RESULTS FROM PREVIOUS PROJECTS

1994
Financing agency: JNICT
Project reference: STRDC/C/FAE/1011/93
Financing: 14600 contos
Dates: 1/1/94 to 31/12/94
Title: Neural Methods in High Energy Physics

Summary: Research on algorithms, architectures and neural methods adapted to high energy physics problems, with particular emphasis on the trigger systems of the future LHC experiments. Study of the calorimeter trigger of the CMS experiment. Study of the trigger of the Squash experiment. Beam tests of the electromagnetic calorimeter Shashlik.

Publications:

The Compact Muon Solenoid (CMS), Technical proposal', CERN/LHCC 94-38

Calorimeter trigger in CMS: algorithm studies, Ph. Busson, J. Varela, CMS technical note 94-219, 1994.

Influence of dead materials and cracks in the performance of the CMS e.m. calorimeter, V. Genchev, V. Popov, J. Varela, CMS technical note 94-176, 1994.

New test beam results of Shashlik and preshower prototypes, J. Badier et al., CMS technical note 94-152, 1994.

Multi-bundle Shashlik calorimeter prototypes: beam-test results, J. Badier et al., CMS technical note 94-197, 1994.

Status report: Embedded architectures for second level triggering, RD11 Collaboration, CERN-DRDC-94-20, 1994.

Multibundle shashlik calorimeter prototypes beam test results, RD36 Collaboration (J. Badier et al.). 1995. Nucl. Instrum. Methods A354 (1995) 328-337.

Strangelet, quark and antinuclei search at high sensitivity,
Proposal SPSLC/P289, CERN/SPSLC 95-15, 1995.

1995
Financing agency: JNICT
Project reference: PCERN/P/FAE/130/94
Financing: 31500 contos
Dates: 1/1/95 to 31/12/95
Title: R&D on Calorimeter Trigger Systems

Summary:
Study of the calorimeter trigger of the CMS experiment and study of the trigger of the Squash experiment.

Study of trigger algorithms:
During 95, the LIP group developed a study based on a more complete simulation, using the CERN software packages Pythia (event generator) and Geant (detector simulation). A detailed description of the CMS detector implemented in the CMSIM package was used, and a method which combines the Geant hadronic shower description with a parametrization of the electron showers was developed.
In 1995, the portuguese group proposed an improved version of the trigger algorithms, known as 'fine grain trigger', which combines the good features of the previous algorithms and which takes profit of the fine granularity of the e.m. crystal calorimeter.

System design
Encouraged by the results of the study of the 'fine grain' trigger, we decided to investigate in 95-96 the engineering feasibility of this concept. This implied the investigation of the fine grain trigger primitive generation close to the front-end and the study of the implications of the new primitives on the Regional Crate backplane and on the Processor Card. The first aspect was studied by the portuguese group together with LPNHE-Palaiseau.

Development of prototypes
The LIP group, together with LPNHE-Palaiseau and the CMS calorimeter electronics group, developed an integrated prototype of the front-end calorimeter electronics, trigger primitive generator and optical transmission, and test, control and readout functions. Design work was performed during 1995.

Publications:
Physics at the Large Hadron Collider,
J. Varela, in Proceedings of the 'XV Autumn School', Nuclear Physics B (Proc. Suppl.) 37C (1995) 121-134, Lisbon, 1993
A contribution for the trigger strategy of CMS,
C. Lourenço, J. Varela, CMS technical note 95-025, 1995.
Towards a fine granularity calorimeter trigger for CMS,
C. Lourenço, J. Varela, CMS technical note 95-027, 1995.
A low Pt 1st level single electron trigger for beauty studies in CMS,
C. Lourenço, A. Nikitenko, J. Varela, CMS TN 95-197, 1995.
A study of the 1st level t trigger,
A. Nikitenko, J. Varela, CMS TN 95-195, 1995.
A simulation study of the ECAL/HCAL interface region,
A. Nikitenko, J. Varela, CMS TN 95-196, 1995.
A neural network trigger with a RICH detector,
R. Nóbrega, J. Varela, in Proceedings of '4th International Workshop on Software Engineering and Artificial Intelligence for High Energy and Nuclear Physics, Pisa, 1995.
A RICH counter for trigger and detection of exotic particles,
R. Nóbrega, P. Sonderegger, J. Varela, in Proceedings of 'RICH95 Workshop', Upsala, 1995.
Requirements for a fine grain calorimeter trigger,
J. Varela, in Proceedings of 'First Workshop on Electronics for LHC Experiments', Lisbon, 1995.
Beam test results of a shashlik calorimeter in high magnetic field,
RD36 Collaboration (P. Aspell et al.). CERN-PPE-95-152, Sep 1995. 20pp. , Nucl.Instrum. Methods

