CHEF2019 - Calorimetry for the High Energy Frontier 2019

Report of Contributions

Contribution ID: **1** Type: **not specified**

PFA Oriented Scint-ECAL R&D for CEPC

Monday 25 November 2019 18:00 (20 minutes)

The Circular Electron Position Collider (CEPC) has been proposed as a Higgs or Z factory. Particle flow-oriented electromagnetic (ECAL) and hadronic calorimeters (HCAL) comprise a baseline design of the CEPC calorimetry system. The ECAL consists of alternating tungsten and scintillator layers, with the scintillator bottom-coupled to SiPMs. Advanced studies of the single photon response curves of the SiPM will be presented. New ideas for scintillator-SiPM coupling, have also been studied. Readout electronics based on the SP2B/E design have been prototyped. A two-layer prototype using bottom-coupling has been developed and preliminary cosmic ray test results will be presented.

Author: NIU, Yazhou (University of Science and Technology of China)

Presenter: NIU, Yazhou (University of Science and Technology of China)

Session Classification: Future detector systems

Contribution ID: **3** Type: **not specified**

The status of CEPC AHCAL R&D

Monday 25 November 2019 17:40 (20 minutes)

Circular Electron Position Collider(CEPC) is aimed at being Higgs and Z bosons factory and precisely measuring the mass of Higgs. High granularity calorimeter which is based on particle flow algorithm(PFA) could achieve the jet energy resolution 3%˜4%. One proposal of Hadronic Calorimeter(HCAL) is Analog HCAL(AHCAL) consists of stainless as absorber and scintillator as active layer. This presentation would introduce the progress of it. Including the optimization of detector cell from distinguishing the minimum cluster based on simulation and comparing the light output and uniformity by experiment. Also we had some measurements of scintillators and they can satisfy the requirement of massively production. Effective and fast ways of integrating the detector cells are under development such as automatic packaging machine and pasting experiments. Some merged readout of detector cells had some preliminary result and it was proved a feasible method to reduce the number of electronic channels. Also the construction of a AHCAL prototype has been started.

Author: JIANG, Jiechen (Institute of High Energy Physics(CAS))

Presenter: JIANG, Jiechen (Institute of High Energy Physics(CAS))

Session Classification: Future detector systems

Contribution ID: **4** Type: **not specified**

Development of the ATLAS Liquid Argon Calorimeter Readout Electronics for the HL-LHC

Thursday 28 November 2019 09:00 (20 minutes)

Following new TDAQ buffering requirements and high expected radiation doses in the pileup conditions of the high-luminosity LHC, the ATLAS Liquid Argon Calorimeter electronics will be upgraded to readout the 182,500 calorimeter cells at 40 MHz with 16 bit dynamic range.

The triangular calorimeter signals are amplified and shaped by the analogue electronics over a dynamic range of 16 bits, with low noise and excellent linearity. Developments of low-power preamplifiers and shapers to meet these requirements are ongoing in CMOS 130nm. In order to digitize the analogue signals on two gains after shaping, radiation-hard, low-power 40 MHz 14-bit ADCs are developed using a SAR architecture in 65 nm CMOS. Characterization of the first prototypes of the frontend components show good promise to fulfill all the requirements. The signals will be sent at 40MHz to the off-detector electronics, that will make use of FPGAs connected through high-speed links to perform energy and time reconstruction through the application of corrections and digital filtering. Reduced data are sent with low latency to the first level trigger, while the full data are buffered until the reception of trigger accept signals. The data-processing, control and timing functions will be realized by dedicated boards connected through ATCA crates. Results of tests of the first prototypes of front-end components will be presented, along with design studies on the performance of the off-detector readout system.

Authors: HRYN'OVA, Tetiana (Centre National de la Recherche Scientifique (FR)); ATLAS LIQUID ARGON CALORIMETER GROUP

Presenter: HRYN'OVA, Tetiana (Centre National de la Recherche Scientifique (FR))

Session Classification: Electronics, DAQ

Contribution ID: **5** Type: **not specified**

ATLAS LAr Calorimeter Performance in LHC Run-2

Wednesday 27 November 2019 09:50 (20 minutes)

Liquid argon (LAr) sampling calorimeters are employed by ATLAS for all electromagnetic calorimetry in the pseudo-rapidity region $|\eta| < 3.2$, and for hadronic and forward calorimetry in the region from $|\eta| = 1.5$ to $|\eta| = 4.9$. In the first LHC run a total luminosity of 27 fb^{-1} has been collected at center-of-mass energies of 7-8 TeV. After detector consolidation during a long shutdown, Run-2 started in 2015 and about 150fb-1 of data at a center-of-mass energy of 13 TeV have been recorded.

In order to realize the level-1 acceptance rate of 100 kHz in Run-2 data taking, the number of readout samples recorded and used for the energy and the time measurement has been modified from five to four while keeping the expected performance.

The well calibrated and highly granular LAr Calorimeter reached its design values both in energy measurement as well as in direction resolution.

This contribution will give an overview of the detector operation, hardware improvements, changes in the monitoring and data quality procedures, to cope with increased pileup, as well as the achieved performance, including the calibration and stability of the electromagnetic scale, noise level, response uniformity and time resolution.

Authors: SPALLA, Margherita (Max-Planck-Institut fur Physik (DE)); ATLAS LIQUID ARGON CALORIMETER GROUP

Presenter: SPALLA, Margherita (Max-Planck-Institut fur Physik (DE))

Session Classification: Running performance, upgrade

Contribution ID: **6** Type: **not specified**

The Phase-I Trigger Readout Electronics Upgrade of the ATLAS Liquid Argon Calorimeters

Thursday 28 November 2019 09:20 (20 minutes)

Electronics developments are pursued for the trigger readout of the ATLAS Liquid-Argon Calorimeter towards the Phase-I upgrade scheduled in the LHC shut-down period of 2019-2020. Trigger signals with higher spatial granularity and higher precision are needed in order to improve the identification efficiencies of electrons, photons, tau, jets and missing energy, at high background rejection rates, already at the Level-1 trigger. The LAr Trigger Digitizer system will digitize the 34,000 channels (SuperCells) at a 40 MHz sampling frequency with 12 bit precision after the bipolar shaping of the front-end system. The data will be transmitted to the LAr Digital Processing system in the back-end to extract the transverse energies and perform the bunch-crossing identification. A demonstrator has been installed during Run-2, and the results of the data-taking have helped to validate the chosen technology. Results of ASIC developments including QA/QC and radiation hardness evaluations, performance of the pre-production boards, results of the system integration tests, QA/QC test of final production boards will be presented along with the overall system design and status of the installation and commissioning.

Authors: VALLIER, Alexis (CERN); ATLAS LIQUID ARGON CALORIMETER GROUP

Presenter: VALLIER, Alexis (CERN)

Session Classification: Electronics, DAQ

Contribution ID: **7** Type: **not specified**

A High-Granularity Timing Detector for the Phase-II upgrade of the ATLAS Calorimeter system: detector concept, description and R&D and beam test results

Tuesday 26 November 2019 09:00 (30 minutes)

The increase of the particle flux (pile-up) at the HL-LHC with luminosities of L ⍰ 7.5×10^{34} $cm^{-2}s^{-1}$ will have a severe impact on the ATLAS detector reconstruction and trigger performance. The end-cap and forward region where the liquid Argon calorimeter has coarser granularity and the inner tracker has poorer momentum resolution will be particularly affected. A High Granularity Timing Detector (HGTD) is proposed in front of the LAr end-cap calorimeters for pile-up mitigation and for luminosity measurement.

It will cover the pseudo-rapidity range from 2.4 to 4.0. Two Silicon sensors double sided layers will provide precision timing information for MIPs with a resolution better than 30 ps per track in order to assign each particle to the correct vertex. Readout cells have a size of 1.3 mm × 1.3 mm, leading to a highly granular detector with 3 millions of channels. Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides enough gain to reach the large signal over noise ratio needed.

The requirements and overall specifications of the HGTD will be presented as well as the technical proposal. LGAD R&D campaigns are carried out to study the sensors, the related ASICs, and the radiation hardness. Laboratory and test beam results will be presented.

Authors: ATLAS LIQUID ARGON CALORIMETER GROUP; KUWERTZ, Emma Sian (CERN)

Presenter: KUWERTZ, Emma Sian (CERN)

Session Classification: Calibration, R&D, test beams

Contribution ID: **8** Type: **not specified**

CMS ECAL upgrade for precision timing and energy measurements at the High-Luminosity LHC

Tuesday 26 November 2019 09:30 (20 minutes)

The High Luminosity upgrade of the LHC (HL-LHC) at CERN will provide unprecedented instantaneous and integrated luminosities of around $5 \times 10^{34}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$ and 3000 fb^{-1}, respectively, from 2025 to 2035. During this operational period, an average of 140 to 200 collisions per bunch-crossing (pile up) is expected, posing a challenge to the event reconstruction. In order to cope with these extreme pile up conditions, harsh environment, and increased data rates, the Compact Muon Solenoid (CMS) detector is undergoing a radical Phase II upgrade program. In the barrel region of the CMS electromagnetic calorimeter (ECAL), the lead tungstate crystals and avalanche photodiodes (APDs) will keep performing well and will therefore be maintained, while the entire readout and trigger electronics will be replaced. A dual gain trans-impedance amplifier and an ASIC providing two 160 MHz ADC channels, gain selection, and data compression will be installed. The noise increase in the APDs, due to radiation-induced dark current, will be contained by reducing the temperature at which ECAL is operated. The trigger decision will be moved off-detector and performed by powerful and flexible FPGA processors, allowing for more sophisticated trigger algorithms to be applied.

The upgraded ECAL will be capable of high-precision energy measurements and will greatly improve the time resolution for photons and electrons above 10 GeV. Together with the introduction of a new timing detector designed to perform timing measurements with the resolution of a few tens of picoseconds for minimum ionizing particles, the CMS detector will be able to precisely reconstruct the primary interaction vertex under the described pile up conditions.

In this talk the status of the ongoing R&D activities for the ECAL barrel upgrade will be presented.

Authors: SALVATICO, Riccardo (Universita e INFN Torino (IT)); ON BEHALF OF THE CMS COLLABORATION

Presenter: SALVATICO, Riccardo (Universita e INFN Torino (IT))

Session Classification: Calibration, R&D, test beams

Contribution ID: **10** Type: **not specified**

Reconstruction and simulation of the performance of the MPD/ECal

Friday 29 November 2019 11:10 (20 minutes)

The main goal of NICA/MPD is to investigate the hot and dense baryonic matter in heavy-ion collisions over a wide range of atomic masses, from $Au + Au$ collisions at a center-of-mass energy of $\sqrt{s_{NN}} = 11GeV$ (for Au^{79+}) to proton-proton collisions with $\sqrt{s_{NN}} = 20GeV$. Electromagnetic calorimeter (ECal) is an important detector of the MPD to identify electrons, photons and measure their energy with high precision. The parameters of the ECal such as the multiplicity, energy spectrum, kinematics and PID information are simulated and analyzed.
π^0 signal can be reconstructed from two photons and it is a very important probe to give information of the chiral symmetry restoration and flow signal. The characteristics of the π^0 reconstruction such as the mass spectra, efficiency and $\theta_{\gamma\gamma}$ are analyzed. The angle deviation between the reconstructed and generated theta caused by the offset of the interacting point Z position in the projective geometry is corrected and applied to the π^0 reconstruction. As the overlap of the clusters, it is an important task to improve the reconstruction of the ECal signals, especially for high occupancy. Two different clusterize methods are took and compared in the performance of the reconstruction of γ and π^0.

Author: HUANG, Yan (Tsinghua University)

Co-authors: Ms DABROWSKA, Boyana (Veksler and Baldin Laboratory of High Energy Physics); Prof. TYAPKIN, Igor (Veksler and Baldin Laboratory of High Energy Physics); Prof. WANG, Yi (Tsinghua University)

Presenter: HUANG, Yan (Tsinghua University)

Session Classification: PID, test beams

Contribution ID: **11** Type: **not specified**

Design and performance studies of the calorimeter system for a FCC-hh experiment

Monday 25 November 2019 14:35 (20 minutes)

The physics reach and feasibility of the Future Circular Collider (FCC) with centre of mass energies up to 100 TeV and unprecedented luminosity has delivered a Conceptual Design Report early 2019. The new energy regime opens the opportunity for the discovery of physics beyond the standard model. 100 TeV proton-proton collisions will produce very high energetic particle showers in the calorimeters from both light jets and boosted bosons/top. The reconstruction of such objects sets the calorimeter performance requirements in terms of shower containment, energy resolution and granularity. Furthermore, high-precision measurements of photons and electrons over a wide energy range are crucial to fully exploit the FCC-hh physics potential, especially given the large amount of collisions per bunch crossing the detectors will have to face (pile-up of ⟨⌧⟩=1000).
We will present the current reference technologies for the calorimeter system of the FCC-hh detector: Liquid Argon (LAr) as the active material in the electromagnetic calorimeters, and the hadronic calorimeters for |⌧|>1.3 (Endcap and Forward region), and a Scintillator-Steel (Tile) calorimeter as hadronic calorimeter in the Barrel region. The talk will focus on the performance studies for single particles and jets in the combined calorimeter system. We will introduce the simulation framework and the reconstruction chain, that includes the calibration and clustering of calorimeter cells and the estimation of pile-up induced, and electronics noise. In conclusion, the achieved performances will be compared to the physics benchmarks of the FCC-hh experiment.

Authors: HELSENS, Clement (CERN); ALEKSA, Martin (CERN); HENRIQUES CORREIA, Ana Maria (CERN); VOLKL, Valentin (University of Innsbruck (AT)); FALTOVA, Jana (Charles University (CZ)); ZABOROWSKA, Anna (CERN); SELVAGGI, Michele (CERN); NEUBUSER, Coralie (CERN)

Presenter: ALEKSA, Martin (CERN)

Session Classification: Future detector systems

Contribution ID: **12** Type: **not specified**

Physics object performance of the FCC-hh calorimeter system

Monday 25 November 2019 14:55 (20 minutes)

The feasibility of a future proton-proton collider (FCC-hh), will deliver collisions at a center of mass energies up to 100 TeV and unprecedented instantaneous luminosity (L=30^{34}), resulting in extremely challenging radiation conditions up to a maximum of 5e18 neq/cm2 and dose up to 5 GGy in the forward calorimeters (up to $|\eta|$=6) and up to 1000 simultaneous proton-proton interactions per bunch-crossing. By delivering an integrated luminosity of few tens of ab-1, the FCC-hh will provide an unrivalled discovery potential for new physics. Requiring high sensitivity for resonant searches at masses up to tens of TeV imposes strong constraints on the design of the calorimeters. Resonant searches in final states containing jets, taus and electrons require both excellent energy resolution at multi-TeV energies as well as outstanding ability to resolve highly collimated decay products resulting from extreme boosts. In addition, the FCC-hh provides the unique opportunity to precisely measure the Higgs self-coupling in the di-photon and b-jets channel. Excellent photon and jet energy resolution at low energies as well as excellent angular resolution for pion background rejection are required in this challenging environment. In this talk we will briefly review the electromagnetic and hadronic calorimeter current design and requirements (granularity, energy resolution, acceptance,⋯) and discuss the expected performance of the physics objects based on calorimeter reconstruction. We will then examine the impact of the object performance on the final sensitivity of the relevant benchmark physics analyses.

