Calor 2012

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Book of abstracts

Table of contents

Opening Session / 74

Welcome and Opening Remarks

Prof. AKCHURIN, Nural [1]

[1] *TTU*

Welcome and Opening Remarks

Opening Session / 72

The Role of the LAr Calorimeter in the Search for H->gamma gamma in ATLAS (invited)

Dr. UNAL, Guillaume [1]

[1] *CERN*

In the low mass range (~100 to ~140 GeV) one of the most promising search channel for the Higgs boson at the LHC is the rare decay in a pair of photons. Photon identification and energy as well as direction measurements are key ingredients to reduce backgrounds and maximize the sensitivity to the Higgs boson signal. This talk will describe the analysis of the Higgs boson search in the two photon decay channel performed by the ATLAS experiment using ~5 fb-1 of pp collisions data recorded in 2011 at the LHC. The role of the ATLAS Liquid Argon calorimeter in this analysis will be emphasized.

Opening Session / 82

Role of the CMS Electromagnetic Calorimeter in the Hunt for the Higgs Boson in the Two-gamma Channel (invited)

TABARELLI DE FATIS, Tommaso [1]

[1] *Universita' & INFN Milano-Bicocca*

The distinctive signature of the two-photon decay of a low-mass Higgs boson (H → γ γ) would be a narrow resonance, smeared by the photon energy and direction resolution, over a non-resonant background of di-photons or spurious events. The sensitivity to this decay mode greatly benefits from the energy and position resolution and photon identification capabilities of the electromagnetic calorimeters at the LHC. In this context, the performance of the electromagnetic calorimeter (ECAL) of CMS - a hermetic, fine grained and homogeneous calorimeter made of lead-tungstate ($PbWO_4$) crystals, completed by a silicon/lead preshower installed in front of the endcaps - is presented.

Large Hadron Collider / 83

Universal Scaling Phenomena in Biological Systems and in Urban Environments (keynote)

Prof. WEST, Geoffrey [1]

[1] *Santa Fe Institute*

Geoffrey West is a theoretical physicist whose primary interests have been in fundamental questions in physics, especially those concerning the elementary particles, their interactions and cosmological implications. West served as SFI President from July 2005 through July 2009. Prior to joining the Santa Fe Institute as a Distinguished Professor in 2003, he was the leader, and founder, of the high energy physics group at Los Alamos National Laboratory, where he is one of only approximately ten Senior Fellows.

His long-term fascination in general scaling phenomena evolved into a highly productive collaboration on the origin of universal scaling laws that pervade biology from the molecular genomic scale up through mitochondria and cells to whole organisms and ecosystems. This led to the development of realistic quantitative models for the structural and functional design of organisms based on underlying universal principles. This work, begun at the Institute, has received much attention in both the scientific and popular press, and provides a framework for quantitative understanding of problems ranging from fundamental issues in biology (such as cell size, growth, metabolic rate, DNA nucleotide substitution rates, and the structure and dynamics of ecosystems) to questions at the forefront of medical research (such as aging, sleep, and cancer). Among his current interests is the extension of these ideas to understand quantitatively the structure and dynamics of social organizations, such as cities and corporations, including the relationships between economies of scale, growth, innovation and wealth creation and their implications for long-term survivability and sustainability.

He is a Fellow of the American Physical Society and was one of their Centenary Speakers in 2003. He has been a lecturer in many popular and distinguished scientist series worldwide, as well as at the World Economic Forum. Among recent honors he was a co-receiver of the Mercer Award from the Ecological Society of America, the Weldon Memorial Prize (2005), Oxford University and the Glenn Award for research on Aging. In 2006 he was named one of Time magazine's"100 Most Influential People in the World" and his work selected as one of the breakthrough ideas of 2007 by the Harvard Business Review. He is the author of several books, a visiting Professor of Mathematics at Imperial College, London, and an Associate Fellow of the Said Business School at Oxford University.

West received his BA from Cambridge University in 1961 and his doctorate from Stanford University in 1966, where he returned in 1970 to become a member of the faculty.

Large Hadron Collider / 15

First Years of Running for the LHCb Calorimeter System

PERRET, Pascal [1]; LHCB COLLABORATION, Calorimeter group [2]; VILASIS CARDONA, Xavier [3]

[1] *Laboratoire de Physique Corpusculaire Universite Blaise Pascal - CNRS/IN2P3*

[2] *CERN*

[3] *Universitat Ramon Llull*

The LHCb experiment is dedicated to precision measurements of CP violation and rare decays of B hadrons at the Large Hadron Collider (LHC) at CERN (Geneva) [1, 2]. LHCb is a single-arm spectrometer with a forward angular coverage from approximately 10 mrad to 300 mrad. It comprises a calorimeter system composed of four subdetectors [3], selecting transverse energy hadron, electron and photon candidates for the first trigger level (L0), which makes a decision 4µs after the interaction. It provides the identification of electrons, photons and hadrons as well as the measurement of their energies and positions. The set of constraints resulting from these functionalities defines the general structure and the main characteristics of the calorimeter system and its associated electronics. A classical structure of an electromagnetic calorimeter (ECAL) followed by a hadron calorimeter (HCAL) has been adopted. In addition the system includes in front of them the Scintillating Pad Detector (SPD) and Pre-Shower (PS), which are two planes of scintillating pads separated by a 2.5 radiation length lead sheet, aimed at tagging the electric charge and the electromagnetic nature of the calorimeter clusters for the first level of trigger. ECAL, PS and SPD account for about 6000 channels each with three degrees of granularity, concentric around the beam pipe, namely, the inner, the middle and the outer parts. HCAL is made of about 1500 channels and is divided into two parts only. All four detectors are arranged in pseudo-projective geometry and follow the general principle of reading the light from scintillator tiles with wave-length shifting fibers, and transporting the light towards photomultipliers, all following the 25 ns readout.

The calorimeter has been pre-calibrated before its installation in the pit, and the calibration techniques have been tested with the data taken in 2010. During 2010 and 2011 operation, hadronic, leptonic and photon triggers of particular interest for hadronic B decays and radiative decays were provided by the calorimeter system.

The design and construction characteristics of the LHCb calorimeter will be recalled. Strategies for monitoring and calibration during data taking will be detailed in all aspects. Scintillating fibres, plastics and photomultipliers suffer from ageing due to radiation damage or high currents. Different methods which are used to calibrate the detectors and to recover the initial performances will be presented. The performances achieved will be illustrated in selected channels of interest for B physics.

References:

[1] LHCb Collaboration, The LHCb Detector at the LHC, JINST 3 S08005 (2008), and references therein.
[2] LHCb Collaboration, A large Hadron Collider Beauty experiment, Technical Proposal, CERN/LHCC 1998-004.
[3] LHCb Collaboration, LHCb calorimeters Technical Design Report, Technical Design Report, CERN/LHCC 2000-036.

Large Hadron Collider / 17

Status of the ATLAS Liquid Argon Calorimeter and its Performance after Two Years of LHC Operation

Mr. ABOUZEID, Hass [1]

[1] *University of Toronto*

The ATLAS experiment is designed to study the proton-proton collisions produced at the Large Hadron Collider(LHC) at CERN. Liquid argon sampling calorimeters are used for all electromagnetic calorimetry covering the pseudo-rapidity region up to 3.2, as well as for hadronic calorimetry in the range 1.4-4.9. The electromagnetic calorimeters use lead as passive material and are characterized by an accordion geometry that allows a fast and uniform azimuthal response without any gap. Copper and tungsten were chosen as passive material for the hadronic calorimetry; whereas a classic plate geometry was adopted at large polar angles, an innovative one based on cylindrical electrodes with thin argon gaps was designed for the coverage at low angles, where the particles flow is higher. All detectors are housed in three cryostats kept at 87 K. After installation in 2004-2006, the calorimeters were extensively commissioned over the three years period prior to first collisions in 2009, using cosmic rays and single LHC beams. Since then, around 5 fb^{-1} of data have been collected at a center of mass energy of 7 TeV. During all these stages, the calorimeter and its electronics have been operating almost optimally, with performances very close to the specification ones. The talk will cover all aspects of these first years of operation, including the calibration efforts, the data quality assessment procedure, and the final performance.

Large Hadron Collider / 46

Operational Experience with the CMS Hadronic Calorimeter in the 2011 LHC Run

Dr. GOLDENZWEIG, PABLO [1]

[1] *UNIVERSITY OF ROCHESTER*

The Hadronic Calorimeter (HCAL) of the CMS experiment has successfully recorded data at a center-of-mass energy of 7 TeV during the 2011 LHC run. Performance of the HCAL detector components and operational experience gained will be reviewed, as well as the overall impact of the HCAL on the physics reach of the CMS experiment.

Large Hadron Collider / 13

The CMS HF Status

Dr. RAHMAT, Rahmat [1]; Prof. AKCHURIN, Nural [2]

[1] *University of Mississippi*

[2] *TTU*

The experiments at the Large Hadron Collider will have to deal with unprecedented radiation levels. The design of the CMS forward calorimetry detector (HF) is now finalized. The present design of CMS calls for the HF calorimeter to be based on quartz fiber technology. It consists of two modules, located symmetrically at about 11 meters from either side of interaction point. They cover the pseudorapidity range 3-5. The length along the beam is 1.65m or 10 nuclear interaction lenghts. Each calorimeter consists of a large steel block that serves as the absorber. Embedded quartz fibers in the steel absorber run parallel to the beam and constitute the active component of the detector. In order to optimize energy resolution for E and ET flows and forward jets, the calorimeter is effectively segmented longitudinally by using two different fiber lengths. The present status will be discussed.

Large Hadron Collider / 21

The ATLAS Tile Calorimeter Performance at LHC

Dr. FRANCAVILLA, Paolo [1]

[1] *IFAE Barcelona*

The Tile Calorimeter (TileCal), the central section of the hadronic calorimeter of the ATLAS experiment, is a key detector component to detect hadrons, jets and taus and to measure the missing transverse energy. Due to the very good muon signal to noise ratio it assists the spectrometer in the identification and reconstruction of muons. TileCal is built of steel and scintillating tiles coupled to optical fibers and read out by photomultipliers. The calorimeter is equipped with systems that allow to monitor and to calibrate each stage of the read-out system exploiting different signal sources: laser light, charge injection, a radioactive source and the signal produced by minimum bias events. The performance of the calorimeter has been measured and monitored using calibration data, random triggered data, cosmic muons, splash events and most importantly the large sample of pp collision events. Results are discussed that demostrate how the calorimeter is operated, how is monitored and what performance has been obtained. These results demonstrate that the Tile Calorimeter is performing well within the design requirements and is giving essential input to the physics results.

