Accelerator Technology and High Energy Physic Experiments, WILGA 2012; EuCARD Sessions

Romaniuk, R S (Warsaw University of Technology Poland)

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Accelerator Technology and High Energy Physics Experiments Photonics Applications and Web Engineering WILGA May 2012

Ryszard S.Romaniuk
Warsaw University of Technology, Institute of Electronic Systems, Poland

ABSTRACT

The paper is the second part (out of five) of the research survey of WILGA Symposium work, May 2012 Edition, concerned with accelerator technology and high energy physics experiments. It presents a digest of chosen technical work results shown by young researchers from different technical universities from this country during the XXXth Jubilee SPIE-IEEE Wilga 2012, May Edition, symposium on Photonics and Web Engineering. Topical tracks of the symposium embraced, among others, nanomaterials and nanotechnologies for photonics, sensory and nonlinear optical fibers, object oriented design of hardware, photonic metrology, optoelectronics and photonics applications, photonics-electronics co-design, optoelectronic and electronic systems for astronomy and high energy physics experiments, JET and pi-of-the sky experiments development. The symposium is an annual summary in the development of numerable Ph.D. theses carried out in this country in the area of advanced electronic and photonic systems. It is also a great occasion for SPIE, IEEE, OSA and PSP students to meet together in a large group spanning the whole country with guests from this part of Europe. A digest of Wilga references is presented [1-270]. Wilga Sessions on HEP experiments were organized under the umbrella of the EU FP7 Project EuCARD – European Coordination for Accelerator Research and Development.

Keywords: nanomaterials, optical fibers, optoelectronics, photonics, measurement systems, astronomy, high energy physics experiments

1. INTRODUCTION

2XXXth Jubilee Symposium of young scientists WILGA 2012 on Photonics and Web Engineering has gathered over 250 participants. There were presented over 200 papers – mainly concerning the realized Ph.D. theses and participation in research projects relevant to the topical area of the meeting. There were also presented a few plenary papers introducing the audience into new research areas of photonics and electronics. The symposium is organized under the auspices of the SPIE – The International Society for Optical Engineering, IEEE (Poland Section and Region 8), Photonics Society of Poland, KEiT PAN, PKOpto SEP and WEiTI PW. The symposium is organized annually by young researchers from the PERG/ELHEP Laboratory of ISE PW with cooperation of SPIE and IEEE Student Branches. Media patronage over the symposium is extended by Elektronika monthly technical magazine, Symposium proceedings are published by Elektronika, JET - Journal of Electronics and Telecommunications KEiT PAN and Proceedings SPIE. Wilga Symposium is topically associated with the cyclic research meetings on optical fibers and their applications organized in Bialowieza (prof.J.Dorosz, Bialystok Uni. Technology) and Krasnobrod (UMCS Univ., and Lublin Univ. Technology, prof.W.Wojcik) every 18 months. Below, there are debated some presentations from the main of the most interesting sessions or topical tracks of WILGA 2012 Symposium, May Edition. This part 2/5 debates the sessions on Accelerator Technology and High Energy Physics Experiments.

2. TOPICAL TRACKS OF THE JUBILEE XXXTH SYMPOSIUM WILGA MAY 2012

The topical session and tracks of WILGA 2012 were as follows: nanotechnologies and nanomaterials for optoelectronics and photonics, optical fibers for sensors and all-photonic devices for sensors, active optical fibers, sensors and sensory networks, object oriented design of optoelectronic and photonic hardware, photonics applications, advanced bioelectronics and bioinformatics, co-design of hybrid photonic – electronic systems, computational intelligence in optoelectronics and robotics, development in the wide-angle astronomic observations of the whole sky – pi-of-the-sky project, processing and imaging of multimedia data streams, machine vision, vehicles – quadrocopter and Mars rover, analog transmission systems in noisy conditions with digital reverse transmission channel, optoelectronic and photonic metrology, reconfigurable measurement systems, high performance – low-jitter low-latency transmission systems – White Rabbit, thermonuclear fusion experiments – JET and ITER, research results update from HEP experiments – TOTEM and CMS/LHC in CERN. A number of Wilga sessions concerned applications aspects of photonic and electronic circuits and systems, including in this advanced applications which combine hardware and software. A separate session track was organized by SPIE, IEEE, OSA and PSP - Photonics Society of Poland students for the new students beginning their adventure with the science of photonics and electronics.

