

THE USE OF ACCELERATORS IN RADIATION PROCESSES

PMT DARK NOISE MONITORING SYSTEM FOR NEUTRINO DETECTOR BOREXINO BASED ON THE DEVICENET PROTOCOL AND WEB-ACCESS

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Monitoring of PMT dark noise in a neutrino detector BOREXINO is a procedure that indicates condition of the detector. Based on CAN industrial network, top level DeviceNet protocol and WEB visualization, the dark noise monitoring system having 256 channels for the internal detector and 256 channels for the external muon veto was created. The system is composed as set of controllers, converting the PMT signals to frequency and transmitting them over CAN network. The software is the stack of the DeviceNet protocols, providing the data collecting and transporting. Server-side scripts build web pages of user interface and graphical visualization of data.

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INTRODUCTION TO BOREXINO

Borexino, a real-time device for low energy neutrino spectroscopy is nearing completion of construction in the underground laboratories at Gran Sasso, Italy (LNGS). The experiment's goal is the direct measurement of the flux of ⁷Be solar neutrinos of all flavors via neutrino-electron scattering in an ultra-pure scintillation liquid. The new technology developed for Borexino enables sub-MeV solar neutrino spectroscopy for the first time resolving the solar neutrino problem. Borexino will also address several other frontier questions in particle physics, astrophysics and geophysics.

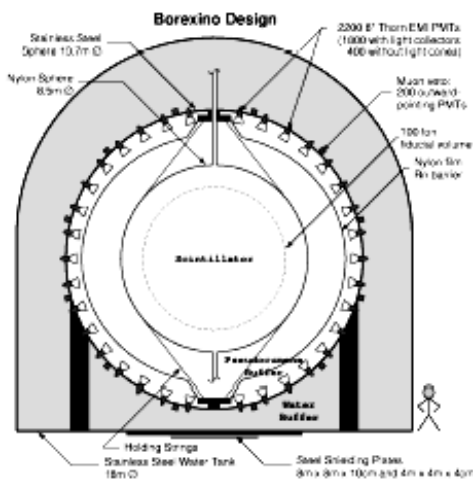


Fig. 1. Sketch of the Borexino detector. About 300 tons of liquid scintillator are shielded by 1040 tons of a transparent buffer liquid. The scintillation light is viewed by 2200 PMT's. Reconstruction of the position of point-like events allows the determination of a 100 ton fiducial inner mass - the solar neutrino target. Outward looking tubes on the steel sphere surface act as the muon veto detector. They use the Cherenkov light produced by muons that intersect the outer water buffer

The basic observables for the identification of neutrino events in Borexino are the total energy released in

the scintillator, as measured by the number of photons emitted. The electronic signal processing scheme shown in Fig.2 is designed to achieve the timing properties needed for a variety of key tasks: reconstruction of the event position, pulse shape discrimination of α - and β -type of events, and the identification of a variety of delayed coincidence tags with a wide range of time bases.

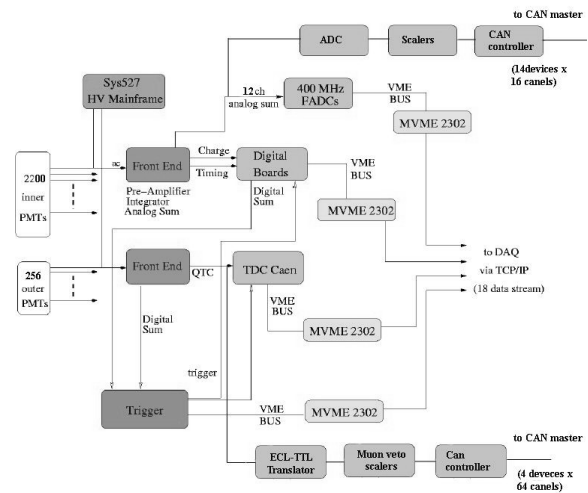


Fig. 2. Block diagram of the Borexino electronics layout

The DAQ software is entirely custom made, with extensive use of multi-tasking techniques. User interfaces are all based on WEB techniques.

CHALLENGE OF DARK NOISE

The phenomenon of a one-photoelectric pulse in the photomultiplier lies in the fundamentals of event registration techniques used in Borexino. Only coincidence of many pulses from different devices during short period allows the conclusion about the presence of a substantial physical event in the detector volume. But the essential property of photomultipliers is to produce sporadic pulses; each one taken separately is almost indistinguishable from the one bearing the information on physical event. These spurious pulses, being mainly a result of photocathode thermoemission, followed by re-

lease of electrons with the subsequent amplification, are called photocathode dark noise. Other sources of dark noise are: radioactive decay in the glass bulb of PMTs, cosmic rays, auto emission under electrical field supplement etc.