Large Hadron Collider / 26

Single Hadron Response Measurement in ATLAS

Dr. STAROVOITOV, Pavel [1]

[1] *DESY*

Single hadron response measurement in minimum bias proton-proton collisions at a center of mass energy of sqrt(s)=7 TeV are presented. Together with test-beam results, these measurement form the basis to evaluate the calorimeter energy response uncertainty of jets at high transverse momenta. A novel technique to evaluate the jet energy response from the single particle response will be presented.

The single hadrons response is measured in the momentum range of 0.5 to about 20 GeV in-situ, by comparing the calorimeter response of all energy deposits in a cone around an isolated track with the more precisely measured track momenta. The agreement between data and Monte Carlo simulation is on the level of a few percent.

Using kaon and Lambda particles, the calorimeter response of identified pions, proton and anti-proton is studied. The MC simulation describes the energy response of pions and protons well, but differences are observed for anti-protons. It is discussed how the jet calorimeter response uncertainty and its correlation between transverse momentum bins is determined from these measurements.

Large Hadron Collider / 2

Calorimeter Performance for Tau Reconstruction and Identification at ATLAS

Dr. VOLPI, Matteo [1]

[1] *The University of Melbourne*

The ATLAS tau physics program ranges from Standard Model measurements involving W, Z, and top pair production, to searches for Higgs, Supersymmetry and other beyond the Standard Model signatures. The ATLAS calorimeter plays a large role in the reconstruction and identification of hadronically decaying tau leptons at ATLAS. This talk discusses the role of the calorimeter in reconstructing the tau energy, as well as methods to measure the systematic uncertainties on the tau energy scale. The calorimeter is further a key component in building identification variables used to differentiate tau candidates from hadronic jets. The role of these variables is presented, and challenges in correcting these variables in high luminosity environments is also discussed. A brief overview of the impact of the energy scale and identification efficiency uncertainties in searches for new physics with tau-based signatures is also given.

Large Hadron Collider / 76

Missing ET Reconstruction with the CMS Detector

Dr. SAKUMA, Tai [1]

[1] *Texas A&M University*

The results of comprehensive studies of missing transverse energy as measured by the CMS detector are presented. The missing transverse energy reconstruction from the calorimeter information alone and also from the combination of all the sub-detector information using the particle-flow technique is deployed for various physics analyses. The scale and resolution for missing transverse energy are validated using vector boson and dijet events, and severe mismeasurements due to the detector are studied. We also discuss the effects of the multiple pp interactions on the missing ET resolution and the method to improve the missing ET resolution.

Large Hadron Collider / 27

Measurement of the Missing Transverse Energy with the ATLAS Calorimeter

Dr. VICHOU, Eirini [1]

[1] *University of Illinois at Urbana-Champaign*

The measurement of missing transverse momentum in the ATLAS detector makes use of the full event reconstruction and a calibration based on reconstructed physics objects. The performance of the missing transverse momentum reconstruction is evaluated using data collected in pp collisions at a center-of-mass energy of 7 TeV in 2010 and 2011. Minimum bias events and events with jets of hadrons are used from data samples corresponding to an integrated luminosity of about 0.3/nb and 600/nb respectively, together with events containing a Z-boson decaying to two leptons (electrons or muons) or a W-boson decaying to a lepton (electron or muon) and a neutrino from a data sample corresponding to an integrated luminosity of about 36/pb. An estimate of the systematic uncertainty on the missing transverse momentum scale is presented.

Large Hadron Collider / 25

Jet Energy Scale Uncertainties in ATLAS

Dr. BARILLARI, Teresa [1]

[1] *Max-Planck-Inst. fuer Physik*

About one year after the first proton proton-proton collisions at a centre of mass energy of sqrt(s)= 7 TeV, the ATLAS experiment has achieved an accuracy of the jet energy measurement between 2-4% for jet transverse momenta from 20 GeV to 2 TeV in the pseudo-rapidity range up to |eta|=4.5. The jet energy scale uncertainty is derived from in-situ single hadron response measurement along with systematic variations in the Monte Carlo simulation. In addition, the transverse momentum balance between a central and a forward jet in events with only two jets at high transverse momentum is used to set the jet energy uncertainty in the forward region.

The obtained uncertainty is confirmed by in-situ measurements exploiting the transverse momentum balance between a jet and a well measured reference object like the photon transverse momentum in photon-jet events.

Jets in the TeV-energy regime were tested using a system of well calibrated jets at low transverse momenta against a high-pt jet. Preliminary results from the 2011 run based on an integrated luminosity of 5/fb reducing further the uncertainties on the jet energy scale will also be presented.

Large Hadron Collider / 58

Determination of Jet Energy Scale in CMS

Mr. KIRSCHENMANN, Henning [1]; Prof. VOLOBOUEV, Igor [2]

[1] *University of Hamburg*

[2] *Texas Tech University*

We present a summary of the measurements of the jet energy scale in CMS, performed with a data sample collected in proton-proton collisions at a centre-of-mass energy of 7 TeV, corresponding to an integrated luminosity of 4.9 fb−1. Dijet and photon/Z+jets events are used to measure the jet energy response in the CMS detector. The results are presented for the "Particle Flow" approach, which attempts to reconstruct individually each particle in the event, prior to the jet clustering, based on information from all relevant subdetectors.

Large Hadron Collider / 50

Jet Energy Uncertainties: Reducing their Impact on Physics Measurements

EUSEBI, Ricardo [1]

[1] *Texas A&M University*

The measurement of any physical quantity at CMS includes the estimation of a systematic error propagated from the uncertainties on the jet energy calibration. For some physical quantities the main systematic error results from this propagation. This talk will present the main uncertainties sources considered on the jet energy calibration, the effect these have on some particular analyses, and a novel way of handling uncertainties recently deployed at CMS to reduce the dependence on these uncertainties.

Calorimeter Techniques / 18

Upgrade Plans for ATLAS Forward Calorimetry for the HL-LHC

Prof. RUTHERFOORD, John [1]

[1] *University of Arizona*

Although LHC data-taking is expected to continue for a number of years, plans are already being developed for operation of the LHC and associated detectors at an increased instantaneous luminosity about 5 times the original design value of 10^{34} cm^{-2} s${^-1}$. The increased particle flux at this high luminosity (HL) will have an impact on many sub-systems of the ATLAS detector. In particular, in the LAr forward calorimeter (FCal), which was designed for operation at LHC luminosities, the associated increase in the ionization load at HL-LHC luminosities poses a number of problems that can degrade its performance, related to beam heating, space charge effects in the LAr gaps, and HV losses due to increased current draws over the HV current-limiting resistors. One solution to these problems, which would require the opening of both endcap cryostats, is the construction and installation of a new FCal, with cooling loops, narrower LAr gaps, and lower value protection resistors. A second proposed solution, which does not involve opening the cryostats, is the installation of a small warm calorimeter in front of the FCal, resulting in a reduction of the particle flux to levels at which the existing device can operate normally.

The talk will review the design of the ATLAS forward calorimeter and discuss the effects that are expected to degrade the performance at HL-LHC luminosities as well as the proposed upgrade scenarios.

Calorimeter Techniques / 6

Luminosity Limits for Liquid Argon Calorimetry

Prof. RUTHERFOORD, John [1]; Mr. WALKER, Robert [1]

[1] *University of Arizona*

We have irradiated liquid argon ionization chambers with betas using high-activity Strontium-90 sources. The radiation environment is similar to that in the liquid argon calorimeters which are part of the ATLAS detector installed at CERN's Large Hadron Collider (LHC). We measure the ionization current over a wide range of applied potential for two different source activities and for three different chamber gaps. These studies provide operating experience at exceptionally high ionization rates. We can operate these chambers in the normal mode or in the space-charge limited regime and thereby determine the transition point between the two. From the transition point we indirectly extract the positive ion mobility.

Calorimeter Techniques / 20

Liquid Argon Calorimeter Performance at High Rates

Mr. SEIFERT, Frank [1]

[1] *TU Dresden, Germany*

The expected increase of luminosity at HL-LHC by a factor of ten with respect to LHC luminosities has serious consequences for the signal reconstruction, radiation hardness requirements and operations of the ATLAS liquid argon calorimeters in the endcap, respectively forward region. Small modules of each type of calorimeter have been built and exposed to a high intensity proton beam of 50 GeV at IHEP/Protvino. The beam is extracted via the bent crystal technique, offering the unique opportunity to cover intensities ranging from 10^6 p/s up to 10^{12} p/s. This exceeds the deposited energy per time expected at HL-LHC by more than a factor of 100. The correlation between beam intensity and the read-out signal has been studied. The data show clear indications of pulse shape distortion due to the high ionization build-up, in agreement with MC expectations. This is also confirmed from the dependence of the HV currents on beam intensity.

Calorimeter Techniques / 10

Upgrade of the CMS Hadron Outer Calorimeter with SiPM Sensors

Dr. LUTZ, Benjamin [1]

[1] *DESY*

The CMS Hadron Outer Calorimeter (HO) is undergoing an upgrade to replace the existing photodetectors (HPDs) with SIPMs. The chosen device is the Hamamatsu 3X3mm^2, 50µm pitch MPPC. A system has been developed to be a "drop-in" replacement of the HPDs. A complete control system of bias voltage generation, leakage current monitoring, temperature monitoring, and temperature control using solid state Peltier coolers has been developed and tested. 108 channels of the system have been installed into CMS and operated for more than 1 year. The complete system of more than 2000 channels is in production and will be installed in the first LHC long shutdown scheduled for 2013.

Calorimeter Techniques / 16

Upgrade of the CMS Hardron Calorimeter for an Upgraded LHC

Dr. ANDERSON, Jake [1]; Dr. WHITMORE, Julie [1]; Dr. FREEMAN, Jim [1]

[1] *Fermilab*

The CMS Barrel (HB) and Endcap (HE) Hadron Calorimeters are scintillator sampling calorimeters with embedded wavelength shifting fibers (WLS) in the scintillator tiles. The fibers from the sampling layers are ganged together to form towers whose light is detected by photo-sensors. The photo-sensors that are currently used are hybrid photodiodes (HPDs). The HCAL upgrade is required for the upgraded luminosity (5*10^34) of the LHC. A key aspect of the HCAL upgrade is to add longitudinal segmentation to improve background rejection, energy resolution, and electron isolation at L1 trigger. The increased segmentation can be achieved by replacing the hybrid photodiodes (HPDs) with multi-pixel Geiger-mode avalanche photodiodes (also known as silicon photomultipliers (SiPMs)). The upgraded electronics are required to operate in a harsh environment and are constrained by the existing infrastructure. The proposed solutions span from chip level to system level. They include the development of a new ADC ASIC, the design and testing of higher speed transmitters to handle the increased data volume, the evaluation and use of circuits from other developments, evaluation of commercial FPGAs, better thermal design and improvements in the overall architecture.