3. ACCELERATOR TECHNOLOGY AND HIGH ENERGY PHYSICS EXPERIMENTS

High energy physics (HEP) experiments involve big infrastructure like superconducting accelerators and detectors. At least 10 % of the costs of these infrastructures are consumed by electronic and photonic systems for the construction of detectors, control and measurements systems, reference timing and synchronization systems, safety and protection systems, etc. The biggest and most important research processes going on now in the domain of HEP are associated with the Higgs boson discovery and neutrino oscillations. Both fields, apart from some other ones, are expected to lead to the new physics and open new clues to explanations of such unknown fields as dark matter and dark energy. Also big research infrastructural investments concern free electron lasers. The biggest one in Europe is the E-XFEL under construction in DESY.

There are very strong motivations for the research on free electron lasers. Photons of different wavelengths are one of the most useful tool in different types of measurements. IV generation light sources are the only ones to generate coherent, very intense laser light from IR, visible, through UV up to X band. This is not achievable in any other type of laser. In FEL the light is generated by the energetic relativistic electrons traveling in the undulation path, during SASE process (spontaneous amplified self emission). The electrons are accelerated to relativistic energies in a linear accelerator.

4. THE CMS EXPERIMENT

Higgs search by the CMS experiment

CERN has just announced the discovery of the Higgs like boson with no spin, with the mass of 125,3±0,6Gev/c^2. This is very probably the first boson of the Higgs family. The announcement is based on combined data from the CMS and ATLAS experiments. Warsaw Group (UW, Faculty of Physics, NCBJ, WUT) is one of the founding members of CMS Collaboration. The CMS (compact muon solenoid) is running in parallel to ATLAS experiment, both of them located on the LHC ring accelerator (large hadron collider), both are optimized to hunt for the Higgs particle. The LHC potential of discovery in now unrivalled. Among the potential discoveries are: Higgs boson, heavy supersymmetric partners of elementary particles, weakly interacting charged heavy particles, non-barionic candidates for dark mater particles, dark photons, new properties of neutrinos, phase boundaries and properties of QGP (quark gluon plasma), micro dark holes, potential internal structure of quarks, and many more. Higgs particle is linked to the masses of all particles in the baseline SM (standard model). There are several channels to observe potentially Higgs particle production and decay. The dominant production mechanism is gluon fusion $gg \rightarrow H$. The best channels for Higgs searches are: $H \rightarrow \gamma\gamma$, $H\text{-}\rightarrow WW \rightarrow 2l2\nu$, $H \rightarrow \tau\tau$, $H \rightarrow bb$. The golden channel, for all Higgs masses, is $H \rightarrow ZZ \rightarrow 4\mu$, or generally 4l (4e,2e2μ, 4μ). Basing on the 2010-2011 and part of 2012 publically available CMS data the existence of Higgs particle is excluded at the confidence level 95% in Higgs mass range 127-600GeV. The excess of events is visible at masses around 124GeV. Till now CMS has not noticed any deviations from the SM. Sme results come from CMS HI (high intensity) program.

A team from Warsaw Universities (WU and WUT) is participating in the maintenance of the CMS experiment and development of some of its internal detectors. CMS inner detectors, situated inside a superconducting coil with the field of 4T, are: Tracker – silicon microstrip pixels, ECAL – scintillating $PbWO_4$ crystals, HCAL – plastic scintillator brass sandwich. The detectors outside the coil, situated in the field of 2T of opposite sign are: muon barrel and muon endcaps – interleaved with iron yoke. They consist of detector layers: DT – drift tube chambers, CSC – cathode strip chambers, and RPC – resistive plate chambers. Particles are searched with big transverse momentum in reference to the bunch crossing longitudinal axis. Different particles deposit their transverse energies in different layered detectors adjacent and more distant from the interaction point. Silicon tracker determines the individual vertex of each interaction with some accuracy in space and time. Then the particles reveal their passage through CMS. Photons and electrons are trapped in the Electromagnetic Calorimeter (ECAL). Neutrons deposit their energies in the Hadron Calorimeter (HCAL). The most permeable particles of these, the muons leave their tracks behind in the Muon Chambers. Outside the superconducting solenoid the iron return yoke is interspersed with muon chambers. DT response time is 380ns and spatial resolution 100-150μm. RPC response time is 2ns with effectiveness >95%. CSC response time is 3ns and resolution 150μm. The RPC are fast gas detectors for efficient muon measurements. Their layered structure consists of isolator, graphite, Bakelite, gas chamber, readout strips (width 0,5-4cm, length 20-130cm) and high voltage Al foil. The supply voltage is 9,5kV. Noise is smaller than $5Hz/cm^2$. Muon tracks are recorded in the CMS. Inside the solenoid the magnetic flux density of 4T bends tracks of charged particles. In the outer region the magnetic field is directed the opposite way, which causes a bend in the other direction. The bending radius is a function of charge to mass ratio. Muons with transverse momentum $p_t<3{,}5$ GeV are bent inside the solenoid. Muons of the transverse momentum in the range of $4<p_t<8$ GeV are following less and less curved path. Muons are fast (relativistic) and leave tracks inside their bunch crossing window. The key sub-system for particle detection in CMS is TRIDAQ (trigger and data acquisition). Coarse data from particle collisions go to the FLT. FLT (first level trigger) is dedicated electronics consisting of ASICs and FPGAs, working at 40MHz, and doing only logic functions. FLT analyses every event taking place at each bunch crossing BX. The processing is pipeline type with latency 3μs, including 2μs for optical fiber data transmission between the detector and counting room. The output from FLT is 100kHz. The data are stored in readout buffers for 128 events. DAQ readouts the data for the selected events (the events are fragmented). Event Builder is a switching network which gathers data from one event into one HLT computer. HLT (high level trigger) is a huge computer farm, consisting of more than 10^3 nodes, 10^4 cores and nearly 20TB memory, which runs the software events selection algorithms. The output from HLT, substantially smaller than 1kHz, is stored on a permanent memory. FLT is made of custom electronics and is pipeline at 40MHz, and multilayer including calorimeter trigger, muon trigger and global trigger. The role of trigger system is to identify, measure and sort the trigger objects. Global trigger applies cuts for single or multiple objects and searches topological correlations.