Authors: HELSENS, Clement (CERN); ALEKSA, Martin (CERN); NEUBUSER, Coralie (CERN); ZABOROWSKA, Anna (CERN); HENRIQUES CORREIA, Ana Maria (CERN); VOLKL, Valentin (University of Innsbruck (AT)); FALTOVA, Jana (Charles University (CZ))

Presenter: HELSENS, Clement (CERN)

Session Classification: Future detector systems

Contribution ID: **13** Type: **not specified**

APRIL : a novel Algorithm for Particle Reconstruction at ILC.

Thursday 28 November 2019 16:20 (20 minutes)

The current developments for future electron-positron colliders are driven by the Particle Flow concept. In these developments, high granularity calorimeters play a central role. This presentation will focus on a new Particle Flow Algorithme (PFA) developed for high granularity calorimeters, and especially for the Semi-Digital Hadronic CALorimeter (SDHCAL) option of the International Large Detector (ILD) project. The first PFA for ILD was PandoraPFA. This new PFA (APRIL) is based on the PandoraPFA Software Development Kit, but implements a different clustering inspired from the ARBOR PFA approach. The presentation will describe briefly the APRIL algorithm and discuss its performance against that of PandoraPFA.

Authors: GRENIER, Gerald (IP2I, CNRS, Univ Lyon 1 (FR)); LI, Bo (Centre National de la Recherche Scientifique (FR)); ETÉ, Rémi (CNRS/IPNL); LAKTINEH, Laktineh (Universite Claude Bernard-Lyon I (FR))

Presenter: GRENIER, Gerald (IP2I, CNRS, Univ Lyon 1 (FR))

Session Classification: Simulation, Geant4, PFA

Contribution ID: **14** Type: **not specified**

Performance study of HGCROC-V2: the front-end electronics for the CMS High Granularity Calorimeter

Thursday 28 November 2019 09:40 (20 minutes)

The High Granularity Calorimeter (HGCAL), presently being designed by the CMS collaboration to replace the CMS endcap calorimeters for the High Luminosity phase of LHC, will feature six million channels. The requirements for the front-end electronics are extremely challenging, including high dynamic range (0-10 pC), low noise (˜2000e- to be able to calibrate on single MIP throughout the detector lifetime), high accuracy time information in order to mitigate the pileup effect (25 ps binning) and low power consumption (˜15mW/channel), as well as the need to select and transmit trigger information with a high granularity. The front-end electronics will face a harsh radiation environment which will reach 200 Mrad at the end of life. It will work at a controlled temperature of minus 30 ℃.

HGCROV-V2 is the second prototype of the front-end ASIC. It has 72 channels of the full analog chain: low noise, high gain preamplifier followed by single-to-differential 25ns shapers, 10-bit ADC 40 MHz SAR-ADC, which provides the charge measurement over the linear range of the preamplifier up to 100 fC. In the saturation range of the preamplifier, from 100 fC to 10 pC, a discriminator and TDC provide the charge information from TOT (Time Over Threshold) over 200 ns dynamic range and 50 ps binning. A fast discriminator and TDC provide timing information to 25 ps accuracy. The both charge and time measurements are kept in a DRAM memory waiting for a L1 accept. At the bunch crossing rate of 40 MHz, compressed charge data are sent out to participate to the L1 generation.

We will report the performances study with the evaluation boards, including signal-to-noise ratio, ADC and TDC performances, and the behavior after irradiation. The first prototype showed a strong digital coupling to the preamplifier input leading to a large coherent noise on charge and time measurements. In order to reduce this effect, the power supply rejection of the preamplifier was improved, the shaper and ADC architectures were changed, and especially we replace the wire bonding scheme by a bump bonding: the improvements on the performances will be showed as well.

Authors: THIENPONT, Damien (IN2P3/OMEGA); Mr THIENPONT, Damien (OMEGA - Ecole Polytechnique - CNRS/IN2P3)

Presenter: Mr THIENPONT, Damien (OMEGA - Ecole Polytechnique - CNRS/IN2P3)

Session Classification: Electronics, DAQ

Contribution ID: **15** Type: **not specified**

Electromagnetic Calorimeter for MPD Spectrometer at NICA Collider

Monday 25 November 2019 11:00 (20 minutes)

The Multy-Purpose Detector (MPD) is designed to study a hot and dense baryonic matter formed in heavy-ion collisions at $\sqrt{s_{NN}}$=4-11 GeV at the NICA accelerator complex (Dubna, Russia). Large-sized electromagnetic calorimeter (ECal) of the MPD spectrometer will provide precise spatial and energy measurements for photons and electrons in the central pseudorapidity region of $|\eta|$<1.2. The Shashlyk-type sampling structure of the ECal is optimized for the photons energy range from about 40 MeV to 2-3 GeV. Fine segmentation and projective geometry of the calorimeter allow to deal with high multiplicity of secondary particles from Au-Au reactions. In this talk, we report on a design, a construction status and expected parameters of the ECal.

Authors: Dr SEMENOV, Andrei (JINR); Prof. TYAPKIN, Igor (Veksler and Baldin Laboratory of High Energy Physics); Ms DABROWSKA, Boyana (Veksler and Baldin Laboratory of High Energy Physics); GOLOVATYUK, Viacheslav (Joint Institute for Nuclear Research (RU)); Dr KRECHETOV, Yuri (Joint Institute for Nuclear Research (RU))

Presenter: Dr SEMENOV, Andrei (JINR)

Session Classification: Nuclear, astro, non-collider

Contribution ID: **16** Type: **not specified**

Recent results on calorimetry for future e+e- colliders

Thursday 28 November 2019 17:00 (20 minutes)

We present optimisation studies for detectors being designed for future e^+e^- colliders such as CLIC and FCC-ee, using particle-flow calorimetry. Surrounding a large silicon tracker volume, a very fine-grained ECAL is envisaged, with 40 silicon-tungsten layers and a lateral segmentation of 5×5 mm^2. Beyond the ECAL, a steel-scintillator HCAL is foreseen, with 60 layers (for CLIC) or 44 layers (for FCC-ee) and scintillator tiles, coupled to SiPMs, with lateral dimensions of 30×30 mm^2.

In this talk, new results on jet energy and angular resolution in light flavour di-jet events for the two detector models are shown. A detailed study on the separation power between di-jet masses of W and Z hadronic decays is described, which demonstrates the capability of these detectors to measure heavy resonance masses in hadronic decay channels. Also, an investigation of the ECAL performance for different sampling options is presented as part of the optimization process of the detector at FCC-ee. The newly developed software chain based on the DD4Hep detector description toolkit is used for the studies, together with the PANDORA particle flow algorithms.

Author: VIAZLO, Oleksandr (CERN)

Presenter: VIAZLO, Oleksandr (CERN)

Session Classification: Simulation, Geant4, PFA

Contribution ID: **17** Type: **not specified**

A highly granular, digital electromagnetic calorimeter prototype

In light of the upgrade program of the ALICE detector a calorimeter at forward rapidities (FoCal) is being considered. This detector would measure photons, electrons, positrons and jets for rapidities $\eta > 3$, offering a wealth of physics possibilities. Its main focus will be on measurements related to the structure of nucleons and nuclei at very low Bjorken-x and possible effects of gluon saturation. The FoCal electromagnetic calorimeter must be able to discriminate between decay photons and direct photons at very high energy, which requires extremely high granularity.

A dedicated R&D program is ongoing to develop the technology needed for such a high-granularity device. Within this program we have constructed a unique prototype of a digital electromagnetic calorimeter based on CMOS monolithic active pixel sensors (MAPS). This prototype has demonstrated the unique capabilities of such highly granular digital calorimeters, providing unique shower profile measurements and good linearity and energy resolution. The prototype calorimeter was based on the MIMOSA chip, which, with its rolling shutter readout, is not fast enough for application in a full detector at LHC.

As a next step, the ALPIDE chip, developed for the ALICE Inner Tracker Upgrade, is being investigated for performance with high occupancy. The ALPIDE chip has a size of 30 x 15 mm^2 with a pixel matrix of 1024 x 512, and a pixel size of 29.24 x 26.88 μm^2. The readout is hit driven, where each double column of pixels is read out via a priority encoder, at a maximum readout speed of 1.2 Gb/s.

A new small calorimeter prototype based on this chip, called mTower, has been designed and is under construction at the moment. It will consist of 24 layers, each of 2 ALPIDE chips and 3 mm of tungsten absorber. The sensitive area will thus be 3 x 3 cm^2. This prototype allows to test the performance of the ALPIDE in a digital calorimeter application and as such will provide input into the final FoCal design parameters. It allows the testing of the electronics, cabling and readout. In a test beam at SPS a few of these single calorimeter layers with ALPIDE chips were tested in August 2018. Currently, a small stack of several layers is tested for performance, with charge injection (occupancy tests) and cosmic muons. A test beam for the full mTower is planned for early 2020.

This contribution will present both results from the first prototype, as well as demonstrate the performance of the ALPIDE in a calorimeter in first measurements with this new prototype under development.

Author: VAN DER KOLK, Naomi (Nikhef National institute for subatomic physics (NL))

Presenter: VAN DER KOLK, Naomi (Nikhef National institute for subatomic physics (NL))

Session Classification: Calibration, R&D, test beams

Contribution ID: **18** Type: **not specified**

Particle identification using Boosted decision trees in the semi-digital hadronic calorimeter

Friday 29 November 2019 10:00 (20 minutes)

The CALICE Semi-digital Hadronic CALorimeter (SDHCAL) prototype using Glass Resistive Plate Chambers as a sensitive medium is the first technological prototype in a family of high-granularity calorimeters developed by the CALICE Collaboration to equip the experiments of future leptonic colliders. It was exposed to beams of hadrons, electrons and muons several times on the CERN PS and SPS beamlines in 2012, 2015 and 2016. We present here a new method of particle identification within the SDHCAL using the Boosted Decision Tree (BDT) method applied to the data collected in 2015. The performance of the method is tested first with GEANT4-based simulated events and then on the data collected in the SDHCAL in the energy range between 10 and 80˜GeV with 10˜GeV energy step. The BDT method is then used to reject the electrons and muons which contaminate the SPS hadron beams.

Authors: Mr LIU, BING (Shanghai Jiao Tong University and University Lyon 1); LIU, Bing (Shanghai Jiao Tong University (CN))

Co-authors: LAKTINEH, Imad (Centre National de la Recherche Scientifique (FR)); YANG, Haijun (Shanghai Jiao Tong University (CN))

Presenter: LIU, Bing (Shanghai Jiao Tong University (CN))

Session Classification: PID, test beams

Contribution ID: **19** Type: **not specified**

Photon identification in the ALICE photon spectrometer PHOS with charged-particle veto detector CPV

Friday 29 November 2019 10:50 (20 minutes)

PHOS is one of the two electromagnetic calorimeters of ALICE. It is designed for high precision measurements of direct photon and neutral meson spectra and their correlations in high and low multiplicity environments. These measurements rely on a high purity photon spectrum. PHOS consists of four modules of $PbWO_4$ crystals with a charged-particle veto (CPV) detector installed in front of it. CPV is a multi-wire proportional chamber with pad readout. The first of three CPV modules was put into operation during LHC Run 2.

Fine granularity of PHOS allows photon identification based on the transverse shape of the shower developed in the detector. We discuss variables which can be used in the method of shower shape identification and the impact it has on the purity of the photon spectrum. Another criterion is the neutrality of the particle detected. It can be found either by extrapolating tracks reconstructed by the central tracking system or by using the CPV information. We will discuss the efficiency of the charged-particle track reconstruction and photon identification in the CPV. After presenting its performance in low multiplicity pp collisions at $\sqrt{s} = 13$ TeV and high multiplicity Pb-Pb collisions at $\sqrt{s_{\rm NN}} = 5.02$ TeV we compare both methods and discuss the impact on the purity of the photon spectrum.

Author: Mr KONDRATYUK, Evgeny (Institute for High Energy Physics of NRC Kurchatov Institute (R)

Presenter: Mr KONDRATYUK, Evgeny (Institute for High Energy Physics of NRC Kurchatov Institute (R)

Session Classification: PID, test beams

Contribution ID: **20** Type: **not specified**

New forward hadron calorimeter for the BM@N heavy ions experiment

Monday 25 November 2019 11:20 (20 minutes)

Forward hadron calorimeter with transverse and longitudinal segmentation has been developed and constructed for the upgraded fixed target BM@N experiment at JINR, Dubna. The main purpose of this calorimeter is to provide event-by-event centrality and reaction plane orientation measurements in nucleus-nucleus collisions.
The design of the hadron calorimeter composed of sampling lead/scintillator modules with a beam hole in the center will be discussed. The light collection from longitudinal sections in modules is provided by Wave Length Shifting (WLS) fibers embedded in scintillator plates. Micropixel photodetectors (Hamamatsu MPPCs) are used for light detection from each longitudinal section of modules. The measured light yield is about 50 ph.el. per section for MIPs. Sampling ADCs are used for signal readout in the calorimeter.
To measure charged fragments escaped the calorimeter through the beam hole the quartz beam hodoscope is developed. The expected doses and neutron fluences for the BM@N forward hadron calorimeter at high heavy ion beam rates has been simulated by the Fluka program. The response of the supermodule composed of 3 x 3 array of modules measured at proton beam energies 1 - 9 GeV at CERN will be shown.