Calorimeter Techniques / 70

EM Calorimeters for SoLID at Jefferson Lab

ZHAO, Zhiwen [1]; Dr. HUANG, Jin [2]

[1] *University of Virginia*

[2] *Los Alamos National Lab*

Several approved experiments at Jefferson Lab Hall A for the 12 GeV era will use a proposed detector, the Solenoid Large Intensity Device (SoLID). Two EM calorimeters with total area of 15 square meters are required for electron/pion separation. The challenge is to build the calorimeters to withstand high radiation dose in high magnetic field region and bring photon signals to low field region for readout. Several type of calorimeters were considered and we are favoring Shashlyk type as a result of balancing the features and cost. Our preliminary design and simulation of SoLID EM calorimeters will be presented.

Calorimeter Techniques / 34

Secondary Emission Calorimetry

Prof. WINN, David [1]

[1] *Fairfield University*

We describe compact, planar secondary emission (SE) ionization modules that can be used to detect and measure the energy of ionizing particle particle in electromagnetic and hadronic calorimeters, in very high raddam environments and at high rates, using both simulation and data. In a Secondary Emission detector module, Secondary Emission electrons (SEe) are generated from an SE cathode when charged hadron or electromagnetic particles or particularly shower particles penetrate the sampling module placed between absorber materials (usually Fe, Cu , Pb, W) in calorimeters, but could also be quasi-homogeneous "dynodes". The SE cathode is usually a thin (10-50 nm thick) simple metal-oxide film (but could be higher yield materials) on the surface of a metal plate, which serves as the entrance "window" to a compact vacuum vessel (metal or metal-ceramic); this SE film cathode is exactly analogous to a photocathode, and the SEe serve essentially identically to p.e. in an optical calorimenter. The SE sensor modules make use of modern electrochemically etched/machined or laser-cut metal mesh dynode sheets, as large as ~30 cm square, to amplify the Secondary Emission Electrons (SEe), much like those that compact PMT's use to amplify p.e.'s. The construction is easier than a PMT, since the entire final assembly can be done in air; there are no critical controlled thin film depositions nor vacuum activation and consequently bake-out can be a refractory temperatures; the module is sealed by welding or brazing or other high temperature joinings, with a simple final heated vacuum pump-out and tip-off. With 10 micron diameter wire W mesh, a module with about 45% of the density of W is possible. SE modules are compact, high gain, high speed, exceptionally radiation damage resistant, rugged, and cost effective, and can be fabricated in arbitrary tileable shapes. The SE sensor module anodes can be segmented transversely to sizes appropriate to reconstruct position of the core of the energy with high precision (~1mm). The GEANT4 and existing signal data give an estimated calorimeter response performance is a high as 10 Secondary Emission electrons (SEe) per electromagnetic MeV, with a signal gain per SEe >105 per SEe. The calorimeter pulse width is estimated to be <10 ns. The pi to electron signal is simulated to be above 75%.

Calorimeter Techniques / 30

Tests of a Semi-digital Hadronic Calorimeter

Prof. LAKTINEH, Imad [1]

[1] *Université de Lyon*

A high-granularity semi-digital Hadronic calorimeter using GRPC as the sensitive medium has been proposed for the future International Linear Collider project. A prototype of 1m3 was built within the CALICE collaboration in order to validate this option. The prototype intends to be as close as possible to the one proposed in the ILD Letter Of Intent. The active media of this HCAL are large GRPC detectors equipped with semi-digital electronics readout and 1 cm2 lateral granularity. The GRPC detector was designed to provide high detection efficiency, excellent homogeneity and negligible dead zones. The readout electronics was developed to associate performance and compactness. 48 GRPCs with their embedded electronics were tested in cosmic rays bench before to be assembled into the HCAL prototype. The HCAL was then tested with pion beams at CERN. The preliminary results confirm the expectations. Ongoing tests at the CERN PS and SPS will allow to validate definitely the choice of the GRPC as a good candidate for the sensitive medium of a semi-digital hadronic calorimeter.

Calorimeter Techniques / 69

Directly-coupled Tiles for Fine Granularity Scintillator Calorimetry

ZUTSHI, Vishnu [1]

[1] *Northern Illinois University*

We present results on the direct i.e. fiberless coupling of scintillator tiles to Multi-pixel Photon Counters. The fiberless option has the potential of simplifying the assembly and construction of a finely segmented scintillator-based calorimeter with solid-state photomultiplier readout. In this talk we show studies on the response and uniformity of directly coupled tiles to a source and particle beams and describe our concept of an integrated readout layer.

Calorimeter Techniques / 41

The Large-angle Photon Veto System for the NA62 Experiment at CERN

MOULSON, Matthew [1]

[1] *INFN/Frascati*

The branching ratio (BR) for the decay K^+ \to \pi^+\nu\bar{\nu} is a sensitive probe for new physics. The NA62 experiment at the CERN SPS will measure this BR to within about 10%. To reject the dominant background from channels with final state photons, the large-angle vetoes (LAVs) must detect photons with energies as low as 200 MeV with an inefficiency of less than 10^{-4}, as well as provide energy and time measurements with resolutions of \sim 10% and 1 ns for 1 GeV photons. The LAV detectors make creative reuse of lead-glass blocks recycled from the OPAL electromagnetic calorimeter barrel. We describe the mechanical design and challenges faced during construction, the development of front-end electronics to allow simultaneous time and energy measurements over an extended dynamic range using the time-over threshold technique, and the development of an in-situ calibration and monitoring system. Our results are based on test beam data collected using prototypes of the LAV detectors.

Calorimeter Techniques / 33

R&D on a New Construction Technique for W/ScFi Calorimeters.

Mr. TSAI, Oleg [1]; Prof. HUANG, Huan [1]; Prof. GAGLIARDI, Carl [2]; Prof. HEPPELMANN, Steven [3]; Dr. TRENTALANGE, Stephen [1]

[1] *UCLA*

[2] *Texas A&M University*

[3] *Penn State University*

We have been carrying out a R&D project to develop new simple and cost effective technique to build compact sampling calorimeters utilizing tungsten powder and scintillation fibers. Such calorimeter detectors are under consideration for the planned Electron Ion Collider experiment and for future upgrade of the STAR experiment at RHIC (BNL). In the first year of this R&D project we built two prototypes of very compact electromagnetic calorimeters and both prototype detectors were studied at FNAL test beam T1018 in January 2012. Details of the construction technique, results of the test run and our future plan will be presented.

Calorimeter Techniques / 59

Design Studies for the Calorimeter Systems for the sPHENIX Detector at RHIC

Dr. KISTENEV, Edouard [1]

[1] *Brookhaven National Laboratory*

The PHENIX Experiment at RHIC is planning a major upgrade to enable a comprehensive measurement of jets in relativistic heavy ion collisions, and to enhance its physics capabilities in nucleon-nucleus interactions, polarized proton collisions, and eventually electron-nucleus collisions at the Electron Ion Collider. This upgrade, sPHENIX, will include two new major calorimeter systems. One will be a hadronic calorimeter, which will be the first hadron calorimeter ever built for any experiment at RHIC, and the second will be a new compact electromagnetic calorimeter that will replace the existing lead-scintillator shashlik and lead glass calorimeters in the central region in PHENIX. These new calorimeters will cover a region of ±1.1 in pseudorapidity and 2 pi in phi, which will result in a factor of 3 increase in acceptance over the present PHENIX detector. The hadron calorimeter will have an energy resolution ~ 75%/√E and the electromagnetic calorimeter will have a resolution ~ 15%/√E. Both calorimeters will have nearly constant azimuthal segmentation and approximate projectivity back to the interaction vertex. However, due to their design, they will have a slightly varying sampling fraction as a function of depth, which will affect certain performance parameters such as compensation and energy resolution. This contribution will describe the physics requirements for combined calorimeter system, the overall design of the two calorimeters, and the simulation studies that have been carried out to understand their expected performance. A separate contribution to this conference will describe the technology choices for both detectors and the R&D efforts currently being pursued to develop them along with their readout systems.

Calorimeter Techniques / 68

Technology Choices for the sPHENIX Calorimeter Systems

Dr. WOODY, Craig [1]

[1] *Brookhaven National Laboratory*

The upgraded PHENIX Experiment, sPHENIX, will include two new major calorimeter systems. One will be a new hadronic calorimeter that will enable total energy jet measurements for the first time at RHIC, and the second will be a new compact electromagnetic calorimeter. The hadron calorimeter will be based on scintillator plates interspersed between steel absorber plates that are read out using wavelength shifting fibers. It will have a total depth of ~ 5 hadronic absorption lengths and will be divided into two longitudinal sections. These sections will be tilted slightly (~ 5 degrees) in order to avoid channeling of particles through the scintillator alone. The electromagnetic calorimeter will be an accordion design that uses scintillating fibers embedded into a matrix consisting of tungsten plates along with a tungsten powder and epoxy composite. It will have a total depth of ~ 17 radiation lengths, ~ 1 hadronic absorption length (adding to the hadronic calorimeter), an average radiation length ~ 5 mm, and a Moliere radius ~ 1.5 cm. It is envisioned that silicon photomultipliers will be used as the readout device for both calorimeters since both detectors will be located in a rather strong fringe field from a superconducting solenoid magnet. This contribution will describe the technology choices for both detectors and the R&D efforts currently being pursued to develop them along with their readout systems. A separate contribution to this conference will describe the physics requirements for combined calorimeter system, the overall design of the two calorimeters, and the simulation studies that have been carried out to understand their expected performance.

Calorimeter Techniques / 54

A Study on Radiation Hardness of PWO-II and BGO Crystals

Dr. YANG, FAN [1]; Dr. MAO, Rihua [1]; Dr. ZHANG, Liyuan [1]; Dr. ZHU, Renyuan [1]

[1] *Crystal Lab, HEP, Caltech*

We report in this paper an investigation on radiation hardness of 20 cm long PWO-II crystals produced at BTCP for the proposed Panda experiment at GSI and 20 cm long BGO crystals produced at SIC. The optical and scintillation properties of PWO-II and BGO crystal samples, such as transmittance and emission spectra, light output and response uniformity, were measured before and after Gamma-ray irradiations at 2, 8 and 30 rad/h. The result of PWO-II and BGO crystals is compared respectively to the PWO crystals used in the CMS experiment and the BGO crystals used in the L3 experiment. Progresses are observed in the radiation hardness for both PWO and BGO crystals. Their use for crystal calorimeters in future high energy physics experiments will be discussed. To maintain crystal precision a precision light monitoring system is mandatory to trace crystal transparency variations in situ, which is common for these two crystals.

