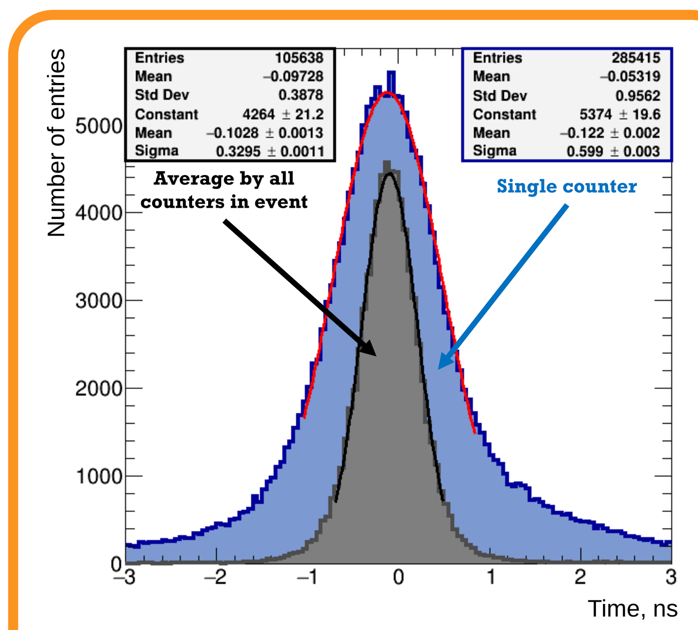


$$t^{l,r}_{measured} = t_{flight} + t^{l,r}_{light}(Z) + t^{l,r}_{delay}(A)$$

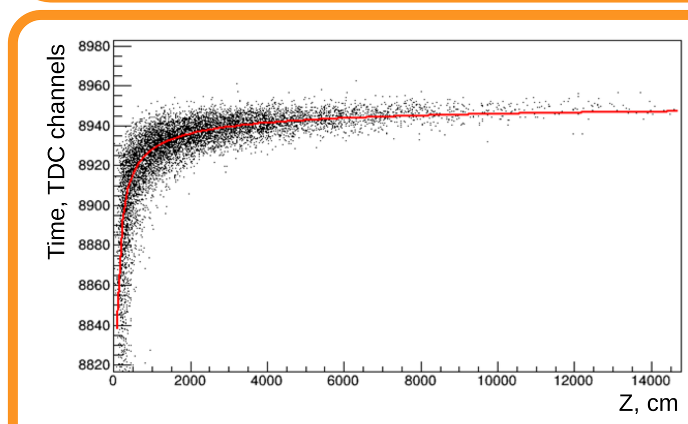
The measured time interval ($t_{measured}$) is determined by the difference between the time of the beam collisions in the detector and the arrival of the signal at the output of the electronics. The measured time consists of 3 main components: the time of flight (t_{flight}), the time of light propagation through the scintillation plate (t_{light}) and the electronic path delays (t_{delay}). The purpose of the calibration is to determine the unknown parameters and to develop an algorithm to determine the time of flight from the measured time. Calibration was done using $e^+e^-\to e^+e^-$ events.



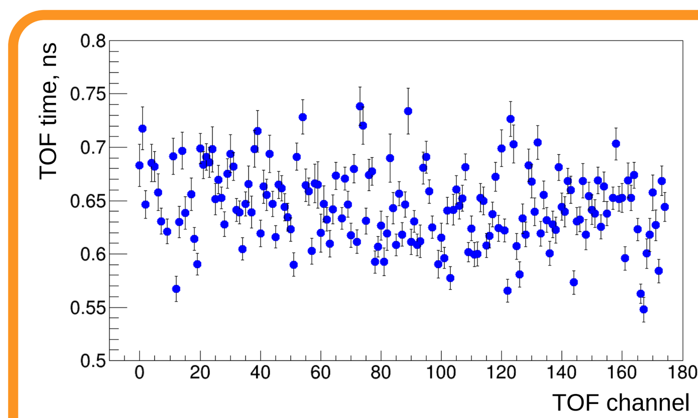
Example of the time dependency on the place of the interaction of a particle and a scintillation plate (time from one SiPM). Reverse velocity of the signal propagation on the scintillation plate is 5.4 - 7 ns/meter depending from the plate.



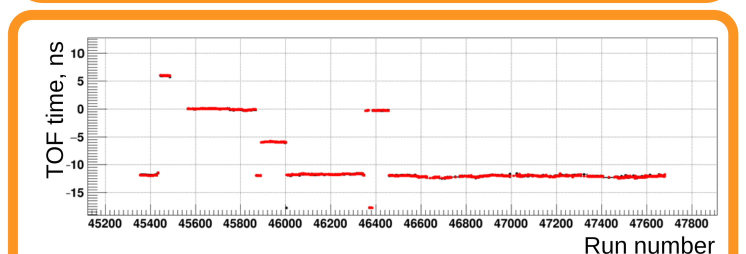
Time resolution after calibration (average time from two SiPMs on one plate).



Example of the time dependency on the signal amplitude (time from one SiPM).



Time resolution after calibration for all channels in TOF (average time from two SiPMs for each plate).



Time stability on the run number (time from one SiPM).

Contacts

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