Author: GUBER, Fedor (Russian Academy of Sciences (RU))

Co-authors: IVASHKIN, Alesandr (Russian Academy of Sciences (RU)); GOLUBEVA, Marina (Russian Academy of Sciences (RU)); MOROZOV, Sergey (Russian Academy of Sciences (RU))

Presenter: GUBER, Fedor (Russian Academy of Sciences (RU))

Session Classification: Nuclear, astro, non-collider

Contribution ID: **21** Type: **not specified**

Methods of signal processing and cosmic muon calibration for the BM@N and CBM sampling lead/scintillator hadron calorimeters.

Tuesday 26 November 2019 12:00 (20 minutes)

Recently developed new forward lead/scintillator sampling hadron calorimeters with transverse and longitudinal segmentation will be used in the upgraded BM@N (Baryonic Matter at Nuclotron) experiment at the Nuclotron-NICA acceleration complex in JINR (Dubna) as well as in the CBM (Compressed Baryonic Matter) experiment at the future Facility for Antiproton and Ion Research (FAIR, GSI). These calorimeters are very important for measurements of centrality and reaction plane orientation in heavy-ion collisions. Digitizing of analog signals in a wide dynamic range with sampling ADC is led to strong fluctuations of the measured charge. The new procedure of signal processing based on the Prony least squares fit method has been developed to improve the response and minimize the machine time. In addition, fitting of the signals with a known function allows one to select effectively weak signals on the level of electronic noise, that is important for performing a calibration of calorimeter sections on cosmic muons for the BM@N and CBM experiments.

New methods of signal processing for forward hadron calorimeters will be presented. The application of this method for energy calibration will be shown for finding tracks of cosmic muons based on transverse and longitudinal segmentation using the CBM calorimeter prototype with the sampling ADC readout and the recently constructed forward hadron calorimeter at BM@N.

Author: MOROZOV, Sergey (Russian Academy of Sciences (RU))

Co-authors: IVASHKIN, Alesandr (Russian Academy of Sciences (RU)); GUBER, Fedor (Russian Academy of Sciences (RU)); GOLUBEVA, Marina (Russian Academy of Sciences (RU))

Presenter: MOROZOV, Sergey (Russian Academy of Sciences (RU))

Session Classification: Calibration, R&D, test beams

Contribution ID: **22** Type: **not specified**

CALICE SiW ECAL - Development and first beam test results of detection elements using Chip-on-Board Technology

Friday 29 November 2019 09:40 (20 minutes)

A highly granular silicon-tungsten electromagnetic calorimeter (SiW-ECAL) is the reference design of the ECAL for International Large Detector (ILD) concept, one of the two detector concepts for the detector(s) at the future International Linear Collider. Prototypes for this type of detector are developed within the CALICE Collaboration.

The contribution will report for the first time on the development of a and beam test results obtained with detection elements (ASU. combination of ASIC, PCB and Si Wafers) that are based on a PCB type, called Chip-on-Board (COB), that features wirebonded ASICs. This latter design allows to keep the height of the PCB as thin as 1.2\,mm compared to a height of aabout 3mm for a variant using BGA packaging. The tight space constraints leave little room for extra components such as decoupling capacitances such that particular emphasis will be put on the performance in terms of noise sensitivity.

Authors: POESCHL, Roman (Centre National de la Recherche Scientifique (FR)); ON BEHALF OF THE SIW ECAL GROUPS IN THE CALICE COLLABORATION; IRLES, Adrian (LAL -CNRS/IN2P3)

Presenter: IRLES, Adrian (LAL -CNRS/IN2P3)

Session Classification: PID, test beams

Contribution ID: **23** Type: **not specified**

CALICE SiW ECAL - Development and performance of a highly compact digital readout system

Thursday 28 November 2019 11:10 (20 minutes)

A highly granular silicon-tungsten electromagnetic calorimeter (SiW-ECAL) is the reference design of the ECAL for International Large Detector (ILD) concept, one of the two detector concepts for the detector(s) at the future International Linear Collider. Prototypes for this type of detector are developed within the CALICE Collaboration.

During the last year a highly compact digitial read out card, called SL-Board, has become available. The SL-Board combines data acquisition, power regulation and signal buffering for up to 10000 readout channels on a surface as small as $18 \times 4\,\mathrm{cm}^2$. With this size the systems complies with space constraints in modern particle physics detectors such as ILD. The SL-Board can be readout by a regular computer USB interface via a FTDI Module or through dedicated module, called CORE Module, via a custom developed PCB using UART. The CORE module delivers also the clock and fast commands and synchronises the SL-Boards. The CORE Module acts also as a data concentrator since it receives input from up to 15 calorimeter layers. The entire system SL-Board CORE Module is designed for a data throughput of up to 80 MBit/s.

The system has been used for the first time in a beam test in Summer 2019 at DESY. The contribution will summarise the main features of the system and report on its performance during the beam test

Authors: POESCHL, Roman (Centre National de la Recherche Scientifique (FR)); ON BEHALF OF THE SIW ECAL GROUPS WITHIN THE CALICE COLLABORATION

Presenter: POESCHL, Roman (Centre National de la Recherche Scientifique (FR))

Session Classification: Electronics, DAQ

Contribution ID: **24** Type: **not specified**

Precision timing calorimetry with the CMS High Granularity Calorimeter

Wednesday 27 November 2019 12:00 (20 minutes)

The existing CMS endcap calorimeters will be replaced with a High Granularity Calorimeter (HGCAL) for operation at the High Luminosity (HL) LHC. Radiation hardness and excellent physics performance will be achieved by utilising silicon pad sensors and SiPM-on-scintillator tiles with high longitudinal and transverse segmentation. One of the major challenges of the HL-LHC will be the high pileup environment, with interaction vertices spread not only in position, but also in time. In order to efficiently reject particles originating from pileup, precision timing information of the order of 30 ps will be of great benefit. In order to meet such performance goals, the HGCAL will provide timing measurements for individual hits with signals above 12 fC (equivalent to 3-10 MIPs), such that clusters above 30 GeV will reach a timing resolution about 30 ps. Given the complexity and size of the system, this poses a particular challenge to the readout electronics as well as to the calibration and reconstruction procedures. We present the challenges for the front-end electronics design, results from prototype tests in laboratory and beam environments, as well as anticipated timing performance from simulation.

Author: LOBANOV, Artur (LLR –Ecole Polytechnique (FR))

Presenter: LOBANOV, Artur (LLR –Ecole Polytechnique (FR))

Session Classification: Running performance, upgrade

Contribution ID: **25** Type: **not specified**

ECAL trigger performance in Run 2 and improvements for Run 3

Wednesday 27 November 2019 11:00 (20 minutes)

The CMS Electromagnetic Calorimeter (ECAL) is a high resolution crystal calorimeter operating at the CERN LHC. It is responsible for the identification and precise reconstruction of electrons and photons in CMS, which were crucial in the discovery and subsequent characterization of the Higgs boson. It also contributes to the reconstruction of tau leptons, jets, and calorimeter energy sums, which are are vital components of many CMS Physics analyses.

The ECAL trigger system employs fast digital signal processing algorithms to precisely measure the energy and timing information of ECAL energy deposits recorded during LHC collisions. These trigger primitives are transmitted to the Level-1 trigger system at the LHC collision rate of 40 MHz. These energy deposits are then combined with information from other CMS sub-detectors to determine whether the event should trigger the readout of the data from CMS to permanent storage.

This presentation will summarize the ECAL trigger performance achieved during LHC Run 2 (2015-2018). It will describe the methods that are used to provide frequent calibrations of the ECAL trigger primitives during LHC operation. These are needed to account for radiation-induced changes in crystal and photodetector response and to maintain stable trigger rates and efficiencies up to |eta|=3.0. They also minimize the spurious triggering on direct signals in the photodetectors used in the barrel region (|eta|<1.48). Both of these effects have increased relative to LHC Run 1 (2009-2012), due to the higher luminosities experienced in Run 2.

Further improvements in the energy and time reconstruction of the CMS ECAL trigger primitives are being explored for LHC Run 3 (2021-23), using additional features implemented in the on-detector readout. These are particularly focused on improving the performance at the highest instantaneous luminosities (which will reach or exceed 2x10ˆ34 cm-2 s-1 in Run 3) and in the most forward regions of the calorimeter (|eta|>2.5), where the effects of detector aging will be the greatest. The main features of these improved algorithms will be described and preliminary estimates of the expected performance gains will be presented

Authors: PETYT, David Anthony (Science and Technology Facilities Council STFC (GB)); VALSECCHI, Davide (Università degli Studi e INFN di Milano-Bicocca (IT))

Presenter: VALSECCHI, Davide (Università degli Studi e INFN di Milano-Bicocca (IT))

Session Classification: Running performance, upgrade

Contribution ID: **26** Type: **not specified**

Reconstruction in an imaging calorimeter for HL-LHC

Thursday 28 November 2019 16:40 (20 minutes)

The CMS endcap calorimeter upgrade for high luminosity LHC in 2025 uses silicon sensors to achieve radiation tolerance, with the further benefit of a very high readout granularity. Small scintillator tiles with individual SiPM readout are used in regions permitted by the radiation levels. A reconstruction sequence is being developed to fully exploit the granularity and other significant features of the detector like precision timing, with a view to deployment in the high pileup environment of HL-LHC. An iterative clustering framework (TICL) has been put in place, and is being actively developed. The framework takes as input clusters of energy deposited in individual calorimeter layers delivered by an "imaging" algorithm which has recently been revised and tuned. Mindful of the projected extreme pressure on computing capacity in the HL-LHC era, the algorithms are being designed with GPUs in mind. Very significant speedup has recently been obtained for the clustering algorithm run on GPUs. Machine learning techniques are being developed and integrated into the reconstruction framework. This talk will describe the approaches being considered and show first results.

Author: DI PILATO, Antonio (Universita e INFN, Bari (IT))

Presenter: DI PILATO, Antonio (Universita e INFN, Bari (IT))

Session Classification: Simulation, Geant4, PFA

Contribution ID: **27** Type: **not specified**

Performance of the ALICE electromagnetic calorimeters in LHC Run 1 and Run 2 and upgrade projects

Wednesday 27 November 2019 09:00 (20 minutes)

ALICE (A Large Ion Collider Experiment) incorporates two kinds of electromagnetic calorimeters: highly granulated photon spectrometer PHOS and large acceptance calorimeter EMCAL/DCAL. Both are located in the central part of the ALICE detector.

The PHOS spectrometer is an electromagnetic calorimeter based on scintillating $PbWO_4$ crystals dedicated to the precise measurements of spectra, collective flow and correlations of thermal and prompt direct photons, and of neutral mesons in ultra-relativistic nuclear collisions at LHC energies. The choice of active media allowed for the operation in a high multiplicity environment, the ability to reconstruct neutral pions up to very high transverse momenta and to reach excellent energy and position resolutions. In order to increase light yield of crystals and even further improve the energy resolution, PHOS is cooled to a constant temperature of -25° C. Dedicated L0 and L1 triggers allowed for an increased collected integrated luminosity in data taking.

EMCAL/DCAL is a sampling calorimeter based on lead/scintillator layers used for the measurement of electrons from heavy flavour decays, and the electromagnetic component of jets, spectra and correlations of isolated direct photons and spectra of neutral mesons. EMCAL/DCAL provides single photon and jet triggers which are used for high transverse momentum measurements.

PHOS and EMCAL participated in LHC Run 1 (2009-2013) and Run 2 (2015-2018), and a large amount of physical data were collected for pp collisions at $\sqrt{s}$ = 0.9, 2.76, 5.02, 7, 8, 13 TeV, p-Pb collisions at $\sqrt{s_{NN}}$ = 5.02, 8 TeV and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76, 5.02 TeV. We give an overview of their performance in Run 1 and Run 2 in low and high multiplicity environments as well as plans for respective upgrades for future LHC runs.

Author: Dr BLAU, Dmitry (NRC "Kurchatov Insitute")

Presenter: Dr BLAU, Dmitry (NRC "Kurchatov Insitute")

Session Classification: Running performance, upgrade

Contribution ID: **28** Type: **not specified**

The CALICE AHCAL - a highly granular SiPM-on-tile hadron calorimeter prototype

Monday 25 November 2019 17:10 (30 minutes)

The Analogue Hadron Calorimeter (AHCAL) developed by the CALICE collaboration is a scalable engineering prototype for a Linear Collider detector. It is a sampling calorimeter of steel absorber plates and 3*3 cm^2 plastic scintillator tiles read out by silicon photomultipliers (SiPMs) as active material (SiPM-on-tile). The front-end chips are integrated into the active layers of the calorimeter. They are designed for minimal power consumption by rapidly cycling the power according to the beam structure of a linear accelerator. In 2017 and 2018, a new large prototype with 38 active layers of 7272* cm^2 size has been built. Each active layer contains 576 single channels, arranged on four readout boards and grouped according to the 36-channel SPIROC2E readout chips. The prototype has been assembled using techniques suitable for mass production, such as injection-moulding and semi-automatic wrapping of scintillator tiles, assembly of scintillators on electronics using pick-and-place machines and mass testing of detector elements. The calorimeter was commissioned at DESY and took muon, electron and pion data at the CERN SPS.

The contribution gives an overview of the construction, commissioning, calibration and first test beam results of the large CALICE AHCAL engineering prototype.

Author: KRUGER, Katja (Deutsches Elektronen-Synchrotron (DE))

Co-author: CALICE COLLABORATION

Presenter: KRUGER, Katja (Deutsches Elektronen-Synchrotron (DE))

Session Classification: Future detector systems

Contribution ID: **29** Type: **not specified**

Using Machine Learning to Speed Up and Improve Calorimeter R&D

Thursday 28 November 2019 15:00 (20 minutes)

Design of new experiments, as well as upgrade of ongoing ones, is a continuous process in the experimental high energy physics. Frontier R&Ds are used to squeeze the maximum physics performance using cutting edge detector technologies.

The evaluation of physics performance for particular configuration includes sketching this configuration in Geant, simulating typical signals and backgrounds, applying reasonable reconstruction procedures, combining results in physics performance metrics.

Since the best solution is a trade-off between different kinds of limitations, a quick turn over is necessary to evaluate physics performance for different techniques in different configurations.

Two typical problems which slow down evaluation physics performance for particular approaches to calorimeter detector technologies and configurations are:
- Emulating particular detector properties including raw detector response together with a signal processing chain to adequately simulate a calorimeter response for different signal and background conditions. This includes combining detector properties obtained from the general Geant simulation with properties obtained from different kinds of bench and beam tests of detector and electronics prototypes.
- Building an adequate reconstruction algorithm for physics reconstruction of the detector response which is reasonably tuned to extract the most of the performance provided by the given detector configuration.