CMS RPC Muon Trigger

Warsaw group works on RPC PAC muon trigger. The signals from FEB (front end boards) connected directly to RPCs detectors go to Link Boards via LVDS cables. Then, 10^3 optical fiber cables carry the 1,6Gbps signals to the counting room, where there are 84 Trigger Boards located in 12 Trigger Crates. Trigger algorithm bases on pattern comparison in pattern comparators PAC. The chamber signals (fired strips) are compared with the predefined set of patterns. Each pattern has assigned a transverse momentum p_t and sign – depending on the track bending by the magnetic field. A pattern is a set of AND gates connected to selected strips. Muon candidate is recognized if RPC hits fit to the pattern and are in the same 25ns clock period (BX). A candidate is produced even if not all layers have hits. The minimum required number of fired layers is 3 (out of 3,4,5 or 6 layers available – depending on a detector region). In this way the trigger efficiency does not suffer from the limited geometrical acceptance and inefficiency of the chambers. The number of fired planes defines the candidate quality. The quality is used for the candidates sorting and “ghost busting” – which is cancellation of duplicated candidates. The trigger algorithm is implemented in the FPGA circuits. 300 chips are needed to cover full detector. Each PAC chip comprises up to 576 chamber strips and contains $3 - 14 \times 10^3$ patterns. Out of these patterns most concern low p_T. The patterns are stored in the firmware logic. Each PAC contains different patterns, therefore a separate compilation is needed for each chip. The patterns are generated based on the simulated muon track. Advanced algorithms are used to create the patterns from the simulated patterns hits, assign p_T, and then select optimal set of patterns. The goal is to achieve best possible trigger efficiency and purity with patterns set that can be fit into the PAC FPGAs. The software framework for patterns generation and firmware compilation on the computer cluster was created. As the PAC algorithm is implemented in the reprogrammable FPGAs, it can be easily changed, e.g. corrected, improve performance, implement new features.

The system has to deal with SEU mitigation problem. Link boards and control boards are exposed to radiation and therefore can be affected by SEUs. Experiments show that configuration memory of FPGA chips are susceptible, while flash memories are unaffected. To mitigate the effects of SEUs we have several measures in place: triple modular redundancy in critical paths; re-reading of configuration registers in the background and check for flipped bits; checksum of all data stored in flash; periodic reloading of configuration from flash memories in a synchronized way and detector-wide. To make reconfiguration faster and independent from the control software running on PCs we have small automaton, which can read commands from flash memory and set values of registers, communicate over I2C and so on. Reset signals are transmitted together with the clock signal over TTC (fiber optic) and do not depend on the bus used for usual communication with PC software (CCU).