Calorimeter Techniques / 52

LSO/LYSO Crystals for Future Crystal Calorimeters in High Energy Physics

Dr. ZHU, Ren-Yuan [1]

[1] *Caltech*

Because of their high stopping power (X$_0$ = 1.14 cm), fast (t = ~40 ns) and bright (4 times of BGO) scintillation and excellent radiation hardness, cerium doped silicate based heavy crystal scintillators (LSO and LYSO) have attracted a broad interest in the high energy physics community to pursue crystal calorimeters in severe radiation environment. This paper provides a brief summary of the R&D work carried out since 2004. The optical and scintillation properties and their radiation hardness are reported for large size crystals up to 28 cm long. Uniformization of the light response along 20 cm long SuperB LYSO crystals of tapered geometry is elaborated. Applications of this material for total absorption and sampling calorimeters in future high energy physics experiments, such as Mu2e, SuperB and CMS endcap upgrade, are discussed.

Calorimeter Techniques / 5

Simulation and Test of LYSO+APD Matrix with Photon Beams from 50 to 350 MeV

Dr. SARRA, Ivano [1]

[1] *LNF INFN*

Understanding the energy resolution terms for LYSO based calorimeters with APD readout at low energy (< 500 MeV) is relevant both for the experimentation of the KLOE-2 experiment, at DAFNE, and for the design of the mu2e calorimeter.

In this work, we present a dedicated comparison between experimental data, taken in 2011 at the MAMI tagged photon beam facility with a matrix prototype, and a full Geant-4 simulation of the detector.

The crystal prototype matrix consisted of 9 2x2x13 cm**3 LYSO crystals read-out by 10x10 mm**2 Hamamatsu avalanche photodiodes (APD) surrounded by 12 PBWO for outer leakage recovery read-out by Bialkali photomultipliers for a total transverse coverage of 3 Rm. read-out by bialkali photomultipliers. We obtained an energy resolution of ~ 5.4% at 100 MeV and we fit the energy dependence on data with the following parametrization: Sigma/E = 2.1%/E**(1/4) + 3.6% where the sum is in quadrature.

The noise term is completely negligible as expected by the reduced level of the electronic noise achieved. The constant term is still leakage dominated. However, in order to reproduce data with simulation we were forced to add a 3-4% intrinsic fluctuation term to each crystal. After having inserted this correction, an excellent reproducibility of the energy distributions both in the integral and in the shower shape in the transverse direction is observed. This result has been achieved both for the inner and for the recovery matrix.

We have finally simulated and studied also the non-linearity in response and the longitudinal non-uniformity of response along the crystal. While we find that the first contribution is negligible, we can explain the ad-hoc term with a non-uniformity of 20%. Measurement of this effect is in progress on the used crystals.

Simulated data The calorimeter prototype shows also a very good energy resolution of ~5% at 100 MeV as measured at the very precise tagged photon beam of MAMI. We have also tested time performances and dependence of the response on rate firing the crystals with a UV LED and reading them out with large area SIPMs.

In this report, we will show the status of the project and the final choice for readout.

Calorimeter Techniques / 12

Why a homogeneous dual calorimeter won't work

GROOM, Don [1]

[1] *Lawrence Berkeley Lab*

If the response to a hadronic shower in a semi-infinite uniform calorimeter structure is S relative to the electronic response, then S/E = [fem + (1-fem)(h/e)], where E is the incident hadron energy, fem is the electronic shower fraction, and h/e is the hadron/electron response ratio. In most cases the resolution is dominated by the stochastic variable fem, whose broad, skewed pdf has an energy-dependent mean. The slow increase of the mean with E is responsible for response nonlinearity, and the response distribution is non-Gaussian because of the distribution's skewness. Both problems are avoided if <h/e> is unity (a "compensated" calorimeter), since in this case <S/E> = 1. There are many other contributions to the resolution. Especially important are fluctuations in invisible energy loss and (if it is a sampling calorimeter) far greater fluctuations in the fraction of the energy deposit sampled by the active medium. While <h/e> is a robust energy-independent quantity, h/e must be treated as a stochastic variable, different from event to event. (Variations in h are much larger than variations in e, so it is more appropriate to treat h/e, rather than e/h, as the stochastic variable.) Compensation is possible because (a) in a sampling calorimeter a relatively large fraction of the electromagnetic energy is absorbed in the inert higher-Z absorber, and (b) in a hydrogenous detector n-p scattering produces ionizing recoil protons. The first effect decreases e and the second increases h, both enhancing the efficiency ratio h/e. Neither mechanism is available in a homogeneous crystal or glass scintillator. <h/e> is substantially smaller than unity; values around 0.4 are to be expected. In a dual-readout calorimeter, the two readout channels (typically scintillator(S) and Cherenkov (C)) have different values of <h/e>. The two versions of the equation above are linear in 1/E and fem, and so can easily be solved for both E and fem on an event-by-event basis. The corrected energy resolution is sensitive to the "h/e contrast," the difference in the detection efficiency ratios between the S and C channels, and diverges as the S channel becomes predominantly sensitive to the electronic component. We have analyzed the resolution as a function of <h/e> contrast analytically and with elementary Monte Carlo simulations, with the conclusion that at interesting energies (e.g. 100 GeV) the corrected energy distribution, while linear in E and Gaussian, can be wider than either the S or C distribution. In some of the schemes under discussion the difference between S and C will likely be further reduced by incomplete signal separation.

Calorimeter Techniques / 53

Crystals for the HHCAL Detector Concept

Dr. ZHU, Ren-Yuan [1]

[1] *Caltech*

Crystal calorimeter has traditionally played an important role in precision measurement of electrons and photons in high energy physics experiments. Recent interest in calorimeter technology extends its application to measurement of hadrons and jets with dual readout for both Cherenkov and scintillation light. Optical and scintillation properties of crystal scintillators commonly used in particle physics experiments are reviewed. Technologies to discriminate Cherenkov and scintillation light is elaborated. Candidate crystals for the homogeneous hadronic calorimeter detector concept and their recent development are discussed.

Calorimeter Techniques / 8

Preliminary Results from a Test Beam of ADRIANO Prototype

Dr. GATTO, Corrado [1]; T1015, Collaboration [2]

[1] *INFN*

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The physics program at future colliders demands an energy resolution of the calorimetric component of detectors at the limits of traditional techniques. The ADRIANO technology (A Dual-readout Integrally Active Non-segmented Option) is under development with an expected excellent performance. Results from detailed Monte Carlo studies on performance with respect to energy resolution, linear response and transverse containment and a preliminary optimization of the layout are presented. A baseline configuration is chosen with an estimated energy resolution of $\sigma(E)/E \approx 30\%/\sqrt{E}$, to support an extensive R&D program recently started by T1015 Collaboration. Preliminary results from a test beam at FTBF of a ~1 lambda_I prototype are presented, along with simulation studies. Future prospects with ultra-heavy glass are, also, summarized.

Calorimeter Techniques / 78

Application of Large Scale Gas Electron Multiplier Technology to Digital Hadron Calorimetry

Prof. WHITE, Andy [1]; Dr. YU, Jae [1]; Dr. PARK, Seongtae [1]

[1] *U. Texas at Arlington*

The detectors proposed for future e+e- colliders (ILC and CLIC) demand a high level of precision in the measurement of jet energies. Various technologies have been proposed for the active layers of the digital hadron calorimetry to be used in conjunction with the Particle Flow Algorithm (PFA) approach. The High Energy Physics group of the University of Texas at Arlington has been developing Gas Electron Multiplier (GEM) detectors for use as the calorimeter active gap detector. To understand this application of GEMs, a series of prototype double-GEM detectors has been tested ranging in size from 10x10 cm2, to 30x30 cm2, and with 100x33 cm2 chambers now in development. These chambers have been characterized using cosmic rays, radioactive sources, and test beams of muons, pions, and protons. These results obtained in these tests, as applicable to digital hadron calorimetry, will be discussed together with plans for the exposure of a number of 1mx1m planes in a calorimeter stack.

Calorimeter Techniques / 57

Belle2 Calorimeter Upgrade (Status and Plan)

NAKAMURA, Isamu [1]

[1] *KEK*

Upgrade of KEKB Accelerator and Belle2 Detector are on going, aiming for starting physics data taking with 50 times higher instantaneous luminosity in FY2015. The belle electromagnetic calorimeter consists of CsI(Tl) crystals read out by two photodiodes, covering polar angle of 12-155 degrees. A total of 8736 counters are installed in a barrel and two endcap modules. The Belle2 upgrade of electromagnetic calorimeter is in two steps. For the beginning of Belle2, all readout electronics will be replaced to cope with higher event rate. A waveform sampling will be introduced to reduce an effect from severe accelerator background. Replacement of CsI(Tl) crystals to faster undoped CsI crystals are also planned. In the talk, detail of Belle2 upgrade will be presented as well as status of preparation and plans for crystal replacement.

Astrophysics & Neutrinos / 40

The Fermi Gamma-ray Space Telescope : The Gamma-ray Sky above 20 MeV (invited)

Dr. BRUEL, Philippe [1]

[1] *Laboratoire Leprince-Ringuet, Ecole polytechnique, CNRS/IN2P3*

The Fermi Gamma-ray Space Telescope (formerly known as Gamma-ray Large Area Space Telescope, GLAST) was successfully launched on June 11 2008. Its main instrument is the Large Area Telescope (LAT), which detects gamma-rays from ~20 MeV to more than 1 TeV. It is a pair-conversion telescope with 16 identical towers (tracker and calorimeter), covered by an anti-coincidence detector to reject charged particles. The calorimeter is an hodoscopic array of CsI(Tl) crystals, arranged in 8 alternating orthogonal layers, with a total thickness of 8.8 radiation lengths. In this talk we will review the performance of the LAT, focusing on the role of the calorimeter, and some of its scientific results after 4 years of operation.