Being approached from the first principles, both problems require significant development efforts. Fortunately, both problems may be addressed by using modern machine learning approaches, that allow a combination of available details of the detector techniques into corresponding higher level physics performance in a semi-automated way.

In this paper, we discuss the use of advanced machine learning techniques to speed up and improve the precision of the detector development and optimization cycle, with an emphasis on the experience and practical results obtained by applying this approach to optimizing the electromagnetic calorimeter design as a part of the upgrade project for the LHCb detector at LHC.

Authors: RATNIKOV, Fedor (Yandex School of Data Analysis (RU)); DERKACH, Denis (National Research University Higher School of Economics (RU)); BOLDYREV, Alexey (NRU Higher School of Economics (Moscow, Russia)); Mr SHEVELEV, Andrew; Mr FAKANOV, Pavel; Mr MATYUSHIN, Leonid

Presenter: RATNIKOV, Fedor (Yandex School of Data Analysis (RU))

Session Classification: Simulation, Geant4, PFA

Contribution ID: **30** Type: **not specified**

Silicon sensors for the HGCAL upgrade: challenges, sensor design & electrical characterization

Tuesday 26 November 2019 17:00 (20 minutes)

The CMS detector will undergo significant improvements to face the 10-fold increase in integrated luminosity of LHC, the so-called High-Luminosity LHC, scheduled to start in 2026. This will include a completely new calorimeter in the CMS endcap regions, which should be able to withstand fluences of up to 10ˆ16 n_{eq}/cmˆ2. The new High Granularity Calorimeter (HGCAL) will have unprecedented transverse and longitudinal readout and trigger segmentation that will facilitate the particle-flow approach to reconstruct electromagnetic and hadronic particle showers and their energies. In regions of low radiation, HGCAL will be equipped with small plastic scintillator tiles as active material coupled to on-tile silicon photomultipliers. In the higher radiation zone silicon has been chosen due to its intrinsic radiation hardness. The silicon sensors will be of hexagonal shape, with three nominal thicknesses of 120 um, 200 um and 300 um, optimized for regions of different radiation levels. They will be segmented into several hundred cells with hexagonal shape of 0.5 to 1.1 cmˆ2 in size, each of which is read out individually. A comprehensive campaign is in progress to converge on optimal sensor design choices and parameters, such as bulk doping, layouts and production methods. In this talk, results from full electrical sensor characterization are presented for different sensors, together with first results from an irradiation campaign of large-area silicon sensors.

Author: BRONDOLIN, Erica (CERN)

Presenter: BRONDOLIN, Erica (CERN)

Session Classification: Sensors

Contribution ID: **31** Type: **not specified**

The Phase 2 Upgrade of the LHCb Calorimeter system

Monday 25 November 2019 14:05 (30 minutes)

The Phase 2 LHCb Upgrade, which is now being developed by the LHCb Collaboration, is supposed to make LHCb able to work at high luminosity, up to 2*10ˆ34 /cmˆ2/s.
The plan is to collect ˜300 fbˆ{-1} of data in a few years.
The Phase 2 Upgrade will require a major revision of the LHCb Calorimeter system.

The increased instantaneous and integrated luminosity will result in very high particle density and radiation doses in the areas close to the beam pipe. In these conditions, ECAL has to provide high quality energy and position measurements for electromagnetic showers, as well as separation of two closely lying showers. Another requirement for the LHCb Phase 2 Upgrade ECAL is the ability to measure the time of arrival of the photon or electron with an accuracy of few tens of picosecond. At high luminosity, such time measurement is a powerful tool helping to correctly assign electromagnetic showers to primary vertices.

The choice for the central part of ECAL can be a sampling calorimeter with dense tungsten-based converter and radiation hard crystal scintillator.
Concerning the particular structure type, it was found that the Spaghetti Calorimeter (SPACAL) concept meets all the requirements, including limits on radiation degradation, if its active elements are made of GAGG:Ce or YAG:Ce scintillators. The peripheral areas with moderate radiation doses can be instrumented with calorimeter modules based on plastic scintillator.

An R&D campaign was started to optimize the Upgrade 2 ECAL structure. It includes:
- studies of scintillating materials, in particular irradiation measurements;
- beam test studies of the performance of various ECAL module prototypes, both for central (SPACAL) and peripheral areas;
- simulation studies to find the optimal detector layout, longitudinal segmentation and granularity.

In this talk we present the R&D results and the current status of the LHCb Calorimeter upgrade.

Authors: SCHOPPER, Andreas (CERN); PIZZICHEMI, Marco (CERN)

Presenter: PIZZICHEMI, Marco (CERN)

Session Classification: Future detector systems

Contribution ID: **32** Type: **not specified**

Status and plans for the CMS High Granularity Calorimeter upgrade project

Monday 25 November 2019 13:45 (20 minutes)

The CMS Collaboration is preparing to build replacement endcap calorimeters for the HL-LHC era. The new high-granularity calorimeter (HGCAL) was first discussed publicly at CHEF 2013. As the name implies, it is a highly-granular sampling calorimeter with approximately six million silicon sensor channels (˜1.1cmˆ2 or 0.5cmˆ2 cells) and about four hundred thousand channels of scintillator tiles readout with on-tile silicon photomultipliers. The calorimeter is designed to operate in the harsh radiation environment at the HL-LHC, where the average number of interactions per bunch crossing is expected to exceed 140. Besides measuring energy and position of the energy deposits the electronics is also designed to measure the time of their arrival with a precision on the order of 50 ps. Many of the design ideas employed in HGCAL were first developed by the CALICE collaboration in the context of the ILC detectors. We will present the current status of the project, the many lessons learnt so far and our future plans.

Author: SEFKOW, Felix (Deutsches Elektronen-Synchrotron (DE))

Presenter: SEFKOW, Felix (Deutsches Elektronen-Synchrotron (DE))

Session Classification: Future detector systems

Contribution ID: **33** Type: **not specified**

Performance of CMS High Granularity Calorimeter prototypes in testbeam experiments

Tuesday 26 November 2019 09:50 (20 minutes)

The present electromagnetic and hadronic calorimeters of the CMS experiment will be upgraded to cope up with the harsh radiation environment and pileup conditions posed by the high luminosity operations of LHC (HL-LHC) expected to start in 2026. CMS has opted for a sampling calorimeter, based on silicon and scintillator technologies, with unprecedented transverse and longitudinal segmentation to facilitate particle identification, particle-flow reconstruction and pileup rejection. As part of the ongoing development and testing phase of the HGCAL, prototypes of both the silicon and scintillator based calorimeter sections have been tested in 2018 in beams at CERN. We report on the performance of the prototype detectors in terms of stability of noise and pedestals, MIP calibration, and energy linearity and resolution for electrons and pions. We compare the measurements with a detailed GEANT4-based simulation.

Authors: PANDEY, Shubham (Indian Institute of Science Education and Research (IN)); SHARMA, Seema (Indian Institute of Science Education and Research (IN)); LOBANOV, Artur (LLR –Ecole Polytechnique (FR))

Presenter: LOBANOV, Artur (LLR –Ecole Polytechnique (FR))

Session Classification: Calibration, R&D, test beams

Contribution ID: **34** Type: **not specified**

CALorimetric Electron Telescope (CALET) on the International Space Station

Monday 25 November 2019 10:10 (30 minutes)

The CALorimetric Electron Telescope (CALET) space experiment, which has been developed by Japan in collaboration with Italy and the United States, is a high-energy astroparticle physics mission installed on the International Space Station (ISS). The primary goals of the CALET mission include studying the details of galactic cosmic-ray acceleration and propagation, and searching for possible nearby sources of high-energy electrons and dark matter signatures. The CALET experiment will measure the flux of cosmic-ray electrons (including positrons) to 20 TeV, gamma-rays to 10 TeV and nuclei with Z=1 to 40 up to 1,000 TeV.
The instrument consists of two layers of segmented plastic scintillators for the cosmic-ray charge identification (CHD), a 3 radiation length thick tungsten-scintillating fiber imaging calorimeter (IMC) and a 27 radiation length thick lead-tungstate calorimeter (TASC). CALET has sufficient depth, imaging capabilities and excellent energy resolution to allow for a clear separation between hadrons and electrons, and between charged particles and gamma rays. The instrument was launched on August 19, 2015 to the ISS with HTV-5 (H-II Transfer Vehicle 5) and installed on the Japanese Experiment Module-Exposed Facility (JEM-EF) on August 25.
Since the start of operation in mid-October, 2015, a continuous observation has being kept mainly by triggering high energy (>10 GeV) cosmic-ray showers without any major interruption. The number of the triggered events over 10 GeV is nearly 20 million per month. By using the data obtained during the first two-years, we will have a summary of the CALET observations: 1) Electron+ Positron energy spectrum, 2) Proton and Nuclei spectrum, 3) Gamma-ray observation, with results of the performance study on orbit. Moreover, we are carrying out follow-up observations of the electromagnetic counterparts to LIGO-VIRGO gravitational wave events.
We will present a brief summary of the scientific results obtained by observations over 4 years on the ISS, and explain the characteristics of the CALET instrument developed in cooperation with Japan Aerospace Exploration Agency (JAXA) with the performance in space.

Authors: Prof. TORII, Shoji (WISE, Waseda University); ON BEHALF OF THE CALET COLLABORATION

Presenter: Prof. TORII, Shoji (WISE, Waseda University)

Session Classification: Nuclear, astro, non-collider

Contribution ID: **35** Type: **not specified**

The SiPM-on-Tile Section of the CMS High Granularity Calorimeter

Wednesday 27 November 2019 11:40 (20 minutes)

We present developments towards an engineering design of the phase 2 upgrade of the CMS endcap calorimeter with a focus on the section instrumented with scintillator tiles directly read by SiPMs. With respect to earlier developments targeted at a future e+e- collider, additional challenges in terms of radiation hardness, data rates and mechanical integration including cooling need to be addressed. We will present the evolving design, results on the performance of irradiated SiPMs, the optimisation of scintillator tiles, the status of active element prototypes with integrated electronics, and the preparations for automated production.

Authors: KOLBERG, Ted (Florida State University (US)); ON BEHALF OF THE CMS COLLABORATION

Presenter: KOLBERG, Ted (Florida State University (US))

Session Classification: Running performance, upgrade

Contribution ID: **36** Type: **not specified**

Calibration of MPD Electromagnetic Calorimeter with Muons

Tuesday 26 November 2019 11:40 (20 minutes)

Shashlyk-type electromagnetic calorimeter (ECal) of the Multy-Purpose Detector at heavy-ion NICA collider is optimized to provide precise spatial and energy measurements for photons and electrons in the energy range from about 40 MeV to 2-3 GeV. To deal with high multiplicity of secondary particles from Au-Au reaction, ECal has a fine segmentation and consists of 38,400 cells (”towers”). Given the big number of “towers” and the time constraint, it is not possible to calibrate every ECal “tower” with beam. In this presentation, we describe the strategy of the first-order calibration of ECal with cosmic muons, and discuss this calibration strong and weak points.

Authors: SEMENOV, Andrei (Joint Institute for Nuclear Research); Mrs SEMENOVA, Irina (Joint Institute for Nuclear Research (Dubna)); Ms DABROWSKA, Boyana (Veksler and Baldin Laboratory of High Energy Physics); DURUM, Artur (Institute for High Energy Physics (RU)); Dr KRECHETOV, Yuri (Joint Institute for Nuclear Research (RU)); KULIKOV, Viacheslav; Mr MAMONOV, Ilya (ITEP (RU)); MARTEMIANOV, Maxim; Prof. TYAPKIN, Igor (Veksler and Baldin Laboratory of High Energy Physics)

Presenter: SEMENOV, Andrei (Joint Institute for Nuclear Research)

Session Classification: Calibration, R&D, test beams

Contribution ID: **37** Type: **not specified**

A relation between track length and deposited energy in homogeneous calorimeter by GEANT4 simulation at high energy

Thursday 28 November 2019 14:40 (20 minutes)

We have simulated the track length and the total energy deposited by high energy particles, and found a very good correlation between these two observables in large homogeneous calorimeter. A straight-line fit does not pass through the origin, but the intercept of energy deposited is proportional to the incident energy. Moreover, for both electrons and hadrons the slope of the straight line is independent of the incident energy. The energy resolution of the calorimeter can be expressed in term of the distribution around the correlation, which we find to be very good, about $25\%\sqrt{E}$(GeV). We have extracted these results from GEANT4 simulations.

Authors: Mr TERADA, Reima (Shinshu university); Dr TAKESHITA, Tohru (Shinshu university); TAKESHITA, Toru (Shinshu University (JP))

Presenters: Dr TAKESHITA, Tohru (Shinshu university); TAKESHITA, Toru (Shinshu University (JP)); TAKESHITA, Toru (Shinshu University (JP))

Session Classification: Simulation, Geant4, PFA

Contribution ID: **38** Type: **not specified**

Performance study of GAGG:Ce crystal

Tuesday 26 November 2019 14:00 (20 minutes)

Inorganic scintillators with high density and high light output are widely used for the detection of ionizing radiation in high energy physics, space exploration, modern medical imaging and industry. Recently developed cerium-doped Gd3AL2Ga3O12 (GAGG:Ce) crystal is a promising scintillator with high density, high light yield , fast scintillation decay time and non-hygroscopicity used for calorimetry. In addition, the presence of Gd isotopes with a very high thermal neutron capture cross section makes the GaGG:Ce crystal efficiently sensitive for neutron detection. In this paper, performance of gamma and neutron detection based on GAGG:Ce scintillator has been studied. Emission spectra and decay time of different GAGG:Ce samples are studied. Energy resolution and linearity of GAGG:Ce crystals coupled with PMT and different SiPMs are compared. The excellent energy resolution of 3.4% at 662 keV measured with Hamamatsu S12571-6075CS SiPM is obtained. Besides the continuum gamma rays, Gd isotopes also produce low energy conversion electrons and X-rays at 34 and 74 keV. Thanks to very high light yield, the photopeaks due to these low energy radiations are successfully observed and can be used as n/gamma discrimination. In future, the time information of GAGG:Ce will be studied to do particle identification.