The trigger system has to be fully and precisely synchronized. The time of muon flight from the point to the different chambers varies from 14 to 42ns, i.e. more than a single BX. This stems from the dimensions (muon travel path) varying from 4 to 14m. The time of signal propagation from the chambers to the Link Boards varies from 33 to 107ns, due to the difference in cable lengths. The chamber hits must be in the coincidence on the PAC input to produce the muon candidate. They have to be recognized as originating from the same BX, which means 25 ns clock period. Thus, the system synchronization is crucial for triggering performance. The chamber hits are synchronized to the 40MHz LHC clock in the link boards. The hits are quantized to the full BX (the timing is measured with the 25ns precision) with the use of synchronization window. Window position can be adjusted with 0,1ns accuracy. The hits are then aligned between the Link Boards (LBs) by applying full BX delays. The goal is to have all hits of all muons from given event within 25ns on all LBs. The initial position of the synchronization window is calculated from muon hits timing (muon time of flight and signal propagation in cables), known length of optical fiber transmitting the clock. After the initial synchronization in most of the LBs the chamber hits are concentrated in one or two neighboring BXs: -1, 0, +1. The timing correction is calculated by comparing the hits distribution from data with distributions obtained from timing simulations. In practice, LB synchronization is tuned very rarely and the residual out-of-time hits originate from cosmics, muons from other BXs or chamber noise. The upper limit for the pre-triggering and post-triggering is 0,04%. The efficiency of RPC PAC trigger for identifying muons is a convolution of: geometrical acceptance of the RPC detector (fraction of muons crossing at least 3 chambers), chamber intrinsic efficiency, patterns efficiency – probability thet the chamber hits of a triggerable muon fit to any pattern. RPC total efficiecy is 92% in barrel and 80% in endcaps. A triggerable muon is identified when hits are in at least 3 RPC layers inside the eta-phi cone covered by one PAC unit and appearing in the same BX. The current performance (as of 2011) of the RPC PAC trigger is very good. The work is continued on the pattern optimization with increasing LHC luminosity and higher muon rate and keeping high trigger efficiency for high momentum muons.

Search for Heavy Stable Charged Particles
Another modification of the PAC algorithm is motivated by search of new particles (A.Zagozdzinska, ISE PW). Some supersymmetry models foresee Heavy Stable Charged Particles (HSCPs), like stop, gluino, stau. Their mass is of the order of hundreds GeV, thus if they are produced at the LHC their velocity would be significantly smaller than c. In the CMS these particles will look like slow muons. Their hits in muon chambers (all or only outermost) can be up to 1 BX (25ns) later than the hits of the regular muons. Thus, they will not produce the muon trigger, because the hits are not in coincidence within one BX. The alternative is that they will produce muon trigger but 1 BX later. Thus, the tracker hits will not be recorded, because pixel detector stores hits from a single BX event only. There is a new algorithm to trigger on the HCSPs with the PAC trigger. In the PAC logic, the detector signals are extended in time to 2BXs. On the Global Muon Trigger input the PAC candidates delay is reduced by 1BX with respect to the DT and CSC candidates. Hits of the late particle generate trigger in the proper BX. In-time muons candidates appear in two BXs. The first candidate is too early and the second is in the proper BX. The first candidate is masked on the GT by the BPTX veto – a signal synchronous with collision, but advanced of 1BX (used for all triggers to eliminate the pre-triggering). Significant increase of the efficiency is obtained to trigger on lower momentum, slower moving super-symmetric particles.

5. TOTEM EXPERIMENT

TOTEM experiment – upgrade of data acquisition system. Upgrade of the Data Acquisition System of the TOTEM experiment includes the Scalable Readout System (A.Fiergolski. CERN and ISE WUT). The signals are carried via GbE from detector to the S-Link Mezzanine OptoRx bords. These are connected via PCIe-PMC LVDS connector to FEC, and further via DTS 800Mbps to SRU, Second Level Trigger, and next to a PC and disk array via GbE 4x5Gbps. Opto-Fec card was designed. The test board links the OptoRx and the FEC and features the following components: 8xLVDS channels, full-duplex 2Gbps SERDES, clock generator and jitter cleaner, 64-bit parallel bus, TTC interface, I2C configuration, TTS support, JTAG support and independent power supply mode. There is a proposal of the new OptoRx firmware which would include second level filtering algorithms and new, more efficient data formats. The new OptoRx architecture would include: easily extendable output interfaces, AXI, and would base on the experience with TOTEM detectors. Testing environment (testbench) was designed to research new releases of the OptoRx firmware. The emulation environment of the detectors uses: SystemVerilog IEEE 1800, UVM – Universal Verification Methodology - Accelera, and TLM – transaction Level Modeling.

6. ATLAS EXPERIMENT

ATLAS TRT – transition radiation tracker

Detector control system for the ATLAS transition radiation tracker was designed and implemented by the TRT DCS Team (E.Banas, Institute of Nuclear Physics PAS, Krakow). TRT is the outermost of the ATLAS inner Detector Tracker. It is a gaseous detector providing tracking through individual drift tubes (straws) and particle identification via detection of transition radiation. It is positioned in barrel, end cap A and end cap C of ATLAS and contain nearly 300000 straws. Each straw, filled with active gas (Xe, CO_2, O_2), is a proportional counter with the wall biased to over 1,5kV and wire grounded. Signals from the straws are read with the TRT front end electronics, nearly 900 FEBs. The DCS consists of many subsystems like: gas gain stabilization system, finite state machine, HV and LV softare interlocks, TRT temperature hardware interlock, etc. The TRT DSC is operating the detector in a very stable way and reliably. The system is subject to continuous growing and developing, like new tools are added, together with the detector needs. System upgrade is predicted for long shutdown of the LHC during 2013-14. New front end hardware is predicted for this upgrade as well as new communication software (OPC UA) and move from XP to Linux, where available.