Astrophysics & Neutrinos / 75

The AMS ECAL Design and Performance (invited)

Dr. ROSIER-LEES, Sylvie [1]; Prof. AKCHURIN, Nural [2]

[1] *Laboratoire d'Annecy-le-Vieux de Physique des Particles*

[2] *TTU*

The Alpha Magnetic Spectrometer, AMS-02, is operating on board the International Space Station since the 19th of May 2011 and has collected more than 15 billion events. The main scientific goals of the experiment are the search for antimatter and dark matter, the high precision measurement of charged cosmic ray spectra and fluxes, and the study of gamma rays in the GeV to TeV energy range. The Electromagnetic Calorimeter (ECAL) of AMS02 is required to measure e+, e- and gamma spectra and to discriminate electromagnetic showers from hadronic cascades. To fulfill these requirements ECAL is based on a lead/scintillating fiber sandwich, providing a 3D imaging reconstruction of the showers. The electronics, with low noise and challenging dynamic range readout, were designed following stringent requirements on mechanical and thermal stability, power consumption, radiation hardness and double redundancy. The full system had successfully gone through the space qualification tests. AMS-02 was tested during Summer 2010 in a test beam at CERN, using 10 to 250 GeV electron and positron beams and proton beam at 400 GeV. After presenting a summary of the AMS02 performance in space, results on the measurements of ECAL parameters and its performance will be reported.

Astrophysics & Neutrinos / 66

Physics Highlights from the ANTARES Neutrino Telescope

Dr. CARLOGANU, Cristina [1]

[1] *LPC Clermont Ferrand / IN2P3 / CNRS*

Since its completion in 2008, ANTARES, the largest operating water Cherenkov detector, is searching for cosmic neutrinos. Twelve detector lines holding a total of 885 Optical Modules are deployed in the Mediterranean Sea at a depth of about 2475m. As for all telescopes, the three-dimensional detection matrix is mainly optimized for pointing resolution, though ANTARES is also a good imaging calorimeter. The physics outreach is therefore rather broad, covering in addition to searches for cosmic neutrinos (steady or transient, diffuse or from point-sources), the measurement of the oscillations of atmospheric neutrinos, indirect searches for dark matter, searches for exotic particles as magnetic monopoles or nuclearites. The collaboration is also active in the development of multi-messanger networks, providing transient-phenomena alerts to optical telescopes or conjointly looking with VIRGO-LIGO for gravitational waves correlated with high energy neutrinos. In addition, ANTARES is a testbed for technological developments for the future KM3NET telescope and a complementary detection technique for ultra high energy neutrinos through acoustic triangulation.

The talk will offer a brief overview of the detection technique and detector performance, before concentrating on the main physics results obtained so far.

Astrophysics & Neutrinos / 55

The NOvA Neutrino Calorimeter

Dr. MAGILL, Stephen [1]

[1] *Argonne National Laboratory*

The NOvA experiment is a long baseline neutrino facility designed to 1) observe oscillations of muon neutrinos to electron neutrinos, 2) determine the ordering of the neutrino mass states, and 3) observe CP violation in neutrinos if it exists. To accomplish this, the NOvA detector is a unique low-Z, high sampling fraction calorimeter capable of precise measurements of the particles produced in a neutrino interaction while also being able to reject particles from background cosmic rays. Some experience has already been obtained with the operation of a prototype near detector on the Fermilab site, and construction of the 14 kiloton far detector is just beginning in northern Minnesota. The calorimetric properties of the NOvA detector will be described with emphasis on relevance to the overall experimental goals.

Astrophysics & Neutrinos / 71

The LBNE Near Detector

Dr. GUARDINCERRI, Elena [1]

[1] *LANL*

The Long Baseline Neutrino Experiment is a next generation neutrino oscillation experiment currently proposed for construction in the United States with the main goal of studying muon (anti)neutrinos oscillations into electron (anti)neutrinos over a distance greater than 1000 km and over a wide range of neutrino energies. Its main physics results will be the precision measurement of δCP and all three mixing angles. A value of δCP different from 0 or π will appear in the LBNE data as a small (0% to 40%) asymmetry on the oscillation probability of neutrinos versus antineutrinos. Such a small effect requires a very good control of the systematic uncertainties affecting the measurement and this can only been accomplished using a near detector. I will report on the status of the LBNE near detector project focusing primarily on its baseline design, which includes a set of muon detectors to monitor the beam and a magnetized liquid argon TPC surrounded by muon/pion identifier detectors to measure the neutrinos at the near site.

Astrophysics & Neutrinos / 79

The LBNE Far Detector

Prof. BUCHANAN, Norm [1]

[1] *Colorado State University*

The Long-Baseline Neutrino Experiment (LBNE) is a proposed neutrino oscillation experiment utilizing high-power muon neutrino and anti-neutrino beams originating at Fermilab and traversing a 1300 km baseline to a large far detector at the Homestake mine in Lead, South Dakota. The primary goals of LBNE are to precisely determine neutrino oscillation (appearance and disappearance) parameters, the neutrino mass hierarchy, and ultimately to measure the CP violating phase angle. I will discuss the two far detector technologies studied over the past few years and the reasoning behind the selected option. I will also briefly cover the phasing options currently under consideration, including potential alternate far detector locations.

Astrophysics & Neutrinos / 29

Measuring Ultra High Energy Cosmic Rays using the Atmosphere and the Telescope Array

Prof. MATTHEWS, John [1]

[1] *University of Utah*

The Telescope Array (TA) Experiment is the largest Ultra-High Energy cosmic ray detector in the northern hemisphere. This follow up to the High Resolution Fly's Eye and AGASA experiments is located near Delta, Utah, about 200 kilometers southwest of Salt Lake City. The detector consists of 507 three square meter scintillator counters distributed in a square grid with 1.2 km spacing. Three fluorescence detector stations (12, 12, and 14 telescopes) sit on the corners of a ~30 km equilateral triangle overlooking the array of surface detectors. The stations view 108, 108, and 114 degrees in azimuth and 3-31 degrees in elevation. They provide full hybrid coverage with the scintillator array above 10 EeV. The Telescope Array underwent commissioning in 2007 and began routine data collection operations at the beginning of 2008. A low energy extension to TA (TALE) will add 11 new telescopes to the Middle Drum site and increase the elevation angle view up to about 60 degrees, providing for cosmic ray observation down to about 10^17 eV. In conjunction with the new telescopes, a graded array of infill scintillator counters will be added. An overview of the experiment and its measurements will be presented.

Astrophysics & Neutrinos / 67

Cosmic Ray in the Northern Hemisphere: Results from the Telescope Array Experiment

Prof. JUI, Charles [1]

[1] *University of Utah*

The Telescope Array (TA) is the largest ultrahigh energy (UHE) cosmic ray observatory in the northern hemisphere. TA is a hybrid experiment with a unique combination of fluorescence detectors and a stand-alone surface array of scintillation counters. We will present the spectrum measured by the surface array alone, along with those measured by the fluorescence detectors in monocular, hybrid, and stereo mode. The composition results from stereo TA data will be discussed. Our report will also include results from the search for correlations between the pointing directions of cosmic rays, seen by the TA surface array, with active galactic nuclei.

Astrophysics & Neutrinos / 73

Radio Detection of Neutrino Collisions In-ice

Prof. BESSON, Dave [1]

[1] *University of Kansas*

I'll review and compare the primary existing experiments (ANITA, ARA, ARIANNA) which seek to exploit the "Askaryan Effect" to observe neutrinos interacting with cold polar ice, as well as discuss future prospects and perspectives.

Operating Calorimeters / 4

Long Term Performance of the MINOS Calibration Procedure

Dr. MATHIS, Mark [1]

[1] *College of William and Mary*

The MINOS detectors are steel-scintillator sampling tracking calorimeters and are calibrated using an in-situ light-injection system and cosmic ray muons. The MINOS near and far detectors have been operating almost continuously since 2003 and 2005, providing opportunity to quantify the behaviour of the various detector components, many of which are used in the next generation neutrino oscillation experiments, under long-term experimental operation. We will report on the calibration procedure and its stability, as well as the time and temperature dependencies of the scintillator, wavelength-shifting fibers and photo-multiplier tubes.

Operating Calorimeters / 9

Current Status and Performance of the BESIII Electromagnetic Calorimeter

Dr. WANG, Zhi Gang [1]

[1] *Institute of High Energy Physics,Chinese Academy of Science*

The design and construction of the BESIII electromagnetic calorimeter is introduced briefly. Radiation dose of CsI(Tl) crystals is monitored and history graph of integral dose of crystals is showed. LED system is used for monitoring the EMC conditions, and large decrease of light output of some crystal is discussed. After calibration the energy resolution and position resolution reached design values.

Operating Calorimeters / 47

Monitoring and Correcting for Response Changes in the CMS Lead-tungstate Electromagnetic Calorimeter

Mr. FERRI, Federico [1]

[1] *CEA/Saclay Irfu/SPP*

The CMS Electromagnetic Calorimeter (ECAL) comprises 75848 lead-tungstate scintillating crystals. Changes in the ECAL response, due to crystal radiation damage or changes in photo-detector output, are monitored in real time with a sophisticated system of lasers and LEDs to allow corrections to the energy measurements to be calculated and used. The excellent intrinsic resolution of the CMS ECAL requires the monitoring system itself to be calibrated to a high precision and its stability to be controlled and understood. The components of the CMS ECAL monitoring system, and how it has evolved to include modern solid-state lasers, are described. Several physics channels are exploited to normalize the ECAL response to the changes measured by the monitoring system. These include low energy di-photon resonances, electrons from W and Z decays (using shower energy versus track momentum measurements), and the azimuthal symmetry of low energy deposits in minimum bias events. This talk describes how the monitoring system is operated, how the corrections are obtained, and the resulting ECAL performance.

Operating Calorimeters / 49

A Diode-Pumped DP2-447 Blue Laser for Monitoring CMS Lead Tungstate Crystals Calorimeter at the LHC

Dr. ZHANG, Liyuan [1]

[1] *California Institute of Technology*

Monitoring the transparency of the lead tungstate crystals of the CMS electromagnetic calorimeter (ECAL) plays a crucial role in maintaining the ECAL energy resolution. To meet the stringent requirements on the light monitoring precision and stability a new commercial diode-pumped blue laser ("DP2-447") has been commissioned and installed at CERN for the 2012 operation of the CMS ECAL. The laser unit has a simple structure and is expected to be more reliable than the existing lamp-pumped lasers used by the monitoring system. The stability of critical quantities such as the intensity, width and timing, is better than that of the lamp-pumped lasers. The characteristics of the new blue laser will be elaborated. Its performance in-situ in CMS will be described and the prospects for improving the light monitoring precision will be discussed.