1996
Financing agency: JNICT
Project reference: PCERN/P/FAE/1033/95
Financing: 42100 contos
Dates: 1/1/96 to 31/12/96
Title: Participation in the CMS/LHC experiment (Development of the Calorimeter Trigger System)

Summary:
Development of the calorimeter trigger of the CMS experiment
   A significant contribution to *the simulation study of the trigger algorithms* was done in 1996.
   In 1996 the main milestone (CMS Trigger/DAQ milestone D21) was *the test of a Trigger Primitive Prototype System,* in conjunction with the ECAL FERMI electronics prototype, and with the crystal calorimeter prototype in the H4 beam. This milestone was successfully completed.
   The *design of the trigger control system* was pursued according to the schedule. During 1996 we pursued the definition of the control and readout model, which in this phase was translated in a rather extensive User Requirements Document. The first release of the document was submitted to comments by the collaboration in October 1996.
   In 1996, the LIP group developed a conceptual design the *trigger data synchronization system.*
   In the software area an activity on the evaluation of object-oriented design methods and tools, object-oriented data-bases and on the use of the CORBA standard in control systems was foreseen. A collaboration with the portuguese software company OBLOG was also planned. These activities were severely suppressed or postponed due to lack of resources.

Publications:
   Energy and spatial resolution of a shashlik calorimeter and a silicon preshower detector,
   RD36 Collaboration (P. Aspell et al.). CERN-PPE-95-151, Sep 1995. 34pp.
   Nucl. Instrum. Methods A376:17-28, 1996
   CMS electron/photon trigger - A simulation study with CMSIM data,
   R. Nóbrega, J. Varela, CMS TN 96-21, 1996.
   Preliminary specifications of the baseline trigger algorithms,
   CMS Calorimeter Trigger Group, CMS-TN-96-10, 1996
   Hermetic EM Calorimetry in CMS,
   R. Ribeiro, J. Varela, CMS-TN-96-64, 1996
   Second level e/γ calorimetr trigger in CMS,
   R. Nóbrega, J. Varela, CMS NOTE 1996/010.
   CMS Calorimeter Trigger Primitives Boards,
   Ph. Busson, D. Lecouturier, E. Machado, P. Matricon, J.C. Silva, J. Varela,
   CMS IN 1996/008
   A method for synchronization of the trigger data,
   J. Varela, CMS NOTE/1996-011
   A Compression Scheme for ECAL Trigger Primitives,
   Ph. Busson, R. Nobrega, J. Varela, CMS IN 1996/007

1997
Financing agency: JNICT
Project reference: PCERN/C/FAE/1106/96
Financing: 30000 contos
Dates: 1/1/97 to 31/12/97
Title: Participation in the CMS/LHC experiment (Development of the Calorimeter Trigger System)