Author: WANG, Zhigang (Chinese Academy of Sciences (CN))

Co-authors: Dr ZHU, Yao; QIAN, Sen (Institute of High Energy Physics,CAS); CHEN, Pengyu; GUO, Hao; Dr MA , Lishuang

Presenter: WANG, Zhigang (Chinese Academy of Sciences (CN))

Session Classification: Sensors

Contribution ID: **39** Type: **not specified**

R&D of the Energy Calibration for the SiD EM Calorimeter based on Machine Learning

Thursday 28 November 2019 17:20 (20 minutes)

We have developed an energy calibration method for the ILC SiD EM calorimeter (ECAL), a sampling calorimeter consisting with 30 Silicon-Tungsten layers, using machine learning.
Our approach uses a deep neural network (DNN) in a regression problem to obtain the energy of the incident particle from the list of measured energy deposits (energy calibration).
The DNN is used to express the non-linear detector response and to get the particle ID information, electron or photon, in a particle-depend calibration.
We report on the status of the R&D and future plans.

Authors: STEINHEBEL, Amanda Lynn (University of Oregon (US)); NAGAHARA, Hajime (Institute for Datability Science, Osaka University); STRUBE, Jan Fridolf (PNNL); BRAU, Jim (University of Oregon (US)); MORIKAWA, Koki (Osaka City Univ.); BREIDENBACH, Martin (SLAC); IWASAKI, Masako (Osaka City Univ. / RCNP, Osaka Univ.); TAKEMURA , Noriko (Institute for Datability Science, Osaka University); NAKA, Yusuke (Osaka City Univ.); NAKASHIMA, Yuta (Institute for Datability Science, Osaka University)

Presenter: IWASAKI, Masako (Osaka City Univ. / RCNP, Osaka Univ.)

Session Classification: Simulation, Geant4, PFA

Contribution ID: **40** Type: **not specified**

Time synchronization and DAQ for electromagnetic calorimeter of MPD experiment at NICA

Thursday 28 November 2019 10:20 (20 minutes)

Time synchronization and data acquisition systems are designed for the Electromagnetic Calorimeter (ECAL) of Multi Purpose Detector at NICA collider. The DAQ system comprises 43,000 readout channels with waveform digitizers and with pulse reconstruction algorithms signal magnitude and time of arrival are found.

Clock distribution and time tag synchronization are performed with White Rabbit technology. It is an extension to Ethernet and provides sub-nanosecond accuracy and picoseconds precision for distributed system. MPD timing network topology is tree with Grand-Master at root connected to GPS receiver, two levels of distribution switches, control boards and finally endpoints in readout boards. All readout boards have same notion of frequency and time and digitize detector signals synchronously. Low jitter ADC sampling clocks are derived from tunable local crystal oscillators controlled by FPGA on readout boards.

Control boards perform hardware data merging per-event and deliver data stream to DAQ computer farm by 10 Gbit/s Ethernet links. TCP/IP is run on FPGA and include endpoint discovery and automatic configuration protocols.

Readout electronics will be installed on ECAL modules inside MPD and is designed to operate in magnetic field. 672 FPGA readout boards have 10 kW total power dissipation and liquid cooling system is designed.

Prototype system has been running at BM@N detector in 2018 at Nuclotron extracted beam and ECAL test setups are operational now.

Author: Mr SLEPNEV, Ilia (Joint Institute for Nuclear Research (RU))

Presenter: Mr SLEPNEV, Ilia (Joint Institute for Nuclear Research (RU))

Session Classification: Electronics, DAQ

Contribution ID: **41** Type: **not specified**

Concepts and design of the CMS High Granularity Calorimeter Level 1 Trigger

Thursday 28 November 2019 10:00 (20 minutes)

The CMS collaboration has chosen a novel high granularity calorimeter for the endcap regions as part of its planned upgrade for the high luminosity LHC. The calorimeter will have fine segmentation in both the transverse and longitudinal directions and will be the first such calorimeter specifically optimised for particle flow reconstruction to operate at a colliding-beam experiment. The calorimeter data will form part of the Level 1 trigger of the CMS experiment and, together with tracking information that will also be available at this level, should allow particle-flow techniques to be used as part of this trigger. The trigger has tight contraints on latency and rate and will need to be implemented in hardware. The high granularity results in around six million readout channels in total, a million of which are also used as part of the Level 1 trigger, presenting a significant challenge in terms of data manipulation and processing for the trigger system; the trigger data volumes will be an order of magnitude above those currently handled at CMS. In addition, the high luminosity will result in an average of 140 (or more) interactions per bunch crossing that give a huge background rate in the forward region and these will need to be efficiently rejected by the trigger algorithms. Furthermore, reconstruction of the particle clusters to be used for particle flow in events with high hit rates is also a complex computational problem for the trigger. The status of the trigger architecture and design, as well as the concepts for the algorithms needed in order to tackle these major issues, will be presented.

Author: AHUJA, Sudha (Centre National de la Recherche Scientifique (FR))

Presenter: AHUJA, Sudha (Centre National de la Recherche Scientifique (FR))

Session Classification: Electronics, DAQ

Contribution ID: **42** Type: **not specified**

Study of silicon sensors for precise timing measurement

Tuesday 26 November 2019 17:20 (20 minutes)

We are studying silicon sensors with high time resolution for the particle identification in the International Linear Collider (ILC). In the International Large Detector (ILD), one of two detector concepts for the ILC, particle identification can be achieved with dE/dx measurement with the Time Projection Chamber, but is has insensitive energy range which has similar dE/dx with multiple kinds of particles. With a precise time-of-flight measurement combined with the dE/dx measurement, performance on the particle identification can be improved. In order to identify pions, kaons and protons up to 5 GeV, the time resolution is required to be less than 50 psec. We are studying Low Gain Avalanche Diodes (LGADs) to achieve the resolution.
LGADs already have been proved to realize the time resolution down to 30 psec. However, the normal reach-through LGADs have an issue that the amplification factor heavily depends on the position of the hit, because the amplification region is not uniformly formed due to the surface structure. To overcome this, inverse-type LGADs have been proposed, which has amplification region at the bottom, in contrast to the reach-through type with amplification occurring just below the surface.
As a step to develop LGADs, we are now focusing to characterize Avalanche Photo Diode (APD)s, which are usually used to measure optical photons, with charged particles. Since the APDs has the same multiplication structure as LGADs, this should help determining the structure of the LGADs. We will present the characteristics of reach-through and inverse type of APDs with particles from radioisotopes. We are also preparing to do a beam test for them. Since it is scheduled just before the conference, we will show a quick look of the results of the test beam.

Authors: DEGUCHI, Yuto (Kyushu University); KAWAGOE, Kiyotomo (Kyushu University (JP)); SUEHARA, Taikan (Kyushu University (JP))

Presenter: DEGUCHI, Yuto (Kyushu University)

Session Classification: Sensors

Contribution ID: **44** Type: **not specified**

LHC-ATLAS Phase-I upgrade: Calibration and simulation of new trigger readout system of the Liquid Argon calorimeter

Thursday 28 November 2019 11:30 (12 minutes)

LHC-ATLAS experiment is in the middle of Phase-I upgrade for Run3 from 2021 and High-Luminosity LHC run from 2026, which instantaneous luminosity is going to be higher than it's ever experienced. In order to achieve lower trigger rate than required at the first stage trigger, 100 kHz, Liquid Argon Calorimeter group is working on an upgrade of its trigger readout electronics. Granularity of the calorimeter cell for trigger readout, so-called Super Cell to be introduced from Run3, is going to have 10 times finer granularity than that for Run2. While the production of new electronics and those installation, calibration framework for the energy and timing measurement of the SC readout is also developed. We established it using data taken by calibration runs with pulsing system to set Super Cell specific wave form and constants, i.e. pedestal level, equivalent transverse energy for 1 bit of ADC and coefficients for Optimal Filter for energy calculation. In July 2019, we have obtained them for the first installed digitizer board in the endcap part of the calorimeter. Based on it we have verified the new hardware has performance as its design. We also developed a new simulator of the calorimeter to implement the calibrated constants obtained during commissioning of new trigger readout system. New simulation is taking into account the long bipolar pulse shape for any number of interaction per bunch crossing, which makes highly realistic out-of-time pileup effect. We discuss how the simulator can be used and give some examples of the application.

Author: TATENO, Gen (University of Tokyo (JP))

Co-authors: TANAKA, Junichi (University of Tokyo (JP)); ENARI, Yuji (University of Tokyo (JP)); IGUCHI, Ryunosuke (University of Tokyo (JP)); MATSUZAWA, Nobuo (University of Tokyo (JP)); ATLAS LAR CALORIMETER COLLABORATION

Presenter: TATENO, Gen (University of Tokyo (JP))

Session Classification: Electronics, DAQ

Contribution ID: **45** Type: **not specified**

Development of the FoCal PAD prototype and its test results

Tuesday 26 November 2019 11:00 (20 minutes)

Motoi INABA for the ALICE FoCal collaboration.

We are planning to realize a forward calorimeter (FoCal) as part of a detector upgrade of the ALICE experiment at LHC. The installation of and data taking with FoCal are expected during Long Shutdown 3 (in 2024 - 2026) and Run-4 (in 2026 - 2028), respectively.

FoCal will consist of the Si+W electromagnetic calorimeter and a conventional sampling hadronic calorimeter. The electromagnetic calorimeter has 18 lower-granularity layers using silicon pad sensors (PAD) and 2 higher-granularity layers using silicon pixel sensors (MAPS).

The thickness, width and height of one PAD layer are approximately 5.5mm, 280mm and 93mm, respectively,while the front-end electronics are mounted on top of the PAD layer.

We have developed the prototype, called “mini-FoCal”, which has 20 PAD layers with 3840 silicon pad cells in total. FoCal will be 48 times larger than mini-FoCal.

In order to measure the energy resolution and S/N, we tested mini-FoCal at CERN PS and SPS complexes during 2018. Following these tests, we temporarily installed mini-FoCal in the ALICE cavern and studied its performance under realistic experimental conditions over one month. Finally, we could confirm the better energy resolution and the electromagnetic shower development in mini-FoCal.

Author: Dr INABA, Motoi (Tsukuba University of Technology)

Presenter: Dr INABA, Motoi (Tsukuba University of Technology)

Session Classification: Calibration, R&D, test beams

Contribution ID: **46** Type: **not specified**

The study of photon reconstruction performance at CEPC baseline detector

Thursday 28 November 2019 17:40 (20 minutes)

The Circular Electron Positron Collider (CEPC) is a proposed Higgs/Z factory. The photon reconstruction is critical to its physics program. We study the photon reconstruction at the CEPC baseline detector, a Particle Flow oriented detector. We characterized the objective performance at both single-photon and di-photon samples. At the single-photon sample, we quantify the photon conversion rate, the differential reconstruction efficiency and energy resolution, and the identification performance. Using di-photon samples, our analysis shows that the CEPC baseline detector reaches a relative mass resolution of 1.7 - 2.2\% of the Higgs boson at the $H \rightarrow \gamma\gamma$ sample, and can reconstruct the π^0 with energy as high as 20 - 30 GeV. We also investigate the impact of geometry defects on photon energy resolution and discuss the possible corrections according to the reconstructed photon position.

Author: SHEN, Yuqiao

Co-author: RUAN, Manqi (Chinese Academy of Sciences (CN))

Presenter: SHEN, Yuqiao

Session Classification: Simulation, Geant4, PFA

Contribution ID: **47** Type: **not specified**

High-granularity crystal calorimetry: conceptual designs and studies

Monday 25 November 2019 15:35 (20 minutes)

A new concept of high-granularity calorimetry based on crystals has been proposed for the Circular Electron Positron Collider (CEPC) with an aim to reach unprecedented energy resolution as well as 3D-positioning precision. In this conceptual design, crystals are finely segmented in both transverse and longitudinal directions. Each crystal is optically isolated and read out by a compact semiconductor photodetector (e.g. silicon photomultiplier, SiPM). Simulation models based on Geant4 are developed to study the expected performance of the whole calorimeter as well as essential optical properties of a single crystal. Cosmic-ray measurements have been made with single crystal bars including lead tungstate (PbWO4) and BGO. Performance of SiPMs from different vendors are also compared. A calibration scheme using optical fibres and a laser source is being considered and prototyped. The idea of adding precision timing information for a "5D-calorimeter" is also being investigated to quantify in simulation the improvements of the positioning precision and particle identification performance.

Author: Dr LIU, Yong (Institute of High Energy Physics (CN))

Presenter: Dr LIU, Yong (Institute of High Energy Physics (CN))

Session Classification: Future detector systems

Contribution ID: **48** Type: **not specified**

LHC-ATLAS Phase-1 upgrade: Firmware validation for real time digital processing for new trigger readout system of the Liquid Argon calorimeter.

Thursday 28 November 2019 11:42 (12 minutes)

LHC ATLAS Run3 experiment will start from 2021 with higher instantaneous luminosity. ATLAS experiment uses two staged trigger system, the first trigger system is based on hardware, and the second is performed with PC farm. With two staged trigger system, trigger rate can be suppressed to 1KHz from bunch crossing rate of 40MHz. In order to improve trigger performance under high luminosity and high energy condition, we will readout 10 times more finely segment, so-called supercell, with new trigger readout system. This new system requires high performance ATCA mezzanine card, so-called LATOME board, with Intel Arria-10 FPGA. LATOME firmware has several blocks. User Code block, one of main block, calculates deposited energy from 40 MHz sampling 12 bits ADC by using DSP blocks which multiply 14 bits coefficients with a latency of 125 ns. User Code has some modules. About half of them connect to IP bus controller, and which can be read out register contents from FPGA directly. Other modules are connected to a monitoring readout path, which can extract data contents in conjunction with trigger signals. User Code firmware has beed constructed and currently it is under detailed validation. Simulation base User Code verification scheme has been built up based on Universal VHDL/Verilog Verification Methodology (UVVM), which can set up an automatic validation procedure. Also, on-board validation scheme is under development with appropriate readout system. In the presentation, we summarize simulation based firmware verification, and result of on-board validation.

Author: OISHI, Reiyo (University of Tokyo (JP))

Co-authors: TANAKA, Junichi; ENARI, Yuji; UNO, Kenta; ATLAS LAR CALORIMETER COLLABORATION

Presenter: OISHI, Reiyo (University of Tokyo (JP))

Session Classification: Electronics, DAQ

Contribution ID: **49** Type: **not specified**

Performance of segmented lead glass absorber calorimeter prototype

Friday 29 November 2019 09:00 (20 minutes)

Sampling calorimeter is essential for physics measurements in high-energy frontier collider experiments using Particle Flow Algorithm (PFA). In order to separate the particles in a jet incident on the calorimeter, three-dimensional detailed information is required. Therefore, in calorimeters optimized for PFA, not only energy information but also position information is very important. Location information can be improved by creating a very fine granulated detection layer. However, energy resolution is principally determined by the sampling ratio.