Operating Calorimeters / 51

Calibration of the CMS Electromagnetic Calorimeter at the LHC

Dr. GATAULLIN, Marat [1]

[1] *Caltech*

The CMS electromagnetic calorimeter comprises 75848 lead tungstate scintillating crystals. Achieving precise calibration of each channel is crucial to ensure excellent energy resolution. During the LHC runs of 2010 and 2011 several physics channels were used to derive the inter-calibration and absolute energy scale of the calorimeter. These include low mass di-photon resonances, electrons from Z and W decays and the azimuthal symmetry of low energy deposits from minimum bias events. These calibration methods, including the acquisition of the calibration data samples will be described in detail. The measurement of the calibration precision and energy resolution will also be discussed.

Operating Calorimeters / 43

Mitigation of Anomalous APD Signals in the CMS ECAL

Dr. PETYT, David [1]

[1] *Rutherford Appleton Laboratory*

Anomalous, large signals are observed in the barrel part of the CMS Electromagnetic Calorimeter during pp collisions. Laboratory and beam-test studies, as well as Monte Carlo simulations, have been used to understand their origin. They are ascribed to direct energy deposition by particles in the Avalanche Photo-Diodes used for the light readout. Their properties and rates are summarized, including predictions for the future. The methods that have been employed to reject these signals in the trigger and the reconstructed data are presented. The importance of these signals as backgrounds to physics analyses in CMS is also discussed.

Operating Calorimeters / 62

Identification and Mitigation of Anomalous Signals in CMS HCAL

APRESYAN, Artur [1]

[1] *California Institute of Technology*

The CMS HCAL detector occasionally records anomalous large energy signals that correspond to particles hitting the transducers. Anomalous signals in HCAL can also be produced by rare random discharges of the readout detectors, due to the strong magnetic field. Some of these effects had already been observed during past test beam and cosmic data taking. Detailed studies of these effects have continued with the CMS collision data. Hardware modifications to mitigate one of the largest sources of anomalous energies during the 2010 collision run, scintillation light produced in part of the light guide reflective sleeves in the HF, were implemented during the winter 2010 shutdown period. Several algorithms have been developed to identify and address these problems in the data. The methods have been tested on cosmic ray muon data, test-beam data, and collision data at CMS. Noise rejection algorithms are applied to LHC collision data at the trigger level, and in the offline physics analysis. We present a summary of the various sources of anomalous signals, the algorithms developed to identify them, and the performance of the algorithms in the CMS collision data.

Operating Calorimeters / 84

Pile Up Measurement and Mitigation Techniques in CMS

PERLOFF, Alexx [1]

[1] *Texas A&M University*

In the ever-increasing luminosity environment of the LHC detectors the measurement and understanding of offset energy associated to multiple interactions plays a key role in the correct calibration of jets. This talk will present the latest results on the measurement of this offset energy at CMS, the different effects that contribute to it and the state of the art mitigation techniques used at CMS.

Operating Calorimeters / 22

Signal Reconstruction Performance with the ATLAS Hadronic Tile Calorimeter

Mr. KLIMEK, Pawel [1]

[1] *Stockholm Universitet*

The Tile Calorimeter (TileCal) is the central section of the hadronic calorimeter of ATLAS. It is a key detector for the reconstruction of hadrons, jets, taus and missing transverse energy. TileCal is a sampling calorimeter with steel as absorber and scintillators as active medium. The scintillators are read-out by wavelength shifting fibers coupled to photomultiplier tubes (PMTs). The analogue signals from the PMTs are amplified, shaped and digitized by sampling the signal every 25 ns. The read-out system is designed to reconstruct the data in real time fulfilling the tight time constraint imposed by the ATLAS first level trigger rate (100 kHz). The signal amplitude for each channel and the phases are measured using Optimal Filtering techniques both at on-line and off-line level. We present the performances of these techniques on the data collected in the proton-proton collisions at center-of-mass energy equal to 7 TeV. We will address the performance on the measurements of low amplitude signals such as those produces by muons, on high pile-up environment and on various physics and calibration signals.

Operating Calorimeters / 23

Data Quality System of the ATLAS Hadronic Tile Calorimeter

Dr. NEMECEK, Stanislav [1]

[1] *FZU AVCR Praha*

The Tile Calorimeter (TileCal) is the central section of the hadronic calorimeter of the ATLAS experiment. It is subdivided into a large central barrel and two smaller lateral extended barrels. Each barrel consists of 64 wedges, made of iron plates and scintillating tiles. Two edges of each scintillating tile are air-coupled to two wave-length shifting fibers which collect the scintillating light and transmit it to photo-multipliers. The total number of channels is about 10000. An essential part of the TileCal detector is the Data Quality (DQ) system. The DQ system is designed to check the status of the electronic channels. It is designed to provide information at two levels - online and offline. The online TileCal DQ system monitors continuosly the data while they are recorded and provides a fast feedback. The offline DQ system allows a detailed study, if needed provides corrections to be applied to the recorded data and it allows to validate the data for physics analysis. In addition to the check of physics data the TileCal DQ systems also operate with calibration data. The TileCal calibration system provides well defined signals and the response to the calibration signals allows checking the behaviour of the electronic channels in detail. The Monitoring and Calibration Web System supports data quality analyses at the level of channels. All online, offline and calibration versions of the TileCal DQ system also provide automatic tests, the results of which allow fast and robust feedback.

Algorithms & Simulations / 56

Simulation Studies of a Dual Readout Crystal Calorimeter

Dr. MAGILL, Steve [1]

[1] *Argonne National Laboratory*

The ability to grow clear, dense scintillating crystals presents an opportunity for development of a total-absorption calorimeter that could contain multi-GeV hadrons in a detector volume similar to that of present-day calorimeters. With appropriate crystals and optimized readout elements, both scintillation and cerenkov photons can be produced and detected separately. This dual readout approach allows one to selectively correct particle energies, resulting in significant gains in energy resolution -> 20%/sqrt(E) or even better for hadrons. An R&D program is underway to 1) develop appropriate clear, dense crystals, 2) test innovative readout methods for both scintillation and cerenkov light, and 3) provide test beam capability for crystal and readout sensor testing and simulation verification. As part of this effort, simulation studies have been done assuming a dual readout crystal calorimeter implementation for a future e+e- linear collider detector. By using the dual readout correction, corrections for magnetic field effects on low momentum charged hadrons, and particle flow techniques, substantial improvements in, e.g., dijet mass resolution are obtained.

Algorithms & Simulations / 60

Simulation Studies of a Total Absorption Dual Readout Calorimeter

Dr. WENZEL, Hans [1]; Dr. MAGILL, Stephen [2]

[1] *Fermilab*

[2] *Argonne National Laboratory*

We describe simulation studies of a total absorption dual readout calorimeter. The simulation assumes that with appropriate dense crystals and optimized readout elements, both scintillation and Cherenkov photons can be produced and detected separately. The correlation between the Cherenkov and Scintillation light then allows to selectively correct particle energies event by event, resulting in improved hadronic energy resolution. We describe the flexible Geant4 and ROOT based framework that uses gdml for the detector description and Root reflexion for persistency that we developed and present various studies including:
- the energy resolution that can be achieved,
- the response to various single particles and jets,
- detailed look into the development of hadronic showers.

Algorithms & Simulations / 45

Validation of Hadronic Models Using CALICE Highly Granular Calorimeters

Dr. RAMILLI, Marco [1]

[1] *DESY/Hamburg*

The CALICE collaboration has constructed highly granular hadronic and electromagnetic calorimeter prototypes to evaluate technologies for use in detector systems at a future Linear Collider, and to validate hadronic shower models with unprecedented spatial segmentation. The electromagnetic calorimeter is a sampling structure of Tungsten and silicon with 9720 readout channels. The hadron calorimeter uses 7608 small plastic scintillator cells individually read out with silicon photomultipliers. This high granularity opens up the possibility for precise three-dimensional shower reconstructions and for software compensation techniques to improve the energy resolution of the detector. We discuss the latest results on the studies of shower shapes and shower properties and the comparison to recently developed MC models for hadronic showers. A satisfactory agreement at better than 5% is found between data and MC models for most of the investigated variables. We will also show the improvement of the models over the last few years. We show that applying software compensation methods based on reconstructed clusters, the energy resolution for hadrons improves by a ~15%. The next challenge for CALICE calorimeters will be to validate the fourth dimension of hadronic showers, i.e. their time evolution.

Algorithms & Simulations / 32

Containment of Hadronic Showers

Dr. ZUTSHI, Vishnu [1]

[1] *NICADD, Northern Illinois University*

In designing a calorimeter to be used for jet reconstruction at a future linear collider, an important question is the calorimeter depth. Monte Carlo studies of the particle flow approach have suggested that shower containment becomes a significant issue for jets of energy above 100 GeV or so. However, since the calorimeter depth will have a significant impact on cost, it is important to use test beam data to measure the longitudinal shower development. The highly granular CALICE calorimeters are well suited to this task.

The CALICE setup of Si-W ECAL and Fe-scintillator HCAL was complemented by a "tail catcher" - a further Fe-scintillator structure which could act as a prototype for instrumentation of the return yoke of the detector solenoid in a linear collider detector. Using this setup the effect on energy resolution of a coil at various depths in the system has been emulated, and we report on these results. The fine granularity of the calorimeters also allows detailed measurements of the longitudinal development of individual showers, which can be used to refine the energy measurement. The impact of these techniques on energy resolution and linearity are reported.

At CLIC energies, the cost of installing the HCAL inside the magnet coil becomes prohibitive if iron is used as the absorber. This has led to the possibility of using tungsten as the absorber for both HCAL and ECAL. Hadronic interactions in tungsten have not been so well studied as in iron, so CALICE has also equipped its scintillator HCAL with tungsten absorber. First results are reported.

Algorithms & Simulations / 44

On the Energy Measurement of Jets in High-Energy Physics Experiments

Prof. WIGMANS, Richard [1]; Dr. LEE, Sehwook [1]

[1] *Texas Tech Univ.*

As the energies at which the elementary structure of matter is studied increased, the emphasis in scattering experiments has shifted from detecting individual hadrons to fragmenting quarks and gluons, which manifest themselves as particle jets. We investigate and quantify some systematic effects that affect the precision with which the properties of the fragmenting constituents can be determined. We concentrate on the calorimeters that are used to measure the energies, and in particular how the non-compensating nature of a calorimeter affects the energy measurement of different types of quarks and gluons.

Algorithms & Simulations / 11

The Design and Performance of the Electromagnetic Calorimeters in Hall C at Jefferson Lab

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The design and performance of electromagnetic calorimeters of magnetic spectrometers in Hall C at Jefferson Lab are presented. For the existing HMS and SOS spectrometers, construction information, and comparisons of simulated and experimental results are presented. The design and simulated performance for a new calorimeter to be used in the the new SHMS spectrometer is also presented.