ATLAS TriDAQ

Discrete event modeling method was used for ATLAS TDAQ architectures design (K.Korcyl, Krakow University of Technology and INP, PAS). DEM is a software system simulating system dynamics in time, where state of the system remains constant between events and the processing system in a state may lead to scheduling a new event in the future. ATLAS TriDAQ is now exploited successfully in the LHC system. The system consists of FE pipelines, read-out drivers, readout links, readout buffers and sub-systems, dataflow manager, event building network, sub-farm input, event builder (EB) and filter, sub-farm output and data storage. The first level trigger works at LHC frequency of 40MHz. HLT reduces the frequency subsequently to 75kHz, 2kHz and 200Hz. The HLT (high level trigger) includes RoI builder, L2 supervisor, network and processing unit, and finally event filter processors. 500 CPUs are used for LVL2 and 100 CPUs for the EB. Alternative architectures for the LVL2 network are switch or bus based. The researched issues are respectively: scaling, reliability, number and types of switches for the first case, and network traffic granularity and potential congestions for the second case. A test bed was prepared for checking the options including measurements of EB rates (from 1 to 6 kHz) for various accept ration by the triggers. Full scale switch based model was simulated and measured. Discrete event modeling becomes invaluable tool in design of large scale TriDAQ systems for modern high energy physics experiments. Modeling of ATLAS LVL2/EB traffic network helped to design and implement efficient network, which was recently checked by real new physics discovery of Higgs like particle.

7. PANDA EXPERIEMNT IN HESR FAIR

Event Builder in PANDA – FAIR

The Research Group from Krakow (K.Korcyl) participates in building of PANDA detectors. This is a particle identification experiment at HESR – High Energy Storage Ring in FAIR – Facility for Antiproton and Ion Research at GSI Darmstadt. The particle identification is based on: DIRC – detection of internally reflected Cherenkov, ToF - time of flight system, MD - muon detection system, RIC - ring imaging Cherenkov Detector. The tracking detectors are: Micro Vertex Detector, Central Tracker, GEM stations (gas electron multipliers), Forward Tracker. The trackers are supplemented by the Electromagnetic Calorimeter. The PANDA DAQ requirements are as follows: interaction rate 20 MHz at the luminosity $2*10^{32}cm^{-2}s^{-1}$; typical event size 4kB; expected throughput around 100GB/s; high flexibility in event selection for rich physics program; front end electronics and photonics working in continuous sampling mode; and lack of hardware trigger signal. The architecture is of push only type and consists of: detector FEE, data concentrators, FEE stage, CPU stage, event processing farm. The system is served by SODA – photonic time distribution system. It is a passive point-to-multipoint bidirectional fiber network providing time reference with precision better than 20ps and performing synchronization of the data taking process. The hardware of choice is ATCA standard (advanced telecommunications computing architecture) with full mesh backplane. Compute Node board in equipped with 5 FPGAs and provides high bandwidth connectivity by multi gigabit optical links connected to RocketIO ports and 5 GbEth links. Inter-crate wiring is designed in such a way that the module in slot N at the FEE level connects, with two links trunks, to module at slots N at the CPU level. He odd event packets at the FEEE level are first routed via the backplane and then outbound to the CPU level via a proper trunk line. The even events packets go outbound to the CPU level first and then use backplane to change the slot. The ports are fully parameterized adding flexibility to the design. Models of data source (data concentrator) and data sink (event building CPU) were designed and realized for system work simulations. Work parameters were estimated like: event building latency (architecture is able to switch up to 173GB/s), load distribution between CPUs, monitoring queues evolution (averaged maximal queue length in input ports at the FEE level), monitoring of optical fibers link load, and monitoring FPGA links occupation. In PANDA project the Group from Krakow used modeling to demonstrate that the push-only architecture with Compute Node in ATCA offers over 100GB/s throughput needed to perform burst and super burst building and to run selection algorithms on fully assembled data.

8. NEUTRINO OSCILLATION RESEARCH

Warsaw Group (IRE WUT, prof. K.Zaremba, prof.J.Marzec) takes part in the neutrino T2K experiment. The goal is to find the components of the neutrino mixing matrix. The neutrino beam is propagated from J-Parc to Super Kamiokande for 295 km. The Group participated in the construction of the T2K Near Detector – ND280. The detector, situated 280m from the source, consists of: one gas detector and five fiber optic scintillating detectors. The fibers are surrounded by volume scintillators and coupled to MPPC detectors.