Dark noise is known for its intensity of any single unit of photocathode area to depend mainly on the manufacturing technology and its operating temperature. Also, there is evidence that it can be influenced by other physical factors [1].

Under certain conditions, dark noise can garble a physical picture, and make normal operation of the detector impossible. This is especially important in view of scarcity of neutrino-like and supernovas events Borexino was intended to study. For this reason monitoring and analysis of dark noise is necessary.

A continuous dark noise monitoring system is now being created to separately monitor the internal and external detectors. The measurement of medium frequency of pulses is made for the internal detector photomultipliers in bunches by 12, and for external detector where it was possible to perform an individual analysis for each photomultiplier.

The monitoring system, formed by a set of modules of intellectual frequency meters (modules for external and internal detectors differ mechanically, but inherit the common architecture), integrated in an industrial computer network. Data accumulation and primary processing are done on the central computer of this network. An essential feature of the monitoring system is its independence from the main data acquisition system of the detector. This means that dark noise monitoring system will work continuously throughout the period of detector activity, overlapping whenever possible interspaces between main system runs. During the development of this system, we realized the great potential for data analysis.

The dark noise analysis meets the following tasks:

- Continuous accumulation and storage of entire data array, visual current state mapping and histories by the request on the Web;
- Watching sporadic effects and irreversible failures in a separate photomultiplier and groups of photomultipliers;
- Watching the correlated changes on groups;
- Estimation of the long-time tendencies;
- Estimation of periodic variations using the Fourier analysis;
- Research of response to cutoff of high voltage;
- Research of response to flashes of photographic cameras.
- Research of correlations with other physical characteristics (temperature, vibrations, acoustic noises etc.).
- Issue of the certificate of absence of dark noise anomalies at the supernova trigger release.

CAN-BUS BASED MONITORING SYSTEM

The software of the Borexino dark noise monitoring is designed to collect, store, present and process information about the frequency of PMT dark noise. The data is supplied by the two independent systems of CAN-based scalars – the main system (internal detector) and muon veto (external one).

The main system contains 14 groups of 16 channels each, and only 14 channels in group are used. Thus, the whole system provides 196 independent data streams, each of them has meaning of the average count rate of PMT group of 12. The data rate is 1 value per second, which is in 0 to 500 kHz range.

Apart from the frequency data, the system returns 14 values of power supply temperatures and actual voltages +5V and -5V, used for precision analog circuits. These parameters are very important for the FLASH ADC subsystem operation. Absence of one of the voltages or overheating may fail or even damage the analog adder; hence the PMT signals will be lost for analysis.

The muon veto scaler system consists of 256 information channels; each has meaning of single PMT dark noise frequency. The data rate is 1 value per second, which is in 0 to 500 kHz range. Each channel data width is 4 bytes. The estimate value of internal detector is roughly 10 times more than of external one.

Thus, the total amount of data, coming from the system, is estimated as $196+256=452$ frequency channels by 4 bytes gives 1,808 bytes per second or approx. 1.8 kB/s, equal ~ 155.5 MB per day or ~ 57 GB per year. As the Borexino data taking period is scheduled for 10 years continuously, it gives estimated value of 570 GB.

This estimate shows that the PMT dark noise rate data can be stored in data base located on one modern storage media assembled of a few hard drives. Storing the technological data is inexpedient

The module diagram of the software components and their interaction with other data acquisition facilities is shown in Fig.3. Different processes and data modules can be placed on different CPUs and communicate via network file system.