We have developed and constructed electromagnetic calorimeters from TF-1 type lead-glass blocks for HMS and SOS magnetic spectrometers at JLab Hall C. The HMS/SOS calorimeters are of identical design and construction except for their total size. Blocks of dimension $10~{\rm cm}\times 10~{\rm cm}\times 70~{\rm cm}$ are arranged in four planes and stacked 13 and 11 blocks high in the HMS and SOS respectively. The energy resolution of these calorimeters is better than $6\%/\sqrt E $, and pion/electron ($\pi/e$) separation of about 100:1 has been achieved in energy range 1 -- 5 GeV. Good agreement has been observed between the experimental and GEANT4 simulated energy resolutions. The HMS/SOS calorimeters have been used nearly in all the Hall C experiments, providing good energy resolution and high pion suppression factor. No significant deterioration in the performance is observed in the course of exploitation since 1994.

For the SHMS spectrometer, presently under construction, details on the calorimeter design and accompanying GEANT4 simulation efforts are given. A Preshower+Shower design was selected as the most cost-effective among several design choices. The preshower will consist of a layer of 28 modules with TF-1 type lead glass radiators, stacked in two columns. The shower part will consist of 224 modules with F-101 type lead glass radiators, stacked in a ``fly's eye'' configuration of 14 columns and 16 rows. The active area of $120\times130~{\rm cm}^2$ will encompass the beam envelope at the calorimeter. The anticipated performance of the new calorimeter is simulated over the full momentum range of the SHMS, predicting resolution and yields similar to the HMS calorimeter. Good electron/hadron separation can be achieved by using energy deposition in the Preshower along with total energy deposition in the calorimeter. In this case the PID capability is similar to or better than that attainable with HMS calorimeter, with a pion suppression factor of a few hundreds predicted for 99\% electron detection efficiency.

Algo/Sim and FE/Trig / 65

Simulation Work on Calorimetric Energy Resolution for the TAC-PF Detector

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According to the Turkish Accelerator Center project, a tau-charm factory is proposed based on colliding a 1 GeV electron beam against a 3.5 GeV positron beam. The Particle Factory (TAC-PF) detector will be constructed for the detection of the producing particles from this collision. PbWO4 and CsI(Tl) crystals are considered for the construction of the electromagnetic calorimeter. The photons generated from incident particles in the crystal material are detected by Avalanche photodiodes (APD) or PIN photodiodes placed at the end of the crystal. In this work, the contribution to the calorimetric energy resolution from both the shower fluctuations in the crystal and photoelectron statistics in the detectors have been simulated for PbWO4-APD and PbWO4-PIN combinations.

Algo/Sim and FE/Trig / 80

Detection of Clustering Instabilities for Sequential Recombination Algorithms

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We present a study of clustering stability of sequential recombination jet reconstruction algorithms. Events are reconstructed many times, using random variations of kinematic properties of the initial particles. Sensitivity of different algorithms to initial conditions are quantified by introducing probabilistic assignment of initial particles to jets (fuzzy clustering). A criterion detecting unstable configurations (bifurcation points) is proposed, based on the overall fuzziness of the event.

Algo/Sim and FE/Trig / 37

Precision Timing of the ATLAS Level-1 Calorimeter Trigger: From Beam Splashes to High Luminosity Proton-Proton Collisions

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The ATLAS Level-1 Calorimeter Trigger is one of the main elements of the first-stage online selection of LHC collision events measured at the ATLAS experiment. Using 7168 pre-summed trigger tower signals from the Liquid Argon and Tile calorimeters as input, the hardware-based system identifies high-pT objects and determines the total and missing transverse energy sums within a fixed latency of 2.5 us. The Preprocessor system digitizes the analogue calorimeter signals at the LHC bunch-crossing frequency of 40MHz and provides bunch-crossing identification and energy measurement. Prerequisite for high stability and accuracy of this procedure is a timing synchronization at the nanosecond level of the signals which belong to the same collision event. The synchronization of the trigger tower signals was first established in the analysis of beam splash events in November 2009 and then refined and sustained with data from proton-proton collisions at a centre-of-mass energy of 7 TeV, recorded at the LHC in 2010 and 2011. In order to extract nanosecond precision from signals sampled in 25 ns-steps, a specifically developed fit method was applied to the signals from the energy depositions in the calorimeters. This procedure requires a good understanding of the signal shapes and, especially, its variations between the different calorimeter regions. Overall, a precision synchronization with collision data better than, on average, approximately +/- 1.5 ns has been achieved throughout 2010 and 2011. In this contribution, details on the method as well as selected results from the different synchronizations with beam splashes and proton-proton collisions from 2009 to 2011 are presented.

Algo/Sim and FE/Trig / 35

Evolution and Performance of Electron and Photon Triggers in ATLAS in the Year 2011

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Electron and photon triggers are used for the signal selection in a wide variety of ATLAS physics analyses, with further dedicated triggers for the collection of J/psi->ee, W->enu and QCD background samples for calibration, efficiency and fake rate measurements. In 2011, the increasing luminosity and pile-up conditions at the LHC demanded the use of progressively higher energy thresholds and tighter selections to control the trigger rates. An optimisation of the electron and photon triggers was performed at all three levels of the trigger system. At Level 1, the thresholds were raised and configured separately in various rapidity regions to account for energy losses in the upstream material. In addition, hadronic isolation requirements were implemented. At the high-level trigger (HLT) many variables from
the calorimeters and tracking detectors were tuned to achieve both high efficiency and background rejection. For 2012 LHC operating conditions, significant reoptimisations have been necessary including the use of isolation criteria at the HLT and even tighter selections. This contribution summarises the algorithms and the performance of the ATLAS electron and photon triggers used in 2011 and early 2012 data taking.

Algo/Sim and FE/Trig / 48

Performance of the CMS Electron and Photon Trigger

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The CMS high-resolution electromagnetic calorimeter (ECAL) comprises 75848 lead tungstate (PbWO4) crystals and is optimized for the discovery of the SM Higgs boson in its two-photon decay mode. With the unprecedented collision rate at the Large Hadron Collider (LHC), the electron/photon (EG) Trigger plays a major role in selecting the collisions most likely to yield something new and interesting. Since the start of physics in March 2010 the LHC instantaneous luminosity has increased by six orders of magnitude to more than 5x10e33 cm-2 s-1 today, presenting a major challenge for the stability of the trigger system. This talk will present the performance of the EG trigger based on data recorded by the CMS detector in 2011 and 2012.

Algo/Sim and FE/Trig / 61

Scintillating Glasses for Total Absorption Dual Readout Calorimetry

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Scintillating glasses are a potentially cheaper alternative to crystal - based calorimetry with common problems related to light collection, detection and processing. As such, their use and development are part of more extensive R&D aimed at investigating the potential of total absorption, combined with the readout (DR) technique, for hadron calorimetry. A recent series of measurements, using cosmic and particle beams from the Fermilab test beam facility and scintillating glass with the characteristics required for application of the DR technique, serve to illustrate the problems addressed and the progress achieved by this R&D. Alternative solutions for light collection (conventional and silicon photomultipliers) and signal processing are compared, the separate contributions of scintillation and Cherenkov processes to the signal are evaluated and results are compared to simulation.

Front-End & Trigger / 36

Performance and Improvements of the ATLAS Jet Trigger System

Dr. CONDE MUÍÑO, Patricia [1]

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At the harsh conditions of the LHC, with proton bunches colliding every 50 ns and up to 40 pp interactions per bunch crossing, the ATLAS trigger system has to be flexible to maintaining an unbiased efficiency for a wide variety of physics studies while providing a fast rejection of non-interesting events. Jets are the most commonly produced objects at the LHC, essential for many physics measurements that range from precise QCD studies to searches for New Physics beyond the Standard Model, or even unexpected physics signals. The ATLAS jet trigger is the primary mean for selecting events with high pT jets and its good performance is fundamental to achieve the physics goals of ATLAS. The ATLAS trigger system is divided in three levels, the first one (L1) being hardware based, with a 2 μs latency, and the two following ones (called collectively High Level Triggers or HLT) being softwared based with larger processing times. It was designed to work in a Region of Interest (RoI) based approach, where the second level trigger (L2) is limited to verify the signals provided by the L1 by looking at a region of the detector around them. The last level, EF, has potential full event access. The RoI based strategy was not well-suited for multi-jet events since it lead to pathologies and efficiency losses. A re-design of the jet trigger to overcome this difficulty has happened in between 2011, with the implementation of the full calorimeter unpacking at EF, and 2012 with the introduction of a pseudo-full scan at L2. It is now also possible to run a variety of jet algorithms, both at L2 and at EF, reducing even further possible biases for physics studies. In this presentation, we will describe the challenges of the ATLAS Jet Trigger system, its original limitations and the new developments that were implemented to overcome them. We will also show performance results obtained with 2012 data, including efficiency measurements with respect to the offline reconstructed jets, resolutions and jet energy scale studies.

Front-End & Trigger / 38

The ATLAS Hadronic Tau Trigger

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With the high luminosities of proton-proton collisions achieved at the LHC, the strategies for triggering have become more important than ever for physics analysis. The inclusive single tau lepton triggers now suffer from severe rate limitations. To allow for a large program of physics analyses with taus, the development of topological triggers that combine tau signatures with other measured quantities in the event is required. These combined triggers open many opportunities to study new physics beyond the Standard Model and to search for the Standard Model Higgs.

We present the status and performance of the hadronic tau trigger in ATLAS. We explain how hadronic tau events are identified at trigger level using the ATLAS calorimeter and tracking detector system, and demonstrate several physics case uses of the combined trigger menu. Results from performance studies of the tau trigger are also shown, including measurements of the trigger efficiency using Z->tautau and W->taunu events.