9. LHC ACCELERATOR SYSTEM DEVELOPMENT

Development of Reliable LHC Accelerator Protection System

Photonic and electronic systems are applied in protection systems for high energy particle accelerators. The key role are playing photonic active components and PLDs. Safe Machine Parameters System (SMP) is crucial for the LHC (large hadron collider) operation. It protects the LHC during injection procedure and during normal operation. It is modular, redundant VME system with two independent FPGA chips on each VME board – with monitoring and control tasks. The system receiver redundant information, generates flags and values. It is distributed around the LHC to be used by other protection equipment.

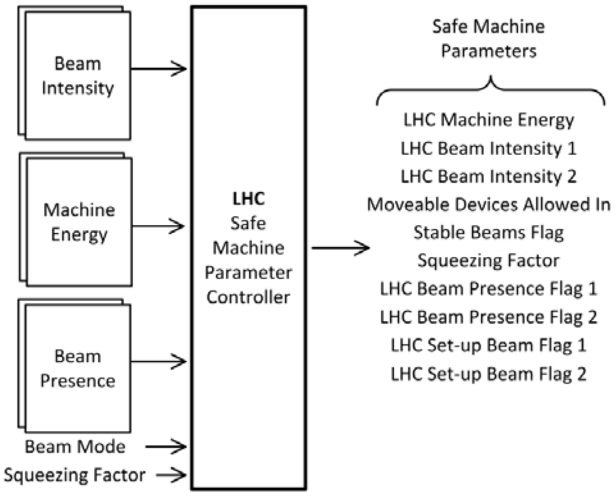

Fig. Safe Machine Parameters System for the LHC

During the SMP development the safety approach was required (Protection System Lifecycle) which included: PSL based on the standard IEC-61508 Lifecycle, good understanding of the EUC, identify hazards, determine protection functions (PF) specifications. The requirements of the Protection Functions are requested by the Machine Protection Panel – which consists of physicists, engineers, risk analysts and decision makers. The focus is on the PF implementation in the PLD devices and systematic failures avoidance. The formal design flow includes: definition of requirements, assessment of critical and non-critical safety factors, preparing specifications, formalization of the process, building functional blocks of the system. All these steps undergo thorough check for completeness and consistency. Then, the process goes on via blocks implementation and simulation. Hardware stages include blocks hardware testing. The full system is then simulated, hardware is again tested in full and the code is reviewed. The whole system simulation and hardware tests process is externally checked for correctness. Thus, there are two levels of testing: in a simulation test bench which is a software wrapped around the model, and in a hardware test bench, which is similar to simulation but concerns the real hardware. The system response at the simulation and at hardware levels should be correct for all stimuli. The simulation tool can examine code coverage. The hardware tool uses embedded logic analysers provided by FPGA vendors (ChipScope, SignalTap, etc). In summary, the approach to dependable PLD design goes on top of dependable electronics design and consists of the following levels: formalization of the specification, splitting of risk factors to critical and non-critical, reduction of the problems to minimum functions, exhaustive source code simulation, full code coverage, hardware testers, code reviews, external reviews.

10. WHITE RABBIT

WR is a synchronous and deterministic version of the Ethernet. It is back compatible with the classical Ethernet. White Rabbit is predicted for accelerator control and timing. Is developed by international collaboration (M.Lipinski, CERN and ISE WUT), bases on well-known technologies and on open hardware and software. The main features are: transparent, high accuracy synchronization, low-latency, deterministic data delivery, designed for high reliability, and plug and play. The existing and near future as well as potential applications of WR installations are: CERN neutrino to Gran Sasso, GSI, HiSCORE – Gamma and Cosmic Ray Experiment in Tunka, Large High Altitude Air Shower Observatory in Tibet, Cherenkov Telescope Array, ITER, European Deep Sea Research Infrastructure –KM3NET. The WR provides two essential enhancements of the Ethernet: high accuracy/precision synchronization, and deterministic, reliable and low latency control data delivery. WR system consists of time and data master, network of WR switches, WR nodes. Reliability of WRN is based on four pillars: deterministic packet delivery, synchronization resilience, topology redundancy, and data resilience. The basic assumption of the WRN reliability is: WRN is functional if and only if it provides all its services to all its clients at any time. WR transmits two types of data: control data is transmitted with high priority (HP), and standard data is sent using the Best Effort (BE) mechanism – known from the TCP/IP networks. Characteristics of the control data are: sent in Control Messages, sent by Data Masters, Broadcast one to a lot, deterministic and low latency, reliable delivery. One time and data master may serve via a communication channel 2000 nodes distributed over 10 km. Data redundancy is done via Forward Error Correction FEC. Re-transmission of Control Data is not possible. Forward Error Correction is served by an additional transparent layer. One Control Message is encoded into N Ethernet frames. The recovery of a Control Message is done from any of M (M<N) frames. FEC can prevent data loss due to bit error and network reconfiguration. Topology redundancy is based on standard Ethernet solution, using rapid multi spanning tree protocol, with reconfiguration time shorter that 1 s, typically tens of milliseconds. During 1s approximately 82000 Ethernet Frames are lost. Extensive research is carried on to extend the existing standards to prevent this huge data loss.