Summary:
The LIP research activities in CMS in 1997 had four main components: i)analysis of test beam data collected with the trigger prototypes; ii) development of trigger data synchronization prototypes; iii) design of the trigger readout & control system; iv) development of high level trigger algorithms.
Trigger prototypes and analysis of test beam data
   The analysis, performed by the LIP group, of the data collected in June-August 96 in the H4 test beam with a prototype of the trigger and digital processing electronics for the electromagnetic calorimeter of the CMS experiment, coupled to a prototype of the PbWO4 crystal calorimeter, was concluded. The good quality of these data shows that the system performed as expected. A very successful operation was achieved for this system, which runs in synchronous and pipelined mode at the LHC clock frequency, and performs the basic trigger and data acquisition functions needed in the CMS electromagnetic calorimeter. The performance of the trigger front-end electronics is well within the established requirements: a highly efficient bunch crossing identification (>99.9%), a good trigger energy resolution (=9%/ $\sqrt{2}$ %) and a highly efficient electron cluster shape identification (99%) have been achieved. The FERMI digitizing system based on a dynamic analog compressor and a sampling ADC showed a very good performance, in particular the energy resolution for 150 GeV electrons was 0.54%, equal to the resolution obtained with a conventional charge integration ADC system.
Trigger data synchronization prototypes
   The LIP group developed the method to synchronize the trigger data, transmitted through the 4000 optical links, at the input of the regional trigger processors (CMS Note 1996/011 'A method for synchronization of the trigger data'). A specification of the basic components, the Sync TX and Sync RX circuits, was produced ('Specification of the prototype trigger synchronization Tx/Rx circuits', CMS IN 1997/009). The design of this circuits was undertaken by the portuguese enterprise Tecnologias de Microelectronica (TECMIC). This circuits were integrated in the trigger synchronization test setup and were successfully tested.
Design of the trigger readout & control system
    The basic object-oriented tools necessary to the development of a small scale prototype were installed, namely the Rational/Rose C++ CASE system and the object oriented data base Objectivity.
High-level trigger algorithms
    The study of the 2nd level electron/photon trigger was concluded. Using the full granularity of the e.m. calorimeter and a dedicated neural network algorithm, the electron/photon trigger rate is reduced by a factor 7 keeping the electron/photon efficiency at 98%.
    This work is part of a research line in neural networks applied to high energy physics initiated by the group in 1992. The writing of a PhD thesis on the area of neural networks applied to triggers in HEP was concluded.

Publications:
   Modular Neural Networks applied to trigger in high energy physics,
   Ph. Busson, R. Nóbrega, J. Varela, Nucl. Instrum. Meth. A 410 (1998) 273-283
   Beam tests of the trigger and digital processing electronics for the electromagnetic calorimeter of the CMS experiment.,
   R. Benetta et al. Nucl. Instrum. Meth. A 413 (1998) 31-42.
   Neural Networks in HEP triggers
   R. Nobrega, J.Varela, published in the proceedings of 'Computing for High Energy Physics', Berlin, April 1997.
   Trigger Synchronisation Circuits in CMS,
   J. Varela, in Proceedings of 'Third Workshop on Electronics for LHC Experiments', London, 1997.
   Specifications of the prototype trigger synchronization Tx/Rx circuits,
   J.C. Silva, J. Varela, CMS IN 1997/009
   The TPB System Board Technical Documentation,
   A. Almeida, E. Machado, R. Nobrega, J.C. Silva, J. Varela, CMS IN 1997/013

ECAL data volume,
R. Benetta, Ph. Busson, B. Lofstedt, M. Hansen, R. Nóbrega, J.C. Silva, J. Varela,
CMS NOTE 1997/059
Trigger Synchronisation Circuits in CMS
J. Varela, L. Berger, R. Nobrega, A. Pierce, J.C. Silva
CMS CR/1997 - 017

1998

Title: CMS/LHC Experiment at CERN: Collaboration in the Development of the Calorimeter Trigger System

Summary:

A redefinition of the Trigger Primitive Generation (TPG) architecture was produced reflecting the need to increase the flexibility of the trigger algorithms and the need to integrate the TPG with the calorimeter readout functions. The final partition of responsibilities between the institution involved in the ECAL trigger and readout system was defined. A study of a Neural approach for the e/ trigger primitive generation was made showing a potential reduction of the e/ trigger rate by a factor 4.

The functionality and technical choices for the prototype Local Readout Unit (LRU) in the trigger crates were identified. The engineering design of the LRU/PMC prototype was done and the first prototypes were built. A first release of the Ecal DCC System Design Description document was produced.

The develop of a first prototype of the Calorimeter Trigger Read-out and Control System software was started, including the functionality needed to operate the Trigger Primitives System hardware prototypes.

During the first year of the collaboration, INESC has been evaluating the use of the ANSI IEEE 1149.1 Standard at different levels (component, MCM, board, system), the inclusion of self-test techniques, in-system test procedures, as well as, the specification of the system using a high level description approach.