Energy resolution can be dramatically improved if energy information can be read using lead glass as the absorption layer. In order to independently observe the energy in the narrow area required to use PFA, it is necessary to divide the lead glass into small pieces that are independent of each other. A small optical sensor is required to read out the Cherenkov light from a small lead glass block. To read a lot of small lead glass blocks, the dead volume between layers can be reduced by using MPPC, this optical sensor thickness is very thin. This sampling calorimeter using lead glass blocks as the absorption layers is useful for experiments that require the high energy resolution in the future.

We are developing a prototype of a calorimeter with a segmented lead glass absorption layer that takes PFA into account. The prototype absorber layer size is 9x9x4cm^3 and consists of nine 3x3x4cm3 lead glass blocks. The detection layer can read position information of 1x1cm^1 using a plastic scintillator with a width of 1cm. Backward energy leakage is measured with a tail catcher using a single 12x12x25cm^3 lead glass block. All detectors are optically read out using MPPCs.

We tested this prototype using the positron beam at Research Center for ELectron PHoton Science, Tohoku University. First, a positron beam was injected into each lead glass block channel for calibration. Then, the performance of the whole prototype was evaluated by injecting the beam.

As a result of the beam injection test of the prototype with three segmented lead glass absorption layers, the overall energy resolution is 13%. We will report on the performance of this prototype.

Authors: TERADA, Reima (Shinshu University); TAKESHITA, Toru (Shinshu University (JP)); ISHIHAMA, Hiroki (Shinshu University)

Presenter: TERADA, Reima (Shinshu University)

Session Classification: PID, test beams

Contribution ID: **50** Type: **not specified**

Study on Saturation of SiPM for Scintillator Calorimeter using UV Laser

Tuesday 26 November 2019 15:20 (20 minutes)

The saturation of SiPM can be an issue for scintillator calorimeter with SiPM readout. When a large number of particles hit a scintillator and a large number of photons are injected to a SiPM, the output of the SiPM can be saturated due to the limited number of pixels. In order to convert the output of the SiPM into the number of incident photons correctly, it is necessary to understand the behavior of the SiPM saturation.

The saturation curve is usually measured by directly injecting fast laser pulse ($\sim$400 nm) to a SiPM. However, the time constant of the emission of scintillation light (a few ns) is not negligible compared to the recovery time of SiPM pixels (dozens ns), so the saturation is expected to be mitigated. We propose a new method to measure the SiPM saturation with scintillation light excited by UV laser. The measured saturation curve can directly be used for the saturation correction at the calorimeter since the effect of the scintillation emission time is correctly included.

For example, the Scintillator Electromagnetic CALorimeter (Sc-ECAL) is a high-granularity EM calorimeter based on scintillator strips readout by SiPMs for the International Linear Collider (ILC). It realizes the virtual segmentation of 5 mm $\times$ 5 mm with strips of 5 mm $\times$ 45 mm $\times$ 2 mm in x-y configuration. The saturation of SiPM and its correction can be an issue for the Sc-ECAL to measure the dense EM shower at the ILC.

The fast fs UV pulse laser with the a wavelengths of 190 nm is used. The 190 nm laser causes scintillation excitation and is invisible to the SiPM. The laser is injected to the standard scintillator strip (EJ-212) readout by SiPM which is the same configuration as used for the Sc-ECAL. Two types of SiPMs which are the candidates for the Sc-ECAL, S14160-1315PS and S12571-015P, are used. The laser light is split by a half mirror to measure the incident light intensity using the photodiode (S12689-02). SiPM signal is converted into number of photoelectrons (N_{pe}). The current of the photodiode is also converted into N_{pe} using the relation with N_{pe} of SiPM at small N_{pe} region where no saturation is anticipated.

The saturation curves are obtained for a wide range of N_{pe}, and over-saturations are observed for both SiPMs. The saturation curves are measured also by injecting 470 nm pulse laser which doesn't generate scintillation light. A significant difference in the saturation curves between 190 nm and 470 nm is observed. It is considered to be the effect of the time constant of the scintillation emission. It can be a big impact on the saturation correction for the Sc-ECAL.

Author: TSUJI, Naoki (The University of Tokyo)

Co-authors: OOTANI, Wataru (ICEPP, University of Tokyo); LIU, Linghui (The University of Tokyo); YOSHIOKA, Kosuke (The University of Tokyo); GONOKAMI, Makoto (The University of Tokyo); MORITA, Yusuke (The University of Tokyo)

Presenter: TSUJI, Naoki (The University of Tokyo)

Session Classification: Sensors

Contribution ID: **51** Type: **not specified**

Belle II electromagnetic calorimeter and its performance during early SuperKEKB operation

Wednesday 27 November 2019 09:20 (30 minutes)

The Belle II experiment at the SuperKEKB accelerator complex is the intensity frontier electron-positron colliding beam experiment. The electromagnetic calorimeter consists of the 8736 CsI(Tl) crystals with the attached PIN-photodiodes inherited from the Belle experiment. In order to ensure high rate capability and immunity against beam background, the electronics have been upgraded with waveform sampling readout to provide not only energy deposition but also timing for each crystal hit. Design and construction of the upgraded electronics are reviewed and the performance in the early Belle II physics run is reported. We also present results showing the first application of calorimeter pulse shape discrimination at a B-Factory experiment. This novel technique, enabled by the new waveform sampling electronics, allows for discrimination between electromagnetic and hadronic showers, leading to significant improvements in kaon-long vs. photon separation and charged particle identification.

Authors: Prof. MIYABAYASHI, Kenkichi (Nara Women's University); BELLE II ELECTROMAGNETIC CALORIMETER GROUP

Presenter: Prof. MIYABAYASHI, Kenkichi (Nara Women's University)

Session Classification: Running performance, upgrade

Contribution ID: **52** Type: **not specified**

Development of a new inorganic crystal GAGG for the calorimeter capable of the separation between neutrons and gammas

Tuesday 26 November 2019 14:20 (20 minutes)

A new inorganic crystal Gd3Al2Ga3O12(GAGG) is being developed. This crystal is suitable for the electromagnetic calorimeters used in high energy physics experiments because the constant of light emission is short (- 90ns) and the light yield is as high as that of NaI(TI) crystals. In addition, the response of the crystal can be faster by doping materials.

By using GAGG crystals, we aim at developing an electromagnetic calorimeter which can distinguish neutrons from gammas. One possible method for the separation between neutrons and gammas is to use the difference of the pulse shapes. The difference between the signals from gammas and alpha particles were already reported for GAGG crystals. So the signals of gammas and neutrons may be discriminated with the pulse shape. In addition, Information on the depth of interaction positions in the crystal can be used due to the short radiation length (1.6cm) and large interaction length (27cm). We fabricated a prototype detector, in which two GAGG crystals with different doped materials and different constants of light emission were glued to measure the interaction positions from observed pulse shapes.

We carried out a series of beam tests by using neutron and positron beams and evaluated the performance of the prototype. In this talk, results of the beam tests are presented and the expected performance to distinguish neutrons from gammas is evaluated.

Author: SHIOMI, Koji (KEK)

Presenter: SHIOMI, Koji (KEK)

Session Classification: Sensors

Contribution ID: **53** Type: **not specified**

Four-dimensional calorimeter to discriminate gammas from neutrons for the KOTO experiment

Monday 25 November 2019 11:40 (20 minutes)

We study the rare decay $K_L \to \pi^0\nu\bar{\nu}$ at the J-PARC KOTO experiment. The signature of the decay is two gammas from a π^0 decay and no other detectable particles. The two gammas are detected with a calorimeter. The calorimeter composed of undoped cesium iodide(CsI) crystals, and their energy, timing and two-dimensional position are measured. Small 2240 crystals (25 × 25 × 500 mm^3) are used in the inner region close to the neutral beam while large 476 crystals (50 × 50 × 500 mm^3) are used in the outer region. Each crystal is read out with a PMT attached on its rear side.
One of the main backgrounds to $K_L \to \pi^0\nu\bar{\nu}$ is caused by the neutron in the beam halo. If the beam halo neutron produces a hadronic shower in the calorimeter, and another neutron from this shower interacts at a different position of the calorimeter, it can mimic the two electromagnetic showers.
We developed a new method to reduce this background by using the depth of the interaction position in the calorimeter. Gammas interact according to the radiation length, and make a shallow shower. On the other hand, neutrons interact according to the interaction length, and make a deep shower. We attached MPPCs on the front end of the crystals to obtain the depth of interaction .The timing difference between the MPPC signal from upstream and the PMT signal from downstream represents the depth of the interaction. Thus, we can obtain four-dimensional information on the showers from the calorimeter.
We attached 4080 MPPCs on the calorimeter in the autumn of 2018 and took the data during the beam time in 2019.The performance of the upgraded calorimeter was evaluated by using the data. With the time difference of the both-end readout, it was demonstrated that the neutron background is suppressed to be 1/40.

Author: OSUGI, Mayu (Osaka University, Japan)

Presenter: OSUGI, Mayu (Osaka University, Japan)

Session Classification: Nuclear, astro, non-collider

Contribution ID: **54** Type: **not specified**

Current status of Hamamatsu Si detectors for collider experiments

Tuesday 26 November 2019 16:30 (30 minutes)

Hamamatsu photonics has been producing many sensors like a photo-multiplier tube to HEP (high energy physics) experiments. Recently our Si sensors are used in many collider experiments. In LHC project, our SSD (Silicon strip detector) and Si-APD (Avalanche photodiode) were installed in CMS and ATLAS detectors, and contributed to the Nobel-Prize winning discovery of the Higgs boson in 2013. For the upgrade to the HL-LHC (High Luminosity LHC) scheduled for 2026, Hamamatsu photonics will supply new 8 inch silicon pad sensors and new SSDs.
The MPPC, which is a part of the SiPM family, was developed about 10 years ago. The most important feature is its photon counting capability due to high gain and low noise, but the MPPC has many additional features such as compact size, low operation voltage, robustness, high detection efficiency, and immunity to magnetic field. Many scientists have been using MPPCs for HEP experiments like T2K experiment and MEG-II experiment. And new MPPCs are considered for the new detectors in HL-LHC.
In this presentation, we will discuss the feature of our new silicon sensors and MPPCs for collider experiments. And we will talk about new technique of MPPCs for HEP experiments.

Author: Mr OHASHI, Yuto (Hamamatsu Photonics)

Presenter: Mr OHASHI, Yuto (Hamamatsu Photonics)

Session Classification: Sensors

Contribution ID: **55** Type: **not specified**

Performances of the 3-D imaging calorimeter for HERD

Monday 25 November 2019 10:40 (20 minutes)

The High Energy cosmic-Radiation Detection (HERD) facility is a flagship and landmark scientific experiment onboard China's Space Station for search of dark matter, high precision measurement of charged cosmic rays and gamma rays, planned for operation starting around 2025 for about 10 years. The main instrument of HERD is a highly optimized five-sides-effective 3-D calorimeter (CALO) with more than one order of magnitude larger geometric factor than that of previous experiments. CALO is segmented into 7500 LYSO cubic crystals, corresponding to about 55 radiation lengths and 3 nuclear interaction lengths deep. The e/p separation power of CALO is up to 10e-6 thanks to its high granularity. The crystal signals are transferred by wavelength shifting fibers and read out by IsCMOS devices with compact and simple electronics. Energy resolution of electrons, protons and other key performances of CALO were well demonstrated in the CERN beam tests.

Authors: Dr WANG, Junjing (IHEP, CAS); Dr ZHANG, Li (IHEP, CAS); Dr XU, Ming (IHEP, CAS); Dr HU, Peng (IHEP, CAS); Dr WANG, Ruijie (IHEP, CAS); Dr BAO, Tianwei (IHEP,CAS); Dr LIU, Xin (IHEP, CAS); Dr DONG, Yongwei (IHEP, CAS); Dr QUAN, Zheng (IHEP,CAS); Dr WANG, Zhigang (IHEP, CAS)

Presenter: Dr QUAN, Zheng (IHEP,CAS)

Session Classification: Nuclear, astro, non-collider

Contribution ID: **56** Type: **not specified**

Study of Position Sensitive Silicon Detector (PSD) for SiW-ECAL at ILC

Tuesday 26 November 2019 17:40 (20 minutes)

The International Linear Collider (ILC) is a future electron-positron collider for precise measurements of Higgs bosons and various BSM searches. Silicon-tungsten electromagnetic calorimeter (SiW-ECAL) is one of the candidates to be used in the International Large Detector (ILD), one of the detector concepts for the ILC. The silicon sensor of the SiW-ECAL is segmented by 5.5 mm square cells to maximize performance of Particle Flow Algorithm (PFA). We are investigating possibility of implementing Position-Sensitive Detector (PSD) technique to each cell of this sensor in order to improve position resolution of particles, which may lead improvements on PFA performance, pi0 reconstruction with kinematic fit, searching BSM with displaced neutral particles and so on.
Our PSD is a silicon sensor with multiple cells as same as the sensor of SiW-ECAL. Each cell has an electrode at each corner, and the signal is divided to the electrodes with a resistive layer on the surface. The hit position can be obtained from the ratio of the signal on each electrode. In contrast to using smaller cells, the position resolution can be improved with minimal increase of the readout channels if we replace the silicon pads with PSDs in SiW-ECAL.
We have been developing the PSDs for several years. In the first production we found that the charge separation is not optimally done due to the readout impedance. To avoid the issue, we produced new PSDs with higher surface resistance with additional resistive layer on the surface. We also implemented several techniques to decrease position distortion and increase signal-to-noise ratio which is essential for the optimal position resolution. In this talk we will report study of the latest PSD sensors with signal by gamma and beta radiation source and laser injection. We also plan to conduct a test beam with sub-GeV electrons. The setup and quick view of the results of the test beam will also be shown.