The solutions go into the following directions: to take advantage of the FEC mechanism, and to speed up the (R/M)STP protocol to eRSTP enhanced Rapid Spanning Tree Protocol). Together eRSTP and FEC give seamless redundancy which results in maximum loss of two frames. For 500 bytes long message with 288 byte FEC, the maximum reconfirmation time is approximately 2,3 µs. The features of eRSTP are: provides a priori information – alternate and /or backup, limited number of topologies, drop only reception within VLAN except self-sending, take advantage of broadcast characteristic of control data, is going to be done in hardware. TRU – Topology Resolution Unit is an universal and decoupled unit for topology resolution. It is a common firmware base for many different solutions. Currently two solution are considered: eRSTP (enhanced Rapid Spanning Tree Protocol) and eLACP enhanced Link Aggregation Control Protocol. WR switch consists of two layers S/W containing eRSTP/eLACP, and H/W containing TRU (RTU, Swcore and endpoints). The current status of WR system is as follows: Timing-wise WR is working now with focus on data; there is an interest of standardization bodies – WR was presented to ITU-T and IEEE; first deployment at CERN of WR timing and control network for AD; there is observed increasing number of applications; first commercially available WR switch is expected at the end of 2012.

11. MULTI PIXEL PHOTON DETECTORS

Multi-Pixel Photon Counters for particle detectors

Multi-pixel photon counters (MPPC) are used in the particle detectors in high energy physics experiments. The research on MPPC is carried out in the team chaired by prof.J.Marzec at WUT. Multipixel (matruix) avalanche photodiodes are very sensitive and manufactured, for example, by Hamamatsu. They may operate in Geiger-mode, above some threshold value of supply voltage, with very high gain 10^6. Active pixels are discharged from some higher o lower voltage, while the output current flow recharges the pixels. Histogram peaks, in pixel response, shows particular counts of photons.Peaks distance is determined by the electron gain. The main parameters of MPPC are: electron gain, junction capacitance, breakdown voltage, photon detection efficiency, dead time, dark rate, correlated noise. MPPC are used as PMT (photomultiplier tube) replacement. In comparison with PMT they have some advantages like: high gain and sensitivity, low price, small dimensions, are immune to magnetic fields, high reliability, moderate supply voltage around 100V, time resolution 300ps. In comparison with PMT they have also some disadvantages like: high dark noise

$10^6 s^{-1}$, display correlated noise effects, have low active area (a few mm^2). MPPC are used in the T2K experiment (Tokai to Kamioka) for research of neutrino oscillations. A measurement lab for mass testing of MPPC was constructed at IRE WUT, consisting of pulse generator, MPPC power supply, light hermetic case, temperature control, signal amplifier, multichannel amplitude analyzer. The system featured: compact design and modular electronics, high degree of automation, controlled measurement conditions and advanced data processing. There were applied two methods of dark rate evaluation: a direct method based on discriminator and scaler, and histogram based method. In the latter method the influence of correlated noise can be removed, while the first method is correlated noise sensitive. Correlated noise analysis is based on dark histogram. Correlated noise shows up as a difference between real histogram shape and Poisson distribution. Measurement of photon detection efficiency is based on light histogram, where the dark rate and noise must be taken into account.

High-Density Multi-Pixel Avalanche Photodiodes for particle detectors

Super-high density multi-pixel avalanche photodiodes (MAPD) are the next step in development of semiconductor matrix detectors with high gain for nuclear purposes. Structure of MAPD resides on n substrate and n^+ high doped layer. P type epilayer has n^+ microwells and is covered by p^+ contact layer. Photons impinging on the contact layer generate carriers, which are concentrated by n^+ microwells (pixels). Size of the pixels is 8x8μm. The comparison between traditional Silicon Photomultipliers (SiPM) working in Geiger mode (MPPC) with MAPD is as follows: density of pixels is bigger for MAPD and amounts tp $10000/mm^2$, gain is slightly smaller 10^4-10^5, time resolution is 30ns. MAPDs were applied in the development of the Compass experiment in CERN. They had the following parameters: single detector size 3x3mm, granularity $15x10^3$ pixels/mm^3, gain $5x10^4$, working voltage 90V, temperature stabilization. Detectors were coupled by Winston cone with WLS optical fibers.