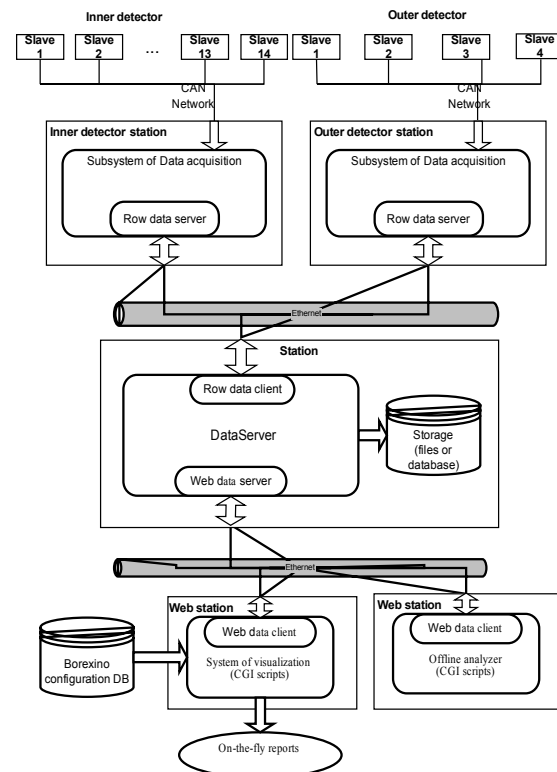


Fig.3. Software chart for Borexino dark noise monitoring system

At present time, the monitoring system for internal detector is completely assembled and in operation, the external system is under final tuning.

As an example of the monitoring system operation results, the Fig.4 presents a fragment of real data, acquired from the detector during the test run in December 2003. The time dependence of average dark pulse frequency for 200 channels is within few minutes with sampling rate 1 Hz. On the diagram one can see dark noise spikes, disabled channels, different average values in different channels, also the detailed analysis finds the cross-channel correlations. All this supports the major assumptions on the dark noise properties stated in [6].

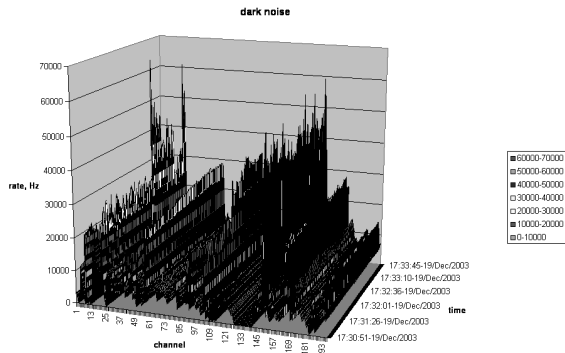


Fig.4. Plot of Borexino single electron noises

CONCLUSIONS

Positive experience of the application allows one to consider the components of CAN-bus technology as a framework useful for development of distributed real-time control systems for big experimental installations.

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СИСТЕМА КОНТРОЛЯ ТЕМНОВЫХ ШУМОВ ФЭУ ДЛЯ НЕЙТРИННОГО ДЕТЕКТОРА BOREXINO С ПРИМЕНЕНИЕМ ПРОТОКОЛА DEVICENET И ДОСТУПОМ ЧЕРЕЗ WEB

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Мониторинг темновых шумов ФЭУ в нейтринном детекторе BOREXINO является необходимой процедурой, показывающей состояние детектора. На основе промышленной сети CAN, протокола верхнего уровня DeviceNet и визуализации WEB была создана система контроля темновых шумов, имеющая 256 каналов для внутреннего детектора и 256 каналов для внешнего мюонного вето. Система состоит из набора контроллеров, которые преобразуют сигналы от ФЭУ в частоту и передают ее по сети CAN. Программное обеспечение представляет собой стек протокола DeviceNet, обеспечивающий сбор и транспортировку данных. Формирование WEB-страниц пользовательского интерфейса и графическая визуализация данных производится с помощью серверных скриптов.

СИСТЕМА КОНТРОЛЮ ТЕМНОВИХ ШУМІВ ФЕП ДЛЯ НЕЙТРИННОГО ДЕТЕКТОРА BOREXINO ІЗ ЗАСТОСУВАННЯМ ПРОТОКОЛУ DEVICENET І ДОСТУПОМ ЧЕРЕЗ WEB

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Моніторинг темнових шумів ФЕП в нейтринному детекторі BOREXINO є необхідною процедурою, що показує стан детектора. На основі промислової мережі CAN, протоколу верхнього рівня DeviceNet і візуалізації WEB була створена система контролю темнових шумів, що має 256 каналів для внутрішнього детектора і 256 каналів для зовнішнього мюонного вето. Система складається з набору контролерів, які перетворюють сигнали від ФЕП в частоту і передають її по мережі CAN. Програмне забезпечення являє собою стек протоколу DeviceNet, що забезпечує збір і транспортування даних. Формування WEB-сторінок користувальницького інтерфейсу і графічна візуалізація даних виробляється за допомогою серверних скриптів.