Author: Mr UESUGI, Yuto (Kyushu University)

Co-authors: Mr MORI, Ryosuke (Kyushu University); Mr YAMASHIRO, Hiroaki (Kyushu University); SUEHARA, Taikan (Kyushu University (JP)); Mr YOSHIOKA, Tamaki (Kyushu University); KAWAGOE, Kiyotomo (Kyushu University (JP))

Presenters: Mr UESUGI, Yuto (Kyushu University); KYUSHU, hep

Session Classification: Sensors

Contribution ID: **57** Type: **not specified**

An adaptative design for the SiW-ECAL of e+e- colliders

Monday 25 November 2019 15:15 (20 minutes)

To exploit at best the physics potential of future e+e–colliders, the particle flow approach combining optimally the information from a precision tracking and an imaging calorimetric systems was adopted by most detector concepts (ILD and SiD for the ILC, CLICdp for the CLIC, CLD for the FCC-ee and the "Baseline detector"for CEPC).
One of the most advanced solutions for an imaging electromagnetic calorimeter (ECAL) suitable for any of these experiments involves Silicon as sensor material interleaved with Tungsten as a radiator in carbon fibre structures, combining flexibility, intrinsic stability and compactness. Its most complete description has been done for ILD SiW-ECAL. The scalable design integrates the testability of every component, an indispensable trait, given the massive number of elements involved.
The base element of the detector, so-called ASU for Assembly Single Unit, is a stitchable electronic board holding, on one side, the readout electronics and, on the other, the Silicon PIN diode matrices. The first bunch of 7 ASUs was successfully tested as a stack in beam tests (DESY-2018, CERN-2018 and DESY-2019), and its performances have been reported at this conference. This work focuses on their implementation in a long slab, as needed for the experiments, holding between 6 and 12 ASUs, depending on the detector geometry.
A model of an "electric"slab, relieved of mechanical constraints w.r.t. the final design, was built with 8 ASUs to investigate CEM, readout and power issues. It was tested in-beam in 2018 and in-lab since. After modifications, the signal-to-noise ratio for mips was found to be appropriate but depending on the position, pointing to the need for power distributions improvements. The results and issues will be discussed here together with possible implications for the high-luminosity schemes.

Authors: ANDUZE, Marc (LLR - CNRS/IN2P3, École polytechnique/IP Paris); BOUDRY, Vincent (LLR - CNRS/IN2P3, École polytechnique/IP Paris); BRIENT, Jean-Claude (LLR - CNRS/IN2P3, École polytechnique/IP Paris); LOUZIR, Marc (LLR - CNRS/IN2P3, École polytechnique/IP Paris); MAGNIETTE, Frederic Bruno (LLR - CNRS/IN2P3, École polytechnique/IP Paris); NANNI, Jérôme (LLR - CNRS/IN2P3, École polytechnique/IP Paris); VIDEAU, Henri (LLR - CNRS/IN2P3, École polytechnique/IP Paris); KUNATH, Jonas (LLR/CNRS)

Presenter: KUNATH, Jonas (LLR/CNRS)

Session Classification: Future detector systems

Contribution ID: **58** Type: **not specified**

Upgrade of the SND electromagnetic calorimeter

Wednesday 27 November 2019 12:20 (20 minutes)

Current status and last results of the SND calorimeter upgrade are described. The main part of SND detector is a three-layer spherical NaI(Tl) electromagnetic calorimeter (EMC). The total thickness of NaI(Tl) in the calorimeter is 35 cm. The vacuum phototriodes (VPT) are used as photosensitive devices for the calorimeter counters. The quantum efficiency of VPT is about 15 %, the average gain is 10, and the light collection efficiency is about 10%.

New spectrometric channel of the electromagnetic calorimeter (EMC) was designed and implemented. It consists of a NaI(Tl) crystal, a vacuum phototriode, a charge-sensitive preamplifier a shaper and digitizing modules. The digitization is performed by 6 ADCs AD9228BCPZ-40 (4 channel, 12 bits, 40 MBPS) and the data go in serial form to the SoC Xilinx Zynq-7000. This SoC is basically a combination of FPGA programmable logic and ARM processor.

The special algorithm for signal waveform processing was developed to determine time of flight and amplitude with high time (1 ns) and amplitude (250 keV) resolution. The algorithm is based on the invariability of the signal waveform. The waveform calibration procedures are developed and implemented.

Successful data taking run was performed with upgraded EMC in 2019.

Author: SURIN, Ilya (Budker INP)

Presenter: SURIN, Ilya (Budker INP)

Session Classification: Running performance, upgrade

Contribution ID: **59** Type: **not specified**

Status of Geant4 simulation of calorimeters

Thursday 28 November 2019 14:20 (20 minutes)

Geant4 is the main software tool for the simulation of calorimeter response.
In this work we report recent developments of Geant4 physics models, which will be available in the coming version 10.6, scheduled for December 2019.
The main directions of Geant4 developments will be discussed: improvements of physics model accuracy, technical modifications to increase CPU performance, and user interface extensions. It is expected that, due to these developments, the responses of electromagnetic and hadronic calorimeters will be slightly affected; validation results from thin-target benchmarks as well as for calorimeter benchmarks will be shown. We will present new features that allow to speed up the simulation and provide recommendations to users on how they may optimize the simulations of their detectors using the new Geant4 interfaces. We will also discuss the role of Birks corrections on the simulation of calorimeter response.

Authors: Prof. IVANTCHENKO, Vladimir (CERN); NOVAK, Mihaly (CERN); RIBON, Alberto (CERN)

Presenter: Prof. IVANTCHENKO, Vladimir (CERN)

Session Classification: Simulation, Geant4, PFA

Contribution ID: **60** Type: **not specified**

Development of double SiPM readout method for ILD scintillator electro- magnetic calorimeter

Tuesday 26 November 2019 15:40 (20 minutes)

One of the concepts for detector mounted on the interaction point of ILC is International Large Detector (ILD). Sc-ECAL is a proposed option for the electromagnetic calorimeter of ILD based on 5 × 45 × 2 mm^3 plastic scintillator strip readout by SiPM. Virtual 5 × 5 mm^2 segmentation is realized by x-y configuration of strips.

SiPMs with small cell pitch such as 10 and 15 μm are required for Sc-ECAL to have a wide dynamic range, but S/N is not good enough due to low gain of the MPPC with small cells.

In order to improve the performance of the scintillator strip, we are developing a new SiPM readout method for the scintillator strip for Sc-ECAL where the scintillator strip is readout by two SiPMs at the strip ends. This technique allows us to eliminate noise by taking coincidence between two MPPCs and thus to improve S/N. A higher light yield is also expected by summing two MPPC signals. Possibility of position reconstruction by using the two MPPC signals is also investigated, although it might be challenging.

A large technological prototype for Sc-ECAL is being constructed as a joint effort with Chinese groups working on CEPC. We are proposing to add detection layers with double SiPM readout to the prototype. We have tested the prototypes for the scintillator strip with double SiPM readout with different configurations. The measured performance of the prototypes will presented.

Author: MASUDA, Ryunosuke (University of Tokyo)

Co-authors: LIU, Linghui (The University of Tokyo); TSUJI, Naoki (The University of Tokyo); OOTANI, Wataru (ICEPP, University of Tokyo)

Presenter: MASUDA, Ryunosuke (University of Tokyo)

Session Classification: Sensors

Contribution ID: **61** Type: **not specified**

Light yield and uniformity measurements of different scintillator tiles and studies of 4th generation Hamamatsu SiPMs

Tuesday 26 November 2019 14:40 (20 minutes)

We present light yield and uniformity measurements of square tiles and hexagonal tiles that are read out with SiPMs via a Y11 fiber or directly from the side or from the top in a dimple. All tiles have an area of 9˜cmˆ2. Their sides are wrapped with two layers of Teflon tape and the top and bottom faces are wrapped with two layers of Tyvec paper. We further show the first light yield and uniformity measurements of ATLAS TileCal tiles with SiPM readout. This study has been motivated to look into a possible phase 3 upgrade for the calorimeter. Finally we present first measurements of the 4th generation SiPMs from Hamamatsu.

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Presenter: EIGEN, Gerald (University of Bergen (NO))

Session Classification: Sensors

Contribution ID: **62** Type: **not specified**

Time performance of large dynamic range SiPM

Tuesday 26 November 2019 15:00 (20 minutes)

The silicon photomultiplier (SiPM) is a novel developed device with excellent single photon detection ability. Large dynamic range SiPM has been studied in high granularity calorimeter due to the advantages of insensitivity to magnetic fields, compactness, robustness, low bias voltage and low power. The Novel Device Laboratory (NDL) developed a low cost and large dynamic range SiPM with high micro cell density. The time performance of the NDL SiPMs was studied in this paper. A 403 nm picosecond laser was used as the light source with a time jitter of 45 ps. When the number of photoelectrons is large (>10), the light source jitter can be neglected. The SiPMs of three manufacturers with different microcell sizes were compared. The results show that as the number of photoelectrons increases, the rise time and transition time spread (TTS) decreased. For a 10 micron SiPM, the time resolution is better than 15 ps with multi-photoelectrons. This time resolution enables calorimeter to do excellent particle identification.

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Presenter: QIAN, Sen (Institute of High Energy Physics,CAS)

Session Classification: Sensors

Contribution ID: **64** Type: **not specified**

ATLAS Tile calorimeter calibration and PMT response

Tuesday 26 November 2019 11:20 (20 minutes)

The ATLAS Tile Calorimeter (TileCal) is the central section of the hadronic calorimeter of the ATLAS experiment. It provides important information for reconstruction of hadrons, jets, hadronic decays of tau leptons and missing transverse energy. This sampling calorimeter uses steel plates as absorber and scintillating tiles as active medium. Scintillating light is transmitted by wavelength shifting fibres to photomultiplier tubes (PMTs) in the rear girders of the wedge-shaped calorimeter modules. Photomultiplier signals are then digitized at 40 MHz and stored on detector in digital pipelines. Event data are transmitted off detector upon a first level trigger acceptance, at a maximum rate of 100 kHz). The readout is segmented into about 5000 cells, each read out by two PMTs on opposite sides of the cell. To calibrate and monitor the stability and performance of each part of the readout chain during the data taking, a set of calibration systems is used. The TileCal calibration system comprises Cesium radioactive sources, laser, charge injection elements and an integrator based readout system. Combined information from all systems allows to monitor and equalise the calorimeter response at each stage of the signal production, from scintillation light to digitisation.

After exposure to scintillator light for almost 10 years, variations in gain have been observed when the PMTs are exposed to large light currents. These variations have been studied and correlated to some intrinsic properties of the PMTs, including the quantum efficiency, as well as operation conditions like the High Voltage. Latest results and conclusions will be presented.

Author: BOUMEDIENE, Djamel Eddine (Université Clermont Auvergne (FR))

Presenter: BOUMEDIENE, Djamel Eddine (Université Clermont Auvergne (FR))

Session Classification: Calibration, R&D, test beams

Contribution ID: **65** Type: **not specified**

Performance of the ATLAS Tile Calorimeter

Wednesday 27 November 2019 11:20 (20 minutes)

The Tile Calorimeter (TileCal) is a sampling hadronic calorimeter covering the central region of the ATLAS experiment, with steel as absorber and plastic scintillators as active medium. The scintillators are read out by wavelength shifting fibres to photomultiplier tubes (PMTs at the back of each wedge-shaped calorimeter module. The analogue signals from the PMTs are amplified, shaped, and digitised on the detector every 25 ns, and stored on detector in digital pipeline buffers until a trigger decision is received. The data are then read out to the off-detector systems for further processing.

TileCal employs several calibration systems that, together with the collected collision data, provide the basis for response equalisation and monitoring at each stage of the readout path; from scintillation light production to energy and time reconstruction. Furthermore, the calorimeter performance has been established with test beam data, cosmic ray muons and large samples of proton-proton collision data.

Beam tests using three spare TileCal modules at the CERN SPS accelerator in 2017 measured the energy response and resolution for pions, kaons and protons, and results were compared against a Geant4 based simulation. During LHC run-2, high-momentum isolated muons have been used to study and validate the electromagnetic scale, while hadronic response has been probed with isolated hadrons. The calorimeter time resolution has been studied with multi-jet events.

We present and summarise results of the calorimeter calibration and performance.

Authors: SILVERSTEIN, Samuel (Stockholm University (SE)); KLIMEK, Pawel Jan (Northern Illinois University (US))

Presenter: KLIMEK, Pawel Jan (Northern Illinois University (US))

Session Classification: Running performance, upgrade

Contribution ID: **66** Type: **not specified**

Liquid Xenon Photon Detector with Highly Granular Scintillation Readout for MEG II Experiment

Monday 25 November 2019 12:00 (20 minutes)

The MEG II experiment is in preparation to search for the lepton flavour violating decay, $\mu \to e+\gamma$, aiming at the world's highest sensitivity of 6×10^{-14}, which is ten times better than that of the MEG experiment.
An improved photon measurement is a key to the high sensitivity of the MEG II experiment.
A liquid xenon (LXe) photon detector with highly granular scintillation readout with 4092 VUV-sensitive MPPCs (139\,mm^2 each) has been constructed.
The highly granular and uniform scintillation readout by the VUV-MPPCs will improve the energy and position resolutions by a factor of two compared to the MEG LXe detector based on readout by 2"PMTs.
The VUV-MPPC was developed in collaboration with Hamamatsu Photonics K.K for the MEG II LXe detector, showing an excellent performance in LXe including a high photon detection efficiency (15–20%) for LXe scintillation light, high gain, low probability of optical cross-talk, low dark count rate and a good single photoelectron resolution.
The commissioning of the LXe detector is in progress.
Calibrations and performance studies using various calibration sources and muon beam are in progress although the number of readout channels is limited due to a delay of the production of the full electronics.
The performance measured in the commissioning of the detector and the plan for the engineering run with the full MEG II detector next year being followed by physics data-taking will be presented.

Author: OOTANI, Wataru (ICEPP, University of Tokyo)

Presenter: OOTANI, Wataru (ICEPP, University of Tokyo)

Session Classification: Nuclear, astro, non-collider

Contribution ID: **67** Type: **not specified**

Readiness of the Phase-II upgrade electronics of the ATLAS Hadronic Tile Calorimeter for the High Luminosity LHC

Thursday 28 November 2019 11:54 (20 minutes)

The ATLAS hadronic Tile Calorimeter (TileCal) will undergo major upgrades to the on- and off-detector electronics in preparation for the high luminosity programme of the LHC in 2026, so that the system can cope with the HL-LHC increased radiation levels and out-of-time pileup. The on-detector electronics of the upgraded system will continuously digitize and transmit all photomultiplier signals to the off-detector systems at a 40 MHz rate. The off-detector electronics will store the data data in pipeline buffers, produce digital hadronic tower sums for the Level-1 calorimeter trigger system, and read out selected events. The modular front-end electronics feature radiation-tolerant commercial off-the-shelf components and redundant design to minimise single points of failure. The timing, control and communication interface with the off-detector electronics is implemented with modern Field Programmable Gate Arrays (FPGAs) and high speed fibre optic links running up to 9.6 Gb/s.