Supersensitive multichannel pico-ammeter is under construction using FMC module, including PCB and firmware. The device is predicted to be used in a measuring system in a particle detector (HEP and astrophysical experiments), to cooperate with APD diodes, matrix detectors, and wire chambers.

12. SUPERCONDUCTING MAGNETS

Thermodynamics of superconducting magnets for accelerators. The magnets keep and focus charged particles in an accelerator and in the particle collider. Main dipoles are used to bend the beam in circular accelerators. The higher the magnetic field the higher energy particles can be kept on track. Main quadrupoles are used to keep the beam together, because of repelling forces in the charged particle bunched beam. Corrector magnets are used to preserve the beam quality. Interaction region quadrupoles are used to focus the beam to a waist at the interaction points. The higher is the gradient in the interaction magnets and the bigger aperture, the higher is the luminosity in the colliding beams focus. Superconducting magnets have replaced warm magnets because of energy efficiency and higher fields obtained in compact designs. Iron dominated magnets are limited by saturation at 2 T. The state of the art large size DC magnets are now working in LHC and FLASH. The maximum field in the LHC dipoles, working at the temperature of super-liquid helium 1,9K, is over 8 T. Three critical parameters determine the workspace of a magnet superconductor: current density J [A/mm^2], magnetic field B [T], temperature T [K]. Above these critical values, which are property of the used superconducting material like Nb, NbTi, NbSn, the magnet quenches, leading to beam dump. For example, the temperature of the superconductor may rise due to beam induced heat load, or too big current density in the coil. The machine and beam recovery after the dump my be quite time and effort consuming, depending on the cause of the loss (from a few h to a few tens of h). Beam loss monitors (BLM) are used in accelerators to prevent beam loss and thus avoiding the full accelerator recovery processes. Only the beam cycling, filling, ramping and squeezing processes are repeated which last approximately for 2h only. After these processes the collisions may be resumed. It is apparent that an efficient BLM leads to a substantial increase in the accelerator availability. Energy deposits in the accelerator magnets is a complex process because of a complex construction of the components and thus the heat dissipation paths.

The heat load in the LHC IR magnets is 10W/m and for the LHC upgrade will increase to 50W/m. Precise thermal study of the magnets leads to: optimization BLM threshold settings, increase integrated luminosity, reduce quench number, optimize magnet cooling (D.Bocian, IFJ Krakow). The primary mechanisms of the heat load in the LHC magnets were fully recognized. Heat transport in superconducting magnet along the full path from the conductor to the cold source, including electrical insulation, was recognized and modeled. The network model includes all relevant parameters like material properties, detailed geometry of the construction, heat load profile, temperature margins, helium, cabling, magnets, etc. The built model, bases on thermal – electrical analogy, leads to a temperature map. The assumed equivalents are: temperature – voltage T – V, heat – charge Q – Q, q – I heat transfer rate – current, k – s thermal conductivity – electrical conductivity, R – R thermal resistance – electrical resistance, C – C thermal capacitance - capacitance. The analogy of temperature rise is voltage difference. The analogy of heat diffusion is signal transmission in RC transmission line. The model was validated by measurements and simulated, and allowed for precise quench limit calculations. The model is used in CERN to study new magnets design parameters impact on magnet thermal performance.

13. PHOTONICS AND ELECTRONICS APPLICATIONS

A number of session concerning the applications of photonic and electronic circuits and systems included work on particular engineering and technical solutions for various fields like: car industry, airborne industry, robotics, management of the road traffic, remote control methods for utility systems via the Internet, audio and video techniques, biomedicine, safety techniques, home appliances. A group of work concerned the development of a mobile platform for a universal robot equipped with advanced devices like cameras, grippers, Other group concerned the development of distributed measurement networks for minimum energy service of the network of self configuring environmental sensors. These sensors are expected to use a lot of energy harvesting.

14. CONCLUSIONS AND WILGA 2013

The WILGA May 2012 meeting was a fruitful event gathering young researchers from the fields of photonics and electronics systems. The 2013 Symposia on Photonics and Internet Engineering will be held on 24-27 January 2013 at WEiTI PW building in Warsaw and on 27.05 – 02.06 2013 in Wilga Resort by PW. The organizers warmly invite young researchers to present their work. The WILGA Symposium web page is under the address: http://wilga.ise.pw.edu.pl .

15. ACKNOWLEDGMENTS

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WILGA Symposium has produced more than 2500 articles, out of which over 1000 were published in Proc.SPIE. Several hundred of them are associated with the research activities of the PERG/ELHEP Research Group at ISE WUT. The Group is an initiator and major organizer of the WILGA Symposia. The paper was prepared using the invited and contributed presentations debated during Wilga 2012 May Edition. Some fragments of the text were quoted from these presentations and from session discussions.

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