Publications:
Calorimeter Trigger Primitives, System Requirements Specification, edited by J. Varela, TriDAS/CT/TPS/SRS/2.0/1.0, 12 May 1998.
Study of a Neural Approach for lower level e/γ calorimeter trigger in CMS, N. Leonardo, J. Varela, CMS NOTE 1998/081
ECAL Data Concentrator - System Design Description, J.C. Silva, C. Tully, J. Varela, G. Varner, Preliminary Specification, Draft 0.1, 4 June 1998, CMS Technical Document
DCP, A Data Communications Protocol framework for a HEP Data Acquisition System, Software Requirements Document, I. Videira, S. Silva, CARDS SRD-DCP-vDraft
CARDS Front-end Sub-system, Software Requirements Document, S. Silva, CARDS TPS-SRD-vDraft, CMS Technical Document
Using the Boundary Scan testing at System Level, N. Cardoso, INESC, March 1998
Proposed Methods for Testing a Board Composed of Several Modules, N. Cardoso, INESC, 1998.
Application of Boundary Scan at Board and System Level, N. Cardoso, C, Beltran, INESC, Intermediate Report of Task 4.2, Project Nº CERN/P/FAE/1147/97
Study of Rates from High-level Trigger of B0s Events, N. Leonardo, J. Varela, CMS NOTE 1998/082

Summary:

The specification of the second version of the synchronization circuit was written and the design was done at TECMIC. An implementation in FPGA was produced and tested.

The new Synchronization circuit was integrated in a prototype of the SLB (Synchronization and Link Board.

In parallel a new VME test board to evaluate the performance of the new circuit was developed.

As part of the quality control tasks developed by INESC, the circuit design was analyzed by the INESC group in order to include built-in self-test structures. The BIST was integrated in the FPGA version.

Publications:

Specifications of the Calorimeter Trigger Synchronization Circuit, Version 2.2, J. C. Silva, J. Varela, CMS Internal Note to be published.

Introduction of Built-In Self Test (BIST) in the Sync Tx/Rx IC, M. B. Santos, J. P. Teixeira, INESC, June 1998.

Using an LHC-like Test Beam to Study the Trigger and Front-End Readout Synchronization of the CMS Detector
J. Varela, CMS IN 1998-012

1999
Financing agency: FCT
Project reference: CERN/P/FIS/1193/98
Financing: 35000 contos
Dates: 1/1/99 to 31/12/99
Title: Collaboration in the CMS/LHC Experiment at CERN

Summary:
   The SLB prototype was successfully tested in a dedicated test system built on purpose. The SLB prototype includes all the functionality except the trigger links.
   The concept of ECAL selective readout for reducing the amount of data to be collected without damaging the physics, developed by LIP, was simulated in order to estimate data volumes and impact on physics.
   A study of selective readout implementations and an architectural design of the data collection were performed. Preliminary system simulations were done in order to estimate buffer sizes and readout latencies.
   The design of the Trigger Control Software was pursued, in particular the calorimeters front-end software.
   During the second year of the collaboration, INESC has been evaluating the use of the ANSI IEEE 1149.1 Standard (BoundaryScan) (BS) at different levels (component, MCM, board, system), the inclusion of self-test techniques in system test procedures, the validation of test effectiveness and system specification and simulation using a real-time object-oriented modeling technique.

Publications:
   Recent developments in the CMS Calorimeter Trigger,
   T. Monteiro and CMS ECAL Upper-Level Readout and Trigger group, to be published in Proceedings of Int. Conf. on Calorimetry in HEP (CALOR99) Lisbon (Portugal), 1999.
   Selective Readout in the CMS ECAL
   T. Monteiro, Ph. Busson, W. Lustermann, T. Monteiro, J. C. Silva, C. Tully, J. Varela, in Proceedings of 'Fifth Workshop on Electronics for LHC Experiments', Snowmass, Colorado, USA, 1999.
   Testability Issues In The CMS Ecal Upper-Level Readout And Trigger System,
   Carlos Beltrán Almeida, Isabel Cacho Teixeira, Joao Paulo Teixeira, José Augusto, Marcelino Santos and Nuno Cardoso, INESC, Lisboa , Joao Varela, CERN Geneve/LIP Lisbon in Proceedings of 'Fifth Workshop on Electronics for LHC Experiments', Snowmass, Colorado, USA, 1999.
   Study of the ECAL Data Concentrator,
   C. Tully, J. Varela, J.C. Silva, G. Varner, CMS IN-1999/012
   Techical Specifications of the ECAL trigger Synchronization and Link Board, S. Silva, J. Varela, CMS IN-2000/005
   ECAL Data Synchronization, J. Varela et al., CMS IN-2000/006