The TileCal upgrade program has included extensive R&D and test beam studies, and a Demonstrator module with reverse compatibility with the existing system inserted in ATLAS in August 2019 for testing in actual detector conditions. We present the status and results of Demonstrator tests and calibration runs to assess the readiness of the upgraded design.

Authors: SILVERSTEIN, Samuel (Stockholm University (SE)); ABDALLAH, Jalal (University of Texas at Arlington (US))

Presenter: ABDALLAH, Jalal (University of Texas at Arlington (US))

Session Classification: Electronics, DAQ

Contribution ID: **68** Type: **not specified**

The sampling electromagnetic calorimeter with longitudinal segmentation.

Monday 25 November 2019 16:30 (20 minutes)

The electromagnetic (EM) calorimeter with longitudinal segmentation , his design and beam test results are presented. The EM calorimeter of "shashlik" type was divided longitudinally on 4 tiles. The idea of such calorimeter type was an improving the particles identification take in account longitudinal shower profile for electrons, muons and hadrons. This calorimeter via a single module was tested at IHEP U-70 and CERN PS in 2007. The experimental results were presented for particles identification in 5 GeV beam with 80% pions, 15% positrons and 5% muons. In current report are presented new idea for design and construction for calorimeter based on "shashlik" type with longitudinal segmentation with SiPm photo sensors.

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Co-authors: Dr NAGAITSEV, Alexandre (JINR, Dubna, Russia); Mr KOZHIN, Mikhail (JINR, Dubna, Russua); Mr GRAPHOV, Nikita (JINR, Dubna, Russia); Dr SEMENOV, Vitaliy (IHEP, Protvino, Russia); Dr KOVTUN, Vladimir (Khsrkov State University, Ukraine)

Presenter: Dr GAVRISHCHUK, Oleg (JINR, Dubna, Russia)

Session Classification: Future detector systems

Contribution ID: **69** Type: **not specified**

Resistive Plate Chamber digitisation for highly granular calorimeter

Thursday 28 November 2019 15:20 (20 minutes)

The CALICE Semi-Digital Hadron Calorimeter technological prototype that was completed in 2011 is a sampling calorimeter using Glass Resistive Plate Chamber detectors as the active medium. This technology is one of the two options proposed for the hadron calorimeter of the International Large Detector for the International Linear Collider. The prototype was exposed to beams of muons, electrons and pions of different energies at the CERN Super Proton Synchrotron.

The use of this technology for future experiments requires a reliable simulation of its response. The prototype is simulated using GEANT4 and a custom digitisation algorithm. It describes the full path of the signal: showering, gaz avalanches, charge induction and hit triggering. This simulation was tuned using muon tracks and electromagnetic showers in order to account for detector inhomogeneity and tested on hadronic showers collected in test beam.
Initial digitisation algorithm was described in JINST 11 (2016) 6 P06014. Further developments of the algorithm will be reported including additional test beam data.

Authors: BOUMEDIENE, Djamel Eddine (Université Clermont Auvergne (FR)); GRENIER, Gerald (IP2I, CNRS, Univ Lyon 1 (FR))

Presenter: BOUMEDIENE, Djamel Eddine (Université Clermont Auvergne (FR))

Session Classification: Simulation, Geant4, PFA

Contribution ID: **70** Type: **not specified**

Versatile systems for characterization of large-area silicon pad sensors for highly-granular calorimetry

Tuesday 26 November 2019 10:10 (20 minutes)

High-granularity calorimeters utilizing silicon pad sensors as main active material are being designed for the CMS endcap calorimeter upgrade and have been proposed for the electromagnetic calorimeters at CLIC, ILC and FCC-ee. The silicon sensors in such experiments are foreseen to cover a very large area of O(1000m2). They are typically produced from 6- or 8-inch wafers and consist of a few hundred smaller cells, each with an area of O(0.1 to 1.1cm2). Currently the CMS endcap calorimeter upgrade is in a prototyping phase with the aim of choosing the final sensor design. Flexible systems are needed for quick sensor characterization as close as possible to operating conditions, for testing of prototypes and for quality control during mass production. The "ARRAY" system consists of an active switching matrix PCB with 512 input channels and a passive probe card specific for each sensor layout. The probe card makes contact with each individual pad through spring-loaded pins. ARRAY is designed to measure the leakage current and capacitance per-cell for different bias voltages, keeping the entire sensor area under bias. The "Hexaboard" probe card follows a similar principle: readout electronics foreseen to be used in the final CMS detector are mounted on a PCB that makes contact with the sensor through spring-loaded pins. Its main goal is to perform noise and charge collection efficiency measurements with irradiated sensors without the need for module assembly. We present the design of the ARRAY and Hexaboard systems as well as measurements performed on different CMS prototype silicon sensors. We also compare the results with alternative multi-needle setups.

Author: DIAS DE ALMEIDA, Pedro (Universidad de Cantabria and CSIC (ES))

Presenter: DIAS DE ALMEIDA, Pedro (Universidad de Cantabria and CSIC (ES))

Session Classification: Calibration, R&D, test beams

Contribution ID: **72** Type: **not specified**

Analysis of SiW-ECAL technological prototype beam test with electron beam

Friday 29 November 2019 09:20 (20 minutes)

The next-generation Higgs Factory, such as the International Linear Collider (ILC) project, can be a powerful approach to new physics based on Higgs precision measurements. The International Large Detector (ILD) which is one of the detector concept for the ILC is designed to be optimized for the Particle Flow Algorithm (PFA) to enable the most sensitive measurement with the highest sensitivity. The PFA is expected to improve basic particle level reconstruction and energy resolution.

There are two types of candidate for ILD electromagnetic calorimeter, SiECAL and ScECAL. The SiECAL, which we are researching and developing, is a sampling type calorimeter consisting of 30 layers with a silicon pixel sensor for the detection layer and tungsten for the absorption layer. The PFA requires its silicon pixel size of 5mm × 5mm.

In this talk, we will report the results of the SiW-ECAL technical prototype beam test that was conducted from June to July 2019 at DESY in Germany using electron beam (1-5 GeV). In the beam test, there are two main programs: MIP program (without tungsten) and Shower program (with tungsten). The main purpose of the MIP program are energy calibration, pedestal uniformity/stability assessment, TDC operation test, and retriggering verification. On the other hand, The Shower program aims to evaluate energy resolution through beam energy measurement. In addition, FEV13 operation tests such as individual threshold control and auto gain mode were also conducted. We will also report on the current state of simulation research on this beam test.

Authors: Mr KATO, Yu (The University of Tokyo); Mr GOTO, Kiichi (Kyushu University); SUEHARA, Taikan (Kyushu University (JP))

Co-authors: ILD SIW-ECAL GROUP; YAMASHITA, Satoru (University of Tokyo)

Presenter: Mr KATO, Yu (The University of Tokyo)

Session Classification: PID, test beams

Contribution ID: **73** Type: **not specified**

The electronics of the upgraded LHCb calorimeter system

Thursday 28 November 2019 12:14 (20 minutes)

The LHCb detector foresees a major upgrade for the next data taking period of the LHC, in 2021. The main characteristics of this upgrade is a full software trigger running at 40MHz. The calorimeter system of LHCb is part of this upgrade and the major evolution consists in replacing the electronics of the electromagnetic and hadronic calorimeters in order to send the full data flow to the counting room at 40MHz by means of four optical links per front-end board (FEB). The former earliest-level trigger calculations performed on the FEB during the runs 1 and 2, will be kept for the upgrade and will be sent to the PC farm in order to optimize the software trigger. The gain of the photomultipliers will also be reduced by a factor 5. This will be partially compensated by an increase of the gain of the electronics by a factor 2.5. The remaining factor 2 will be used to extend the dynamics of the calorimeter and to extend the physics case to some new topics.
The development of this electronics is well-advanced. The analog part has been designed, produced and the production has been tested last year. Several prototypes of the FEB have been realized during the last years. The last one is the pre-production sample and the almost three hundred boards needed should be fabricated in the next months. The firmware of the nine BGAs that equip the boards is mostly written and tested and only limited evolutions are foreseen in the future. The software for the configuration, the control and the tests of the FEB during data-taking has been conceived in parallel to the design of the electronics.
The new FEB of the calorimeters of LHCb will be presented in the context of the upgraded detector. The analog part relies on two integrators running alternatively at 20MHz and is fully differential so that it provides an accurate energy measurement in a 25ns window with a very limited spill-over and leading to a low-noise system, estimated to ˜1.3 ADC (˜7 MeV) per channel, in spite of the increased gain. The performances of the board in term of noise, linearity, diaphony, etc... will be given. The digital treatments and calculations performed in the FPGA to remove the low noise contributions and to determine the quantity needed for the software trigger will be described and illustrated by the test beams performed as well as the tolerance to radiations.

Authors: MACHEFERT, Frederic (Centre National de la Recherche Scientifique (FR)); PIZZICHEMI, Marco (CERN)

Co-author: THE LHCB COLLABORATION

Presenter: PIZZICHEMI, Marco (CERN)

Session Classification: Electronics, DAQ

Contribution ID: **74** Type: **not specified**

Expected performances of the IDEA Dual-Readout fully projective fiber calorimeter

Monday 25 November 2019 16:50 (20 minutes)

Traditional energy measurements in hadron detection have always been spoiled by the non-compensation problem. Hadronic showers develop an electromagnetic component, from neutral mesons'decays, over-imposed on the non-electromagnetic one. As the calorimeter samples the two with different responses, fluctuations between them directly spoil the hadronic energy resolution. This sets an unsurmountable limit in hadronic and jet energy measurements in the current high-energy physics experiments. Future electron-positron colliders, proposed for the post-LHC era, all aim at measuring the Higgs boson couplings with an order-of-magnitude better precision than the LHC measurements. As a consequence, for a significant measurement of the Higgs boson couplings to the IVBs, it is mandatory to statistically separate the 4-jets final states from $H \rightarrow ZZ^*$ and $H \rightarrow WW^*$, where the only discriminant is the W/Z invariant mass.
A promising solution to the problem comes from dual-readout calorimetry. This calorimetric technique is capable of measuring the electromagnetic component on an event-by-event basis and correcting energy measurements for its fluctuations. The performance obtained with this method makes a dual-readout calorimeter especially suitable for high-precision experiments at future leptonic colliders. The IDEA detector proposed for the Circular electron positron Collider (CepC) and the Future Circular Collider (FCC-ee) currently adopts a dual-readout calorimeter for all the energy measurements.
First results with GEANT4 simulations of the IDEA dual-readout fully projective calorimeter will be presented. While electromagnetic performances show already a good agreement with test-beam data, results for hadrons are under investigation and indicate that a resolution of $\sigma/E \simeq 30\%/\sqrt{E}$ is reachable. Eventually, physics events concerning jets final states ($e^+e^- \rightarrow jj$) and the reconstruction of complex final states through the use of Machine Learning algorithms will be presented.
On the hardware side, a new silicon photomultiplier based readout has opened the possibility to sample light from each fiber independently. This feature, coupled with a fully projective calorimeter, leads to an unprecedented 2-dimensional spatial and angular resolution and, together with timing information, may provide sensible powerful input to particle-flow algorithms. First results concerning the calorimeter spatial and angular resolution and particle identification capabilities will be presented as well.

Author: PEZZOTTI, Lorenzo (Università di Pavia and INFN (IT))

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Presenter: PEZZOTTI, Lorenzo (Università di Pavia and INFN (IT))

Session Classification: Future detector systems

Contribution ID: **76** Type: **not specified**

Geant4 status and prospect

Thursday 28 November 2019 14:00 (20 minutes)

Geant4 is a software toolkit for the simulation of the passage of particles through matter. It is used by a large number of experiments and projects in a variety of application domains, including high energy physics, astrophysics and space science, medical physics and radiation protection. Over the past several years, along with the new Geant4 version 10 series, major changes have been made to the toolkit in order to accommodate the needs of these user communities, and to efficiently exploit the growth of computing power made available by advances in technology. The adaptation of Geant4 to multithreading, advances in physics, detector modeling and visualization, extensions to the toolkit, including biasing and reverse Monte Carlo, tools for physics and release validations and near- and longer-term perspective will be discussed.

Authors: ASAI, Makoto (SLAC National Accelerator Laboratory (US)); ASAI, Makoto (SLAC); ON BEHALF OF THE GEANT4 COLLABORATION

Presenter: ASAI, Makoto (SLAC National Accelerator Laboratory (US))

Session Classification: Simulation, Geant4, PFA

Contribution ID: **77** Type: **not specified**

Calibration and Performance of the CMS Electromagnetic Calorimeter in LHC Run 2

Wednesday 27 November 2019 10:10 (20 minutes)

Many physics analyses using the Compact Muon Solenoid (CMS) detector at the LHC require accurate, high resolution electron and photon energy measurements. Excellent energy resolution is crucial for studies of Higgs boson decays with electromagnetic particles in the final state, as well as searches for very high mass resonances decaying to energetic photons or electrons. The CMS electromagnetic calorimeter (ECAL) is a fundamental instrument for these analyses and its energy resolution is crucial for the Higgs boson mass measurement. Recently the energy response of the calorimeter has been precisely calibrated exploiting the full Run 2 data, aiming at a legacy reprocessing of the data. A dedicated calibration of each detector channel has been performed with physics events exploiting electrons from W and Z boson decays, photons from pi0/eta decays, and from the azimuthally symmetric energy distribution of minimum bias events. This talk presents the calibration strategies that have been implemented and the excellent performance achieved by the CMS ECAL with the ultimate calibration of Run 2 data, in terms of energy scale stability and energy resolution.

Authors: KUO, Chia-Ming (National Central University (TW)); CMS ECAL COLLABORATION

Presenter: KUO, Chia-Ming (National Central University (TW))

Session Classification: Running performance, upgrade

Contribution ID: **79** Type: **not specified**

Welcome

Monday 25 November 2019 10:00 (10 minutes)

Presenter: KAWAGOE, Kiyotomo (Kyushu University (JP))

Session Classification: Welcome

Contribution ID: **80** Type: **not specified**

Summary

Friday 29 November 2019 11:30 (30 minutes)

Author: LAKTINEH, Imad (Centre National de la Recherche Scientifique (FR))

Presenter: LAKTINEH, Imad (Centre National de la Recherche Scientifique (FR))

Session Classification: Summary