Front-End & Trigger / 24

Upgrade for the ATLAS Tile Calorimeter Readout Electronics at the High Luminosity LHC

Prof. SANTIAGO CERQUEIRA, Augusto [1]

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The Tile Calalorimeter (TileCal) is the hadronic calorimeter covering the most central region of the ATLAS experiment at LHC. It is a sampling calorimeter with iron plates as absorber and plastic scintillating tiles as the active material. The scintillation light produced by the passage of charged particles is transmitted by wavelength shifting fibers to photomultiplier tubes (PMTs). The TileCal readout consists of about 1000 channels. The main upgrade will occur for the High Luminosity LHC phase (phase 2) which is scheduled around 2022. The upgrade aims at replacing the majority of the on- and off-detector electronics so that all calorimeter signals are directly digitized and sent to the off-detector electronics in the counting room. This will be done with minimum latency and maximum robustness. It will provide maximum TileCal information to the first level of the calorimeter trigger (probably called level 0) to improve the trigger efficiency as required to cope with the increased luminosity. An ambitious upgrade development program is pursued studying different mechanics and electronics options. There options are presently being investigated for the front-end electronic upgrade. The first option is an improved version of the present system built using discrete components. The second alternative is based on the development of a dedicated ASIC, which will provide most of the functionality including the digitization. The third alternative is the development of a new version of the "QIE", a custom integrated circuit that incorporates a 4-range current integrator, on-board digitization, and timing. Although the phase 2 upgrade will occur only in 10 years from now, a demonstrator prototype read-out for a slice of the calorimeter with most of the new electronics, but also compatible with the present system, is planned to be inserted in ATLAS already in phase 0 (2013 to mid 2014). The presentation will give an overview of the proposed design and summarize the status of the on-going work.

Front-End & Trigger / 77

Upgraded Readout Electronics for the ATLAS LAr Calorimeter at the High Luminosity LHC

Dr. ANDEEN, Timothy [1]

[1] *Columbia University*

The ATLAS Liquid Argon (LAr) calorimeters produce a total of 182,486 signals which are digitized and processed by the front-end and back-end electronics at every triggered event. In addition, the front-end electronics is summing analog signals to provide coarsely grained energy sums, called trigger towers, to the first-level trigger system, which is optimized for nominal LHC luminosities. However, the pile-up noise expected during the High Luminosity phases of LHC will be increased by factors of 3 to 7. An improved spatial granularity of the trigger primitives is therefore proposed in order to improve the identification performance for trigger signatures, like electrons or photons, at high background rejection rates. For the first upgrade phase [1] in 2018, new digital tower builder boards (sTBB) are being designed to receive higher granularity signals, digitize them on detector and send them via fast optical links to a new digital processing system (DPS). The DPS applies a digital filtering and identifies significant energy depositions in each trigger channel. The refined trigger primitives are then transmitted to the first level trigger system to extract improved trigger signatures.

This talk will present the general concept of the upgraded LAr calorimeter readout together with the various electronics components to be developed for such a complex system. The R&D activities and architectural studies undertaken by the ATLAS LAr Calorimeter group will be described. Details of the on-going design of mixed-signal front-end ASICs, of radiation tolerant optical-links, and of the high-speed off-detector FPGA based DPS units will be presented.

[1] ATLAS Collaboration, "Letter of Intent for the Phase-I Upgrade of the ATLAS Experiment", CERN-LHCC-2011-012.

Front-End & Trigger / 19

Neutron and Proton Tests of Different Technologies for the Upgrade of Cold Readout Electronics of the ATLAS Hadronic Endcap Calorimeter

Dr. NAGEL, Martin [1]

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The expected increase of total integrated luminosity by a factor ten at the sLHC compared to the design goals for LHC essentially eliminates the safety factor for radiation hardness realized at the current cold amplifiers of the ATLAS Hadronic Endcap Calorimeter (HEC). New more radiation hard technologies have been studied: SiGe bipolar, Si CMOS FET and GaAs FET transistors have been irradiated with neutrons up to an integrated fluence of 2.2 x 10^16 neutrons/cm^2 and with 200 MeV protons up to an integrated fluence of 3.4 x 10^14 protons/cm^2. Comparisons of transistor parameters such as the gain for both types of irradiations are presented.

Future Calorimetry / Closing Session / 3

The Electromagnetic Calorimeter of the PANDA Detector at FAIR

Dr. NOVOTNY, Rainer W. [1]

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The PANDA collaboration at FAIR, Germany, will focus on undiscovered charm-meson states and glueballs in antiproton annihilations to study QCD phenomena in the non-perturbative regime. For fixed target experiments at the storage ring HESR a 4pi-detector for tracking, particle identification and calorimetry is under development and construction to operate at high annihilation rates up to 20 MHz. The electromagnetic calorimeter (EMC) is composed of a target spectrometer [1] based on PbWO4 (PWO) crystals and a shashlik-type sampling calorimeter at the most forward region. The high resolution PWO-detector, comprising more than 15000 crystals, is operated at a temperature of -25°C and read-out via large-area avalanche photo-diodes or vacuum photo-triodes/tetrodes. Individual crystals will be exposed to single-detector hit rates up to 500 kHz. The photo-sensor signals are continuously digitized by sampling ADCs (SADCs) and analyzed on-line in FPGAs to detect hits and extract energy and time information. In order to gain flexibility and selectivity at high data rates, a trigger-less readout system is under development. More than 50% of the high quality PWO-II crystals are delivered and tested. The excellent performance with respect to energy, timing and position information was determined over an energy range from 10MeV up to 15GeV of the reconstructed electromagnetic shower by operating several prototype detectors [2] at different beam facilities. In addition, the concept of stimulated recovery has been investigated to recover radiation damage on- and off-line during the calorimeter operation. Besides the overall concept of the target spectrometer the response function of the shashlik spectrometer down to photon energies even below 100MeV will be presented.
The project has been supported by BMBF, GSI and EU.

[1] PANDA EMC Technical Design Report, The PANDA Collaboration, arXiv:0810.1216v1.
[2] M. Kavatsyuk et al., Nucl. Instr. and Meth. in Phys. Res. A 648 (2011) 77.

Future Calorimetry / Closing Session / 14

Crystals for Dual-Readout Crystal Calorimeters

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[1] *INFN-Pavia*

Dual-Readout calorimetry was proposed as a technique which allows to eliminate the factors that limit the performance of the hadron calorimeters such as electromagnetic fraction fluctuation and invisible energy fluctuation. By comparing the signals generated in the form of Cerenkov and scintillation light, it is possible to determine the electromagnetic shower fraction on an event-by-event basis. Experimental tests with the DREAM calorimeter have clearly demonstrated the validity of this principle. Some high-Z scintillating crystals offer the possibility to distinguish the contributions from the scintillation and Cerenkov mechanisms to the generated signals. Among these crystals are BGO and PbWO4. We have tested matrices of these crystals as electromagnetic calorimeters and studied the properties of the Cerenkov and scintillation components of the signals generated by high-energy electrons showering in these detectors. We evaluated the performance of such matrices as detector for the dual readout technique

Future Calorimetry / Closing Session / 28

The SuperB Factory Electromagnetic Calorimeter

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The SuperB project is an asymmetric e+e− accelerator of 10^36cm−2s−1 luminosity, capable of collecting a 50−75 ab^−1 data sample in five years of running. The SuperB electromagnetic calorimeter (EMC) provides energy and direction measurement of photons and electrons and identification versus other charged particles for electrons. A matrix of 25 LYSO crystals has been tested at the Beam Test Facility at Frascati (BTF) in May 2011 at energies between 100 MeV and 500 MeV. Results from this test will be presented. Design and Monte Carlo studies for the general EMC system will be presented too.

Future Calorimetry / Closing Session / 31

Realization and Tests of the Highly Granular CALICE Engineering Calorimeter Prototypes

Dr. TERWORT, Mark [1]

[1] *DESY*

The CALICE collaboration is currently developing engineering
prototypes of electromagnetic and hadronic calorimeters for a future linear collider detector. This detector is designed to be used in particle-flow based event reconstruction. In particular, the calorimeters are optimized for the individual reconstruction and separation of electromagnetic and hadronic showers. They are conceived as sampling calorimeters with tungsten and steel absorbers, respectively. Two electromagnetic calorimeters are being developed, one with silicon-based active layers and one based on scintillator strips that are read out by silicon photomultipliers, allowing highly granular readout. The hadonic calorimeter is based on scintillating tiles that are also read out individually by silicon photomultipliers. The multi-channel, auto-triggered front-end chips are integrated into the active layers of the calorimeters and are designed for minimal power consumption (power pulsing). The goal of the construction of these prototypes is to demonstrate the feasibility of building and operating detectors with fully integrated front-end electronics. The concept and engineering status of the prototypes, the different subcomponents, the DAQ system, the functionality of the ASICs, as well as results from beam test campaigns are reported here.

Future Calorimetry / Closing Session / 81

A Silicon-tungsten Electromagnetic Calorimeter for SiD

Mr. FREY, Raymond [1]; Mr. GRAF, Norman [2]

[1] *University of Oregon*

[2] *SLAC*

We present an update of the development of an electromagnetic calorimeter for the SiD detector concept for a future linear electron-positron collider. After reviewing the design criteria and related simulation studies, we discuss progress in the R&D of the detector. This concept has from the outset made the case for highly integrated electronic readout with small (1 mm) readout gaps in order to maintain a small Moliere radius for electromagnetic showers and to avoid active heat removal. We now have fully functioning 1024-channel readout chips (KPiX) which have been successfully bonded to 15 cm silicon sensors. We will present initial results from these assemblies.

Future Calorimetry / Closing Session / 63

The New RD52 (DREAM) Fiber Calorimeter

Prof. WIGMANS, Richard [1]; Prof. VOLOBOUEV, Igor [1]

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Simultaneous detection of the Cherenkov light and scintillation light produced in hadron showers makes it possible to measure the electromagnetic shower fraction event by event and thus eliminate the detrimental effects of fluctuations in this fraction on the performance of calorimeters. In the RD52 (DREAM) project, the possibilities of this dual-readout calorimetry are investigated and optimized. In this talk, the first test results of prototype modules for the new full-scale fiber calorimeter will be presented.

Future Calorimetry / Closing Session / 64

Micromegas for Imaging Calorimetry

Dr. CHEFDEVILLE, Maximilien [1]

[1] *CNRS/IN2P3/LAPP*

Two Micromegas chambers of 1 m2 size and 1 cm2 cell segmentation have recently been built. Designed for Particle-Flow hadron calorimetry, each chamber features ten thousand channels with embedded front-end electronics and three readout thresholds (concept of semi-digital hadron calorimeter or SDHCAL). The chambers have been tested in a muon beam and also exposed to hadron showers inside a steel structure. Excellent performance such as low noise, high efficiency and very uniform spatial response have been measured and will be reported. The measurements will be confronted to the predictions of a Monte Carlo simulation for which a complete digitisation procedure has been established. Finally, prospects towards the use of a Micromegas SDHCAL at a future linear collider will be discussed based on the scalability of current prototypes to larger sizes and on the expected energy resolution and linearity of such a device.

Future Calorimetry / Closing Session / 85

Closing Remarks

Prof. AKCHURIN, Nural [1]

[1] *TTU*

Closing Remarks